Assessing the Impact of RO Refractivity on the Analysis and Prediction of Typhoon Morakot (2009) with a New Data Assimilation Strategy

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April 2, 2012

Objective:

To improve the performance of local operator of refractivity for typhoon analysis and forecast

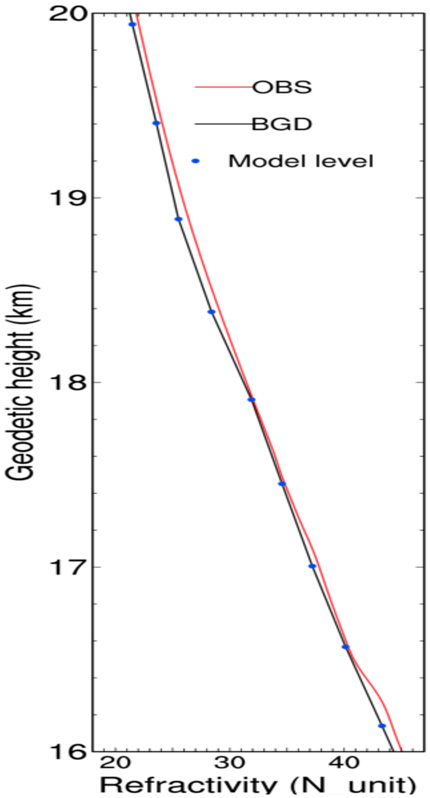
Outline:

1. A new data assimilation strategy for refractivity
2. Case overview of Typhoon Morakot (2009)
3. Experiments design
4. Encouraging positive results
5. Conclusions and discussions

A new data assimilation strategy for refractivity

Observation resolutions of N
--- Clarify "vertical resolution"

1. N_ar vertical resolution of retrieval
   ~10-50m (observation density)
2. N_ar vertical resolution of information
   ~100-200m near surface,
   ~500-1000m in troposphere,
   ~1000-2000m in stratosphere
3. N_mod vertical resolution
   --- Vary with NWP model



1 & 2 → specific treatment for vertical error correlation

2 & 3 → specific representative errors

Observational error correlation

1. Variable transformation -- n/a for N
2. Thinning via super-obs -- n/a for monotonic N
3. Non-diagonal error matrix -- n/a for ensemble
4. Cost function down-weighting -- n/a for ensemble
5. Adaptive inflation -- OK for ensemble, still developing
6. ✔ Thinning via down-sampling
   - -- OK for N
   - -- OK for both ensemble and variational
   - -- Simplest to implement

This deserves further investigation…

Our new strategy (see Fang 2011, Ph.D. thesis)

"Assimilating RO refractivity on thinned exact heights"

- How to thin?

1. To exact heights.
2. Global altitude-dependent intervals.
3. Determine intervals by "observation resolution".

- Why to exact heights?

--- Much easier to assume more accurate height-specific observational errors.

Our new strategy (see Fang 2011, Ph.D. thesis)

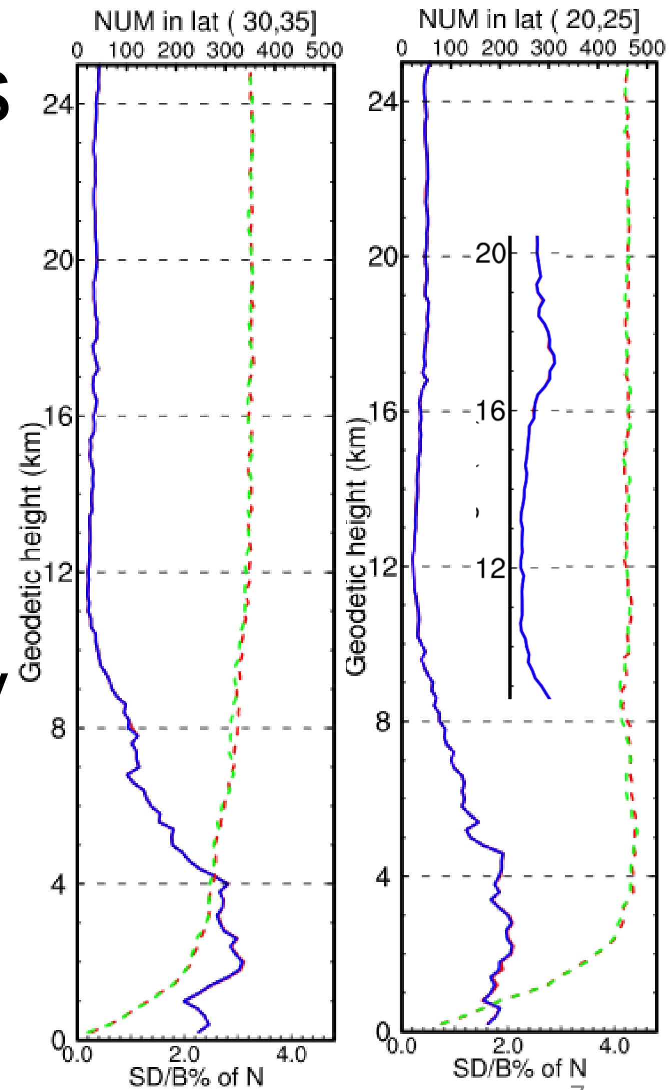
"Assimilating RO refractivity on thinned exact heights"

- Vertical structure of errors

--- Vary significantly with altitude

--- Vary significantly with latitude

--- Neither latitudinal nor altitudinal explicit fitting functions applicable for error interpolation onto arbitrary heights.



Thinning scheme A (for comparison)

--- 60 exact levels to 20 hPa

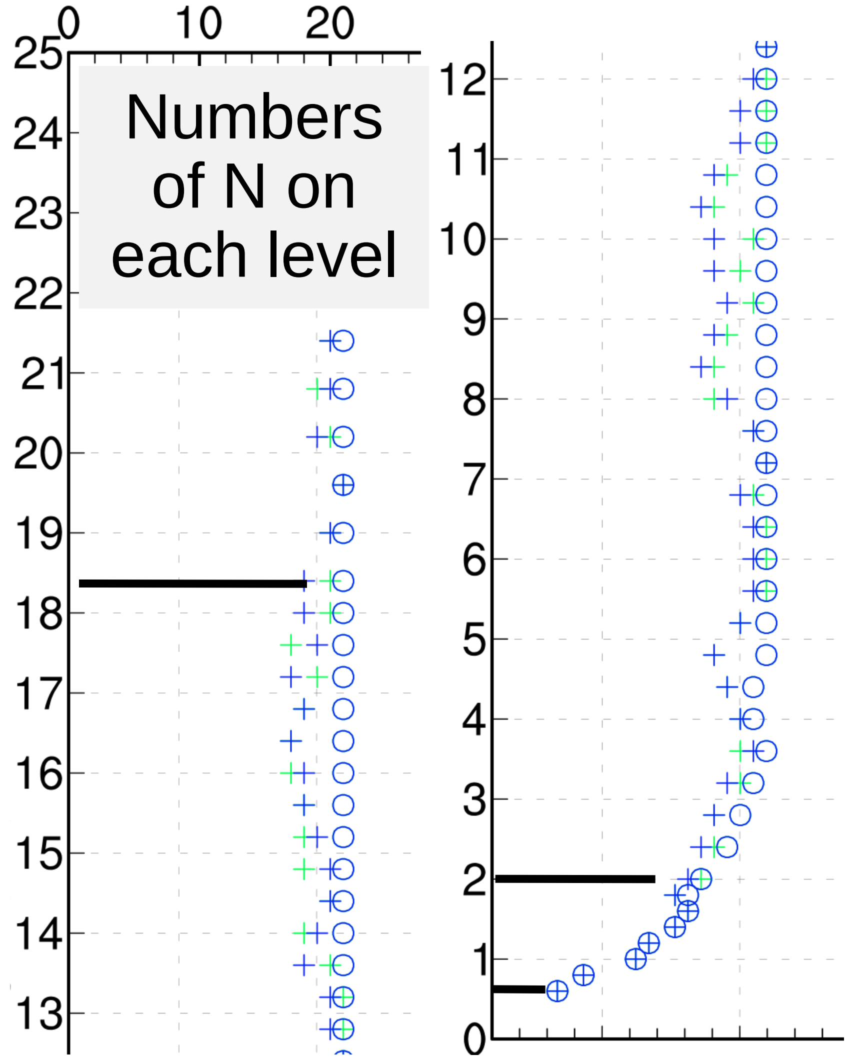
- Every 200m for 600-2000m
- Every 400m for 2,000-18,400m
- Every 600m for 18,400-25,000m

--- Vertical resolution of N

~100-200m near surface,

~500-1000m in troposphere,

~1000-2000m in stratosphere



Thinning scheme B (tested)

--- 26 exact levels to 20 hPa

- Every 800m for 800-13,600m
- Every 1200m for 13,600-23,200m
- Every 1800m for 23,200-25,000m

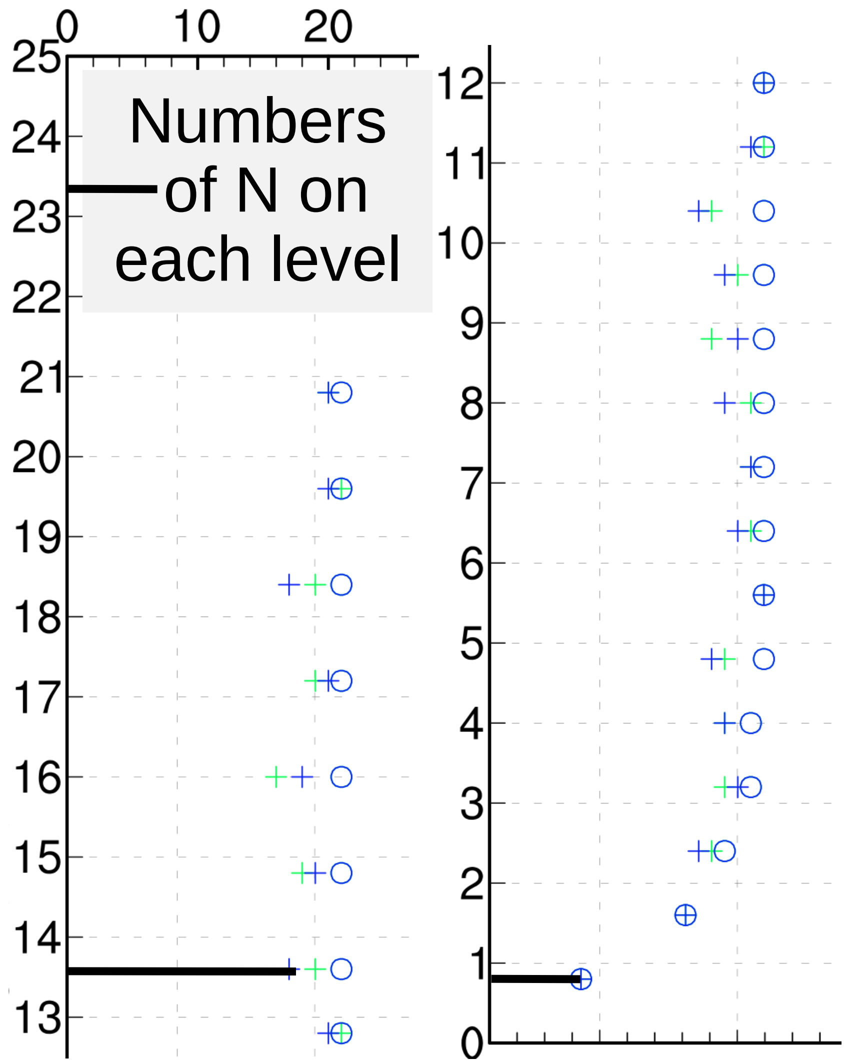
--- Vertical resolution of

N

~100-200m near surface,

~500-1000m in troposphere,

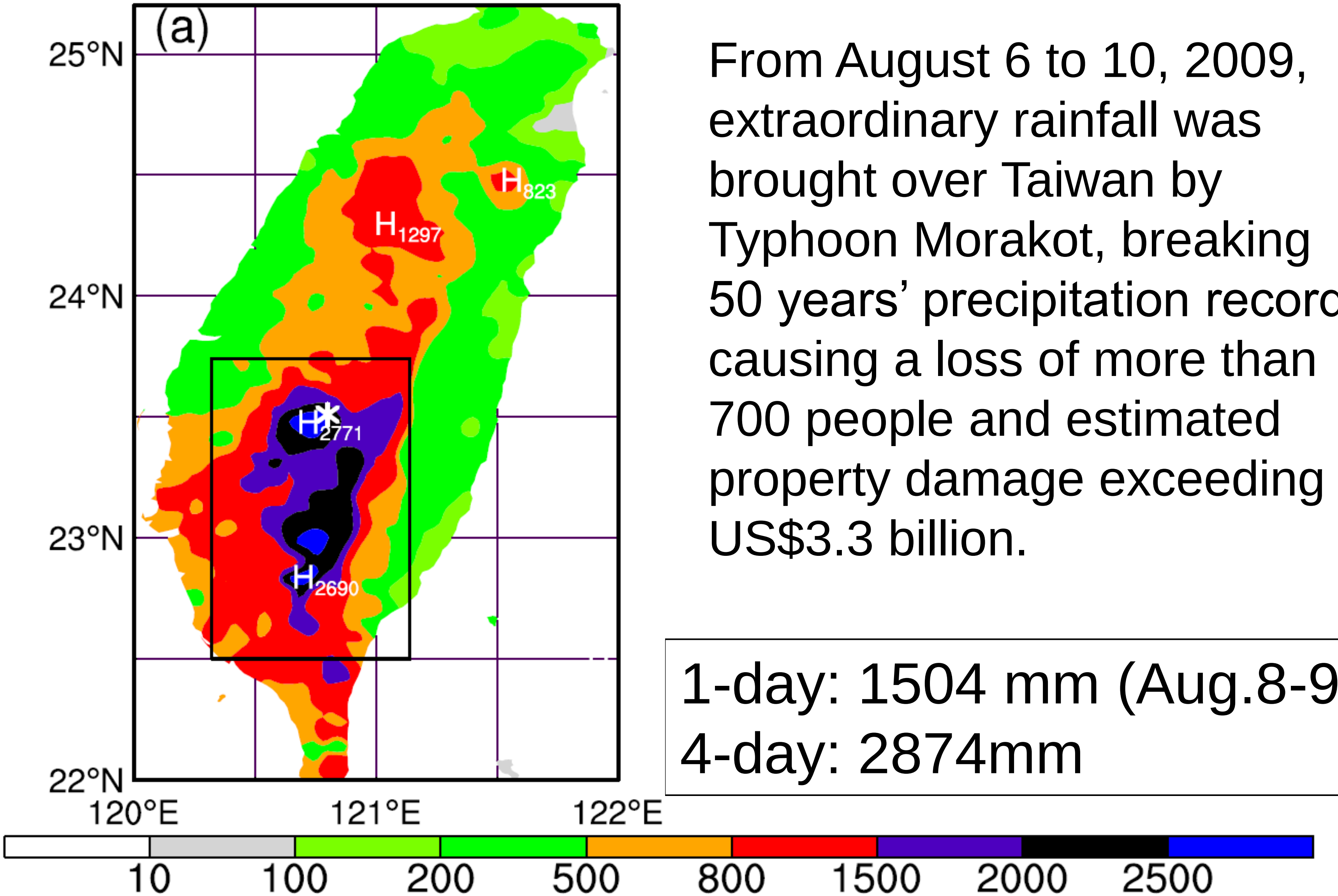
~1000-2000m in stratosphere



Case overview of

Typhoon Morakot (2009)

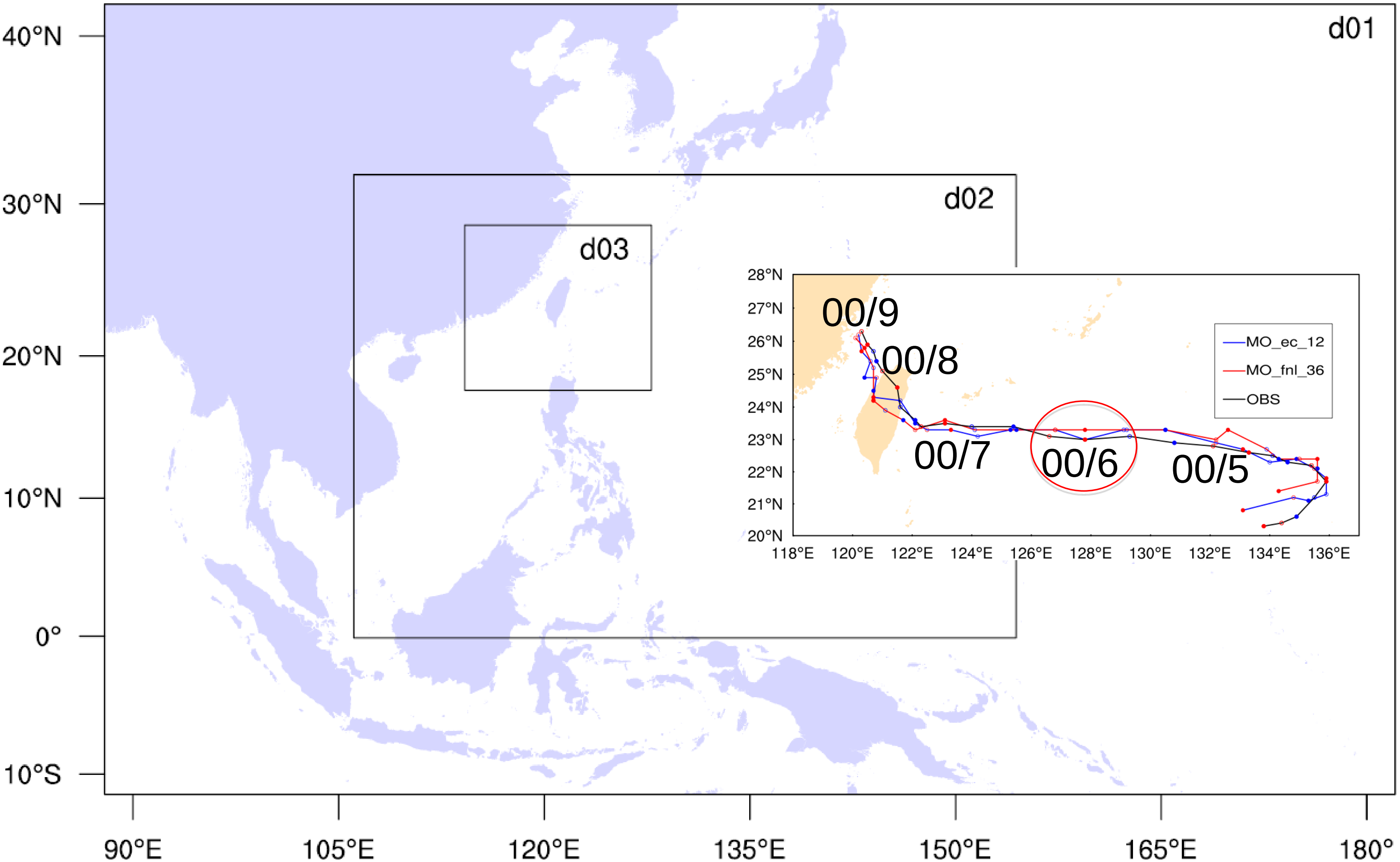
Record-breaking rainfall



From August 6 to 10, 2009, extraordinary rainfall was brought over Taiwan by Typhoon Morakot, breaking 50 years' precipitation record, causing a loss of more than 700 people and estimated property damage exceeding US$3.3 billion.

1-day: 1504 mm (Aug.8-9)
4-day: 2874mm

West-bounding track impinging Taiwan



Experiments design

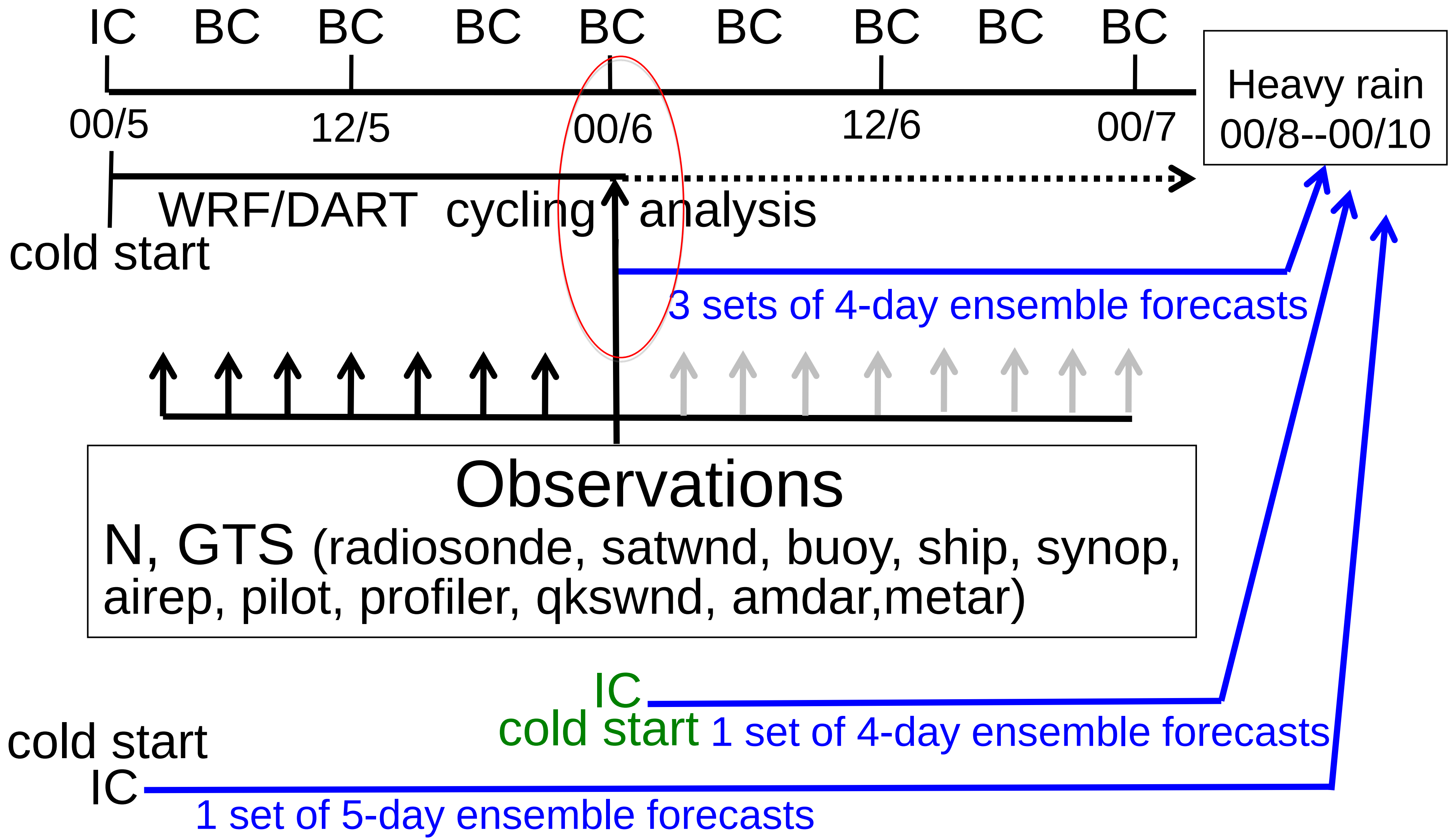
- Model: regional WRF-ARW, 36 km, 64 levels, 20 hPa
- Method: ensemble-based WRF/DART (EAKF)
- IC, BC: ECMWF analysis
- Errors of N: latitude-dependent height-specific errors
- QC of N: simple, against-background-check
- Four experiments:

  NoDa: No data assimilation

  GTS: Assimilate GTS

  NA: Assimilate GTS and N (scheme A)

  NB: Assimilate GTS and N (scheme B)
- Targeting analysis: August 6



5 sets of 36-km 32-mem 4-d or 5-d ensemble forecasts:

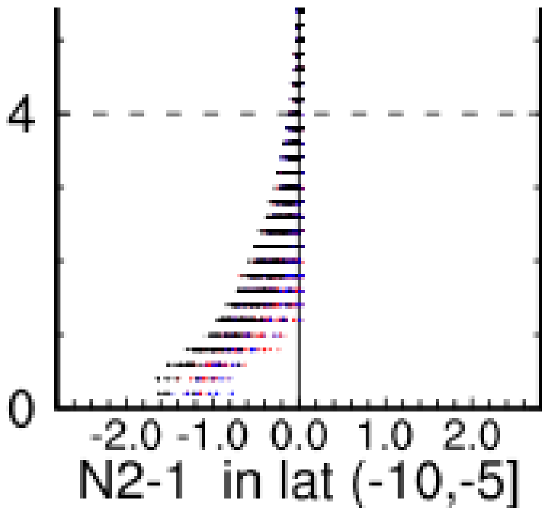
GTS, NA, NB, NoDa, EC

N expression used in forward operator

$$N = N_0\left(1 + \frac{1}{6} \times 10^{-6} N_0\right)$$

(Aparicio et al., 2011)

$$N_0 = (222.682 + 0.069 \cdot \tau) \cdot \rho_d + (6701.605 + 6385.886 \cdot \tau) \cdot \rho_w$$



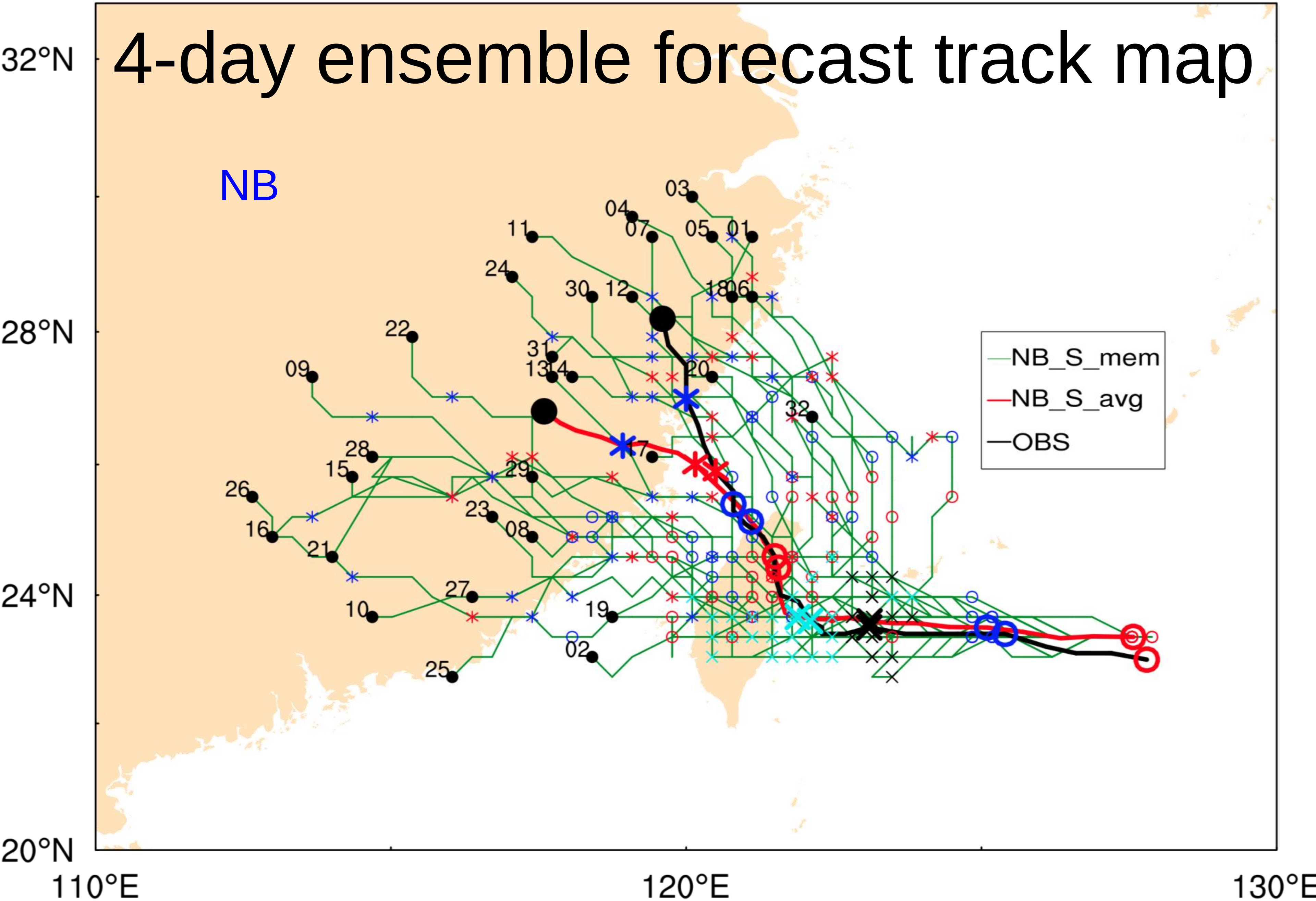
- It gives smaller N_model at LT

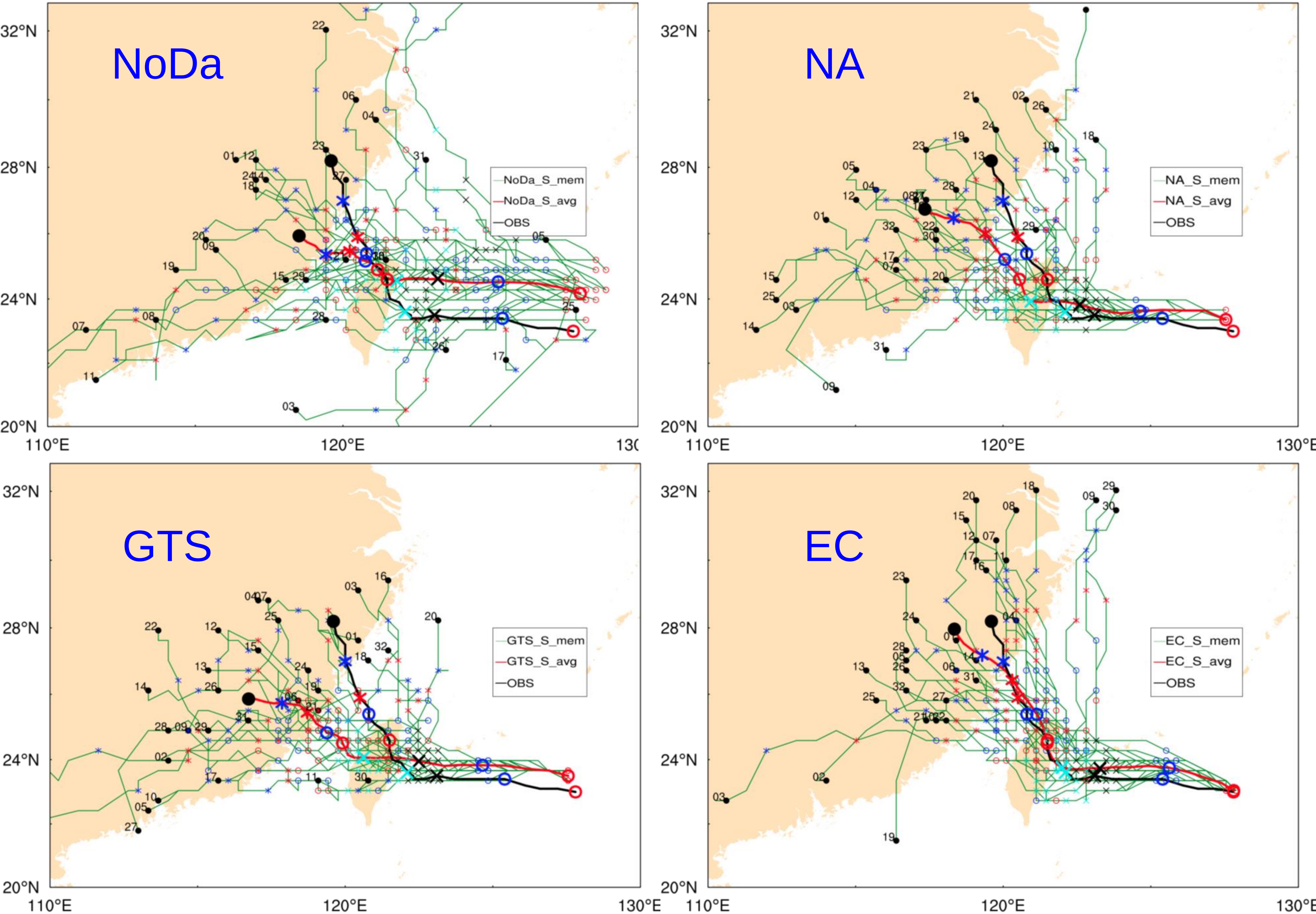
<u>Fang, X., and Y.-H. Kuo, 2012:</u>
Observational Error Analysis of GPS Radio Occultation Refractivity Data for Regional Data Assimilation.
(http://www.cosmic.ucar.edu/inside_cosmic/groupAct/activitiesStaff.html)

Time	Number
2009-08-05-03	11
2009-08-05-06	11
2009-08-05-09	14
2009-08-05-12	12
2009-08-05-15	21
2009-08-05-18	11
2009-08-05-21	8
2009-08-06-00	8
Total	96

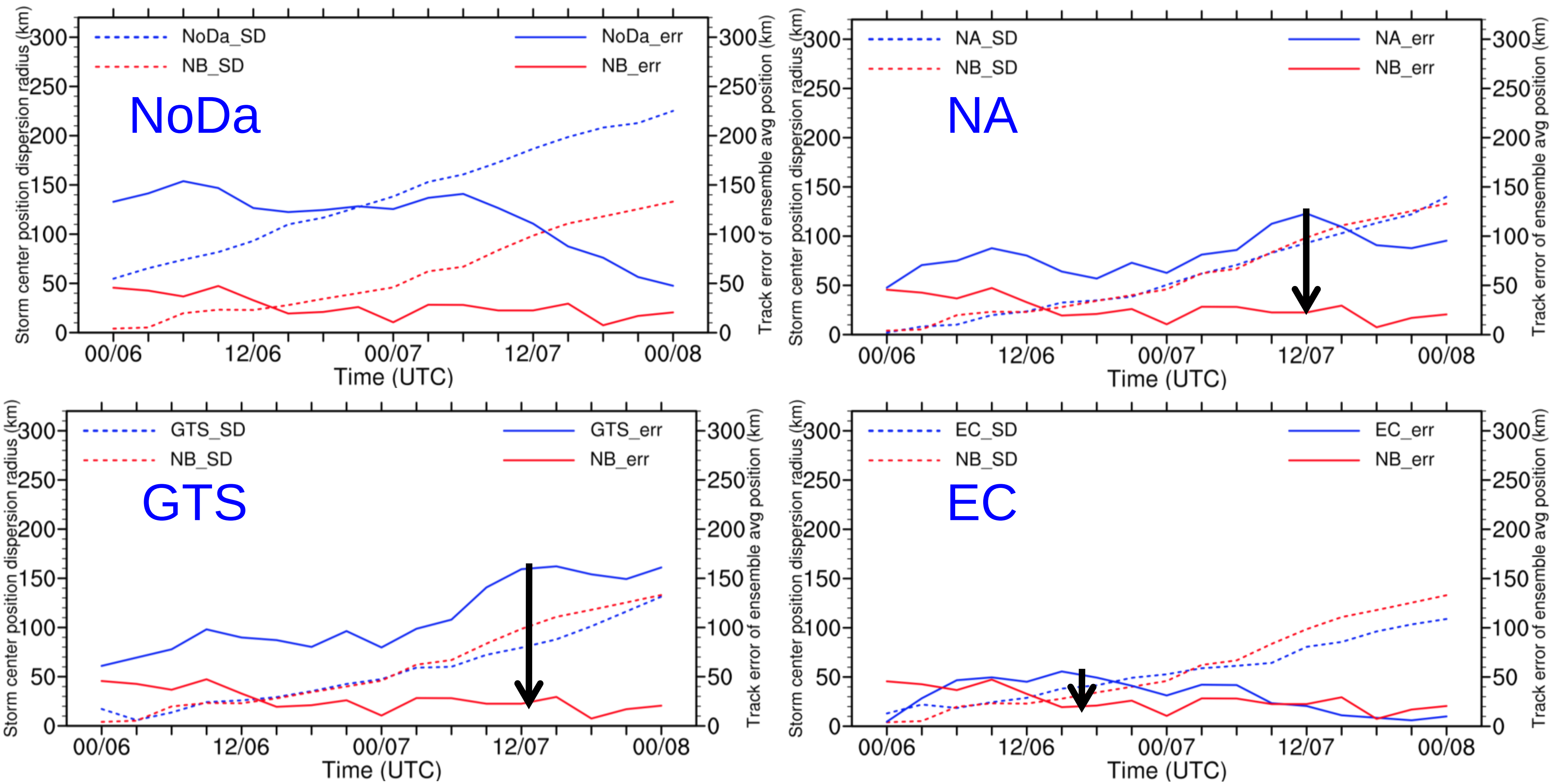
Encouraging positive results

4-day ensemble forecast track map



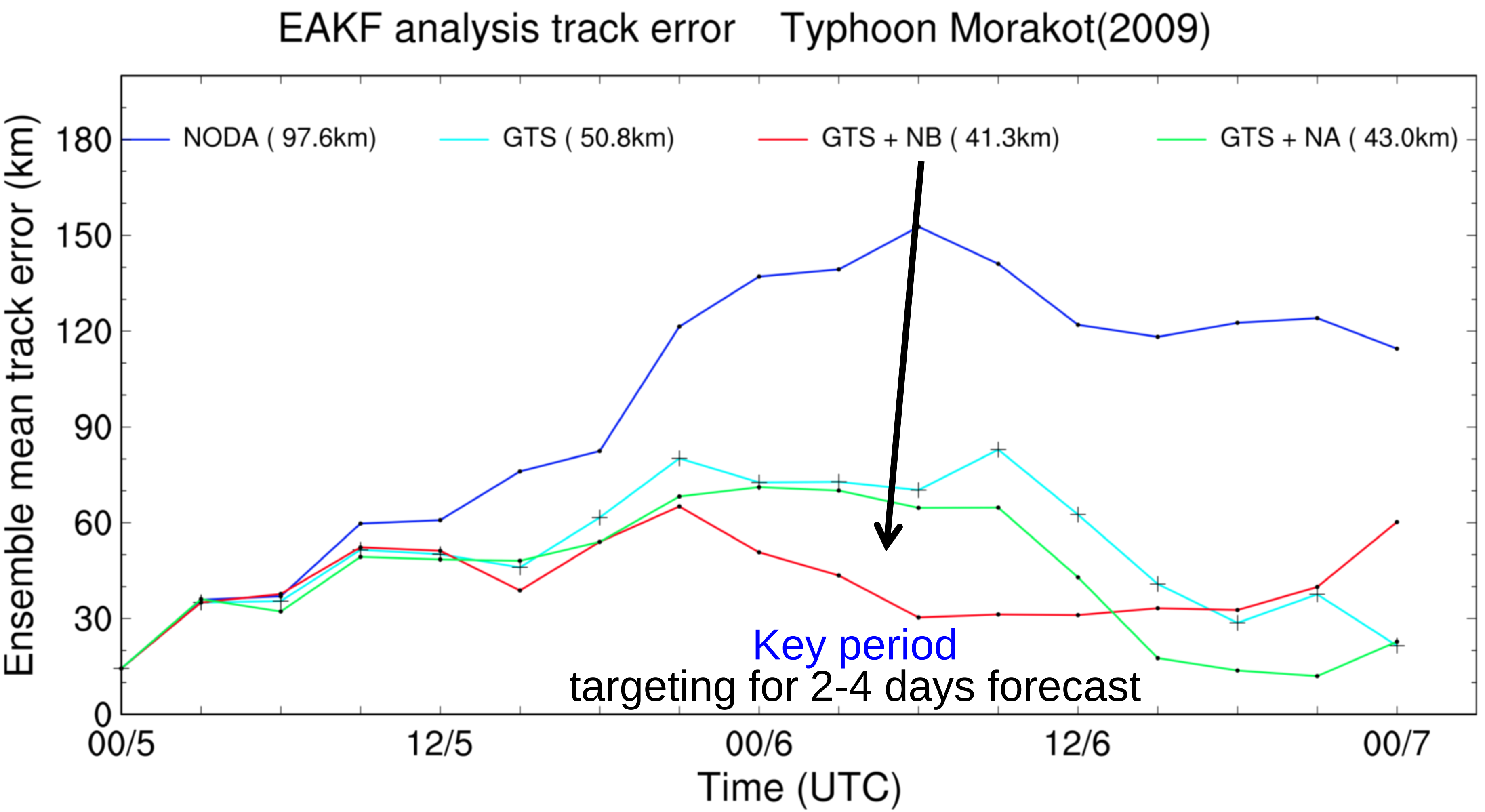

NoDa
NoDa_S_mem
NoDa_S_avg
OBS
NA
NA_S_mem
NA_S_avg
OBS
GTS
GTS_S_mem
GTS_S_avg
OBS
EC
EC_S_mem
EC_S_avg
OBS
32°N
28°N
24°N
20°N
110°E
120°E
130°E

Improved track forecast

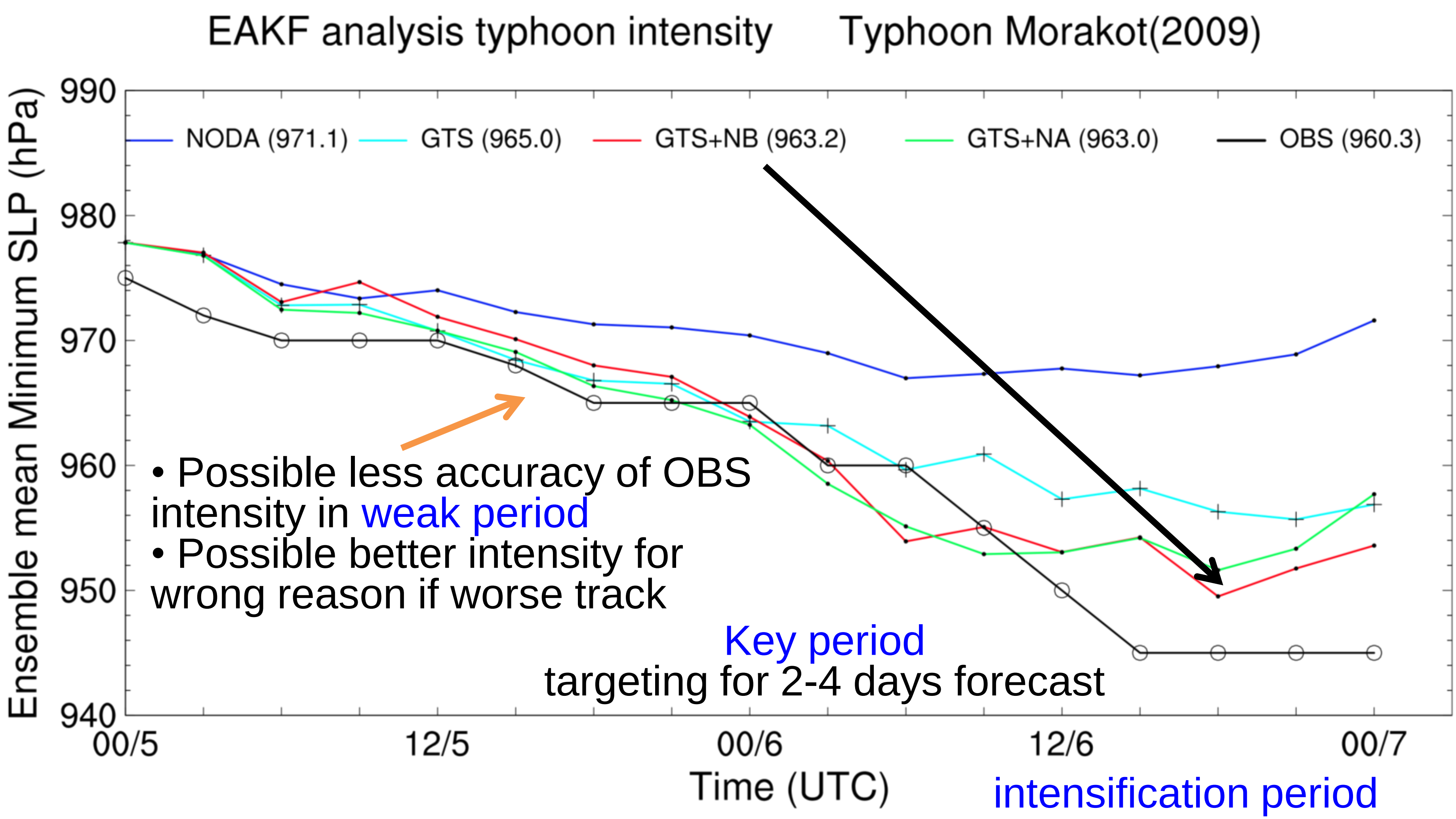


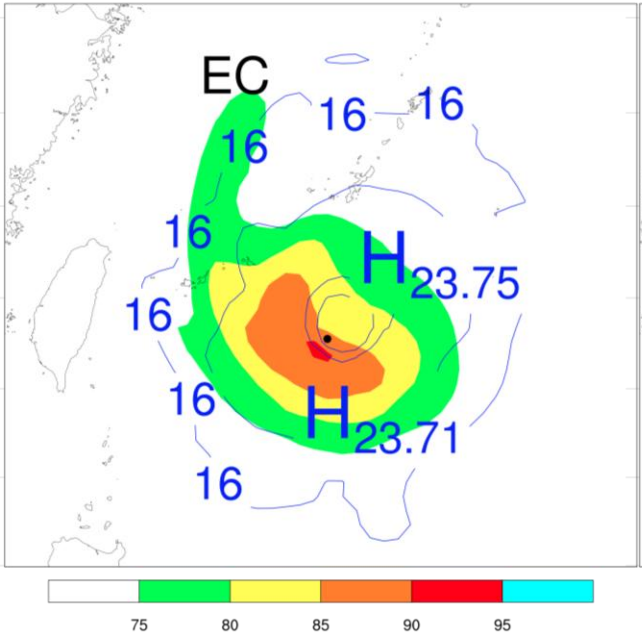
Ensemble mean track error & spread

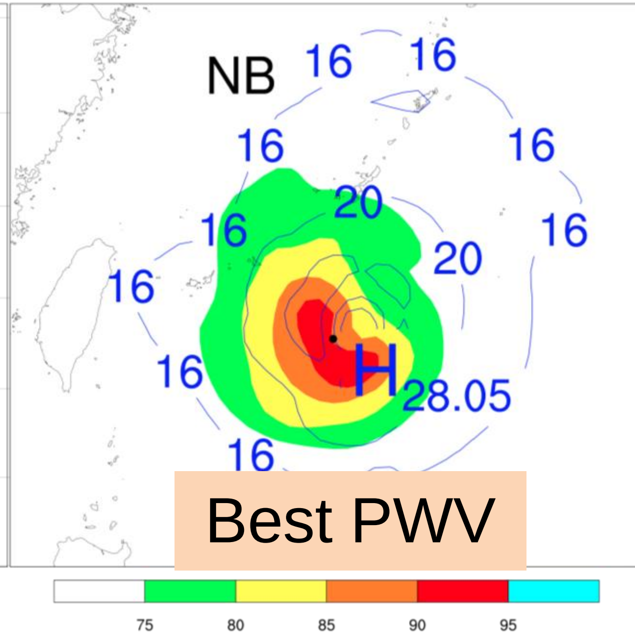
Improved track analysis in key period



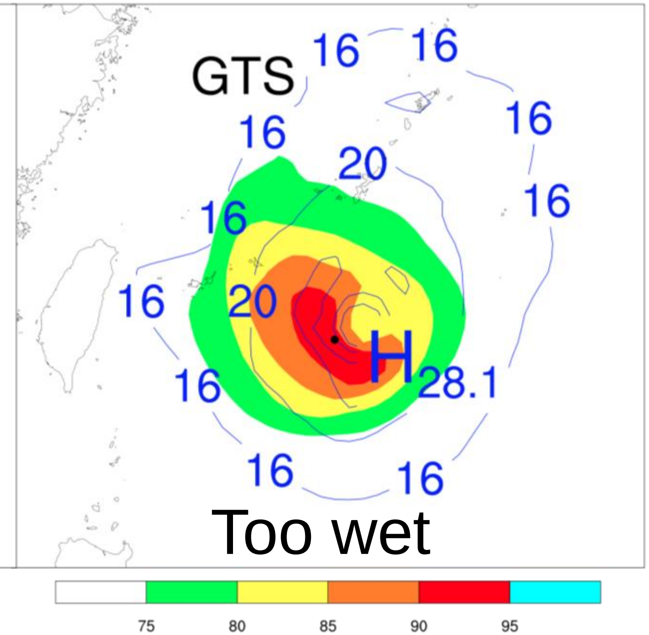
Reasonable intensity analysis in key period
Improved intensity analysis in intensification period



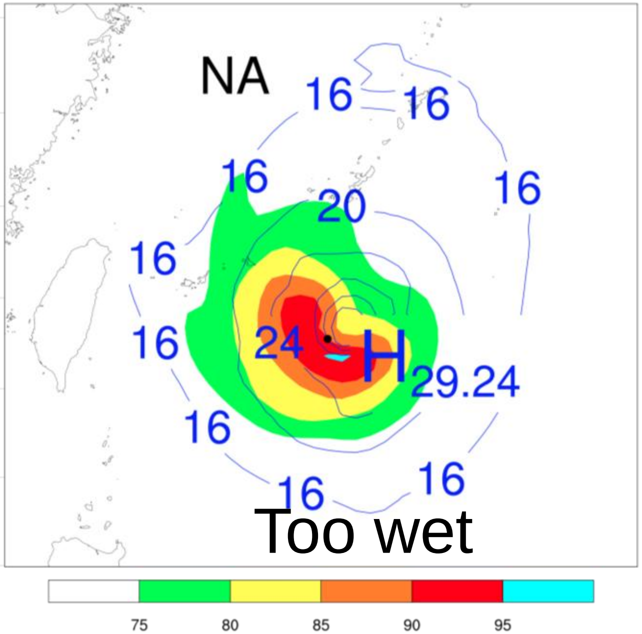




Best PWV

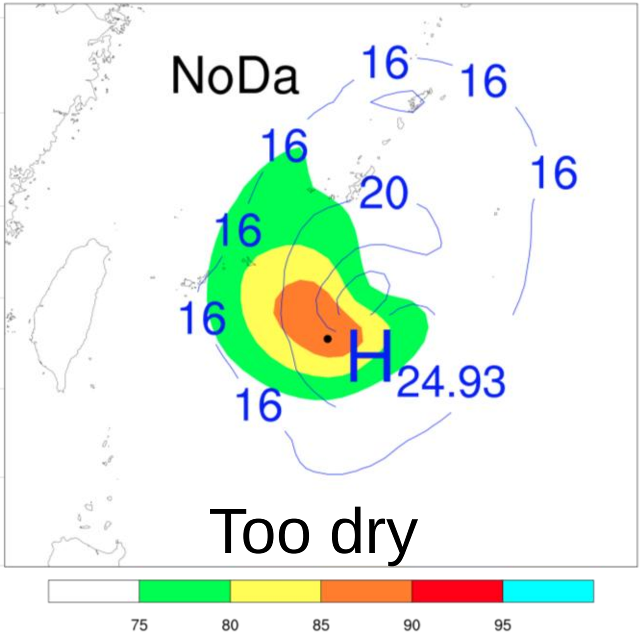


Too wet



Too wet

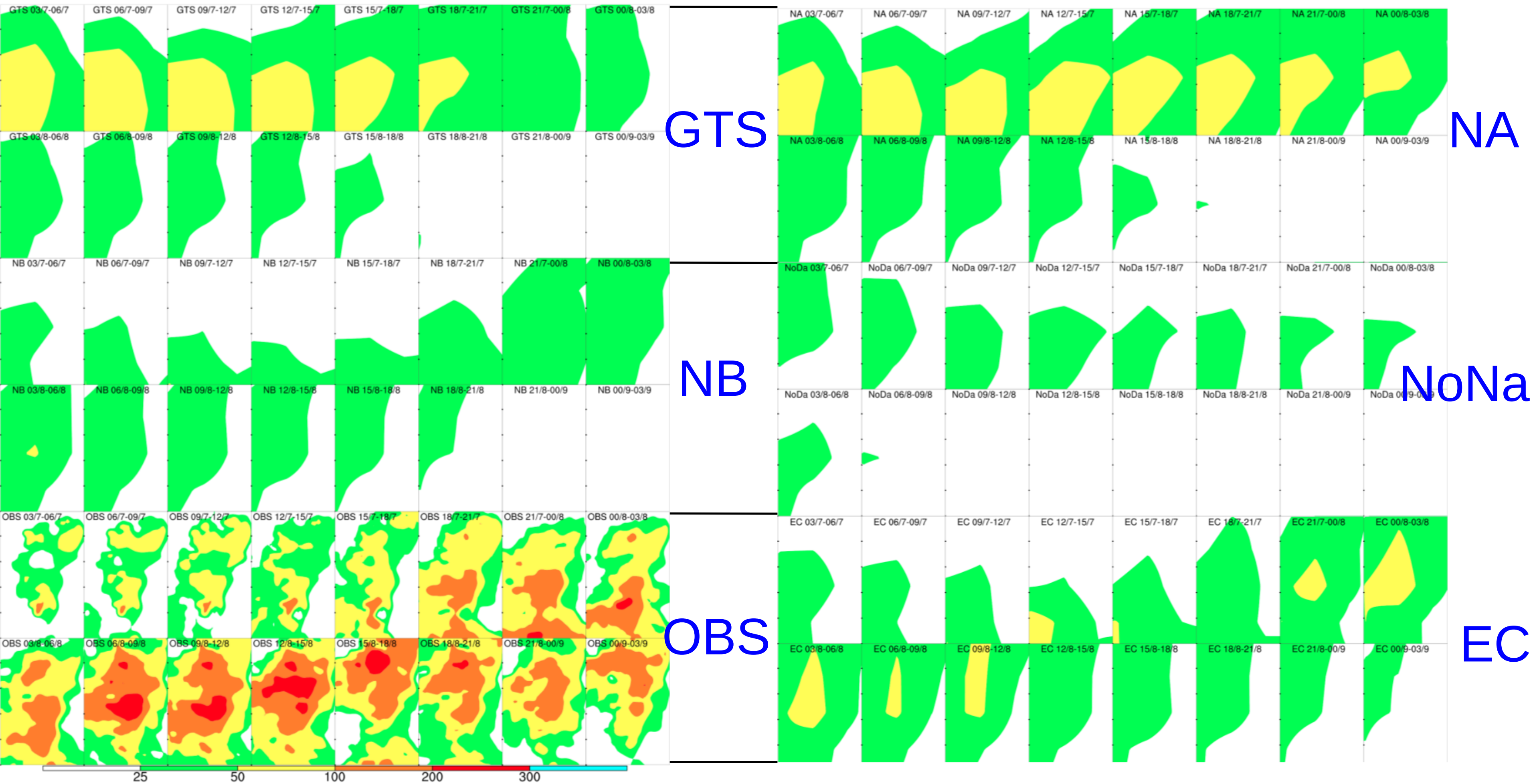
PWV and Wnd_{10} in 0600 analysis compared against ECMWF analysis



Too dry

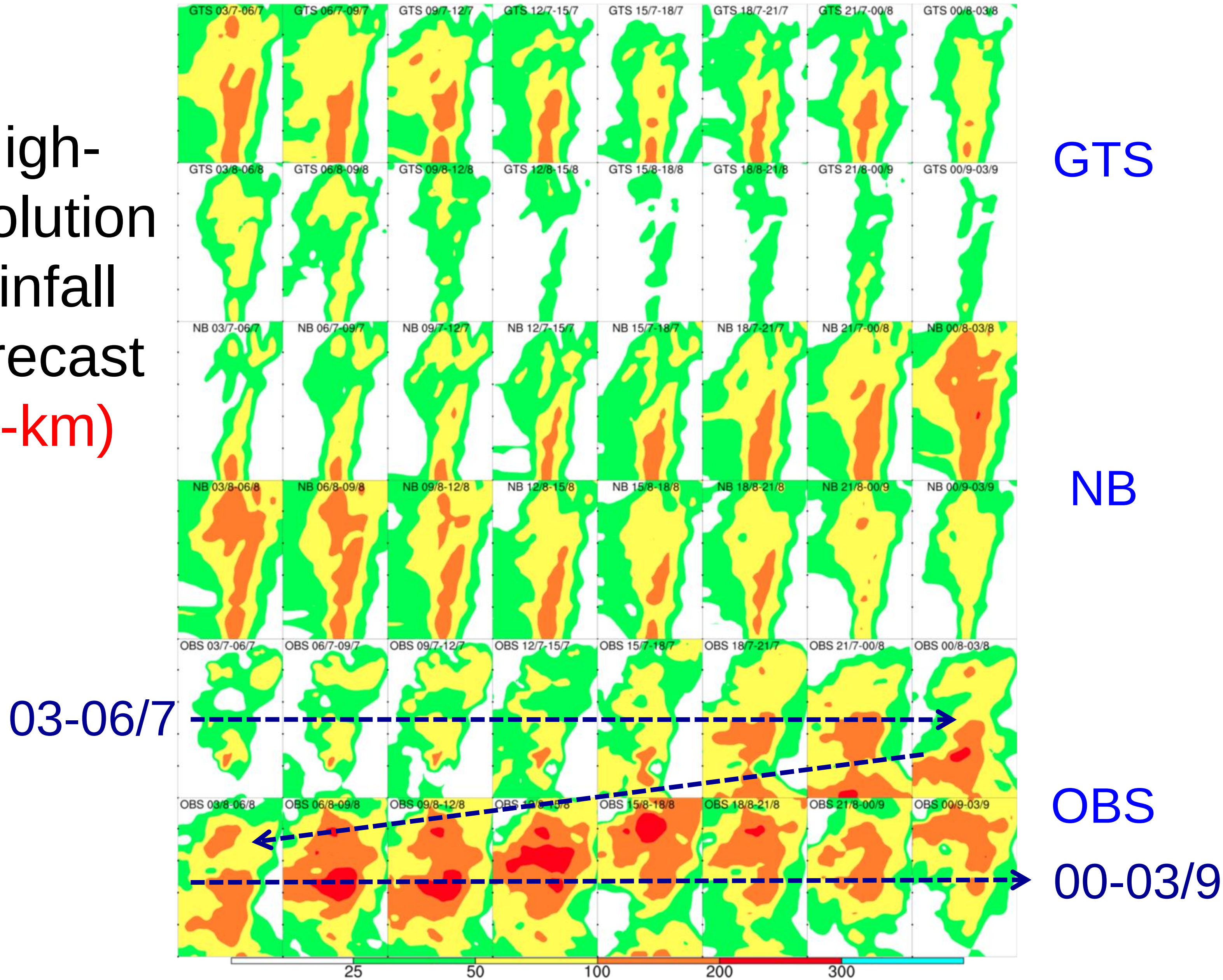
Improved rainfall forecast

- Improved rainfall forecast in terms of rainfall evolution trend.
- Valuable guidance for rainfall forecast if combined with statistical forecast.
- The systematic under-prediction of rainfall suffers from the model resolution



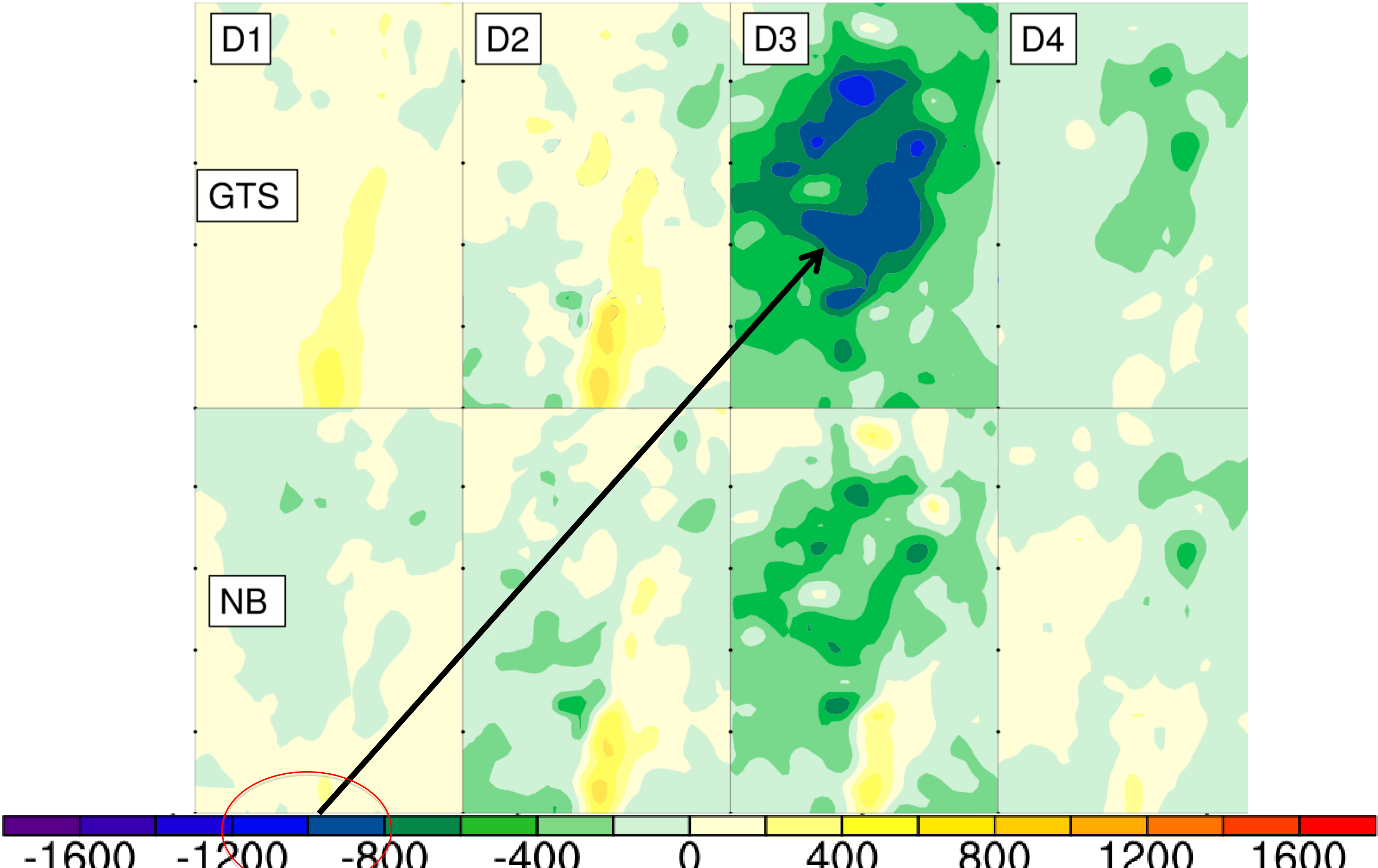
3-h rainfall evolution from Aug.7 to Aug.9 (32-member mean, 36-km)

High-resolution rainfall Forecast (4-km)



Ensemble mean 3-h rainfall evolution from Aug.7 to Aug.9

Rainfall mean forecast error



Conclusions:

1.A new data assimilation strategy of refractivity is introduced to improve the performance of the local operator of refractivity. GPS refractivity retrievals are vertically correlated. Thinning the refractivity profile in a manner consistent with the true information content improves the performance of refractivity data assimilation.

2.The artful point of this new strategy is to thin the profile on exact heights rather than arbitrary heights, which is helpful in assuming more accurate height-specific observational errors.

3.The assimilation of GPS refractivity data using this new strategy with a high-resolution WRF/DART ensemble-based data assimilation system improves the typhoon track and moisture analysis and the rainfall forecast.

--------- End -------

Thanks for you attention!