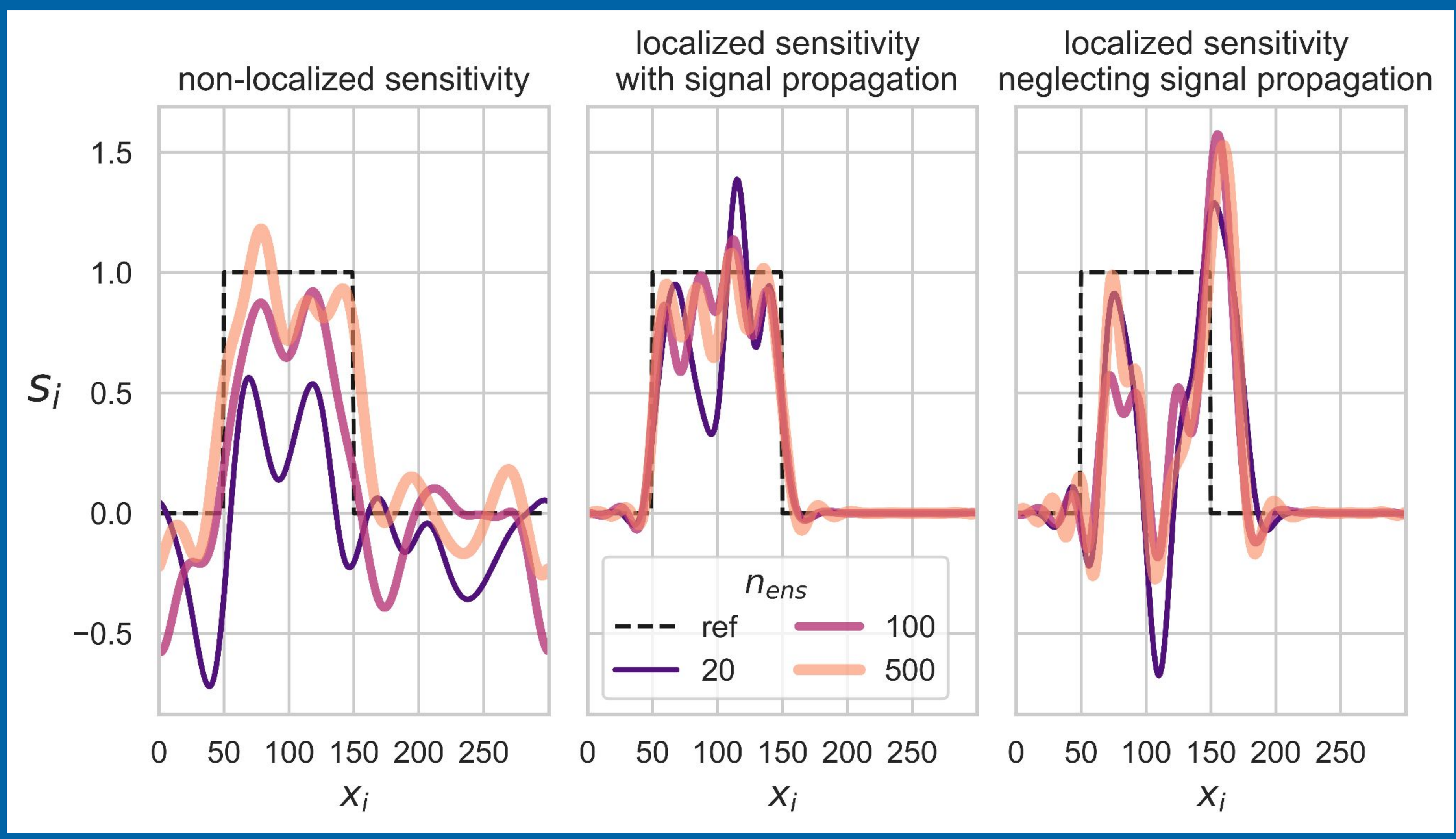
Localizing ensemble sensitivity and observation impact estimates (EFSOI)

Philipp J. Griewank, Tobias Necker, Martin Weissmann
Institut für Meteorologie und Geophysik, Universität Wien, Vienna, Austria

philipp.griewank@univie.ac.at



Examples of sensitivity calculated from toymodel test shown below. Goal is to lie close to the dashed ref line. The different lines mark different ensemble sizes.

- **Sensitivity localization ≠ analysis localization**
- **Sensitivity localization greatly reduces necessary ensemble size, but requires estimating signal propagation.**
- **The ideal sensitivity localization length is just wide enough to cover the area the signal could propagate to.**

Introduction

Ensemble methods to estimate the benefit of assimilated observations (e.g. EFSO, Kalnay 2012) or potential observations (e.g. ESA, Ancell 2007) on the forecast commonly do not cleanly distinguish between two types of localization:

a. Analysis localization, a component of the forecast system.
b. Sensitivity localization, applied to ensemble covariances between initial conditions and forecast to avoid spurious correlations.

In this poster we use a toymodel to discuss the benefits and drawbacks of sensitivity localization, which can be set equal to the analysis localization to simplify the calculation (Griewank 2023).

Sensitivity localization

Ensemble Sensitivity Analysis (ESA): Ensemble deviations of forecast metric $\mathbf{\delta j}$ are linearly dependent on the initial state ensemble deviations $\mathbf{\delta X}$ via sensitivity vector $\mathbf{s}$:

$$s\delta X \approx \delta j \qquad \rightarrow \qquad s \approx \delta j \delta X^T [\delta X \delta X^T]^{-1}$$

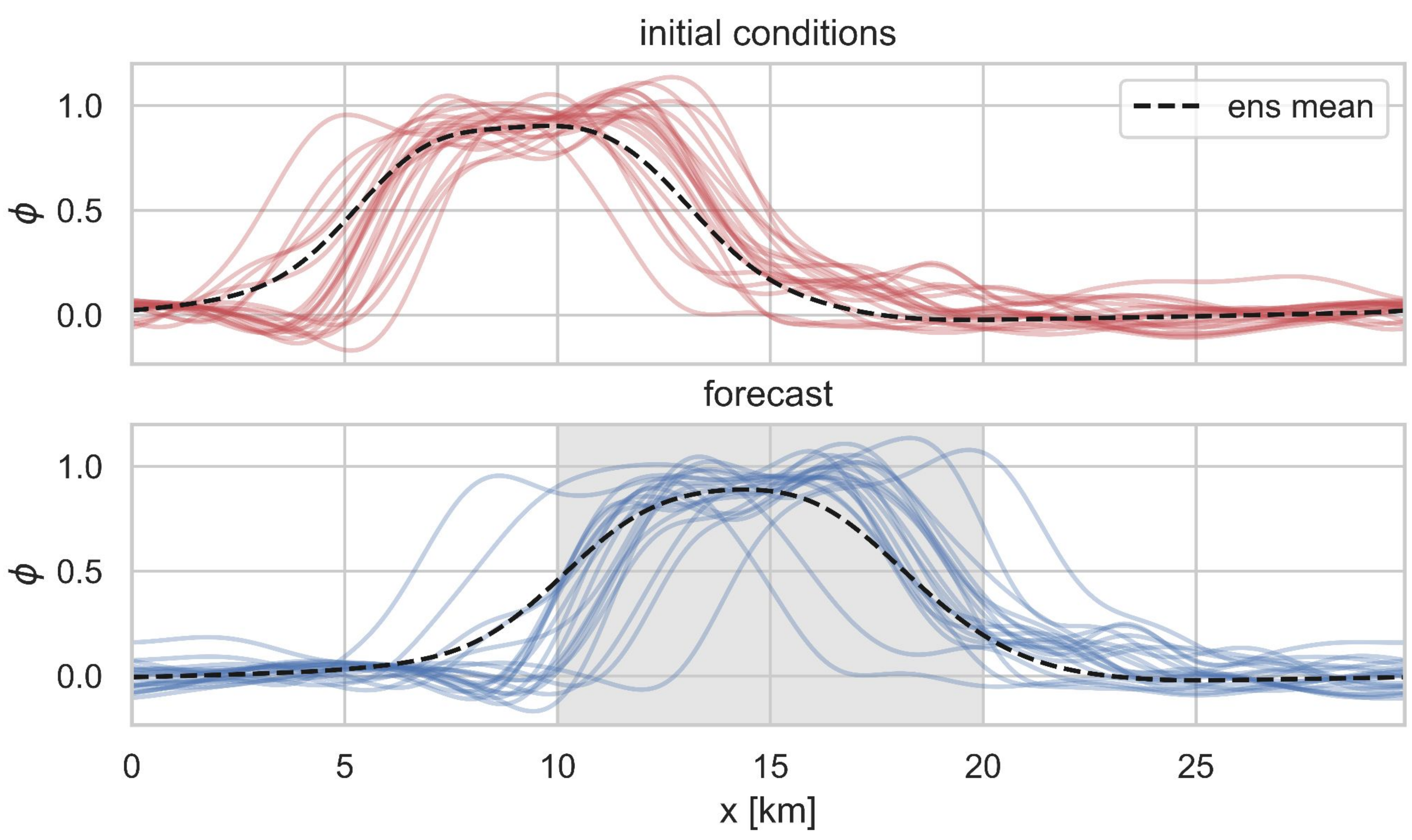
Localization of $\mathbf{\delta j \delta X}^T$ needs to be applied to local subcomponents (i) while taking signal propagation into account. Localization of $\mathbf{\delta X \delta X}^T$ remains static:

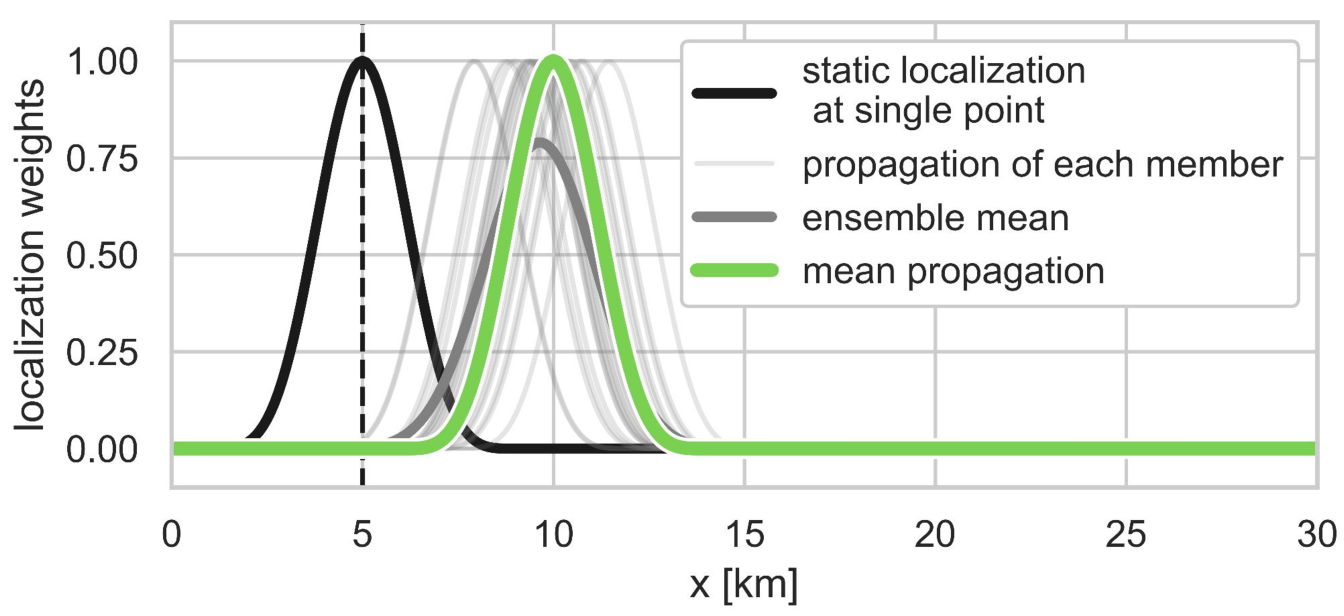
$$s_{loc} = \sum_i \left[\vec{C}_i \circ \delta j_i \delta X^T\right] [C \circ \delta X \delta X^T]^{-1}$$

Ensemble Forecast Sensitivity to Observation Impact (EFSOI): Equivalent, but for a verification observation $\mathbf{Y}^v$ instead of a forecast metric:

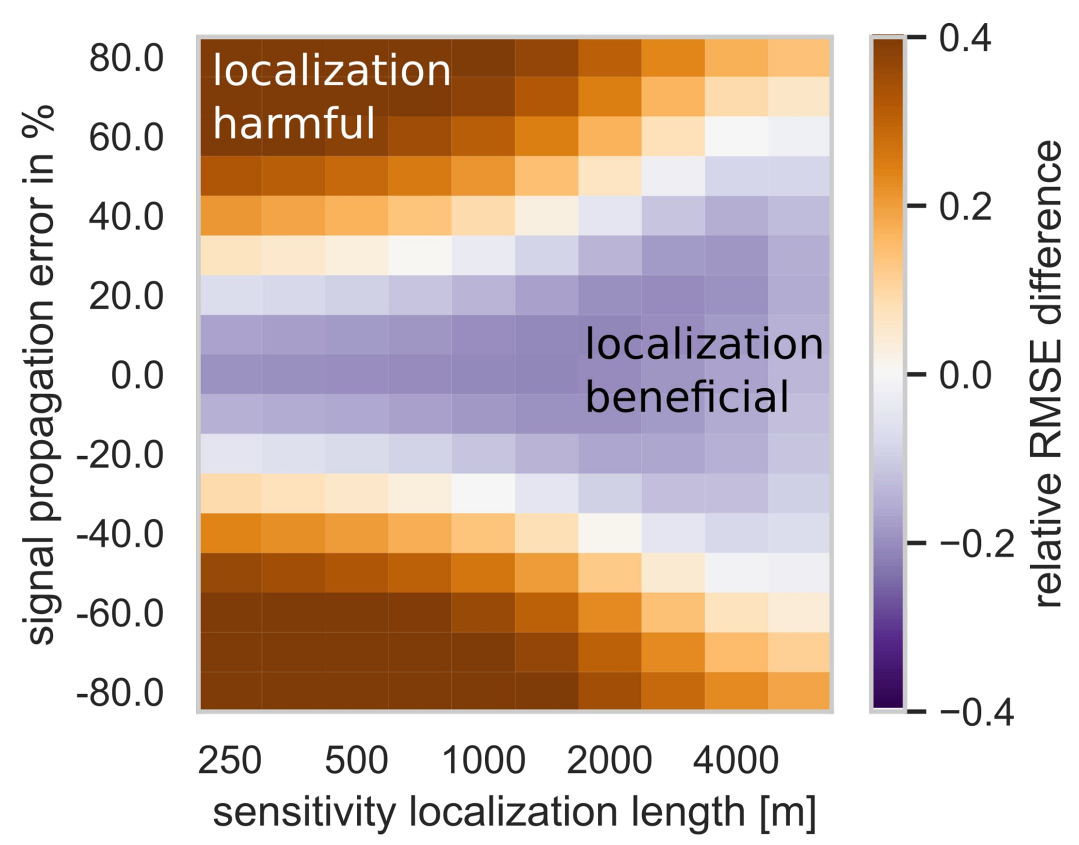
$$\delta Y^v \approx HM\delta X \qquad\qquad s \approx HM$$

Toymodel & signal propagation illustration





Implications for observation impact studies



The better signal propagation is known, the tighter the sensitivity localization can be set.

References

Griewank et al (2023): Ensemble-based estimates of the impact of potential observations https://doi.org/10.1002/qj.4464
Kalnay et al (2012): A simpler formulation of forecast sensitivity to observations: application to ensemble Kalman filters
Ancell & Hakim (2007): Comparing Adjoint- and Ensemble-Sensitivity Analysis with Applications to Observation Targeting