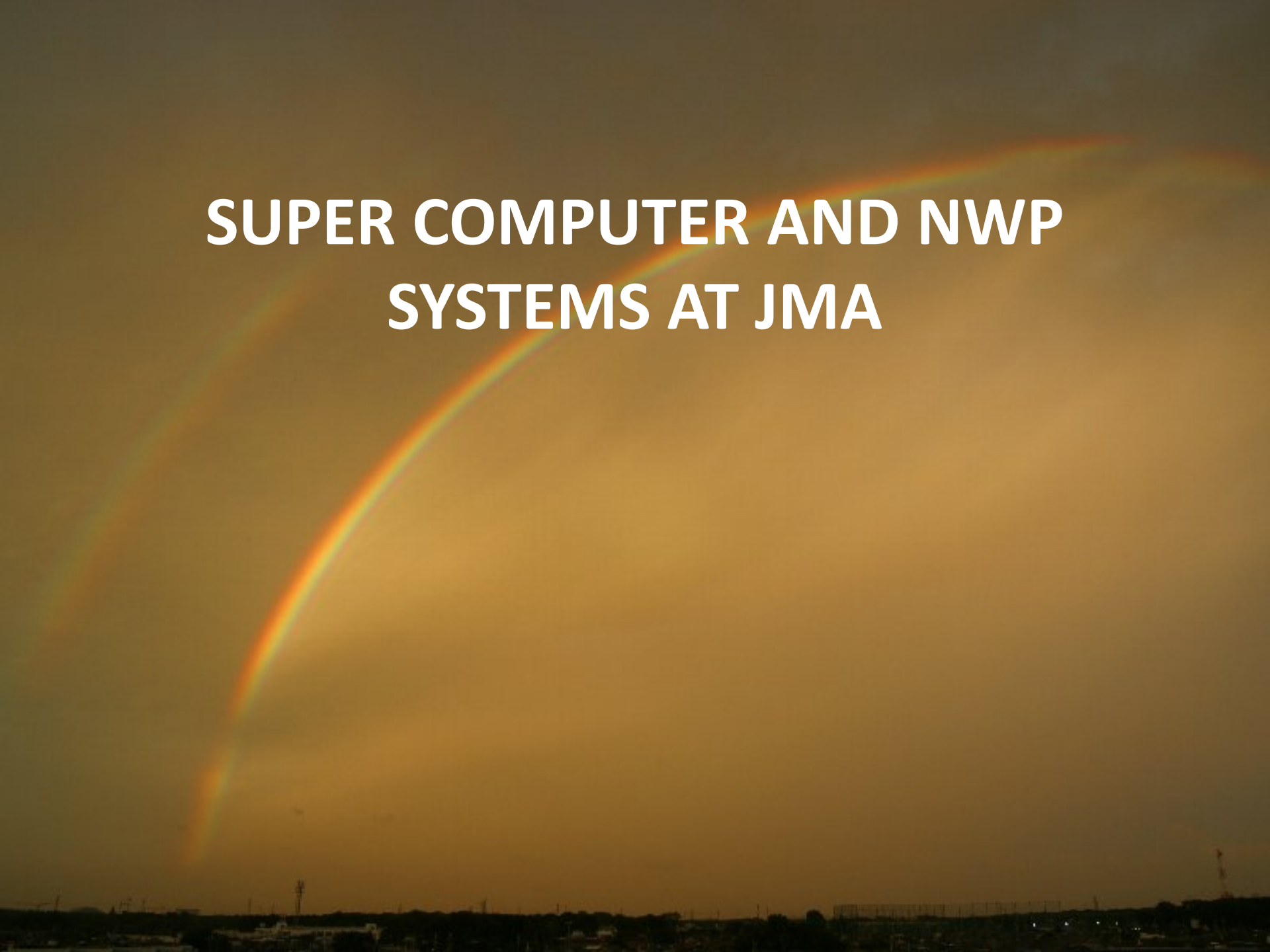
Center Report
- JMA 2015 -

Junichi Ishida and colleagues at JMA

23-26 Mar. 2015, College park, United States

WGNE-30

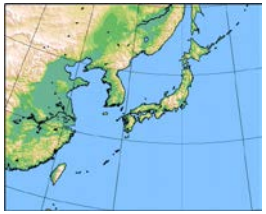
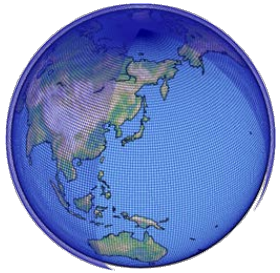


SUPER COMPUTER AND NWP SYSTEMS AT JMA

Super Computing System

	New
Machine	Hitachi SR16000/M1
CPU	Power 7 (3.83GHz, 8core)
CPU/NODE	4 processors (total 32cores)
NODE	864 (432x2)
Peak Performance	847 (423.5x2) T Flops
Main Memory	108 T Byte
operation was started on	5 June 2012 -

Current NWP models of NPD/JMA

	Global Spectral Model GSM	Meso-Scale Model MSM	Local Forecast Model LFM	One-week Ensemble WEPS	Typhoon Ensemble TEPS
Objectives	Short- and Medium-range forecast	Disaster reduction Aviation forecast	Aviation forecast Disaster reduction	One-week forecast	Typhoon forecast
Forecast domain	Global 	Japan and its surroundings (4080km x 3300km) 	Japan and its surroundings (3160km x 2600km) 	Global 	
Horizontal resolution	TL959(0.1875 deg)	5km	2km	TL479(0.375 deg)	
Vertical levels / Top	100 0.01 hPa	48+2 21.8km	58 20.2km	60 0.1 hPa	
Forecast Length (Initial time)	84 hours (00, 06, 18 UTC) 264 hours (12 UTC)	39 hours (00, 03, 06, 09, 12, 15, 18, 21 UTC)	9 hours (00-23 UTC hourly)	264 hours (00, 12 UTC) 27 members	132 hours (00, 06, 12, 18 UTC) 25 members
Initial Condition	Global Analysis (4D-Var)	Meso-scale Analysis (4D-Var)	Local Analysis (3D-Var)	Global Analysis with ensemble perturbations (SV)	

Data assimilation systems of NPD/JMA

	Global Analysis (GA)	Meso-scale Analysis (MA)	Local Analysis (LA)
Analysis scheme	4D-Var		3D-Var
Analysis time	00, 06, 12, 18 UTC	00, 03, 06, 09, 12, 15, 18, 21 UTC	hourly
Data cut-off time	2 hours 20 minutes [Early Analysis] 11 hours 50 minutes (00, 12 UTC) 7 hours 50 minutes (06, 18 UTC) [Cycle Analysis]	50 minutes	30 minutes
Horizontal resolution (inner-model resolution)	TL959 / 0.1875 deg (TL319 / 0.5625 deg)	5 km (15 km)	5km
Vertical levels	100 levels up to 0.01 hPa	48+2 levels up to 21.8km	58 levels up to 21.8km
Assimilation window	-3 to +3 hours of analysis time	-3 hours to analysis time	-3 hours to analysis time (1hourly update cycle)

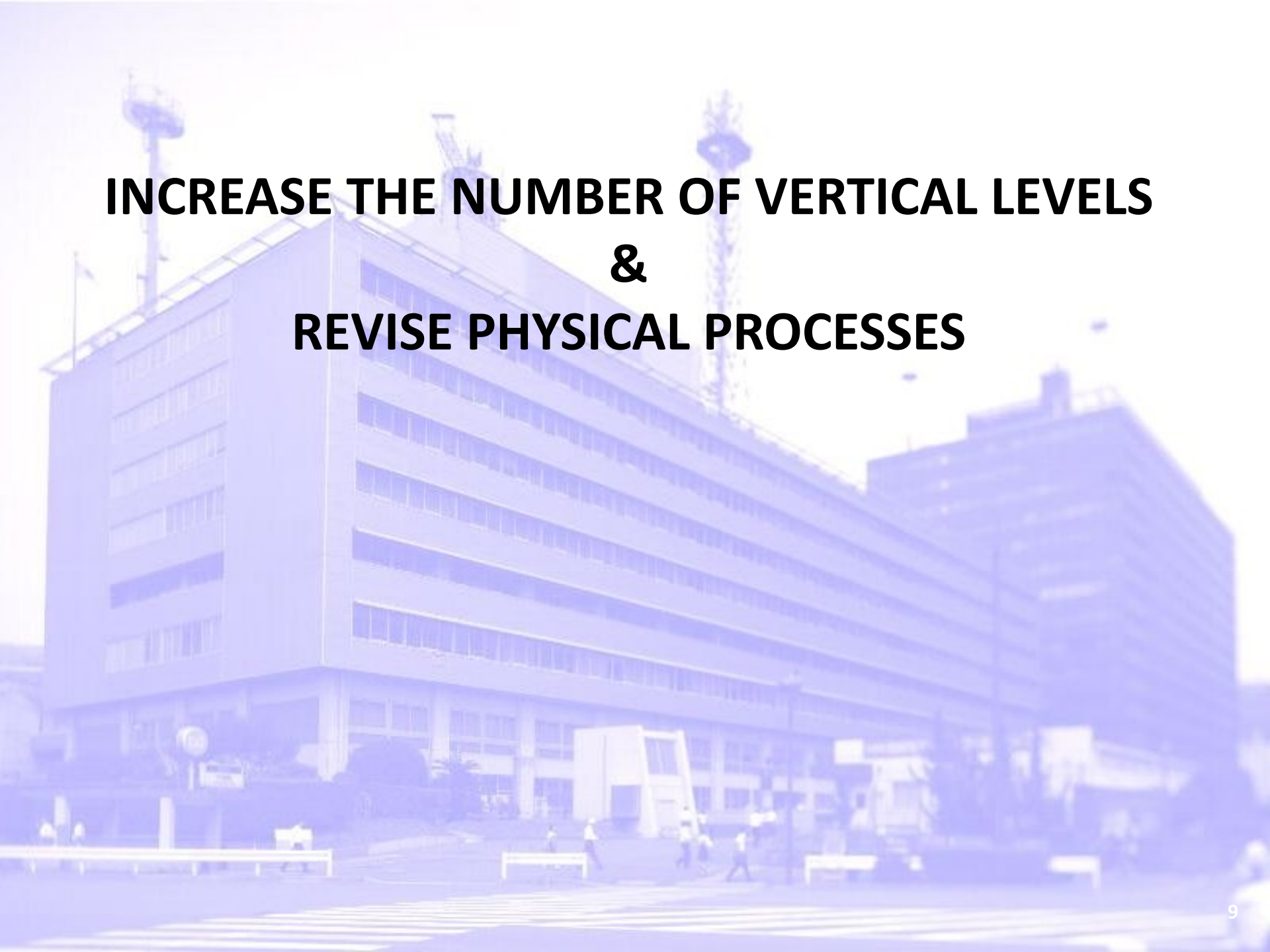
Specifications of seasonal EPSs

	1-month EPS	4/7-month EPS
Model	AGCM	CGCM
Resolution	Horizontal: approx. 55 km (TL319) Vertical: 60 levels (~0.1 hPa)	* Atmospheric component Horizontal: approx. 180 km (TL95) Vertical: 40 levels (~0.4hPa) * Oceanic component Horizontal: 1.0º longitude, 0.3–1.0º latitude (75˚S – 75˚N) Vertical: 50 levels
Forecast range	Up to 34 days	7-months (for summer/winter forecast) 4 months (other initial month)
SST	Persisted anomaly	Prognostic variable of CGCM
Sea ice	Climatology	
Ensemble method	Combination of Breeding of Growing Modes (BGM) and Lagged Average Forecast (LAF)	
Ensemble size	50 (25 BGMs & 2 days with 1-day LAF)	51 (9 BGMs & 6 days with 5-day LAF)
Frequency of operation	Every Tuesday and Wednesday	Every 5 days
Frequency of model product creation	Once a week Every Thursday	Once a month Around the 20th (no later than the 22nd) of every month

RECENT CHANGES AND DEVELOPMENT

Development
– physics and dynamics-

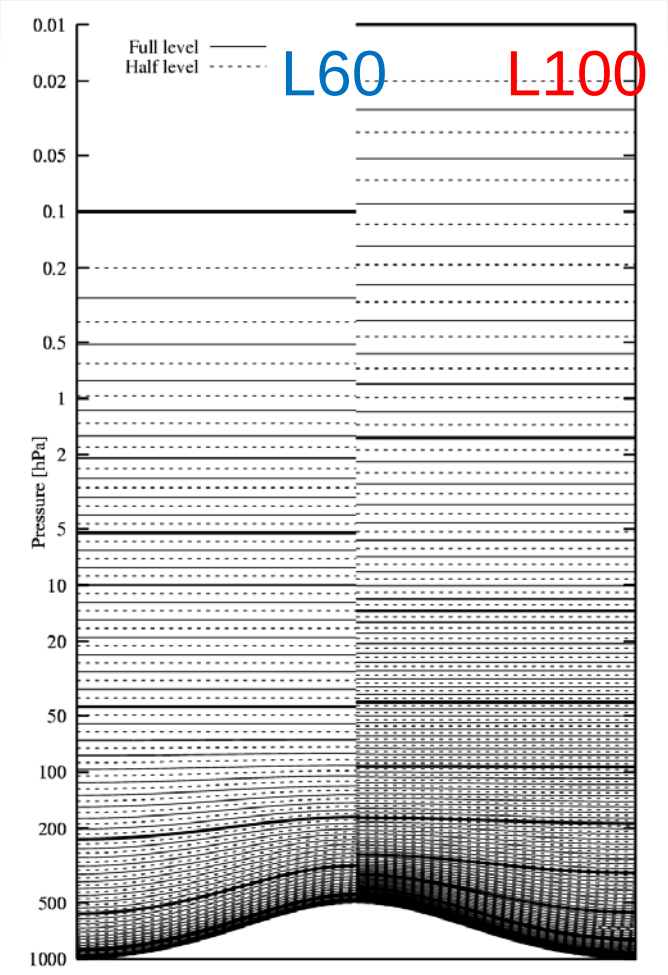
- Recent changes
  - ***18 Mar. 2014 :***
    - ***Increasing the number of vertical levels (top:0.1→0.01 hPa)***
    - ***Revise physical processes***
      - ***stable boundary layer scheme***
      - ***albedo parameters in the desert areas***
      - ***two-stream approximation for long wave radiation scheme***
      - ***non-orographic gravity wave forcing scheme***
      - ***modification of convective parameterization***
      - ***4th-order linear diffusion as a sponge layer etc.***
- Under development
  - Update of physical processes
    - Land surface, sea surface, boundary layer, ***cumulus convection, cloud,*** gravity wave, radiation
  - ***Verification against multiple analyses***



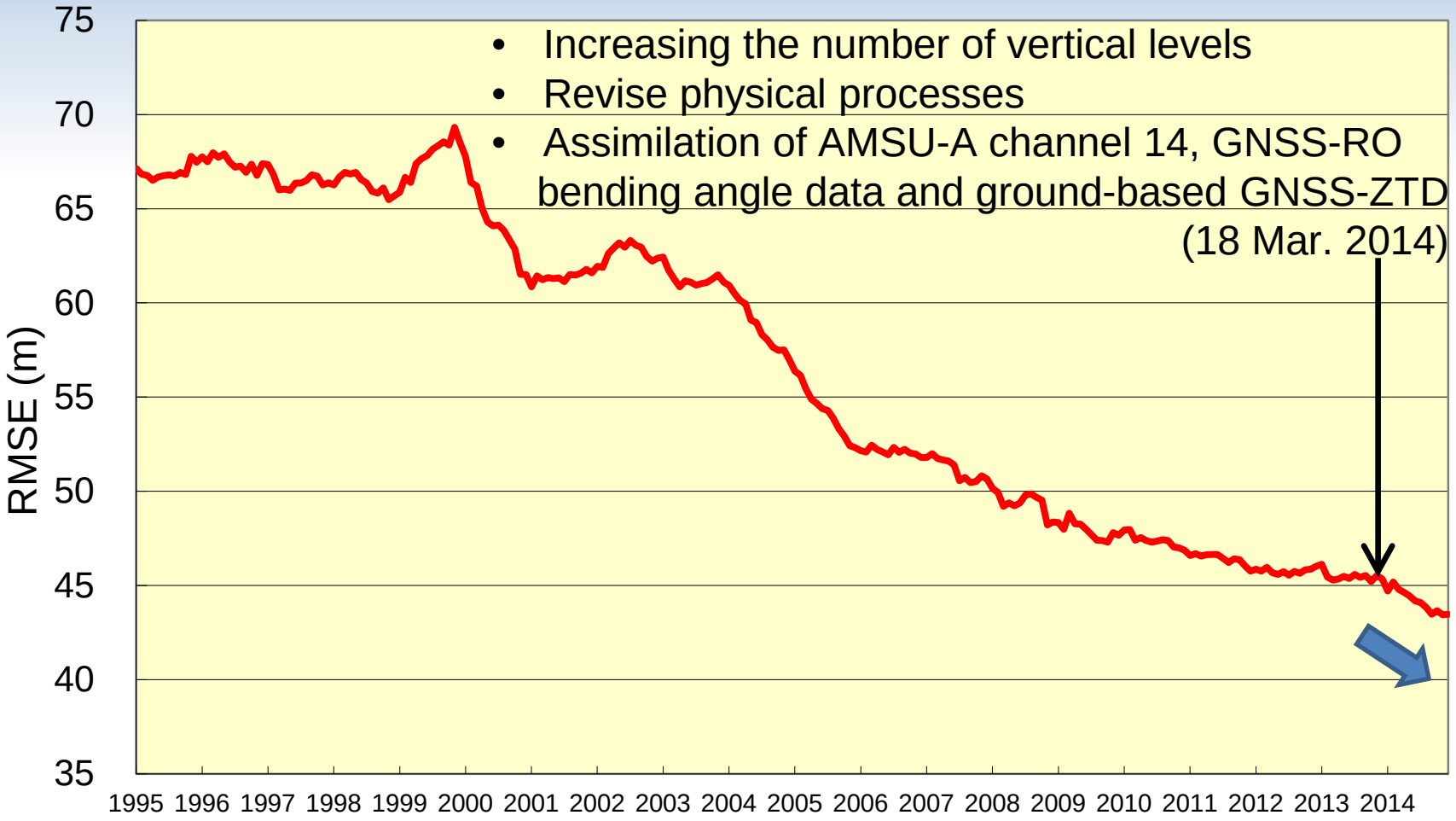
INCREASE THE NUMBER OF VERTICAL LEVELS
&
REVISE PHYSICAL PROCESSES

Enhancement of GSM (18 Mar. 2014)

- The number of vertical levels in GSM was enhanced from 60 to 100.
- The top level of the model was raised from 0.1 hPa to 0.01 hPa.
- Time Step: 600s → 400s



Verification score



Twelve months mean 500-hPa NH HGT Day-5 RMSE

The upgrade in March 2014 improved forecast skill significantly.

UNDER DEVELOPMENT
CUMULUS CONVECTION AND CLOUD SCHEME

Update of cumulus convection and cloud scheme

- Under Development -

- Cumulus convection (Arakawa-Schubert)

1. Revising budget equation of moist static energy
   → Improving energy conservation
2. Revising estimation of static energy at cloud base
   - Entrainment rate based on Jakob and Siebesma (2003), adding static energy perturbation at cloud base

   → Improving convective heating profile
3. Revising snow melting process
   → Improving convective heating profile
4. Introducing fallout of precipitation between cloud base and cloud top
   - Iterative calculation to estimate entrainment rate

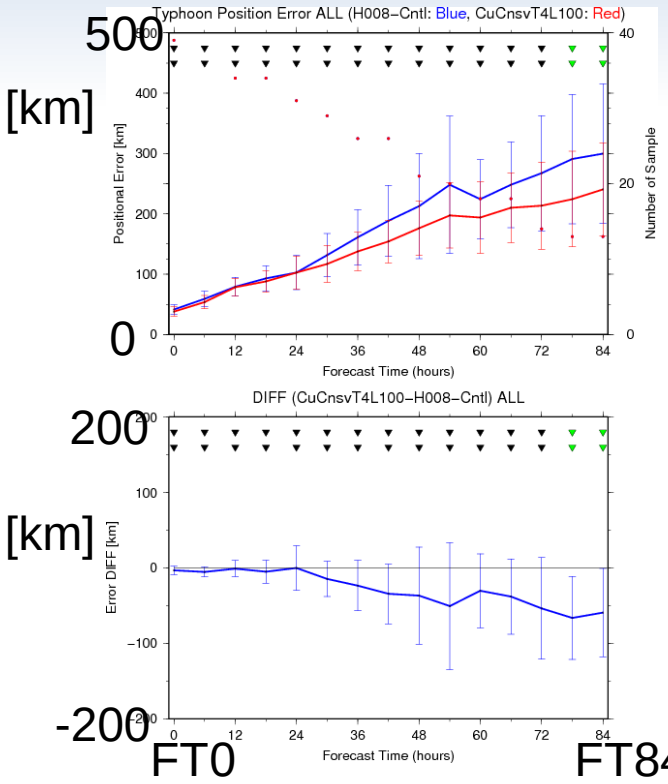
   → Improving convective heating profile

- Cloud (PDF-based parameterization (Smith 1990))

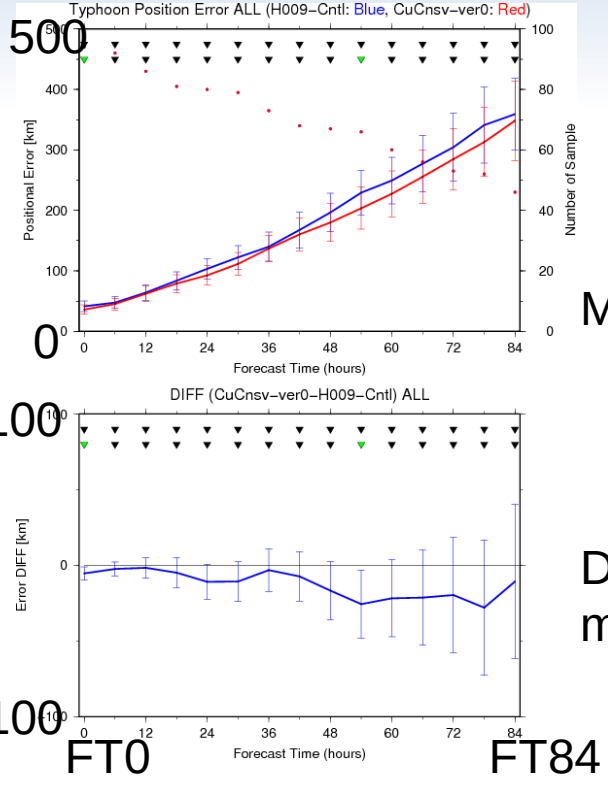
1. Removing increase of PDF width by cumulus effect
   → Reducing dry bias in the middle troposphere
2. Revising cloud ice falling process
   → Reducing time step dependency

Tropical cyclone track forecast errors

Aug. 2013



Jul. – Sep. 2014



TEST

CNTL

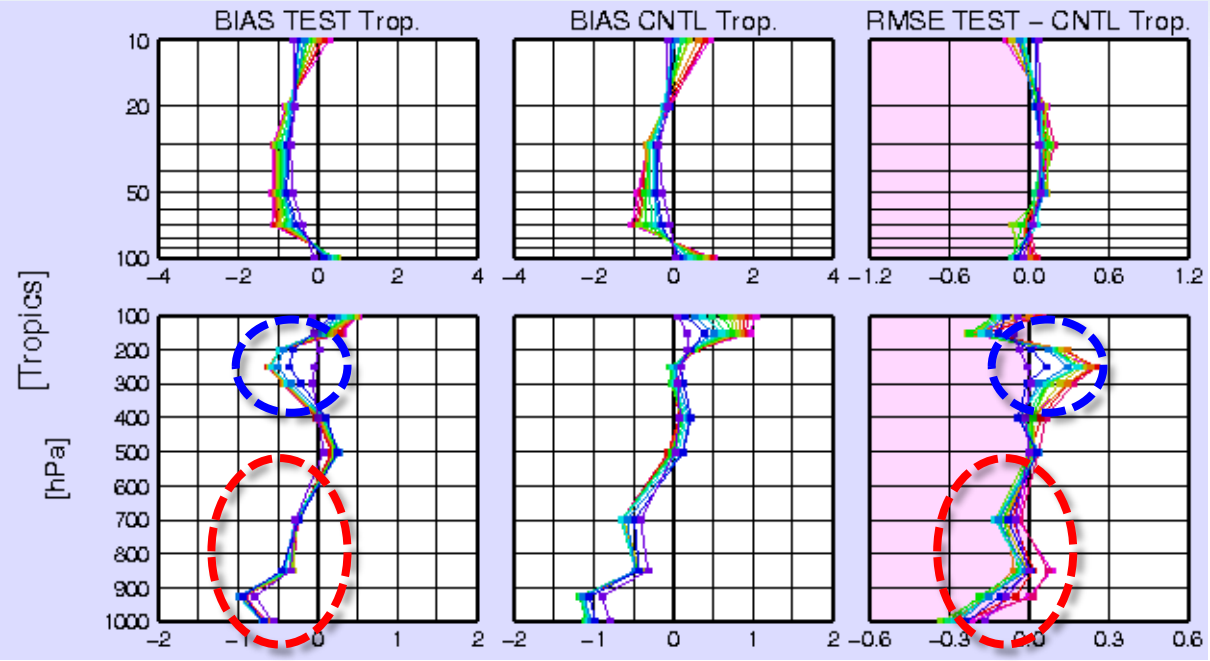
▼: statistically significant

Mean track errors

Difference of mean track errors

The updated scheme reduces TC track forecast errors.
TEST has smaller initial track error (due to better representation of TC genesis ?).

Tropical temperature bias and RMSE verified against Radiosonde observations



Aug. 2013

FT=0	FT=96	FT=192
FT=24	FT=120	FT=216
FT=48	FT=144	FT=240
FT=72	FT=168	FT=264

Cold bias in the lower and middle troposphere is reduced.
On the other hand, cold bias increase in the upper troposphere.

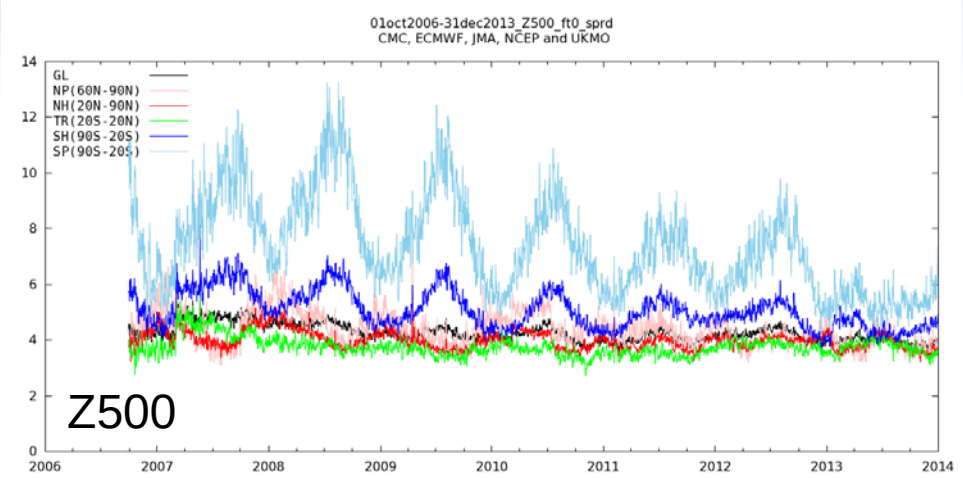
RMSE change correspondently.

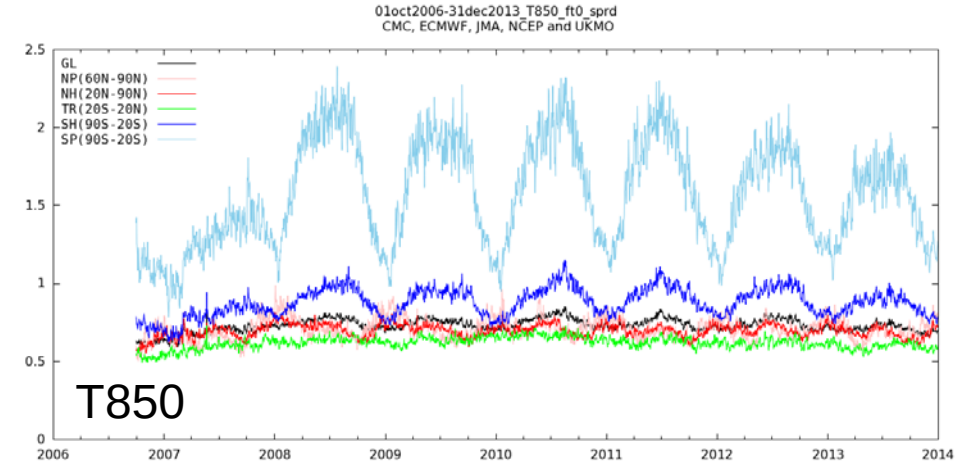
VERIFICATION AGAINST MULTIPLE ANALYSES

Study on analysis fields discrepancies

- At WGNE-29, JMA showed verification of TIGGE forecasts against multiple analyses.
  - with only rare exceptions, each of the centres' models verified best against their own analysis; discrepancies among centres' analysis
- JMA is investing the discrepancies.
  - Using TIGGE data, analysis fields are taken from initial fields of ensemble unperturbed control run initialized at 12UTC to calculate their spread.

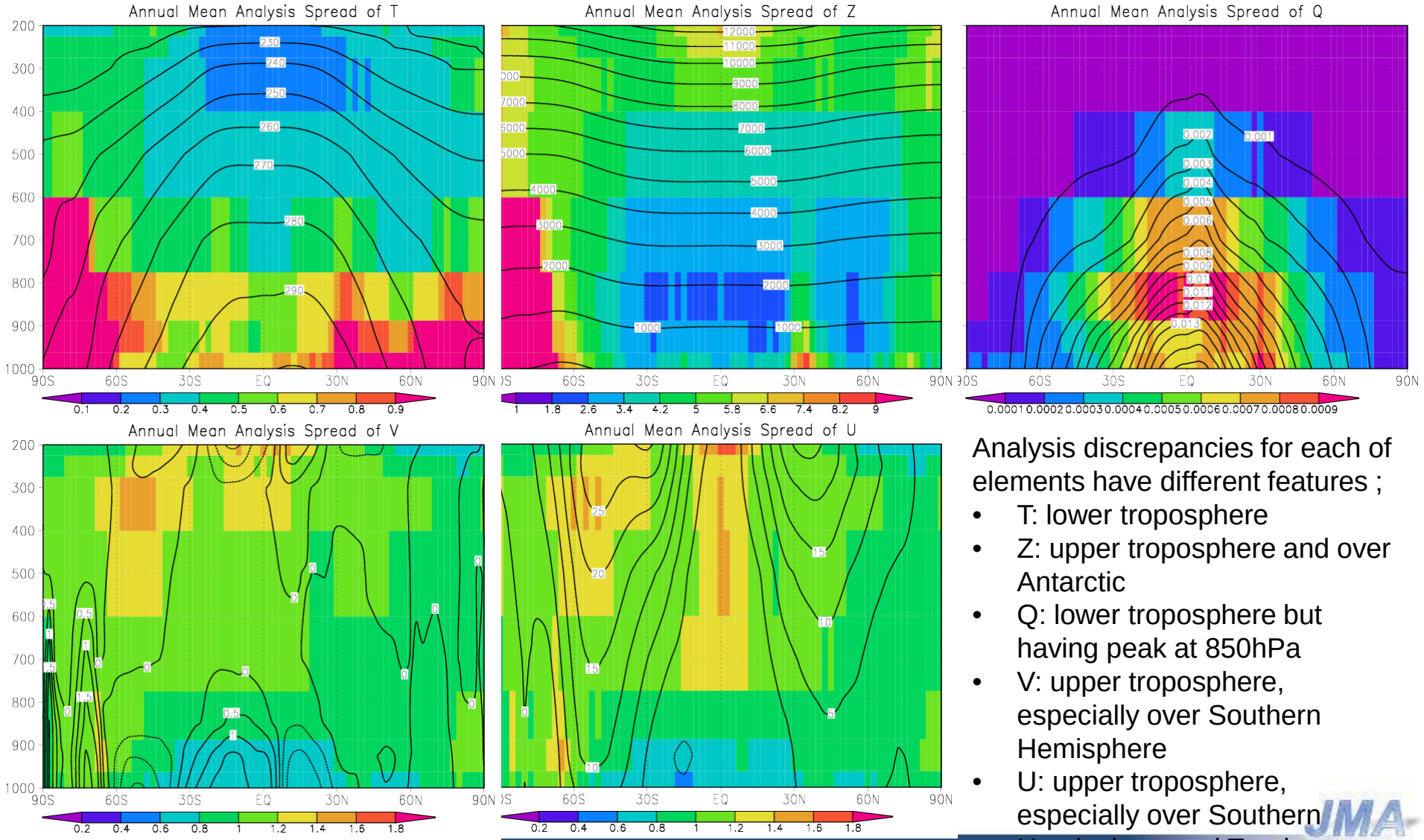
Time series of Z500 and T850 analysis spread between CMC, ECMWF, JMA, NCEP and UKMET





Analysis spread of Z500 from multiple analyses is decreasing over recent years, especially over the Southern polar regions. Result of polar regions are consistent with Bauer et al. (2014). In contrast to geopotential height at 500hPa, analysis field discrepancies for temperature at 850hPa seem to be almost unchanged over recent years. Similar results are obtained by Jung and Matsueda (2014) but for T2m analysis over polar regions.

2013 annual mean zonally averaged analysis spread between CMC, ECMWF, JMA, NCEP and UKMET



Analysis discrepancies for each of elements have different features ;

- T: lower troposphere
- Z: upper troposphere and over Antarctic
- Q: lower troposphere but having peak at 850hPa
- V: upper troposphere, especially over Southern Hemisphere
- U: upper troposphere, especially over Southern Hemisphere and Tropics

Development – EPS -

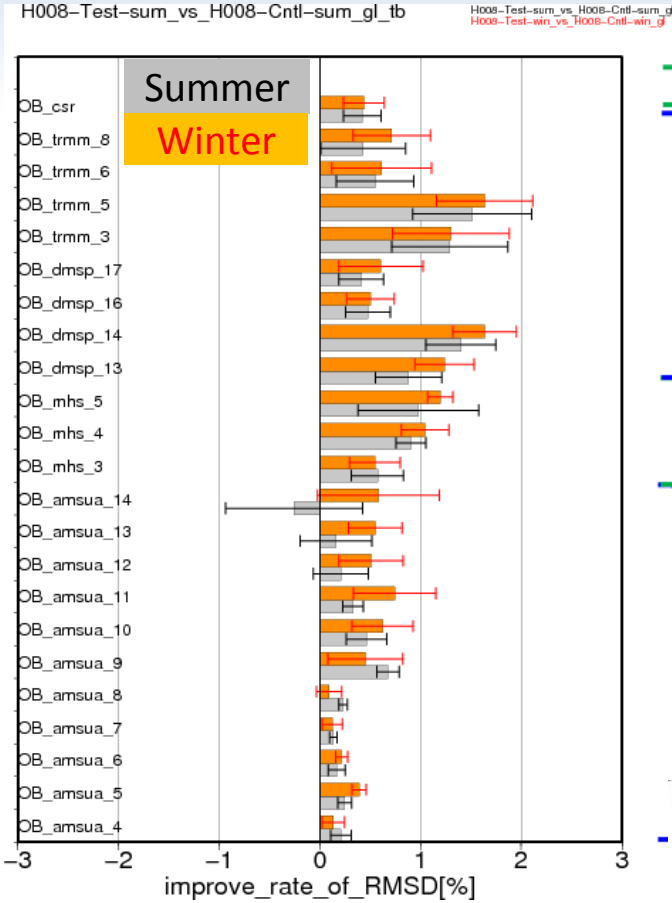
- Under development
  - Extension of forecast range up to 432 hours ahead
  - Introduction of the latest version of GSM (TL479L100)
  - Reduction of tropical initial perturbation amplitude
  - Revise of sea surface temperature and sea ice during the time integration
  - Introduction of snow analysis with both SSM/I and SSMIS data and land cycle system as a land initial condition generator

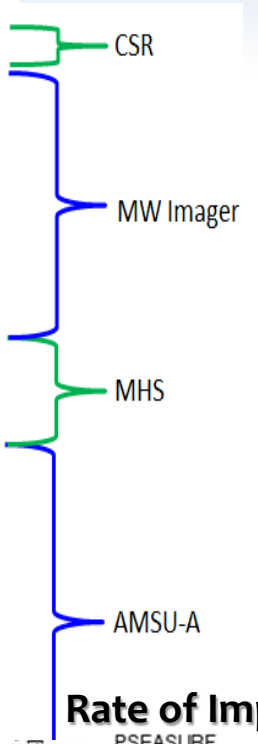
Development – assimilation, data-

- ***18 Mar. 2014: Started assimilating the following data into the JMA's Global Data Assimilation (DA) System***
  - ***AMSU-A channel 14***
  - ***GNSS-RO bending angle data at the altitude up to 60km (In the previous system, refractivity data up to 30km)***
  - ***ground-based GNSS-ZTD (Zenith Total Delay) data***
- 22 May 2014: Improved Typhoon Bogus for the JMA's Mesoscale DA System
- ***4 Sep. 2014: Upgraded the JMA's Global DA System***
  - ***Started assimilating hyper-spectral IR sounder (Aqua/AIRS and Metop-A,B/IASI) into the JMA's DA System***
  - ***Improved Typhoon Bogus for the JMA's Global DA System***
- 29 Jan. 2015: Upgraded Local DA System with a new 3D-Var DA system (ASUCA-Var) and started assimilating the MTSAT AMVs into the JMA's Local DA System

Aqua/AIRS and Metop/IASI

operationalized on 4 September 2014





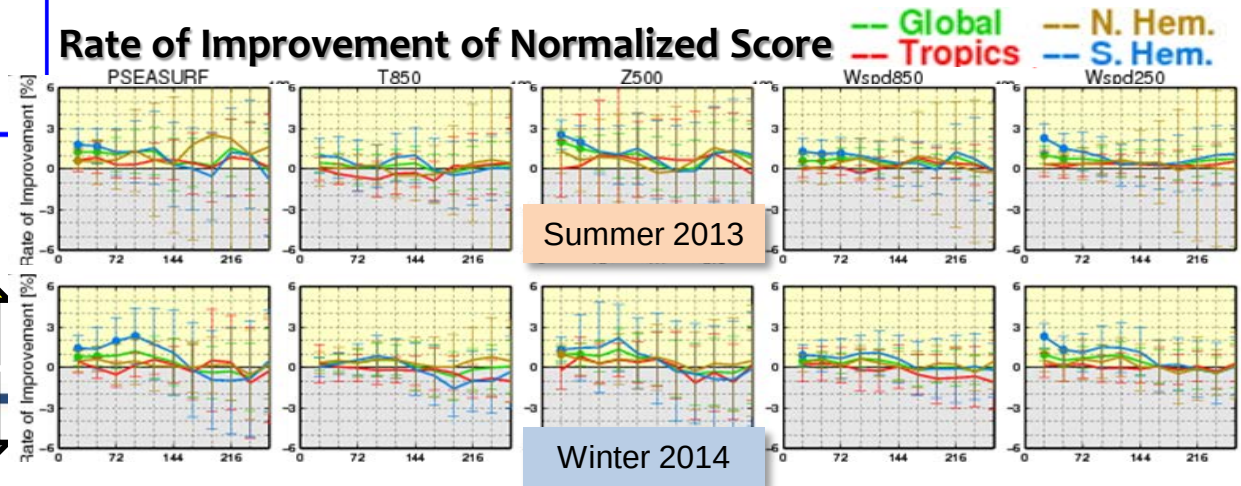
|O-B| stats of the other observations

worse ← → better

better ↑

worse ↓

- Assimilate Only Clear Sky Radiances
- Channel Selections:
  AIRS 85 CHs, IASI 69 CHs.
- OSEs using Global NWP system reveals that the forecasts are improved, especially for the beginning of forecast period.

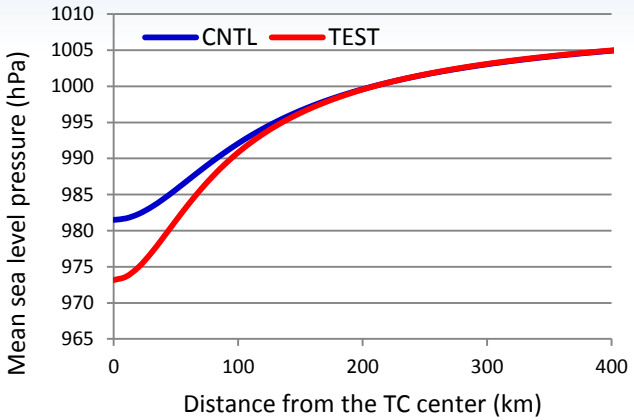


気象庁
Japan Meteorological Agency

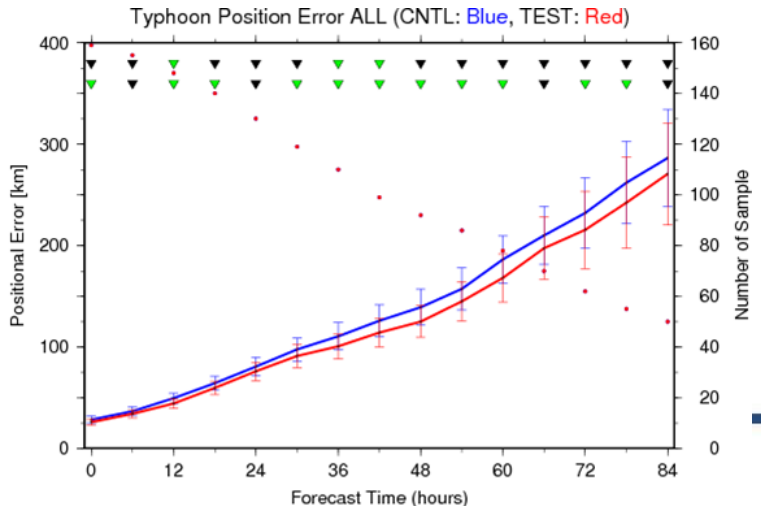
Improved Typhoon Bogus

operationalized on 4 September 2014

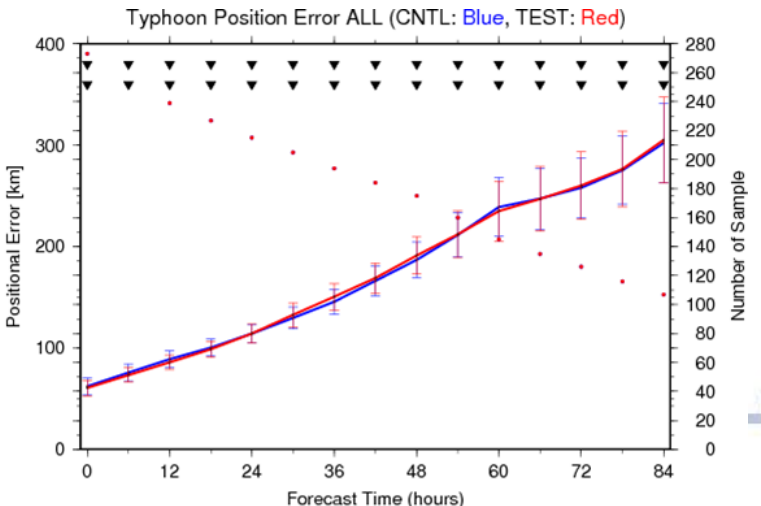
- Typhoon bogus is modified to allow a model to represent a typhoon whose pressure gradient is steep around the typhoon center.
- Mean typhoon position error of typhoons that have steeper pressure gradient around their centers is improved while that of other typhoons is neutral.



Mean typhoon position error of typhoons with steeper pressure gradient around their centers



Mean typhoon position error of other Typhoons



Development – regional -

- Recent changes
  - ***27 Nov. 2014: Improvement of Snow Analysis on the Domestic Region in 5km-MSM***
  - ***29 Jan 2015: Introduction of ASUCA (dynamical core), the Physics Library and ASUCA 3D-Var for 2km-LFM***
- Under development
  - Introduce of ASUCA and the Physics Library for 5km-MSM
  - Increase the model levels (from 50 to 75) for 5km-MSM
  - Development of ASUCA 4D-Var based on ASUCA
  - Mesoscale Ensemble Prediction System

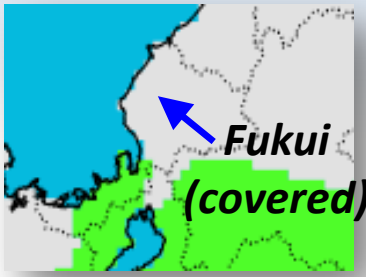
Improvement of Snow Analysis on the Domestic Region in 5km-MSM

Old Analysis

Snow Depth OBS

Modified

JMA Global Snow Analysis (1x1 deg)



high resolution

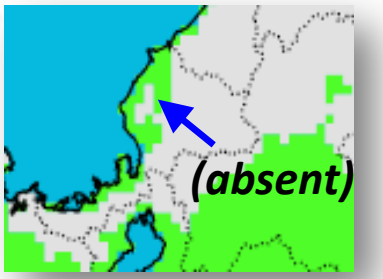
New Analysis !!

Initial snow condition

Snow Depth FG (Offline LSM with 5km)

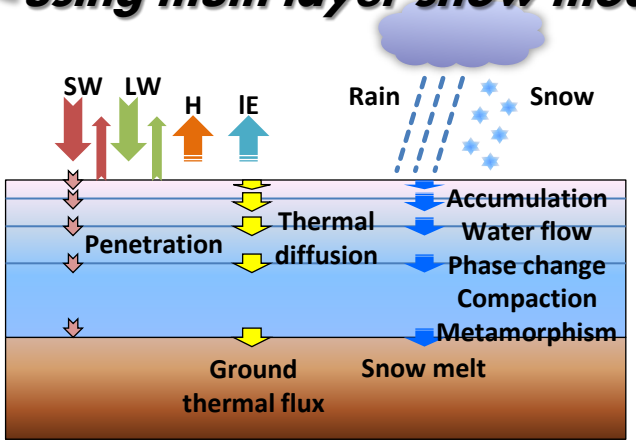
Snow Depth OBS

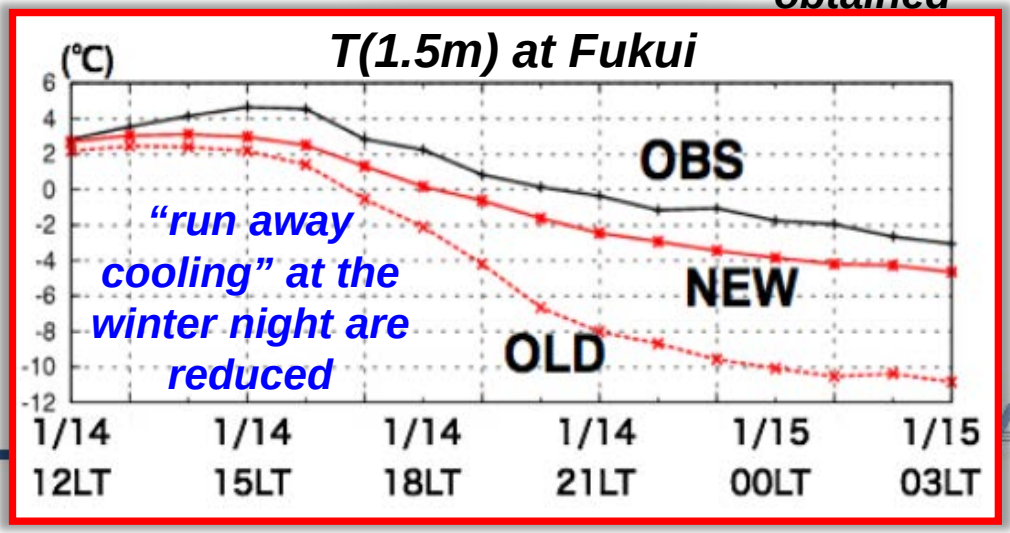
2D-OI Snow Analysis



more realistic fields of snow covers are obtained

using multi layer snow model



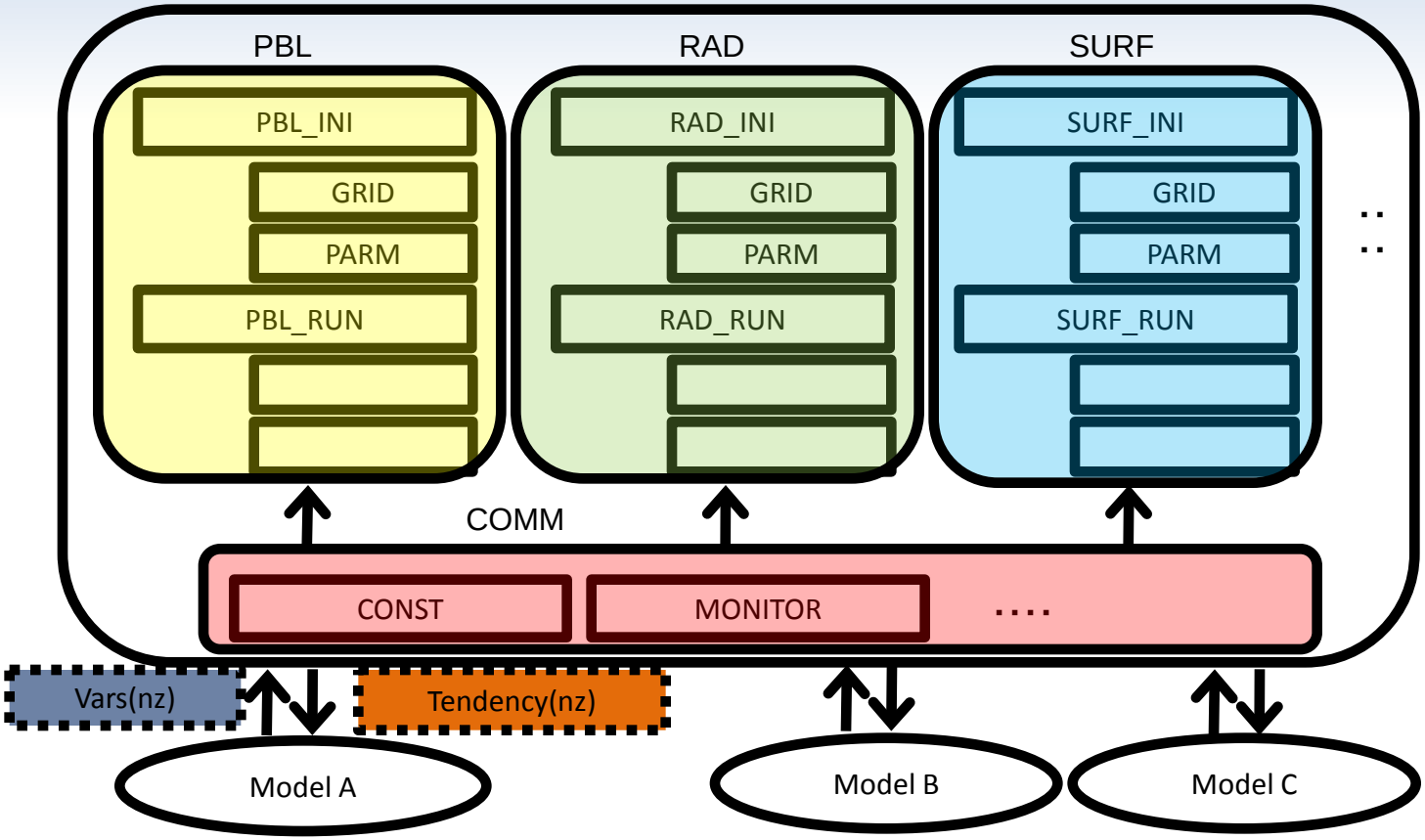


DYNAMICAL CORE “ASUCA”
PHYSICS LIBRARY
“ASUCA-VAR” : VAR-DA SYSTEM BASED ON ASUCA

Comparison of the specification of the dynamical core between ASUCA and JMA-NHM

	ASUCA	JMA-NHM
Governing equations	Flux form Fully compressible equations	Quasi flux form Fully compressible equations
Prognostic variables	ρu, ρv, ρw, $\rho\theta_m$, ρ	ρu, ρv, ρw, θ, p
Spatial discretization	Finite volume method	Finite difference Method
Time integration	Runge-Kutta 3rd (long and short)	Leapflog with time filter (long) Forward backward (short)
Treatment of sound	Conservative Split explicit	Split explicit
Advection	Combining 3rd and 1st order upwind with flux limiter by Koren(1993)	4th (hor.) and 2nd(ver.) order with advection correction
Numerical diffusion	None	4th order linear and nonlinear diffusion
Treatment of rain-drop	Time-split	Box-Lagrangian
Coordinate	Generalized coordinate or Conformal mapping + Hybrid-Z	Conformal mapping (hor.) Hybrid – Z (ver.)
Grid	Arakawa-C (hor.) Lorentz (ver.)	Arakawa-C (hor.) Lorentz (ver.)

Schematic structure of the "**Physics Library**"

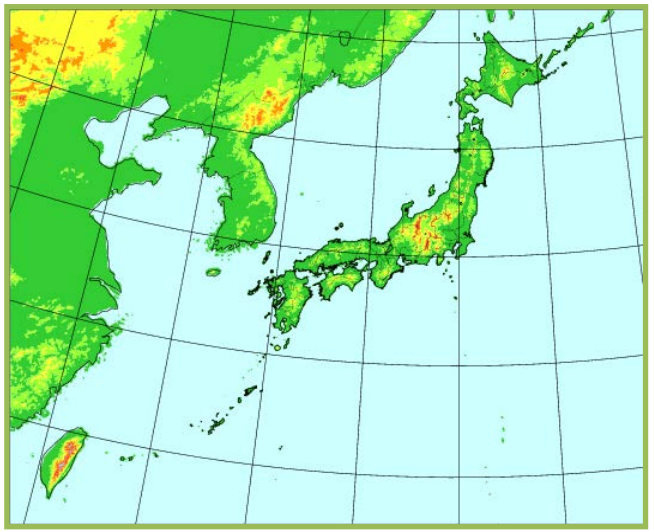


- The "Physics Library" is designed to be easily plugged into any models
- The physical processes implemented in the "Physics Library" are vertically one-dimensionalized.
- ASUCA passes **inputs (Vars(nz))** to library, then receives **tendencies (tendency(nz))** from library.

Specification ASUCA 3D-Var

	ASUCA 3D-Var
Control variables	u(x-component wind) v(y-component wind) [Tg,(skin and underground temperature), Psrf,(surface pressure) θ(potential temperature)] [wg (soil moist contents), $\mu=qv/qv^{b}_{sat}$(pseudo relative humidity)]
Background covariance	Variable in each grid
MPI parallelized	2-D domain decomposition

Analysis domain	
Horizontal resolution	5 km
Vertical Layer	50 layer, up to about 22 km

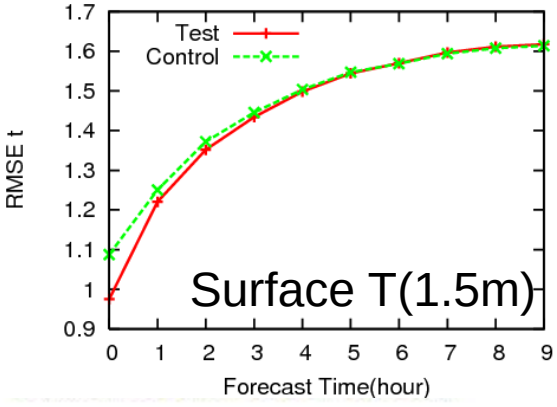


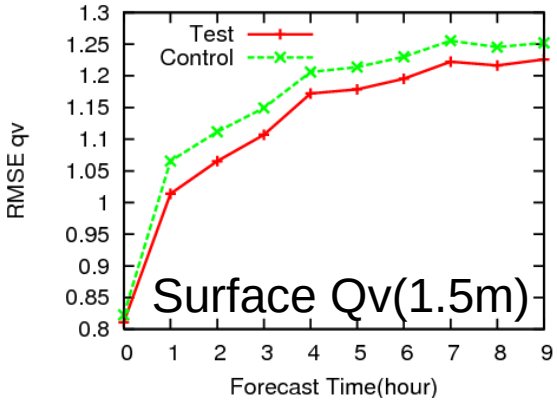
■ Forecast impact by ground variables

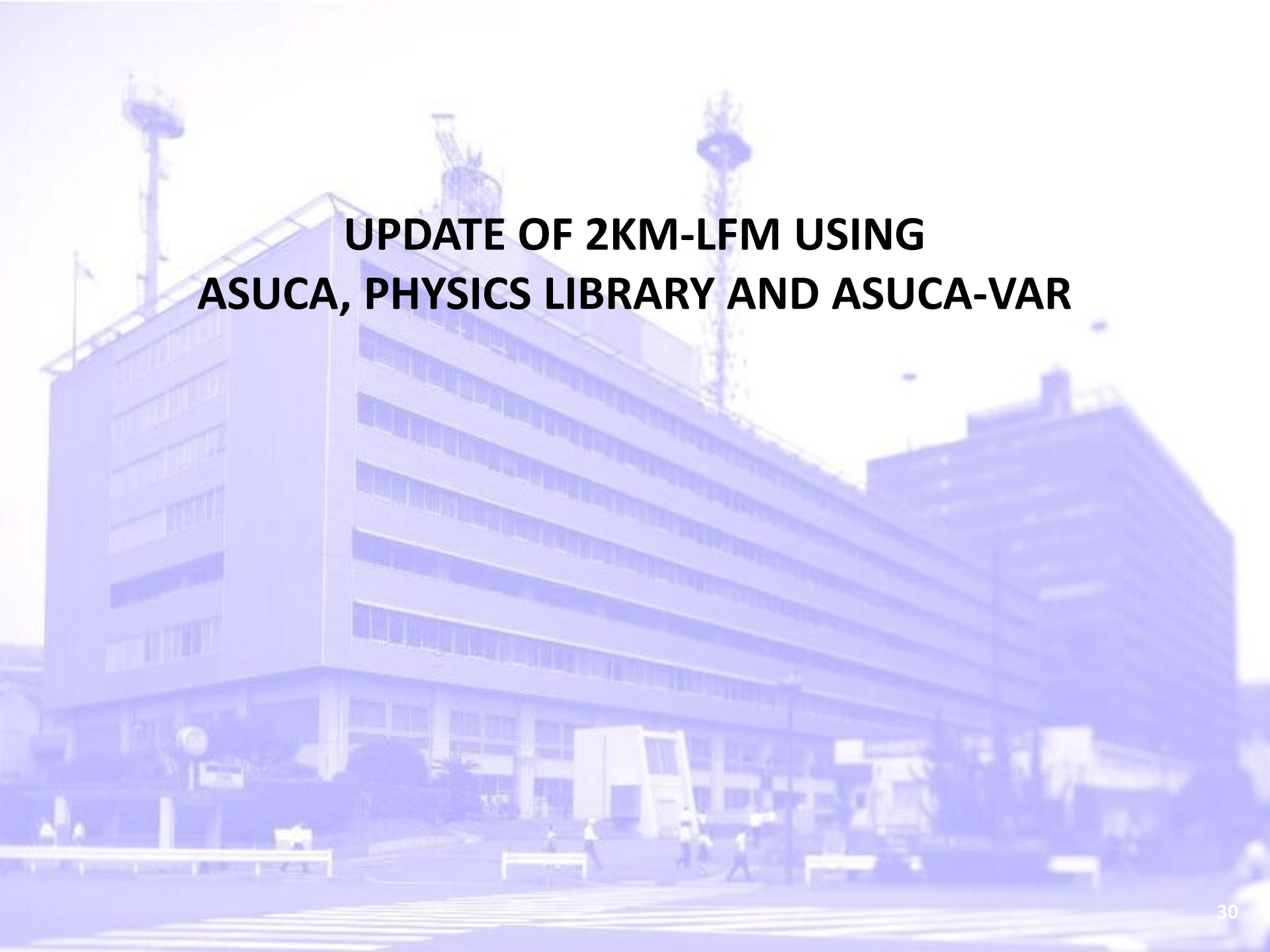
Control : Tg, wg are not analyzed

Test: Tg, wg are analyzed

Verification period is 12Jul2012 -22Jul2012







UPDATE OF 2KM-LFM USING ASUCA, PHYSICS LIBRARY AND ASUCA-VAR

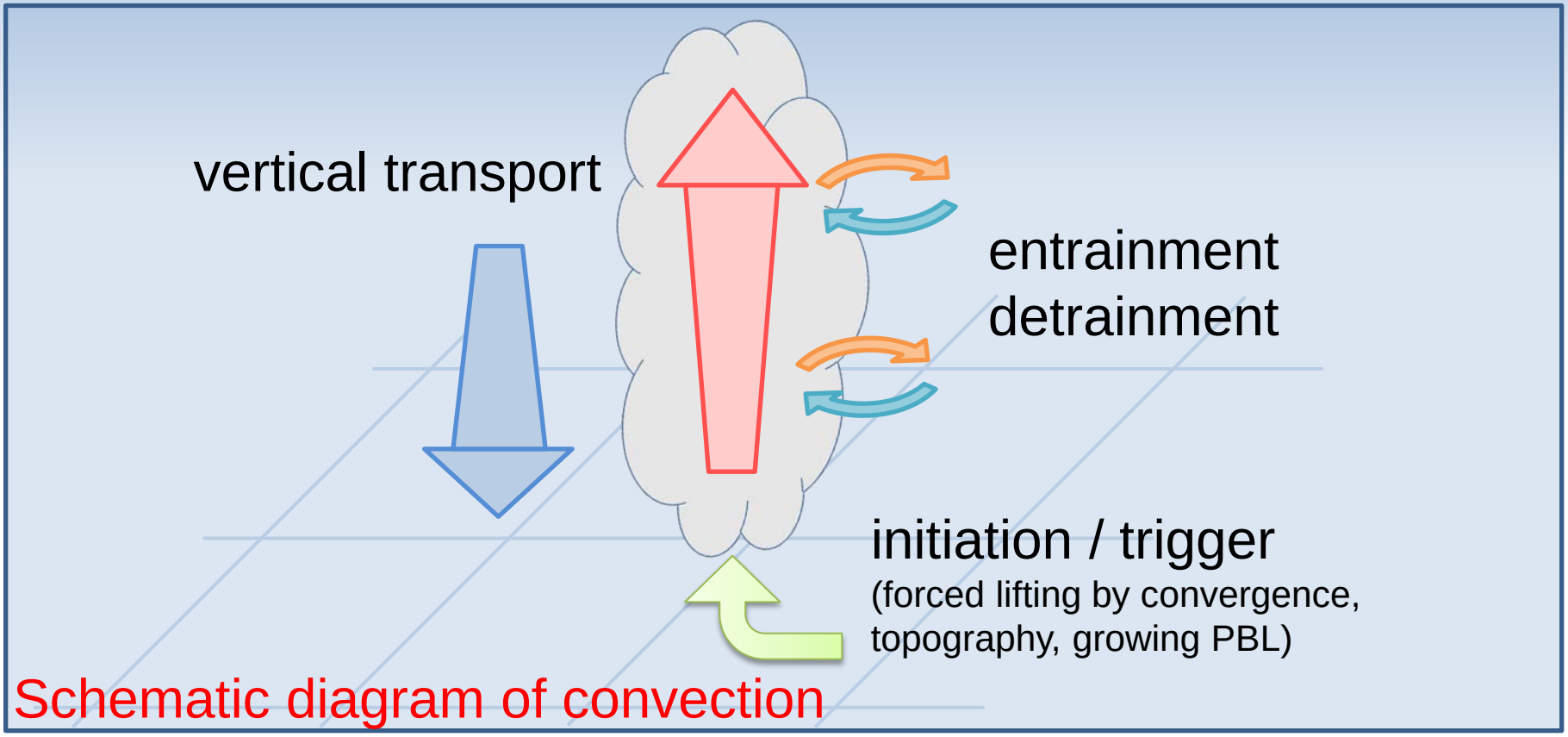
Improvement of physical processes

- Physical processes equivalent to or more enhanced than those of previous 2km-LFM have been implemented using the Physics Library.
- Some enhancements are developed
  - improved MYNN-3
  - implicit coupling of boundary layer and surface flux scheme
  - tiling surface flux
  - parameterization of convective initiation
  - and so on

Performance of new 2km-LFM

- Basic performance from the statistical point of view is similar to or better than that of previous system.
- Some aspects are improved though the overall accuracy of precipitation forecast are similar.
  - Diurnal cycle of the rainfall for the free convection
  - Mountain wave
  - Karman Vortex Streets
  - and so on

Parameterization for convective initiation(PI)



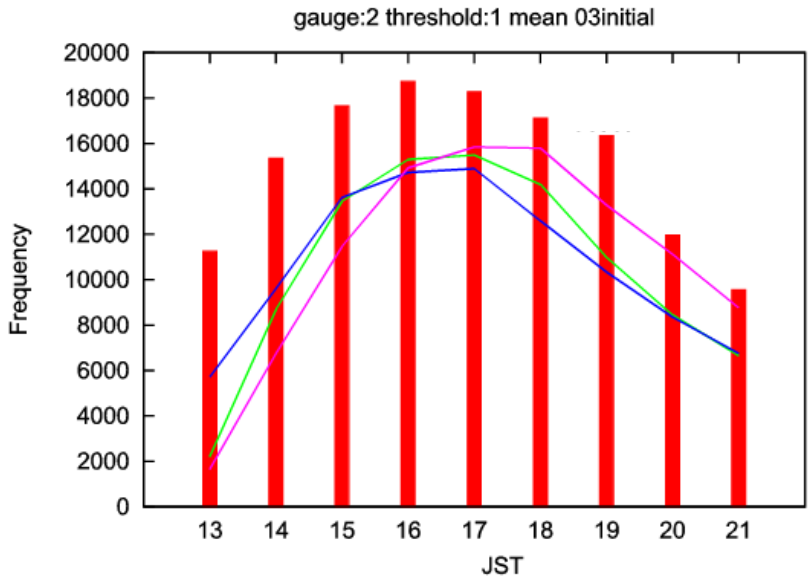
Schematic diagram of convection

Based on the existing KF scheme, but assuming slower convective stabilization; tendency from convective process is much smaller than the original scheme
Weak vertical transport of heat and moisture and release of latent heat produce local low pressure area which promotes convection by dynamical process.

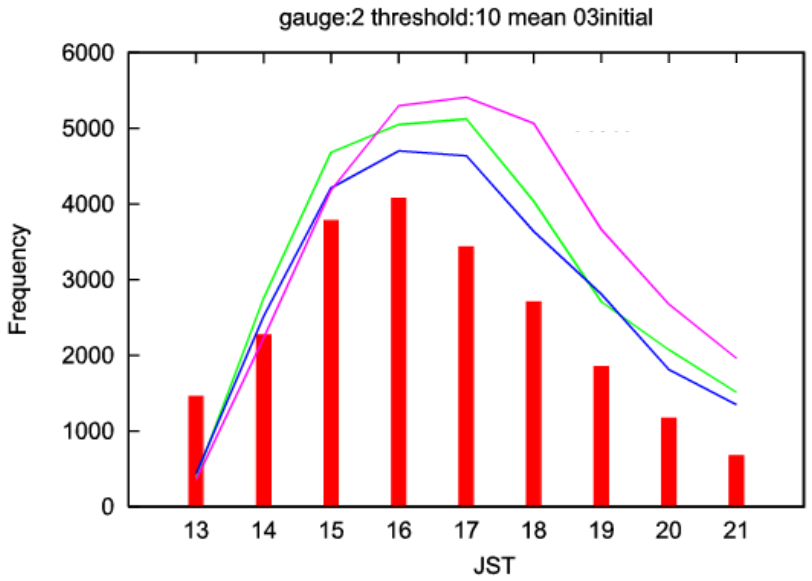
Time series of precipitation frequency

- Red bars: observation
- Pink lines : previous LFM
- Green Lines: new LFM without PI, Blue Lines: new LFM with PI

over 1mm/h



over 10mm/h

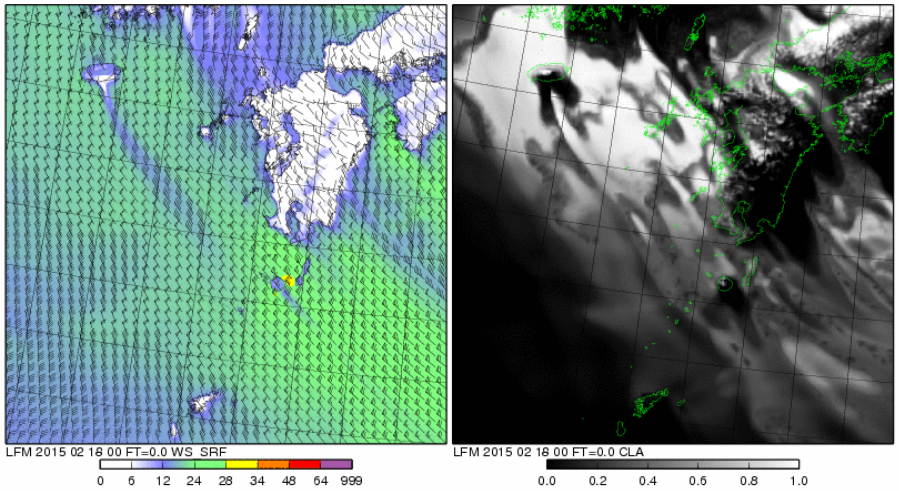


Even without PI, new LFM improves peaks of frequency compared with previous LFM. By employing PI, peaks of frequency almost coincide with observed ones, though frequency of prep >= 1mm/h is still too low and that of prep >=10mm/h is still too large

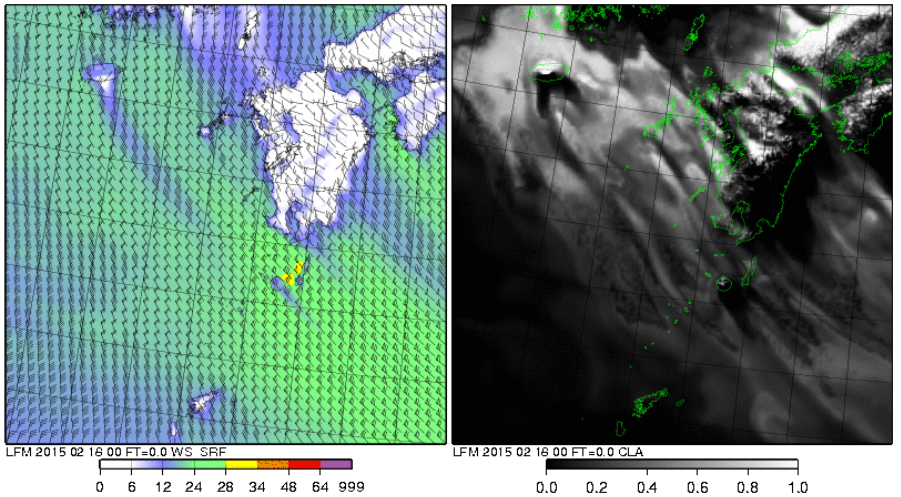
Karman Vortex Streets

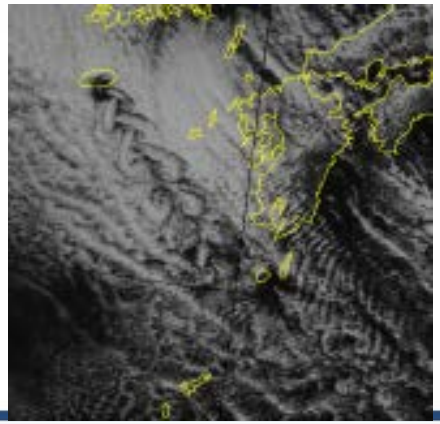
Initial time at 2015/02/18/00UTC (T+0 to T+9)

New 2km-LFM



Previous 2km-LFM





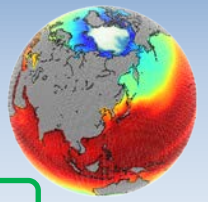
Observation at 2015/02/18/04UTC

Karman vortex streets on the leeside of Jeju island are well reproduced by the new 2km-LFM.

Development – climate -

- Under development
  - ***Upgrade of the seasonal forecast model in June 2015***
    - JMA/MRI-coupled prediction system 2
    - Increased resolution
    - Stochastic physics
    - Sea-ice model
    - Land and atmospheric initial condition is provided by JRA-55

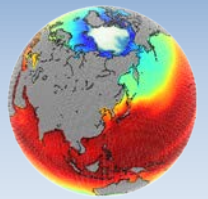
New Seasonal Ensemble Prediction System (JMA/MRI-CPS2, June 2015-)



- ✓ Improved physics
- ✓ Interactive sea ice model
- ✓ GHGs
- ✓ Increased resolution
- ✓ Land initialization
- ✓ Stochastic physics

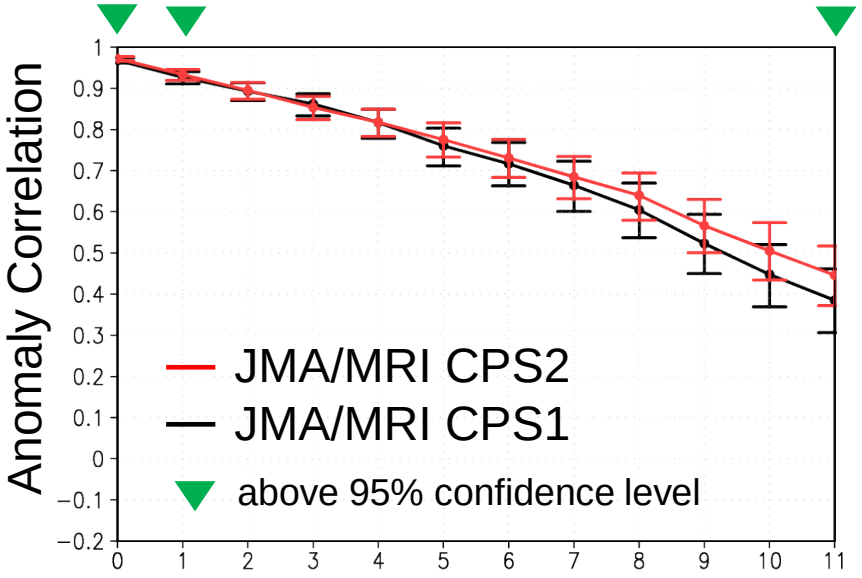
	JMA/MRI-CGCM1 (Current)	JMA/MRI-CGCM2 (Next)
Atmosphere (JMA-GSM)	***TL95L40***, ~180km, Up to ***0.4hPa***	***TL159L60*** , ~110km, Up to ***0.1hPa*** ***Stochastic Tendency Perturbation*** ***GHG forcing*** from RCP4.5 scenario
Ocean (MRI.COM) (Tsujino et al 2010)	1.0° (lon) x ***0.3-1*** ° (lat) ***L51*** 75°S-75°N Ocean ***Sea-ice climatology***	1.0° (lon) x ***0.3-0.5*** ° (lat) ***L53*** ***Global Ocean with Tripolar Grid*** ***Sea-ice model***
Coupler (Scup) (Yoshimura and Yukimoto 2008)	1-hour coupling interval ***Momentum and heat flux adjustments***	1-hour coupling interval ***No flux adjustment***
Initial Condition	Atmosphere: ***JRA-25*** Land: ***Climatology with ERA-15 forcing*** Ocean: ***MOVE/MRI.COM-G*** T, S&SSH (Usui et al. 2006) ***Sea-ice climatology***	Atmosphere: ***JRA-55*** Land: ***JRA-55 land analysis*** Ocean: ***MOVE/MRI.COM-G2*** T, S & SSH ***Sea-ice model***
Ensemble Size	51 (***9*** BGMs, ***6*** days with 5-day LAF)	51 (***13*** BGMs, ***4*** days with 5-day LAF)

Performance of Seasonal EPS

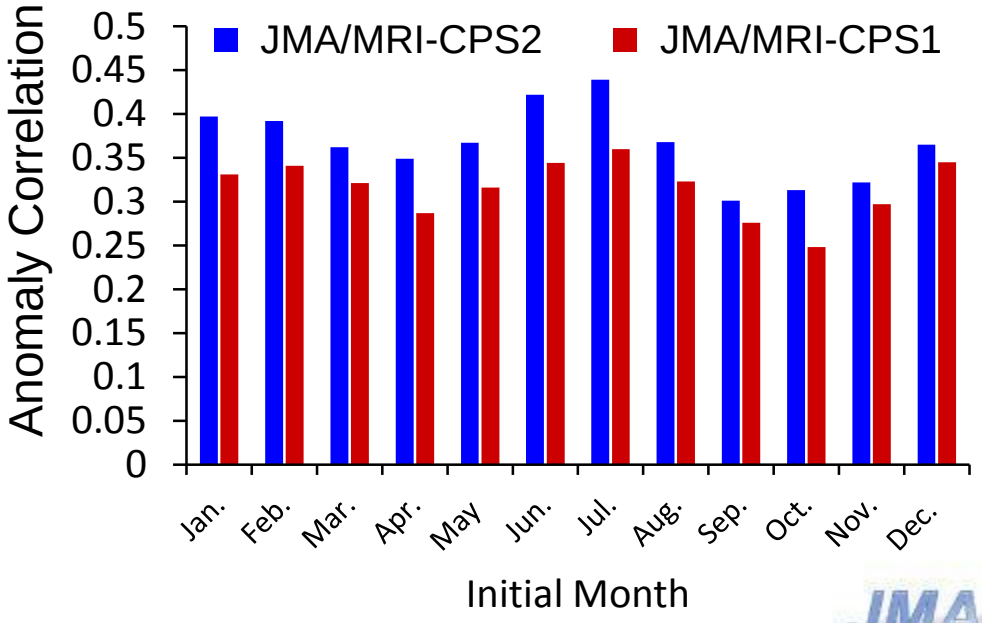


- Improved ENSO prediction skills (NINO3, NINO3.4 SST)
- Improved 3-month and warm/cold season prediction skills (in particular for surface temperature over land)

ACCs of NINO3 SST (all months, 10 members)



ACCs of surface temperature averaged in NH (3-month prediction, 1-month lead time)



JAPANESE REANALYSIS : JRA-55

JRA-55 family (Japanese Reanalysis)

JRA-55 (JRA Go! Go!) (1958~2012, 2013 to present)

Shinya Kobayashi et al. 2015 (JMSJ)

JRA-55C (JRA-55 conventional) (1972~2012)

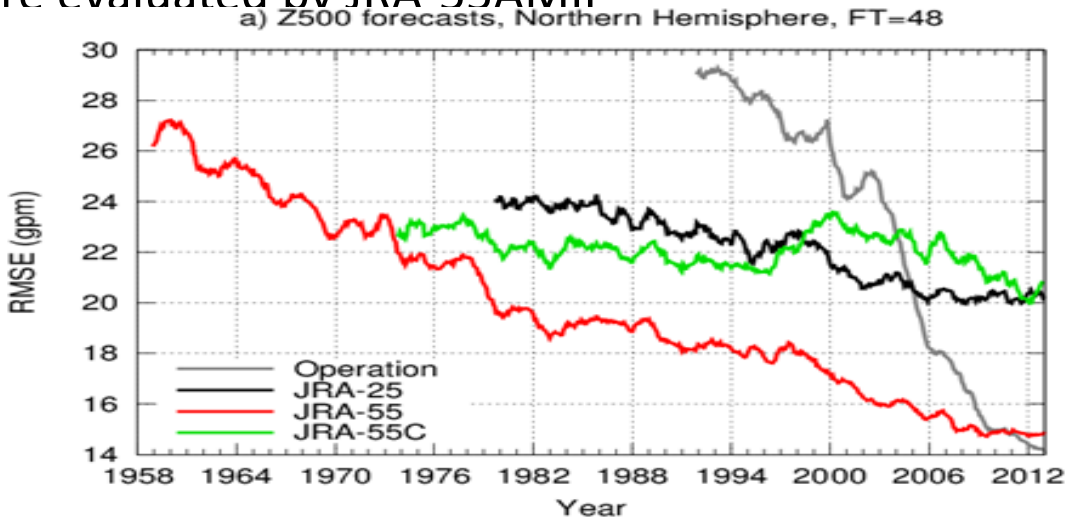
Chiaki Kobayashi et al. 2014 (SOLA)

- JRA-55C used conventional data only, without satellite data.
- To avoid being affected by observing system changes, and to detect "unrealistic" changes.
- JRA-55C has priority for consistency rather than quality.

JRA-55AMIP (JRA-55 AMIP type run) (1958~2012)

- Systematic model biases are evaluated by JRA-55AMIP
- No observation is used.

- JRA-55 family data are available from JMA, DIAS(U of Tokyo), and NCAR.
  (JRA-55AMIP is still in preparation)



気象庁

http://jra.kishou.go.jp/

THANKS FOR YOUR ATTENTION

A rainbow observed near meteorological satellite center of JMA in 23rd April 2011