Introduction of NWP systems in JMA

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Training Workshop on the Latest Developments on the Use and Interpretation of NWP Models

HKO, 3-7 Dec 2012

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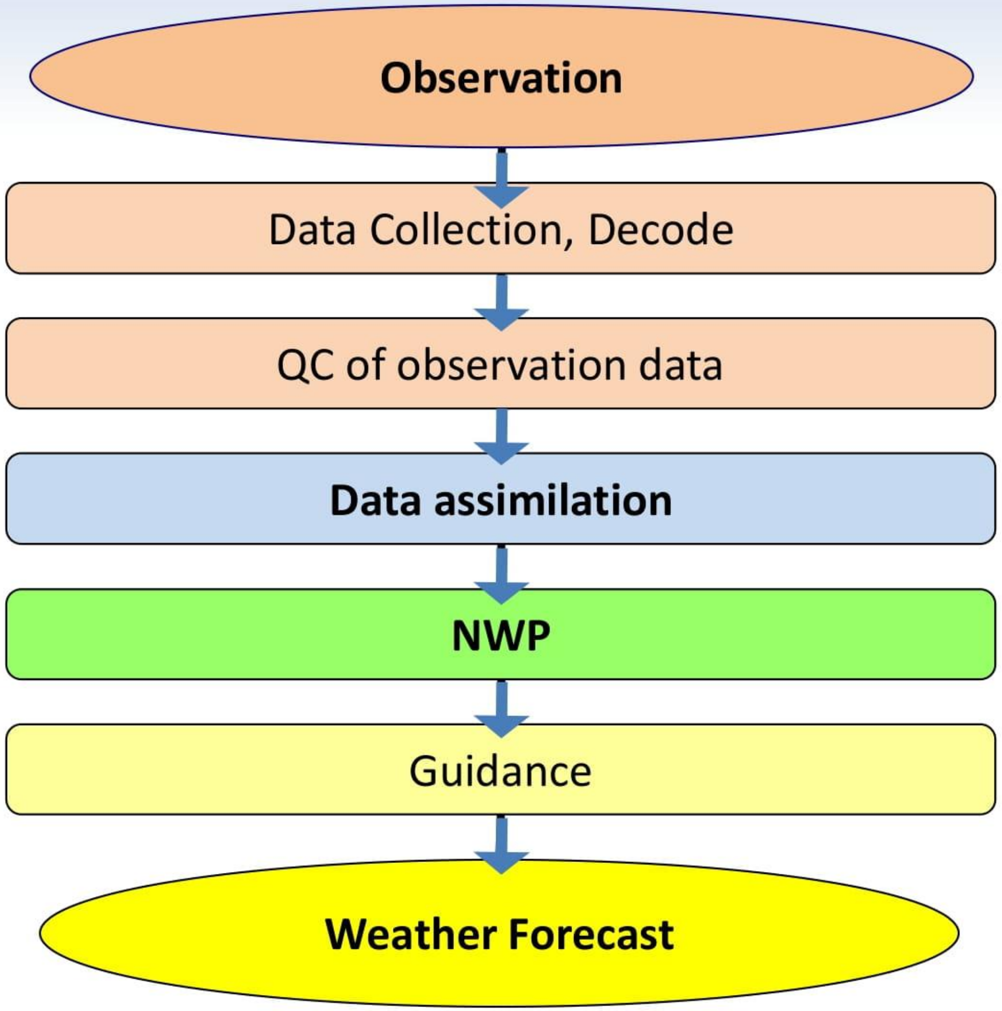
JMA

Self Introduction

- 2007.04 – 2008.09 :
  - Observation Division, Kansai Aviation Weather Service Center, JMA
- 2008.10 – 2010.03 :
  - Kobe Airport Branch, Kansai Aviation Weather Service Center, JMA
    - Aviation weather observation
- 2010.04 – Current :
  - Numerical Prediction Division, JMA
    - Development of regional NWP models at JMA

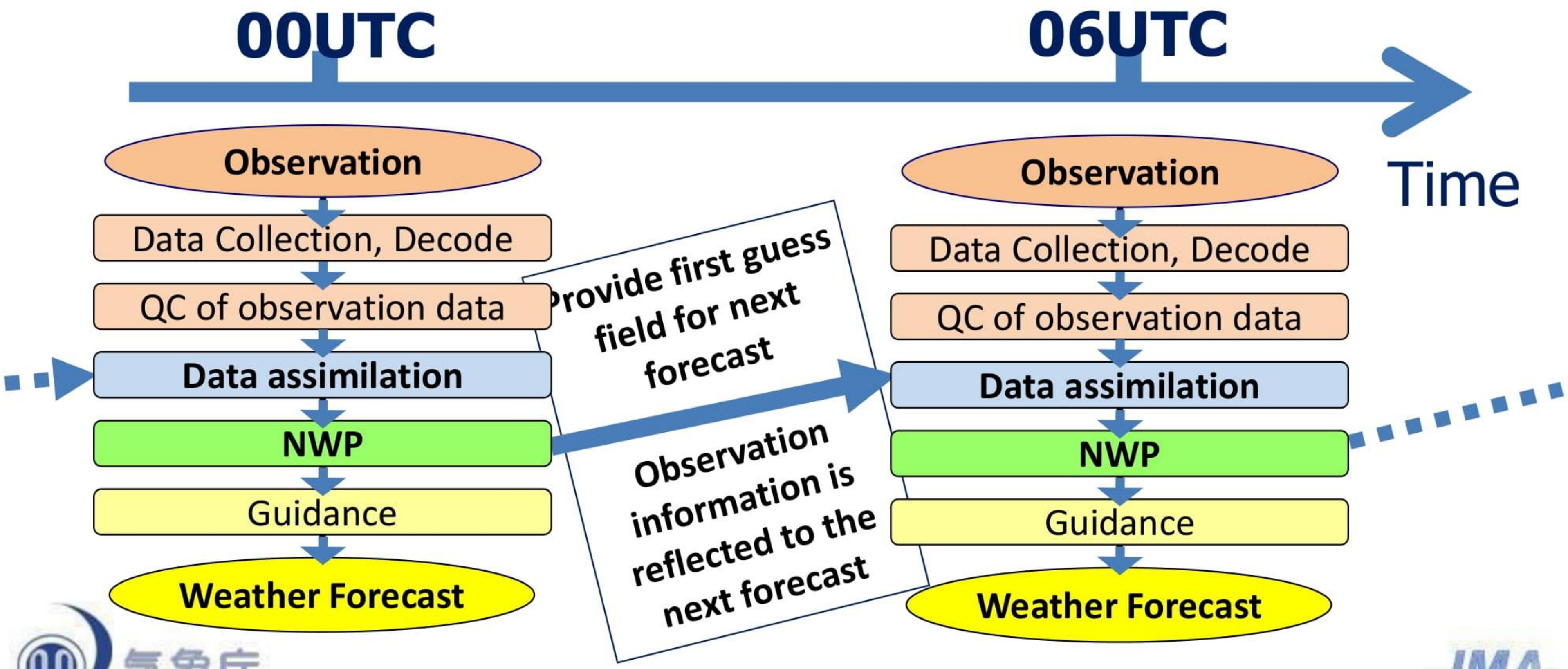

BASIC INSTRUCTIONS OF
THE NUMERICAL WEATHER
PREDICTION

Flow of NWP System

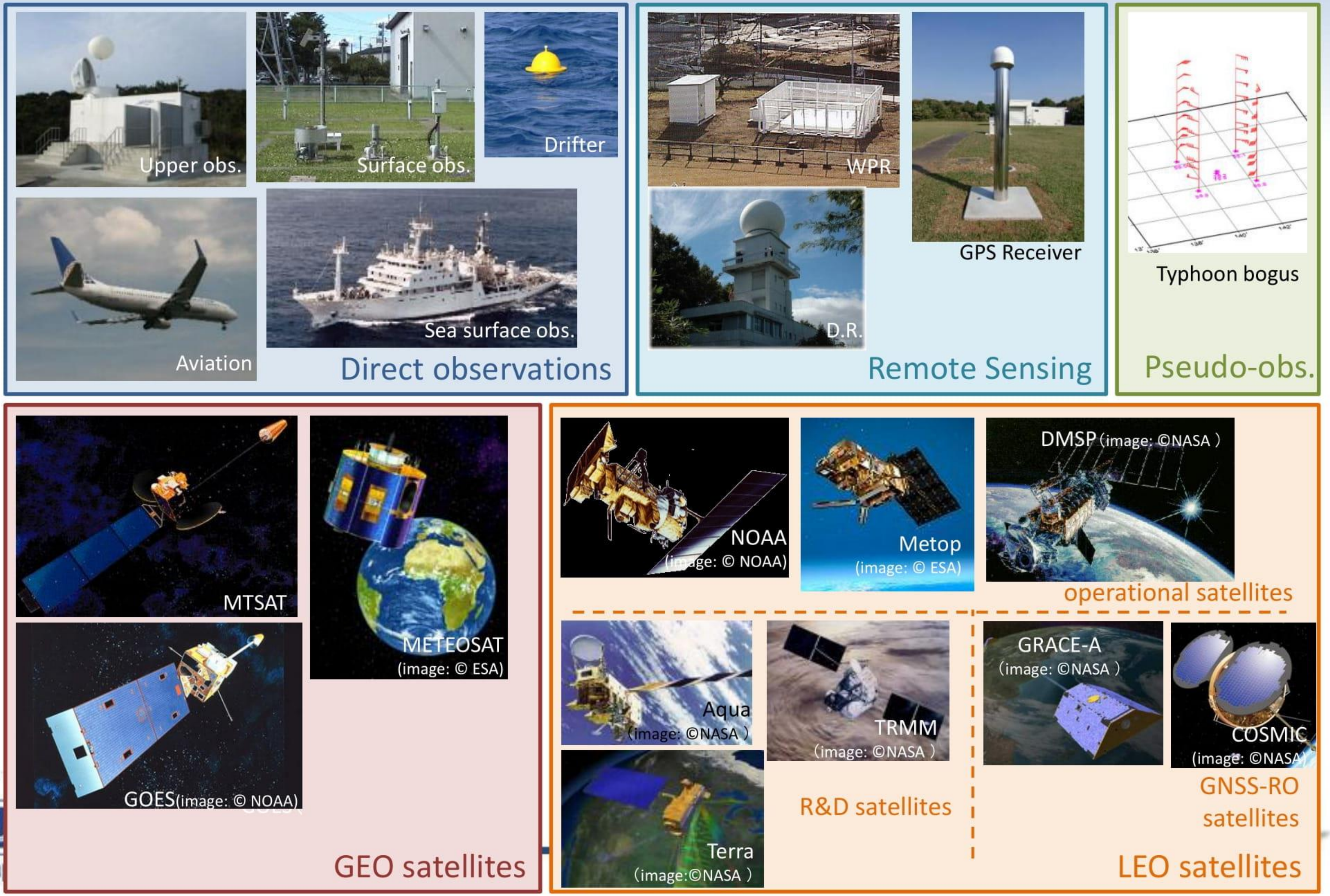


Data flow of daily NWP

- **Repeat of analysis (data assimilation) and forecast**
- **How to make initial condition?**
  - **Modification of previous forecast field by observation**

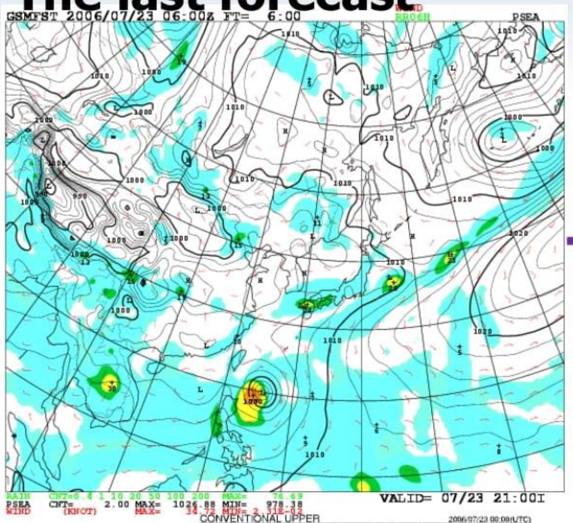


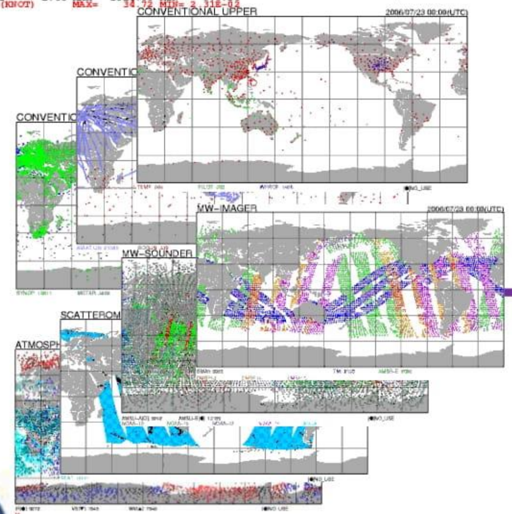
Assimilated observations



Data Assimilation & Forecast

The First Guess
The last forecast

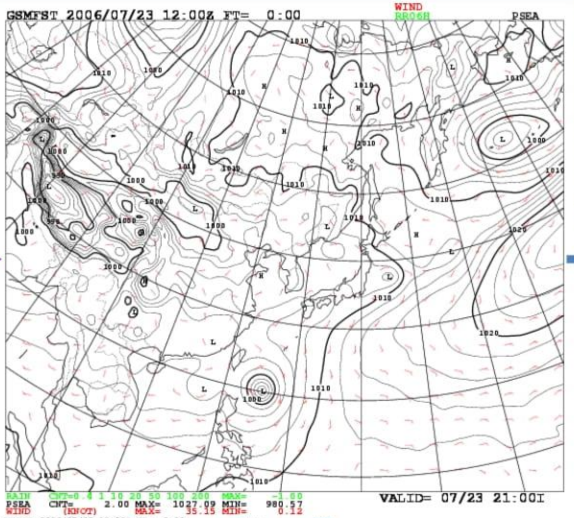


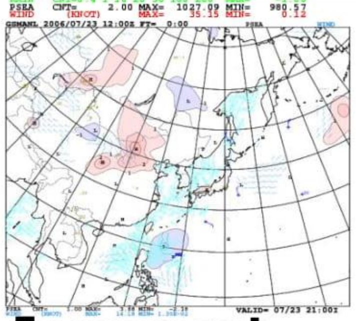


Various Observations

Data Assimilation

Initial Condition

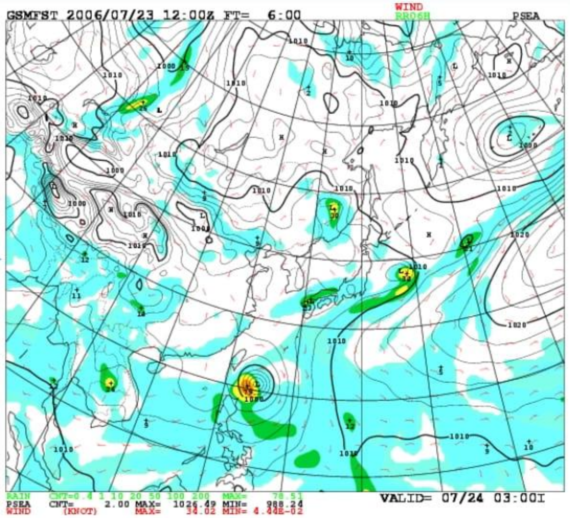




Increment

NWP forecast

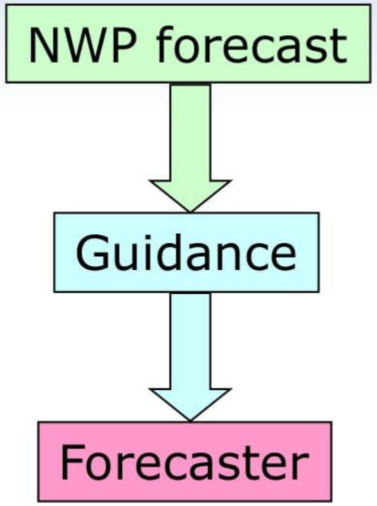
The next forecast

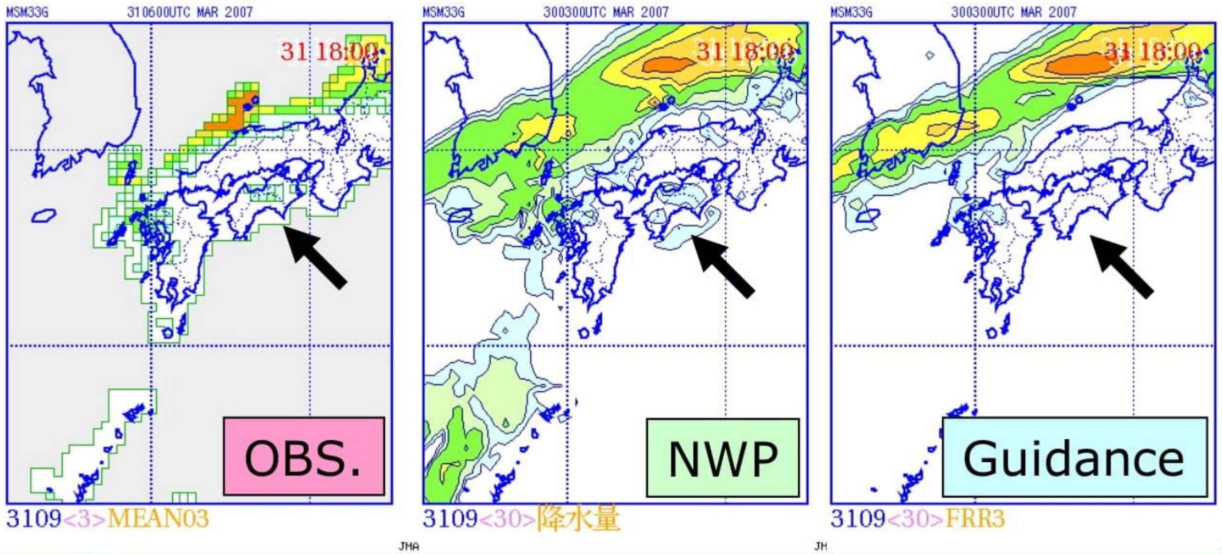


In the DA system, the given model state (first guess) is corrected by accumulating various observations information with the constraints in the NWP model. In the "cyclic operation", the first guess is the forecast from the latest DA result.

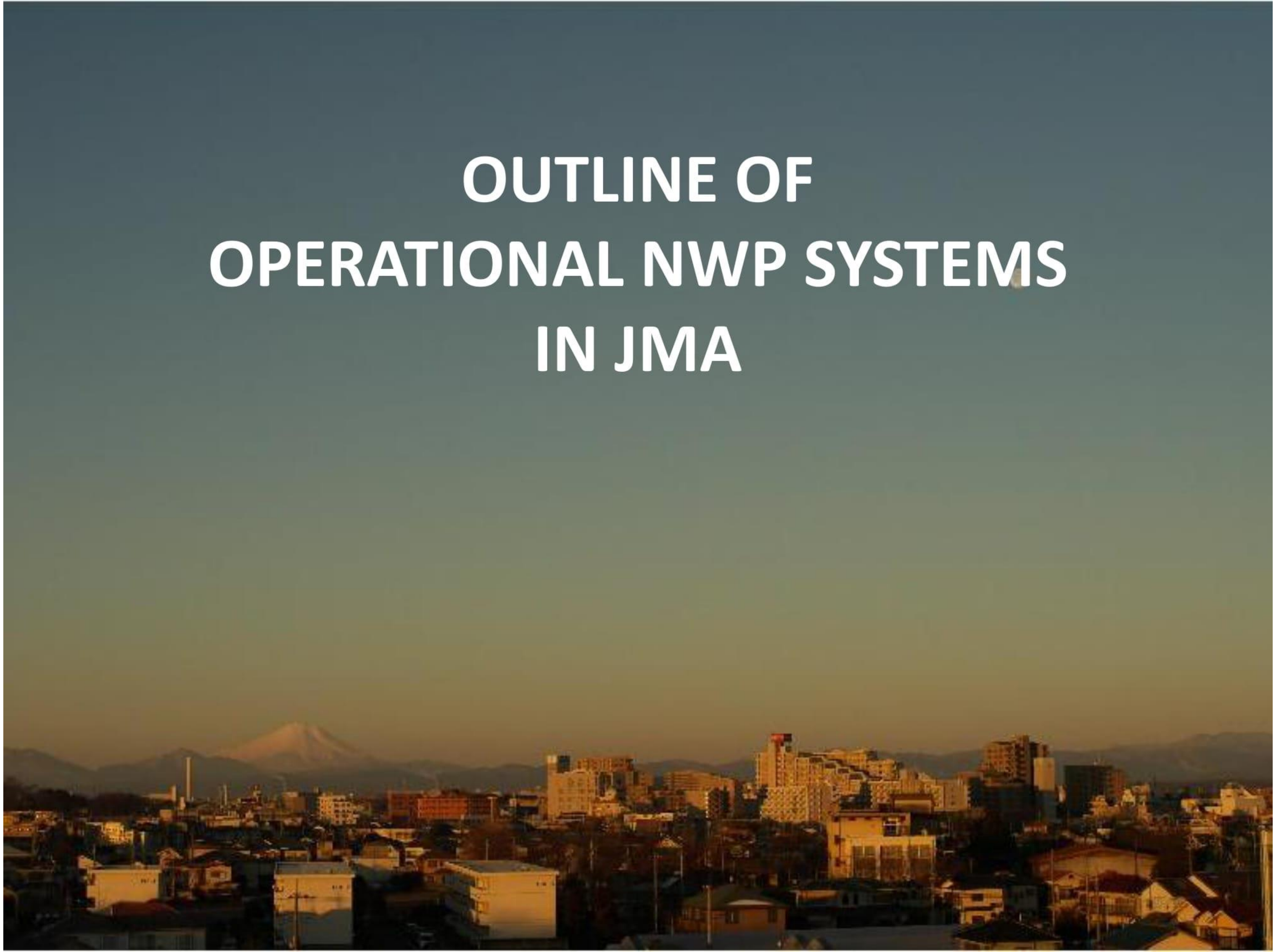
Guidance (post-process of NWP)

- Purpose
  - Translation (easy to use)
  - Correct model errors, especially bias
- Algorithm
  - Neural network
  - Kalman filter





OUTLINE OF OPERATIONAL NWP SYSTEMS IN JMA



Current NWP models of NPD/JMA

NEW

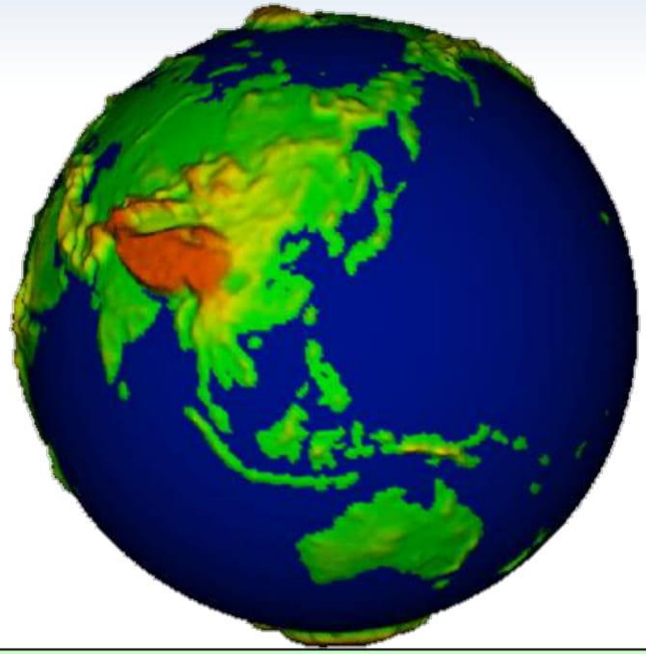
	Global Spectral Model (GSM)	Meso-Scale Model (MSM)	Local Forecast Model (LFM)	One-week Ensemble (WEPS)	Typhoon Ensemble (TEPS)
Objectives	Short- and Medium-range forecast	Disaster reduction Short-range forecast	Disaster prevention Aviation forecast	One-week forecast	Typhoon forecast
Forecast domain	Global	Japan and its surroundings (3600 km x 2880 km)	Eastern part of Japan (1100 km x 1600 km)	Global	
Horizontal resolution	TL959 (0.1875 deg)	5 km	2 km	TL319 (0.5625 deg)	
Vertical levels / Top	60 0.1 hPa	50 21.8 km	60 20.2 km	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 Perturbations are produced by SV-method	

Data assimilation systems of NPD/JMA

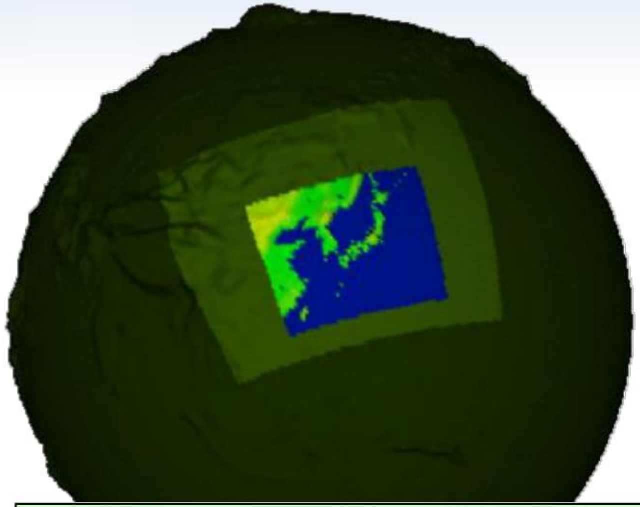
NEW

	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	00, 03, 06, 09, 12, 15, 18, 21 UTC
Data cut-off time	2 hours 20 minutes [Early Analysis] 11 hours 35 minutes (00, 12 UTC) 5 hours 35 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)	5 km
Vertical levels	60 levels up to 0.1 hPa	50 levels up to 21.8 km	50 levels up to 21.8 km
Assimilation window	-3 hours to +3 hours of analysis time	-3 hours to analysis time	-

Main Operational NWP Systems at JMA



- Global NWP system
- Horizontal Resolution: 20 km
- Updates: 4 times a day
- Forecast domain: Global



- Regional NWP system
- Horizontal Resolution: 5 km
- Updates: 8 times a day
- Forecast domain: Japan and its surrounding areas

JMA GLOBAL NWP SYSTEM

Operational global NWP at JMA/NPD

GSM: Global Spectral Model

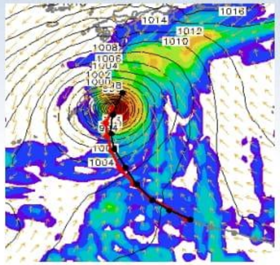
Forecast domain: whole the Globe
Purpose: short- and medium-range forecast
Horizontal resolution: TL959 (0.1875 deg.)
Vertical layers: 60 Layers up to 0.1hPa
Forecast Hours:
- up to 84-hours at 00, 06, 18 UTC,
- up to 216-hours at 12 UTC

GA: Global Analysis (4D-Var)

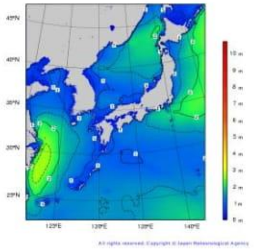
Model resolution:
- Outer: TL959 (0.1875 deg.)
- Inner: TL319 (0.5625 deg.)

Data cut off time
for Early Analysis: +2h20m
for Cycle Analysis: +11h35m(00,12)/5h35m(06,18)
Assimilation Window: -3h to +3h

Roles of GSM



- basic information for a short- and one week forecasts
- basic information for typhoon track and intensity forecasts
- assist of aviation and ship routing forecasts
- provision of lateral boundary condition for Mesoscale Model
- input data for ocean wave model and regional storm surge model
- wind information for input of chemical transport model



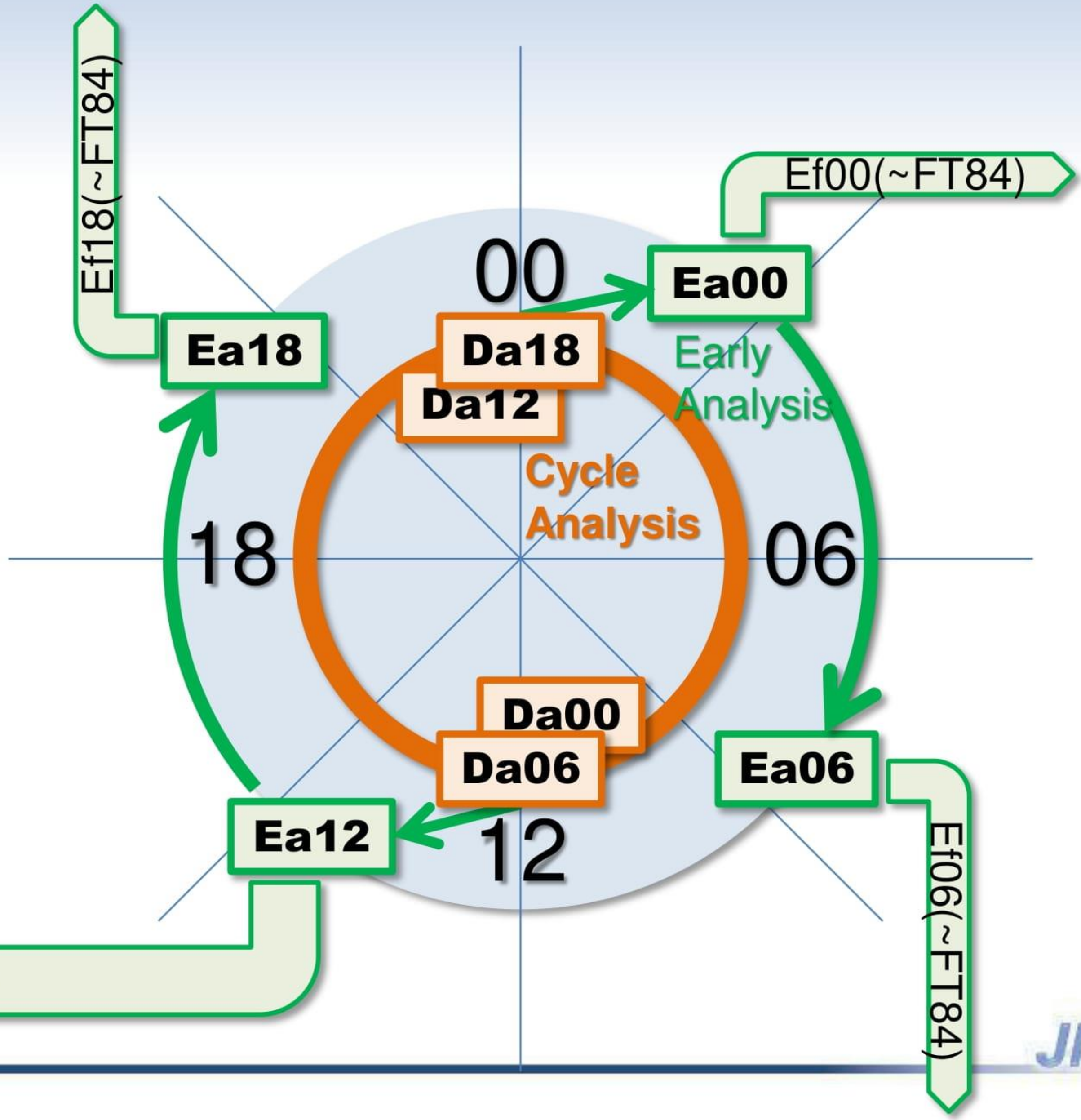
Operation of GSM

For Global Analysis,
We have two systems:

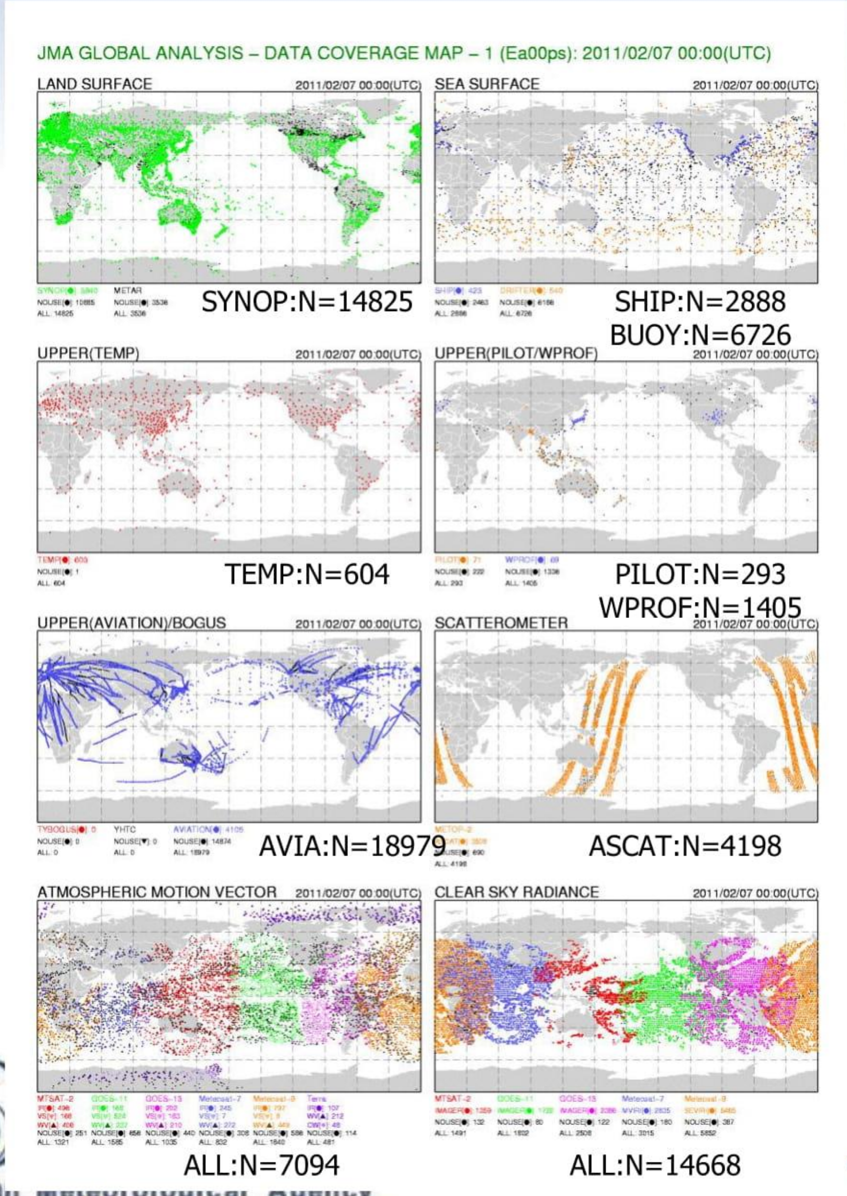
Early Analysis (**EA**)
for weather forecast

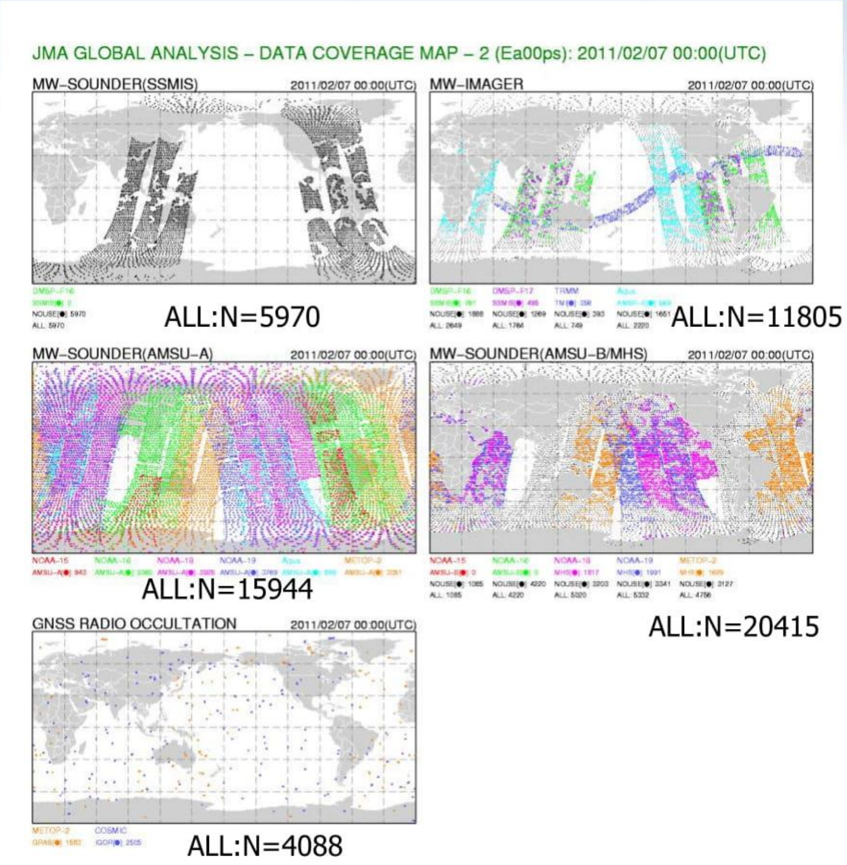
Cycle Analysis (**DA**)
for the better analysis

Data Cutoff Time
Da00/12: 11^h35^m
Da06/18: 05^h35^m
Ea: 2^h20^m



Data distribution for Early Analysis





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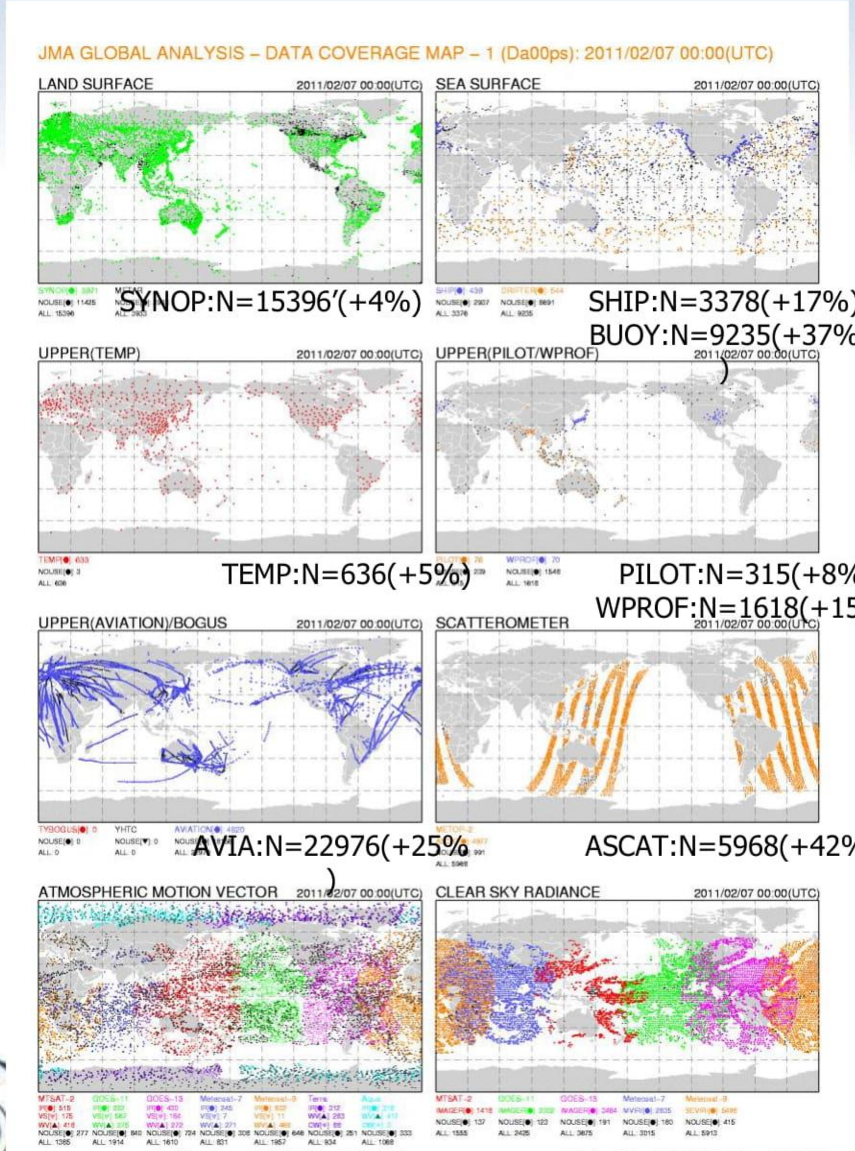
Data distribution for Cycle Analysis



SYNOP:N=15396′(+4%)

SHIP:N=3378(+17%)
BUOY:N=9235(+37%)

TEMP:N=636(+5%)

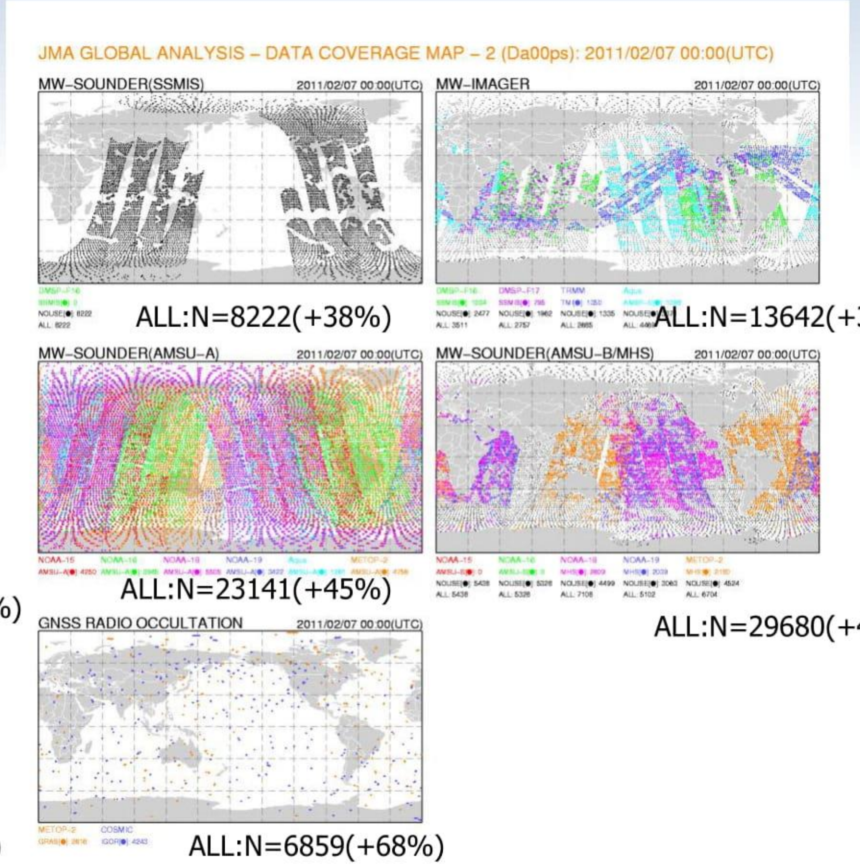
PILOT:N=315(+8%)
WPROF:N=1618(+15%)

AVIA:N=22976(+25%)

ASCAT:N=5968(+42%)

ALL:N=9719(+37%)

ALL:N=16783(+15%)



ALL:N=8222(+38%)

ALL:N=13642(+30%)

ALL:N=23141(+45%)

ALL:N=29680(+45%)

ALL:N=6859(+68%)

With the longer waiting time in DA, the available data number is much larger than the one in EA ! (Total+30%)

NWP global models in the world

Nation (Center)	Global model		Global EPS			Regional model
	Resolution	Forecast period	Resolution	Member s x runs per day	Forecast period	Resolution
Japan (JMA)	20km L60	9 days	60km L60	51x1	9 days	5km L50 2km L60
Europe (ECMWF)	16km L91	10 days	32km L62 65km L62	51x2 51x2	10 days +5 days	-
U.K. (Met Office)	25km L70	6 days	60km L70	24x2	15 days	12km L70 1.5km L70
France (Meteo France)	25km L70	4 days	37km L65	35x2	4 days	2.5km L60
Germany (DWD)	30km L60	7 days	-			7km L40 2.8km L50
U.S.A. (NCEP)	27km L64 105km L64	8 days 16 days	70km L28	21x4	16 days	12km L60 4km L50
Canada (CMC)	33km L80	10 days	100km L28	20x2	16 days	10km L80 2.5km L58

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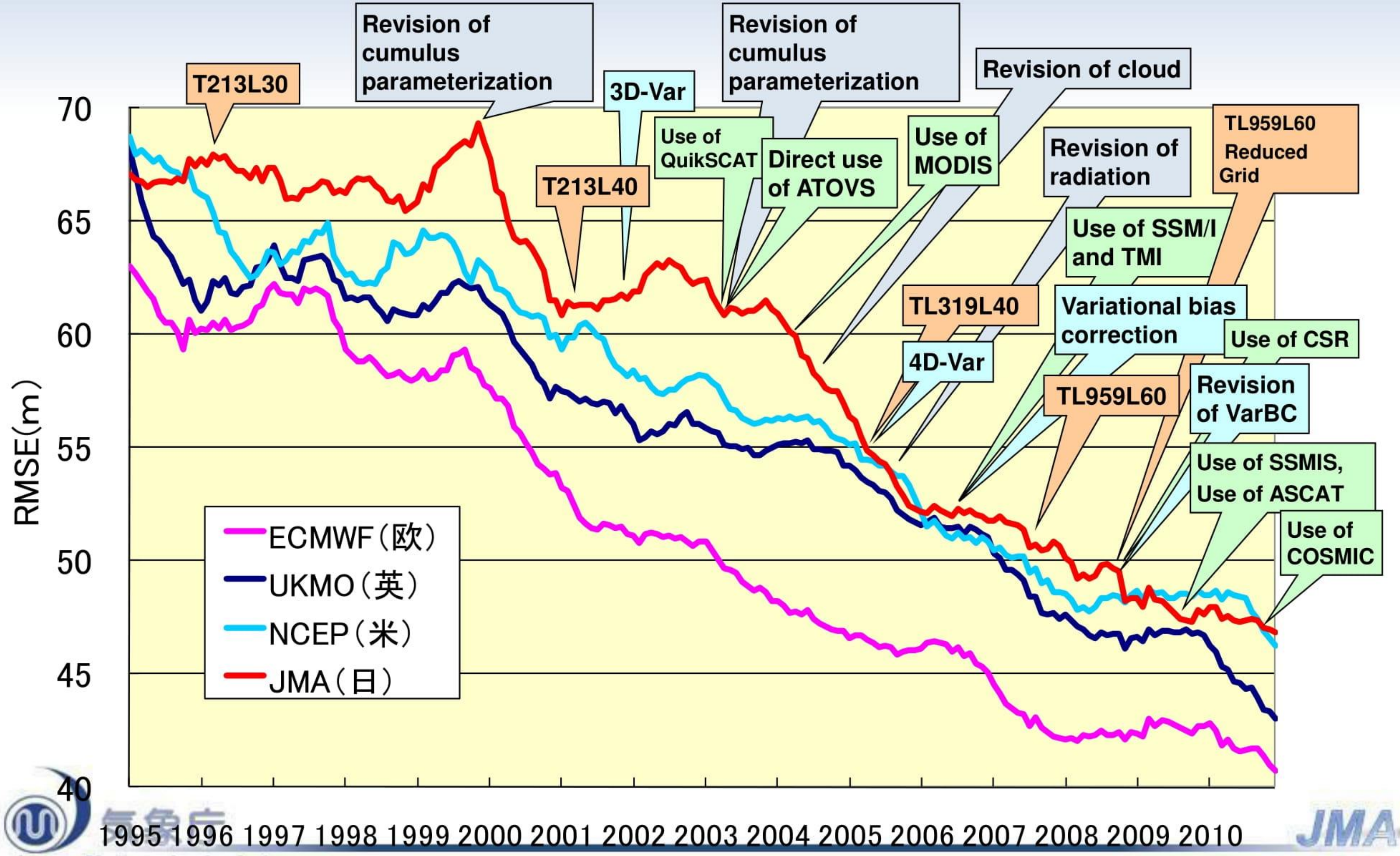
As of June 2011

GSM RMSE Sequence on Z500

for 120 hrs forecast at N.H.



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JMA REGIONAL NWP SYSTEM

Operational regional NWP at JMA

MSM: Meso-Scale Model

Non-hydrostatic grid model based on JMA-NHM

Forecast domain: Japan and its surroundings
Purpose: Disaster reduction, short-range forecast
Horizontal resolution: 5 km
Vertical layers: 50 Layers up to 21.8 km
Forecast Hours:
- up to 15-hours at 00, 06, 12, 18 UTC,
- up to 33-hours at 03, 09, 15, 21 UTC

Boundary condition: GSM forecast

MA: Meso-scale Analysis

4DVar-system based on JMA-NHM (JNoVA)

Model resolution:
- Outer: 5 km
- Inner: 15 km

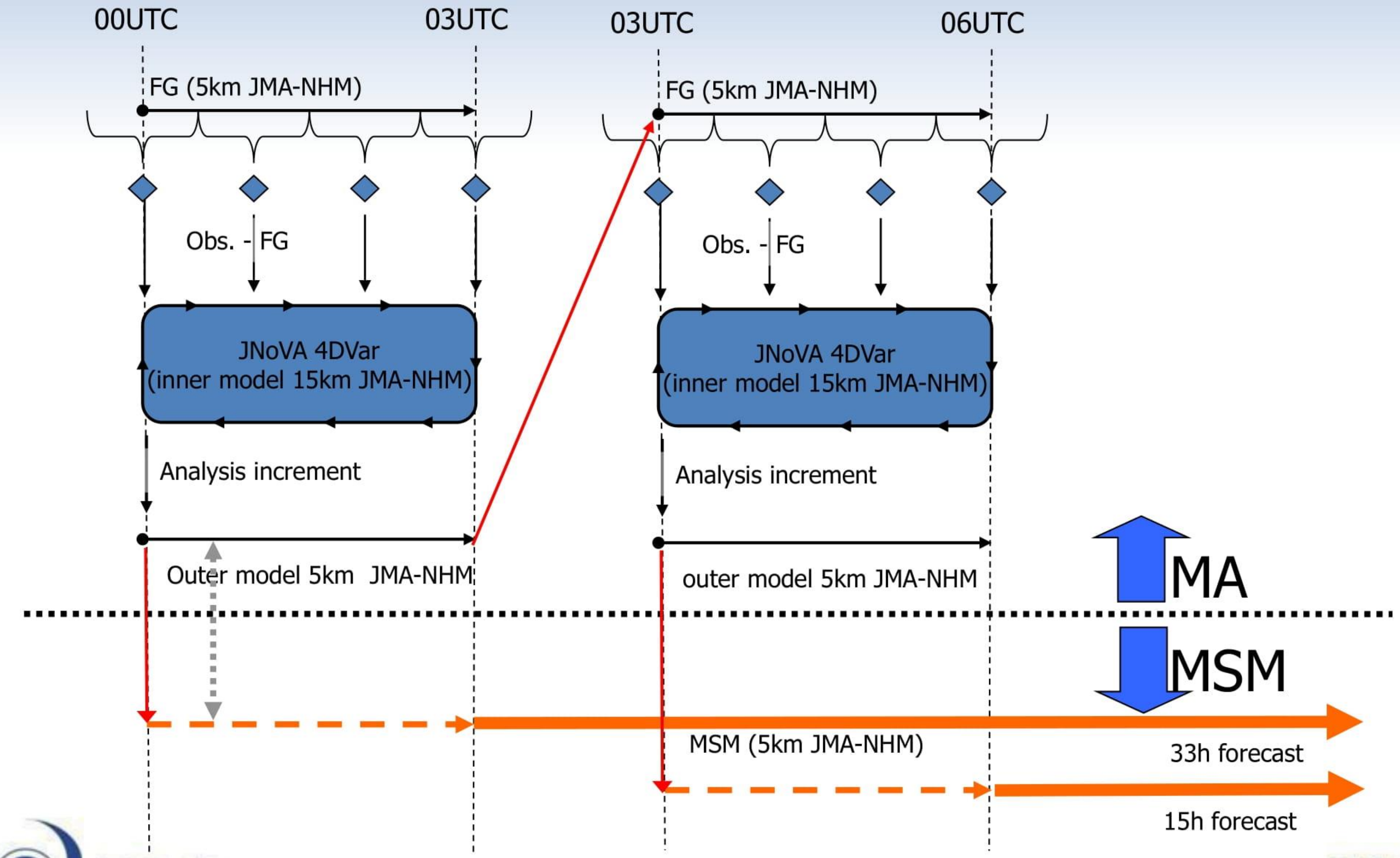
Data cut off time: +50 min.
Assimilation Window: -3h to Analysis time

Objectives of Mesoscale NWP System

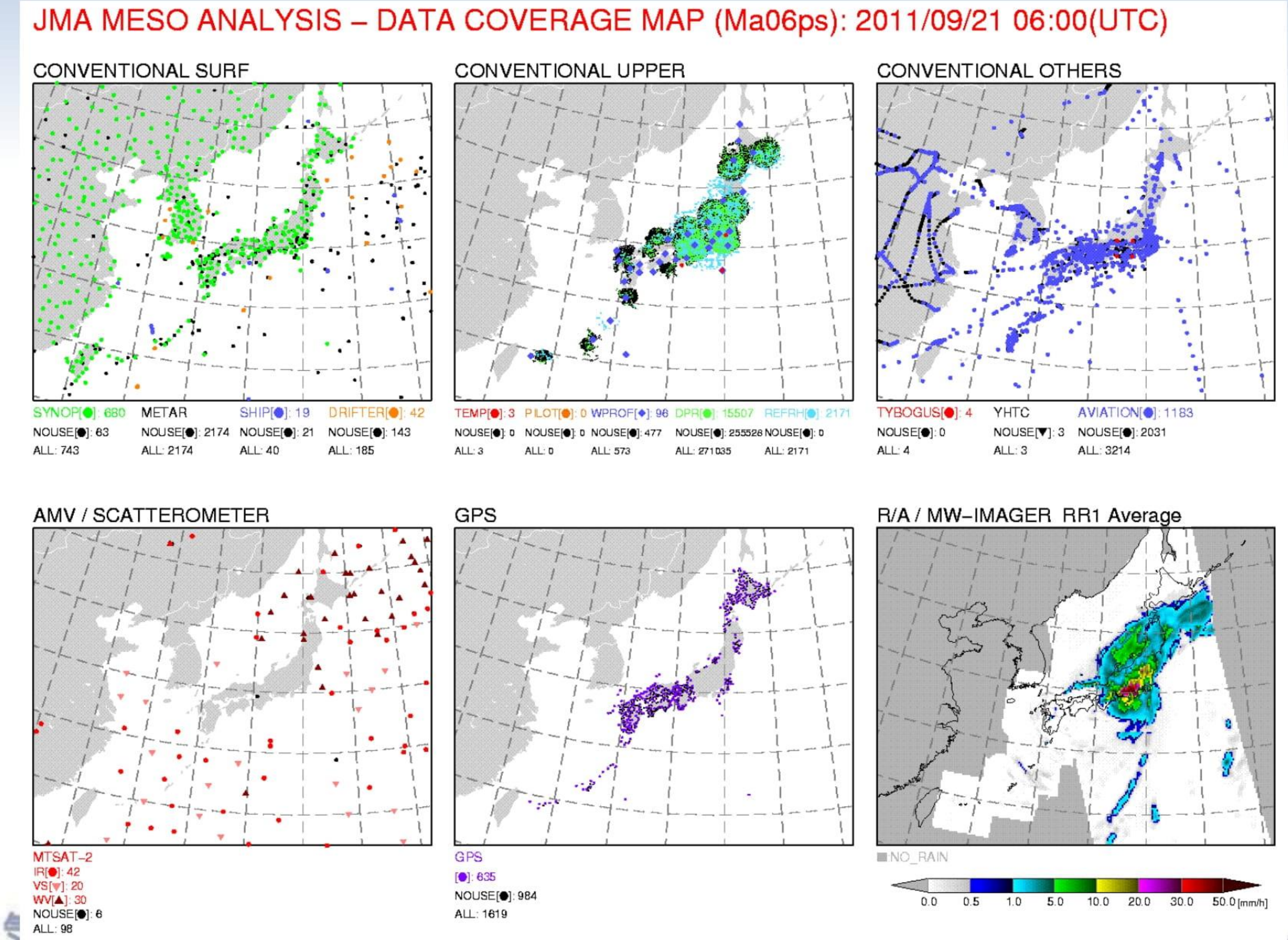
- Disaster Prevention
  - Prediction of severe weather such as heavy rainfall is one of the main targets for mitigation and reduction of damage to property and loss of life.
  - Input to very short-range precipitation forecast system
  - Input to storm surge model

- Aviation Weather Forecast
  - Enrichment of the weather information for aviation safety
  - Terminal Area Forecast (TAF) Guidance and so on.

Operation of MSM



MA Coverage Maps of Observation Data



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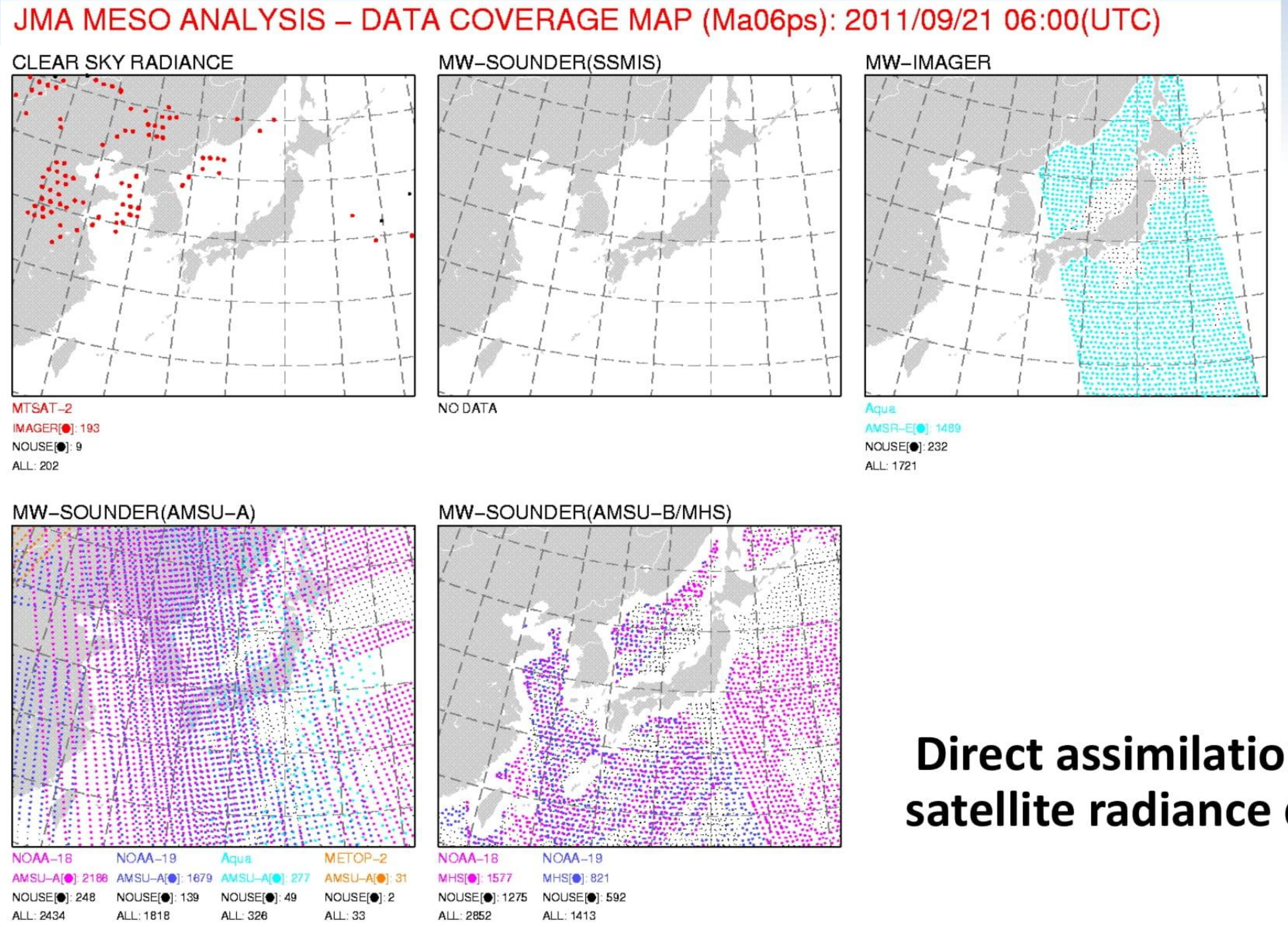
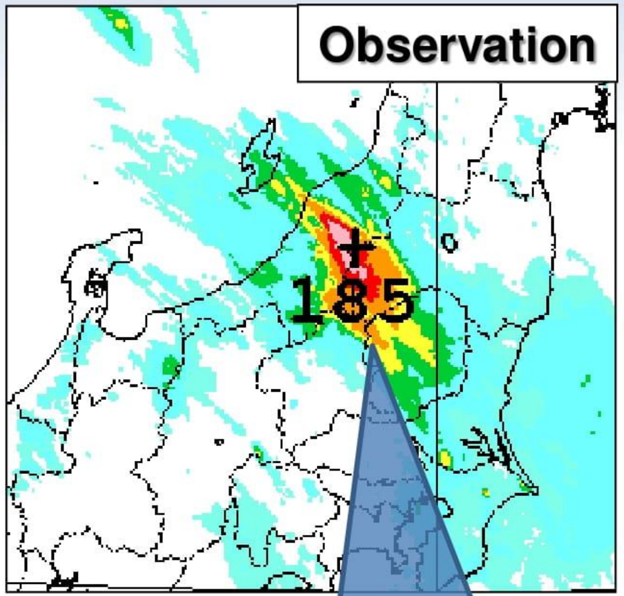
MA Coverage Maps of Observation Data

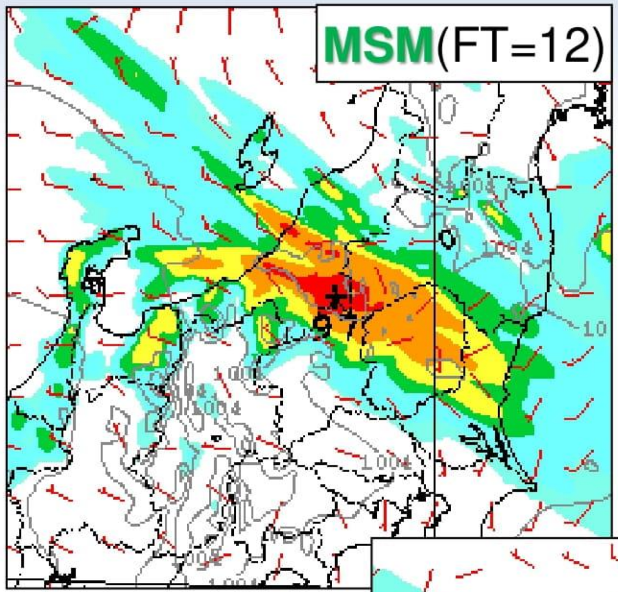


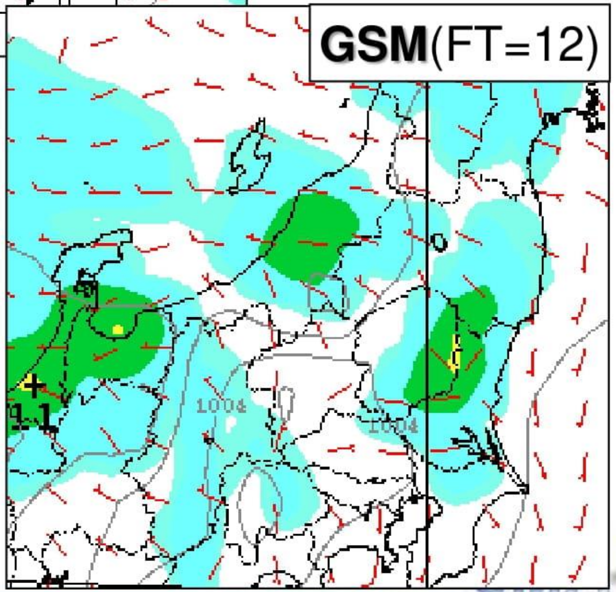
Direct assimilation of satellite radiance data

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

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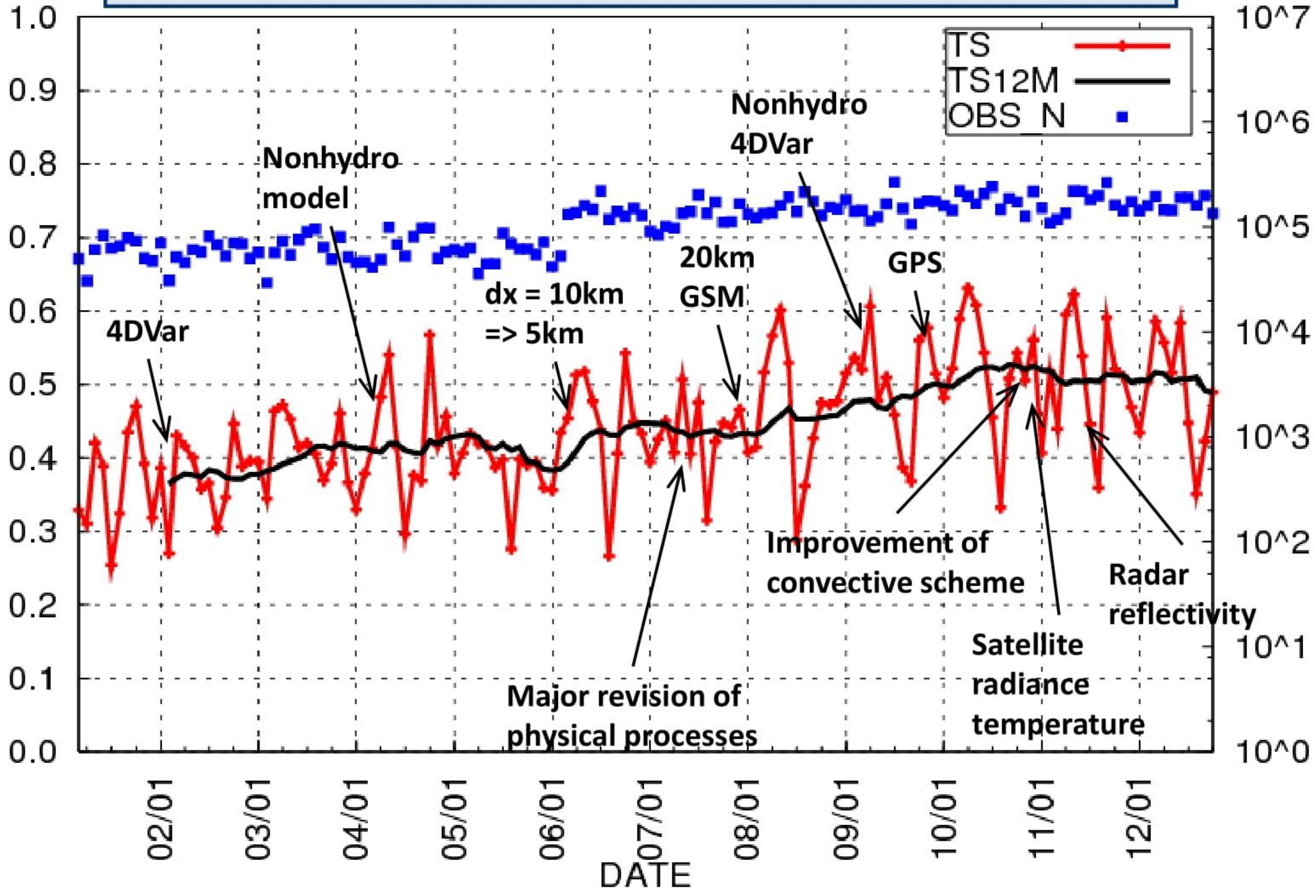
Score of MSM Precipitation Forecast

Threat Score
Verification Grid : 20km Square
Verified Element: 1mm/3hr
Verification Period :From Mar. 2001 to Oct. 2012

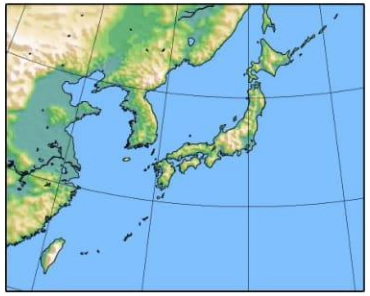


Japan M

JMA

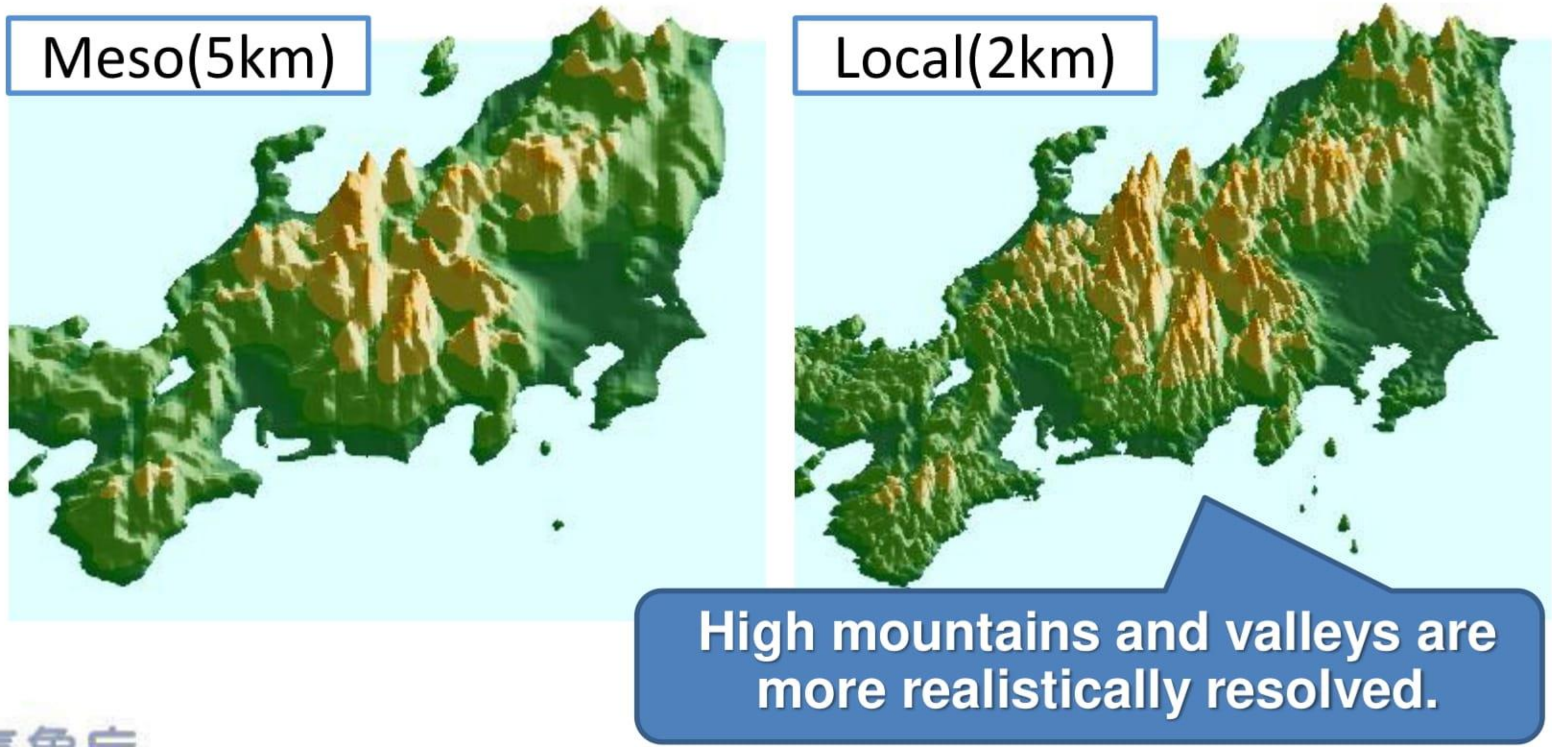

LOCAL NWP SYSTEM
– NEW OPERATIONAL HIGH RESOLUTION
NWP SYSTEM –

Specifications of LFM

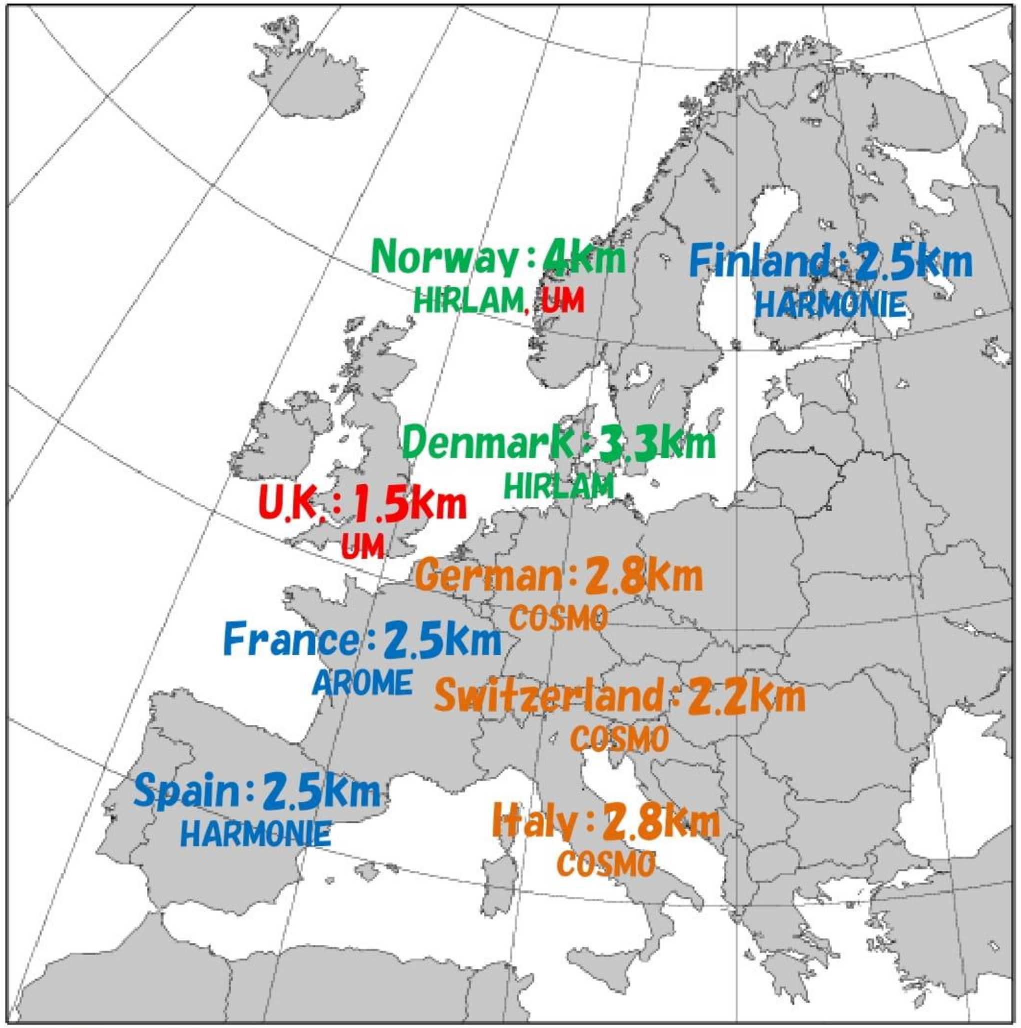
	Local Forecast Model (LFM)	Meso-Scale Model (MSM)
Horizontal Resolution	2km (551x801) 	5km (721x577) 
Vertical Layers	60 Layers, up to 20km	50 Layers, up to 22km
Integration Time Step	8 second	20 second
Initial Condition	3D-Var RUC	4D-Var
Boundary Condition	MSM	GSM
Forecast hours	9 hours	33/15 hours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

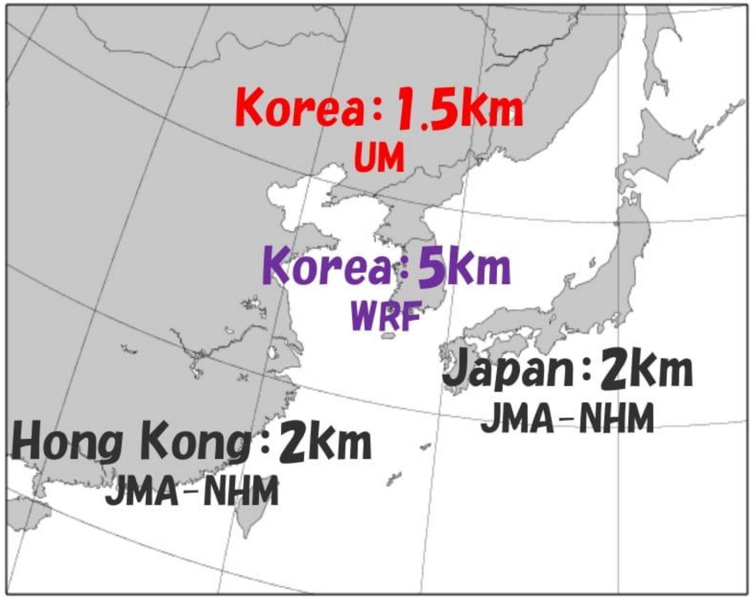
Development of Local NWP system

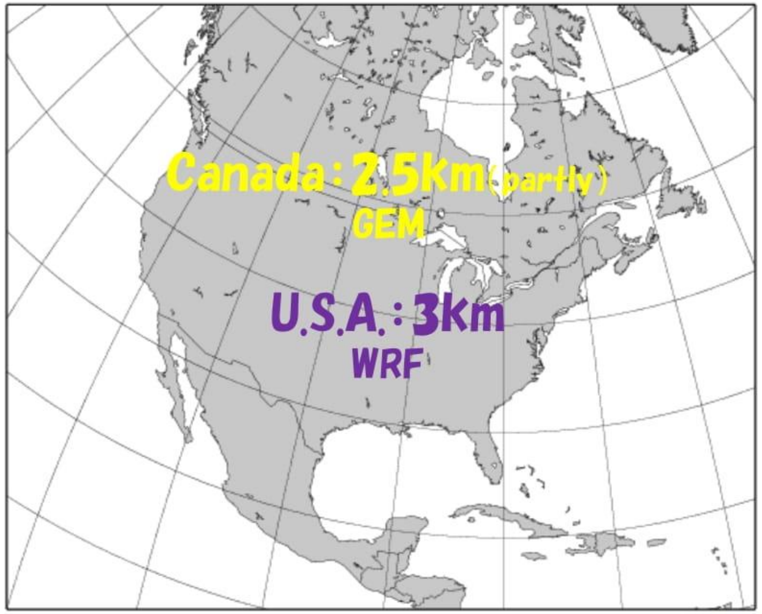
- The objectives are to provide information for aviation weather forecast and disaster prevention with high resolution NWP
- Operation has just started in Aug. 2012



High-resolution model in the world

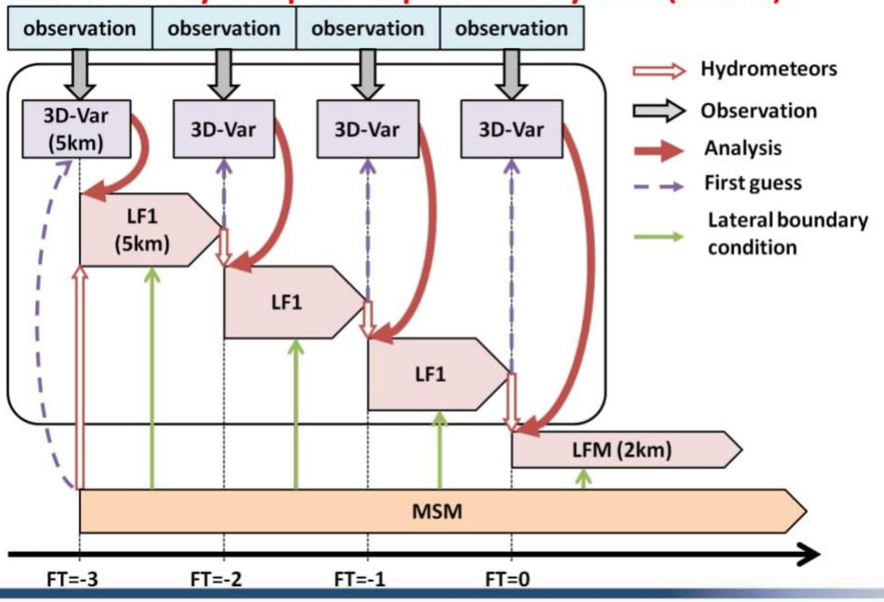






Local Analysis

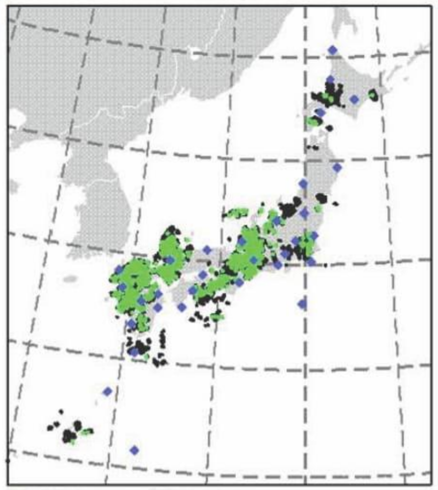
- Specifications
  - Horizontal resolution is 5km, 50 vertical layers
  - Model domain: 2200km x 2500km (441x501grid)
  - Analysis time: 00,03,06,09,12,15,18,21（UTC）
    - hourly observations are assimilated
  - Observation cut off time is 30 minutes (Very Short!)
  - Data assimilation method: 3D-Var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



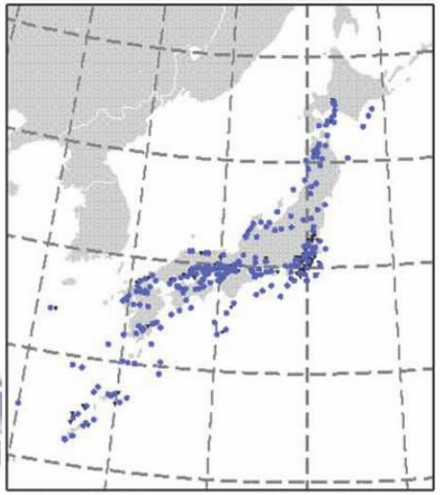
LA Coverage Maps of Observation Data

Surface stations
(temperature and wind)

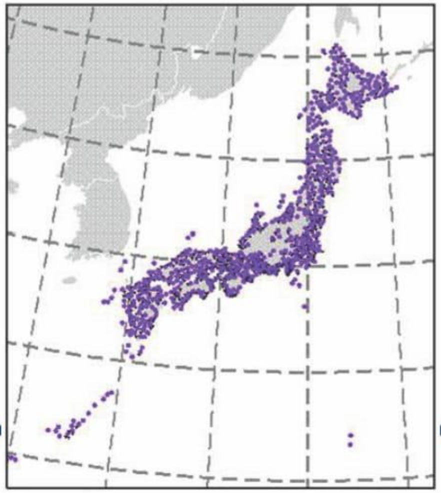
Wind Profiler
(horizontal wind)
Doppler radar
(radial velocity)



Aviation(temperature
and horizontal wind)



Ground-based GPS
(total column water vapor)



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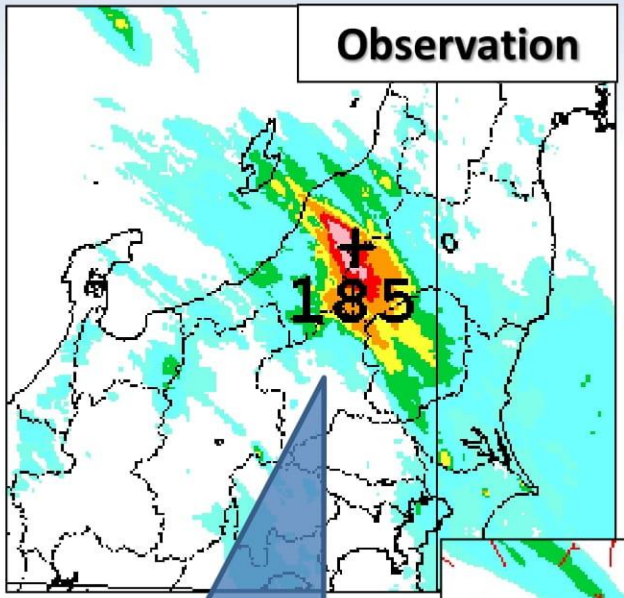
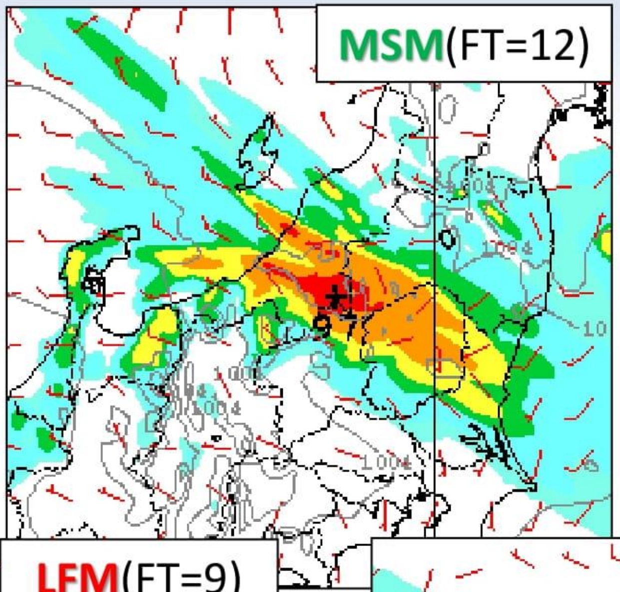
Quantitative precipitation forecast

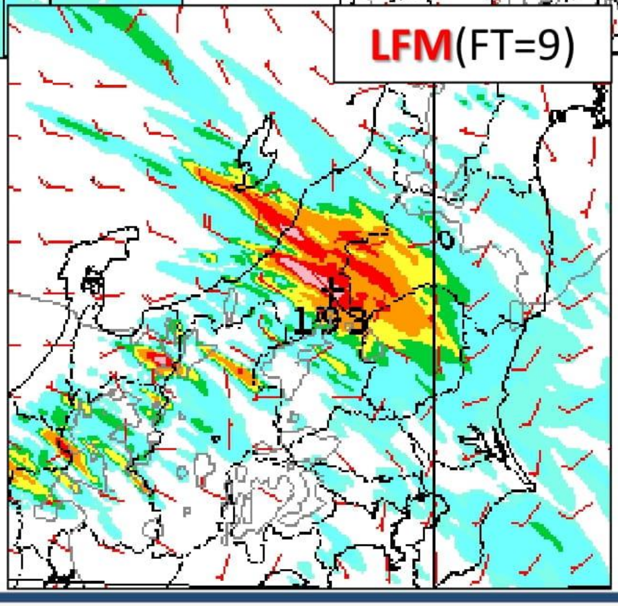
2011 July. 29 06UTC 3hourly precipitation

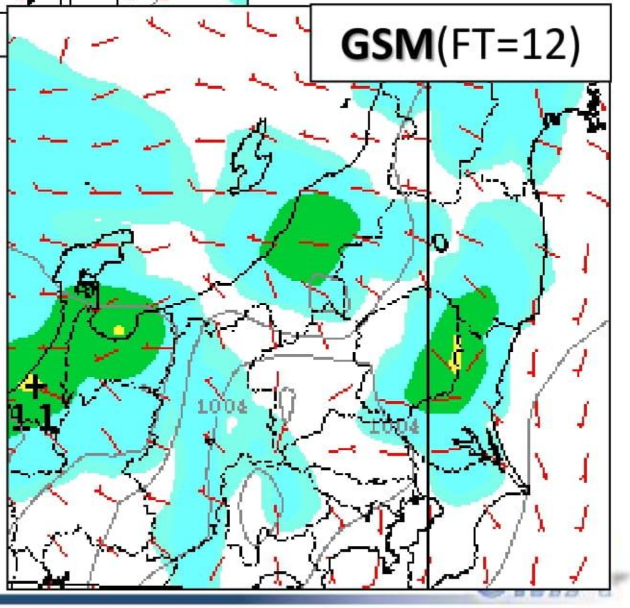




A heavy rainfall in Niigata and Fukushima Prefectures on July 2011

The maximum daily precipitation amount ~ 1000mm



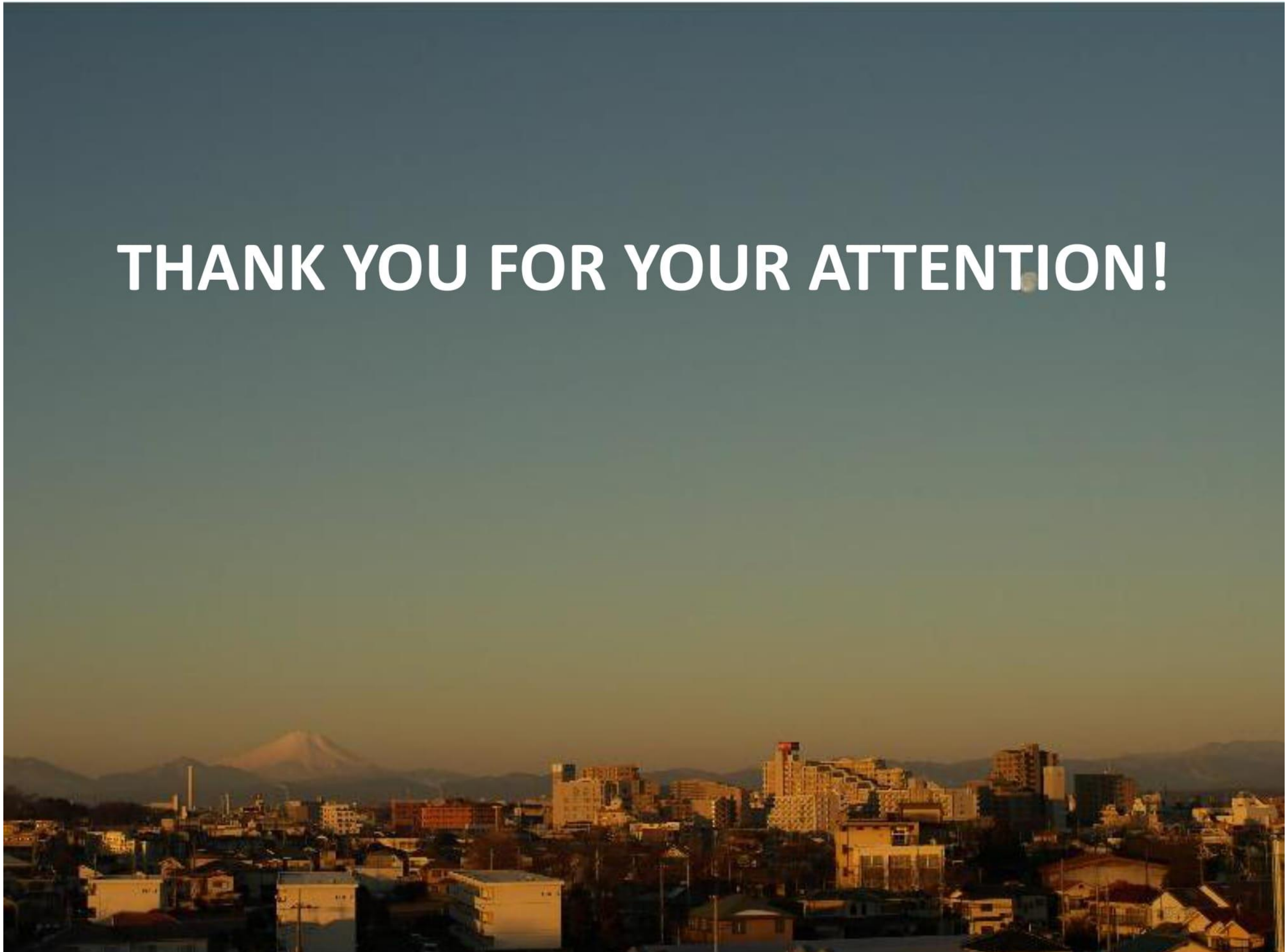


Future Plan

- 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 Japan and its surroundings	Aug. 2012 – May 2013 May 2013 –


THANK YOU FOR YOUR ATTENTION!

DATA COLLECTION

Data collection

- Observed data are collected via GTS, internet etc.
  - There would be time lag between observation and arrival to the computer system.
- The calculation of NWP system should be finished before deadline.
  - The calculation of forecast for noon should be finished in the morning (before noon).
- The deadline of the data collection is employed.
  - The data which reaches after the deadline can not be used.
  - It is about 2h20m for JMA global model.

QUALITY CONTROL OF OBSERVED DATA

Quality check of observed data

- Observed data might contain various errors
  - Necessity of quality check

- Comparison with climate value
- Consistency in the vertical direction (height, temperature, wind)
- Consistency of observation position
- Consistency in the observation time
- Spatial consistency (comparison with near-by data)
- Comparison with recent result of NWP

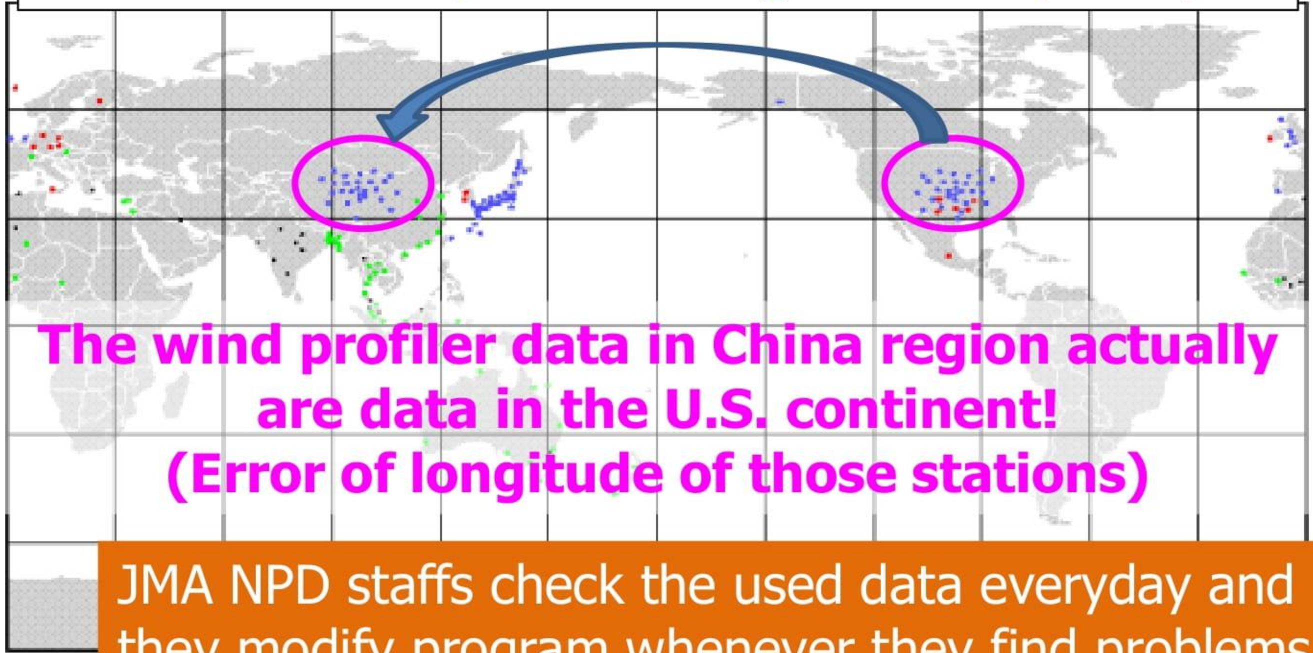
Reject of observed data by quality control

After the quality control, the data with errors should be rejected and not be used in the NWP.

Sometimes unbelievable error occurs as follows.

Upper observation used in global analysis at 18UTC, 9th April, 2008

TEMP, PILOT (red, green), **wind profiler (blue)**



JMA NPD staffs check the used data everyday and they modify program whenever they find problems

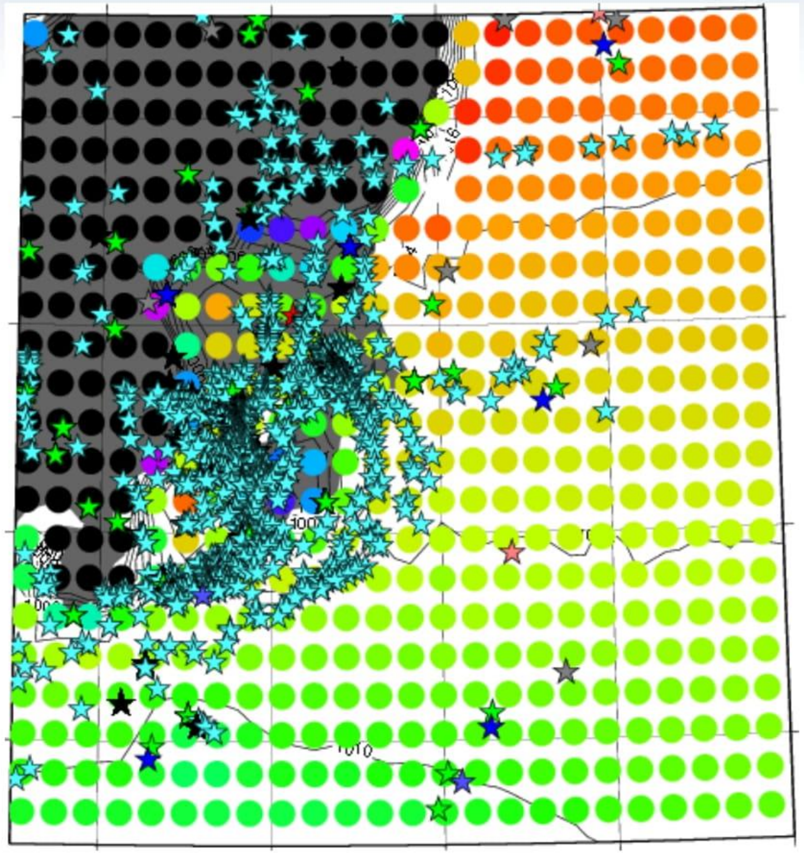
Errors in observed data

- Observed data may contain various errors.
- The quality control technique will reject such data in order not to bring error into the NWP model forecast.
- The variety of error types are so big that the QC system unfortunately can not assure the perfect rejection of data error.
  - The incorrect data which cannot be rejected might cause NWP model error.

DATA ASSIMILATION

What is data assimilation?

How to prepare initial field for NWP model ?



GSM grid point value data (circle) and observed data (star)

Characteristic of observation data and first guess field

	Observation	First guess field
◎	Basically they reflect realistic atmosphere	**Fully set of every grid points and every element**
△	Include observation error	Include forecast error
×	**Sparse spatial distribution and element**	Compared with the observation, it is not clear the field reflects actual atmosphere

First guess field is supplied by previous forecast.

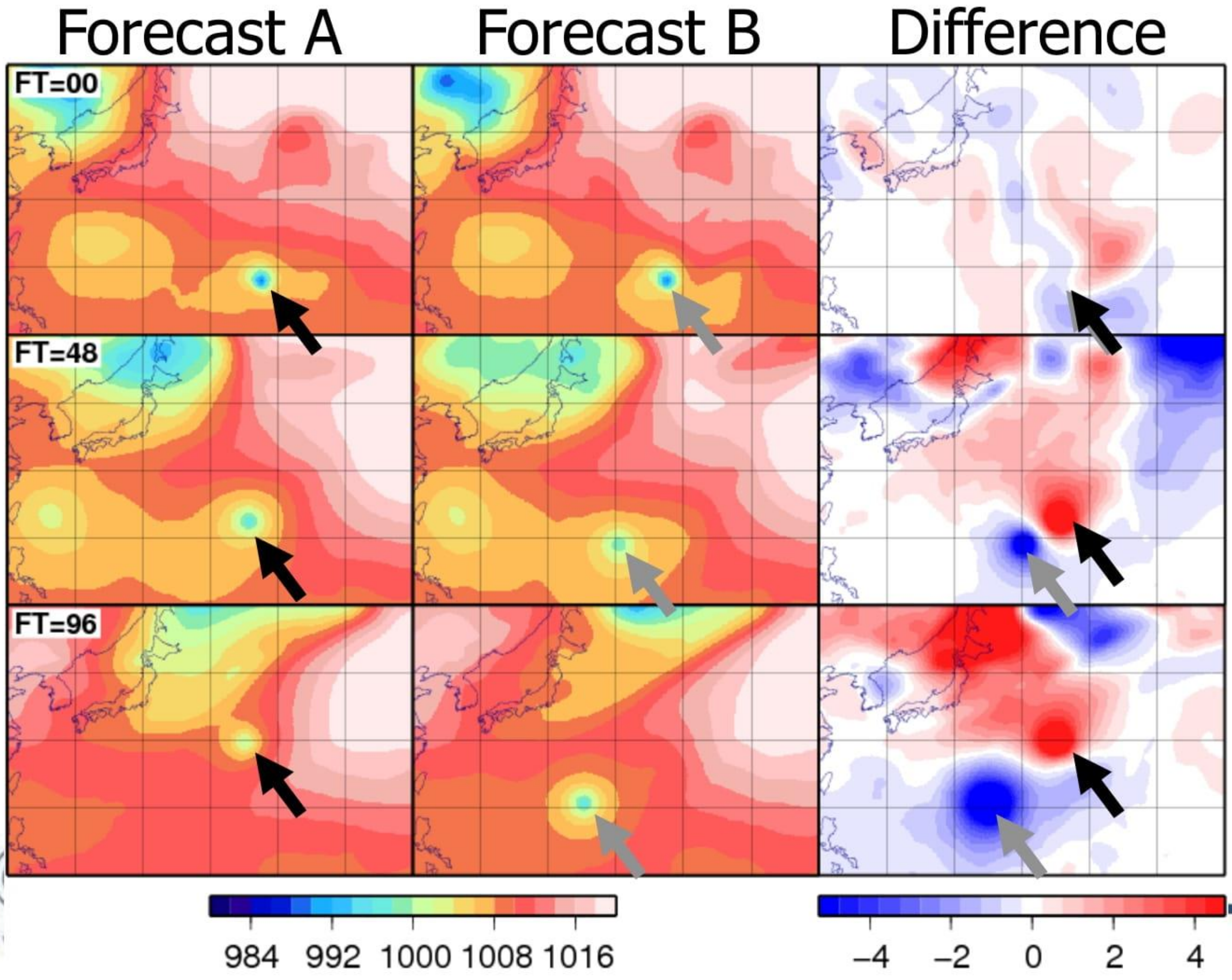
- It gives fully set of the field

The field is modified by the observed data

- The field will come up to realistic.

Initial field is quite important

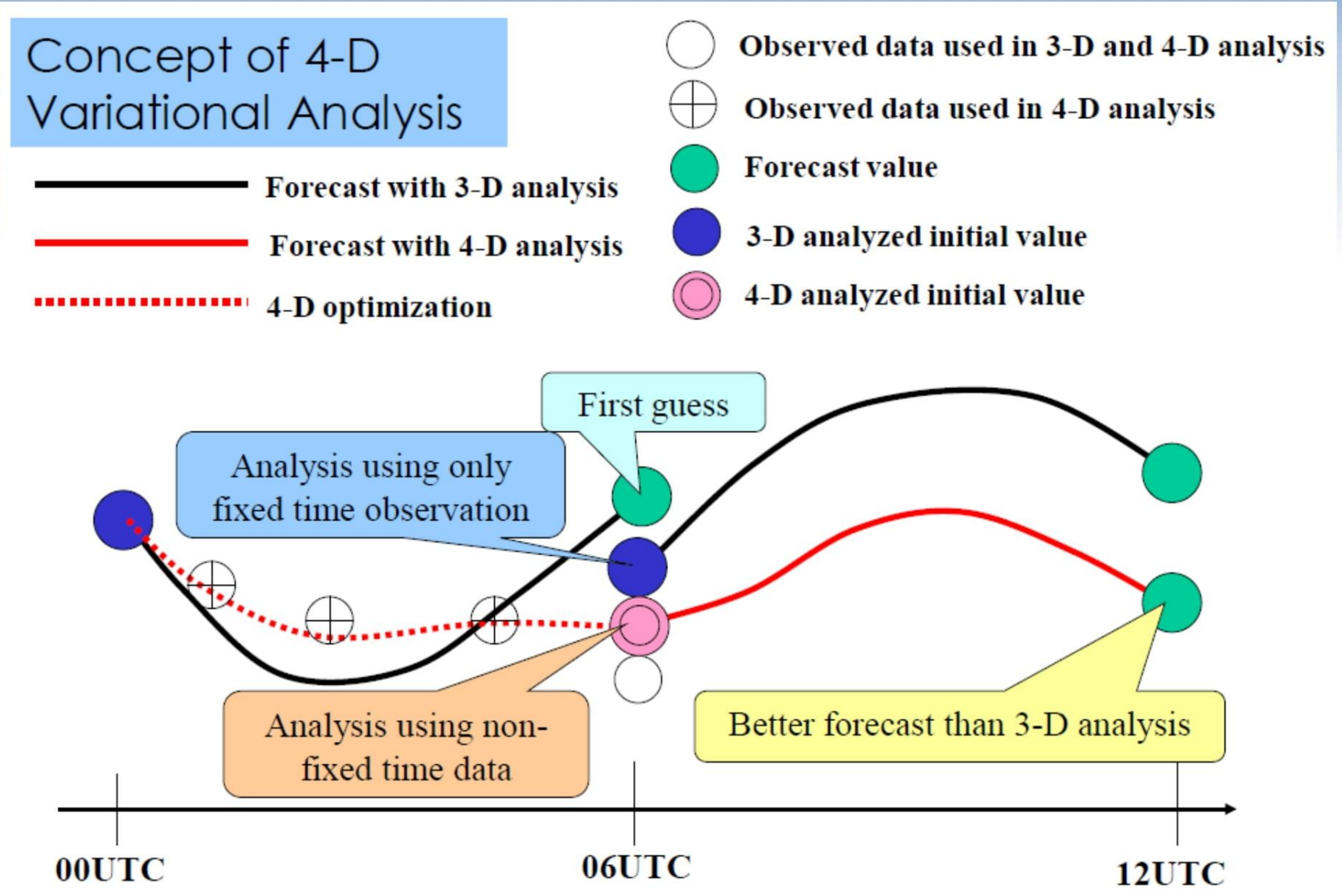
Non-linearity of NWP : Very small error in initial field may cause significant error in forecast



The difference in the initial field is very small

The course of TC is quite different.

JMA


Concept of 4-D Variational Analysis
Observed data used in 3-D and 4-D analysis
Observed data used in 4-D analysis
Forecast value
3-D analyzed initial value
4-D analyzed initial value
Forecast with 3-D analysis
Forecast with 4-D analysis
4-D optimization
First guess
Analysis using only fixed time observation
Analysis using non-fixed time data
Better forecast than 3-D analysis
00UTC
06UTC
12UTC

NUMERICAL WEATHER PREDICTION

Basic concept of NWP

Changes in the forecast variables *F* (ex. *U*, *V*, *T* etc.) are calculated at each grid point of the atmosphere.

$$F(t) = F_0 + \int_0^t \frac{\partial F}{\partial t}\, dt \rightarrow F_0 + \sum_0^t \frac{\partial F}{\partial t} \Delta t$$

Basic Forecast variables:

U, V, W	wind
T	temperature
Ps	surface pressure
Q	moisture

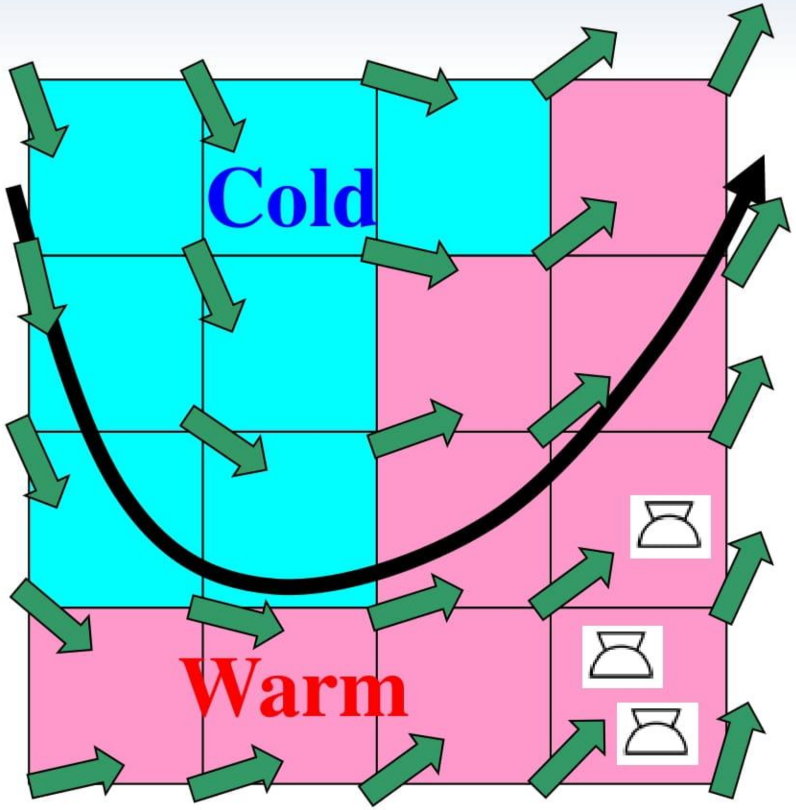
The main and big problem is how to calculate the time derivative of F.

Governing Equation System for NWP

Equation of motion (horizontal)	Time change of hor. wind	=	Advection	+	Coriori's force	+	Hor. Pressure gradient force			+	Friction (Physics)
Equation of motion (vertical)	Time change of ver. wind	=	Advection			+	Ver. Pressure gradient force	+	Grav.	+	Friction (Physics)
or											
Hydrostatic equation (GSM)	0	=					Ver. Pressure gradient force	+	Grav.		
Continuity equation	Time change of density	=	Advection	+	Divergence / convergence						
Thermo dynamic equation	Time change of theta	=	Advection							+	Diabatic term (Physics)
Equation of moisture	Time change of moisture	=	Advection							+	Diabatic term (Physics)

… and equation of state

Grid scale and sub-grid scale



- Flow along trough and advection of warm / cold air can be represented using grid point value:

Grid scale phenomena

- Individual CB cannot be resolved by grid point value:

Sub-grid scale phenomena

Meteorological phenomena whose scale is less than 5 to 8 times of grid size can not be resolved

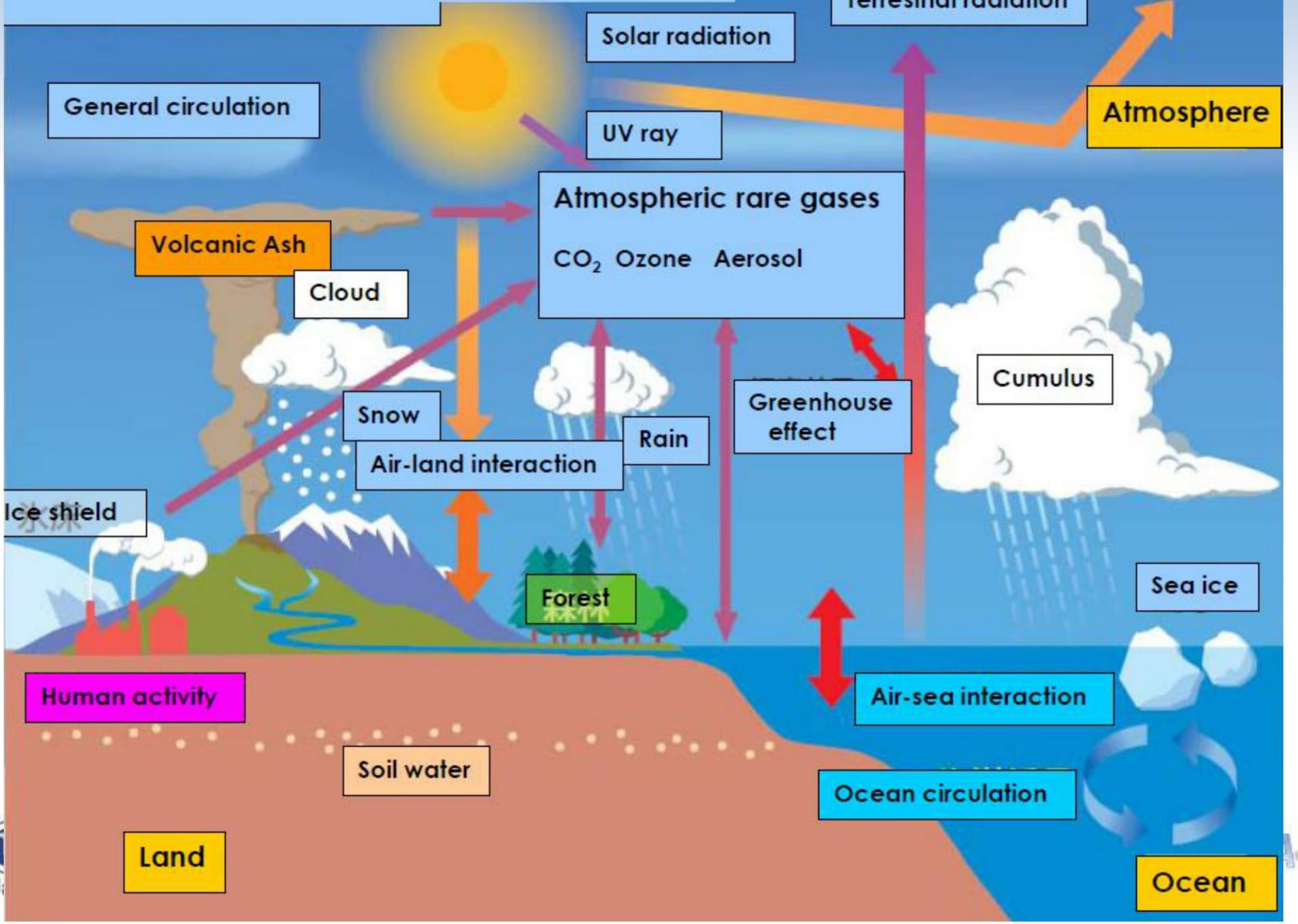
Physical Processes and Parameterization

- Parameterization : The representation, in a dynamic model, of physical effects in terms of admittedly oversimplified parameters, rather than realistically requiring such effects to be consequences of the dynamics of the system.

  Glossary of meteorology (AMS website)

- To calculate the time change of grid point value caused by the total effects of sub-grid scale phenomena using grid point value.

Concept of the Earth System

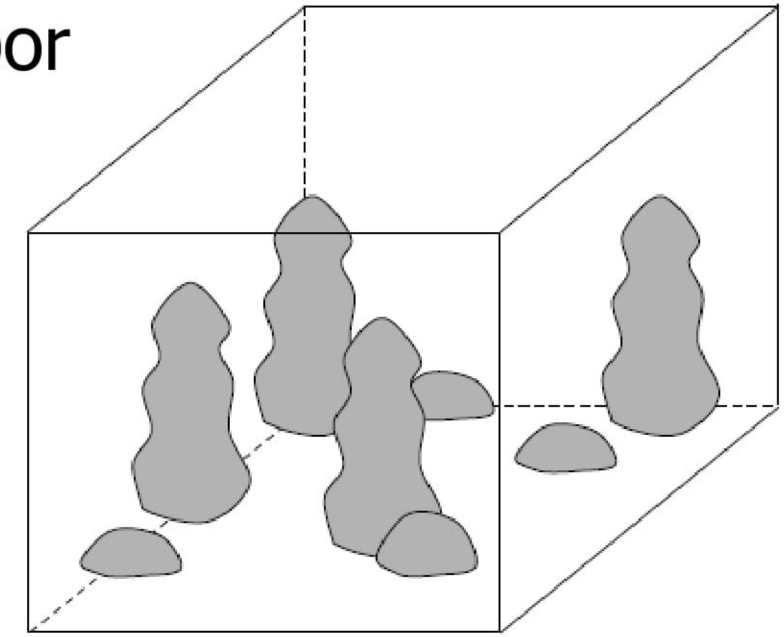


Physical processes

- Turbulence
- Condensation of water vapor
- Cumulus convection
- Radiation
- Surface process
- Mountain drag

etc.

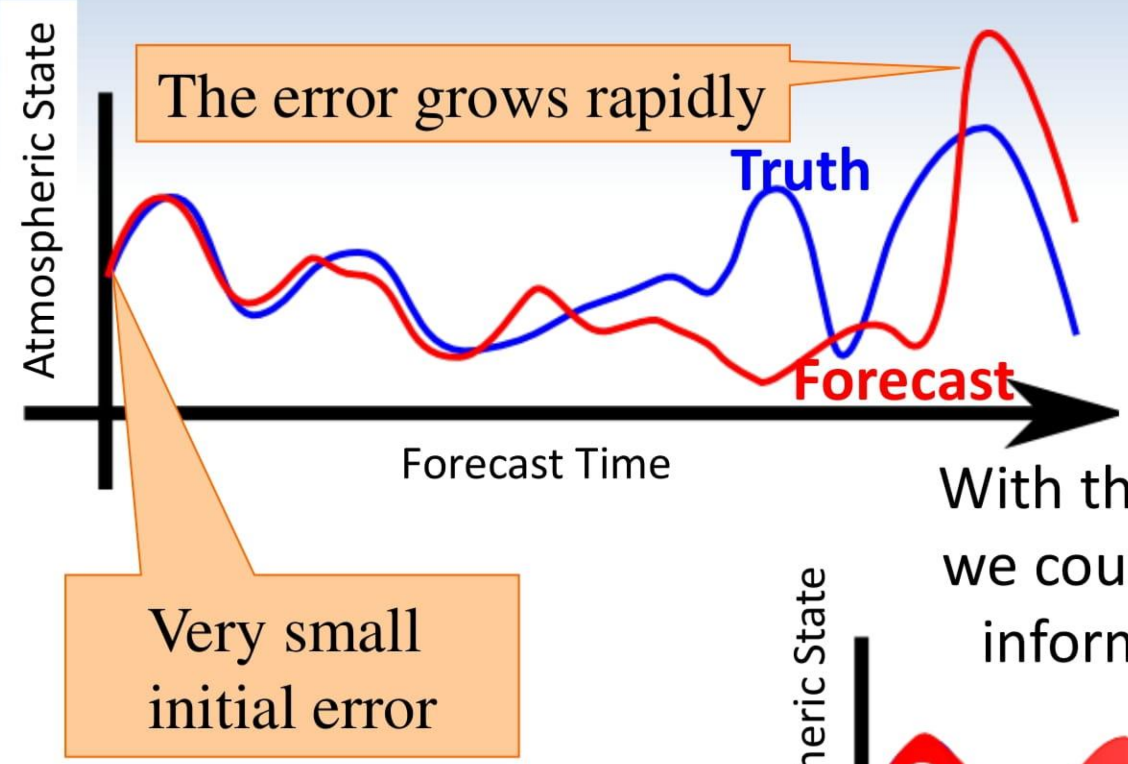
cumulus convection



$$T, q \rightarrow \left(\frac{\partial T}{\partial t}\right)_C, \left(\frac{\partial q}{\partial t}\right)_C$$

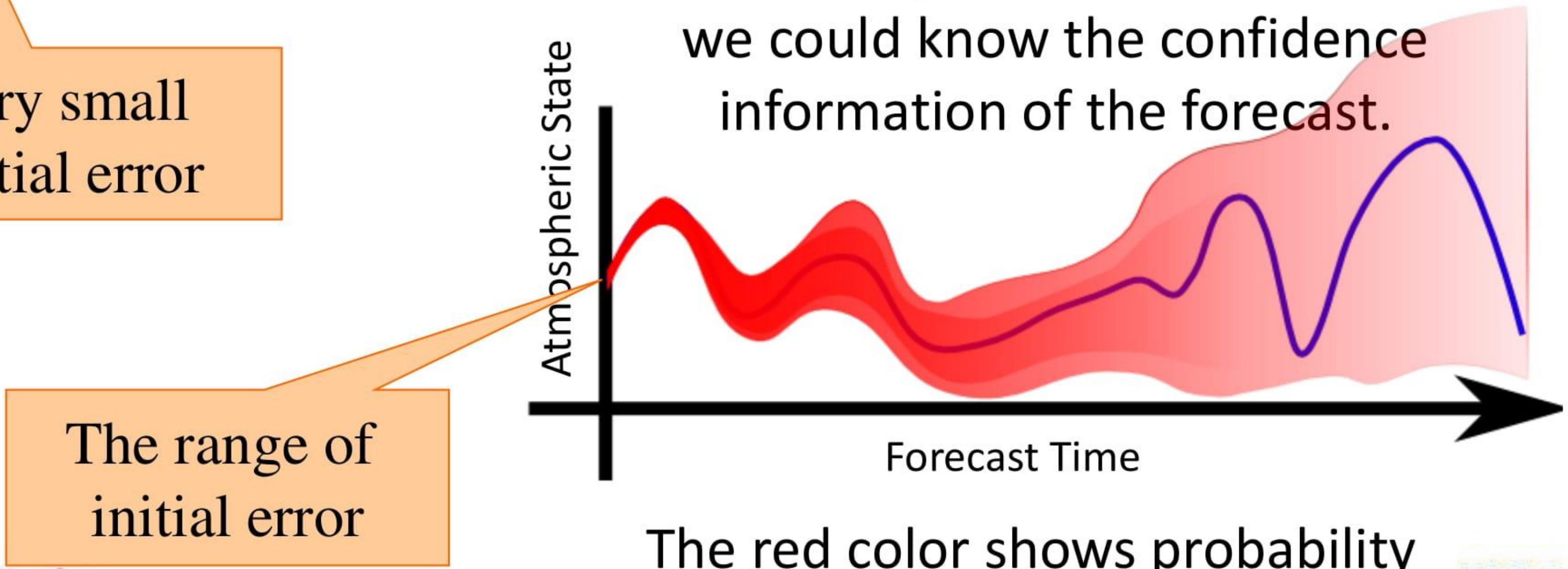
ENSEMBLE FORECAST

Probabilistic Forecast



With the integration,
the deterministic forecast
has large error

With the probabilistic forecast,
we could know the confidence
information of the forecast.

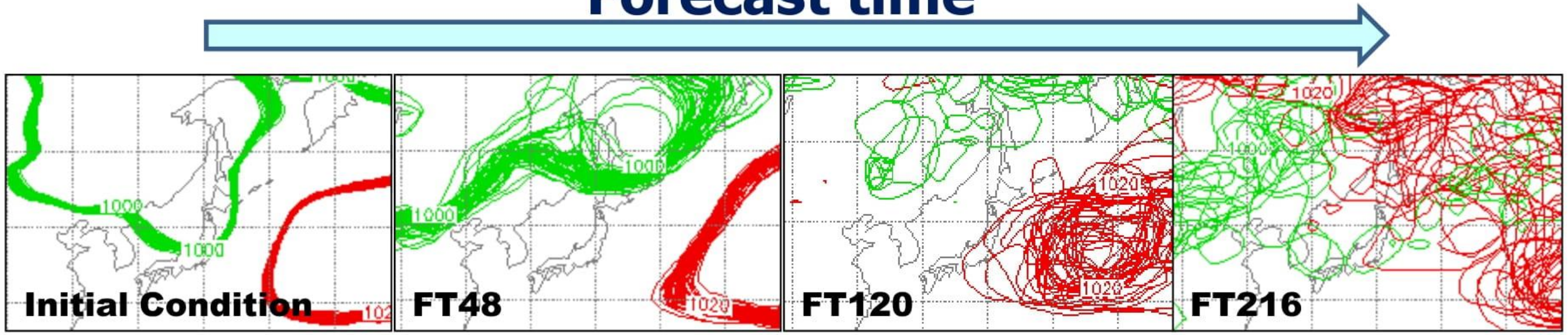


The red color shows probability

Ensemble Prediction Systems

- In the EPS, the multiple forecasts are conducted using slightly different initial conditions and/or different forecast settings.
  - This is a form of Monte Carlo analysis.

Forecast time



Perturbations in the initial condition are very small

Spaghetti diagram [51-member P_{msl} forecasts]

Perturbations in the 9-days forecast are quite large.

Ensemble Mean - characteristics -

Advantages

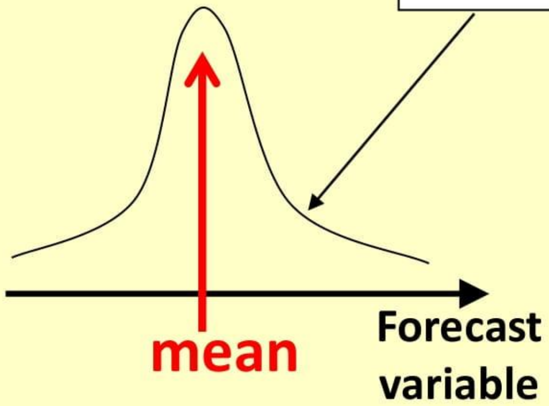
- 'Ensemble Mean' takes entire data sample into account.
- This has the effect of filtering out features of the forecast that are less predictable. We can know effective signal of forecast.
- This is the maximum likelihood value.

Disadvantages

- The probability is not always high.
- The forecast fields is not real (smoothed).

Ensemble Mean - member distribution -

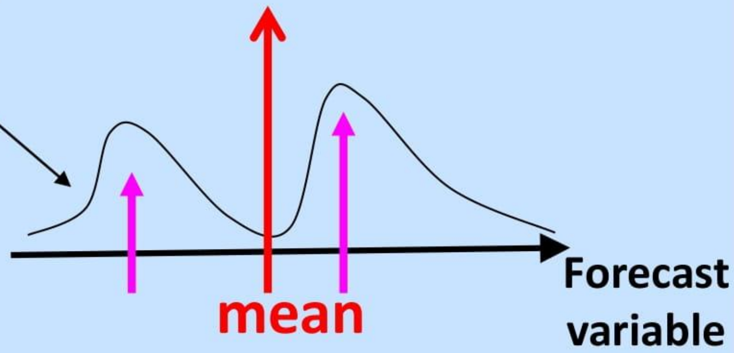
Normal Distribution



The simple average of ensemble members is the best estimation of most likely forecast.

Distribution of EPS forecasts

Multi-modal Distribution



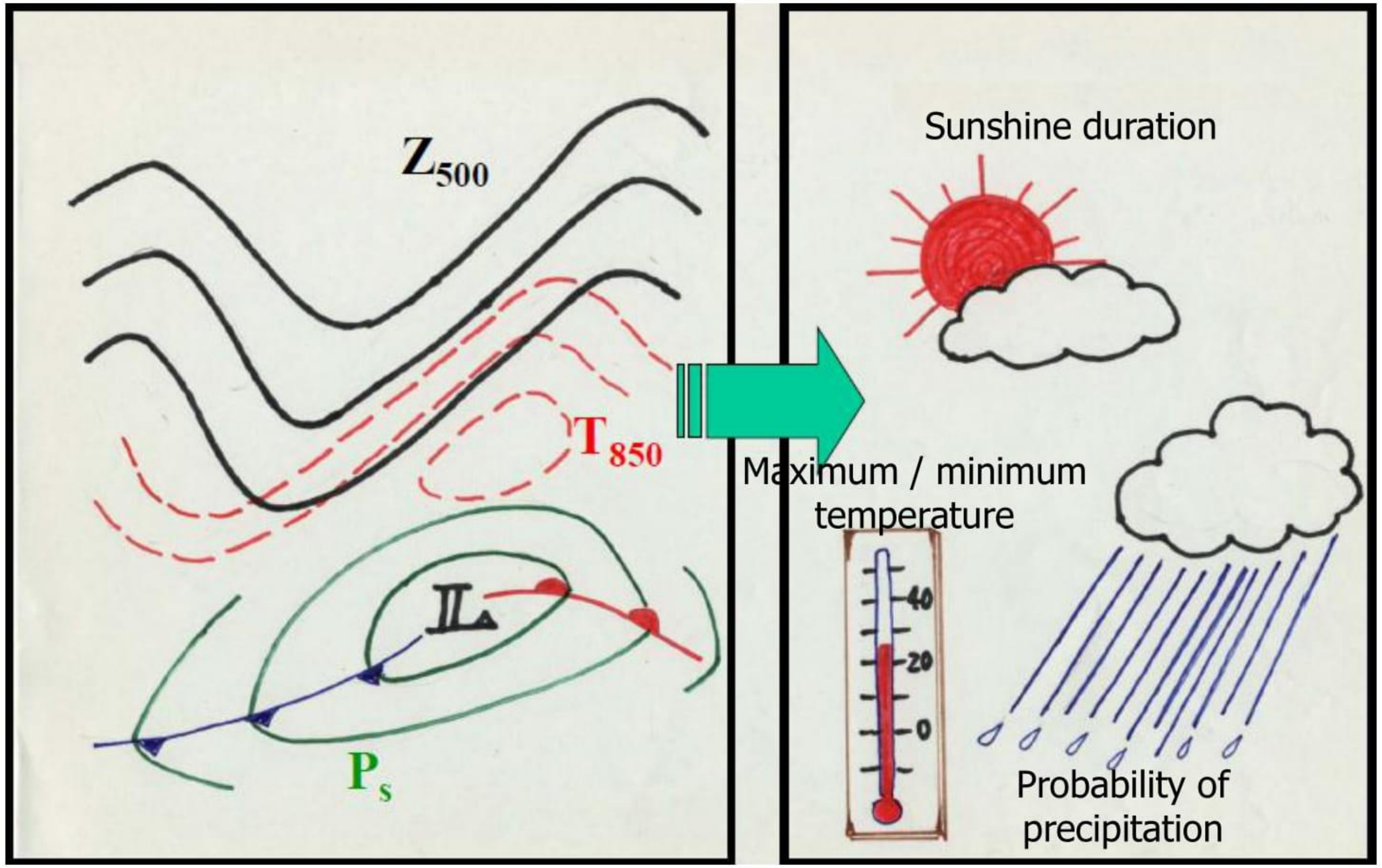
The simple average of ensemble members is **not always** the best estimation of most likely forecast.

Additional information is required to interpret the ensemble forecast.


GUIDANCE

What is guidance?

Guidance can give information which is connected forecast directly



How to make guidance?

- Model Output Statistics (MOS)
  - Relationship between model output and observation is derived by statistics

Y : Prognostic variables

$X_1, X_2, X_3, \ldots$: Model Output

$C_1, C_2, C_3, \ldots$: Coefficient

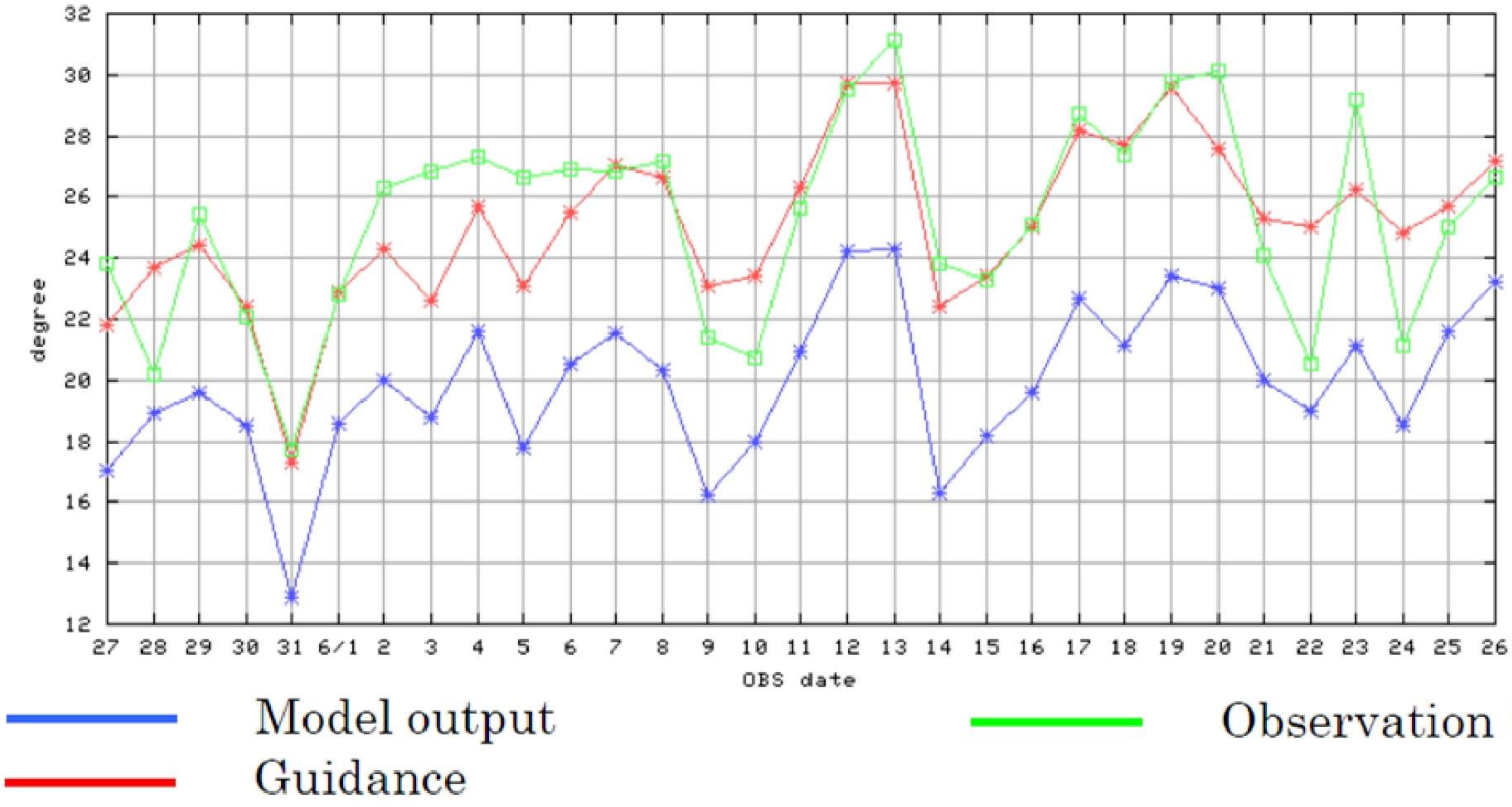
Above coefficients are derived statistics method

multilinear regression, kalman filter, and so on

$$Y = C_0 + C_1X_1 + C_2X_2 + C_3X_3 + \cdots\cdots\cdots + C_nX_n$$

Example of maximum temperature

Guidance can remove bias in the model output



Usefulness of Guidance

- Not "skillful expert forecast" but a base for objective forecast
- Elimination of systematic error of NWP model
- Variables which are not explicitly forecast by NWP model
  - Probability of precipitation
  - Maximum / minimum temperature
  - Probability of heavy precipitation
  - Probability of thunder storm

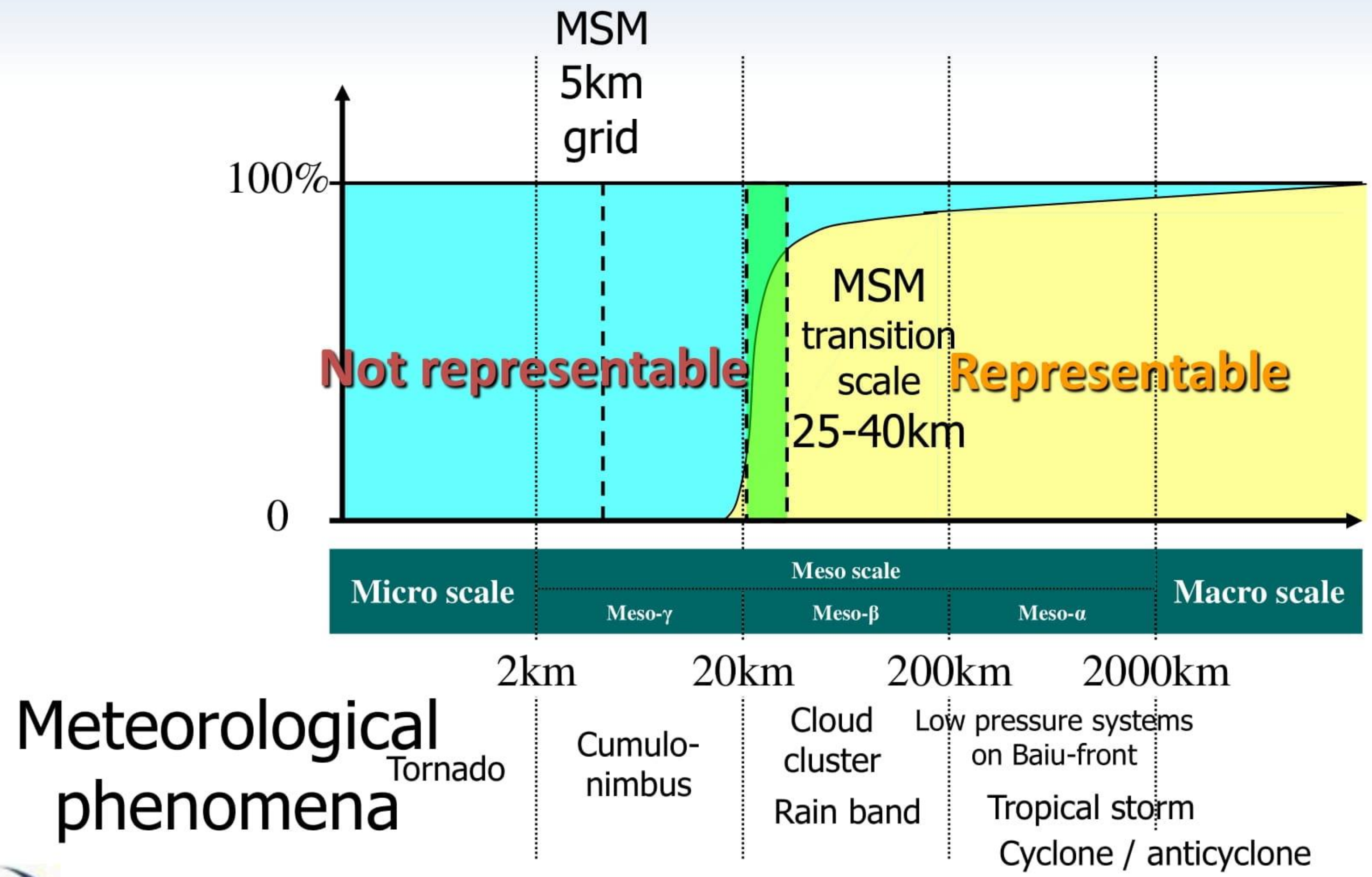
Limitation of guidance

- Low accuracy for not frequent phenomena such as heavy rainfall

- Adaptive correction scheme (ex. Kalman filter) cannot follow an abrupt change in large scale weather situation


HOW TO USE NWP PRODUCTS

Model resolution and representation of atmospheric phenomena



Important point when using NWP

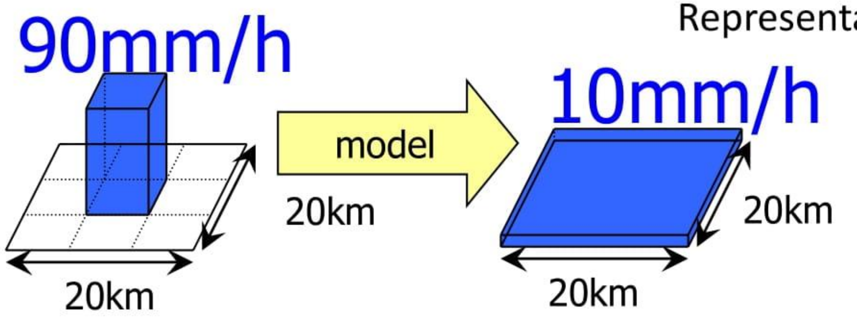
- Do not take NWP product on trust
  - Examine carefully what is reliable and what is not
- Limitation of NWP
  - NWP model can not represent meteorological phenomena completely
    - Uncertainty in initial condition
    - Uncertainty in model
- What is important is to understand limitation of NWP and characteristics of error

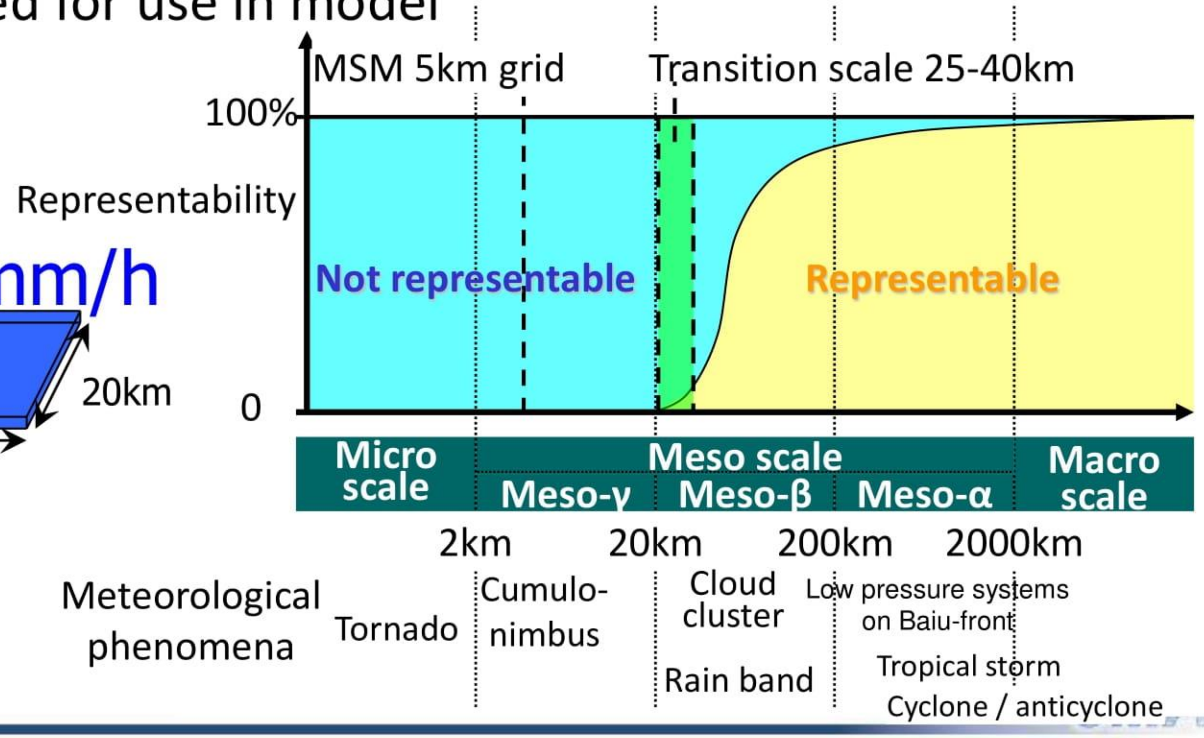
What determines predictability

- Scale of the phenomena is resolvable for the NWP model
- Appropriate set of equations is used and is calculated precisely
- Influential physical processes and boundary conditions are included in the model
- Initial condition captures “seed” of perturbation

Representability from model resolution

- Sub-grid scale processes are not resolved by large scale models
  - Minimum representable scale: grid spacing x 5 - 8
  - Phenomena caused by fine topography or restricted to small area can not be represented
  - Structures of boundary layer and inversion layer are not resolved enough
  - Grid point value corresponds to average value in the grid
  - Topography is smoothed for use in model



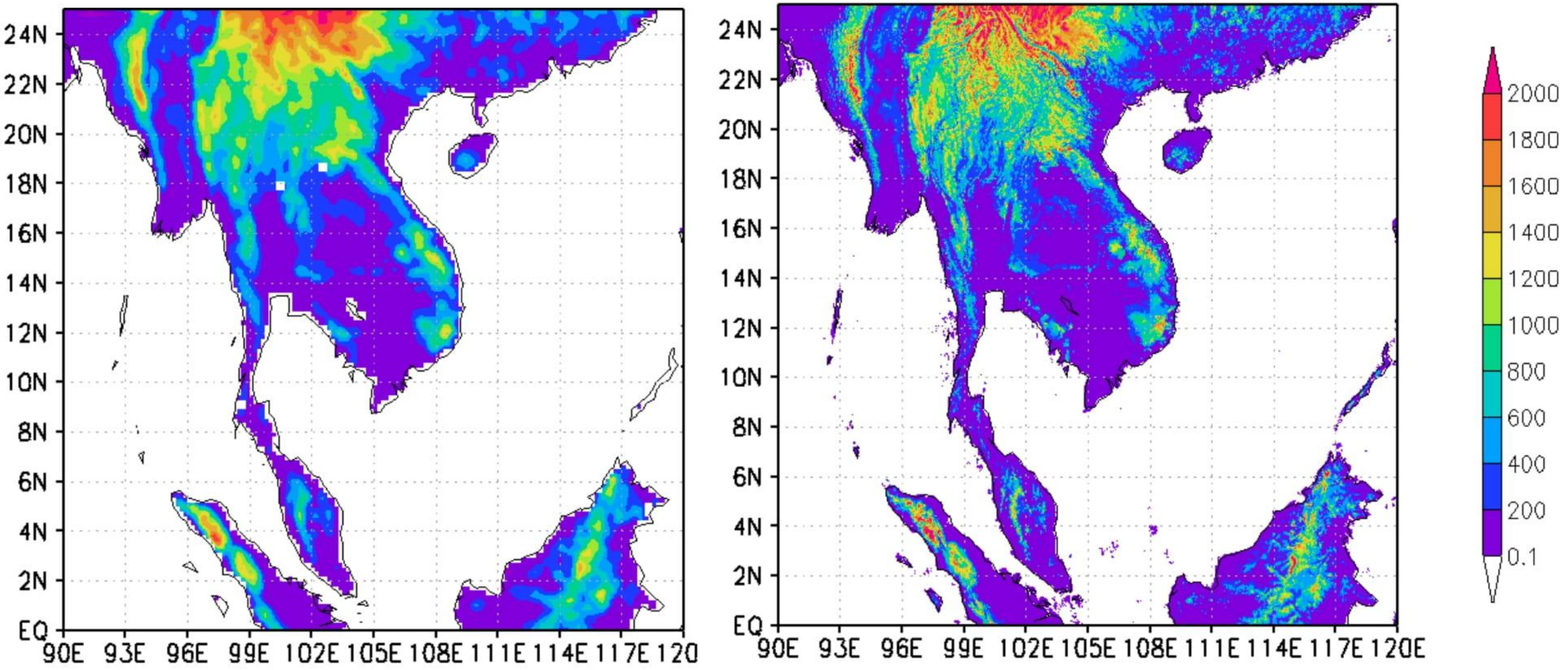


Uncertainties in physical processes

- Parameterization schemes representing effect of sub-grid scale process express only part of the process
  - Limitation of computational resources (ex. conversion from cloud water to rain, from cloud ice to snow)
  - Limitation of understanding of physical process (ex. formation of ice crystal)
  - Simplification of process due to its complexity (ex. cloud and wavelength dependency in radiation scheme, turbulence, convection)

Model topography and real topography

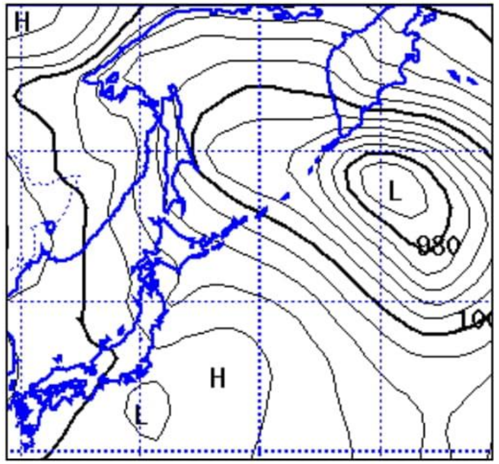
Model topography may be different from real topography. It's necessary to pay attention to the forecast for the phenomena which is highly affected by topography.



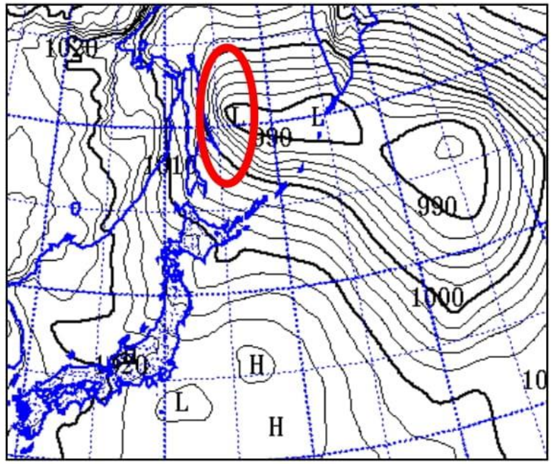
Model (～20 km) Original (GTOPO30, ～1 km)

Uncertainties in initial condition

- Observation
  - Observed value includes various errors
  - Irregular distribution in space and time
    - Less reliability for perturbation in sparse observation area
- First guess
  - Reliability depends on previous forecast



Global Analysis



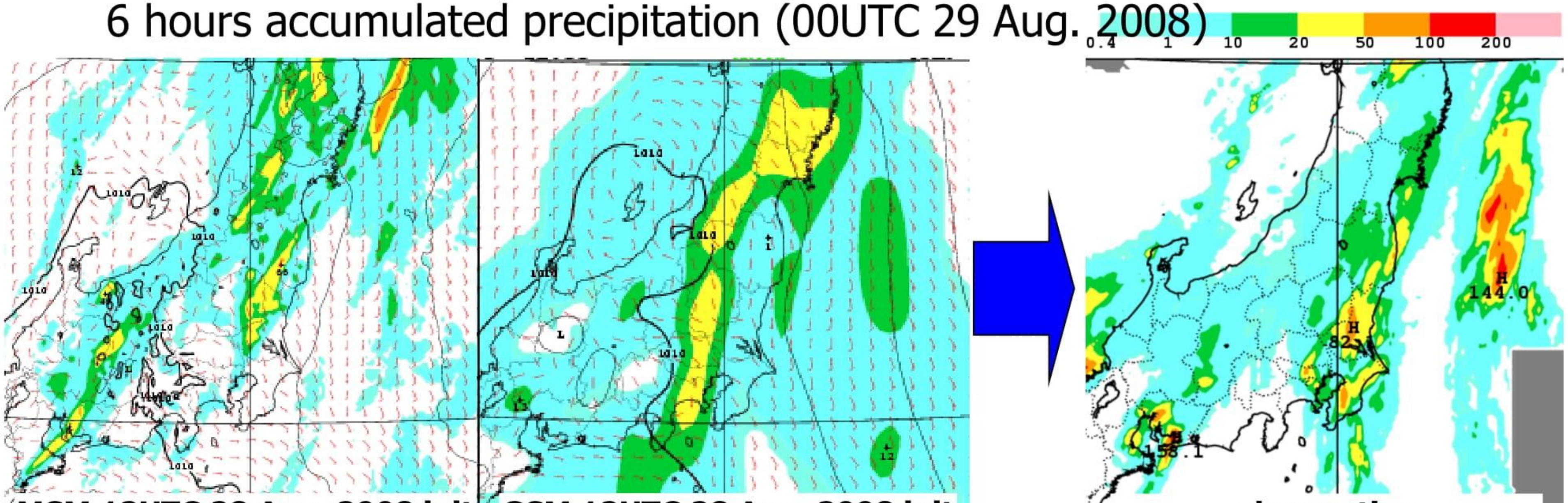
Regional Analysis

False cyclone calculated by Regional Model at the Sea of Okhotsk resulted in bad analysis in the Regional Analysis

Position error and time error

- It is not appropriate to be bound by forecast at certain point / area / time
  - Pay attention to surrounding area
  - Consider position error and time error

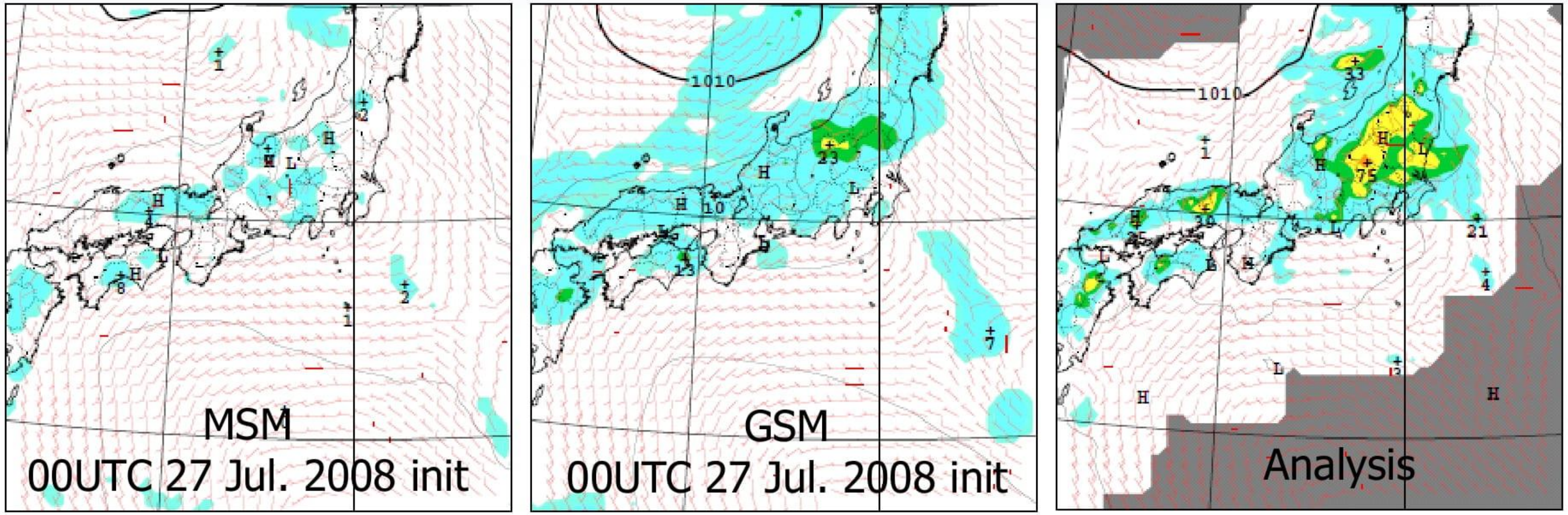
6 hours accumulated precipitation (00UTC 29 Aug. 2008)



MSM 12UTC 28 Aug. 2008 init | GSM 12UTC 28 Aug. 2008 init | observation

Model tendency

6 hours accumulated precipitation (12UTC 27 Jul. 2008)



MSM tends to underpredict convective precipitation

GSM tends to predict too weak convective precipitation over too wide area

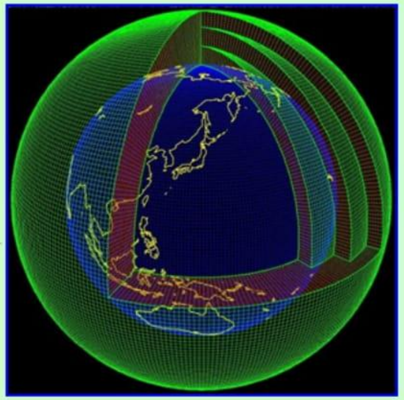
It is important to estimate possibility of convective precipitation from indications such as CAPE, not only from predicted precipitation.


END

“Outline” is Here

http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/nwp-top.htm

Numerical Weather Prediction of JMA



- Introduction
- Specifications of Analysis Models
- Specifications of Forecast Models
- Verification
- The Major Upgrade of NWP Models on November 21, 2007

Numerical Weather Prediction (NWP) at Japan Meteorological Agency (JMA)

JMA started the operation of numerical weather prediction in June 1959. Since then, Performance of NWP models have been advanced thanks to the progress in earth sciences, information technologies such as dramatically increased computer resources and efficient telecommunication systems, and improved observing systems, especially meteorological and earth-observing satellite systems.

JMA currently operates several NWP models to cover various types of forecasts, such as very-short-range prediction of meso-scale disturbances and short-/medium-range prediction of synoptic-scale disturbances. In addition, JMA utilizes ensemble prediction systems and/or a coupled ocean-atmosphere model for the other forecasts including one-week/one-month/seasonal prediction and El-Nino forecasts.

JMA introduced the meso-scale model with higher horizontal resolution, and increased the number of its daily run (operation) in March 2006. As the resolution of the global model was consequentially improved, one-week EPS using the global model products was also improved in November 2007. JMA plans to introduce the EPS for typhoon forecasts within a few years.

Data assimilation systems for NWP are based on the four-dimensional variational (4D-Var) method. The 4D-Var system for the meso-scale analysis and the global analysis were introduced in March 2002 and February 2005, respectively.

In August 2011, to provide our regional analysis and short-term forecast based on the global model, JMA started operation as DCPC (Data Collection or Production Centre) of WMO Information System.

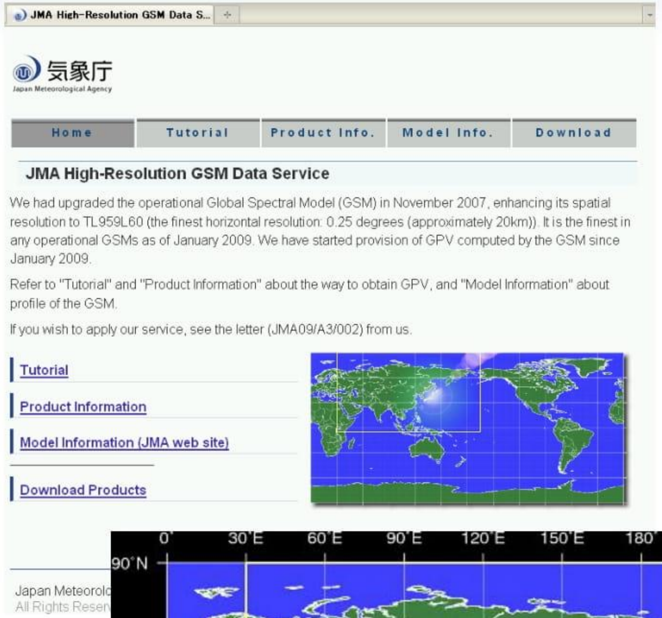
Reference

- "Outline of the Operational Forecast and Analysis System of the Japan Meteorological Agency (March 2006)"
- "Outline of the Operational Numerical Weather Prediction at the Japan Meteorological Agency (March 2007)"

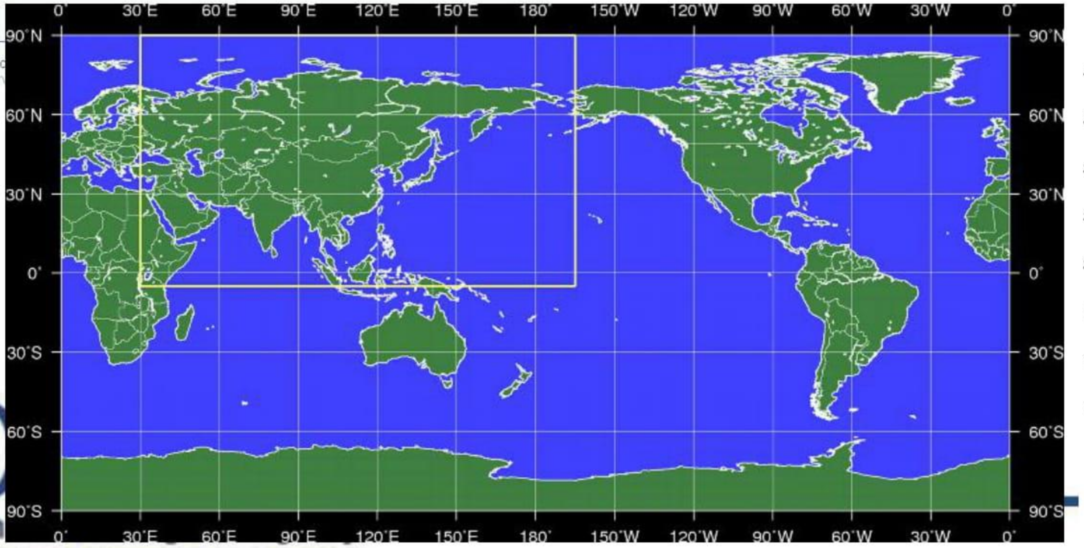
Last update: August 1,2011

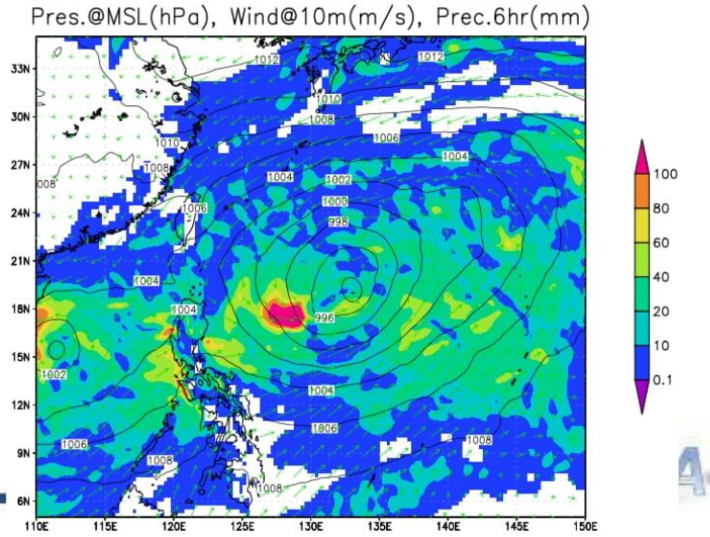
The Latest Version will be updated in Mar, 2013.
Coming Soon…

JMA High-Resolution GSM Data Service



- Established in Jan. 2009
- Target: NMHSs
  - Mainly in WMO Region II
- Model: GSM(TL959)
- Data Format: GRIB2
- Preservation Term: Latest 7 days





Profile (WMO Region II)

	Upper Air	Surface	
Resolution	0.5deg (331 x 191)		0.25deg (661 x 381)
Region	Lon: 30E – 180 – 165W, Lat: 5S – 90N		
Initial Time	00, 06, 12, 18 UTC (4 times per day)		
Forecast Time	00 to 84 hours by 3 hours (any initials) 90 to 216 hours by 6 hours (12UTC initial only)		
Levels	21 (1000, 975, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10 hPa) * Separated 21 files by levels	1 (surface)	
Elements	U, V, T, Rh, Z, Omg Stream Function, Velocity Potential (at 850, 250 hPa) Vorticity (at 500 hPa)	U, V, T, Rh, Ps, Psea, Rain, Cloudiness (total, high, middle, low)	
File size (gzip compressed)	500 – 700KB	800KB	3MB

Understanding of NWP limitation

- NWP has become an indispensable tool for the forecaster, but it is important to understand its limitations. There are many sources of possible error in an NWP forecast. If you keep these sources in mind as you examine NWP products, you should be able to make more intelligent use of the products in your forecasts.
  - By Dr. Frederick Carr, University of Oklahoma
- This is the reason why we need to learn the basic introductions of NWP.