Assimilation issues for the exploitation of humidity sensitive radiance observations from GEO satellites

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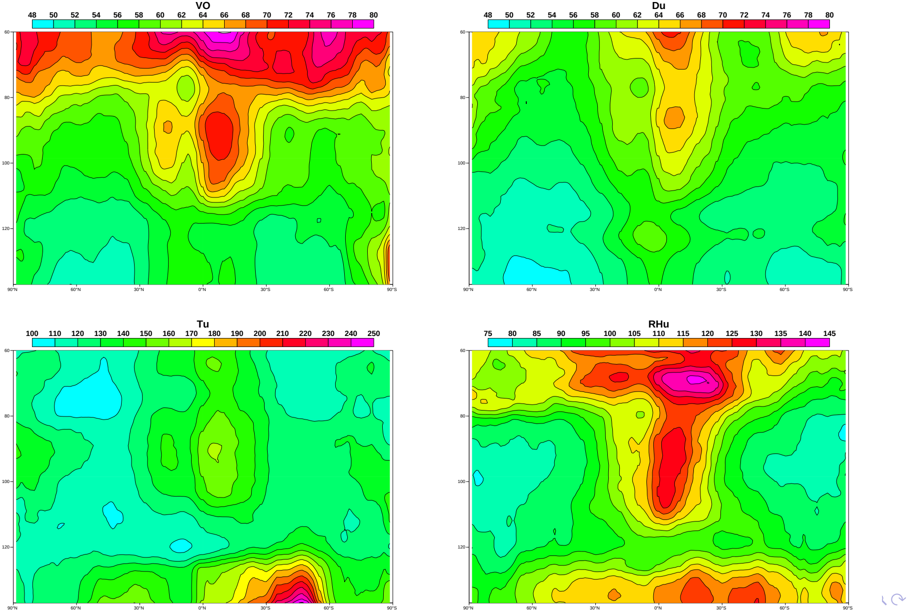
Background errors influence on the analysis

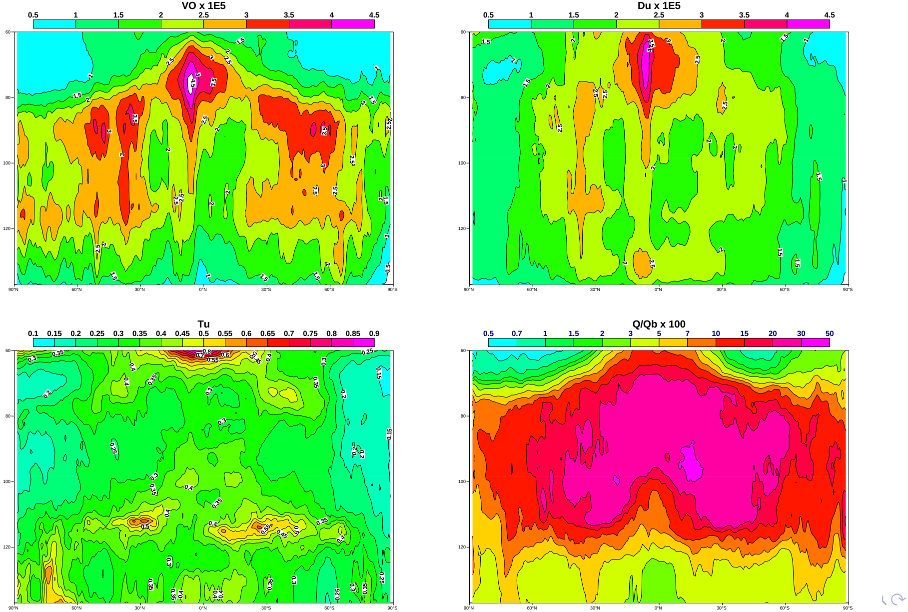
The Ensemble of Data Assimilation is input to update the background error covariance matrix **B** every analysis cycle:

- Standard deviations of all analysis variables are fully flow-dependent.
- Length-scales of the correlations are flow-dependent with climatological length-scales mixed in particularly for the low wavenumbers.
- How does it look?
- New: Use relative humidity background errors σ_{rh}^{ses} from EDA like for other variables.
- Results show improved O-B fits for humidity and wind sensitive observations.

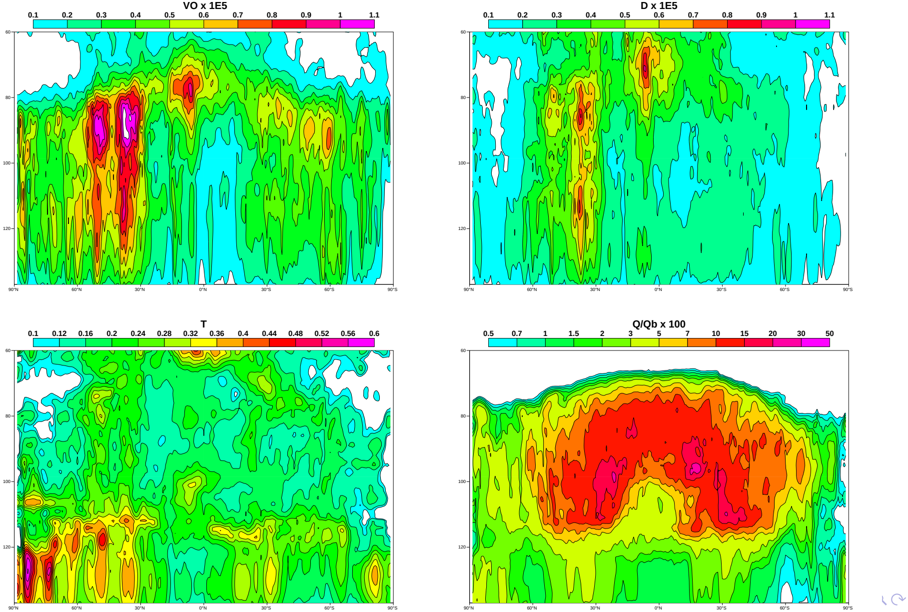
Lengthscales **B** [km], zonal ave



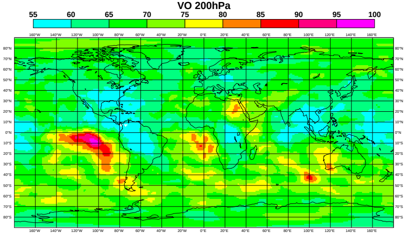
Standard deviations **B**, zonal ave

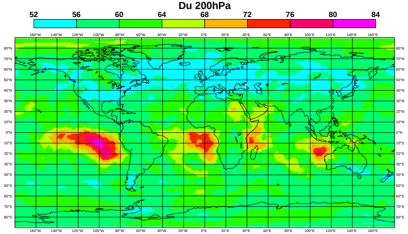


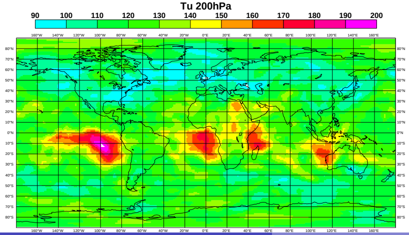
Analysis increments absolute values, zonal ave

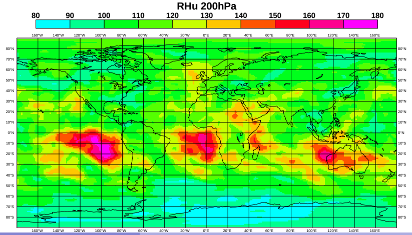


Lengthscales **B** [km], level 74 200hPa









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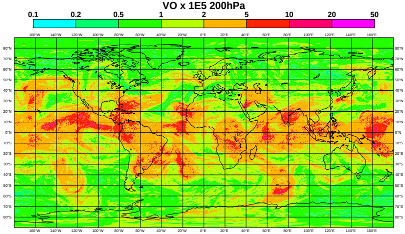
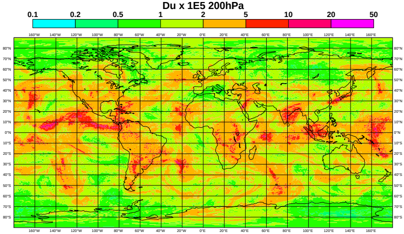
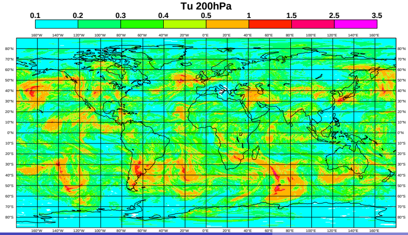
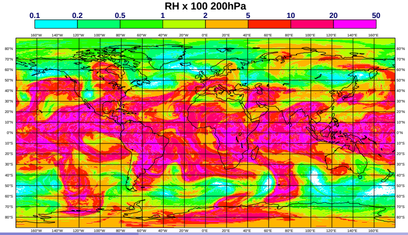
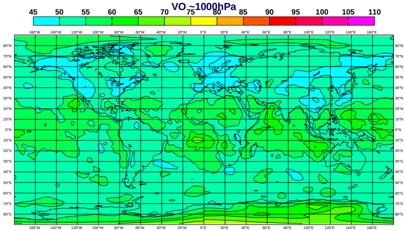


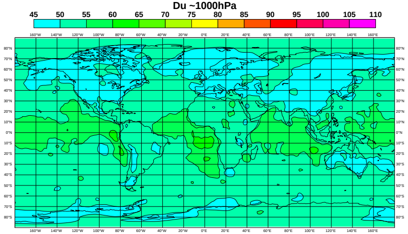


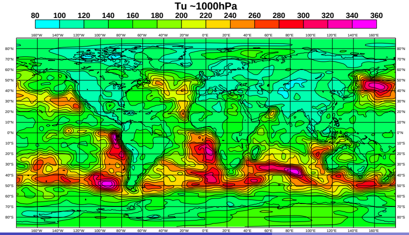


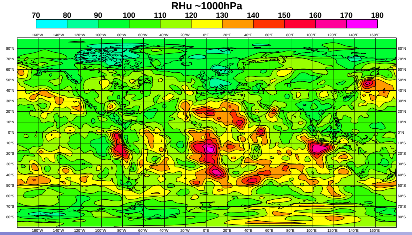


Lengthscales **B** [km], level 137 1000hPa









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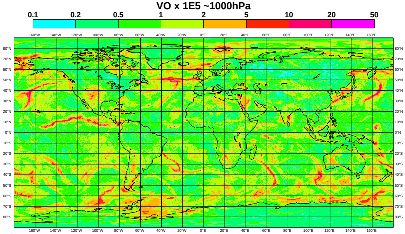
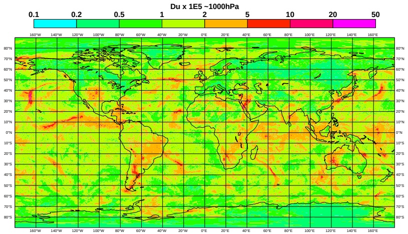
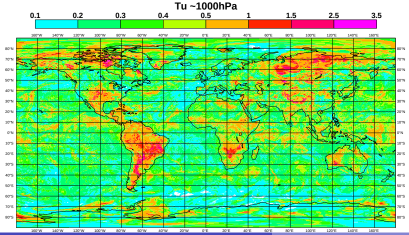
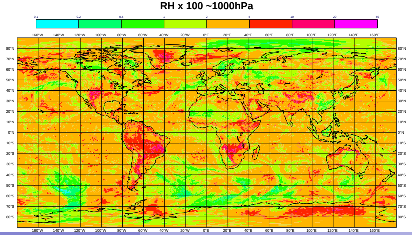
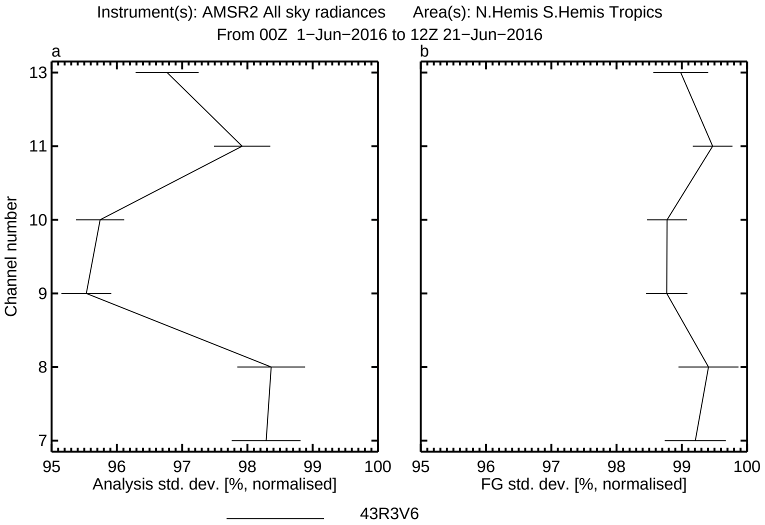




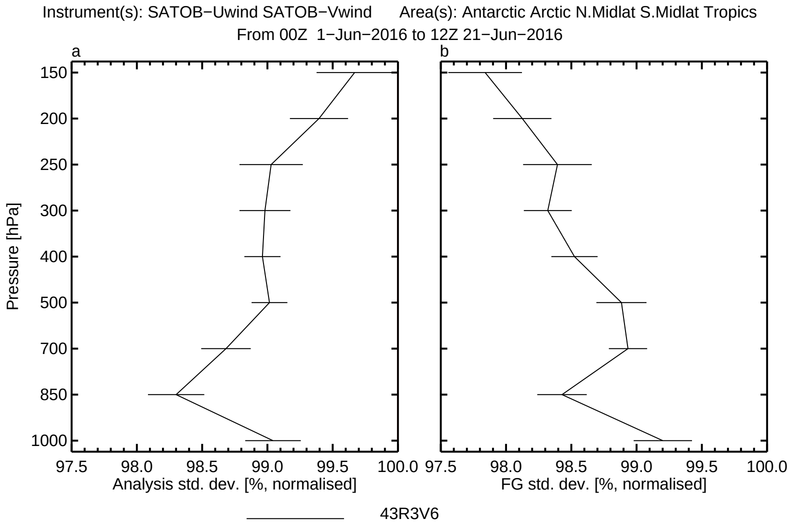




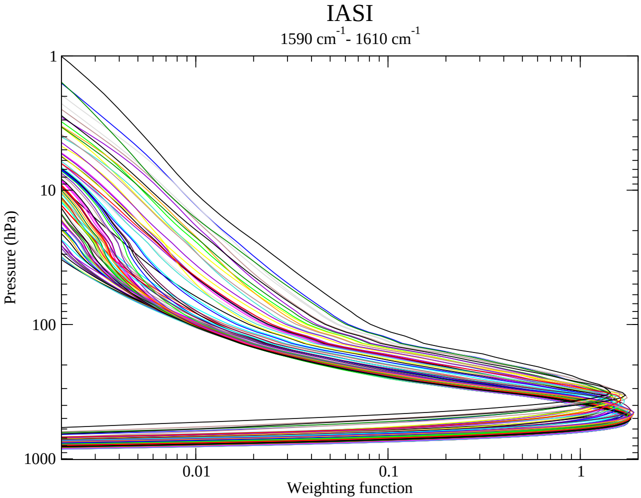
Improving humidity **B** improves humidity: O-B for AMSR2



Improving humidity **B** improves wind: O-B for SATOB



Weighting function selected IASI humidity channels



Stratospheric humidity analysis OFF

- There are long-standing issues with lower stratospheric model biases, which get worse if humidity sensitive radiances are assimilated in that region.
- Humidity sensitive channels with peak sensitivity in upper troposphere often have long tail of sensitivity in the stratosphere, up to 1hPa.
- Bias-correction of these channels is mainly against the upper tropospheric model column.
- This leaves any inaccuracies to affect the humidity in the lower stratosphere, where humidity values are much lower.
- Systematic analysis corrections in upper troposphere lead to systematic tendencies in the stratosphere.
- Radiation interaction of water vapour in the lower stratosphere then leads to degraded forecasts of temperature.
- Until we have better control over lower stratospheric humidity (through e. g. microwave limb sounders) we set the humidity background errors to low values above the 'humidity-minimum tropopause' to suppress humidity increments.

What is unique about MTG-IRS and GIIR from assimilation point of view?

- These observations combine high resolution in three dimensions: space, time, spectral.
- Marco will present ideas how to use more of the spectrum through PCA assimilation.
- Alan will present ideas how to use more of the data in cloudy regions through allsky assimilation.
- The horizontal density of MTG-IRS varies from 4 to 10km from the centre to the edge of the disk.
- The horizontal density of GIIR is about 16km.
- In global NWP we normally thin observations to 50km-100km, which fore these data would be up to 2 orders of magnitude reduction.
- Is there some other way we can make use of the high horizontal density of these observations in global NWP? Distribute!

How to use more of the available satellite data? Distributed observations in ensemble data assimilation

- The current analysis system uses only a few percent of all available satellite data: thinning, redundancy, blacklisting, channel selection.
- Reasons: Dense observations require accurate error correlation and bias specification, otherwise the analysis can degrade with more observations.
- Issue: The information content of the analysis can be increased by adding more satellite data.
- Proposal: Distribute satellite data randomly between ensemble analyses, maintaining similar observation density as before in each ensemble member.

Current and proposed EDA

- Current EDA: The same observations are used in each member, but with a different random perturbation added,

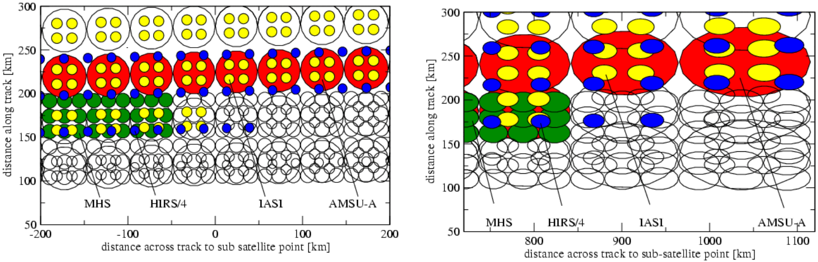
$$y^{(i)} = y_o + \eta_o^{(i)} \qquad \text{where } \eta_o^{(i)} \sim \mathcal{N}(0, R). \tag{1}$$

- Proposed EDA: Different unperturbed observations in each member, with each observations considered as the sum of the true observed state and an error,

$$y_o^{(i)} = y^* + \epsilon_o^{(i)} \qquad \text{where } \epsilon_o^{(i)} \sim \mathcal{N}(0, P^R). \tag{2}$$

  where P^R is the true observation error covariance (which may be different from R) and y^* is the true observed state.
- Combine same set of sparse observations, with perturbations, in all members (e. g. conventional) with different subsets of dense observations, unperturbed, in each member.
- This approach does rely less on the assumption $R = P^R$, contributing to more accurate background error estimates.

Example Scan Geometry (left=nadir, right=edge)



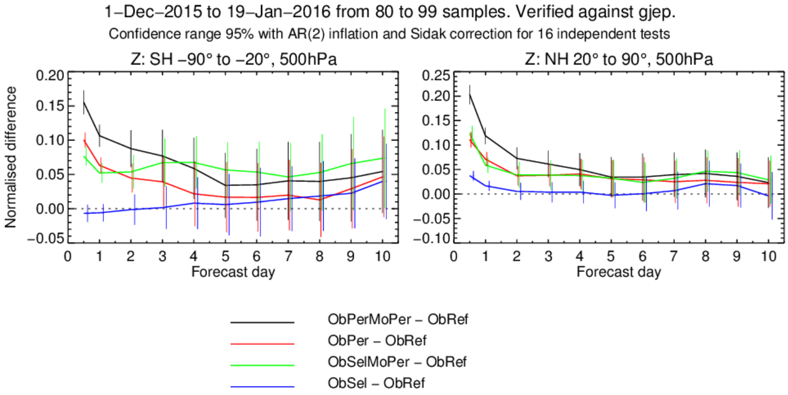
- For $N = 25$, $L_N \approx$ 150km (AMSU-A), 100km (HIRS,IASI), 50km (MHS), 40km (GIIR), 17km (MTG-IRS).
- Horizontal lengthscale $L_K \approx$ 300km+ (temperature), 150km+ (humidity)
- When $L_N \ll L_K$ observations within L_N are practically collocated from the analysis point of view.

Source of plots: http://oiswww.eumetsat.org/WEBOPS/eps-pg/IASI-L1/IASIL1-PG-4ProdOverview.htm

Distributing unperturbed observations between members

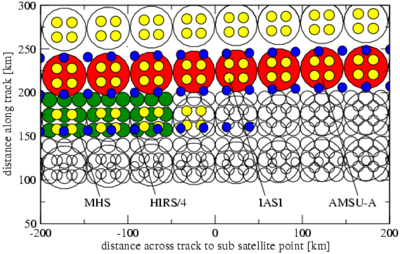
- Distribute columns of data randomly between ensemble members.
- Example ratio of used/screened obs from one cycle:
  - IASI – 1/20
  - MHS – 1/3.7
  - AMSUA – 1/13
  - HIRS – 1/6.7
- In general, fewer observations per member than in control.
- Each analysis does the standard thinning etc as the control, in practice should not do much but guarantees behaviour of each analysis without needing to account for observation error correlations differently than in the control.

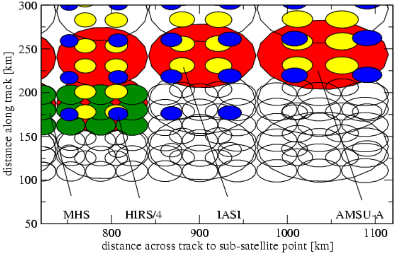
Effect distributing vs. perturbing observations on forecast skill



- Distributing observations (blue) increases accuracy of members.
- Distributing observations also seems to maintain spread of the ensemble in preliminary tests.

Distributing observations in ensemble DA





- Distributing observations is currently area of active research, with exciting initial results and several open questions.
- This research aims to use higher proportion of the available data.
- Geostationary hyper-spectral data would fit very well for exploring distributing observations because of their high density.