Assimilation of geostationary radiances at ECMWF

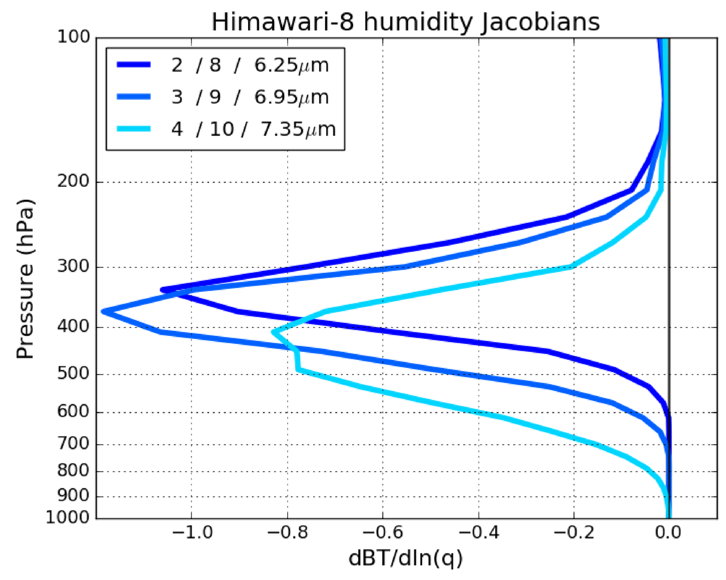
Chris Burrows, Niels Bormann, Tony McNally, Pete Weston, Cristina Lupu and Julie Letertre-Danczak.
Research Department, ECMWF, Reading, United Kingdom.

Introduction – assimilated data

ECMWF currently assimilates clear-sky/all-sky radiance data from Meteosat-10, Meteosat-8, Himawari-8, GOES-15 and GOES13.

Clear sky radiances (CSR) from all water vapour channels are assimilated. Over ocean, the window channel first guess departures are used to screen undetected cloud (i.e. if |ob-fg|>3K). Over land, radiances are only used if the percentage of clear pixels is greater than 70%. Observation errors are 2K, and VarBC is used.

For SEVIRI, all sky radiances (ASR) from the water vapour channels are also assimilated in overcast conditions (percentage of cloudy pixels>99%). For these observations, channels 6 and 8 (window channels) are used to provide an initial estimate of the cloud top pressure (C_P) and effective cloud fraction (C_F). These variables are then adjusted as elements of the 4D-Var control vector (Lupu and McNally, 2012).



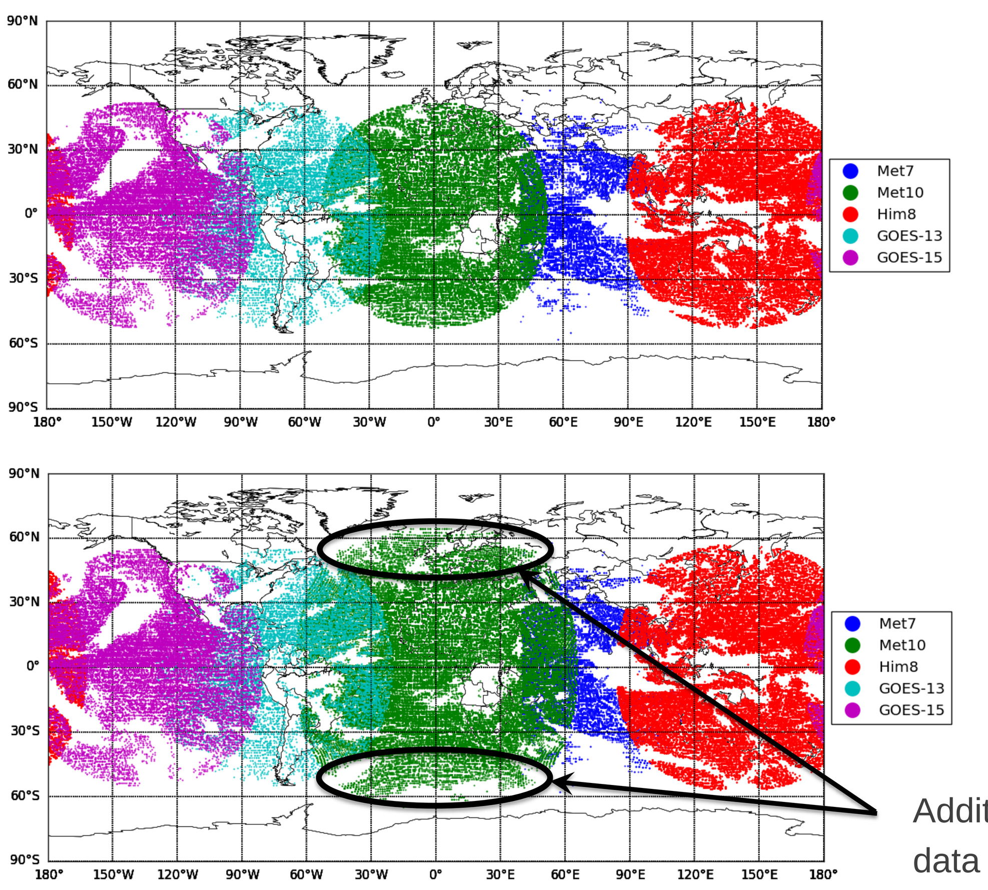
The use of data at high zenith angles and accounting for slant path

Observations are currently rejected if the zenith angle is >60º.

Can we make use of more data by extending this limit to 74º? The change in data coverage is shown below (one cycle from Dec 2016):

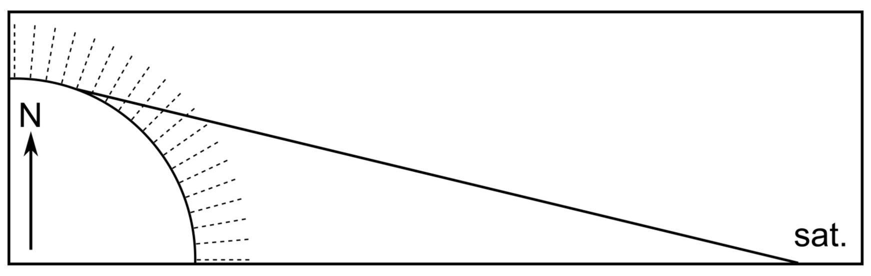
60º

74º



Additional data

But, at high zenith angles, the line of sight from the satellite crosses several model columns.



Neglecting this in the radiative transfer calculations will lead to errors of representation. Accounting for the true line of sight direction in the assimilation is known as "slant path" processing.

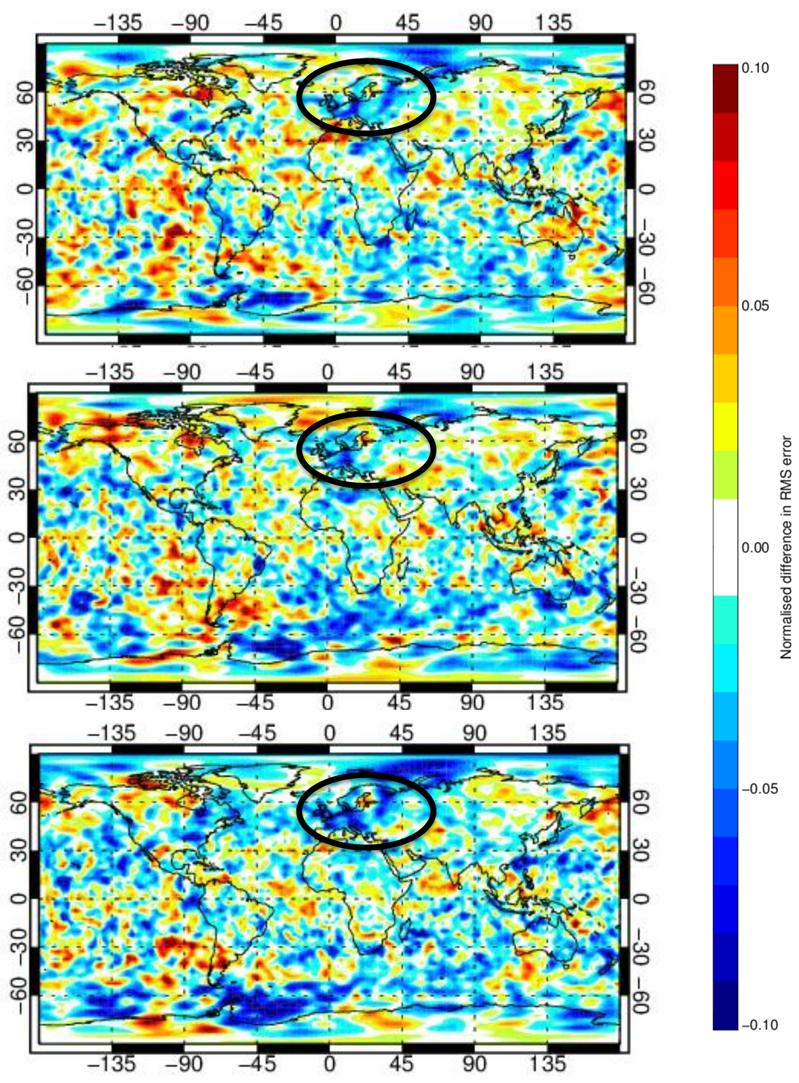
Slant path processing is already implemented for radiances measured by polar-orbiting satellites (Bormann, 2017).

Change in T+96h 200hPa vector wind RMS error. Experiment ran for 83 days:

1) Data up to **Φ=74º**
No slant path

2) Data up to Φ=60º
With **slant path**

3) Data up to **Φ=74º**
AND slant path



Inter-channel observation error correlations

Currently, the assumed observation error for all geostationary radiances is 2K. The "Desroziers" method of diagnosing observation errors (Desroziers et al., 2005) uses statistics of first guess and analysis departures.

$$\mathbf{R}_{diag} = \overline{(\mathbf{y} - H(\mathbf{x}_a))(\mathbf{y} - H(\mathbf{x}_b))^T}$$

Such a covariance matrix has been calculated for the water vapour channels of the geostationary instruments SEVIRI, AHI, GOES and MVIRI using data from 2016.Below are the covariance matrices and their factorisations in terms of their correlation matrices and sqrt(diag(var)).

$$\mathbf{R}_{AHI} = \begin{pmatrix} 0.55 & 0.43 & 0.22 \\ 0.43 & 0.46 & 0.31 \\ 0.22 & 0.31 & 0.35 \end{pmatrix} = \begin{pmatrix} 0.74 & 0 & 0 \\ 0 & 0.68 & 0 \\ 0 & 0 & 0.59 \end{pmatrix} \begin{pmatrix} 1 & 0.86 & 0.51 \\ 0.86 & 1 & 0.78 \\ 0.51 & 0.78 & 1 \end{pmatrix} \begin{pmatrix} 0.74 & 0 & 0 \\ 0 & 0.68 & 0 \\ 0 & 0 & 0.59 \end{pmatrix}$$

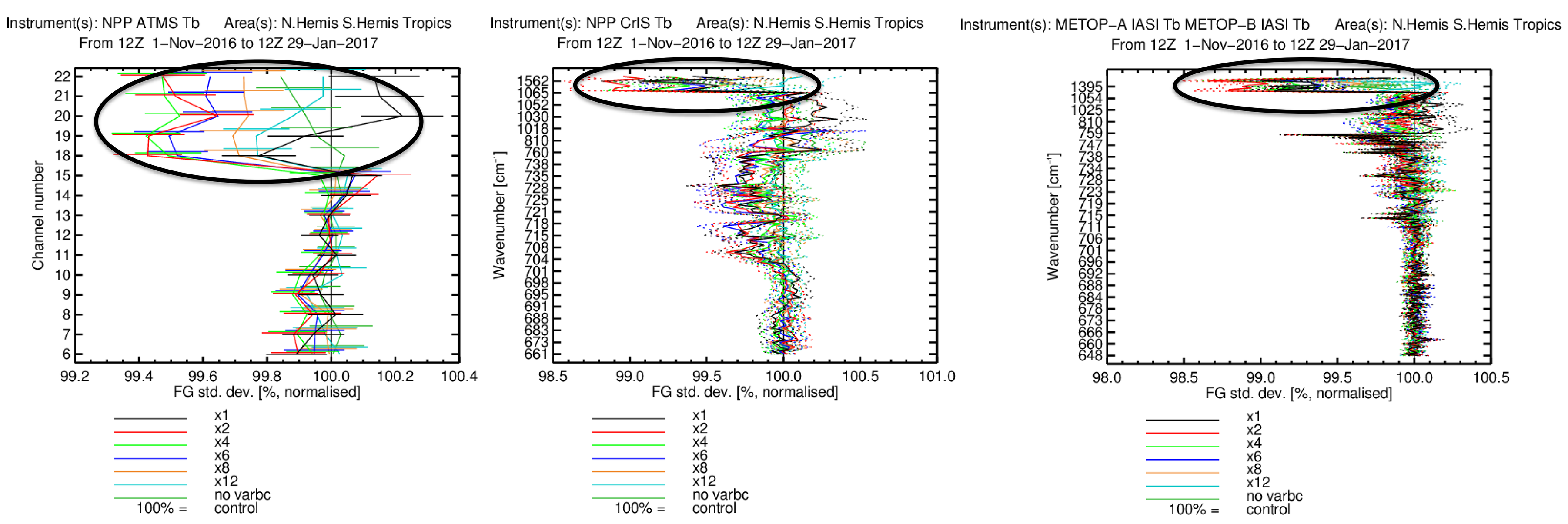
$$\mathbf{R}_{SEVIRI} = \begin{pmatrix} 0.46 & 0.20 \\ 0.20 & 0.30 \end{pmatrix} = \begin{pmatrix} 0.68 & 0 \\ 0 & 0.55 \end{pmatrix} \begin{pmatrix} 1 & 0.54 \\ 0.54 & 1 \end{pmatrix} \begin{pmatrix} 0.68 & 0 \\ 0 & 0.55 \end{pmatrix}$$

$$\mathbf{R}_{GOES} = (0.53) = (0.73)(1)(0.73)$$

$$\mathbf{R}_{MVIRI} = (0.35) = (0.59)(1)(0.59)$$

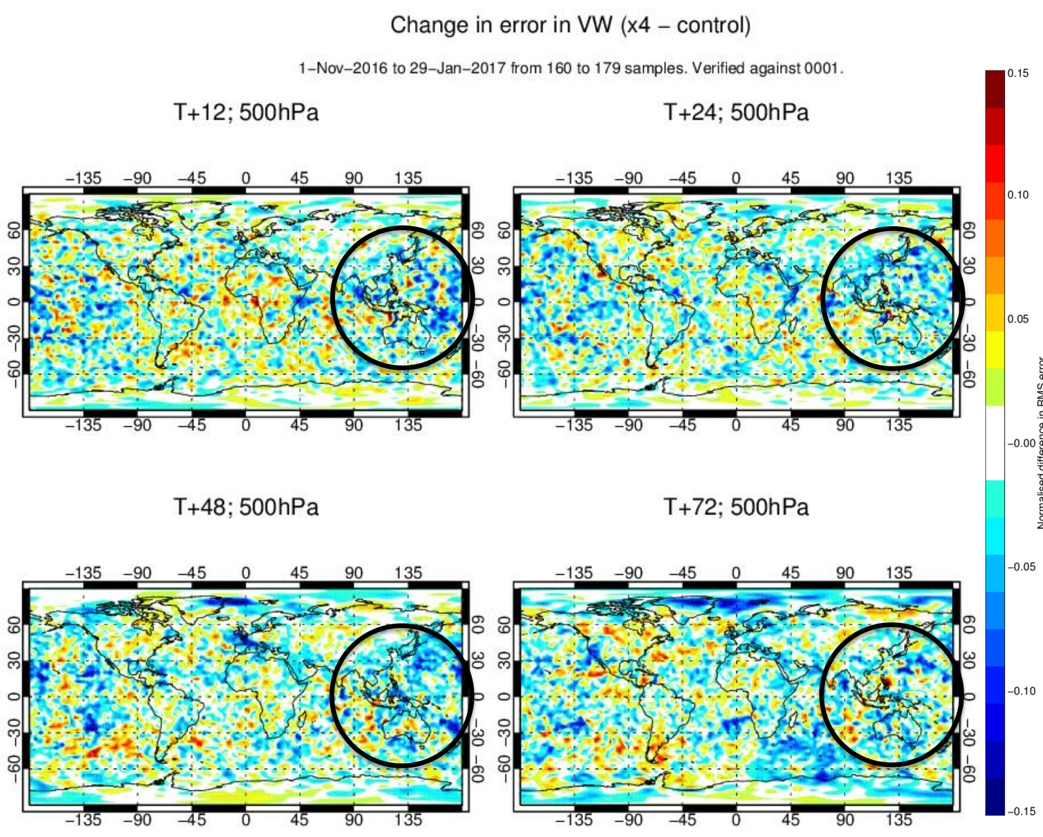
As with Desroziers-derived errors for polar-orbiting satellites, if these error covariances are used directly in the assimilation, the resulting forecasts are degraded (Bormann and Collard, 2012). To produce a beneficial impact, the error covariances can be inflated in such a way as to preserve the correlation structure. The choice of scaling factor is determined by experimentation, using metrics such as the first guess fit to independent humidity-sensitive observations.

Improved first guess fits to ATMS, CrIS and IASI water vapour channels for different scaling factors (scaled in terms of variance):



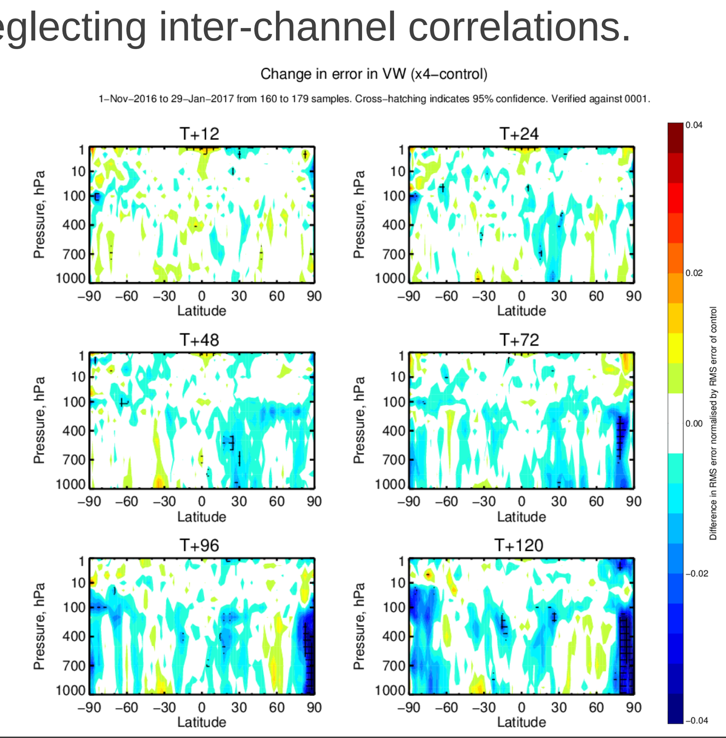
Impact of accounting for error correlations

The optimal scaling factor depends on the metric chosen, so it is not clear which factor should be used. The first-guess fit to ATMS, CrIS and IASI suggests it is between 2 and 6 in variance space (i.e. between 1.4 and 2.4 in terms of standard deviation). For a factor of 4, in terms of variance, these plots show the change in forecast RMS error of 500hPa vector winds for several forecast lead times, verified against operational analyses:



Note that the largest impact is within the Himawari-8 disk. This is to be expected as, with three channels, there is a larger volume of data than from the other satellites, and the inter-channel correlations are the largest of all the satellites, hence it can be inferred that Himawari-8 is currently being treated the least optimally of all by neglecting inter-channel correlations.

The following zonal plot shows the change in RMSE compared to operational analyses at a range of forecast lead times. Hashed shading indicates statistical significance. In general the signal is fairly neutral, but slightly positive on average. Similar changes are seen for relative humidity, temperature and geopotential height (not shown).



References

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Acknowledgements

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