Assimilation of cloud and precipitation affected microwave radiances at ECMWF

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SSM/I cloudy/rainy radiances have been assimilated operationally at ECMWF using 1D+4D-Var since 28th June 2005.

From each observation, 1D-Var retrieves temperature and humidity profiles and (from cycle 31r1 onwards) surface wind speed. The observation operator includes simplified large-scale and convective cloud schemes, along with microwave radiative transfer.

From each retrieval, total column water vapour (TCWV) is calculated and then included in the main 4D-Var assimilation.

Recent developments include:

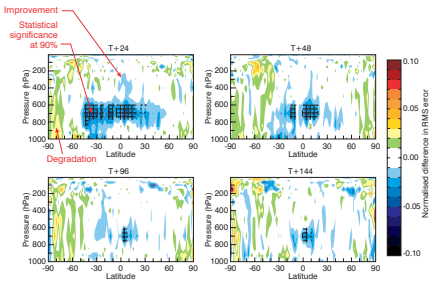
- Improved screening of snow-affected radiances, resulting in improvements to forecast scores in the Southern Hemisphere
- Improved bias correction
- Surface wind speed as a "sink variable" in the 1D-Var retrieval

The impact of 1D+4D-Var is thought to be limited by the "bottleneck" caused by transferring information via TCWV pseudo-observations, and by the normalised relative humidity control variable in use ECMWF. This penalises moistening increments in regions of high relative humidity, such as found in the majority of rain and cloud affected SSM/I observations. Drying increments are not affected, so the net impact is towards a drying of the analyses, particularly in the tropics.

Direct 4D-Var of rain and cloud-affected SSM/I radiances is in testing at the moment and should help solve some of these problems.

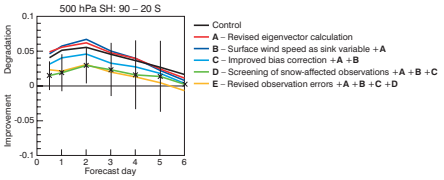
1D+4D-Var assimilation improves relative humidity forecast scores

Normalised difference in RMS relative humidity forecast scores between experiments with and without SSM/I 1D+4D-Var: For the period August to November 2004, assimilation of SSM/I cloudy/rainy radiances results in improved relative humidity forecasts, particularly in the tropics at around 700hPa over the first few days of the forecast.



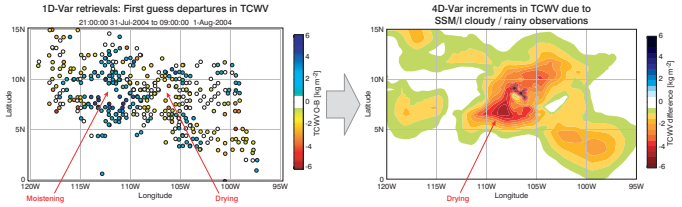
Improvements to 1D+4D-Var

Normalised difference in RMS temperature forecast scores between experiments with and without SSM/I 1D+4D-Var, for the period August 2005. In Southern Hemisphere high latitudes, 1D+4D-Var assimilation was degrading forecast scores in temperature and geopotential. A number of improvements have been made, the most important of which are a revised bias correction, and the screening of snow-affected retrievals.

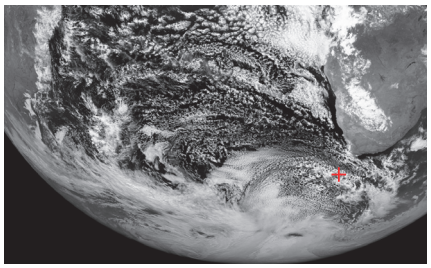


Difficulty of transferring information from 1D to 4D-Var

Balanced moistening and drying TCWV departures are transformed to largely drying increments in 4D-Var. This is because 1D-Var retrievals of cloudy/rainy profiles are made largely in areas close to saturation. In such areas, the ECMWF's normalised relative humidity control variable penalises positive moisture increments. The situation should be improved by direct 4D-Var of cloudy/rainy SSM/I radiances (currently in testing), and perhaps by the adoption of a total moisture control variable.

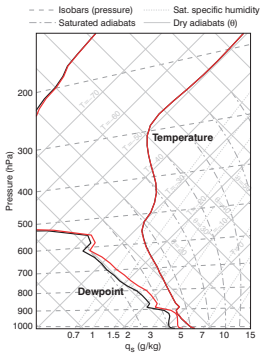


Case study: problems with snow-affected retrievals

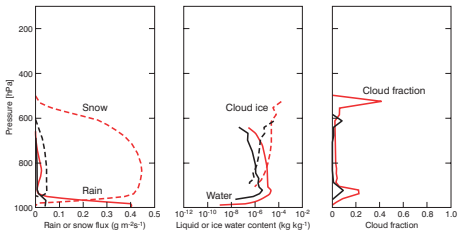


Courtesy NERC Dundee satellite receiving station, © Copyright EUMETSAT, 2005

Meteosat visible channel image for 12Z 14th August 2005: We examine a 1D-Var retrieval in the area of deep convection at the front of an intrusion of cold, unstable, polar air.



Tephigram showing 1D-Var first-guess (black) and retrieved (red) temperature and dewpoint: there is much moistening in the lower atmosphere.



Cloud properties from the 1D-Var observation operator at first guess (black) and retrieval (red): to match observed SSM/I brightness temperatures requires a large increase in rain, snow, cloud ice and water content, and cloud fraction. Convection has been strongly increased.

	TCWV /kgm^{-2}	Tb departure /K						
FG	7.6	4.5	7.9	2.0	4.2	8.8	4.1	12.0
Analysis	8.8	2.0	1.3	-1.1	3.4	-1.8	13.3	5.5
SSMI channel		19v	19h	22v	37v	37h	85v	85h

1D-Var SSM/I brightness temperature departures at first guess and retrieval: Only channels 19v, 19h and 22v are assimilated. These are less sensitive to snow and to rain close to the surface. Channels 37v/h and 85v/h are not used in the retrieval due to their more non-linear behaviour, but are sensitive to snow. Large departures remaining in these channels suggest that snow is poorly retrieved.

References

Bauer, **P.**, **Lopez**, **P.**, **Benedetti**, **A.**, **Salmond**, **D.** and **Moreau**, **E.**: Implementation of 1D+4D-Var assimilation of precipitation-affected microwave radiances at ECMWF. I: 1D-Var, *Quart. J. Roy. Meteorol. Soc.*, to appear, 2006

Bauer, **P.**, **Lopez**, **P.**, **Salmond**, **D.**, **Benedetti**, **A.**, **Saarinen**, **S.** and **Bonazzola**, **M.**: Implementation of 1D+4D-Var assimilation of precipitation-affected microwave radiances at ECMWF, II: 4D-Var, *Quart. J. Roy. Meteorol. Soc.*, to appear, 2006