Climate and Radiation

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Presentation at Caltech

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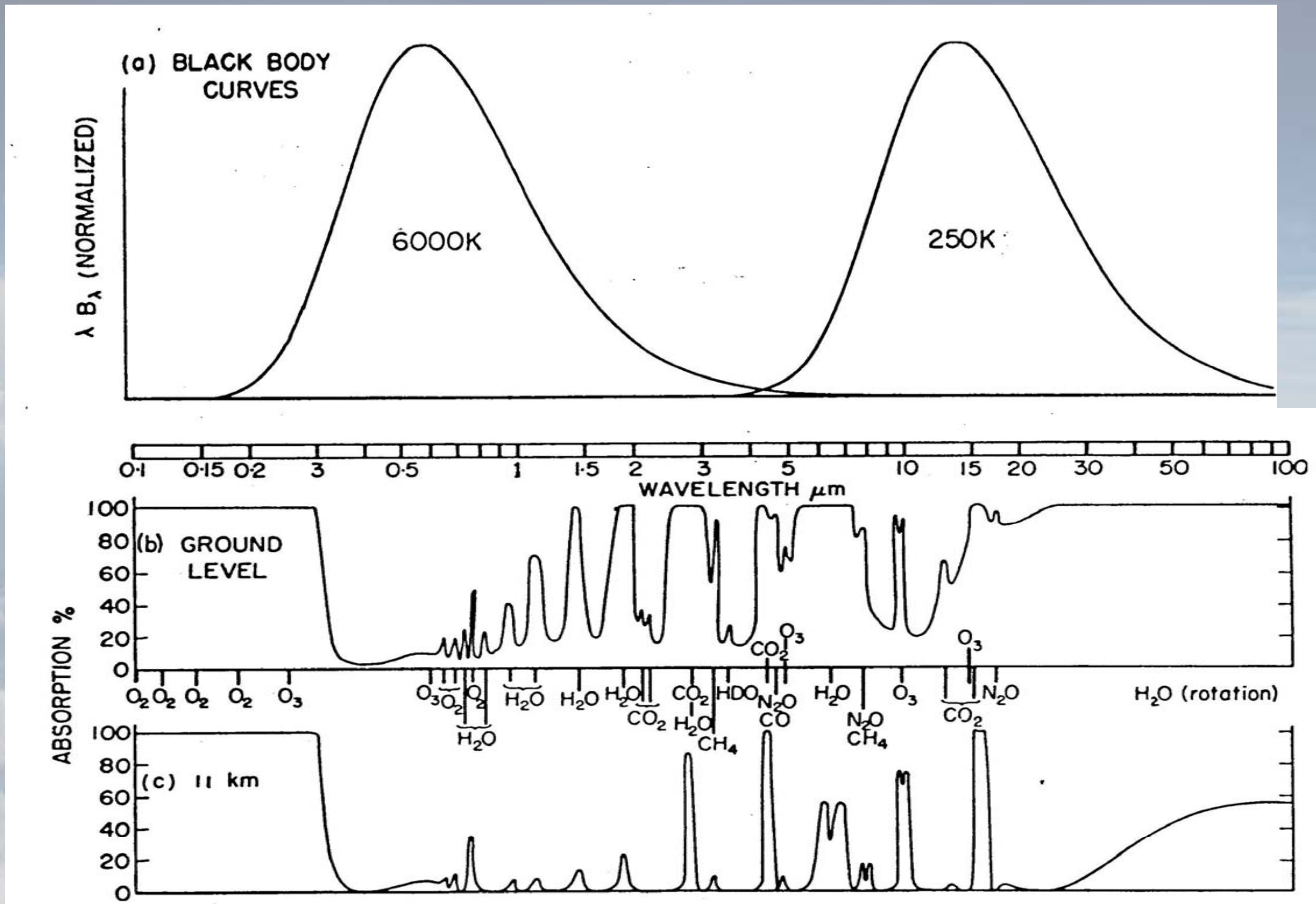
Today’s Outline

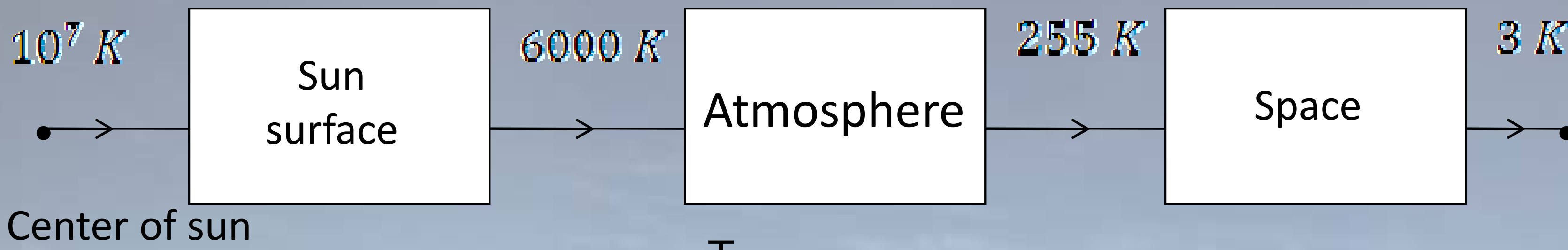
- What is Radiation? (Review)
- What is the Greenhouse Effect? （Review)
- GCM Prediction of Future (IPCC)
- Use of Spectral Data
- Conclusions

Blackbody Radiation

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT} - 1}$$



Goody and Yung (1995)



Ts = 288 K

Atmosphere : Processor of energy

Sunlight = driver of $\left\{ \begin{array}{l} \text{Chemistry} \\ \text{dynamics} \\ \text{biology} \end{array} \right.$

$$\overline{f_\odot} = 350\ W \cdot m^{-2}$$

Mean equilibrium temperature

$$f\,(\pi r^2)(1 - a) = \sigma T^4 (4\pi r^2)$$

$$T = \left(\frac{(1-a)f}{4\sigma}\right)^{1/4}$$

$f = 1400\ W/m^2$

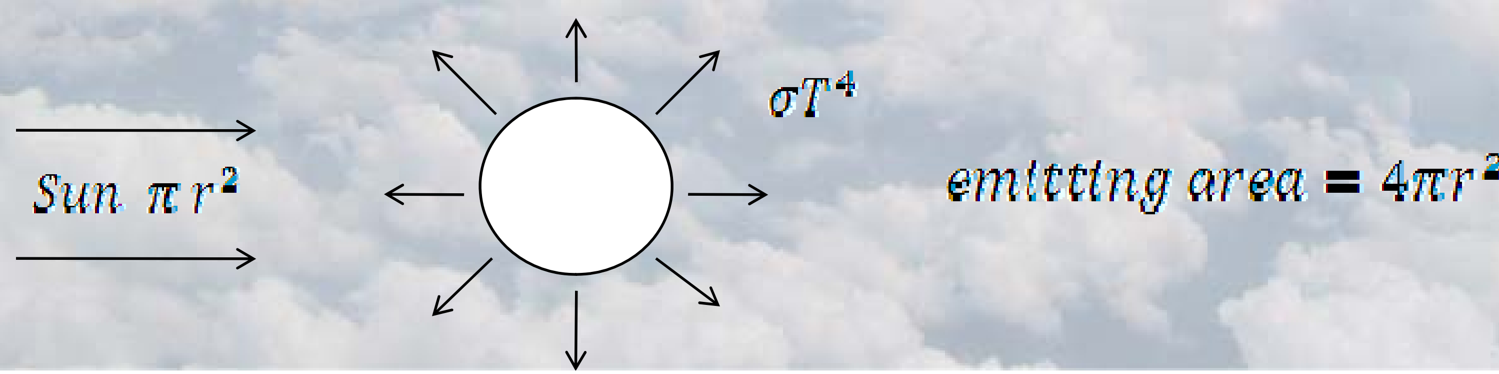
$a = 0.31$

$\sigma = 5.67 \times 10^{-8}\ W m^{-2} K^{-4}$

$(Appendix\ 1, p. 462, G + Y)$

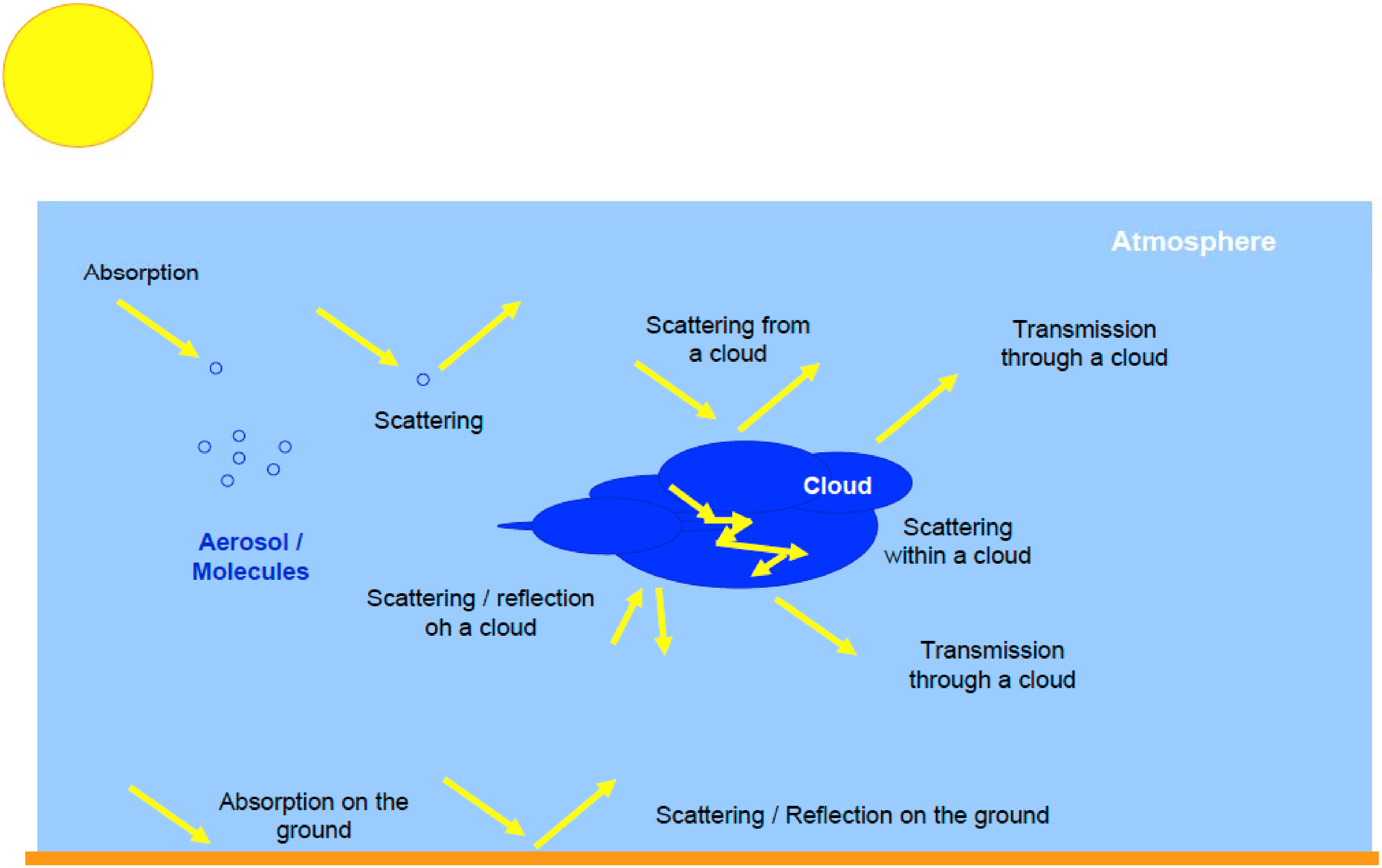
$$T = \left(\frac{(0.69)(1400)}{5.67 \times 10^{-8}}\right)^{1/4} = 255\ K$$

$Ts = 288\ K$ $\therefore \Delta T = 33K$

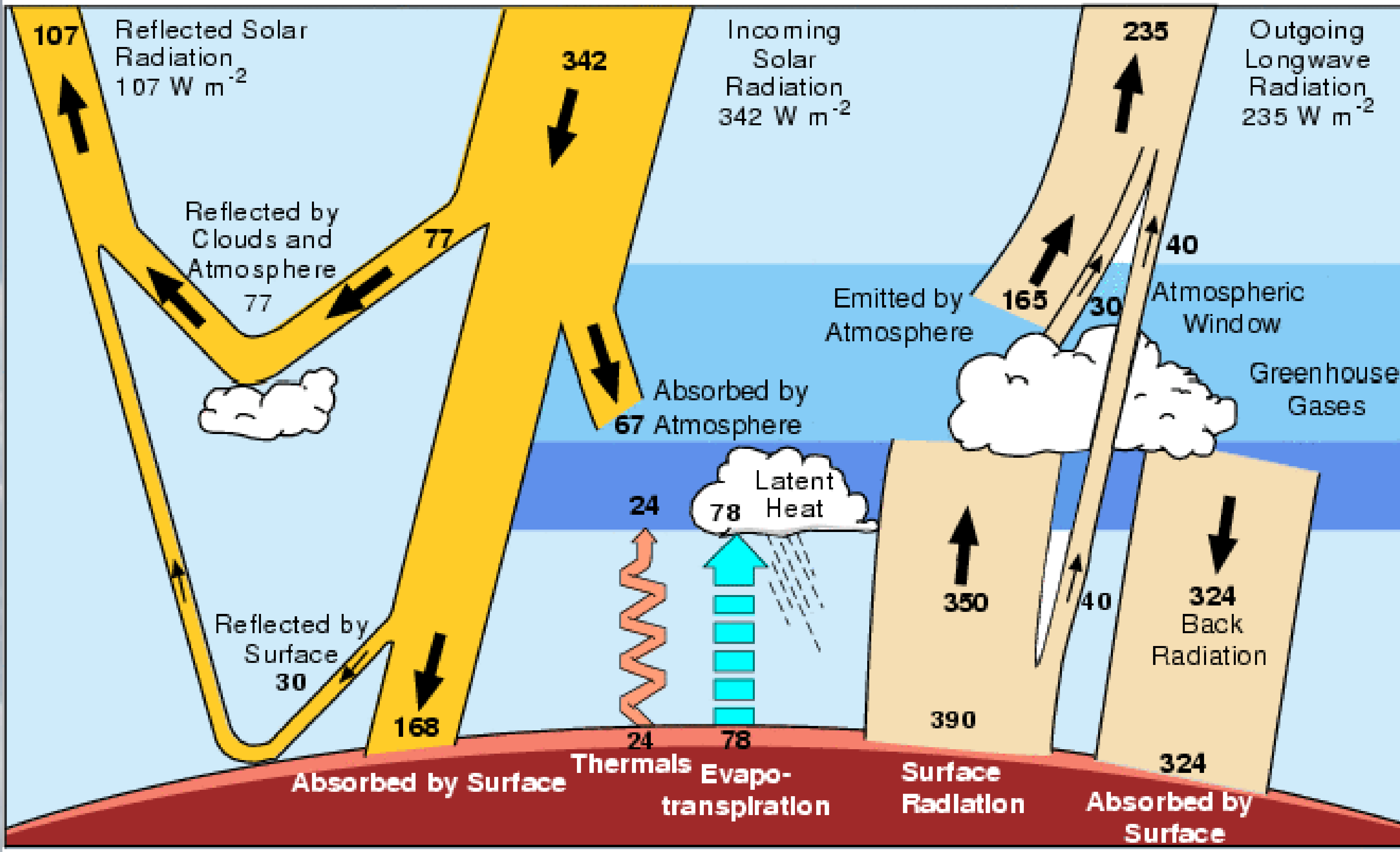


Process	Total Power (Watts)
Sunlight	2×10^{17}
Seawater evaporation	3×10^{16}
Photosynthesis	1×10^{14}
Geothermal flux	3×10^{13}
Tides	2×10^{13}
Energy use by man (1980)	1×10^{13}
UV energy to make O_3 layer	1×10^{13}
Hydroelectric Power	3×10^{11}
Winds	2×10^{11}
Volcanoes	4×10^{10}
Earthquakes	1×10^{10}

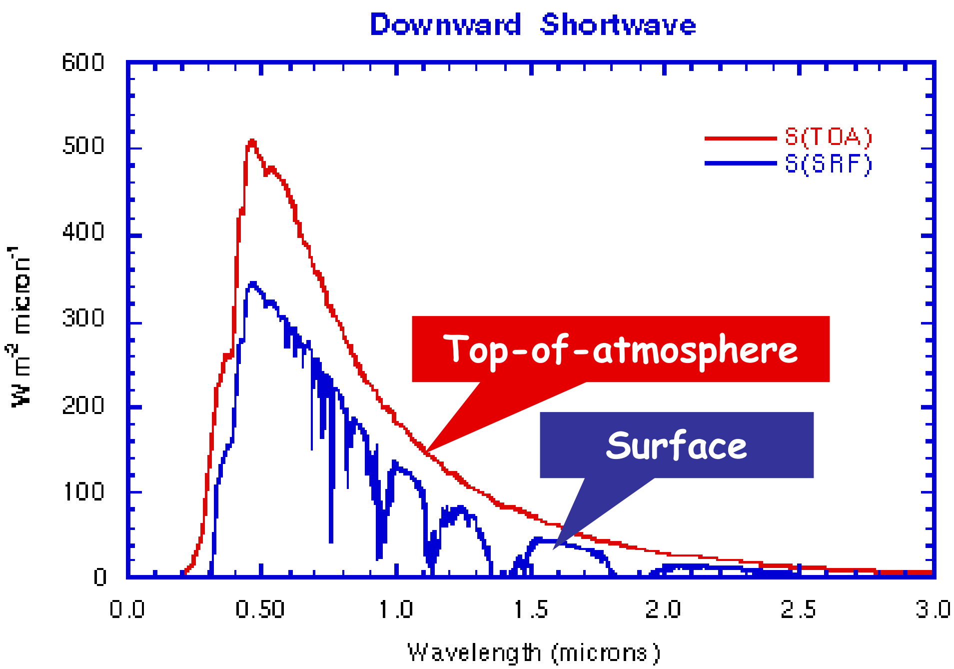
RadiativeTransfer

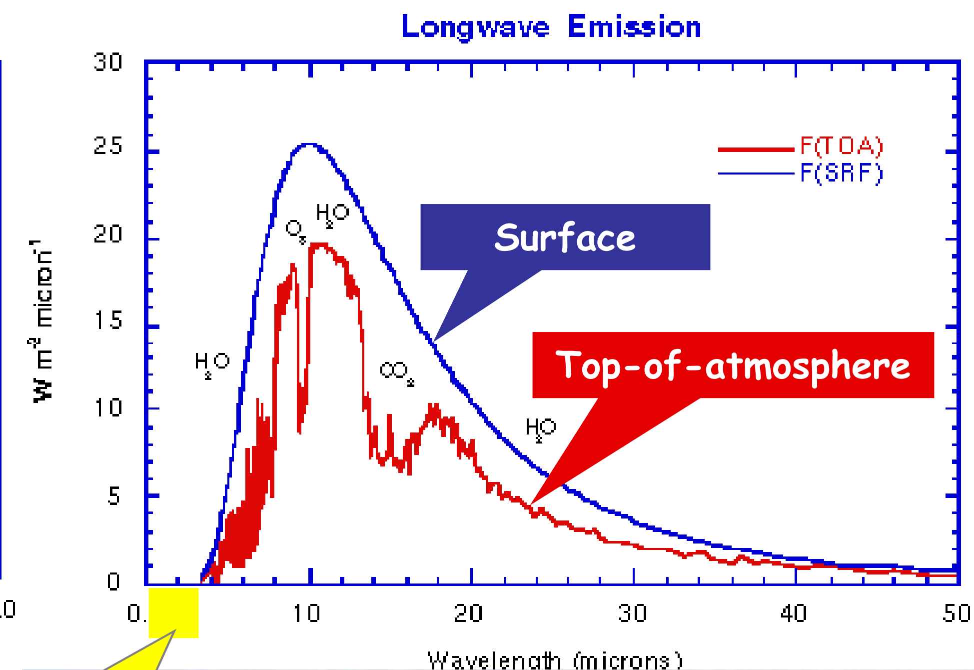


Global Heat Flows



Kiehl and Trenberth 1997

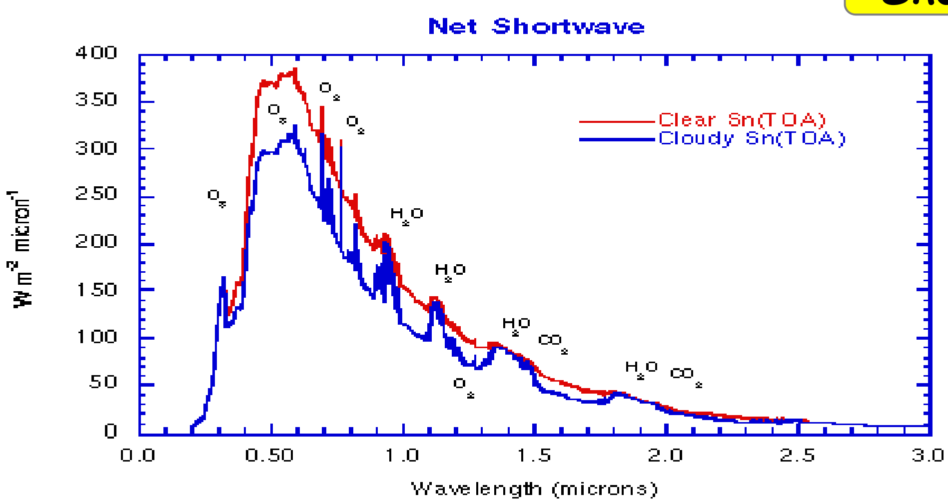


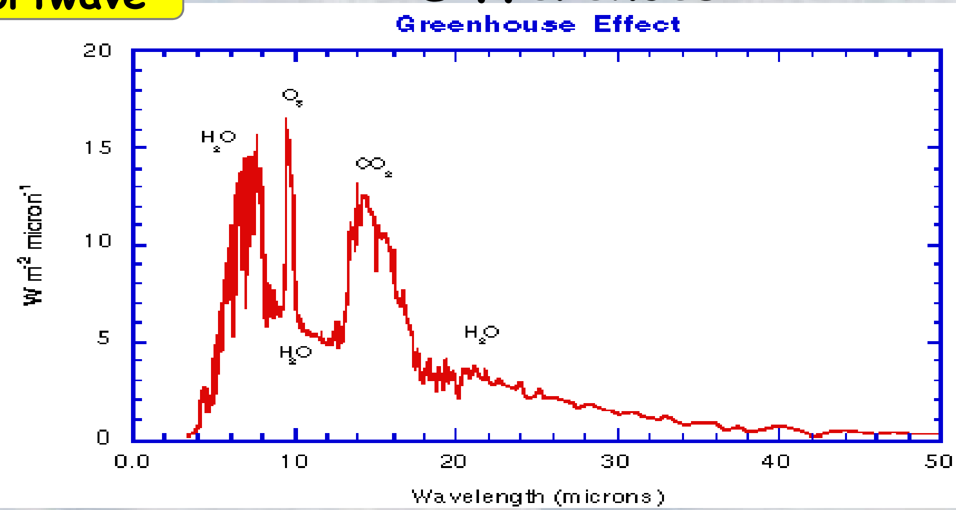


Net

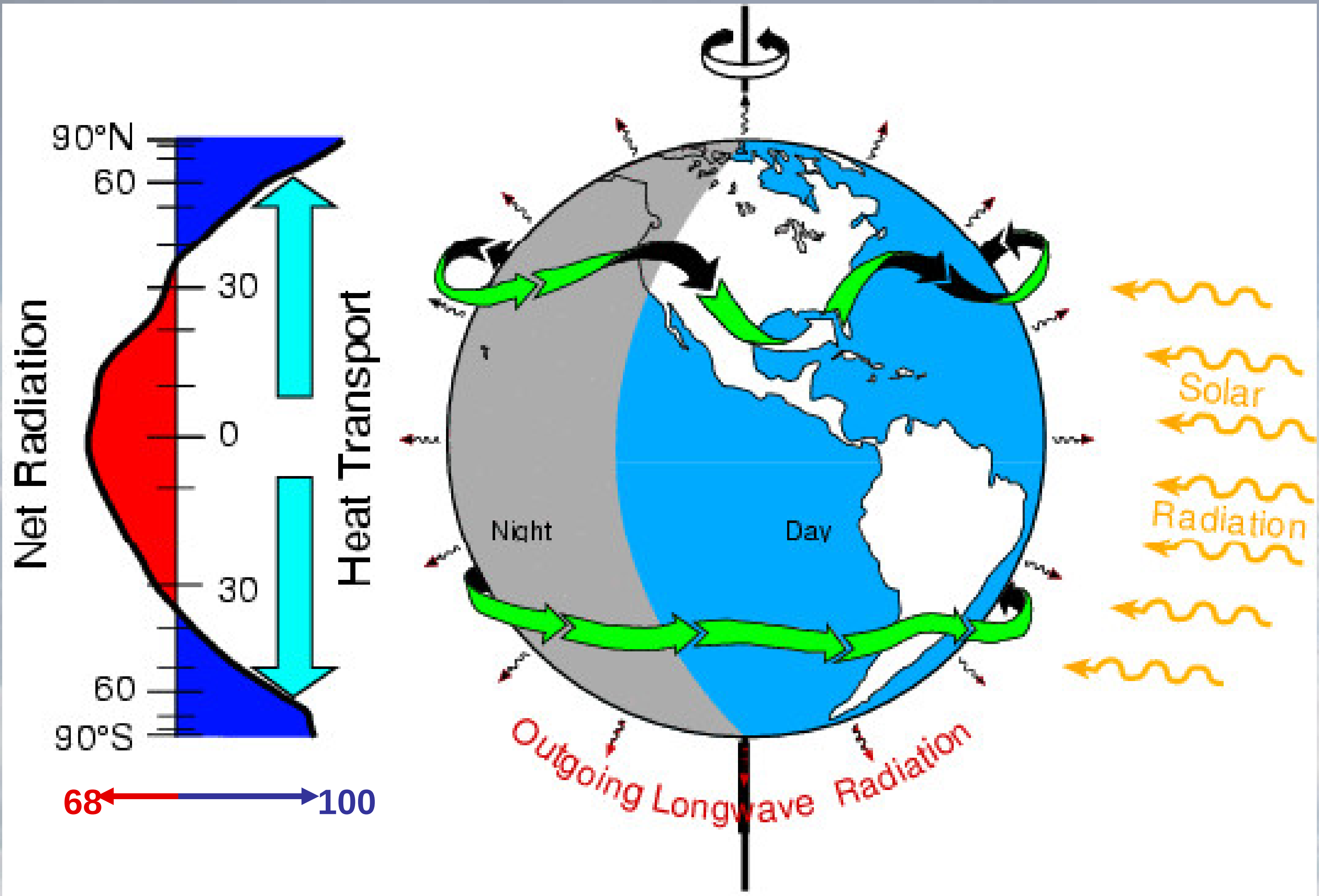
Shortwave

Differences





Kiehl and Trenberth 1997



90°N
60
30
0
30
60
90°S
Net Radiation
Heat Transport
68
100
Night
Day
Solar
Radiation
Outgoing Longwave Radiation

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- What is Radiation? (Review)
- What is the Greenhouse Effect?　（Review)
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- Conclusions

Observational Dataset

- AIRS (Atmospheric Infrared Sounder)

Lifetime: May 2002 – Present

Spectral coverage: 650-2665 cm^{-1}

Spectral resolution (FWHM): ν/1200 cm^{-1}

Field of view: 13.5 km

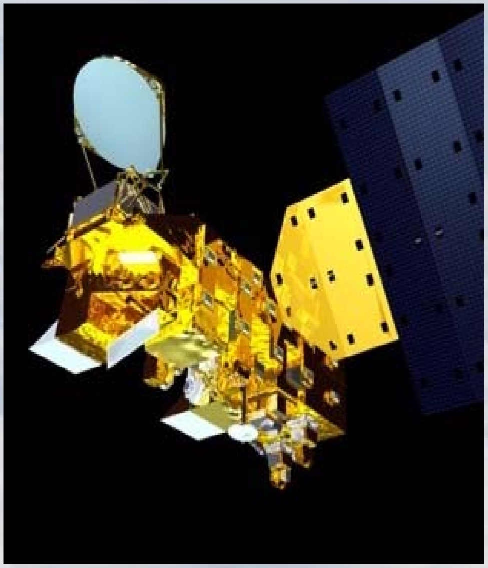
(~9 times of the FOVs per AMSU-A FOV)

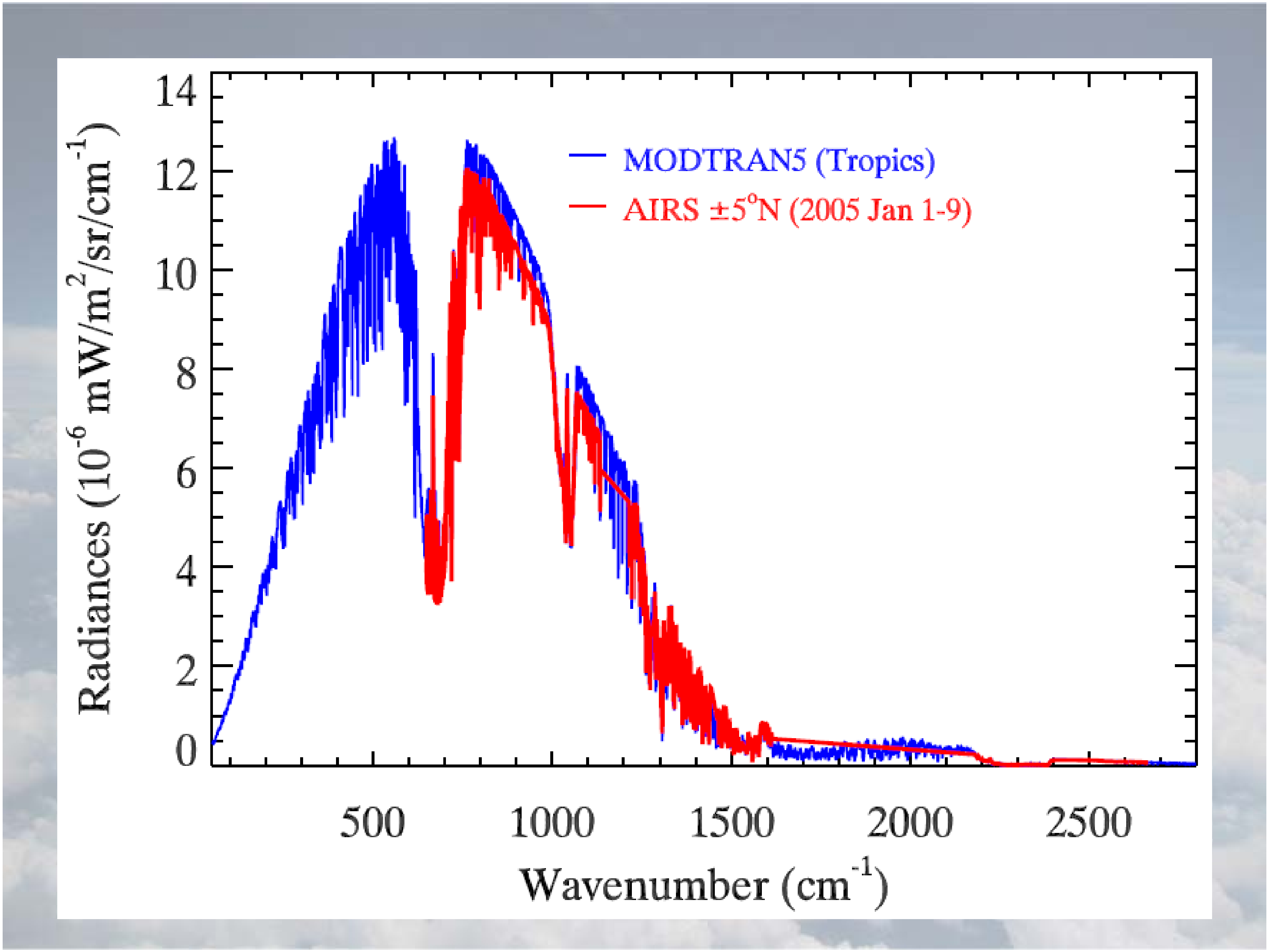
SNR: 600-4000

Calibration bias: 0.07-0.5 K in BT

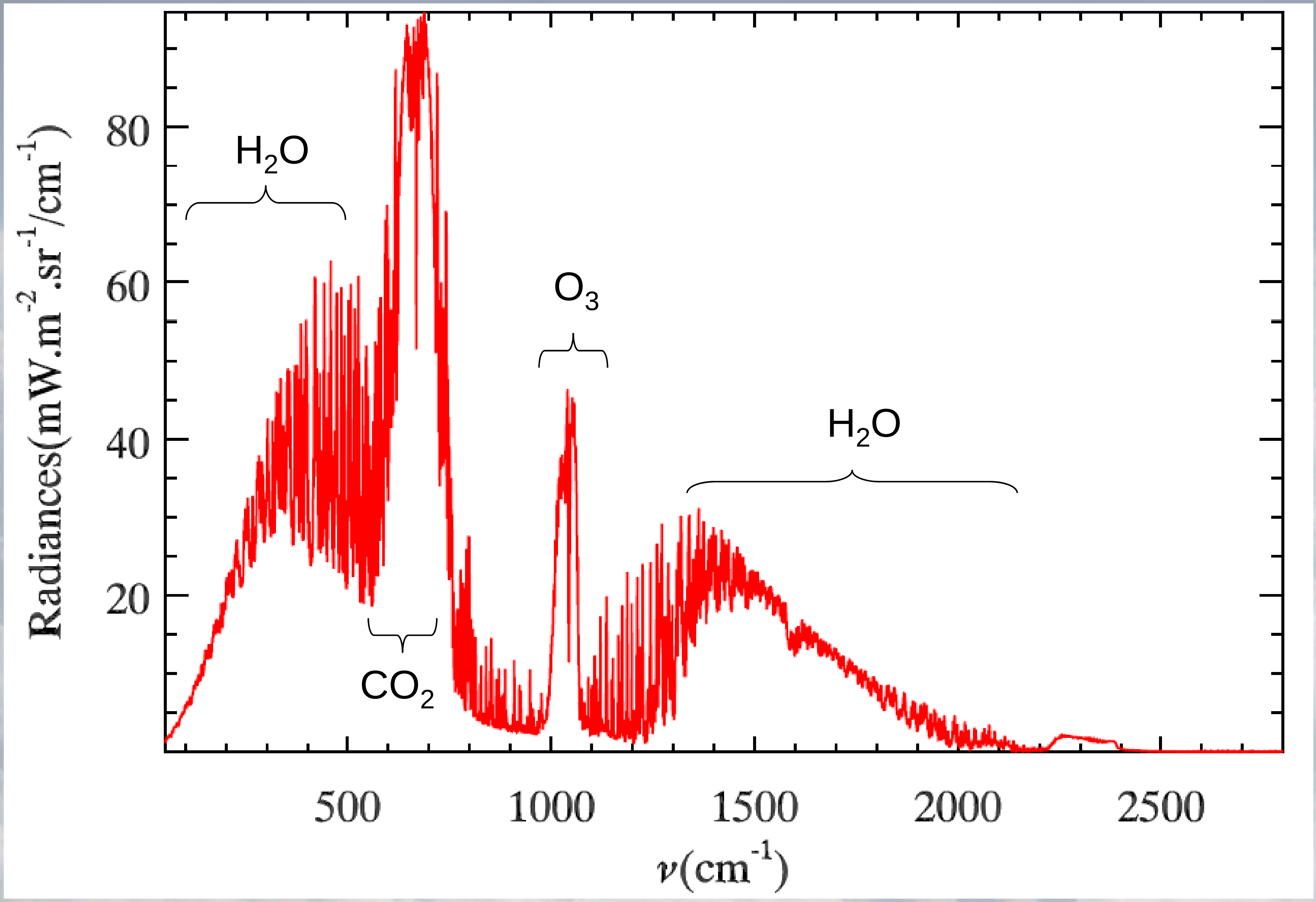
Orbit: Sun-synchronous, 1:30 PM sampling

Swath Width: 1650 km, twice daily swath



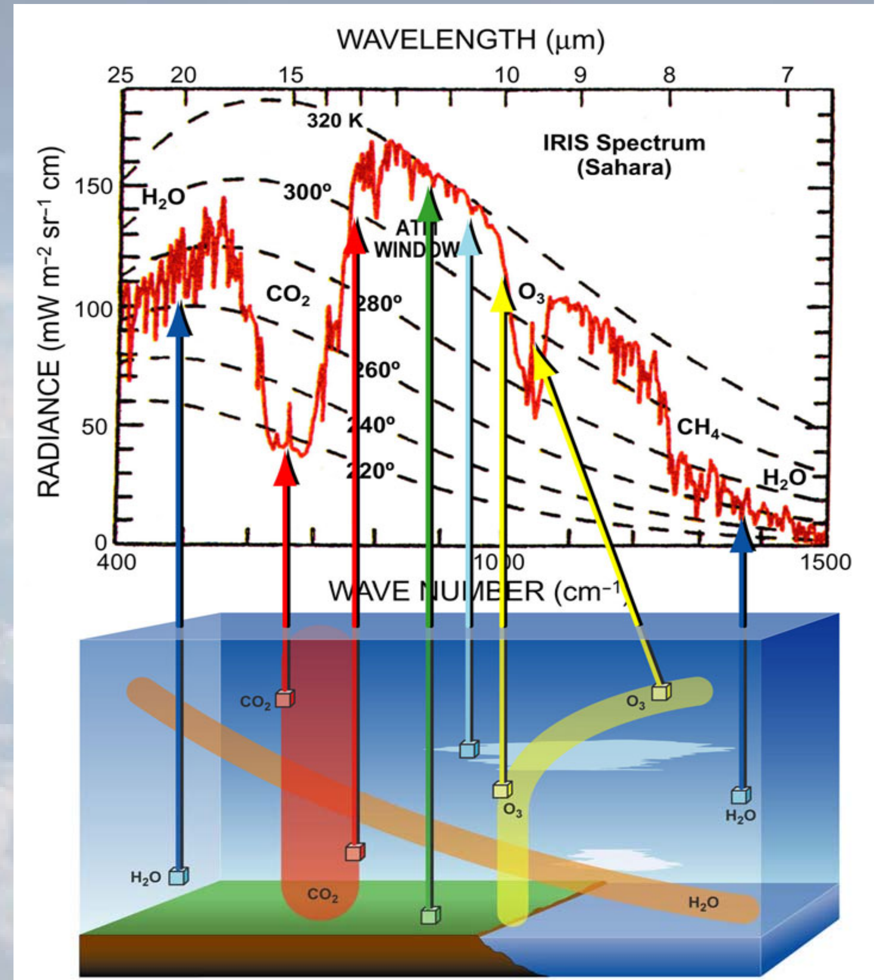

MODTRAN5 (Tropics)
AIRS ±5°N (2005 Jan 1-9)
Radiances (10^-6 mW/m^2/sr/cm^-1)
Wavenumber (cm^-1)
0
2
4
6
8
10
12
14
500
1000
1500
2000
2500

Absorption in Earth's Atmosphere

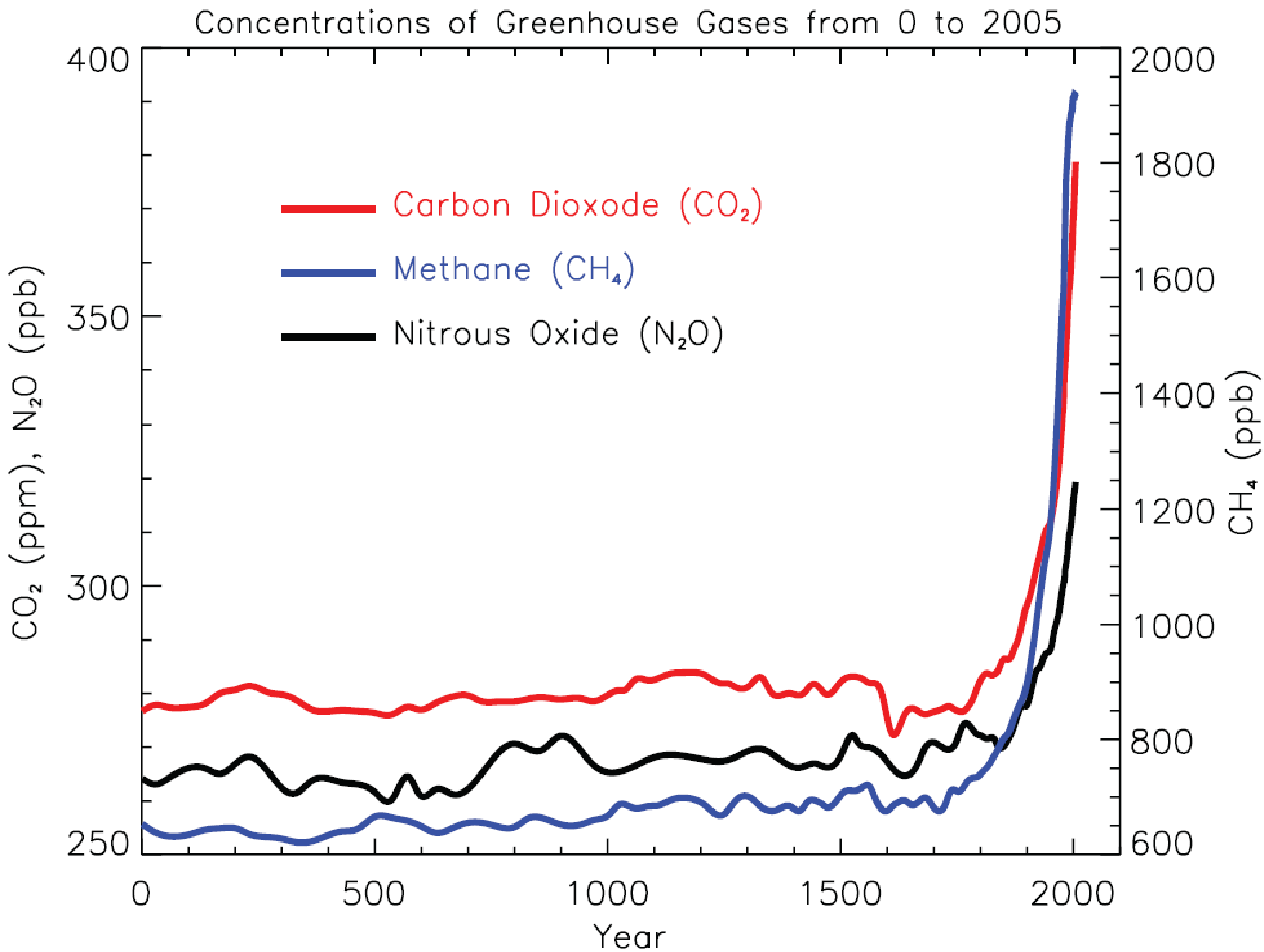


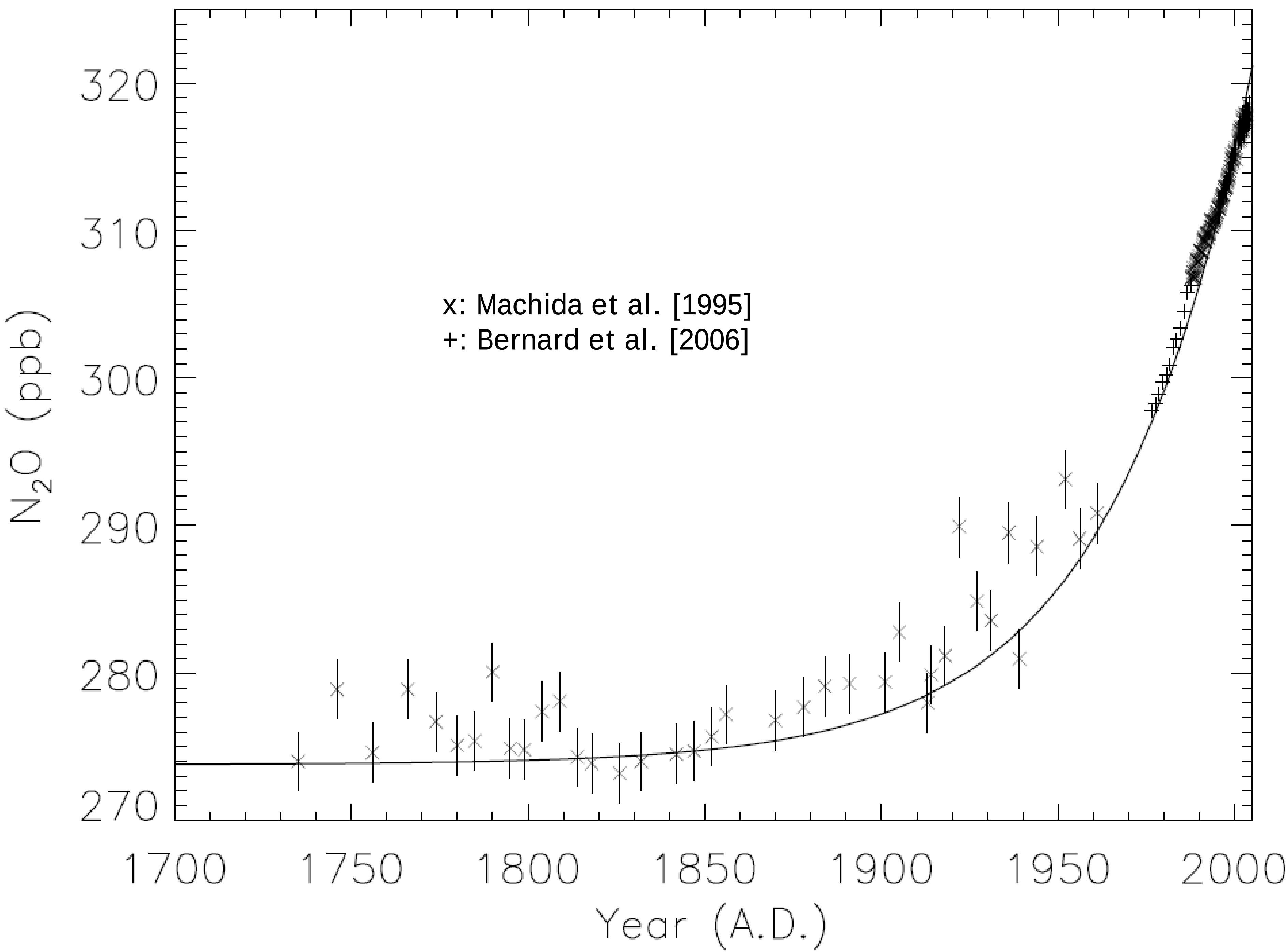
Greenhouse gases and radiance

- Outgoing thermal infrared spectra (W/m^2/cm-1/sr) *I(v)*
  - Integrand of OLR, containing many pieces of useful information
  - Fundamental to climate diagnostics



By courtesy of John Dykema


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000



x: Machida et al. [1995]
+: Bernard et al. [2006]
N_2O (ppb)
270
280
290
300
310
320
1700
1750
1800
1850
1900
1950
2000
Year (A.D.)

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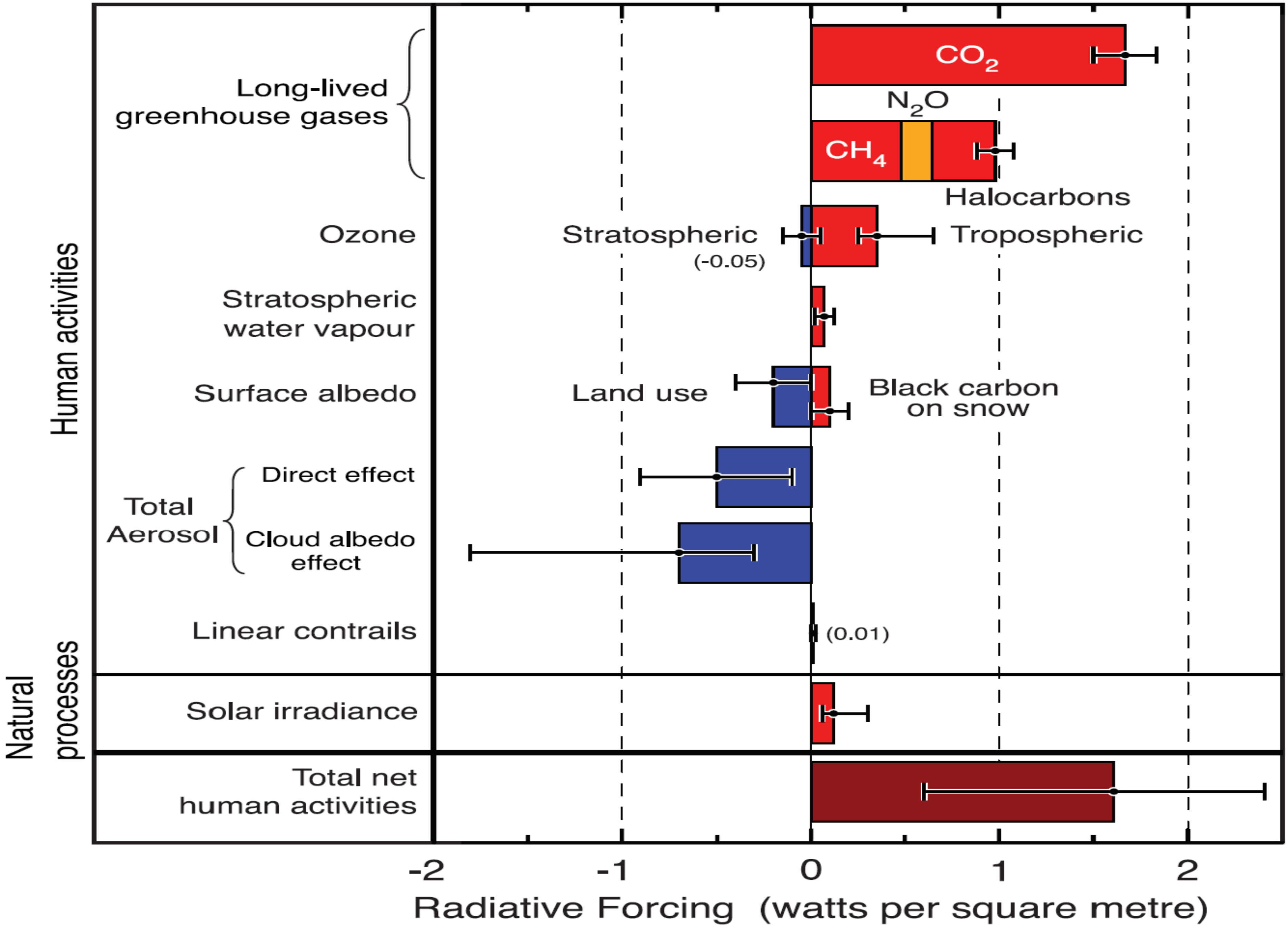
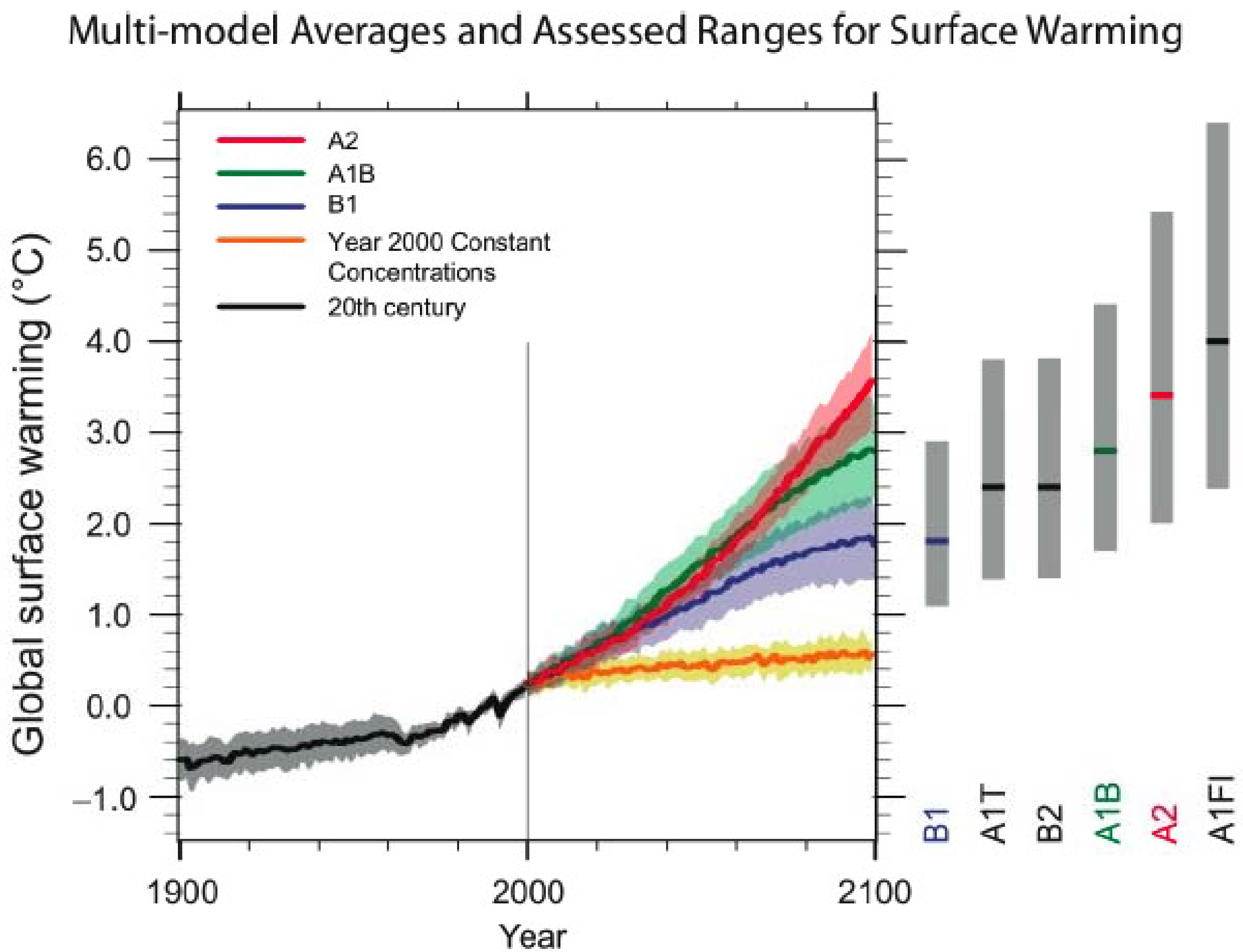
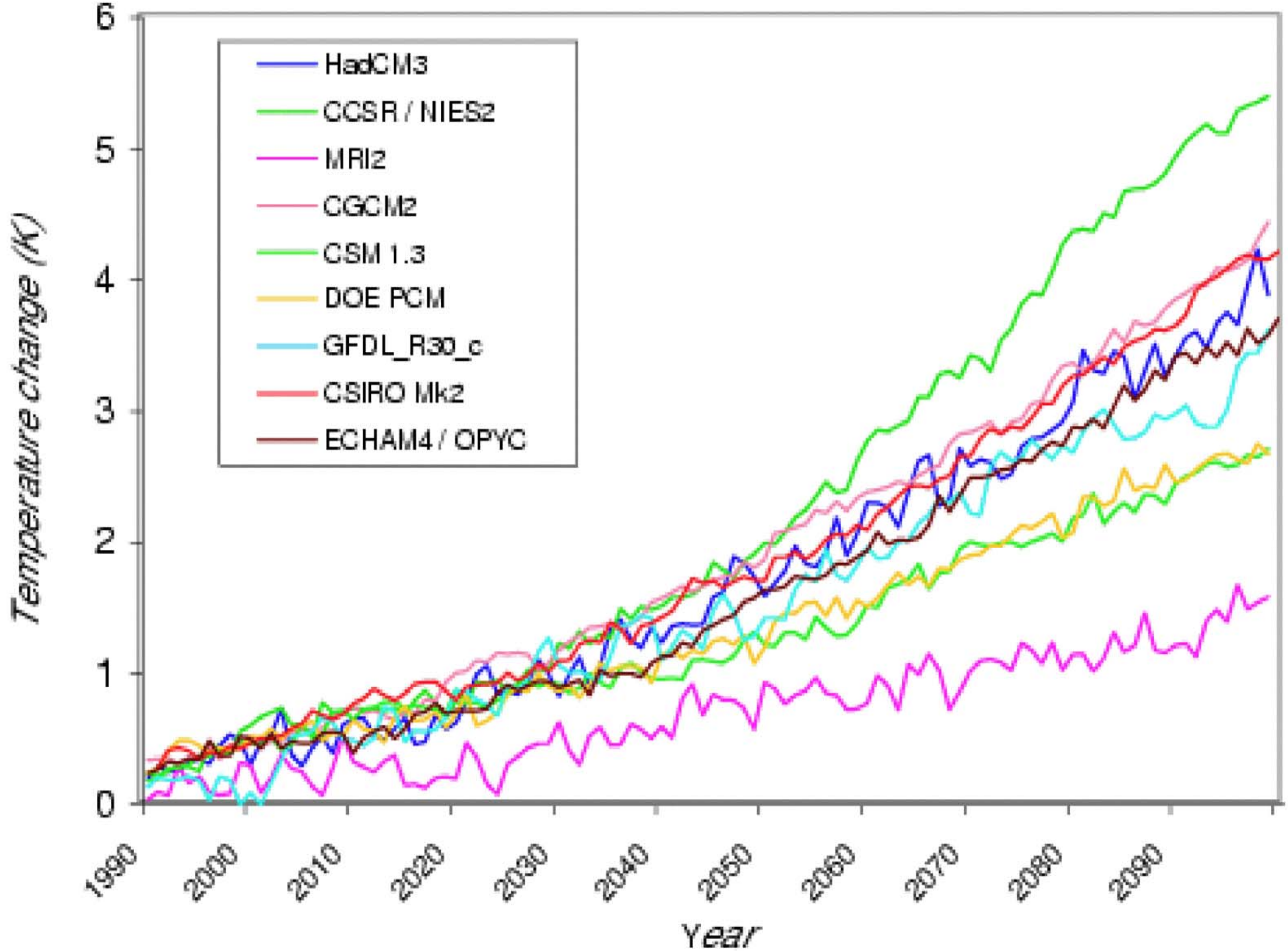
Radiative Forcing Terms





Multi-model Averages and Assessed Ranges for Surface Warming
A2
A1B
B1
Year 2000 Constant Concentrations
20th century
Global surface warming (°C)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
–1.0
1900
2000
2100
Year
B1
A1T
B2
A1B
A2
A1FI



HadCM3
CCSR / NIES2
MRI2
CGCM2
CSM 1.3
DOE PCM
GFDL_R30_c
CSIRO Mk2
ECHAM4 / OPYC
Temperature change (K)
0
1
2
3
4
5
6
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
Year

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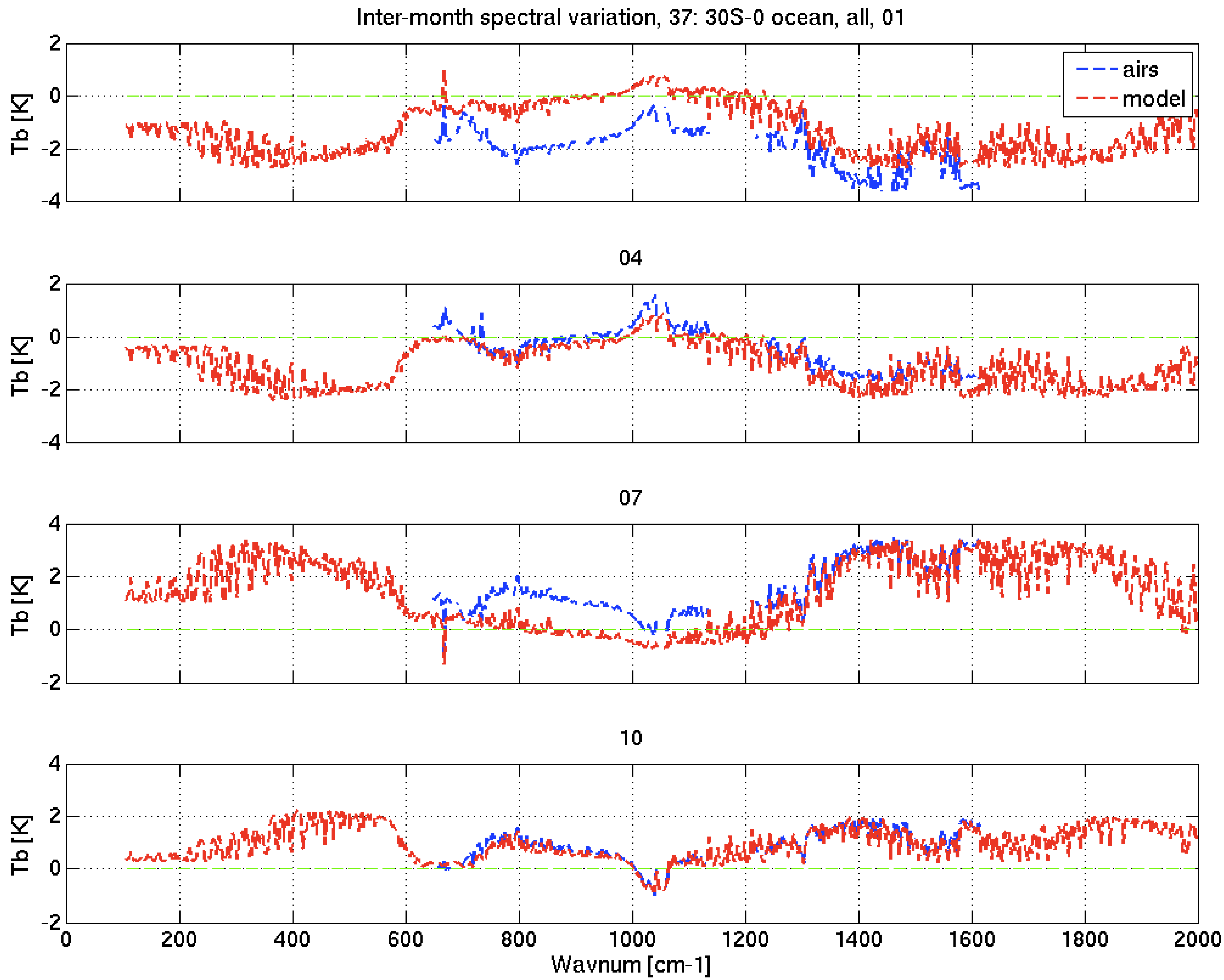
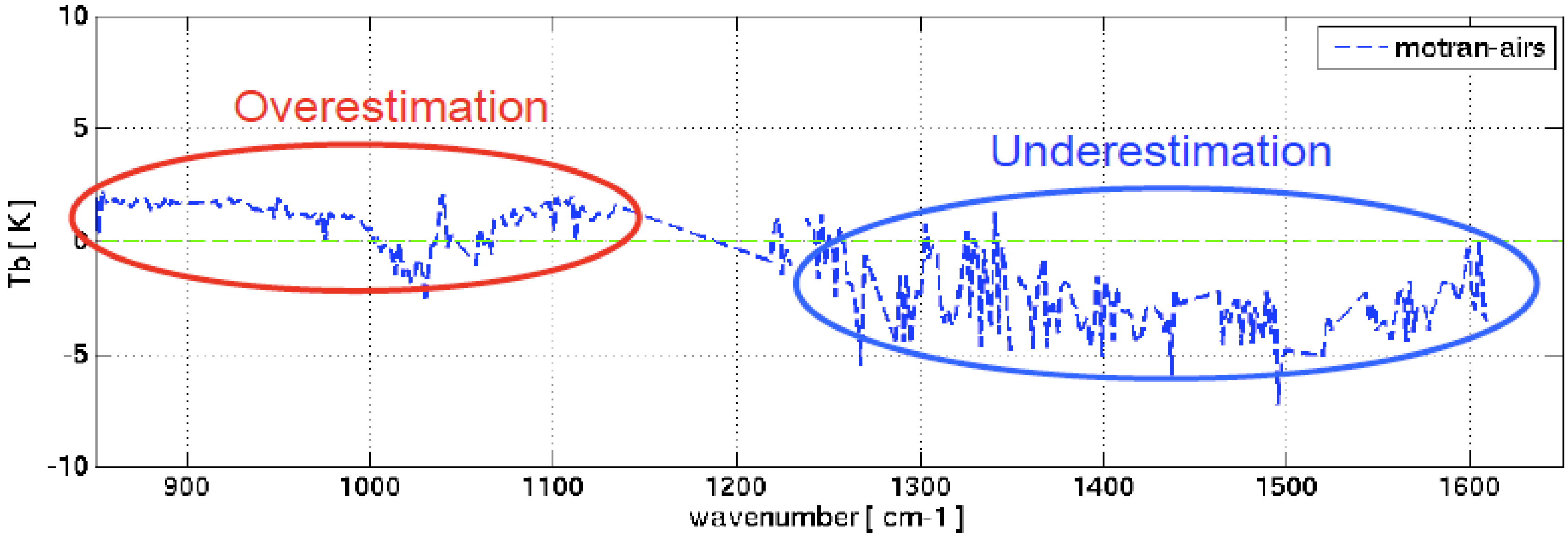

Inter-month spectral variation, 37: 30S-0 ocean, all, 01
airs
model
04
07
10
Tb [K]
Wavnum [cm-1]

Offsetting errors

The seemingly good agreement (-1.1 W m-2 difference) of the total-sky OLR broadband flux may be fortuitous and arise due to a cancellation

Unit: W m^{-2}	OLR		Window band	
	Total sky	Clear sky	Total sky	Clear sky
CERES	**241.73**	**275.87**	**66.94**	**83.28**
AM2	**240.63**	**263.43**	**73.99**	**87.56**
AM2-CERES	**-1.10**	**-12.44**	**7.05**	**4.28**



Observational Dataset

- IRIS (Infrared Interferometer Spectrometer)

Lifetime:	Apr 70 – Jan 71
Spectral coverage:	400-1600 cm^{-1}
	(in this study, 400-1400 cm^{-1})
Spectral resolution (FWHM):	2.8 cm^{-1}
Field of view:	95km in diameter

(~6.25 times of the FOV of ERBE, 15% of an AM2 grid box)

SNR:	20~100
Calibration bias:	0.25-0.75K in BT
Orbit:	Sun-synchronous, 10:30AM/PM sampling

700,000 good spectra over 10 months

Observational Dataset

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Spectral coverage: 650-2665 cm^{-1}

Spectral resolution (FWHM): $\nu/1200\ cm^{-1}$

Field of view: 13.5 km

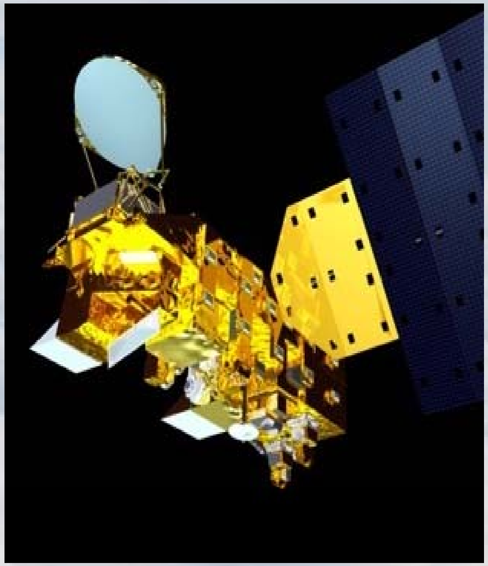
(~9 times of the FOVs per AMSU-A FOV)

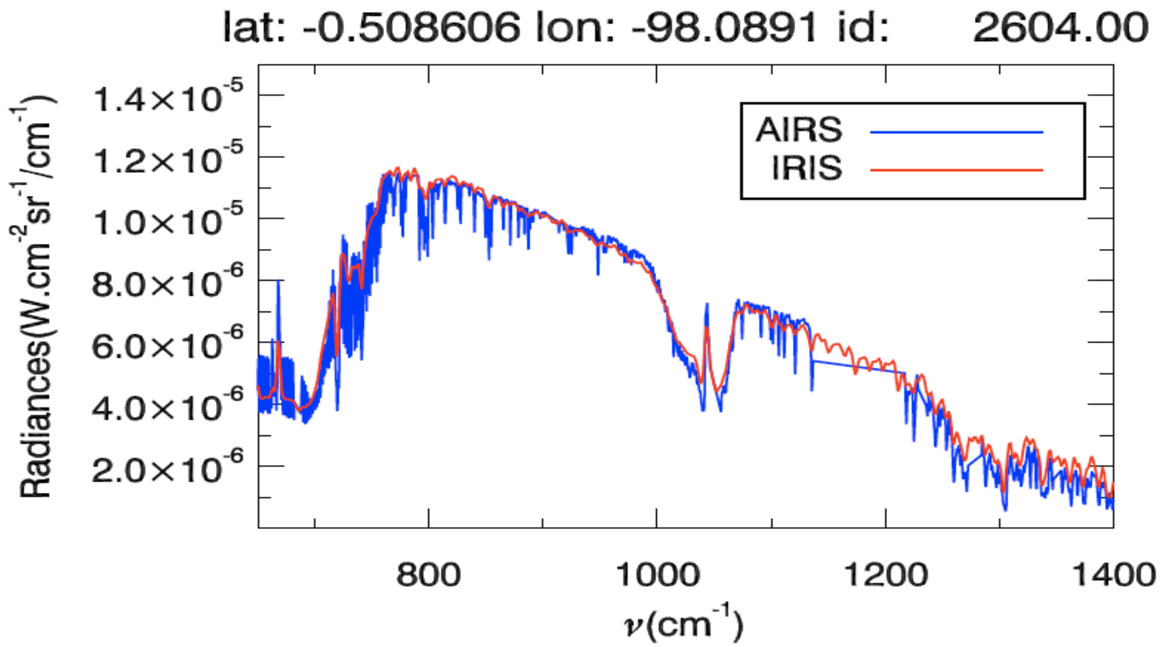
SNR: 600-4000

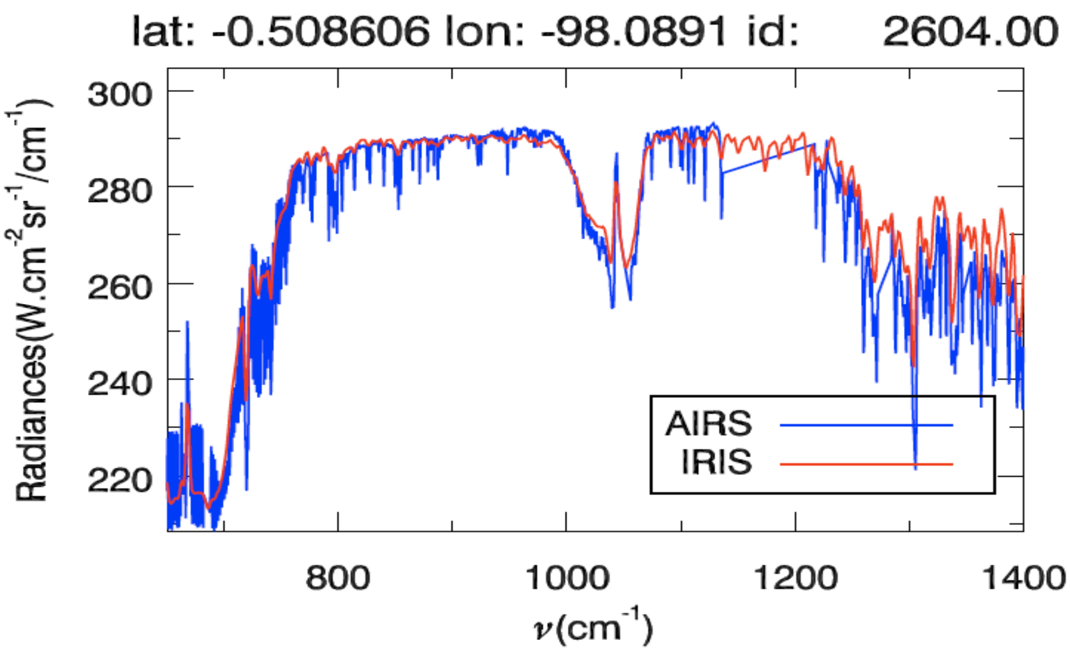
Calibration bias: 0.07-0.5 K in BT

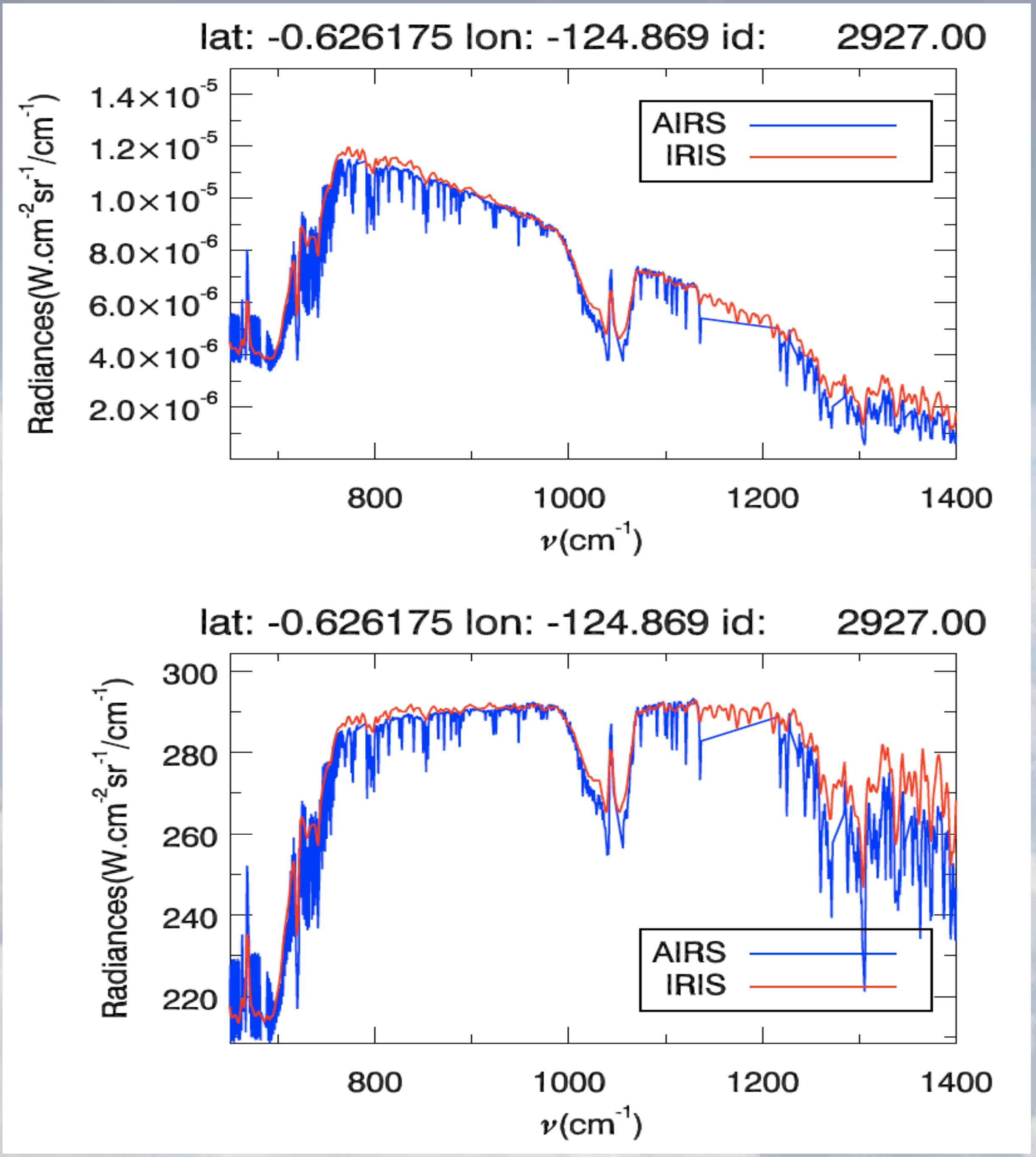
Orbit: Sun-synchronous, 1:30 PM sampling

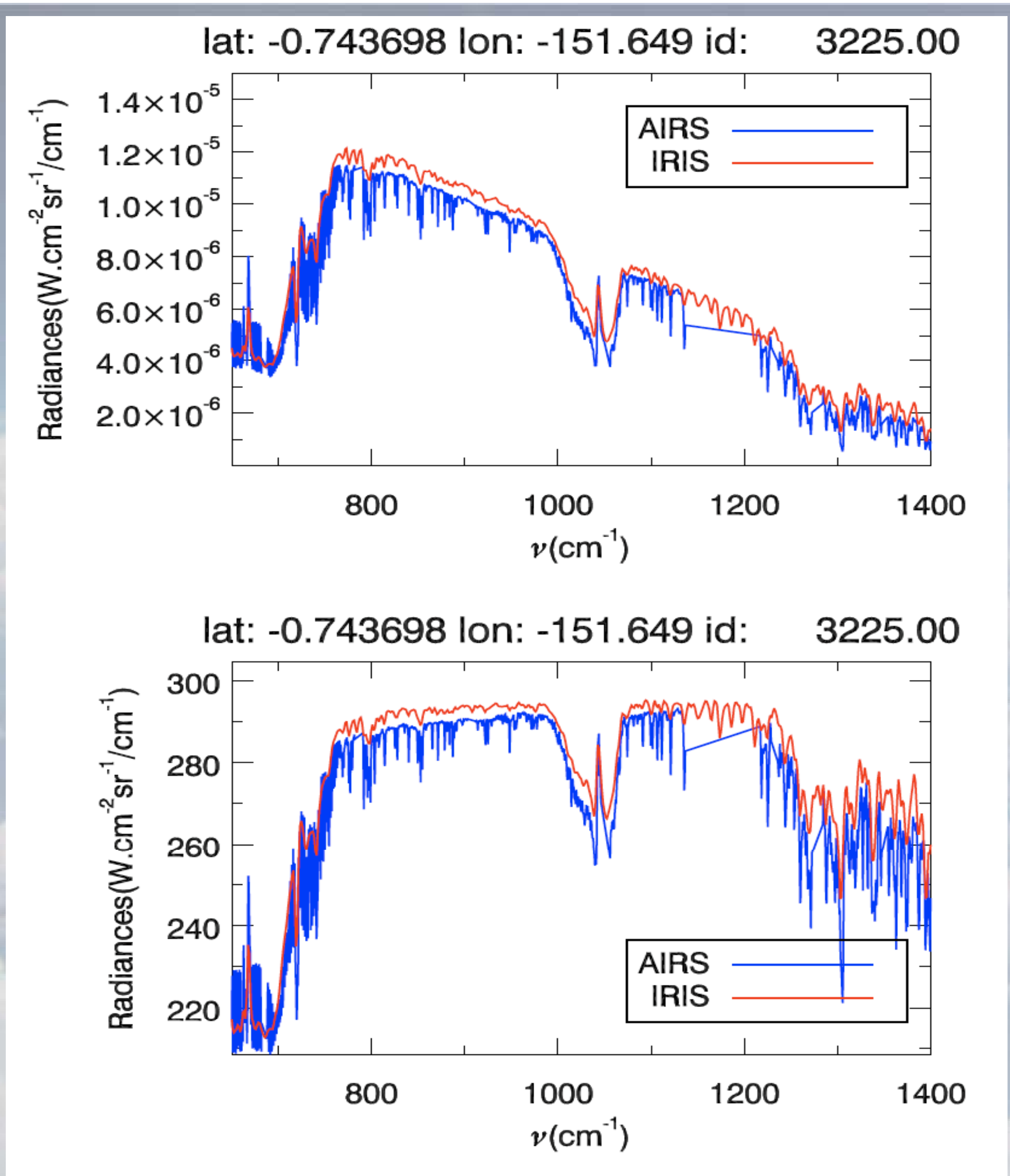
Swath Width: 1650 km, twice daily swath




lat: -0.508606 lon: -98.0891 id: 2604.00
Radiances(W.cm-2sr-1/cm-1)
1.4×10-5
1.2×10-5
1.0×10-5
8.0×10-6
6.0×10-6
4.0×10-6
2.0×10-6
800
1000
1200
1400
ν(cm-1)
AIRS
IRIS


lat: -0.508606 lon: -98.0891 id: 2604.00
Radiances(W.cm-2sr-1/cm-1)
300
280
260
240
220
800
1000
1200
1400
ν(cm-1)
AIRS
IRIS


lat: -0.626175 lon: -124.869 id: 2927.00
Radiances(W.cm^-2sr^-1/cm^-1)
1.4×10^-5
1.2×10^-5
1.0×10^-5
8.0×10^-6
6.0×10^-6
4.0×10^-6
2.0×10^-6
AIRS
IRIS
800
1000
1200
1400
ν(cm^-1)
lat: -0.626175 lon: -124.869 id: 2927.00
Radiances(W.cm^-2sr^-1/cm^-1)
300
280
260
240
220
AIRS
IRIS
800
1000
1200
1400
ν(cm^-1)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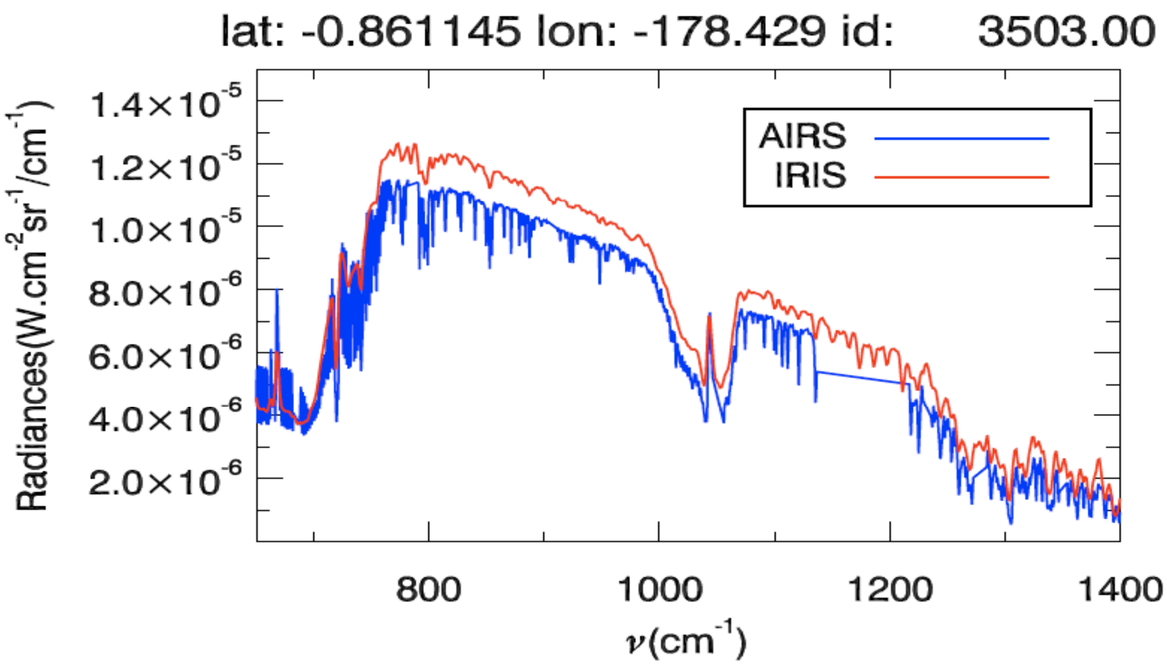
Radiances(W.cm-2sr-1/cm-1)
1.4×10-5
1.2×10-5
1.0×10-5
8.0×10-6
6.0×10-6
4.0×10-6
2.0×10-6
AIRS
IRIS
800
1000
1200
1400
ν(cm-1)
lat: -0.743698 lon: -151.649 id: 3225.00
Radiances(W.cm-2sr-1/cm-1)
300
280
260
240
220
AIRS
IRIS
800
1000
1200
1400
ν(cm-1)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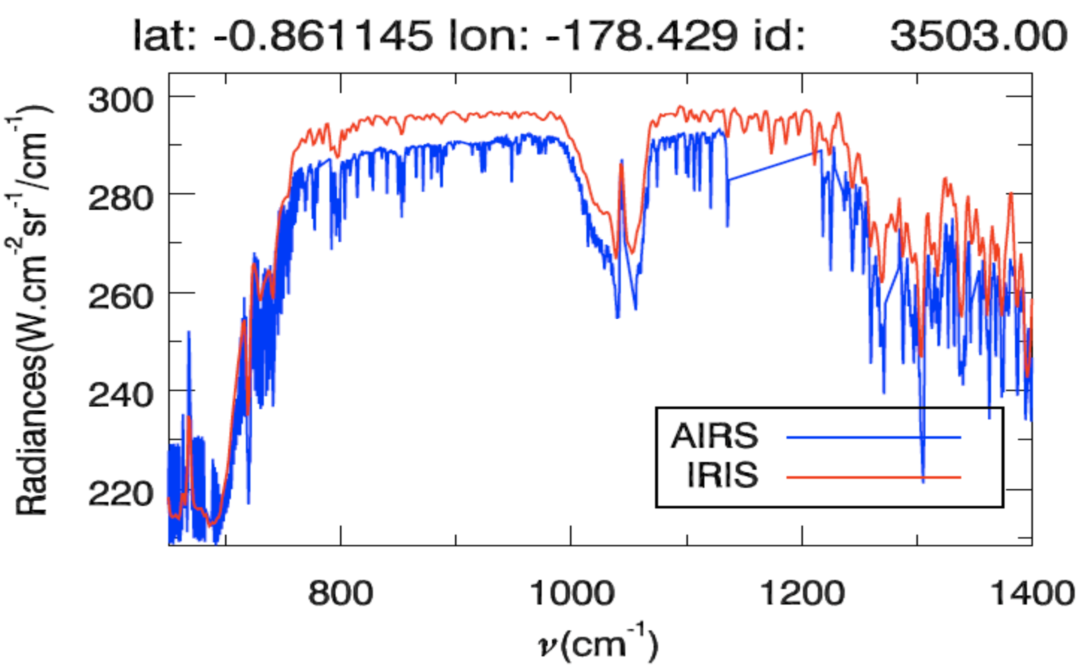
Radiances(W.cm^{-2}sr^{-1}/cm^{-1})
1.4×10^{-5}
1.2×10^{-5}
1.0×10^{-5}
8.0×10^{-6}
6.0×10^{-6}
4.0×10^{-6}
2.0×10^{-6}
AIRS
IRIS
800
1000
1200
1400
ν(cm^{-1})


lat: -0.861145 lon: -178.429 id: 3503.00
Radiances(W.cm^{-2}sr^{-1}/cm^{-1})
300
280
260
240
220
AIRS
IRIS
800
1000
1200
1400
ν(cm^{-1})

Conclusions

Radiation plays a fundamental role as the source of energy

Spectral radiance provides detailed picture of energy exchange

Radiation as diagnostic of climate change (potential)

Thanks

- Yung's Group at Caltech
- Trenberth (NCAR)
- Prof. Xianglei Huang (U Michigan)

- *Ref: Goody and Yung (1989)*
- *Huang and Yung (2005) JGR 110*