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ASSESSMENT OF THE VALUE OF TROPICAL CYCLONE TRACK FORECASTS

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1 INTRODUCTION

Over tropical and subtropical latitudes, a tropical cyclone represents one of the most significant weather-related threats to shore- and sea-based locations. Physically, significant tropical cyclone impacts are due to high winds, high seas, storm surge, and flood-producing rains. Economically, the impact of a tropical cyclone to a shore- or sea-based asset is based on the level of preparation and the physical conditions that occur. The level of preparation for a tropical cyclone threat depends on two factors. The first is the receipt of accurate forecast information at lead times that allow for appropriate preparedness. Second, is the capability of the asset's infrastructure to adequately prepare for the threatening physical conditions. Based on these factors, decisions are made to either protect or not protect life and property. This represents a so-called "cost/loss ratio situation", which is a prototype decision-making problem that has been used to investigate the optimal use and economic value of weather information (Katz and Murphy 1997). A cost is incurred when protective action is taken, but a larger loss is experienced if protective action is not taken and adverse conditions occur.

The cost/loss ratio scenario is typically a static (i.e., one-time) decision problem. But the ultimate impact of a tropical cyclone is determined by a *series* of decisions in which weather information and the natural variability of cyclones are critical components. This study proposes replacing the static "protect or don't protect" decision-making model with a dynamic "protect or wait" model that allows for the incorporation of new information. At each successive warning period and forecast update, the decision maker can revisit an earlier decision not to protect, and choose again whether or not to protect assets based on the new information. The utility of additional types of information that could be used to optimize the series of protect-or-wait decisions is explored in the context of maximizing the economic value associated with adding the new information to the decision process. The model accounts for variabilities in the frequency of tropical cyclone occurrences and in the size of the impacts of each tropical cyclone.

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2 METHOD

A greatly simplified model of tropical cyclone evolution is used to develop information measures, information forecasts, and optimal policies for tropical cyclone preparation. Climatological tropical cyclone data from the HURRDAT data set (Jarvinen et al. 1984) are used to develop estimates of the impact of a dynamic decision process.

In the cost/loss framework, there are exactly two available alternatives (actions, in the terminology of decision science): protect or do-not-protect. We expand the alternatives so that there is a decision point occurring every 6 hours, which reflects the forecast update cycle. At each decision point, the available actions are either protect or do-not-protect. Once the protection has been undertaken, there are no further alternatives available. The optimal policy and expected total cost may then be defined. A policy consists of a designated action for every possible tropical cyclone scenario.

In our model, tropical cyclones are defined by their location on a 1° lat./long. grid in the region 0°N -55° and 10°W - 90°W. A state vector defines the tropical cyclone position and intensity over time. The vector may include climatological, analyzed and forecast information. To develop quantitative policies that account for future updates of the state vector quantities, a probability mass function defines the probability of a given forecast track conditioned on the current analyzed location of the tropical cyclone. Probabilities are calculated based on climatological transitions based on the HURRDAT data set. Therefore, given a starting location probabilities may be defined from the observed counts on the 1° lat./long. grid (Fig. 1).

3 ANALYSIS

The optimal policy and expected total costs are determined for each of four contexts.

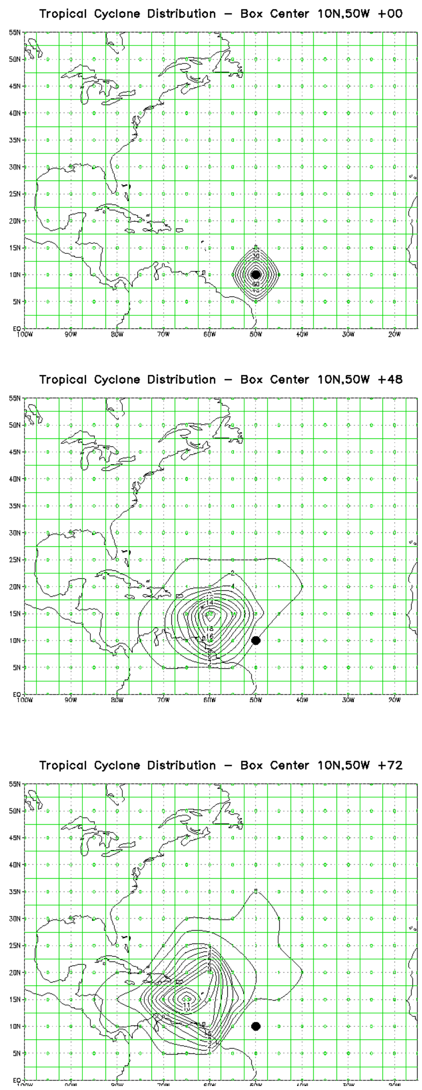

Fig. 1 *Distribution of tropical cyclone locations that (a) started in the 1° lat./long. box centered at 10°N, 50°W at a time (b) 48 h later, and (c) 72 h later. Locations are based on the HURRDAT data set.*

Based on the expected total costs of each decision context, we calculate the value of information for each formulation

The first two decision contexts use a one-time cost/loss framework, where the decision rule is to protect if the cost of protecting (C) is greater than the loss, in the case of a strike on an unprotected target (L) multiplied by the probability (p) of a hurricane eventually striking the target, conditional on its passing through a given 1° cell, i.e. prepare if $C < pL$.

1. The no-skill decision uses climatological data (e.g., Fig. 1) to determine the probability of an eventual strike (p_C). The value of information for other decision contexts is measured against this baseline.

2. A forecast track is used in the second decision context, but the probability of an eventual strike is determined based on a normal distribution of track error around the forecast track, using climatological lead-time error parameters.

The remaining decision contexts adjust for the possibility of delaying a decision. However, there is a penalty for delay: the cost of preparation increases as the lead time decreases.

3. The third optimal policy is the climatological dynamic optimum, calculated using backward induction. Forecasts are not used.

4. The final rule is the same as 3, but adjusted for the value of waiting, which is estimated by comparing the expected costs under decision context 1. and decision context 2. The rule is prepare if $C < p_F L$ –value of waiting. The value of waiting is calculated by comparing the marginal increase in preparation cost with the dynamic optimum for possible future states of the tropical cyclone.

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