Highlights of the Operational WRF-Based Numerical Prediction System at Central Weather Bureau of Taiwan

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NCAR

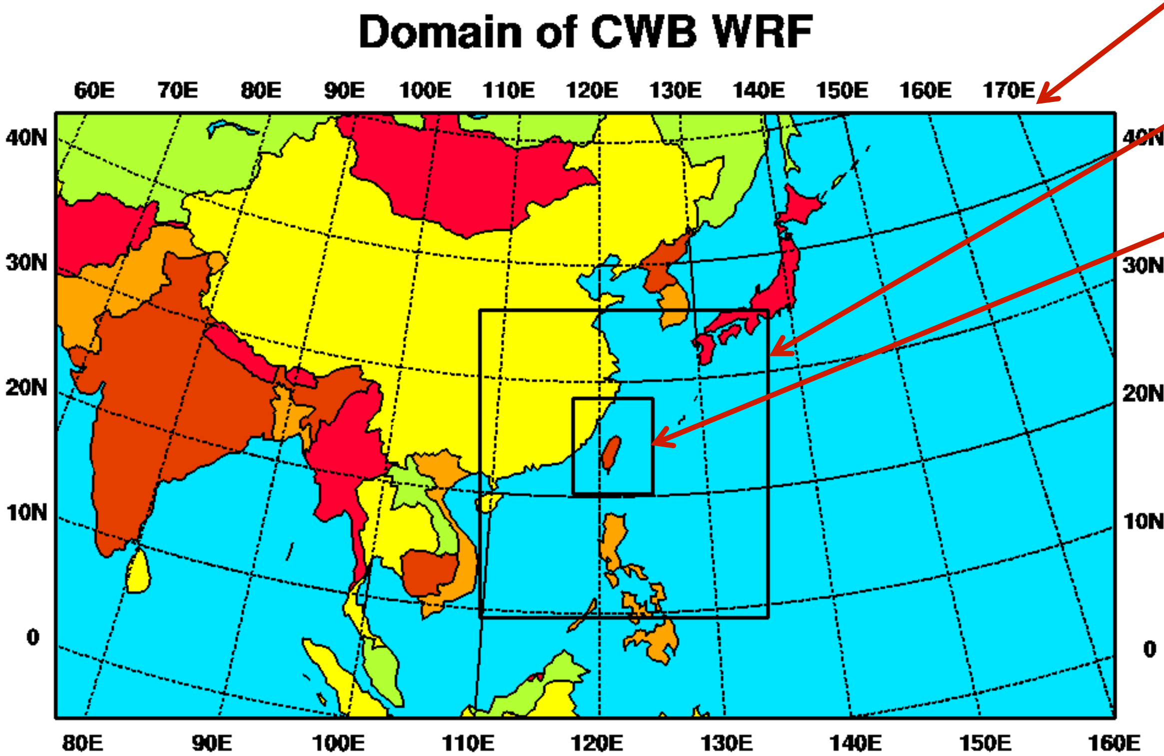
Outline

- Introduction to the CWB WRF DA system
- Recent improvements
- Summary

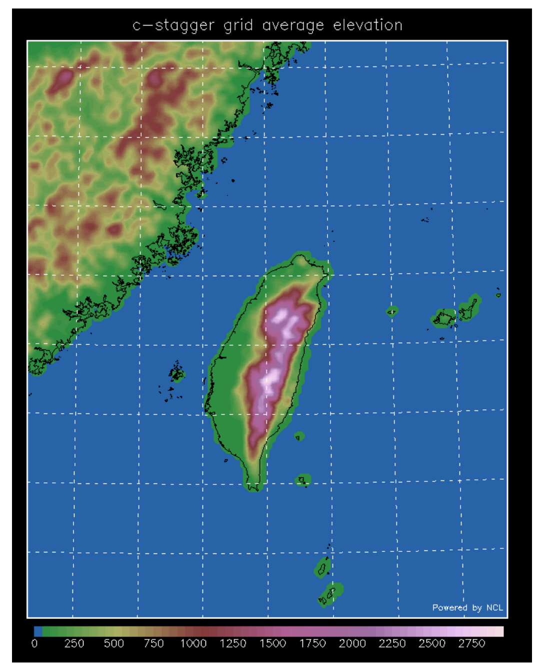
About the History

- CWB began to develop its own NWP system since 1984.
- WRF model was implemented in CWB's operational environment since 2004 and went through comprehensive evaluations.
- By cooperating with NCAR scientists, WRF was operational to be the 3rd generation regional forecast system since Nov 2007.
  - Both deterministic and ensemble prediction system

Domains of CWB WRF



- D1: 45-km resolution
  222 X 128
- D2: 15-km resolution
  184 X 196
- D3: 5-km resolution
  151 X 181
- 45 levels in vertical

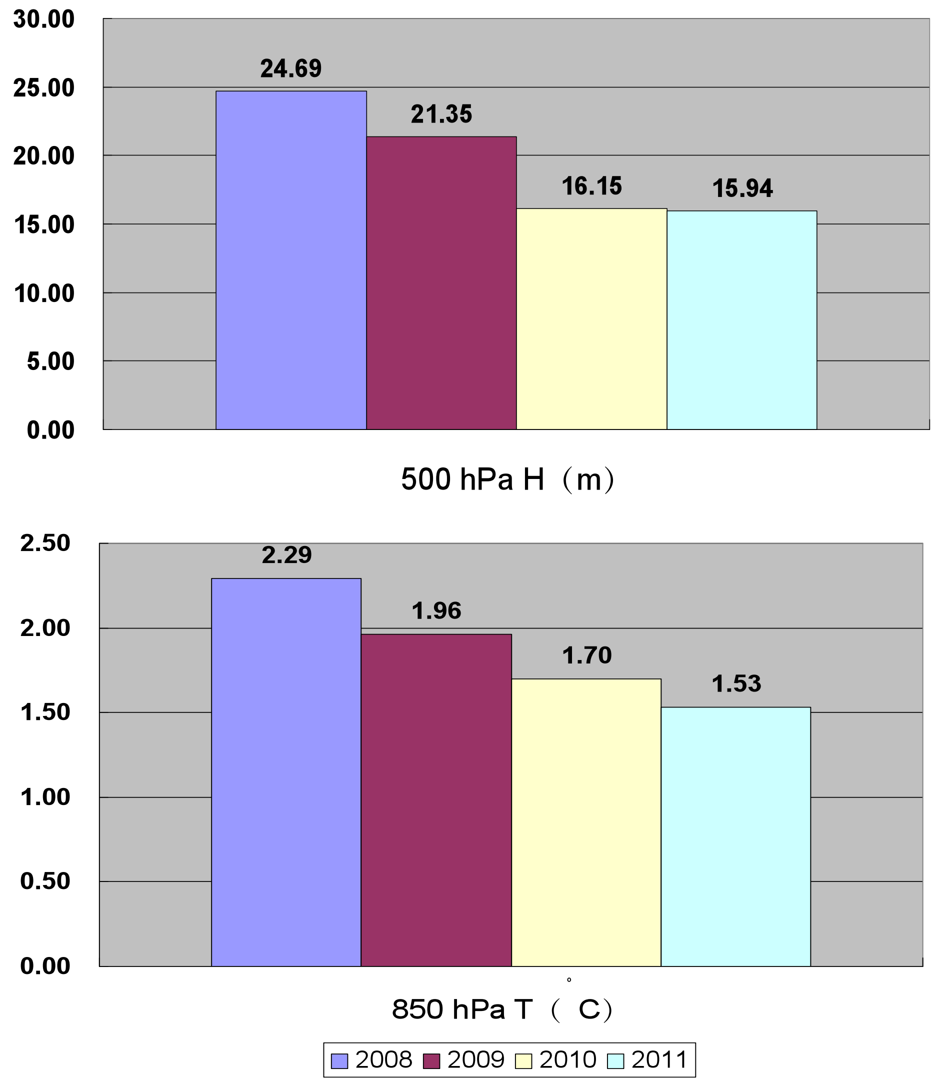


Highest terrain in Domain 3
over CMR/Taiwan ≈ 3,271 m
True elevation is 3,952 m

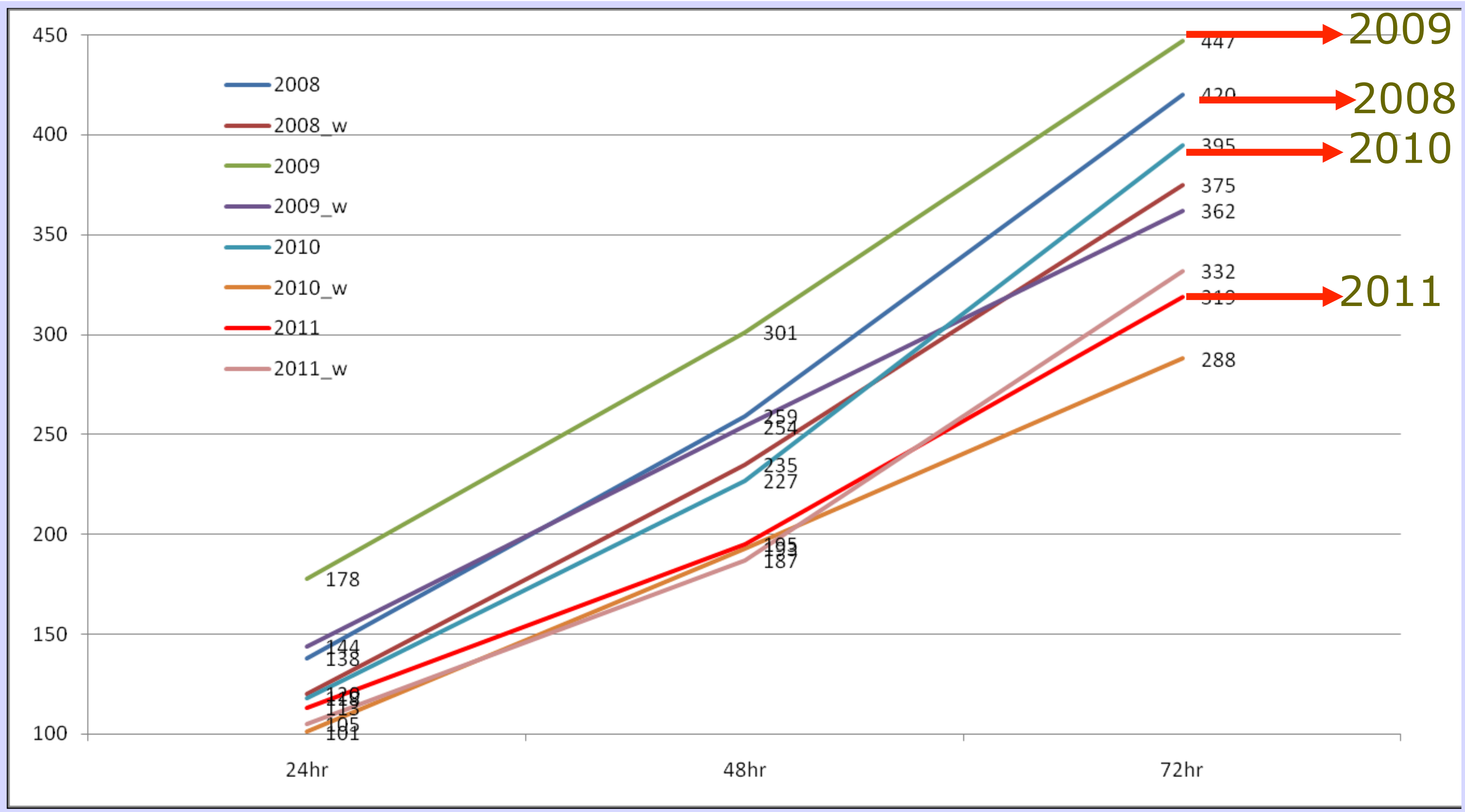
Configuration of DA system

- 4 times per day.
- Partial cycle was constructed by WRF 3D-VAR and WRF model
  - Background error covariance from NCEP GFS statistics (CV3) with length scale and variance tuning was used in 3DVAR
  - Assimilate all the GTS observations and GPSRO/ZTD
  - Typhoon initialization: vortex relocation and bogus synthetic sounding
- Model physics
  - Microphysic: Goddard MPS
  - Cumulus: Kain-Fritch scheme with new trigger function
  - PBL: YSU scheme
  - Surface layer: Monin-Obukhov scheme
  - Land process: NOAH
  - Long wave: RRTM
  - Short wave: Goddard

Performance of the CWB WRF in 2008~2011

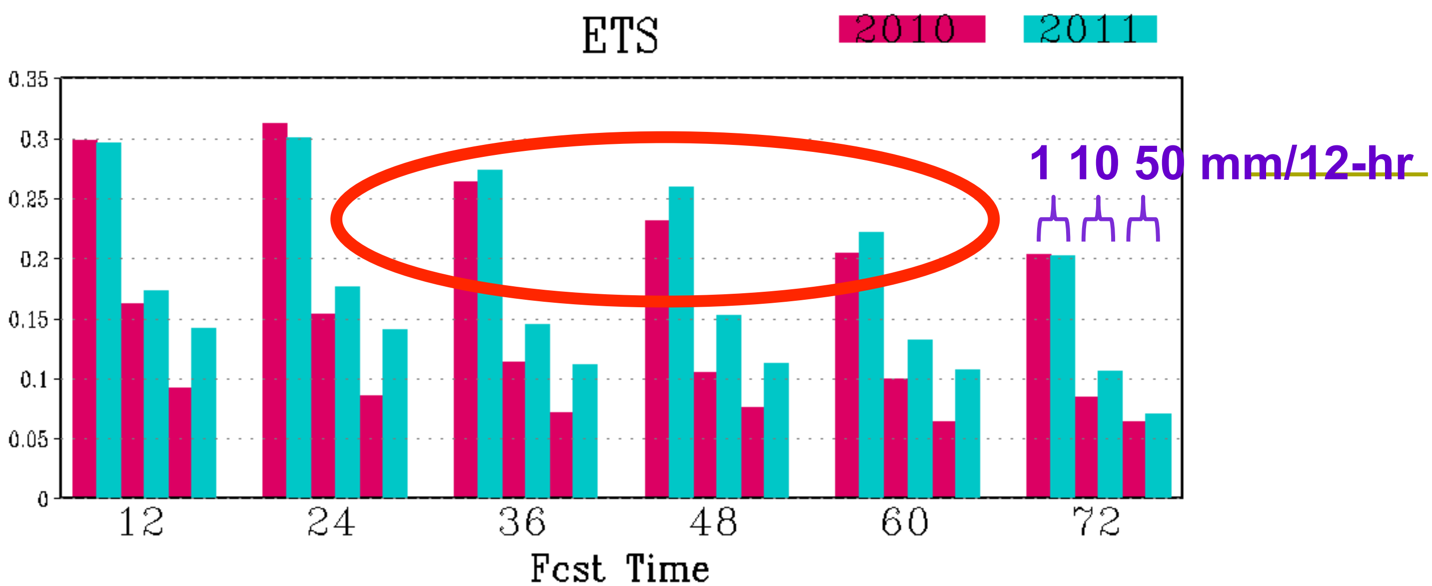


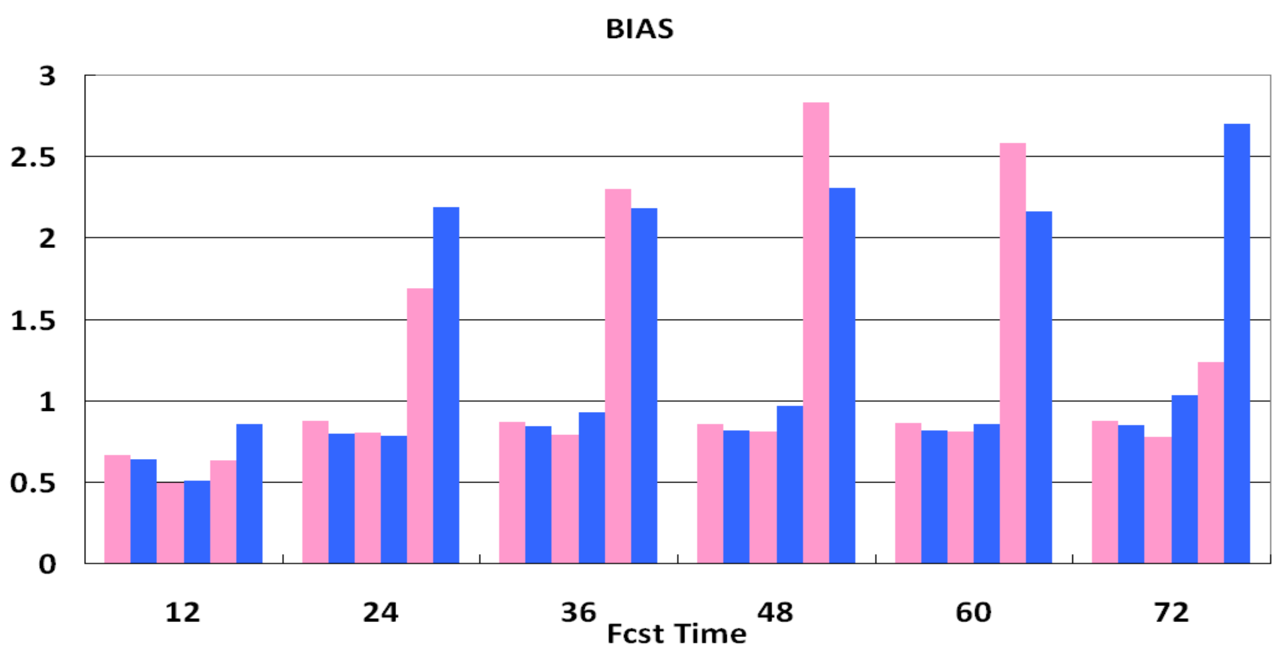
Track forecast errors in 2008 ~ 2011



w: CWB issued warnings

QPF verification at 5-km resolution over Taiwan island





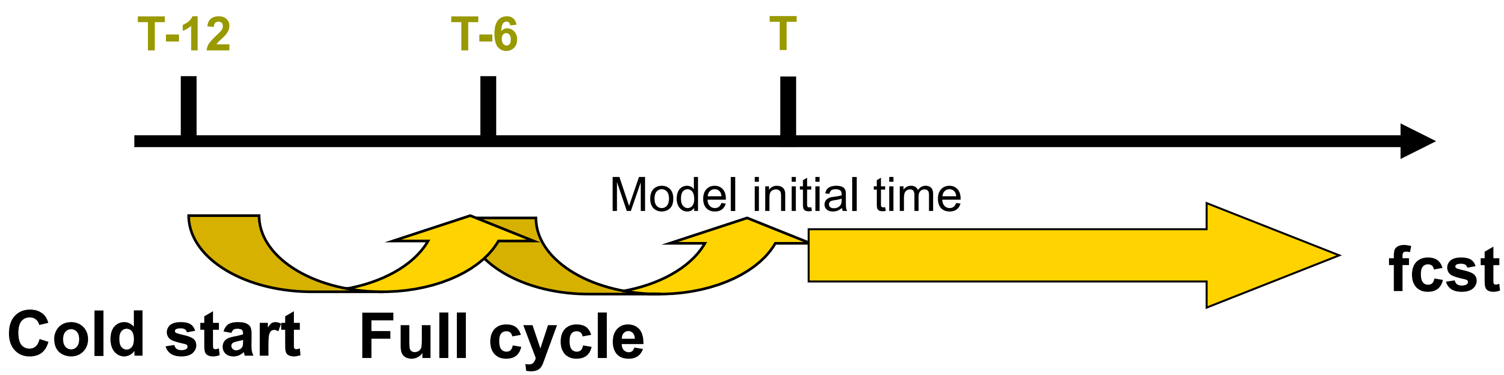
Important issues to improve the forecast performance

- To configure a robust DA system
- Assimilate the ZTD to improve model QPF
- Apply the GWDO parameterization to improve the wintertime forecast
- Remove the warm bias in KF scheme

Configure a robust DA system

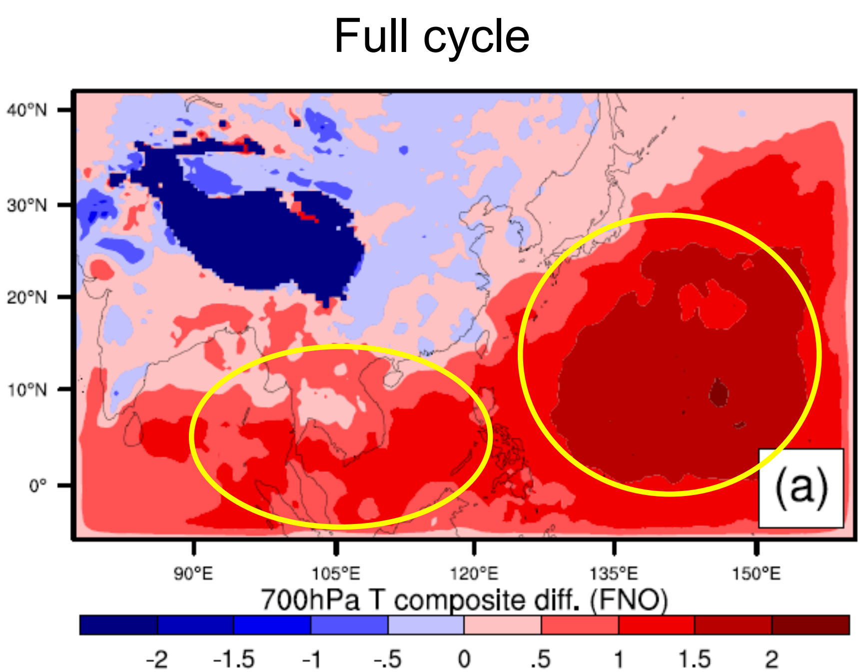
The DA strategy

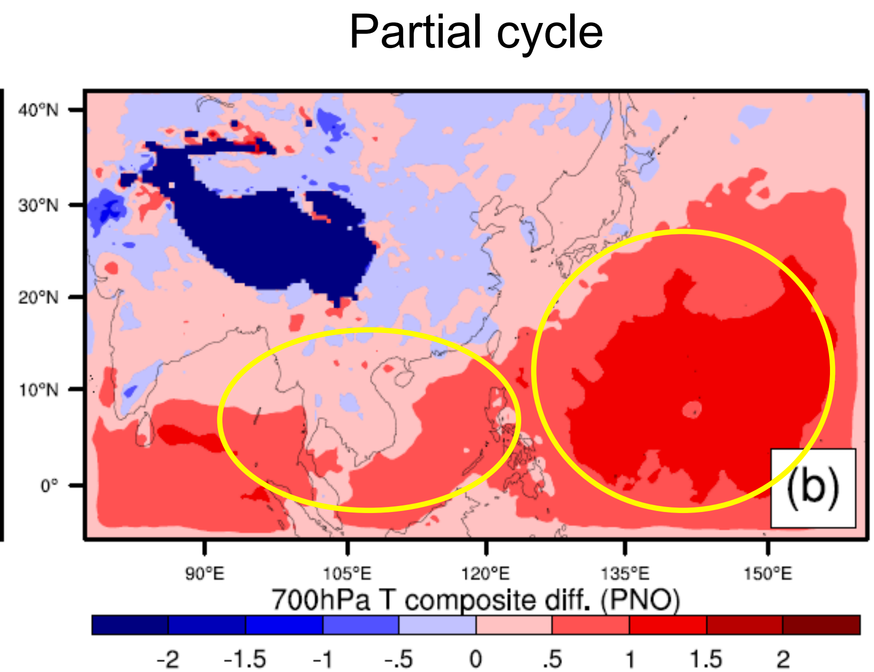
- Applying the partial cycle strategy
  - Cold start from NCEP GFS at the previous-12 hr, and cycling in every 6-hr interval



- Take the advantage from the GFS analysis to avoid the bias drift in the data void area.
- The 12-hr model forecast improve the spin-up problems from the cold-start initial condition.

Impact of the partial cycle strategy

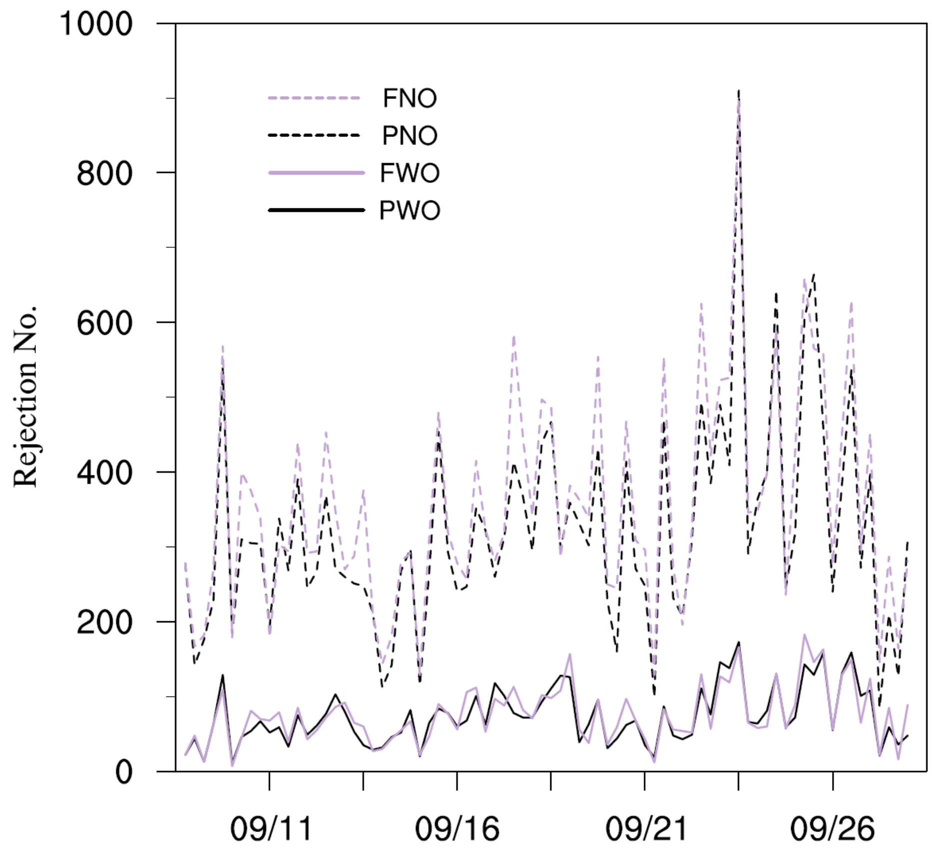




The mean error of the composite analysis of full cycle (left) and partial cycle (right) experiment from 78 cases for 700 hPa temperature

Full cycling accumulated systematic bias over data sparse area.

Impact of the outer-loop

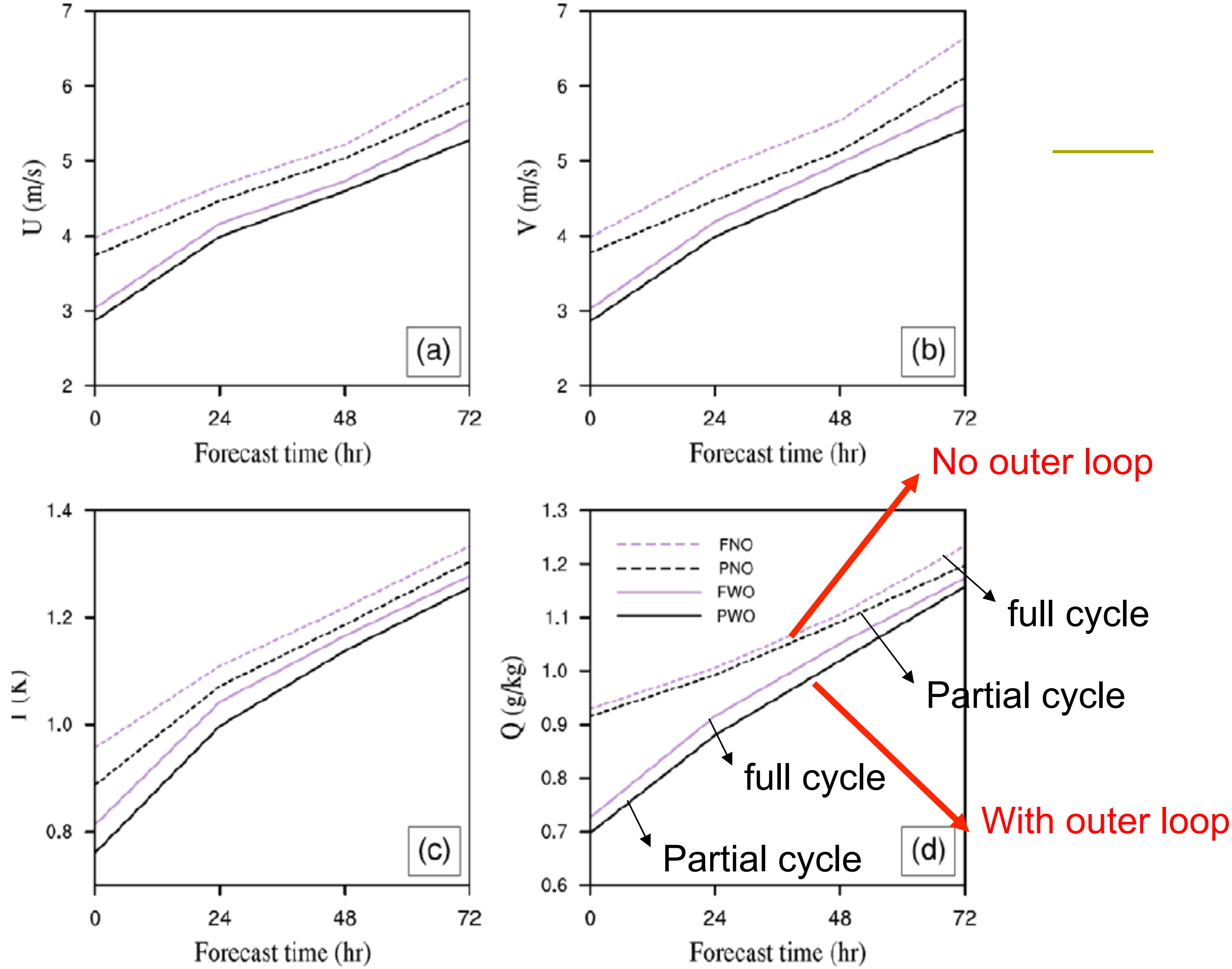


- To include the nonlinearities in the observation operators
- More use of the observations, in particular for GPSRO.
- Produce better model initial state.

Full cycling **without OL**
Partial cycling without OL

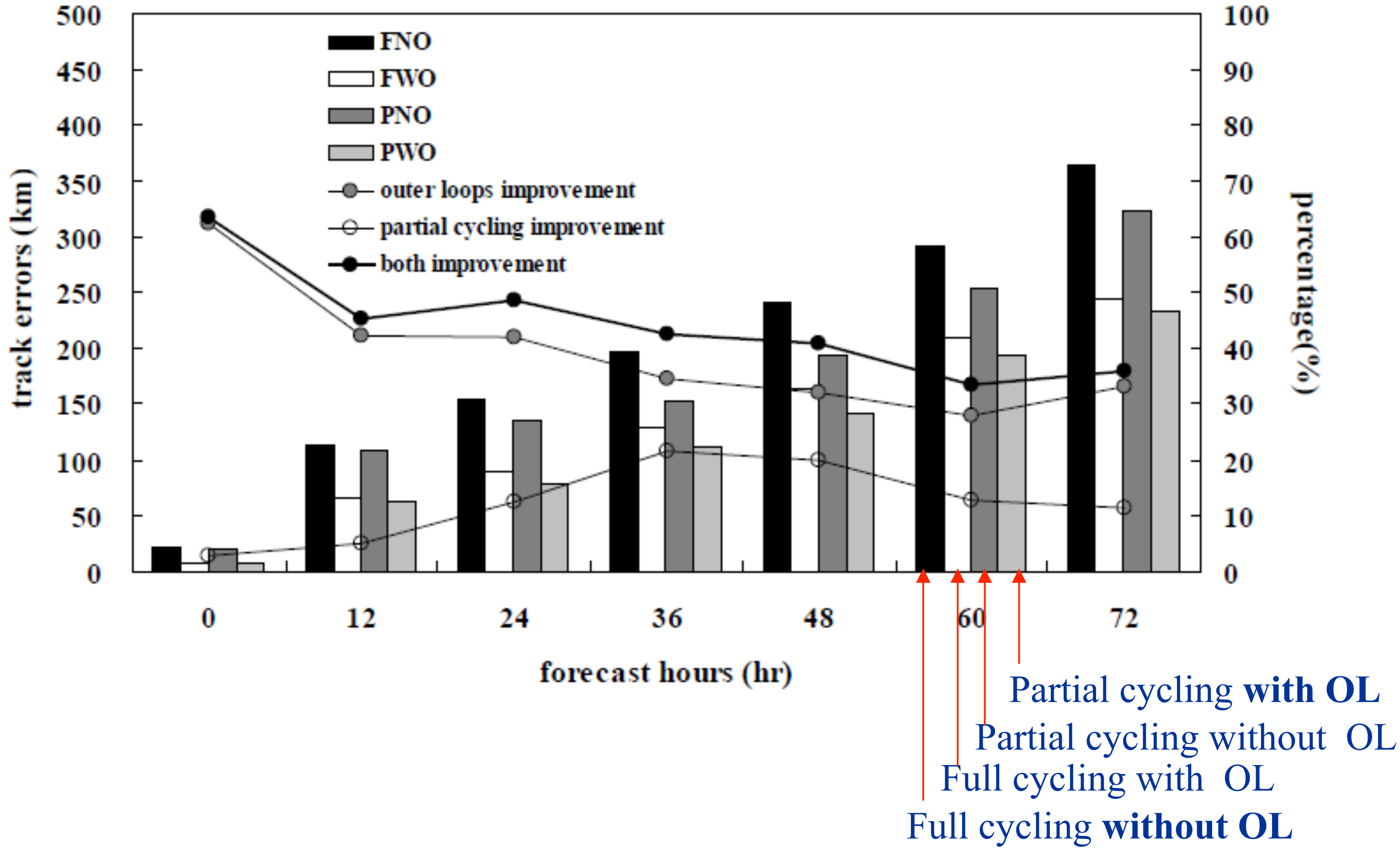
Full cycling with OL
Partial cycling **with OL**

More use of the observations (GPSRO)

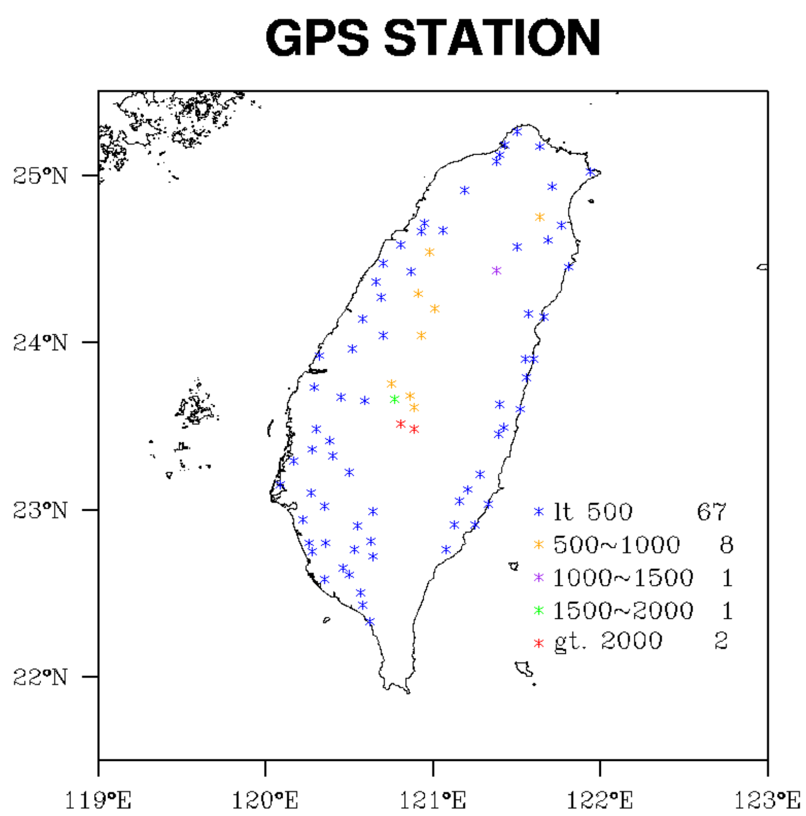


RMSE from 78 forecasts

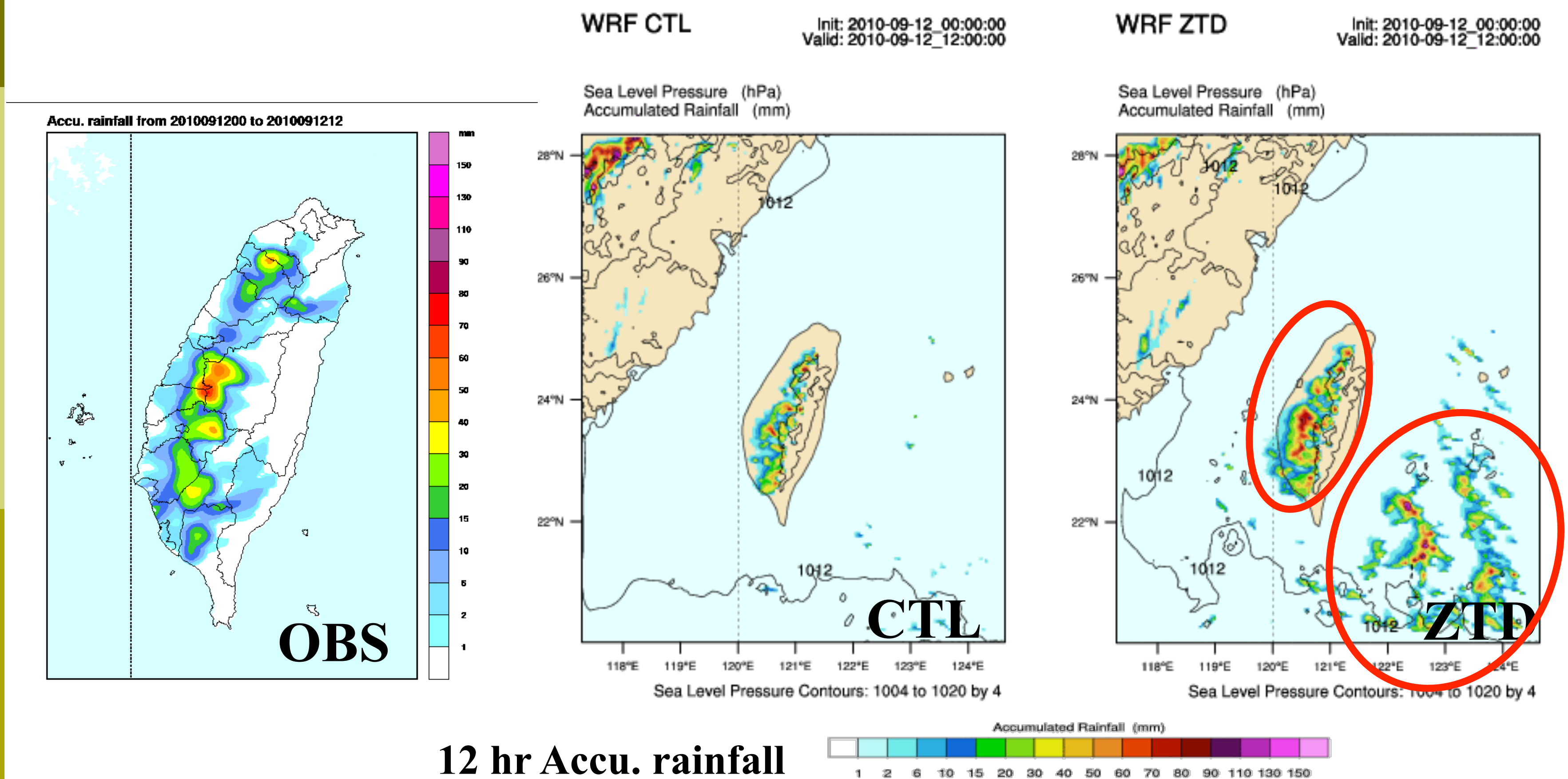
Mean typhoon track errors from 78 typhoon forecasts



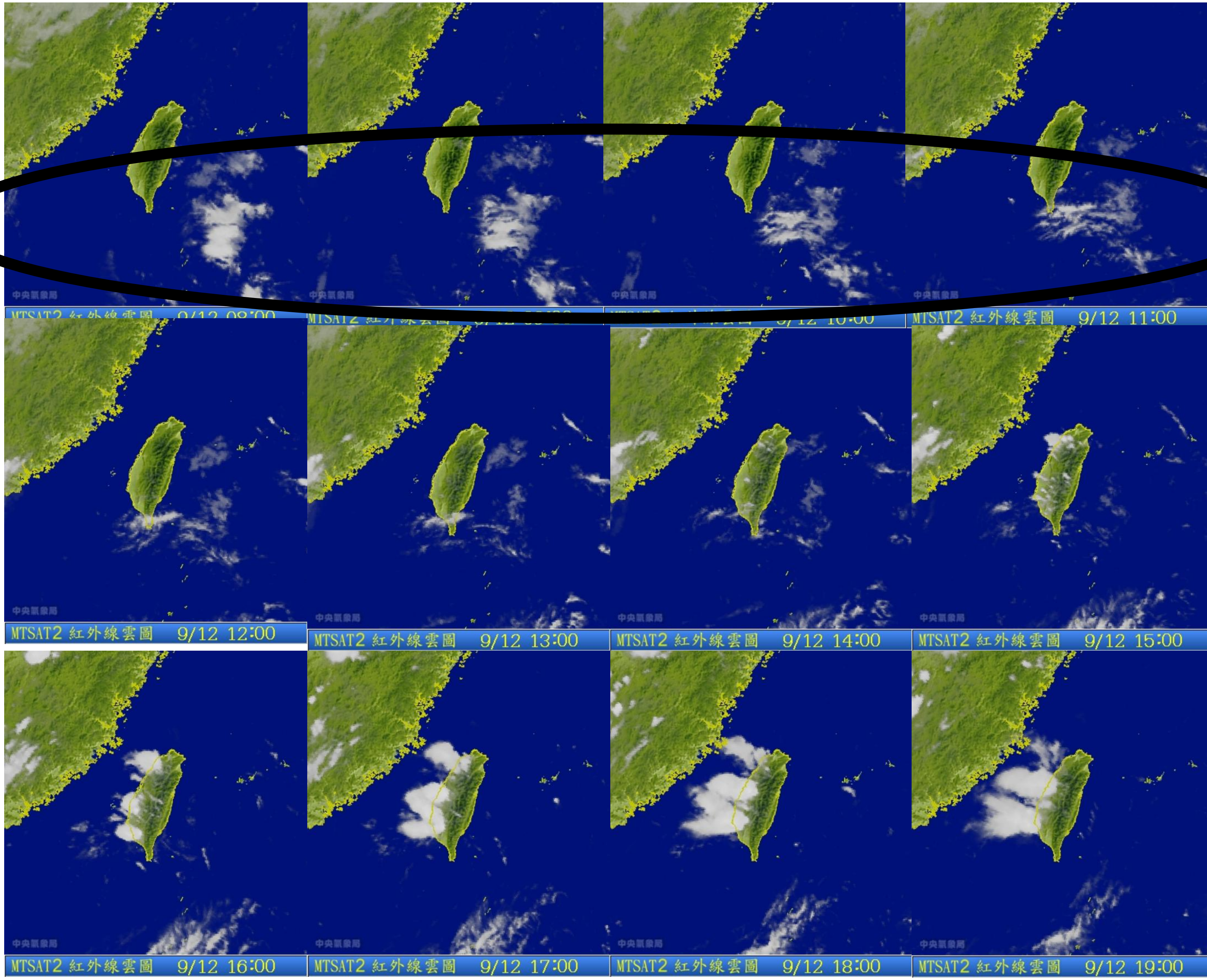
ZTD DA to improve QPF



Impact of assimilating GPS ZTD



12 hr Accu. rainfall


MTSAT2 紅外線雲圖 9/12 11:00
MTSAT2 紅外線雲圖 9/12 12:00
MTSAT2 紅外線雲圖 9/12 13:00
MTSAT2 紅外線雲圖 9/12 14:00
MTSAT2 紅外線雲圖 9/12 15:00
MTSAT2 紅外線雲圖 9/12 16:00
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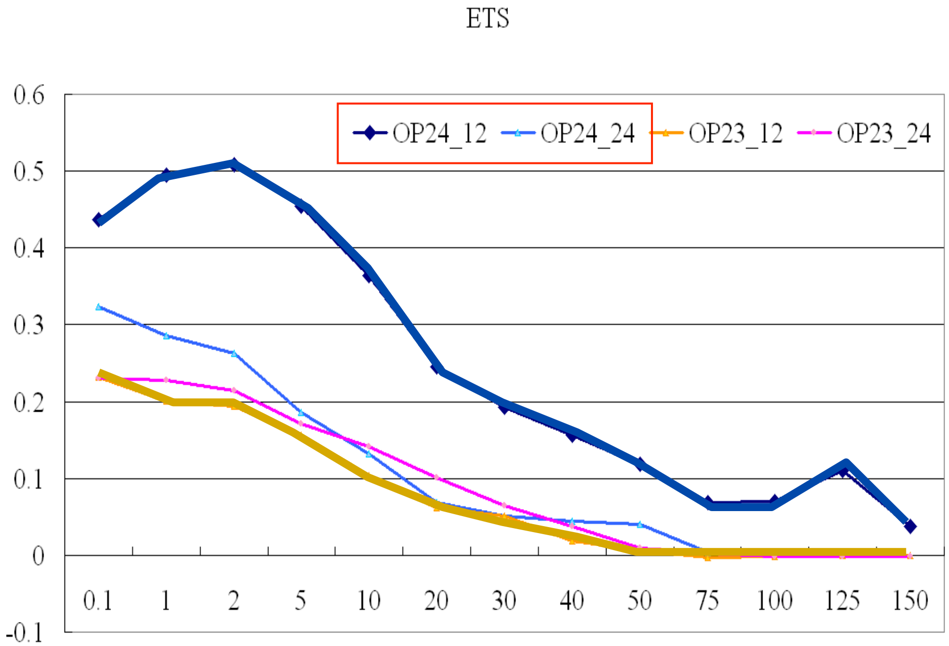
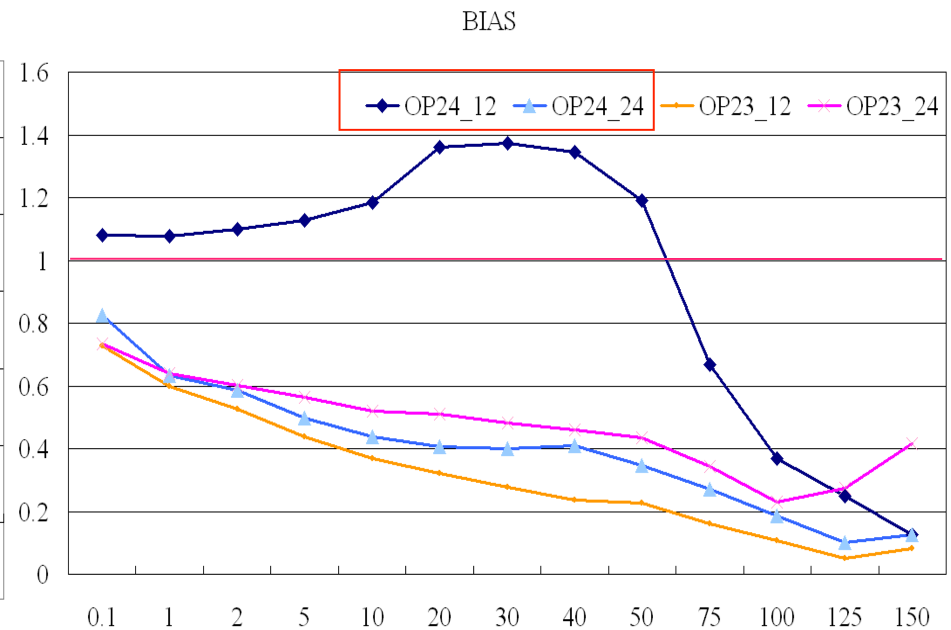
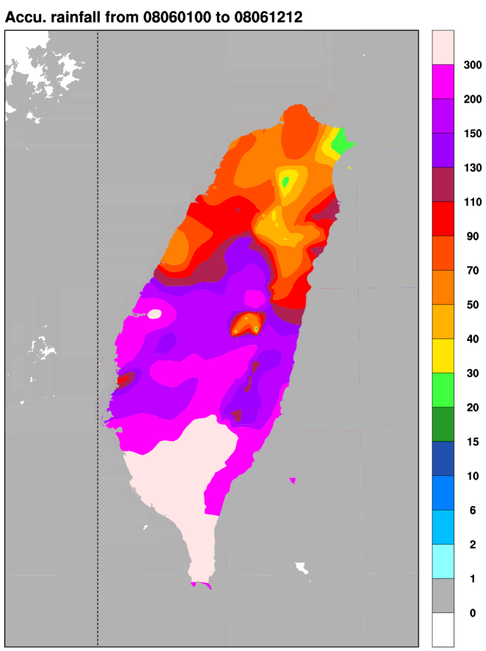
MTSAT2 紅外線雲圖 9/12 19:00

QPF verification: 2008060100~2008061512

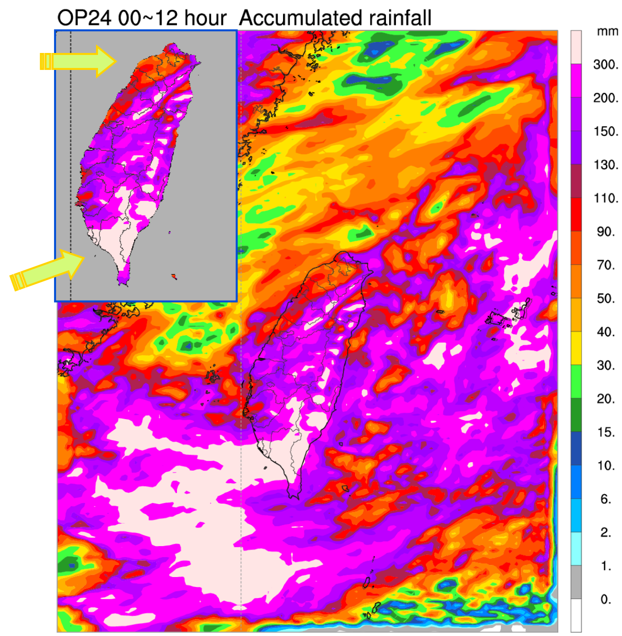




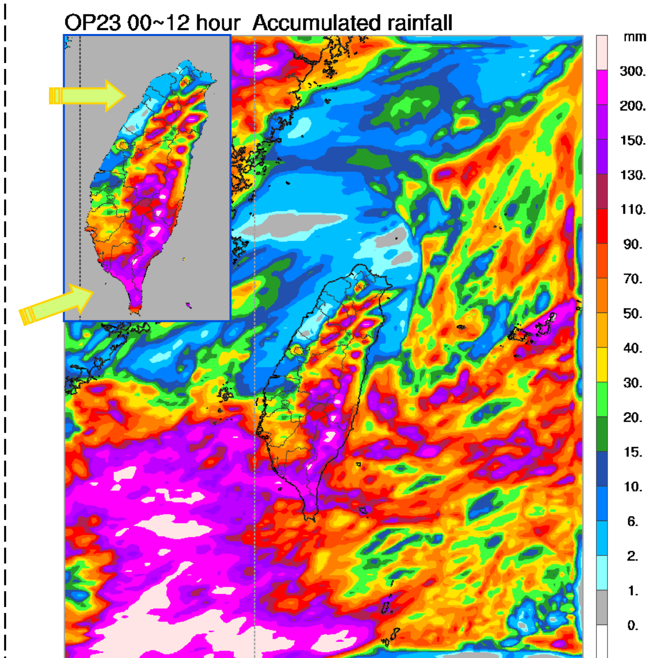
impact of assimilating ZTD during Meiyu season



OBS



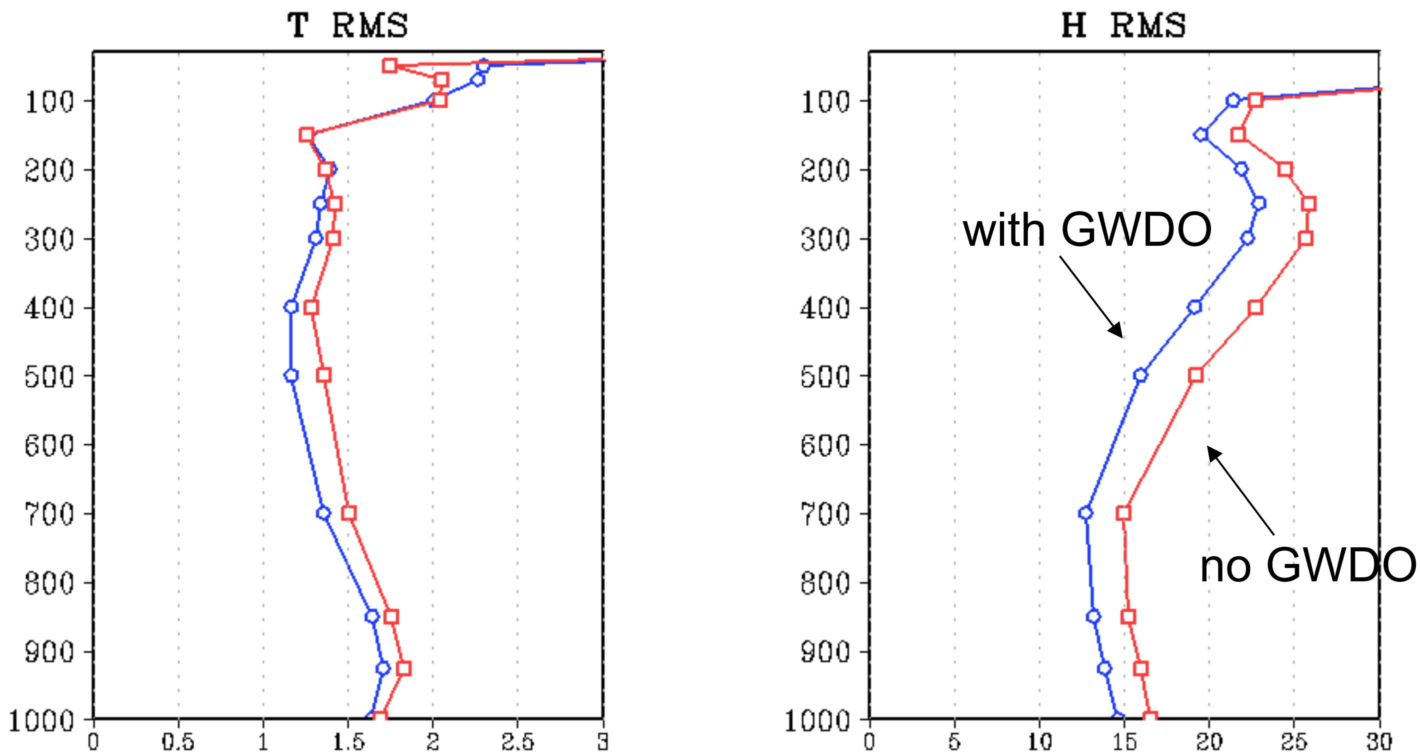
With ZTD



W/O ZTD

GWDO parameterization to improve the wintertime forecast

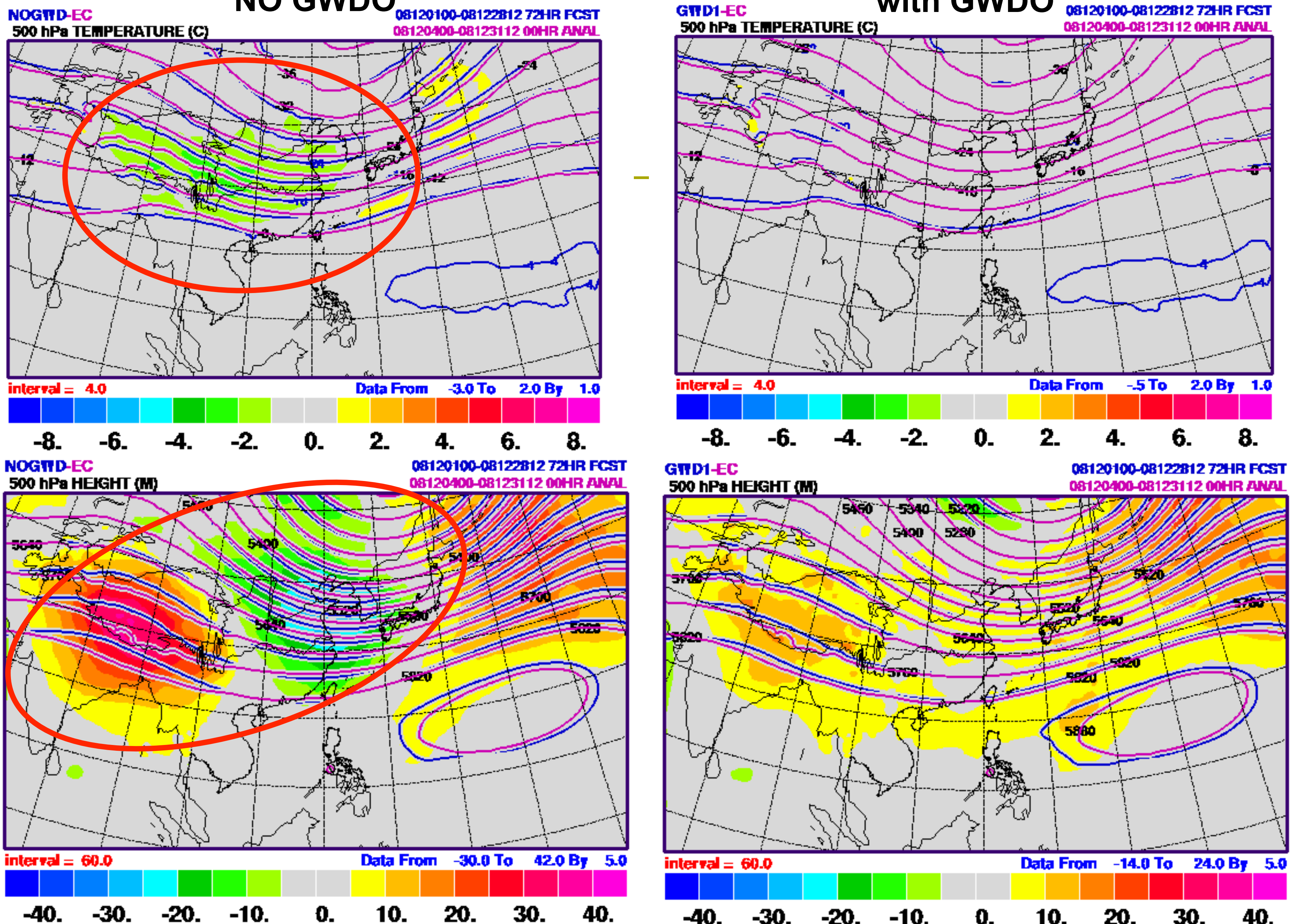
Impact of the GWDO parameterization



RMSE of 72-hr forecast T and H for December 2008

NO GWDO

with GWDO



New trigger function

The default KF trigger function that the temperature anomalies are correlated with vertical velocity only, i.e. related the KF temperature perturbation, [illegible]T, to moisture advection.

The default KF trigger has undesirable characteristics especially in weakly-forced situations as those found in the tropics.

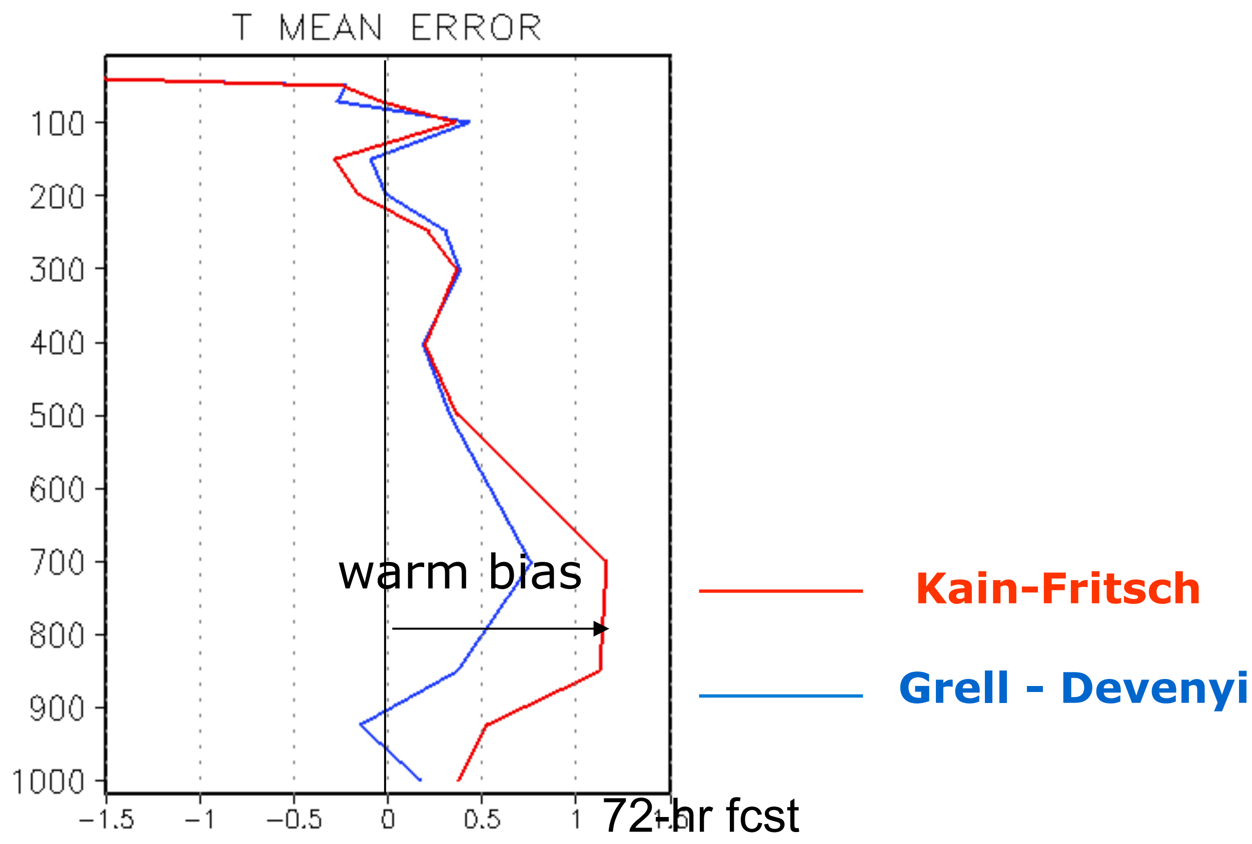
Ma and Tan (2009) proposed a new KF trigger which they tested in MM5.

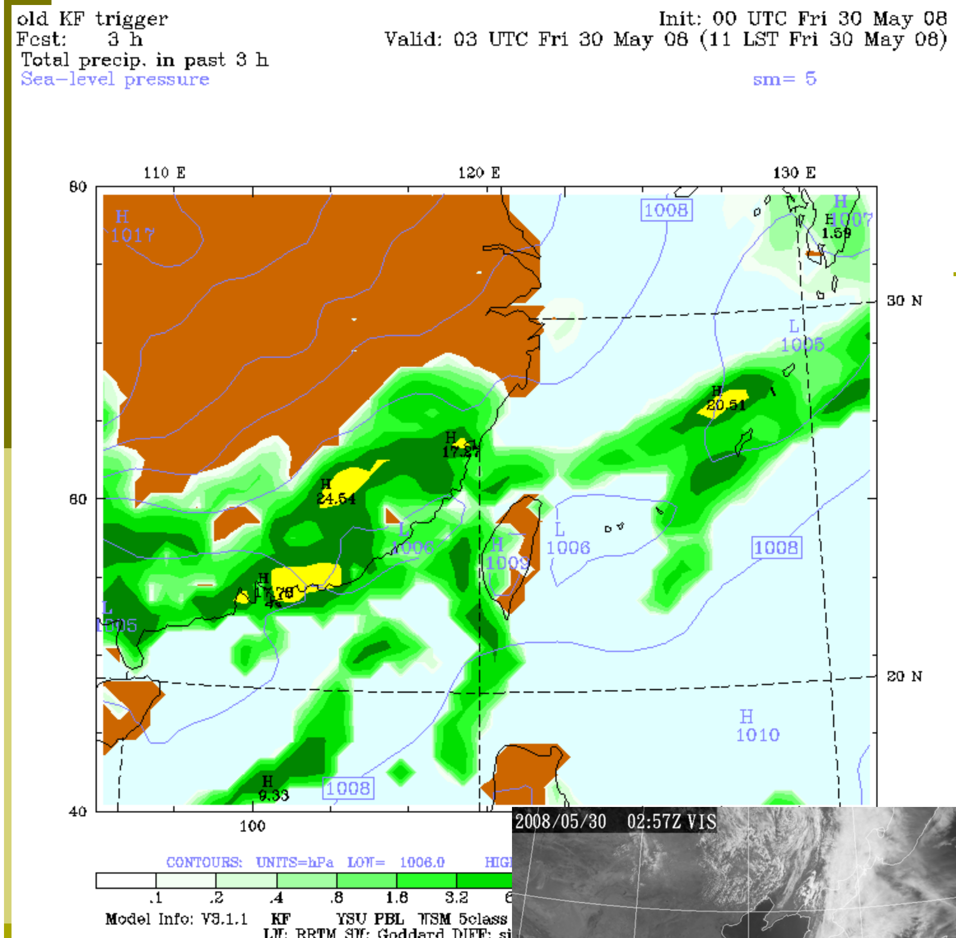
$$\delta T_{vv} = R_h \delta T_{vvh} + R_v \delta T_{vvv}$$

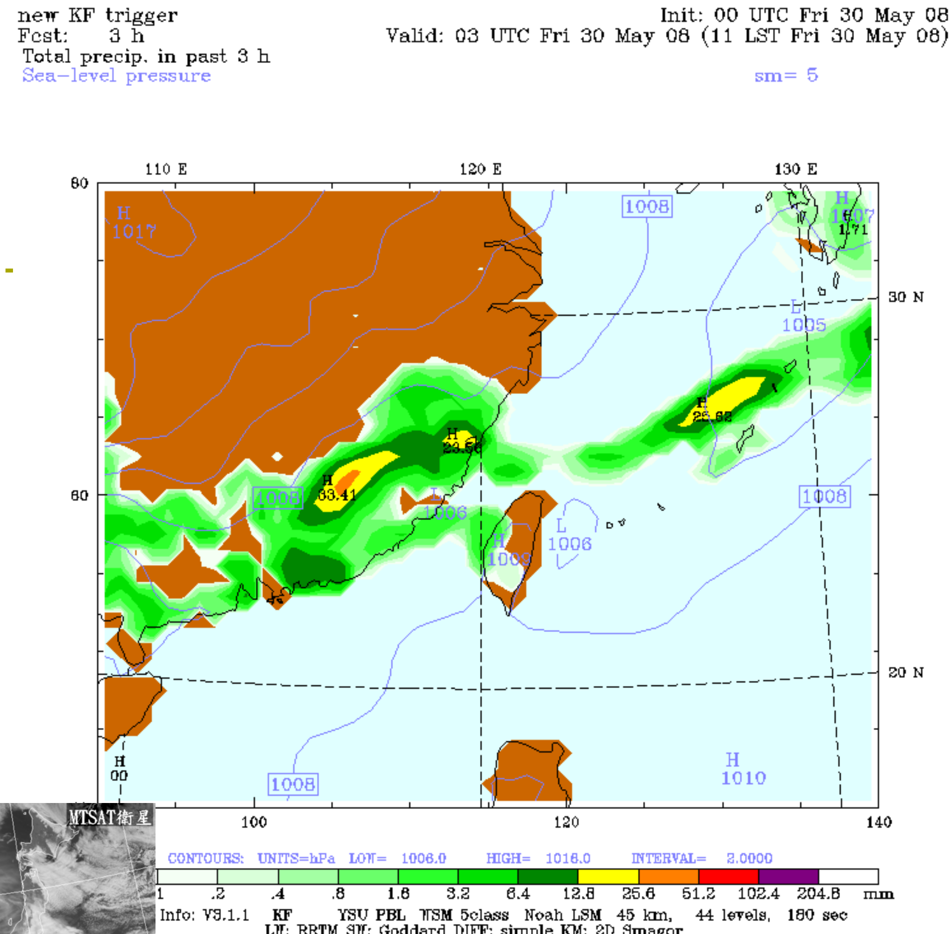
Where
δT_{vv}= temperature perturbation (DTLCL),
R_h = normalized horizontal moisture advection,
δT_{vvh} = horizontal temperature anomaly from the surrounding 9 grid points,
R_v = normalized vertical moisture advection, and
δT_{vvv} = vertical temperature anomaly from the adjacent 3 levels.

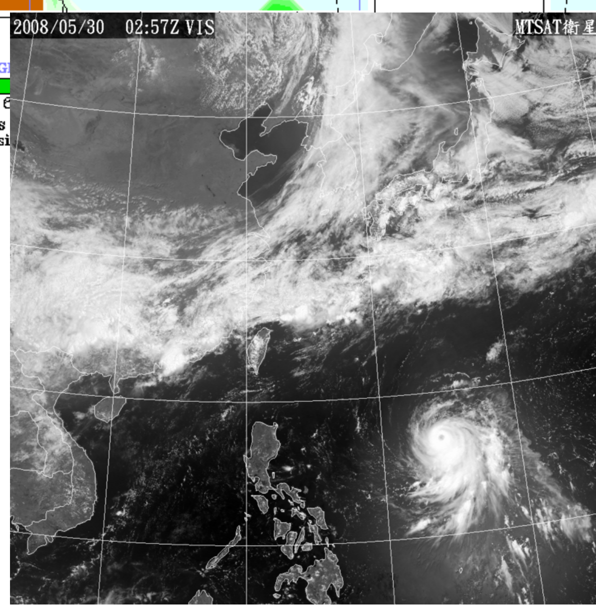
The convection was easier to be triggered as the RH>75%.

Warm bias in KF





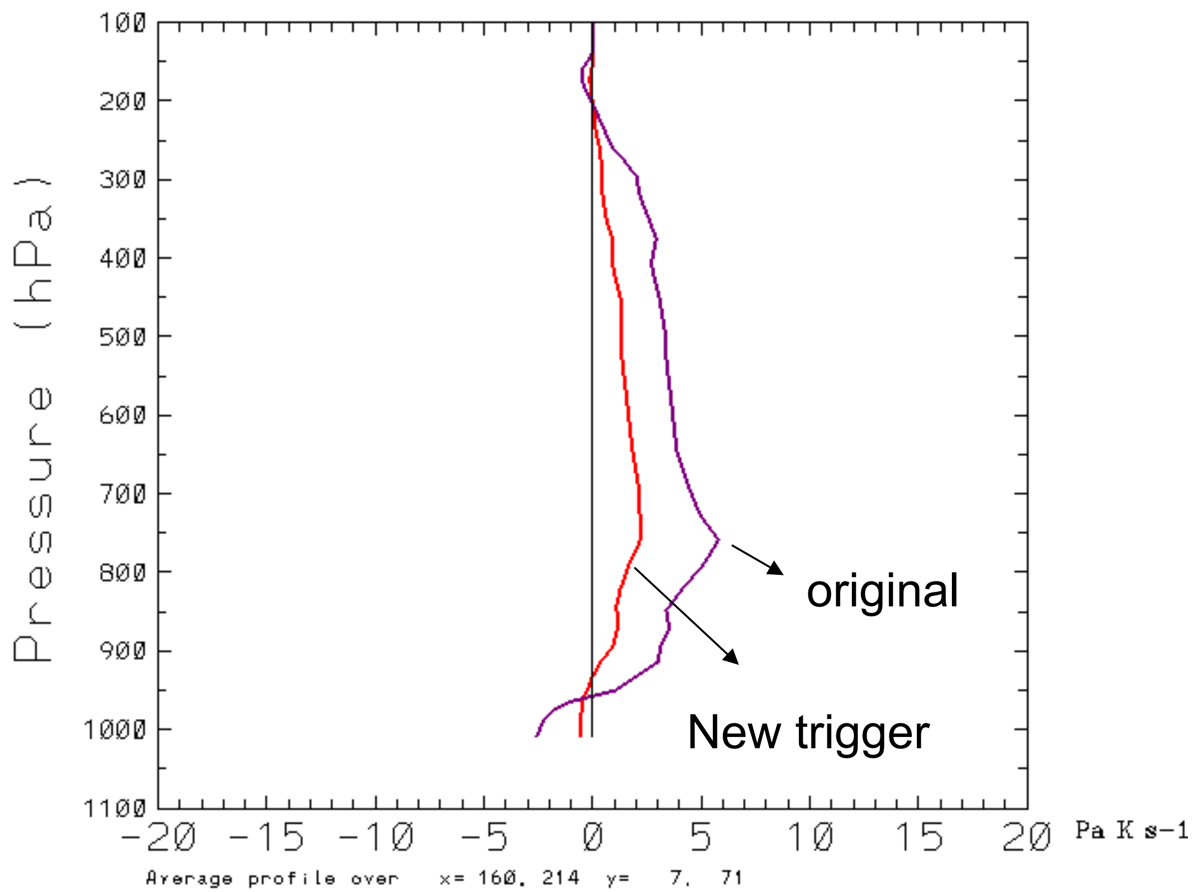




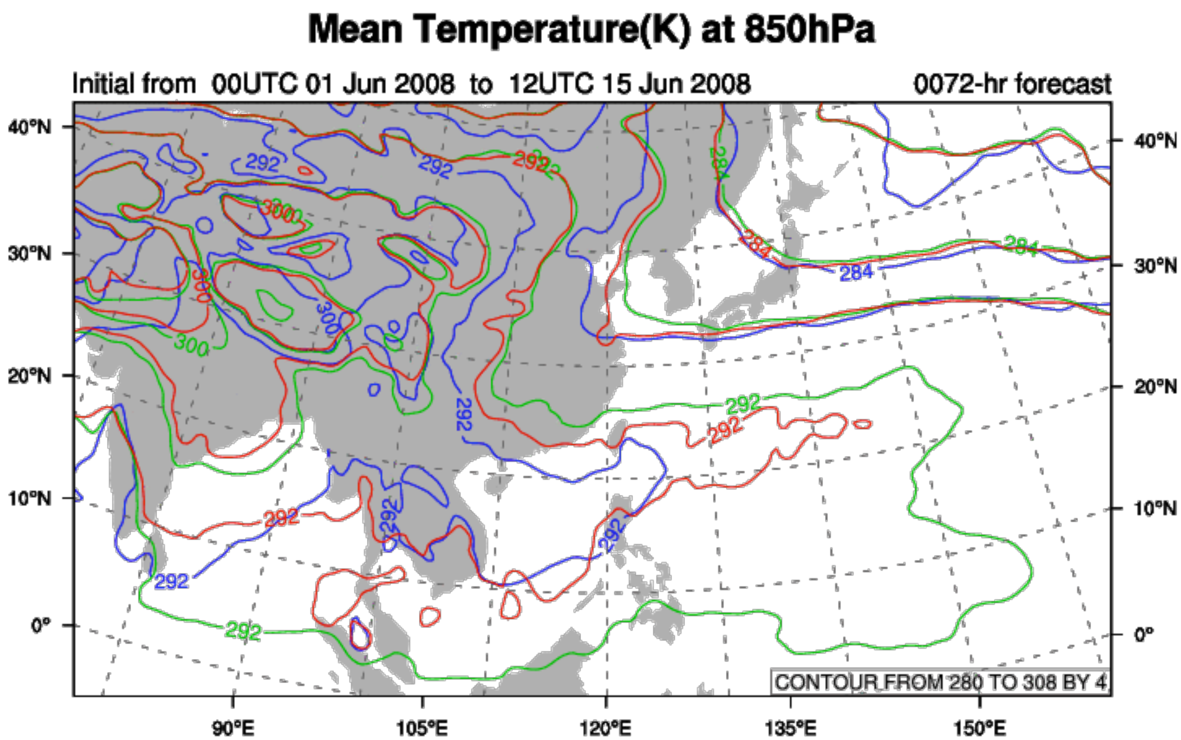
w trigger function, Ma and Tan (2009)

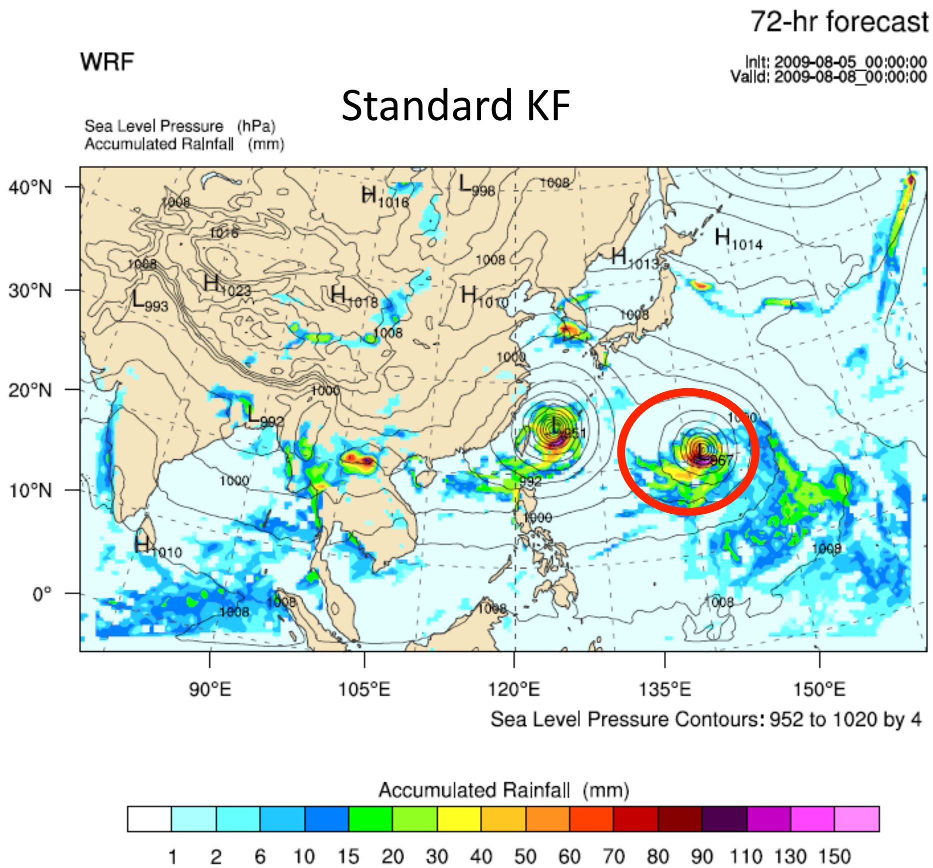
Reducing areas of light rainfall without altering location of stronger systems.

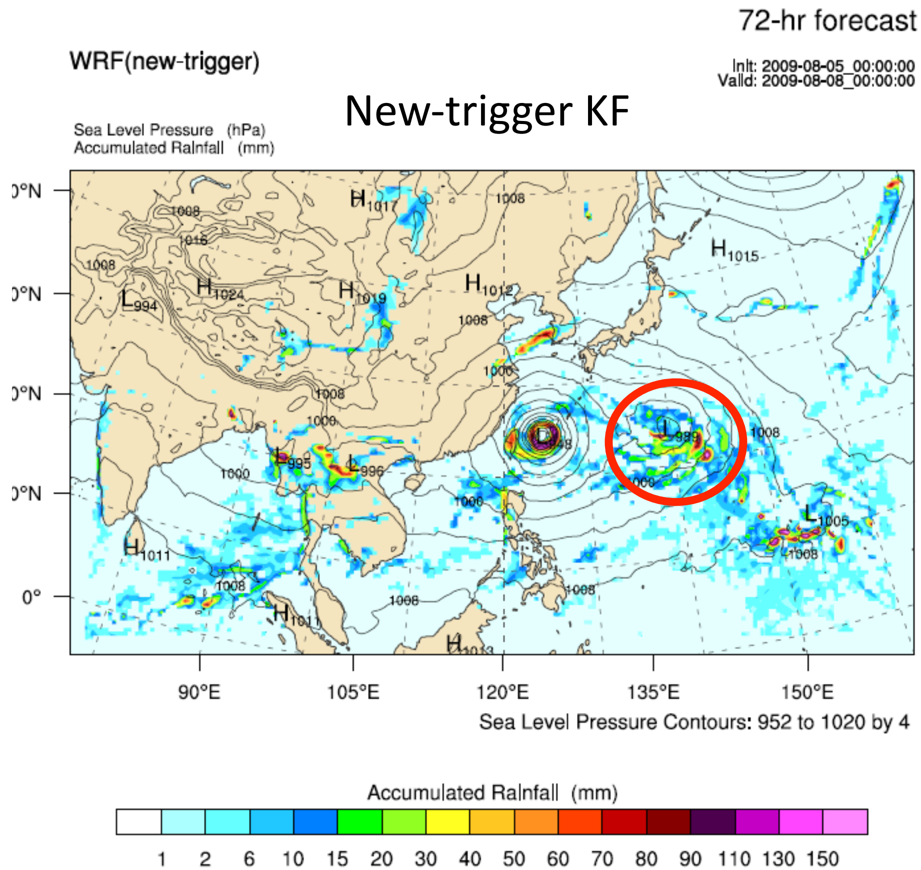
Heating rate from KF



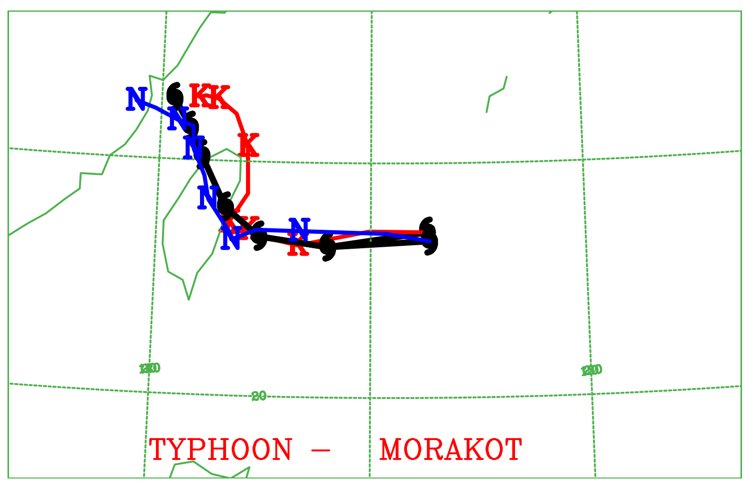
ECMWF analysis, K-F, K-F with new trigger function







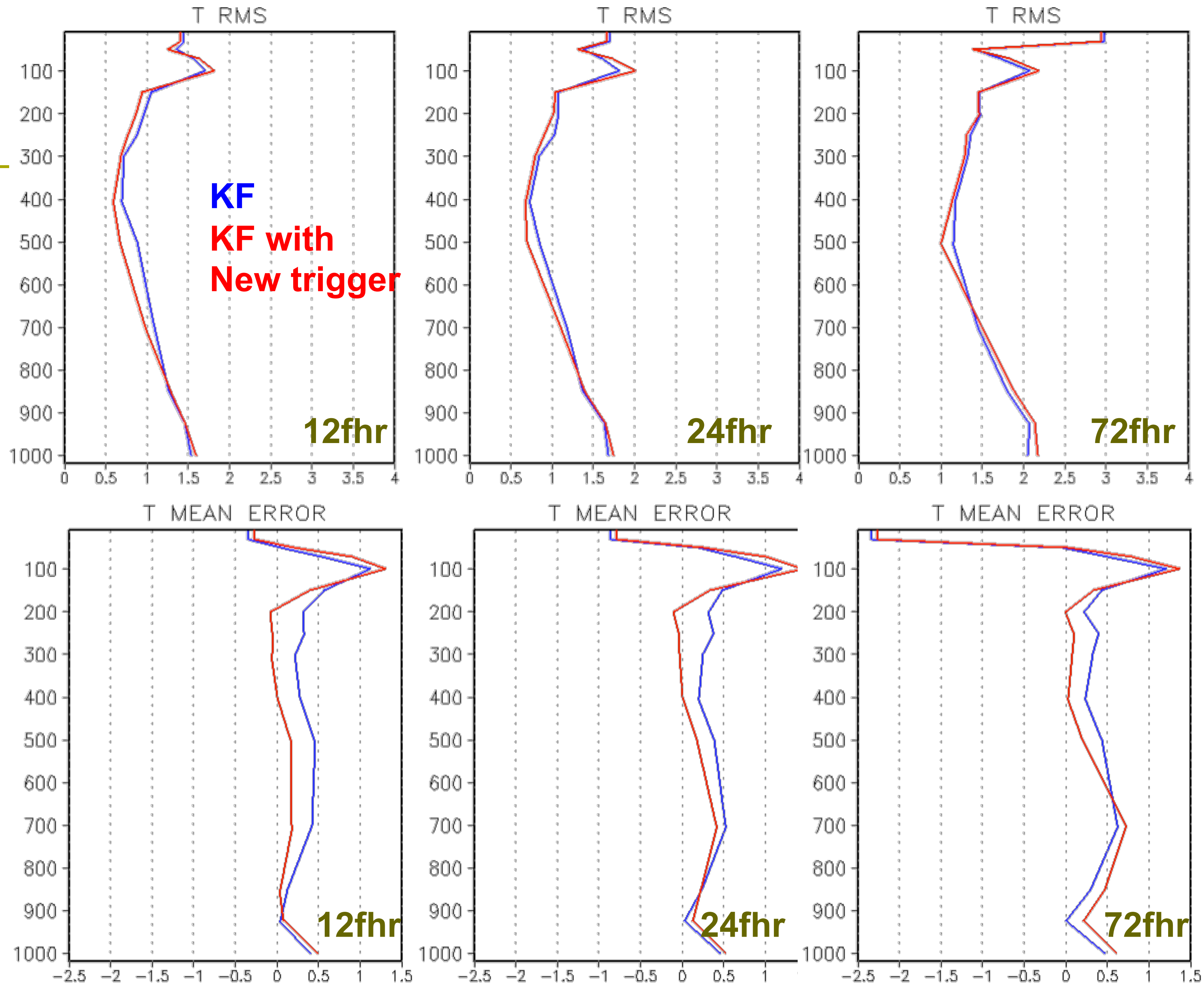
OUTPUT FROM WRF V3.1.1 MODEL
WE = 222 ; SN = 128 ; Levels = 45 ; Dis = 45km ; Phys Opt = 7 ; PBl

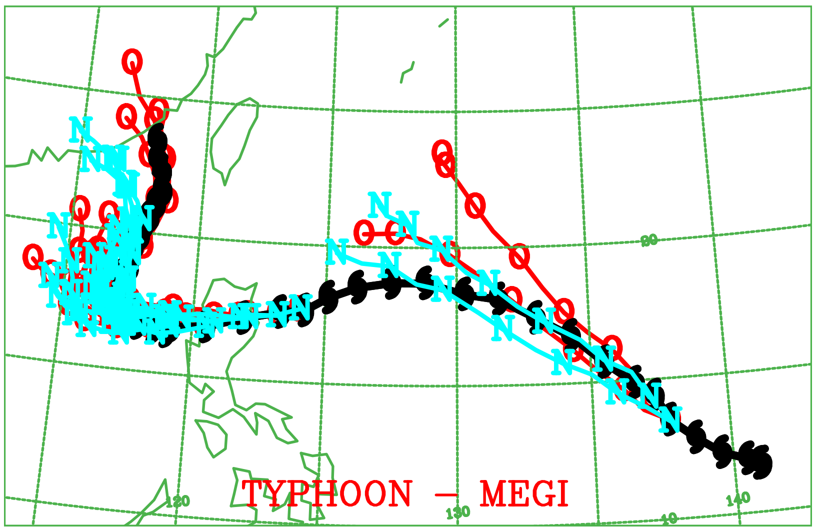


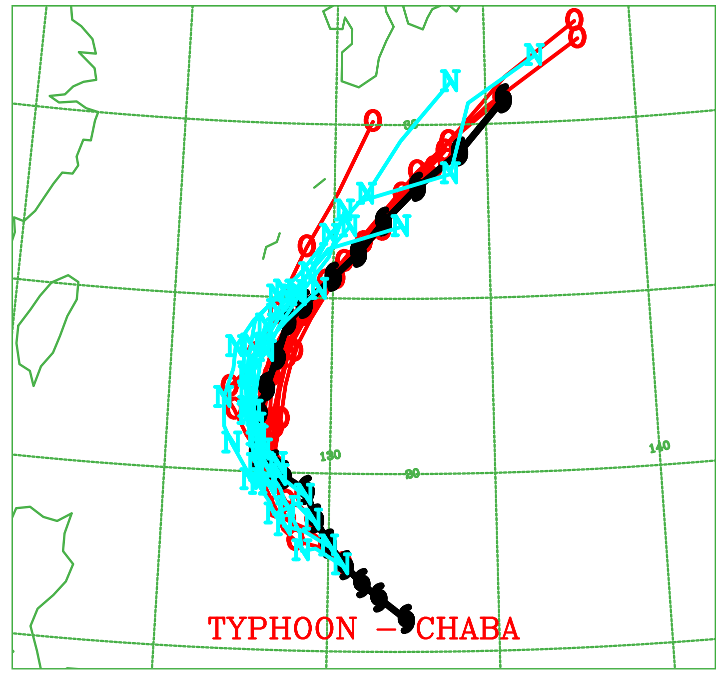
Phys Opt = 7 ; PBL Opt = 1 ; Cu Opt = 1

RMSE

Mean Error

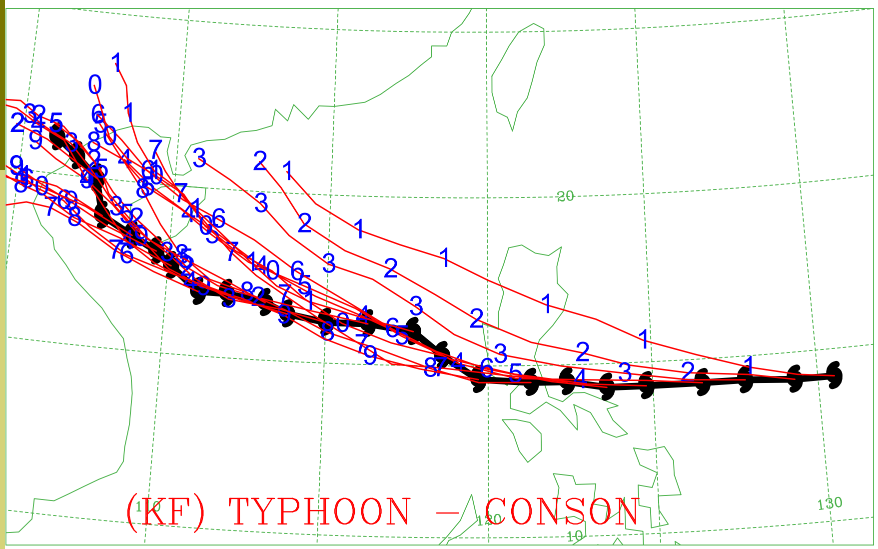


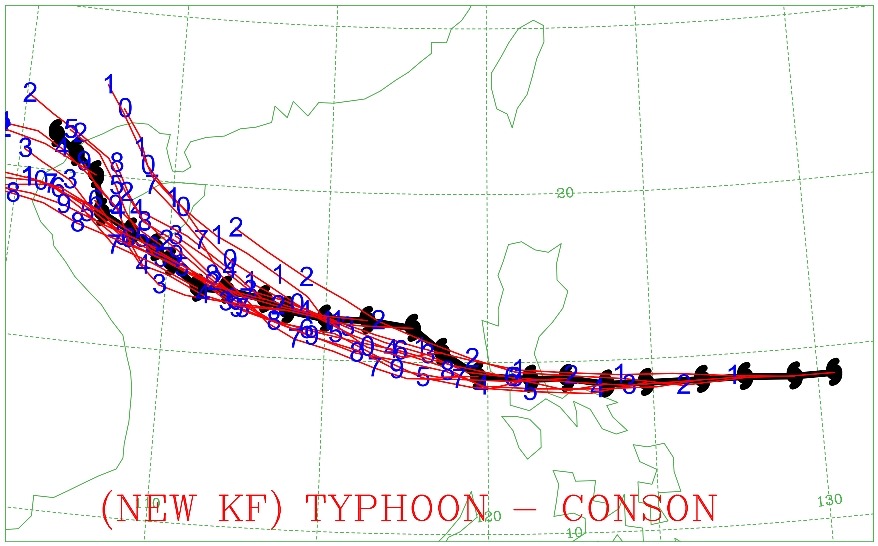




	24 hr	48 hr	72 hr
TWRF_KF	86 km	305 km	655 km
TWRF_KFN	75 km	158 km	427 km

	24 hr	48 hr	72 hr
TWRF_KF	87 km	140 km	496 km
TWRF_KFN	82 km	122 km	172 km





TWRF	0hr	12hr	24hr	36hr	48hr	60hr	72hr
KF scheme (km)	8	124	193	256	306	374	444
new KF scheme(km)	10	103	152	186	189	225	284

Summary

- Continuous improvement on the forecast skill year after year in CWB WRF
  - Related to many efforts in the aspects of model process and data assimilation
  - To demonstrate a successful migration of the data assimilation system from the community to operation
    - Close cooperation between CWB and NCAR scientist