Development of a high resolution Local Forecast Model

Numerical Prediction Division

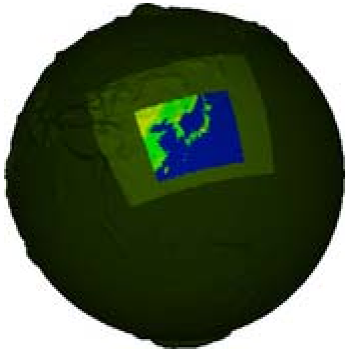
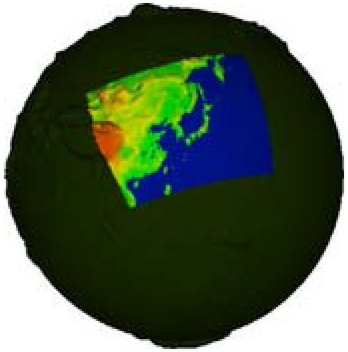
Japan Meteorological Agency

Kohei Aranami, Kensuke Takenouchi, Hiroshi Nakayama,

Tadashi Fujita, Haruka Kurahashi, Yoshihiro Ishikawa

NWP models at JMA

Model	Grid spacing	Target	Forecast time	Forecast frequency
MSM (Meso Scale Model)	**5km**	**Disaster prevention TAF**	**15/33 hours**	**8 times a day**
RSM (Regional Spectral Model)	20km	**1-2 day forecast**	**51 hours**	**Twice a day**
GSM (Global Spectral Model)	60km	**1-2 day forecast Weekly forecast**	36/84/216 hours	**4 times a day**

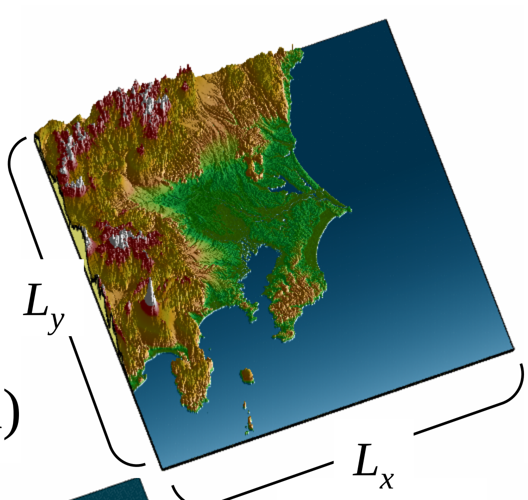

Motivation of the development of the Local Forecast Model (LFM)

- Characteristics of specifications compared with MSM
  - Increase of horizontal resolution from 5km to 2km
  - Increase of vertical layers from 50 to 60
  - Increase of forecast frequency from 3 hourly to hourly
  - Removal (or reduction of the effect) of cumulus parameterization
- Improvement of the forecast of localized phenomena
  - Topography induced phenomena
  - Localized heavy precipitation
  - Detailed low level forecast
    - Aerodrome forecast
  - Potential forecast for disaster prevention
    - Tornado
    - Gust

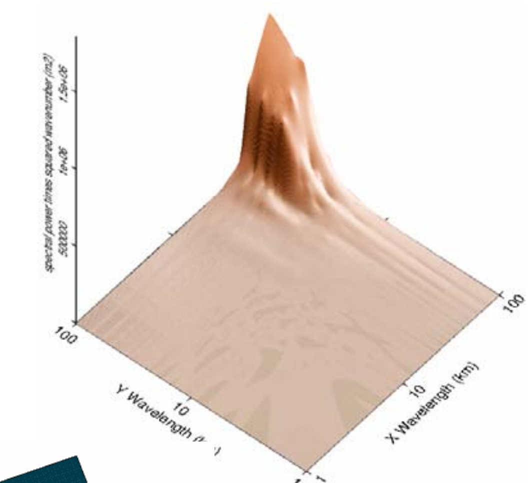
Evaluation of the resolution of model topography (1)

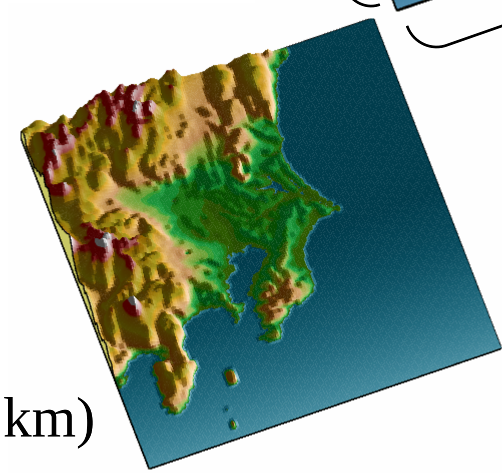
Evaluation of the scale of topography in the wave number scale

Fourier expansion of the topography data, normalizing by the number of grids

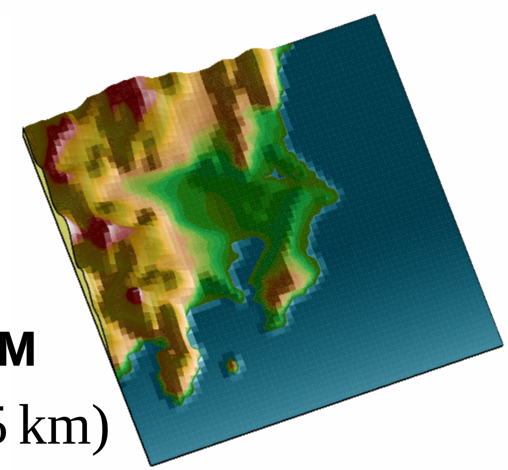


Original data
($\delta x = 250$ m)





LFM
($\Delta x = 2$ km)



MSM
($\Delta x = 5$ km)

Salvador 1999

Evaluation of the resolution of model topography (2)

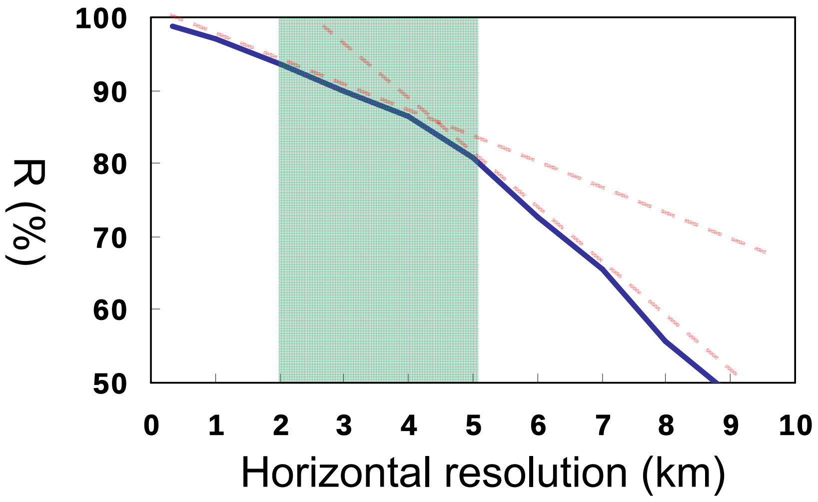
k_x k_y : wave number in x and y direction
E : energy included between k_1 ~ k_2

$$E(k_1,k_2)=\int_{k_1}^{k_2}\int_{k_1}^{k_2}S(k_x,k_y)dk_x dk_y$$

- Shortest wave length resolved by the model : 4Δx
- Energy of the topography resolved by model : Integral of 1/L_x ~ 1/ 4Δx
- Energy of the original topography : Integral of 1/L_x ~ 1/2δx

R : Ratio of the model topography energy to the original topography energy

$$R=\frac{\int_{1/L_x}^{1/(4\Delta x)}\int_{1/L_y}^{1/(4\Delta y)}S(k_x,k_y)dk_x dk_y}{\int_{1/L_x}^{1/(2\delta x)}\int_{1/L_y}^{1/(2\delta y)}S(k_x,k_y)dk_x dk_y}$$

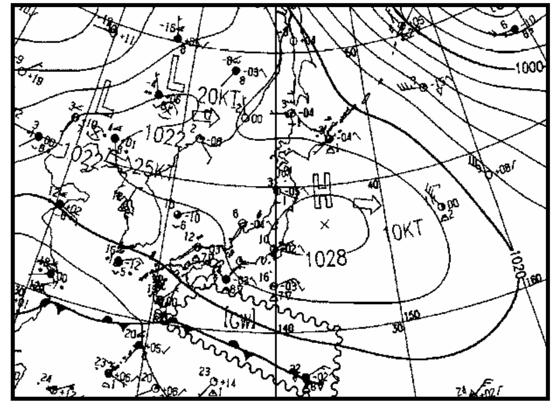


- An inflection point between 4 km and 5 km
- 5km : 80 %, 2km : 95 %

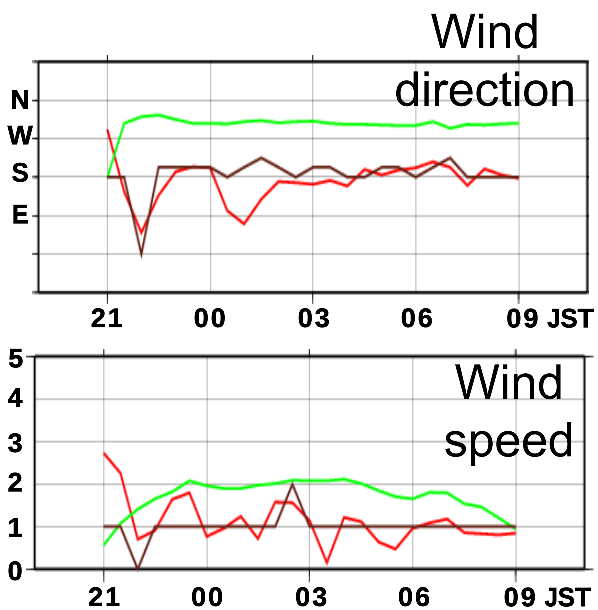
Moderate wind by slope wind circulation

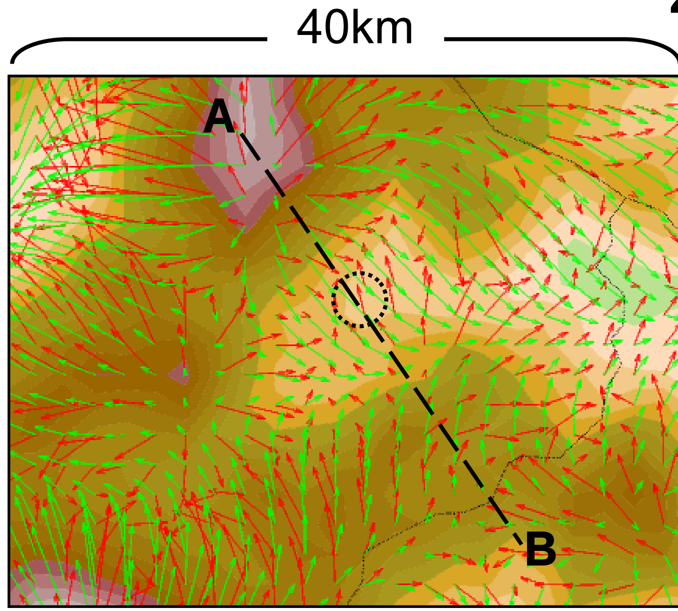
LFM : Moderate southerly wind by slope wind circulation

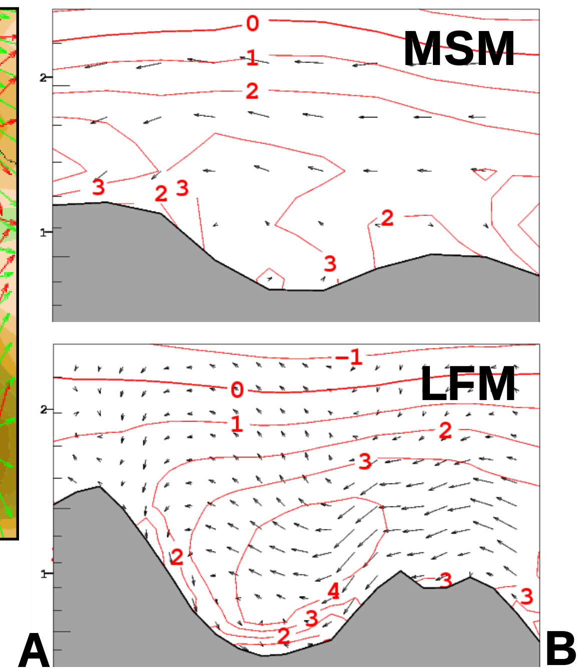
MSM : North westerly wind because of the insufficiency of the valley structure



21 JST 25 Nov. 2006



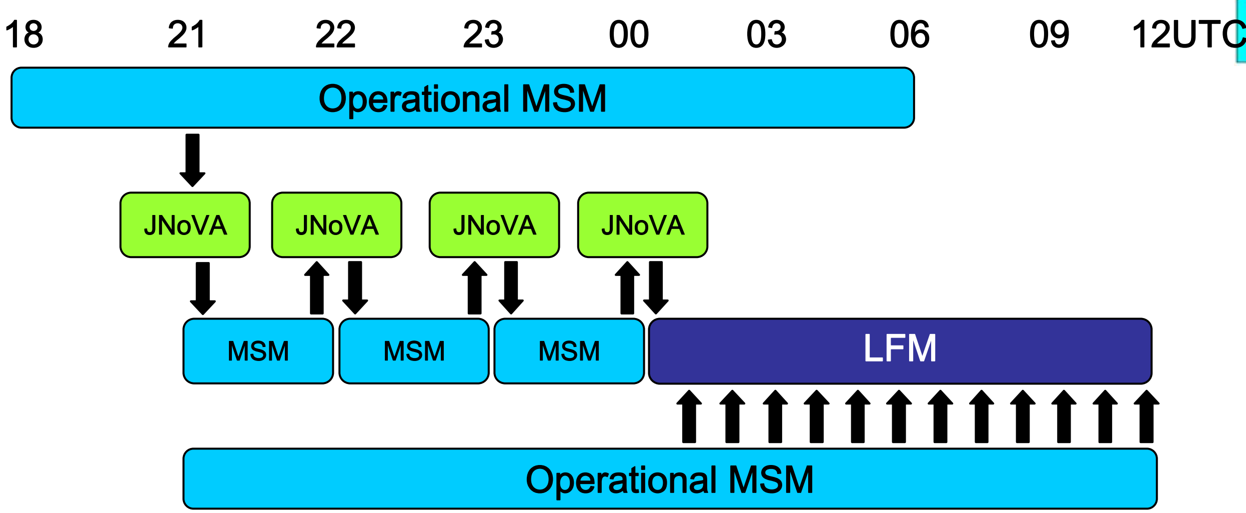




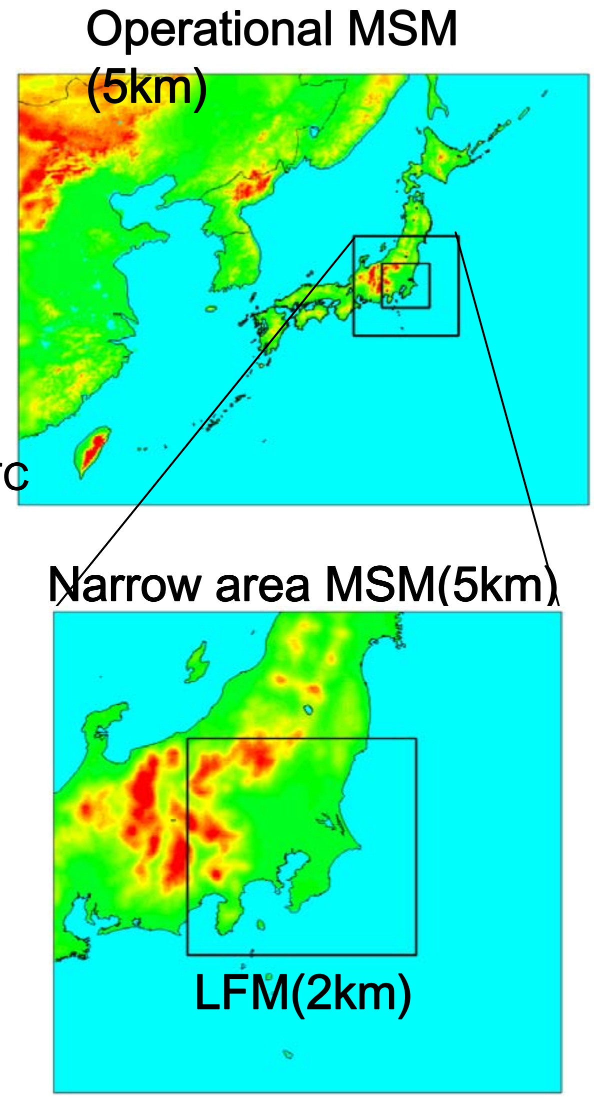
– Obs (Ootsuki point) - LFM - MSM

Analysis forecast system of the daily experiment to evaluate the performance of LFM

- Horizontal resolution : 2km
- Area size : 151 x 151 x L60
- 12 hour forecast, 8 times a day
- Data assimilation using a 3DVAR system (JNoVA-3DVar)
- Since 1 Jun. 200 7

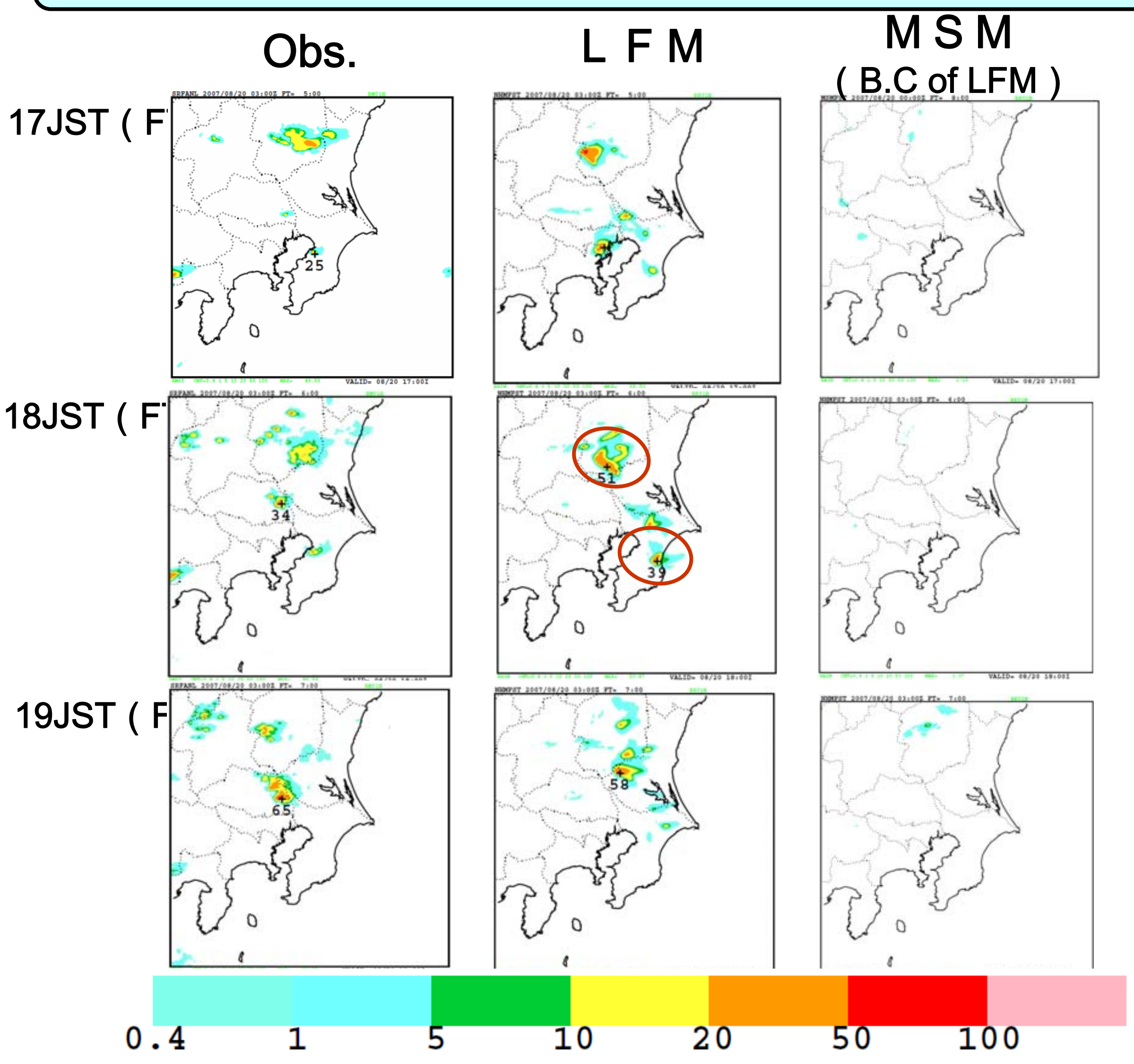


Schematic diagram of the analysis forecast system of LFM



A case of localized severe event on 03UTC 20 Aug. 2007

Improvement of the localized severe precipitation



Improvement of distribution : because of 3DVAR analysis

Improvement of intensity of precipitation : because of the increase of resolution

Grid scale convection w/o cumulus parameterization (1)

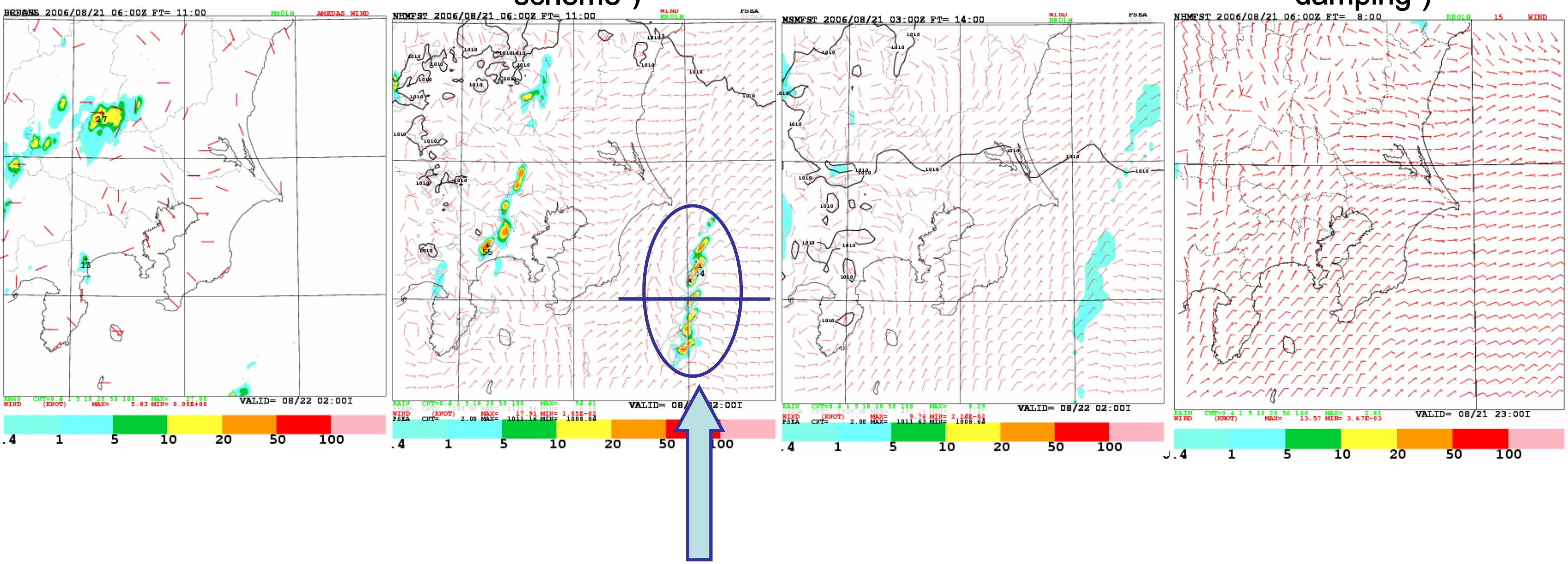
06 UTC, Aug. 21, 2006 initial, FT=10

Obs.

L F M
(w/o K-F scheme)

MSM
(B.C of LFM)

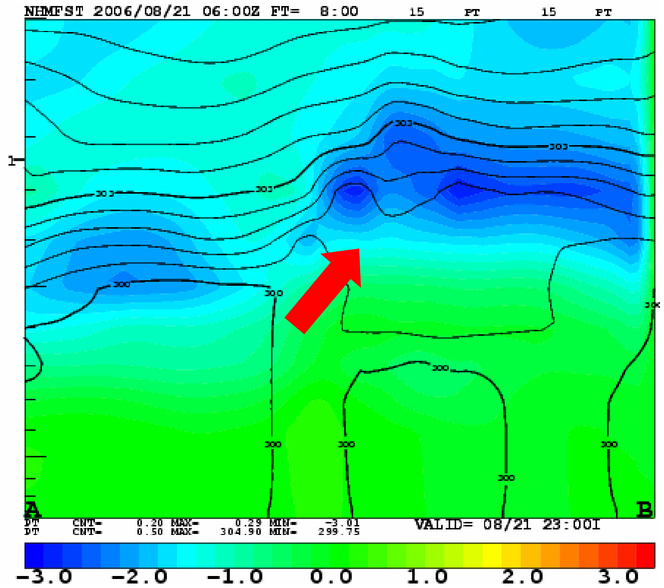
L F M
(w/o K-F, Rayleigh damping)



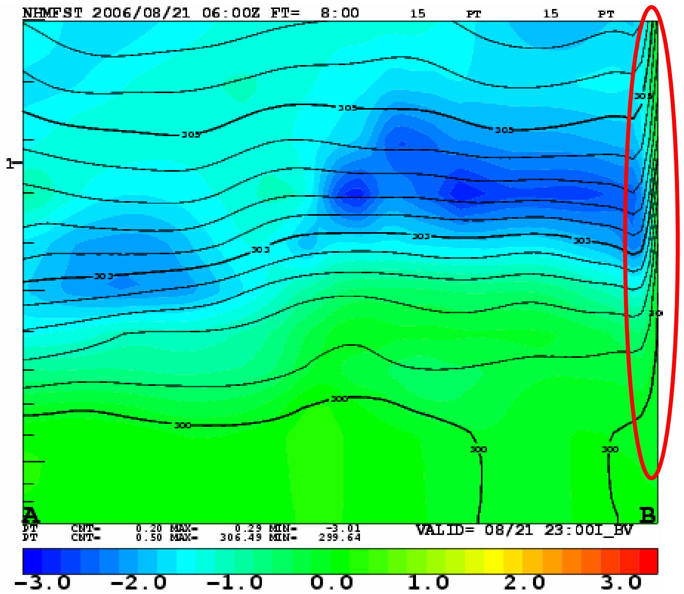
Unnatural heavy precipitation

Grid scale convection w/o cumulus parameterization (2)

L F M
(w/o K-F)



L F M
(w/o K-F, w/o Rayleigh



Contour (black) : potential temperature

Difference of PBL height between inner and outer model

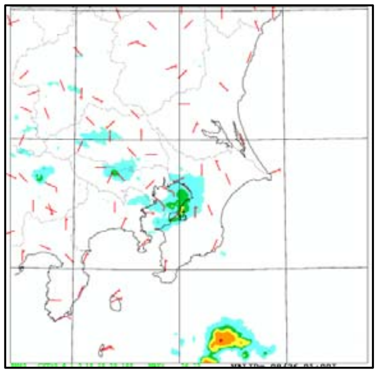
- Issue of the nested model.

But, there are similar patterns caused by other reasons (the reasons remain unknown)

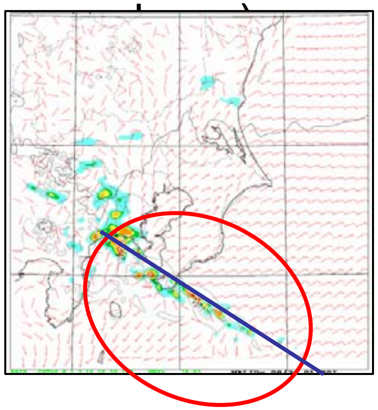
Suppressing the grid scale convection by introducing K-F scheme (1)

06 UTC, Aug. 25, 2006 initial, FT=10

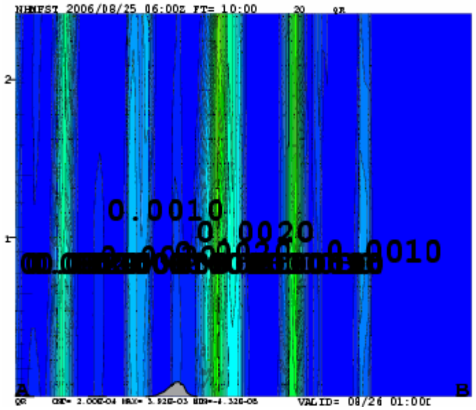
Obs.



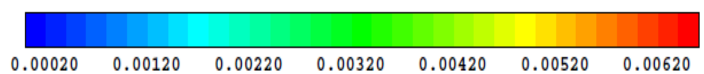
L F M
(w/o K-F scheme)

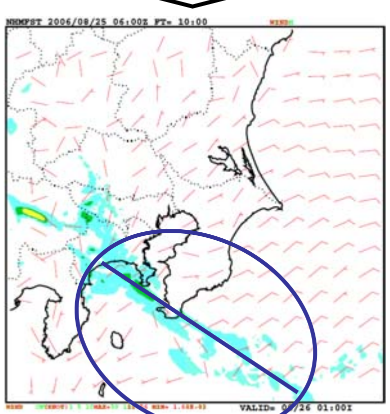


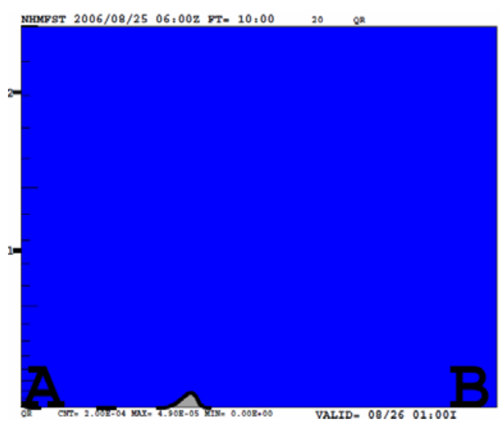
Distribution of Qr (kg/kg)



Introduction of K-F







Suppressing the grid scale convection by introducing K-F scheme (2)

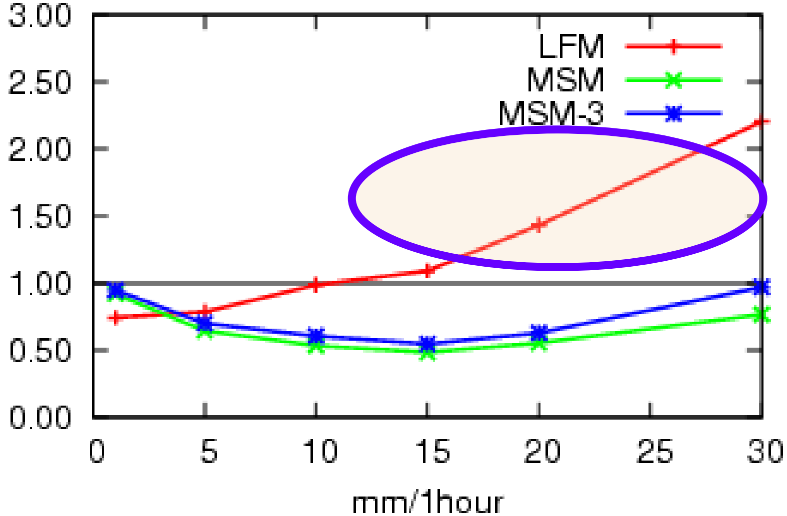
- Adjusting parameters in order not to lose the feature of model with 2km grid spacing
  - reduction of the removal ratio of CAPE
  - switch off the perturbation of trigger based on the gird scale vertical velocity and the relative humidity
- Further investigation needed
  - causes of the grid scale convections
  - need for a cumulus parameterization
  - (If needed,) what is the best scheme ?
    - shallow convection
    - deep convection

2007/06～2007/08　Statistical verification of precipitation

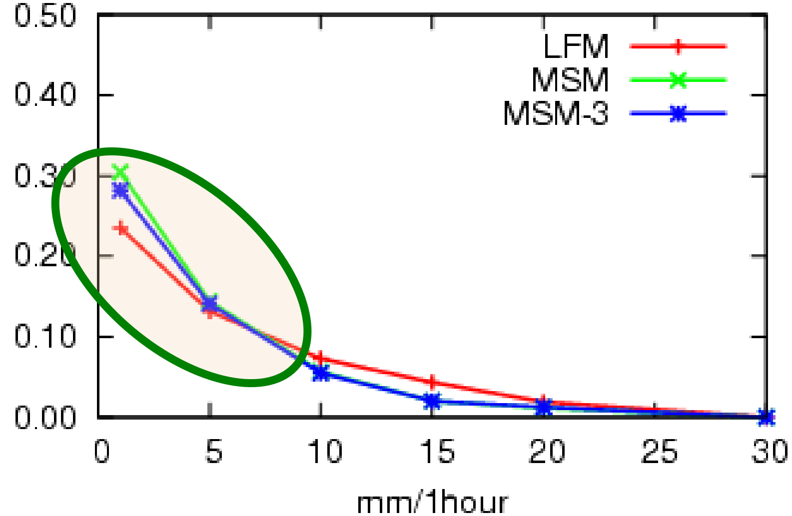
Bias Score ： Excess of heavy precipitation

Threat Score : Worse than MSM for weak precipitation

Bias score



Threat score



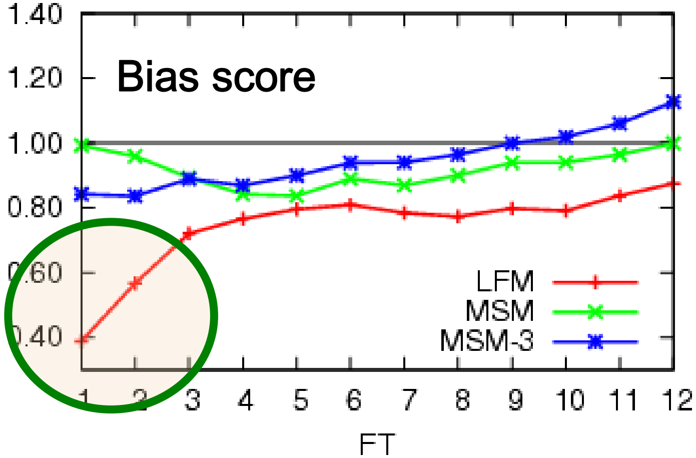
- LFM　- MSM of same initial　- MSM of 3 hours before (*)

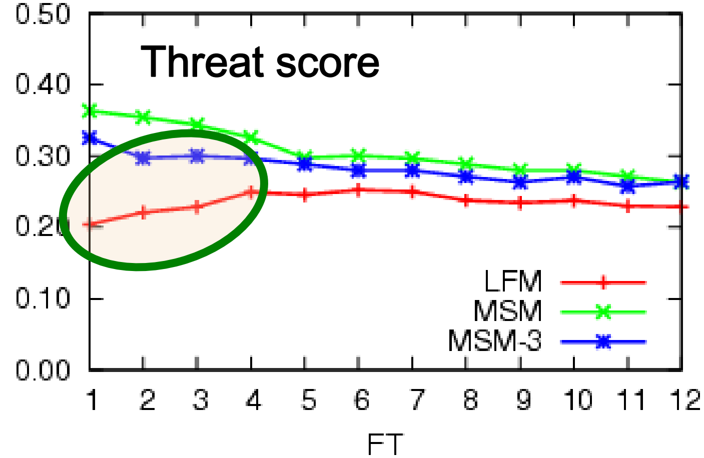
20km grid, 1 hour precipitation against R/A (Rader and rain gauge composite precipitation)

* MSM which provides boundary data for LFM

Spin up problem of precipitation (1)

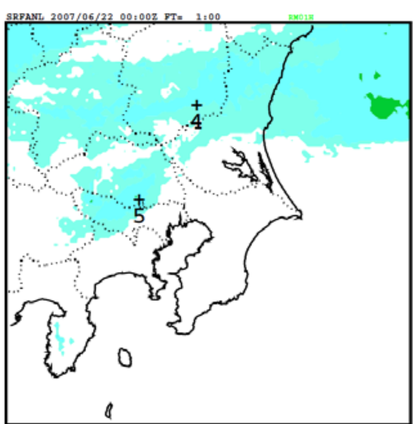
2007/06～2007/08　1mm/hour 20km grid, X axis : forecast time



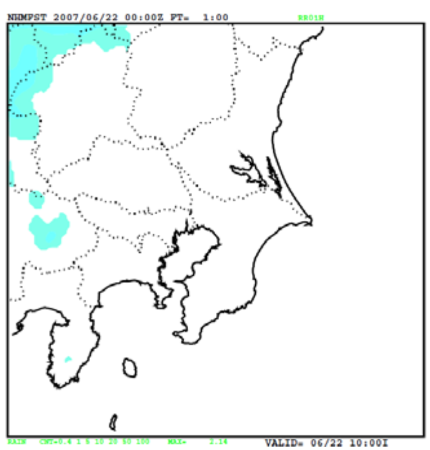


00UTC Jun. 22, 2007 initial, FT=01

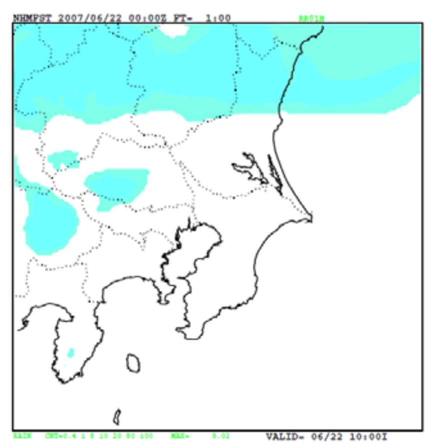
Observation



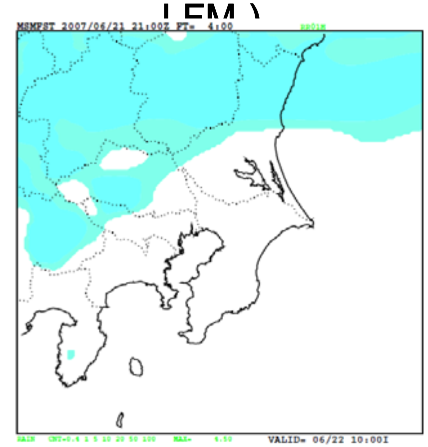
ＬＦＭ



ＬＦＭ
(w/o data assimilation)

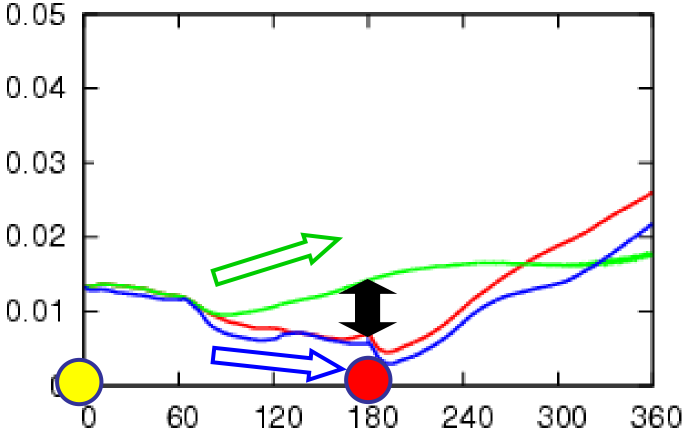


ＭＳＭ
(provides B.C. for

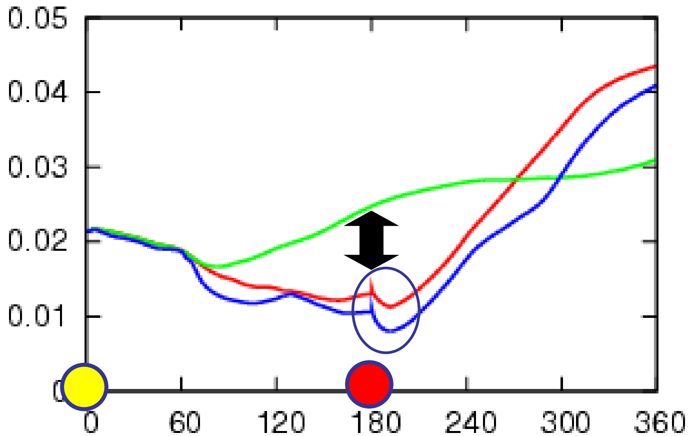


Spin up problem of precipitation (2)

20m height



2000m height



Causes

- Decrease of mixing ratio of (Qr) in the initialization process of the model
- Decrease of Qr in the beginning of 2km model integration

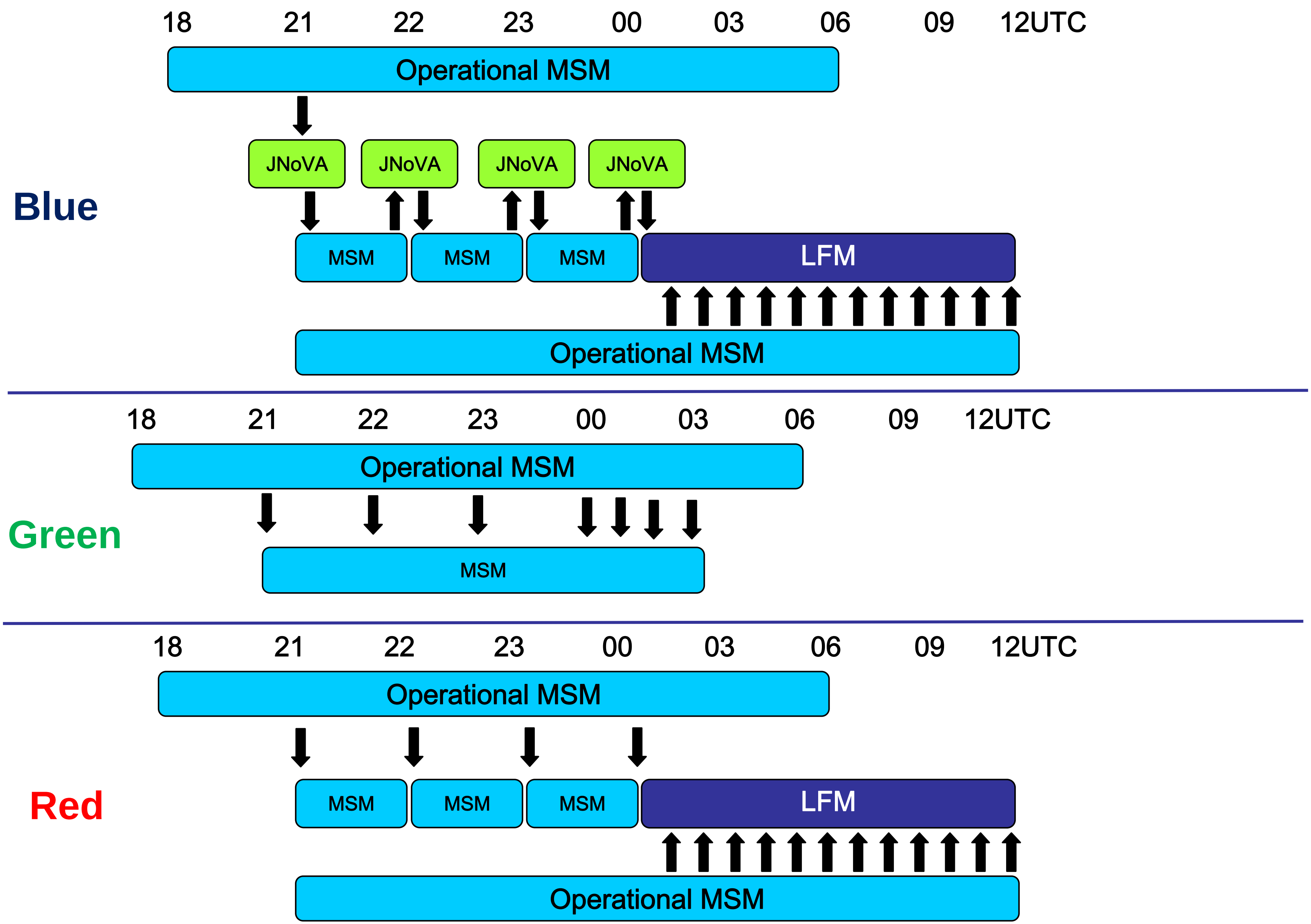
(yellow circle): start of analysis forecast cycle

(red circle): start of 2km forecast

- LFM
- LFM (w/o Analysis, but restart every 1 hour)
- 6 hour forecast w/o restart

Horizontal axis：Forecast time from the start of analysis forecast cycle [min]

Vertical axis：Average of mixing ratio of rain (Qr) [kg/kg×10^{-3}]


18
21
22
23
00
03
06
09
12UTC
Operational MSM
JNoVA
JNoVA
JNoVA
JNoVA
Blue
MSM
MSM
MSM
LFM
Operational MSM
18
21
22
23
00
03
06
09
12UTC
Operational MSM
Green
MSM
18
21
22
23
00
03
06
09
12UTC
Operational MSM
Red
MSM
MSM
MSM
LFM
Operational MSM

Summary

- Daily experiment using LFM with a horizontal grid spacing of 2km
  - Investigation of the performance of high resolution models including the statistical verifications and case studies
- Improvement of the localized heavy precipitation
  - The peak value of precipitation become closer to observation
- Grid scale convection
  - can be suppressed by the introduction of K-F scheme
  - Investigation of the cause of grid scale convection, need of a convection scheme for the model with the horizontal resolution of 2km
  - If a scheme needed, what is the best ?
- Spin up problem of precipitation

Acknowledgement

- This research is supported by the "Innovative Program for Climate Change Projection for 21th Century".