Verification of the near-real-time weather forecasts and study on 2015 typhoon Nangka with the SCALE-LETKF system

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Summary from the
2015 RIKEN AICS HPC Computational Science Internship Program
Advisors: Takemasa Miyoshi and Guo-Yuan Lien

Data assimilation seminar on 16th September, 2015

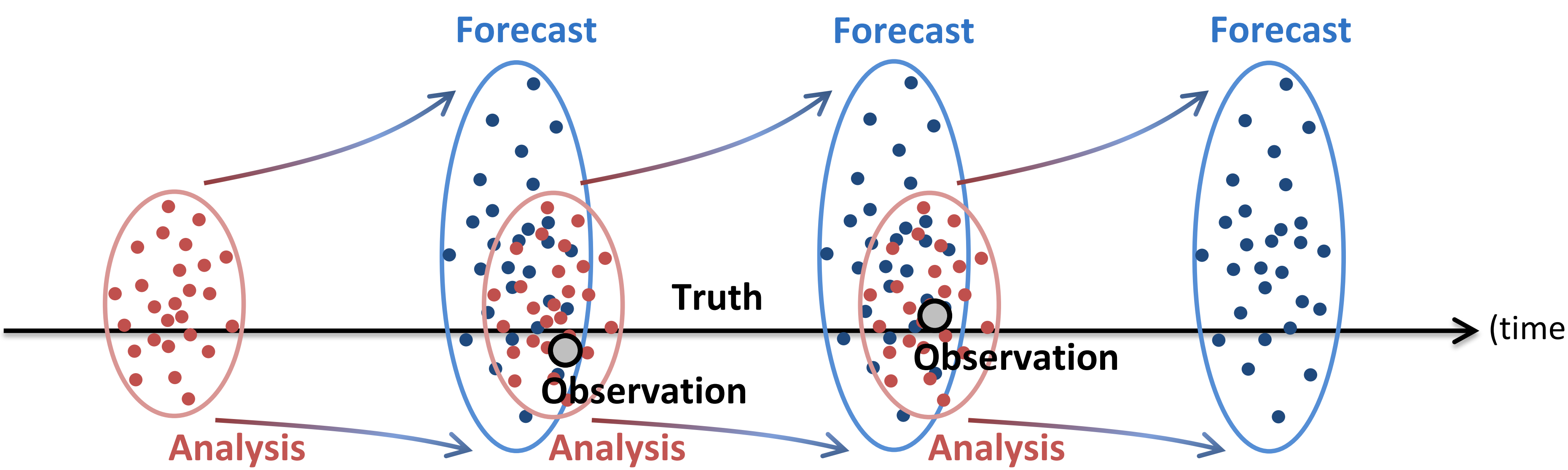
Outline

- Introduction of the SCALE-LETKF
- Verification of the 1.5-month near-real-time SCALE-LETKF results
- Case study: Typhoon Nangka (2015)
- Conclusion

- Scalable Computing for Advanced Library and Environment (SCALE; Nishizawa et al. 2015)
  - An open-source basic library for weather and climate model of the earth and planets aimed to be widely used in various models.
  - Developed by the Computational Climate Science Research Team in RIKEN AICS.
- SCALE-LES model
  - A regional mesoscale weather model designed for high-resolution simulation.

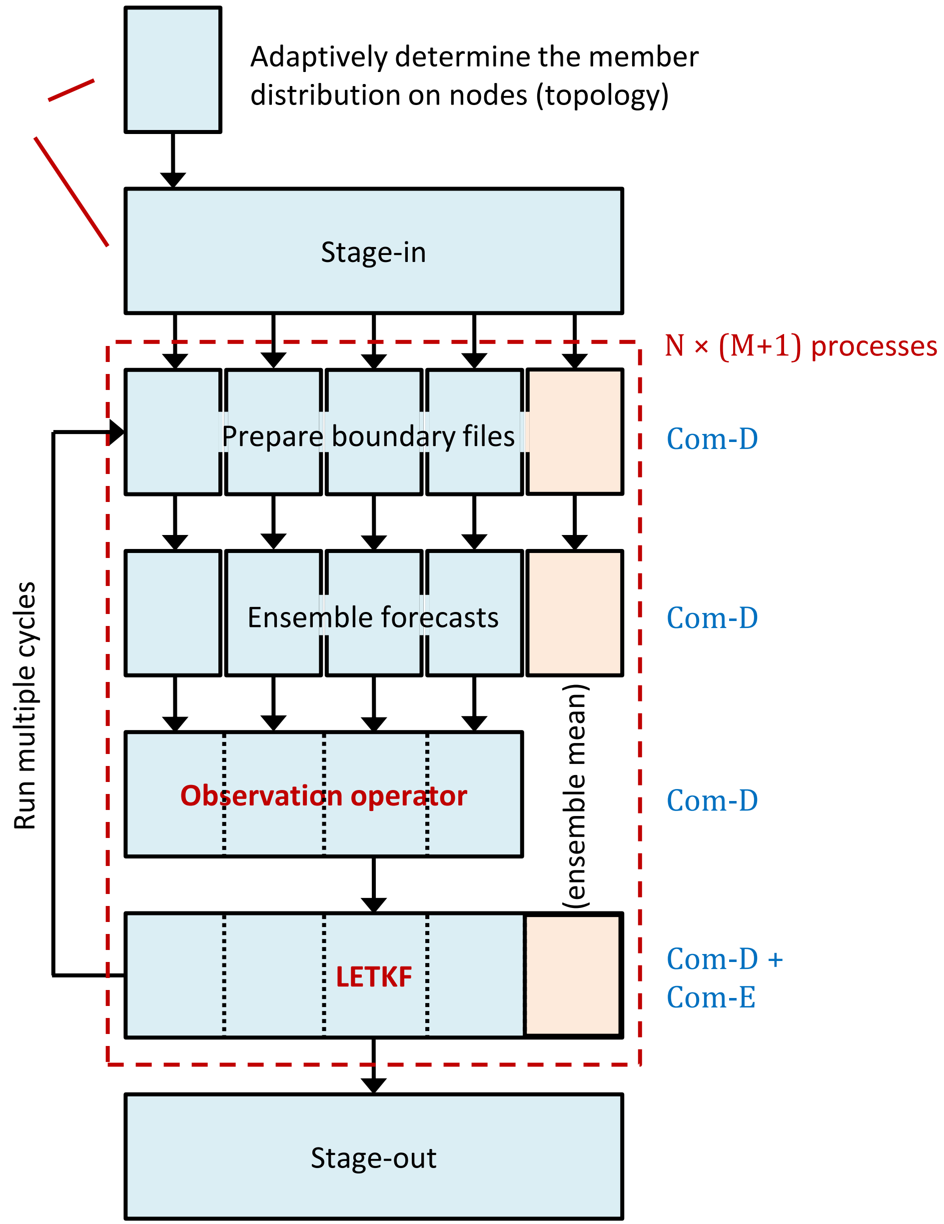
Local Ensemble Transform Kalman Filter (LETKF)

- An ensemble Kalman filter (EnKF) data assimilation scheme.
- Flow-dependent background error covariance without the requirement of the tangent linear model and adjoint model.
- https://code.google.com/p/miyoshi/



SCALE-LETKF

Flexible to different systems:
Linux cluster, K-computer



(will also be open-source)

Near-real-time SCALE-LETKF system: Motivation

- Goals:
  - High-resolution,
  - short-term,
  - real-time rainfall prediction using SCALE-LETKF
- First test lower resolution, large domain set-up:
  - Test the performance and stability of the SCALE-LETKF.
  - Build a dataset of ensemble analyses over large domains, in preparation for the downscaling run for some cases of interest.

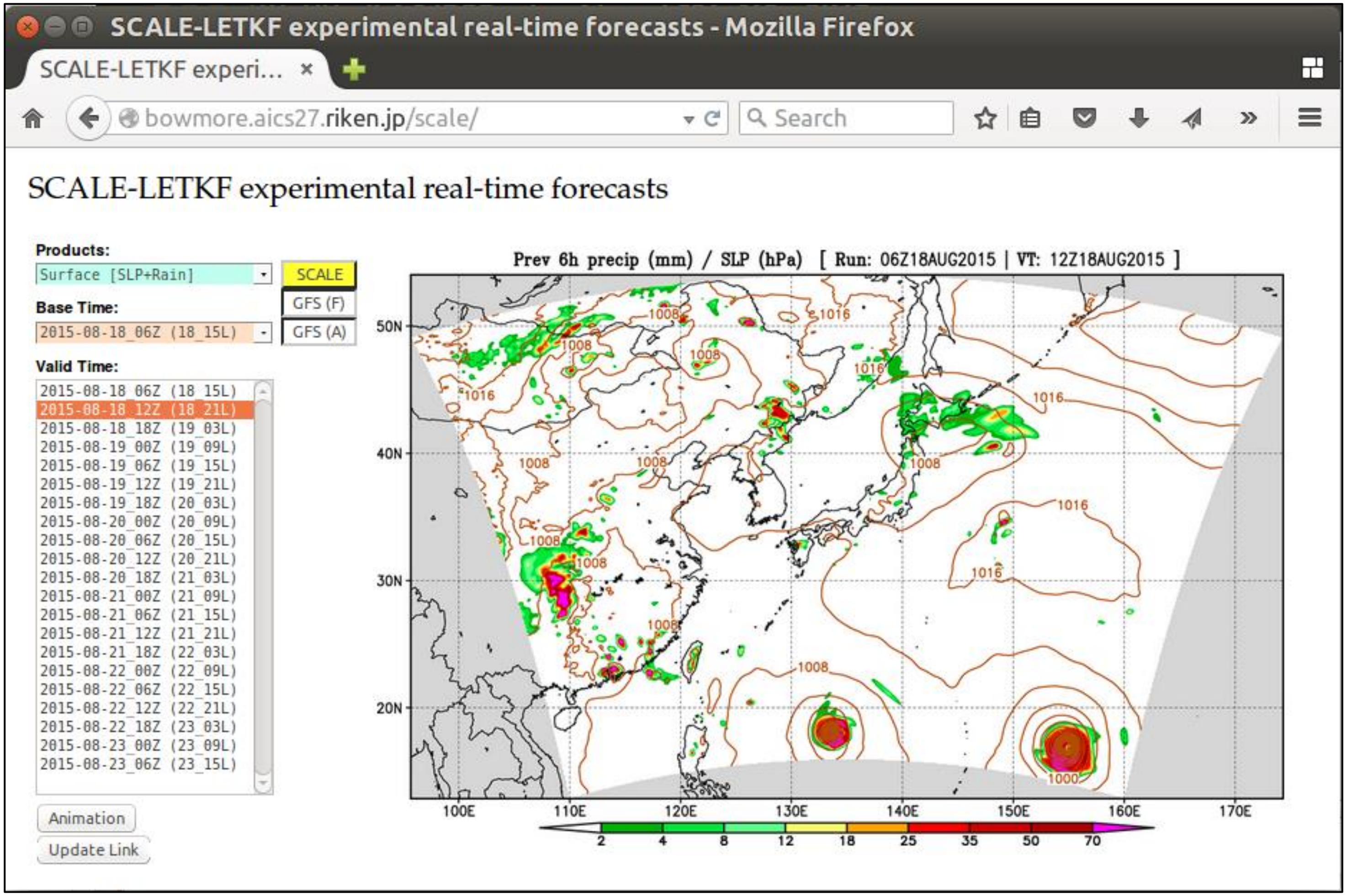
Tasks finished

- Development of the SCALE-LETKF for conventional (non-radiance) data assimilation.
- Automatic preparation of the near-real-time boundary data and observation data:
  - NCEP GFS 0.5-d global analyses and forecasts
  - NCEP PREPBUFR conventional observations (download from the NCEP FTP)
- Automatic submission of the K computer job and the data collection on our team servers.
- Basic tools for visualizing the real-time products.

Tasks ongoing and planned

- Test of the high-resolution (3km - 100m) data assimilation.
- Phased-array weather radar (PAR) assimilation.
- Add more comprehensive validation tools of the real-time results.
  - Online RMSE/bias/increment statistics.
  - Validation with the Japan Automated Meteorological Data Acquisition System (AMeDAS) observations.

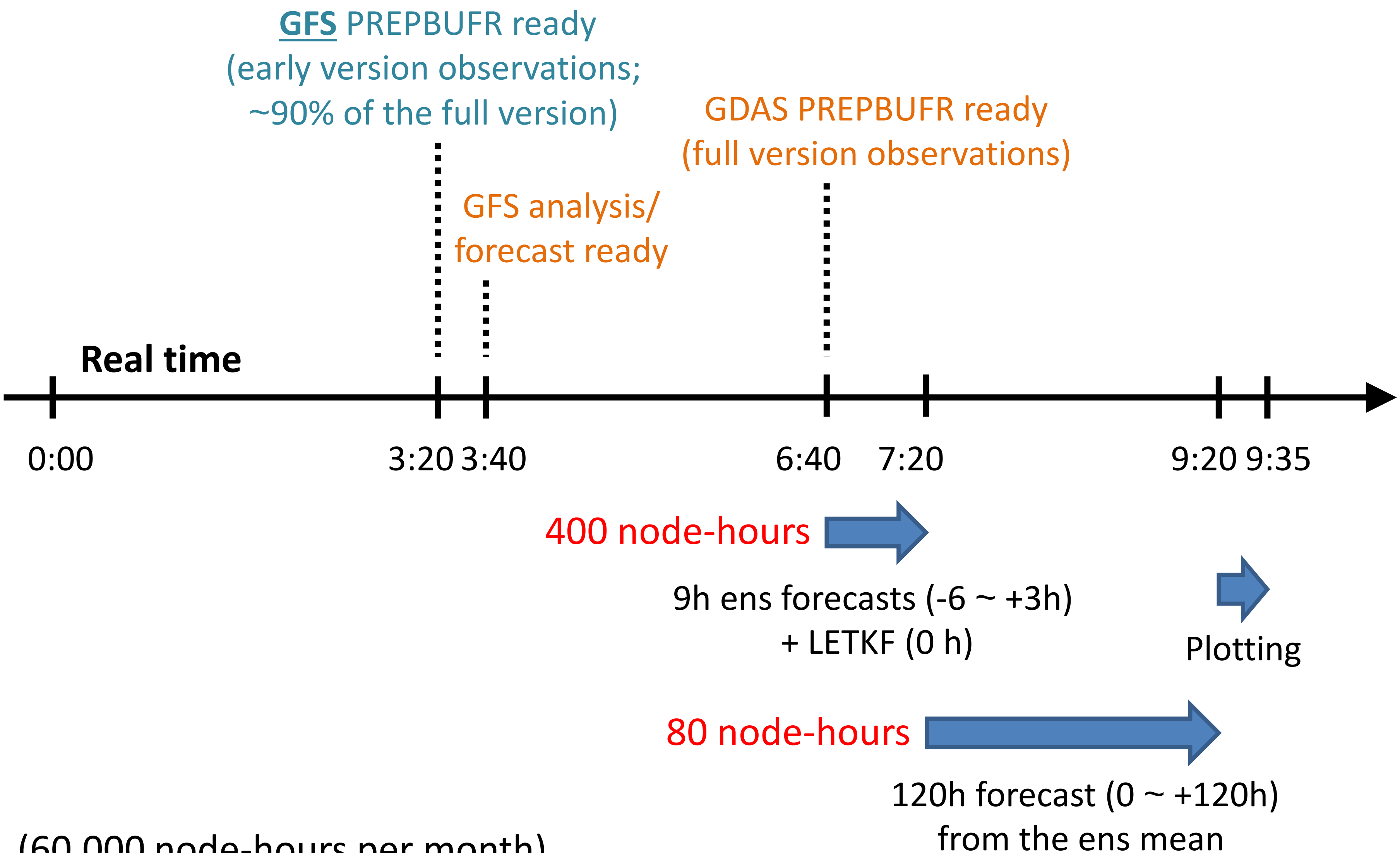
Experimental near-real-time SCALE-LETKF



Experimental near-real-time SCALE-LETKF

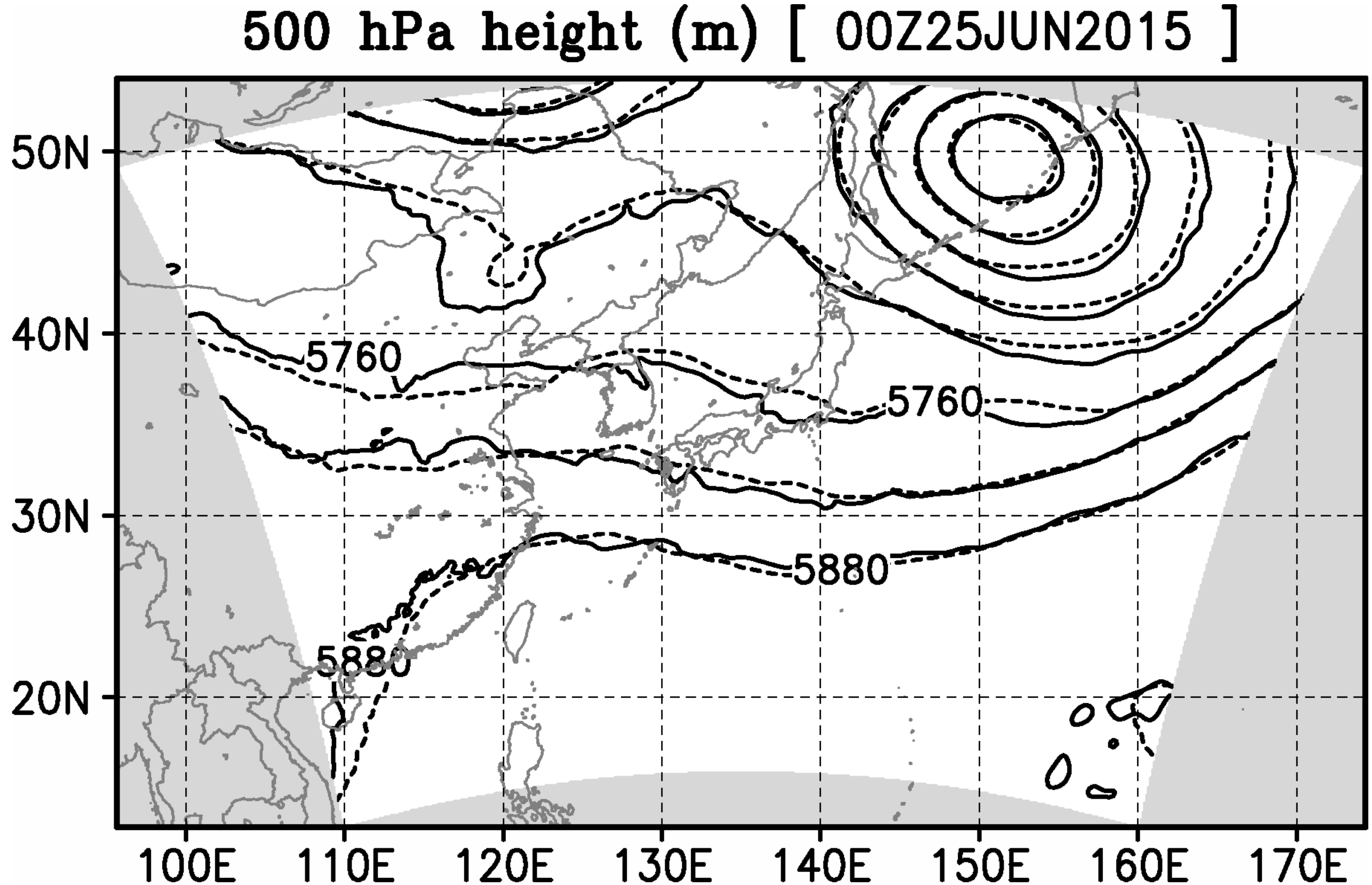
- Domain:
  - Horizontal: 18-km resolution; 320 x 240 grids
  - Vertical: 36 levels (0 ~ 29 km)
- 50 members.
- 6-hourly analysis cycle; 5-day forecasts from the ensemble mean.
- Observations:
  - NCEP PREPBUFR conventional (non-radiance) observation data.

Time frame



(60,000 node-hours per month)

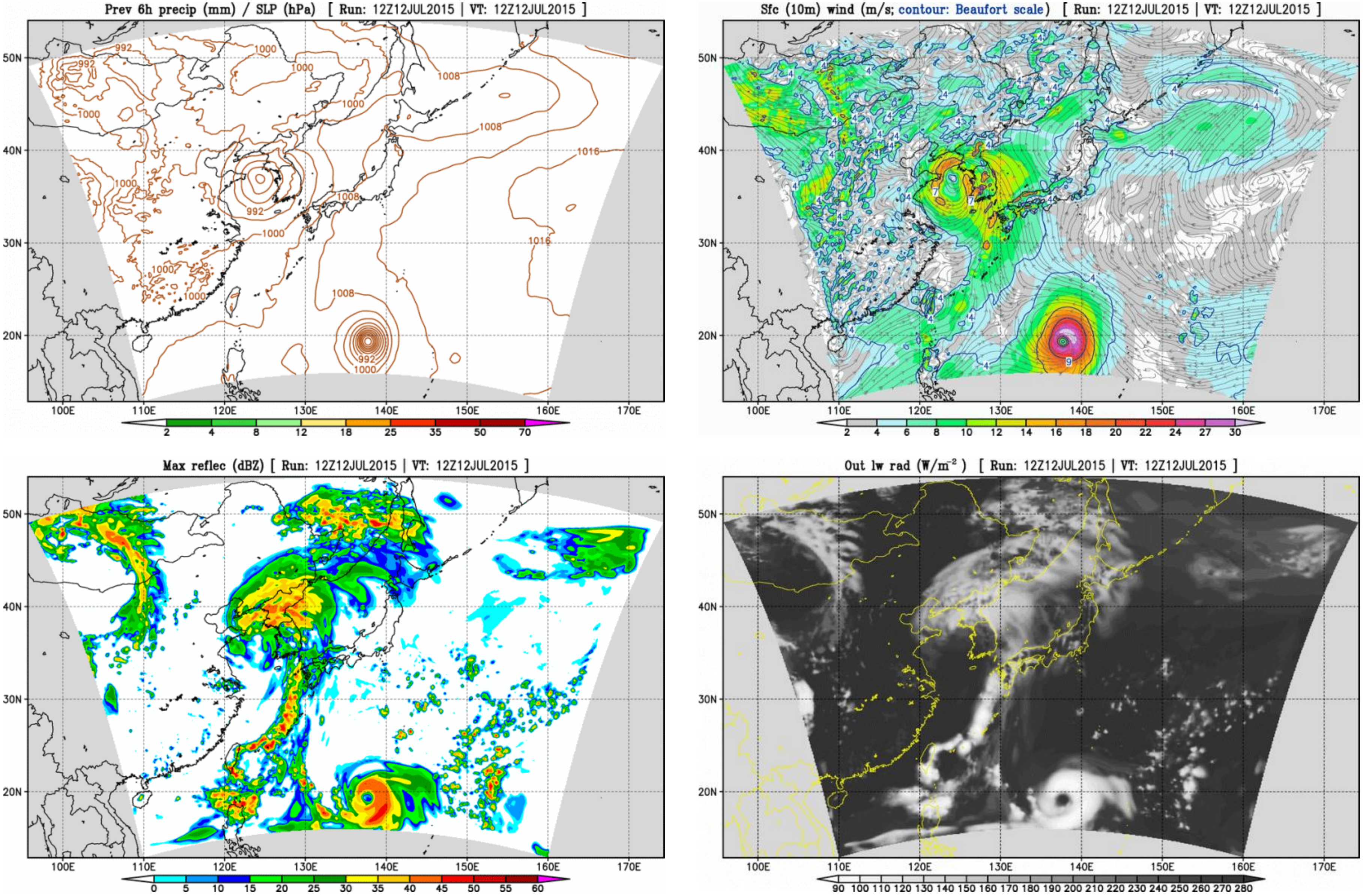
SCALE-LETKF analysis vs. GFS analysis



SCALE-LETKF analysis

GFS analysis

5 day forecast of Typhoon NANGKA (201511) stating at 12:00 UTC July 12



Topics in the internship program

My purpose: Learning a data assimilation system of an atmospheric model

-> Verification of the near-real-time analysis and forecast system
-> Research on 2015 typhoon Nangka
-- Sensitivities of the localization scales to TC track and intensity forecasts
-- TC vital assimilation
-- Ensemble forecasts and downscaling forecasts

Verification of the near-real-time analysis and forecast system

-> Average root-mean-square errors (RMSE) and biases over the 1.5 month period

RMSE and Bias vs. NCEP-GFS anl

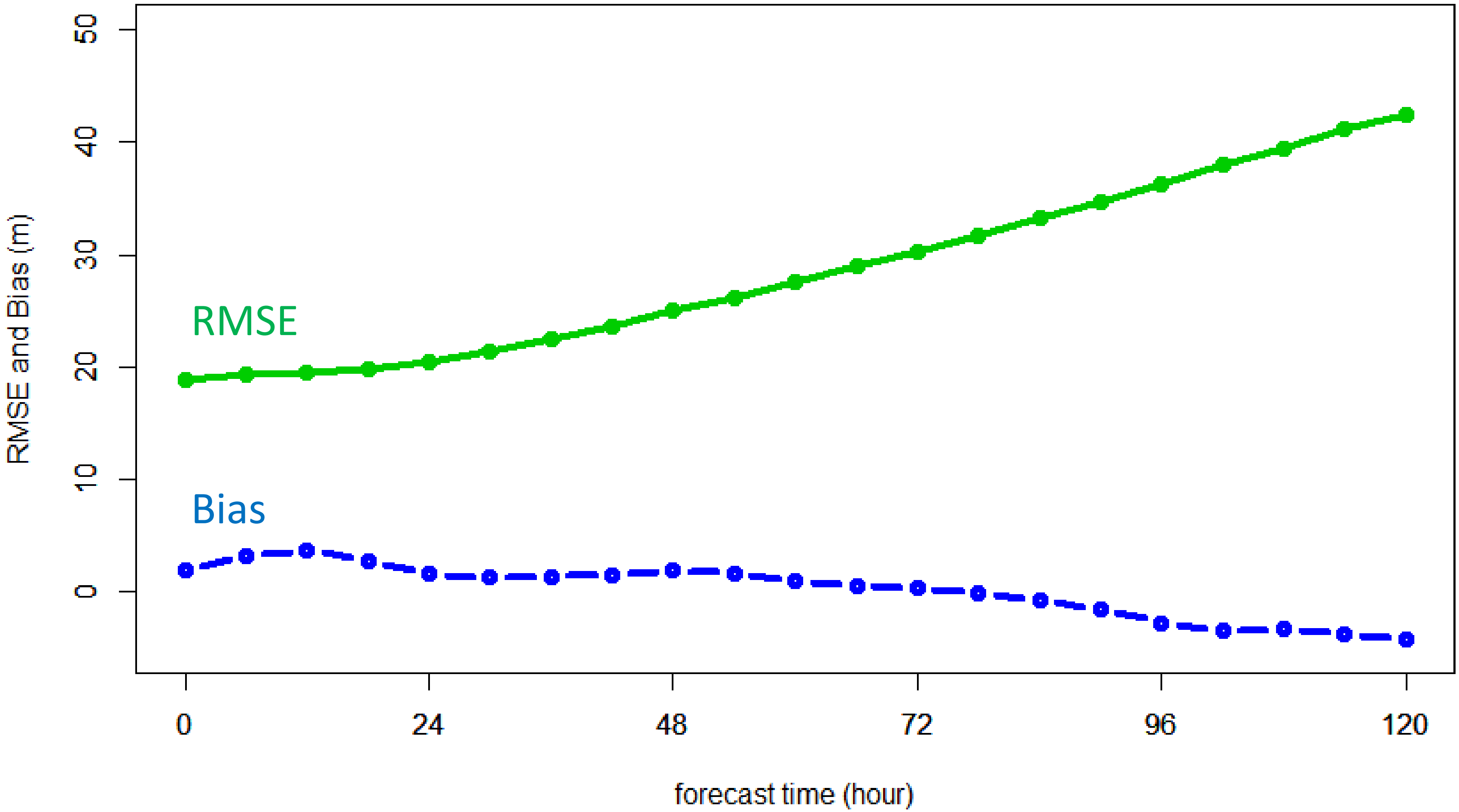


Fig.1 RMSE and Bias of Height (m) on 500hPa level every six hours
Period: 2015/06/01 – 2015/07/18

RMSE and Bias vs. NCEP-GFS anl

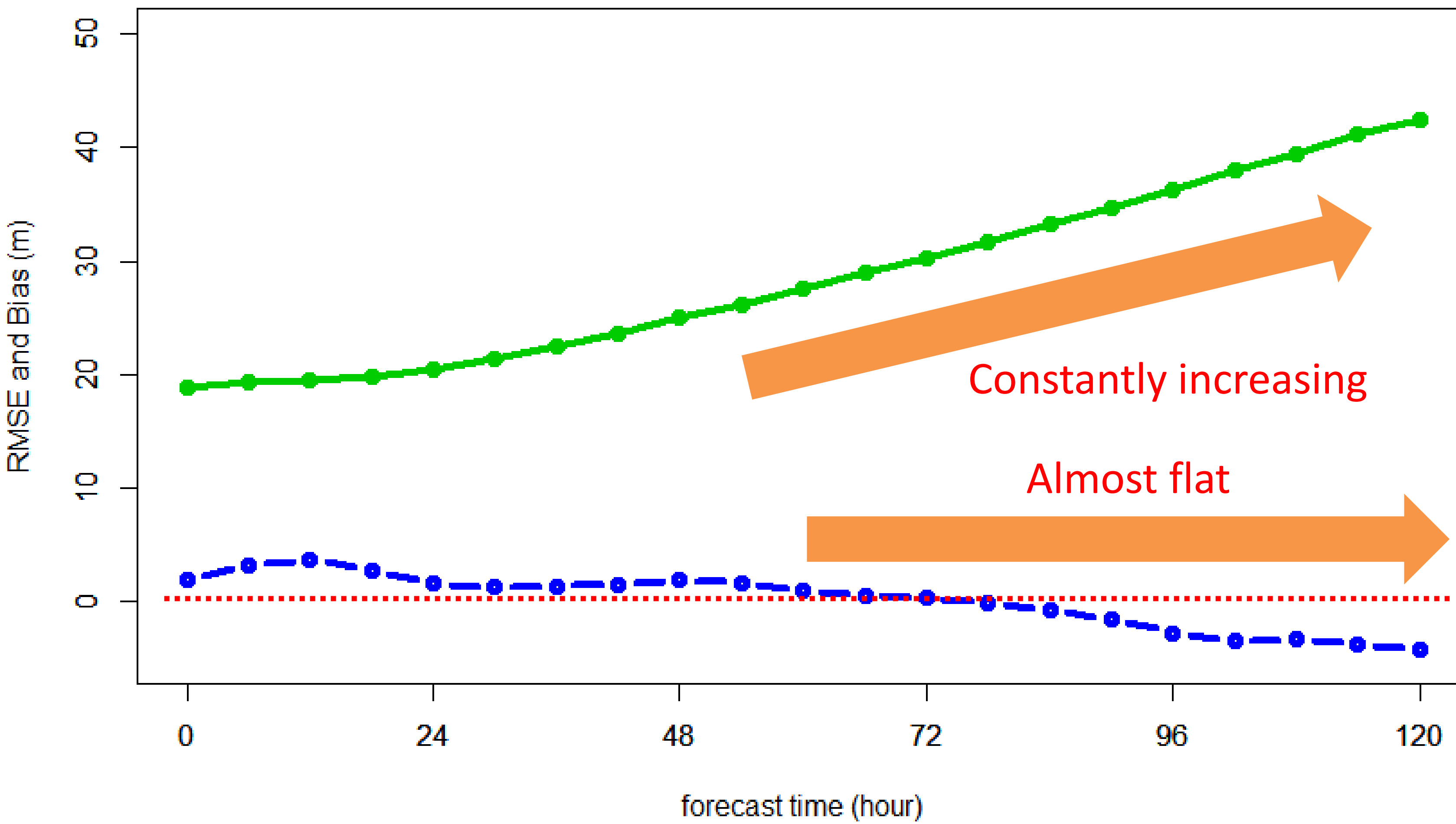


Fig.1 RMSE and Bias of Height (m) on 500hPa level every six hours
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RMSE and Bias vs. NCEP-GFS anl

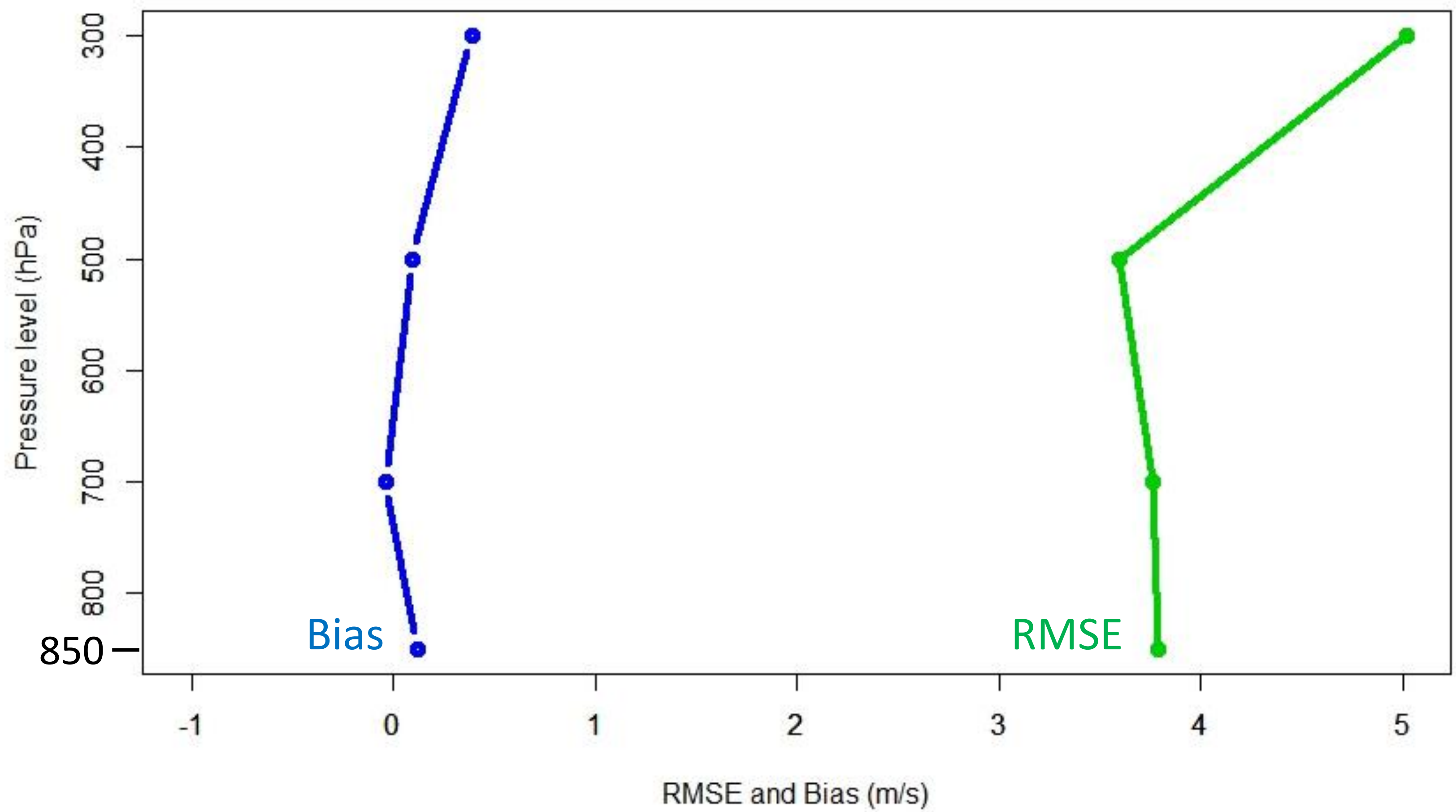


Fig.2 RMSE and Bias of U wind (m/s) on each height at forecast time = 24 hr
Period: 2015/06/01 – 2015/07/18

RMSE and Bias vs. NCEP-GFS anl

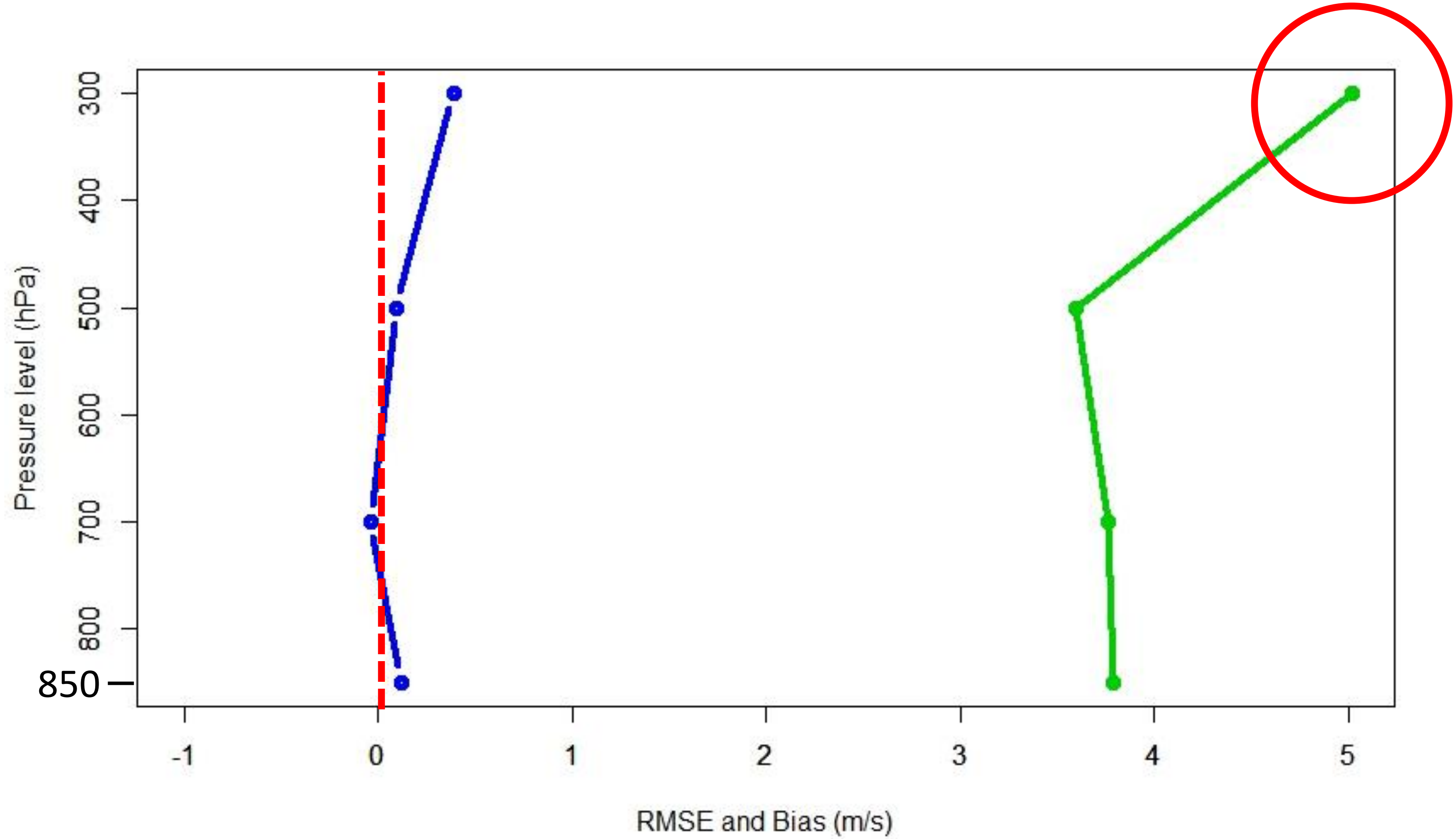


Fig.2 RMSE and Bias of U wind (m/s) on each height at forecast time = 24 hr
Period: 2015/06/01 – 2015/07/18

Summary of the verification

・The results of the near-real-time analysis and forecast system with the SCALE-LETKF are reasonable

Study on
2015 typhoon Nangka

- Background of the typhoon event
- Assimilation and forecast experiments (CTL)
- Sensitivity experiments
  -> Change horizontal localization parameter
  -> Change vertical localization parameter
  -> TC vital data assimilation
- Ensemble rainfall forecasts
- High resolution experiment

Background

・Typhoon Nangka made a landfall in Shikoku on July 16th

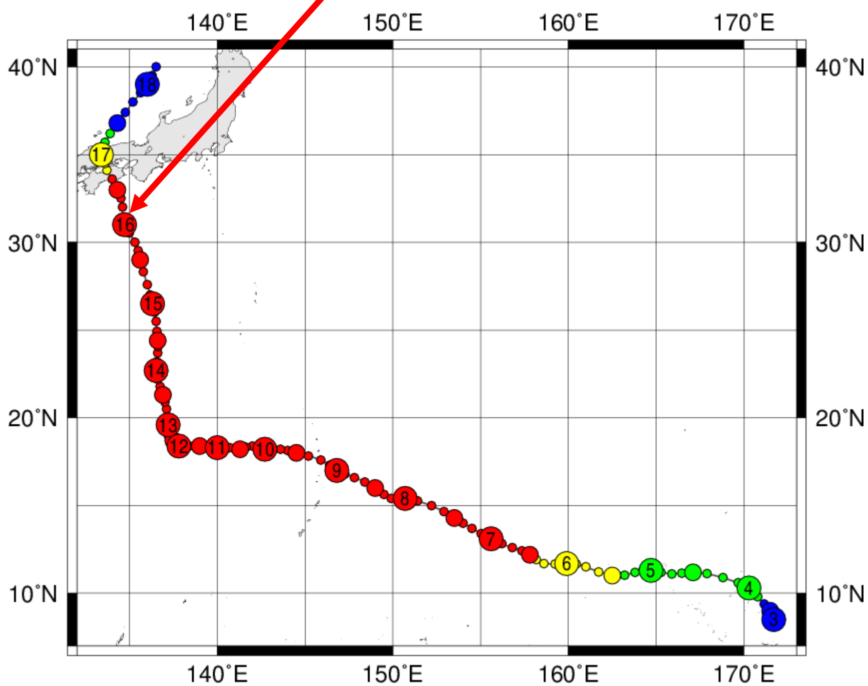


Fig. 3 The track of typhoon Nangka(Reprinted from Digital typhoon web site)

Surge by typhoon Nangka (July 2015)

People waiting for train services to resume (July 2015)
(report by Kobe newspaper company)

Background

・Typhoon Nangka made a landfall in Shikoku on July 16th

・Break a record of maximum daily precipitation at several spots

Surge by typhoon Nangka (July 2015)

People waiting for train services to resume (July 2015)
(report by Kobe newspaper company)

Distribution of the rainfall

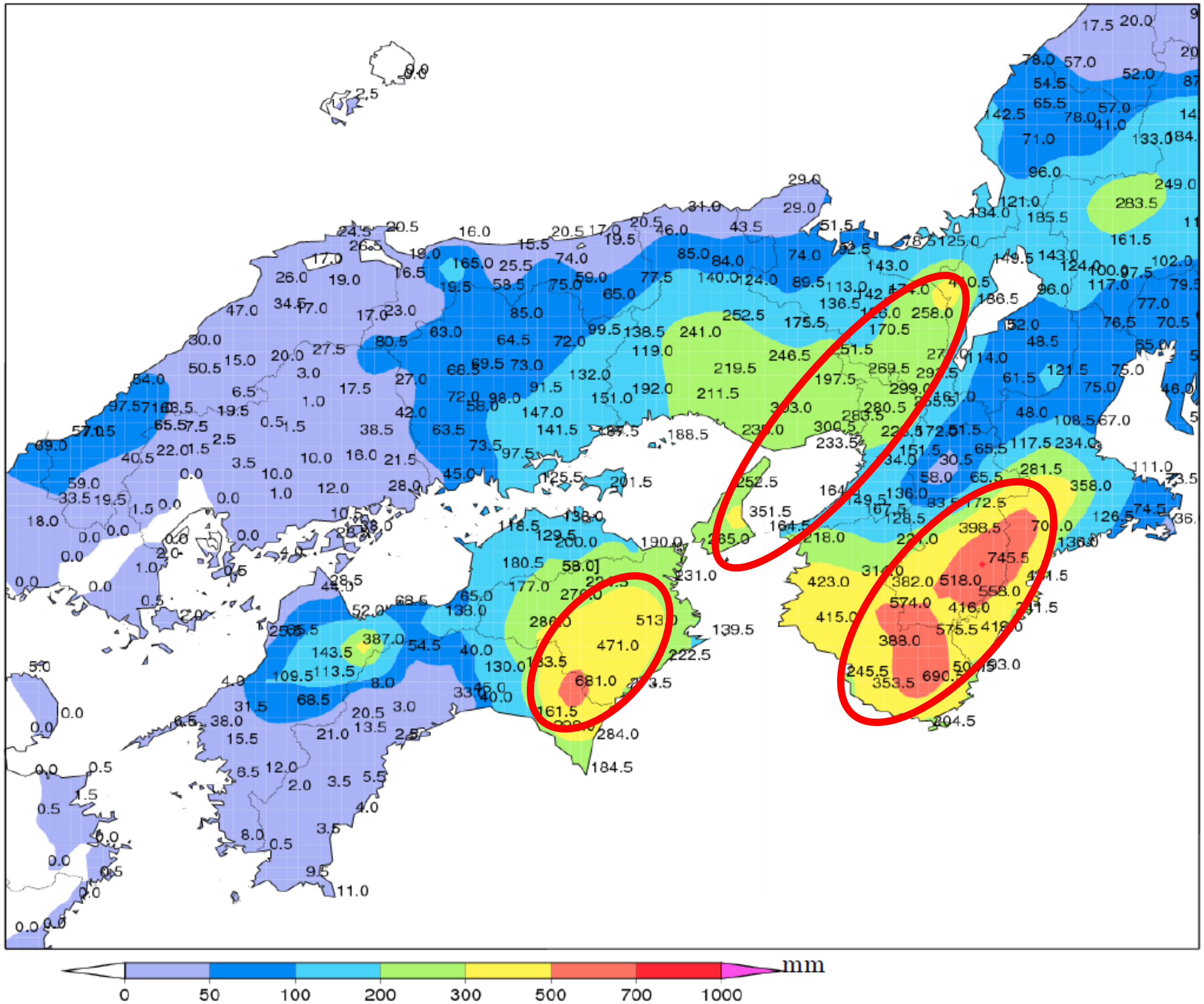


Fig. 4 Distribution of accumulated precipitation from 13L Jul 15th to 13L Jul 18th by AMeDAS
(Reprinted from http://www.jma-net.go.jp/osaka/kikou/saigai/pdf/sokuhou/20150718.pdf)

Time series of the rainfall in Hyogo

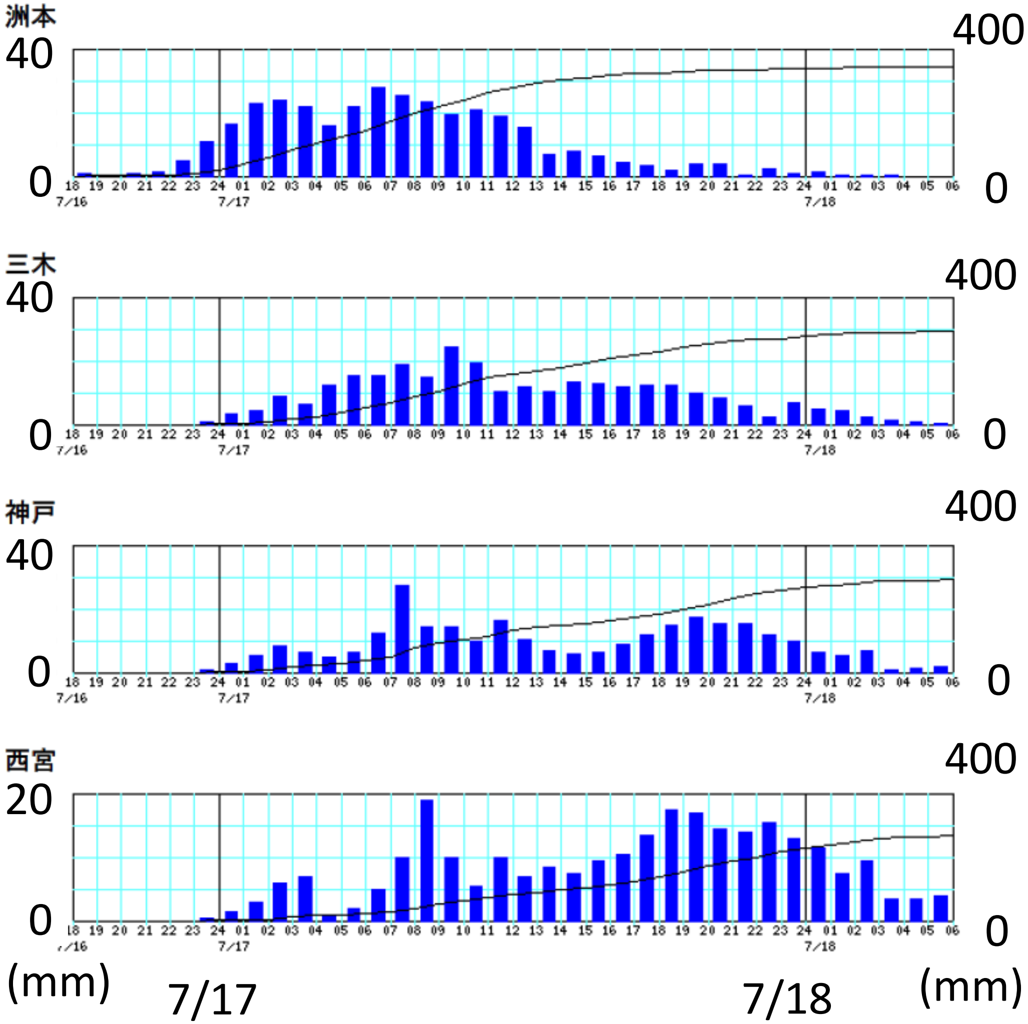
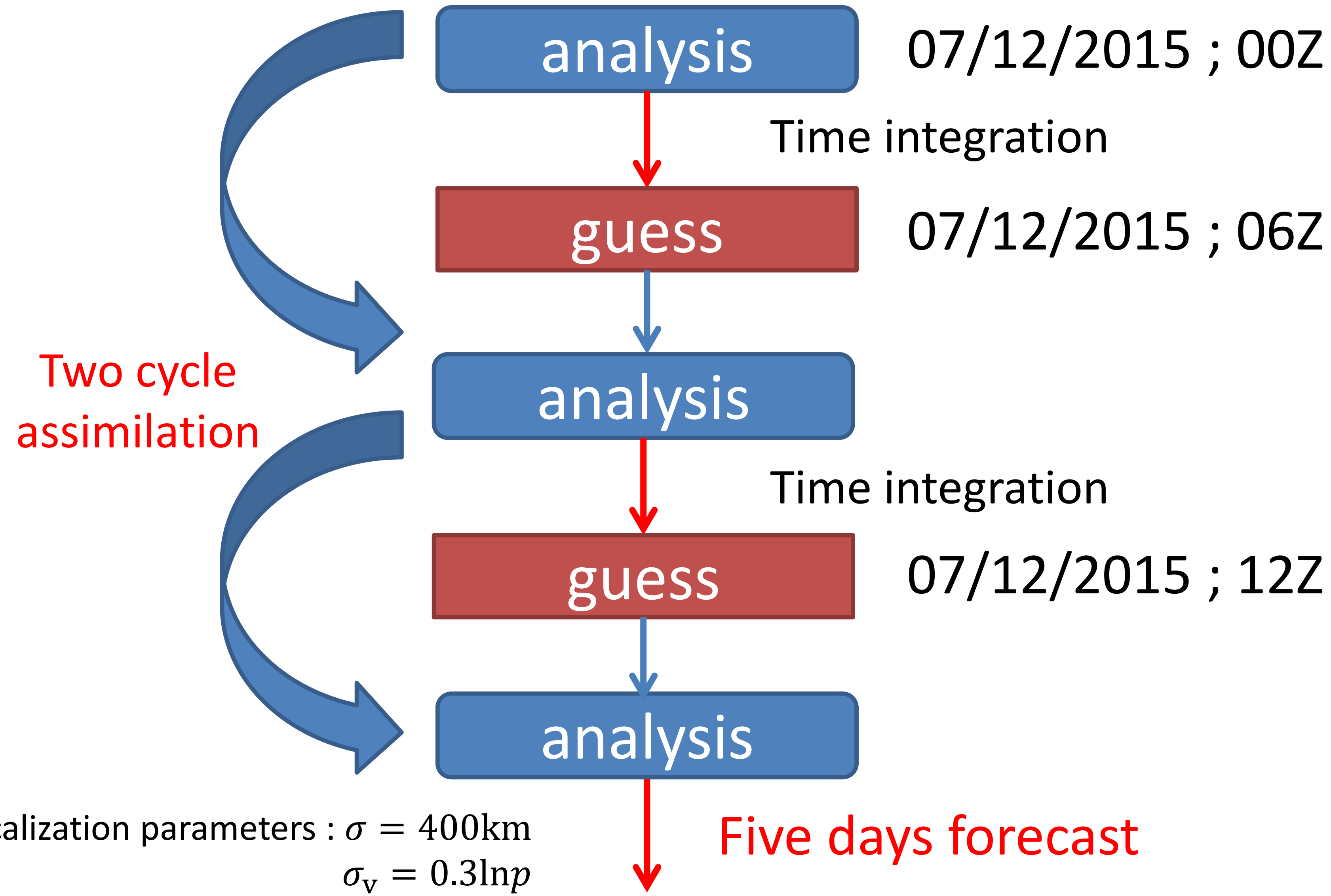


Fig.5 Time series of hourly precipitation at AMeDAS stations in Hyogo
(Reprinted from http://www.jma-net.go.jp/osaka/kikou/saigai/pdf/sokuhou/20150718.pdf)

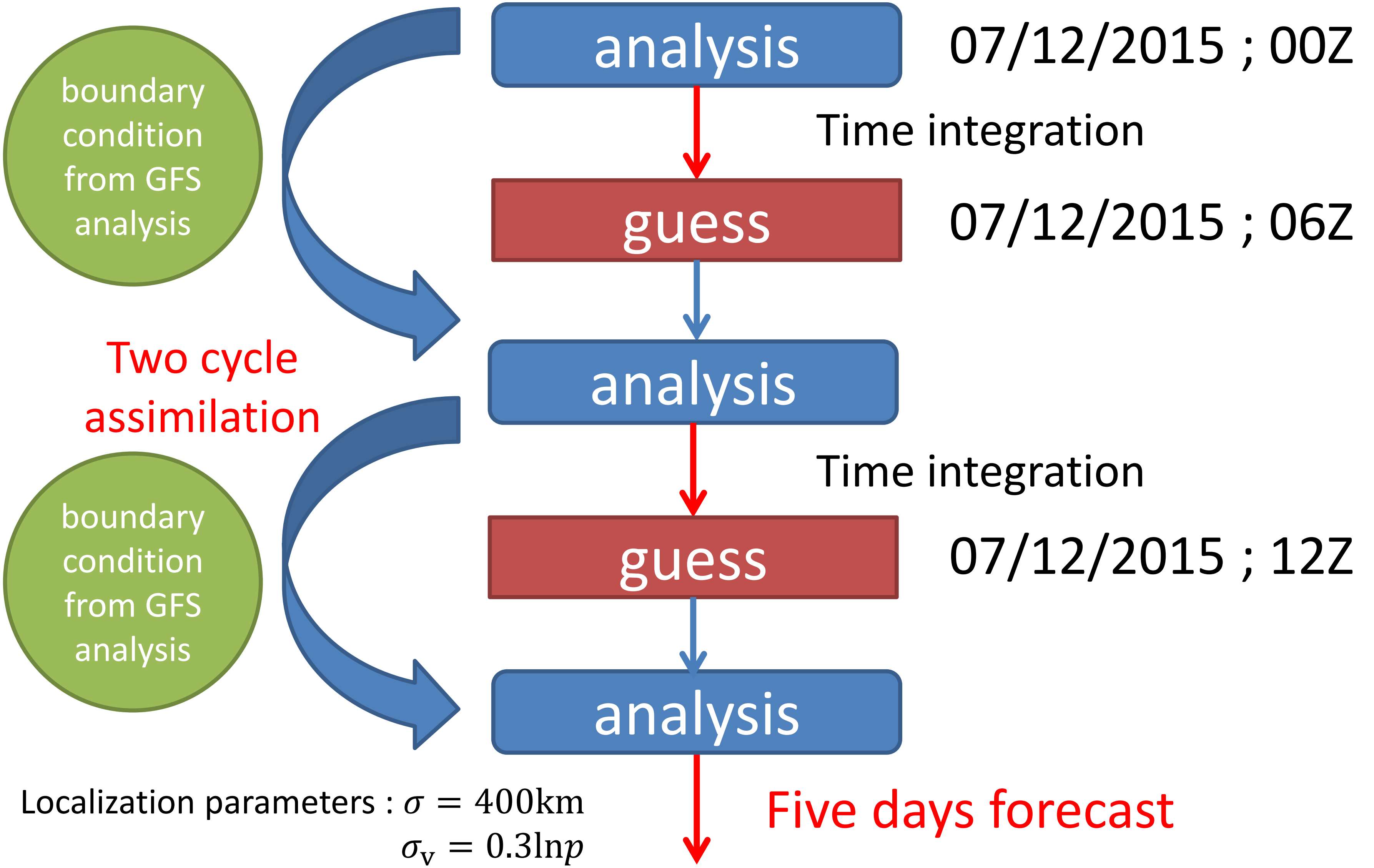
Overview of the control(CTRL) experiment



Localization parameters : $\sigma = 400\text{km}$

$\sigma_{\text{v}} = 0.3\ln p$

Overview of the CTRL experiment



Localization parameters : $\sigma = 400\mathrm{km}$

$\sigma_{\mathrm{v}} = 0.3 \ln p$

Tracks in the CTRL experiment

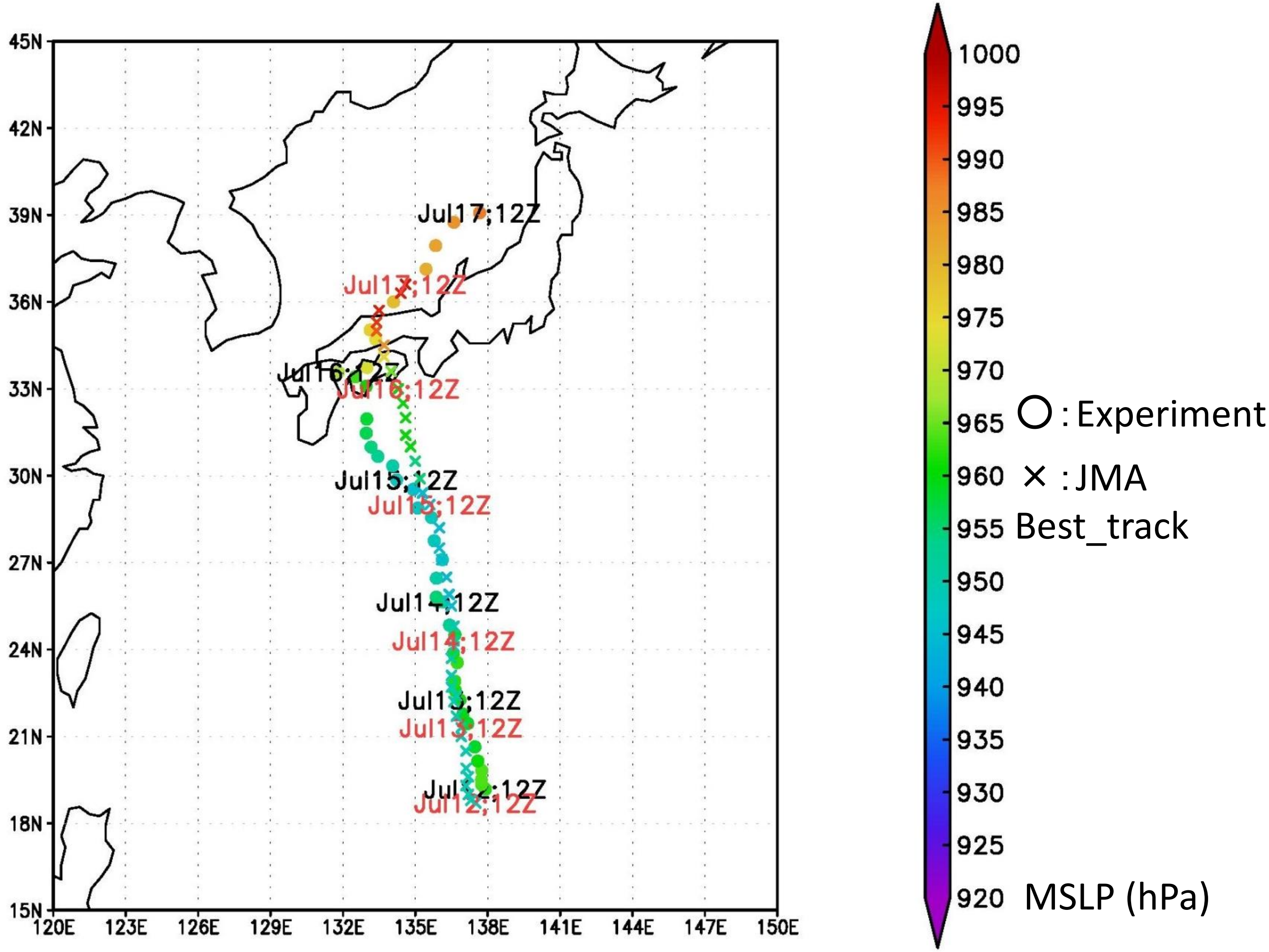


Fig.6 Typhoon tracks in the control run (circle) and the JMA best track data (cross)

Time series of the track and intensity errors

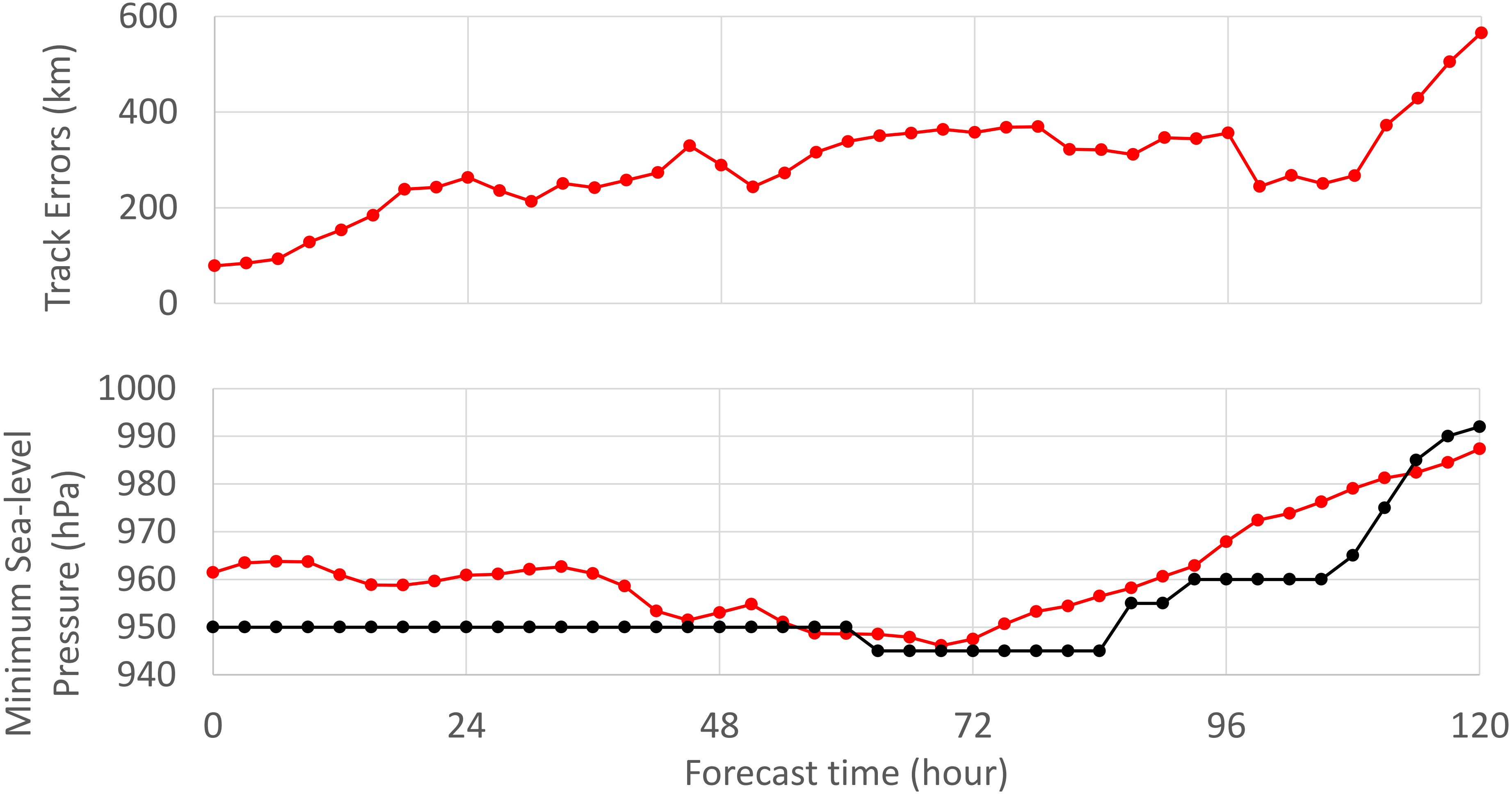


Fig.7 Typhoon track errors of the CTRL exp. (upper) and sea-level pressure at the center of the typhoon (lower). (black line: best track data, red line: CTRL exp.)

Time series of the track and intensity errors

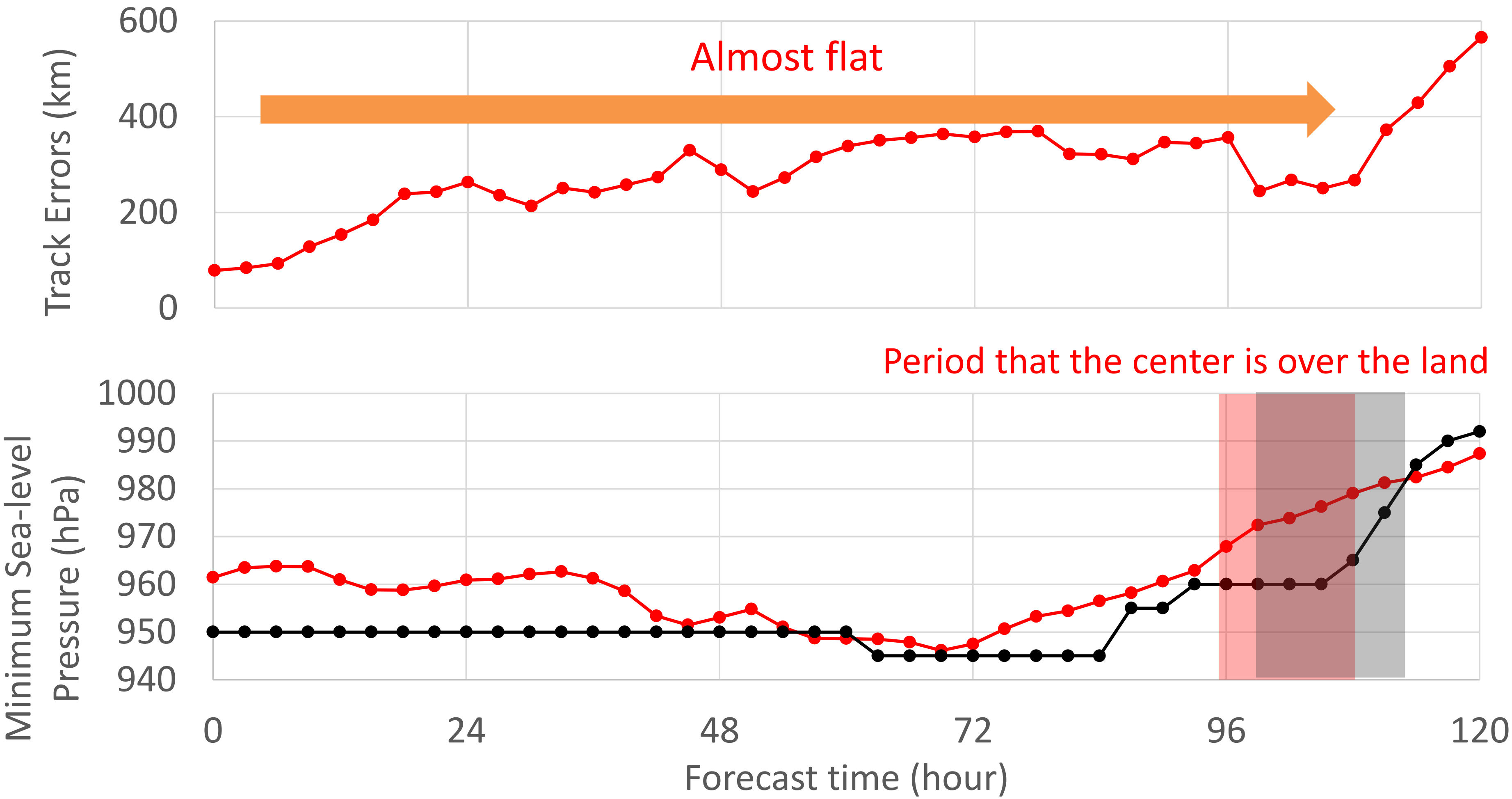
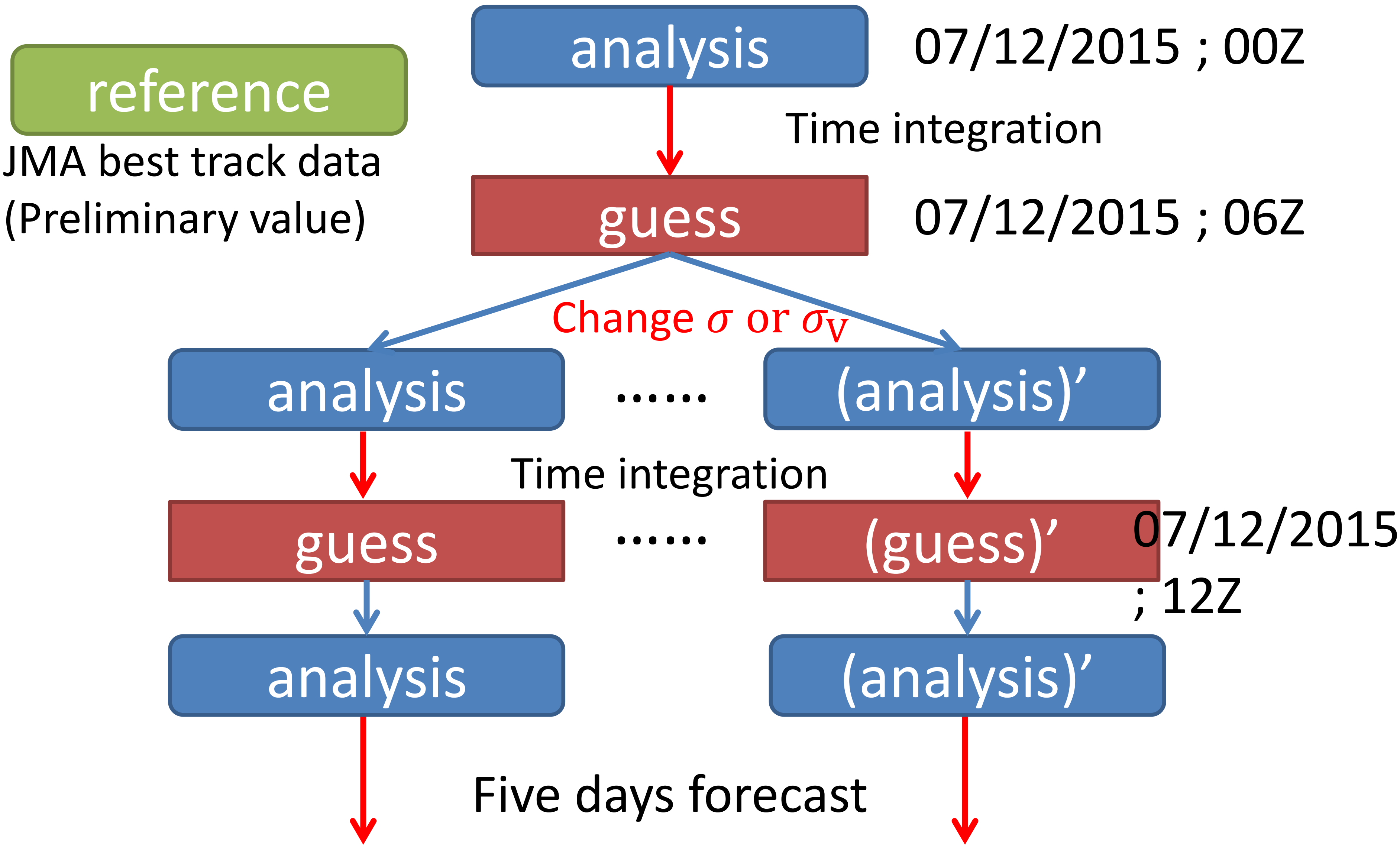


Fig.8 Typhoon track errors of the CTRL exp. (upper) and minimum sea-level pressure (lower). (black line: best track data, red line: CTRL exp.)

Overview of the sensitivity experiments



Impact of the horizontal localization scales

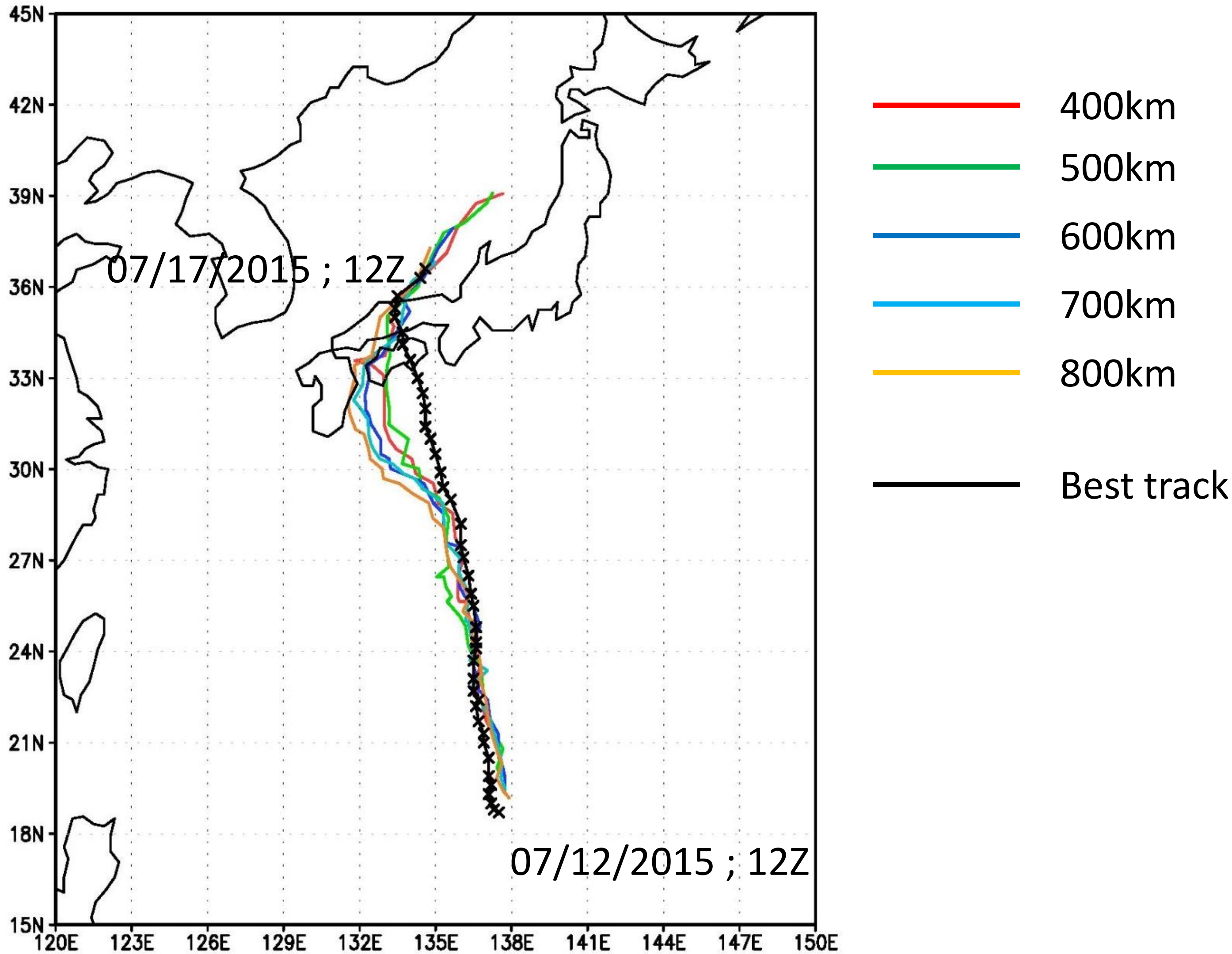


Fig.9 Typhoon tracks in the sensitivity experiments and best track data

The time series of track errors

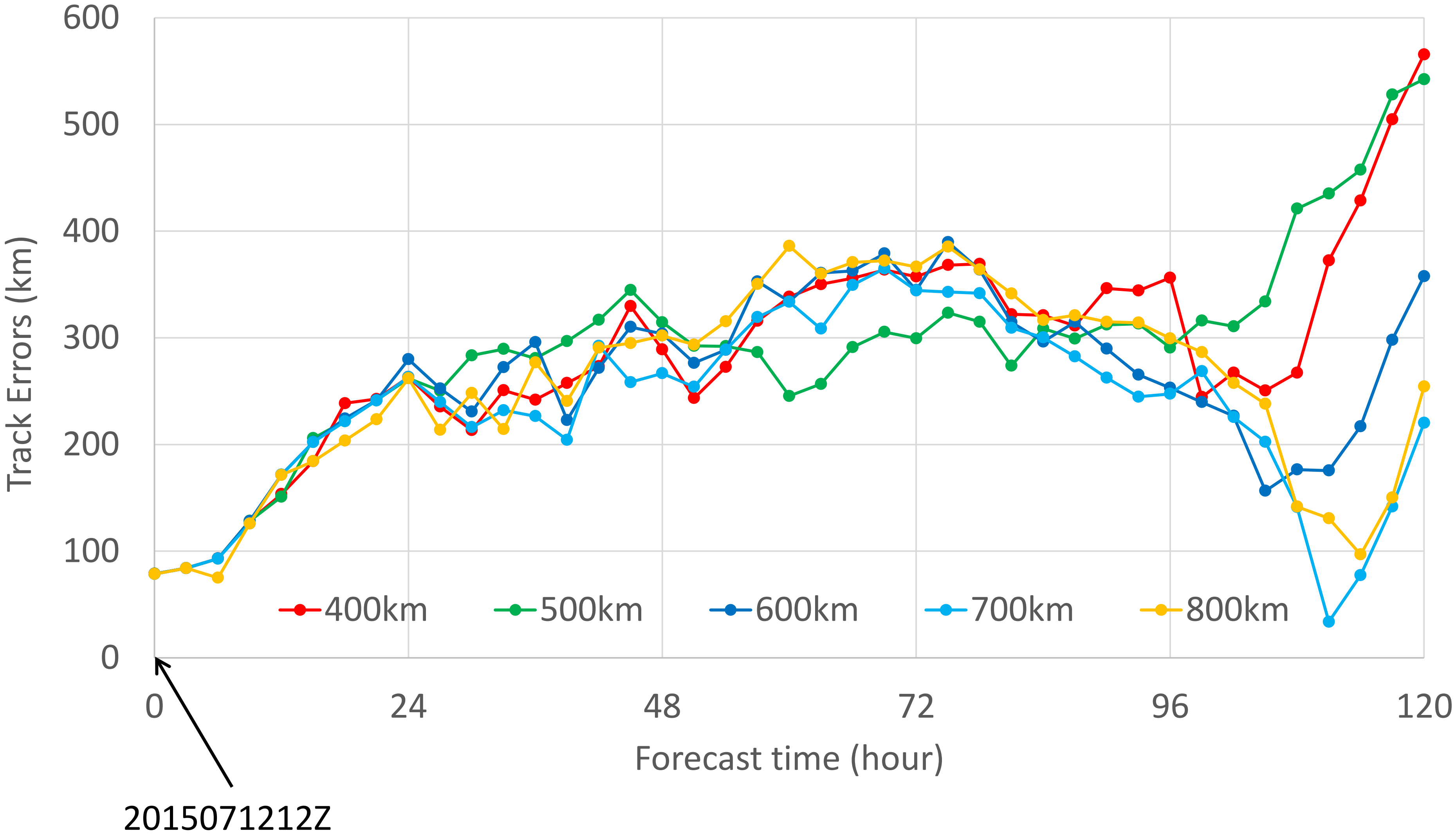


Fig.10 Typhoon tracks errors of the sensitivity experiments

The time series of intensity

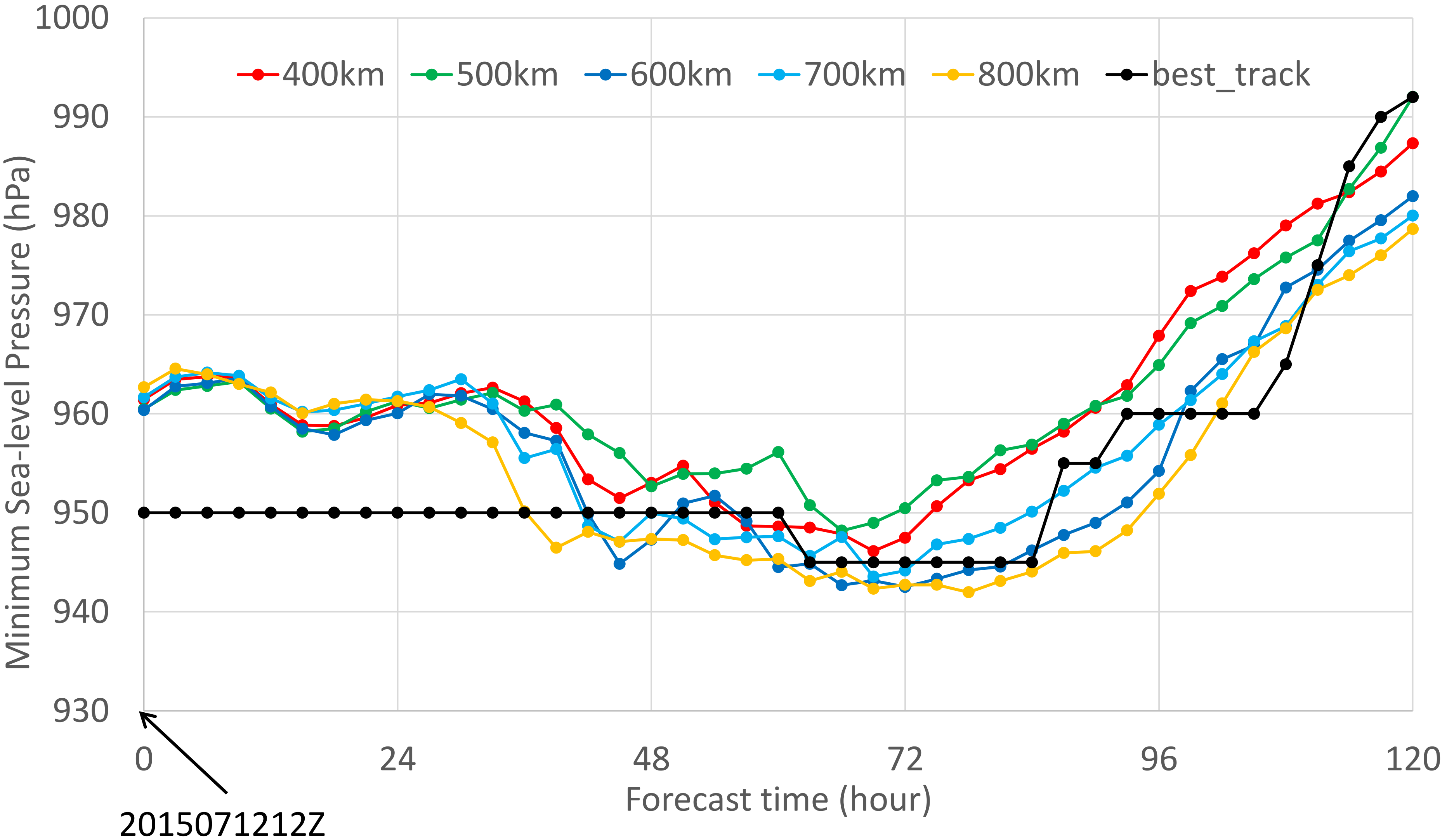


Fig.11 Typhoon intensity of the sensitivity experiments

Impact of the vertical localization scales

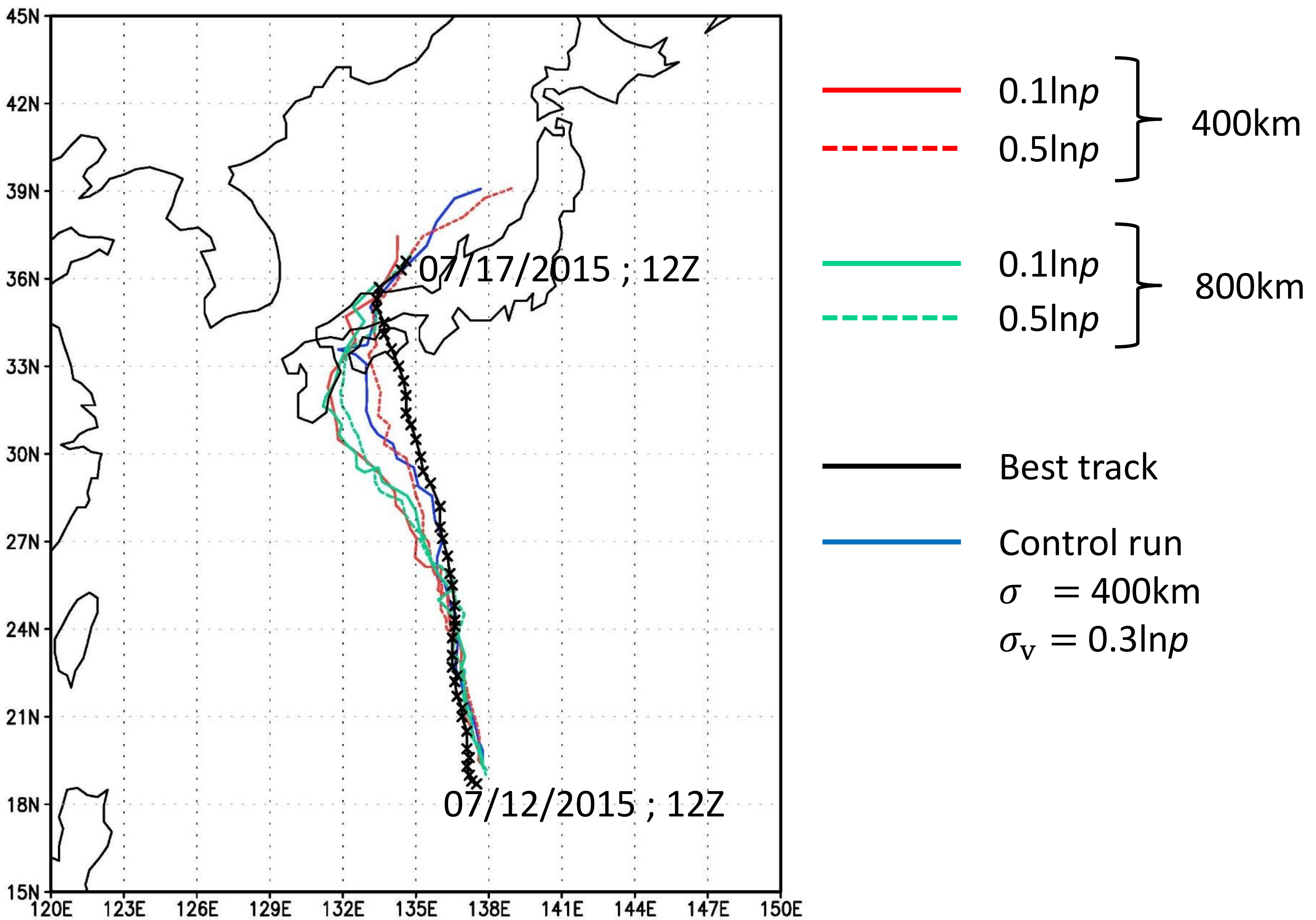


Fig.12 Typhoon tracks in the sensitivity experiments and best track data

The time series of track errors

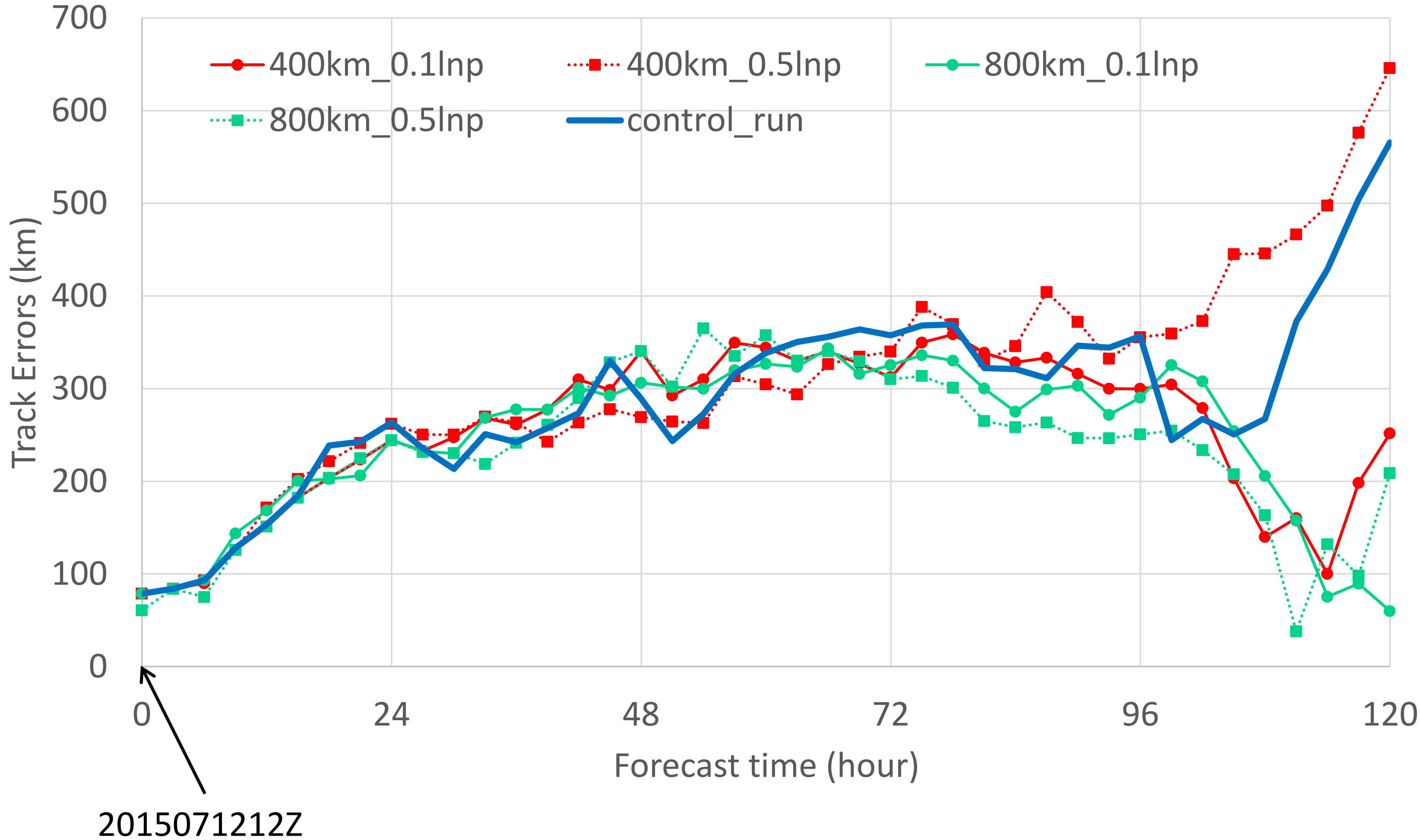


Fig.13 Typhoon tracks errors of the sensitivity experiments

The time series of intensity

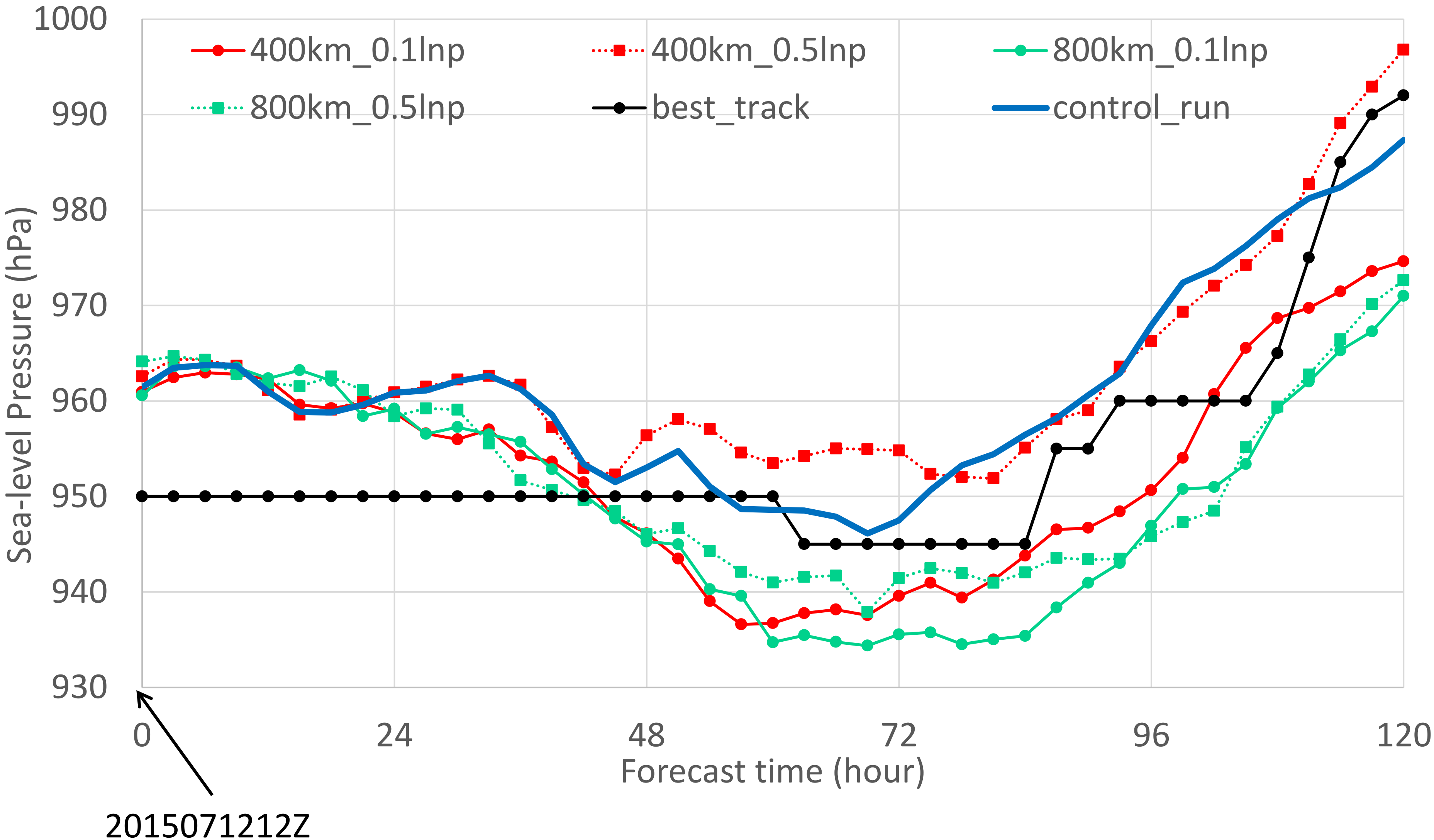


Fig.14 Typhoon intensity of the sensitivity experiments

Summary of the sensitivity experiments

・Horizontal

-> Changing horizontal localization scales has little impacts on the model results

-> The trend of the track and intensity changes using from 400-km to 800-km localization scales is not very clear

・Vertical

-> Changing vertical localization scales has also little impacts on the model results

-> Track and intensity using $\sigma = 400\mathrm{km}, \sigma_{\mathrm{v}} = 0.5\ln p$ is similar to the control experiment

Introduce TC vital assimilation

- Initializing a representative vortex in the correct position and of appropriate intensity remains a serious challenge
(Kleist, 2011; Wu et al. 2010; Kunii, 2015)
- A strategy for vortex initialization is TC vital assimilation
- In this case, we used minimum sea-level pressure(MSLP) and the position data as a TC vital data
- Tested only one cycle at 00Z 13th July 2015

The analysis increment without TC vital data

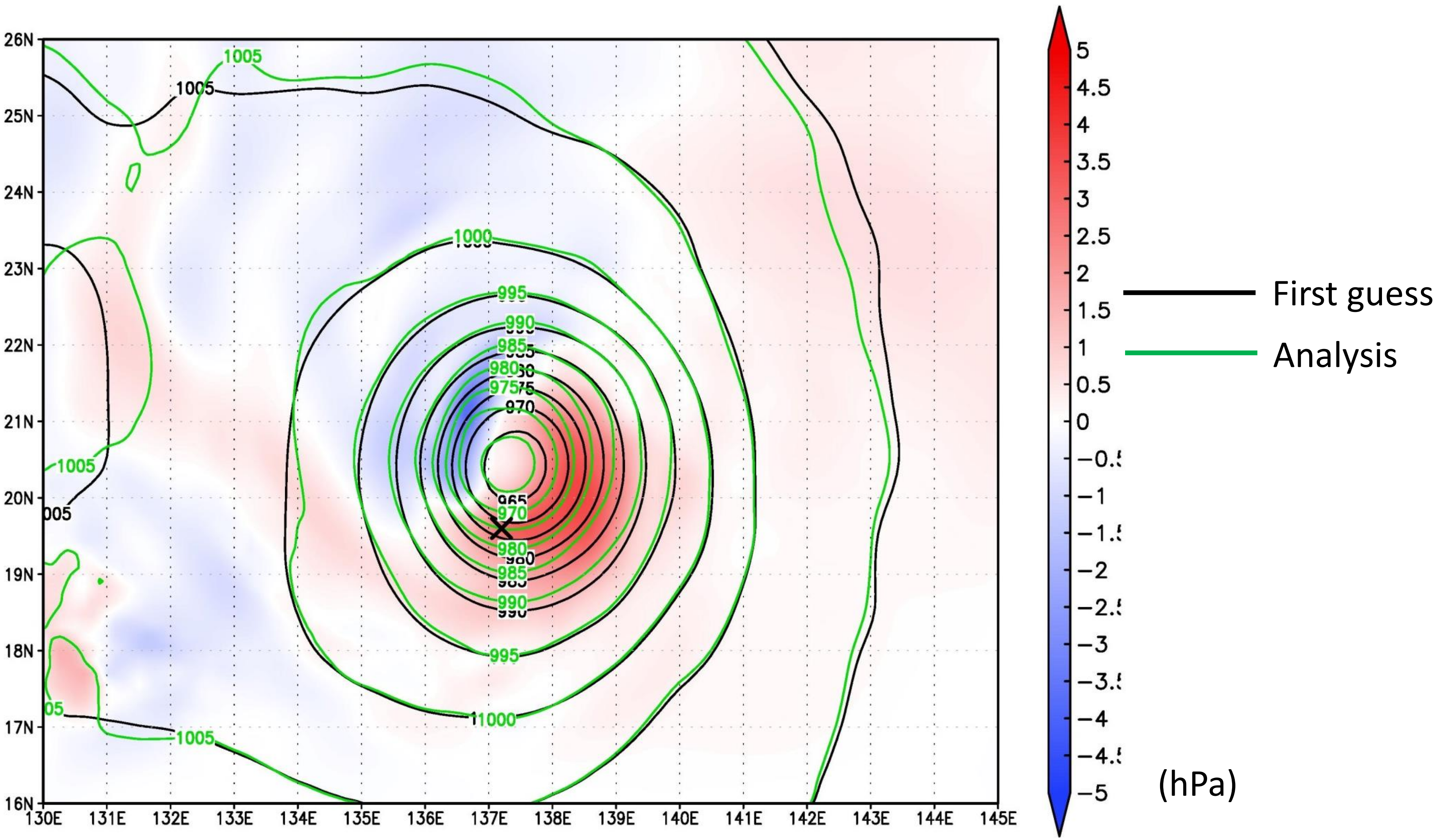


Fig. 15 Horizontal distribution of the SLP (hPa;contour) at 00Z 13th July 2015 without TC vital data.

The analysis increment with TC vital data

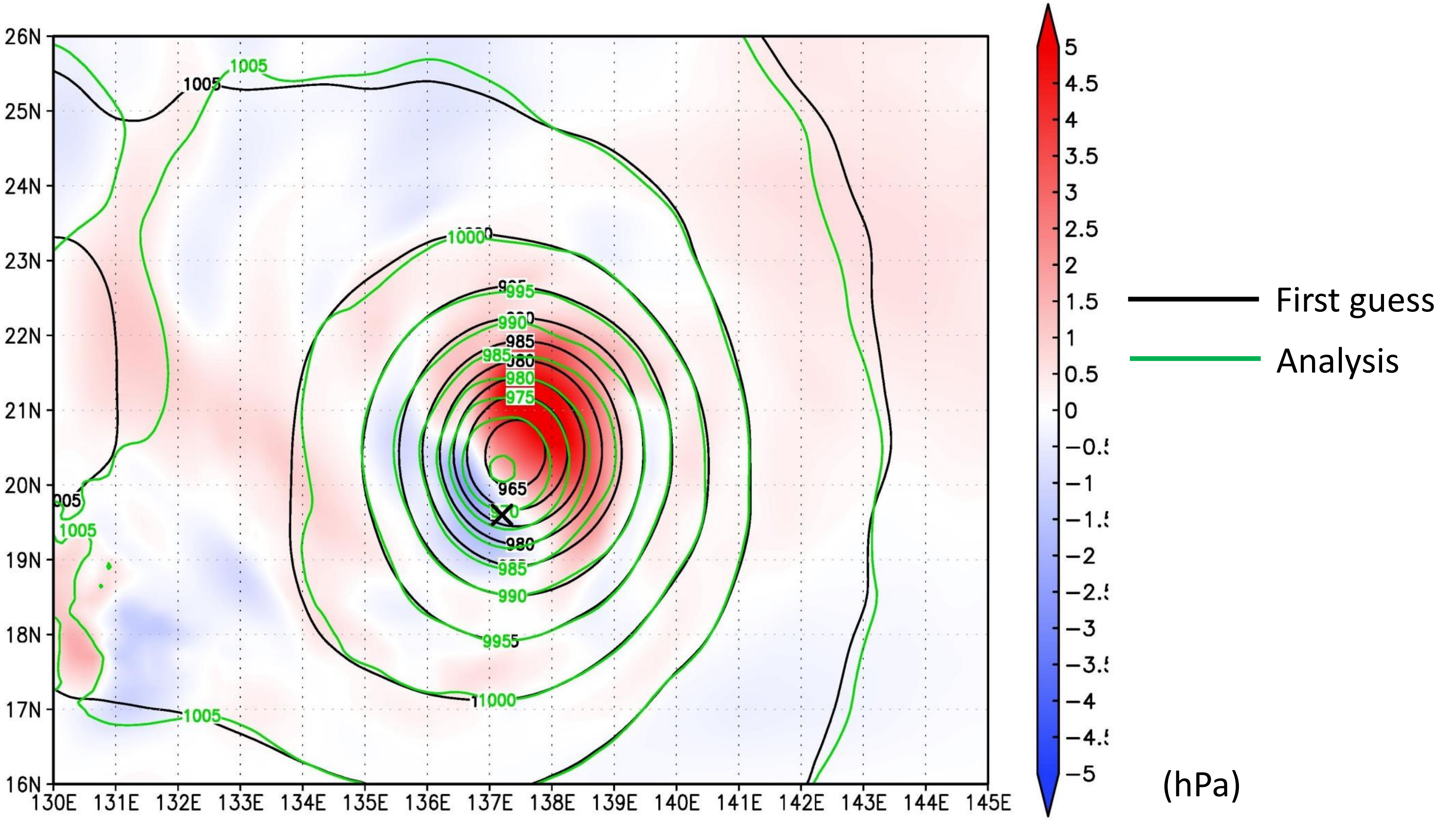


Fig. 16 Horizontal distribution of the SLP (hPa;contour) at 00Z 13th July 2015 with TC vital data.

The time series of track errors

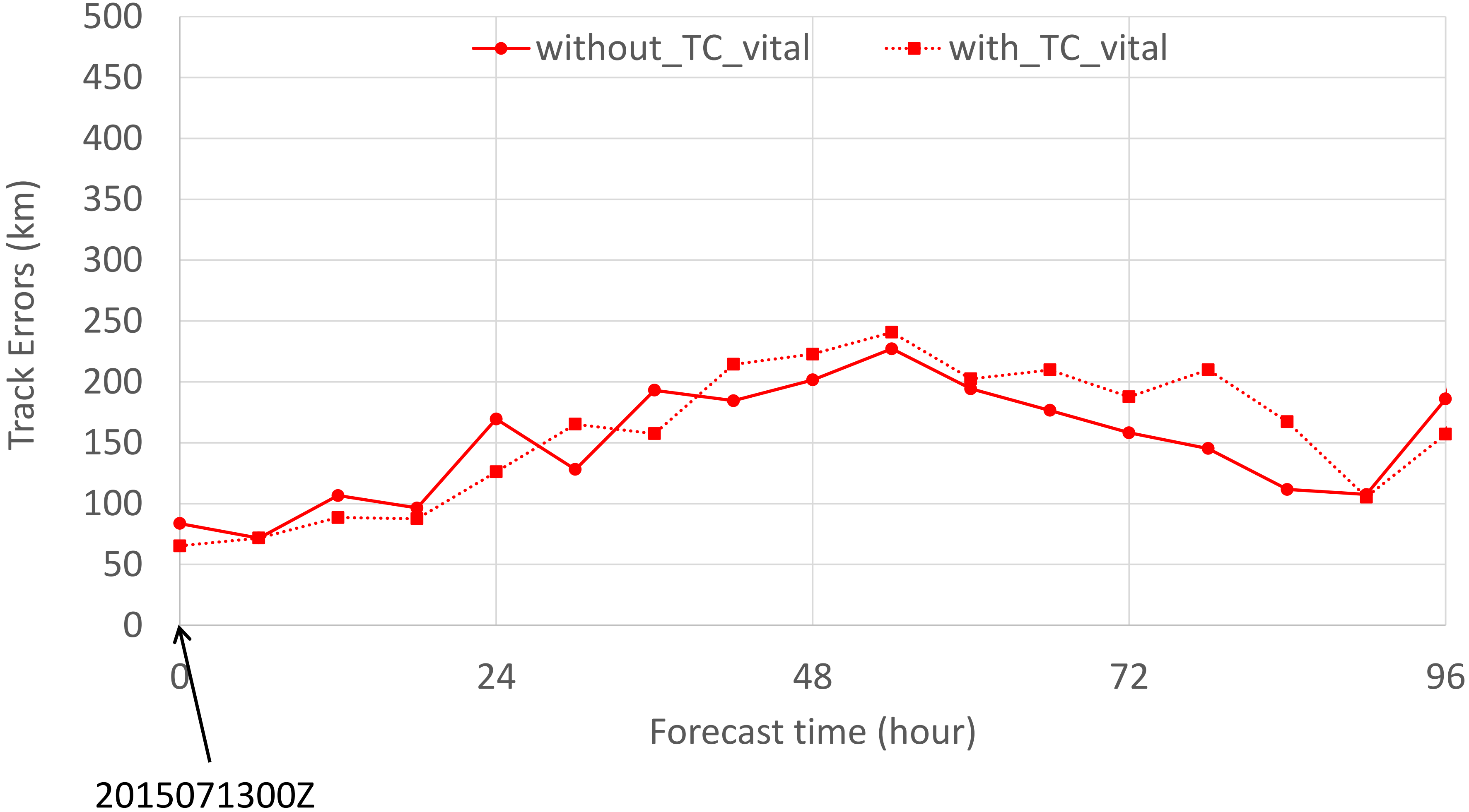


Fig.17 Typhoon tracks errors of the sensitivity experiments

The time series of sea-level pressure

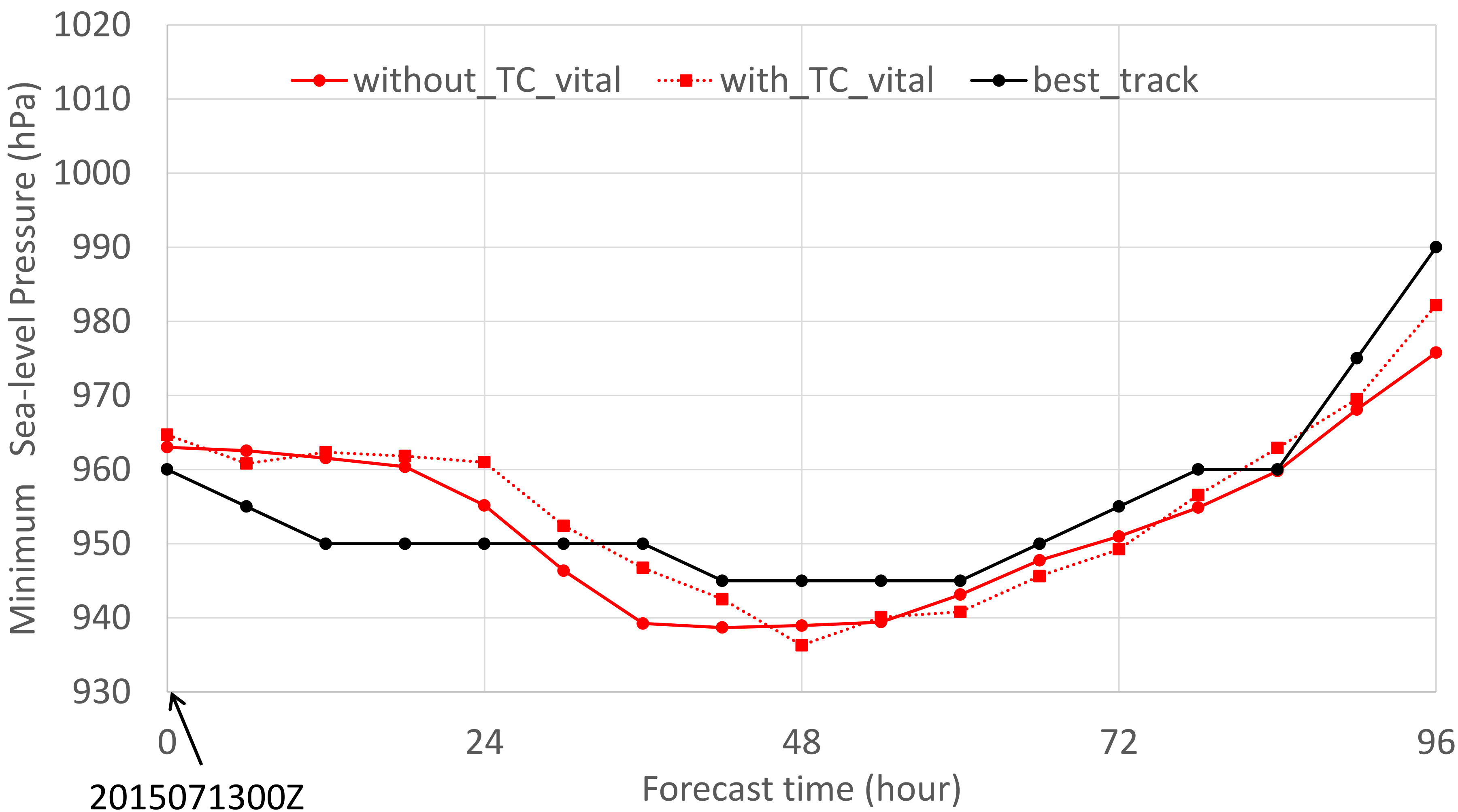


Fig.18 Typhoon intensity of the sensitivity experiments

The time series of sea-level pressure

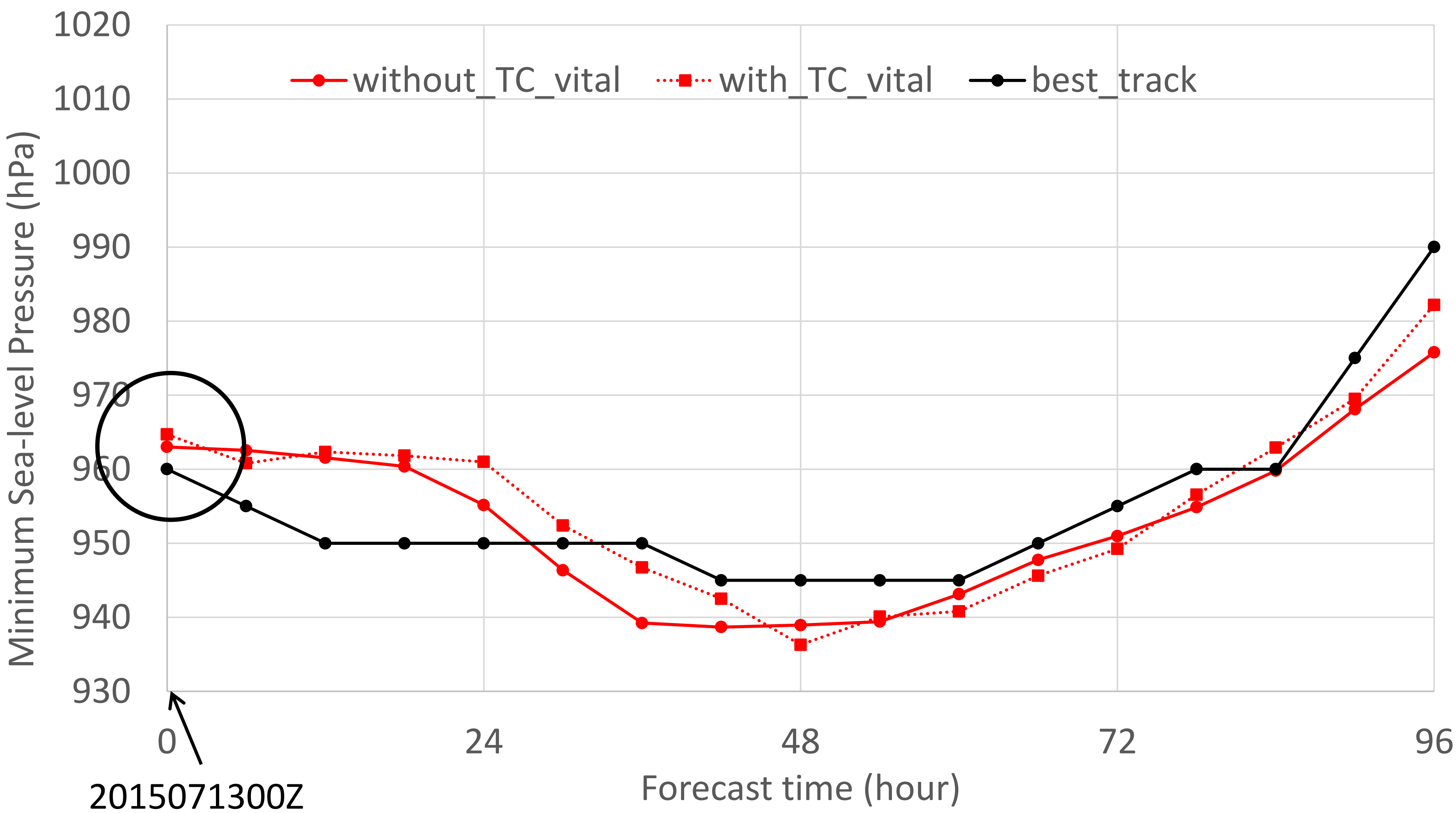


Fig.18 Typhoon intensity of the sensitivity experiments

Summary of the TC vital assimilation

- The TC vital assimilation helps to move the TC center towards the observed location

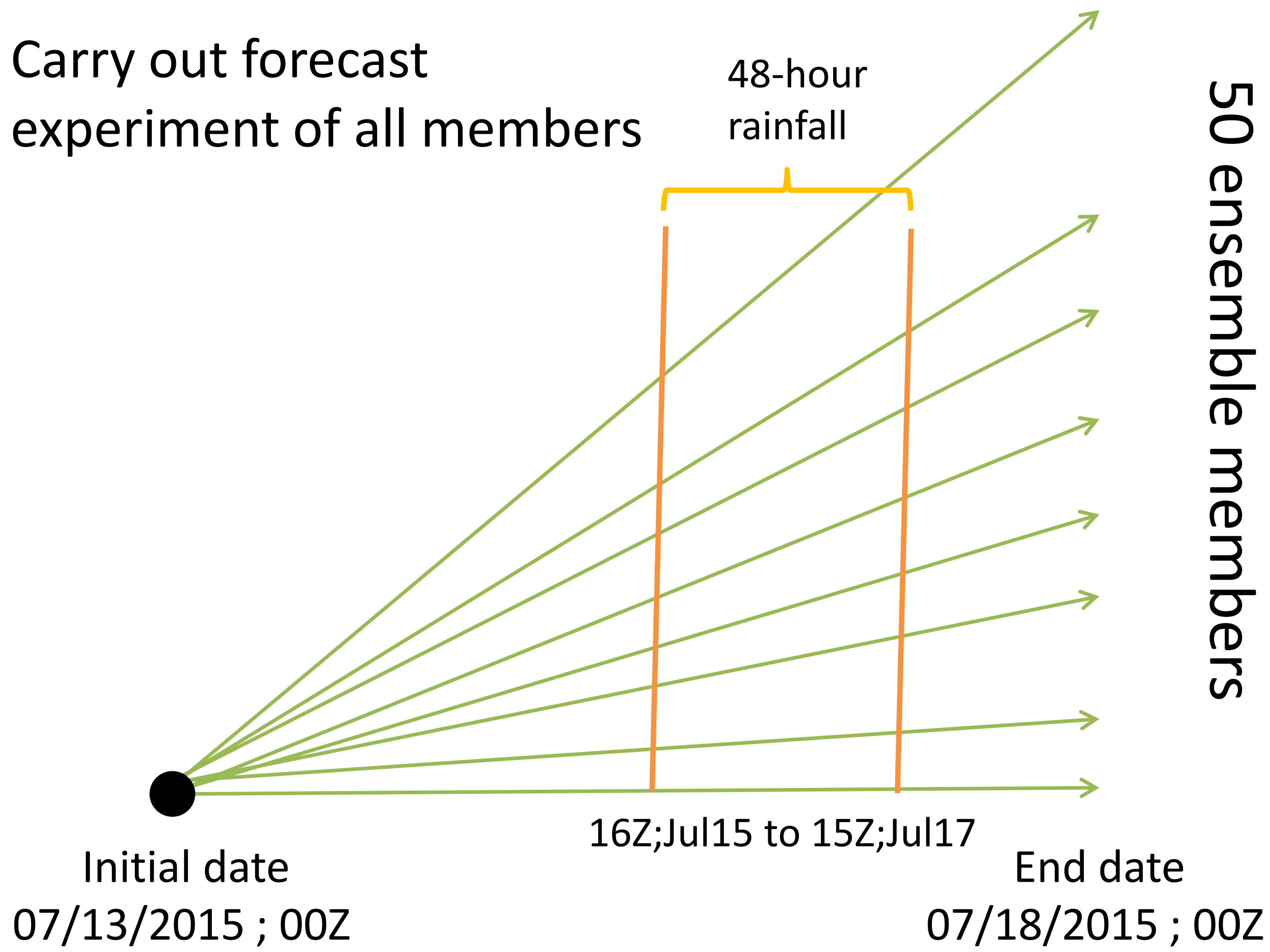
- It also improves the track forecasts until 24 hours

Ensemble rainfall forecasts

- Motivation -> I'd like to investigate heavy rain by the typhoon Nangka in more detail. However, the SCALE model has not been implemented in cumulus parameterization.

- Purpose -> Investigating predictability of ensemble forecasts and the rainfall event by typhoon Nangka in Kobe.

Overview of the ensemble forecasts



Comparison of the result vs. obs.

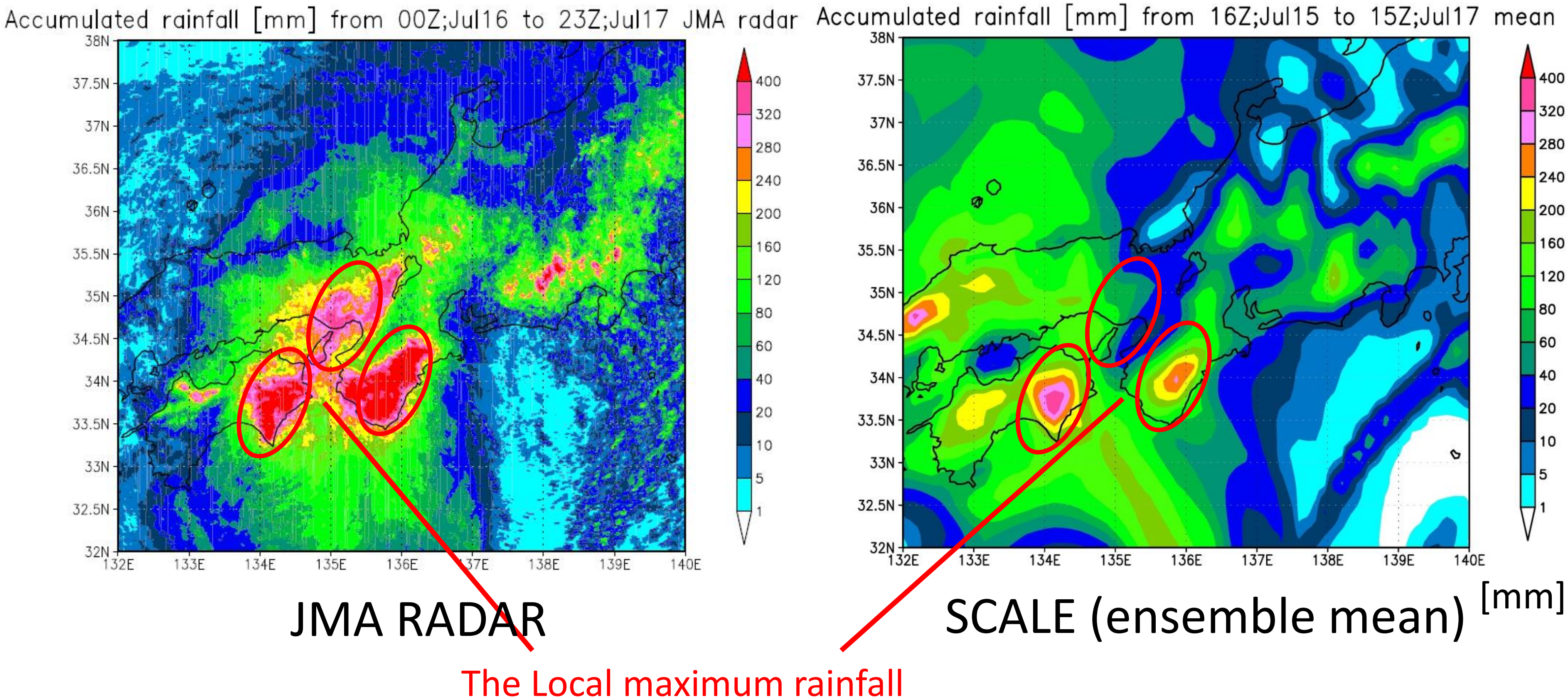


Fig.19 48-hour accumulated precipitation by JMA radar echo data (left)
48-hour accumulated precipitation in low resolution experiment (right)

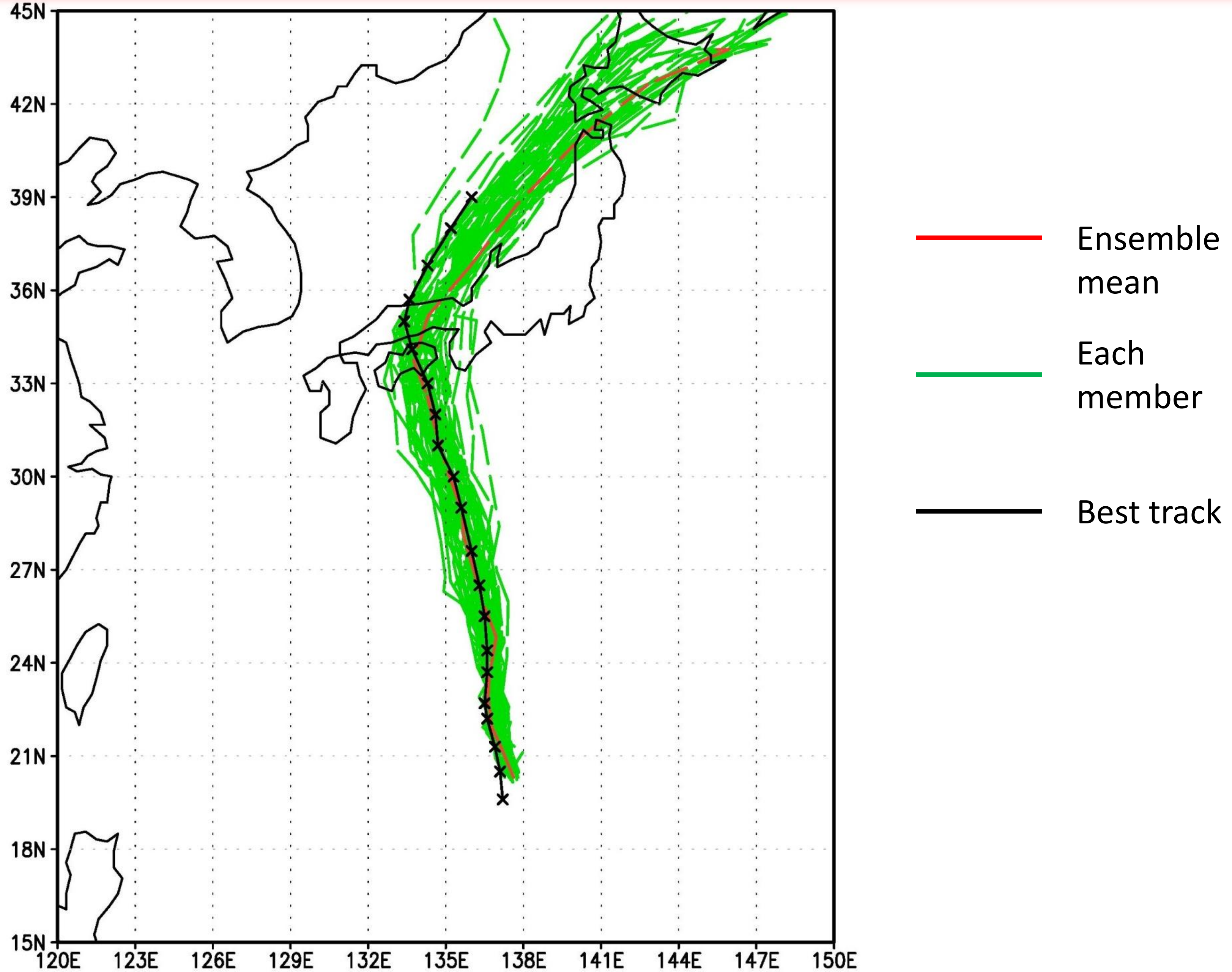
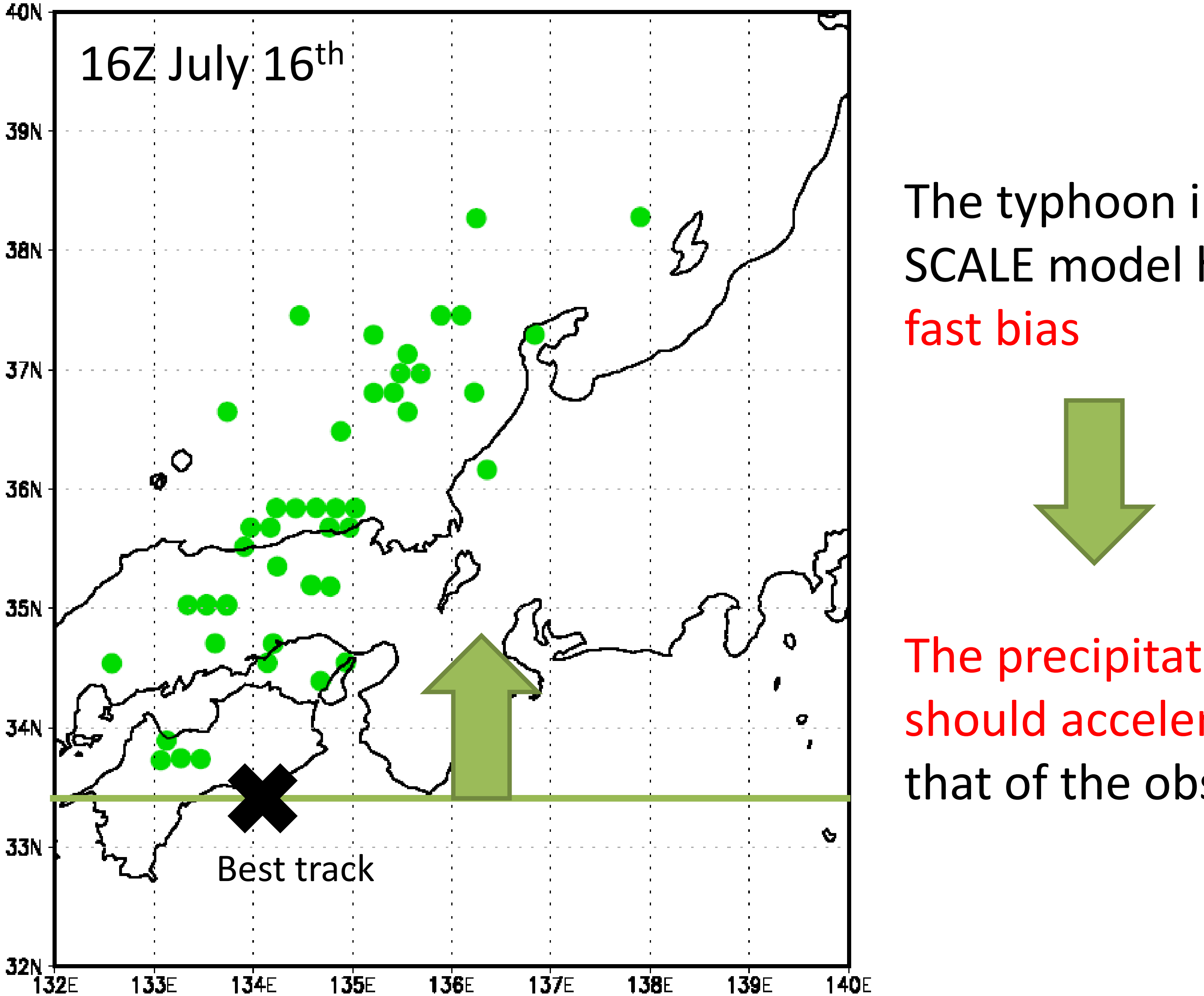


Fig.20 Tracks of the result each member, ensemble mean, and JMA best track data



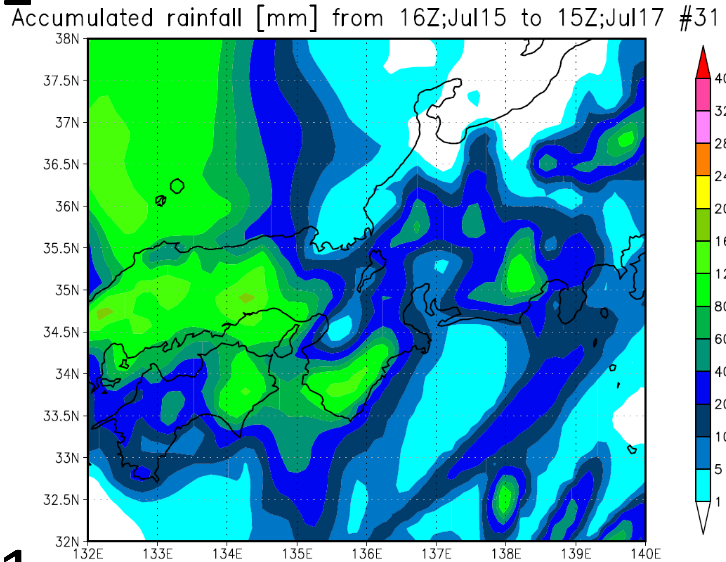
The typhoon in the SCALE model has fast bias

The precipitation period should accelerate than that of the observation

Fig.21 The center position of the typhoon each member at 16Z;Jul16th

Distinct four members

#31



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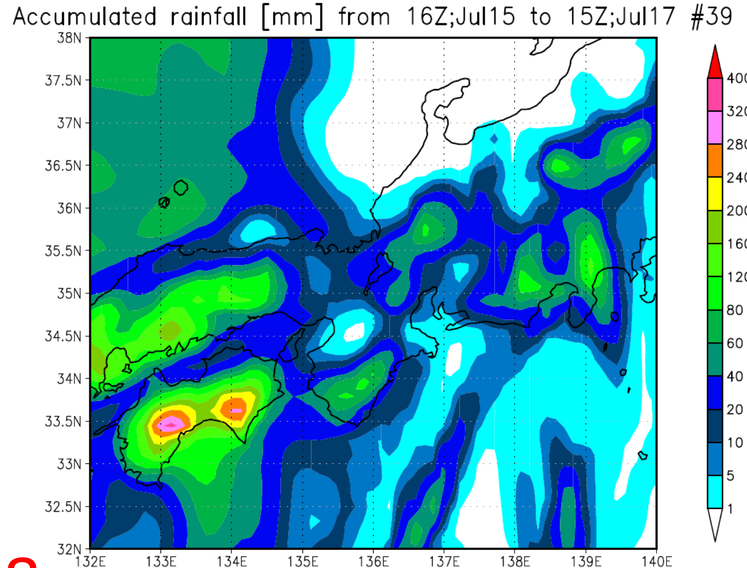

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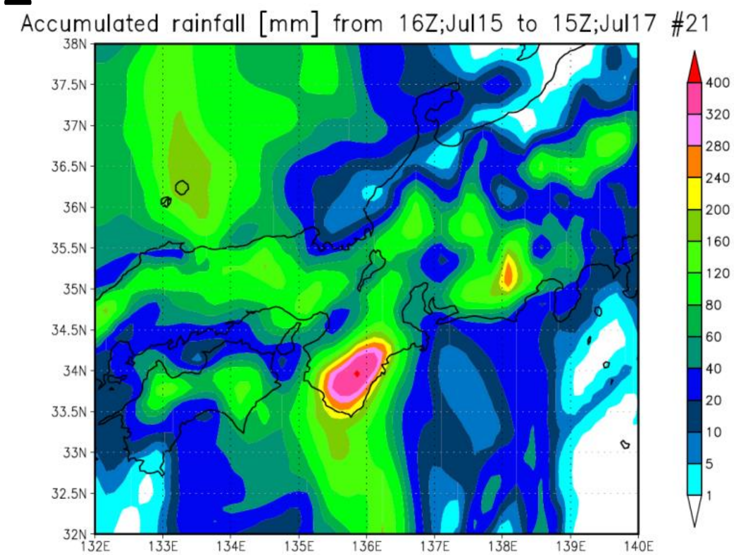

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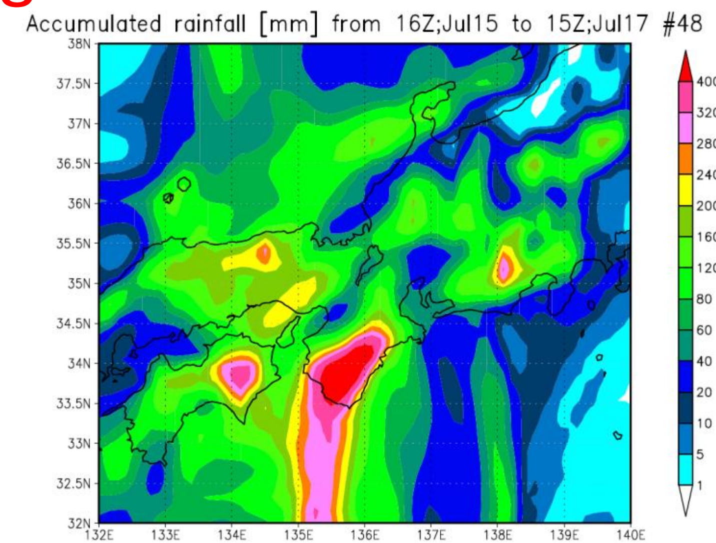


Fig.22 Disturibution of 48-hour accumulated rainfall of four each member

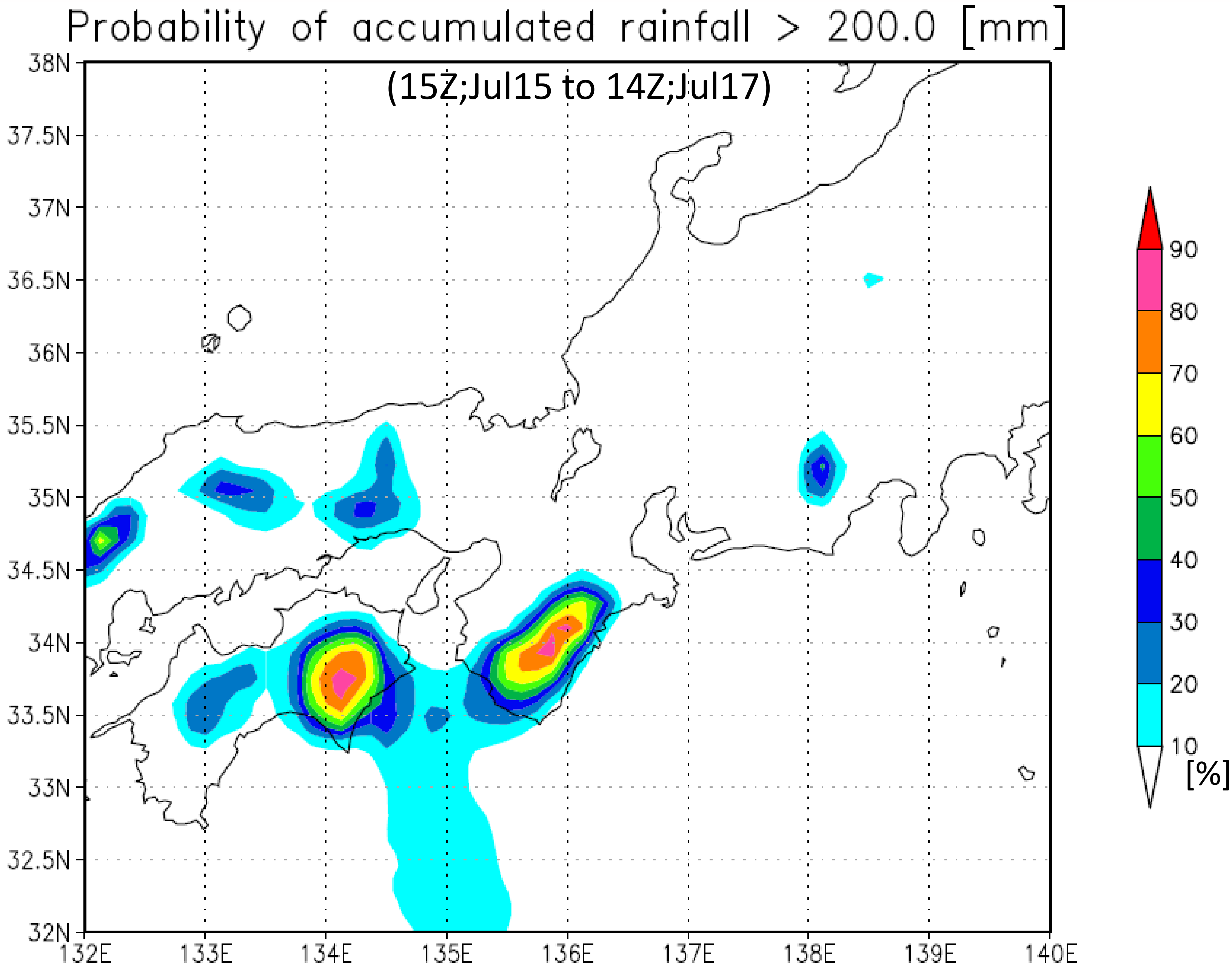


Fig.22 Probability about accumulated precipitation of getting beyond 200 [mm]

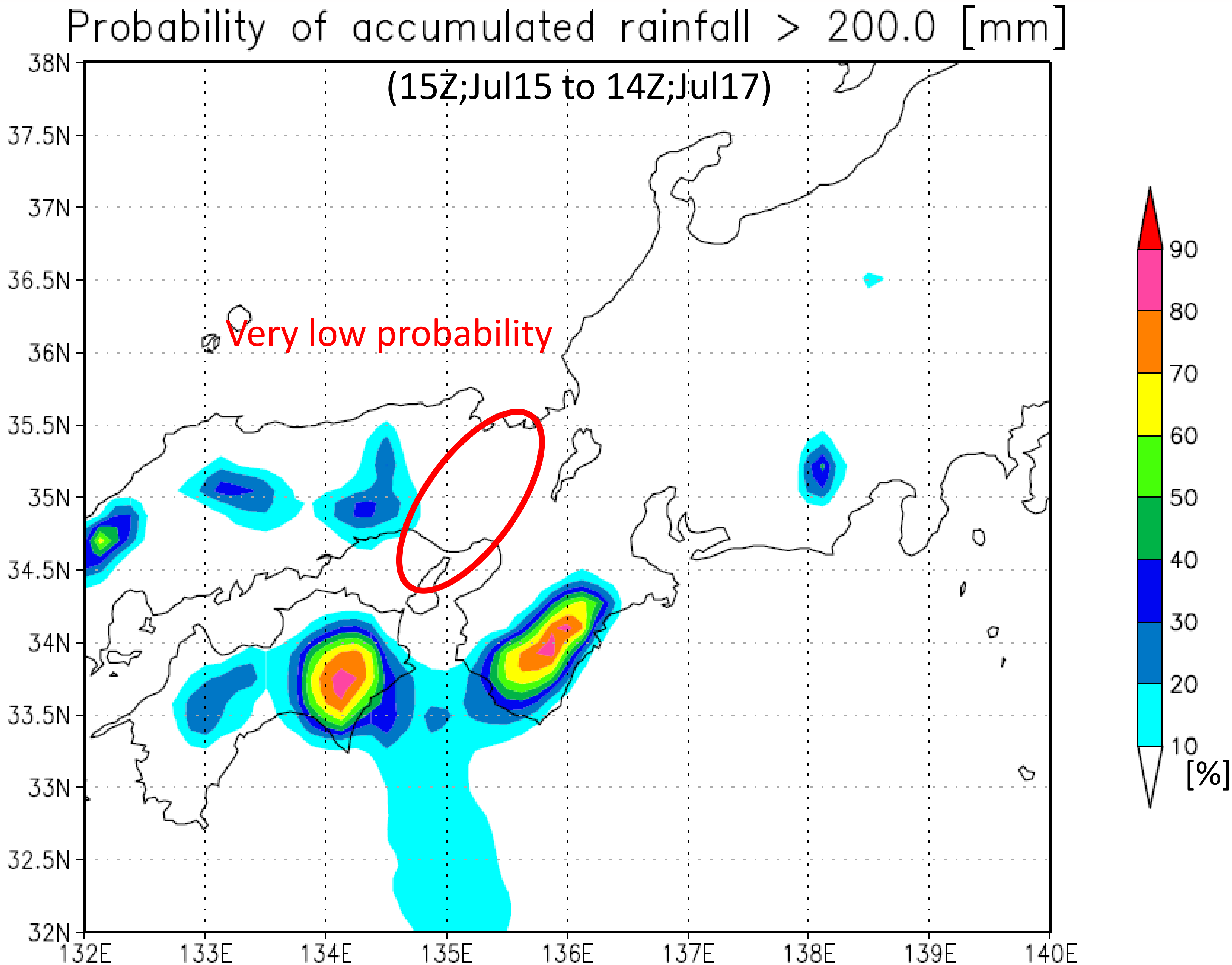


Fig.22 Probability about accumulated precipitation of getting beyond 200 [mm]

High-resolution (3km) forecasts experiment

- The 50-member near-real-time SCALE-LETKF is run at 18-km resolution, which is too low for simulating the local heavy rainfall event
  - The SCALE model does not have cumulus parameterization

- We run downscaling (offline nesting) forecasts at 3-km resolution based on one best (18-km resolution) member

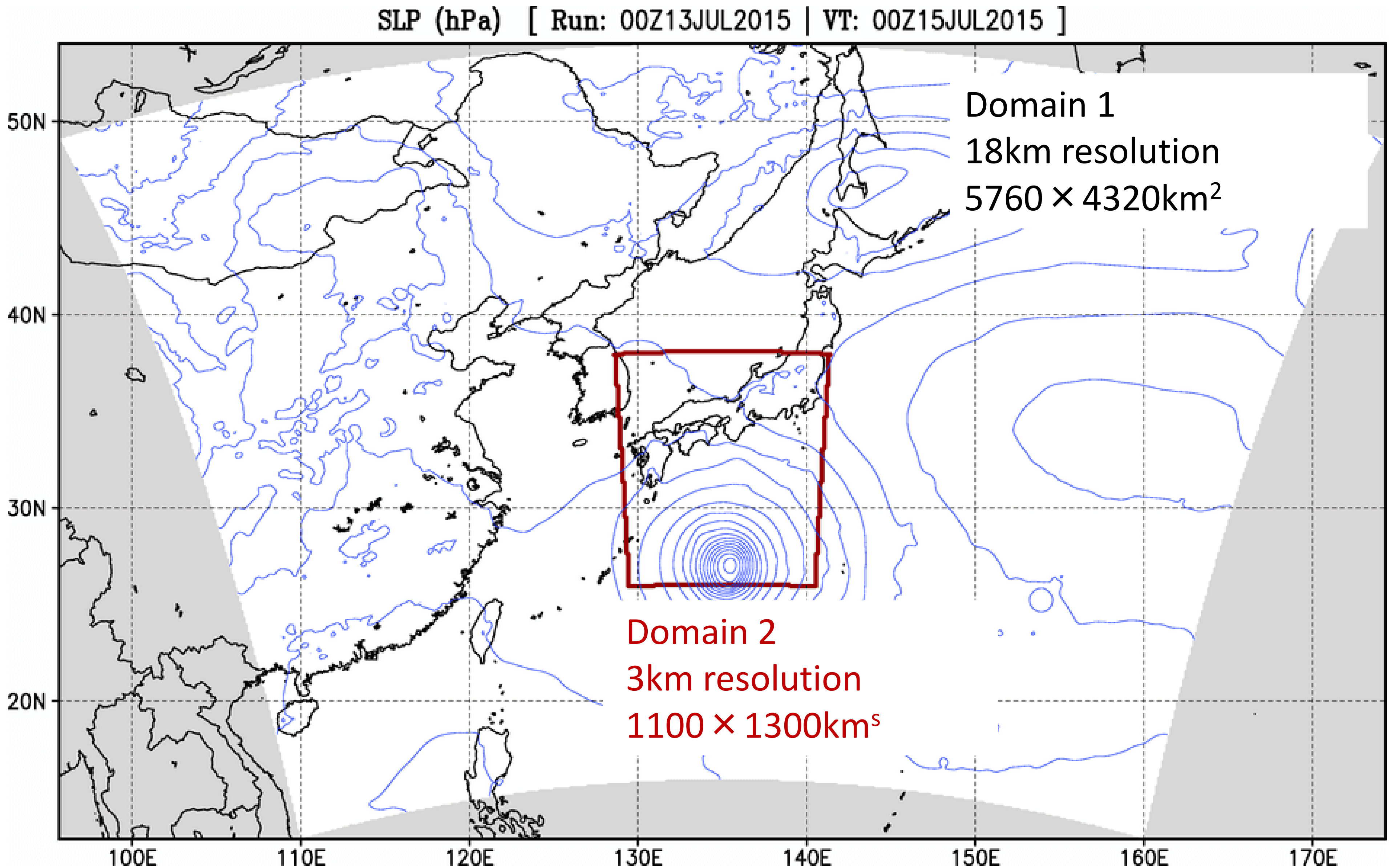
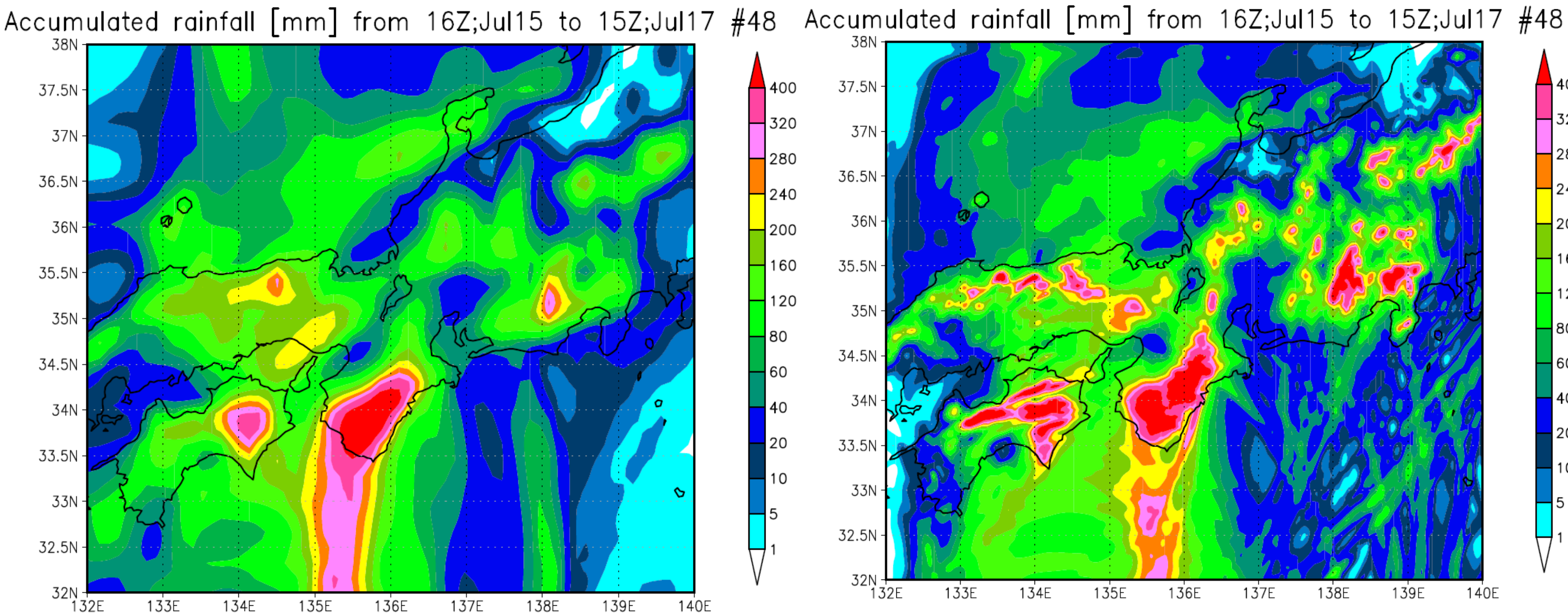


Fig.23 Domain 1 and Domain 2 size

Comparison between low-resolution and high-resolution model simulation

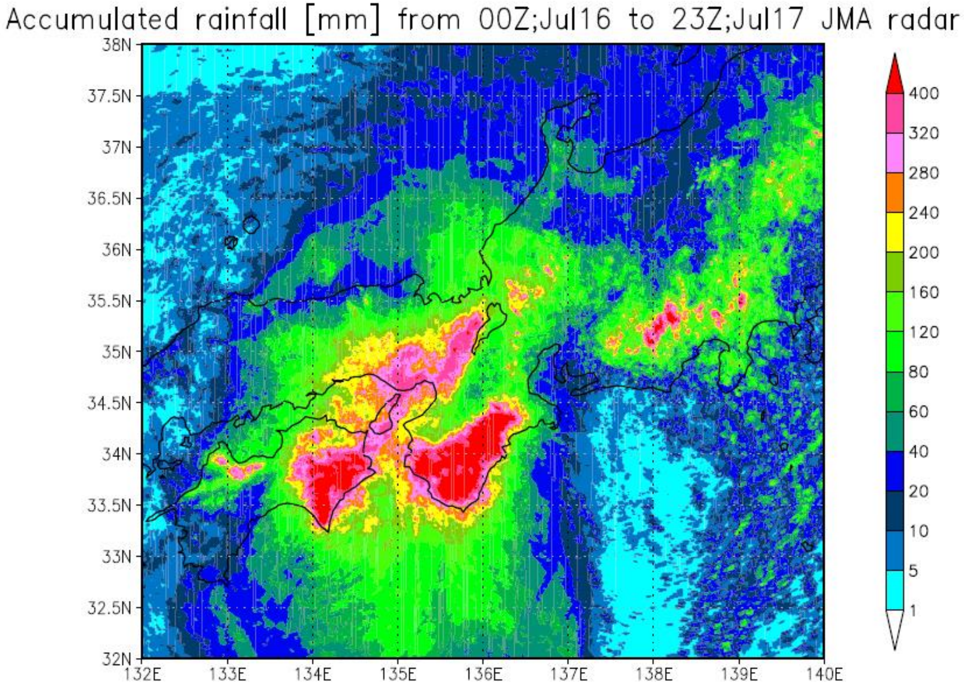


MAX: 533.9 mm

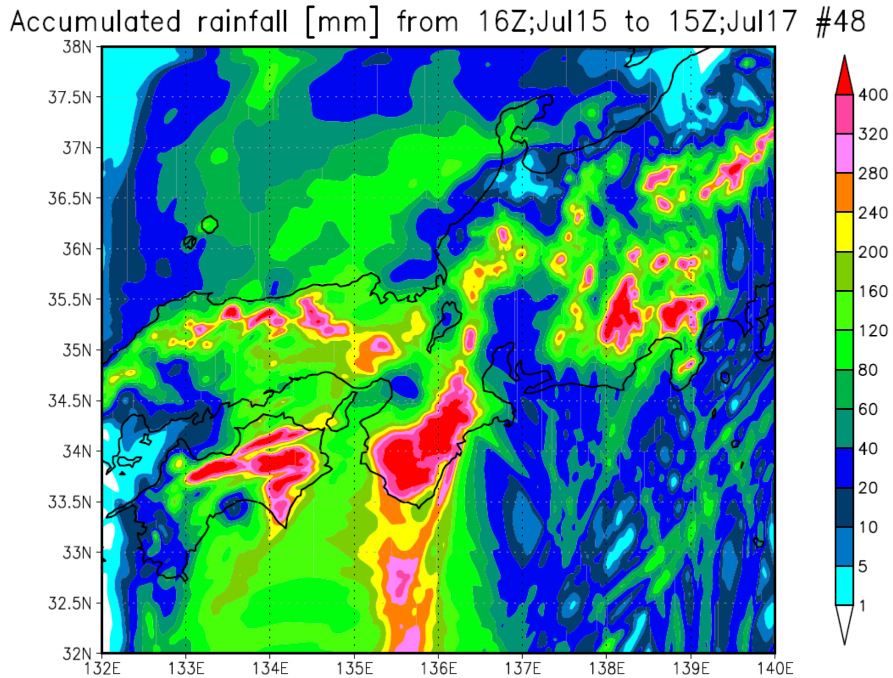
MAX: 921.0 mm

Fig.24 48-hour accumulated precipitation of high-resolution experiment is based on member 48 (right) and that of low resolution experiment (left)

Comparison between observation and high-resolution model simulation



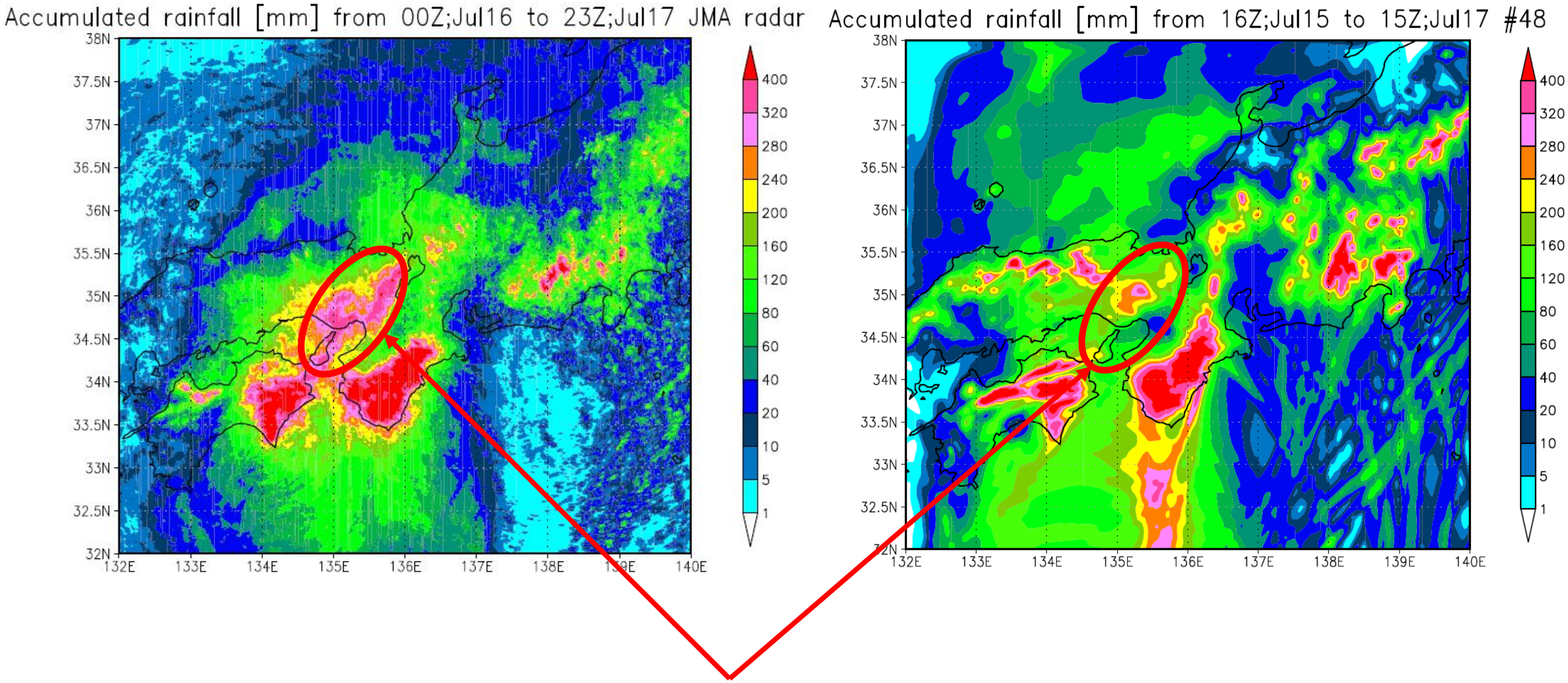
MAX: 913.45 mm



MAX: 921.0 mm

Fig.25 48-hour accumulated precipitation of high-resolution experiment is based on member 48 (right) and that of observation (left)

Comparison between observation and high-resolution model simulation



The Local maximum rainfall in Kobe

Fig.25 48-hour accumulated precipitation of high-resolution experiment is based on member 48 (right) and that of observation (left)

Summary of the ensemble forecasts and the high-resolution experiment

- The SCALE model can simulate the accumulated rainfall of this event reasonably well, but the local maximum rainfall near Kobe city is difficult to be predicted

- Ensemble forecasts shows large variability of the rainfall amounts and distributions even with the small track spread

- Probability forecast maps can be computed from the ensemble forecasts

Summary of the ensemble forecasts and the high-resolution experiment (cont.)

▪3-km resolution forecast shows better results in both the distribution and the peak values of the accumulated rainfall

- The rainfall peak near Kobe is better simulated in the high-resolution experiment, but still not perfect

Conclusion

・The SCALE-LETKF system operates correctly

・Changing localization parameter little impact on the model results

・A high-resolution forecast in SCALE model is able to represent a rainfall event more correctly

Thank you for your kind attention!