

Analysis observation sensitivity calculation within an EnKF

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Analysis observation sensitivity

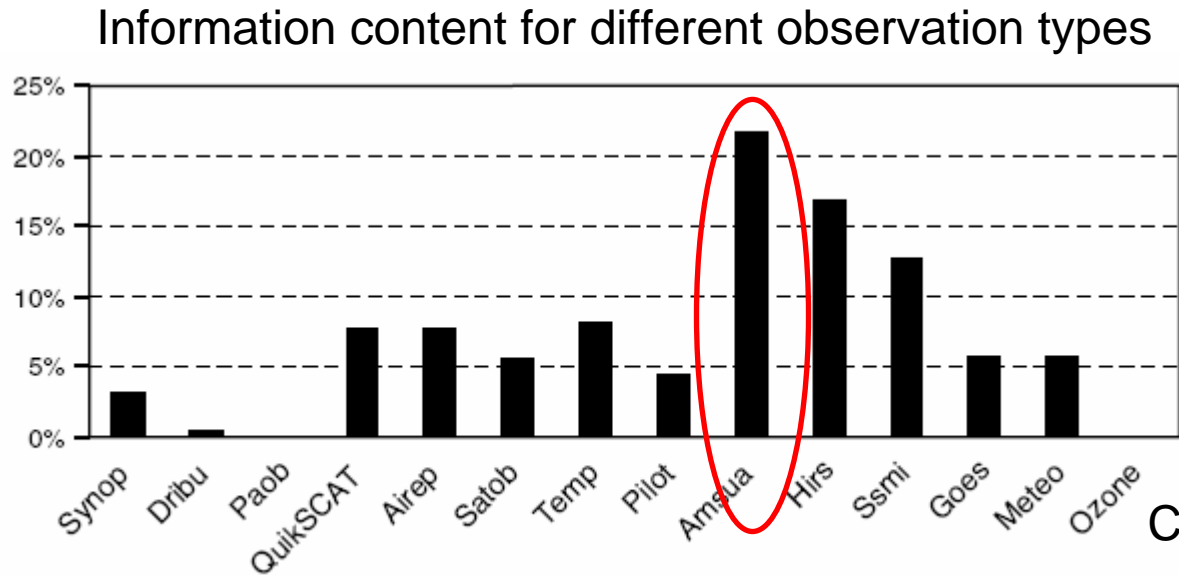
- The analysis state linearly combines background and observations based on weighting matrix \mathbf{K} :

$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{K}(\mathbf{y}_0 - h(\mathbf{x}_b)) \quad \mathbf{H}\mathbf{x}_a = \mathbf{H}\mathbf{x}_b + \mathbf{H}\mathbf{K}(\mathbf{y}_0 - h(\mathbf{x}_b))$$

Influence matrix:
$$\mathbf{S} = \frac{\partial \mathbf{H}\mathbf{x}_a}{\partial \mathbf{y}} = \mathbf{K}^T \mathbf{H}^T = \mathbf{R}^{-1} \mathbf{H}\mathbf{P}^a \mathbf{H}^T$$

- **Analysis observation sensitivity**: diagonal values of the influence matrix (Cardinali et al., 2004)
 - indicates how sensitive the **analysis** is to the **observations**
 - between **0** and **1** (Cardinali et al., 2004)

Calculation of analysis sensitivity within 4D-Var



Cardinali et al., 2004

- Approximate method based on **truncated eigenvalue** decomposition
- **The trace of analysis sensitivity (information content)** qualitatively reflects the importance of different type observations.
 - The **truncated eigenvalue** decomposition **introduces** analysis observation sensitivity value **larger than one**.

Objective and outline

➤ Objective

- **Propose a method** to calculate analysis sensitivity within the Local Ensemble Transform Kalman Filter (LETKF) (Hunt et al., 2007)
- **Study the relationship** between **information content** and the actual observation impact calculated from **data denial** and **data addition** experiments.

➤ Outline

- Calculation method and verification in Lorenz-40 variable model
- Experiments with a primitive equation model
- Summary

Calculation of analysis sensitivity within the LETKF

Reminder: analysis sensitivity is the diagonal value of the influence matrix:

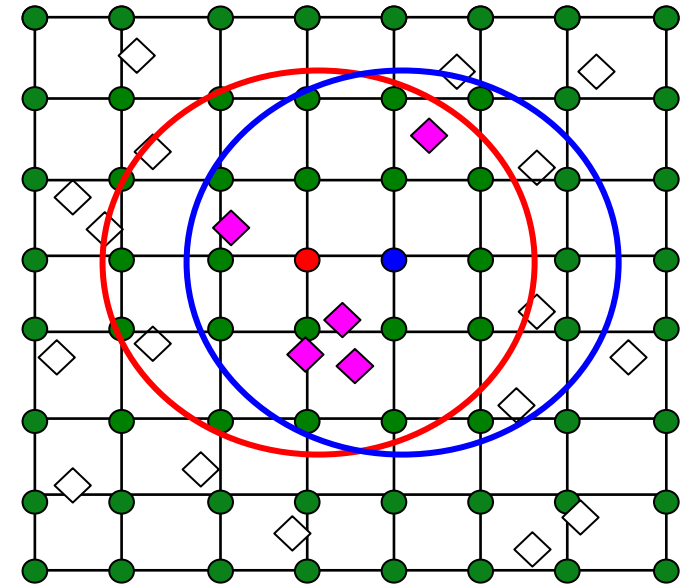
$$\mathbf{S} = \frac{\partial \mathbf{H} \mathbf{x}_a}{\partial \mathbf{y}} = \mathbf{K}^T \mathbf{H}^T = \mathbf{R}^{-1} \mathbf{H} \mathbf{P}^a \mathbf{H}^T$$

- In 4D-Var (Cardinali et al., 2004), it requires an **approximation to get \mathbf{P}^a**
- **$\mathbf{P}^a \mathbf{H}^T \mathbf{R}^{-1}$ is directly calculated** in any EnKF.

In the LETKF, each observation is **used more than once** in different local patches

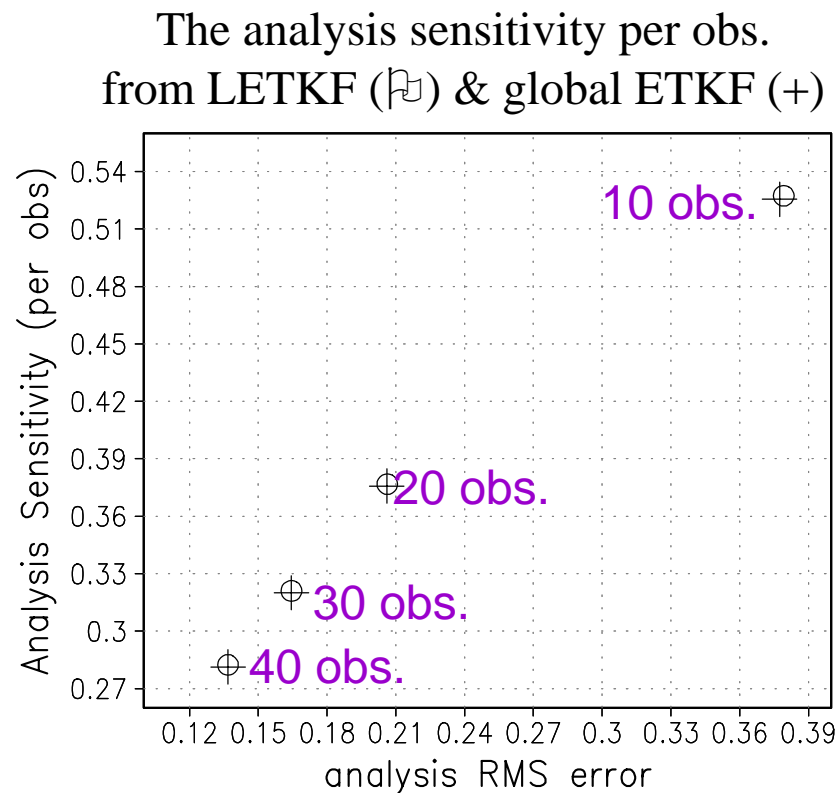
? The analysis sensitivity is **different** with respect to **the same observation** in different local patches.

⇒ **We average** the analysis sensitivity over the **different local patches**.



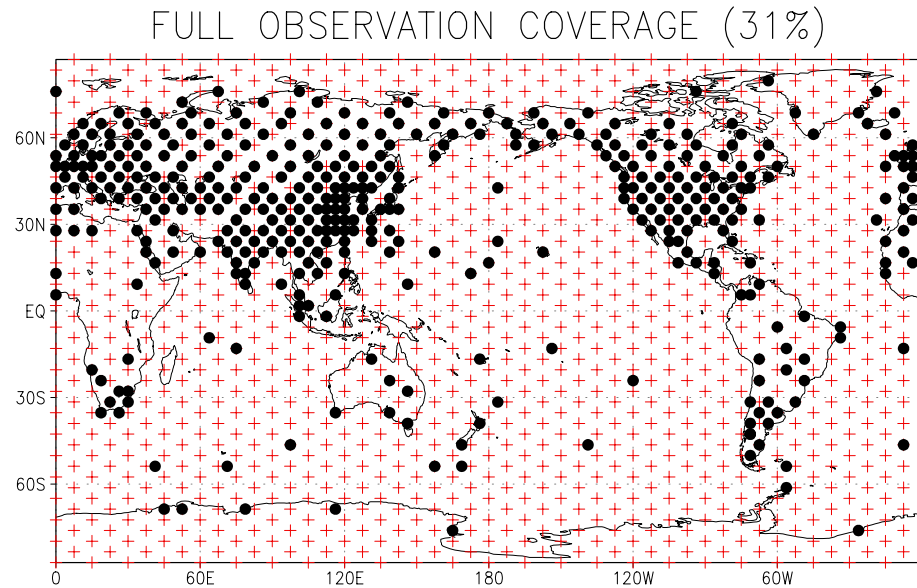
Localization scheme in the LETKF

Verification of analysis sensitivity calculation method within the LETKF with Lorenz-40 variable model



- LETKF gives same results as global ETKF without averaging
- It decreases with the increasing of observation coverage, increases with the magnitude of the analysis error.

Simulated data denial experiments with SPEEDY



SPEEDY (Molteni, 2003): 96 by 48 grid points horizontally, and 7 vertical levels

Data denial experiments:

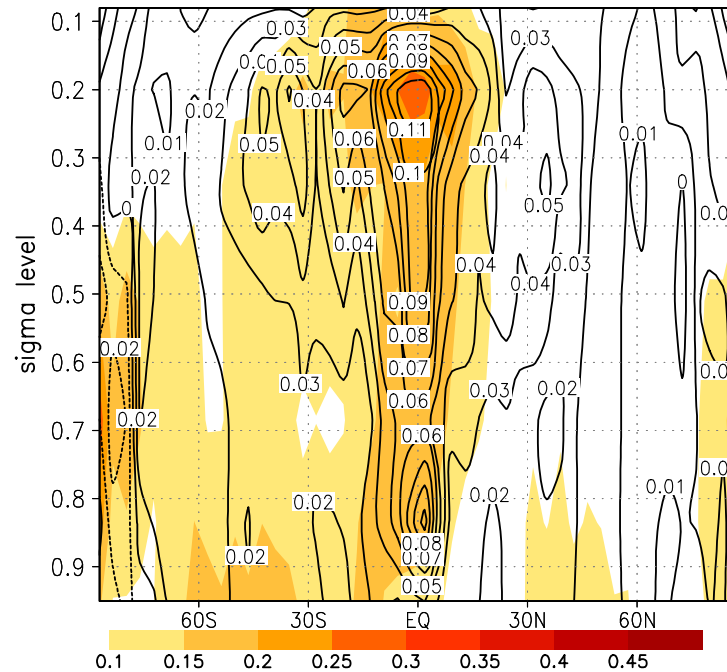
Control run: full coverage for all dynamical variables (u , v , T , q , P_s).

Sensitivity experiments: u/q is not observed in locations with red +

- Compare **information content** (the trace of analysis sensitivity) of zonal wind/specific humidity at locations with red + from **control run** to the RMS error difference between **sensitivity experiment** and **control experiment**.

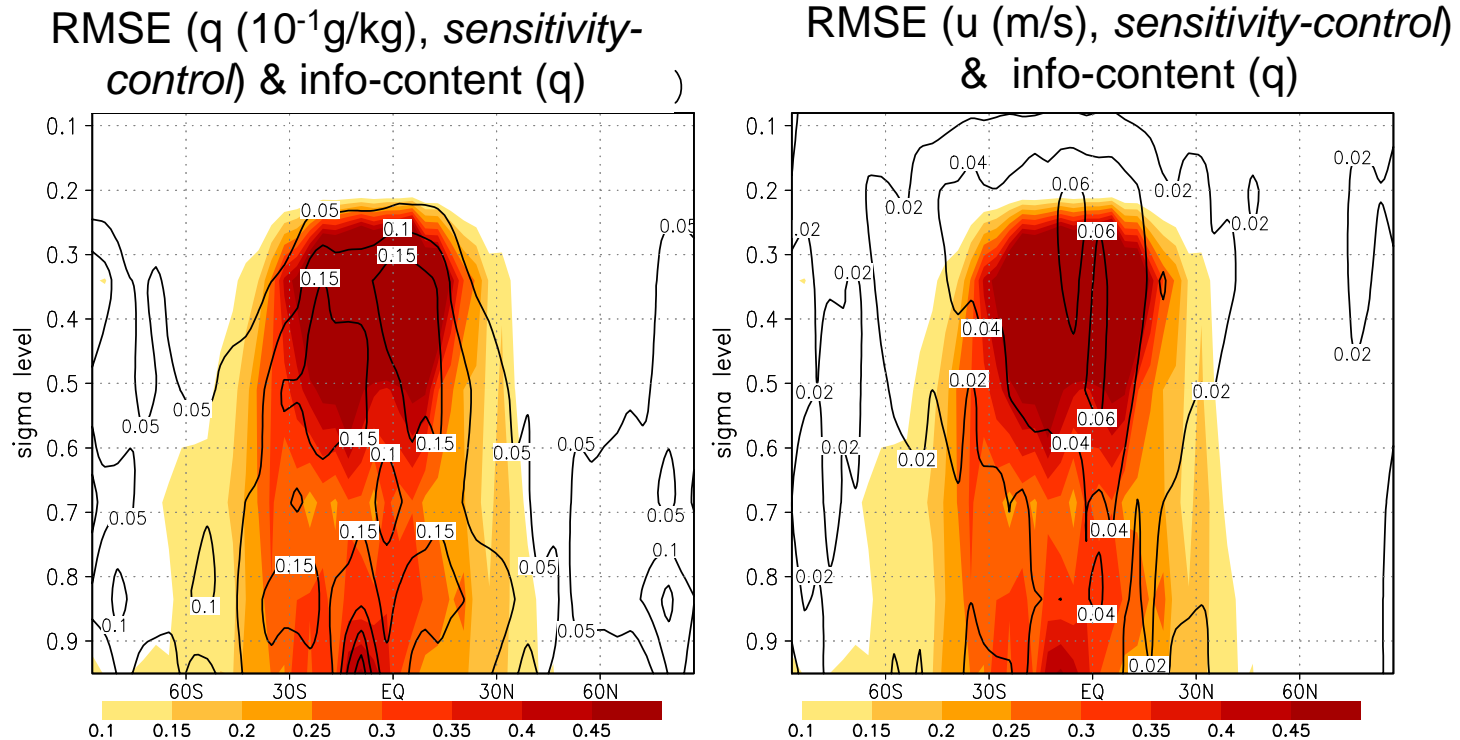
Information content (control, shaded) vs. the difference of RMSE ((data denial)-control, contour)

RMSE (u, *sensitivity-control*) & info-content (u)



- Information content **qualitatively reflects** the actual **observation impact** from data-denial experiments.

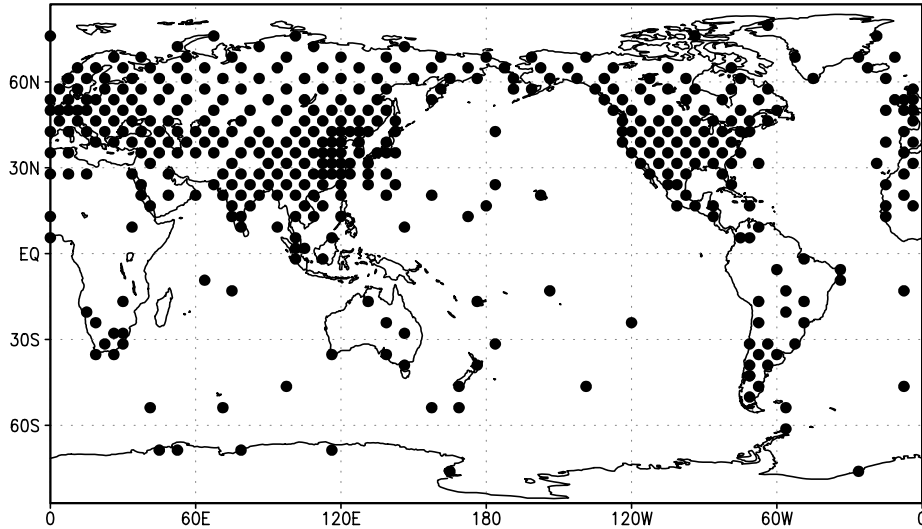
Information content (control, shaded) vs. the difference of RMSE ((data denial)-control, contour)



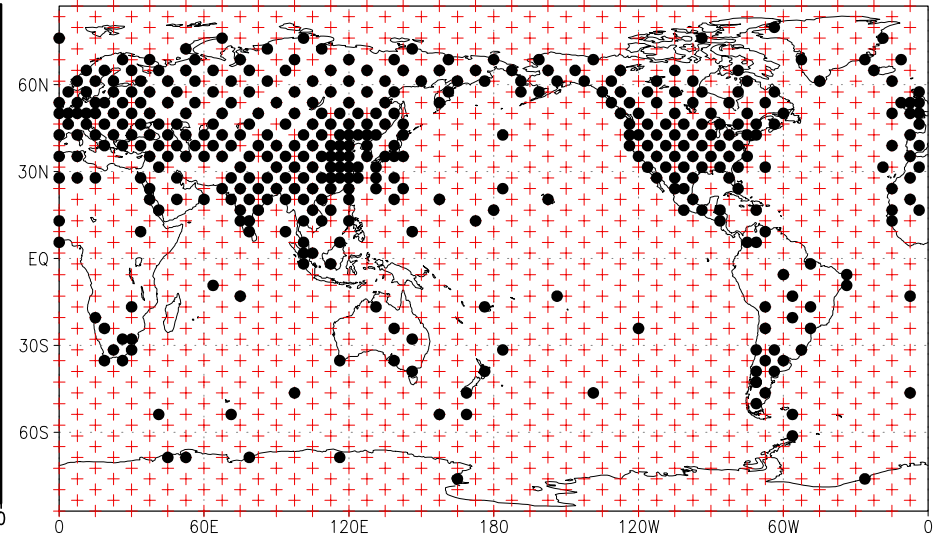
- Information content **not only qualitatively** reflects the observation impact **on the same type** dynamical variable, but also **on different type of** dynamical variables

Simulated **data addition** experiments with SPEEDY

Observation coverage for control run



Observation coverage for data addition



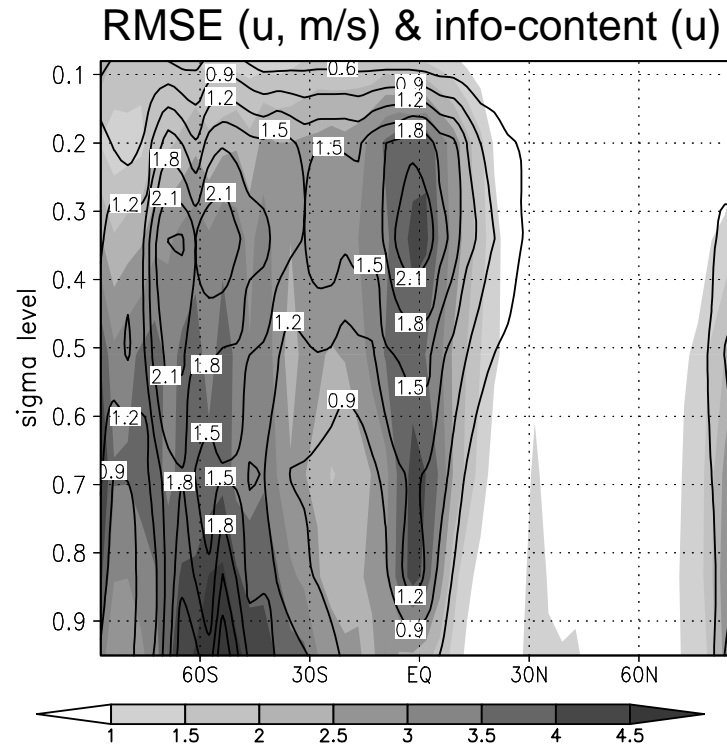
Data addition experiments:

Control run: assimilates observations in the closed circles (left panel).

Sensitivity experiment: u at the red plus signs are added into the observation data set

- Compare **information content** of u wind at locations with **red +** calculated along with **control run** to the RMS error difference between **sensitivity experiment** and **control experiment**.

Information content (control, shaded) vs. RMSE difference (control-(data addition), contour)



- Information content also **qualitatively reflects** the actual **observation impact** from **data addition** experiments.
- It could be used to **design observation** network.

Summary

- ✓ The calculation of analysis sensitivity needs **no approximation** and can be **calculated along** with the data assimilation in the LETKF.
- ✓ The trace of analysis sensitivity **qualitatively reflects** the actual observation impact from much more expensive **data-denial** and **data addition** experiments
- ✓ Information content **not only qualitatively** reflects the observation impact **on the same type** dynamical variable, but also **on different type of** dynamical variables
- ✓ The information content **cannot quantitatively** reflect the observation impact, and **cannot detect** observations with poor quality.
- ✦ This is done in our **observation impact study** (like Langland and Baker, 2004) method **but without adjoint model**. (See presentation 6.3)