Workshop on WMO/WWRP Research and Development Project High Resolution Prediction of Landfalling Typhoon, 16-18 May 2014, Nanjing, China

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A Proposal for WWRP/WMO Research and Development Project (RDP)

Understanding and PreDiction of Rainfall Associated with landFalling Tropical cyclones

(UPDRAFT)
Aim & Purpose

- Improving the understanding and forecasting on the landfalling typhoon rainfall
  - UNDERSTANDING: Basic research
  - FORECASTING: Application research
Objective I

• To identify the deficiencies of state-of-the-art operational numerical models in forecasting landfalling typhoon rainfall
• **Truth sets:** Conventional and unconventional observational data of 12 landfalling typhoons from the outcome of the National Basic Research Program of China

• **Objective methods:** Object-oriented verification techniques, e.g. Method for Diagnostic Evaluation (MODE), Contiguous Rain Area (CRA), etc.

• **Quantitative estimations:** Errors in rainfall size, location, intensity, distribution pattern, orientation angle, etc.

• **Diagnostic verifications:** Storm location, interaction with underlying surface, large-scale environment, vortex structure, microphysical processes, etc. (possible sources of rainfall forecasting error)

• **Potential results:** What is the main weakness in forecasting landfalling typhoon rainfall? How do other factors influence the rainfall prediction?
Objective II

• To improve the understanding of key physical processes governing landfalling typhoon rainfall
  – To quantitatively estimate the individual contributions of potential sources of error
  – To investigate how physical processes influence the landfalling typhoon rainfall
  – To improve representations of surface forcing, boundary layer, microphysical and radiative processes
• **Strom track**  
  – To evaluate the effect of track forecast uncertainty on rainfall prediction

• **Interaction with underlying surface and PBL**  
  – To identify suitable drag parameter, flux and turbulence transfer coefficients used in PBL schemes
  – To evaluate the effect of topography
  – To test the potential value of LES

• **Interaction with environmental features**  
  – To evaluate the impact of monsoon flow, vertical wind shear, midlatitude circulations, etc.

• **Vortex structure**  
  • To investigate the impact of initial vortex structure on eyewall, rainbands, convective bursts, etc.

• **Convective and microphysical processes**  
  – To recommend one or more parameterization schemes capable of representing the convective and microphysical processes
Objective III

• To develop an optimum forecasting system for predicting landfalling typhoon rainfall
  – To improve deterministic and probabilistic forecast techniques
  – To develop new consensus and ensemble forecasts
Innovation

• 1 Radar net-work + aircraft obs.
• 2 vortex initialization
• 3 vortex spin-down after landfall
• 4 better parameterization schemes
• 5 new consensus rainfall forecast system
Evaluation of tropical cyclone rainfall forecasts from operational NWP models
(Two case studies)

- Fitow (2013)
Case study - 1
Kompasu (2010) and Lionrock (2010)

Qi L.B. and Cao X.G., 2013
00-06UTC
Rainband in N-S direction
Interaction between Kompasu and cold air
06-12UTC
Rainband in W-E direction
Interaction between the northerly wind of Kompasu and inverted trough of Lionrock
All the available operational models failed in predicting this heavy rain process one day before.
(ECMWF, CMA, JMA, SMB-WARMS)

ECMWF Ini: 12UTC 31 Aug.
Small track error (60-80km) leads to the missing of the two flows:

**Red:** warm and moist air

**Blue:** dry and cold air

ECMWF Ini. 12UTC31 Aug

Fcst. 12UTC1 Sep 850hPa wind

Small track error (60-80km) leads to the missing of the two flows
A patch of rainfall is forecast over Shanghai, but too weak.
MODE products for 24h precipitation initialized at 00 UTC August 31. 
(a) forecast of SMB-WARMS; (b) Observation.

Forecast has a larger precipitation (>10mm) area than observation. 
The area ratio of forecast and observation is 1.49. 
The distance between the centroids of forecast and observed objects is \(~70\) km and angle difference of the axis is only 5.7 degree.

Table 5  TS scores of SMB-WARMS when the East China Region was affected by Kompasu (1007)

<table>
<thead>
<tr>
<th>Leading time</th>
<th>East China Region</th>
<th>Shanghai</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial time</td>
<td>24h</td>
<td>48h</td>
</tr>
<tr>
<td>00UTC</td>
<td>0.74</td>
<td>0.71</td>
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<tr>
<td>12UTC</td>
<td>0.71</td>
<td>0.68</td>
</tr>
<tr>
<td>00UTC</td>
<td>0.85</td>
<td>0.85</td>
</tr>
</tbody>
</table>
SMB-WARMS 9km Ini: 00UTC 1 Sep.
6h surface wind and 6-12h precipitation

~100km west to the observation
Rainband of Kompasu

South-easterly wind of the inverted trough

Northerly wind of Kompasu

SMB-WARMS 9km Ini: 00UTC 1 Sep.
12UTC 1 Sep. Surface wind
Rainband of Kompasu

Northerly wind of Kompasu

South-easterly wind of the inverted trough

SMB-WARMS 9km Ini: 00UTC 1 Sep.
14UTC 1 Sep. Surface wind
The predicted shear line lasts ~ 4 hours.
SMB-WARMS 9km Ini: 00UTC 1 Sep.
16UTC 1 Sep. Surface wind

The predicted shear line lasts ~ 4 hours.
The predicted shear line lasts ~ 4 hours.
The predicted shear line lasts ~ 4 hours.
TC position error - error in ‘meeting’ position (west) and time (late) of the two flows.

Need to predict correctly the position and intensity of three TCs.
Case study - 2
Fitow (2013)

Yuyao of Ningbo
West Lake after Fitow
Shanghai
Observed precipitation

1. Fitow’s rainband
2. Fitow & Danas & frontogenesis
Very good track forecasts

Track error for “Fitow”

- NCEP-GFS
- ECMWF
- UKMO-MetUM
- JMA-GSM
- CMA-T213
- CMA-T639
- KMA-GDPS
- ACCESS-TC
- GRAPES-TCM
- TRAMS
- TWRF
- STI-BDA

Regional models

0 100 200 300 400 500 600 700 800
Track error (km)

24h 48h 72h
Lead time

Courtesy to Mr. Chen Guomin
Track Error of ACCESS-TC for 1323 “FITOW”

Intensity Error of ACCESS-TC for 1323 “FITOW”

Resolution—A relocatable grid with $0.11^\circ \times 50$ level dimensions, with the TC near the center of the domain, but offset based on the past motion of the storm, with an option for higher-resolution forecasts.
Tracks of Typhoons Fitow and Danas

Red: Forecast
Black: Observation

Comparison of Fitow's intensity

Comparison of Danas's intensity

Fitow’s Rainband

Fitow & Danas & Frontogenesis

Track of Fitow: to the north of Obs.
Track of Danas: slower than Obs.

18UTC 6

18UTC 7
Extremely heavy rain events as a result of interactions among multiple systems (two or three TCs + dry cold air intrusion) are great challenges for NWP models.

(location & time)