Investigations with High Spectral Resolution Data from AIRS

Lectures in Maratea
22 – 31 May 2003

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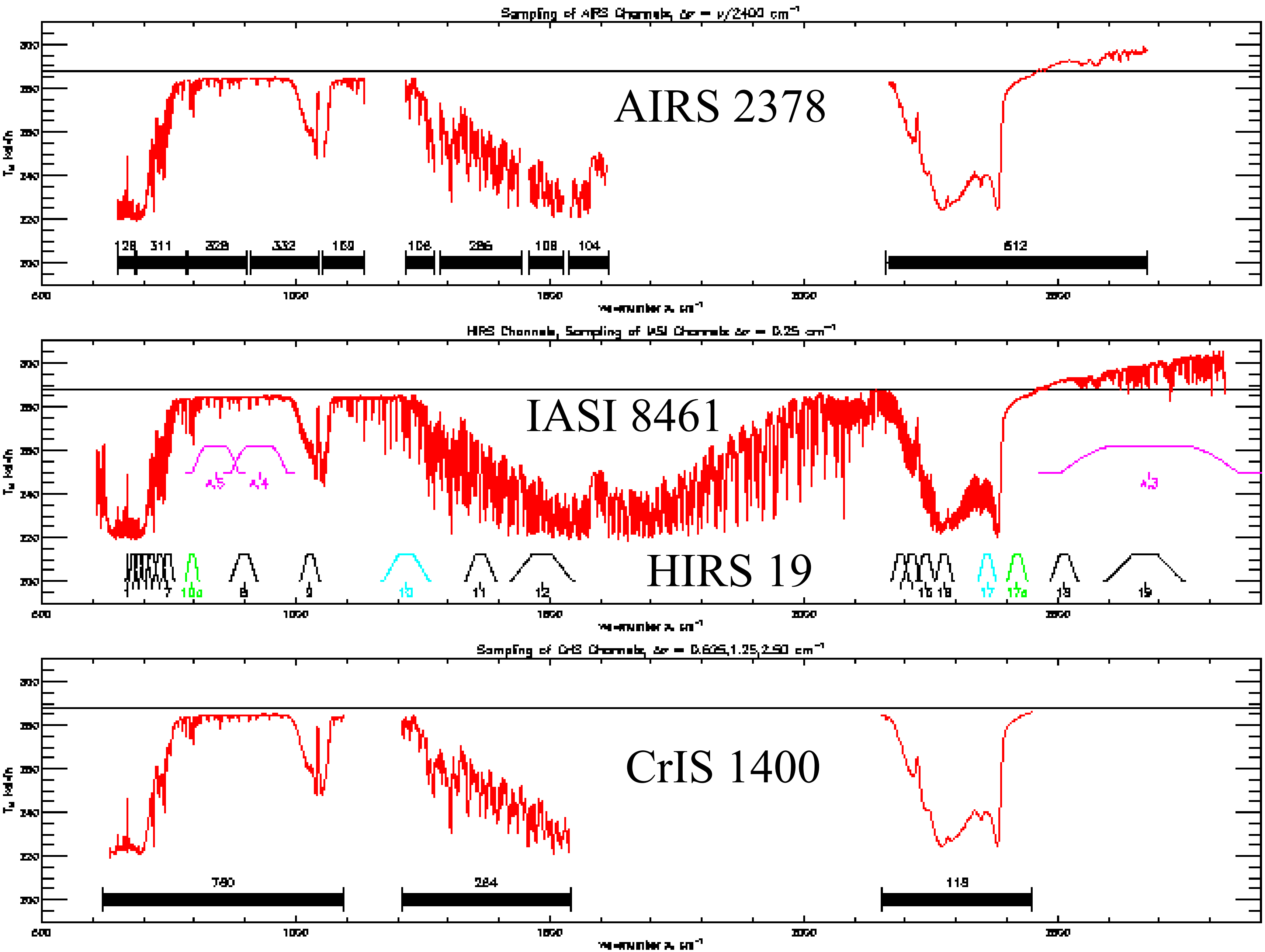
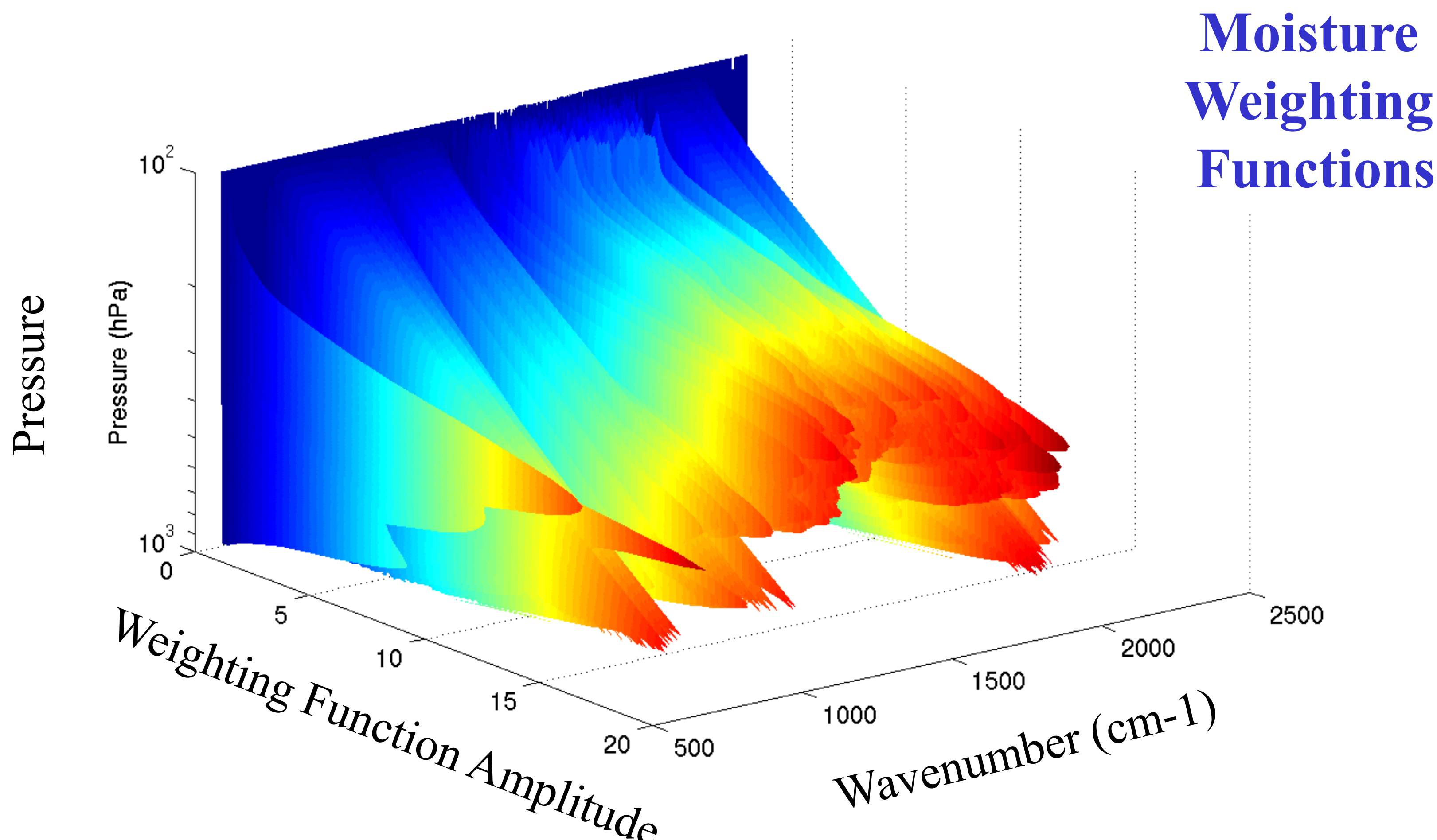
NOAA/NESDIS/ORA



Sampling of AIRS Channels, Δσ = ν/2400 cm⁻¹
AIRS 2378
128
311
328
332
169
108
286
108
104
512
HIRS Channels, Sampling of IASI Channels Δσ = 0.25 cm⁻¹
IASI 8461
HIRS 19
Sampling of CrIS Channels, Δσ = 0.625,1.25,2.50 cm⁻¹
CrIS 1400
780
284
118

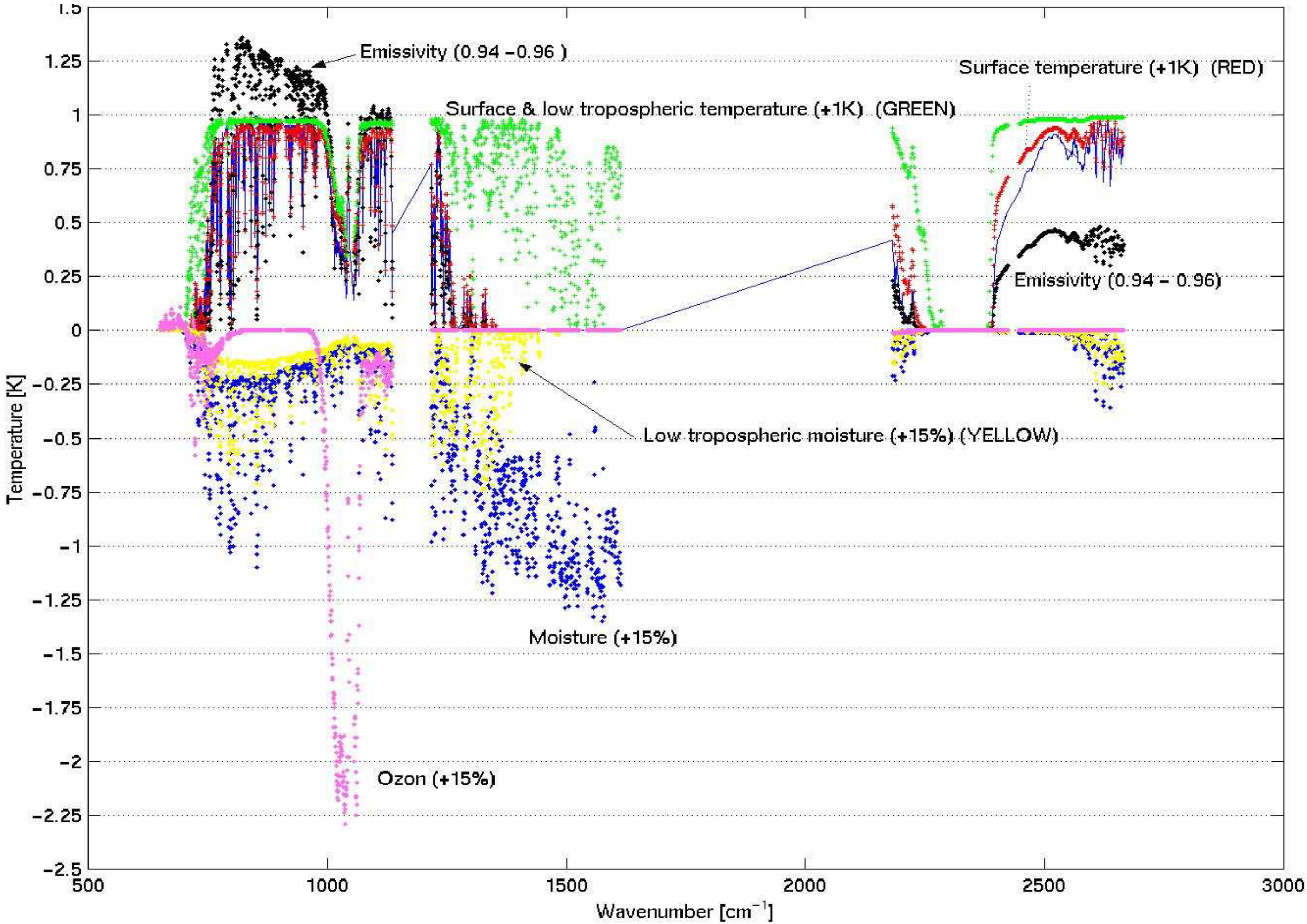
These water vapor weighting functions reflect the radiance sensitivity of the specific channels to a water vapor % change at a specific level (equivalent to dR/dlnq scaled by dlnp).



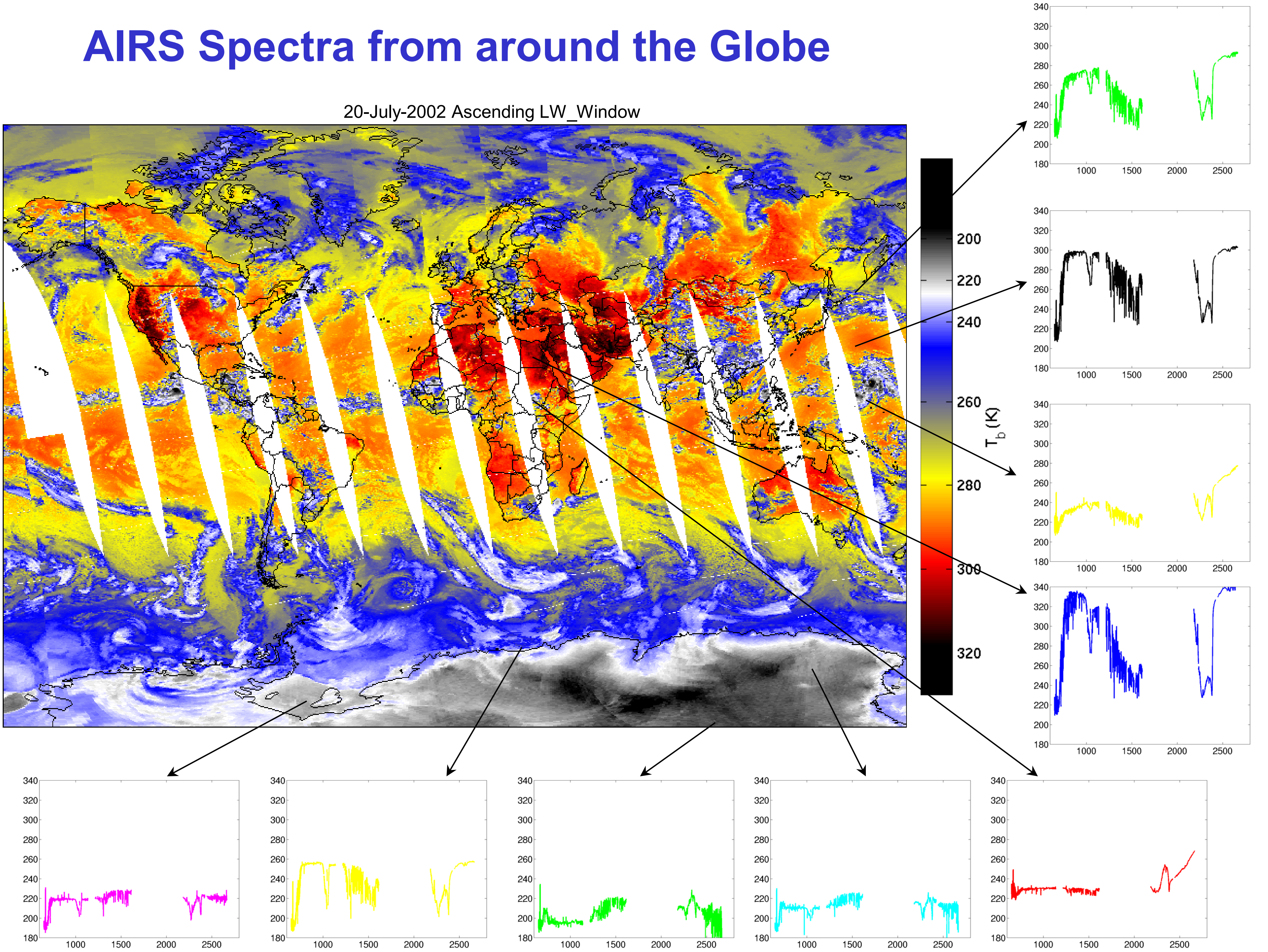
UW/CIMSS

The advanced sounder has more and sharper weighting functions

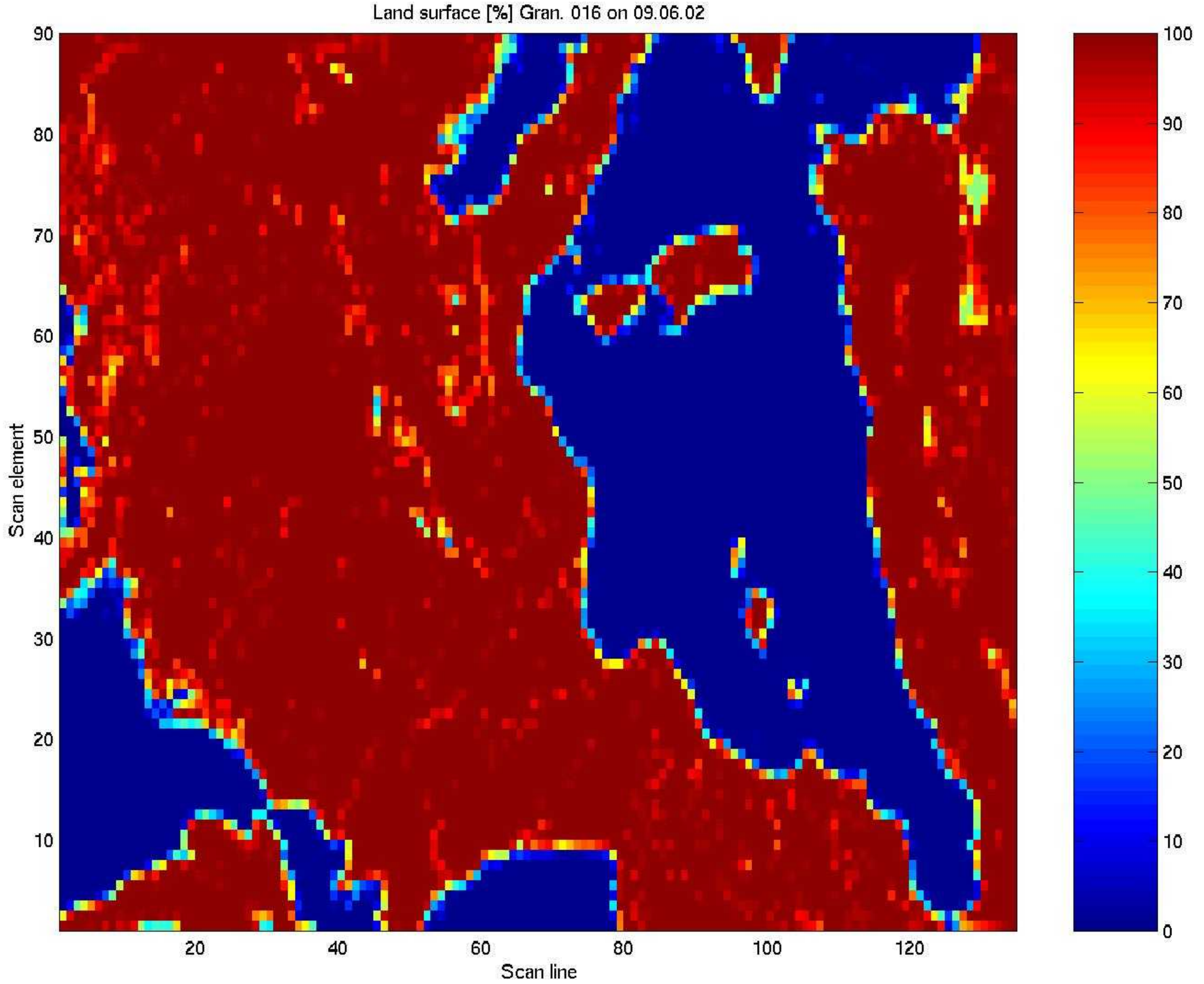
AIRS radiance changes (in deg K) to atm & sfc changes



AIRS Spectra from around the Globe



AIRS over Europe on 6 Sep 02



RTE for IR measurements

$$\left.\begin{aligned}\tilde{\mathrm{J}}(\theta) = \varepsilon(\theta) B[\mathrm{T_s}]\tau_s^{\uparrow}(\theta) + \int_{\tau_s^{\uparrow}(\theta)}^{1} \mathrm{B}[\mathrm{T}(\mathrm{p})]\mathrm{d}\tau^{\uparrow}(\mathrm{p},\theta) \\ + (1-\varepsilon(\theta))\tau_s^{\uparrow}(\theta) \int_{\tau_0^{\downarrow}(\vartheta^*)}^{1} \mathrm{B}[\mathrm{T}(\mathrm{p})]\mathrm{d}\tau^{\downarrow}(\mathrm{p},\vartheta^*) + \xi\end{aligned}\right\}$$

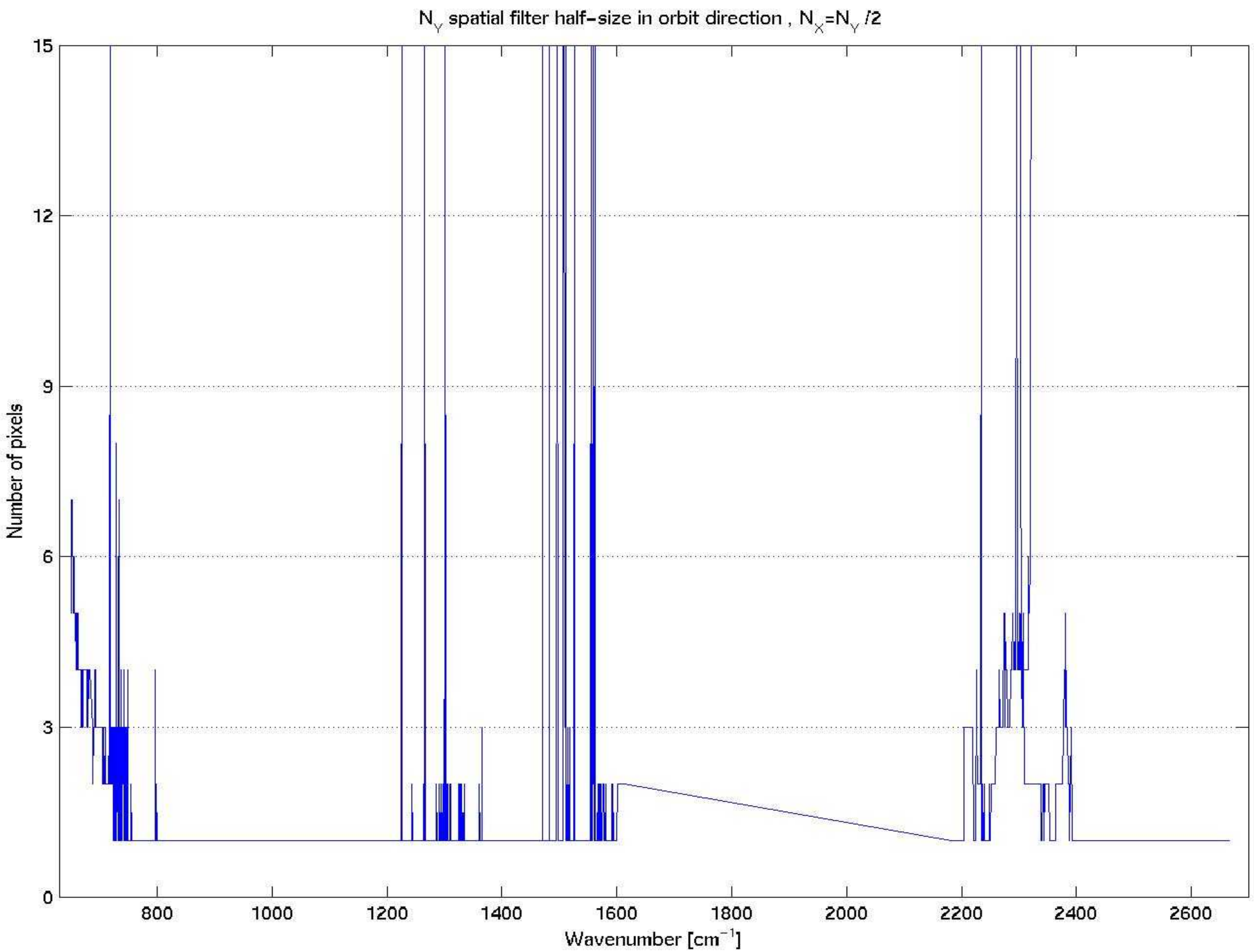
A correct description of the error structure in the IR spectral measurements is important for the solution of the atmospheric remote sensing inverse problem because:

* errors, reinforced by the instability of the inverse problem, can drastically reduce the accuracy of the retrievals;

* first guess moisture-temperature profiles are already quite accurate thus AIRS measurements must be of high quality to add new information; thus to make satellite soundings effective, measurement error structures have to be properly described;

* to improve the relative signal to noise ratio of the AIRS measurements to the existing background first guess, the spatial structure of the measurements errors has to be correctly modeled, and measurements errors have to be filtered.

Spectral distribution of spatial smoothing filter (half-size given in pixel



Diagnostic tests for new data set

(1) Spatial variability of radiances

Is upper atmosphere smoother than lower atmosphere?

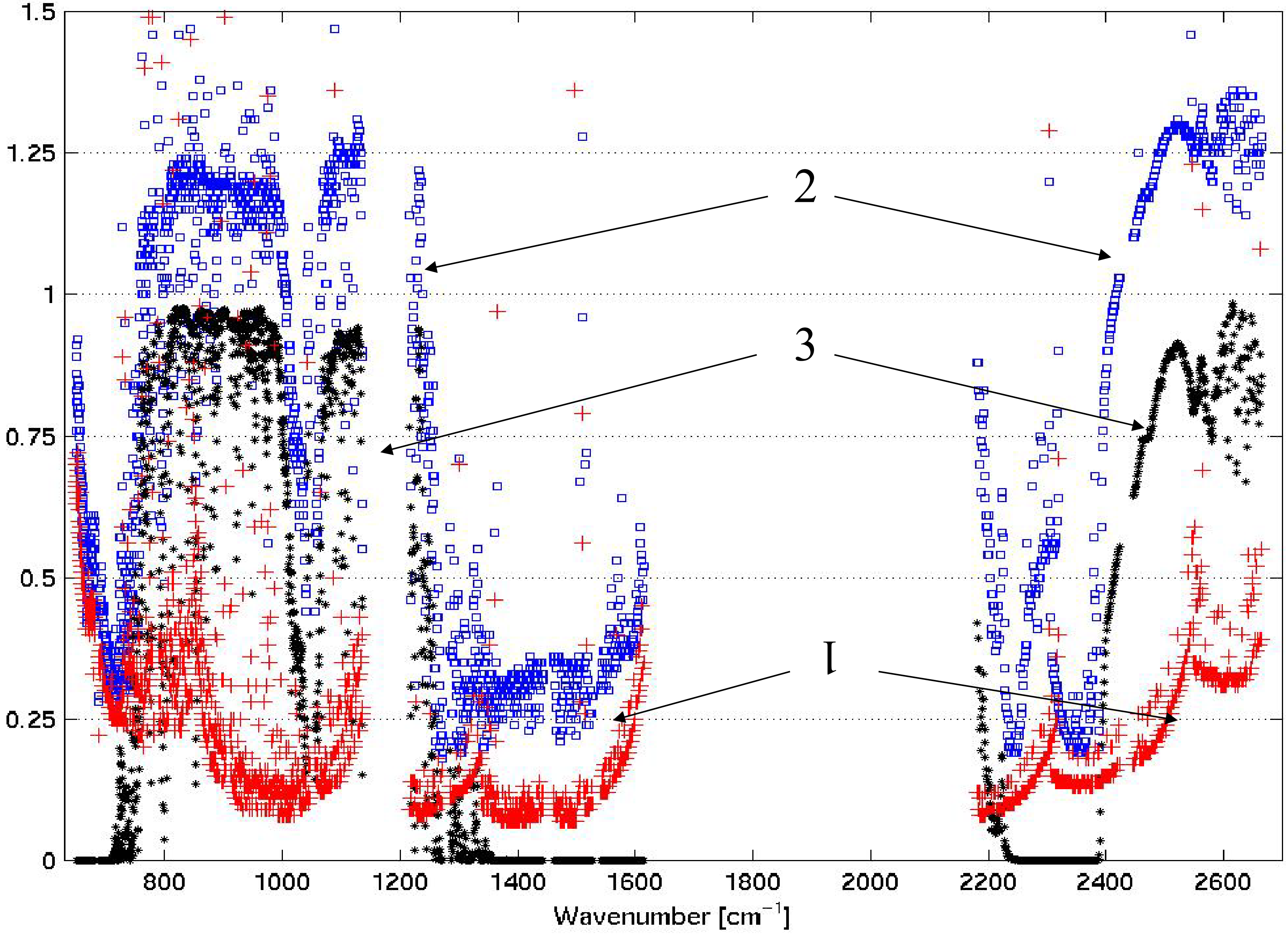
(2) Spectral variability of radiances

Are SW and LW channels with similar weighting functions showing similar scenes?

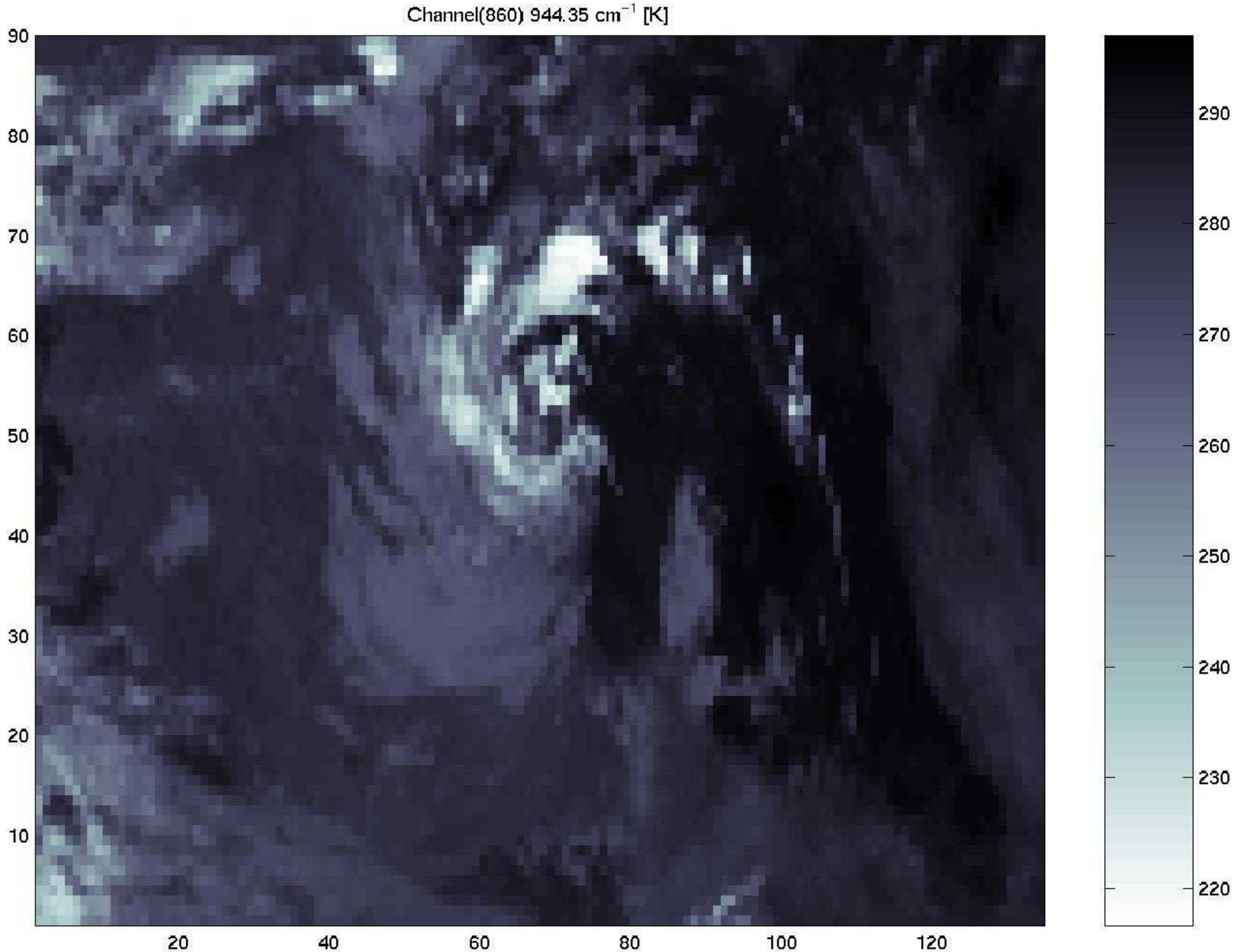
(3) Noise of radiances

Can the noise be reduced with spatial averaging?

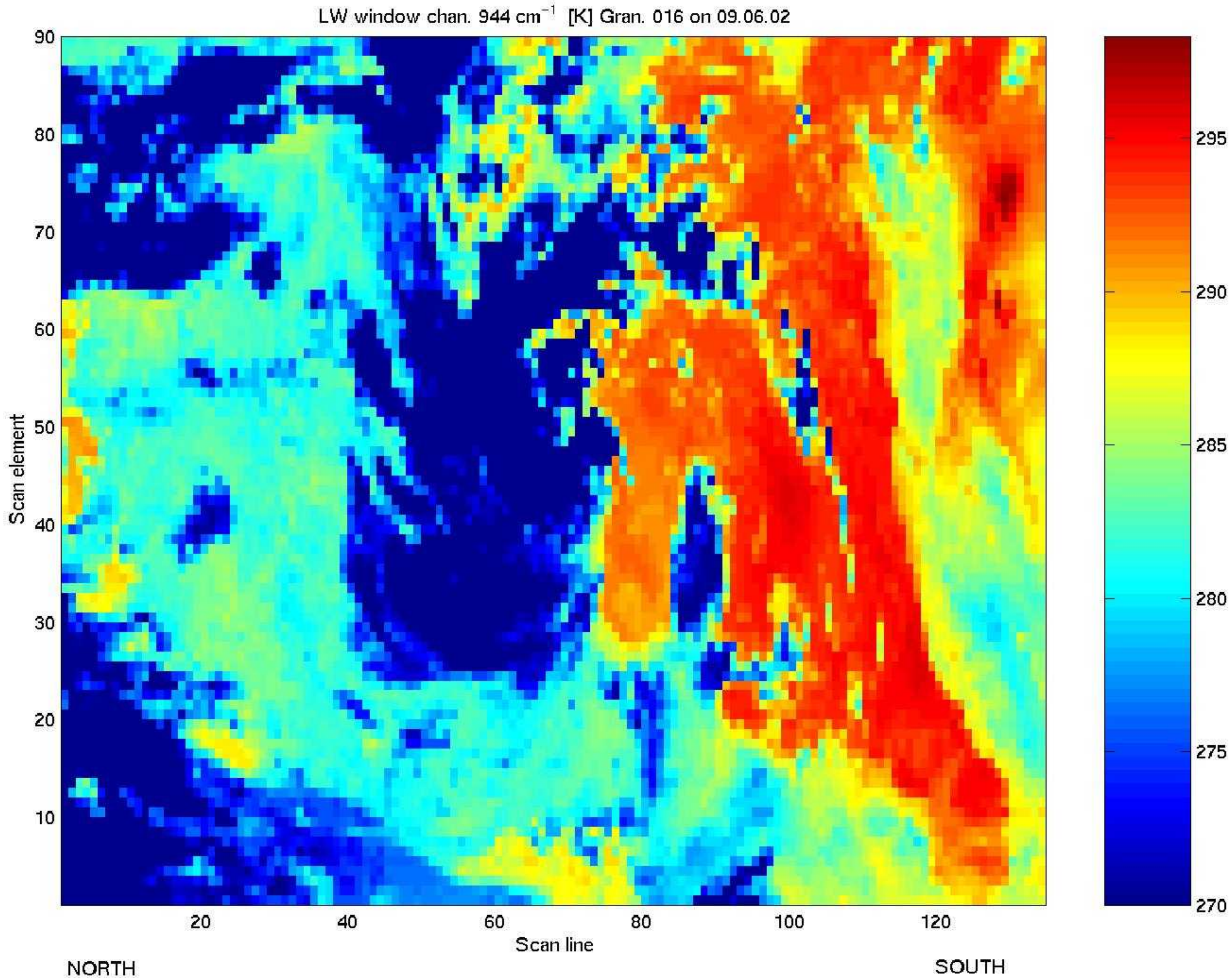
1 - StDev of bb measurement error [K] (RED), 2 - StDev of earth measurements [K] (BLUE); 3 - total atmospheric transmittance (BLAC



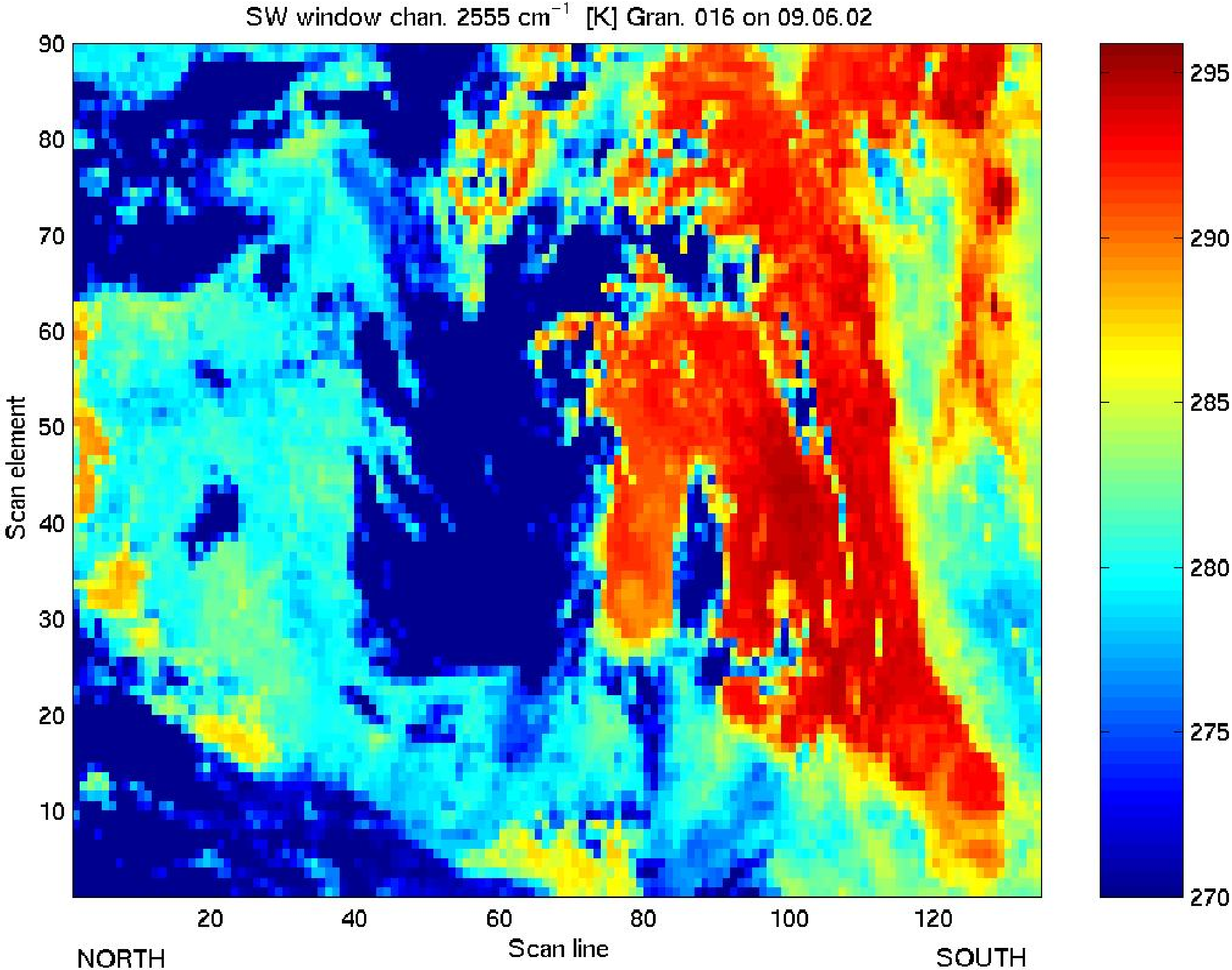
Spatial distribution of 944.1 [1/cm] measurements [K]



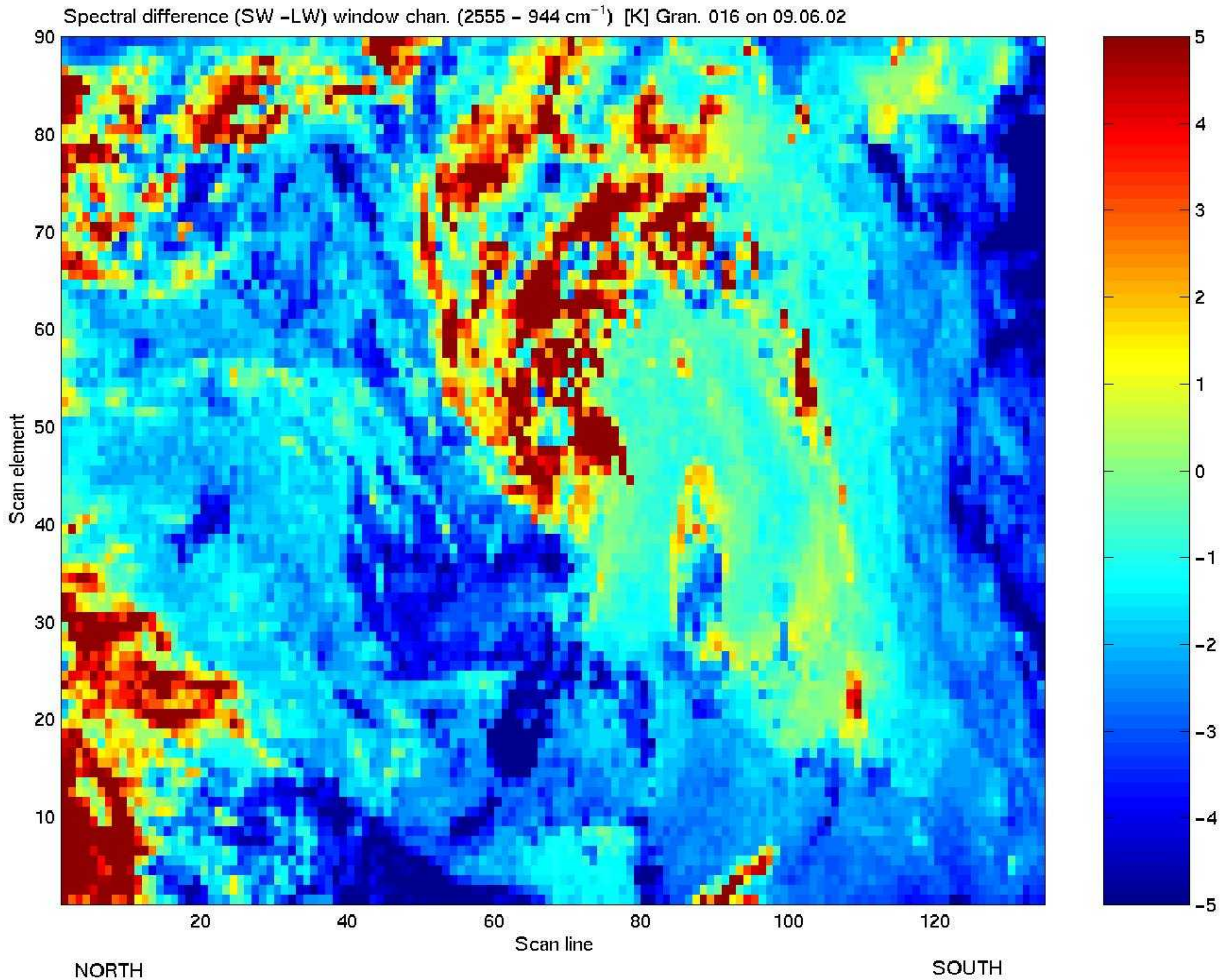
Spatial distribution of 944.1 [1/cm] measurements [K]



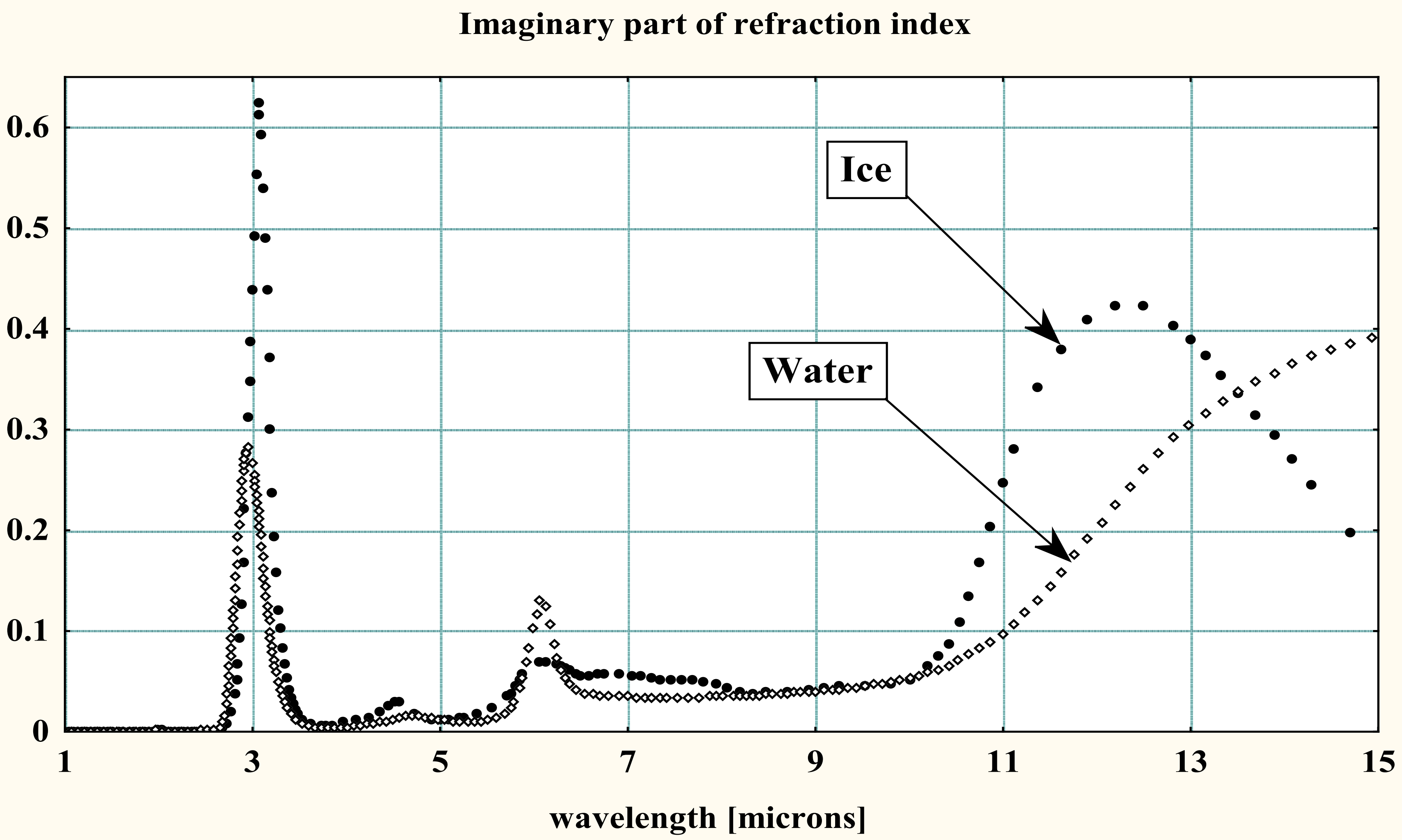
Spatial distribution of 2555 [1/cm] measurements [K]



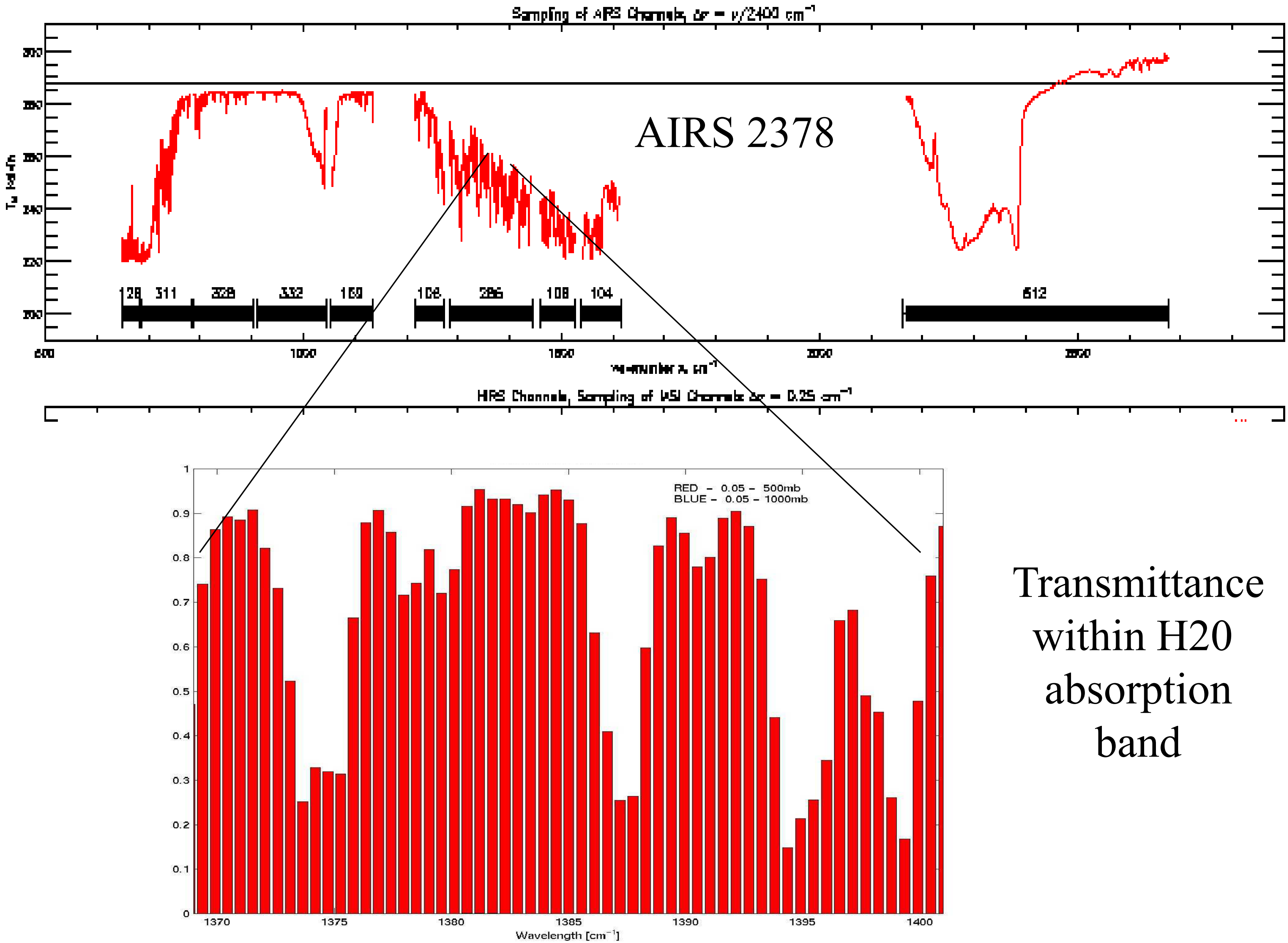
Spatial distribution of 2555 – 944.1 [1/cm] measurements [K]



Optical properties of cloud particles: imaginary part of refraction index

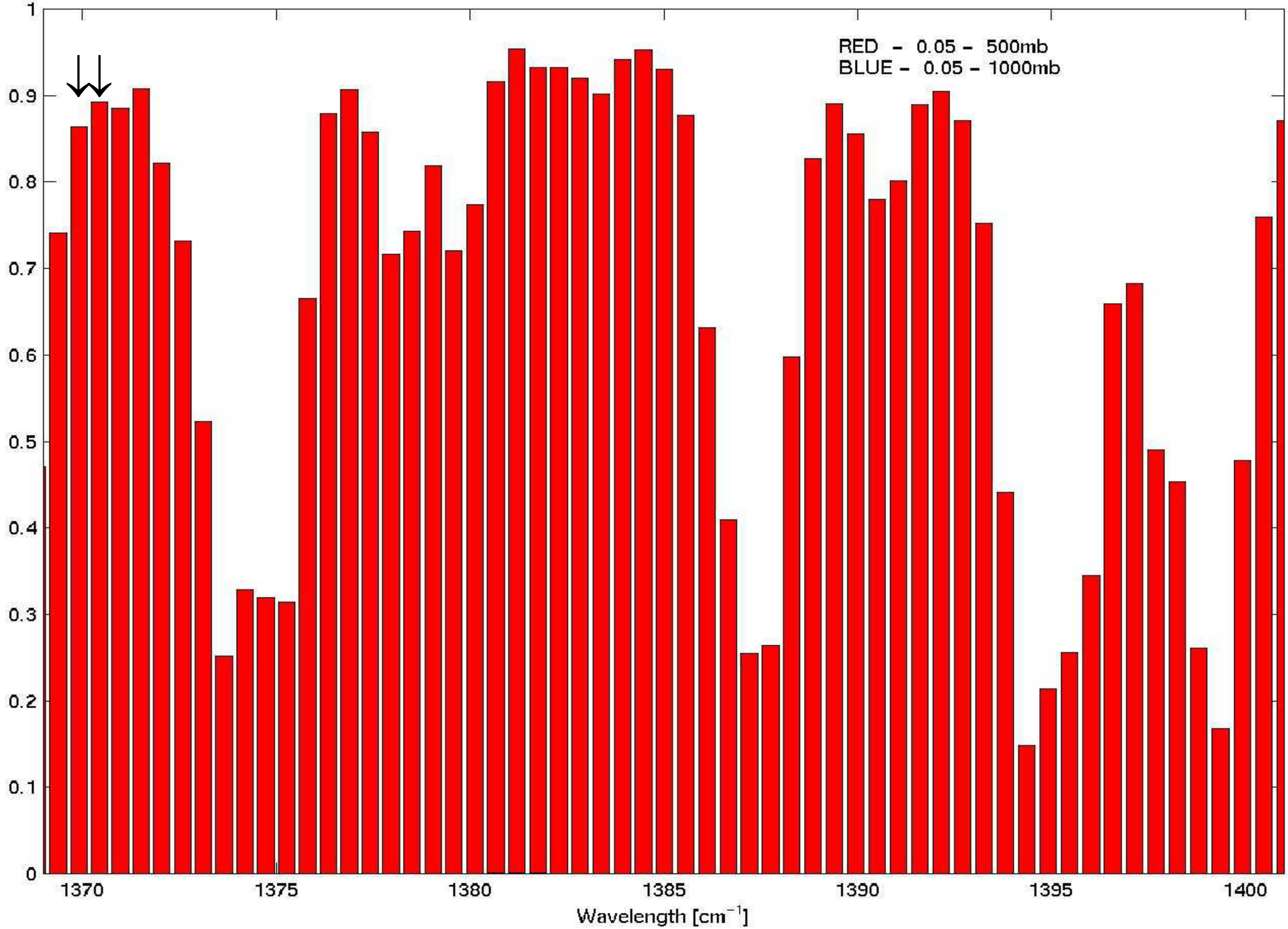


SW & LW channel differences are used for cloud identification
{4 µm - 11µm}, {4.13 µm - 12.6µm}, and {4.53 µm - 13.4µm}

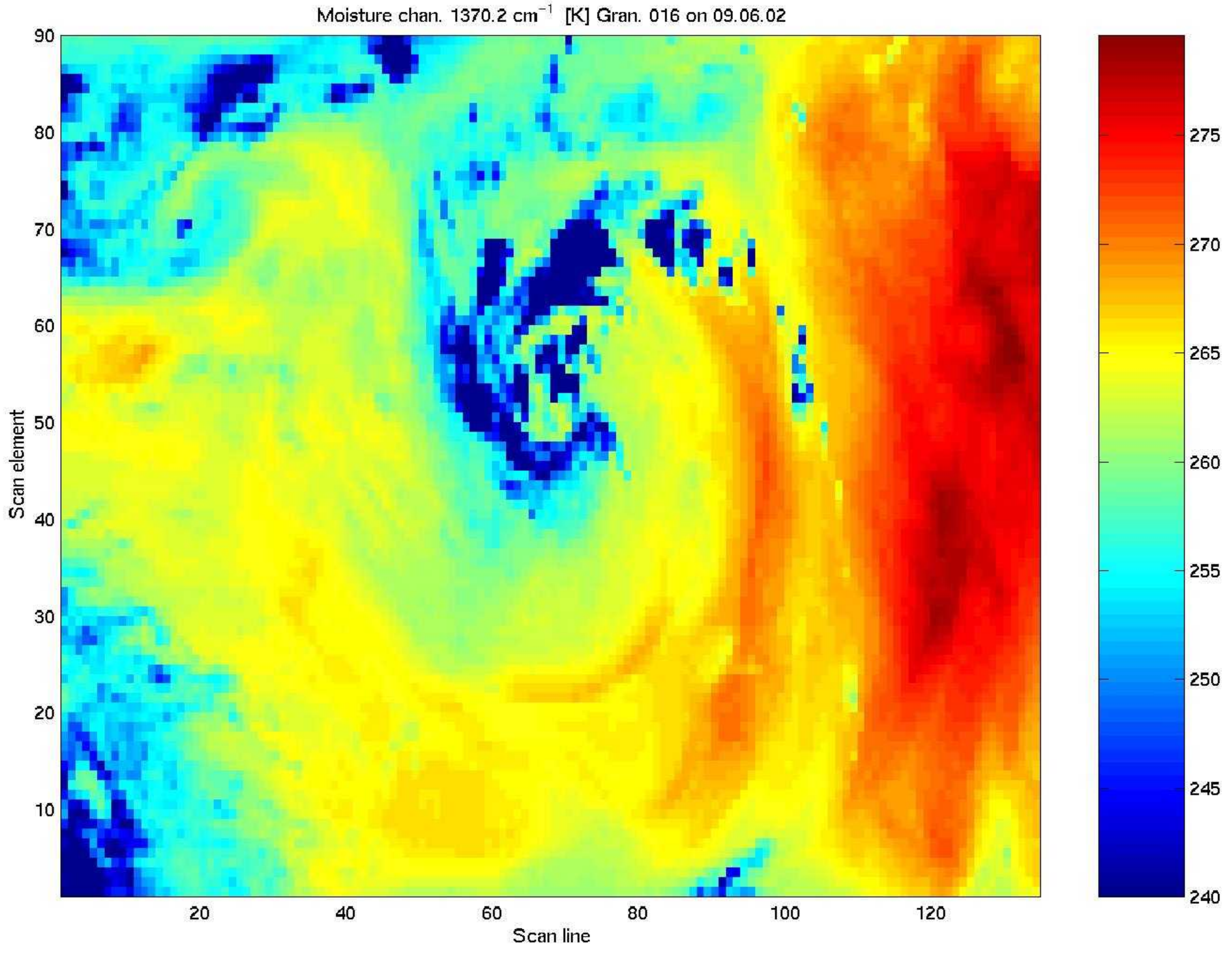


Transmittance within H20 absorption band

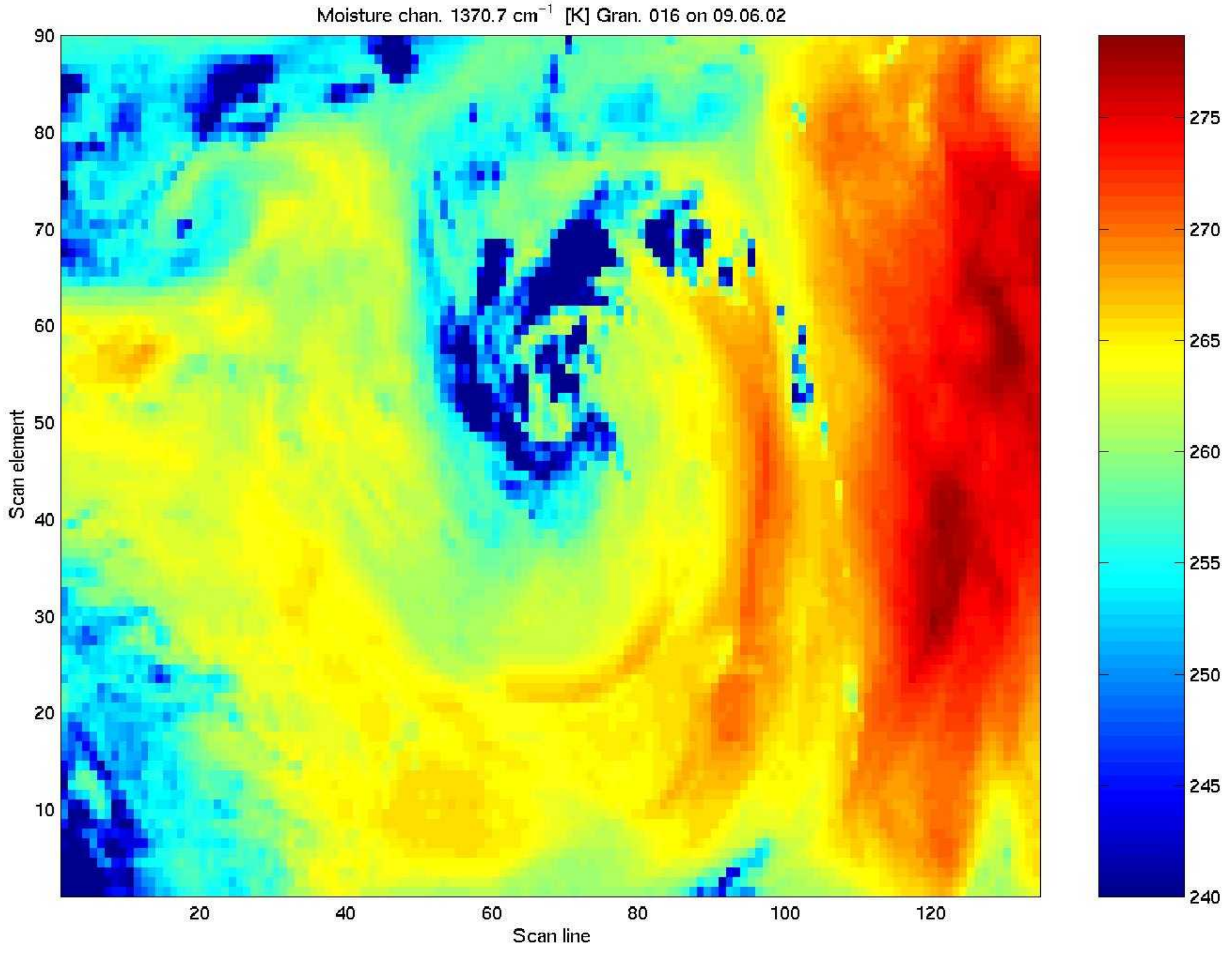
Atmospheric transmittance in H2O sensitive region of spectrum



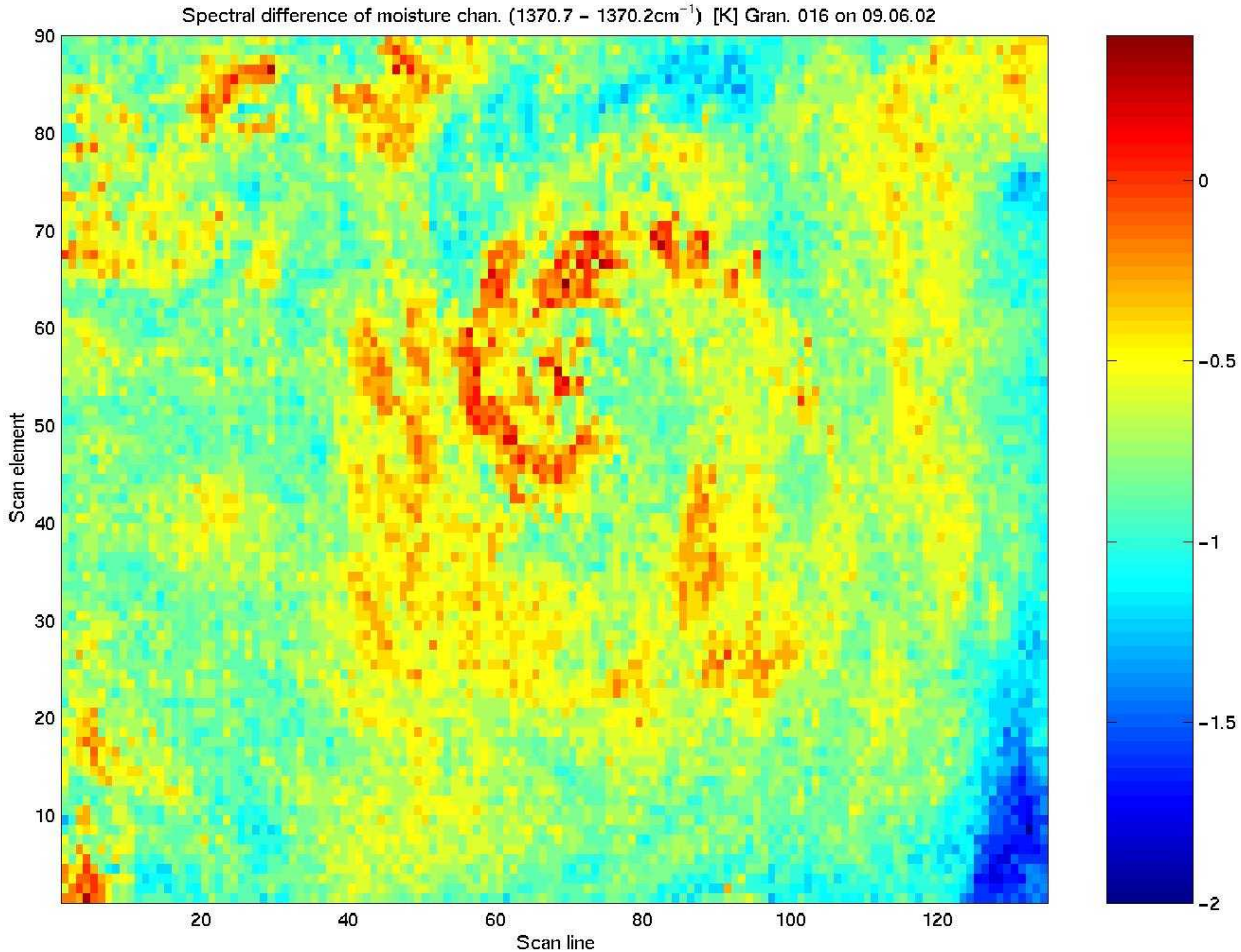
Spatial distribution of 1370.2 [1/cm] measurements [K]



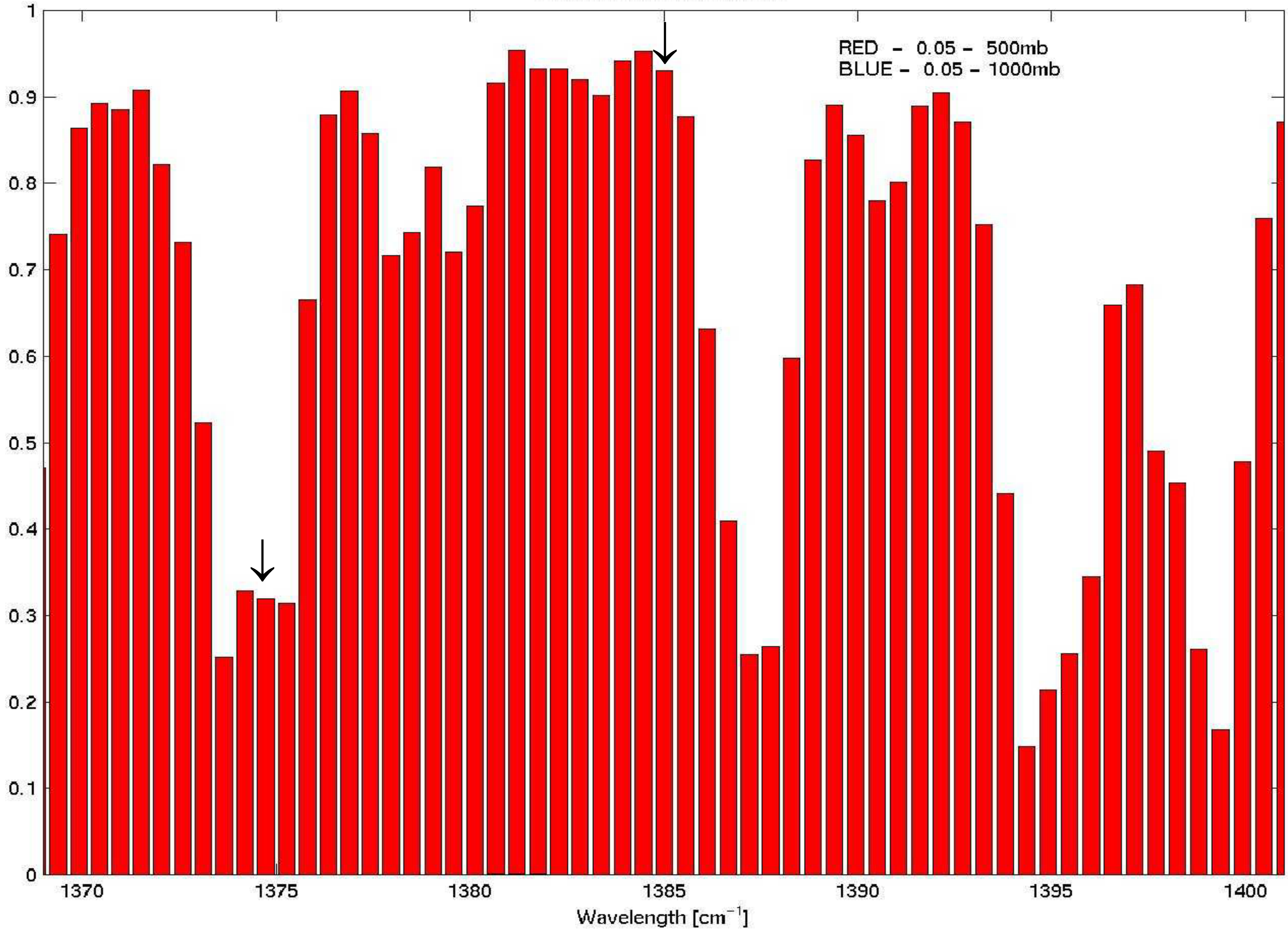
Spatial distribution of 1370.7 [1/cm] measurements [K]



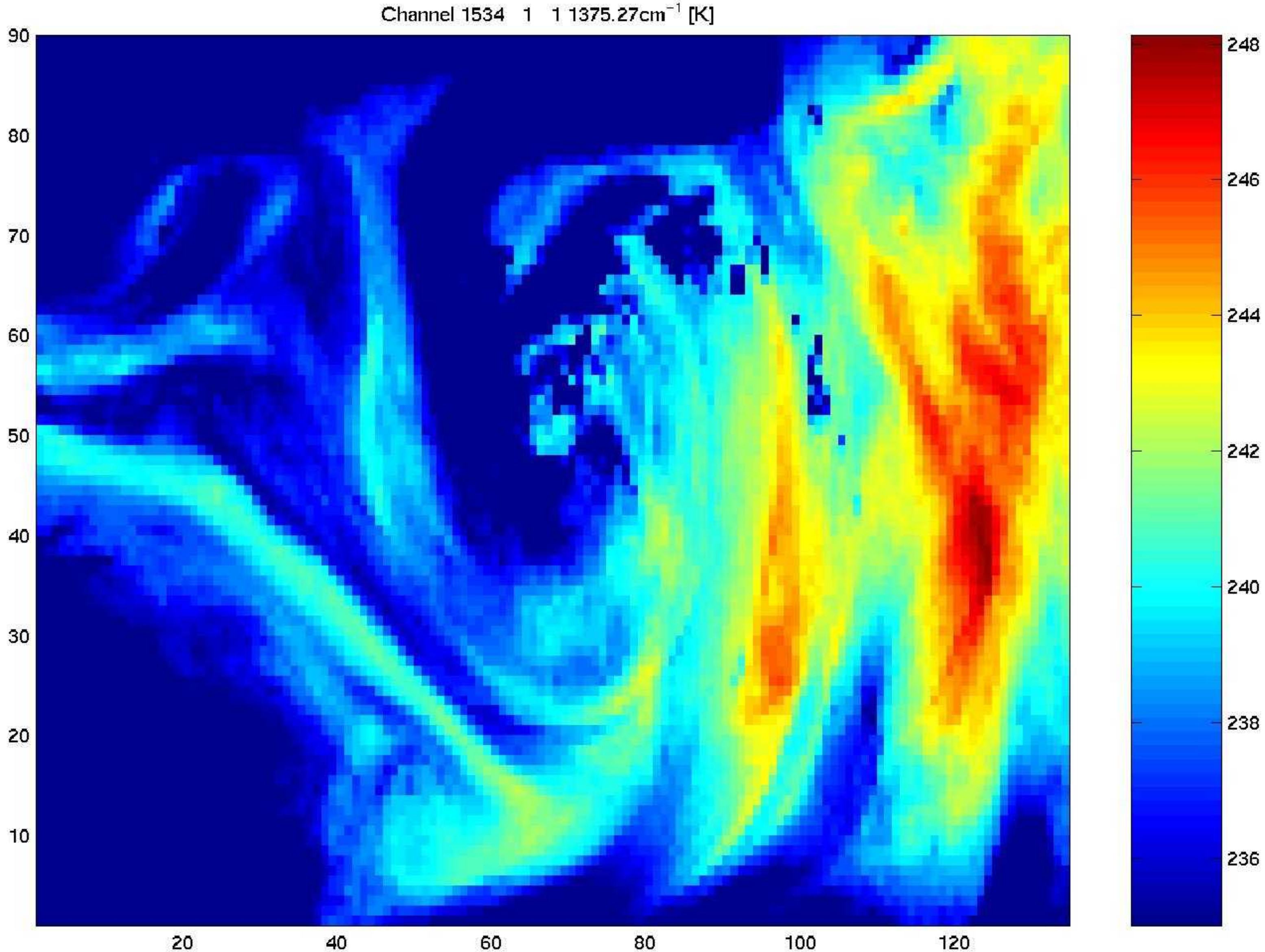
Spatial distribution of 1370.2 – 1370.7 [1/cm] measurements [K]



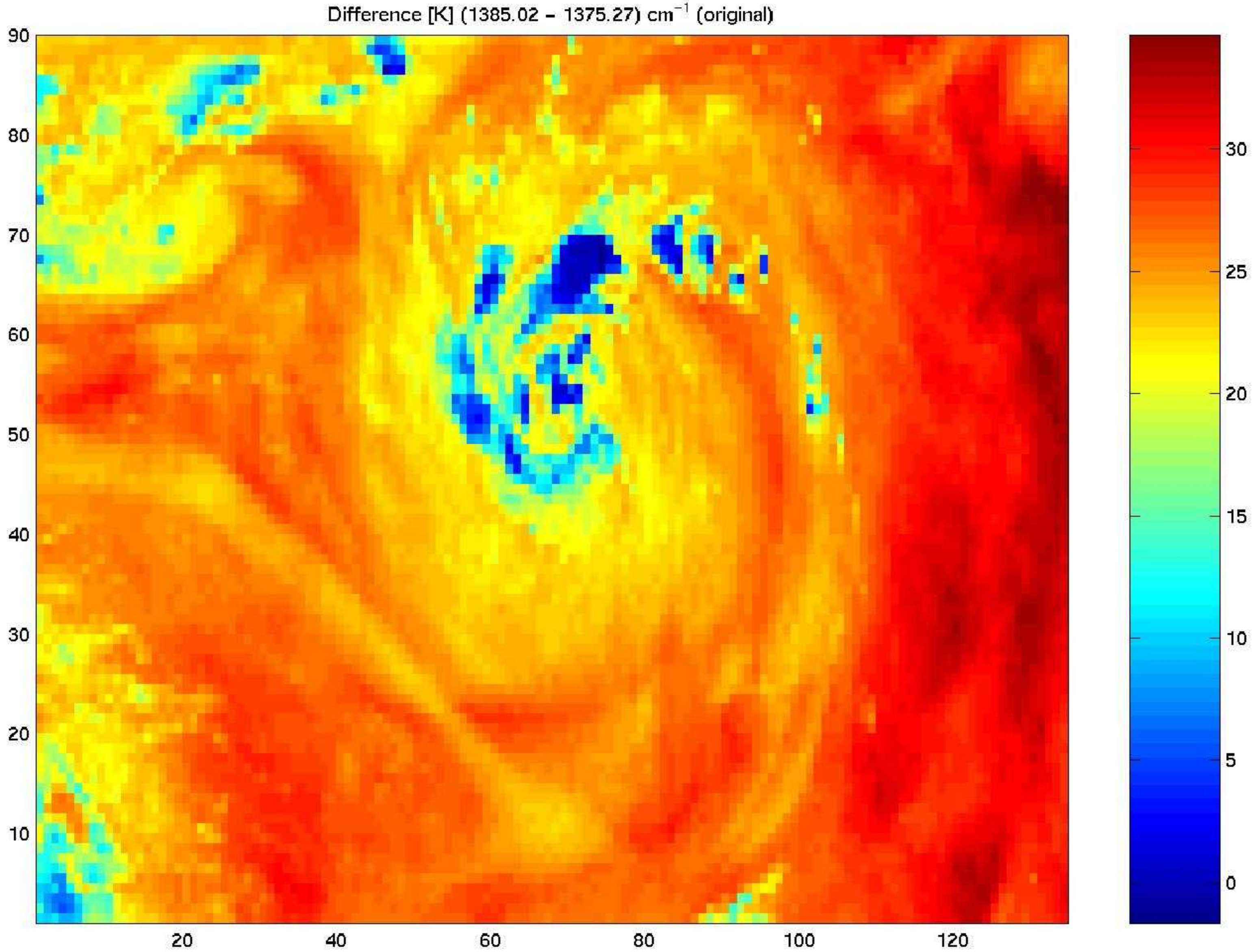
Atmospheric transmittance in H2O sensitive region of spectrum



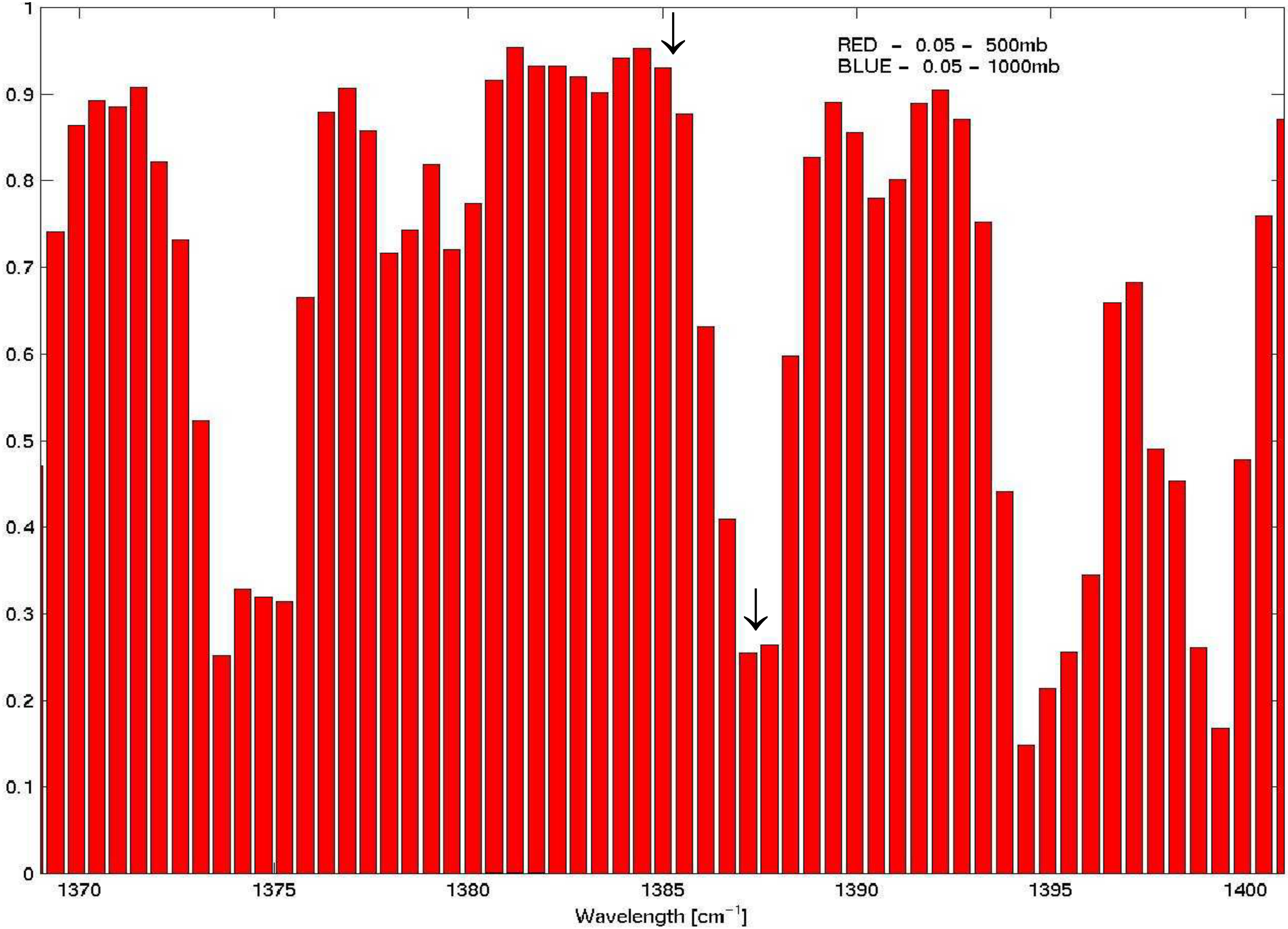
Spatial distribution of Ch 1534 at 1375.27 [1/cm] measurements [K]



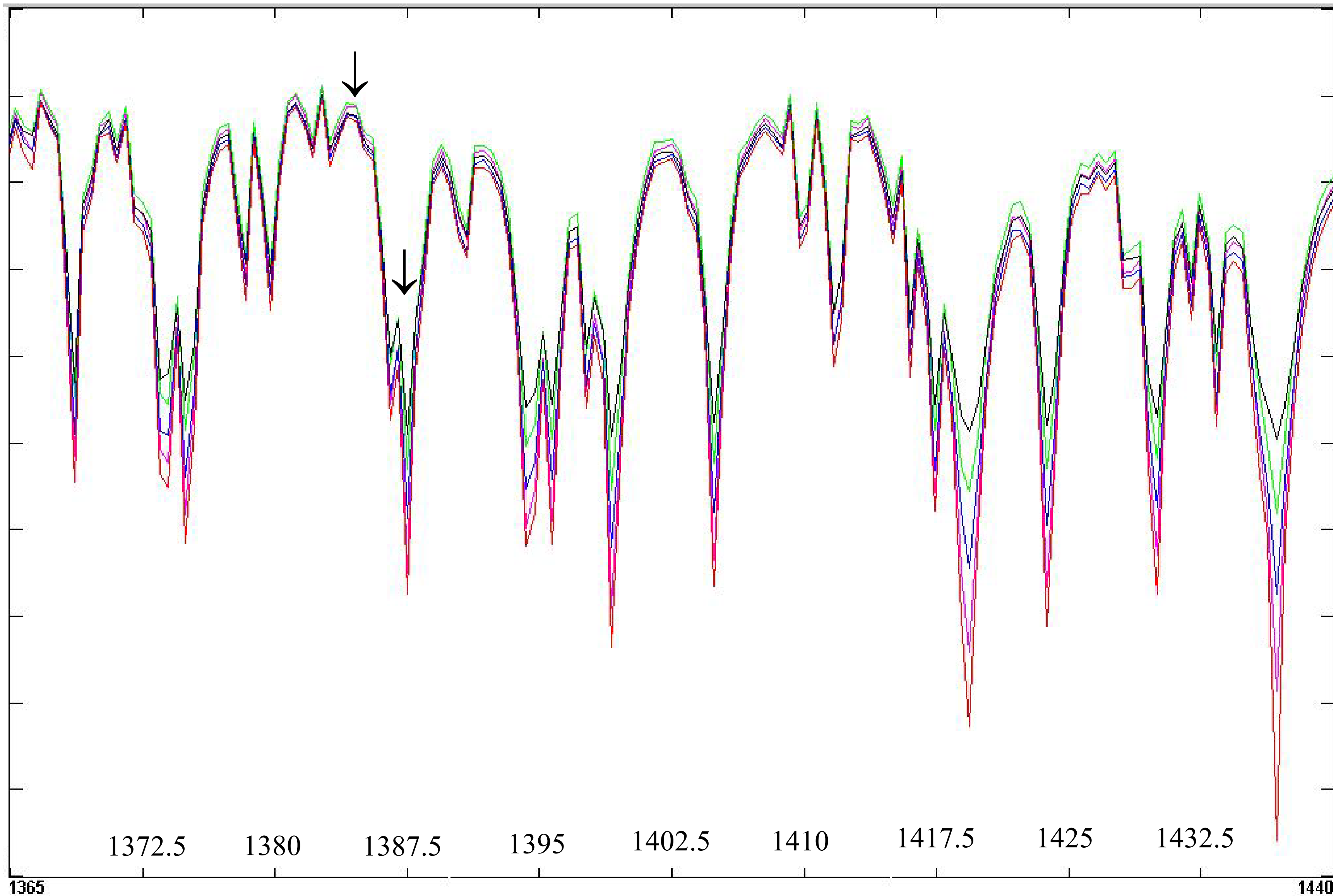
Spatial distribution of 1385.02 – 1375.27 [1/cm] measurements [K]



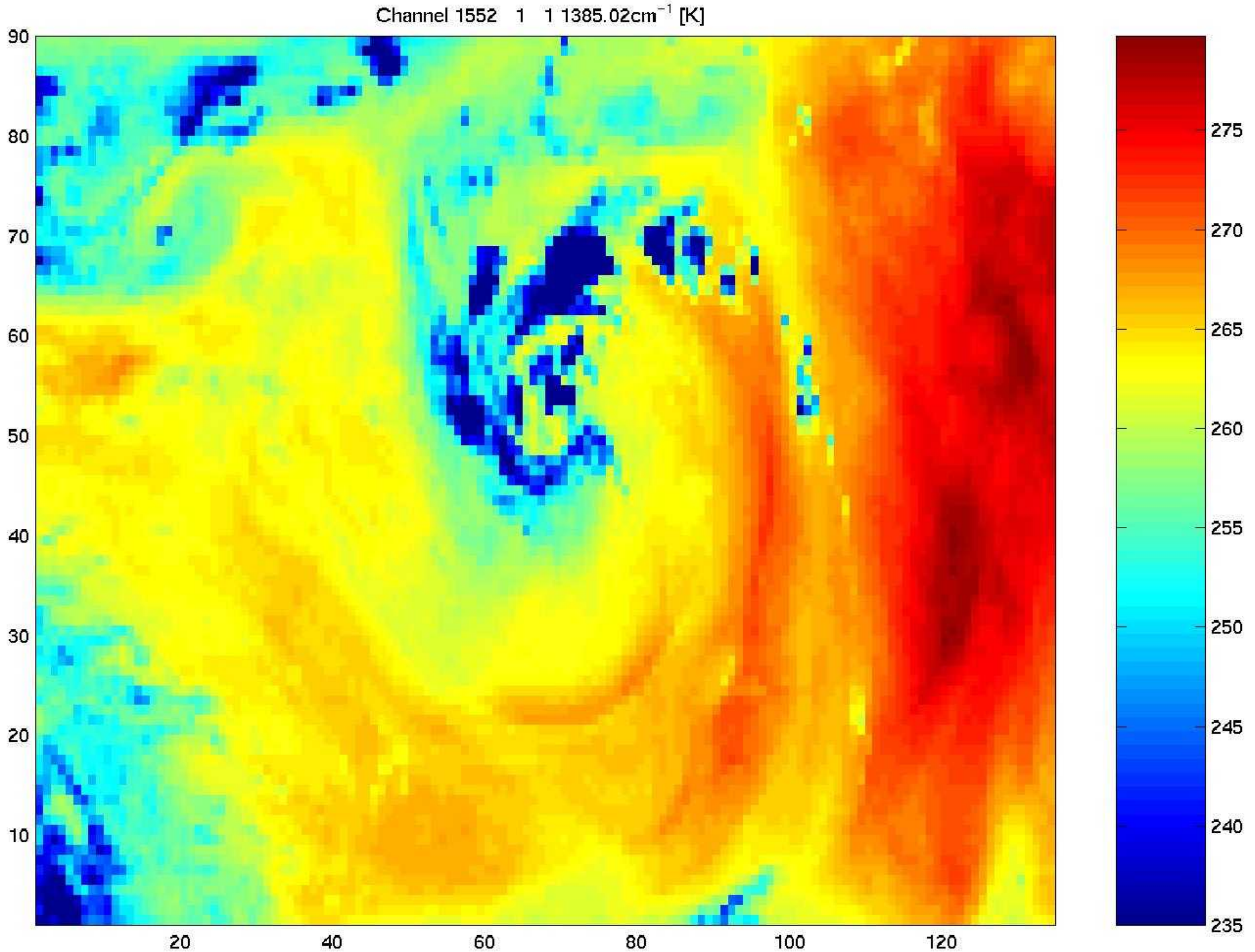
Atmospheric transmittance in H2O sensitive region of spectrum



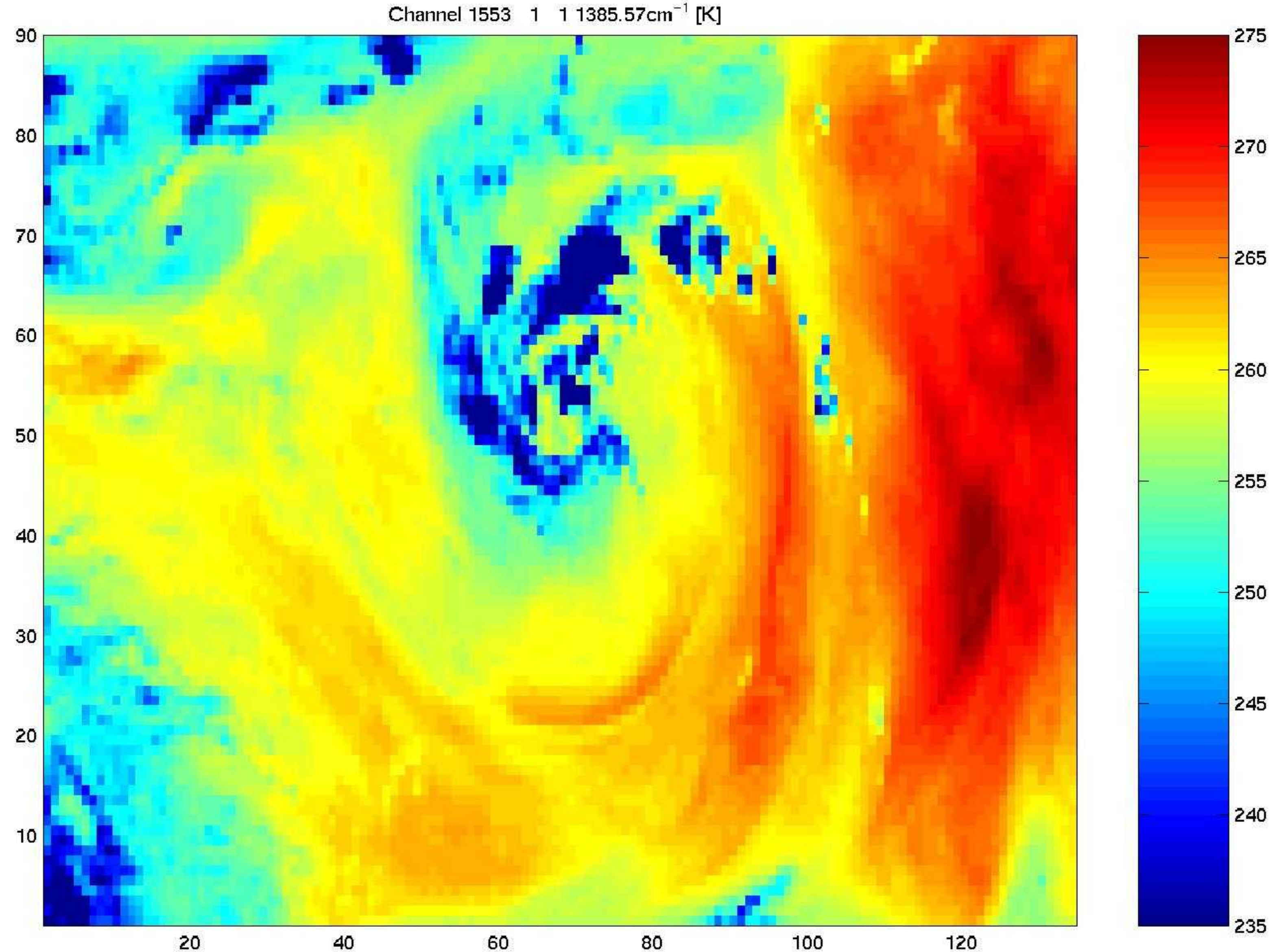
1365 to 1440 cm-1earth emitted spectrum



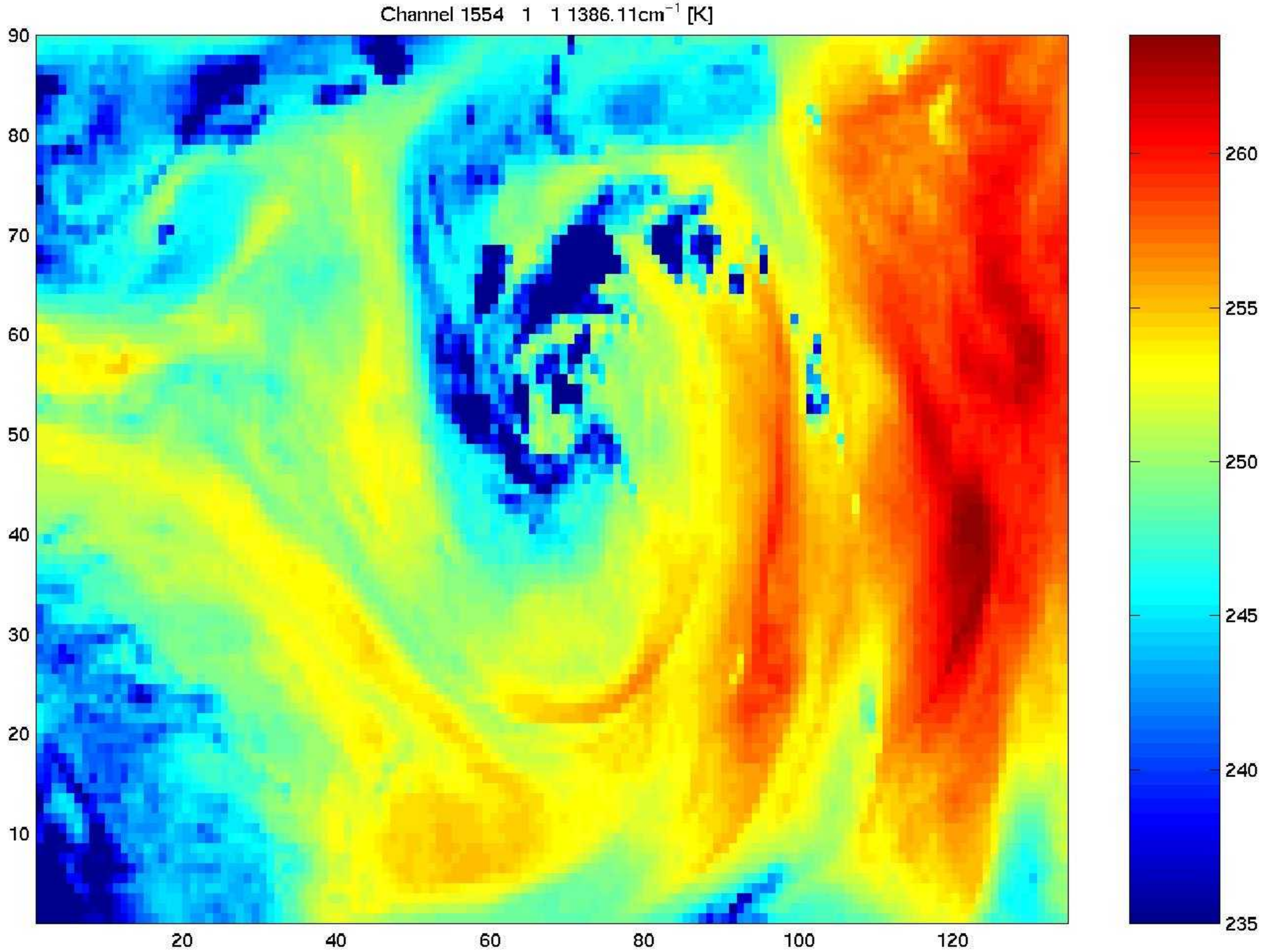
Spatial distribution of Ch 1552 at 1385.02 [1/cm] measurements [K]



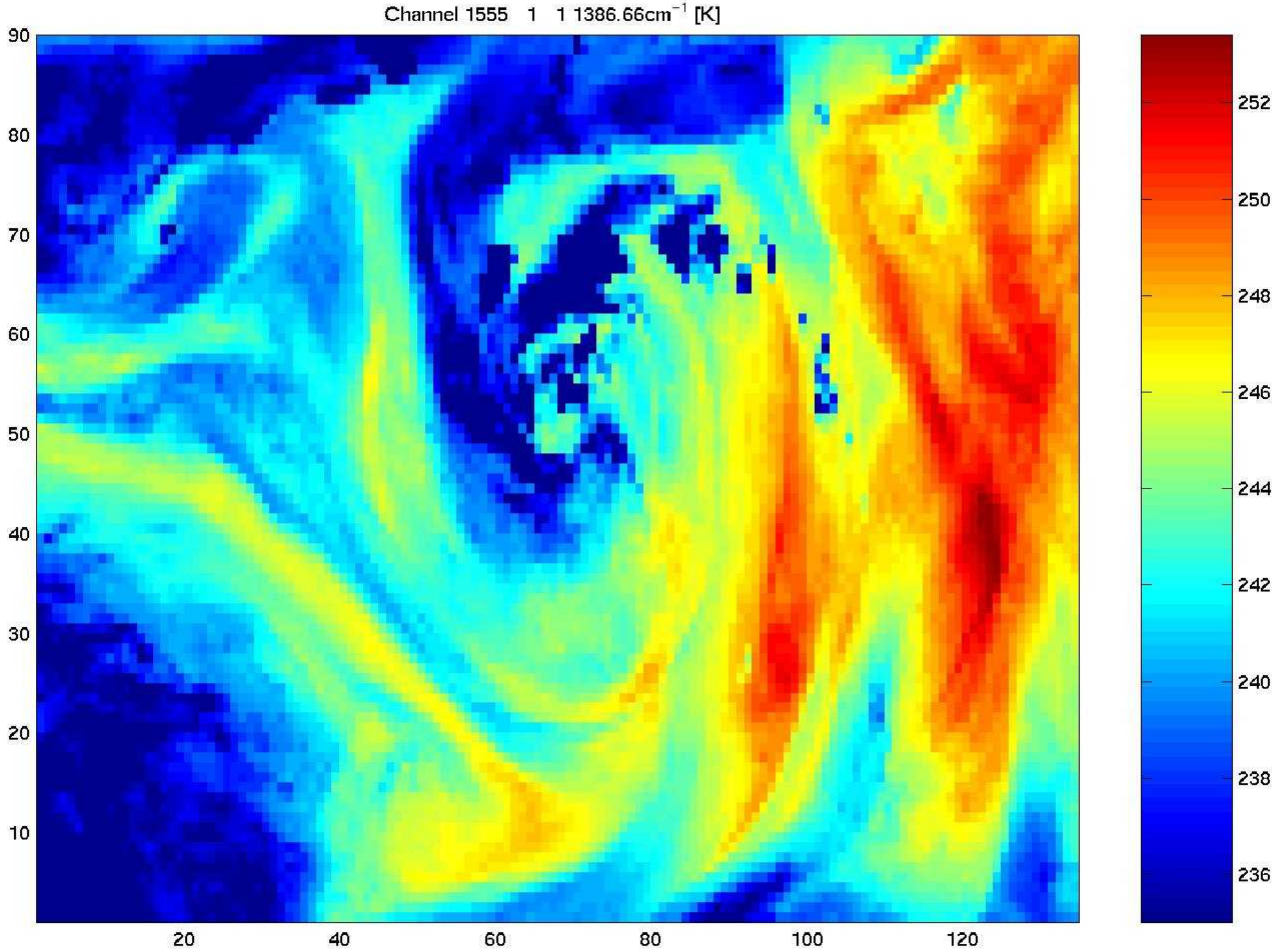
Spatial distribution of Ch 1553 at 1385.57 [1/cm] measurements [K]



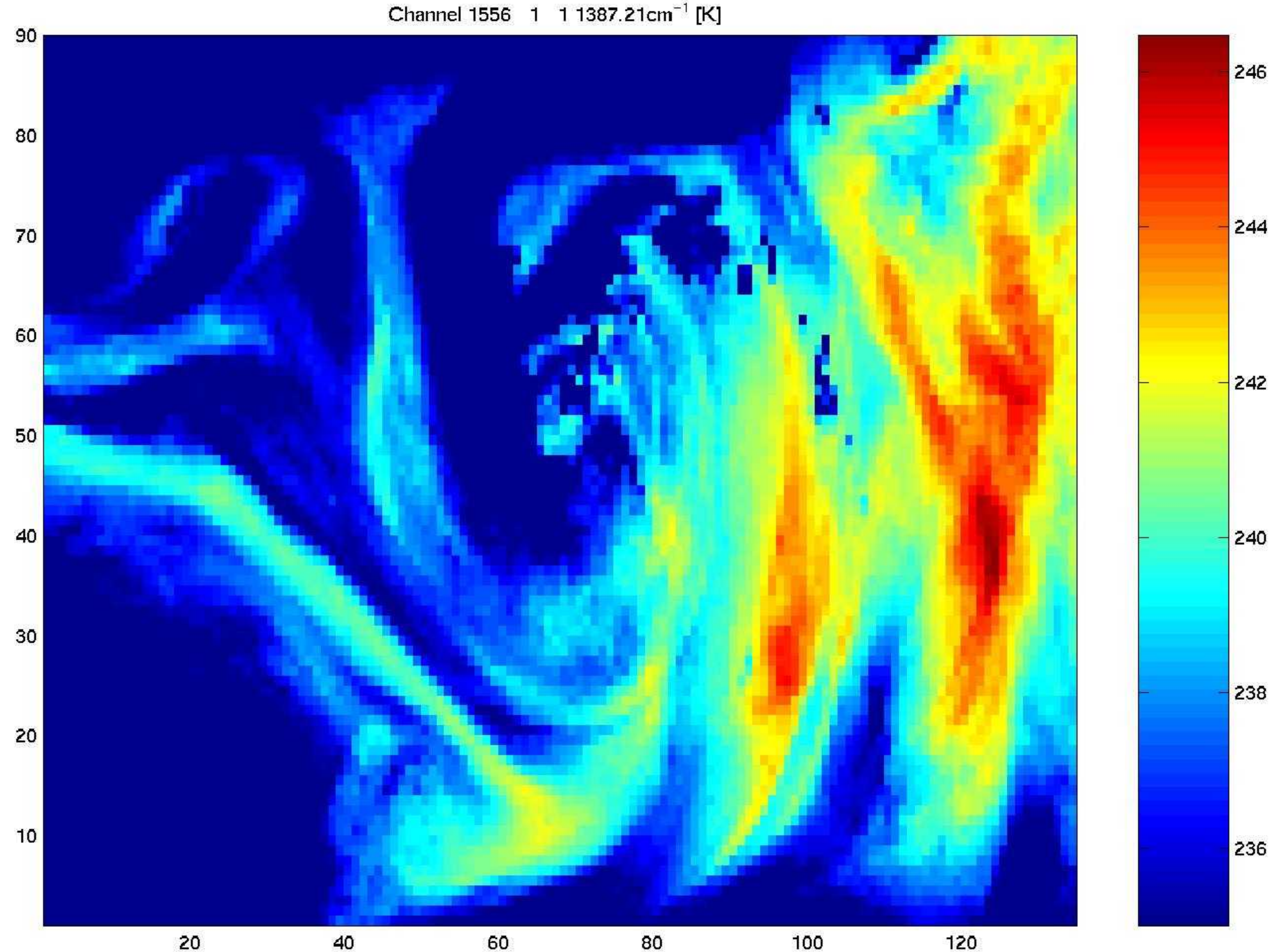
Spatial distribution of Ch 1554 at 1386.11 [1/cm] measurements [K]



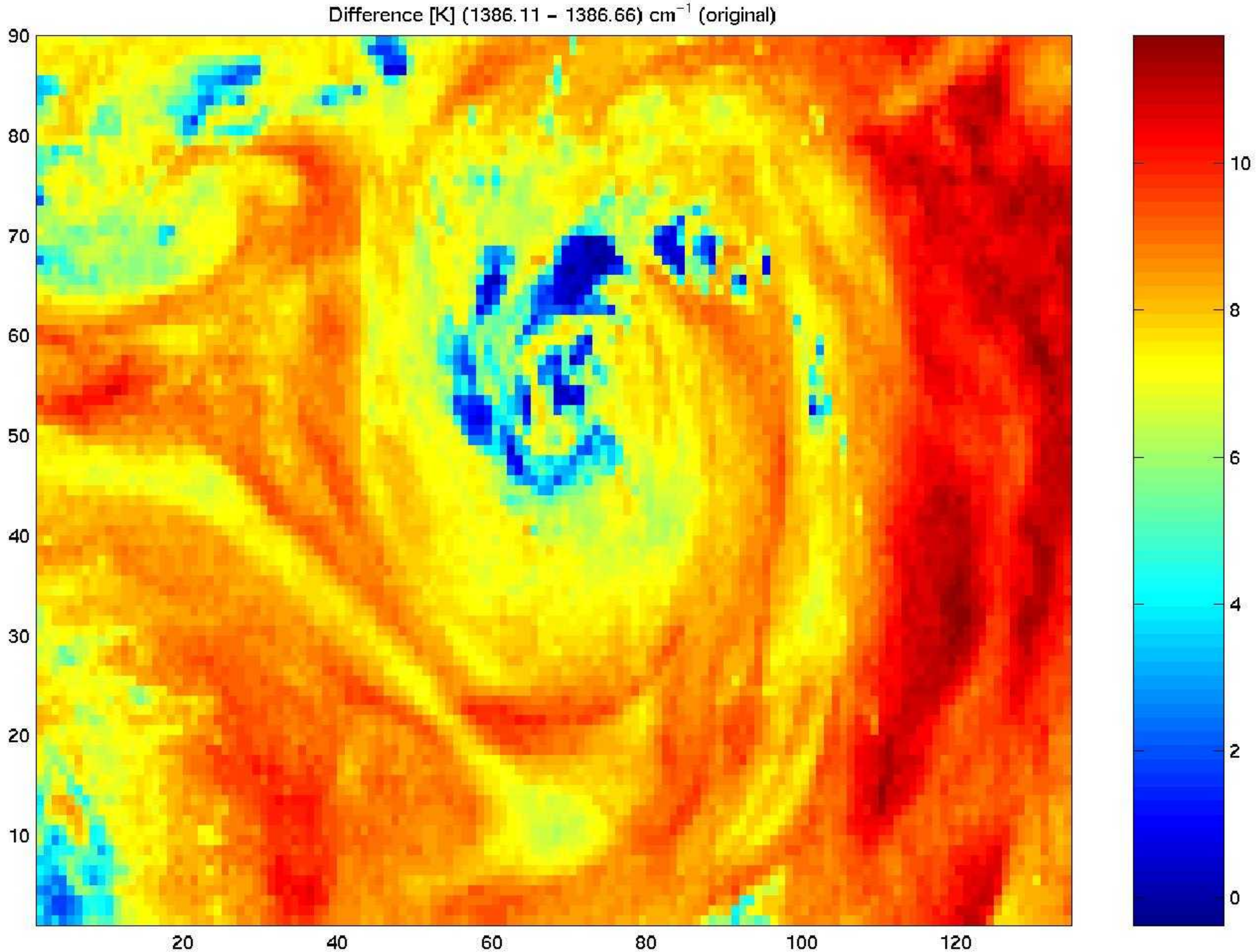
Spatial distribution of Ch 1555 at 1386.66 [1/cm] measurements [K]



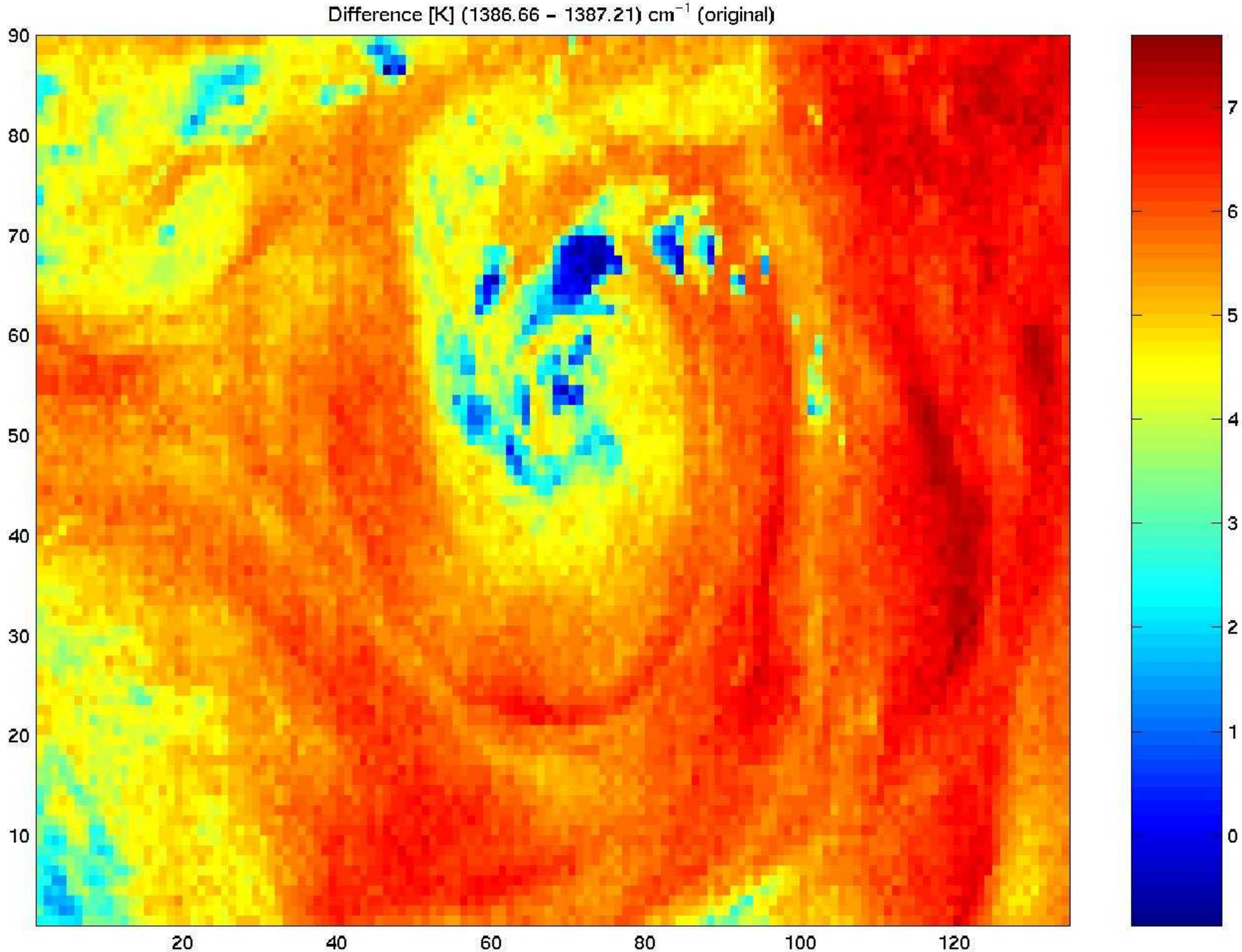
Spatial distribution of Ch 1556 at 1387.21 [1/cm] measurements [K]



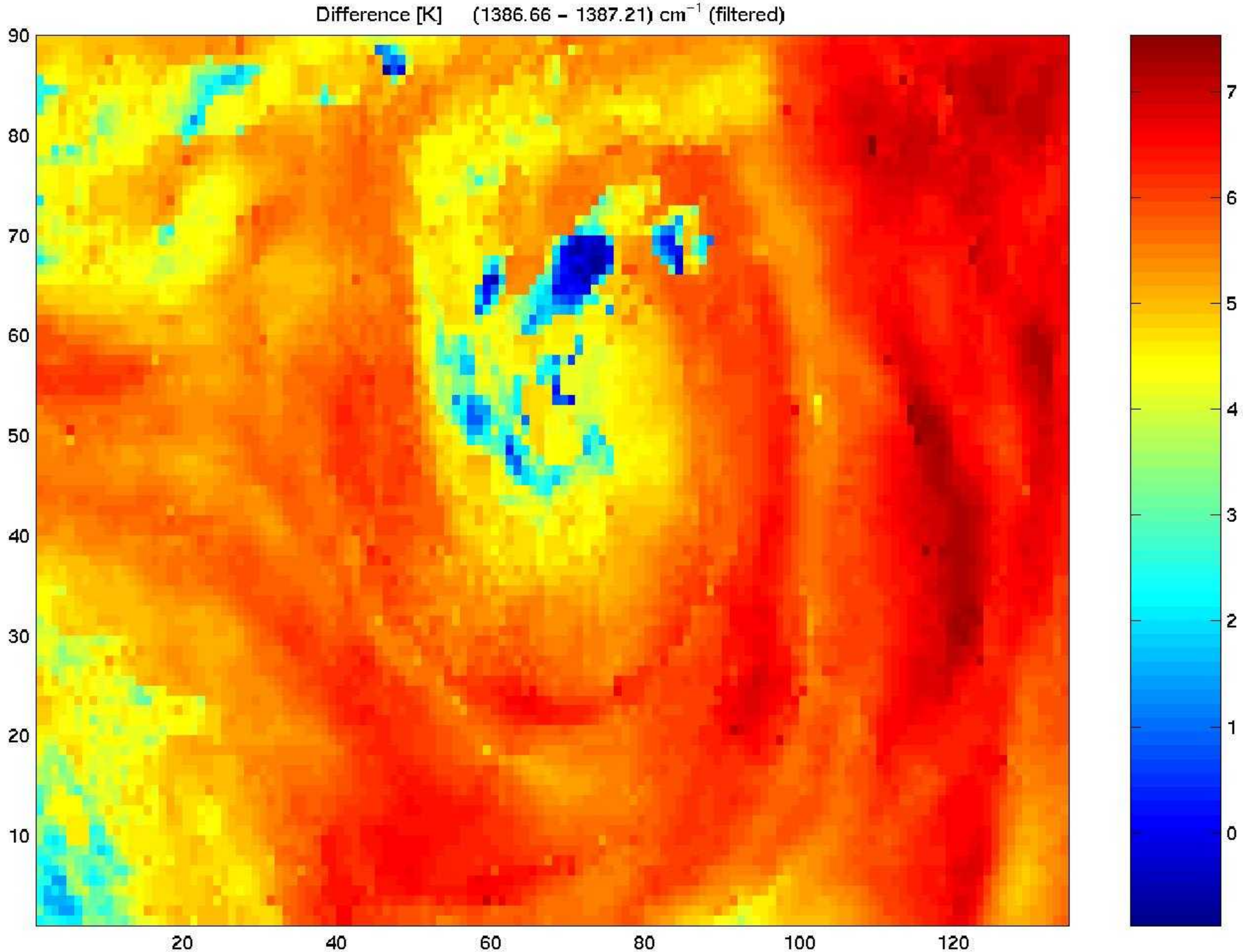
Spatial distribution of 1386.11 – 1386.66 [1/cm] measurements [K]



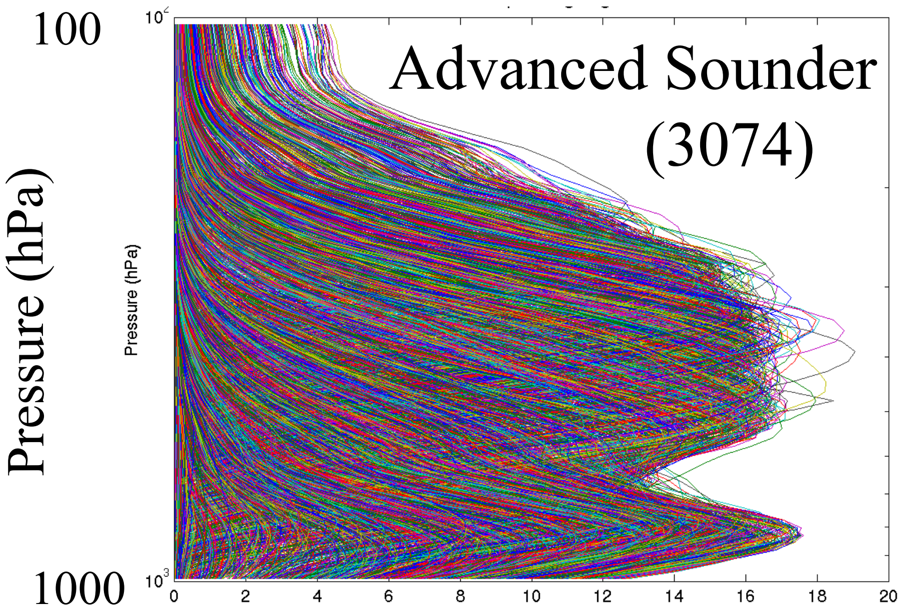
Spatial distribution of 1386.66 – 1387.21 [1/cm] measurements [K]



Spatial distribution of 1386.66 – 1387.21 [1/cm] measurements [K]

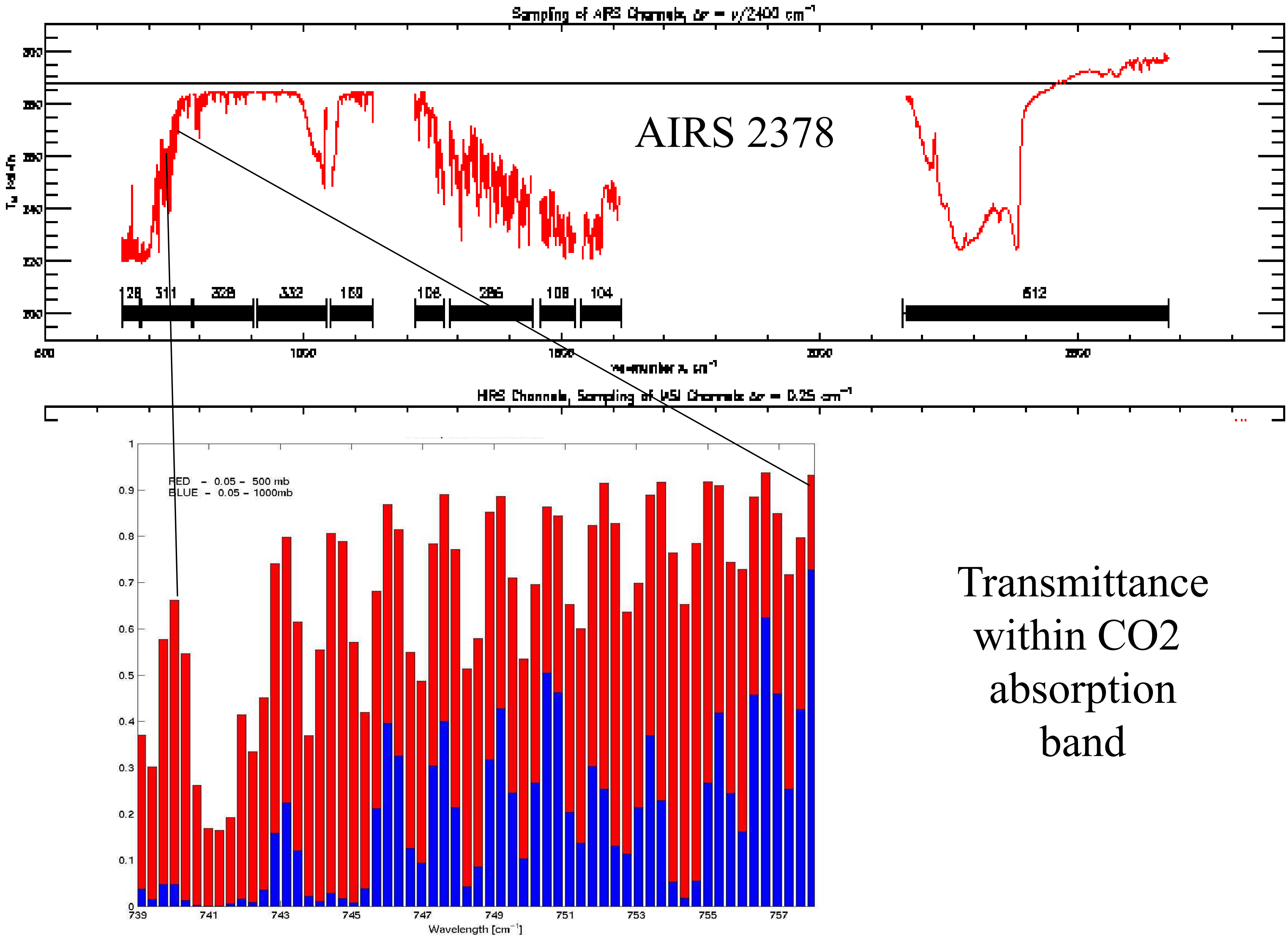


H2O spectral bands receive radiation from overlapping layers of the atmosphere



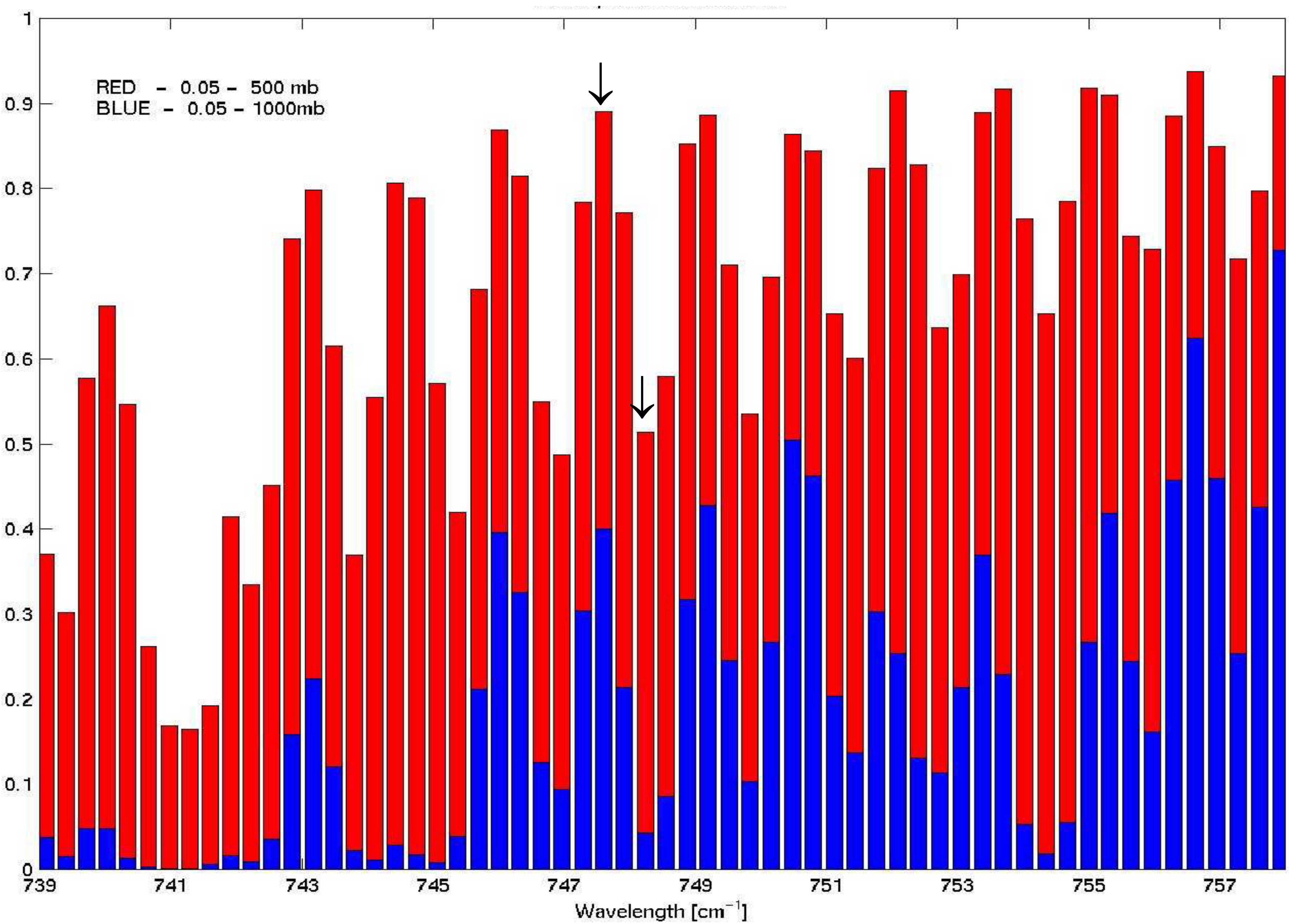
Moisture Weighting Functions

High spectral resolution advanced sounder will have more and sharper weighting functions compared to current GOES sounder. Retrievals will have 2 to 3 x better vertical resolution.

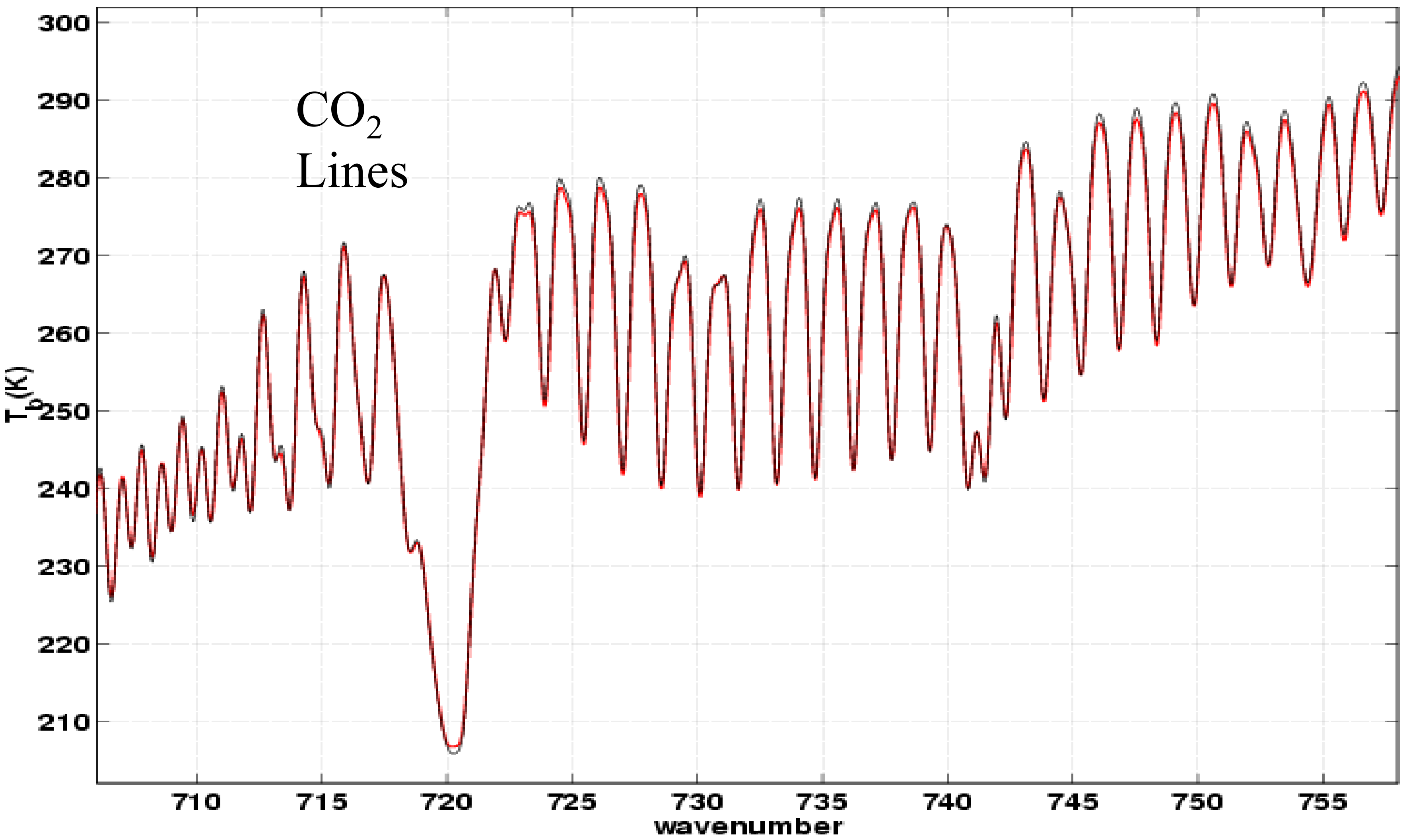


Transmittance within CO2 absorption band

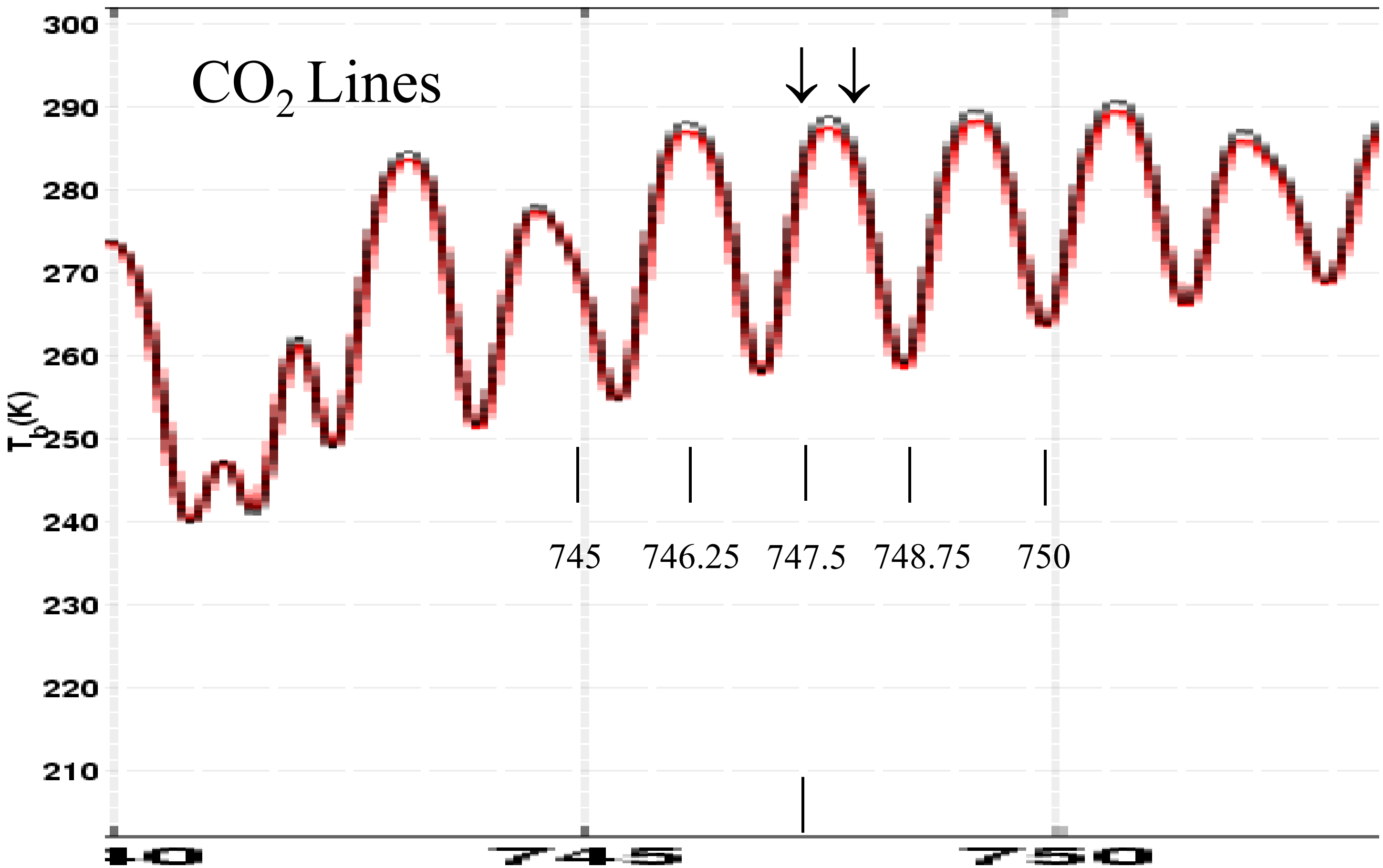
Atmospheric transmittance in CO2 sensitive region of spectrum



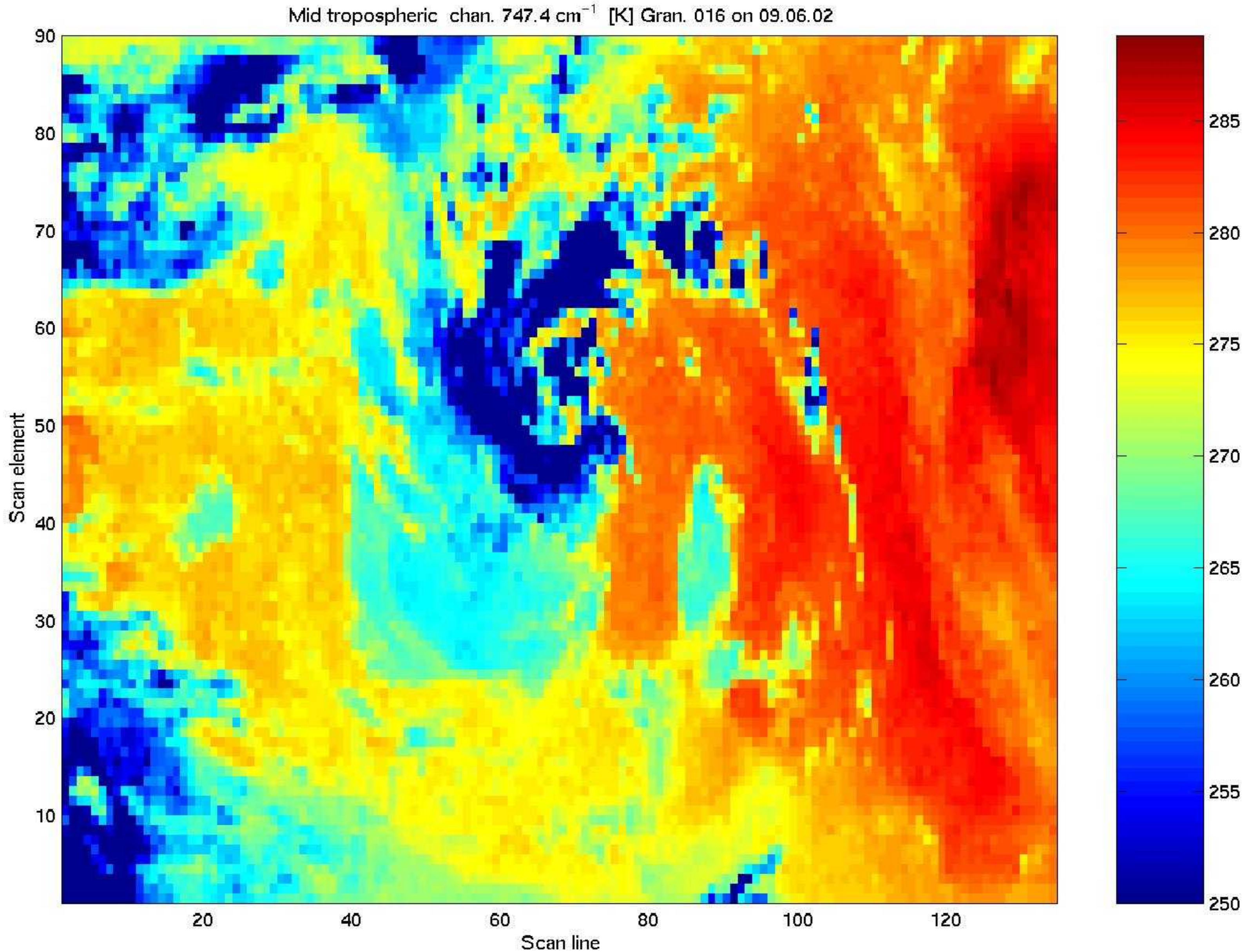
Earth emitted spectrum in CO2 sensitive 705 to 760 cm-1



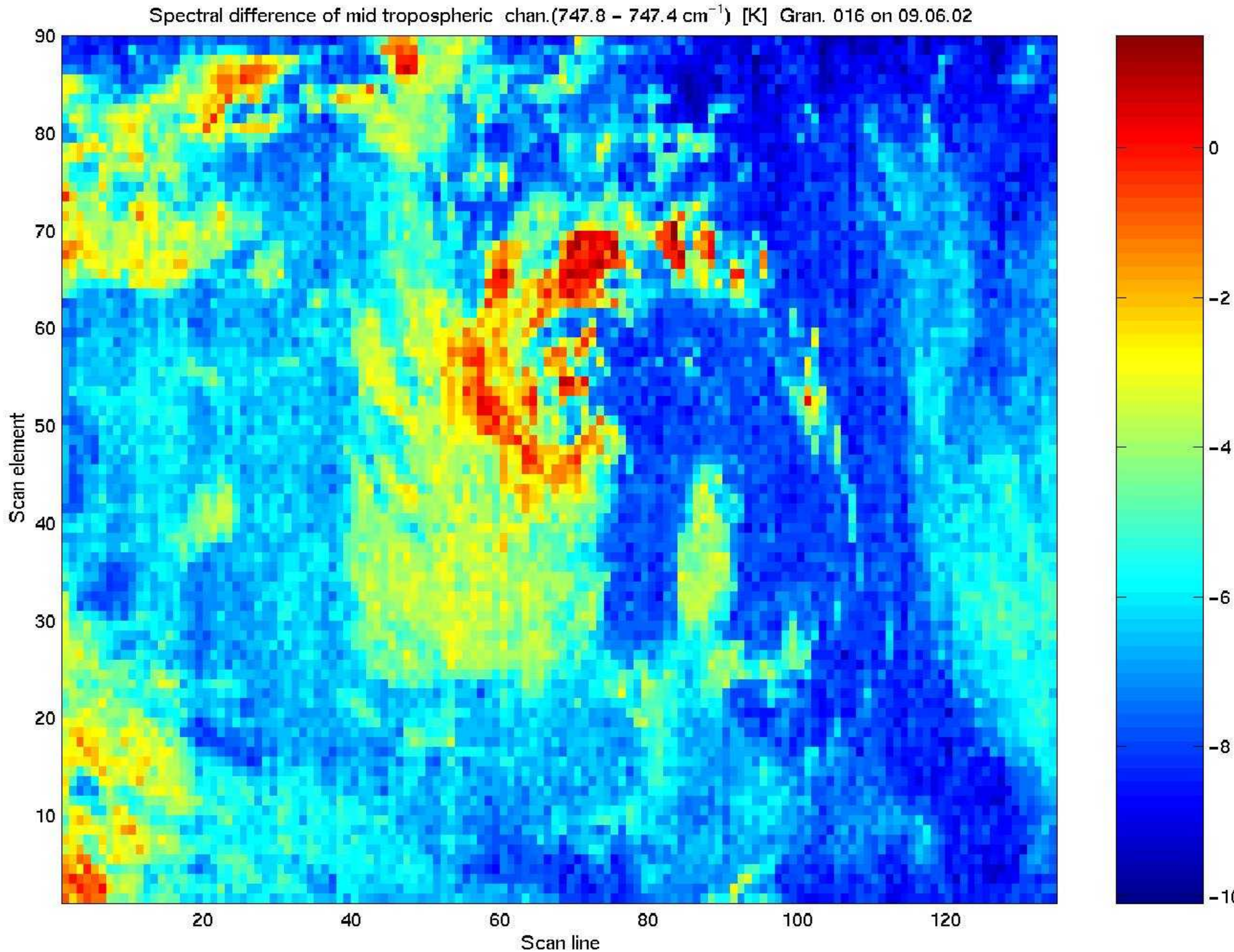
Earth emitted spectrum 740 to 755 cm-1



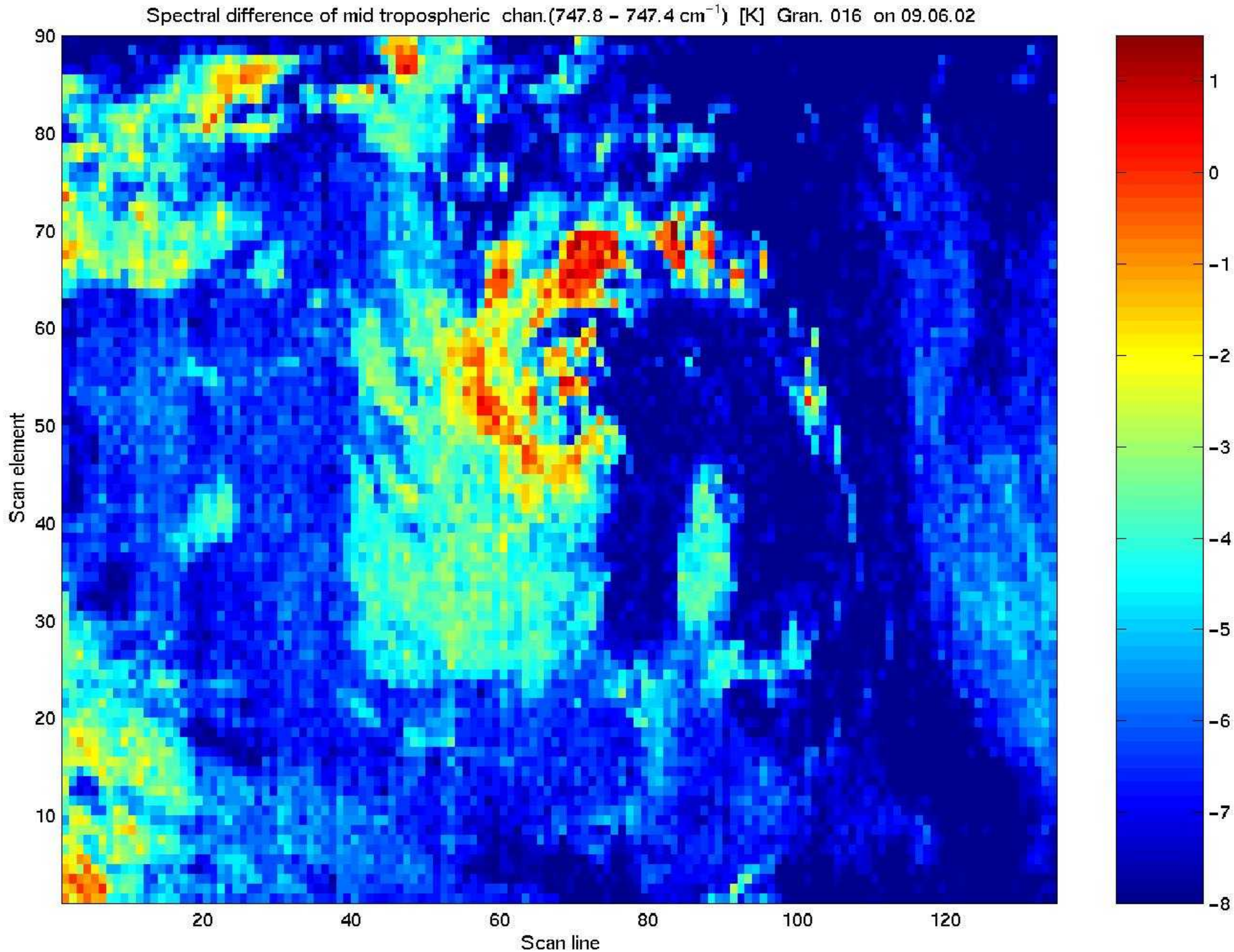
Spatial distribution of 747.4 1/cm measurements [K]



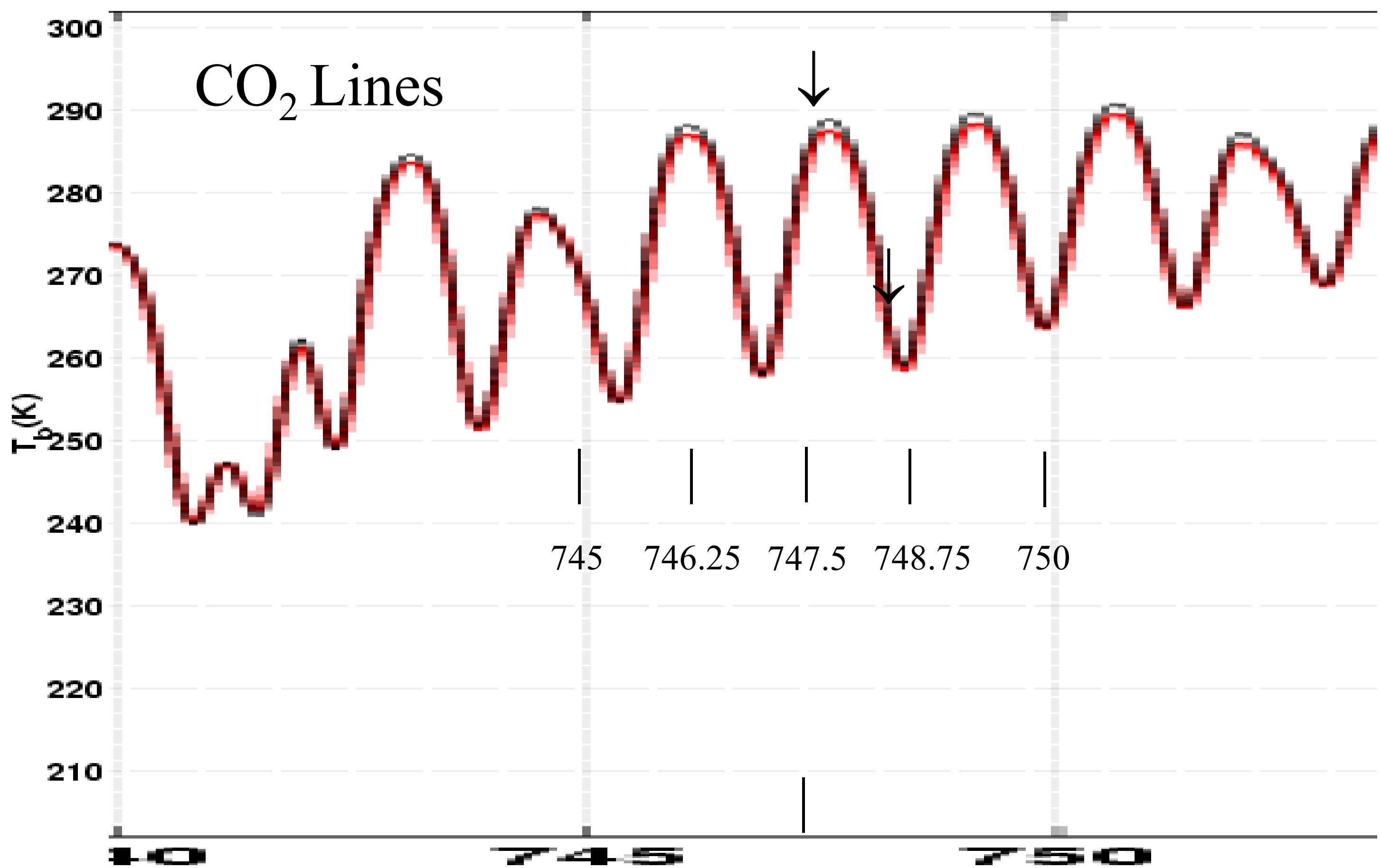
Spatial distribution of 747.8-747.4 1/cm measurements [K]



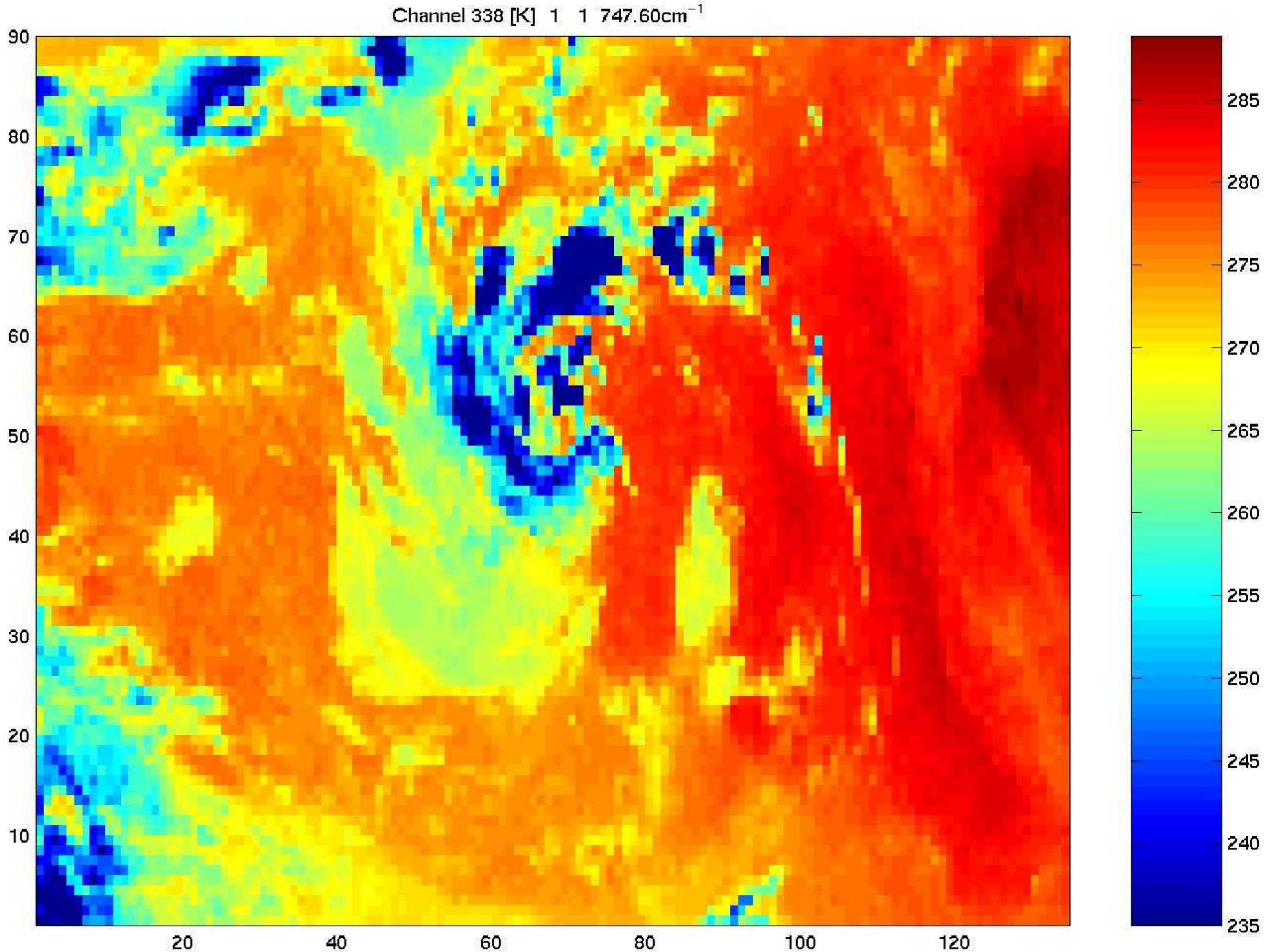
Spatial distribution of 747.8-747.4 1/cm measurements [K]



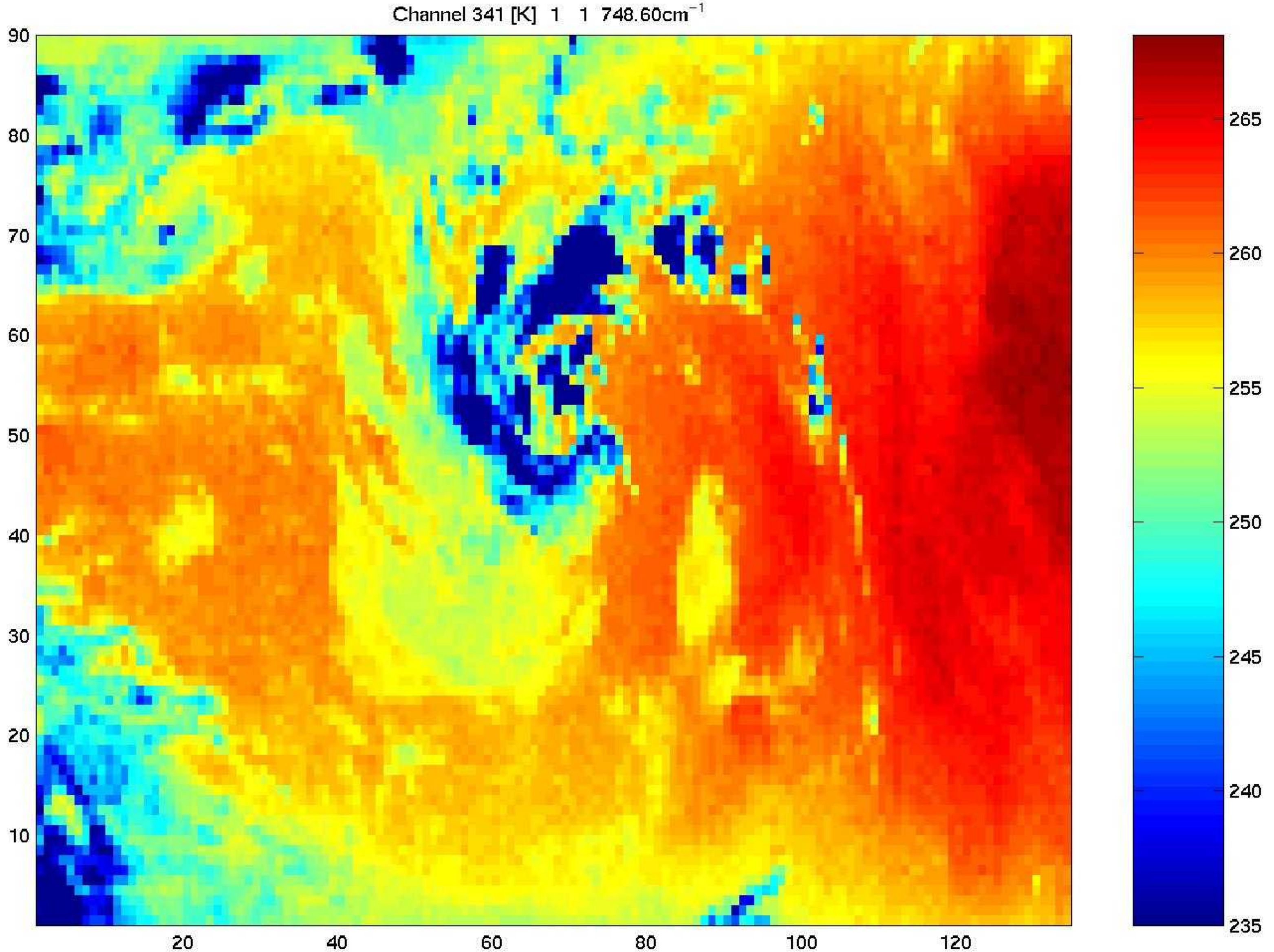
Earth emitted spectrum 740 to 755 cm-1



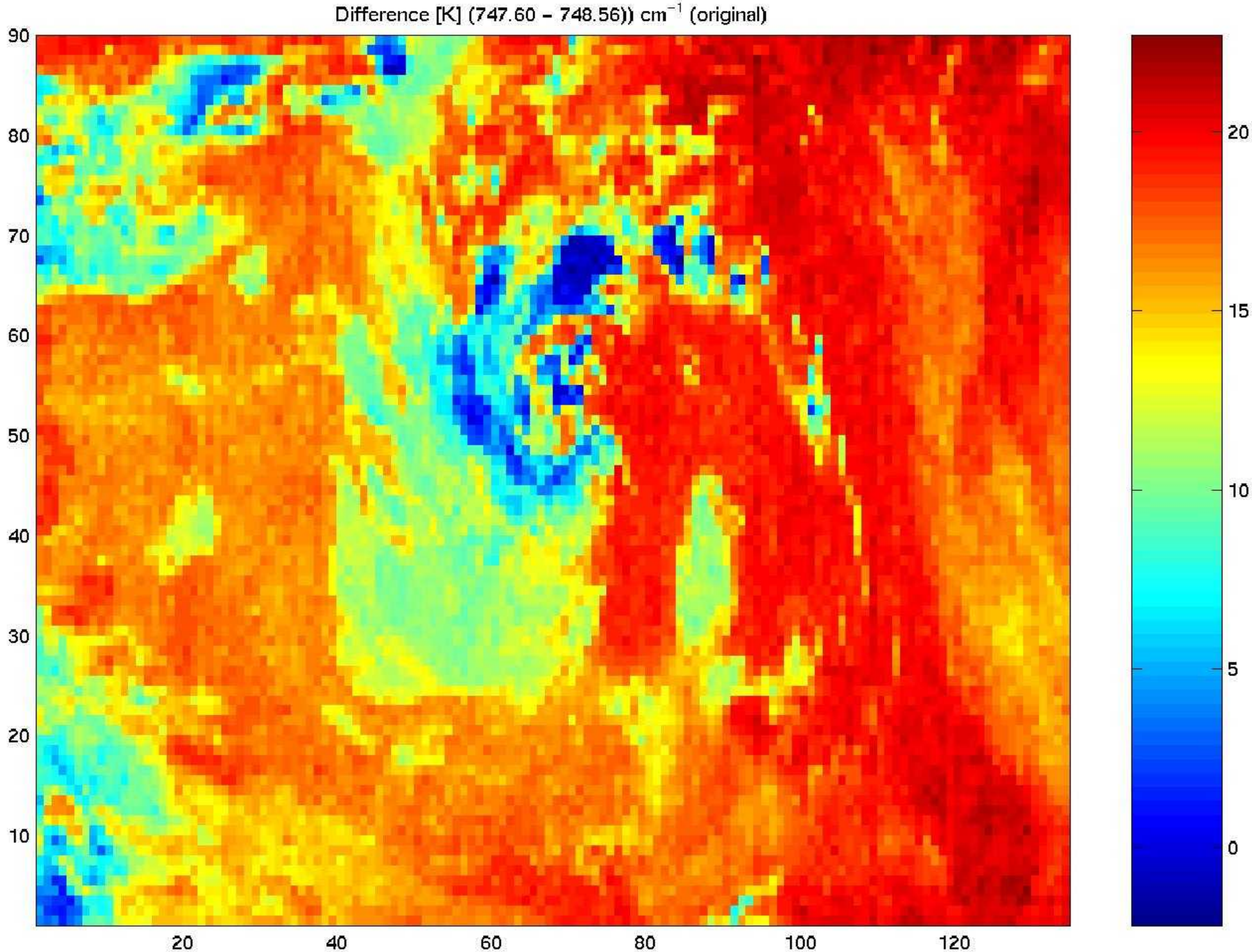
Spatial distribution of Ch 338 747.60 1/cm measurements [K]



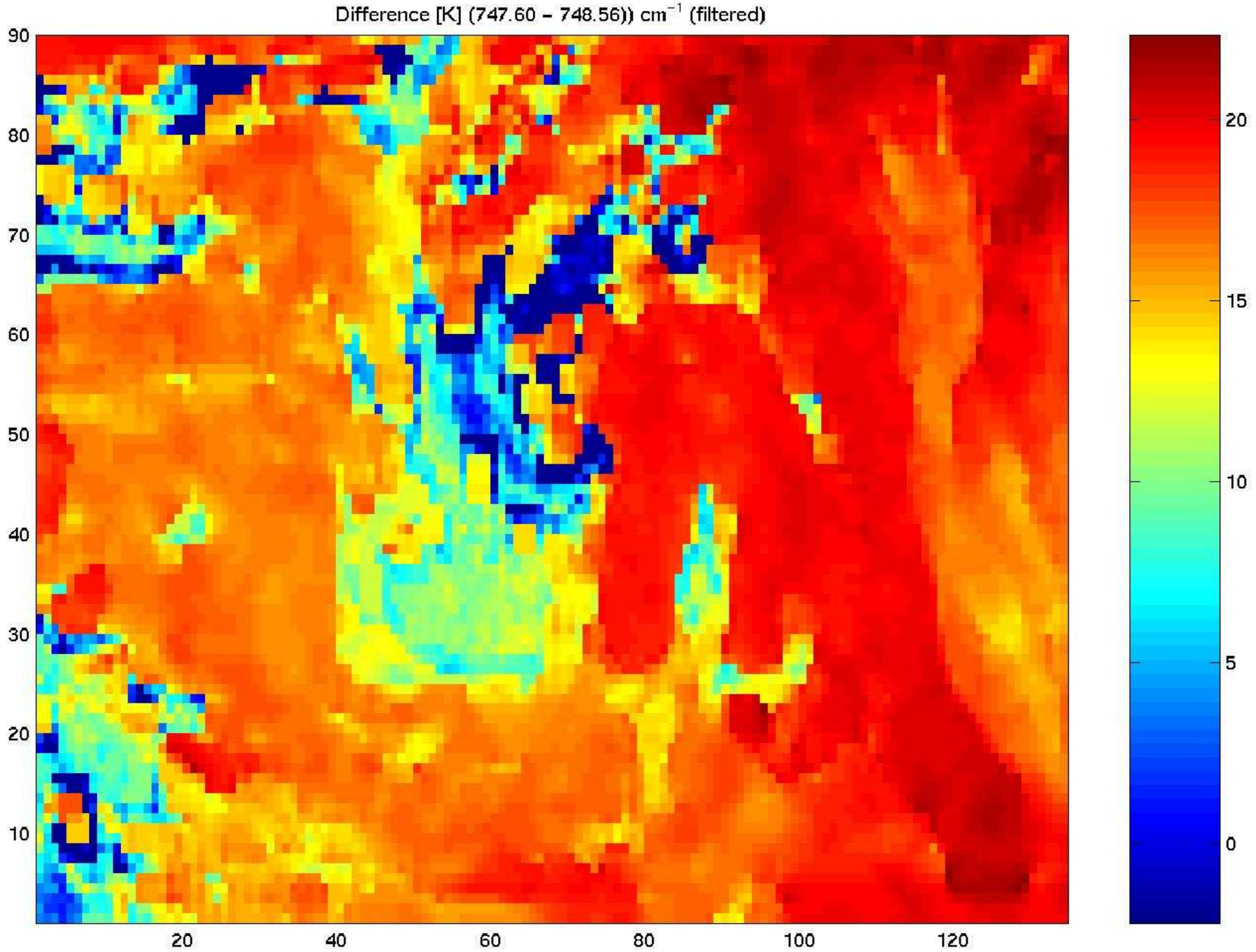
Spatial distribution of Ch 341 748.60 1/cm measurements [K]



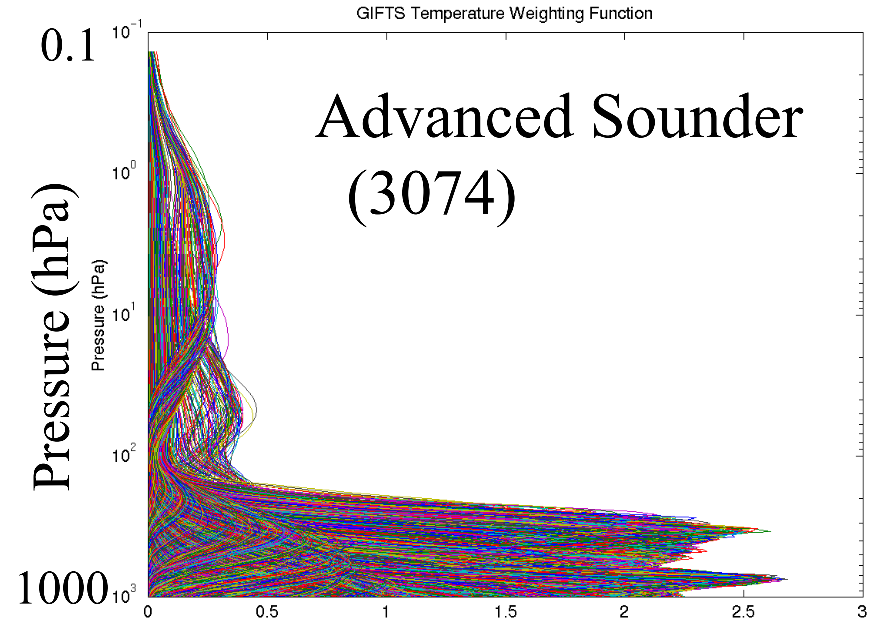
Difference {747.6 - 748.6 [1/cm]} [K] original data



Difference {747.6 - 748.6 [1/cm]} [K] filtered data

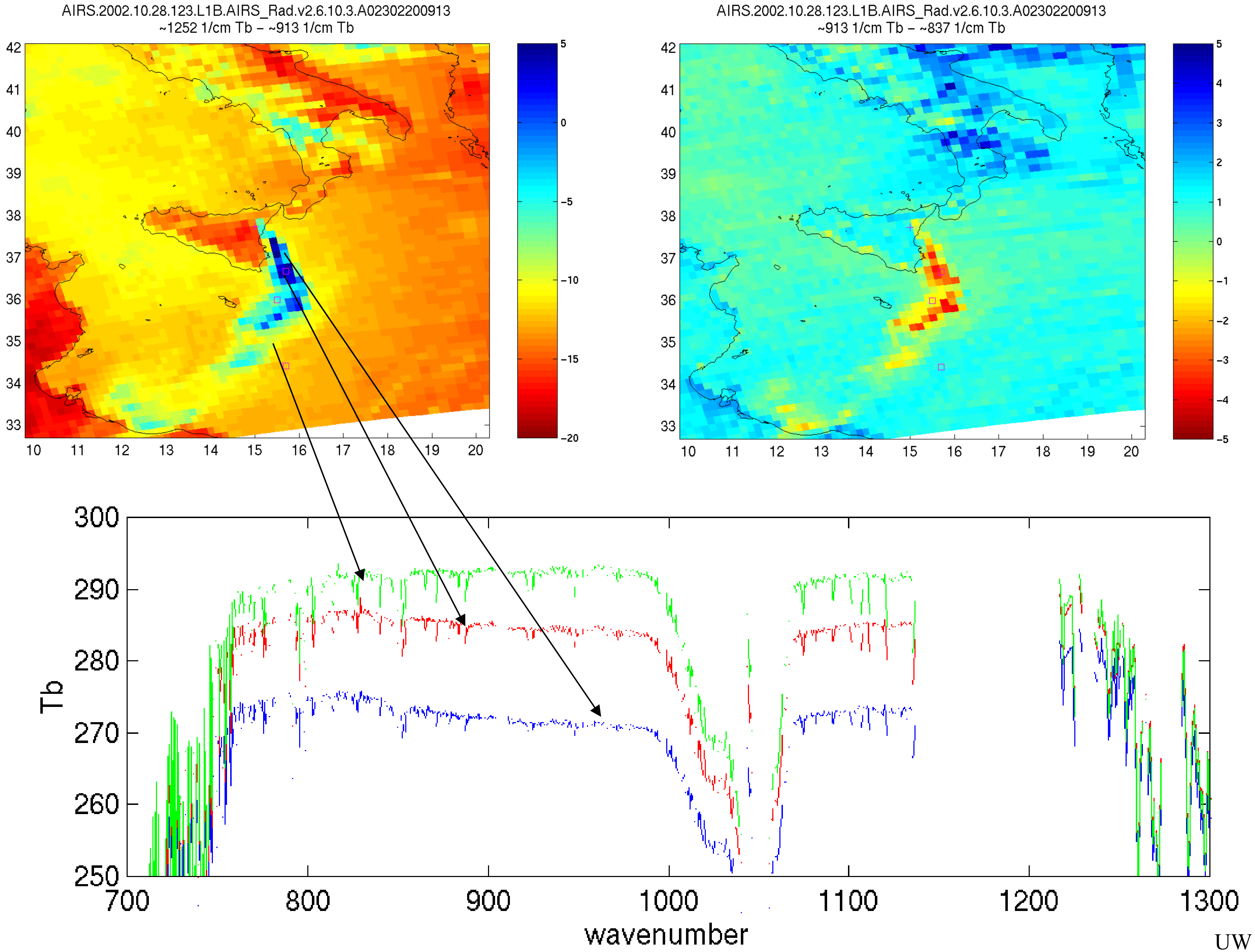


CO2 spectral bands receive radiation from overlapping layers of the atmosphere



Temperature Weighting Functions

High spectral resolution advanced sounder will have more and sharper weighting functions compared to current GOES sounder. Retrievals will have 3 to 4 x better vertical resolution.

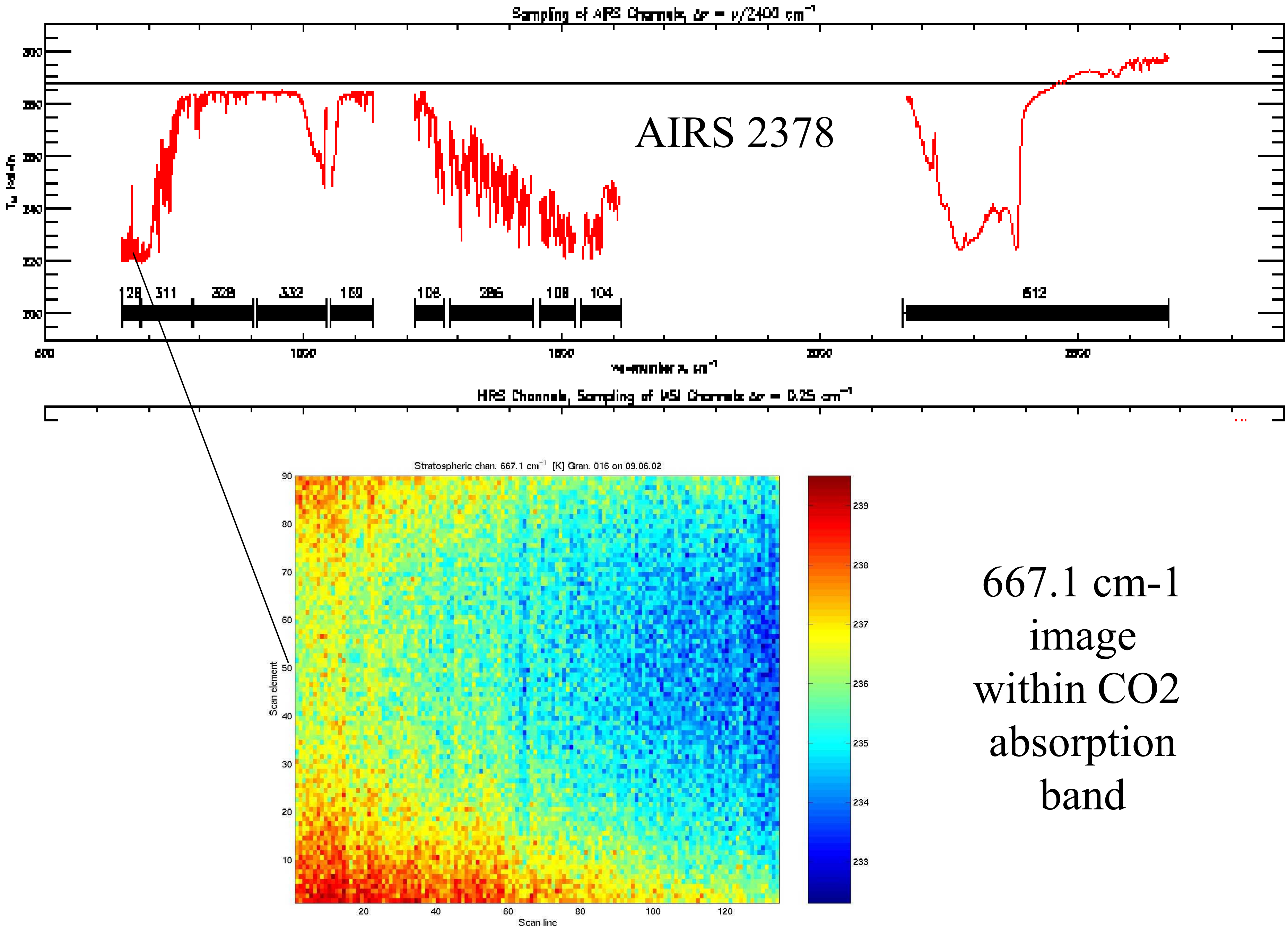

AIRS.2002.10.28.123.L1B.AIRS_Rad.v2.6.10.3.A02302200913
~1252 1/cm Tb – ~913 1/cm Tb
AIRS.2002.10.28.123.L1B.AIRS_Rad.v2.6.10.3.A02302200913
~913 1/cm Tb – ~837 1/cm Tb
Tb
wavenumber

UW
CIMSS

Mt Etna eruption

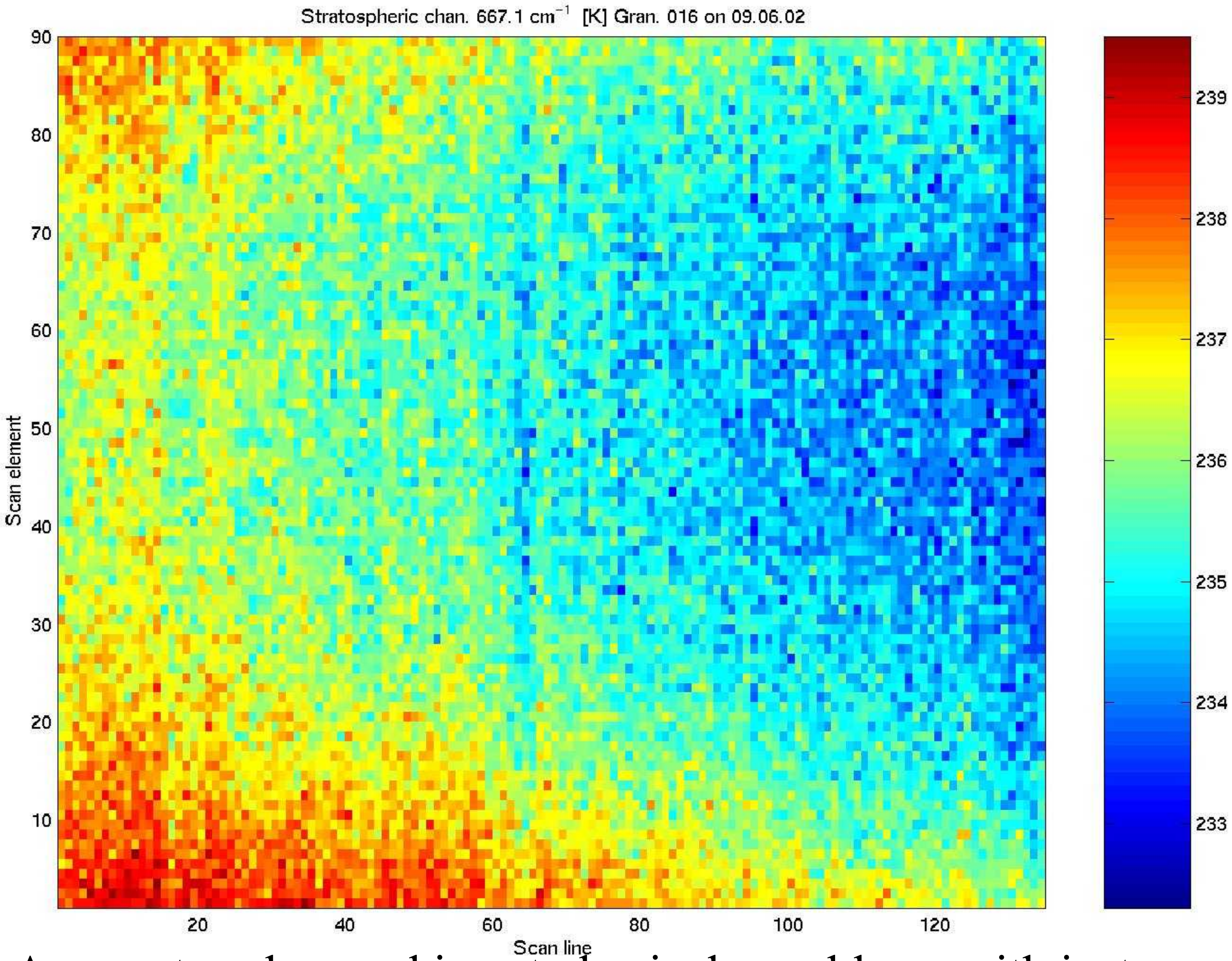
28 October 2002
ISS photo

28 October 2002
MODIS Aqua



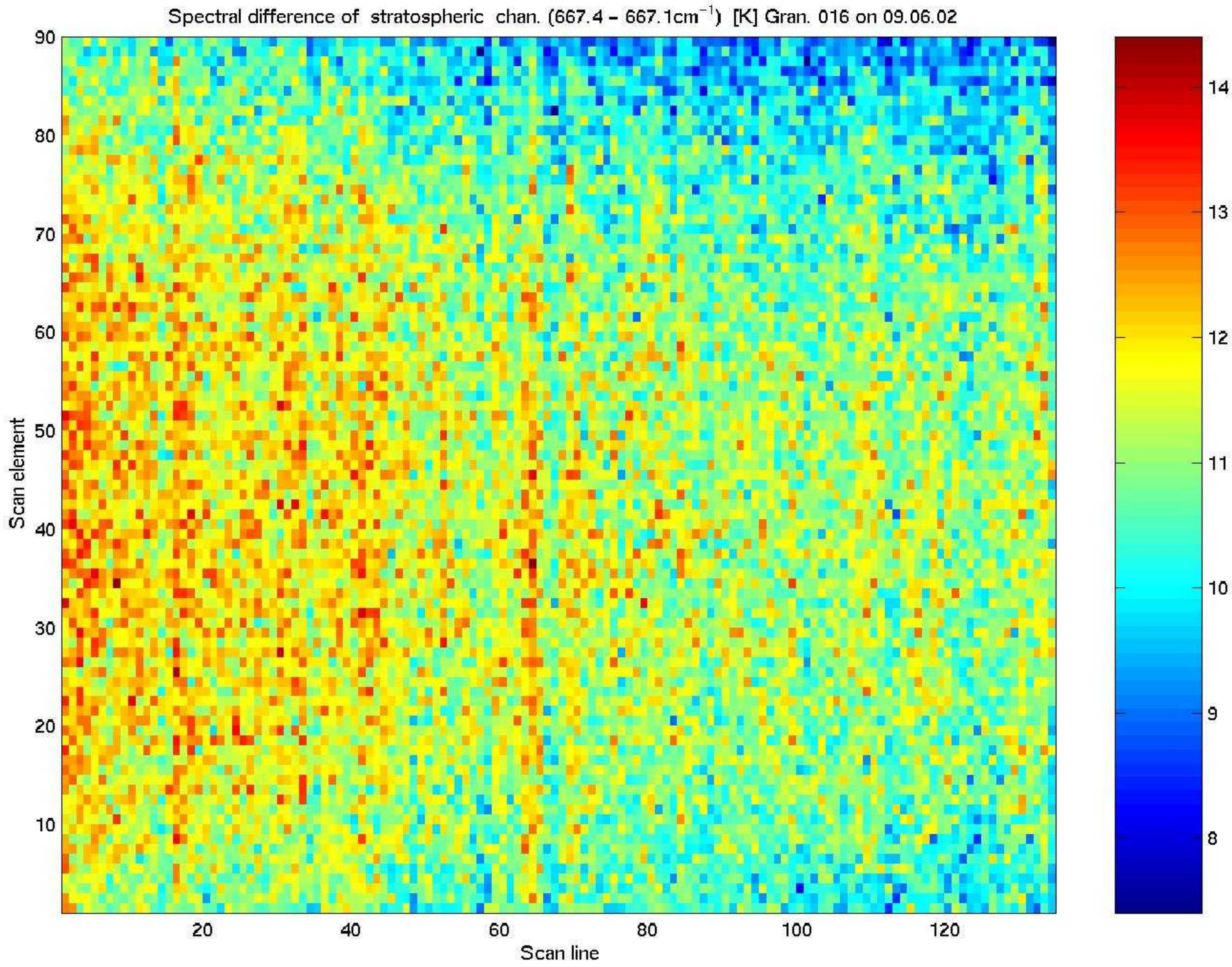
667.1 cm-1 image within CO2 absorption band

Spatial distribution of 667.1 [1/cm] measurements [K]

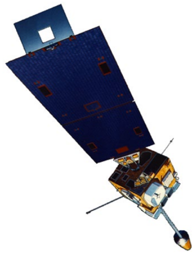


Assymetry observed is not physical - problems with instrument?

Spatial distribution of 667.4-667.1 [1/cm] measurements [K]



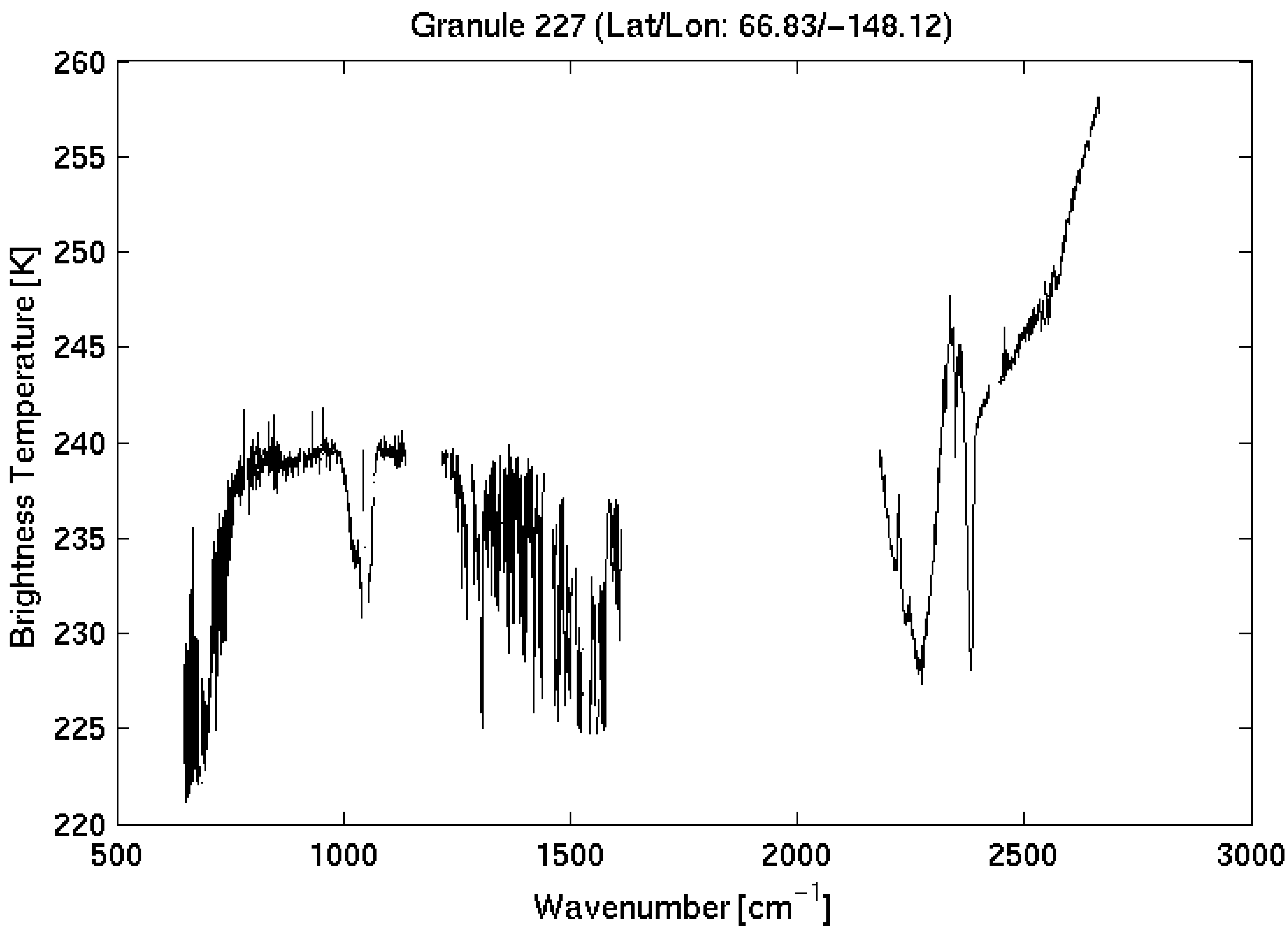
Evolving to Future Satellites



Future remote sensing will address all four key remote sensing areas

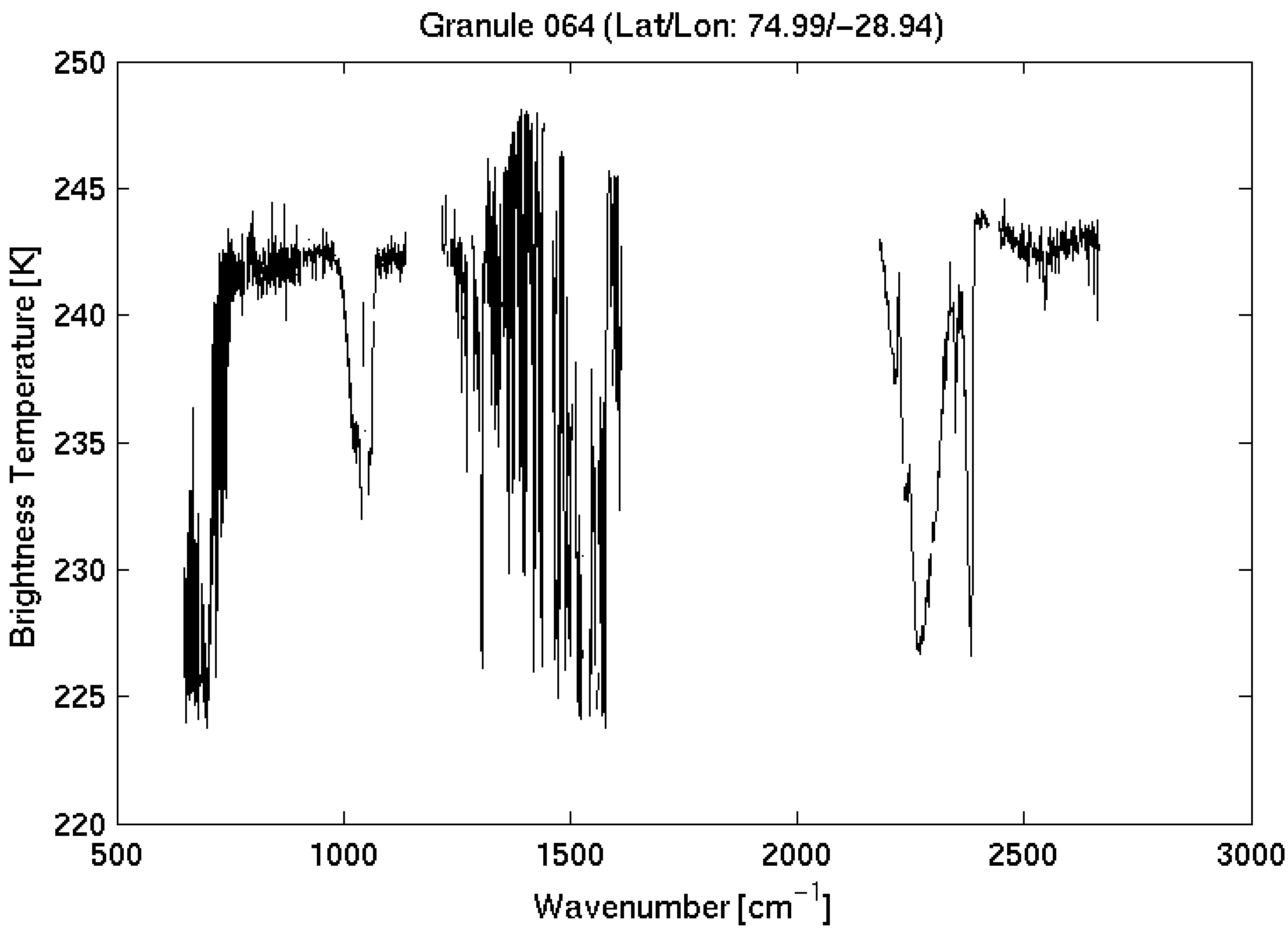
* **spatial resolution** – what picture element size is required to identify feature of interest and to capture its spatial variability;
* **spectral coverage and resolution** – what part of EM spectrum at each spatial element should be measured, and with what spectral resolution, to analyze an atmospheric or surface parameter;
* **temporal resolution** – how often does feature of interest need to be observed; and
* **radiometric resolution** – what signal to noise is required and how accurate does an observation need to be.

Example Spectra

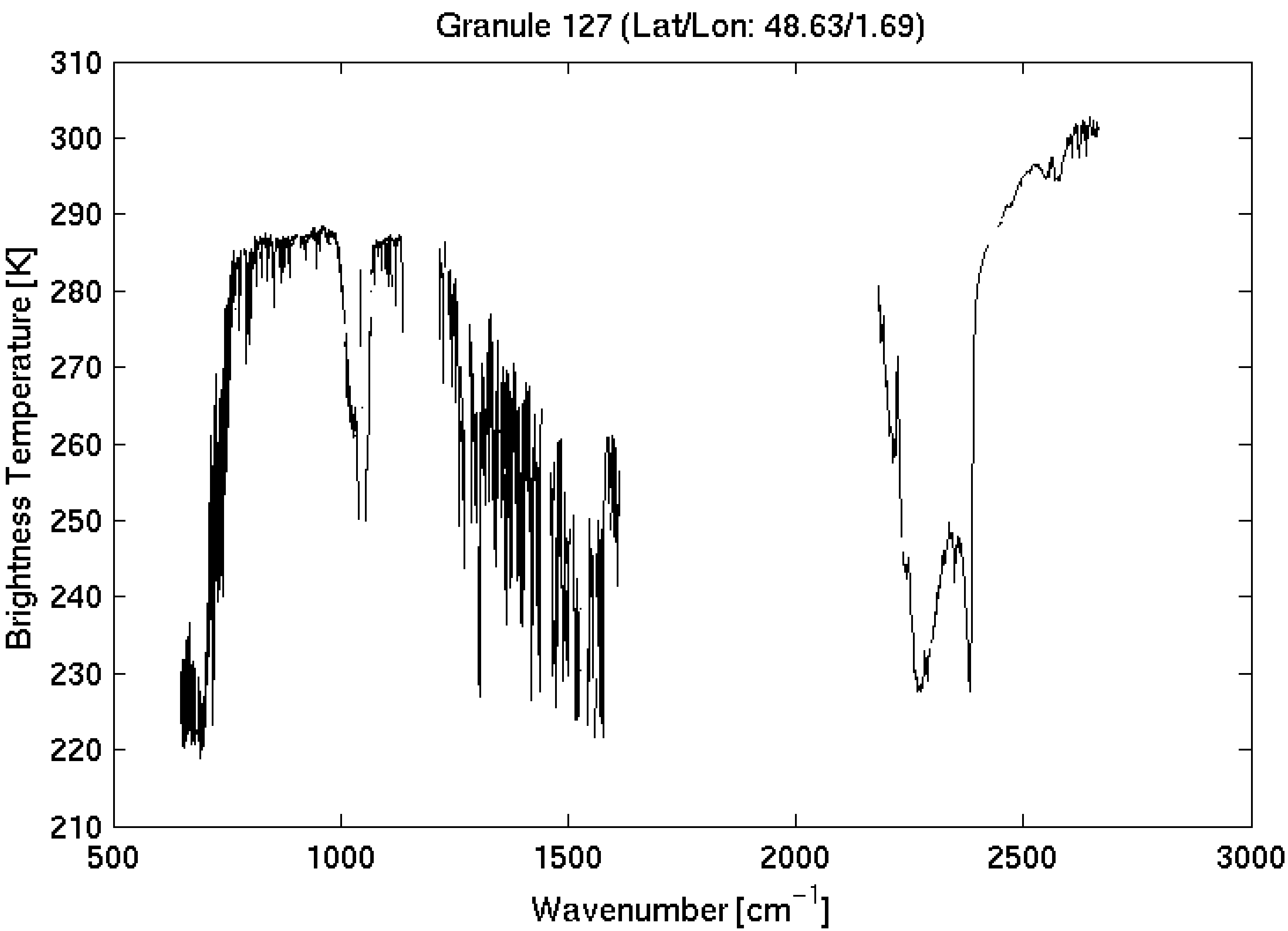


Granule 227 (Lat/Lon: 66.83/−148.12)
Brightness Temperature [K]
Wavenumber [cm^{-1}]
260
255
250
245
240
235
230
225
220
500
1000
1500
2000
2500
3000

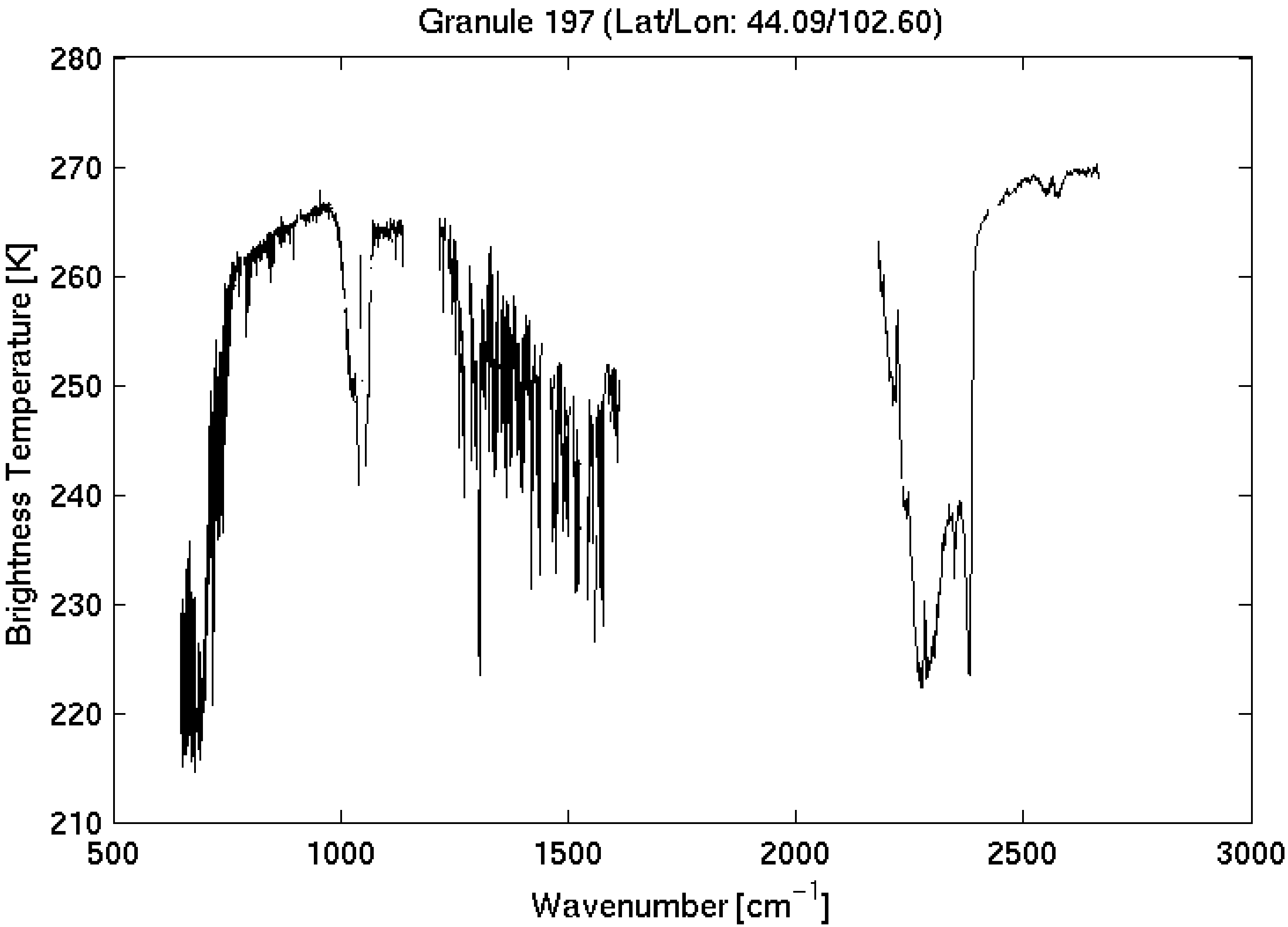
Day or night?



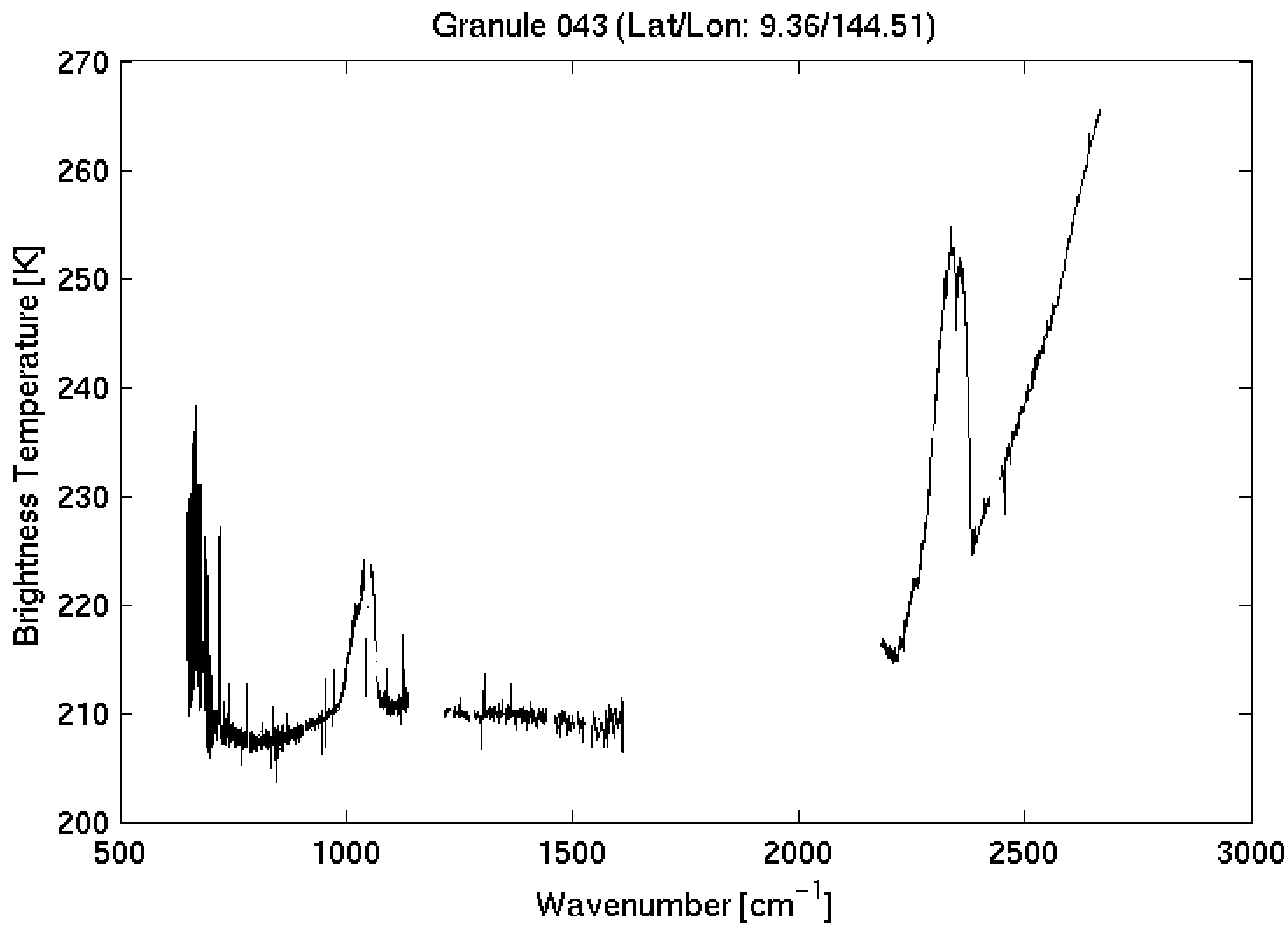
Day, night, desert, or ice/snow?


Granule 127 (Lat/Lon: 48.63/1.69)
Brightness Temperature [K]
310
300
290
280
270
260
250
240
230
220
210
500
1000
1500
2000
2500
3000
Wavenumber [cm^{-1}]

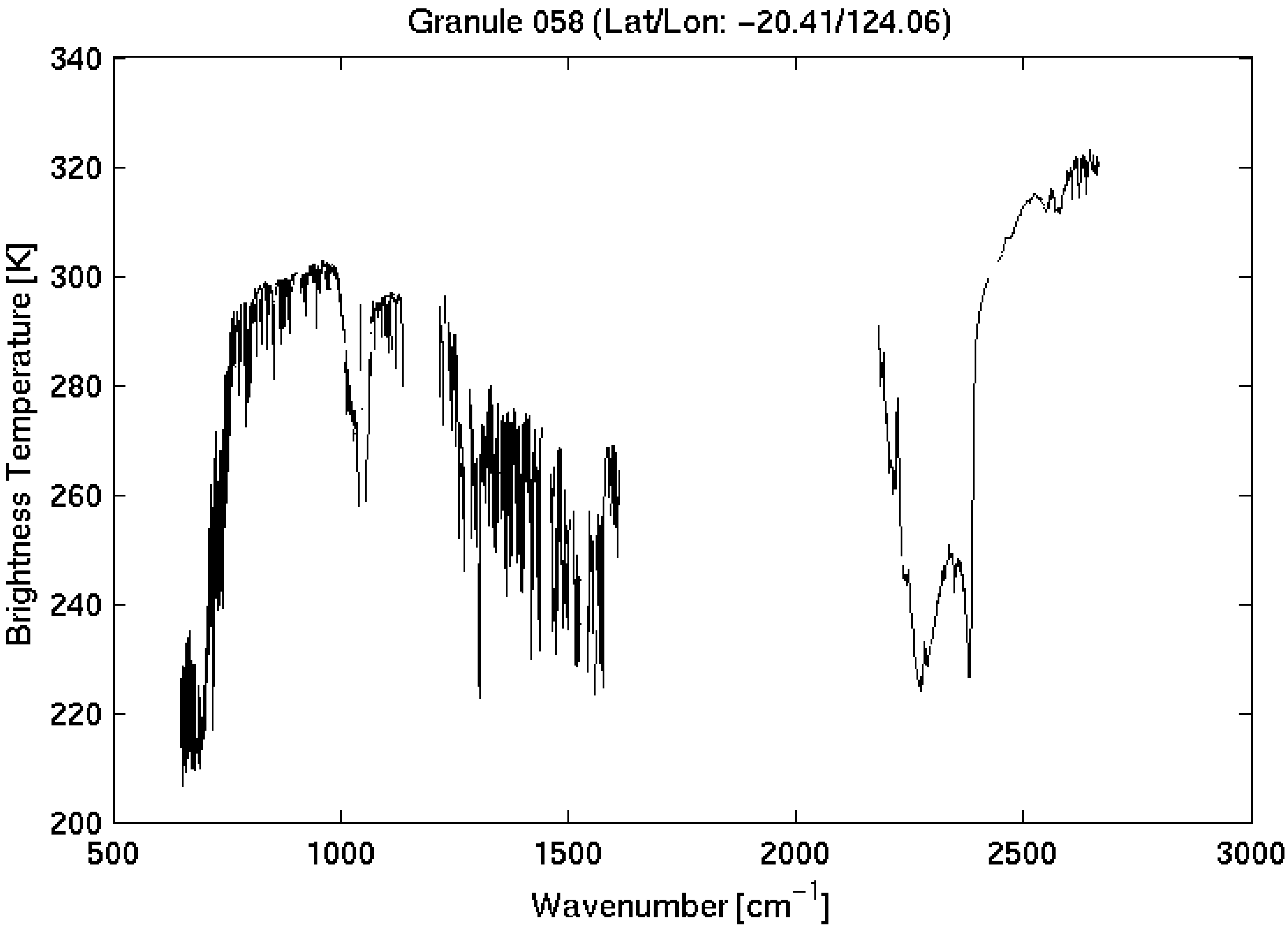
Day or night?



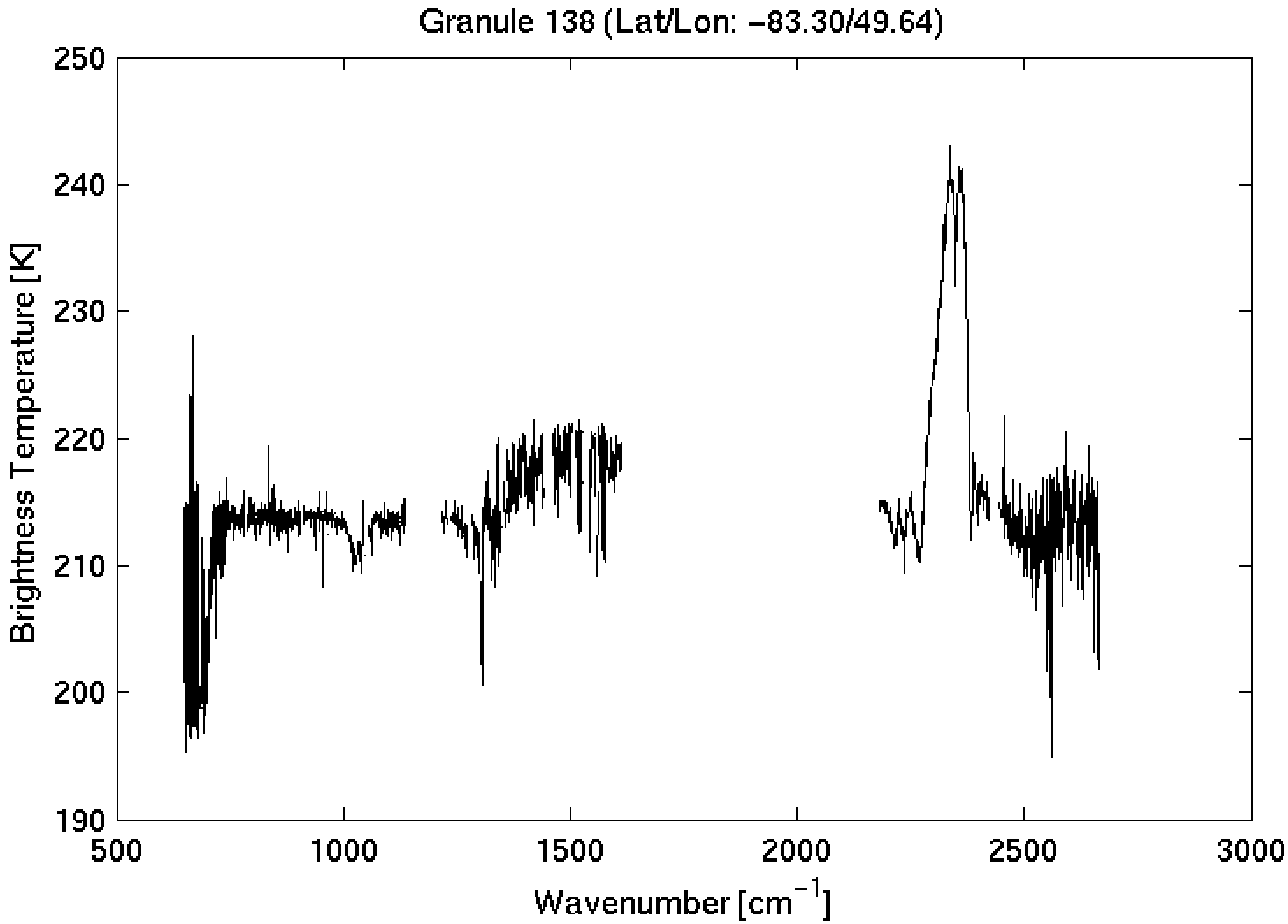
Land or ocean?



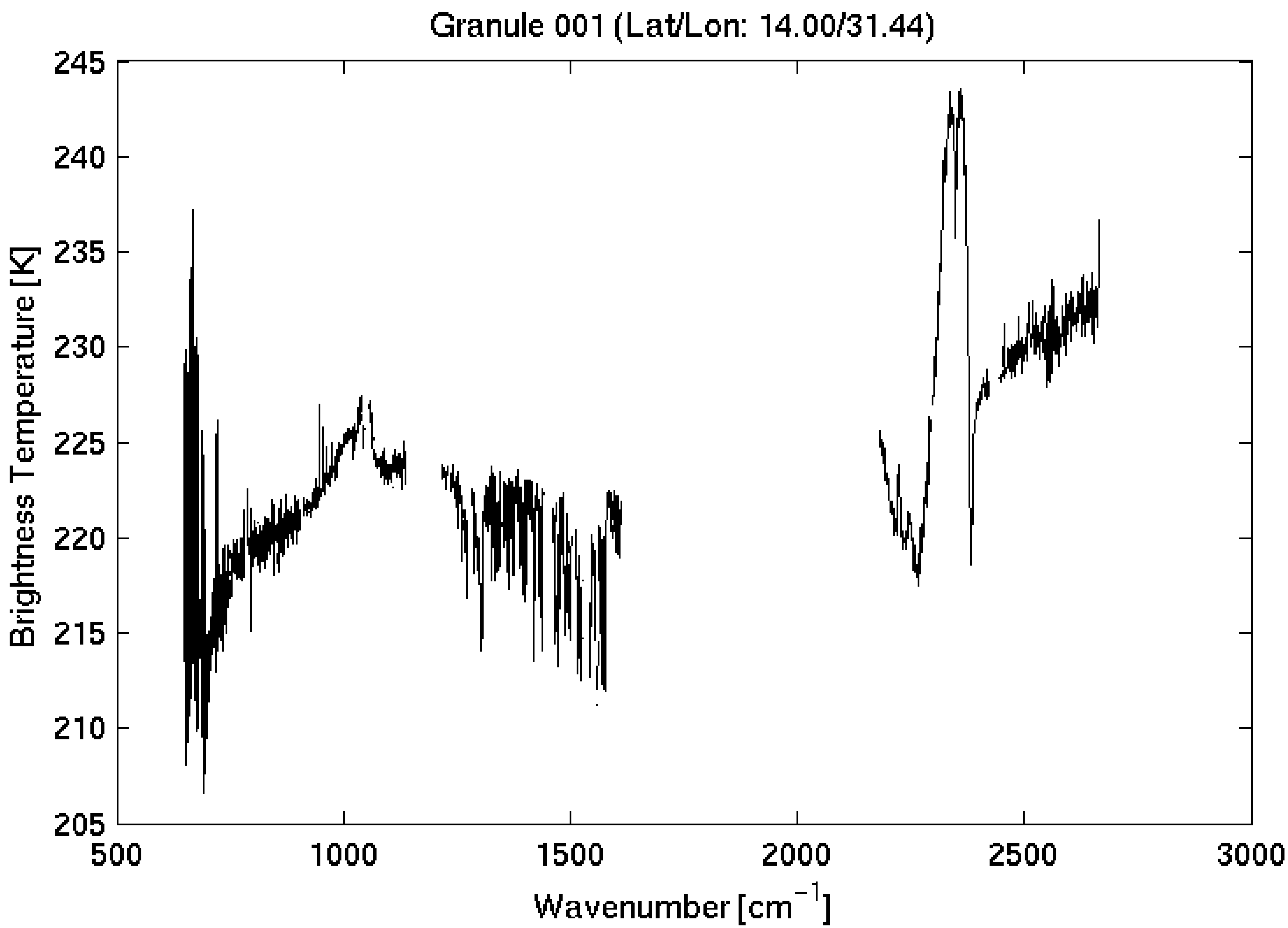
Desert, ocean, or cloudy?



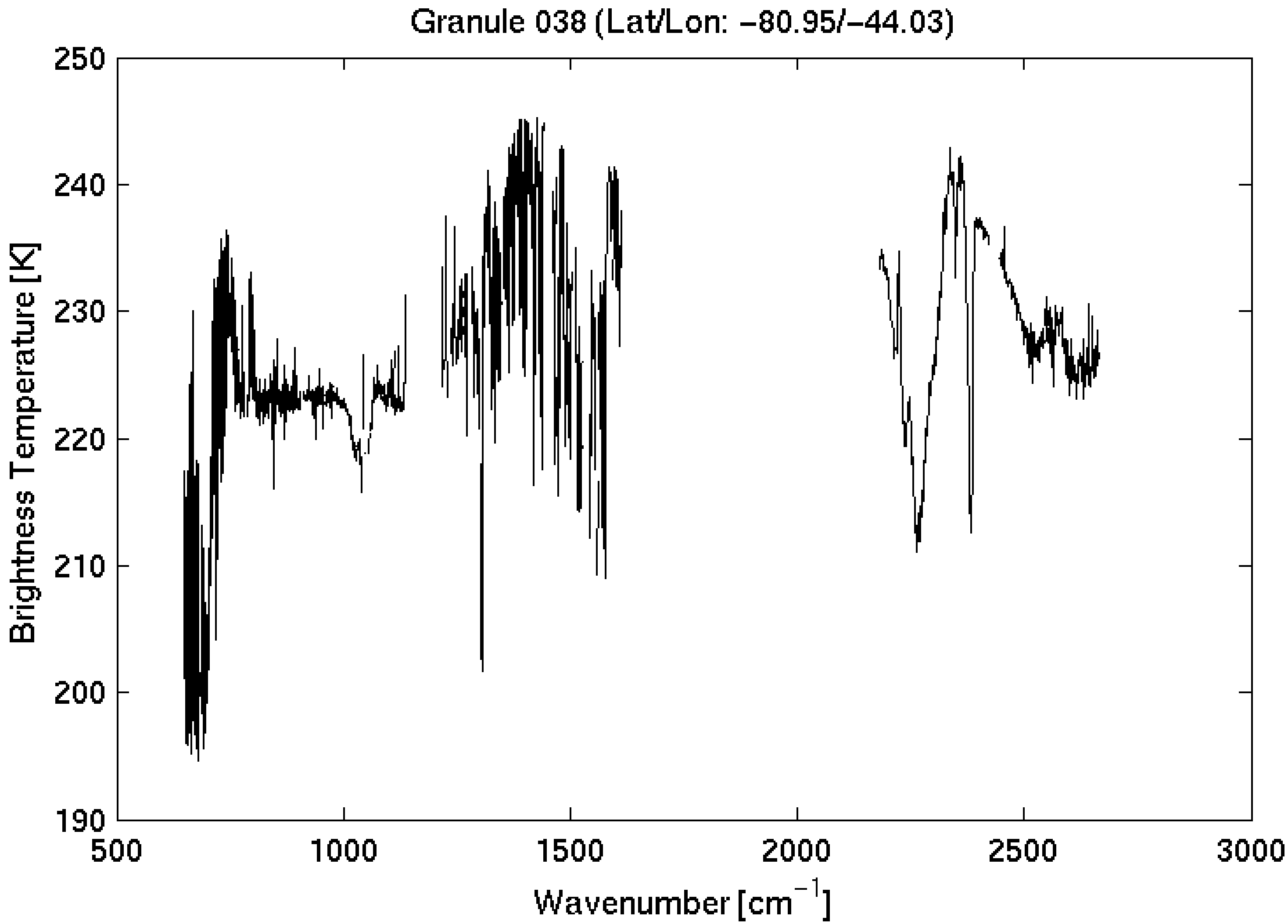
Day, night, desert, or ocean?



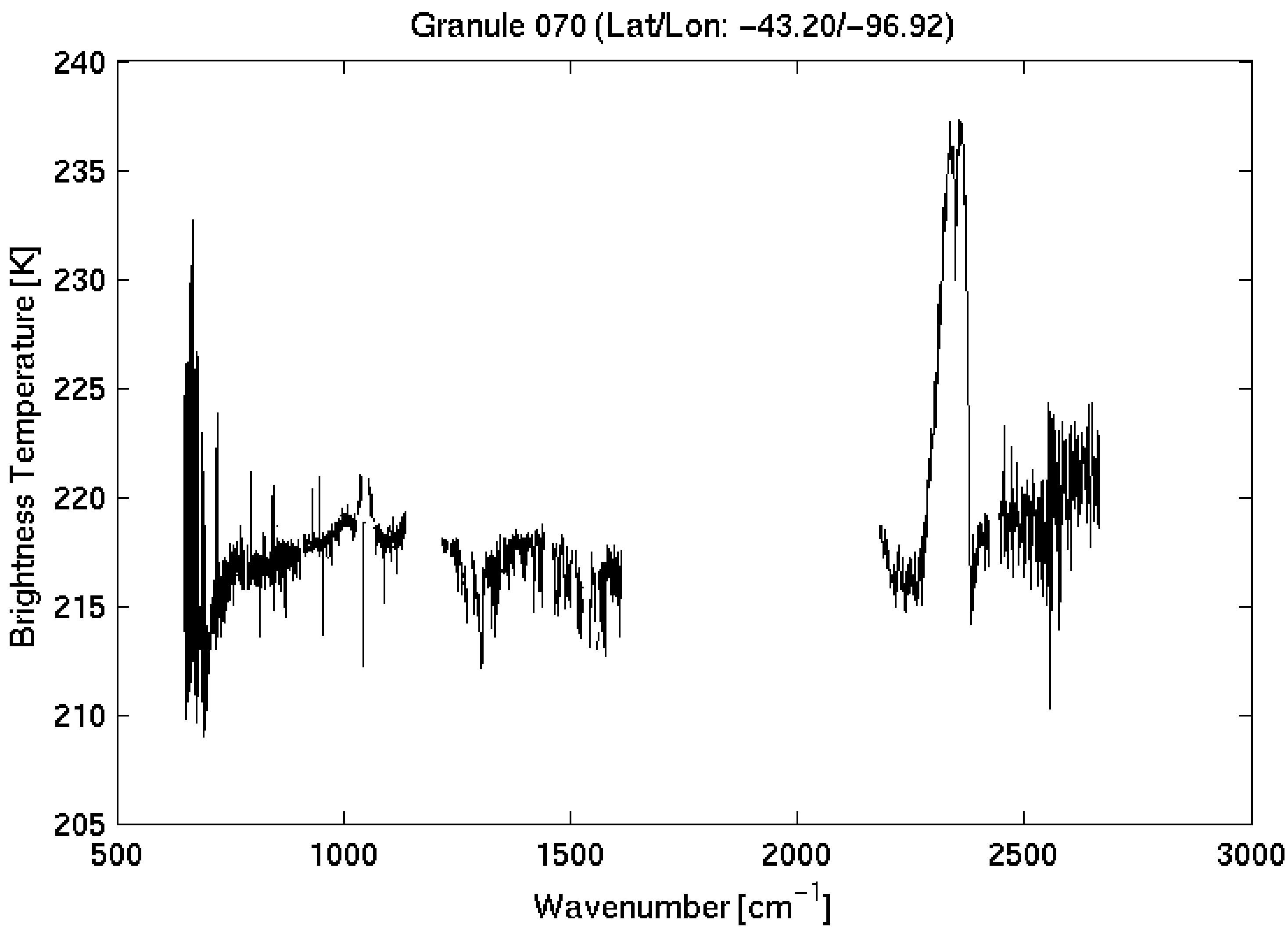
Ocean, cloudy, snow/ice, or desert?



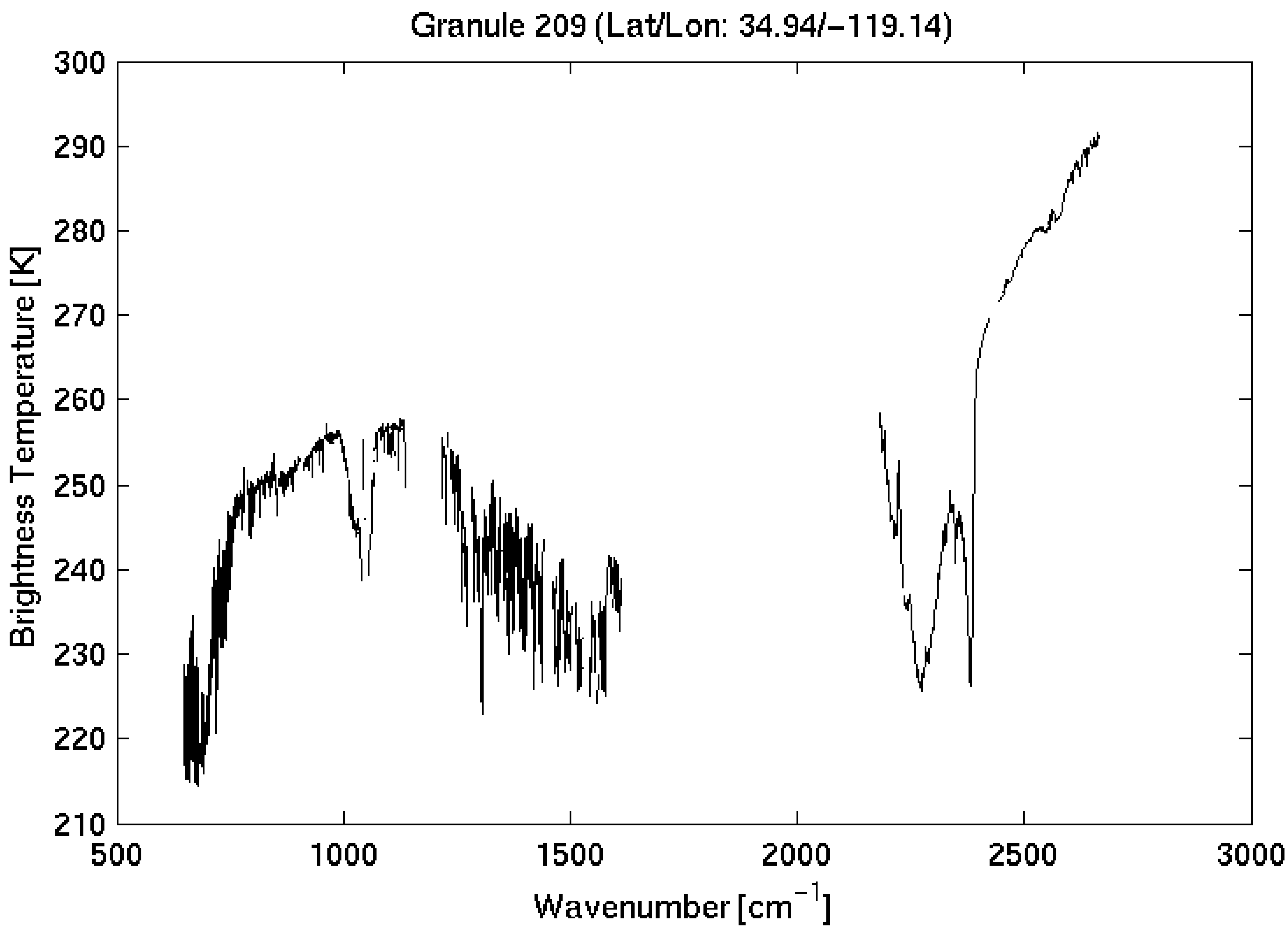
Day, night, desert, or cloudy?



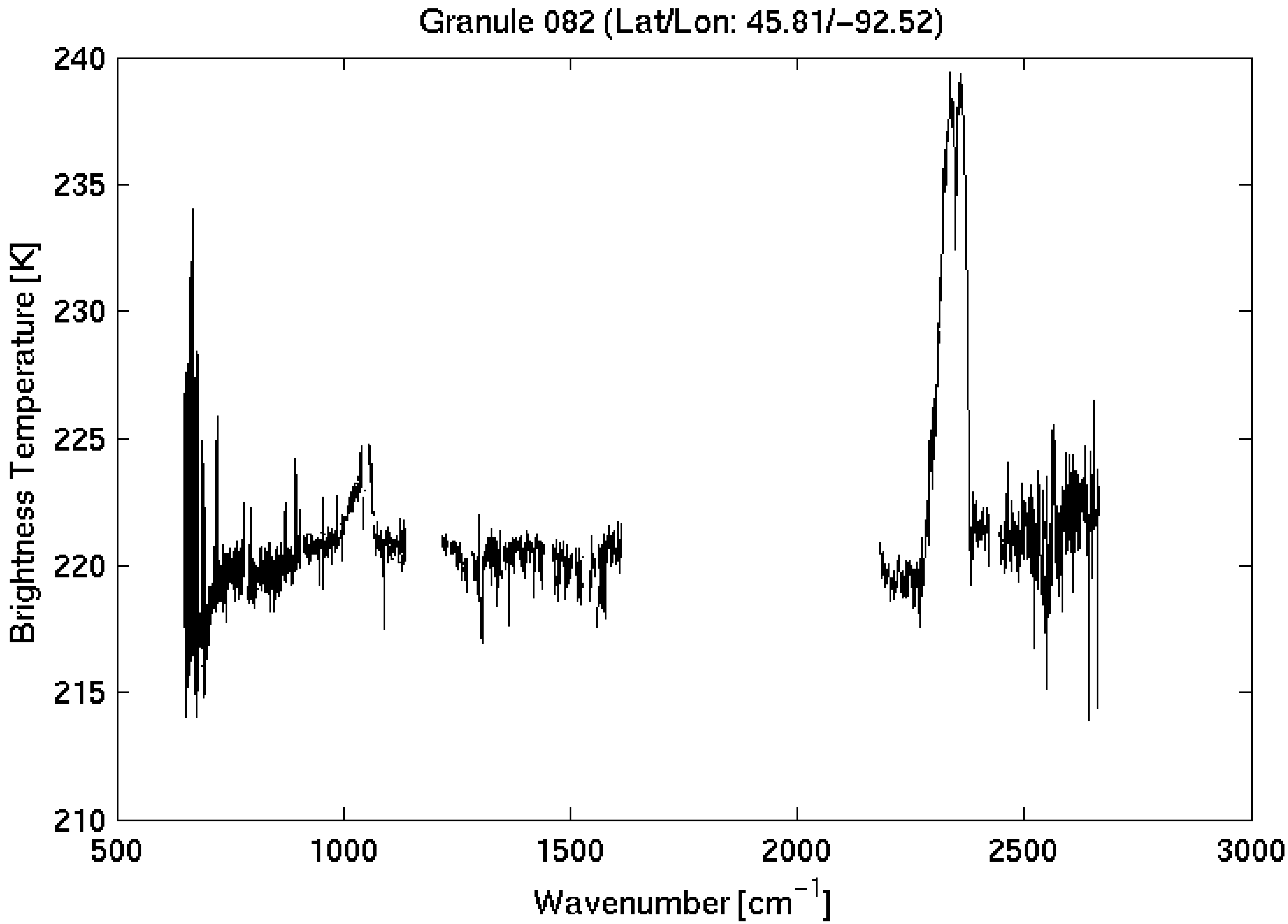
Cloudy, desert, or ocean?



Land, desert, ice/snow, or ocean?



Day, night, desert, or cloudy?



Day, night, ocean, or cloudy?