An Empirical Localization of Observations for Ensemble Kalman Filter Data Assimilation in Global Atmospheric Models

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Definition of Covariance Localization

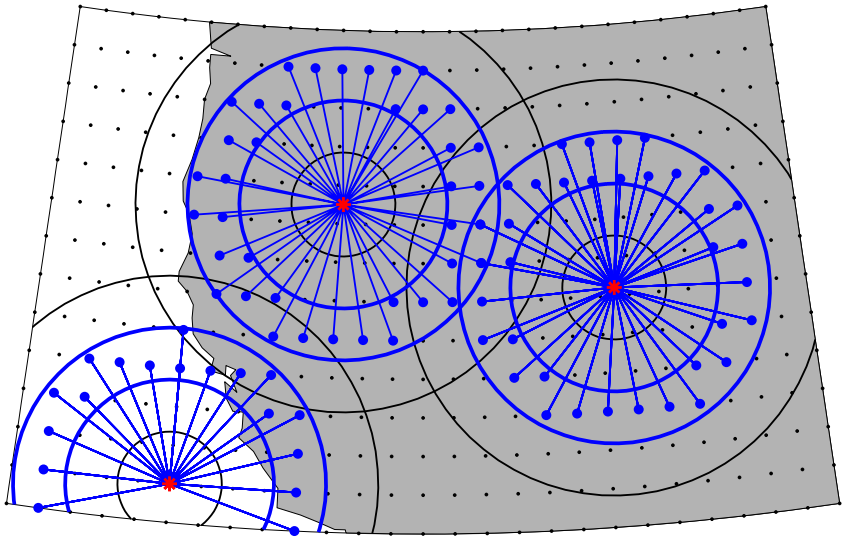
For an observation y and state variable x, the increment for the ensemble members of x are:

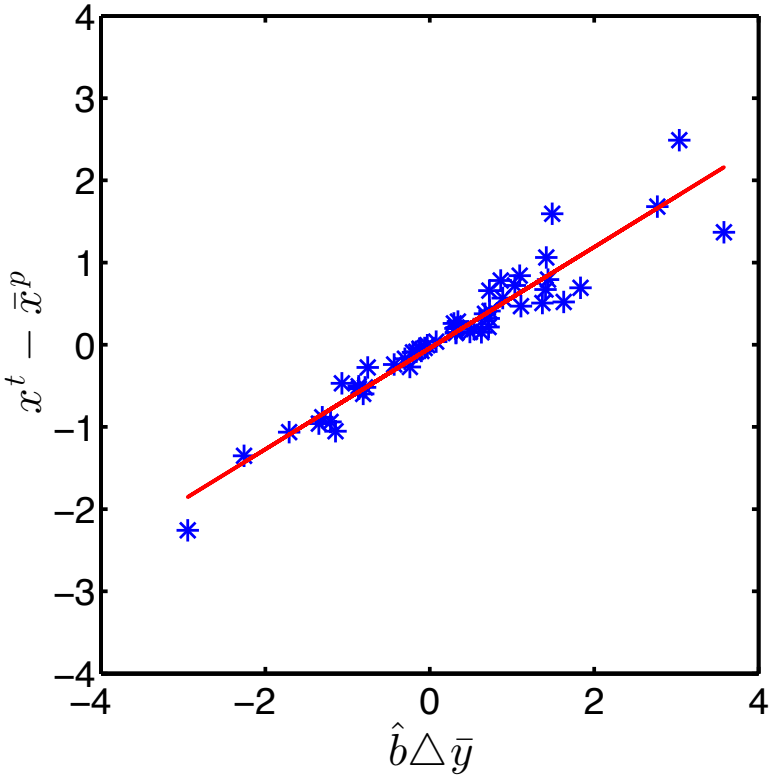
$$\Delta x_n = \alpha \hat{b} \Delta y_n, \quad n = 1, \ldots, N$$

where $\hat{b}$ is a sample regression coefficient,

and α is a localization.

Empirical Localization Function (ELF)

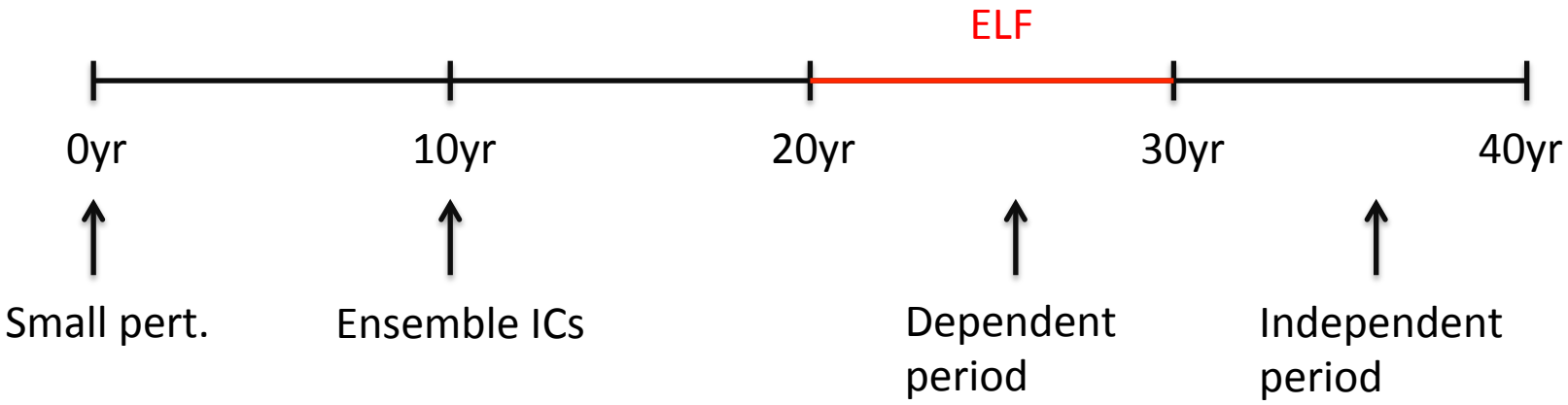




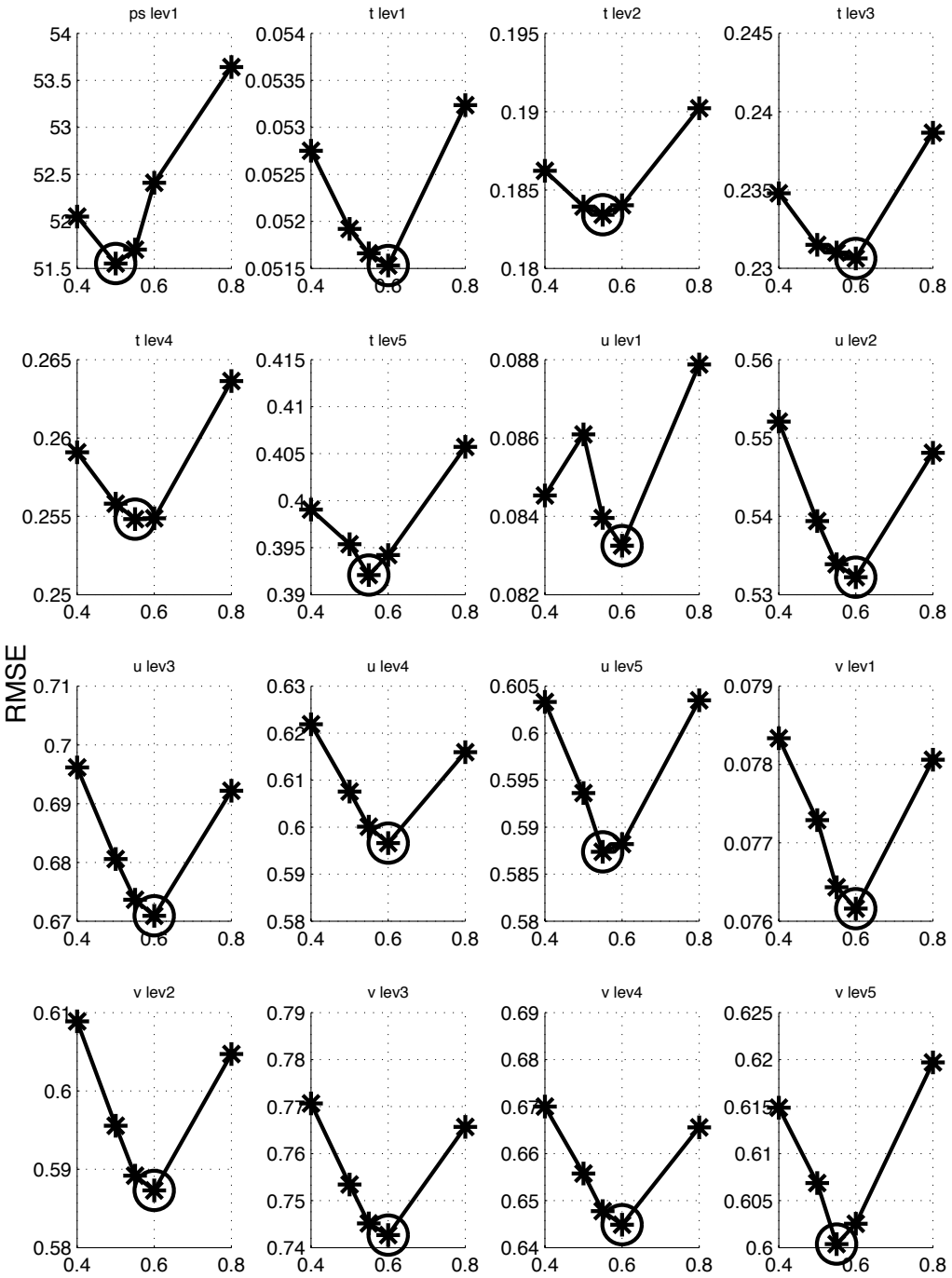
B-grid: Experimental Design

- An OSSE is conducted using the dynamical core of the GFDL B-grid atmospheric model (Anderson et al. 2004).
- The B-grid model has state variables of surface pressure, temperature, and zonal and meridional wind components.
- The horizontal model grid points are 30 latitudes × 60 longitudes and there are 5 vertical levels; the model time step is 1h.

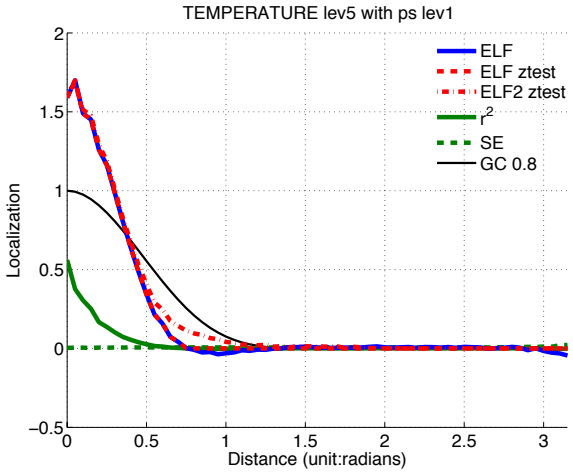
B-grid: Experimental Design



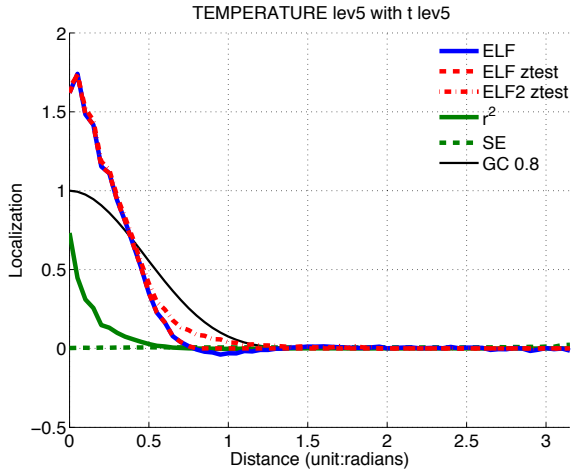
- The observation error variances are 2000 Pa^2 for surface pressure, 2 K^2 for temperature, and 8 m^2/s^2 for zonal and meridional wind components. The synthetic observations are available once per day and there are 300 approximately evenly distributed profiles.
- The ensemble Kalman filter with perturbed observations (e.g., Burgers et al. 1998, Houtekamer and Mitchell 1998) in the Data Assimilation Research Testbed (DART, Anderson et al., 2009) is used. Ensemble size is 32. Time-varying but spatially uniform state space adaptive inflation (Anderson 2009) is applied.


ps lev1
t lev1
t lev2
t lev3
t lev4
t lev5
u lev1
u lev2
u lev3
u lev4
u lev5
v lev1
v lev2
v lev3
v lev4
v lev5
RMSE
GC localization halfwidth

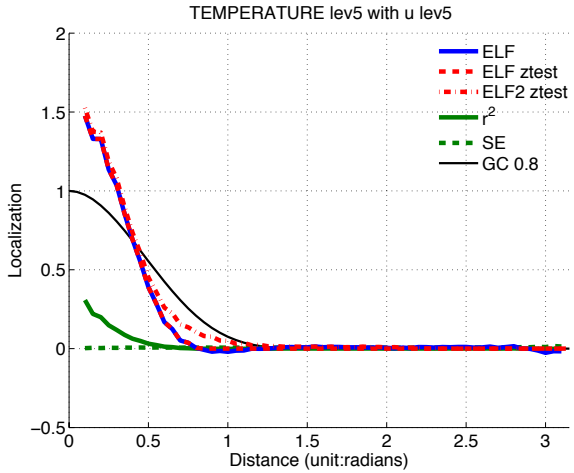
(a)


TEMPERATURE lev5 with ps lev1
ELF
ELF ztest
ELF2 ztest
r2
SE
GC 0.8
Localization
Distance (unit:radians)

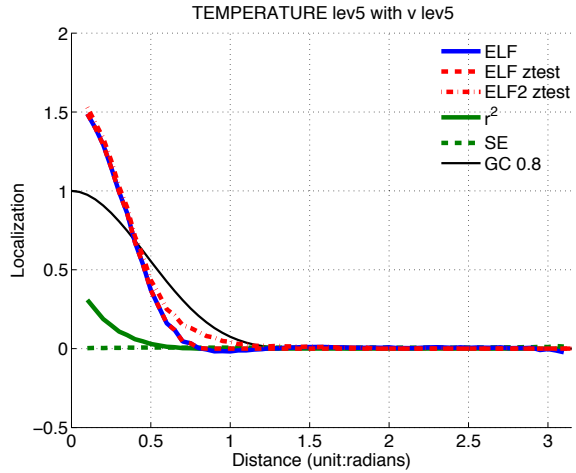
(b)

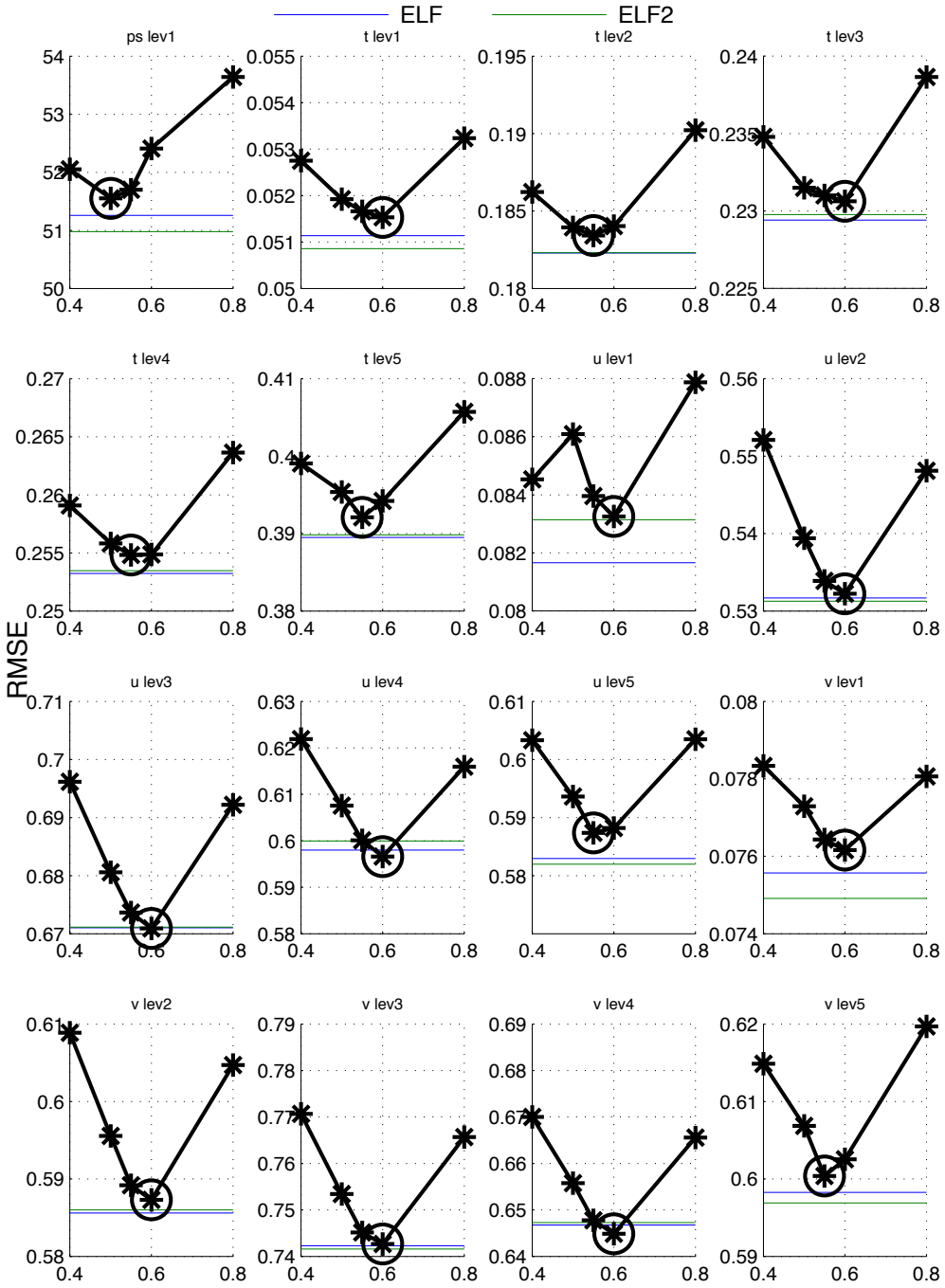

TEMPERATURE lev5 with t lev5
ELF
ELF ztest
ELF2 ztest
r2
SE
GC 0.8
Localization
Distance (unit:radians)

(c)


TEMPERATURE lev5 with u lev5
ELF
ELF ztest
ELF2 ztest
r2
SE
GC 0.8
Localization
Distance (unit:radians)

(d)


TEMPERATURE lev5 with v lev5
ELF
ELF ztest
ELF2 ztest
r2
SE
GC 0.8
Localization
Distance (unit:radians)


ELF
ELF2
ps lev1
t lev1
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t lev3
t lev4
t lev5
u lev1
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u lev4
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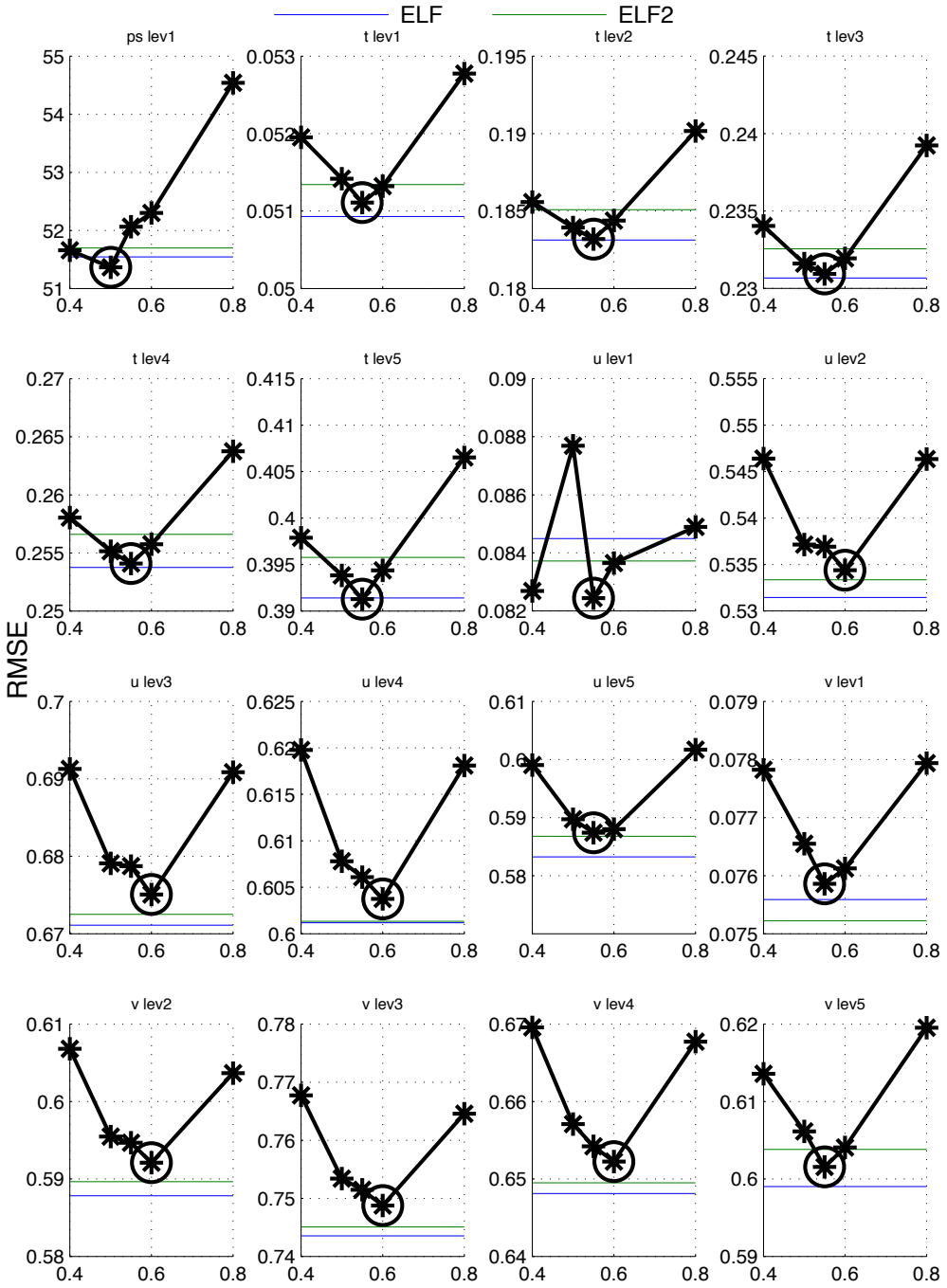
v lev1
v lev2
v lev3
v lev4
v lev5
RMSE
GC localization halfwidth


ELF
ELF2
ps lev1
t lev1
t lev2
t lev3
t lev4
t lev5
u lev1
u lev2
u lev3
u lev4
u lev5
v lev1
v lev2
v lev3
v lev4
v lev5
RMSE
GC localization halfwidth

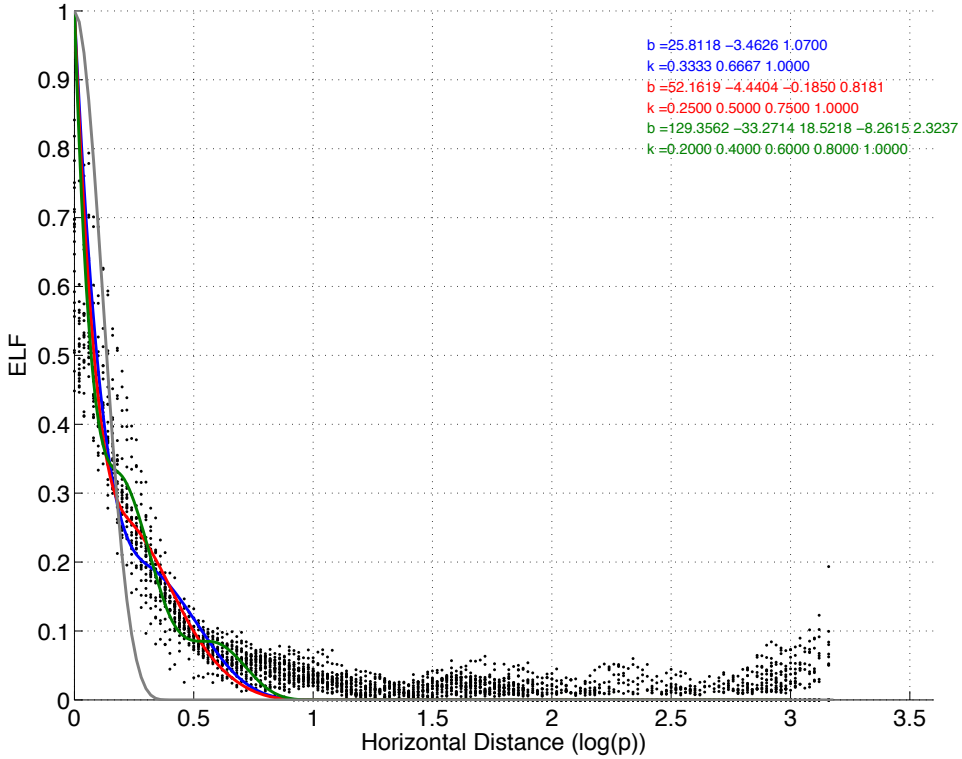
CAM: Experimental Design

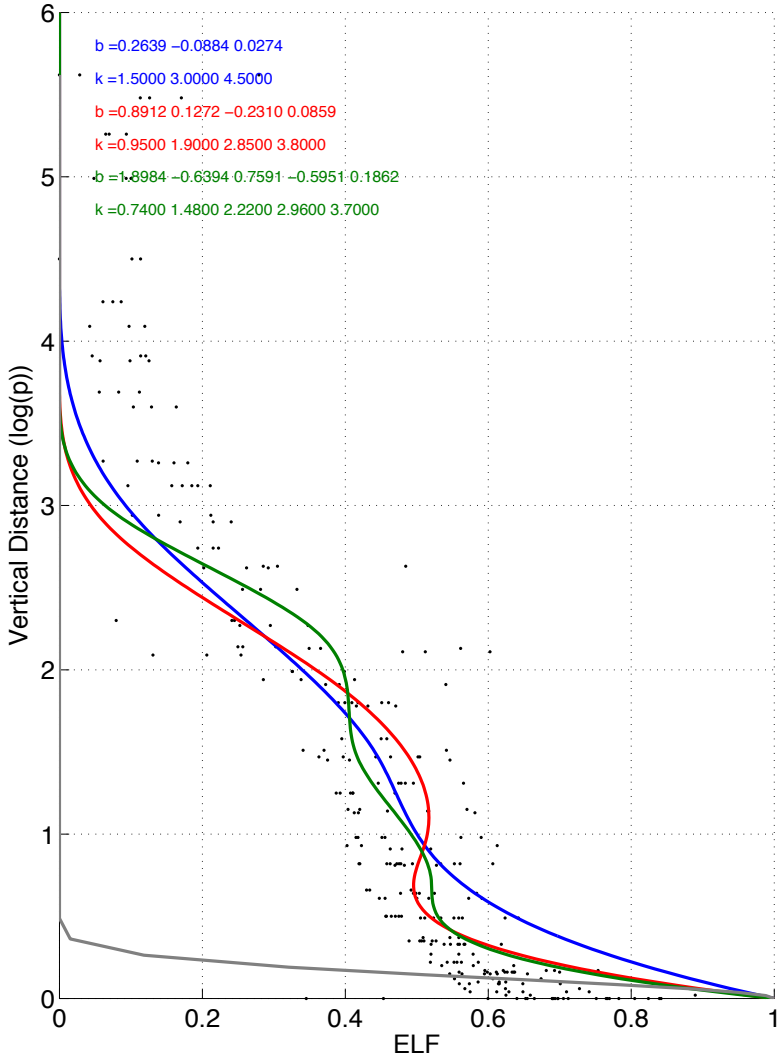
- The Community Atmospheric Model (CAM) is the atmospheric component of the Community Earth System Model (CESM). Use version CESM-1.1 and standalone configuration (F_AMIP).
- The horizontal resolution is 2° and there are 30 vertical levels.

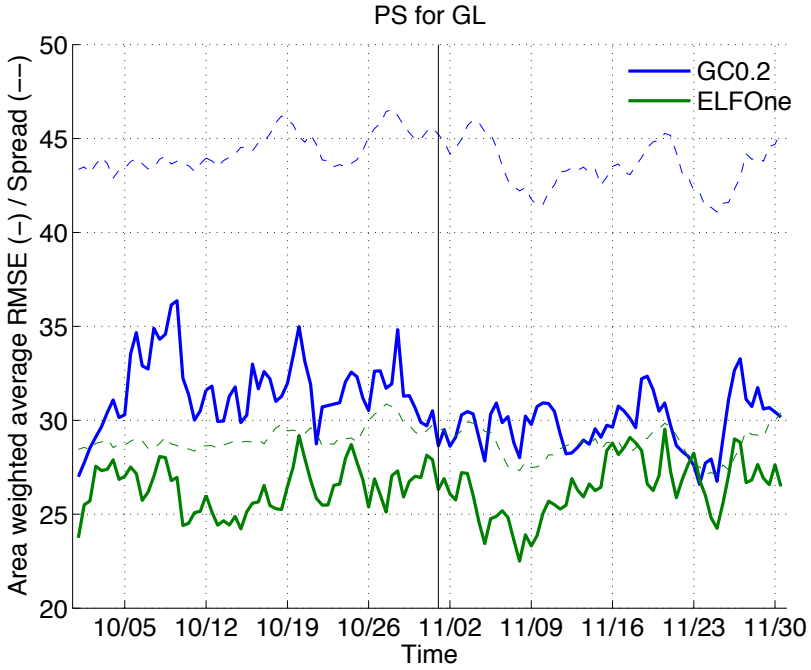
CAM: Experimental Design

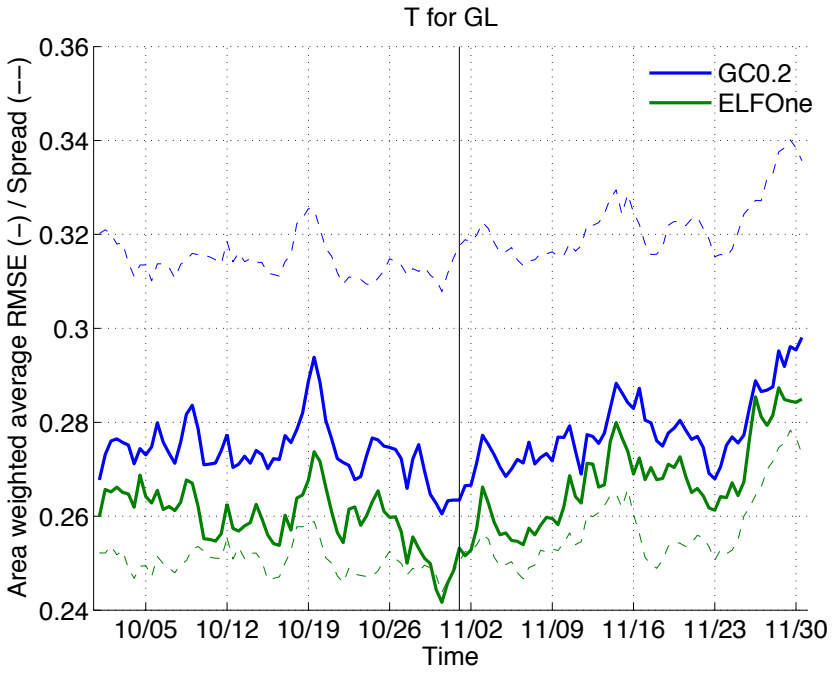
- These synthetic observations are nearly uniformly distributed in the horizontal and ranged from 1000 to 50 hPa in the vertical. There are 27000 synthetic observations available every 12 hours.
- The ensemble adjustment Kalman filter (Anderson 2003) in the Data Assimilation Research Testbed (DART, Anderson et al., 2009) is used. Ensemble size N is 80.
- Time-varying and spatially-varying state space adaptive inflation (Anderson 2009) is applied.
- The simulation experiment is performed from September 2008 to November 2008. The data of October/November is used for dependent/ independent evaluation.

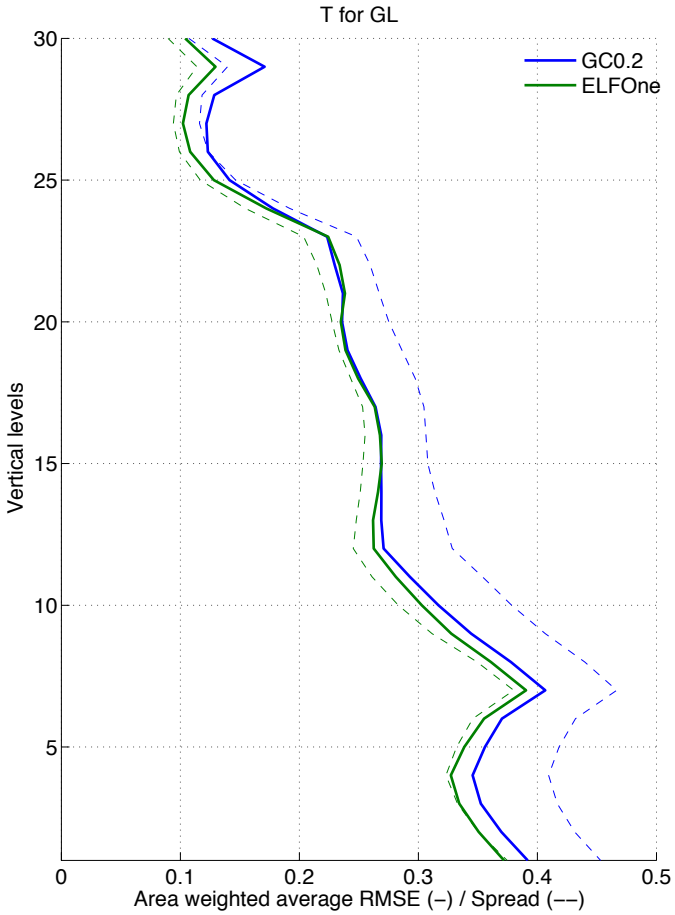
Horizontal & Vertical ELFs






PS for GL
GC0.2
ELFOne
Area weighted average RMSE (–) / Spread (––)
Time
50
45
40
35
30
25
20
10/05
10/12
10/19
10/26
11/02
11/09
11/16
11/23
11/30


T for GL
GC0.2
ELFOne
Area weighted average RMSE (–) / Spread (––)
Time
0.36
0.34
0.32
0.3
0.28
0.26
0.24
10/05
10/12
10/19
10/26
11/02
11/09
11/16
11/23
11/30

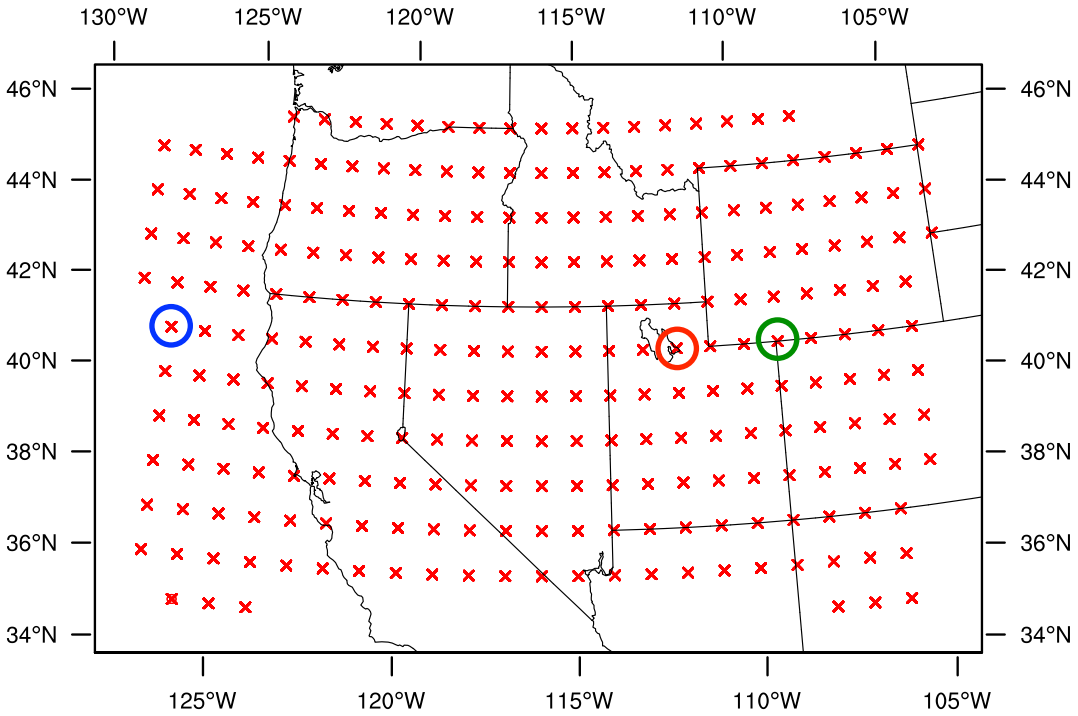

T for GL
GC0.2
ELFOne
Vertical levels
Area weighted average RMSE (–) / Spread (––)
30
25
20
15
10
5
0
0.1
0.2
0.3
0.4
0.5

Conclusions

- In an OSSE conducted with the B-grid climate model, the ELFs can have values larger than 1.0 at 0 separation indicating insufficient prior ensemble spread. Thus the ELF can correct the underestimated spread and play the role of an inflation when the ensemble spread is too small.
- In both dependent and independent data verification periods, the ELF generally has smaller RMSE than the best GC half width, thus the ELF can outperform the optimal GC localization function without assuming a Gaussian like localization function or requiring intensive computational effort to tune the localization scale.
- In an OSSE conducted with the CAM, the ELF outperforms the generally used GC with cutoff 0.2 radians.

Examine ELFs at three observation locations

- Ocean
- Valley
- Mountain

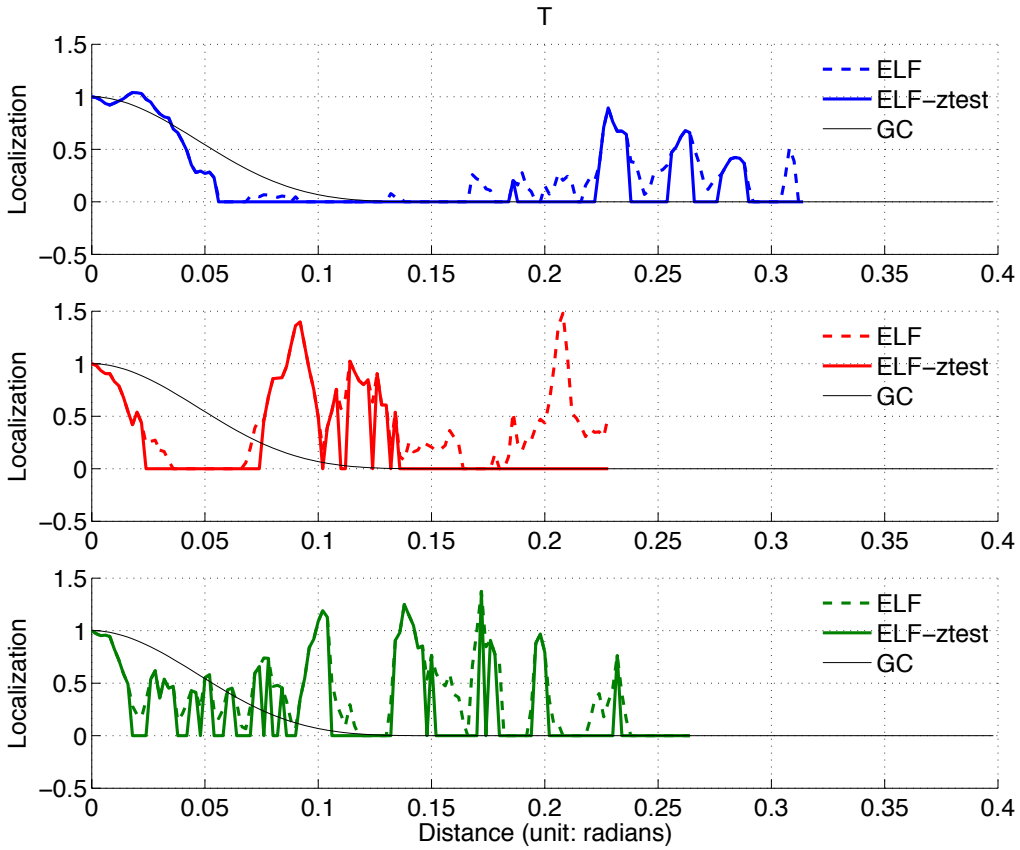


Horizontal ELFs of T with T at three observation locations

Ocean

Valley

Mountain



The ELF of the observation over ocean (blue) is wider than the others.

The ELFs are highly structured, especially at tails.

THANK YOU!