Accounting for localization in ensemble network design experiments

Philipp Griewank[W], Ulrich Löhnert[K], Tobias Necker[W], Tatiana Nomokonova[K], and Martin Weissmann[W]

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Goal

Estimate benefit of *potential* observations without running additional forecasts.

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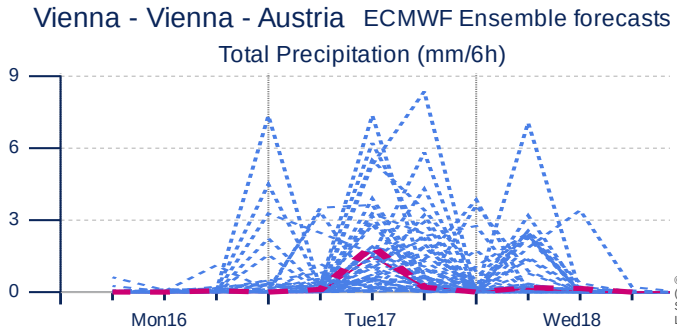
E.g. How much would an observation of a certain type at a specific location reduce spread in predicted rainfall?



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Ensemble approach (e.g. Hakim 2020, Hill 2020)

Combines estimated analysis increment $\boldsymbol{K}\delta\boldsymbol{Y}_b$ determined by Kalman gain $\boldsymbol{K}$, with ensemble forecast sensitivity $\boldsymbol{s}(\boldsymbol{B}^{-1})$

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With localization $\boldsymbol{K}(\boldsymbol{L} \circ \boldsymbol{B})$

- $\boldsymbol{B}^{-1}$ of $\boldsymbol{s}$ does not cancel out with localized $\boldsymbol{L} \circ \boldsymbol{B}$
- Neglecting localization overestimates benefits (Hill 2020)
- How to incorporate localization has not been addressed yet

Hill et al Factors Influencing Ensemble Sensitivity–Based Targeted Observing Predictions at Convection-Allowing Resolutions 2020
Hakim et al Optimal Network Design Applied to Monitoring and Forecasting Surface Temperature in Antarctica 2020

Question:

How can localization be accounted for?

Our contribution (Griewank 2022, in prep)

- Step-by-step derivation of two methods to account for localization
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Explicit method applied in state space

$$\Delta\sigma_j^2 \approx \text{var}\left(\boldsymbol{s}_\alpha[\boldsymbol{\delta X}_\text{b} - \hat{\boldsymbol{K}}_{loc}\boldsymbol{\delta Y}_\text{b}]\right) - \text{var}(\boldsymbol{s}_\alpha\boldsymbol{\delta X}_\text{b})$$

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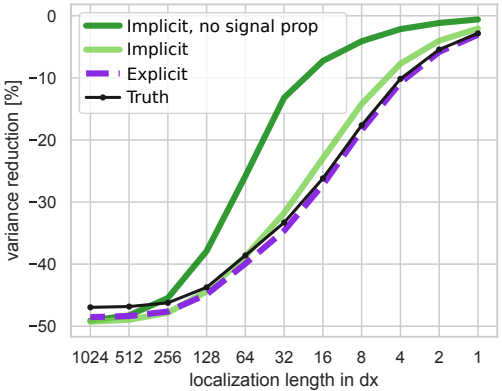
Implicit method that needs to be provided with signal propagation

$$\Delta\sigma_j^2 \approx -\frac{1}{(n-1)^2}\sum_{i=0}^{p}(\vec{\boldsymbol{L}}^{mp} \circ \boldsymbol{\delta j}_\text{ff}\boldsymbol{\delta Y}_\text{b}^T)_i \left[\frac{\boldsymbol{L}^{pp} \circ \boldsymbol{\delta Y}_\text{b}\boldsymbol{\delta Y}_\text{b}^T}{n-1} + \boldsymbol{R}\right]^{-1} \left[\boldsymbol{\delta j}_\text{ff}\boldsymbol{\delta Y}_\text{b}^T\right]^T$$

Results



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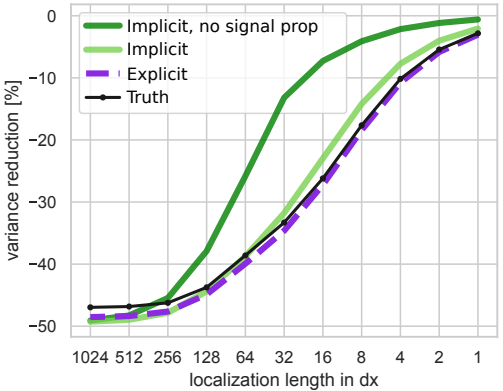

- Implicit method works if signal propagation can be provided
- In NWP propagation impossible to track, implicit only suited for short lead times
- Explicit method works, but is more expensive and needs larger ensemble
- We applied the explicit method to 1000-member weather forecast over Germany (Tatiana Nomokonova, today 15:45, AS2.2)