# Recent Development of regional NWP system at JMA

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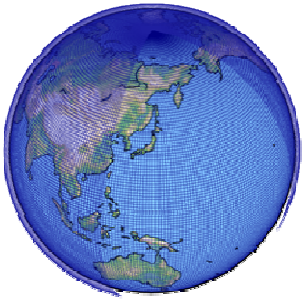
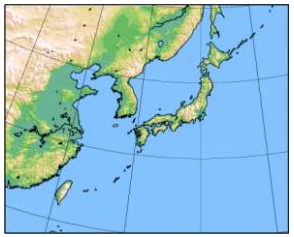
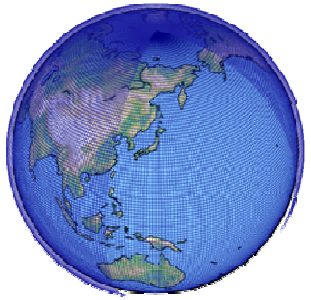
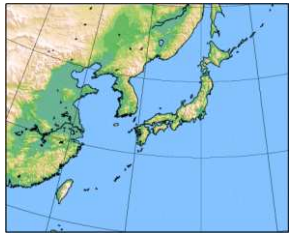
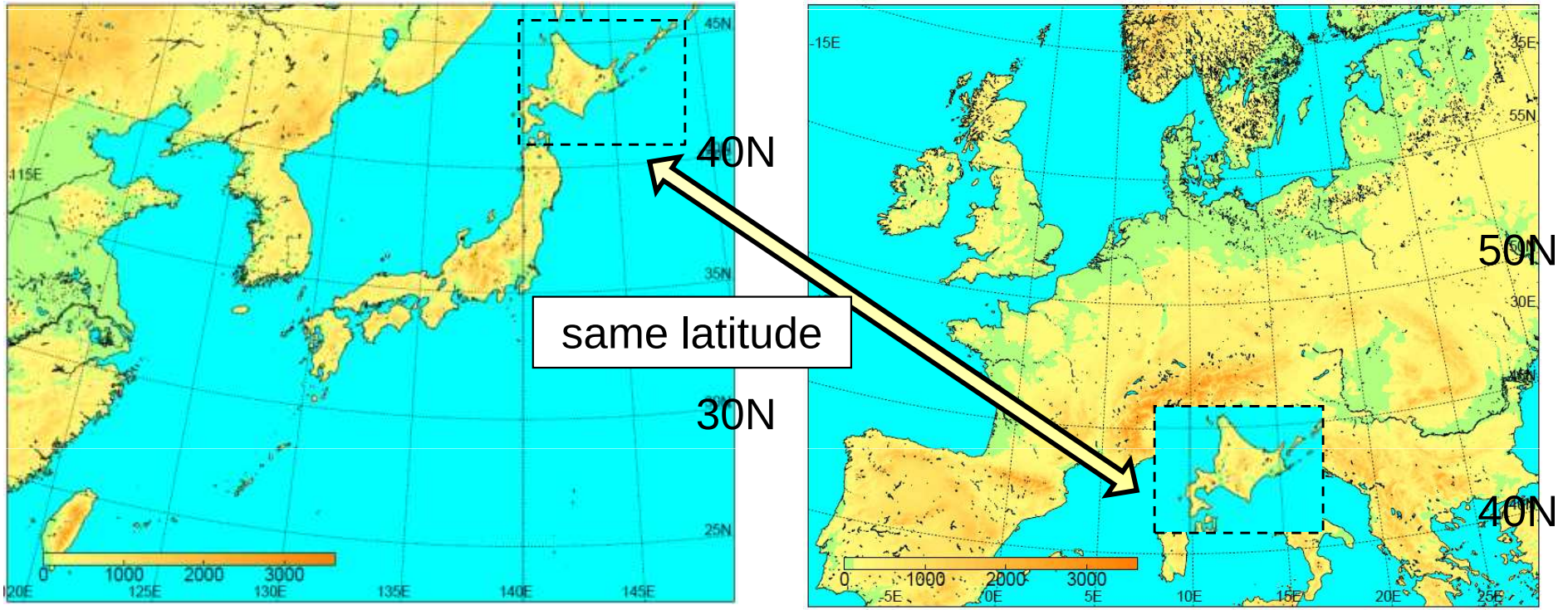
# Current NWP models of NPD/JMA

| | In Operation | | | | | In Test Operation |
|---|---|---|---|---|---|---|
| | Global Spectral Model **GSM** | Meso-Scale Model **MSM** | Local Forecast Model **LFM** | One-week Ensemble **WEPS** | Typhoon Ensemble **TEPS** | **Meso-scale Ensemble MEPS** |
| objectives | Short- and Medium-range forecast | Disaster reduction Aviation forecast | Aviation forecast Disaster reduction | One-week forecast | Typhoon forecast | Uncertainty and probabilistic information of MSM |
| Forecast domain | Global  | Japan and its surroundings (4080km x 3300km)  | Japan and its surroundings (3160km x 2600km)  | Global  | | Japan and its surroundings (4080km x 3300km)  |
| Horizontal resolution | TL959(0.1875 deg) | 5km | 2km | TL479(0.375 deg) | | 5km |
| Vertical levels / Top | 100 0.01 hPa | 48+2 21.8km | 58 20.2km | 60 0.1 hPa | | 48+2 21.8km |
| Forecast Hours (Initial time) | 84 hours (00, 06, 18 UTC) 264 hours (12 UTC) | 39 hours (00, 03, 06, 09, 12, 15, 18, 21 UTC) | 9 hours (00-23 UTC hourly) | 264 h (00, 12 UTC) 27 members | 132 h (00, 06, 12, 18 UTC) 25 members | 39h , 11 members |
| Initial Condition | Global Analysis (4D-Var) | Meso-scale Analysis (4D-Var) | Local Analysis (3D-Var) | Global Analysis with ensemble perturbations (SV) | | Meso-scale Analysis with ensemble perturbations (SV) |

# Operational high resolution model at JMA

operational domain of LFM

A region of the same size (for reference)



# New three frameworks

- ASUCA: new dynamical core: developing since 2007
  - Improved computational stability,
  - Higher efficiency on massive parallel scalar multi-core architecture,
  - Exclusion of artificial parameters such as numerical diffusion, etc.
  - In operation in Jan. 2015 for 2km-LFM, plan to be used for 5km-MSM in 2016
- Physics Library: developing since 2010
  - Repository for various subroutines related to physical processes with unified coding and interface rules
  - Allows physical processes to be shared among various forecast models
  - More efficient development environment due to the simpler code structures
  - In operation in Jan. 2015 for 2km-LFM, plan to be used for 5km-MSM in 2016
- ASUCA-Var: 3D and 4D variational DA system based on ASUCA: developing since 2011
  - Collaborative development of Non-linear, Tangent-linear and Adjoint models by numerical modelling and assimilation scientists
    - NL, TL, AD codes are written in a same Fortran module.
  - 4D-Var system is under development.
  - 3D-Var is in operation in Jan. 2015, 4D-Var will be in operation in FY2016

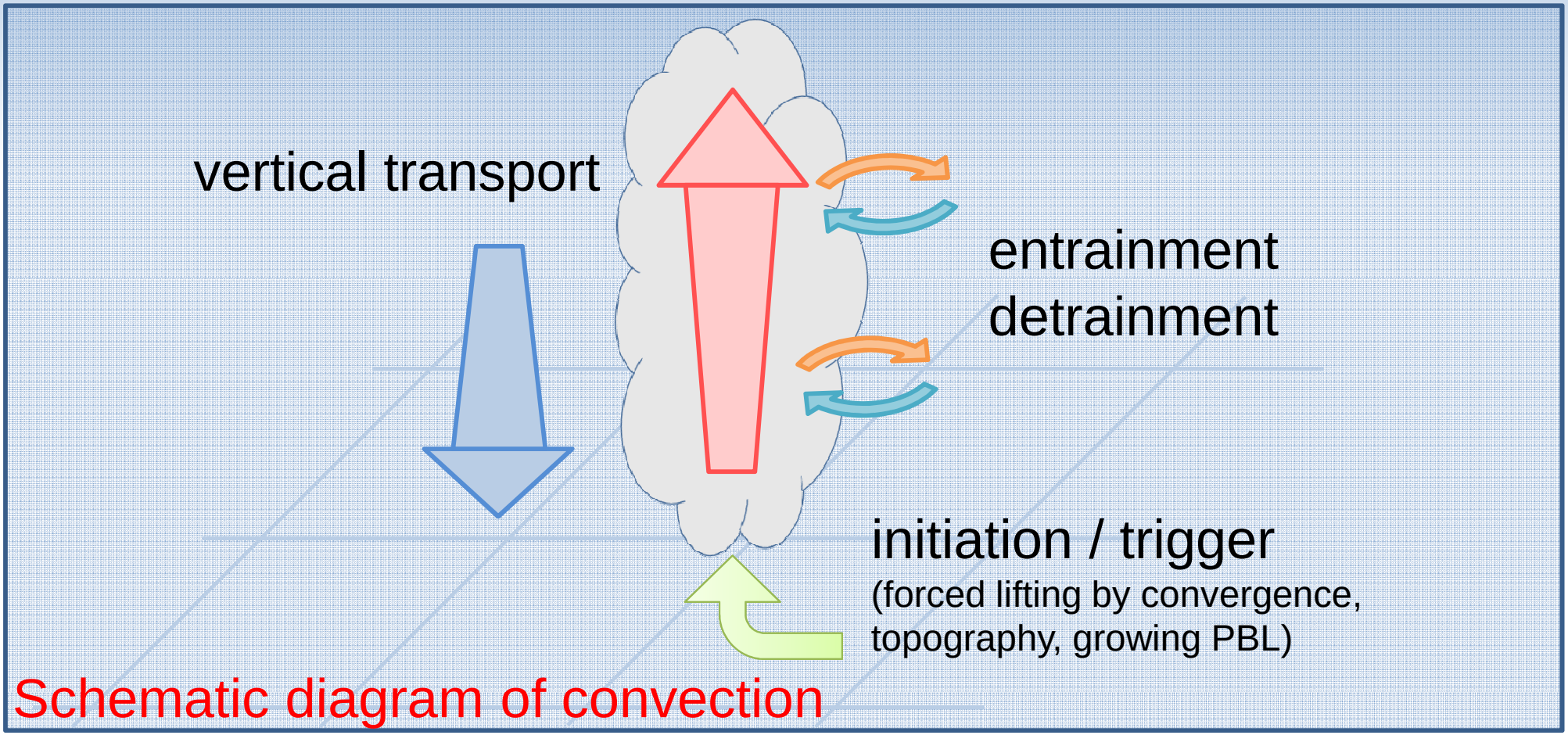
# Upgrade of 2km-LFM

- The new frameworks have replaced previous generation system (JMA-NHM and JNoVA 3D-Var) since January 2015.
- Following upgrades are developed by using them.
  - Dynamics (ASUCA)
    - Finite Volume Method
    - Runge-Kutta 3 steps time integration (Wicker and Skamarock 2002)
    - Split explicit treatment for sound and gravity waves
    - Optimisation
  - Physics (Physics Library)
    - Improved PBL scheme (Mellor Yamada Nakanishi Niio Level 3)
    - Implicit coupling of boundary layer and surface flux scheme
    - Tiling surface flux
    - Introduction of parameterization of convective initiation (PI)
  - 3D-Var (ASUCA-Var)
    - Soil temperature and moisture as new control variables
    - Optimisation

# Comparison of the specification of the dynamical core between ASUCA and JMA-NHM

| | ASUCA | JMA-NHM |
|---|---|---|
| Governing equations | Flux form<br>Fully compressible equations | Quasi flux form<br>Fully compressible equations |
| Prognostic variables | ρu, ρv, ρw, $\rho\theta_m$, ρ | ρu, ρv, ρw, θ, p |
| Spatial discretization | Finite volume method | Finite difference Method |
| Time integration | Runge-Kutta 3rd<br>(long and short) | Leapflog with time filter (long)<br>Forward backward (short) |
| Treatment of sound | Conservative Split explicit | Split explicit |
| Advection | Combining 3rd and 1st order upwind with flux limiter by Koren(1993) | 4th (hor.) and 2nd(ver.) order with advection correction |
| Numerical diffusion | None | 4th order linear and nonlinear diffusion |
| Treatment of rain-drop | Time-split | Box-Lagrangian |
| Coordinate | Generalized coordinate or<br>Conformal mapping + Hybrid-Z | Conformal mapping (hor.)<br>Hybrid – Z (ver.) |
| Grid | Arakawa-C (hor.)<br>Lorentz (ver.) | Arakawa-C (hor.)<br>Lorentz (ver.) |

# Parameterization for convective initiation(PI)

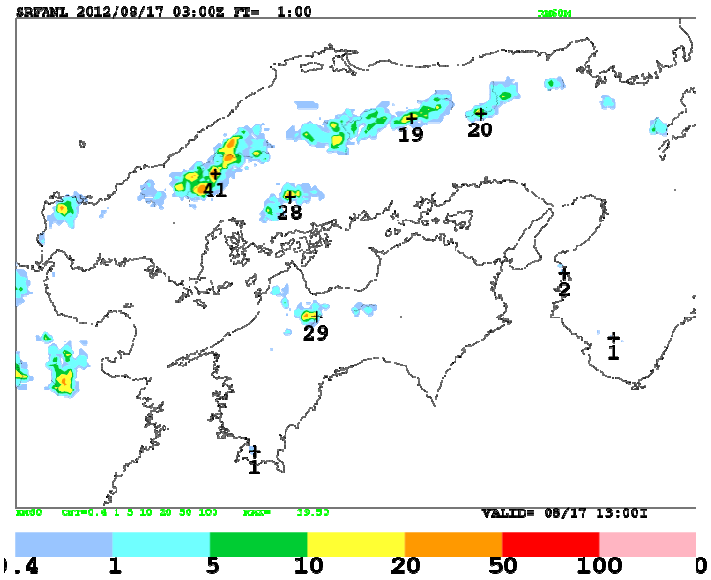



Based on the existing KF scheme, but assuming slower convective stabilization; tendency from convective process is much smaller than the original scheme
Weak vertical transport of heat and moisture and release of latent heat produce local low pressure area which promotes convection by dynamical process.

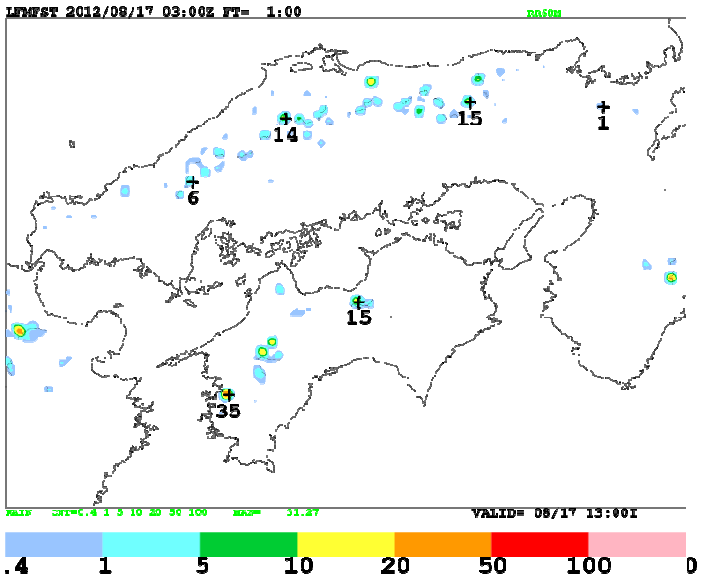
- Improvement of convective initiation

2012/08/17 03UTC initial T+1 (13:00 at local time)

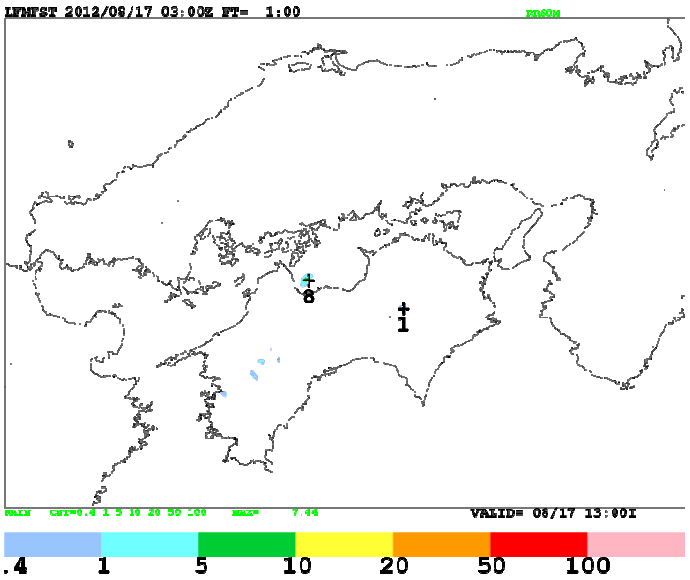
Observation




ASUCA




JMA-NHM

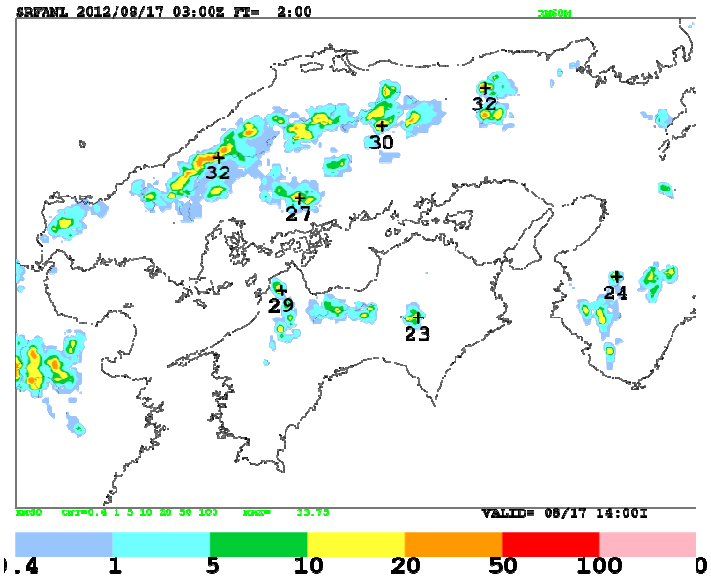



ASUCA improves initiation of convection, while JMA-NHM shows significant spin-up problem of precipitation.

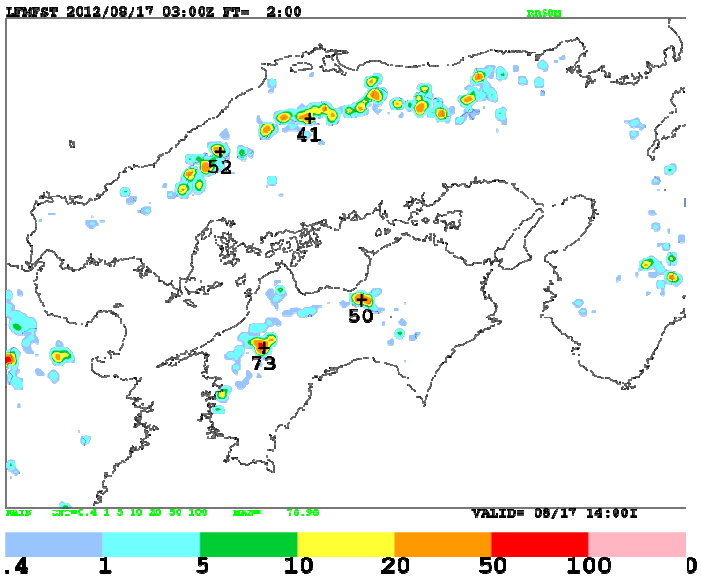
- Improvement of convective initiation

2012/08/17 03UTC initial T+2 (14:00 at local time)

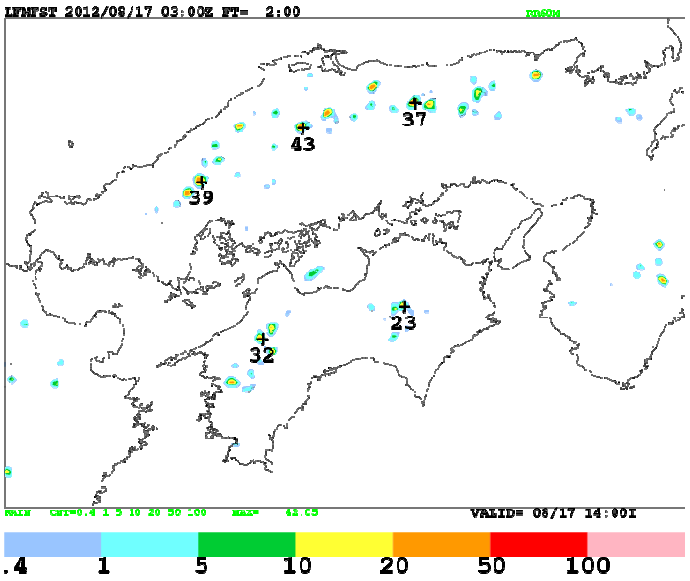
Observation




ASUCA



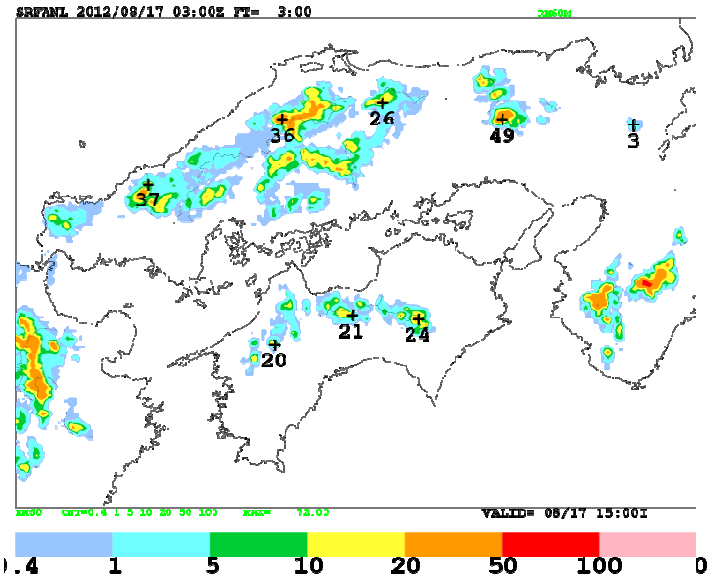

JMA-NHM



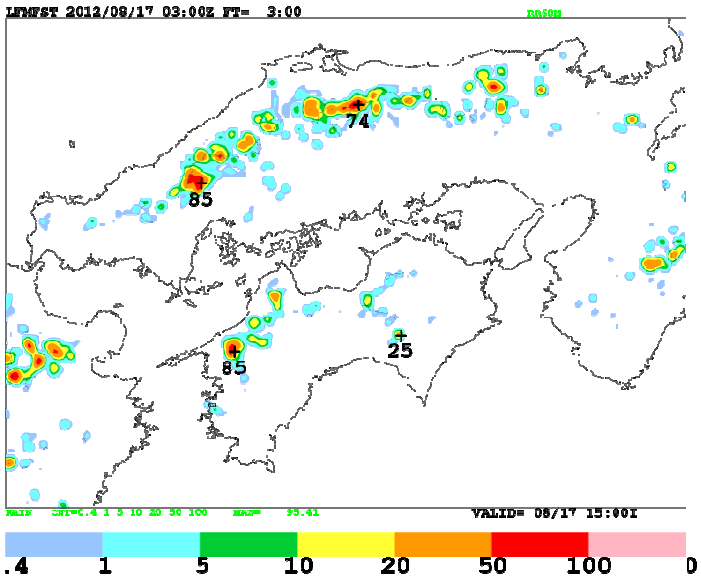
- Improvement of convective initiation

2012/08/17 03UTC initial T+3 (15:00 at local time)

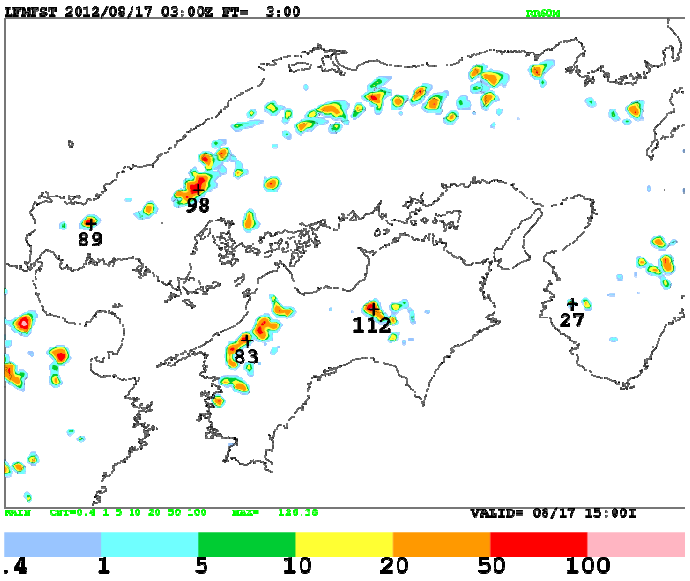
Observation




ASUCA



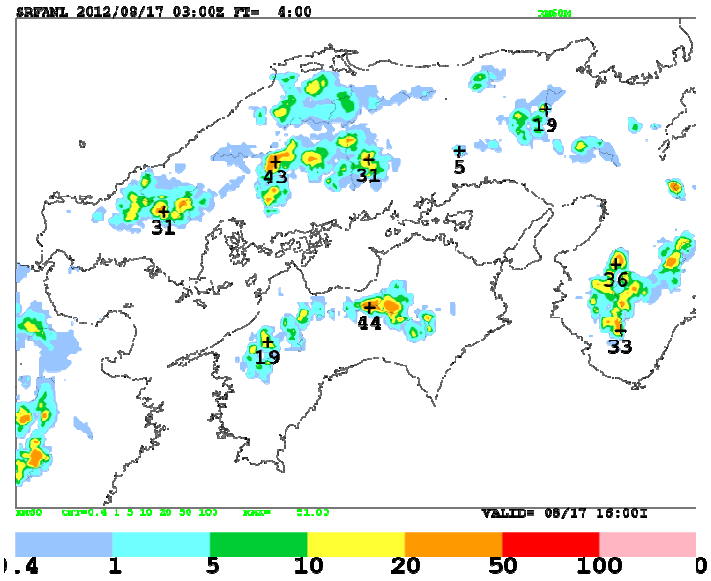

JMA-NHM



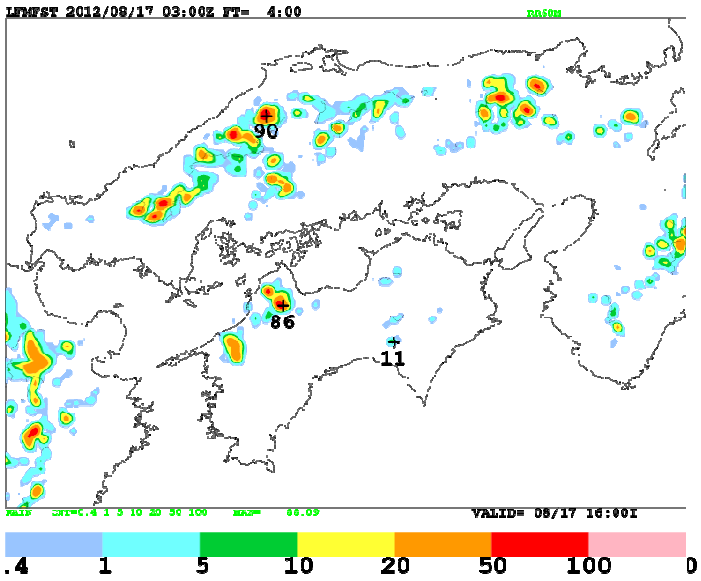
- Improvement of convective initiation

2012/08/17 03UTC initial T+4 (16:00 at local time)

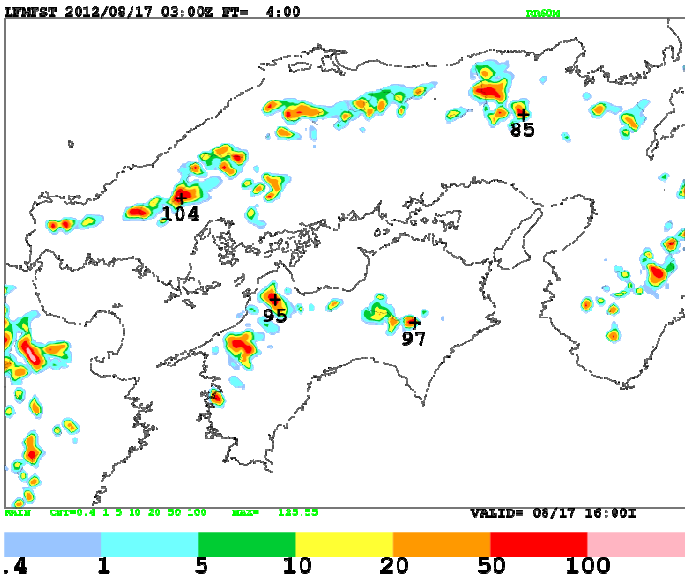
Observation




ASUCA



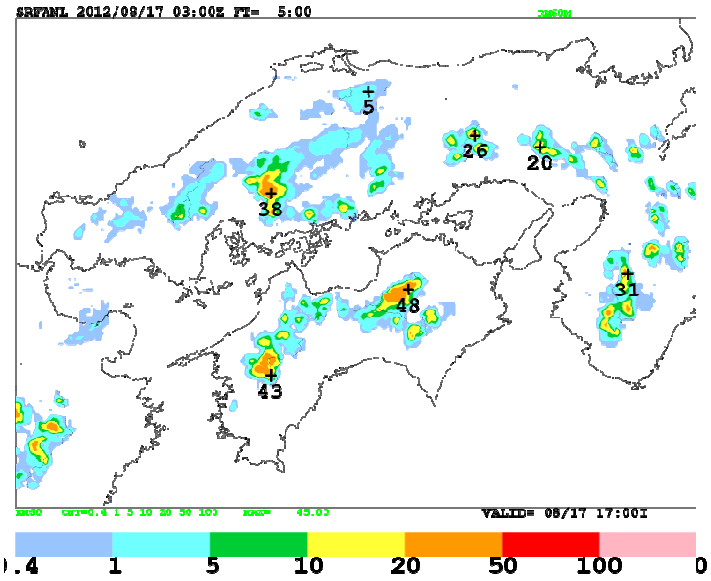

JMA-NHM



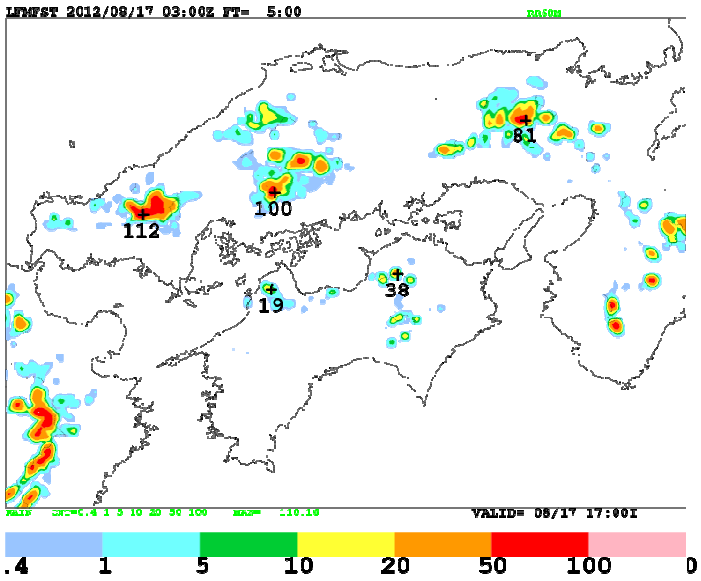
- Improvement of convective initiation

2012/08/17 03UTC initial T+5 (17:00 at local time)

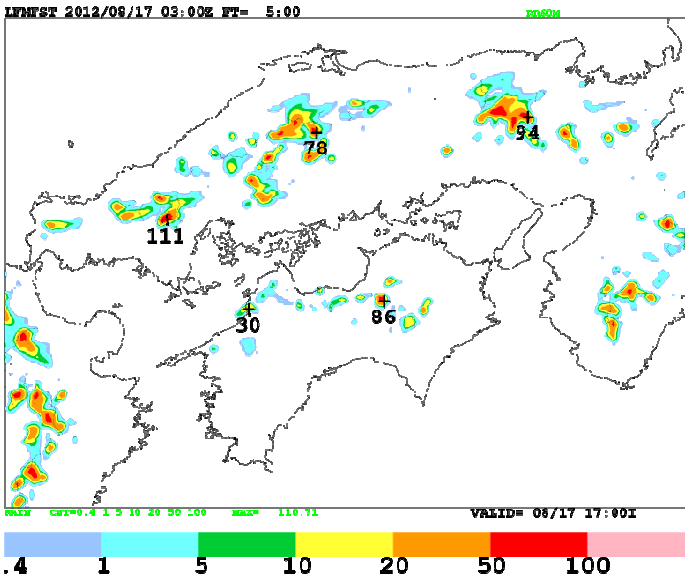
Observation




ASUCA



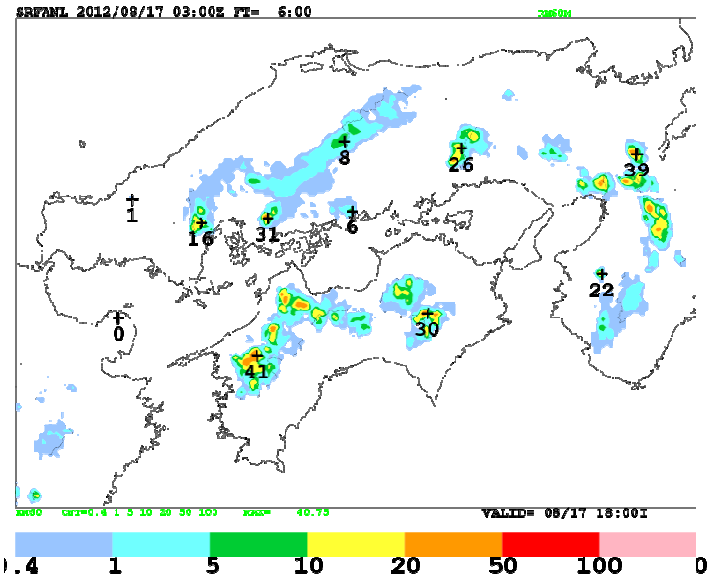

JMA-NHM



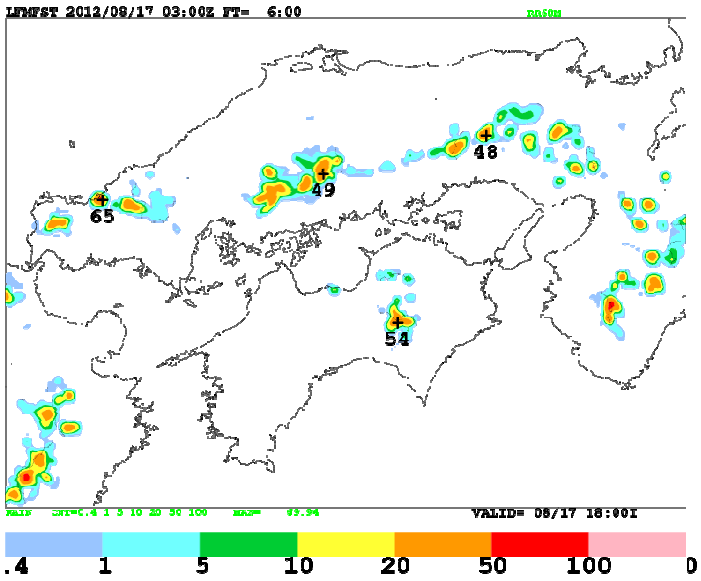
- Improvement of convective initiation

2012/08/17 03UTC initial T+6 (18:00 at local time)

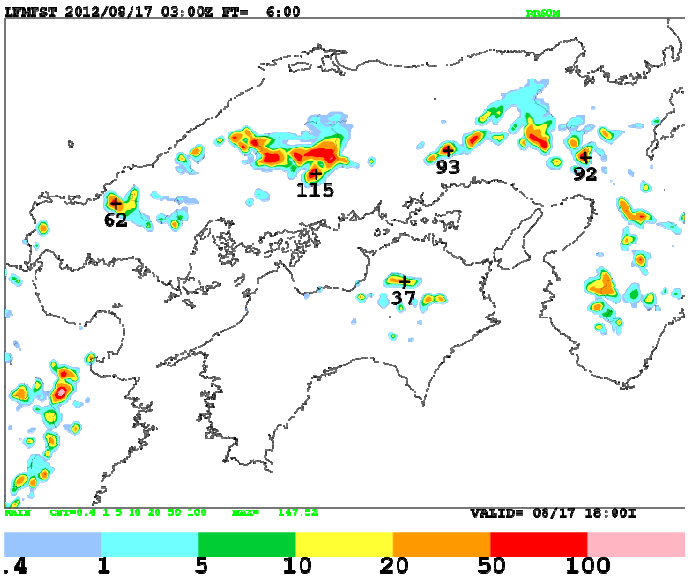
Observation




ASUCA



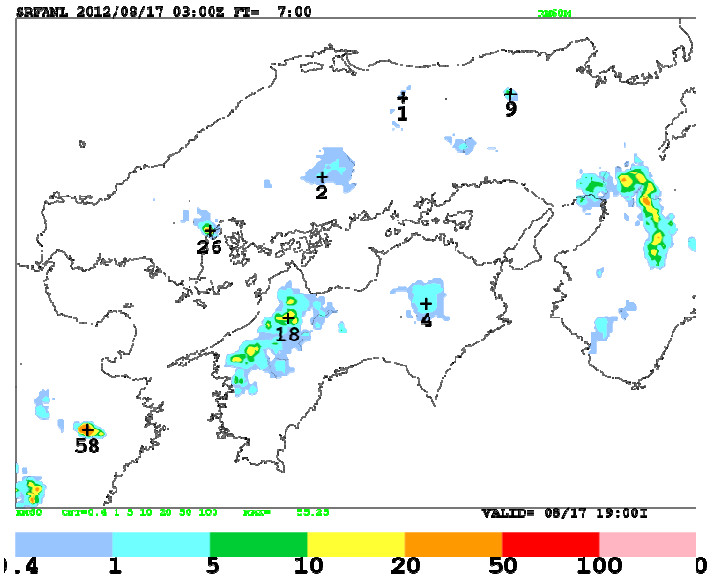

JMA-NHM



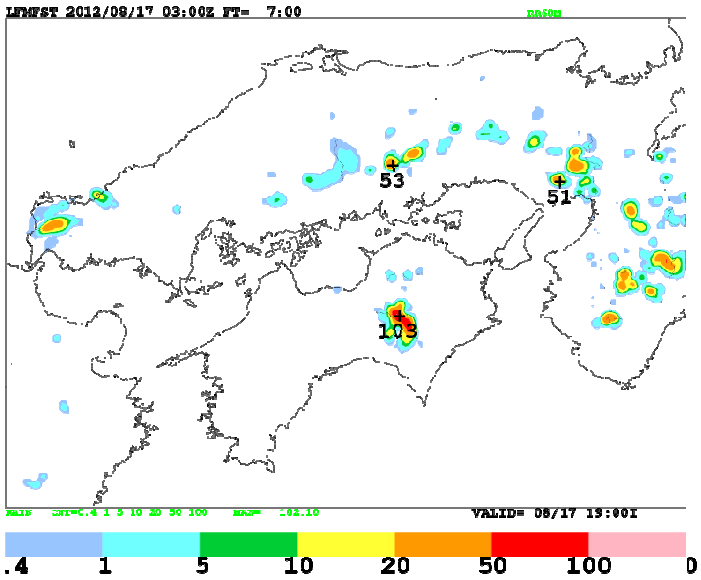
- Improvement of convective initiation

2012/08/17 03UTC initial T+7 (19:00 at local time)

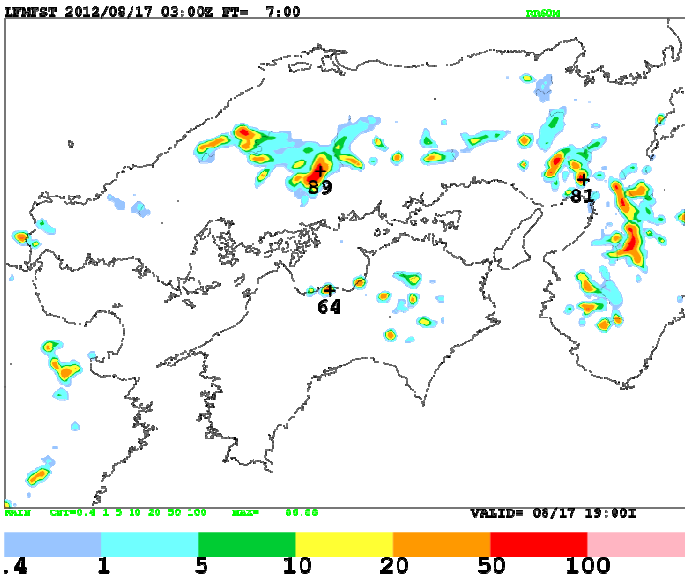
Observation




ASUCA



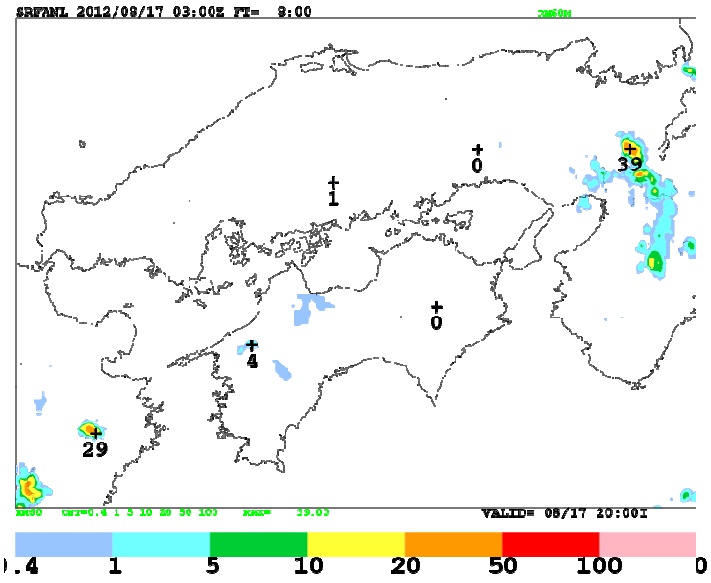

JMA-NHM



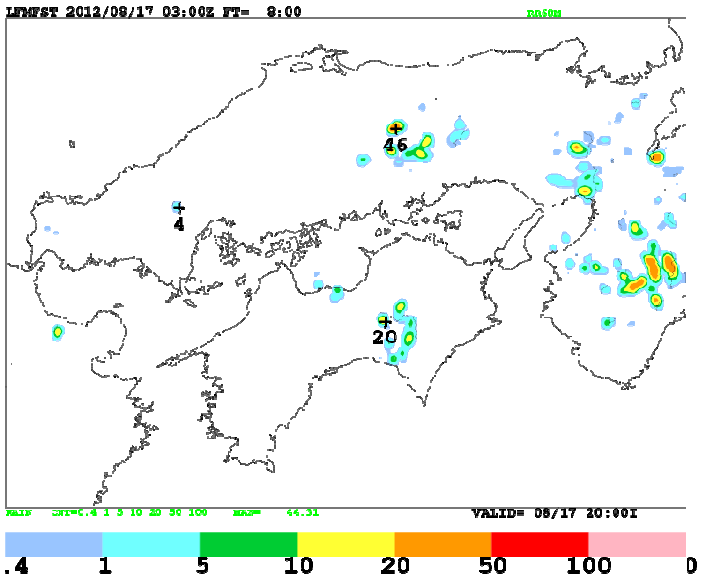
- Improvement of convective initiation

2012/08/17 03UTC initial T+8 (20:00 at local time)

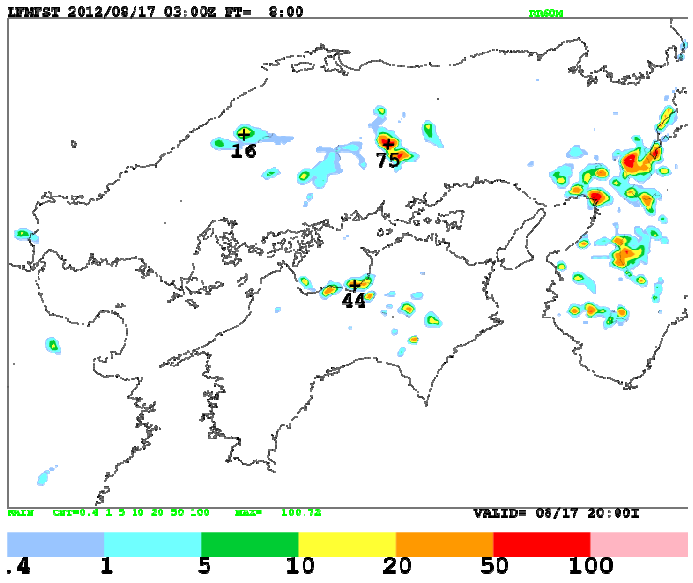
Observation




ASUCA




JMA-NHM

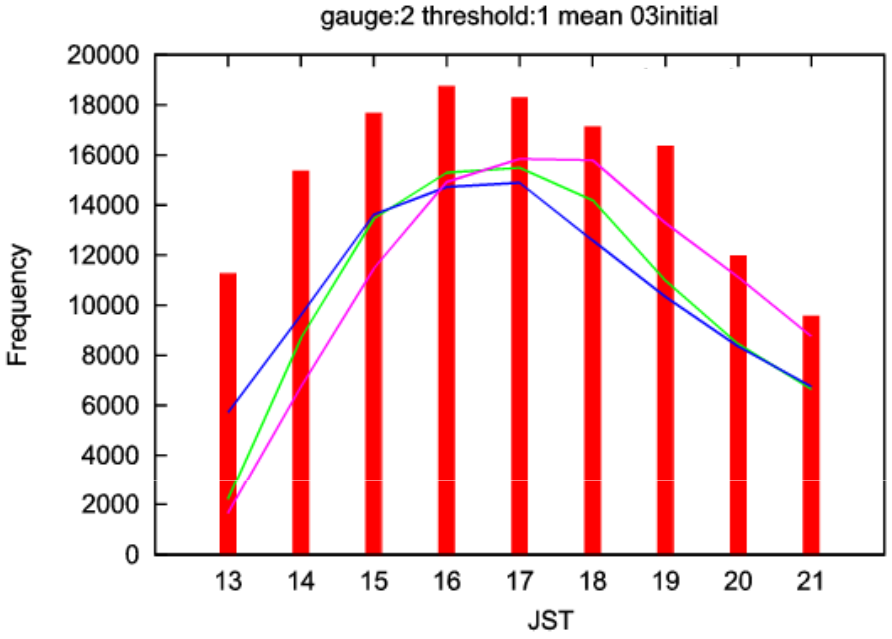



Convective precipitation is almost finished in night. While JMA-NHM still predicts heavy precipitation, ASUCA has improved.

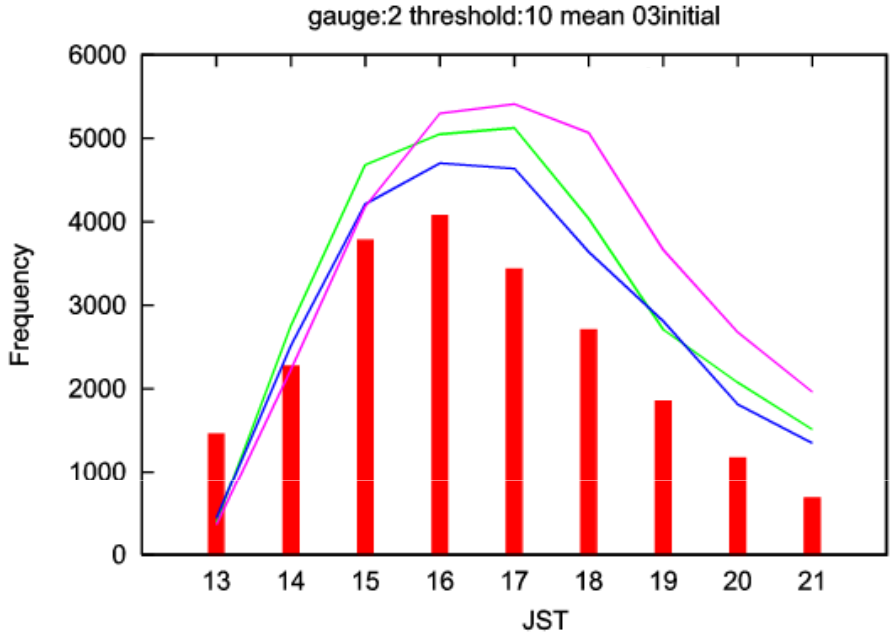
# Time series of precipitation frequency

- Red bars: observation
- Pink lines : previous LFM
- Green Lines: new LFM without PI,  Blue Lines: new LFM with PI

over 1mm/h



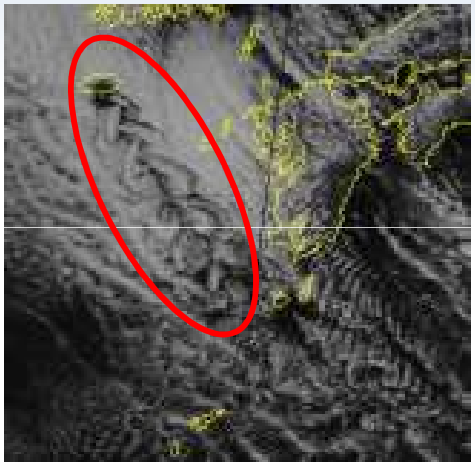

over 10mm/h




Even without PI, new LFM improves peaks of frequency compared with previous LFM. By employing PI, peaks of frequency almost coincide with observed ones, though frequency of prep >= 1mm/h is still too low and that of prep >=10mm/h is still too large

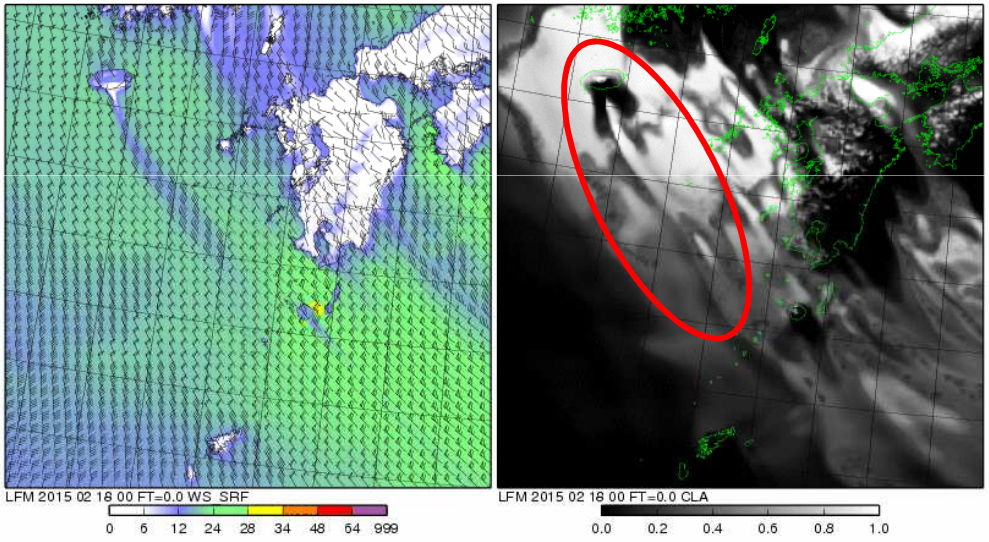
# Karman Vortex Streets

Initial time at 2015/02/18/00UTC (T+0 to T+9)

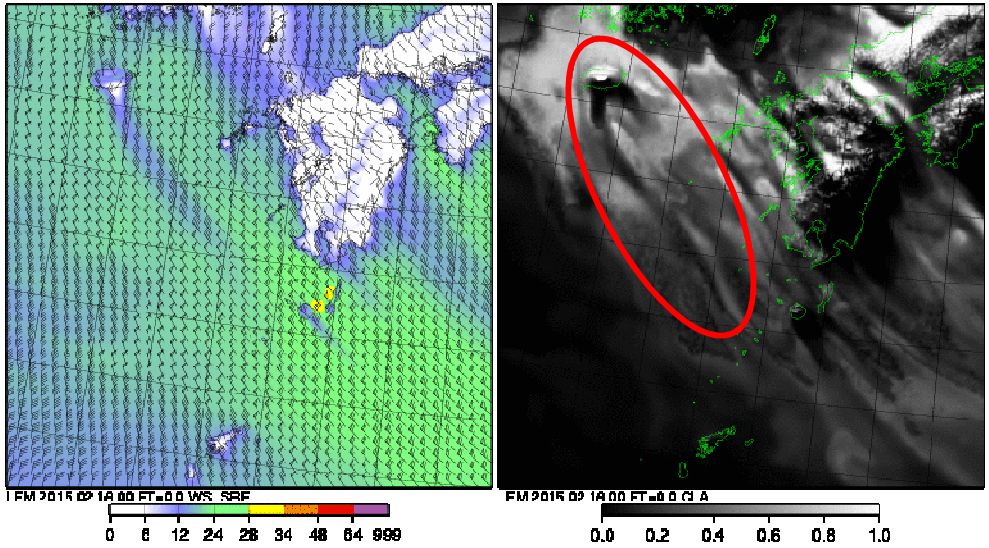


Observation at 2015/02/18/04UTC

Karman vortex streets on the leeside of Jeju island are well reproduced by the ASUCA-based new 2km-LFM.



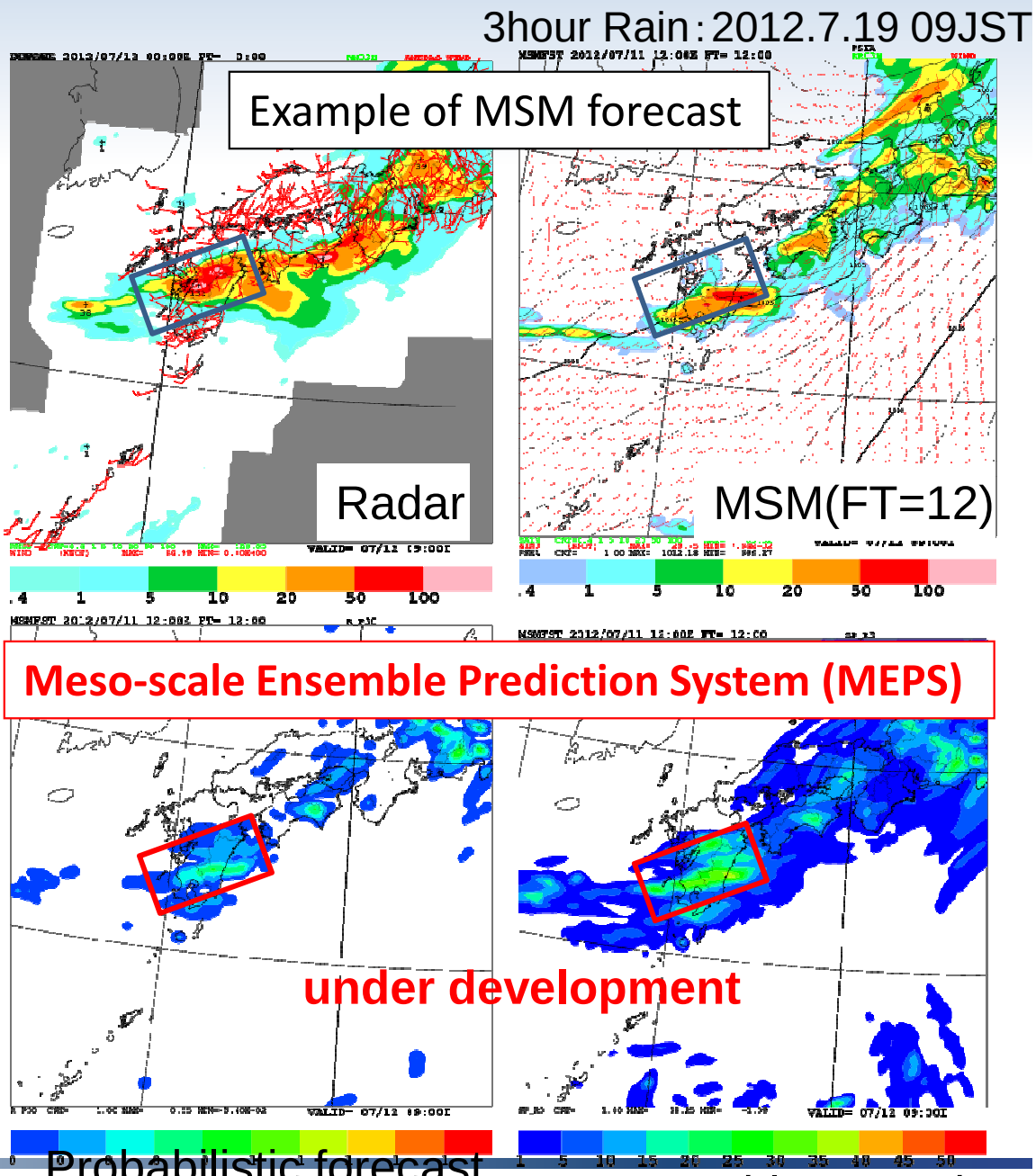

ASUCA-based new 2km-LFM



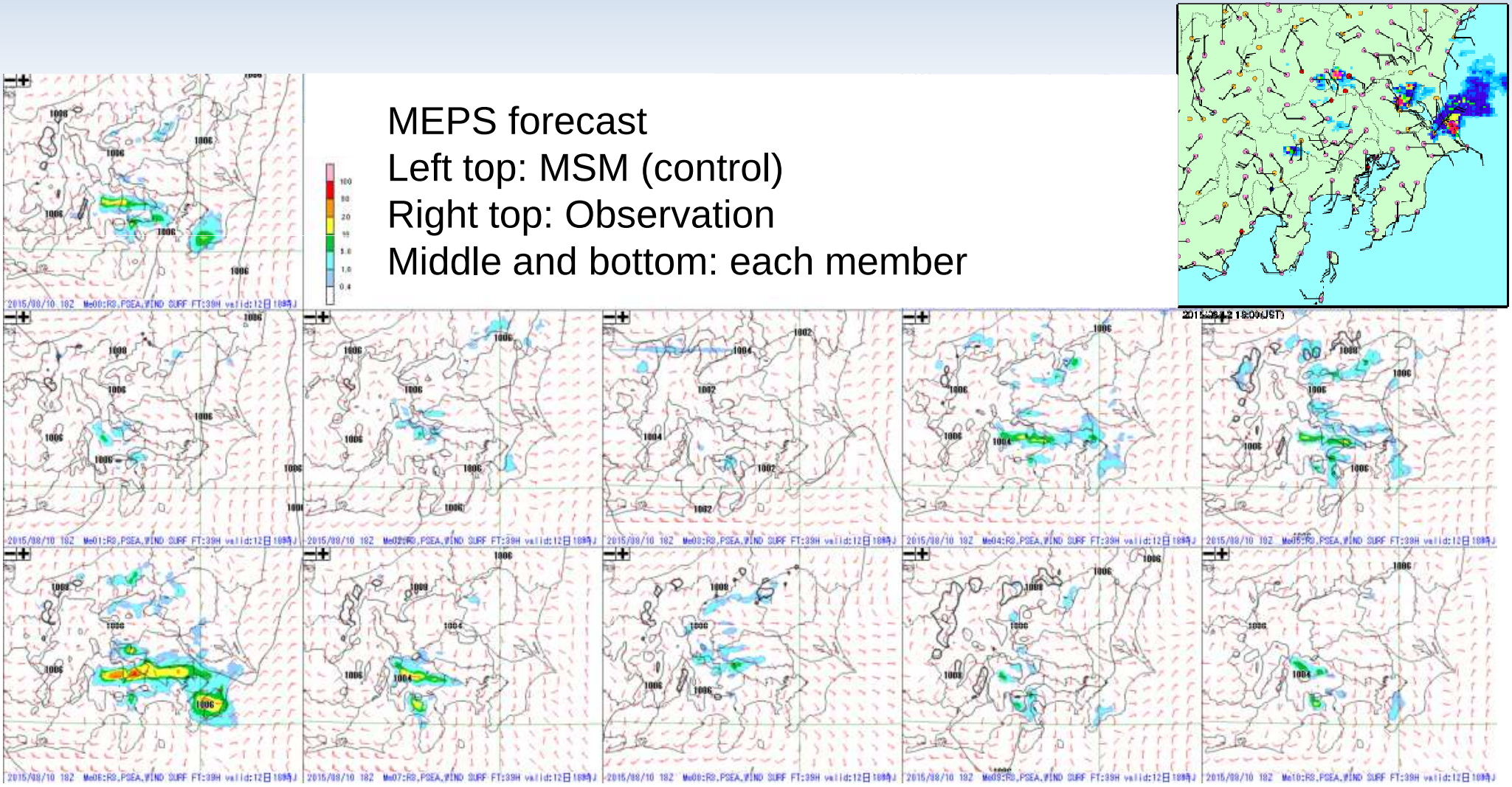

Previous 2km-LFM

# Mesoscale Ensemble Prediction System (MEPS)

- **Purpose**
  - Uncertainty and probability information of MSM
- **Schedule**
  - Test operation started in the March 2015
- **Ensemble forecast**
  - Forecast model : JMA-NHM (Saito et al. 2006)
  - Resolution : 5km
  - Ensemble size: 11
    - 10 perturbed forecasts + 1 control forecast
- **Perturbation**
  - Initial : Singular vector (SV)
    - Blending of Global SV and Regional SV(dx of 40km and 80km)
  - Lateral boundary : Global EPS
    - Based on SV
  - Physics and lower boundary
    - Under development



# A case of heavy rain caused by windshear



MEPS forecast
Left top: MSM (control)
Right top: Observation
Middle and bottom: each member

The scale of the precipitation was so small that 5km-MSM did not reproduce it at all. Though it did not predict the precipitation, MEPS provided information about possibility of windshear generation, which may be useful for forecasters to grasp the heavy precipitation “potential”.

# Future plan and under development

- Plan
  - Full operation on next super computer system
  - Number of members will be increased from 11 to 21
  - Frequency of calculation will be increased from 1 time a day to 4 times a day
- Under development
  - Physics and lower boundary perturbation method
  - Reduction of inconsistency between initial and lateral boundary perturbation
  - Technique to select best (or better) skill member

# Under Development of 5km-MSM

JMA has a plan to introduce ASUCA and Physics Library into 5km-MSM in the first half of the next year.

Following upgrades will be in operation at the same time.

- Dynamics
  - Modification of the treatment of pressure gradient force term
  - Split treatment of vertical advection for higher computational stability
  - Modification of Rayleigh damping near lateral boundary
- Physics
  - New radiation scheme (Delta-Eddington approximation; identical to that of JMA GSM)
  - Implicit treatment of a lot of cloud microphysics processes
  - Modification of mass-size relationship of snow in the cloud microphysics
  - Modification of size distribution of snow particle
  - Implement of sequential time splitting in the cloud microphysics
  - Change treatment of detrainment of KF cumulus parametrization scheme
- System
  - Clean up source code and optimisation

# Future Plan
## - on the current and next super computer system -

- On the current super computer system
  - ASUCA-based 4D-Var (plan to be in operation in FY2016)
- On the next super computer system
  - Raising MSM model top height (from about 22km to about 37km (5hPa))
  - Increasing vertical resolution of MSM (from L76 to L96)
  - Increasing vertical resolution of LFM (from L58 to L76)
  - Extension of forecast period of LFM from 9 hour to 15 hour
  - Full operation of Meso-EPS
  - Hybrid data assimilation for MSM and LFM