Using Hyperspectral IR Sounder Data Over Land - PC radiative transfer and 1d-Var.

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Me and 1d-Var

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Assimilation of IR satellite sounder data

- AIRS instrument on Aqua satellite, IASI on Metop and soon CrIS on NPOESS all measure the upwelling radiance at 1000's of wavelengths.
- The Met Office started assimilating IASI data from the Metop platform in November 2007 and trials have shown it to have a big impact on NWP skill. However, current assimilation techniques only allow 183 of the 8461 available channels on IASI to be utilised and these are only assimilated in cloud free conditions. Over land the number of channels is reduced further to around 40 that have their peak sensitivity at altitudes above 400hPa.
- Met Office and ECMWF have had difficulties assimilating water vapour channels in 4d-Var
- Currently only assimilate data over ocean in cloud free conditions.
- We would like to assimilate data over any surface (land, sea ice or ocean) and in the presence of clouds and through thin cirrus.

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HT-FRTC – how does it work?

Perform Singular Value Decomposition on training set of profiles – the resulting Empirical Orthogonal Functions are fixed: They represent the basic spectral physical characteristics of gases / surfaces / aerosols / clouds and the instrument

PC scores depend on the actual atmosphere state:
Only they need to be re-calculated
('Calculation *in EOF space*') – dealing in Principal Components means by definition there are no issues with correlated errors.

So represent ~8500 channels with ~200 leading Principal Components.

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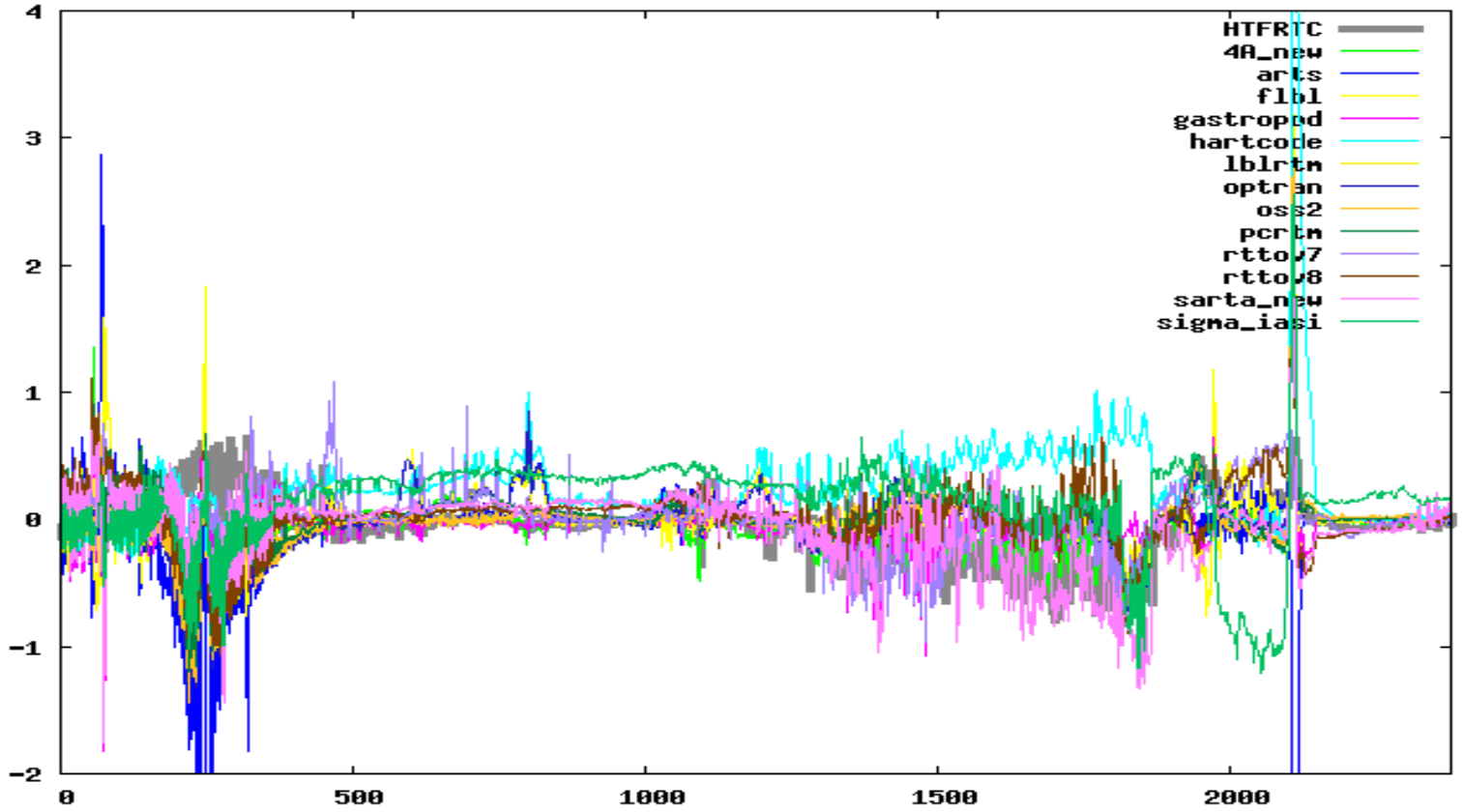
Model Intercomparison : Biases



- HTFRTC based on GENLN2, Ozone variable

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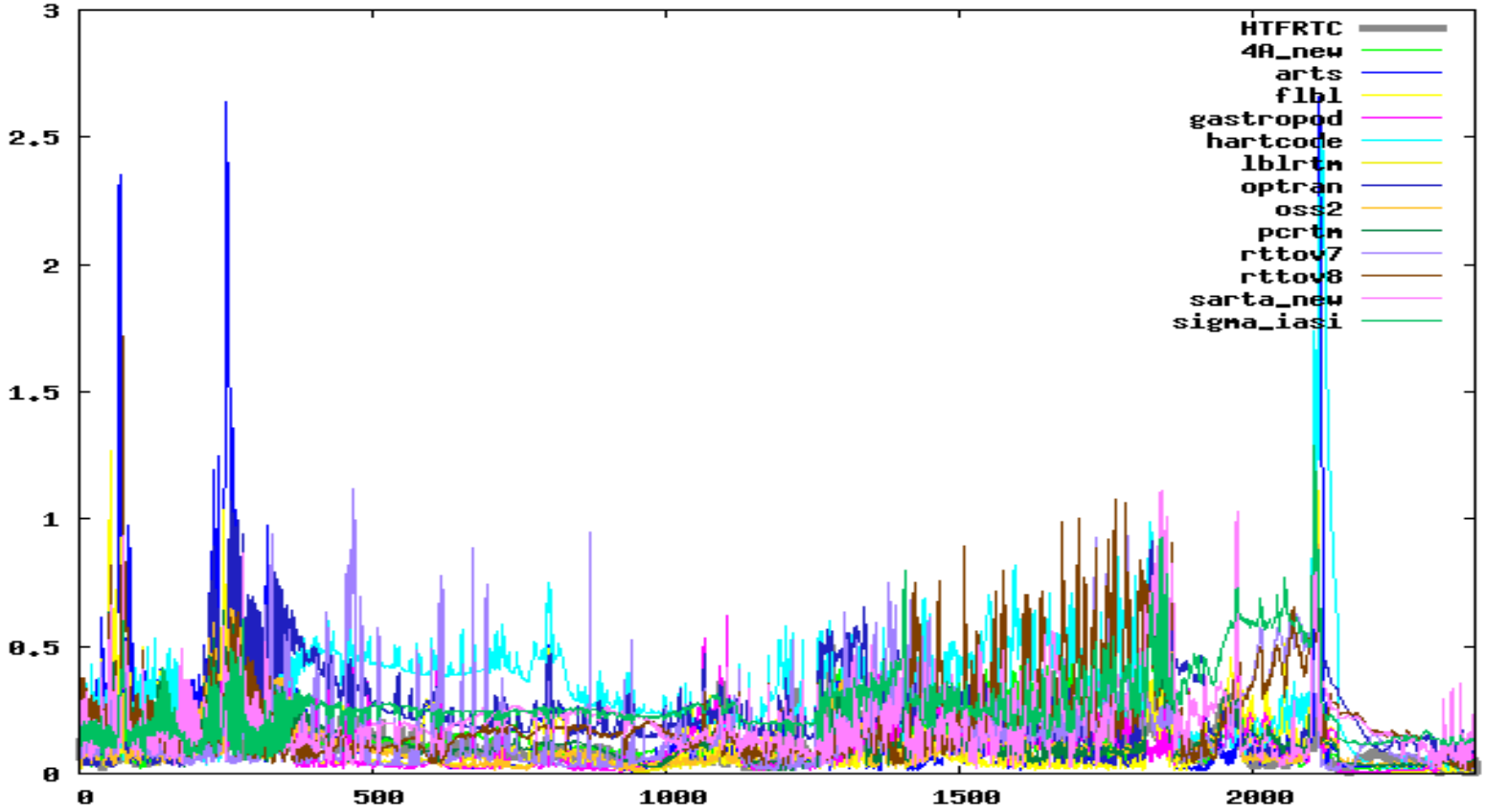
Model Intercomparison : STDEV



- HTFRTC based on GENLN2, Ozone variable

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How to deal with Surface Emissivity

- IR sounder data in some spectral regions is sensitive to the temperature and emissivity of the surface
- Over the ocean this is well known and hence we are easily able to use data here
- Over land/sea ice/snow the emissivity is highly spectrally variable and prior information is not sufficient.
- Here we represent the spectrally variable emissivity by a set of 15 principal components

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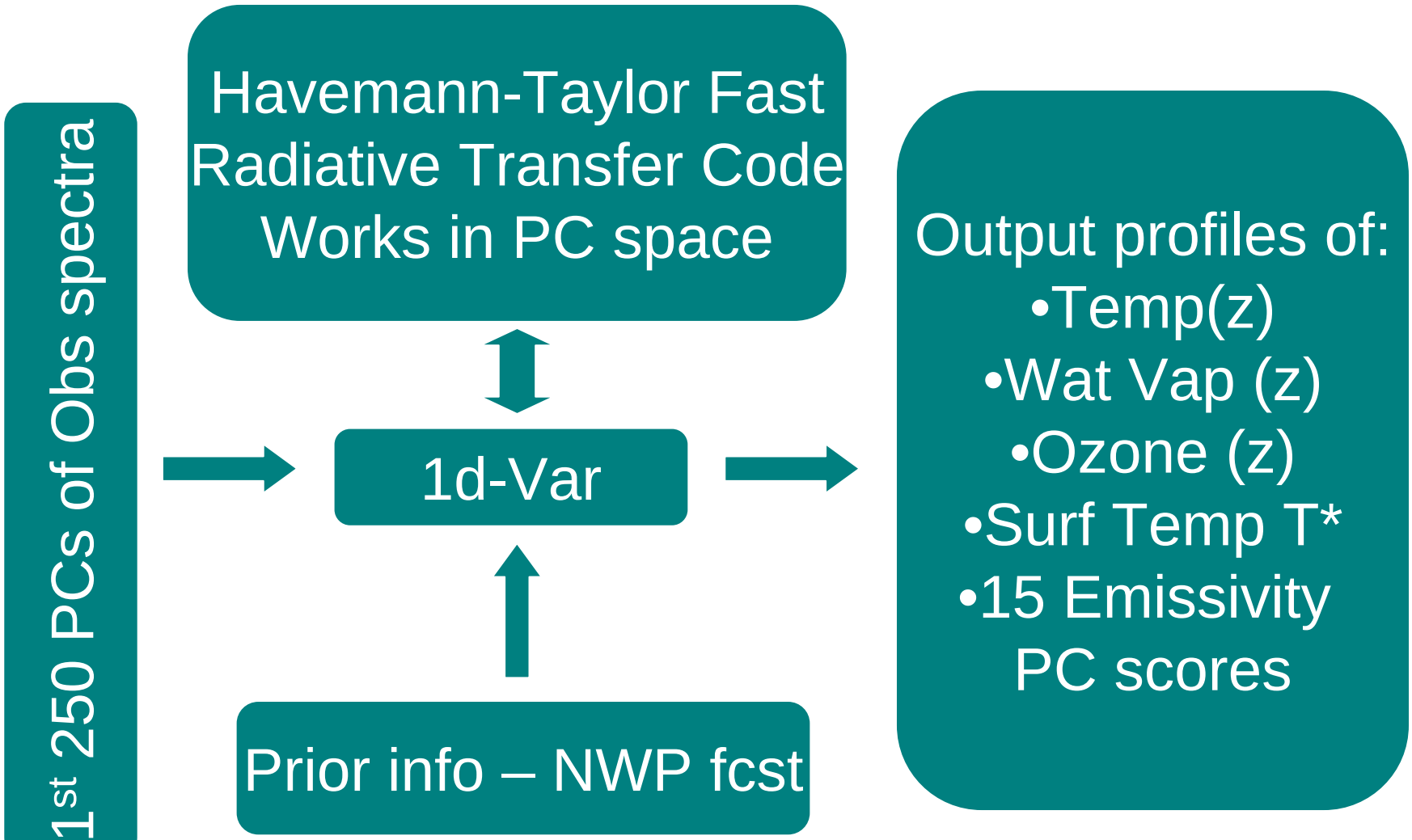
Couple HT-FRTC to 1d-Var



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1d-Var – minimization of the cost function

x = atmospheric state
T(z), q(z), O3(z), T*, E(PCs)

y = observations
Represented as PCs of the Radiance spectra

$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x_0})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x_0}) + (\mathbf{y} - \mathbf{y}(\mathbf{x}))^T \mathbf{R}^{-1} (\mathbf{y} - \mathbf{y}(\mathbf{x}))$$

B = Error covariance
of Background profile
– extended to include a block matrix with the error covariances of the surface emissivity PC scores

R = Error covariance
of measurements
– extended to include the error covariances of the sum of the observational and model errors in Principal Component Space

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Flight B284 18 Apr 2007 ARM Site – Night time.

- Low level run at 3000ft, Emissivity and Surf temp retrieval using upwards and downwards views with ARIES interferometer.
- Profile from 3000ft to 35,000ft measuring T, q, O3, CO , aerosols etc.
- Run at 35,000ft coordinated with WB-57 and IASI overpass, dropped 11 dropsondes.
- Will show 1d-Var results using ARIES data gathered at 35,000ft – using 4948 channels from ARIES represented as their PCs.

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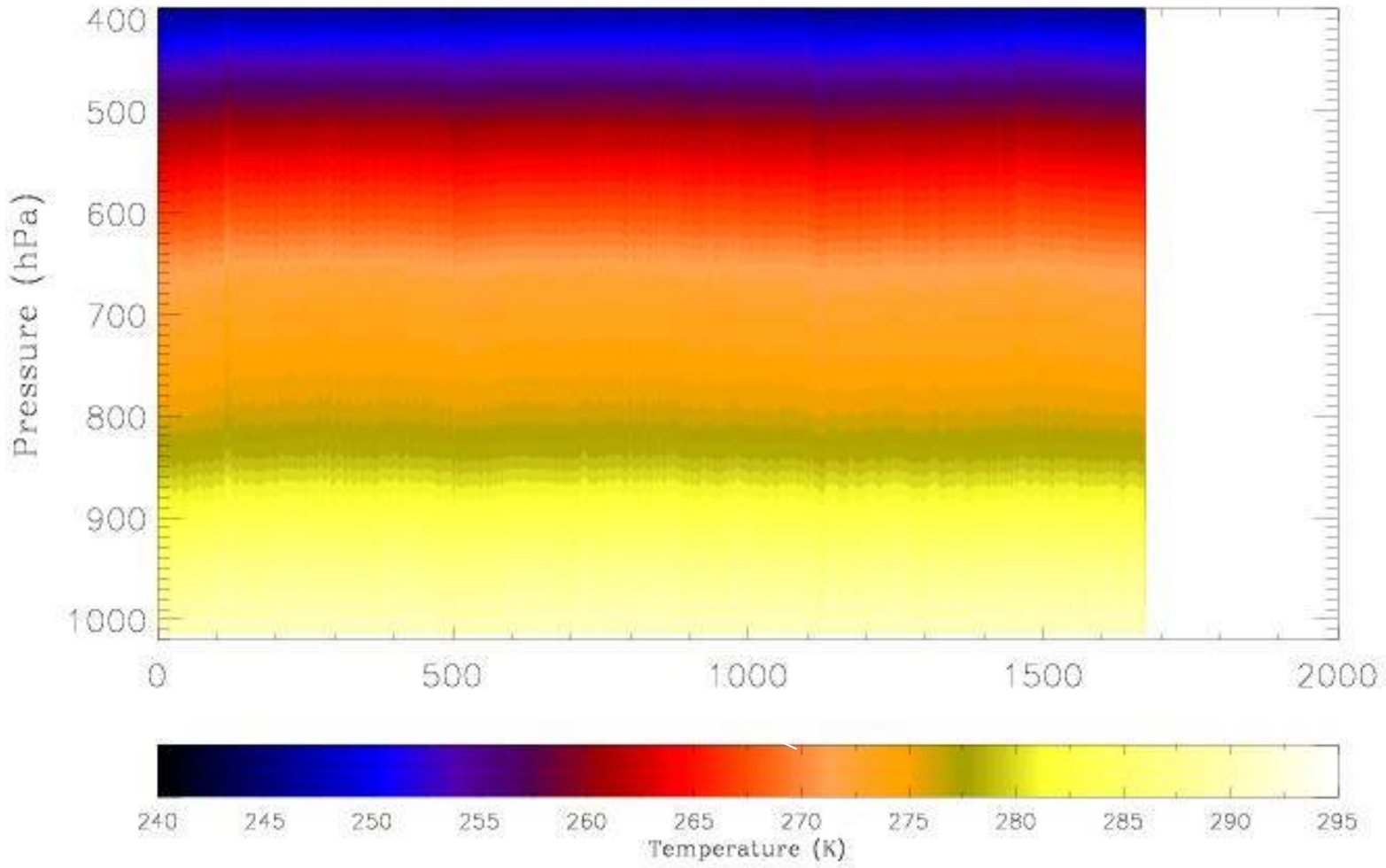
Temperature Retrieval



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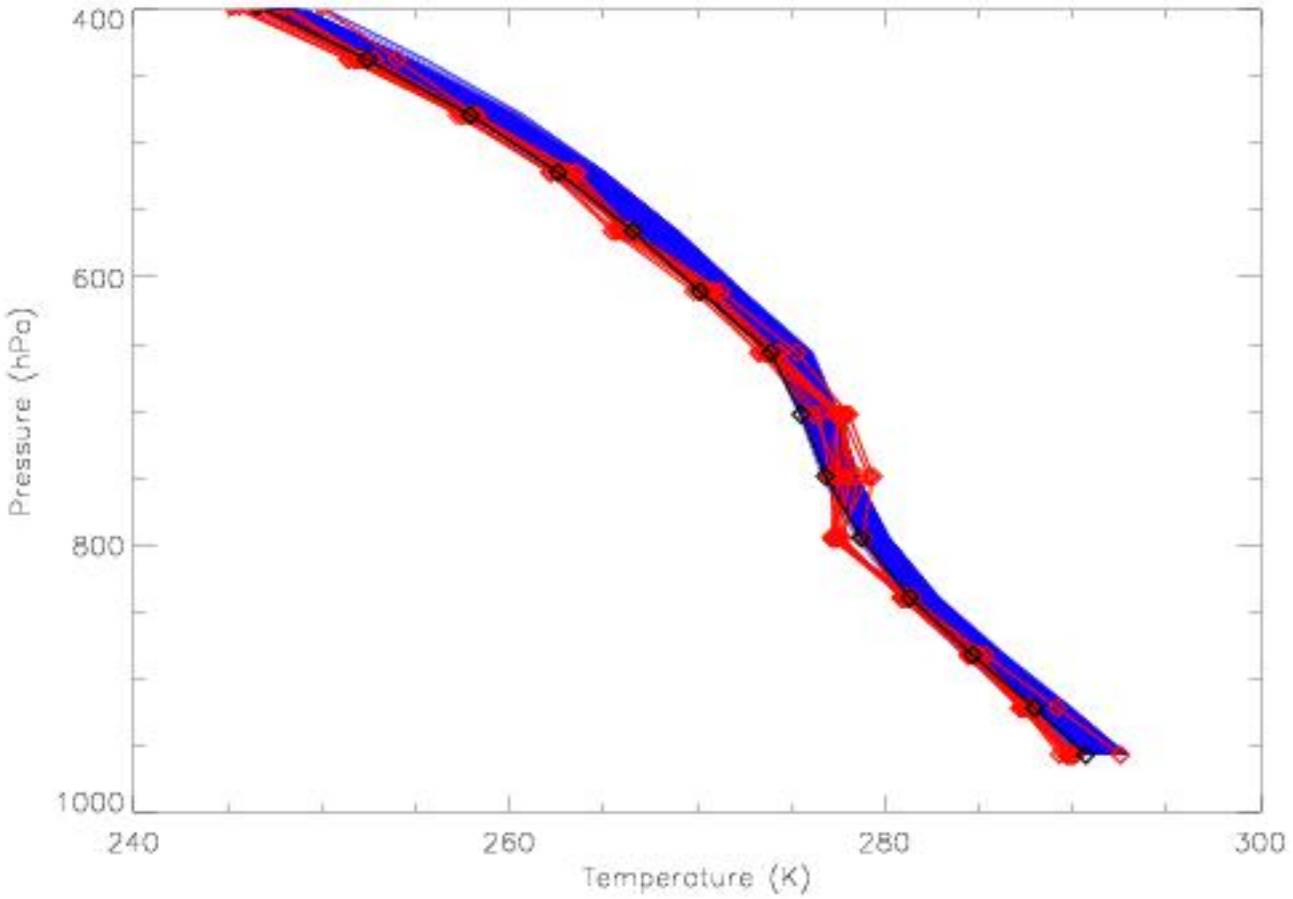
Temperature Retrieval



Background

Retrieval

Dropsondes

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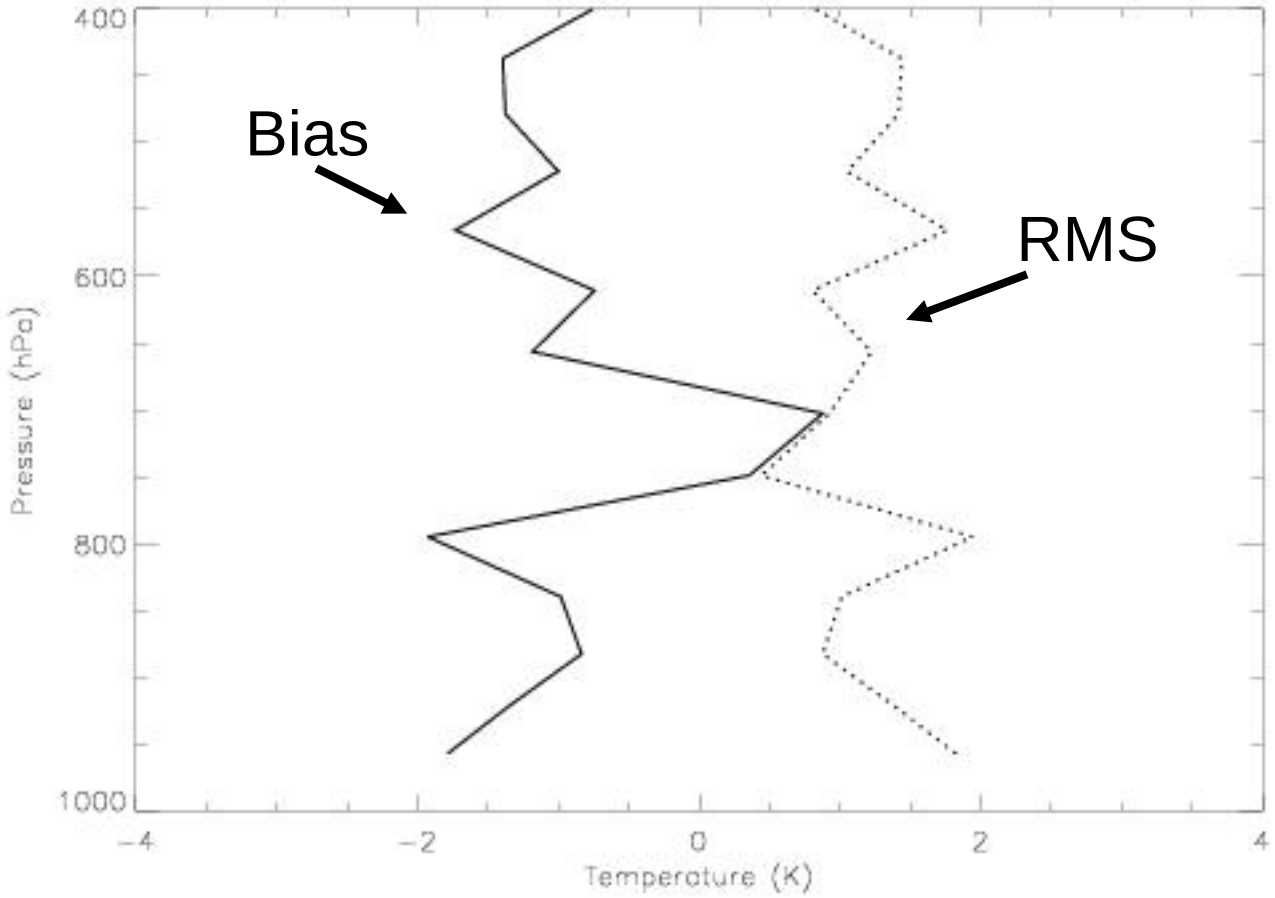
Temperature Retrieval



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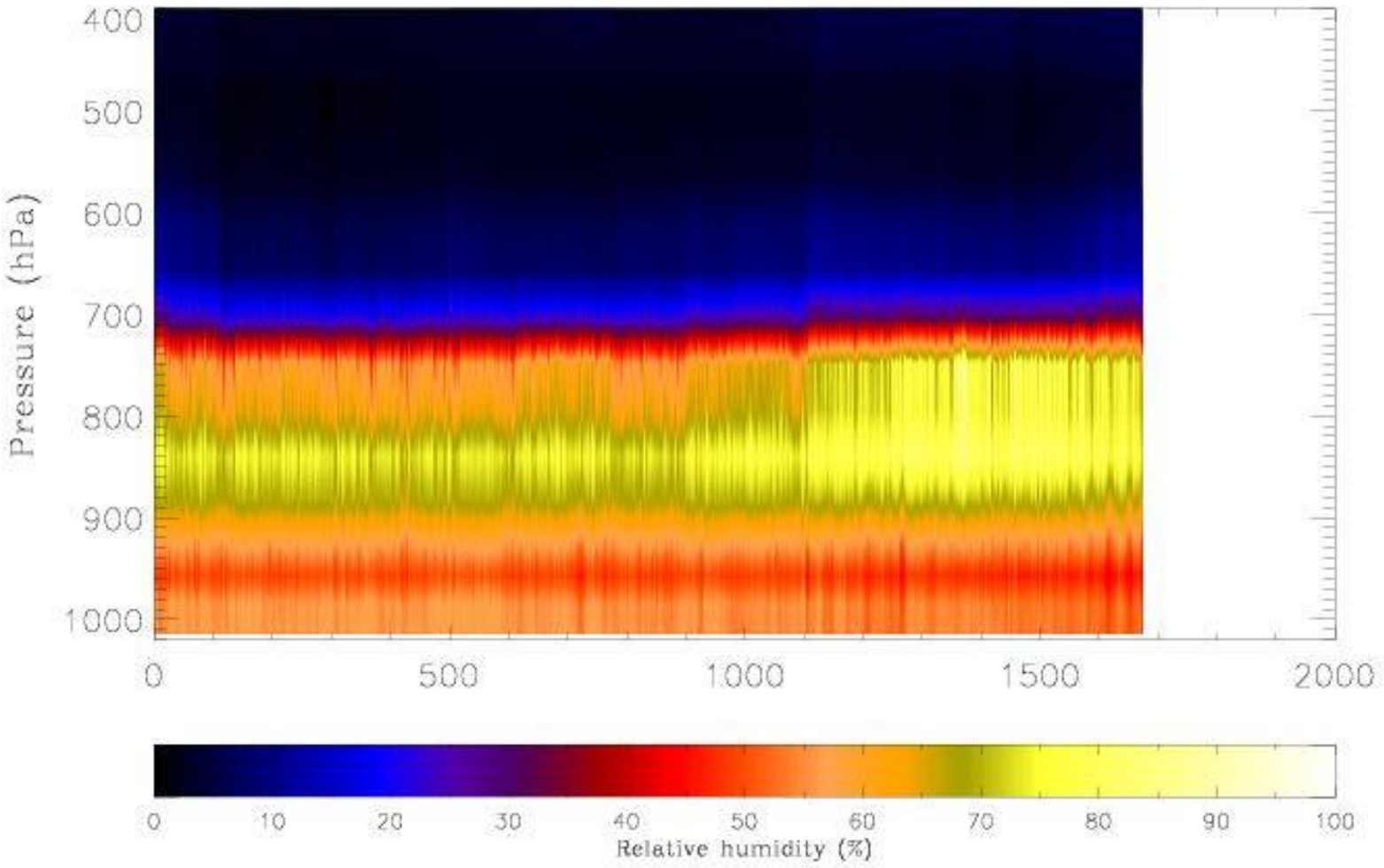
Water Vapour Retrieval



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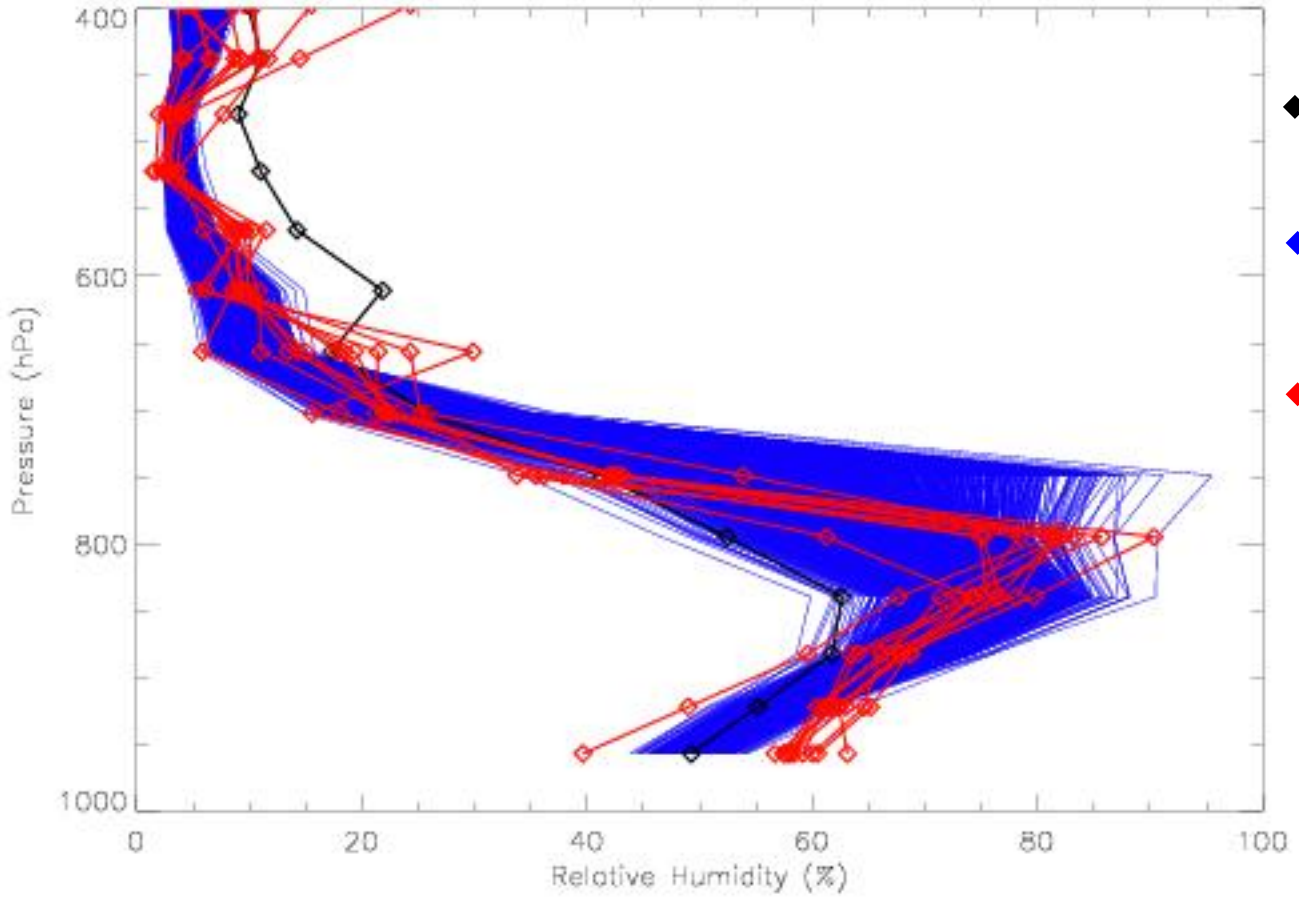
Water vapour retrieval



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Retrieval

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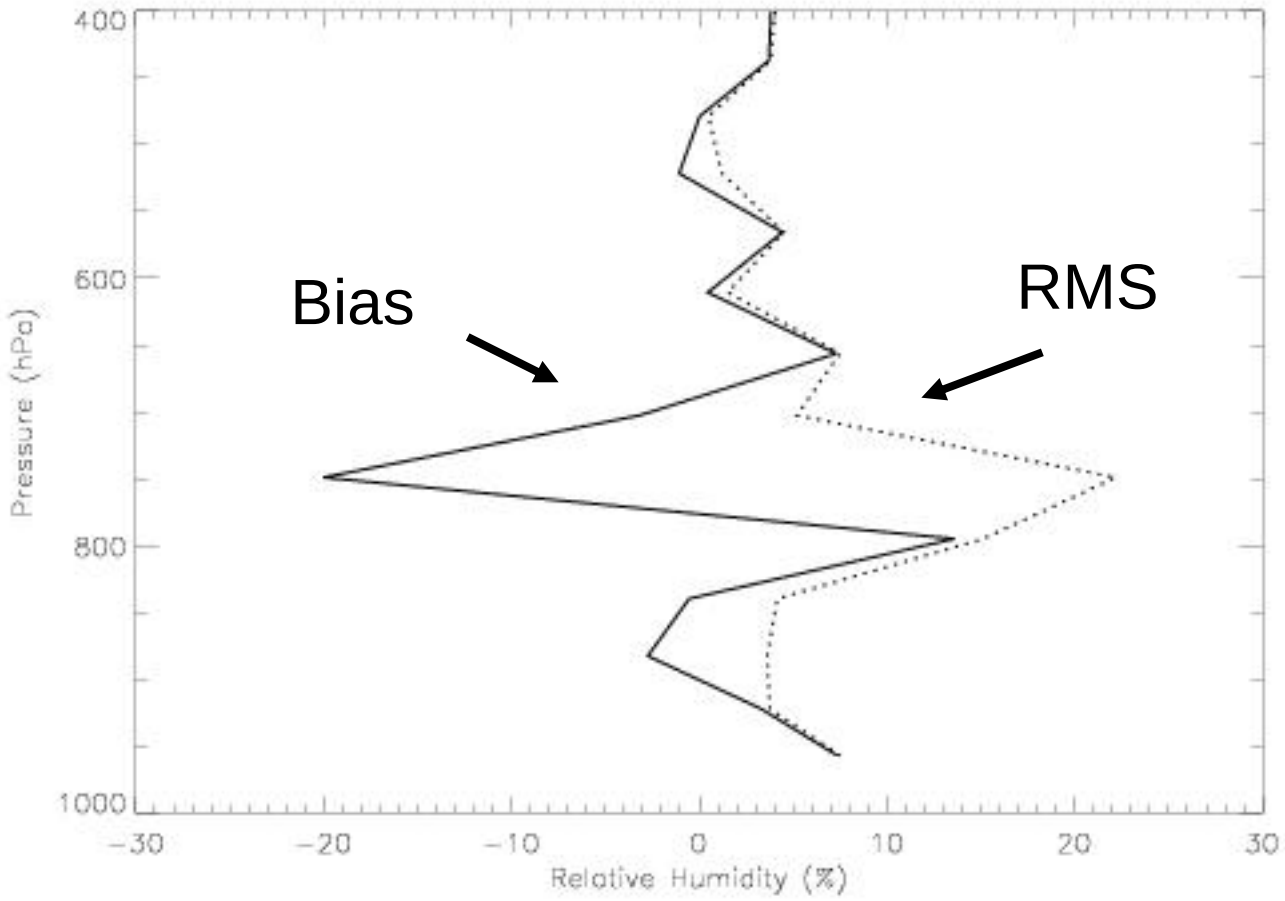
Water vapour retrieval



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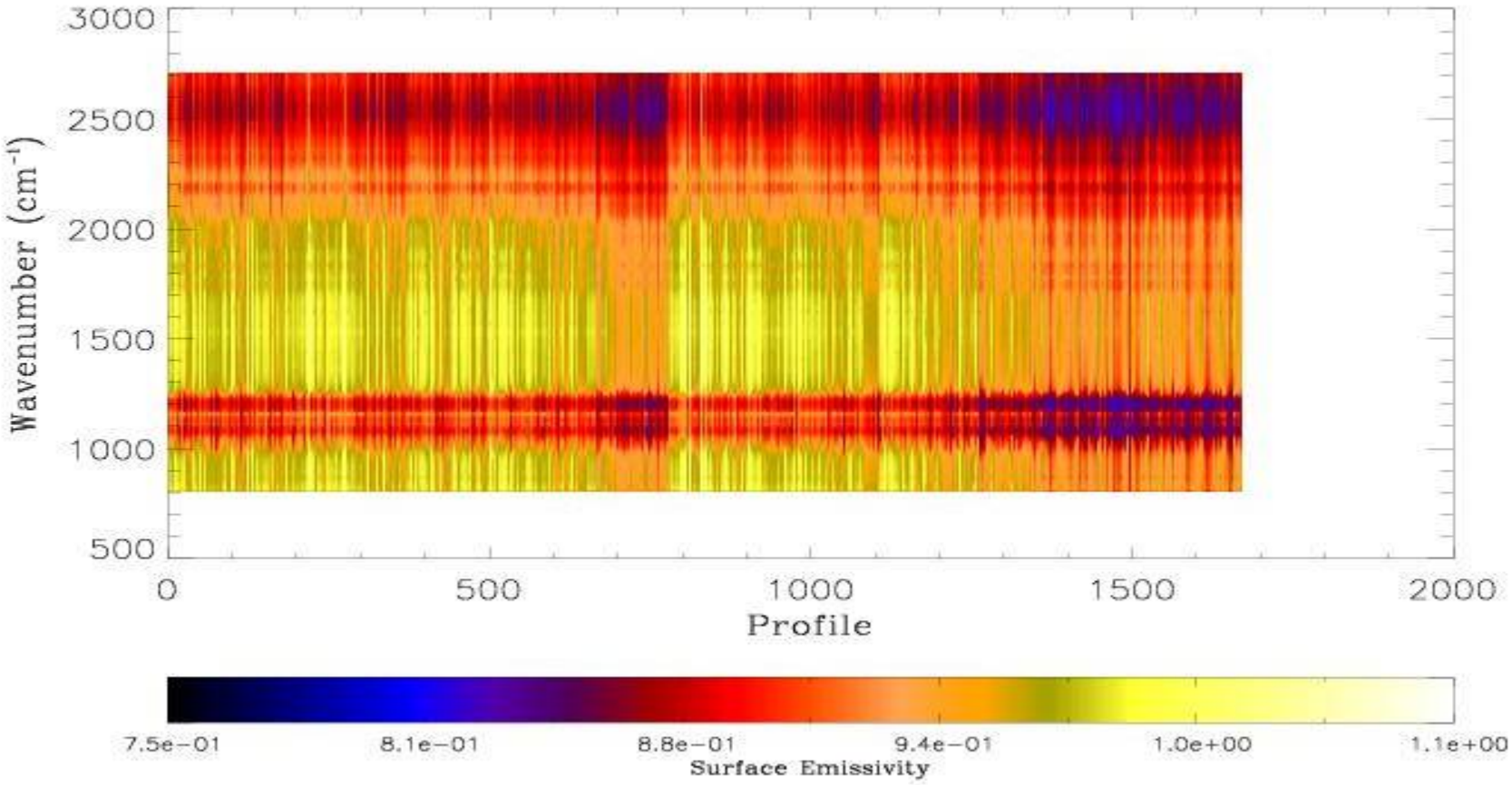
1d-Var Emissivity Retrieval



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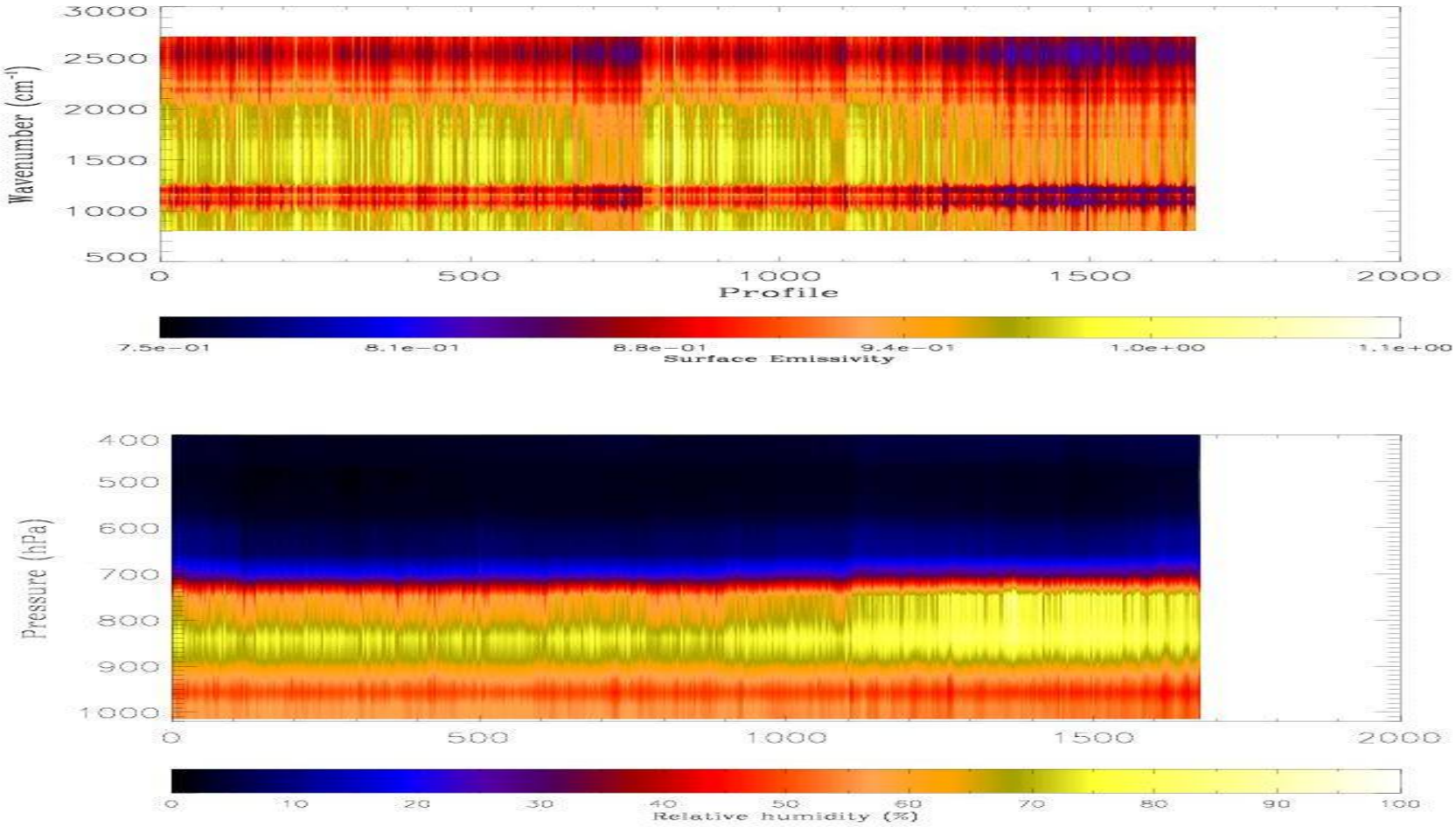
1d-Var Emissivity Retrieval



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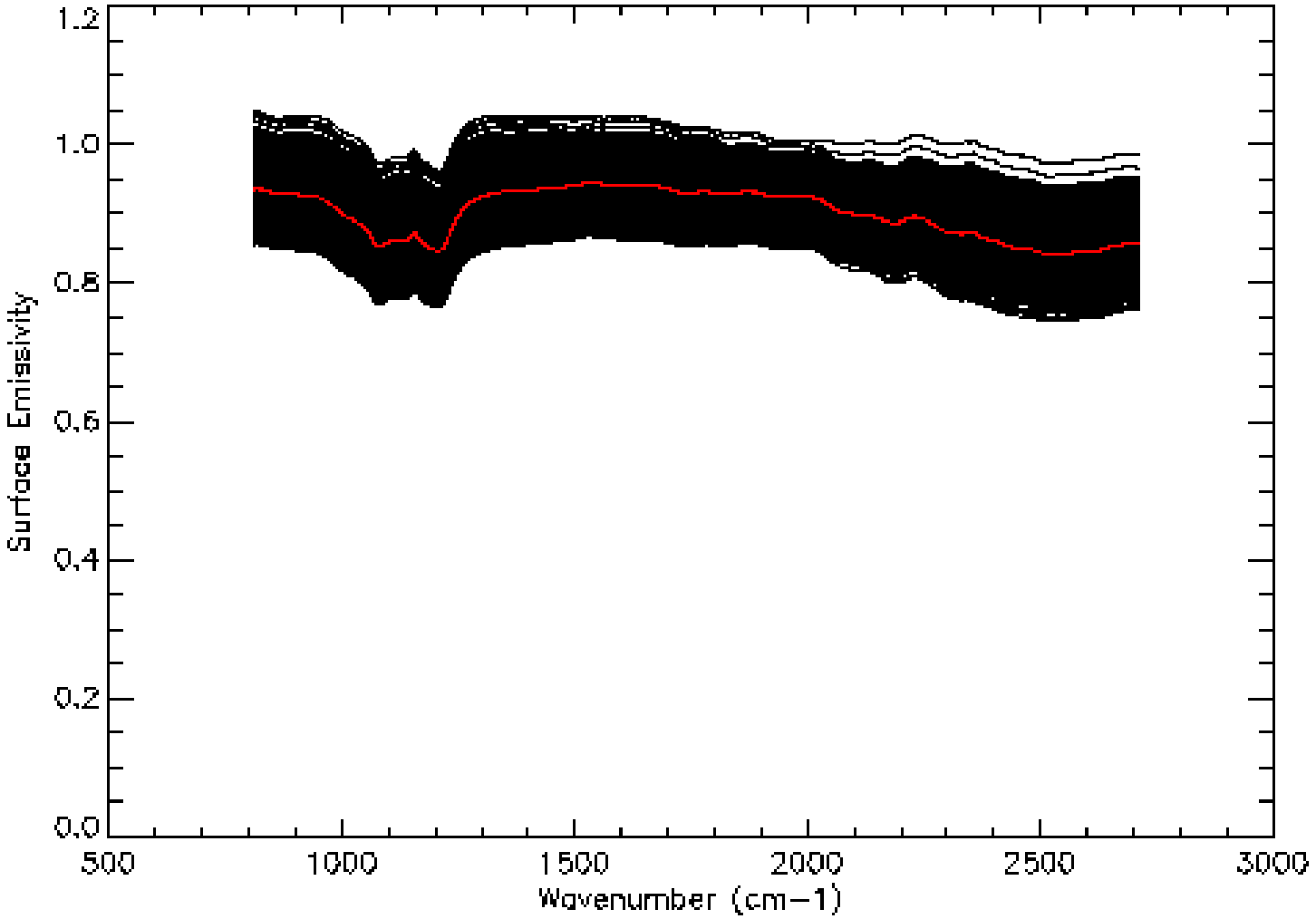
Emissivity Retrieval (2)



ARIES fov from 35,000ft is ~450m

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ARIES emissivity retrievals

- Radiance leaving sea surface is

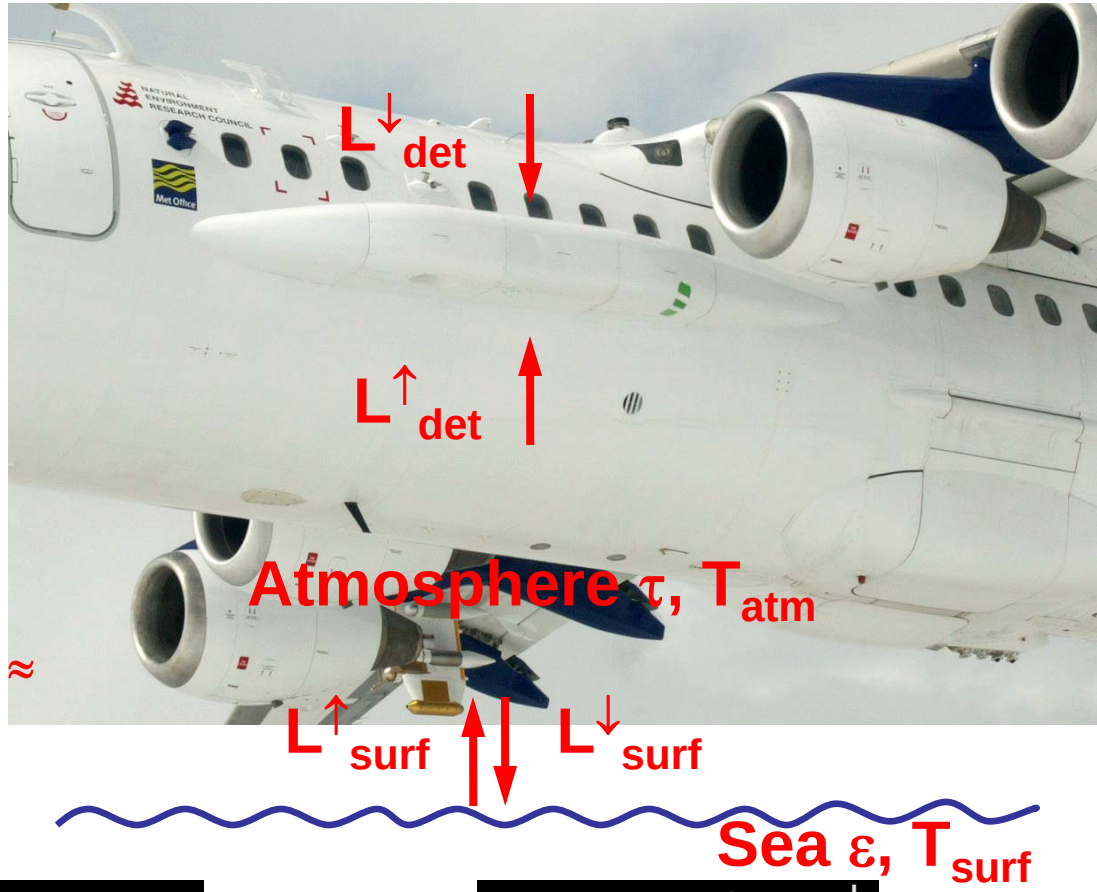
$$L^{\uparrow}_{surf} = \varepsilon B(T_{surf}) + (1-\varepsilon)L^{\downarrow}_{surf}$$

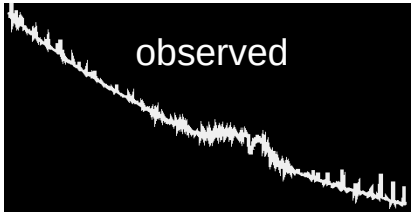
- Solve for r = (1–ε) to reproduce smooth surface radiance:

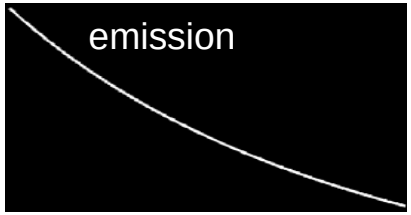
$$L^{\uparrow}_{surf} - r.L^{\downarrow}_{surf} = \varepsilon B(T_{surf})$$

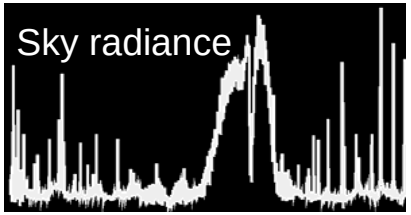
- Important to include effects of intervening atmosphere:

$$L^{\uparrow}_{det} = \tau L^{\uparrow}_{surf} + (1-\tau)B(T_{atm}) \qquad L^{\downarrow}_{det} \approx L^{\downarrow}_{surf}$$









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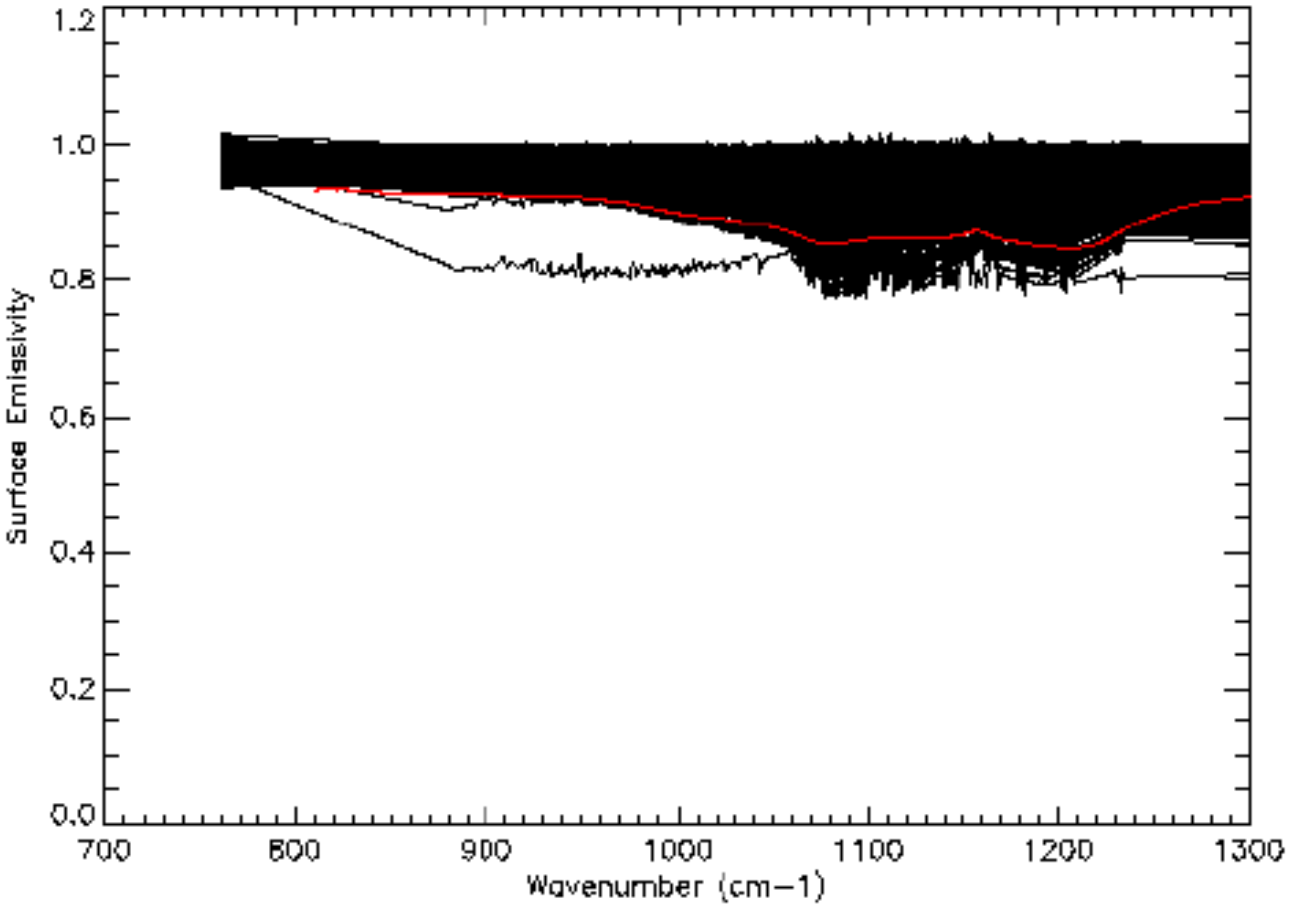
Emissivity Retrieval (3)



ARIES measurements At low level have an fov 40m so able to resolve Small features

Red line is average Of 1601 retrievals from 35,000ft

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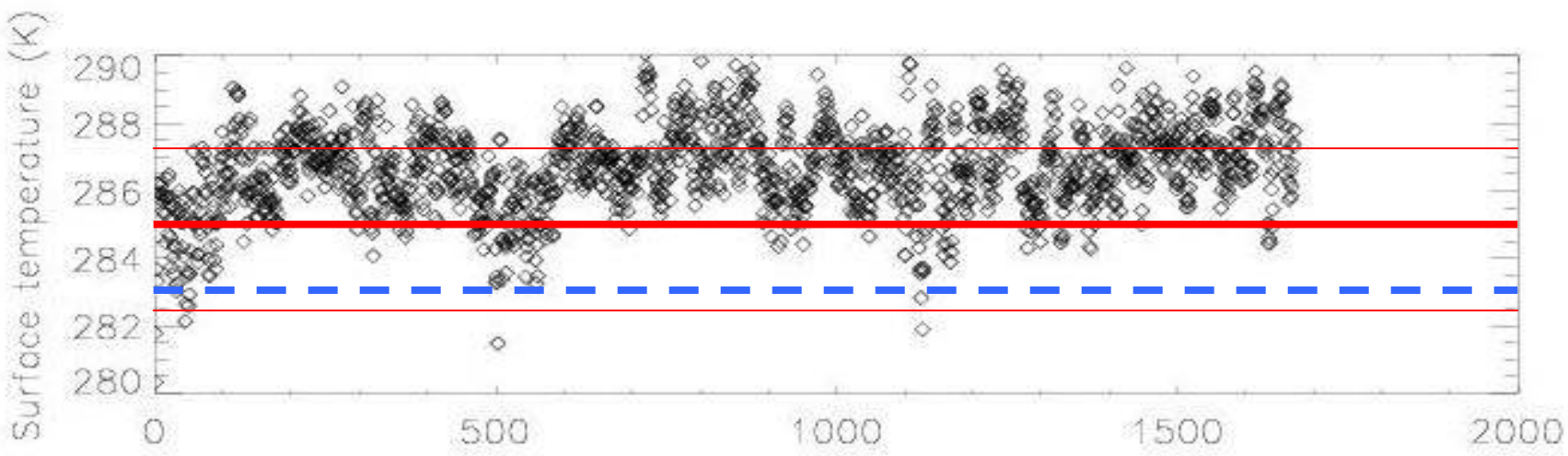
Surface Temperature Retrieval



Low level data before high level – mean +/- 1 st devn. First guess = 283K

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Summary

- HT-FRTC code performing well
- Successfully coupled HT-FRTC with 1d-Var Scheme – using 4948 ARIES channels
- Ability of BAe146 to fly low over surface allows measurement of surface emissivity and temperature and coincident drop sondes give “truth” measurements
- 1d-Var retrievals from high level (~10km) show skill in T, q, T* and Emissivity retrievals (ozone to come)
- Shows that it is possible to use hyperspectral sounder data (1000’s of channels) over any surface has the potential to significantly increase usage of AIRS and IASI data which would increase NWP skill

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Future Developments

- 1d-var scheme being further tested with aircraft observations – initial results look very encouraging further investigation of B and R matrix is required
- Direct comparisons with dropsondes, ARM data and aircraft profiles from other flights
- Run 1d-Var retrieval scheme for IASI data
- Include treatment of scattering in HT-FRTC
- Inclusion of cloud/aerosol properties in the 1D-Var control vector.

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JAIVEx Data Release

- The JAIVEx team have put together a case study of data that anyone can use for their own research.
- The data set contains
  - IASI, NAST-I, S-HIS and ARIES interferometer spectra
  - Aircraft profiles and dropsonde data
  - ARM site data
  - Surface properties
  - Model fields
- Email: stu.newman@metoffice.gov.uk to be sent a copy on a DVD.

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Questions and answers

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International TOVS Study Conference, 16th, ITSC-16, Angra dos Reis, Brazil, 7-13 May 2008. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2008.