Improved assimilation of IASI radiances at the UK Met Office

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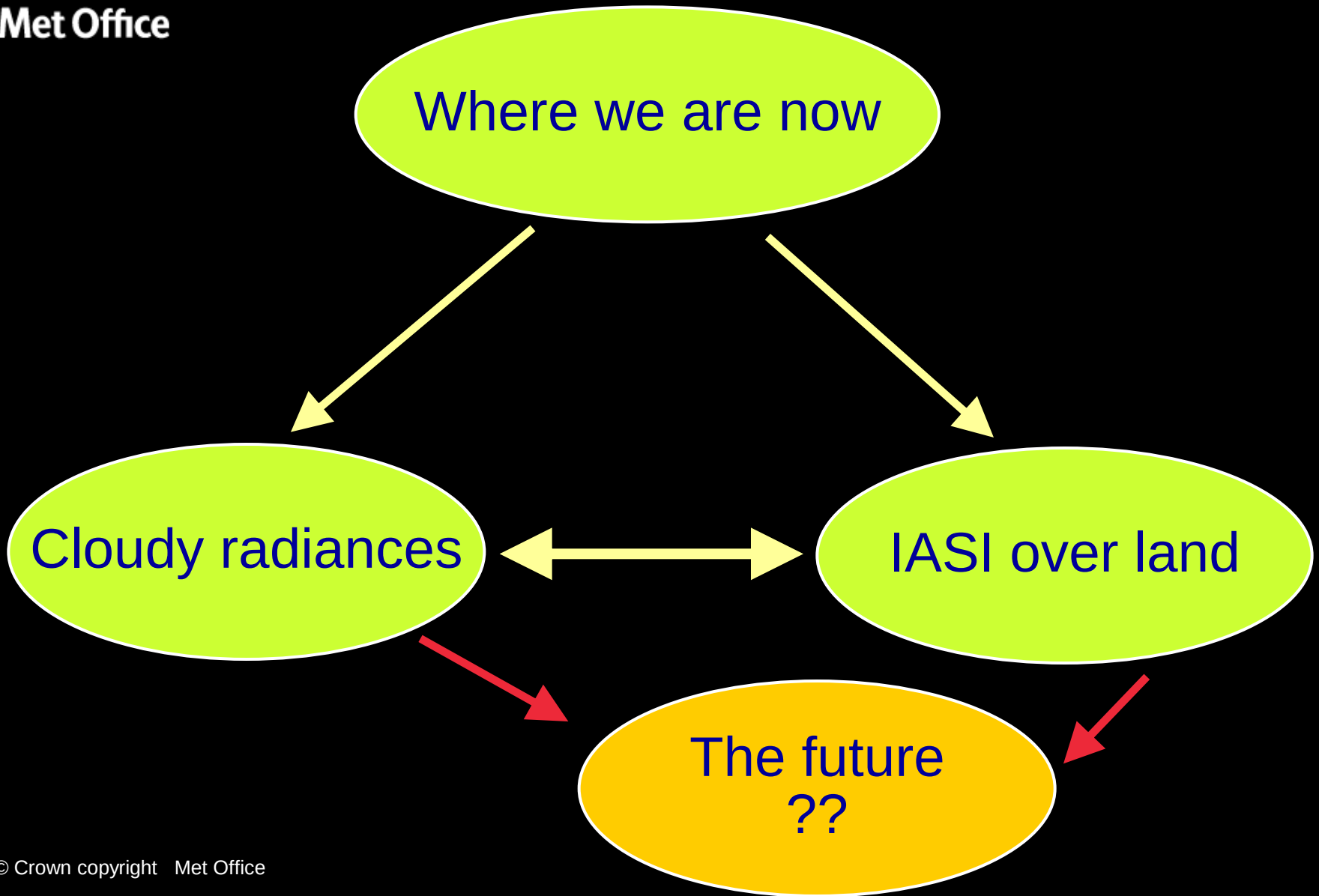
Talk outline

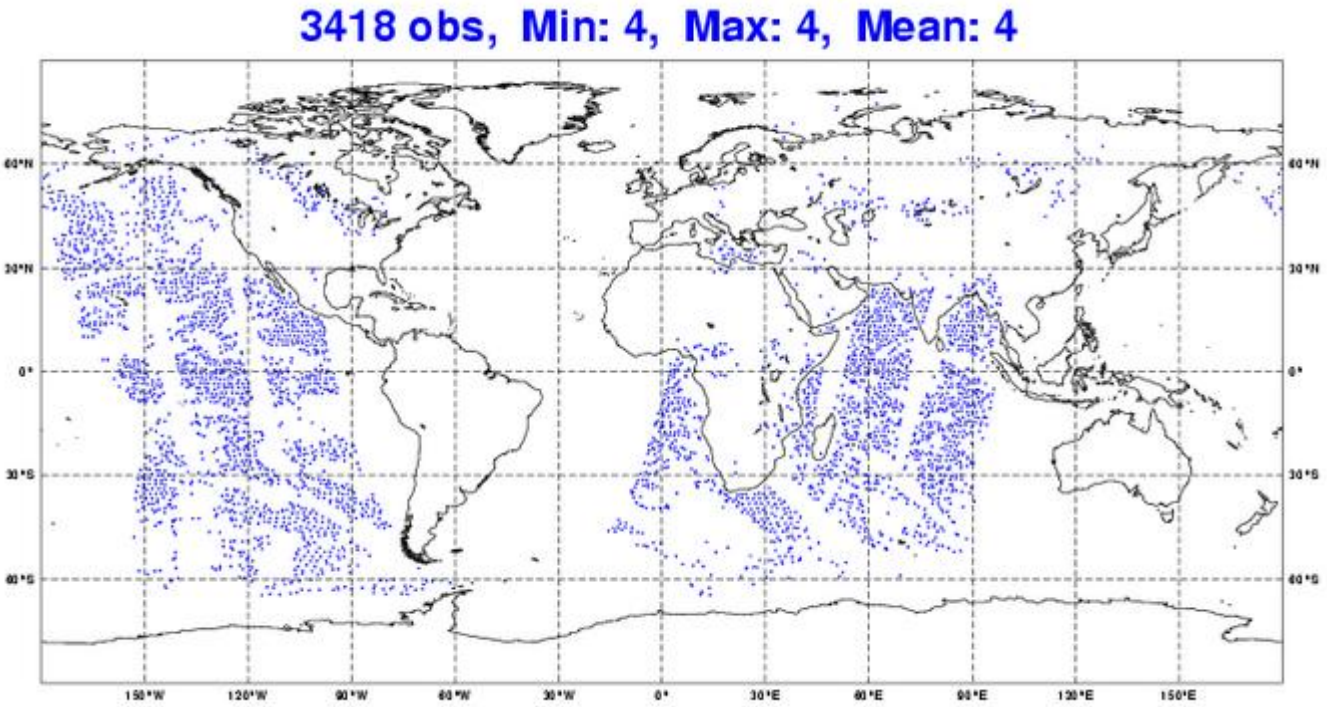


Current operational assimilation of IASI (Jan 2010)

- 1D-Var pre-processor (OPS)
  - Quality control – check for convergence
  - Retrieve auxiliary parameters: cloud, surface
- 4D-Var: Assimilate BTs from 138 channels
- Cloud detection: ‘Hole-hunting’ scheme
  - Patchy global coverage
  - Low sensitivity to “active” weather systems
- Only high-peaking channels over land
  - Select channels peaking above 400 hPa
  - Limited tropospheric information over land

Current usage of IASI data

- IASI currently only assimilated in **cloud-free** areas
  - Only ~ 4% of data used after thinning
  - Example: 20 Jan 2010:
    3418 of 80340 IASI observations assimilated



Assimilation of cloudy radiances

Motivation

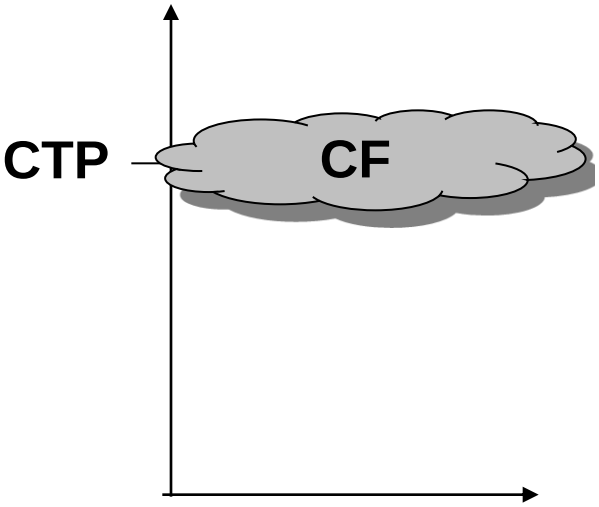
- Majority of IASI soundings are affected by cloud
  - Reject cloudy scenes → Throwing away a lot of data!

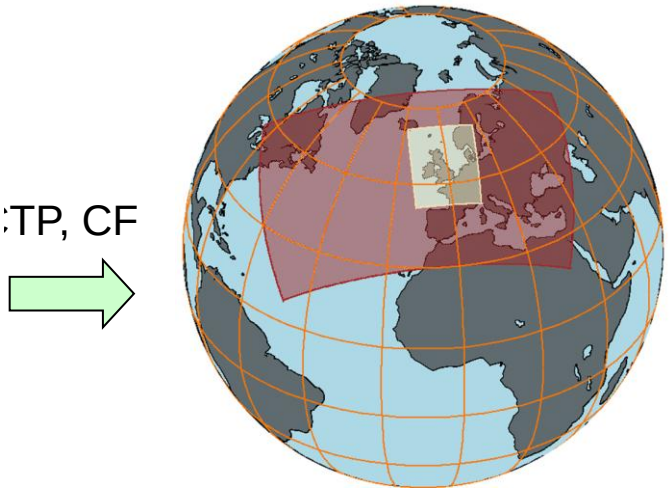
- Forecast is particularly sensitive to cloudy regions
  - Meteorologically active! (e.g. McNally, 2002, QJRMS 128, 2551-2556)

- Expect cloudy soundings to have a large impact on the analysis

- **Simple cloudy IR assimilation scheme already proven operationally with AIRS (Pavelin et el, 2008, QJRMS)**

1D-Var cloud analysis





4D-Var

- Retrieve cloud parameters in 1D-Var
  - Using RTTOV: Single level “grey” cloud
- Choose channels with minimal sensitivity below cloud top
- Pass cloudy radiances, retrieved CTP and CF to 4D-Var

Limitations in cloud model

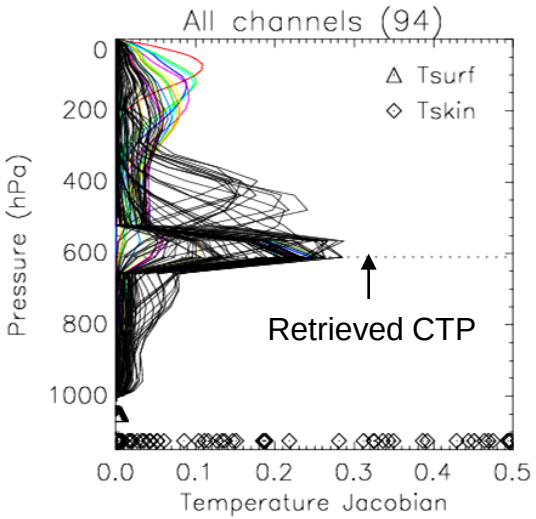
- In many cases, 1D-Var cloud model is unrealistic
  - Not (generally) single-level grey cloud
  - Cloud is generally multi-level, 3D
  - Leads to biases below cloud top

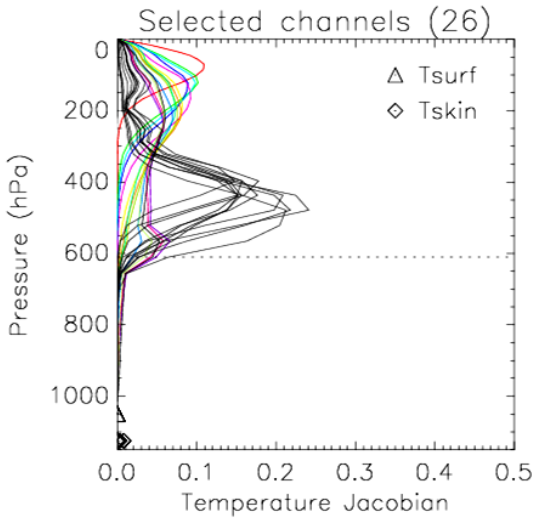
- **Solution: Remove channels most likely to be poorly modelled**

- Simple automatic channel selection:
  - Reject all channels peaking below retrieved cloud top
  - 10% of weighting function area allowed below cloud top
  - Channel selection carried out for each sounding

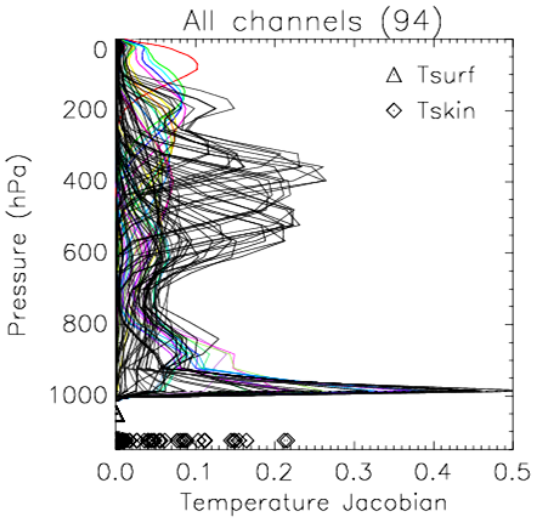
Example cloudy weighting functions ($\partial B_i/\partial T_j$)

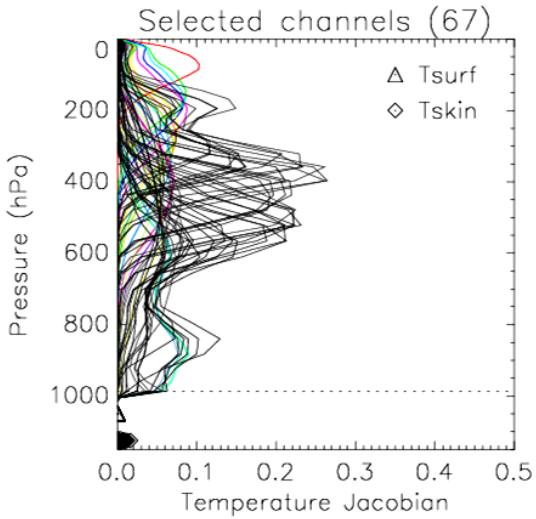
Mid-level cloud
- Use 26 of 94 channels



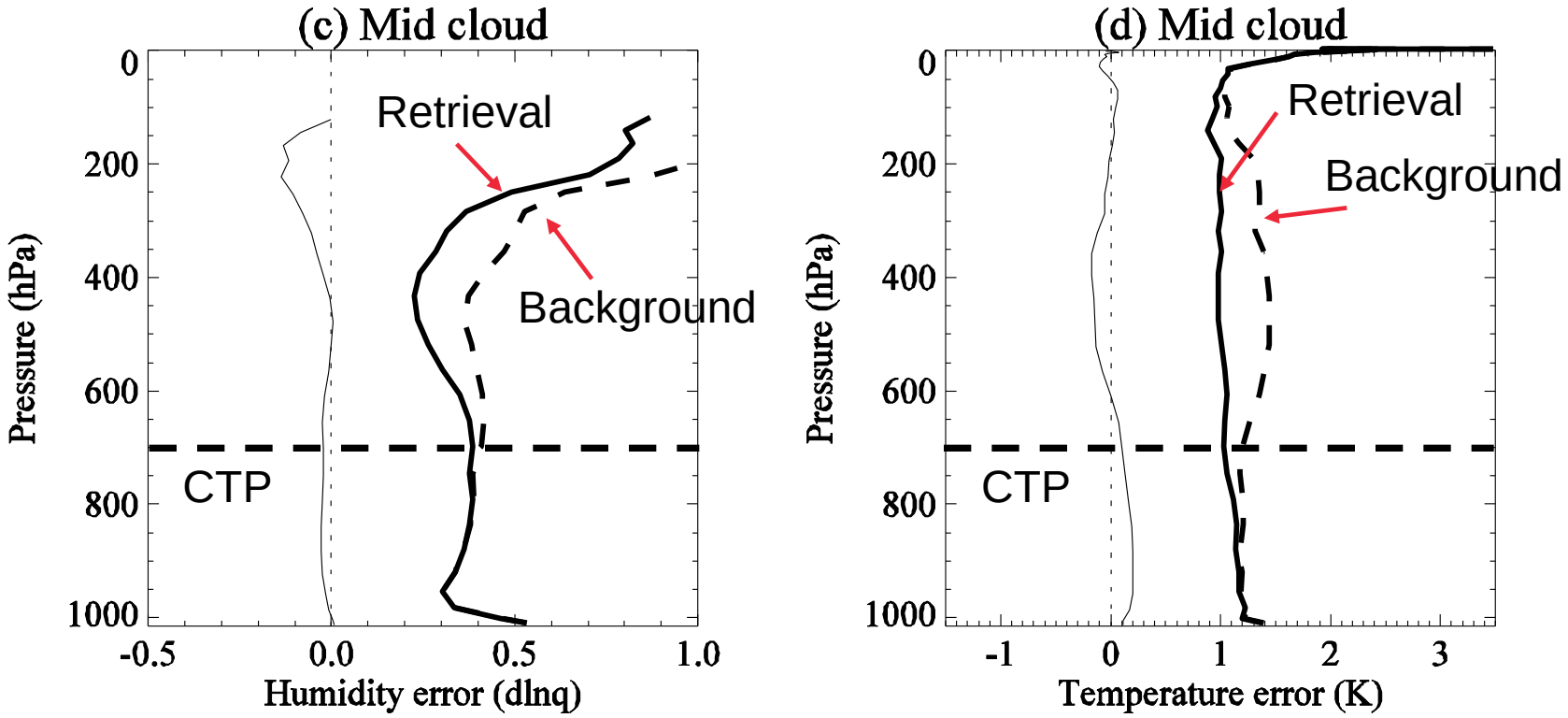


Low cloud
- Use 67 of 94 channels





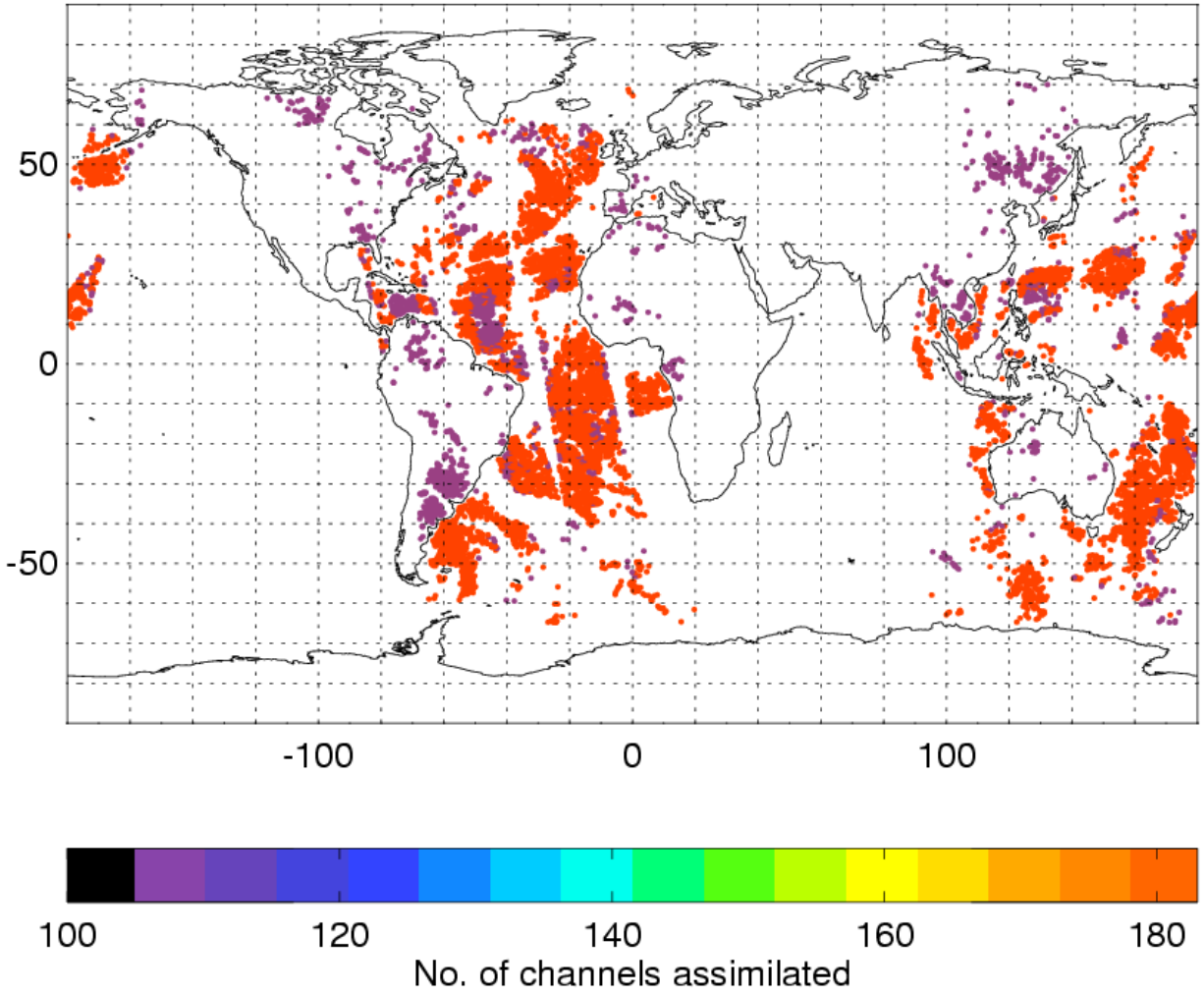
Simulated 1D-Var analysis errors: Mid-level cloud cases



From: Pavelin, English and Eyre, 2008, *Q. J. Roy. Met. Soc.*

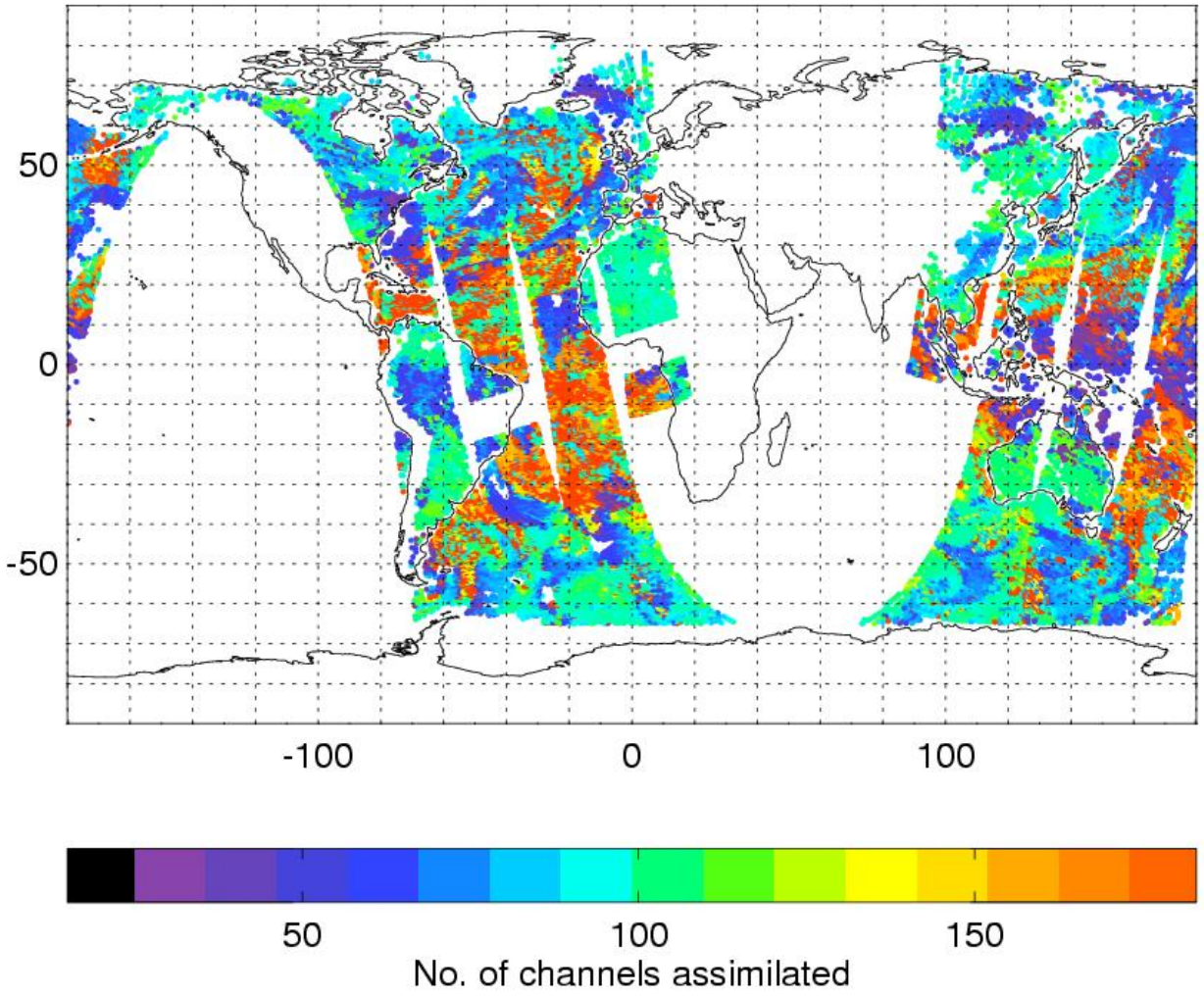
Coverage: “Clear” IASI

No. of channels passing 1D-Var QC

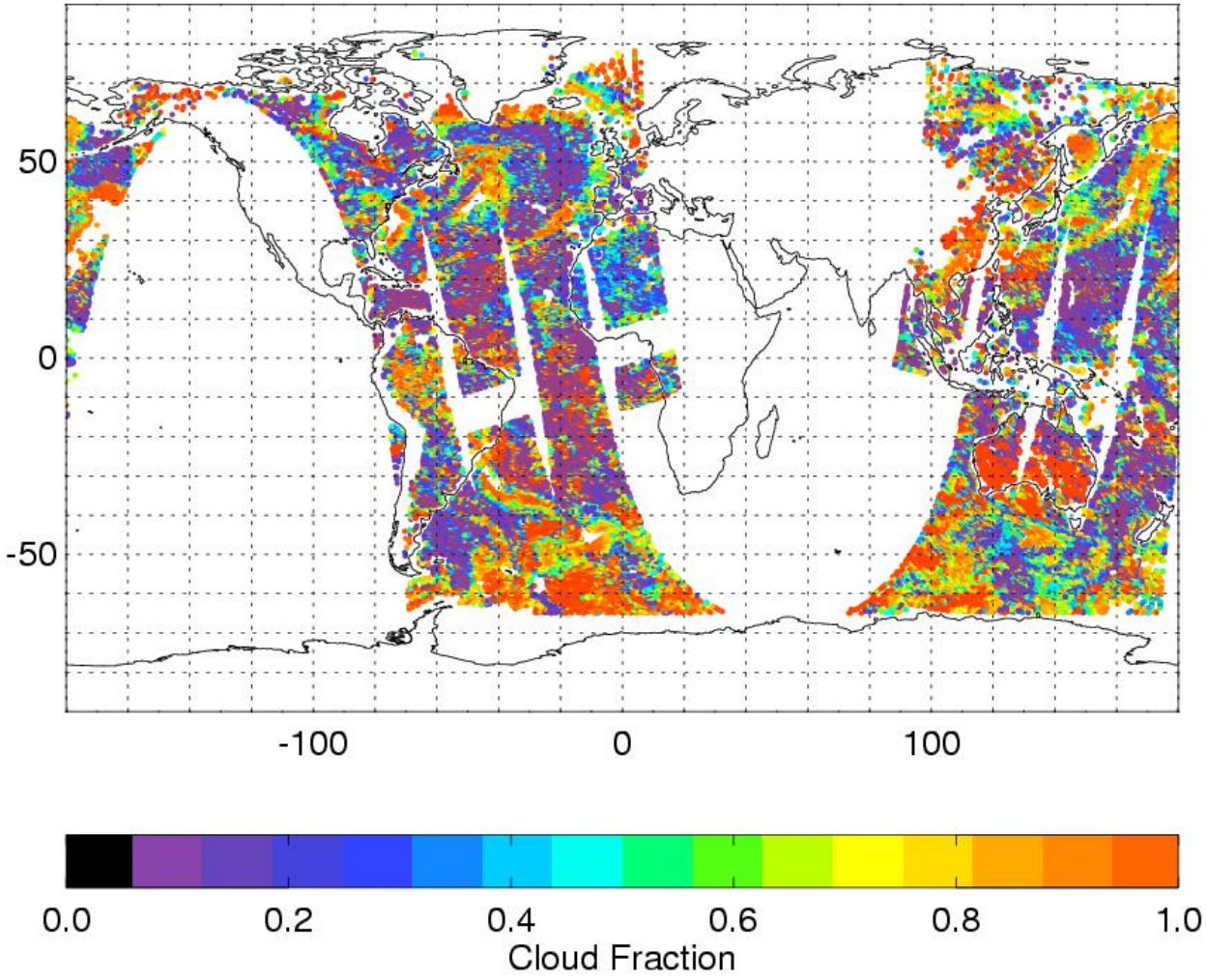


Coverage: Cloudy IASI

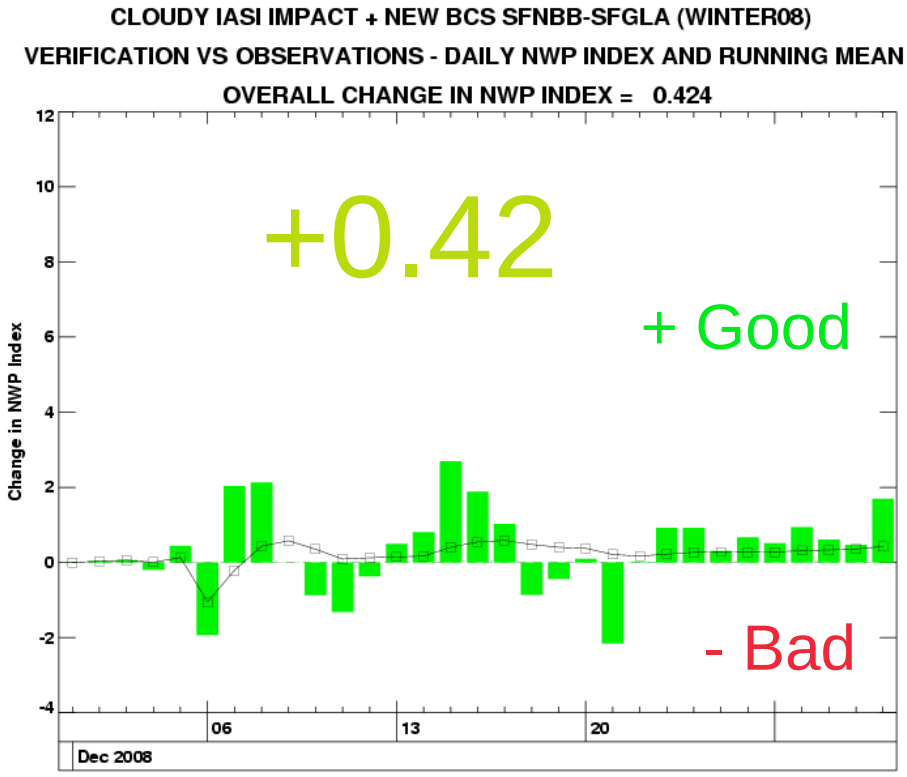
No. of channels passing 1D-Var QC

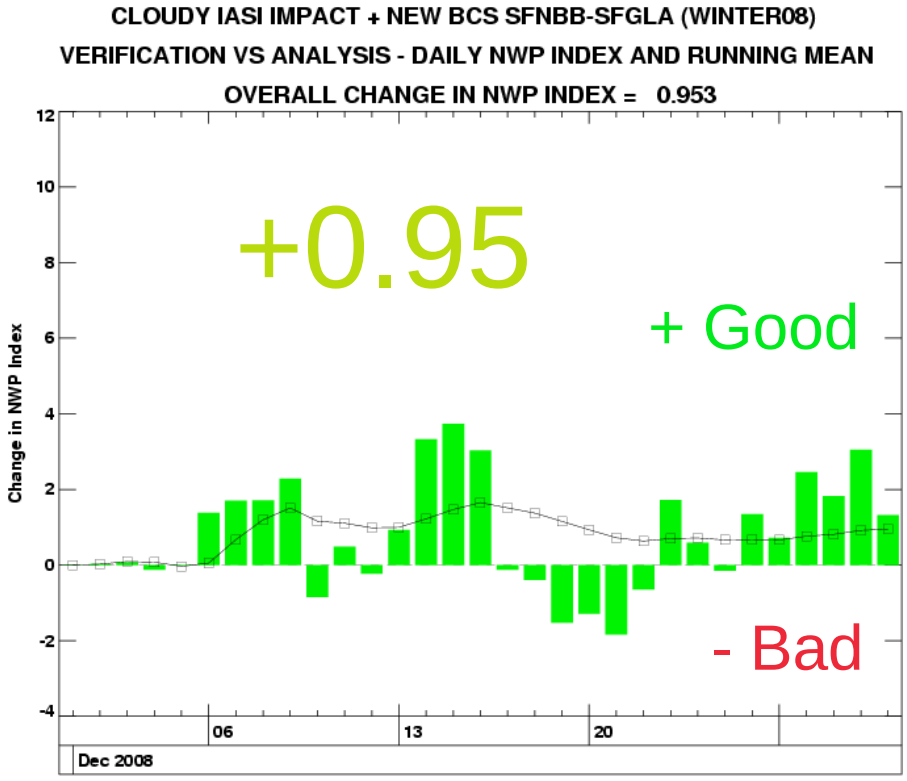


Retrieved effective cloud fraction



Forecast impact (Winter 2008)





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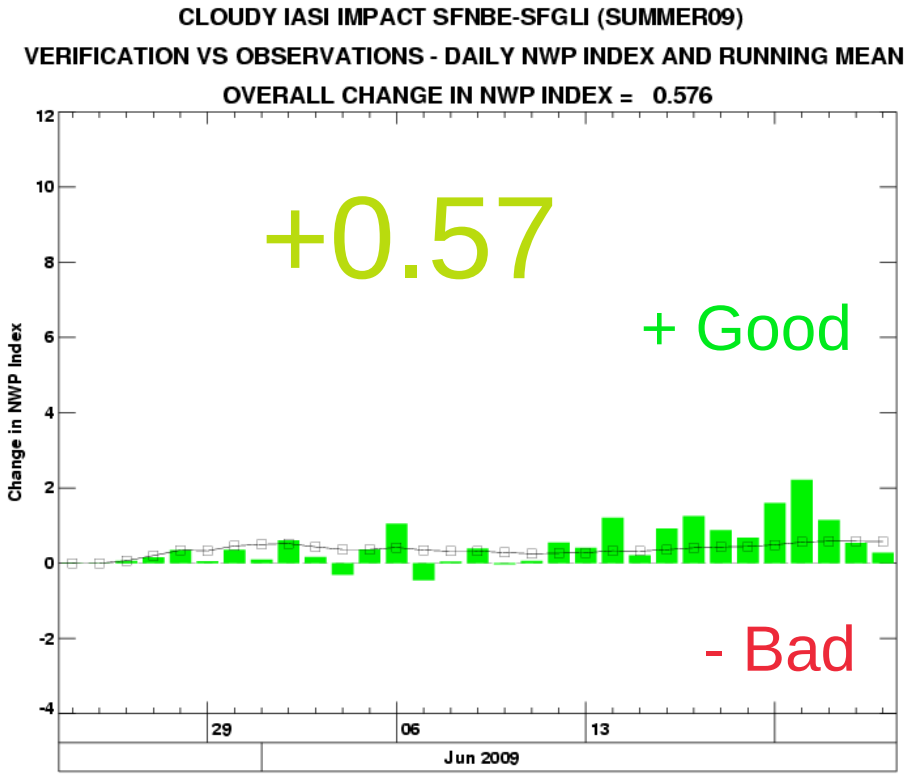
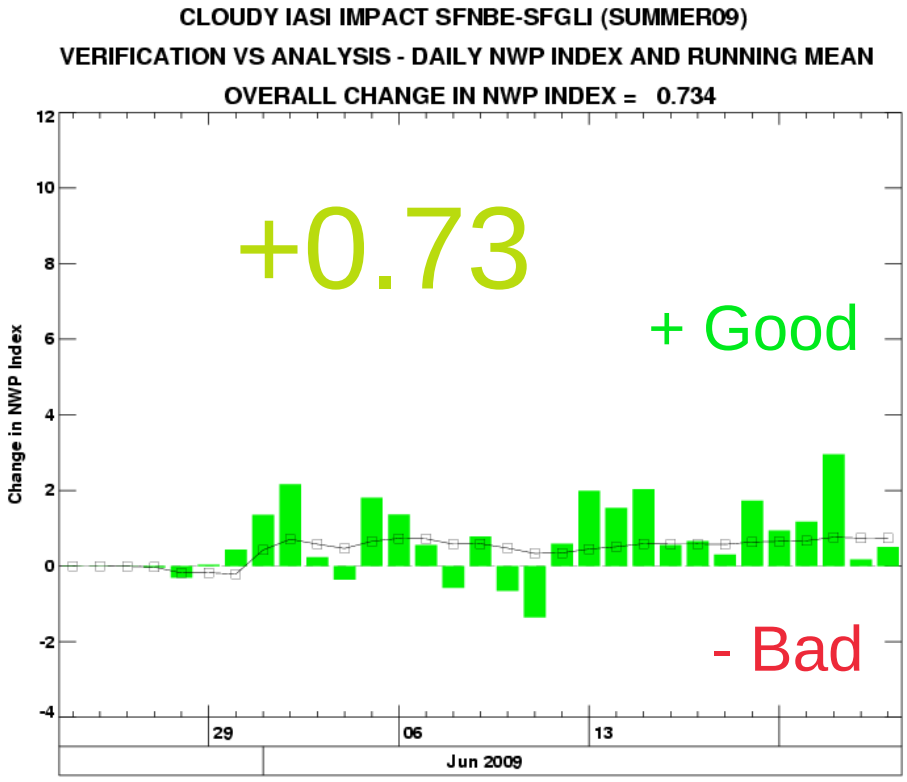
Forecast impact (Summer 2009)





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Cloudy radiances: Next steps

- System is very conservative
  - Fewer low-peaking channels used than in previous system
  - Over-detection of low cloud in clear sky

- Use more low-peaking channels
  - Low-level water cloud
  - More use of MetOp AVHRR cluster analysis?

- More advanced cloud analysis
  - Collaboration with PhD student at University of Reading (Cristina Prates)
  - Better handling of multi level & semitransparent cloud

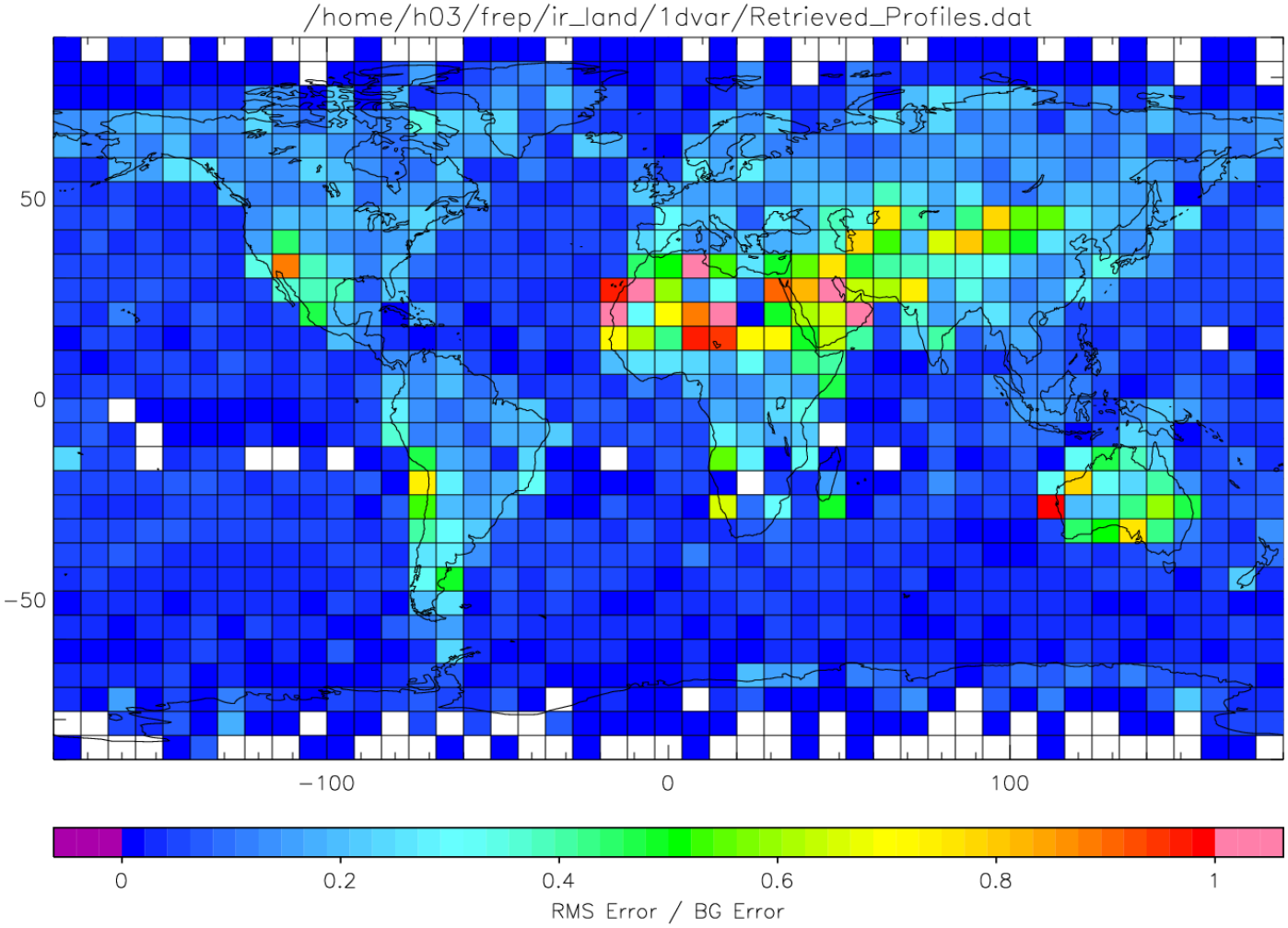
Assimilation of IASI over land

Using IR radiances over land

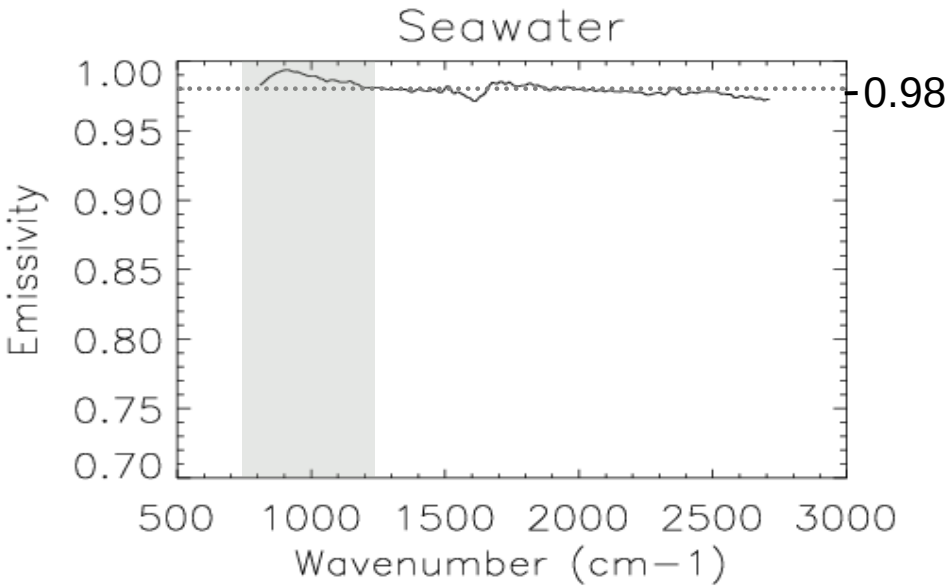
- Currently:
  - Assume emissivity $\varepsilon = 0.98$ for IR sounders over land
  - Not always good enough – don't use surface channels!
  - Channels below ~ 400hPa sensitive to surface
    $\rightarrow$ don't use those either!
- Options to increase data use over land
  - Use fixed emissivity atlas
  - Use land surface model / surface type atlas
  - Retrieve surface emissivity from observations

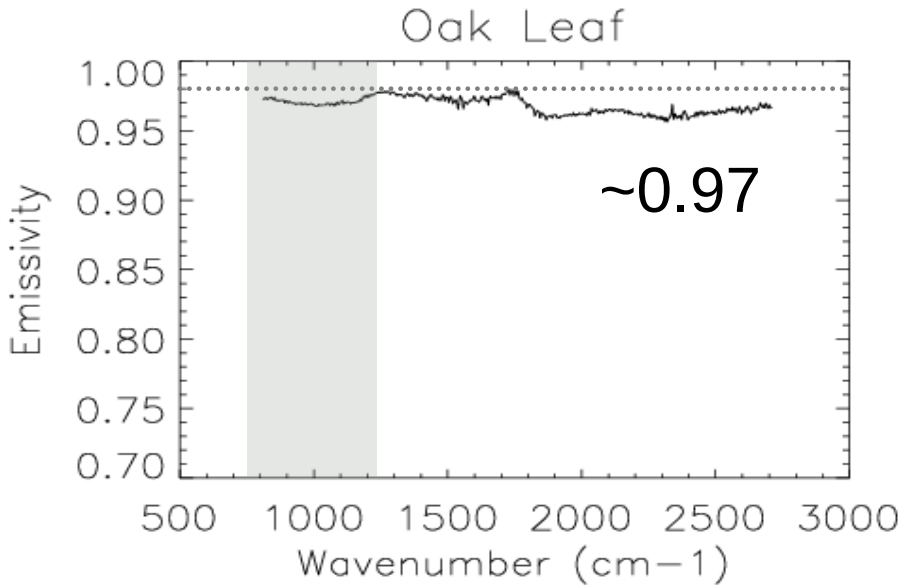
Simulation: (using U. Wisc. atlas)

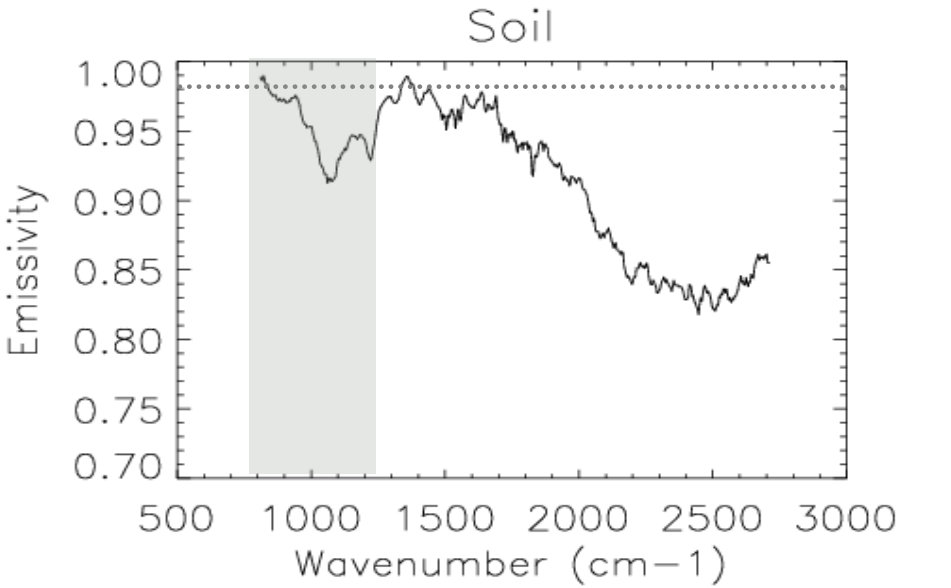
Retrieved Tskin RMS Assuming $\varepsilon = 0.98$

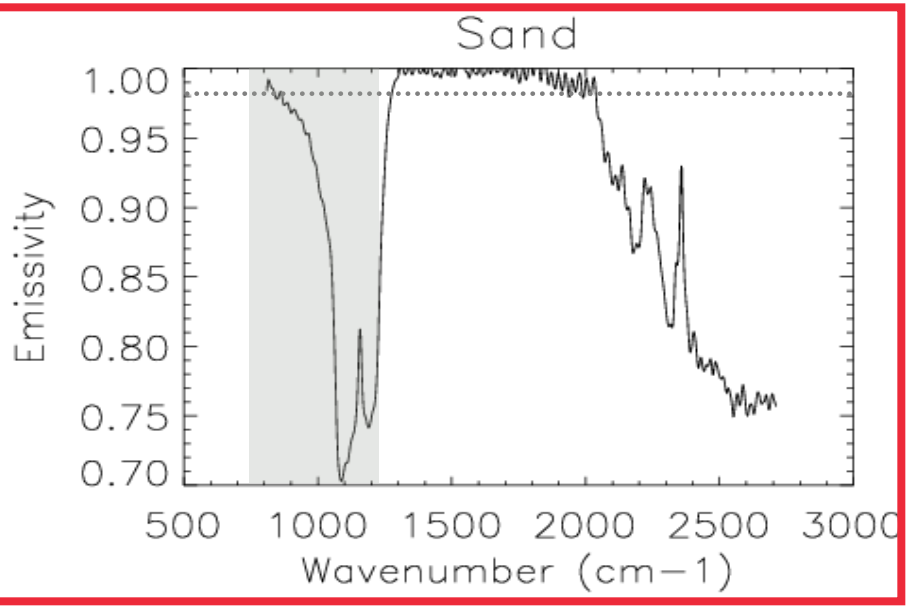


Example emissivity spectra









How can we represent emissivity in a retrieval?

- IR surface emissivity has large spectral variability
- Retrieving emissivity in *n* channels adds *n* unknowns to state vector
- Use **principal component analysis** to *compress* the emissivity spectrum
  - **Just a few unknowns**

Advantages of PC-based emissivity analysis

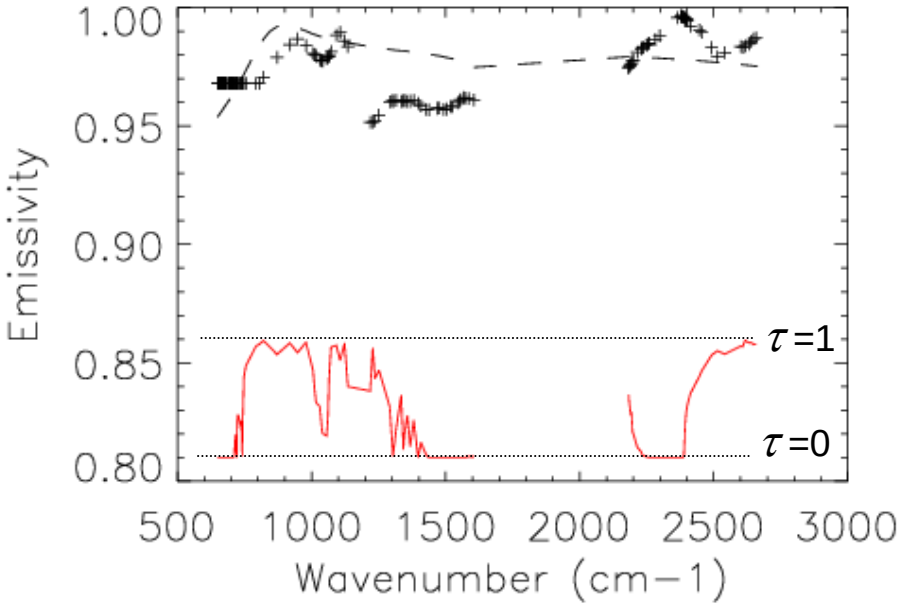
- PC-based approach
  - Use prior knowledge of spectral variation of emissivity
    (from lab measurements)
  - Constrains solution to realistic values
  - Retains realistic correlations between channels

→ **Helps to separate T_{skin} and $\varepsilon(\lambda)$**

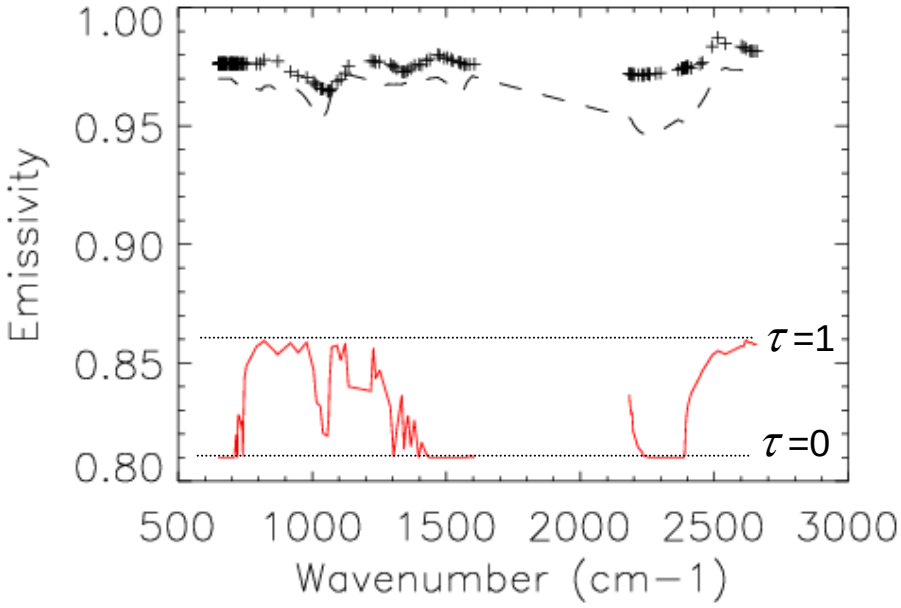
Retrievals from simulated radiances

(Using UWisc emissivity atlas)

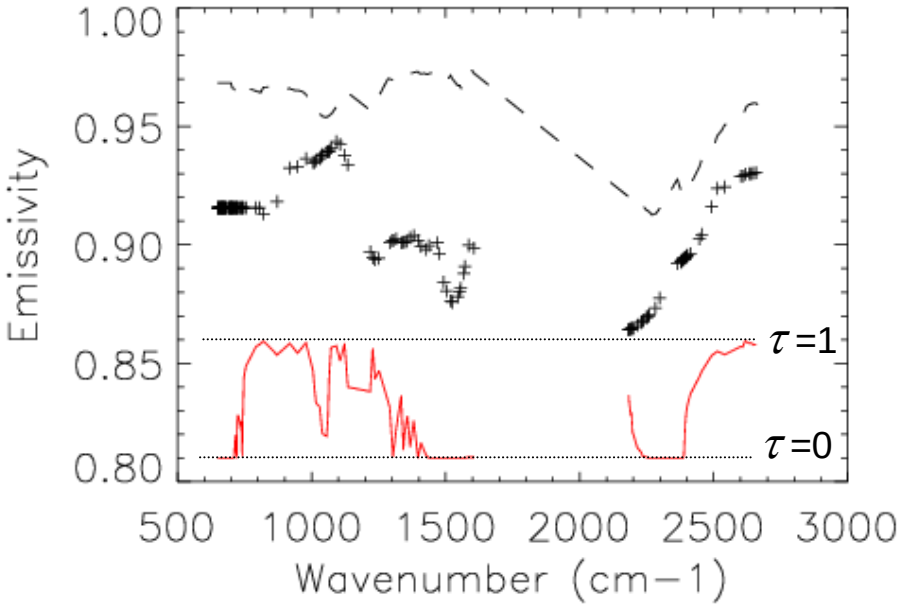
Sea



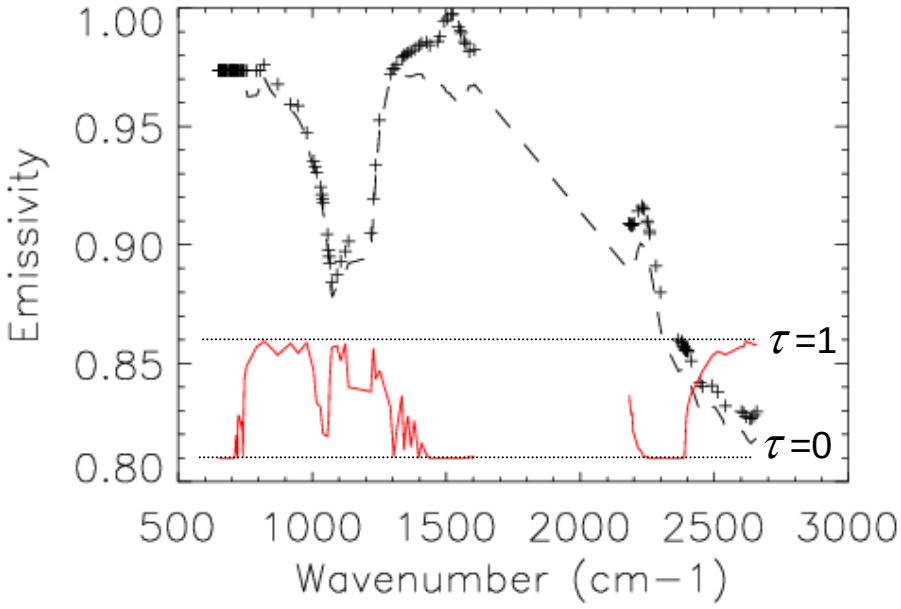
Vegetation?



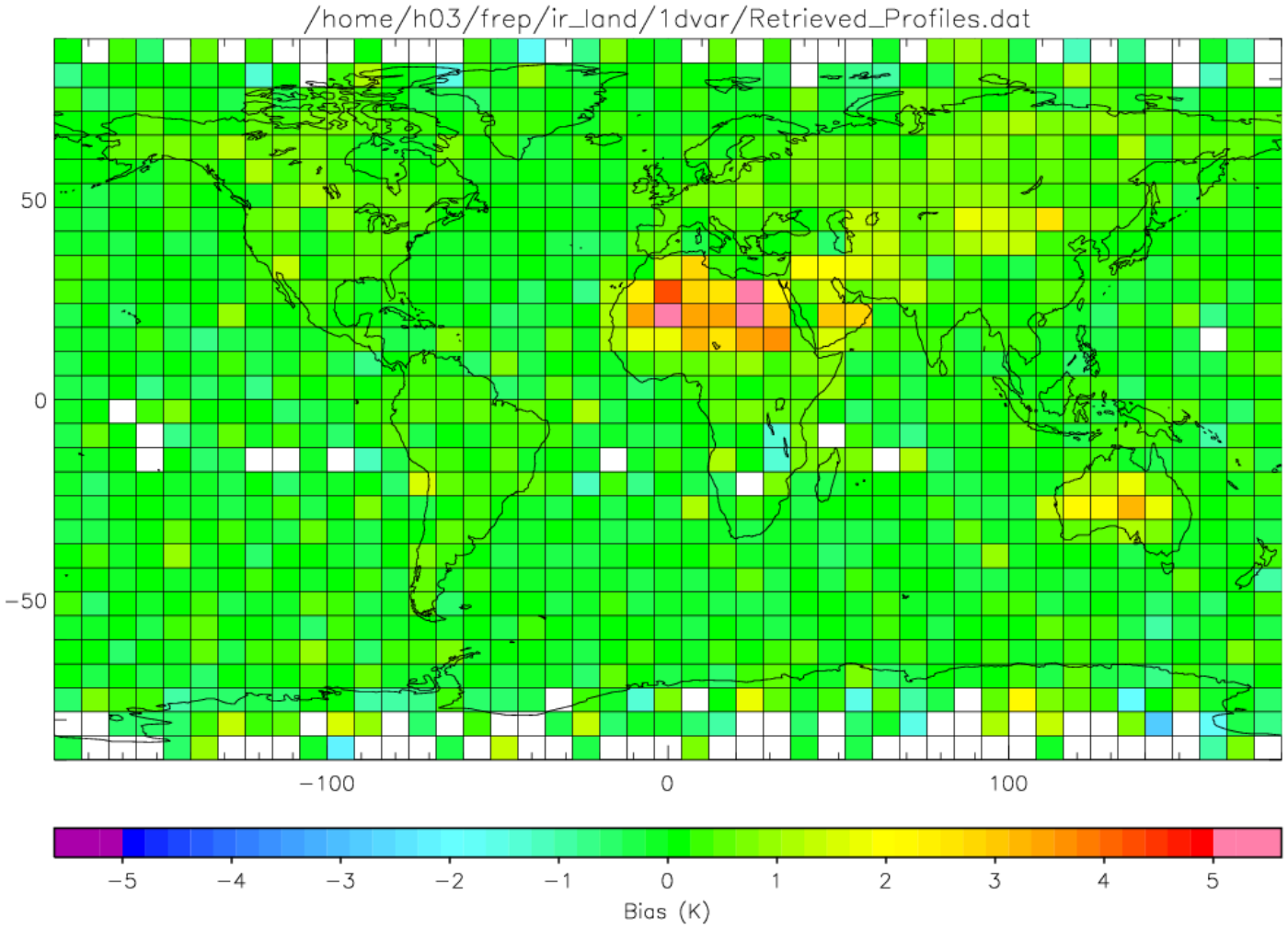
Bare soil?



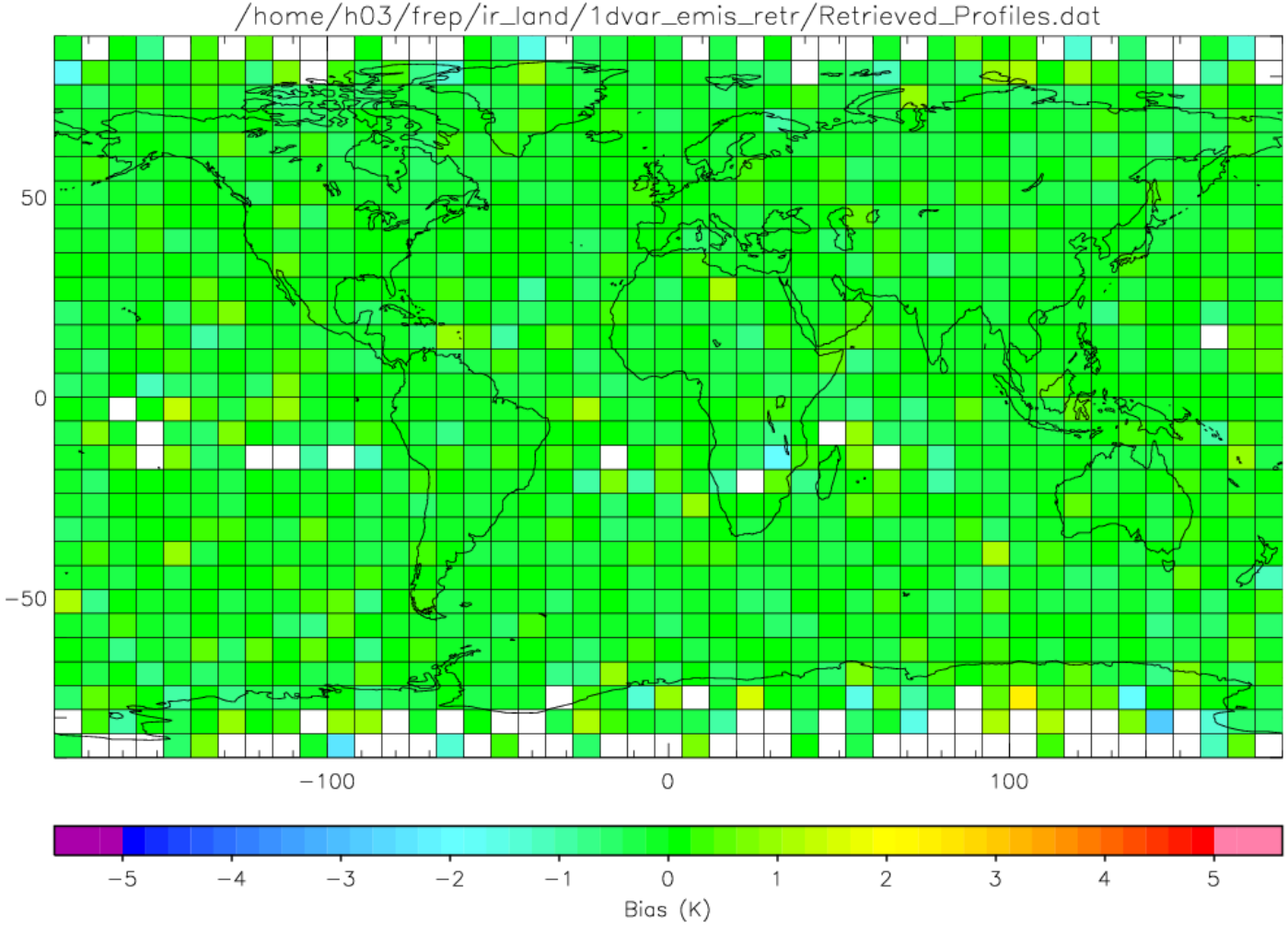
Desert



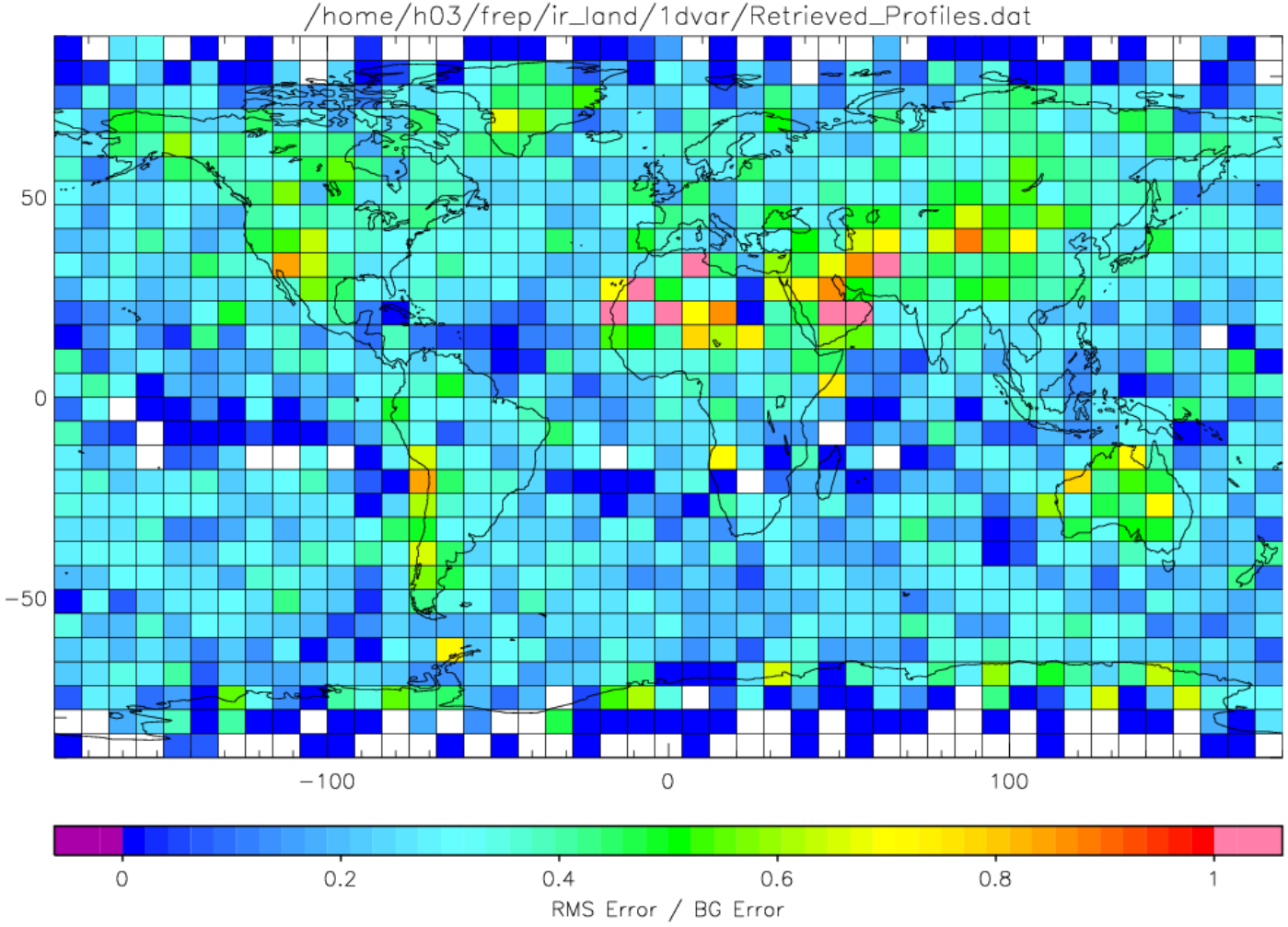
920 hPa T bias
Without emis retrieval



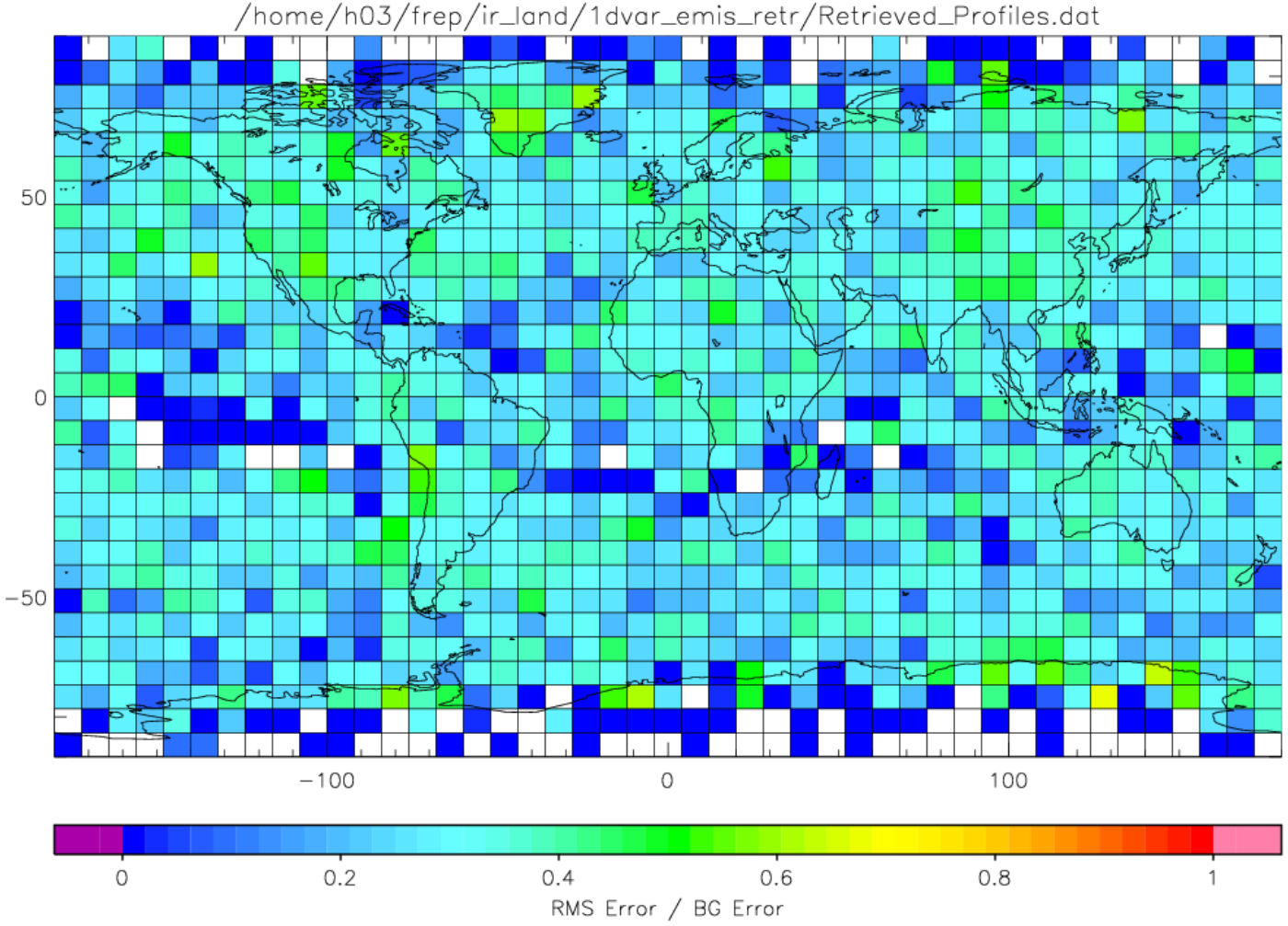
920 hPa T bias
Without emis retrieval



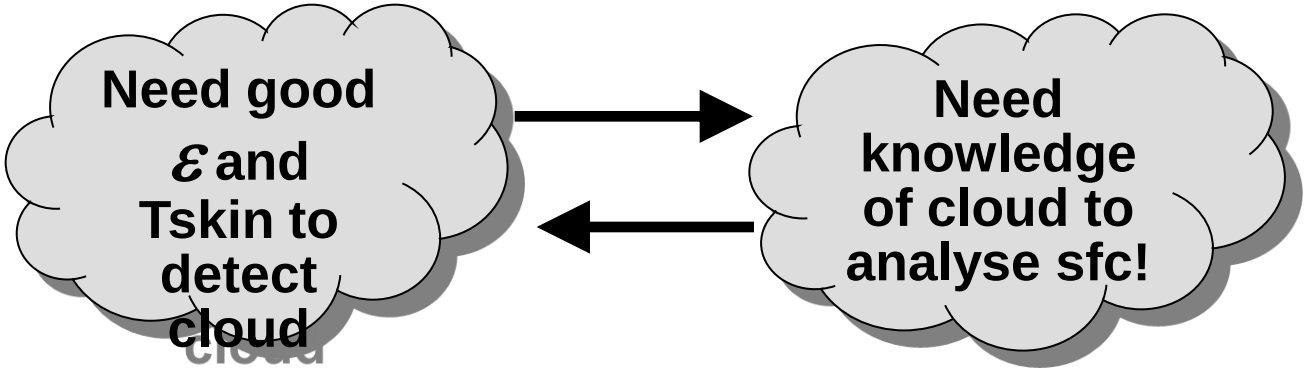
920 hPa T RMS
Without emis retrieval



920 hPa T RMS
With emis retrieval

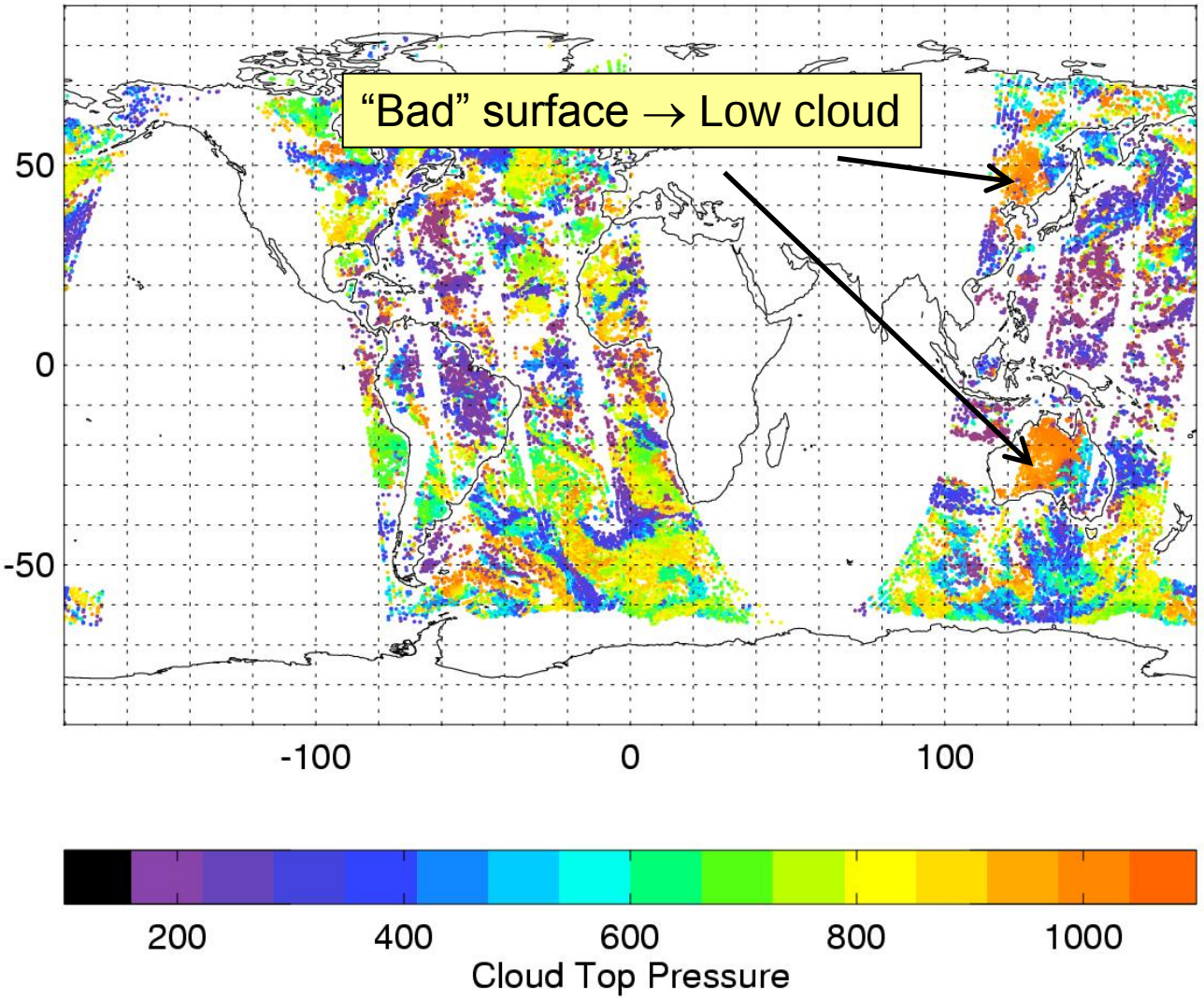


What about clouds?



Analysed cloud top pressure (IASI)

(fixed surface emissivity)



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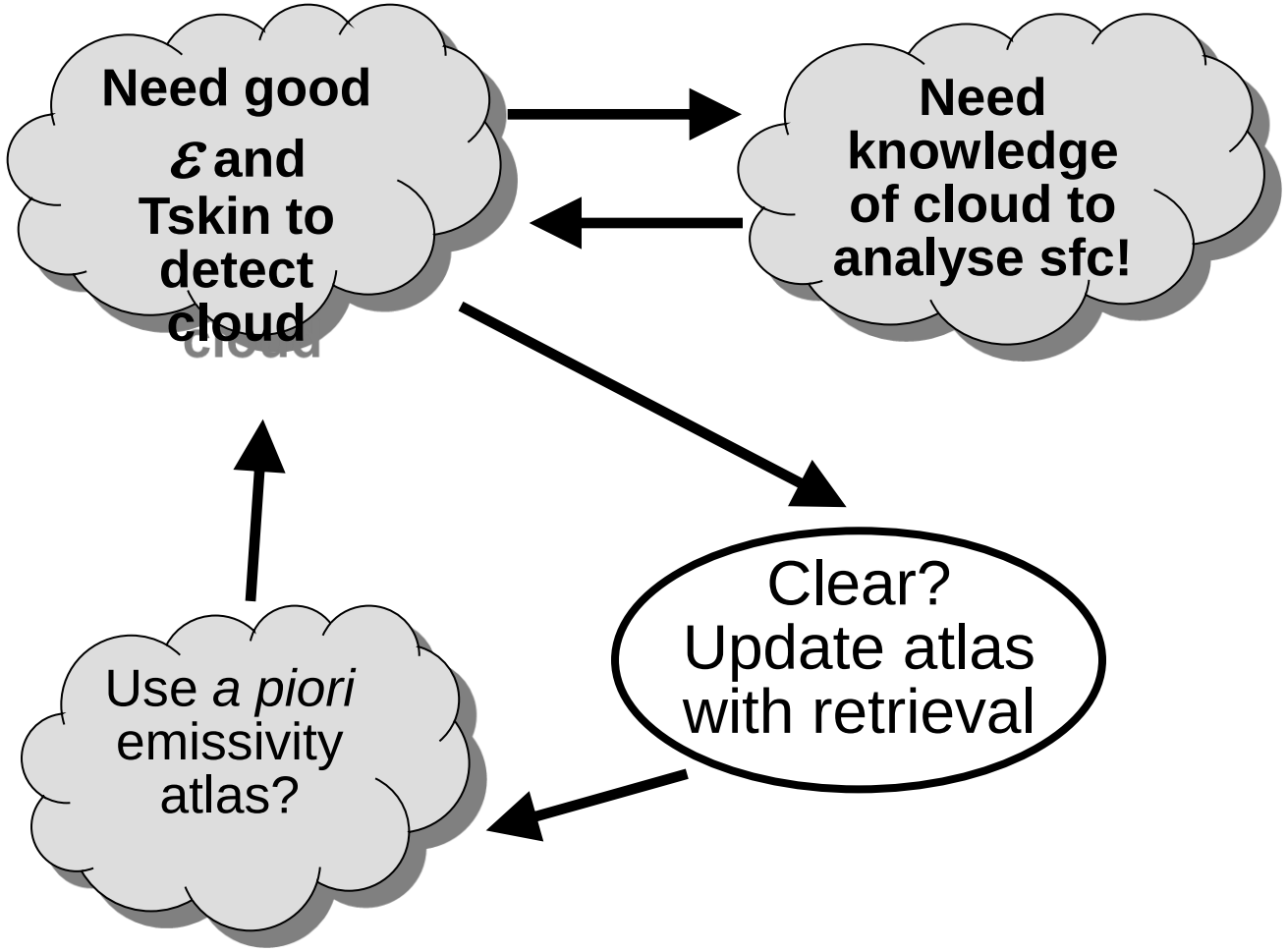

Summary

- 1D-Var cloud analysis: Operational for IASI within a couple of months
  - Retrieve CTP, CF
  - Use channels peaking above cloud
  - Significant forecast improvement
    - Approx. double the impact from IASI
  - (Already operational for AIRS since 2008)

- Actively investigating assimilation over land
  - Testing eigenvector emissivity retrieval
    - Proved useful in 1D-Var experiments
  - Not tested in NWP system yet!