# An approach to multi-scale localization

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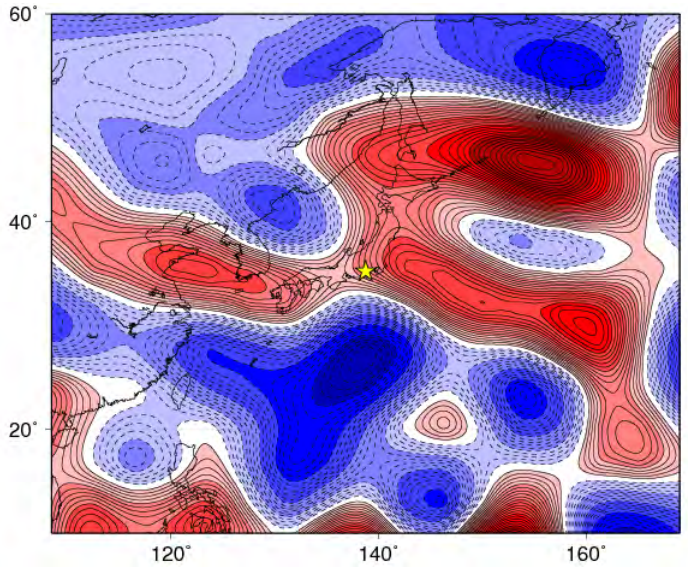
# Motivation

Localization plays an essential role in an EnKF to cope with limited ensemble size.

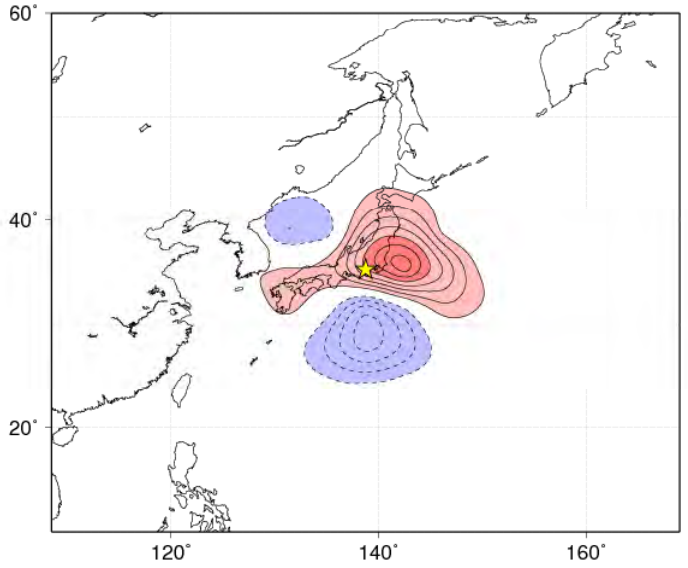
Higher resolution requires more localization, limiting the use of observations.

We look for better use of observations by separating the scales.

No localization




Localized

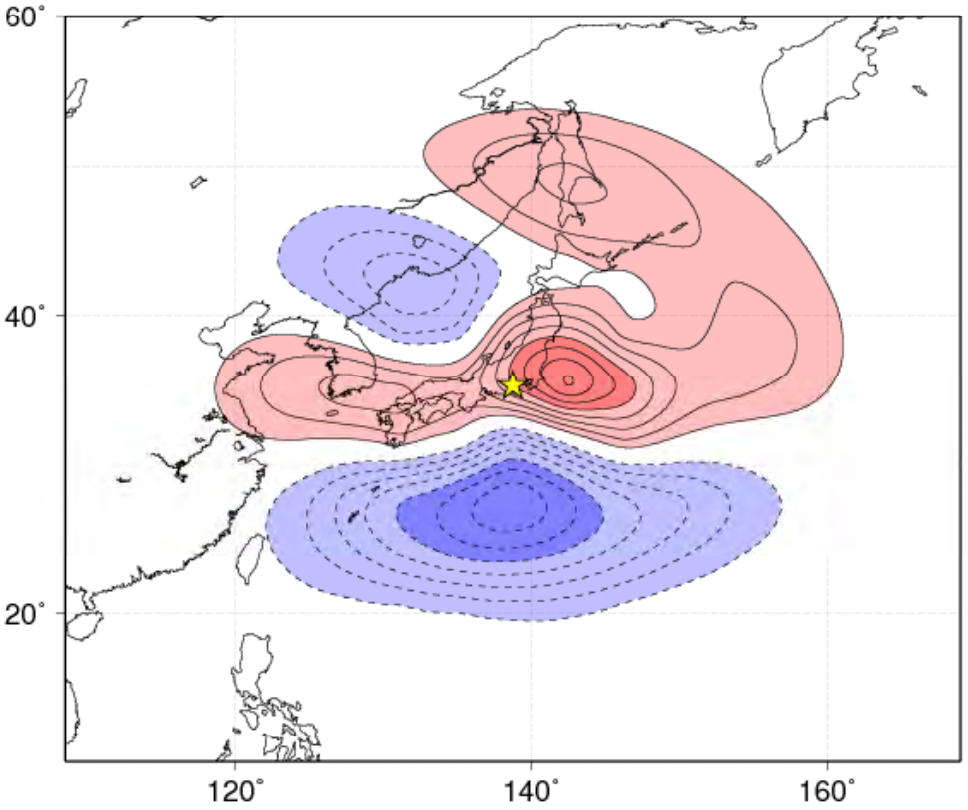


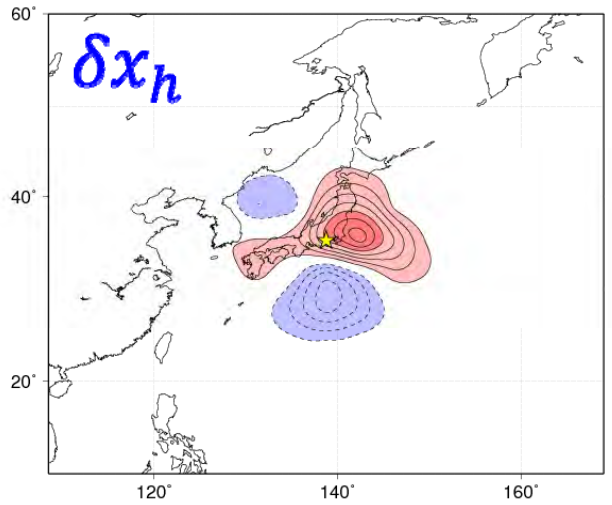

Analysis increment from a single profile observation (20 members)

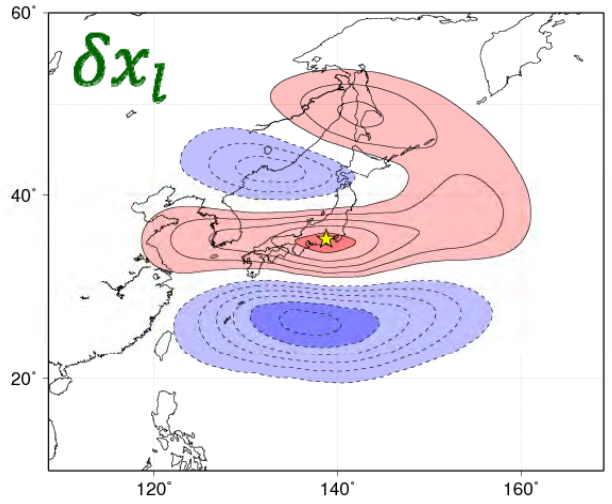
# Scale-separated analysis increments

We will construct analysis increments at high ($h$) and low ($l$) resolutions separately.

$$\delta x = \delta x_h + \delta x_l$$



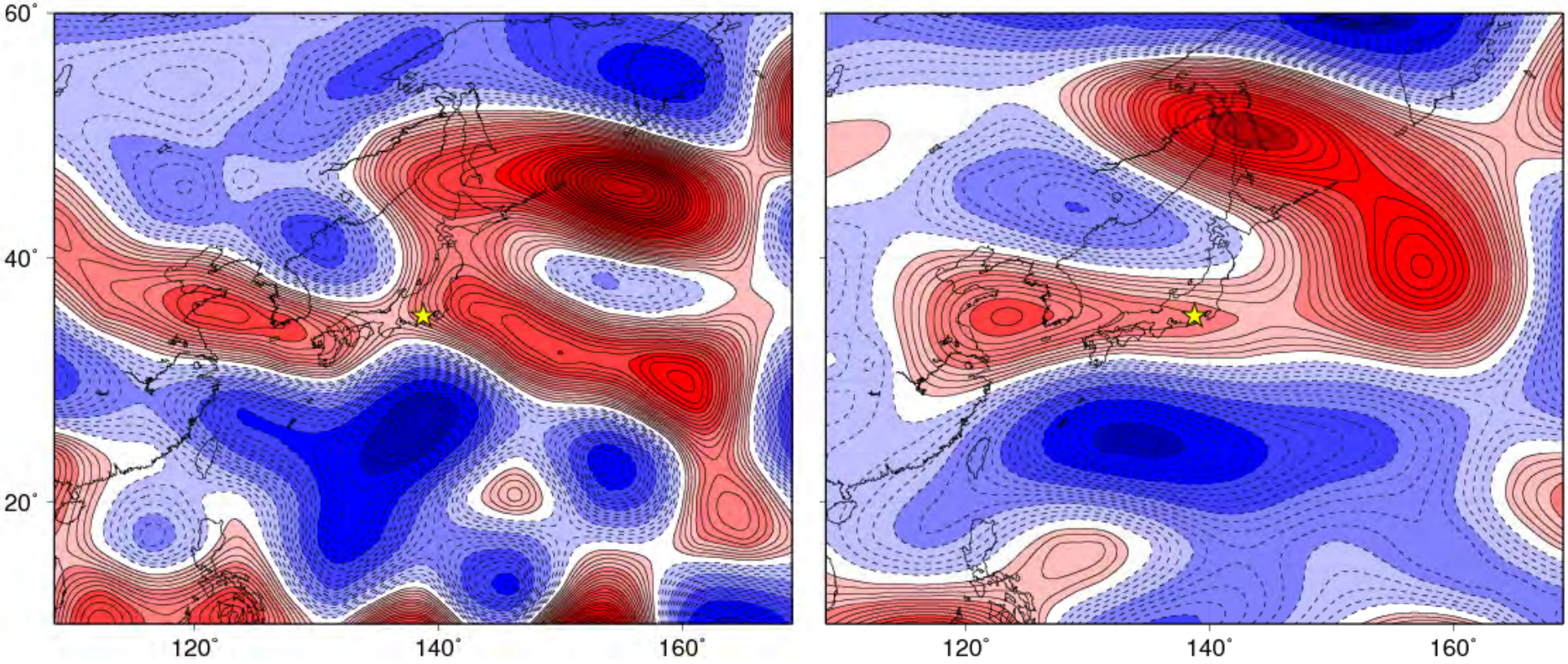



# Longer-range covariance

Motivated by Buehner (2012), we apply spatial smoothing to the ensemble perturbations to reduce noise in longer-range covariance.

Full-range (T30) analysis increment

Analysis increment from reduced-resolution (T21) ensemble perturbations

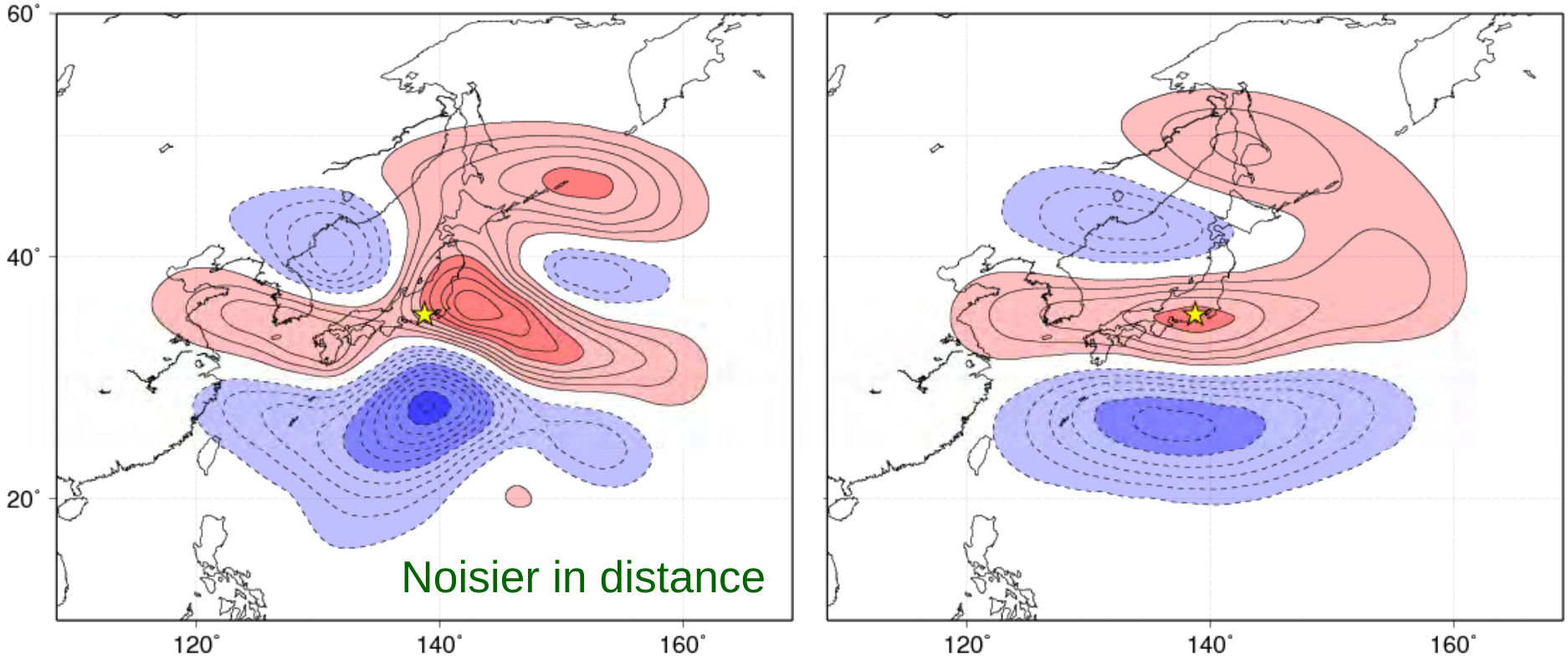


# Larger-scale localization

Applying a 1000-km (larger scale) localization.

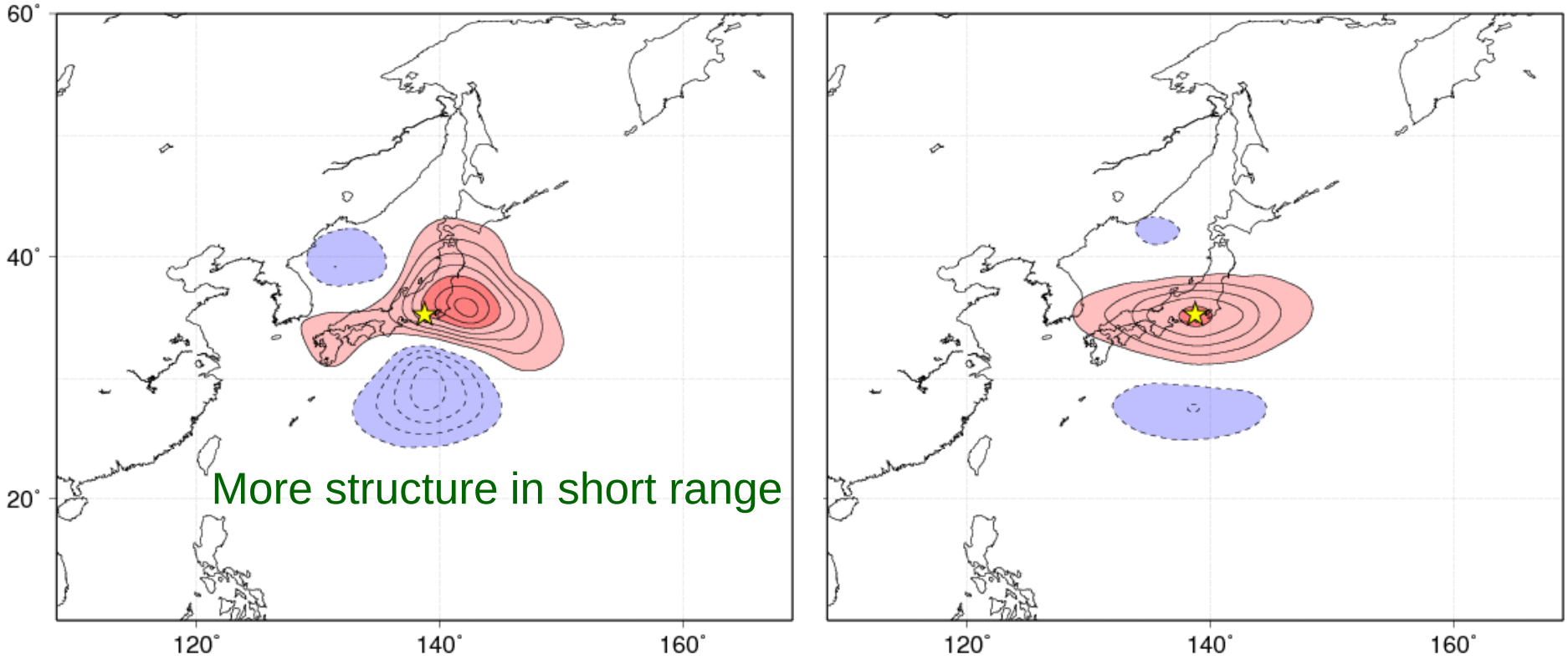
Full-range (T30) analysis increment

Analysis increment from reduced-resolution (T21) ensemble perturbations



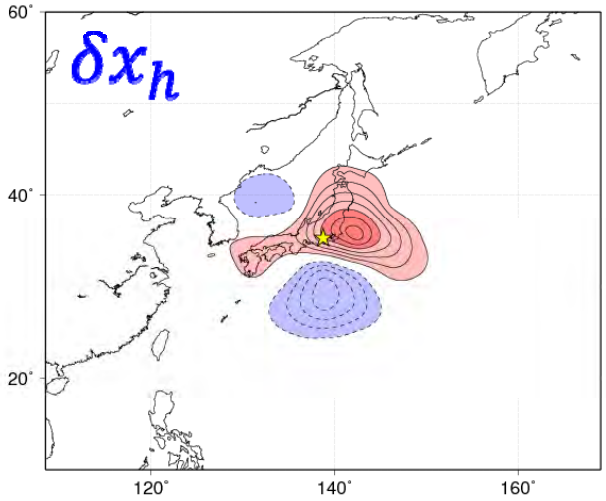
# Smaller-scale structure

Applying a 500-km (smaller scale) localization.



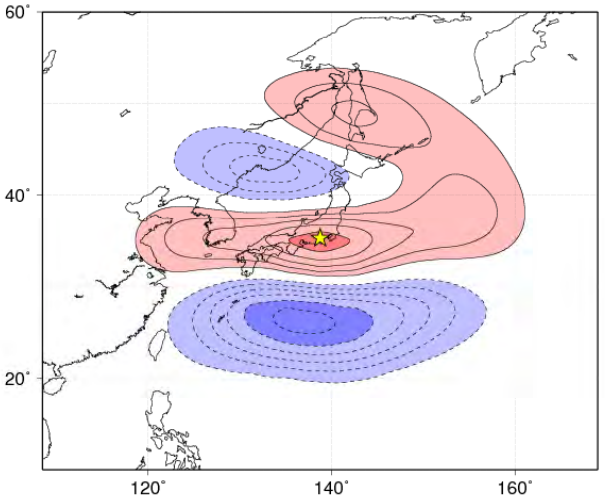
# Merging the two scales

Original covariance with 500-km (smaller scale) localization

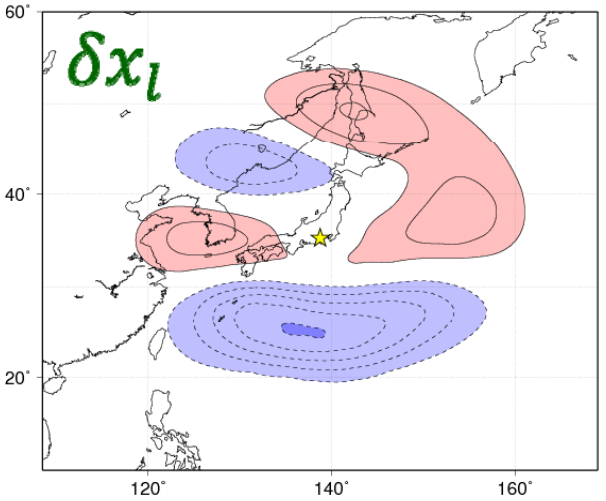



Preserve the smaller-scale structure in short range

Large-scale covariance with 1000-km (larger scale) localization



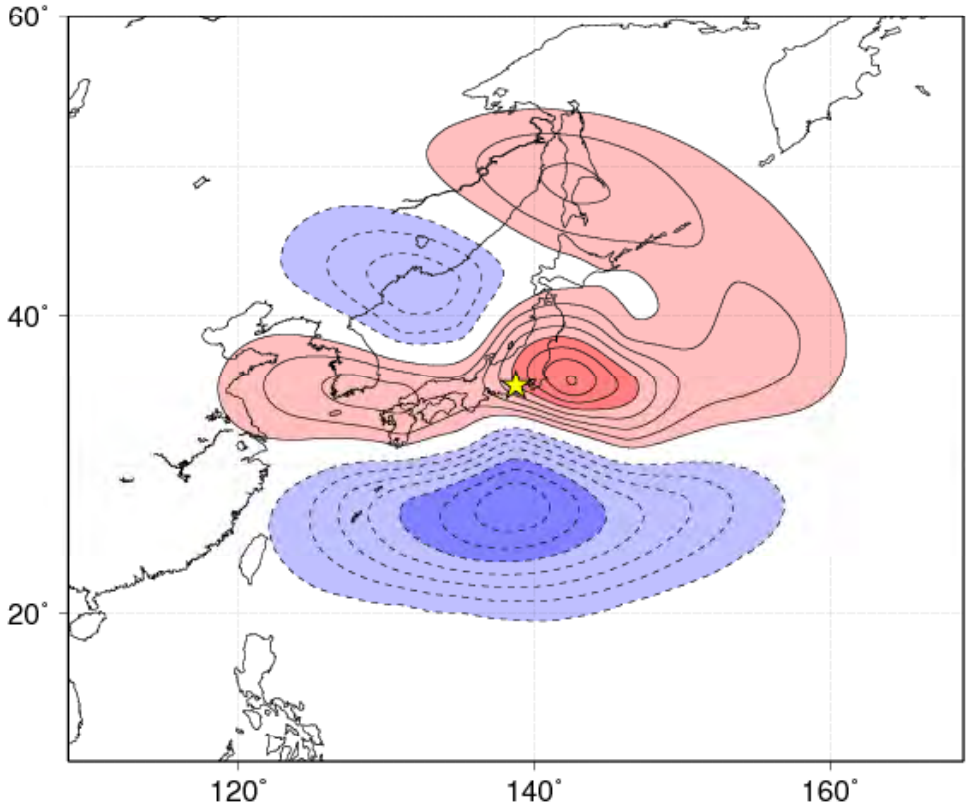

Removing the short-rage structure

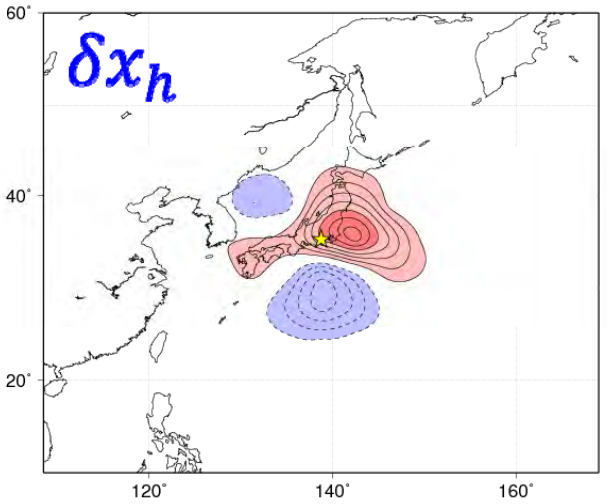


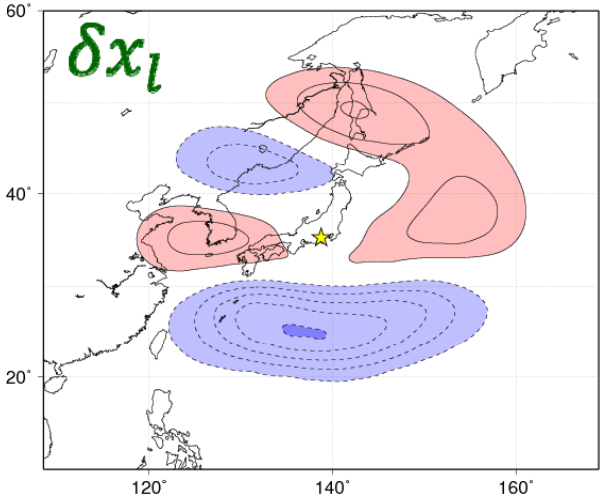

$$\delta x = \delta x_h + \delta x_l$$

# Merged analysis increment

$$\delta x = \delta x_h + \delta x_l$$

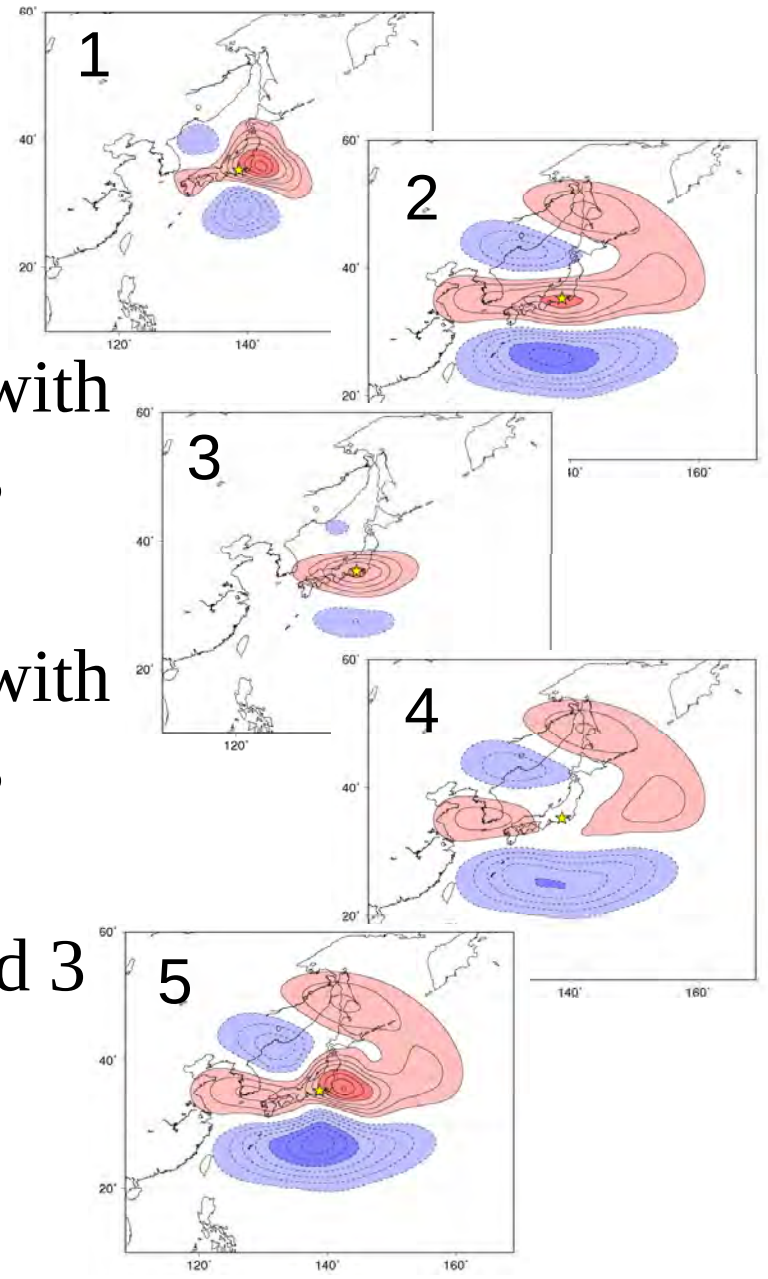


# Review: the algorithm

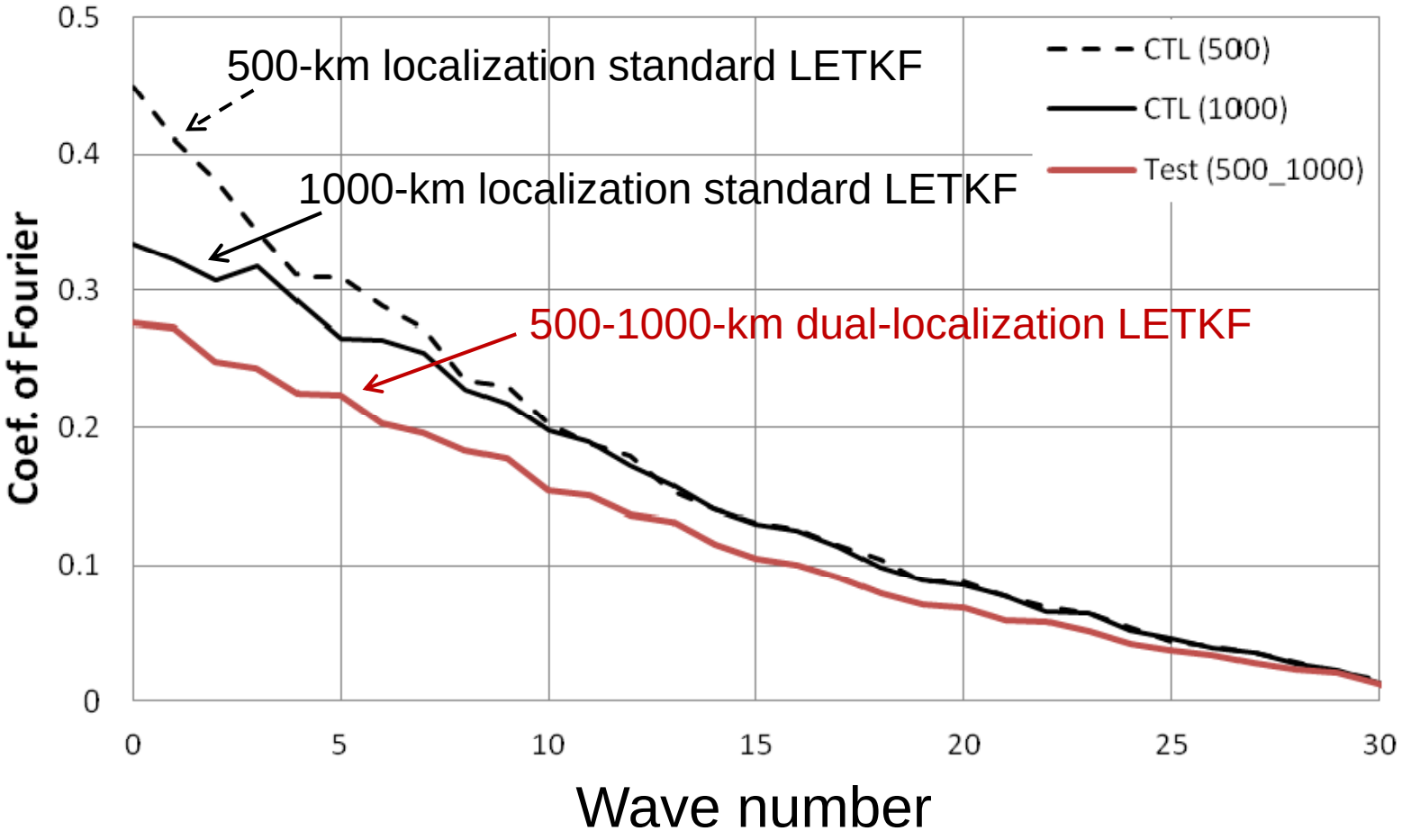
1. Compute the analysis increment regularly
   (with smaller-scale localization)
2. Compute the analysis increment with smoothed ensemble perturbations
   (with larger-scale localization)
3. Compute the analysis increment with smoothed ensemble perturbations
   (with smaller-scale localization)
4. Take the difference between 2 and 3
5. Add 1 and 4



# Results are promising.

Successfully reducing the errors at almost all scales.

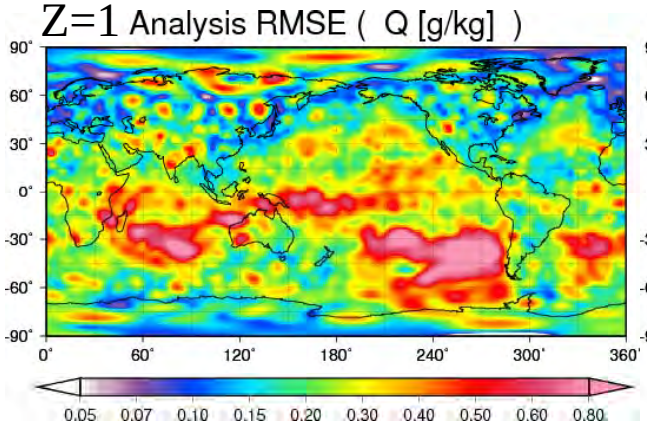
1-month average global analysis error power spectrum

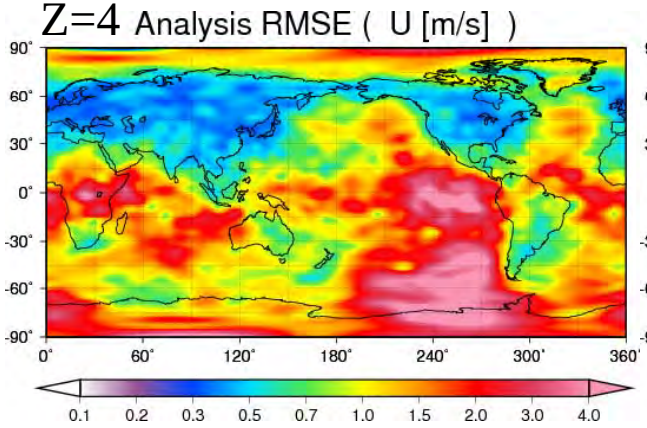


# Improvements are almost everywhere for all variables.

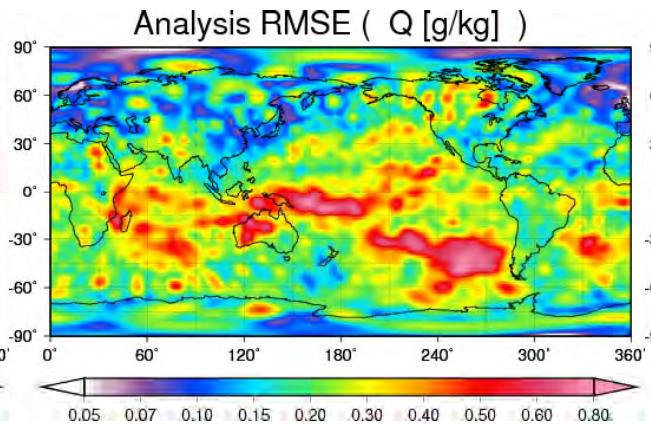
1-month average RMS errors

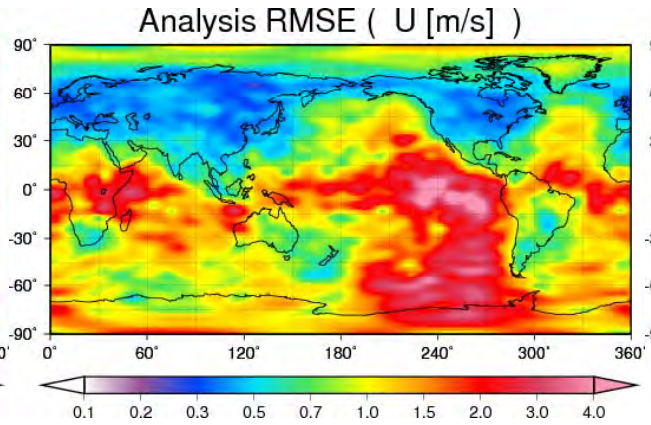
500-km regular



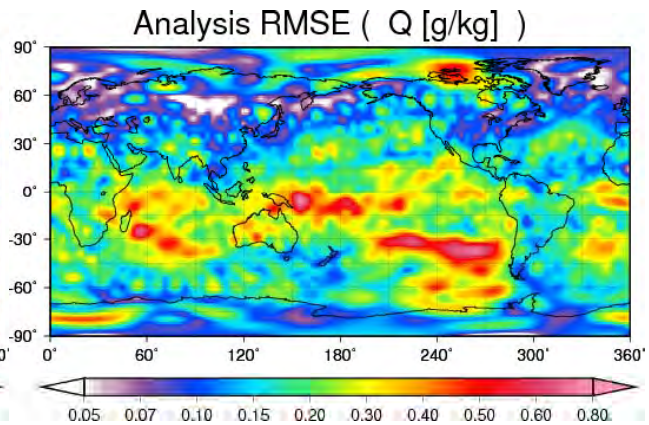



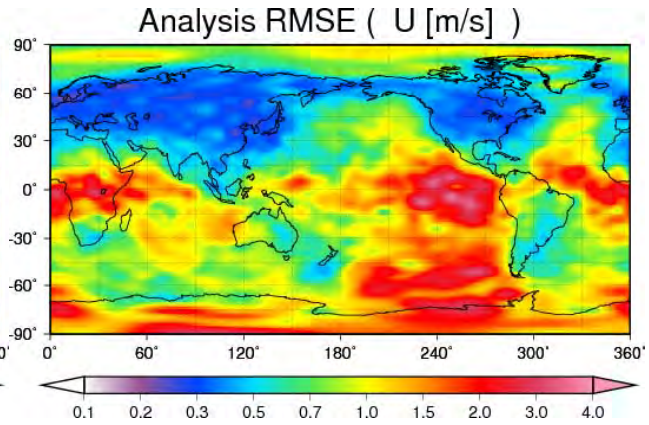

1000-km regular




500-1000-km dual



# Summary and future plans

- Dual-localization LETKF analysis (with single resolution forecasts) showed promising results.
  - LETKF computations are tripled for this approach.

- Future plans
  - Improving the algorithm for saving computations
  - Applying to higher-resolution models
    - Multi-scale considerations are more important with higher resolutions.