Remote Measurements of Greenhouse Gases Under Cloud With The AERI FTS Instrument

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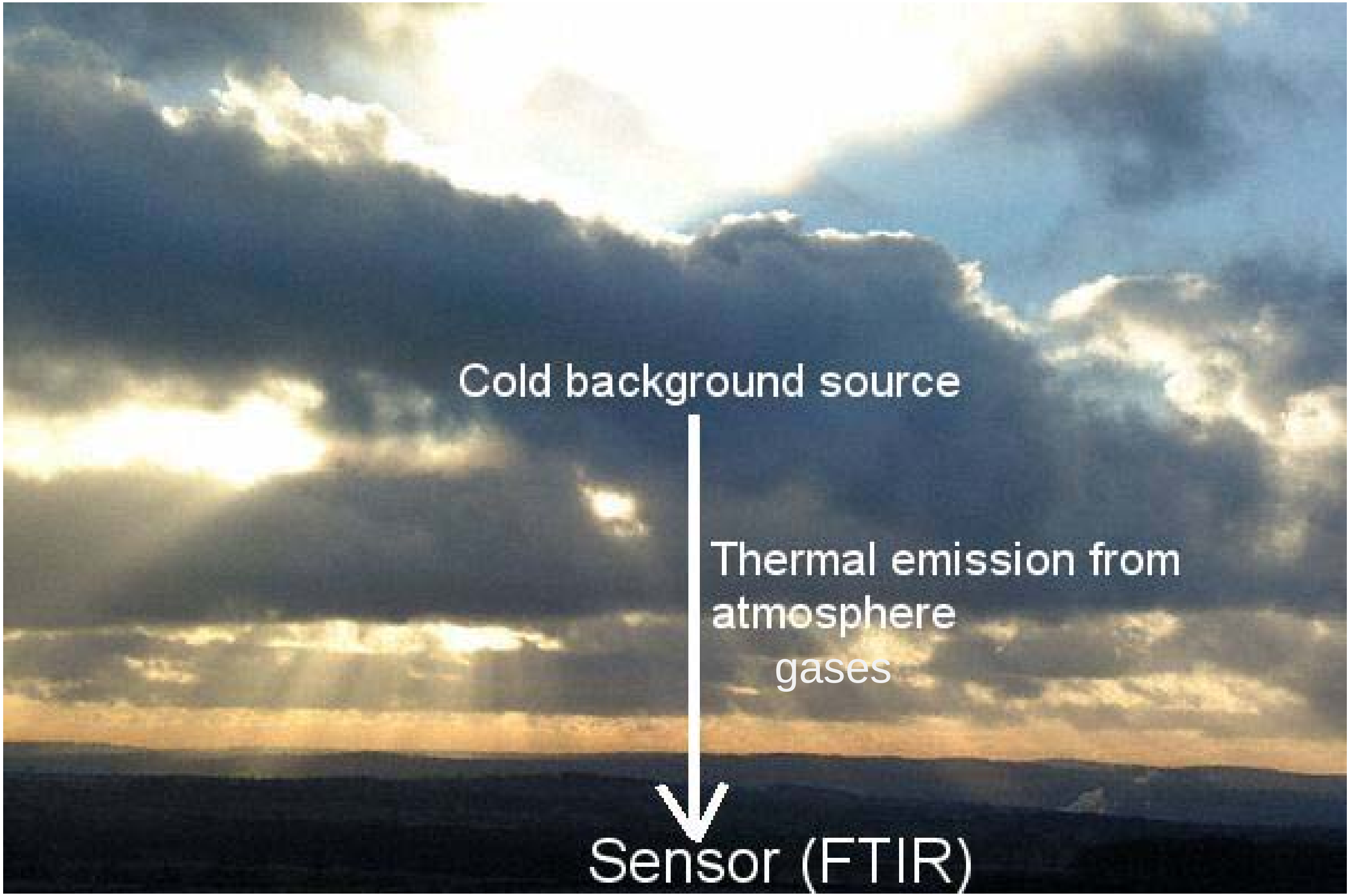
The Measurement Concept

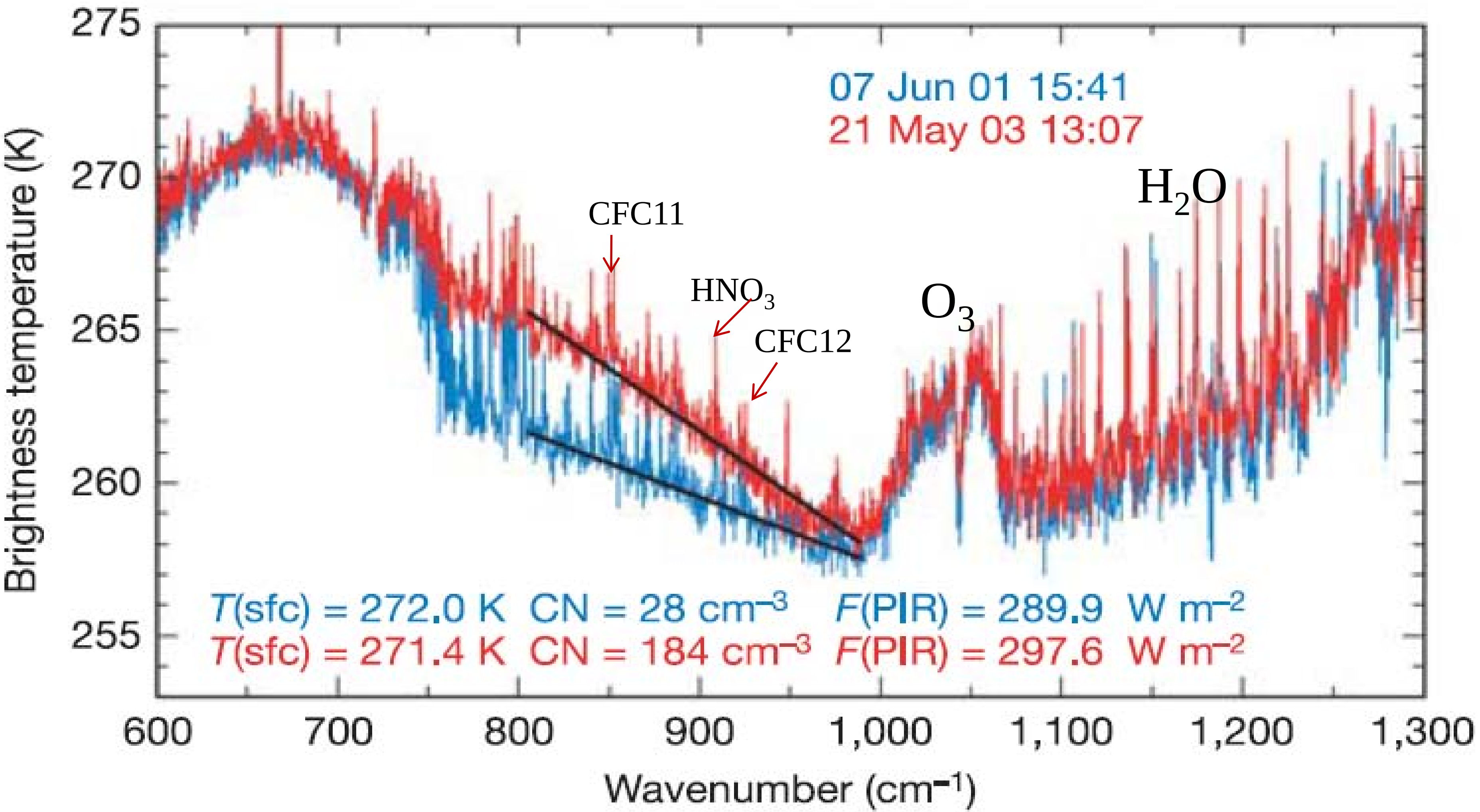


The new AERI Automatic FTS for Atmospheric Monitoring

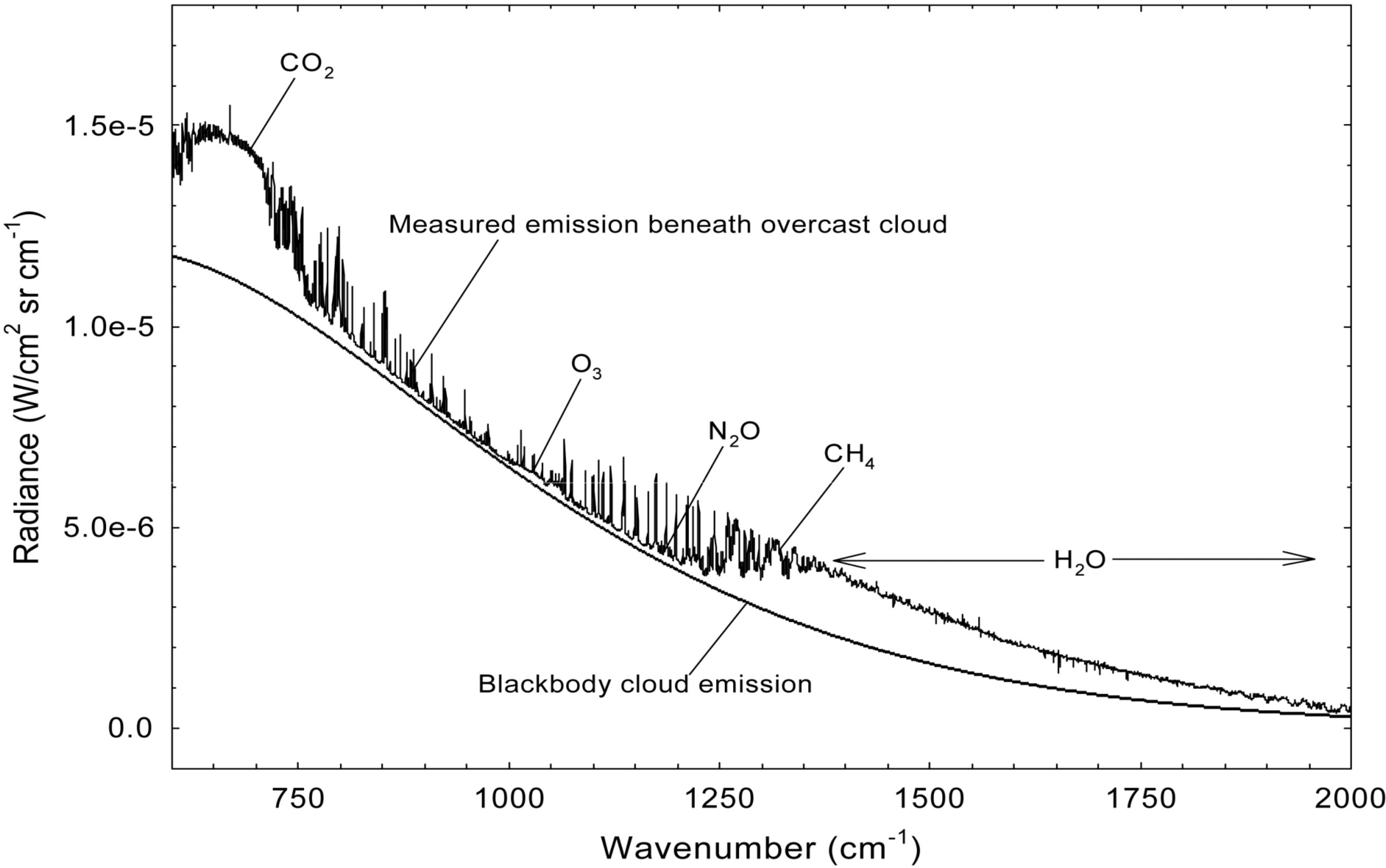
Measures concentrations and climate forcing of gases

AERI Spectra under Clouds

after Lubin (2006)



Thermal Emission Beneath Cloud Cover



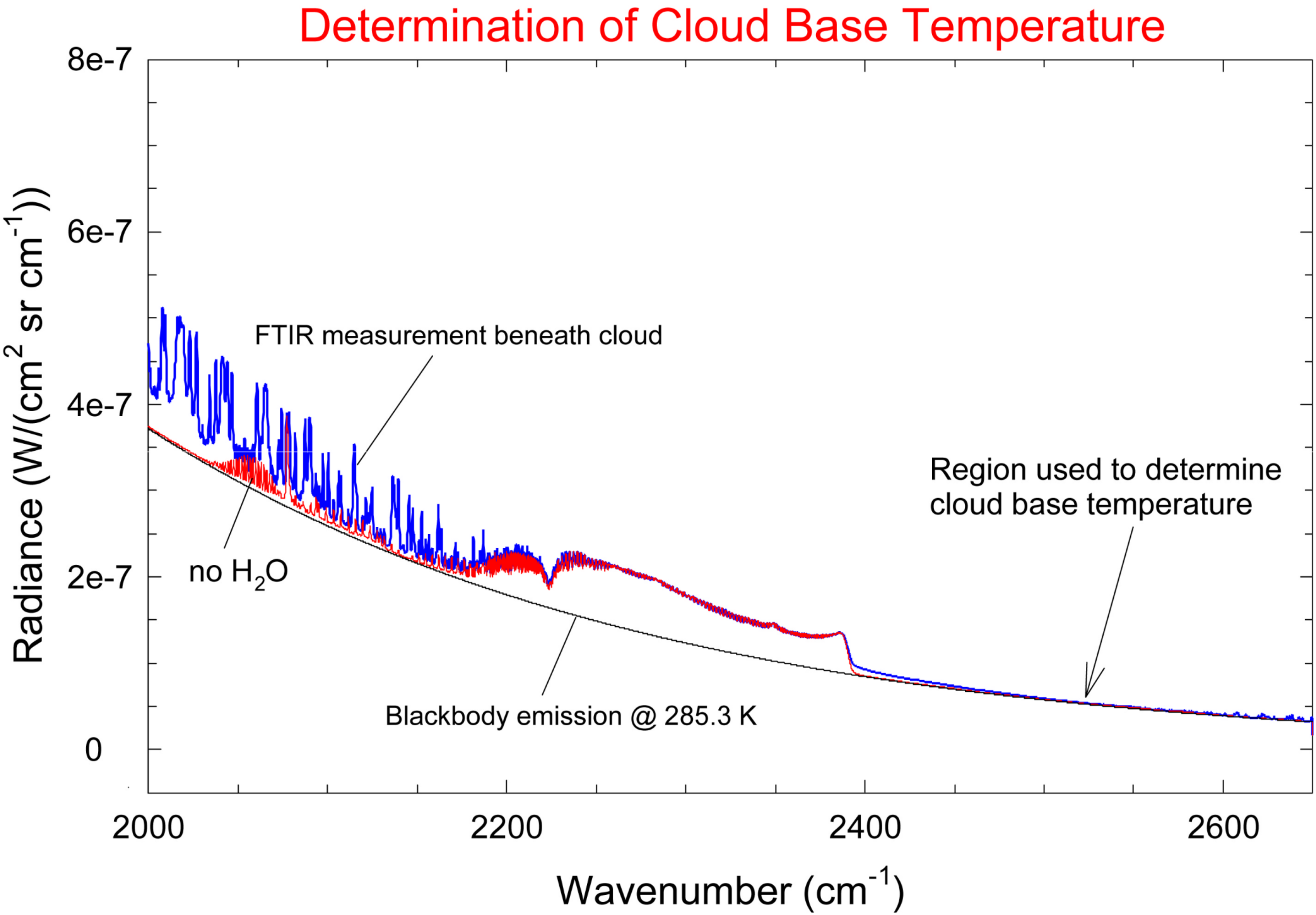


Figure 8.1: The measurement of the thermal radiation measured beneath a cloud on July 27, 1998 using the the InSb detector. The thermal emission of the atmosphere beneath the cloud is superimposed on the background emission of a blackbody at a temperature of 285.3 K. The cloud altitude is at 1.6 km.

Surface forcing of O_3 beneath Overcast Cloud

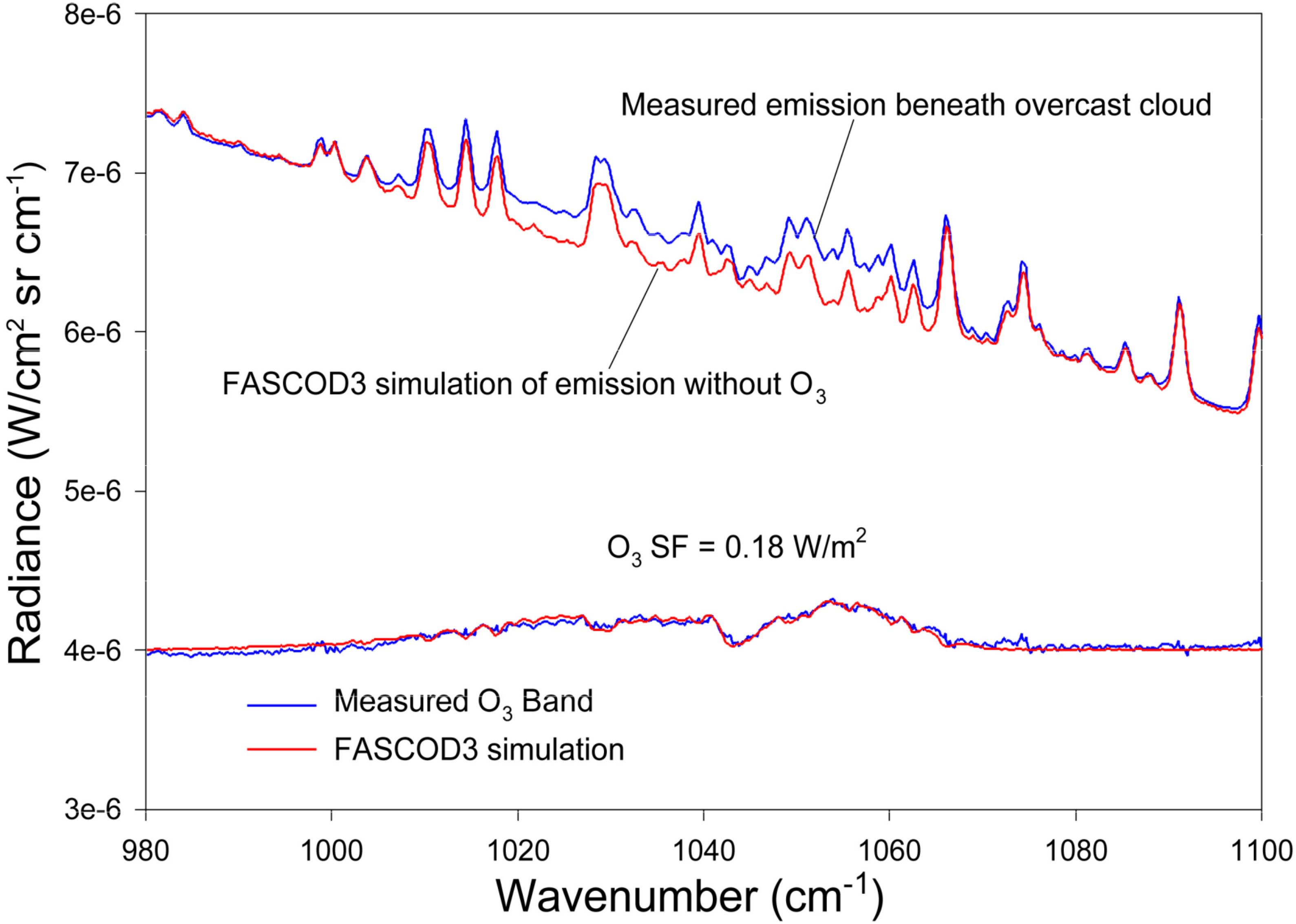


Figure 2: Measurement of the thermal emission of ozone beneath a cloud at an altitude of 2.13 km on August 20, 1999. The background emission corresponds to a blackbody with a temperature of 273.75K.

Measured O_3 Concentrations and Resulting Radiative Forcing

Date	Time	O3 Concentration (ppb)	Radiative Forcing (W/m^2)	Cloud Height (km)	Radiative Factor ($W/m^2/DU$)
Aug 14/02	16:00	58	0.1642	1.21	0.0233
Aug 19/02	10:00	105	0.3561	1.4	0.0242
Sept 20/02	10:40	85	0.2299	2.73	0.01
Sept 30/02	12:30	80	0.2088	0.91	0.0289
Oct 7/02	12:57	67	0.125	0.91	0.0244
Oct 9/02	10:00	65	0.1254	2.42	0.008
Oct 9/02	13:00	63	0.163	2.42	0.0107
Oct 9/02	16:00	65	0.1642	2.42	0.0103
Oct 9/02	17:40	75	0.4011	2.42	0.022
Oct 29/02	14:30	78	0.3901	3.03	0.0165
Dec 20/02	12:15	5	0.0065	1.24	0.0105
July 15/03	16:30	88	0.4709	2.121	0.0252
July 18/03	13:30	85	0.2457	1.7	0.017
Aug 26/03	12:30	117	0.2466	2.73	0.0077
Sept 2/03	15:35	85	0.1928	2.55	0.0105

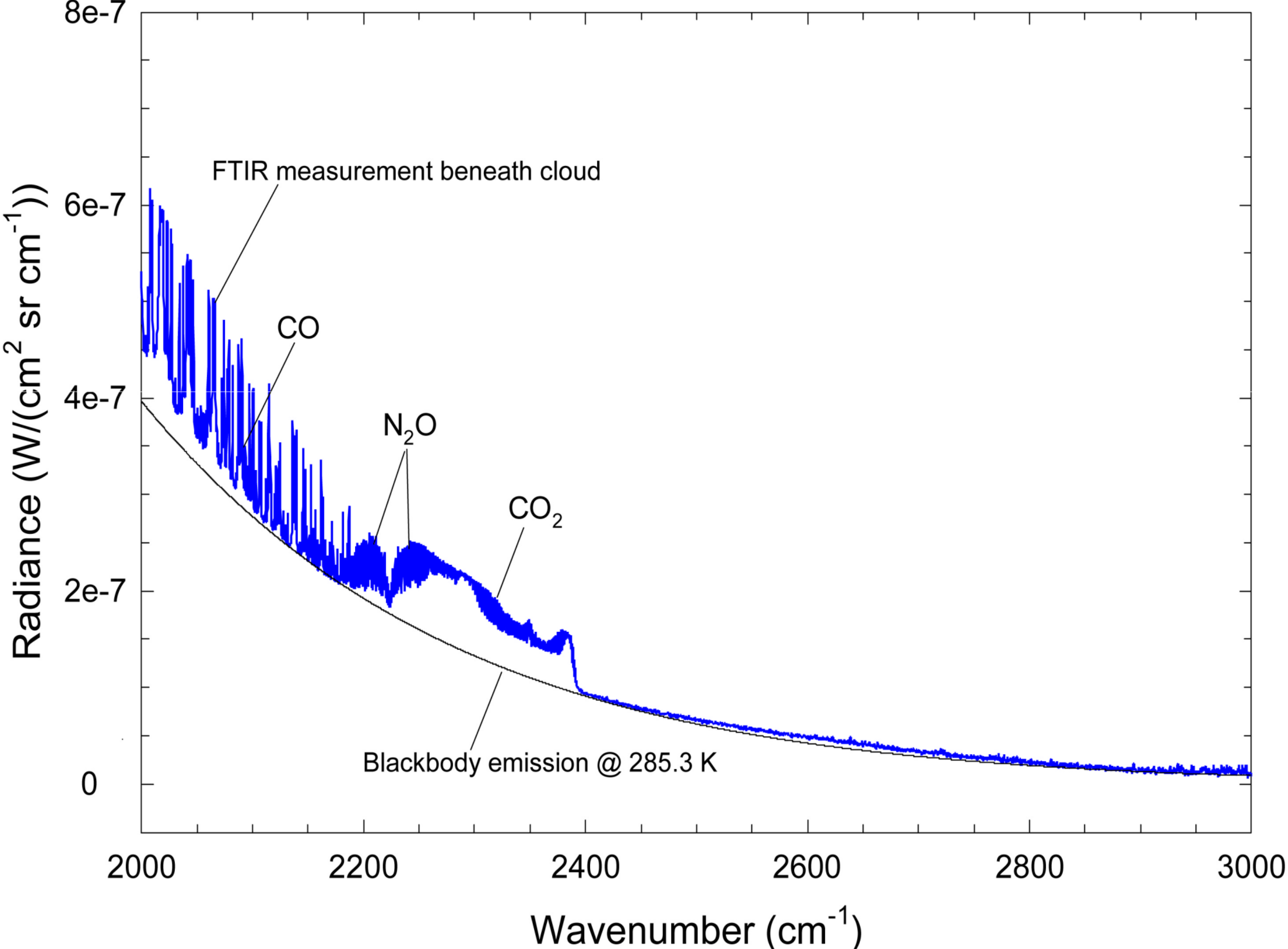
Comparison between Ozone Concentrations at the Surface and in the Lower Troposphere

Date	Time /hours	$[O_3]_{Lower\ Tropospheric}$ /ppbv	$[O_3]_{Surface}$ /ppbv	Difference /ppbv	% Difference[1]
01/07/99	14:30	62	72.5	-10.5	-17%
06/07/99	14:00	25	43	-18	-72%
06/08/99	**8:30**	**35**	**15.4**	**19.6**	**56%**
10/08/99	**9:00**	**64**	**19.1**	**44.9**	**70%**
13/08/99	**9:00**	**105**	**31**	**74**	**70%**
13/08/99	15:00	80	52.9	27.1	34%
16/08/99	16:00	95	50.2	44.8	47%
19/08/99	**11:30**	**53**	**58**	**-5**	**-9%**
20/08/99	**8:30**	**64**	**30.5**	**33.5**	**52%**
24/08/99	**11:30**	**63**	**55.6**	**7.4**	**12%**
26/08/99	**9:30**	**100**	**N/A**		
16/09/99	**9:30**	**66**	**21**	**45**	**68%**
04/03/00	13:00	19	N/A		
01/05/00	**11:00**	**38**	**29**	**9**	**24%**
05/06/00	15:00	44	40.2	3.8	9%
14/07/00	14:00	92	27	65	71%

[1] Percent difference between ozone concentrations measured beneath a cloud and surface ozone concentration. Negative (-) sign indicates that ozone concentration at the surface was greater than lower tropospheric ozone level

Surface ozone measured with a TECO ozone analyzer

Other Radiatively Active Gases in InSb Region

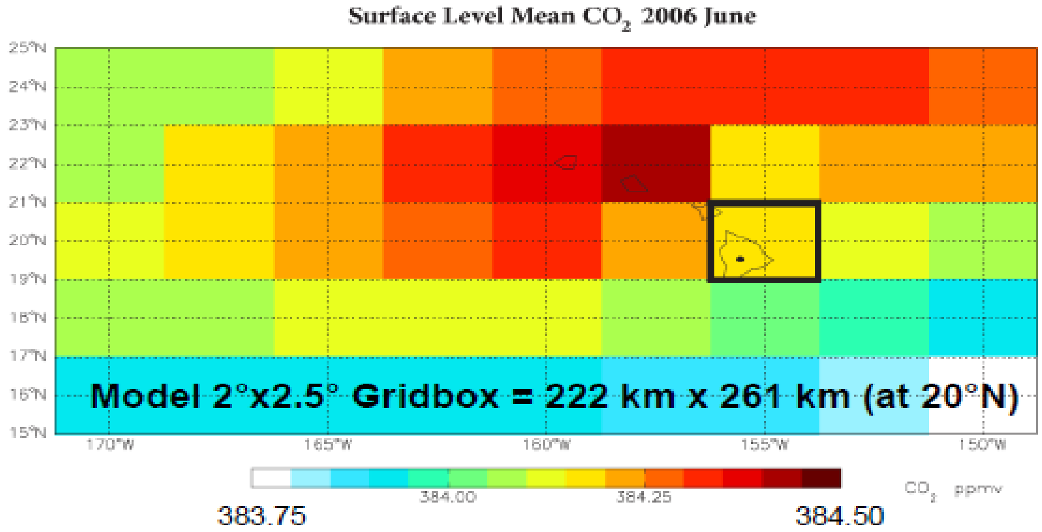


Greenhouse Gas Radiative Surface Fluxes and Mixing Ratios Below Clouds

Parameter	O_3 Surface Forcing (W/m^2)	CO_2 Surface Forcing (W/m^2)	N_2O Surface Forcing (W/m^2)	CO Surface Forcing (W/m^2)	CFC12 Surface Forcing (W/m^2)	Total Surface Forcing from all Gases (W/m^2)
Flux **(W/m^2)** Mixing ratio (ppbv)	0.43 80	0.24 374,000	0.13 312	0.0041 100	.01est	
Band (cm^{-1})	950-1075	2200-2390	2170-2250	2160-2200	900-940	

Representativeness Errors

Nassar et al. (2010), Geoscientific Model Development, 3, 689-716



Model near Mauna Loa site

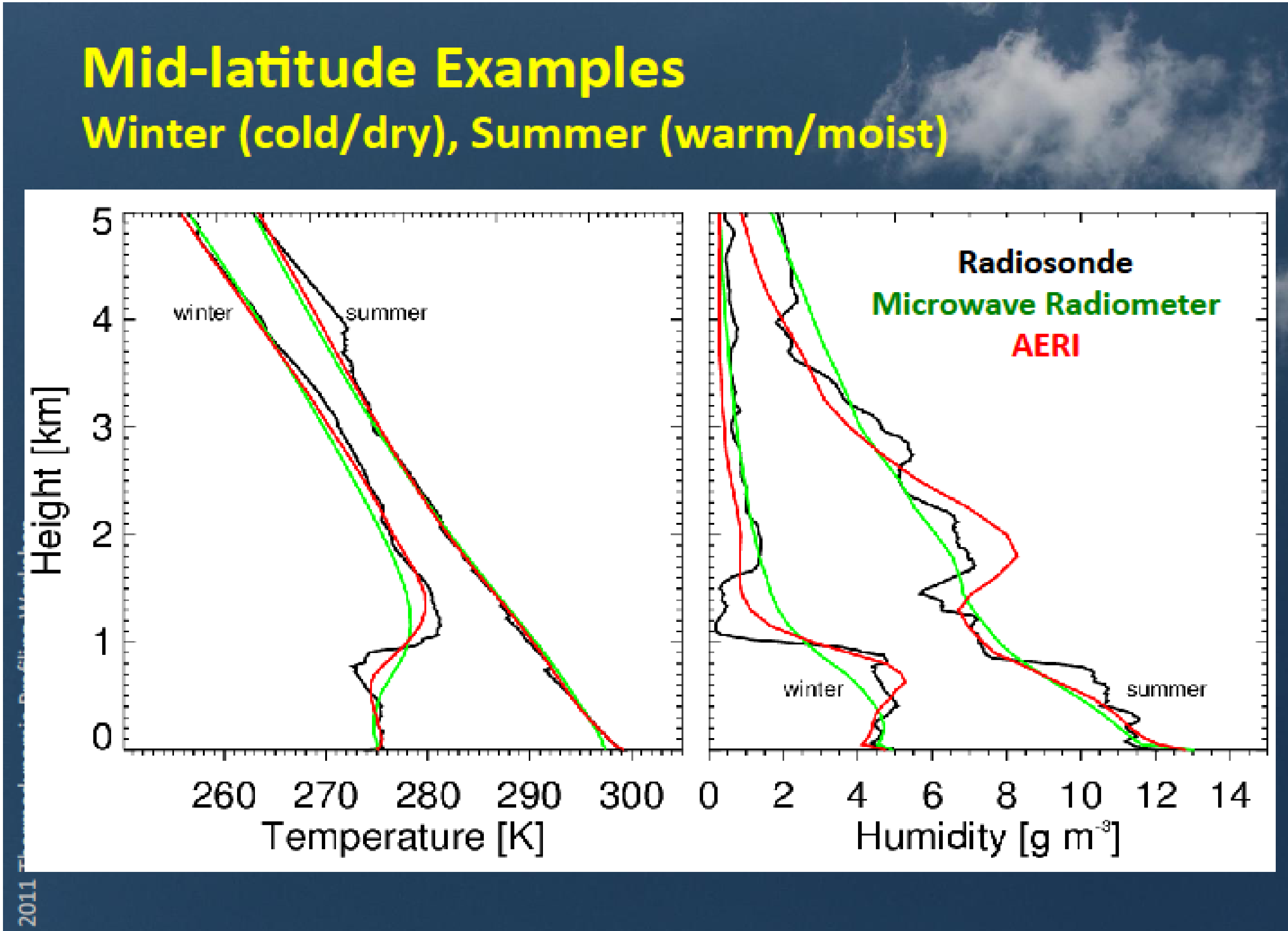
1) CO_2 flask data have precision and accuracy on the order of 0.1-0.2 ppm but it is difficult to take advantage of this due to representativeness errors

2) **TES and Flask CO_2 are Complementary**

Nassar et al. (2011), ACPD, 11, 4263-4311

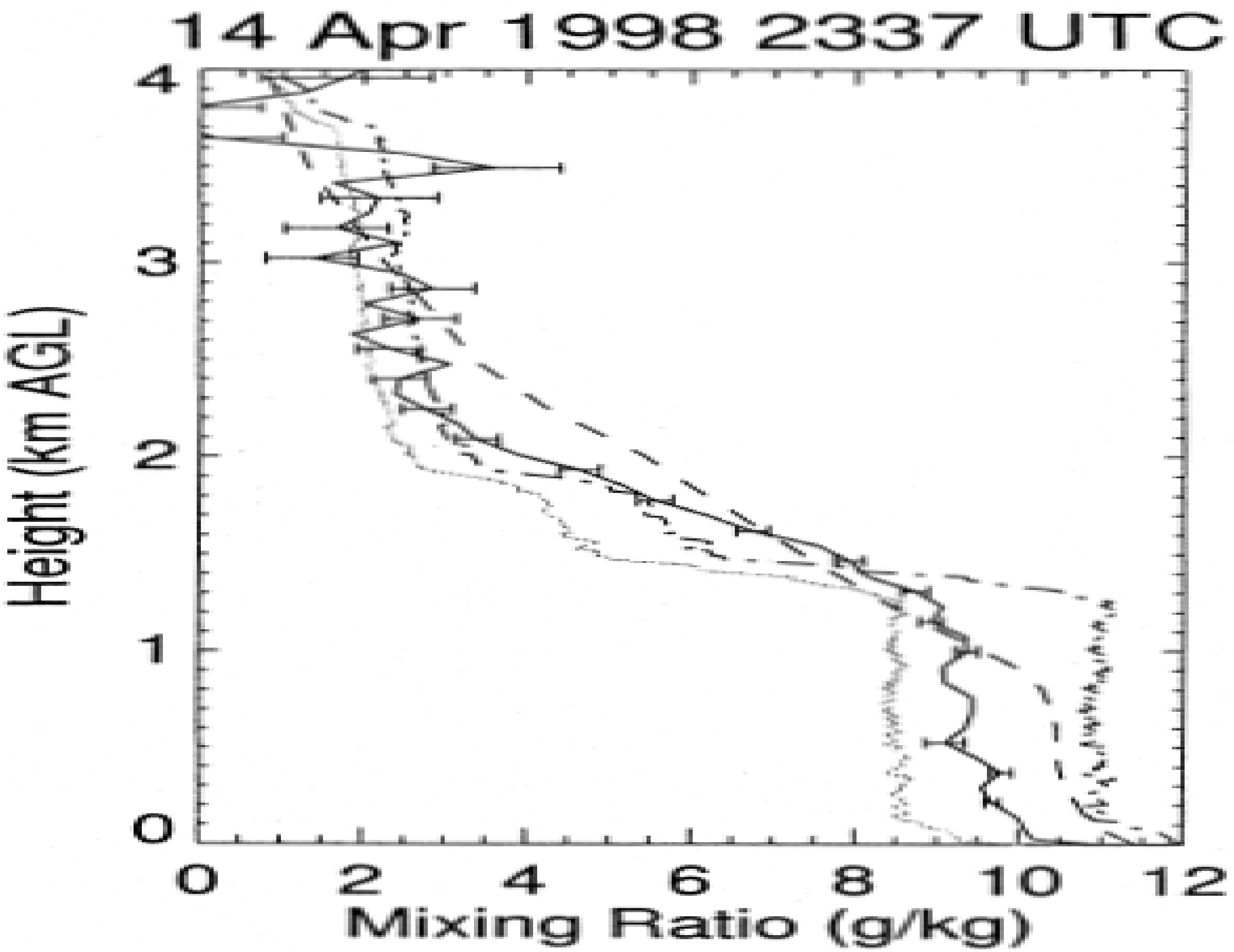
TES and flask data together give the best agreement with independent ship (NOAA) and aircraft (CARIBIC) flask data as a result of the complementary vertical and horizontal information

Validation of AERI vs Radiosondes



after Turner (2011)

Night water vapor profiles from AERI showing effects of the boundary layer up to 1200 m *(Turner, 2008)*

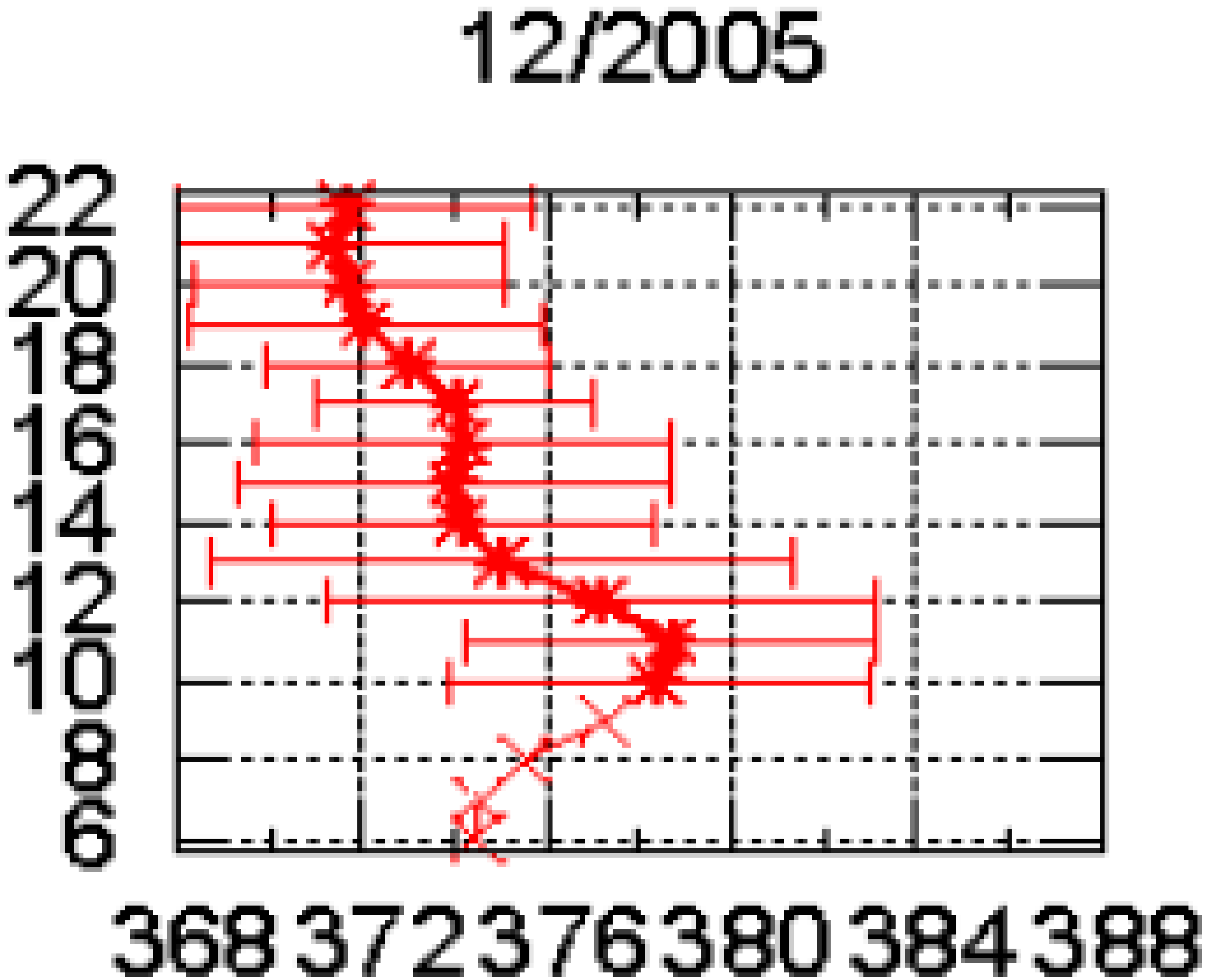


Vertical Representativeness

- Satellite and aircraft measurements show strong variations in the vertical mixing ratio profiles of CO_2.

Increasing CO_2 profiles with height in the troposphere from the ACE FTS in late winter

(Foucher et al, 2011)



Aircraft vertical profiles of CO_2 *(Gurk et al ,2008)*

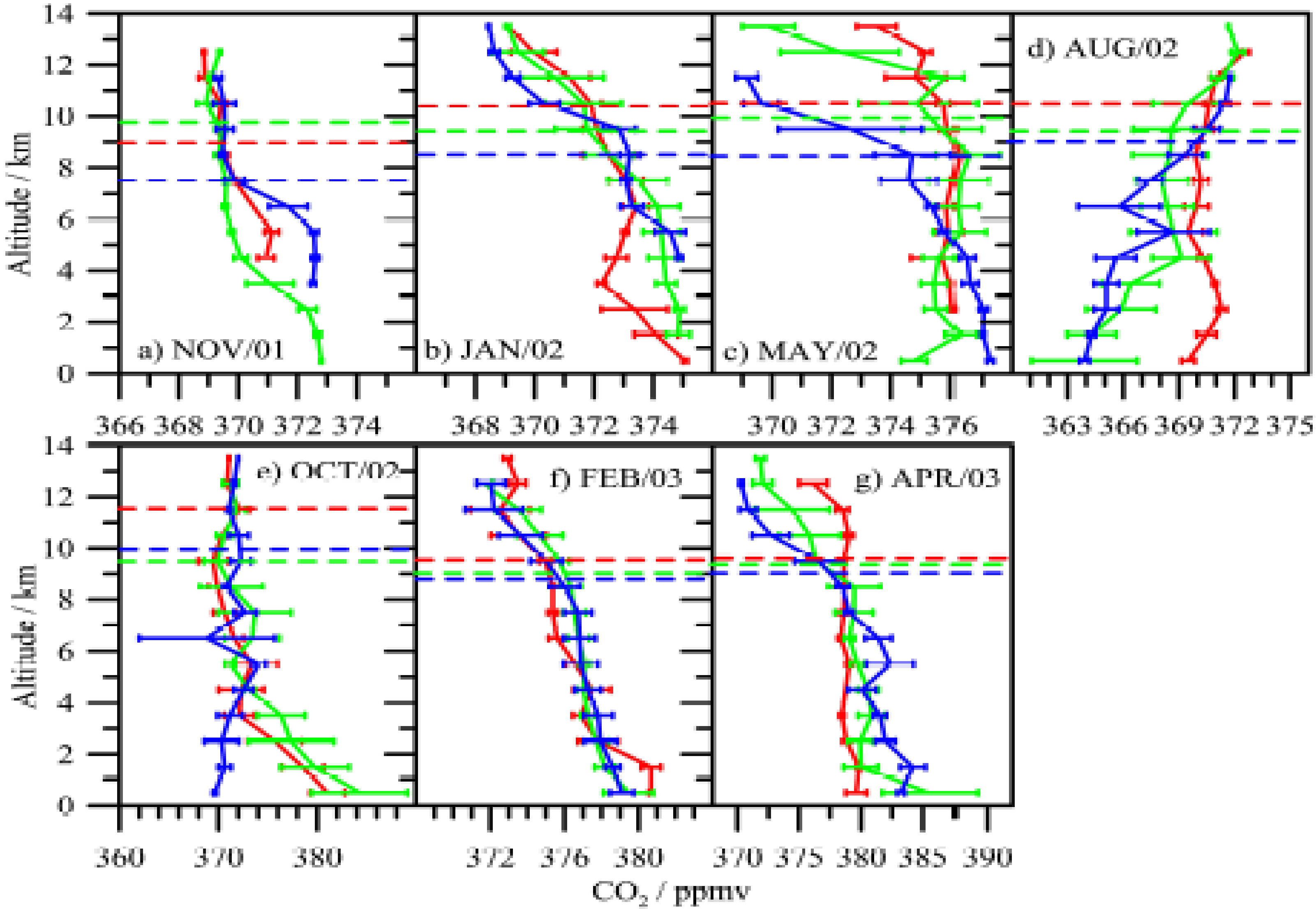


Fig. 3. Means and 1σ-standard deviation for 1 km altitude bins calculated from take-offs and landings at high (>65° N, blue lines), middle (approx. 55° N, green lines) and subtropical latitudes (<40° N, red lines). Horizontal dashed lines indicate the tropopause altitude.

CONCLUSIONS

- **The remote measurement of lower tropospheric gas concentrations by utilizing thermal emission under cloud has been demonstrated.**

- **Well calibrated infrared spectral measurements of the downward infrared thermal radiation have been routinely made by the robotic AERI instruments at the three main ARM sites for over a decade.**

- **In the thermal spectral region, there are emission bands from the GHGs : O_3, CO_2, N_2O, CO, CH_4, CFCs, and from air quality gases (NO, HNO_3 , CO). Measurements of fluxes and mixing ratios of O_3, CO_2, N_2O and CO were demonstrated.**

- **Fluxes are converted to mixing ratios by simulation RT modeling; time series measurements of surface ozone vs the ozone mixing ratio in the lower troposphere below clouds were shown. LBLRTM**

- **Satellite and aircraft height profiles of CO_2 indicate the need to correct surface measurements for seasonal altitude variations; AERI could facilitate these corrections for representativeness.**

END

Cloud Emission for Various Optical Depths