All-sky assimilation of selected water vapour infrared IASI channels at ECMWF: initial results

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Motivation and definition of the problem

A more extensive use of available satellite data has been a long-standing goal of operational meteorology. Amongst the current strategies to increase the information yield from satellite instruments is to try to make better use of radiative data that are affected by cloud or precipitation. This is a very challenging goal, as numerical weather prediction models’ forecasts of cloud fields can have significant errors, especially in the case of small scale, rapidly varying features. In addition, satellite observations are also needed to deal with the horizontally non-homogeneous atmosphere and to provide an computationally affordable and validated input to climate and Earth system models. Furthermore, the presence of clouds can make it difficult to relate observations and temperature and humidity profiles accurately, to the point that the current operational data assimilation systems may not be able to make an optimal use of these observations. Despite these difficulties, recent studies (Proctor et al., 2013; Simplett et al., 2015) concerning the assimilation of infrared radiance observations in the atmosphere when clouds are present in the instrument’s field of view, confirm the findings of earlier investigations (e.g., Proctor et al., 2008; McNally et al., 2000) and show that the assimilation of a subset of the sounding channels assimilated above the cloud can reduce the mean analysis errors of the atmospheric temperature and water vapour profiles. There is also evidence of error reduction on cloud parameter variables (Moentmann et al., 2012).

These results provide a motivation to carry out a detailed investigation of the informative potential of central spectral infrared soundings in the presence of cloud, particularly regarding channels that are sensitive to water vapour, which are expected to have a smoother response to cloud. The aim is to determine a set of channels of a given infrared sounder that are most suited to estimate humidity fields in all-sky conditions.

All-sky IASI data assimilation experiments

The interface to RTTOV 11 used operationally at ECMWF is configured to model the radiance of the radiance from selected IASI channels in all-sky conditions, while other channels are assimilated only if clear sky.

In the presence of cloud the Jacobian of the IASI observations will further depend critically on the linearity of the state vector. Also, temperature and water vapour errors are not necessarily uncorrelated to the vertical distribution of cloud constituents. For these reasons, forecast sensitivity to all sky-assimilation of IASI data is expected to be flow-dependent and to vary according to the considered set of channels.

Our first experiment consisted on assimilating in all-sky conditions the ten humidity-sensitive IASI channels that are currently assimilated only in clear-sky (channel numbers 2889, 2995, 2993, 3059, 3105, 3110, 3321, 3312, 3580 and 3453). In this test the standard observation error in clear sky for these channels (with magnitudes 2-15) was replaced with a much larger value – 10 K, in accordance with the value estimated by Osbornet al. (2013) – no cloud screening and very few quality control checks were applied so that all observations were assimilated in all-sky conditions. A month-long assimilation experiment, however, showed that a cloud-independent error model and a selection of channels for assimilation optimal in deep clear sky are not sufficient to ensure that an all-sky assimilation of the assimilated IASI data result in a smooth transition skill than an assimilation of the channels only in clear sky (see Figure 3).

Figure 3: Normalised mean square temperature and humidity error difference between experiments with all sky IASI water vapour channels and experiments with some channels only assimilated in clear sky.

Flow-dependent channel selection in all-sky conditions

The iterative channel selection methodology developed by Rodgers (1990) and saved for each current set of IASI channels that are assimilated in clear sky (Colled, 2007) was revised and modified to be used in a consistent way with observations having correlated errors and was applied to IASI simulated observations both in clear sky and overcast conditions using flow-dependent forecast error as an indicator to select the best ensemble of sounding channels. The model was run with long-term climatological conditions and the resulting cloud fields were used to define sub-columns composed of either cloud-free or overcast layers depending on the value of the cumulative cloud cover using the maximum-multi-column cloud model and that when using the single-cloud model in all-sky conditions.

The colour code of channels (see text).

Summary and future work

In this study we set up an 100-channel radiative transfer model, 90 humidity-sensitive IASI channels before 2200 cm–1 (to avoid solar contaminations) were selected at Care et al. (2012) and 10 humiditiesensitive infrared channels at the clear-sky locations for a case study in July 2012. Care was taken to select a final short-list of 22 humidity-sensitive channels and the joint selection of the longwave infrared atmospheric temperature and radiance error, the forecast error uncertainty of the NWP model in all-sky conditions. To this end, a novel channel selection method that depends on flow-dependent estimates of accounting for observation error correlation was developed. Finally, we were able to simulate IASI channels either in clear sky or when emerging radiation is affected by cloud model was introduced in the interface to RTTOV 11 used operationally at ECMWF. The forecast impact of the all-sky clear-sky radiative transfer model selected a final channel list and 22 moisture-sensitive channels was being assessed by means of a set of two experiments. These models, however, indicate that to achieve a positive balance it is essential to ensure the following: a) use of suitable cloud-independent error model and a selection of channels for assimilation optimal in deep clear sky; b) observation error uncertainty levels and quality control strategies used for data assimilation should depend on the presence of cloud in the instrument field of view and/or in the model predictions of the observation.

References

M. Matricardi: "An instrument of remote-sensing and clouds in RTTOV: the EUMETSAT radiosonde model transfer module", in Proc. of the 2nd Workshop on Satellites for Atmospheric Monitoring, pp. 8-12 (2007).

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Figure 4: Number of degrees of freedom for signal (DFS) achieved in a clear-sky (left panel) and a cloudy (right panel) experiment when selecting up to 100 temperature-sensitive IASI channels and then selecting the channel that gave the highest DFS in each sub-column to water vapour. The red dashed line shows the number of degrees of freedom that would be achieved in a clear-sky experiment considered, at the a.s. clear sky and overcast locations which the largest DFS is above the operational number of selected channels. The nine yellow chips of DFS for the channels selected at those locations are denoted by a five digit number of DFS for the channel selected at the locations where the largest DFS is above the operational number of selected temperature channels are denoted by green dots.

Figure 5: Number of degrees of freedom for signal (DFS) achieved in a clear-sky (left panel) and a cloudy (right panel) experiment when selecting up to 100 temperature-sensitive IASI channels and then selecting the channel that gave the highest DFS in each sub-column to water vapour. The red dashed line shows the number of degrees of freedom that would be achieved in a clear-sky experiment considered, at the a.s. clear sky and overcast locations which the largest DFS is above the operational number of selected channels. The nine yellow chips of DFS for the channels selected at those locations are denoted by a five digit number of DFS for the channel selected at the locations where the largest DFS is above the operational number of selected temperature channels are denoted by green dots.

Figure 6: Humidity Jacobians of the 22 selected channels.

Figure 7: Monthly mean assimilation over 91 model levels for a case study during summer 2012.

Figure 8: Monthly mean difference between predicted radiative IASI channel 3576 (1538.75 cm–1) at 1 degree resolution when cloud effects are simulated using the single-column cloud model.

Figure 9: Monthly mean assimilation over 91 model levels for a case study during summer 2012.

Figure 10: Monthly mean difference between predicted radiative IASI channel 3576 (1538.75 cm–1) at 1 degree resolution when using the single-column cloud model.