Testing of variable localization with NHM-LETKF

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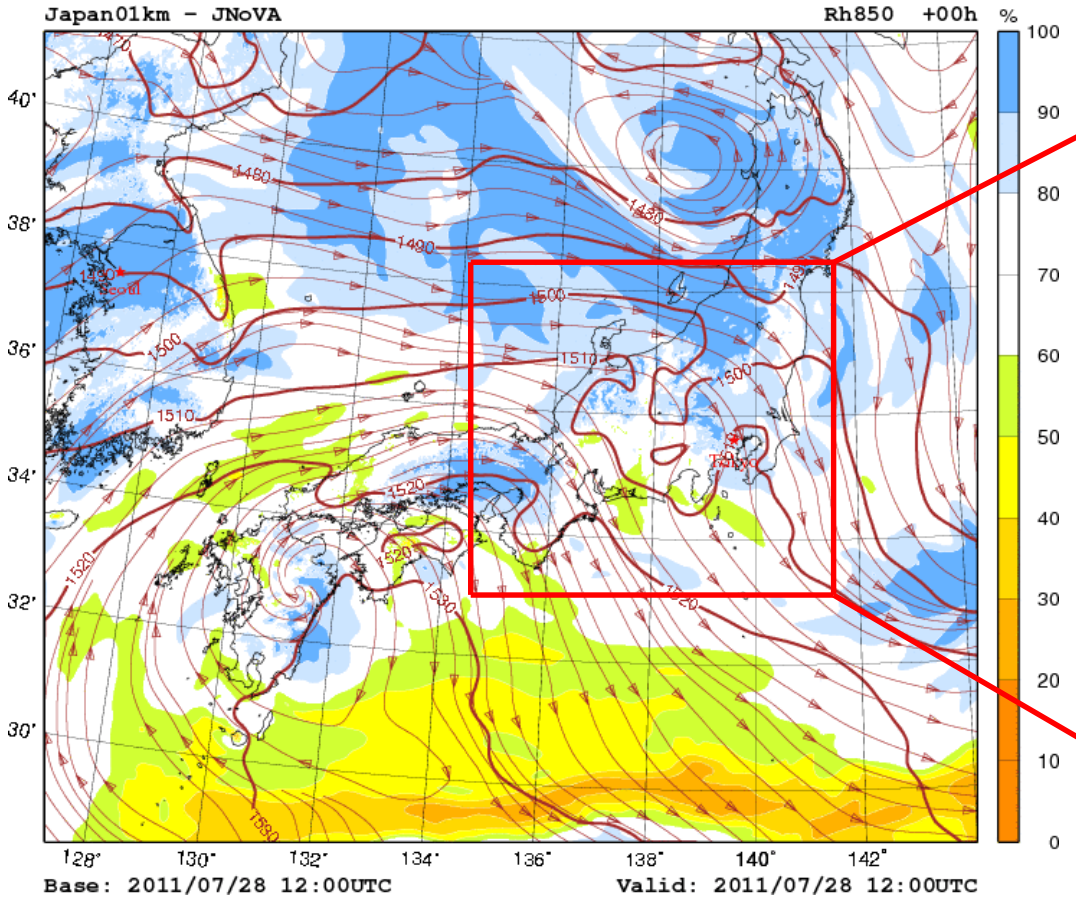
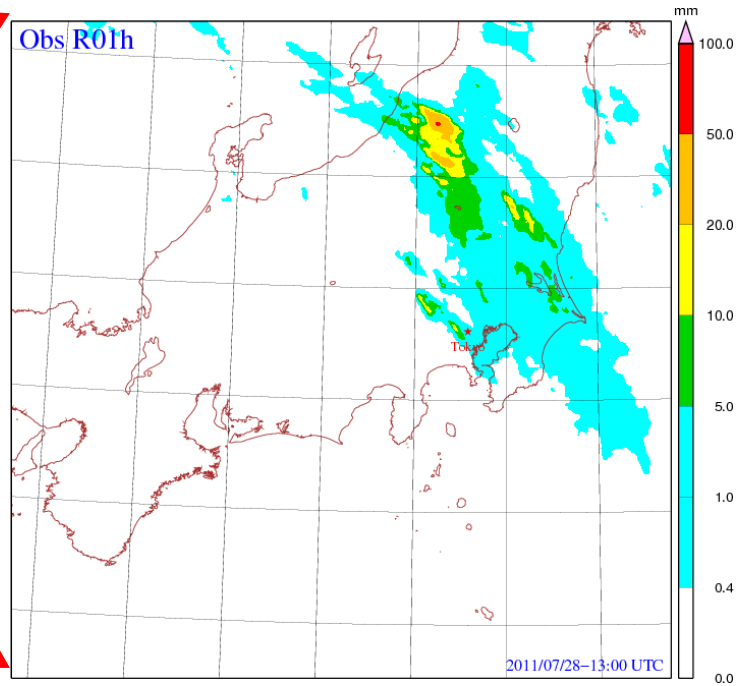
NHM-LETKF

- The NHM-LETKF system originally developed at JMA
- Driving model: JMA-NHM
- Control variables: u, v, t, qv, ps, and gt
- Assimilation method: 4D-LETKF, supporting adaptive inflation, adaptive vertical localisation (precipitation water and radiances), and outer loop as options.
- Observations: the same observation types and quality control programs as JNoVA

Niigata-Fukushima heavy rainfall 28-30/07/2011



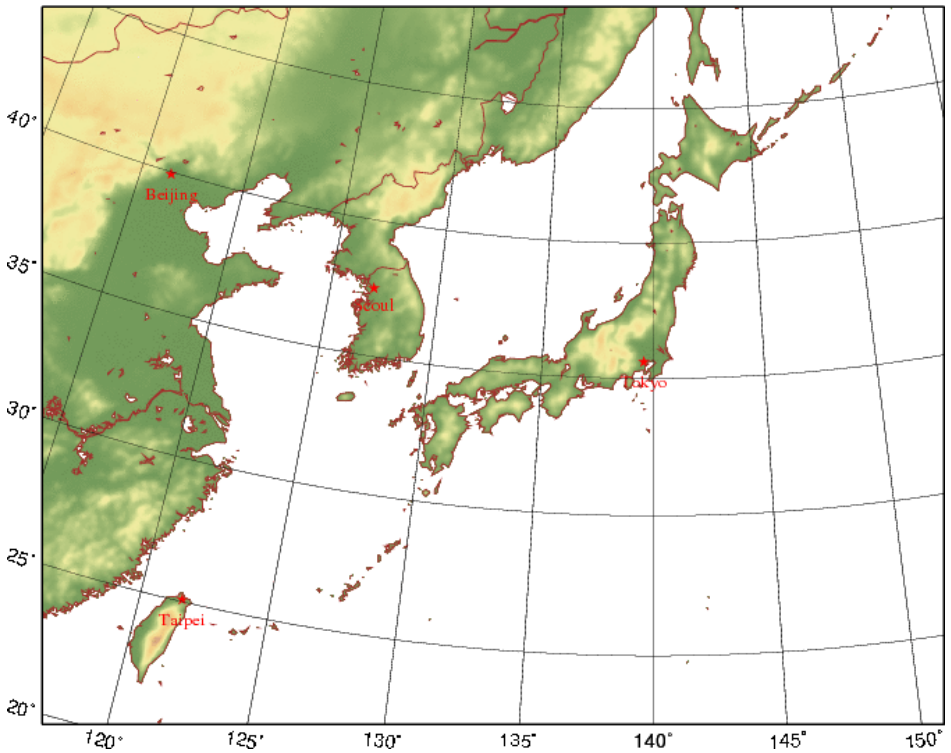


R/A observations

JNoVA analysis at 12UTC-28/07/2011

Experimental settings

- Time: 12UTC-26/07/2011 to 15UTC-28/07/2011
- Cycle: 3 hours
- Domain: 361x289 horizontal grid points, 50 levels, a resolution of 10 km
- Ensemble: 50 members
- Initial seeds: JNoVA analysis + initial perturbations from JMA's one-week EPS
- Boundary conditions: GSM forecasts
- Boundary perturbations: JMA's one-week EPS
- SST perturbations
- Observations: the same as using by JNoVA except precipitation analyses and radar reflectivities



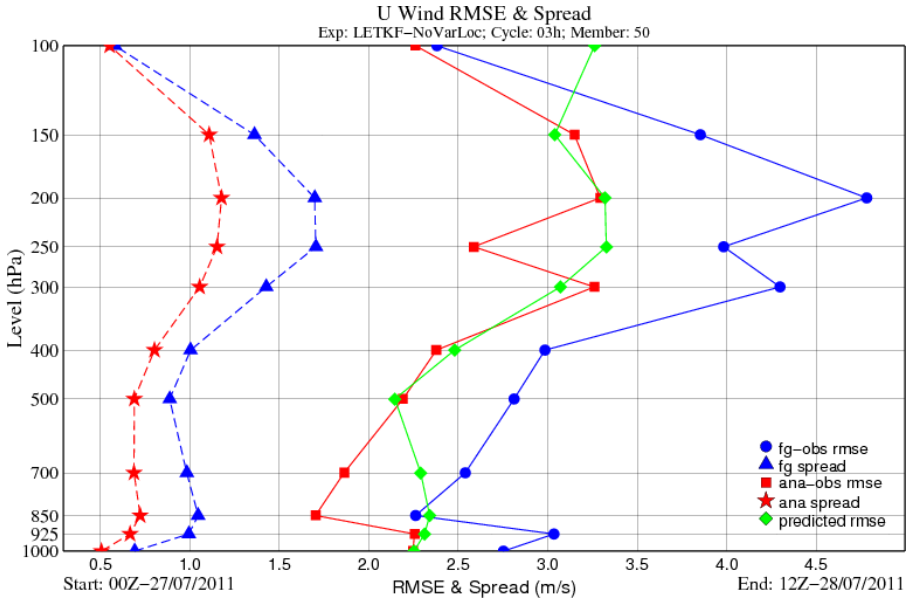
Statistics of innovations

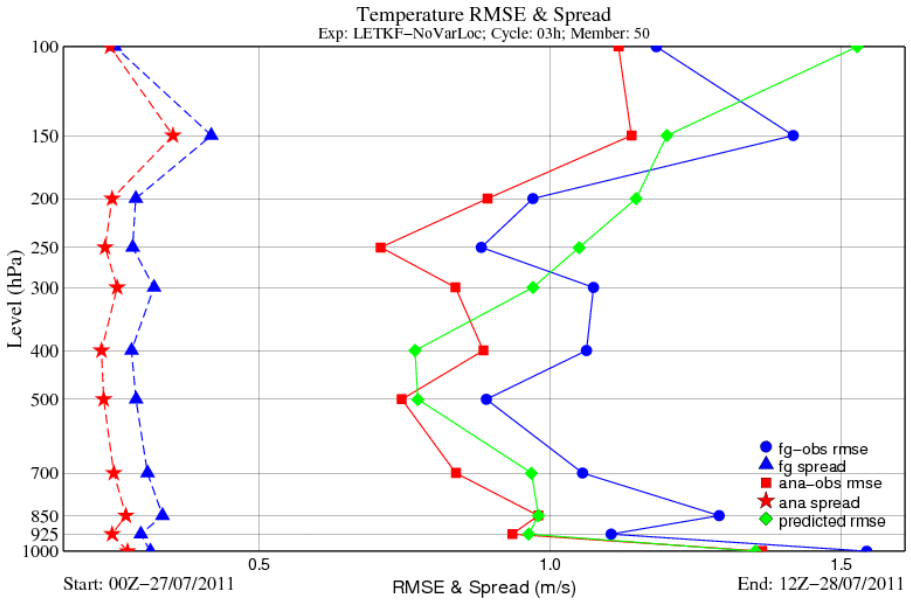
$$\overline{[y - \overline{H(x_f)}][y - \overline{H(x_f)}]^T} = \mathbf{H}P_f\mathbf{H}^T + \mathbf{H}Q\mathbf{H}^T + R$$

Prior RMSE

Predicted RMSE

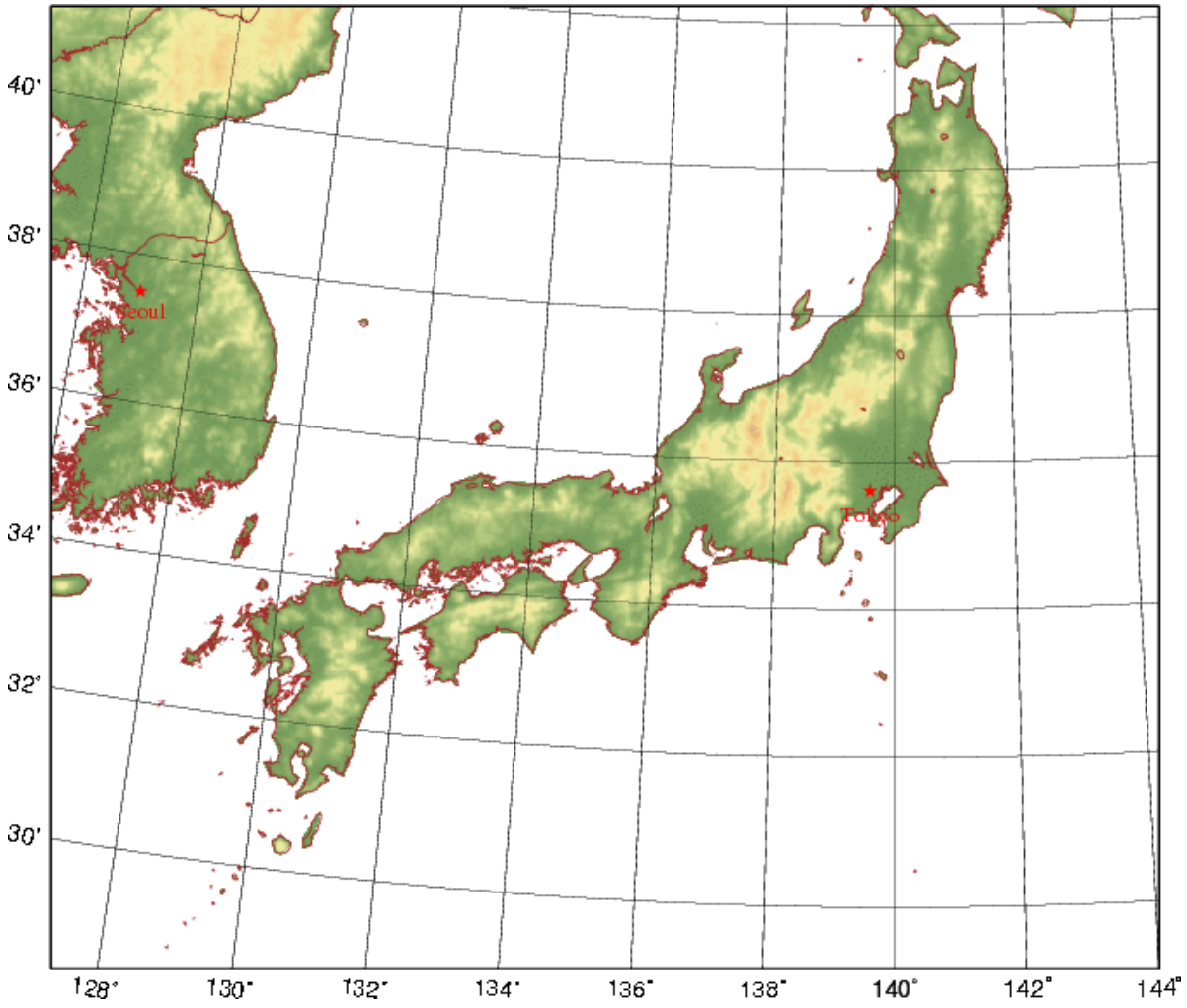
NHM-LETKF uses this equation to estimate Q: adaptive inflation



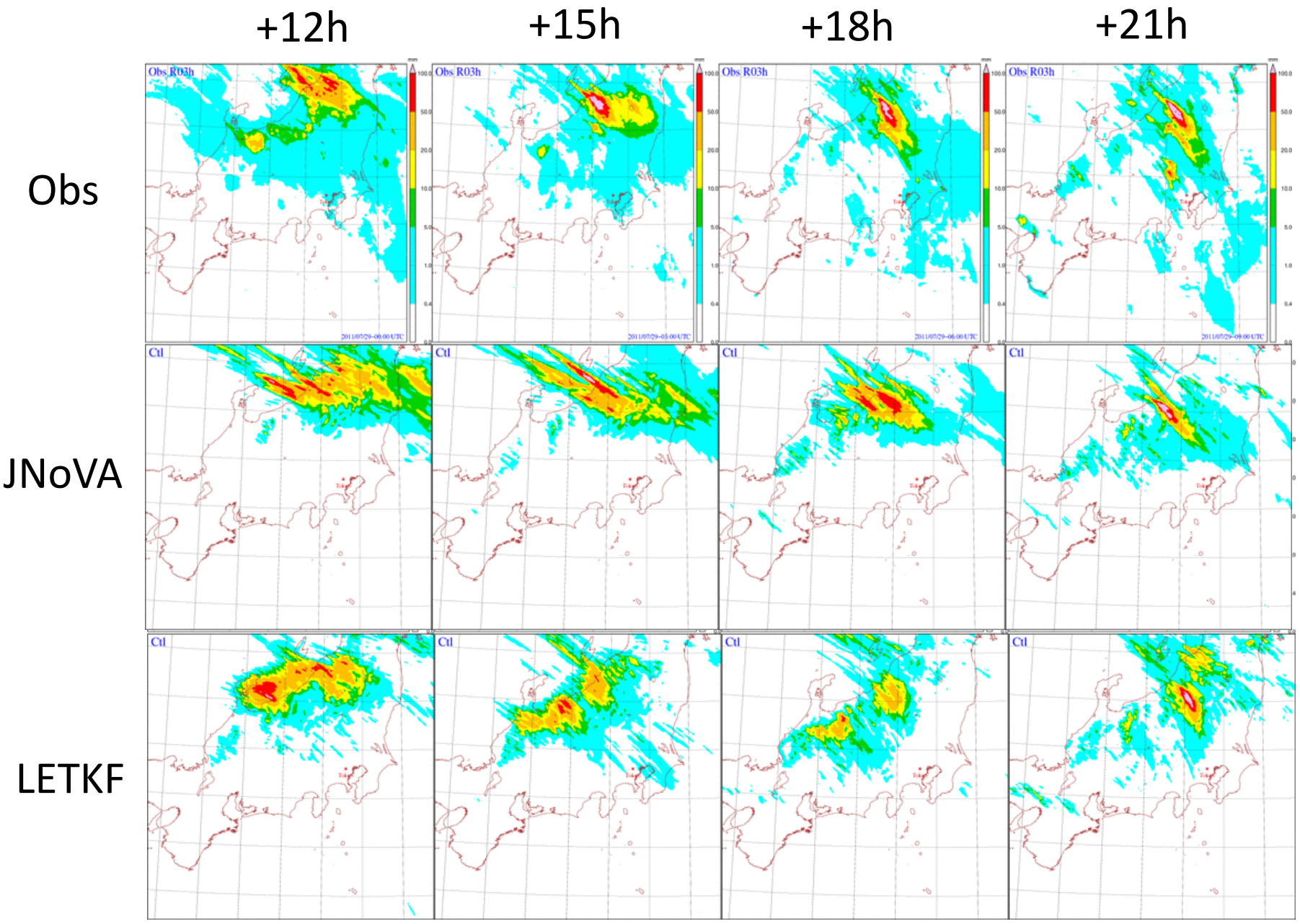


Downscaling experiments

- Domain: 1637x1429 horizontal grid points, 60 levels, a resolution of 1 km
- Forecast range: 30 hours (12UTC-28/07/2011 to 18UTC-29/07/2011)
- Initial condition: JNoVA analysis, NHM-LETKF analysis
- Boundary condition: GSM forecasts
- No cumulus parameterization



Downscaling results



Background correlations

To improve the forecasts, we examined the structure of background error correlations by sampling over forecasts of 50 members of NHM-LETKF and averaging over analysis domain.

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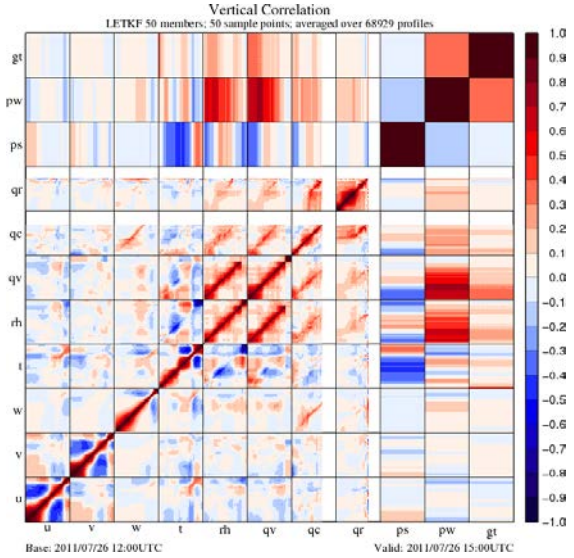

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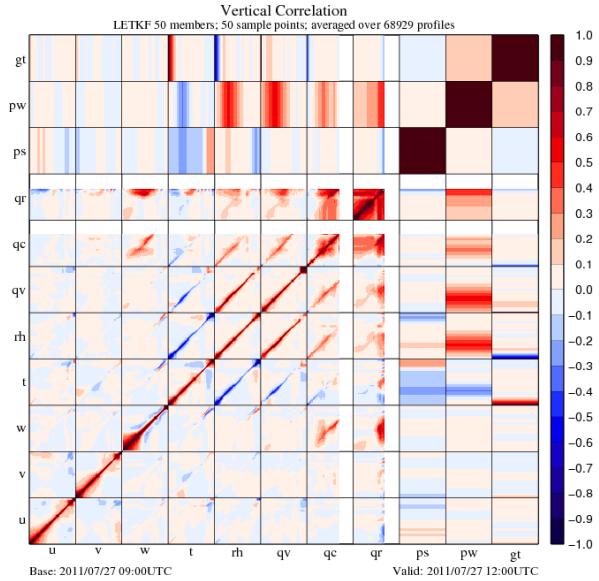

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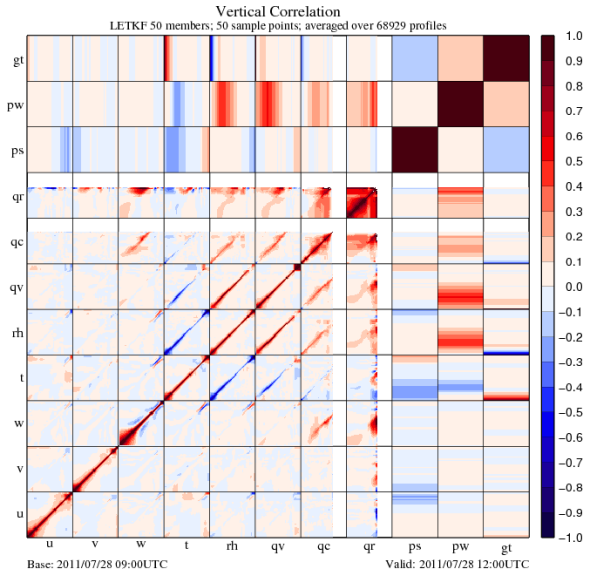
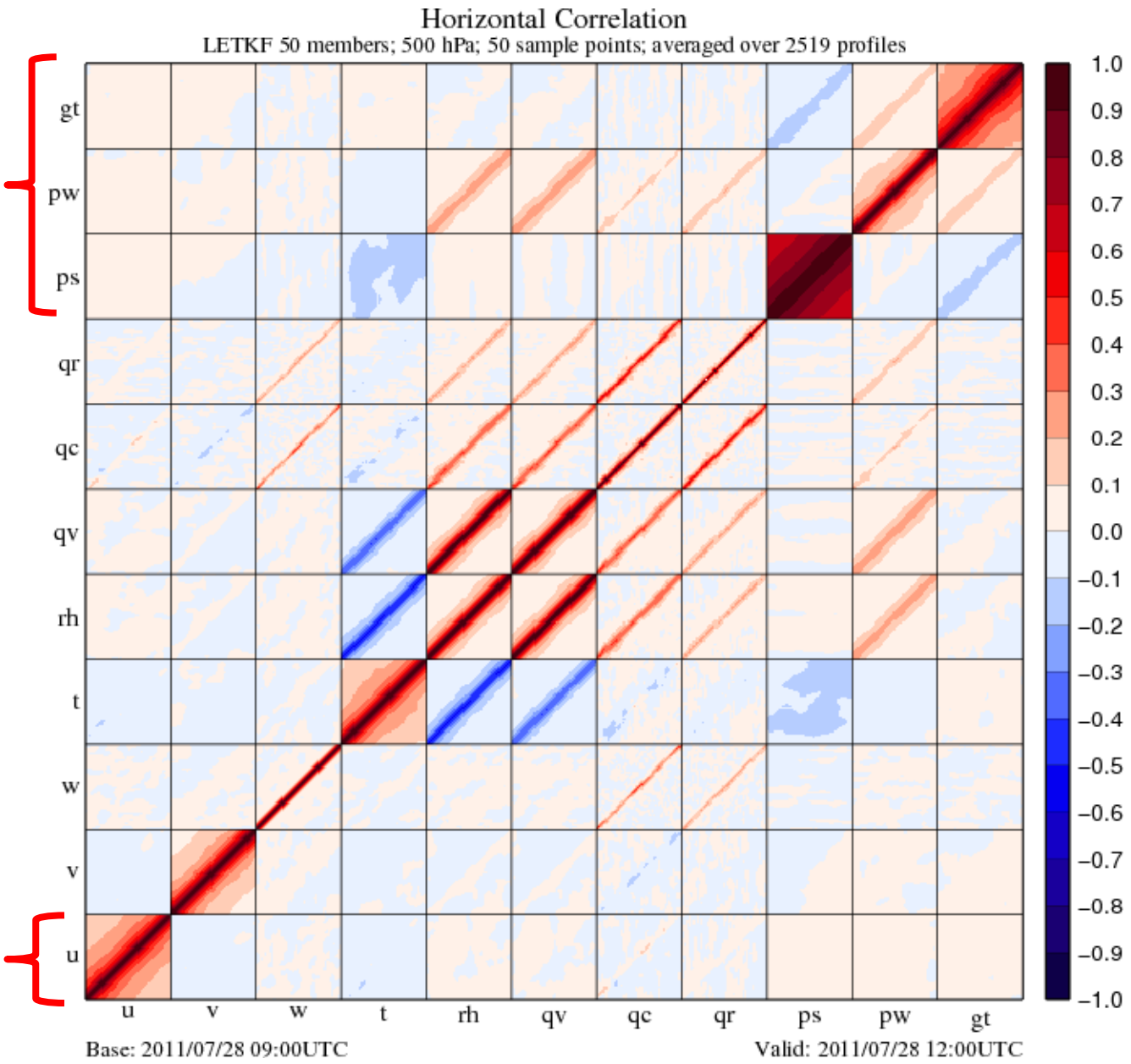


Horizontal correlations

2-dimensional variables

50 sample points, which is equivalent to 500 km

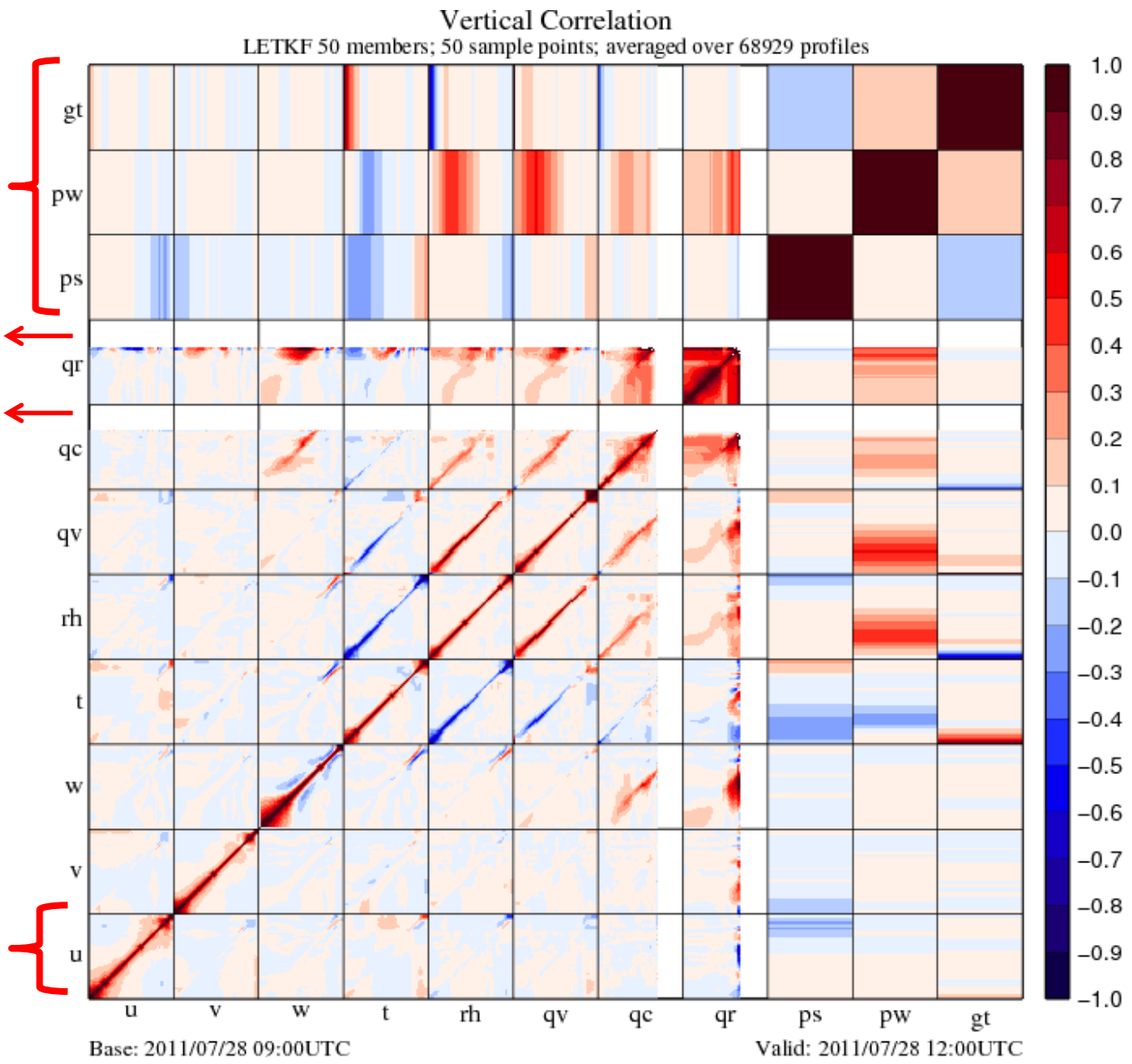


Vertical correlations

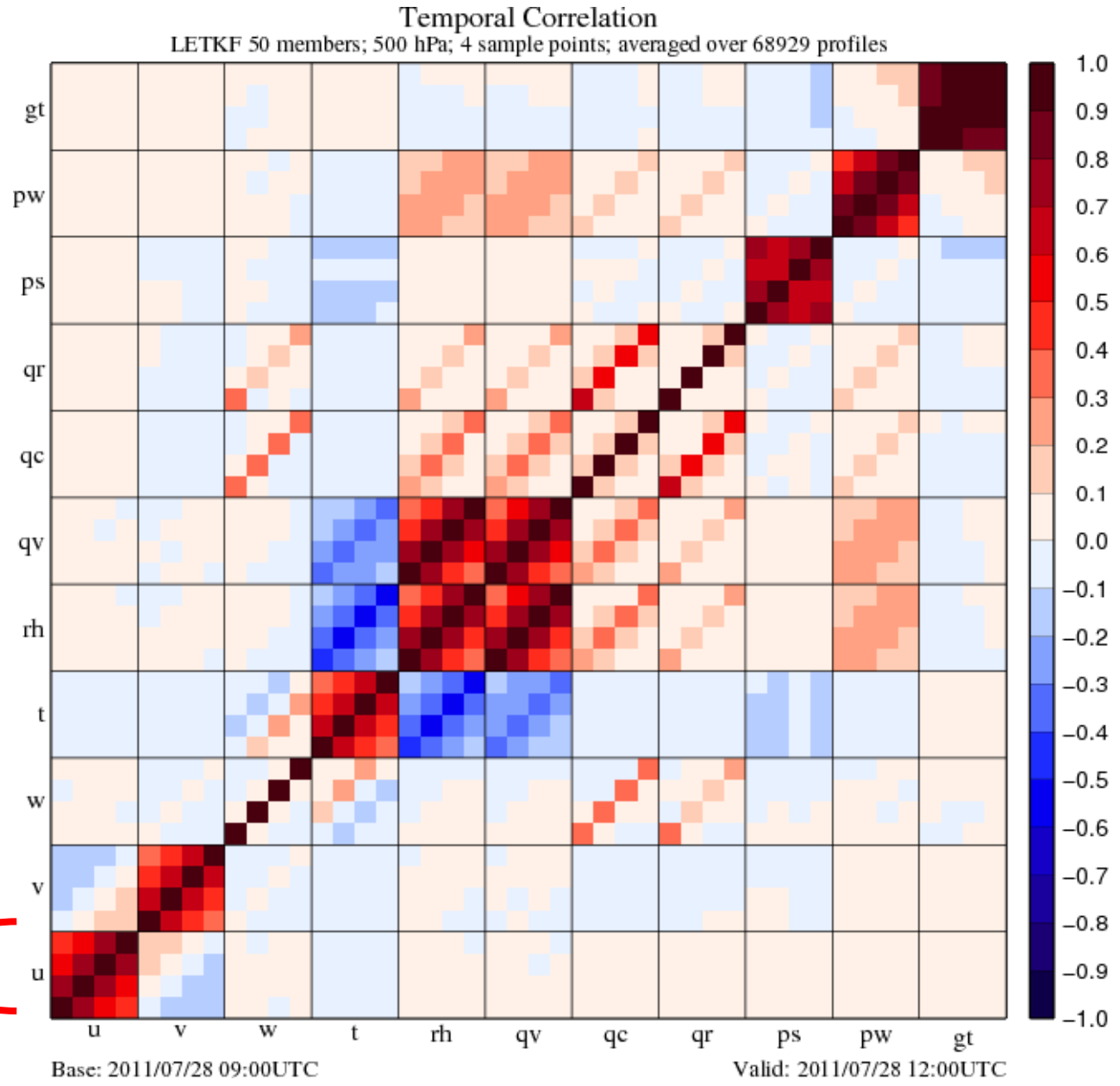
2-dimensional variables: field values are the same for all vertical levels

Undefined since no qc or qr exist here

50 sample points, which is exactly 50 vertical levels



Temporal correlations



4 sample points, which is exactly 4 time slots

Remarks

- There are many weak cross-correlations among control variables and observational variables, which we can consider as spurious correlations.

- The horizontal and vertical localization length scales for moisture variables are smaller than those for wind and temperature. These values are the smallest with hydrometeor variables -> should use different localization volumes for different variables.

- The vertical localization should be applied for 2-d observational variables (ps, pw, gt) in relation with 3-d control variables.

Variable localization

Obs Vars

Control Vars

	uv	T	ps	qv	gt
uv	1	0	0	0	0
T	0	1	1	1	1
rh	0	1	0	1	1
rvl	1	0	0	0	0
ps	0	0	0	0	0
pw	0	1	0	1	0
tb	0	1	0	1	0

Localization length scales (km)

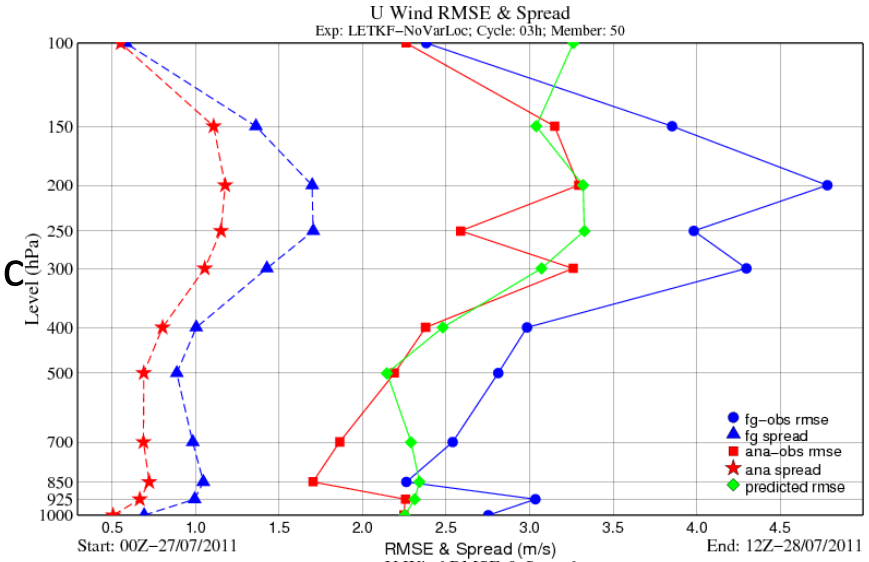
Obs Vars

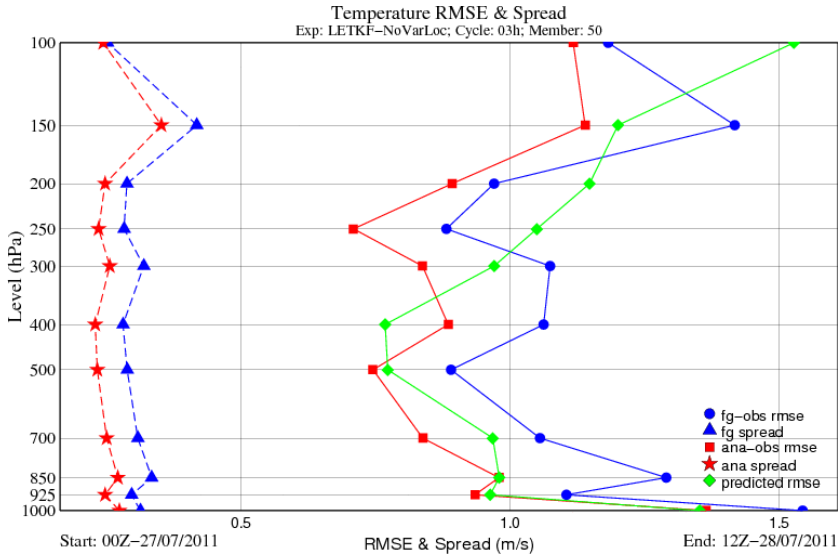
Control Vars

	uv	T	ps	qv	gt
uv	800	0	0	0	0
T	0	800	300	300	800
rh	0	300	0	300	300
rvl	800	0	0	0	0
ps	0	0	0	0	0
pw	0	300	0	300	0
tb	0	800	0	300	0

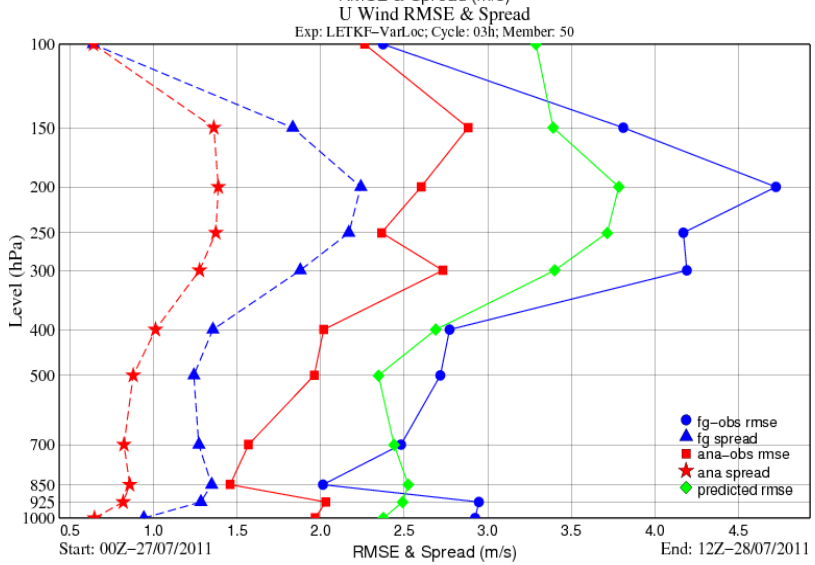
Statistics of innovations

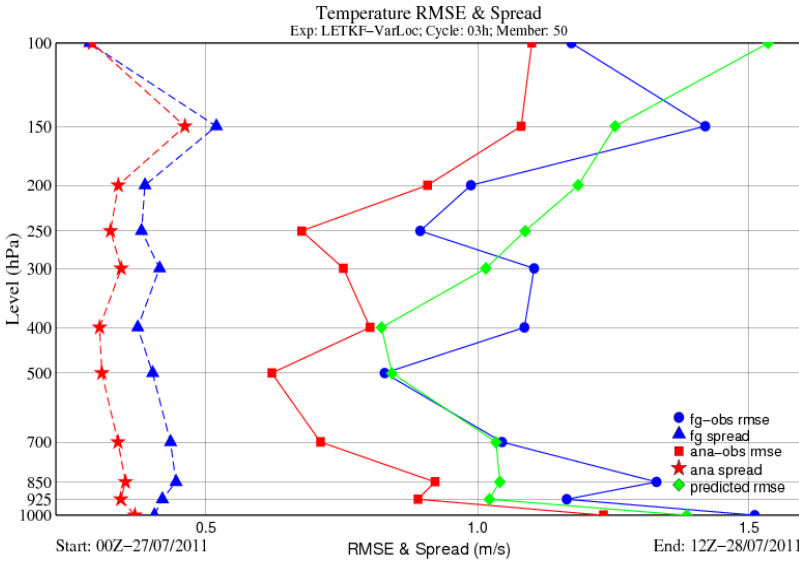
NoVarLoc



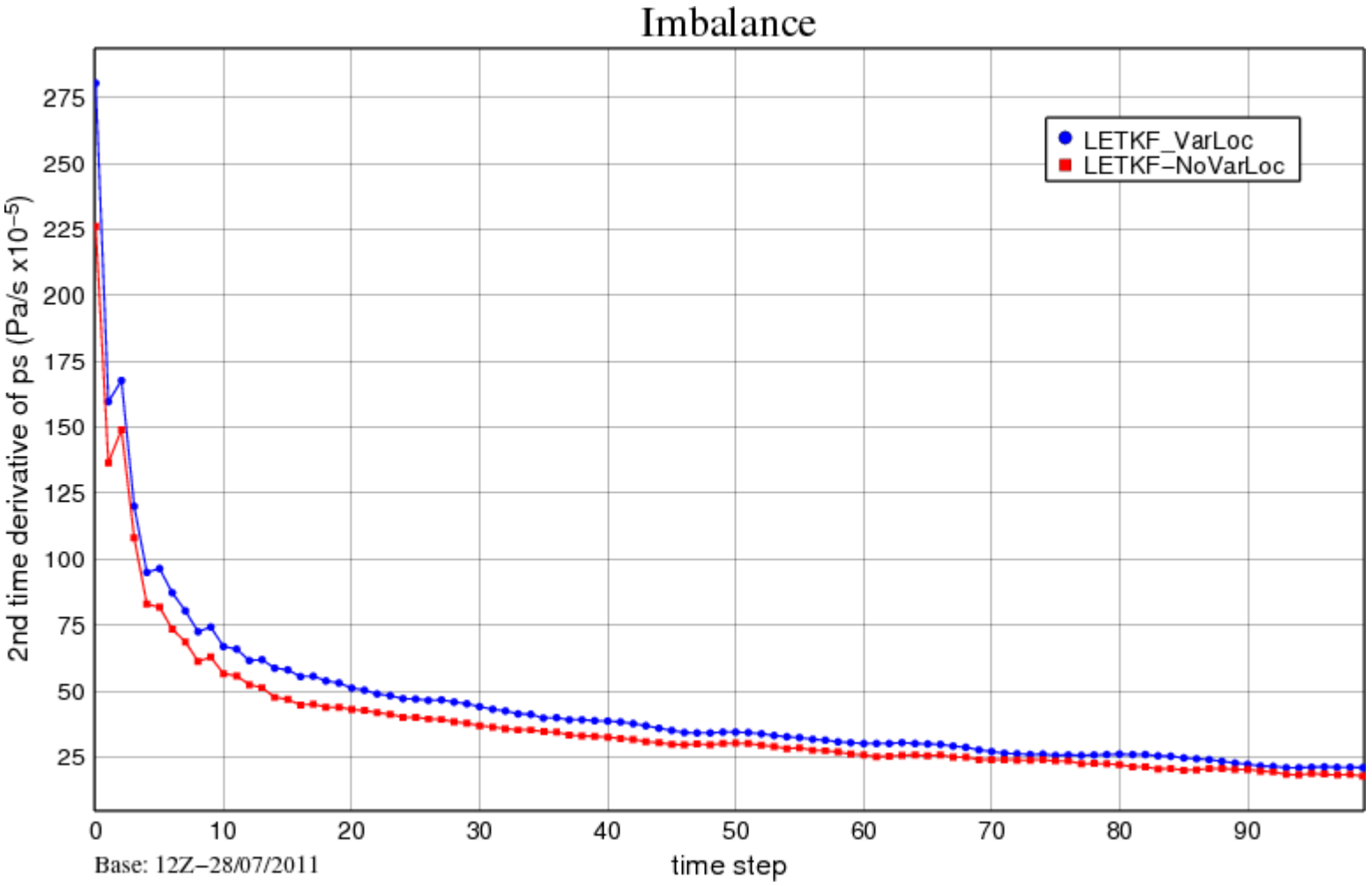


VarLoc



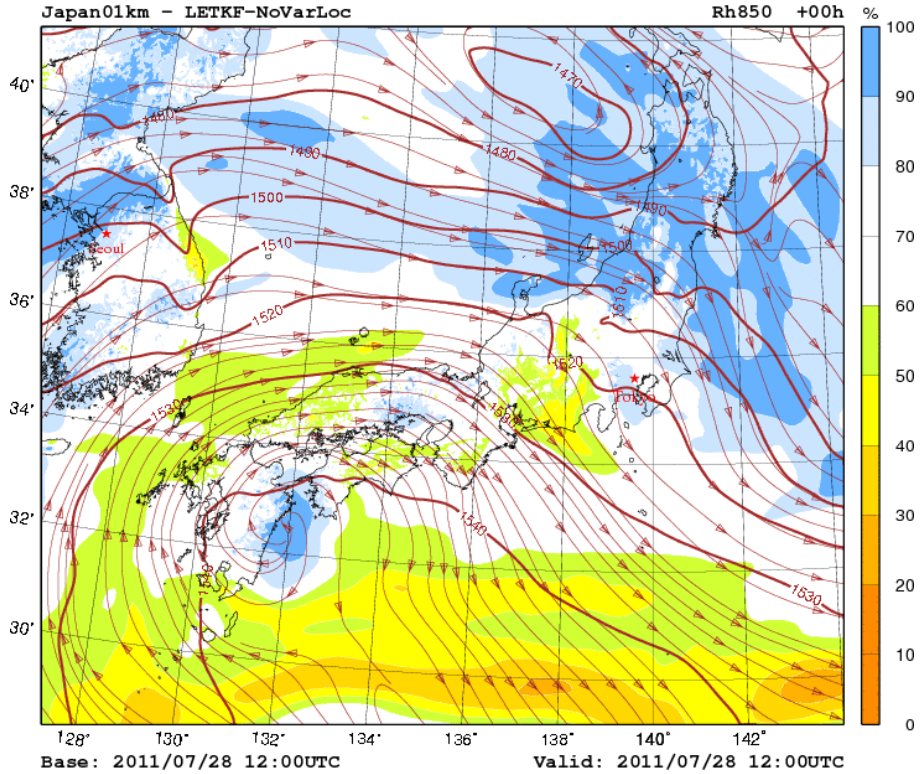


Imbalance

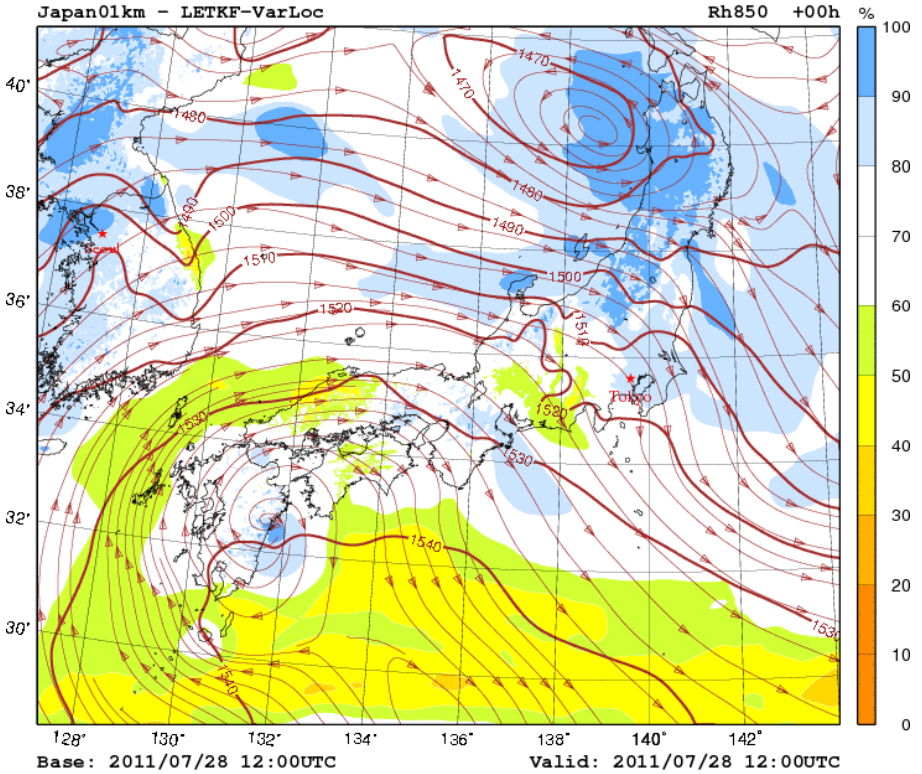

Imbalance
LETKF_VarLoc
LETKF–NoVarLoc
2nd time derivative of ps (Pa/s x10−5)
275
250
225
200
175
150
125
100
75
50
25
0
10
20
30
40
50
60
70
80
90
time step
Base: 12Z–28/07/2011

Comparison of analyses

NoVarLoc

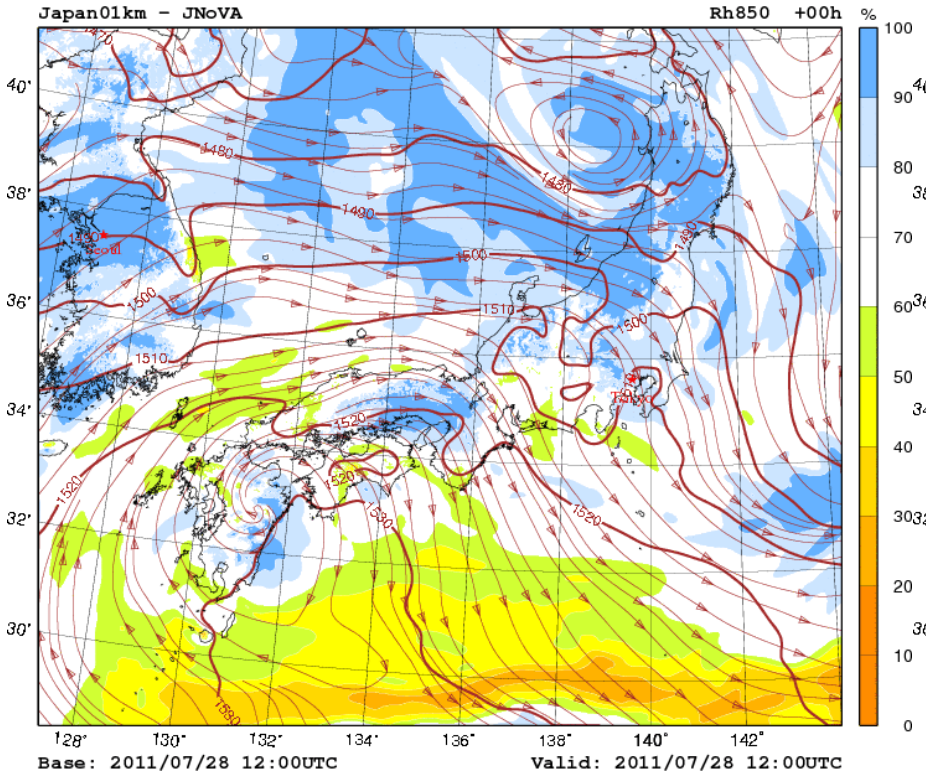


VarLoc

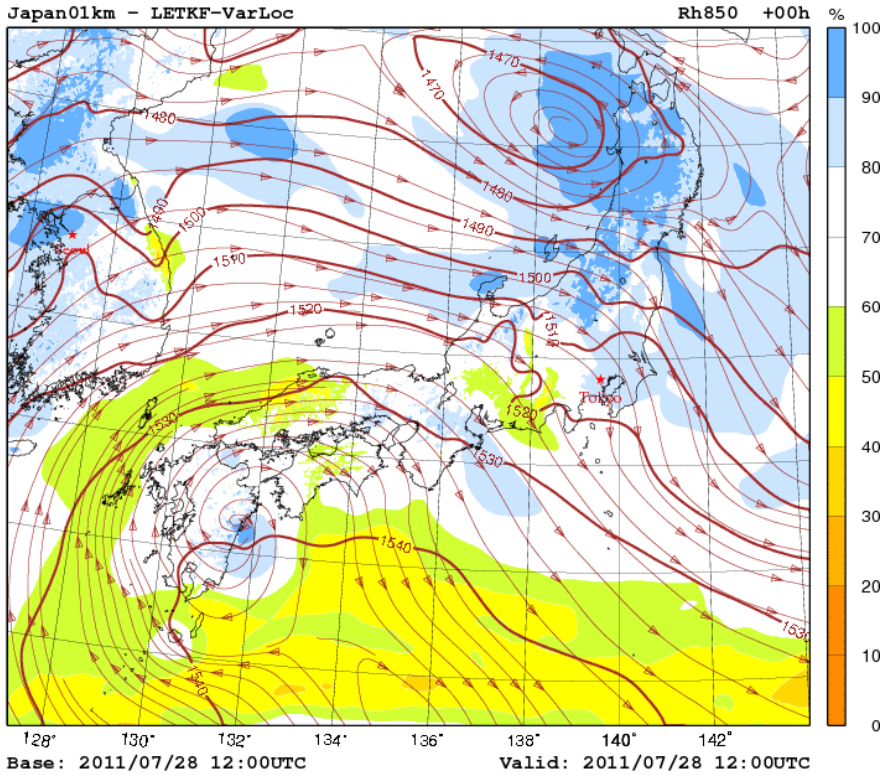


Comparison of analyses

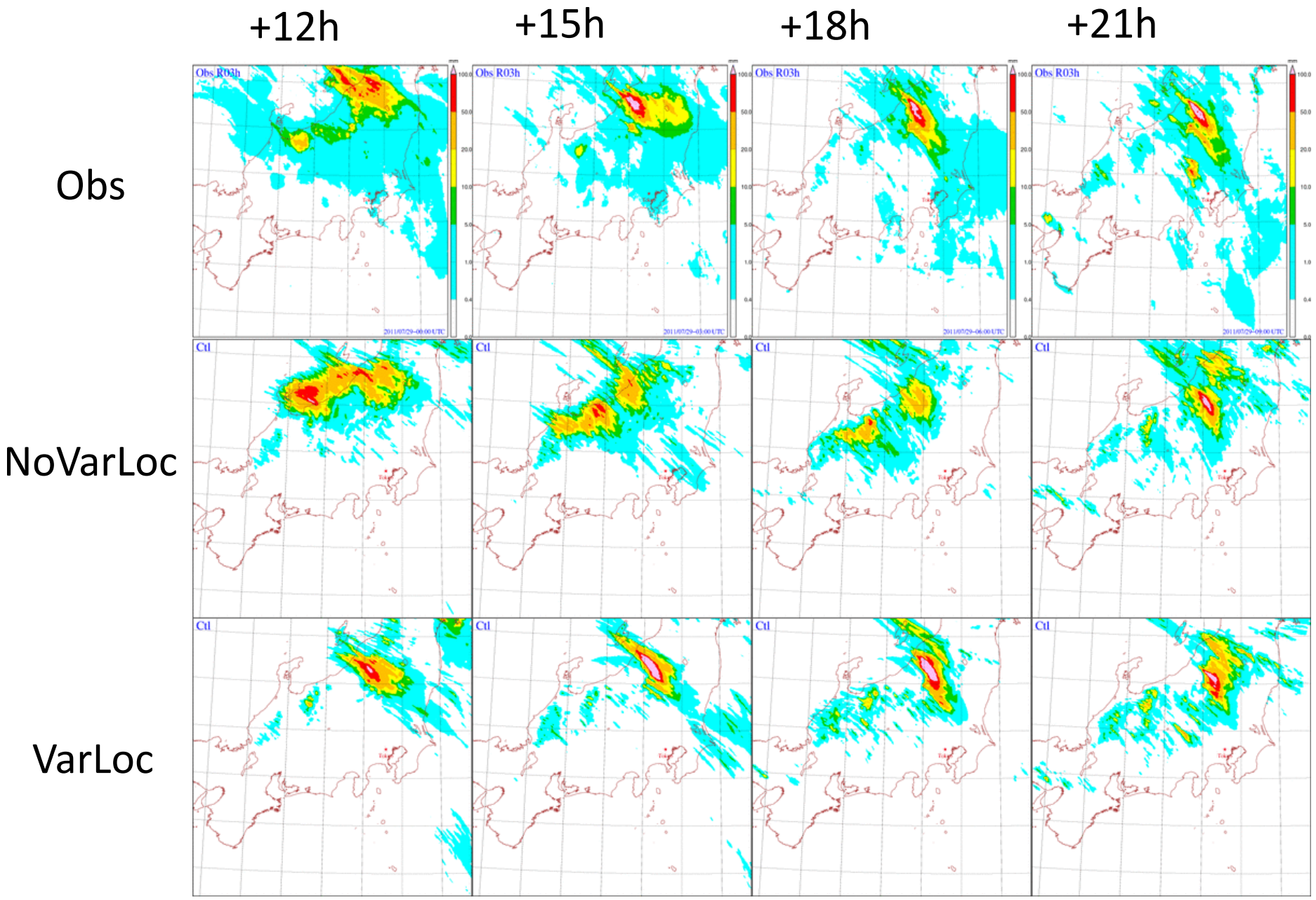
JNoVA



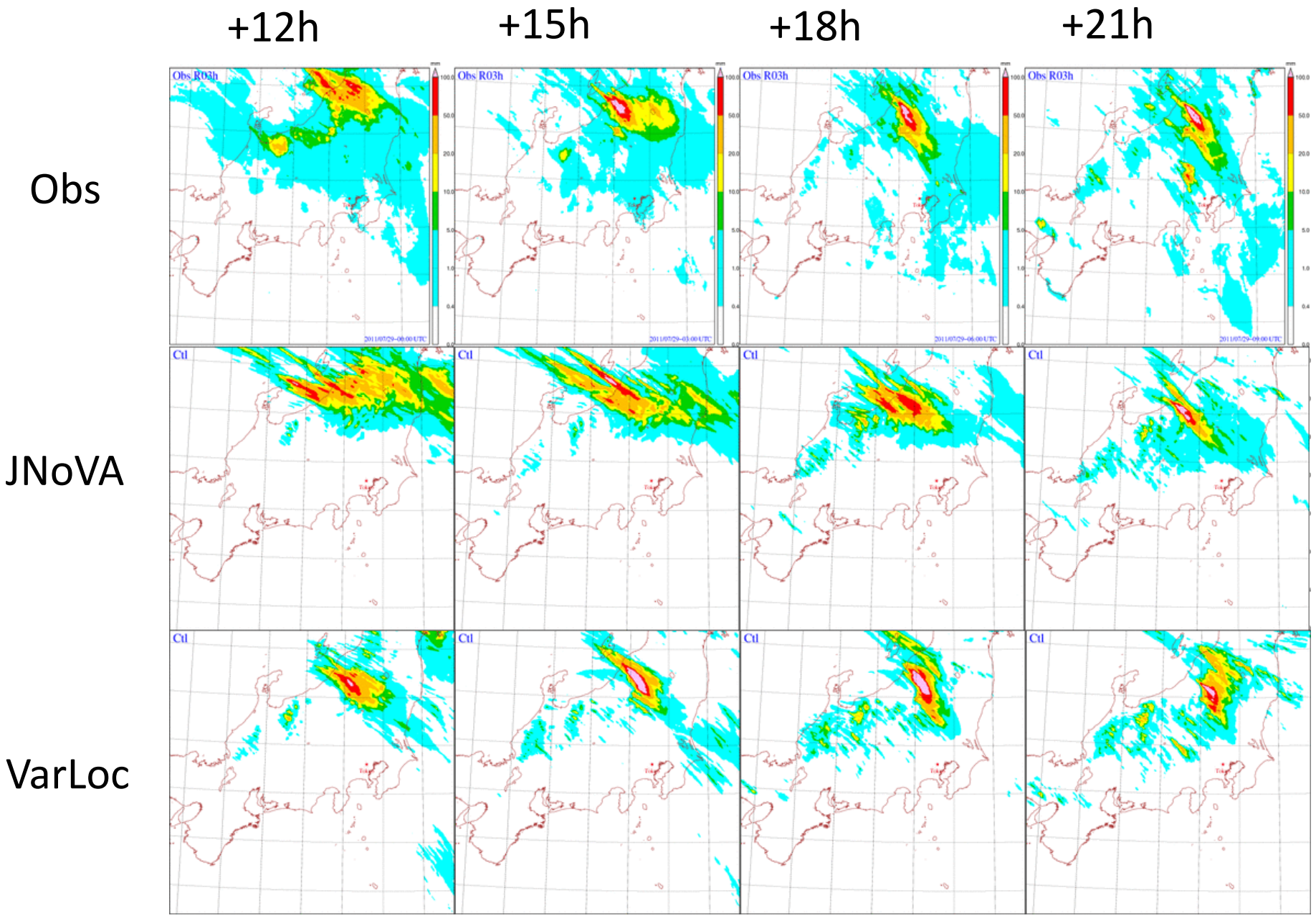
VarLoc



Downscaling results



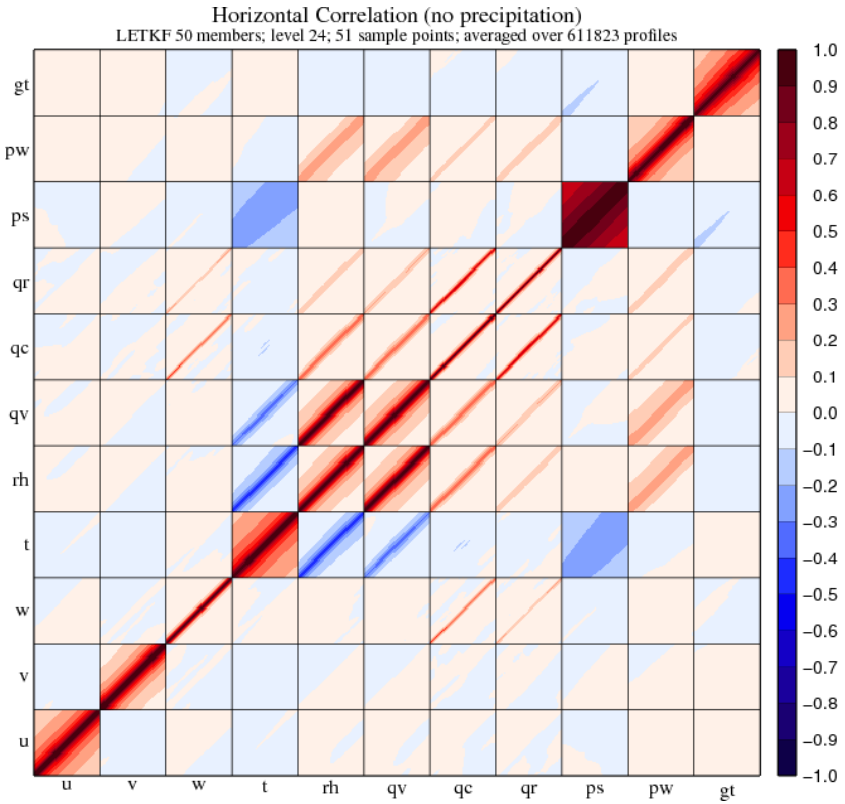
Downscaling results

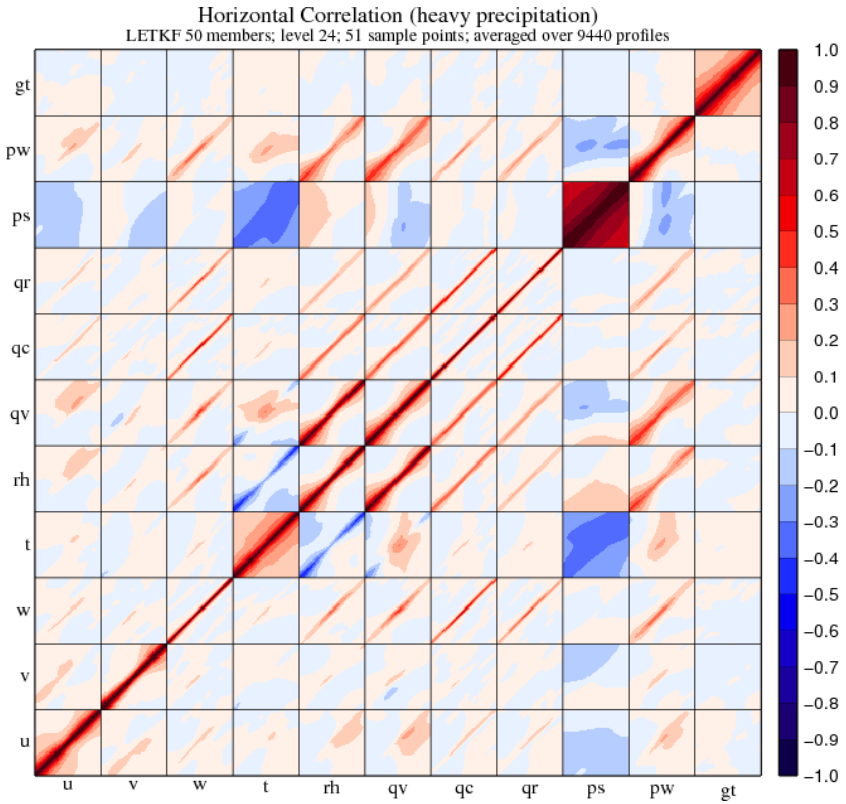


Summary

- The use of variable localization and different localization volumes causes an increase of spread and a small increase in imbalance of the analysis fields. In the case of Niigata-Fukushima heavy rainfall variable localization improves the analysis.
- For very high-resolution precipitation forecasts the probabilistic information is necessary. Therefore ensemble forecast based on NHM-LETKF should be considered also.
- The correlation length scales depend on weather phenomena. The background error correlations in this study were specified by averaging over analysis domain, therefore it is desirable to have a flow-dependent variable localization.

Horizontal correlations





Vertical correlations