Earth Atmospheric Temperature Response to Solar Cycle Variability

Analysis of the AIRS Dataset

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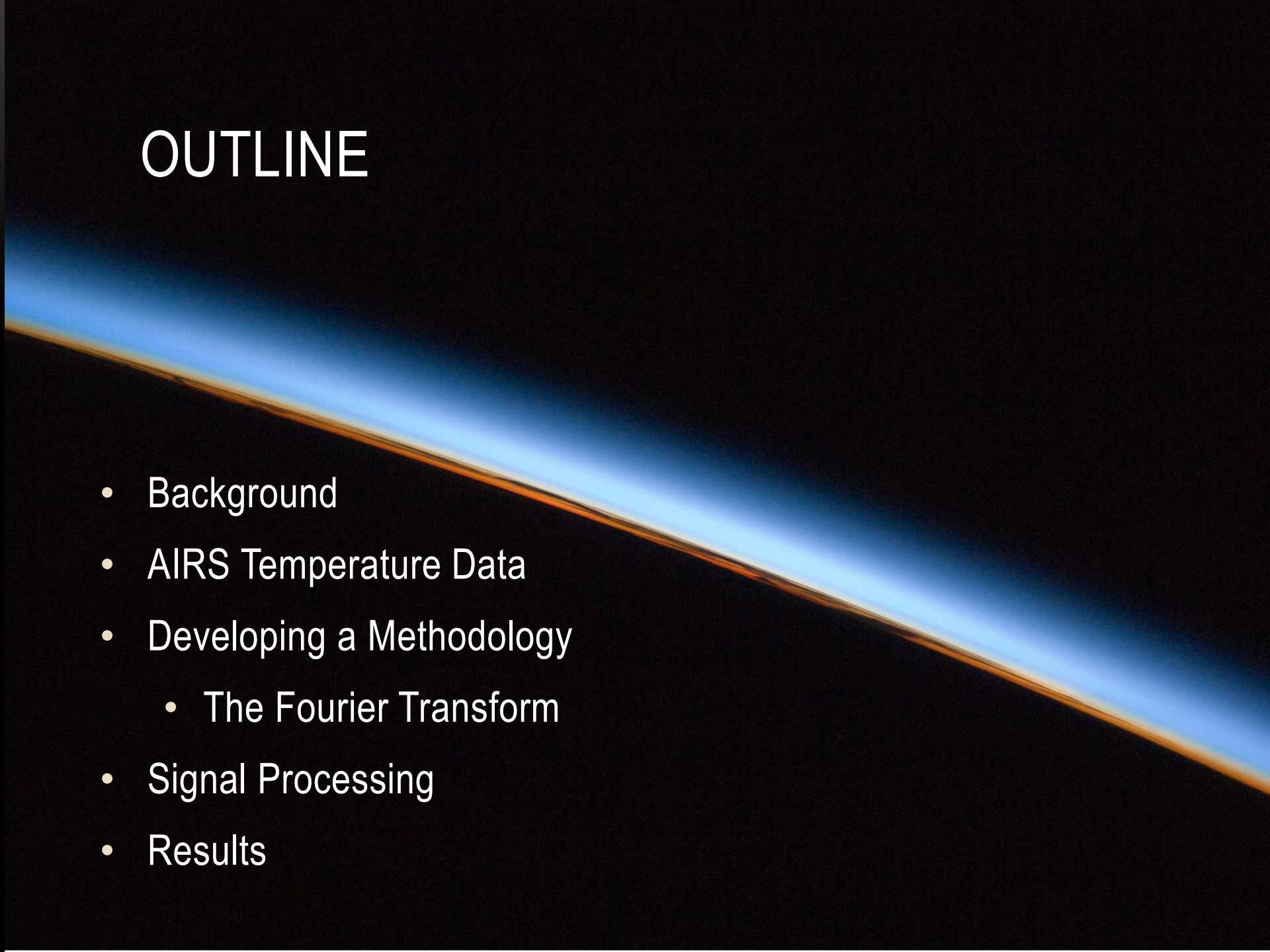
OUTLINE



- Background
- AIRS Temperature Data
- Developing a Methodology
  - The Fourier Transform
- Signal Processing
- Results

Background: Solar-Atmosphere Energy Flux

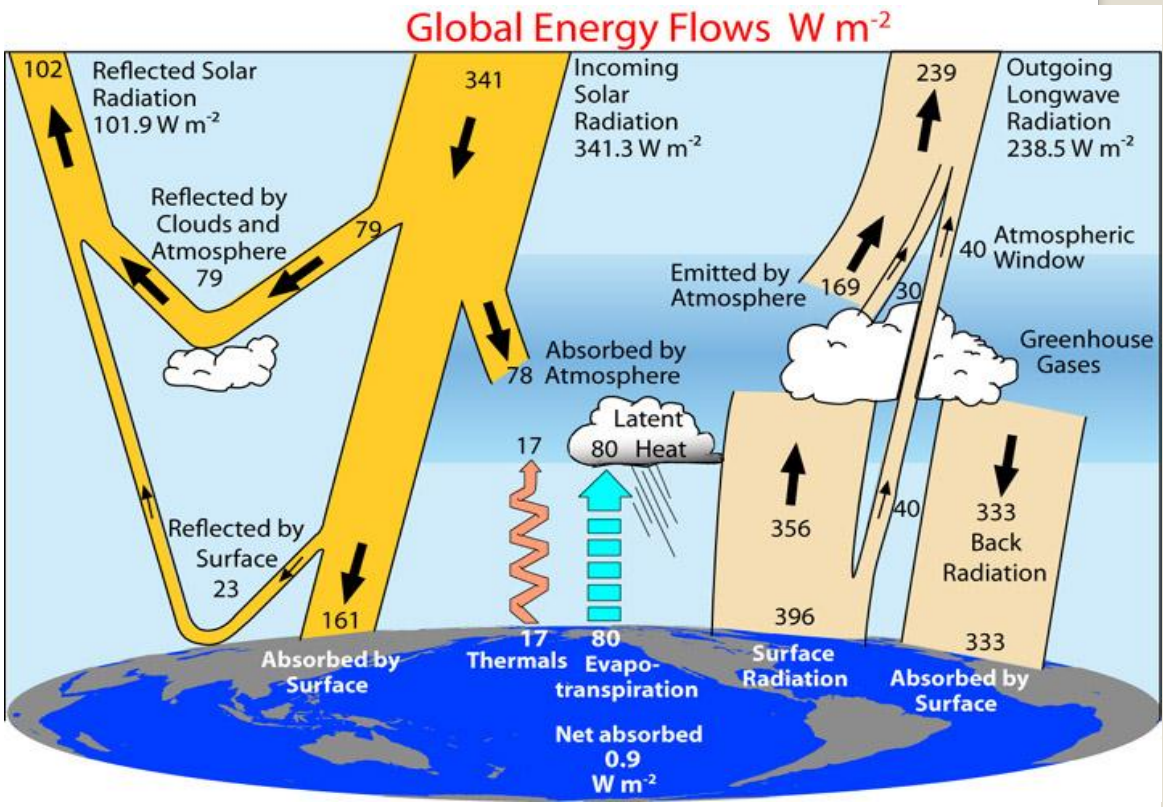
Energy in Earth's Atmosphere

- "The sun is the source of energy for the Earth's climate system and observations show it to be a variable star."

Effects of Variability due to the Solar Cycle?

- Solar Variability is thought to account for about .07% of TSI, or about 0.17 W/m^2
- This is still twice as large as energy input from the sum of all regularly occurring non-solar sources

[*Gray et al.*, 2010]

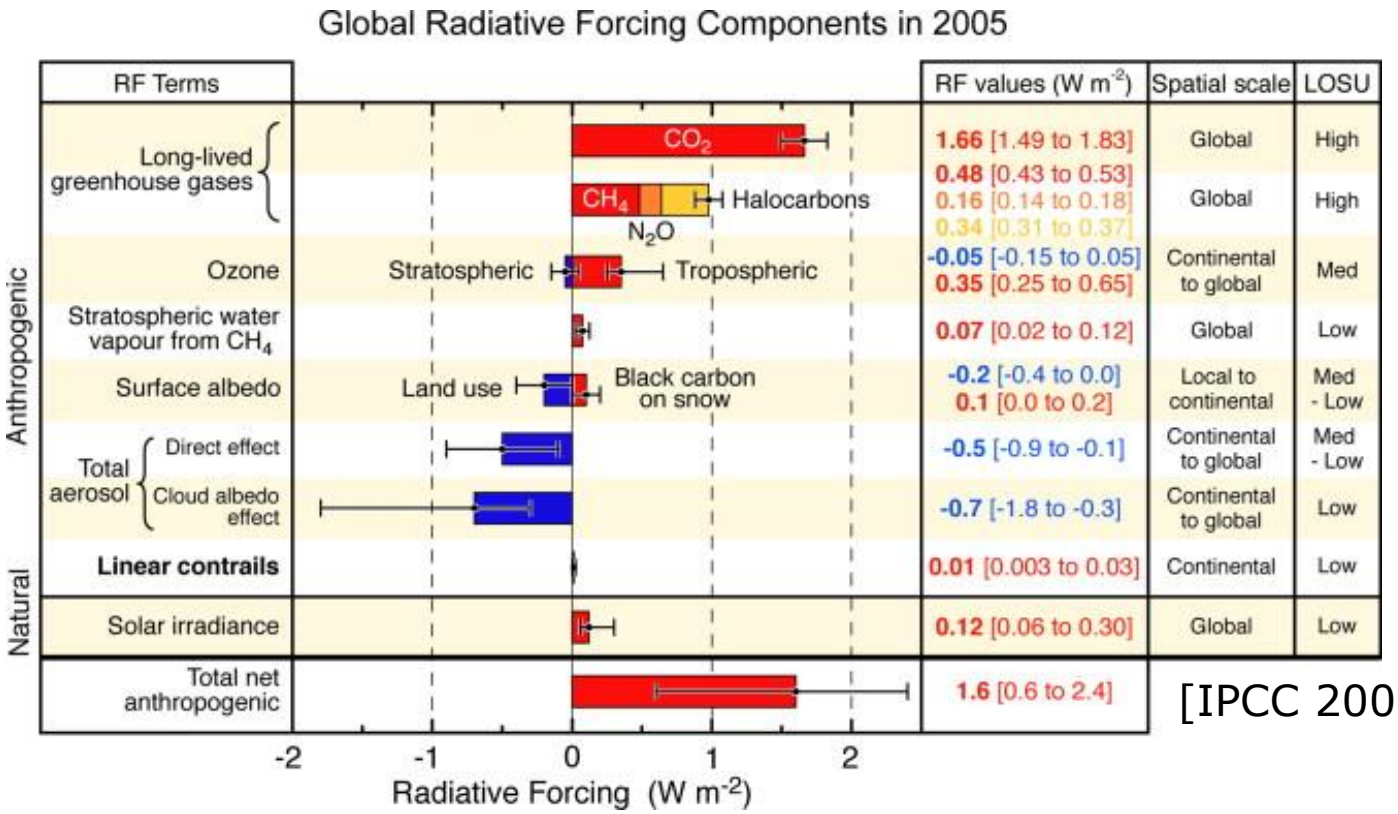


Heat Source	Heat Flux* [W/m ^{2}]	Relative Input
Solar Irradiance	**340.25**	**1.000**
Total of All Non-Solar Energy Sources	***0.0810***	***2.4E-04***

* global average

Physical Climatology, W.D. Sellers, Univ. of Chicago Press, 1965
Table 2 on p. 12 is from unpublished notes from
H.H. Lettau, Dept. of Meteorology, Univ. of Wisconsin.

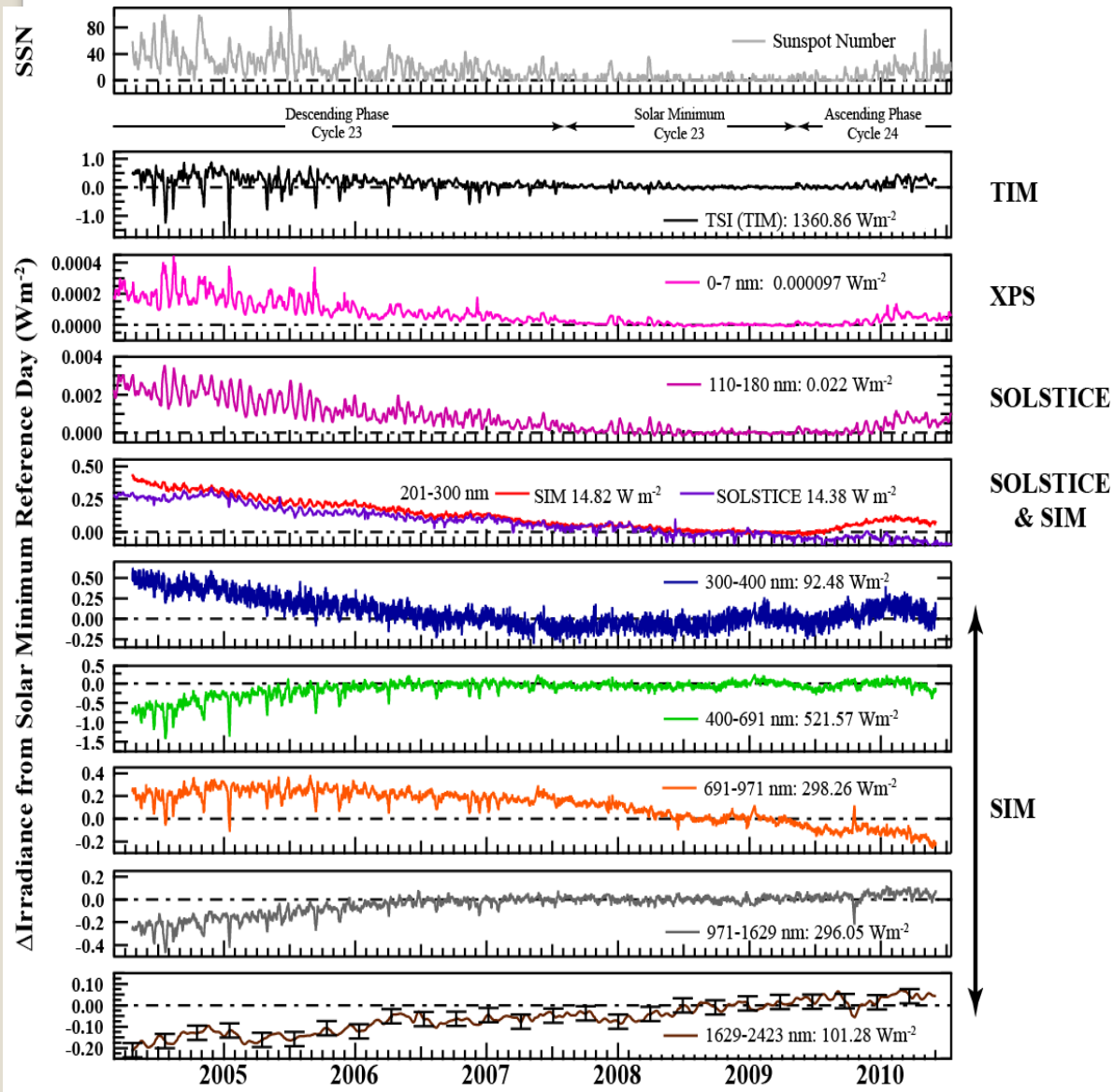
TSI and Temperature Response



[IPCC 2007]

- Just from TSI calculations, using IPCC radiative forcing parameters, solar cycle variance could produce a global surface temperature variation of about 0.07K. [*Gray et al.*, 2010]
- The IPPC report also notes that additional climate forcing through solar UV contributions and other solar mechanisms are also possible.

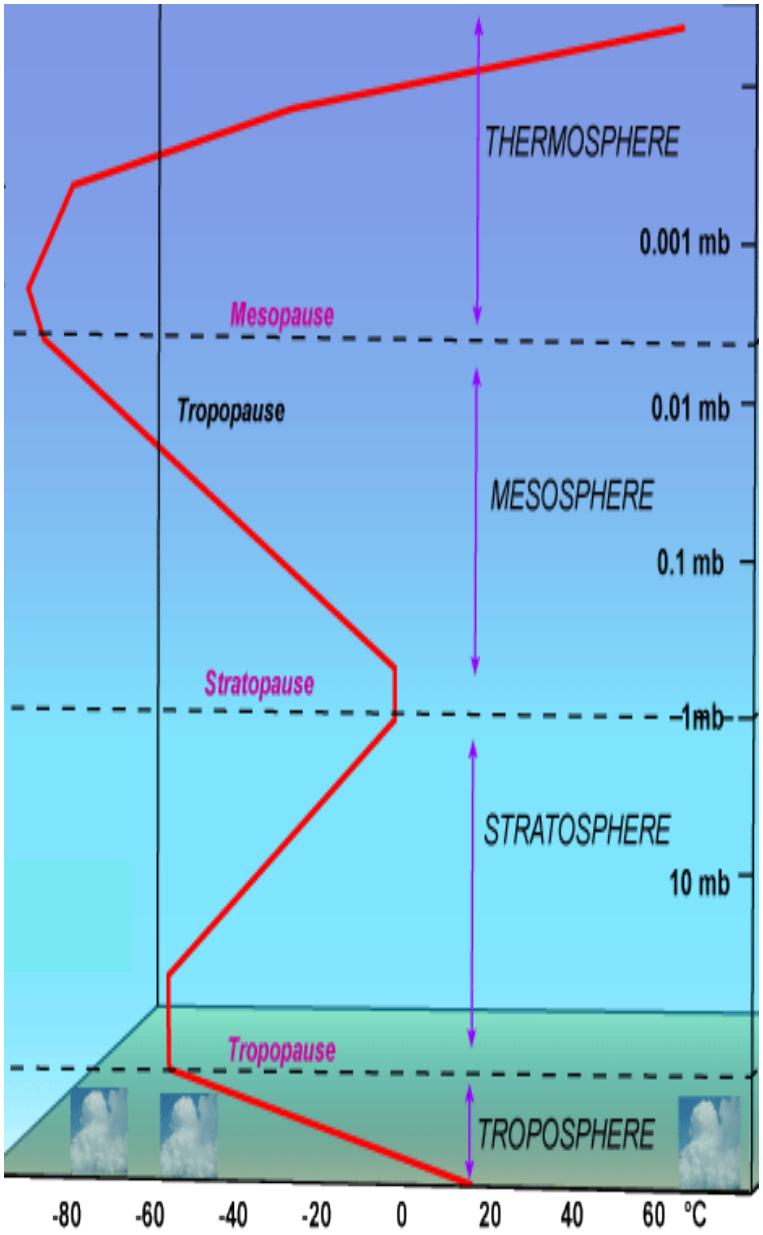
SSI and Temperature Response



[Harder et al., 2009]

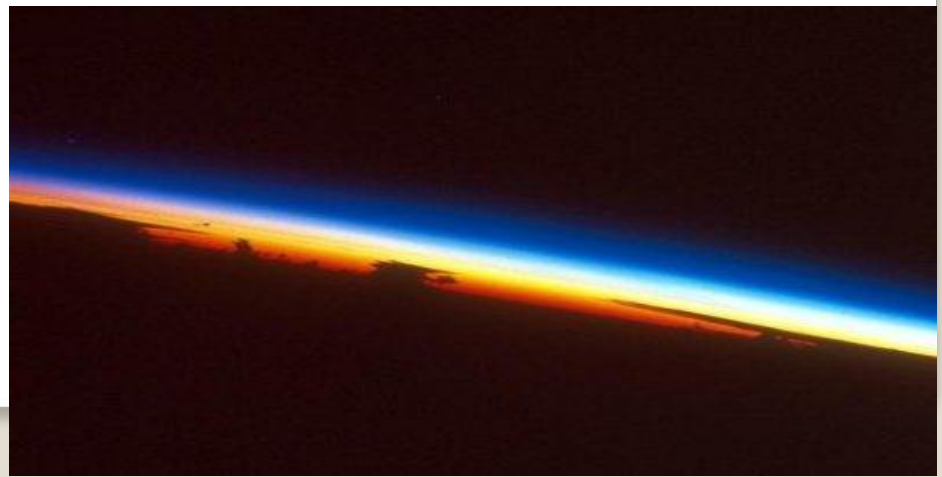
- Calculations with Spectral Solar Irradiance values have shown more variance in temperature
- Studies have increasingly been looking at variability in solar irradiance due to solar cycle influences as a function of wavelength.
- Increased UV in the stratosphere during solar maximum could result in a 1°-2° temperature change at these levels.

[Gray et al., 2010]

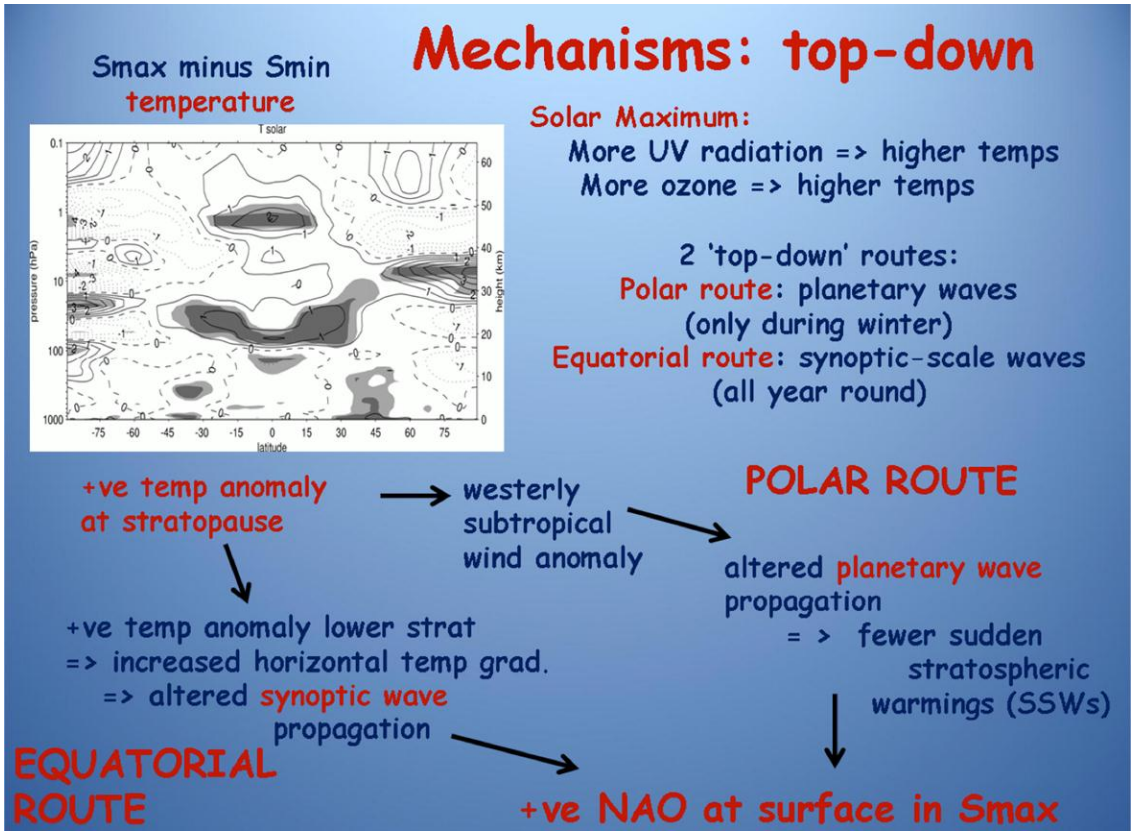


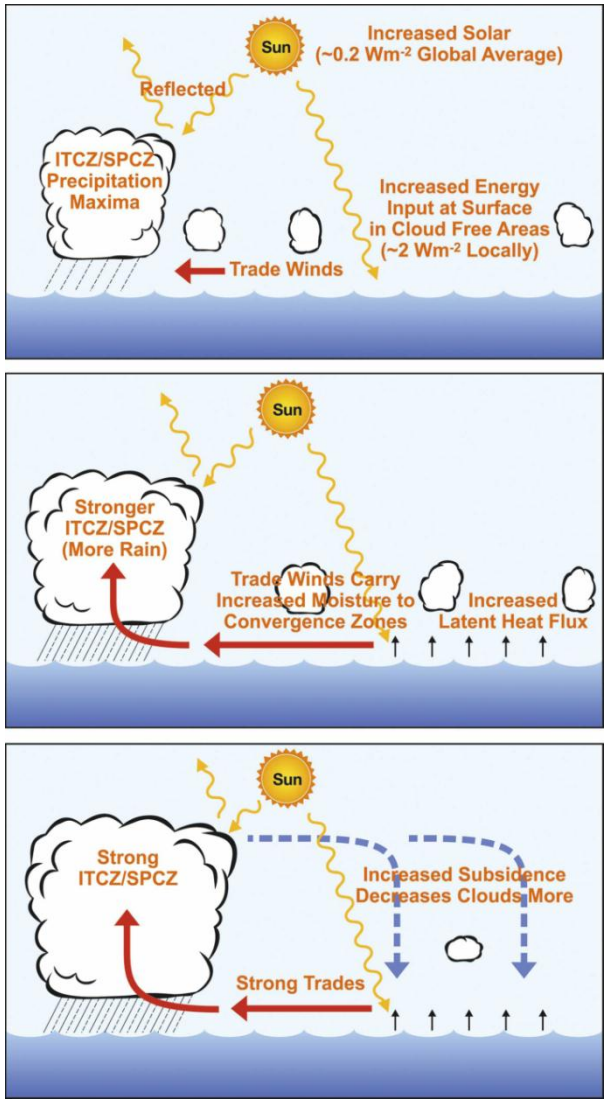
Temperature Profile of the Atmosphere

- In the troposphere, temperature cools with height until the tropopause.
- Warming occurs in the stratosphere due to absorption of UV by the ozone layer
- Warming also occurs in the thermosphere due to absorption of solar radiation by oxygen molecules.



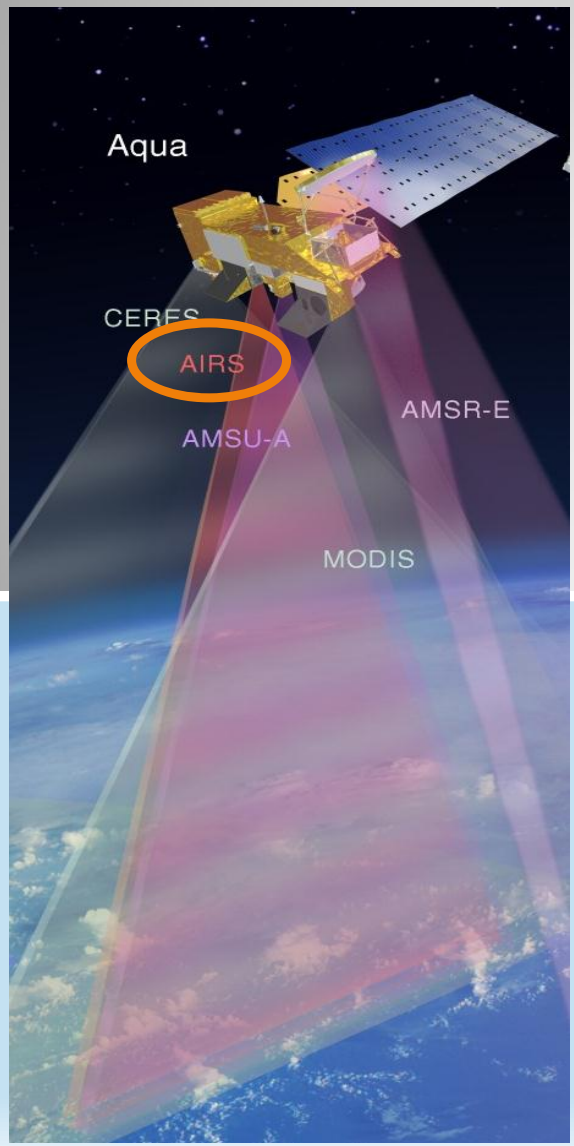
Mechanisms for Solar Cycle Influence on Earth's Atmosphere





Top-Down **Bottom-Up**

[Leslie Gray, Reading University] [*Meehl et al.*, 2008]

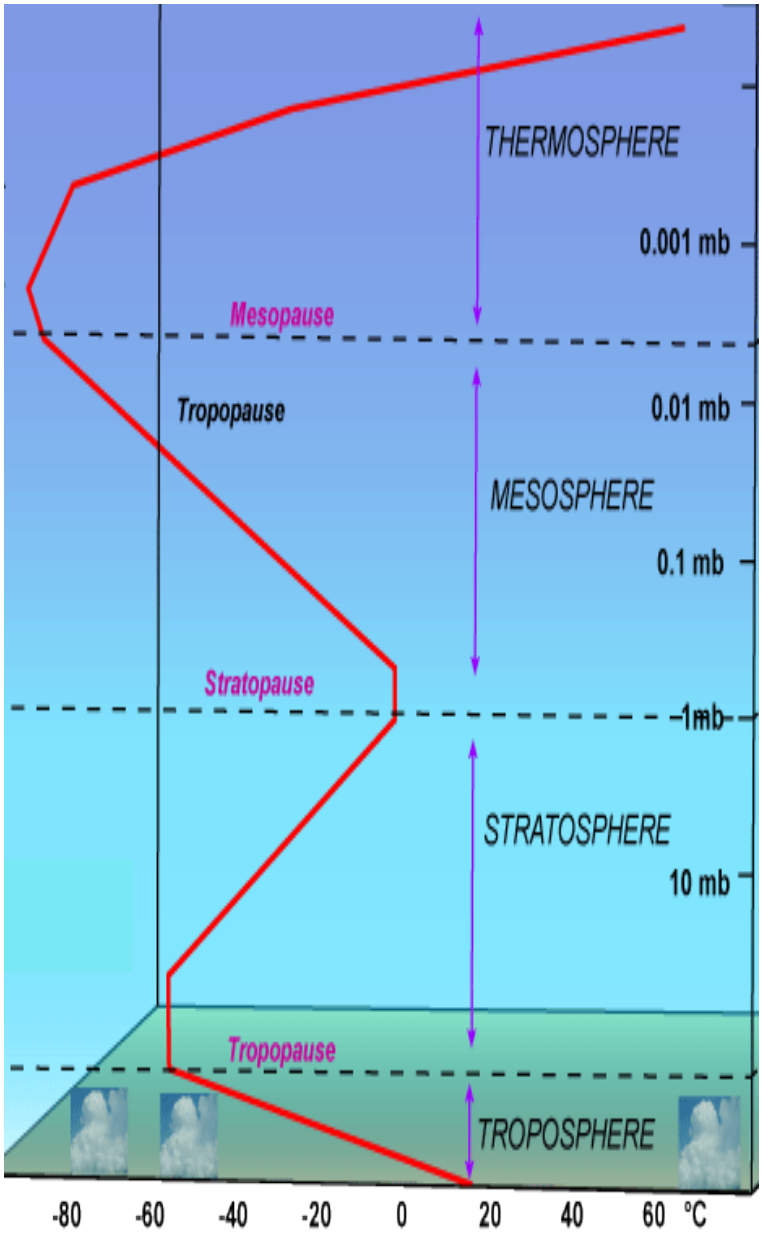


AIRS

The Atmospheric Infrared Sounder

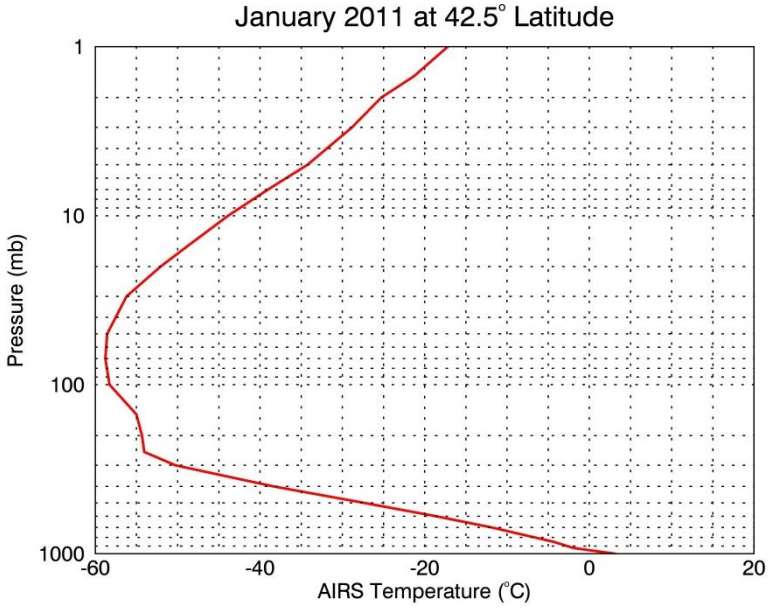
On the Earth observing satellite Aqua

- Data covered near global range of latitudes
- Provided monthly averaged values
- First time we can look at AIRS temperature data over the length of a solar cycle, from September 2002 to February 2013

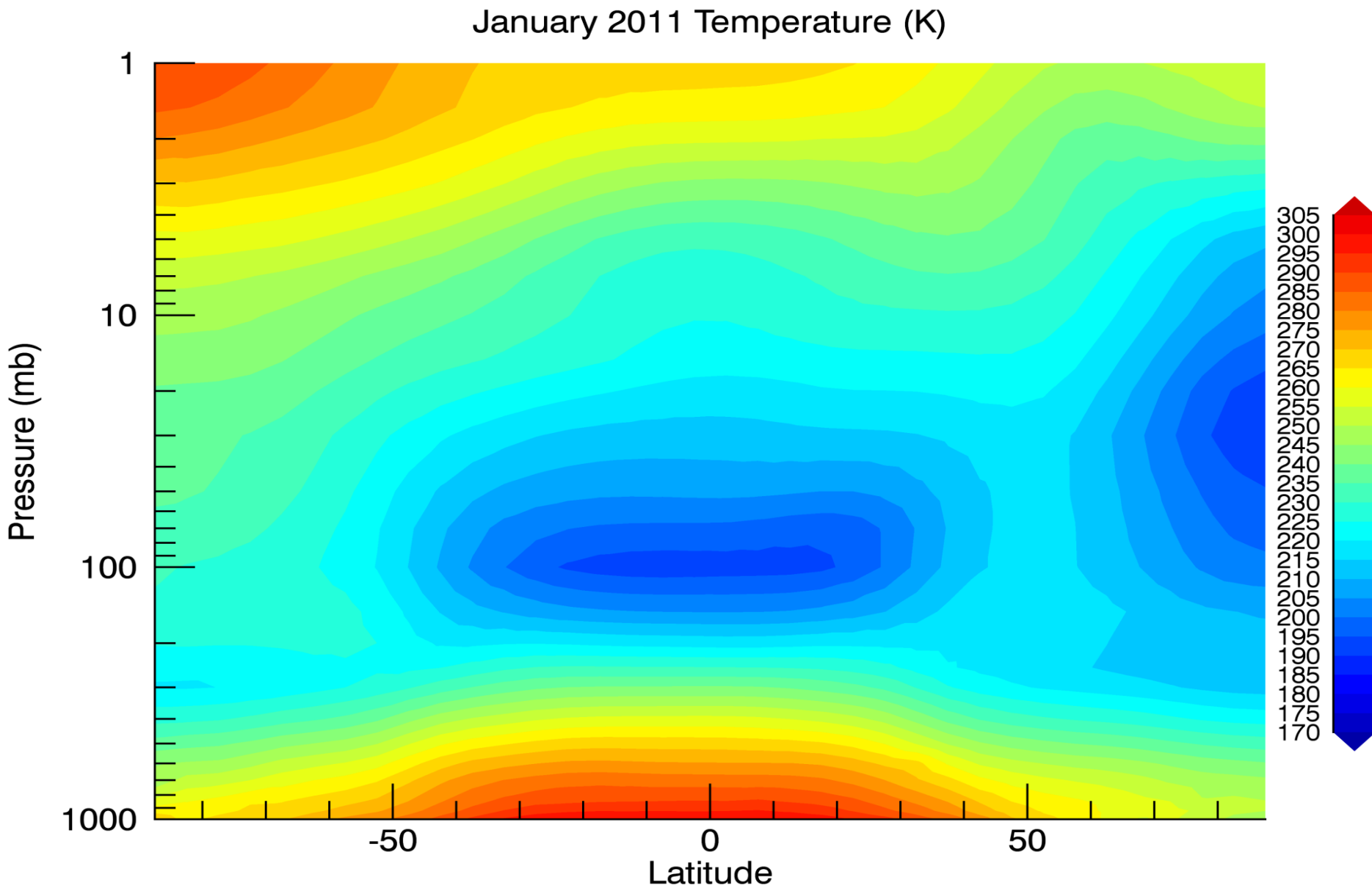


A Sounding Instrument

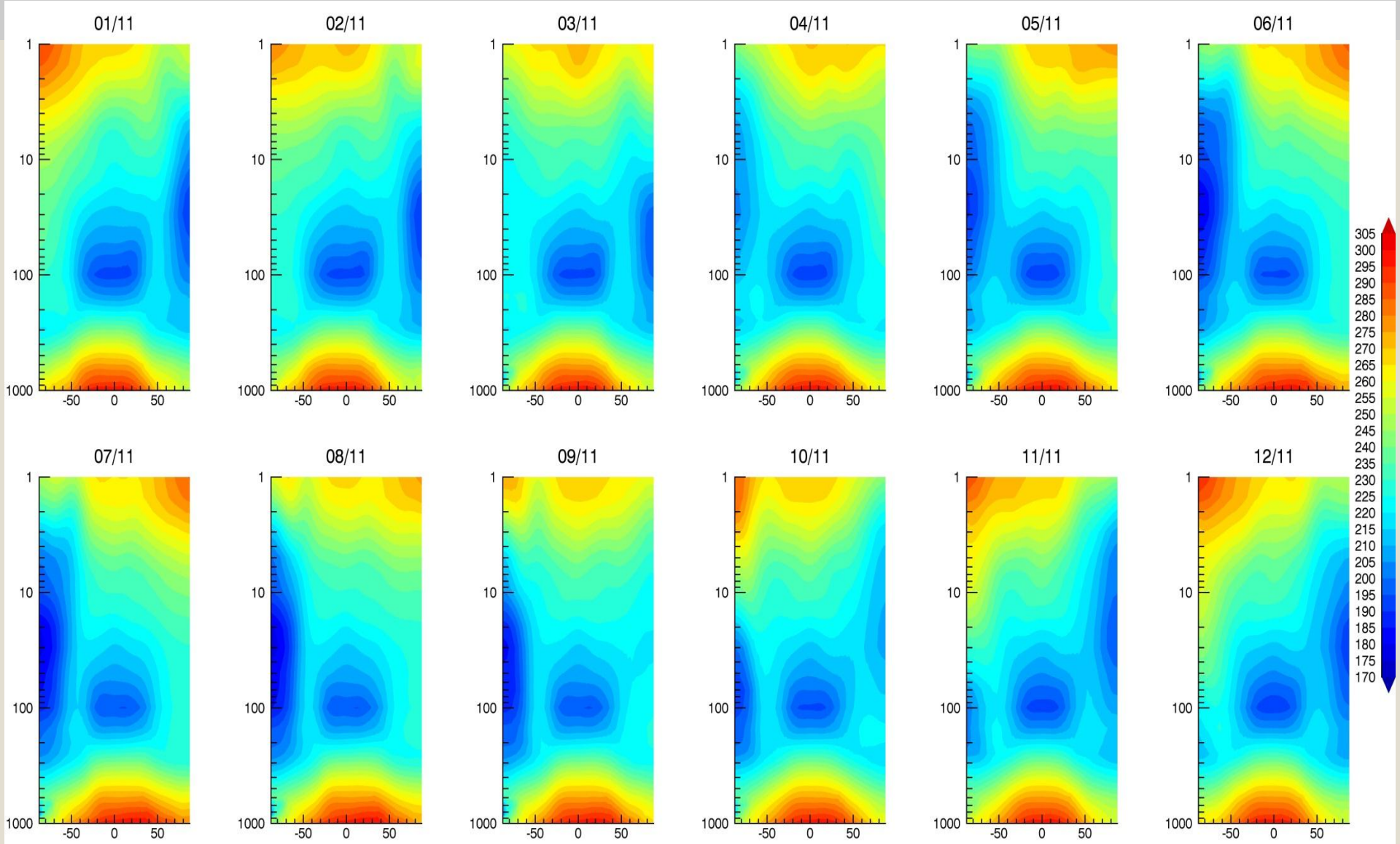
AIRS data has a pressure range that includes 24 levels through the troposphere and stratosphere.



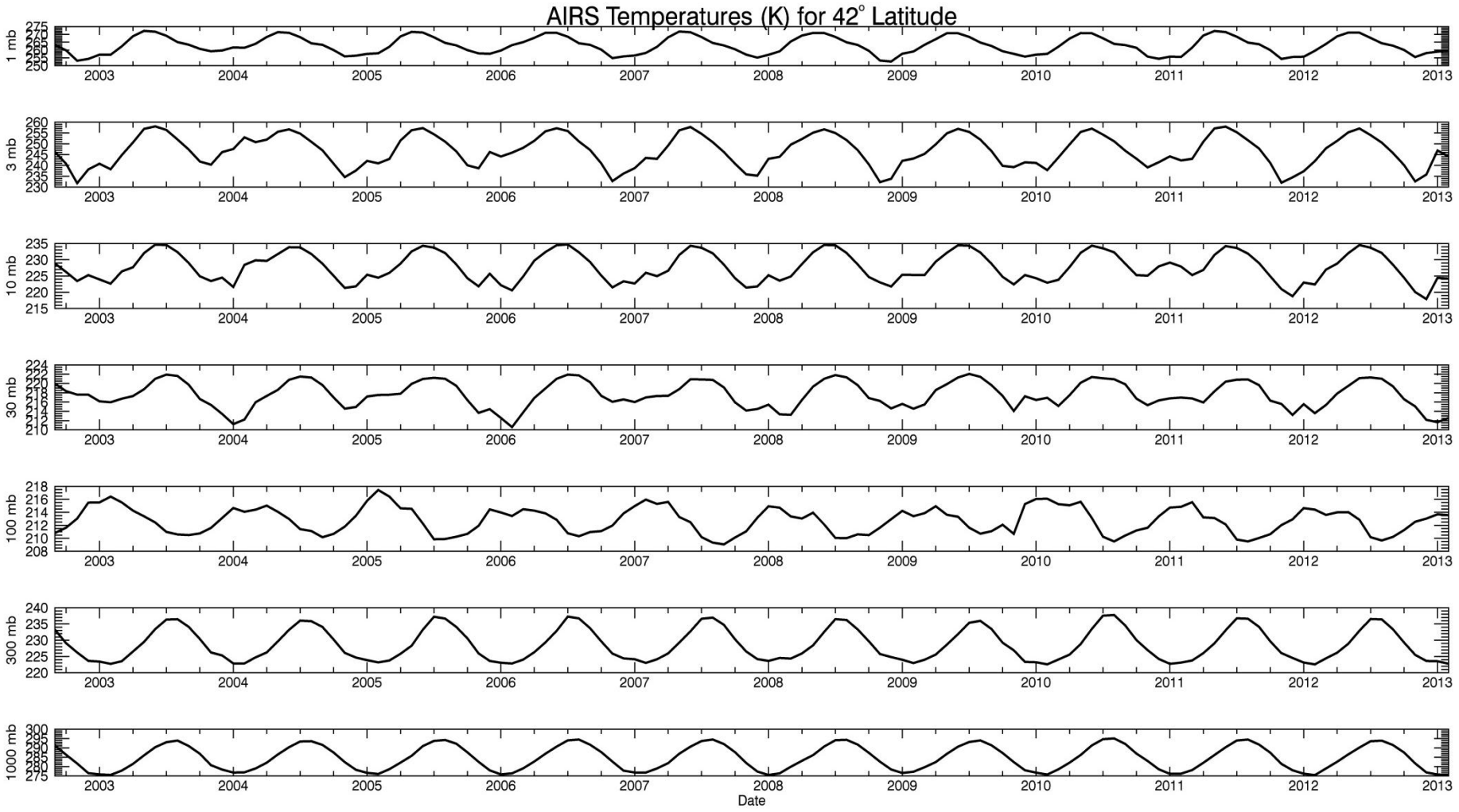
Vertical Temperature Structure of the Atmosphere



AIRS Temperature Data Spanning a Year

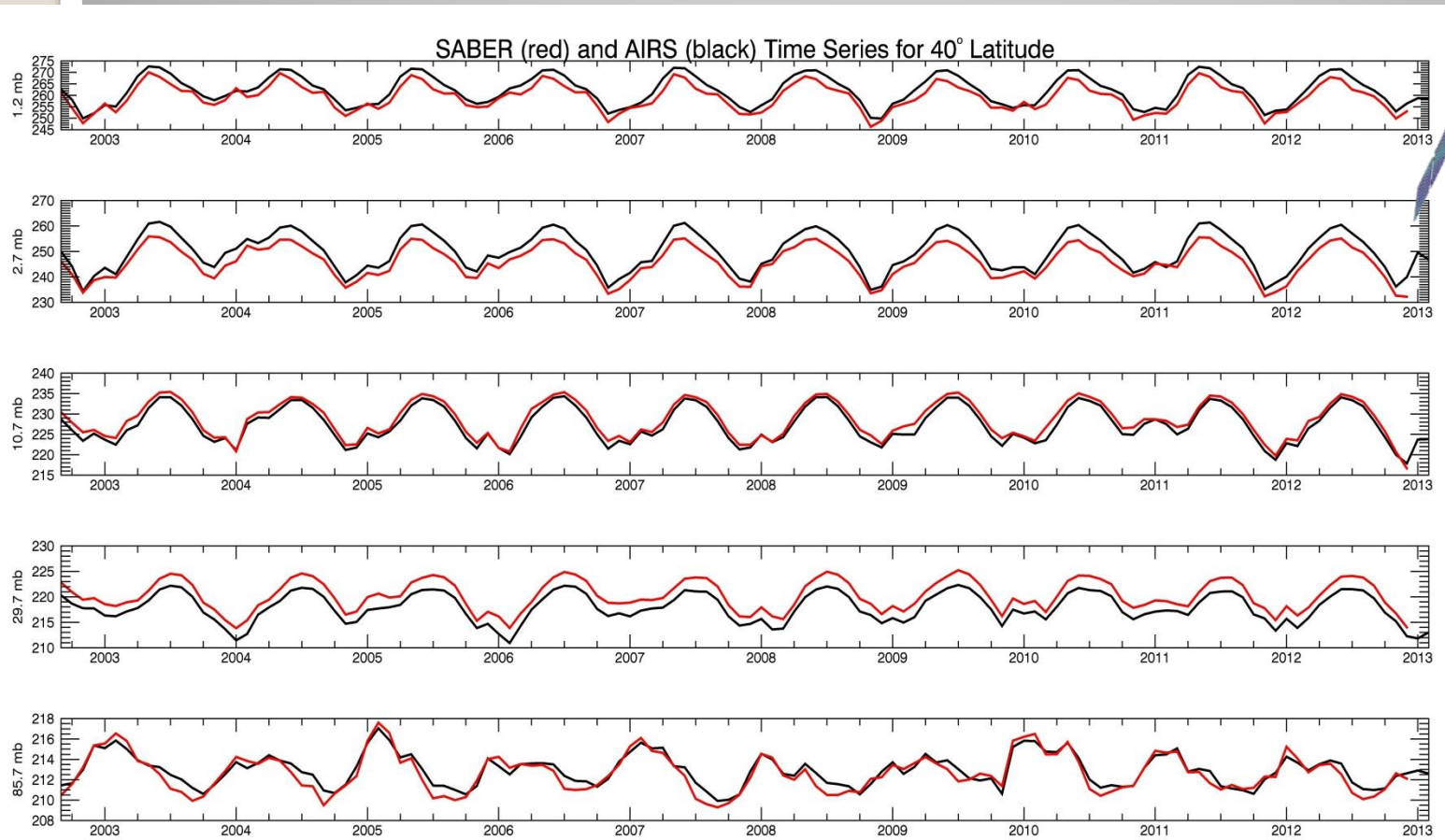


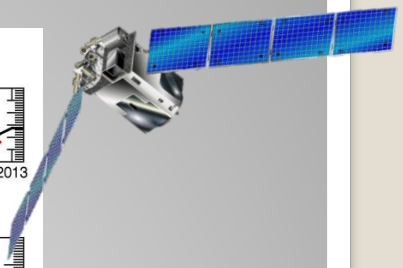
Temperature Trends in the Atmosphere



The Method: Verifying Data Sets

- To make sure any trend is a real trend in the atmosphere, first compare multiple satellite temperature records

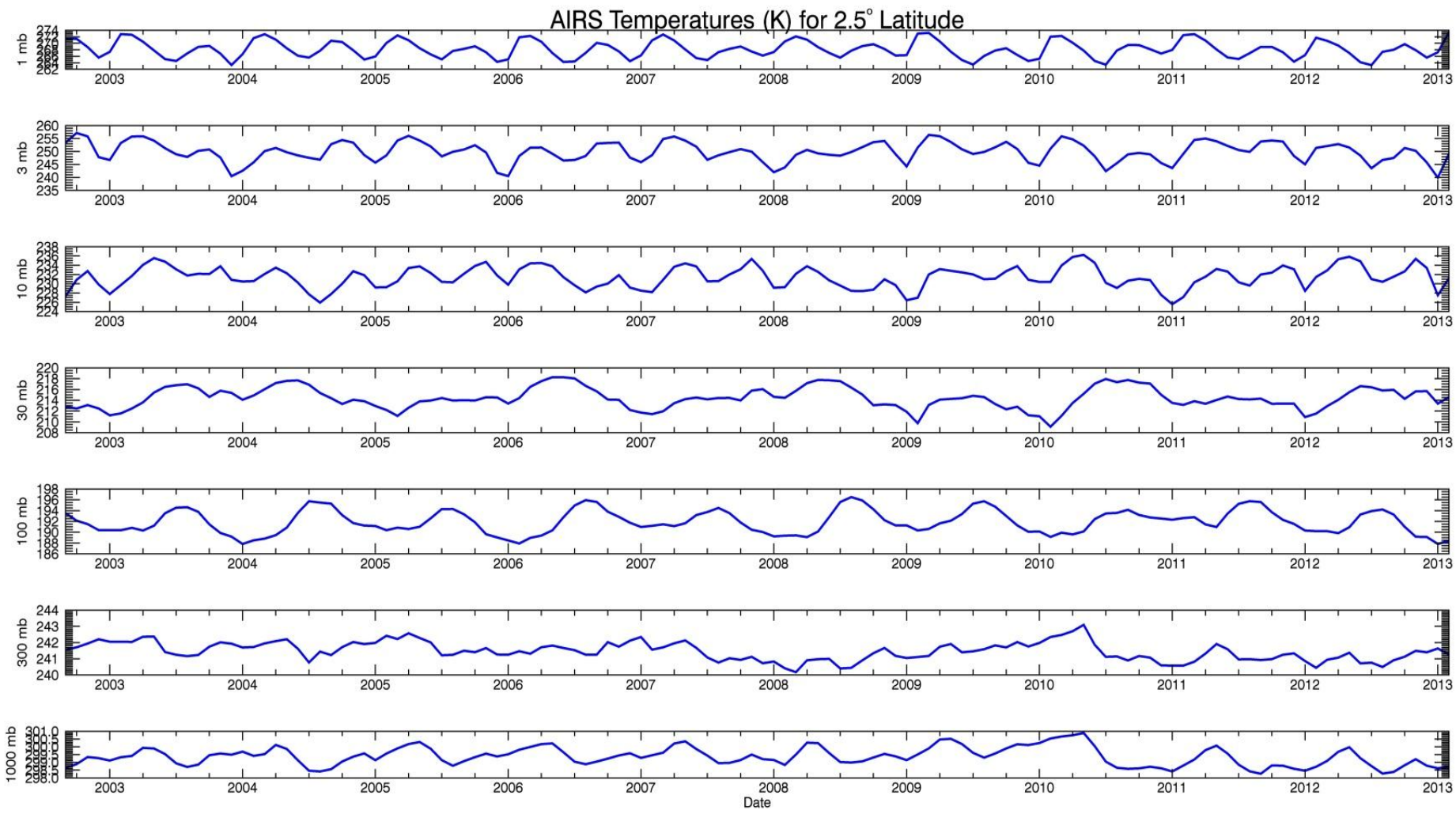




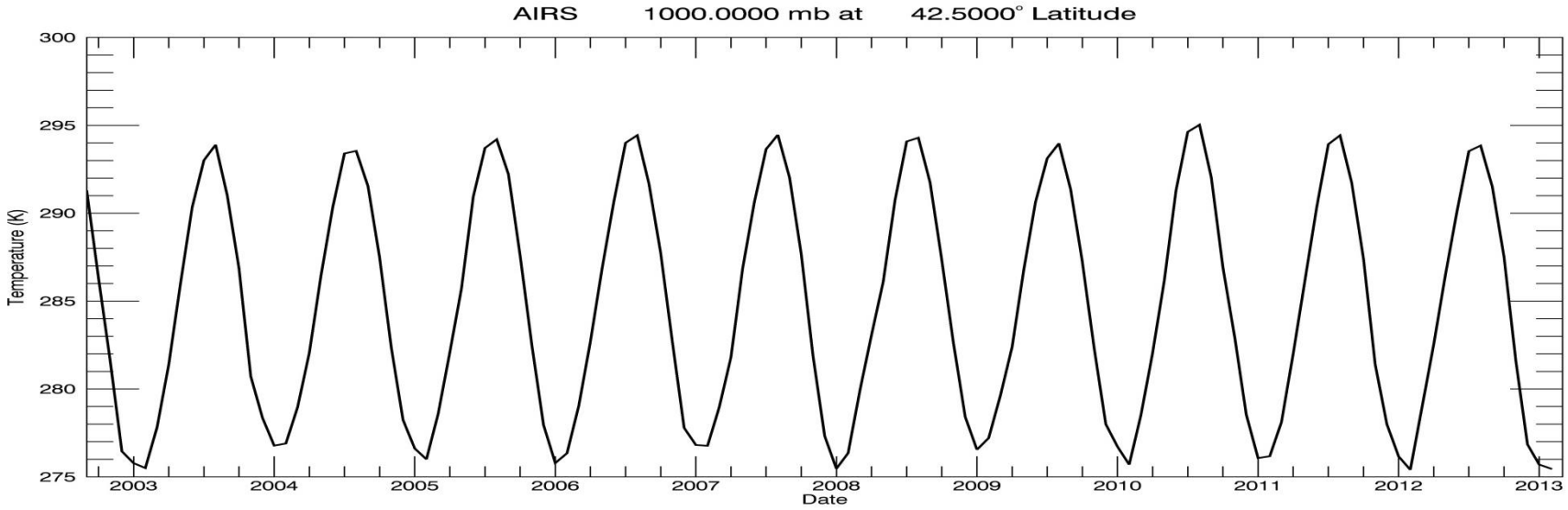
SABER (the Sounding of the Atmosphere using Broadband Emission Radiometry) on TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite.

The Method: Fourier Transform

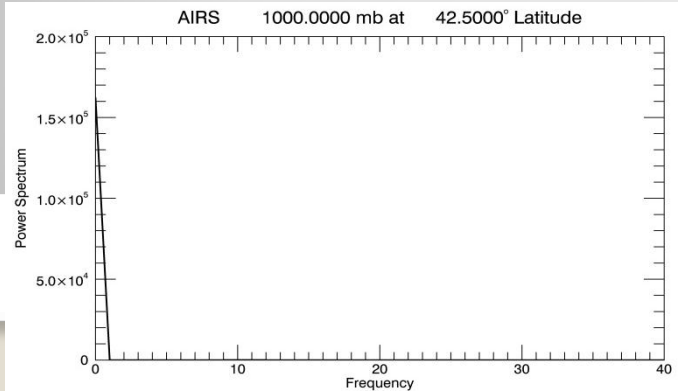
- Analyzing the data to identify different cycles of regularly occurring temperature trends



The Method: Fourier Transform

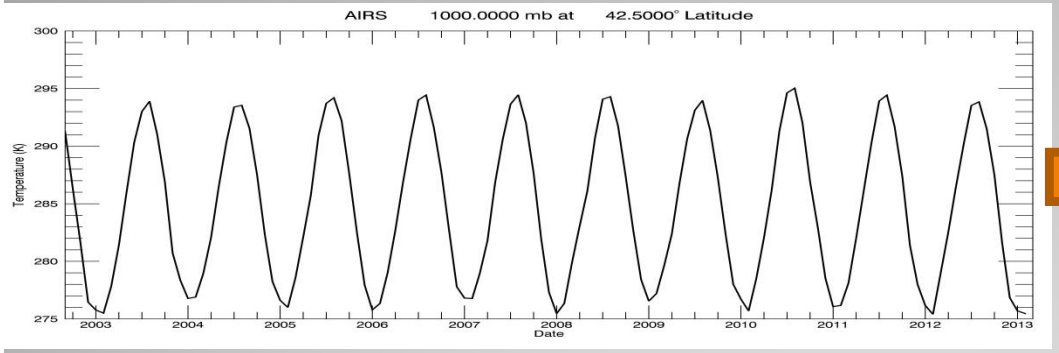


IDL>> FFT(data)

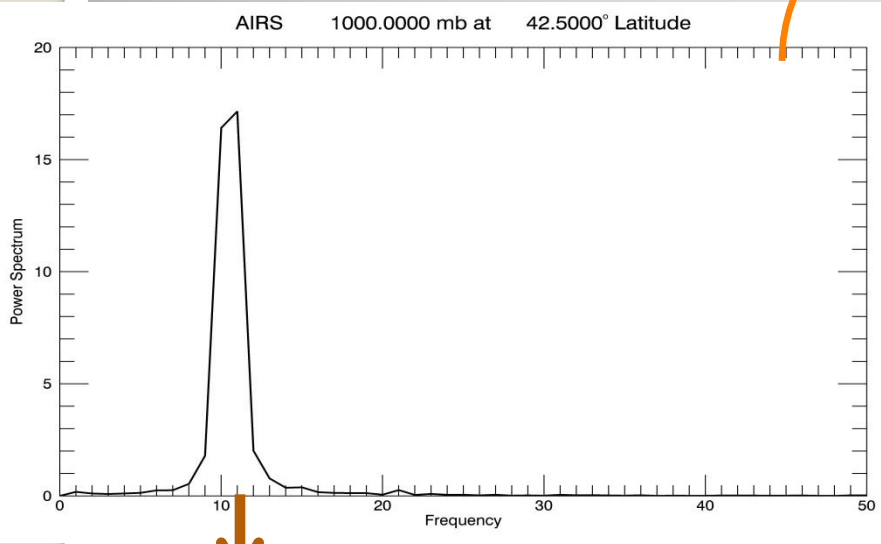


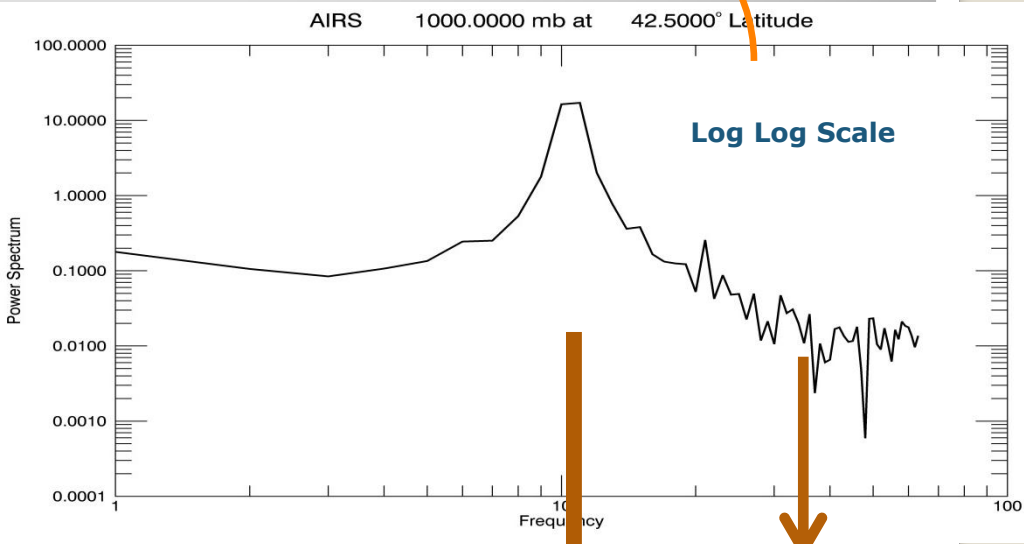
- **Converts time domain to a frequency domain**
- **This will isolate important frequencies of different temperature trends.**

The Method: Fourier Transform



IDL>> FFT(data)

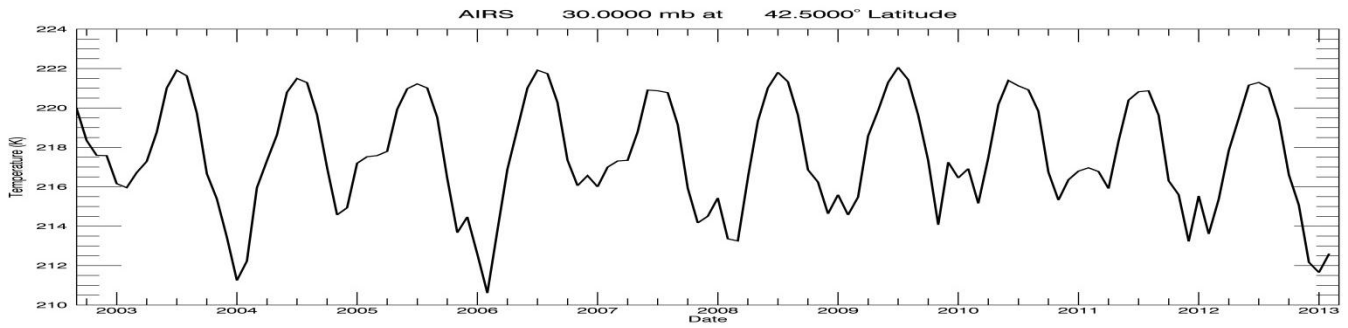


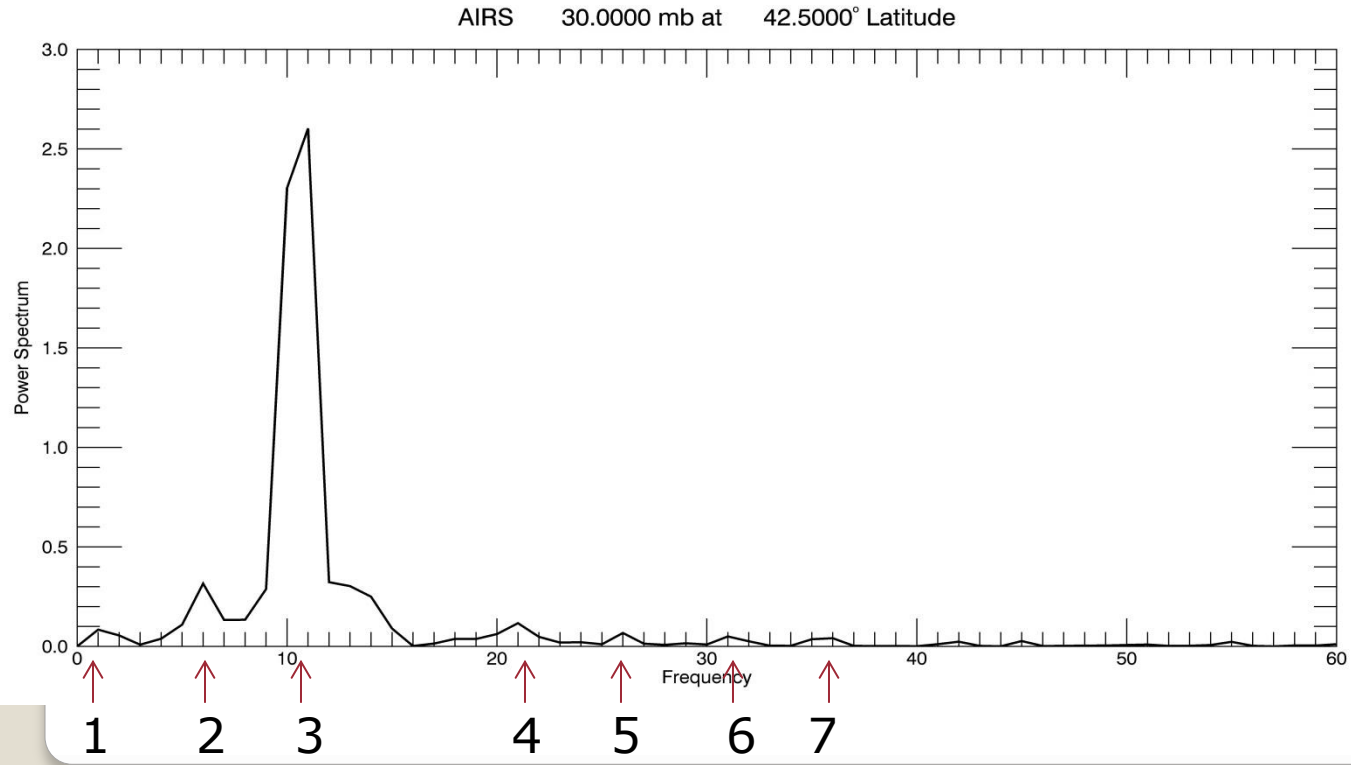


~12 Month Frequency - the Annual Cycle

Random noise

The Method: Fourier Transform



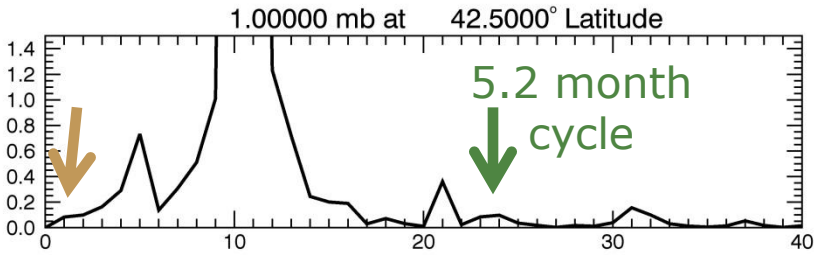


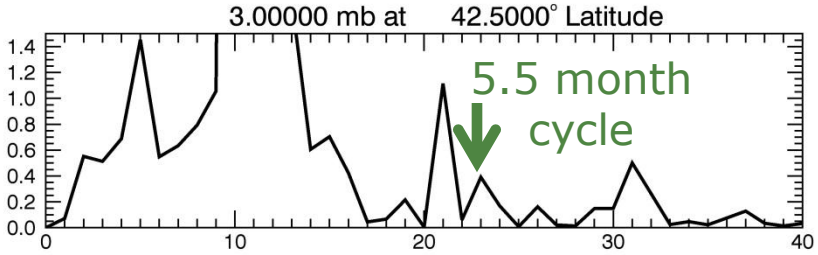
Original data from 30mb at 45°

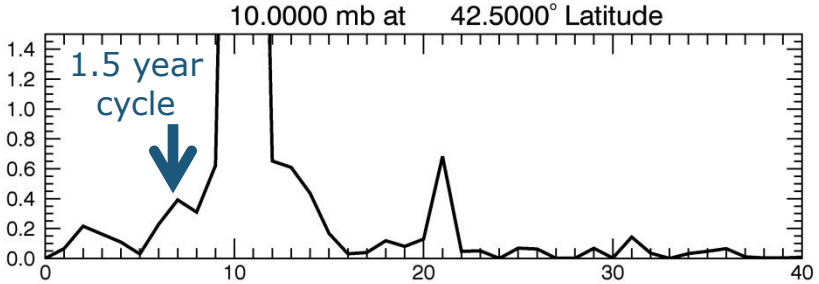
Main Frequencies Identified:

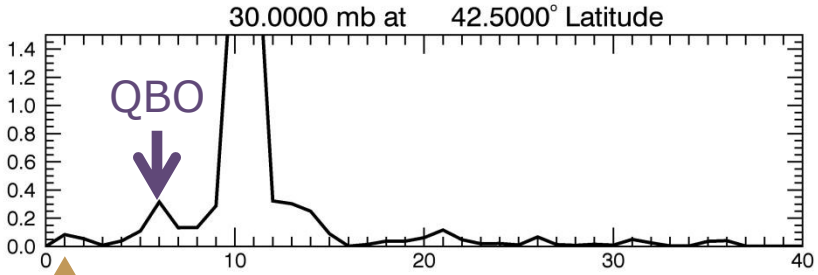
1. 10.5 year
2. 1.8 year
3. 12.6 month
4. 6 month
5. 4.8 month
6. 4.1 month
7. 3.5 month

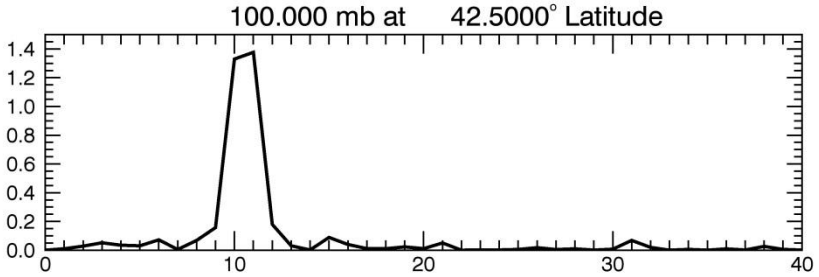
Signal Processing

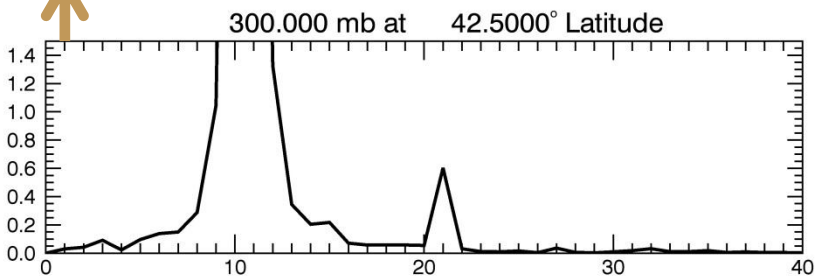




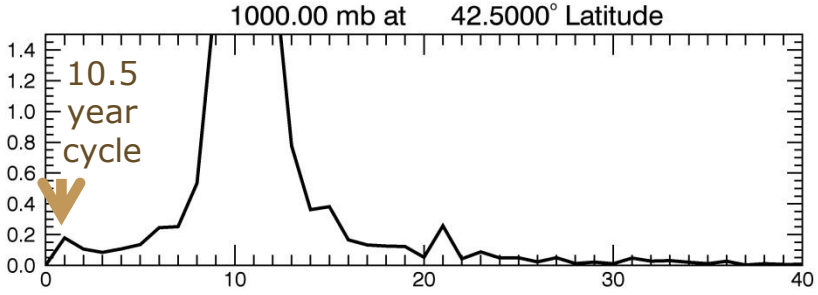






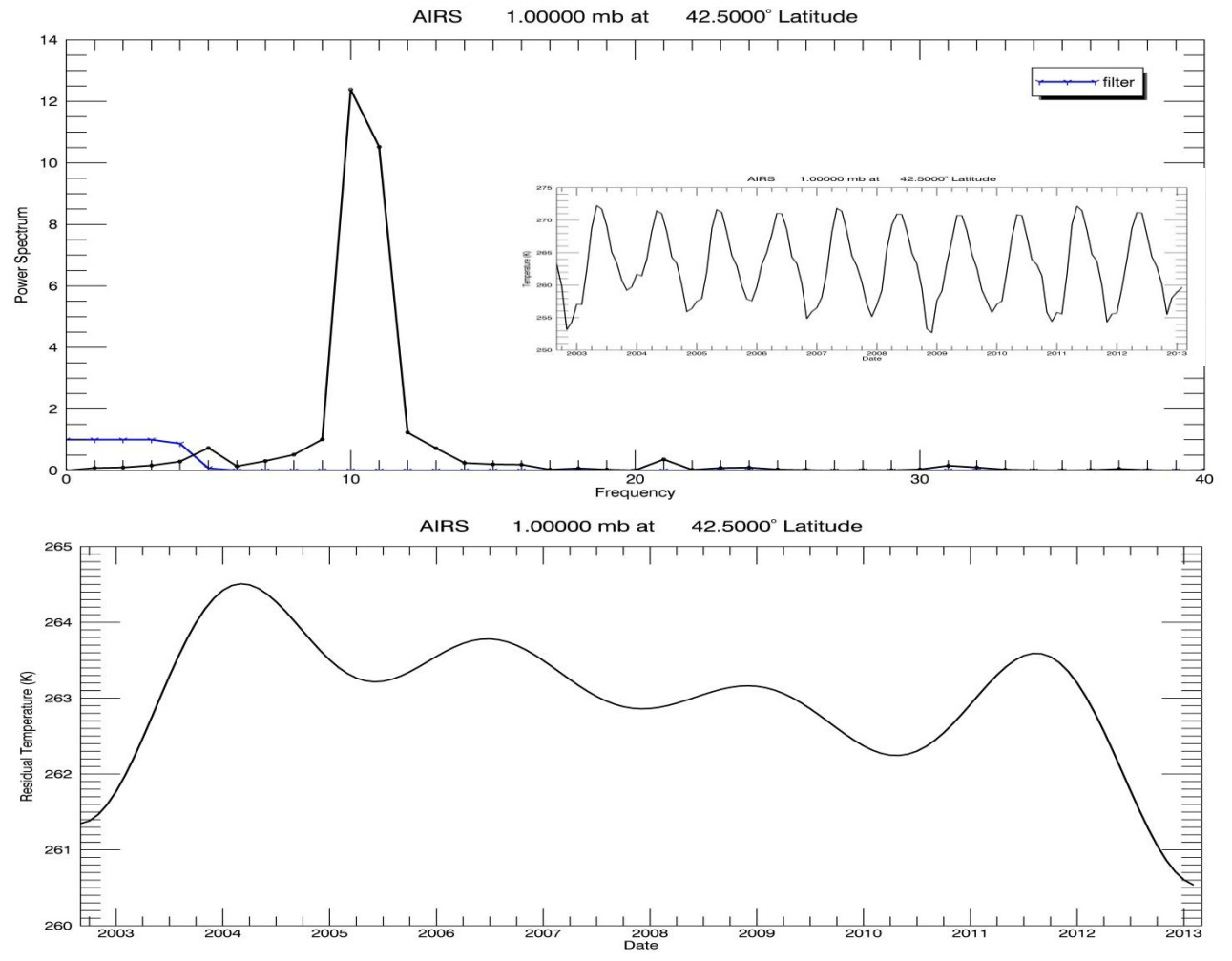


Annual Cycle



Signal Processing:

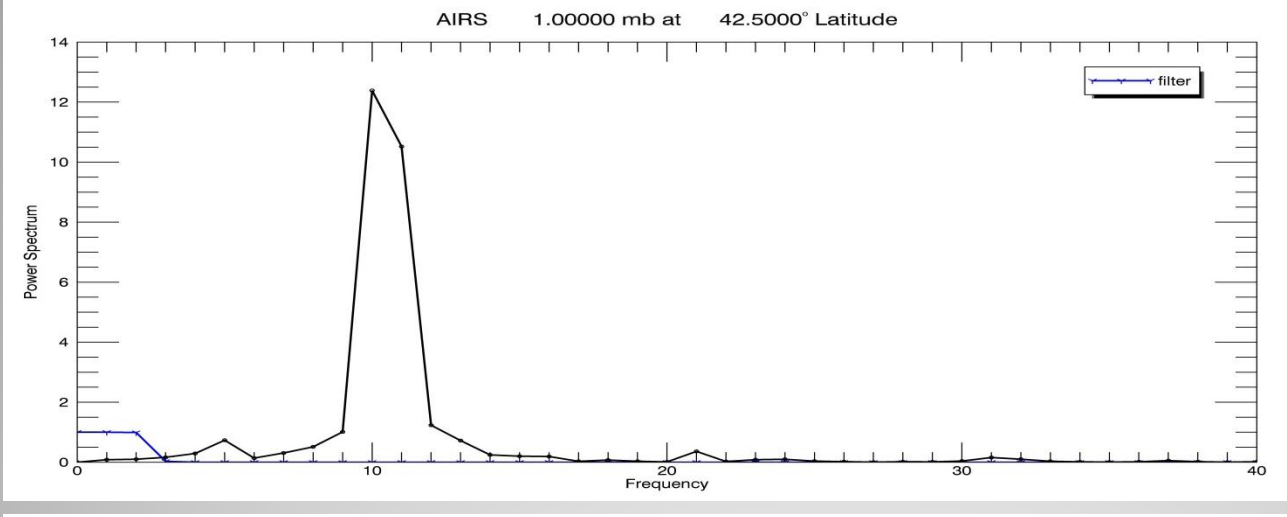
Filtering out High Frequencies

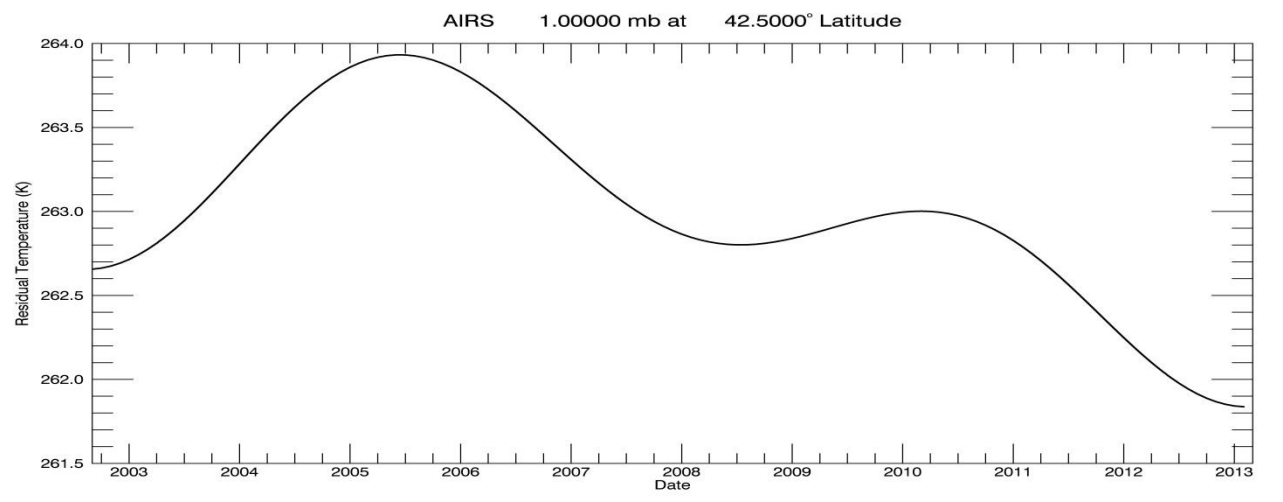


- Fourier sharp-cut filter used to attempt to isolate longer signals.
- This particular filter removes all frequencies greater than about 2.5 years.
- Still has some ~ 2 year QBO elements within the filter

Signal Processing:

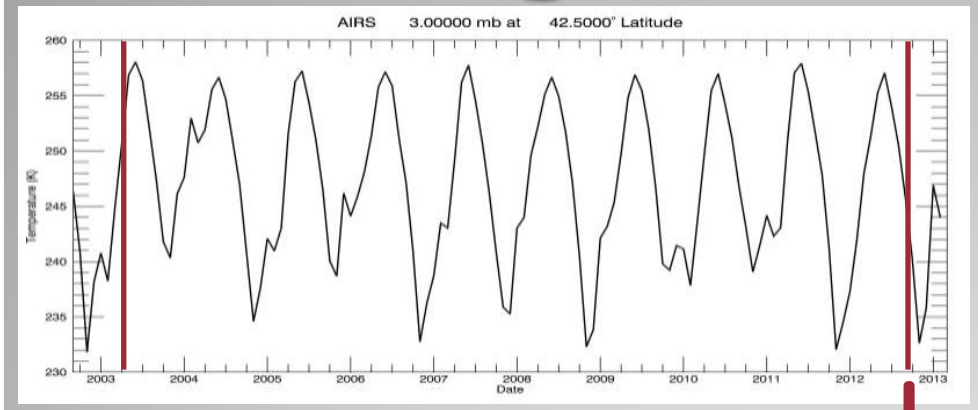
Filtering out High Frequencies





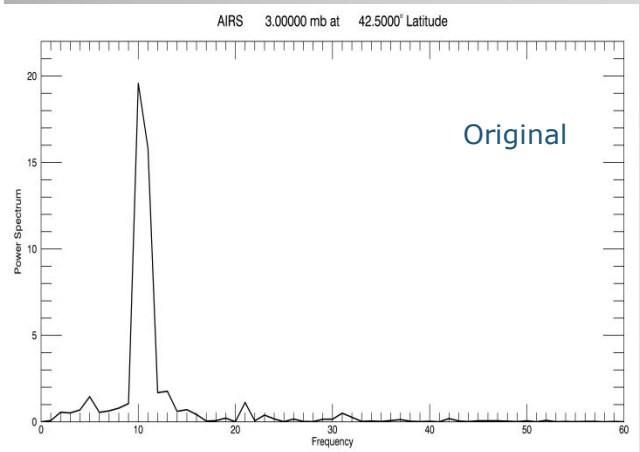
- This filter removes all frequencies greater than about 4 years.
- Few frequencies remain, so the residual temperature signal results in a very smooth curve
- Temperature minimum during 2008 and about 1° amplitude in residual temperature curve

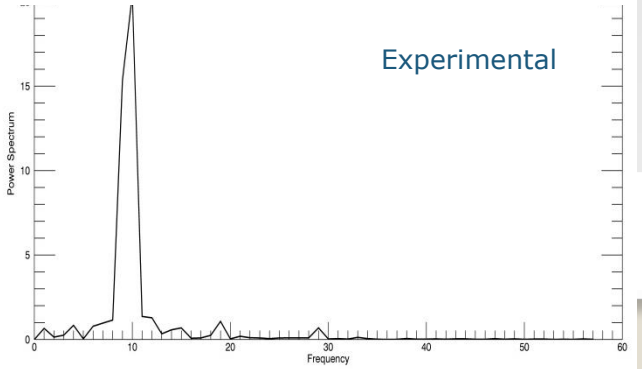
Examining Bias Issues with FFT

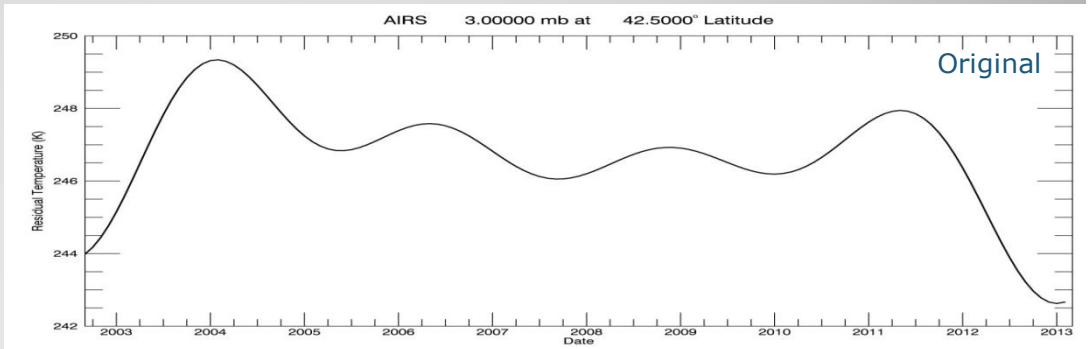


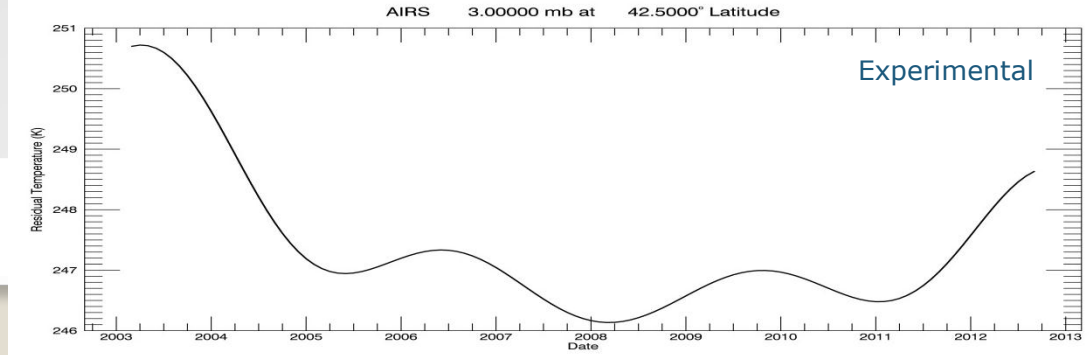
- To attempt to detect a possible downward trending bias due to location of the endpoints of the data, the range of the data was changed.

Experimental data range cut-off

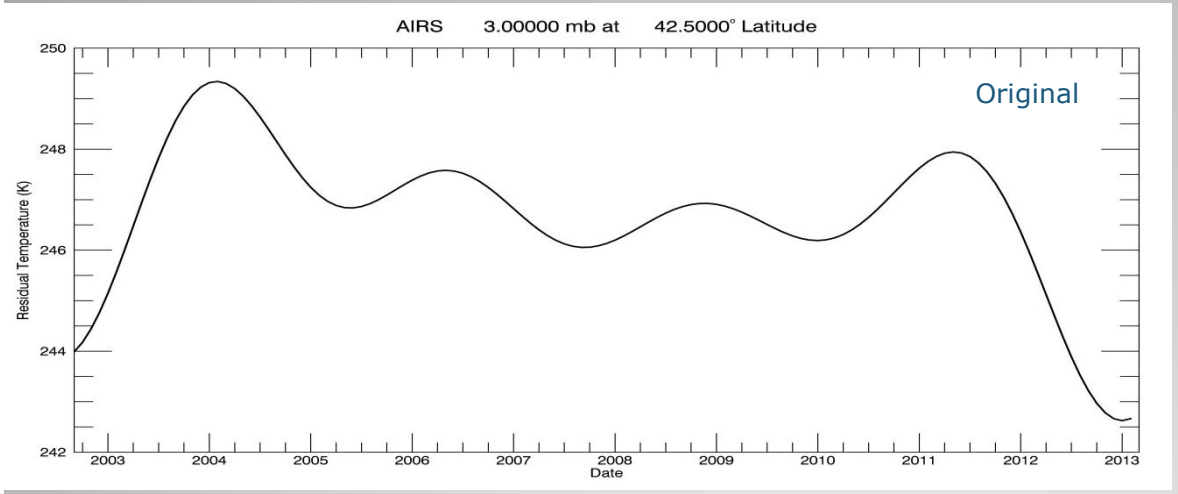


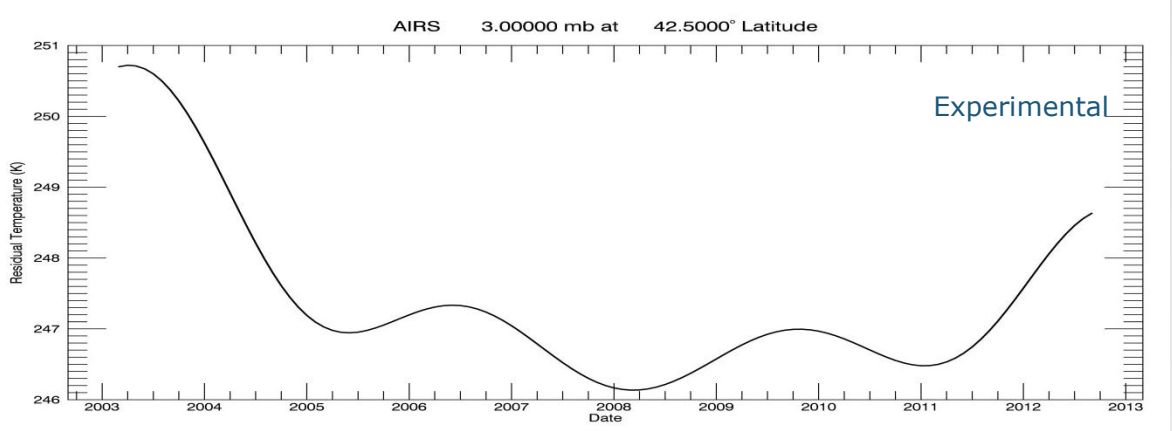






Examining Bias Issues with FFT





- There is a significant dependence on endpoints of the data using Fourier transform and filtering
- This may exaggerate any solar cycle impact in the experimental data range
- However, structure of trend in experimental signal remains generally close to that of original.

Whole Atmosphere Community Climate Model

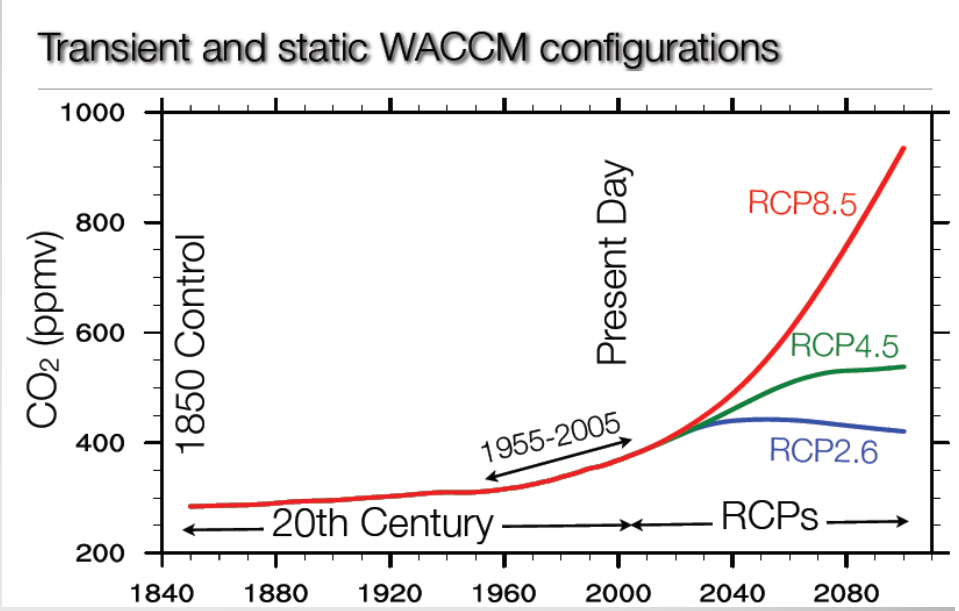
Community Earth System Model

CESM

NCAR

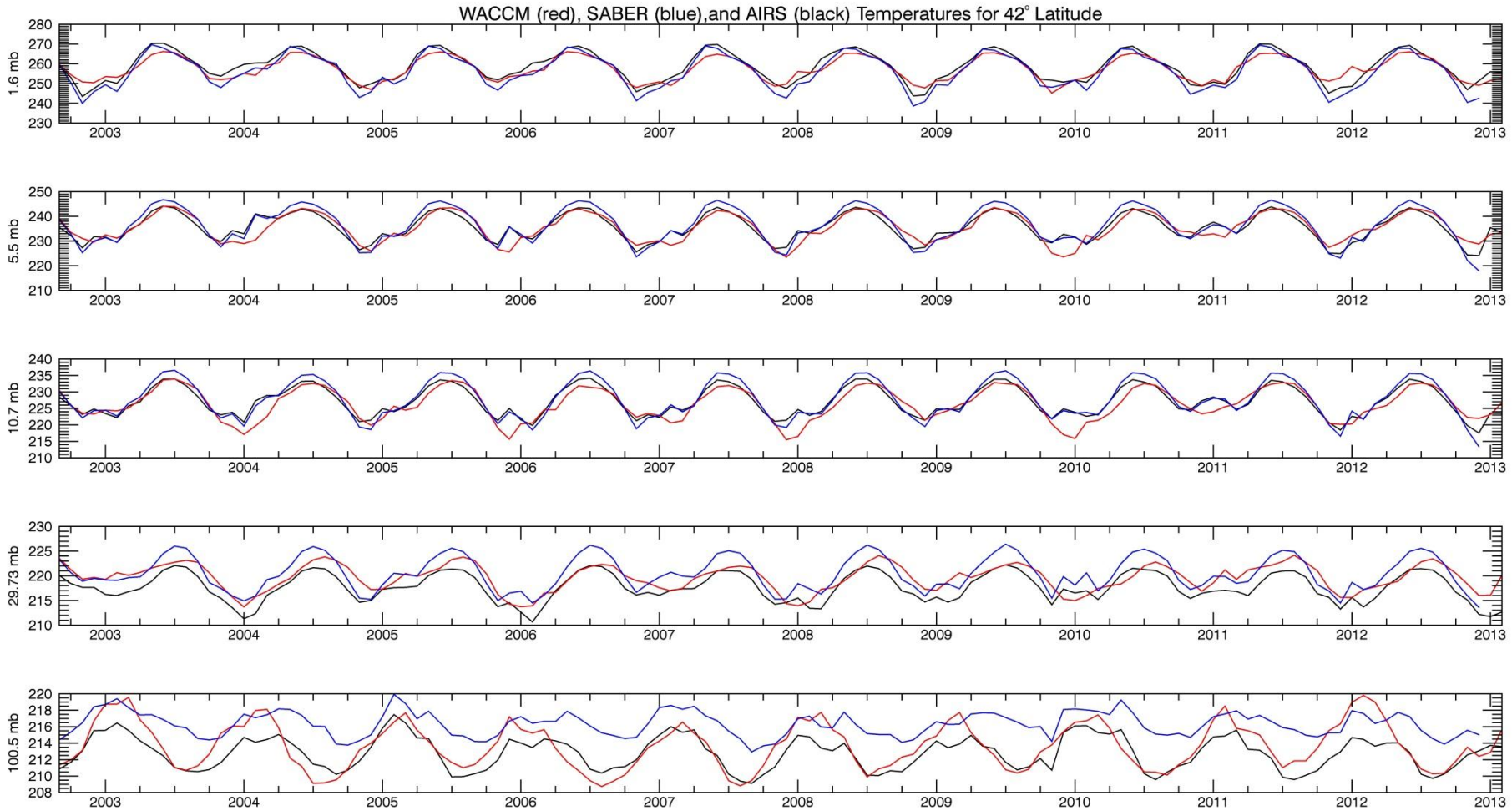
WACCM

- The Community Earth System Model is a coupled climate model for simulating the Earth system.
- WACCM is a climate-chemistry general circulation model for the atmosphere, from the surface to thermosphere
  - ❑ Using 1955-2005 run for the Coupled Model Intercomparison Project phase 5 (CIMP5)
  - ❑ Also looking at a RCP4.5 predicted run for 2005-2065.



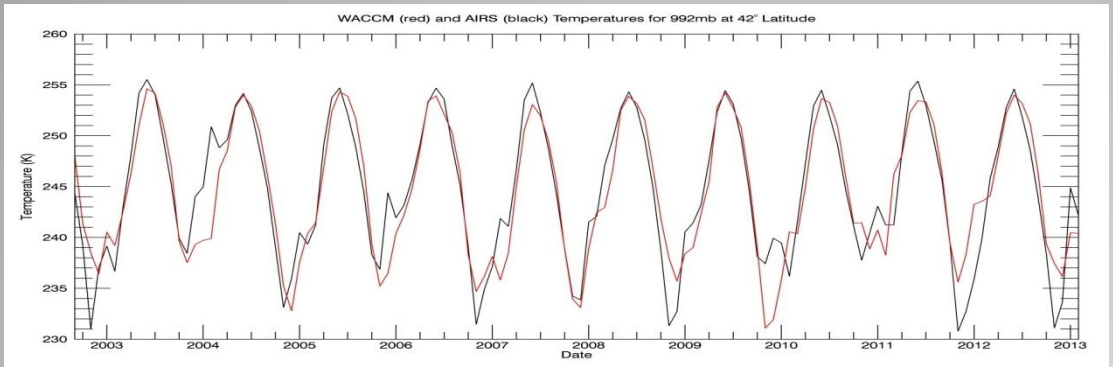
WACCM can be used to evaluate our current knowledge of climate variability as well as to predict future conditions.

WACCM

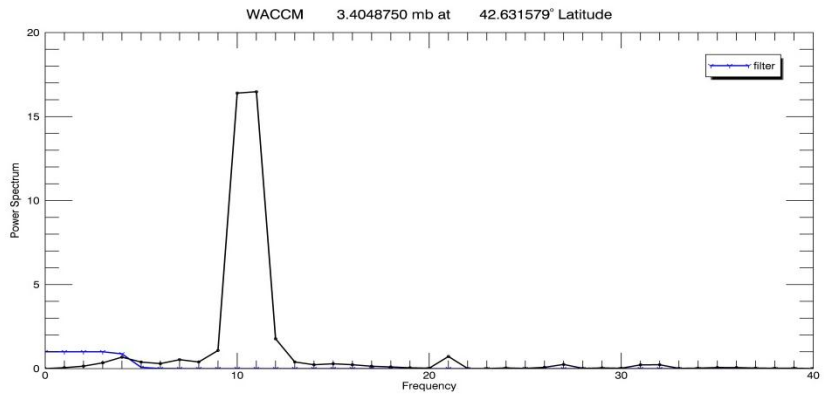


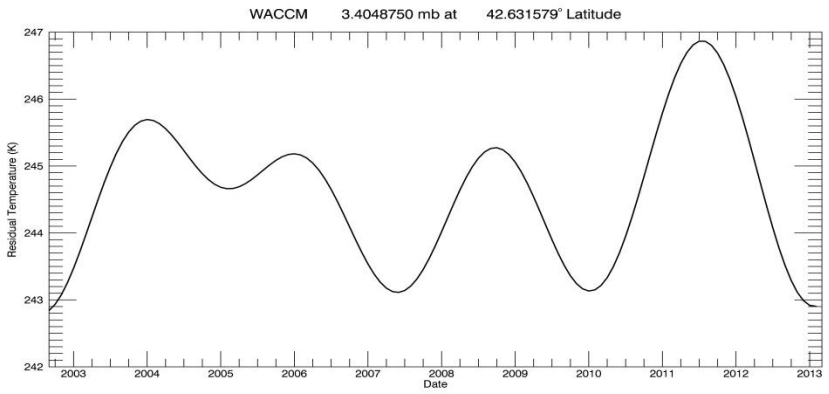
Generally strong correlation between WACCM and satellite temperature observations!

Fourier Transform on WACCM data

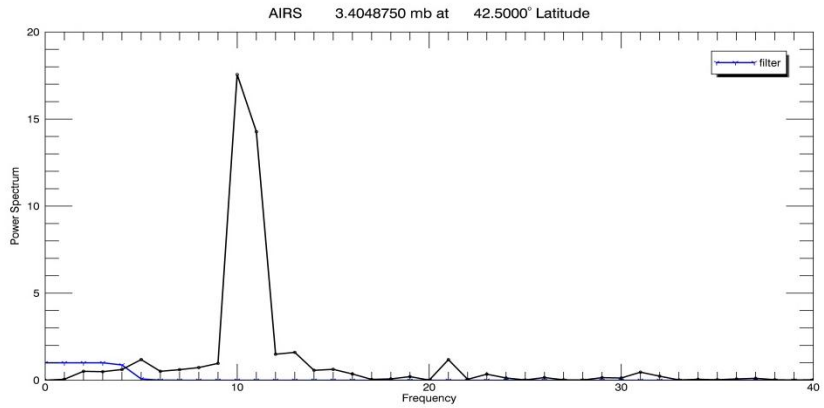


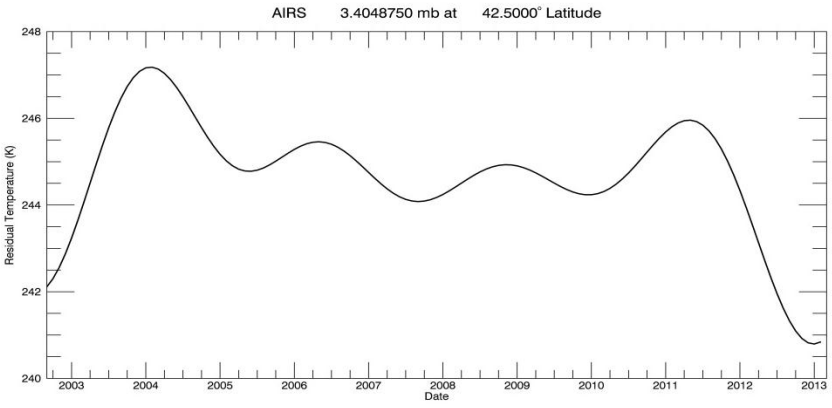
- Similar FFT and filter results
- More longer frequencies appear in AIRS temperature data than in WACCM





WACCM

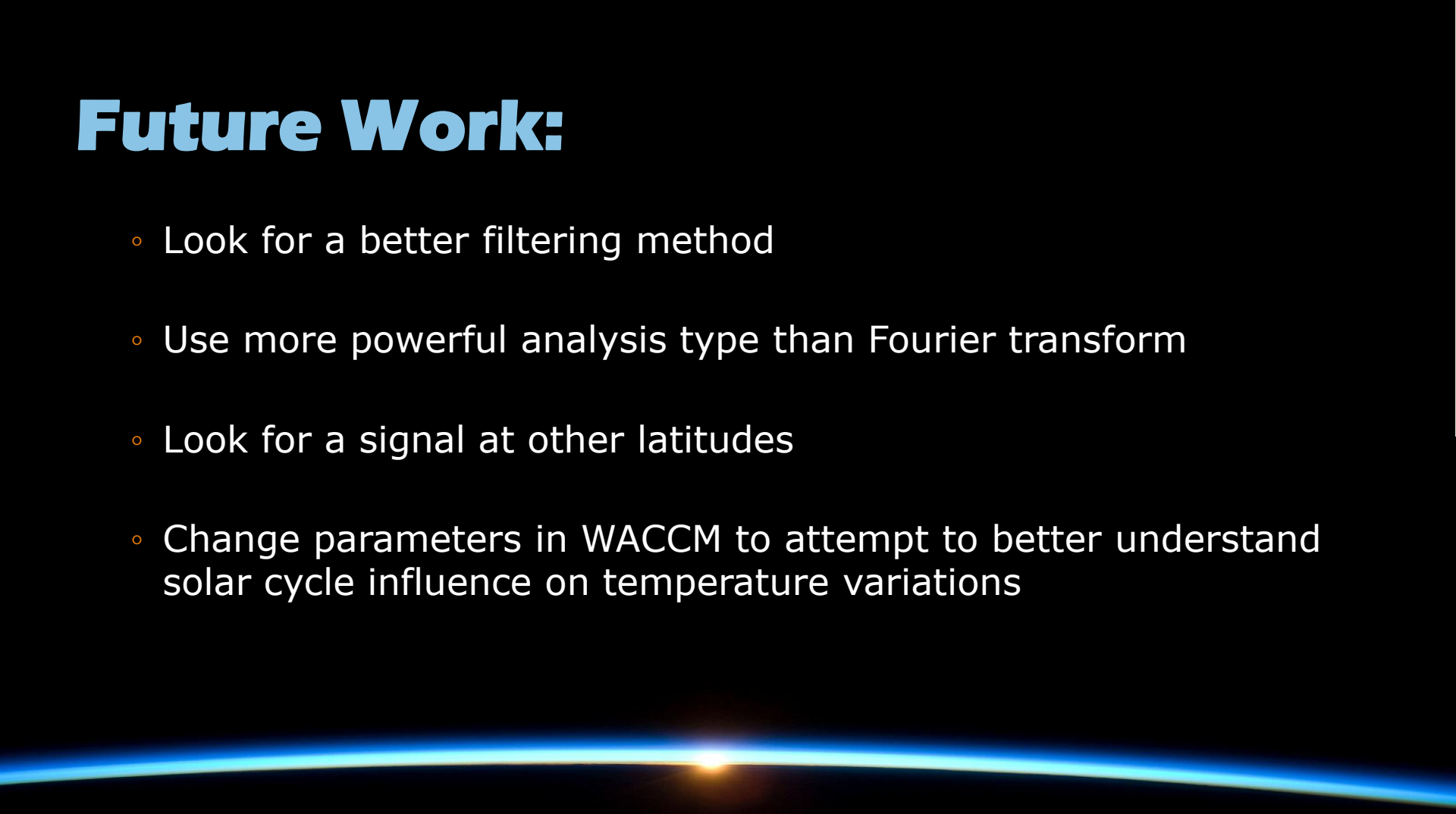


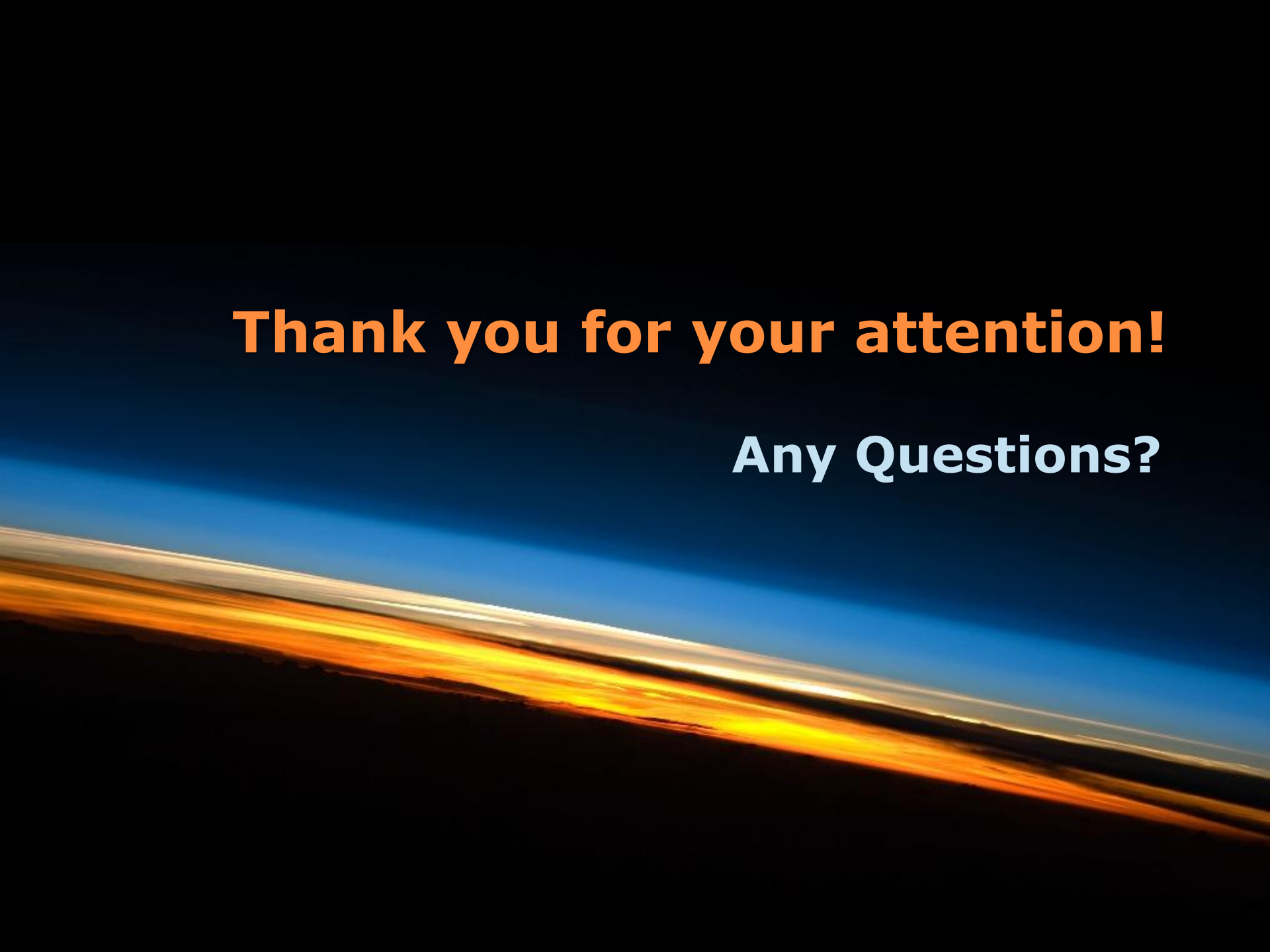


AIRS

Future Work:

- Look for a better filtering method
- Use more powerful analysis type than Fourier transform
- Look for a signal at other latitudes
- Change parameters in WACCM to attempt to better understand solar cycle influence on temperature variations




Thank you for your attention!
Any Questions?

References

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