Observation space localizations for the maximum likelihood ensemble filter

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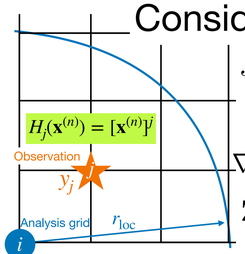
Background & Objectives

- Ensemble Variational methods (EnVar) are appropriate for indirect measurements nonlinearly related to forecast variables.
- A localization method such as observation space localization (OL) is required for high-dimensional problems, but how to introduce OL to EnVar has been less investigated.
- In this study, we introduce two types of OL to the maximum likelihood ensemble filter (MLEF)[1].

Optimization with OL

Consider local costs at n-th iteration;



$$J_i^{(n)} = \frac{1}{2}\mathbf{w}_i^{(n)\mathrm{T}}\mathbf{w}_i^{(n)} + \frac{1}{2}[\mathbf{y} - H(\mathbf{x}^{(n)})]^{\mathrm{T}}\mathbf{R}_i^{-1}[\mathbf{y} - H(\mathbf{x}^{(n)})]$$

$$\nabla_{\mathbf{w}} J_i^{(n)} = \mathbf{w}_i^{(n)} - \mathbf{Z}_i^{(n)\mathrm{T}}\mathbf{R}_i^{-1/2}[\mathbf{y} - H(\mathbf{x}^{(n)})]$$

$$\mathbf{Z}_i^{(n)} = \mathbf{R}_i^{-1/2}[H(\mathbf{x}^{(n)} + \mathbf{X}_f) - H(\mathbf{x}^{(n)})]$$

$\mathbf{w}$ around $\mathbf{y}_j$ are required to update $H_j(\mathbf{x})$, which prevents independent analysis.

Global optimization (LMLEFG)

Update $\mathbf{x}^{(n)}$ globally in each iteration[2]. This is equivalent to optimizing sum of J_i.

Local optimization (LMLEFL)

Update $[\mathbf{x}^{(n)}]^j$ by $\mathbf{w}_i^{(n)}$ assuming locally constant weights[3]. J_i can be optimized independently.

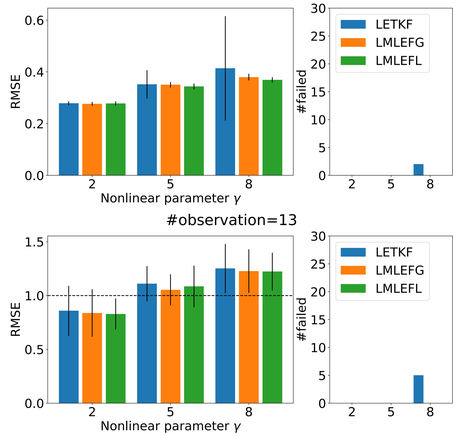
Comparison to LETKF

Ensemble size is 20. r_{loc} is optimized for each model.

Lorenz96[4]

$$H(\mathbf{x}) = 0.5\mathbf{x}\{1 + (0.1|\mathbf{x}|)^{\gamma-1}\}$$[5]

Averaged RMSE of 50 trials

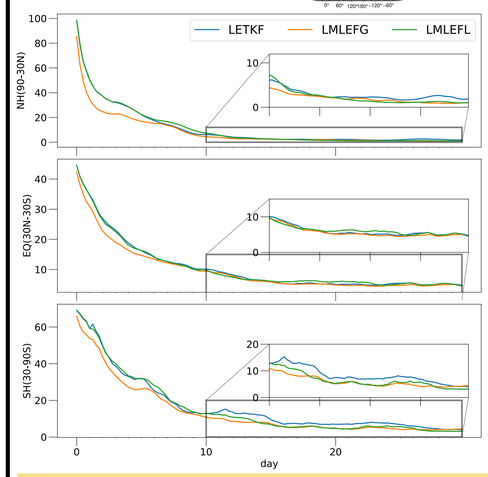


- **LMLEFs outperform LETKF with stronger nonlinearity or less observations.**
- **LETKF is unstable with strong nonlinearity.**

SPEEDY[6]

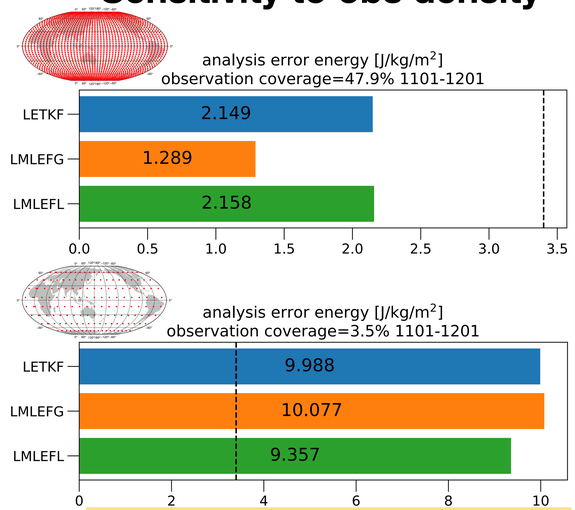
Obs: **RH**, U, V, T, Ps (error : 3.4 J/kg/m²)

Error in total energy



- **LMLEFG shows faster improvement.**
- **LMLEFL is better than LETKF in high latitudes.**

Sensitivity to obs density



- **LMLEFG is much better when densely observed.**
- **LMLEFL is relatively better with sparse observations.**

Summary

- Optimization provides more robust and accurate analysis than LETKF.
- Global optimization accelerates spin-up.
- Local optimization is suitable for sparse observations in AGCM.

Discussions

SPEEDY results are just 1 trial in NH winter and vary with different initial guesses, observations or season. Dependency of DA performance on natural variability is future work.

Acknowledgements

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References

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