NOAA Technical Memorandum NWS FCST 29

PUBLIC RESPONSE TO HURRICANE PROBABILITY FORECASTS

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U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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Jay Baker

Washington, D.C.
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UNITED STATES DEPARTMENT OF COMMERCE
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ABSTRACT

In the spring of 1983, an experiment was conducted to measure the effect which hurricane probability forecasts would have on public response. One group of respondents in Pinellas County, Florida was presented with 16 hypothetical hurricane threat situations described in terms of storm severity, storm location, National Hurricane Center "alert" (watch, warning, neither), and local officials' statements regarding evacuation (advised, ordered, neither). Another group of residents was presented with exactly the same 16 threat situations, plus the probability that the storm would affect their area and the probabilities of its affecting other coastal locations. People in both groups were asked whether they would evacuate in each of the 16 situations. The 16 threats were constructed such that the variables involved (severity, NHC alert, etc.) were statistically independent of one another.

Overall, probabilities were found to have little, if any, effect on public response one way or the other. People clearly compared their probability of being affected to the probability of other locations being affected. If people perceived their probability to be notably higher than others, evacuation rate was enhanced slightly compared to the no probability situation. If they perceived their probability to be notably lower than others, evacuation rate was reduced slightly compared to the no probability situation.

By far the most important variable affecting response was local officials' statements, regardless of whether probability information was available or not.

PUBLIC RESPONSE TO HURRICANE PROBABILITY FORECASTS[1]

Purpose of the Study

In deciding whether and how to implement its probability forecast system for hurricanes in 1983, the National Weather Service was concerned about the effect which probabilistic forecasts would have on public response to the potential threats. Recent studies have calculated that in an extremely severe hurricane, some congested coastal areas might need to commence evacuation 30 hours before landfall in order to ensure that everyone at risk would be able to reach safety.

When a hurricane is still an expected 30 hours from landfall, however, the highest probability that any single coastal location would have of eventually experiencing hurricane conditions from that storm would be about .30 (or 30%). Implicit in that statement is the fact that other locations would have probabilities less than 30 percent, but it is more likely than not that at least one of the locations will experience hurricane conditions. Table 1 gives the maximum probability values any location can expect when the projected times to landfall are 12, 24, 36, 48, and 72 hours (Carter, 1983).

TABLE 1

MAXIMUM PROBABILITIES FOR ANY COASTAL LOCATION WHEN A STORM IS VARIOUS NUMBERS OF HOURS FROM EXPECTED LANDFALL

Number of Hours Before Landfall	Maximum Probability
72	10%
48	13-18%
36	20-25%
24	35-45%
12	60-70%

A concern is that the numbers earlier than 12 hours might be so low that the public would (correctly) decide that the storm probably won't cause hurricane conditions in their location and therefore refuse to evacuate early enough to ensure their safety. The problem, of course, is that in many locations the evacuation must begin well before forecasters can predict where the storm is going to go. Local emergency preparedness officials have been particularly fearful that the new forecasts would keep the public from heeding local orders to evacuate during watch conditions or before.

The study reported here was undertaken to ascertain just what effect probability forcasts of hurricane conditions would have on public response. The results were to serve two purposes: (1) help NWS staff decide whether and how to implement the probability forecast system; and (2) guide local preparedness planning as it might be influenced by public response to the probability forecasts.

Method

The research consisted of a controlled experiment in which coastal residents in one group were asked whether they would evacuate in a variety of hypothetical hurricane threat situations described without any probability information. Their responses were compared to those of a second group's in which the same hypothetical threats were described, but in this case supplemented with expressions of the probability that the threatening storms would cause hurricane conditions in the respondents' location and in other locations.

The Experimental Design

Sixteen hypothetical hurricane threat scenarios were presented to respondents. In the group receiving no probability information, the threats were described in terms of four variables. The following are descriptions of the variables and introduction to the study actually used by interviewers.

Introduction

Whenever a hurricane threatens this part of the coast, you have to decide what to do. I realize that there are a lot of different things you might do, depending on how serious you thought the threat was, but what I'm mainly interested in right now is whether you would evacuate or not.

When I say evacuate, I mean leaving your home and going someplace where you would feel safer. It might be way out of town or it might be a fairly short distance. It might be to a public shelter or it might be to a friend or relative's. Any of those would be evacuation.

Part of the problem is that in order to be sure you can get out safely, you might have to leave before you definitely know the storm is going to hit. Some people evacuate earlier than others, and some people never leave at all. We're interested in finding out whether you think you would evacuate in several different kinds of hurricane threat situations.

I'm going to describe these situations in terms of four different things that might influence your decision whether to evacuate or not.

- Severity of the Storm. Not all hurricanes are equal in terms of strength. Some are a lot more dangerous than others, although they all can do damage. In some of these situations, I'll tell you that the storm is what experts call a "Category 1" storm. It has sustained winds of 85 m.p.h. That's worse than some hurricanes, but not what they call a "major" storm. It would, however, cause some flooding of lowlying areas.

In other situations, we'll say that the hurricane is major. It's an extremely severe storm--what they call a "Category 4", with wind speeds equal to 150 m.p.h. In addition to wind damage, it would cause very dangerous flooding of a large area.

- Track and Position. In some of these situations, we'll say that the storm is closer to our area than in other situations. Here's one case (see Figure 1). We'll call that "Position B." It's the closer of the two positions. And here's "A" (see Figure 2). The storm is farther away in this case. B is about 275 nautical miles from here, and A is about 425 nautical miles.

- National Hurricane Center Alert. The National Hurricane Center is the part of the Weather Service mainly responsible for warning the public about hurricanes. They make a prediction about where the hurricane might hit, and based on the size of the storm, how far it is from land, how fast it's moving, and so forth, they issue what we'll call an alert, reflecting how soon the storm might possibly hit certain locations.

  If they don't think it will threaten any U.S. land areas within the next 36 hours, they don't issue any kind of alert at all--so in our threat situations, we'll call that "none" under the "alert" heading.

  If they believe it could hit within the next 36 hours, they issue a "watch" for a wide area of coastline. They can't say exactly where in that area it will hit.

  If they believe it could hit within the next 24 hours or less, they issue a "warning" for a wide area of coastline. Again, they can't say where in that area--usually 200 to 300 miles wide--the storm will hit. A warning is their most serious alert.

- Officials' Evacuation Notice. Local elected officials consult with civil defense people, state officials, and Weather Service people to decide whether the public should evacuate or not.

  They might decide not to recommend anything at all, if they don't think the threat is severe enough, and just let people make up their own minds. In that case, we'll put "none" under the heading "officials' evacuation notice."

  On the other hand, if they think the threat is serious enough, they might "advise" that people evacuate. In some cases, they might even "order" that people evacuate.

The actual scenarios appear in Table 2. One reads across the rows: the first situation is an 85 m.p.h. storm in position A; the NHC has issued neither a watch

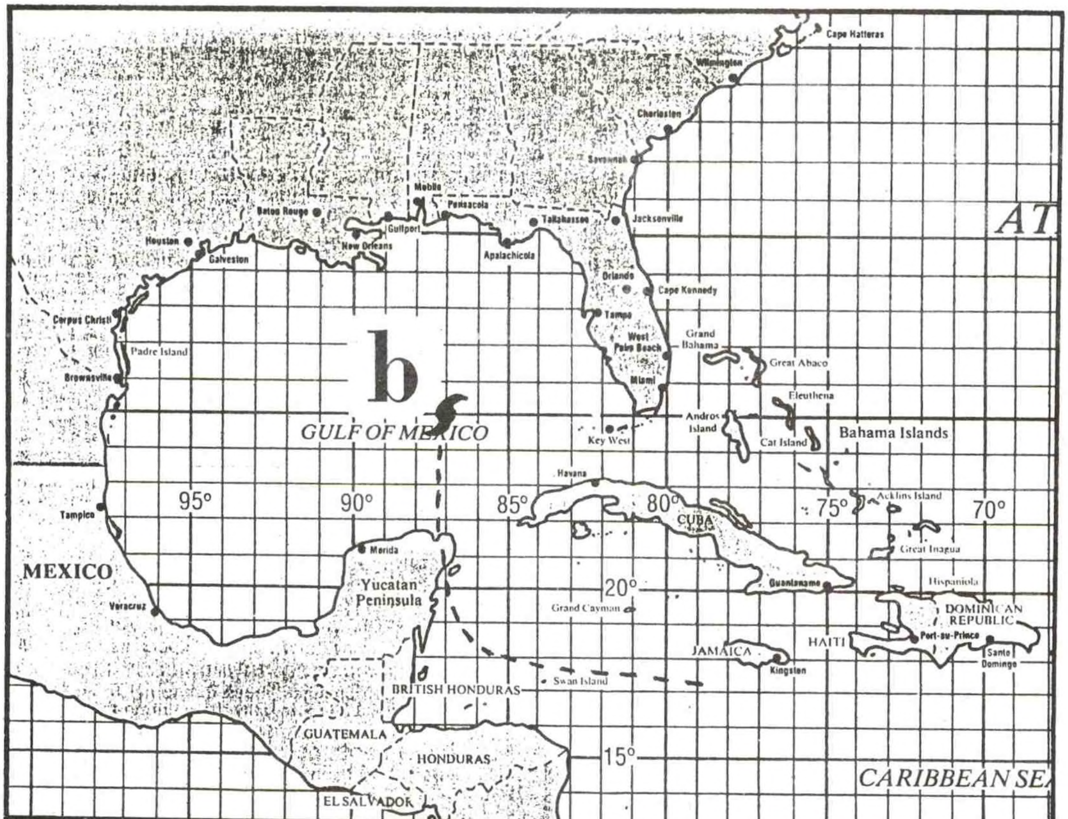


Fig. 1. Storm position B (reduced).

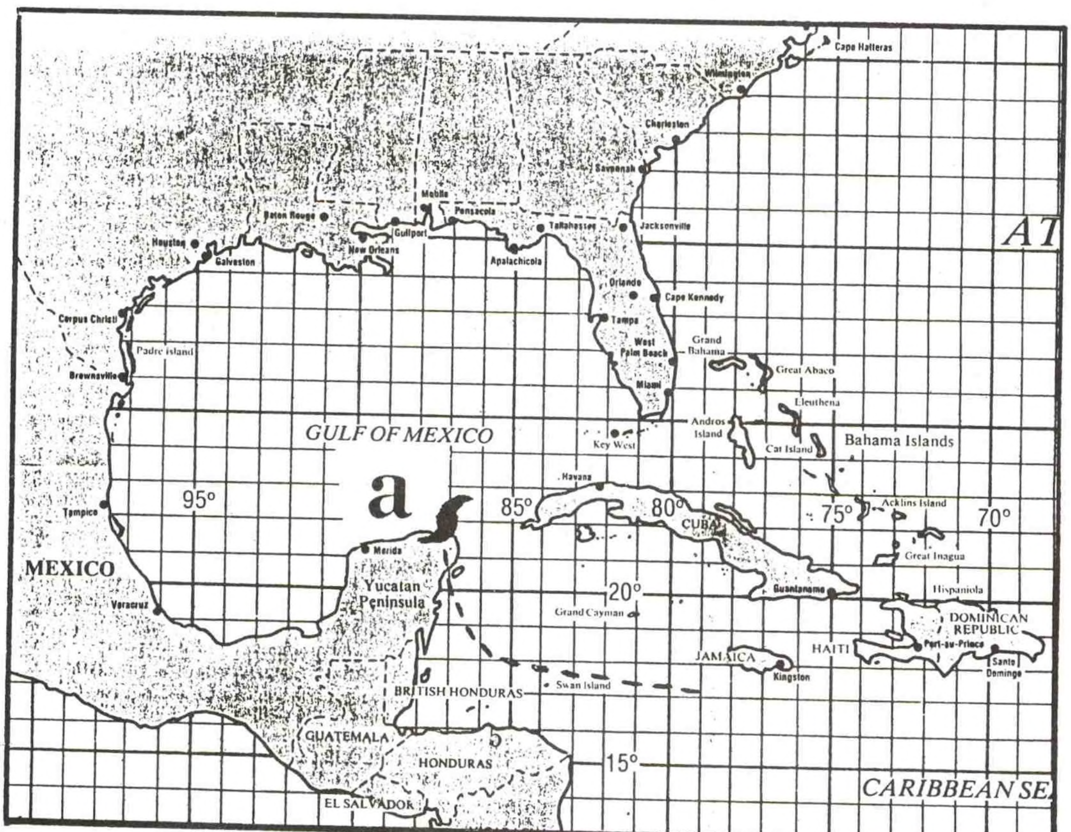


Fig. 2. Storm position A (reduced).

HURRICANE THREAT SITUATIONS

	Severity of Storm	Position	NHC Alert	Officials' Evacuation Notice	YOUR RESPONSE	
1	85 MPH	A	none	none	Leave	Stay
2	150 MPH	A	none	advised	Leave	Stay
3	150 MPH	B	none	ordered	Leave	Stay
4	85 MPH	B	none	advised	Leave	Stay
5	150 MPH	B	watch	advised	Leave	Stay
6	85 MPH	B	watch	none	Leave	Stay
7	85 MPH	A	watch	advised	Leave	Stay
8	150 MPH	A	watch	ordered	Leave	Stay
9	85 MPH	B	warning	ordered	Leave	Stay
10	150 MPH	B	warning	advised	Leave	Stay
11	150 MPH	A	warning	none	Leave	Stay
12	85 MPH	A	warning	advised	Leave	Stay
13	150 MPH	A	watch	advised	Leave	Stay
14	85 MPH	A	watch	ordered	Leave	Stay
15	85 MPH	B	watch	advised	Leave	Stay
16	150 MPH	B	watch	none	Leave	Stay

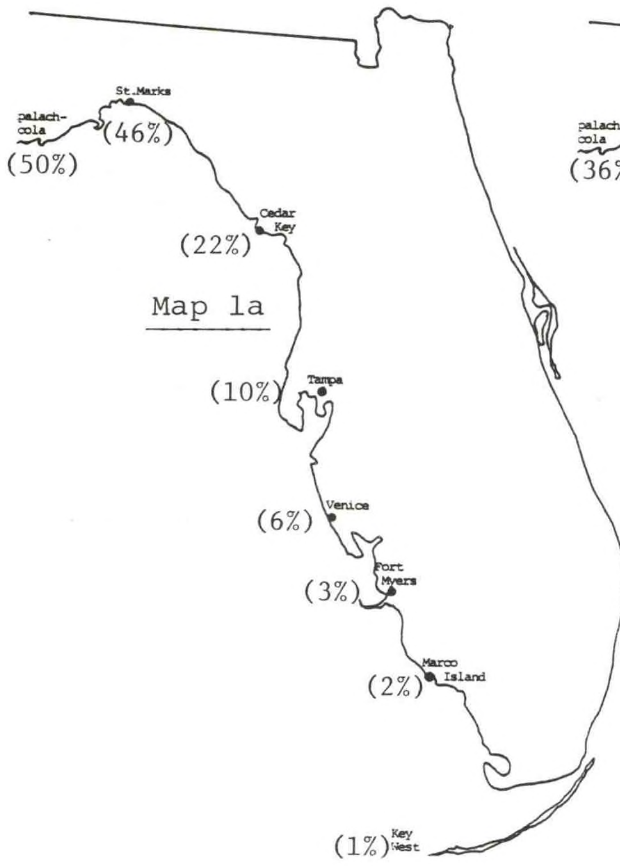
Table 2. No-probability threat scenarios.

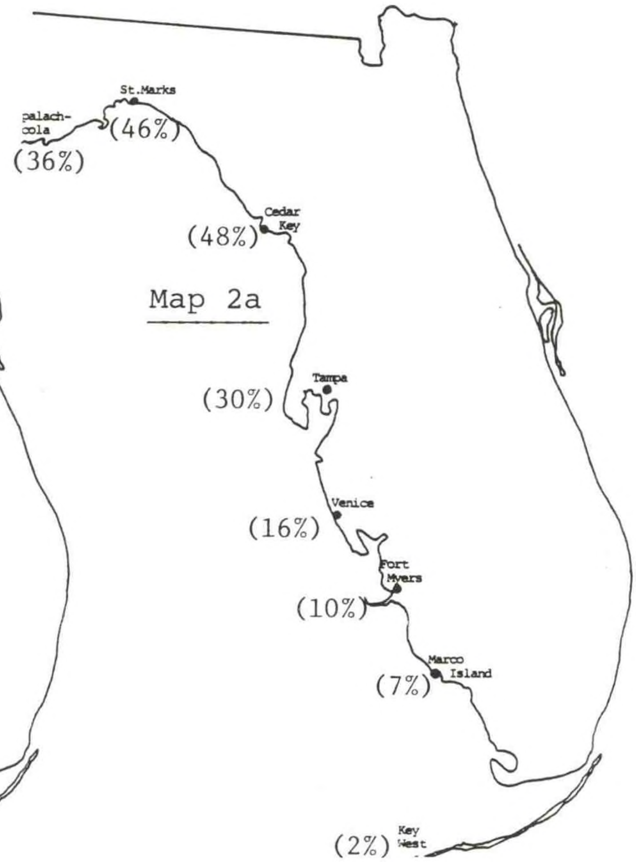
nor a warning, and local officials have neither advised nor ordered evacuation. Respondents were told:

> Each of these 16 situations is different. You might plan to evacuate in all of them or none of them. Or you might plan to evacuate in some and not in others, depending on the circumstances in each. All I want you to do is tell me whether you would leave--that is, evacuate--or not in each situation.

Other respondents were presented with precisely the same instructions and explanations as the above but with one important difference. In addition to being told the severity and location of the storm, whether there was a watch or warning in effect, and whether local officials had advised or ordered evacuation, they were told the probability that the storm would cause hurricane conditions. Three different sets of probabilities were used, each with a different group of respondents. So after having the first four threat variables described as indicated earlier with the first group, remaining respondents were given one of the following explanations--50% Max, 30% Max, or 10% Max:

> Although the Hurricane Center can't say exactly where a storm will hit, they do know that it's more likely to hit some locations than others. They express the chance that it'll eventually hit a certain place as what they call "probability of hurricane conditions".
>
> a. 50% Max
>
> In the situations I'm going to describe to you, sometimes I'll say the probability of having hurricane conditions here is 10 percent--that is, a one-out-of-ten chance. Whenever I say that, here's what the chances of its hitting other places are (show Map 1a): As you can see, it's most likely to hit further north, but it's more likely here than south of here.
>
> Remember now, they can't say for sure where it's going to hit, just that some places are more likely to be hit than others--like when they say it's more likely to rain some days than others, they can't say for sure whether it will rain or not.
>
> In other situations, I'll say there's a 30 percent, or three-out-of-ten chance of the storm hitting here. That's higher than the other case, but as you can see on this map (show Map 2a), nearby places are still a little higher.





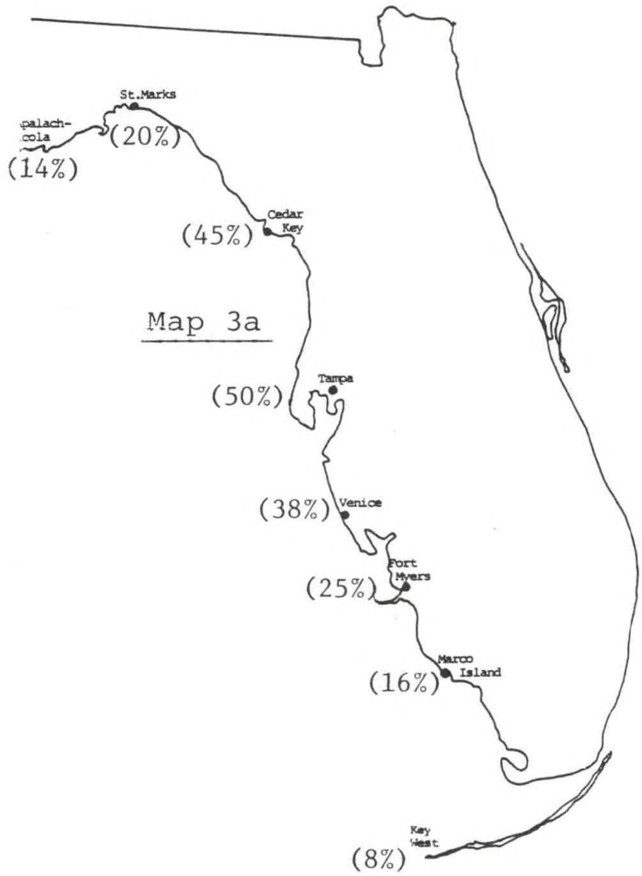


Fig. 3. 50% Max probability distributions (reduced).

Finally, in some cases, I'll say there's a 50 percent chance, that is, a five-out-of-ten, or 50/50 chance the hurricane will hit here. In those situations, we have the highest chance of being hit of any of these locations (show Map 3a).

b. 30% Max

In the situations I'm going to describe to you, sometimes I'll say the probability of having hurricane conditions here is 10 percent--that is, a one-out-of-ten chance. Whenever I say that, here's what the chances of its hitting other places are (show Map 1b): As you can see, it's most likely to hit further north, but it's more likely here than south of here.

Remember now, they can't say for sure where it's going to hit, just that some places are more likely to be hit than others--like when they say its more likely to rain some days than others, they can't say for sure whether it will rain or not.

In other situations, I'll say there's a 20 percent, or two-out-of-ten chance of the storm hitting here. That's higher than the other case, but as you can see on this map (show Map 2b), some nearby places are still a little higher.

Finally, in some cases, I'll say there's a 30 percent chance, that is, a three-out-of-ten chance the hurricane will hit here (show Map 3b). In those situations, we have the highest chance of being hit of any of these locations, although the chance is still less than 50/50.

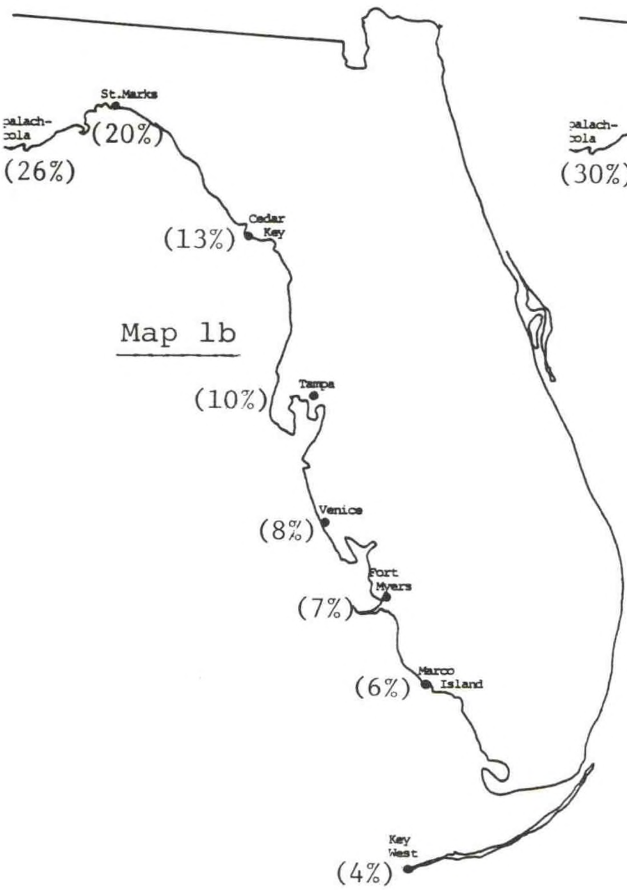
c. 10% Max

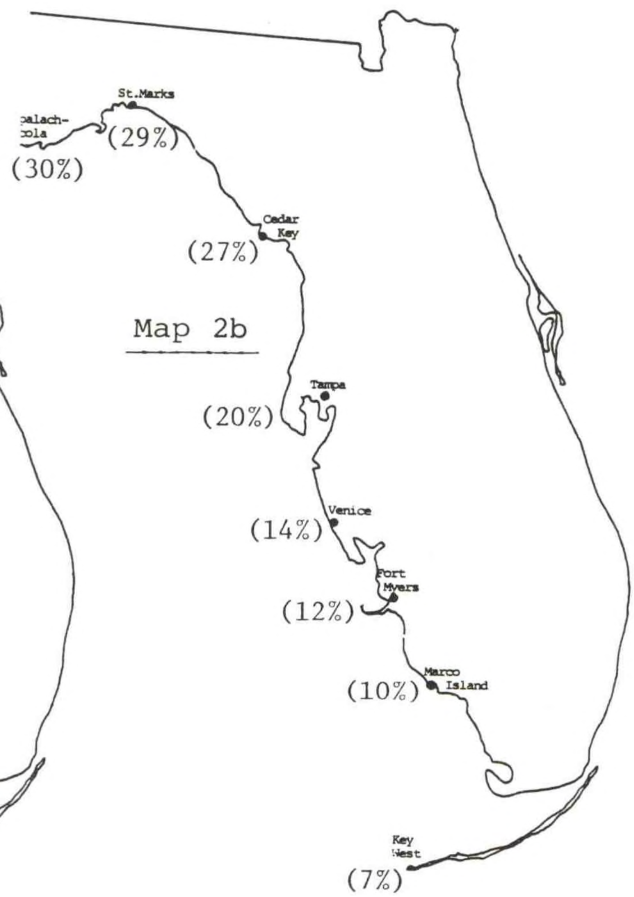
In some of the situations I'm going to describe to you, sometimes I'll say the probability of having hurricane conditions here is 2 percent--that is, a two-out-of-a-hundred chance. Whenever I say that, here's what the chances of its hitting other places are (show Map 1c): As you can see, it's more likely to hit further north.

Remember now, they can't say for sure where it's going to hit, just that some places are more likely to be hit than others--like when they say its more likely to rain some days than others, they can't say for sure whether it will rain or not.

In other situations, I'll say there's a 5 percent, or one-out-of-twenty chance of the storm hitting here. That's higher than the other case, but as you can see on this map (show Map 2c), some places are still a little higher.

Finally, in some cases, I'll say there's a 10 percent chance, that is, a one-out-of-ten chance the hurricane will hit here. In those situations, we have the highest chance of being hit of any of these locations (show Map 3c).





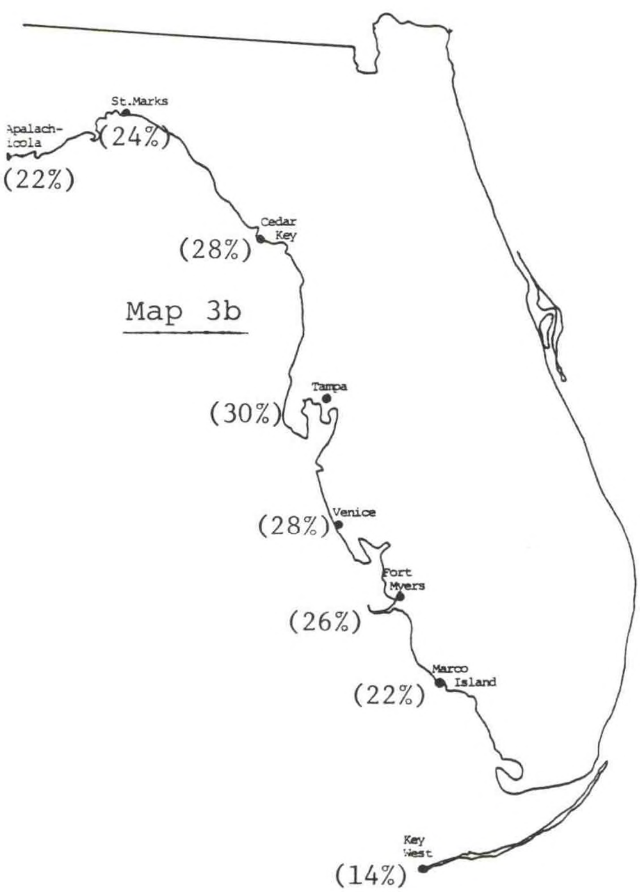
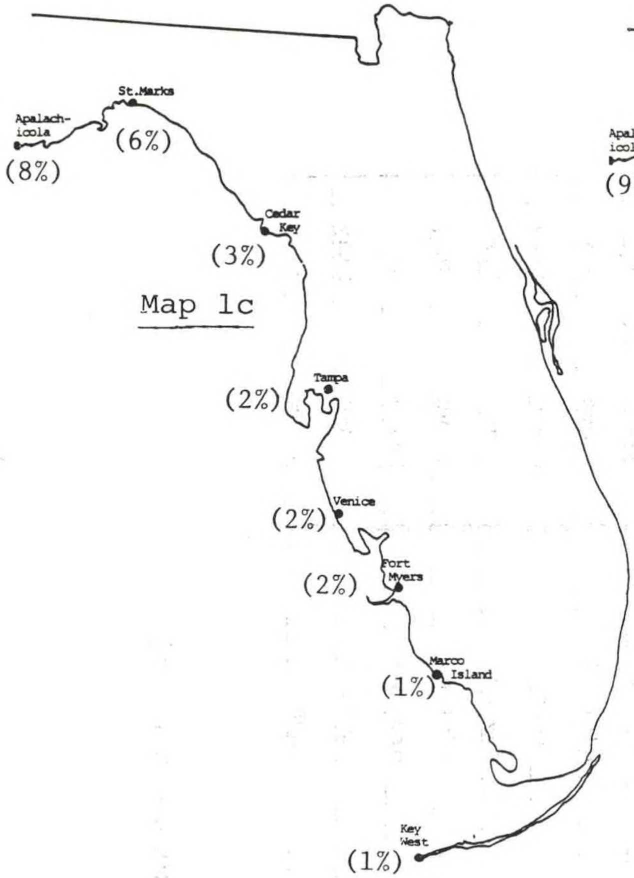
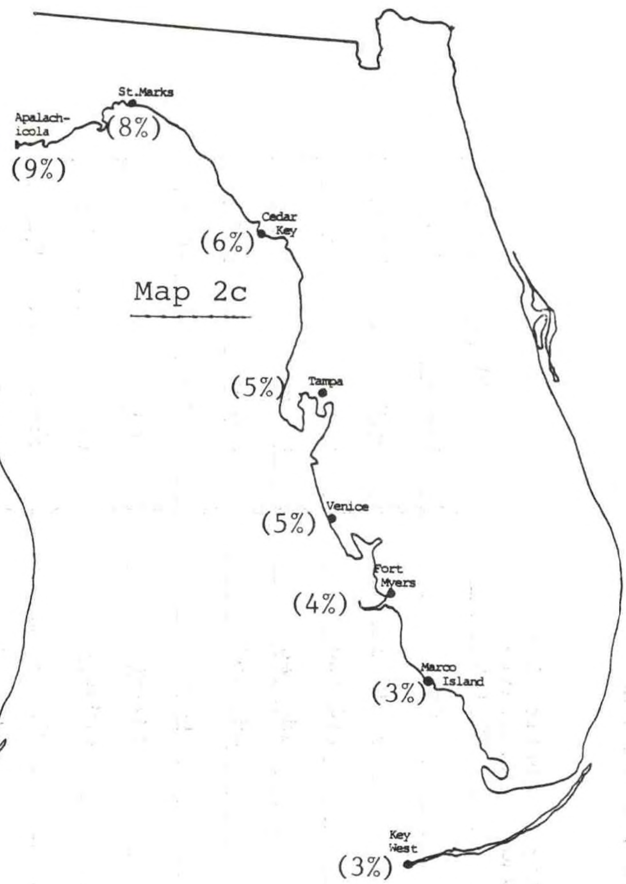


Fig. 4. 30% Max probability distributions (reduced).





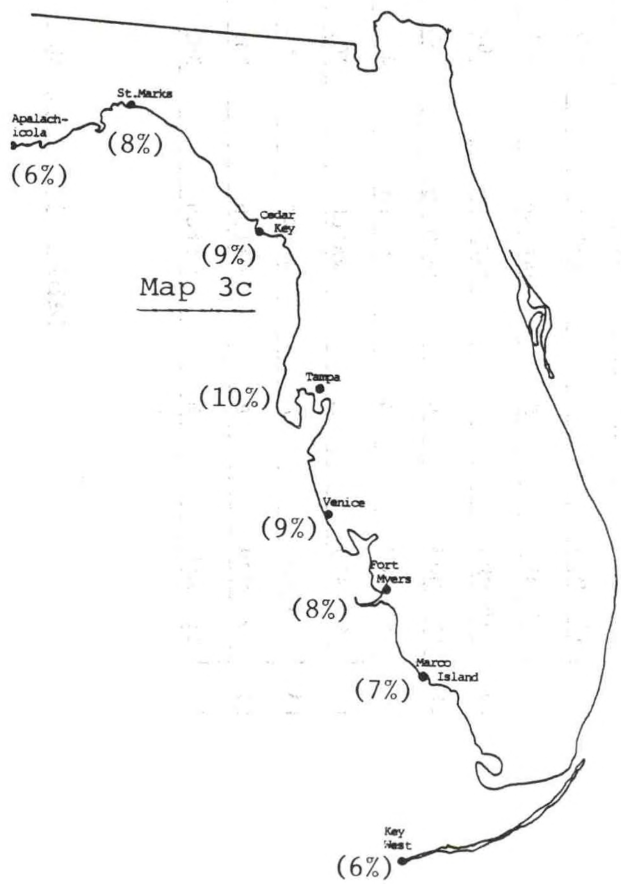


Fig. 5. 10% Max probability distributions (reduced).

HURRICANE THREAT SITUATIONS

	Severity of Storm	Position	NHC Alert	Probability of Hurricane Conditions	Officials' Evacuation Notice	YOUR RESPONSE	
1	85 MPH	A	none	10%	none	Leave	Stay
2	150 MPH	A	none	30%	advised	Leave	Stay
3	150 MPH	B	none	50%	ordered	Leave	Stay
4	85 MPH	B	none	30%	advised	Leave	Stay
5	150 MPH	B	watch	10%	advised	Leave	Stay
6	85 MPH	B	watch	30%	none	Leave	Stay
7	85 MPH	A	watch	50%	advised	Leave	Stay
8	150 MPH	A	watch	30%	ordered	Leave	Stay
9	85 MPH	B	warning	10%	ordered	Leave	Stay
10	150 MPH	B	warning	30%	advised	Leave	Stay
11	150 MPH	A	warning	50%	none	Leave	Stay
12	85 MPH	A	warning	30%	advised	Leave	Stay
13	150 MPH	A	watch	10%	advised	Leave	Stay
14	85 MPH	A	watch	30%	ordered	Leave	Stay
15	85 MPH	B	watch	50%	advised	Leave	Stay
16	150 MPH	B	watch	30%	none	Leave	Stay

Table 3. 50% Max threat scenarios.

HURRICANE THREAT SITUATIONS

	Severity of Storm	Position	NHC Alert	Probability of Hurricane Conditions	Officials' Evacuation Notice	YOUR RESPONSE	
1	85 MPH	A	none	10%	none	Leave	Stay
2	150 MPH	A	none	20%	advised	Leave	Stay
3	150 MPH	B	none	30%	ordered	Leave	Stay
4	85 MPH	B	none	20%	advised	Leave	Stay
5	150 MPH	B	watch	10%	advised	Leave	Stay
6	85 MPH	B	watch	20%	none	Leave	Stay
7	85 MPH	A	watch	30%	advised	Leave	Stay
8	150 MPH	A	watch	20%	ordered	Leave	Stay
9	85 MPH	B	warning	10%	ordered	Leave	Stay
10	150 MPH	B	warning	20%	advised	Leave	Stay
11	150 MPH	A	warning	30%	none	Leave	Stay
12	85 MPH	A	warning	20%	advised	Leave	Stay
13	150 MPH	A	watch	10%	advised	Leave	Stay
14	85 MPH	A	watch	20%	ordered	Leave	Stay
15	85 MPH	B	watch	30%	advised	Leave	Stay
16	150 MPH	B	watch	20%	none	Leave	Stay

Table 4. 30% Max threat scenarios

HURRICANE THREAT SITUATIONS

	Severity of Storm	Position	NHC Alert	Probability of Hurricane Conditions	Officials' Evacuation Notice	YOUR RESPONSE	
1	85 MPH	A	none	2%	none	Leave	Stay
2	150 MPH	A	none	5%	advised	Leave	Stay
3	150 MPH	B	none	10%	ordered	Leave	Stay
4	85 MPH	B	none	5%	advised	Leave	Stay
5	150 MPH	B	watch	2%	advised	Leave	Stay
6	85 MPH	B	watch	5%	none	Leave	Stay
7	85 MPH	A	watch	10%	advised	Leave	Stay
8	150 MPH	A	watch	5%	ordered	Leave	Stay
9	85 MPH	B	warning	2%	ordered	Leave	Stay
10	150 MPH	B	warning	5%	advised	Leave	Stay
11	150 MPH	A	warning	10%	none	Leave	Stay
12	85 MPH	A	warning	5%	advised	Leave	Stay
13	150 MPH	A	watch	2%	advised	Leave	Stay
14	85 MPH	A	watch	5%	ordered	Leave	Stay
15	85 MPH	B	watch	10%	advised	Leave	Stay
16	150 MPH	B	watch	5%	none	Leave	Stay

Table 5. 10% Max threat scenarios

The scenarios used in each of the three groups appear in Tables 3, 4, and 5. The distribution of probabilities along the coast in the 50% Max, 30% Max, and 10% Max groups are similar to those which one might see when a storm is an expected 20, 30, or 72 hours away from landfall, respectively. As well as having the maximum probability vary from group to group, variation in the degree of uncertainty in the predicted storm paths is also apparent. That is, in the 50% Max case, a narrower reach of coastline is clearly the likely impact area than in the other two cases. In the 30% Max and 10% Max groups, there is relatively little variation in the probabilities over large sections of coastline.

The Sample

The experiment was administered to a random sample of coastal residents in selected areas of Pinellas County, Florida during the spring of 1983.[2] Pinellas County is a peninsula on Florida's west coast, bordered on one side by the Gulf of Mexico and on the other by Tampa Bay. Across the bay is the city of Tampa. The Tampa Bay Regional Planning Council prepared an evacuation plan for the region in 1981, concluding that evacuation should begin as much as 17 hours before landfall in a major storm. The Council has been active in public awareness efforts in recent years, but the county has not experienced a major hurricane since 1921. As recently as the spring of 1983, however, a disturbance now known as the "no-name" storm caused several million dollars of damage along the Pinellas County shoreline.

One hundred respondents were interviewed in each of the four sets of threat situations (no probability, .50 Max, .30 Max, .10 Max). The interviews were conducted in seven clusters along the Pinellas County shore, the sample having been stratified with respect to two criteria: First, all the interviews were administered in "high risk" areas; i.e., areas which would probably need evacuating even in a minor hurricane. Second, the median age of the census tracts in which the sample was taken was between 30 and 40 years of age, except for two tracts on the Gulf side whose median age was in the low 40's. The latter criterion was imposed to make the sample more representative of other coastal areas with respect to age than would have been the county as a whole. Respondents were assigned to the four interview groups at random.

Analysis

The purpose of any experiment is to assess cause and effect. This was made possible by the way in which the 16 threat scenarios were constructed. Specifically, the situations were such that the five threat variables were statistically independent of one another, thus permitting one to "control" any four of the variables and assess whether the fifth caused any variation in evacuation response rate. It should be noted that in "real world" threat situations, this is hardly if ever possible, as the variables tend to vary together, thus confounding one another.

Marginal Means

There were eight threat scenarios in which the storm severity was 85 m.p.h. and eight in which it was 150 m.p.h. The average evacuation rates (percent evacuating) for the eight 85 m.p.h. situations and for the eight 150 m.p.h. situations are referred to as "marginal means." Any difference in the two evacuation rates (i.e., the 85 m.p.h. average and the 150 m.p.h. average) must be attributable to the difference in storm severity -- 85 m.p.h. vs 150 m.p.h.--because the effects of the other variables has been averaged out or "controlled." Thus, the marginal means allow one to assess the magnitude of effect on evacuation rate which stems from each of the threat variables.

Predictive Models

In order to predict to specific threat situations other than the 16 used in the interviews, regression models were fitted to each of the four groups. One model was calculated to predict evacuation rate for the no-probability group, another for the .50 Max group, and so forth. In each case the model was a "binary logit" equation (due to the 1, 0 dependent variable), fitted using BMD's Stepwise Logistic Regression (PLR) program.[3]

Given the four models, one can compare evacuation responses in the four groups, specifying any threat scenario of interest. For example, one can specify a 150 m.p.h. storm that is nearby (Position B), for which there is a watch in effect and local officials have ordered an evacuation. One can compute the percent of respondents who say they would evacuate if no probability information is given; the percent who say they would evacuate if the probability were .02, .05, or .10 in the .10 Max situation; if the probability were .10, .20, or .30 in the .30 Max situation; and if the probability were .10, .30, or .50 in the .50 Max situation.[4]

Findings

Marginal Effects

Figure 6 summarizes the relative effect of each threat variable on evacuation response--the steeper the slope of a line, the greater was the effect of the variable. Change in response from one level of a variable to another in each graph is attributable solely to changes in that variable, as effects due to other variables have been "held constant". In the graph of severity, for example, the only thing which would account for the increased evacuation rate between 85 m.p.h. and 150 m.p.h. storms is severity, as the effects of the other threat variables have been averaged out. The severity, position, NHC, and officials' graphs each have four lines: one for the non-probability group; one for the .10 Max group; one for the .30 Max group; and one for the .50 Max group. The probability graph has lines for each of the three probability groups.

There are several conclusions suggested by the marginal plots:

1. By far the most important variable is local officials' advice or orders. Evacuation rate increases by an average of 47 percentage points as one goes from a condition of no advice to an order. That's four times the increase resulting from the next strongest variable (severity).

2. Averaging over all threat situations, probabilities tend to increase overall response in the .30 Max and .50 Max situations, and reduce response in the .10 Max situation. This is revealed in each of the graphs in which the .30 Max and .50 Max lines are above and the .10 Max line is below the no-probability line. All three effects are relatively small (around 5 percent).

3. The effect of local officials' advice is reduced somewhat when probabilities are included in the threat information, but in a beneficial sense. Most of that reduction stems from the fact that evacuation response in

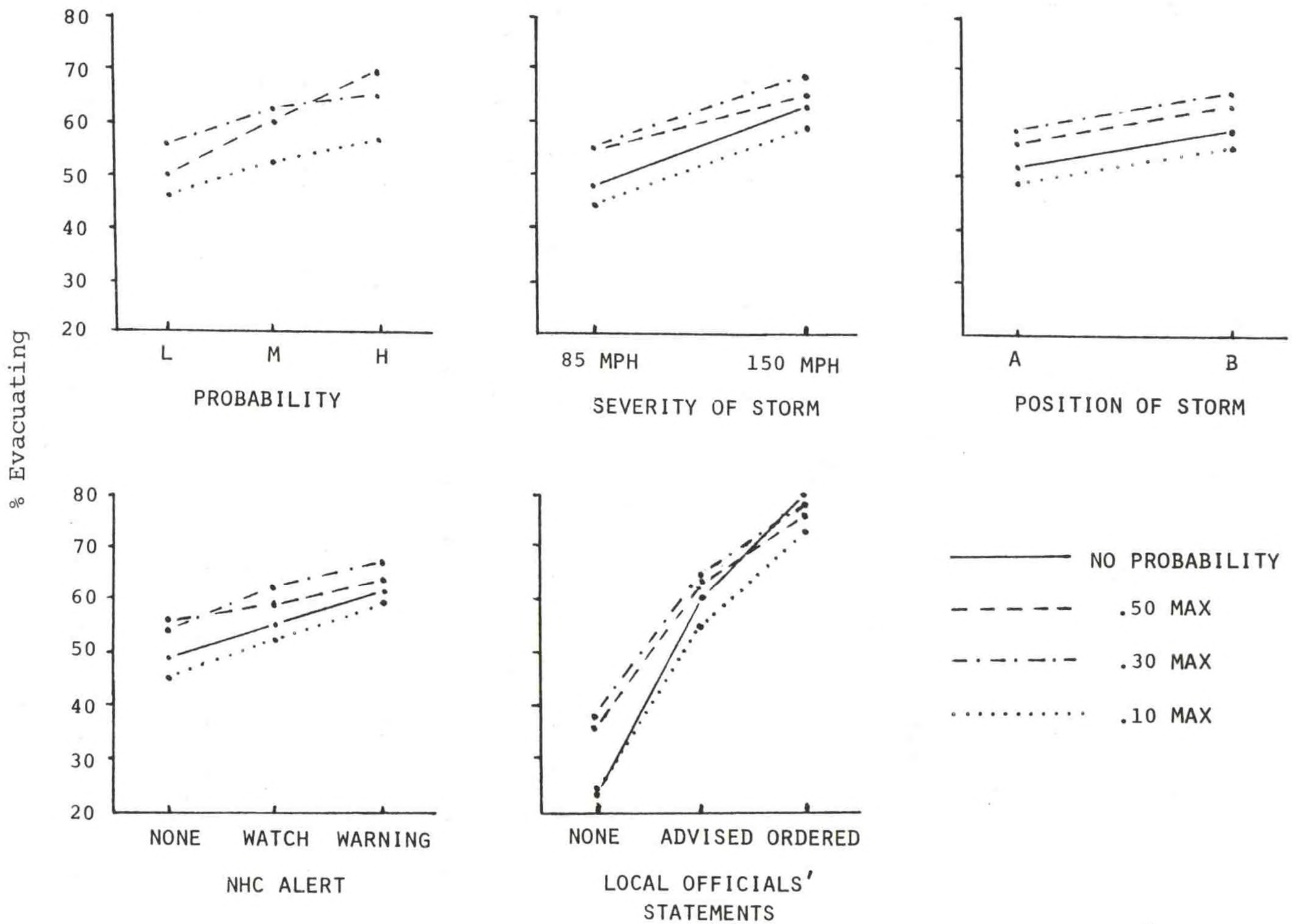


Fig. 6. Marginal means of evacuation response

the absence of any local advice or order is higher with probability information than without it. That is, when local officials order evacuation, response is about the same in the no-probability, .30 Max and .50 Max situations (.79, .78, and .76 respectively; .73 in the .10 Max situation). When officials don't order or advise evacuation, response is 23 percent in the no-probability situation, but 38 percent and 36 percent in the .30 Max and .50 Max probability situations. When officials advise evacuation (rather than order it), response is 60 percent with no probability information and 65 percent and 64 percent in the .30 Max and .50 Max situations.

4. Overall, response was greater in the .30 Max situation than in the .50 Max situation. This is, perhaps, the most surprising finding in the study. People apparently compared their chance of being hit to other people's chances in other locations. In the .30 Max condition, people with .10 or .20 probabilities noted that there wasn't much difference in their probabilities and .30--the highest probability anyone had. Thus, they all perceived the threat to be reasonably serious, supposedly being implicitly if not explicitly aware of the uncertainty in the forecast track of the storm in that situation.

   People seemed to note the lower degree of uncertainty in the .50 Max situation, and people having a .10 probability of being hit saw themselves as being relatively safe, as their chances were appreciably lower than those of people having a .50 probability of being hit. People with the .50 probability perceived a very serious threat and responded accordingly, while people having a .30 chance of being hit were about midway between the other two groups in response. The probability graph depicts a crossover in the .30 Max and .50 Max lines: In the .30

Max situation, response was greater in areas having a .10 probability of being hit than when people had a .10 probability of being hit in the .50 Max situation. In the .30 Max situation response was slightly greater in areas having a .20 probability of being hit than in areas having a .30 probability of being hit in the .50 Max situation. But, in the .30 Max situation, response was lower in areas having a .30 probability of being hit than when people had a .50 probability of being hit in the .50 Max situation.

Modelling Results

Revealing as inspection of the marginal means can be, the averaging procedure employed obscures specific comparisons which are of interest. Therefore, models were computed to forecast evacuation response in virtually any specific situation describable in terms of the threat variables used in the interviews.[5]

Table 6 gives the evacuation rates predicted by the models in 150 different threat situations. There are 15 basic scenarios varying with respect to severity, location, NHC alert, and local notice. For each of the 15, the table gives evacuation rate for no probability information and for low (.02, .10, .10), moderate (.05, .20, .30), and high (.10, .30, .50) probabilities in the .10 Max, .30 Max, and .50 Max probability situations, respectively.

Not all the situations are plausible, so the reader is encouraged to choose a basic threat situation of relevance and find the no-probability response for that situation. Then decide which probability situation (.10 Max, .30 Max, or .50 Max) would most reasonably fit that basic threat (recall that .10 Max would usually apply to storms 72 hours away; .30 Max to storms 30 to 36 hours away; and .50 Max to storms 20 to 24 hours away).

Table 6.
Predicted evacuation response rates for selected hypothetical threat situations

THREAT SITUATION						EVACUATION RATE BY GROUP		
Severity	Location	NHC Alert	Local Notice	Probability	No Prob.	Max .10	Max .30	Max .50
85	Far	None	None	None	.10			
				Low		.07	.18	.15
				Mod		.09	.21	.22
				High		.13	.25	.32
85	Far	None	Advised	None	.39			
				Low		.26	.42	.39
				Mod		.33	.47	.51
				High		.42	.52	.63
85	Far	Watch	Advised	None	.47			
				Low		.34	.48	.42
				Mod		.42	.54	.54
				High		.51	.59	.66
150	Far	None	None	None	.19			
				Low		.13	.29	.23
				Mod		.18	.33	.33
				High		.24	.39	.44
150	Far	None	Advised	None	.57			
				Low		.42	.57	.51
				Mod		.51	.62	.64
				High		.60	.67	.74
150	Far	Watch	Advised	None	.65			
				Low		.51	.64	.55
				Mod		.60	.68	.66
				High		.68	.73	.76

Table 6 . (Continued)

Severity	Location	NHC Alert	Local Notice	Probability	No Prob.	Max .10	Max .30	Max .50
150	Far	Watch	Order	None	.83			
				Low		.71	.77	.69
				Mod		.78	.81	.79
				High		.83	.84	.86
85	Near	Watch	Advised	None	.55			
				Low		.42	.57	.51
				Mod		.50	.62	.63
				High		.59	.67	.74
85	Near	Watch	Order	None	.76			
				Low		.62	.72	.66
				Mod		.70	.76	.76
				High		.77	.80	.84
85	Near	Warning	Advised	None	.63			
				Low		.51	.63	.54
				Mod		.59	.68	.66
				High		.68	.73	.76
85	Near	Warning	Order	None	.81			
				Low		.71	.77	.69
				Mod		.77	.81	.78
				High		.83	.84	.85
150	Near	Watch	Advised	None	.72			
				Low		.60	.71	.63
				Mod		.68	.76	.74
				High		.75	.79	.82
150	Near	Watch	Order	None	.87			
				Low		.77	.83	.76
				Mod		.83	.86	.84
				High		.87	.88	.90

Table 6 . (Continued)

Severity	Location	NHC Alert	Local Notice	Probability	No Prob.	Max .10	Max .30	Max .50
150	Near	Warning	Advised	None	.79			
				Low		.68	.76	.66
				Mod		.75	.80	.76
				High		.81	.83	.84
150	Near	Warning	Ordered	None	.90			
				Low		.83	.87	.79
				Mod		.88	.89	.86
				High		.91	.91	.91

In general, the following conclusions are indicated:

1. In low threat situations (e.g., 85 m.p.h., far, no alert, no advice), probability information would have little or no effect on response in the .10 Max situation, but would increase response substantially in the .30 Max situation.

2. In moderate threat situations (85 m.p.h., far, watch, advised), probability information would enhance response slightly in some areas and decrease it in others in the .10 Max situation, but would increase response in the .30 Max situation.

3. In high threat situations (150 m.p.h., near, warning, order), probability information would have little, if any, effect within the warning area. Outside the warning area, response might be decreased in the .50 Max situation, but there is probably a drop-off in response outside the warning area even without probability information.

Limitations of the Study

Presumptions About Dissemination

There are a number of caveats which should be added at this point. The study methodology was based upon certain assumptions about the way in which probabilities will be disseminated to the public: 1) Television stations will present the distribution of probabilities for several locations along the coastline, rather than the probability for their locality alone; 2) The "72-hour total" probability will be disseminated rather than the various less-than-24 hours, less-than-36 hours, and less-than-48 hours probabilities included in the NOAA advisories; 3) The actual probabilities will be given, rather than a categorization or relabelling such as high, moderate, and low; 4) No interpretations, explanations, or embellishments of the numbers substantially different from those included in our instructions will accompany the dissimination of the probabilities. The degree to which variation in the manner in which the probability information is disseminated will affect response is open to conjecture. The approach employed in the study was based largely upon approaches advocated and urged by the Weather Service in a series of media briefings held in coastal areas during the spring of 1983 and upon presentations believed most likely to be employed by the media.

Temporal Changes in Probabilities

One aspect of probability presentation which was not included in the study but which will surely face the public involves temporal changes in the probabilities as a storm's location changes. That is, as a storm moves closer to land as its direction changes, coastal locations' probabilities of being affected by the storm will change accordingly. Presumably the public will perceive a trend in their probabilities over time one way or the other or note what might be regarded as erratic fluctuations up and down. Due to funding and time constraints the present study was unable to assess whatever changes in response might result from temporal trends in the probabilities.

The Sample Location

Other caveats are in order regarding the sample used. Pinellas County, Florida is obviously not exactly the same as every other coastal community in the United States, but it is similar to many. The sample was stratified to make it more representative of the national median with respect to age, and the sample included nine different communities in the county -- some on the Gulf of Mexico, some on Tampa Bay. Moreover, past studies of people's actual responses to hurricane threats have found surprisingly little difference in response based upon variables such as income, hurricane experience, length of coastal residence, and knowledge about hurricanes (Baker, 1979). A pilot study carried out in Apalachicola, Florida found patterns of results almost identical to those in Pinellas County.

Sample Size

Throughout this report differences in evacuation rates have been noted from time to time. Strictly speaking, however, such differences could simply be a function of sampling error and might not pertain to the larger population of people from which the sample was drawn. Given the sample sizes of 100 in each group, not much emphasis should be placed upon differences less than .10.

Hypothetical Threats vs Actual Threats

To many people there is a question whether responses to hypothetical situations such as the 16(x4) used in this study bear any resemblance to how people would respond to actual threats. Certainly there is a vast literature in the behavioral sciences concerning the correspondence of behavioral intentions to actual behaviors. The closeness of their correspondence tends to vary with the specific situation being predicted, but in general the correspondence is highest when the hypothetical situation is specified in detail. For example, asking people whether they would evacuate in a hurricane will provide a less reliable response than asking people whether they would evacuate if there was an 85 mph storm 200 miles away, with a warning in effect, and local officials having advised evacuation. The modelling approach used in this study has yielded very accurate predictions for a wide range behaviors in other studies (Levin et al, 1983).

The primary intention of this study was not to provide accurate estimates of actual responses but to provide valid estimates of comparisons of responses. That is, if responses were overestimated by 20 percent, that would be acceptable so long as both the probability and non-probability group models made that same error. In fact, however, the model results appear to conform extremely well to what has been observed in actual evacuations. The models probably overpredict response by about 10 percentage points in the low risk situations (no watch/warning, no local advice/order) but are much closer in the high risk situations.

Understanding Probabilities

Much of the pessimism about how the public would respond to probability forecasts stems from a belief that most people simply don't understand probabilities and would therefore misinterpret them. Controlled experiments have shown that most of us do make quite a few judgmental errors which relate in one way or another to our (mis)understanding of probability theory (Slovic, Kunreuther, and White, 1974). Some of those studies, however, show that scientists trained in the application of probabilities and inferential statistics to their research make many of the same judgmental errors as the lay public in "everyday" situations involving probabilities. There are of course different levels of understanding regarding probabilities and stochastic processes, and people can make probabilistic misjudgments of one type or another but still have a workable understanding of other forms of probabilistic information.

Concern has been expressed by some that the public doesn't even understand rainfall probabilities. A study appearing in the AMS Bulletin, however, suggests that people understand the probabilistic part of the forecast quite well; whatever confusion exists stems from beliefs about the event being forecast (i.e., area vs point forecast).

Most evidence suggests that people have a sufficient understanding of probabilities to use them reasonably in decision making.

Conclusions and Preparedness Implications

The purpose of this study was to assess the effect which probability forecasts will have on public response, but the motivation for doing so was to enhance public preparedness policy. For the first time local officials are having the uncertainty of hurricane forecasts quantified for them, and it's going to make their job harder, not easier. Hopefully, however, it will result in more "correct" response decisions.

Possibly the most important finding in this study is that local officials' advice or orders regarding evacuation remain by far the most important element in effecting evacuation, regardless of whether probabilities are included in people's information or not. This places even greater burden on officials to employ the probability information "correctly."

Overall, the probabilities aren't going to affect response tremendously one way or the other. In low risk situations probability information might increase response somewhat; if local officials <u>don't want</u> such response, then they should plan to take measures to discourage evacuation in those situations. As a storm nears land (say, 20 hours away), people just outside the warning area might be deterred somewhat from evacuating when they observe that their probability is only 1/5 as high as another location's in the center of the warning area; thus, if local officials in these areas still believe that evacuation is necessary, they should plan to explain that necessity to their public.

Clearly, people will compare their own probability to other locations' probabilities in reaching their response decision. They can do that only if the media tells them the probabilities for other locations. Therefore, it is important to implore the local media to do so.

Finally, it's likely that the increased information load, by making decisions more difficult, will slow down the decision process for local officials. To minimize that effect it is terribly important for decision makers to work through their decision process in a number of hypothetical threat situations in advance of a real threat. What should emerge is a kind of decision algorithm (including the role of probability information) which should facilitate response decision-making.

FOOTNOTES

1. This research was supported by Florida State University's Policy Sciences Program and by the National Weather Service. I would like to thank Mike Carter for his role in arranging NWS support and for his many valuable inputs to the research design, Cliff Holmes for assisting with arrangements in Pinellas County, and Jami Waddell and Gina DeGirolamo for their invaluable work in the field.

2. Less sophisticated versions of the threat scenarios were pretested in the spring of 198 in Apalachicola and East Point, Florida by a class of geography students from F.S.U.

3. Variable levels were specified by orthogonal polynominal coding.

4. One can also predict to intermediate levels of the variables (e.g., 120 mph), but that requires an untested assumption regarding the functional form of the relationship between response and each variable, especially the two-level variables (severity and location). If willing to assume that response increases linearly as a function of severity (as implied by the marginal mean plot in Figure 6), for example, then the appropriate orthogonal polynomial code for, say, 120 mph can be determined by interpolating between the codes used for 85 mph and 150 m.p.h. (-1 and 1).

5. The actual models were as follows:

$$\text{Non-Probability Evacuation Rate} = \frac{e^{P_{np}}}{1 + e^{P_{np}}}, \text{ where}$$

$$P_{np} = .157 + .378 \text{ Severe} + .160 \text{ place} + .347 \text{ Alert} + 1.329 \text{ Local} - .132 \text{ Local}^2.$$

$$.50 \text{ Max Evacuation Rate} = \frac{e^{P_{.50 \text{ Max}}}}{1 + e^{P_{.50 \text{ Max}}}}, \text{ where}$$

$$P_{.50 \text{ Max}} = .388 + .258 \text{ Severe} + .179 \text{ Place} + .130 \text{ Alert} + .485 \text{ Prob.} +. 949 \text{ Local} -.109 \text{ Local}^2$$

$$.30 \text{ Max Evacuation Rate} = \frac{e^{P_{.30 \text{ Max}}}}{1 + e^{P_{.30 \text{ Max}}}}, \text{ where}$$

$$P_{.30 \text{ Max}} = .466 + .314 \text{ Severe} + .176 \text{ Place} + .270 \text{ Alert} + .220 \text{ Prob.} + .934 \text{ Local} - .086 \text{ Local}^2$$

$$.10 \text{ Max Evacuation Rate} = \frac{e^{P_{.10 \text{ Max}}}}{1 + e^{P_{.10 \text{ Max}}}}, \text{ where}$$

$$P_{.10 \text{ Max}} = -.031 + .364 \text{ Severe} + .170 \text{ Place} + .365 \text{ Alert} + .351 \text{ Prob.} + 1.206 \text{ Local} - .122 \text{ Local}^2$$

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