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Adaptive localization for satellite radiance observations in an ensemble Kalman filter

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Motivation (1)

- Assimilation of satellite radiances has been proven to have positive impacts on the forecast skill, especially for regions with sparse conventional observations.
- Localization is an essential component to effectively assimilate satellite radiances in ensemble Kalman filters with affordable ensemble sizes.
- But localizing the impact of radiance observations is not straightforward, since satellite radiances are integral observations whose location and distance are not well defined in the vertical.

Motivation (2)

- An adaptive global group filter (GGF) was proposed by use of climatological ensembles to provide theoretical estimate of vertical localization functions for the AMSU-A radiance observations (Lei et al. 2016).
- Two questions remain:
  - Can the localization function be estimated adaptively along with the assimilation?
  - Can the adaptive localization be applied to every observation type that are assimilated?

Global Group Filter (GGF)

Collecting ensemble priors of observations and state variables in an assimilation cycle

- Define $\mathbf{Y}^o$ as the set of all ensemble prior estimates for one type of observations (e.g., NOAA-15 AMSU-A channel 6).

$$\mathbf{Y}^o = \{y_{l,n}\} \quad l \in \{1,\ldots,L\},\ n \in \{1,\ldots,N\}$$

L is the total number of observations of this given type, and N is the ensemble size

- Define $\mathbf{X}^v$ as the set of one kind of state variables (e.g., temperature) that are interpolated to the horizontal locations of observations .

$$\mathbf{X}^v = \{x_{l,n}^k\} \quad k \in \{1,\ldots,K\}$$ K is the number of model vertical levels

Global Group Filter (GGF)

- At each vertical level k, the sample correlations between the observations and state variables can be computed by

$$r_l^k = \frac{\sum_{n=1}^{N}\left(x_{l,n}^k - \overline{x_l^k}\right)\left(y_{l,n} - \overline{y_l}\right)}{\sqrt{\sum_{n=1}^{N}\left(x_{l,n}^k - \overline{x_l^k}\right)^2}\sqrt{\sum_{n=1}^{N}\left(y_{l,n} - \overline{y_l}\right)^2}}$$

the overbar denotes the ensemble mean

- Randomly subset the sample correlations r_l^k to G groups, and the rearranged sample correlations by $r_{m,g}^k$, $g \in \{1,\ldots,G\}$ and $m \in \{1,\ldots,M\}$, where M is sample size

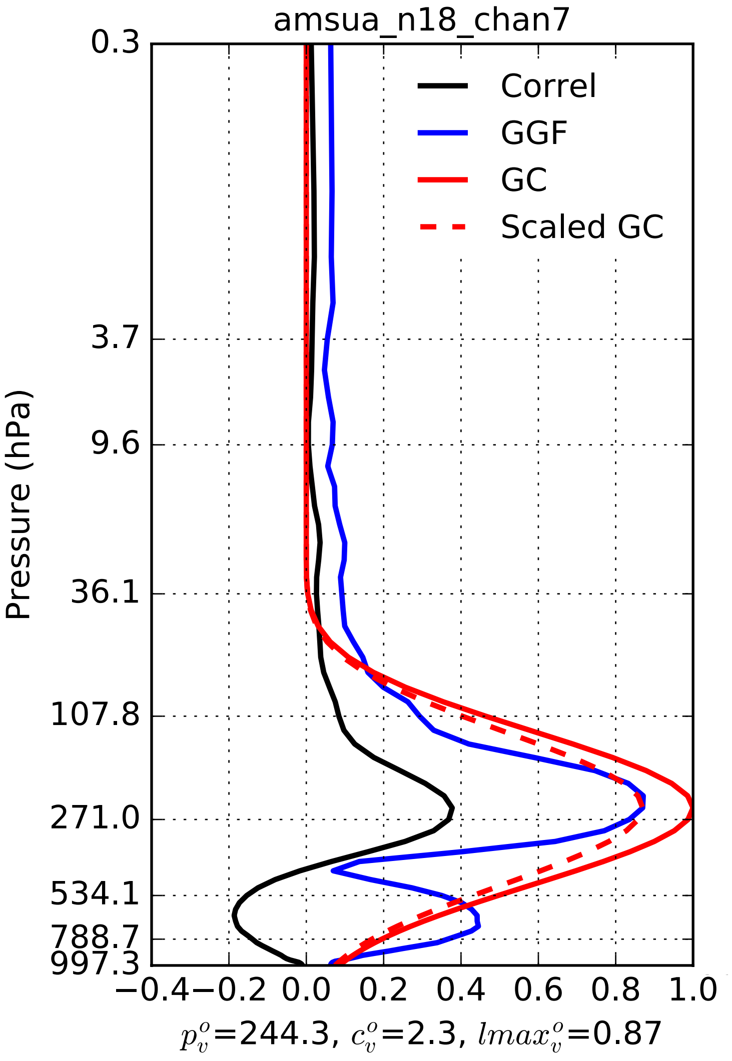
Global Group Filter (GGF)

- The localization value α^k for model level k is defined to minimize the sampling error of the sample correlations, which gives

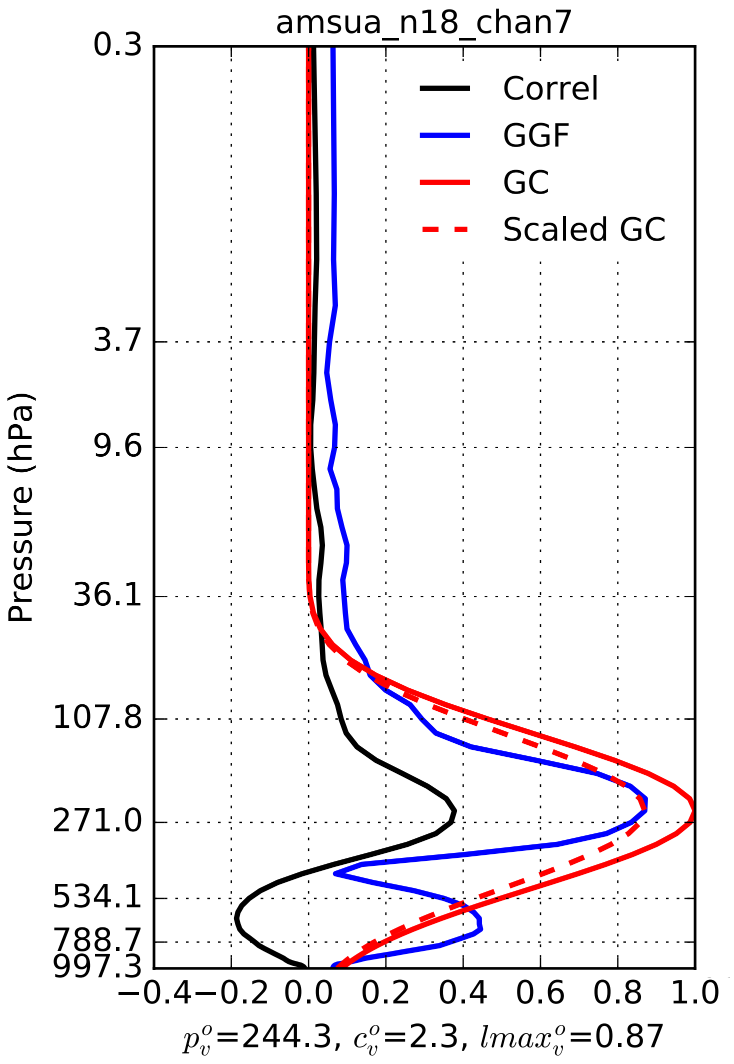
$$\alpha^k = \frac{\sum_{m=1}^{M}\left(\sum_{g=1}^{G} r_{m,g}^k\right)^2 \Big/ \sum_{m=1}^{M}\sum_{g=1}^{G}\left(r_{m,g}^k\right)^2 - 1}{G-1}$$

- After computing α^k for each model vertical level k, an adaptive vertical localization function (GGF) for a given observation type and state variable kind is obtained.

GGF of NOAA-18 AMSU-A channel 7 with temperature



GGF of NOAA-18 AMSU-A channel 7 with temperature

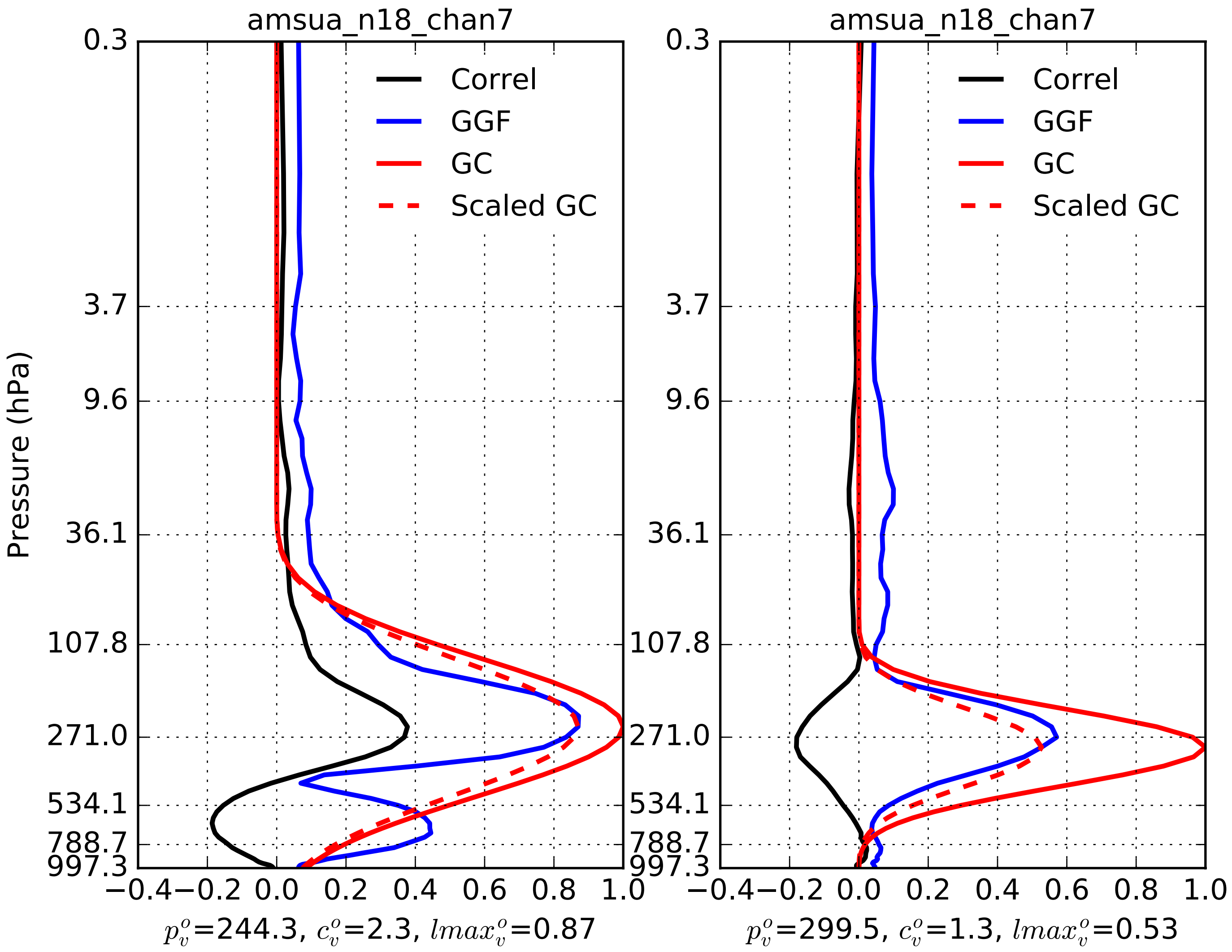


p_v^o , observation vertical location, where maximum mean correlation occurs

c_v^o , localization width of the fitted GC function to the GGF

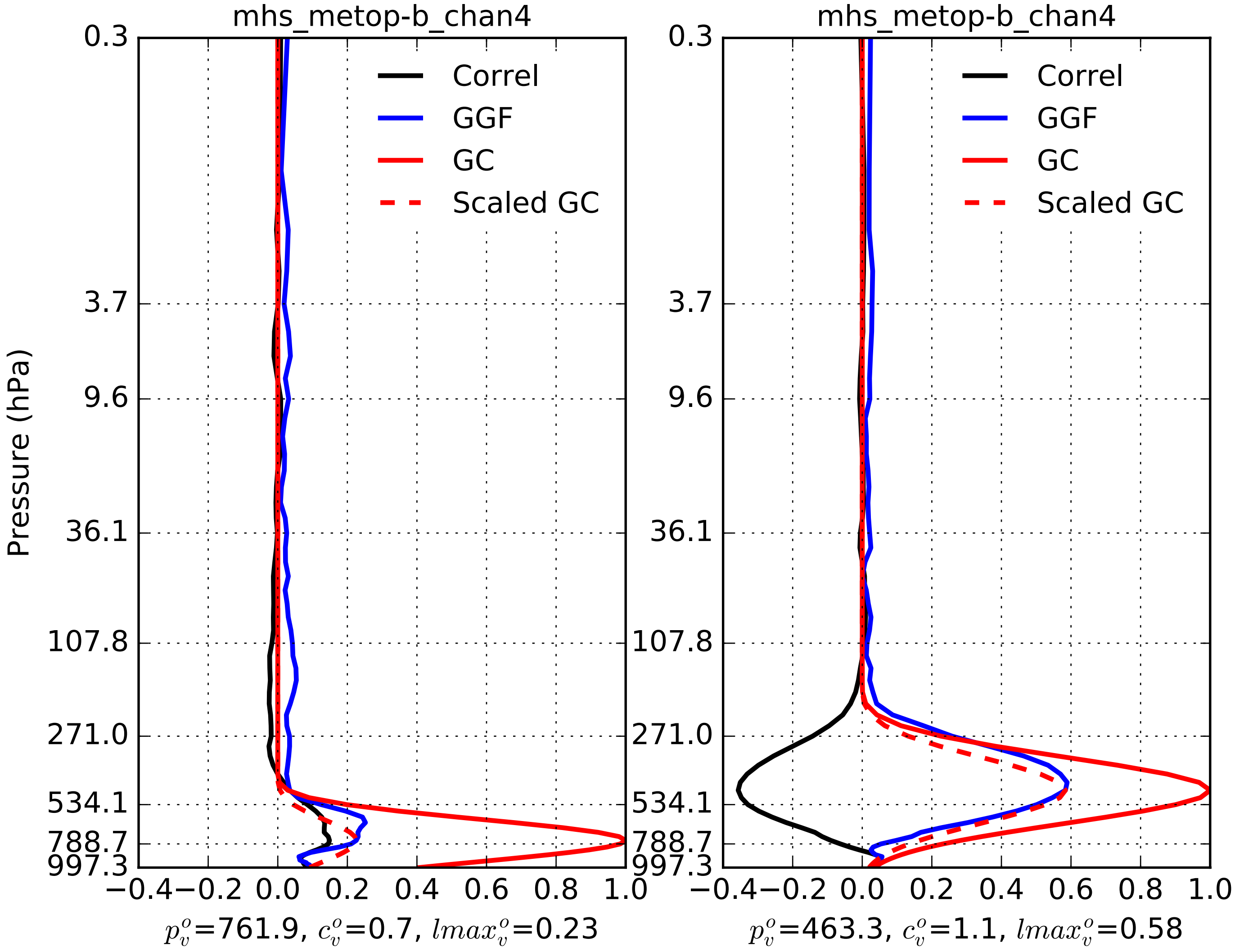
$l\max_v^o$, GGF localization value at p_v^o, which gives the maximum of GC function

GGFs of NOAA-18 AMSU-A channel 7



The three localization parameters that gives the largest mean sample correlation are used.

GGFs of MetOp-B MHS channel 4



The three localization parameters from the GGF with state variable humidity are used.

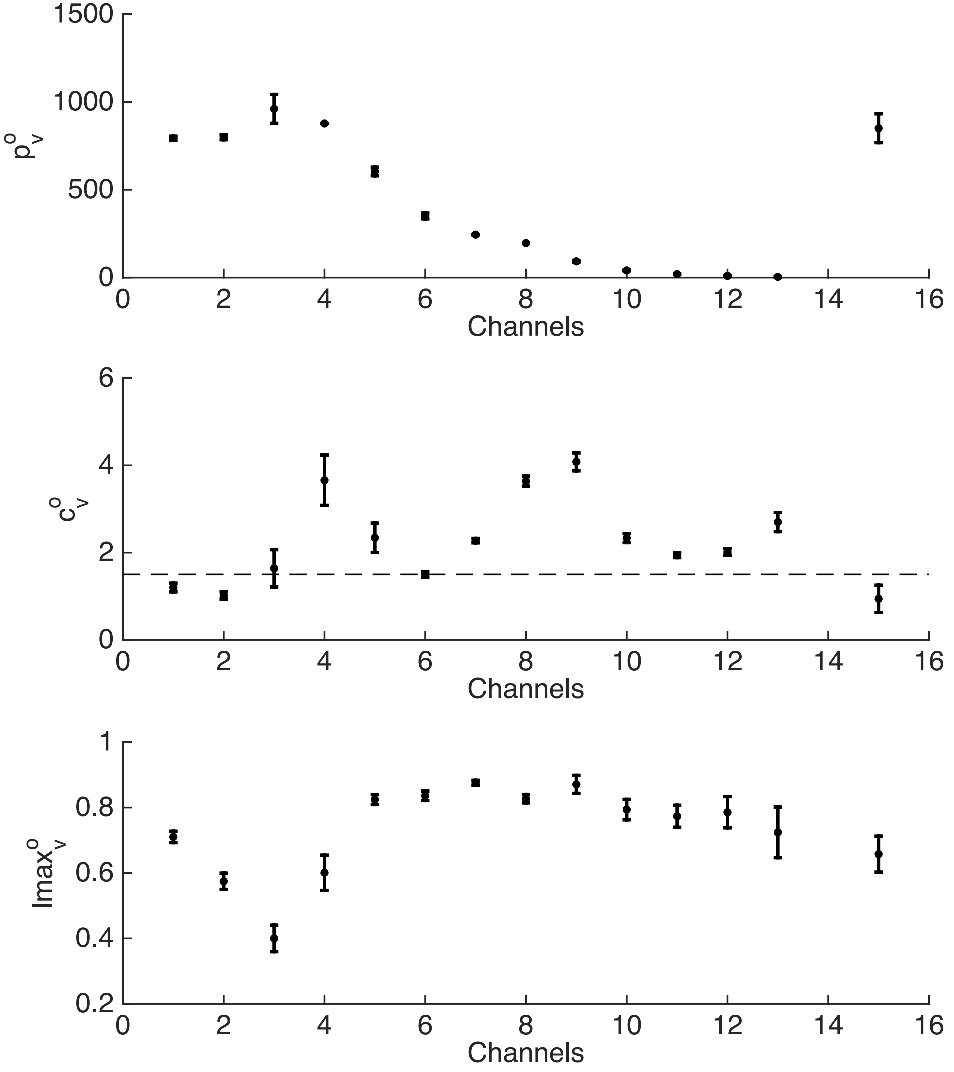
Experimental Design

- Ensemble assimilation experiments with 80 ensemble members are conducted using the NCEP Global Forecast System (GFS) model with a resolution T254L64.
- All radiance observations that are used in the NCEP Global Data Assimilation System (GDAS) are assimilated every 6 h.
- The gridpoint statistical interpolation (GSI) is used to compute the observation priors for the ensemble mean and each ensemble member. The bias correction is adapted from an experiment assimilating both conventional and radiance observations.
- The observation error variance $\mathbf{R}$ uses the same values as in the NCEP GDAS.

Experimental Design

- The ensemble square root filter (EnSRF) in the NOAA operational EnKF is used to assimilate the observations.
- Multiplicative covariance inflation that relaxes posterior ensemble spread back to prior ensemble spread is used with relaxation coefficient 0.85.
- During model integration, stochastic physics are used to represent the model uncertainty. No additive inflation is applied.
- Horizontal localization uses the GC localization function that tapers the observation impact to 0 at 1250 km.
- Vertical localization uses the GC localization function with a given localization width (default value is 1.5 (*ln*(hPa)) or adaptively estimated localization parameters.

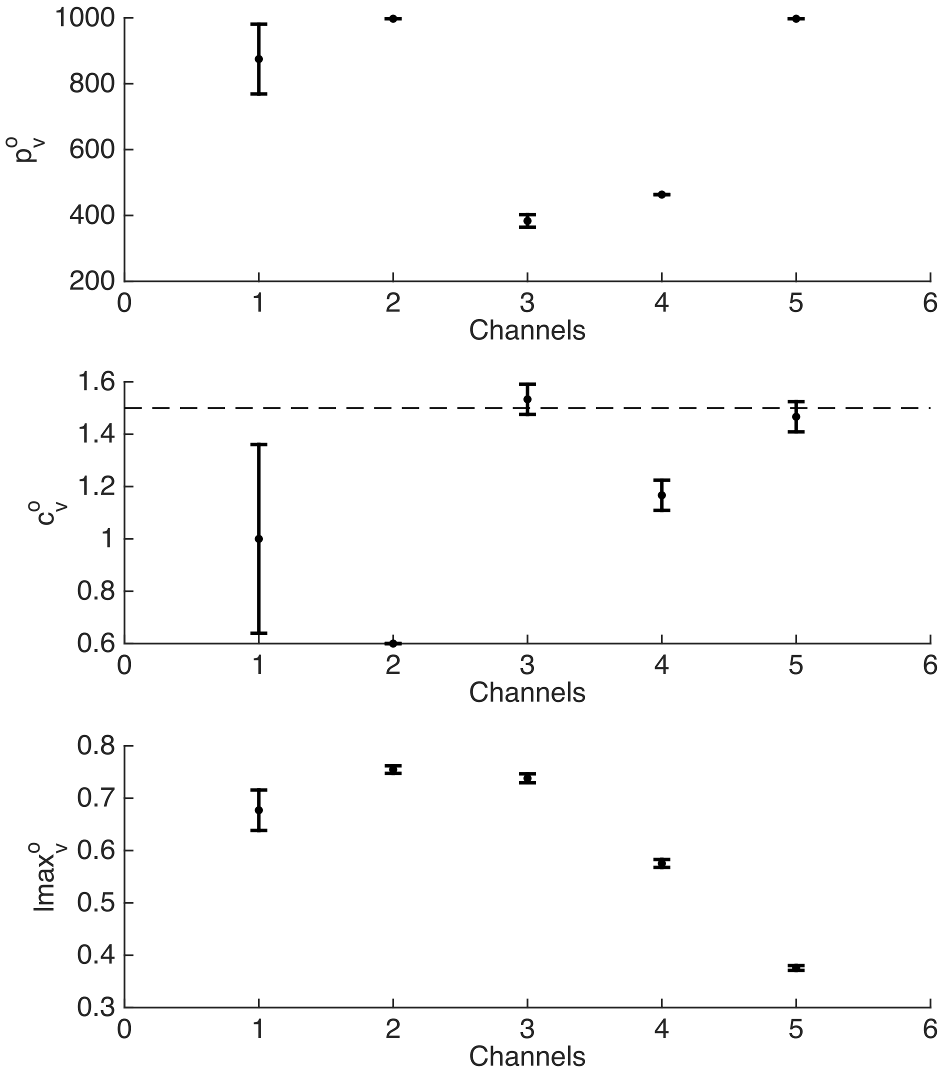
Adaptively estimated localization params. for AMSU-A



The estimated localization parameters vary among the channels.

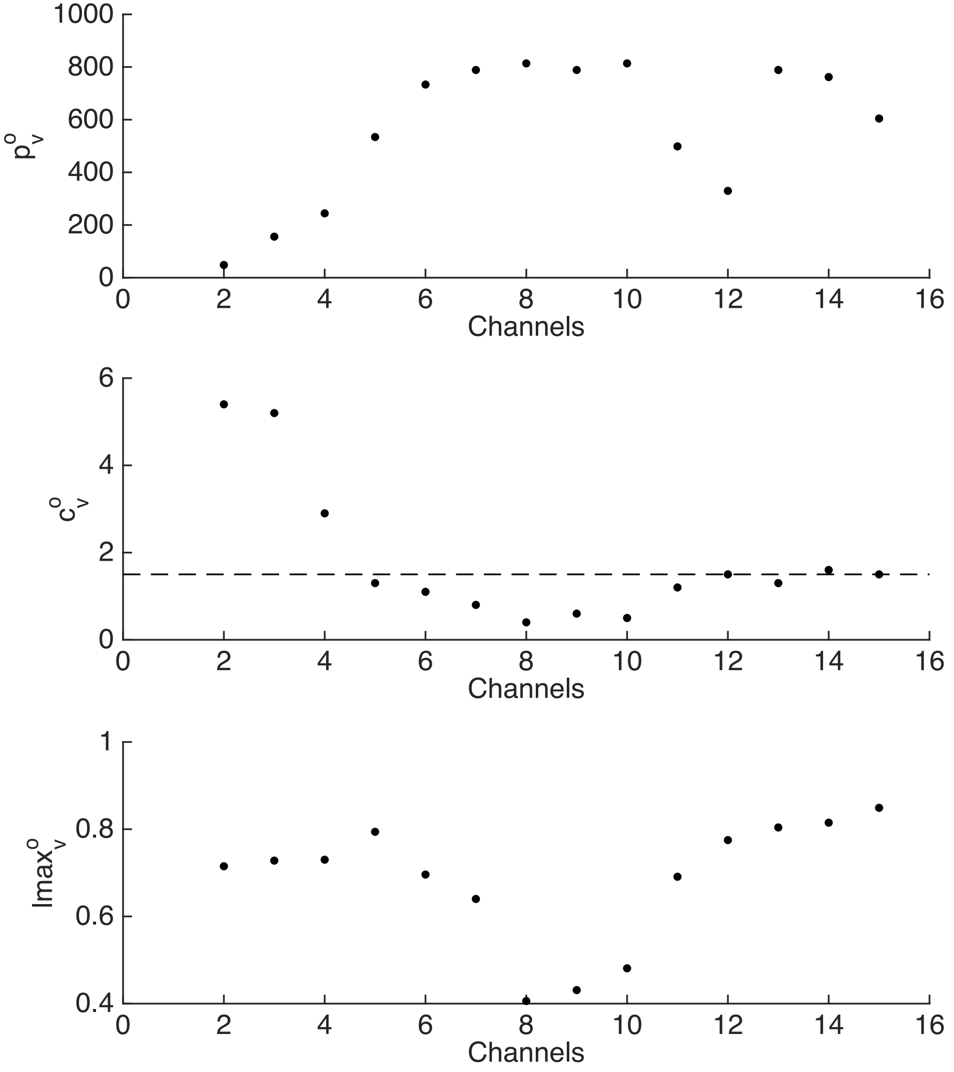
They generally agree with each other among different satellite platforms.

Adaptively estimated localization params. for MHS



The estimated localization width c_v^o and maximum localization value $l\max_v^o$ for MHS radiance observations are generally smaller than those for AMSU-A radiance observations.

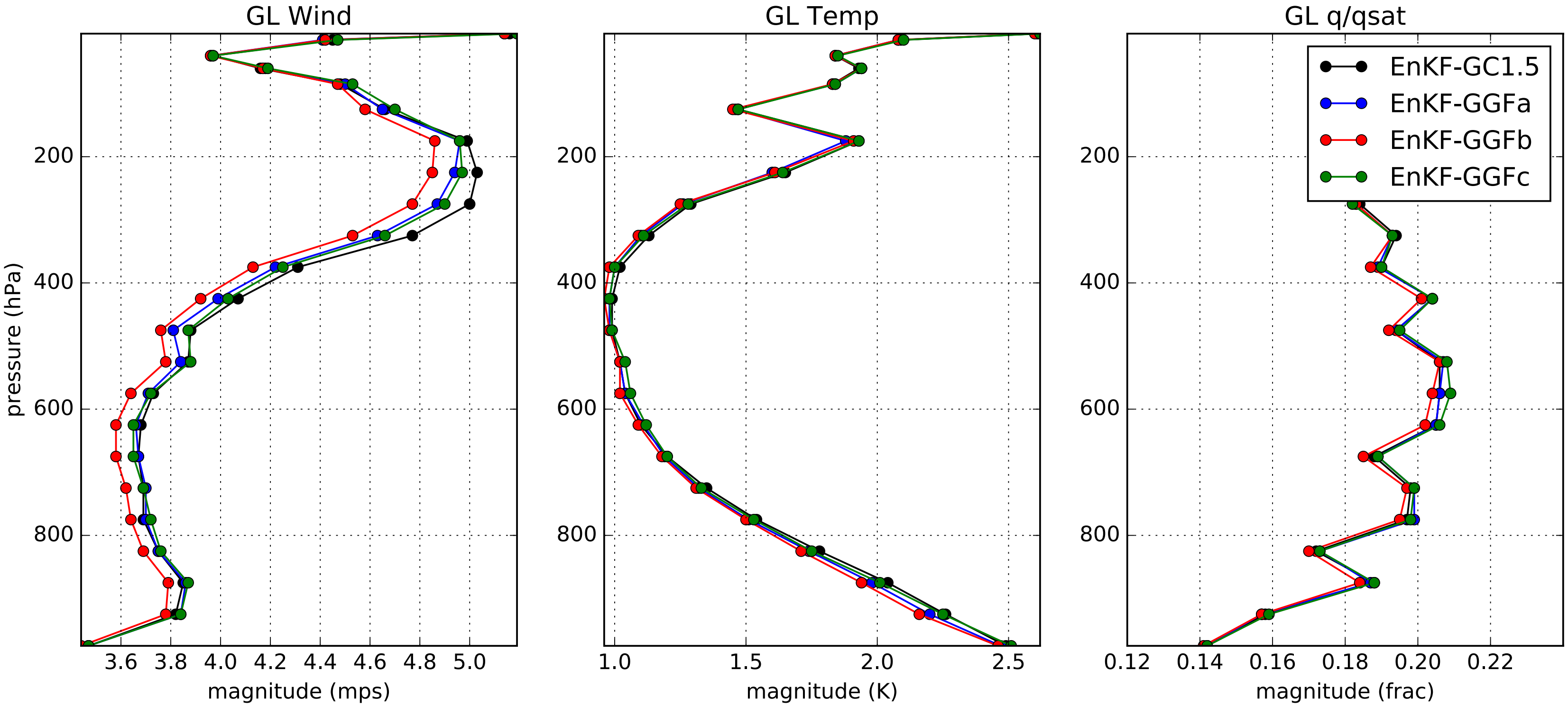
Adaptively estimated localization params. for HIRS/4



The results from the infrared sounder HIRS/4 onboard MetOp-A are consistent with those from microwave sounders AMSU-A and MHS.

Therefore, the three localization parameters can be adaptively estimated for each channel of both microwave and infrared sounders.

6-h priors verified relative to conventional observations

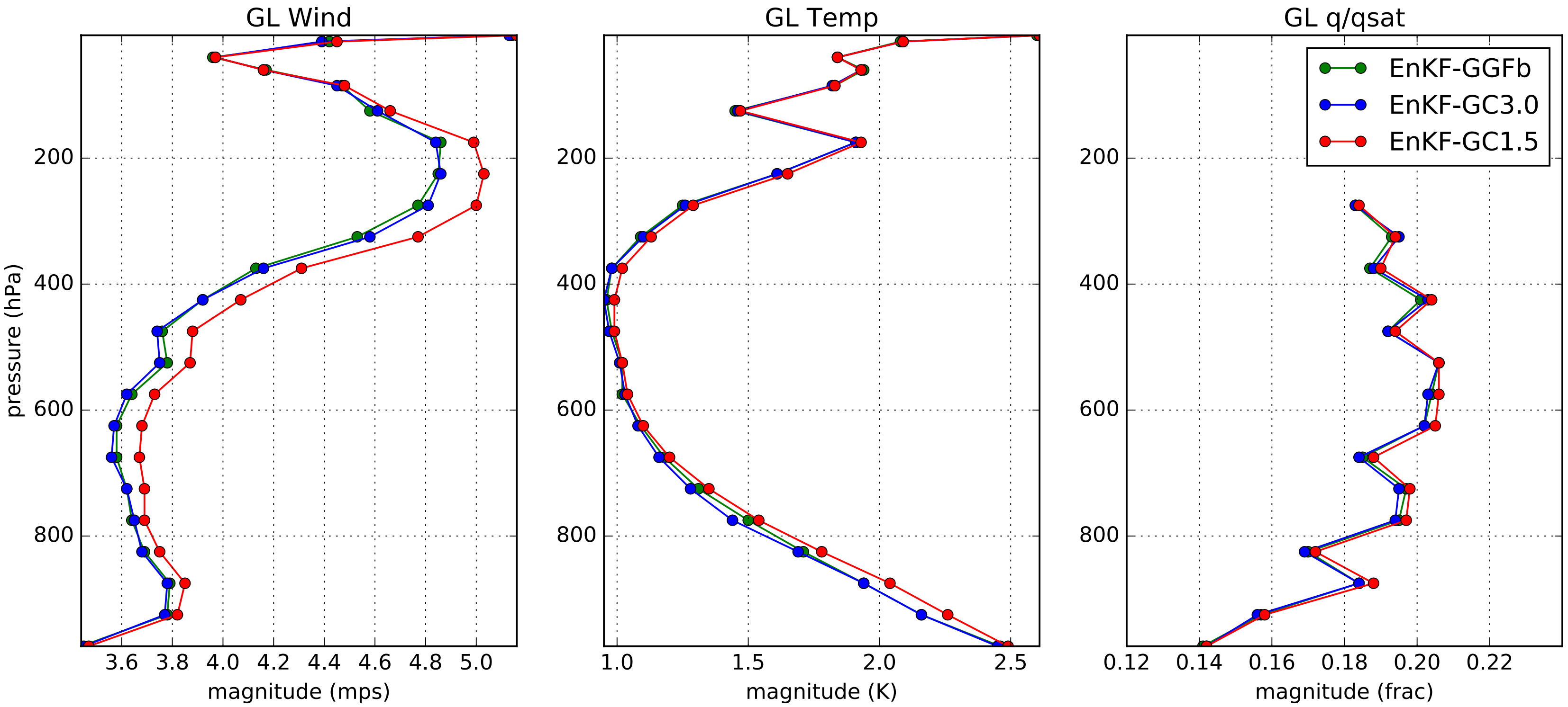


EnKF-GGFa: uses the estimated localization width c_v^o

EnKF-GGFb: uses c_v^o and the estimated obs. vertical location p_v^o

EnKF-GGFc: uses c_v^o, p_v^o, and the maximum GC value $l\max_v^o$

6-h priors verified relative to conventional observations



Experiment GGFb produces very similar results to experiment EnKF-GC3.0 that is the optimal GC width.

Experiment GGFb does not require additional computational cost to tune the best GC width.

Conclusions

- A global group filter (GGF) is used to adaptively estimate the vertical localization function for radiance observations. Using a GC function t fit the GGF, three localization parameters, observation vertical location p_v^o, localization width c_v^o, and maximum localization value $l\mathrm{max}_v^o$, are obtained.
- These localization parameters can be adaptively estimated for each channel of both microwave and infrared sounders from any satellite platform.
- Verifications relative to the conventional observations show that the estimated localization width reduces errors than the default GC width, and the estimated observation vertical location further increases the advantages, but the maximum localization value decreases the advantages.