An adaptive covariance localization method with the LETKF

Takemasa Miyoshi*

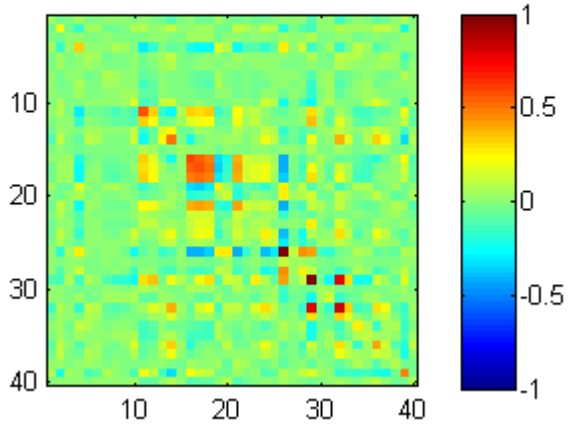
University of Maryland, College Park

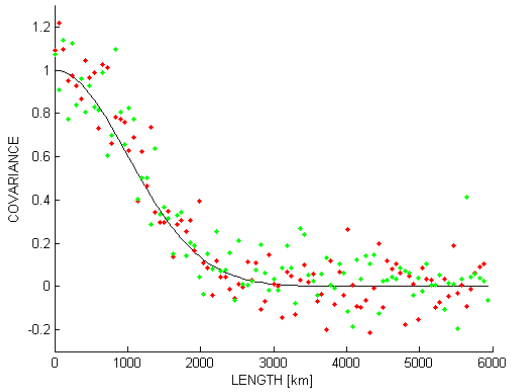
miyoshi@atmos.umd.edu

Covariance localization (e.g., Houtekamer and Mitchell 1998)

Empirical treatment for…
- reducing sampling noise
- increasing the rank

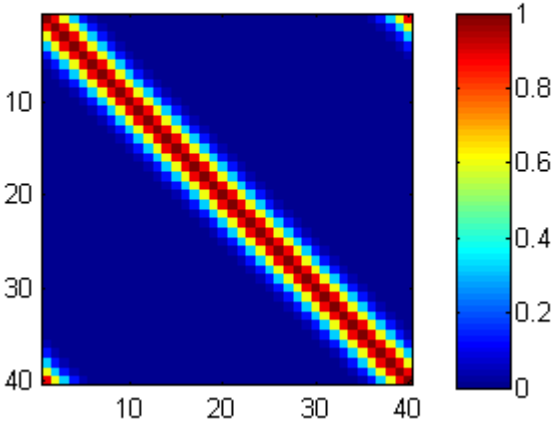
$\mathbf{P}^f$



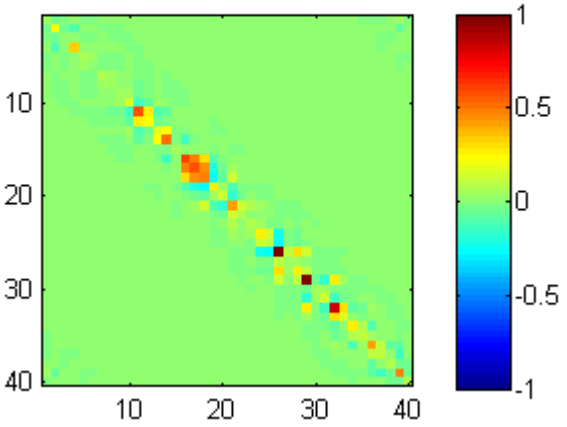


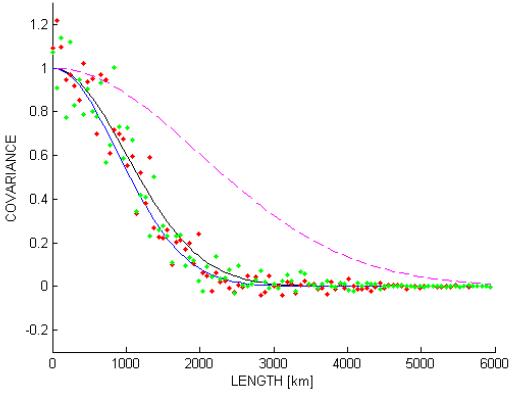
Localized

ρ



$\rho \circ \mathbf{P}^f$



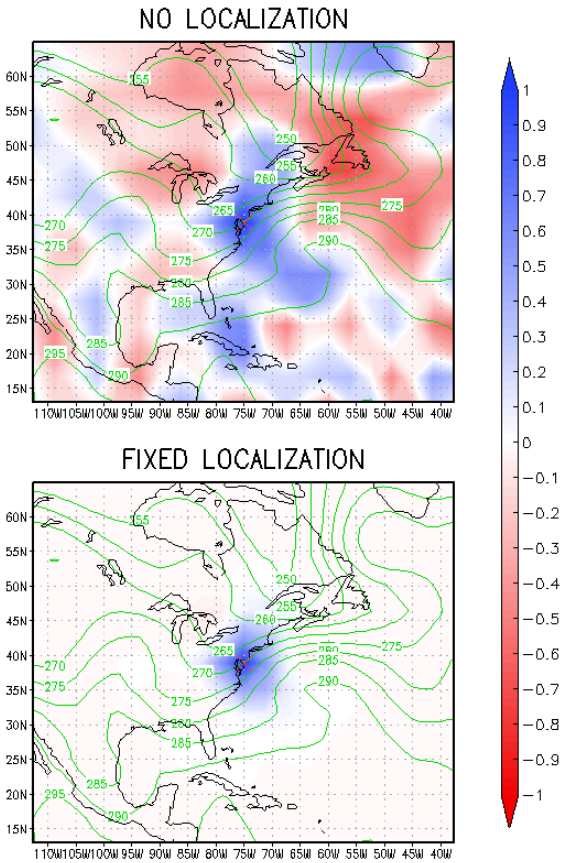


Difficulties of localization

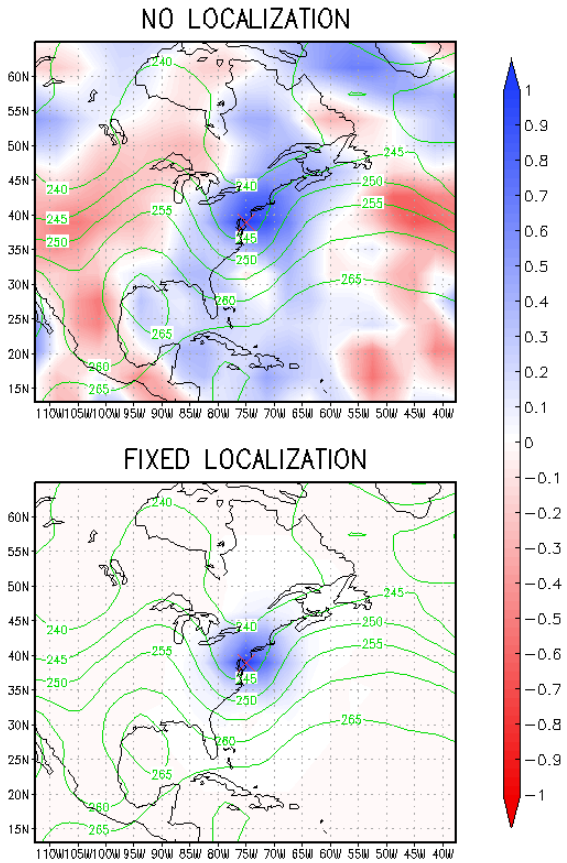
Difficulties include…

- depending on (x, y, z, t)
- reducing flow-dependence

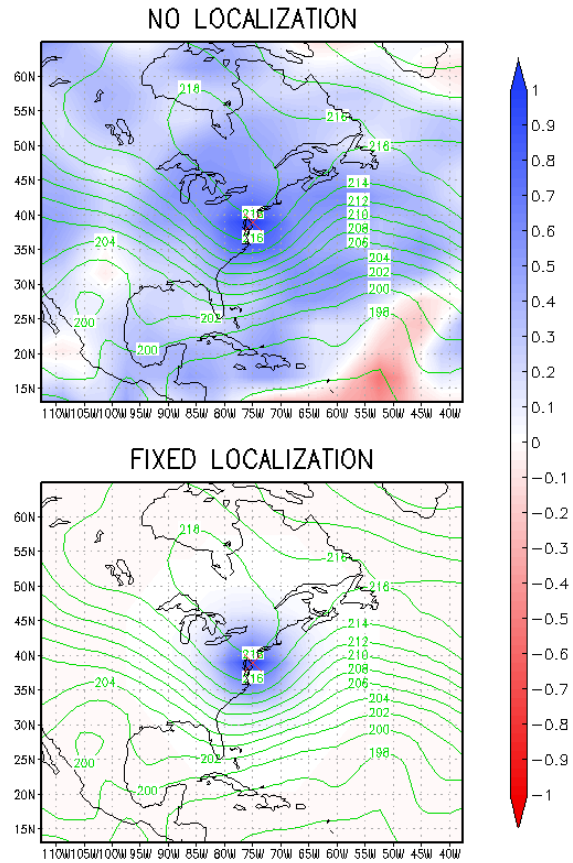
$\sigma = 0.95$



$\sigma = 0.51$

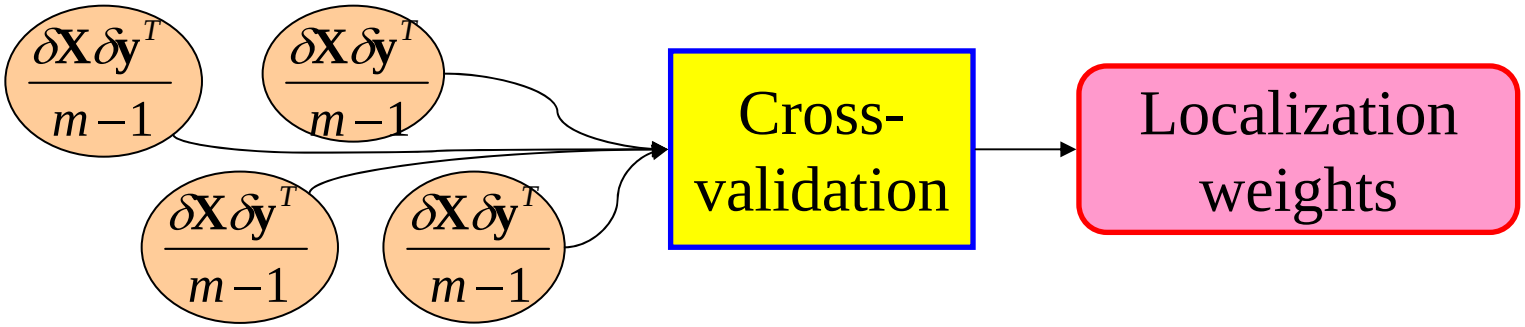


$\sigma = 0.08$



Adaptive localization

- Hierarchical filter by Anderson (2007)
  - Cross-validation by groups of ensembles

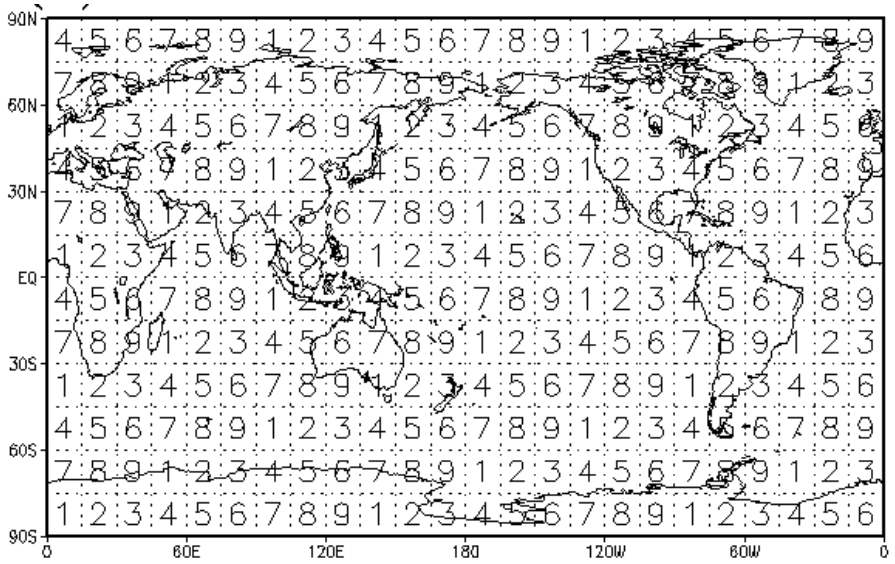


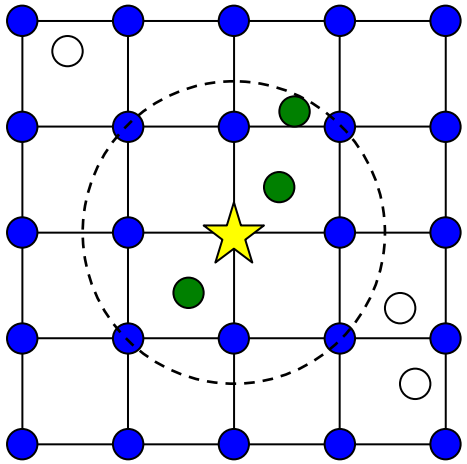
- ECO-RAP by Bishop and Hodyss (2009)
  - Smooth the sample correlations raised to a power
    - High sample correlation = more reliable = more weight
    - Spatial smoothing to reduce noisiness of the sample correlation

LETKF algorithm (Hunt et al. 2007)

Local Ensemble Transform Kalman Filter

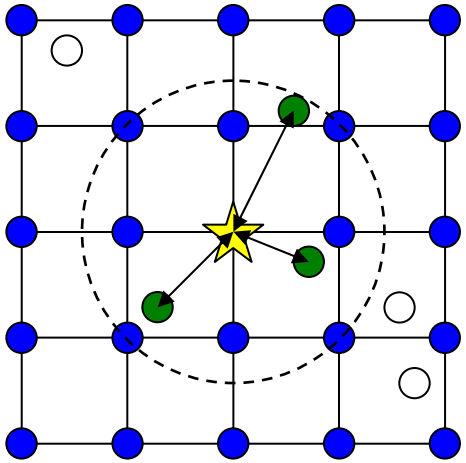
Each grid point is treated independently.





Multiple observations are treated simultaneously.

Localization in LETKF



Analysis of the *i*-th variable:

$$\underset{(N\times m)}{\mathbf{x}_i^a} = \underset{(N\times m)}{\bar{\mathbf{x}}_i^f \mathbf{1}_{1\times m}} + \underset{(N\times m)}{\delta\mathbf{x}_i^f} \underset{(m\times m)}{\mathbf{T}_i}(\delta\mathbf{Y}_i^f, \mathbf{R}_i, \mathbf{d}_i)$$

Two steps of localization:

1. Selecting a subset of global obs for the *i*-th variable

   $\delta\mathbf{Y}_i^f, \mathbf{R}_i, \mathbf{d}_i$ are composed of only selected local obs.

2. Obs error std. is weighted by the localization factor

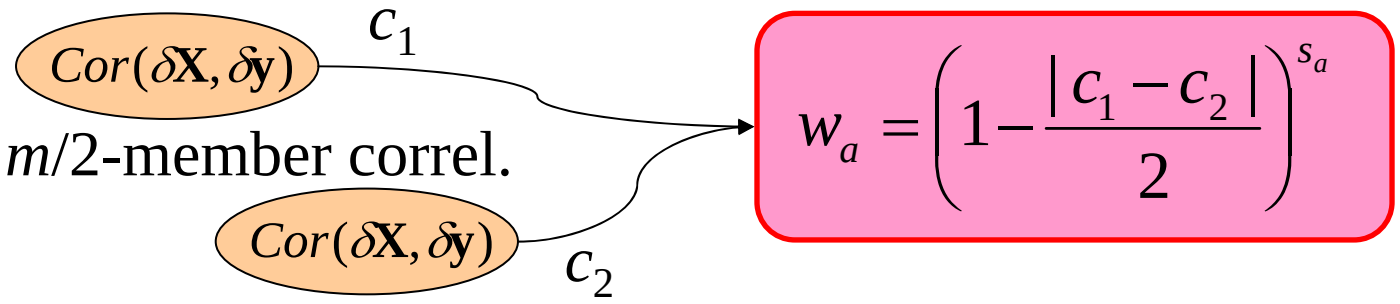
   $\mathbf{R}_i$ is modified, so that far-away obs have large error.

   R-localization, Hunt et al. (2007)

Adaptive localization with LETKF

The localization factor for R-localization is given by two adaptive components:

A. Cross-validation (Anderson 2007)



B. Use the sample covariance (Bishop and Hodyss 2009)

High sample correlation = more reliable = more weight

$$w_b = |c|^{s_b}$$

m-member correl.

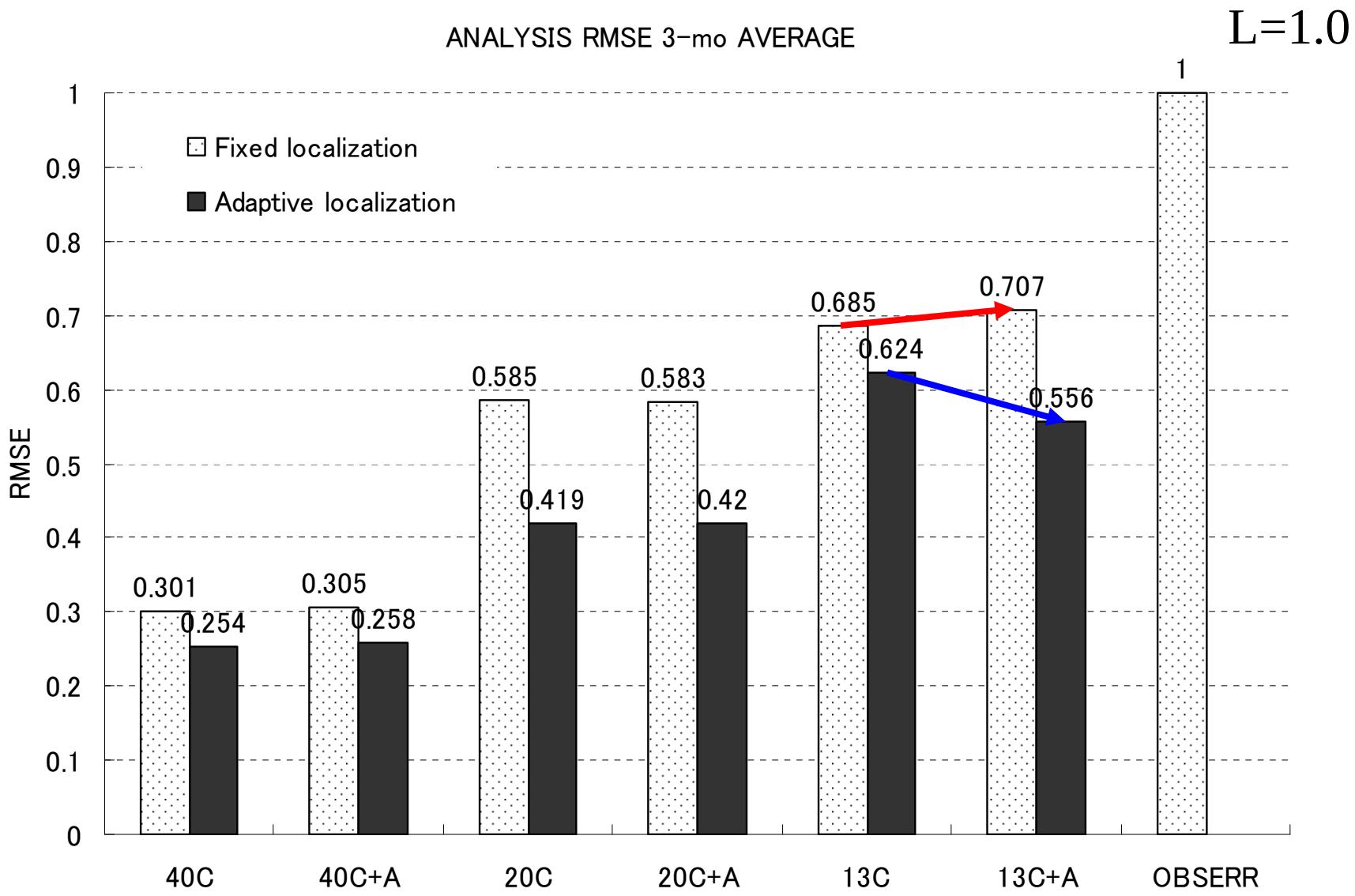
Advantages and disadvantages

- Advantages:
  - Minimal additional computations
  - Minimal changes to the existing LETKF code
  - Automatic inter-variable 4-D localization

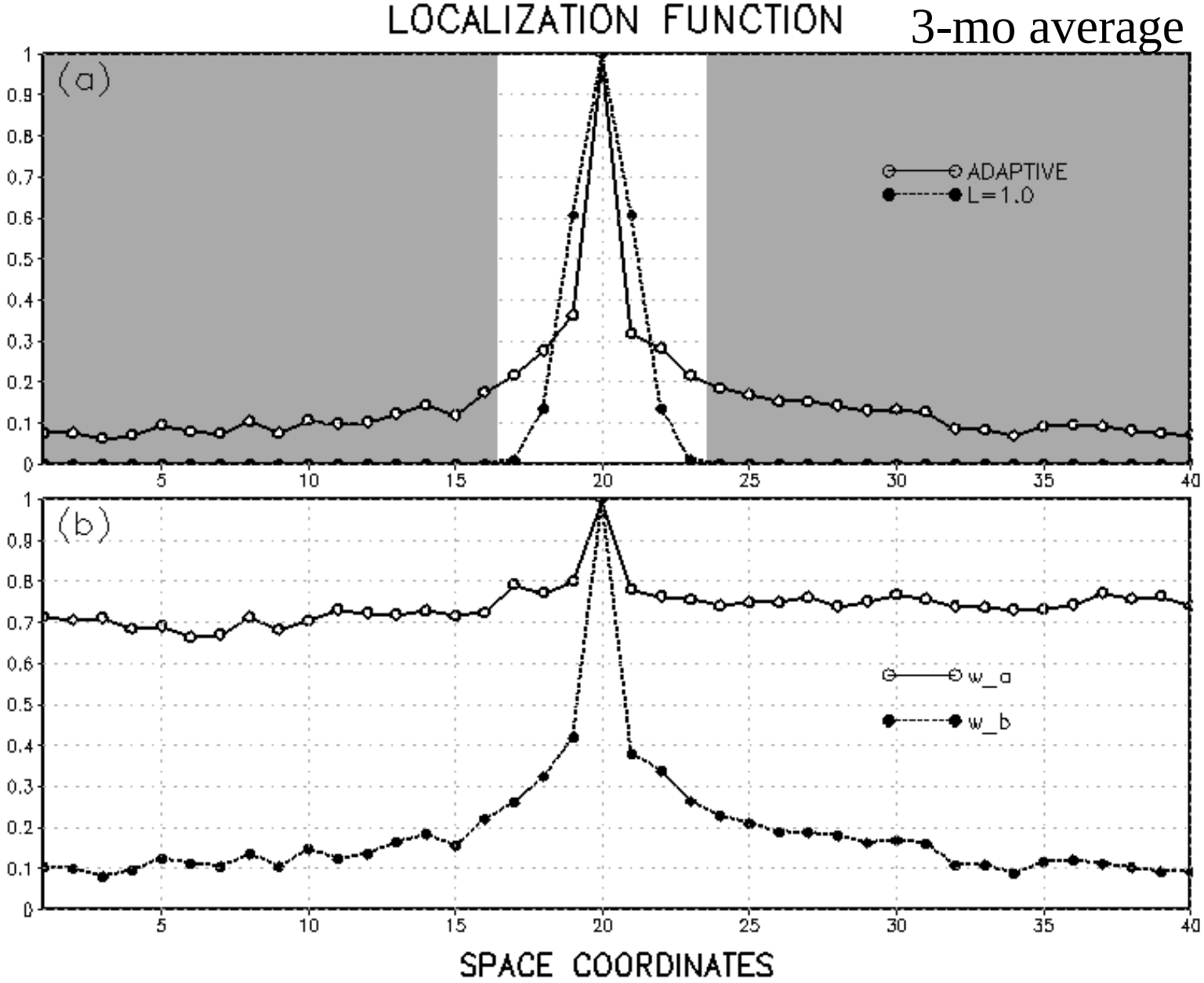
- Disadvantages
  - Sampling error issue remains.

Results with Lorenz-96

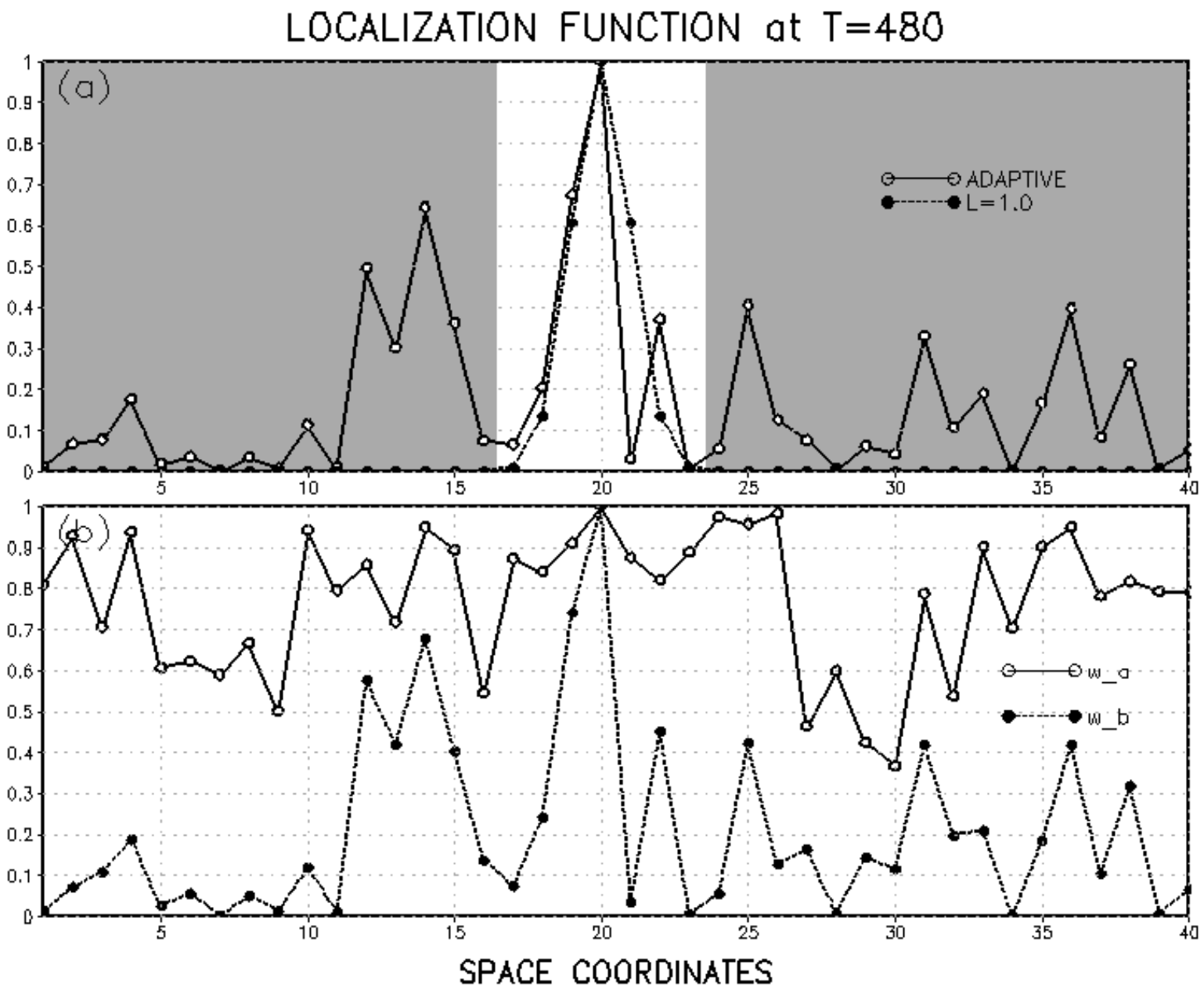
Assimilating conventional obs (C) and global average obs (A)



Adaptive localization function

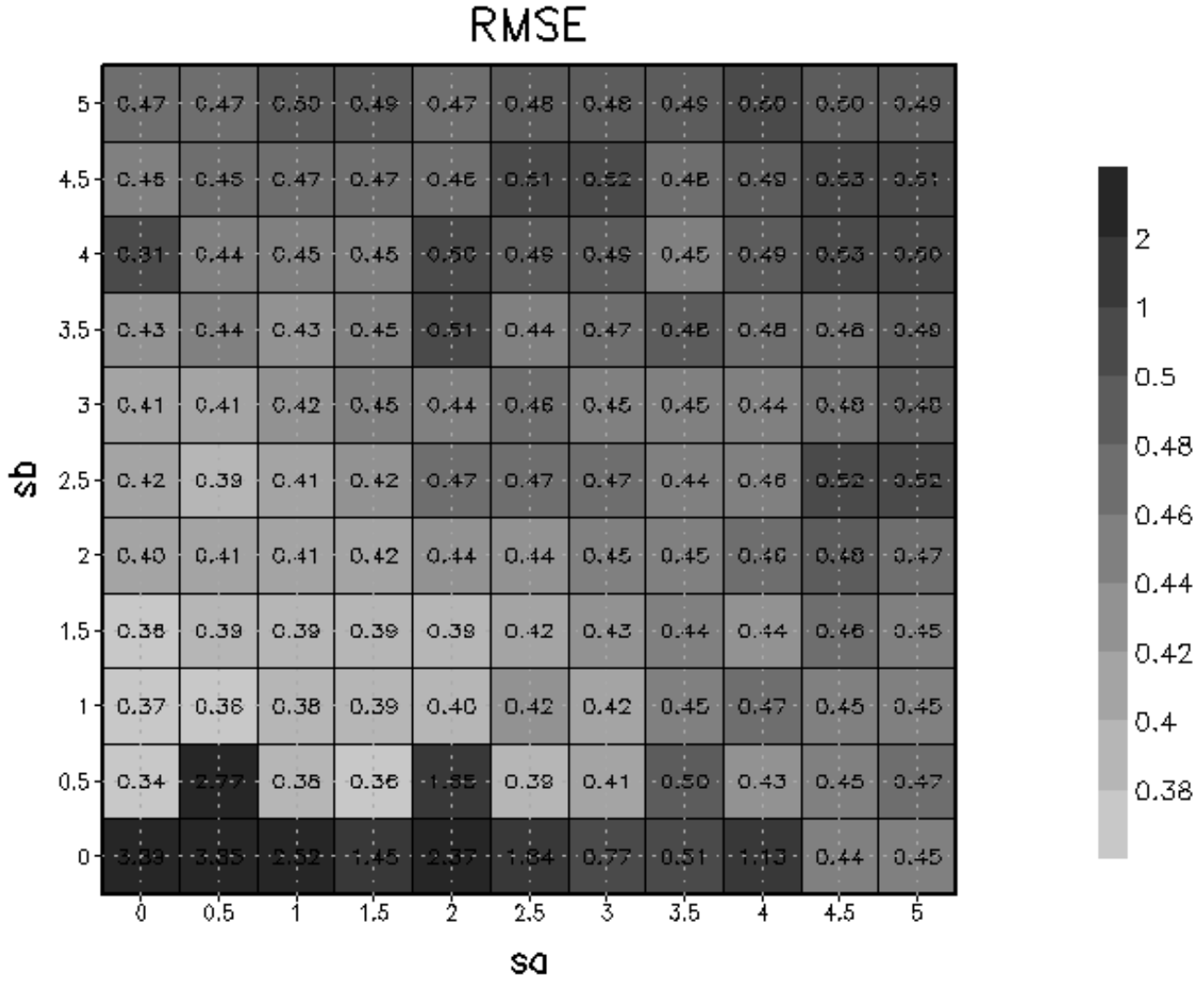


Instantaneous



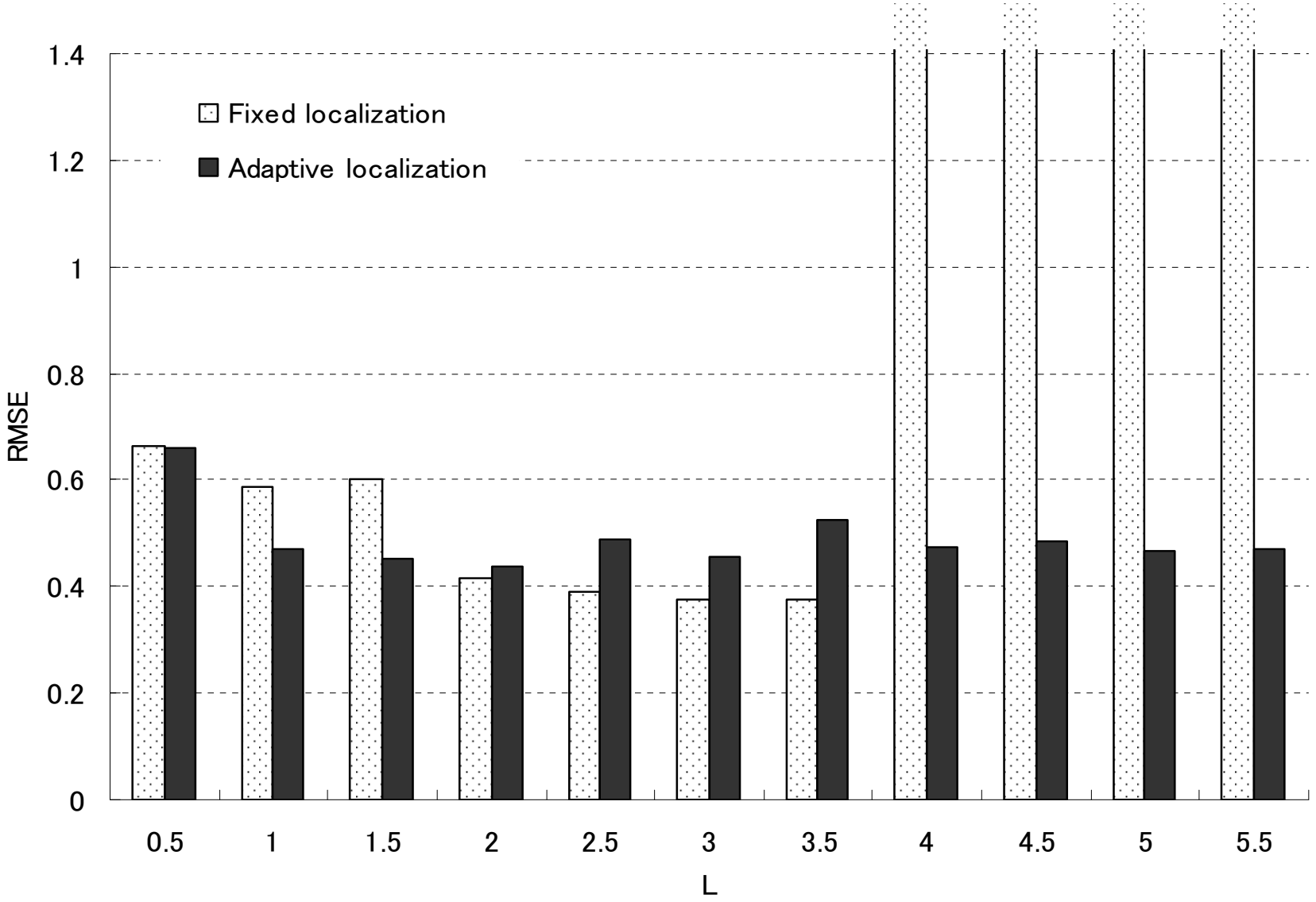
Sensitivity to parameters

Assimilating 20 conventional obs and global average obs (20C+A)



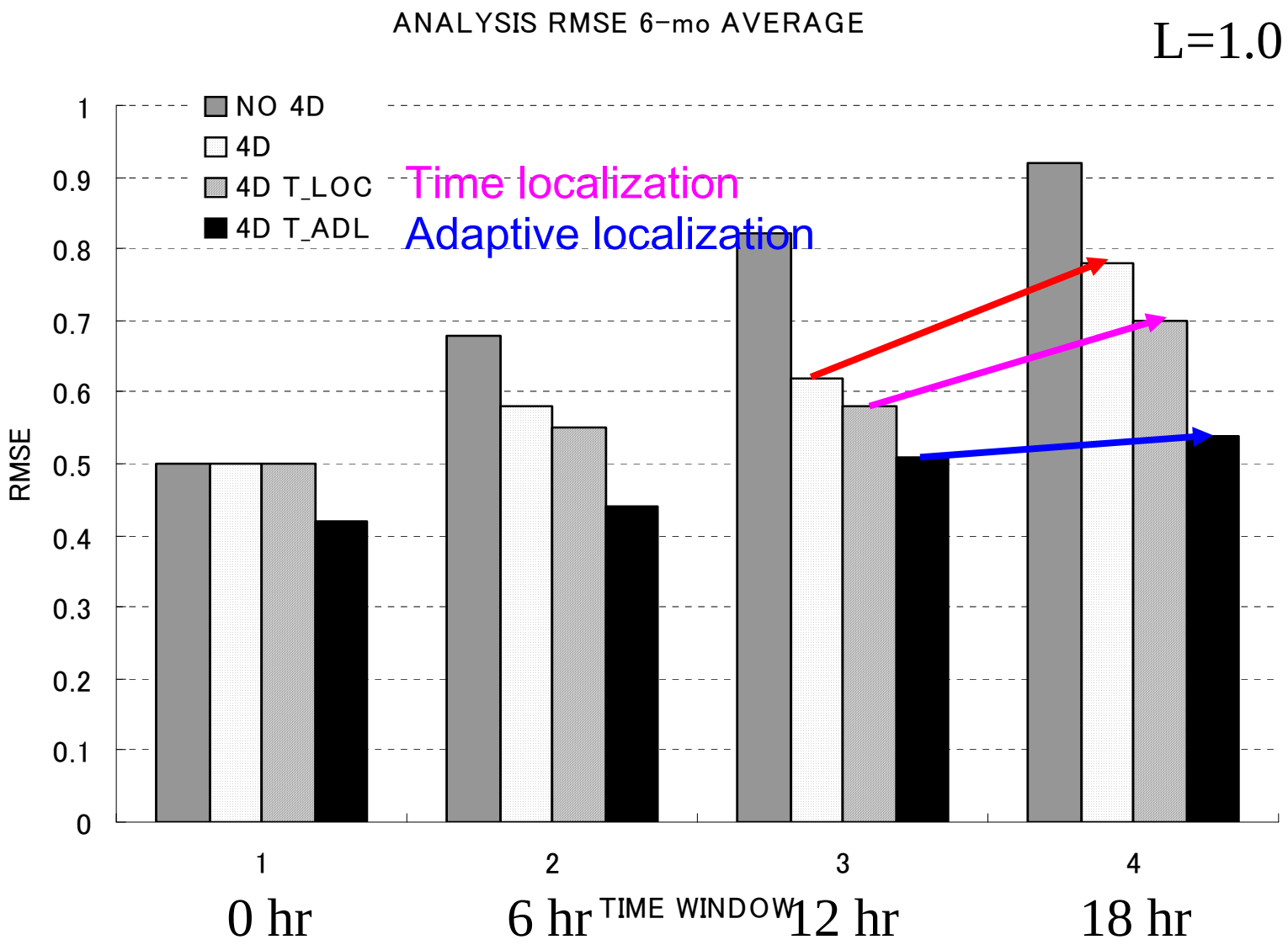
Sensitivity to localization parameter

Assimilating 20 conventional obs (20C)

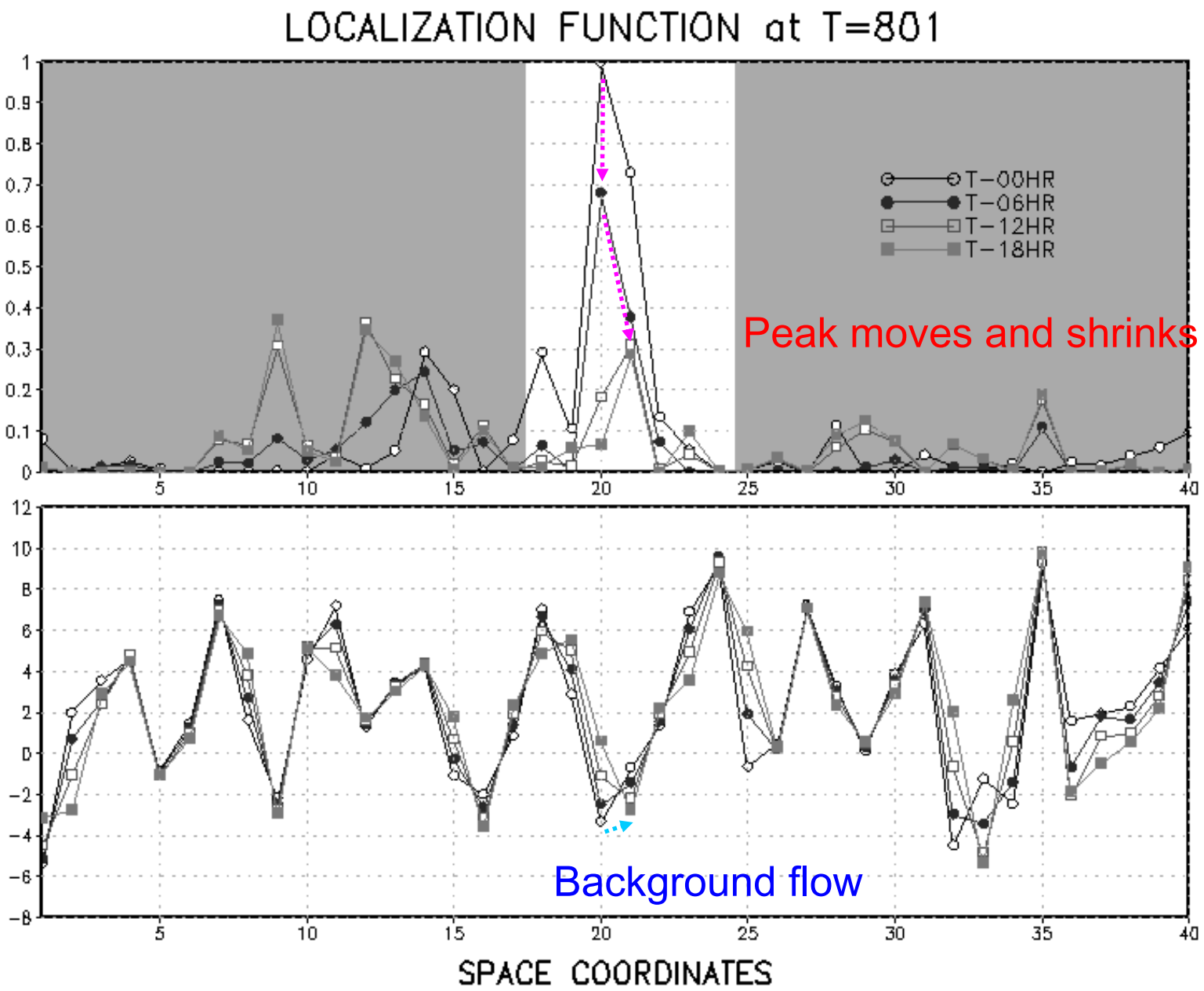


4D-LETKF

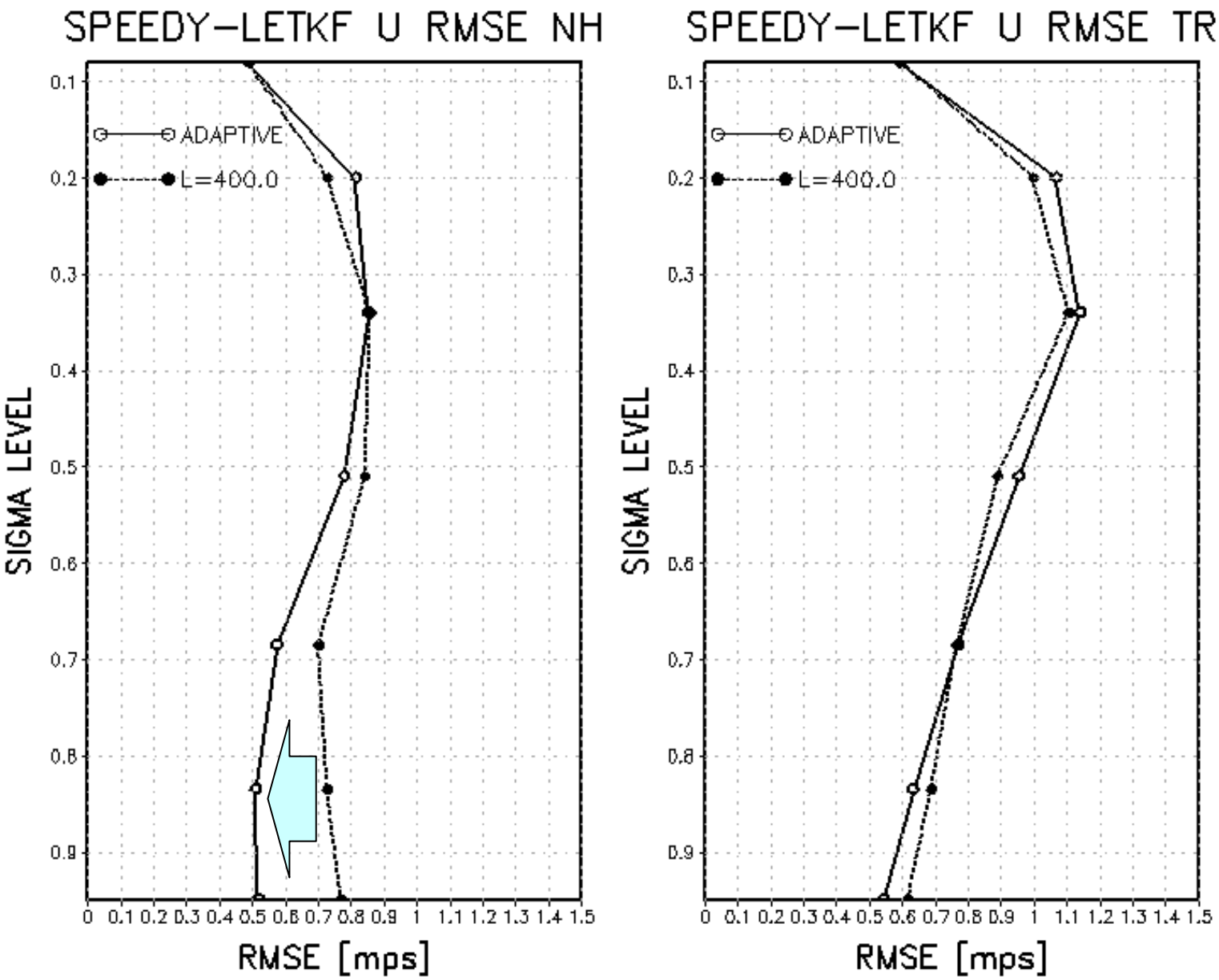
Assimilating 20 conventional obs (20C)



4-D localization function



Preliminary results with an AGCM



Summary and future work

- An adaptive localization method was proposed
  - Efficient with LETKF
  - Automatic inter-variable localization
- Tested with Lorenz 40-variable model
  - Not the best, but reasonably good without tuning
- More investigations with an AGCM