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Physical processes in present and future large-scale models

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Summary

Assimilation of cloud and rain from satellite - Alan Geer

Cloud and precipitation-affected radiance observations are now routinely assimilated in global NWP systems, bringing improvements in forecast scores as well as better constraints on modelled cloud and precipitation. Developments are most advanced in the use of passive microwave radiances. In this part of the spectrum humidity sounding channels and window channels (sensitive to the surface as well as to the atmosphere) observe a mixture of information, mainly on water vapour, cloud and precipitation. Rather than trying to explicitly separate this information, radiance observations are assimilated in "all-sky" conditions, relying on the data assimilation system to improve the modelled atmospheric state in such a way to better fit the observations (e.g. Bauer et al., 2010). To assimilate cloud and precipitation observations, it has been necessary to develop simplified models for moist physics (e.g. Janisková and Lopez, 2014) and a fast radiative transfer model capable of simulating satellite radiances affected by scattering from hydrometeors (Bauer et al., 2006).

In a four-dimensional data assimilation system (e.g. 4D-Var) one of the most useful aspects of cloud, precipitation and water-vapour is their dependence on the large-scale dynamical structure of the atmosphere. If an observation indicates a discrepancy in modelled cloud or precipitation, the 4D-Var system can often trace the problem back to the dynamical initial conditions. In one example, the all-sky observations identified excessive frontal precipitation, and this was corrected by a small reduction in the strength of a low-pressure system 1000 km away, nearly 12 h earlier (Geer et al., 2014). However, the predictability of cloud and precipitation features, particularly convection, is poor when considered on very local scales. Hence the approach is not to attempt to put every cloud and precipitation feature "in exactly the right place" in the analysis, but to infer broader corrections to the large-scale state. All-sky microwave observations can provide almost as much information on midlatitude wind fields as can more traditional clear-sky temperature sounding observations. Seven instruments are now assimilated operationally for their information on water-vapour, cloud and precipitation: three microwave imagers and four humidity sounders.

From the perspective of forecast model development, cloud and precipitation assimilation can be useful for identifying biases in the models. The mean differences between observed and simulated radiances indicate problematic areas. For example, Kazumori et al. (2015) identified an insufficiently strong diurnal cycle in marine stratocumulus areas, with the model underestimating the morning peak liquid water amounts. Developments are also in progress at ECMWF to improve the representation of supercooled liquid water. Microwave observations identified an almost complete lack of liquid water in modelled shallow cumulus convection in cold-air outbreaks, but this can be corrected by allowing the model to form liquid water at lower temperatures than in the current parametrisation. However, not all biases between model and observations can be traced to the forecast model, as there are still aspects of the forward modelling of satellite radiances that rely on major assumptions, notably the sizes and shapes of frozen particles. Still, the continued development of all-sky microwave assimilation, plus the addition of more cloud and precipitation affected satellite observations (for example at infrared or visible frequencies, and from active sensors such as cloud and precipitation radar) offers the possibility to guide new developments in moist physical parametrisations using a global, observational constraint.

References

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