Typhoon researches in Taiwan and the DOTSTAR

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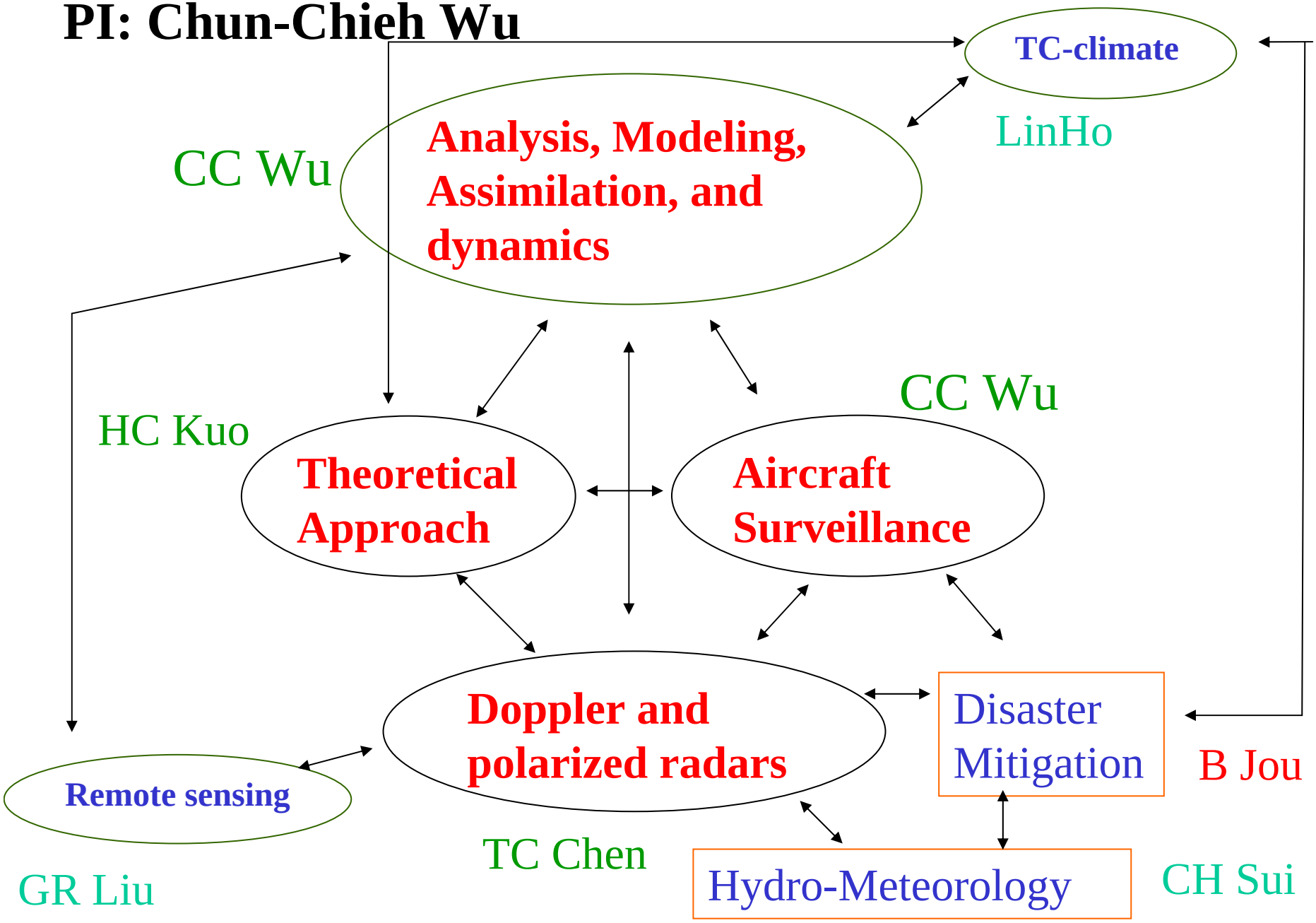
Outline

- Typhoon researches in Taiwan
- DOTSTAR in 2003-2004
- Targeted observations in DOTSTAR
- Adjoint-Derived Sensitivity Steering Vector (ADSSV)
- Future plans

(Wu et al. 2005a, b, c)

National Priority Typhoon Research Project (2002-2005)

PI: Chun-Chieh Wu



國家科學委員會「颱風重點研究」

侵台颱風之飛機偵察及投落送觀測實驗

代號： 追風計畫

Dropsonde Observation for Typhoon Surveillance near the TAiwan Region (DOTSTAR)

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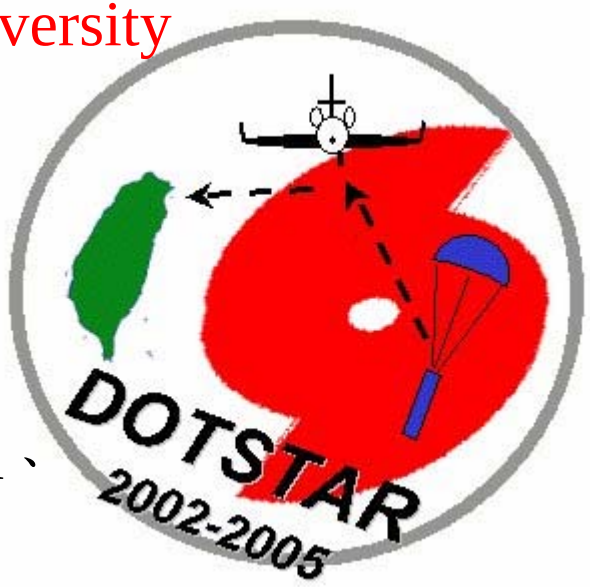
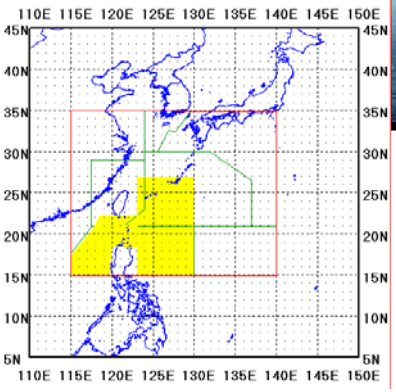
Tien-Chiang Yeh（Co-PI）
Central Weather Bureau



Acknowledgements：NSC、STAG、CWB、CAA、AIDC、HRD、NCEP 、FNMOC 、NRL、JMA

Flow chart of DOTSTAR

Astra jet



GPS Dropsonde

Satellite communication

AVAPS
On-board data reception

CWB

JMA,
UKMO,
KMA

Global/TC model

NCEP/FNMOC

in real time

Global/TC model
（Inform. Center）

Ana./Fcst.
（Forecasting
center）

NTU/Research team
Archive Research

(Wu et al. 2005a)

Results of DOTSTAR in 2003-2004

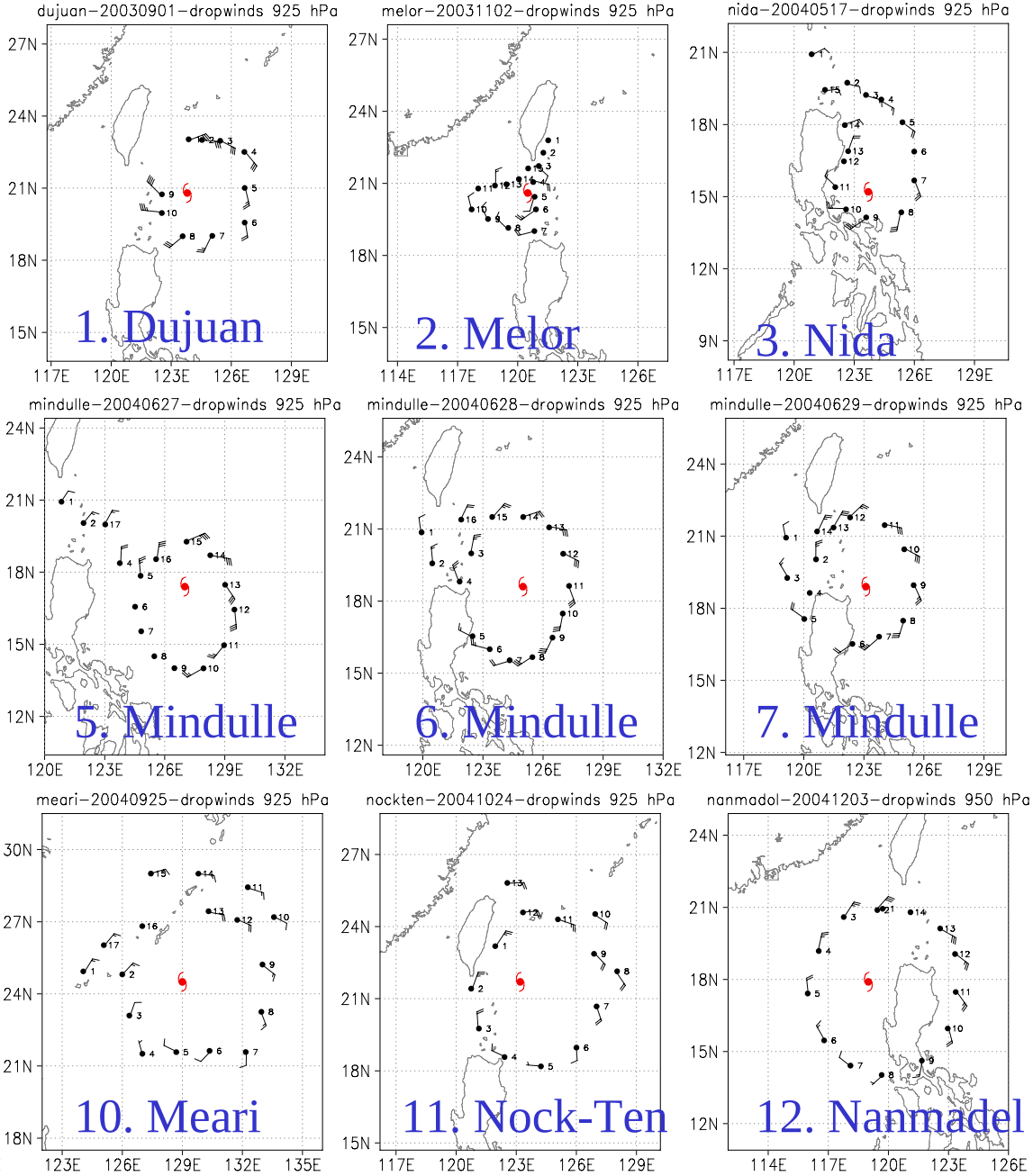
- Overview of DOTSTAR in 2003-2004
- Real-time data use at CWB
- Surface wind analyses
- Validation with the remote-sensing data
  - Satellite wind and temperature fields
  - Radar data
  - GPS/MET data
- Model impact study (NCEP, CWB, NOGAPS, JMA, UKMO)
- Research on the targeted observation and data assimilation
- Data assimilation
- International collaboration

DOTSTAR obs. in 2003 & 2004

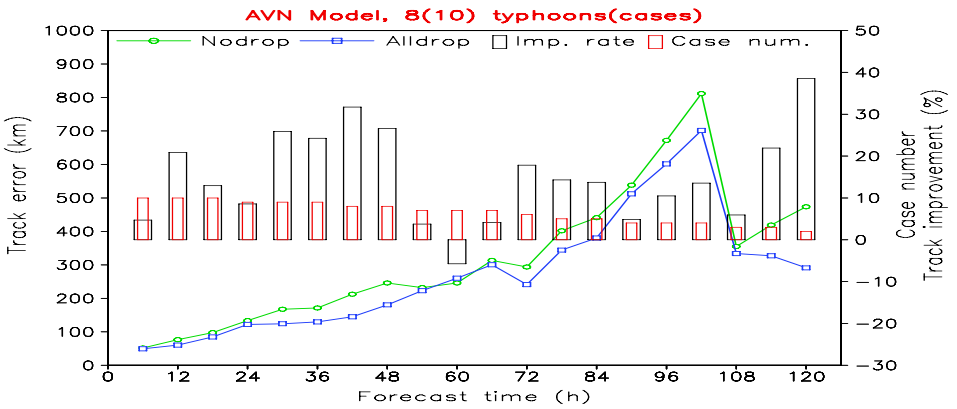
10 TCs, 12 missions, 58 flight hours, with 193 GPS dropwindsondes released.

An average 20% improvement for the 12-72h track forecasts in NCEP-AVN.

(Wu et al. 2005b)

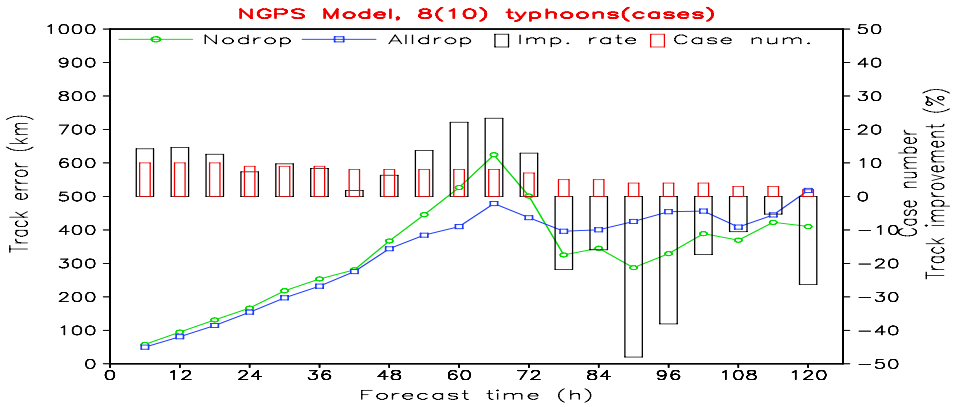


NCEP GFS



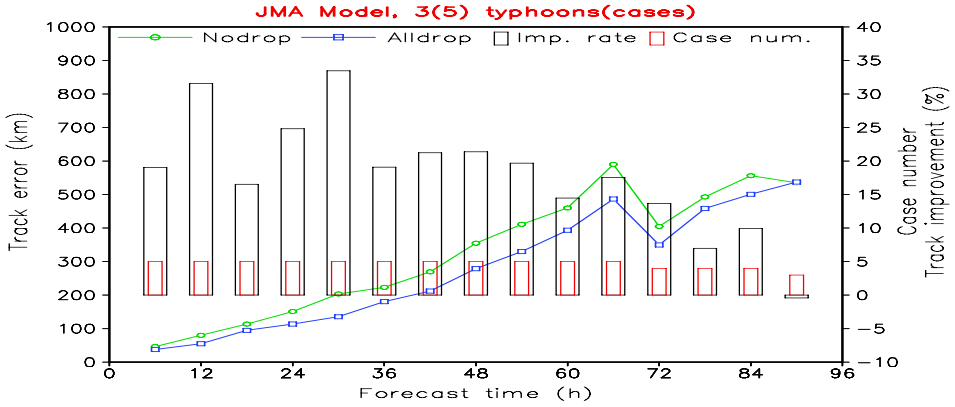
+ 18 %

FNMOC NOGAPS



+ 12 %

JMA GSM

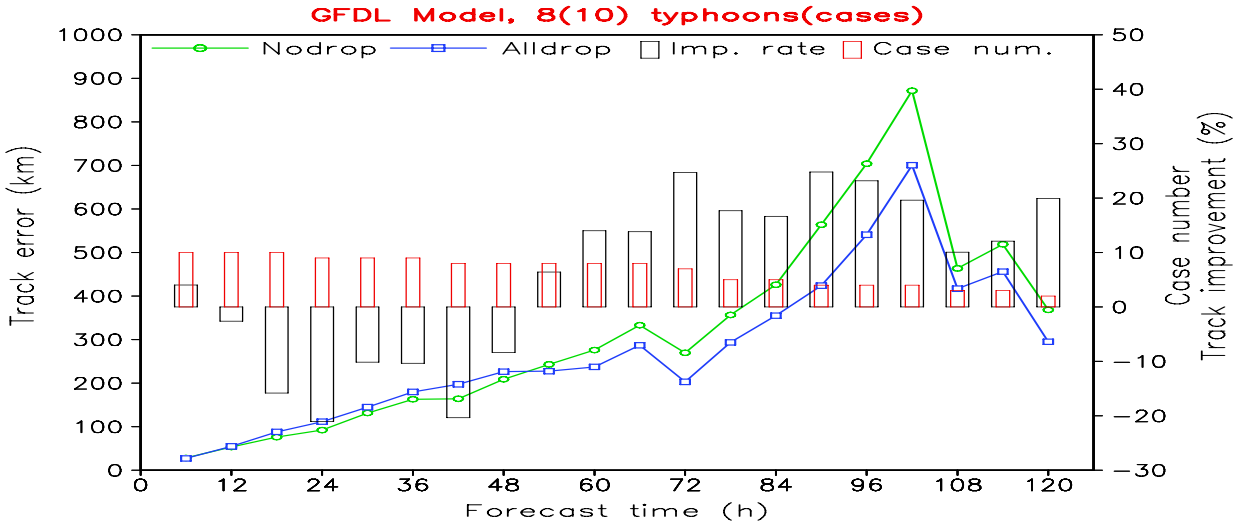


+ 23 %

(Wu et al. 2005b)

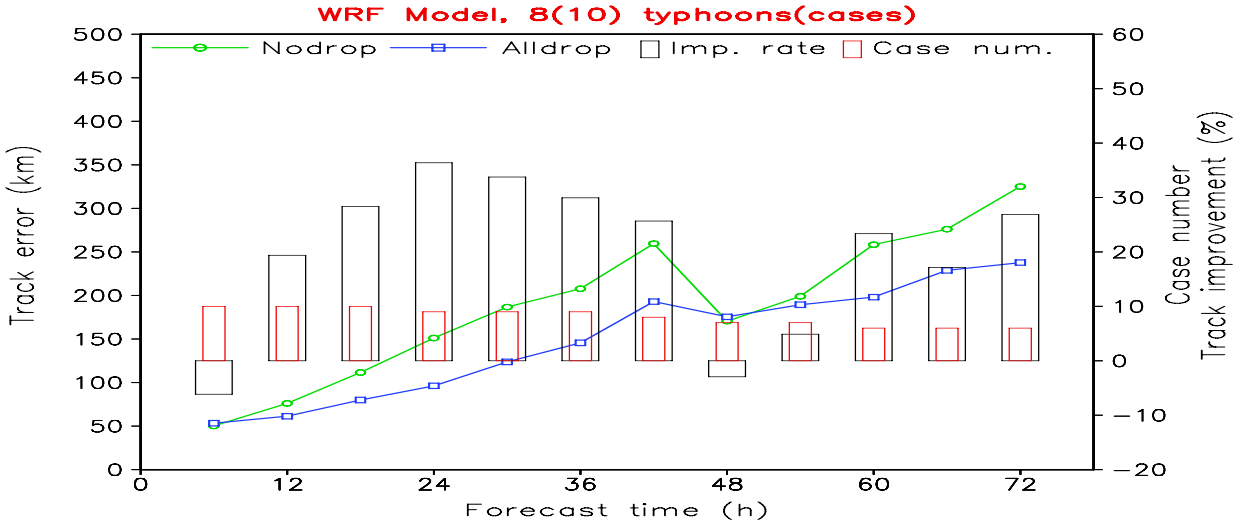
Impact of DOTSTAR dropsondes to global models

GFDL



- 10 %

WRF



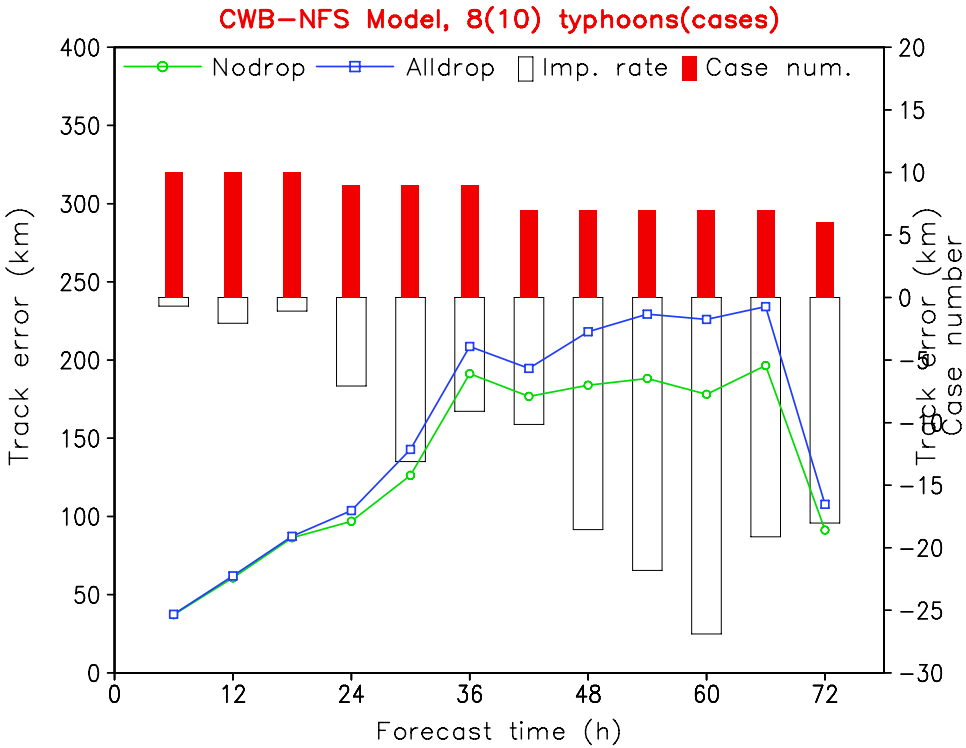
+ 20 %

(Wu et al. 2005b)

Impact of DOTSTAR dropsondes to regional/mesoscale models

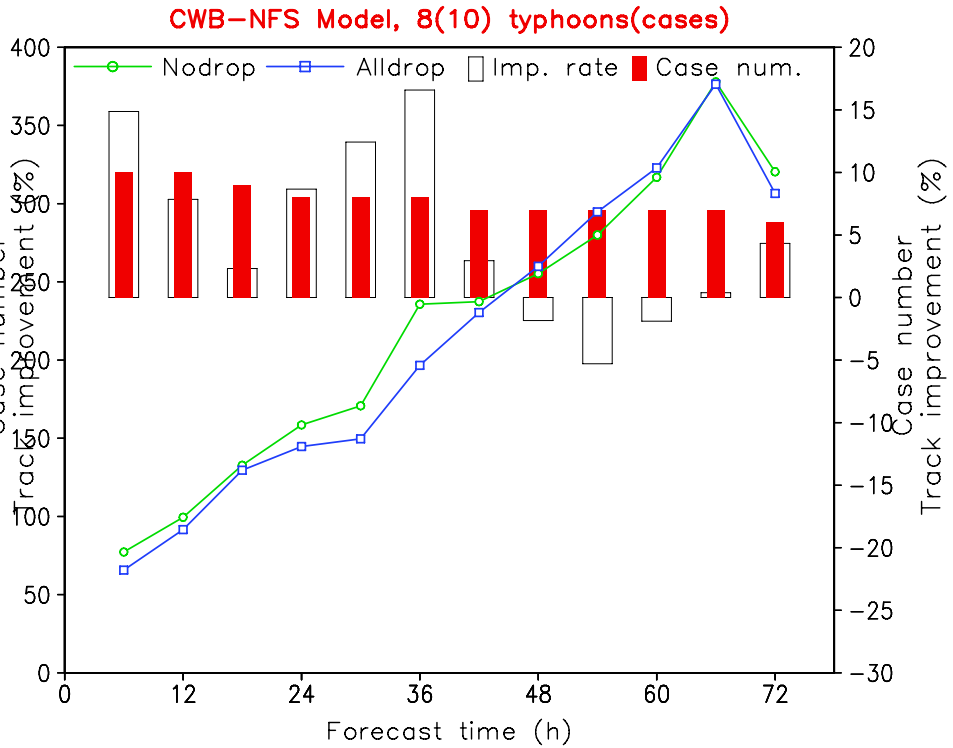
Impact of DOTSTAR dropsondes to regional/mesoscale models

- 12 %



With Bogus and Relocation

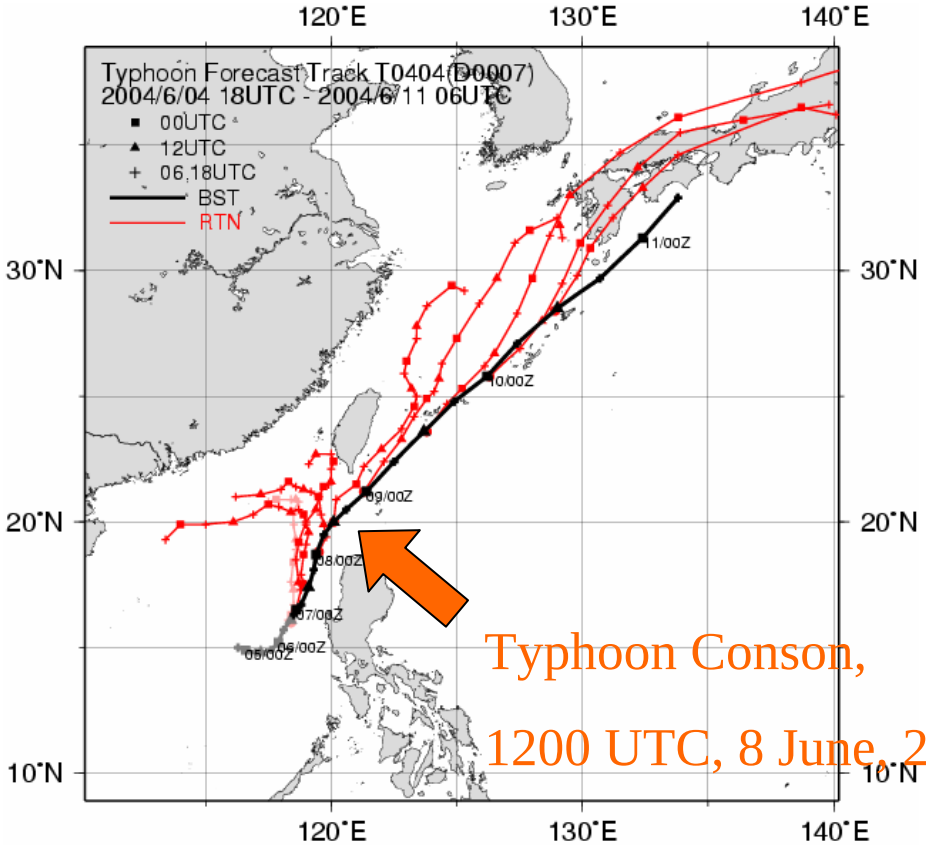
+ 8 %



Without Bogus and Relocation

(Wu et al. 2005b)

Dropsonde Observations for Typhoon Track Forecasts (GSM/JMA)

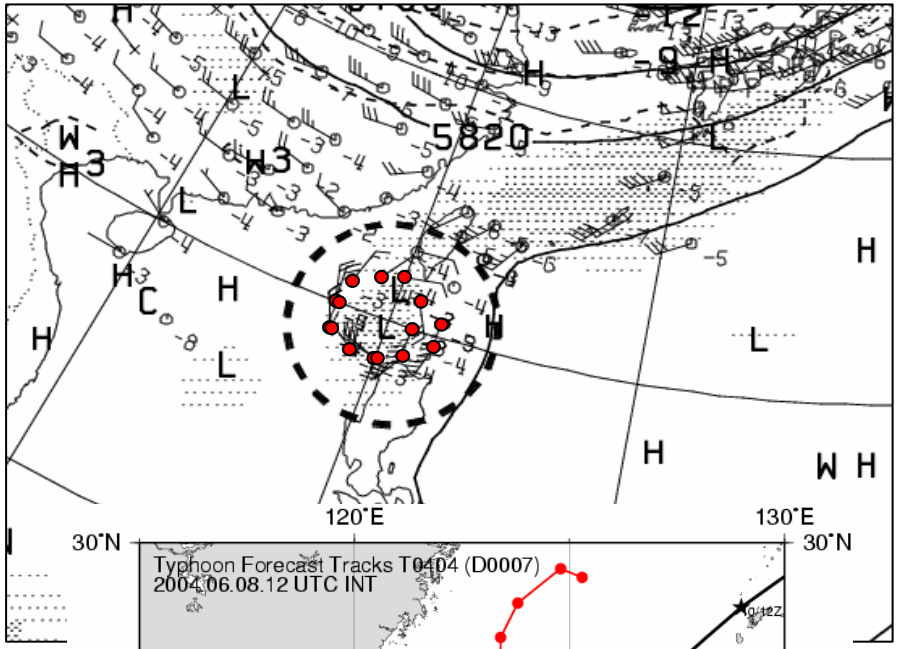


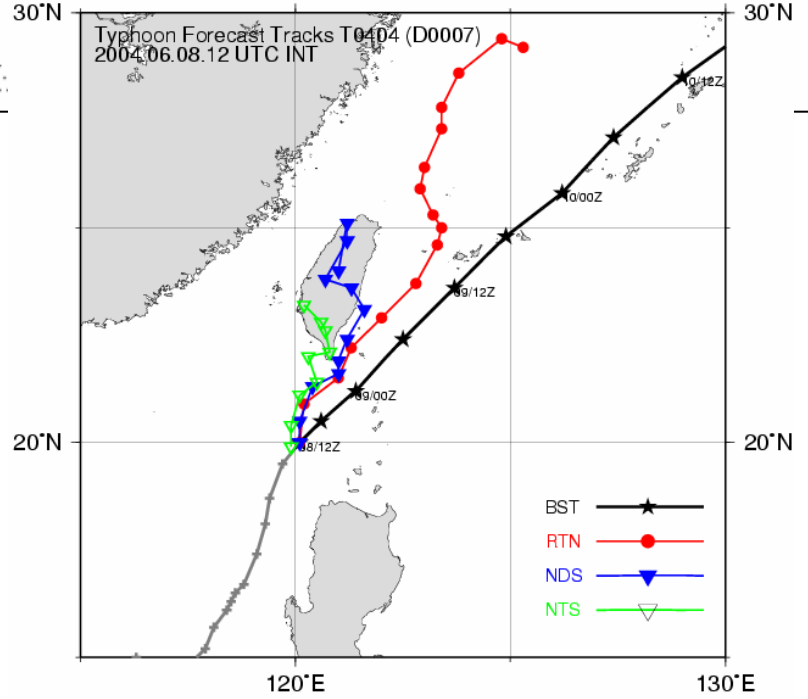
Typhoon Conson,

1200 UTC, 8 June, 2004

(Nakazawa 2004,

WMO-THORPEX meting)





Targeted observations in DOTSTAR

- The sensitivity products used in DOTSTAR to decide the adaptive observing strategies :
  - **NOGAPS Singular Vector** (collaborating with Reynolds)
  - **AVN ETKF** (collaborating with Majumdar)
  - **AVN DLM variance** (collaborating with Aberson)

(Wu et al. 2005a, BAMS)

  - **MM5 adjoint sensitivity** (ADSSV perspective)

(Wu et al. 2005c)

Experiment design

- **Model：**

  MM5 Adjoint Modeling System

  (Zou et al. 1997) (Wu et al. 2005a)

- **Case：**
  - **Typhoon Meari**

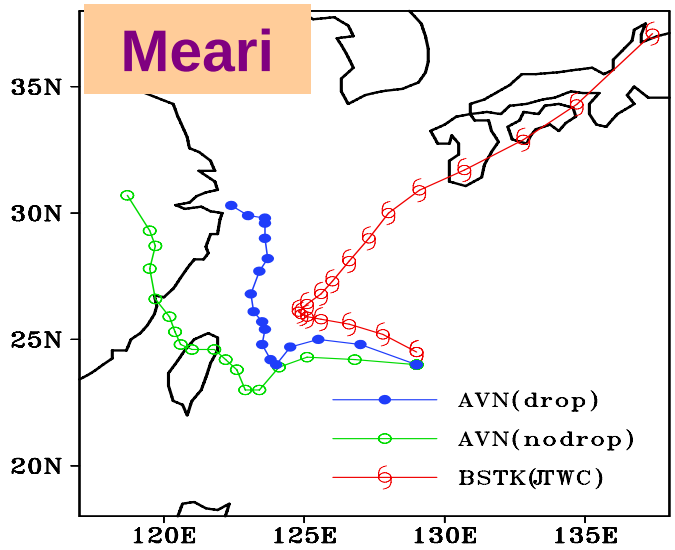
    (1200 UTC 25 Sept. 2004)
  - **Typhoon Mindulle**

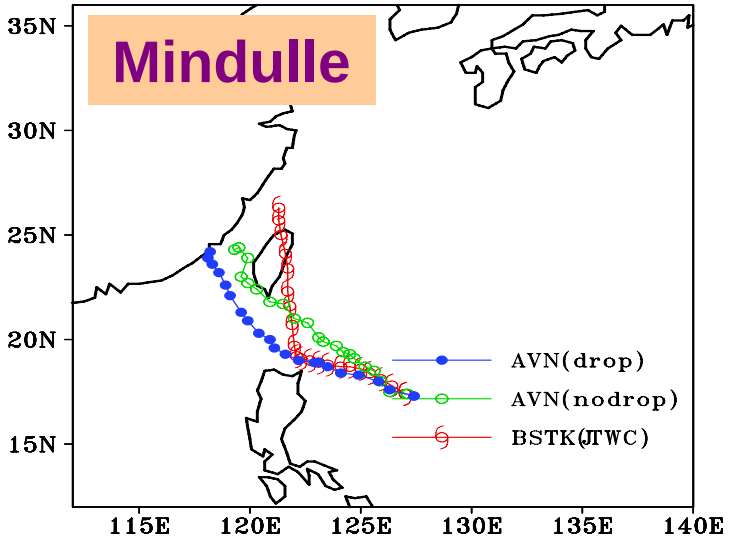
    (1200 UTC 28 June 2004)

- **Data：**

  NCEP/AVN Global analysis

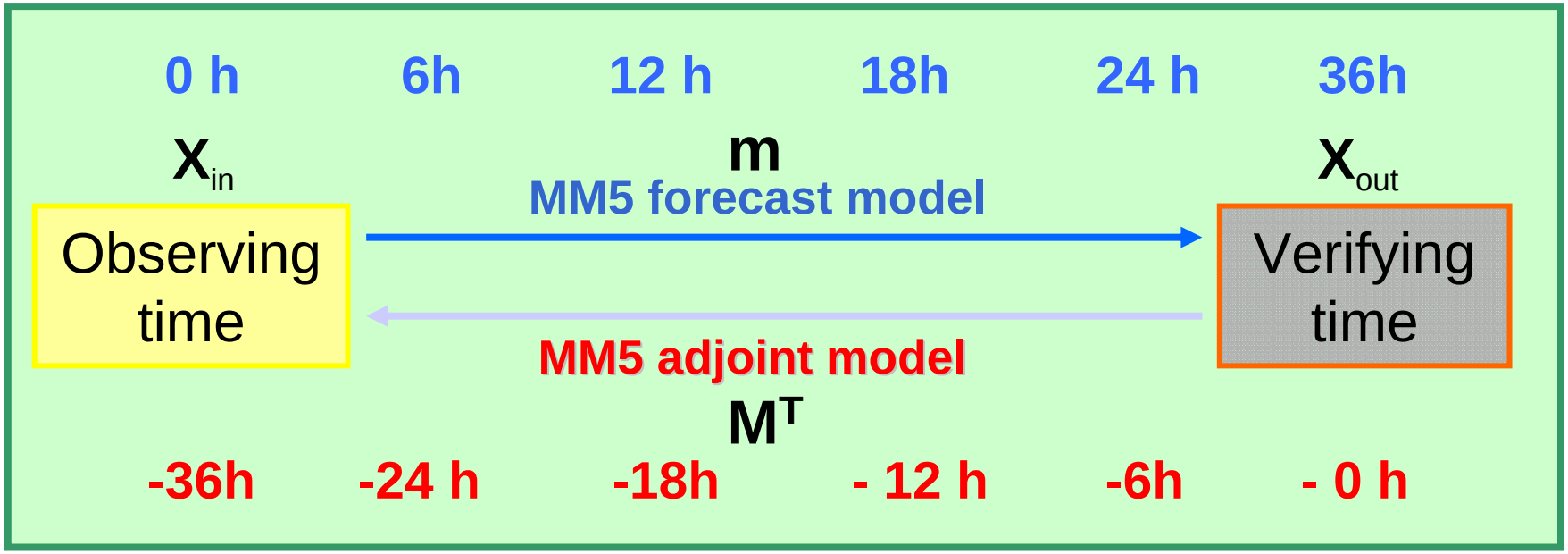
  (1°×1°)





Experiment design

- The forward and backward integrations of the adjoint modeling system



Goal：To identify the sensitivity areas at **the observing time**, that will affect **the steering flow** of the typhoon at the **verifying time**.

Experiment design

- **Verifying area：**

  A box is centered on the storm's forecasted location at the verifying time.

- **Response function：**

  A unique new definition to represent the steering flow **--**

  Define the average wind field within the verifying area at the verifying time.

$$R_1 = \frac{\int_{850hPa}^{300hPa}\int_A udxdydp}{\int_{850hPa}^{300hPa}\int_A dxdydp} \qquad R_2 = \frac{\int_{850hPa}^{300hPa}\int_A vdxdydp}{\int_{850hPa}^{300hPa}\int_A dxdydp}$$

  – **(R_1, R_2) = steering flow at the verifying time**

(Wu et al. 2005c)

- Adjoint-Derived Sensitivity Steering Vector (**ADSSV**)
  - A unique new definition to identify the sensitive (and targeted observing) areas to the steering flow at the verifying time.

ADSSV w.r.t. vorticity : $\left(\frac{\partial R_1}{\partial \varsigma}, \frac{\partial R_2}{\partial \varsigma}\right)$

ADSSV w.r.t divergence : $\left(\frac{\partial R_1}{\partial D}, \frac{\partial R_2}{\partial D}\right)$

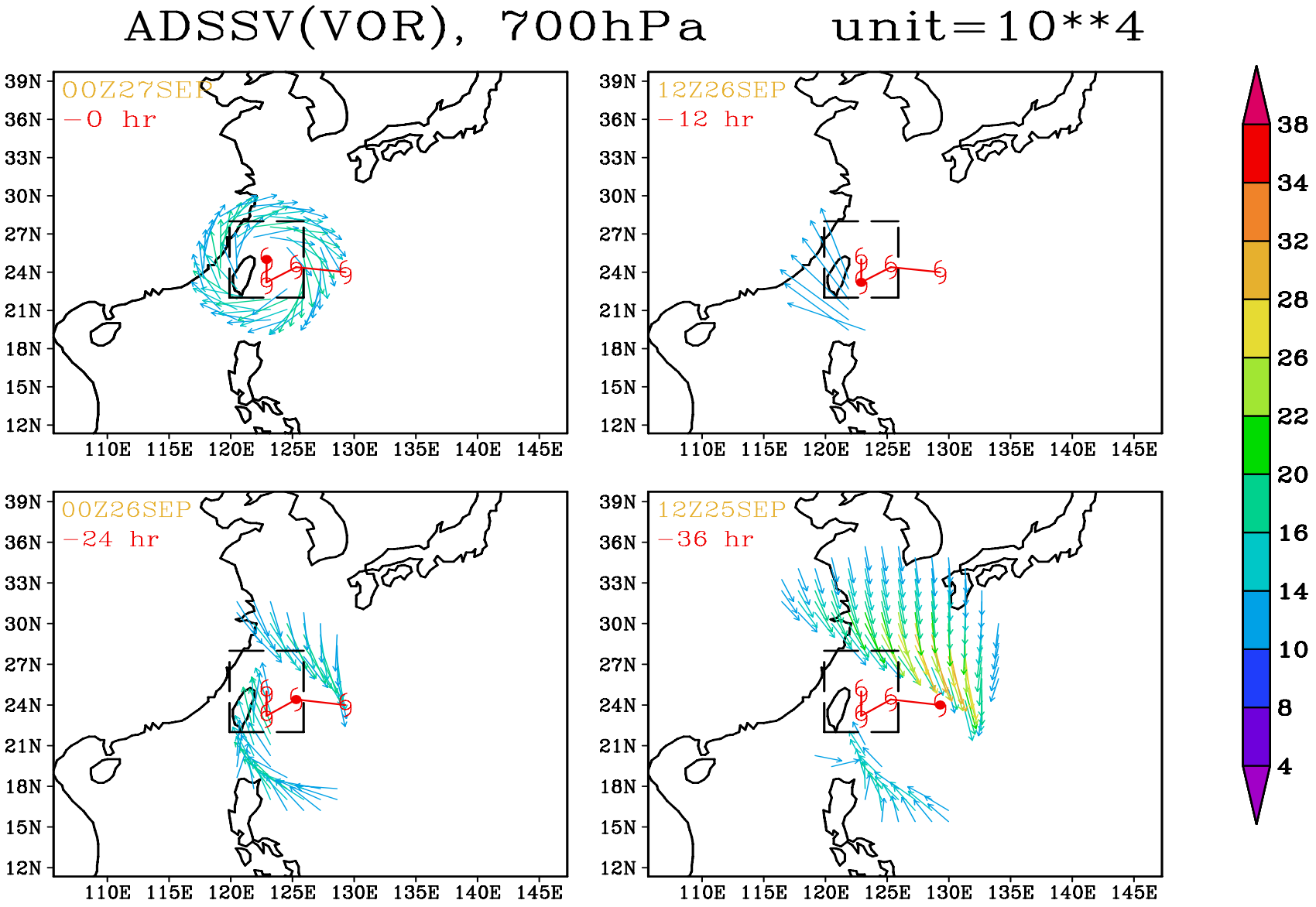
Magnitude – the **degree of sensitivity**

Direction – the change of the **steering flow direction** w.r.t. the vorticity or divergence variation.

(Wu et al. 2005c)

- Typhoon Meari **CTRL_ADJ36**

ADSSV (Vorticity)

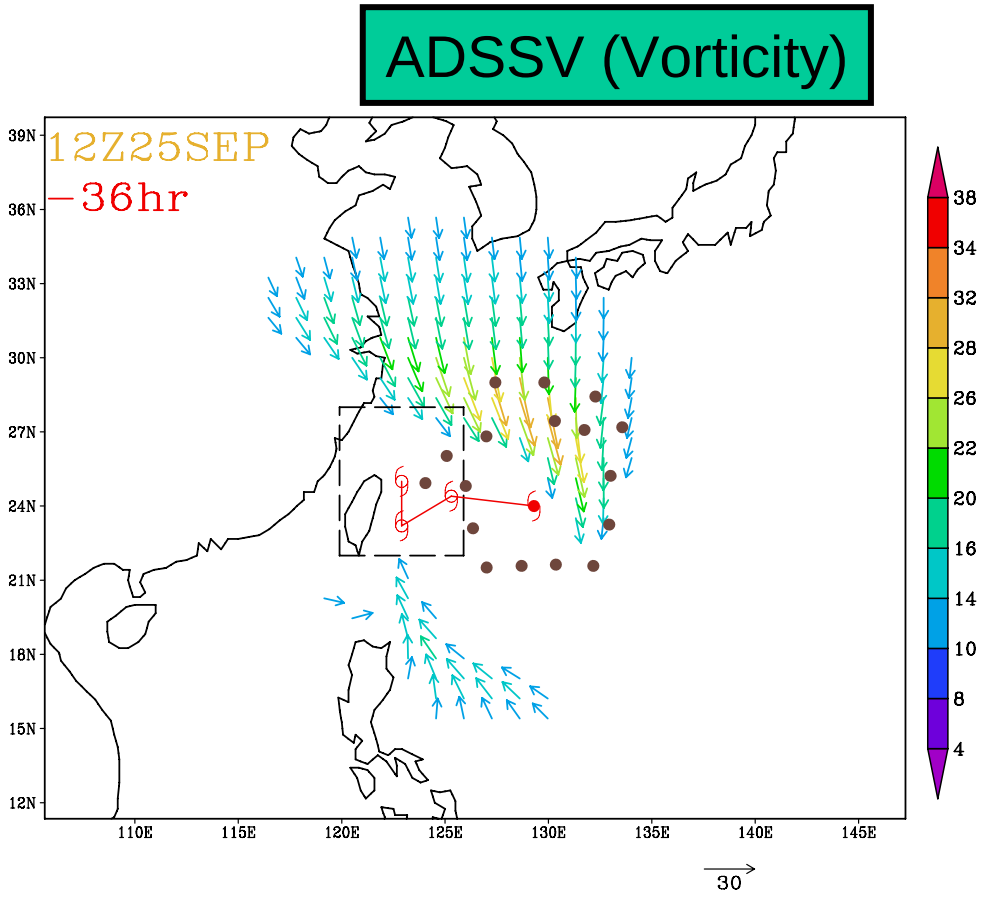


The ADSSV sensitive areas to Meari's track

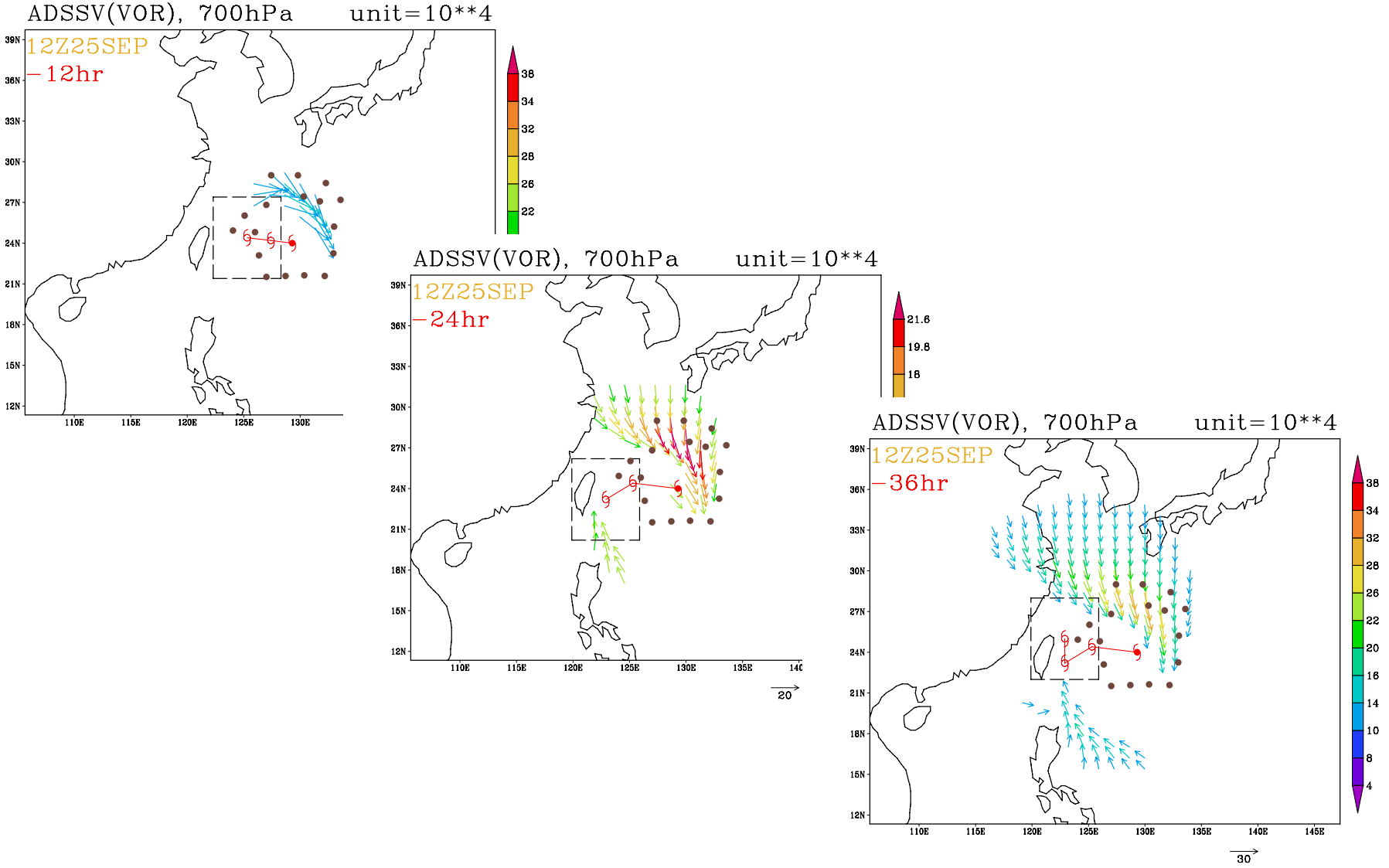
- Higher sensitivity to the north of Typhoon Meari
- More impact on the meridional movement
- The sensitive areas match some of the dropsondes deployment locations in DOTSTAR

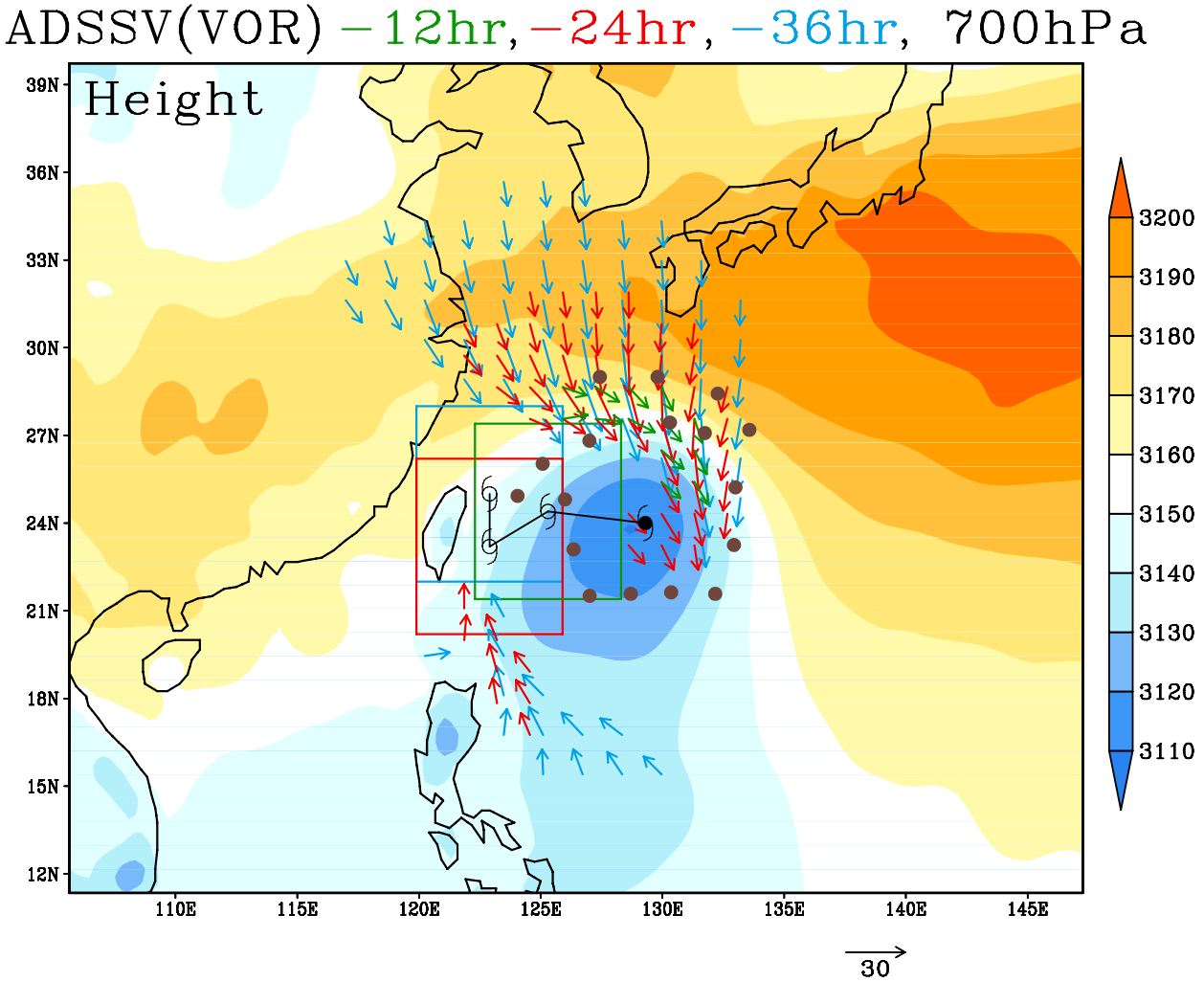
This shows the sensitive areas at the observing time (1200 UTC 25 Sept.) which will affect the steering flow at the verifying time (0000 UTC 27 Sept.).

However, where are the sensitive areas which will affect the **entire typhoon track** ?



- Combine the sensitive areas (ADSSV) of the steering flow from different verifying times to get the sensitive areas for the entire typhoon track in the observing time.

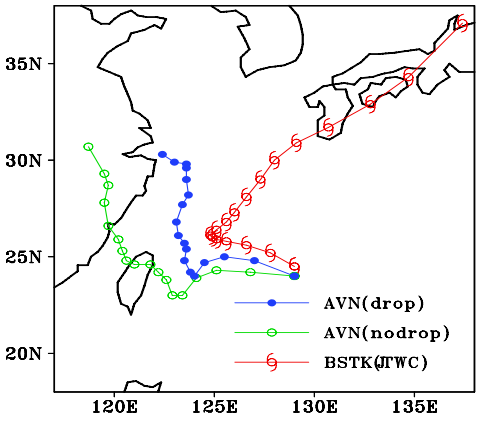


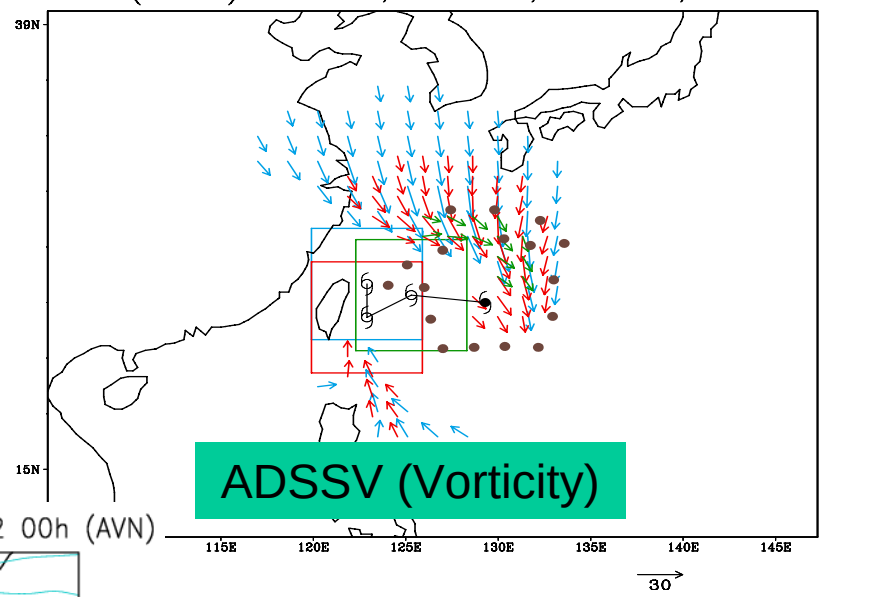


- Sensitive areas for different verifying times well collocate with one another.
- High sensitivity at the edge of the subtropical high.
- Potential role of the GPS Refractivity data?

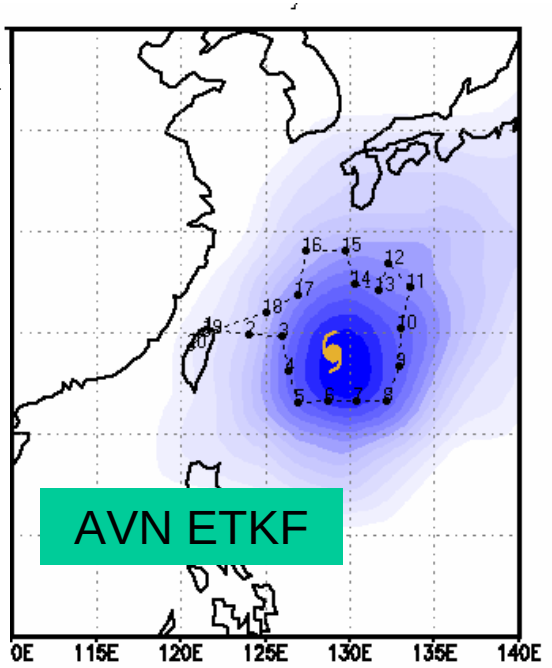
Comparison among all sensitivity products

Typhoon Meari

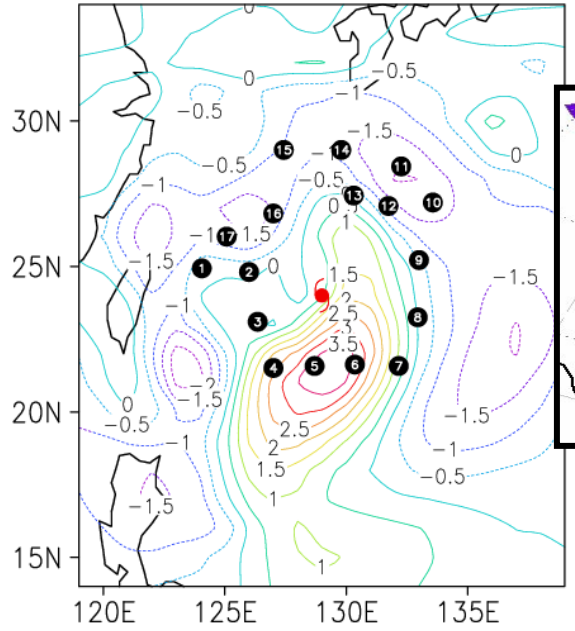


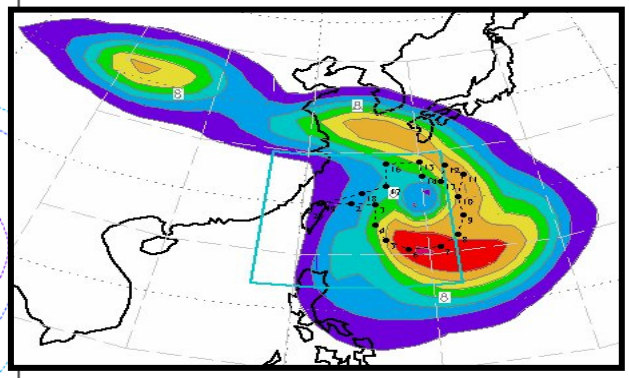


ADSSV (Vorticity)

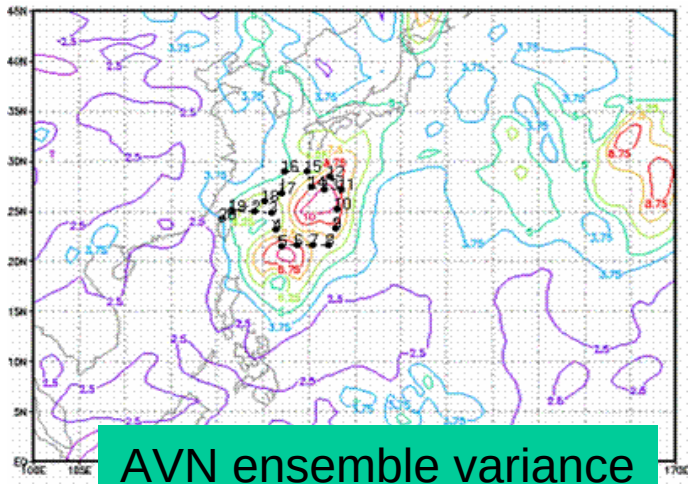


AVN ETKF





GAPS Singular Vector

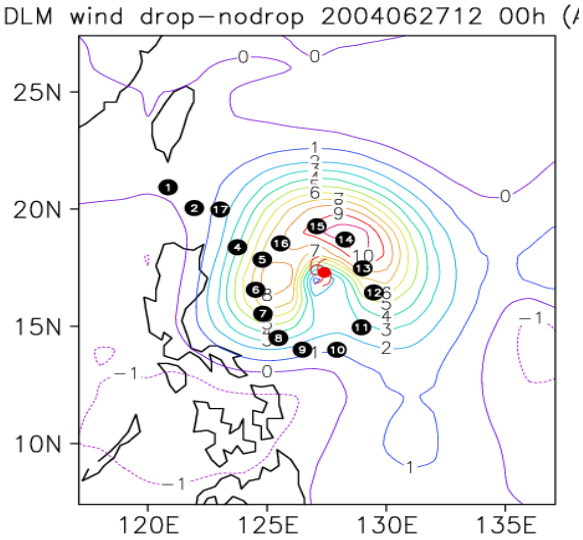


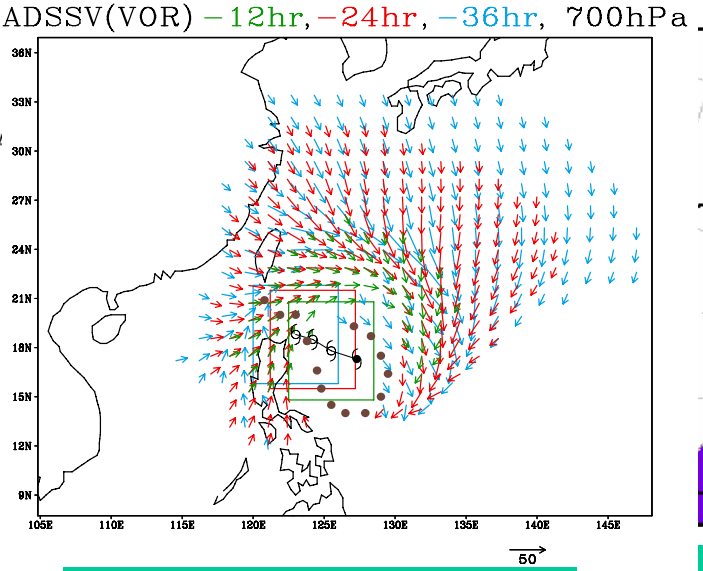
AVN ensemble variance

(Wu et al. 2005c)

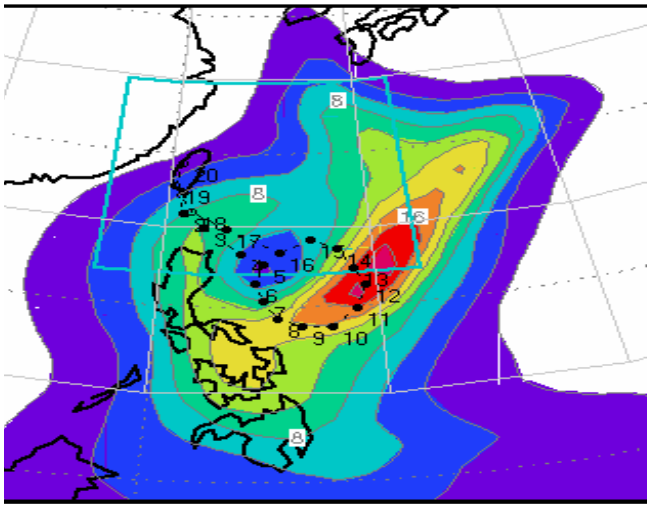
Comparison among all sensitivity products

Typhoon Mindulle

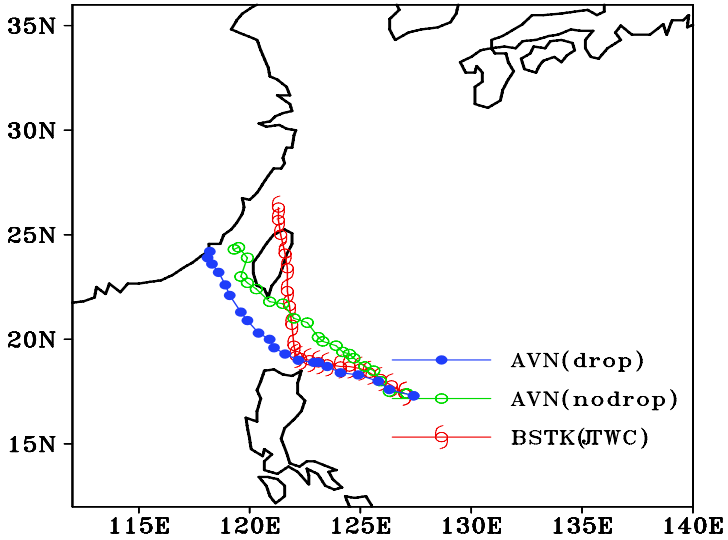




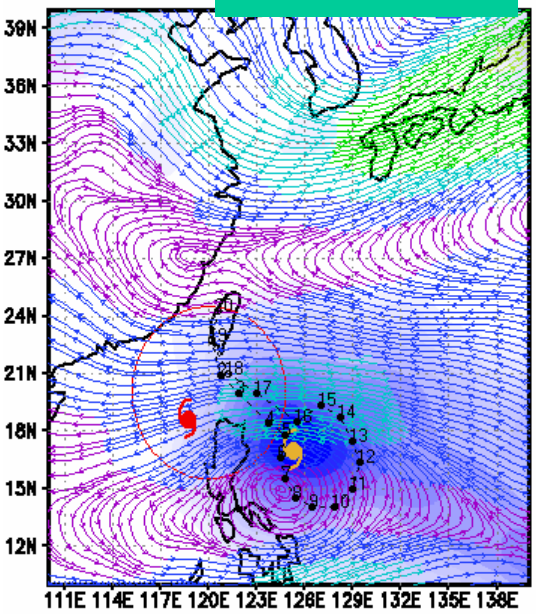
ADSSV (Vorticity)



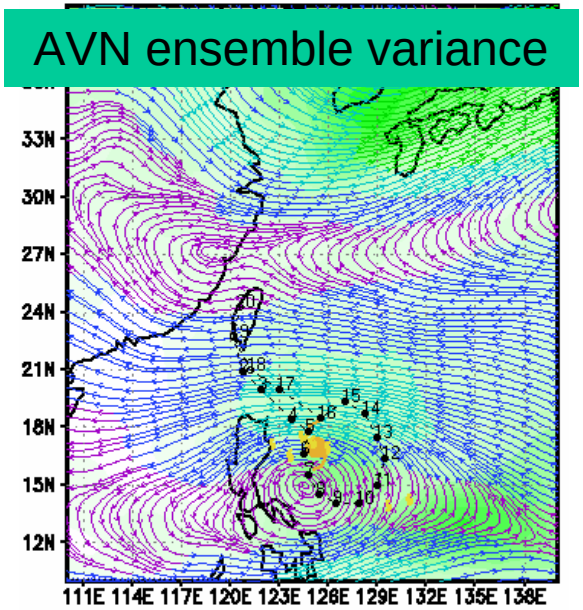
NOGAPS Singular Vector



AVN ETKF



AVN ensemble variance



(Wu et al. 2005c)

Future work on ADSSV

- **Linearity test**
  - To validate the linearity assumption, perturbations that evolves linearly via the TLM need to be compared with difference fields obtained from two nonlinear model forecasts.
- **Impact study**

-- In order to validate the adjoint modeling system, we will modify the wind/temperature fields in the initial time based on the ADSSV sensitivity areas to investigate the response of the simulated typhoon track.

--- Links to data assimilation.

- **Other case studies**
  - A thorough investigation of other DOTSTAR cases, such as Conson, Meari and Nock-Ten, is ongoing.
  - Test specific event: such as trough effect, binary interaction…
  - Detailed comparisons of different targeted techniques.
  - Data-denial experiments and diagnosis.
- **Operation in the field program**
  - We plan to implement the currently designed method (using ADSSV) for real-time use in DOTSTAR, as well as for Atlantic hurricanes, in 2005.

Future perspectives

『National Priority Typhoon Research Project』

Phase I : **2002/08 – 2005/07**

- ❑ Improved understanding → research excellency
- ❑ Improved forecast → Disaster mitigation
- ❑ Typhoon research in Taiwan → Unique and leading role in the international typhoon research arena

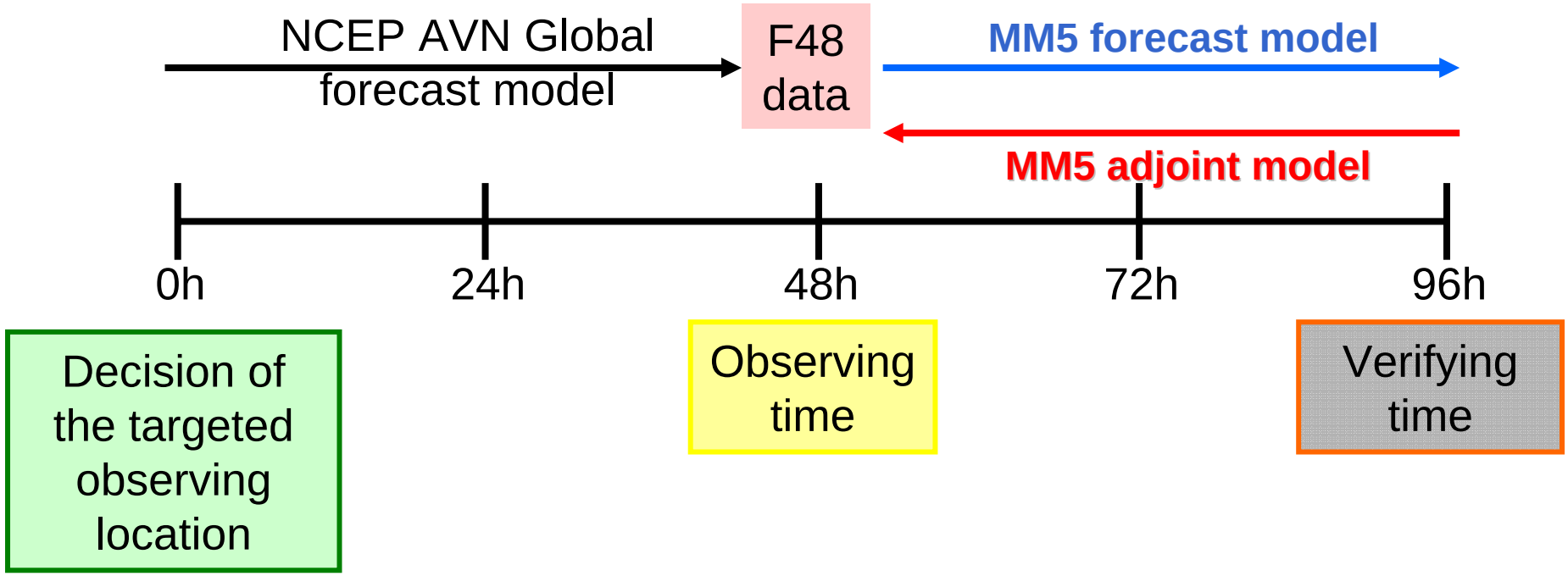
Phase II : 2005/08-2008/07

Phase III: Establishing the “Typhoon Research Center”

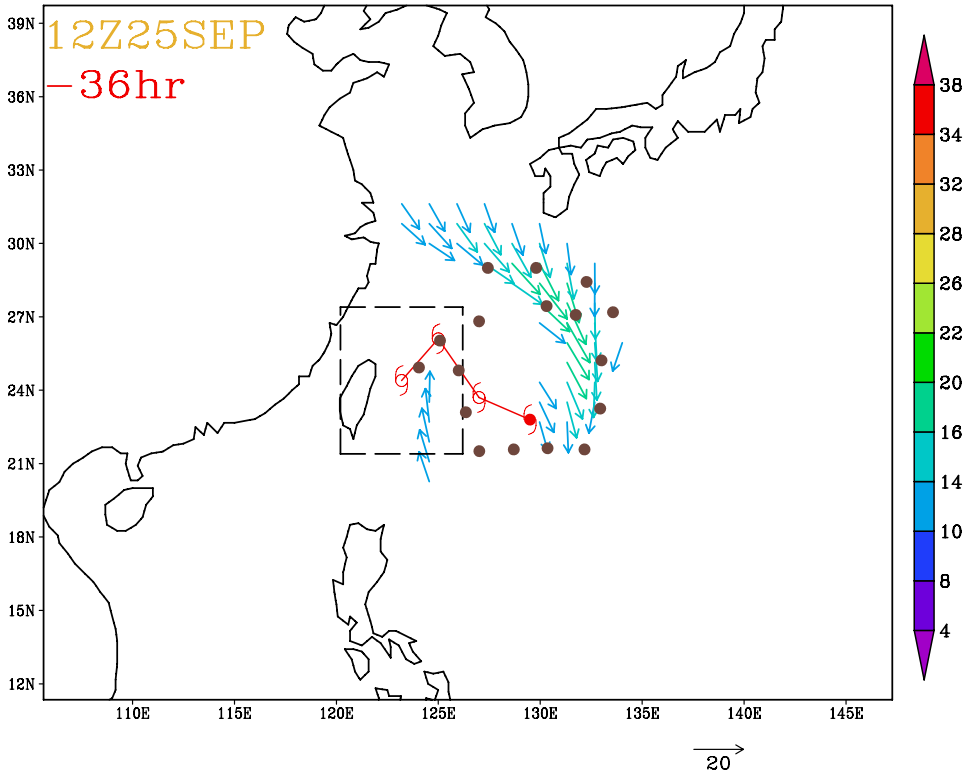
Hardware + **Software** + **Brainware**

Operational use of ADSSV in the field program (DOTSTAR)

- Using AVN 48 hours forecast field as the initial condition of MM5 adjoint system.



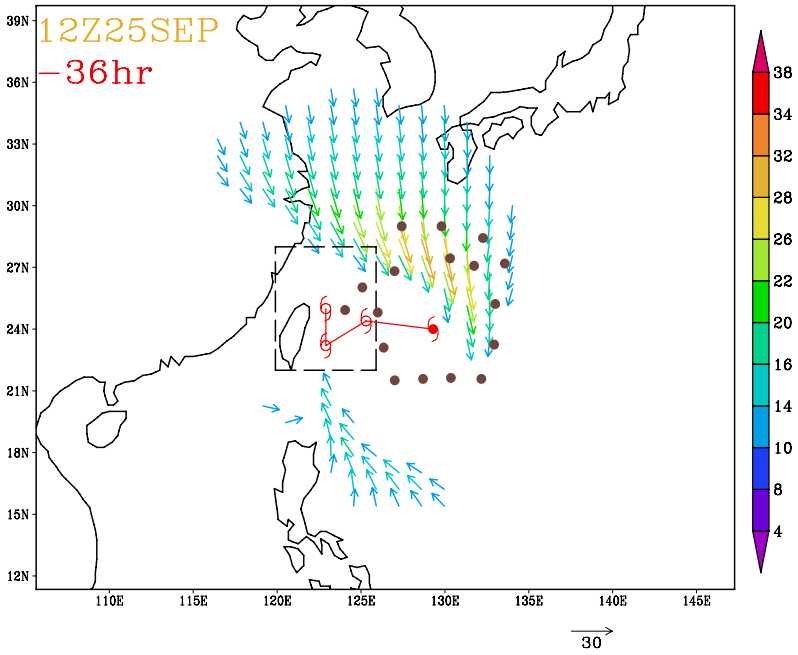
ADSSV (Vorticity)



F48_ADJ36

Indicating the feasibility of the theoretical idea in the real-time field experiment.

CTRL_ADJ36



『National Priority Typhoon Research Project』

Funded by NSC, 2002/08 – 2005/07

PI：Chun-Chieh Wu

Primary tasks -

(Observation/equipment) + (analysis/modeling/theories)

(2M） ＋ (1M） ＝ 3 M （3-year funding, US $）

Principal goals -

- ❑ Improved understanding → Research excellency
- ❑ Improved forecast → Disaster mitigation
- ❑ Typhoon research in Taiwan → Unique and leading role in the international typhoon research arena

（Wu et al. 2005, BAMS）