Probability Forecast Model of Tropical Cyclone Heavy Rainfall Area Based on Multi-element Diagnosis

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Motivation

External influences
- Dynamics
  - Vertical wind shear
  - Upper-level divergence
  - Trough/ridge interactions
- Thermodynamics
  - Static stability
  - Atmospheric moisture content

Internal influences
- Latent Heat Release (LHR) is the primary heat source within TCs
- Eyewall Dynamics
- Rainbands and Vortex Rossby Waves
- Mesoscale vortices
Motivation

Case: Tropical Cyclone, Soulik (2013)

Fig. 1 24_h rainfall accumulation from 20130708_00Z (unit: mm)
Physical elements

- **Specific Humidity**
- **Helicity (Lilly D.K. 1986)**
- **Pseudo-equivalent temperature**
- **Wet enthalpy $E_1$ (Ye, et al, 1960)**
- **Wet enthalpy advection**
- **Pressure energy $E_p$ (Chen 2007)**
- **Pressure energy vorticity**

\[ E_1 = c_p T + Lq \]

\[ E_p = gZ' + \frac{1}{2}V^2 \]

(Shou et al., 1981; Xu, 1996; Huang et al, 2002)
Pattern-matching criterion

Diagram of rainfall and physical element entity

**Criterion 1: Relative centroid**

\[ A_p(x_i, y_i) = R_p(x_i, y_i) - H_p(x_i, y_i) \]

**Criterion 2: Accuracy rate**

\[ CS1 = \frac{n_1}{\delta_1} \times 100\%; \]
\[ CS2 = \frac{n_2 - n_1}{\delta_2 - \delta_1} \times 100\%; \]
\[ SS1 = CS1 \times C1 + (100-CS2) \times C2 \]

wherein, \( C1 = 0.6, \ C2 = 0.4. \)
Pattern-matching statistics (2001-2012)

Table 1 Diagnostic Scheme for different TC Category

<table>
<thead>
<tr>
<th>TC Category</th>
<th>Specific Humidity</th>
<th>Helicity</th>
<th>Wet Enthalpy</th>
<th>Pressure Energy Vorticity</th>
<th>Pseudo-Equivalent temperature</th>
<th>Wet enthalpy advection</th>
<th>Pressure energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical Depression</td>
<td>750hPa</td>
<td>850hPa</td>
<td>750hPa</td>
<td>600hPa</td>
<td>500hPa</td>
<td>850hPa</td>
<td>850hPa</td>
</tr>
<tr>
<td>Tropical Storm</td>
<td>800hPa</td>
<td>700hPa</td>
<td>750hPa</td>
<td>550hPa</td>
<td>500hPa</td>
<td>850hPa</td>
<td>850hPa</td>
</tr>
<tr>
<td>Severe Tropical Storm</td>
<td>600hPa</td>
<td>600hPa</td>
<td>600hPa</td>
<td>500hPa</td>
<td>500hPa</td>
<td>850hPa</td>
<td>850hPa</td>
</tr>
<tr>
<td>Typhoon</td>
<td>750hPa</td>
<td>700hPa</td>
<td>650hPa</td>
<td>500hPa</td>
<td>500hPa</td>
<td>850hPa</td>
<td>850hPa</td>
</tr>
</tbody>
</table>

Sorted in a descending order to characterize the heavy rainfall area!
Probability forecast model

- OBS → TC Category → Rain?
  - Y: Pattern-match → Updated diagnosis scheme
  - N: Historical diagnosis scheme

- Probability rainfall forecast
Case study

Case: Tropical Cyclone, Soulik (2013)

Fig. 2 24_h rainfall accumulation from 20130708_00Z (unit: mm)

Improved!
Case study

Fig. 3 24_h rainfall accumulation from 20130712_00Z (unit: mm)

Failure!
Specific humidity, helicity, wet enthalpy, pressure energy, vorticity, pseudo-equivalent temperature, enthalpy advection and pressure energy, can be sorted in a descending order to characterize the heavy rainfall area.

The multi-element diagnosis schemes will change with TC intensity.

The probability forecast can decrease the displacement error of the heavy rainfall area of TC.
Thank You!