Using Hyperspectral Data from AIRS for the Validation of Climate Models

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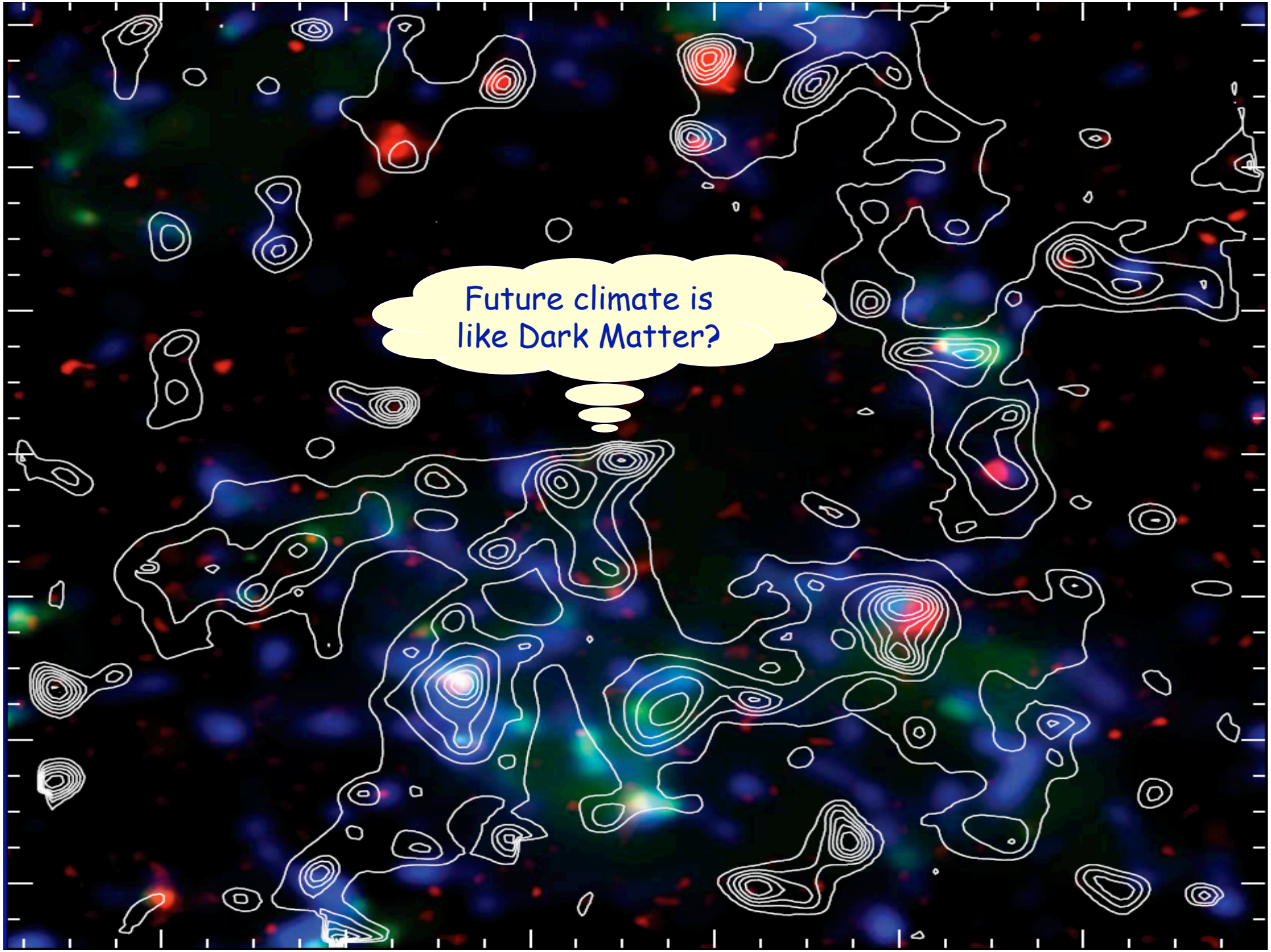
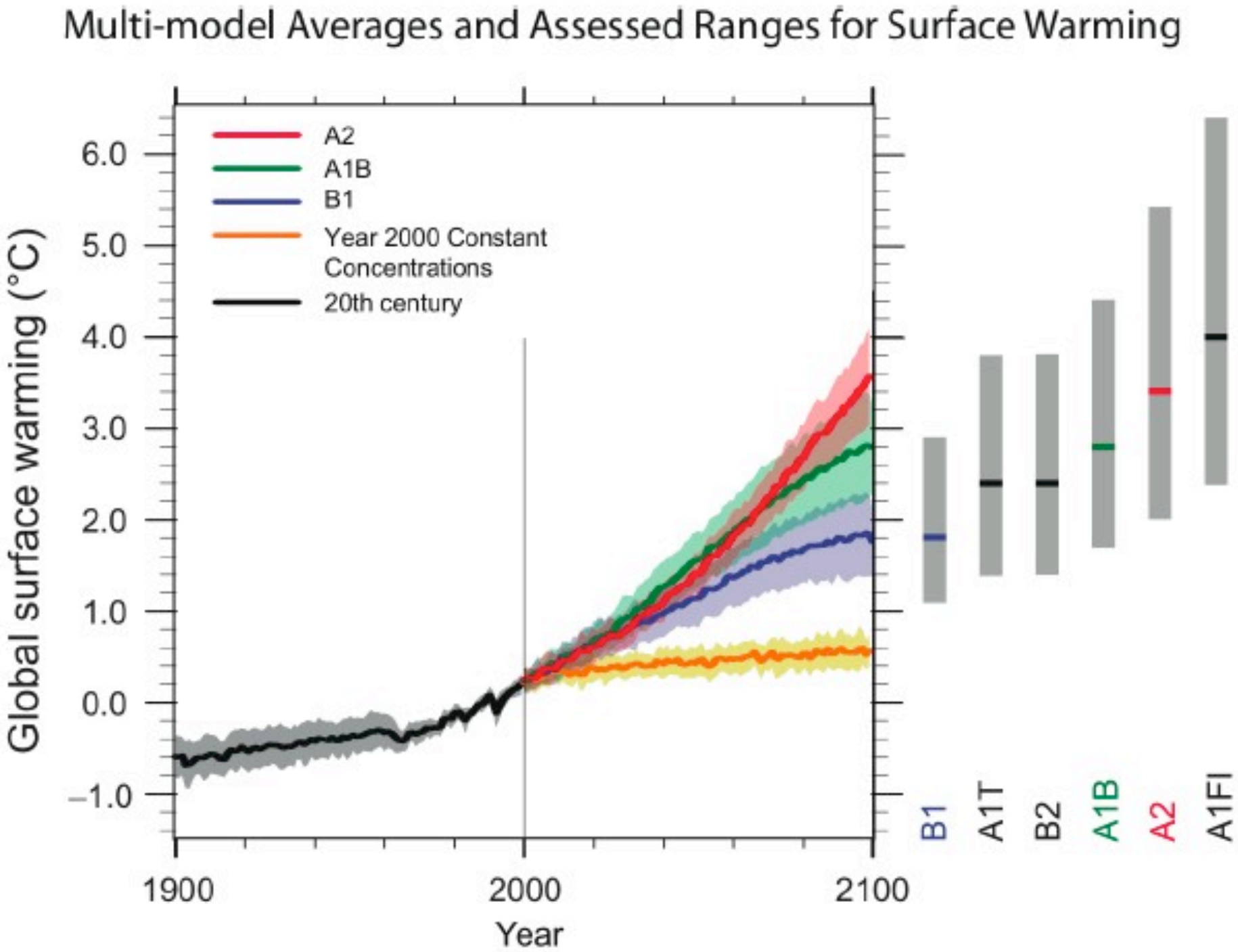
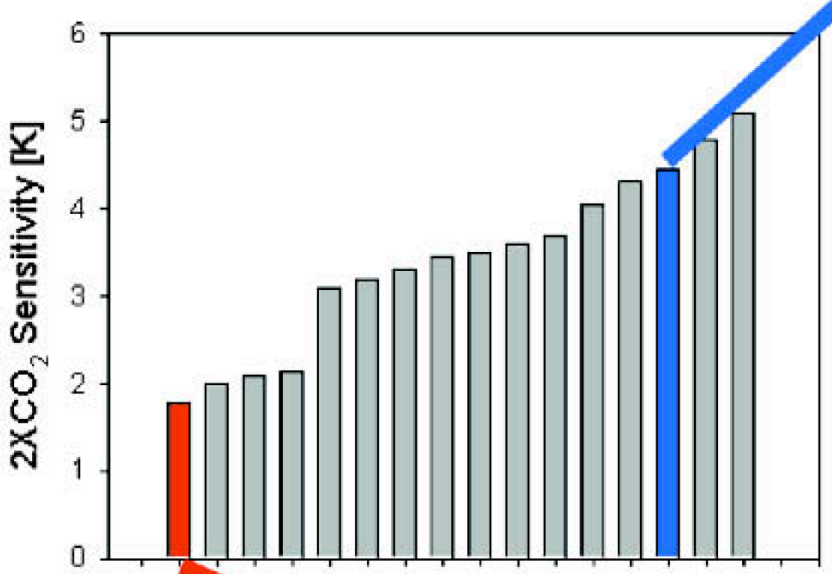
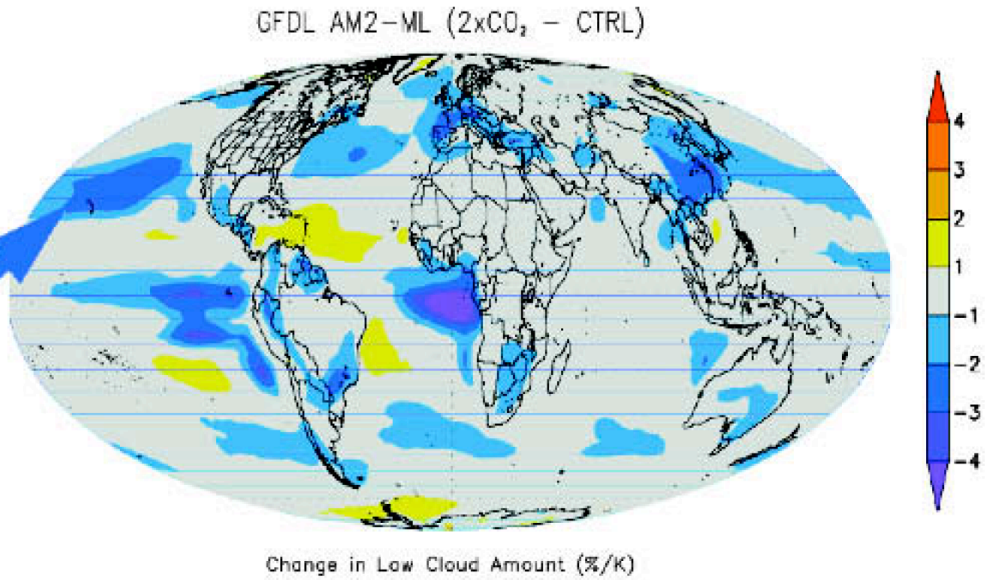
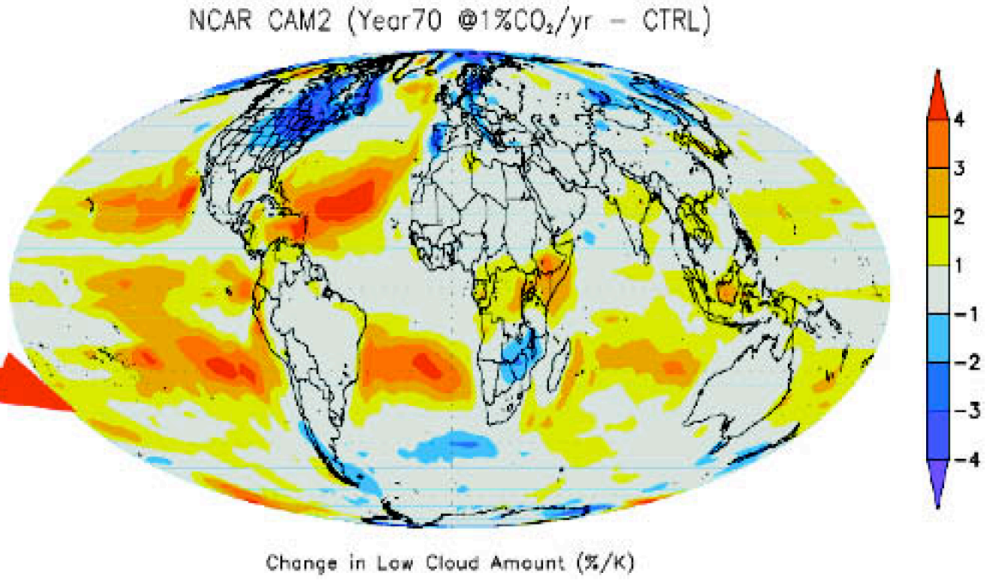
Mar 27 2007


Future climate is
like Dark Matter?


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







Reference

Stephens, GL. "Cloud feedbacks in the climate system: A critical review." *Journal of climate,* **18**(2), 2005:237-273.

Origins:

- Hanel, R. A., Salomons, V., *et al*., 1972: Nimbus 4 Infrared Spectroscopy Experiment .1. Calibrated Thermal Emission-Spectra. *J. Geophys. Res.*, 77, 2629-2641.
- Haskins, R., R. Goody, and L. Chen, 1999: Radiance covariance and climate models. *J. Climate*, 12, 1409-1422.

Recent work:

- Huang, X., and Y. L. Yung. (2005). "Spatial and spectral variability of the outgoing thermal IR spectra from AIRS: A case study of July 2003." *J. Geophys. Res.*: 110 D12102/2004JD005530.

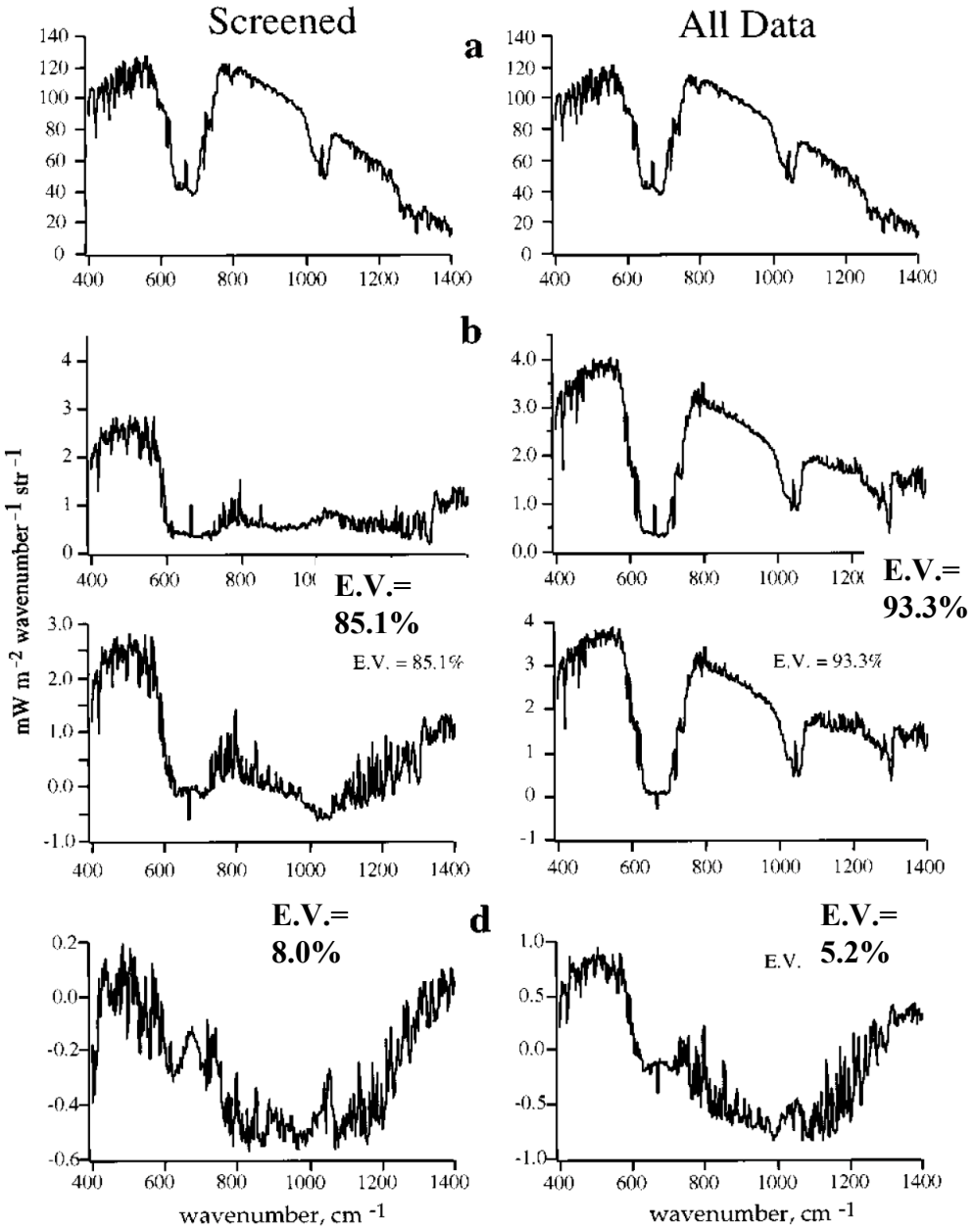


FIG. 5. IRIS data for the central Pacific. Details as for Fig. 4. "All data" involves 9872 spectra, while "screened" involves 5006.

Reference

Haskins, R. "Radiance covariance and climate models." Journal of climate **12**(5), 1999:1409-1422.

Principal Component Analysis (PCA)

Data Matrix X (N time steps $\times$ M stations)

$\downarrow$

Covariance Matrix $C = \frac{1}{N-1} X^T X = E \Lambda E^T$ ($M \times M$ entries)

- EOFs (e_k = eigenvectors of C): Modes of Spatial Pattern
- PCs ($p_k = X \cdot e_k$): Time-dependent Amplitudes of EOFs
- Eigenvalue: the fraction of variance captured by each EOF
- The original data can be represented by

$$X = \sum_k p_k(t) e_k^T(\theta, \varphi)$$

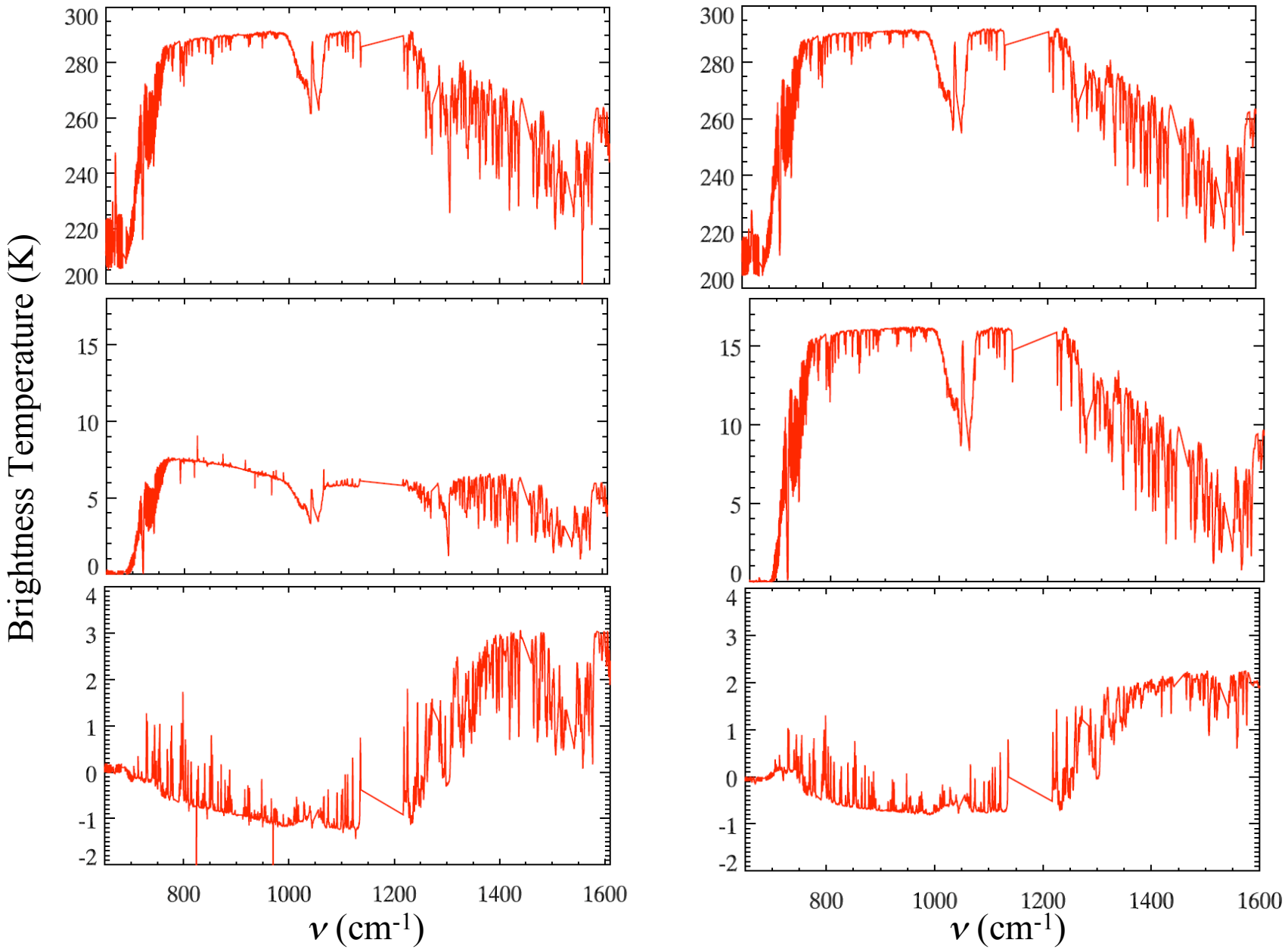
Spectral PCA: Replace time t by frequency ν

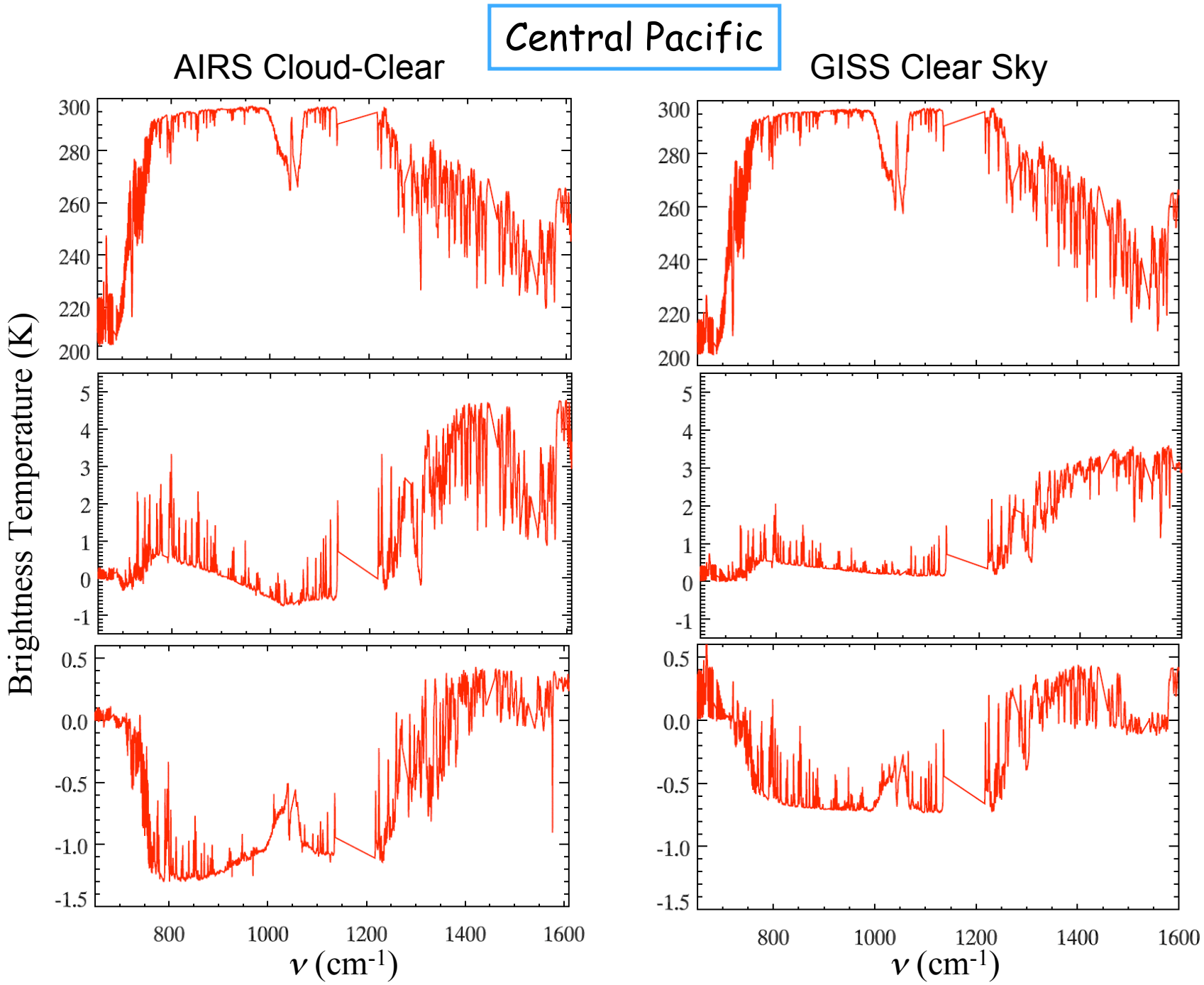

Central Pacific
(140W, 0N)

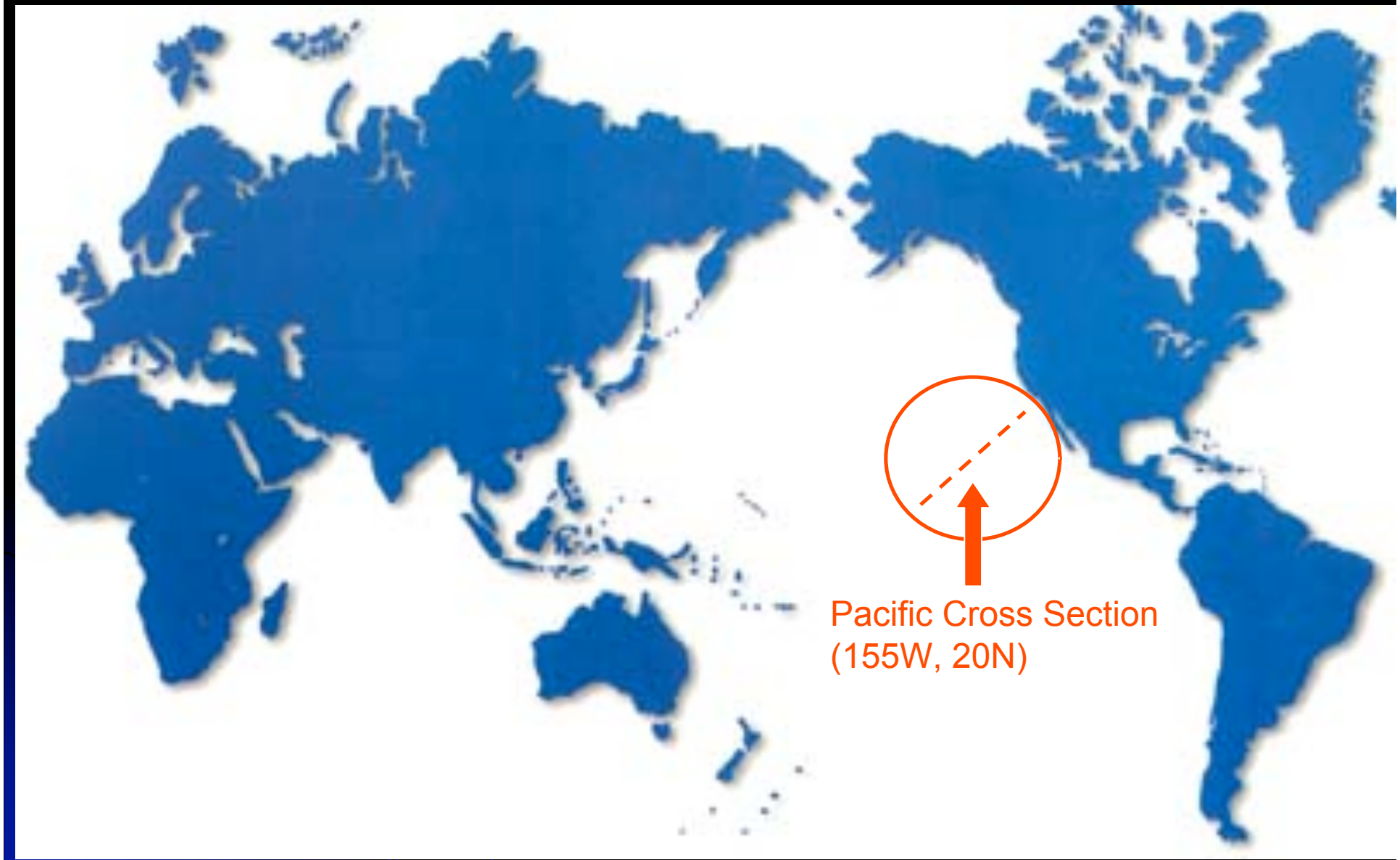
Central Pacific

AIRS Raw Data

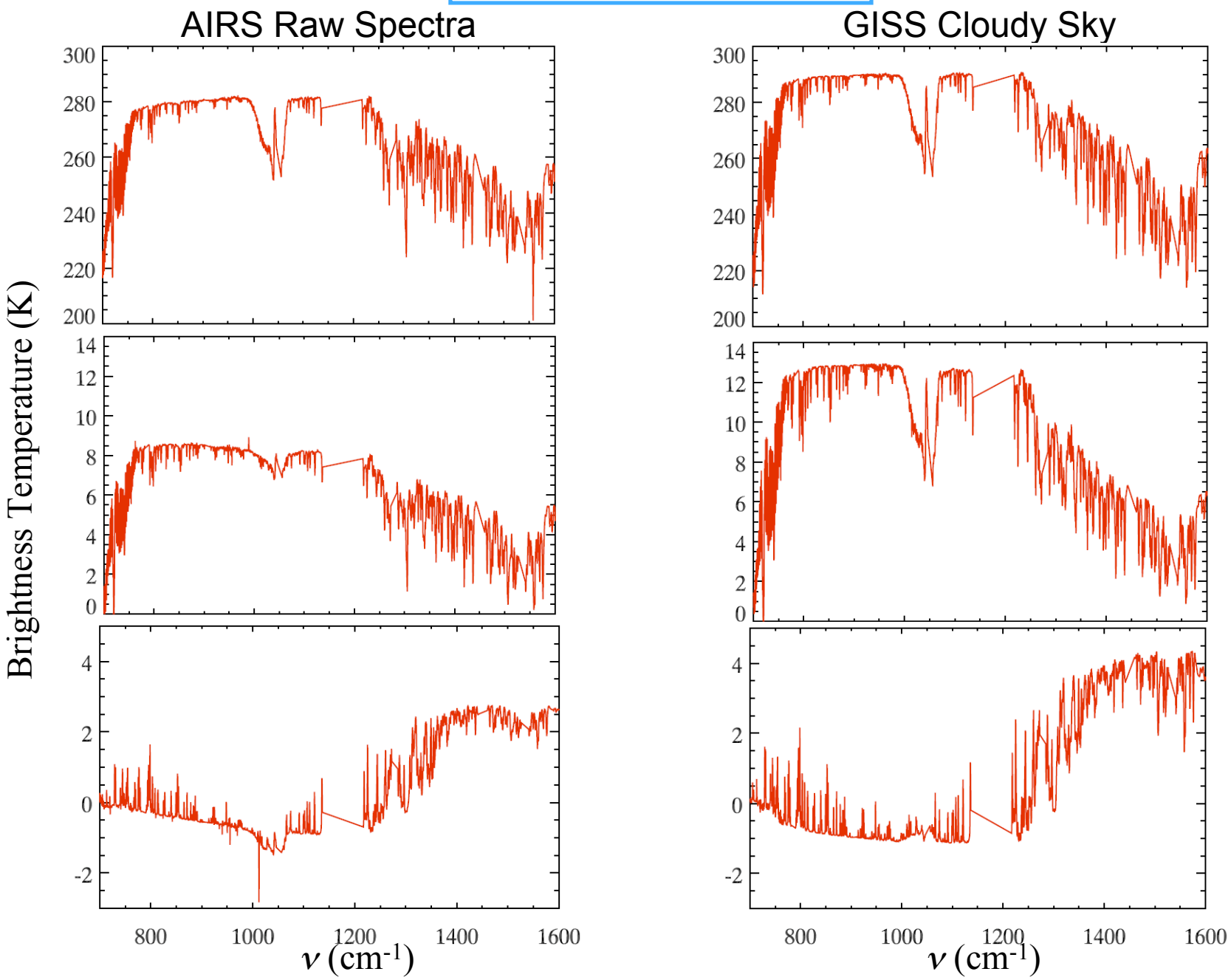
GISS Cloudy Sky



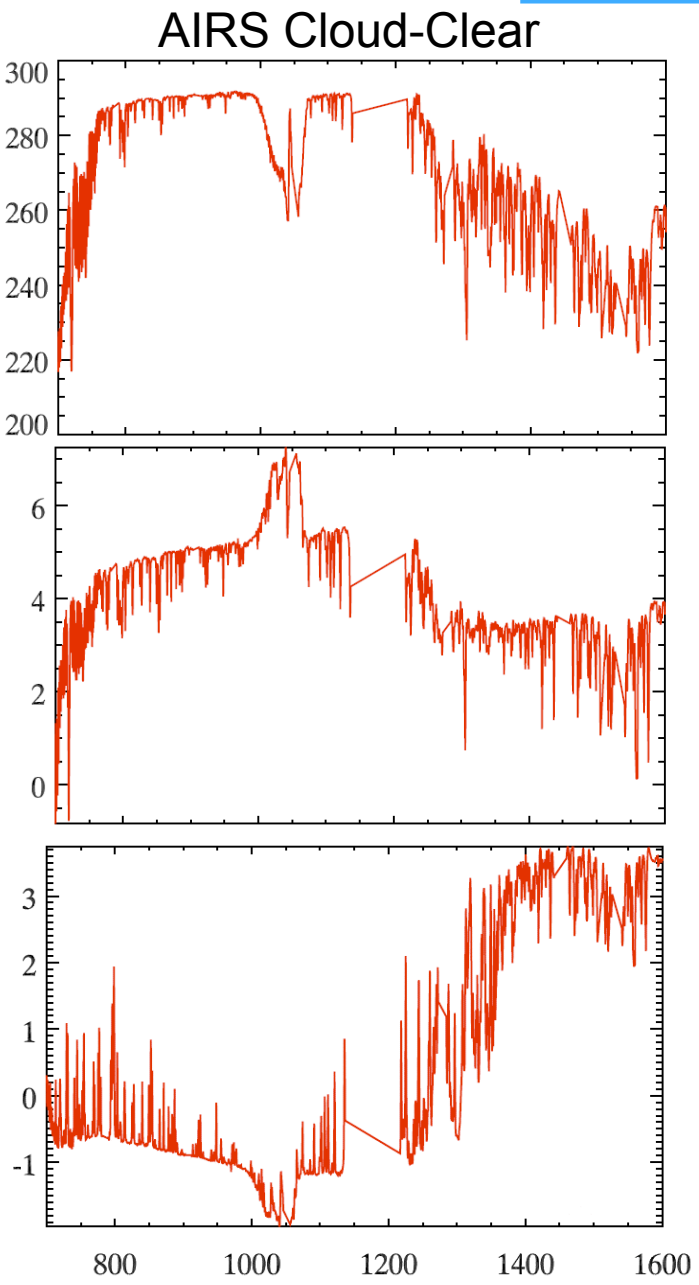

Central Pacific
AIRS Cloud-Clear
GISS Clear Sky
Brightness Temperature (K)
300
280
260
240
220
200
5
4
3
2
1
0
-1
0.5
0.0
-0.5
-1.0
-1.5
800
1000
1200
1400
1600
ν (cm-1)

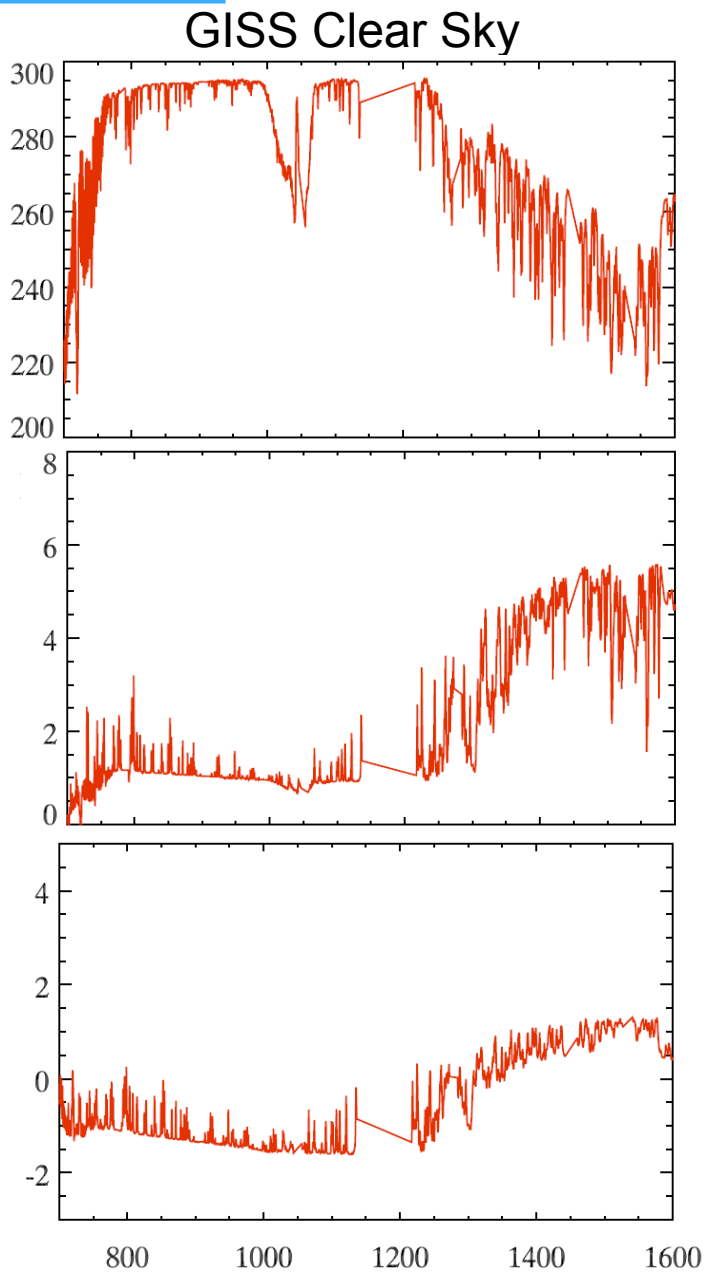

Pacific Cross Section
(155W, 20N)

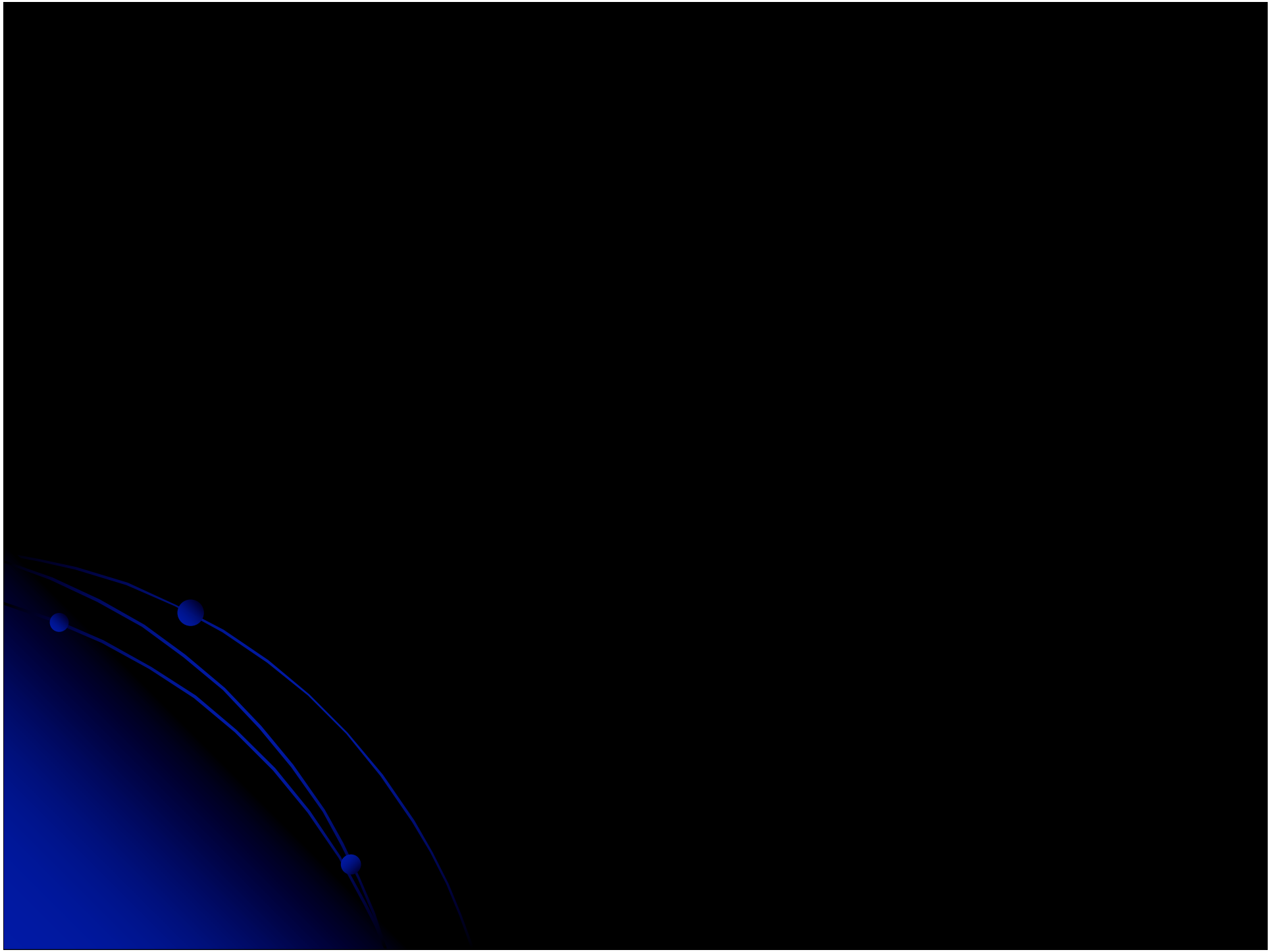
Pacific Cross Section



Pacific Cross Section







Arrival of Golden Age

- *(1) Extensive Database.* There now exist three extensive datasets taken in 1970-71, 1996-1997, and since 2003, by the *Infrared Interferometer Spectrometer (IRIS), the Interferometric Monitor for Greenhouse gases (IMG), and the Atmospheric Infrared Sounder (AIRS) missions, respectively.* In traditional meteorological studies, only a few channels in the thermal infrared are used to constrain the energy budget of the atmosphere. The spectral radiances contain thousands, and even tens of thousands of channels.

- *(2) Quality of Satellite Data.* The quality of the AIRS data is unprecedented. The precision of the data is 0.1 K in brightness temperature, based on an absolute on-board calibrator, making the data ideally suited for climate variability studies. The spectral resolution is 1 cm-1, allowing individual rotational lines of water vapor to be resolved. The spatial resolution is about 10 km, so that cloudy and neighboring clear atmospheres can be separated, thereby isolating the effect of clouds from water vapor.

Arrival of Golden Age

- *(3) Quantity of Satellite Data.* The quantity of data is staggering. To date, AIRS has collected 10 billion (1010) spectra of the Earth's outgoing spectral radiances. These data, together with their high quality, will be used to produce the best climate statistics, especially second order moments, for comparison with climate models.

- *(4) Comparison between Observations and Models.* Second-moment statistics are related to the sensitivity of the climate system to an external forcing. At present, two climate models from the National Center for Atmospheric Research (NCAR) and the Goddard Institute for Space Studies (GISS) are being run at JPL for comparison with spectral radiances. We are provided data from GSFC/GEOS-5 (NASA's newest GCM) and GFDL.