Guidance on how to improve vertical covariance localization based on a 1000-member ensemble

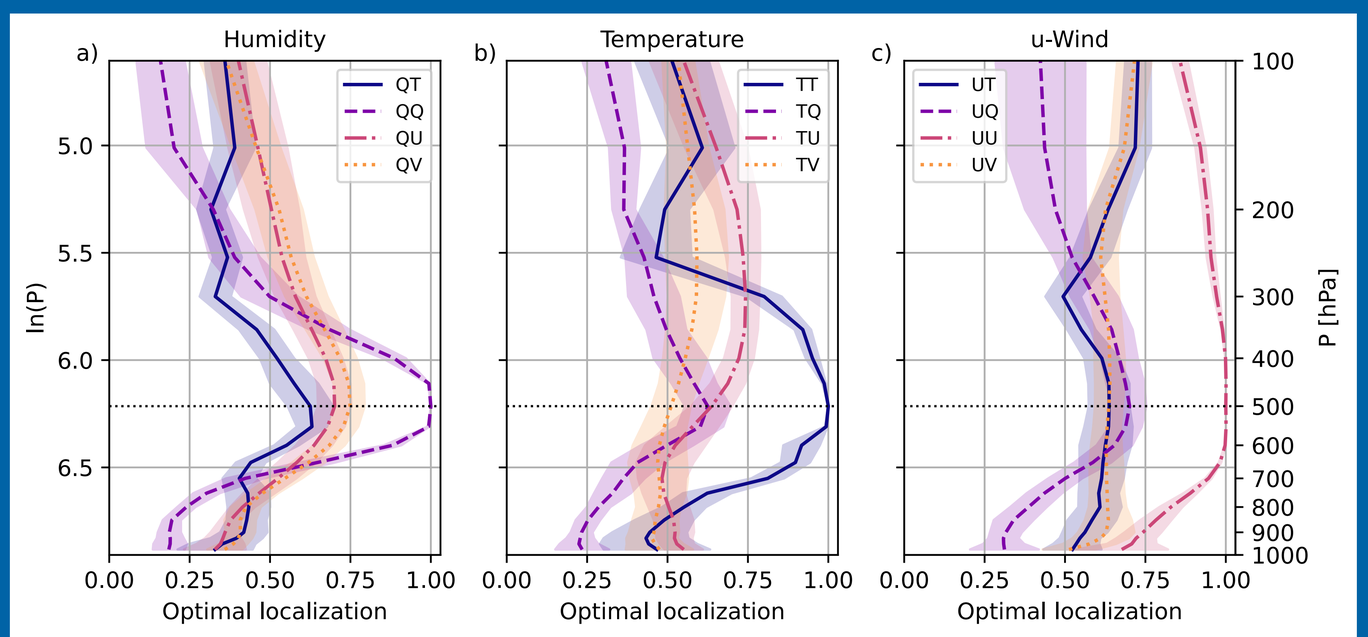
universität wien

Department of Meteorology and Geophysics

philipp.griewank@univie.ac.at

Philipp Griewank[1], Tobias Necker[1], David Hinger[1], Takemasa Miyoshi[2], Martin Weissmann[1]

1) Institute für Meteorology und Geophysics, Universität Wien, Vienna, Austria 2) RIKEN Center for Computational Science, Kobe, Japan



The empirical optimal localization (EOL) method allows to derive optimal covariance localization from large ensembles

SCAN ME

doi

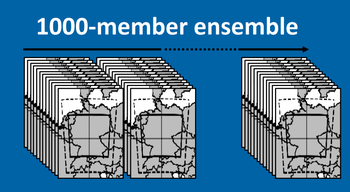


***Figure caption**: Empirical Optimal Localization (EOL) for vertical sample correlations of 40-member ensembles from reference level 500hPa: (a) humidity; (b) temperature; (c) u-wind. Mean and standard deviation over 10 forecasts from 29 May to 2 June 2016.*

Research questions

1. How to optimally localize vertical error correlations from small ensembles?
2. How much can different localization approaches reduce the sampling error?
3. How can we achieve positive semi definiteness for localization?

Take home messages

1. Vertical correlation length scales strongly vary within the troposphere
2. A variable-dependent domain-uniform EOL localization reduced the sampling error by 27% (Gaspari-Cohn only 11%)
3. The NCM-method can help to acchieve a SPSD localization matrix

Empirical Optimal Localization (EOL) method

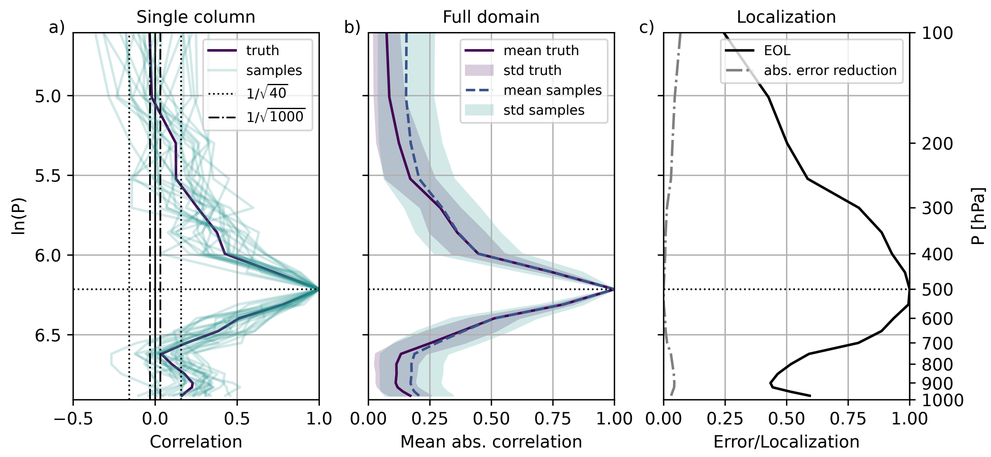
- Minimize cost function J to derive empirical optimal localization - α

$$J(\alpha,t,z,p,A) = \sqrt{\sum_{s=1}^{S}\sum_{k=1}^{K}(\alpha r_{s,k}^{40} - r_k^{1000})^2}$$

- „ α minimizes the root mean square difference between subsamples and 1000-m correlation“

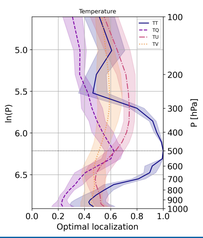
$$\alpha = \frac{\sum_{s=1}^{S}\sum_{k=1}^{K} r_{s,k}^{40} r_k^{1000}}{\sum_{s=1}^{S}\sum_{k=1}^{K} (r_{s,k}^{40})^2}$$

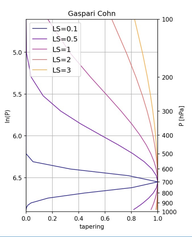
J: Cost function
α: localization
r: correlation
t: time index
z: ref. Level
p: pressure level
A: Variable pair
S: Subsamples
K: Grid points

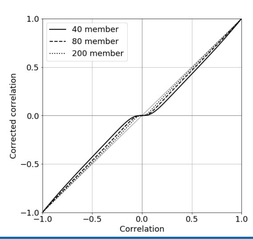


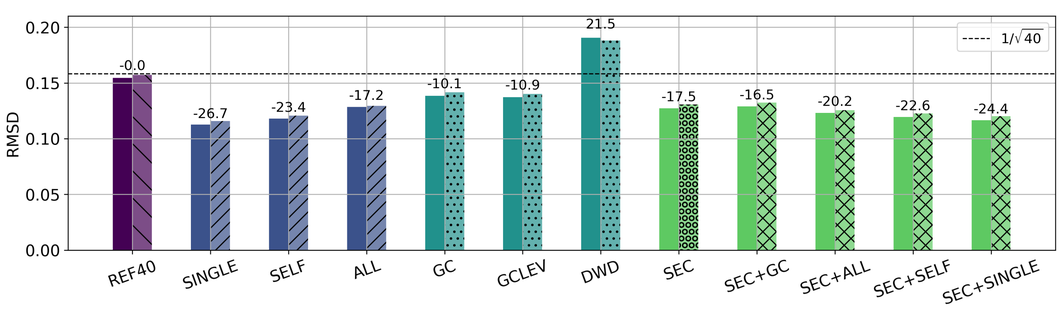
Error reduction: Comparison of different localization approaches

EOL	GC	SEC
Empirical Optimal Localization (EOL) • Derived from 1000-member ens. • Domain-uniform / non-adaptive	**Gaspari-Cohn localization (GC)** • Gaspari & Cohn 1999 • Tuned localization scales • Domain-uniform / non-adaptive	**Sampling Error Correction (SEC)** • Anderson 2012 • Look-up table-based approach • Adaptive localization







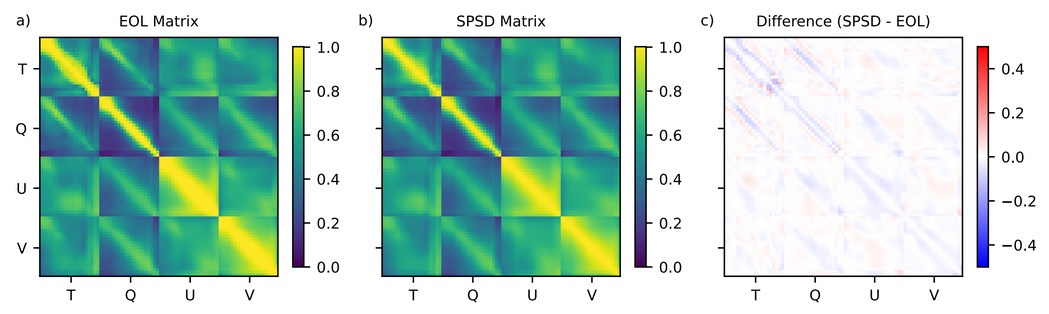


Settings
- SINGLE: Variable-dependent EOL
- SELF: Correlation-dependent EOL
- ALL: Unifrom EOL
- GCLEV: Height-dependent GC
- SEC+: Combinations

Conclusions from comparison
- ALL vs. GCLEV: Better localization shapes needed
- SINGLE / SELF: Variable or correlation dependence is beneficial
- DWD: Bad performance in our case as it was tuned for LETKF
- SEC vs ALL: SEC performs similar to domain-uniform localization
- COMBINATION: SEC+GC = beneficial / SEC+EOL = neutral

Ensuring a symmetric positive semidefinite covariance matrix

- Constructing a localization matrix based on the **EOL does not guarantee a symmetric positive semidefinite (SPSD)** localized covariance matrix.
- The **Nearst-Correlation-Matrix (NCM) algorithm (Higham, 2002)** allows to achieve positive semi-definiteness, which resulted in only minor changes in the EOL



Reference

Necker, T., Hinger, D., Griewank, P. J., Miyoshi, T., and Weissmann, M. 2023: Guidance on how to improve vertical covariance localization based on a 1000-member ensemble, Nonlin. Processes Geophys., 30, 13–29, https://doi.org/10.5194/npg-30-13-2023.