Motivation and research questions

Sampling errors pose a severe issue in ensemble data assimilation. Better vertical localization is important to mitigate sampling errors and improve future predictions. Especially vertical localization of satellite observations in observation space is challenging.

1. How to optimally localize vertical error covariances?
2. How do different methods perform in terms of error reduction?
3. How to vertically localize visible and infrared satellite observations?

Empirical Optimal Localization (EOL) method

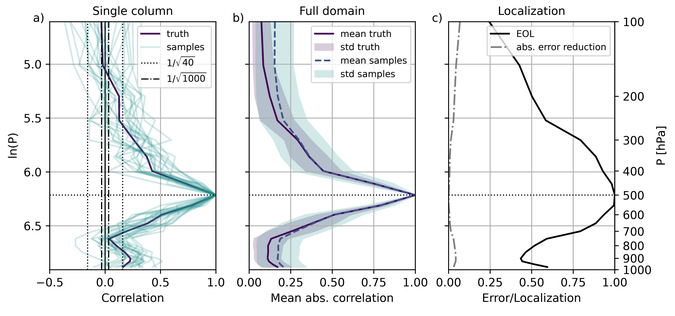
- Minimize cost function J to derive empirical optimal localization

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

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

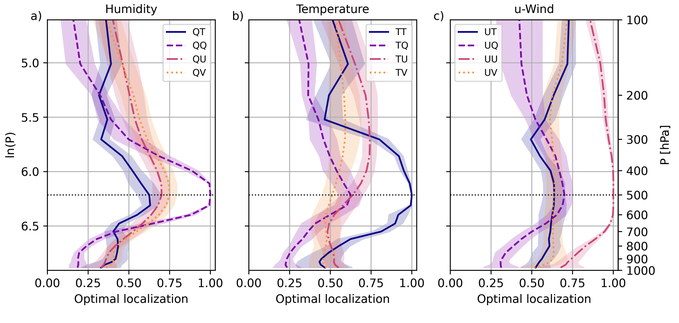
$$\alpha = \frac{\sum_{s=1}^{S}\sum_{k=1}^{K} r_{s,k}^{40} r_k^{1000}}{\sum_{s=1}^{S}\sum_{k=1}^{K}(r_{s,k}^{40})^2}$$

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



Example of vertical localization for level 500hPa (EOL)

Examples of derived EOL vertical localization for vertical sample correlations of 40-member ensembles from reference level 500hPa during a convective summer period over Germany.



tobias.necker@univie.ac.at

universität wien

Department of Meteorology and Geophysics

Empirical optimal vertical localization derived from large ensembles

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

1) Institut für Meteorologie und Geophysik, Universität Wien, Vienna, Austria
2) RIKEN Center for Computational Science, Kobe, Japan

Remember: The EOL method allows to derive optimal localization using large ensembles

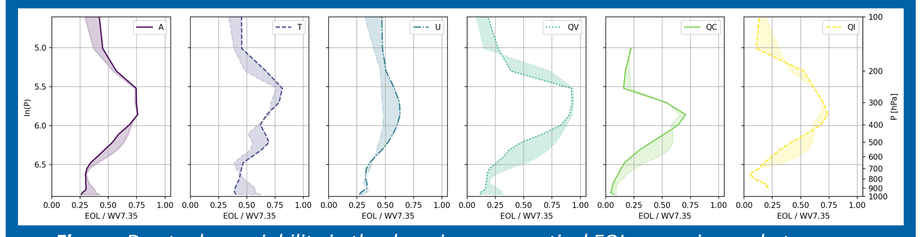


***Figure**: Day to day variability in the domain mean vertical EOL - covariances between Himawari 8 IR 7,3µm and different model variables*

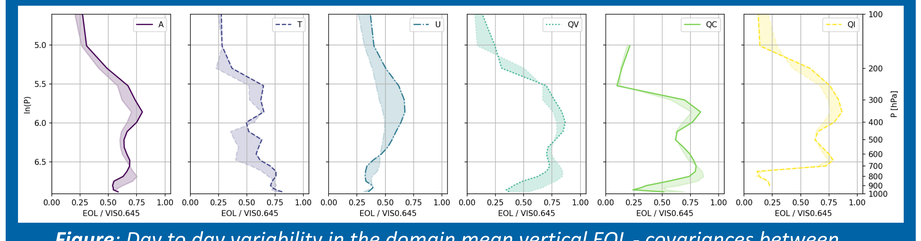


***Figure**: Day to day variability in the domain mean vertical EOL - covariances between Himawari 8 VIS 0,6µm and different model variables*

New findings: Satellite observations require channel, variable, and cloud-dependent vertical observation-space localization

Error reduction: Comparison of localization approaches

EOL

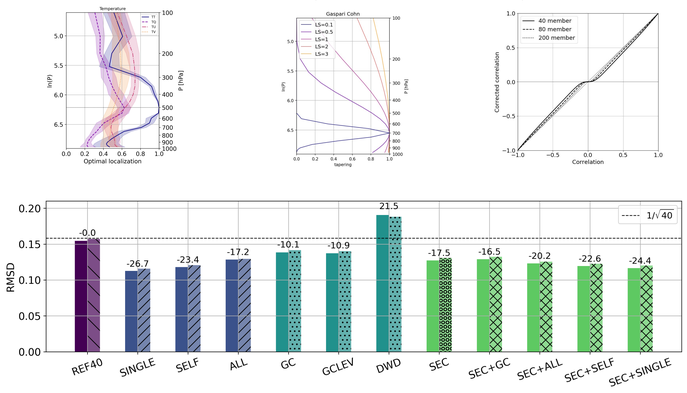
Empirical Optimal Localization
- Derived from large ensemble
- non-adaptive

GC

Gaspari-Cohn localization
- Gaspari & Cohn 1999
- Tuned localization scales
- non-adaptive

SEC

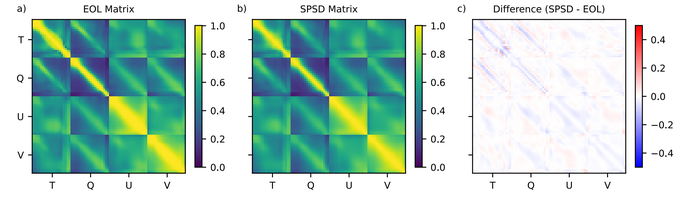
Sampling Error Correction
- Anderson 2012
- Look-up table-based approach
- Adaptive localization



Legend: SINGLE: Variable-dependent domain uniform EOL; SELF: Correlation-dependent domain uniform EOL; ALL: Domain Uniform EOL; GCLEV: Height-dependent domain uniform GC; SEC+: Combinations of different localization approaches

Ensuring a sym. positive semidefinite covariance matrix

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



Take home messages

1. Vertical correlation length scales strongly vary within the troposphere and for different variables
2. A variable-dependent domain-uniform EOL localization reduces the sampling error by 27% (vs. Gaspari-Cohn 11%)
3. Satellite observations require channel, variable, and situation-dependent vertical observation space localization

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.