Partially Adaptive Ensemble Covariance Localization in 4D-VAR

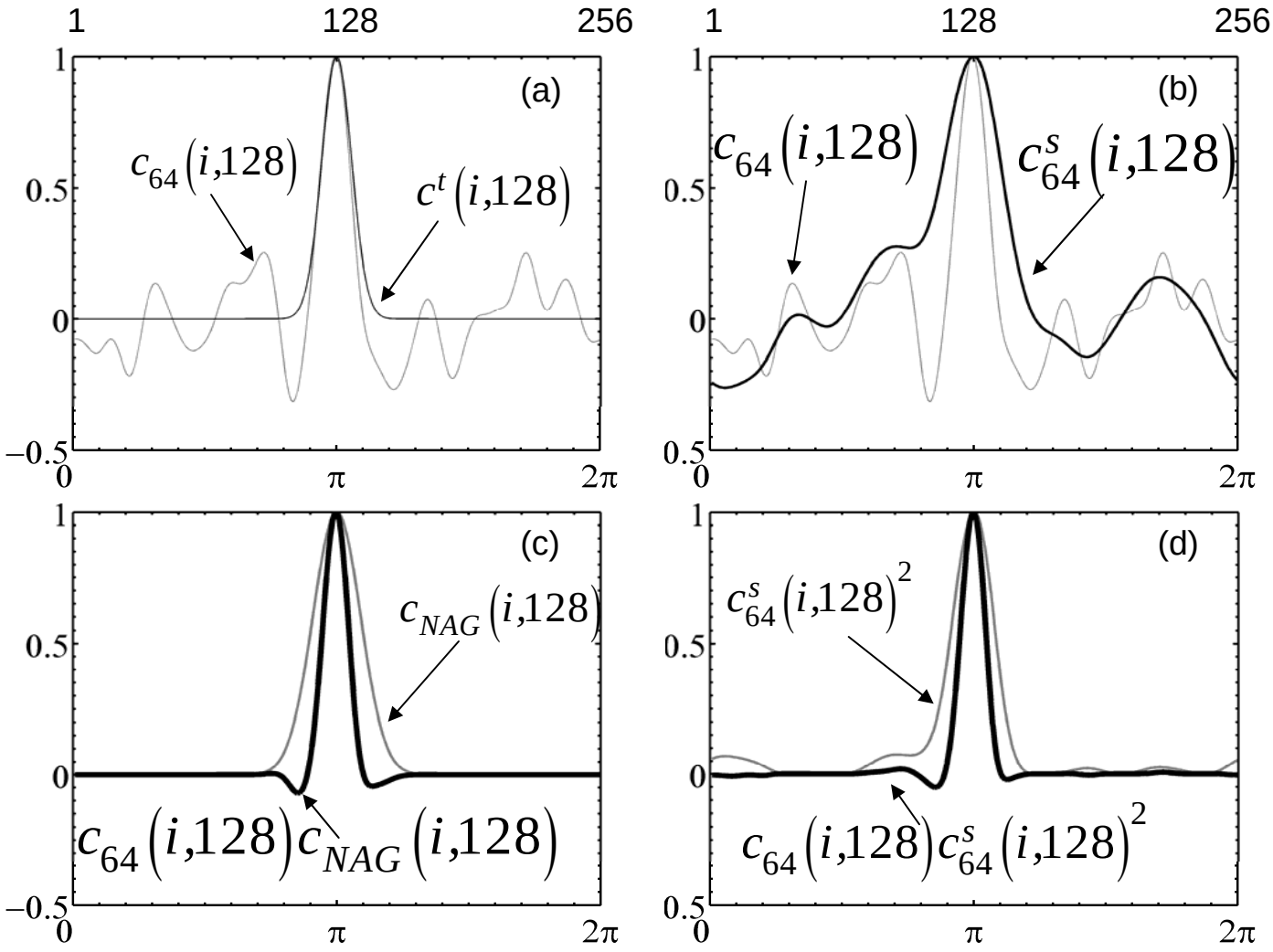
Craig H. Bishop, Daniel Hodyss

Naval Research Laboratory, Monterey, California

Aims

- Demonstrate flow adaptive ensemble covariance localization in dual form of global 4D-VAR (AR)
- Describe an ensemble covariance localization scheme that blends non-adaptive localization and adaptive localization.
- Discuss how localization function simplification can be used to greatly reduce the cost of ensemble covariance localization within 4D-VAR.

A simple adaptive localization technique



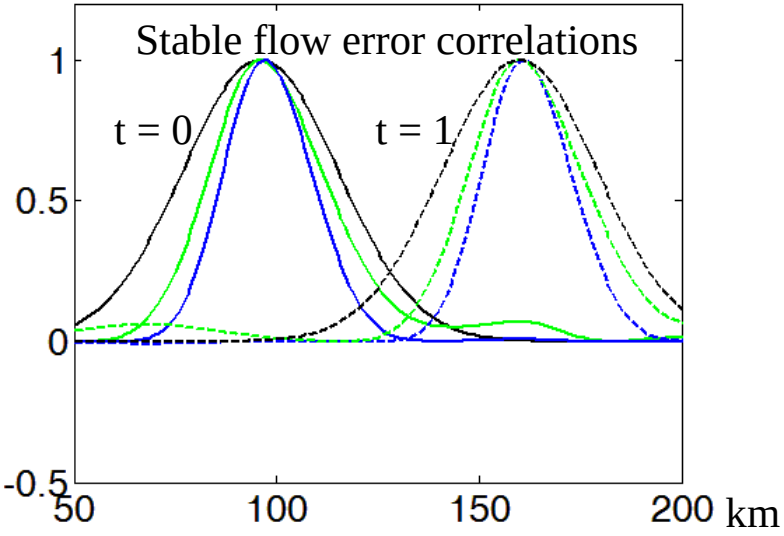
Bishop and Hodyss, 2007, QJRMS.

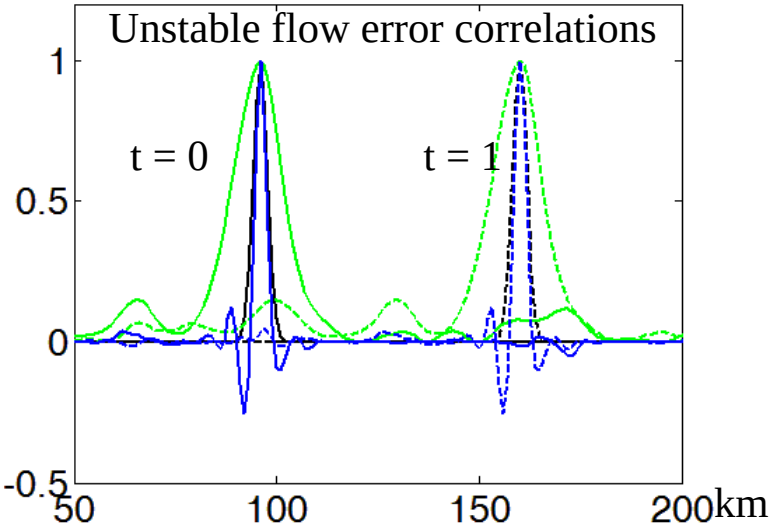
In matrix form,

$$\mathbf{P}^f = \mathbf{P}^f_K \odot \mathbf{C}_s \odot \mathbf{C}_s$$

A simple adaptive localization technique

- Green line now gives an example of one of the adaptive localization functions that are the subject of this talk.





Moderation functions based on smoothed ensemble correlations provide scale adaptive and propagating localization functions.

Non-adaptive localization

$$\mathbf{P}^f = \mathbf{P}_K^f \odot \mathbf{C}_N$$

- Storage problems solved by representing square root of **C_*N*** in terms of separable functions that can be computed on the fly.
- (Bishop et al., 2010 MWR under review) were able to show that localization is much faster when one or more of the following conditions are met:

a. localization function is a separable product of a function of the horizontal coordinate and a function of the vertical coordinate and/or

b. the localization length scale is much larger than the model grid spacing and/or

c. there are many variable types associated with each grid point and/or

d. 4D ensemble covariances are employed.

Non-adaptive localization is much faster than adaptive localization!

Partially adaptive localization

$\mathbf{P}^f = \mathbf{P}_K^f \odot \mathbf{C}_A \odot \mathbf{C}_N$ is partially adaptive localization

$\mathbf{C}_A = \left(\mathbf{C}_s \odot \mathbf{C}_s\right)$ is adaptive localization

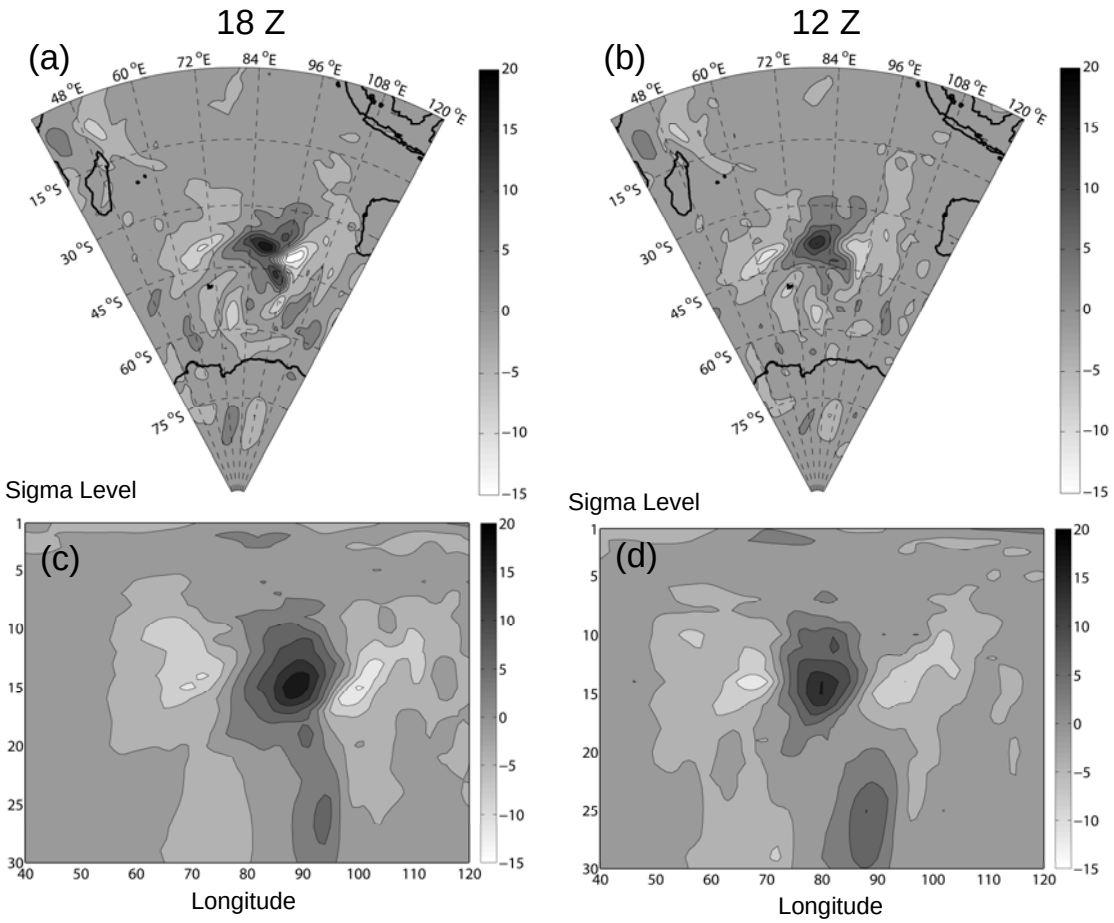
$\mathbf{C}_N$ is non-adaptive localization

- This formulation gives localizations ranging from non-adaptive to fully adaptive.
- Makes it easier to do adaptive localization with small ensemble sizes.

The partial adaptive localization approach combines adaptive and non-adaptive localization

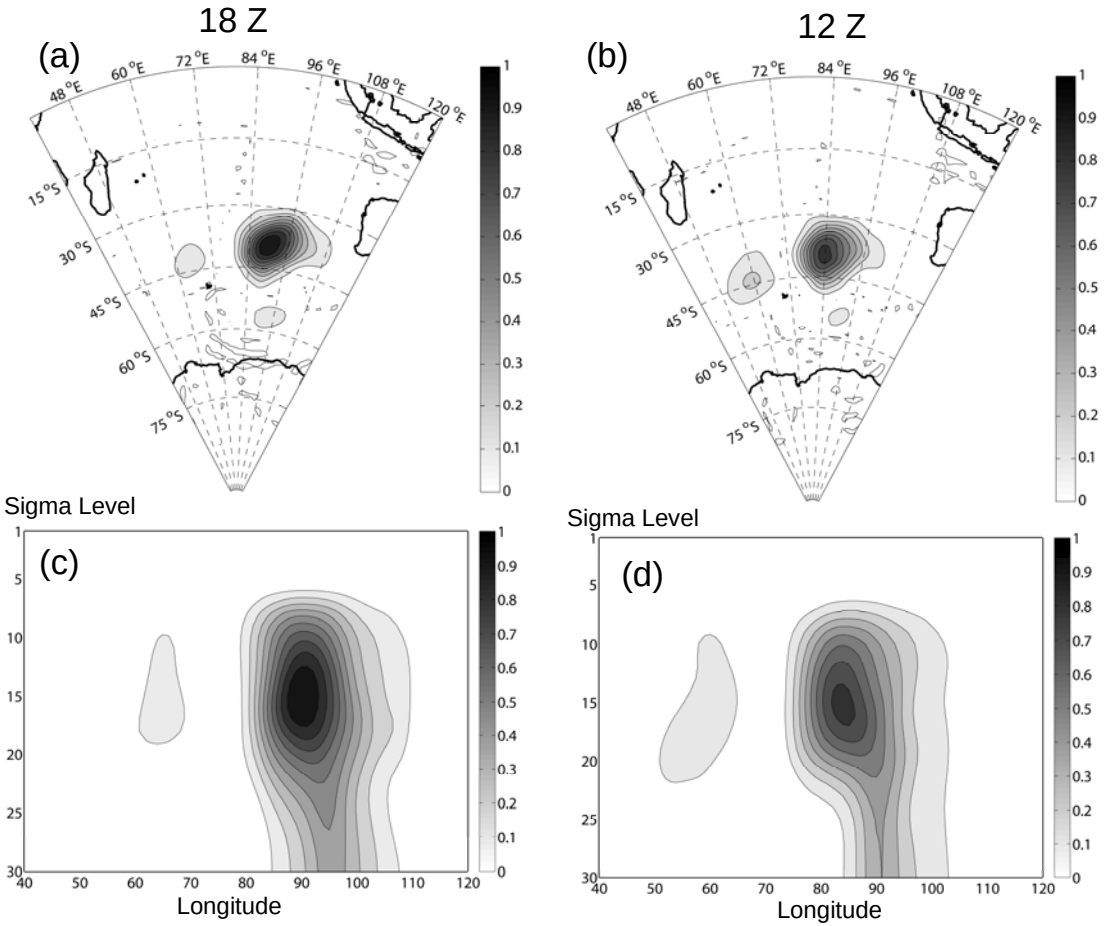
Experimental Set-up

- True state 30 hr – 42 hr NOGAPS forecast (T119L30). 1st guess is 6 hr – 18 hr forecast valid at the same time as the 30 hr – 42 hr truth run.
- Two obs networks considered. 6 hr DA window with obs at 9UTC, 12UTC and 15UTC. 12 hr DA window with obs at 6UTC, 12UTC and 18UTC.
- Rms ob error 2 m/s for (*u,v*) the 1 K for T. Every 3rd point in both the zonal and meridional directions and every 3rd grid point in vertical observed. No obs poleward of 80 S and 80 N.
- 128 member ensemble using ET technique. Cycled for 6 days preceding the first DA window.
- Localizations tuned to minimize analysis error in center of DA window (12 UTC),



Unlocalized ensemble covariance function of meridional wind at 18 UTC and 12 UTC with 18 UTC meridional wind variable at 90E, 40S sigma-level 15 (about 400 hPa).

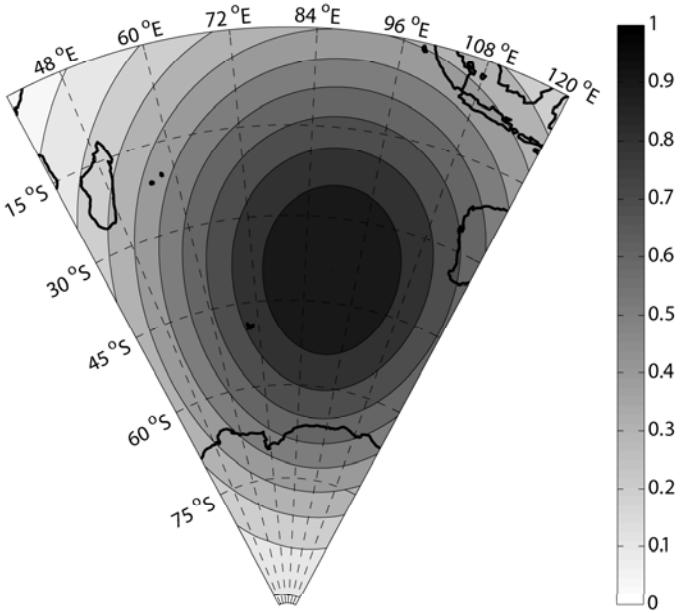
Adaptive ensemble covariance localization



This localization function is the element-wise square of the correlation function of a 128 member ensemble of smoothed and normalized streamfunction fields.

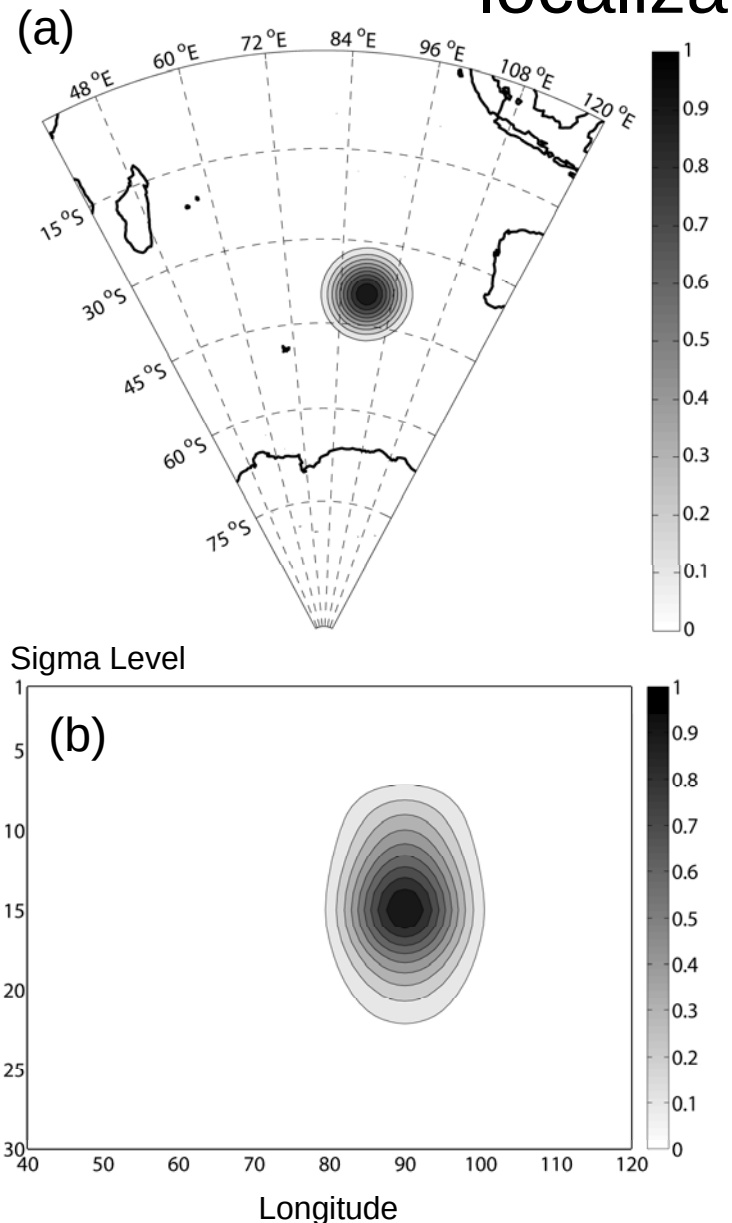
However, this localization function includes spurious oscillations as large as 0.1 in the Northern Hemisphere

Non-adaptive part of partially adaptive localization function



This non-adaptive localization function, when applied to the adaptive localization function, is broad enough to retain local adaptivity while narrow enough to suppress spurious far-field oscillations in the adaptive localization function.

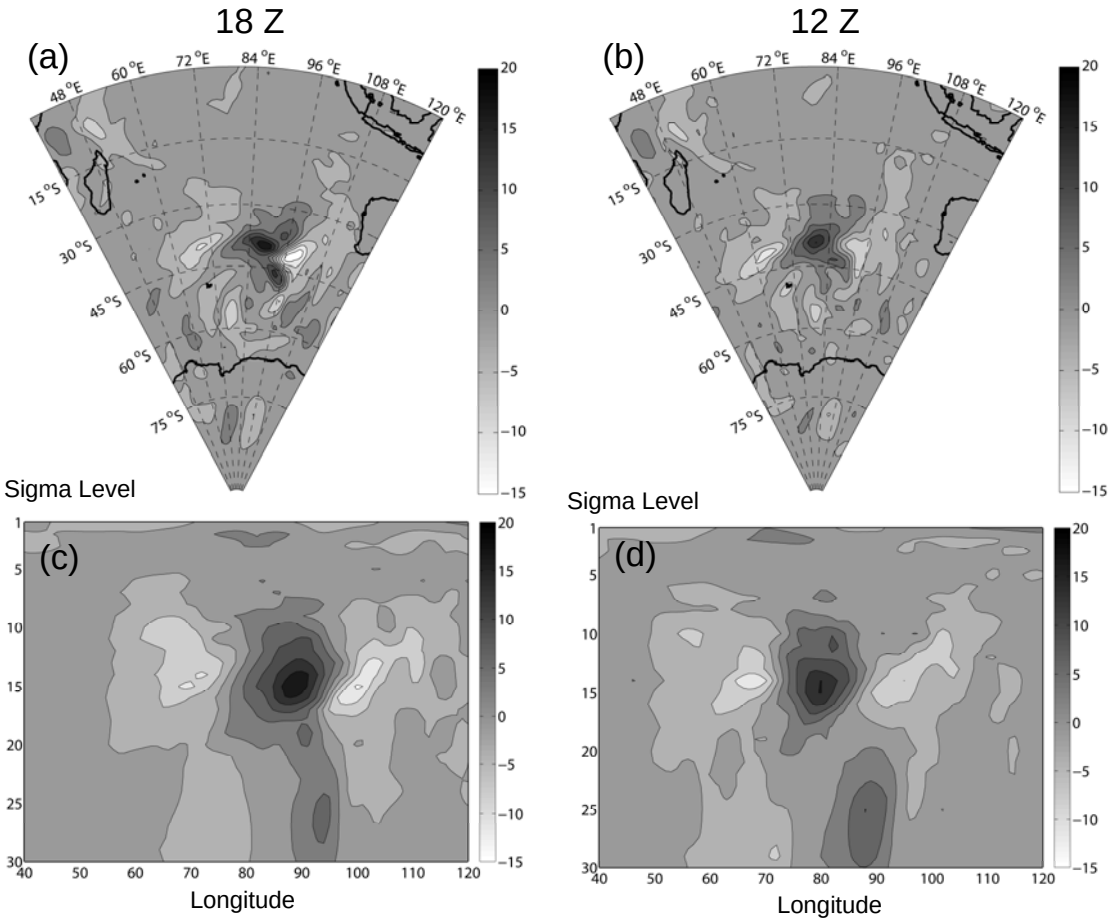
Non-adaptive ensemble covariance localization function



(The function is the same at 18 UTC and 12 UTC).

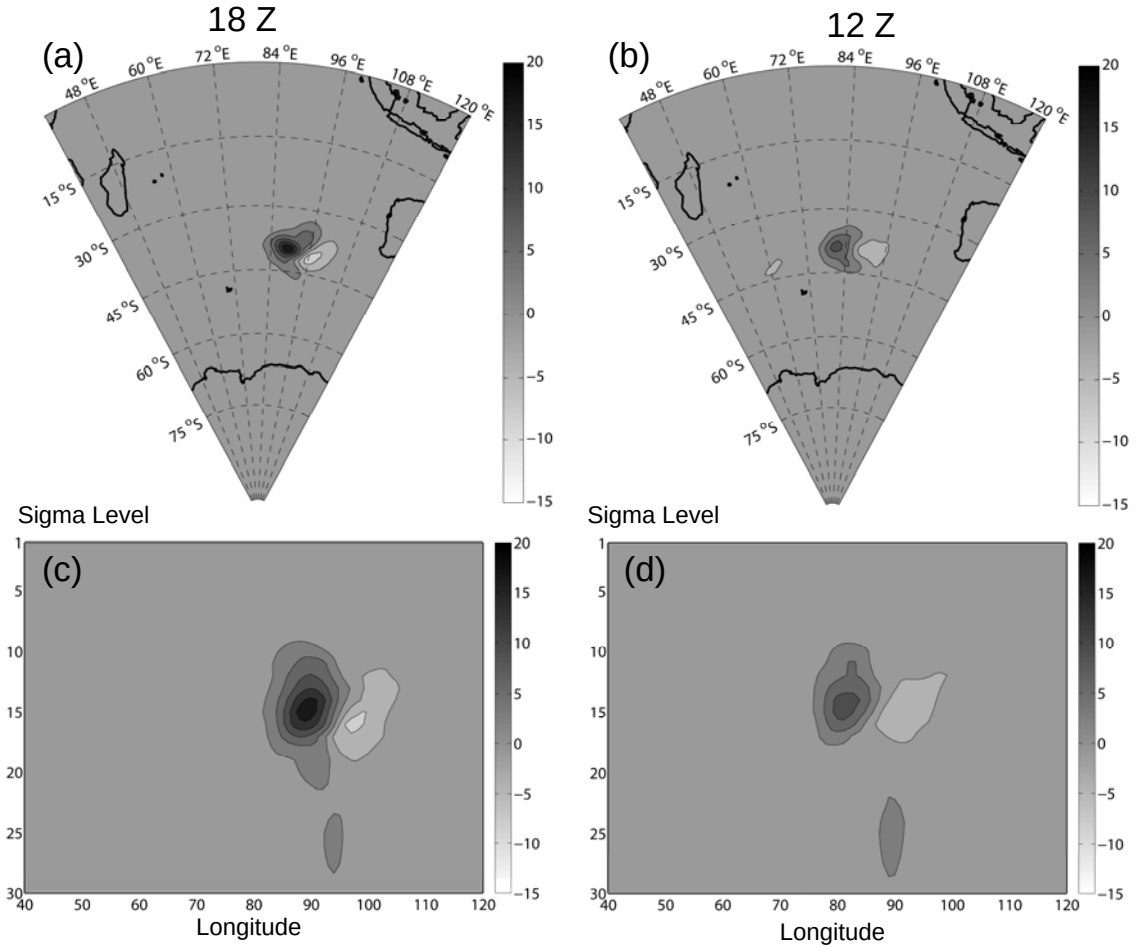
Pure non-adaptive localization is much tighter in the vertical

No localization



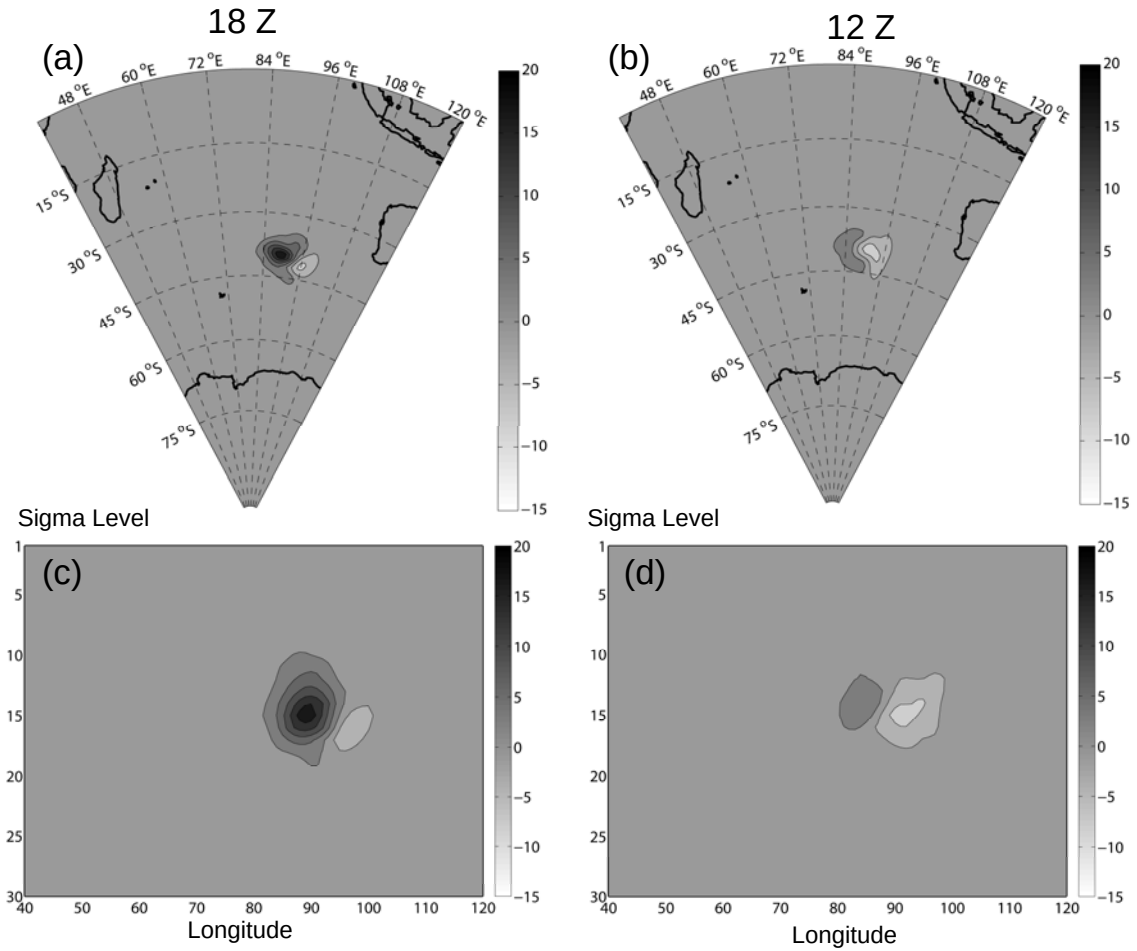
Unlocalized ensemble covariance function of meridional wind at 18 UTC and 12 UTC with 18 UTC meridional wind variable at 90E, 40S sigma-level 15 (about 400 hPa).

Partially-adaptive localization

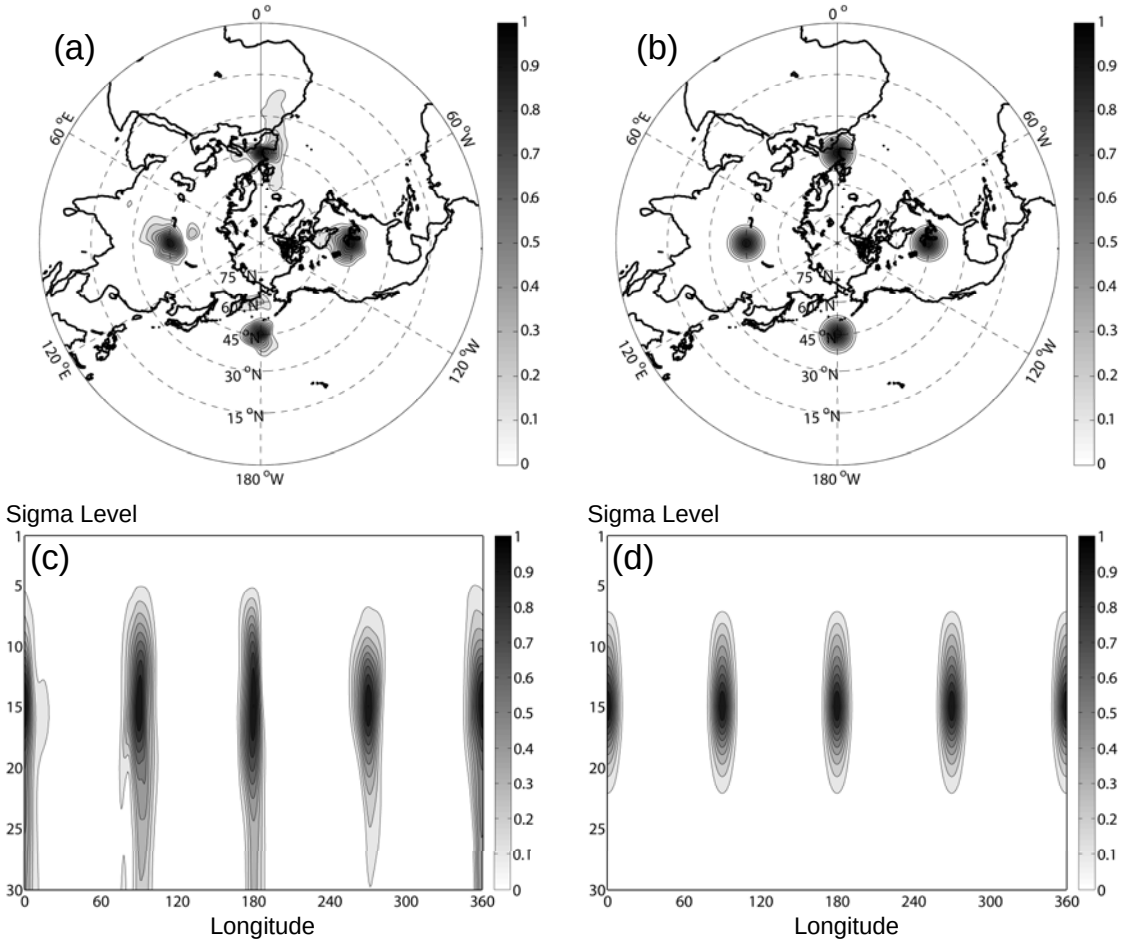


Ensemble covariance function localized with the partially adaptive ensemble covariance localization function (PAECL).

Non-adaptive localization

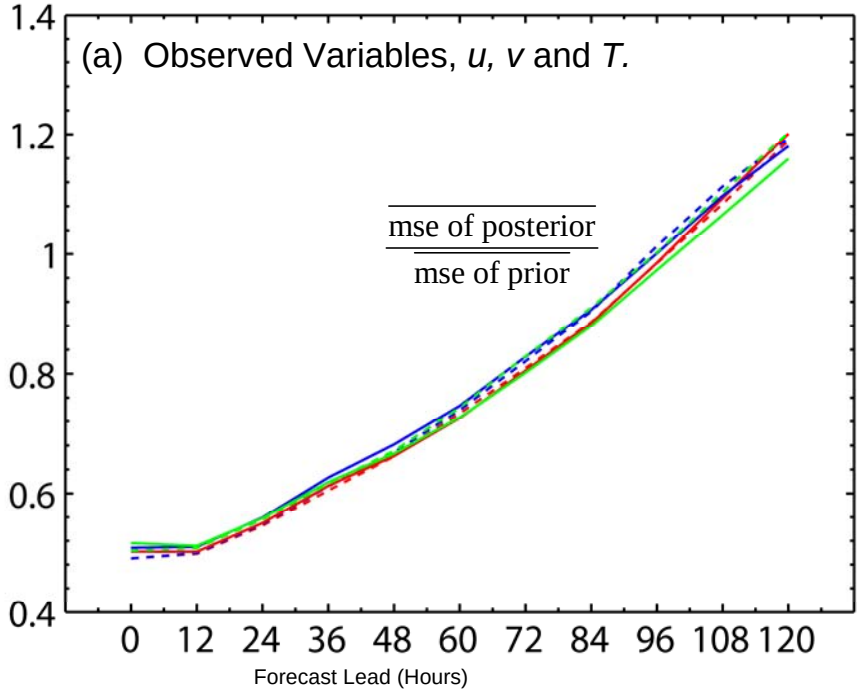


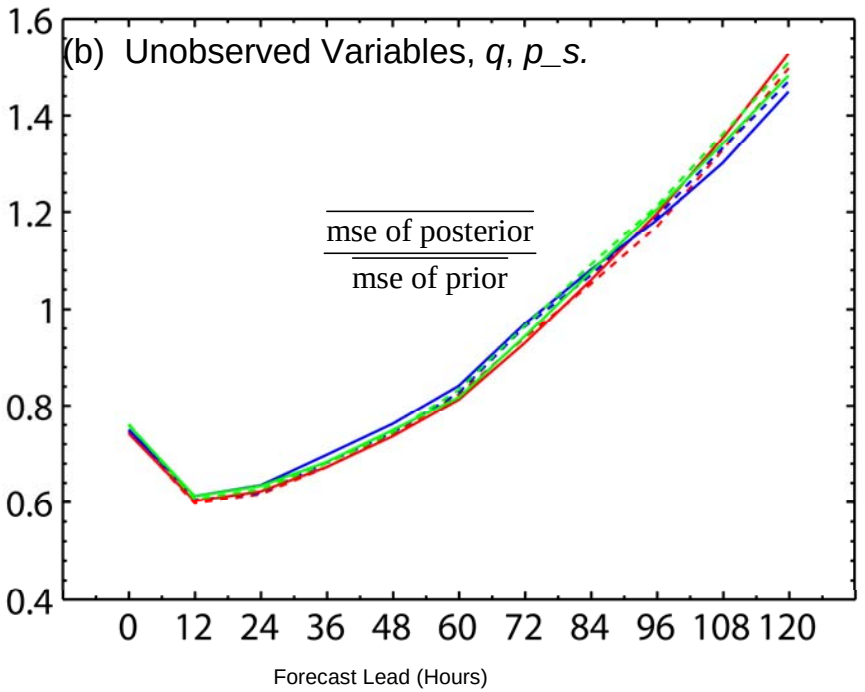
Ensemble covariance function localized with the non-adaptive ensemble covariance localization (NECL).



Comparison of structure of optimally tuned adaptive (a) and non-adaptive (b) localization functions at 12 UTC. Fig's (c) and (d) give the corresponding vertical structure of the adaptive and non-adaptive localization functions along the N latitude circle.

Adaptive Localization Versus Non-Adaptive Localization Versus Partially Adaptive Localization





Colors mark results for non-adaptive, partially adaptive and purely adaptive localization. Dashed and solid curves pertain to 6 hr and 12 hr DA window, respectively.

All schemes profoundly reduced state estimation error. However, no statistically significant difference between DA performance.

Why?

- Lack of variability of length scale of true error correlation functions?
- Lack of propagation of true error correlation functions?
- ET ensemble maybe a too poor model of the difference between short and long-term forecasts.
- All schemes were highly effective at removing state estimation error. Perhaps marginal gain from changes to covariance model was too small to see a significant performance difference.
- When we incorporate ensemble covariances into NAVDAS-AR, will we see the same result?

Concluding Remarks

- Adaptive localization is more expensive than non-adaptive localization.
- Significant performance differences were not evident in our idealized experiments using NOGAPS for 6 hr or 12 hr DA experiments.
- Partial adaptive localization smoothly combines adaptive and non-adaptive localization.
- Would the differences still be insignificant if we had cycled?
- What about if our DA scheme included an outer loop?
- What if our DA window was 24 hr long?
- Different ensemble?
- Currently in process of incorporating ensemble covariances with partially adaptive localization in NAVDAS-AR. Will be in a better position to answer these questions once this work is completed.