Use of satellite radiances in the global assimilation system at JMA

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Satellite data assimilated in JMA operational system

- Radiances
  - NOAA-15,16/AMSU-A
  - Aqua/AMSU-A
  - NOAA-15,16,17/AMSU-B

  ATOVS radiances
  - DMSP-13,14/SSMI
  - TRMM/TMI
  - Aqua/AMSR-E

  MWR radiances
- Other satellite data
  - AMV from MTSAT1R, GOES-11,12, Meteosat-5,8
  - AMV from Aqua+Terra/MODIS
  - sea surface winds from QuikSCAT/SeaWinds

- Under development
  - CSR (Clear Sky Radiance) from MTSAT-1R

    CSR
  - refractivity index from GPS occultation
  - radiances from Aqua/AIRS

JMA global assimilation system

- 4DVar
  - incremental method
  - outer: TL319L40, inner: T106L40
  - model top : 0.4 hPa
  - Background error covariance based on NMC method
  - Physical processes included are simplified versions of gravity drag, long wave radiation, convection, cloud condensation.
  - VarBC (Variational Bias Correction)
- assimilation window: 6h
  - 1h time slot X 6
- cut off time: 2h20m for early anal, 5h35m-11h35m for final anal

VarBC (1/2)

- adaptive bias correction scheme incorporated in a variational scheme (Derber and Wu 1998; Dee 2004)
- bias correction coefficients are analyzed as analysis variables

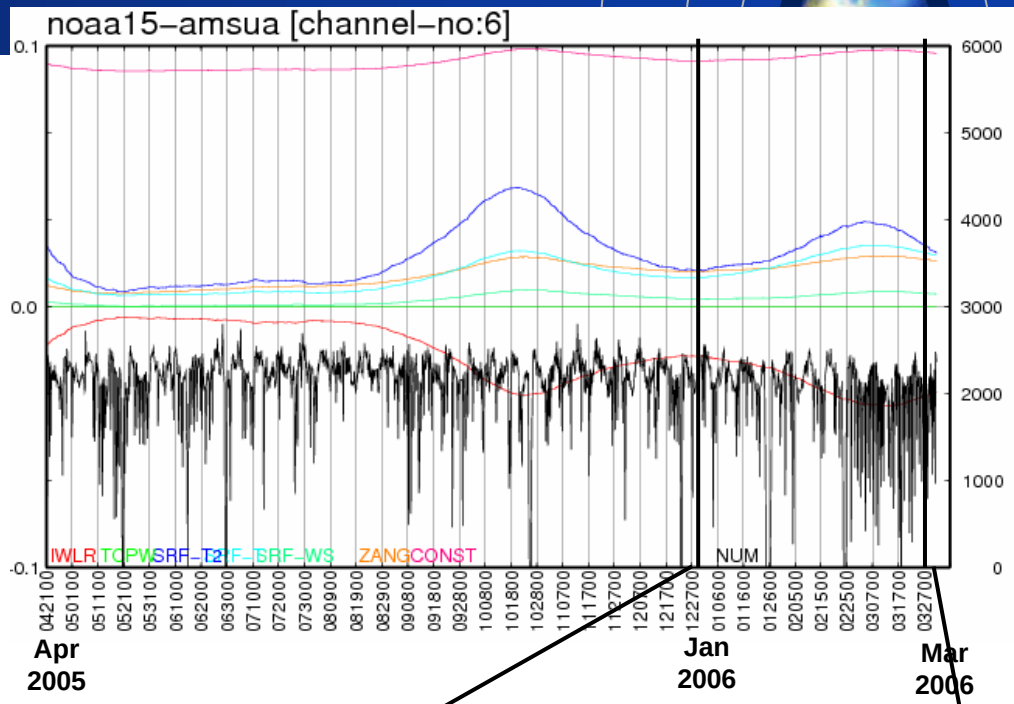
$$J(x)=(x-x_b)^T\mathrm{B}^{-1}(x-x_b)+[y-H'(x)]^T\mathrm{R}^{-1}[y-H'(x)]+(\beta-\beta_b)\,\mathrm{B}_{\beta}^{-1}(\beta-\beta_b)$$

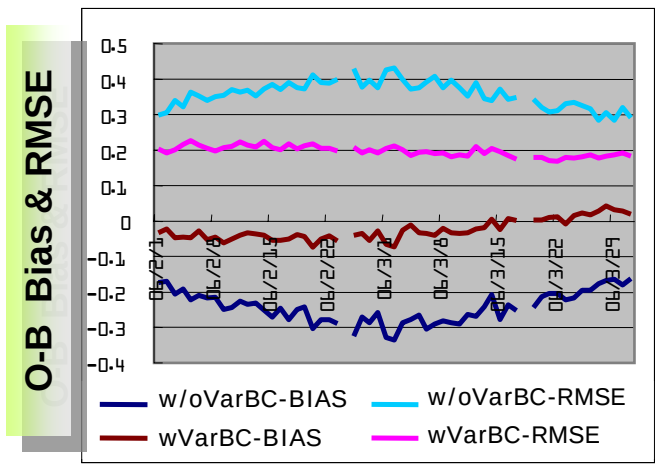
$$H'(x)=H(x)+\sum_{i=1}^{N}\beta_i p_i(x_b) \quad \beta:\text{BC coef.},\ p_i:\text{predictors}$$

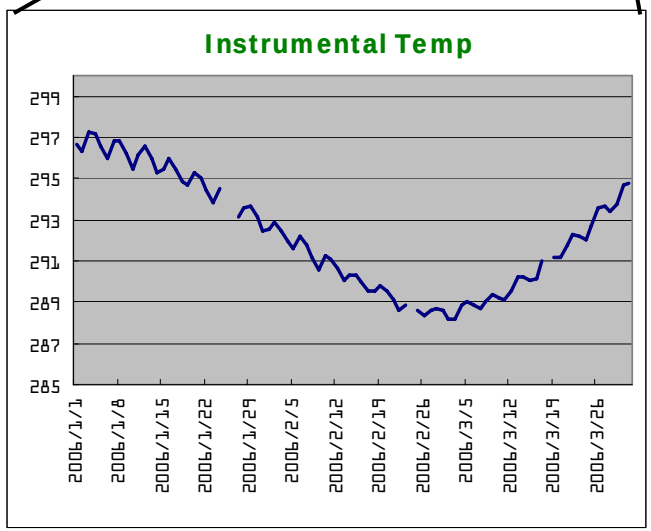
- obtain balanced coefficients among targeted obs, model, and other obs
  - BC coeffs obtained from only guess could be contaminated by model biases
  - easy to adjust to model and data changes
  - BC coef time-sequence monitor may be used as instrumental quality monitor
- applied to all radiance data
  - predictors for AMSU-A/B: ILR, Ts, TCCLW, 1/cosθ□const
  - predictors for MWR: TCWV, Ts, Ts2, wind.speed, 1/cosθ□const
    - ILR: integrated (weighted) lapse rate
    - TCCLW: total column cloud liquid water retrieved by AMSU-A
    - TCWV: total column water vapor retrieved by MWR

VarBC (2/2)

- BC coef variation monitor may be used as instrumental quality monitor
- ex. NOAA15 AMSU-A ch6
  - Fluctuation of VarBC coef well correspond to instrumental temperature fall







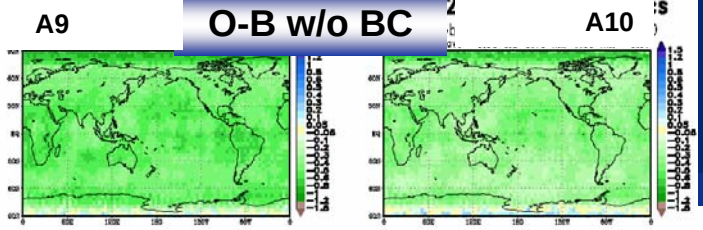
ATOVS radiance assimilation

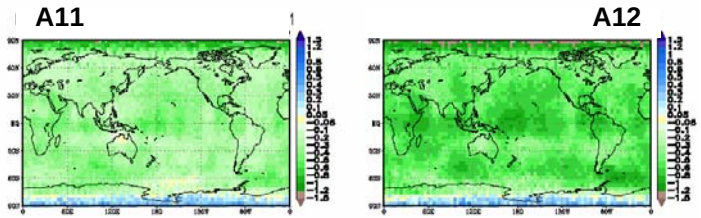
- NOAA-15,16,17,Aqua/AMSU-A,-B
  - level-1C AMSU-A ch.4-13 and AMSU-B ch.3-5
- QC
  - less cloudy-affected radiances are used depending on surface conditions
- thinning
  - AMSU-A:250km, -B:180km
  - choose one satellite among overlapped satellites in each 1-h time slot
- BC
  - 2-step scheme: scanBC + airmassBC
  - scanBC removes predefined O-B average at each scan position
  - airmassBC removes the residual using VarBC

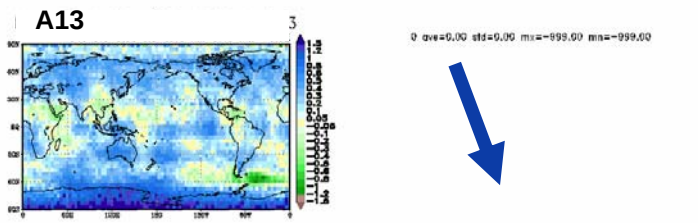
Bias Corr

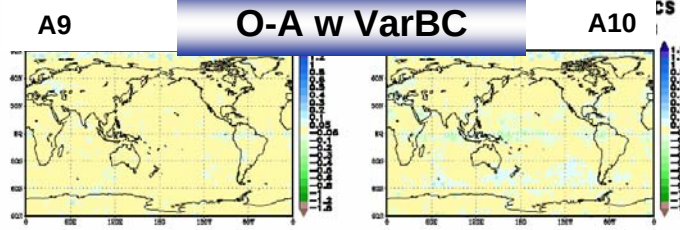
monthly average
O-B & O-A

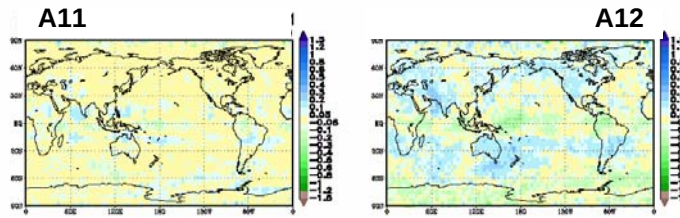
AMSU-A9-13
NOAA16
Aug2004

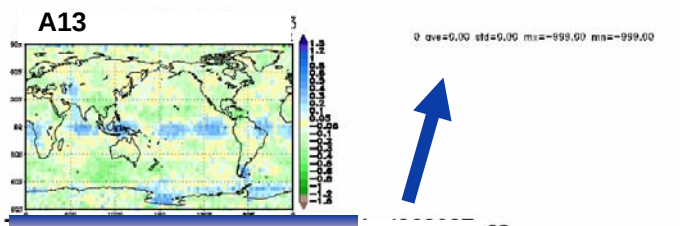


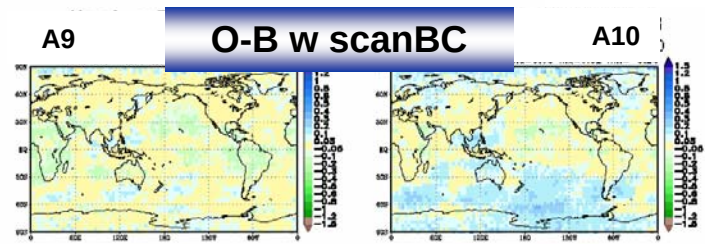


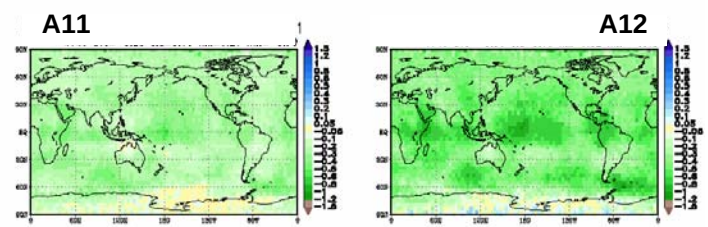


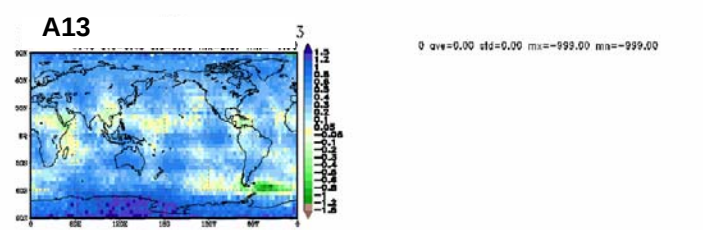


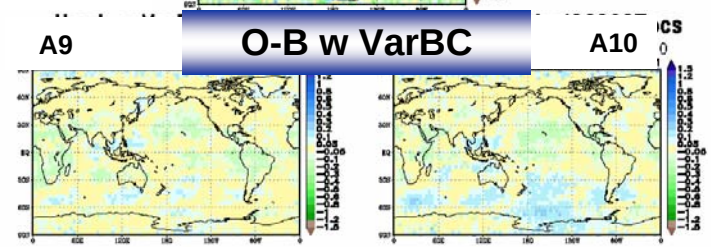


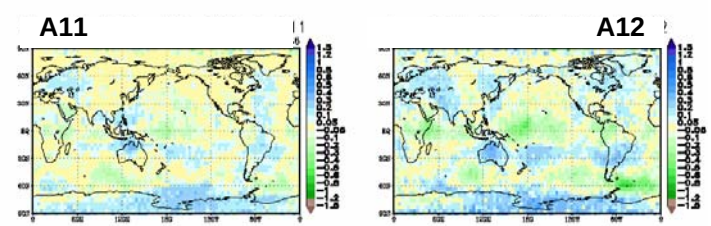


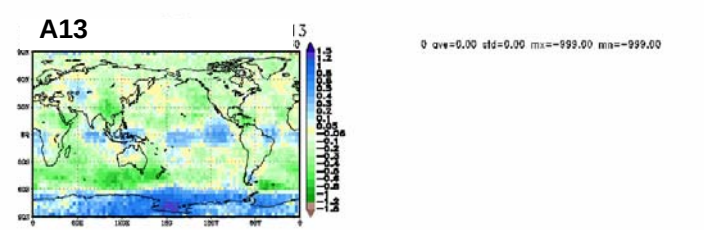






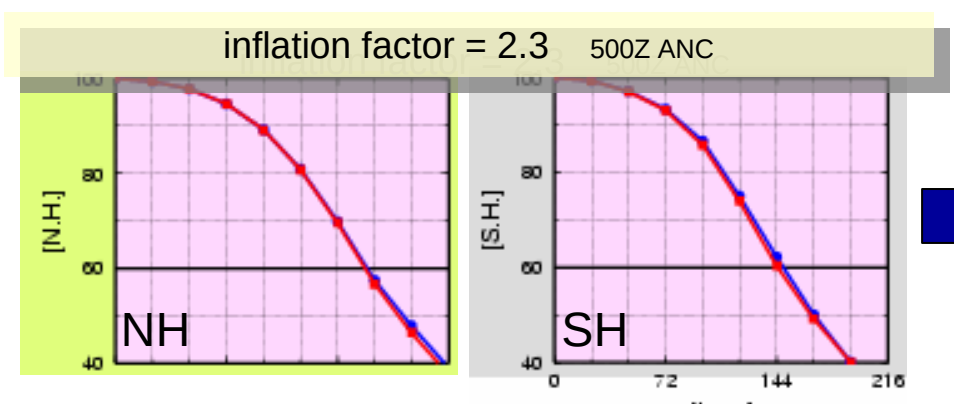


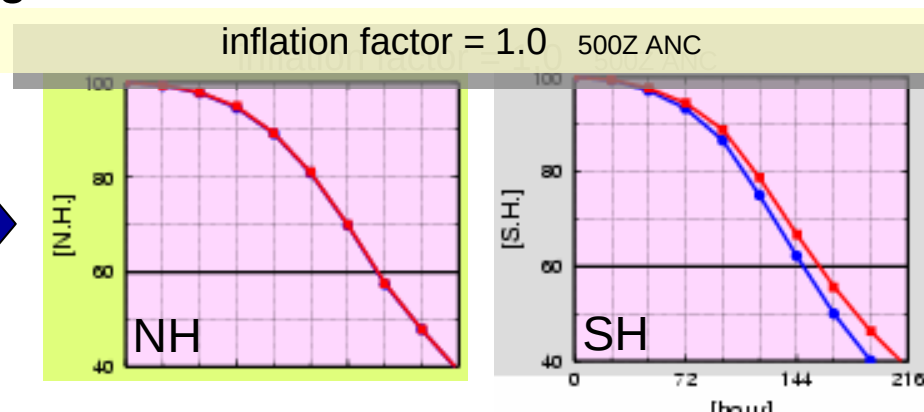




ATOVS assimilation changes in Aug2006

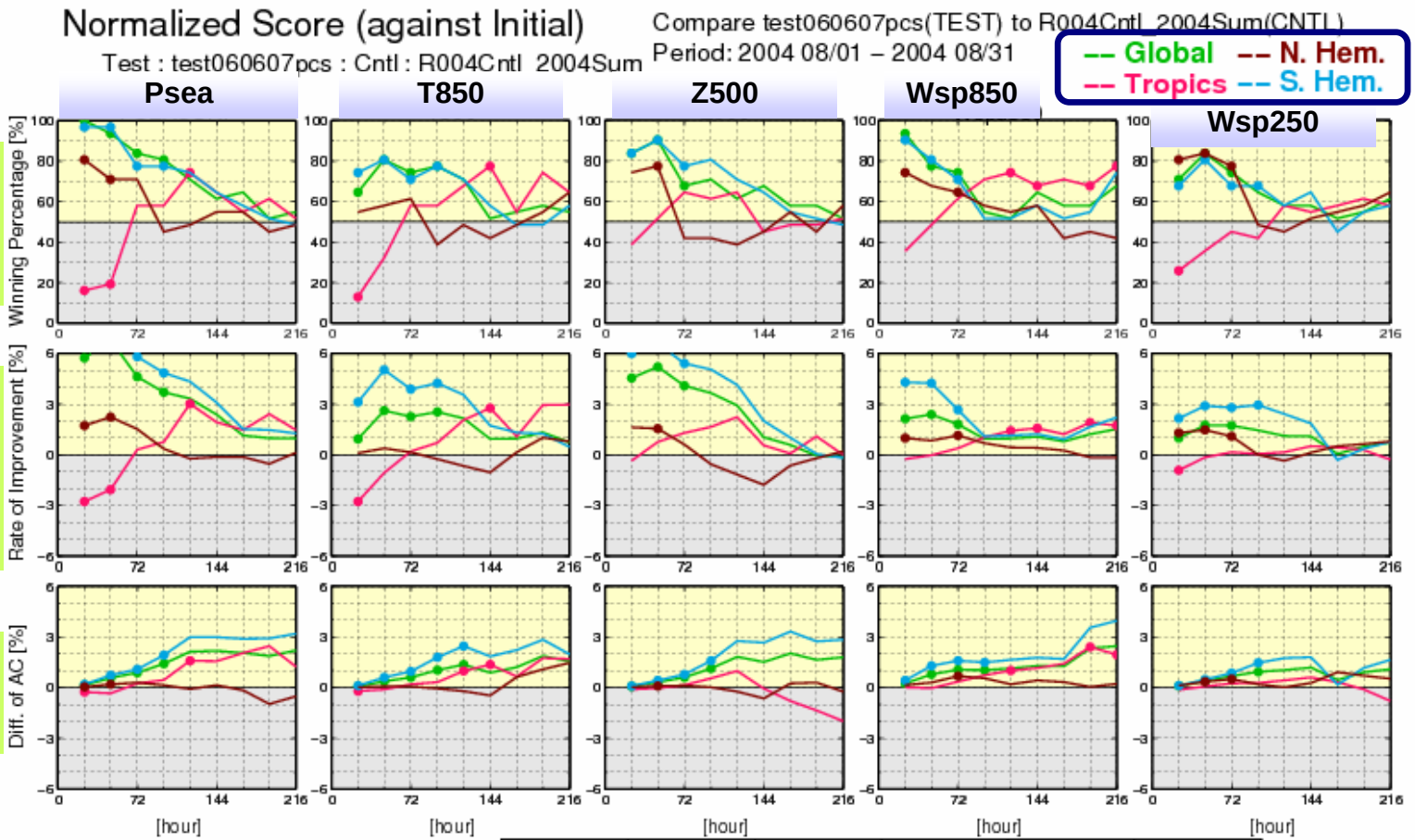
- improve QC
  - adopt MSPPS latest version for MW-cloud detection
  - stricter gross error QC, remove edge scans
- recalculate scanBC
- change VarBC predictors
- modify obs errors of AMSU-A
  - reduce obs error inflation factor, 2.3 to 1.2
    - obs errors are inflated in 4DVar main analysis to complement neglecting horizontal error correlation and balance among contributions from other observations and guess.
  - O-B has been getting smaller due to using level-1C data, revising scanBC and including VarBC





ATOVS assimilation changes in Aug2006

- impacts on forecasts



winning percentages :

(test-cntl)/all

Improvement rate wrt RMSE :

(cntl-test)/cntl

ANC diff :

test-cntl

average of 1 to 9 day forecasts:

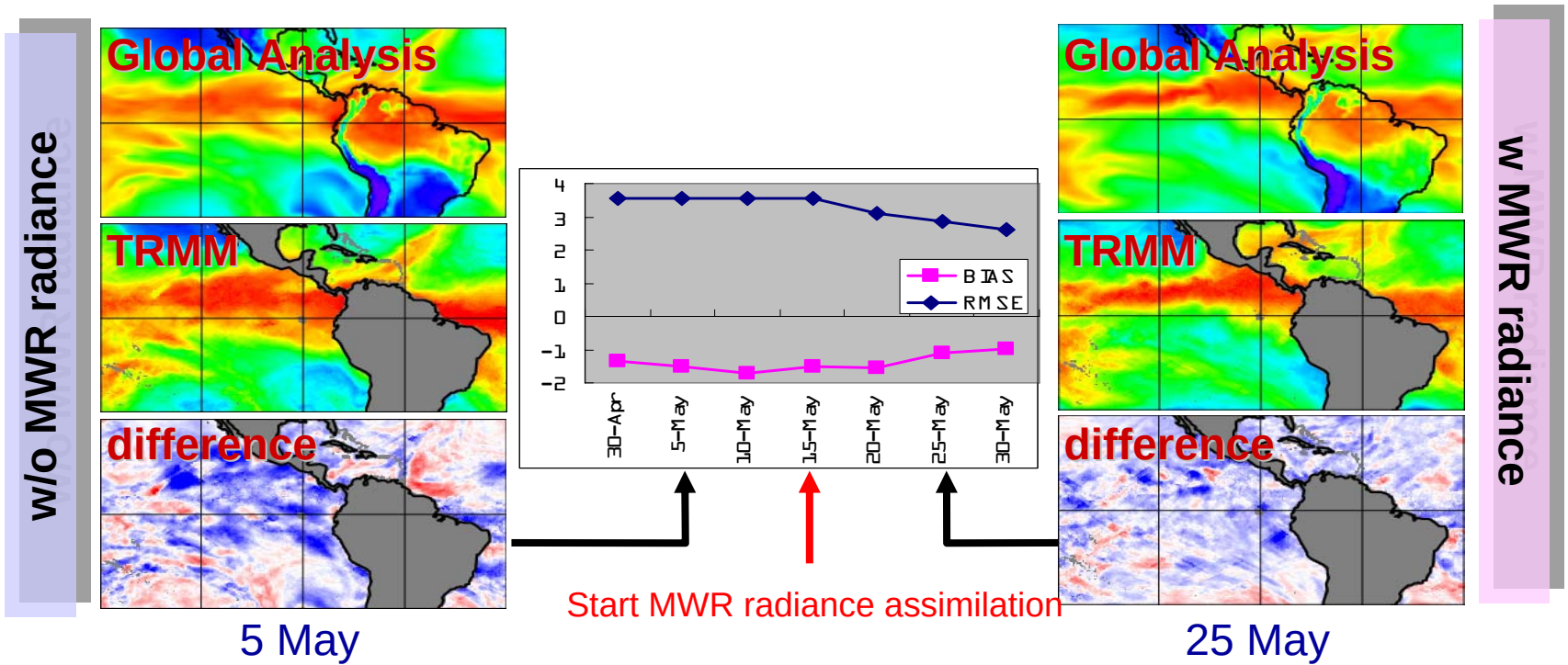
cntl-test

	PseaSurf	T850	Z500	Wspd850	Wspd250
Global	3.29	1.61	2.42	1.42	1.03
N. Hem.	0.55	0.07	−0.04	0.49	0.62
Tropics	0.72	0.99	0.80	0.99	0.02
S. Hem.	4.43	2.73	3.34	2.16	1.76

better
neutral
worse

MWR radiance assimilation (1/2)

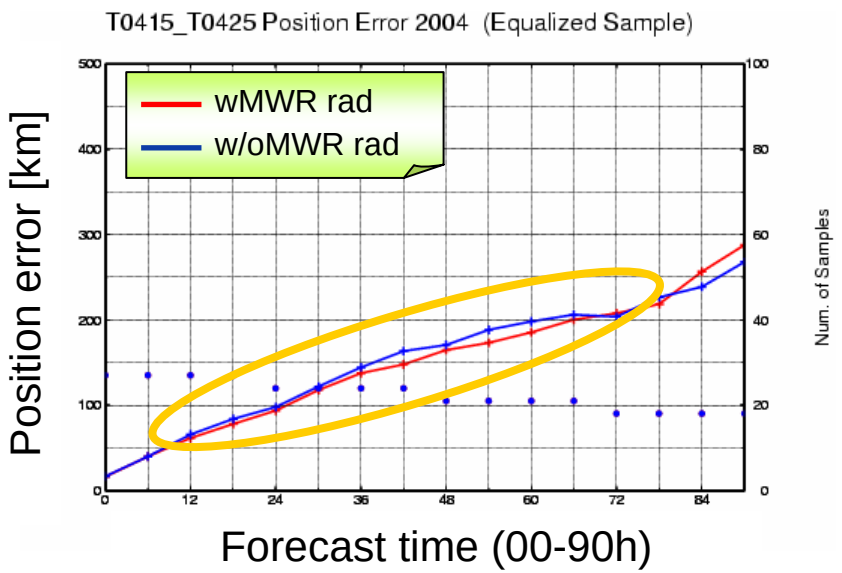
- DMSP/SSMI, TRMM/TMI, Aqua/AMSR-E
  - less cloud-affected radiances over the ocean with SST > 5 deg.C
  - assimilate only vertical polarized channels at 19 – 89 GHz
  - not change surface variables through emissivity Jacobian
  - VarBC corrects biases against model
- Comparison with TRMM 3-day-averaged TCPW
  - MWR radiance assimilation leads to better representation of TCPW



MWR radiance assimilation (2/2)

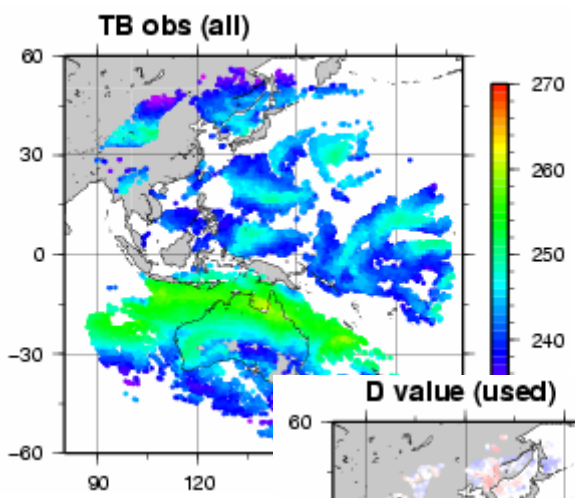
- Impacts on forecasts
  - better precipitation
    - Correlations of 1day-forecast against GPCP:
      - w/oMWR:0.881 vs. wMWR:0.891 (Aug2004)
      - w/oMWR:0.835 vs. wMWR:0.841 (Jan2004)
  - better typhoon track
  - smaller errors in Psea and wind speed at both 850 and 250 hPa

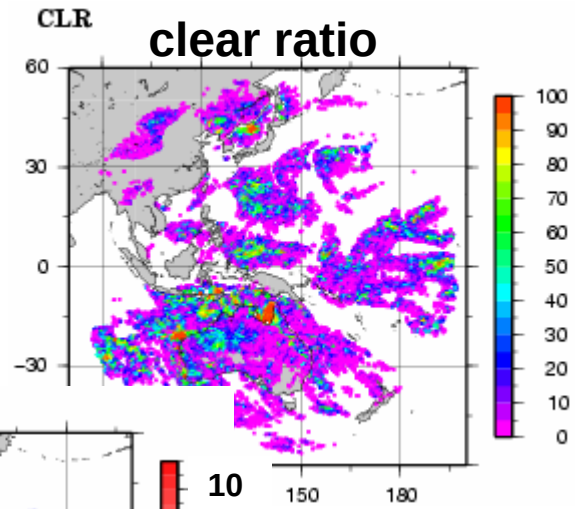
- operational in May 2006

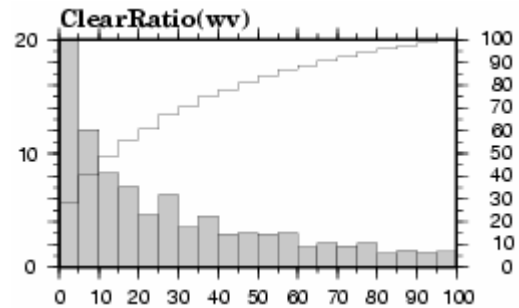


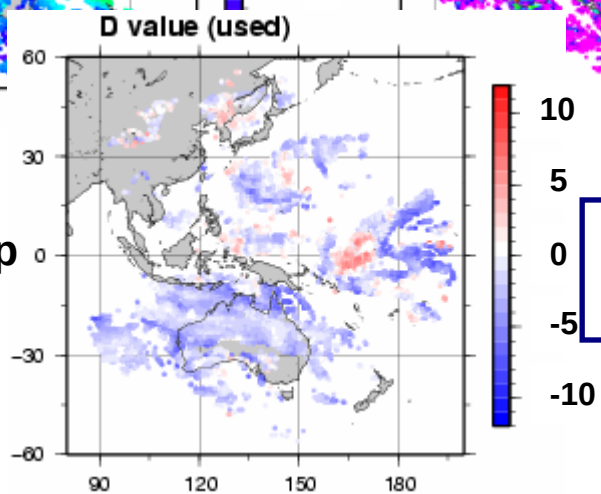
MTSAT-1R CSR assimilation (1/2)

- clear sky radiances (CSR) from MTSAT-1R WV channel
  - Meteorological Satellite Center (MSC) of JMA produces
  - ready for dissemination to NWP community



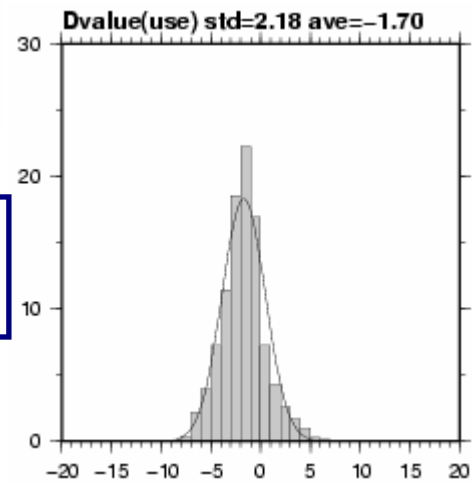






O-B map

00 UTC
Sep.14 2006



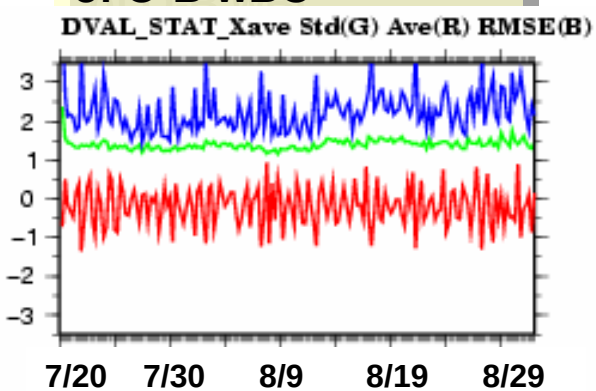
O-B

mean=-1.7
std=2.18

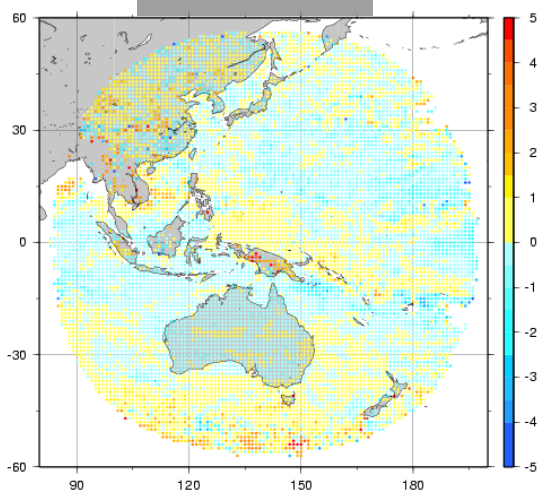
MTSAT-1R CSR assimilation (2/2)

- under development
  - improve forecast skills, including 500T, in the Tropics and summer hemisphere
  - However, forecast skills in the winter hemisphere are degraded
    - may conflict with AMV (biases)?
  - revising
    - thinning interval (now every 1-h time slot)
    - observation errors (now 1.5K)

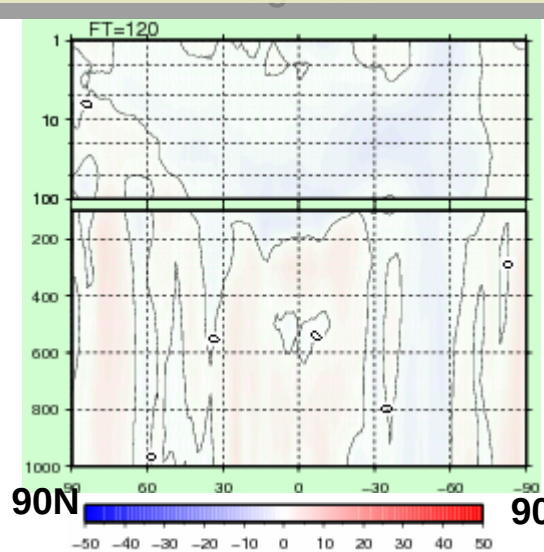
Mean, Std and RMSE of O-B wBC



O-B wBC



(Cntl-Test)/Cntl in zonal mean RMSE of Z at FT=5d Aug.2005



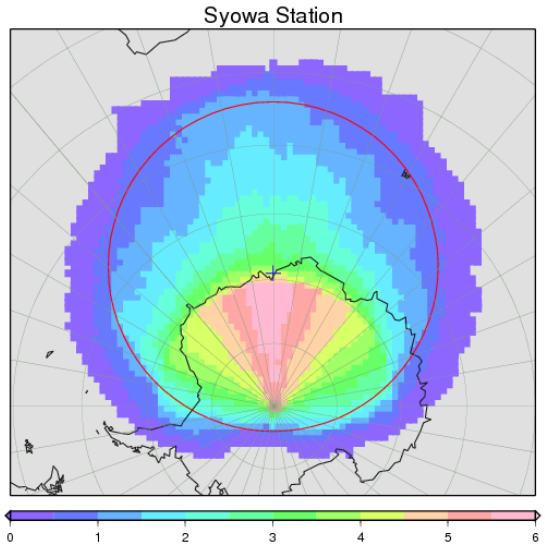
Plans

- ATOVS
  - improve MW emissivity to use more data over land/snow/sea-ice
  - add NOAA18
  - use AP-RARS data in early analysis
- CSR from geostationary satellites
- AIRS and IASI radiances

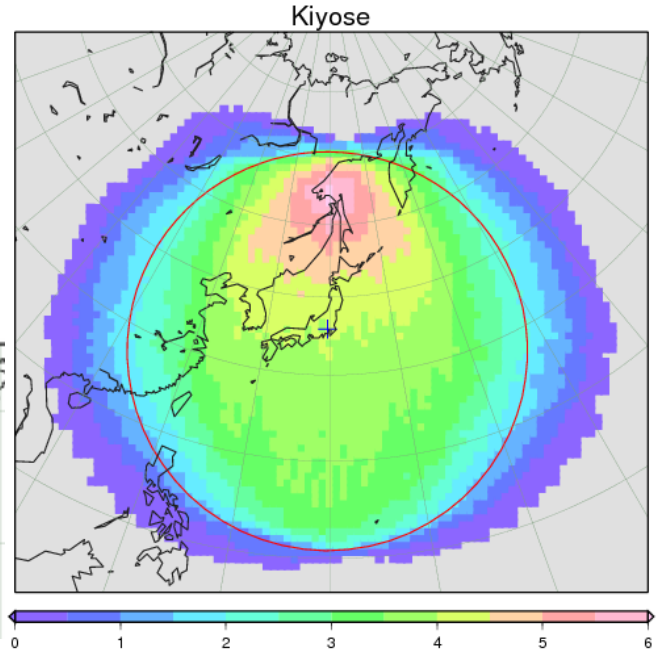
- SSMIS radiances (Global DAS) and retrievals (Meso-scale DAS)
- GPS occultation as refractive index
- ASCAT (ambiguity) winds
- cloud/rain-affected radiances of MW and IR sensors

AP-RARS (Asia-Pacific Regional ATOVS Retransmission Service)

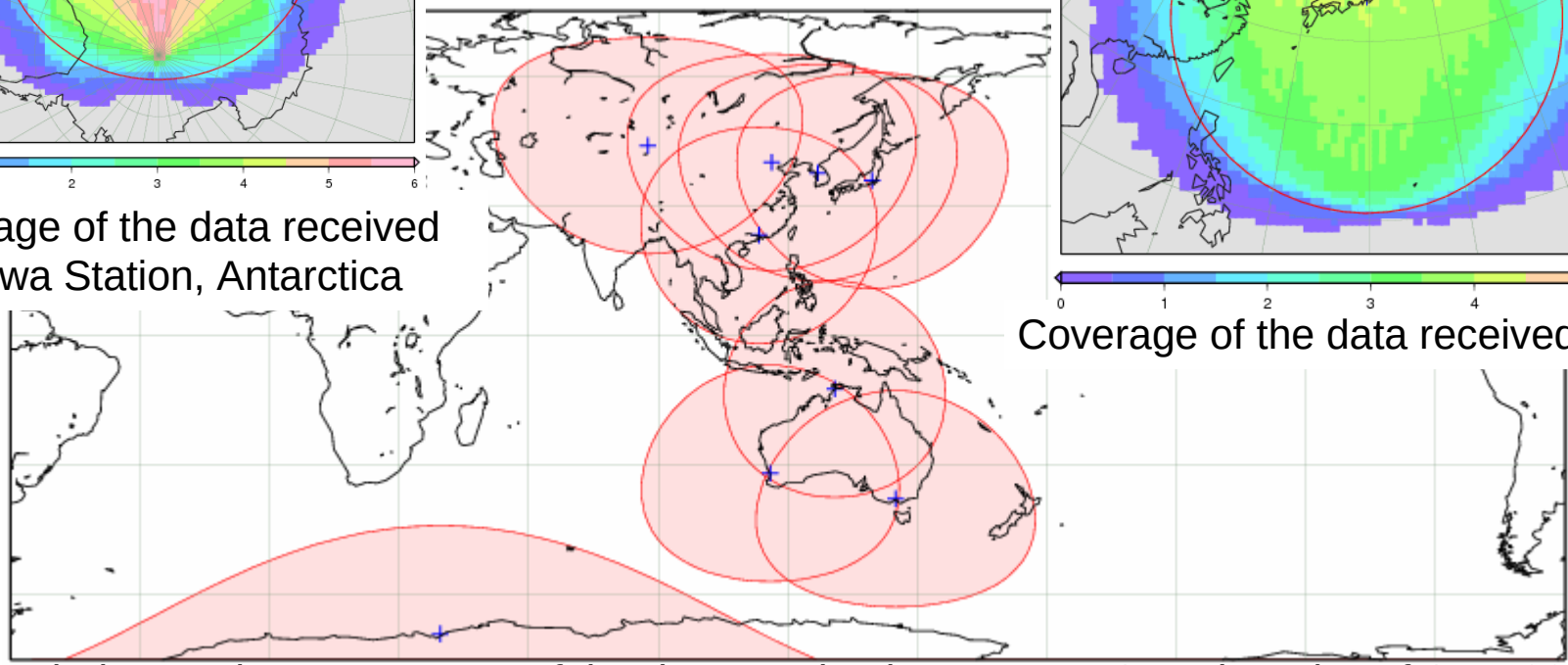
- 10 stations from Japan(2), China(3), Australia(4), Korea(1).



Coverage of the data received at Syowa Station, Antarctica



Coverage of the data received at MSC

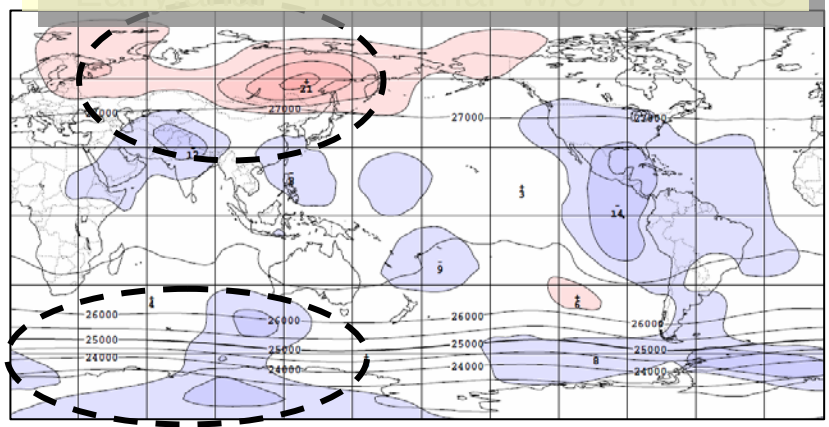


Shaded area shows coverage of the data received at AP-RARS stations (as of Sep. 2006).

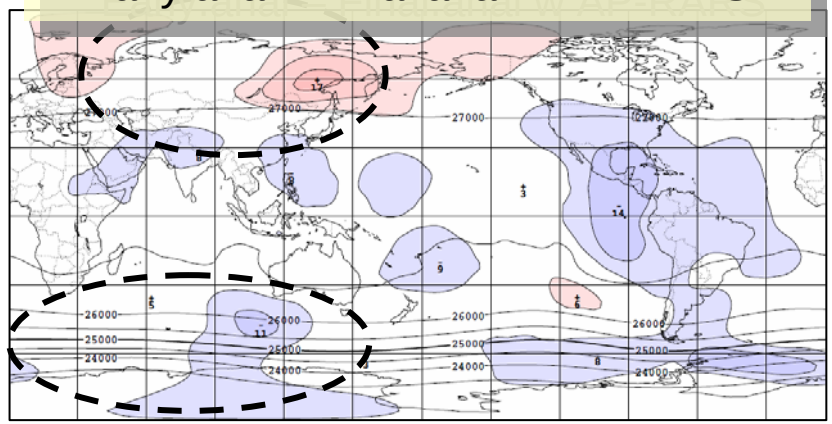
Impacts of AP-RARS

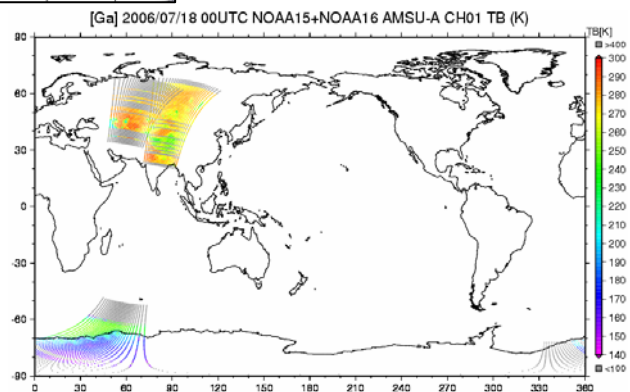
- expected to improve early analysis by adding early delivery data
  - shrink the difference from data-rich final analysis
- comparison of early analysis with final analysis w and w/o AP-RARS
  - Z30 at 00UTC on Jul 18, 2006

Early.anal – Final.anal w/o AP-RARS



Early.anal – Final.anal w AP-RARS





data distribution of AP-RARS
(NOAA16 AMSU-Ach1)

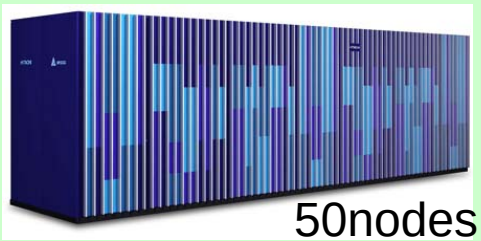
Supplemental slides

NWP operational system (as of Sep.2006)

	Global Model (GSM)	Regional Model (RSM)	Typhoon Model (TYM)	Mesoscale Model (MSM)	One-week Ensemble
Objectives	Medium-range forecast	Short-range forecast	Typhoon forecast	Disaster reduction	One- week forecast
Forecast domain	Global	East Asia	Typhoon and its surrounding	Japan and its surrounding	Global
Grid size / Number of grids	0.5625 deg 640 x 320 (TL319)	20 km 325 x 257	24 km 271 x 271	10 km 721 x 577	1.125 deg 320 x 160 (TL159)
Vertical levels / Top	40 0.4 hPa	40 10 hPa	25 17.5 hPa	50 21,800m	40 0.4 hPa
Forecast hours (Initial time)	90 hours (00 UTC) 216 hours (12 UTC) 36 hours (06, 18 UTC)	51 hours (00, 12UTC)	84 hours (00, 06, 12, 18 UTC)	15 hours (00, 03, 06, 09, 12, 15, 18, 21 UTC)	9 days (12 UTC) 51 members
Analysis	4D-Var	4D-Var	Interpolated from Global Analysis	4D-Var	Global Analysis with ensemble perturbations

super computer at JMA

Satellite Data Processing
Mar 2005-



HITACHI
SR11000J1

50nodes

6.1Tflops

=1.9 GFlops x
16 processors
x 50 nodes x 1

Numerical Weather Prediction
Mar 2006-

HITACHI
SR11000K1

160nodes

21.5Tflops

=2.1 GFlops x
16 processors
x 80 nodes x 2

- **13.1TB Main memory**
- **36.2TB Disk**
- **2.0PB Tape**

ATOVS VarBC predictors

- ILR, Ts, TCCLW, 1/cosθ□ const
- dependence on the predictors
  - TCCLW dependence for AMSU-A4 and lower tropospheric ch.
  - Separation of ocean and land may be needed for Ts
  - unclear dependence for AMSU-B

predictors vs. O-B-scanBC