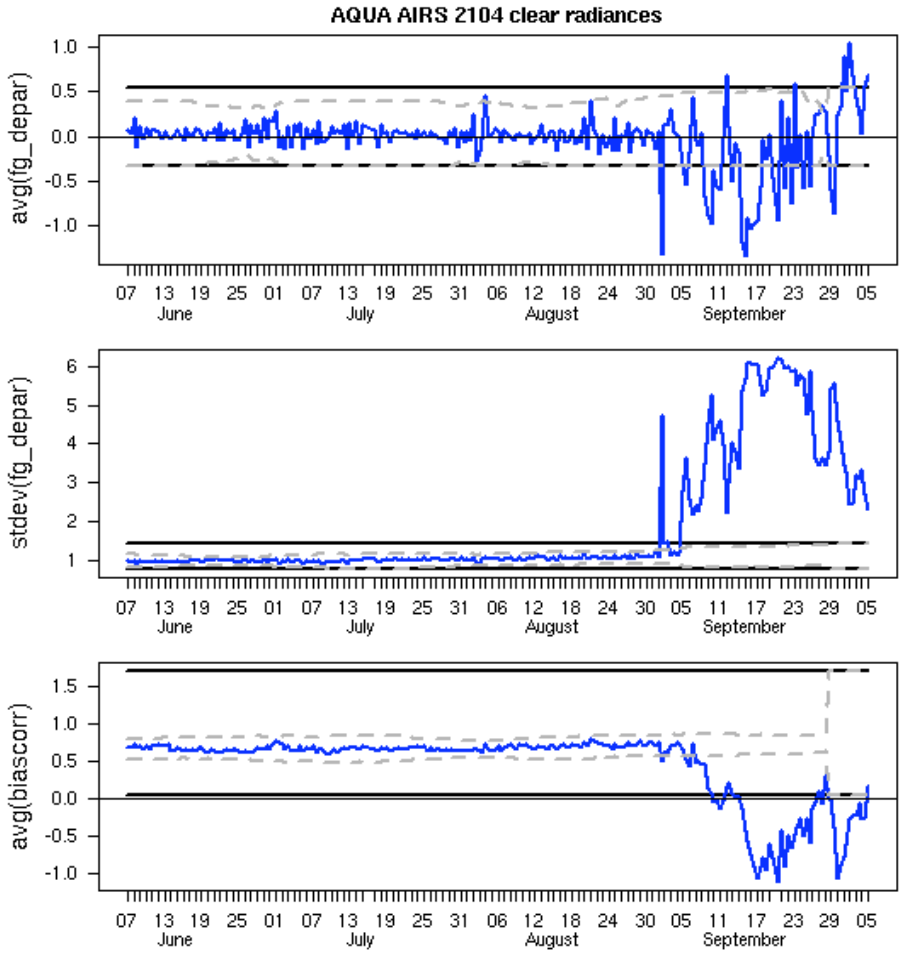
AIRS / IASI

at

ECMWF

ECMWF Operational Status

- AIRS and IASI used in tandem since June 2007
- Upgrade to surface emissivity model
- Upgrade to LBL and fast RT model
- Extra bias correction for residual non LTE introduced
- AIRS channel **2104** gone very noisy recently…



Cloudy IR assimilation

Fundamental cloud issues

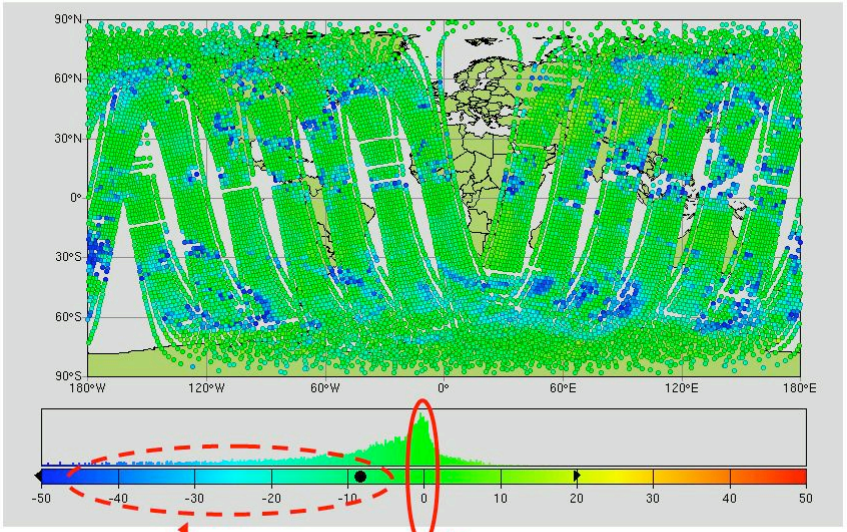
- The cloud uncertainty in radiance terms may be an order of magnitude larger than the T and Q signal (i.e. 10s of kelvin compared to 0.1s of kelvin)

- 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 difficult to quantify and model

- 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

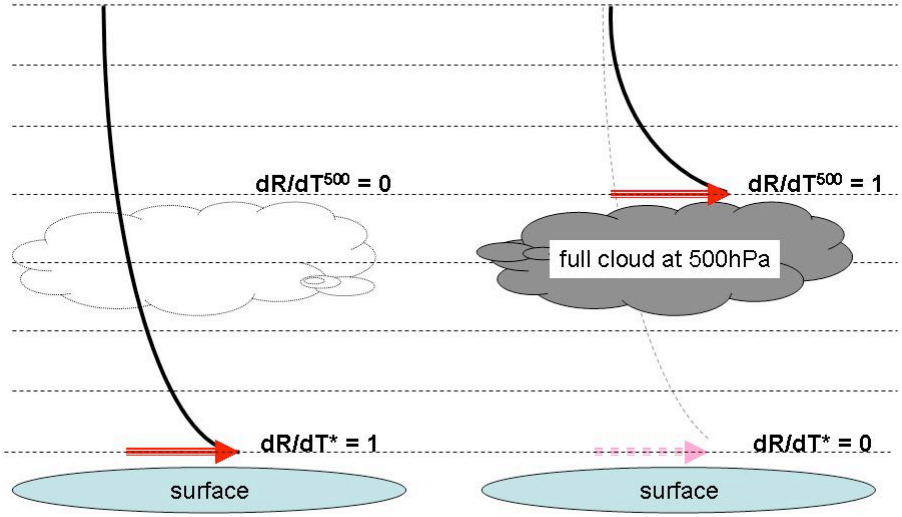
Observed radiance at 11 microns minus radiance calculated in clear sky



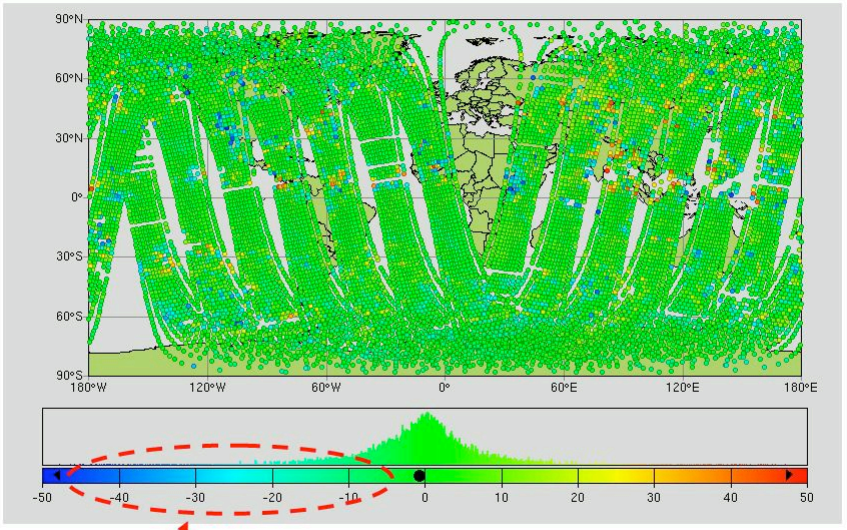
Cold departures indicating cloud contamination in OBS

Clear population

Clear and Cloudy Jacobians



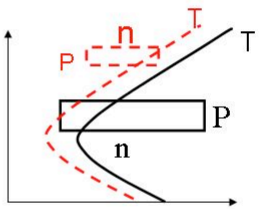
Observed radiance at 11 microns minus radiance calculated from NWP cloud background profile



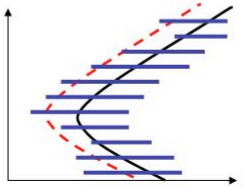
Many clouds with significant radiance signals are accurately represented by the NWP model and RT modelled !

Choice of cloud parameters and ambiguity with T and Q

A very simple cloud model (e.g. single layer grey cloud amount and pressure) should more readily estimated from the data (independently of T and Q), but will make the forward RT calculation very inaccurate in many cloud conditions



A more complex cloud model (e.g. cloud liquid and ice at each model level) will allow a more forward RT calculation, but may be difficult to estimate independently of T and Q and may alias into erroneous increments



Prototype cloudy infrared assimilation system

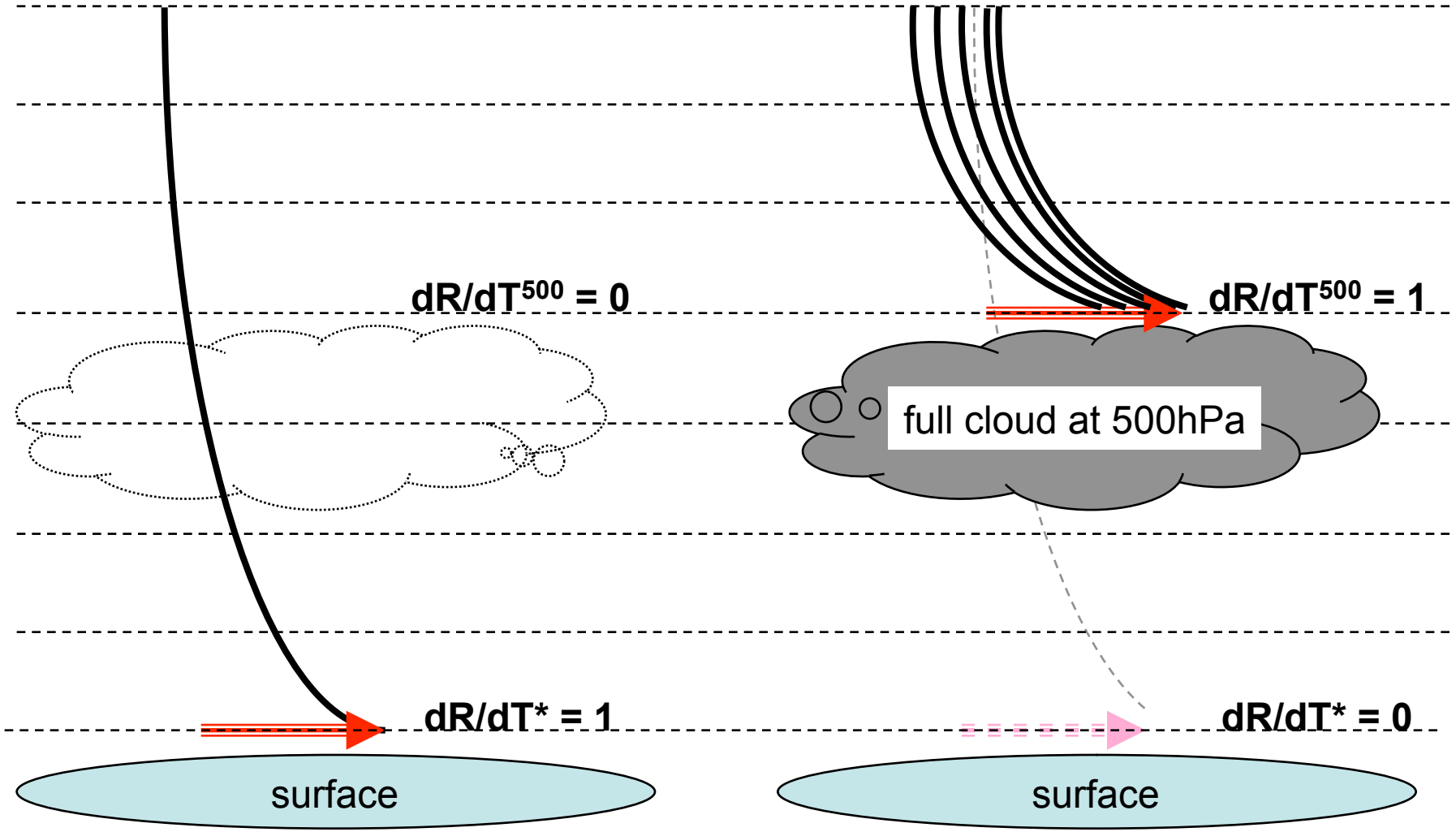
- Only cloudy IR radiances from completely overcast scenes are used
- One additional variable (local) added to 4D-Var control vector (P_{CTOP})
- Background values estimated from the observations (not NWP model)
- QC rejection of marine inversion / physically unreasonable clouds
- All IR sensors treated identically (AIRS / IASI / HIRS)

Why overcast scenes…?

Why use cloudy radiances only in overcast conditions ?

- Overcast conditions are least ambiguous in the radiance data*
- Cloud control vector collapses to a single number (P_{CTOP})
- Problems with cloud overlap assumptions vanish
- Termination of jacobians at cloud top provides new information*
- We can measure temperature above clouds better than in clear sky
- No cross-talk between cloud and surface skin sink variables

Enhanced temperature estimation at the cloud top



Background cloud parameters…

Background cloud parameters
(2D least squares method)

We find ***N*** (*cloud fraction*) and **P** (*cloud top pressure*) which minimize the squared radiance departures summed over *J* (currently *J*=3) channels:

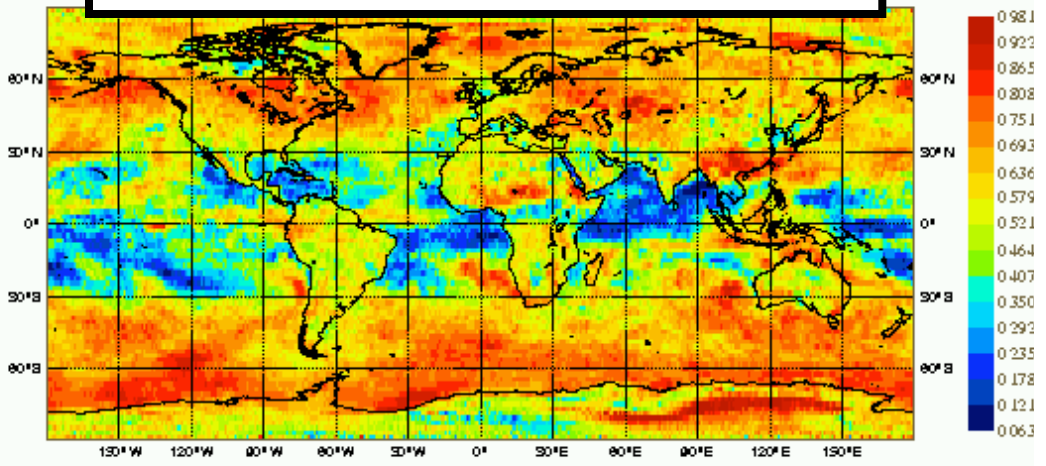
$$\sum_j \delta^2 = \sum_j [(R_j^{obs} - R_j^{\circ}) - N(R_j^{\bullet}(p) - R_j^{\circ})]^2$$

Analytically solving for N:

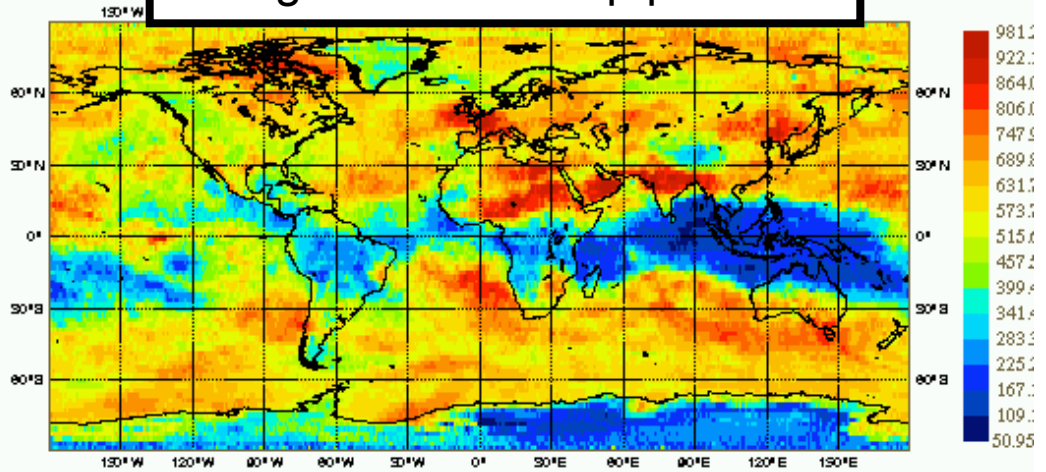
$$N_p = \frac{\sum_j [(R_j^{obs} - R_j^{\circ})[R_j^{\bullet}(p) - R_j^{\circ})]}{\sum_j [R_j^{\bullet}(p) - R_j^{\circ})]^2}$$

and numerically finding the value of *P* that gives the overall minimum departure.

Background effective cloud fraction

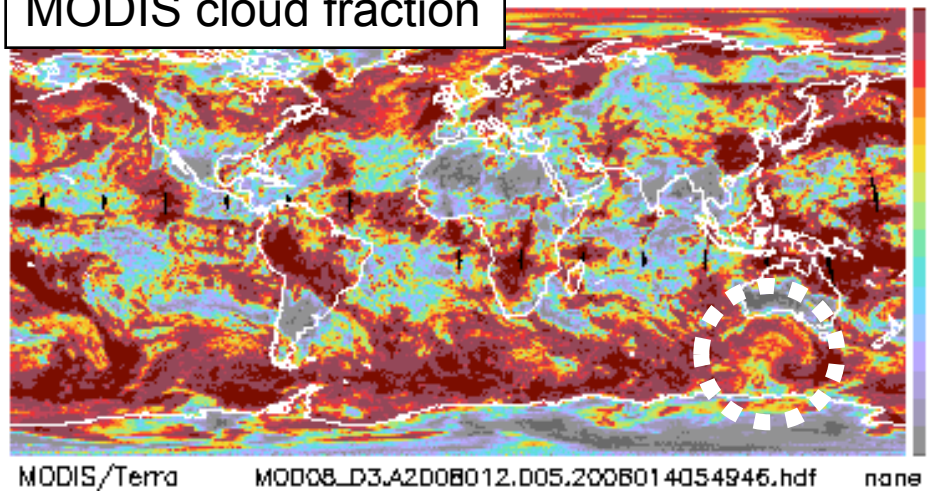


Background cloud top pressure

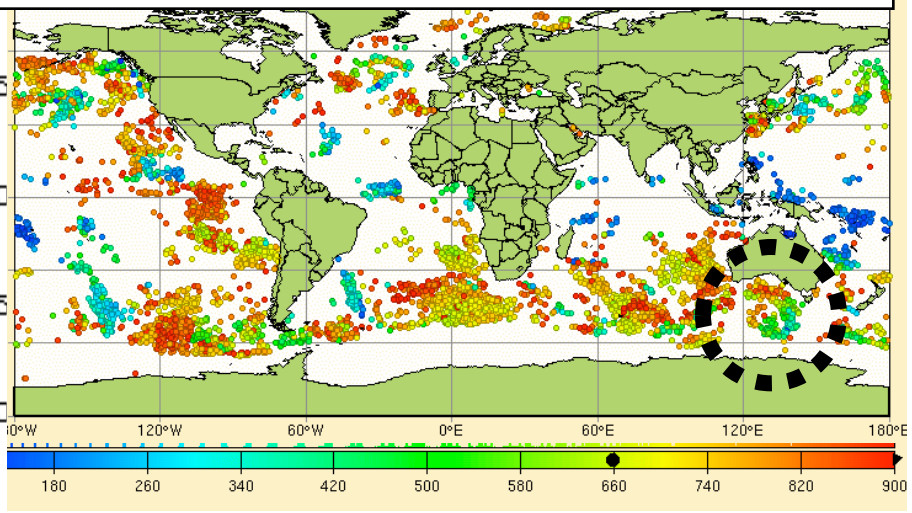


Background 2D cloud parameters
(comparison to MODIS values)

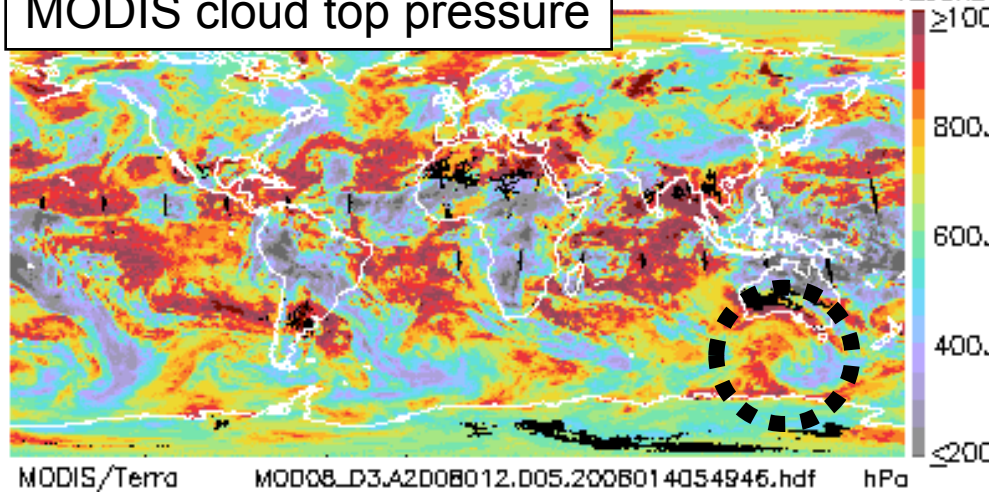
MODIS cloud fraction



Background cloud top pressure (overcast)



MODIS cloud top pressure

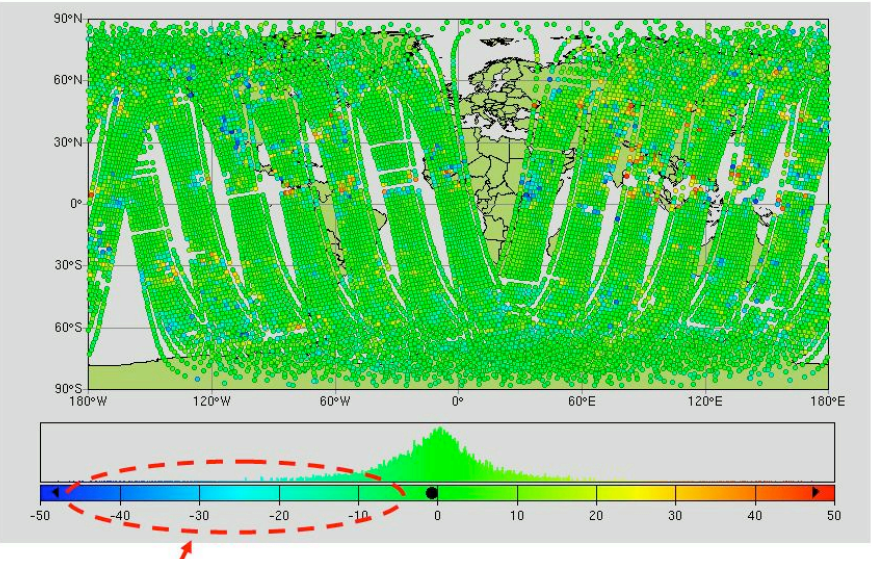


Qualitatively – the location and altitude of **overcast** locations seems reasonable when compared to MODIS equivalent products

Why not use the NWP model for background cloud parameters ?

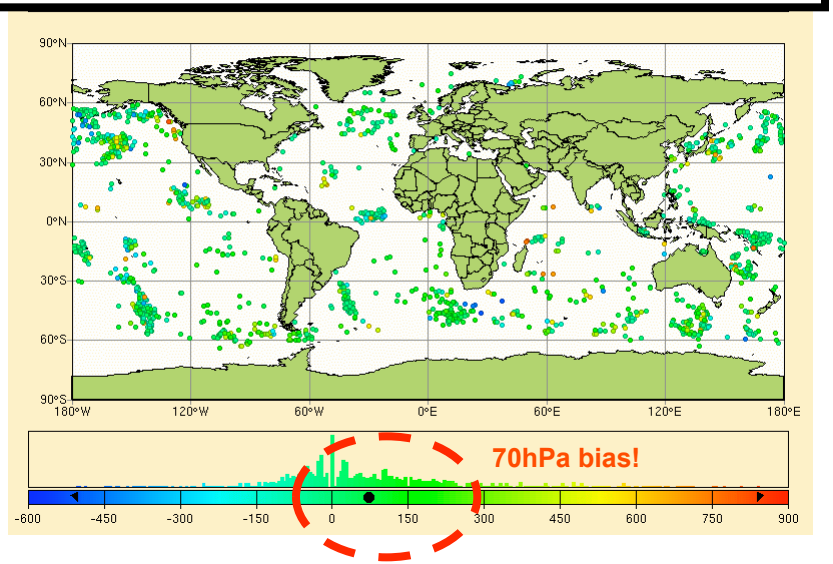
The disagreement between the OBS and the model is not excessive, but still **large enough** to often stretch the TL approximation and limit convergence

Observed radiance at 11 microns minus radiance calculated from NWP cloud background profile



There also a difficulty in post- processing the model cloud profile variables to the quantity **representative** of that seen by the radiance observations

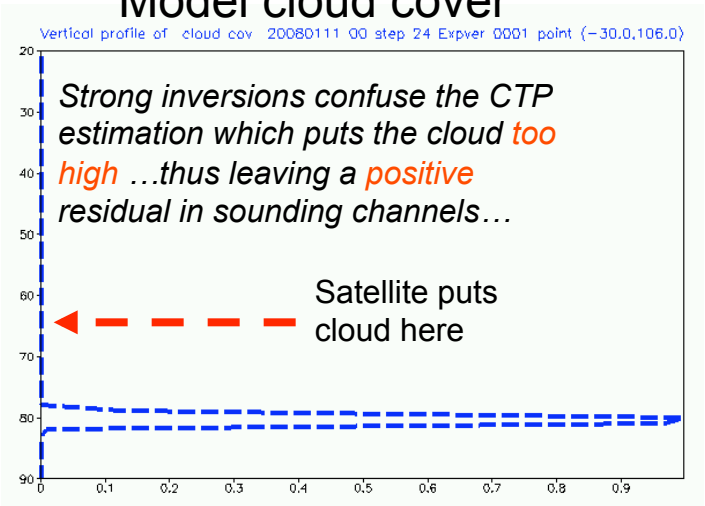
CTOP: NWP minus 2D least squares



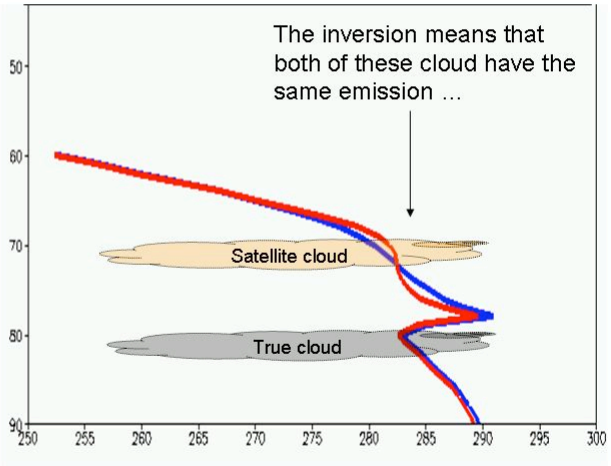
Quality Control…

Problem in MSC regions / inversions

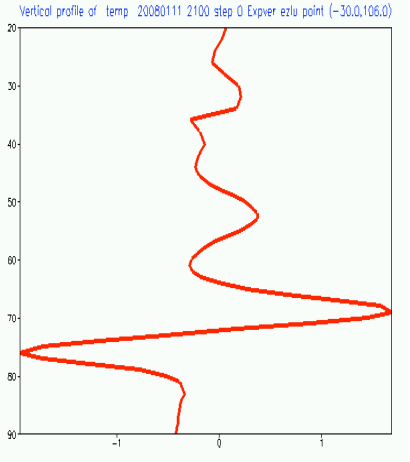
Model cloud cover

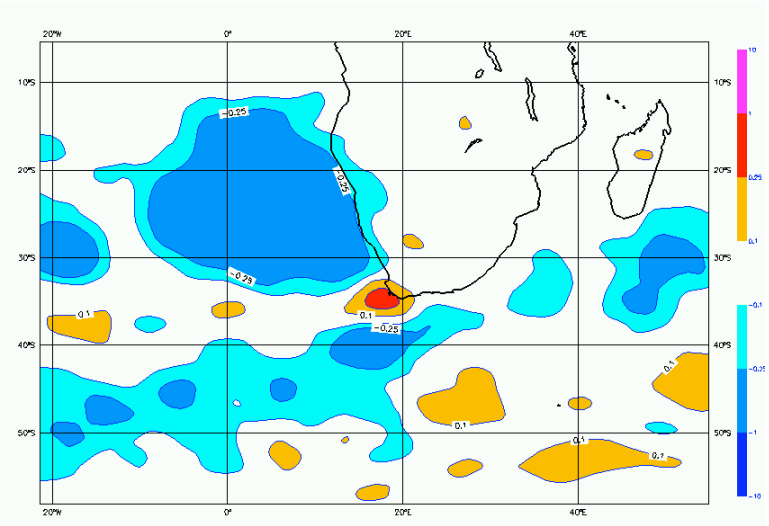


Temperature profiles



Temperature increments

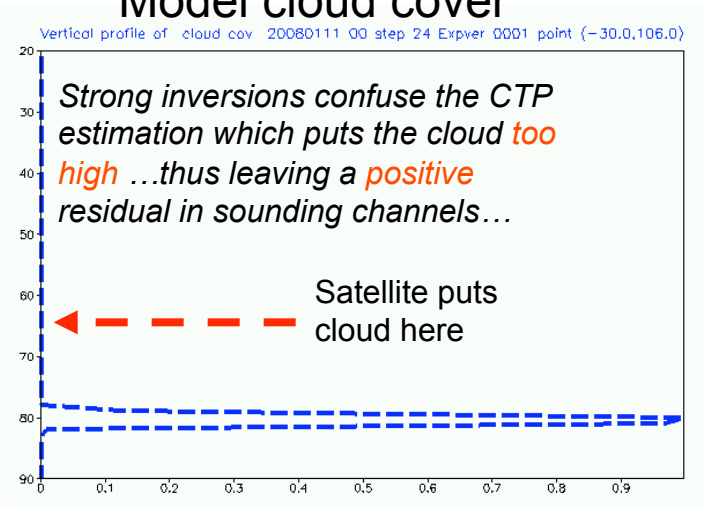




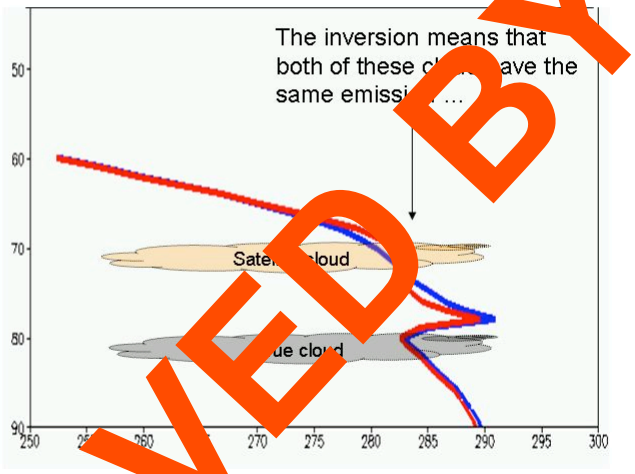
Note: there is some **LIDAR evidence to suggest the model clouds are too low** in the (SH) MSC regions and thus the associated model temperature / humidity profile (from which initial cloud parameters are computed) is unlikely to be correct!

Problem in MSC regions / inversions

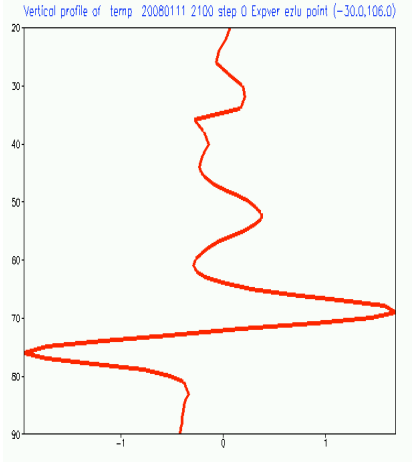
Model cloud cover

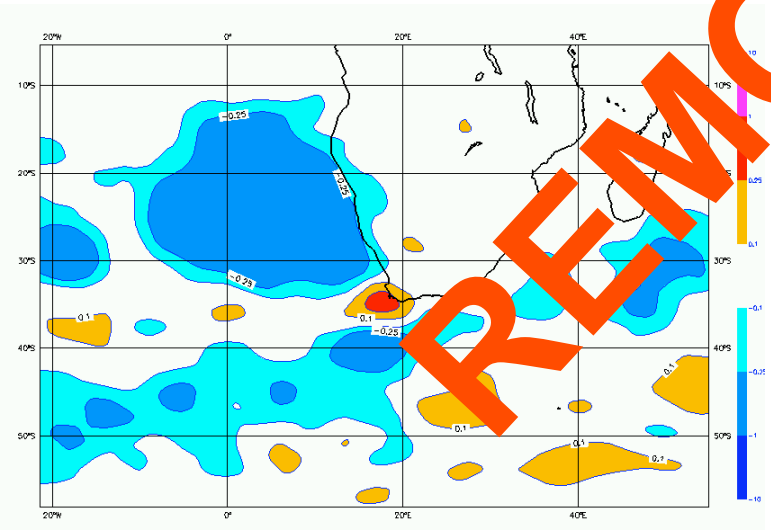


Temperature profiles



Temperature increments





REMOVED BY QC

Note: there is some **LIDAR evidence to suggest the model clouds are too low** in the (SH) MSC regions and thus the associated model temperature / humidity profile (from which initial cloud parameters are computed) is unlikely to be correct!

Prototype cloudy assimilation system applied to combined HIRS / AIRS / IASI

Experiment design

Period = 3 months in January/February/March 2008

Resolution = T255

HIRS radiances from METOP-A and NOAA-17 used (LW)
AIRS radiances from AQUA used (LW/WB/SW)
IASI radiances from METOP-A (LW)

CNTRL = ECMWF operations (clear channels from HIRS / AIRS / IASI)

EXPT = CNTRL + HIRS / AIRS / IASI in overcast locations

Background cloud conditions from 2D least squares fit to 4 channels

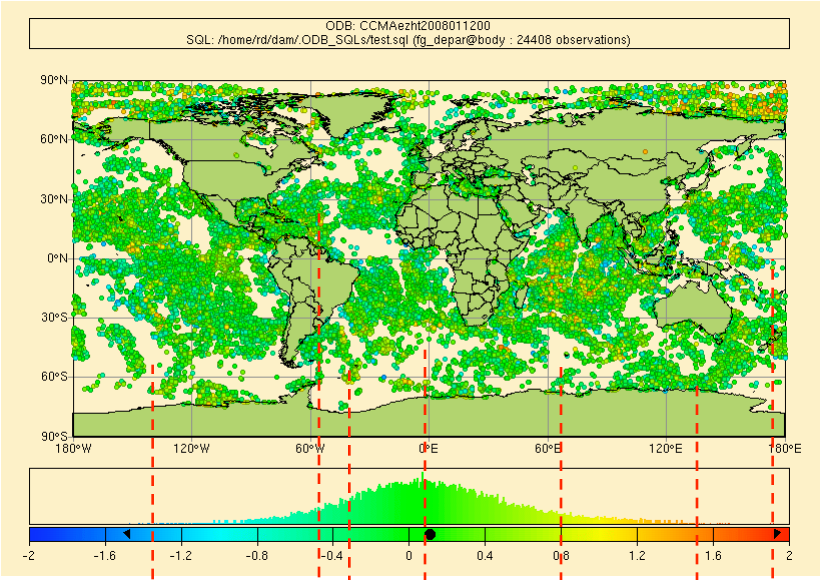
Background errors CTOP = 5hPa and CFRAC = 0 (local sink variables)

QC applied rejecting low clouds (below 700) and “bad” 2D solutions

Where are the extra overcast data

Combined clear data coverage of mid/ lower tropospheric sounding radiances:

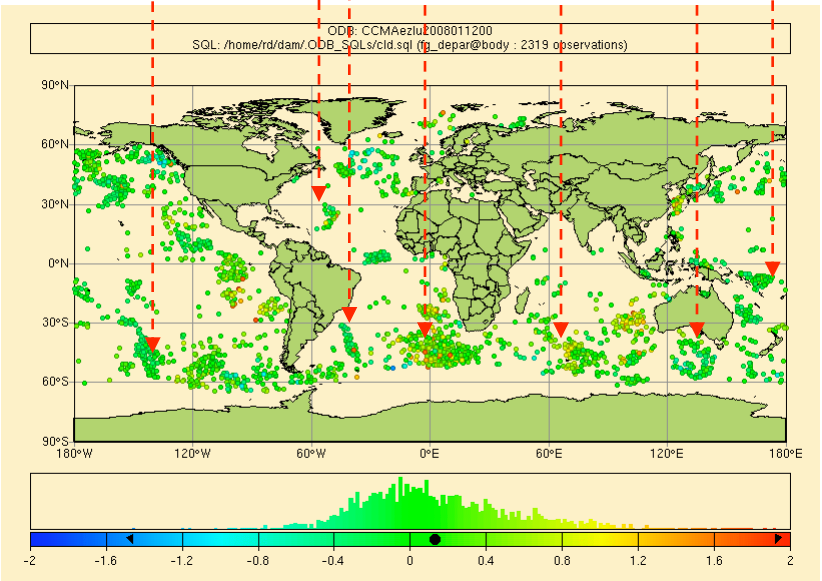
IASI channel 434 (METOP-A)
AIRS channel 355 (AQUA)
HIRS channel 7 (NOAA-17 / METOP-A)



Additional overcast locations where cloudy radiance analysis **fills gaps** due to cloud detection rejections:

IASI channel 434 (METOP-A)
AIRS channel 355 (AQUA)
HIRS channel 7 (NOAA-17 / METOP-A)

(Colour indicates first guess departure)

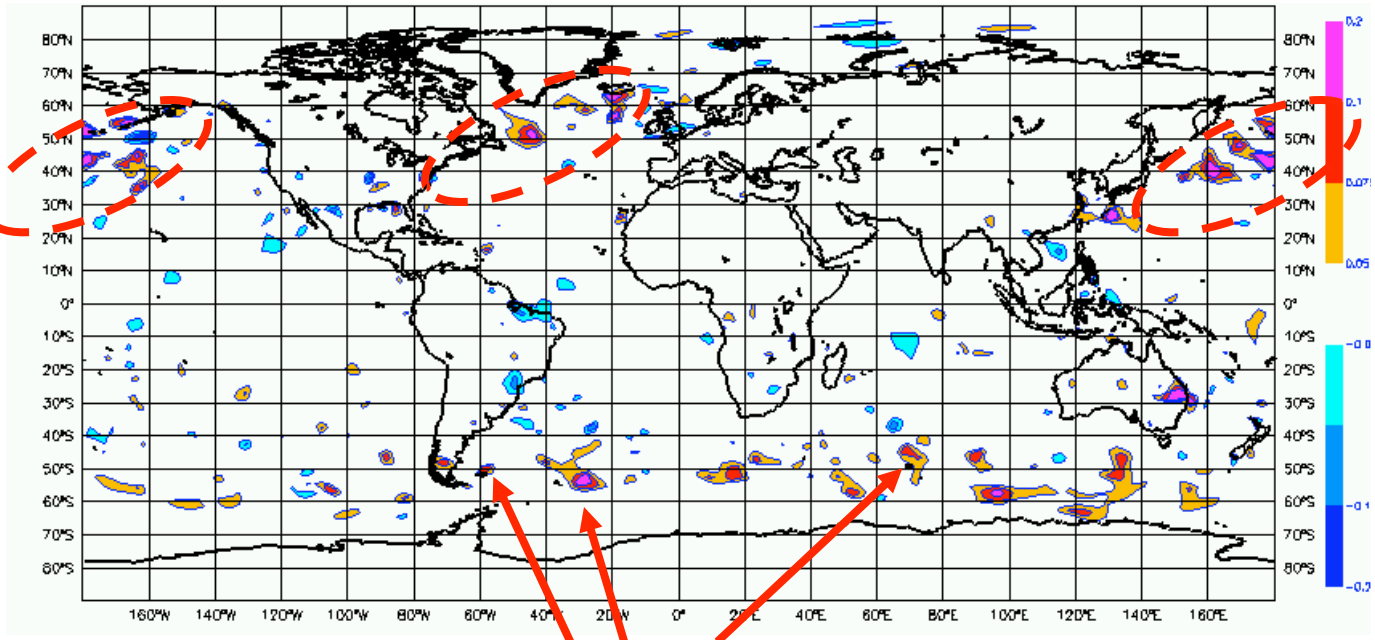


Impact on the analysis…

Analysis / increments statistics

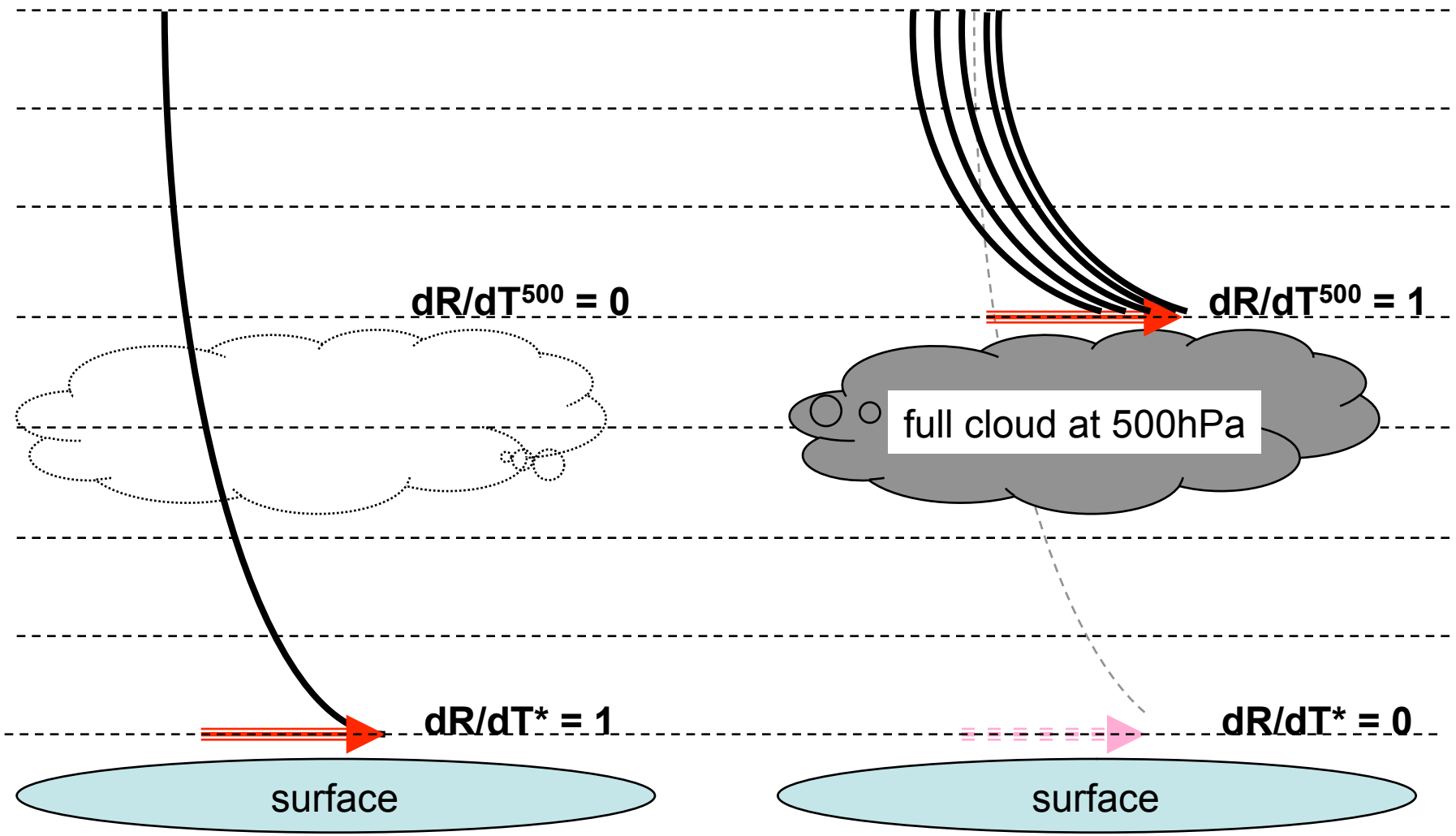
The data fits and **bulk analysis / increment statistics** for the CTRL and EXPT systems are **very similar** - possibly due to the small amount of extra radiance data currently being used. A highly magnified view shows some reduced temperature increments at **isolated sonde locations and in the storm tracks**.

1 month averaged RMS temperature increments at 500hPaCTRL minus EXPT

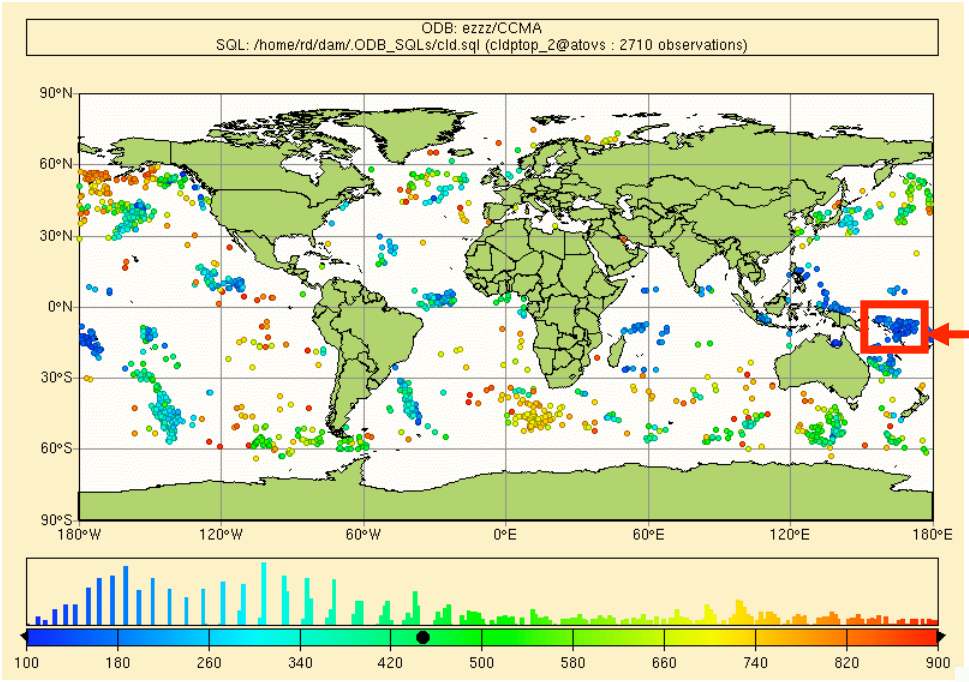


reduced increments at isolated radiosonde stations

…remember this …?

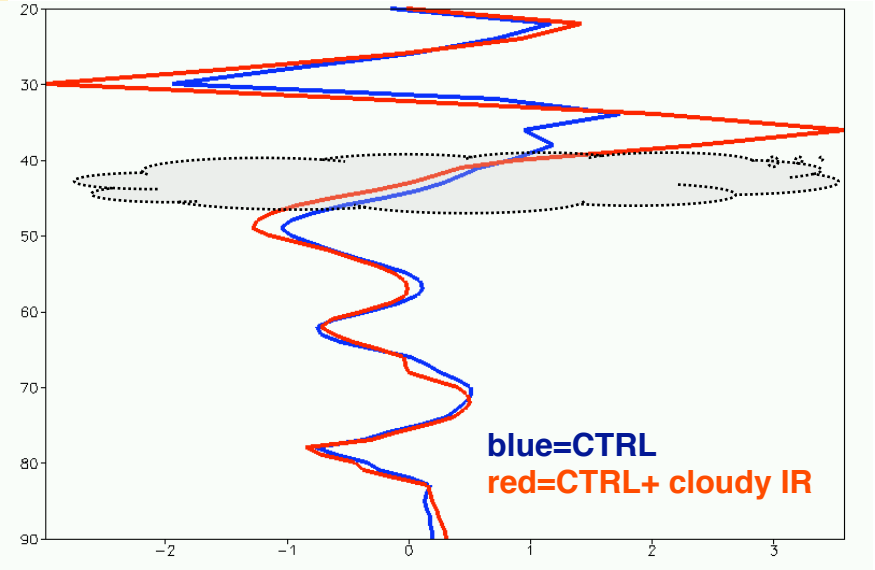


Temperature increments at the cloud top



Cell of very high overcast clouds off the coast of PNG seen by IASI

Temperature increments (point)

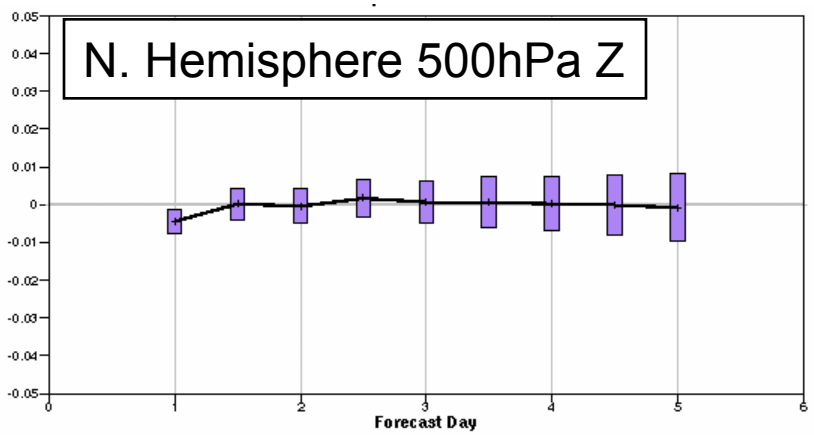


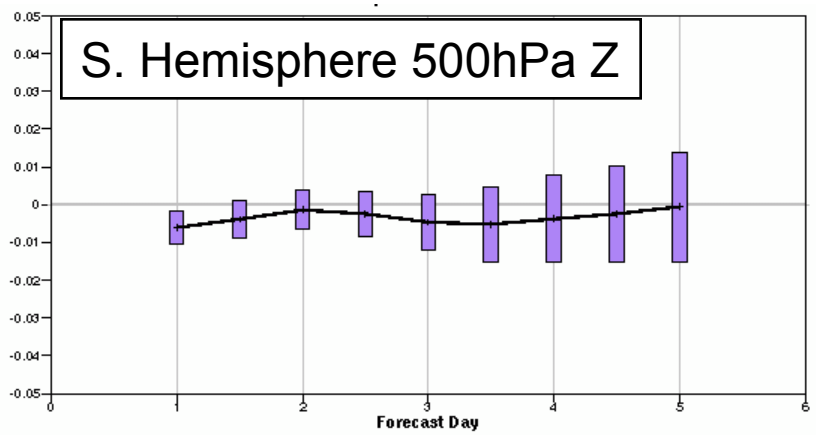
All IASI channels collapse to near **delta-functions** at the cloud top giving very **high vertical resolution** temperature increments just above the diagnosed cloud

Impact on forecasts …

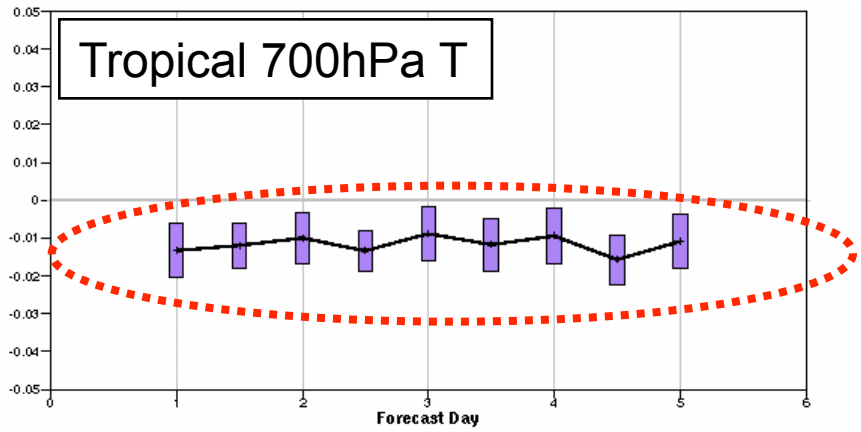
Forecast performance

Forecasts verified against own analyses for **91** cases (20080112 to 20080411)
vertical bars indicate 95% significance testing of normalized RMS error differences defined as EXPT minus CTRL





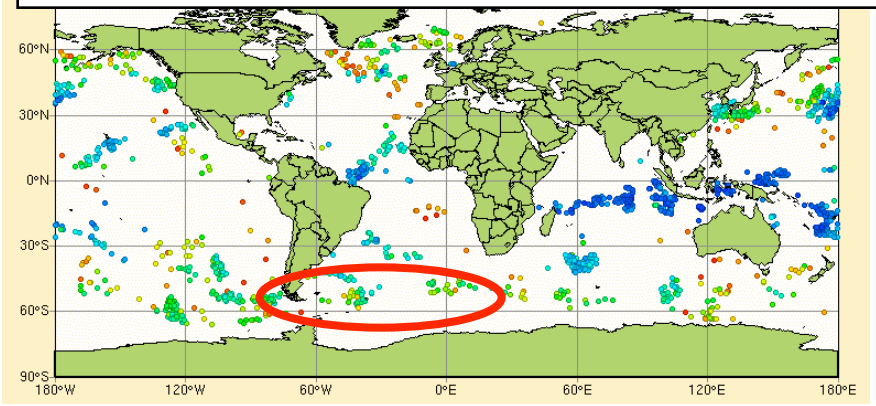
No statistically significant forecast impact of the extra overcast radiances apart from in the Tropics where temperature forecasts are improved at all ranges



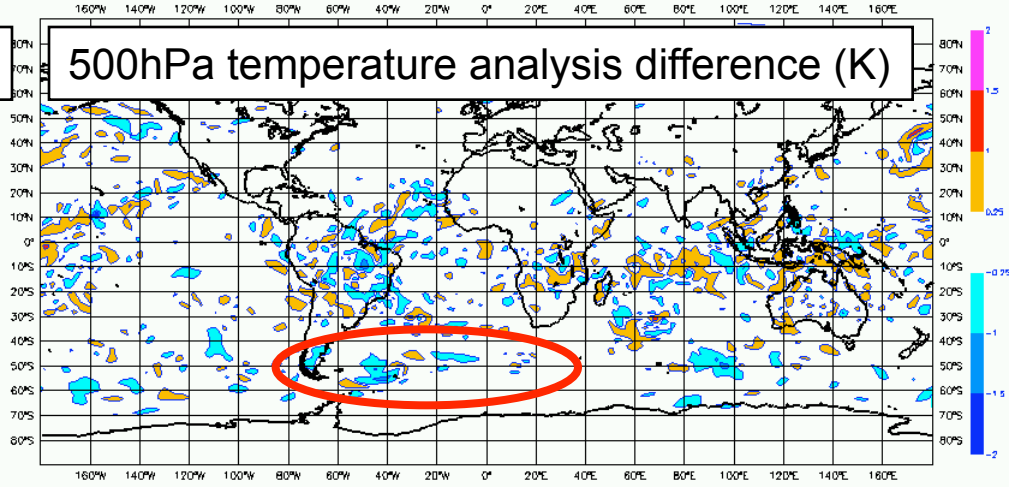
Cloud obscured singular vector ?

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

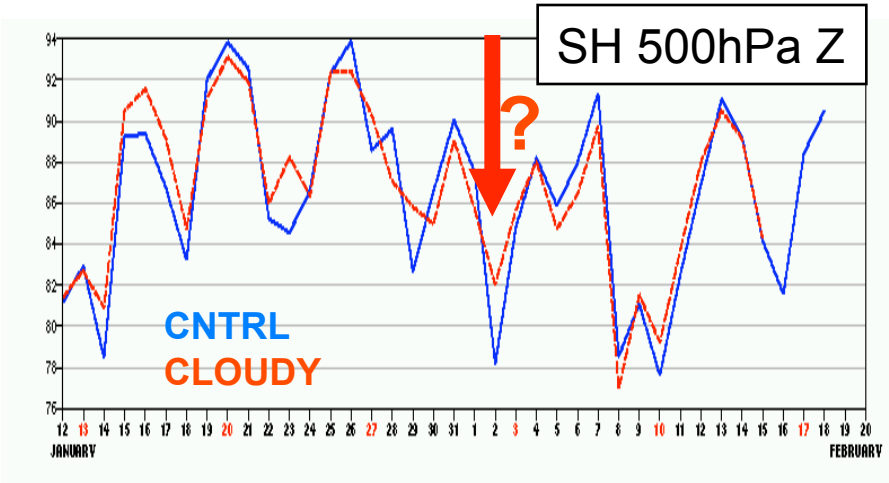
Extra overcast data used compared to CTRL



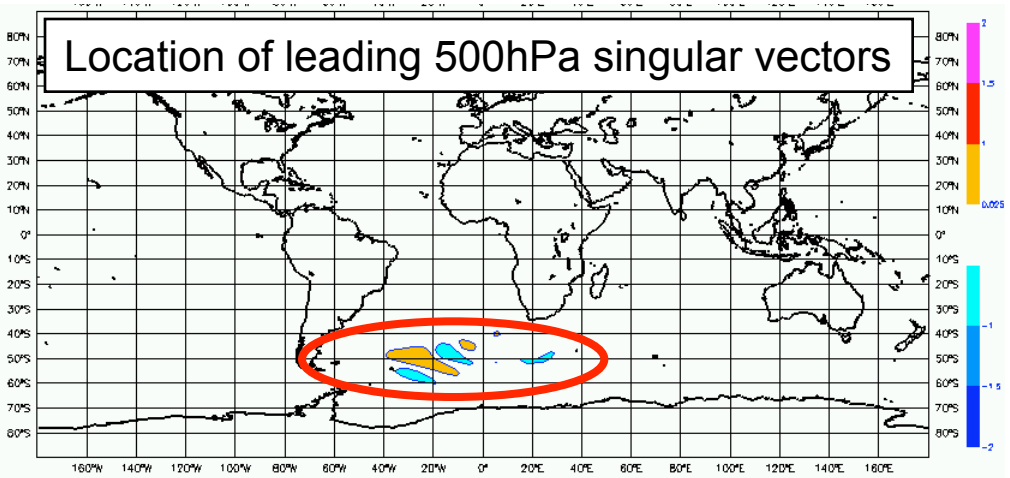
500hPa temperature analysis difference (K)



SH 500hPa Z



Location of leading 500hPa singular vectors



Summary

- Technically the code works for AIRS/IASI and HIRS (GEOS will follow soon) and the analysis is stable
- The restriction to overcast scenes and the applied QC currently yields < 10% extra radiance data
- The small amount of additional data do not significantly influence the bulk characteristics of the analysis or departure statistics – although some isolated reduction of increments is observed.
- At locations where there are extra radiance observations - high vertical resolution increments (above overcast cloud top) look reasonable, but need further detailed validation
- No significant impact on forecast performance apart from improved Tropical temperature scores

Next Steps

- Use imager data (MODIS/AVHRR) to validate 2DLS background cloud estimates and investigate the possibility of using imager identification of overcast scenes for data selection / QC rejection
- Use CLOUSAT data to validate the 2DLS background cloud top estimates in overcast conditions (particularly MSC)
- Continue to search for individual cases of forecast impact – possibly using singular vectors or adjoint sensitivity diagnostics
- Investigate use of a post-processed NWP cloud background for the cloudy IR analysis to replace the 2DLS

End