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NOAA Reports on the Economic Impacts of Weather- and Climate-Related Disasters

Analysis of Data & Methodologies

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

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Executive Summary

As part of its responsibility to "monitor and assess the climate," the National Ocean and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) tracks and analyzes extreme weather and climate events in the U.S. and globally that have great economic and societal impacts. This report and the supporting research further that mission by examining the data sources and methodologies used in production of the NCDC economic impact estimates. The research team examined the documentation and data used to produce estimates of cost from extreme weather-related damage by organizations within NOAA, other outside organizations producing similar or relevant estimates, as well as identifying data sources that could be useful to incorporate in further analysis. This report broadly summarizes these findings and identifies key areas of difference both between NOAA estimates as well as those of industry.

This report is part of a larger project, whose goal is to ensure that the estimates of economic loss produced by NOAA, and by the NCDC in particular, employ the most up-to-date and valid approaches used in industry, academia, and government, as well as insuring that all estimates are consistent throughout time and in different regions of the US. Improving estimates of the economic impacts of weather events are particularly important given that they are fundamental for effective policy decisions that mitigate future impacts of disasters, including decisions made during recovery from events and future infrastructure investments. This report supports this goal by chronicling several of the approaches used to estimate economic costs, including those used by different groups within NOAA, those used by others that are commonly available, and identifying key sources of data that could be used in the future to improve and enhance the process. This report also summarizes key issues surrounding NOAA's estimates, from internal consistency to differences from industry best practices. Additionally, this report outlines relevant federal mandates and guidance that NCDC must meet to fulfill its mission.

Introduction

As part of its responsibility to "monitor and assess the climate," NOAA's National Climatic Data Center (NCDC) tracks and analyzes extreme weather and climate events in the U.S. and globally that have great economic and societal impacts. To ensure that it is fulfilling this mission, the NCDC sponsored a workshop to identify weaknesses and deficiencies in the methodologies used to calculate economic impacts of disasters. The workshop concluded that the NCDC methodologies required further examination and review to ensure they dovetail with the most up-to-date and valid approaches used in industry, academia, and government, and are consistent over time, space, and event. This report is a summary of the examination and review findings, outlining potential inconsistencies between NOAA estimates and industry estimates.

Another key focus of the NCDC's workshop was that the analysis of the impact of extreme weather and climate events provides significant social value and accurate estimates are vital for policy decisions for state and local governments as well as at the federal level. Both governmental agencies and the public at large demand accurate estimates of the impacts of weather and climate events, as these estimates play significant roles in contingency planning and investment spending. Additionally, while the accuracy of these estimates have improved over time, the overall difficulty of producing accurate estimates, and the current methods used to do so, leave significant room for improvement. Specifically, the conference identified six main areas of concern that should be addressed:

1. The methods for estimating the economic impacts of weather and climate events have not been peer-reviewed. This includes the NCDC aggregate "billion dollar" estimates (which are currently undergoing peer review), the estimation of weather damage by the National Weather Service's Weather Forecasting Offices (WFOs) and hurricane damage estimates from the National Hurricane Center (NHC).
2. The methods for estimating the economic impacts of weather and climate events do not appear to have been developed in a way that builds on existing peer-reviewed methods, accounting for and explaining departures from those methods.
3. No staff economists were involved in NOAA's estimation of economic impact estimates.
4. Estimates of impacts from NCDC, WFO, and NHC rely on economic multipliers to account for damages that are not directly measured. These multipliers are not always sufficiently supported by statistical evidence or data.
5. Methods, multipliers, and sources of data used are not consistent across different types of events, geographies, or years.
6. Despite the fact that damage estimates are often used inappropriately, they are currently provided without sufficiently clear explanations of appropriate and inappropriate uses of the estimates and the inferences that should and should not be made from them.

With the goal of addressing these issues, this report provides a full analysis of the loss calculations, including identifying areas of inconsistency and areas for improvement. It also includes a review of the economics and disaster literature and the methodologies that are currently used in academia, business, and government. Further, the NOAA estimates are reviewed for internal consistency both as stand-alone estimates as well as in the context of the work of other economic impact estimates.

Additionally, the researchers have identified many sources of data that could be useful in future estimation, as well as key studies of estimated multipliers and data estimates that aide in robust estimation. This report summarizes these findings and identifies areas for further analysis. The report should serve as a guide to the process of economic impact estimation used by the NOAA groups, other government and industry estimates, and relevant databases that could be useful in future analysis.

This report is divided into three large sections: (1) Data & Methodologies Overview, (2) Relevant Federal Policy and Guidelines, and (3) General Findings, Analysis and Conclusions.

1. **Data & Methodologies Overview:** The first section of the report focuses on current efforts by NOAA, government, and industry to estimate the economic impacts of weather- and climate-related disasters. This first analysis is divided further into four parts: (a) a comprehensive review of these estimates within NOAA; (b) relevant industry sources of data and estimates used both by NOAA and others; (c) a literature review; and (d) a discussion of additional data sources that could be useful in cataloguing future estimates. This first section of the report is concluded with brief discussions of several potentially useful datasets and online tools. These discussions are focused on resources that are not currently in use in determining the overall economic costs of these disasters but that might provide useful information in future estimates.

2. **Relevant Federal Policy and Guidelines:** The second section of the report provides a brief overview of the current statutory requirements on NOAA agencies regarding performing economic impact analysis, as well as relevant guidance and mandates that apply to the three primary estimators.

3. **General Findings, Analysis and Relevant Conclusions:** The third section of the report focuses on the consistency of NOAA economic impact estimates. This section first examines the consistency of the three primary estimators with respect to each other, thoroughly discussing where the three agencies differ in methodology, scope, and consistency. There is then analysis of the NOAA estimates with regard to other government and industry estimates. This section is concluded with the general findings of the report.

This report is one of three documents produced under the task order. A report on specific recommendations to aide calculation of specific 2012 disaster impact costs was produced in January, 2013. A third report on recommendations for future actions by NOAA will be produced in May, 2013.

I. Economic Impacts of Disaster – Data & Methodologies Overview

This data and methodologies overview is divided further into four parts: (a) a comprehensive review of these estimates within NOAA; (b) relevant industry sources of data and estimates used both by NOAA and others; (c) a literature review; and (d) a discussion of additional data sources that could be useful in cataloguing future estimates.

In the comprehensive review of the estimates within NOAA, the research team thoroughly reviewed the procedures used by the three main economic impact estimators within NOAA: the Billion Dollar Weather/Climate Disasters (BDWCD) Database, the National Hurricane Center (NHC), and the National Weather Service's (NWS) Weather Forecasting Offices (WFO). The research team also examined the economic impact analyses on fisheries by the National Marine and Fisheries Service (NMFS), though these estimates are restricted to the direct impact on fisheries and coastal fishing industries. In reviewing each of these organizations, the team structured its research approach to identify six key areas of analysis for each data source that was identified. With each data set, the researchers identified the **source** and type of data that was used in estimation (including the characteristics of the data collected), the **methodology** used in estimation and/or collection, the **purpose** for which the estimate/database was produced, the **application** for the estimate or database (i.e., public use, proprietary modeling, etc), the **context** under which the estimate was produced or the data were collected, and the historical **consistency** of the estimates as well as any concerns about data quality.

The research team also provided in-depth reviews of both the data sources and other government as well as industry estimates of weather- and climate-related disasters. As part of this effort, the team evaluated the primary sources of data used by NOAA in their estimation efforts. Additionally, the research team provided further information concerning other government and industry estimates surrounding weather- and climate-related data; these included some sources that are occasionally used in some NOAA estimates, as well as data and cost estimates that NOAA does not regularly incorporate into their process. In addition, the team provides findings from research on several relevant economic, energy, and agriculture models that, while not designed specifically to analyze weather- and climate-related disasters, are flexible enough to provide useful information on the economic disruptions caused by weather- and climate-related disasters.

Furthermore, the research team also conducted an extensive literature review on the data and methods currently used in estimating economic impacts of these disasters; the literature review focused on the studies and techniques that were directly applicable to the loss estimation efforts, with particular attention paid to economic impact analyses.

A. NOAA Data & Methodologies for Estimating Economic Impacts

There are three primary efforts within NOAA that produce estimates of economic impact of severe climate- and weather-related disasters. At the National Climactic Data Center (NCDC), the examination of these events is primarily done as a part of the **Billion Dollar Weather/Climate Disasters (BDWCD) project**[1]. The National Weather Service (NWS) produces estimates of weather-related damages at its **National Hurricane Center (NHC)** and **Weather Forecast Offices (WFO).** A fourth effort, the **National Marine Fisheries Service (NMFS)** produces economic impact analyses for fisheries, commercial, and recreational fishing industries in areas declared a federal fisheries disaster. This section delves into the data and methodologies that these three offices use in the production of cost- and impact-analyses.

1. Billion Dollar Weather- and Climate Disasters (BDWCD)

The BDWCD is a NOAA project designed to monitor and catalogue high-impact events that have occurred in the United States. The intent of the estimates is to provide a historically descriptive record of high-impact weather- and climate- disasters. Traditionally, these estimates only applied to disasters that inflicted $1 billion (B) in nominal damage; however, the database is now being updated to include all disasters that inflicted direct losses of $1B in real 2012 dollars (i.e., accounts for inflation according to the 2012 Consumer Price Index[2]). Due to the different types of disasters, affected regions, and timelines of the disruptions that the events cause, a wide variety of data sources and methodologies have been employed to properly assess each case. However, each estimate generally draws from a similar pool of sources including local, state, and federal emergency agencies, insurance companies, and other NOAA resources (i.e., NCDC statistics, NWS, NHC, WFO, Office of Ocean Resources Conservation and Assessment, regional climate centers, etc). Additional sources are also identified through media reports and event-specific research or criteria. Generally, the largest losses tend to occur with hurricanes, though the database also includes events such as floods, heat waves, droughts, localized storms, wildfires, freezing episodes, and winter storms.

Broadly, the criterion for inclusion of an event in the BDWCD is that $1B of **direct losses** be inflicted. The definition of direct losses is based on actual losses sustained to physical property. Indirect losses are based on the counter-factual analysis of non-property losses that would not have occurred had the weather or climate event not happened.[3] Thus, in addition to cleanup costs and replacement of physical assets, the analysis also examines the estimated losses of economic activity as a result of suspended commerce or the value that is no longer generated from impaired or

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[1] These estimates can be viewed at http://www.ncdc.noaa.gov/billions/.
[2] This adjustment from nominal to real has led to an additional nineteen events being added to the database.
[3] Note that this distinction is different from the insured/uninsured estimates that are discussed at length later in this section. Generally, both insured and uninsured losses are direct losses.

destroyed physical capital. Indirect costs associated with these disruptions are not included; issues such as interest costs of rebuilding infrastructure using debt-financing, crowding out of other investment from that debt, and other long-lasting disruptions (e.g. time-value of commuter disruptions, loss of local tax revenue from reduced economic activity, reduced tourism or other seasonal activities) are not included.

Finally, while the NCDC tabulates number of deaths resulting from a disaster, economic impacts from those deaths and other health issues caused by the disaster[4] are not included. While these losses are tragic, applying a dollar figure to them is usually very subjective and can be problematic in consistent recording; the BDWCD acknowledges these losses but declines to attempt quantifying their cost in dollar terms.

Data

The BDWCD routinely uses several datasets in calculating economic impacts. Many of the primary data sources that the BDWCD uses in estimation come from insurance estimates. When measuring direct losses, aggregate insurance claims following a disaster helps to identify data on the size and extent of the damage suffered at local levels. **Insured loss** calculations generally come from the following organizations:[5]

- Insurance Services Office Property Claims Services* (ISO/PCS)
- Federal Emergency Management Agency National Flood Insurance Program* (FEMA/NFIP)
- Presidential Disaster Declaration assistance (PDD)
- United States Department of Agriculture National Agricultural Statistics Service* (USDA/NASS)
- United States Department of Agriculture Risk Management Agency* (USDA/RMA)

In order to verify or calibrate the insured loss estimates for accuracy and robustness, NOAA compares the results from these data sets with other estimates, such as those from reinsurers (primarily Munich Re*) and insurance catastrophe modelers (EQECAT*, AIR Worldwide*, RMS*). Note that these compared estimates almost exclusively cover only *insured* losses. As a result, there are provisions to exclude deductibles on plans as well as ignoring any lost value that exceeds a cap on the damages. Thus, the final published insured losses estimates are missing damage estimates from three categories: deductibles (initial outlays by the insured before payment), overages (damages over caps on the amount of coverage), and uncovered (damage to property that either lacks a policy or is excluded from a policy). The BDWCD estimates are adjusted to reflect these discrepancies.

For the **uninsured losses**, NCDC contacts several other organizations to provide data used to supplement estimations. In all cases, state and local agencies are contacted for more information

[4] For example, hospital admittances for asthma attacks, heart attacks, and strokes increase during heat waves.
[5] An "*" is used to denote a dataset that is discussed in detail elsewhere in this document.

and data concerning the effects of the disaster. Additionally, in the cases of wildfires, the National Interagency Fire Center (NIFC) is contacted, and the U.S. Army Corp of Engineers (USACE) is contacted in cases of flooding. After incorporating this data, the non-insured losses are modeled using multipliers that assume the distribution of non-insured loss is roughly in line with similar historical disasters.

While the BDWCD uses insurance as its main cost estimator, the type of losses estimated will depend on the type of disasters that occur. As a result, the BDWCD also directly consults with the agencies involved in the disaster response or the tabulation of data associated with the disaster. Table 1 below outlines the sources of information NOAA uses based on the disaster type. This information is from the NCDC documentation from the data workshops mentioned in the introduction.

Table 1 – Data sources used by hazard type. Source: Primer on BDWCD Methodology

Disaster Types		Hurricanes/ Tropical Storms	Severe Local Storms	Winter Storms	Crop Freeze	Wildfire	Drought / Heat Wave	Flooding
Primary data used in assessments	**ISO/PCS**	x	x	x		x		
	FEMA (state/local disaster assistance)	x	x	x	x	x		x
	FEMA (NFIP)							x
	USDA	x	x	x	x	x	x	x
Supplemental data used in assessments	**NIFC**					x		
	USACE							x
	State Agencies	x	x	x	x	x	x	x

Each of these sources provide different types of data, with different variables, lag lengths in availability, granularity of geographical scope, and historical length. Table 2, on the following page also reproduced from the NCDC documentation, outlines some of the characteristics of the data produced by the organizations highlighted in Table 1.

The BDWCD team may also employ other data on an ad hoc basis as necessary.

Table 2 – Summary of data sources used in BDWCD estimates. Source: Primer on BDWCD Methodology

	ISO/PCS	FEMA (state/local disaster assistance)	FEMA (NFIP)	USDA	Army Corps	NIFC	State Agencies
Data	Provided: Residential Commercial property: Business interruption; Vehicles (insured w/ comprehensive cover); Boats; Inland marine Not provided: Agriculture, Flooding, Aviation, Ocean Marine, Loss above limits	Provided: Government disaster assistance, debris removal, financial aid Public Assistance, Housing Assistance, Individual Assistance, Small Business loan Assistance	Provided: Insured flood loss for residential and commercial properties	Provided: Insured multi-peril crop/ livestock insurance payouts, crop progress and quality reports market value of crop production	Provided: Annual flood event summaries and major flood event reports that detail levee damage, other damages	Provided: Wildfire losses to structures; commercial timber; wildfire suppression costs, deaths; acreage burned	Provided: Total estimated crop losses; Surveyed % of properties with multi-peril and flood insurance
Temporal Resolution	1949- present	1964-present 1989-present	1968-present	1948-present 1989-present	1983-present	1960-present	Regarding a specific disaster event
Spatial Resolution	State-level	State-level County-level	State-level	State-level County-level	River-basin, State-level	Region, State, county (depending on data product)	State-level
Update Lag Time	Weekly; Months for final insured loss estimate	Weeks to months	Several months	Weekly, monthly, Annual (depending on data product)	Annual report	Days to weeks	Several months
Data Sources	Surveys of insurers, market share analysis, air/ground damage surveys, interviews, etc.	State and local disaster needs / grants	Flood insurance payouts	Farmer and field surveys; data from partner insurance companies	Floodplain, household and business surveys	Fields reporting, state and local fire authorities	Local and State farm reporting to USDA; city / state damage assessment
Changes in Recording Threshold	\$1 M (1949-1981) \$5 M (Jan. 1982-1997) \$20 M (Jan. 1997-present)	County/per capita indicators adjusted each fiscal year to reflect changes in CPI. Assists in FEMA's evaluation of disaster impact at county-scale (e.g., \$2.83, \$2.94)	Single-family dwelling limits: 1977-1994 Structure\$150k Content: \$50k. 1994-2009 Structure\$250k Content: \$100k. Policy revisions were enacted in 1973, 1977, 1994, and 2004	Insurance policy changes and additions are complex. Many programs (SURE, NAP, LIP) offer assistance from 50% -85%. Major crop insurance policy revision in 1994		Stats after 1983 were compiled by states and agencies. Stats before 1983 undergoing reanalysis	

Table 3 – Method for developing billion-dollar disaster event loss calculations by disaster type and data sources using a factor approach to convert from insured to total losses

- **Severe Storm or Winter Storm when <$1 Billion PCS total for each State**
  $Loss = PCS \times 1.25 + FEMA_{PDD} \times 0.25 \times D^{a} + NFIP \times 4.00^{c} + SR^{d}/USDA \times 2.00 + \ Other$
- **Severe Storm or Winter Storm when >$1 Billion PCS total for each State**
  $Loss = PCS \times 1.42 + FEMA_{PDD} \times 0.42^{a} + NFIP \times 4.00^{c} + SR^{d}/USDA \times 2.00 + \ Other$
- **Tropical Cyclone**[b]
  $Loss = PCS \times 2.00 + FEMA_{PDD} \times 1.00^{a} + NFIP \times 1.00^{c} + SR^{d}/USDA \times 2.00 + \ Other$
- **Non-Tropical Flooding**
  $Loss = FEMA_{PDD} \times 1.00 + NFIP \times 4.00^{c} + SR^{d}/USDA \times 2.00 + \ Other$
- **Drought/Heat Waves**
  $Loss = FEMA_{PDD} \times 1.00 + SR^{d}/USDA \times 2.00 + \ Other$
- **Wildfire**
  $Loss = PCS \times 2.00 + FEMA_{PDD} \times 1.00^{a} + SR^{d}/USDA \times 2.00 + \ Other$
- **Freezing Episode**
  $Loss = FEMA_{PDD} \times 1.00 + NFIP \times 4.00^{c} + SR^{d}/USDA \times 2.00 + \ Other$

a Only incorporate the higher factor of PCS or FEMA_PDD in addition to original to represent underinsured loss. As such, if the PCS number is large than the FEMA PDD number, D = 0; if the FEMA PDD value is greater than the PCS value, D = 1.
b For hurricane wind/water damage, state reports may inform how the PCS to NFIP insurance ratio is adjusted
c NFIP factor adjusted based on available data (i.e., NFIP participation rates, state or river-basin assessments, etc.)
d State reports may supersede USDA crop loss data if it produces a more complete total agriculture loss estimate

Source: Smith, A. B., Katz, R. W. "US Billion-dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy, and Biases." Nat Hazards (2013): published online.

Methods

NCDC's methodology for producing loss estimates is built on a straightforward process that incorporates disaster-specific factors into a formula to estimate non-insured direct losses based on observed insured losses. Specifically, the loss information from the insurance numbers are increased by a pre-determined factor of coverage based on the disaster type, then calibrated based on the regional coverage of insurance (where coverage rates are available). These event loss calculations are based on historical averages associated with the disaster type, and a specific multiplier is used based on the disaster type (see Table 3). The following data sources are used:

- Insurance Services Office Property and Claims Service (PCS)
- FEMA Presidential Disaster Declaration ($FEMA_{PDD}$)
- FEMA National Flood Insurance Program (NFIP)
- State Reports on disaster costs (SR)
- USDA National Agricultural Statistics Service (NASS)
- USDA Risk Management Agency (RMA)
- Additional relevant information (Other)

These equations can be altered over time, as further revisions to data and additional reports or data sources are introduced to improve the estimates as they become available. In fact, the revision to data inputs is fairly common, and the more robust data creates more accurate estimates.

The BDWCD also incorporates different uninsured loss multipliers based on the disaster type. For example, in the case of flooding, the BDWCD uses different NFIP uninsured-loss multipliers for different weather/climate disasters. These can be seen in the following lines, where "Z" is an indicator based on the insurance penetration rate in the afflicted areas:

- Severe Storm or Winter Storm: (Z x NFIP) x 4.0
- Hurricane Loss: (Z x NFIP) x 1.0
- Non-tropical flooding: (Z x NFIP) x 4.0
- Wildfire: (Z x NFIP) x 1.0

In inland regions of the U.S. where flooding is infrequent, many structures do not have flood insurance coverage. As such, when these areas are hit with a disaster, the NFIP uninsured-loss multiplier value is likely to be particularly high; with a low percent of NFIP penetration, most losses must be paid for out of pocket. For example, in the 1990's, there were two floods in North Dakota where very few communities in the area had flood insurance. In areas with such low flood risk, the NFIP multiplier may need to be even higher than 4.0 to accurately capture total flood losses. Conversely, the NFIP uninsured-loss multiplier tends to be lower in high-risk hurricane regions; since the percentage of people with flood insurance is higher, the NFIP multiplier doesn't need to be as high. For example, the state with the highest participation rate is Florida, where 40% of all NFIP's policies are held. However, even in Florida, there is still a large portion of the population who have not purchased policies. Further, information on the relative risk of those with insurance is lacking; the data do not identify high-risk structures (e.g. in low-elevation areas or near water sources that frequently flood), so communities with similar coverage rates may have drastically different risk profiles for uninsured loss if few of the high-risk properties are covered. As such, knowing the insurance penetration rate of a community may not be sufficient to calculate the appropriate uninsured-loss multiplier.

Ultimately, the focus of the disaster losses are primarily based on data that is measurable, collected using a consistent methodology, and routinely available after every disaster. As such, these focus primarily on property damage and foregone economic activity. Issues such as loss of life, direct decreases in consumer confidence, network effects associated with a disruption, and changes to the path of potential output are not explicitly included in the estimates; while these are very real costs that can be somewhat or totally attributed to these events, these valuations can be difficult to identify precisely and there is some debate over the proper valuation of each. However, these effects do have an impact on the more concrete numbers involved in the analysis, and thus are implicitly incorporated into the models based on historical multipliers and growth patterns reflected in the counter-factual analysis.

Purpose

The purpose of the BDWCD estimates is to provide a robust analysis of the costs of large weather- and climate-related disasters over time. Understanding the losses associated with the disasters can provide a better understanding of how damage is inflicted to a region, as well as what can be expected of future events; thus, the estimates can aide risk management and investment decisions.

Application

The application of BDWCD data is fairly widespread; as such, a full cataloguing of who is using it and for what purpose is difficult. The primary application is for the data to be provided to the general public, which it is, free of charge. This data has also provided a valuable resource to emergency planning groups, including both in the long-run (for budgetary planning and infrastructure investments) as well as in the short-term (for areas facing imminent disasters, understanding the likely costs and damage can help marshal the appropriate resources for the response). For example, the ultimate cost of these events is determined in the cost-benefit calculations done by the U.S. Army Corp of Engineers (USACE) in the Priorities for Infrastructure Improvements, which are presented to congress annually. Similarly, the Subcommittee on Disaster Reduction has cited several of the BDWCD estimates and aggregate costs in its reports. It is likely that insurance and reinsurance agencies throughout the U.S. use the BDWCD data as a guide to predict potential exposure to natural disasters, though the agencies that we spoke with declined to comment on whether they used the data or not.

Context

The context of these estimates is always done in regards to large-scale disasters that create significant damage to property, infrastructure, output (such as crops), and economic activity. The NCDC has a statutory mission to describe and archive anomalies of weather and climate, and no requirement to forecast weather and climate events. As such, these estimates are set to determine the historic overall costs of the events to the economy as a whole, without needing to predict likely future costs or adjustments based on the intensity or size of the event. Thus, these estimates focus on a broad set of potential losses that can be measured, both public and private, in order to provide information for policy makers and the public at large; they are meant to be a backwards looking, recording only actual damages. These results are calculated based on the best available data at the time, including revisions where appropriate.

Consistency

The BDWCD has been fairly consistent, with broadly the same approach taken to estimating the nominal costs of large disasters since 1980. Further, the BDWCD has begun evaluating historical events using real costs, based on the value of 2012 dollars, to include events that would have cost $1B in damages today. This has expanded the database by 19 events, and the analysis of this report has identified several candidate events[6] that may also be included.

One potential concern with regards to consistency is that the different types of events in this database exhibit different patterns of impact. While some of the disasters and their corresponding impacts are clearly defined and detectable (i.e., hurricanes, flood, etc.), events such as droughts and crop damage have potentially harder-to-quantify issues associated with them as they are incurred over a longer period of time (temporally diffuse), over a larger portion of land (spatially diffuse), and the damage is not clearly demarcated from other potentially confounding factors. Specifically, capturing the marginal cost of a drought or heat-wave can be complicated by the duration of the

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[6] These are highlighted in the companion report on 2012 estimates.

event and the region in which it is located, as different regions and durations of disasters provides different opportunities for substitution and mitigation.[7] The timing of a heat wave or drought during the planting season can lead to very different results. For example, a region may have multiple planting options that provide for better alternative outcomes if farmers switch early enough, and the multiplier on state reports/USDA statistics may vary nonlinearly with duration of the drought/heat-wave. Thus, while the overall methodology may appear to be consistent, further examination of how the intensity and duration of a disaster impacts the multiplier may be warranted.

2. National Hurricane Center (NHC)

The NHC tracks the development and formation of cyclones and hurricanes. The organization has several roles, including storm tracking, issuing watches, warnings, and forecasts of the storm's projected path, as well as helping coordinate preparation efforts and supporting response operations. Additionally, the NHC provides information to the public and training for various emergency management organizations throughout the country. Further, NHC catalogues data concerning each new cyclone; this effort includes an estimate of the overall economic costs of the damage inflicted by cyclones, as well as tallies of direct and indirect fatalities. This data effort overlaps with those of the BDWCD in many ways.

Data

The data sources and definitions used by the NHC have varied over time. As a result, the NHC estimates have changed over time as well, depending on which data source and methodology was being used.

There are three main periods of time that distinct data sources were used in constructing the database:

- **1915-1965:** Storm damages and fatalities use data from published research in Genry (1966)
- **1966-1994:** Damage estimates and fatalities were taken from the Monthly Weather Review, a publication of the American Meteorological Society. These estimates tend to be less consistently estimated than desired, often using incomplete or subjective judgments in creating the estimates; calculations were primarily based on information from the American Red Cross, the U.S. Office of Emergency Preparedness, insurance companies, and press reports.

[7] For example, a significant drought that restricts crop production may be devastating to the regional economy, but less so to a national economy that sees increased production and prices given to unaffected crop producers (especially if the planting is in direct response to the drought); thus, local losses may over-reflect national losses in a way that hurricane damage (sudden loss of capital assets, etc.) may not due to fewer axes of substitution.

- **1995- present:** Calculation of damages and fatalities relies on the Insurance Services Office Property Claims Services (ISO/PCS) and the National Flood Insurance Program (NFIP) run by FEMA, which is a consistent methodology and is discussed further in the next section.

For modern estimates, in addition to these sources, the NHC also incorporates internal data as necessary; it thus includes information from the Storm Prediction Center, the Mariner's Weather Log, and previous hurricane and cyclone data from the Hurricane Database (HURDAT).

Methods

The NHC uses a consistent[8] methodology for estimating the economic impacts of storm losses based on the insurance data provided by NFIP and PCS.

- First, the NHC collects insured loss estimates from PCS and doubles them to estimate non-insured property losses to residential, commercial, and automotive property.
- Next, the costs of flooding are modeled based on the estimated insured losses of the NFIP, and then scaled based on the relative amount of flood coverage of the affected area (this is done on a case-by-case basis, as there is extensive heterogeneity in the amount of flood coverage in different areas).

The NHC has also recently updated its database of historical events. Like most databases, the NHC has both the original value of damage that a storm inflicts as well as the inflation-adjusted cost of that damage. Additionally, following the work of Pielke et al (2008), the NHC has re-estimated previous damage estimates to determine monetary loss that historical hurricanes *could* inflict on the current property-at-risk in the same location. Thus, each hurricane event in the NHC database now has three associated estimates: (1) the nominal cost of the damage, (2) the real (inflation-adjusted) cost of the damage and (3) the real projected cost of the damage if the current population distributions in place when the storm hit (including a wealth adjustment).

Given the distinct data sources used over time outlined in the previous section, the NHC has also had inconsistency on the definition and measurement of specific factors.

- **Definition of Direct hit and storms**: varies between 1931 and 1989, being inconsistent with those both before and after.
- **Measure of strength of the cyclones** differs for the 1931-1989 time-period. Before and after this period of time, wind-speed was used as the only determinant. However, during this period of time, several criteria were used to evaluate storm strength.
- **Older cyclones** were based on estimates by Gentry (1966), which uses costs inflation-adjusted using 1957-1959 as the base years. After 1966, the cost estimates were based on numbers from the Monthly Weather Review, as described in the data section. However, the

[8] NHC methodology is consistent within each of its three iterations of loss estimations. However, across all three iterations, both the methodology and the definition of a direct loss have changed and thus do not align consistently.

inclusion and updating of the NFIP data in recent years has significantly altered several of the estimated costs of several storms

Finally, the NHC has compared several prior estimates to PCS costs estimates of insured loss and has found the need to readjust some historical estimates to be more in line with PCS findings.

Note that the NHC also calculates the number of lives lost due to the storm for both direct and indirect measures. This information is determined through official reports and confirmed deaths based on state and local information, following the procedure laid out by the National Weather Service Instructions manual on Storm Data Preparation. Note that the official definitions of direct and indirect fatalities and injuries have changed over time; the most recent definitions have been applied to the historical events, resulting in revisions to the number of deaths caused by cyclones prior to 2006. Also note that the reports for each storm come out generally within three-months of the storm, though larger and more costly events have taken slightly longer (for example, Sandy took 106 days, while Katrina took 112 days); these larger events are often revised, including years after the event, in order to ensure more accuracy as data are not always available in such a short time-period.

Purpose

The NHC produces these estimates to be part of HURDAT, as well as estimates made publically available. These data estimates are meant to provide the public with an idea of the relative cost associated with these storms. Additionally, the NHC recently updated its historical data to include the Pielke et al methodology which tries to project the expected current cost of historical storms. These modified estimates could aide in preparations and more clearly define risks if a similar storm were to strike.

Application

The applications of the NHC estimates are used as part of creating public information on the relative costs of storms on the U.S. economy. These estimates are often used by state and local agencies to determine the relative destructiveness of past storms, and the likely damage that a future storm might produce. These estimates can be used both publically and by private institutions for loss planning, infrastructure and business investment planning, etc.

Context

These estimates are produced under the general directives of the National Weather Service (NWS). The data are meant to serve in the context of violent cyclone damage. The numerical economic impacts are estimates meant to be comparable to other potential storms, both in real-dollar comparisons, as well as in the property-at-risk comparisons that the NHC has started producing using the methodology of Pielke et al. These estimates attempt to normalize economic impacts over time and are provided for policy makers and the public at large. As such, the estimates and numerical adjustments are meant to be both historically descriptive (how much damage the storm inflicted) and useful for forecasting and comparing future damage from similar storms. Thus, the primary focus of the data collection is the meteorological implications of the event, and the economic costs of the disaster augmenting the analysis of the storm strength and geographical effect. These results are calculated based on the best available data at the time, including revisions where appropriate.

Consistency

As described in the Data and Methods sections, the NHC methodology has gone through several different iterations resulting from the combination of changes in data sources of cost estimates and definitions of key factors. Specifically, the NHC database is constructed using three different primary data sources (pre-1965, 1965-1994, and 1994-present), and these different sources have had three different definition of a direct hit (pre 1931, 1931-1989, and 1989-present), making it difficult have consistency across these time periods. The data and methodology since 1994, however, has been much more consistent. Further, NHC has made strides to correct some of these inconsistencies in the historical data prior to 1994, using both the NFIP and PCS data to substantially revise estimations to reflect current methods.

3. National Weather Service (NWS) - Weather Forecast Office (WFO)

The 124 Weather Forecast Offices in the U.S. are responsible for producing local weather forecasts, as well as local weather-related watches and warnings. Each office is located within its coverage region, usually covering between 20 and 50 U.S. counties, depending on size, population, and geography. Each of these offices focuses on local weather events, including predictions of storm activity and in many cases the local costs of damage inflicted by severe storms. Specifically, the WFOs are tasked by the NWS to be the primary compiler of flood damage information for NOAA; however, they are also asked to compile economic costs of any storm they cover, when possible. The processes by which these estimates are created vary greatly from office to office, storm to storm, and even across different office personnel and county-specific data sources within the same field office; as such, these cost estimates are more likely to be inconsistent than the other NOAA estimates.

Data

While each WFO has slightly different resources available to them based on the size of the district and the state and local resources within, each primarily relies on data obtained from local emergency managers, the U.S. Geological Survey, the U.S. Army Corp of Engineers, power utility companies, and relevant media reports. When these sources are unable to provide an exact number, the WFOs generate estimates according to guidelines on storm damage as set out by the NWS. Generally, the smaller events (those relying on a single employee to assess, especially those without an on-site presence) are much more likely than larger events (with multiple staff making several on-site assessments) to be estimated based on a 2007 handbook[9] that the NWS provided to each WFO as an appendix to the Storm Data Directive 10-1605 cost-estimating directive. The

[9] Available at http://www.nws.noaa.gov/directives/sym/pd01016005curr.pdf

appendix is basic and rarely updated with information of limited use and accuracy. Data are cross-referenced by other WFOs for larger events, or storms that cross regions, and are aggregated nationally at the NWS. Costs from previous years are inflation-adjusted using the McGraw Hill Construction Cost Index.[10] The data, while generally reported by federal, state, or county-level officials, are also quality-checked and calibrated to the extent that is reasonable.

The data and presentation of the data on the NWS website, explicitly notes that the flood damage data is not intended to include damage from a cyclone's storm surge, but rather only fresh-water flooding from rainfall.[11] As such, the most consistently reported damage type is fresh-water flooding. Further, as discussed in the next section, this mandate creates potential data issues with flood losses that other estimators do not have to deal with.

Methods

Since the WFOs are responsible for cataloguing all weather-related impacts of storms, large or small, the amount of resources devoted to each event is dependent on both the size of the impact and the number of events that are reported. An example of an event recorded by a WFO agent could be as small as a single branch being knocked off of a tree during a winds storm (if the owners decided to call the event into either the WFO or other authorities). These smaller situations are generally handled with a simple phone call or log entry. However, as the amount of damage caused by each weather event increases, more time, effort, and personnel are devoted to accurately cataloguing the data and estimating the overall economic impacts of the damage. As such, the procedure for cost estimation varies based on the size of the damage.

For larger events, where multiple staff members (or even multiple WFOs) are making multiple on-site inspections, the primary method of data collection and cost estimation is based almost exclusively on the interviews conducted with officials at various levels of government and homeowner or business owners directly affected by the storm itself.

With some smaller events, where a single staff member may be estimating costs based on a single phone interview or damage report, estimators do not contact the local authorities unless there is an injury or other issue requiring local aide; additionally, the afflicted site may not be visited by the researcher, relying more on written and oral reports from those affected, with cost estimates derived from the 2007 NWS guidance handbook for types of damage.

When officials are not able to provide enough information to create a robust estimate, the WFO staff may make an approximation of the ultimate costs based on the information set available. The NWS notes that these estimates have the potential for subjective error based on the relative lack of

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[10] Note that many of the other estimates in this report use different inflation numbers, usually the Consumer Price Index – U or the chained GDP deflator. The choice of this index is most likely due to the nature of the damage storms tend to inflict, and thus the costs associated with fixing damage associated with these storms, though the research team was unable to locate an official explanation for the choice of price index.

[11] Informal interviews with several of the staff at WFOs around the Great Lakes (including Buffalo, Chicago, Duluth, and Cleveland) have suggested that there is not a similar attempt to disaggregate lake- or seiche-related flooding from inland flooding, though this is partially due to the paucity of such events (especially with such events causing large amounts of damage).

information. The NWS primary mission is to provide weather information and services to prevent property loss and fatalities; the NWS indicates that standardizing these estimates is subordinate to this mission.[12] Specifically, the focus of any event study is accurate collection of meteorological and other storm-related data with economic impacts a secondary concern.

Purpose

The purpose of compiling the economic impact data is to create a centralized database of damage information that is made available to the public as part of the NWS mission; the NWS has a statutory requirement to estimate the costs of fresh-water flooding and thus makes a concerted effort to generate an estimate in these situations. These data estimates are meant to provide the public with an idea of the relative cost associated with these events. This information conveys the potential costs of flooding and other storm-related costs, allowing for proper preparation and loss provisions, as well as allowing for better cost-benefit analyses related to flood-prevention infrastructure and other public investments.

Application

The flood damage estimates are used as a part of creating public information on the relative costs of localized and large-scale flooding on the U.S. economy. These estimates can be used by state and local agencies to determine the relative destructiveness of floods in similar geographic locales, and the likely damage that a future storm might produce. These estimates can be used both publically and by private institutions for loss planning, infrastructure and business investment planning, etc. For example, the U.S. Army Corp of Engineers uses these data as part of the annual assessments of required public infrastructure investment that is presented to congress.

Context

These estimates are produced under the general directives of the NWS. The data are meant to serve in the context of flood damage associated with non-cyclone storm surge flooding. The numerical economic impacts are meant to be comparable to other potential floods that may occur in the future. These estimates are done in the auspice of providing a public service for policy makers and the public at large and are based on the best available data, though the diffusion of potential evaluators at the various field offices also introduces the potential for inconsistent methodologies and estimates.

Consistency

The consistency of the WFO estimates is of particular concern, especially when the damages inflicted are relatively small. The NWS has provided a manual with broad guidance on the value of property loss associated with different types of damage, though the manual is not updated annually nor is it calibrated to identify regional differences between costs and property values. Further, the application of these estimates may differ from office to office and even differ between individual estimators within the same office. Additionally, the reporting requirement that all data be reported to storm data within 60 days of the event can create a level of time-pressure whereby partial or

[12] Both the NWS website and one of the cost estimators whom the research team interviewed took care to emphasize the subordination of these estimates to other data concerns.

incomplete estimates are submitted before full insurance-claim or rebuilding operations are completed. Further, in cases of non-flood related damage, there are often no cost estimates produced due to time and geographic constraints on agents. However, as the size of an event increases, the consistency and rigor applied to the estimates increases as well. Thus, estimates of larger events tend to be more consistently constructed based on similar methodologies used by the NHC and the BDWCD.

Further, as there are 124 different field offices, the procedure for collecting this information (and combining the various estimates into a single cost number) has the potential for variability and inaccuracy across the different regions and different timeframes of events. The staffs' relationship with local emergency managers and other government personnel can vary from county to county within an office's range, and the accuracy and consistency of information provided by those personnel can be difficult to ascertain. As such, storms inflicting similar amounts of damage in different WFO districts may have drastically different profiles and impact estimates in the NWS database due to idiosyncrasies of the offices. These differences are more likely to occur when examining smaller events that had few staff members examining the events.

Also, the economic impact estimates are more consistent as the size of the impact increases. In many instances, particularly smaller and non-flood cases, the estimators may simply report that the costs are unknown. The smaller the event, the less likely it is to carry a cost estimate and the more likely there is higher uncertainty with the number.

4. National Marine Fisheries Service (NMFS)

The National Marine Fisheries Service (NMFS) produces economic and socio-economic impact analysis on disasters that are declared federal fishery disaster areas. These estimates are derived as part of the compliance effort to record and describe the damage caused in a disaster, as well as the relevant background needed to aide decision-makers in their rebuilding efforts. Additionally, these numbers can help direct resources to those most affected as well as guide future preparedness and prevention actions. These estimates will be done for all federal fisheries disaster declarations, including those that are not caused by weather- or climate-related disasters, or other types of disasters such as prolonged bouts of Red Tide algal blooms not covered by other NOAA agencies' estimates

Data

These reports focus on several factors, and incorporate both historical data as well as damage assessments to fisheries and fishing industries. In the process of assessing economic impacts, the overall size of the recreational fishing and seafood industries prior to the disaster, including information on employment, net output (sales), and value added (commercial profits) are identified. These include sub-industries such as commercial harvests, seafood processing and sales, importers of seafood, seafood wholesalers and distributors, aquaculture and retail sales of seafood.

These baseline numbers are usually constructed using data from the previous 12-month period. The data are constructed using Census data, data internally generated by NMFS on commercial fisheries, Marine Recreational Information Program (MRIP) site survey data on recreational fishing activities, as well as several other state and local datasets, as available. These data are synthesized into several key indicators for analysis, broadly covering three categories:

- "Social Vulnerability" – Community characteristics, including diversity, poverty rates, population composition, and personal disruption measures.
- "Gentrification Pressure" – Demographic and population information, including age of community residents; land conversion pressure, and marine and waterfront access and permitting
- "Fishing Dependence" – Relative importance of commercial and recreational fishing to the economy, including the size of the industry, the size of the population directly dependent on fishing for livelihood, and those indirectly dependent on fishing

These indicators are used by NMFS to identify communities throughout the US that are particularly dependent on fishing and fisheries, as well as those communities that are susceptible to disruption. NMFS use these three criteria to annually (or semiannually) update their list of communities most heavily dependent on commercial and recreational fishing. When a disaster is declared, these community lists are then used to determine the most efficient places to deploy resources to assess the damage. To comply with the quick timeline of producing the economic impact analysis reports, the estimators, often in conjunction with state and local authorities, will focus their research in areas that fit both of the two criteria: communities highly-dependent on fisheries and communities most impacted by the disaster. This allows the researchers to conduct economic impact interviews and collect field data from a representative sample of those areas where most of the damage occurred, and to have more robust data inputs into their estimates.

The reports produce several standardized values for each sub-industry affected in each state. These values include the amount of direct structural damage and loss incurred, product damage and losses incurred, insurance rates of affected structures and business losses, insurance coverage rates and policy sizes, commercial operation rates over time (i.e. how many shops or vessels are back in operation one week after the event, two weeks, etc), and employment figures over time.

Methods

The primary method of data collection is to conduct interviews of those individuals who participate in the recreational or commercial fishing industries in the afflicted areas. The interviewers generally prefer to use in-person interviews, as well as follow-up contact, to ensure a large and representative sample of those affected. These in-person interviews allow for direct assessments of the impacts in certain communities, as well as how those impacts differ across communities. Additionally, the interviewers can make visual assessments of the affected communities and document the damage photographically. The interviewers do not follow a formal or set script, but rather try to get as much information on loss and damages as possible from the interviewees based on a more conversational tone that is more appropriate to deal with individuals suffering from a significant loss related to their livelihood.

The information from these interviews is then used to estimate the disruption to different elements of the recreational and commercial fishing industries. The estimators determine the number of affected individuals and businesses, aggregate the costs incurred by category (e.g. aquaculture, bait & tackle shops, for-hire recreational tours, etc.), then extrapolate those costs to each sub-industry. This extrapolation uses the best available information on the size of the sample relative to the sub-industry (from Census and NMFS data), the representativeness of those interviews, and the consistency of the damage incurred in a particular community. These techniques help estimators determine the average damage incurred by those sampled, which is then multiplied by the total number of industry participants. For an example of the number of interviews and the resources involved in this estimation, a table from the Hurricane Sandy report is reproduced on the next page.

The estimators also distinguish between uninsured and insured losses. These calculations are done by taking the total estimated direct costs of the event, as determined by the interviews and extrapolation described in the previous paragraph, and subtracting off insurance coverage information. The information on insurance coverage comes from the interviews of those affected, information from local authorities, and other sources that are available to NMFS.

Purpose

These estimates are produced for decision-makers in affected federal fisheries disaster areas to assess damage, plan recovery and rebuilding efforts, as well as determine mitigation measures for possible future disasters. These estimates are required to be produced within 2 months of the event and are based on the best available information within this timeframe mandated by law; specifically, the report's purpose is to provide the governors of any affected state with a preliminary impact analysis on the communities affected by the disaster, and the implications for both commercial and recreational fishing and fisheries industries. Additionally, the reports also inform on the environmental impact for habitats and protected species in the affected regions.

Application

Numbers generated from these reports have been included in several requests for emergency aid from the federal government, and also have been cited in capital project plans and recovery bills. Additionally, these numbers can be used in market analysis of fishing industries as well as tourism and recreational industry studies.

Context

The context of these estimates is always done in regards to federal fisheries disaster declarations. The scope of the reports is always focused on the fishing and fisheries industries, with particular focus on supporting the goals of the Magnuson-Stevens Fishery Conservation and Management Act. Specifically, these efforts are part of the goal to conserve and protect fishery resources, sustainability of fishing and fishery industries over time, fully utilizing coastal and fishery-based assets of coastal communities, and protecting coastal ecologies and habitats.

Table 4 – A reproduction of a sources and interviews table from the NMFS report on Hurricane Sandy:

Firm Type	Number of Interviews Conducted	Population Frame	Source of Population Frame
New Jersey			
Aquaculture	9	12	Northeast Regional Office, supplemented by New Jersey Division of Fish & Wildlife, Bureau of Marine Fisheries
Bait & Tackle (B&T)	75	171	194 from New Jersey Department of Environmental Protection (NJ DEP) (some of which are included in Marina & Other category below); additional contacts provided by key informants
For-Hire	28	956 Charter; 42 Headboats	NMFS MRIP 2012 Wave 6 For Hire Directory
Seafood Dealers	41	116	NJ DEP; NMFS Northeast Regional Office
Harvesters	51	505	NMFS Federal Fishing Permit File, Northeast Regional Office, 2012. Note frame excludes state-licensed vessels as well as fishing vessels with Atlantic Highly Migratory Species permits.
Marinas	34		None. Firms identified via field work.
Marina & Other	40		None. Firms identified via field work.
Other	14		None. Firms identified via field work.
Seafood Processors	4	7 federal	NMFS Office of Science
New York			
Bait & Tackle	45	139	New York Fishing Tackle Trade Association
For-Hire	63	543 Charter; 37 Headboats	NMFS MRIP 2012 Wave 6 For Hire Directory
Dealer	59	453	New York Department of Environmental Conservation; NMFS Northeast Regional Office
Harvester	32	313	NMFS Federal Fishing Permit File, Northeast Regional Office, 2012. Note frame excludes state-licensed vessels as well as fishing vessels with Atlantic Highly Migratory Species permits.
Marina	63		None. Firms identified via field work.
Other	30		None. Firms identified via field work.
Processor	4	11 Federal	NMFS Office of Science & Technology Federal Processor Directory

Consistency

The consistency of the estimates, which are primarily based on interviews, is an area of particular concern. While robust data exist on the size and structure of commercial and recreational fishing industries in most afflicted areas, the combination of the primary data collection methodology (interviews) and the tight timeframe under which the report must be produced (2 months) can create an undesirable level of variability in the responses. The interviews are conducted under less than ideal circumstances, with individuals who have suffered a significant personal setback and in a time-frame where the full extent of damages may not be fully assessed (in some cases prior to insurance appraisals), and are often dependent on the cost estimates of owners who may not fully capture the true cost of the damages. Additionally, storms or other disasters that do not hit during peak season can make tracking down business owners and individuals difficult if they do not run a year-round operation. Also, disasters that also impair infrastructure or create unsafe environments can further hamper rapid-collection of data. All of these factors can limit the amount of data collected which restricts the size of the sample, or even prevents the construction of a true representative sample. As such, the assumptions implicit in extrapolating losses must be thoroughly considered in such case to prevent bias. However, later revisions to the data are relatively straightforward and can increase the accuracy and consistency of the true direct costs of these disasters.

B. Relevant Alternative Sources of Data & Methodologies for Estimating Economic Impacts

1. Primary data used by NOAA estimates & other economic estimates

This section discusses the sources of data that are regularly used by NOAA organizations in the production of cost estimates. Each of the sources in this section underwent exhaustive review of methodologies for collection, defining, and developing data, including interviews and official correspondence with the organizations. These data sources represent the backbone of most NOAA weather- and climate-related economic loss estimates, and these data are integral to the consistency of current NOAA estimates.

i. ISO PCS

Insurance Services Office Property and Claims Services (PCS), a Verisk Analytics company, compiles and reports estimates of insured property losses resulting from catastrophes.

Data & Methods

The PCS database goes back to 1950 with estimates done at the state level (zip code estimates are done internally solely by insurance modelers), and uses losses reported by primary insurance companies which it then extrapolates to cover all insurance claims. PCS only reports covered losses. Thus, additional losses such as deductibles and uninsured losses are not included in PCS estimates.

To develop the best estimate in the shortest possible time, PCS generally combines two methods: (1) a confidential survey of insurers, agents, adjusters, public officials, and others to gather data on claim volumes and amounts, and (2) an analysis of the data combined with trend factors[13] to determine a loss estimate.

The majority of emphasis is placed on the survey of insurers and other experts. Just days after an event, PCS completes its first survey and releases a preliminary estimate of losses. For large or unusual events, PCS resurveys the affected insurers to assure accuracy and to identify loss components and relevant claim issues. PCS continues the process until its staff is confident of a fully developed estimate, which averages 6-8 months per catastrophe. For each catastrophe, the PCS loss estimate represents anticipated industry-wide insurance payments for property lines of insurance covering:

- fixed property

[13] Although PCS mentions a "trend factor" as part of its insured loss estimation in its methodology, there is not necessarily an actual trend factor used in its calculations. The trend factor is not a relevant element in PCS estimates. For example, PCS does not take into account outside factors such as inflation, population growth, or wealth accumulation when tallying total insured catastrophe loss estimates. Rather, PCS only attempts to gauge the amount of nominal damage to insured property that occurred to existing infrastructure at the time of the event. Thus, the trend factor that they include in estimates is for accuracy of nominal estimates; it is not an attempt to normalize estimates across time or region.

- building contents
- time-element losses
- vehicles
- inland marine (diverse goods and properties)

Using its national network of insurer claim departments, insurance adjusters, emergency managers, insurance agents, meteorologists, and fire and police officials, PCS collects data on insured losses following catastrophes. When collecting data, PCS determines the extent and type of damage, dates of occurrence, and geographic areas affected. Then, PCS assigns serial numbers to track the losses from each catastrophe.

PCS maintains consistency of estimates primarily by using a simple, short, specific questionnaire provided to member insurance agents, followed by substantial follow-up and investigation. For this questionnaire, PCS contacts local insurance companies and agents in the affected areas and asks six specific questions[14] on the overall loss that the insurers expect based on initial incoming claims. This survey is repeated several weeks later in order to allow all claims to come in. PCS initial estimates of total insured losses are thus based on the amount of insured property in the afflicted area, and are dependent on the consistency of the insurers' responses. However, PCS also further investigates outliers whose data appear to be out of line with other respondents, as well as incorporate additional data as they come in. PCS has used very consistent methodology over time, having little changes in estimates and methods. However, the minimum amount of insured damage that they require for an event to enter their database has increased several times (see Context & Consistency below).

PCS covers three main types of claims: personal, commercial, and automobile. The dollar figure that PCS publishes for each storm is the amount insurance companies ultimately pay for those losses. The policies held are either Commercial Multi-Peril (CMP) or Business Owners Policy (BOP). Generally, PCS does not cover flood insurance except in the case of comprehensive automobile insurance. FEMA's National Flood Insurance Program (NFIP) handles flood related insurance claims. In estimating the total insured losses of a disaster, PCS assembles spreadsheets of commercial buildings affected by the catastrophe. PCS also categorizes significant damage to infrastructure; for example, after Post-Tropical Storm Sandy, this included damages to piers.

PCS only uses insured loss claims information from primary insurance providers; it does not use information from re-insurance providers. PCS aims to issue a preliminary estimate two to three weeks after each disaster. If the damages sum to greater than $250 million, PCS enters a re-survey process in which analysts solicit new updated information from primary insurance companies or additional companies which had not been surveyed in the original data pull. The re-survey process usually lasts anywhere from six to eight months, though it can take up to 12 months for more complicated or larger disasters such as hurricanes.

[14] There are two questions each on losses from personal, commercial, and automotive losses.

PCS also maintains a proprietary database containing information on the number and types of structures, by ZIP code, for every state in the country. PCS uses this data to determine the number of insurable risks in a specific geographic area.

Interview with Primary Insurance Agent

The foundation behind PCS's reported insurance claims numbers are the values provided directly by primary insurance providers. While PCS aggregates the numbers in a unified fashion, it is the Primary Insurance Providers who provide the rata data. Obviously, the large number of insurers reporting to PCS poses potential consistency issues, but the lack of alternative data sources and large expense associated with creating such an alternatives makes the PCS process the best practical solution available. Note that this review is based on interviews with a single primary insurer; several other primary insurers refused to comment, viewing internal processes as proprietary. With the caveat that one interview cannot be sufficient to determine the consistency of the overall approach of insurers, the research team was able to interview a primary insurance provider concerning procedures and processes for reporting claims data to PCS.

Liberty Mutual, a primary insurance provider, reports its catastrophe claims information to PCS in a real-time format. This automated referral function transfers the claims reported in the system by catastrophe code, date of loss, claimed loss, insured loss, peril type, damage specifics, and other relevant information. Each disaster has its own individual catastrophe code or "cat code" which is associated with all claims resulting from it. The cat code is restricted to a specific designated time frame – for example the time frame might stretch over multiple days if a large wind storm spanned multiple states.

The biases associated with catastrophe codes are two-fold, weighted towards underreporting:

1. Claims occurring long after the disaster after PCS has already pulled the data for its claims estimates are often left out from PCS final calculations[15]
2. Claims not filed under the proper associated catastrophe code, when agents "miss the small stuff," result in potential missing claims from the full total

While an understanding of primary insurance provider's reporting process does not suggest any adjustments to the final loss estimates in the BDW/CD database, it does provide insight into the collection of the data and the fidelity and accuracy of the primary insurance sources.

Purpose

According to the Verisk Analytics website, ISO is the property/casualty insurance industry's leading supplier of statistical, actuarial, underwriting, and claims data. ISO serves insurers, reinsurers,

[15] Note that this is less of a concern with large disasters (primary reports of greater than $250 million), as PCS resurveys in this cases.

agents and brokers, insurance regulators, risk managers, and other participants, including NOAA NCDC, in the property/casualty insurance marketplace. ISO PCS offers the following products:

- data to help insurers make independent decisions about pricing
- statistical and actuarial services
- insurance policy language
- rules needed to write and rate insurance policies
- tools for predictive modeling and scoring of risk
- information about specific properties and communities
- claims data and other information for underwriting
- tools for identifying and preventing insurance fraud
- criminal records and other public information
- motor vehicle records and related information
- information for marketing, loss control, and premium audit
- advanced statistical modeling systems to help customers assess and manage the risk of natural and man-made catastrophes
- tools to help insurers identify and correct rating errors
- tools for estimating property replacement costs and repair costs
- risk consulting services
- specialized consulting, claims-management, and litigation-support services
- rate-quote, underwriting, and policy-management systems for all commercial and personal lines insurance

Context & Consistency

PCS relies on reports from insurers regarding claims and loss payments and reserves to estimate ultimate insured property damage payment for each catastrophe event. Over the years, there have been several changes to the overall catastrophe identification system. The threshold for a catastrophe designation has changed three times. In 1949, when the system began, the threshold was $1 million. The threshold increased to $5 million in January 1982, and the last increase to $25 million took place in January 1997. Since 1998, PCS has reported the number of claims for personal, commercial, and auto losses by state for each catastrophe typically within a few months after each catastrophe. The timeless of the PCS estimates help NOAA describe damages nearly in real time.

PCS assessments are generally extremely accurate and reliable. PCS has four professional staff that review and approve the final estimated numbers before issuing them to the public. One example of the quality control process involves when insurance companies change the reported numbers for a loss event; the PCS staff investigates the changes before approving the final official estimate. Regulatory audits routinely confirm the reliability and accuracy of PCS estimates. Historically, after such regulatory data audits, the final adjusted estimate has differed by at most five percent.

Fraud is another potential concern with consistency and accuracy of the overall impact of a disaster, as the widespread damage can limit the resources of insurers to make proper investigations of fraudulent claims. PCS has no assumptions in its loss estimates regarding fraud. While some claims are indeed fraudulent, PCS relies on primary insurance agencies to determine which claims are worth investigating the validity and which claims are best left alone. Generally, larger claims are given more critical attention, and those potentially fraudulent claims which could make an impact on the total loss calculations are investigated thoroughly by primary insurance companies.

Another potential consistency issue with the insured loss estimate is regulatory policy. Regulatory policies affect insurance companies on the size of claims paid for different catastrophic events. For example, insurers were not allowed to classify Post-Tropical Storm Sandy losses as Hurricane damages on insurance deductible reports because the National Hurricane Center (NHC) declared Sandy to be a Post-Tropical Storm at landfall. PCS keeps track of insurance regulators' decisions and actions to better understand survey results and ensure accuracy of the data collected.

ii. Federal Emergency Management Agency – National Flood Insurance Program (FEMA/NFIP)

The NFIP is an insurance program created in 1968 by the federal government and is currently administered by FEMA. The program provides flood insurance to many markets that otherwise would not have flood insurance available. Historically, insurers tended not to offer flood protection, due in large part to the concentration of risk and damage that floods tend to inflict. As such, insurers often were unable to adequately balance risk if they had a geographically concentrated customer base (this was particularly true when there were less robust reinsurance markets available, as well as by the state-level regulation that tended to make balancing risk nationally more difficult due to idiosyncratic differences between state-level requirements).

The national program developed by the federal government was designed to complete the missing market, using the benefits of a national client pool to better diversify risk. The NFIP is designed to mitigate future flood losses nationwide through sound, community-enforced building and zoning ordinances and to provide access to affordable, federally backed flood insurance protection for property owners. The NFIP provides an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods. Participation in the NFIP is based on an agreement between local communities and the Federal Government whereby a community adopts and enforces a floodplain management ordinance to reduce future flood risks to new construction in Special Flood Hazard Areas (SFHAs); in exchange, the Federal Government makes flood insurance available within the community.

Individuals seeking out a policy are only able to do so if their community has applied and been accepted into the program, as the costs of the insurance are entirely based on NFIP-determined community rating. The community ratings are based on the flood risk of the area (including mitigating infrastructure provided by the community). As such, coverage is highly concentrated in certain geographical regions (Texas, Louisiana, and Florida), and the NFIP has been amended by congress several times to provide better risk-adjusted premiums in order to provide incentive for public investment in flood mitigation infrastructure. This is in part due to the high concentration of payouts in certain states, with 61% going to Florida, Texas, and Louisiana,[16] and the desire to further enhance the diversity of risk in the program. However, the coverage has also been

[16] Numbers are current as of August 31st, 2012.

expanding over the past several decades, with roughly double the number of household policies in force at the end of 2011 than there were in 1993, as seen in Figure 1:

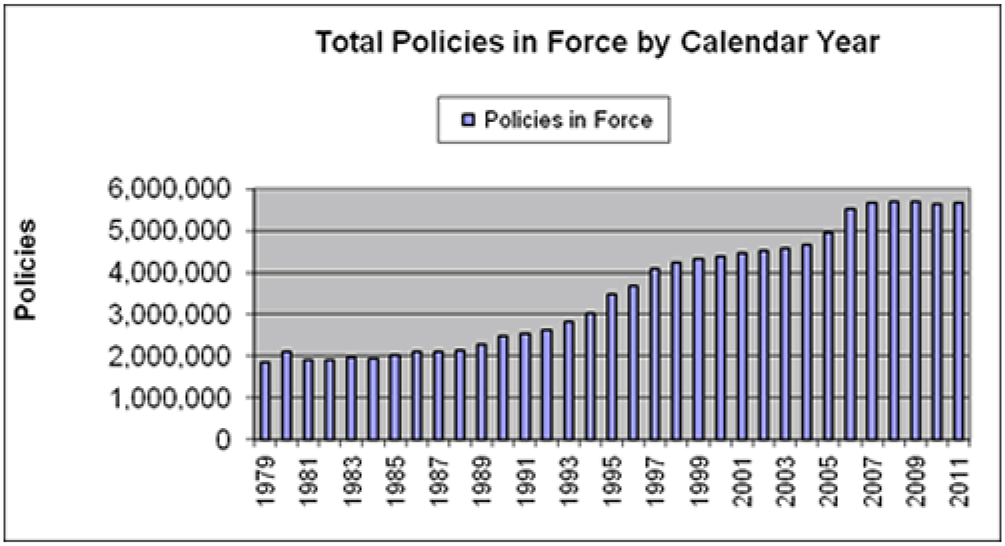

Figure 1 – Flood insurance policies in force, by year. Source: FEME/NFIP - http://www.fema.gov/policy-claim-statistics-flood-insurance/policy-claim-statistics-flood-insurance/policy-claim-13-14

Data & Methods

The data used in estimating the overall insured losses due to flooding are almost entirely derived from the programs internal policy information. The data are based on the number of policies that the NFIP has in an area that was flooded, as well as the initial and subsequent claims of the residents. These estimates do not include deductibles or values exceeding the policy caps on coverage (usually $250,000, though it varies by community). First, data are collected by local agents and claims representatives. Next, data are aggregated by the member of the national NFIP staff. Currently, the NFIP does not have a database with regional flood insurance participation statistics. However, NFIP is focusing on the communities which are in special flood hazard areas and is hoping to have a complete dataset by the end of fiscal year 2014.

Purpose

The purpose of the data is primarily to facilitate the fulfillment of claims activities and risk-balancing for the NFIP program. Specifically, the damage and claims data are necessary to determine cash-flow requirements (for example, the NFIP has had to borrow from the Treasury on occasion to ensure prompt payments to claimants), future premium determinations for continuing operations, and actuarial purposes. Additionally, the data are provided to comply with FOIA issues, as well as enable other government departments within FEMA, and other government agencies involved in the disaster response, to assess the requirements for recovery.

Applications

The NFIP uses the data to assess its own responsibilities in servicing claims. Several firms and government agencies also employ the NFIP data in development of loss estimates. As mentioned in the NOAA section, the NCDC uses the NFIP data in BDWCD estimates, the NHC uses the insured flood losses as a part of hurricane assessments, and the WFO also uses the NFIP data in producing estimates of flood losses.

Consistency

NFIP estimates of loss are fairly consistent over time, as they are entirely based on the amount of insured losses covered under the claims that they receive. One important distinction relevant to the analysis of NOAA is that NFIP can cover both fresh water flooding as well as storm surge-related flooding; the WFO estimates attempt to isolate only the former, with storm surge-related losses meant to be excluded (or at least broken out) from the estimates. Additionally, the time after a flood at which payouts are made and production of data can have significant consequences for those using the data. Further examination of the release of funds and the time-frames under which the data are produced will be an area of further analysis for the recommendations document.

iii. FEMA Presidential Disaster Declarations (PDD)

Though FEMA's National Flood Insurance Program was discussed in the previous section, FEMA has several other programs that provide valuable information to NOAA. When FEMA (and the president) declares a disaster, many assistance programs can be declared:

- IH – Individuals and Households Program
- IA – Individual Assistance Program
- PA – Public Assistance Program
- HM – Hazard Mitigation Program

All program areas provide valuable pieces of information for estimating disaster impacts, though not all of this information has typically been centralized at FEMA; this can create complications and requires additional resources for disaster impact estimators to appropriately use the information. FEMA publishes some of its data with public access at the following websites:

- Data Feeds (PA) http://www.fema.gov/data-feeds
- Flood Claim Statistics (NFIP) - http://www.fema.gov/policy-claim-statistics-flood-insurance/policy-claim-statistics-flood-insurance/policy-claim-13-9
- Hurricane Impact Analysis (FEMA MOTF) - http://www.arcgis.com/home/webmap/viewer.html?webmap=307dd522499d4a44a33d7296a5da5ea0&extent=-81.7662,36.4579,-66.0557,43.1342

The FEMA Modeling Task Force (MOTF) program provides Geographic Information Systems (GIS) county-level analysis of weather disaster impacts. The FEMA MOTF is a group of modeling and risk analyst experts located in Atlanta and Denver;[17] they may be activated by the FEMA NRCC for Level 1 events in support of disaster response operations. The group consists of individuals with experience in multi-hazard loss modeling and impact assessments, including earthquakes, hurricanes, riverine and coastal floods (surges, tsunamis), winter storms and other disasters. The

[17] Officially, they are listed as being located in FEMA Regions IV & VIII, respectively.

MOTF plays an important role in coordinating hazard and modeling information from a variety of sources, including other federal agencies, universities, the National Labs, and state and local agencies; they use these data to develop consensus for best estimates of impacts before, during, and after events. The MOTF integrates observed information throughout disasters to verify and enhance impact assessments.

For example, MTOF developed a county-by-county analysis of impacts due to Post-Tropical Storm Sandy. The report covers the following covered in Table 5 (see next page). There are two elements reported from the FEMA MOTF analysis of particular interest: (1) Advisory 34 HAZUS Estimated Wind Loss ($K) and (2) Category 1 Building Damage (CFLA $K). The estimated wind loss and building damages values of a specific storm could provide useful comparisons for NOAA BDWCD estimates.

1. **Advisory 34 HAZUS Estimated Wind Loss ($K):** Hazards-United States (HAZUS)[18] is a standardized program that FEMA uses to estimate potential losses from earthquakes, floods, and hurricanes. HAZUS uses GIS to estimate physical, economic, and social impacts of disasters. The program graphically illustrates high-risk locations that are potentially susceptible to earthquake, hurricane, and floods. Users can then visualize the spatial relationships between populations and other more permanently fixed geographic assets or resources for the specific hazard being modeled, a crucial function in the pre-disaster planning process.

2. **Category 1 Building Damage (CFLA $K):** The FEMA Region IV Risk Analysis Team developed the Coastal Flood Loss Atlas (CFLA)[19] as part of a comprehensive risk management strategy of the Mitigation Division to better assess and properly mitigate the risks and vulnerabilities associated with storm surge. The CFLA unites the National Hurricane Center's (NHC) Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model with FEMA's loss estimation model, HAZUS, creating an easily and readily accessible atlas of possible coastal flood conditions and losses to support pre- and post-hurricane landfall strategies.

Table 5 – Example of FEMA MOTF information sources

Data Points included in FEMA MOTF Hurricane Sandy Impact Analysis				
State	County	FEMA Region	Population	Households
Population Exposed to Storm Surge	Households Exposed to Storm Surge	**Advisory 34 HAZUS Estimated Wind Loss ($K)**	**Category 1 Building Damage (CFLA $K)**	Precipitation (inches)
Snow	Maximum	Precipitation	Impact Rank	Landslide Threat

[18] Available online at http://www.fema.gov/HAZUS
[19] Available online at http://fema.maps.arcgis.com/home/item.html?id=b4ae0b42789447b18c4b919682b848ad

	Snowfall in County (inches)	Rank		
Waste Water Facilities Exposed to Surge/Impacted by Heavy Snow	Electric Facilities Exposed to Surge/Impacted by Heavy Snow	Chemical Facilities Exposed to Surge/Impacted by Heavy Snow	Communication Facilities Exposed to Surge/Impacted by Heavy Snow	Oil and Gas Facilities Exposed to Surge/Impacted by Heavy Snow
Fire Stations Exposed to Surge/Impacted by Heavy Snow	Care Facilities Exposed to Surge/Impacted by Heavy Snow	Police Stations Exposed to Surge/Impacted by Heavy Snow	Schools Exposed to Surge/Impacted by Heavy Snow	FEMA Disaster Declaration
FEMA IA Applicants in County	Inundated NFIP Policies in County	IA Households Affected	IA Households Minor Damage	IA Households Destroyed
IA Households with Damages	Estimated Structural Debris	Estimated Tree Debris	Estimated Total Debris (cubic yards)	FEMA IA Applicant Verified Loss in Dollars

iv. USDA RMA

The USDA Risk Management Agency (RMA) helps producers manage business risks through effective, market-based risk management solutions. RMA's mission is to promote, support, and regulate sound risk management solutions to preserve and strengthen the economic stability of America's agricultural producers. The RMA has three divisions: Insurance Services, Product Management, and Risk Compliance. Insurance Services is responsible for program delivery (for example, managing contracts with the companies that sell and service policies), and local program administration and support. Product Management is responsible for overseeing product development. Risk Compliance monitors compliance with program provisions by both producers and the 17 insurance companies that sell and service policies.

As part of this mission, RMA operates and manages the Federal Crop Insurance Corporation (FCIC). RMA was created in 1996; the FCIC was founded in 1938. RMA, through FCIC, provides crop insurance to American producers. Seventeen private-sector insurance companies sell and service the policies. RMA develops and/or approves the premium rate, administers premium and expense subsidies, approves and supports products, and reinsures the companies. In addition, RMA sponsors educational and outreach programs and seminars on the general topic of risk management. The Federal Crop Insurance Reform Act of 1994 resulted in a major increase in U.S. crop acreage insured, along with providing catastrophic coverage. The FCIC has grown dramatically since its inception – in crop year 2010, RMA managed nearly $78 billion worth of insurance liability (see table 6 below). In 1980 the subsidies were increased, and in 1998, the private sector took over servicing the policies. Liability grew substantially, especially after 2004, which was driven by the price of commodities (see Figure 2 below). Revenue program coverage also skewed the amount of damages paid. Net insured acres have increased since 1980. Crop coverage has increased over time as well; in 1990, USDA covered 50 crops while in 2011 it covered over 100 crops. For example, there are different crop codes for citrus by state (one for FL, CA, TX); and corn is not just corn but is rather popcorn, sweet corn, or grain corn.

Recently, Congressional decisions have continued to expand RMA-managed farmer insurance's role as the main safety net for many farmers (including losses from drought); as such, direct payouts from disaster relief organizations could decrease even more in the future. As the importance of RMA-managed insurance increases and the direct payouts from disaster relief decrease, the process to adequately capture the cost of a weather- or climate-related disaster should respond (See Table 6 for the current size of the program and Figure 2 for growth in insurance over time). A shift towards crop insurance and away from direct payments both leaves less acreage uncovered (making the appropriate value of the uninsured-loss multiplier lower). This shift could also reduce the amount of FEMA PDD aid that is provided, which would move costs that currently have a multiplier of 1.00 into a category that has a multiplier of 2.00; these changes bias the current BDWCD techniques into overestimating the amount of uninsured losses relative to historical estimates. Loss estimators could compensate for these changes by monitoring these USDA RMA quarterly reports for updates on definitions and deviations from traditional numbers, including the historical loss by crop, state, and county.

Table 6 – Statistics about the Risk Management Agency program in 2010. Source: RMA Fact Sheet 2010

Crop Year 2010 RMA Program Size	
Number of Policies	1.14 million
Premium Volume	7.57 billion
Crop Value Insured	$77.9 billion
Acres Insured	256 million

Additionally, USDA RMA publishes state level Crop Insurance Profiles that do provide state specific details including: insurable crops, insured acreage by crop type, total acreage by crop type, and percent of crop insured that could be incorporated into the BDWCD crop loss estimates. For example, the Crop Insurance Profiles may allow for more precise calibrations of the USDA multiplier per event.

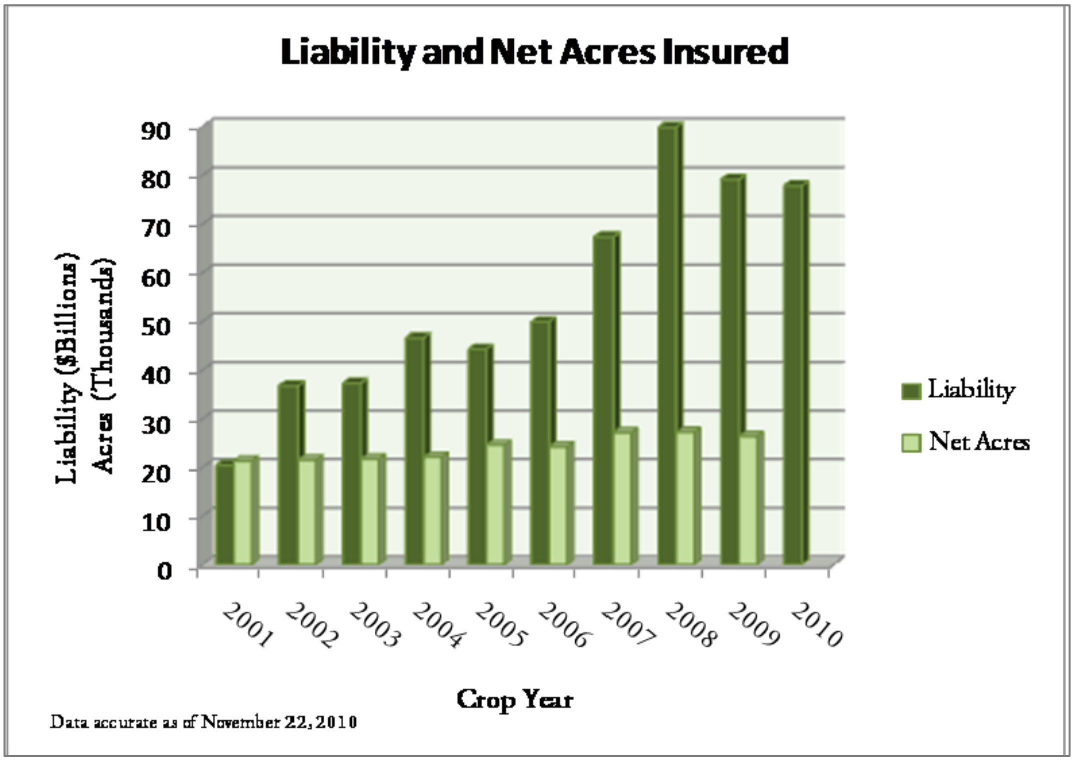

Figure 2 – Net acres covered and total liability insured by RMA. Source: RMA Fact Sheet 2010.

The main data sources for the estimates are Official USDA information, including the Crop Production report, Crop Progress summaries, state-specific disaster reports, and FEMA Aid. At present, BDWCD usually prefers state reports because they detail the percentage of crop yield loss (by crop type) rather than USDA indemnity payments that do not reflect total crop value lost due to a disaster.

Another recent concern with the BDWCD drought cost estimates is with second planting and crop substitution due to drought conditions. USDA RMA insurance exports suggest that these issues are sufficiently rare (at least mid-season) such that creating an offsetting number for drought-related responses is probably unnecessary for accurate account of drought-related costs; ex ante planting decisions may be influenced by the likelihood of a drought, and could potentially be a significant cost, but those are difficult to measure as the crop switching may have been for a variety of reasons unrelated to a potential drought.

v. USDA NASS

The USDA National Agricultural Statistics Service (NASS) conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. Production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use, and changes in the demographics of U.S. producers are only a few examples. The NASS provides timely, accurate, and useful statistics in service to U.S. agriculture. This data can be used for BDWCD and WFO weather disaster cost estimates. However, if resources are limited, the use of more aggregated information from USDA RMA can be more efficient.

Data

The NASS publishes weekly state Crop Progress and Condition reports which document crop progress and condition relative to data from years past. This includes crop condition (percent very poor to percent excellent), soil moisture (percent very short to surplus), progress in the harvesting cycle (percent harvested), and a weather summary for individual cities within the state on temperature, cumulative growing degree days, and precipitation relative to "normal."

Methods

Crop progress and condition estimates are based on survey data from approximately 5,000 reporters whose occupations provide them opportunities to make visual observations and frequently bring them in contact with farmers in their counties. NASS collects these surveys each week from early April through the end of November.

From a consistency of data standpoint, there is obviously subjectivity in these survey responses. Based on standard definitions, these reporters qualitatively estimate the progress of crops through various stages of development, as well as the progress of producer activities. They also provide subjective evaluations of crop conditions. NASS validates the data for reasonableness and consistency by comparing a given survey with data reported the previous week and data reported in surrounding counties for the current week. Each State Field Office summarizes the reported data to district and state levels, weighting each county's reported data by NASS county acreage estimates. As with the individual surveys, the summarized/aggregated data are compared with previous week estimates, and progress items are compared with earlier stages of development and historical averages to ensure reasonableness. The field offices may also adjust these summarized/aggregated data based on weather events and reporter comments. These progress and condition estimates are incorporated into the Crop Progress report; this publication is released at 4:00 pm ET on the first business day of the week. These estimates are subject to revision the following week.

2. Other estimates of economic impacts, models resources, and disaster costs used in NOAA Estimates databases

In addition to the primary data sources described in the previous section, the NOAA estimates often incorporate additional information from other sources to supplement the disaster estimates. This section describes several sources of data that have been used in past estimates or are key components in economic loss estimates when a disaster warrants the calculation.

i. USDA Office of the Chief Economist (OCE)

The USDA Office of the Chief Economist (OCE) advises the Secretary on the economic implications of policies and programs affecting the U.S. food and fiber system and rural areas. OCE supports USDA policy decision-making by analyzing the impact of proposals and coordinating a response among several USDA agencies. Requests for analyses come from the Secretary, other Administration officials, and members of Congress. These requests may concern proposed changes in USDA programs, policies, and legislation. Yet, OCE does not do weather disaster cost estimates. OCE also coordinates, reviews, and approves the Department's commodity, farm sector, and weather forecasts, which are available to the public.

OCE publishes the monthly World Agricultural Supply and Demand Estimates (WASDE) report, which shows U.S. farmers, policymakers, and traders what's going on in the world of farm commodity forecasts at a single moment in time. The WASDE report provides USDA's comprehensive forecasts of supply and demand for major U.S. and global crops and U.S. livestock. The report gathers information from a number of statistical reports published by USDA and other government agencies, and provides a framework for additional USDA reports. Note that many of these forecasters are likely incorporating real-time NOAA data into their forecasts; these estimates may also include historical disaster-loss estimates into their estimates, including disasters that are currently being quantified.

The WASDE reports provide monthly forecasts of several key crops in the United States. Reviewing the month-by-month changes of these forecasts for the same period can provide a calibrated estimate for the effect of the drought. Using the root-mean-square deviation (RMSE) of WASDE forecasts (usually provided on pages 35-37 of the spreadsheets that WASDE produces each month) to generate the confidence bounds, the deviations from prior forecasts represent the forecaster's best estimates of how much damage the drought is inflicting on current crop yields; these changes can be translated into a rough estimate of the overall compensated impact of the drought. Large movements in the forecasted supply, along with discussion and analysis of these forecasts that are provided in the monthly outlines, can help formulate the projected effects on actual output.

OCE houses the Joint Agricultural Weather Facility, which produces the Weekly Weather and Crop Bulletin (WWCB), an international summary of crop-related weather developments, provides a vital source of information on weather, climate and agricultural developments worldwide, along with detailed charts and tables of agro-meteorological information that are appropriate for the season.

ii. USDA National Resource Conservation Service (NRCS)

The USDA Natural Resource Conservation Service (NRCS) was originally established by Congress in 1935 as the Soil Conservation Services. The NRCS's role has expanded to include all natural resources. It helps ensure private lands are managed to provide sustainable, nutritious, abundant food supply and thriving ecosystems that are more resilient to environmental changes such as climate change. NRCS provides programs, reports, guidance documents, and tools to help decision makers, resource managers, and others make informed decisions regarding land use, soils, water, air, plants and animals, energy, climate change, and people.

One of the programs the NRCS administers is the Emergency Watershed Protection Program (EWP). The EWP responds to emergencies created by natural disasters relieving imminent hazards to life and property caused by floods, fires, wind-storms, and other natural occurrences. Two other programs are Drought Assistance that provides the latest information on droughts, and National Water and Climate Center (NWCC) that provides current water and climate information. For the EWP program, NRCS publishes financial and technical assistance funding for the current fiscal year by state. NRCS may bear up to 75 percent of the construction cost of emergency measures. The remaining 25 percent must come from local sources and can be in the form of cash or in-kind services. Funding is subject to Congressional approval. Generally, direct effects from weather disasters do not need to consider these construction costs of emergency measures.

The NRCS publishes weekly Drought Monitor maps and drought summaries documenting current areas of dryness and drought. This information can help with BDWCD cost estimates when timely drought information is needed.

For the NWCC program, NRCS publishes water and climate data including water supply, forecasts, reservoirs, surface water, climate, wind data, Snotel data, Soil Climate Analysis Network (SCAN) data and snow course data. Wind and climate data is obtained from U.S. climate stations across the country. Snotel data provides real-time daily snow, precipitation, and soil temperature data obtained from an extensive automated system in the Western U.S. This system evolved from the NRCS's mandate in the mid-1930's to measure snowpack in the mountains of the West and forecast the water supply. Soil moisture data across most of the U.S. is provided by SCAN.

The NWCC provides climate analysis based on the soil surveys generally on a county level. They also provide digital climate map products through the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM uses point data, a digital elevation model, and spatial data sets to create mapped estimates of monthly, yearly, and event-based climatic parameters. For drought monitoring, the NRCS closely observes drought on a daily bases from surveys and provides financial and technical assistance to farmers and ranchers to cope with drought.

iii. USDA Economic Research Service (ERS)

The USDA generally does not do weather disaster cost estimates. However, the USDA Economic Research Service (ERS) occasionally calculates crop price impacts from prolonged droughts. ERS's calculations are based on USDA staff including commodity analysts, food price analysts, and experts in farm production and land use. When available, these reports on crop price impacts from prolonged droughts can be used to compare or calibrate BDWCD crop price impacts for drought events.

iv. National Interagency Fire Center (NIFC)

The NIFC, located in Boise, Idaho, is the nation's support center for wild land firefighting. Eight different agencies and organizations are part of NIFC, though decisions are made using the interagency cooperation concept as NIFC has no single director or manager. The Boise Interagency Fire Center (BIFC) was created in 1965 because the US Forest Service, Bureau of Land Management (BLM), and NWS saw the need to work together to reduce the duplication of services, cut costs, and coordinate national fire planning and operations. The National Park Service, Bureau of Indian Affairs, U.S. Fish and Wildlife Service, and U.S. Fire Administration-FEMA have since joined.

As a result of its coordinated wild fire management, NIFC makes detailed reports on U.S. wildfires available, which include firefighting cost-to-date information, burned/destroyed structures, lives lost, acreage burned, and many other variables of use to better understand the economic costs and historical context associated with specific wildfires. Since 2003, NIFC has been reporting year-to-date statistics, including number of fires and number of acres. Further, daily reports are issued with statistics such as number of new large fires, number of active large fires, fires contained that week of the daily report, states currently reporting large fires, and year to date large fires contained. NIFC publishes a weekly Incident Management Situation Report (SitRep) which includes national wildfire activity data. Wildfire data-points include the following incident information described in Table 7:

Table 7 – Information provided by NIFC Situation Reports

NIFC Weekly SitRep Incident Information Available		
Name	State	Size
Size change in 24 hours	Structures Lost	Percent of Fire Contained
Cost to date to combat the fire ($)	Cumulative Acres	Crews
Engines	Helicopters	Total Personnel Involved

Noticeably missing from available incident information is the cost to date of actual damages and the economic impacts of these losses. NIFC does not calculate the economic or physical losses from wildfires, nor does it maintain any records/numbers/statistics on losses. The cost to date (CTD) value published by NIFC in the SitRep is determined by a finance team, but still only covers the costs to combat the fire: equipment, helicopters, personnel, etc.

There are three main types of wildfire losses that NIFC recommended for consideration in loss calculations:

- Residential
- Infrastructure
  - Power Lines
  - Roads
  - Water Delivery Sources
- Automotive

Although NIFC doesn't measure the economic impact or direct losses from wildfires, it does measure the severity of a fire season. At NIFC, quantifying fire season severity and comparing one year with another depends entirely on context and what elements of the fire season are measured.[20] For most in the firefighting community, the number of fatalities is the most critical measure of a fire season's severity. Counter to what one might expect, the number of acres burned is a less of a measure of an individual fire season's severity and more of a long-term (multi-year) indicator of overall fire conditions (fire growth and fire trends on the landscape). Additional less-critical measures of fire season severity include structure losses, and the number of resources mobilized to respond (particularly in incident management teams which are deployed for the more complex, longer-duration fires).

v. U.S. Army Corp of Engineers (USACE)

The U.S. Army Corp of Engineers is a branch of the U.S. Army that provides services to infrastructure investment, environmental stability, and research and development. The USACE has several missions, including those devoted to Emergency Operations. This mission is serviced by generating Disaster Impact Models, as well as working on waterway and navigation guidance during droughts (which are events listed in the BDWCD database) and hurricane response. Additionally, the USACE provides support during emergency to rapidly assess infrastructure damaged by the disaster, as well as commercial and residential property; these assessments assist FEMA in managing the disaster and prioritizing emergency responses that might require significant monetary resources to prevent further damage or ensure properly functioning public systems (such as water and waste treatment facilities). Additionally, these estimates can contribute to the estimates of organizations (such as PCS) that determine losses on large idiosyncratic structures.

Disaster Impact Models

The Disaster Impact Models[21] are of particular relevance to the estimation of economic impacts of disasters. The models use geospatial tools, combined with forecasts from the NHC (or the Central Pacific Hurricane Center – CPHC – on the west coast) to estimate likely debris volumes, households affected, and the likely resources required to service those who are displaced or in need of assistance. These models can be particularly valuable in accounting for the disaster response costs (as the models estimate the amount of water and ice, amongst other things, that are required in response). The model is designed to calculate the likely scale and scope of the storm 72 hours before making landfall, with more specific predictions of response requirements coming 48 hours beforehand. The data used in these estimates are based on historical response needs, as well as the inputs about the storm from either the NHC of CPHC. Note that, while explicit cost data are not projected, the estimates of these models may be appropriate in assessing the likely cost of response teams to be incorporated into BDWCD estimates. The overall consistency of these estimates are usually quite good, as they are revised to incorporate the actual costs incurred in responding to the disasters; however, these revised values are in nominal dollars and need to be adjusted for inflation when incorporated into any historical estimate.

[20] In considering a fire season's severity, NIFC measures the following elements: total number of fires, acres burned, length of season, number of homes and structures lost, team mobilizations, and fire-related fatalities.
[21] Available publicly on ENGLink Interactive: http://eportal.ACE.army.mil/sites/ENGLink/default.aspx

Flood Event Summary Data
The Corps annually produces estimates of flood damages and damages prevented as a result of individual storm events. This data is compiled and submitted to Congress in a yearly report. The BDWCD directly uses the flood information that the USACE calculates including annual USACE Flood Event Summary Data reports on levee damage as well as other damages. This information is derived from household and business surveys, as well as from previous cost-benefit work that is produced as part of project commission; however, recently the updating of this information has not occurred as frequently due to funding constraints. The information is assembled from district and division level assessments of the actual damage that is incurred. All of the flood damage events that occur over a calendar year, both large-scale and smaller events, are aggregated by state to reach a flood damage total. This calculation is augmented by a "damages prevented" calculation, whereby infrastructure improvements and other USACE projects are assumed to have prevented a certain amount of damage. This "damages prevented" number is based on the flood stage that registers from an event and the likely impact it would have had on an area based on USACE's initial cost curve used in the development of a project's Cost-Benefit Analysis (CBA). Additionally, the USACE report includes a tally of the number of lives lost in the flooding events; this is sourced from NWS estimates.

Deviations from original CBA calculations are estimated using internal documents[22] based on local costs of construction material and other inputs relevant to repairing flood damage, such as the cost of labor for construction. These recalculations are expected to occur at minimum every two years with index values standing in for any intermediate usage of the numbers. These inflation adjustments are based on local factors associated with each project, and they are re-tabulated with as much frequency as is reasonable and within the ability of the local district. The USACE national numbers are adjusted using an internal construction cost index (The Civil Works Construction Cost Index System – CWCCIS EM 1110-2-1304). Further, each state has an individual adjustment factor that can be applied to each project type to reflect localized differences in costs of projects.

Traditionally, the total losses incurred has been calculated at the state level, though starting in 2012 the information is at the project level, with information on each flooding event at each piece of infrastructure constructed and maintained by the USACE. All data had traditionally been calculated at that project level, but was only provided to the annual report at the state-level aggregation. Now, the newly more robust granular data is sent upwards prior to aggregation. The local-level data are compiled using standardized guidance, as well as from the pre-calculated flood stage information. These costs do not incorporate the actual emergency operations response costs. The data currently includes only riverine events but is being expanded to also encompass coastal damages prevented.

vi. AIR Worldwide

AIR Worldwide® is a scientific leader and a respected provider of risk modeling software and consulting services. More than 400 insurance, reinsurance, financial, corporate, and government clients rely on AIR software and services for catastrophe risk management, insurance-linked securities, and property replacement-cost valuation. AIR's ALERT™ (AIR Loss Estimates in Real

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[22] The USACE has labeled these proprietary and are not available to non-USACE personnel.

Time) service is the industry standard online service providing up-to-date information and loss estimates for major natural catastrophes worldwide. Obtaining reliable catastrophe loss information quickly as an actual event unfolds has become increasingly important for insurers, reinsurers, and investors. This, coupled with the availability of financial instruments that can be used to hedge against events in real time, makes access to timely information regarding potential catastrophe losses exceedingly valuable.

vii. Verisk Catastrophe Index

Verisk Analytics is a leading source of information about risk. Verisk's mission is to help risk-bearing businesses understand and manage their risk. Verisk is a parent company to many risk assessment and decision analytics-focused subsidiaries such as ISO PCS and AIR Worldwide. The Verisk Catastrophe Index supplies highly detailed insured property loss estimates — by county and line of business — after catastrophes. The Verisk Catastrophe Index builds upon the strengths of two industry leaders — Property Claim Services® (PCS®) and AIR Worldwide® (AIR). PCS is a unit of, and AIR is a wholly-owned subsidiary of ISO, a Verisk Insurance Solutions company. The index combines information that PCS and AIR each develop independently and without mutual influence. Verisk's risk assessment business serves customers — mainly in the property/casualty insurance industry — by helping to define, measure, and manage risk. The risk assessment operations include the flagship ISO subsidiary and several other units. All of those units provide data, software, and information services to property/casualty insurers and reinsurers in the United States, as well as many international carriers. Verisk Risk Assessment also sells products and services to insurance agents and brokers, insurance associations and service organizations, government agencies, and the risk-management functions of firms in all industries. Verisk's decision analytics business serves customers in a variety of industries with tools that help them make informed decisions about managing their assets and the associated risk.

viii. Munich Re

Munich Reinsurance's (Munich Re's) Natural Catastrophe Service (NatCatSERVICE) is a database with one of the most comprehensive collections of natural catastrophe data, overall and insured loss figures in the world. NatCatSERVICE analyses and statistics are used in insurance and finance, science and politics. Munich Re NatCatSERVICE Database is used in assessing overall losses; accounting for direct losses and indirect losses adds value while consequential or secondary losses are not taken into account.

The NatCatSERVICE includes around 28,000 data sets. A complete dataset for natural catastrophes worldwide is available since 1980. It allows trend analyses and statistics at global, continent and country levels. The Munich Re NatCatSERVICE records up to 1,000 loss events per year. The resulting information and analyses are available in the form of annual statistics dating back to 2004. The statistics show the number of events and fatalities, overall and insured losses and the percentage breakdown for the different continents. Annually Munich Re provides the following statistics and reports:

- Worldmap of Natural Disasters: category, date, location

- Natural Disasters - percentage distribution ordered type of event: by category, # fatalities, overall and insurance $US losses
- Natural Disasters - percentage distribution ordered type continent: by continent, # fatalities, overall and insurance $US losses
- 10 costliest disasters - overall losses: time period, category event, affected area, overall losses, insured losses, fatalities
- 10 costliest disasters - insured losses: time period, category event, affected area, overall losses, insured losses, fatalities
- 10 deadliest natural disasters: time period, category event, affected area, overall losses, insured losses, fatalities

Munich Re Data includes the following entries per loss event:

• Key Figures	• Loss Data	• Scientific facts and figures
- Date of loss and time record	- Insured losses	- Description of the event
- Type of Event	- Overall losses	- Wind strength
- Geocoding of main loss areas	- Bodily injuries	- Precipitation levels
- Nature of the event	- Infrastructure/industries affected	- Earthquake magnitude

On the basis of the information received, as well as the reports by offices abroad and insurance associations, NatCatSERVICE provides definitive figures concerning the insured losses associated with a natural catastrophe. Depending on the information available, Munich Re uses different sources and calculation methods when determining the overall losses. In the case of roughly one-third of all loss events, reliable data on economic losses are provided by governments, statistical offices, the World Bank, and development banks. These are entered in the database by Munich Re after close scrutiny and verification of plausibility. If suitably verified data concerning the economic losses are not available, Munich Re take as its basis the figures concerning the insured losses, extrapolate these via the insurance density of the affected region and determine the amount of loss with the aid of specially developed algorithms. These loss estimates take account of the type of event, as well as the risk exposure of the region affected. Among other things, this includes information on the structure of affluence in the country affected, as well as details concerning damaged industrial plants, infrastructure and supply systems. Even if an insured loss has not been incurred, Munich Re can still determine the overall losses. To this end, a realistic picture of the loss is drawn up by experts on the basis of the type of event, the nature of the region affected, its population density and information on damage to buildings and infrastructure, as well as injuries, and then uses this to arrive at the overall losses.

3. Other estimates of economic impacts, models resources, and disaster databases

In addition to those data sources that are currently used by the three NOAA estimates, there are several other relevant data and estimation sources that look at weather- and climate-related disasters. This section looks at additional resources that NOAA can consider using in future estimates of economic impacts, providing a discussion of each. The focus of the research team was primarily to identify useful data sources that are used by other agencies attempting to estimate disaster impacts, as well as other disaster-cost related information; however, the research team has also included relevant information on related economic impact estimates that are made by other government or industry sources.

- The first group of estimates reviewed are those that do not use NOAA data in their calculation of economic impacts.

i. National Drought Mitigation Center, Drought Impact Reporter (DIR)

The National Drought Mitigation Center launched the DIR in July 2005 as the nation's first comprehensive database of drought impacts. This update, released in fall 2011, collects and displays more types of information, providing researchers and interested members of the public with more context and detail, as well as more readily summarized information. The DIR drought database could provide relevant information on the status and overall cost of droughts. For example, the BDWCD uses "% Yield loss multiplied by market price for each affected commodity for each affected state" to calculate drought loss. The Drought Impact Reporter may be able to provide better granularity on the topics.

The database includes location of incidents, time-search parameters, the categories affected by the drought (Agriculture, Business & Industry, Energy, Fire, Plants & Wildlife, Relief Response & Restrictions, Society & Public Health, Tourism & Recreation, and Water Supply & Quality), the known direct impact dollar costs, and a field for any positive impacts. There are also other fields to help identify events and define the sources that contribute to the data entry.

The database is constructed from several sources. Data come from user reports, Community Collaboration Rain, Hail, & Snow Network Reports, media reports, burn bans, water restrictions, National Weather Service Drought information statements, other agency reports, Hawaii reports, and legacy information from prior databases are used in the creation of the database.

ii. State and Local Government Estimates

State and local government agencies often provide localized estimates of the overall costs associate with disasters that struck them. While a systematic analysis of the various state and local estimates is impractical, brief searches of news reports and media coverage surround disasters often provides several estimates produced by state and local agencies, including from state governors, comptrollers, and other executive agencies. These estimates can provide additional information in the calibration procedure, though generally these estimates would require a thorough investigation of what the agency did and how they arrived at the final numbers.

iii. Small Business Administration (SBA) Disaster Loan Program

The SBA provides financial assistance to home owners (or renters), small businesses and agricultural cooperatives located in disaster declared areas. SBA provides disaster loans and mitigation loans. Disaster loans are for homeowners (or renters), businesses and nonprofits to repair or replace disaster damaged personal property losses including automobiles, real estate, inventories, supplies, machinery and equipment. Small businesses, small agricultural cooperatives, and nonprofits can also apply for Economic Injury Disaster Loans to help cover daily operational obligations that cannot be met as a direct result of the disaster. Mitigation loans are available to cover improvement costs that protect private property from future damages (e.g., retaining walls, sump pumps, seawalls, etc.). Mitigation loans may not exceed 20 percent of the total amount of disaster damage, up to $200 thousand dollars for home loans and $2 million dollars for business loans. The SBA publishes weekly lending reports detailing lending activities for SBA loan programs. SBA also publishes quarterly data on the number of loans and gross approval amounts provided by the 100 most active SBA lenders. Deviations in the time series around disasters could be used to calibrate property loss estimates from disasters.

iv. DesInventar

DesInventar, or the Disaster Inventory System, is a database and conceptual methodology that is a system designed to acquire data concerning disasters of all sizes in Latin America. The conceptual framework was developed by a consortium of researchers and other organizations, led by the Network of Social Studies and Prevention of Disasters in Latin America (LA RED).

The system collects data from Latin American governments, insurers, and disaster responders as available. Data includes duration of the disaster, location, cause, death toll, magnitude, affected victims, infrastructure damage, cost in USD, and sectors affected. The DesInventar methodology proposes the use of historical data about the impact of disasters, collected in a systematic and homogeneous manner in the process of identifying hazards and vulnerabilities and thus risks on specific regions. Data must be collected following a set of standards and is time-stamped and geo-referenced and disaggregated to a relatively small geographic unit, usually a low level administrative unit. The basic criteria guiding DesInventar are:

- All inventories must use the same variables to measure the effects and the same homogeneous and basic classification of events.
- The information compiled and processed must be entered in a scale of time and at a geo-referenced spatial level;
- The information comprising DesInventar inventories MUST be spatially disaggregated in order to show (and later analyses) the effects of disasters at local level. For country level disaster inventories it is recommended a minimum disaggregation level equivalent to Municipality, usually one or two levels below the first administrative/political division (Province/State/Department, depending on each country).
- The inventories can then be analyzed following a number of existing and emerging methodologies, starting with the Preliminary Analysis Methodology, which give users an immediate understanding of the impact of disasters in a country or region, the possibilities of comparative research and support to decision-making processes related to risk reduction actions (including Risk Assessments) and risk management as a whole.

LA RED has conducted formal research of the above subject, with very interesting results showing that inventories made entirely based on media sources can be extremely comprehensive, and usually equally reliable as inventories made from official sources. However, it's important to concede that information in the databases is only as reliable as its source. The International Federation of Red Cross and Red Crescent Societies acknowledge that "...most reporting sources have vested interests, and figures may be affected by socio-political considerations.

NOAA does not currently use DesInventar but could if it chooses to expand its sources when computing its loss estimates. Effects in DesInventar are the sum of losses or adverse effects which take place in a specific geographical unit. These are the direct indicators of conditions of vulnerability in communities, regions and countries. DesInventar works with a list of variables of effects commonly generated by a disaster such as, those that affect people, homes, vital infrastructure, and economic sectors. In addition to the disaggregation of information, the geographical reference (resolution level), and the definitions of types of detonating events, the Effect fields definitions are at the heart of DesInventar's methodology. The effects of disaster have been classified in four groups: Related to people; Related to homes; Related to infrastructure and Economic losses.

v. GLobal IDEntifier number (GLIDE) database

The Asian Disaster Reduction Center (ADRC) created a database to standardize the identification and labeling of disasters throughout the world; the group built the database to house these common identifiers, as well as information on the disasters.

GLIDE contains information on major disasters throughout the world. Entries include identifying the country that the disaster took place in, the type of disaster, and the date, as well as a comment field that provides a brief description of the disaster and the damage that was caused. This number is posted by the above organizations (University of Louvain in Brussels (Belgium), OCHA/ReliefWeb, OCHA/FSCC, ISDR, UNDP, WMO, IFRC, OFDA-USAID, FAO, La Red and the World Ban) on all the documents relating to that particular disaster and gradually other partners include it in whatever information they generate. As information suppliers join in this initiative, documents and data pertaining to specific events may be easily retrieved from various sources or linked together using the unique GLIDE numbers. The success of GLIDE depends on its widespread use and its level of utility for practitioners.

ADRC has been implementing web-based GLIDE-associated disaster database development project in ASEAN countries since 2008 with the financial support by Japan ASEAN Integration Fund. The objective of this project is to facilitate all ASEAN countries to develop a national disaster databases with GLIDE numbers incorporated by training government officials in charge of disaster information in ASEAN countries. ADRC held operator training for both GLIDE and DesInventar with kind support from National Disaster Management Center (NCDM) and UNISDR at Brunei University. About 25 government officials from related departments participated in the training and actively exchanged views and opinions for future enhancement of the systems in Brunei.

ADRC includes wildfire data which might be useful for NOAA's database.

vi. Food and Agriculture Organization of the United Nations (FAO) – FAO Statistical Database (FAOSTAT)

FAOSTAT is a comprehensive database that keeps panel data on the world food output and demand.

FAOSTAT provides time-series and cross sectional data relating to hunger, food and agriculture for approximately 245 countries and 35 regional areas from 1961 through the present. It also offers an innovative tool, FAOSTAT Analysis, for basic statistical analysis of the data. Metadata methodology is very specific and detailed. Data are collected from UN member nations concerning food output, trade, and price level and inflation data. Key data series include producer prices on agricultural and livestock products (in USD), Agricultural trade flows by origin and destination, and agricultural production indices. The production indices are based on the sum of price-weighted quantities of different agricultural commodities produced, less quantities used as seed and feed. All the indices at the country, regional and world levels are calculated by the Laspeyres formula

If NOAA wants to consider livestock and agriculture statistics when calculating overall weather disaster losses, FAOSTAT could be a good place to collect these data.

vii. Swiss Re

Swiss Reinsurance Property and Casualty (Swiss Re) translates its global expertise and local knowledge into sound risk transfer and risk financing solutions in all lines of business. The Property & Casualty product offerings encompass traditional P&C across lines such as Engineering, Marine, Aviation and Agriculture as well as insurance products for corporate clients.

Swiss Reinsurance Company maintains the Sigma database, a limited access global natural (excluding drought) and man-made disaster database. Events are recorded from 1970 to the present. There are approximately 7,000 entries in the database with 300 new entries per year probably due to the more stringent inclusion criteria. Sigma requires at least one of the following for inclusion in the database; =20 deaths and/or, =50 injured and/or, =2000 homeless and/or, insured losses of >US$14 million (Marine), >US$28 million (Aviation), >US$35 million (all other losses), and/or total losses in excess of US$70 million. Disasters are recorded on an event entry basis and recorded information includes dead, missing, injured, and homeless along with detailed accounting of insured and uninsured damages. Sigma does not report "affected" nor does it clearly define the variables of dead and homeless. Sources of information include newspapers, Lloyds, primary insurance and reinsurance periodicals, internal reports, and online databases (although no primary source is suggested; it is possible that some NOAA data are included in the database). The database is not publicly accessible but Sigma does provide a yearly publication of "raw information" listing all disasters for the year available to clients.

viii. LANDFIRE

The LANDFIRE program evolved from increased concern about the number, severity, and size of wildland fires. LANDFIRE delivers consistent, recent, reliable data to support natural resource and fire management activities. Enhancements and improvements to the data products account for change in vegetation across the landscape such as those resulting from wildland fire, fuel and vegetation treatments, and/or management. Typical vegetation growth across all lands is also incorporated. Using these data, the LANDIFRE Data Distribution Site provides a dynamic online map interface that can be used to view USGS datasets.

The LANDFIRE products were designed to support national, regional, and sub-regional analysis activities. The program has several key considerations

- The native spatial resolution of LANDFIRE raster spatial products is 30-meters; however, the appropriate application scale is much larger than 30 meters, and varies by a combination of product, location, and specific use.
- Users should refer to the metadata and local, regional or expert knowledge to determine if LANDFIRE products are appropriate for application in their area.
- LANDFIRE products are not intended to replace local products, but serve as a rich supplemental data source with complete areal coverage, regardless of ownership.

LANDFIRE might be a good place for NOAA to use as a QA/QC on its wildfire losses data, in addition to insurance and NIFC data.

ix. EQECAT

EQECAT is a consulting firm that services insurance, reinsurance, and financial clients concerning risk of losses from catastrophic events. The firm produces several Catastrophe Risk Models and Perils, including several that cover U.S. disasters (with individual models predicting the effects of earthquakes, floods, hurricanes, offshore energy disruptions, convective storms, wildfire, and several others). The models are proprietary, but are available to be licensed to clients using EQECAT software for risk modeling. Data are primarily based on insurance information, though the lack of public model documentation makes ascertaining inputs and specific data difficult.

x. RMS Natural Catastrophe Modeling

RMS is a consulting firm for insurance, reinsurance, industry, and governmental clients that is capable of producing estimates of disasters impacts. Similar to the EQECAT and AIR models, the RMS models also attempts to estimate the likely damage from catastrophes, including creating estimates based on imperfect information and limited data. The models used are proprietary, so the workings and consistency is difficult to ascertain. However, the RMS models appear to provide real-time estimates of damage and incorporate all information that is readily available in order to provide as much information on damage and recovery as possible. However, the limited documentation of RMS models leaves the primary data sources and collection methods unclear.

xi. CDC WONDER Online Databases

The Center for Disease Control's (CDC) Wide-ranging Online Data for Epidemiologic Research (WONDER) online database utilizes a rich ad-hoc query system for the analysis of public health data. Reports and other query systems are also available. It is an easy-to-use, menu-driven system that makes the information resources of the Centers for Disease Control and Prevention (CDC) available to public health professionals and the public at large. It provides access to a wide array of public health information. WONDER furthers CDC's mission of health promotion and disease prevention by speeding and simplifying access to public health information for state and local health departments, the Public Health Service, and the academic public health community. CDC

WONDER is valuable in public health research, decision making, priority setting, program evaluation, and resource allocation. The WONDER databases provide information on Environment, Mortality, and Population topics among other subjects as well. Selected examples of information available in WONDER include the AIDS Public Use Data, Cancer Statistics, Online Tuberculosis Information System, Underlying Causes of Death, and Vaccine Adverse Event Reporting. The NOAA may find some of this information valuable for estimation of indirect deaths/health impacts due to weather and climate disasters, the WONDER data is a useful source for future indirect studies.

- The following sources are those that have traditionally incorporated NOAA data into their estimates. We have included an asterisk (*) to further indicate that they have including the economic impact estimates of the BDWCD, NHC, or NWS.

xii. U.S. Global Change Research Program (USGCRP) *

The USGCRP produces several models and climate estimates that look to determine the evolution of climate over time, including data that is generated by the NCDC and other NOAA divisions. Using NOAA data, as well as predictions and data from other sources, the USGCRP produces estimates of environmental impacts and vulnerabilities to climate change; these can include the frequency of disasters and potentially derive a cost associated with the "average" of such disasters. However, explicit and systematic modeling does not appear to be part of the USGCRP mandate.

The USGCRP has aggregated a significant amount of data from other sources, and some of the findings may provide useful reference for comparison of NOAA estimates. For example, one key finding from the 2009 report is a spike in weather-related U.S. electric grid disturbances, which could be an area of future research in economic impact estimations. The USGCRP annual reports could serve as a strong source of information in determining and defining future areas of research or need as the nature of damage inflicted by disasters evolves with an ever growing and changing economy.

xiii. Subcommittee on Disaster Reduction (SDR) *

The SDR employs estimates of economic impact of disasters from several agencies (including those of the BDWCD and other NOAA groups) and redeploys those estimates in discussions of potential savings from reducing the size and scope of those disasters. While most SDR reports do not explicitly model the effects of disaster reduction (at least not systematically), the reports carry an implicit economic impact value to reducing the number of disasters; they do so by using the total costs estimate from previous disasters and discussing mitigation of future catastrophic results as avoided cost.

xiv. Centre for Research on the Epidemiology of Disasters (CRED)*

CRED, the Centre for Research on the Epidemiology of Disasters, has been active for over 30 years in the fields of international disaster and conflict health studies, with research and training activities linking relief, rehabilitation and development. CRED promotes research, training and technical expertise on humanitarian emergencies, with a special focus on public health and epidemiology. In addition to providing information on the human impact of disasters, such as the number of people killed, injured or affected, EM-DAT provides disaster-related economic damage estimates and disaster-specific international aid contributions.

CRED has a long history of standardized data compilation, validation and analysis. It provides free and open access to its data through its website. One of CRED's core data products is the International Disaster Database (EM-DAT). EM-DAT provides an objective basis for vulnerability assessment and rational decision-making in disaster situations. For example, it helps policymakers identify disaster types that are most common in a given country and have had significant historical impacts on specific human populations. The database also has query functionality, where users may specify data acquisition along the follow axes:

- Location, Region, Country
- Timeframe, Decade, Year
- Disaster
- Disaster Group (Natural, Biological, Climatological, Complex Disasters, Geophysical, Hydrological, Meteorological, Technological)
- Disaster Type (Complex Disasters, Draught, Earthquake - seismic activity, Epidemic, Extreme Temperature, Flood, Industrial Accident, Insect Infestation, Mass movement dry, Mass movement wet, Miscellaneous accident, Storm, Transport Accident, Volcano, Wildfire).
- Total number of deaths
- Total number affected

Table 8 – EM-DAT sources by disaster type

Source Type	Source Name	Natural and/or Technological Disasters
National Governments	ADRC Alzheimer Disease Research Center	Natural Disasters
	CDERA Caribbean Disaster Emergency Management Agency	Natural Disasters
U.S. Governments	FEMA Federal Emergency Management Agency	Natural Disasters (America)
	NOAA National Ocean and Atmospheric	**Natural Disasters**

	Agency	
	OFDA Office of Foreign Disaster Assistance, USAID	Natural and Technological Disasters
	USGS, US Geological Service	Earthquakes
	Smithsonian	Volcanoes
	DFO Dartmouth Flood Observatory	Floods, slides, and windstorms
	CDC Centers for Disease Control	Epidemics
Non-Governmental Organizations	IFRC International Federation of Red Cross	- - - -
Inter-Governmental Organizations	World Bank	Major Natural Disasters
Reinsurance Companies	Lloyd Casualty Week, Insurance Company	Natural and Some Major Technological Disasters
	SwissRe, Leading Global Reinsurer	Natural and Technological
	MunichRe, Leading Experts on Risk Solutions Worldwide	Major Natural and Technological Disasters
Press	AFP American Free Press	Natural and Technological Disasters
Others	AirDisaster	Air Accidents
	Emerg. Manag.	Natural and Technological Disasters

The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. Most of the data comes from the UN agencies, member governments, and the International Federation of Red Cross and Red Crescent Societies. Table 8 (on next page) shows the variety of sources which feed into the EM-DAT database by source type, source name, and type of disaster data captured. New and old data are subjected to frequent quality checks to avoid redundancy, inconsistencies and incompleteness. Data are consolidated on a daily basis, with further checks monthly. Revisions are implemented annually. EM-DAT also includes NOAA data in the database, however preliminary comparisons reveal that the NOAA data incorporated is not directly acquired from BDWCD, NHC, or WFO.

EM-DAT disaster criteria differ from that of the NOAA organizations and results in a much larger database of disasters by both scope (coverage of epidemics and earthquakes) and number (lower threshold for event inclusion). Specifically, one of the following criteria must be fulfilled for a disaster to be entered into the EM-DAT database:

- Ten (10) or more people reported killed
- Hundred (100) or more people reported affected
- Declaration of a state of emergency
- Call for international assistance

The database is used for a variety of purposes. Development and relief agencies have long recognized the important role played by data and information in mitigating the impacts of disasters on vulnerable populations. Systematic collection and analysis of these data provides invaluable information to governments and agencies in charge of relief and recovery activities. It also aids the integration of health components into development and poverty alleviation programs.

4. Non-Disaster Models

There are several models that are capable of estimating the economic impacts of various disruptions to the U.S. economy from climactic- or weather-related disasters based on the initial damages. More formalized write-ups of each of these models can be found in the appendix. A high-level inventory of models that could be beneficial to cost estimation is listed in Table 9 below.

While the primary purpose of the NOAA estimates are to determine direct losses associated with the disasters, many of these modeling tools can be used to augment the estimations by using historically-based economic multipliers and sector-specific estimates of impacts based on the functionality of each tool. Additionally, **these models do not rely on NOAA-generated data, and thus could introduce additional information into the estimation of direct and indirect costs of a disaster.** For example, there are several energy-related models that might provide more robust analysis of the effect to electricity grid disruptions, pipeline damages, power plant outages, or fuel price spikes. Similarly, food- and crop-based models can simulate potential disruptions based on data collected to identify more robust estimates of the supply disruptions and price-changes. Additionally, some of these models already are used for analysis of disaster-related losses and severe weather events. For example, the Short-Term Energy Outlook model has a hurricane model that estimates lost oil-production in the Gulf of Mexico due to cap-in practices during cyclones; these estimates are initially derived from the NHC's seasonal forecast of expected hurricane activity in the Atlantic and historical cap-in production loss.

Broadly, there are three categories of models included here: **macroeconomic models**, **energy and environmental models** (usually with macroeconomic feedbacks), and **agricultural models**. These are listed here as tools capable of estimating economic, agricultural, energy, or environmental effects that could potentially augment disaster estimates. Specific write-ups of the models in Table 9 can be found in the appendix. A full discussion of how to incorporate these models into the impact analysis projects can be found in the Recommendations document.

Table 9 – Potentially useful models for running counter-factual and indirect impact analyses

Macro Models	Energy & Environmental Models	Agricultural Models
-GTAP	- ASPEN	- AGLINK
-IHS (several)	- MARKAL	- FAPRI
-IMPLAN	- STEO (EIA)	- FASOM
-REMI	- NEMS (EIA)	- IMPACT
-MSMNE-02		- POLYSYS
-FAIR Model		
-SEBAS		

C. Other Useful Resources, Literature on Cost Estimation

This section briefly reviews several relevant academic articles, white papers, and other published resources relevant to the estimation of weather- and climate-related disasters which the BDWCD can reference when considering future adjustments or changes to the current methodologies. These studies are listed by relevance to the methodological review; studies that focus on quantification of direct losses (rather than indirect losses), potential input values to the NOAA estimates (rather than those that rely on the NOAA data to arrive at their conclusions), and scope of the study (US-centric versus global analysis) will be found earlier in the list.

i. Measures of Economic Impacts of Weather: Extremes Getting Better but Far from What Is Needed— A Call for Action - Stanley D. Changnon (2003)

The author discusses the practices used to estimate the economic impact from extreme weather- and climate-related events, and generally finds them to be lacking. He further identifies 4 studies (Kunreuther [1998], Heinz Center [2000], Mileti [1999], & NRC [1999]) that also identify deficiencies in the loss data. The author has a brief rundown of several of the key issues and problems associated with providing an accurate and comprehensive loss evaluation, most notably the **lack of consistent data collection** and the infeasibility of collection in some cases. **The author's primary recommendation is that a federal agency be formed within NOAA that would have responsibility to collect, standardize, and analyze data in the event of a disaster**, including a multidisciplinary staff that could adequately execute all aspects of the mandate (in collaboration with other federal, state, and local agencies measuring impacts on the ground).

ii. Normalized Hurricane Damage in the United States: 1900–2005 – Pielke et al (2008)

As described in the NHC section, the authors of this study developed methodology for **adjusting historical direct losses from cyclones to compensate for current population and infrastructure**. Essentially, in addition to altering nominal disaster estimates for inflation, the authors look at the current makeup of the regions that were affected by historical storms and project the impact that those storms would have had were they to occur today. First, they adjust the traditional estimates by normalizing for inflation (in the same manner as most other studies, using the Implicit Price Deflator for GDP as the inflation measure) using the most current year in the dataset as the base year. Secondly, they adjust the loss estimates by changes in wealth per capita; to do this, they use the BEA's estimates of current-cost net stock of fixed assets and consumer durable goods produced each year. Finally, they adjust the economic loss for populations by comparing the Coastal Services Center's detailed list of affected counties for each storm with the current population's information from the Census Bureau (linearly extrapolating population growth for years that a decennial census does not occur). These three adjustments are combined to normalize the historical estimates and simulate the expected cost of a similar strike today. They find that these procedures mute or eliminate entirely the upward trend in storm costs found in the data. That is, the authors find that storms do not appear to be inflicting more damage than they had in the past, conditional on price level, wealth, and population density.

iii. Results from an Assessment of the National Weather Service's Storm Data Loss Estimation Methodology – Laidlaw, Lazo, & Bushek (2010)

This information was presented at the 2012 American Meteorological Society's annual meeting. The three presenters from the National Center for Atmospheric Research (NCAR) made **specific recommendations on how to improve the Extreme Weather Sourcebook**. The researchers surveyed 123 employees at different WFOs about the data collection and estimation methodologies, and ran a quantitative survey of 647 events from the database (all events occurred between August, 2007 and July, 2008). Specifically, the NCAR's own work and examination of the literature find that there are differences across hazard and disaster types in reporting and representation, changes in loss data methodology that make estimates from different years potentially incompatible for comparison, inconsistency in setting a minimum threshold for examination (i.e., there may be some storms that inflicted larger losses than the smallest storms in the database), inconsistent definitions of what is or is not included as a loss, and differences between the methodologies of the various loss databases. The authors indicate that several process improvements have been implemented and are ongoing.

iv. Insurance in a Climate of Changes – Evan Mills (2005)

This article is a discussion of the rising costs associated with disasters and the role that the insurance companies has played in the past, as well as advocating for further involvement in the future. Most of the discussion is of **insured losses**, as well as the relative **size of the insurance industry's share of these losses relative to the entire cost of the damages**. The focus is on the world at large rather than on the U.S., and the data are mostly composed of those from Swiss Re (a large reinsurer). The author demonstrates that the overall cost of disasters, both on aggregate and more specifically to insurers, has been growing faster than world income and world premiums; were this trend to continue, the current insurance system would become inadequate as premiums would no longer be actuarially appropriate and the required premiums would exceed an economically feasible value.

v. Disaster Cost Estimates: FEMA can Improve Its Learning from Past Experience and Management of Disaster-Related Resources – GAO report (2008)

The U.S. Government Accountability Office (GAO) produced a report summarizing key areas that FEMA could improve its cost estimates of disaster costs. The report outlines both **past failings and process improvement that FEMA has made in the estimation process**, while also suggesting **ways in which the process could be improved further** (primarily, better quality assurance of historical and new data, more robust historical estimates to draw upon, more consistency across program requirements, and further sensitivity analysis of current practices). Specifically, they found that FEMA's initial and near-term estimates were not precise enough to be sufficiently valuable in cases where federal liabilities were under $500 million, as the size of later revisions were unacceptably high. They also found inconsistencies in methodology based on the different program that was used to deliver support, with the Public Assistance, Individual Assistance, Hazard Mitigation Grant Program, and Mission Assignments estimate all using slightly different methodologies. Additionally, the data collection and quality management systems were substandard, making historical inference less precise or even biased, as the consistency of data labeling and indexing was poor. The report acknowledges that FEMA has taken steps to address many of these deficiencies, though they also highlight several areas for improvement by laying out specific recommendations on dealing with imprecision and uncertainty in short-run estimates. The report ultimately advocates nine specific recommendations concerning process improvement of the cost estimates and procedures, mostly relating to data quality and calibration of initial estimates with historical data.

vi. Shifting Economic Impacts from Weather Extremes in the United States: A Result of Societal Changes, Not Global Warming – Changnon (2003)

This is a paper on the difficulties of estimating losses (both **direct losses** and indirect) from disasters, while also discussing the main drivers of increased disaster losses over time. The author defines losses as market-based negative economic impacts and includes the costs associated with the aftermath of extreme events (i.e. **indirect losses**). The author states that all forms of historical loss data need adjustments for inflation and shifting risks of damages[23]. A recent in-depth study of thunderstorm extremes (lightning, hail, tornadoes, heavy rains, and high winds) in the U.S. revealed (1) there had been no increase in storm frequencies or intensities during 1950–1997, but (2) storm losses had increased over time and were clearly tied to measurable demographic shifts into high risk areas. Inadequate loss data and lack of awareness of the changing risks were the causes underlying the large insured losses, not increases in storms resulting from global warming. The author also points out deficiencies in previous direct loss estimates, such as most environmental damages.

vii. Modeling catastrophe claims with left-truncated severity distributions – Chernobai, Burnecki, Rachev, Truck, & Weron (2006)

This study examines the impact on disaster models using different distribution specifications of the likely scale and scope of an event. Using PCS data, the authors find that **the insured loss estimates of the models are highly sensitive to certain specifications, and that an appropriate approach to modeling risk requires that the distribution of losses based on PCS data requires using a truncated distribution** (that is, one where the traditional "bell" shape of the curve has one side flattened). This is required because the PCS data on disasters have a lower threshold for estimated property damage (currently set at $25 million in nominal insurance losses, though previously this threshold was $5 million), with events that cause less damage than the threshold being excluded

[23] Ultimately, the desires of the author appear to be met by the techniques of Pielke et al (2008).

from the database. Similarly, this framework is also applicable to reinsurance companies, whereby insurers are not subject to reimbursement from catastrophes unless the overall loss from the event is higher than minimum threshold. These corrections are of particular importance, as misjudging the expected losses from disasters, a failing which not accounting for the truncation would create, could lead to the bankruptcy of the insurer and thus inefficient distribution of risk within an economy. The authors conclude that a **Truncated Lognormal distribution provides the best fit for both historical analysis and out-of-sample forecasting**.

viii. Federal Financial Exposure to Natural Catastrophe Risk - J. David Cummins, Michael Suher, and George Zanjani

The authors of this study, relying primarily on data similar to those used by the BDWCD and NHC, estimate the **expected annual costs to the federal government of its current policy on emergency management and response to natural disasters**. The authors primarily use PCS data and AIR models, data from Munich Re, and **overall disaster tallies taken directly from the NCDC BDWCD**. The authors estimate that the federal government should expect to expend $20B per year in disaster cleanup and relief, with a likely upper bound of $100B in an extreme year. These estimates are based on a dataset and methodology quite similar to that used in the BDWCD approach, and forecasting that methodology outwards onto AIR forecasts in order to back out future government liabilities. Specifically, the authors rely on using insurance loss data from the same PCS database and then scale those estimates up to match the uninsured losses. However, as the authors are undergoing a forecasting exercise, they do appear to use a distributional approach to define the size of the uninsured losses based on the forecasted events.

ix. Efficiency of Weather Derivatives as Primary Crop Insurance Instruments – Dmitry V. Vedenov and Barry J. Barnett (2004)

The authors design a model to create a set of weather derivatives that would **optimally cover crop losses from storm activity**. The authors find that the optimal policies for different crops and regions vary widely; additionally, the amount of risk-reduction possible from these derivatives is also highly variable across crops and regions. The authors use extremely generous assumptions and several potential specifications of preferences, as well, which suggest that these estimates represent a lower bound of the requisite actuarially fair prices and/or the upper bound on the amount of risk-reduction provided by the existence of the insurance product. The authors also find that their out-of-sample forecasts of their instruments, based on in-sample estimations, perform poorly. The authors also find that the actuarially fair contracts require very specific realizations of weather and yield.

x. Temporal Fluctuations in Weather and Climate Extremes That Cause Economic and Human Health Impacts: A Review – Kenneth E. Kunkel, Roger A. Pielke Jr., and Stanley A. Changnon (1998)

This article is a thorough literature review on the data and methodologies of estimating weather- and climate-related disasters over the previous 25 years before publication. The article cites 76 articles, and provides an extensive discussion on the work related to **trends of disaster costs and estimates**, as well as floods, hurricanes, thunderstorm-related losses (including hail storms and tornados), winter storms, droughts, and extreme heat and cold spells. They conclude that, while the costs associated with these disasters appears to be steadily increasing over time, the frequency of disasters has not seen much of a rise; rather, shifting demographics and concentrations of population and wealth have exacerbated the effects and costs of these disasters.

Additionally, they have a discussion of the key elements that go into the data collection, methodologies used in calculating loss estimates, and some of the pitfalls of making cross-comparisons of studies. Specifically, the timeframe and region size of the estimator's loss area, as well as the definition of what is considered attributable to the disaster (quantifying lost lives, economic knock-on effects, etc), unquantifiable effects, and proper identification of factors influencing the losses (did the affected area see increased population growth in recent years, has there been significant investment in disaster mitigation infrastructure, etc) are all important considerations that must be understood to properly analyze any loss estimates in context.

xi. The Economics of Natural Disasters: Concepts and Methods – Stephane Hallegatte & Valentin Pryzluski (2010)

This paper, produced for the World Bank's Policy Research Working Paper Series, examines the methodologies that different organizations and institutions use in producing estimates of the cost of a disaster. The authors highlight several key elements that lead to discrepancies between estimated costs, including scope, temporal period, definitions, and purpose of the estimate. The authors propose a codified definition of what should be included in the calculations of cost, as well as highlighting the important determinants of that cost. They stress that **the direct costs (property and infrastructure) are only a limited part of the calculation, as rebuilding expenditures and foregone economic activity represent significant elements of any calculation**. The paper examines both developed nations and developing/pre-industrial ones, as the focus is primarily on how to adequately measure indirect costs in disasters in any geographic area. The authors highlight several key differences between methodologies that occur, both based on the purpose of the estimate's producer (e.g. insurers vs. government agencies) and by hazard type (e.g. hurricanes vs. droughts).

The authors highlight several of the potential problems and pitfalls related to the calculating indirect costs. They discuss the issues with choosing a baseline scenario, as well as issues surrounding displaced activity offset by reconstruction efforts. These issues are further complicated by analysis of the disasters effects on price levels and exchange rates, whose influence on the rest of the economy can be hard to properly identify (especially since previous estimates of elasticities might no longer be valid if the economy is out of the sample in which the estimates were identified). They also discuss the **changes to the relative value of non-affected assets and capital**, as the Tobin's Q-value of individual assets would likely be significantly changed both by interest rate movements and by the relative capital stock remaining in the country. Finally, the authors also discuss the changing socioeconomic factors that occur, as the dynamics of the economy in terms of poverty reduction and wealth accumulation may be significantly altered.

A literature review of past attempts at measuring indirect costs is included in this report. The review includes attempts at capturing the information through surveys and other information directly, econometric modeling, other parametric attempts to model the damage based on historical data, and a few non- or semi-parametric attempts.

The authors conclude that **a universal definition of "cost" is nearly impossible to systematically define**, and thus that any analysis of a disaster requires a significant amount of judgment that should be determined by the overall purpose of the estimate. Additionally, the authors find that the current methodologies and data collection/quality control are both lacking. They propose that more research be focused on an equilibrium disturbance approach that might better define out-of-sample elasticities and economic agent preferences in these situations. They also suggest differentiating between natural disasters and other macroeconomic shocks to determine if the dynamics of recovery differ and, if so, how they do. They suggest further investigation and quantification of network effects to better understand the ultimate costs of disruptions. Finally, they suggest further investigations into the role of credit and finance in reconstruction based on the wealth and substitution effects specific to disaster-related losses.

xii. The Use of Computer Modeling in Estimating and Managing Future Catastrophe Losses – Karen M. Clark (2002)

The author describes the general development of computer models in estimating models, some of the current purposes for which models are being used, and potential for future uses. After a brief description of the models developed, including several described in this document (AIR, RMS, EQECAT), the author describes how the models function, outline the flow of information from the disaster to the afflicted areas, the probabilistic distribution of damage, **and the generation of the likely insured losses**. The author then discusses the "back-end" calibration and validation of the model's estimates, and includes a section on the most recent developments; these developments are primarily based on better data with longer historical records, improved computing power, incorporation of more sophisticated weather predictions developed by climate and weather scientists, geologists, and other experts. The author also discusses how best to use and interpret the results of these models, particularly for insurers and policy makers.

xiii. Tracking insurance industry exposures to CAT risks and quantifying insured and economic losses in the aftermath of disaster events: a comparative survey - Monti and Claudio Tagliapietra (2009)

This paper examines the economic impact of catastrophic risk exposures. Specifically, they focus on the lack of standardization of terminology, data collection efforts, classifications, and both domestic and cross-border integration of collection efforts. **This study describes the process that PCS uses to collect data. The authors also do a similar discussion of the European equivalent to PCS, Pan-European Risk Insurance Linked Services (PERILS AG)**. Additionally, the authors describe insured risk databases and disaster database compiled by Swiss Re, Munich Re, the Centre for Research on the Epidemiology of Disasters, and the ADRC Global Disaster Identifier Number (GLIDE) project. The authors then compare and contrast the different purposes and components of the various databases, finding that the consistency across databases is lacking, as is transparency of discretion used in the collection and estimation processes, and coverage in different regions of the world is inconsistent. The authors conclude that the scope of analyses, as well as the definitions and methodologies used, can create large discrepancies across organizations in terms of the overall economic impacts that are estimated for the same disaster.

xiv. The Economic Impact of Crop Losses: A Computable General Equilibrium Approach – Sherony, Knowles, and Boyd (1991)

The authors generate a Computable General Equilibrium model to analyze the direct and indirect costs associated with crop losses due to global warming. The authors parameterize the model based on historical data, including several sectors of production, demand, as well as other economy-wide variables. They provide **a complete list of estimated elasticities**, which could be useful in other studies looking to capture the macroeconomic feedback from a natural disaster that creates large-scale crop losses. They conclude that, based on the estimated elasticities and the feedback between the agricultural sector and the economy at large within the model, there is likely a relatively small adverse effect from an instance of crop failures in terms of impact on the greater economy.

xv. Dynamic Data-Driven Wildfire Modeling – J. Mandel et al.

This paper proposes a system for real-time modeling of wild-fires. Specifically, the model pulls publically available data on the fires, weather, and fuels from several sources on the internet and uses them to model the likely direction and intensity of the spread of active wildfires. The system is composed of five component sections: a numerical coupled atmosphere/fire models; a data acquisition model that pulls information from the internet on GIS maps, fire information, and weather while also incorporating data from the field in aerial photos and sensors; a visualization interface that presents user the information; a control module that manages the inflow of data and the outputs of the various models; a secure communications infrastructure that is capable of broadcasting the real-time results into the field for use by firefighters and other emergency support services.

The structure primarily relies on an existing prediction models for updating the likely path and intensity of the overall structure: the National Center for Atmospheric Research's coupled atmosphere-fire model, which is a combination of an "empirical fire spread model such that sensible and latent heat fluxes from the fire feed back to the atmosphere to produce fire winds, while the atmospheric winds drive the fire propagation" and a meteorological model using "three-dimensional non-hydrostatic numerical model based on the Navier-Stokes momentum, thermodynamic, and conservation of mass equations using the inelastic approximation."

The model relies on inputting data from government GIS maps, raw data from various weather sources (including NOAAPORT broadcasts), MesoWest weather stations, and NOAA's Rapid Update Cycle (RUC) weather system. Fire information comes from U.S. Geological Survey's GeoMAC project, as well as potential sensor and infrared/thermal data from unmanned drones over the fires (when possible).

xvi. The Economics of Natural Disasters: A Survey –Cavallo & Noy (2010)

This report, sponsored by the Inter-American Development Bank (IDB), provides an extensive **literature review of disaster impacts on economic development**. The paper has an excellent review of the data sources available for the analysis. The datasets described are most those relevant to developing and pre-industrial nations, such as the set maintained by the Center for Research on the Epidemiology of Disasters (CRED), data from Munich Re and Swiss Re, NOAA databases, and the Pielke et al (2008) database. The report then summarizes a model for the determinants of initial costs, cross-country studies of the short- and long-run effects of indirect impacts, several case studies, papers that examine policy response and ex-ante best practices, and finally discusses several gaps in the literature on the impacts that disasters can have on developing and pre-industrial nations.

xvii. A Survey of Demand Elasticities in Support of the Development of NEMS – Dahl (1993)

This paper represents a comprehensive look at the demand elasticities of various energy sources, fuels, and prices. The author **provides several hundred estimates of elasticity parameters** that are found throughout the economics/energy literature. This document is both a valuable resource for estimating energy-related effects after a disaster, and also a potential template for similar analysis that could be produced on local economies. A similar document that summarizes the local and state demand-elasticities could be invaluable in estimation of indirect economic effects of weather- and climate-related disasters.

xviii. Disaster Loss Data Standards (2008)

Prepared by the Working Group on Disaster Data, the Disaster Loss Data Standards (DLDS) is a manual that **proposes an international codification and harmonization of data collection and loss estimation procedures**. The report strongly advocates that a standardized approach would carry significant benefits that outweigh the costs and difficulties of implementing such a process. Specifically, they advocate standardizing use cases, terminology and content of data, transaction compatibility, and interoperability specification. The report outlines current efforts by several groups to standardize practices including Munich Re, CRED, GLIDE, and LA RED. The manual also contains a thorough guide to proposed standardized categories, coding procedures and interoperability specifications.

xix. Economic Crises and Natural Disasters: Coping Strategies and Policy Implications – Emmanuel Skoufias (2003)

This paper is a review of several studies presented at a conference titled "Crises and Disasters: Measurement and Mitigation of their Human Cost" which was held by the International Food Policy Research Institute (IFPRI), the Inter-American Development Bank (IDB), and with support of the World Bank and U.S. Agency for International Development (USAID). The report primarily focuses on the **impacts that disasters can have on developing and pre-industrial nations**, with analysis of the way that households in these countries mitigate and cope with disasters as well as similar strategies and policies of the governments in the institutions. The paper identifies factors that affect growth, poverty, and nutrition in these countries, as well as the characteristics of the affected countries that appear to result in different outcomes. Findings of particular relevance to the U.S. include discussions of **the relative outcome of self-insurance and loss provision significantly influencing how resources are deployed within the affected regions**, and the intergenerational impacts that disasters have on families, and the relative flexibility of labor markets, trade, and exchange rates can influence the permanence of the shocks and the speed of recovery.

xx. Understanding the Economic and Financial Impacts of Natural Disasters – World Bank Special Report - Disaster Risk Management Series No. 4 – Charlotte Benson & Edward J. Clay (2004)

This report provides a review of **financial impacts of natural disasters on developing and pre-industrial economies**, as well as three case studies of countries that experienced natural disasters. The study focuses on both the short- and long-run effects that disasters can have, as well as factors that contribute to a country's sensitivity to a disaster, its resiliency and ability to recover, as well as its ability to mitigate long-run impacts. The report finds that, while the short-run effects of a natural disaster can be devastating for an economy, many countries have the ability to return to a long-run growth path and even erase any long-term effects of the disaster (though not all do so). The authors suggest that finalized tallies and impact analyses should be recalculated 18-24 months after an event to get a more accurate accounting of the disasters impact. **The researchers use a significant amount of qualitative factors** in the analysis which makes consistency of results and transferability to U.S. analyses less ideal.

xxi. The Macroeconomic Consequences of Disasters –Ilan Noy (2007)

The author examines data concerning natural disaster recoveries across a panel of countries in diverse stages of development. The author focuses primarily on the **ex-ante factors that predict a faster and more robust recovery from a natural disaster**. Using baseline forecasts compared to actual output after the disaster, the author assumes the residual to be the foregone economic output of a number of years. Under this framework, the author finds that many of the traditional hallmarks of positive development (literacy rate, income per capita, institutional quality) are all indicators of faster recovery. Additionally, the size of the government sector is predictive of faster recovery (with larger governments usually allowing for faster recovery), as well as the openness of the financial markets as measured through the capital account (less free flow of capital tends to lead to faster recovery, presumably due to both the ex-ante non-reliance on foreign capital as well as the potential inability of foreigners to withdraw funds), while well-developed credit markets and large foreign exchange reserves also predict faster recoveries.

D. Potentially Useful Sources of Information

In order to maintain consistency across estimates of different disasters, NOAA must find data sources that are consistently constructed and routinely available after weather- and climate-related events. In addition to the data sources and research discussed in the previous sections, the research team has also identified several publically-available databases that could augment economic impact assessments. This section outlines those data sources that, while not specifically focused on weather- and climate-related disaster, might provide relevant information for estimating or calibrating disaster estimates. The information that these data sources provide ranges from data on recovery from disasters of all sorts, to data that address specific economic- or infrastructure-related information that might have been disrupted by a climatological disaster.

Stafford Act Data Application Information – FEMA receives applications from states and local governments concerning recovery from disaster as part of the Disaster Relief and Emergency Assistance Act, specifically for reconstruction, repair, or restoration of a facility or facilities. Accessing these applications, whereby states or local governments have applied for aid, could further augment disaster cost estimates by recalculating the total costs of reconstruction. Both the applications (with state and local estimates of the costs) and the ultimate awards by FEMA (administered through the Public Assistance Program) could help refine and verify previous estimates.

U.S. Fire Administration (USFA) – The USFA (part of FEMA) provides information on fires in the U.S., aggregated up from local fire departments responding to an annual survey. These estimates include overall direct dollar losses in structures for various categories, including causes and fatalities. As they have the data separated out by cause (including "natural", which should include wildfires; they do have an "acreage affected" number for wildfires in the database), these data could provide another source for calibrating disasters related to fires. However, the data appear to be more robust for non-disaster related fires. Note that all dollar values are scaled using the CPI-U. The USFA joined the National Interagency Fire Center (NIFC) in 2003; the USFA contributes to NIFC by working with county and local fire departments which provide primary fire protection on public and private lands covering additional hundreds of millions of acres across all 50 states.

U.S. Department of Housing and Urban Development - Community Development Block Grant (CDBG) Program & HOME Investment Partnership Program – Disaster Recovery Assistance – This program, run by HUD, is one of the block grant programs that provide money to rebuild areas affected by a disaster. Specifically, these funds tend to be appropriated by congress on a disaster-specific basis to provide additional resources in the post-disaster rebuilding effort. These funds are run through the CDBG program to supplement funds from FEMA, the Small Business Administration (SBA), and USACE. Application and funding data from these programs could also refine estimates of total losses beyond those covered by insurance payouts; this could be particularly informative, as HUD funds tend to be distributed to low- or moderate-income areas where insurance coverage could be less than that found in more affluent communities, thus allowing for a more appropriate calibration of estimates.

St. Louis Federal Reserve Economic Database (FRED) – This database pulls data from 48 domestic and international sources including BLS, BEA, Census, etc. This resource is particularly valuable for pulling data from several different sources simultaneously. These data include nearly all data available from the various website of the BEA, BLS, Census, and other relevant databases (including regional, state, and MSA information where available). This resource is particularly valuable for finding data related to lost economic activity and employment due to disaster. The database can quickly access several key data series, such as employment, population, per capita income, coincident economic activity indices, weekly unemployment claims, construction, prices/inflation, etc. Data are of varying duration (weekly, monthly, quarterly, annual), and are collected by different government agencies working under individual mandates.

Energy Information Administration (EIA) – Several Sources (Including STEO Query System, and fuel-specific statistical databases) – In addition to offering several modeling tools (NEMS, STEO), the EIA publicly produces information concerning prices and quantities of various fuels and products concerning energy, as well as other information on energy-specific topics (such as refinery capacity). These data could be particularly useful in determining the overall costs of certain disaster types that have had a large impact on energy or energy-related production. Mostly, these tend to be at the monthly frequency, and regional information on most of the variables is available. STEO also publishes forecasts of many of these prices at the monthly frequency, so unexpected volatility outside of normal forecast error ranges in these estimates could serve as a useful counter-factual due to disaster-specific events. Similarly, NEMS (the long-term forecasting tool) has the capability to examine regional and even plant-specific factors that could occur due to a disaster, though only at the annual frequency. Additionally, the EIA Major Disturbances and Unusual Occurrences database can provide disaster-specific detail on power outages and grid disruptions. These disruptions can be anything that hinders generation, transmission, or distribution of electricity in a normal manner. Data include dates, utility or power pool, time, area affected, type of disturbance (including severe storms and other natural phenomena), total loss of electricity, the number of customers affected, and the restoration time.

Food & Agricultural Organization (FAO) – The FAO (part of the United Nations) has several databases and software tools that can provide time-series information on agricultural production, livestock, food supplies, fisheries and marine activity, and farm inputs such as fertilizer. For disasters that impact agriculture or commodities markets, this data could be useful in fleshing out overall effects and changes in trends.

Lloyd's Excess Flood Information – Private insurer Lloyd's offers policies that cover flood damage in excess of NFIP coverage limits. While their data are proprietary, NOAA could attempt to facilitate a working relationship with Lloyd's to acquire the information in exchange for highlighting the data sources used in calculation.

II. Relevant Federal Policies and Guidelines

Federal agencies have decades of experience with economic analyses of weather (and more recently climate) related damages driven by regulatory and statutory requirements. However, guidance and methodologies for assessing damages and economic impacts sometimes vary depending on organization's mission and the classes of weather- and climate-related damages.

The Environmental Protection Agency (EPA) - National Center for Environmental Economics Office of Policy's Guidelines for Preparing Economic Analysis manual published in Dec. 2010 sites several of the regulations and statues federal programs must follow for conducting economic analyses:

- Executive Orders:
  - Executive Order 12866, "Regulatory Planning and Review"
  - Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations"
  - Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks"
  - Executive Order 13132, Federalism"
  - Executive Order 13175, "Consultation and Coordination with Indian Tribal Governments"
  - Executive Order 13211, "Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use"
- Statutes:
  - The Regulatory Flexibility Act of 1980 (RFA) as amended by The Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA), (5 U.S.C. 601-612)
  - The Unfunded Mandates Reform Act of 1995 (UMRA) (P.L. 104-4)
  - The Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3501)

The researchers found two additional statutes that likely have meaningful implications for storm damage assessments. The first is among the most significant federal regulations for ecological analysis and quantification. It is the National Environmental Policy Act of 1969, as amended Pub. L. 97-258, §4(b), Sept. 13, 1982. (Scarlett and Boyd, 2011). Ecosystem analysis likely benefits weather and climate related damage and economic impacts. The second is statute S. 601 Weather Mitigation Research and Development Policy Authorization Act of 2009. This act establishes a Weather Mitigation Research Office within National Science Foundation for the purpose of coordinating studies and provides grants to academia, state agencies, and nonprofit organizations to explore methods to reduce the impact of server weather.

Two Federal agencies, EPA and U.S. Army Corps of Engineers (USACE), provide relatively current, general economic impact analysis guidance overviews/primers/manuals. These guidance documents provide high level standard economic impact analysis methodologies that are applicable to weather and climate related damages and the associated economic impacts. These documents include:

- EPA - National Center for Environmental Economics Office of Policy's Guidelines for Preparing Economic Analysis
- USACE – Economics Primer
- USACE – National Procedures Overview Manual: Overview
- USACE – Regional Economic Development Procedures Handbook
- USACE – Coastal Storm Risk Management
- USACE – Flood Risk Management Manual

However these guidance documents generally exclude assessment methods for most classes of weather and climate damages.

NOAA's NWSPD 10-16 Storm Data Preparation Directive is the most comprehensible Federal guidance for accessing all classes of weather and climate related damages and the associated economic impacts. During our review, the research team did not find another Federal agency that provided guidance on all classes of weather and climate related damages. The Federal Records Act of 1950 (P.L.754, 81st Congress) defines NOAA NCDC's statutory mission as the official US archive for climatic data records. Thus, the NCDC describes historical trends and anomalies of weather and climate rather than weather and climate forecasts.

Additionally, the Magnuson-Stevens Fishery Conservation and Management Act (MSA), under section 315, requires that NOAA's National Marine Fisheries Service produce economic and socio-economic impact analysis of any storm or event that is declared a federal fisheries disaster area. These reports must be produced within two months of the disaster being declared.

Several agencies do provide guidance on estimating specific classes of storm damages. Impact guidance from floods is one of the most prevalent associated with storm damage. USACE, the Bureau of Reclamation, the Tennessee Valley Authority, and the National Resource Conservation Service follow the same flood damage guidance from the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) issued March 10, 1983 by the Water Resource Council. (Corps, 2009) The U.S. Depart of Agriculture (USDA) also has flood damage assessment guidance based on the P&G. However, USDA's Water Resource Handbook for Economics published in 1998 focuses on flood damage specific to agriculture and provides methodologies to estimate flood damage, crop and pasture damage, other agriculture damage, and damage to transportation.

USDA's National Emergency Watershed Protection Program Manual includes a "Damage Survey Report" (DSR) tool and guidance that can be used to estimate impacts of most weather and climate related damage. "The DSR… is the primary document in the planning process to record all assessments, evaluation, and planning decisions for [emergency watershed protection] recovery measures. A DSR must be completed for every site determined eligible for EWP assistance. The DSR must include sufficient data and information to document eligibility in accordance with Section 511.3, of this manual." (USDA, 2010)

Federal Emergency Management Agency (FEMA) also has documentation and tools to estimate physical, economic, and social impacts of storm damages. For example, the HAZUS model is used to determine losses and the most beneficial approaches to take to minimize them for earthquakes, hurricanes, and floods. (FEMA, 2012) A similar tool called Seismic Rehabilitation Cost Estimator is available for earthquake damage. (Ibid)

III. General Findings, Analysis, and Relevant Conclusions

This section provides analysis on the consistency of NOAA estimates of economic impacts of weather- and climate-related disasters. The first section compares the three primary NOAA estimates with each other, noting areas of overlap, as well as key gaps in data sources, methodology, and estimates. The second section provides a similar gap analysis between current NOAA estimation methods and sources and those of other government agencies and industry sources. Overarching and general conclusions about the findings are also provided.

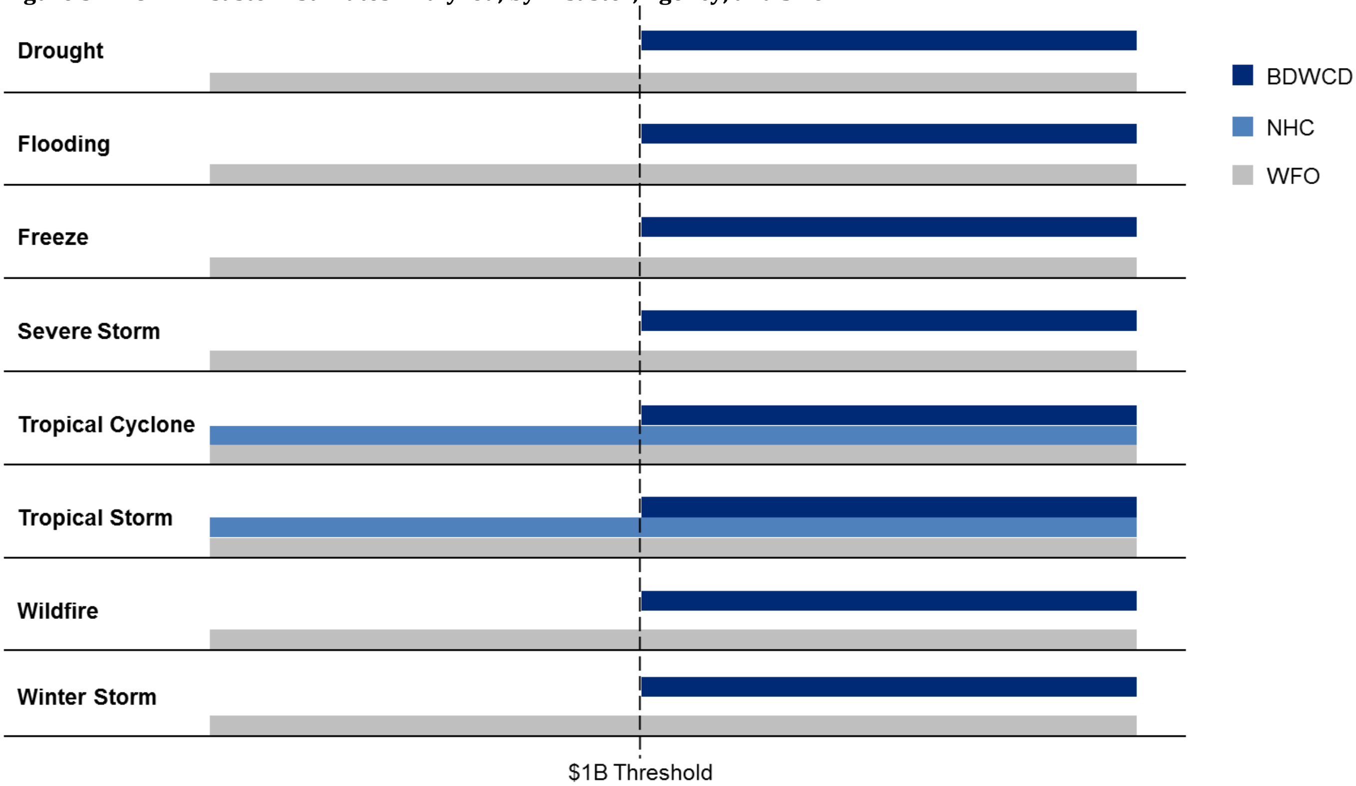
A. Internal Consistency of NOAA Estimate – Comparisons Across Agencies

Brief Overview

The disaster loss estimates within NOAA's organizations differ by assumptions, methodologies, and data inclusion. As the scope and purpose of each disaster estimate is slightly different, there are deviations across the NOAA organizations' calculations when assessing the economic impacts of storms and other weather- and climate-related disasters. These deviations, while small in nature, can lead to potentially different values of components used in the estimates; refining some of the procedures used and addressing these issues could provide a more unified voice in the assessment of disaster impacts from NOAA as an organization. Further, there are several overlapping issues on which the agencies could either create a common guidance or directly collaborate to potentially improve consistency in estimation (see Figure 3 on next page). However, all are valuable estimates for specific audiences and purposes. Generally, the methodologies used by NOAA tend to converge in process as the size of the disaster increases. Below is a discussion of the similarities and differences of each of these agencies. A table outlining these findings is included in the Appendix.

Broadly, the BDWCD is designed to examine all large and costly disasters using a consistent methodology and approach focused primarily on direct costs (property damage and immediate loss of economic activity); this methodology is expected to include multiple disaster types that inflict damage over different time periods (as the nature of droughts-related losses are quite different than storm-related ones). Both the BDWCD and NHC quantify direct/indirect deaths associated with the disasters. The NHC estimates are designed to measure a specific subset of the BDWCD categories in hurricane and cyclone damage (including cyclones that inflict under $1B in damages); however, the NHC also attempts to update historical loss estimates to capture current population growth and wealth. This additional NHC analysis approach for temporal disasters such as drought would be extremely complicated and very sensitive to the estimator's assumptions, so producing a similar number for disasters of longer durations would be an inefficient use of resources. Finally, the WFOs are responsible for estimating the direct costs of flooding (excluding storm-surge), and are asked to estimate weather-related property and economic loss in storms of all sizes.

Figure 3 – NOAA Disaster Estimates Analyzed, by Disaster, Agency, and Size



There are also differences associated with the scope and application of the loss estimates. While the BDWCD's primary role is to examine these losses, the cost estimates are only a part of the goals of the NHC and WFO estimates (both of whom also track information concerning the meteorological characteristics of weather events, as well as playing a role in the issuances of watches and warnings). Further, the BDWCD and NHC each have (relatively) centralized staff that produce the estimates, the WFO estimates are generally produced by individuals with little uniformity in method beyond guidance issued by the central office, and with little follow-up on estimates (particularly smaller-sized ones).

However, in cases where there may be overlap between the estimates (flooding related to hurricanes or large/costly storm events), the data sources used as inputs for the estimates tend to converge. For example, all three organizations do not adjust for hedonic pricing of replacement costs (see box on this page). Additionally, each estimate often relies on information from emergency responders, insurance and reinsurance adjusters (or aggregators of such information like PCS), and other relevant information such as local newspaper reports. Differences of loss estimates in these cases are almost entirely attributed to methodology, scope, or subjective parameter values. The use of slightly different insured-loss multipliers and differing definitions of what is counted as a direct or indirect loss can each contribute to significant divergences between the estimates.

For example, the NHC estimates of flood damage caused by a hurricane may not rigorously attempt to demarcate storm-surge flooding and fresh-water flooding (based on the value of NFIP claims paid out and multiplied by the area covered), whereas the WFO is required to estimate such demarcation. Similarly, the NHC generates counter-factual loss estimates (or forecasts) of how damaging a historical storm would have been had it hit under current demographics to isolate the overall characteristics of the storm itself, whereas the BDWCD estimates is designed to merely monitor and catalog losses in order to be historically descriptive. The following subsections examine these potential discrepancies in more depth; the analysis is presented by broad disaster category.

The figure above illustrates the disasters for which each WFO, NHC, and BDWCD conduct estimates. The WFO comprehensively calculates the loss estimates for every disaster, no matter the size, however the accuracy and detail of each estimate is not precise across the board. The BDWCD calculates loss estimates for all disasters which result in economic losses over $1 Billion. The NHC calculates loss estimates for hurricanes (tropical cyclones) and tropical storms, no matter the size.

A Note on Hedonic Pricing & Direct Losses

Large disasters often require significant repair or complete replacement of old or obsolete infrastructure. This can provide an opportunity for significant upgrades in quality of infrastructure or other capital goods that might not have been possible with simple retrofitting or maintenance, and may not be included in the replacement price (as older, lower-quality versions of the good are no longer produced). Adequately capturing the value of improvements in quality of the upgrade infrastructure is difficult, and existing estimates can be quite subjective.

Limiting direct costs to the cash outlays for fixing or replacing capital is thus the preferred methodology in cases where there was no plan to replace depreciated or obsolete infrastructure, since the costs were incurred as a direct result of the storm. This method often does not capture the full depreciation of previous goods nor the improvement in the quality of capital; however, due to complications of trying to calculate the market value of the component improvement, this is often considered an acceptable omission in the calculation of direct losses.

This is the preferred methodology of BDWCD NHC, and WFOs' estimations.

Cyclones

Cyclonic storms, such as hurricanes and tropical storms, are the one disaster type for which all three NOAA organizations actively estimate the costs of a disaster. As such, this category serves as the primary focus for methodological approach and data usage comparisons across the NOAA organizations.

Ten examples of estimate comparisons between BDWCD, NHC, and WFO are shown in Table 10. Tropical Storms and Hurricanes are the disasters shown as examples because all three NOAA organizations estimate losses for the two categories. Values are shown in real dollars in $ Billions. Inflation is not considered or calculated for this comparison. While the BDWCD and NHC estimates are generally quite similar, the WFO values frequently seem to be under-estimated. There is not a clear pattern of the BDWCD estimate or NHC estimate being higher/lower than the other. Although in 2002 Hurricane Lili may not have caused greater than $1B in damages, BDWCD may want to consider adding it to its list due to its inflation-adjusted direct losses approaching the billion dollar threshold. The NHC estimate in 2012 dollars rises to $1.18 Billion, which is over the BDWCD $1B threshold.

Table 10 – Comparison of Selected BDWCD, NHC, and WFO Hurricane and Tropical Storm Estimates

Historic Disaster ($B, Real Dollars)	Year	BDWCD	NHC	WFO
Hurricane Katrina	2005	125.00	108.00	33.51
Hurricane Ike	2008	27.00	29.52	6.50
Hurricane Wilma	2005	16.00	21.01	10.20
Hurricane Charley	2004	15.00	15.11	5.82
Hurricane Ivan	2004	14.00	18.82	13.04
Hurricane Isabel	2003	5.00	5.37	1.79
Tropical Storm Allison	2001	5.00	9.00	5.15
Hurricane Dennis	2005	2.00	2.55	1.79
Tropical Storm Dolly	2008	1.20	1.05	0.56
Hurricane Lili	2002	NA	0.93	0.69

National Hurricane Center & Billion Dollar Weather- and Climate-Related Disasters

The methodology behind cyclonic storm estimates between the BDWCD estimates and the NHC estimates tend to be relatively similar and tend to rely primarily on the same data. While NHC calculations all cyclone losses regardless of storm size, the BDWCD only captures disasters with losses exceeding $1billion. This difference does not reflect the organizations' loss methodologies but does clarify the variance in database entries. **The methodologies have been nearly identical since 1994, though the definition of what is included as direct losses has been different.** This convergence occurred when the definitions and methodologies used in the NHC calculations were more formalized.[24] Both organizations' estimates attempt to capture the large-scale cost of hurricanes and tropical storms, and they do so by extrapolating the amount of insured damage to calculate a rough measure of the amount of uninsured losses. **Both organizations build**

[24] Note that the NHC has recently made an effort to standardize many of the estimates prior to 1994 and bring them in line with the current methodologies, revising many historical estimates based on PCS and NFIP information. Many of these revisions were substantial and almost always involved increasing past estimates.

uninsured loss estimates using high-level (aggregated) data rather than focusing on identification of localized losses; theoretically, this prevents the accumulation of small-scale bias and statistical inefficiency,[25] as well as limiting complications that would plague a county-by-county or district-by-district approach.[26] Thus, the consistency of approach from these two agencies is relatively in line with each other.

Table 11 –Comparison of BDWCD & NHC Multipliers

Comparison of Multipliers - Cyclones		
Data Source	**BDWCD**	**NHC**
Uninsured Loss - PCS Data	2.0**	2.0
Uninsured Loss - NFIP Data*	Variable	Variable
Uninsured Loss - USDA Crop Insurance	2.0	0.0
FEMA - PDD Information	0.0 / 1.0**	0.0

*If FEMA-PDD costs exceed those of PCS estimates, then the FEMA-PDD values are used in lieu of PCS data.
**Value is calculated for each event based on insurance penetration and other local factors.

While each uses roughly the same data and approach, **differences in overall estimates can arise from the determination of flood-loss multipliers and the inclusion or exclusion of other relevant data** (see Table 11). Generally, both of the agencies double the PCS estimates on insured losses to approximate uninsured cyclone losses, so that procedure is equivalent for both NHC and BDWCD. Further, both create an uninsured flood loss estimate based on an ad hoc multiple of NFIP (National Flood Insurance Program) losses sourced via coverage rates of the afflicted areas. Still, **differences in estimates of flood loss can occur because the calculation of the flood-loss multiplier can vary between the two agencies**, as they do not regularly confer on the construction of each disaster event's multiplier.[27]

Regarding the data sources, **the BDWCD estimates regularly incorporate either USDA or state-level reports into economic impact estimates, whereas the NHC does not.** Additionally, the BDWCD also includes spending levels from FEMA Presidential Decision Directives if in excess of the estimated insured losses that PCS reports. This addition would suggest that the BDWCD estimates should consistently be higher than those of the NHC. However, the NHC estimates sometimes are higher than those of BDWCD. This unexpected result is because the flood-loss multipliers

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[25] Note that the use of the term "statistical inefficiency" refers primarily to the variance of the estimate produced, and not to the manner in which data are collected or employed.
[26] Note that that county-by-county coverage information is included in the multiplier calculation, as that is the level at which NFIP provides insured information. However, in most cases, the uninsured flood loss damage is assumed to be roughly equally distributed within the county in proportion to the insurance penetration.
[27] Presumably they are based on the same coverage information provided by FEMA and the flooding information provided by the NWS (National Weather Service), USACE (Army Corps of Engineers), and state responders, though information on event-by-event construction of these multipliers is limited.

differences can have an opposing (and much larger) effect when the NHC multiplier is higher. It is important to note that no definitive trend presents itself consistently, and that these effects need to be addressed in an event-by-event analysis.

Additionally, **special storm-specific situations might prompt further divergence between the NHC and BDWCD estimates**. The multipliers that the two organizations use are based on the "average" historical effects of cyclones, and deviations from these historical norms (for example the extreme Hurricane Katrina) can present significant potential errors as the agencies grapple with the potentially changing nature of uninsured losses. Because most insurance policies have explicit bounds on coverage (a deductible on initial losses and a cap on total coverage), particularly large storms or concentrated damage can create situations where a multiplier may need to be altered to adequately reflect the amount of uninsured loss incurred; similarly, damage may be concentrated in areas with especially low or high insurance rates.[28] Further, as the dollar-value of disasters continues to increase (through inflation, expansion and concentration of population in more areas, and the accumulation of wealth in vulnerable areas), events with different uninsured loss profiles may require further adjustments to the multipliers.

<u>Some Factors Influencing Multipliers</u>

- Variations in deductibles sizes
- Aggregation error from large number of small claims
- Insurance penetration rate
- Ease of getting an insurance policy
- Underinsurance of covered assets
- Number of claims exceeding coverage limits
- Storm Size
- Severity/Intensity of the Storm
- Duration of Storm (Time)
- Type of Storm (Cyclone, Winter Storm, etc)
- Region/Geography/Location of Storm Damage
- Local Source of Data
- Consistency of Direct/Indirect loss definitions
- Recent Local Economic Conditions
- Breakdown of Commercial Losses between (1) contents, (2) structure, (3) business interruption

Additionally, unanticipated situations may also require flexibility and coordination to determine the appropriate way to treat odd/outlier events. For example, in 2012, Post-Tropical Storm Sandy's classification created a legal issue with how insurance deductibles were to be treated; since the storm was no longer considered a cyclone when it hit shore (due to the tropical storm merging with a front off of the coast), insurers were forced to use traditional damage deductibles rather than the (often higher) hurricane deductibles on initial damage. The net effect was that the multiplier should be lower than for a traditional tropical storm because of these higher insured outlays. As this incident demonstrates, the derivation of multipliers may have to respond to unexpected changes in the treatment of variables; **lack of coordination across agencies in these instances could create inconsistent or incompatible damage estimates.**

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[28] From a practical perspective, both of these situations that require altering the multiplier are more likely to be identified after initial calculations, as most of this information must come from local responders or state government reports. This is due in part to neither the NHC nor the BDWCD teams having the resources to conduct the on-the-ground research required to properly identify the extent of these issues. However, some events are large enough that revisions are implemented by the team, and several estimates have been revised as more information became available.

A Note on NOAA Estimates Based on PCS and Other Insurance Information

The two primary data sources for NHC and BDWCD estimates primarily rely on information from two insurance programs, PCS and NFIP, and calculating a proper multiplier for non-insured losses. Ultimately, proper calibration of an uninsured-loss multiplier requires consideration of **deductibles and insurance caps.** While PCS's insured loss results are accurate in terms of paid insurance claims for a specific disaster, there is no information on the structure of the policies' deductible or the value of the insurance coverage cap relative to the afflicted properties**.** While the NFIP policies tend to be much more standardized, the issue with not knowing the distribution of loss applies to these policies as well.

With extreme events, the appropriate uninsured-loss multiplier is likely to have a different value due to the **coverage limits**. PCS does not include information on the number of insurance claims that meet or exceed the claim cap, so actual property losses could be significantly higher than the amount covered; this is especially true with commercial properties. For example the NYC World Trade Center buildings were insured with a policy for $3.5 million. Upon destruction by the September 11th attacks, PCS reported insured property losses at $3.5 million even though the actual losses were much higher than this; the building was severely underinsured for destruction of that size.

Similarly, the NFIP information on coverage limits is not reported. Currently, all policies generally have coverage limits of $250K.[29] This $250K/structure cap has not always been consistent over time, being raised four times in the past forty years. Further, the cap is not indexed to inflation, thus the real value of the fixed cap erodes over time; thus, the appropriate uninsured-loss multiplier may "drift" over time as less damaging floods may cause damage that reaches the coverage limit.

Deductibles are another consideration for evaluating total losses. The size of deductibles paid out relative to the size of the insured payments should influence the level of the uninsured loss multiplier. For example, a storm that inflicts significant damage on a small number of properties will have a relatively low amount of non-insured deductible loss compared to a storm which inflicts the same amount of insured losses but does so by creating small amounts of damage over a greater number of insured claimants. Thus, the multiplier would ideally be adjusted to reflect the number of policies affected to better capture uninsured losses associated with deductibles.

Unfortunately, the deductible information is not readily available from current sources. PCS insurance claims reports do not include these values. Further, while some deductibles are static, many hurricane deductibles are based on variable values; for example, residential hurricane deductibles can reach up to five percent of total property value. With a storm the size of Hurricane Katrina, that five percent adds to a large sum of losses which are not included in the PCS reported values. This is less of an issue with NFIP, however, as the standard deductible is $1000; this is true

[29] Some communities have lower caps; more information can be found here: http://www.floodsmart.gov/floodsmart/pages/faqs/how-much-flood-insurance-coverage-is-available.jsp

of both structures and content policies; an appropriate multiplier can then be calculated with just the total insured flood loss and the number of claims paid.

Finally, **insurance penetration rate** are another concern. Both the NHC and BDWCD adjust multipliers based on NFIP coverage of an affected area, but no such change is done for PCS data. While availability of such information is much more limited than with the NFIP data, there are undoubtedly differences across regions, with wealth and density factors influencing penetration rates. Additionally, the ease of getting a policy and the actual rate of insurance in regions can change over time. Both of these factors should influence the multiplier; this represents a significant area for improvement for future estimates.

National Weather Service (Weather Forecasting Offices) compared with National Hurricane Center, Billion Dollar Weather/Climate Disasters

As just discusses, the broader estimates of the BDWCD and the NHC follow roughly the same methodology (albeit with different multipliers and scope for data inclusion), **the WFO follows a very different approach to estimating cyclone damage. As a result, the aggregation of costs from each forecasting office has the potential to be quite different.** While the NHC and BDWCD both estimate the economic impacts of the storm based on data aggregated by other organizations, the NWS estimate is an aggregation of each afflicted WFO region. **This means that several methodologies can be employed with different multipliers - local forecasting offices use subjective analyses in disaster estimates.** The net effect on accuracy could be either positive (localized estimates could be more accurate by employing more robust information to create more accurate estimates) or negative (inconsistent, inappropriate, or incomplete approaches could create bias or statistical inefficiency).

Further, the statutory requirements for the WFOs can create further discrepancies or inconsistencies between the methodologies of the agencies. In the cases of cyclones, **each WFO that has flooding in its district is statutorily required to separate the amount of flood damage that occurred from storm surge versus fresh-water flooding from precipitation, and then estimate the economic impacts of the fresh-water storm flooding that occurred.** It should be noted that neither the NHC nor BDWCD attempt to disentangle the two types of flood damage since both fall under NFIP coverage. In several cases, a WFO's disentangled flood distinctions do not aggregate to the NFIP value, suggesting bias or misattribution of flooding cost.

Beyond the freshwater flooding issue, there are other discrepancies between the data used by the WFO and those used by the NHC and BDWCD. The WFOs primarily derive data on economic loss estimates from state and local government officials, local business and home-owners, and other relevant agencies involved in the response (FEMA, USACE, etc), as well as from a cost hand-guide issued by the NWS. However, **for large events there is still a great deal of overlap in data between the WFO estimates and those of the NHC and BDWCD**, as much of the local information used in WFO estimates are also reported to PCS, NFIP, and state/local agencies. Regardless, these localized numbers are still somewhat removed from the primary sources used in estimating the aggregate effect of a cyclone, and some variation is thus expected if the panel of insurers and local responders do not match up exactly with those that report to PCS and NFIP.

Non-Cyclone Storm Disasters

Non-cyclone storm disasters include severe storms, strong wind events, and other short-duration weather phenomena. The BDWCD and the WFO derive disaster cost estimates for non-cyclone disasters while the NHC does not. **For storm-type disasters (i.e., winter storms, derechos, etc.), the issues of consistency are much the same as with cyclonic storms.** It should be reiterated that the WFOs generally attempt to define the economic costs of all weather-related events including those storms that inflict relatively small amounts of damage (even <$10,000). Additionally, **the BDWCD uses different multipliers for estimating losses of different disaster types, including those that are more dependent on the size of the storm.** The BDWCD multipliers for freshwater flood loss data and related information are derived in part from NWS data (usually collected by the WFO) based on historical damage caused by storms, in developing BDWCD total direct flood losses. In this way, the aggregate estimates are based on the historical records of loss and the work of the NWS forecasting offices (including the WFO). As discussed in the NWS section, the various WFO estimates can be inconsistent and sometimes nonexistent, and the same comparison issues between BDWCD and WFO estimates still exist.

Non- Storm Disasters

Non-storm disasters include drought, heat waves, prolonged freezes, and other long-duration weather events. In the cases of these less discrete events, **only the BDWCD estimators attempt to gauge the economic impacts of the events.** Branches of the NWS collect data on these events and attempt to forecast the severity of future events but do not calculate loss information. For droughts, the NWS makes estimates and outlooks from the Climate Prediction Center on the size and severity of the drought; these forecasts are derived from the same data as those used by USDA (U.S. Department of Agriculture), which ultimately feed into the BDWCD estimates. Similarly, the NWS forecasts the likelihood of wildfires from the NWS Storm Prediction Center; further, these forecasts are based on the same NWS data that is integral for National Interagency Fire Center (NIFC) wildfire severity estimates.[30]

Also note that the extended time-frame over which many of these events occur complicates both the calculation of the event's true direct costs as well as diminishes the ability to make severity-based comparisons using anything other than an inflation adjustment. Specifically, a comparison of droughts using a similar approach to the NHC's Pielke cost adjustments would likely be infeasible due to the extraordinarily large number of adjustments that would need to be made; for example, secular changes in crop yield, continued development of global markets, crop choice, and changes in industrial organization all could introduce significant bias into the estimates. As such, we find that a simple inflation-adjustment is likely more accurate for comparison of long-duration events, as the complexity and evolution of an economy introduce excess error and subjectivity into any further adjustments.

[30] Note, however, that the NIFC does not create economic impact calculations.

NMFS Estimates vs. BDWCD/NHC/WFO

The NMFS estimates of economic impact specifically focus on very narrow elements of economic damages from disasters. These estimates will generally be a small subset of total direct economic losses in cases such as cyclones and storms, and the work that the NMFS interviewers conduct could be valuable for the other estimators when calculating a disaster's overall economic impact. These NMFS methodology is most closely aligned with the type of investigations that the WFOs conduct, especially with regards to the smaller and mid-sized storms, whereby estimates are constructed using interviews and the agency is the primary collector of local data. However, the NMFS is essentially constructing their data (and extrapolating it to get to total costs) in a way that the BDWCD and NHC do not do, and the NMFS relies less on local responders for data than the WFOs. As such, the NMFS' methodology can be considered to be that of data collection as compared to the other three agencies' process of aggregating and employing other's data.

A Note on Inflation Calculations

Each of the disaster economic impact estimates are generated in nominal terms. However, each database of each agency's historical economic impacts uses different inflation indices to adjustment historical estimates.

- **BDWCD** adjusts all historical estimates using the Consumer Price Index (CPI); further, this adjustment has led to the inclusion of more historical events as the present value of economic damage inflicted by historical storms to exceed $1B in real terms, even if the disaster was not close to cause $1B in nominal economic damage (this is particularly true earlier in the dataset, as inflation has been positive in every year since the database began).
- **NHC** adjusts its historical numbers using the McGraw-Hill Construction Cost Index for real cost estimates.[31]
- **NWS** numbers are from the WFO reports and are strictly in nominal terms,[32] though the Hydrologic Information Center's Flood Loss Data does adjust the WFO information using the McGraw-Hill index.

There are many options for calculating inflation for the loss estimates depending on the purpose of the inflation index, the type of storm, and other factors. Many options are listed in the Table 12 on the next page. Each inflation index has a specific purpose and focus which can be used pointedly for specific factors of disaster impact calculations. Some indices may be worth considering for specific disasters as a whole. For either of these approaches, it is important to take care in avoiding false precision. For a more broad consideration of inflation for disaster impact estimates, another option is to consider using a more general inflation index across the different NOAA organizations which could improve consistency across estimates.

[31] The NHC also has a third value in its database, whereby the estimates are adjusted to account for current population and wealth concentrations in the storm's track.

[32] Additionally, the NWS handbook that aides in valuation of certain types of damage is not updated for inflation, so in some cases current damages are being priced based on nominal costs that may no longer be accurate.

Table 12 – Inflation Index Options Available for Potential Use in Historic Estimates

Inflation Index Options		
Index	**Description**	**Considerations**
Consumer Price Index (CPI)	The CPI and its variants (Core, trimmed mean, etc.) track changes to goods consumed regularly by households, and weight those changes according based on historical expenditure. The basket of goods in the index tracks the impact of rising prices that could alter consumer behavior.	- Most widely known index - Adjusts costs to reflect consumer behavior, easily relatable - Isolates welfare effects by using fixed basket - Multiple variations and sub-indices for quick comparisons (including chain-type index)
Personal Consumption Expenditures Index (PCE)	The PCE Index is an alternative to CPI, measuring the prices influencing households and individuals, but allowing for more substitution in the face of inflation. This can more accurately track behavioral responses to inflation, but is less precise in measuring welfare loss from rising prices	- Adjusts costs to reflect consumer behavior, easily relatable - Compensates for actual substitution of goods by consumers
Producer Price Index (PPI)	The PPI measures the cost of primary inputs used in industry. Conceptually, this index is similar to a CPI for domestic industry, particularly those in manufacturing and construction.	Focuses on costs to industry and business, costs which are excluded by CPI and PCE measures
GDP Deflator	The GDP Deflator attempts to measure the inflation level across the entire economy, across all sectors and industries. The methodology is similar to the PCE deflator in that behavioral responses to rising prices are included in calculation.	- Broadest measure of inflation - Compensates for actual substitution of goods by economic agents
McGraw Hill Construction Index	This index is a measure of costs associated with local construction, including labor, materials, and other associated costs. The index is proprietary.	Most closely reflects replacement costs for local consumers and businesses
The Civil Works Construction Cost Index System	This index, produced by the U.S. Army Corp of Engineers, examines the local costs of construction including labor and materials, with a weighting towards large-scale infrastructure projects.	Most closely reflects replacement costs of infrastructure for governments

B. External Consistency of NOAA Estimate – Comparisons with Industry

As within NOAA, there are also several differences in relation to the practices used in industry for estimating disaster-loss calculations. It is important to note that **many industry sources calculate overall economic loss estimates using proprietary methodology**, and in many case the research team was not granted access to this information during the investigation. This was especially true with both reinsurers and financial institutions, where interviewees would often only direct us to public documents that usually contained little or no information on the methodological approach or data sources used in calculation. Thus, it should also be noted that, while no systematic comparison was conducted,[33] **anecdotal review of many private estimates suggest that the estimated impacts are relatively close to those produced by NOAA**. Further, there are several examples of news reports which suggest that some of the multipliers may be similar to those used by NOAA. For example, one news report[34] suggested that Goldman Sachs predicted that the range of total property loss to be twice that of insured losses, which would put the uninsured-loss multiplier at 2, or the same as both the NHC and BDWCD multipliers for PCS information. Similar types of statements can be found in several other news articles concerning other estimates and other disasters. Nevertheless, there are potentially several methodological differences or data sources that were not identified due to the nature of many of the estimators.

One of the main differences between the NOAA efforts and private estimates of total economic impact of weather- and climate-related disasters is the **use of sophisticated large-scale economic models.** Many of the public releases of cost estimates, particularly by financial firms and private companies that license proprietary models tend to rely on generic models of the US economy. As most large economic models tend to be based on structural systems of equations[35] that are tied together with equilibrium conditions, this almost certainly means that the input data (such as PCS or Munich Re's estimates of insured property loss) are introduced into the model's datasets as a negative innovation, and **the impacts of the storm are measured as deviations from the baseline forecasts.**

While different structural models are estimated differently and have distinct behaviors, **the net effect is similar to the BDWCD approach of assigning a loss multiplier to the data as a way to capture economic loss.** However, the large-model approach allows for recalculation of multipliers (the parameter estimates in the individual equations may shift over time as more data are added

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[33] While outside the scope of this report, the researchers advocate that a full quantitative analysis of differences between private estimates and BDWCD estimates. A full description of how the methodological approach for such analysis could be conducted can be found in the forthcoming companion report Recommendations for Future Actions.
[34] http://www.forbes.com/sites/afontevecchia/2012/11/06/despite-50b-in-damages-hurricane-sandy-will-be-good-for-the-economy-goldman-says/
[35] Note that a rough equivalent is true in Dynamic Stochastic General Equilibrium models, as measuring the impact of an event involves solving the model twice: once in the presence of the disaster, once not. Thus, changes in the outcome of the constrained optimization decisions are roughly analogous to the multiplied effects of a negative innovation in a structural model.

and the model is re-estimated). Additionally, these models usually have very granular structures, with state or regional estimates of top-line numbers (gross product, inflation, unemployment) as well as the many components of those numbers that can lead to more robust or consistent estimates (industrial production, personal consumption expenditures, gross fixed capital formation, etc). Essentially, **these methodologies recalculate the multiplier for each event based on recent economic conditions as well as historical impacts.**

Additionally, there are several academic papers that use a forecast error as a determinant of the impact of natural disasters. Similar to the approach described in the previous paragraph, several academic papers[36] and white papers use an ex ante **analysis of forecasts and actual values** to determine the effects of certain disasters. In these cases, where the cost and/or effort of creating an entire general- or partial-equilibrium model is prohibitive, a simpler approach can be taken. A priori forecasts of certain numbers (output, employment, etc.) are treated as a baseline, while either actual data or changes to these forecasts after the disasters provide the "new path" that result from the disaster. **The residual between the baseline and updated numbers captures the size of disaster's impact**, quantifying the event. For further accuracy, the standard errors of the forecasts can be calculated by evaluating historical RMSE. Further, there are many resources of forecast evaluation that could improve the performance of such methods, bringing out a more accurate measure of the uncertainty associated with this approach.

There are also some disaster-cost estimators that rely on **direct sampling methods**. Some of the more well-known sampling organizations, such as PCS and Munich Re, are already used by NOAA to ascertain certain components of the economic impact of an event. However, there are some organizations that provide further sampling, some by volunteers' reports rather than an organized network, that attempt to determine the impact of events. The National Drought Mitigation Center's Drought Impact Reporter is one example of these attempts, whereby several existing sources of information are combined with direct user reports. **These direct sampling methods can provide information on certain questions that may not be asked or addressed in existing sources used by NOAA estimates**, though there is also a potential for subjective judgments and non-standard information to enter these surveys due to the nature of respondent selection.

Another issue that several sources point out is that the **definitions of economic impacts** are not consistent across estimators. **A movement towards codifying what is or is not included in the disaster estimates could provide further consistency across countries and estimates from various groups.** Often, large deviations in two economic impact estimates of a disaster can be attributed as much or more to the definition of what is included rather than a methodological difference. Since many of the estimates of disaster costs use similar or identical data sources (particularly PCS in U.S. estimates), the role of differences in multipliers and estimates become particularly more obvious.

Another consideration that arises from the literature is that of truncated distribution of data entered into these estimates. Nearly all primary data incorporated into these estimates revolves

[36] Several of these are described in the literature section of this report.

around insured property; thus, nearly every data point inflicted is subjected to non-normal distribution of insured losses. **Deductibles and insurance caps make the data and the uninsured-loss multiplier potentially inconsistent from disaster to disaster.** Even if losses from disasters are normally distributed over affected areas, the mean value of insured losses is likely to change from disaster to disaster; as such, the proportion of individuals in the "tail events" (those suffering damage values under the deductible or over the coverage cap) would then be different. As such, the multipliers used for determining uninsured losses are almost always statistically inefficient (whether they are based on simple historical averages or even estimated econometrically using historical data).

In the specific case of wildfires, there is also potential for additional changes. The NIFC's methodology rates the severity of the season[37] primarily based on several factors that, while correlated with economic losses, are not directly translated into economic loss.[38] As such, **NOAA's economic impact calculations do not align to the NIFC fire season severity calculations**. For example, if a wildfire season results in an unusually high number of deaths but an average amount of property losses, the NIFC would report a severe season while NOAA may not. **A thorough annual review of the NIFC reports, even in relatively mild seasons, may identify potential events for the BDWCD database.** However, as wildfires tend to makeup a very small portion of total damage from weather- and climate-related disasters most years, this is less critical than some other improvements that could be implemented.

Another major consideration for the estimation of uninsured crop losses is recent changes in the penetration rate of crop insurance. **Overall, the acreage of uninsured crops has dropped significantly, which would require a lowering of the uninsured-loss multiplier.** The USDA RMA publishes state level Crop Insurance Profiles which the BDWCD could use in recalculating estimation; these profiles could require a rethinking of how RMA data enter the equations. The higher penetration rates may require lowering the current USDA multiplier of 2.00 down closer to 1.00.

[37] There is a full discussion of this in Section B.I.ix
[38] For example, the number of number of fire and number of structures lost both contribute to severity, regardless of how destructive the fires were and without regard for the property value of the structures.

C. Further Areas of Research

There are several areas of future research relevant to estimating the economic impacts of disasters that could be incorporated into disaster loss estimates. These recommendations generally fall into three categories: (1) **improving coordination** within NOAA organizations; (2) **improving estimates of direct costs;** and (3) enhancing the **estimation of indirect and total costs**.

Improving Coordination within NOAA Organizations

There is sufficient scope for improvement of all NOAA economic impact estimates by increasing coordination and cooperation between the estimators. As highlighted in the previous section, **calculation of loss multipliers and formalized definitions of what is included as a direct loss can help harmonize the different efforts**; this also could help reduce some redundancy in analysis and collection across groups. This would be particularly relevant in the determination of the NFIP Flood Loss multiplier in cases of hurricanes, where the NHC and BDWCD both independently calculate a unique multiplier. Similarly, **a common database or repository of the different estimates** could help normalize some of the procedures in benchmarking and analyzing data across the groups; for example, a centralized database could simplify analyzing the impact of using different inflation indices, as well as helping identify discrepancies between estimates.

Additionally, the **different estimators can pool resources or commission studies on the appropriateness or historical accuracy of certain assumptions** associated with current methodologies. For example, both the NHC and BDWCD could benefit from a local analysis of private property insurance coverage, including insurance penetration rates, average deductible size, and the number of policies reaching their cap limits; these data could help verify the validity of the current PCS multiplier. Further, the WFOs (and NMFS in coastal communities) could be directly involved in the research effort of these insurance studies, as they regularly conduct local interviews and have working relationships with local responders and agencies that might facilitate such a pilot survey. **Similar economies of scale may also exist with other governmental agencies**, including USDA, USACE, and FEMA, who either are collecting some of the data used in NOAA's estimates or are making estimates of their own.

Improving Estimates of Direct Costs

The NOAA sub-agencies could also improve their current estimates of direct losses in a few ways. In some cases, **the current methodology or incorporation of direct costs of the disaster may need to be reevaluated**. For example, as discussed above, the appropriate BDWCD multiplier on USDA losses may be changing due to the recent use of different programs by farmers; also, the NHC does not include these data in their estimates at all, and different WFOs may be using the data differently. Further **analysis of the appropriate multiplier in the cases of crop losses** could be warranted. Similarly, particularly in the case of drought/heat waves and other long-duration events, further **refinement of definitions could ease the burden of data collection and analysis**. In addition, employing expert analysis and forecasting into these costs through residual analysis (especially with regards to crops) might help formalize the analytical process. Finally, a standardized list of data requirements and considerations could streamline the procedure.

Also, when considering changes to methodology or analysis of direct costs, the **quantification of statistical uncertainty** in the estimates should also be considered. There are many sophisticated techniques that can help measure uncertainty in variables, surveys, cost estimates, and aggregation techniques. Adding procedures to account for the amount of statistical uncertainty in the NOAA estimates could improve the information content what is presented to the public. These procedures could include creating **graphical representations of the uncertainty** in the estimates by employing fan charts or error bars; this could help create more effective communication on what the estimates represent and thus better fulfill NOAA's mission.

The BDWCD can also be improved by creating a more robust procedure to **identify historical events whose direct losses have surpassed $1B due to inflation**. For example, USDA economists have identified three potential cases of drought not the database whose direct costs were below $1B in nominal terms, but whose inflation-adjusted numbers are likely at or above $1B. Similarly, there are events in the EM-DAT that may also require addition to the BDWCD database. While the BDWCD has recently added 19 such events, **a more formalized identification procedure may be necessary**. Alternatively, indexing the billion dollar threshold to inflation may also be a potential consideration if significant resources are devoted to upgrading and investigating decades-old events now passing the threshold due to inflation.

The WFOs can also have significant scope for improving consistency of estimates and procedures. **Creating an online tool or incorporating an automatic procedure into the Storm Data software or Performance Management site that helps staff generate costs estimates could further refine the direct loss estimates they produce**.

Also, **there are several sources of direct loss data that the NOAA organizations could attempt to procure**, either through direct purchase or through partnership opportunities. Outreach to private groups to obtain additional information could provide more refined estimates on loss (for example, obtaining Lloyd's or Chubb excess flood insurance information or additional data from Munich Re or Swiss Re might be possible private relationships). Similarly, contact with local or state-level insurance regulators may help acquire better data on what is or is not included in some of the PCS loss information that is the backbone of these estimates.

Further, as there is no consensus in the broader community on what to include or exclude in direct (or indirect) costs of a disaster, an external outreach by NOAA to other agencies, NGOs, academic institutions, and foreign governments could help create such a standard. **Additional refinement of these standards could help streamline and validate NOAA's processes for estimating disaster costs**. This could also be an opportunity to pair with other government organizations that are end-users of NOAA data; for example, the Weather & Climate Extremes Working Group or the Subcommittee on Disaster Reduction.

Enhancing the Estimation of Indirect and Total Costs

Finally, NOAA also has an opportunity to expand their current cost estimates to include indirect cost estimates. **Expanding the scope of cost estimates to include an analysis of indirect and total costs could provide several benefits**. First, attempting to estimate all costs, both direct and indirect, could aide in formalizing the process of defining some of the impacts. Additionally, having all three numbers (direct, indirect, total) could help explain divergences between NOAA estimates and those of private industry, as well as identifying where those estimates may be diverging from NOAA's current approaches.

This expansion into indirect cost account could be accomplished using resources that already publically exist. Further research into **local multipliers and demand/supply elasticities could prove relevant for analysis of lost economic output**; there are numerous articles in the economics literature that estimate or aggregate local demand- and supply-elasticities that could be used. Additionally, these estimates could be augmented by tapping into local, regional, and state data releases to further estimate loss impacts as statistics are produced (though most data are released with significant lags, so these would probably have to be used only in the revised impact numbers). Current data exist that allow for a more formalized examination of the multipliers used on uninsured losses, particularly as the coverage rates vary over time. Combining these data with increases in computing power and better real-time risk models of many insurance and reinsurance companies can likely provide better estimates of coverage in a timely way. Finally, **formalized modeling of demand and employment responses to previous disasters** (including those estimated in the literature) could prove valuable in creating an initial approximation of indirect disaster costs; this estimate could be calibrated as data are released.

D. General Thoughts and Conclusions

This study has discussed a significant number of data sources and differing methodologies that currently are instrumental in NOAA estimation of disaster impacts, as well as identified several potential sources that could be used in the future economic impact analysis of disasters. Broadly, there are extensive resources available to enhance the process of estimating costs associated with disaster, particularly those that are associated with indirect costs and economic recovery from the disasters. There are many peer-reviewed articles that describe approaches in general, and in some cases specific methodologies, to appropriately capture the losses associated with different types of disaster. There are several databases and data sources that could provide additional information concerning losses to economic activity, disaster response preparations and implementation, environmental and energy-system damage, agricultural disruptions, and other potentially relevant estimation. However, not all of these resources provide a clear and transparent translation into dollar values; these translations (if so desired) could be aided by some of the numerous models and software products (several of which are available at no cost) that can be useful in establishing baselines, estimating effects of the damages inflicted, and providing contextual data for individual analyses. Also of note: nearly all estimates and studies use PCS data, either exclusively or relying heavily on the dataset.

This report also provided analysis of the significant differences between internal NOAA estimates. Many of these differences can provide guidance on how to improve and advance the estimates of economic impacts of weather- and climate-related disasters. For example, better coordination between NHC and BDWCD estimators could refine the calculation of uninsured-loss multipliers. Additionally, the overlap in data used by the NOAA groups allows for a clearer distinction between what is and is not included in each estimate. Additionally, this report reviewed the differences and key gaps with economic impact estimates between those made by NOAA and those by other government and industry sources. Many of the private estimates are proprietary, and often they rely on sophisticated models that focus on the entire economy. Additionally, many other disaster impact estimators who rely on less sophisticated models use expert forecast errors to determine the size of an event. Other estimators have researched ways to reduce error in uninsured-loss multipliers by accounting for insurance deductibles and coverage caps. These and other issues were identified through the course of investigation

Ultimately, this document is both a reference guide to current disaster loss estimation techniques and data sources, as well as comparison and analysis of these projects. This report also has identified several issues that could be improved in future estimation, and a full discussion of how to implement these will be produced in a subsequent report.

Appendix

Acronyms and Abbreviations

ADRC	Asian Disaster Reduction Center
ASEAN	Association of Southeast Asian Nations
BDWCD	Billion Dollar Weather and Climate Disasters
BEA	Bureau of Economic Analysis
BI	Business Interruption
BLM	Bureau of Land Management
BLS	Bureau of Labor Statistics
CBA	Cost-Benefit Analysis
CBI	Contingent Business Interruption
CDBG	Community Development Block Grant Program
CDC	Center for Disease Control and Prevention
CPHC	Central Pacific Hurricane Center
CPI	Consumer Price Index
CRED	Centre for Research on the Epidemiology of Disasters
CSC	Coastal Services Center
DIR	Drought Impact Reporter
DLDS	Disaster Loss Data Standards
DSR	Damage Survey Report
EIA	Energy Information Administration
EM-DAT	International Disaster Database
EPA	Environmental Protection Agency
EWP	Emergency Watershed Protection
FAO	Food and Agriculture Organization of the United Nations
FCIC	Federal Crop Insurance Corporation
FEMA	Federal Emergency Management Agency
GAO	U.S. Government Accountability Office
GIS	Geographic information system
GLIDE	Global Identifier number
HUD	U.S. Department of Housing and Urban Development
HURDAT	Hurricane Database
IDB	Inter-American Development Bank
IFPRI	International Food Policy Research Institute
ISO/PCS	Insurance Services Office/ Property Claims Services
LA RED	Network of Social Studies and Prevention of Disasters in Latin America
MRIP	Marine Recreational Information Program
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NASS	National Agricultural Statistics Service
NCAR	National Center for Atmospheric Research

NCDC	National Climatic Data Center
NDMC	National Drought Mitigation Center
NEMS	National Energy Modeling System
NFIP	National Flood Insurance Program
NHC	National Hurricane Center
NIFC	National Interagency Fire Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
NWCC	National Water and Climate Center
NWS	National Weather Service
OCE	Office of the Chief Economist
PCS	Property Claims Services
PDD	Presidential Disaster Declaration
PERILS	Pan-European Risk Insurance Linked Services
RMA	Risk Management Agency
RUC	Rapid Update Cycle
SBA	Small Business Administration
SCAN	Soil Climate Analysis Network
SDR	Subcommittee on Disaster Reduction
STEO	Short Term Energy Outlook
UN	United Nations
USACE	U.S. Army Corp of Engineers
USAID	U.S. Agency for International Development
USDA	United States Department of Agriculture
USFA	U.S. Fire Administration
USGCRP	US Global Change Resource Program
USGS	US Geological Survey
WFO	Weather Forecast Office
WWCB	Weekly Weather and Crop Bulletin

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Tables Examining Data Sources for NOAA estimates and their Sources

Tables A-1 and A-2 show various categories of information that are provided for each disaster type. Each row describes a type of loss or impact that a disaster can inflict. Each column represents a different disaster type. For table A-1, each cell is populated by the NOAA estimates of disaster impact that include that data type in their economic impacts (if any). For table A-2, each cell is populated by the agency that produces that type of data (if any). Note that any cell filled with "State Agencies" does not imply that an agency in every state will provide this type of analysis, just that they might under certain circumstances.

Table A – 1 Examines:

BDWCD – Billion Dollar Weather- and Climate-related Disasters

NHC – National Hurricane Center

WFO – Weather Forecasting Office

Table A – 2 Examines:

PCS – Property Claims Service

NFIP – National Flood Insurance Program

FEMA – Federal Emergency Management Agency

NIFC – National Interagency Fire Center

USACE – U.S. Army Corp of Engineers

USDA – U.S. Department of Agriculture

SA – State Agencies

Table A-1– Consideration of Losses to Include in Disaster Estimates

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Commercial Property: Structure & Content	-	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Vehicles	-	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Residential Property: Structure & Content	-	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Infrastructure/Roads	-	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Business Loss	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Crops	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Deaths	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Diseases/Sick*	-	-	-	-	-	-	-	-	-	-	-
Environmental Loss	NMFS	NMFS	NMFS	NMFS	NMFS	NMFS	NMFS	-	-	NMFS	NMFS
Electricity/ Power Loss	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Missing*	-	-	-	-	-	-	-	-	-	-	-
Injured*	-	-	-	-	-	-	-	-	-	-	-
Relocated	-	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-

Table A-1– Consideration of Losses to Include in Disaster Estimates(continued)

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Crop Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Evacuated	-	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Livestock	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Communications Losses*	-	-	-	-	-	-	-	-	-	-	-
Water Supply & Quality Losses	-	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Sewerage Losses*	-	-	-	-	-	-	-	-	-	-	-
Education Losses	-	-	-	-	-	-	-	-	-	-	-
Fisheries	BDWCD NMFS	BDWCD WFO NMFS	BDWCD NMFS	BDWCD WFO NMFS	BDWCD WFO NMFS	BDWCD WFO NMFS	BDWCD WFO NMFS	-	-	NMFS	NMFS
Minery*	-	-	-	-	-	-	-	-	-	-	-
Insured Losses	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Uninsured Losses	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Underinsured Losses	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Losses over the Insurance Cap	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-

Table A-1– Consideration of Losses to Include in Disaster Estimates(continued)

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Timeframe	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Number of Acres of Loss	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Location	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD NHC WFO	BDWCD WFO	BDWCD WFO	-	-	-	-
Homeless*	-	-	-	-	-	-	-	-	-	-	-
Aviation Losses*	-	-	-	-	-	-	-	-	-	-	-
Marine Losses	BDWCD NMFS	BDWCD WFO NMFS	BDWCD NMFS	BDWCD WFO NMFS	BDWCD NHC WFO NMFS	BDWCD WFO NMFS	BDWCD WFO NMFS	-	-	NMFS	NMFS
Plants & Wildlife*	-	-	-	-	-	-	-	-	-	-	-
Society & Public Health*	-	-	-	-	-	-	-	-	-	-	-
Tourism & Recreation*	NMFS	NMFS	NMFS	NMFS	NMFS	NMFS	NMFS	-	-	NMFS	NMFS
Relief Response	BDWCD	-	-	-	-	-	-	-	-	-	-
Imports/Exports*	-	-	-	-	-	-	-	-	-	-	-
Prices	BDWCD	BDWCD WFO	BDWCD	BDWCD WFO	BDWCD WFO	BDWCD WFO	BDWCD WFO	-	-	-	-

* Items with an asterisk may be addressed in State-level reports, and therefore may be incorporated into the BDWCD estimates.

Table A-2– Consideration of Losses in Data Sources used by NOAA

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Commercial Property: Structure & Content	-	NFIP FEMA USACE SA	-	PCS NFIP FEMA USACE SA	PCS NFIP FEMA USACE SA	PCS FEMA NIFC SA	PCS NFIP FEMA USACE SA	-	-	PCS FEMA SA	PCS NFIP FEMA USACE SA
Vehicles	-	FEMA USACE SA	-	PCS FEMA USACE SA	PCS FEMA USACE SA	PCS FEMA SA	PCS FEMA USACE SA	-	-	PCS FEMA SA	PCS FEMA USACE SA
Residential Property: Structure & Content	-	NFIP USACE SA	-	PCS NFIP FEMA USACE SA	PCS NFIP FEMA USACE SA	PCS FEMA NIFC SA	PCS NFIP FEMA USACE SA	-	-	PCS FEMA SA	PCS NFIP FEMA SA
Infrastructure/Roads	-	USACE SA	-	PCS FEMA USACE SA	PCS FEMA USACE SA	PCS FEMA NIFC SA	PCS FEMA USACE SA	-	-	PCS FEMA SA	PCS FEMA USACE SA
Business Loss	SA	SA	SA	PCS FEMA SA	PCS FEMA SA	PCS FEMA SA	PCS FEMA SA	SA	SA	PCS FEMA SA	PCS FEMA SA
Crops	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA

Table A-2– Consideration of Losses in Data Sources used by NOAA (Continued)

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Deaths	FEMA SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA USACE SA	FEMA NIFC SA	FEMA USACE SA	FEMA SA	FEMA SA	FEMA SA	FEMA USACE SA
Diseases/Sick	FEMA SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA USACE SA	FEMA NIFC SA	FEMA USACE SA	FEMA SA	FEMA SA	FEMA SA	FEMA USACE SA
Environmental Loss	SA	SA	SA	SA	SA	NIFC SA	SA	SA	SA	SA	SA
Electricity/Power Loss	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA NIFC SA	FEMA SA	-	-	FEMA SA	FEMA SA
Missing	-	FEMA SA	-	FEMA SA	FEMA SA	FEMA NIFC SA	FEMA SA	-	-	FEMA SA	FEMA SA
Injured	FEMA SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA USACE SA	FEMA NIFC SA	FEMA USACE SA	-	FEMA SA	FEMA SA	FEMA USACE SA
Relocated	FEMA SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA SA	FEMA SA	FEMA SA	FEMA USACE SA

Table A-2– Consideration of Losses in Data Sources used by NOAA (Continued)

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Evacuated	FEMA SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA SA	FEMA SA	FEMA SA	FEMA USACE SA
Livestock	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA
Communications Losses	SA	SA	SA	SA	SA	SA	SA	-	-	SA	SA
Water Supply & Quality Losses	USDA SA	USDA USACE SA	USDA SA	USDA USACE SA	USDA USACE SA	USDA SA	USDA USACE SA	-	-	USDA SA	USDA USACE SA
Sewerage Losses	SA	SA	SA	SA	SA	SA	SA	-	-	SA	SA
Education Losses	-	SA	SA	SA	SA	SA	SA	-	SA	SA	SA
Fisheries	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	-	-	USDA SA	USDA SA
Minery	-	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	-	FEMA SA	FEMA SA	FEMA SA
Timeframe	SA	SA	SA	SA	SA	NIFC SA	SA	SA	SA	SA	SA

Table A-2– Consideration of Losses in Data Sources used by NOAA (Continued)

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Insured Losses	SA	SA	SA	PCS SA	PCS SA	PCS SA	PCS SA	SA	SA	PCS SA	PCS SA
Uninsured Losses	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA
Underinsured Losses	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA
Losses over the Insurance Cap	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA
Number of Acres of Loss	USDA SA	USDA USACE SA	USDA SA	USDA USACE SA	USDA USACE SA	USDA NIFC SA	USDA USACE SA	USDA SA	-	USDA SA	USDA USACE SA
Location	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA NIFC SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA
Homeless	-	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	-	-	FEMA SA	FEMA USACE SA
Aviation Losses	-	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA

Table A-2– Consideration of Losses in Data Sources used by NOAA (Continued)

Loss	Drought/ Heat Wave	Non-Cyclone Flooding	Freeze	Severe Storm	Cyclone	Wildfire	Winter Storm	Insect Infestation	Epidemic	Earthquake/ Volcano	Technical Disaster
Marine Losses	FEMA SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	FEMA USACE SA	FEMA SA	FEMA USACE SA	-	-	FEMA SA	FEMA USACE SA
Plants & Wildlife	SA	SA	SA	SA	SA	NIFC SA	SA	SA	-	SA	SA
Society & Public Health	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA
Tourism & Recreation	SA	SA	SA	PCS SA	PCS SA	PCS SA	PCS SA	SA	SA	PCS SA	PCS SA
Relief Response	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA
Imports/Exports	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA	FEMA SA
Prices	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	USDA SA	SA	USDA SA	USDA SA

Economic, Agricultural, & Energy and Environmental Model Descriptions

Macro Models

Global Trade Analysis Project – Energy-Environment Version

The GTAP open-source system is a publicly edited and available Input-Output model that incorporates different substitutions and uses across the various systems and entities within the model. This means that the model is based off of past relationships between industries that exist in the production process (e.g. a certain amount of steel output is used as an input into the car industry), and the data are provided by the public at large through an open source collection system (like a Wikipedia of I/O models). While the I/O tables can be aggregated or disaggregated as needed, the model has a strong international focus that may make U.S. analysis less robust. GEMPACK coded open access estimating system. There are several versions of the GTAP model, including versions that specifically focus on greenhouse gases, biofuels, and other specializations.

IHS Models

IHS is a large consultancy that produces several robust models that can effectively run policy and disaster scenarios on the U.S. economy. For example, IHS houses the Global Insight suite of models, which cover everything from macroeconomic and regional models to commodity, chemical, and energy models (CERA).

IMPLAN

IMPLAN is a software system that generates local economy models. It relies on Social Accounting Matrices (SAM) to capture regional business transactions. These transactions then propagate through the model economy using multipliers to estimate the knock-on effects from increases or decreases in activity. The SAM is similar conceptually to an input-output framework

- Based on an IMPLAN structure and using its data, Socio-Economic Benefits Assessment System (SEBAS) uses a modified Input-Output approach to modeling project-specific investments at the county level. The model looks to estimate the effects of any change from the project in terms of income changes across the socioeconomic ladder. There is a SEBAS model available for each U.S. county, and a (non-specified) number of inter-regional aggregators that allow for trade and feedback in neighboring areas. The model uses the BEA's I/O matrix, with slight modifications to the data. Estimates are easily scaled up to the regional level. SEBAS produces extremely detailed information about household income and sectoral/occupational employment, as well as 54 NAICS industries.

REMI

Regional Economic Models, Inc. licenses a large U.S. model with regional- and state-level data and information. The model relies on an input-output base framework, but incorporates econometric and general equilibrium methodologies, as well as improvements from economic geography. With a focus on state-level multipliers, the model can examine the ultimate effects related to disruptions from catastrophic events.

Microsimulation Model of National Economy MSMNE-02

An excel-based macroeconomic model that is available for free, the MSMNE-02 model estimates several different sectors of the economy using multiple agents for each. The model focuses primarily on agricultural, industrial, and service sectors for the supply side of the economy, while also modeling households, labor markets, government, and foreign trade. The model is based off of an input-output platform.

Fair Model

The Fair Model is a macroeconomic model produced by Yale economist Ray Fair and is freely available to the public. Programmed in Eviews, the model estimates most macroeconomic and financial variables; the model code is also freely distributed, allowing users to modify assumptions, model structure, and produce individually tailored counter-factual scenarios.

Energy & Environmental Models

National Energy Modeling System (NEMS)

NEMS is a complex forecasting system for the entire energy economy of the U.S. (and the some aspects of world energy, too). NEMS has a modular structure, with the ability to model any combination of the 12 modules in any given run. There are demand models (residential, commercial, industrial, transportation), supply models (coal, natural gas, petroleum, electricity, renewables), and others (NG distribution, macroeconomic, international). The model is based off of a convergence logic, which means that the model is not solved like an equation but rather estimated and refined over a series of econometric iterations to arrive at the most precise estimate possible based on the data; an iteration of the model usually takes 2+ hours to run, and some scenarios can take several iterations in order to fully converge. As such, the model requires extremely powerful computers and whole host of different software to run properly (Fortran, Ketron OML, Eviews, Microsoft Visual Studio).

The different modules are based on different systems, but the model is broadly based on linear programming. Specifically, the Electricity Market Module (EMM) and other supply models optimize the likely investment choices that expand supply of energy for future years in the forecasting window (currently annual estimates to 2035) based on current supply, current demand, and price projections within the model. The model produces an extremely rich source of outputs and can run under a whole host of assumptions (including perfect, adaptive, or myopic foresight, allowing for very different investment decisions in the LP estimates), modeling every aspect of supply and demand in the model composition. This includes plant and county level information on many variables.

The model is updated annually by the EIA, the input files and estimation codes can be changed, and all elements of the model are publically available.

Short Term Energy Outlook (STEO)

STEO is monthly model that forecasts a 2-year period ahead for the entire U.S. energy economy, as well as making similar estimates at the regional level. The model incorporates most EIA and other publicly available data in producing the estimates, including NOAA weather and hurricane forecasts. The entire system runs a series of models for each energy market, including supply, demand, and transmission/ distribution of energy. The data are publicly available, and the outputs and estimation equations can be found on the website. The model is econometrically estimated using structural equations, and primarily focuses on the prices and quantities that clear each energy market. The model also has a macroeconomic and international component.

MARKAL Models

MARKAL Models are a series of energy systems models that try to estimate the important aspects of energy markets (supply, demand) based on current technology, likelihood of continued adoption and improvements, and other probable changes. There is a regional version. The model runs on a partial equilibrium basis across time periods to better model the responses to changes in demand & supply through the price signals that any shocks to the equilibrium generate.

The model is primarily structured around demand for energy for specific markets or regions, the supply of energy to that market, exports of energy out of that market, technology (including existing technology, learning curves as efficiency improves, and adoption rates), and commodities (inputs used up in the energy market). The CGE is a cost minimization model over the time period, so it assumes 1) that there is no excess supply or demand in any period (i.e. there is no waste), 2) investments and adoptions are made with perfect foresight over the modeled time period, and 3) there are no market distortions in the baseline case (markets are perfectly competitive and there are no barriers to technology adoption or implementation beyond time to install). The models have a flexible forecasting window.

ASPEN

Produced by the Environmental Protection Agency, ASPEN is a computer simulation model designed to model toxic air pollution. The model produces extremely granular estimates of pollution, down to the census track. This model would be valuable in measure indirect effects of natural disasters on emissions and environmental impacts.

Agricultural Models

The OECD Partial Equilibrium Model – AGLINK

The AGLINK model is produced by the OECD and is updated annually for the Agricultural Outlook publication. The model is geared towards modeling and forecasting agricultural prices and trade balances throughout a host of different countries and regions. Using a modular structure, the model can be solved for individual modules or combinations of some or all modules at once. This allows for flexibility of outputs, isolation of country-specific effects, and a marshaling of computing resources in cases of country-specific sensitivity analyses. The model also focuses on being robust to policy changes and looks to model policy proposals effective. Modules include Australia, Canada, Japan, New Zealand, South Korea, Mexico, EU, U.S., Argentina, China, & Rest-of-World. Certain equations also include country-specific details concerning non-module countries as appropriate.

The model outputs (and inputs) include roughly 30 agricultural sectors; broadly include submarkets of grains, oilseeds, livestock, and dairy. These markets are modeled as being competitive and homogenous across countries, with outputs being substitutable for imports. Production and consumption decisions are done using behavioral equations (linear optimizations), relying on constant-elasticity reactions to prices (that is, consumers respond to relative price changes in the same way regardless of the current consumption level). The model uses limited dynamics mostly to model land use and longer supply chain issues (e.g. cattle take several years to come to market, and thus past knowledge of cattle stocks informs about current year cattle output capacity). The model also incorporates add factors to smooth or calibrate equations that misbehave or produce strange results; documentation of these is less clear in terms of frequency.

Equations in the solvable model generally focus on supply, utilization, trade, price transmissions, or market clearing conditions. Specification is based on modeling behavioral decisions, technical relationships, or identities in the data.

Food and Agricultural Policy Research Institute Model (FAPRI)

This model relies on a series of econometrically estimated equations, parameterized with values from empirical/academic estimates, as well as identities (i.e. relationships that are known to exist and not change). The model links 20+ commodity markets that are cleared simultaneously, representing nearly all of the agricultural economy of the U.S. The model is very flexible in that it can model both as a defined answer (deterministic) or solved by simulations with uncertain outcomes (stochastically); the model is also solved in levels rather than growth rates, which can be valuable if looking specifically at quantity estimates. The documentation is pretty complete in listing the linkages and specifications of the model, though the discussion of the framework is somewhat limited. The model estimates the supply and demand equations for each market, incorporating the cross-elasticity of substitution between the markets in each demand and supply equation. These, coupled with the equilibrium conditions, create the simultaneous system of equations that can then be modeled. The model forecasts a 10-year window.

Forest and Agricultural Sector Optimization Model (FASOM)

FASOM is an extremely large and complex dynamic non-linear programming model that estimates land usage between forestry and agriculture. There are two sub-models for each of the two broad categories, but they do allow for significant feedback between the two when land-owners optimize land use. The forecasts are made in 5-year chunks over 100-year window, with ending portfolio value a key component to maintain consistent decision making of the agents. The model can be broken down to 11 Market regions and 63 sub-regions. The program models the behavior and equilibrium based on a top-down approach, looking for competitive markets based on the current configuration (that is, how the land is currently being used and the production markets are currently being supplied). To ensure excessive convergence/non-corner solutions, there are perturbation and artificial variables that are added, which can minimize some of the problems and potential strange results, but also likely makes some of the calculations opaque. The model is deterministic with perfect foresight, so there is no space for stochastic estimation (uncertainty).

In addition to the commodity and factor prices, this versions primary output change is GHG in carbon equivalents. The model is written in GAMS.

International Model for Policy Analysis of Agricultural Commodities & Trade (IMPACT)

The IMPACT-WATER model attempts to build up agricultural production from 281 food-producing areas, composed of 115 economic regions and 126 individual water basins to measure total world agricultural production. These include 40+ commodity markets, with supply and demand for those commodities clearing in each food-producing area in each period (with any excess production or demand clearing due to interregional or international trading). All inter-regional trading must sum to zero (i.e. supply = demand for the entire system of equations), with trade being optimized based on geo-spatial preference (e.g. trading within a country is "cheaper" than exporting to another country).

Production equations are determined by area of land available for production within a region, as well as the potential yields from those areas for each of the 40+ commodities. Producers optimize based on price of output, input costs, and input availability (including water availability and contribution to yields). Regional demand for commodities is a function of price, income, population, etc. This creates a world price & quantity for each of the commodities. Implications of the results are then interpreted for water usage (determined simultaneously in the model), nutritional matters, and security issues.

Note that the U.S. has one of the most disaggregated modeling treatments, having 14 river basins modeled.

The model is written in GAMS, and has a 30-year forecast horizon.

POLYSYS Modeling Framework

The POLYSYS framework is a granular forecasting tool that looks to measure the deviations from baseline estimates as a means of forecasting policy. Specifically, the structure is one of Equilibrium Displacement; preset estimates and relative changes can be inputted into the model and the resulting changes to the agricultural economy. The model primarily focuses on changing 2 broad market types (crops & livestock) and disseminating any inputted changes throughout the entire system; this produces estimates as to the changes in all crop & livestock markets in 305 regions, with resultant income, output, and price changes. The model works by estimating the supply and demand curves for each of the 12 crop types and 7 livestock types, then optimizes (LP) at the regional level. Essentially, producers are given perfect foresight as to what the changes entered mean, and then change land use and crop/livestock selection according to what is the most profitable (can be modeled in two separate ways). Optimization occurs using known elasticity measures from observation, academic studies, and pre-processed estimates. These changes are then estimated and aggregated, measuring total deviations from the original equilibrium in order to calculate changes in income. Various policy and alternative estimate scenarios can be done, including the use of government programs.