Status of satellite data assimilation in polar regions at the Met Office

James Cameron, Brett Candy, Mary Forsythe, Fiona Hilton,

Colin Parrett, Ed Pavelin, Roger Saunders

Outline

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- Review of satellite data usage over poles.
- Preliminary results from trials of assimilating IASI over Antarctica.
- Plans for retrieving surface emissivity.

Data Usage

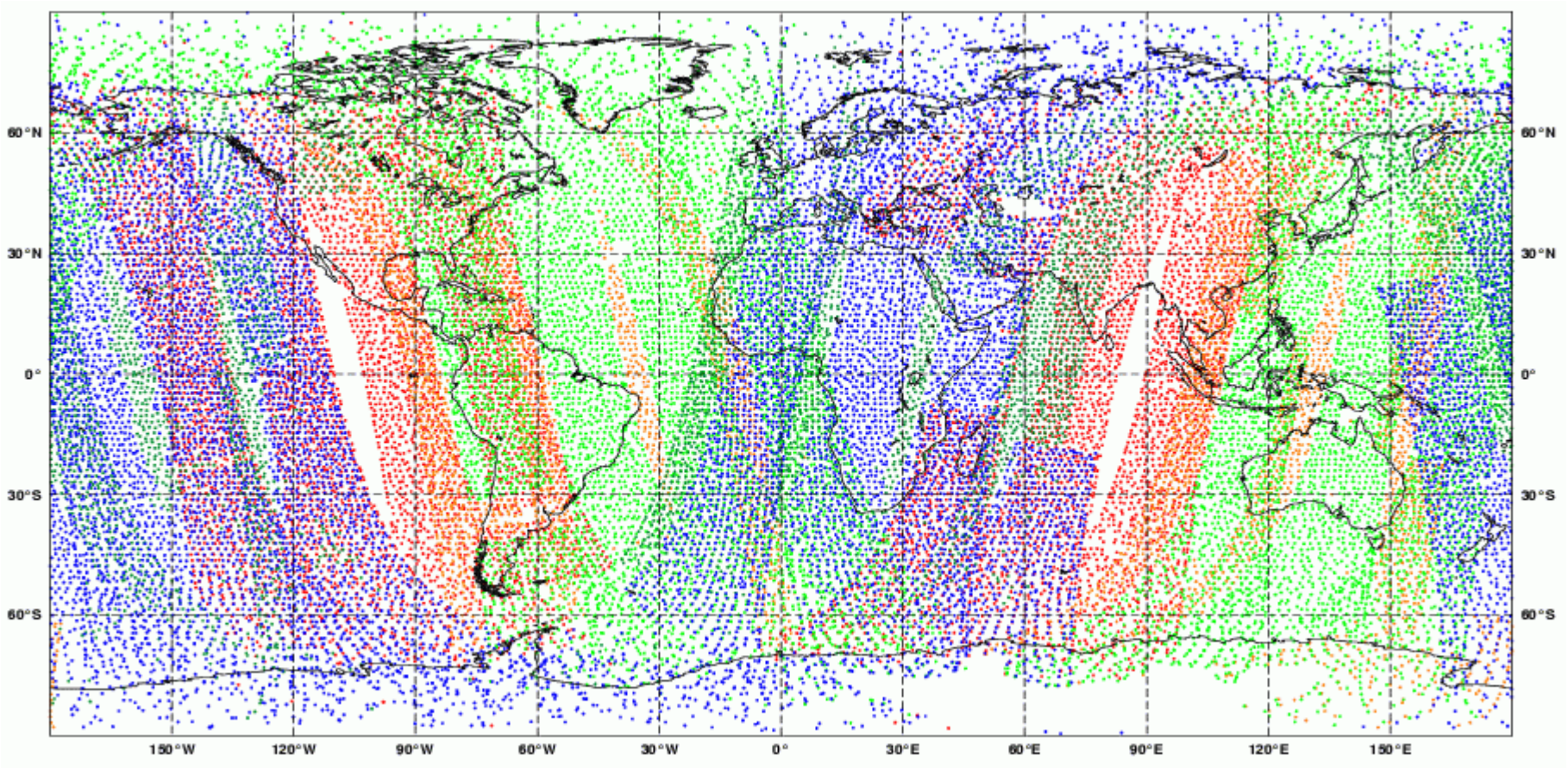
ATOVS data usage

Satellites: Metop-A, **NOAA-19** (MHS noisy), **NOAA-18** (no HIRS), **NOAA-17** (HIRS only), **NOAA-15** (no HIRS)

	Sea	Sea Ice	Land	High Land >1000m
AMSU-A	1, 2, 4-14	6-14	6-14	7-14
AMSU-B	3-5	Nil	Nil	Nil
HIRS	4-7, 11, 12, 15	Nil	Nil	Nil

ATOVS data coverage

8667 NOAA-15
3753 NOAA-17
10966 METOP-A
4486 NOAA-18
11069 NOAA-19



SSMIS

Satellite: DMSP F16

(temporarily removed due to solar array movement and misnavigations – should be back in operations soon)

	Sea	Sea Ice	Land	High Land >1000m
SSMIS	2-7, 9-16, 23	4-7, 23	4-7, 23	5-7, 23

IASI and AIRS

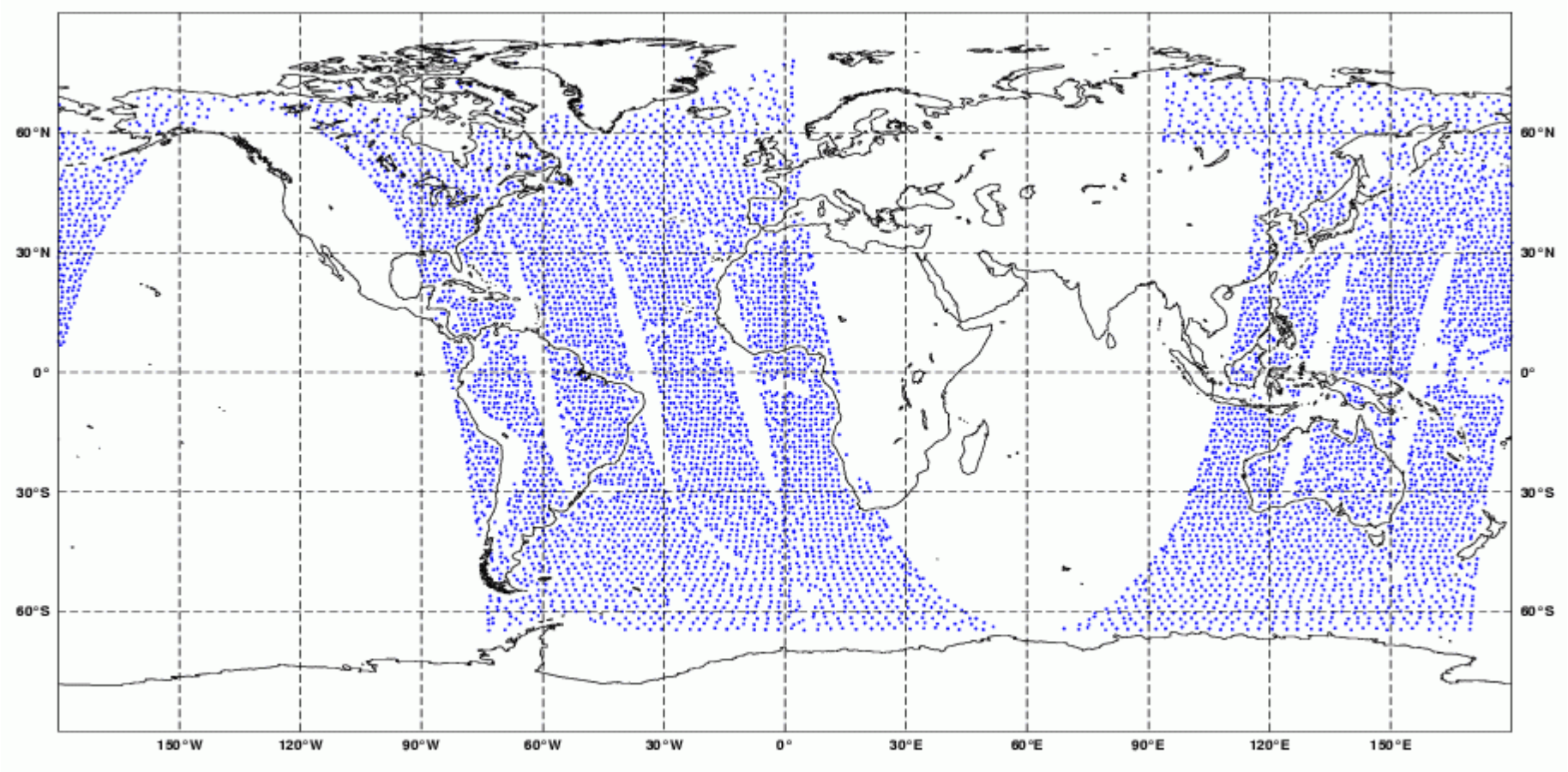
IASI

- 138 channels over sea
- 63 channels over land
- Nothing over sea-ice or high land
- Nothing below -65° latitude
- Long-wave CO_2 uses 0.5K errors
- Water vapour band uses 4K errors

AIRS

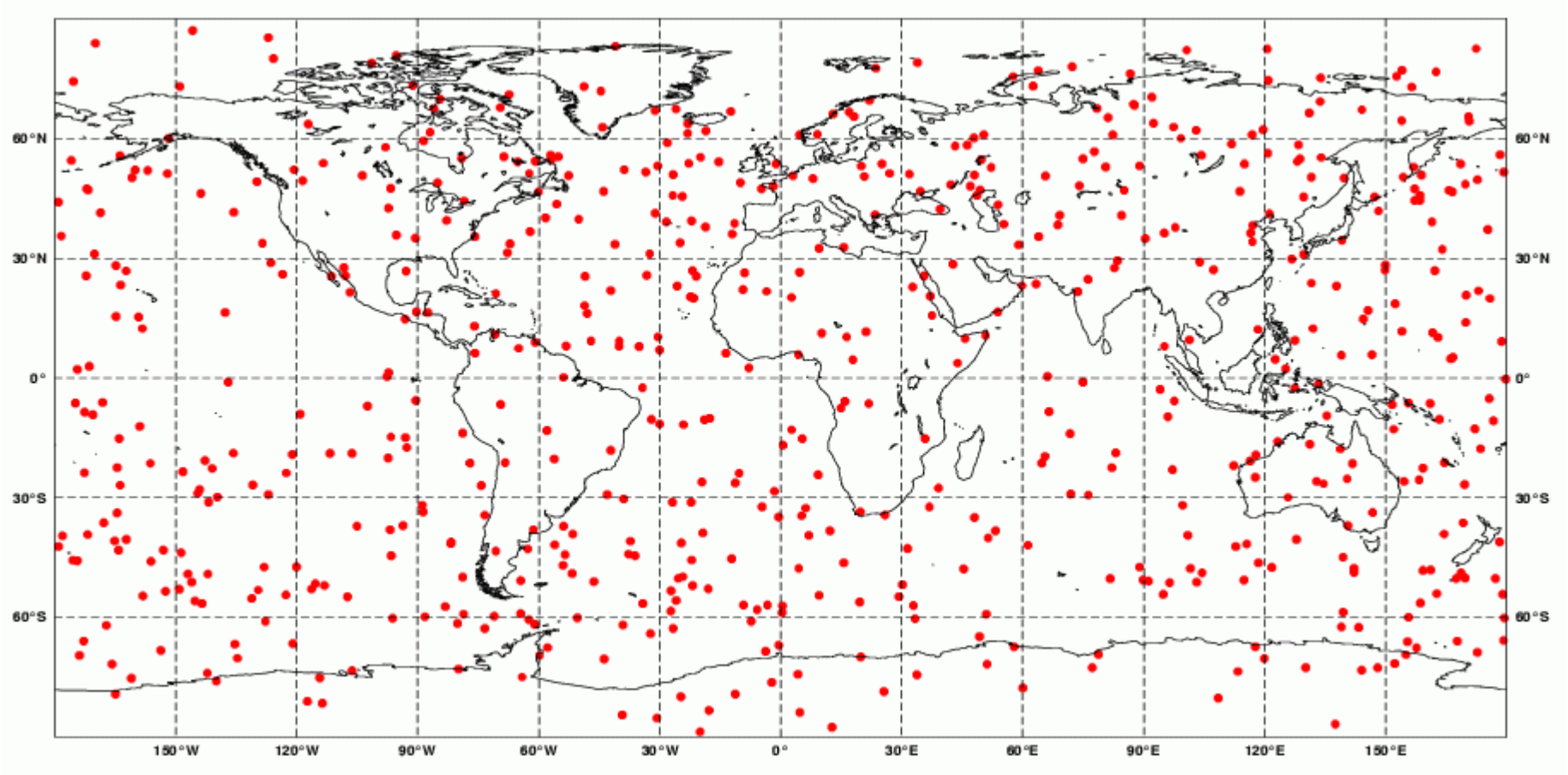
- 48 channels, sea only.
- Long-wave CO_2 uses 1K errors
- Water vapour band uses 4K errors

IASI data coverage

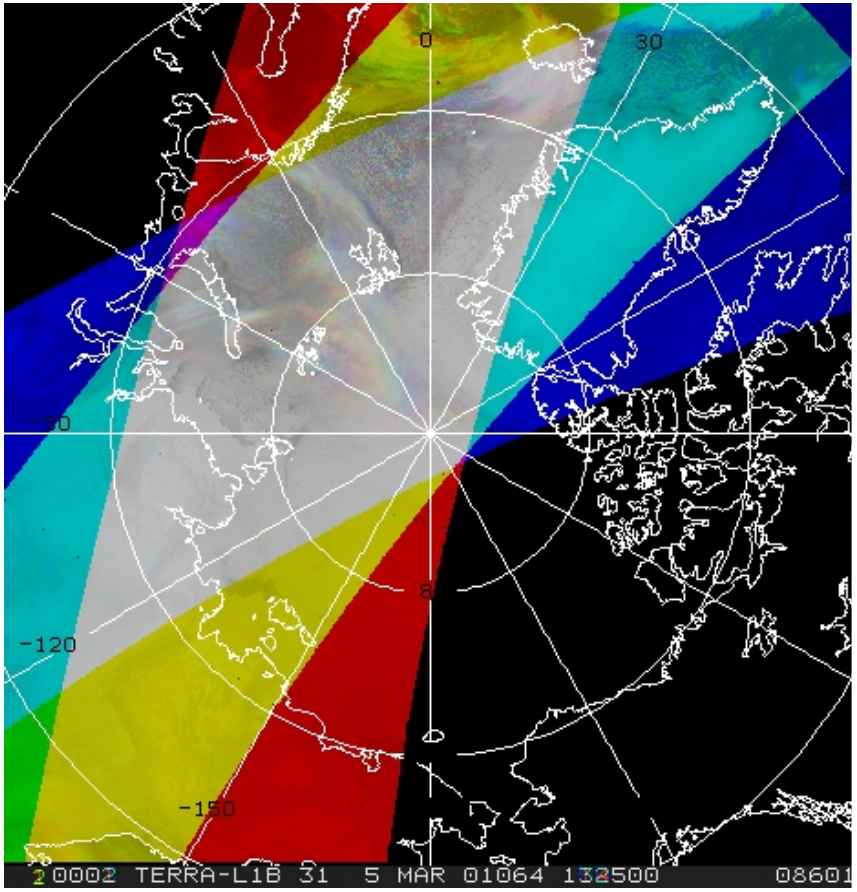


GPSRO

Bending angles from: COSMIC, GRACE-A, and GRAS



Polar AMVs



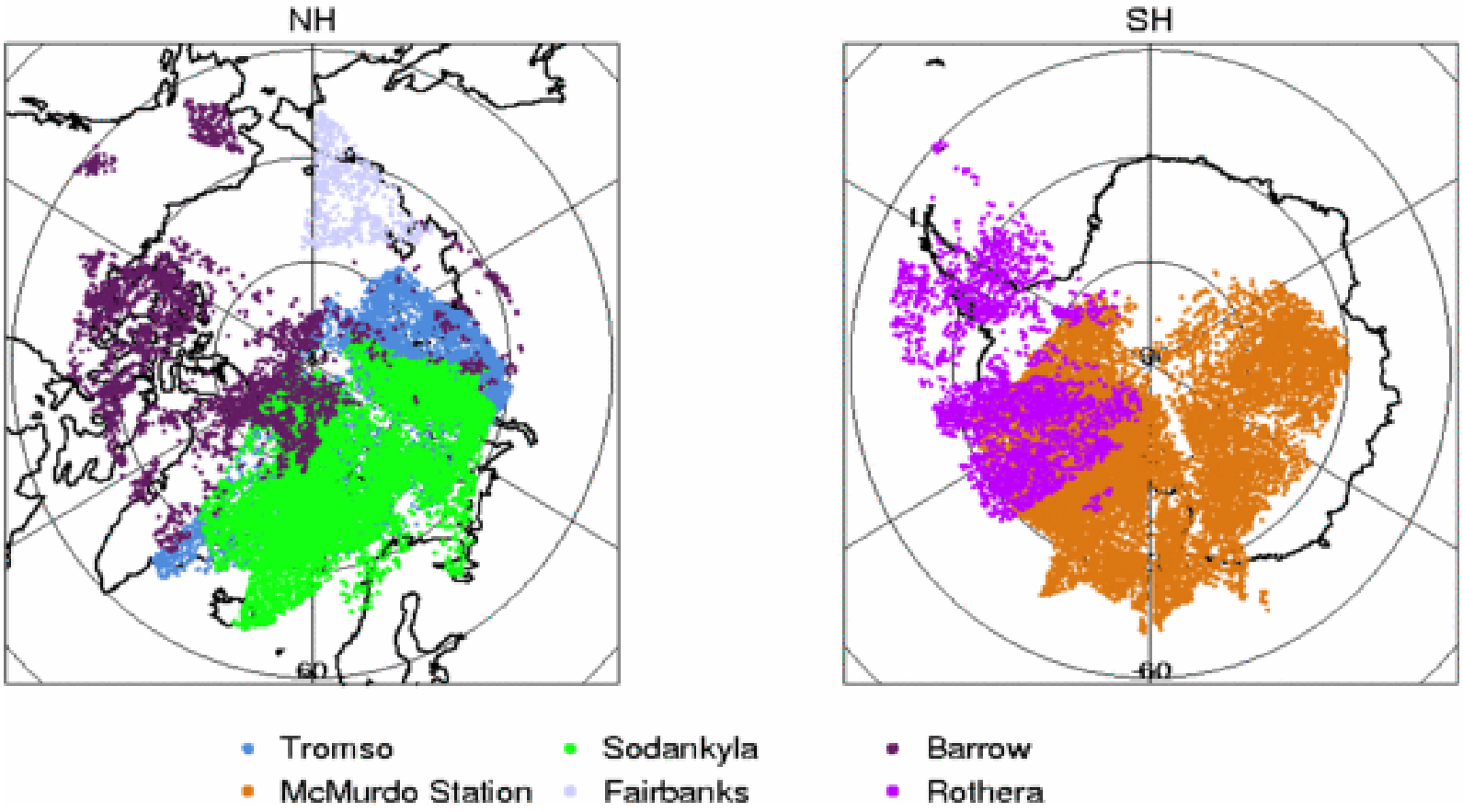
	MODIS	AVHRR
Platforms	Terra, Aqua	NOAA 15-19 Metop
Channel	IR, WV	IR only
Available since	2002	2007 (NOAA platforms)

Polar winds are derived in the overlap region (shown in white) between three successive orbits, by tracking clouds or WV features.

Picture from Dave Santek

Polar AMVs direct broadcast

Available from Tromsø, McMurdo Station, Sodankyla, Fairbanks, Barrow and Rothera – example coverage for 1200 UTC on 19 Nov 2009 shown below.



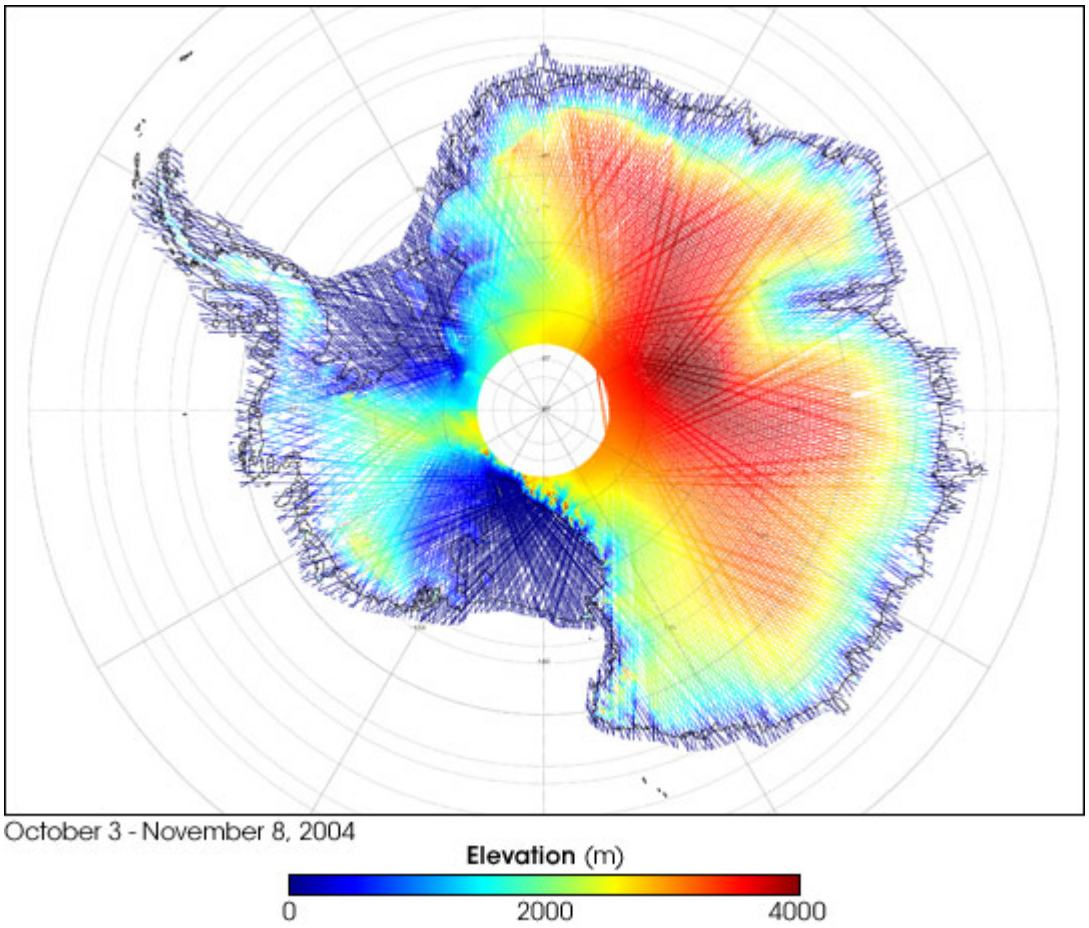
AMDARS and sondes

- Since 9 March, we are assimilating temperatures and winds from the 2 gondolas launched from the Seychelles and winds only from a balloon launched on the 8 February.
- We have been assimilating the drop sondes from the gondolas since the 10 February

- The Met Office is providing radiosondes to the British Antarctic Survey to launch during the Concordiasi campaign.

Trials

ICESat Elevation



Lots of high land

> 1000m

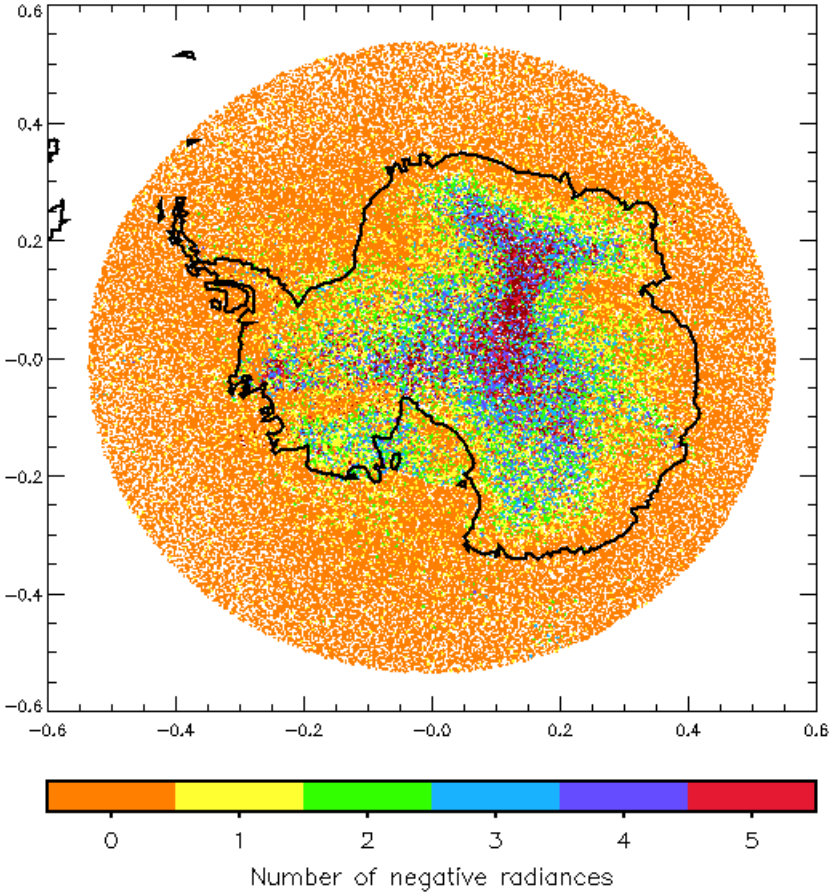
IASI trials

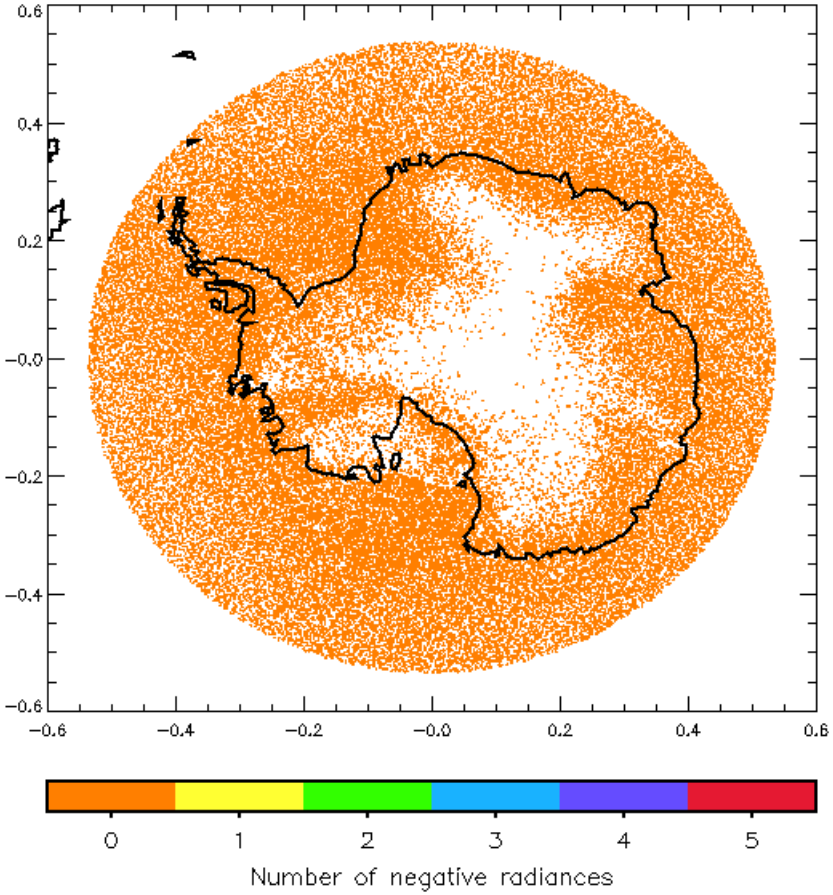
Trial period: 22-August to 30 September 2009

- Control (no IASI assimilation below -65°)
- Sea-ice
  - Turn on sea-ice below -65°
  - Same channel selection as over sea
  - Emissivity of 0.99.
- Sea-ice+land
  - Turn on sea-ice, land and high land below -65°.
  - High land channel selection the same as land
    (includes 6 high peaking water vapour channels!)
  - Emissivity of 0.98 for land.
- Sea-ice+land+QC fix
  - No quality control on short-wave channels
  - Add a fix to the relative humidity quality control.

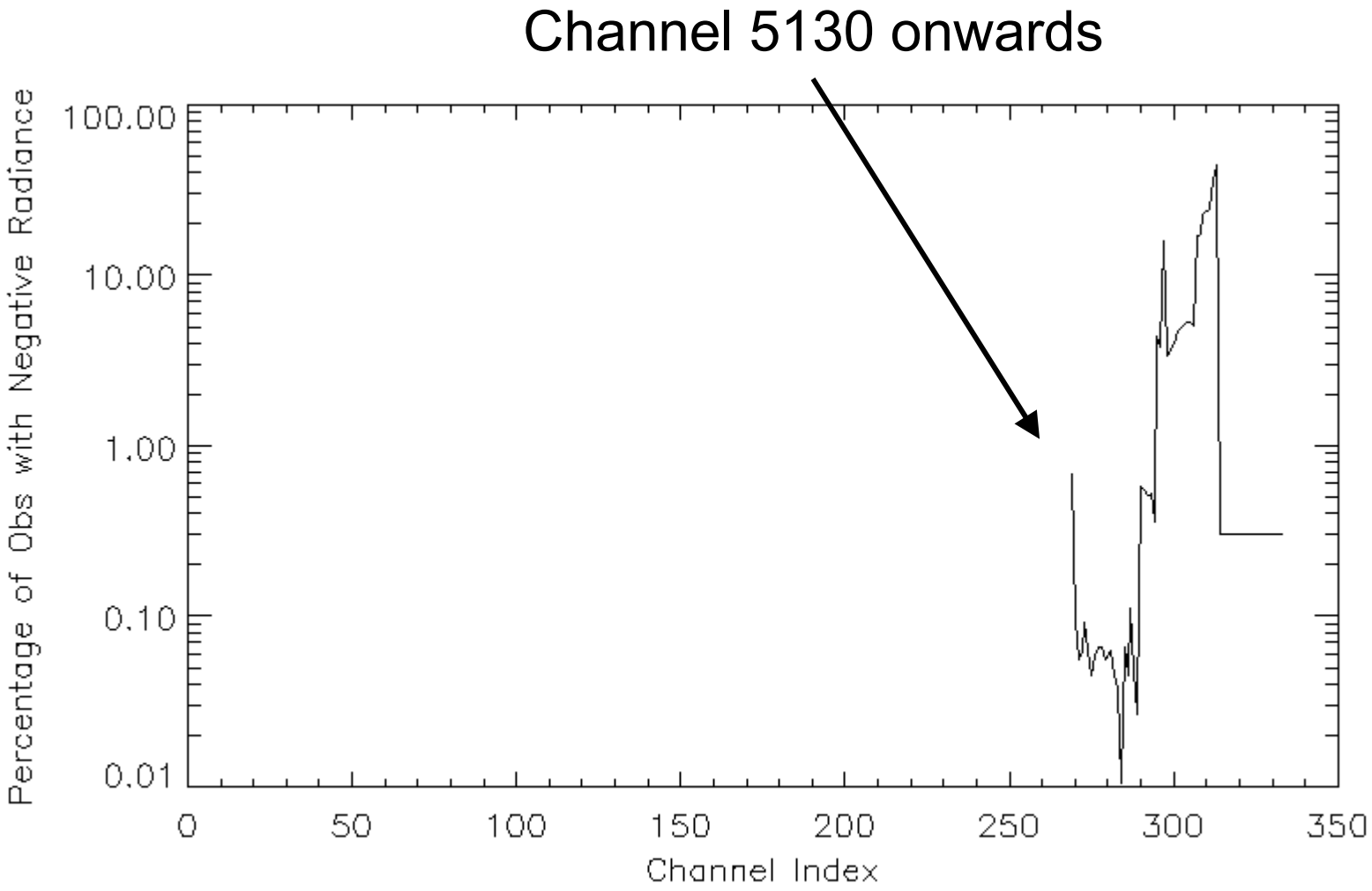
Short-wave channels

Number of Negative Radiances

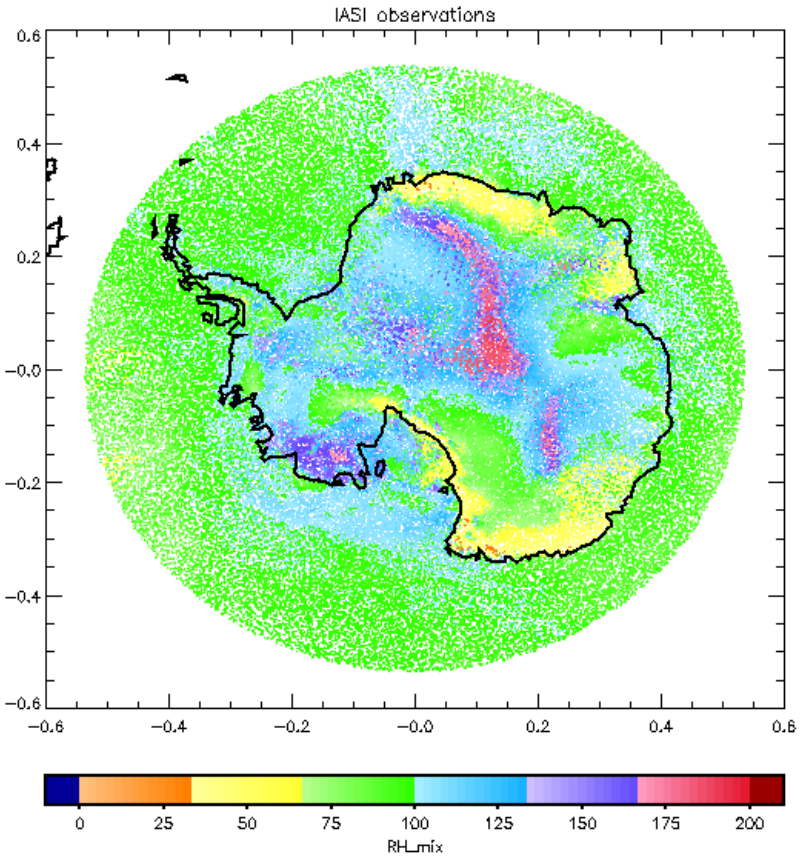




Negative Radiances

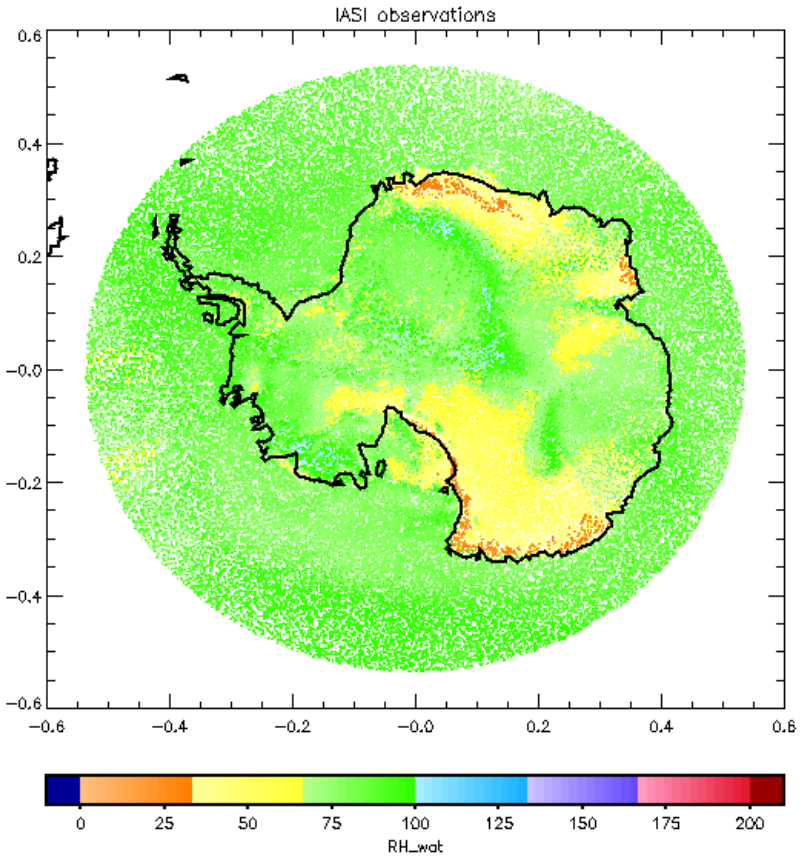


Relative Humidity Quality Control



T>0 RH w.r.t.water

T<0 RH w.r.t. ice



RH w.r.t.water

Trial results

Trial validation from 1 September 2009

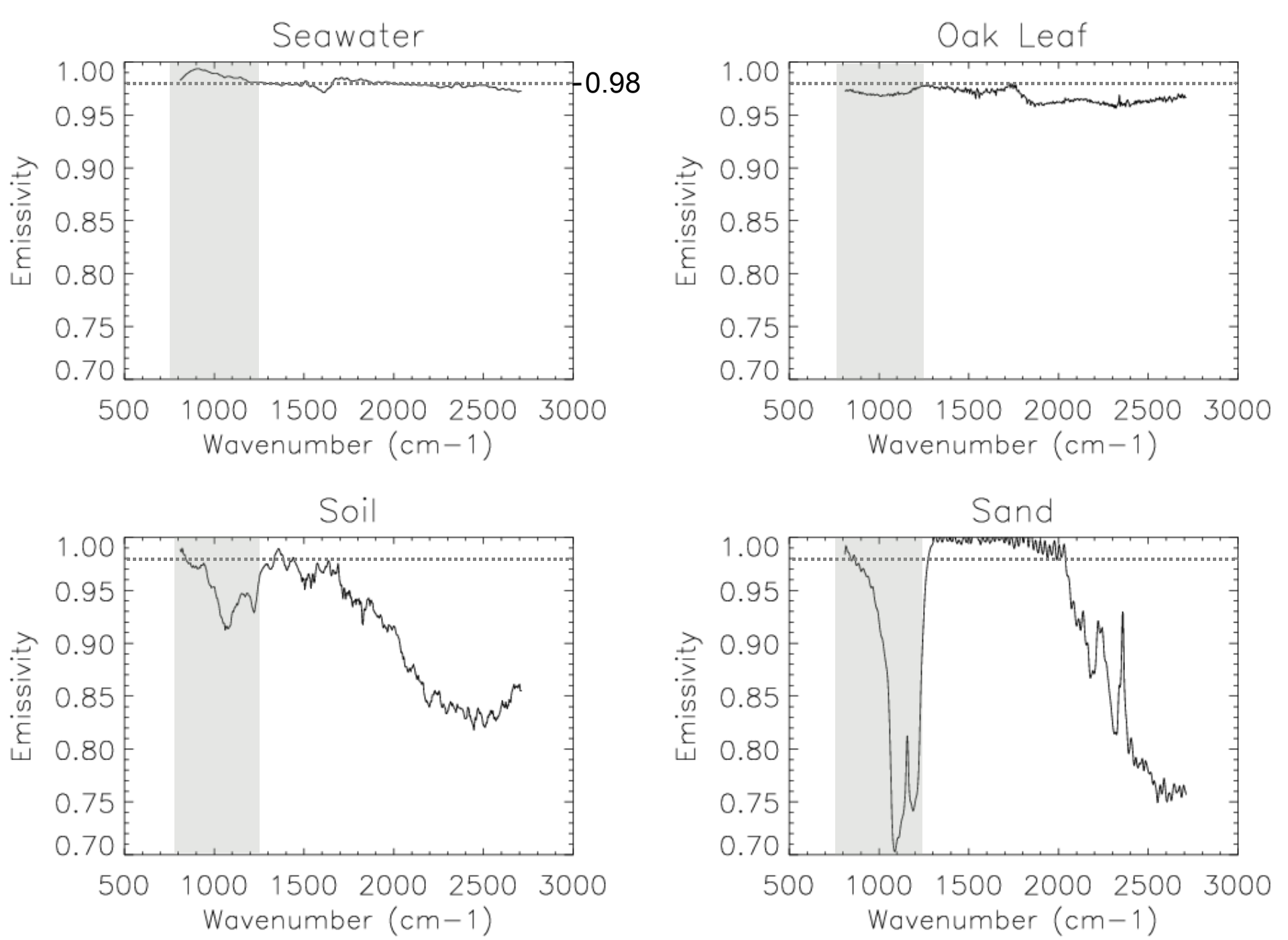
Trial	# days	NWP Index vs. Obs	NWP Index vs. Ana
Sea Ice	26 days	-0.1	0.0
Sea-Ice + Land	26 days	0.1	0.2
Sea-Ice + Land + QC fix	10 days	-0.2	0.2

Surface Emissivity

Ed Pavelin

Using IR radiances over land

- Currently:
  - Assume emissivity $\mathcal{E}$ = 0.98 for IR sounders over land
  - Not 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


Seawater
Oak Leaf
Soil
Sand
Emissivity
Wavenumber (cm−1)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
500
1000
1500
2000
2500
3000
0.98

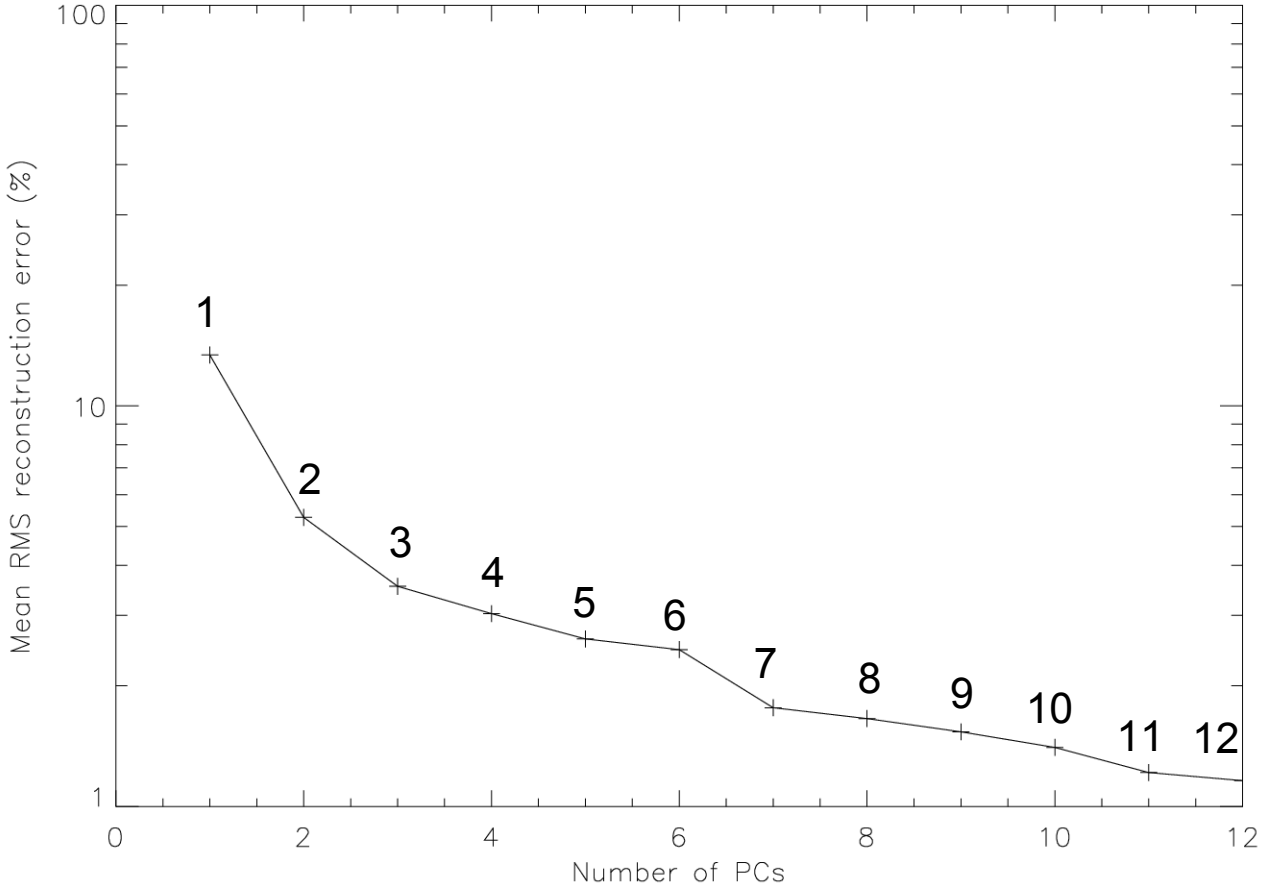
PCA training

(With thanks to Stephan Havemann!)

- Training dataset
  - As used in Havemann-Taylor Fast RTM
  - Based on laboratory measurements
    - ASTER spectral library
    - MODIS UCSB library
    - Snyder (1998)
- Do Singular Value Decomposition

  → Eigenvectors and PCs (~ weights) corresponding to training dataset

PC reconstruction errors



Simulation study

- Simulate AIRS radiances using profile data set, RTTOV8 and emissivity atlas
  - Add simulated measurement errors
- Simulate model background profiles
  - Add errors consistent with Met Office B-Matrix
- Perform retrievals using stand-alone 1D-Var code
  - Retrieve emissivity principal components.
- Compare retrieval to true profiles / emissivity.

Simulated AIRS Radiances

- Simulated using **RTTOV8**
- Atmospheric profiles from ECMWF/Chevallier 13495-profile dataset
- Surface emissivity from **UWisc/CIMSS IR emissivity atlas** (2006 data used)
  - Derived from MODIS observations, fitted to laboratory spectra
  - Independent of training dataset
  - A few uncertainties, but OK for simulation studies
- Simulated observation errors corresponding to expected AIRS brightness temperature errors

1D-Var retrievals

- **NWP SAF Met Office 1D Var** with **RTTOV 9**

- **+ PC wrapper subroutines**
  - **PC2Emis**:
    Transforms PCs into emissivity spectrum
  - **EmisK2PC**:
    Transforms emissivity Jacobians into PC Jacobians

- Add 12 emissivity PCs to retrieval vector
- Idealised case: Use all channels
  - Actually use every *alternate* channel (to reduce cost)

- **ONLY CLEAR SKY at the moment!**

Background emissivity for 1D-Var

- Need good first guess
- Possible sources of background information:
  - Fixed 0.98 emissivity
  - Emissivity of sea water
  - IR emissivity atlas

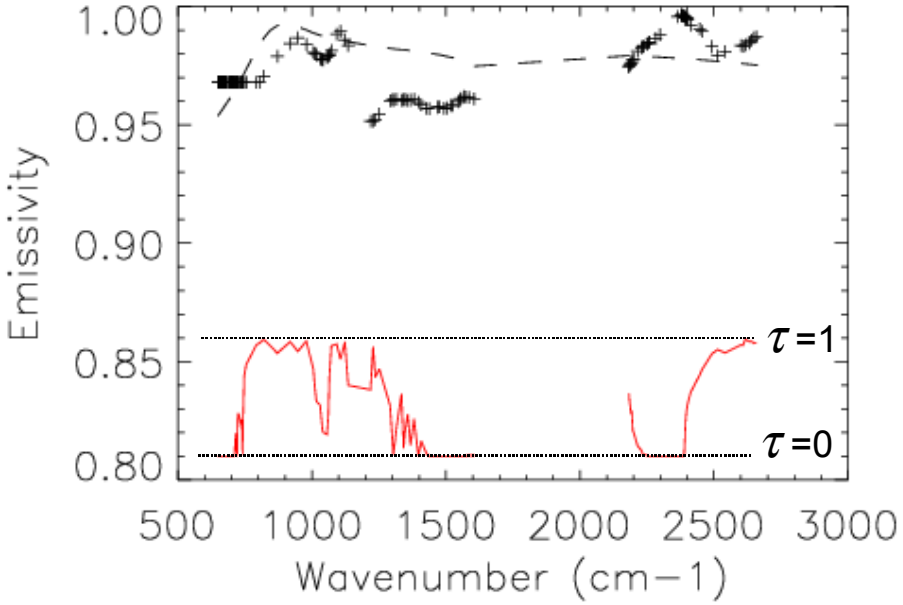
Land: 0.98

Sea: Sea water from lab measurements

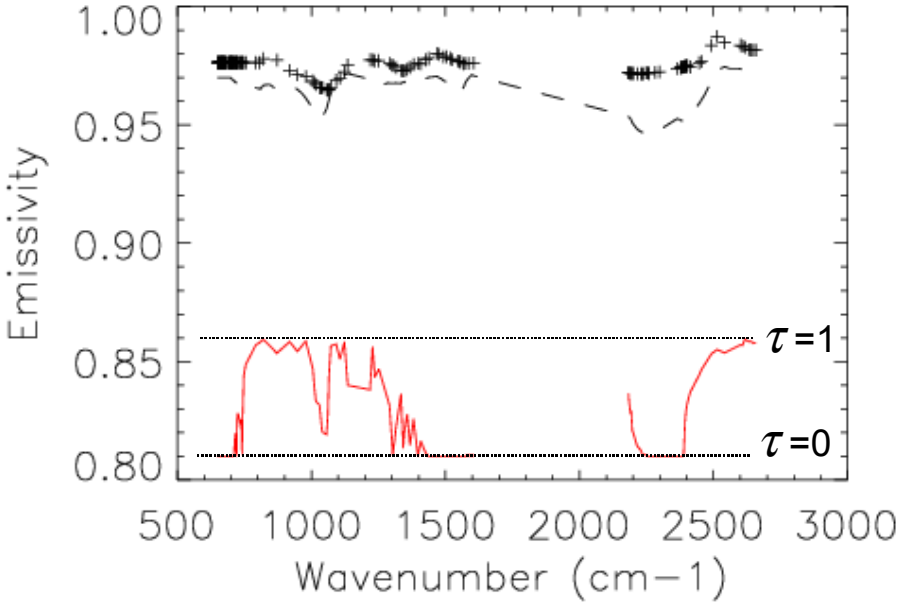
- Assume **B** = covariance of training dataset

N.B.: Retrievals are **independent** of ε atlas

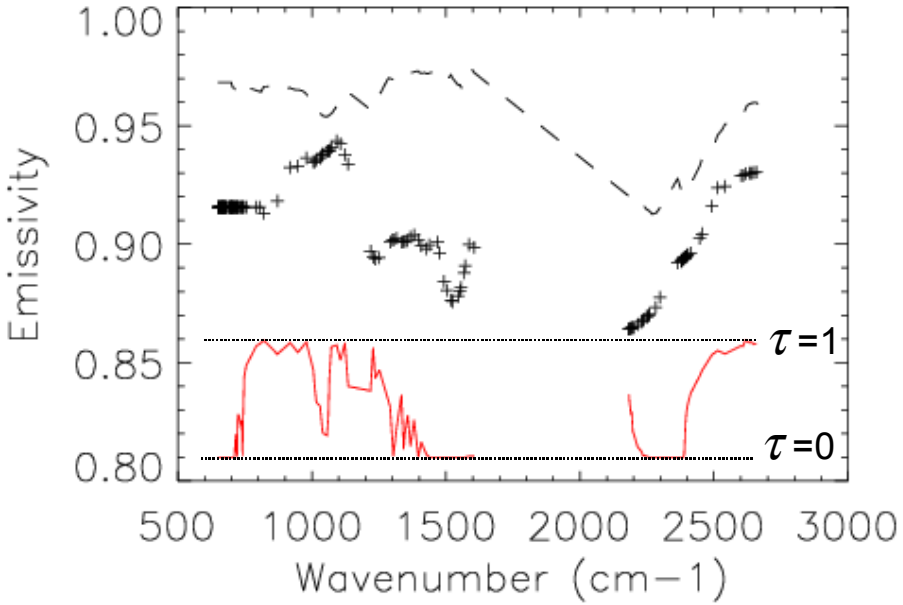
Sea



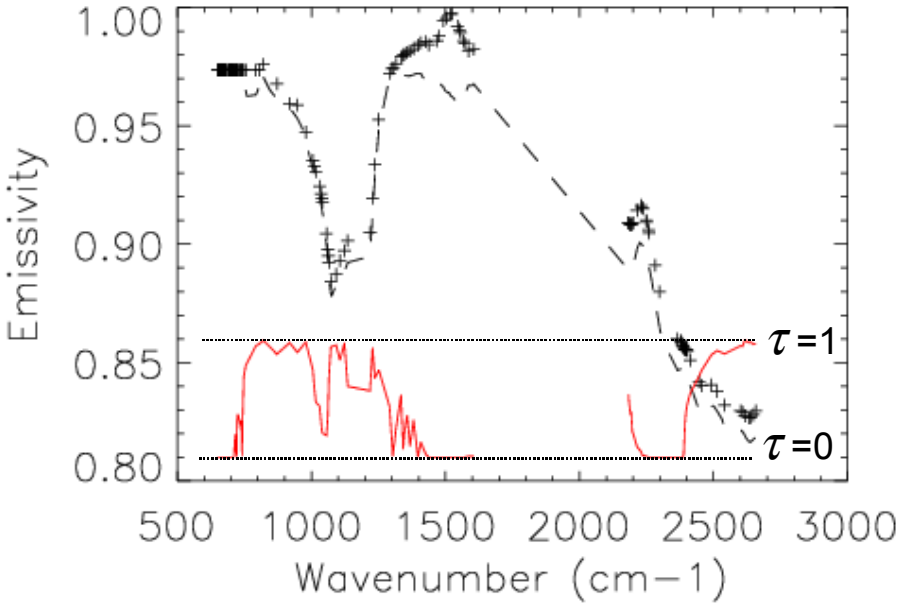
Vegetation?



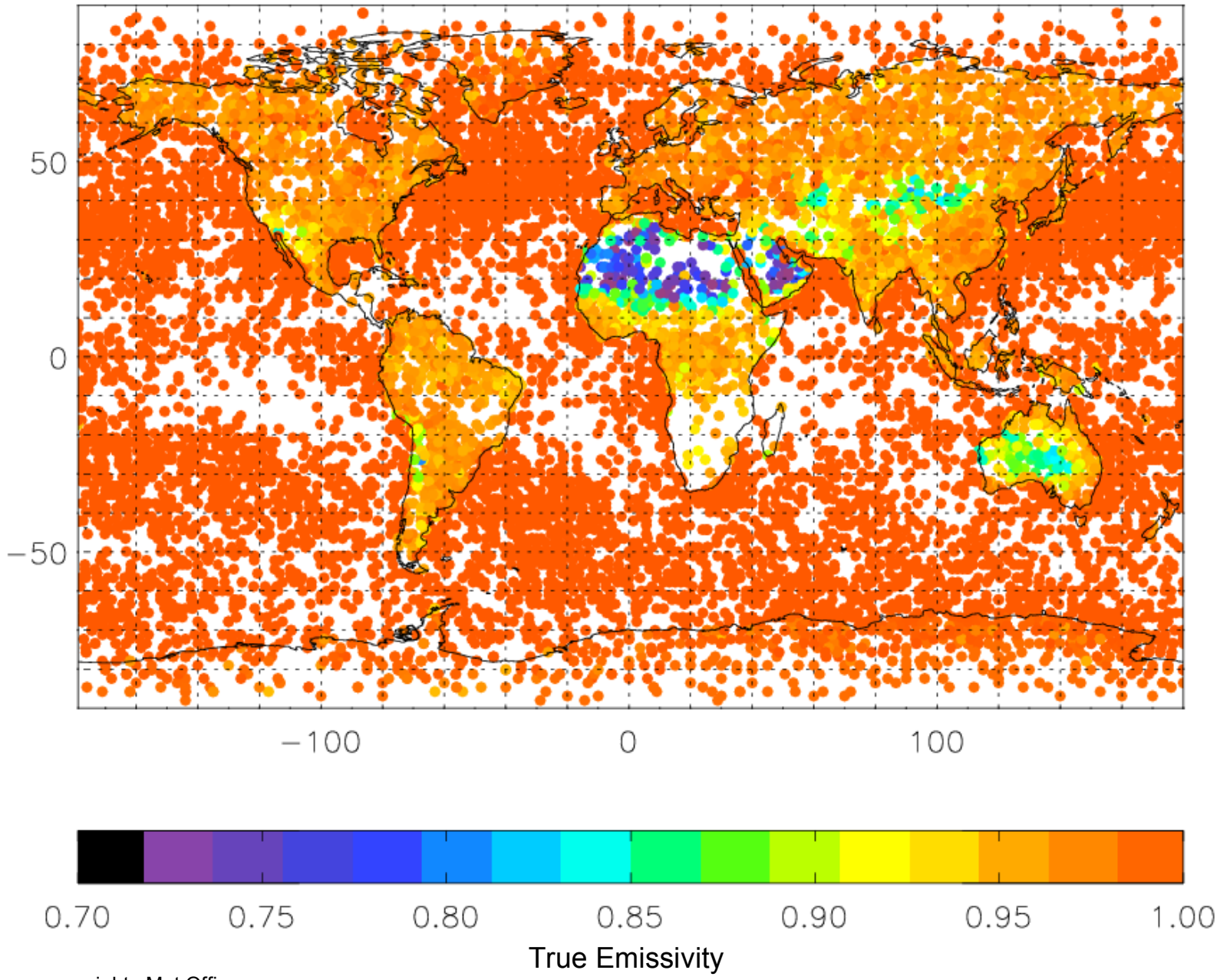
Bare soil?



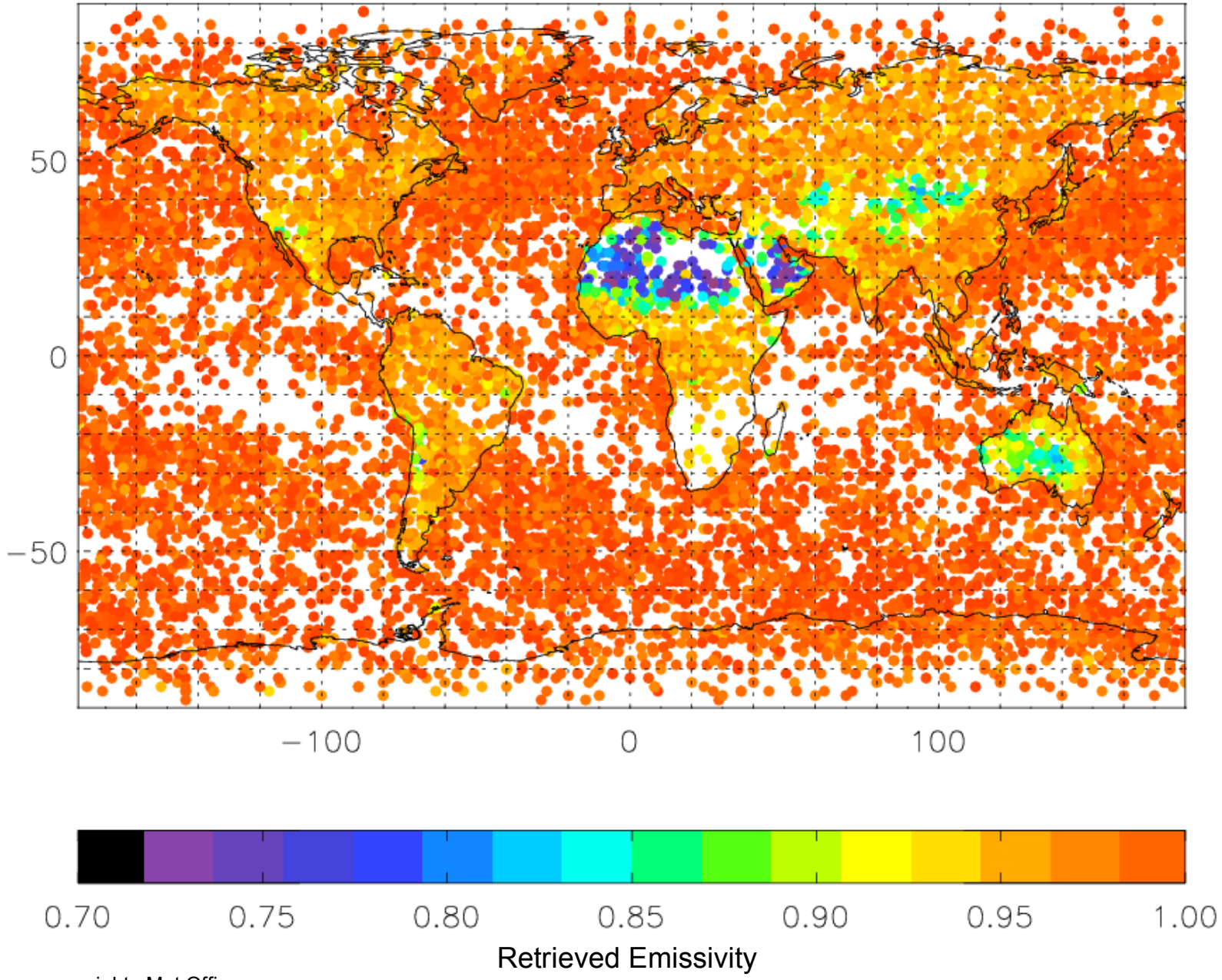
Desert



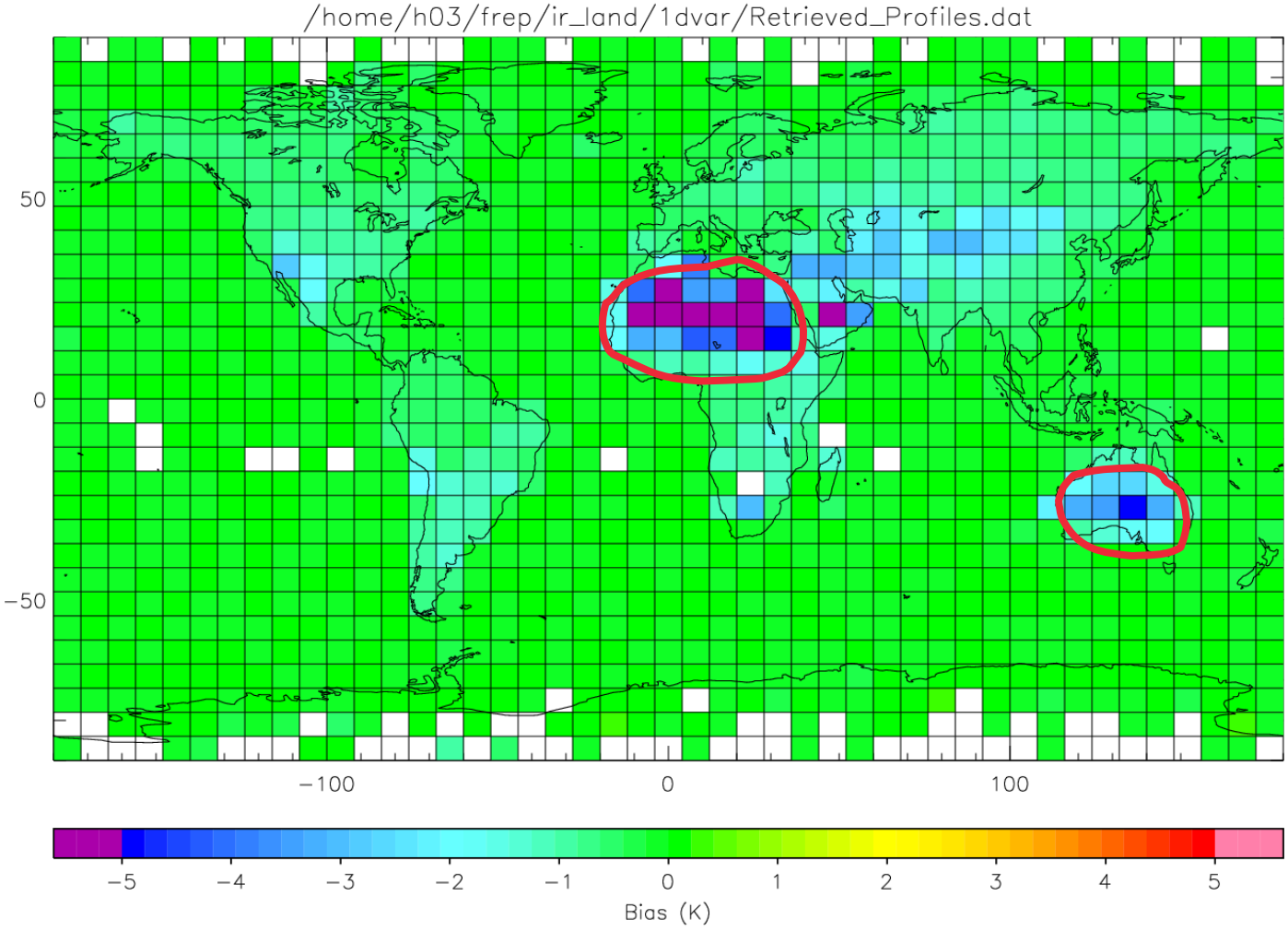
ATLAS: 9.32 μm (Mineral signal)



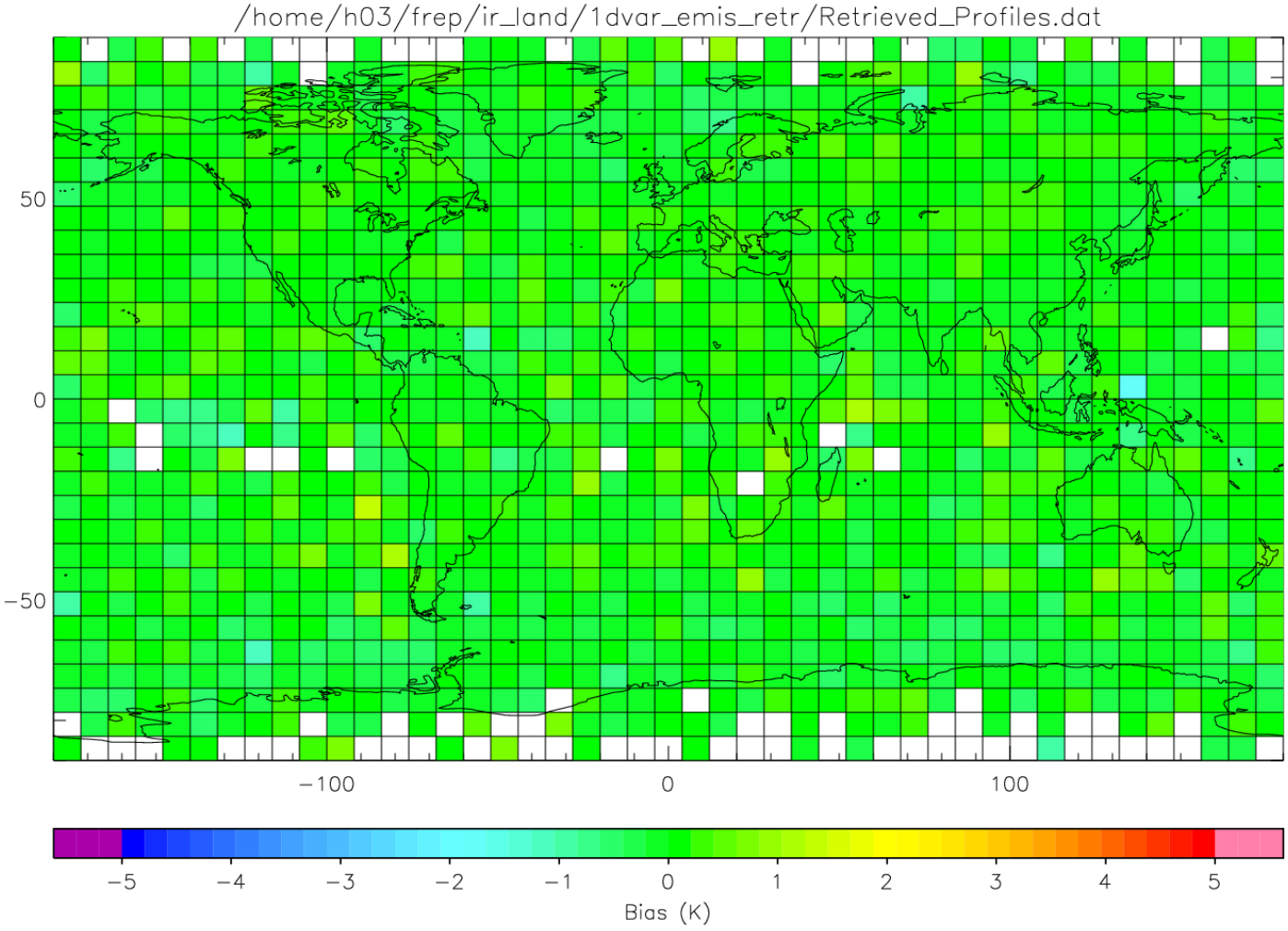
RETRIEVAL: 9.32 μm (Mineral signal)



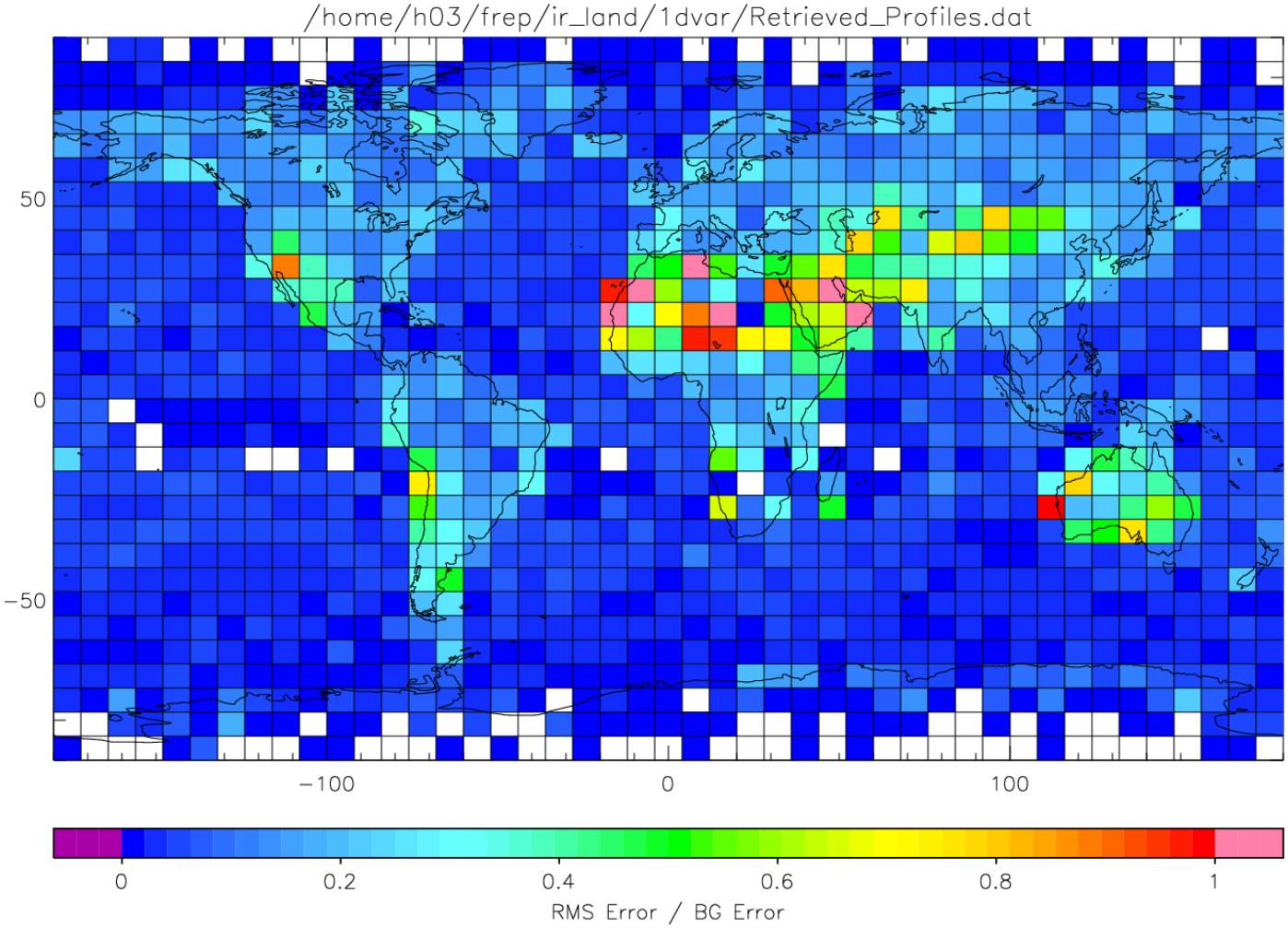
T_{skin} bias Assuming $\varepsilon = 0.98$



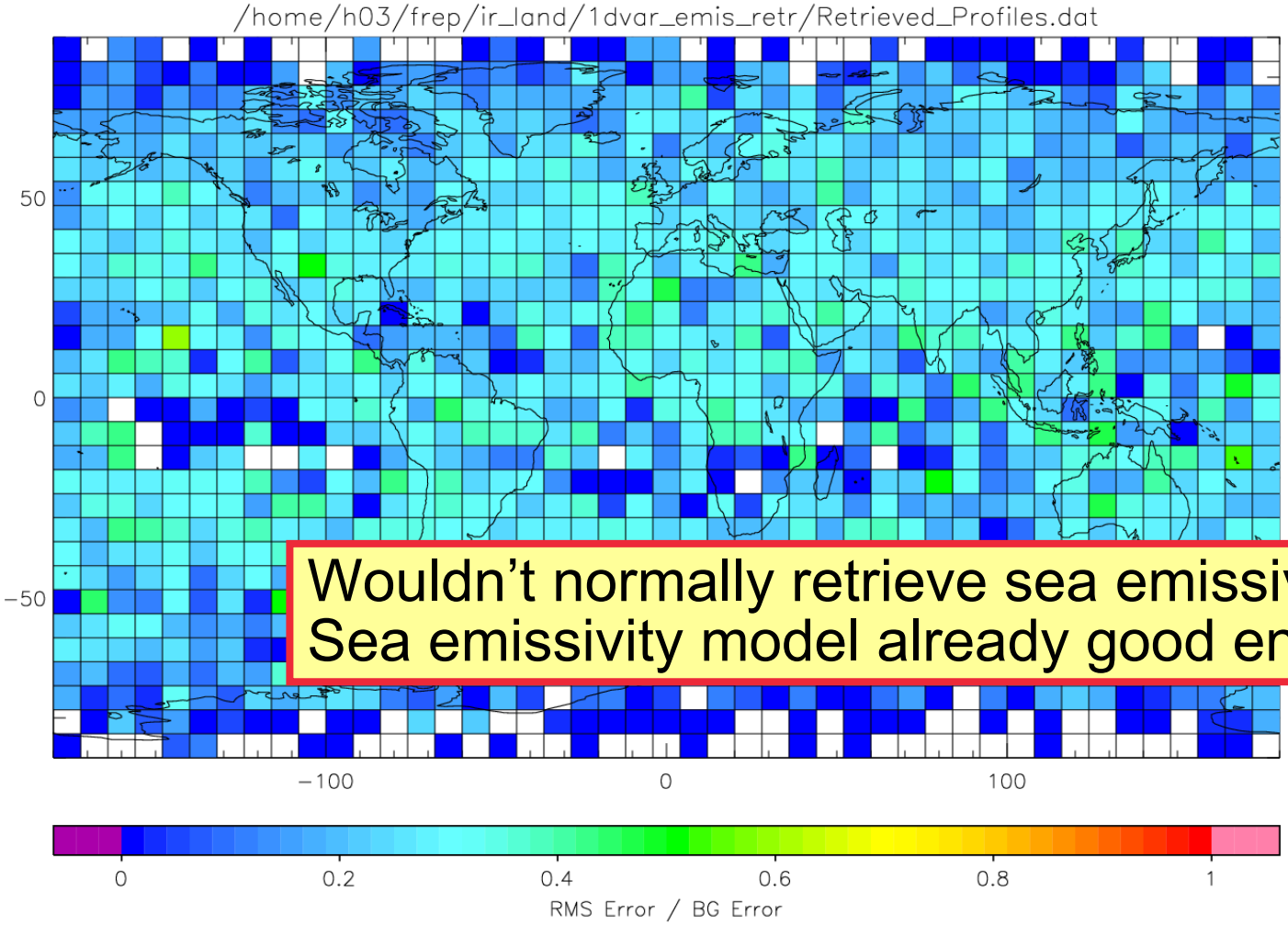
T_{skin} bias With emis retrieval



T_{skin} RMS Assuming $\varepsilon = 0.98$

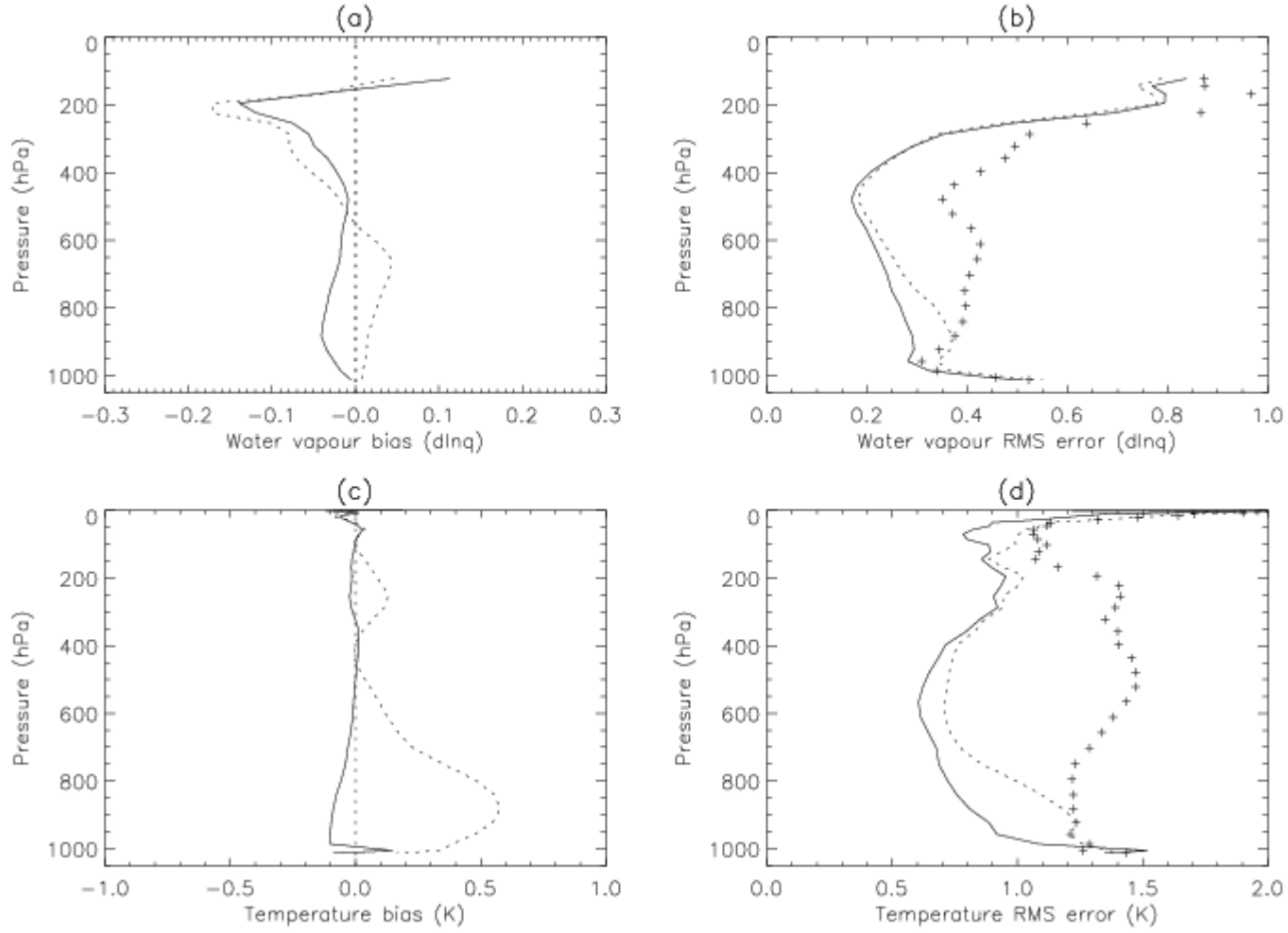


T_{skin} RMS With emis retrieval



Wouldn't normally retrieve sea emissivity:
Sea emissivity model already good enough!

Mean and RMS retrieval errors: Land



Next steps

- Refine training dataset
  - More representative of global land surface distribution
- Investigate problems in cloudy conditions
- Try with real data!
  - In standalone 1D-Var or OPS
  - Pass retrieved emissivity into 4D-Var
- Variable observation errors (Brett)
  - Characterise residual Tskin / $\mathcal{E}$ errors

  $\rightarrow$ Feed into an error model in 4D-Var

Other applications for surface emissivity analysis?

Questions and answers