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Mesoscale ensemble prediction system using singular vector method

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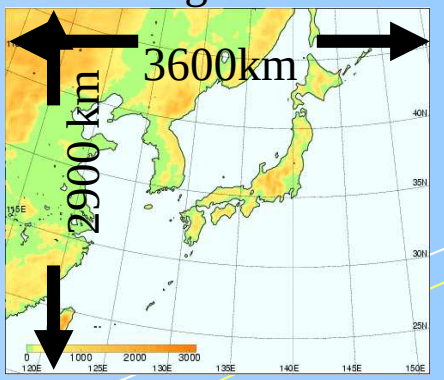
- Outline of singular vector method at JMA
- Results of experiment with initial perturbation by singular vector method
- Effects of lateral boundary perturbation
- Summary and future plans

Development of meso ensemble prediction system at JMA

- Purpose
  - To provide probabilistic and reliability information about operational mesoscale model(MSM) at JMA
    - MSM : dx = 5km, forecast period is 15 or 33 hours

Forecast region of MSM



- Generation of perturbation
  - We have been researching for the best method in 3 ensemble initial perturbation methods
    - **Singular vector**
    - Local ensemble transform Kalman filter
    - Breeding of growing mode

- Schedule
  - In 20xx, pre-operational experiment will start
  - Specifications have not been decided yet

Outline of singular vector method developing at JMA

- Singular vector method based on 2 kinds of TL/AD model
  - Meso singular vector(**MSV**)
    - TL/AD model is based on JMA non hydrostatic model(JMA-NHM)
  - Global targeted singular vector(**GSV**)
    - TL/AD model is based on global spectral model at JMA

- Purpose in this presentation
  - Which method is best performance as initial perturbation in SVs?
  - Effect of lateral boundary perturbation

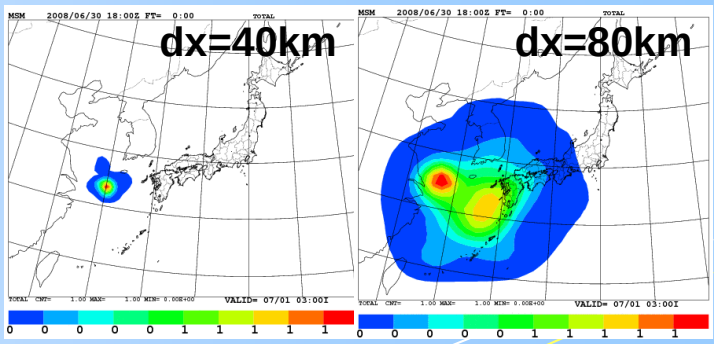
1. Results of experiment with initial perturbation by SV methods

Experiments with initial perturbation

Conducted 4 ensemble forecast experiments

- Target is short range(about after half a day) forecast of precipitation
- Grid spacing of ensemble forecast(using JMA-NHM) is 20km

An example of MSV



- **MSV40**
  - dx = 40km
  - Standard experiment
- **MSV80**
  - Low resolution experiment(dx=80km)
- **GSV**
  - Simple downscaling method
  - Adopted as an initial perturbation method at *B08RDP within the perturbation methods experimented at JMA/MRI
- **BSV**
  - Blend MSV40 and MSV80
  - To add high wave number component of MSV40 to MSV80

*the WWRP Beijing Olympic 2008 Research and Development Project

Specification of each experiment

Specification of calculating each SV

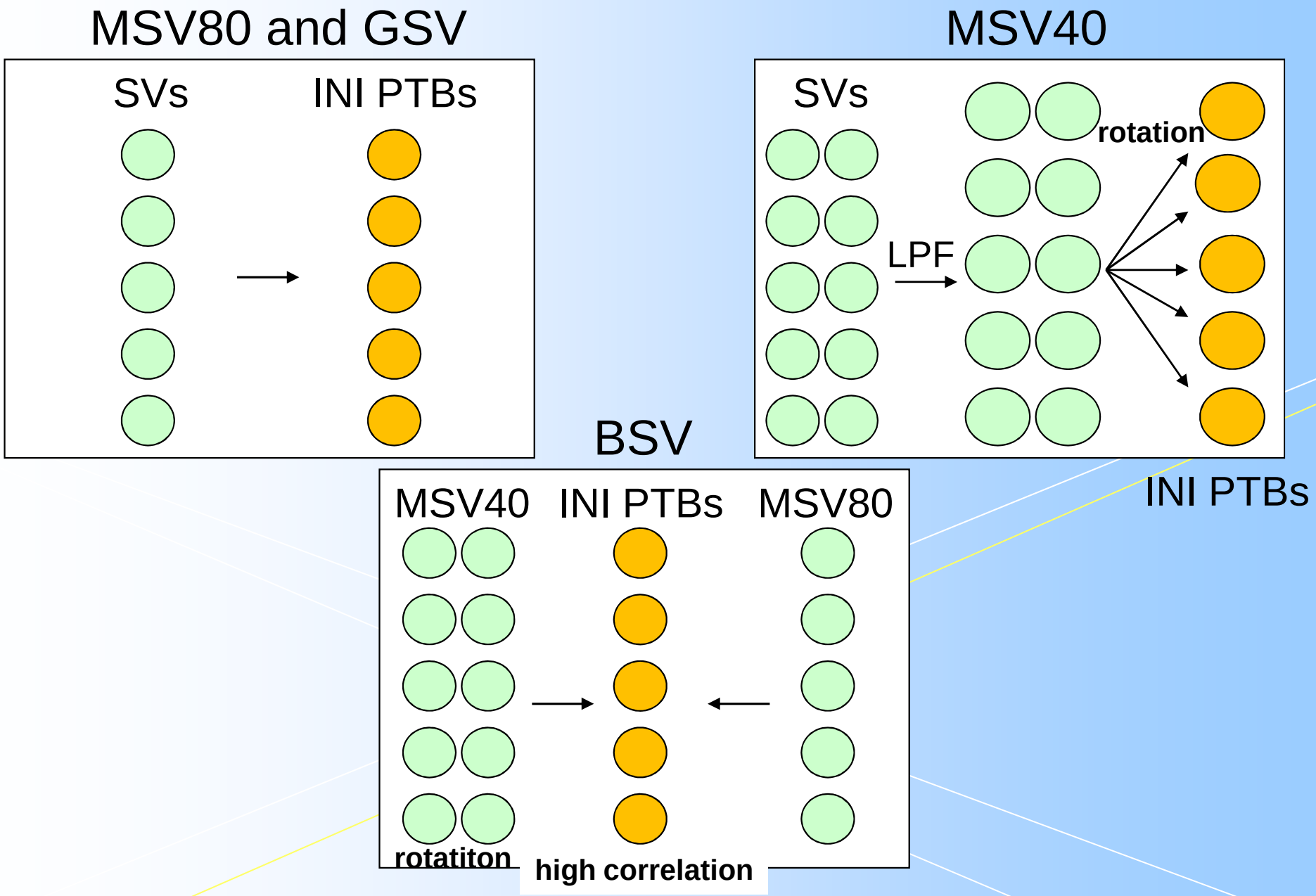
	MSV40	MSV80	GSV	BSV
Resolution	40km	80km	about180km	40km/80km
Norm	Moist total energy			
Optimization time	15 hour	15hour	24hour	6hour/15hour
Number of singular vectors	10	5	5	10/5

Specification of ensemble forecast using JMA-NHM

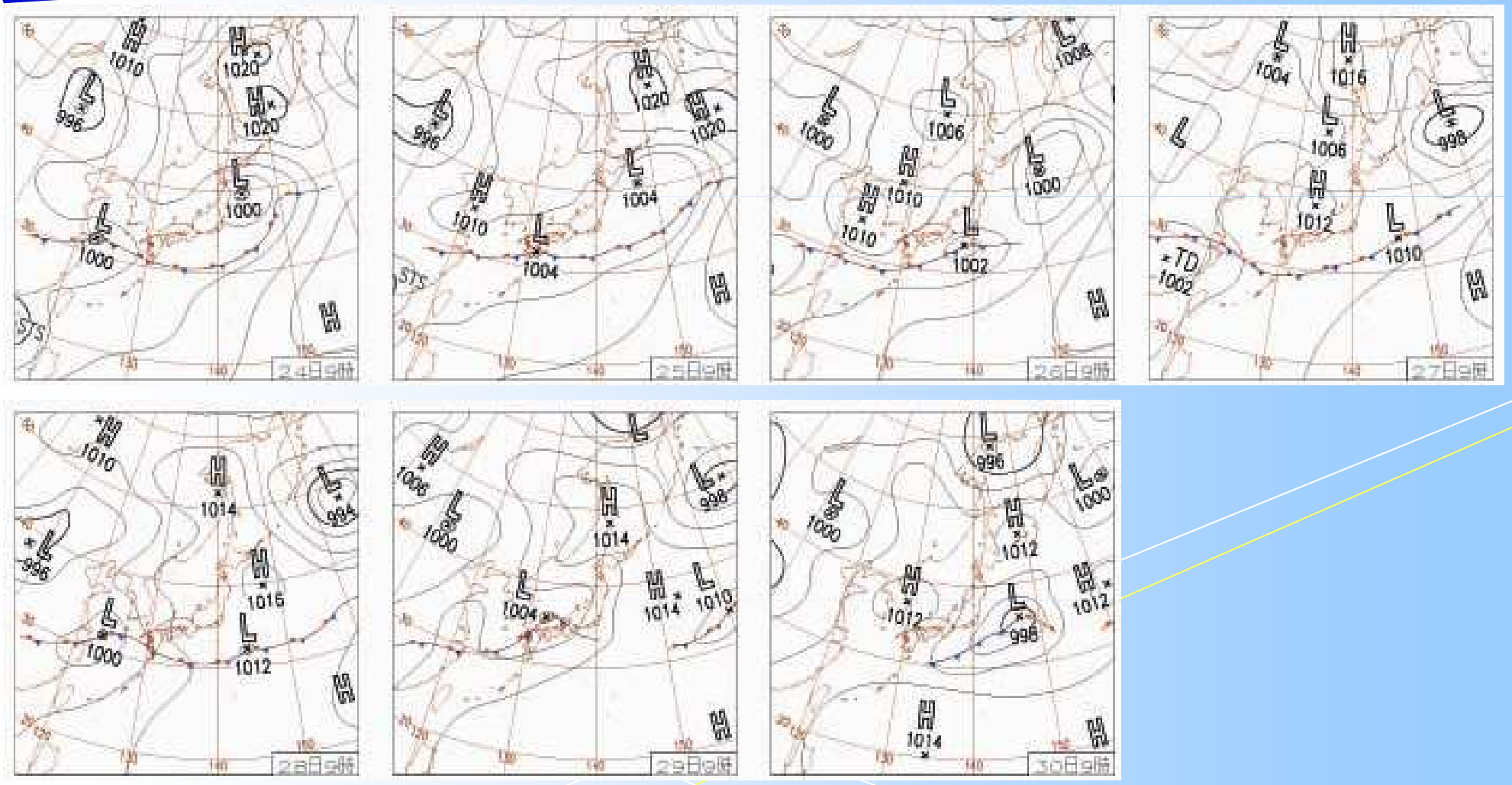
Resolution	20km
Number of ensemble members	11(10PTBs + 1CTL)
Boundary perturbation	None

Forecast region and target region

Methods of generating initial perturbations

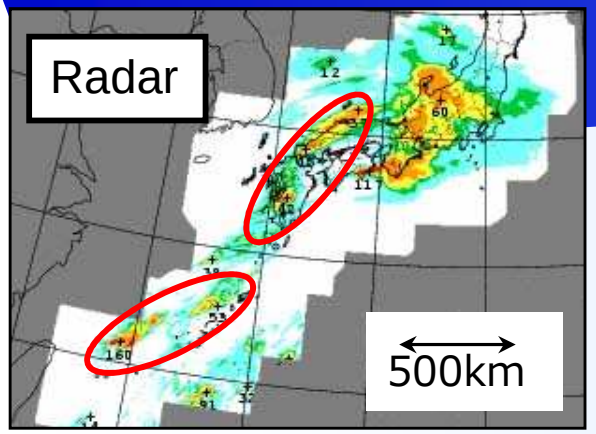


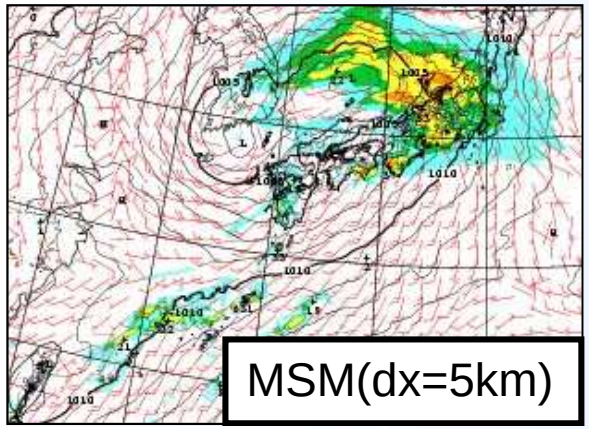
Experiment period : 24-30 June 2008. All initial is 18UTC

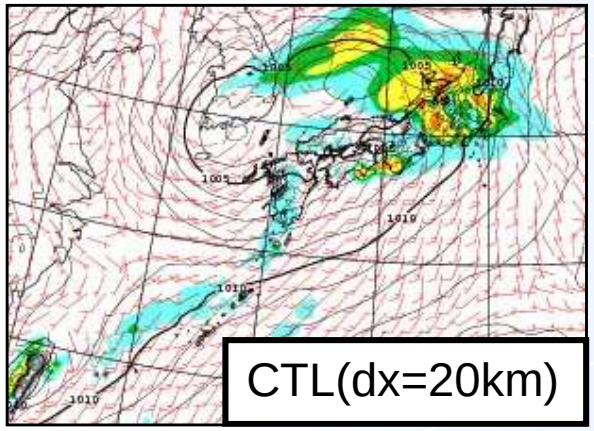


There was a stationary front around Japan
24-28 June 2008, 7 initials(18UTC)

Ensemble forecast : Ini.00UTC 28 June 2008, FT=06

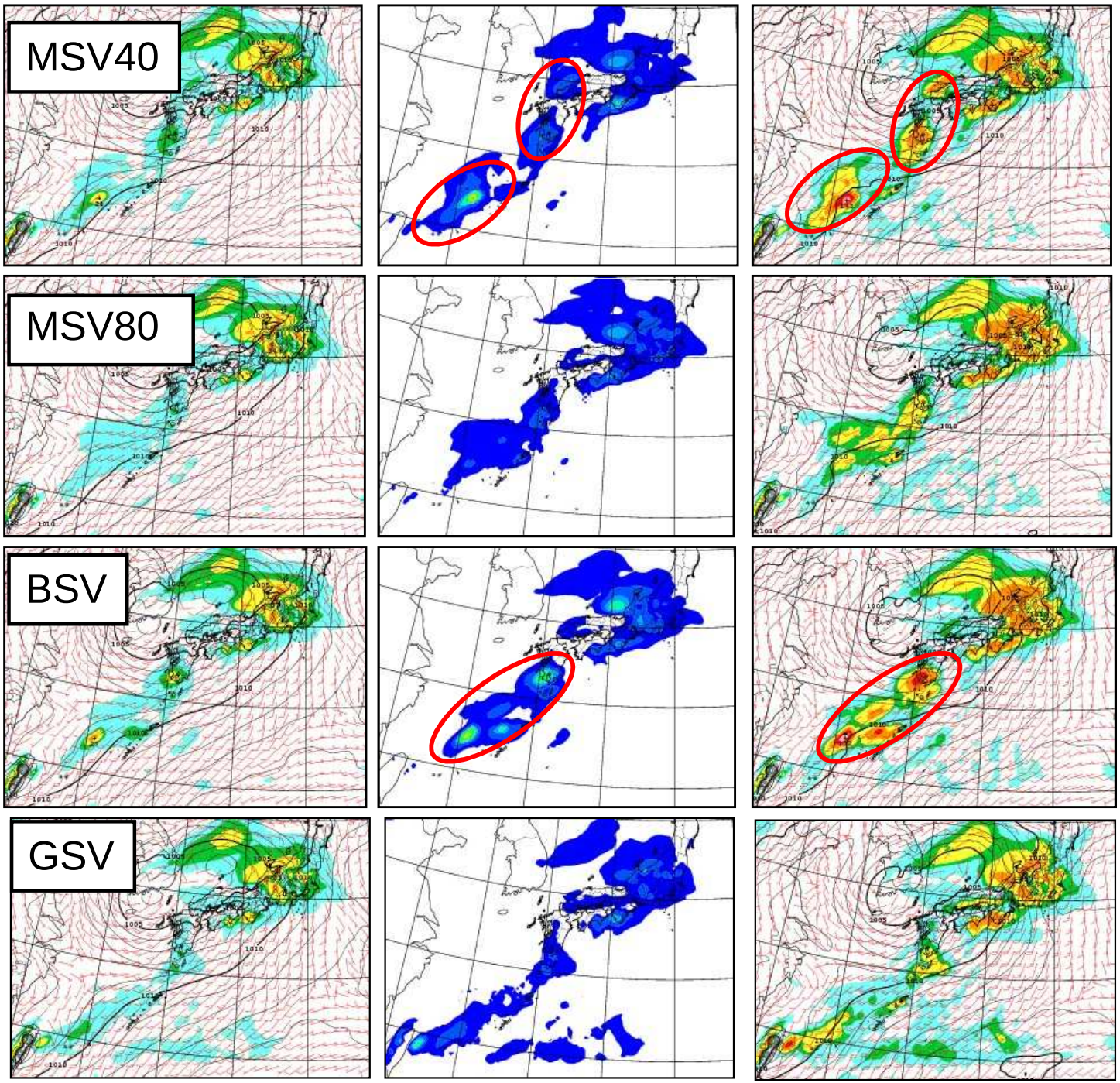






Unit is mm/3hour

Ensemble mean | Ensemble spread | Max precipitation



Initial perturbation

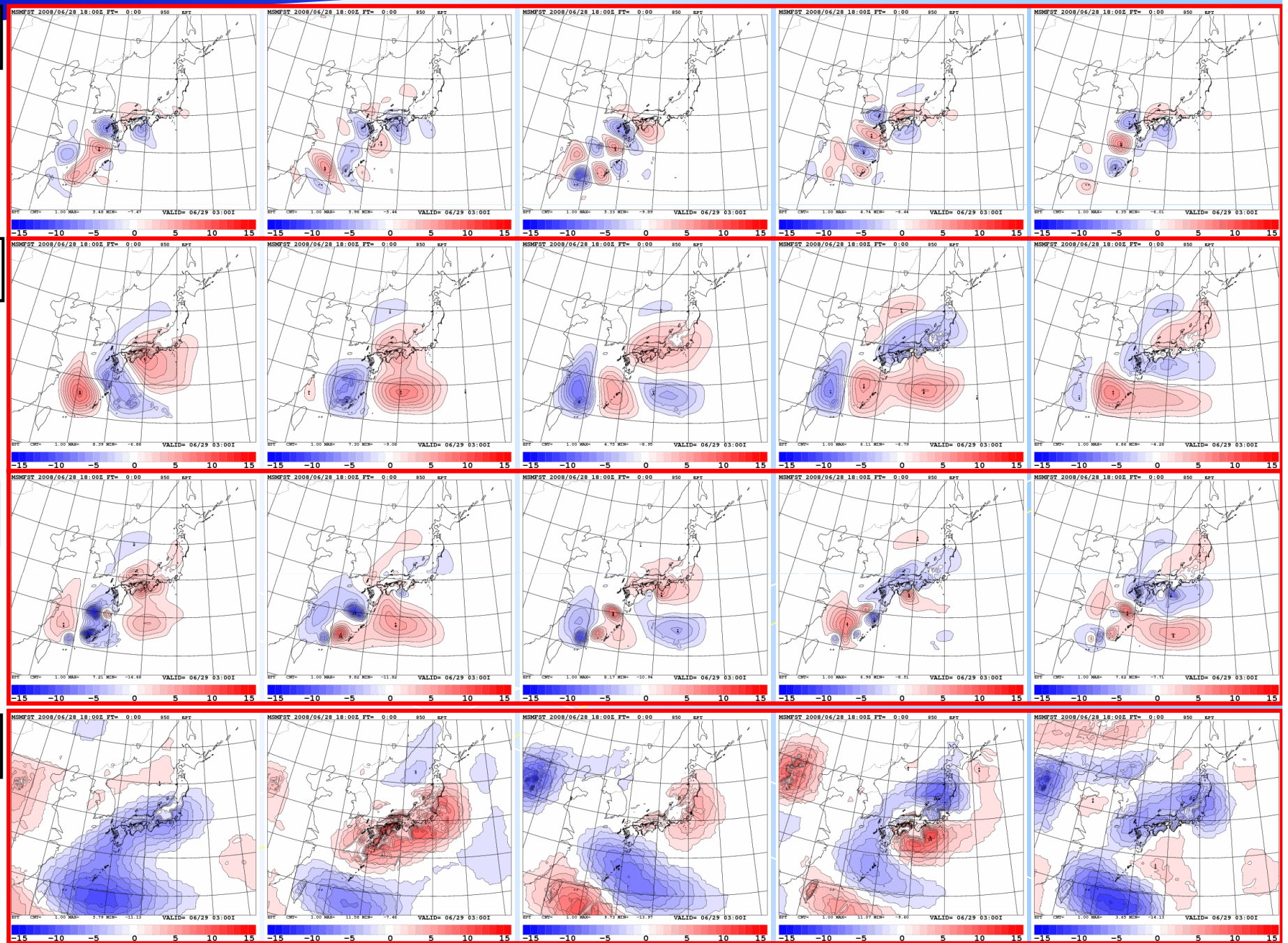
Equivalent potential temperature on 850hPa

MSV40

MSV80

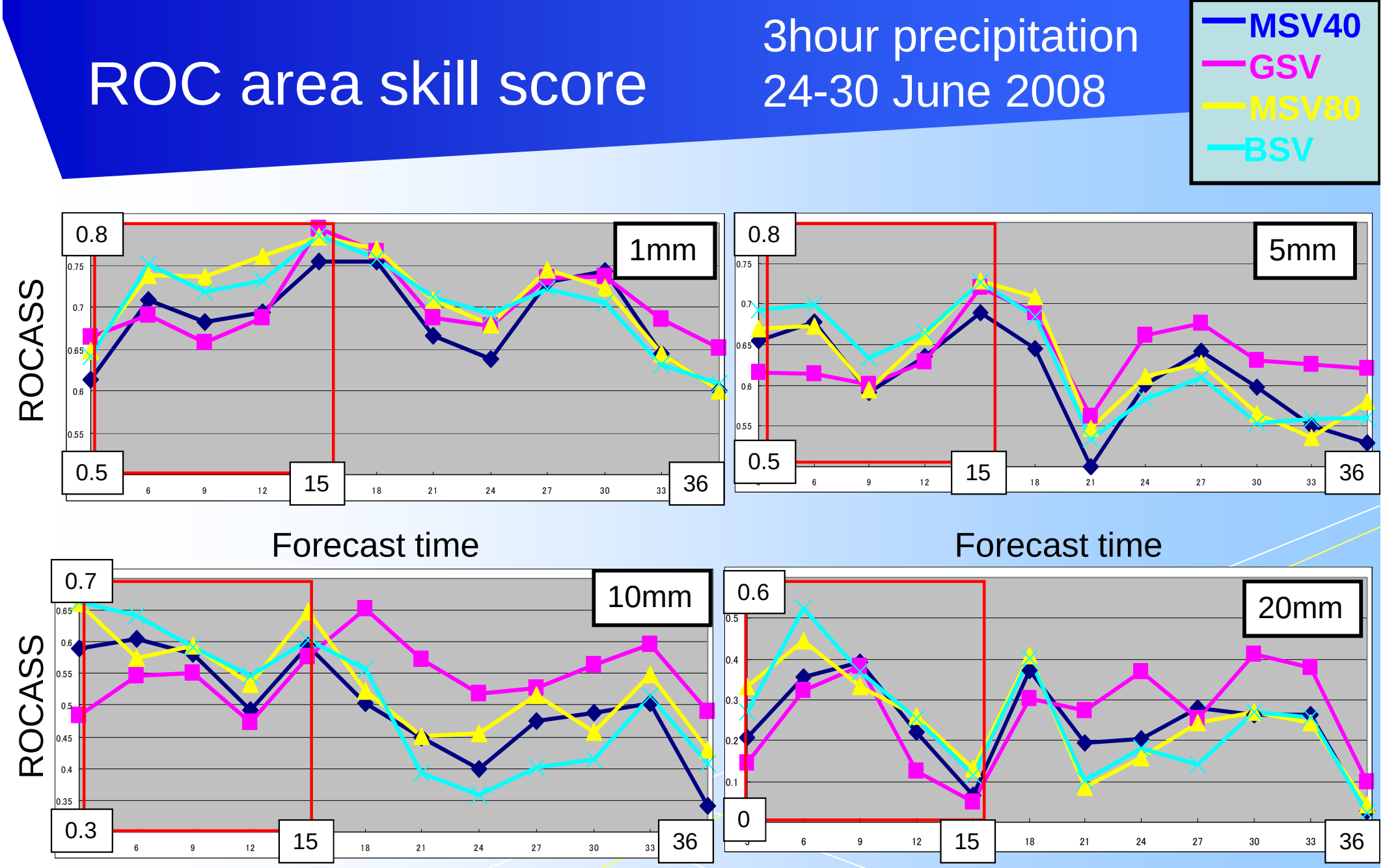
BSV

GSV



ROC area skill score

3hour precipitation
24-30 June 2008

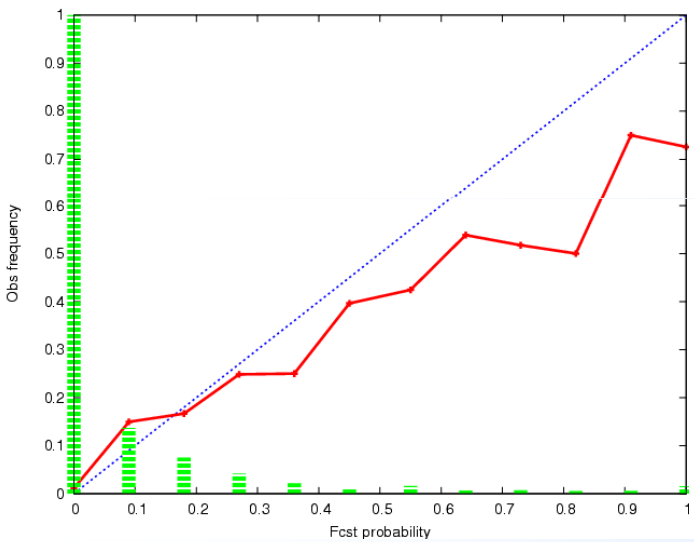


Until FT=15, BSV>MSV80>MSV40>GSV
After FT=15, GSV is the best performance

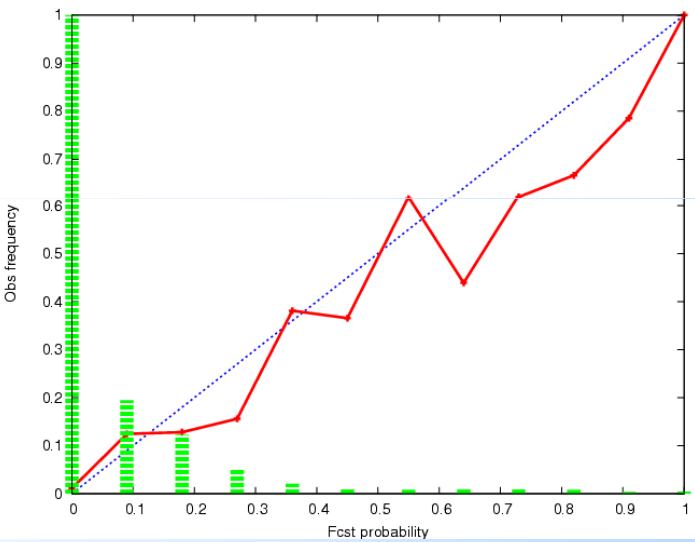
Reliability diagram

10mm/3hour precipitation
24-30 June 2008, FT=09

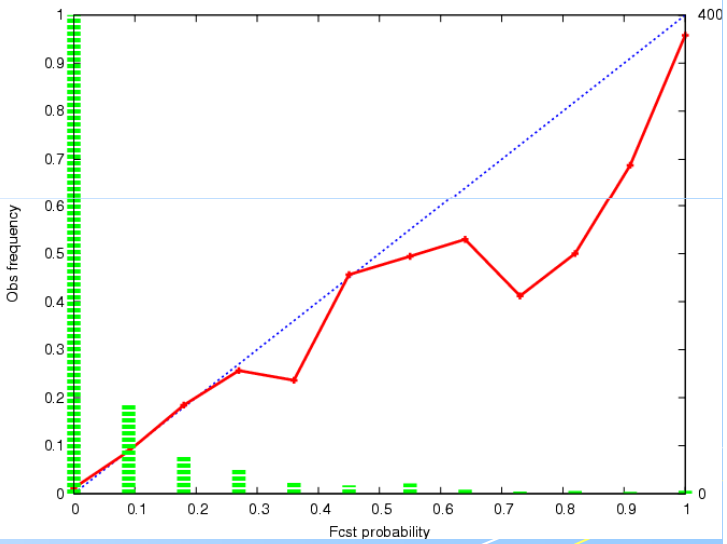
MSV40



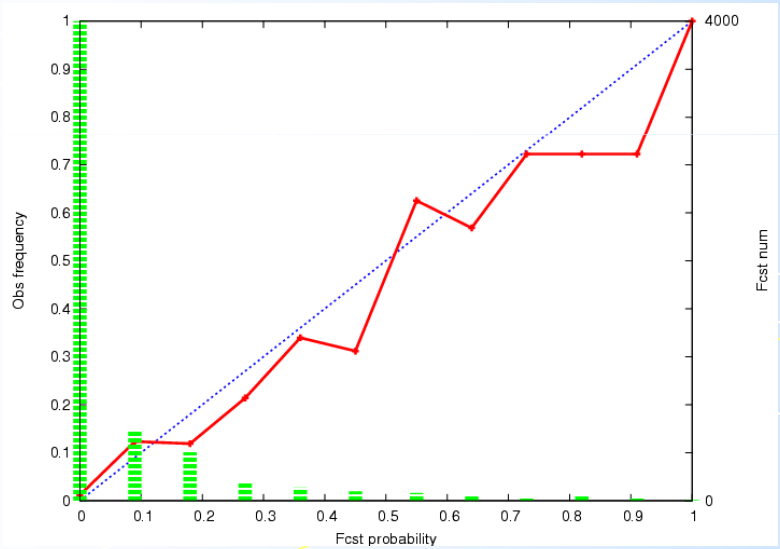
MSV80



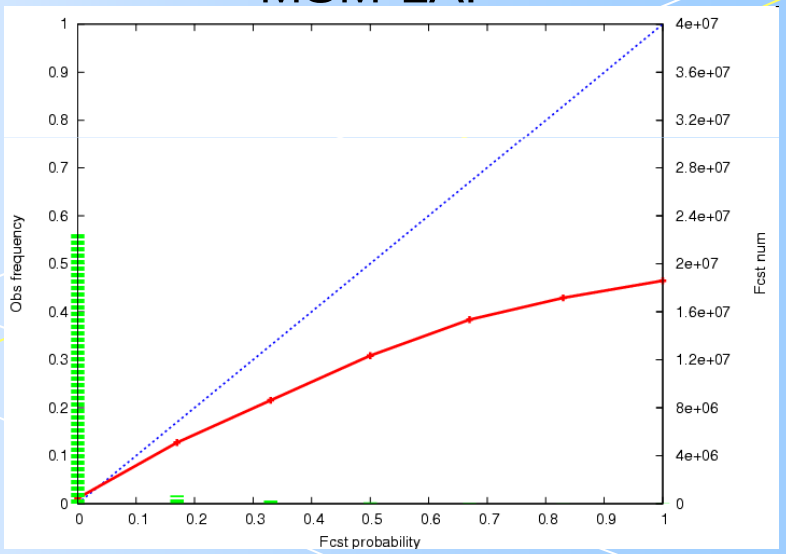
BSV



GSV



MSM-LAF



forecast frequency
observation frequency against forecast

Verification period : 2008.6.1- 8.31
Number of ensemble members : 6

2. Effect of lateral boundary perturbation

Generation of lateral boundary perturbation

- To improve the score of BSV in the latter half of the forecast period

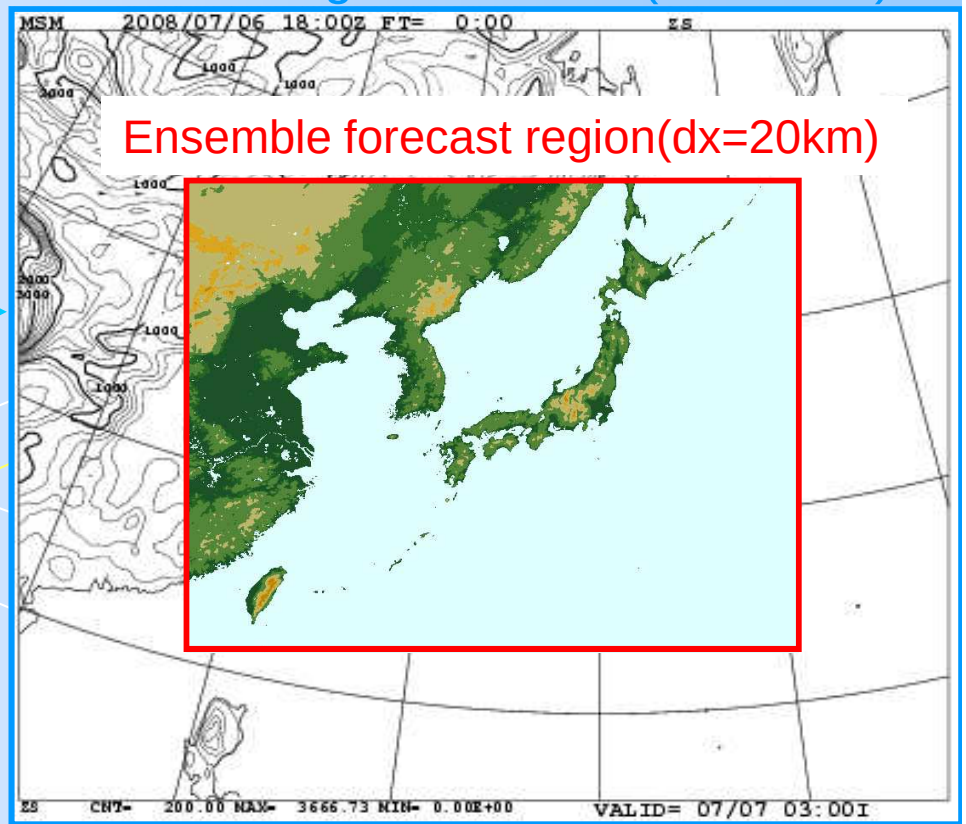
Generation of lateral boundary perturbation by GSV

1. Calculate 5GSVs(configuration is same as previous one)
2. Run control forecast and 5 perturbed forecasts using 5GSVs by JMA-NHM
3. PTB = PTBFCST – CTLFCST
4. Add PTBs to lateral boundary values

Specifications of forecasts for LBPs

Forecast model	**JMA-NHM**
Resolution	**40km**
Initial and boundary value	**Global analysis at JMA**
Forecast region	

Forecast region for LBPs(dx=40km)



Initial perturbation is BSV(MSV40+MSV80)

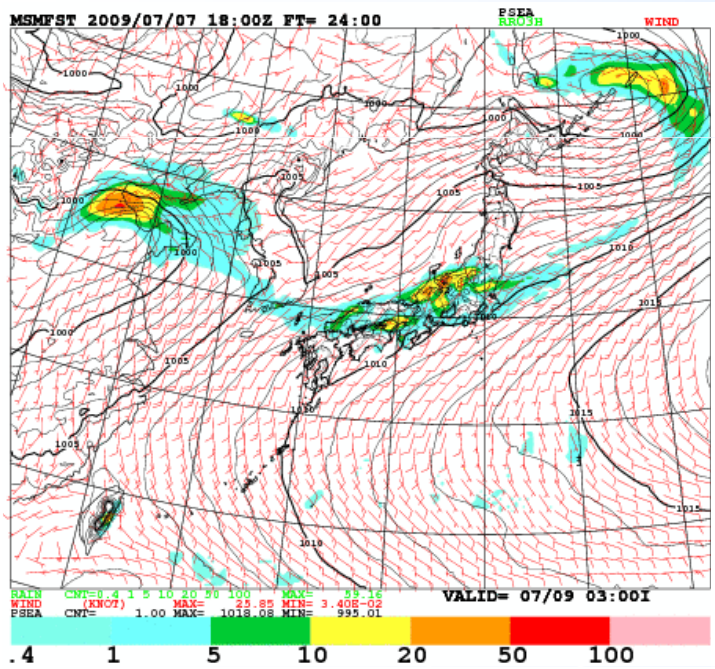
The reason for this method

- LBPs match high resolution ensemble forecasting grid
- If we use BSV as MSV40 + GSV(not MSV80), this method can save computation time

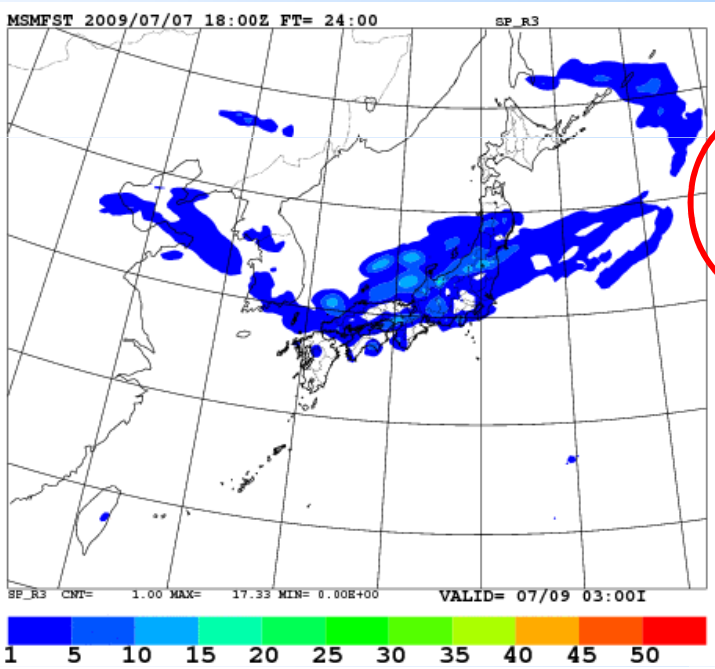
Ensemble spread of 3hour precipitation

Initial : 18UTC 07 July 2009, FT=24

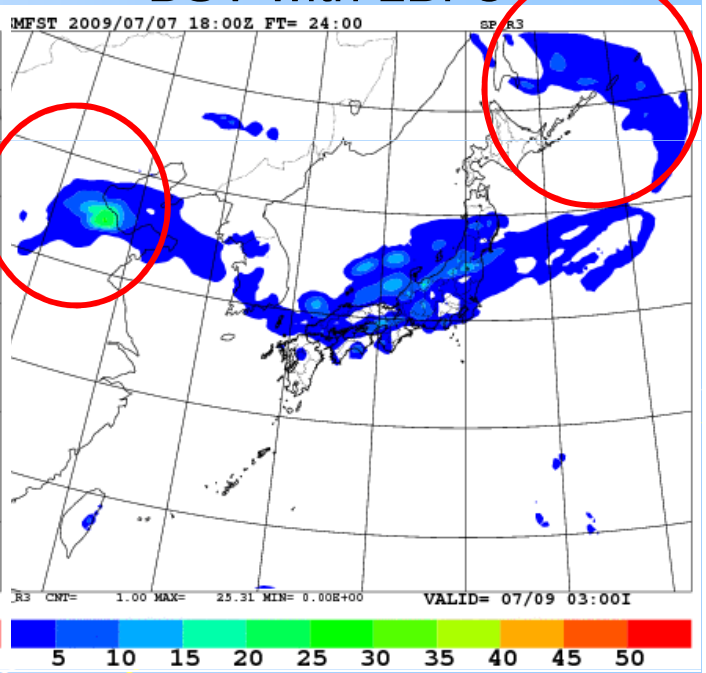
CTL forecast



BSV



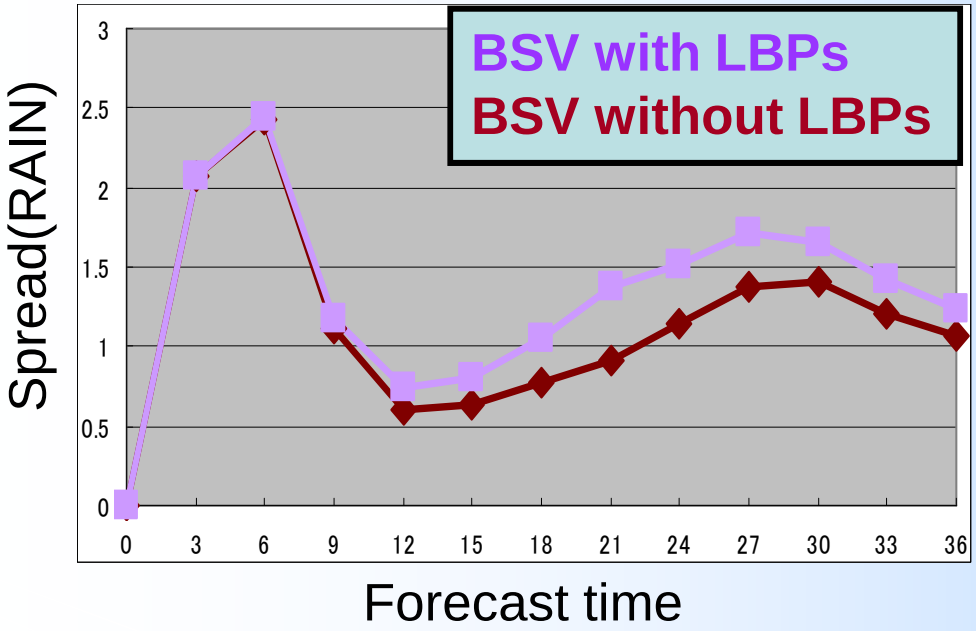
BSV with LBPs

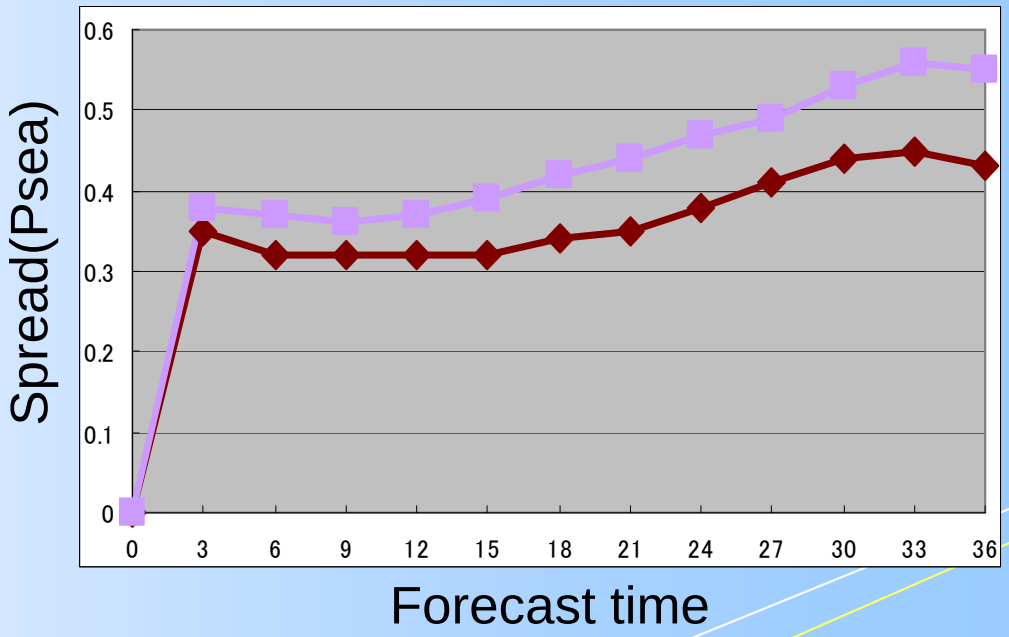


BSV with LBPs get a larger spread near the boundaries

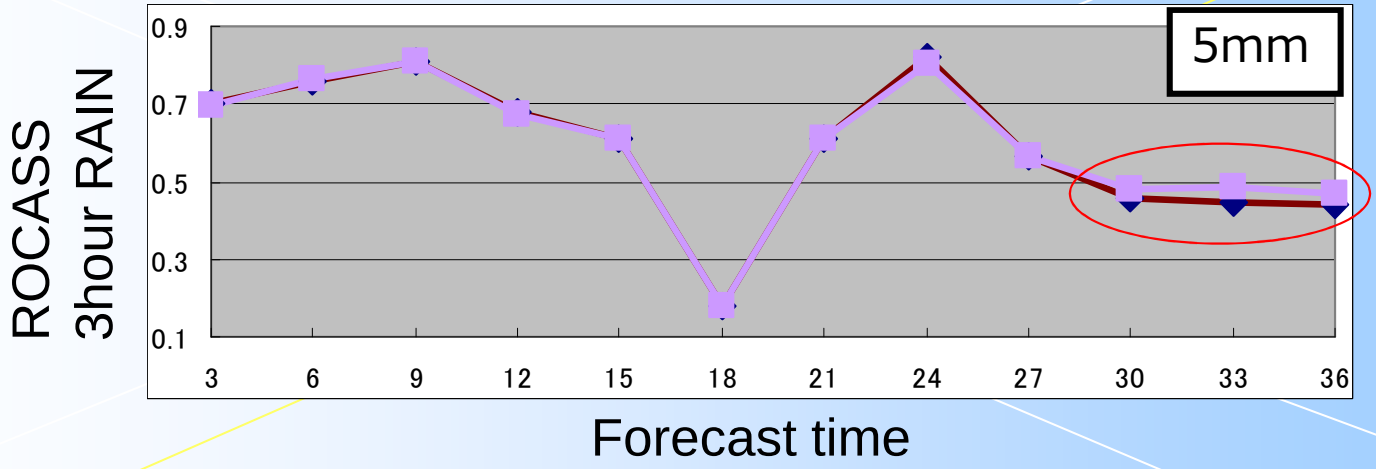
Ensemble spread and ROC area skill score

Initial : 18UTC 07 July 2009





BSV with LBPs is larger spread than BSV without LPBs



In the latter half of the forecast period, ROCASS improves a little by LBPs

3. Summary and future plan

Summary and future plan

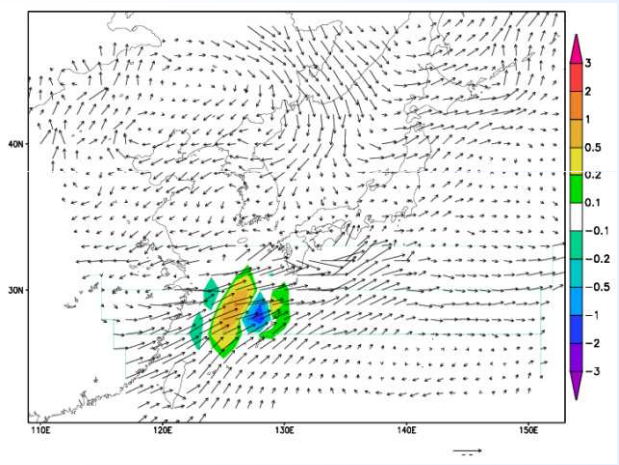
- Summary
  - Conduct 4 experiments with initial perturbation using SV
    - **In the first half of the forecast period, BSV showed the best performance.**
      - Because of larger distribution and higher wave number
    - **In the latter half of the forecast period, GSV showed the best performance.**
      - Because GSV is the largest scale
  - Generate LBPs and confirm its Effects
    - Confirming the effect of lateral boundary perturbation using GSV

- Future plan
  - Research for the way of generating BSV perturbation
    - Best way of SV combination
    - Which method is best, MSV40+MSV80 or MSV40 + GSV?
  - Compare with other LBP generation method
    - Downscaling of perturbations of weekly ensemble prediction at JMA etc…

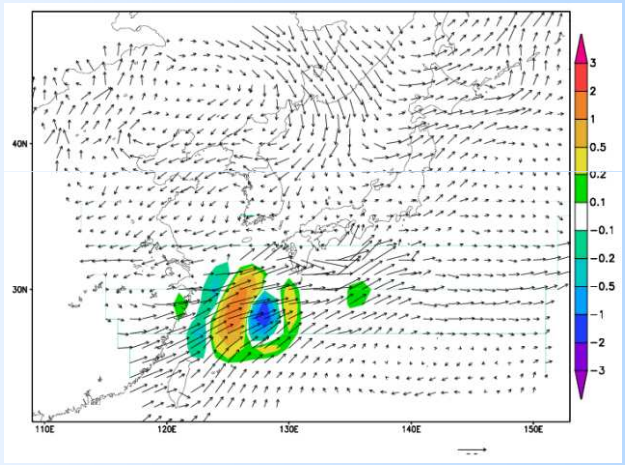
Generation of initial perturbation from MSV40

- Effect of low pass filter and comparion with MSV80

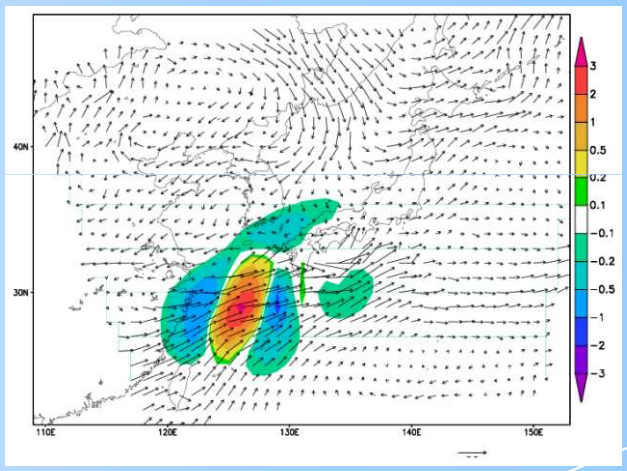
Its trancated wave length is about 300km



MSV40

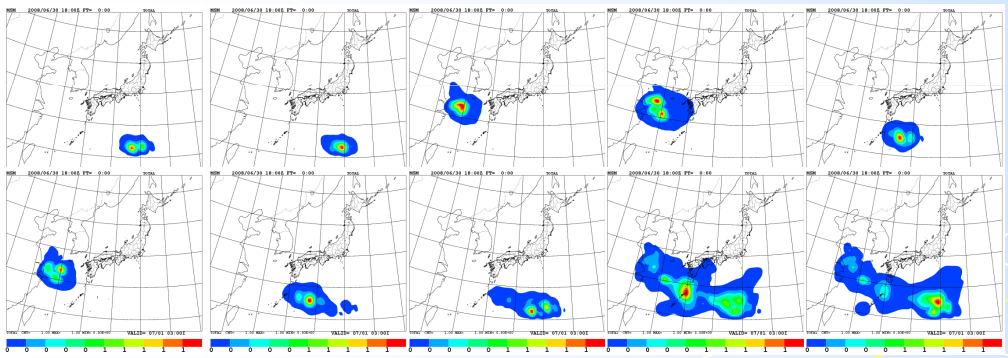


MSV40 using a LPF



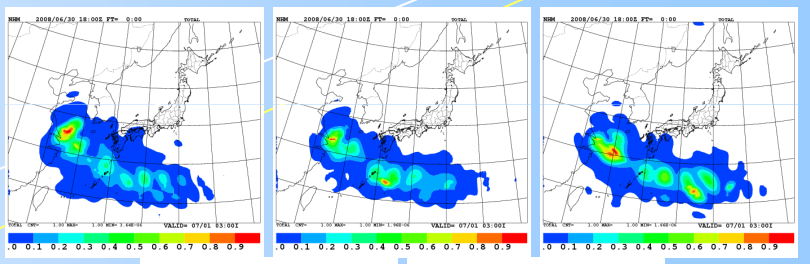
MSV80

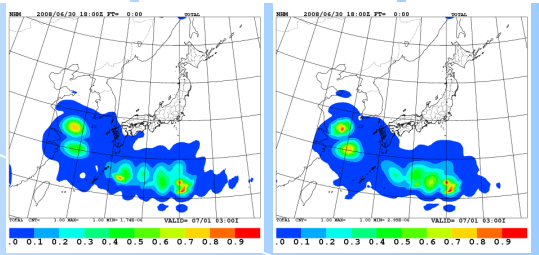
- After rotation, each vector is presented as a linear combination of SVs



singular vectors

rotation





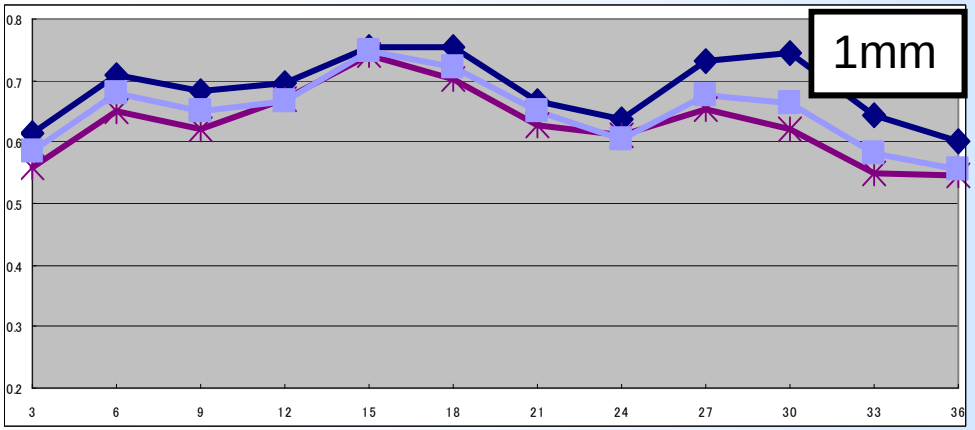
Initial perturbations

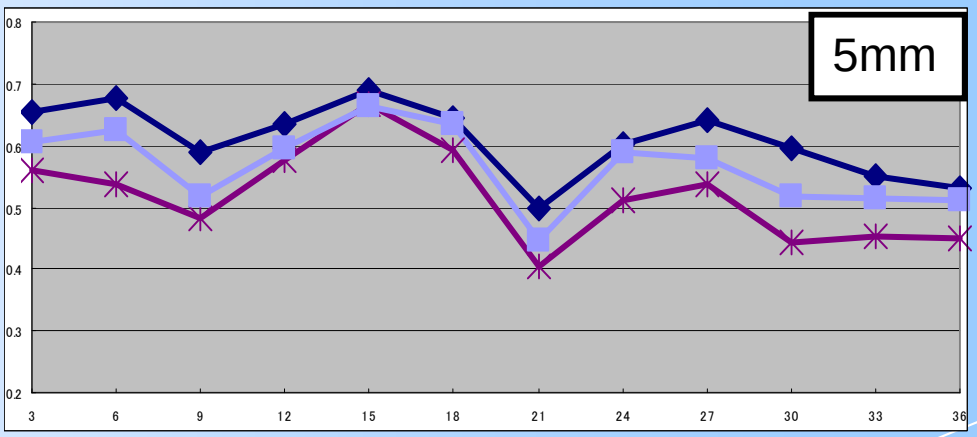
- orthogonal matrix for rotation of singular vector

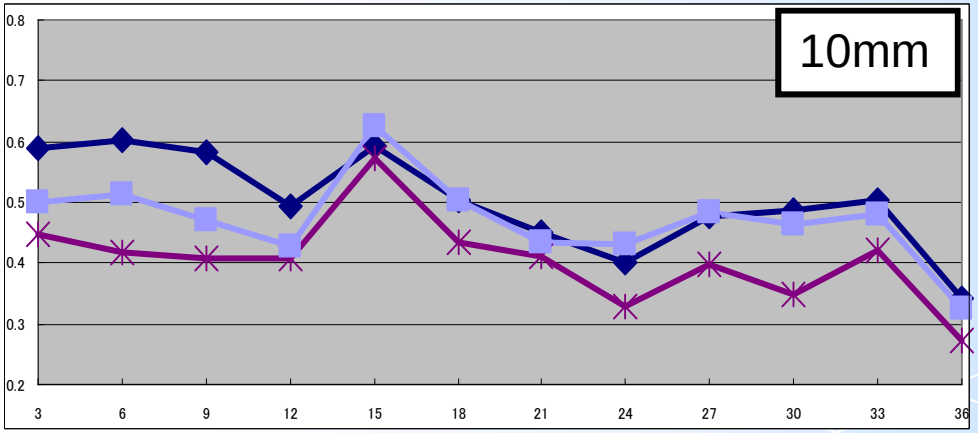
$$V = \sum_{i=1}^{\alpha}\left[\frac{1}{n}\sum_{j=1}^{n}\left(b_{ji}^2 - \frac{1}{n}\sum_{k=1}^{n} b_{ki}^2\right)^2\right] \longrightarrow \text{minimum}$$

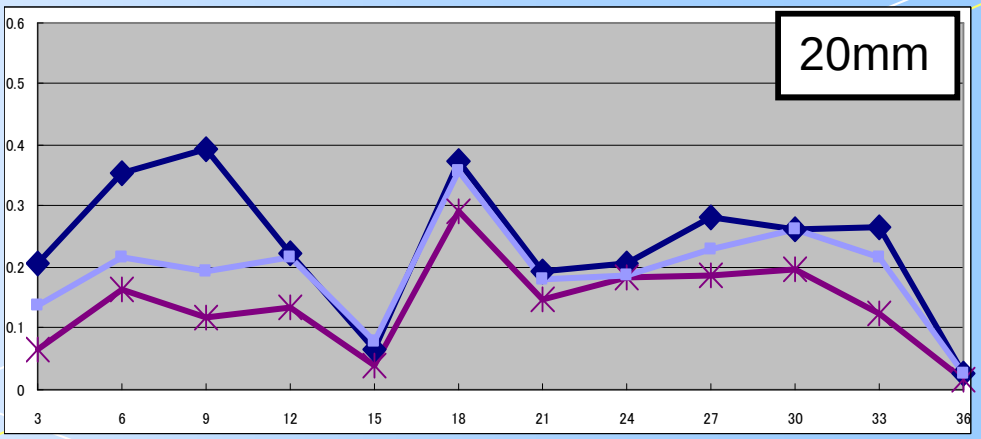
Effect of low pass filter and number of SVs

ROC area skill score (3hour precipitation, 2008.6.24-30)









5MSVs, rotation
10MSVs, rotation
10MSVs, LPF + rotation