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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

Using covariance based impact diagnostics for assessing the localization of observations

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The recent cross-validation (C-V) method (Stiller 2022) presents a consistency test whether two different types or groups of observations pull the model state into the same direction. Typically this is used to assess the suitability of new or problematic observations while using well trusted observations for verification.
Collecting statistics in adequate bins, and using in situ measurements for verification, the method can also be used to assess the suitability of localization methods.

This poster starts with a short summary of the C-V diagnostics and then gives two examples where the method is applied
i. to assess the suitability of different methods for computing the localization height for satellite radiance and
ii. to show at which heights the assimilation of surface pressure could improve the temperature field (and how this changes with weather regime and when the employed ensemble covariances are taken from runs where latent heat nudging perturbations have been applied in the DA cycle).

1. The Cross-Validation Diagnostics

The main C-V diagnostic $\mathcal{J}_\alpha^b$ (blue curves) can be derived

- either as a component of the standard (E)FSOI diagnostic
- or as a consistency relation between
  (1) the background error covariances (**BGEC**s) employed in the DA system (i.e., obtained from the ensemble)
  (2) and an estimate of the **BGECs** directly from the observations.

A reference value $\langle \mathcal{J}_\alpha^b \rangle_{est}$ (green curves) was derived which allows a more direct test for the correspondence between estimates (1) and (2).
The diagnostics can be computed with different localizations.
For the diagnostics shown here, the vertical localization length was infinite but statistics were collected in bins of vertical distance which gives a visual impression of the impact different localization lengths would have.

2. Vertical localization (p-level) for satellite radiances

Tested are 3 Methods to compute the p-level (from the Jakobian **H**):
Assign the p-level for satellite radiances at:

I. centre of mass of |**H**|
II. the peak of |**H**|
III. the peak of |**HB**| (instead of |**H**|)

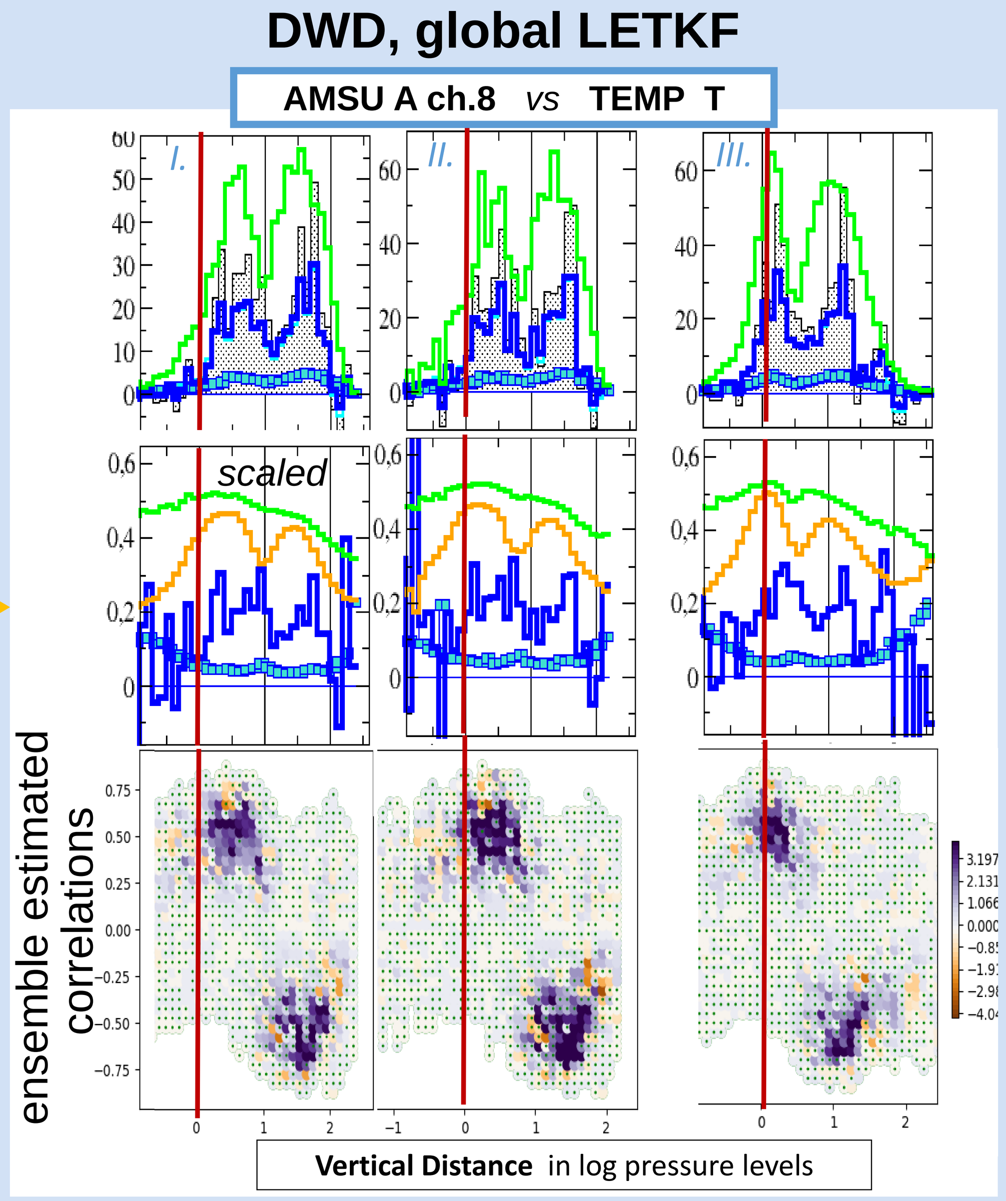
Best agreement is found for version *III.*

Orange curves: weighted mean of abs.value of **ensemble correlation**

Blue and green curves: see text and C-V Tool descr..

Contributions to the **blue curve** from different sub-bins

DWD, global LETKF



3. Correlations between surface p and upper air T

Different types of perturbations have been imposed in the LETKF to enhance the ensemble spread. Considered here: The impact of stochastic perturbations of the latent heat nudging coefficients (LHN perturbations).

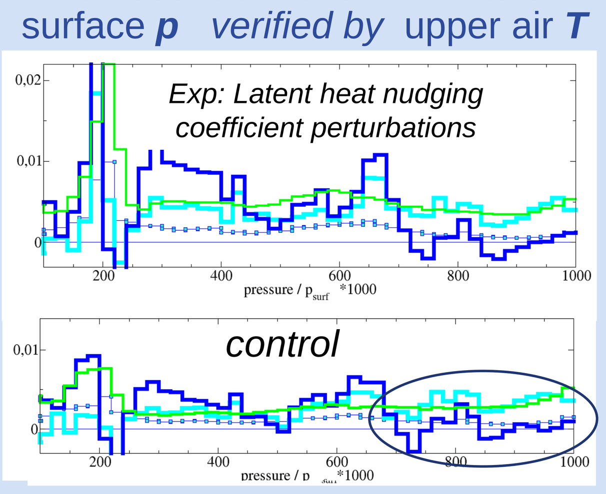
For blue and green curves: see text and C-V Tool description.

Cyan curves: Pressure bias removed from blue curves

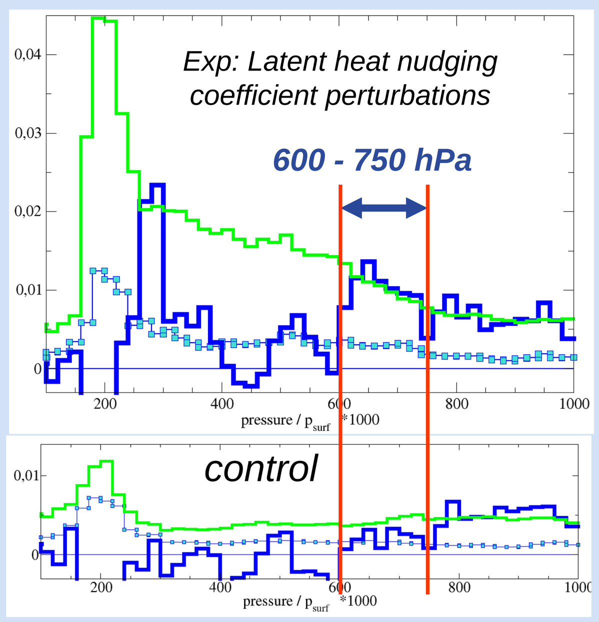
DWD, KENDA June 2021:

weeks 1+2 *"weak convection"*

*Radiosonde measurements of surface **p** verified by upper air **T***



weeks 3+4 *"forced convection"*



The cross-validation Tool

- y_v^o : *verification data*
- y_v^b : *model equivalent background*
- y_v^a : *model equivalent analysis*
- y_α^o : *assimilated observation*

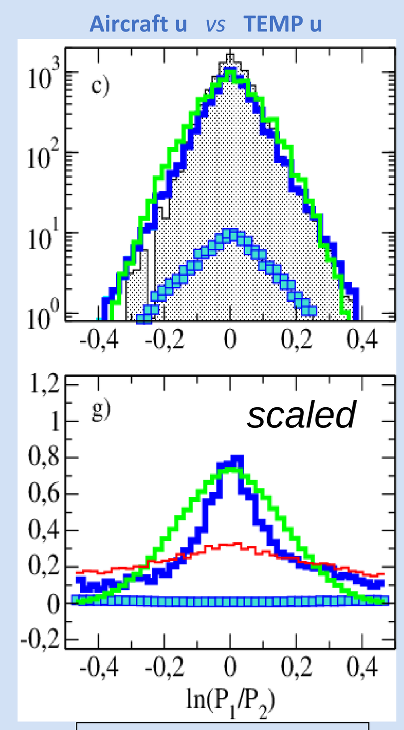
$\mathcal{J}$: *verification function*

$$\mathcal{J} = \frac{1}{2}\left(\|y_v^a - y_v^o\|^2 - \|y_v^b - y_v^o\|^2\right)$$

$$\mathcal{J} = -\left(2\mathcal{J}^b - \mathcal{J}^{ab}\right)$$

Does the assimilation of $(y_\alpha^o - y_\alpha^b)$

- *improve the fit to the verification data* y_v^o *?* FSOI $\mathcal{J}_\alpha \overset{?}{<} 0$
- *pull the model in the direction of the* y_v^o *? Cross-validation* $\mathcal{J}_\alpha^b \overset{?}{>} 0$



Vertical Distance in log pressure levels

$$\mathcal{J}_\alpha^b \propto \sum_{\alpha,v} P_{ens}^{a,loc}[\alpha,v]\,(y_\alpha^o - y_\alpha^b)(y_v^o - y_v^b) \overset{?}{>} 0$$

$$\langle \mathcal{J}_\alpha^b \rangle_{est} \propto \sum_{\alpha,v} P_{ens}^{a,loc}[\alpha,v] \quad P_{ens}^{b,loc}[\alpha,v]$$

Check of consistency relation for ensemble covariance:

$$P_{ens}^{b,loc}[\alpha,v] \overset{!}{=} \langle (y_\alpha^o - y_\alpha^b)(y_v^o - y_v^b) \rangle$$

blue curves $\overset{?}{\sim}$ **green curves**

: **Noise indicator** for blue curves
(Here: noise estimate for a sum $\sum_j A_j$ is $\sqrt{\sum_j A_j^2}$)

3. (continued) Surface p vs upper air T

The BGECs between surface pressure and upper air temperature were tested for

- different types of convective situations
- ensemble covariances with and without LHN perturbations

Weak convection:

- Pressure bias removes C-V impact below 700 hPa
- LHN perturbations increase BGECs but not very strongly and do not improve consistency with observations

Forced convection:

- Pressure biases less dominant (not shown)
- LHN perturbations
  - increase ensemble covariances drastically
  - increase consistency between ensemble and observation based BGECs between 600 - 750 hPa.

4. Conclusions

The C-V diagnostics give a powerful tool to assess in which locations:

- the ensemble sees covariances/correlations
- ensemble covariances are consistent with BGECs estimated from the observations.
  - This is a necessary condition for obtaining a beneficial impact in these locations
  - and allows allocating the localization region where one has a potentially beneficial impact

Stiller, Olaf (2022): "New impact diagnostics for cross-validation of different observation types." Quarterly Journal of the Royal Meteorological Society 148.747 2853-2876.

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