# Assimilation of radiance data at JMA: recent developments and prospective plans

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## 1. Outline of NWP systems at JMA

### Deterministic models and analysis schemes

| Model | Global Model (GSM) | Meso-scale Model (MSM) |
|---|---|---|
| Horizontal res. | TL959 (20km) | 5km |
| Vertical res. (model top) | 60 (0.1hPa) | 50 (21.8km) |
| Forecast range (Initial time) | 84h (00,06,18UTC) 216h (12UTC) | 15h (00,06,12,18UTC) 33h (03,09,15,21UTC |
| frequency | 4/day | 8/day |
| Target | One-week forecast Short-range forecast Aeronautical forecast | Disaster prevention information |
| Data Assimilation (outer/inner loop) | 4D-Var (TL959/T159 or 20km/80km) | 4D-Var (10/20km) |
| Assimilation window | 6h | 6h |
| Radiance assimilation | RTTOV7, VarBC | X |
| Cut off time | Early Analysis (EA) : 2h25m Cycle Analysis (CA): 11h15m(00,12), 5h15m(06,18) | 50m |

### Satellites operationally assimilated

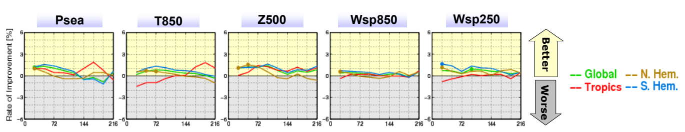
Data introduced after ITSC15 are shown in red, and those under development or suspended are in parentheses

* TCWV : total column water vapor, RR : rain rate, AMV : atmospheric motion vector

| Satellite/Instrument | Global Anal (GDAS) | Meso Anal (MDAS) |
|---|---|---|
| NOAA15-17 | AMSU-A/-B Radiance | Temperature retrieval |
| NOAA18 | AMSU-A/MHS Radiance (2007.4) | Temperature retrieval |
| Aqua/AMSU-A | Radiance | X |
| Metop | AMSU-A/MHS radiance (2007.11) | Temperature retrieval (2008.1) |
| Aqua/AIRS | (Radiance) | X |
| Metop/IASI | (Radiance) | X |
| DMSP13,14/SSMI | Radiance | TCWV,RR |
| TRMM/TMI | Radiance | TCWV,RR |
| Aqua/AMSR-E | Radiance | TCWV,RR |
| (DMSP16/SSMIS) | (Radiance) | (TCWV,RR) |
| MTSAT-1R, Meteosat-7,9, GOES-11,12 | AMV, (CSR 2007.6) | AMV |
| Aqua,Terra/MODIS | AMV | X |
| QuikSCAT/SeaWinds | Sea surface wind | Sea surface wind |
| Metop/ASCAT | (Sea surface wind) | (Sea surface wind) |
| (CHAMP, GRACE) | (Refractivity, 2007.2) | X |
| (Metop/GRAS) | (Refractivity) | X |

## 2.1 Metop/AMSU-A & MHS (2007.11)

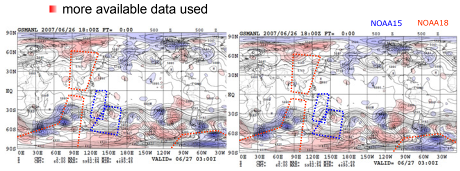
- Assimilate radiances that are less cloud-affected and less surface-dependent as other ATOVS on NOAA.
- Static scan-dependent Bias Correction (BC) and adaptive air-mass dependent BC using a Variational Bias Correction (VarBC) method
- Significantly positive impact on forecast, especially, of the geopotential height even when NOAA15-18 and Aqua ATOVS were already assimilated.
- Moreover, great benefits of early and stable data dissemination



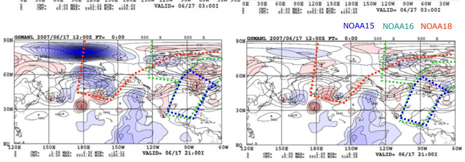

Forecast improvement rate when Metop/AMSU-A and MHS are assimilated in GDAS. The rate is calculated with (Cntl-Test)/Cntl with respect to RMSE for 1-9 day forecasts. Cntl uses NOAA15-18 and Aqua, and Test adds Metop to Cntl. Dots on lines indicate that the rate is statistically significant. The assimilation period is 23 May to 13 July 2007.

## 2.2 RARS ATOVS impact ( AP-RARS 2007.2, EARS 2007.8)

- Assimilates 12 AP-RARS stations in Japan(2), China(4), Australia(5) and Korea(1), and EARS
- AP-RARS ATOVS data improve Early Analysis (EA)
  - reduce the difference from data-richer, more accurate cycle analysis (CA)
  - but indiscernible impact on forecast
- EARS ATOVS data have a more positive impact on EA and forecast
  - more available data used



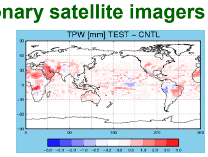

Difference between EA and CA for geopotential height at 500 hPa (Z500) when AP-RARS ATOVS not assimilated (left) and when assimilated (right) at 18UTC on 26 June 2007. Blue (red) shades depict positive (negative) value of the difference and contours indicate Z500. The area of ATOVS used in this analysis are surrounded by dashed lines.




Same as above , but for EARS ATOVS assimilation at 12UTC on 17 June 2007.

## 2.3 Clear Sky Radiances (CSRs) of WV-ch from geostationary satellite imagers (2007.6)

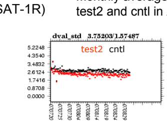
- Increase humidity in the mid- to upper-troposphere in wet areas, and even in the lower-troposphere in dry areas
  - Frequent measurements over the land compliment microwave radiometer
- Bring analysis/guess humidity closer to RAOB around 500hPa and MHS/AMSU-B ch3
- Positive impact on forecast, especially at day 1 to 3
  - Impact from 5 satellites are much greater than that from 1 satellite (MTSAT-1R)



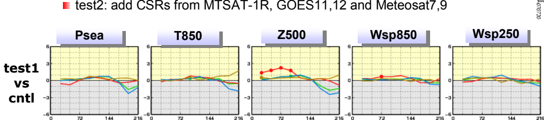

Monthly averaged TCWV between test2 and cntl in August 2007

Cycle assimilation experiment in August 2007 and January 2008:

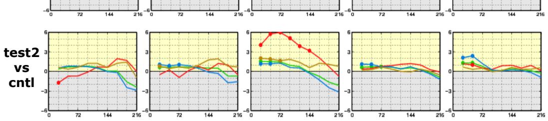
- cntl: no CSRs from geostationary satellites
- test1: add CSRs from MTSAT-1R only
- test2: add CSRs from MTSAT-1R, GOES11,12 and Meteosat7,9




Time sequence of TB O-B STD of test2 and cntl



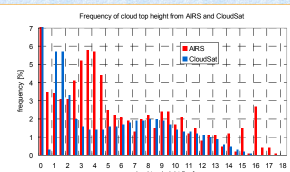

Forecast Improvement rate when MTSAT CSRs are added in GDAS. The rate are calculated from one month forecast of August 2007.



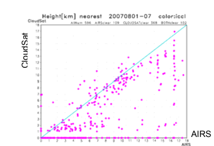

The same as above but for CSRs of five geostationary satellites added.

## 3.1 AIRS radiance assimilation

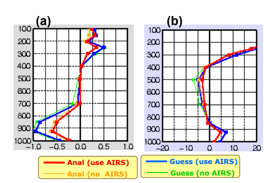
- Assimilate clear radiances of 54ch/324ch over the seaice-free sea
  - Channel selection is based on Entropy Reduction (Rodgers 2000)
- Detection of cloud-affected radiances using a 2-step schemes
  - [1] Clear pixel detection using
    - At daytime, cloud cover from VIS~NIR ch
    - AT night, TB difference between shortwave ch and longwave ch and between SST predicted and SST analyzed at nighttime
  - [2] Cloud-affected channel detection based on McNally and Watts (2003)
- Verification of the cloud top height derived from AIRS against CloudSat
  - AIRS clouds tend to be higher than CloudSat clouds.
  - AIRS, generally, more frequently finds clouds than CloudSat but often misses low clouds.
  - These characteristics of the scheme may not be accurate enough to estimate the cloud top height but safe from the view point of avoiding the inclusion of cloud contaminated channels in the assimilation.
- Bias correction scheme is the same as ATOVS except VarBC predictors
  - VarBC predictors: background TB, 1/cosθ, constant
- Positive impact on analysis but neutral or negative on forecast
  - Reduce model biases of temperature and humidity in the analysis and first-guess
  - Degrade forecast skills of the lower tropospheric temperature



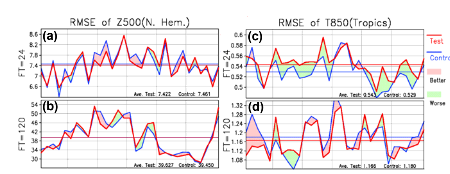

Frequency of cloud top height from AIRS and CloudSat/CPR (2B-GEOPROF) from 1 to 7 2007. The frequency is normalized by their total numbers.




Comparison of cloud top height from AIRS and CloudSat/CPR closest to the center of AIRS FOV from 1 to 7 2007.



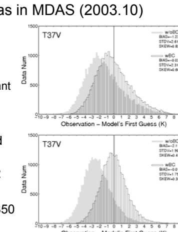

Fits of analysis and first-guess to RAOBs with and without AIRS radiance assimilation. (a) Biases of temperature in the Southern Hemisphere and (b) biases of relative humidity in the tropics are calculated from a one-month cycle experiment in August 2007.



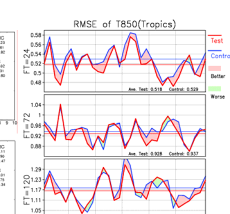

Time sequence of the forecast at day-1and -5 for Z500 (a, b) and T850 (c, d) from 1 to 31 August, 2007. Test run assimilates AIRS radiances and Control run does not.

## 3.2 MW window channel assimilation

- Operational use of SSM/I, TMI and AMSR-E since May 2007
- TCWV in clear areas and precipitation in other areas in MDAS (2003.10)
- Less cloud-affected radiances in GDAS (2006.5)
  - Only vertical polarized channels assimilated
  - Biases are removed with VarBC
    - TCWV, Ts, Ts², ocean surface wind speed, 1/cosθ, constant
- Test1: Improve QC and BC
  - Stricter cloud screening & addition of Total Column Cloud Liquid Water (TCCLW) predictor in VarBC
    - Reject pixels with retrieved TCCLW over 0.18 kg/m2
  - More symmetric distribution of O-B in radiance space
  - Small but consistent positive impact on the forecast of T850
- Test2: Add SSMIS window channels to Test1
  - 19V, 22V, 37V and 92V radiances are assimilated
  - Neutral impact




O-B of AMSR-E 37V on 1st August 2007 before (upper panel) and after (lower panel) improved QC and BC




Time sequence of the forecast at day-1, -3 and -5 for T850 from 1-31 Aug, 2007. Test run adds improved QC and BC to Control run ("Test1 in the main text )

## 4. Plans on radiance assimilation

- Improve AIRS assimilation processing and introduce IASI
  - Implement Rochon's Jacobian mapping instead of nearest neighbor mapping in the vertical interpolation scheme
  - Review bias correction predictors and tune observation errors especially of short wave channels
  - How to address the conflict with model biases?
- Introduce SSMIS window channels and evaluate sounding channel impact
- Improve AMSU-A/-B/MHS assimilation
  - Switch the current retrieval assimilation to the radiance assimilation in MDAS
    - Is VarBC going to be introduced as GDAS does? => Need to examine effect of sampling errors
  - Land/snow emissivity model or retrieved values are being tested
  - Optimize static observation errors in a variational scheme
- Assimilate cloud affected radiances of IR/MW sounders and imagers