Direct assimilation of cloud affected infrared radiance observations in the ECMWF 4D-VAR

Tony McNally, Bill Bell and Marco Matricardi
ECMWF

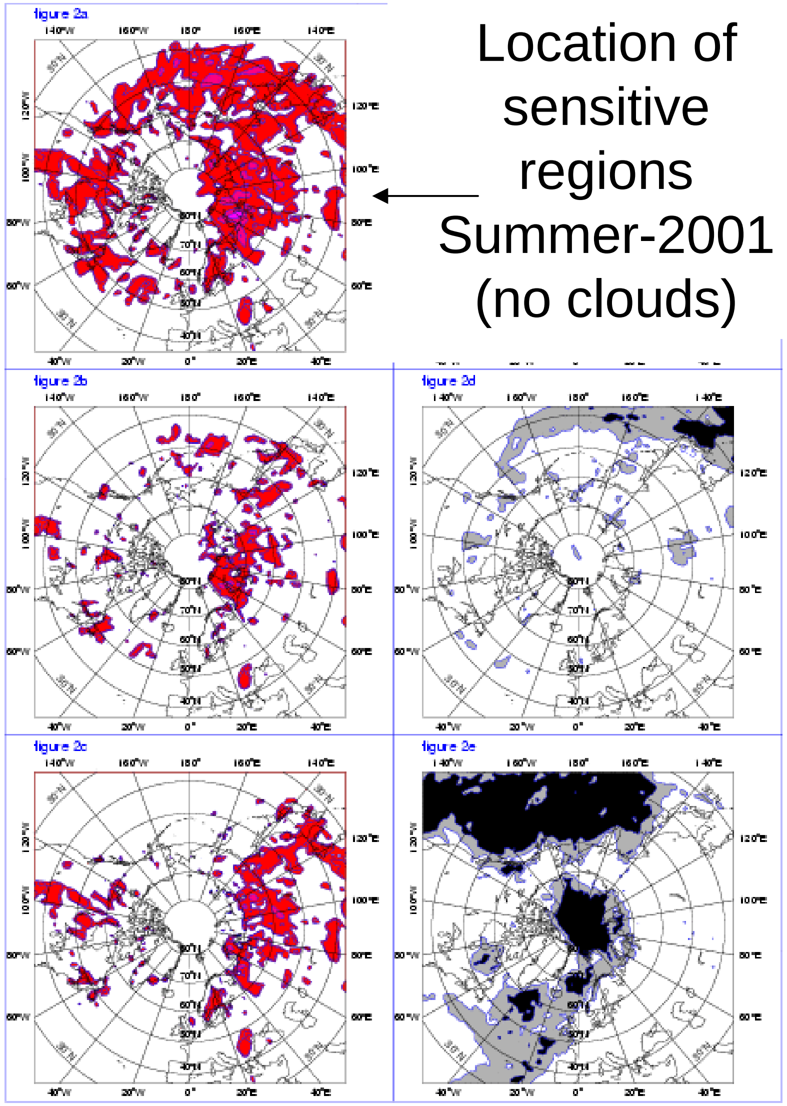
Why do we need to use cloud affected IR data …?

- Just using clear-sky observations is a major under-use of very high cost instruments such as AIRS and IASI

- Use of only clear-sky data could bias the assimilation system to have the characteristics of dry regions

- We believe that cloudy areas are meteorologically sensitive and constraining analysis errors in these regions (i.e. with observations) is important.

Sensitive areas and cloud cover



Location of sensitive regions Summer-2001 (no clouds)

sensitivity surviving **high** cloud cover

monthly mean **high** cloud cover

sensitivity surviving **low** cloud cover

monthly mean **low** cloud cover

From *McNally (2002) QJRMS **128***

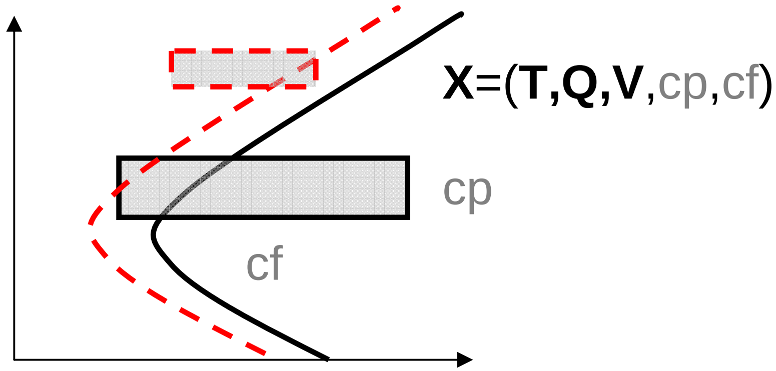
Fundamental issues

- The cloud uncertainty in radiance terms may be an **order of magnitude larger** than the T and Q signal (i.e. 10s of kelvin compared to 0.1s of kelvin)
- The radiance response to cloud changes is **highly non-linear** (i.e. $H(x) = H_x(x)$)
- Errors in background cloud parameters provided by the NWP system may be **too large** to provide an accurate linearization point and **difficult to characterize**
- Trade off between having enough cloud variables for an **accurate RT calculation** while limiting the number of cloud variables to those that can be **uniquely estimated** in the analysis from the observations

Two approaches to assimilate cloud affected infrared radiances

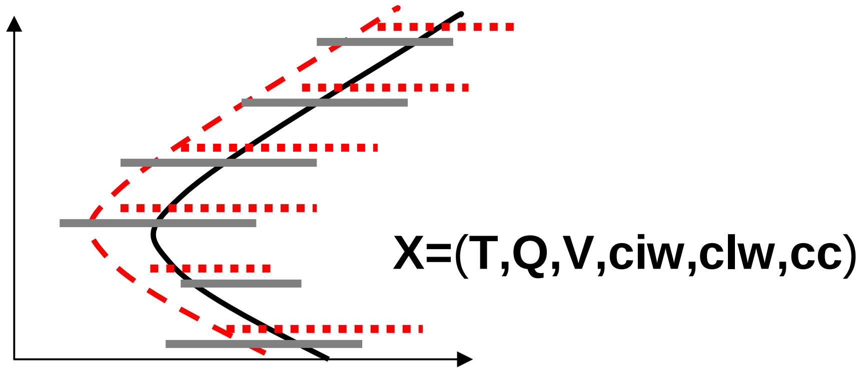
Simplified system:

•very simple cloud representation
•currently limited to overcast scenes
•no information on clouds taken from model
•no back interaction with model via physics



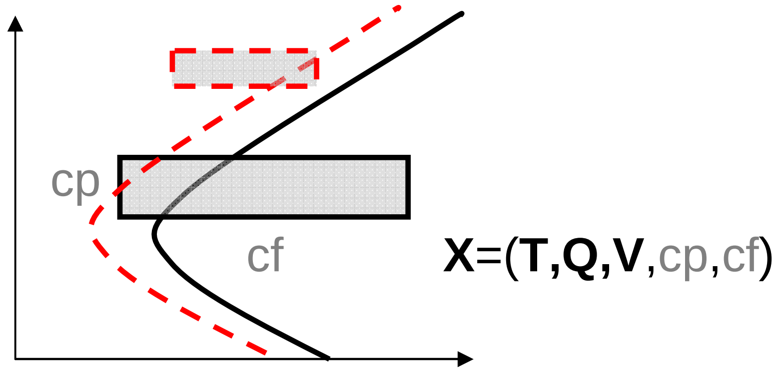
Advanced system:

•very complex cloud representation
•all cloud conditions treated
•information on clouds taken from model
•back interaction with model via physics



Experience with simplified Cloudy IR Radiance Assimilation

(only overcast conditions used)



*See McNally (2009) QJRMS **135**, 1214-1229 for more details…*

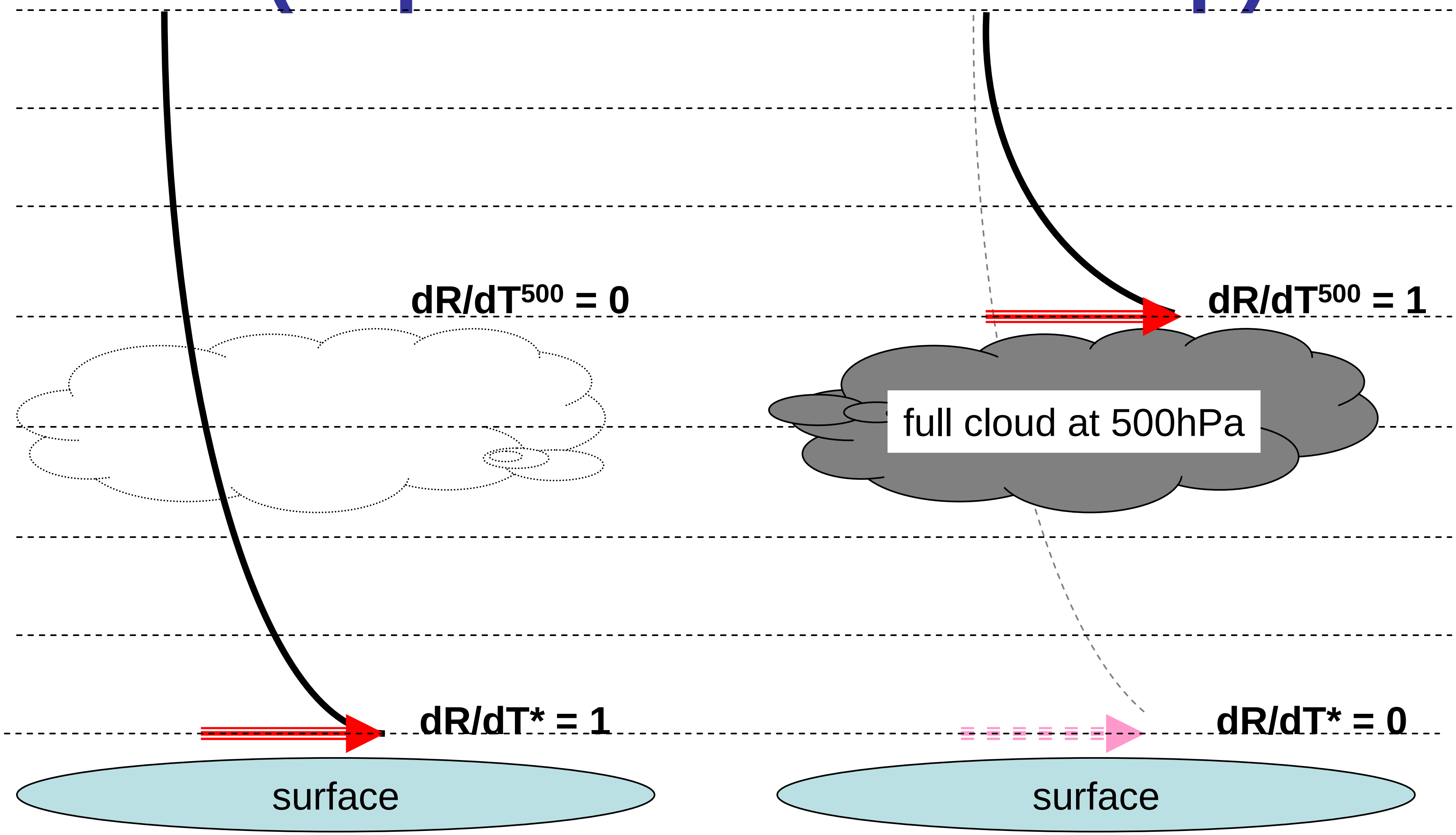
Why overcast scenes…?

Why use cloudy radiances only in overcast conditions ?

- Overcast clouds are least ambiguous in the radiance data
- Cloud control vector collapses to a single number (cp)
- Problems with cloud overlap assumptions vanish
- No cross-talk between cloud and surface variables
- Termination of jacobians at cloud top provides new high vertical resolution Information on temperature

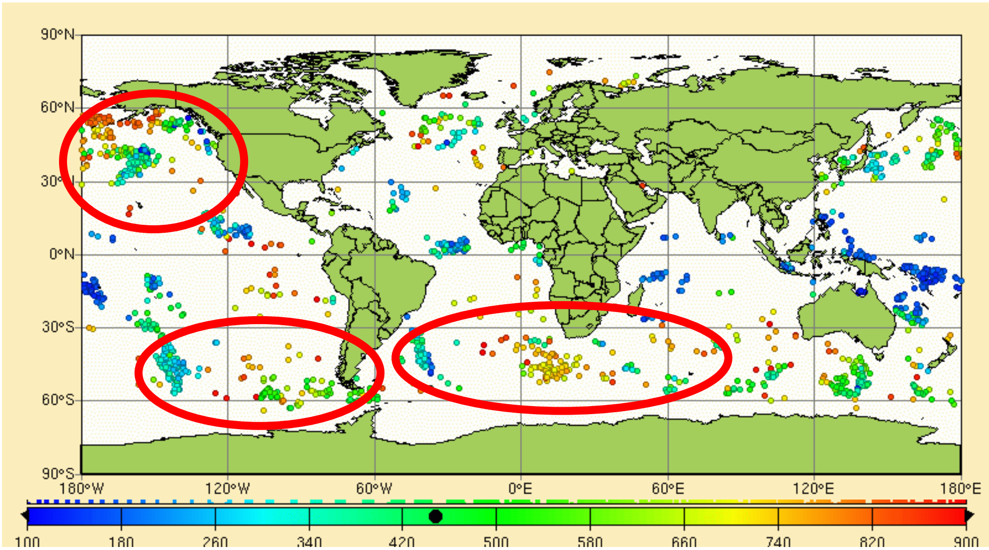
Impact of overcast data on the ECMWF analysis…

Clear and Cloudy Jacobians (impact at the cloud top)



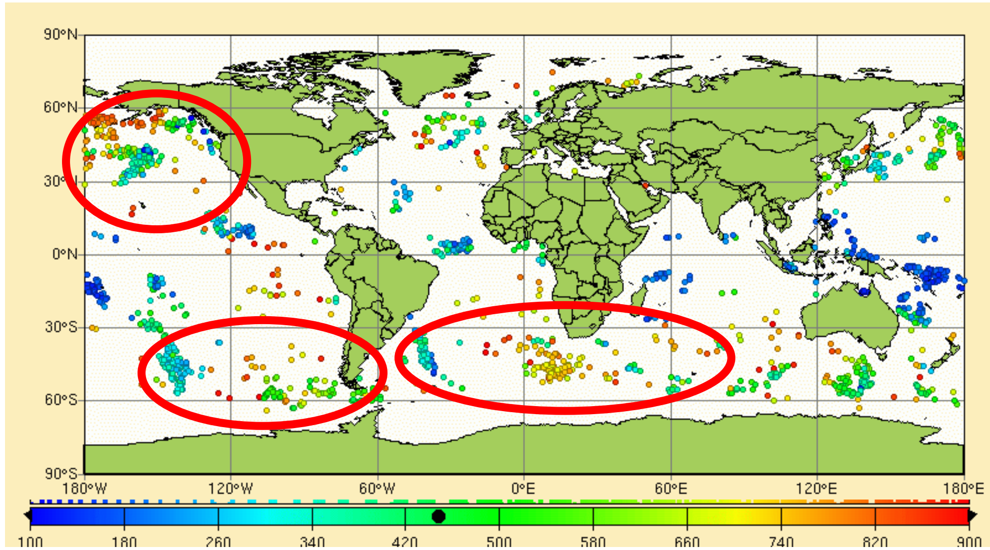
Temperature increments above low clouds

Overcast data coverage from HIRS, AIRS and IASI and the estimated cloud top pressure

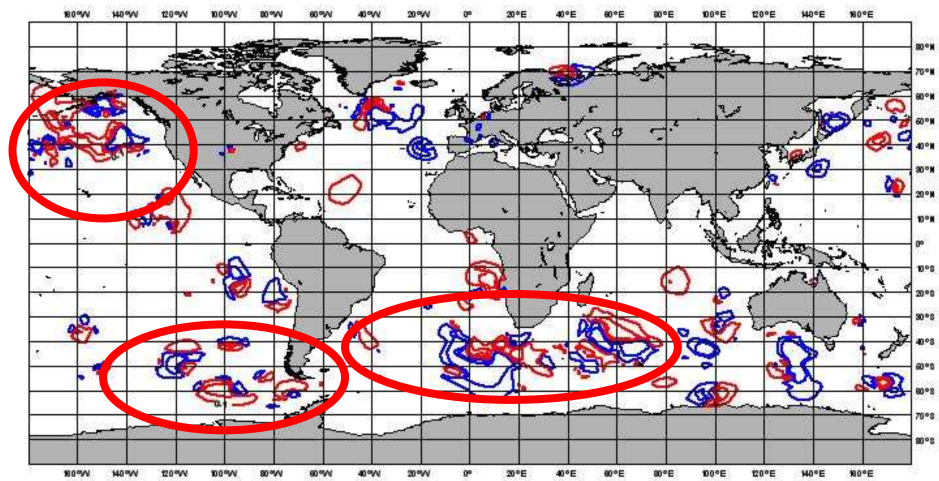


Temperature increments above low clouds

Overcast data coverage from HIRS, AIRS and IASI and the estimated cloud top pressure

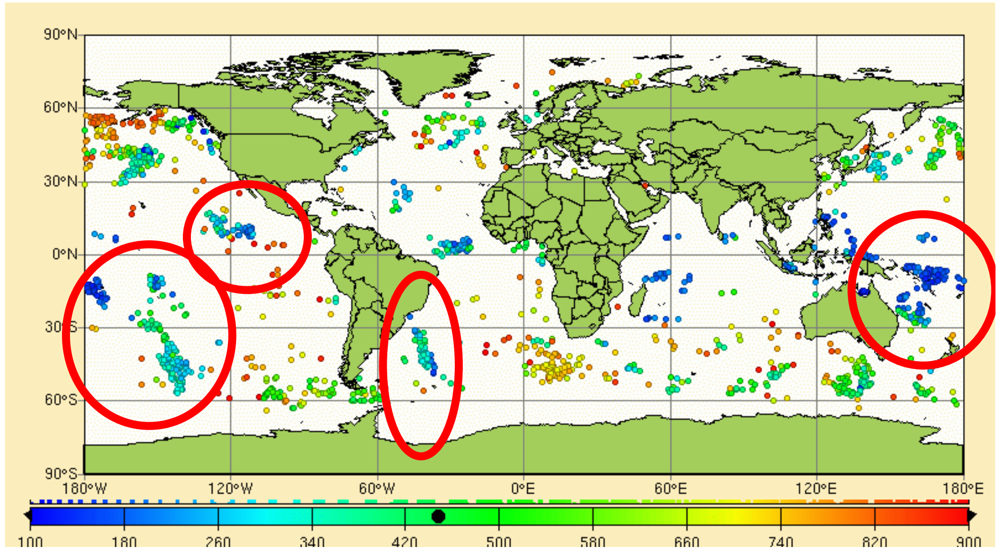


Analysis temperature increments at 700hPa



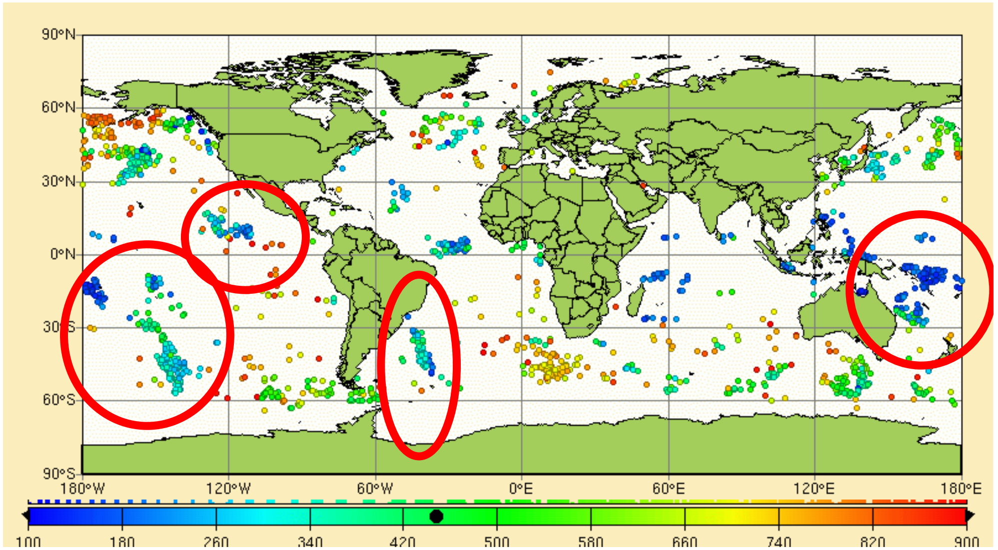
Temperature increments above high clouds

Overcast data coverage from HIRS, AIRS and IASI and the estimated cloud top pressure

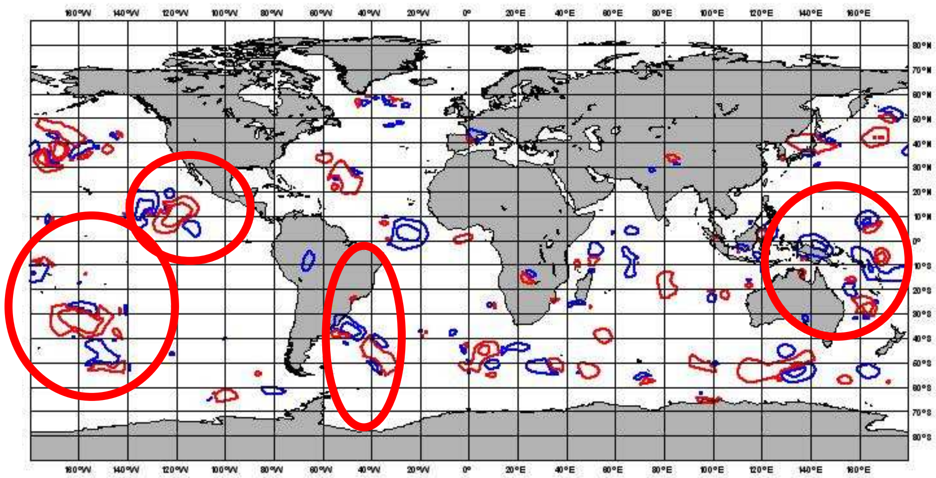


Temperature increments above high clouds

Overcast data coverage from HIRS, AIRS and IASI and the estimated cloud top pressure



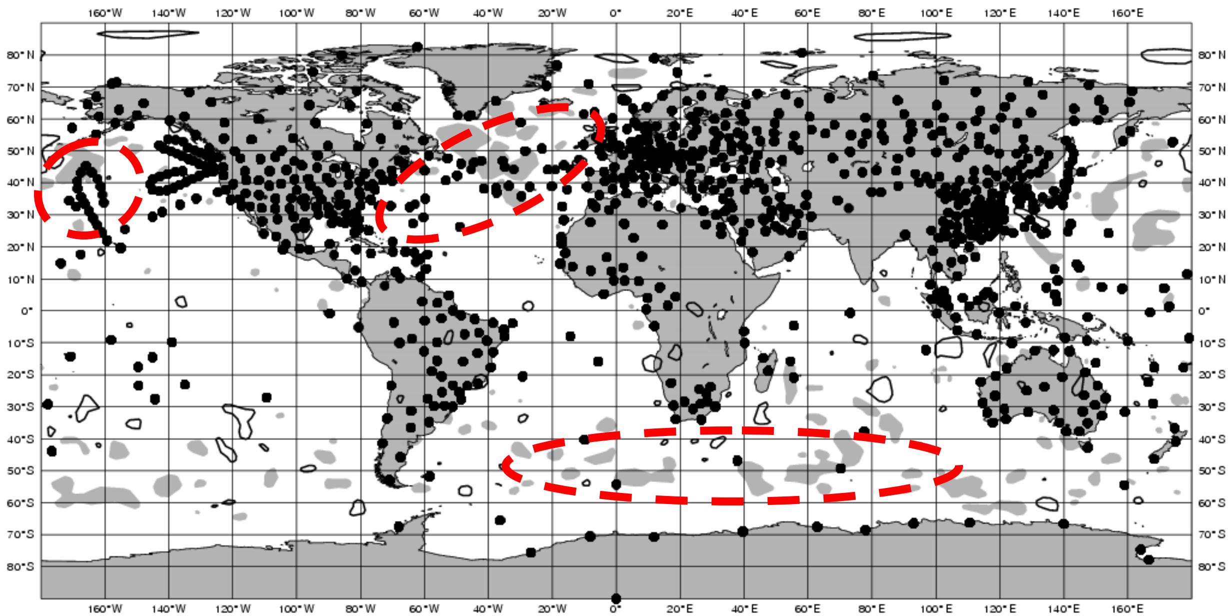
Analysis temperature increments at **250hPa**



....do these extra increments at the cloud top do any good..?

Improved analysis fit to isolated radiosonde observations

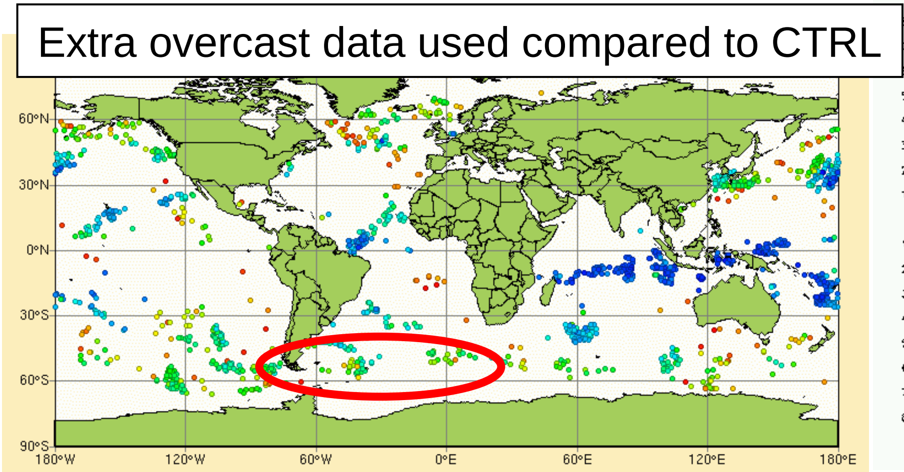
Monthly averaged RMS temperature increment difference (CLOUDY minus CTRL). Shaded areas indicate a reduction in increments in excess of 0.1K when the cloud radiances are assimilated.

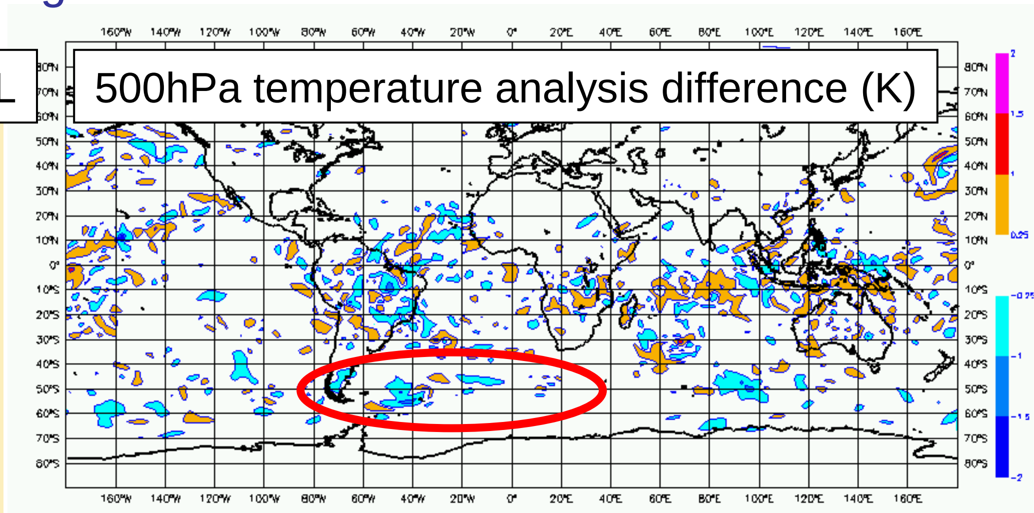


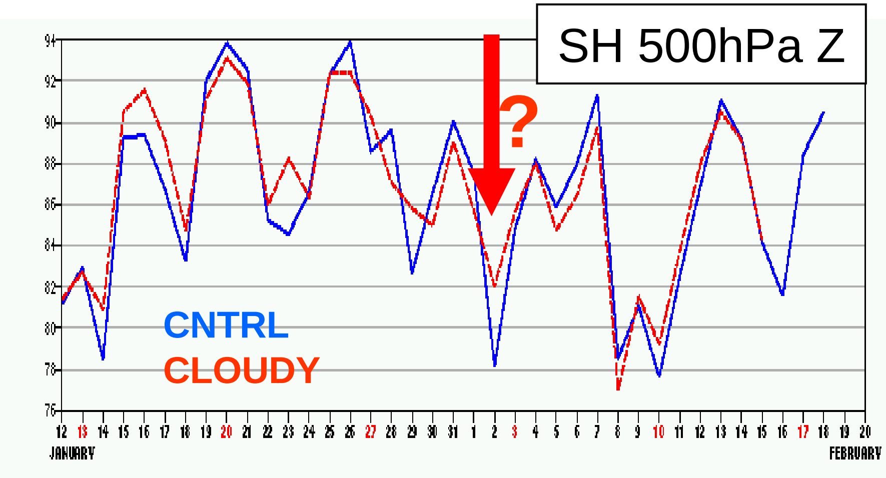
…forecast impact ...?

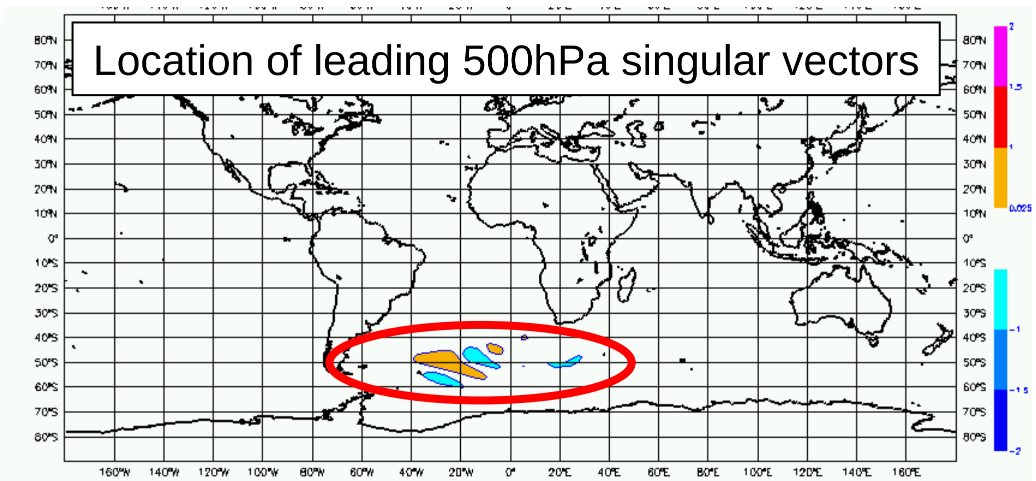
Cloud obscured singular vector ?

In this case the use of overcast observations resulted in analysis differences in an area suggested to be sensitive by the singular vector locations

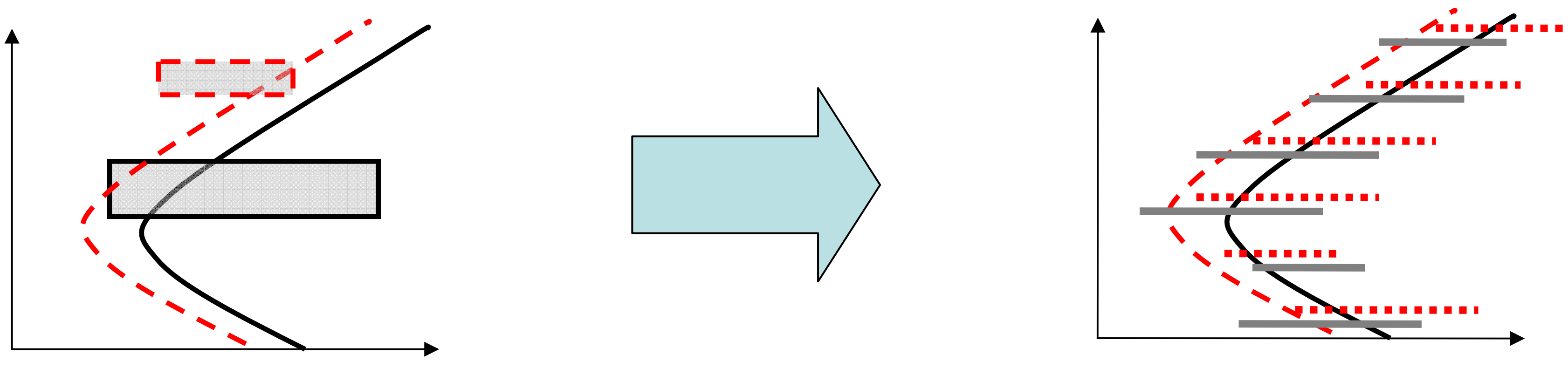




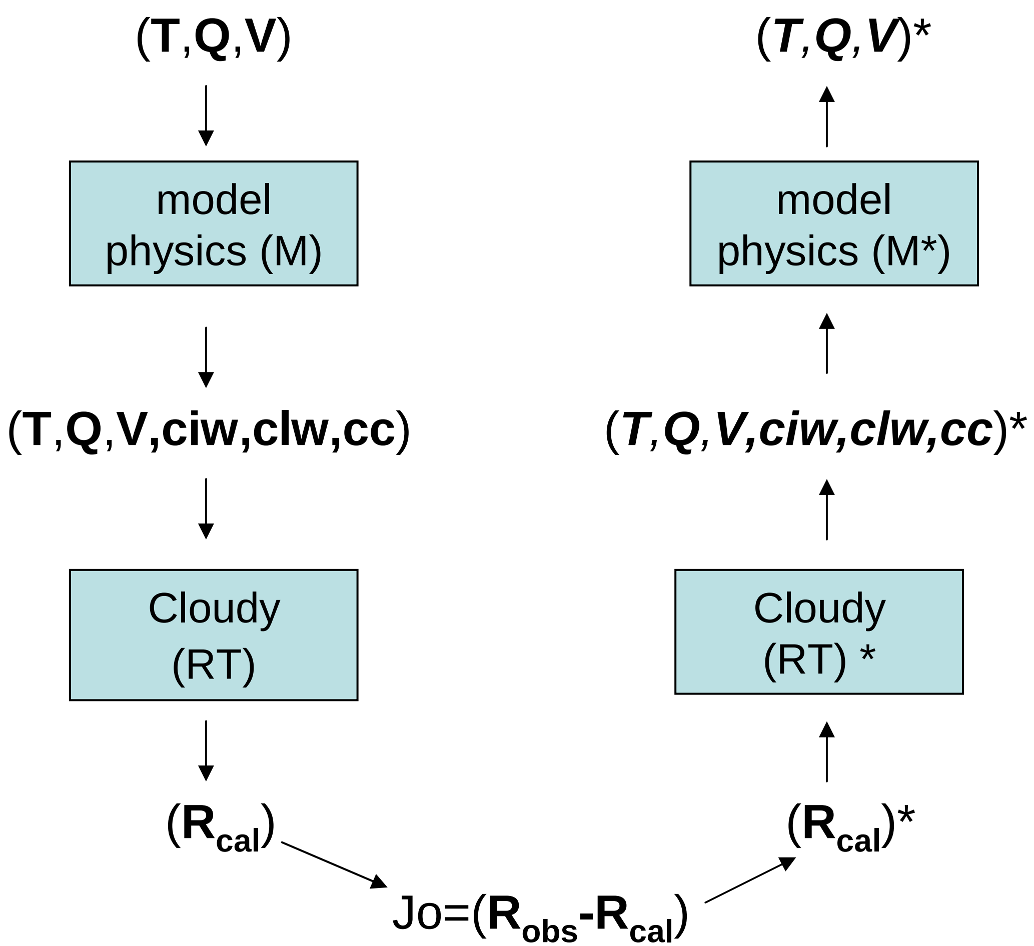




Towards an Advanced Cloudy IR Radiance Assimilation



Towards an Advanced Cloudy IR Radiance Assimilation

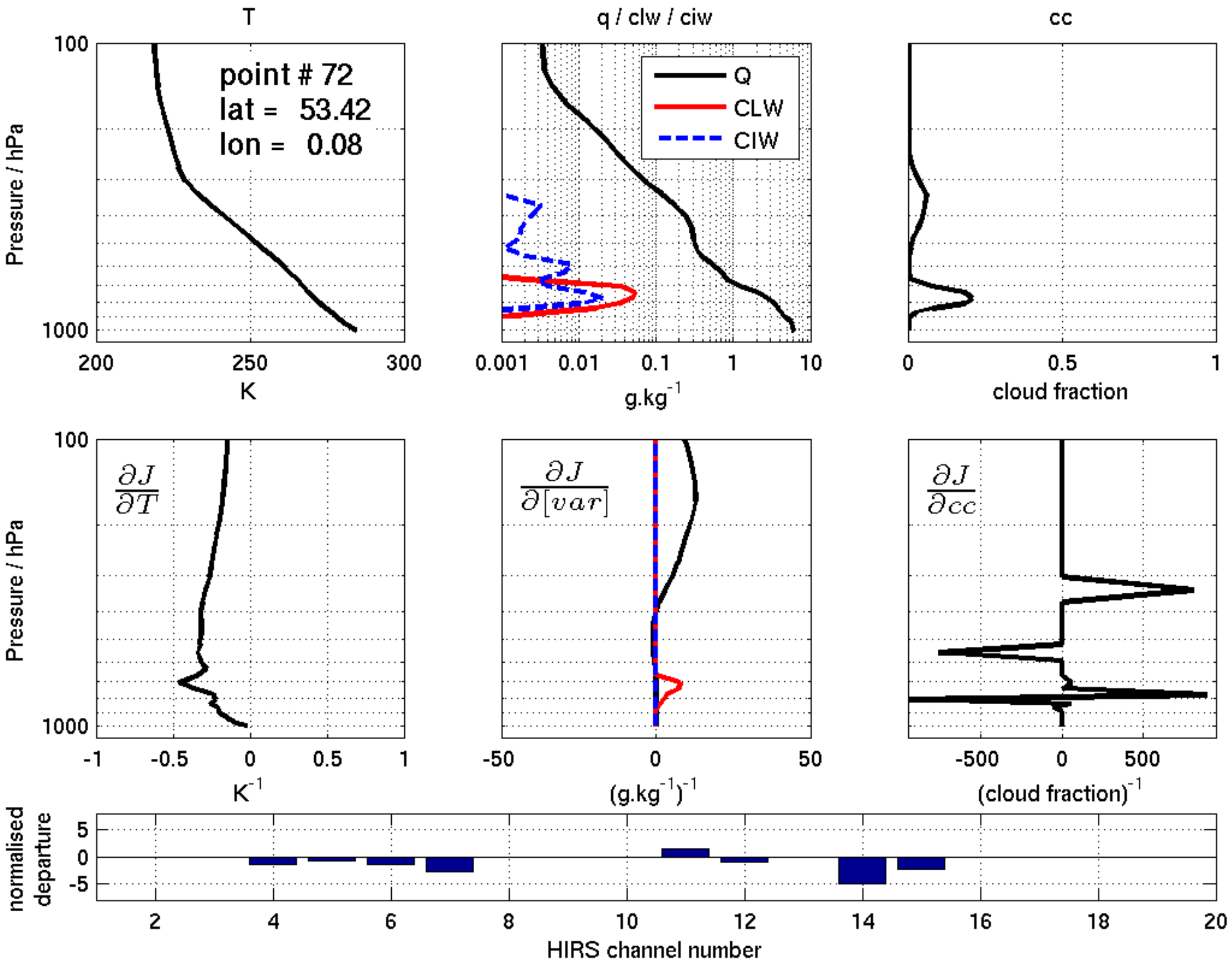


Cloudy radiances $\mathbf{R_{cal}}$ are simulated via a chain of forward operators (M,RT).

The fit of the analysis to the observations is computed (Jo)

Jo is minimized by perturbing the analysis variables according to gradients from a chain of adjoint operators (RT*,M*)

Adjusting analysis variables to fit the cloudy radiance observations



Summary and Plans

- The **simplified assimilation** of overcast HIRS, AIRS and IASI works very well and became **operational** at ECMWF in 2009.

- We are in the process of developing the **advanced cloudy assimilation system** (drawing on experience from a similar scheme for rain affected microwave radiances)

- Initially, cloud parameters (clw,ciw,cc) will be **diagnostic** and driven by the **model physics** via adjustments in the analysis control vector variables (T,Q and V).

- Later the cloud parameters will be tested as full variables in the **analysis control vector** (but this will require accurate background error observations

End

(...almost...)

Assimilation of ozone sensitive IASI radiances in the ECMWF 4D-VAR

Wei Han and Tony McNally

IASI Ozone Experiments

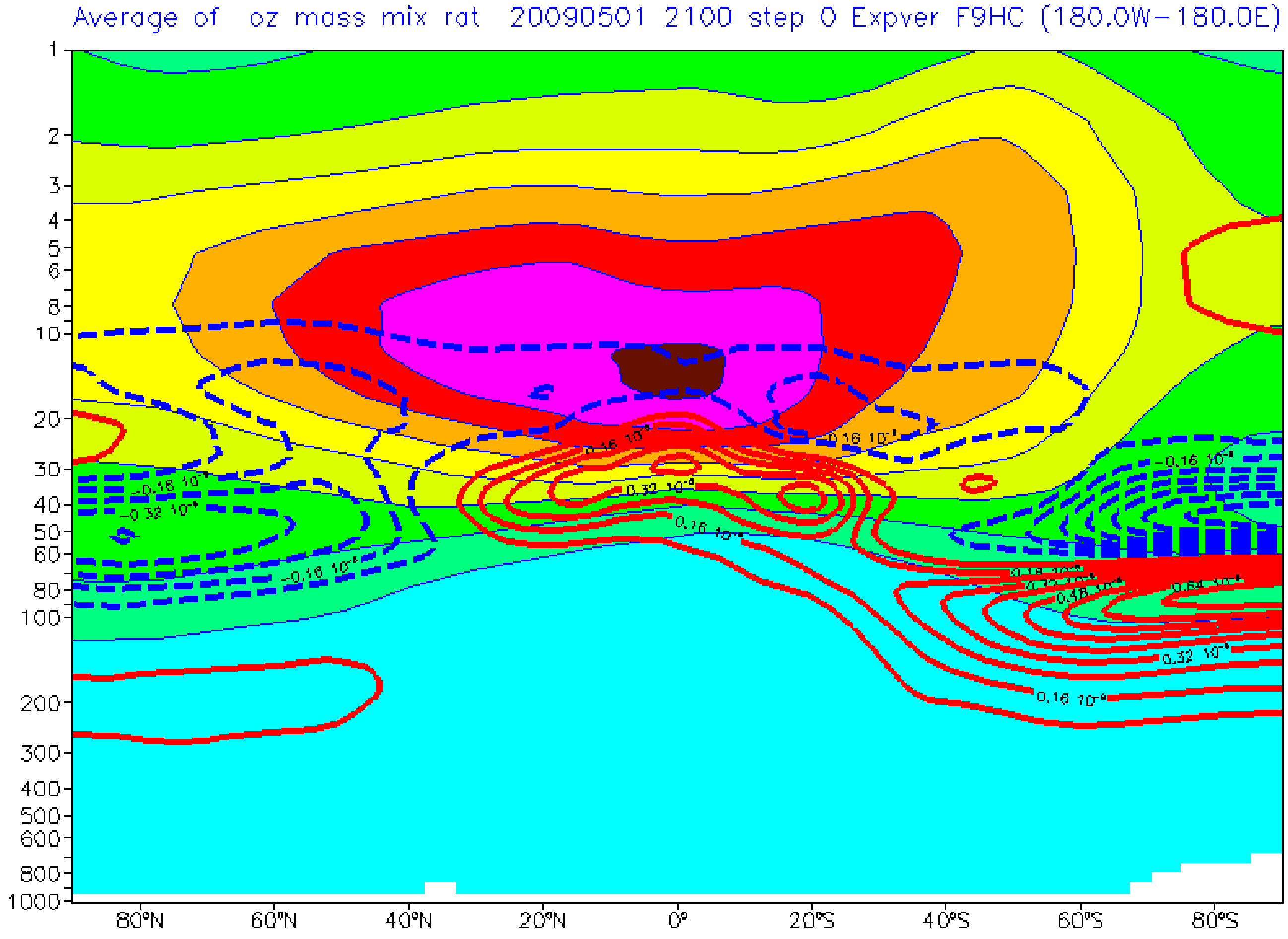
Baseline System:
T511 (40Km) full operational data (no O3 observations)

UV System:
As baseline plus UV data from SBUV and OMI

IASI System:
As baseline plus 16 IASI ozone channels
(LW cloud detection and channel 1585 anchored
to zero bias correction, other channels VarBC)

Impact of IASI Ozone Channels

Zonal mean cross section of full ozone field (shaded) and mean analysis difference With and without IASI ozone channels (units are mass mixing ratio)



Verify against MLS (20090615-20090630)

BASELINE

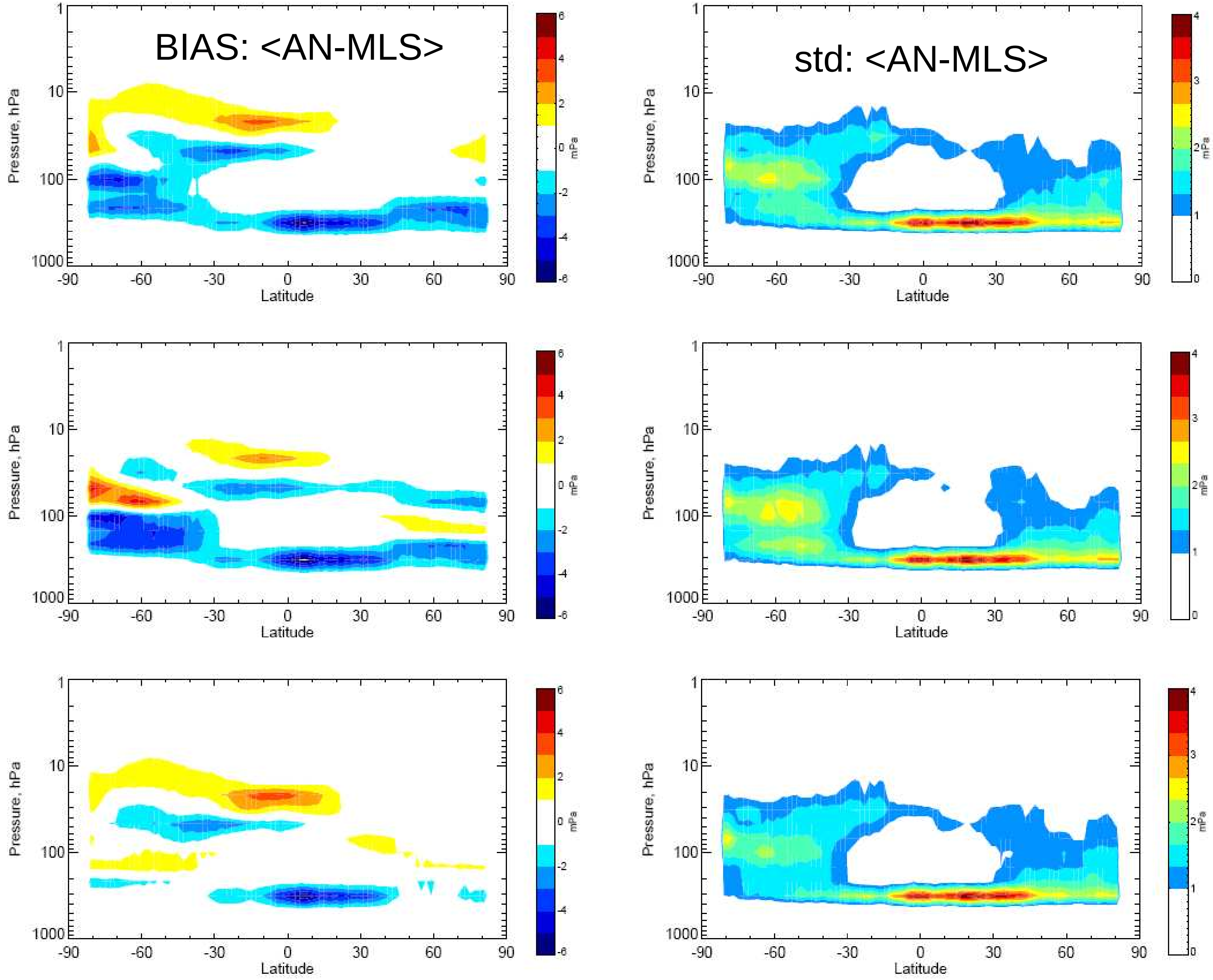
No O3 OBS

BASELINE

+SBUV+OMI

BASELINE

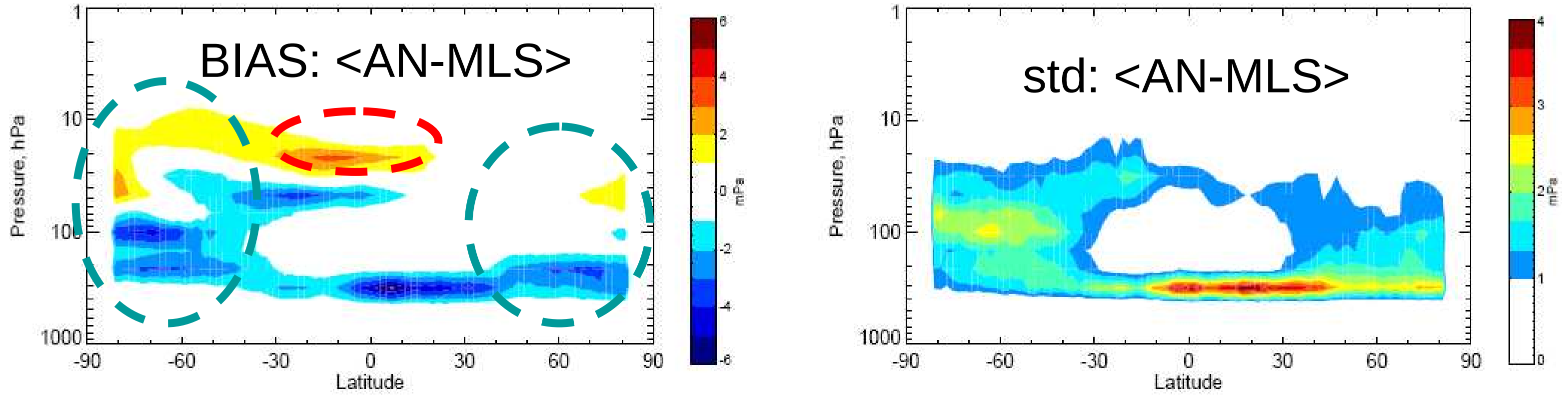
+IASI 16 O3 Channels



Verify against MLS (20090615-20090630)

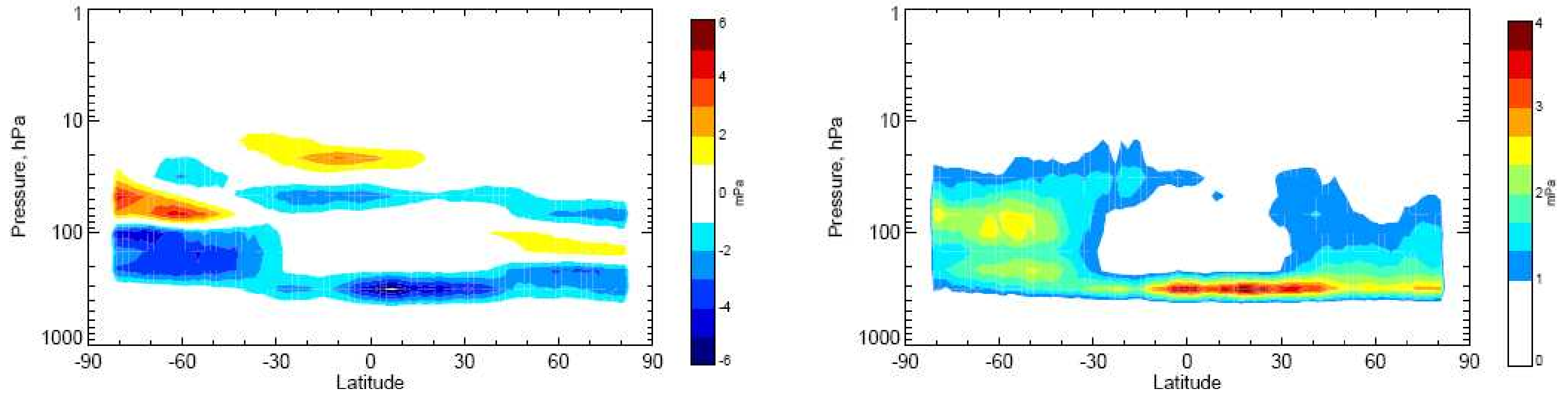
BASELINE

No O3 OBS



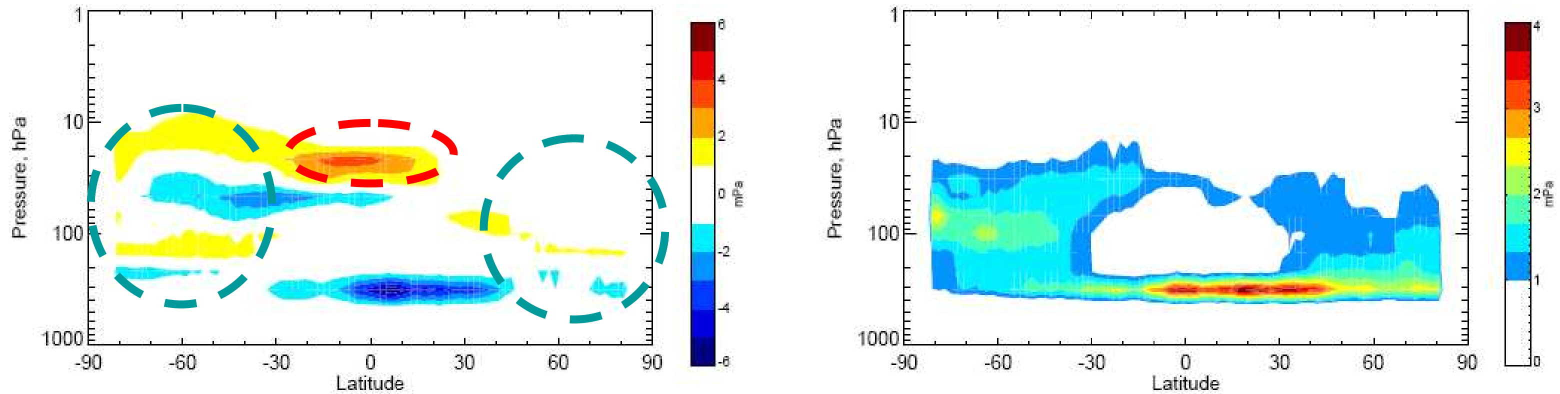
BASELINE

+SBUV+OMI



BASELINE

+IASI 16 O3 Channels



Summary and Plans

- The assimilation of **16 IASI ozone channels** produces an analysis in **good agreement with MLS data**. This agreement is better than a baseline system (with no ozone observations), but also better than a system using SBUV and OMI data.

- The use of **cross-band cloud detection** using IASI LW channels is crucial to identify clouds in the presence of ozone errors.

- The **anchoring of the assimilation** to one uncorrected IASI ozone channel is also important, the system cannot be bias corrected against the NWP model.

- Exploring the potential for 4DVAR **stratospheric wind tracing is a priority**.

End

Background 2D cloud parameters (comparison with AVHRR)

AVHRR cluster analysis based on imager pixels within the IASI filed of view – one week of data 2008-08-07 to 2008-08-14