Center Report
- JMA 2012 -

Chiashi Muroi and colleagues at JMA

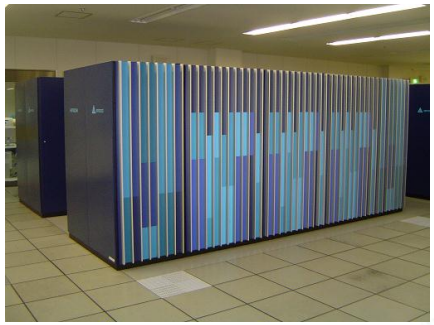
5-9 Nov. 2012, Toulouse

WGNE-28

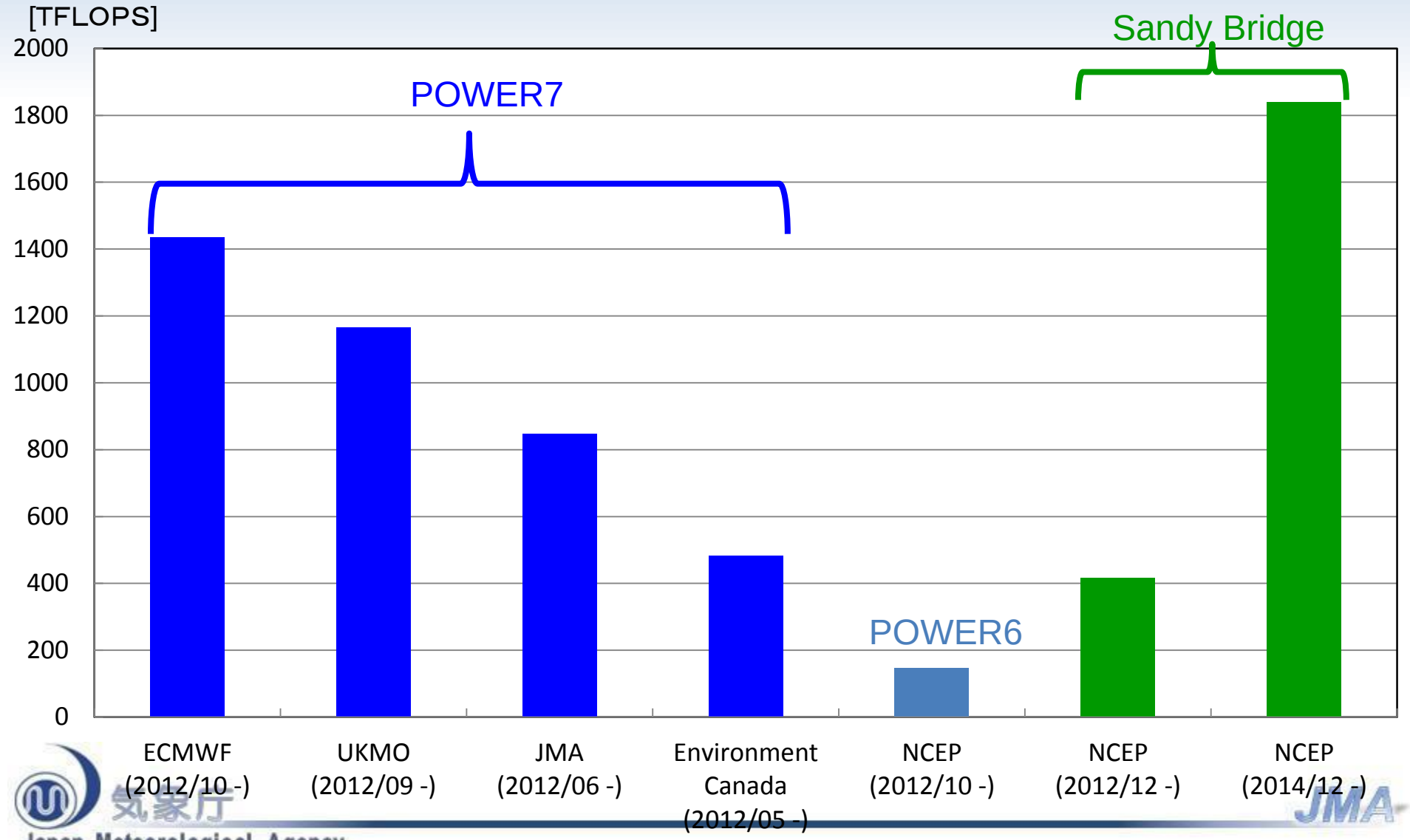

SUPER COMPUTER UPGRADE
AND NWP SYSTEMS AT JMA

New Super Computing Systems

	New	Old
Machine	Hitachi SR16000/M1	Hitachi SR11000/K1 Hitachi SR11000/J1
CPU	Power 7 (3.83GHz, 8core)	Power 5 (1.9GHz), Power 5+ (2.1GHz)
CPU/NODE	4 processors (total 32cores)	16 processors
NODE	864 (432x2)	210 (80x2+50)
Peak Performance	847 (423.5x2) T Flops	27.5 (10.75x2+6) T Flops
Main Memory	108 T Byte	13.1 T Byte
operation was started on	5 June 2012 -	1 March 2006 -

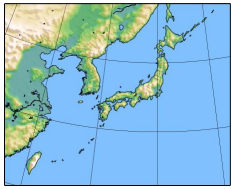


HPC at NWP centers



Current NWP models of NPD/JMA

New

	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, Short-range forecast	Disaster preventing Aviation forecast	One-week forecast	Typhoon forecast
Forecast domain	Global	Japan and its surroundings (3600km x 2880km) 	Eastern Part of Japan (1100km x 1600km) 	Global	
Horizontal resolution	T_L959(0.1875 deg)	5km	2km	T_L319(0.5625 deg)	
Vertical levels / Top	60 0.1 hPa	50 21.8km	60 20.2km	60 0.1 hPa	
Forecast Hours (Initial time)	84 hours (00, 06, 18 UTC) 216 hours (12 UTC)	15 hours (00, 06, 12, 18 UTC) 33 hours (03, 09, 15, 21 UTC)	9 hours	216 hours (12 UTC) 51 members	132 hours (00, 06, 12, 18 UTC) 11 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

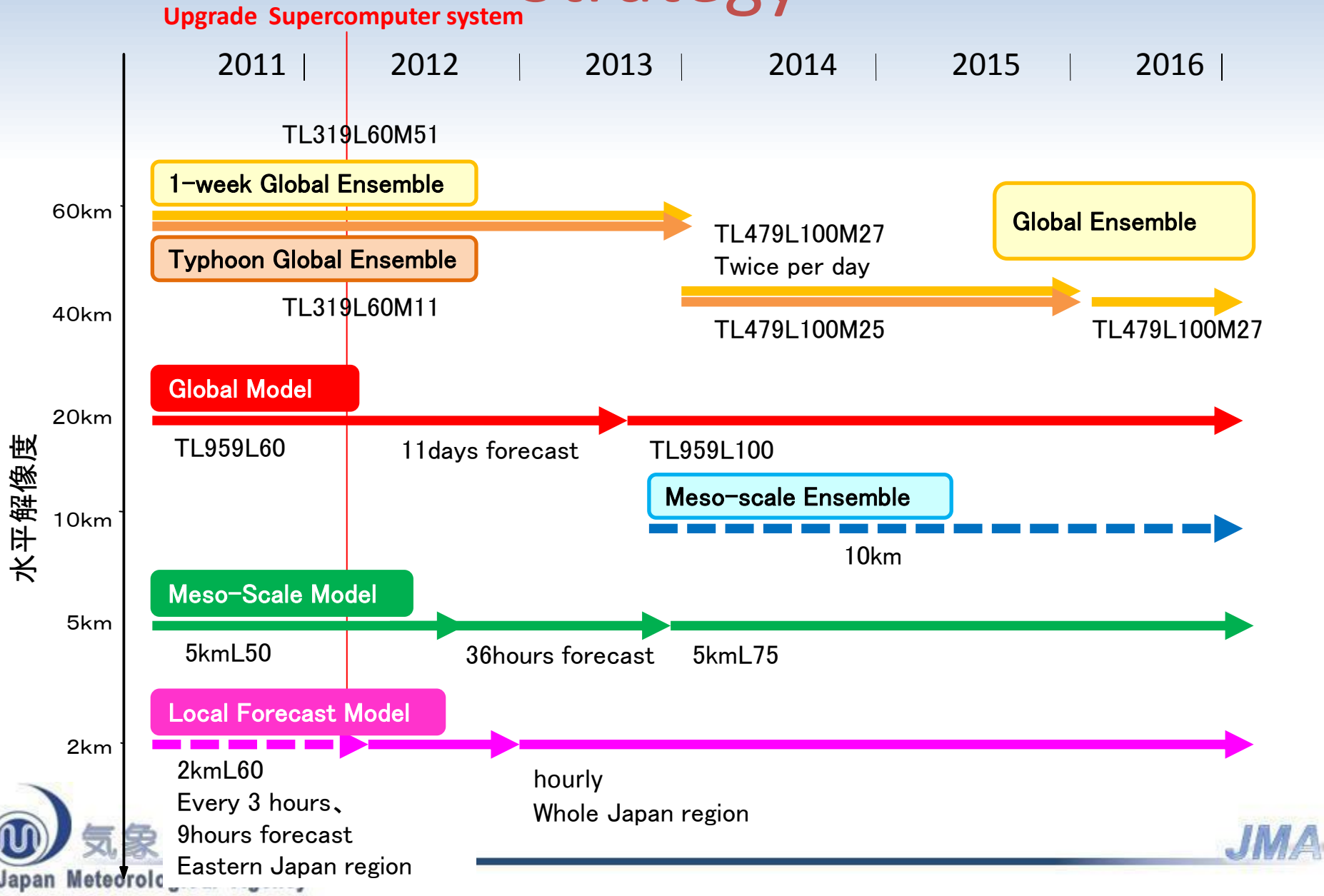
New

	Global Analysis (GA)	Meso-scale Analysis (MA)	Local Analysis (LA)
Analysis scheme	4DVar		3DVar
Analysis time	00, 06, 12, 18 UTC	00, 03, 06, 09, 12, 15, 18, 21 UTC	00, 03, 06, 09, 12, 15, 18, 21 UTC
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)	T_L959 / 0.1875 deg (T_L319 / 0.5625 deg)	5 km (15 km)	5km
Vertical levels	60 levels up to 0.1 hPa	50 levels up to 21.8km	50 levels 21.8km
Assimilation window	-3 hours to +3 hours of analysis time	-3 hours to analysis time	-

Specifications of seasonal EPSs

	1-month EPS	4/7-month EPS
Model	AGCM	CGCM
Resolution	Horizontal: approx. 110 km (TL159) 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 Wednesday and Thursday	Every 5 days
Frequency of model product creation	Once a week Every Friday	Once a month Around the 20th (no later than the 22nd) of every month

Strategy

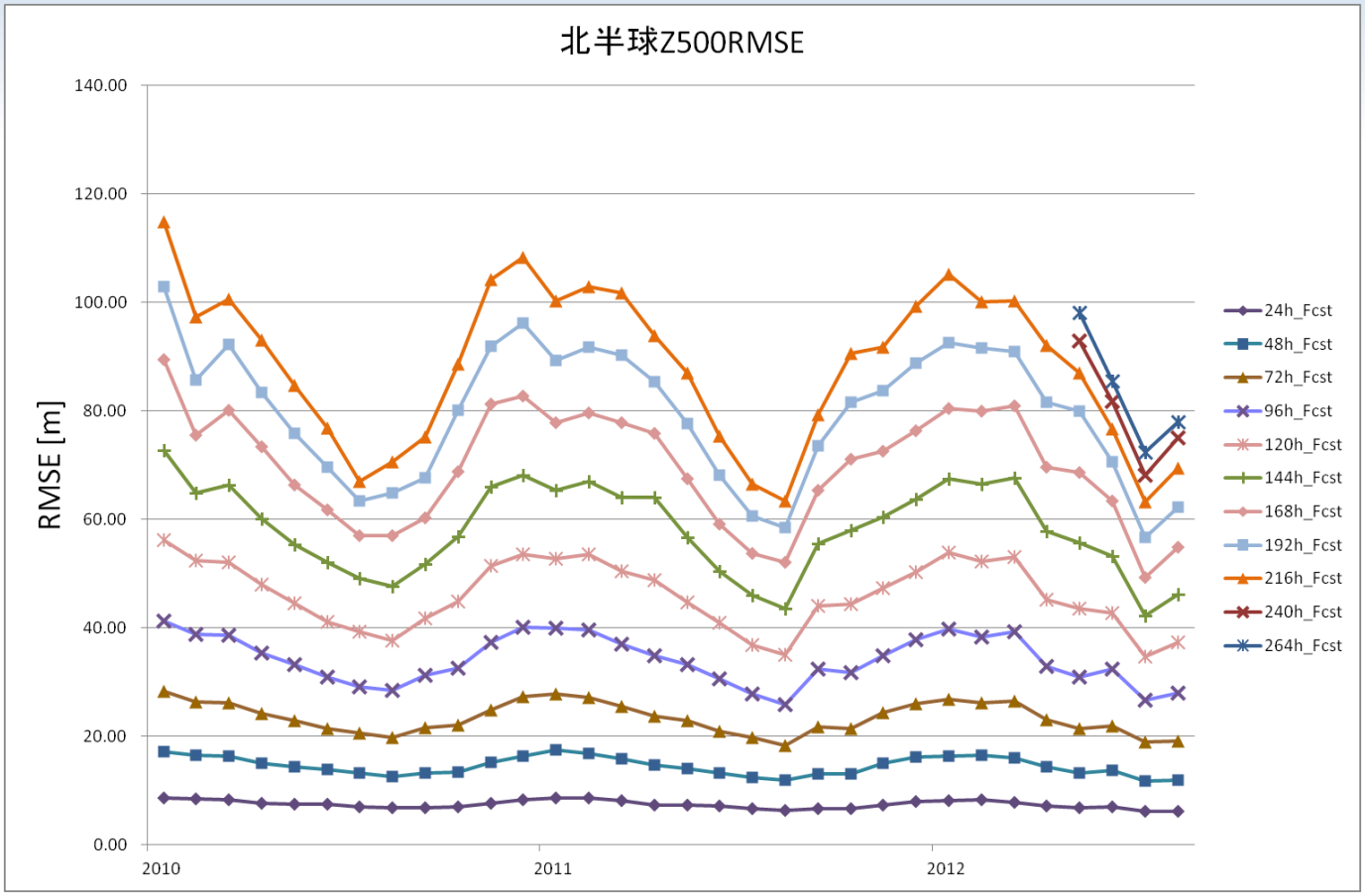

Upgrade Supercomputer system
2011
2012
2013
2014
2015
2016
水平解像度
60km
40km
20km
10km
5km
2km
TL319L60M51
1-week Global Ensemble
Typhoon Global Ensemble
TL319L60M11
TL479L100M27
Twice per day
TL479L100M25
Global Ensemble
TL479L100M27
Global Model
TL959L60
11days forecast
TL959L100
Meso-scale Ensemble
10km
Meso-Scale Model
5kmL50
36hours forecast
5kmL75
Local Forecast Model
2kmL60
Every 3 hours、
9hours forecast
Eastern Japan region
hourly
Whole Japan region
Japan Meteorological Agency
JMA

RECENT CHANGES AND DEVELOPMENT

Development
– physics and dynamics-

- Under development
  - ***Dec.? 2012: 11 days forecast (<- 9 days) for both deterministic and ensemble system.***
  - ***Dec.? 2012: Revise cloud scheme***
  - ***Q1 2013?:***
    - ***Update aerosol optical depth climatology***
    - ***Revise shortwave absorption by water vapor in radiation scheme（Collins et al. 2006）***
  - ***2013?: Increasing the number of vertical levels (top:0.1->0.01 hPa)***

11 days forecast (<- 9 days)



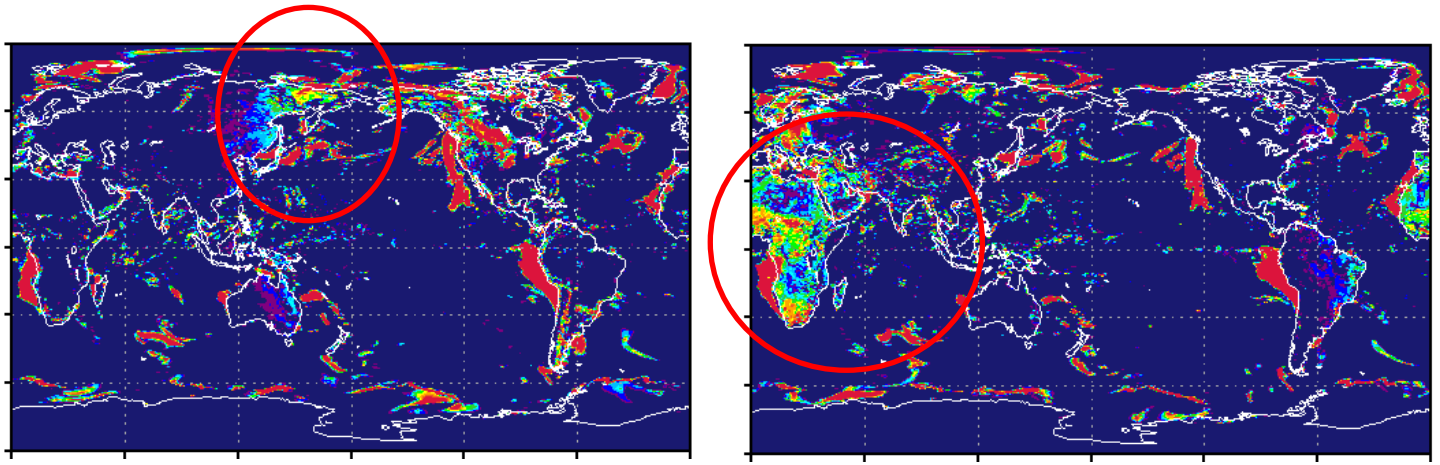
RMSE of Z500 in NH (m)

Revise cloud scheme

- If “inversion layer” is detected in vertical column, low level stratocumulus is generated in the grid.

$$\left|\frac{\partial\theta}{\partial P}\right| > 0.07 \quad [\mathrm{K/hPa}]$$

（θ: Potential temperature、P : pressure）

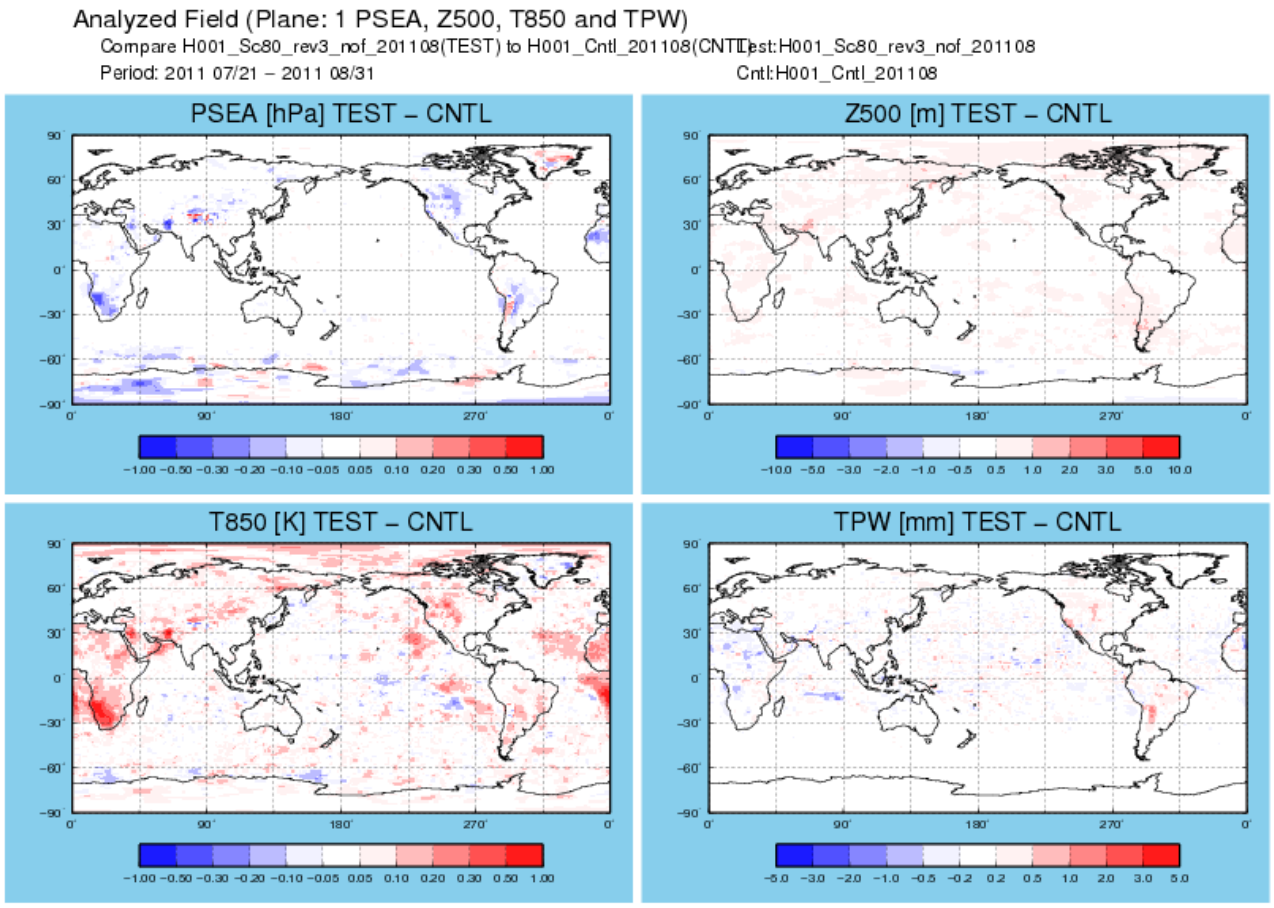


Stratocumulus area

- Stratocumulus is predicted over the Sahara Desert..

Additional condition : RH

$$RH = \frac{q + cwc}{q_{sat}(T_L)} \geq RH_c \qquad T_L = T - \frac{L}{C_p} cwc$$



- Psea: アフリカ南部、北米北西部、南米中部で低下。
- T850: 陸域で上昇。とくにアフリカ南部。ナミビア沖の層積雲領域で上昇。
- Z500: 下層気温上昇で全体的に上昇。

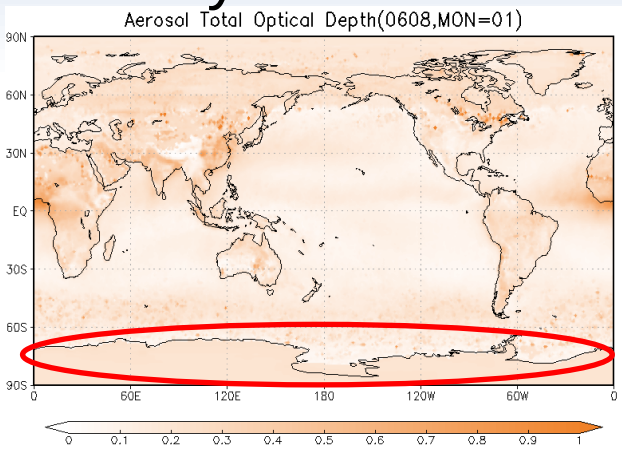
Update of aerosol climatology of GSM

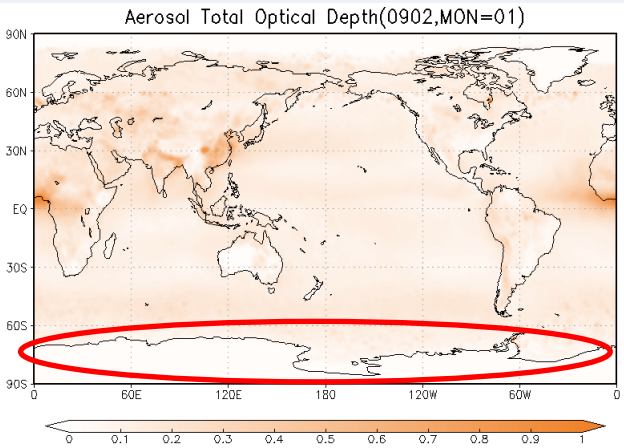
- Climatological aerosol is used in calculation of aerosol direct effect
- Seasonal variation of horizontal distribution is considered
  - Monthly averaged climatological distribution of vertically accumulated optical depth derived from satellite observation is used
- JMA plans to update aerosol optical depth climatology
  - Use new satellite data, extend period for climatology calculation
  - New optical depth tends to be smaller over land (especially over the Antarctica and over desert) than current optical depth
  - Closer to observations by sun photometer
- Seasonal variation is not considered for vertical distribution (not updated)
  - Vertical distribution of optical properties climatology
  - Continental type and maritime type

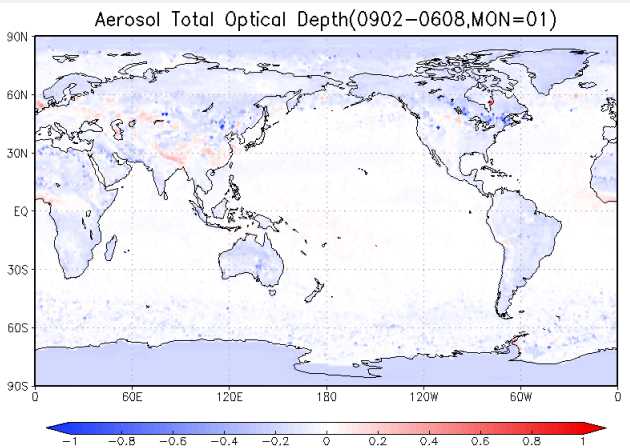
Difference between two optical depths

Current climatology | New climatology | (New)-(Current)

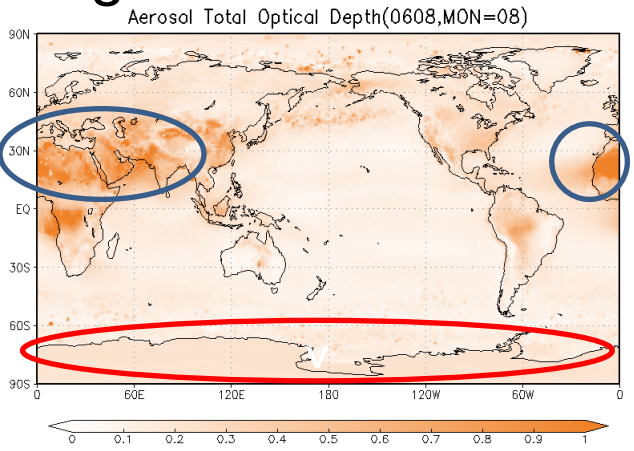
January

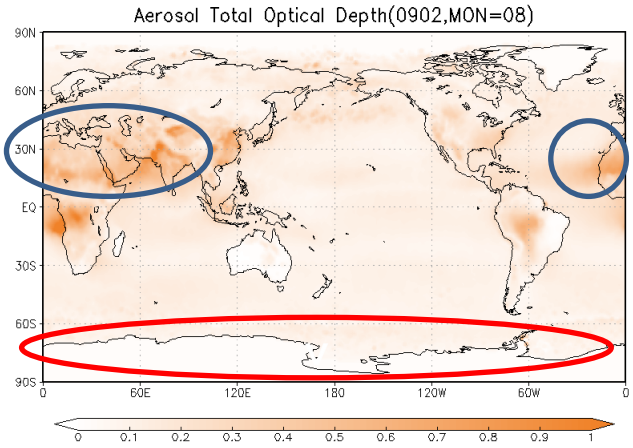


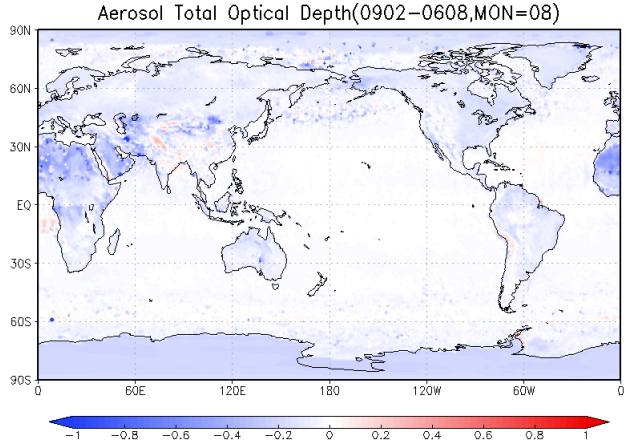




August

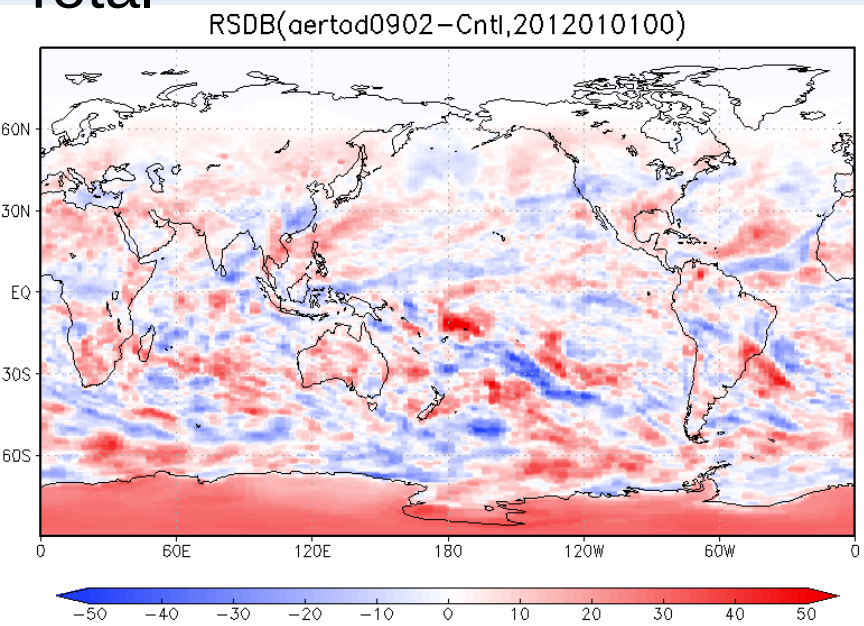




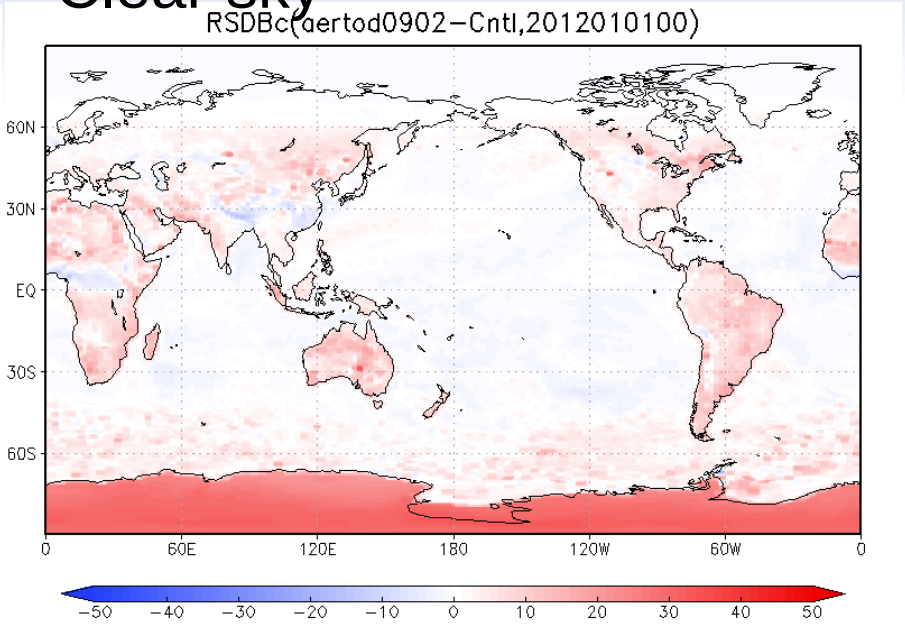


One-month average radiation flux (winter)

Total

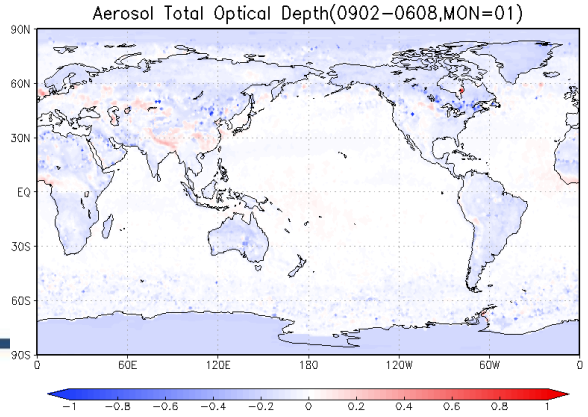


Clear sky



Downward shortwave radiation flux at surface (W/m^2)
(New)-(Current), 2012/01/01 00UTC init

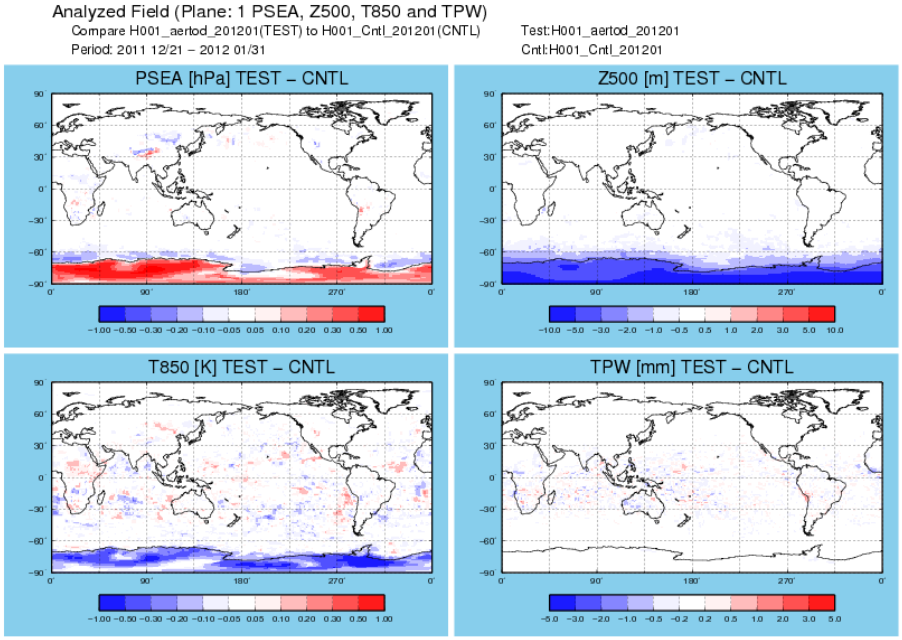
Climatology of vertically accumulated aerosol optical depth in January
(New)-(Current)



気象庁
Japan Meteorological Agency

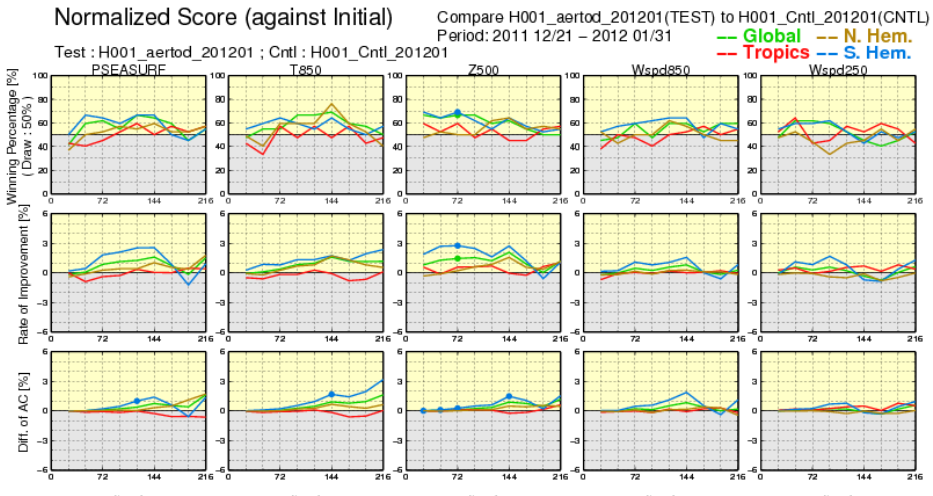
Data assimilation experiment (winter)

Changes in analyzed field



Less shortwave radiation absorption by aerosol → colder lower troposphere → higher surface pressure and lower geopotential height field

Improvement rates of forecast scores



2–days	PseaSurf	T850	Z500	Wspd850	Wspd250
Global	–0.04	0.01	1.03	–0.12	0.29
N. Hem.	–0.26	–0.14	–0.21	–0.21	–0.09
Tropics	–0.46	–0.56	0.22	–0.39	0.38
S. Hem.	0.31	0.56	2.29	0.19	0.47

5–days	PseaSurf	T850	Z500	Wspd850	Wspd250
Global	0.63	0.43	1.25	0.21	0.34
N. Hem.	0.11	0.29	0.25	–0.03	–0.23
Tropics	–0.24	–0.23	0.46	–0.13	0.28
S. Hem.	1.41	0.92	2.29	0.67	0.85

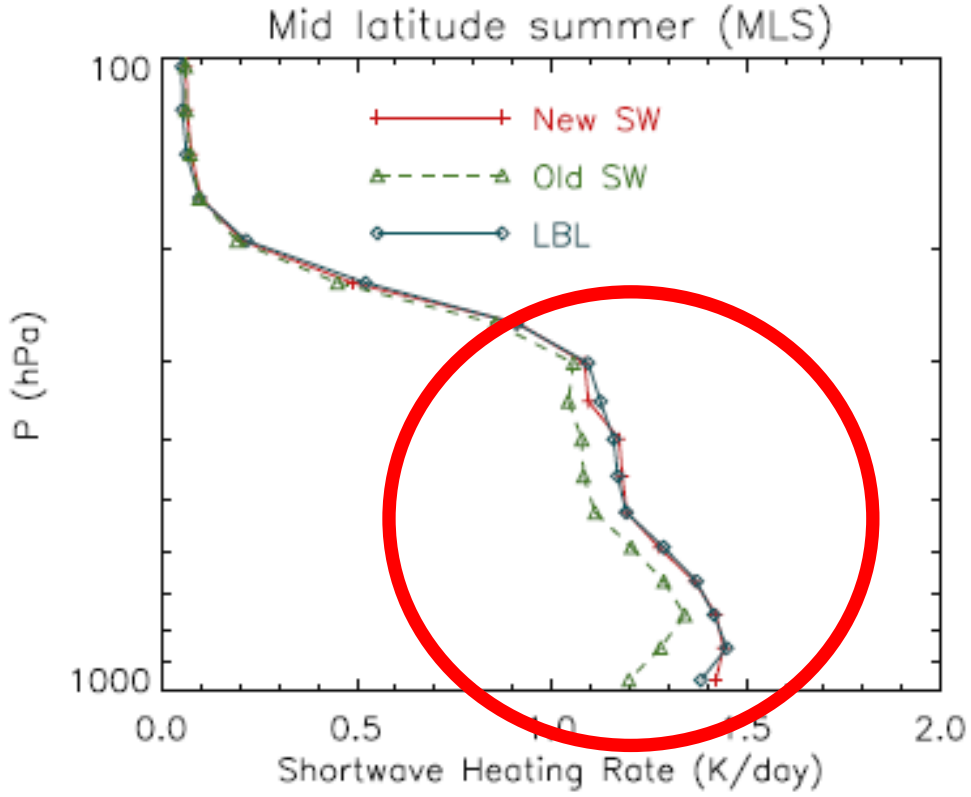
9–days	PseaSurf	T850	Z500	Wspd850	Wspd250
Global	0.76	0.81	1.16	0.23	0.14
N. Hem.	0.48	0.65	0.55	0.02	–0.28
Tropics	–0.03	–0.29	0.41	–0.05	0.38
S. Hem.	1.13	1.32	1.76	0.57	0.48

Rate of Improvement (Average) [%]

Forecast scores are improved mainly over the southern hemisphere.

Shortwave absorption by water vapor

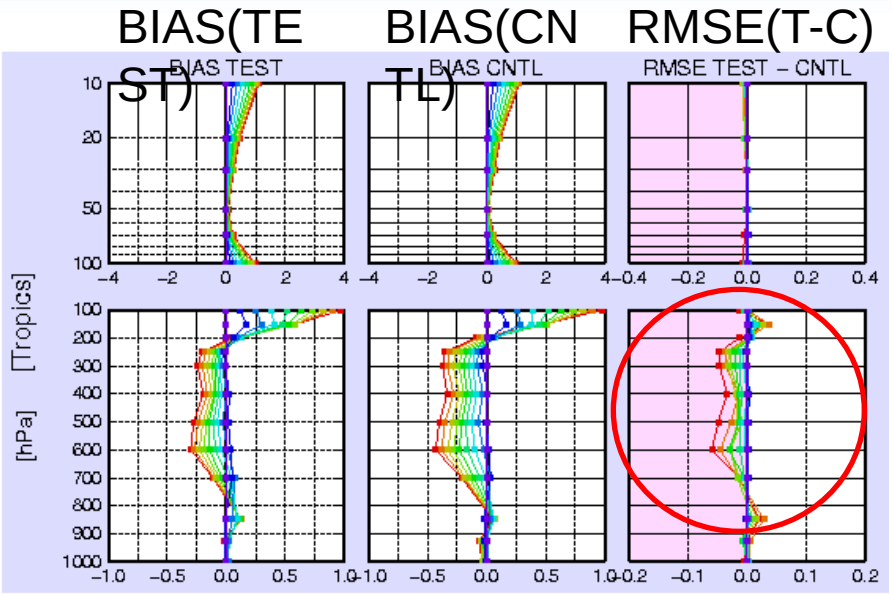
- Collins et al. 2006
  - Revise shortwave heating rate by water vapor



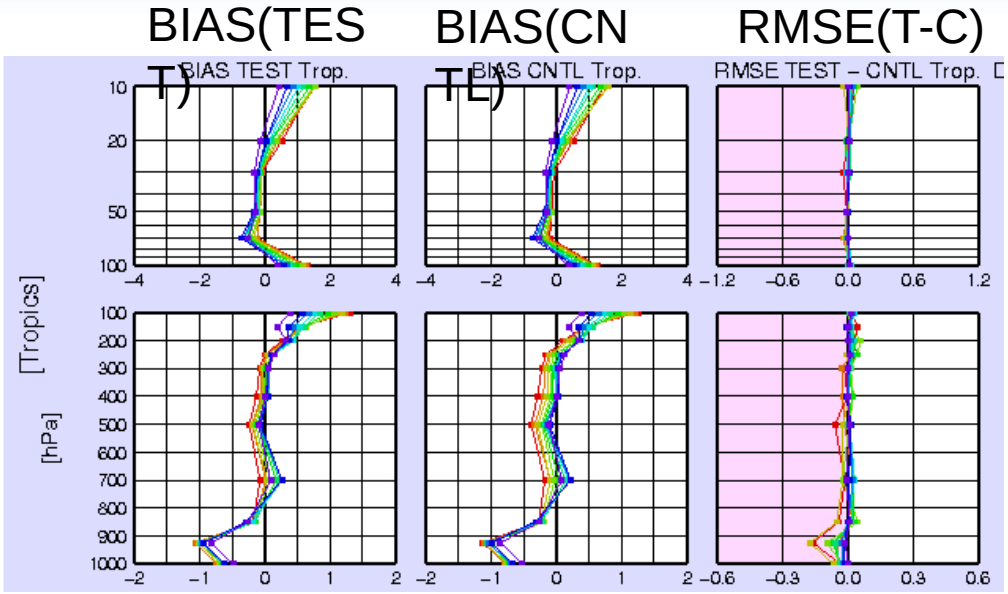
Red : Collins et al.2006
Green : Briegleb 1992
Blue : LBL

Changes of temperature bias in winter in TR

Against analysis



Against sonde



Negative bias of temperature against analysis at the middle-low level troposphere is improved due to the revised shortwave

Development – assimilation, data-

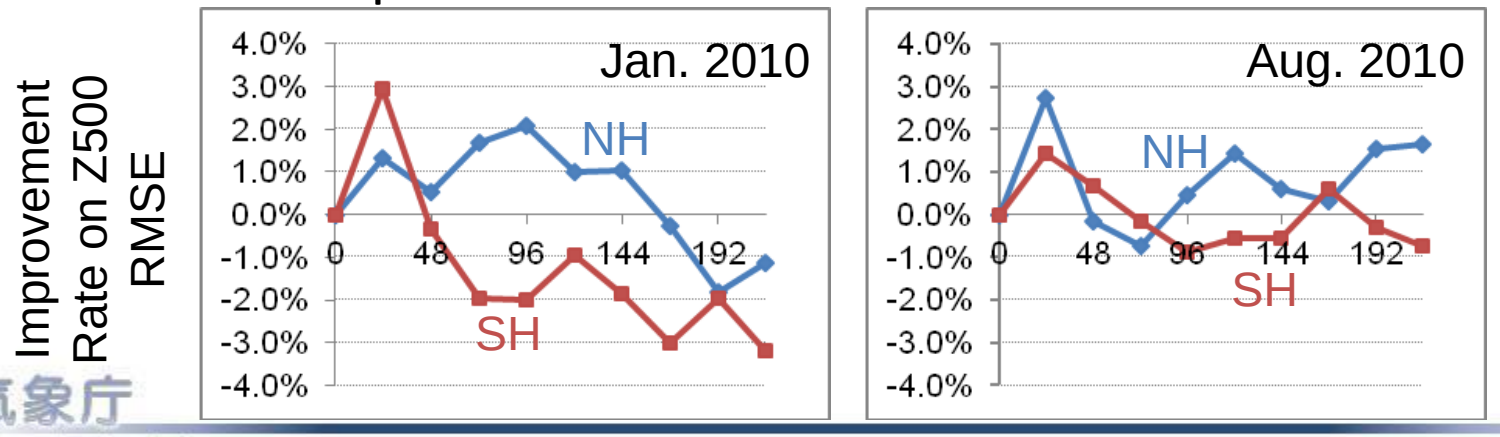
- Recent changes
  - ***25 Oct 2011: Update of Global Analysis inner model of 4D-Var and update observation errors***
  - 30 Aug 2012: Cut-off time changes in cycle analysis
    - For 00 and 12UTC : 11h35m -> 11h50m
    - For 06 and 18UTC : 5h50m -> 7h50m
- Under development
  - ***Nov.? 2012: RTM upgrades (RTTOVv9.3→v10)***
  - ***Dec.? 2012: GNSS-RO observation operator upgrades***
  - Q1? 2013: Introduction of AIRS, IASI
  - EnKF, Hybrid assimilation

Global 4D-Var Enhancement

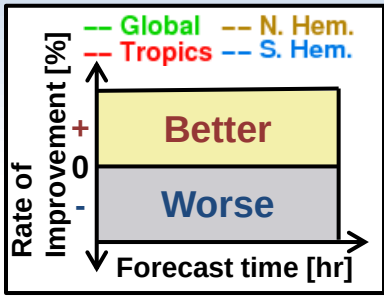
- The inner model was upgraded about
  - adoption of semi-Lagrangian scheme
  - adoption of adaptive grid
  - increase of model resolution (T159 → TL319)

Both of them were already introduced in the forecast model in some years ago.

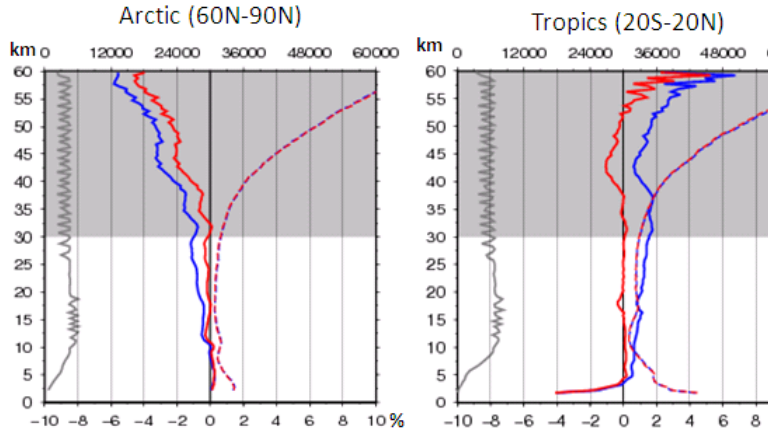
- Observation error variances were revised at the time.
- The impact test
  - showed improvement on Z500 forecast RMSE over NH.

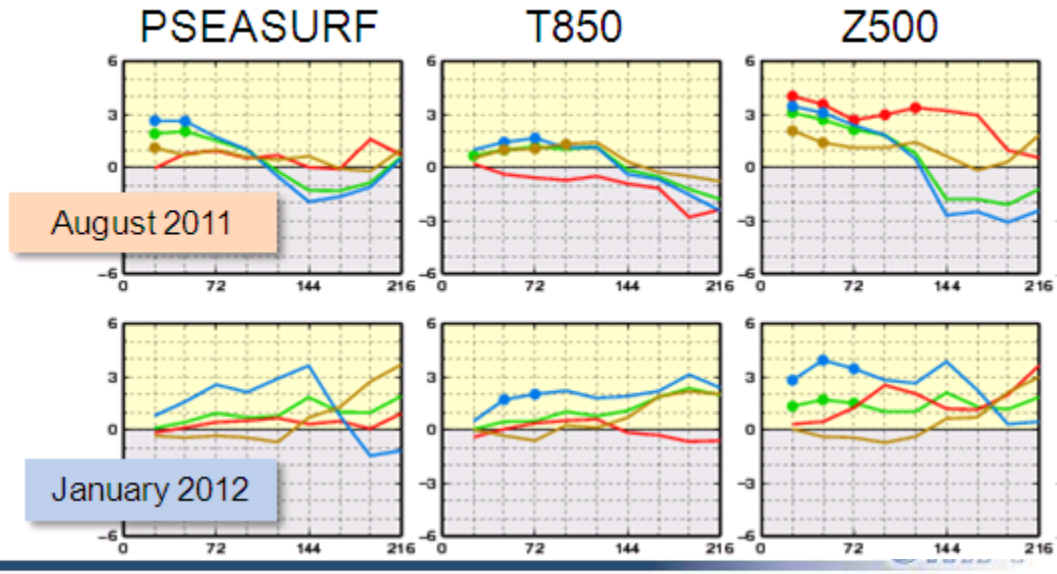


Improvement on GNSS-RO usage



- Addition of new satellites/sensors
  - **SAC-C, GRACE-A, TerraSAR-X and C/NOFS**
- Revision of the observation operator
  - Several inappropriate configurations were fixed,
  - So that the bias correction procedures can be eliminated.
  - # Use of bending angle instead of refractivity is the next step





Solid lines: Bias structure against height
Blue; Cntl / Red: Test

Japan Meteo

Development – EPS -

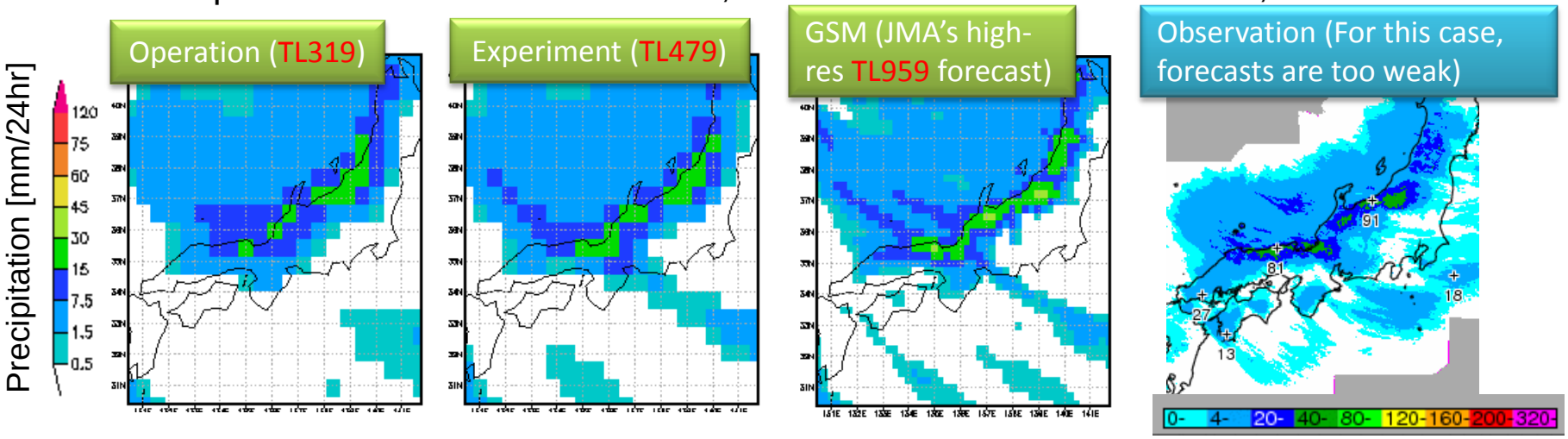
- Under development
  - Dec.? 2012: 11 days forecast (<- 9 days)
  - ***Increase model resolution (from TL319L60 to TL479L100)***
  - ***Increase the members (from M11 to M25) in TEPS***
  - 2013?: Start test operation of Meso-scale regional EPS

	Operation		Planned upgrades	
	One-week EPS	**Typhoon EPS**	**One- week EPS**	**Typhoon EPS**
Horizontal resolution	TL319 (~55km)		TL479 (~40km)	
Vertical levels	60 levels up to 0.1hPa		100 levels up to 0.01hPa	
Initial time	12UTC	00,06,12,18UTC	00,12UTC	*Not changed*
Ensemble size	51	11	27	25

Winter monsoon

- Typical weather with winter monsoon
  - Upwind orographic precipitation and stripe precipitation pattern in Pacific
- Experiments shows finer precipitation pattern
- Not so obvious difference of upwind orographic precipitation between operation and experiment

Unperturbed member of the EPSs, initial time 23 DEC 2011 12UTC, FT 72 hr

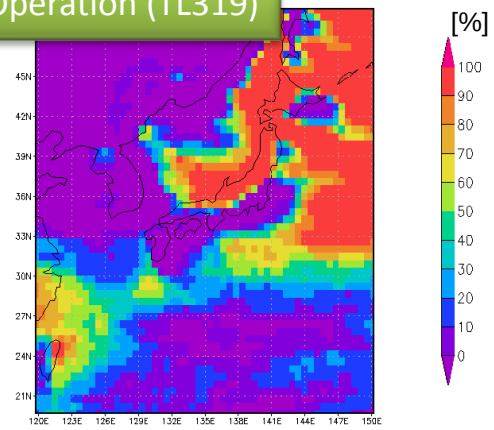


Impact in precipitation probability

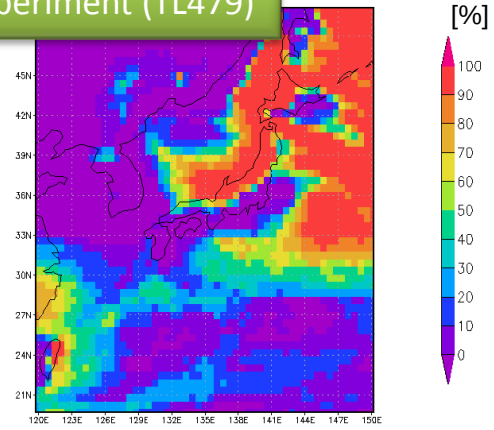
In some cases, there is a difference near border of orographic precipitation

Probability of precipitation exceeding 1mm/24hr

Operation (TL319)

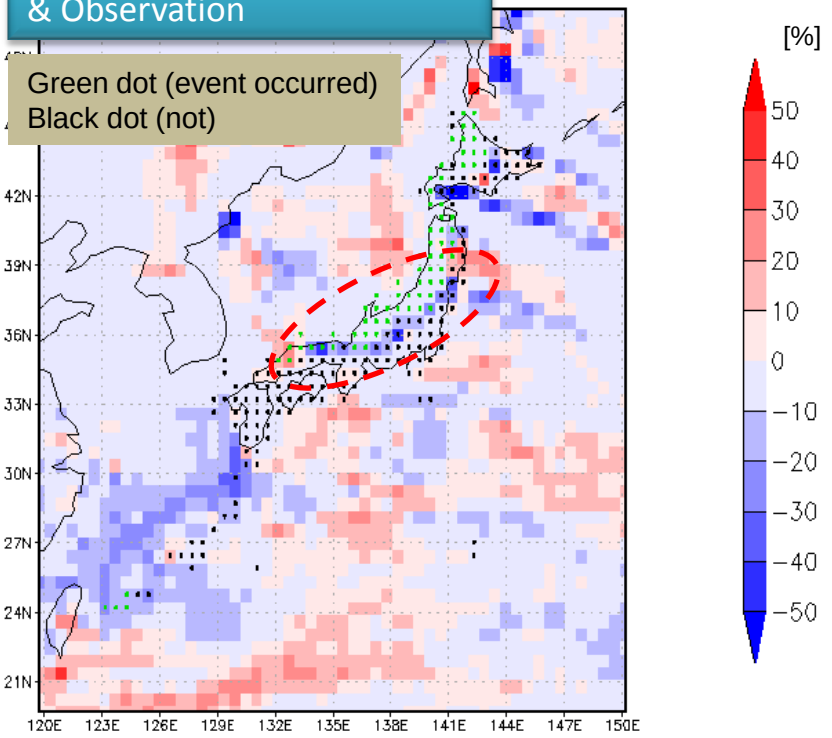


Experiment (TL479)



DIFF(Experiment-Operation) & Observation

Green dot (event occurred)
Black dot (not)

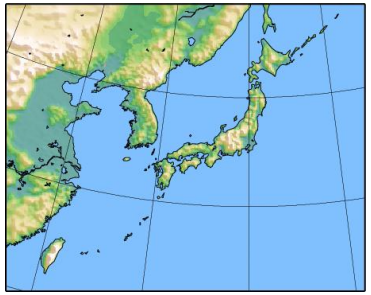


Initial time 2012/1/7 12UTC, FT144

Development – regional -

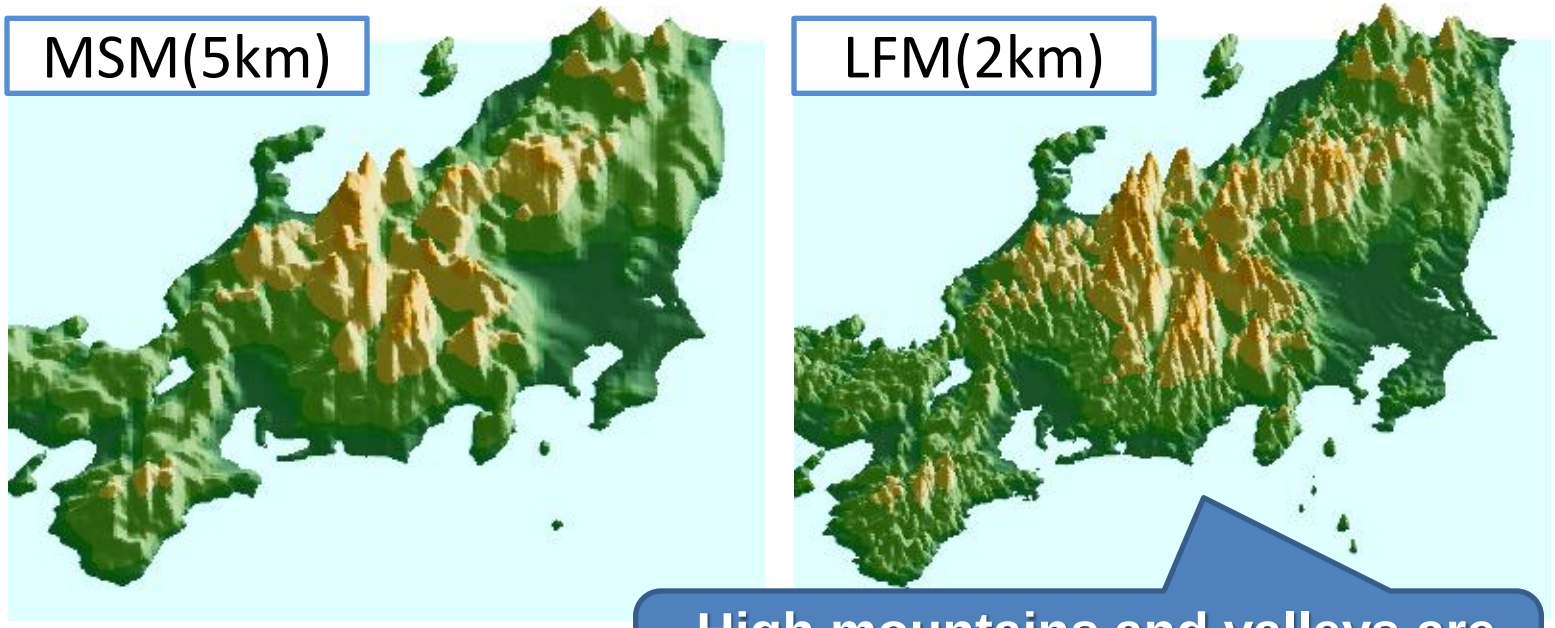
- Recent changes
  - ***Aug 2012: 2km-LFM/LA operation was started***
- Under development
  - Nov.? 2012: RTM upgrades (RTTOVv9.3→v10) in MA
  - ***Mar? 2013:*** 5km-MSM configuration upgrade
    - Expand the model domain
    - Extend the forecast range (36 or 39 hours <-15hours/33hours)
  - ***May? 2013:*** 2km-LFM configuration upgrade
    - Increase the operation frequency from three-hourly to hourly
    - Expand the model domain (whole Japan region <- Eastern Japan)
  - Increase the model levels (from 50 to 75)
  - Raise the model top (TBD). Enhancement of land surface scheme
  - new dynamical core for the non-hydrostatic model “ASUCA”
  - ***2013:*** Start test operation of the EPS system

Specifications of LFM

	Local Forecast Model (LFM)	Meso-Scale Model (MSM)
Horizontal Resolution	2km (551x801) 	5km (721x577) 
Vertical Layers	60 Layers, up to 20km	50 Layers, up to 22km
Integration Time Step	8 second	20 second
Initial Condition	3D-Var RUC	4D-Var
Boundary Condition	MSM	GSM
Forecast hours	9 hours	33/15 hours
Cloud Physics	Qc, Qr, Qi, Qs, Qg	Qc, Qr, Qi, Qs, Qg and Ni
Cumulus convective parameterization	Not Used	Kain-Fritsch scheme

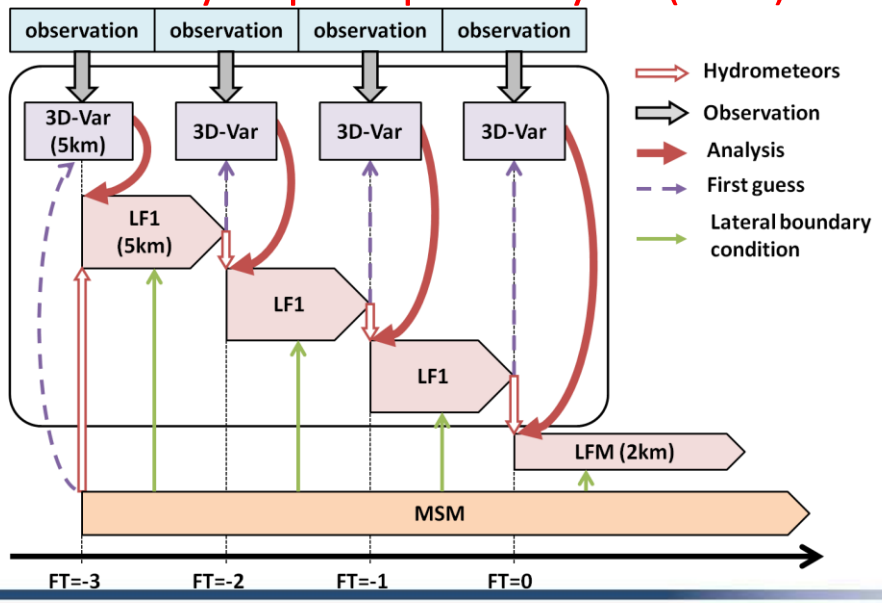
LFM/LA operation

- The objectives are to provide information for aviation weather forecast and disaster prevention with high resolution NWP
- Operation has just started in Aug. 2012



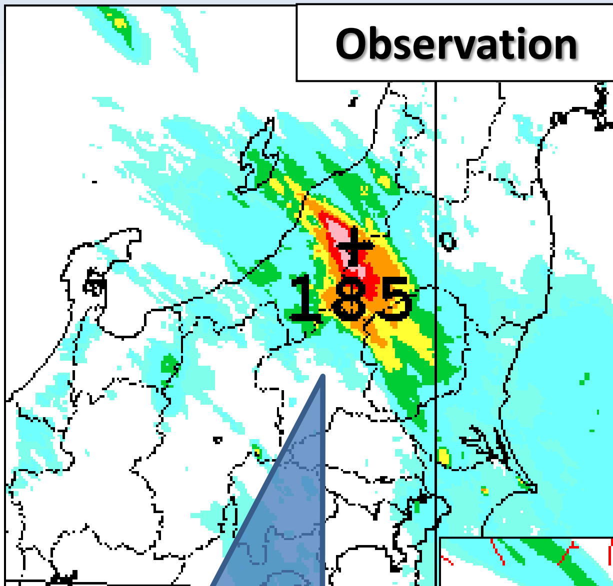
Local Analysis

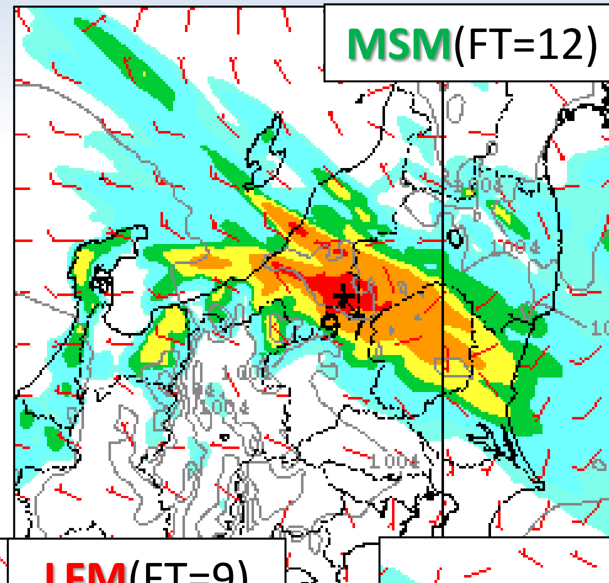
- Specifications
  - Horizontal resolution is 5km, 50 vertical layers
  - Model domain: 2200km x 2500km (441x501grid)
  - Analysis time: 00,03,06,09,12,15,18,21（UTC）
    - hourly observations are assimilated
  - Observation cut off time is 30 minutes (Very Short!)
  - Data assimilation method: 3D-Var by Rapid Update Cycle (RUC)
  - Assimilated observations:
    - AWS (AMeDAS)
    - Aircraft observations
    - WPR (Wind profiler)
    - Doppler velocity
    - Ground based GPS

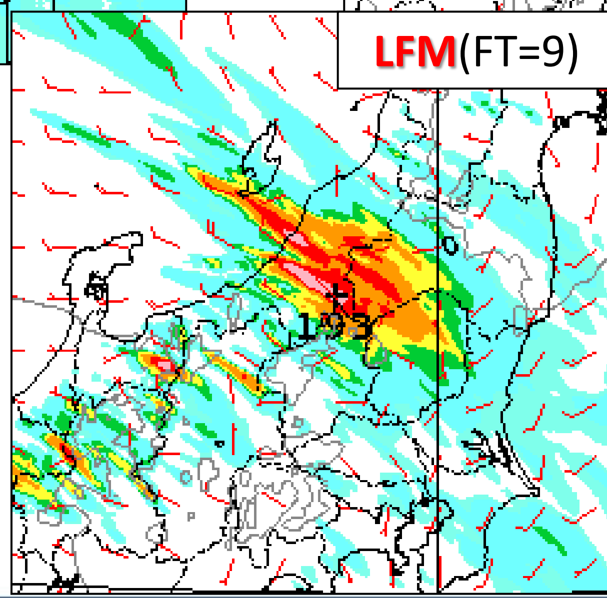


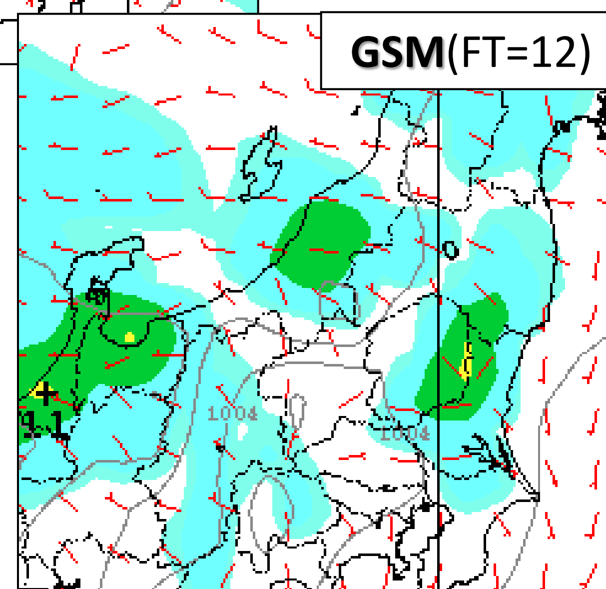
Quantitative precipitation forecast

2011 July. 29 06UTC 3hourly precipitation







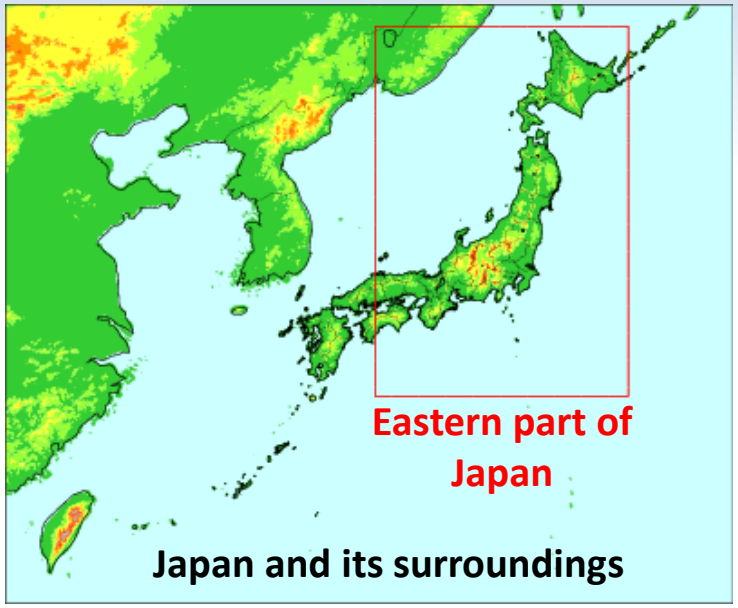


A heavy rainfall in Niigata and Fukushima Prefectures on July 2011

The maximum daily precipitation amount ~ 1000mm

Future Plan

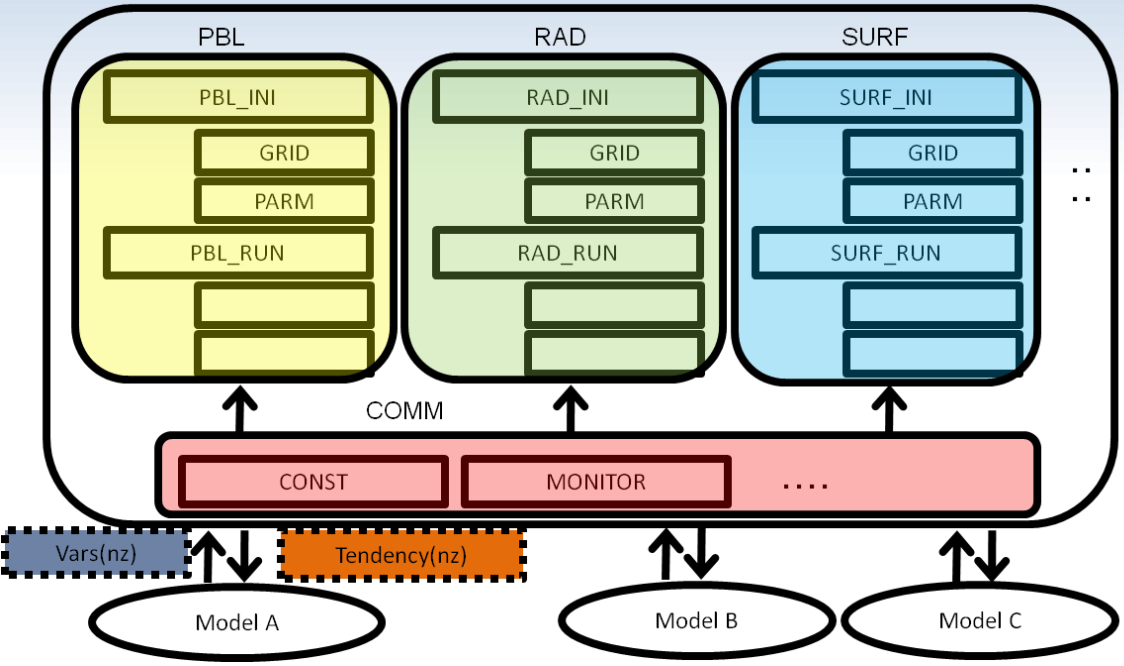
- Review the system enhancement configurations
  - Domain configuration
  - Vertical layer configuration
- Develop and Improve the NWP system
  - Forecast model
  - Data assimilation system



- Develop and improve the assimilation methods of observations
  - Radar (Reflectivity)
  - Satellite (Atmospheric Motion Vector and Clear Sky Radiance)

Timeline	Domain	Period
Operation	Eastern part of Japan	Aug. 2012 – May 2013
	Japan and its surroundings	May 2013 –

Physics Library



- 1-dim implementation
  - Low memory usage to improve cache efficiency as well as easy to develop.
- Independent components and similar structures of public subs.
- Output: temporal tendencies without input variables changed.

- Testing environments: based on some international intercomparison projects
  - As one of the applications of the library
  - Used to evaluate each of the components
  - Serve sample codes to show how to implement the library into users' models.
- Documenting rules: inline documents on interfaces

Code for GPGPU

CUDA
In Dynamical Core

Hybrid
for Physics Library

Our approach: GPU-based ASUCA

- Full GPU Application
- GPU-ASUCA is written from scratch in CUDA

Fortran

```
Program init
implicit none

integer i
integer a(10)

do i = 1, 10
   a(i) = i
end do

end program init
```

✓Original code at JMA

C/C++

```
#include <iostream>

int main()
{
  int i;
  int a[10];
  for(i=0;i<10;i++){
    a[i] = i + 1;
  }
}
```

✓Reference for Implementation & Performance

CUDA

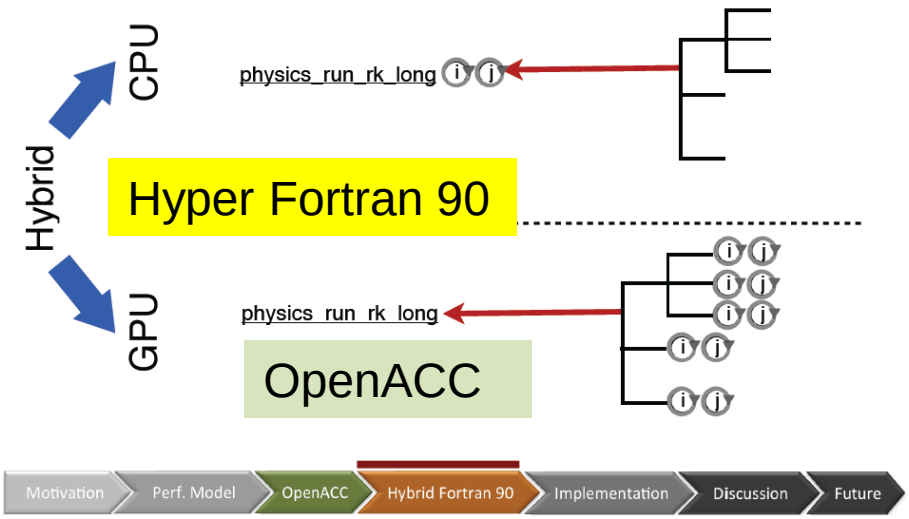
```
include <cuda.h>

global__ void init(int *a){
  a[threadIdx.x] = threadIdx.x+1;
}

int main()
{
  int i;
  int *a;
  cudaMalloc(&a,sizeof(int)*10);
  init<<<1,10>>>(a);
  cudaFree(a);
}
```

✓GPU code

Element order of 3 dimensional arrays

z,x,y (k,i,j)-ordering	x,z,y (i,k,j)-ordering	x,z,y (i,k,j)-ordering

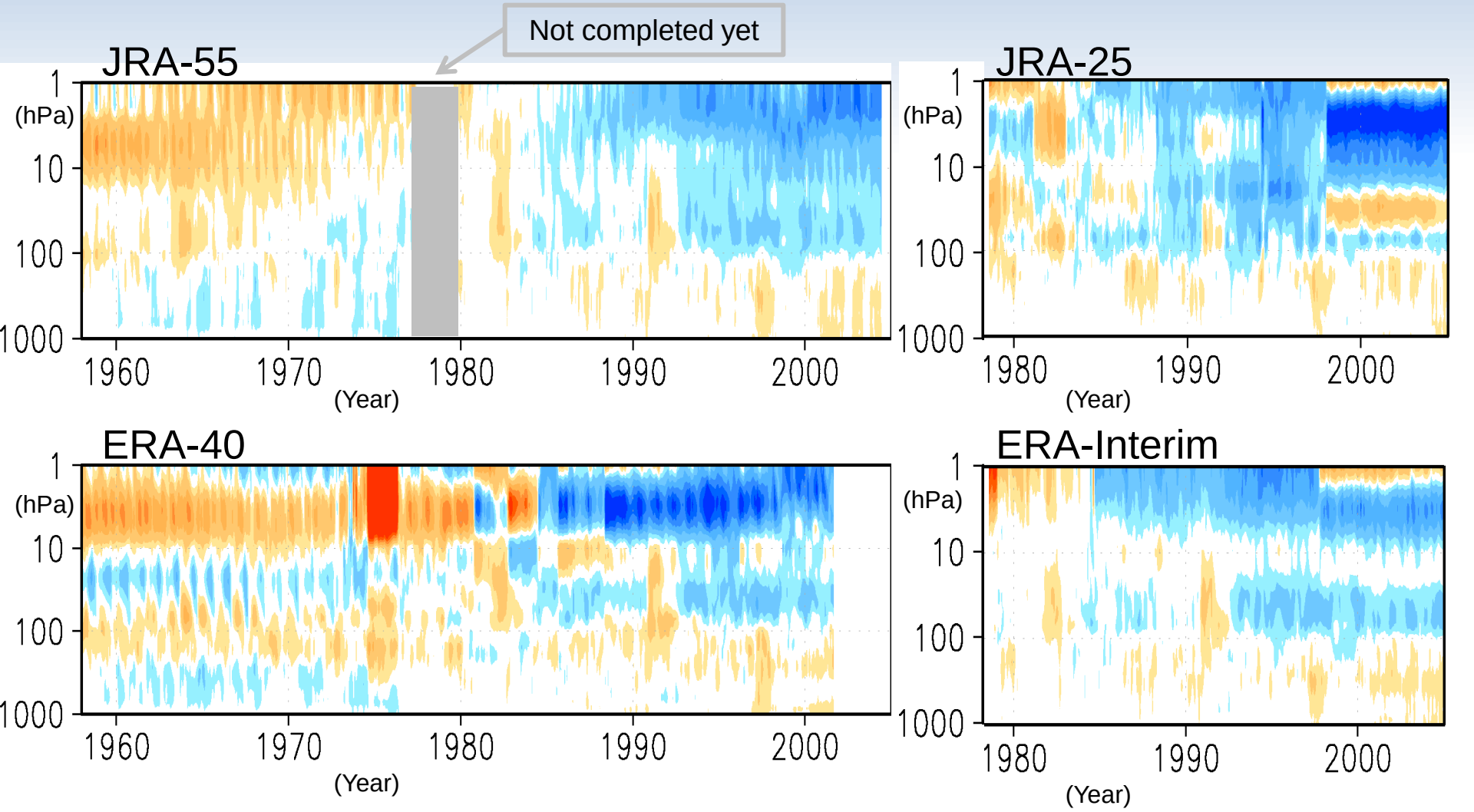
➡ Improve the memory access performance of the GPU computing



Development – climate -

- JRA-55 reanalysis will be completed in 2013.
  - JRA-55 is going to be continued in quasi-real time basis after 2013.
  - New climate values and new hindcast data will be produced.
- Upgrade of the seasonal forecast model probably in 2015
  - A JRA-55 based initial analysis field is used in the new seasonal forecast model.

Global mean Temperature Anomaly of Reanalyses (Time-Level Cross Section)



気象庁
Japan Meteorological Agency
JMA

Anomaly : deviation from the mean value of the period 1980 – 1986 for each reanalysis

THANKS FOR YOUR ATTENTION

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