Assimilating short-wave infrared radiances from CrIS at ECMWF

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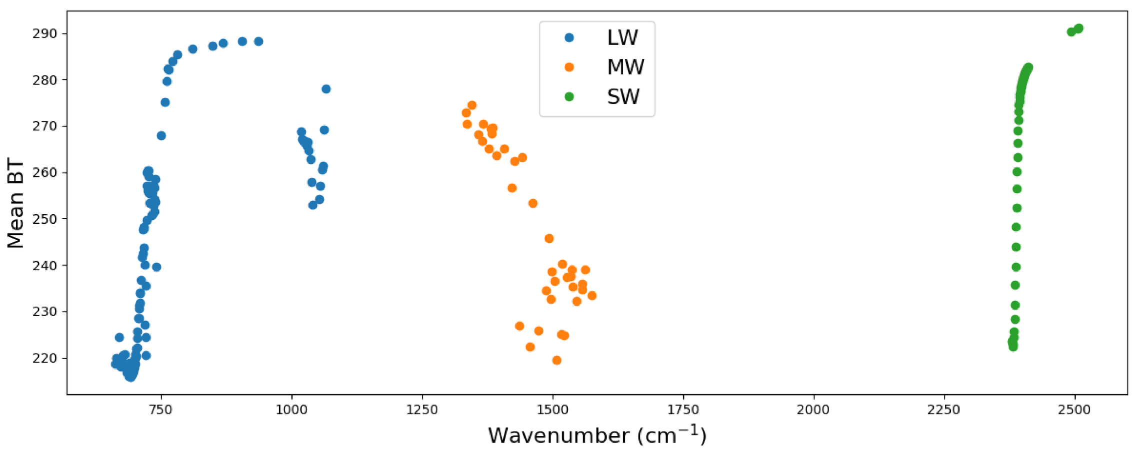
Background

The short-wave (SW) part of the infrared spectrum has not been significantly exploited in NWP. The 4.3μm CO_2 band is remarkably clean in terms of water vapour contamination. This high vertical resolution temperature sounding is potentially valuable for NWP. However, the short-wave band has its challenges: scene-dependent signal to noise, non-local-thermodynamic-equilibrium (NLTE) effects, solar contributions etc.



This poster summarises the methods used to allow CrIS channels in the SW band to be successfully assimilated in addition to the long-wave and mid-wave bands.

Scene-dependent observation errors

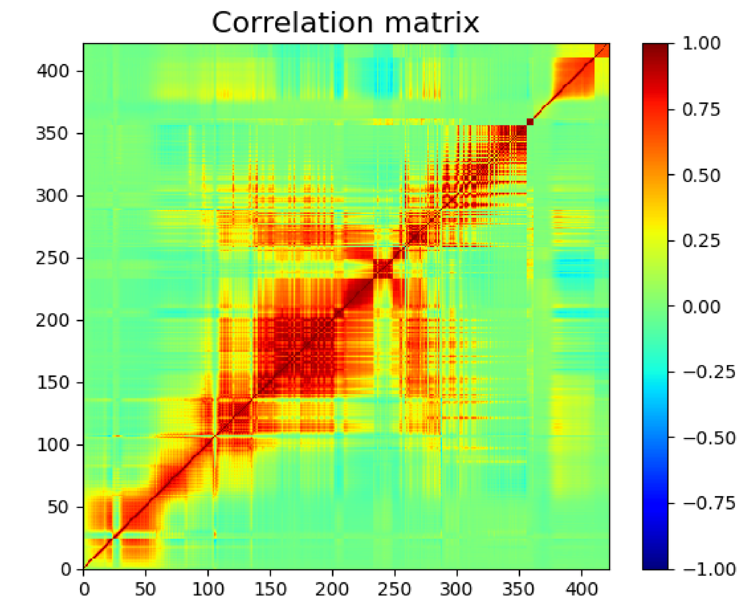
To account for the scene-dependence of the measurement noise (a feature of the non-linearity of the Planck function at these wavelengths), the observation errors are estimated in radiance units rather than brightness temperature (BT). These are then dynamically mapped into BT space and so are dependent on the measured scene brightness temperature. This is performed for the entire set of used channels (LW+MW+SW).

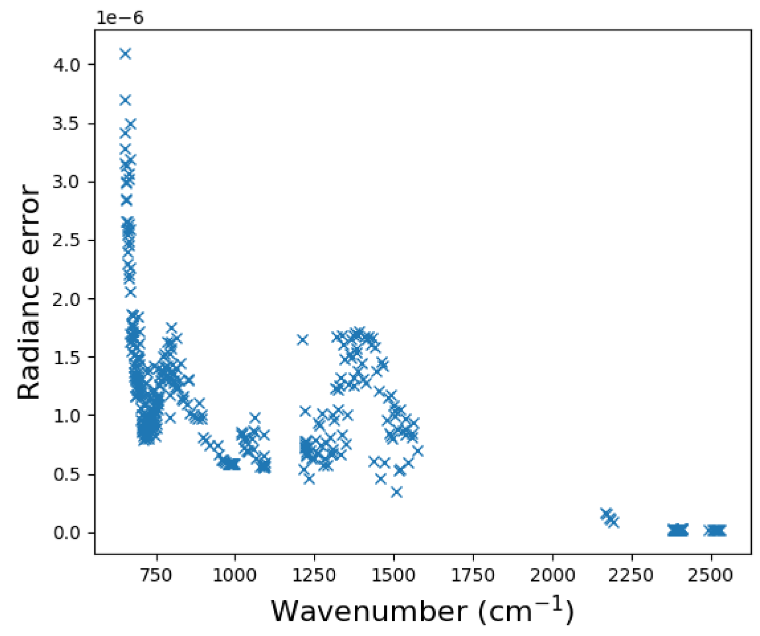
$$R_{BT} = KR_{rad}K^T$$

where the diagonals of **K** are the reciprocal of

$$\frac{dB}{dT} = \frac{c_1 c_2 \nu^4 e^{c_2\nu/T}}{(e^{c_2\nu/T}-1)^2}$$

The Desroziers method of estimating observation error covariances requires a sample of background and analysis departures from an experiment that actively assimilates the observations for which the covariance is sought. Instead, here, we use the covariance of the analysis departures alone as an estimate of the observation error covariance, i.e. assuming the analysis to be "truth". This information can be extracted from a passive experiment, but, as with the output of Desroziers, experimentation is needed to determine an optimal scaling factor.

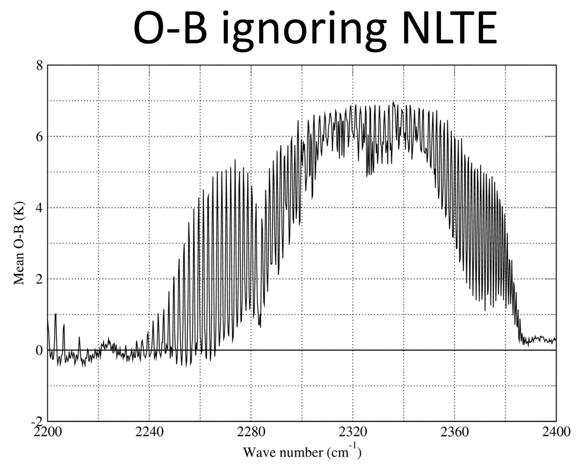




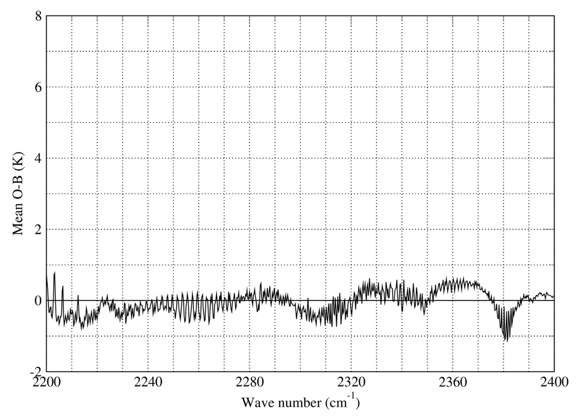
NLTE effects

The exploitation of shortwave data requires the introduction of non-local-thermodynamic equilibrium (NLTE) effects in the direct simulation of the radiances. For CrIS-like satellite sounding applications, NLTE effects occur primarily during daytime above altitudes of ~40 km in the CO_2 spectral region at 4.3 μm due to the strong absorption of the strong solar radiation field. If not accounted for, NLTE effects can introduce significant errors in the simulation of daytime SW radiances. The daytime average of these errors can reach a maximum of ~10 K for channels in the spectral region between 2,210 and 2,386 cm^{-1} where CO_2 represents the only absorbing species.

O-B ignoring NLTE



O-B accounting for NLTE

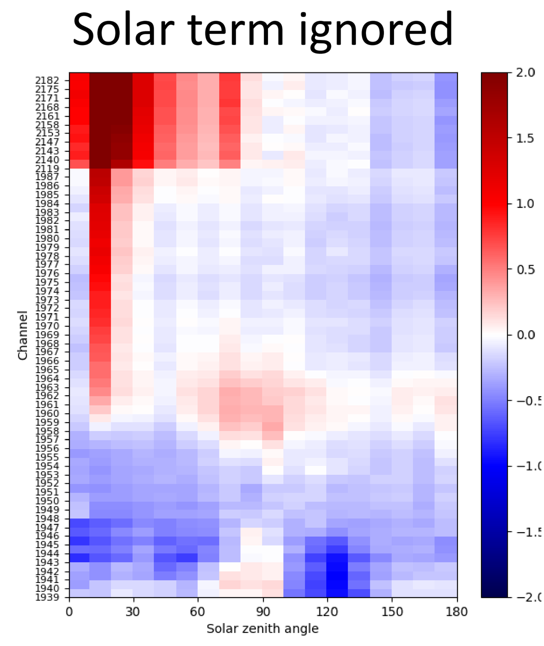


Solar term

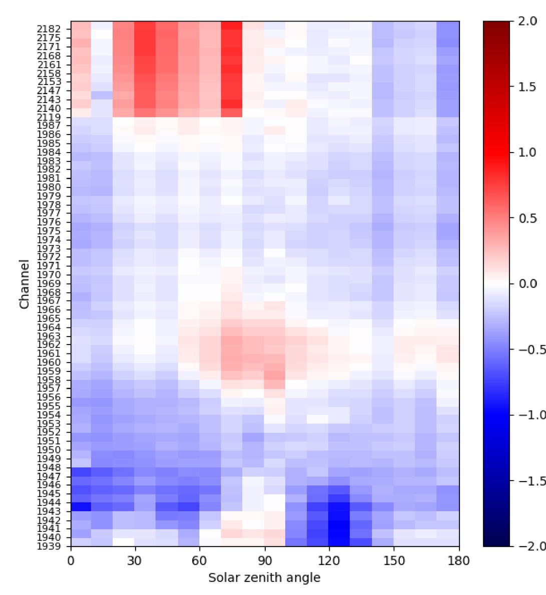
To enable the assimilation of clear-sky shortwave CrIS channels during daytime, the computation of the total radiance requires the introduction of the unscattered solar radiance, i.e. that which is transmitted downward through the atmosphere and then partially reflected back upward through the atmosphere to the receiver. This is geometry-dependent and subject to the bidirectional reflectance distribution function (BRDF) of the wind-roughened water. Solar radiation gives a significant contribution to the TOA radiance for wavenumbers greater than 2000 cm^{-1}.

It can be seen that by accounting for the solar term, the mean daytime O-B for many of the SW channels are improved significantly. The residual bias for channels above 2100 is accounted for by not assimilating these channels during daytime.

Solar term ignored



Solar term included

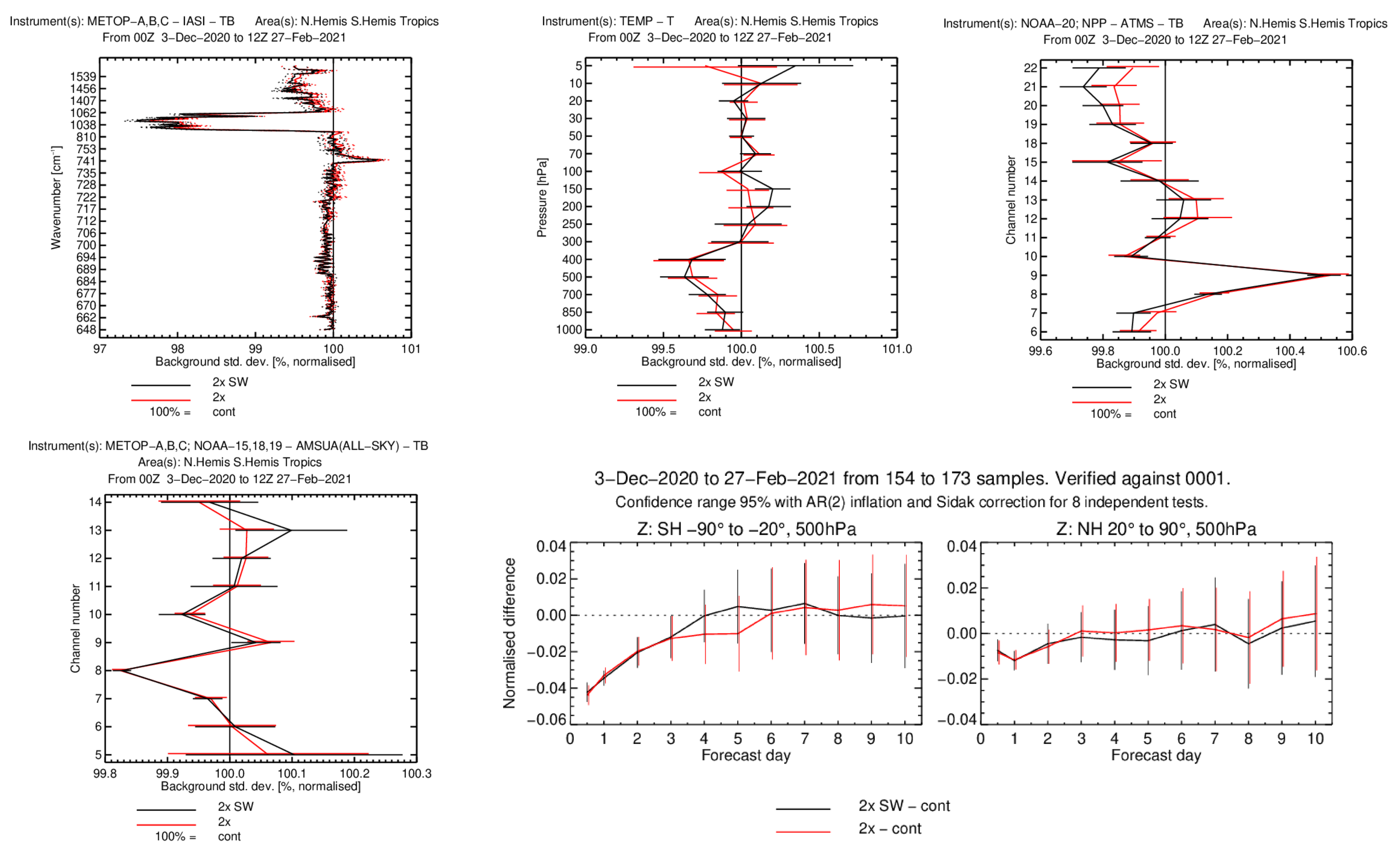


Impact on NWP

A series of experiments were run assimilating 60 SW CrIS channels with the other modifications described above. The observation error scaling factor of 2x was determined to be optimal, and residual daytime biases in channels above ~2380cm^{-1} were accounted for by excluding these channels during daytime. The two experiments are:

- "2x": all changes described here but no SW channels.
- "2x SW": as "2x" but with SW channels added.

The first 4 plots show the change in fit of short-range forecasts to independent observations. The 5th plot shows the Z500 scores at longer lead times.



In general, the improvement is positive (i.e. <100%). Some apparent degradations occur, which are mostly known verification artefacts.

The improvement in Z500 is positive and statistically-significant to day 3, as verified against operational analyses.

Discussion

The impact of the observation error retuning and the addition of short-wave channels both improve the impact of NWP. As expected, the scene-dependent observation errors provide improvements to the water vapour field by better accounting for the noise nonlinearity in the MW band. However, the addition of the SW channels also significantly improves the water vapour field, despite the chosen SW channels being devoid of water vapour lines. The working hypothesis for this is that the clean SW CO_2 band is helping to resolve the water-vapour/temperature ambiguity which exists in the LW band.

Future work may include investigating the residual daytime biases in the surface-sensitive SW channels. Also, exploiting the SW band of IASI may also be considered.

Based on these results, the changes presented here have been tentatively approved for implementation in the next ECMWF operational model upgrade, CY49R1.

Acknowledgements

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References

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