

Review of Remote Sensing Fundamentals IV

Infrared at High Spectral Resolution – Basic Principles & Limitations

Allen Huang

Cooperative Institute for Meteorological Satellite Studies

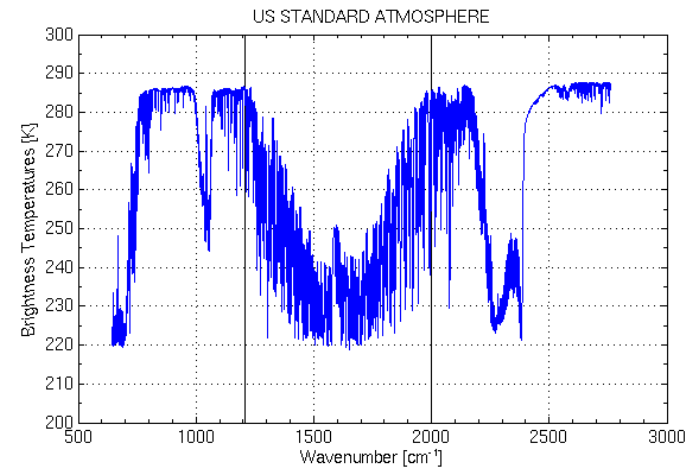
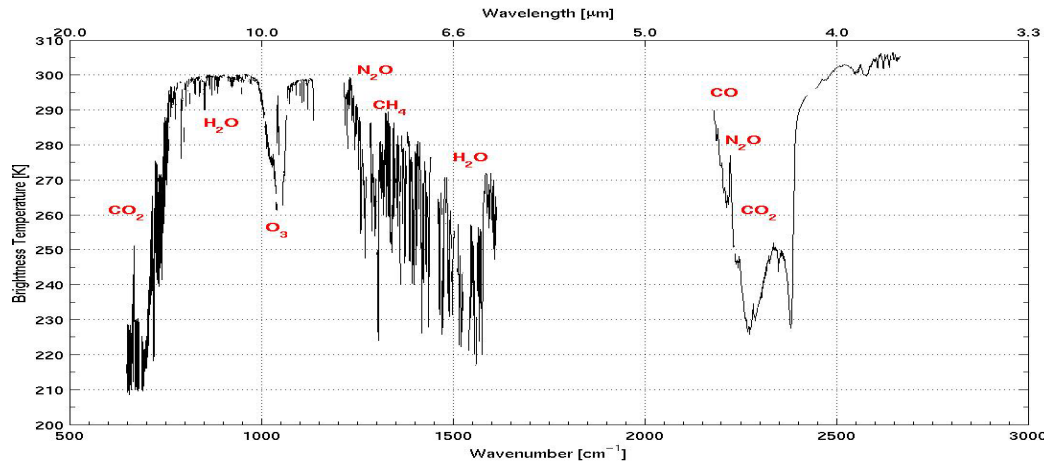
Space Science & Engineering Center

University of Wisconsin-Madison, USA

Materials provided by

Elisabeth Weisz, Paul Menzel, Paolo Antonalli,

Jun Li, Mat Gunshor and Tim Schmit

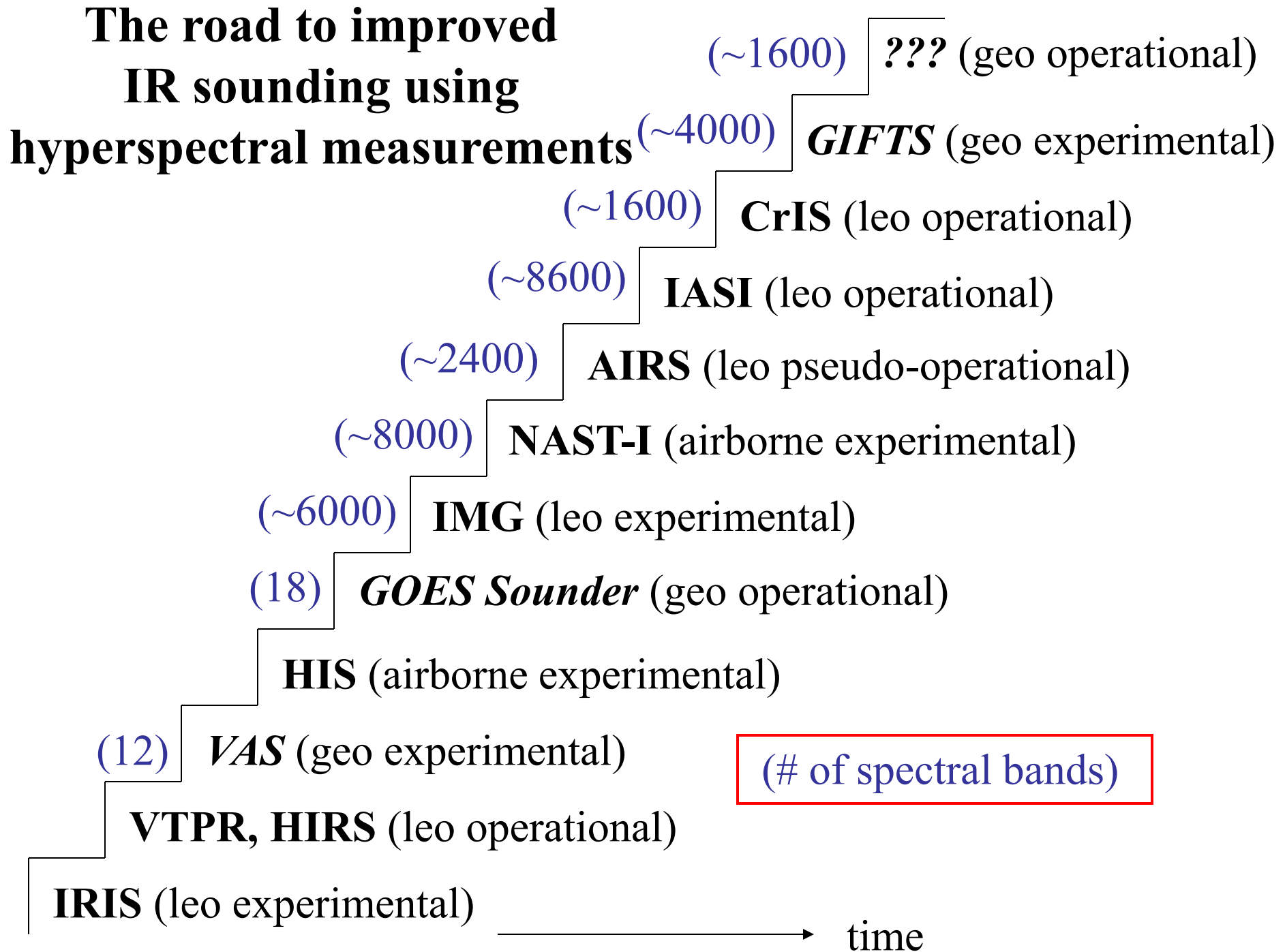


GEOSS Americas/Caribbean Remote Sensing Workshop

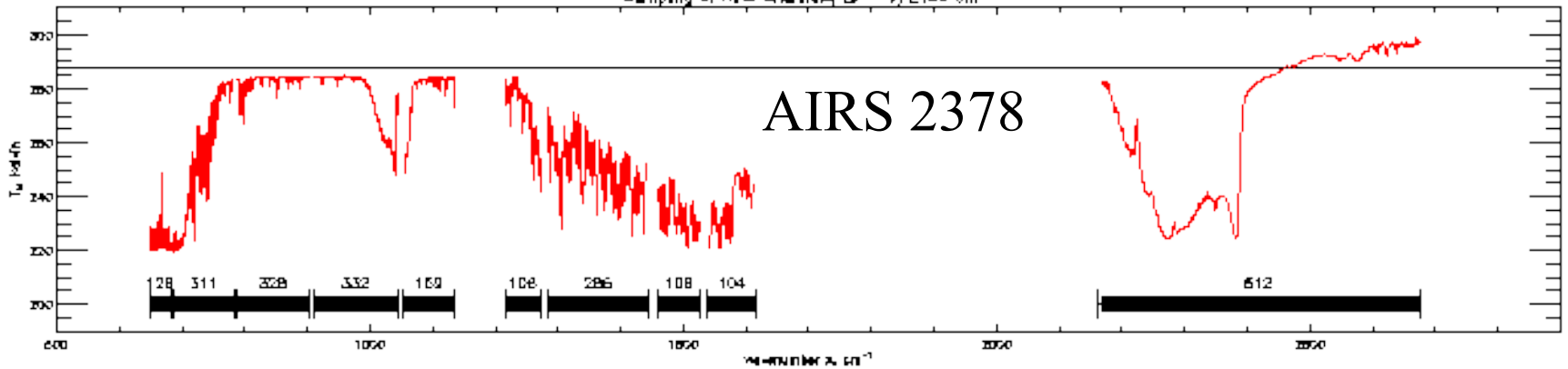
– Transforming Data into Products

26-30 November 2007

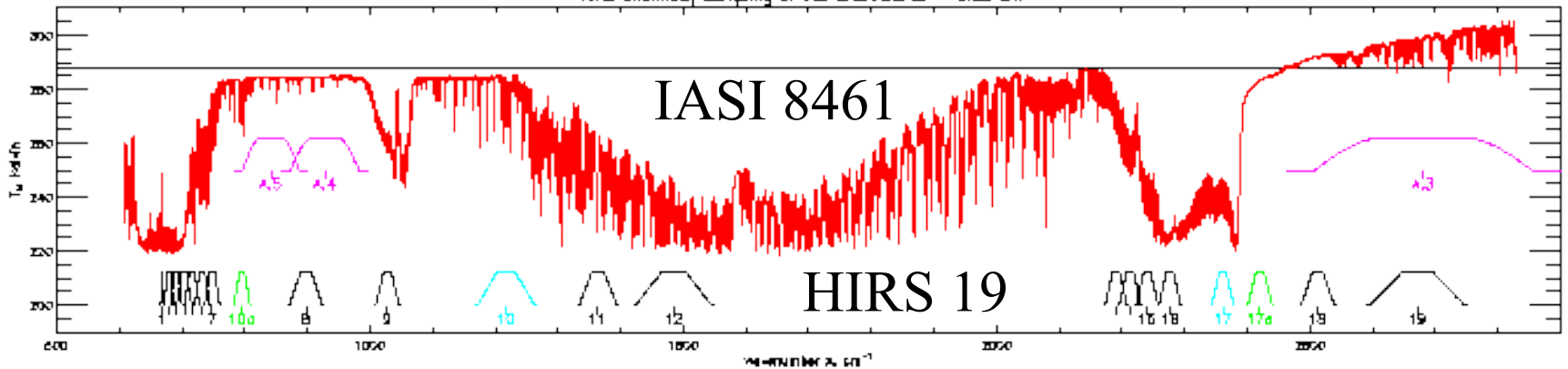
CPTEC/INPE Cachoeira Paulista - São Paulo



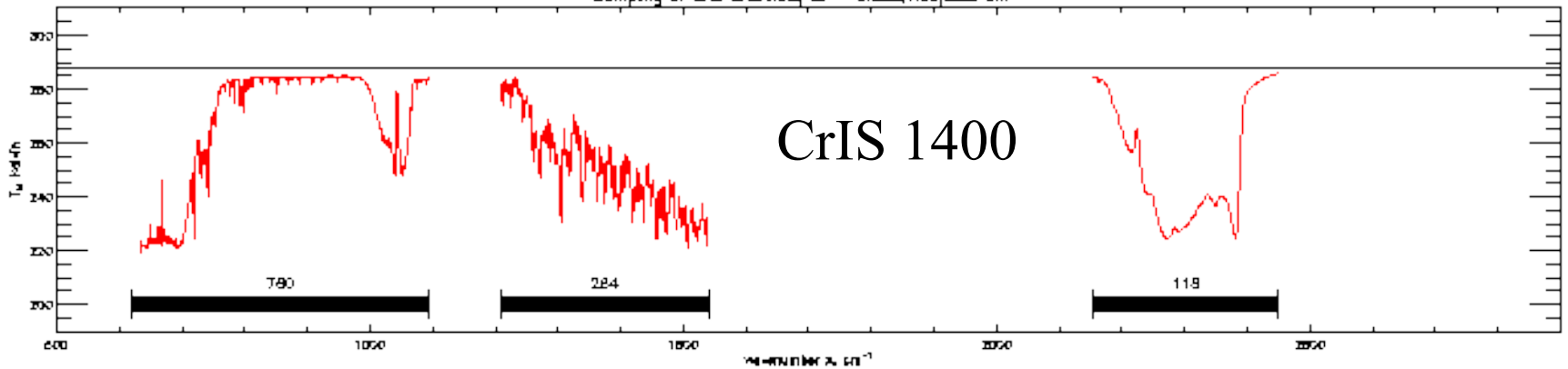
Sampling of AIRS Channels, $\Delta\nu = \nu/2400 \text{ cm}^{-1}$



HIRS Channels, Sampling of IASI Channels, $\Delta\nu = 0.25 \text{ cm}^{-1}$



Sampling of CrIS Channels, $\Delta\nu = 0.625, 1.25, 2.50 \text{ cm}^{-1}$



AIRS IR Specification

Infrared Spectral Coverage:

3.74 μm - 4.61 μm [2674 – 2170 cm^{-1}]

6.20 μm – 8.22 μm [1613 – 1217 cm^{-1}]

8.80 μm – 15.4 μm [1136 – 649 cm^{-1}]

Spectral Resolution: $\lambda/\Delta\lambda=1200$

Spatial Coverage:

$\pm 49.5^\circ$ around nadir

1.1° (~13.5 km dia) IFOV (Instantaneous Field of View)

Sensitivity (NEDT):

0.14 K at 4.2 μm

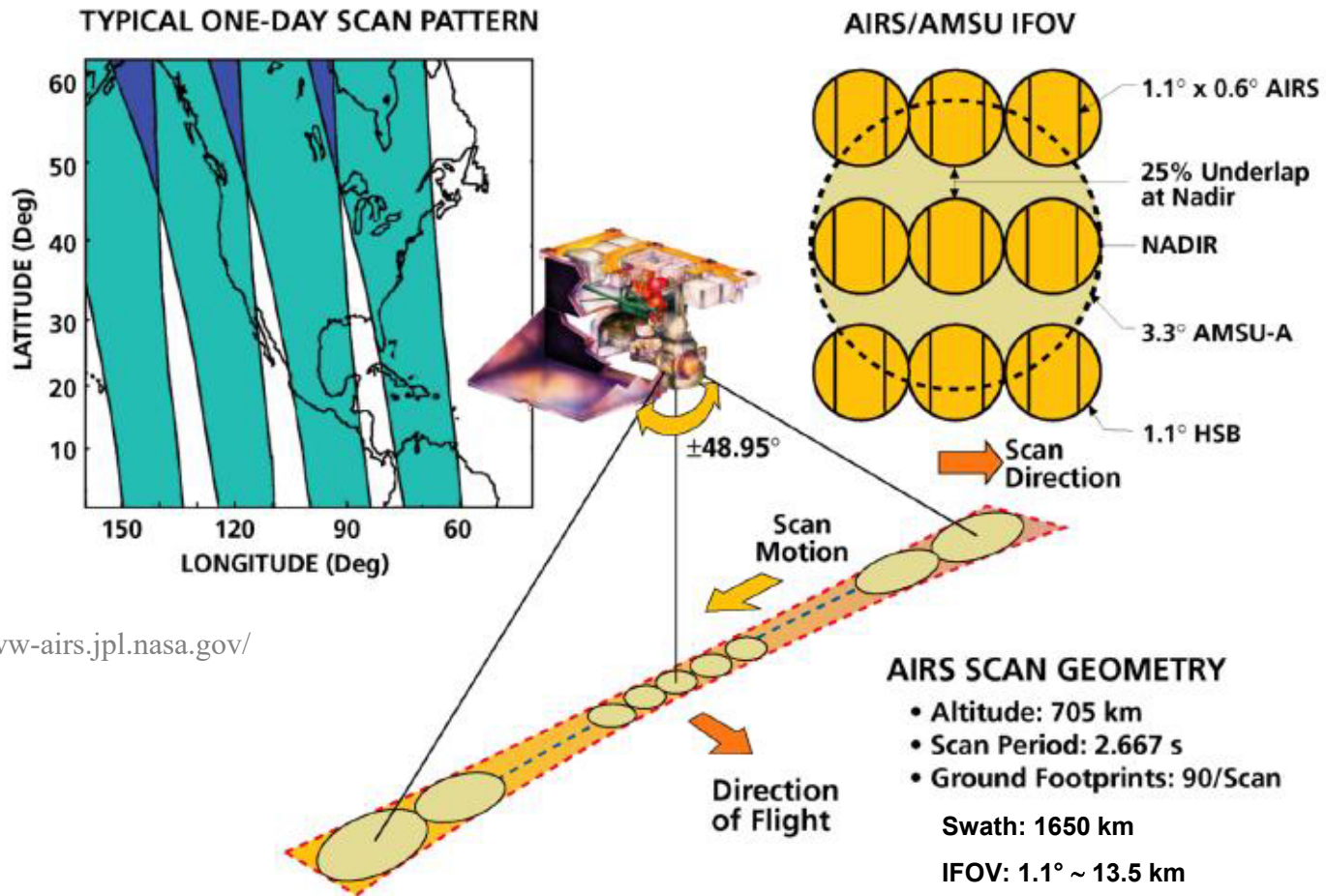
0.20 K from 3.7 to 13.6 μm

0.35 K from 13.6 to 15.4 μm

Power / Mass: 256 W / 166 kg

Lifetime: 5 years

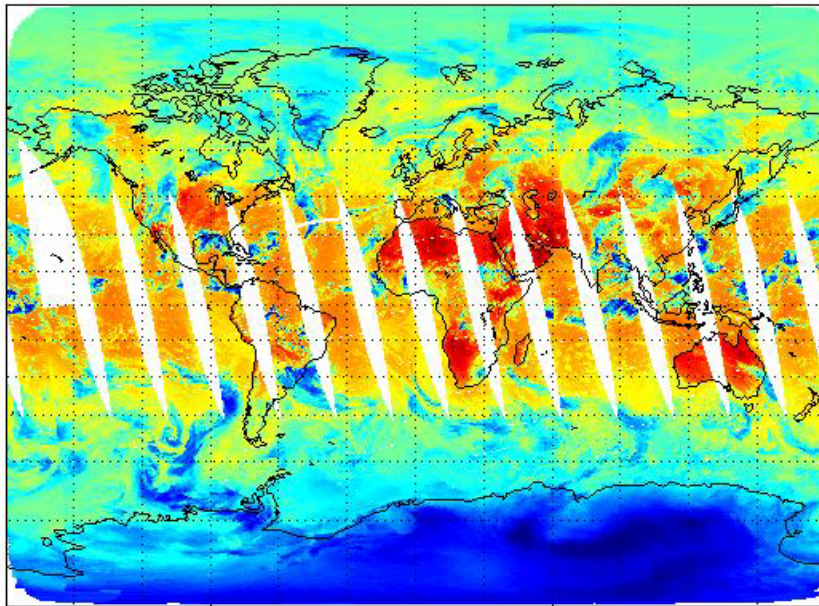
AIRS Spatial Coverage (1)



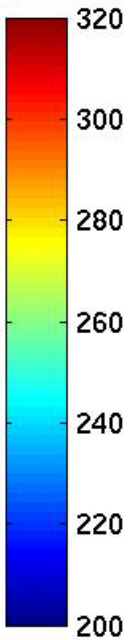
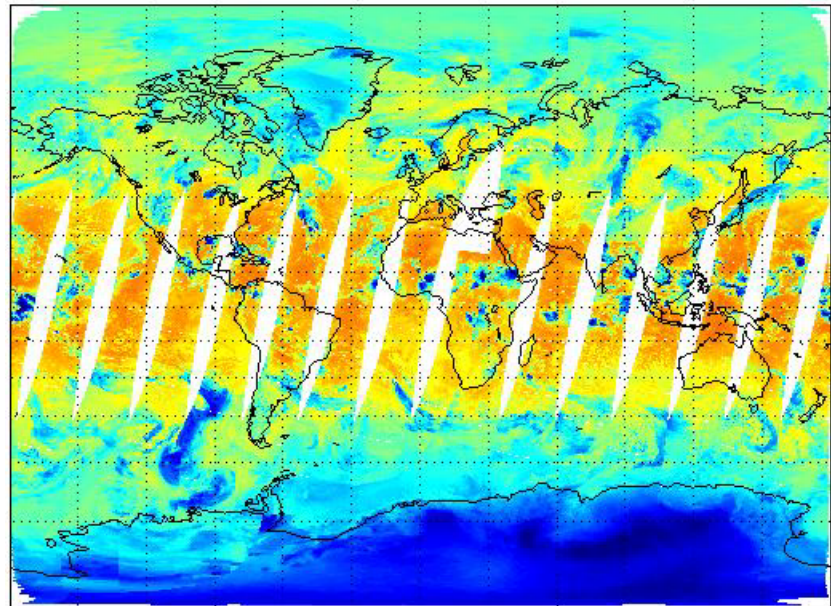
<http://www-air.jpl.nasa.gov/>

AIRS Spatial Coverage (3)

6-Sept-2002, Brightness Temperature [K] at 1000 cm^{-1}
Ascending Granules

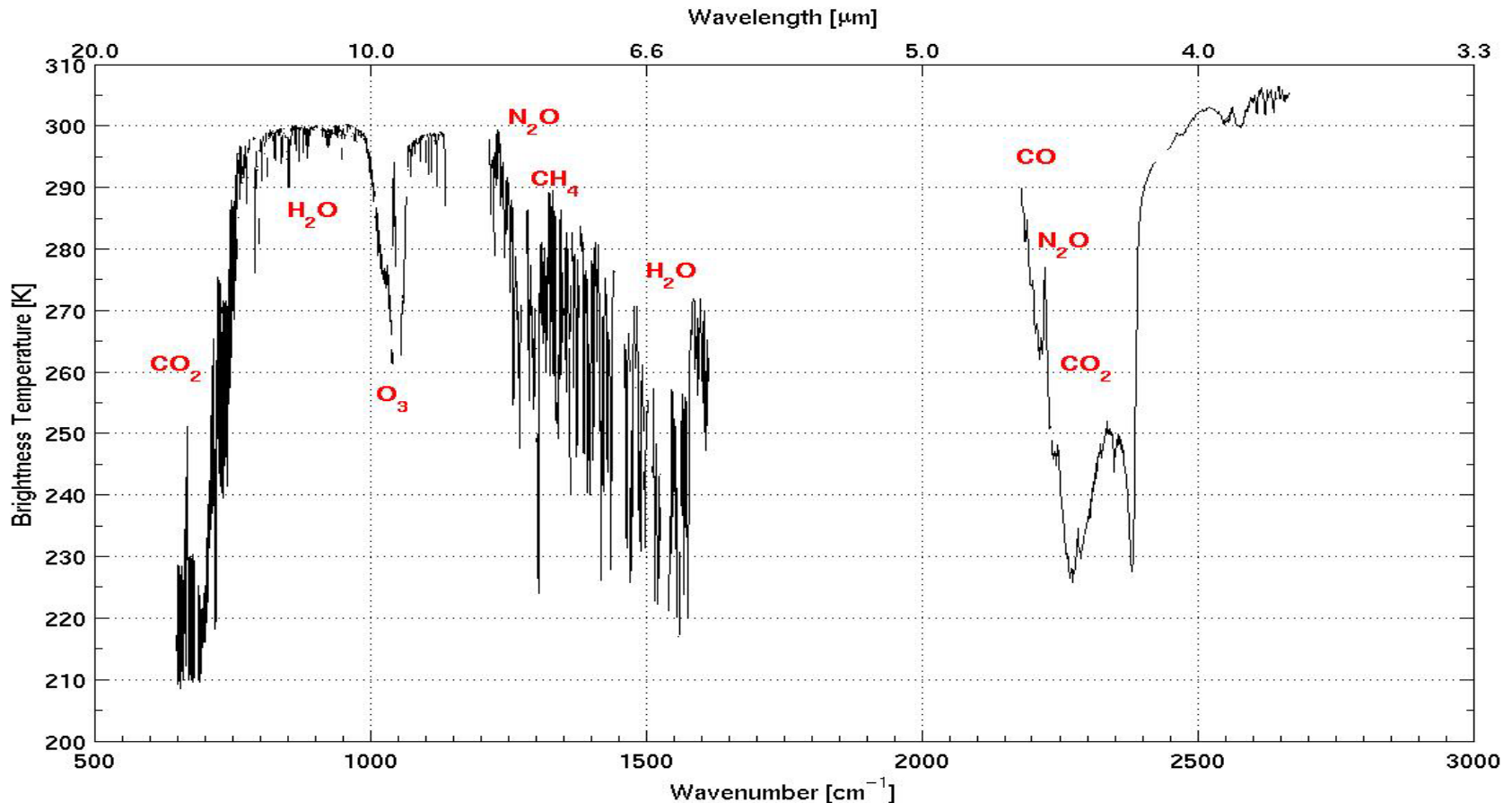


Descending Granules

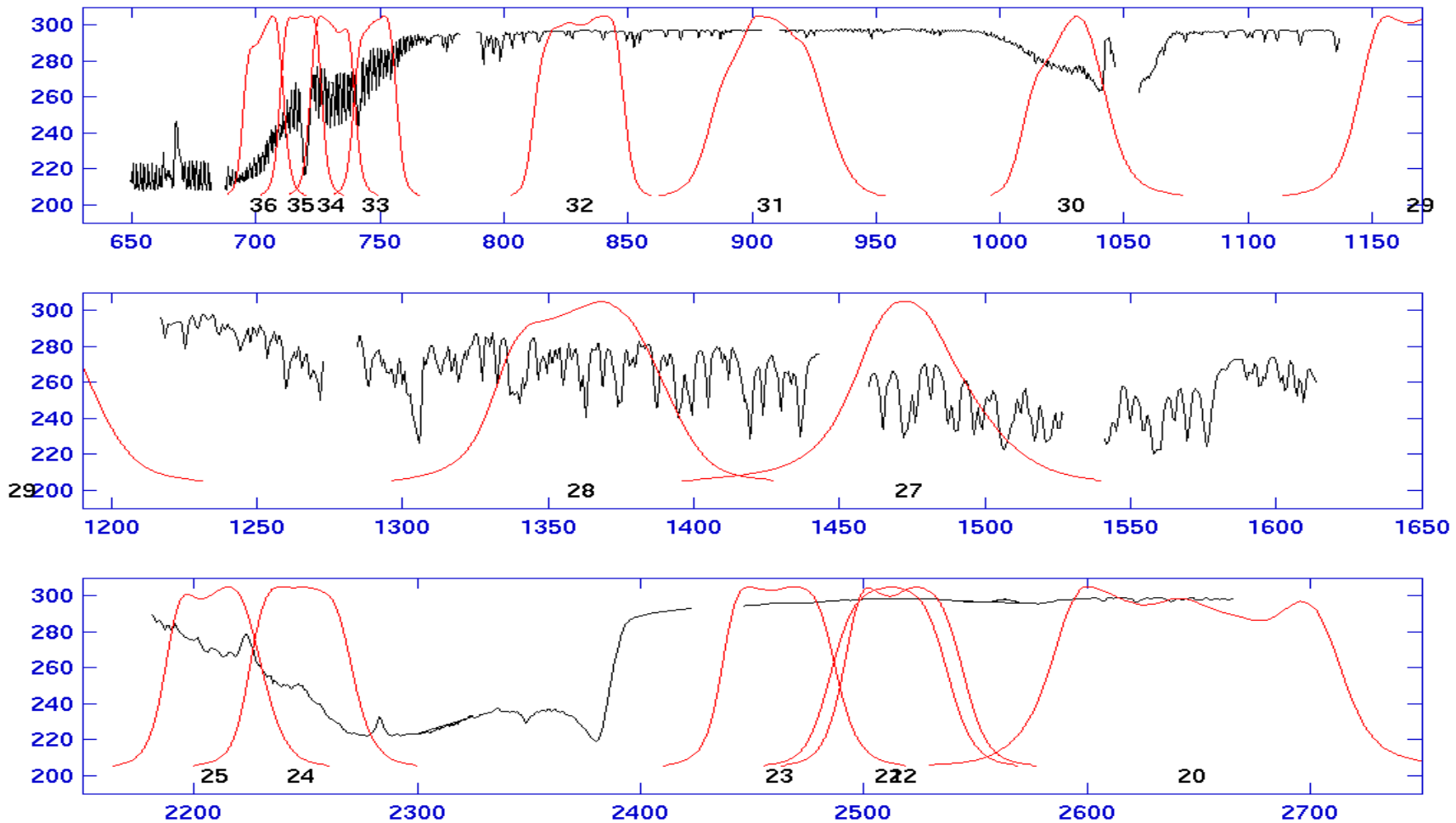


AIRS Spectral Coverage

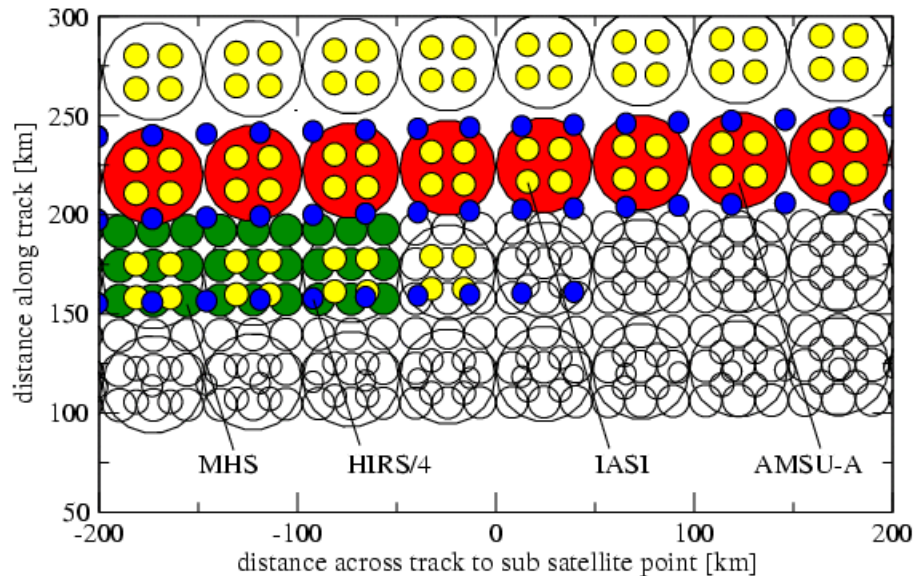
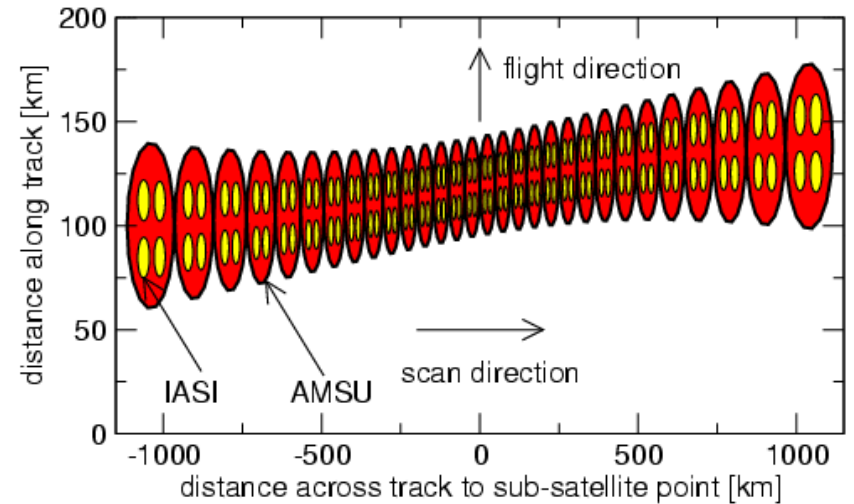
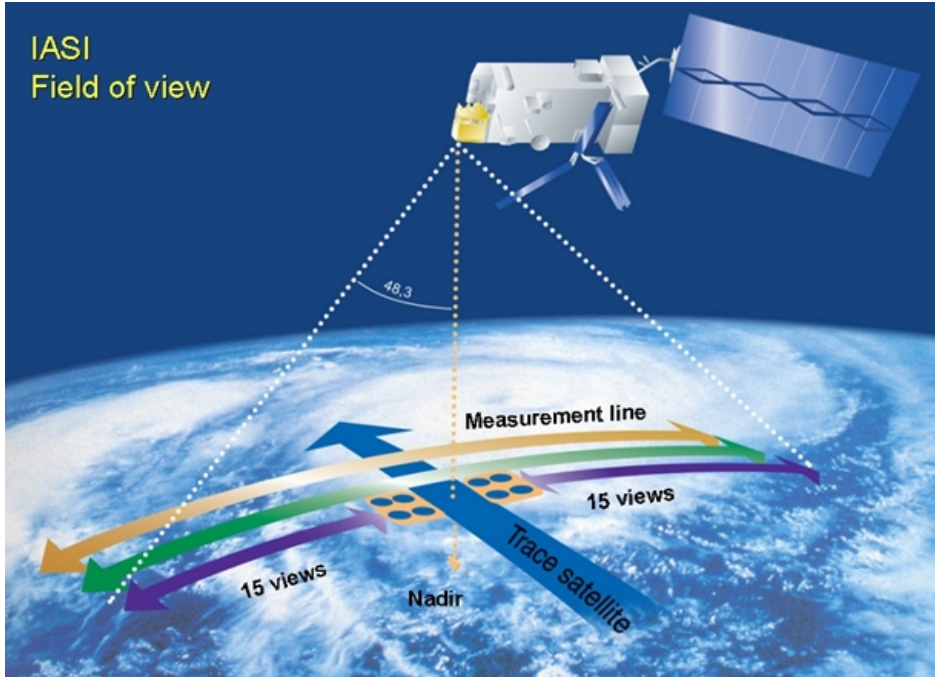
- IR sounder: 2378 channels
- spectral ranges: 3.7 - 4.61 μm , 6.2 - 8.22 μm , 8.8 - 15.4 μm ;



AIRS (Atmospheric Infrared Sounder) & MODIS



IASI Scan Characteristics



EVOF consists of 2x2 matrix of IFOV

30 EFOV per scan line

IFOV size at nadir: 12 km

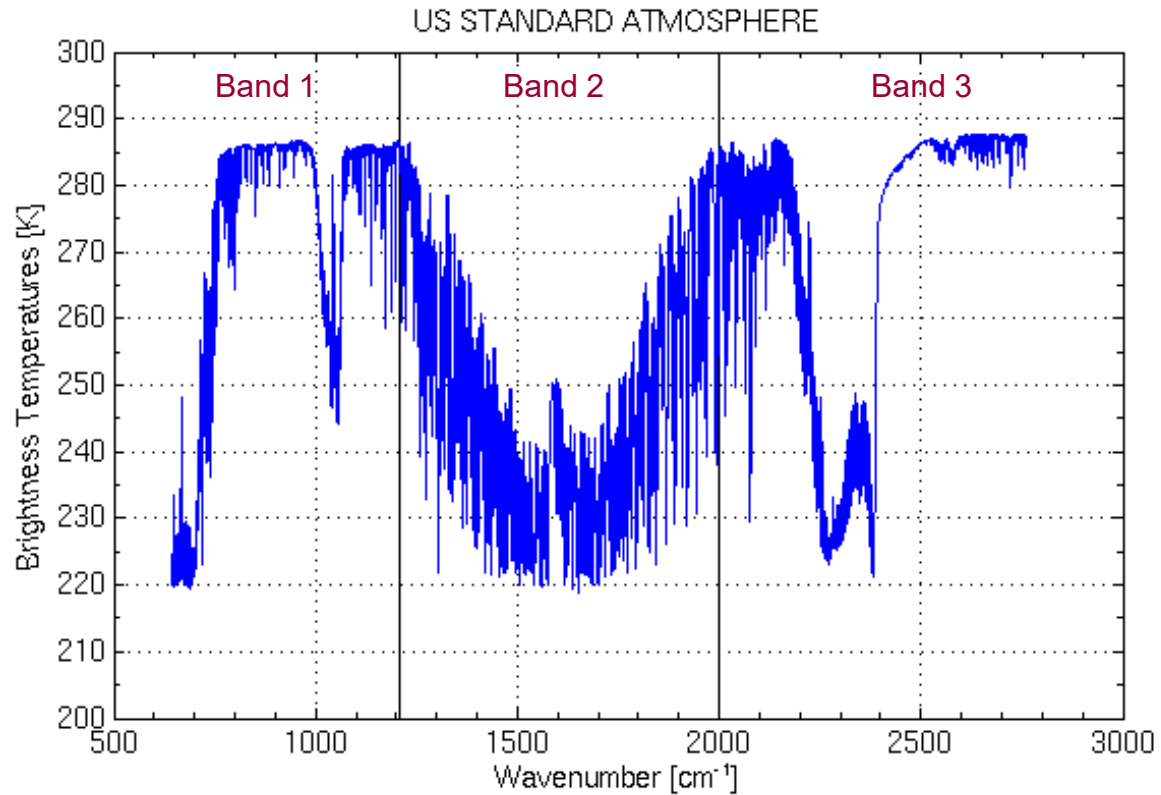
IFOV at edge across/along track: 39/20 km

Swath: ± 48.333 deg

Swath width: ± 1100 km

Mean Altitude approx 817 km

IASI Spectral Characteristics



Band	Wavenumbers cm ⁻¹	Wavelength (μm)
1	645.0 - 1210.0	8.26 - 15.5
2	1210.0 - 2000.0	5.0 - 8.26
3	2000.0 - 2760.0	3.62 - 5.0

Various Infrared spectral resolutions

Standard Atmosphere:

0.2 cm^{-1} (IASI & NAST-I-like)

0.6 cm^{-1} (AIRS & CrIS-like)

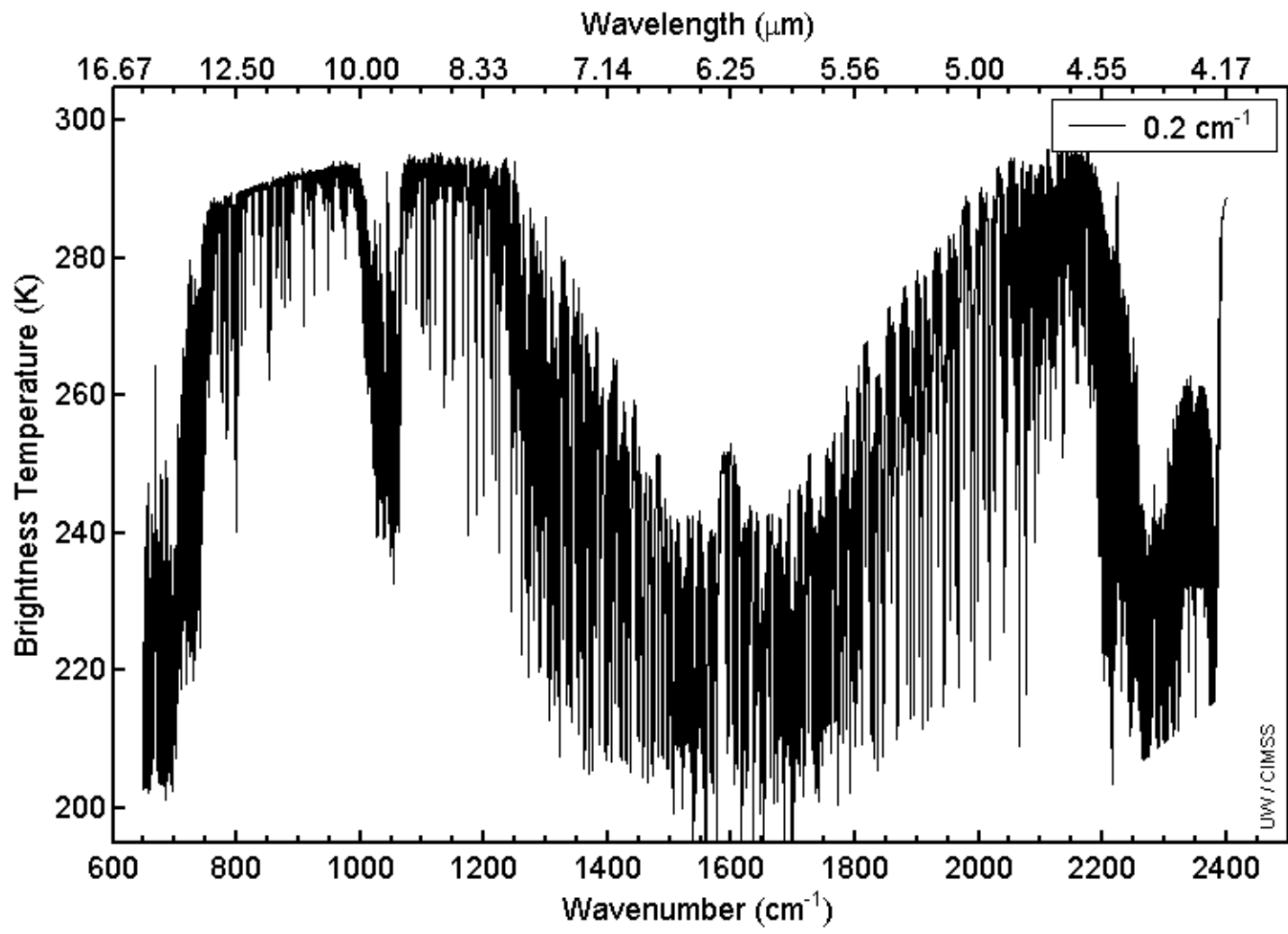
1.2 cm^{-1} (CrIS-like)

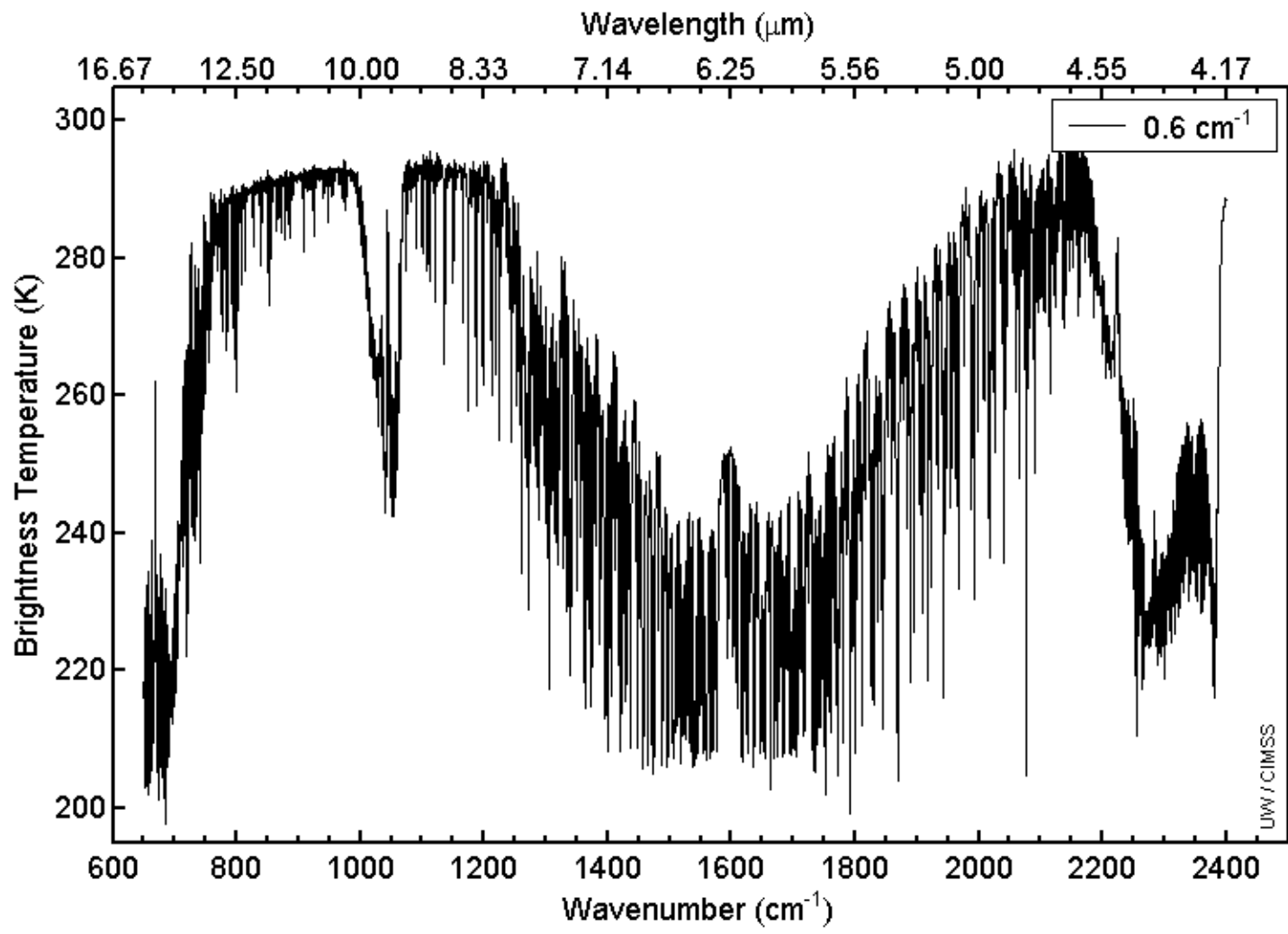
4.8 cm^{-1}

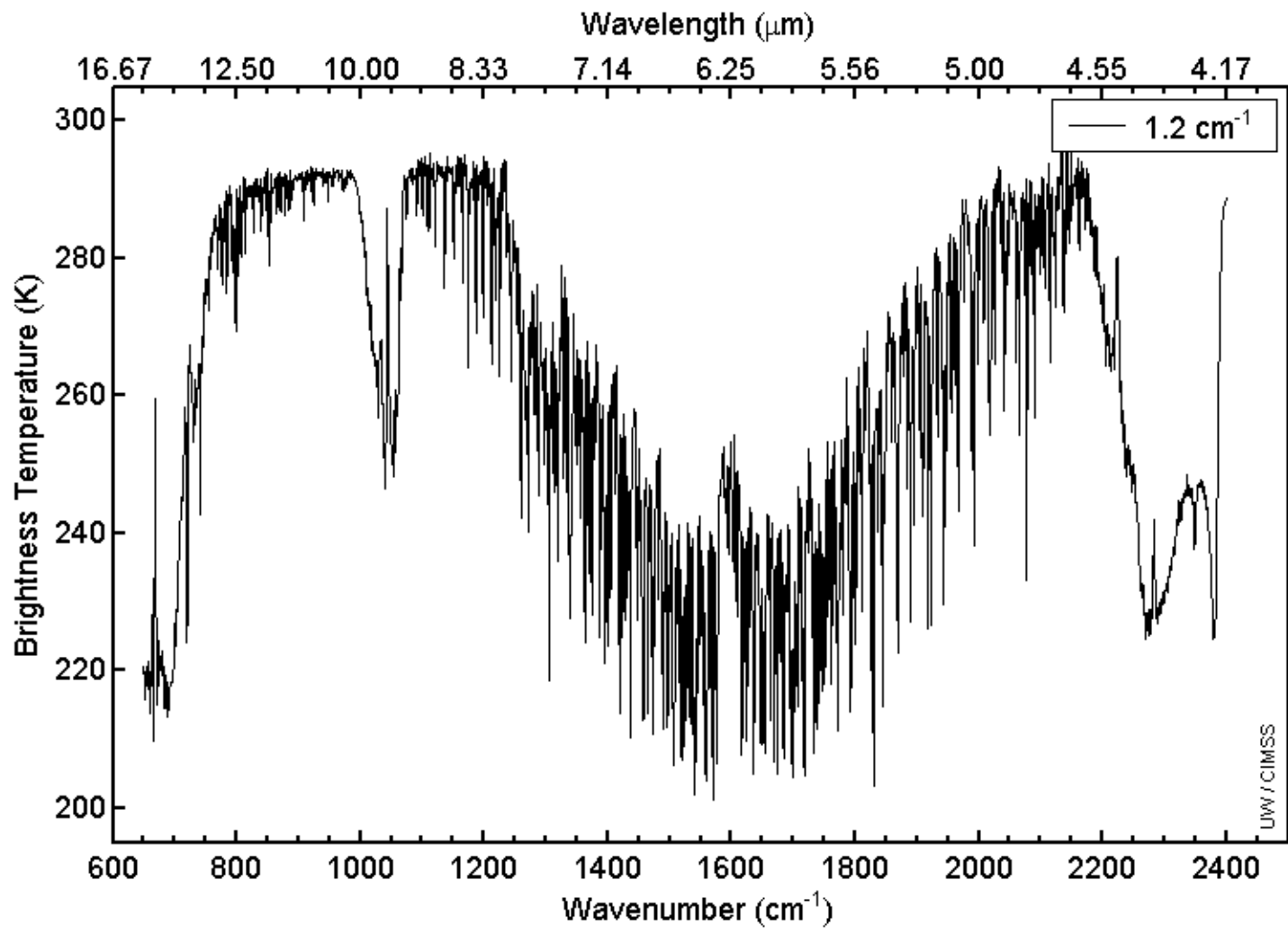
19.2 cm^{-1} (current sounder-like)

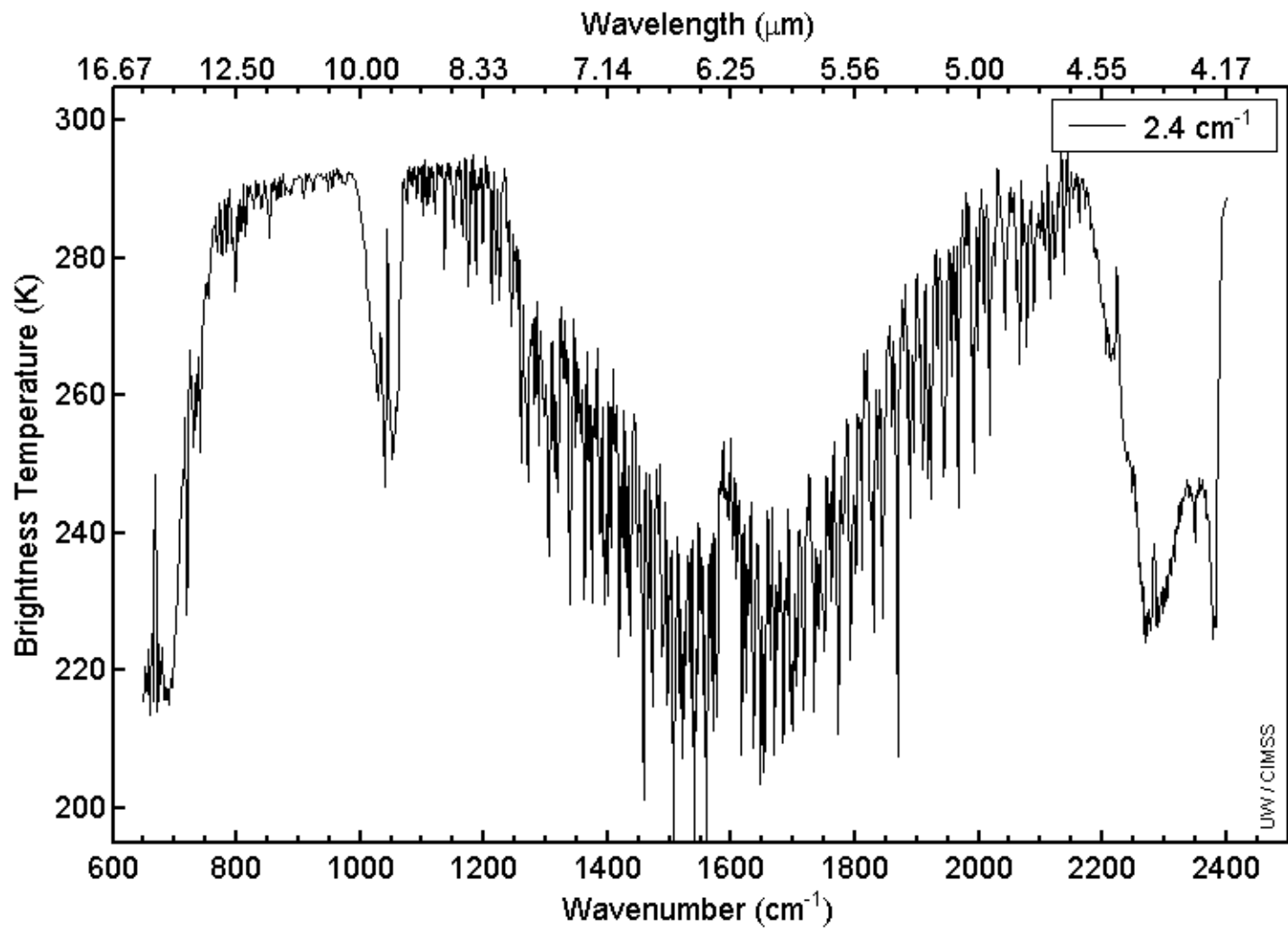
38.4 cm^{-1} (imager-like)

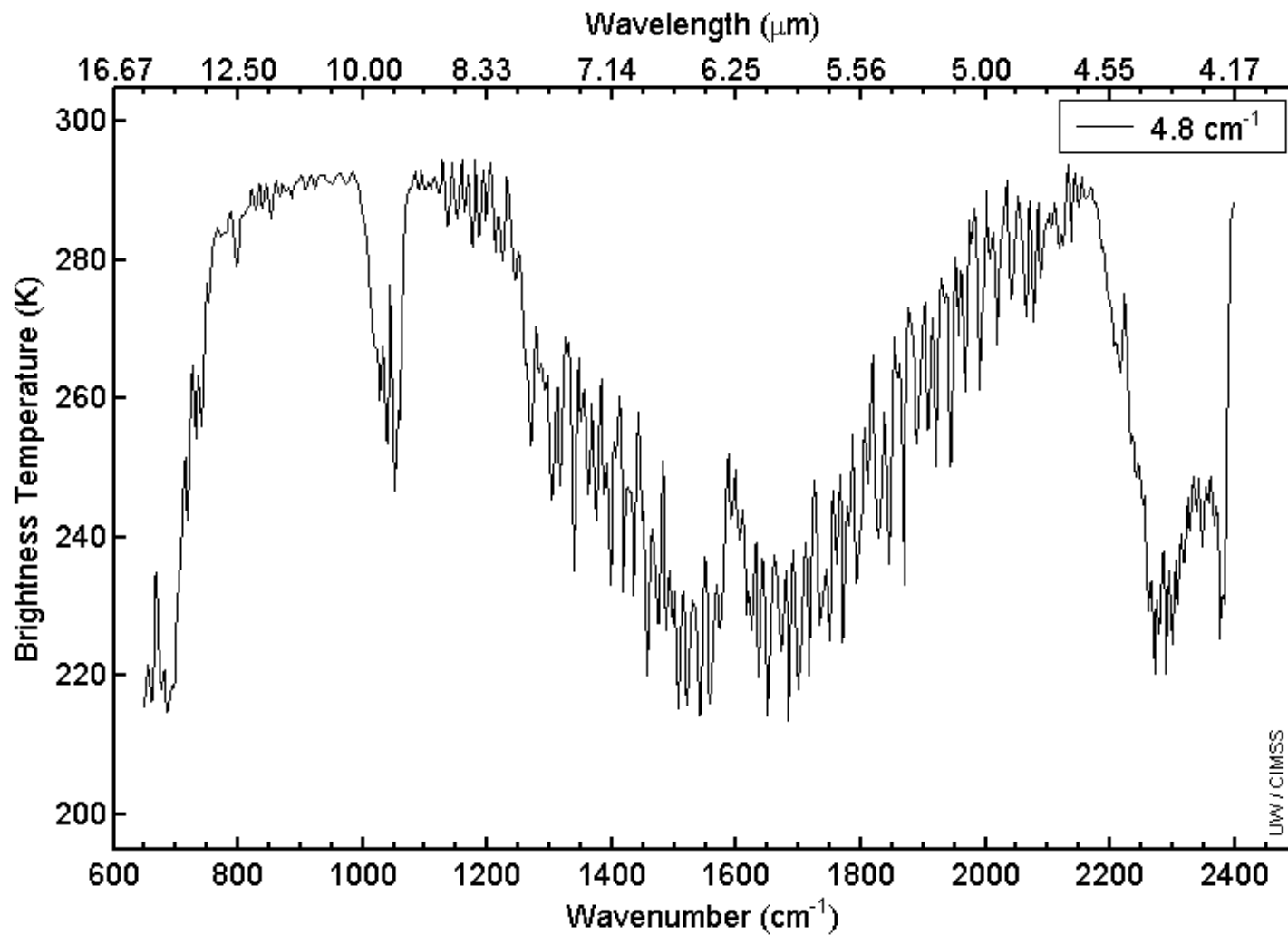
Jun Li, Mat Gunshor and Tim Schmit



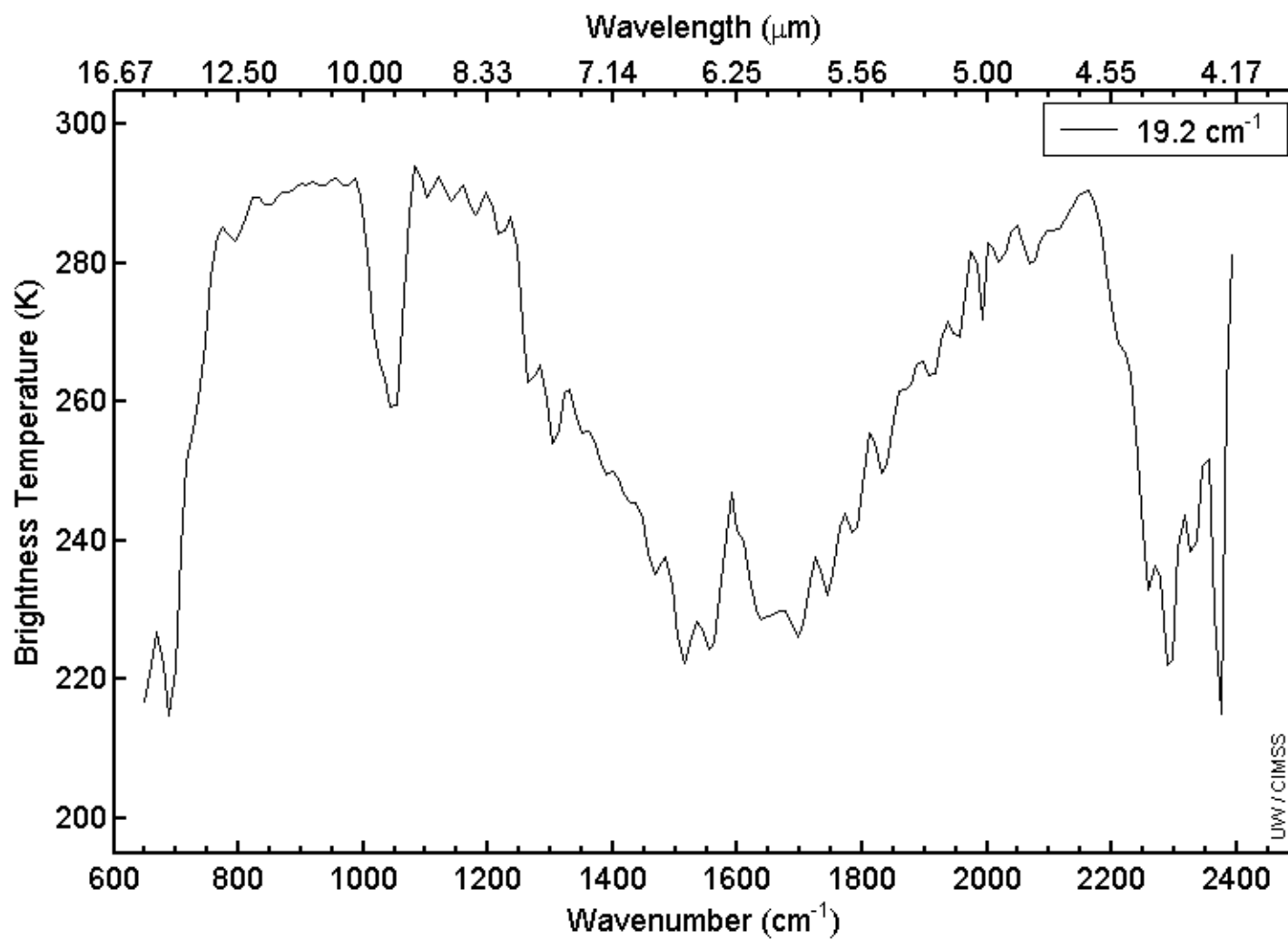


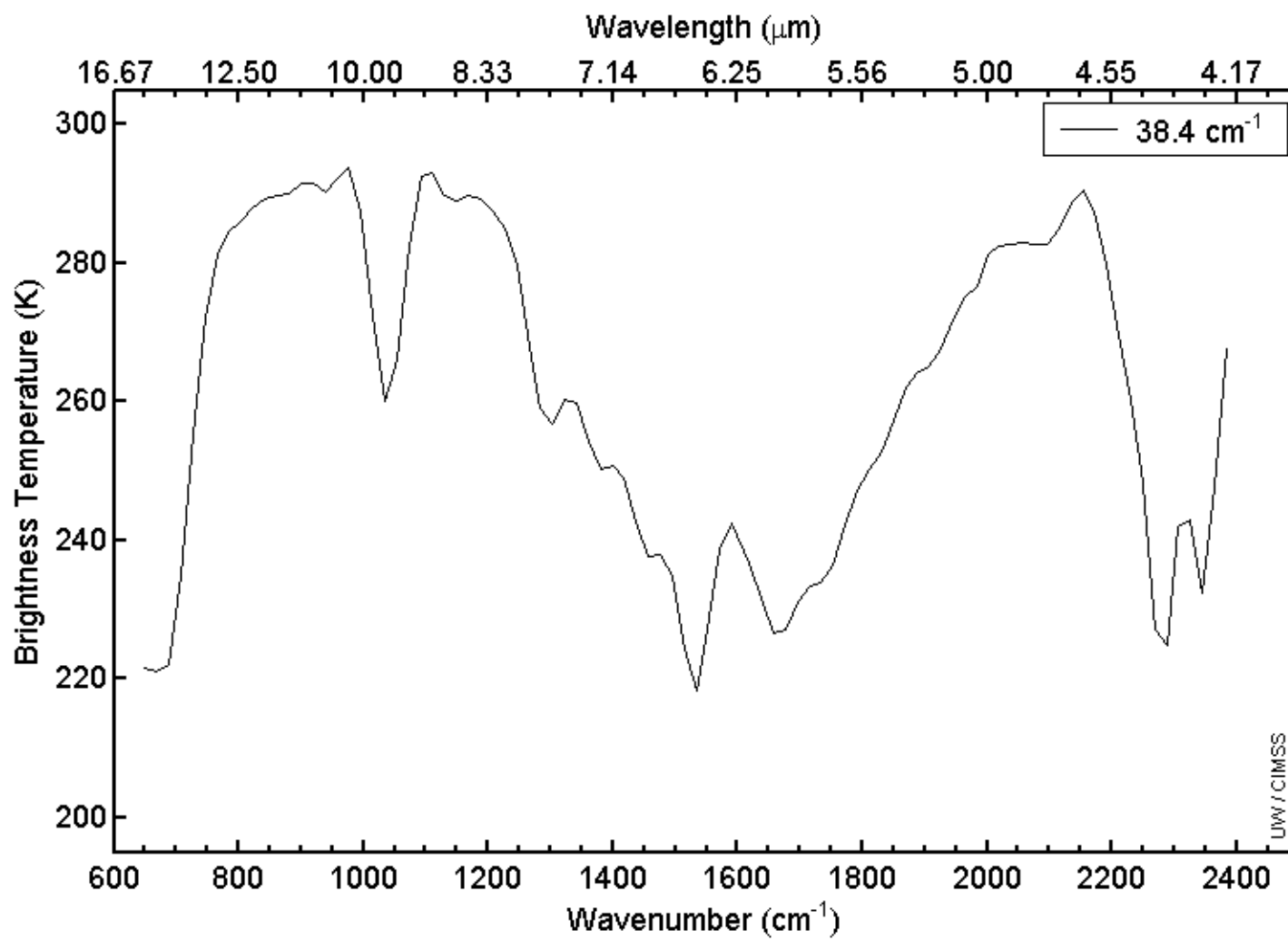


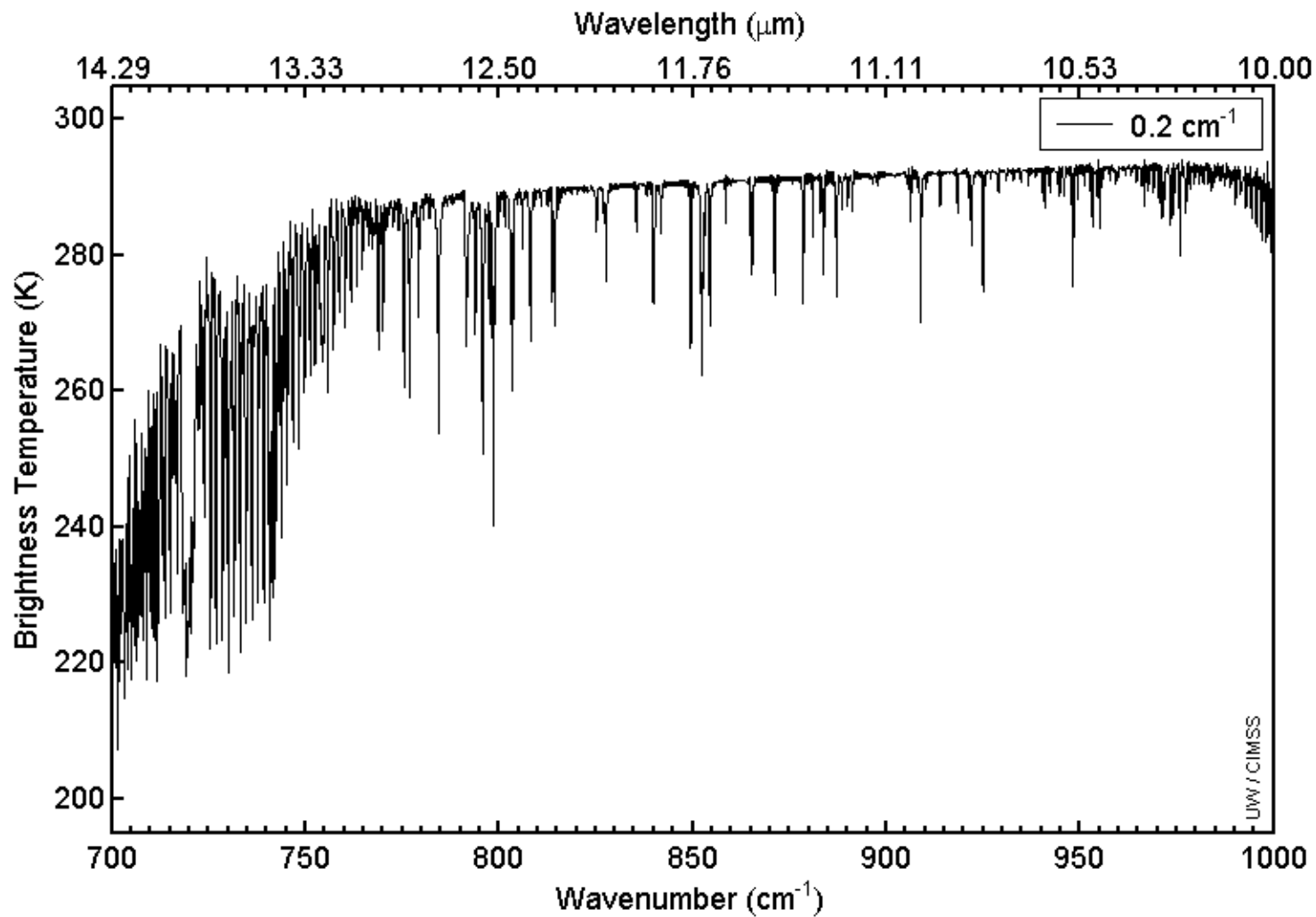




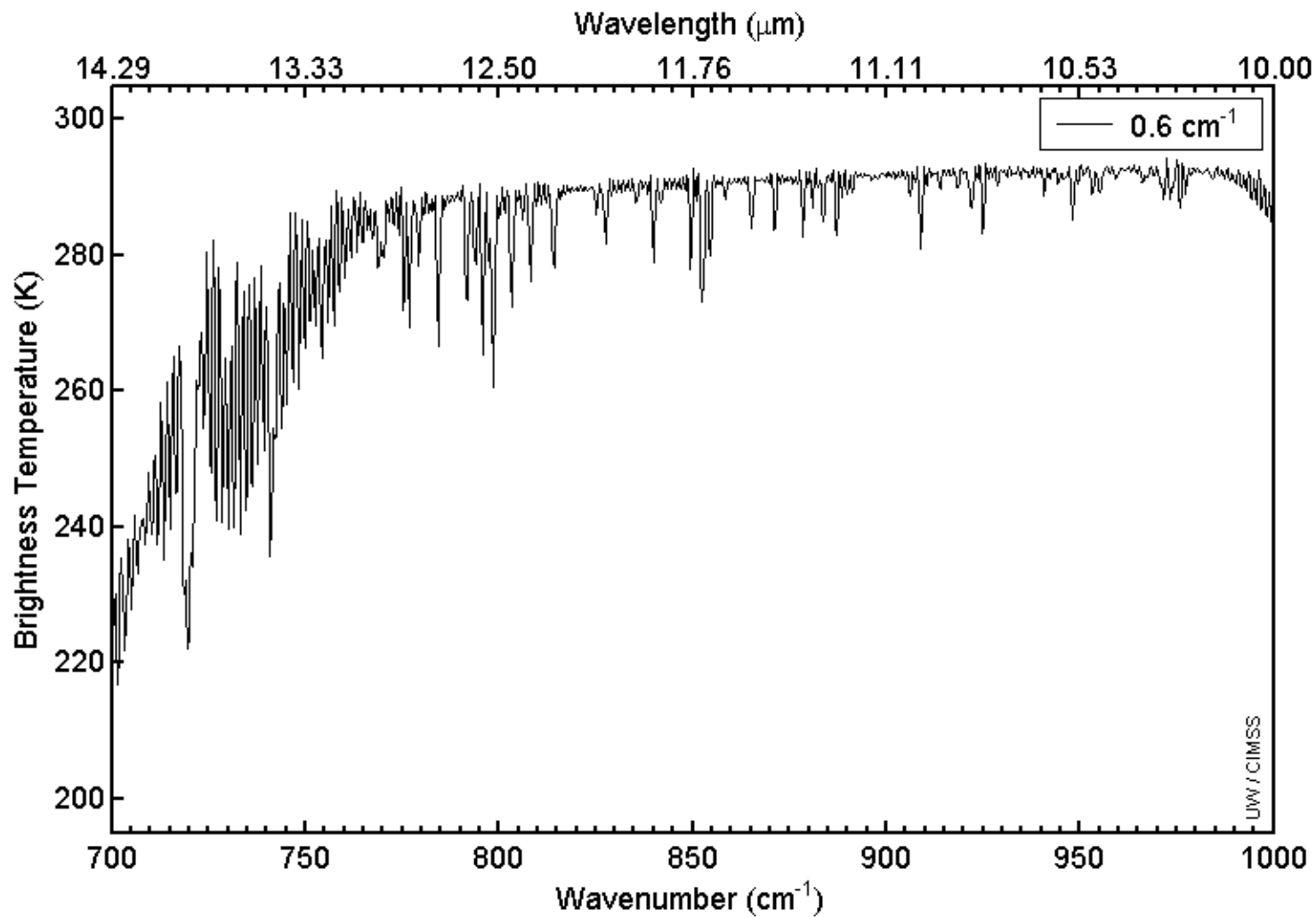
LW/CIMSS



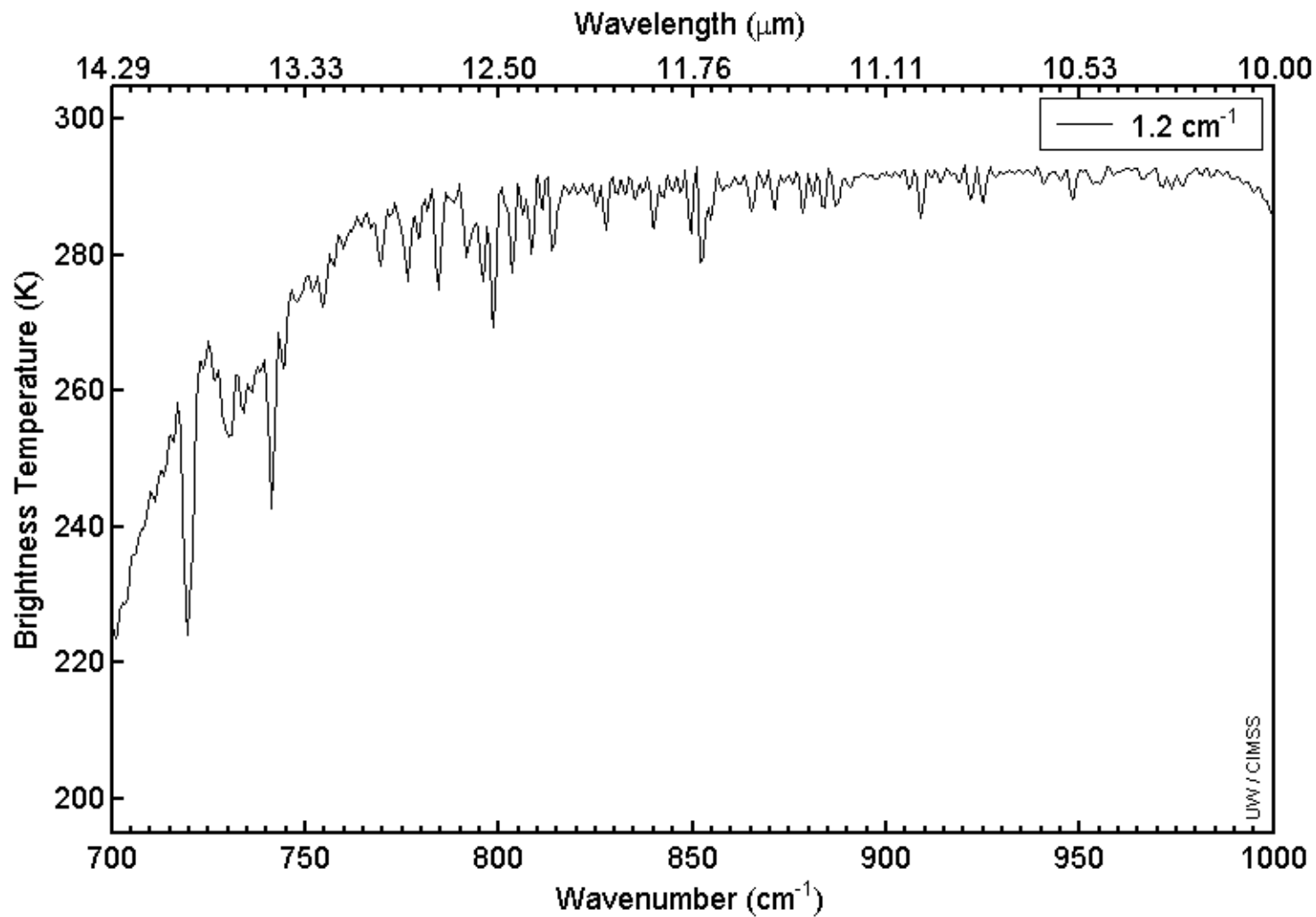




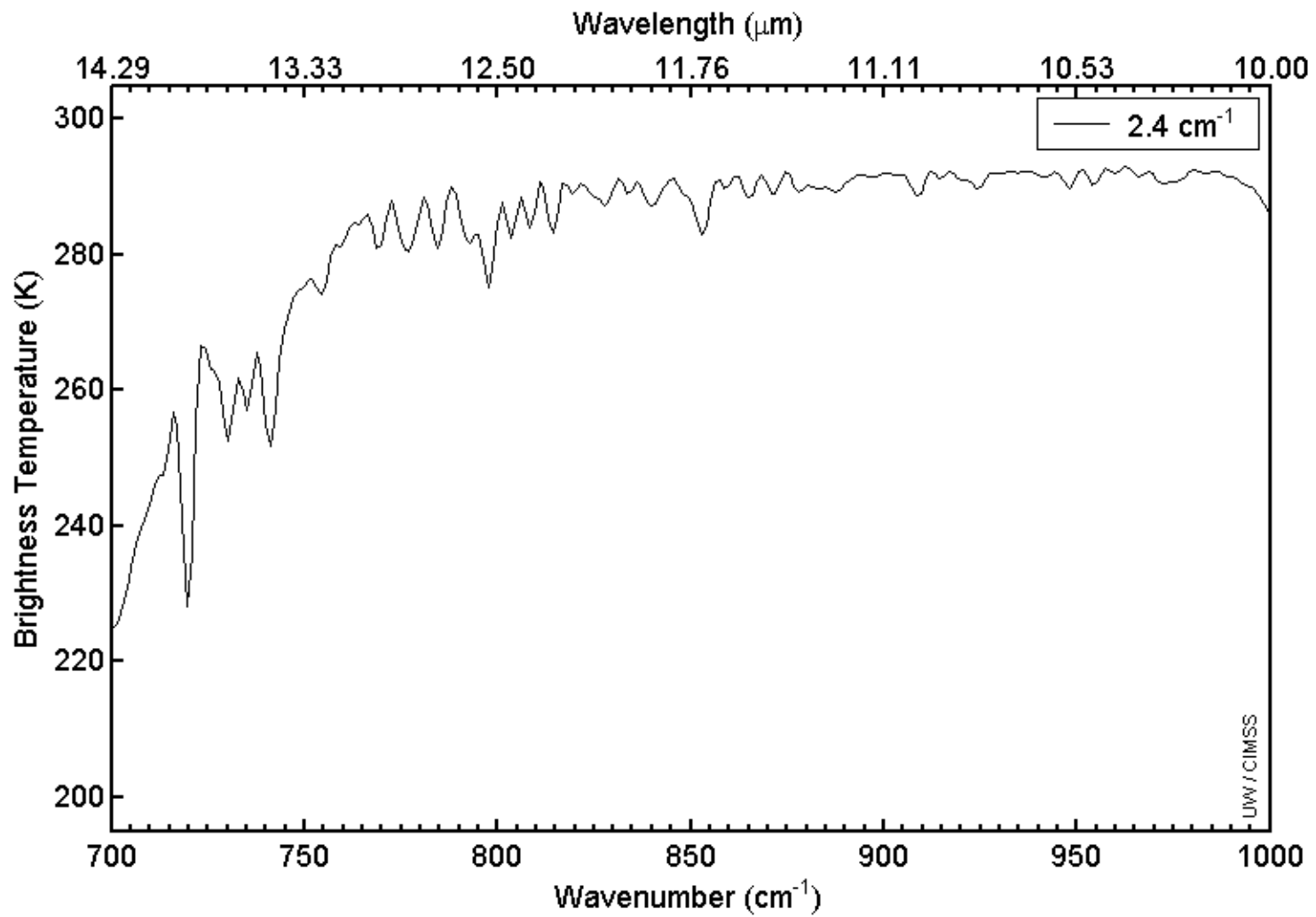
Longwave window region



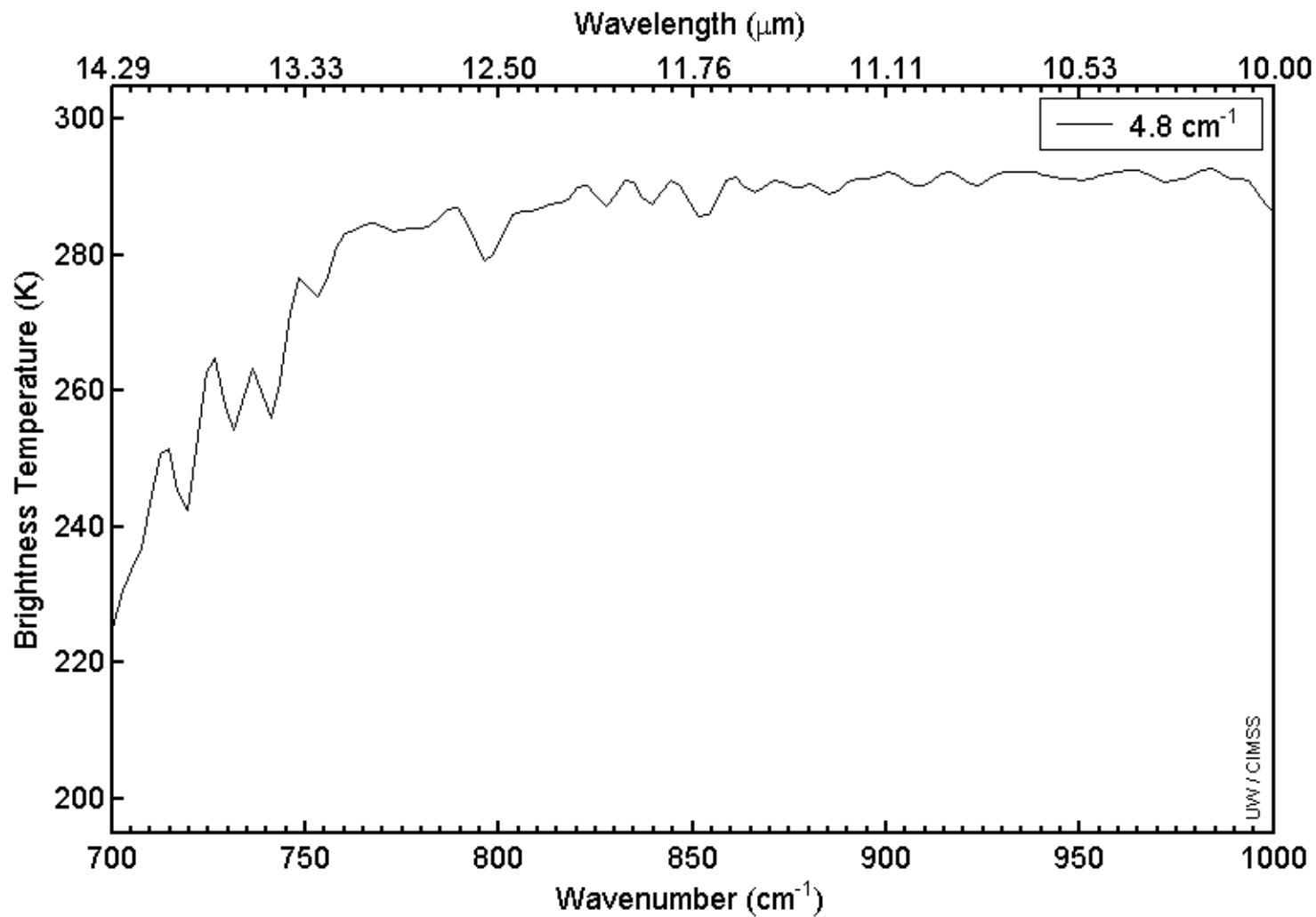
Longwave window region



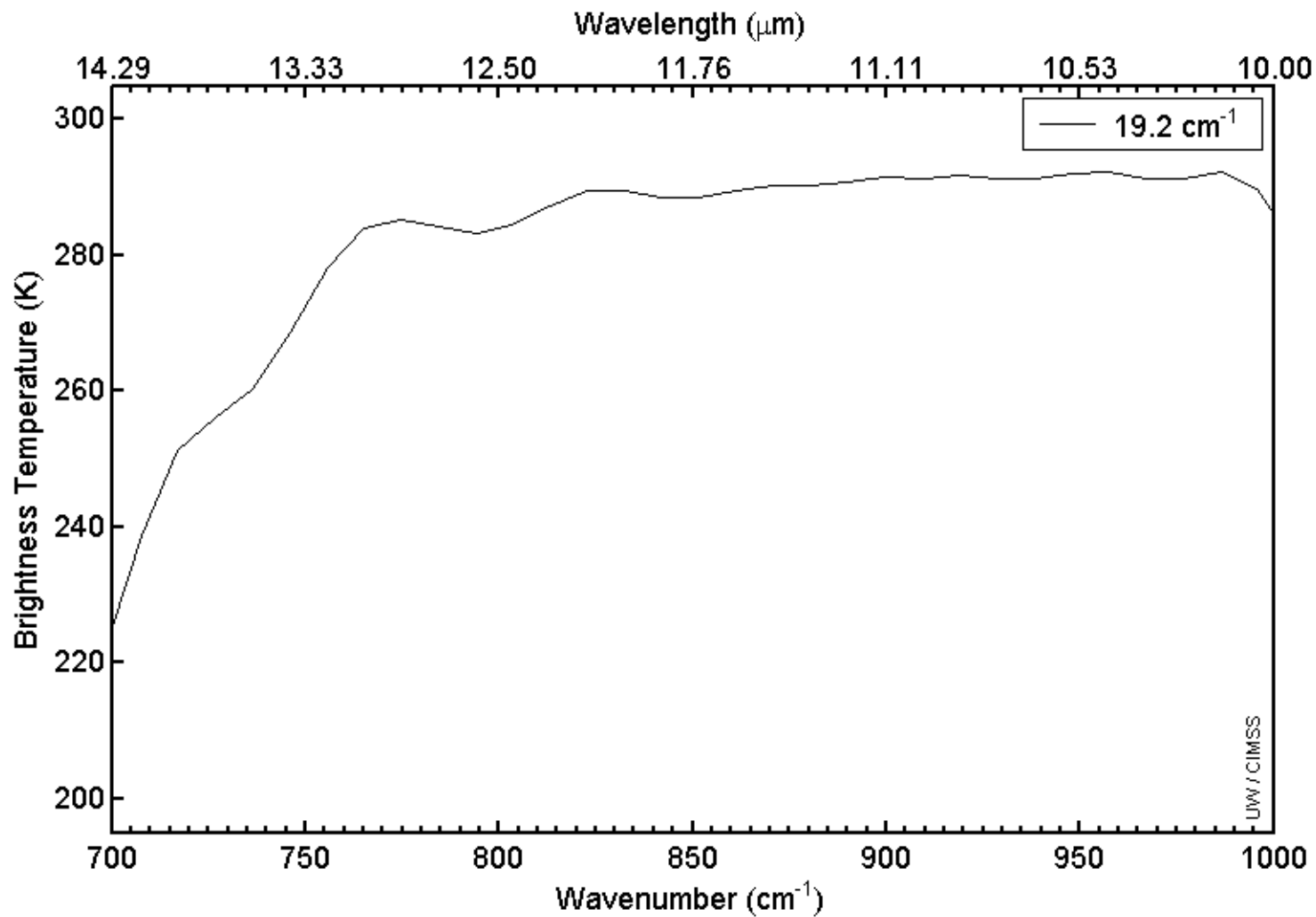
Longwave window region



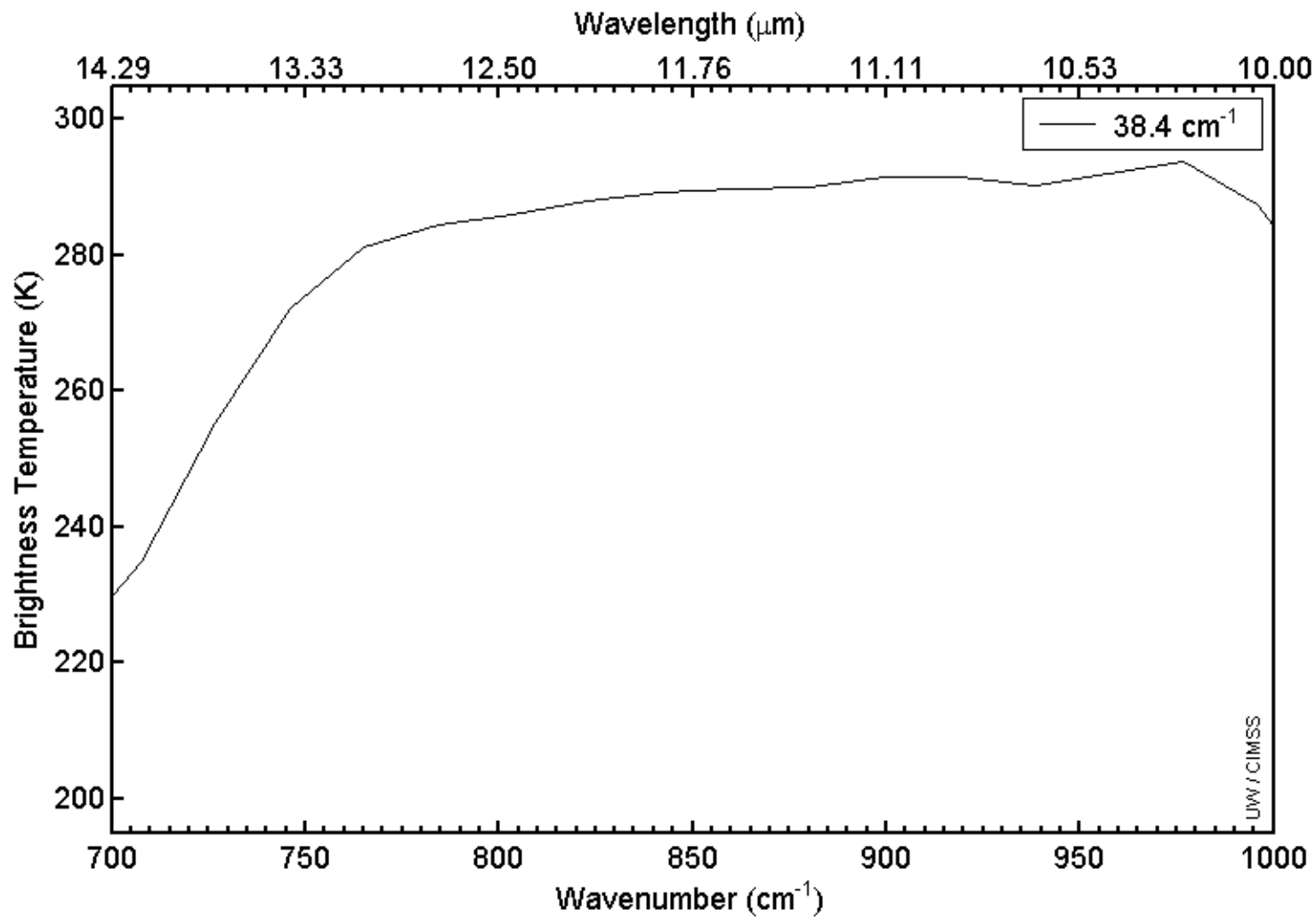
Longwave window region



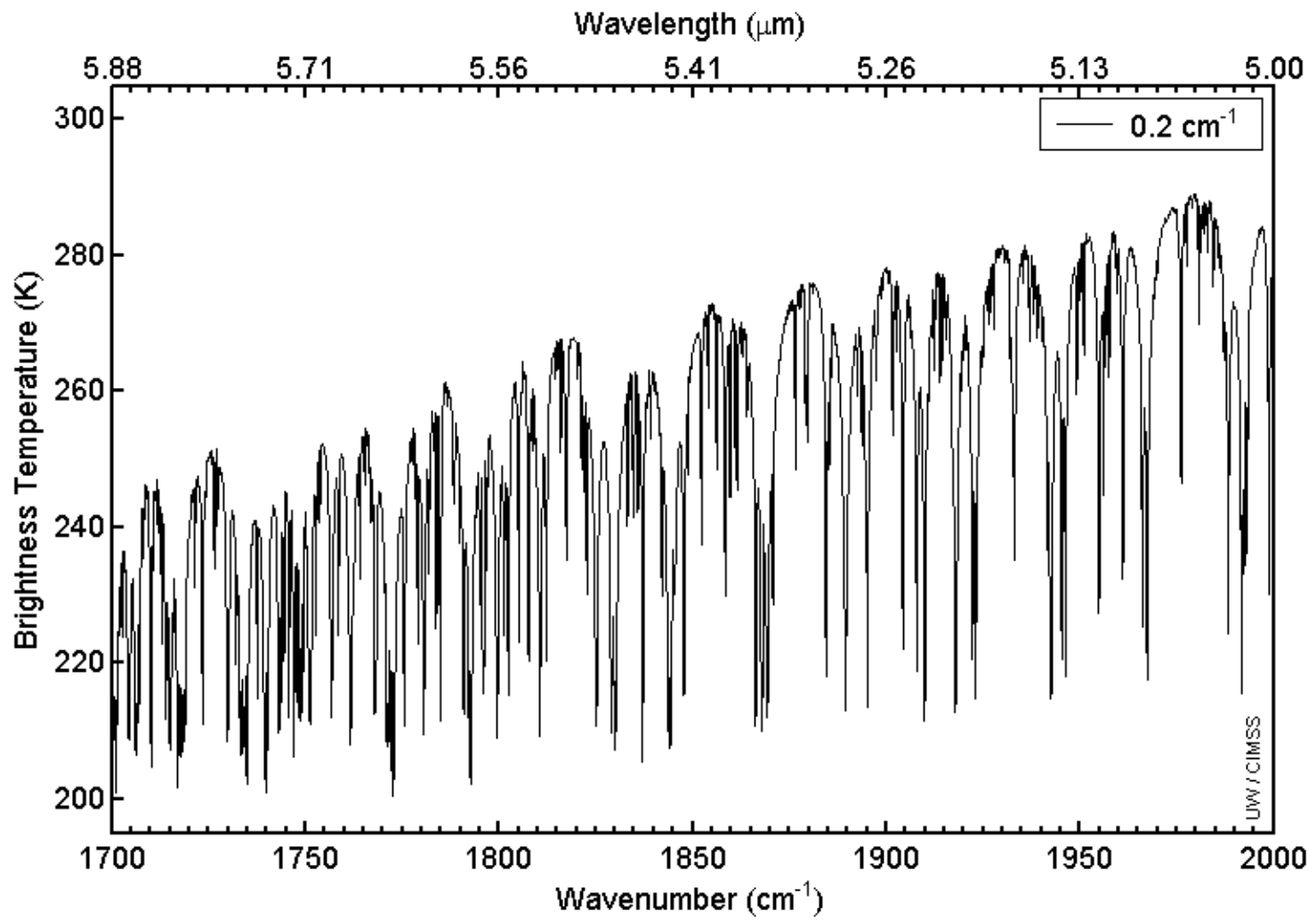
Longwave window region



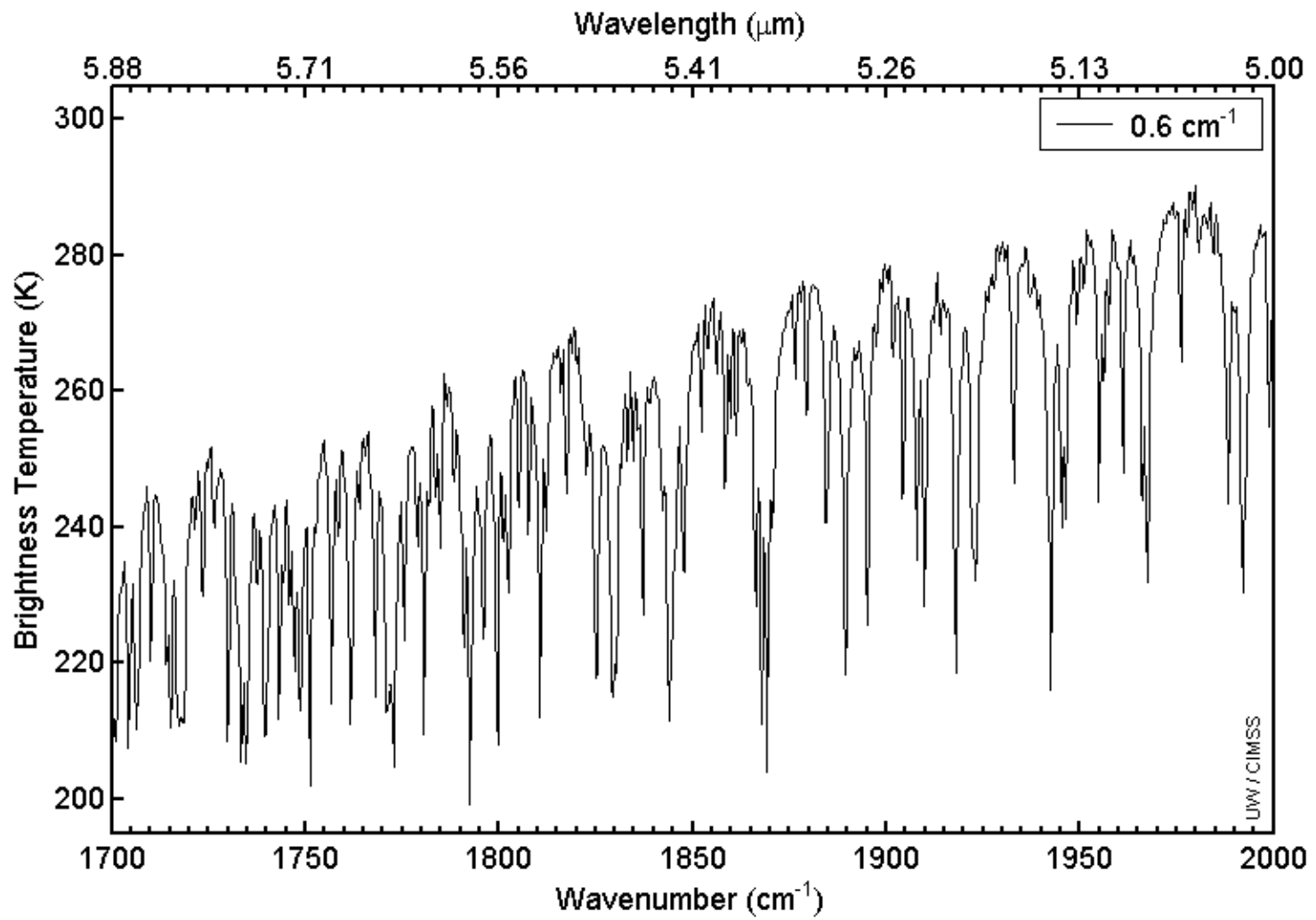
Longwave window region



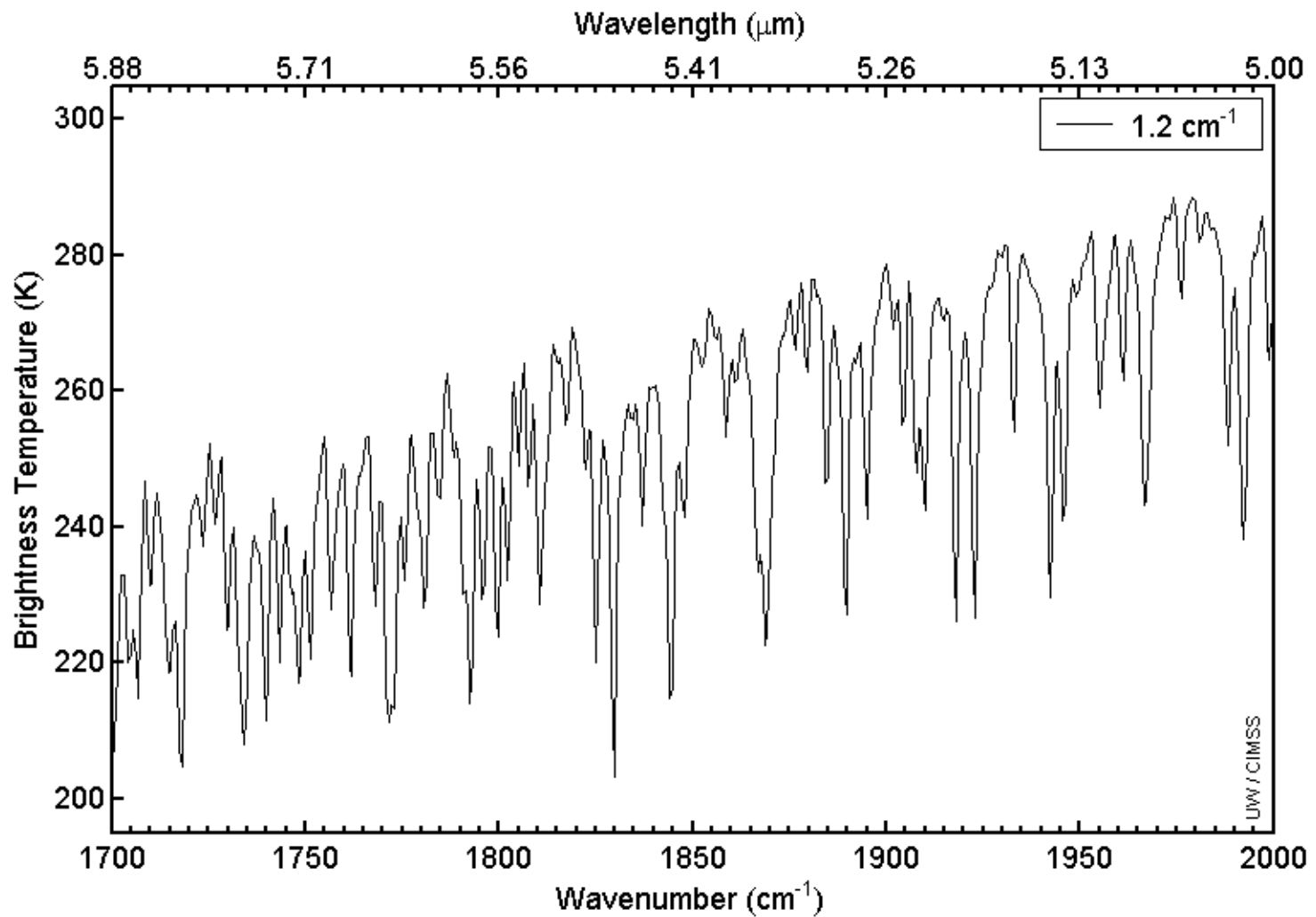
Longwave window region



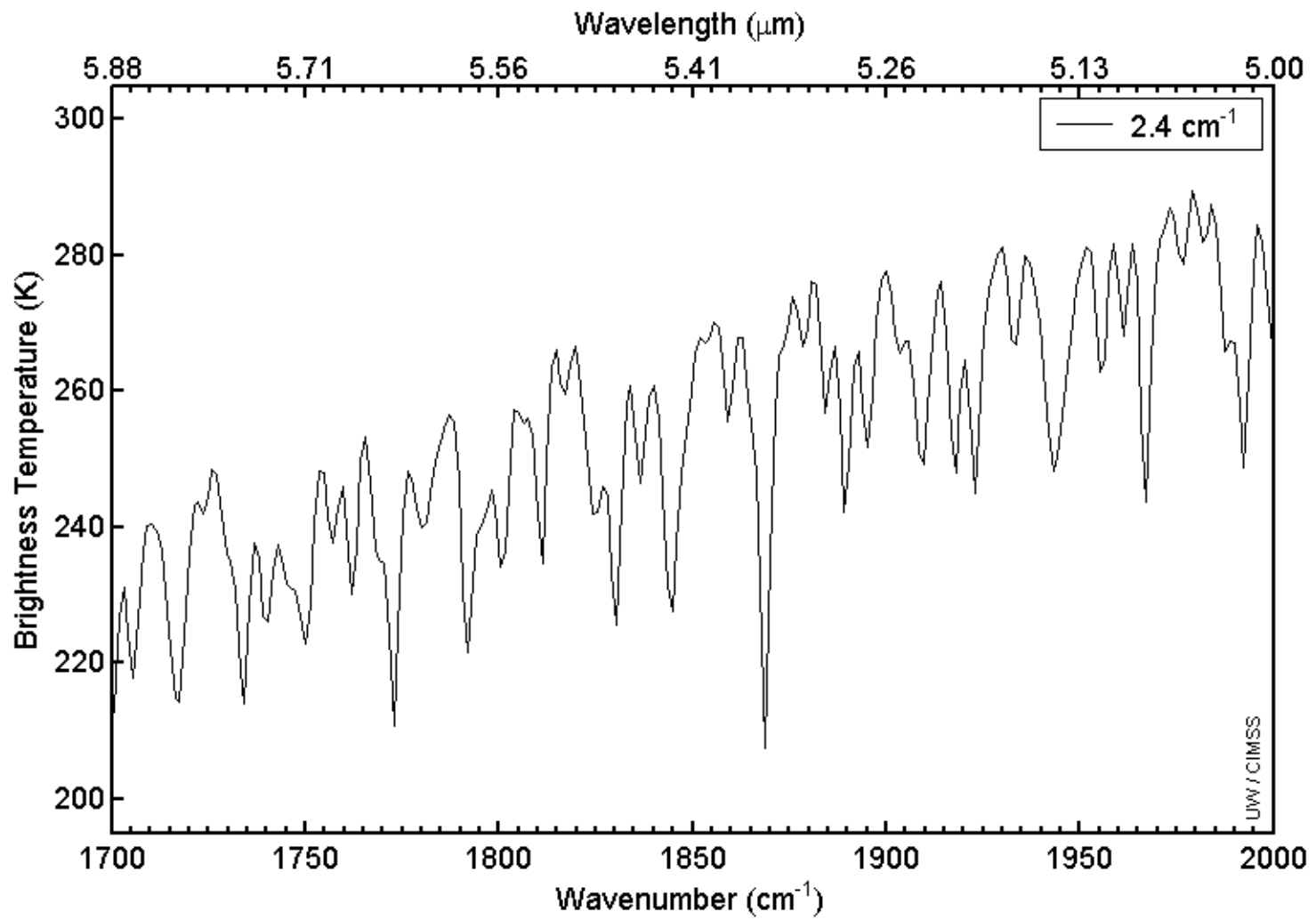
Water vapor region



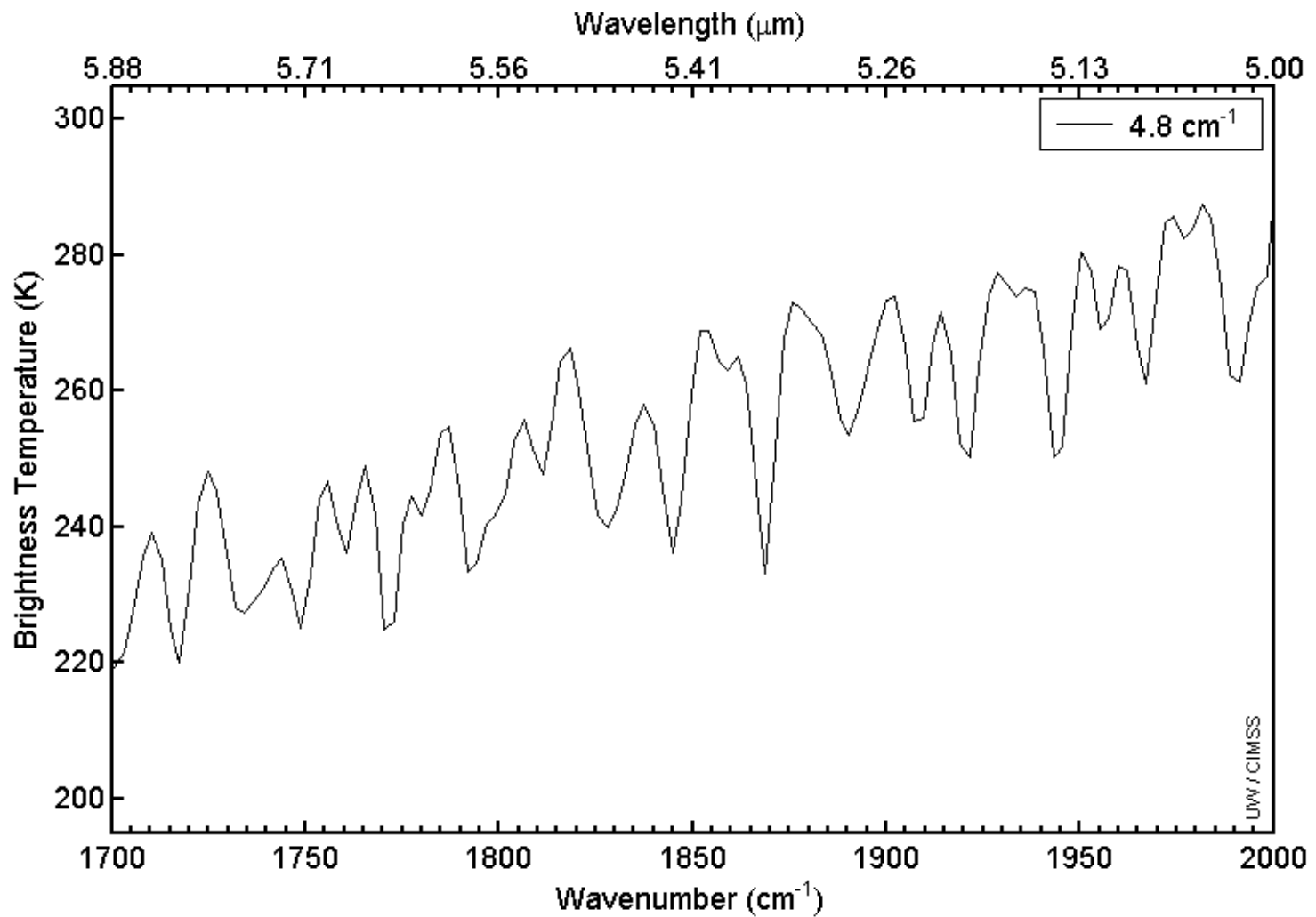
Water vapor region



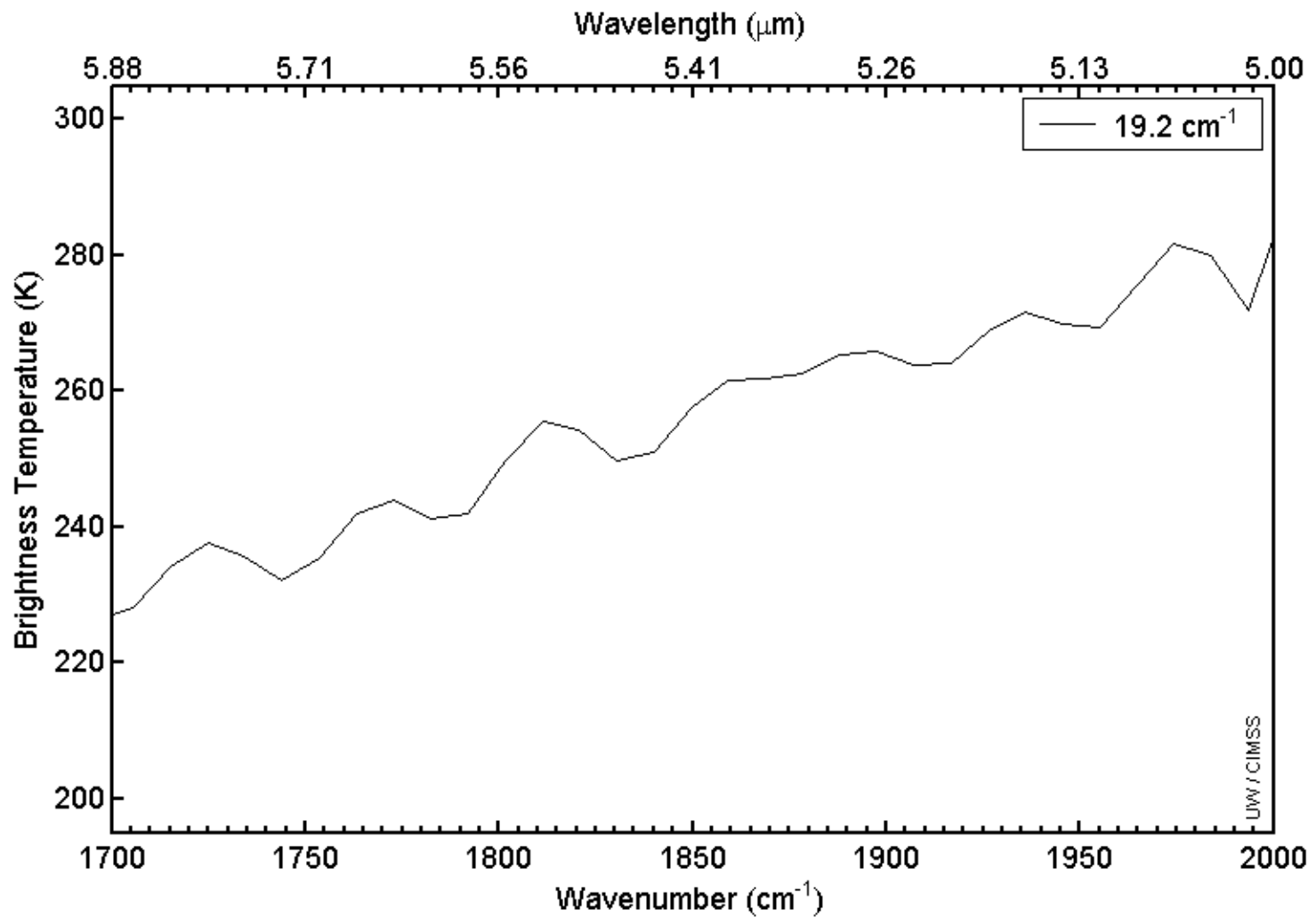
Water vapor region



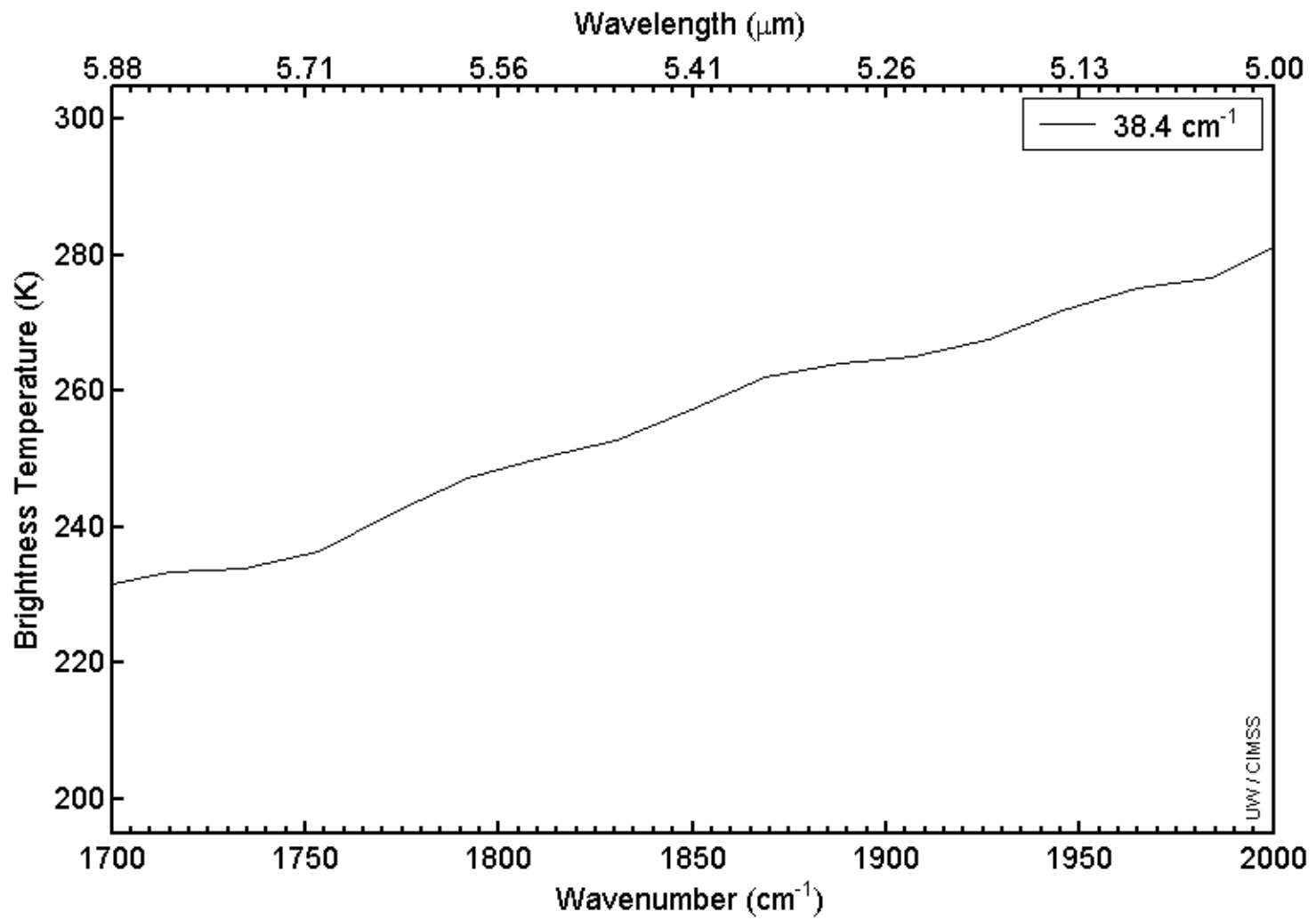
Water vapor region



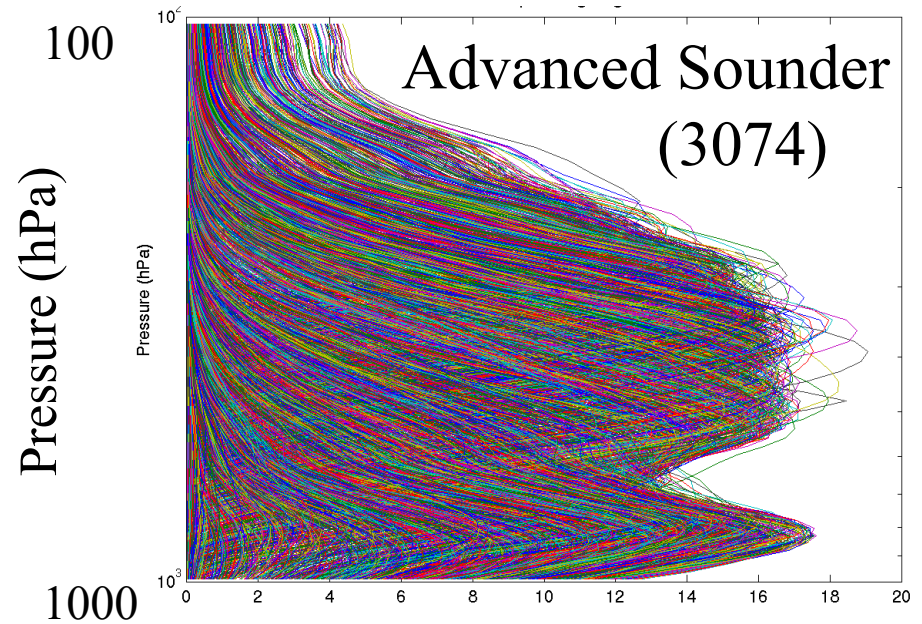
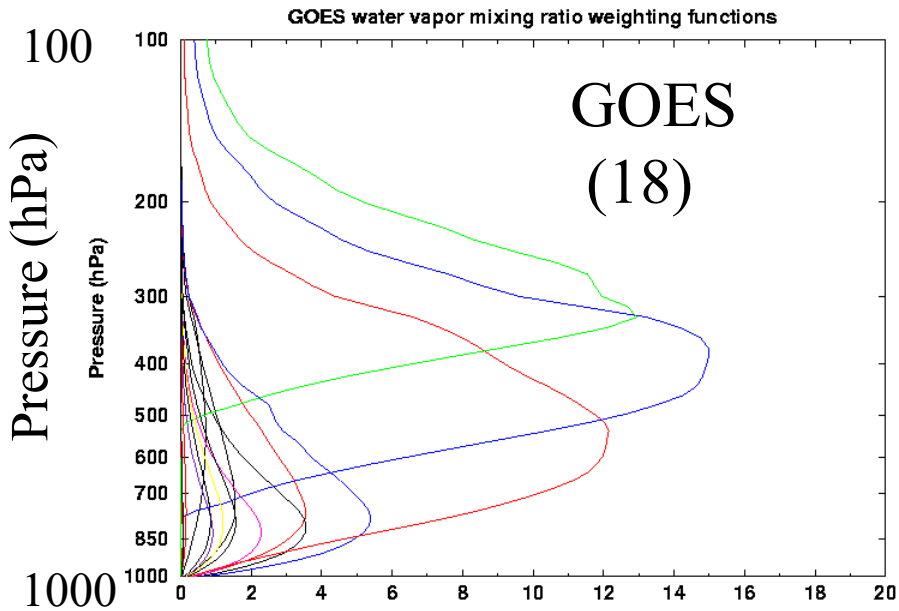
Water vapor region



Water vapor region



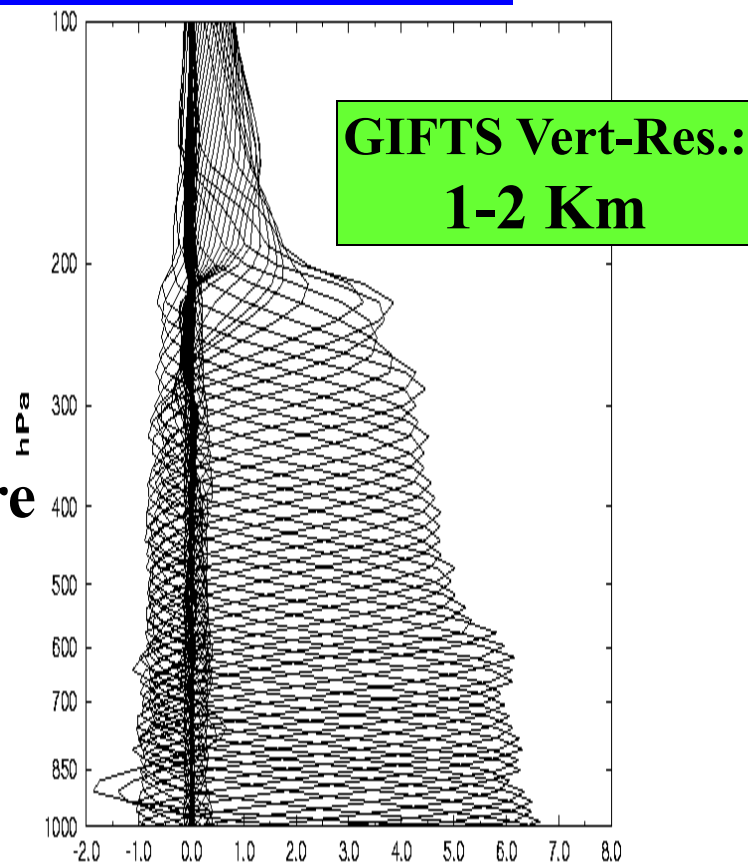
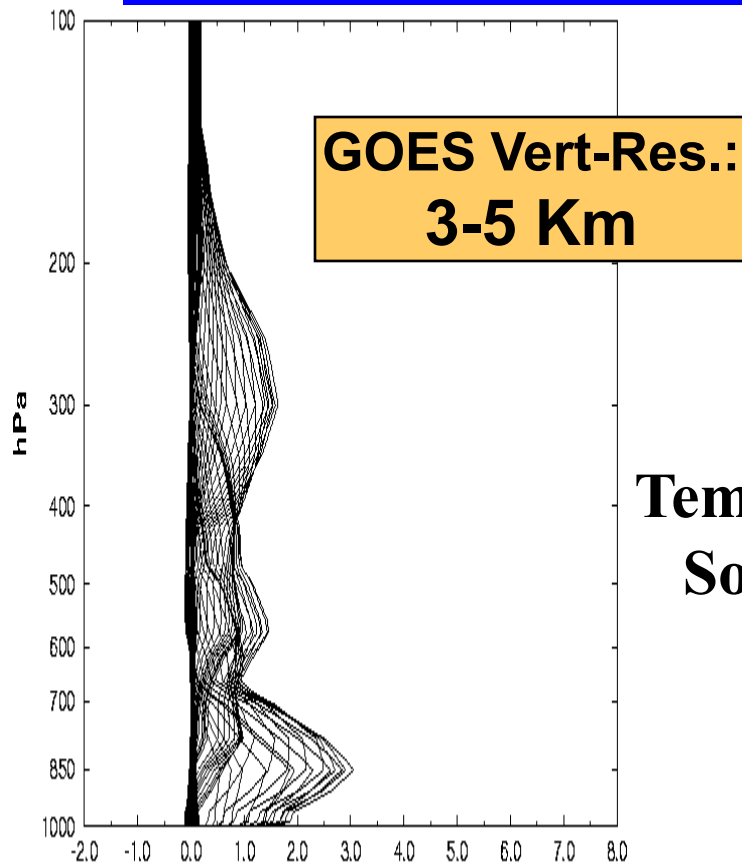
Water vapor region



Moisture Weighting Functions

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

Ultraspectral Infrared Measurement Characteristics - continue



Temperature
Sounding

Current - GOES

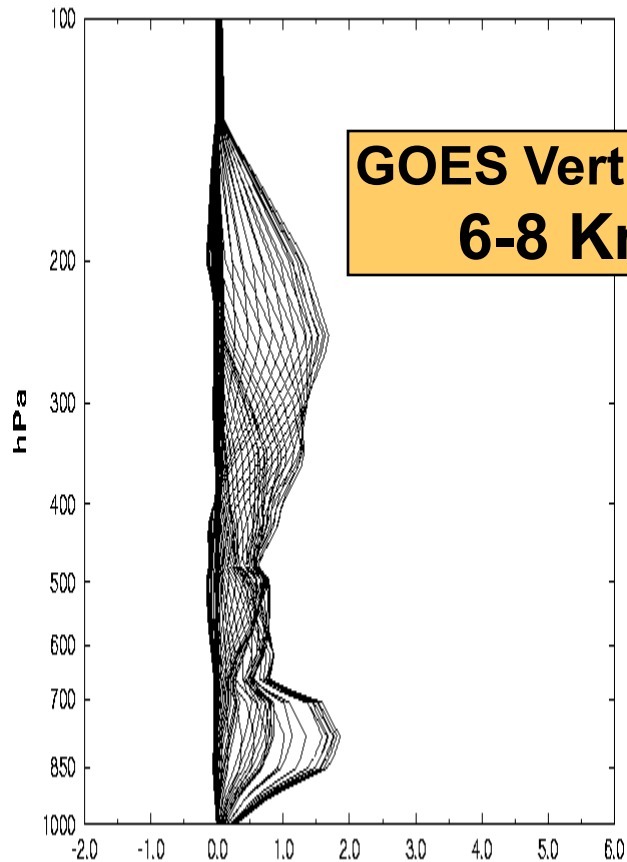
~3 Pieces

GIFTS

10-12 Pieces

Much Enhanced Measurement Information Contents

Hyperspectral Infrared Measurement Characteristics

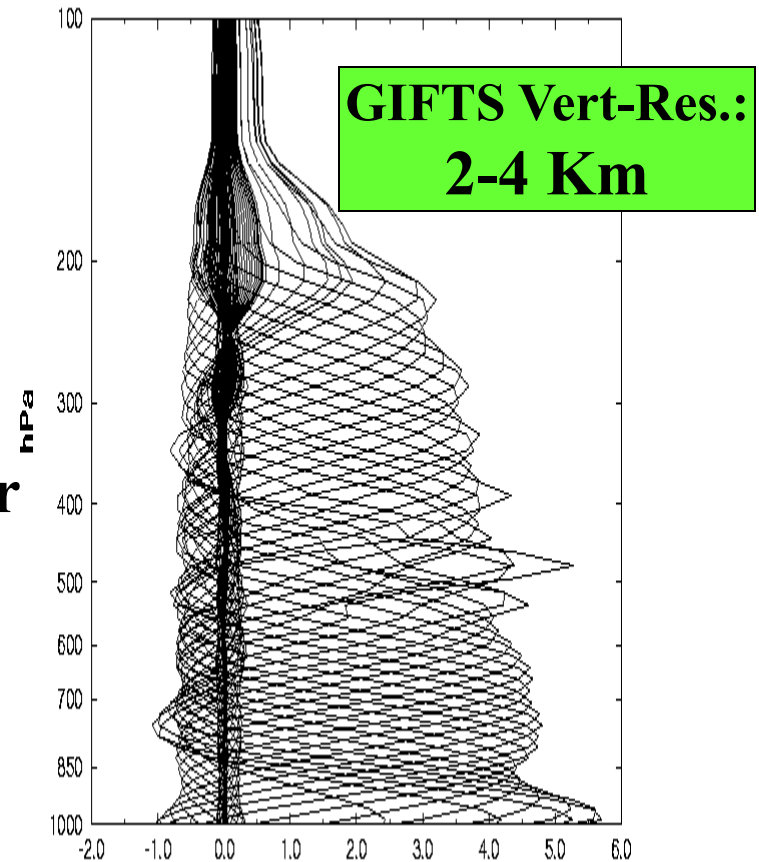


**GOES Vert-Res.:
6-8 Km**

Current - GOES

~2 Pieces

**Water Vapor
Sounding**



**GIFTS Vert-Res.:
2-4 Km**

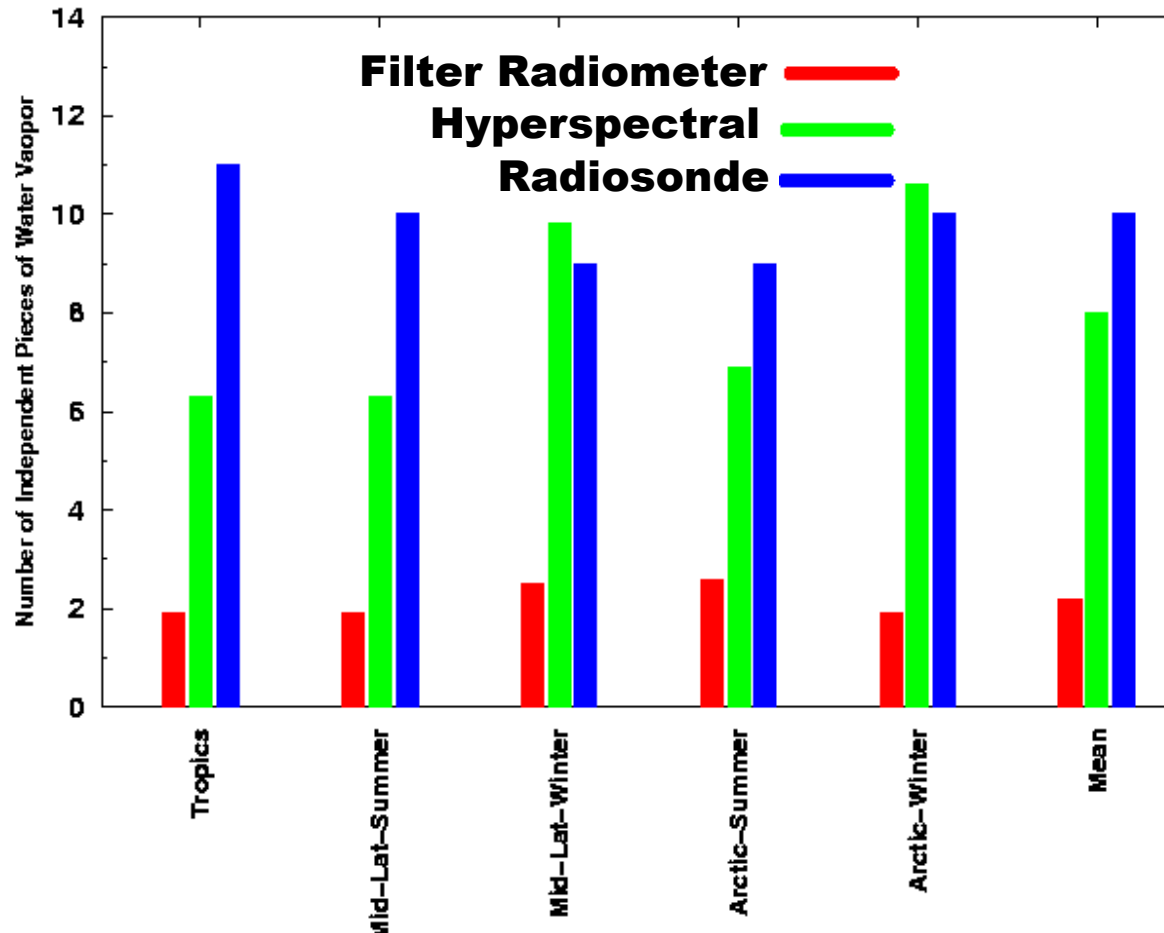
AIRS/IASI/GIFTS

8-9 Pieces

Much Enhanced Measurement Information Contents

Hyperspectral Infrared Measurement Characteristics

Geo Satellite & Radiosonde Water Vapor Information Single FOV or Single Profile

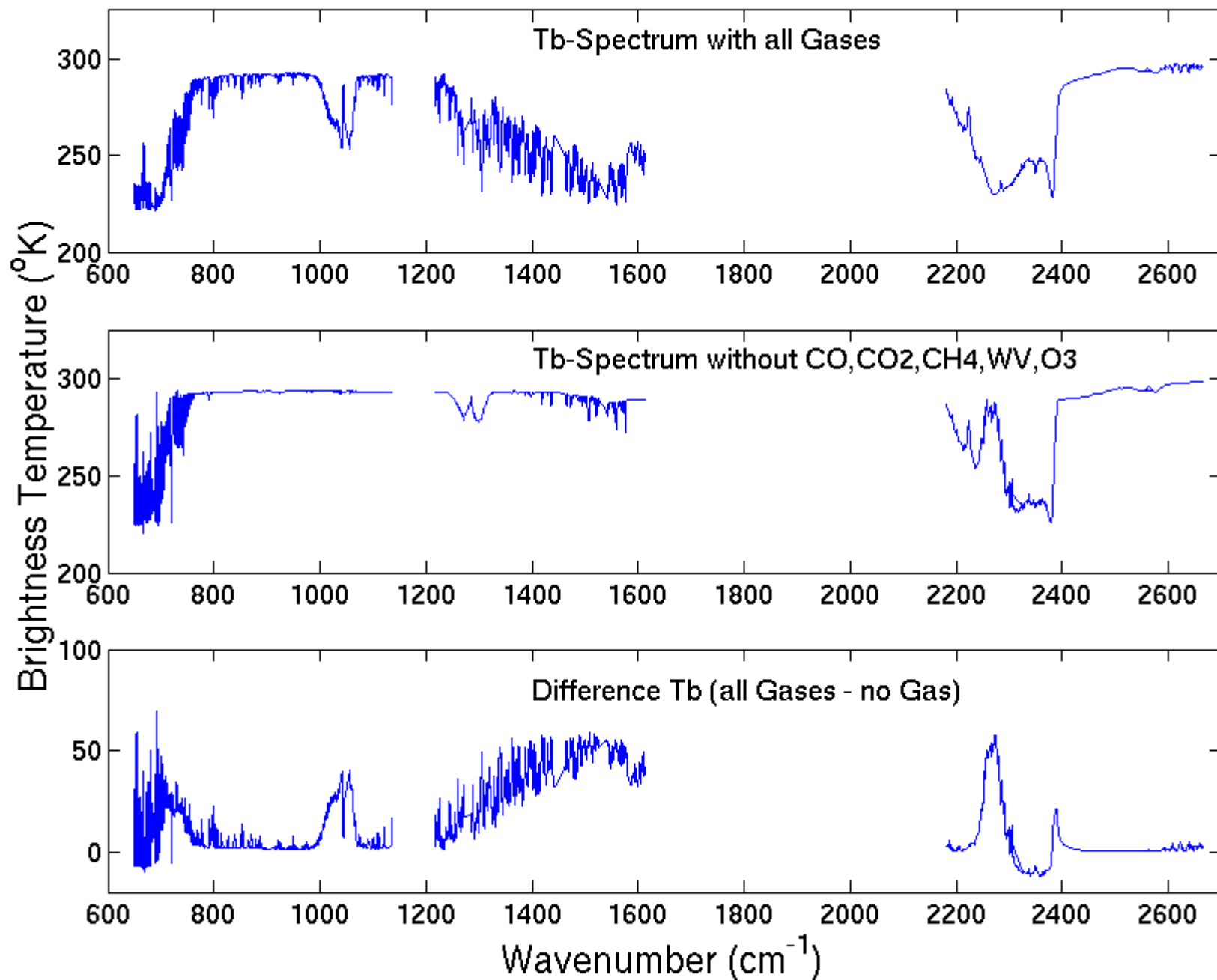


Water Vapor
Sounding

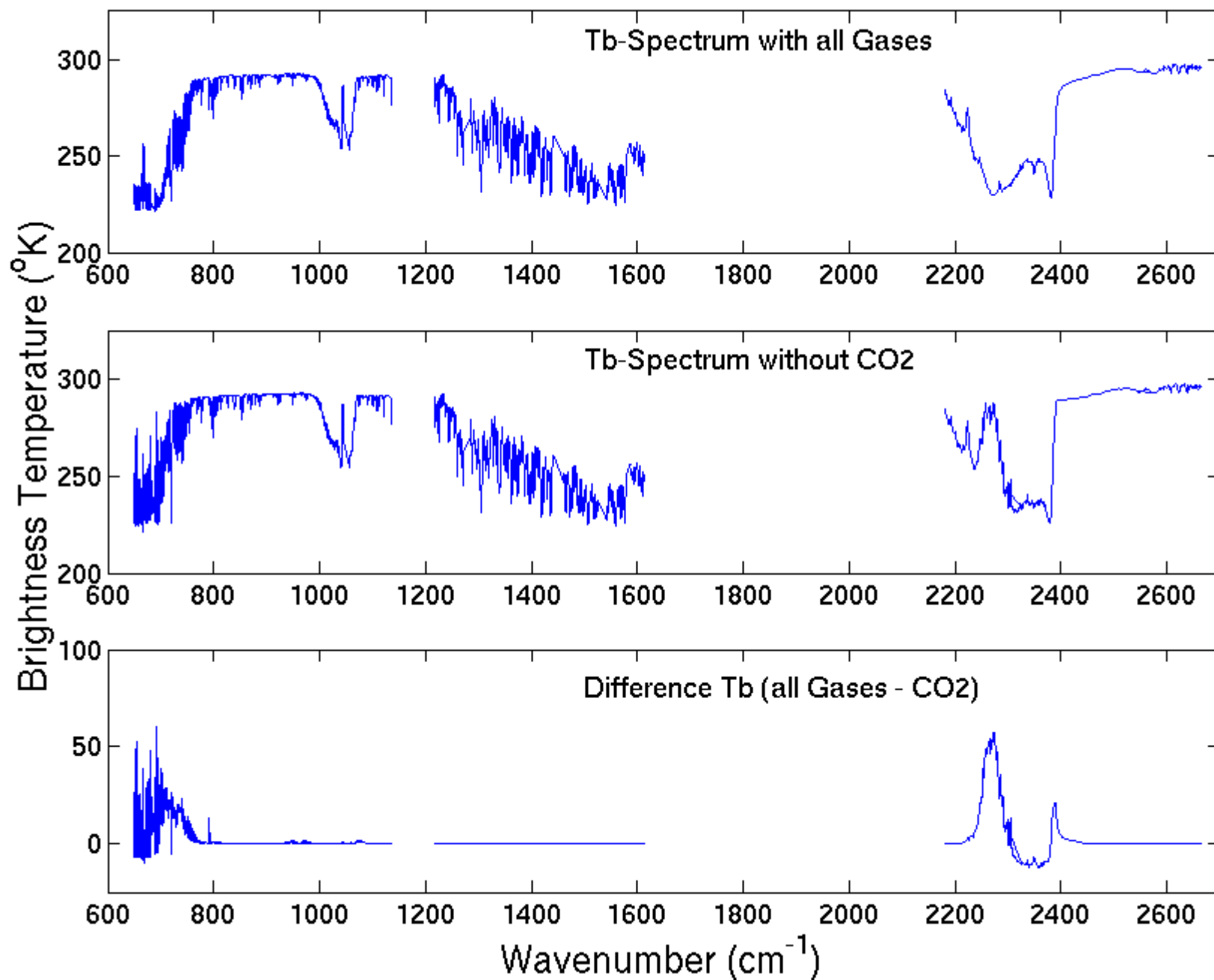
Measurement Vertical Resolution Information Content

Various Infrared Spectral Absorption Features

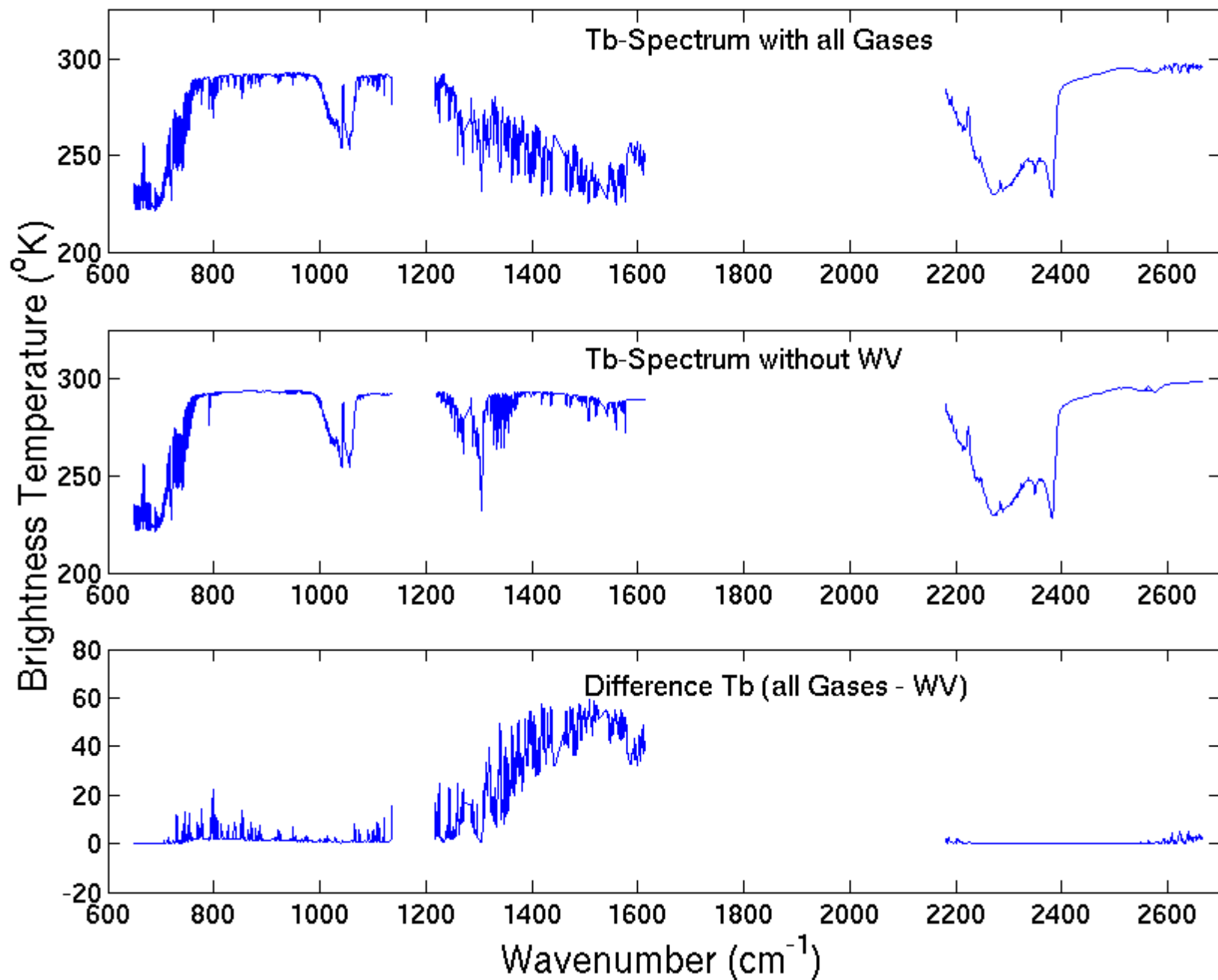
Mid-Latitude Summer Atmosphere - Sensitivity to Gases



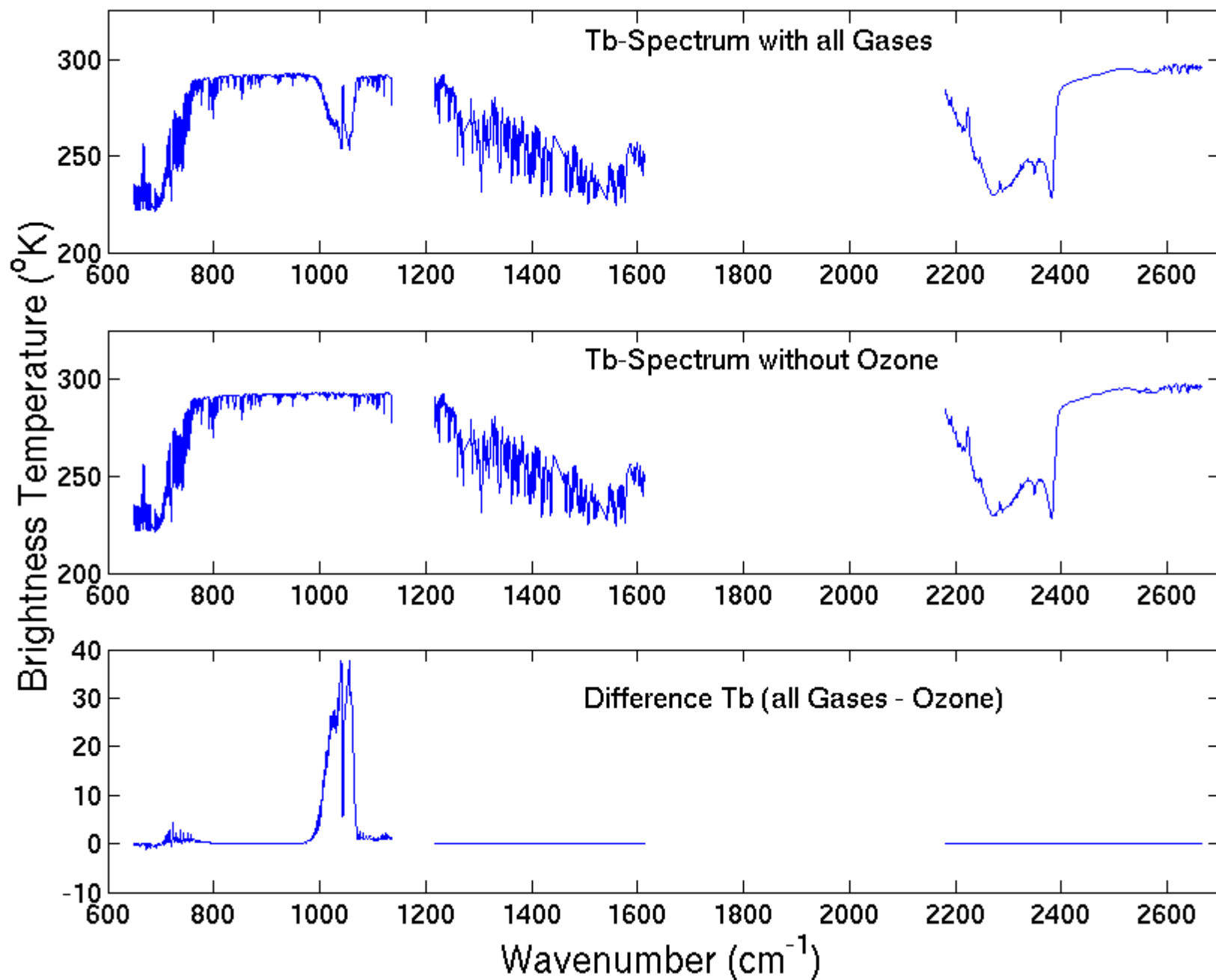
Mid-Latitude Summer Atmosphere - Sensitivity to CO2 Gas



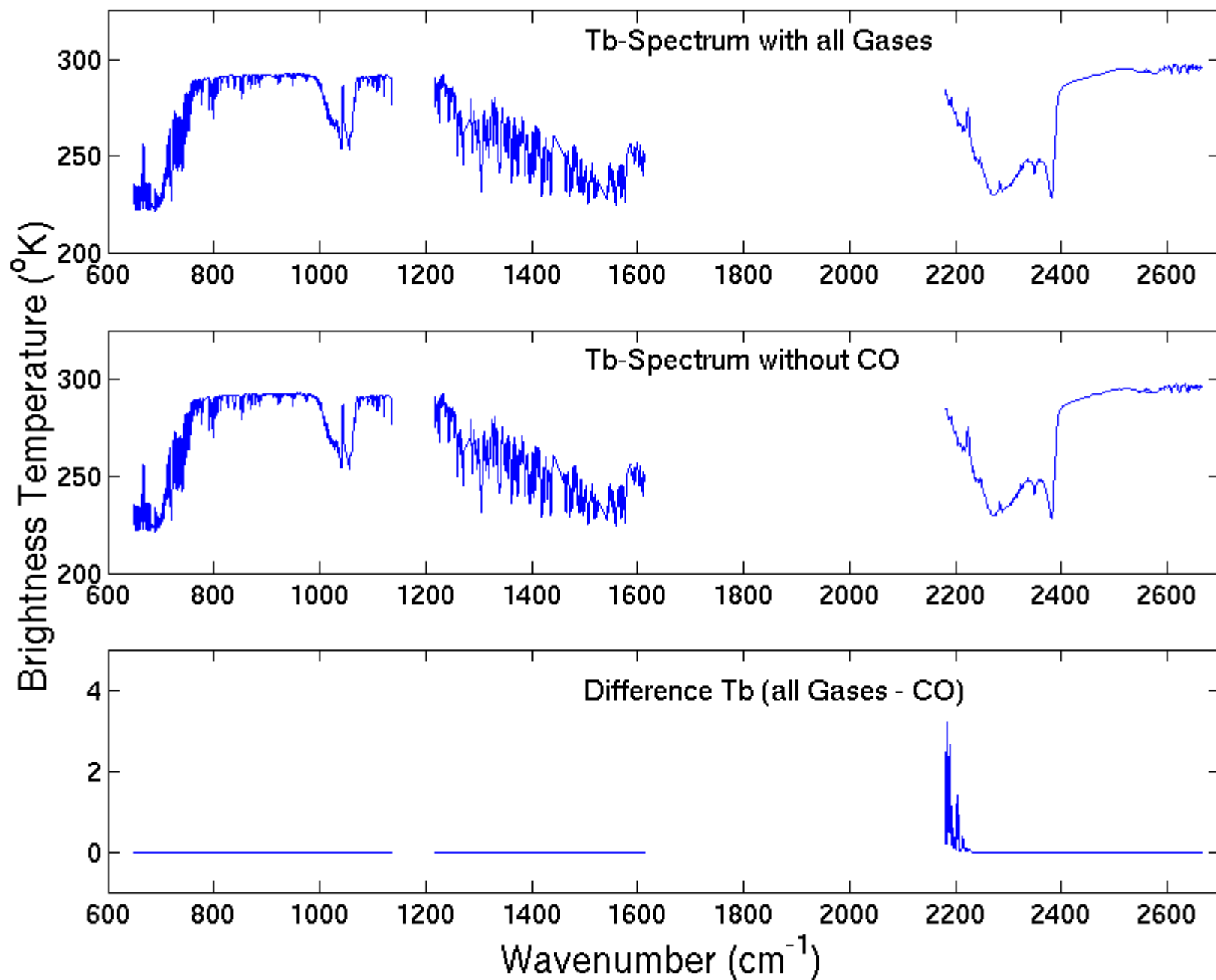
Mid-Latitude Summer Atmosphere - Sensitivity to Water Vapor



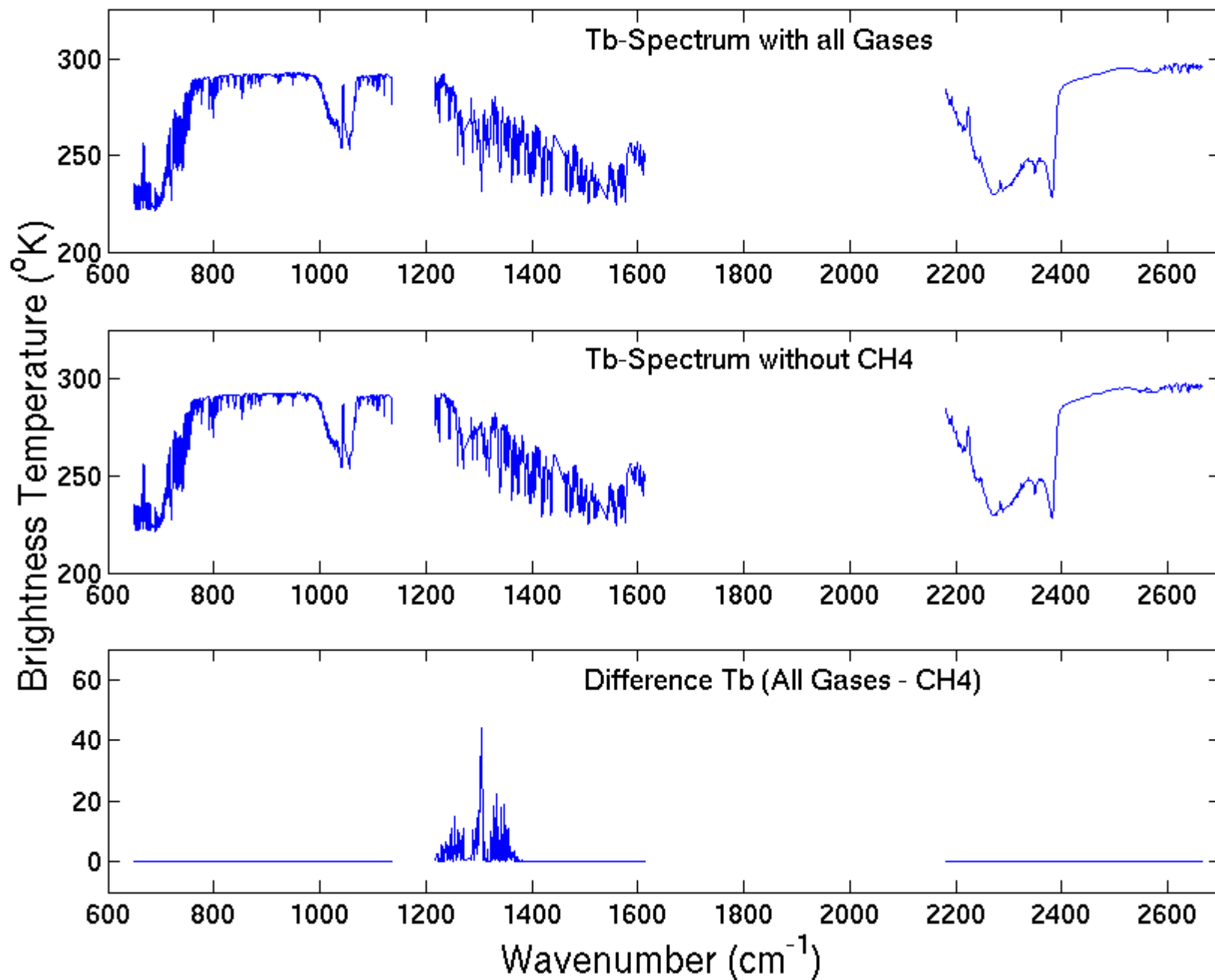
Mid-Latitude Summer Atmosphere - Sensitivity to Ozone



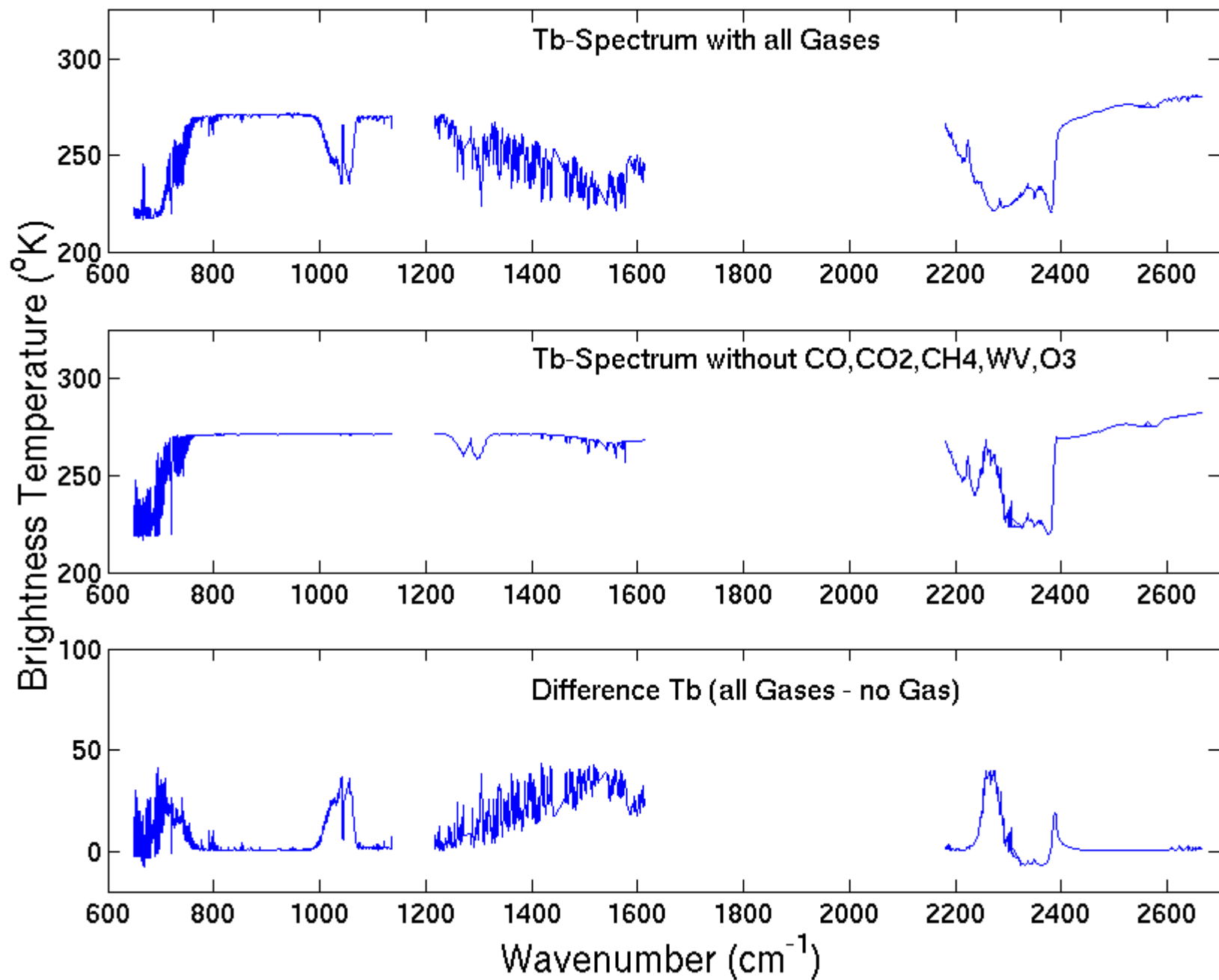
Mid-Latitude Summer Atmosphere - Sensitivity to CO Gas



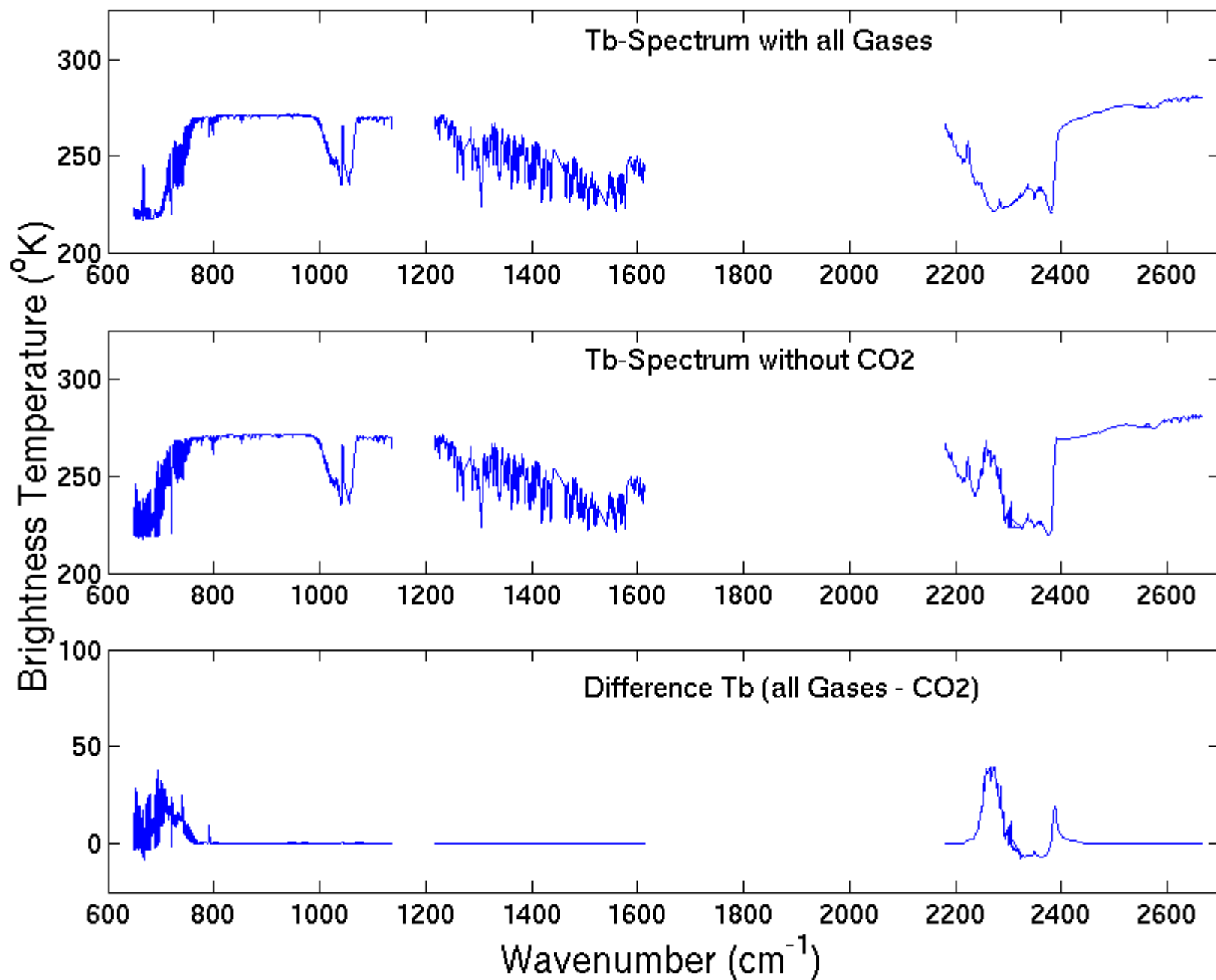
Mid-Latitude Summer Atmosphere - Sensitivity to CH4 Gas



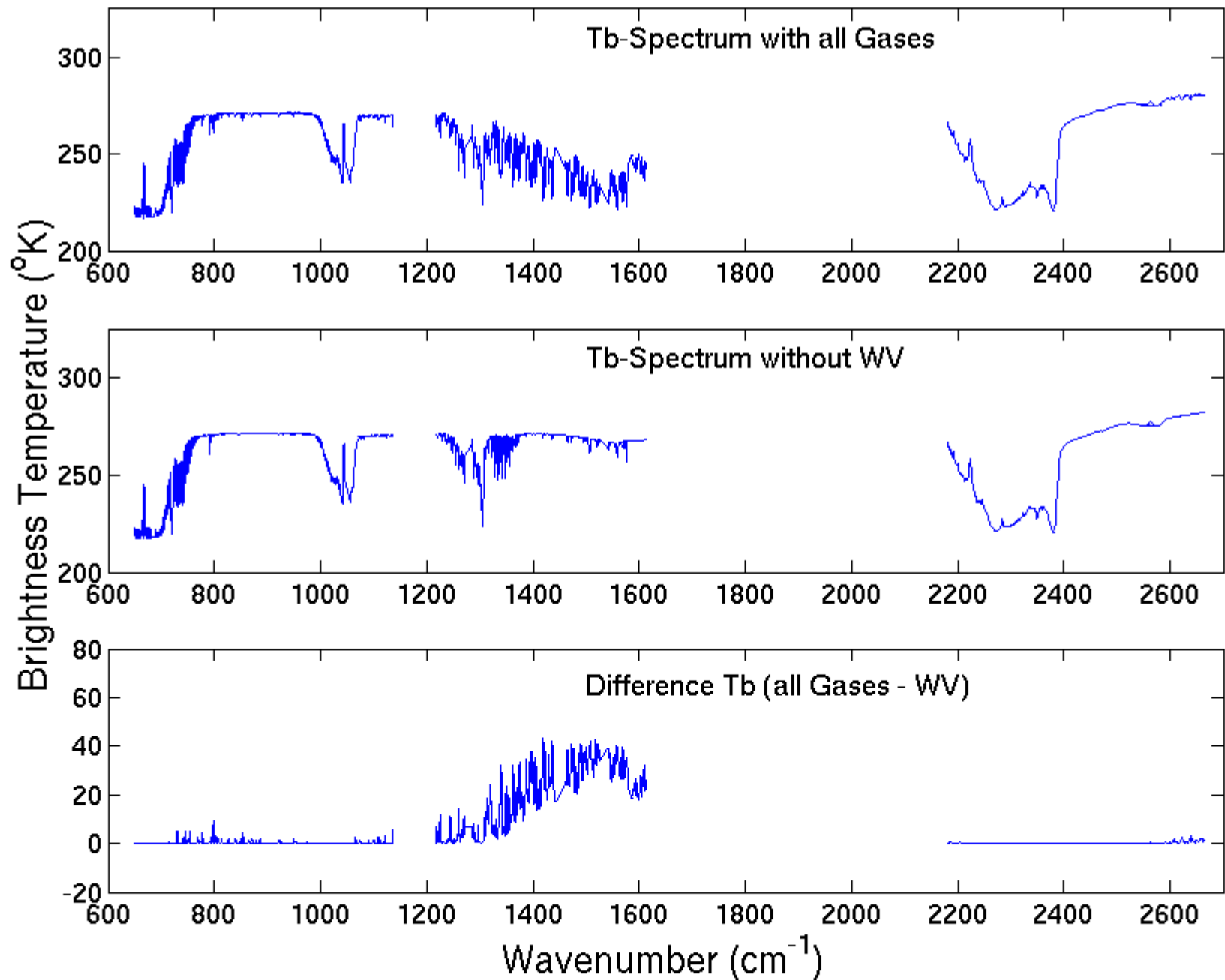
Mid-Latitude Winter Atmosphere - Sensitivity to Gases



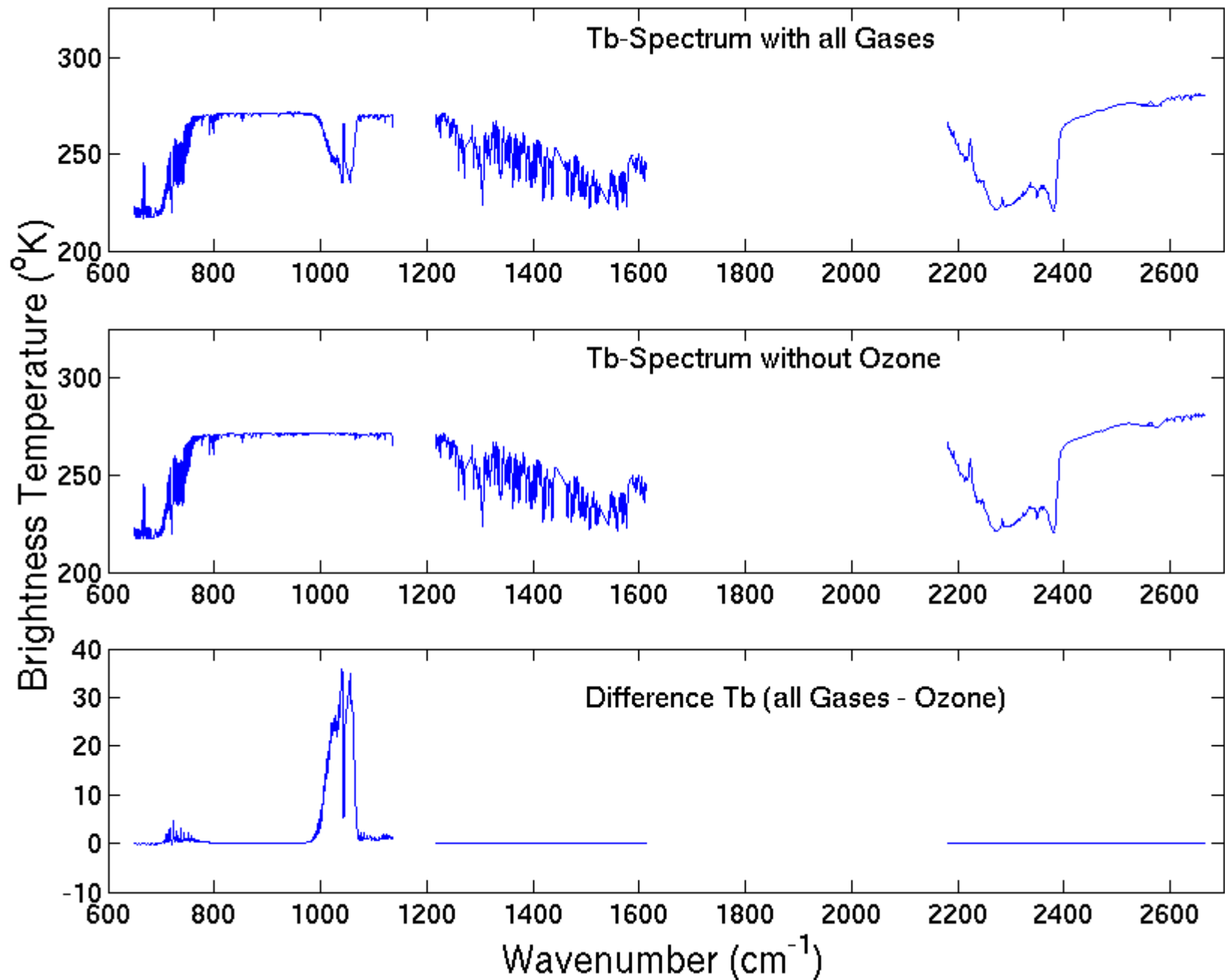
Mid-Latitude Winter Atmosphere - Sensitivity to CO2 Gas



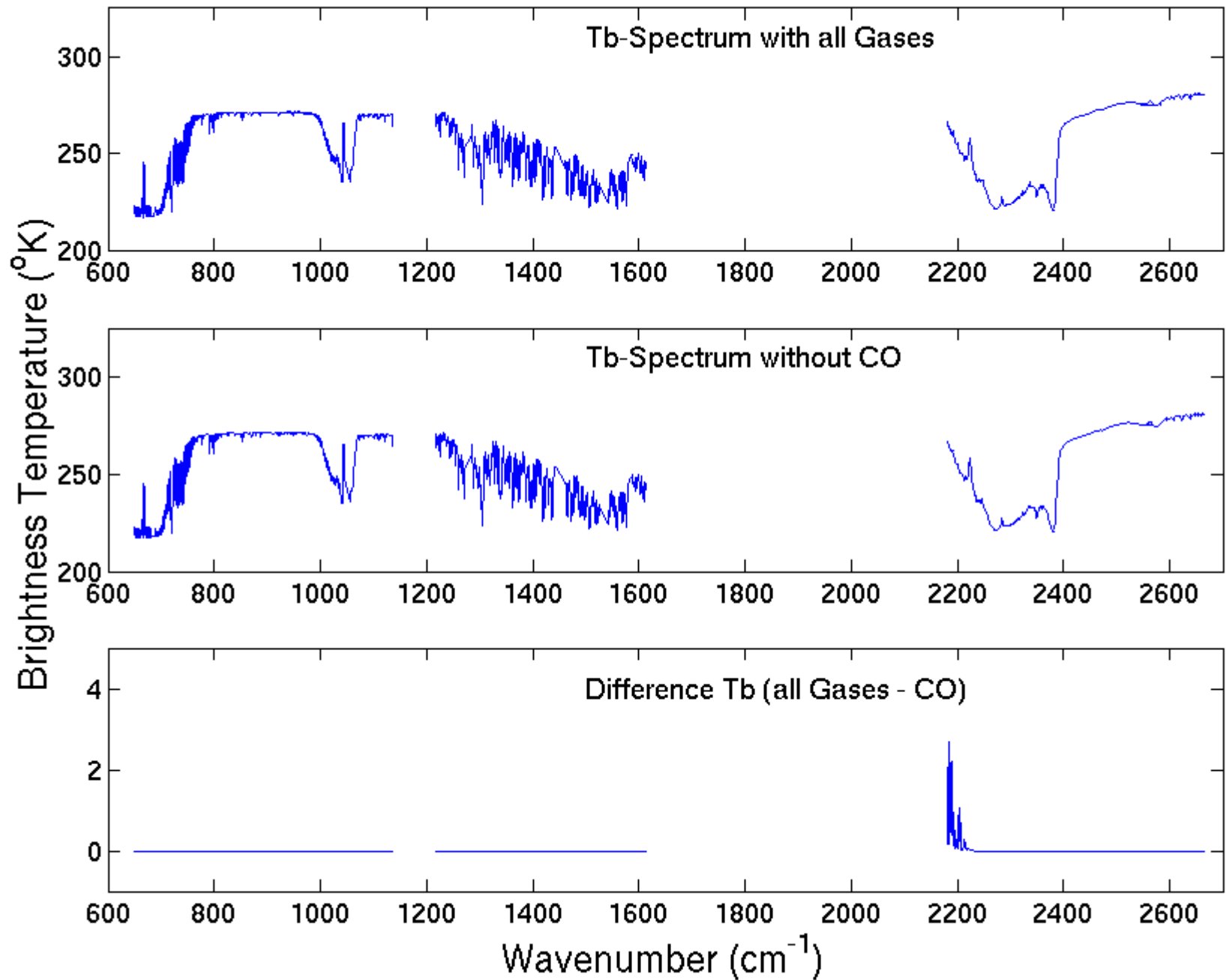
Mid-Latitude Winter Atmosphere - Sensitivity to Water Vapor



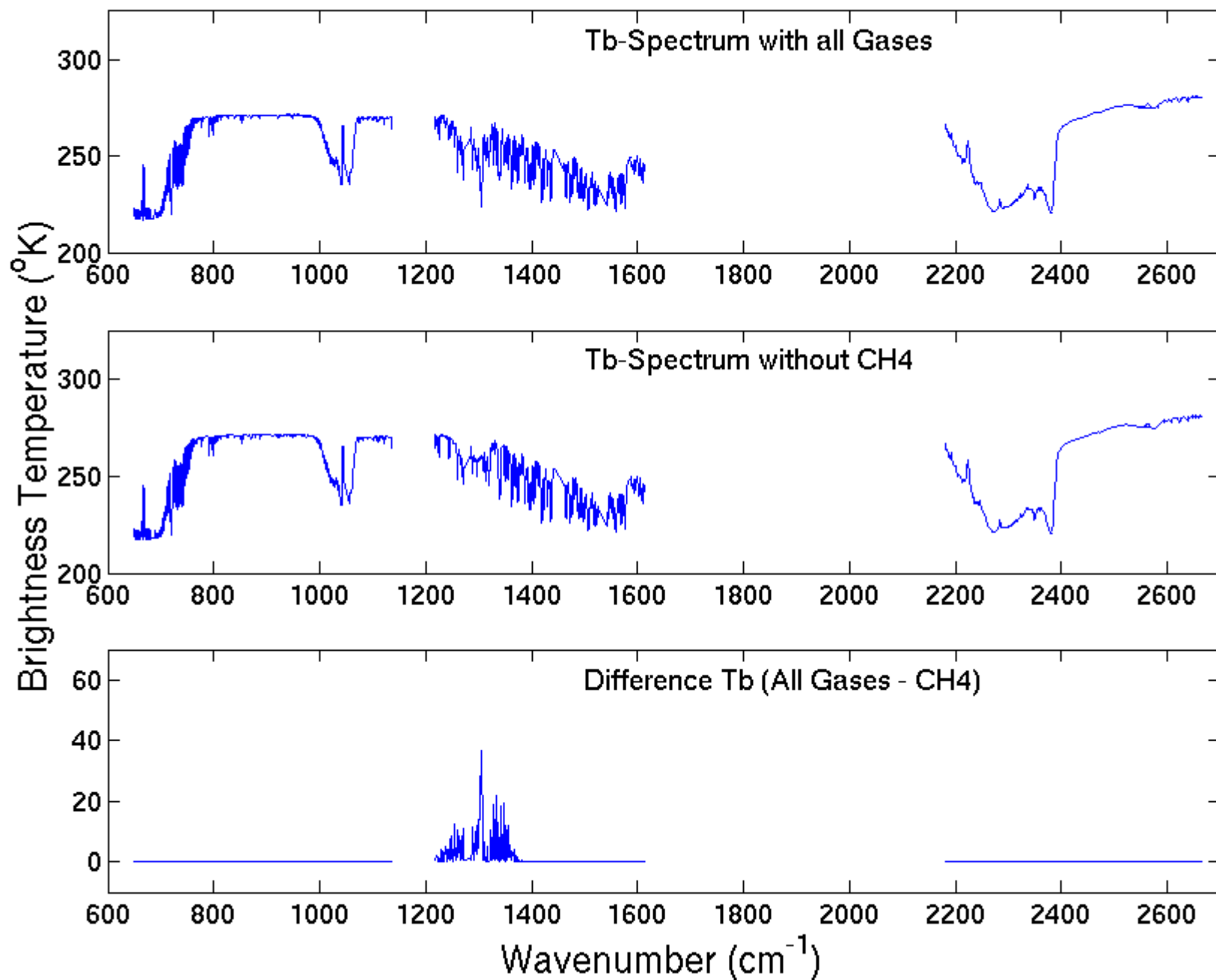
Mid-Latitude Winter Atmosphere - Sensitivity to Ozone



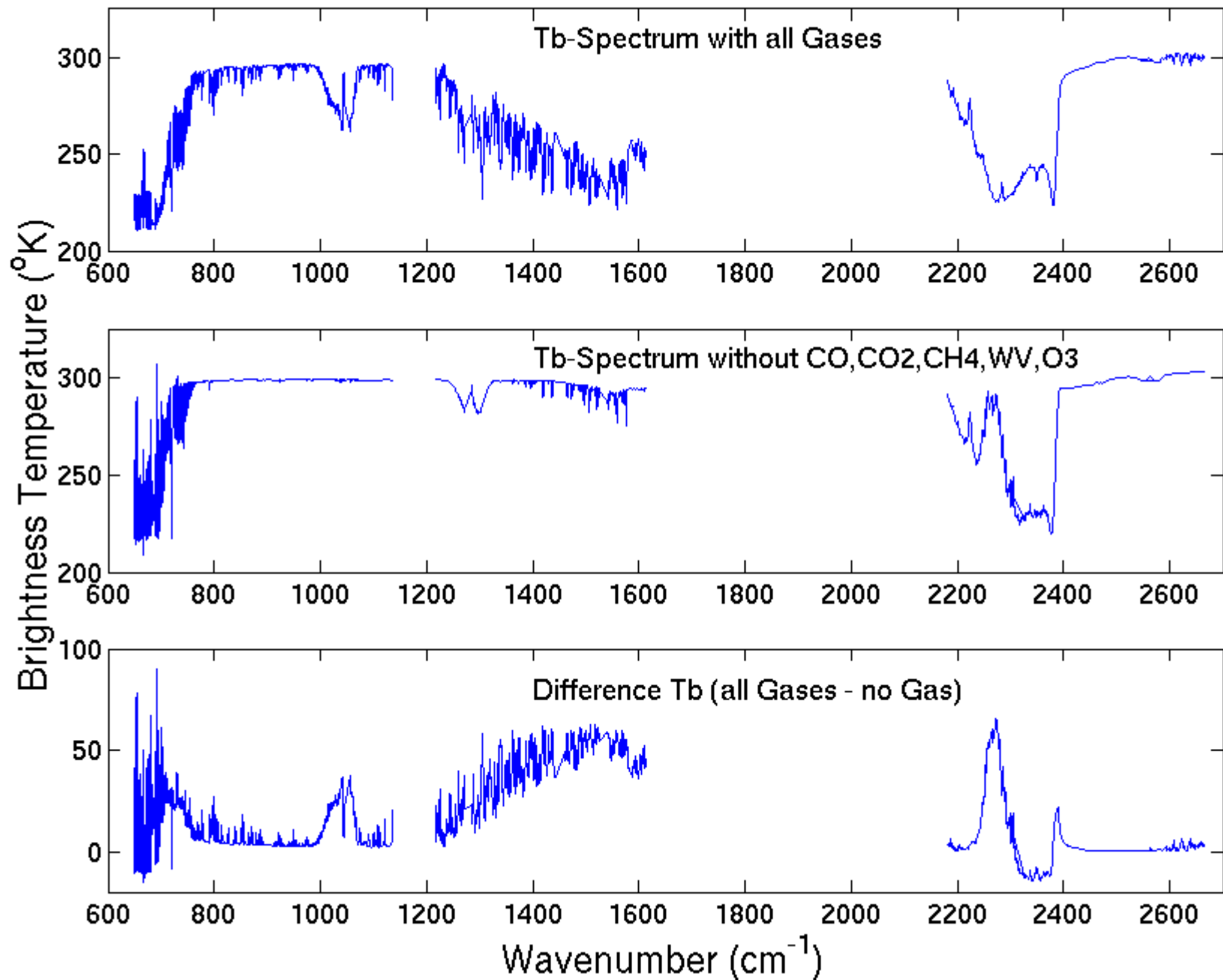
Mid-Latitude Winter Atmosphere - Sensitivity to CO Gas



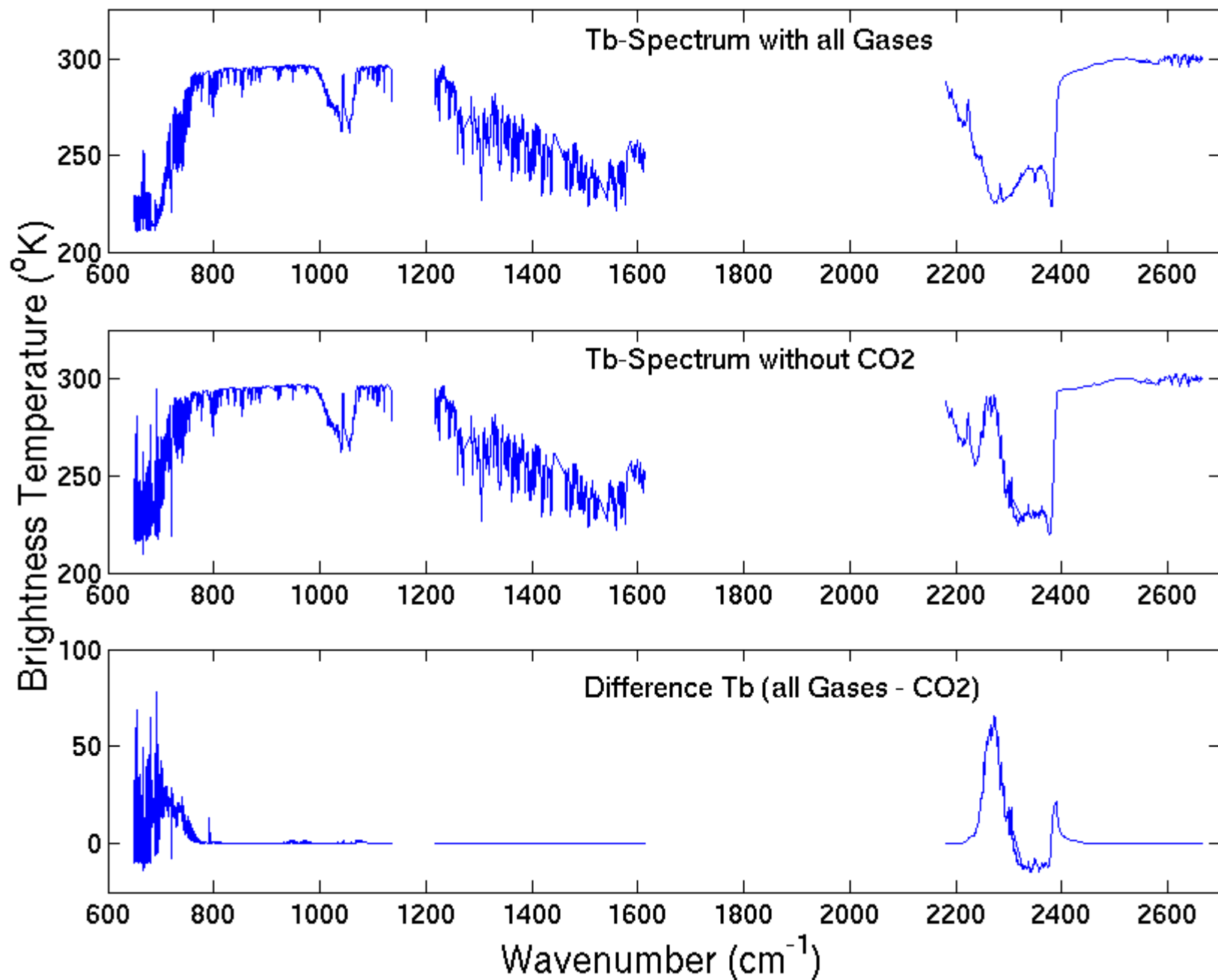
Mid-Latitude Winter Atmosphere - Sensitivity to CH4 Gas



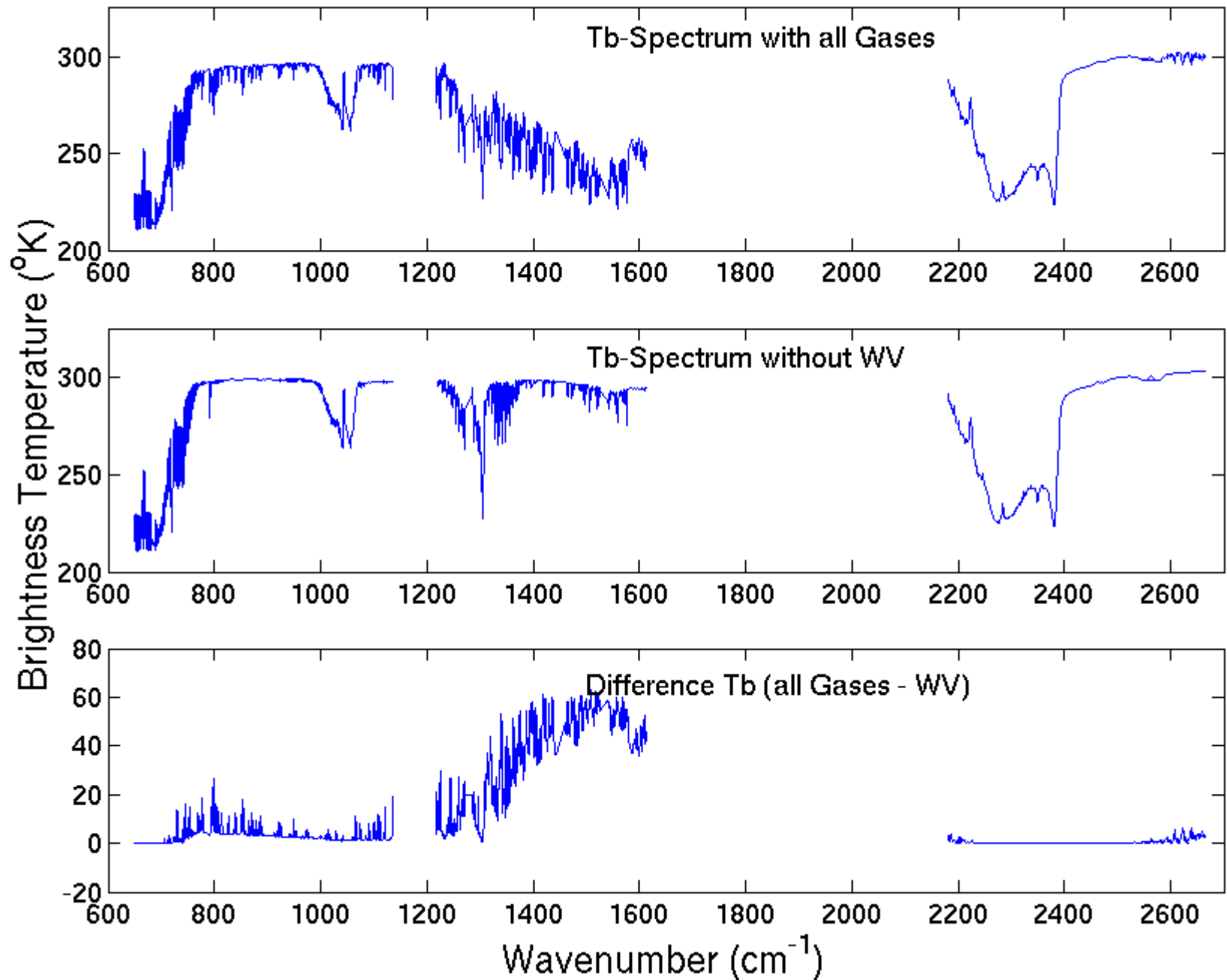
Tropical Atmosphere - Sensitivity to Gases



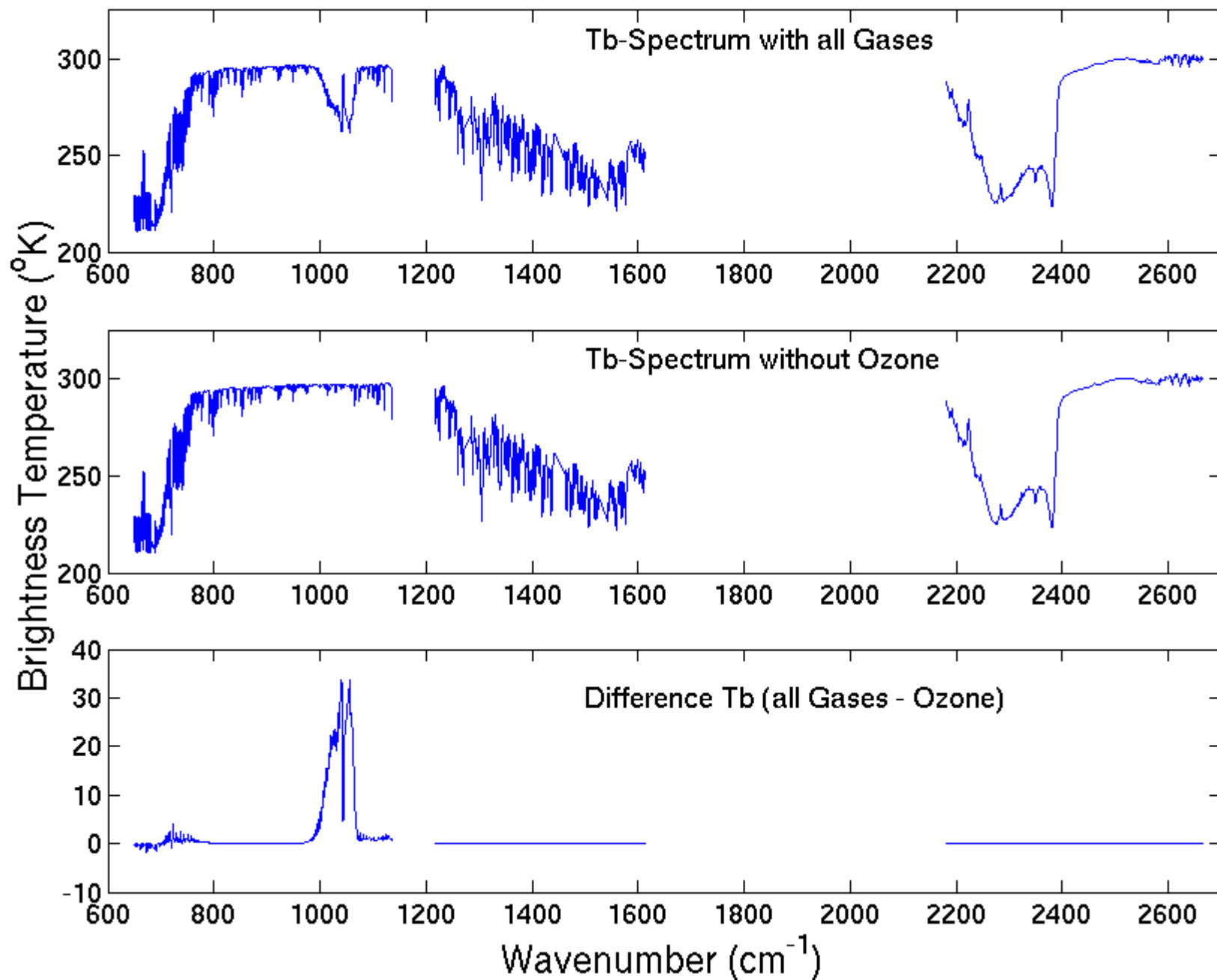
Tropical Atmosphere - Sensitivity to CO2 Gas



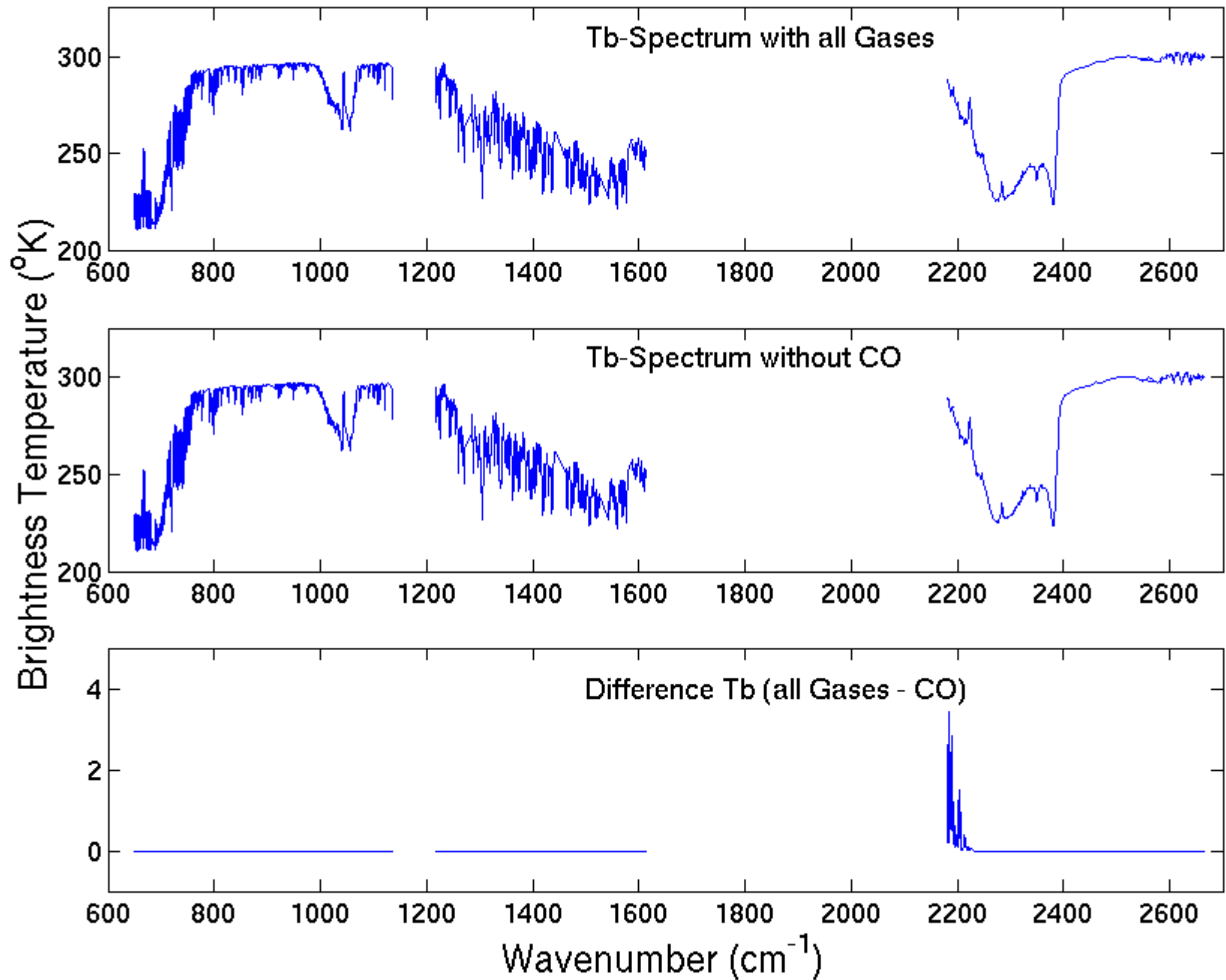
Tropical Atmosphere - Sensitivity to Water Vapor



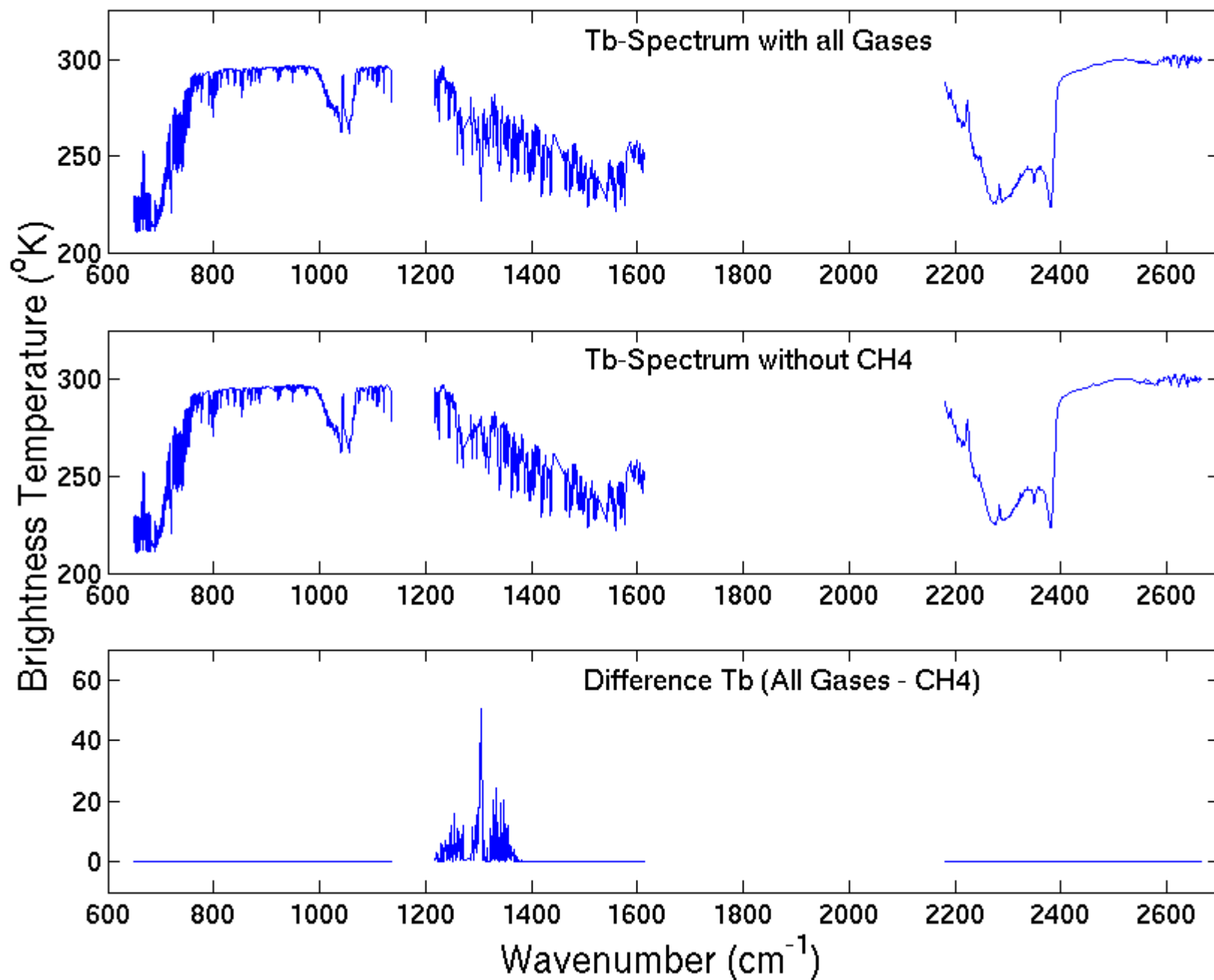
Tropical Atmosphere - Sensitivity to Ozone



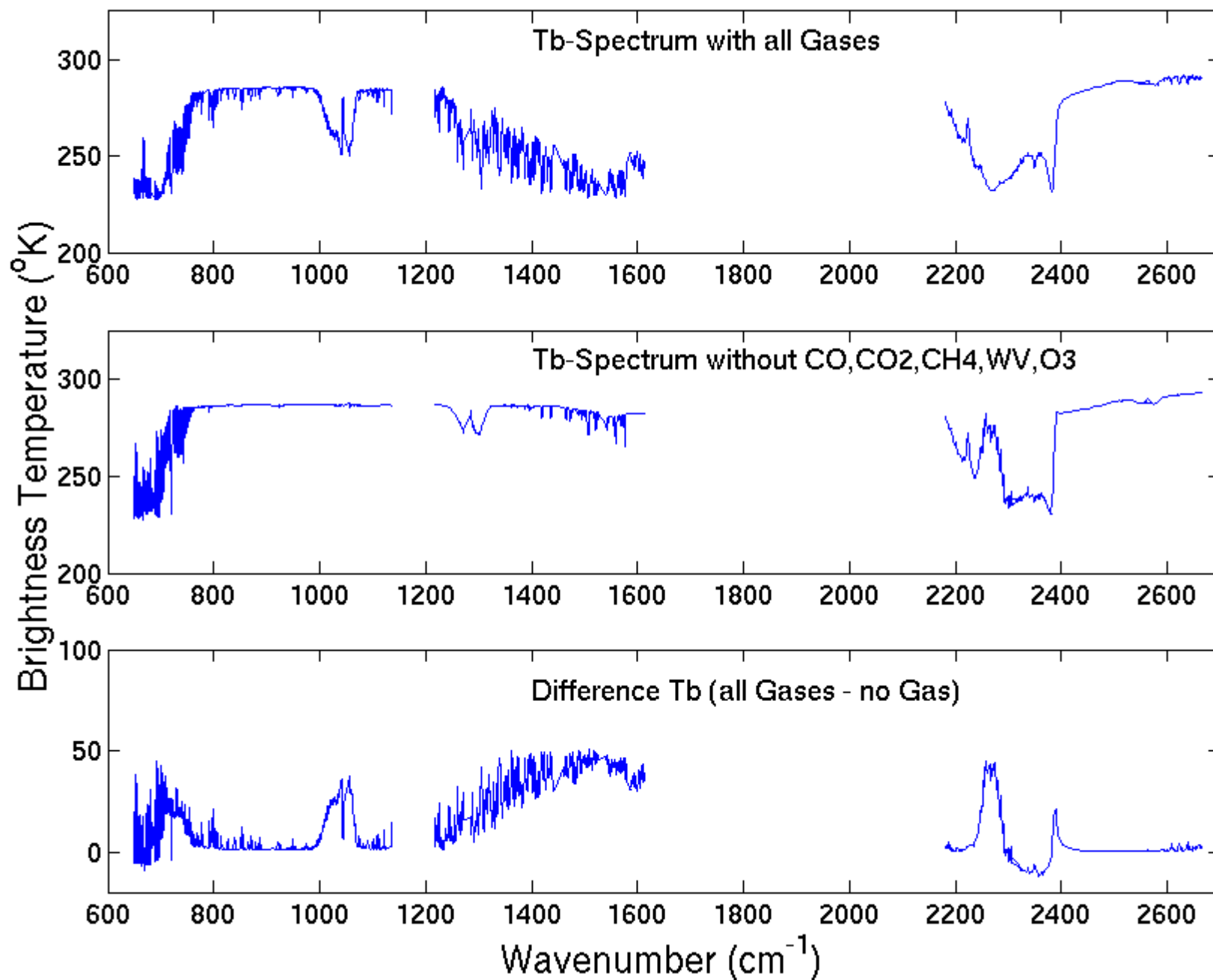
Tropical Atmosphere - Sensitivity to CO Gas



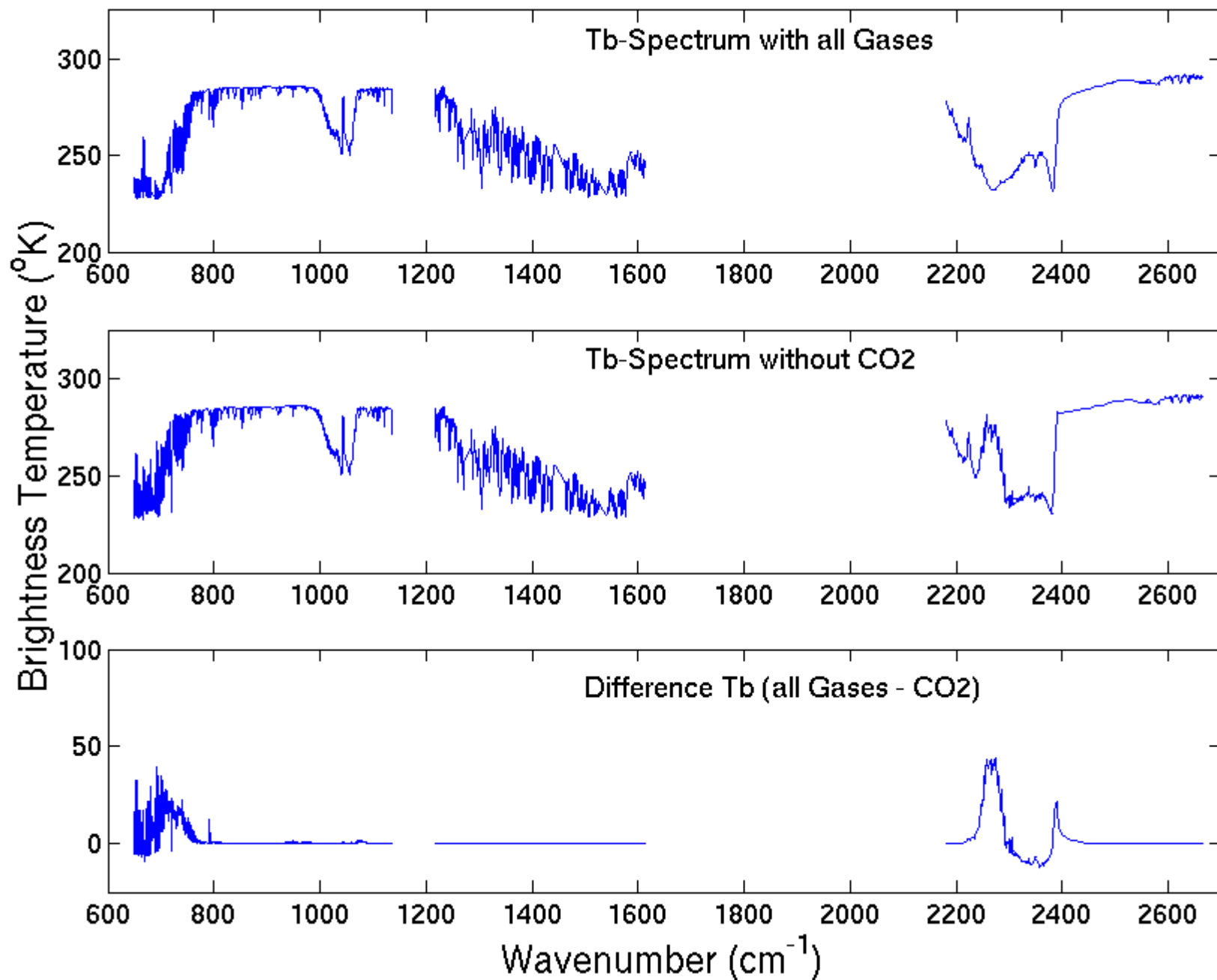
Tropical Atmosphere - Sensitivity to CH4 Gas



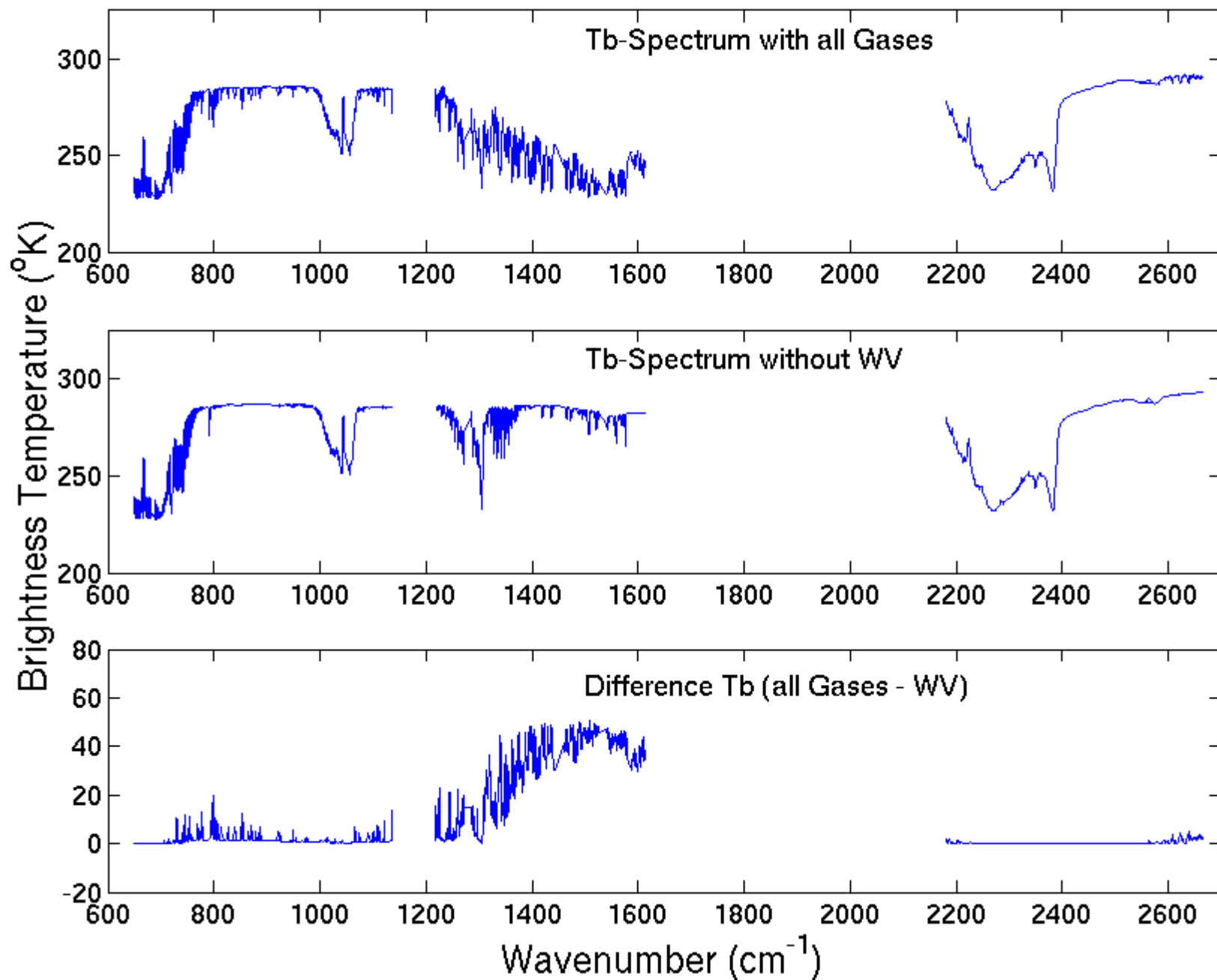
Sub-Arctic Summer Atmosphere - Sensitivity to Gases



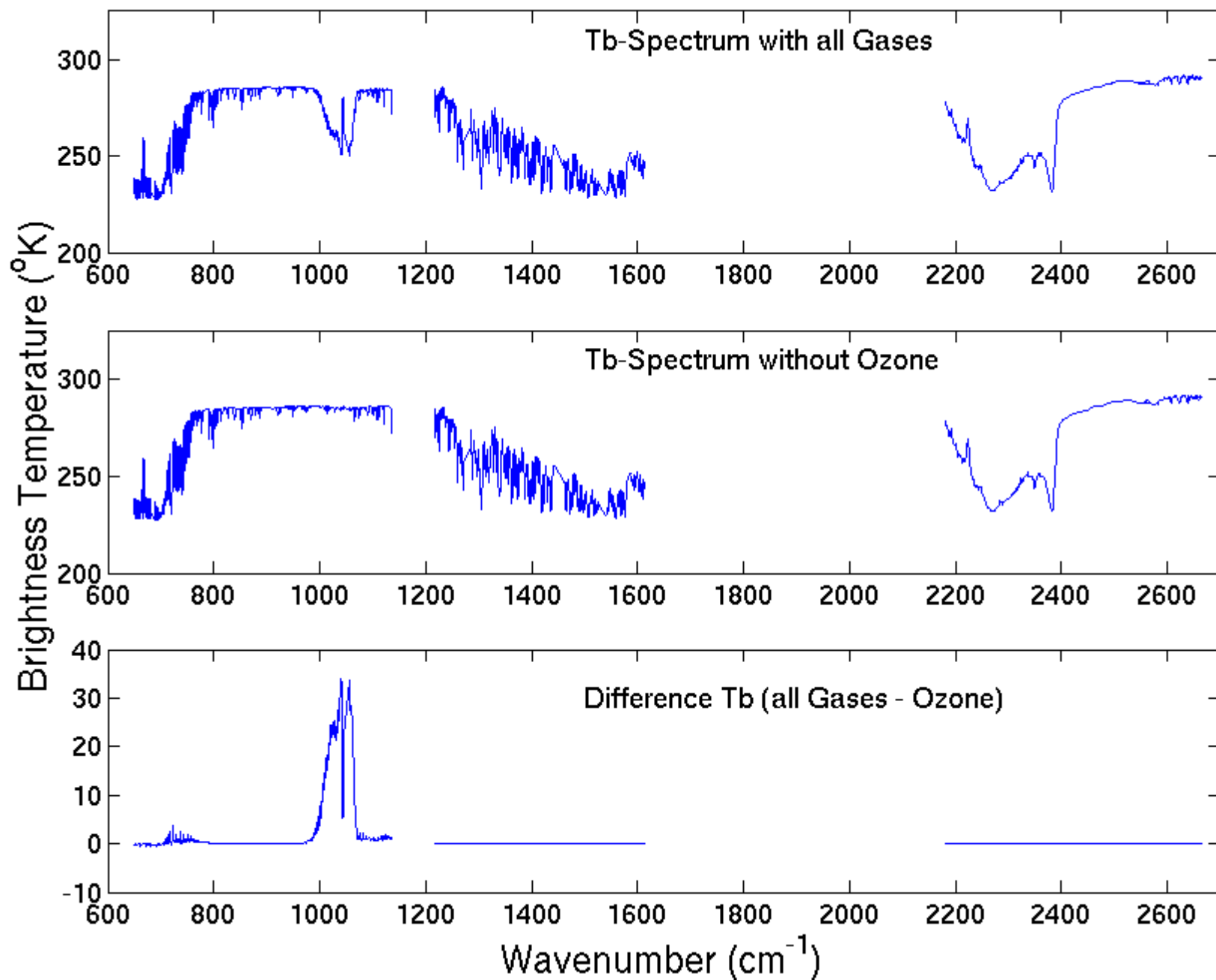
Sub-Arctic Summer Atmosphere - Sensitivity to CO2 Gas



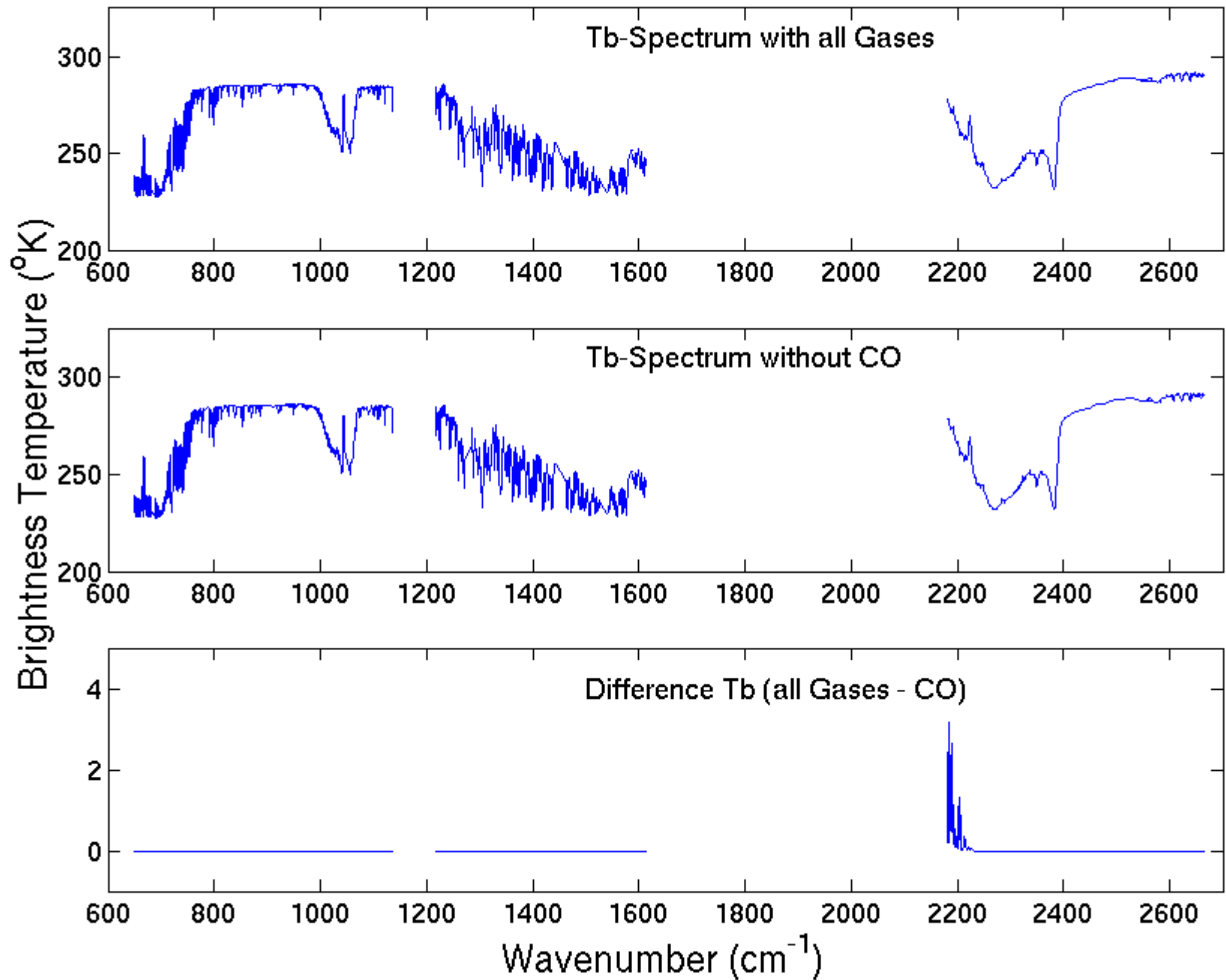
Sub-Arctic Summer Atmosphere - Sensitivity to Water Vapor



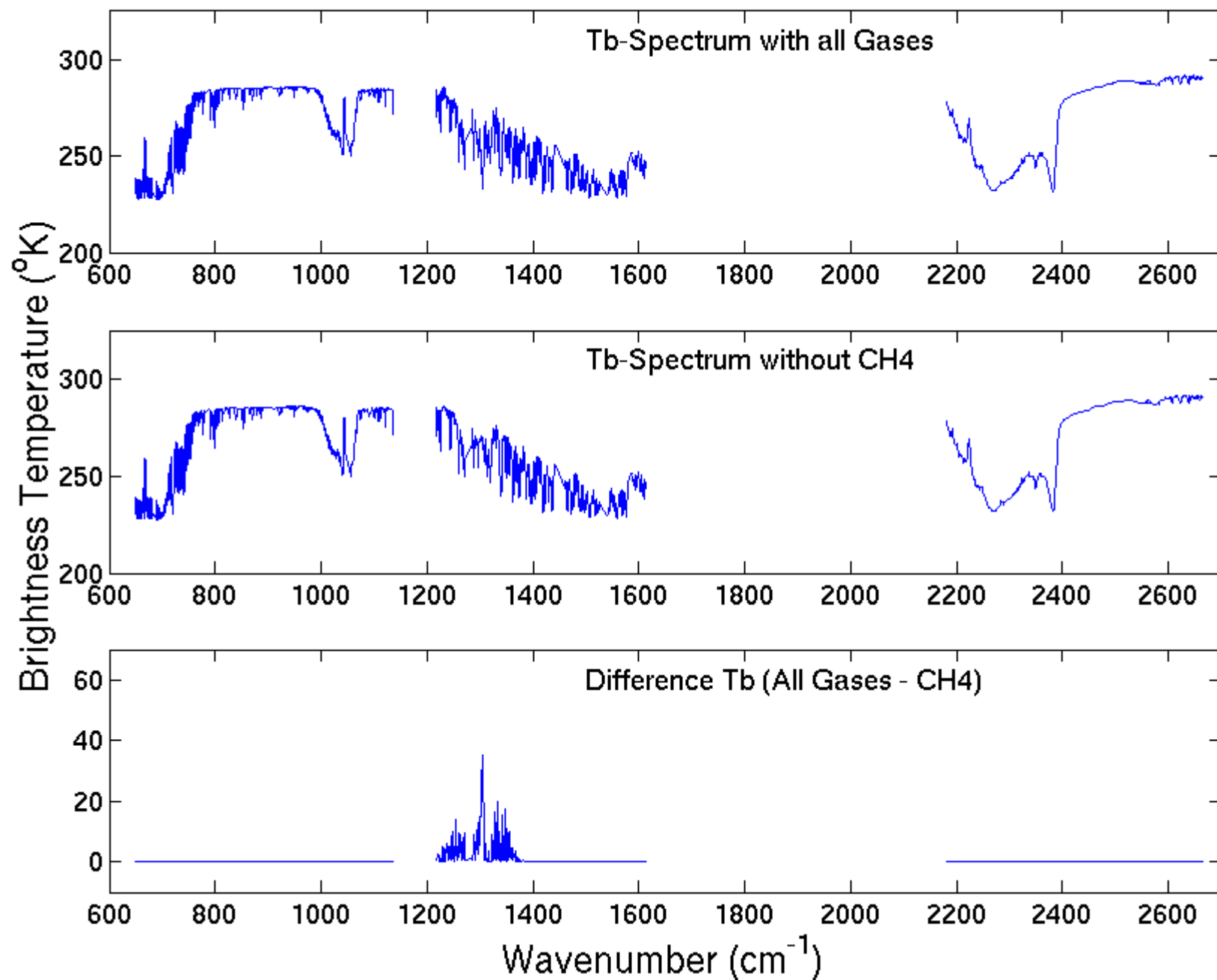
Sub-Arctic Summer Atmosphere - Sensitivity to Ozone



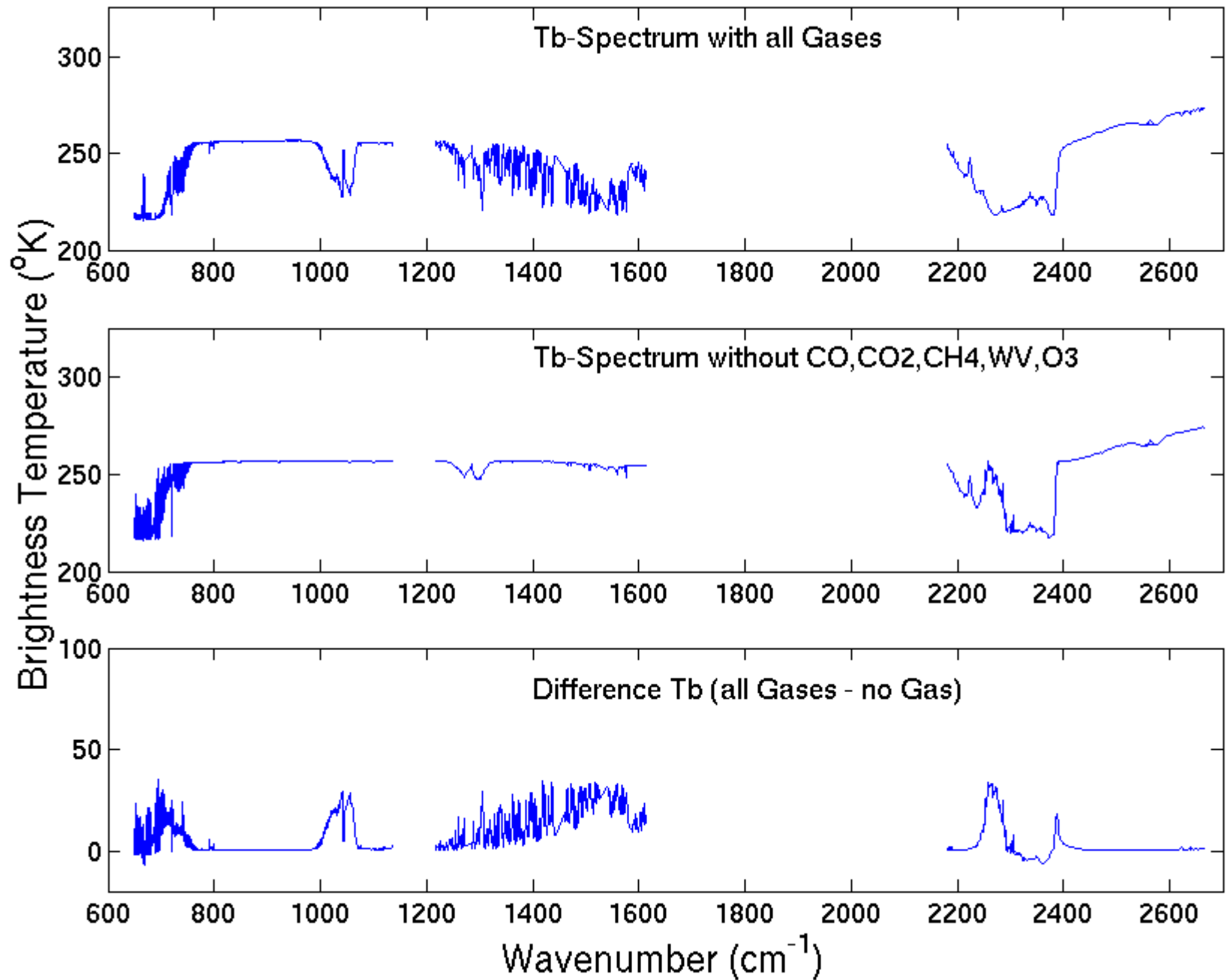
Sub-Arctic Summer Atmosphere - Sensitivity to CO Gas



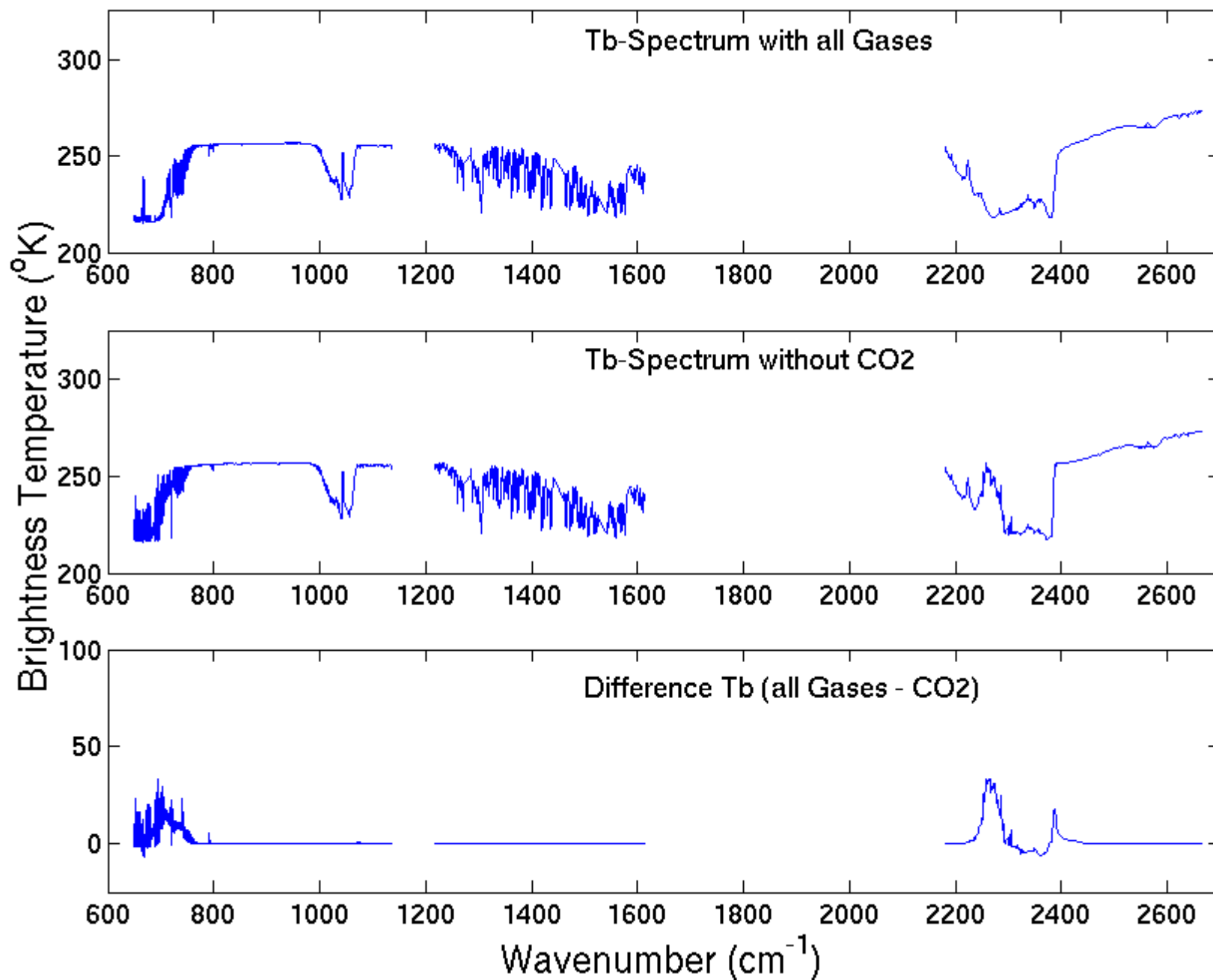
Sub-Arctic Summer Atmosphere - Sensitivity to CH4 Gas



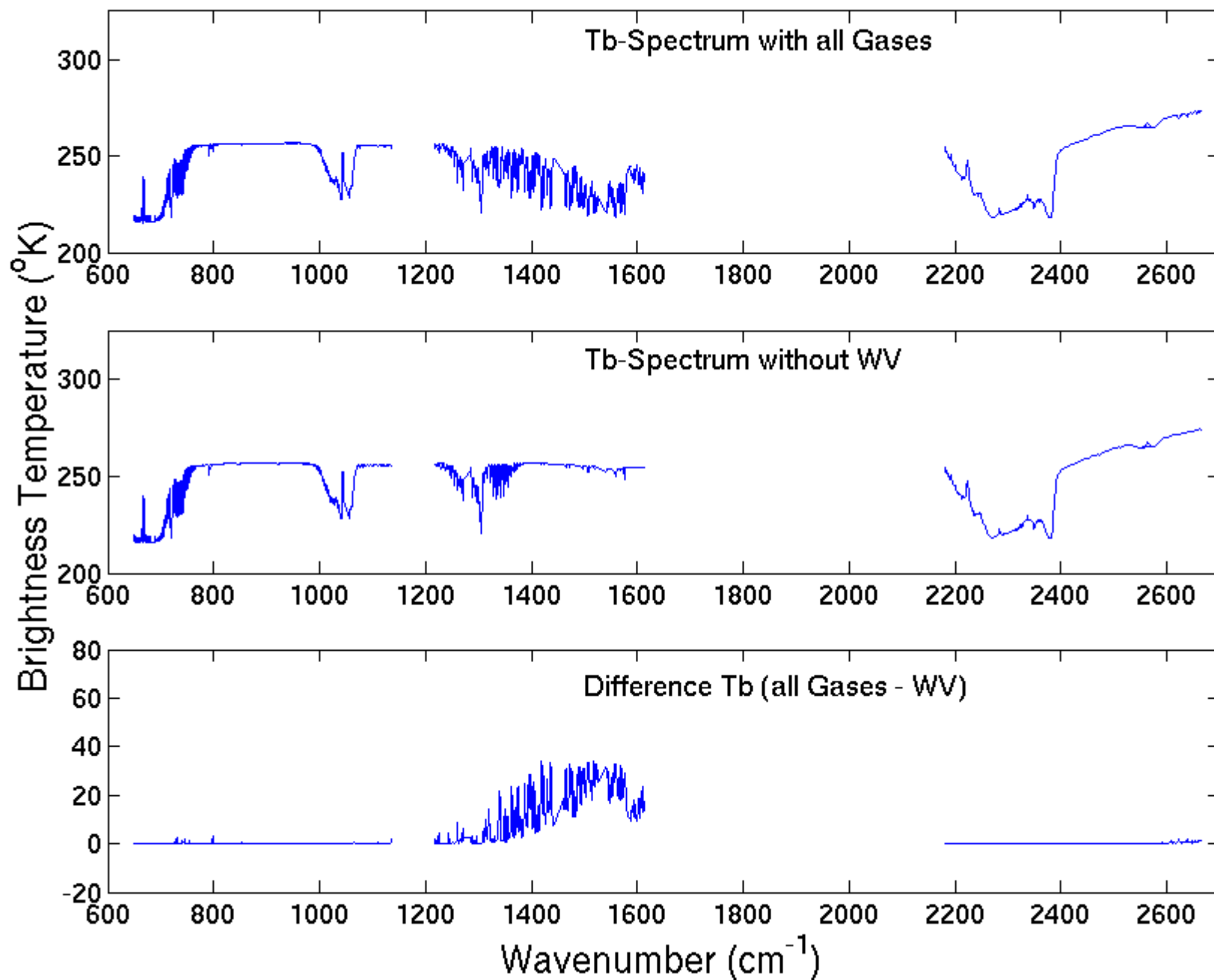
Sub-Arctic Winter Atmosphere - Sensitivity to Gases



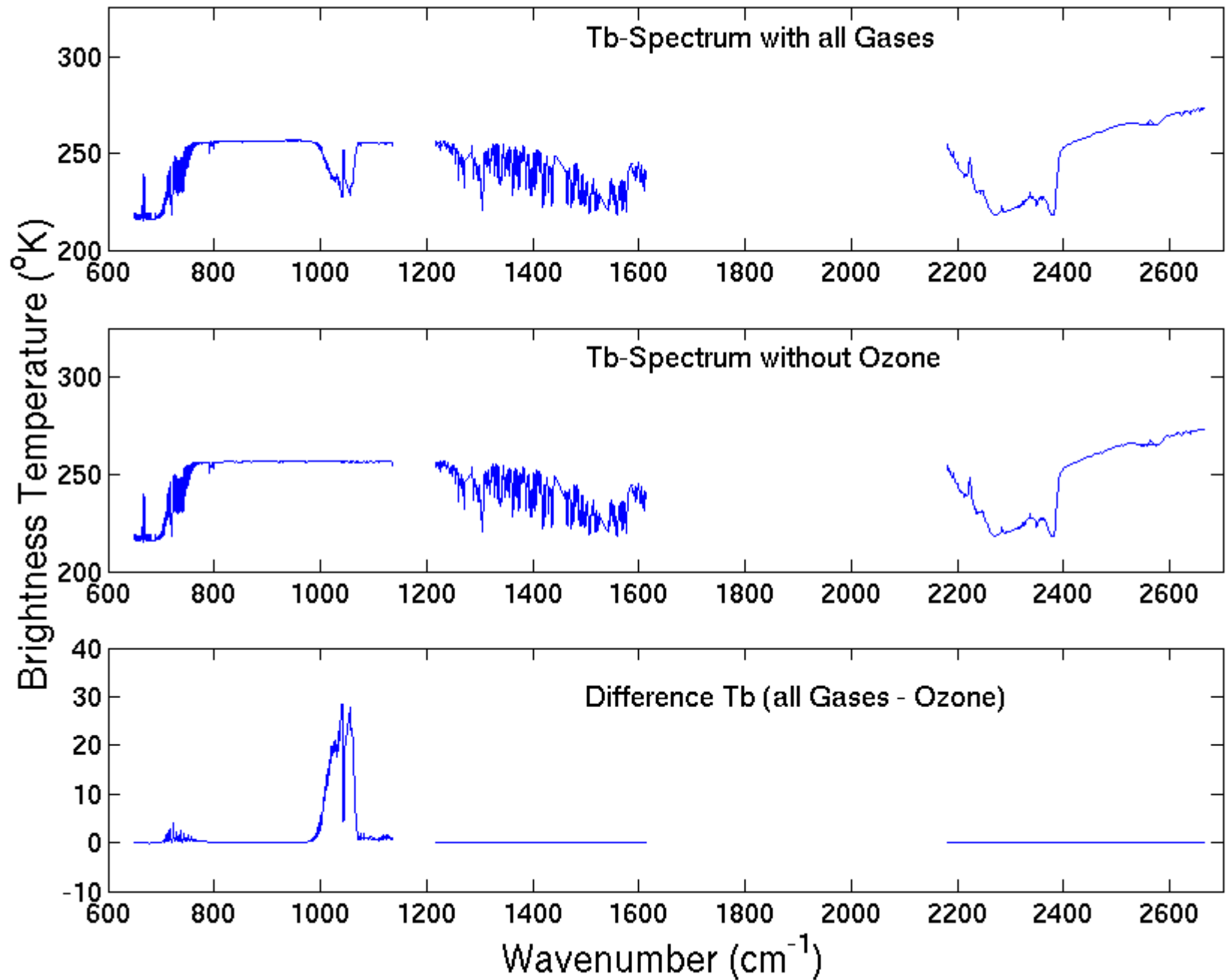
Sub-Arctic Winter Atmosphere - Sensitivity to CO2 Gas



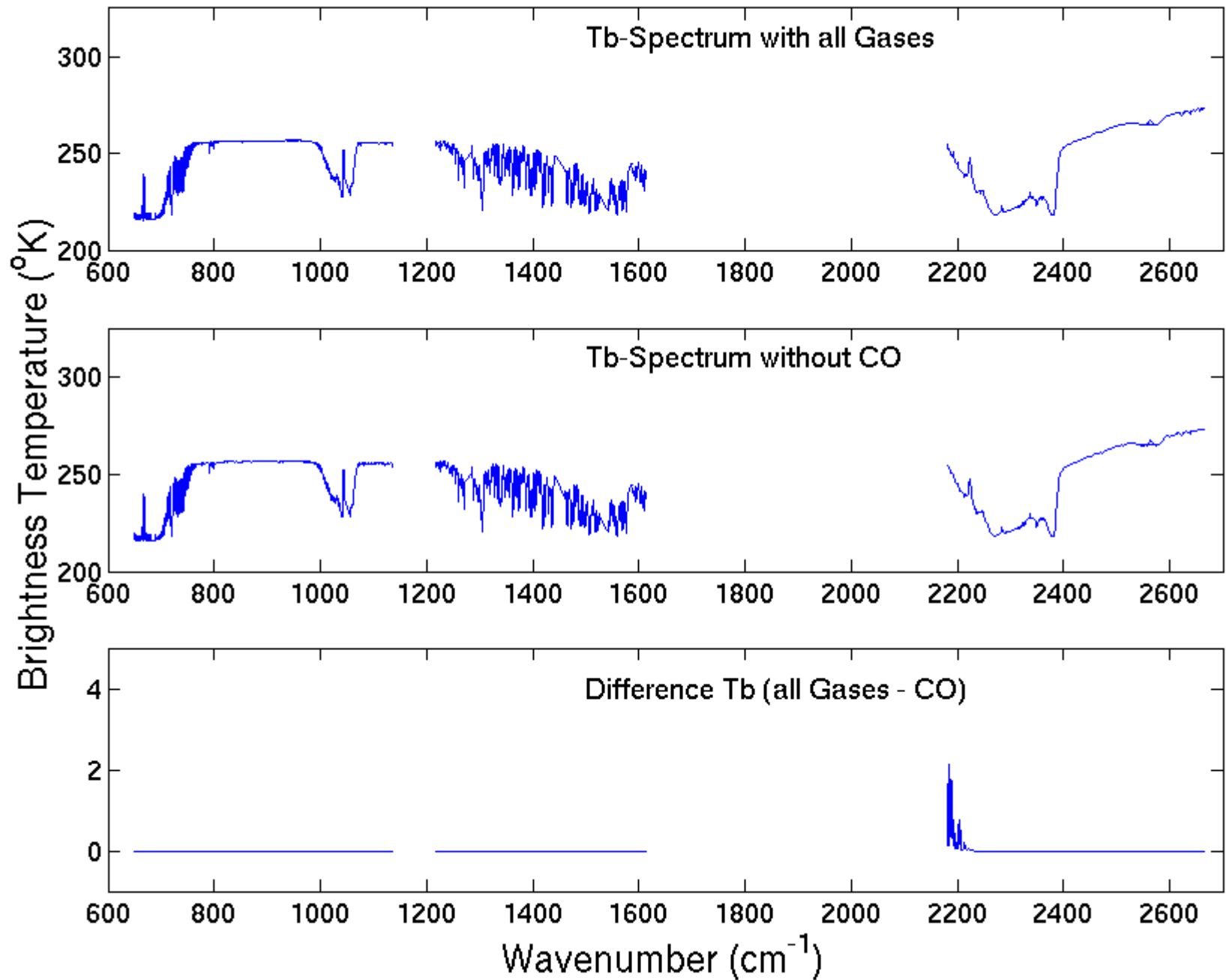
Sub-Arctic Winter Atmosphere - Sensitivity to Water Vapor



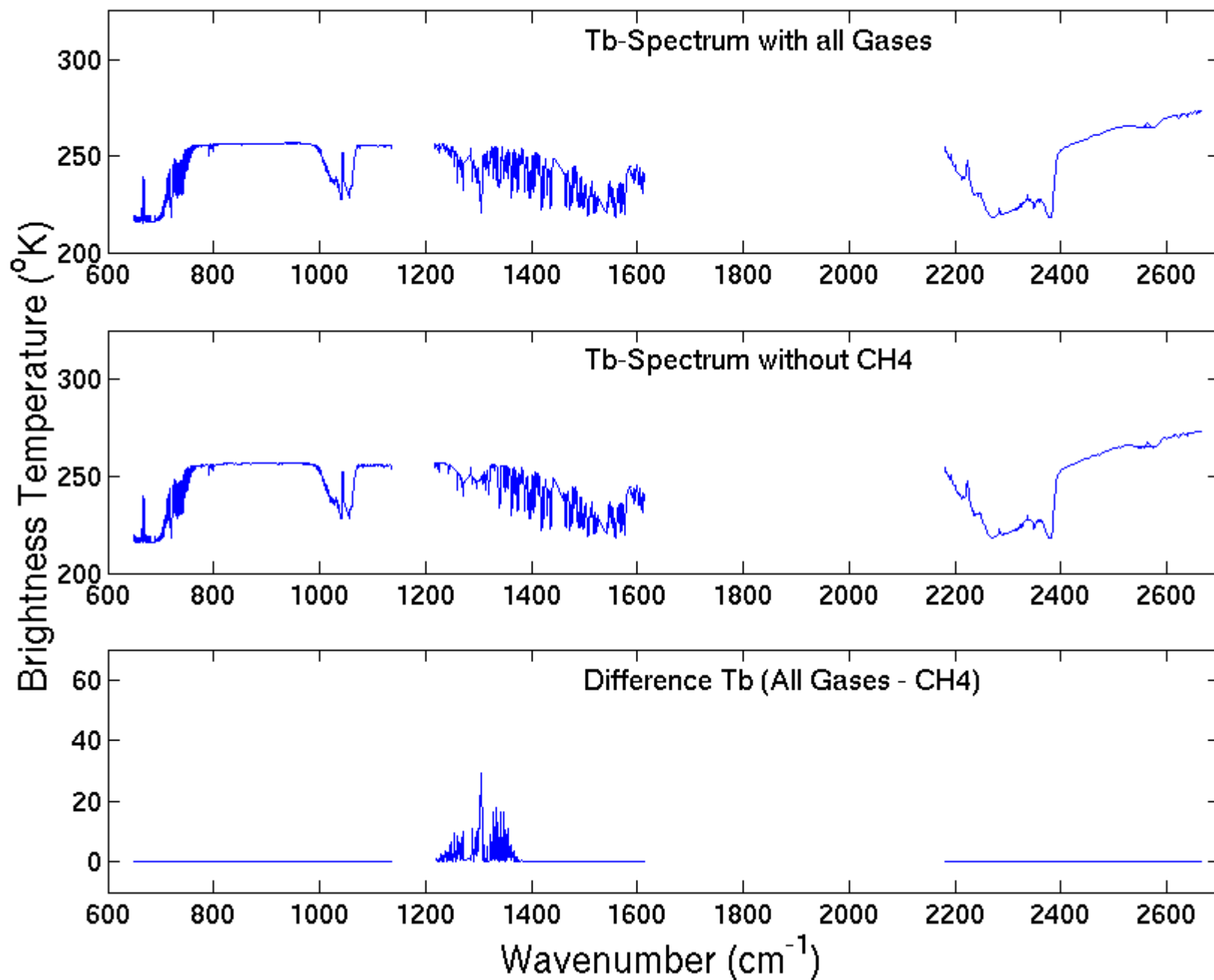
Sub-Arctic Winter Atmosphere - Sensitivity to Ozone



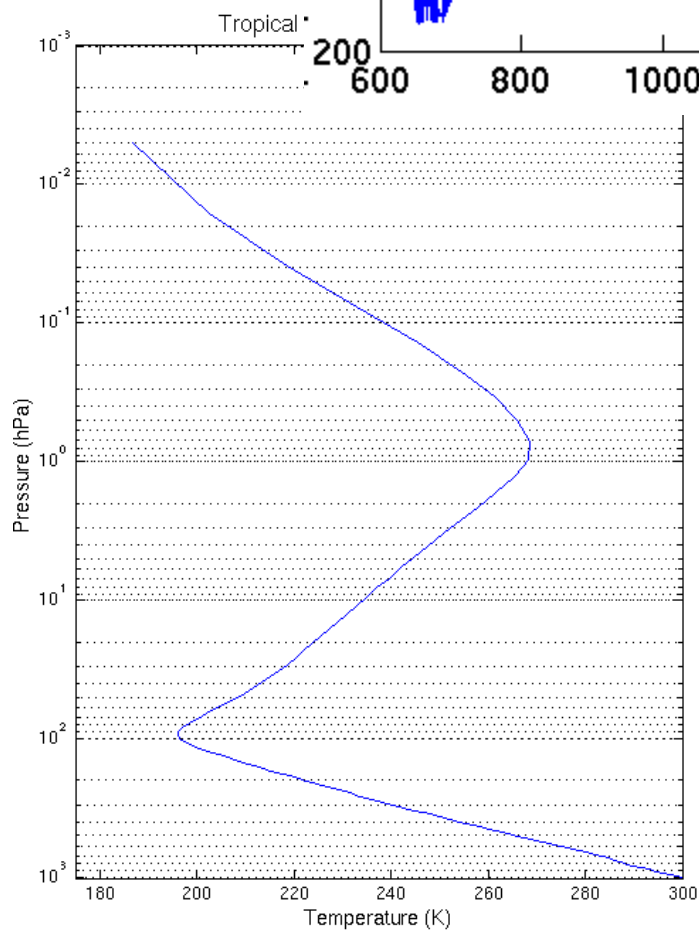
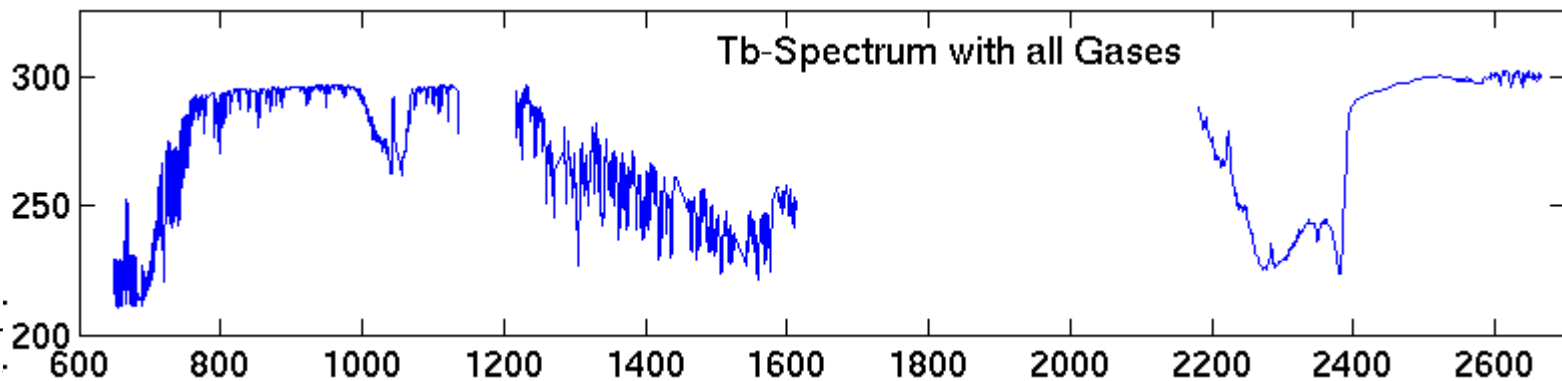
Sub-Arctic Winter Atmosphere - Sensitivity to CO Gas



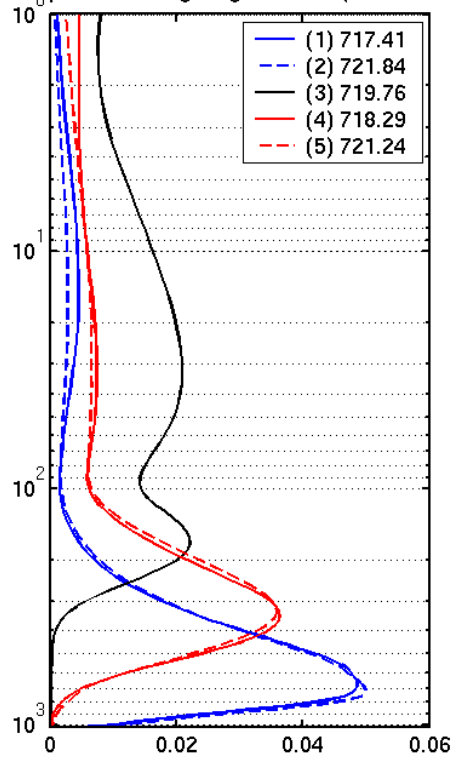
Sub-Arctic Winter Atmosphere - Sensitivity to CH4 Gas



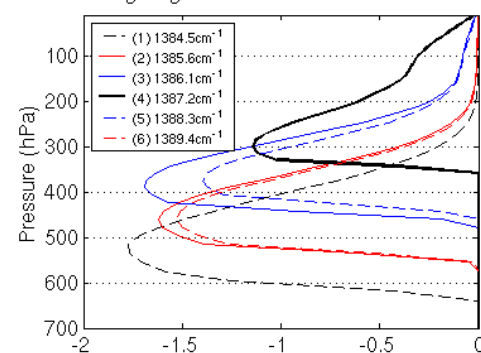
Infrared Spectral Sounding Profile Sensitivities



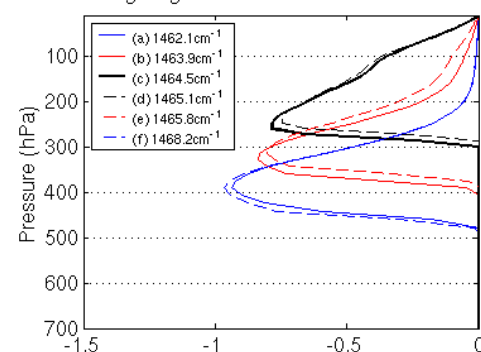
Temperature Weighting Function (719.76 cm⁻¹)



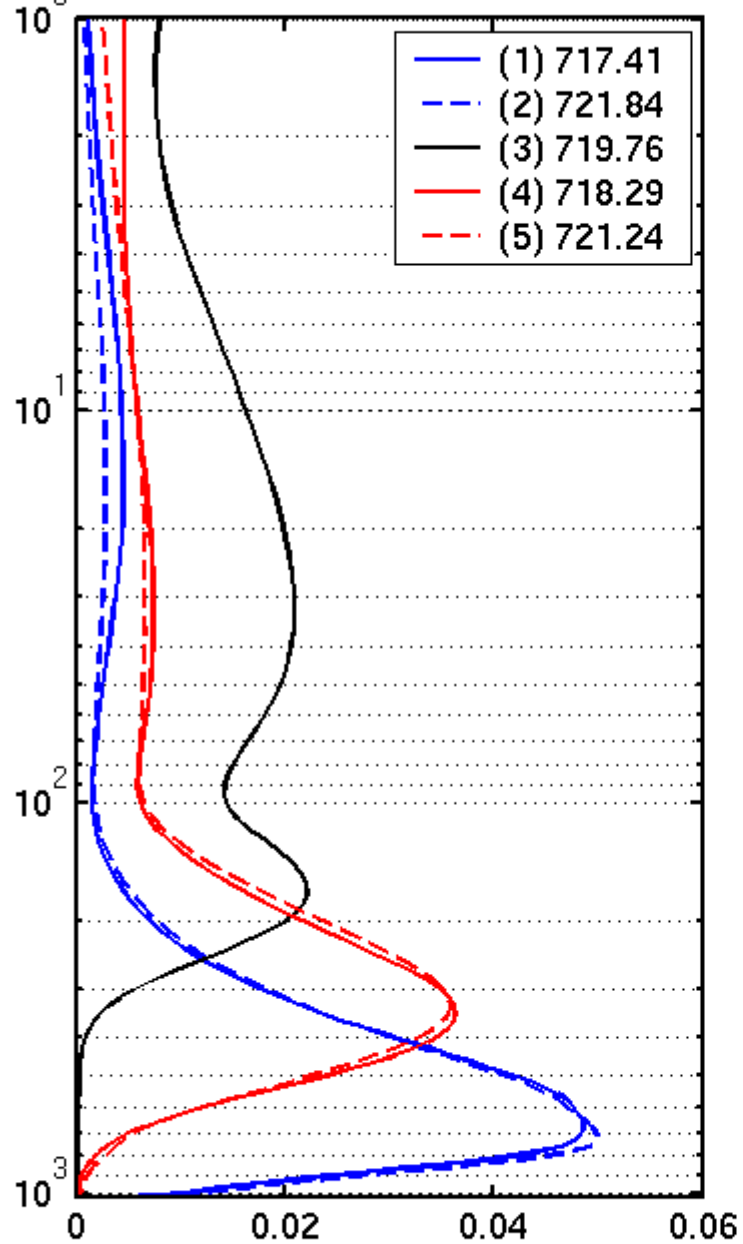
H₂O Weighting Function AIRS Channels : 1387cm⁻¹



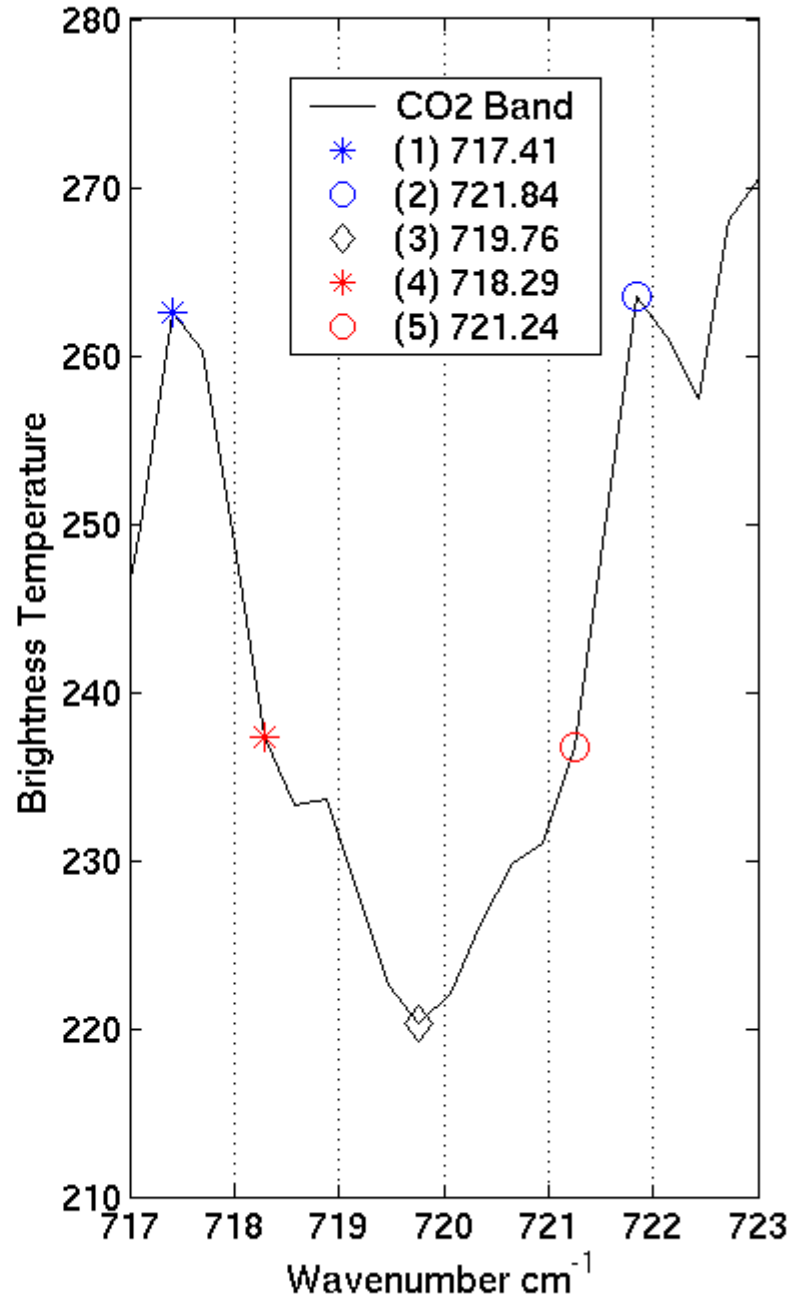
H₂O Weighting Function AIRS Channels : 1465cm⁻¹



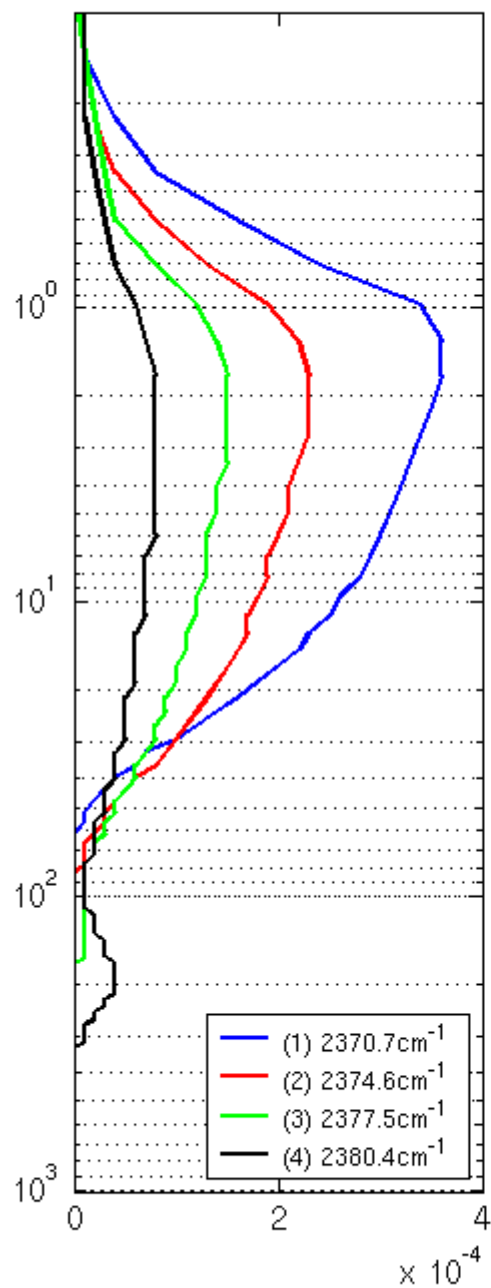
Temperature Weighting Function (719.76 cm^{-1})



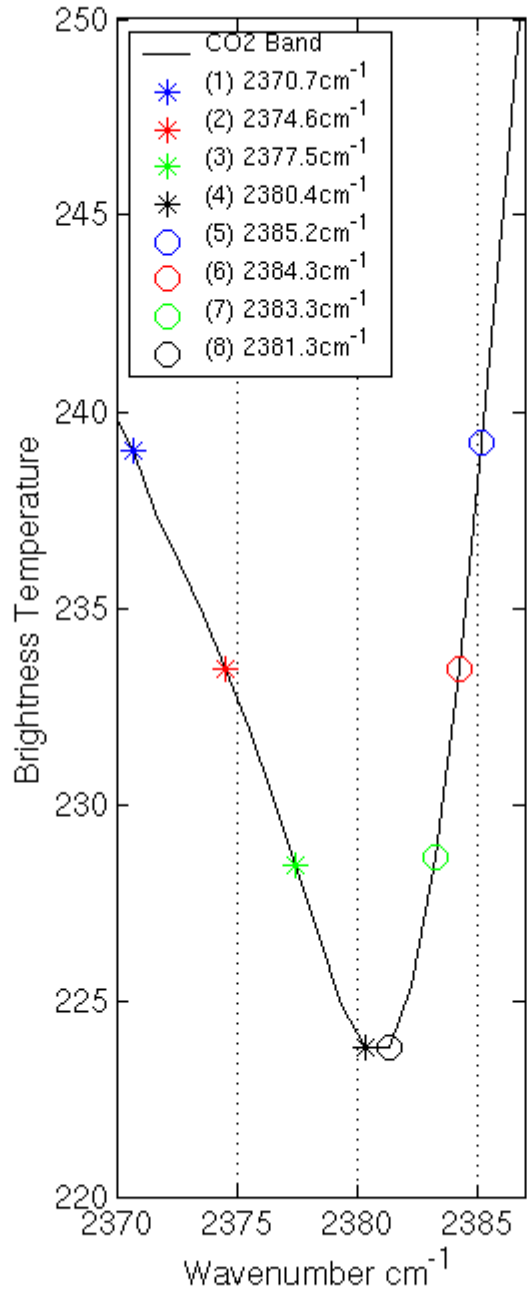
CO2 Absorption line at 719.76 Cm^{-1}



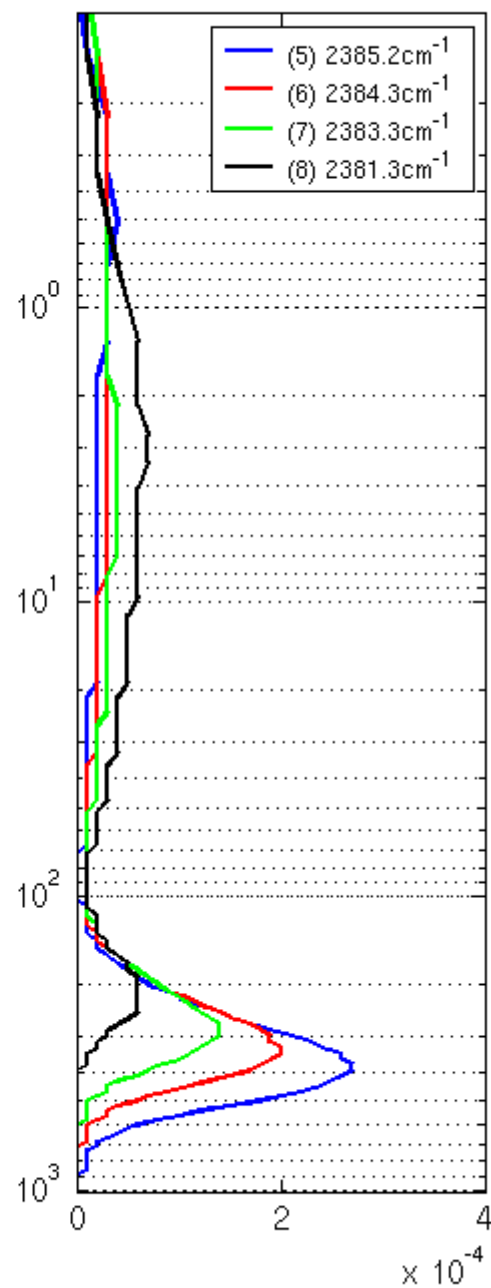
Temperature Weighting Function

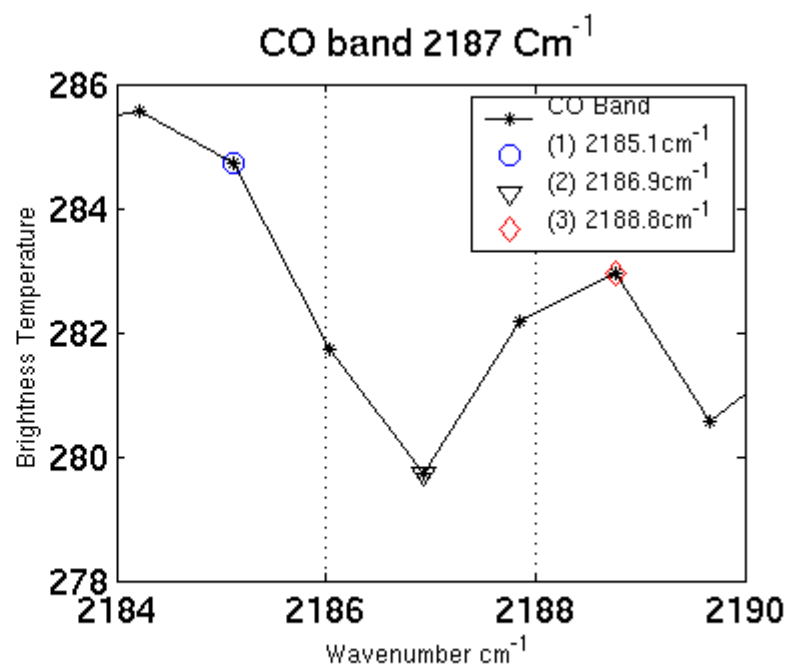
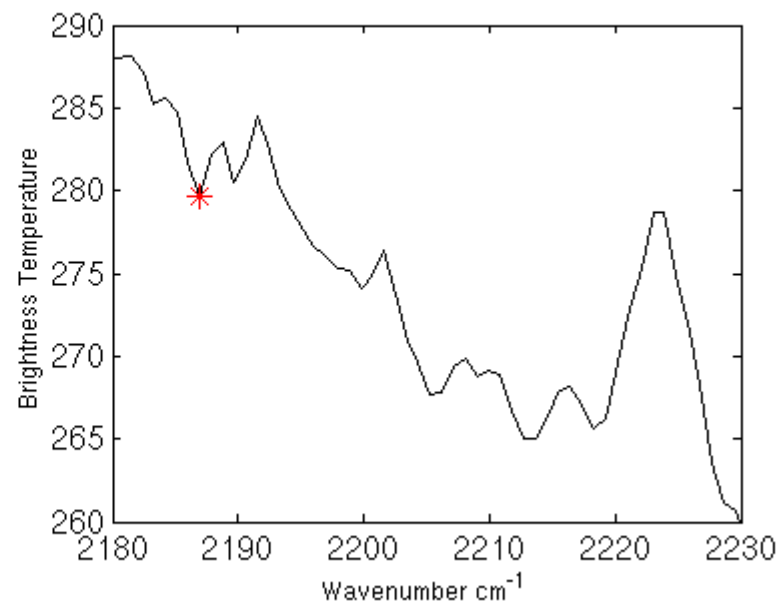
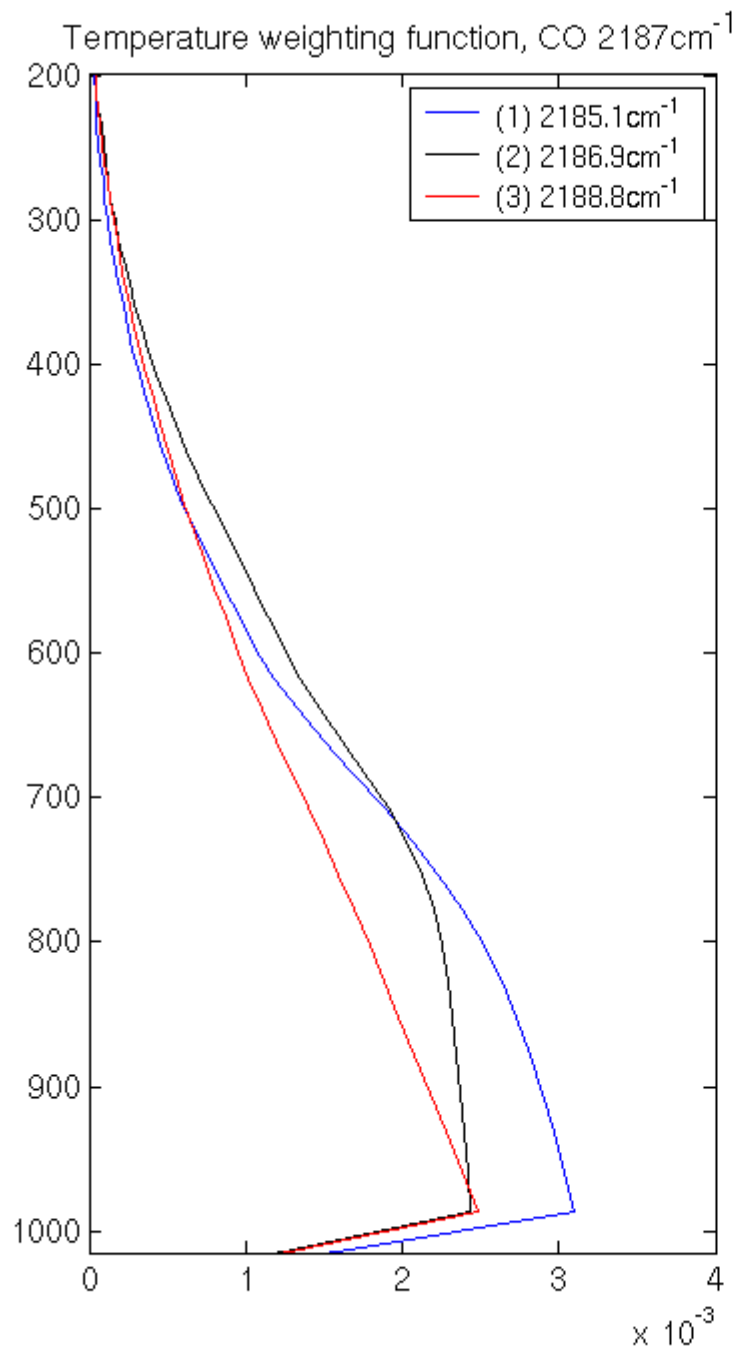


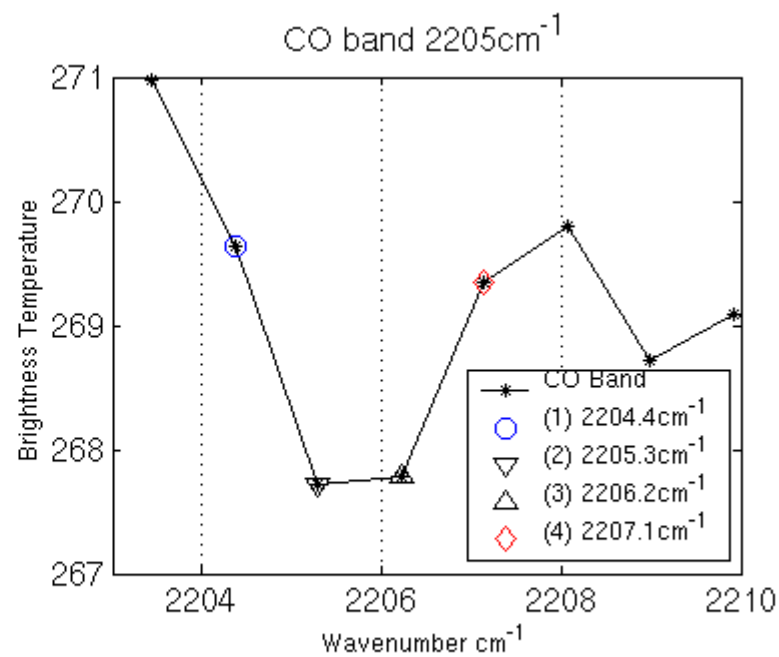
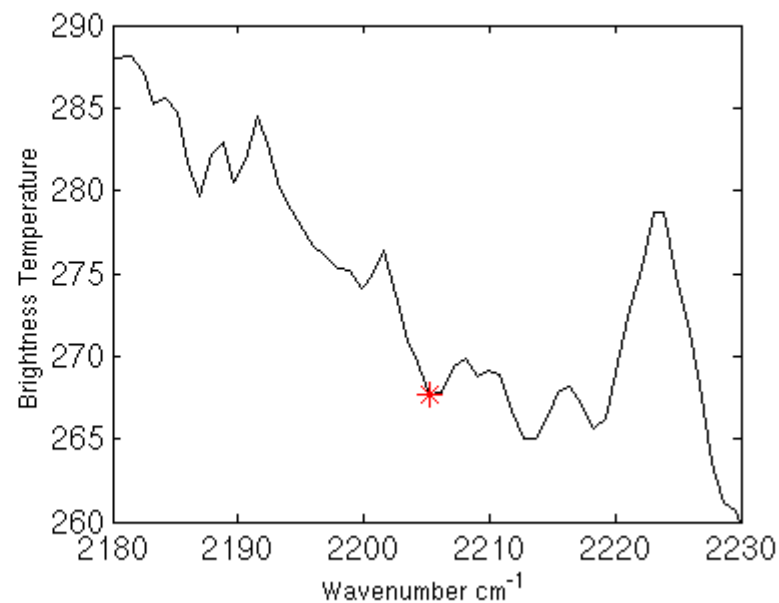
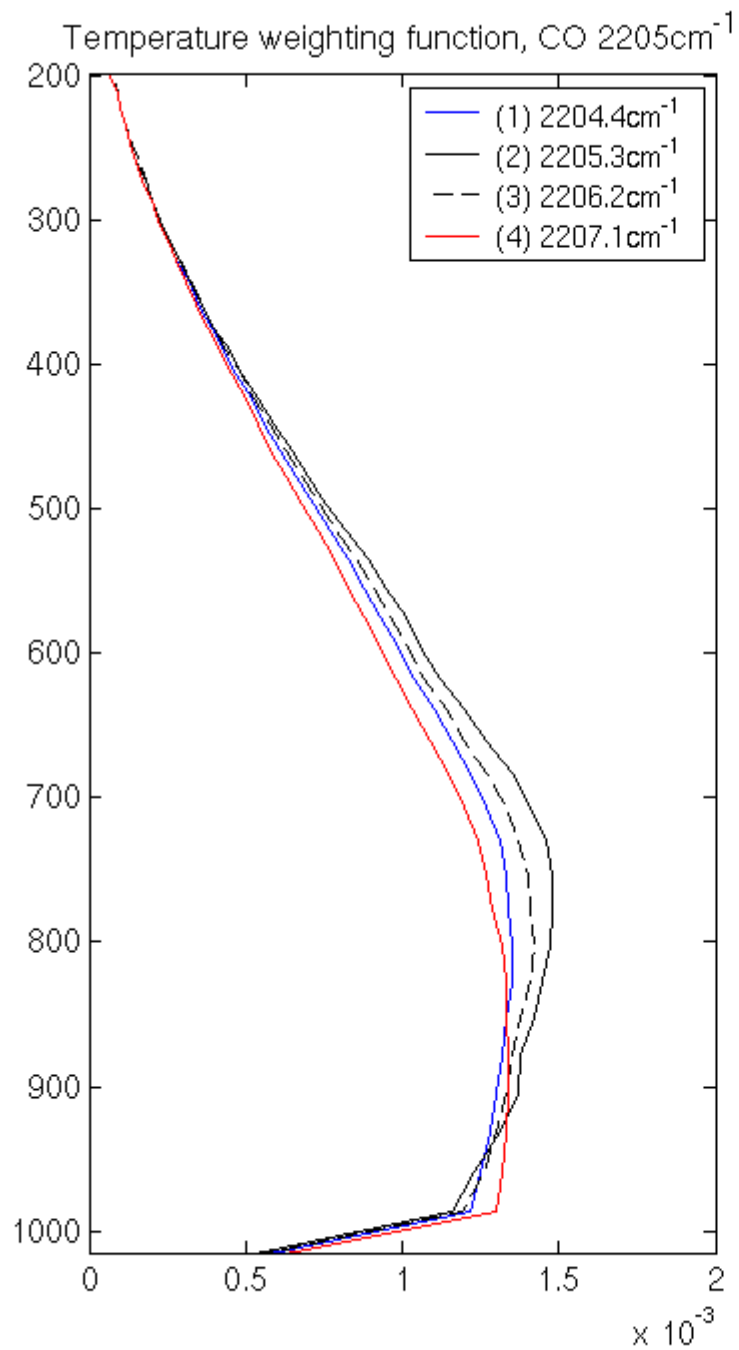
CO2 band at 2380 cm^{-1}



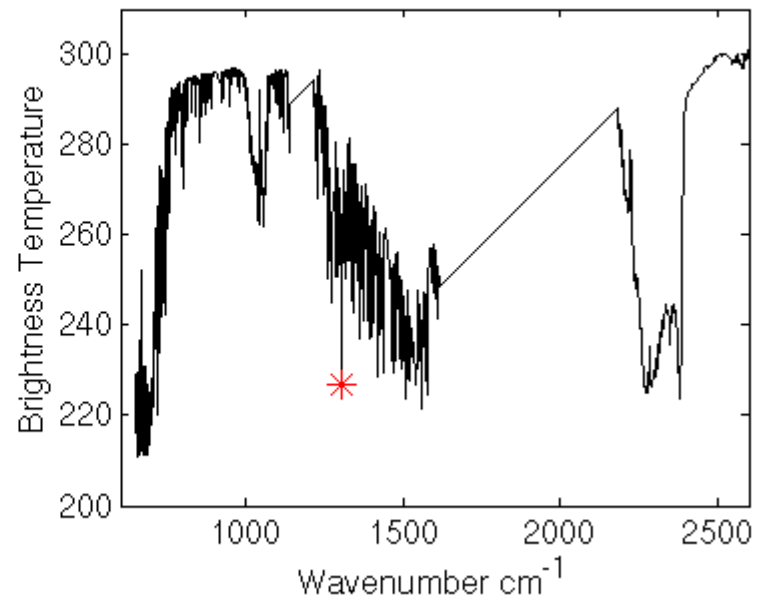
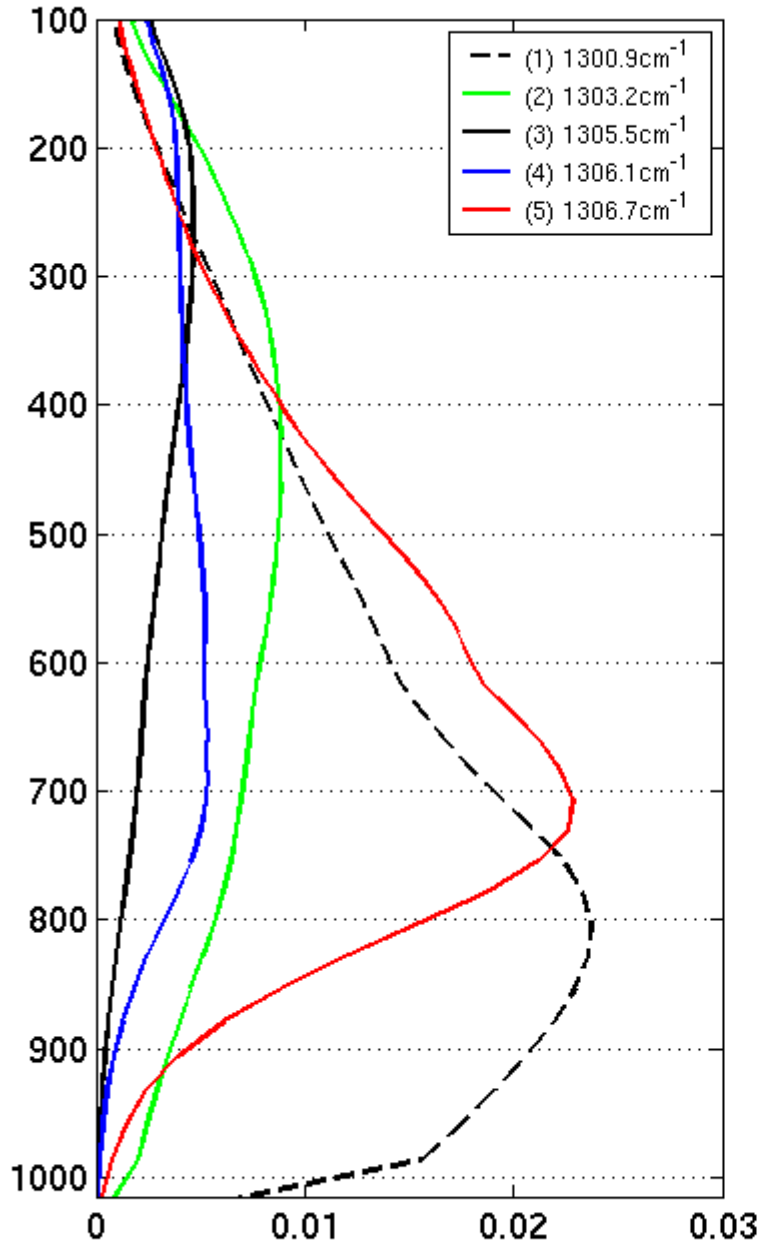
Temperature Weighting Function



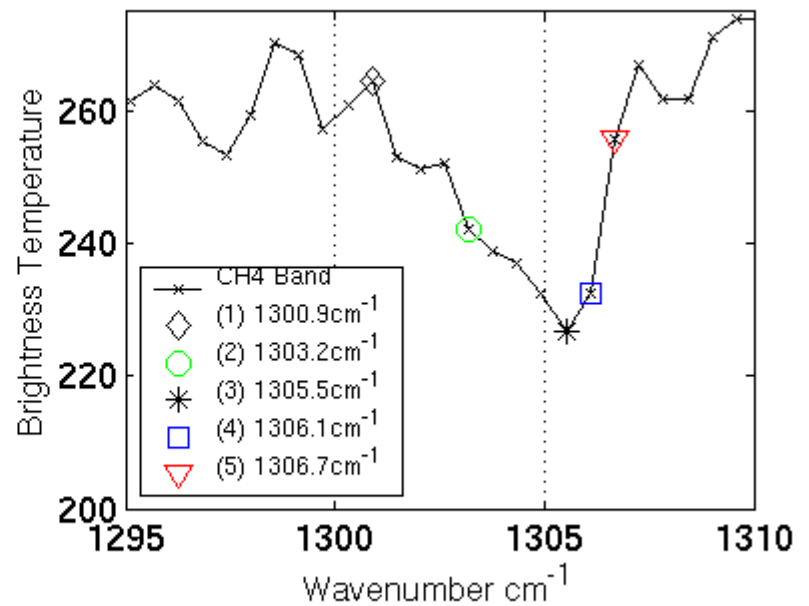




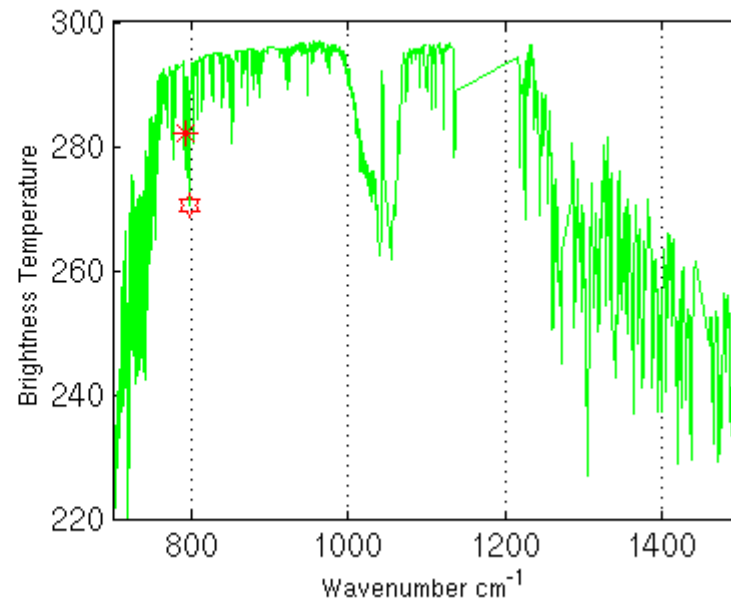
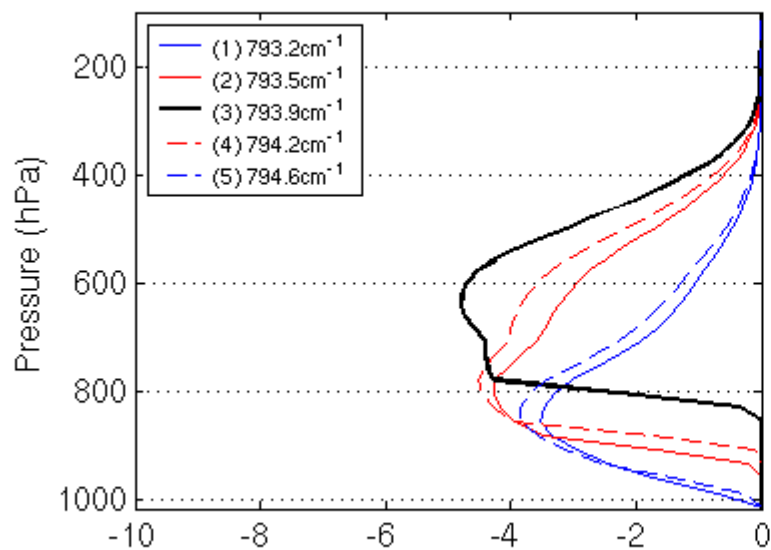
Temperature weighting function - CH4 1305.5cm⁻¹



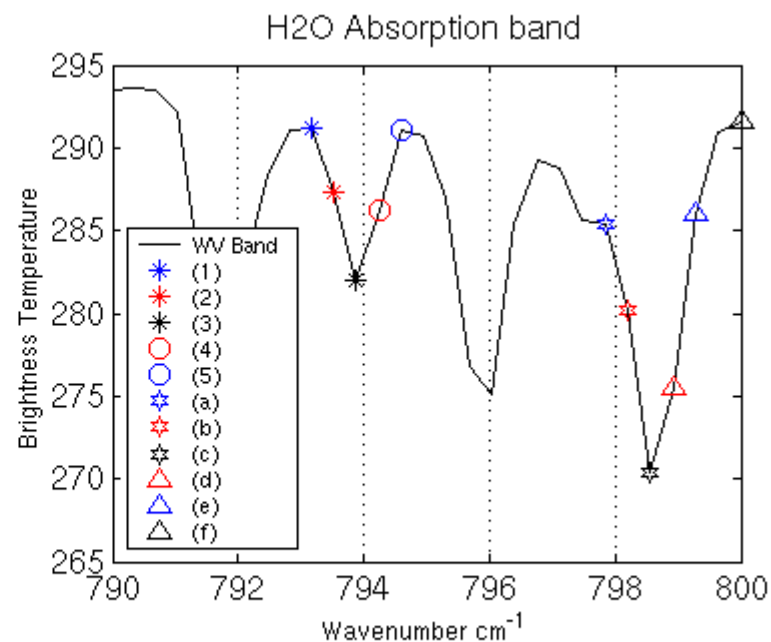
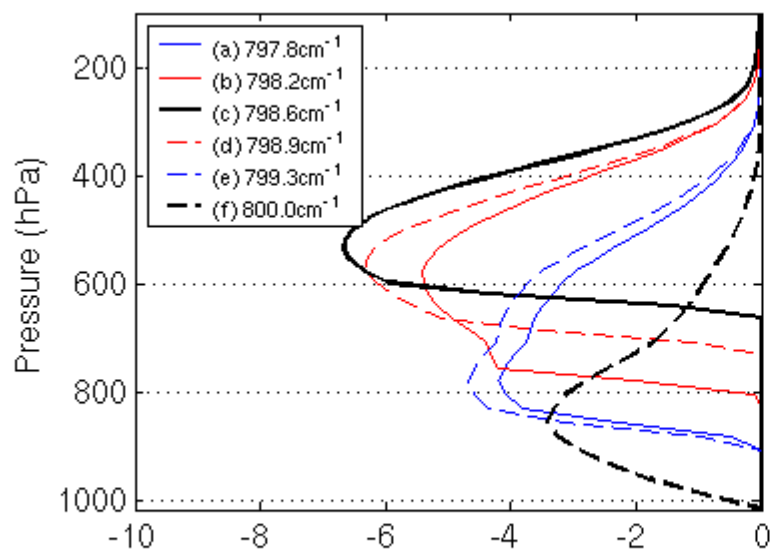
CH4 Band at 1305.5 Cm⁻¹



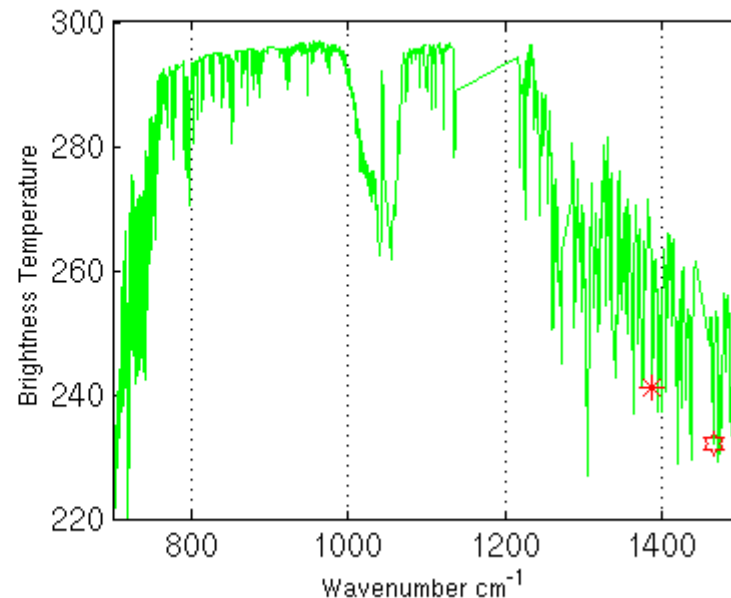
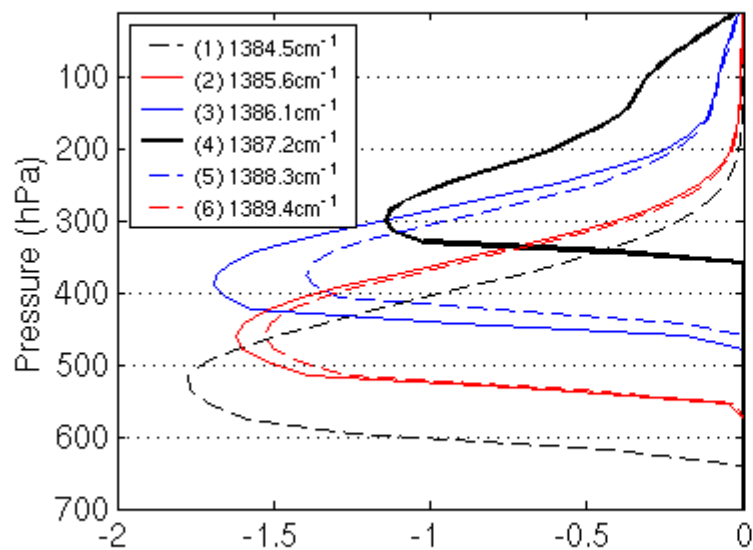
H₂O Weighting Function AIRS Channels : 794cm⁻¹



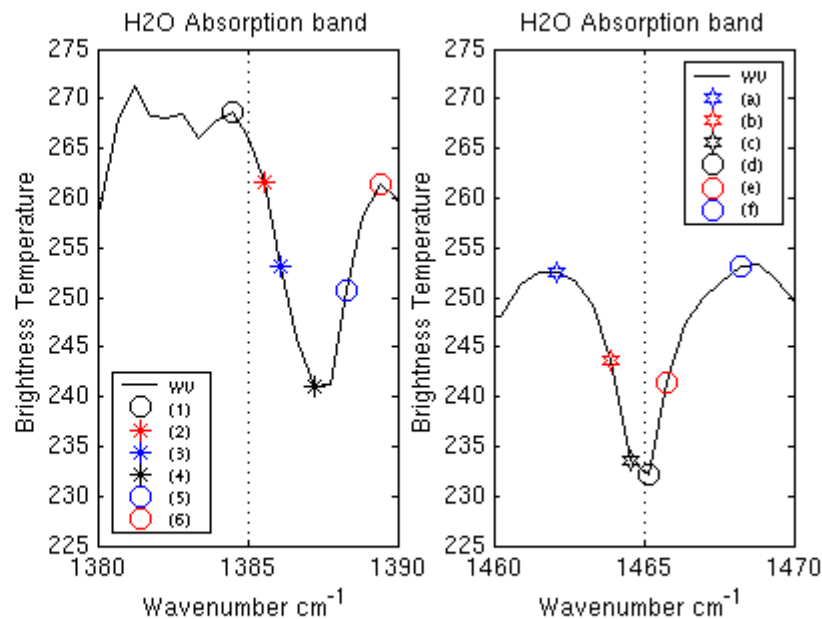
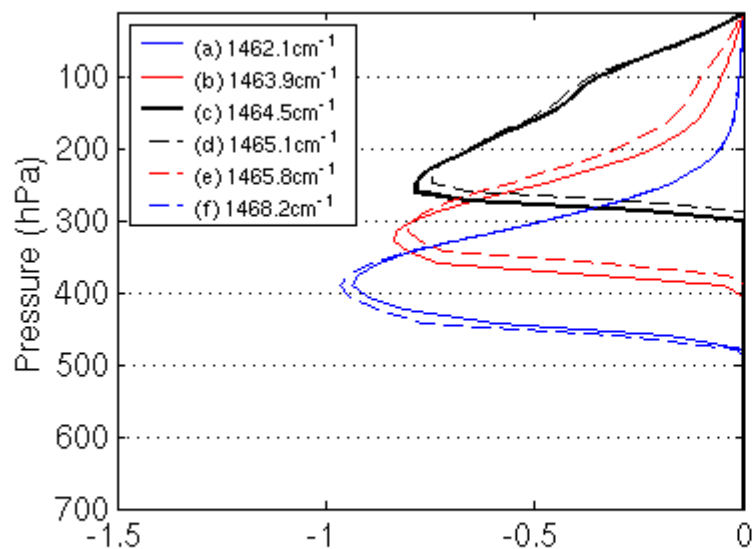
H₂O Weighting Function AIRS Channels : 799cm⁻¹

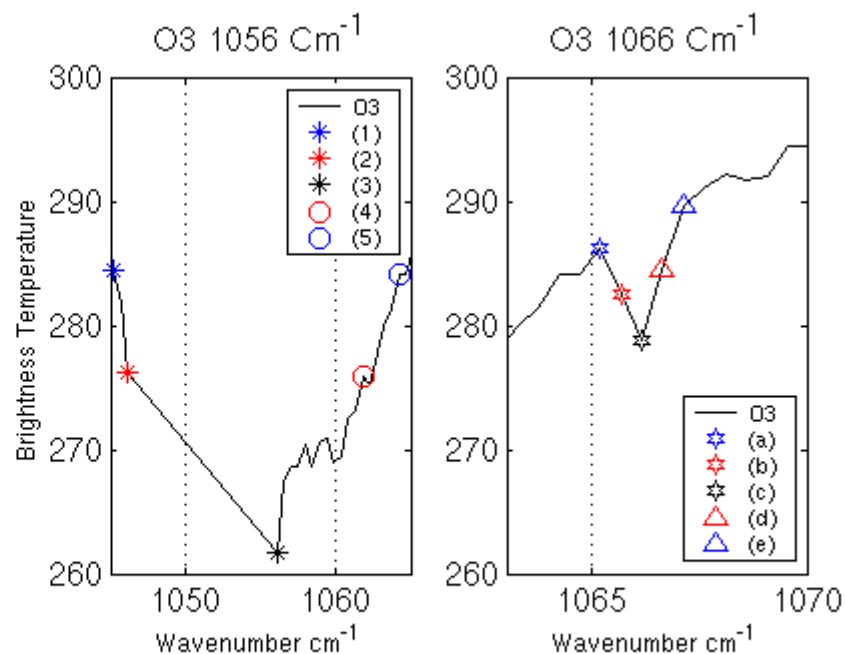
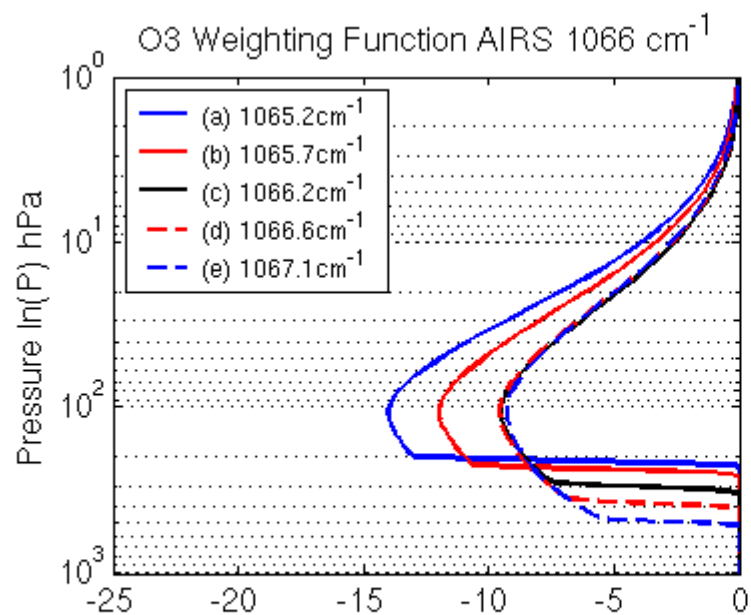
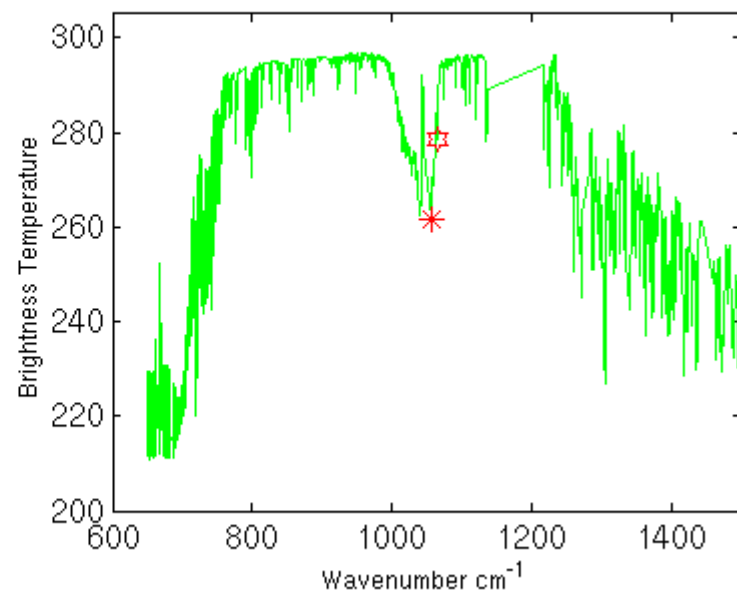
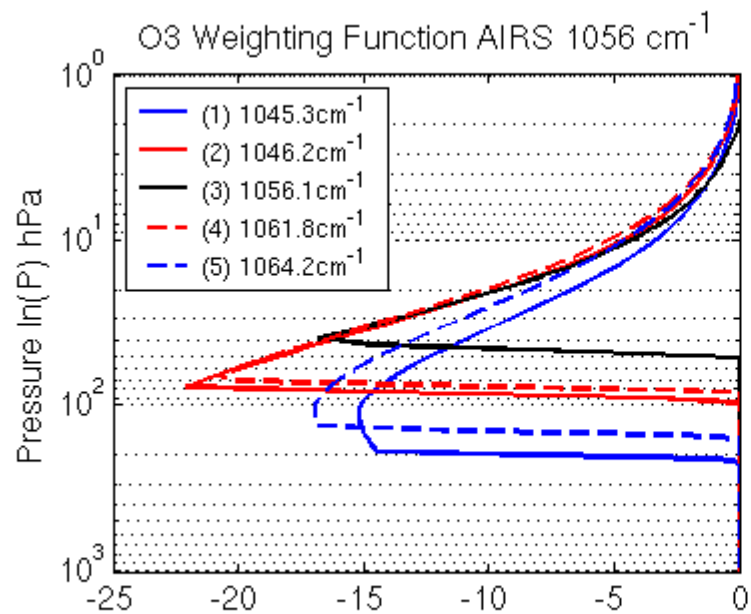


H₂O Weighting Function AIRS Channels : 1387cm⁻¹

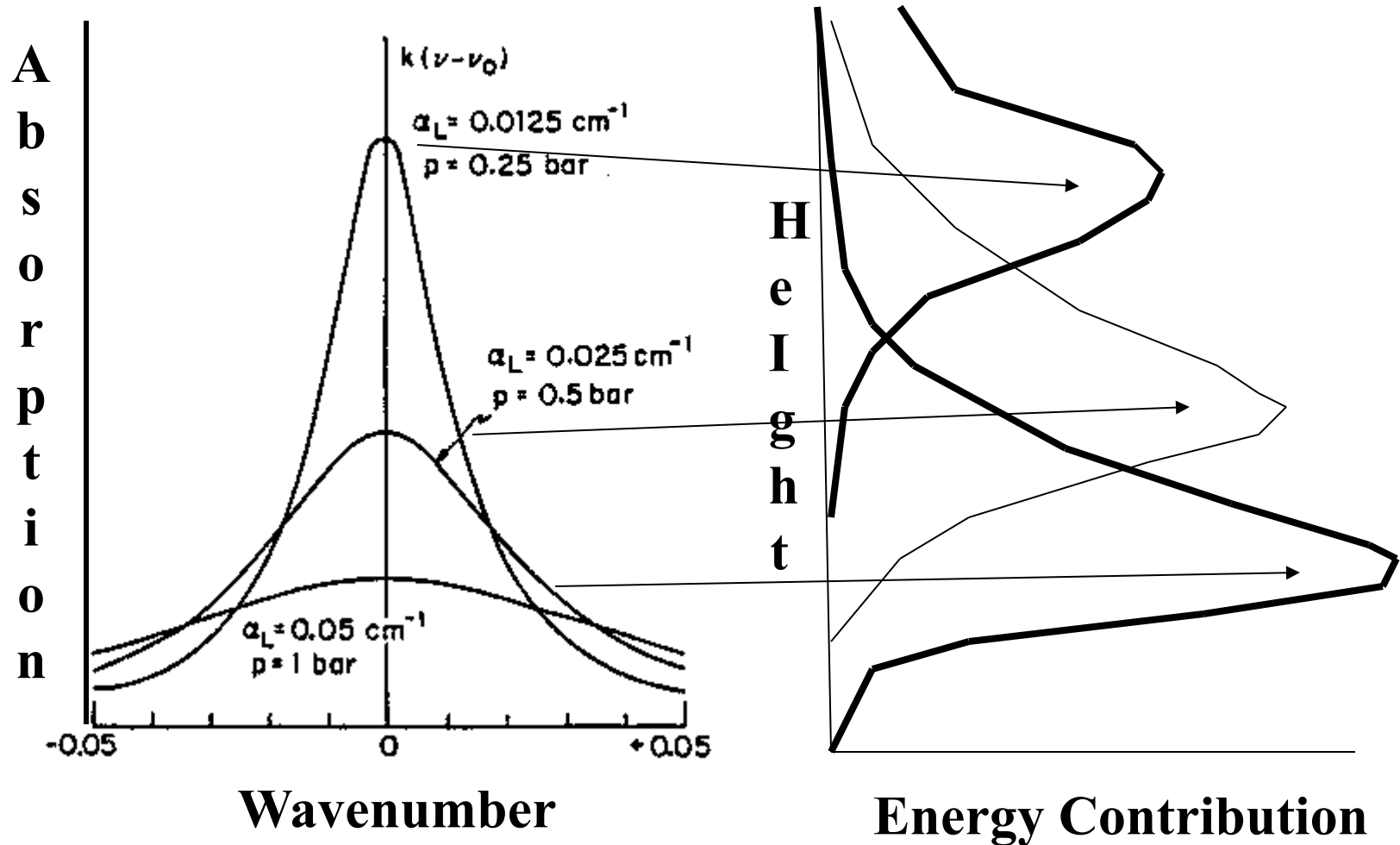


H₂O Weighting Function AIRS Channels : 1465cm⁻¹

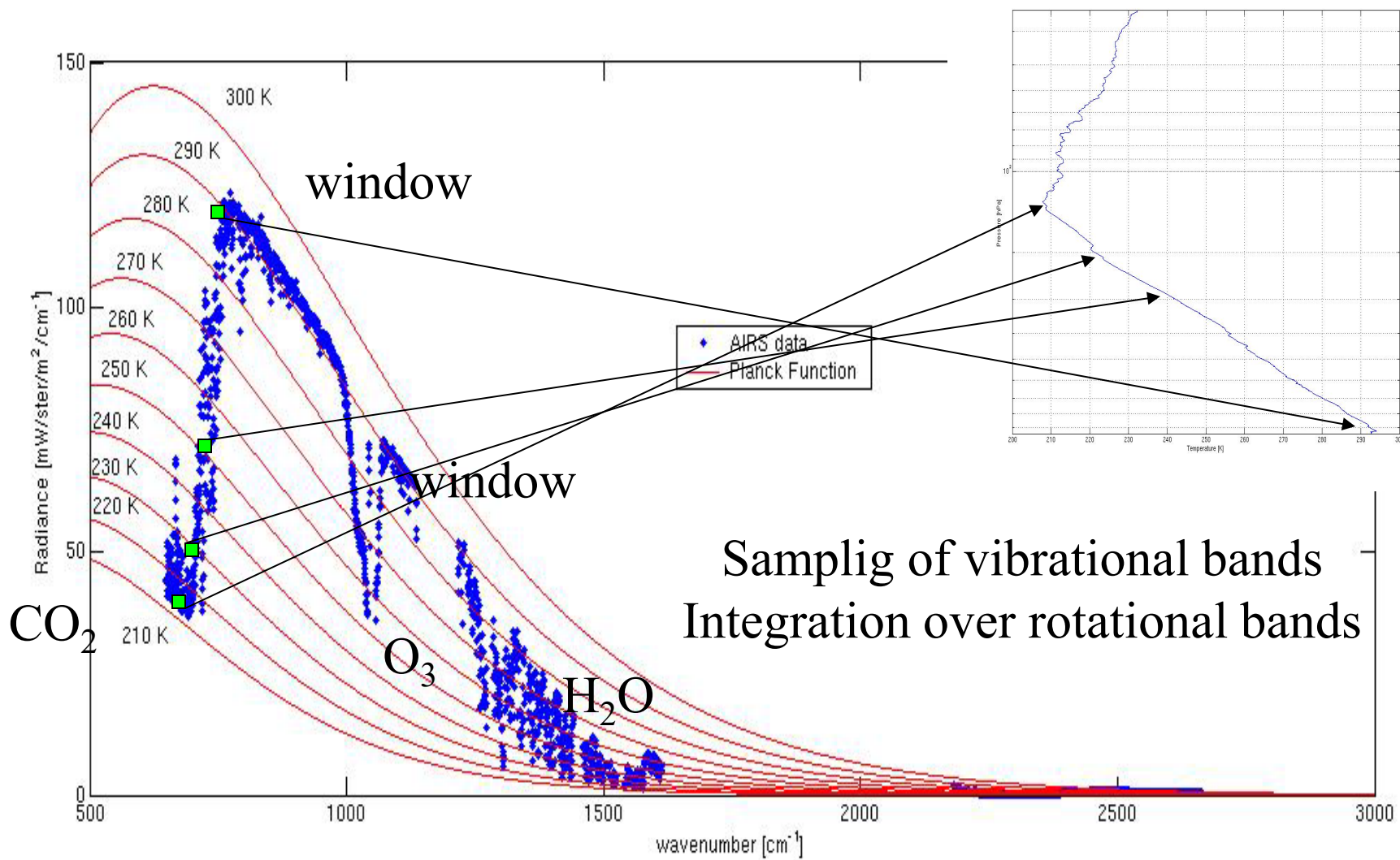




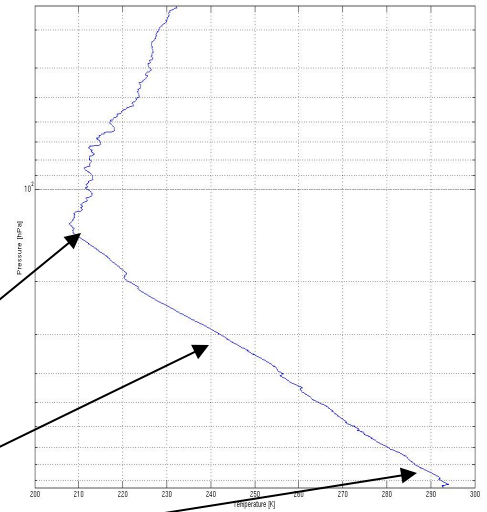
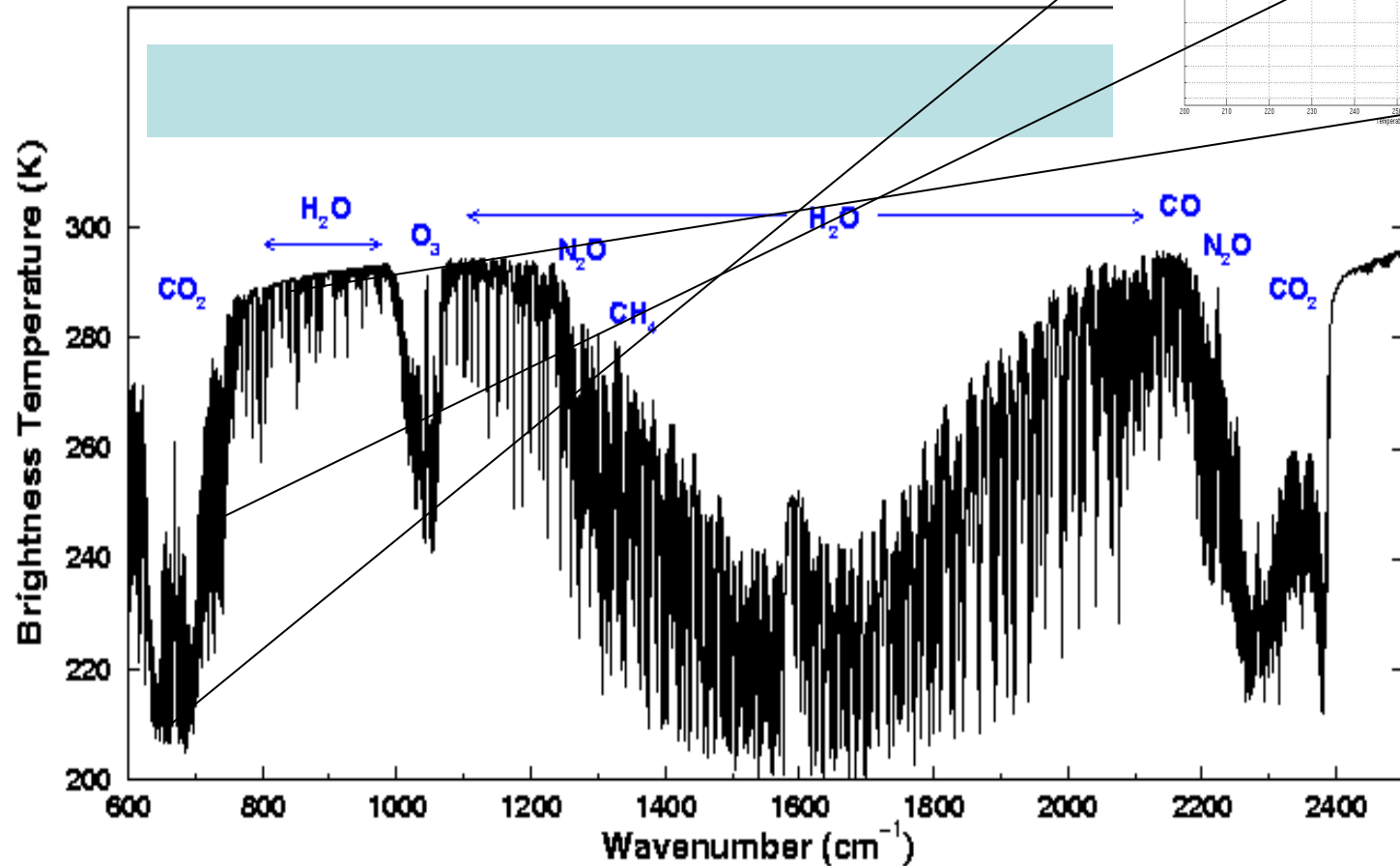
Weighting Functions



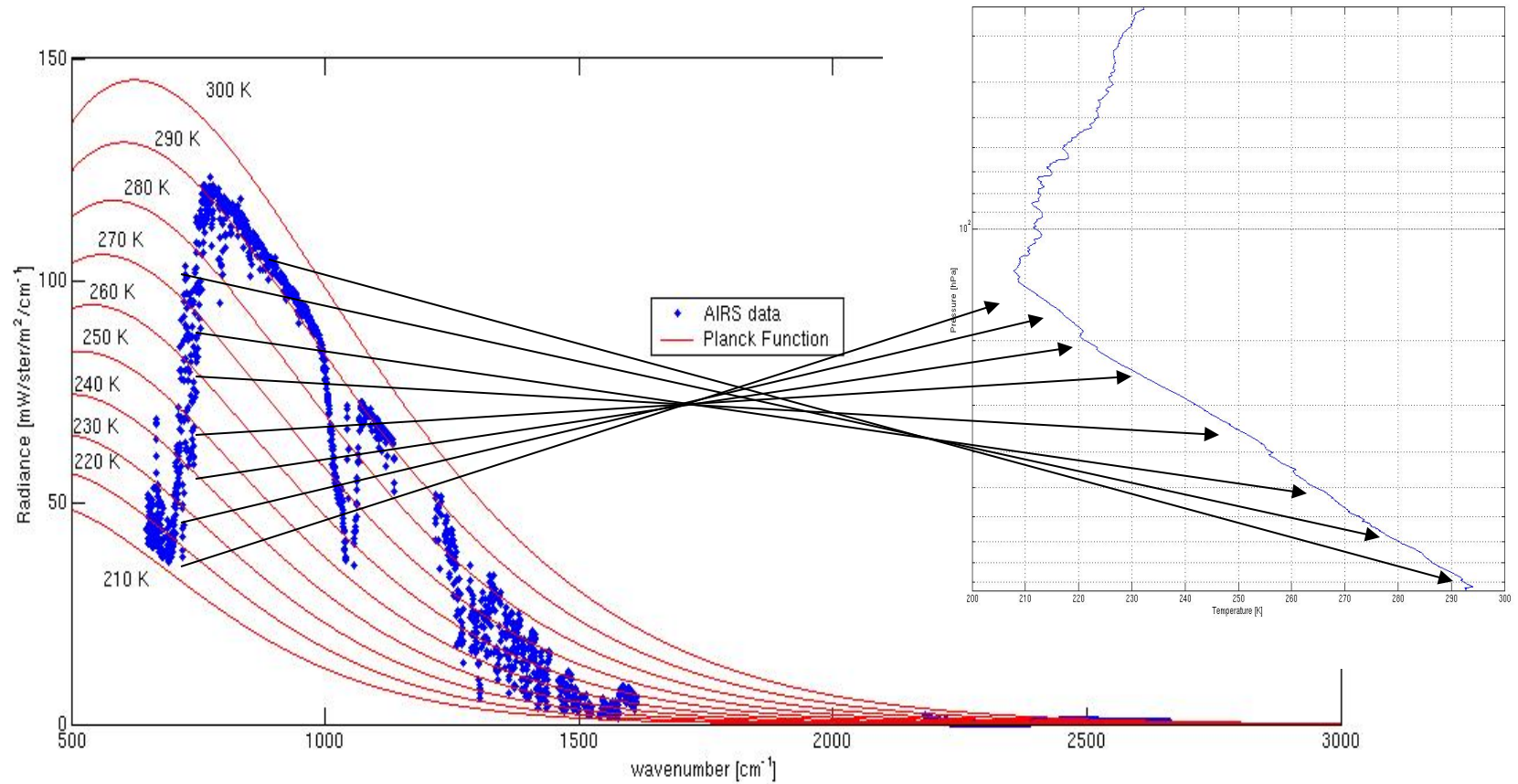
Broad Band



... in Brightness Temperature

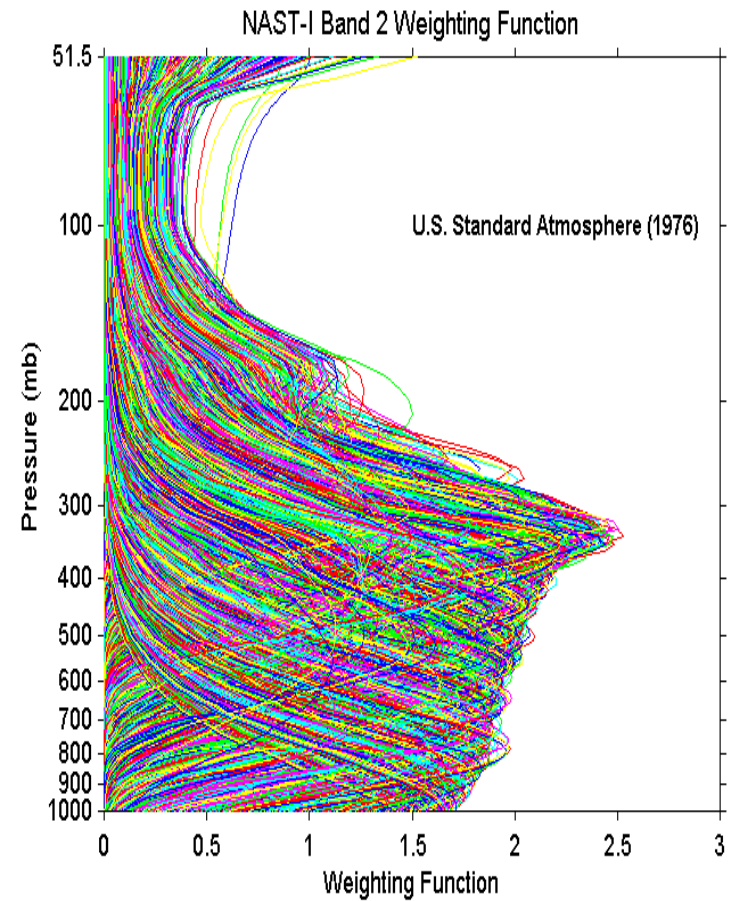
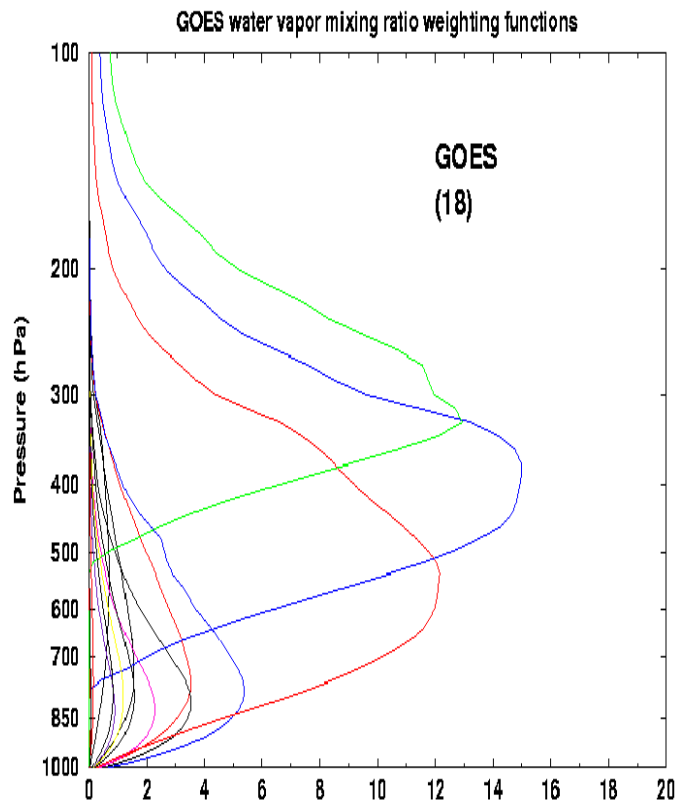


High Spectral Resolution

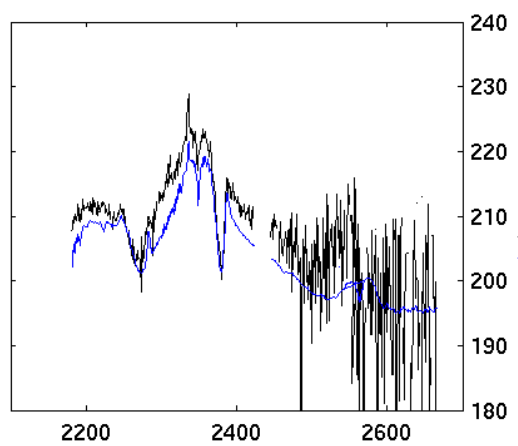
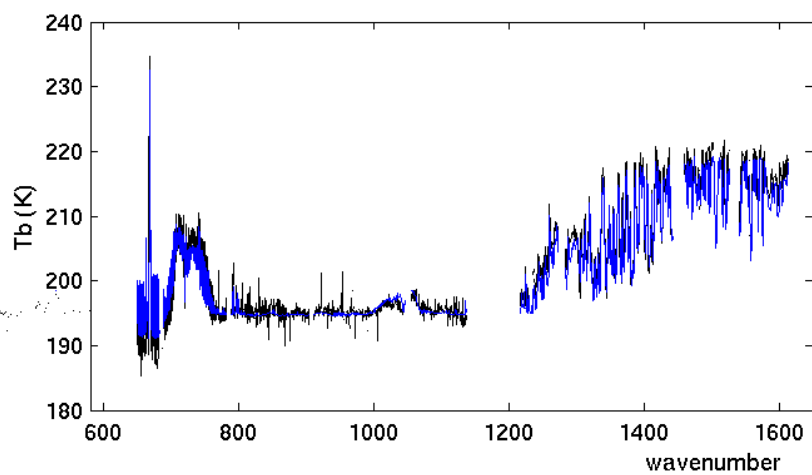
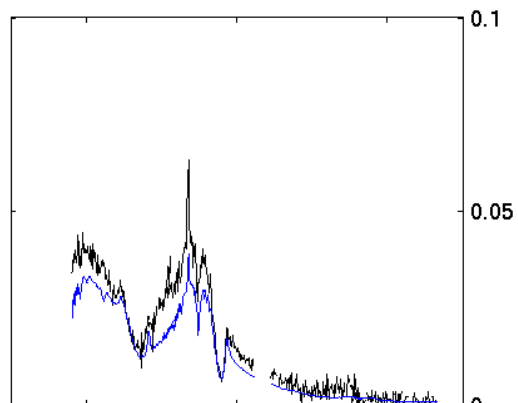
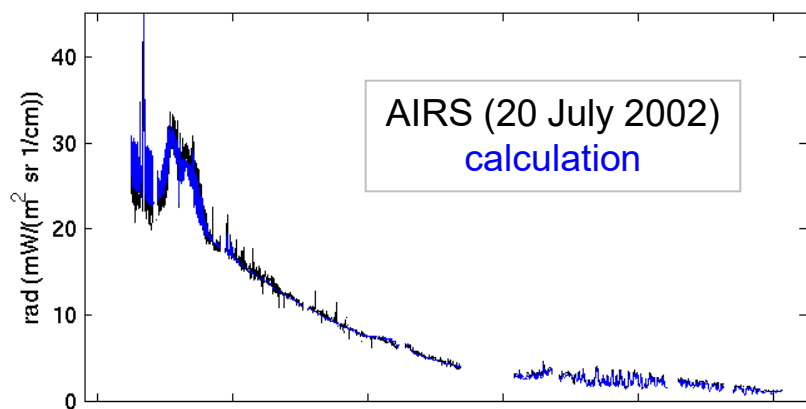
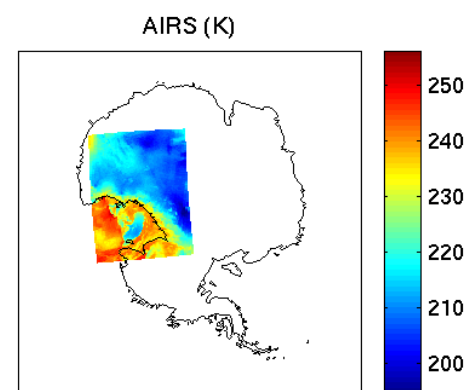


Sampling over rotational bands

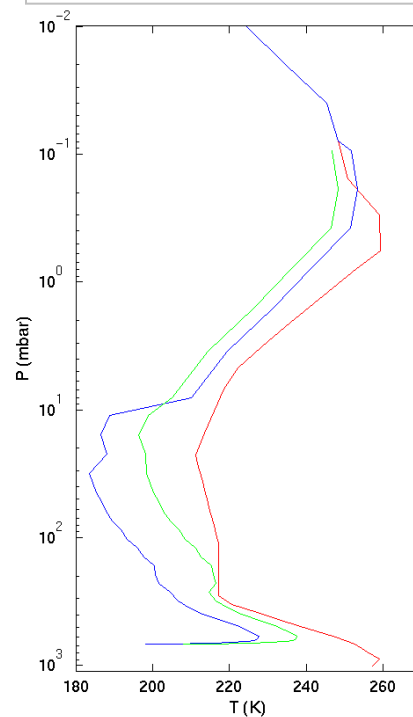
Broad Band vs High Spectral



Temperature Inversions

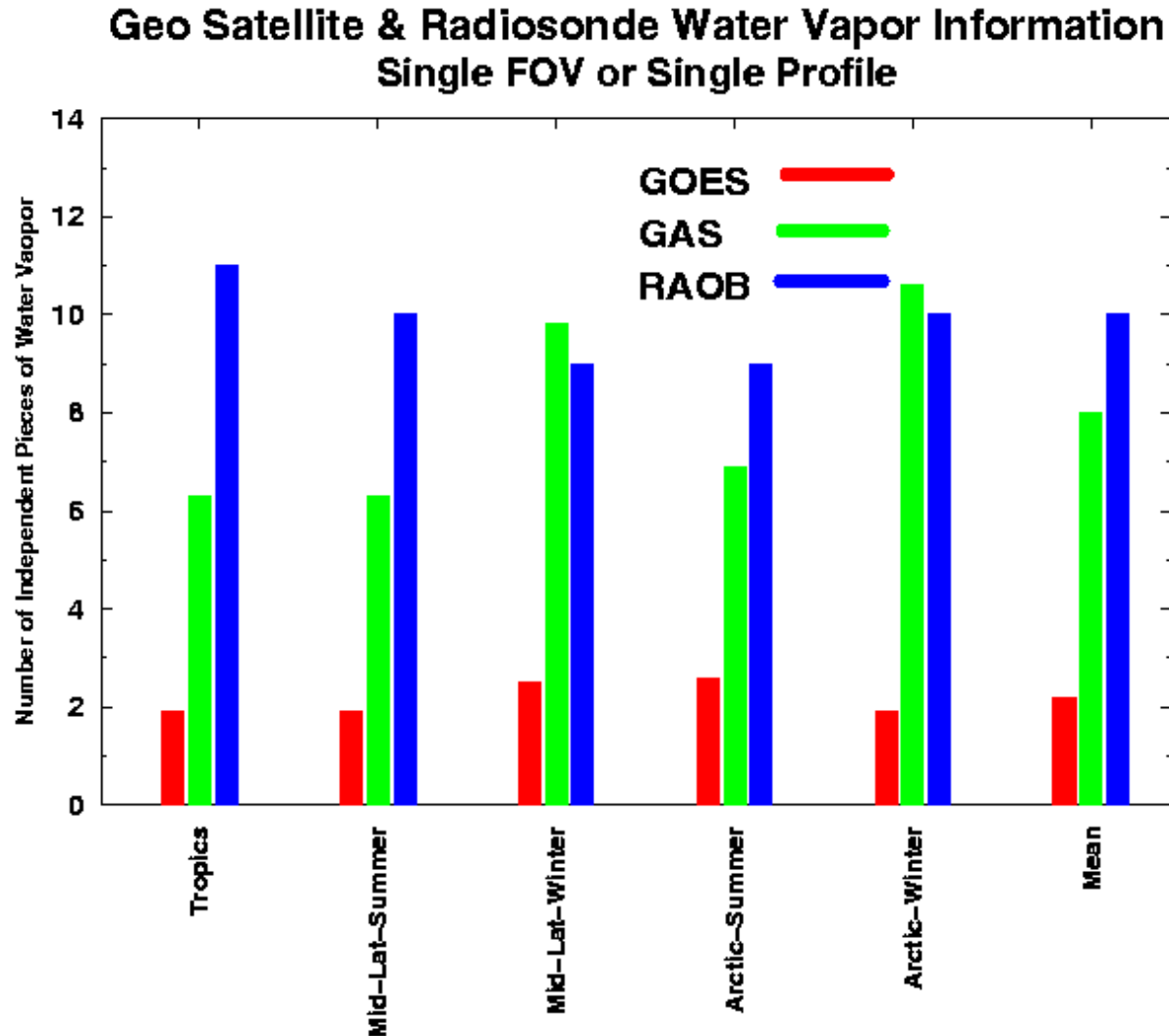


Sub-Arctic Winter
May 2001 S. Pole radiosonde
profile used in calculation
(0.365 mm H₂O)



Summary (1/2)

❖ Hyperspectral Sounder provides much improved atmospheric information content: **Water Vapor (Temp.)**



Summary (2/2)

❖ **Hyperspectral Sounder provides information to detect:**

- **Trace Gases (i.e. O₃; CO; CH₄; SO₂; N₂O...)**
- **Cloud property (phase, size, optical thickness, concentration**)
- **Surface Property/type**
- **Highly accurate radiances for climate study**
- **Validate IR broad band satellite measurements**