BAMS
Meeting Summary

Joint Collaboration on Coupled Data Assimilation and Modeling

Jamese Sims, Tsengdar Lee, Dorothy Koch, Brian Gross, Ivanka Stajner, David Considine, Steven Pawson, Daryl Kleist, Ron Gelaro, Stylianos Flampouris, Youngsun Jung, and Marc Gasbarro

NOAA–NASA Coupled Data Assimilation and Modeling Workshop

What: Scientists came together to discuss potential ideas and specific subjects on data assimilation and Earth system modeling. The workshop was organized by center leads and program managers from NOAA and NASA.

When: 20 April 2021

Where: Online

KEYWORDS: Numerical weather prediction/forecasting; Coupled models; Data assimilation; Ensembles; Numerical analysis/modeling; Model initialization

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Corresponding author: Youngsun Jung, youngsun.jung@noaa.gov

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AFFILIATIONS: Sims—NOAA/NWS/OSTI Modeling Program, Silver Spring, Maryland; **Lee**—Weather Data for Operation and Assessment Program, NASA PO, Washington, D.C.; **Koch**—NOAA/OAR/Weather Program Office, Silver Spring, Maryland; **Gross, Stajner, and Kleist**—NOAA/NWS/EMC, College Park, Maryland; **Considine**—Modeling, Analysis and Prediction Program, NASA PO, Washington, D.C.; **Pawson and Gelaro**—Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, Maryland; **Flampouris**—Tomorrow.io, Boston, Massachusetts; **Jung**—NOAA/NWS/OSTI, Silver Spring, Maryland; **Gasbarro**—NOAA/NWS/OSTI/Science and Technology Corp., Silver Spring, Maryland

The National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA) have a long history of collaborations on modeling and data assimilation (DA). These collaborations are often enhanced by the serendipitous exchange of personnel or driven by the change of programmatic agenda. In the past 20 years, establishment of the Joint Center for Satellite Data Assimilation (JCSDA) initiated by Drs. James Purdom of NOAA National Environmental Satellite, Data, and Information Service (NESDIS), Franco Einaudi of NASA Goddard Space Flight Center (GSFC), and Louis Uccellini of NOAA National Weather Service (NWS) occurred. Also, the National Centers for Environmental Prediction (NCEP) and GSFC's Global Modeling and Assimilation Office (GMAO) initiated joint development of the Gridpoint Statistical Interpolation (GSI)-based hybrid 4D-ensemble variational data assimilation system and the collaboration on Finite Volume Cubed-Sphere Dynamical Core (FV3) by S. J. Lin of the Geophysical Fluid Dynamics Laboratory (GFDL) and William Putman of GSFC. In 2016, NOAA advanced the Next Generation Global Prediction System project (NGGPS) and created the NOAA Earth Prediction Innovation Center (EPIC). Furthermore, the 2017 National Academies Press's Consensus Study Report, "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space" called for more closely coordinated modeling and data assimilation system development and experimentation (recommendation 4.2, 176–177). Because of the significant overlapping interests but sometimes different expertise in Earth system modeling, and the strategic commitment in the use of JCSDA's Joint Effort for Data assimilation Integration (JEDI)-based data assimilation system at NASA and NOAA, both agencies see the tremendous benefit from the continuous and enhanced collaboration to leverage the expertise at both agencies and avoid duplicative efforts.

Recognizing these benefits, program officers at NASA and NOAA started the discussion on future collaboration opportunities. They held three half-day scoping sessions between October 2019 and December 2020 to explore topics for further development. These topics included atmospheric modeling, atmospheric chemistry, and aerosol transport, coupled data assimilation, and ocean modeling just to name a few. It became clear that several opportunities arose with coupled data assimilation as both agencies have similar development and target product generation schedules (both agencies have coupled data assimilation product release planned in the 2025 time frame). In 2020, NOAA's Daryl Kleist and NASA's Ron Gelaro started a series of discussions for a near-term (within 2 years) collaboration focusing on building a shared observation data store to support climate reanalysis that includes quality assurance, validation, and verification. Biweekly meetings continued to discuss the collaboration for longer-term activities; however, it became obvious that a larger group discussion was needed to formulate scientific drivers, validation experiments, development schedule and milestones. This became the motivation to run a workshop focusing on coupled data assimilation and modeling.

The Coupled Data Assimilation and Modeling Workshop

In April 2021, 32 participants, including organizers representing NOAA, NASA, JCSDA, and 10 different offices and centers within or supported by them (Fig. 1), assembled virtually to identify potential collaborative activities between NOAA and NASA that focused on coupled data assimilation and coupled modeling and evaluate possible efficiencies, gained challenges, and costs for each option. The workshop's objective was to gather information on the current status of collaboration and to solicit short-term and long-term joint development, testing, and experimentation ideas along with the corresponding challenges, costs, and benefits.

Much discussion and interest in enhanced coordination and collaboration among the program offices and the senior scientists of NOAA and NASA exist. The motivation for enhanced collaboration is driven particularly by the need to satisfy the reanalysis requirements of both agencies' missions, as well as the current challenges to effectively deploy coupled data assimilation and coupled modeling for analysis/reanalysis and for subseasonal-to-seasonal (S2S) forecasting systems.

Presentations and discussion

For the past two years, a team of modeling center leads and scientists from NOAA and NASA have met to develop a coordinated approach. Specifically, both agencies mutually benefit from sharing expertise and resources to advance the understanding and modeling of the Earth system through NOAA's Unified Forecast System (UFS) and NASA GMAO's Goddard Earth Observing System (GEOS) model. Both agencies share numerous subcomponents (e.g., dynamic core, component models, couplers) and have interest in expanding their infrastructure to serve their scientific goals. There is agreement that the "coupled approach" provides a more accurate representation of the physical processes operating in the Earth system. The term "coupled approach" applies to numerical models, data assimilation, and the observations. The use of ensembles helps quantify uncertainty in Earth system predictions and also improves forecast initialization. However, there are differences among the agencies, particularly the focus of each agency's scientific mission, setup of their Earth prediction system and subcomponents, and administration of such. The goal of this workshop was to synergize efforts for both short-term goals (share observations and data assimilation methods through the JCSDA) and longer-term goals (develop coupled numerical

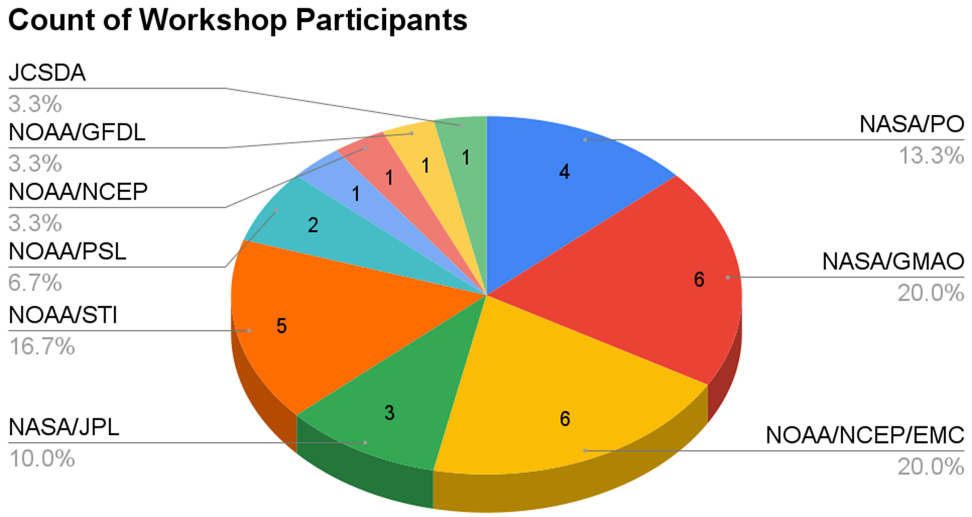

Fig. 1. Count of workshop participants according to their affiliations, NOAA/STI, NOAA/Physical Science Laboratory (PSL), NOAA/NESDIS/Center for Satellite Applications and Research (STAR), NOAA/NCEP/EMC, NOAA/NCEP, NOAA/GFDL, NASA/PO, NASA/Jet Propulsion Laboratory (JPL), NASA/GMAO, and JCSDA.

model systems for reanalysis and reforecasts) to satisfy the reanalysis and prediction mandates of each agency and deliver high-quality products efficiently and cost-effectively.

Both NOAA and NASA collaborated on exploiting common aspects between the two agencies. This included a common objective to expand knowledge of the Earth system and enhance the prediction capabilities of Earth system models from weather to climate time scales. This would meet the two agencies' broad missions and a common scientific approach for both Earth prediction systems with ensemble-based, coupled modeling, and data assimilation subcomponents. Additionally, both NOAA and NASA continue to share data and information systems, observations used for data assimilation, fundamental infrastructure (both agencies use similar or the same program languages, modeling frameworks, workflows, and runtime configurations), and modeling and data assimilation infrastructure [both NOAA and NASA already share model dynamic cores (FV3), current data assimilation systems (GSI system), observations, and active development of JEDI into their forecast systems]. Finally, both agencies recognize the staffing and resource limitations of each as well as the open scientific challenges to develop all the components of the coupled prediction systems: model dynamical cores, physics parameterizations, data assimilation, observations, and the representation of the phenomena at different temporal and spatial scales.

During the workshop, participants identified and discussed several research topics. These topics included developing a specific, coupled system approach for each component interaction (e.g., ocean–atmosphere, land–atmosphere), common metrics and diagnostics relevant to the coupled system and S2S time scales, studies of observation impacts on analyses and forecasts, and systematic experimentation to help isolate impacts of various physical mechanisms on the predictive skill. Other areas of research included developing a scientifically consistent ensemble strategy (including approaches to joint reanalysis efforts), development of observing system experiments (OSEs) and observing system simulation experiment (OSSE) infrastructure to benefit NASA's mission design and NOAA's observation requirements, to aid in building coupled data assimilation infrastructure, to coordinate intercomparison of performance using the different prediction systems, and to address short-term and ongoing infrastructure activities including JEDI-centric observations and/or solvers, shared model components, and common data assimilation systems and inputs. Nine presentations covered these areas (titles and presenters are listed in appendix A).

Benefits

As proved by the past and ongoing collaborations between the two agencies, this effort is expected to be beneficial for the participating scientists, agencies, and the scientific community in general, with direct societal impact through, for example, improved prediction of environmental extremes at S2S lead times. The apparent benefit for each agencies' budget is the potential doubling of the expected gain with the same level of investment. For instance, in the best-case scenario of a common reanalysis, the computational cost for each agency could be potentially reduced by up to 50%.

Independently of the research foci of the collaborative project(s), the main benefits are in the scientific and infrastructure advancements. Collaborative projects offer unique opportunities for a thorough introspection, evaluation, optimization, and further development of the Earth prediction system of each agency, through system calibration and cross validation. Other benefits include expansion of the prediction capabilities' coupled applications (e.g., fine-scale ocean eddy–flux coupling, aerosol processes, emission source–land coupling), acceleration of required infrastructure development for coupled modeling and data assimilation (e.g., toward more strongly coupled data assimilation), improved use of observations (e.g., assimilation of satellite sea surface salinity and the development of coupled forward

operators), and advancement of the appropriate diagnostics and metrics for the temporal and spatial prediction scales (e.g., S2S forecasts).

With a constantly changing climate, the agencies must continue to expand their knowledge of the Earth system and improve the observing, analysis, and forecast capabilities in order to enhance society's resilience to environmental variations, extremes, and hazards.

Conclusions and future plans

Discussions ended with program managers and center leads focused on channeling resources toward future data assimilation and Earth system modeling advancements. Both program offices followed up with preproposal Requests for Information detailing each agencies' objectives, expected efficiencies, and estimated costs and schedule. Both agencies continue to meet in ongoing sessions and working groups.

Appendix: List of presentations

Speaker	Title
Ivanka Stajner, Steven Pawson	Context and workshop charge
Duane Waliser, Andrea Molod	Starting from World Weather Research Programme (WWRP)–World Climate Research Programme (WCRP) S2S Prediction Project, bold new strategies and opportunities for NOAA–NASA collaboration on coupled modeling and data assimilation
Bob Hallberg	Coupling strategies
Yannick Tremolet	JEDI status and potential further NOAA–NASA collaboration
Rolf Reichle, Eric Hackert, et al.	GMAO status and potential further collaboration
Daryl Kleist, Rahul Mahajan	DA for atmospheric composition, land, ocean color
Tony Lee	Sea level and/or OSSE's for coupled boundary layer
Tom Auligne	Joint testbed application and NOAA–NASA
Jeff Whitaker, Sergey Frolov, Tom Hamill	Framework for collaboration on coupled reanalysis/reforecast