Targeted Observations for Improving Tropical Cyclone Predictability – DOTSTAR, TH08, TCS-08, and T-PARC

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Acknowledging collaborators in DOTSTAR and T-PARC:

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Outline:

• Overview of DOTSTAR and T-PARC
• Typhoon Sinlaku (2008)
  • Impact of targeted observation
  • EnKF data assimilation in TC
  • Eyewall evolution
  • Typhoon-ocean interaction
• DOTSTAR, TCS-10 and ITOP
• Future work
Improving the understanding and prediction of the TC systems

(in memory of Dr. Yoshio Kurihara)

Key issues:
• dynamics
• observation
• model simulation/data assimilation

Dynamics of the typhoon system

Initial condition

Data assimilation and/or Initialization

Dynamics of the model

Multi-scale interaction
  Air-sea interaction
  Terrain/PBL effect

Added value
New Observation

(Wu and Kuo 1999, BAMS)
Long-term decreasing trend in TC track prediction errors

From NHC

Why?
Push the limit of predictability?
Sensitivity and vulnerability to track forecast error

Track and total rainfall of Typhoon Torajie on July 29-July 31, 2001.
Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR, 2003 – 2009)

Up to present, 45 missions have been conducted in DOTSTAR for 35 typhoons, with 751 dropwindsondes deployed during the 239 flight hours.

30 typhoons affecting Taiwan
23 typhoons affecting (mainland) China
7 typhoons affecting Japan
3 typhoons affecting Korea
10 typhoons affecting Philippines

- Useful real-time data available to major operational forecast centers
- Impact to the track forecasts to models in major operation centers (NCEP/GFS, FNMOC/NOGAPS, JMA/GSM)
- Targeted observation

Wu et al. (2005 BAMS, 2007a JAS, 2007b WF, 2009a,b,c MWR), Chou and Wu (2008 MWR), Chen et al. (2009 MWR), Yamaguchi et al. (2009 MWR), Chou et al. (2009 JGR)
NCEP GFS Impact from 2003 to 2008
(All 36 cases)

Paired t-test statistical examination
* : statistically significant at the 90% confidence level
** : statistically significant at the 95% confidence level

Wu et al. 2009d
NCEP GFS Impact from 2003 to 2008

- Positive case (%)
- Negative case (%)
- Case numbers

Forecast time (hr):
- AVE
- 12
- 24
- 36
- 48
- 60
- 72

Case percentage (%):
- 0 to 100

Case numbers:
- 0 to 40

Graph showing the percentage of positive and negative cases and case numbers over forecast time intervals from AVE to 72 hours.
Since 2003, several objective methods, have been proposed and tested for operational/research surveillance missions in the environment of Atlantic hurricanes conducted by HRD/NOAA (Aberson 2003) and NW Pacific typhoons by DOTSTAR (Wu et al. 2005).

- **NCEP/GFS ensemble variance**
  (collaborating with Aberson) (Aberson 2003)

- **ETKF**
  (collaborating with Majumdar) (Majumdar et al. 2006)

- **NOGAPS Singular Vector** (Peng and Reynolds 2006)
  (collaborating with Reynolds and Peng)

- **Adjoint-Derived Sensitivity Steering Vector (ADSSV)**

- **JMA moist Singular Vector** (Wu et al. 2007b)
  (collaborating with Yamaguchi) (Yamaguchi et al. 2007)

- **ECMWF Singular Vector** (Buizza et al. 2006)
Impact of DOTSTAR data:

Sensitive analysis result:
- Sensitive region shows vertically accumulated total energy by the 1st moist singular vector.
- Targeted area for the SV calculation is 25N-30N, 120E-130E.

OSE result on CONSON’s (2004) track forecast:

- Red: (I) all dropsonde obs
- Blue: (II) no dropsonde obs
- Green: (III) Three dropsonde obs within the sensitive region
- Light blue: (IV) Six dropsonde obs outside the sensitive region

(Yamaguchi et al. 2009, MWR)
THORPEX-PARC Experiments (2008) and Collaborating Efforts

Understand and improve the lifecycle of TC and its predictability –

• Genesis

• Intensity and structure change,

• Recurvature (targeted obs.)

• Extra-tropical transition (ET)

<table>
<thead>
<tr>
<th>Upgraded Russian Radiosonde Network for IPY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter storms reconnaissance and driftsonde</td>
</tr>
<tr>
<td>NRC P-3 and HIAPER with the DLR Wind Lidar</td>
</tr>
</tbody>
</table>

P-3

U.S. ONR/NSF TCS-08

[NRL P-3, WC-130]

C-130

SCS Exp

DOTSTAR

SCS Exp

U.S. ONR/NSF TCS-08

[NRL P-3, WC-130]
T-PARC planning meeting, Japan, 2008

DOTSTAR + Falcon + P3 + C130,
52h + 85h + 165h + 215h = 507h flight hours, unprecedented!
173 + 328 + 604 + 343 = 1448 dropwindsondes
Typhoon Sinlaku (2008)

- Reintensification
- Recurvature
- Extratropical Transition
- Terrain effect
- Targeted observation
- Intensification
- Structure change
- TC-ocean interaction

- The **concentric eyewall** structure can be clearly viewed from the satellite images at 0445Z, 0900Z, and 1134Z on September 11.

- When Sinlaku went through an eye wall replacement cycle on September 11, it started to weaken.

- The new primary eyewall formed at 2132Z 11 SEP.
Sinclaku. Concept for Targeting Operations. 21 UTC, 20080908

Potential threat of TC to land

Uncertainty in ensemble track forecasts

Uncertainty about strength of steering flow, and landfall location (if any)

Courtesy CIMSS/U.Wisconsin
DOTSTAR Flight Plan (BLUE) and FALCON Flight Plan (1) (Red)
10-11 September 2008 (Targeted observation)
11 September, 2009, **Typhoon Sinlaku**

**DOTSTAR + Falcon + P3 + C130 Flight tracks**

**First time with four aircrafts observing typhoons over NW Pacific ocean**
Impact of dropwindsondes to NCEP GFS forecasts of Sinlaku

00 UTC Sept. 10, 2008; 00 UTC Sept. 11, 2008

Degradation due to the inner-core dropsonde data (Aberson 2008)

12 UTC Sept. 11, 2008

(JMA/GSM, from Nakazawa)

(Wu et al. 2009e)
Impact of dropwindsondes:

- Strengthened storm vortex
- Decreased RMW
- Strengthened subtropical ridge, enhancing northwestward steering flow

Solid Line: steering flow
Dashed Line: translation speed

(Wu et al. 2009e)
EnKF data assimilation

Observations: position, motion vector, axisymmetric structure

- 3 hour besttrack data, interpolated to 30 minutes interval by cubic-spline method.
- TC radius (34, 50 kts) data from JTWC.

(Wu et al. 2009f)

After Willoughby et al. (2006)
3. Experiments on initialization

Experiment “TK-MS”

(Wu et al. 2009f)
4. Experiments on update cycle analysis

Observations (2008/09/08 17:00 ~ 09/13 03:00 UTC)

Axisymmetric tangential wind profile from 4 C-130 flights, DOTSTAR, and JTWC estimate.

<table>
<thead>
<tr>
<th>Conv. radiosonde</th>
<th>DOTSTAR Astra</th>
<th>DLR Falcon</th>
<th>NRL P-3</th>
<th>USAF C-130</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total available</td>
<td>36 (2 flights)</td>
<td>34 (2 flight)</td>
<td>12 (1 flight)</td>
<td>20 (4 flights)</td>
</tr>
</tbody>
</table>

(Wu et al. 2009g)
4. Experiments on update cycle analysis

Experiment “TK-MS-TP-ALL”

(Wu et al. 2009g)
4. Experiments on update cycle analysis

Forecast “TK-MS-TP-ALL” at 1003Z

- Ensemble forecast started from 2008/09/10 03:00

(Wu et al. 2009g)
4. Experiments on update cycle analysis

Forecast “TK-MS-TP-ALL” at 1103Z

- Ensemble forecast started from 2008/09/11 03:00 UTC.

Examine theories: filamentation time scale; Beta-skirt
Future perspectives

- Validation and OSE studies: added value and data assimilation (cost-effective?)
- Understanding and physical interpretation of the structure of the targeted guidance products (ADSSV, SV, ETKF), along with the PV dynamics
- Targeted observations of other data (especially the satellite data: satellite thinning)
- EnKF data assimilation and dynamical analyses
- Intercomparison of targeted schemes - to gain more insights into the physics of targeted observations
- Intercomparison of the data impact to different model systems in T-PARC
- TCS-11 and ITOP
Internal wave and Typhoon-Ocean interaction Project in the Western North Pacific and Neighboring Seas (ITOP, 2010)

- DOTSTAR, TCS-10, and ITOP coordination
- Investigation of the roles of upper ocean thermal structures (eddies and/or wakes) on typhoon-ocean interaction.
- Understanding the feedback of the typhoon-ocean interaction to typhoon intensity and structure evolution.
- Numerical simulation experiments (WRF-PWP coupled model) with the T-PARC (and TCS-10) and ITOP data.