All-sky microwave radiance assimilation in the JMA global NWP system

Masahiro Kazumori, Takashi Kadowaki and Hiroyuki Shimizu

Numerical Prediction Division, Forecast department, Japan Meteorological Agency

Current configuration of JMA global NWP system and satellite radiance data use

Forecast model(GSM: Global Spectral Model) and 4D-Var data assimilation (DA) system

- Outer model: TL959L100 (horizontal reso. 20km, top 0.01hPa)
- Inner model: TL319L100 (horizontal reso. 55km, top 0.01hPa)
- 6-hr assimilation window, incremental 4D-Var DA
- Analysis variables: Wind, surface pressure, specific humidity and temperature
- Climatological background error covariance matrix **B** in 4D-Var DA
- 11 day forecast from 12 UTC and 5.5 day forecast from 00, 06, 18 UTC initials.
- Radiative Transfer Model: RTTOV-10.2
- Bias correction Method for radiance data: VarBC

Satellite radiance data for operational use

- Microwave imager: AMSR2/GCOM-W, GMI/GPM, SSMIS/DMSP
- Microwave sounder: AMSU-A/Aqua, AMSU-A/NOAA, Metop, MHS/NOAA, Metop, ATMS/S-NPP, NOAA-20, SAPHIR/Megha-Tropiques
- Infrared radiance: AIRS/Aqua, IASI/Metop, CrIS/S-NPP, NOAA-20, CSR/GOES, Himawari-8, Meteosat

Monitored and evaluated radiance data

- AMSU-A, MHS/Metop-C, IASI/Metop-C, MWHS-2/FY-3C

Addition of outer-loop update in the DA system

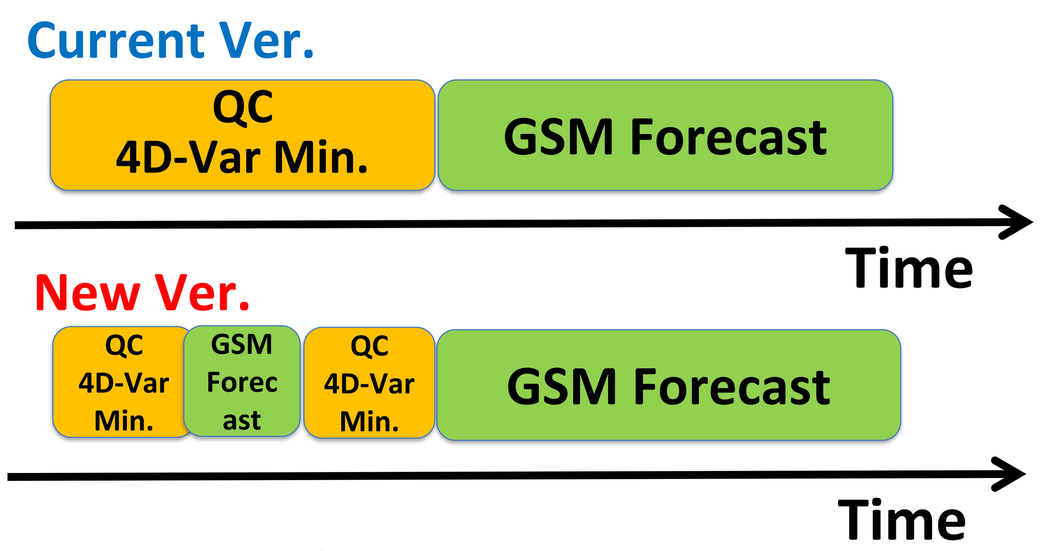
4D-Var cost function:

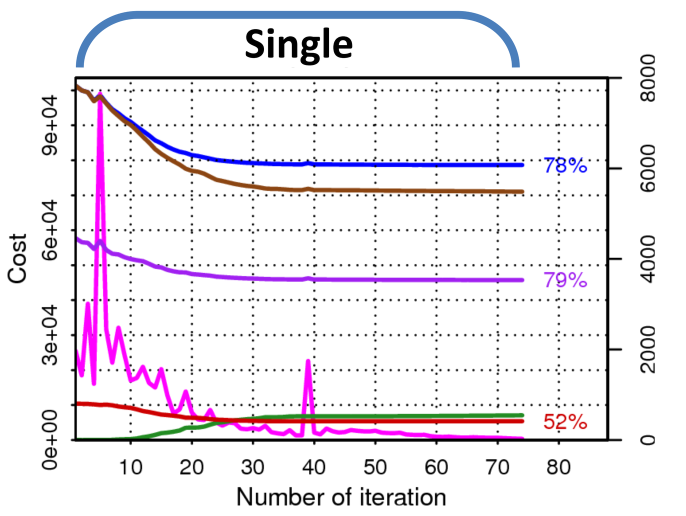
$$J(x)=\frac{1}{2}(x-x_b)^T B^{-1}(x-x_b)+\frac{1}{2}(H(x)-y)^T R^{-1}(H(x)-y)+J_c$$

x is the control variable, x_b is the background state, y is the vector of observations

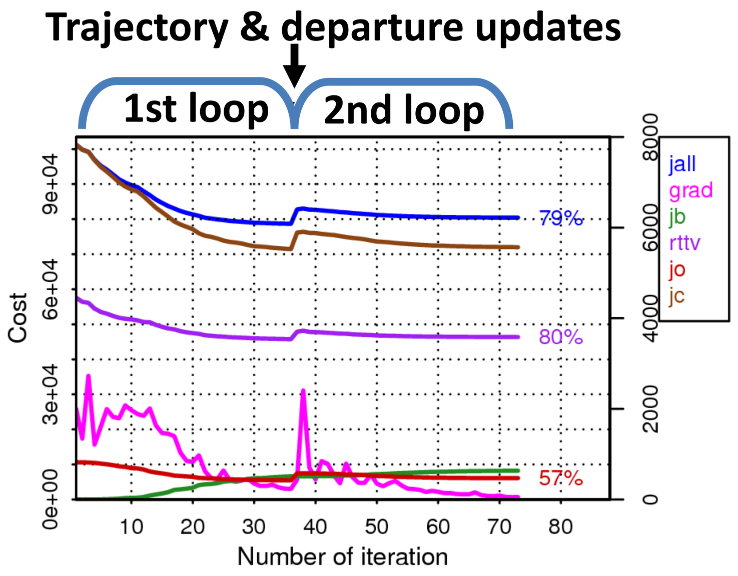
Assimilation = Finding the minimum of *J*

Non-linear effects are considered from the addition of the outer-loop. Comparable convergence of the cost function was obtained at the end of the final minimization.





Trajectory & departure updates



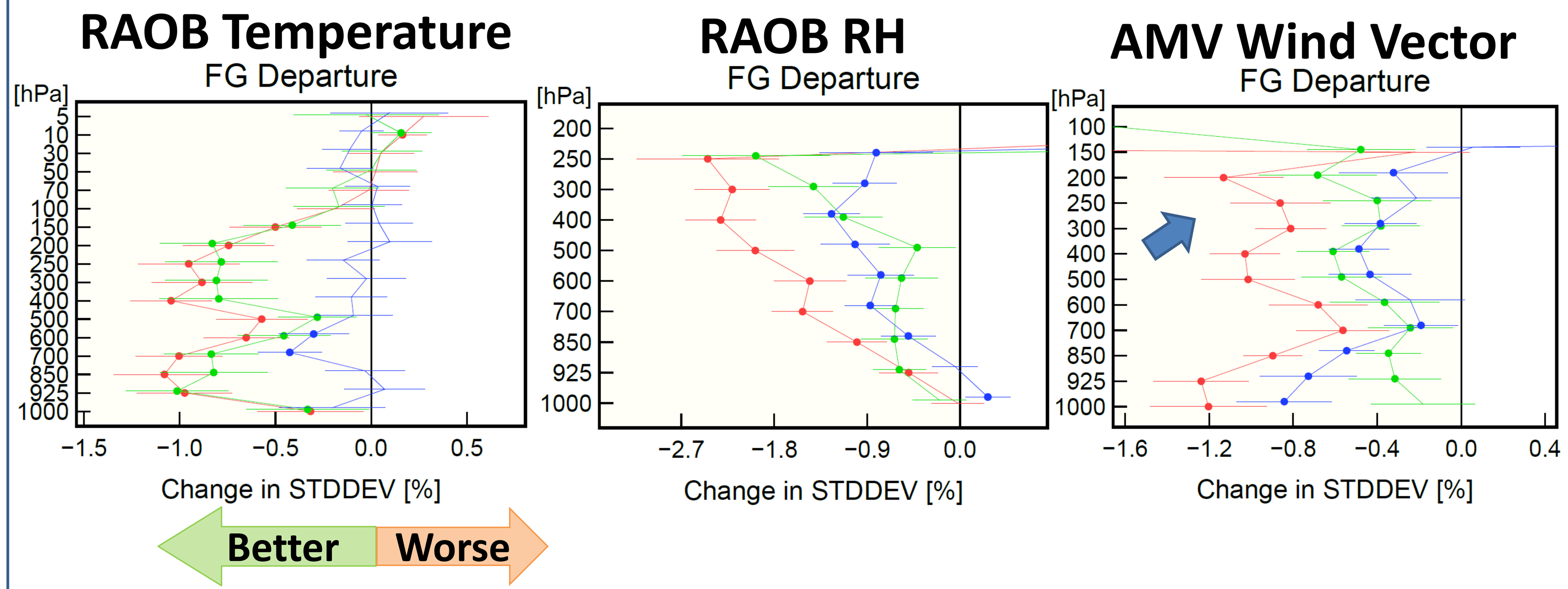
Impact evaluation:

FG fits to Observations

Changes in Std. of FG departure

Blue: J_{all}
Pink: ∇J
Green: J_b
Brown: J_o

CNTL: same as operation
TEST1: all-sky MW imager+sounder
TEST2: CNTL + outer-loop
TEST3: all-sky MW imager+sounder + outer-loop



Improved FG (First-Guess) fields (FT=3～9) of T, RH, WV were improved.

The outer-loop iteration brought significant improvements in the troposphere even when only the same observation dataset was used as the operational system (clear-sky assimilation).

All-sky assimilation of microwave imager and humidity sounder radiance data

All-sky assimilation of AMSR2, GMI, SSMIS F17, F18, MHS and addition of WindSat/Coriolis, MWRI/FY-3B,C

Clear-sky MW radiance assimilation

RTM: RTTOV-10 (rttov_direct, rttov_k)
Input profile: Temperature, Water vapor from GSM
Thinning: 200 km grid-box thinning for MW imager
Used MW imager: AMSR2, SSMIS (F17, F18), GMI
Used channels: 19V, 23V, 37V, 89V clear-sky oceanic data from MW imagers
MW humidity sounding ch. 183 GHz clear-sky data

All-sky MW radiance assimilation

RTM: RTTOV-10 (rttov_scatt, rttov_scatt_ad)
Input profile: Temperature, Water vapor, cloud liquid water, cloud ice water, cloud fraction, rain, snow from GSM
Thinning: Averaging with inner model grid and 150 km distance thinning for MW imagers
Used MW radiance for all-sky assimilation: AMSR2, SSMIS (17,18), GMI, **WindSat, MWRI**
MW Imager's used channels: 19V, 23V, 37V over ocean
MW humidity sounder's used channels: 183 GHz over land and ocean (**GMI, MHS only**. Others are clear sky assimilation)

DA experiments for comparison

DA system: JMA global 4D-Var DA system
Period: From June to October in 2017,
From Nov. 2017 to Feb in 2018
11-day forecast from 12 UTC initial conditions and 5.5-day forecast from 00, 06, 18 UTC initial conditions.

Obs. error setting: Geer A.J. and P. Bauer (2011) symmetric observation assignment based on cloud amount
Super-obs.: MW imager radiance data are averaged in the inner model grid and thinned in 150 km distance.
QC: Data removal in model biased area and convective cloud conditions (e.g., cold sector for MW imager radiance data and deep convective conditions for MW humidity sounder radiance data)

Results of DA experiments

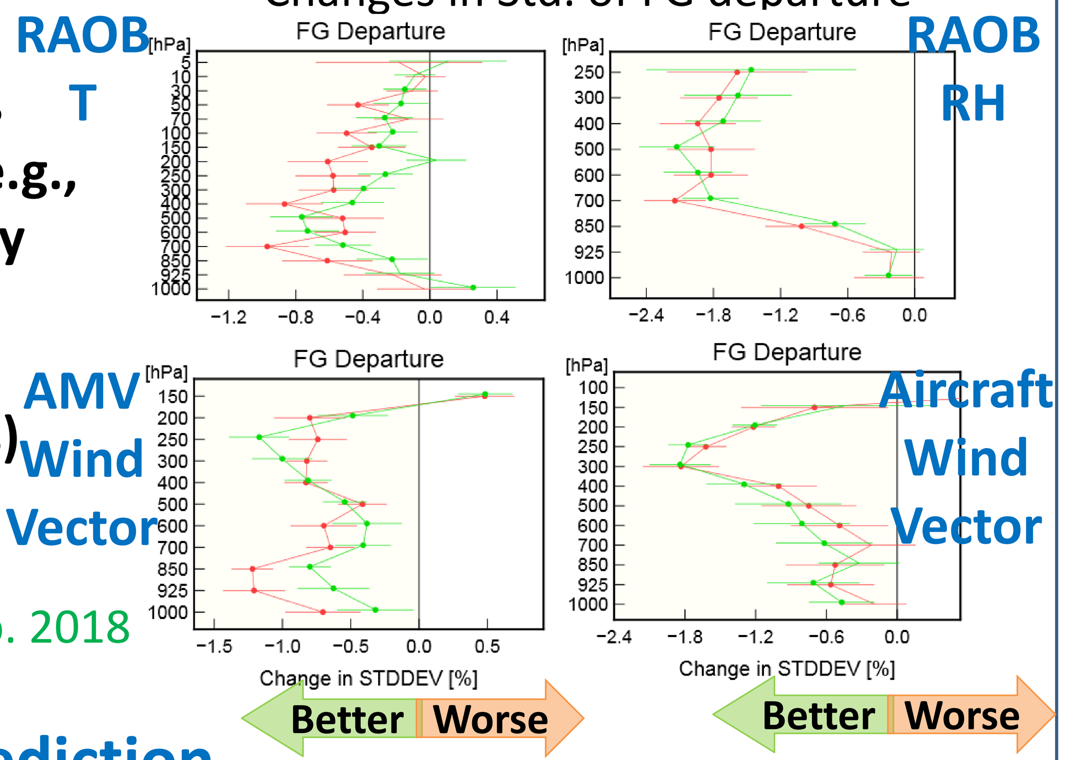
TEST: all-sky + outer-loop
CNTL: same as operation

Improved fits in FG departure

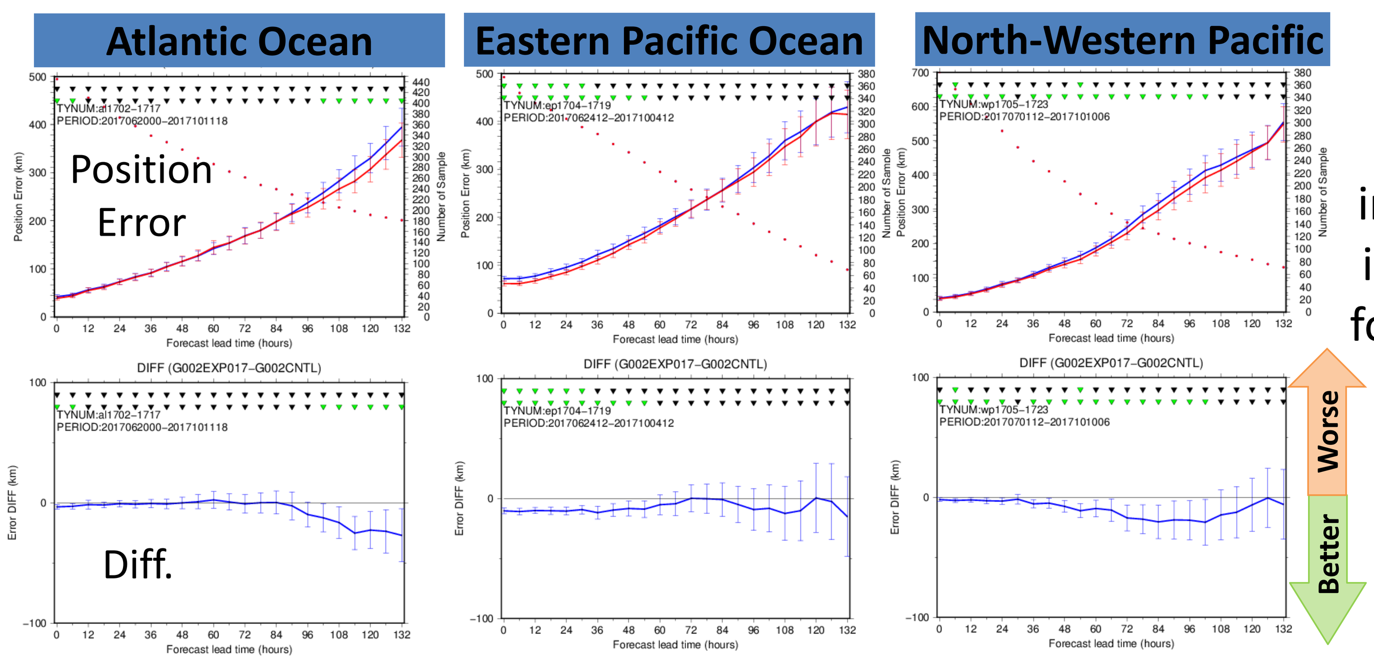
Changes in Std. of FG departure

- **Consistent improvements in various observations (e.g., temperature and humidity sensitive observations)**
- **Improved fits to AMV (i.e. Improved wind fields)**

Red: Jun. to Oct. 2017
Green: Nov. 2017 to Feb. 2018



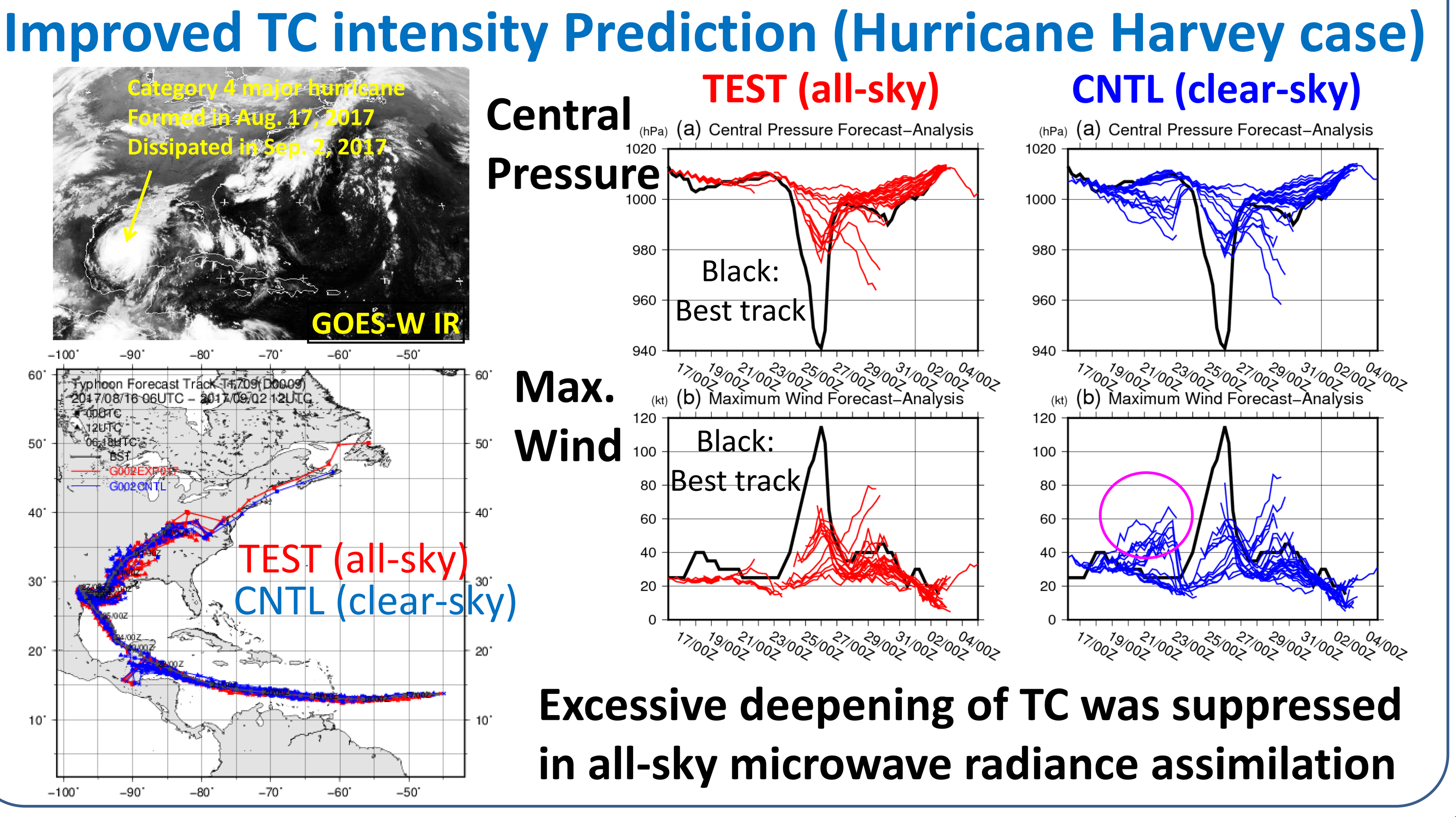
Improved TC track prediction



Consistent improvements in short-range forecasts for all basins.

All-sky MW radiance assimilation improved TC track predictions.

Improved TC intensity Prediction (Hurricane Harvey case)



Excessive deepening of TC was suppressed in all-sky microwave radiance assimilation

Summary and plans

Effects of all-sky MW radiance data assimilation with outer-loop introduction in JMA global DA system were evaluated.

- Positive impacts on temperature, moisture and wind analyses globally.
- Improved TC track and intensity prediction.

The operational implementation is planned in this November together with a hybrid background error covariances in the DA system. All-sky MW radiance assimilation for remaining MW sensors (ATMS, SSMIS 183, SAPHIR, MWHS-2) are planned in next year.

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