Application of Mean Recentering Scheme to Improve the Typhoon Track Forecast: A Case Study of Typhoon Nanmadol (2011)

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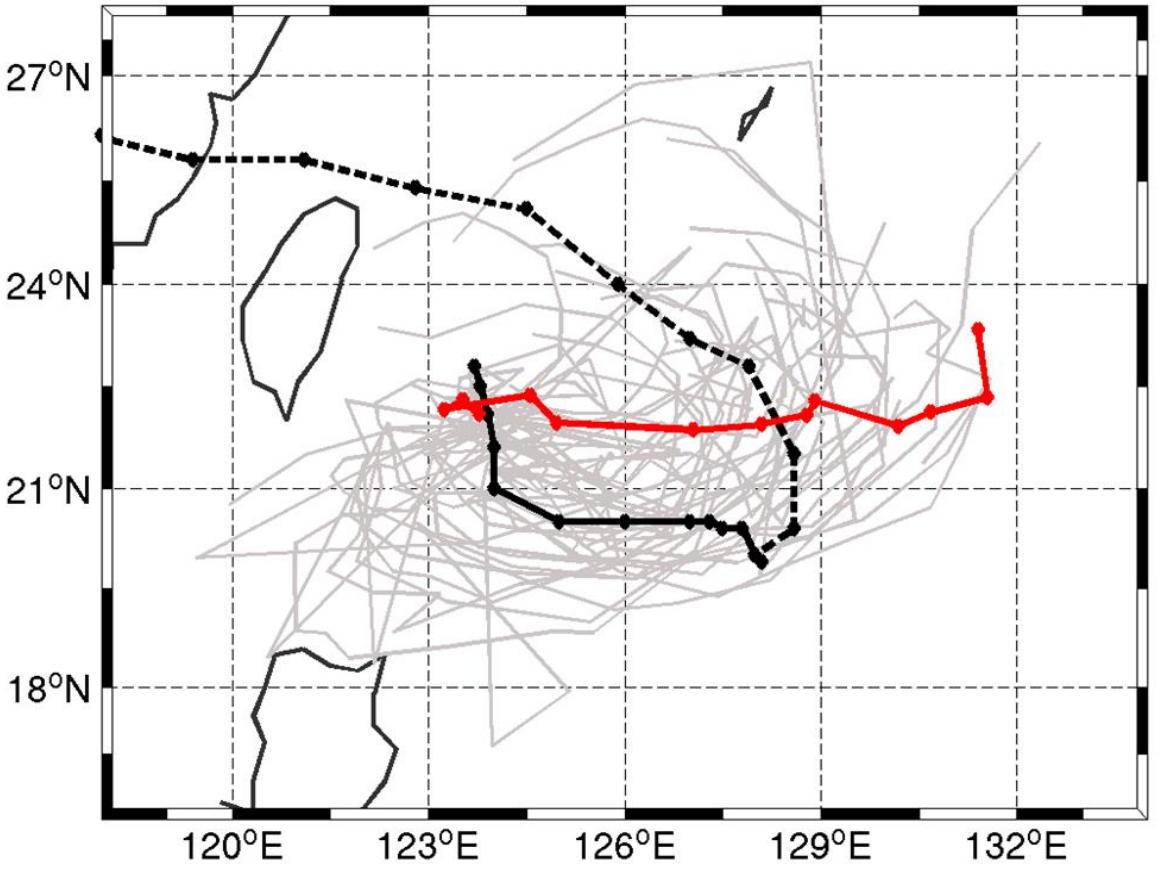
Ensemble forecast for Trami (2013)

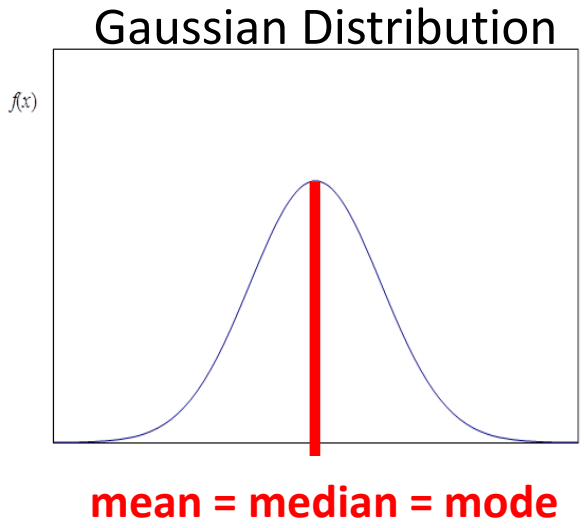
- Cold-started ensemble prediction system(EPS) with 36 members.
- I.C. comes from WRF-based EPS

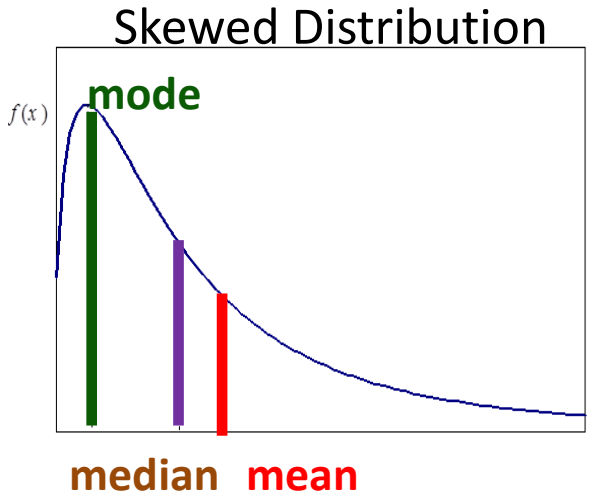
Ensemble forecast initialized at 00z 16 Aug.



Introduction

- If the ensemble is normally distributed, the mean state is the most likely state and can be used as the optimal estimation of the realistic state.
- However, if the ensemble violates the Gaussian distribution, the mean state is not representative for the best estimate.





Introduction

- With a poor ensemble, the ensemble mean cannot well represent the behavior of the realistic state, BUT it is possible that some ensemble members can.

- The purpose of mean recentering scheme (MRC) is to use those members to 'recenter' the ensemble and aims to improve the nonlinear evolution of ensemble.

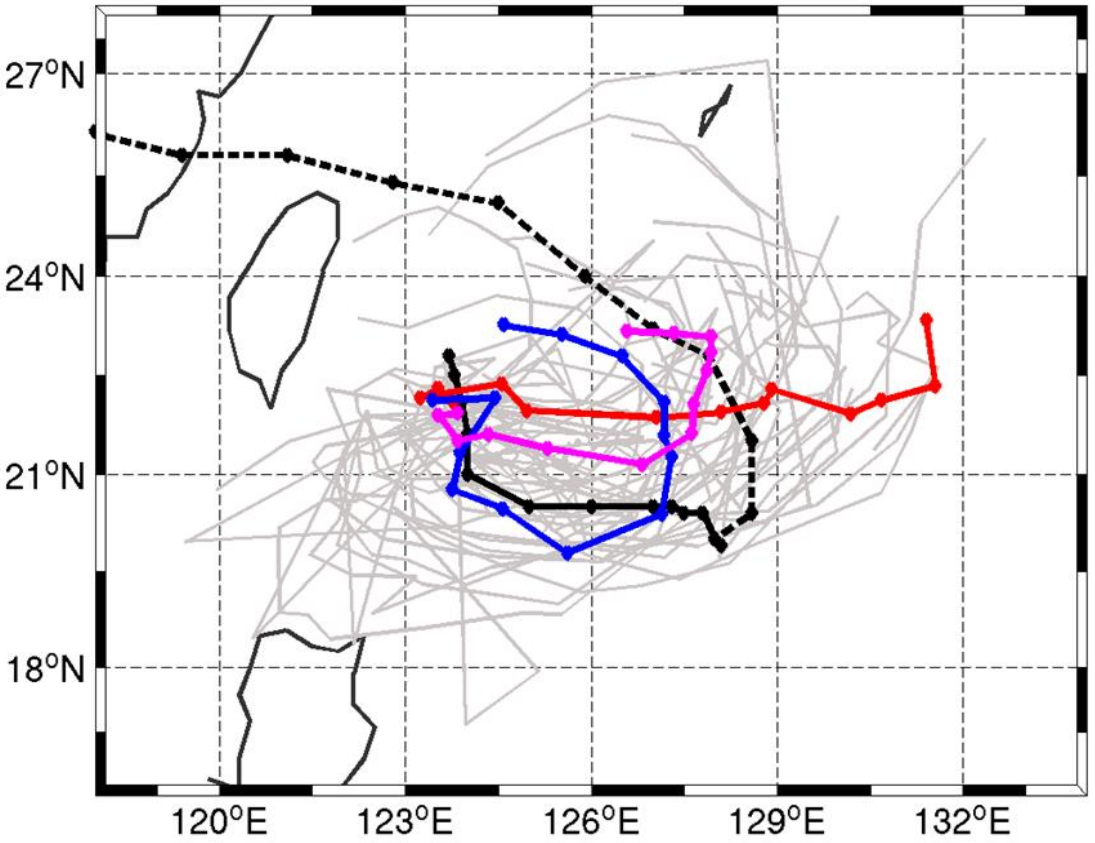
- MRC method is inspired by the ensemble recentering Kalman filter (ERKF) proposed by Keppenne (2013).

Mean Recentering Scheme (MRC)

CWB best track
Ensemble mean
Best member
Ensemble mean with MRC

$$\mathbf{X'_j} = \mathbf{X_j} - \bar{\mathbf{x}},$$
$$\mathbf{X_{new}} = \mathbf{X'_j} + \mathbf{X_{best}}$$

Ensemble forecast initialized at 00z 16 Aug.



Best member selection is based on the accumulated track error

Typhoon Nanmadol (2011)

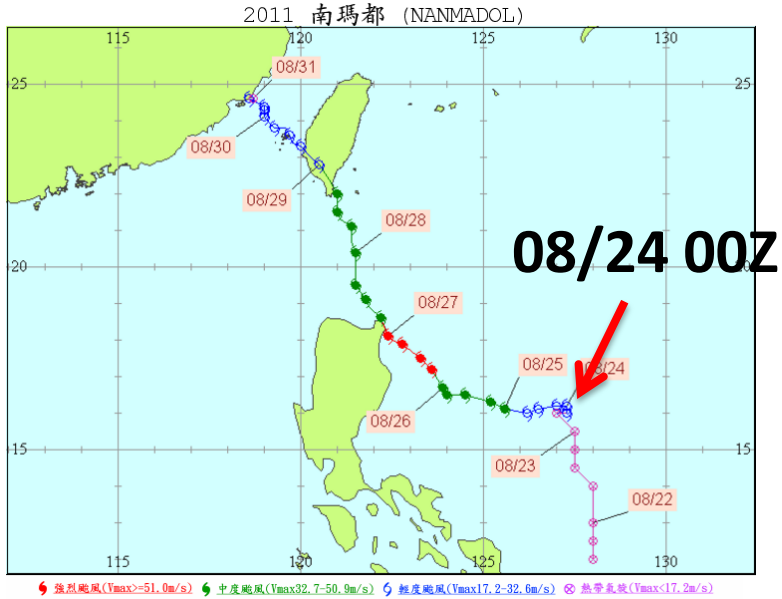
EC global ensemble forecast from TIGGE (THORPEX Interactive Grand Global Ensemble)

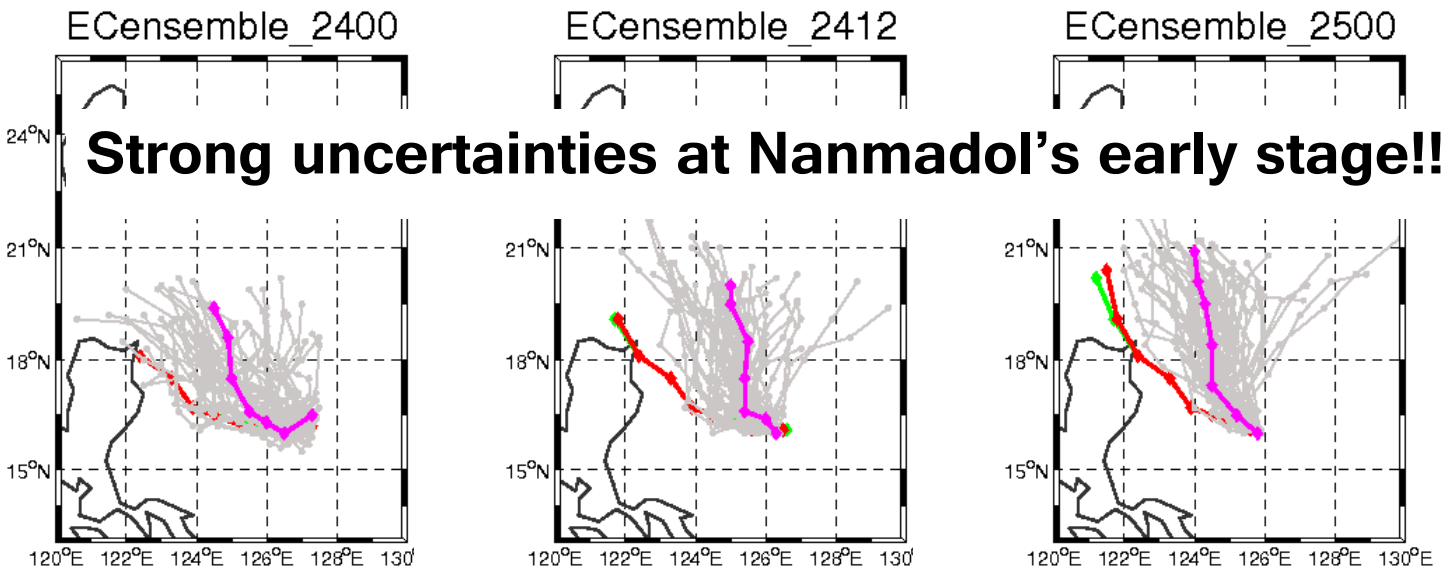
-- Members (51)

-- Mean forecast

-- Analysis

-- CWB best track





Experimental setting

Model Setup :

WRF model v3.2.1 is used in this study and the simulation domain is 171*141*27 with 27 km resolution.

Experiment design:

A) **Ensemble Prediction System (cold-started EPS)** with MRC

- Ensemble: NCEP-AVN analysis + random perturbations (36 members)
- No feedback to next prediction

B) **Ensemble Data Assimilation System (warm-started EPS)** with MRC

- Data assimilation system: **WRF-LETKF** (Yang et al. 2014)
- Feedback to next prediction

Cold-started EPS

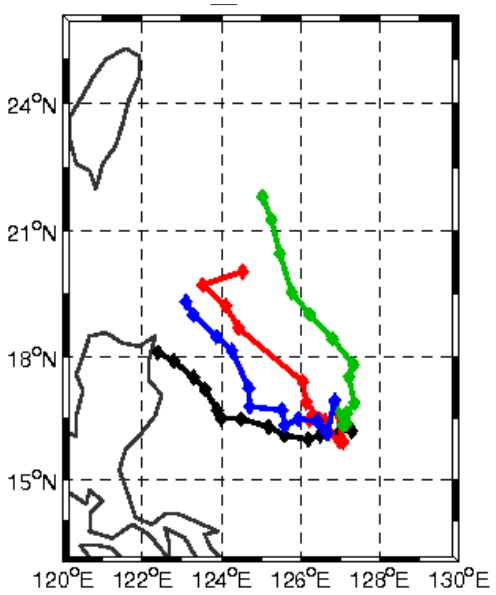
CWB best track

CNT: the control run (standard cold-started EPS)

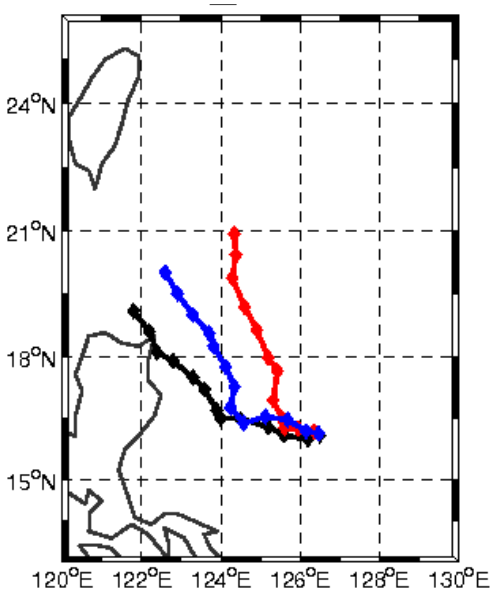
MRC_12 : Use **12hr** accumulated track error to select best member

MRC_24: Use **24hr** accumulated track error to select best member.

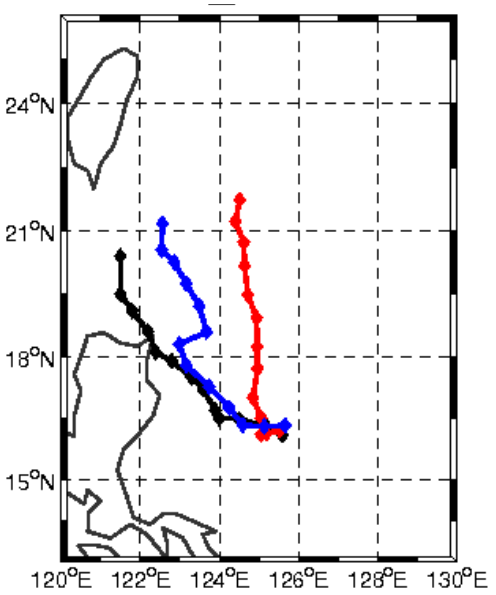
Initialized at 00Z 24 Aug.



Initialized at 12Z 24 Aug.

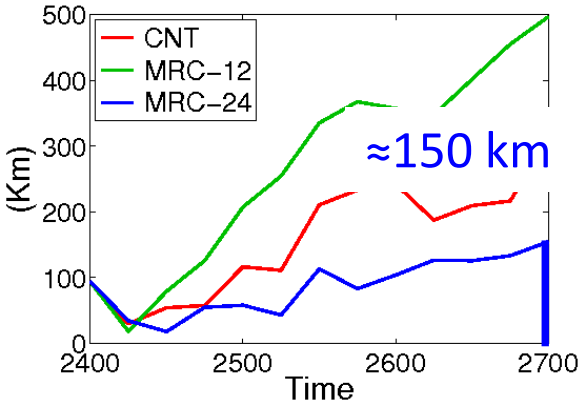


Initialized at 00Z 25 Aug.

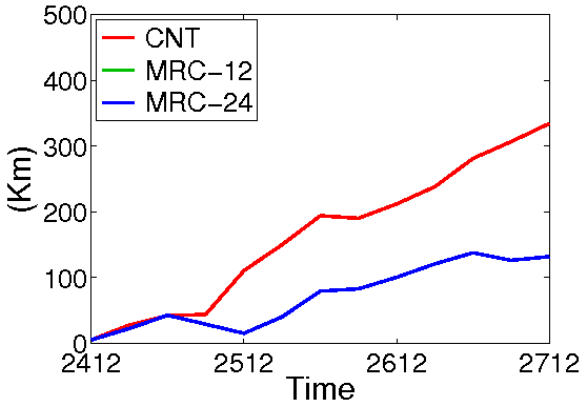


Track error of cold-started EPS

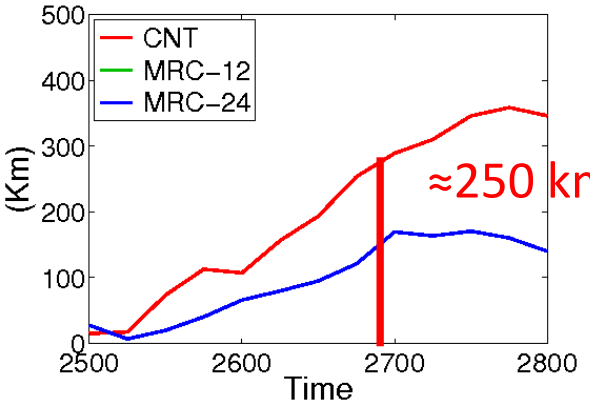
Track error at 00Z 24 Aug.



Track error at 12Z 24 Aug.



Track error at 00Z 25 Aug.



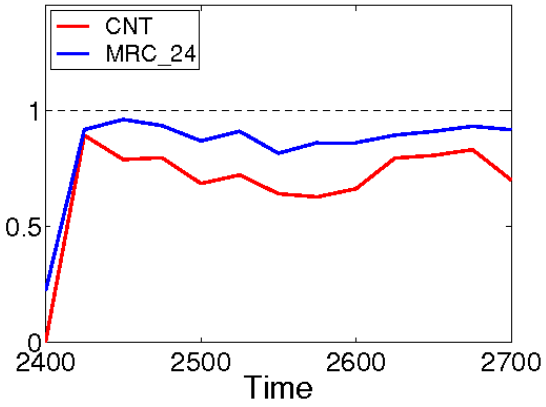
Proper adjustment on ensemble can significantly improve the forecast skill

- It is excepted that MRC_24 outperforms CNT since it contains next 24-h future information.
- However, comparing MRC_24 initialized at 00Z 24 and CNT initialized at 00Z 25, MRC shows better forecast skill than CNT when the observation information is comparable.

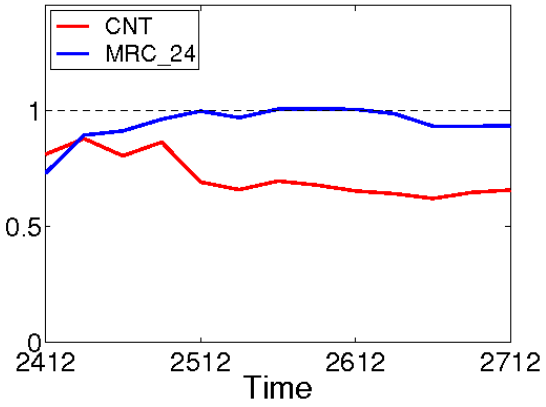
Ensemble spread of cold-started EPS

- For an ideal EPS, the spread of the ensemble can well present the state uncertainty and the ratio of spread (SPRD) and root mean square error (RMSE) is close to one.

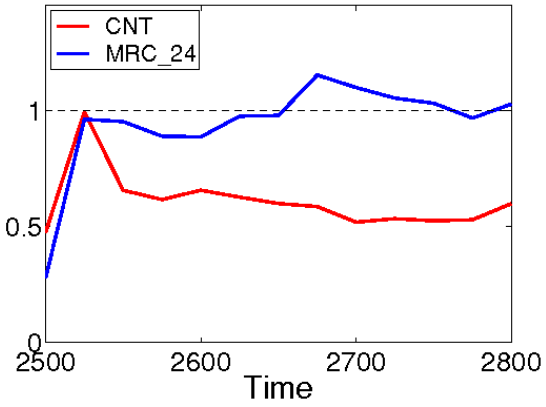
Ratio at 00Z 24 Aug.



Ratio at 12Z 24 Aug.



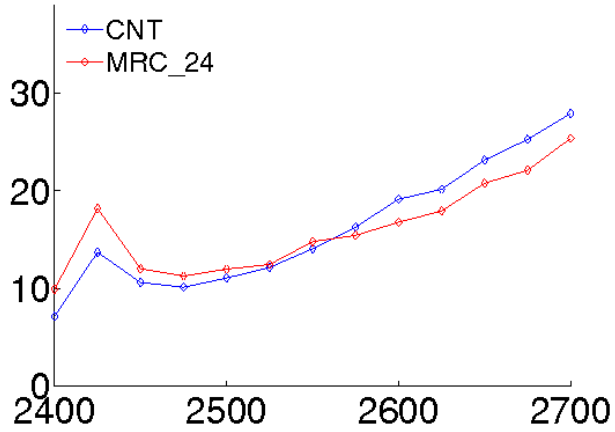
Ratio at 00Z 25 Aug.



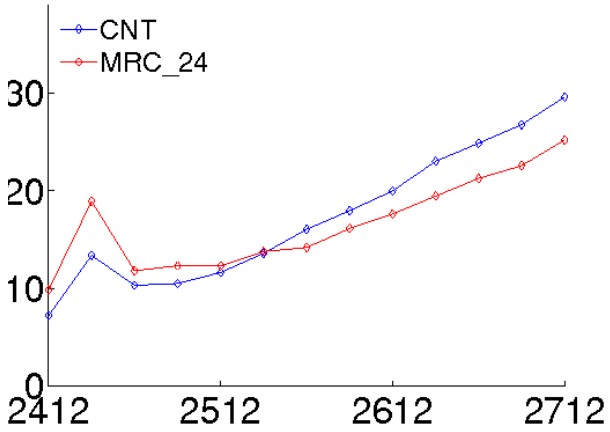
Improvement for synoptic scale

- To emphasize the TC environment, the synoptic RMSE calculation excludes the TC area.

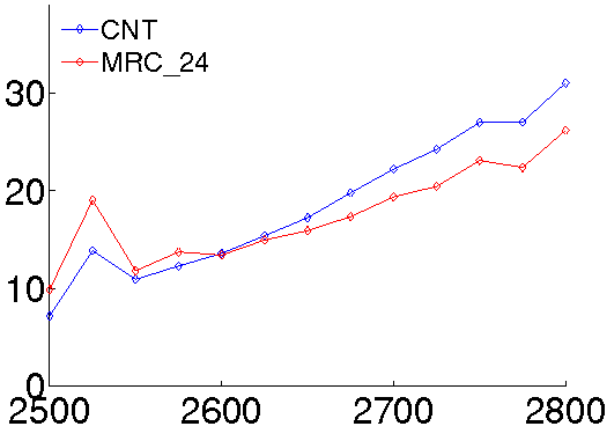
GeoP RMSE at 00Z 24 Aug.



GeoP RMSE at 12Z 24 Aug.



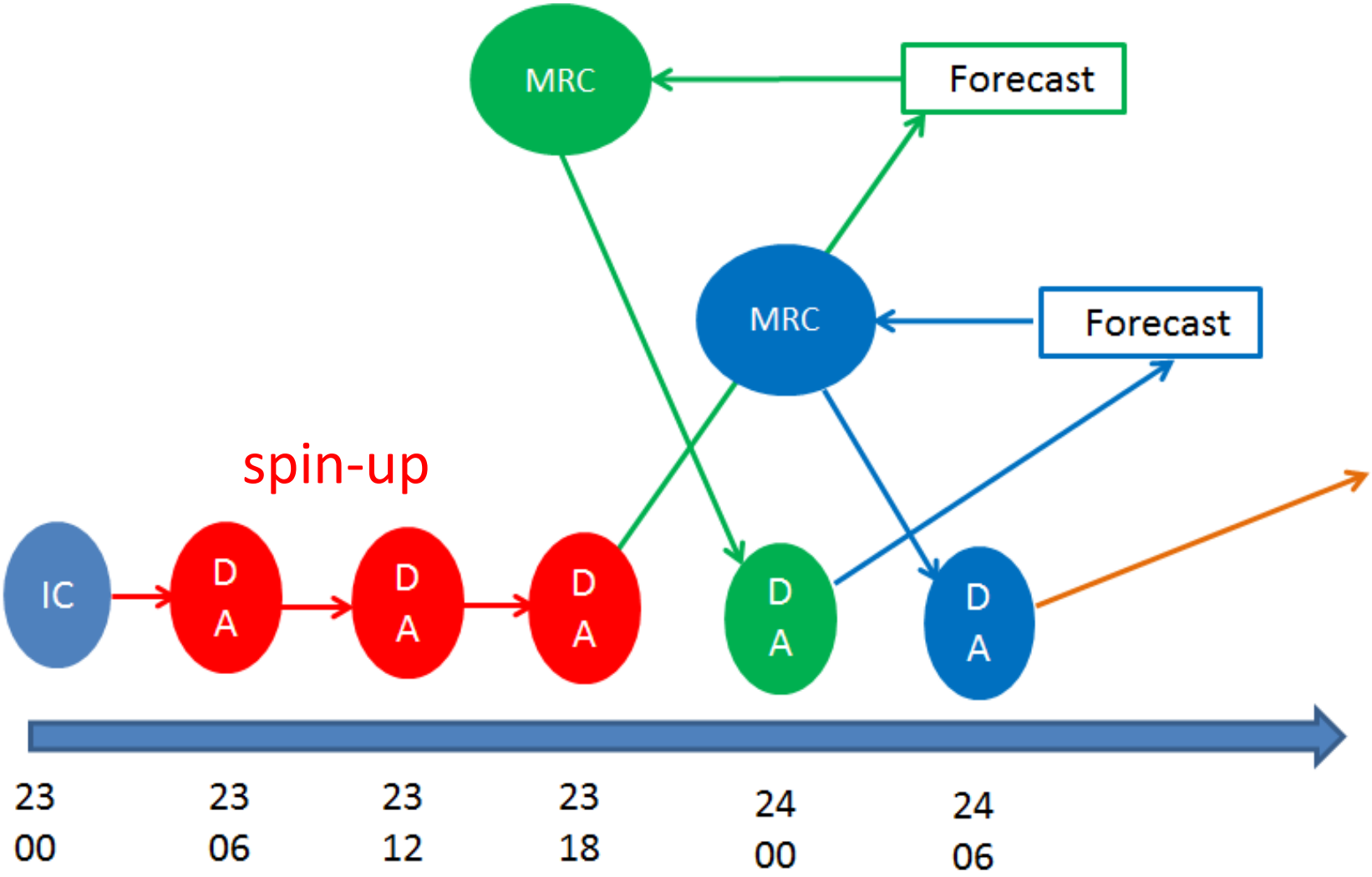
GeoP RMSE at 00Z 25 Aug.



- Although MRC uses track error to determine the best member, the positive impact can be found in the synoptic scale features at longer leadtime.

WRF-LETKF (Warm-started EPS)

Flow chart of MRC cycle



WRF-LETKF (Warm-started EPS)

—— CWB best track

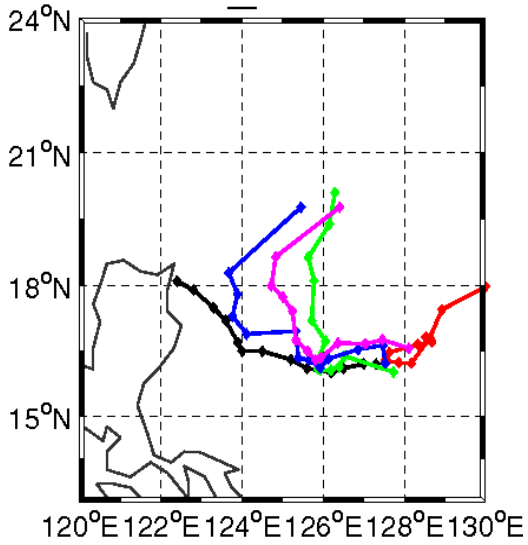
—— DA_CNT: regular Data assimilation cycle

—— MRC_DA24a:One best member with smallest track error.

—— MRC_DA24b: Use average of the best five members as best member.

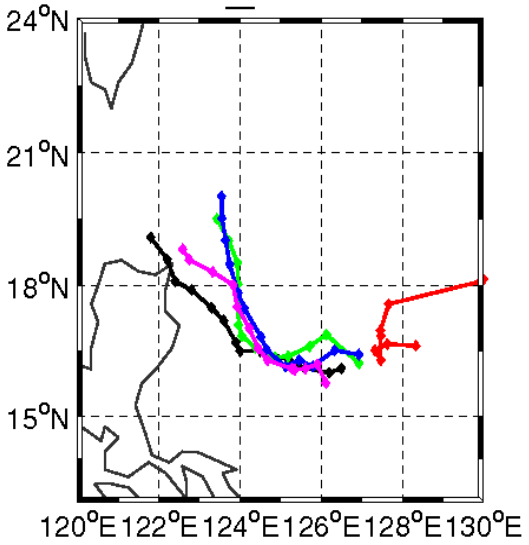
—— MRC_DA24c: Use average of the best group derived by cluster analysis.

Anal. FCST at 00Z 24 Aug.



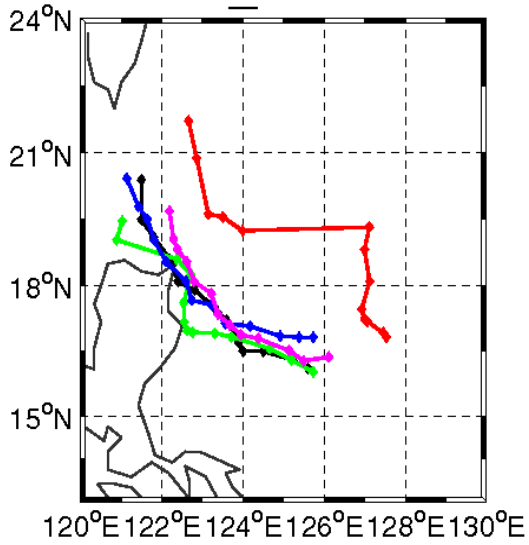
2nd DA/MRC cycle

Anal. FCST at 12Z 24 Aug.



4th DA/MRC cycle

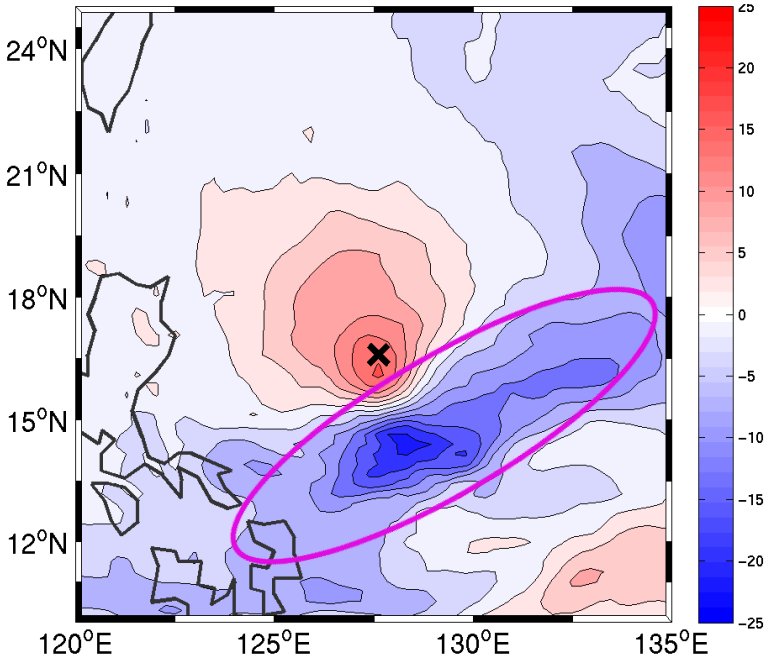
Anal. FCST at 00Z 25 Aug.



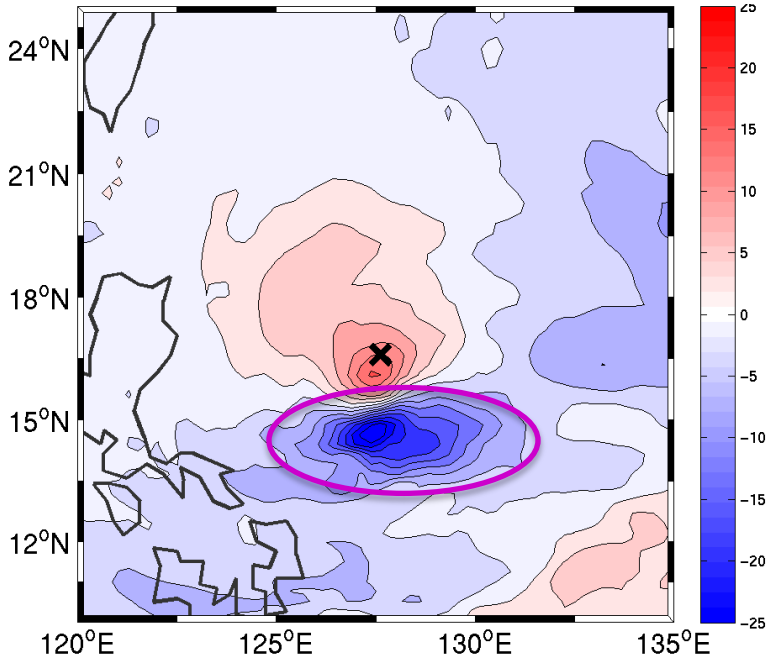
6th DA/MRC cycle

Error covariance structure

Error covariance W/O MRC



Error covariance W/ MRC

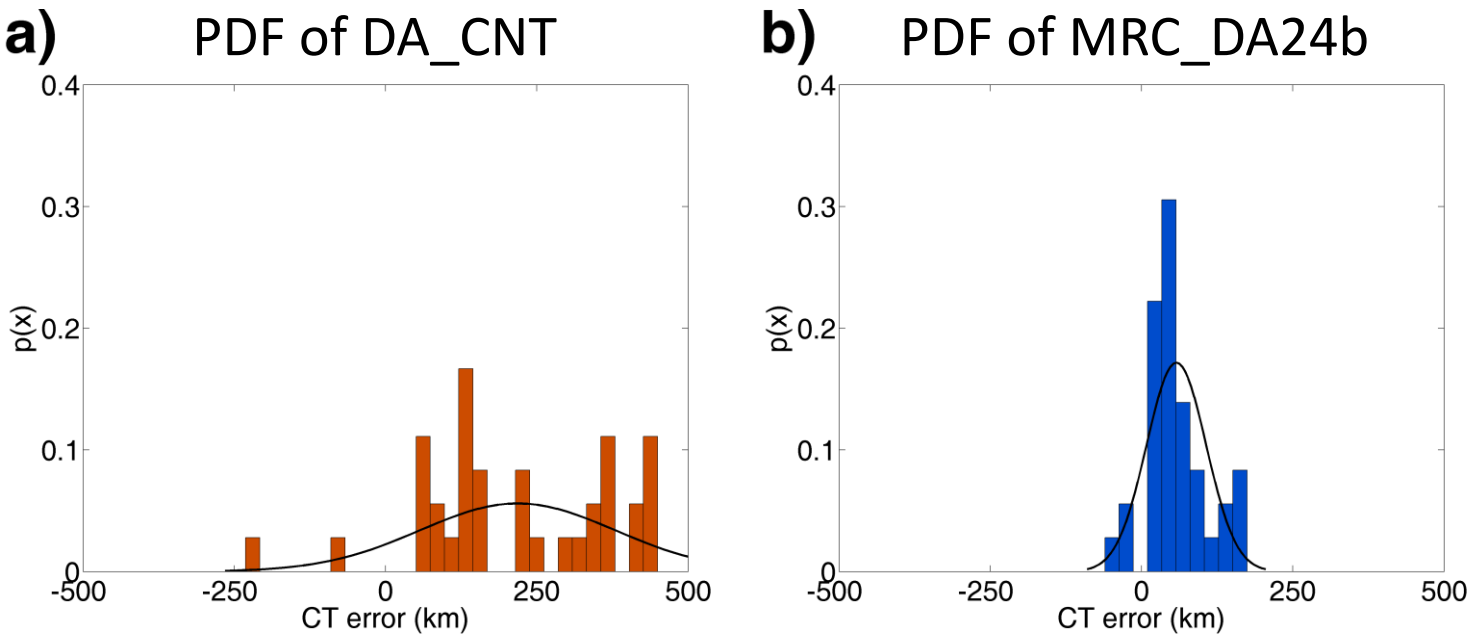


- Without MRC, the negative covariance structure is very board and link to another TC, Talas.
- With MRC, the covariance structure is more symmetric.

Gaussianity

- The Probability distribution of TC cross track error at 00Z 08/24 is used to emphasize the errors associated with the moving direction.

- The PDF of MRC_DA24b fits the normal distribution with 95% confidence level by χ^2 test. But DA_CNT does not.



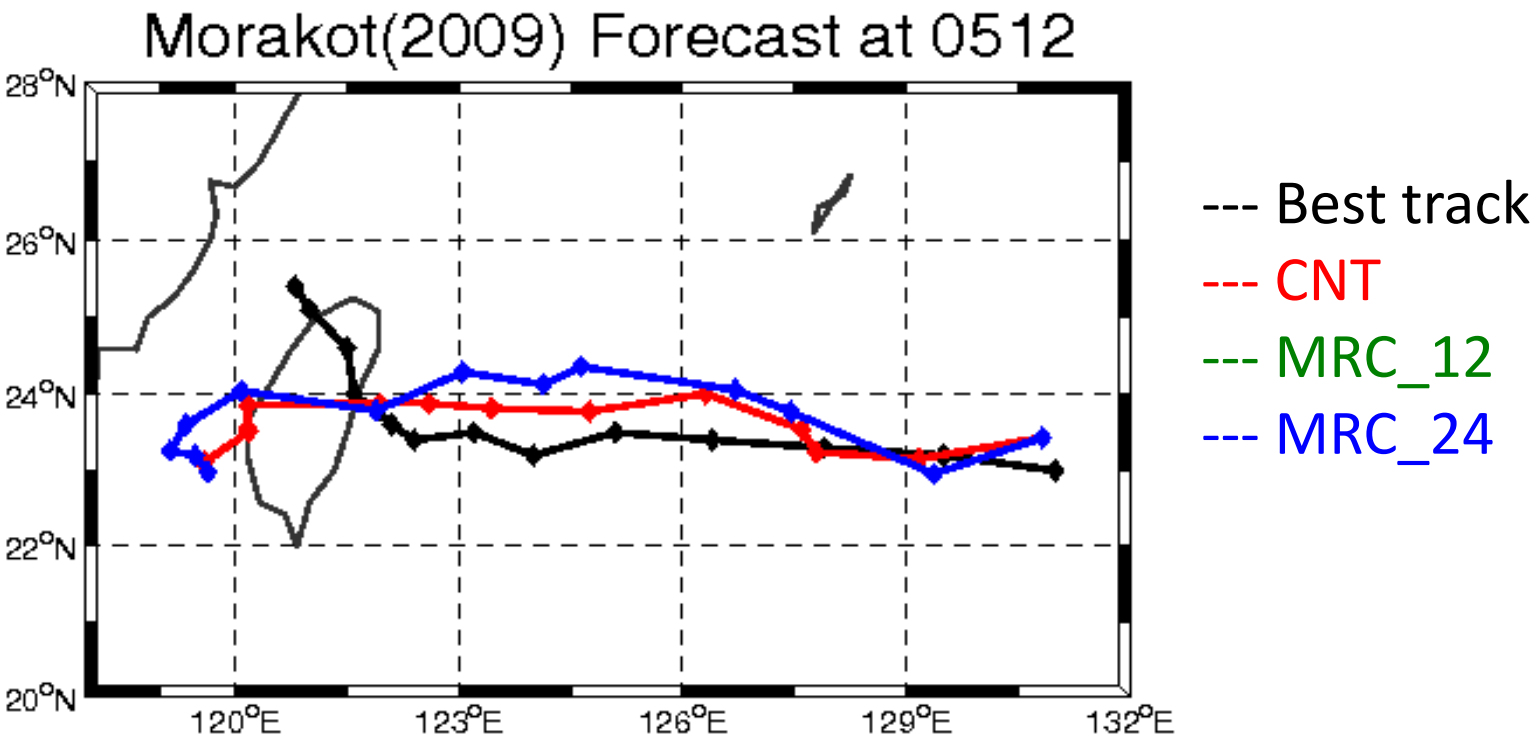
Summary

- For typhoon track prediction, we propose the MRC method to improve the poor ensemble forecast, which suffers from strong uncertainties and non-Gaussian distribution.
- In cold-started EPS experiment, we proof that the MRC is able to improve the TC track forecast.
- In warm-started EPS, with the flow-dependent characteristic of EnKF, the positive impact from the MRC can feedback to the DA system, further improving the background error covariance and analysis accuracy.
- A critical factor for MRC method to have positive impact is the metric for deriving the best member.
  - Results suggest that instead of single member, a better strategy is to define the best initial state with the average of several good members.
- Although MRC requires future information to determine the best member, for operational purpose, this could be an valuable trade off to adjust the ensemble at the early TC developing stage.

Thanks for listening

Cold-started EPS for Morakot (2009)

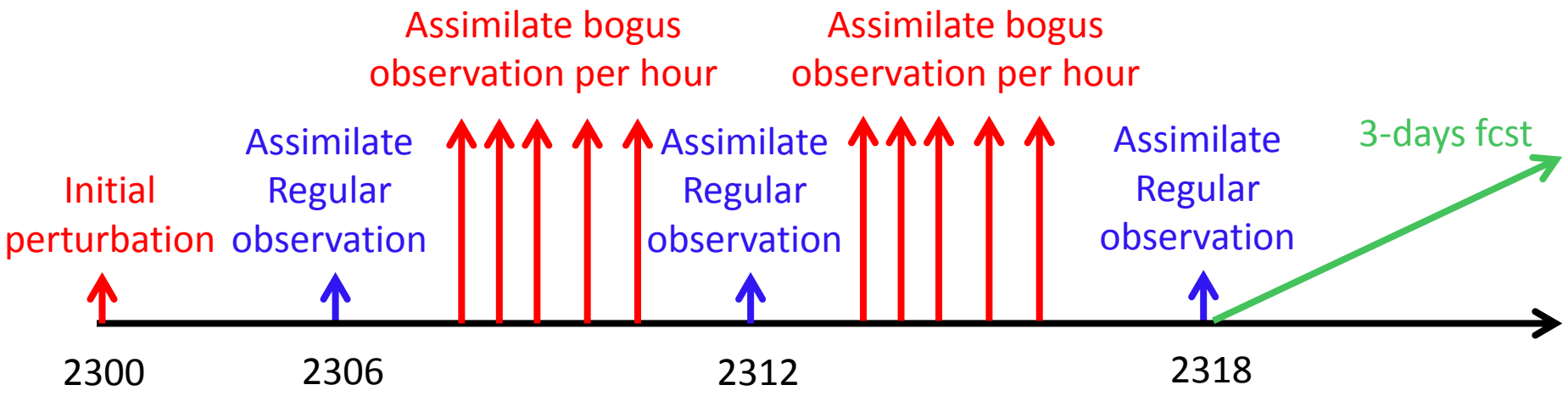
- For normal track forecast, the MRC still has positive improvement.



Bogus Data Assimilation

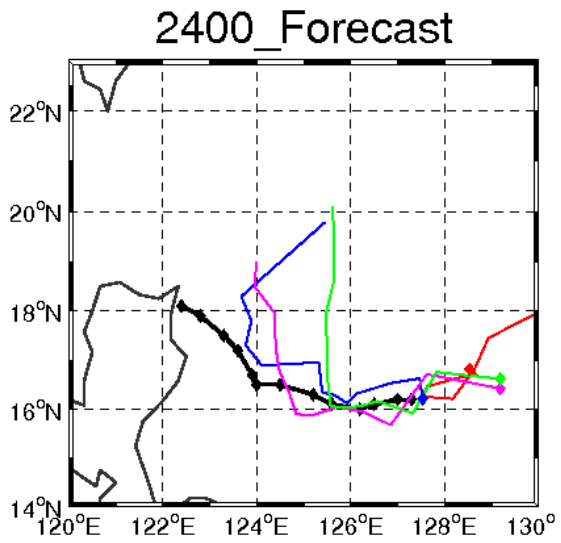
- Initial position and initial intensity errors are important sources of TC track forecast errors.

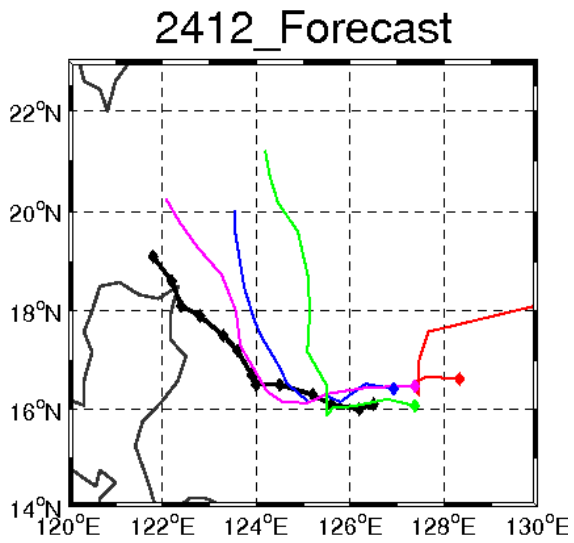
- Bogus assimilation (BDA) is used to improve the TC track forecast.

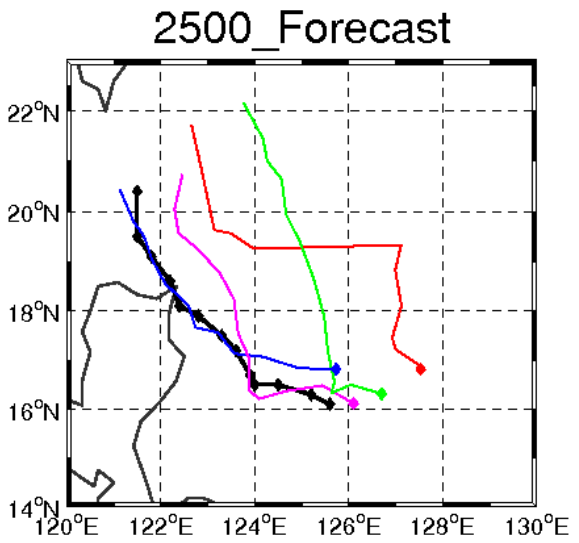


BDA

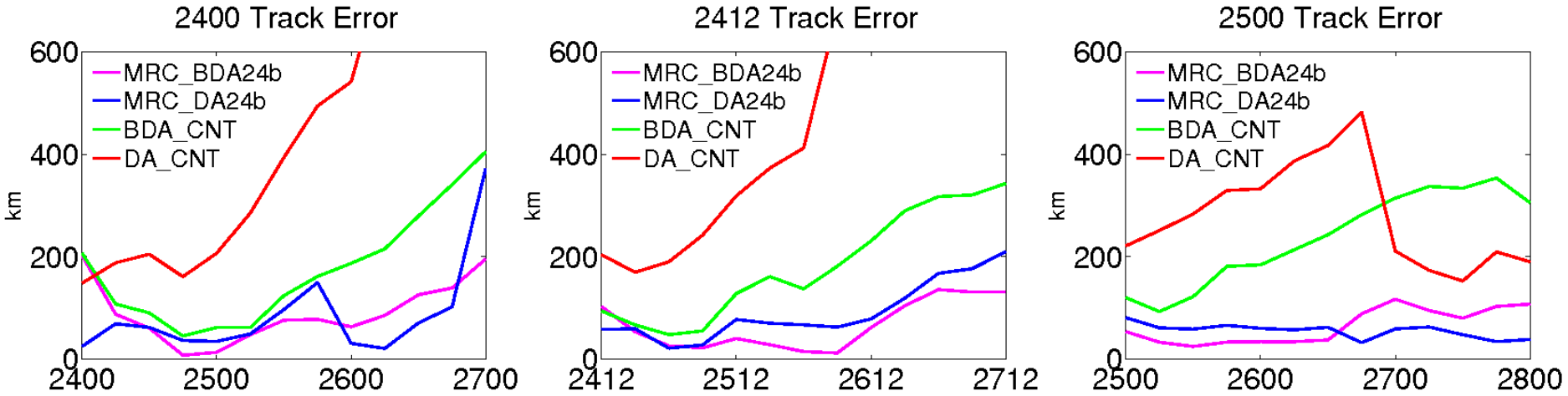
- CWB best track
- DA_CNT: Assimilates regular observation.
- BDA_CNT: Assimilate both regular and Bogus observations.
- MRC_DA24b:Use the average of first five members as best member.
- MRC_BDA24b: Same as MRC_DA24b, but bogus data are assimilated during spin-up period.







BDA



- The initial position has no significant improvement with BDA.

- However, since TC structure is stronger, the interaction of stronger TC circulation and the environment flow has a positive improvement for the track prediction