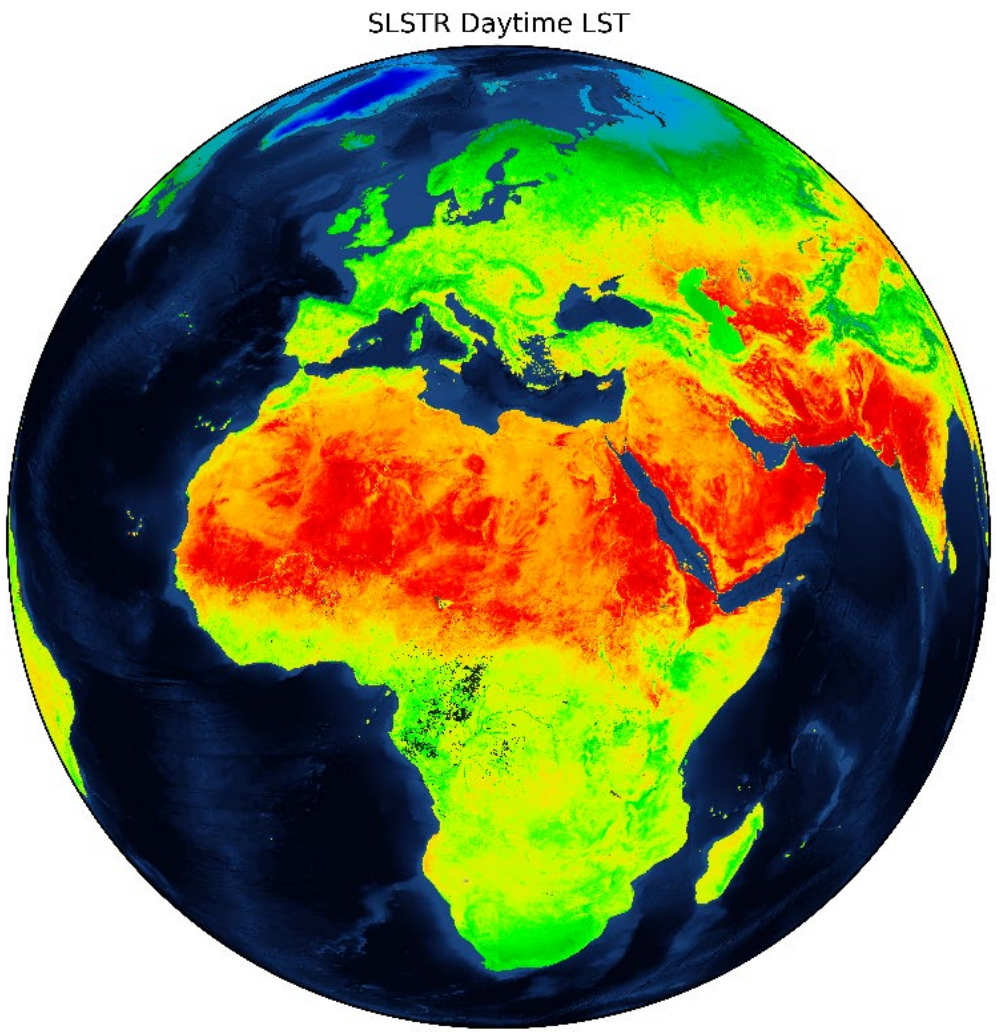

The addressing the Atmosphere in TIR

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What we will cover in this lecture

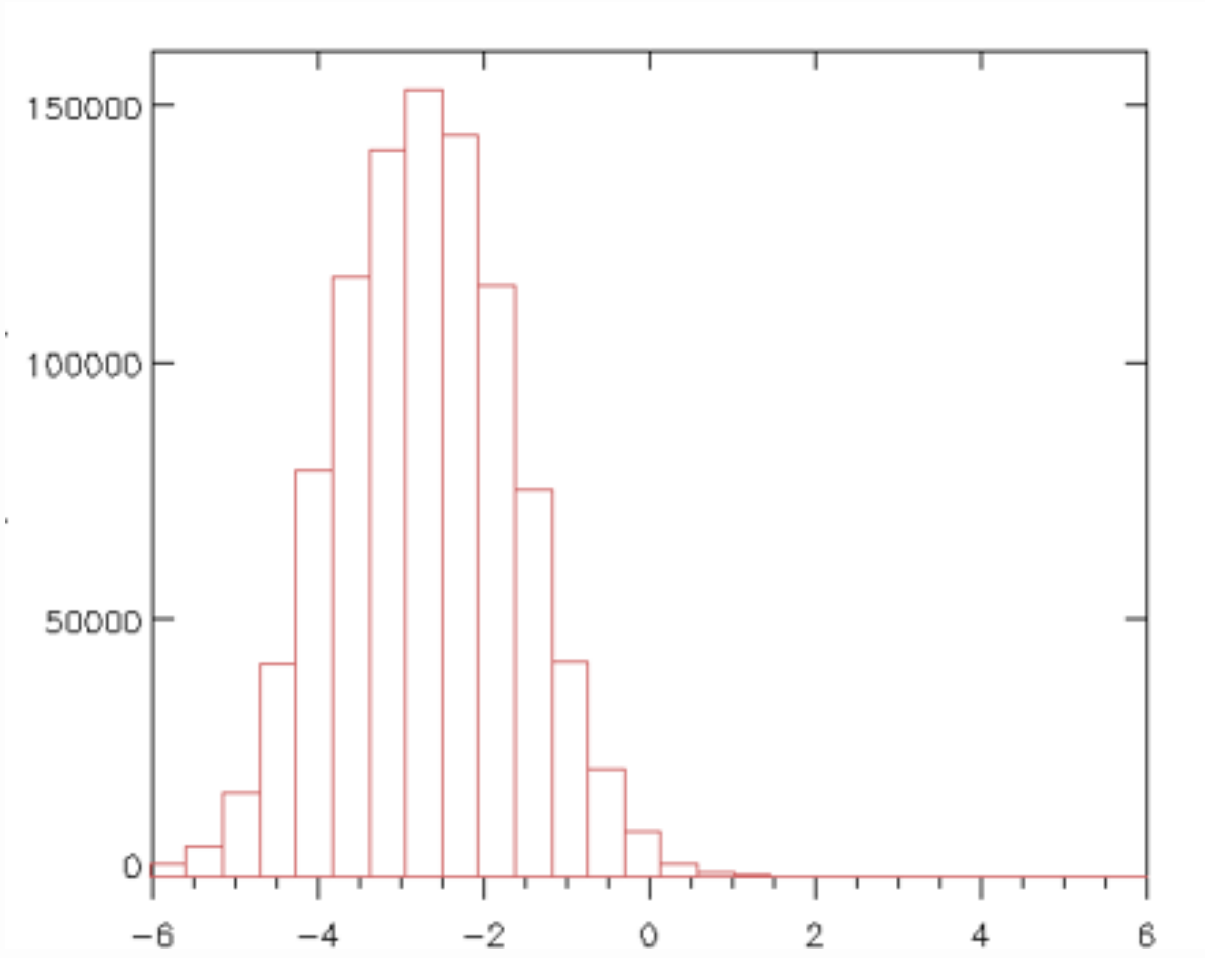
- Why we care about the atmosphere in TIR remote sensing
- How much does it affect retrievals?
- Why do we see atmospheric effects in TIR retrievals?
- How do we account for the atmosphere in our retrievals?

Why do we care about the atmosphere in TIR remote sensing?

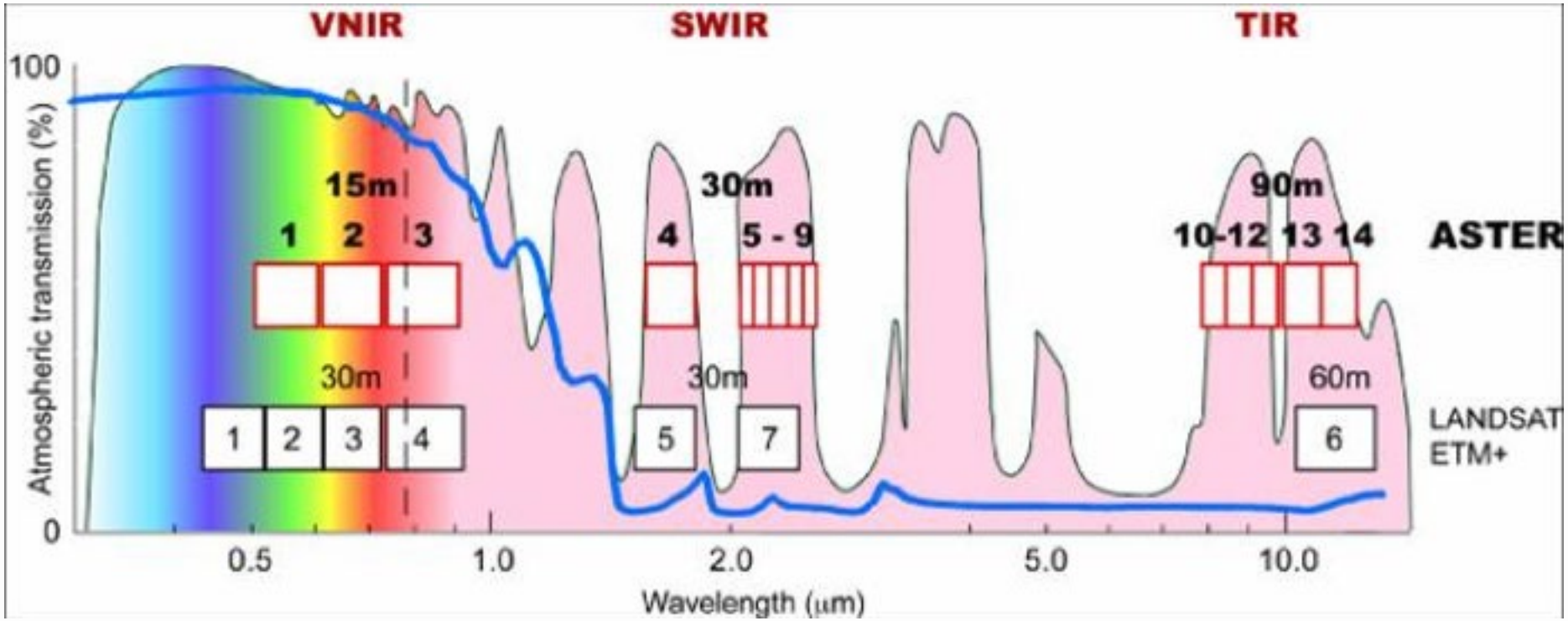
- Even in the atmospheric window of high transmission attenuation is still significant
- Most attenuation at these wavelengths is due to water vapour absorption
- Stratospheric and tropospheric aerosols also depress infrared radiances
- Both atmospheric effects and emissivity variability need to accounted for to avoid retrieval errors of up to **12K** (Sobrino and Raissouni, IJRS, 2000; Sobrino et al., IJRS, 2003)

Why do we care about the atmosphere in TIR remote sensing?

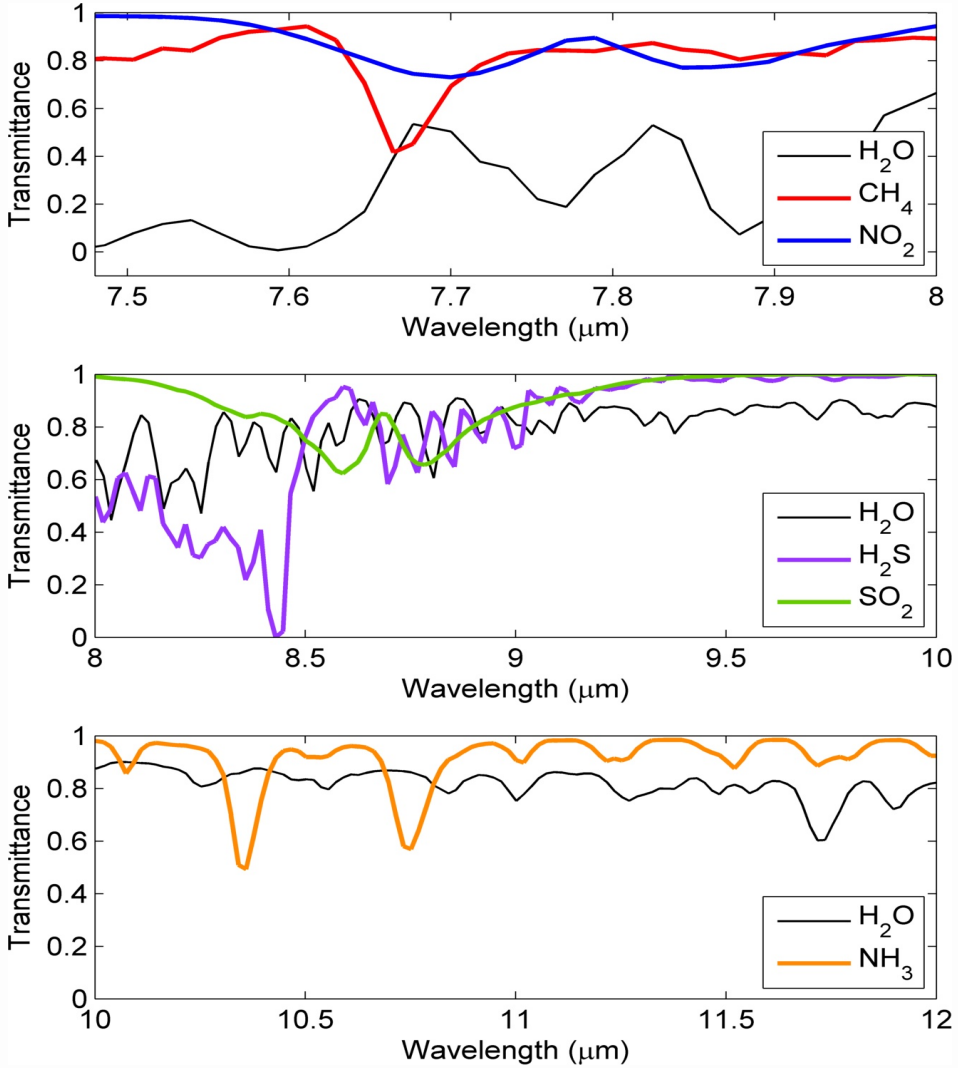
- Airborne is not immune to this, recent campaigns showed that errors in ATM treatment can have significant biases.
- In the example (Right) the incorrect setting of airborne altitude (and hence atmospheric profile) resulted in ~3 K biases

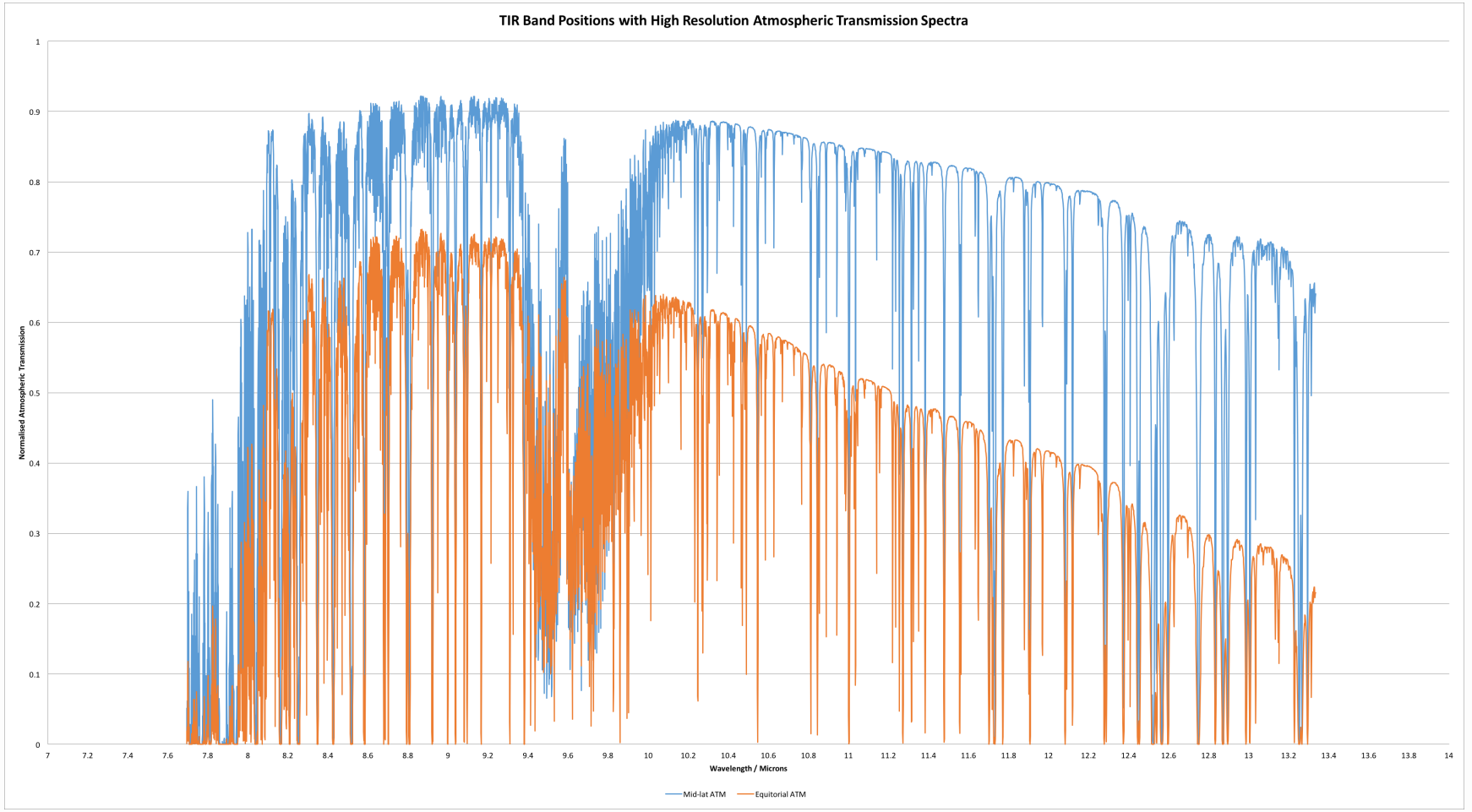


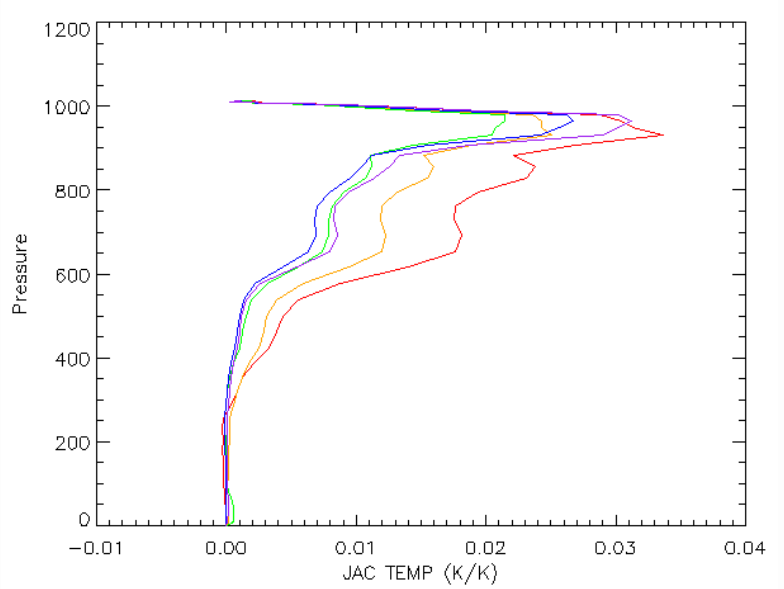
Why do we see atmospheric effects in TIR retrievals?

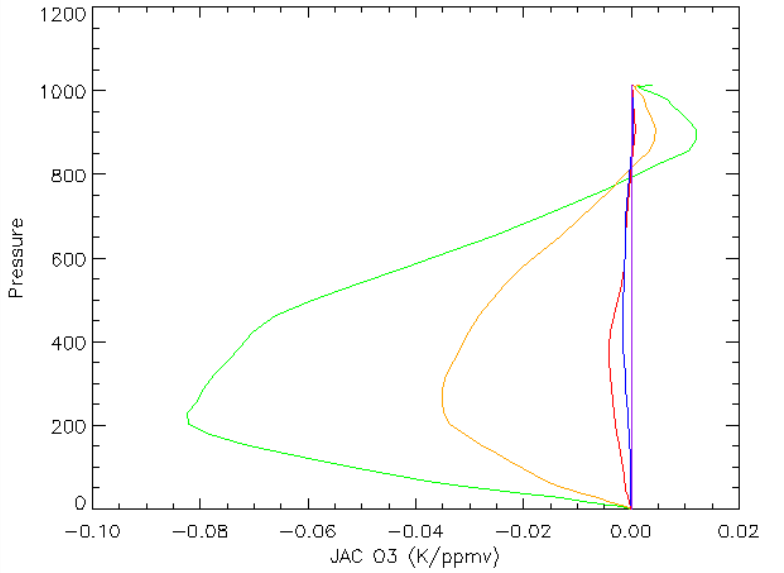


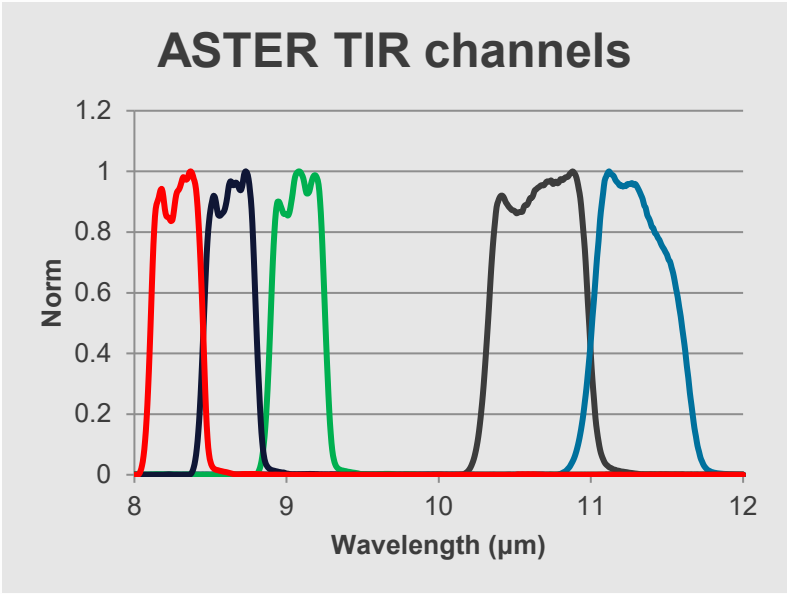
What parts of the atmosphere contribute?

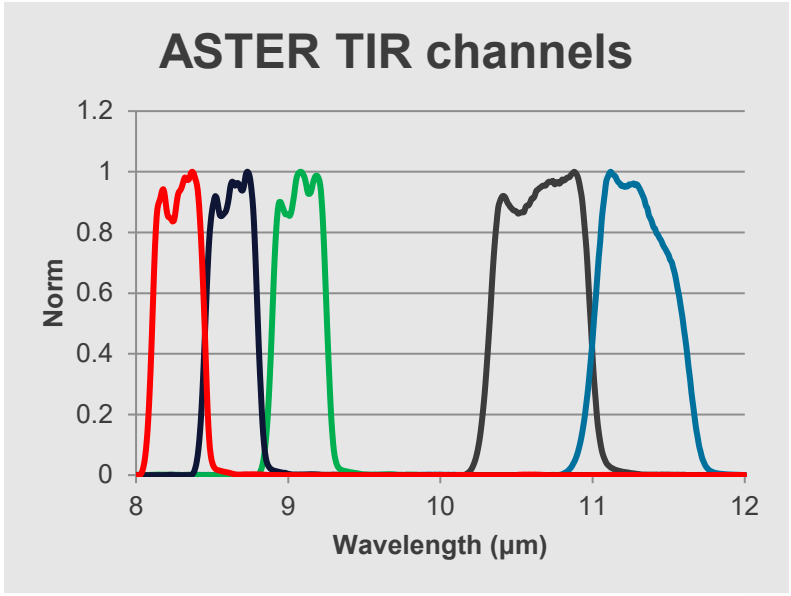


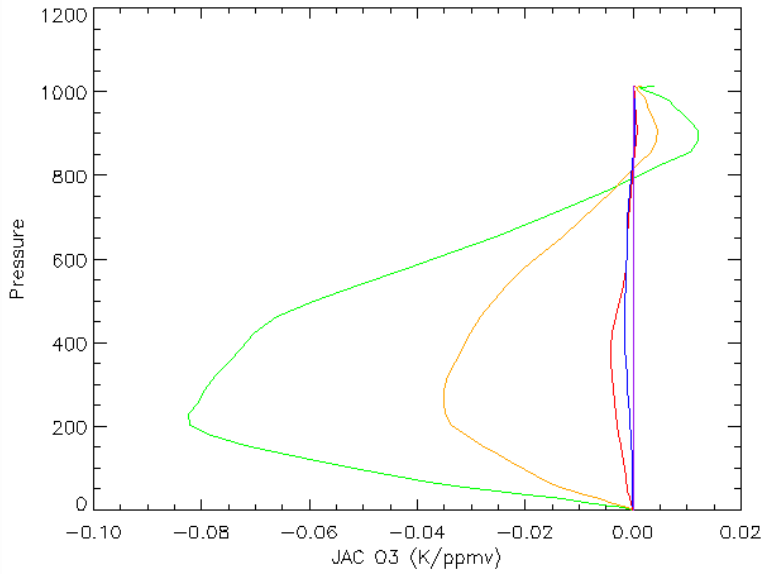

TIR Band Positions with High Resolution Atmospheric Transmission Spectra
Normalised Atmospheric Transmission
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7
7.2
7.4
7.6
7.8
8
8.2
8.4
8.6
8.8
9
9.2
9.4
9.6
9.8
10
10.2
10.4
10.6
10.8
11
11.2
11.4
11.6
11.8
12
12.2
12.4
12.6
12.8
13
13.2
13.4
13.6
13.8
14
Wavelength / Microns
Mid-lat ATM
Equitorial ATM

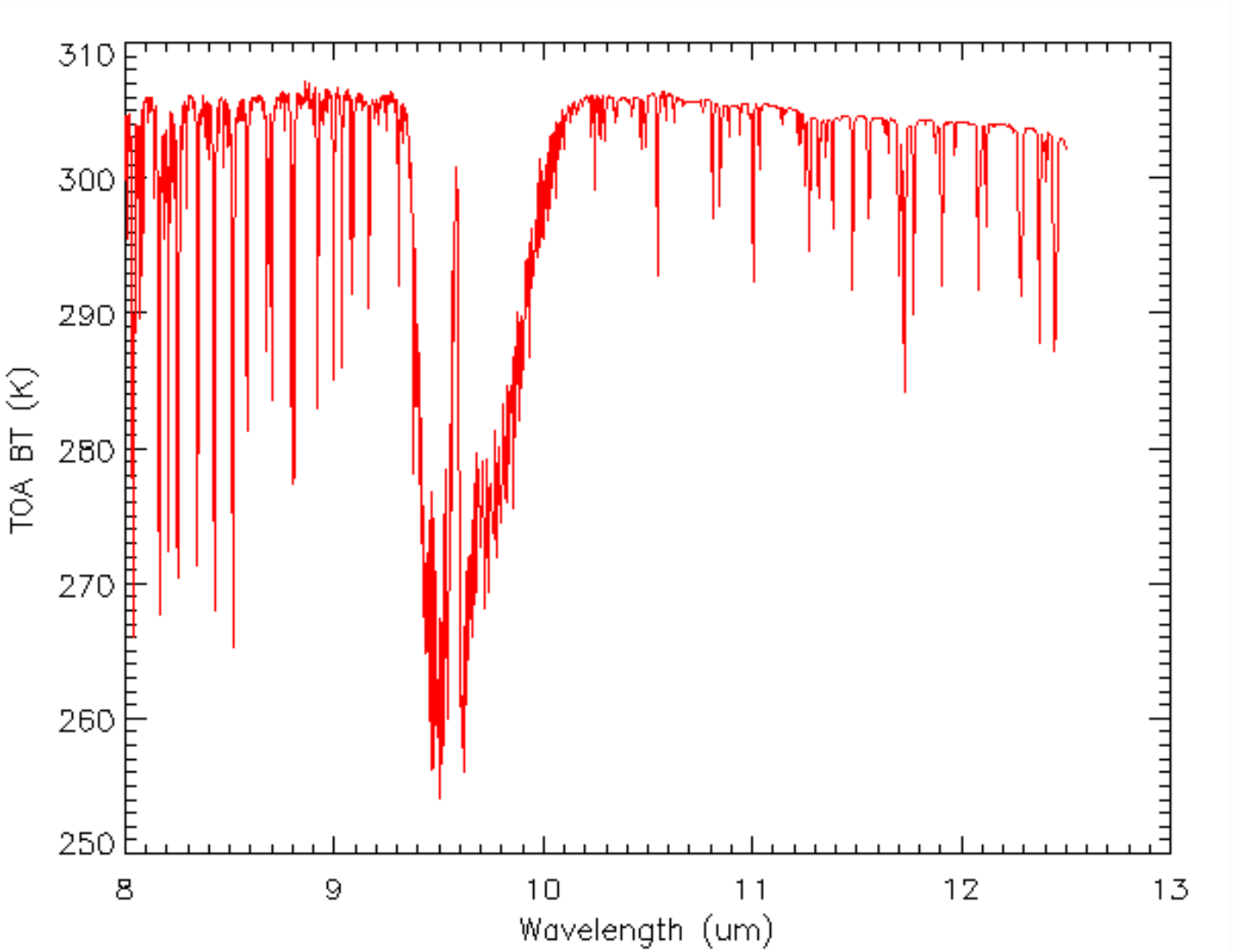

Pressure
1200
1000
800
600
400
200
0
−0.01
0.00
0.01
0.02
0.03
0.04
JAC TEMP (K/K)


Pressure
1200
1000
800
600
400
200
0
−0.10
−0.08
−0.06
−0.04
−0.02
0.00
0.02
JAC O3 (K/ppmv)

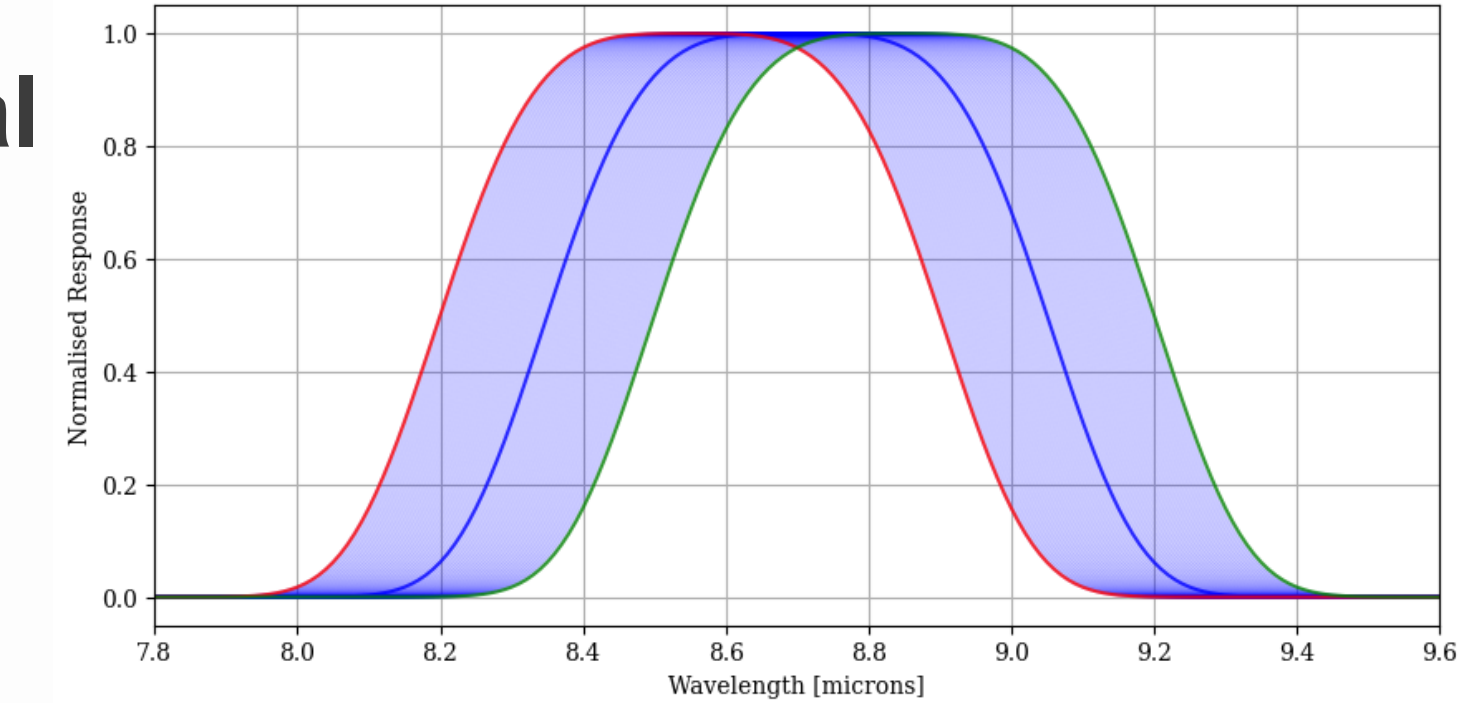

ASTER TIR channels
Norm
1.2
1
0.8
0.6
0.4
0.2
0
8
9
10
11
12
Wavelength (μm)

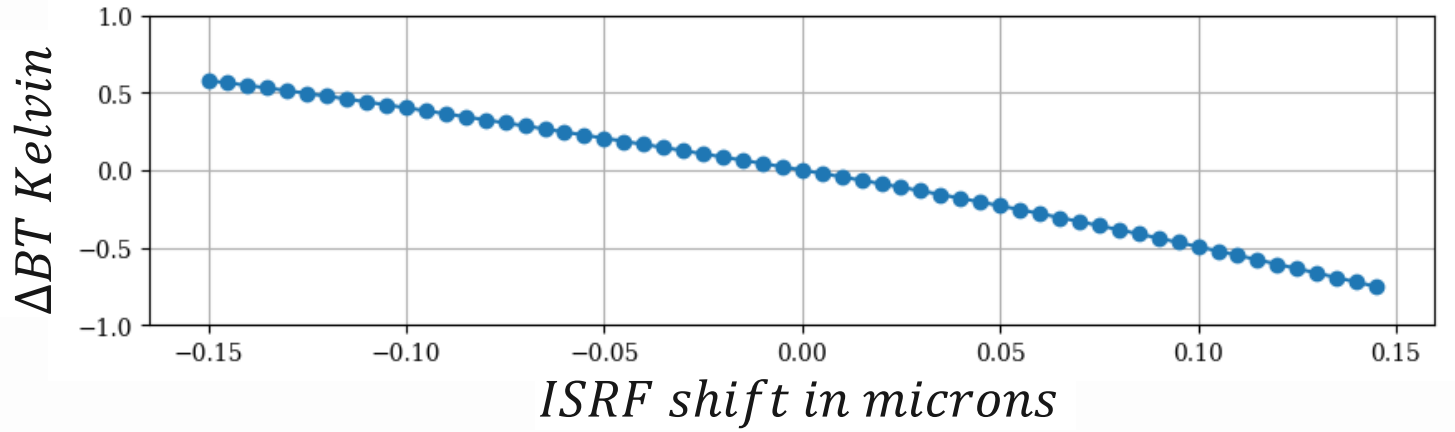

ASTER TIR channels
Norm
Wavelength (μm)
1.2
1
0.8
0.6
0.4
0.2
0
8
9
10
11
12


Pressure
JAC O3 (K/ppmv)
1200
1000
800
600
400
200
0
−0.10
−0.08
−0.06
−0.04
−0.02
0.00
0.02


TOA BT (K)
Wavelength (um)
310
300
290
280
270
260
250
8
9
10
11
12
13

Instrument Spectral Response



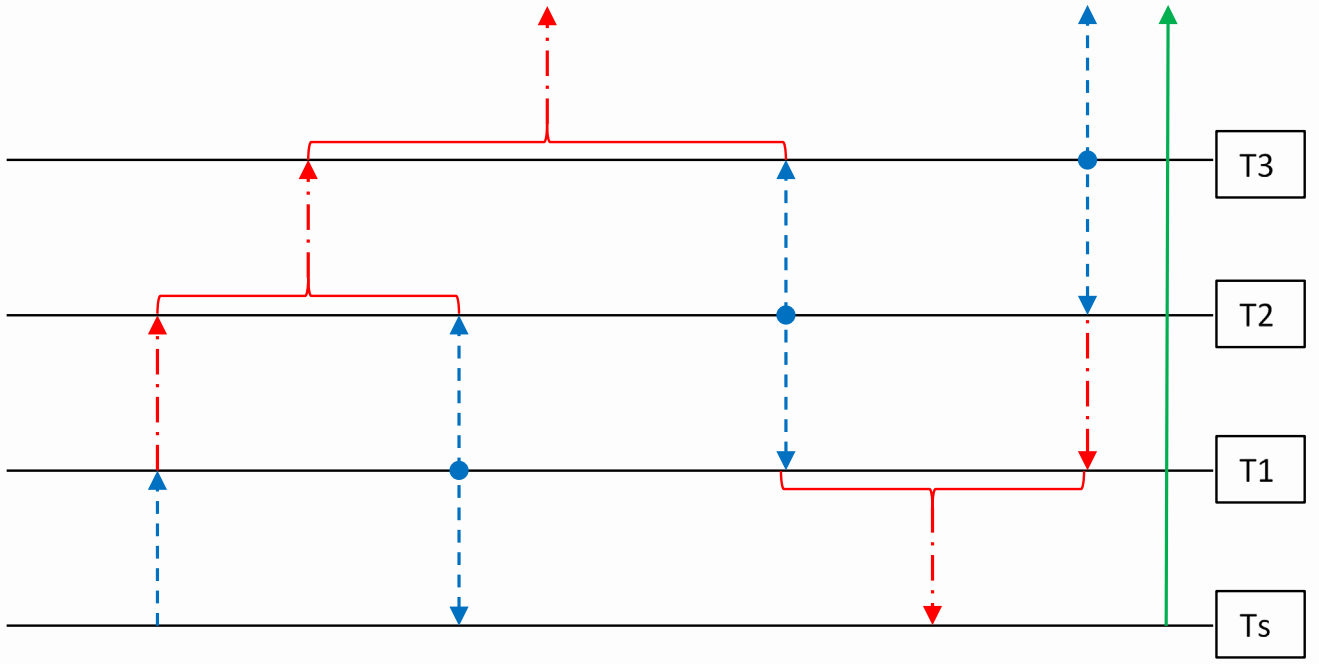


How do we account of the atmosphere in our retrievals?

- Atmospheric correction
- Atmospheric sensitivity / uncertainty

Atmospheric Correction

- Atmospheric correction looks to take the observation and work back to the surface leaving radiation
- But this diagram is obviously too simple

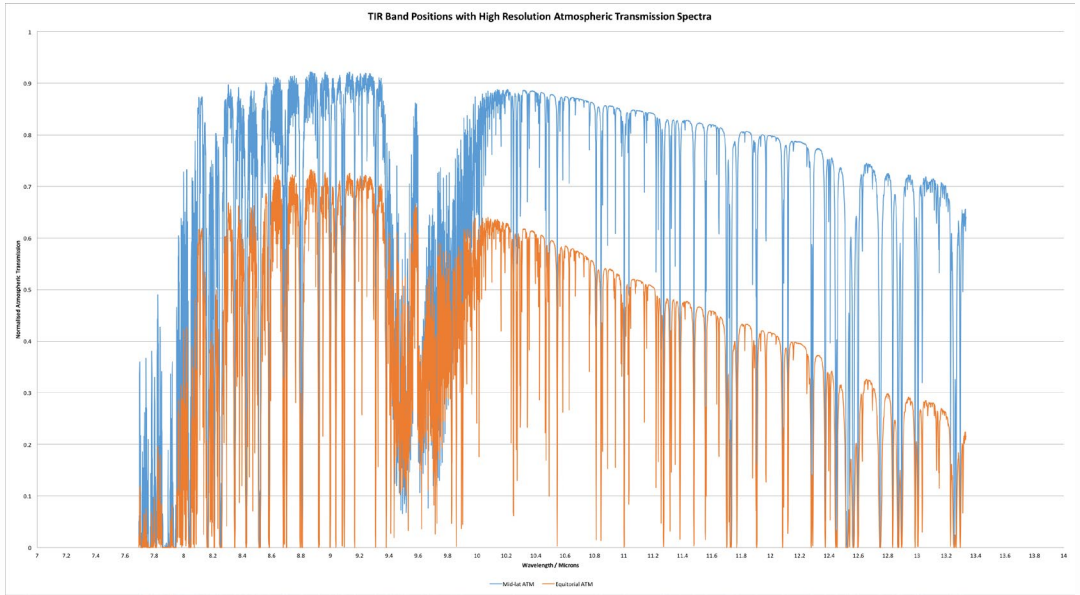


Atmospheric Correction

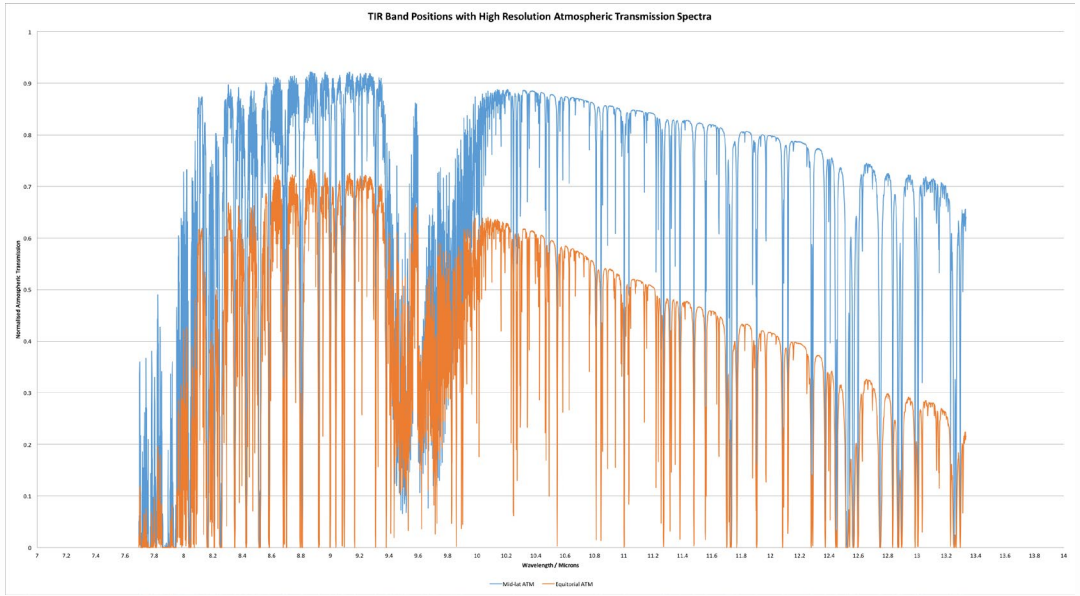
- To treat the physical model in a computationally manageable fashion the atmosphere is divided into layers, such as the simplified arrangement shown before.
- In each of these layers the transmittance and the thermal emission are dependent upon the atmospheric temperature and absorption coefficients of the gases included in the forward model.

Atmospheric Correction: Line-by-line

- Line-by-line models calculate the TOA radiance through the application of radiative transfer functions dependent upon the atmospheric properties relevant to each wavenumber being simulated, and can be computationally expensive. (RFM)

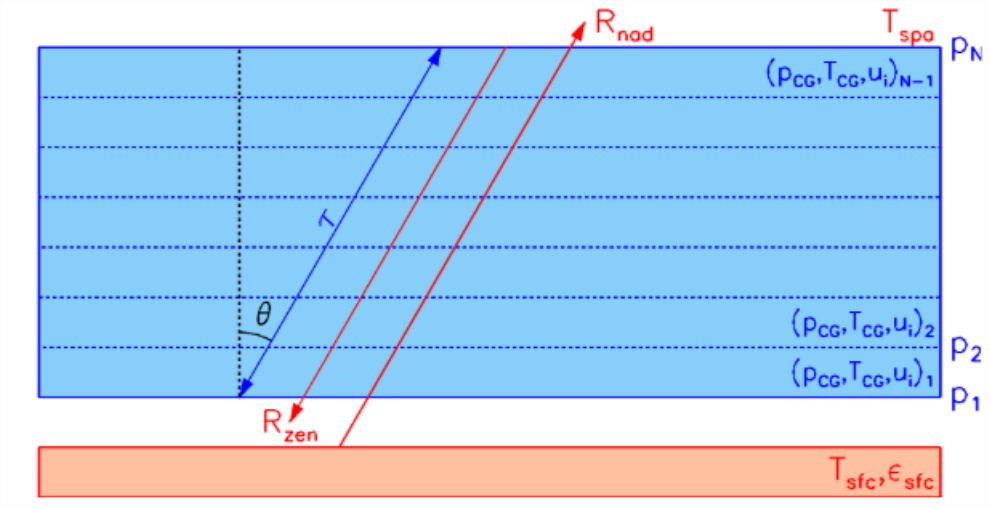


Atmospheric Correction: Line-by-line




```
*SPC                Spectral range / sampling
 714.0 1111.0 0.05
*GAS                List of absorbing species
 H2O O3 CO
*ATM                List of atmospheric profiles
 mls.atm
*SEC                Tangent Heights (1.0 for Nadir)
 1.0038198375433474
*FIN                RFM resolution
 0.01
*HIT                Location of hitran information
 HITRAN2012_gfortran.bin
*SFC          Surface Temperature and Emissivity (Default =1)
 309.3283996582031 pixel.sfc
```

Atmospheric Correction: Line-by-line




```
*SPC                Spectral range / sampling
        714.0 1111.0 0.05
*GAS                List of absorbing species
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        HITRAN2012_gfortran.bin
*SFC          Surface Temperature and Emissivity (Default =1)
        309.3283996582031 pixel.sfc
```

Atmospheric Correction: Coefficient

- Radiative Transfer for TOVS (RTTOV) is a fast radiative transfer model developed by the UK Meteorological (MET) Office.
- It treats spectral windows as independent channels.
- RTTOV gas transmittances within the atmosphere are incorporated as a function of predictors associated with the profile.
- Through the parameterisation of the various transmittances the computational speed of the model is increased significantly compared to the line-by-line methodology (Matricardi, 2009).
- However this increase in computational speed does mean a reduction in the accuracy and spectral resolution of the simulated radiances.
- In comparison to RFM, RTTOV has coarser effective spectral resolution as the forward model uses channel coefficients which rather than a spectral range (Hocking et al., 2014).

Atmospheric Correction: Implementation

- See Agnieszka's lecture for algorithms details

Atmospheric Correction: Implementation

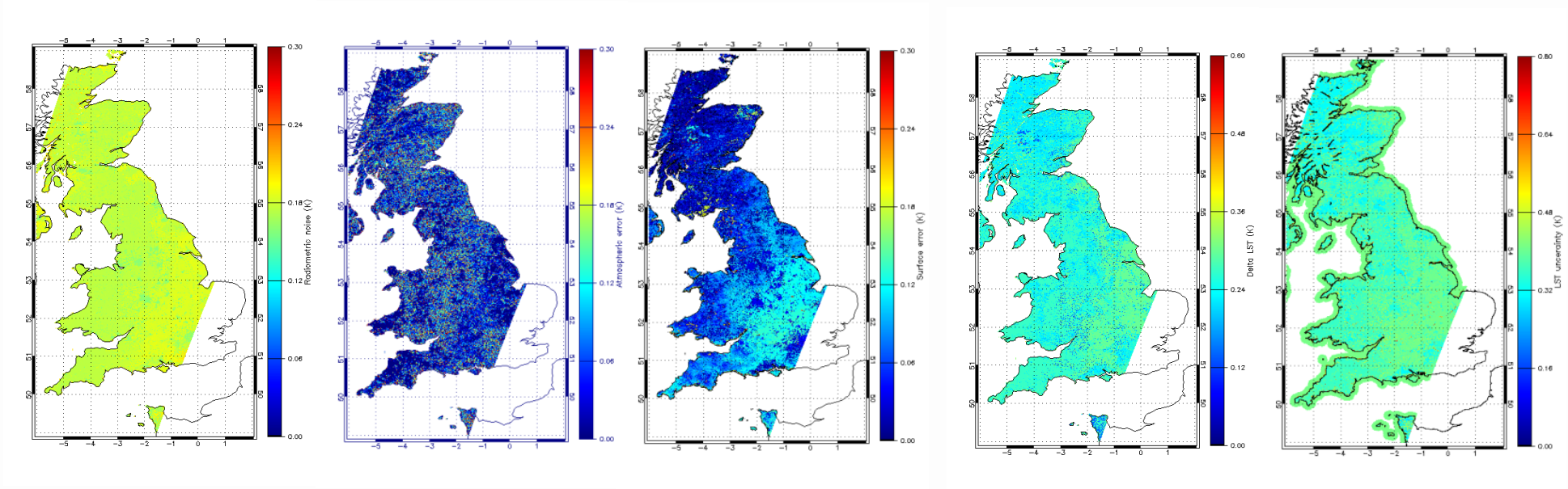
- See Agnieszka's lecture for algorithms details
- In general either you simulate "on the go" or you pre-process to produce coefficients that can parametrised atmospheric correction based on some prior knowledge: latitude, biome, TCWV etc.

Atmospheric Sensitivity

	UOL	GSW	OE	TES	direcTES	HybridOE
TCWV (K/ ΔTCWV)	-0.47	-1.41	0.06	-1.92	-0.49	-1.15
	-0.26	-0.83	0.02	-1.40	-0.47	-0.59
	0.13	-0.40	0.00	-0.87	-0.11	-0.25
	-0.27	-0.76	-0.01	-1.40	-0.48	-0.56
	-0.46	-1.24	-0.04	-1.97	-0.54	-1.06

- Subset of results from an algorithm intercomparison study for LST retrieval from TIR.
- TCWV varies by methodology, most algorithms show significant sensitivity to the TCWV

Atmospheric Uncertainty



Radiometric noise | Geolocation | Surface component | Atmosphere component | Total

Closing Points

- The atmosphere is a key issue in TIR retrievals
- It heavily impacts the spectral location of the channels used in satellite remote sensing
- The “windows” chosen have greater transmittance, but are still strongly impacted by gases in the atmosphere
- All retrieval methodologies must account for the atmosphere in order to retrieve the surface, this impacts both the bias and uncertainty
- A key tool in atmospheric correction is a radiative transfer model, of which there are several that must be selected with care to fit the application.