INFORMATION FORECASTING FOR HURRICANE PREPARATION

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1. INTRODUCTION

At the lead times required to complete a sortie, evacuation, or other preparation, the future track of a tropical cyclone is uncertain. The decision whether and when to prepare is based on a forecast and information about the error implicit in the forecast. On average, later forecasts (with shorter lead time) are more accurate than earlier forecasts. Therefore when deciding whether to initiate a costly preparation, there is a trade-off between lead time and forecast accuracy.

There can be substantial value in accounting for the anticipation of improving forecasts in making hurricane preparation decisions (Regnier and Harr, 2005). In order make the trade-off between the effectiveness of early preparation and the improved accuracy of updated forecasts, decision makers must have an assessment of the value of waiting and the improvement in the forecast that can be anticipated if they wait.

2. INFORMATION FORECASTS

Quantifying the time dimension of forecast quality as a supplement to track forecasts and probabilistic forecasts can help decision-makers to balance the lead-time and accuracy trade-off and evaluate investments to reduce lead times or create flexibility in preparations.

We use the term “information forecast” for a quantitative assessment of the future quality of a weather forecast as a function of time. The design of an information forecast involves decisions about the degree of storm-specificity, target-specificity, and decision-specificity. An information forecast can be as general as the average historic error as a function of lead time. More specific functions can depend on:

- storm-specific indicators of predictability such as spread in the guidance models (Goerss, 2005)
- factors correlated with uncertainty resolution such as discrepancies in model guidance that reflects both recurving and straight tracks; these conflicts will be resolved as the points of possible recurvature approach; and
- decision-specific information such as the degree of flexibility to delay an irreversible preparation and the cost consequences of delay.

Figure 1 shows the time profiles of two measures of information quality for hurricanes. The black curve represents an approximation of the mean landfall track error based on historic landfall errors reported in Powell and Aberson, 2001; these will overstate current errors. This meets our definition of an information forecast, as it indicates how much information will improve, on average, as lead time before landfall declines. This curve, however, represents an average over all storms in the Atlantic basin.

The remaining curves show an information forecast that is specific to a given target location. Specifically, it shows the false alarm rate (as a % of all threatening storms) associated with a 90% hit rate. In other words, this measures the false alarm rate (FAR) that will be incurred under a decision policy that calls for preparation whenever the strike probability exceeds a certain threshold. The threshold is selected (for each lead time) such that 90% of the time, striking storms are correctly identified. The calculation could be repeated for other hit rates. As lead time declines, it is possible to discriminate better between storms that will strike the target and those that will not; therefore, the FAR falls.

The FAR curves show differences in predictability for storms threatening three different locations (Norfolk, New Orleans, and Miami). For example, if there is a preparation that requires 24 hours’ lead time, the FAR will

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range from 36% for a decision maker at Norfolk to 48% for a decision-maker at Miami. If there is flexibility to reduce preparation times—for example by investing in infrastructure to speed evacuation—the biggest gains in New Orleans will come from reducing lead times from 24 to 18 hours. In every city, there is a plateau at about 40 hours' lead time—reductions in preparation time for lead times longer than 40 hours will not appreciably reduce FAR, and may not be worth the cost.

The FAR profiles were calculated based on a Markov chain model of hurricane motion derived from 53 years of historical hurricane tracks and described in Regnier and Harr (2005). This model is simple, purely climatological, and therefore very low skill, but it allows us to explore the stochastic evolution of storm tracks and information about the storm's future movement. The FAR measure is limited of course by the hurricane model. Despite these limitations, they illustrate the discrimination—on the basis of target location and storm-state—that are desirable in an information forecast.

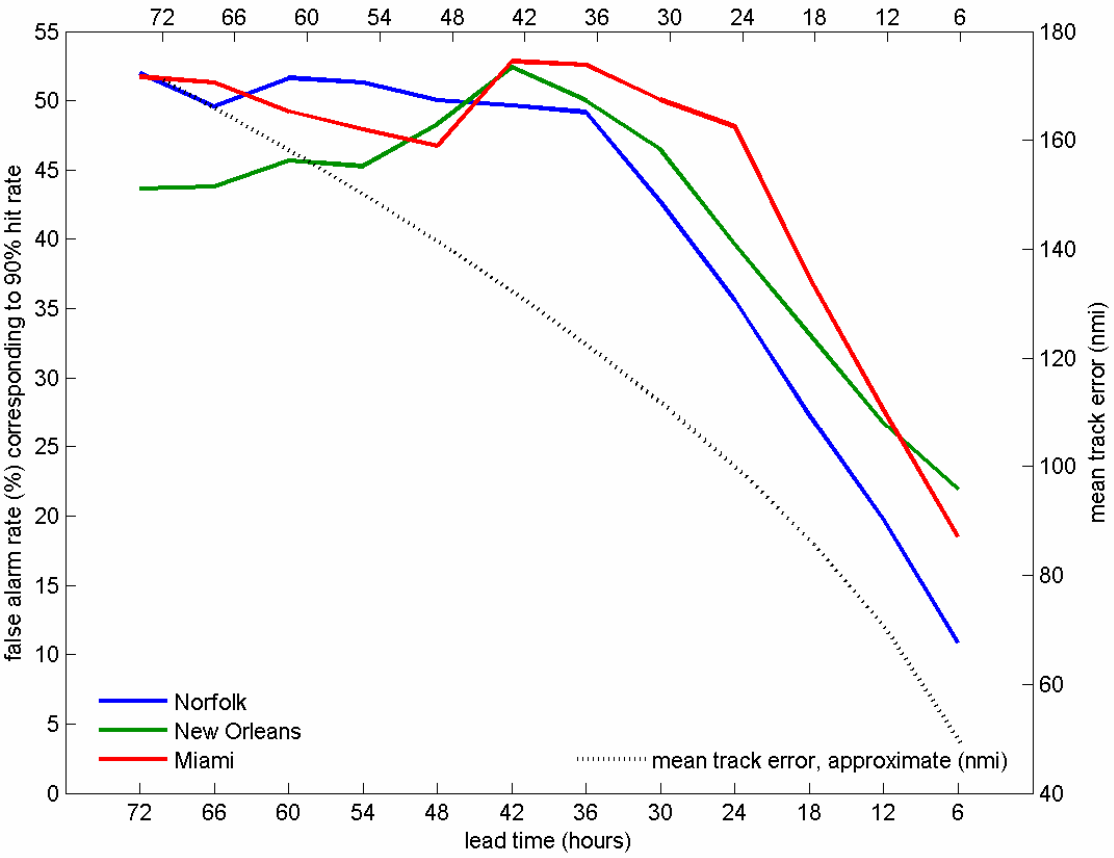

Figure 1: Examples of information forecasts for hurricane track accuracy. The mean track error is an approximation based on results in Powell and Aberson (2001). The false alarm rates for three target locations (Norfolk, New Orleans, and Miami) are based on strike probabilities in the Regnier and Harr (2005) Markov model, applied to a set of 10,000 simulated hurricane tracks, also generated using the Markov model. For each target location, and each lead time, a threshold probability was selected such that 90% of striking storms exceeded that strike probability at the given lead time. The FAR is the percentage of all threatening (strike probability > 1%) storms that exceed the strike probability threshold but do not strike the target location.

3. DISCUSSION

Tropical cyclone meteorologists and experienced forecast users assess their anticipation of improving forecasts intuitively and in some cases explicitly, but not quantitatively. Quantifying this attribute of information about storms can help meteorologists communicate their expertise to users. It can also help in refining hurricane preparation policies to substantially reduce the average costs of preparing for storms.

In theory, a backward induction considering all possible future states of information for each forecast update can identify the optimal time to initiate a costly preparation. However, dynamic optimization in real time is unrealistic in most situations because of the difficulty in quantifying both the stochastic evolution of the weather and forecasts and the costs of delay and false alarms.

An information forecast would convey to decision-makers whether information that will determine the outcome of their decision can be expected in the next one or few forecast updates. The information forecast would reflect critical points when certain meteorological events will have a profound impact on the potential landfall location.

For example, consider two hypothetical scenarios for an elected official with authority to order an evacuation. In each case, a hurricane is forecast to arrive at Category 3 in 36 hours, and the probability, conditional on available information, of hurricane-force winds is 30%.

The official also has access to the FAR “information forecast” in Figure 1. In the first scenario, the official is in Miami. The information forecast indicates that forecast quality is not expected to improve substantially for at least 12 hours. In the second scenario, the official is in Norfolk, and the information forecast shows that information quality can be expected to improve dramatically in the next 6 and 12 hours.

Depending on the time of day, clearance times required for evacuation, and other factors, it could be appropriate to order an evacuation immediately in the first scenario, and delay 12 hours in the second. In the second scenario, if the storm recurves, an evacuation will not be necessary. If the worst happens, an expedited evacuation could be ordered.

In the old NHC strike probability model, the probability distribution of track locations at each lead time is similar to the distribution that would arise from Brownian motion in two dimensions; this may hold for the new wind-speed probability model as well. This property implies that there are no critical points, or lead times at which a 6 or 12-hour delay can be expected to yield a big jump in accuracy.

The development of information forecasts should include efforts to identify differences in landfall predictability, for a given lead time, as a function of landfall location and storm-specific indicators. It is differences in the anticipated value of waiting that will be most useful for users seeking to improve their use of hurricane forecasts.

In real-time decision-making, forecasts of improving information quality could be used in combination with strike probability forecasts to evaluate the trade-off between lead-time and forecast accuracy, estimate the value of waiting for improving forecasts, and thereby reduce false alarms.

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