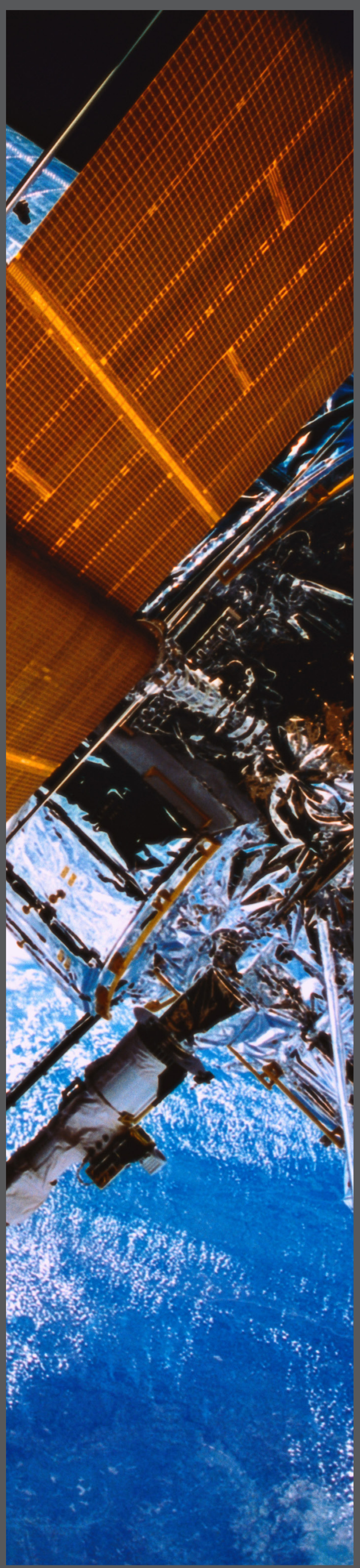

Assimilation of Cross-track Infrared Sounder radiances at ECMWF

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Approach

We aim at operational assimilation of Cross-track Infrared Sounder (CrIS) radiances in the global NWP system of ECMWF. Experience gathered from earlier hyper-spectral radiances, including those from the Atmospheric Infrared Sounder (AIRS) and Infrared Atmospheric Sounding Interferometer (IASI), is applied where possible: the experimental assimilation of new radiances is limited to cloud-free channels over sea and sea ice, and the emphasis is put on the efficient use of temperature sounding channels in the 15 µm CO_2 absorption band.

In contrast to the operational use of IASI radiances, a large number of spectrally-adjacent CrIS channels are assimilated using a relatively aggressive specification for observation error standard deviation. This is hoped to compensate for the poorer spectral resolution of CrIS instrument. A non-diagonal observation error covariance matrix is applied to account for the effect of the signal apodization.

CrIS instrument

CrIS is a Michelson interferometer attached to the Suomi-NPP polar-orbiting satellite launched into an afternoon orbit in October 2011. The infrared sounder provides radiance information on 1,305 channels in the wavenumber range 650 – 2550 cm^{-1}. Field-of-View diameter is 13.5 km in nadir and global coverage is produced every 12 hours.

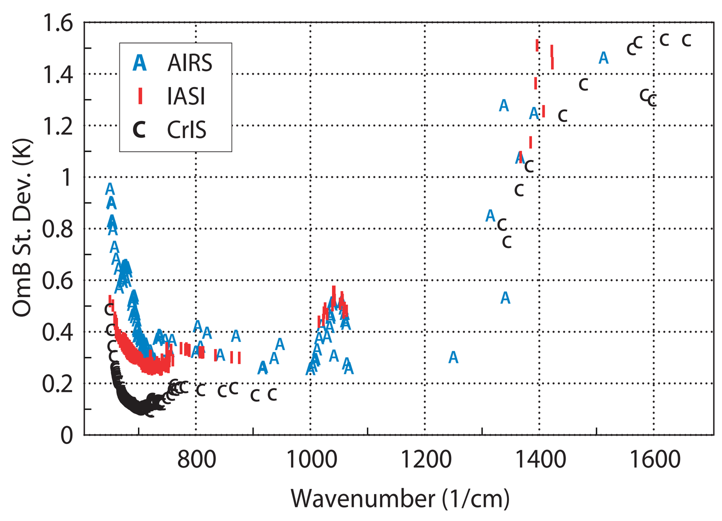


Figure 1 Global background departure standard deviation on selected AIRS (blue), IASI (red) and CrIS (black) channels.

The effect of spectral resolution

In comparison with earlier hyper-spectral infrared sounders, lower instrument noise levels of CrIS compensate for the effect of the relatively poor spectral resolution. While past experience from the assimilation of AIRS and IASI radiances provides a natural starting point for the use of CrIS radiances, modifications are required to properly account for the different trade-off between noise and spectral purity.

We aim at maximizing the meteorological information extracted from apodized radiances by using almost all channels in the most critical spectral range at 670 –730 cm^{-1}. Using a large number of spectrally-adjacent channels means that observation error correlation introduced by the signal apodization has to be taken into account in the assimilation.

Furthermore, the low noise levels are reflected in an aggressive specification of observation error standard deviations during the assimilation.

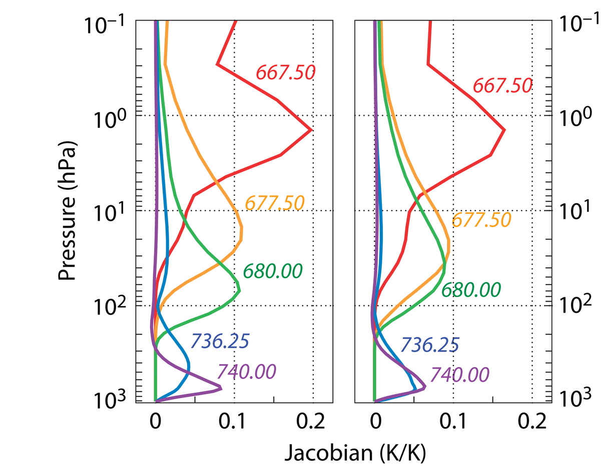


Figure 2 Temperature Jacobians on selected IASI (left) and CrIS (right) channels in a tropical reference atmosphere.

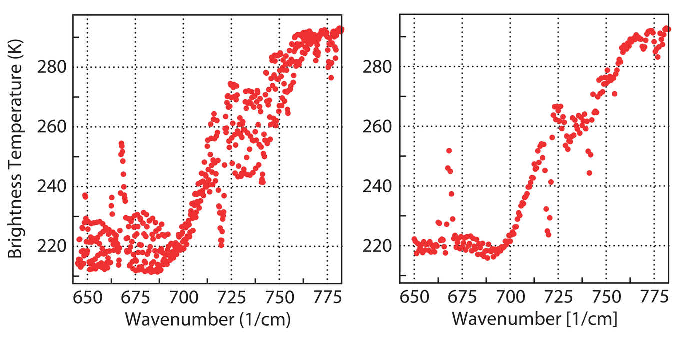


Figure 3 Excerpts of IASI (left) and CrIS (right) long-wave spectra.

Baseline configuration

Used in experiments with the previously operational IFS version (Cy38r2) in resolution T511 / L91

- Pre-select the middle FOV (pixel 5) from each Field-of-Regard
- Assimilate 122 channels from the long-wave CO_2 absorption band
- Set observation error standard deviations to 0.4 / 0.2 / 0.6 K
- Assume signal apodization to be the only source of observation error correlation
- Assimilate data over sea and sea ice only
- Use RTTOV-10 for radiative transfer modelling
- Use variational bias correction with air-mass- and scan-angle-dependent predictors
- Assimilate one FOV per thinning box (1.25° by 1.25°) only

A consistently positive medium-range forecast impact extending over the whole of troposphere is found in the extratropics, while a negative impact is seen in the tropical upper troposphere

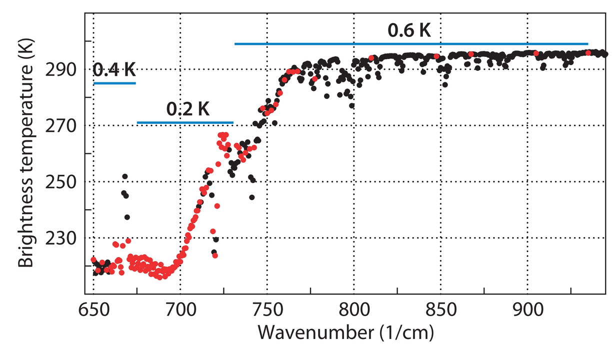


Figure 4 Long-wave CrIS spectrum highlighting assimilated channels. Blue bars indicate the assumed observation error standard deviations.

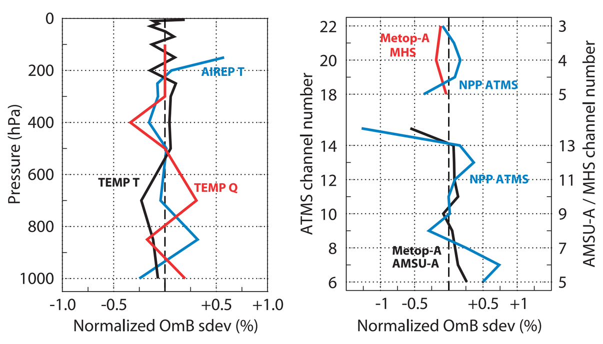


Figure 5 Normalized global background departure standard deviations for some conventional (left) and space-borne microwave radiance (right) observations in a 90-day assimilation experiment. Negative values imply improved background fit when CrIS radiances are assimilated.

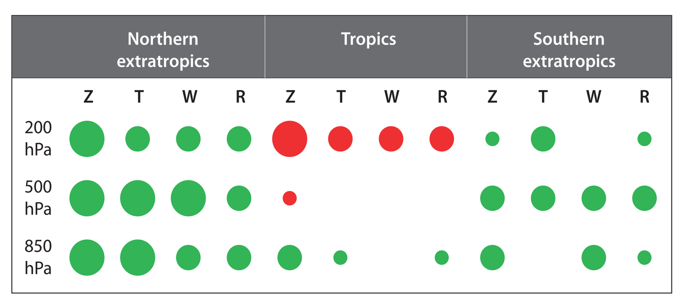


Figure 6 Medium-range forecast impact from adding CrIS radiances in the ECMWF 4D-Var system. Z, T, W, and R refer to geopotential, temperature, vector wind, and relative humidity, respectively. Green (red) indicates positive (negative) impact. Dot size indicates the magnitude of the impact.

The way forward

The positive forecast impact from the baseline configuration does not reproduce in newer experiments based on a more up-to-date IFS version (Cy40r1) and using higher vertical resolution. Further optimization on the use of CrIS radiances is being carried out focussing on the following modifications:

- Pre-selection of the warmest FOV
- 12 channels in the water vapour absorption band added to the assimilation
- Humidity-sensitive channels removed from the long-wave CO_2 absorption band
- Stringent tuning of the cloud detection in response to the low noise levels
- Observation error standard deviation relaxed to 0.5 / 0.3 / 1.2 K

The following approaches will be considered when designing future experiments to improve the assimilation of CrIS radiances:

- Account for inter-channel error correlations other than those introduced during the signal apodization
- Use collocated imager information to assist the cloud detection: VIIRS-based estimates of cloud parameters are available for doing this
- Assimilate stratospheric-peaking channels over land
- Study the impact of CrIS in a degraded assimilation system, where no AIRS radiance data is available

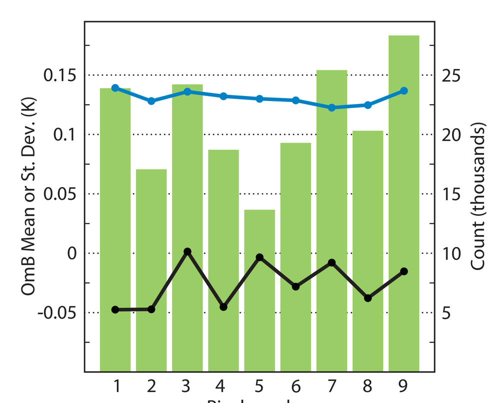


Figure 9 Pixel-number-specific background departure statistics after Warmest-FOV-based data selection: mean (black), standard deviation (blue) and count (green). Statistics are shown for channel 61.

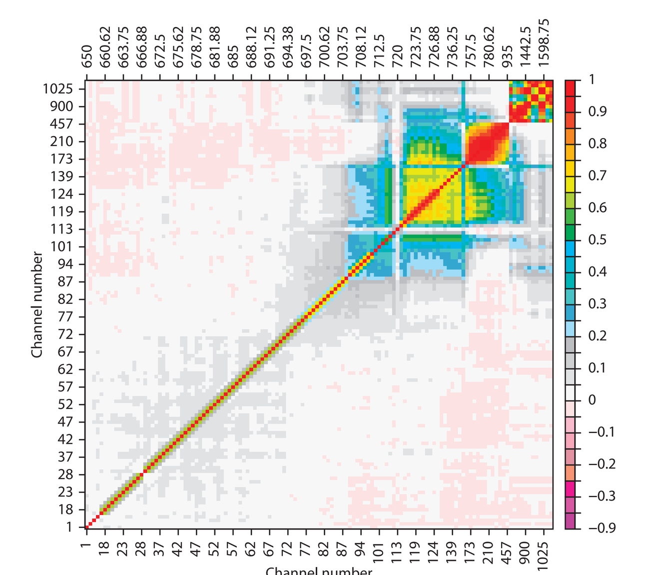


Figure 10 Inter-channel observation error correlations as diagnosed using the *Hollingsworth – Lönnberg method* in a selection of 128 CrIS channels.

Cloud detection

Cloud-contaminated channels are rejected from the assimilation. Cloud contamination is diagnosed using a detection scheme of *McNally & Watts* (2003) and it is based on brightness temperature background departures in a set of vertically-ranked channels in the 15 µm CO_2 absorption band. Because of cloud contamination, typical count of usable data on a window channel is only 20% of that on a high-peaking stratospheric channel.

The low noise level of CrIS results in increased sensitivity to contamination by undetected clouds. Therefore, parameters of cloud detection need to be tuned more stringently for CrIS than for earlier hyper-spectral sounders. In an appropriately-tuned detection scheme cloud-free background departures constitute a nearly symmetrical and Gaussian histogram.

McNally & **Watts** (2003): A cloud detection algorithm for high-spectral-resolution infrared sounders. *Q. J. R. Meteorol. Soc.*, **129**, 3411—3423.

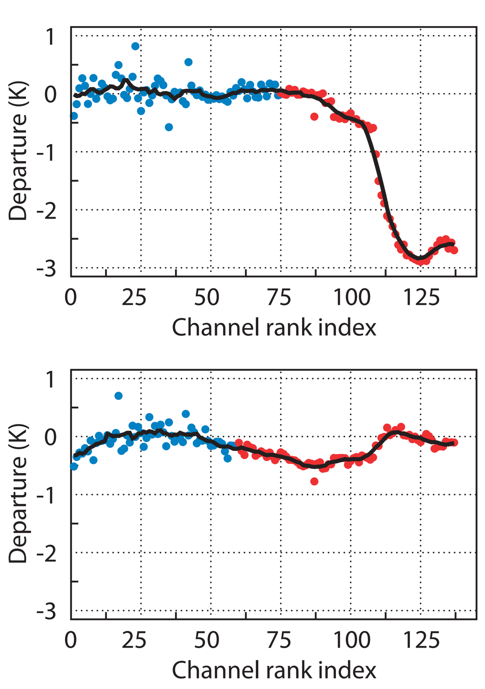


Figure 7 Smoothed (line) and unsmoothed (dots) background departures on vertically-ranked channels in two single cases. Channels diagnosed cloud-contaminated in each case are shown in red.

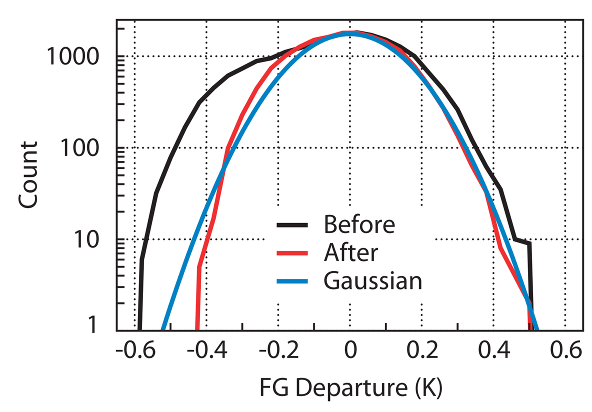
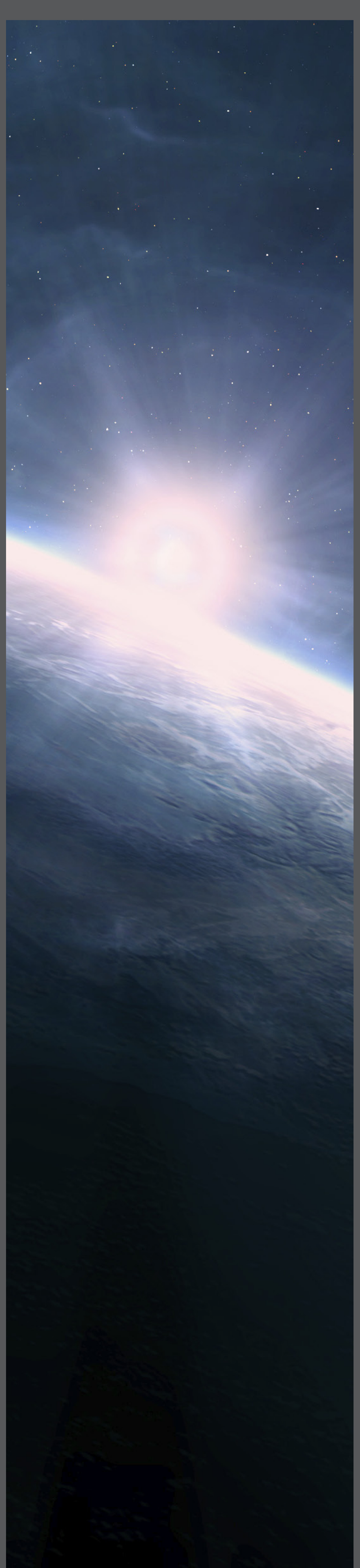


Figure 8 Frequency distribution of background departure on a mid-tropospheric sounding channel before (black) and after (red) the cloud detection re-tuning.

Conclusions

As compared with earlier hyper-spectral sounders, CrIS radiances are affected by a unique trade-off between noise characteristics and spectral resolution. Therefore, experience from the operational assimilation of AIRS and IASI radiances is insufficient to facilitate successful assimilation of CrIS radiances.

We have put emphasis on strong exploitation of cloud-free sounding channels in the 15 µm CO_2 absorption band. We demonstrate a positive medium-range forecast impact in the extratropics from assimilating CrIS radiances into the previously-operational IFS version at ECMWF. However, similar level of performance has not yet been produced in the currently-operational IFS version. Work is in progress to fully understand the nature and impact of CrIS radiance data in the ECMWF 4D-Var system.



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