Predicting Tropical Cyclone Genesis

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LONG-TERM GOALS

The long-term goal of this project is to provide probabilistic genesis forecast guidance to operational forecasters and develop a genesis index to provide guidance for operational dynamical model prediction of tropical cyclone (TC) genesis. Once regions of high TC genesis probability are identified, a movable, multi-nested version of the COAMPS® 1 with resolution of roughly 3 km or less in the innermost grid will be utilized for predicting the genesis event.

OBJECTIVE

The objective of this project is to develop a statistical TC genesis model that is capable of separating developing and non-developing tropical disturbances. A TC genesis index will be constructed to provide the probability of cyclogenesis, based on NOGAPS global analysis and forecast fields.

APPROACH

Our approach is to identify distinctive characteristics associated with developing and non-developing disturbances in the tropical western North Pacific and Atlantic oceans. A box-difference index (BDI) is introduced to quantitatively determine the relative importance of dynamic and thermodynamic parameters in determining the genesis events. Once key genesis parameters in different basins are

1 COAMPS® is a registered trademark of the Naval Research Laboratory.
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determined, then we will develop a nonlinear logistic regression method for TC genesis probability forecast at different basins.

**WORK COMPLETED**

In the past year, we primarily worked on (1) refining genesis predictors and constructing a nonlinear regression model, (2) evaluating the model performance by conducting hindcast TC genesis forecasts in the WNP for year 2009, and (3) extending the approach to the North Atlantic.

A critical factor that affects the performance of a statistical prediction model is the selection of predictors. Previously there were 11 predictors. To overcome the overfitting problem, we intentionally decreased the number of predictors. A BDI methodology (which takes into account of both the mean and spreading of samples within the developing and non-developing groups) was applied to objectively and optimally determine the best predictors for the regression model.

The hindcast of WNP TC genesis during 2009 summer with the refined genesis forecast model shows a much improved result, with a hit rate of 72.2% and a false alarm rate of only 19.2%. The detailed results will be presented next section.

The methodology is now extended to the North Atlantic. A preliminary calculation shows that the BDI-based Atlantic genesis forecast model has a quite high in-sample hindcast skill.

**RESULTS**

With use of the previous 11 predictor model, we conducted the cyclogenesis hindcast experiment for summer of 2009. Figure 1 shows the genesis potential index for all developing and non-developing cases in 2009. It turns out that the hitting rate is quite low (33%).

The model was refined with the BDI-based methodology. For a given variable (say, the relative humidity at 700hPa), the BDI is defined as following:

\[
BDI = \frac{M_{\text{DEV}} - M_{\text{NONDEV}}}{\sigma_{\text{DEV}} + \sigma_{\text{NONDEV}}},
\]

where \( M_{\text{DEV}} \) and \( \sigma_{\text{DEV}} \) (\( M_{\text{NONDEV}} \) and \( \sigma_{\text{NONDEV}} \)) represent the mean and standard deviation of the variables for the developing (non-developing) cases.
We calculated BDI of a number of important genesis parameters for the WNP, based on the NOGAPS analysis fields during 2003-2008. Table 1 lists key genesis parameters in the WNP.

**Table 1  BDI of key genesis parameters in the WNP.**

<table>
<thead>
<tr>
<th>Variable name</th>
<th>BDI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sign</td>
</tr>
<tr>
<td>Maximum 800 hPa vorticity</td>
<td>+</td>
</tr>
<tr>
<td>Rain rate (20°x20°)</td>
<td>+</td>
</tr>
<tr>
<td>800/750 hPa du/dy (10°x10°)</td>
<td>−</td>
</tr>
<tr>
<td>1000 hPa Divergence (10°x10°)</td>
<td>−</td>
</tr>
<tr>
<td>950 hPa relative humidity (10°x10°)</td>
<td>+</td>
</tr>
<tr>
<td>925-400 hPa integrated specific humidity (10°x10°)</td>
<td>+</td>
</tr>
<tr>
<td>SST (20°x20°)</td>
<td>+</td>
</tr>
<tr>
<td>Translational speed</td>
<td>−</td>
</tr>
</tbody>
</table>
While the sign of the BDI reflects the physical nature of a variable, the magnitude of the BDI measures to what extent the variable is capable of differentiating the developing and non-developing disturbance groups. The greater the BDI amplitude is, the better a variable can be used to predict whether or not cyclogenesis will happen.

Based on the table above, we reduce the predictor number from 11 to 8 and replace some of previous predictors with top BDI parameters. Figure 2 shows the 2009 forecast results with the refined genesis prediction model. Same as before, we set threshold as 0.2. The hitting rate increases to 72%, while the false alarm rate is kept about 19%.

![Fig. 2 Same as Fig. 1 except for the refined genesis model.](image-url)
The same methodology was also applied to cyclogenesis in North Atlantic. Table 2 lists top genesis parameters and their BDI values in the North Atlantic.

<table>
<thead>
<tr>
<th>Variable name</th>
<th>BDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>925 - 400 hPa water vapor content (10° x 10°)</td>
<td>+ 0.49</td>
</tr>
<tr>
<td>750 hPa relative humidity (10° x 10°)</td>
<td>+ 0.44</td>
</tr>
<tr>
<td>Rain rate (20° x 20°)</td>
<td>+ 0.35</td>
</tr>
<tr>
<td>750 hPa Divergence (20° x 20°)</td>
<td>– 0.35</td>
</tr>
<tr>
<td>SST (20° x 20°)</td>
<td>+ 0.33</td>
</tr>
<tr>
<td>Maximum 700 hPa relative vorticity</td>
<td>+ 0.32</td>
</tr>
<tr>
<td>600 hPa du/dy (10° x 10°)</td>
<td>– 0.23</td>
</tr>
<tr>
<td>600-1000 hPa vertical shear (20° x 20°)</td>
<td>– 0.19</td>
</tr>
<tr>
<td>Translational speed</td>
<td>– 0.07</td>
</tr>
</tbody>
</table>

Based on the BDI information, we select a set of predictors for Atlantic TC genesis forecast model. Following the same procedures as in constructing the WNP model, we derived a regression model for the North Atlantic. Figure 3 showed the in-sample validation for the Atlantic model during 2003-2008. It shows a hitting rate of 65.3% and a false alarm rate of 20.0%. Next we will conduct hindcast for Atlantic TCs in 2009-2010.
Fig. 3 In-sample validation of a North Atlantic genesis forecast model for the period of 2003-2008. Pink dots are developing cases and blue dots are non-developing cases. Hit rate and False alarm rate are represented by ‘H’ and ‘F’.

IMPACT/APPLICATIONS

The successful completion of this project may provide an operational TC genesis probability forecast system based on the NOGAPS global analysis and forecast fields. Operational TC forecast centers may use this product as a reference for issuing a TC formation alert/warning at a lead of 24-72 hours. This product can also provide guidance about where to place a high-resolution regional model (such as COAMPS) for dynamic TC genesis prediction.

TRANSITIONS

The forecast models developed by this project may readily transition to a 6.4 project for quasi-operational tests.

RELATED PROJECTS

This project is closely related to the NRL 6.2 funding on “Predicting tropical cyclone genesis using NOGAPS”. Knowledge gained from this project will help to improve the prediction of tropical cyclone genesis.

PUBLICATIONS