Application of a 1d-Var retrieval scheme on IASI data gathered during JAIVEX

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Assimilation of IR satellite sounder data

- Advanced IR sounders have 1000's channels.
- Current assimilation is conservative – Met Office assimilates 183 of the 8461 channels 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
- 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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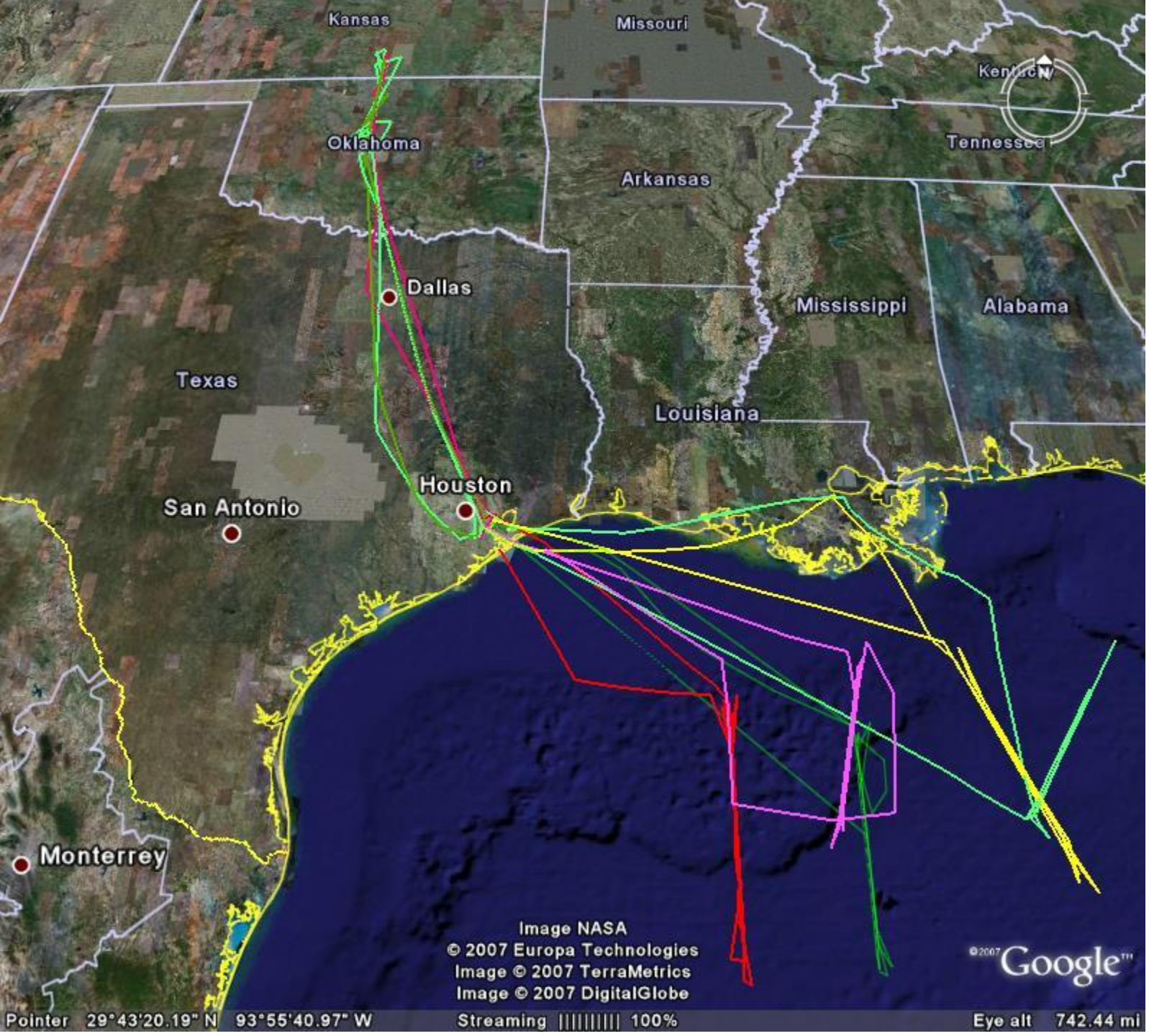

JAIVEX Campaign

Principal Component Radiative Transfer

- The Havemann –Taylor Fast Radiative Transfer Code (HT-FRTC) has been developed:
- Benefits
  - **Fast:** computes entire IASI spectra (8461 channels) in < 1s
  - **Accurate:** has been compared with 14 other codes and is just as good.
  - **More Information:** simulating 8461 channels means that information on surface and clouds can be assimilated plus multiple channels giving same information about temperature and water vapour structure act to reduce the noise of the measurement.

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Couple HT-FRTC to 1d-Var

1st 100 PCs of Obs spectra

Havemann-Taylor Fast Radiative Transfer Code
Works in PC space

1d-Var

Prior info – NWP fcst

Output profiles of:
- Temp(z)
- Wat Vap (z)
- Ozone (z)
- Surf Temp T*
- 15 Emissivity PC scores

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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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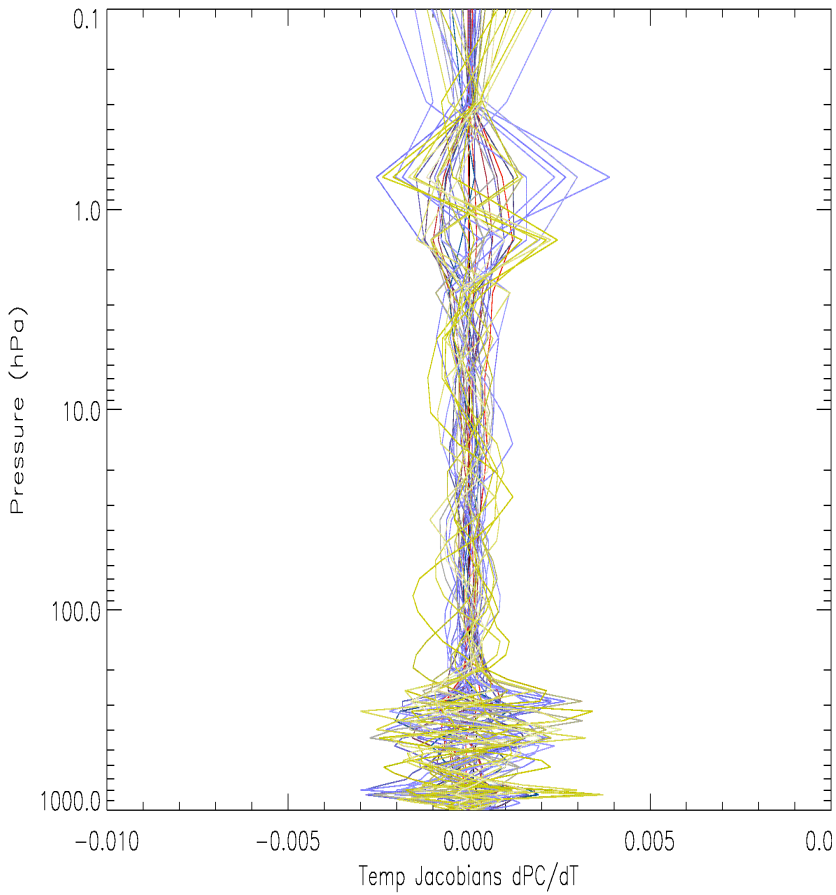
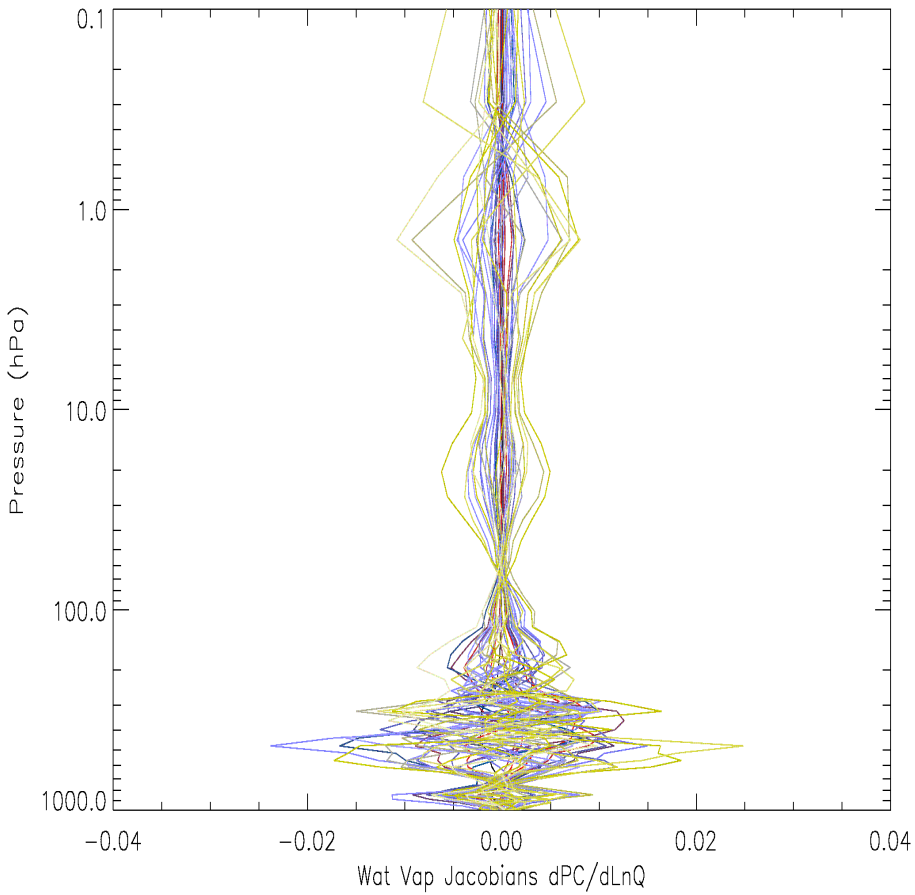
Principal Component Jacobians

Temperature



Water Vapour



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Impact of PC Jacobians

- Jacobians of PCs have complex vertical structure
- Met Office B matrix for water vapour is not defined for top 17 levels of the atmosphere, for historical reasons
- Therefore since water vapour information in PC space is spread across the entire atmospheric column we must use a B matrix which is defined at all levels
- Here we use the ECMWF B matrix which also has a covariance matrix for Ozone which we also require to use all IASI channels.
- At end of presentation will explore impact of removing upper level water vapour elements from ECMWF B matrix on retrievals – gives useful insight in to impact of water vapour channels on temperature retrievals.

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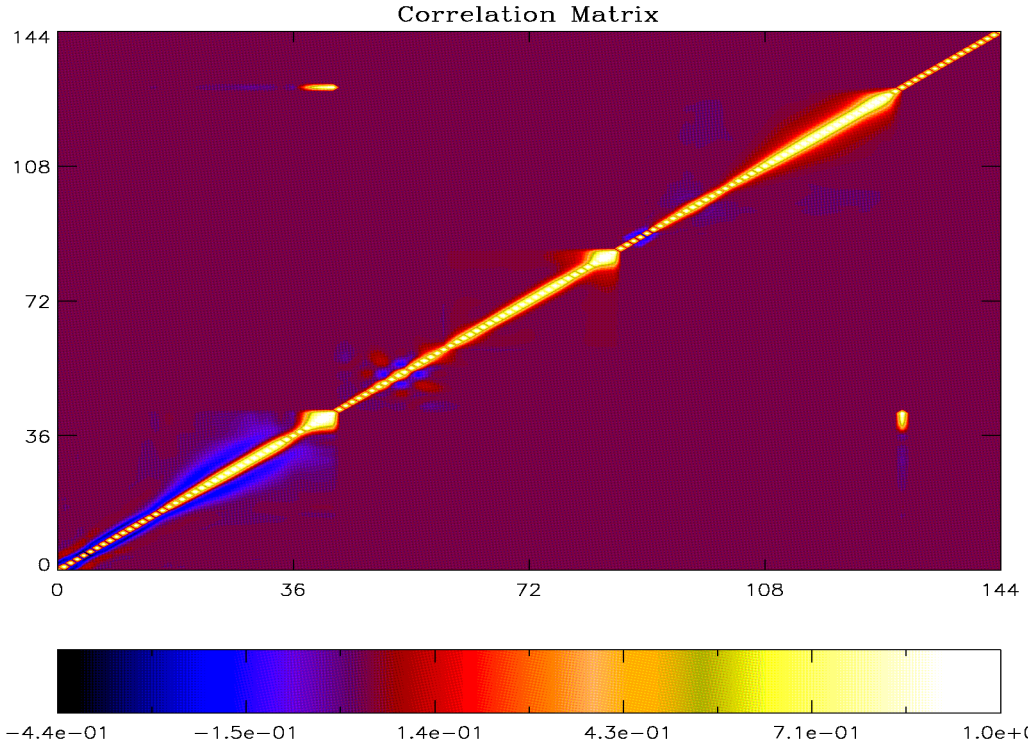
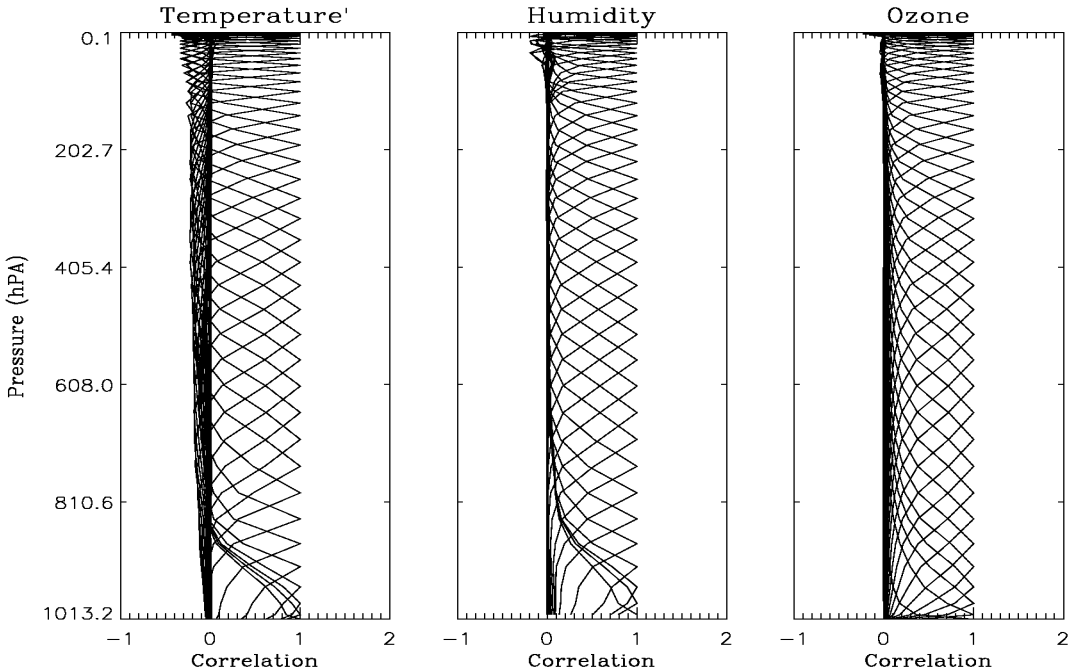
The ECMWF B Matrix – background error covariance matrix





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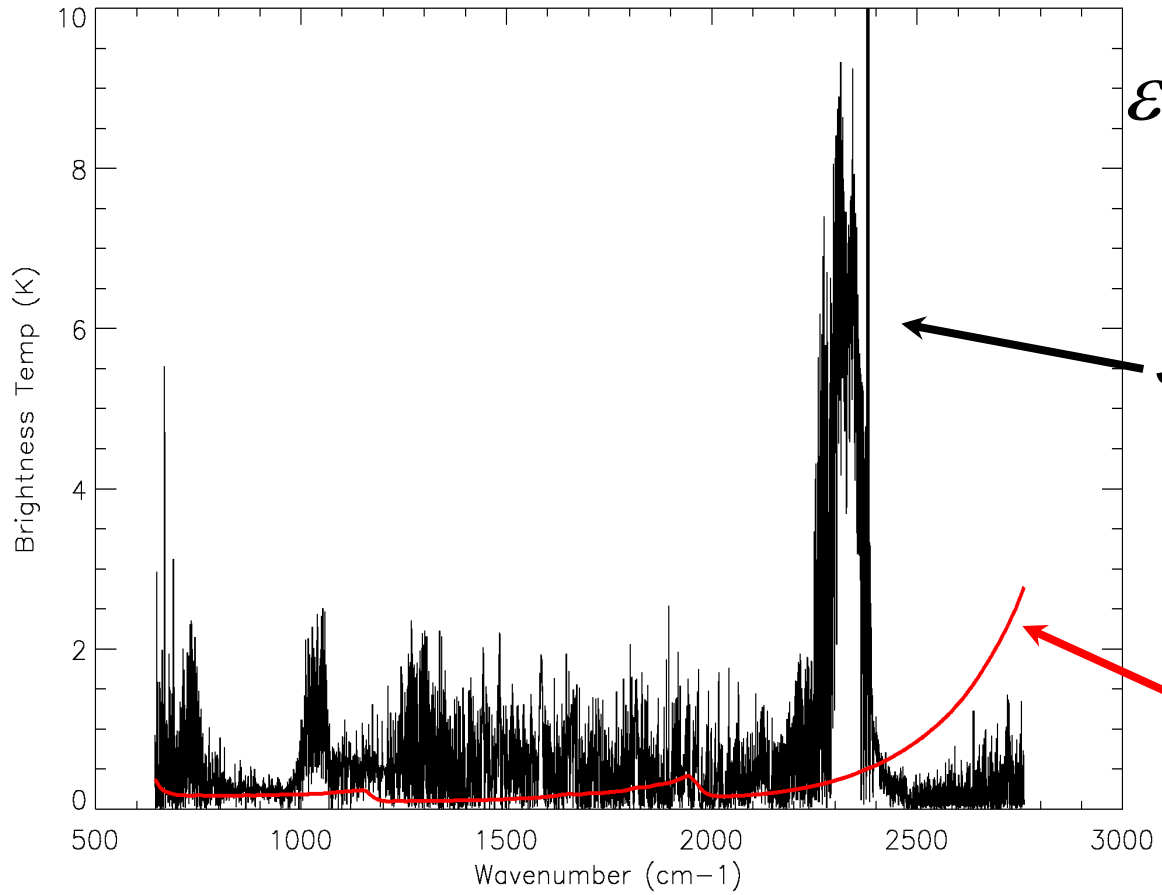
Defining the R Matrix – instrument and measurement error covariance matrix



$$\varepsilon = \sqrt{\varepsilon_{IASI}^2 + \varepsilon_{SPECT}^2}$$

Jaivex - Spectroscopy

IASI NeDT

Case Study – Flight B290 – 30th April 2007 over Gulf of Mexico

- 16 IASI footprints in clear sky conditions
- Day time case – therefore need to compute thermal and solar components
- Validation against drop sondes launched from BAe146-301
- Background profile from ECMWF forecast

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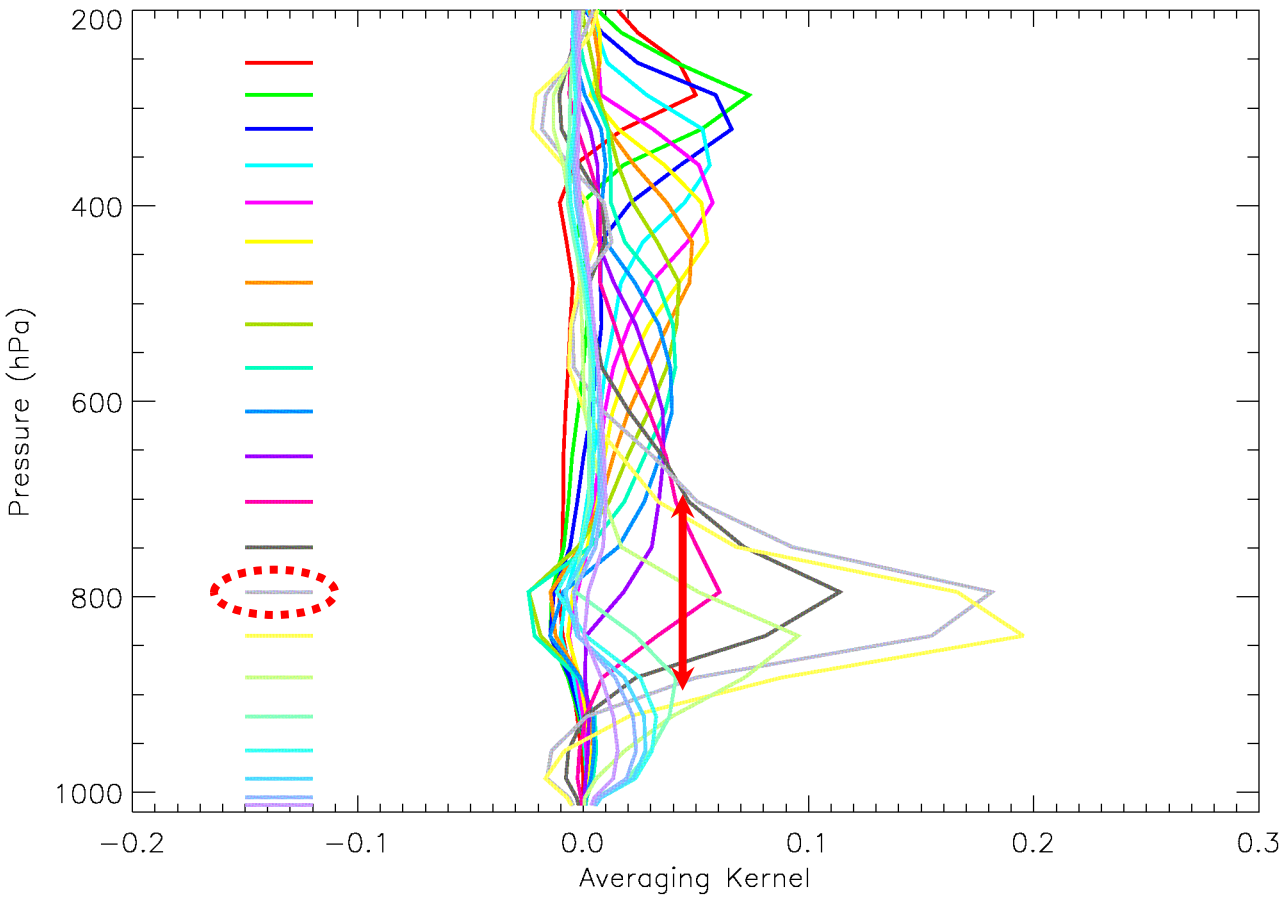
Temperature Averaging Kernel



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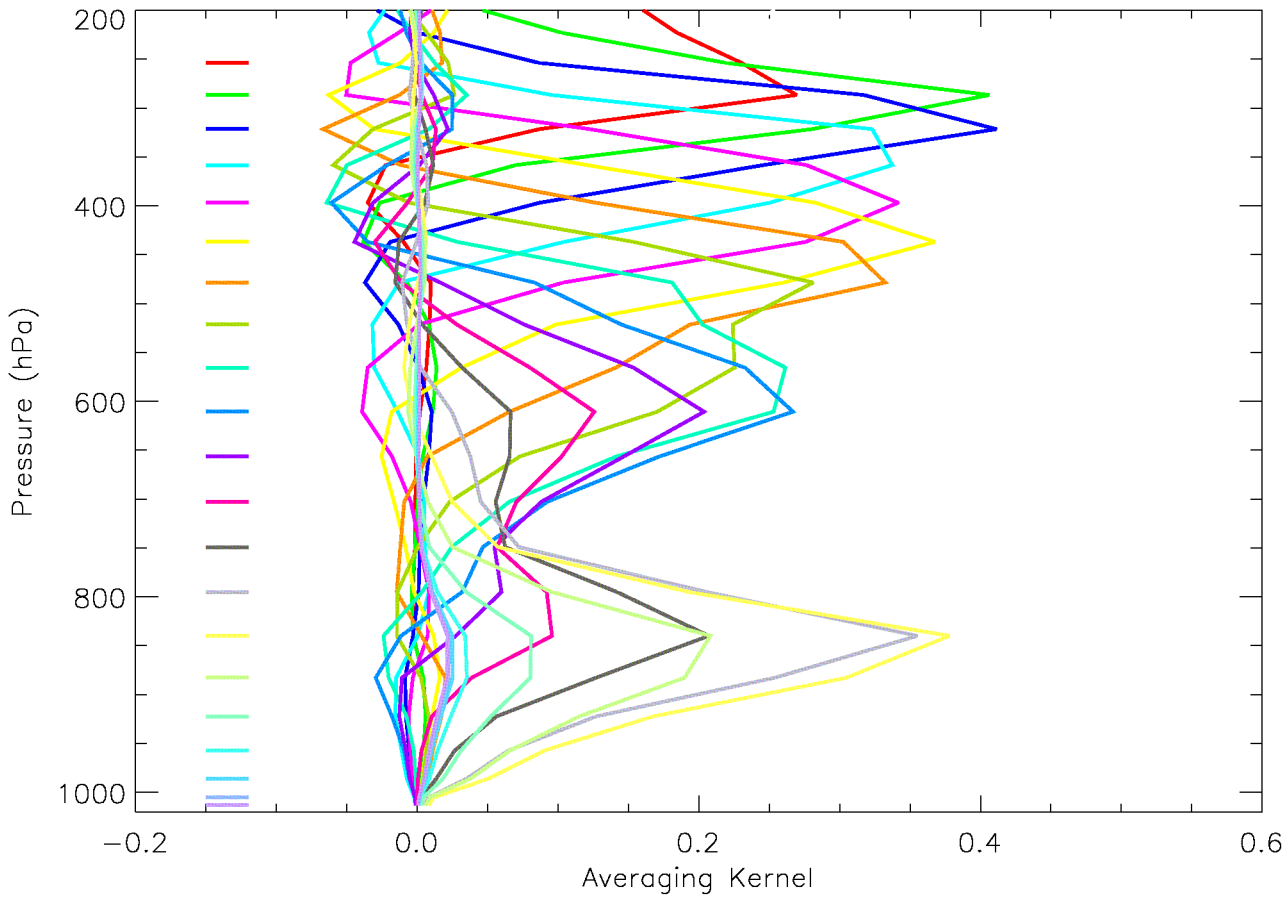
Water Vapour Averaging Kernel



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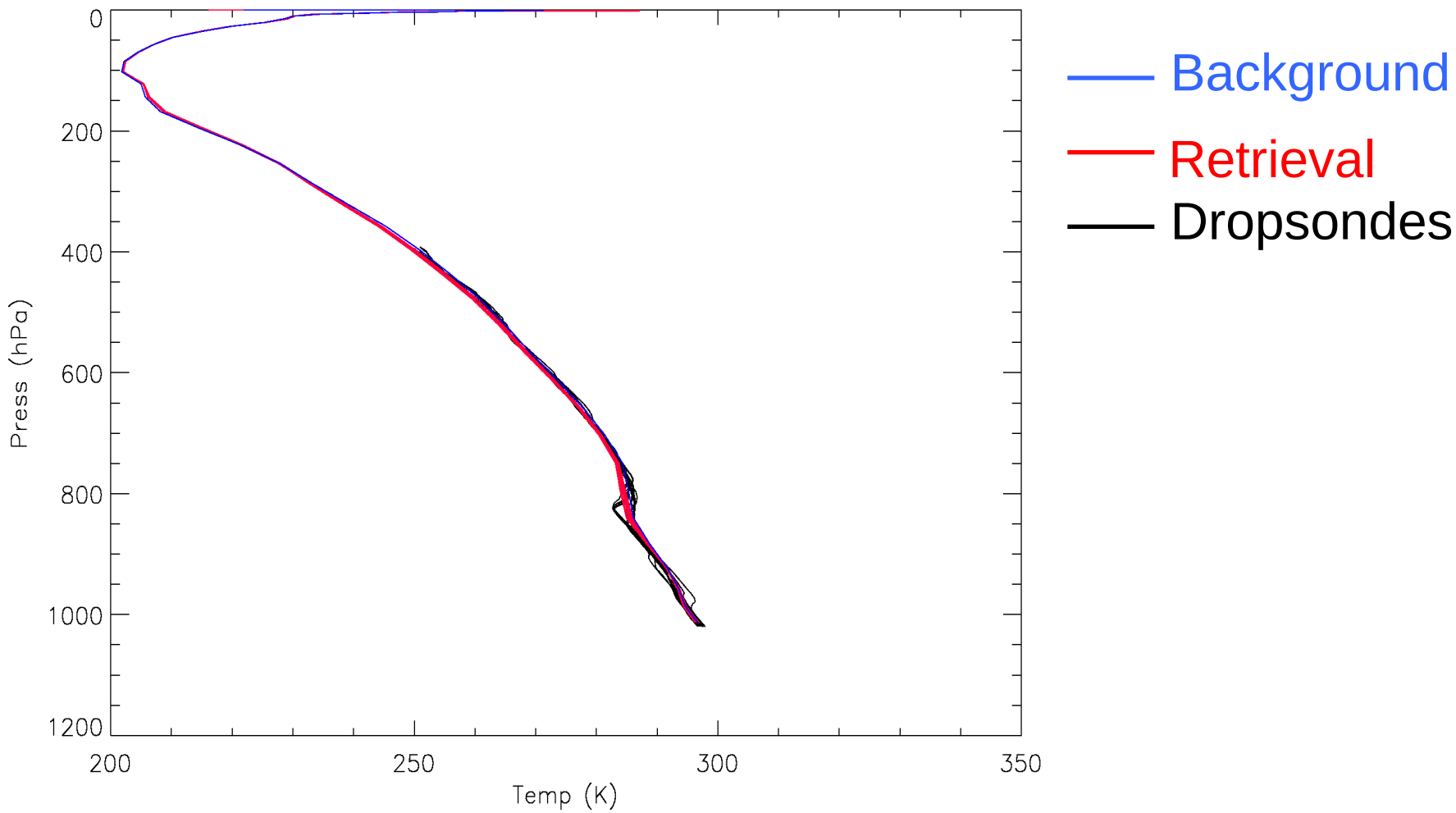
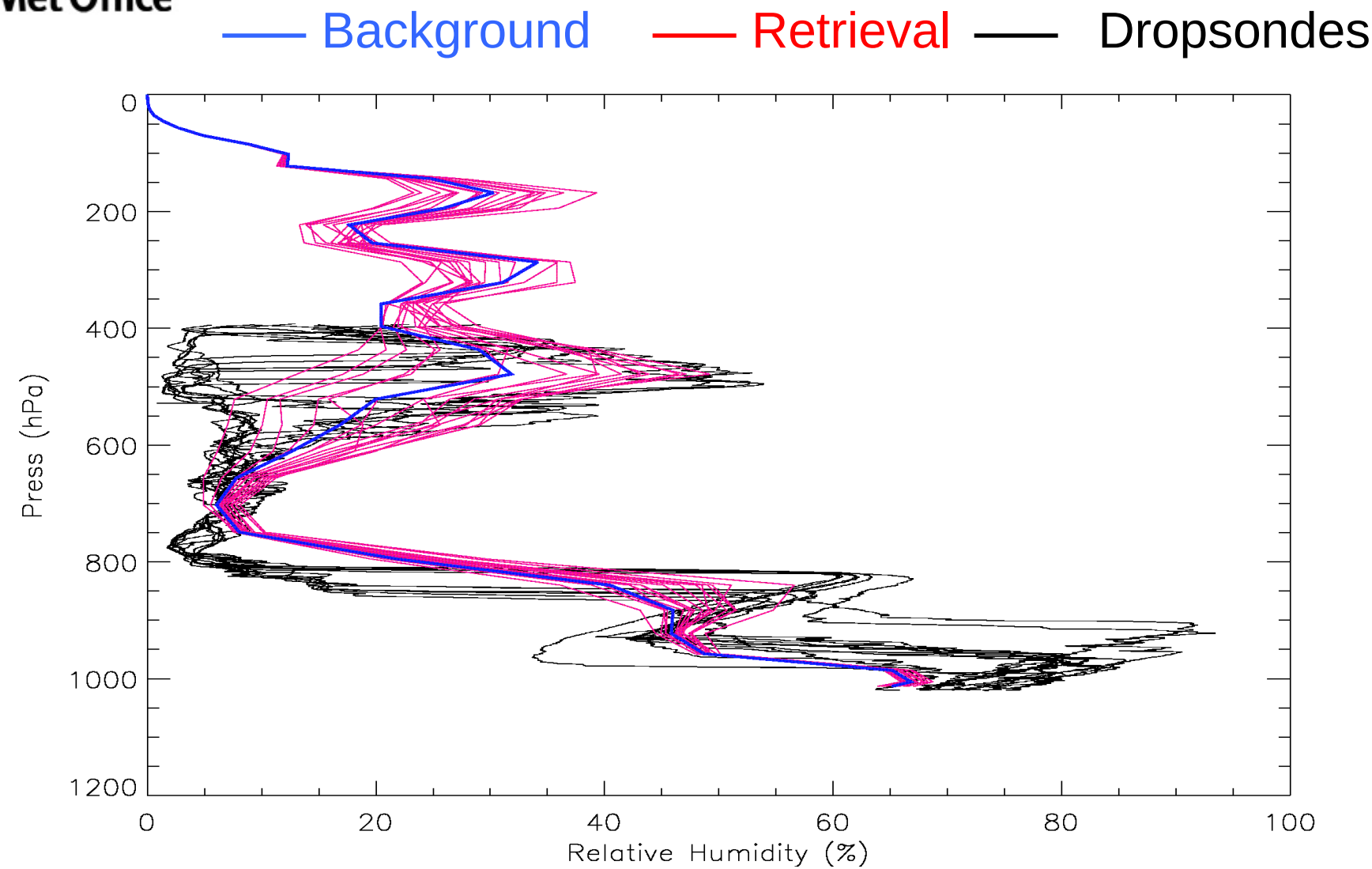
Temperature retrievals



Water vapour retrievals



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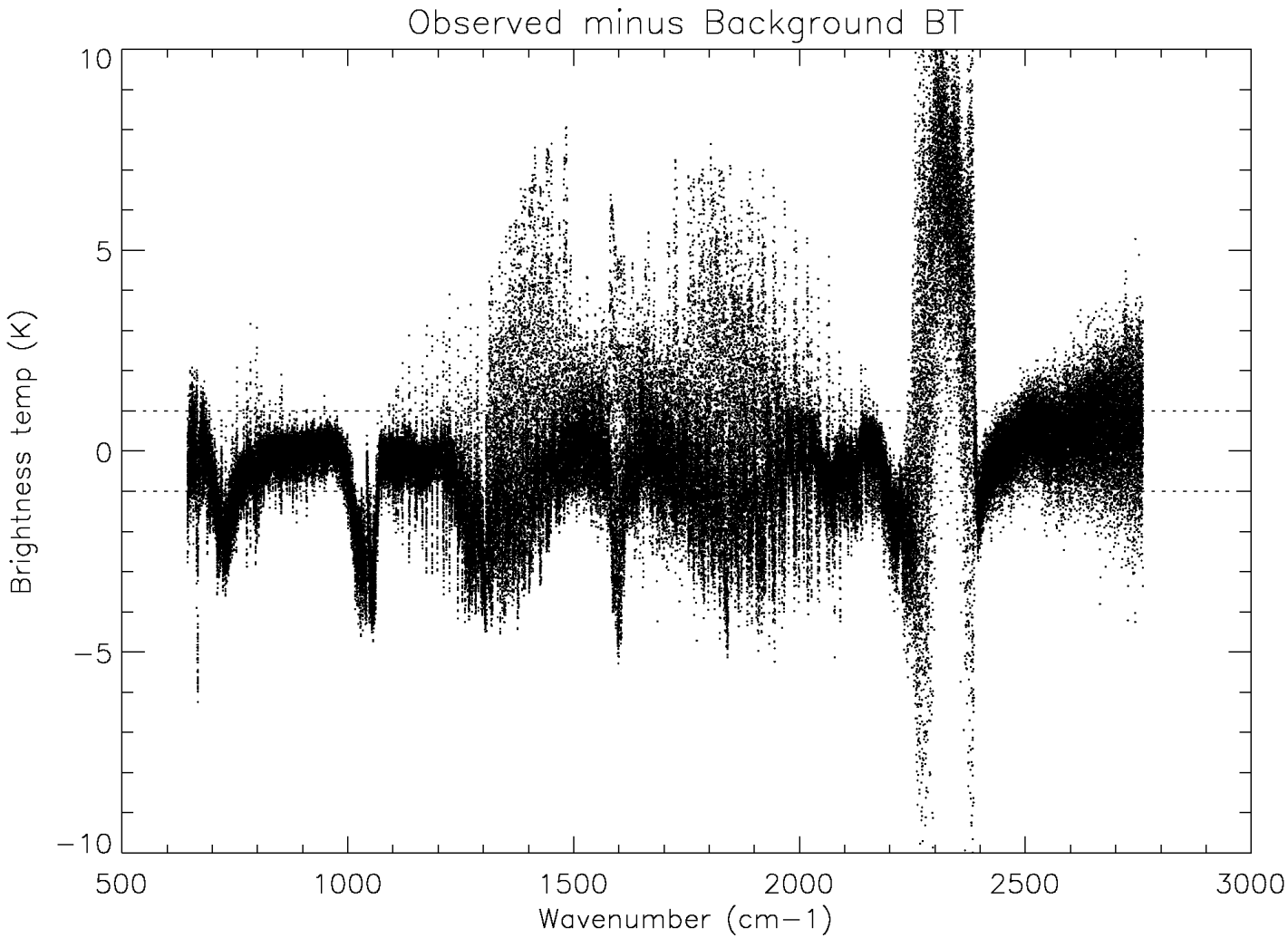
Observed Minus Background Brightness Temps



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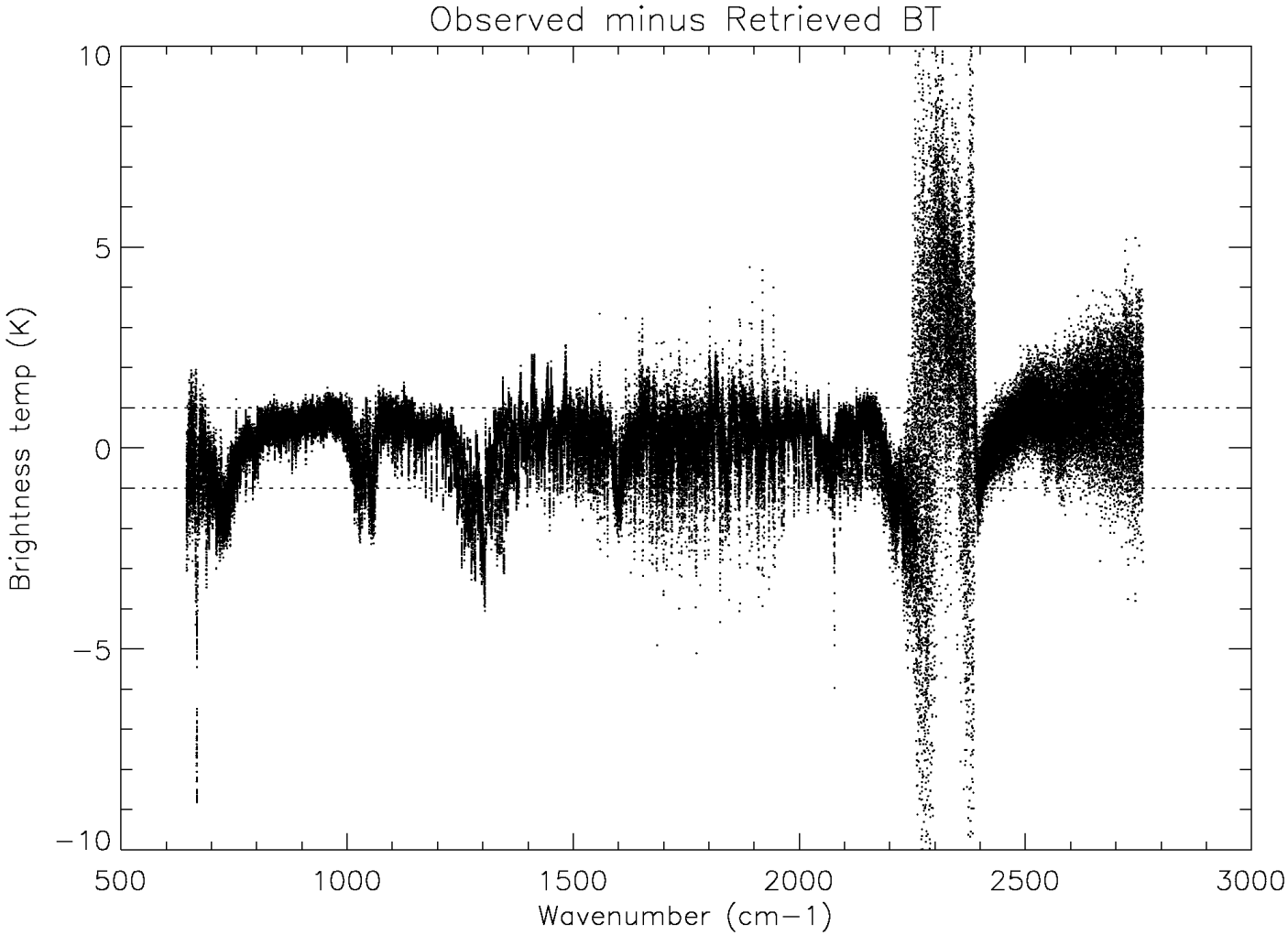
Observed minus Retrieved Brightness Temps



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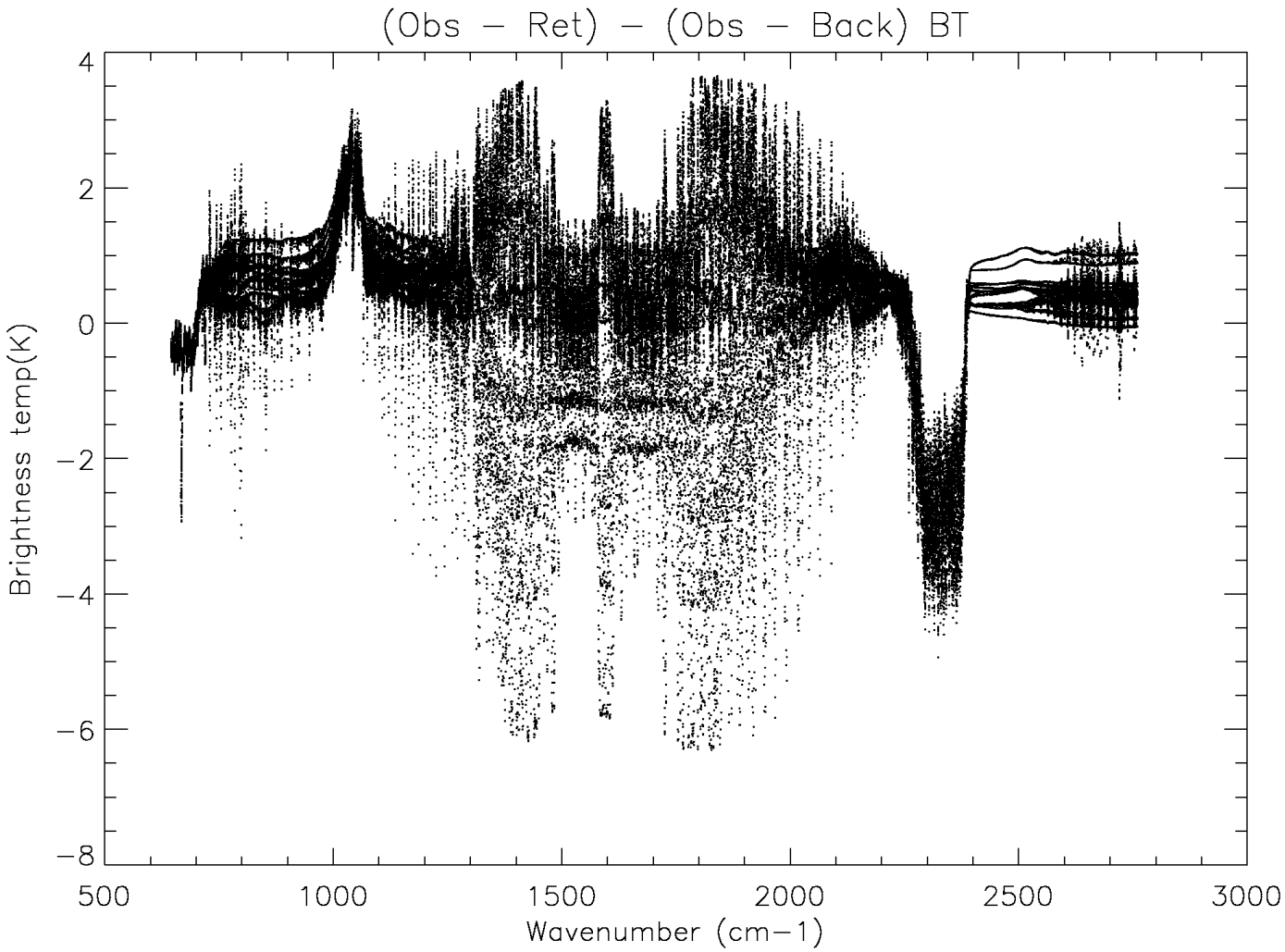
Brightness Temperature Increments



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Covariance of retrieved state vector: the A Matrix

$$A = \left(B^{-1} + K^T R^{-1} K\right)^{-1}$$

Where:
B = background error covariance matrix
R = instrument error covariance matrix
K = Jacobian

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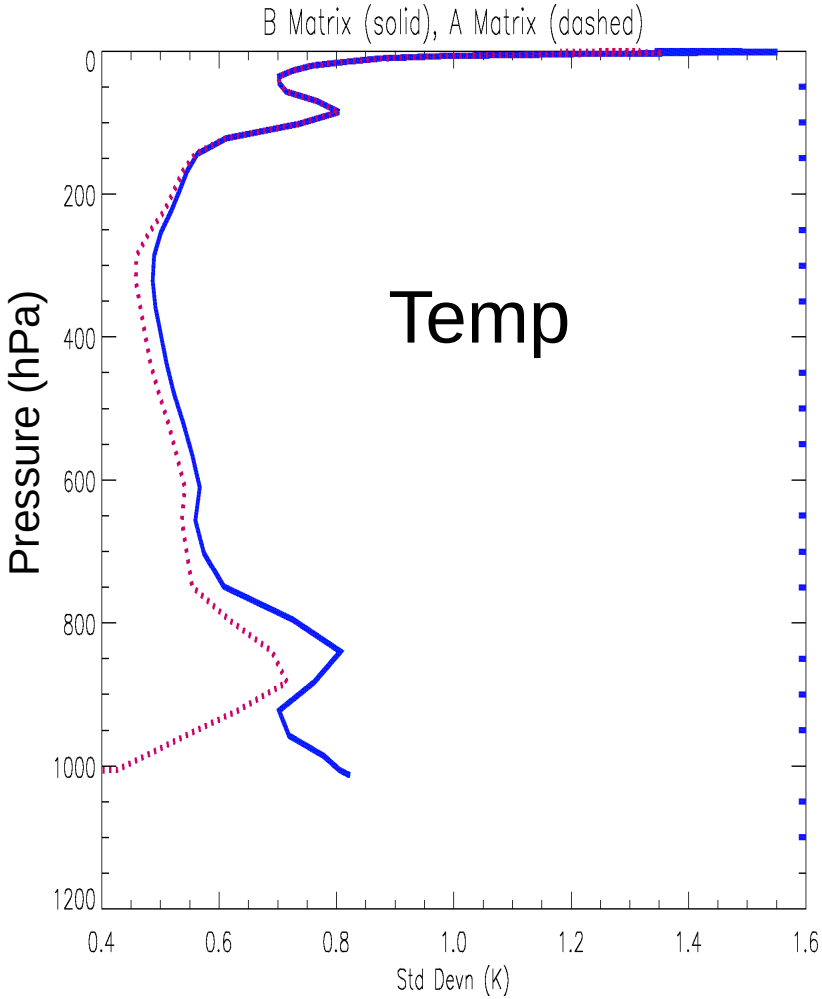
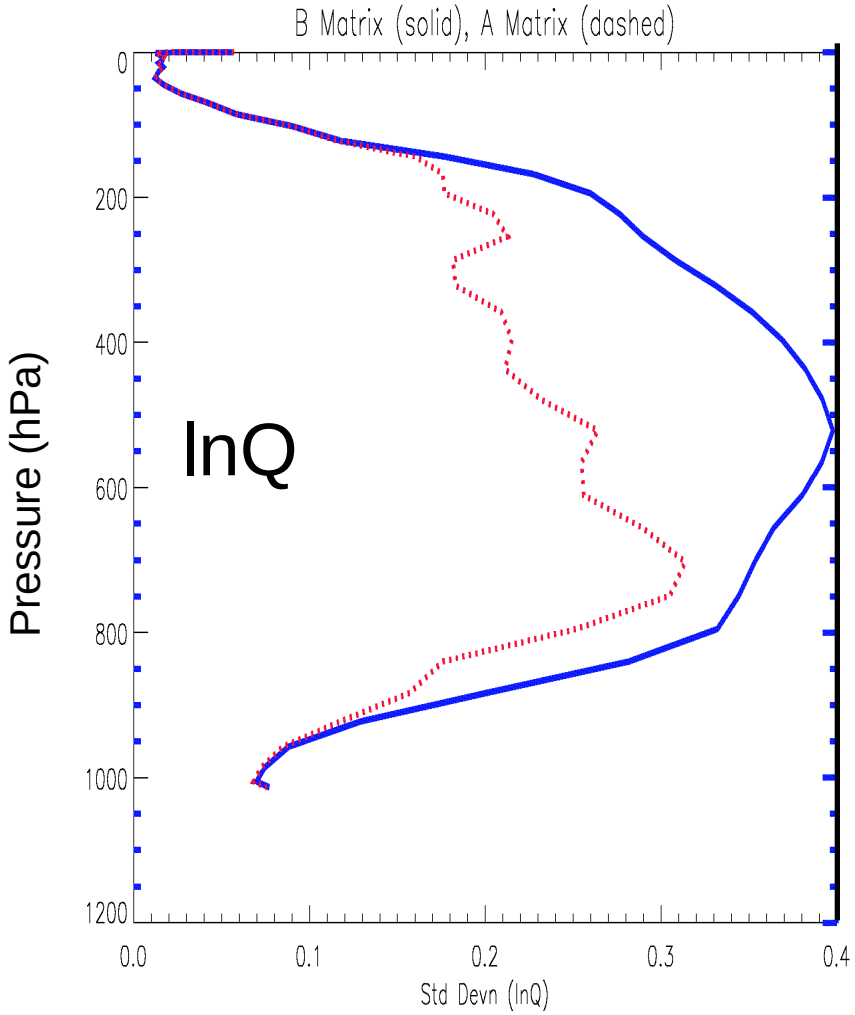
Standard deviations of background and retrievals





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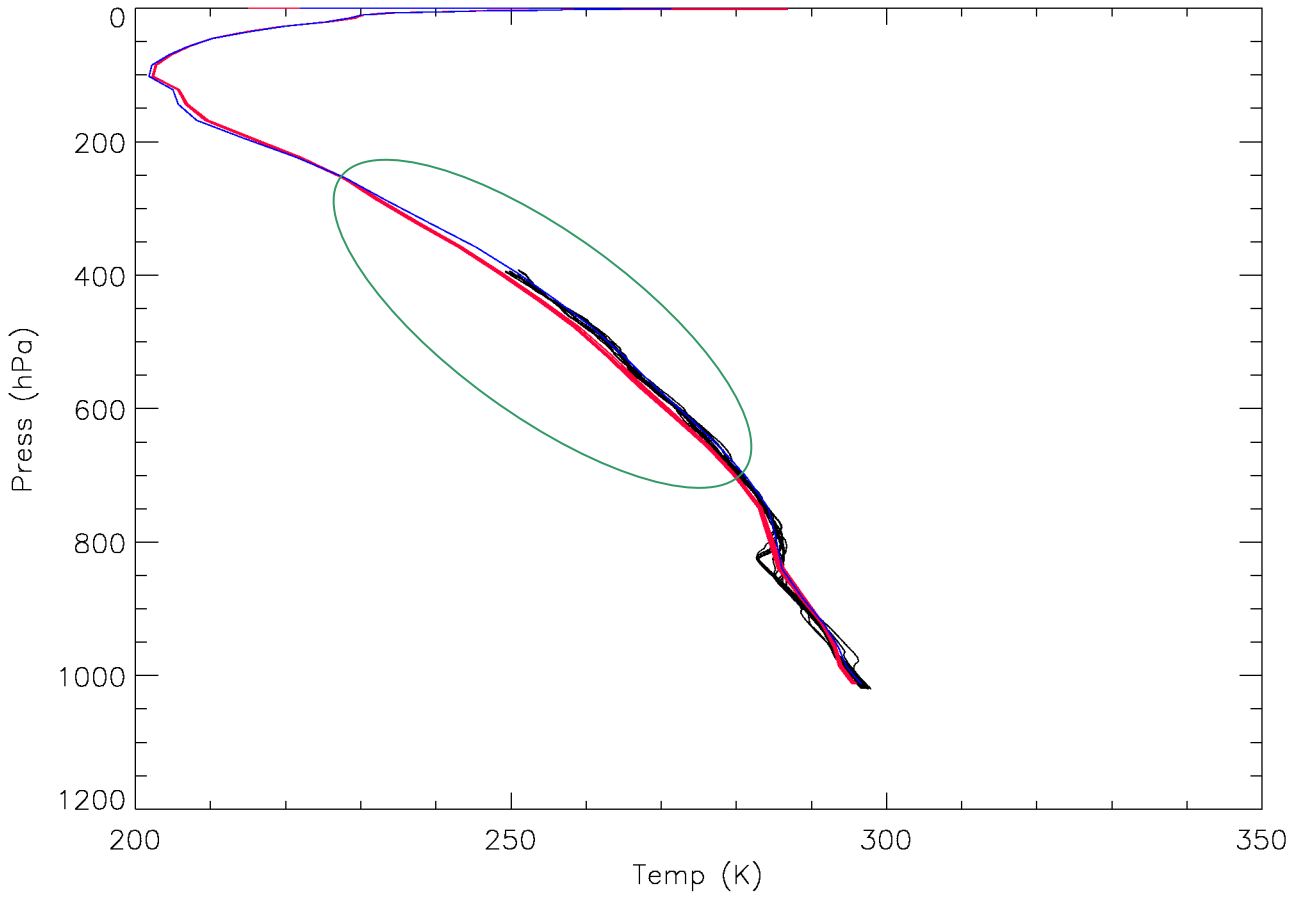
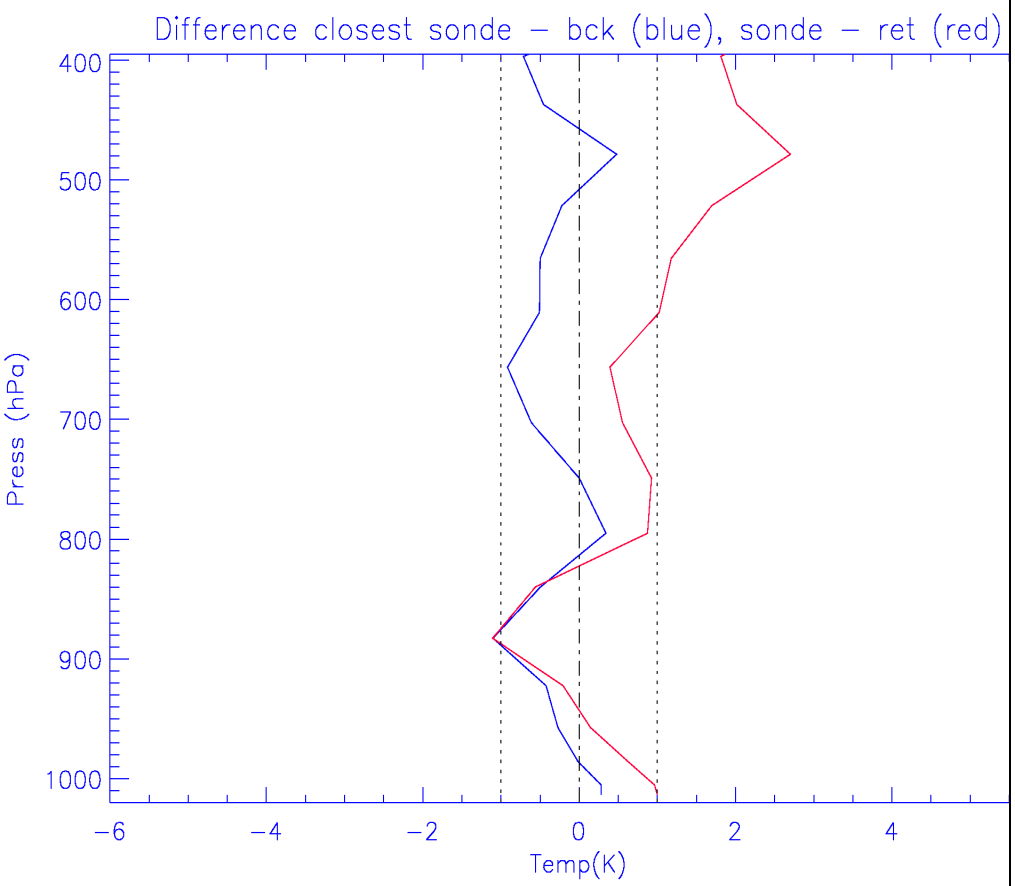
Temperature retrieval with error covariance of water vapour set to 0 for top 17 levels of atmosphere



Evidence that water vapour channels contain a great deal of temperature information!



Note:

Temperature of retrievals now are significantly lower than background and dropsondes

Water channels are trying to change water vapour profile but because they cannot properly influence upper trop/lower stratosphere water vapour they can only compensate by altering the temperature profile - detrimentally

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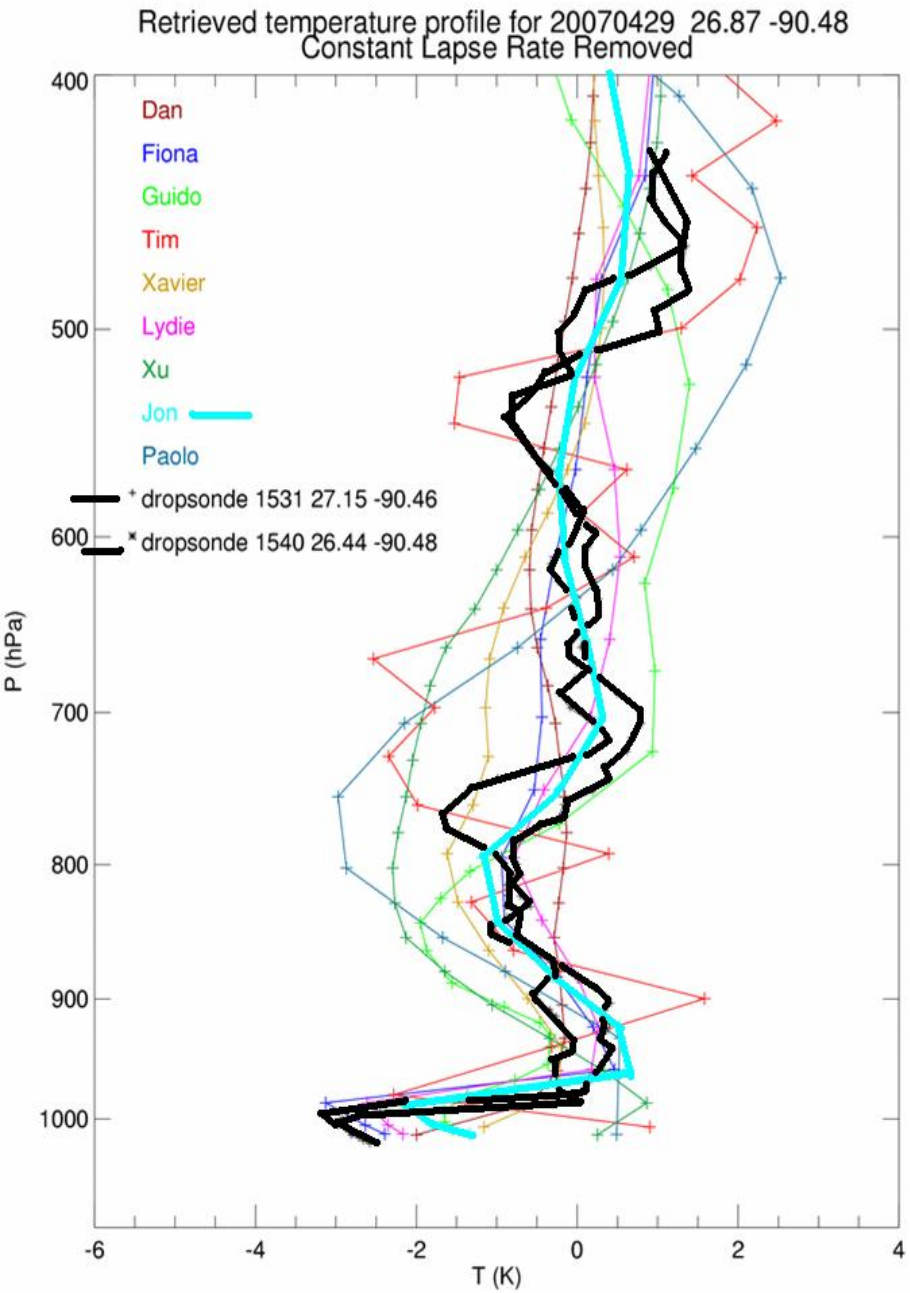
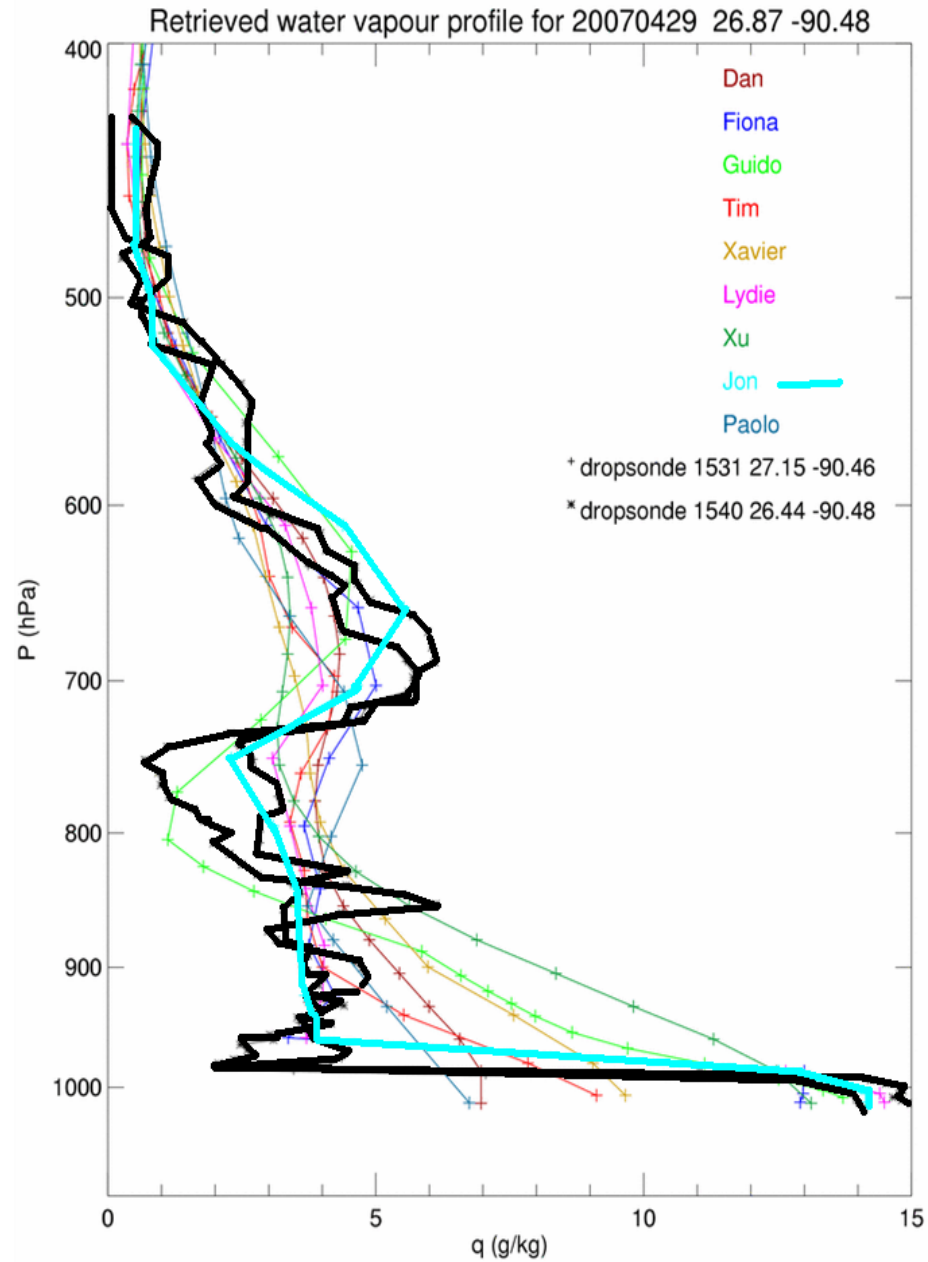

Retrieved temperature profile for 20070429 26.87 -90.48
Constant Lapse Rate Removed
Dan
Fiona
Guido
Tim
Xavier
Lydie
Xu
Jon
Paolo
dropsonde 1531 27.15 -90.46
dropsonde 1540 26.44 -90.48
P (hPa)
T (K)
400
500
600
700
800
900
1000
-6
-4
-2
0
2
4


Retrieved water vapour profile for 20070429 26.87 -90.48
Dan
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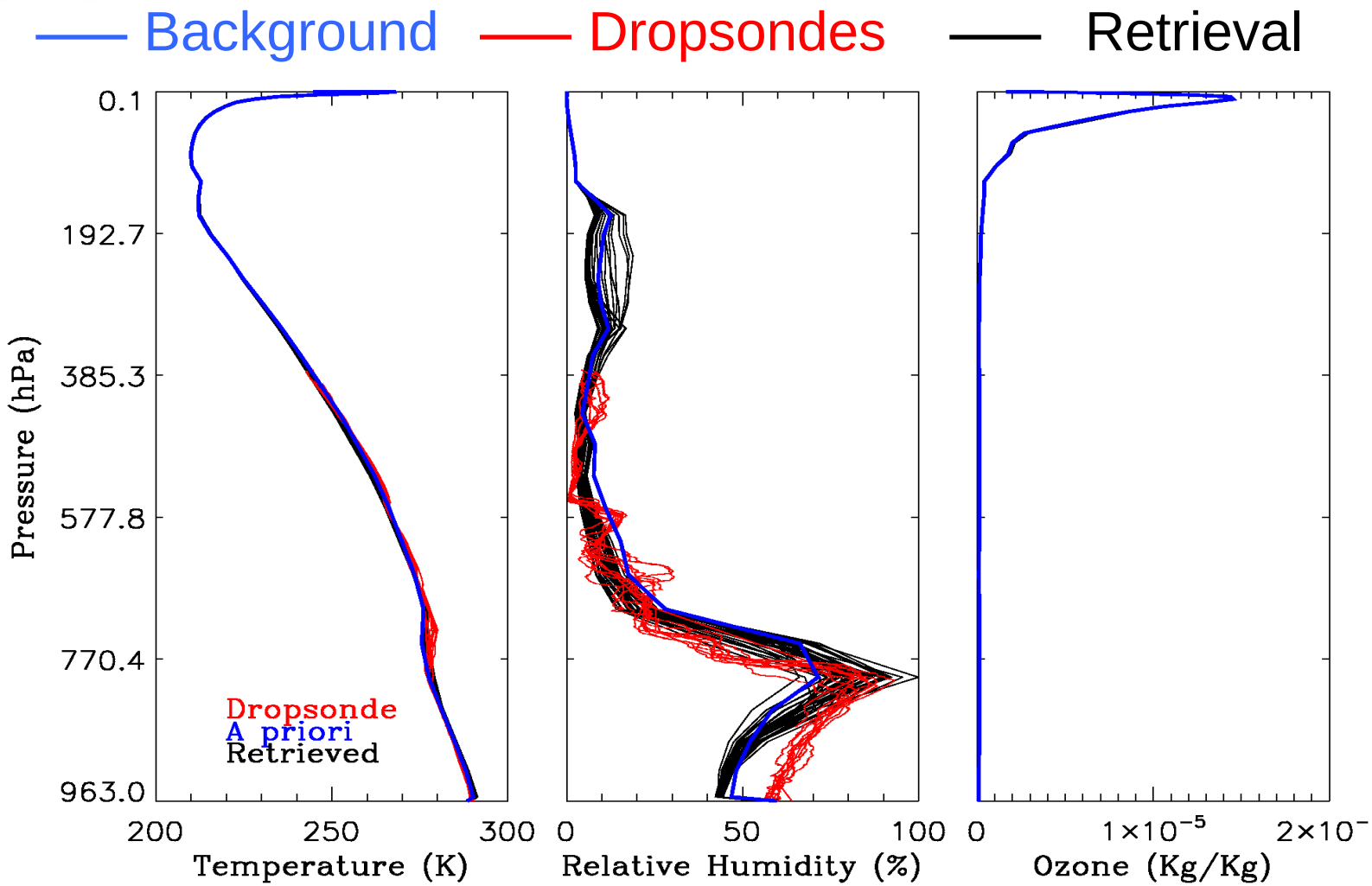
dropsonde 1531 27.15 -90.46
dropsonde 1540 26.44 -90.48
P (hPa)
q (g/kg)
400
500
600
700
800
900
1000
0
5
10
15

Jaivex Flight B284 – over Land at Night



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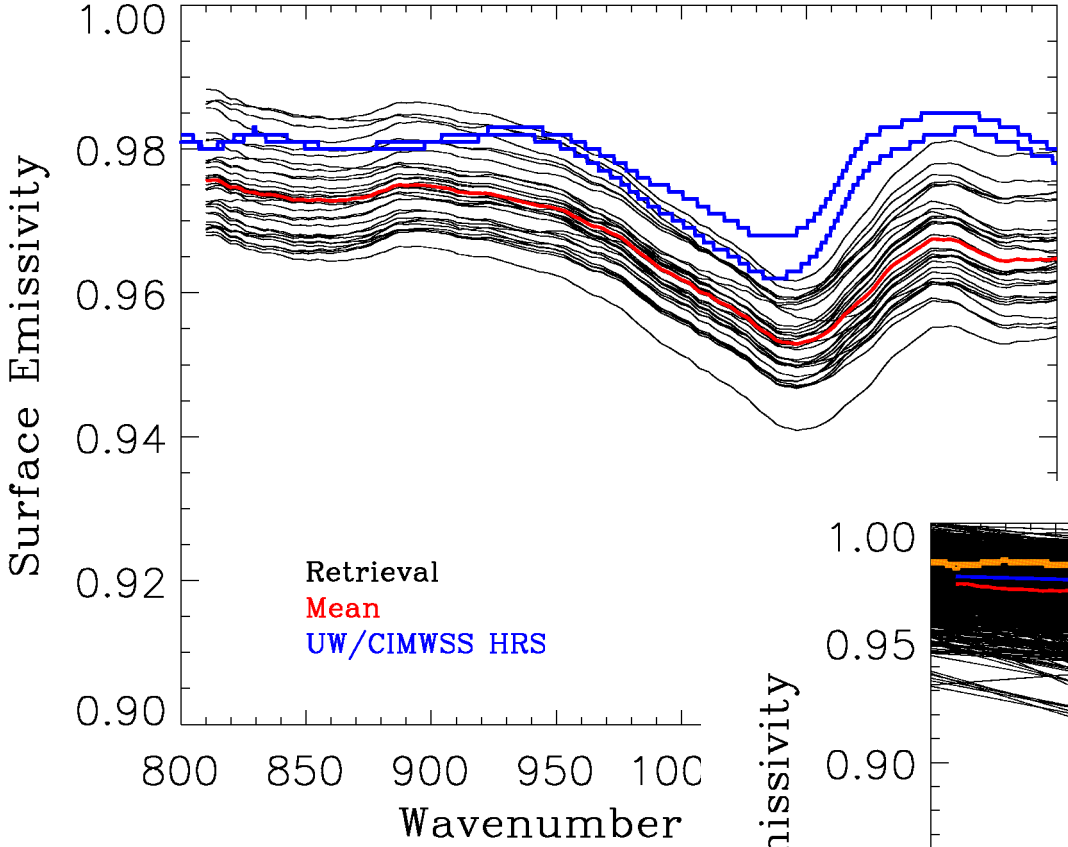
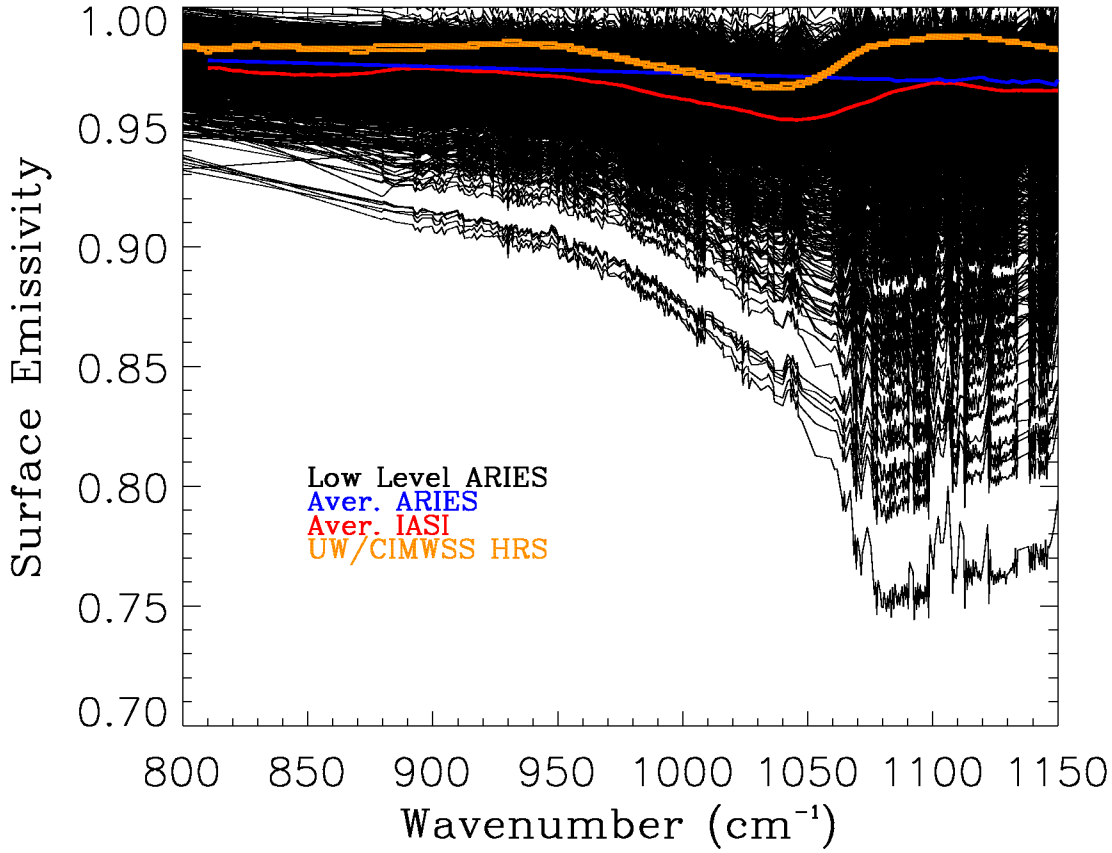
Emissivity Retrieval over Land





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Summary

- We have demonstrated that a PC based 1d-var scheme works well over ocean and land giving realistic profile structure – this is a generic capability not tuned to JAIVEX
- We now have a complete treatment of scattering in HT-FRTC
- Does the retrieval scheme work? - Cannot be stated with a small range of cases like these, the statistics just beat you! Ultimately will require full NWP trial.

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Acknowledgments

- JAIVEX team – Stuart Newman, Allen Larar, Bill Smith, Dan Zhou, all staff supporting the two research aircraft, Eumetsat for part funding.
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- ECMWF – Andrew Collard for the ECMWF B Matrix.

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Questions and answers

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