The assimilation of humidity information from satellites

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1. Background to satellite humidity assimilation at ECMWF

Studies before 1994 had suggested that NWP systems were relatively insensitive to humidity initial conditions. In 1994 experiments performed at ECMWF using moisture sensitive IR radiances from the HIRS instrument (McNally + Vesperini 1996) showed that the assimilation of these data caused large scale changes to the global humidity analysis, accompanied by significant large scale dynamical adjustments. Furthermore, the changes made to the initial conditions were clearly retained in the forecast model out to 5 days (see figure 1). These results highlighted the importance of the assimilation of humidity information from satellites and since then a considerable amount of progress has been made.

2. Current satellite systems providing humidity information

There is currently an enormous volume of humidity sensitive satellite radiance data available in near-real-time to NWP centres. The majority of radiance data comes from instruments on operational spacecraft operated by NOAA, US Navy (DMSP) and EUMETSAT (see figure 2). The instruments operate in both the IR spectrum (e.g. HIRS, MVIRI, GOES) and microwave spectrum (e.g. SSM/I, AMSUB), but are all passive nadir (or near-nadir) viewing (i.e. they are not limb sounders).

3. Vertical resolution and Jb

Due the physics of passive nadir sounding, the radiance data from the current operational instruments provide very little information about the vertical distribution of humidity in the atmosphere. Instead they offer information about the total column moisture content, or at best, the moisture content of 2 or 3 rather deep vertical layers. This limitation puts a huge emphasis upon the ability of the analysis system to correctly distribute the humidity information in the vertical. Experiments have shown that the forecast model physical processes are very sensitive to how a given amount of moisture is vertically distributed in the initial conditions and there are many examples where the assimilation of apparently high quality satellite humidity information has aggravated problems precipitation spin-up. This vertical distribution of increments in the analysis is controlled by the background error covariance combined with any other constraints imposed upon the system. Figure 3 shows how (in 1-dimesional analysis / forecast system) refining the background error covariance reduces near-surface humidity increments and delays/reduces the onset of precipitation (for the same total column of moisture assimilated).

4. Systematic error

Systematic errors in satellite radiance data (or the radiative transfer models used in their assimilation) are a particular problem as they tend to have a global influence. The monitoring of satellite instruments has reached a very mature stage in recent years and has exploited the ability of NWP systems to expose problems in individual instruments and cross-check against other instruments. However, there is obviously a limit below which it is difficult to determine if a source of data systematically wrong or if it is actually exposing a problem in the "standard" against which the monitoring is performed (i.e. the NWP system). Currently we can detect (and generally correct rather well) systematic errors down to a few tenths of a Kelvin, but it is known that even small residual biases can cause significant adjustments to the hydrological cycle over long periods.

5. Future systems

The next generation of advanced IR sounders with many thousands of channels provide significantly more information on the vertical distribution of humidity (see figure 4). However, they will still be limited and rely on a skillful assimilation system to constrain fine vertical structure. The introduction of limb sounding data to operational assimilation systems is an exciting prospect exploiting the synergy between their very high vertical resolution and the very high spatial resolution of the nadir sounders.

References

McNally A.P. and M. Vesperini, 1996: Variational analysis of humidity information

TOVS radiances. *Q.J.R. Meteorol. Soc.* **122**, pp 1521-1544.

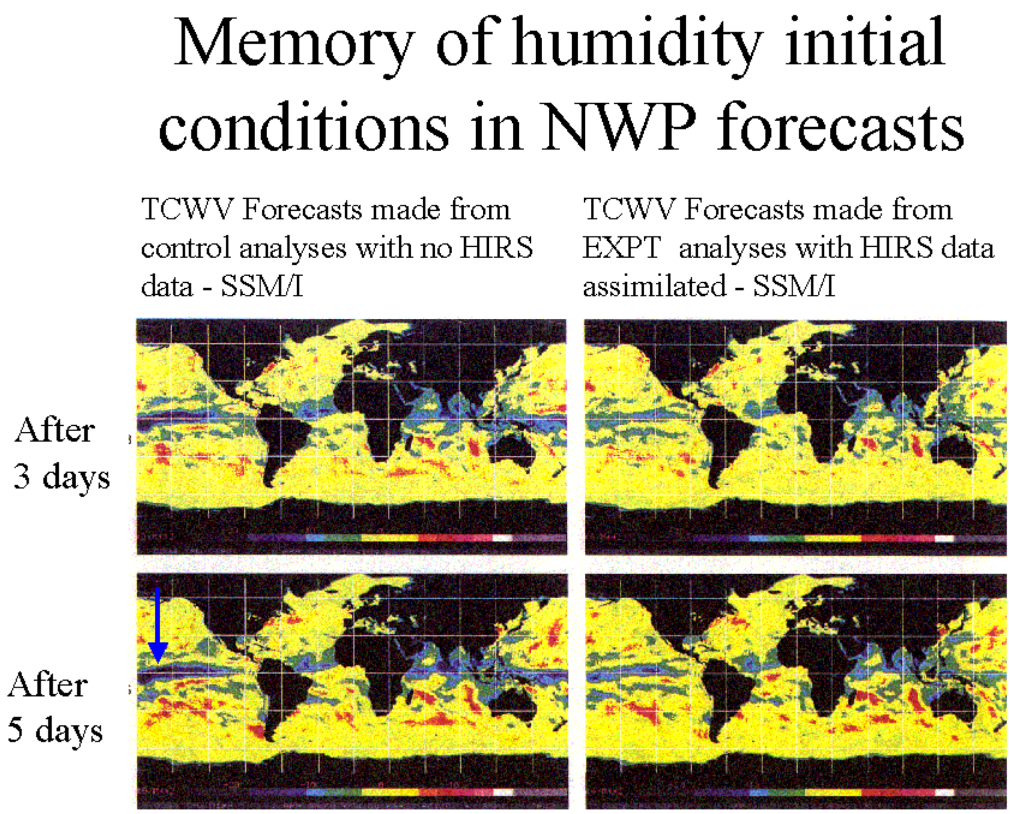

Figure 1

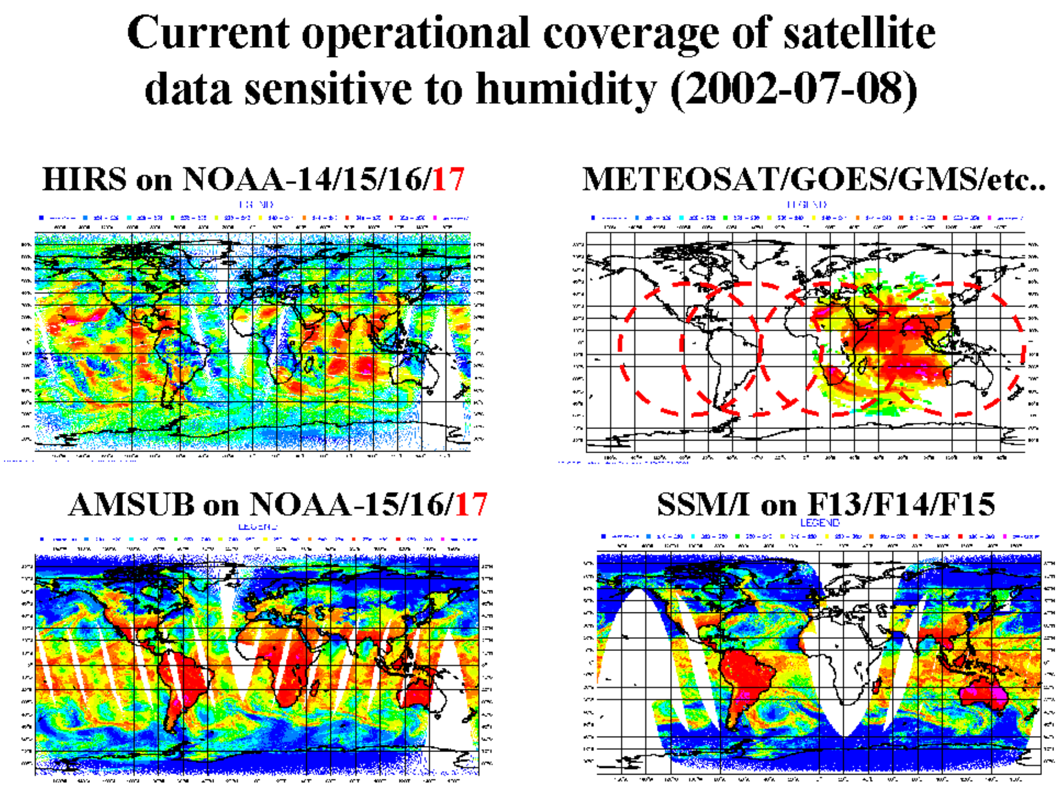

Figure 2

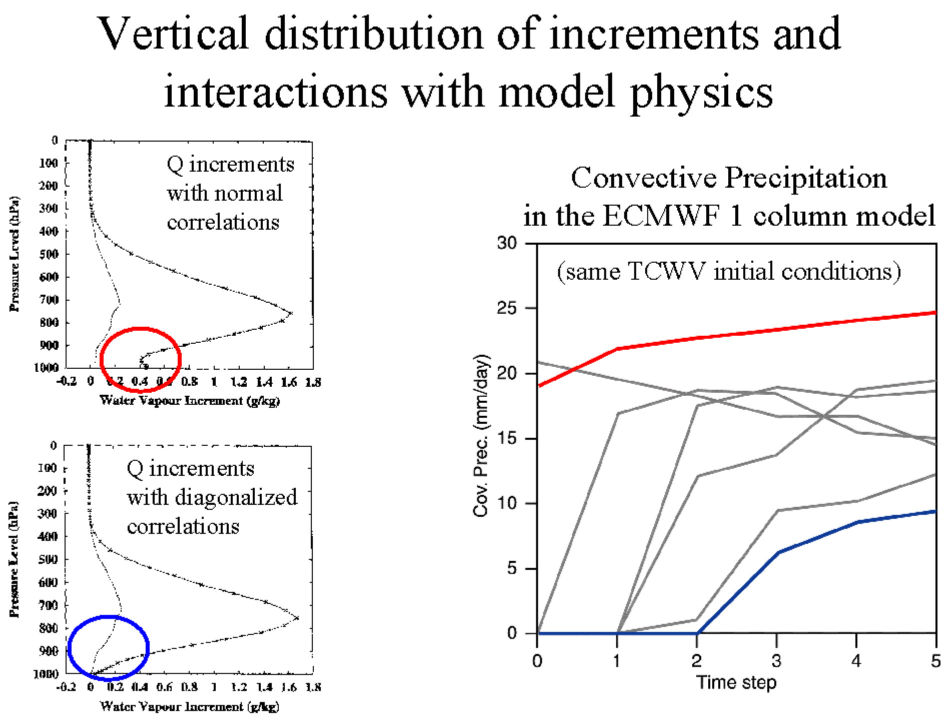

Figure 3

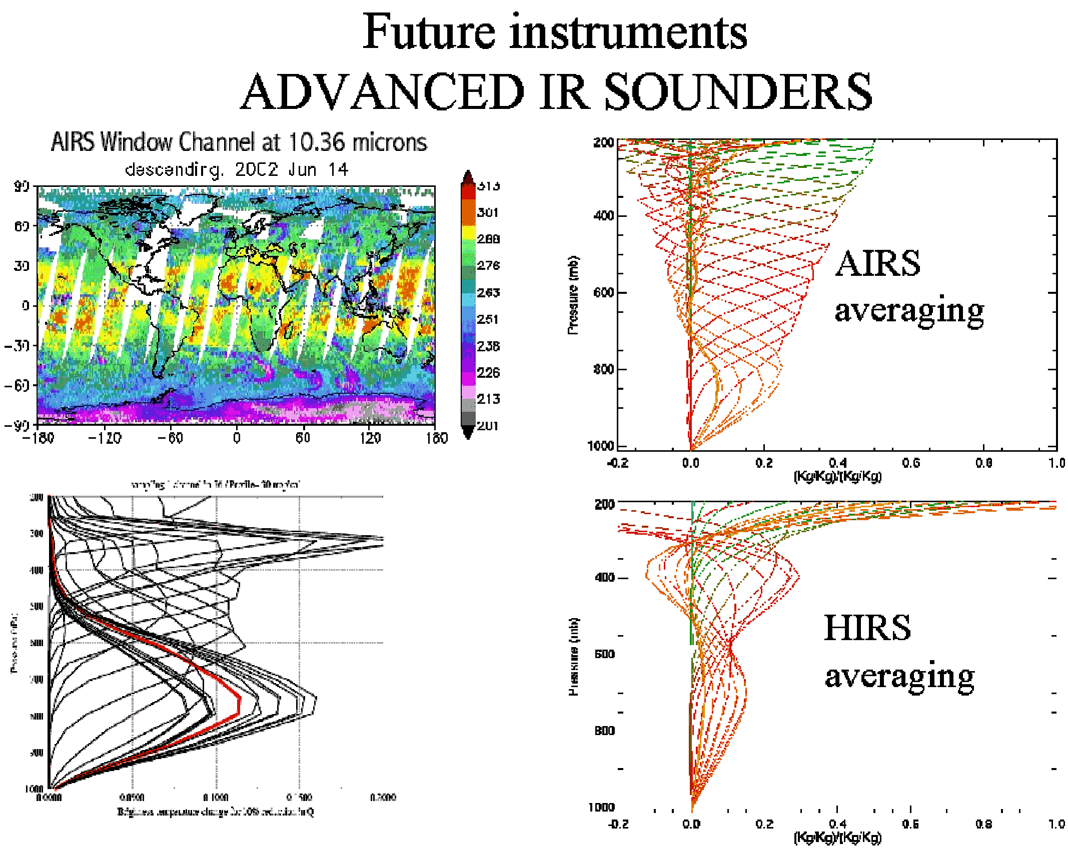
Future instruments
ADVANCED IR SOUNDERS
AIRS Window Channel at 10.36 microns
descending. 2002 Jun 14
AIRS
averaging
HIRS
averaging
Pressure (mb)
(Kg/Kg)/(Kg/Kg)

Figure 4