New operational high resolution regional mesoscale model at JMA

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JMA's New supercomputer system

- The **supercomputer system at JMA** was upgraded in June 2012, and now in operation.

	Mar. 2006- Jun. 2012	Jun. 2012 –
	HITACHI SR11000 	HITACHI SR16000/M1 
Total Peak Performance	27.584TFlops (134.4GFlops/1node)	847TFlops (980.5GFlops/1node)
Total number of nodes	210 nodes (16CPU/1node)	864 nodes (32CPU/1node)
Memory	64GB/node	128GB/node
Memory Bandwidth	134.4GB/s/1node	612GB/s/1node
Network Bandwidth	8GB/s (one-way)	96GB/s (one-way)
System configuration	80nodes x 2 + 50nodes x 1	432nodes x 2

7.3-times up

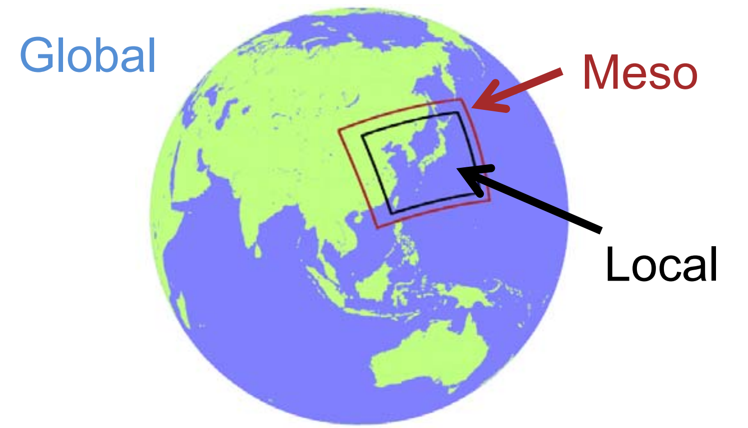
4.6-times up

12-times up

Local NWP system

- Taking advantage of the powerful performance of the new supercomputer system, a high resolution convection-permitting regional NWP system (**Local NWP system**) has been operated since August 2012.
- **The purpose** is providing information on aviation weather and disaster prevention.

NWP systems at NPD/JMA (deterministic) *NEW*

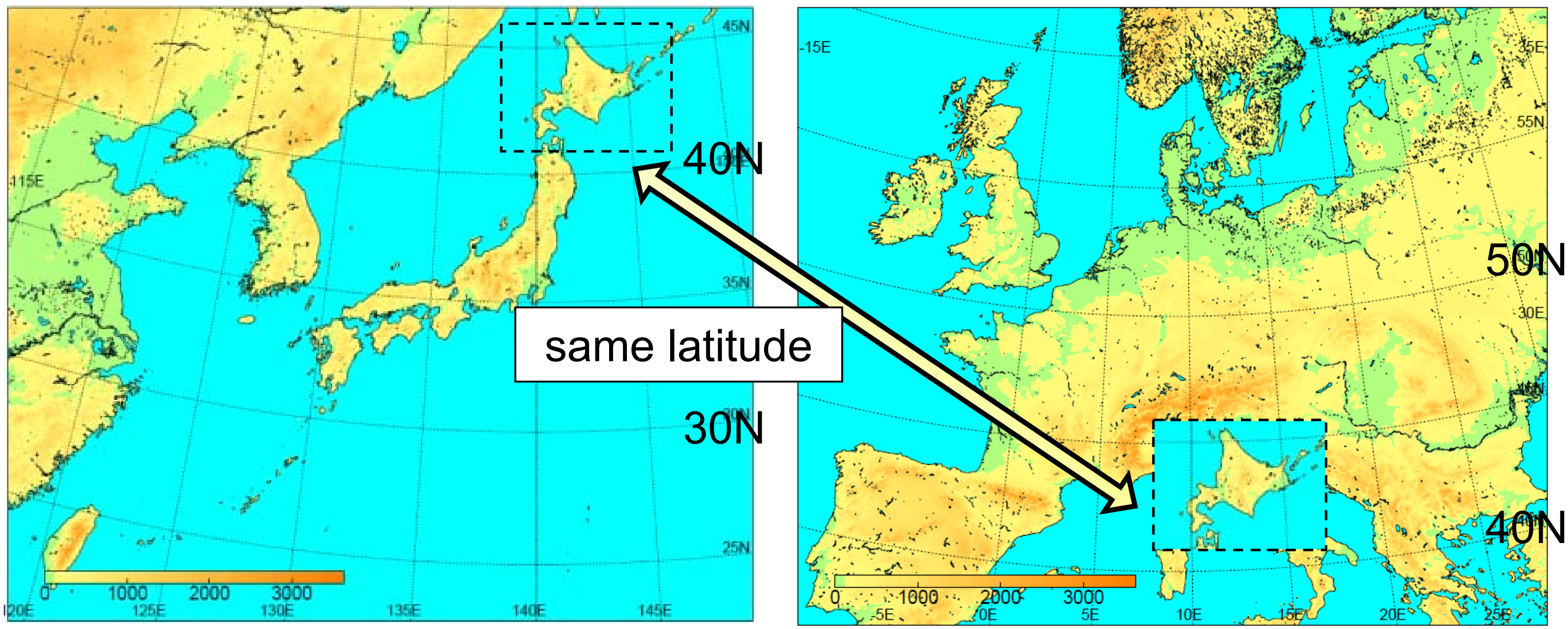
	Global	Meso	Local (plan)
Objectives	**Short- and Medium-range forecast**	**Disaster reduction Short-range forecast**	**Aviation forecast Disaster prevention**
NWP model	**Global Spectral Model(GSM)**	**Meso-Scale Model(MSM)**	**Local Forecast Model (LFM)**
Horizontal resolution	**TL959 (0.1875 deg)**	**5 km (817x611)**	**2 km (1581x1301)**
Vertical levels / Top	**60 0.1 hPa**	**50 21.8 km**	**60 20.2 km**
Forecast Hours (Initial time)	**84 hours (00, 06, 18 UTC) 264 hours (12 UTC)**	**39 hours (every 3 hours)**	**9 hours (every hour)**
Initial Condition	**Global Analysis (4D-Var)**	**Meso-scale Analysis (4D-Var)**	**Local Analysis (3D-Var)**
Forecast Domain			

Japan Meteorological Agency 気象庁

Domain of the Local NWP system

1581x1301 with 2km grids.

operational domain (plan) A region of the same size (for reference)

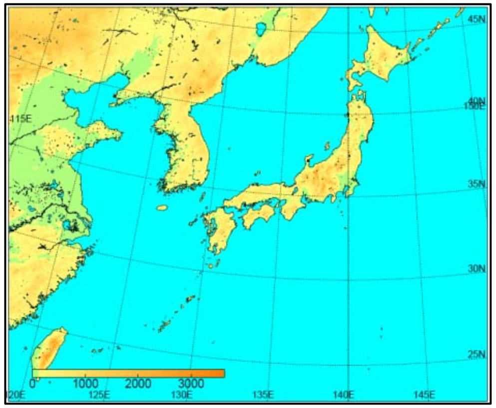


topography in the forecast model

Basic design of the Local NWP system

- The **Local NWP system** provides 9-hour period forecasts every hour.
- In the system design, high resolution to permit explicit convection and frequent updates of forecasts assimilating the latest observation are highly emphasized.

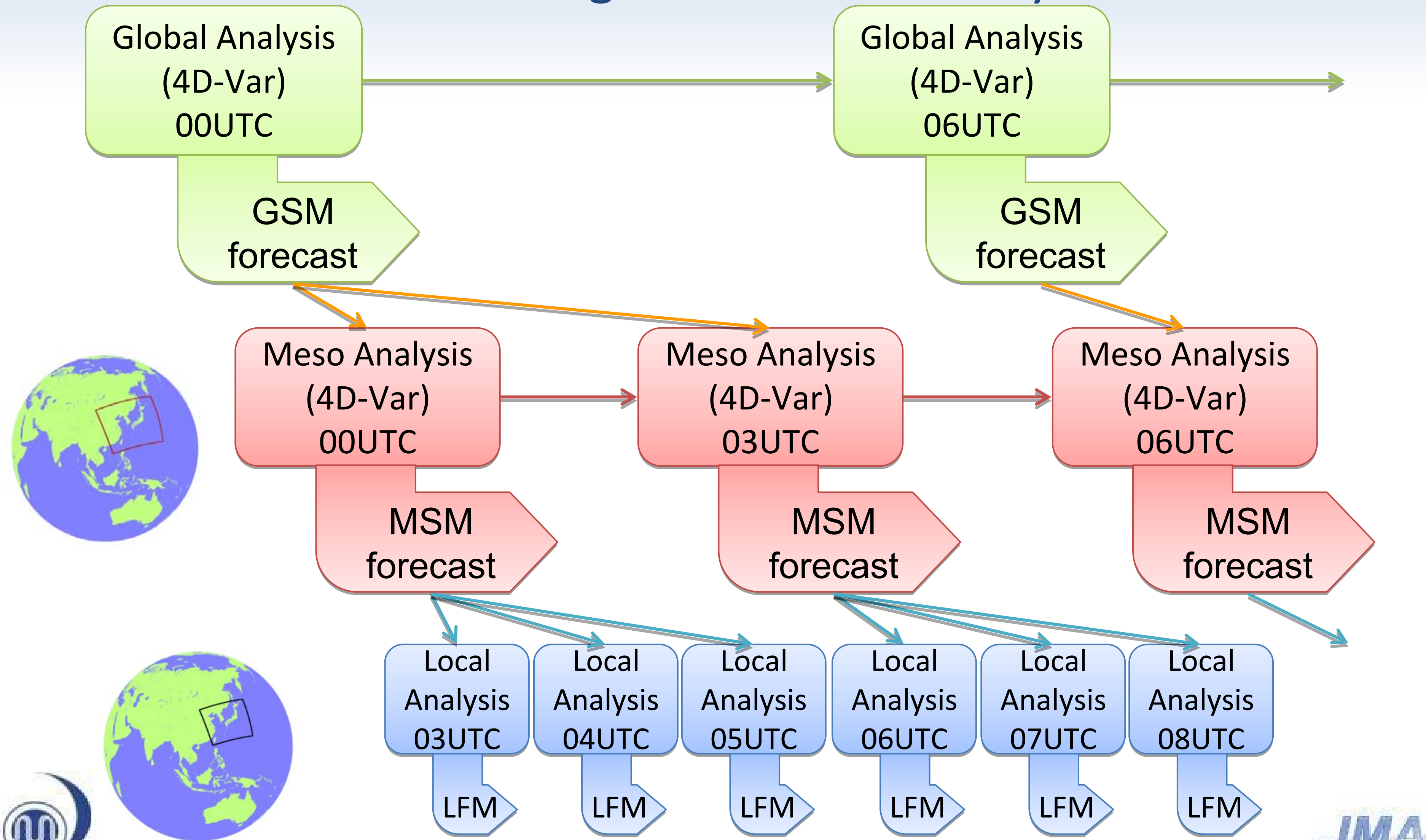
Forecast:1581x1301 (2km grids)
Analysis:633x522 (5km grids)



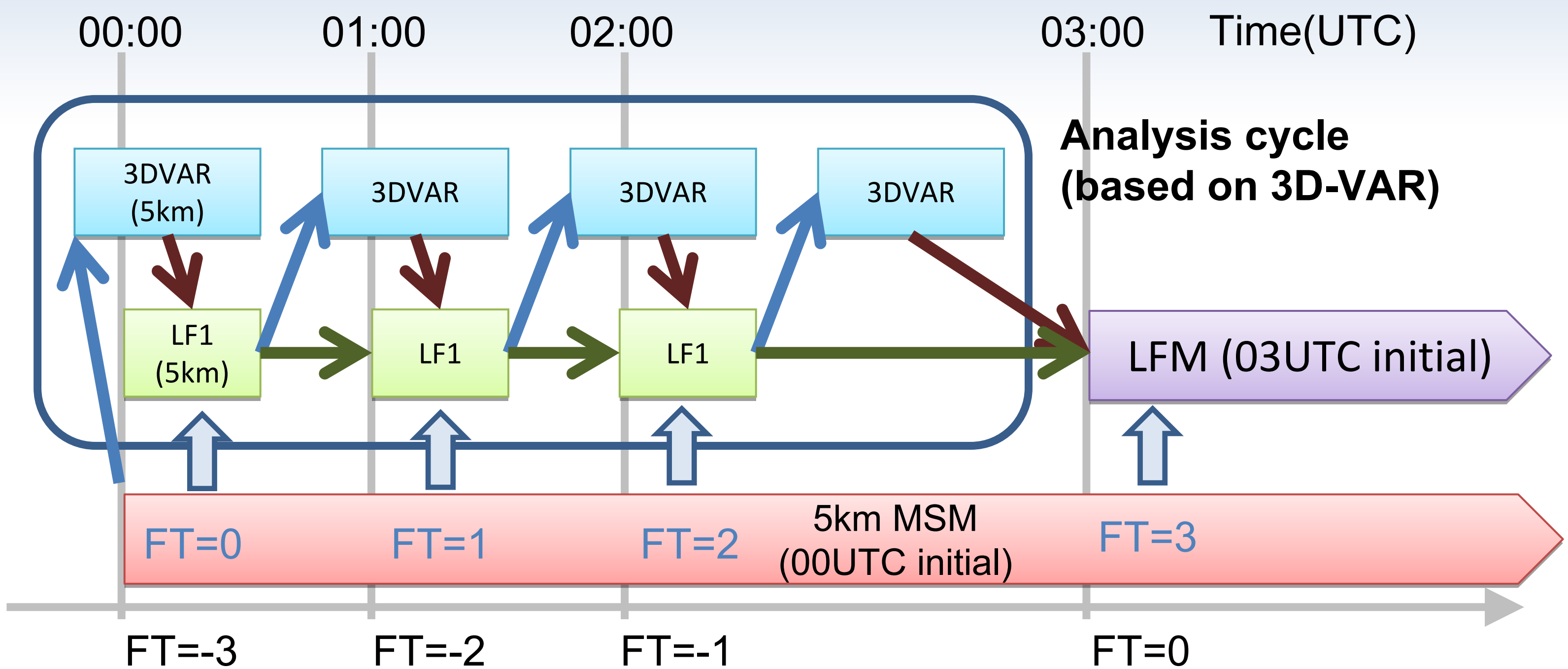
- The Local NWP system consists of two subsystems
  - **NWP model**: The **Local Forecast Model (LFM)** has a 2-km horizontal gridspacing and 60 vertical layers.
  - **Data assimilation system**: The **Local Analysis (LA)** employs an analysis cycle based on the three dimensional variational data assimilation (3D-Var) at a 5-km resolution.

Local Analysis:

The first guess and boundary



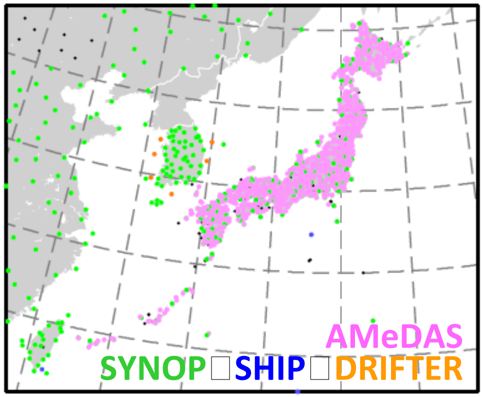
Local Analysis: based on 3D-Var



- Firstly, the first guess of the 3D-VAR at FT=-3 (3 hours before the initial time) comes from forecasts of MSM (5km operational mesoscale model).
- After the analysis at FT=-3 is obtained by assimilating observations around FT=-3,1-hour integration from the analysis is conducted to generate the first guess of the next 3D-VAR at FT=-2.
- The cycle is repeated, then the final analysis is produced by the final 3D-VAR using the first guess obtained from 1-hour forecasts initialized at FT= -1 and observations around FT= 0 (the initial time).

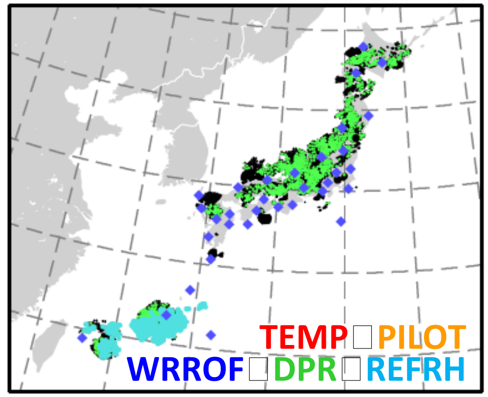
Local Analysis: Assimilated observations

CONVENTIONAL SURF



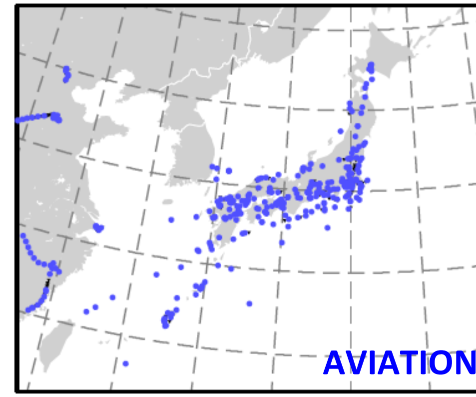
AMeDAS[●]: 896 SYNOP[●]: 290 METAR[●]: 0 SHIP[●]: 3 DRIFTER[●]: 6
NOUSE[●]: 28 NOUSE[●]: 10 NOUSE[●]: 353 NOUSE[●]: 15 NOUSE[●]: 2
ALL: 924 ALL: 300 ALL: 353 ALL: 18 ALL: 8

CONVENTIONAL UPPER



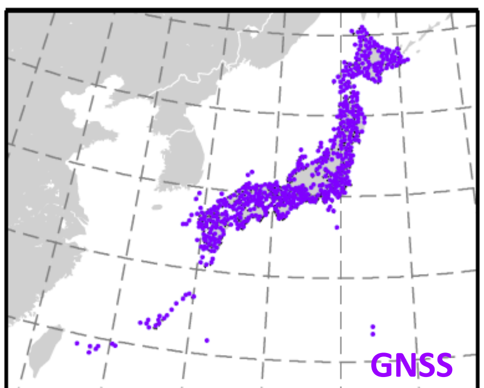
TEMP[●]: 0 PILOT[●]: 0 WPROF[◆]: 33 DPR[●]: 2924 REFRH[●]: 1701
NOUSE[●]: 0 NOUSE[●]: 0 NOUSE[●]: 70 NOUSE[●]: 36267 NOUSE[●]: 0
ALL: 0 ALL: 0 ALL: 103 ALL: 39191 ALL: 1701

CONVENTIONAL OTHERS



AVIATION[●]: 302
NOUSE[▼]: 560
ALL: 862

GPS−PW



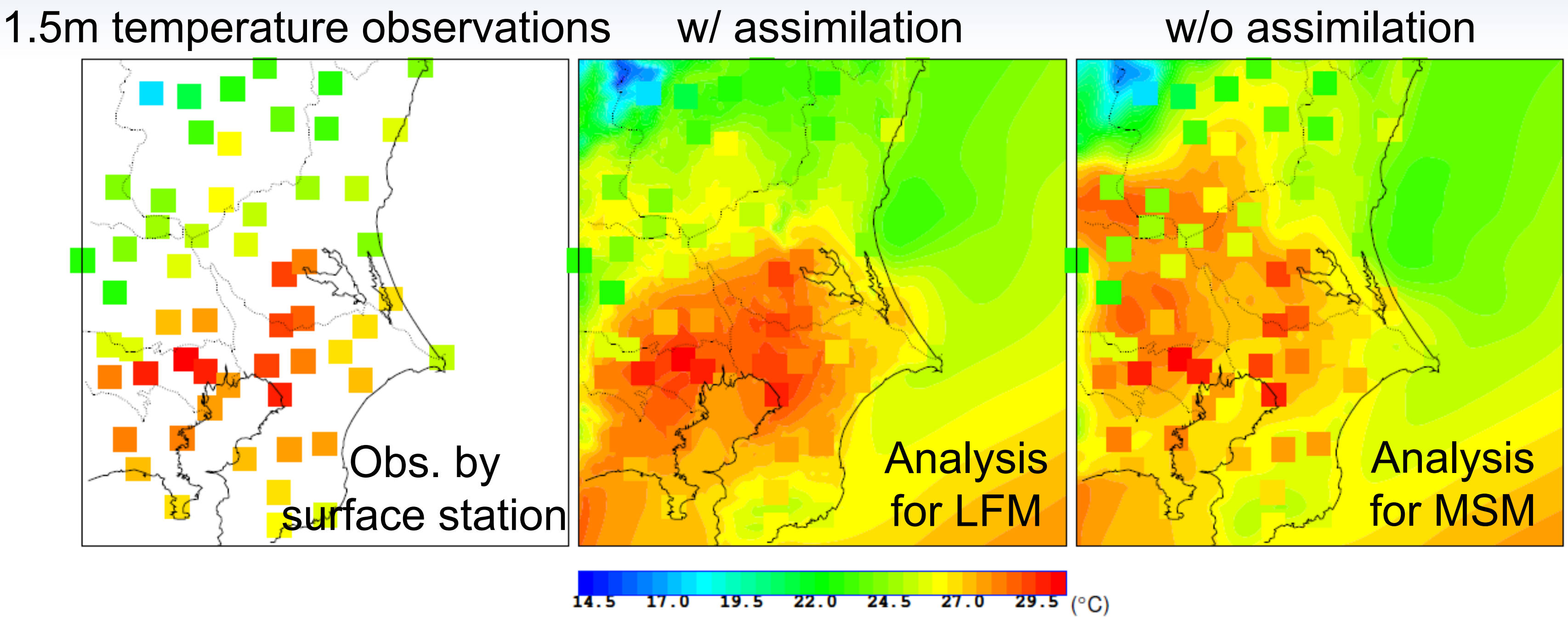
GPS[●]: 544
NOUSE[▼]: 479
ALL: 1023

Observation types	Parameters used in the analysis
SYNOP	pressure
TEMP	wind, temperature, pressure, humidity
Aircrafts	wind and temperature
Wind profilers	wind
Ground-based GNSS receivers	precipitable water vapor
Radars	radial velocity Rh retrieved from reflectivity
Surface observational stations (not SYNOP, placed all over Japan)	1.5-m temperature 10-m wind velocity

LA only

Local Analysis:

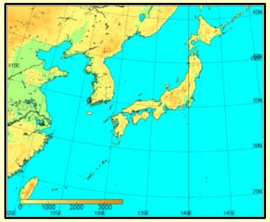
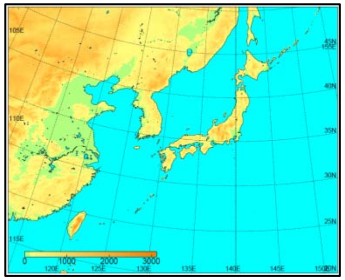
Effects by assimilating observations near the surface



- Features of observed temperature are well represented by an analysis field for the LFM assimilating the surface observations.
- More realistic representations in the lower layer could give considerable impacts to forecast of severe phenomena because temperature and winds at the lower layer are important to generate unstably stratified layers and initiate convection.

Model specification of LFM

- LFM employs the JMA-NHM as its NWP model.
  - The same model package as 5-km operational mesoscale model (MSM).
- **No convective parameterizations**
  - It is expected to represent convective transport by the grid mean vertically velocity, avoiding uncertainty coming from the parameterization.
- Some modifications have been made in physical processes which depend on scales
  - Made a PDF to diagnose cloud fraction narrower because inhomogeneity is smaller as the grid-spacing is smaller.

	LFM (plan)	**MSM**
Horizontal Resolution/ Forecast Domain	2km (1581x1301) 	5km (817x661) 
Vertical Layers	60 Layers, up to 20km	50 Layers, up to 22km
Integration Time Step	8 seconds	20 seconds
Initial Condition	3D-Var analysis cycle	4D-Var
Boundary Condition	MSM	GSM
Forecast hours	9 hours	39 hours
Cloud Physics	Qc, Qr, Qi, Qs, Qg	Qc, Qr, Qi, Qs, Qg and Ni
Cumulus convective paramete-rization	Not Used	Kain-Fritsch scheme

Advantages of LFM

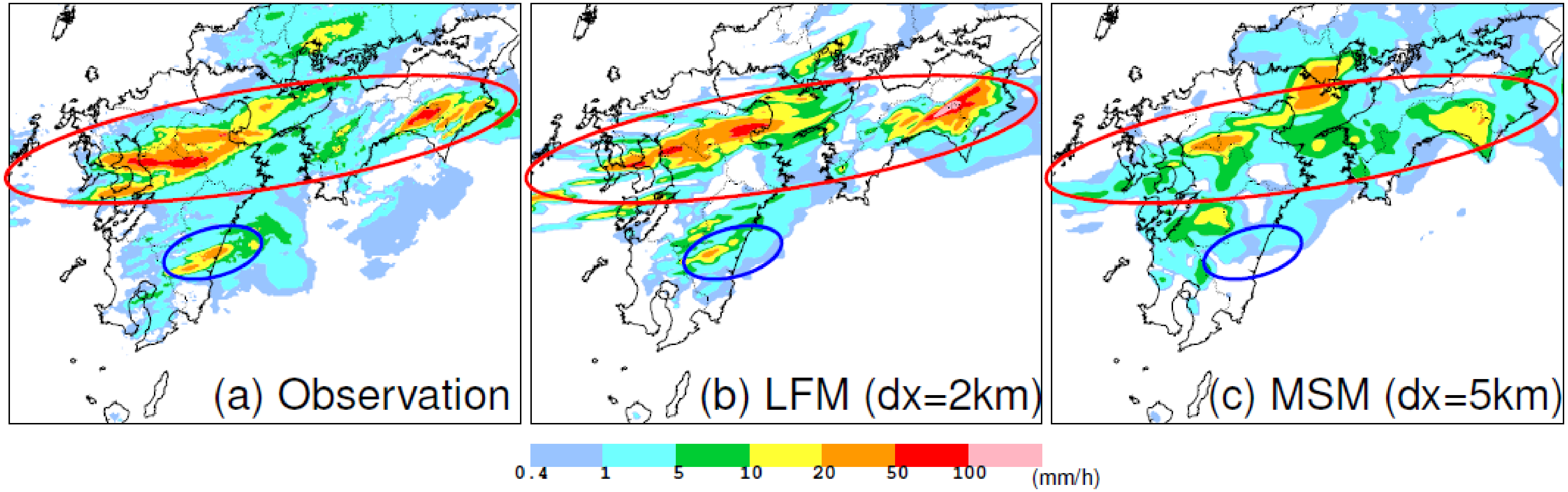
no need to rely on convective parametarization

- It is expected to represent convective transport explicitly by the grid-mean vertical velocity.
  - But it is not clear if all of transport can be resolved by the grid-mean values. Partly resolved? : related to Grey Zone.
- One of the origins of model uncertainty.

Advantages of LFM

accurately predict peak amount of precipitation

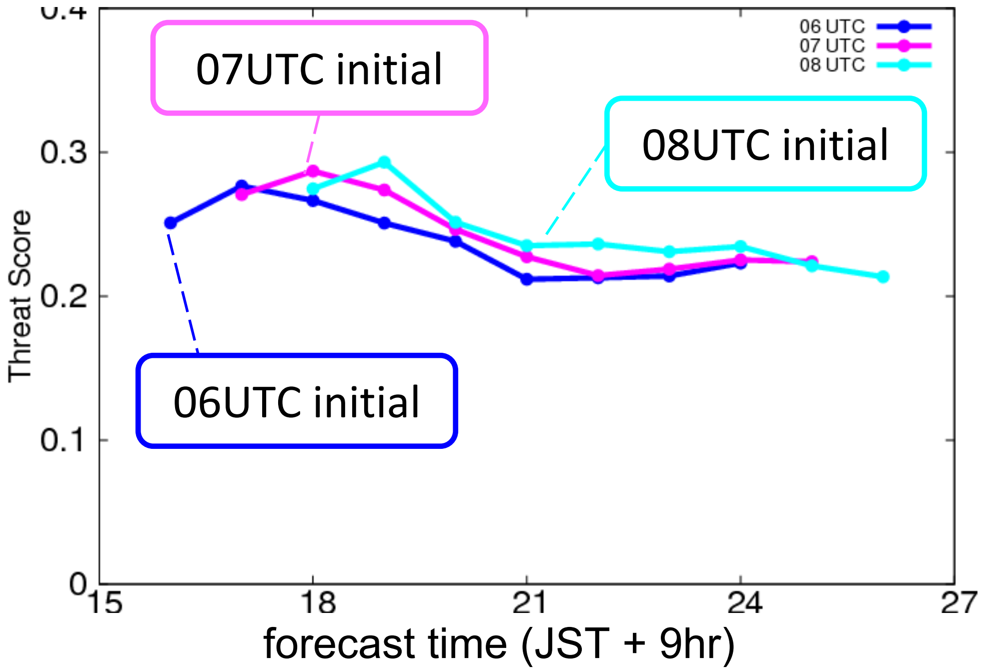
1-hour accumulated precipitation amounts until 1700UTC on July 11 2012



- The **LFM** produced the line-shaped precipitation and the peak strength of the precipitation is well predicted.
- While the **MSM** predicted the position of the front correctly, the line-shaped precipitation area was not generated enough and the peak value of the precipitation is much smaller than the corresponding observation.
- As long as the boundary conditions (i.e. the MSM forecasts in the system), which considerably control synoptic fields in the LFM, give reliable fields, the **LFM** has considerable potential to reproduce peak values more precisely.

Advantages of LFM
frequent updates of forecasts

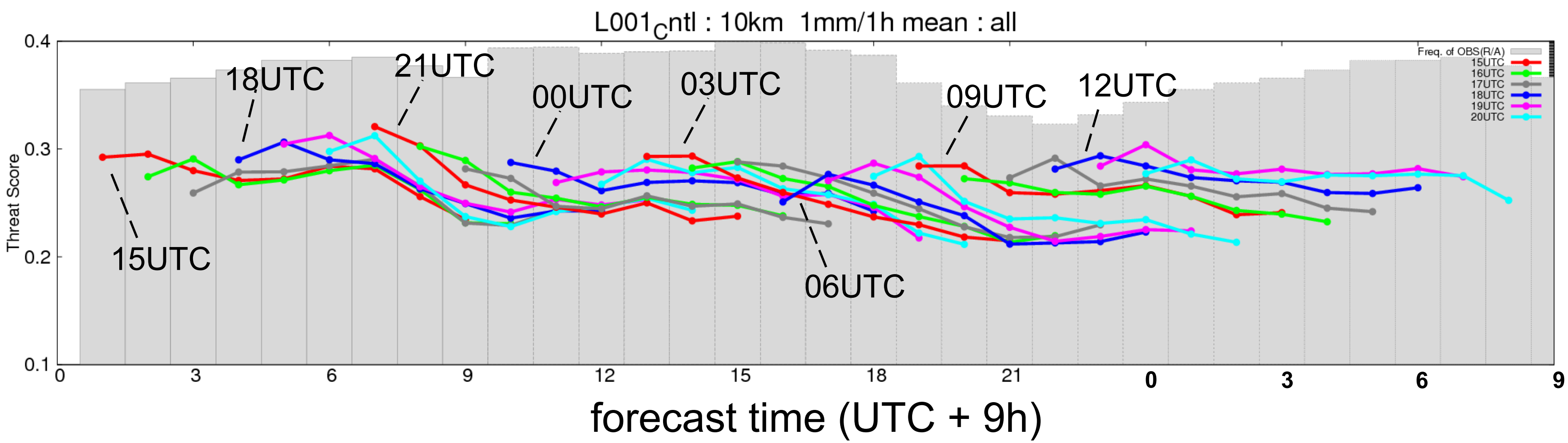
Time Series of Threat Score > 1mm/h, 10km verification grids



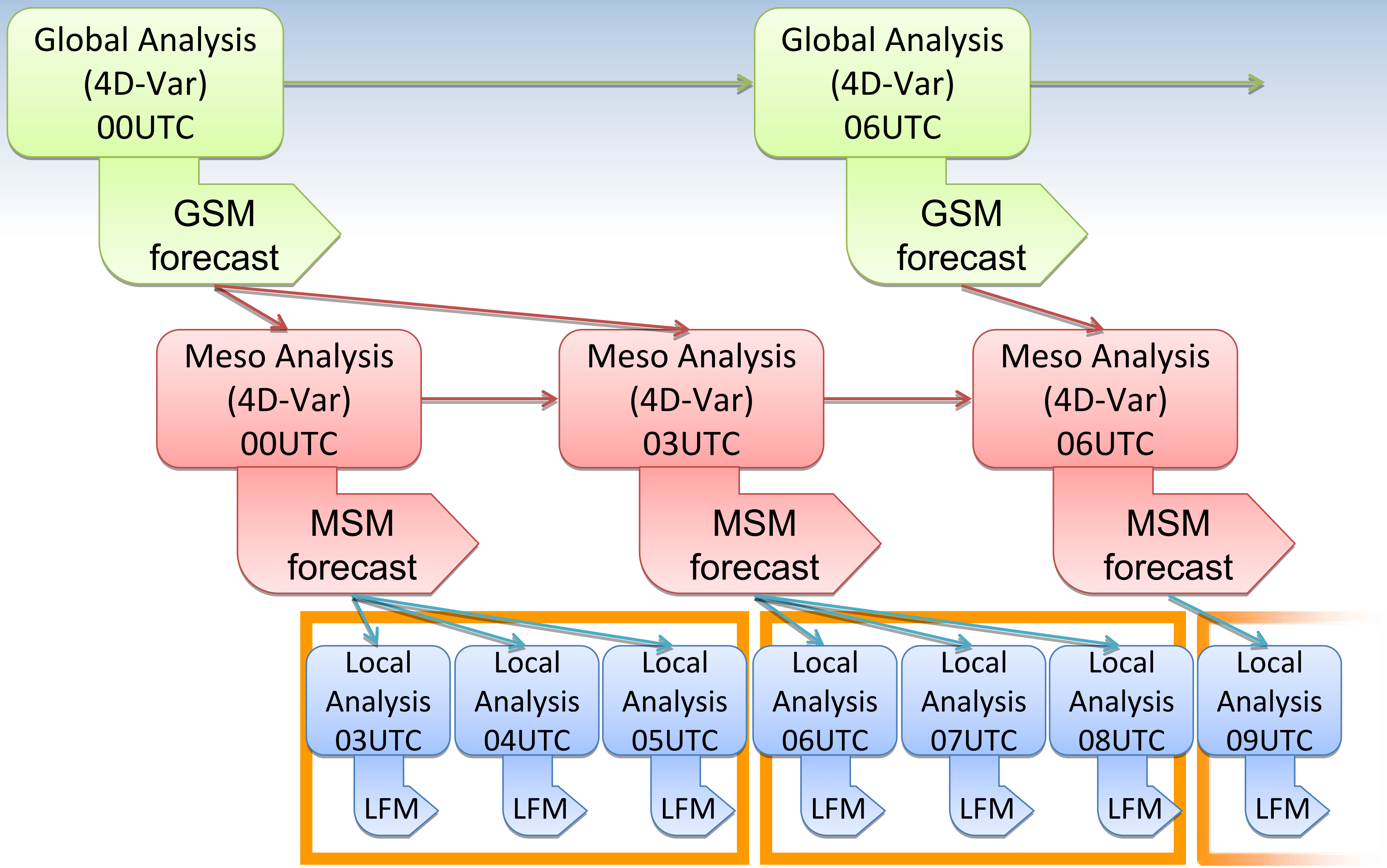
- The latest forecasts are better than older one (except 1 hour forecast), as we aimed at.
- Assimilating the latest observations gains the performance.

Advantages of LFM
frequent updates of forecasts

Time Series of Threat Score > 1mm/h, 10km verification grids



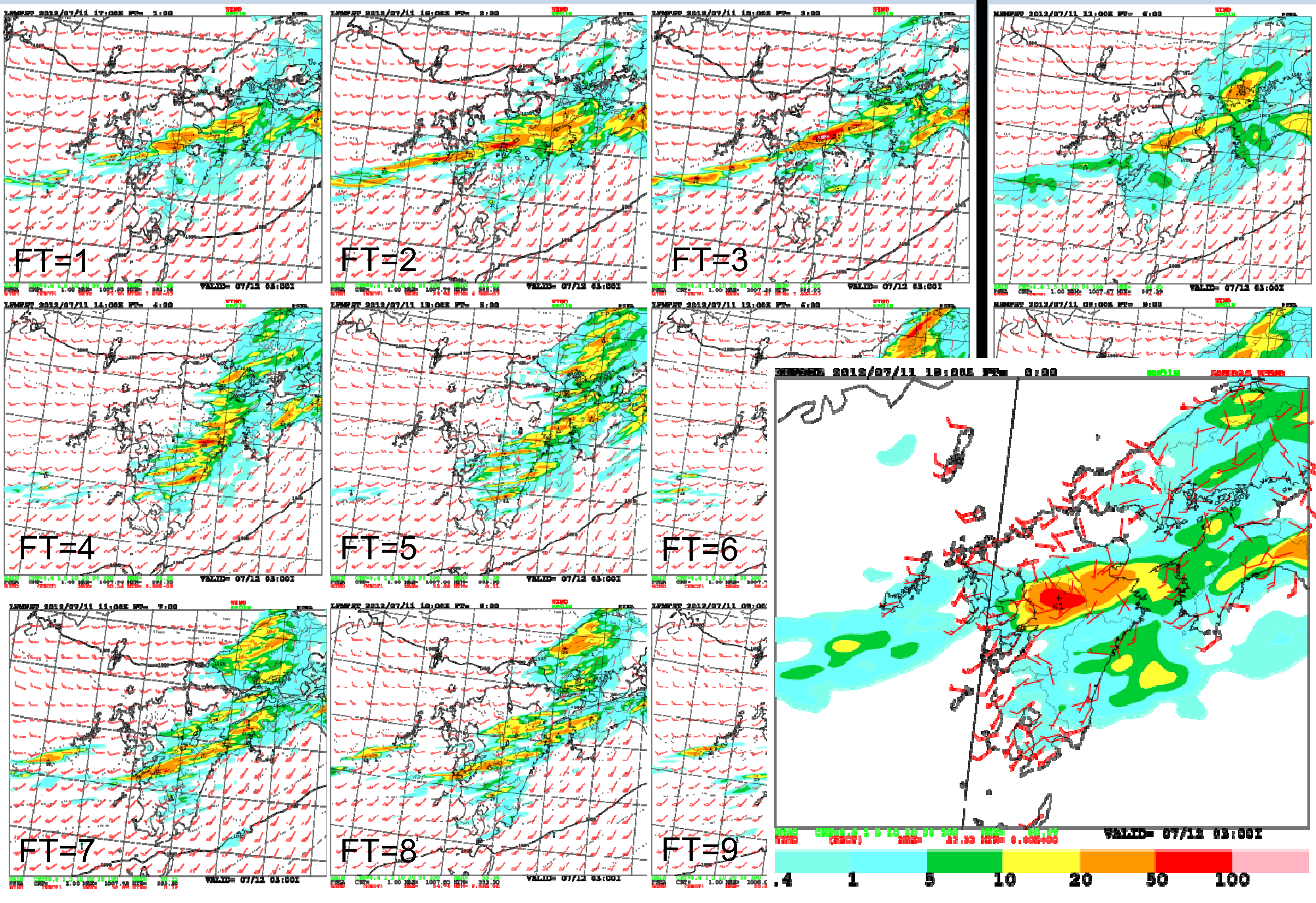
- Forecasts using the same MSM forecasts as the initial guess for the Local analysis behaves similarly each other.
- Considerable part of the LFM accuracy is determined by the MSM performance through the first guess and boundary conditions.



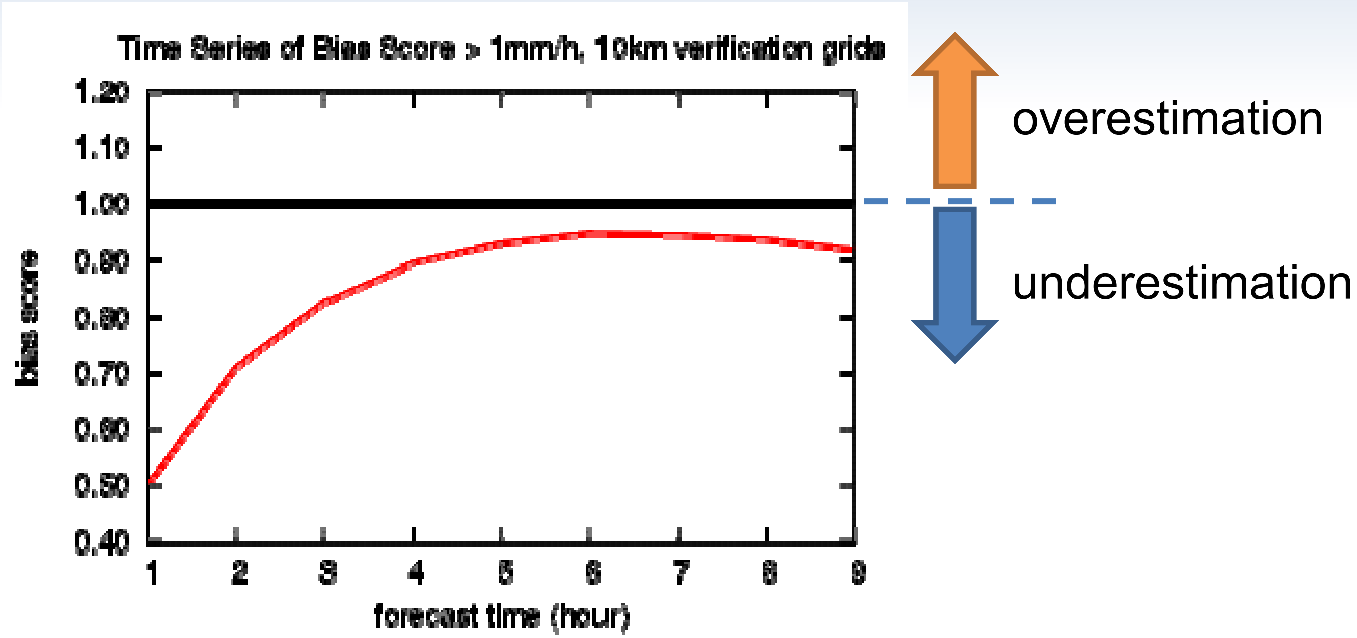
LFM forecasts whose first guess is predicted by the same MSM behaves similarly.

LFM Forecast for 7/11 18UTC by different initial time

MSM forecast



Spin Up problem

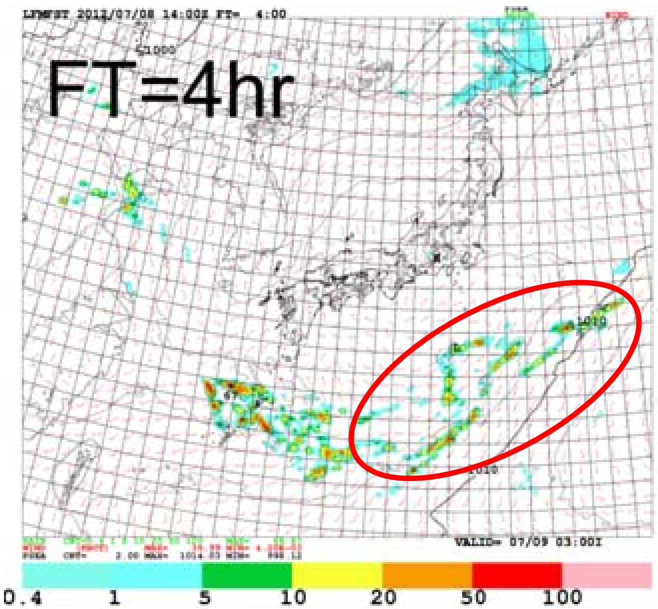


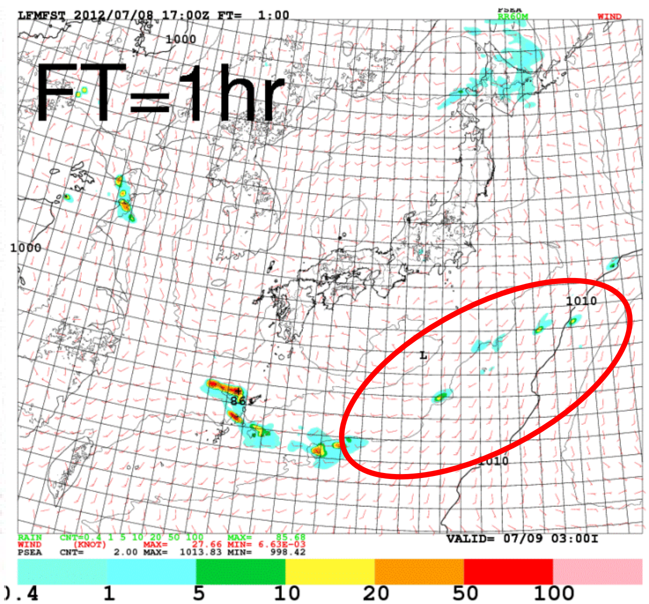
- Clear underestimate of precipitation during the first 3-4 hours.
- It might be related to converting resolution when the model received the initial conditions from the analysis system.
- It needs further investigation to resolve the problem.

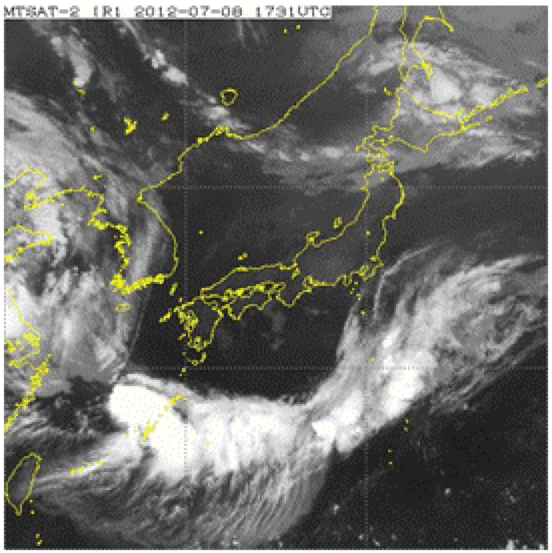
Spin Up problem

LFM forecasts started from different initial time

infrated images（MTSAT）

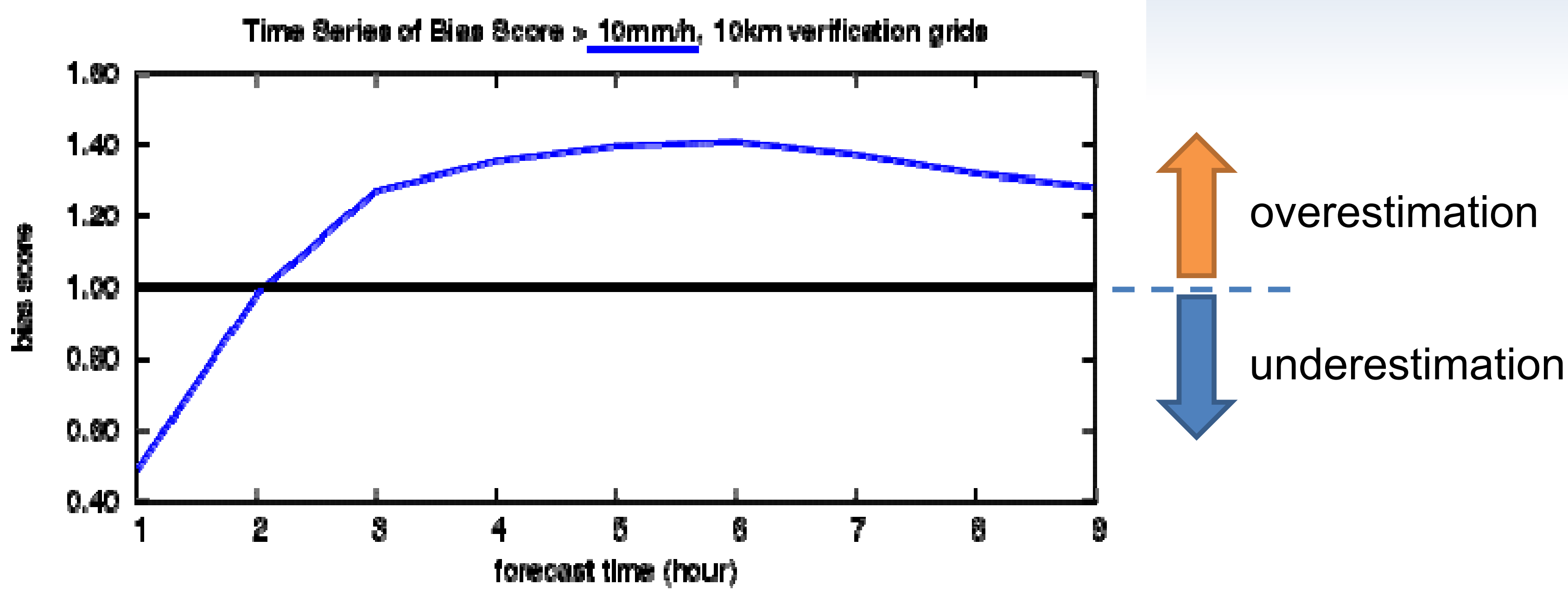






- Too small precipitation in first few hours.(especially in FT=1.)

Initiation of convection / Grid point storm



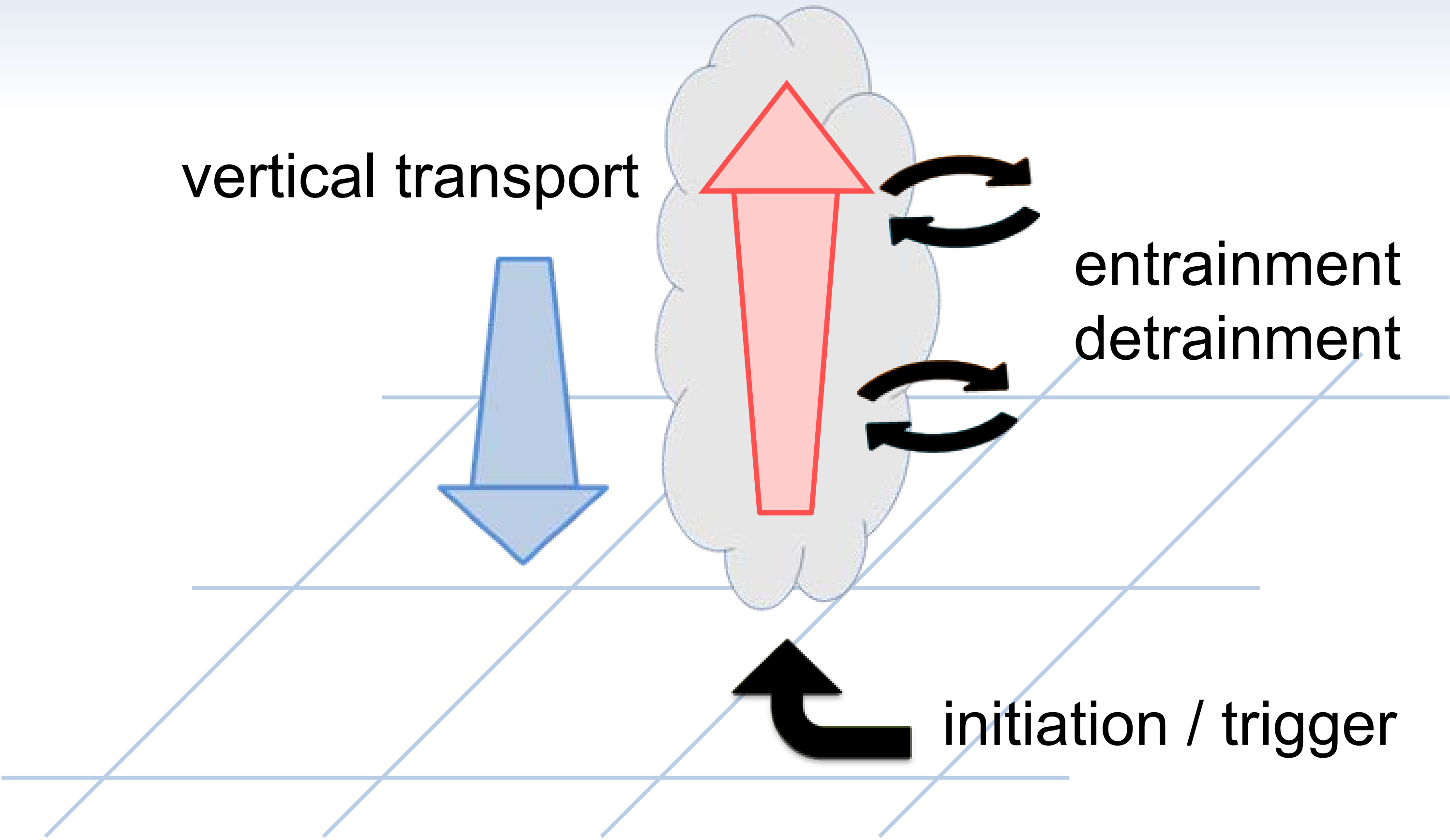
• The underestimate of precipitation in the first 1 hour is common to small precipitation.

• Heavy precipitation is overestimated especially in the middle period.(This corresponds to grid point storm.)

• Smaller convection than 10km is not resolved even in 2km horizontal resolution.

•We should somehow deal with them.

processes in a convection



Although the vertical transport is explicitly represented in the LFM, the entrainment/detrainment and the initiation of convection are not necessary resolved. We need to deal with them.

Summary

- The JMA launched the new operational NWP system (**Local NWP system**) at a convection-permitting resolution.
  - The latest observations are quickly assimilated and forecasts are updated frequently.
  - Some physical processes were modified from the coarser operational model considering their dependency on the resolutions.
  - The LFM shows its potential to predict peak values of precipitation more appropriately.

- There are some problems to resolve.
  - Spin up problem
    - Too small precipitation in the first few hours.(It comes from the difference of the resolution between analysis and forecast.)
  - Initiation of convection / Grid point storm
    - All of convective transport is not resolved.
    - Processes to initiate convection smaller than the resolution, and the entrainment/detrainment of the convection should be parameterized.