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PLANS FOR THE ASSIMILATION OF CLOUD-AFFECTED RADIANCES AT ECMWF

This short note summarizes the current and future activities at ECMWF on the assimilation of cloud-affected radiances, and is deliberately formulated in terms of requirements related to observational products and model developments.
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Plans for the Assimilation of Cloud-Affected Radiances at ECMWF

This short note summarizes the current and future activities at ECMWF on the assimilation of cloud-affected radiances, and is deliberately formulated in terms of requirements related to observational products and model developments.

There is a growing interest in assimilating clouds and precipitation in NWP data assimilation systems, for several reasons:

- The atmosphere is full of clouds. Assimilating satellite data in genuinely cloud-free conditions severely limits the data coverage of such observations
- Clouds contain directly or indirectly very useful information related to other atmospheric quantities (temperature, moisture, horizontal and vertical motion,…).
- The quality of the NWP models, thanks to improvements in physical parameterizations and increase in horizontal and vertical resolution, has reached a degree of realism which allows the satellite observations to be compared to model simulations even in cloudy or rainy conditions
- A number of satellite observations providing information on cloud and rain is already available (SSMI(S), AIRS, MODIS,…) and more will come (CMIS, CrIS, IASI,…)

ECMWF has developed a day-1 strategy to assimilate rain-affected radiances from microwave instruments such as SSMI that essentially provide integral information such as total column water vapour. This system will be improved and refined as progress is made in the cloud physics and scattering radiative transfer, to augment the realism of model simulations. Improvement in the cloud physics parameterization dedicated to the assimilation process is required. The access to hydrometeor profile information, probably only possible through the assimilation of active instruments (radars, lidars), is likely to be another key scientific challenge to progress in this area.

As for the clouds and infrared instruments, at present only data identified as being unaffected by clouds are assimilated at ECMWF. The reason for this is that the cloud signal in the measured spectra can be many times larger than the temperature and moisture signals we wish to detect, complicating the interpretation of the measurement. There is therefore no doubt that in the future, we will still put substantial efforts at identifying clear radiances for which the handling of errors is much simpler and the radiative transfer science easier. Improvements in cloud (and ultimately aerosol) detection will continue. As a consequence, raw radiances from high spectral resolution sounders, documented with cloud information from high horizontal resolution imagery (cloud mask, pdf, …), will be required.
Cloud-cleared radiances (based on the N* method or more sophisticated techniques using imagery) could potentially increase the yield of observations ingestable in our data assimilation system. We expect that the characterization of the associated errors will be more complex and close interactions between space agencies and the users will be required to document these errors. There is a nevertheless a clear interest in the evaluation of these datasets. Such an activity is planned between ECMWF and NESDIS that will provide cloud cleared AIRS data (using a MODIS cloud mask). Potentially, such cloud-cleared radiances

from high spectral resolution sounders, with associated error characterization and documentation of the cloud-clearing algorithm, will be required.

The challenge for the next years will be to successfully partition the two signals (cloud and atmospheric) by the simultaneous estimation of the cloud contribution within the assimilation. Several approaches have been proposed:
Chevallier et al (2004) have demonstrated in a 1D-Var context that the assimilation of weakly cloud affected channels is possible, provided the cloud characteristics are properly diagnosed in the radiative transfer used in the assimilation. This approach is limited to “linear channels” and is unlikely to work for channels strongly affected by clouds (i.e. low tropospheric IR channels). Smith et al. (2004) propose a simultaneous retrieval of cloud parameters and atmospheric profiles and claim that accuracies close to those achieved in totally cloud-free conditions can be achieved down to cloud top levels, provided an accurate cloud radiative transfer model is used. It is clear from these studies that sustained efforts to ensure that radiative transfer models treat clouds (and aerosols) accurately will be required.

The use of principal component (PC) techniques to assimilate radiances from high spectral resolution sounders seems promising at capturing most of the information content of the original spectra, and at a vastly reduced cost (Huang and Antonelli, 2001, Schlüssel, 2004). If the benefit of using these techniques (either via reconstructed radiances or via a PC based radiative transfer) has been demonstrated in clear-sky areas, the efficiency of such methods in cloudy conditions remains to be proved. A full description of the cloud signal in the PC databases will have to be provided.

The success of cloudy radiance assimilation will also depend on how information contained in the measured spectra will be supplemented with a priori cloud information from the NWP model and constraints imposed through the model physics and dynamics. A better characterization of background errors in cloudy conditions as well as errors in the cloudy forward observation operators (cloud physics + radiative transfer) is needed. In order to minimize the representativeness errors, it may be necessary to assimilate cloudy radiances at scales that the NWP model can resolve. This may trigger requirements for averaged cloudy observations, which will have to be model resolution (and therefore application) dependent and for which the errors will have to be characterized carefully.

Geostationary satellites with capabilitites such as Meteosat Second Generation and follow-on platforms will improve the constraints on the temporal evolution and coupling between the atmospheric fields and cloud parameters. Cloudy radiances from geostationary platforms are required at high temporal resolution.

Last, improvements in the cloud physics and radiative transfer models used in the assimilation will only be possible if thoroughly validated against high quality datasets providing information about cloud vertical profiles and optical properties. R&D satellite observations provided e.g. by EARTHCARE, CLOUDSAT,… will be invaluable sources of information for NWP model validation and ultimately cloudy radiance assimilation.

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