## Quick Review of Remote Sensing Basic Theory

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#### Outline

IR at High Spectral Resolution

Basic Principles

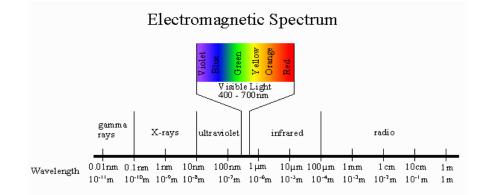
• Limits in IR remote sensing

#### Infrared (Emissive Bands)

# THERMAL LONG WAVELENGTH CLOUD MOSPHERE

#### High Spectral Resolution

#### **High Spectral Resolution**

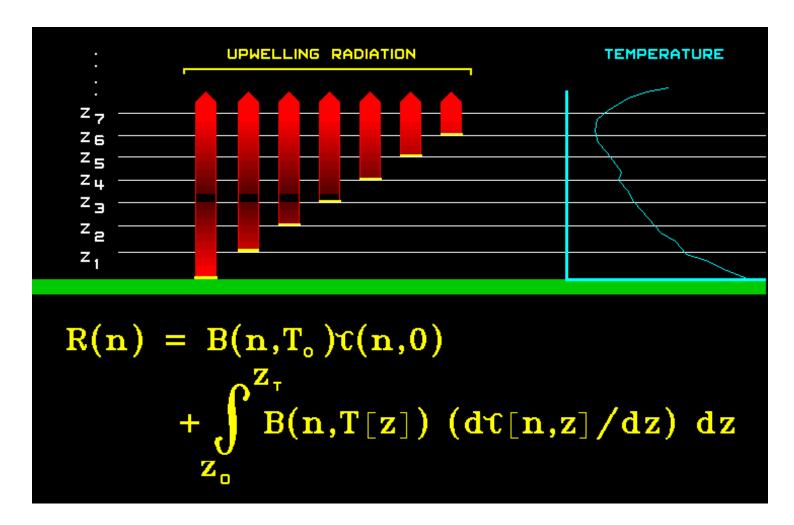


QuickTime™ and a decompressor are needed to see this picture.

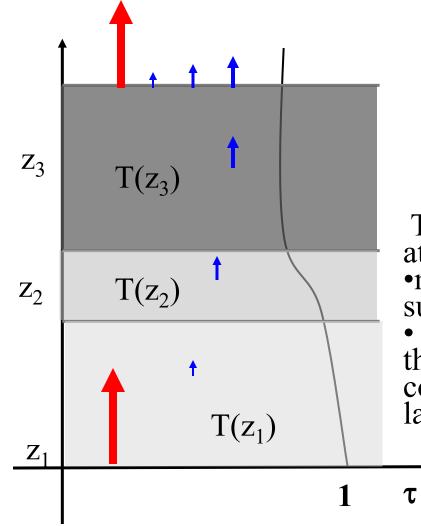
High Spectral Resolution

High Vertical Resolution

#### **Radiative Transfer Equation**



### Transmittance for an off-line Channels



Ζ

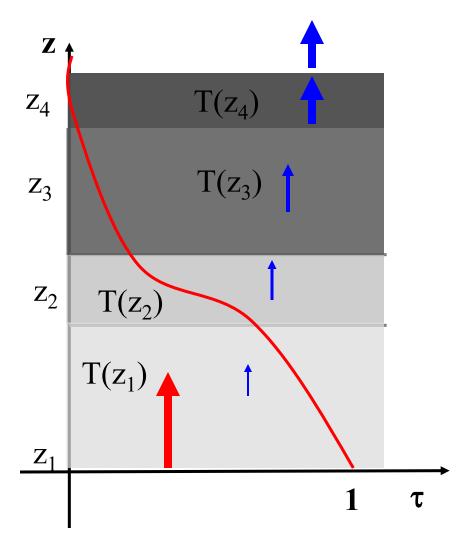
 $\tau + a + \gamma = 1$ 

 $\tau$  close to 1 a close to 0

The molecular species in the atmosphere are not very active:
most of the photons emitted by the surface make it to the Satellite
if a is close to 0 in the atmosphere then ε is close to 0, not much contribution from the atmospheric layers

Surface emission Atmospheric emission

#### Trasmittance on an Absorption Line

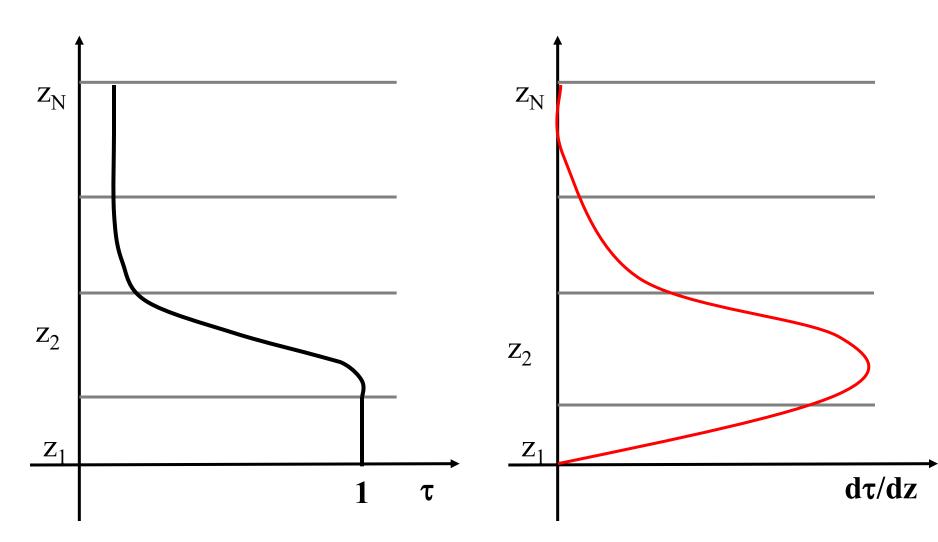


#### Absorption Channel: $\tau$ close to 0 a close to 1

One or more molecular species in the

atmosphere is/are very active:
most of the photons emitted by the surface will not make it to the Satellite (they will be absorbed)
if a is close to 1 in the atmosphere then ε is close to 1, most of the observed energy comes from one or more of the uppermost atmospheric layers

#### Weighting Functions



#### What Causes Absorption?

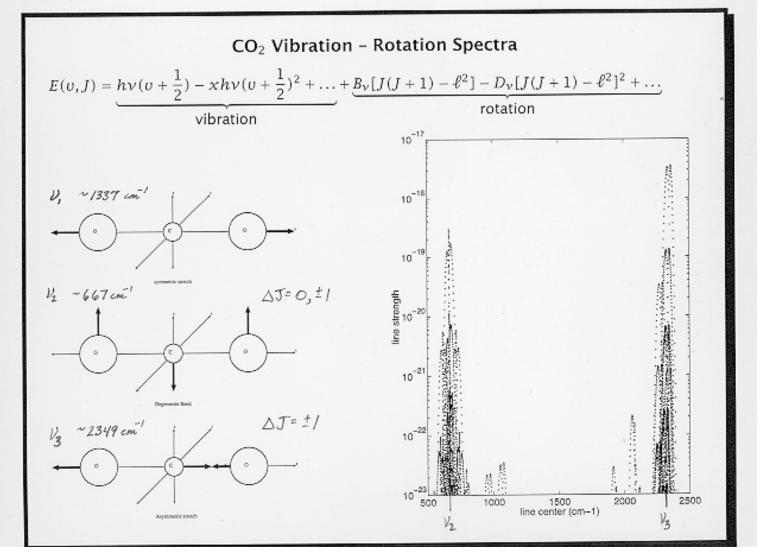
#### Molecules in the Atmosphere.

For any layer of the atmosphere, molecular absorption determines the layer emissivity and trasmittivity

### CO<sub>2</sub> Lines

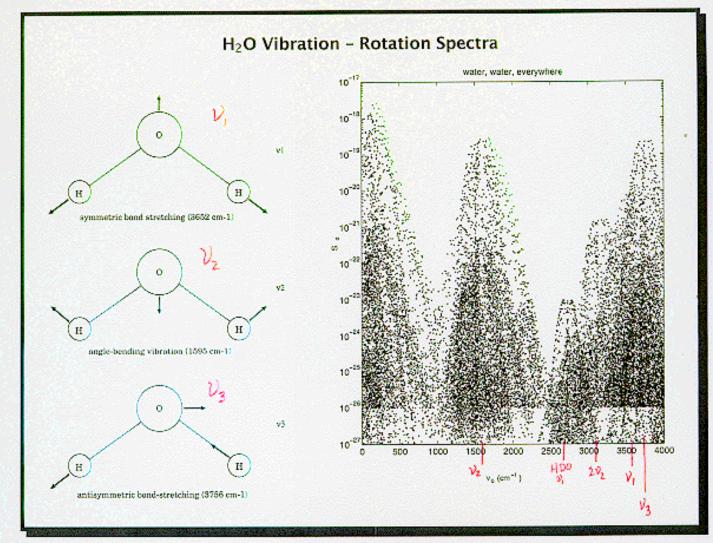
D. Tobin, UMBC

LANL 04/16/96

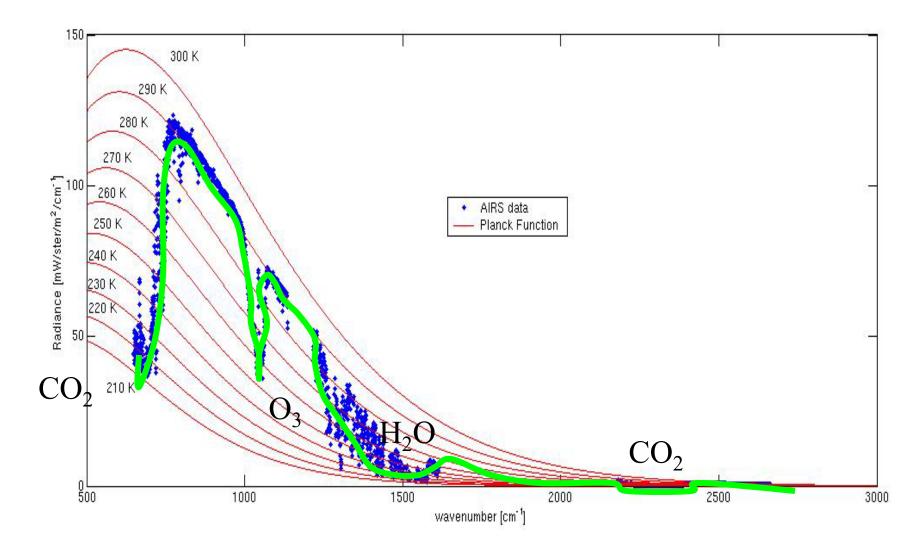


### H<sub>2</sub>O Lines

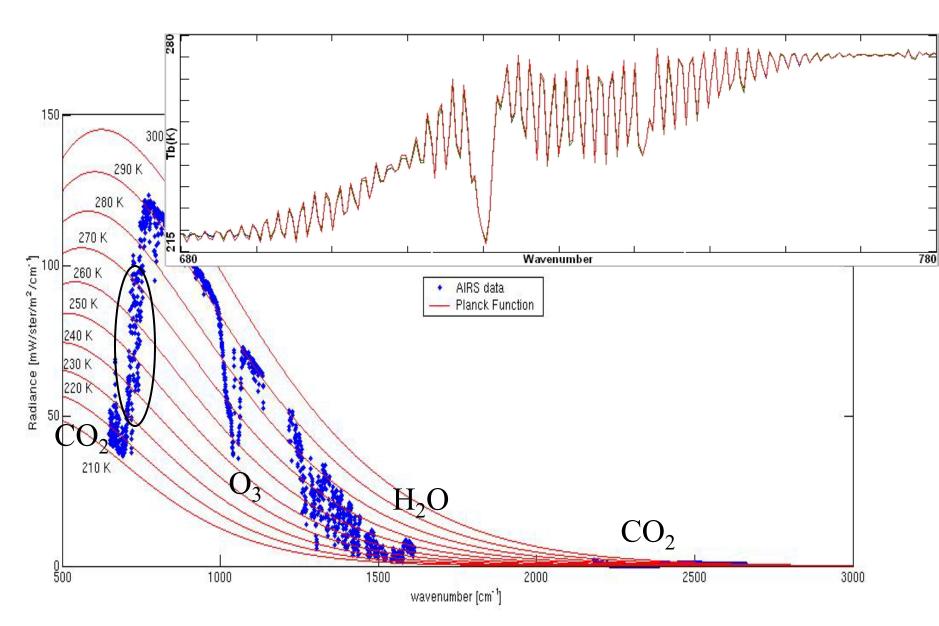
D. Tobin, UMBC



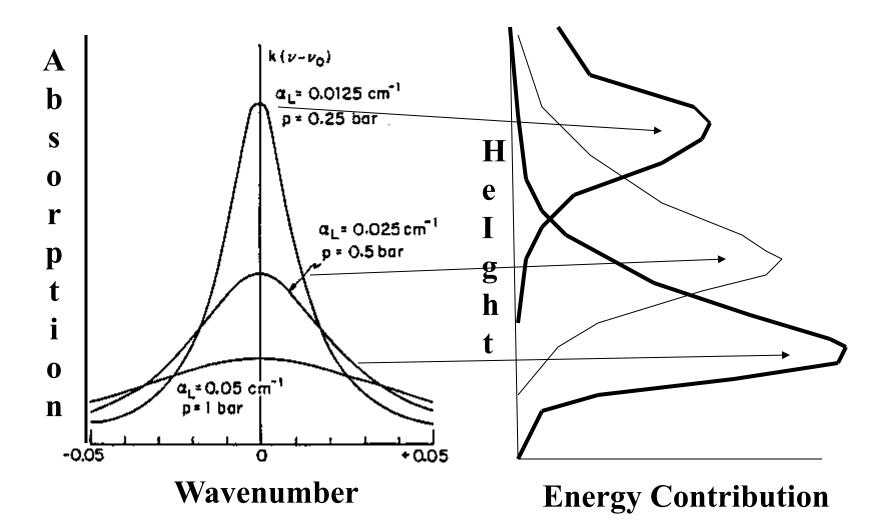
#### **Vibrational Lines**



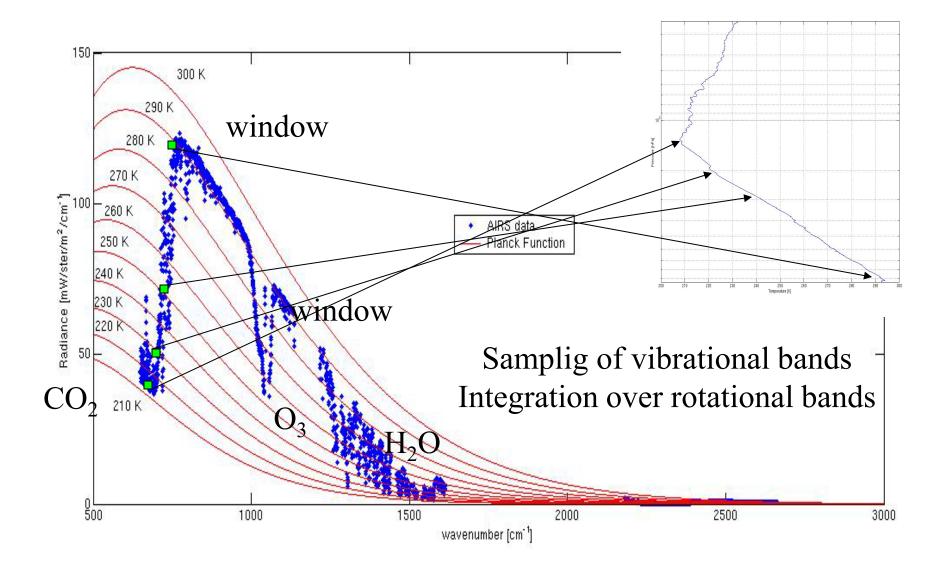
#### **Rotational Lines**

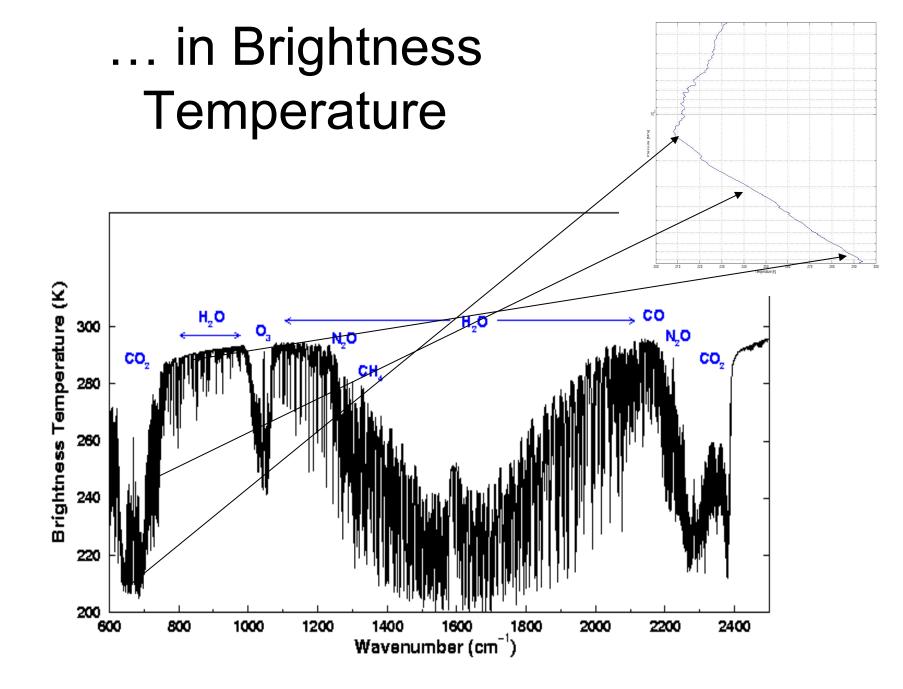


### Weighting Functions

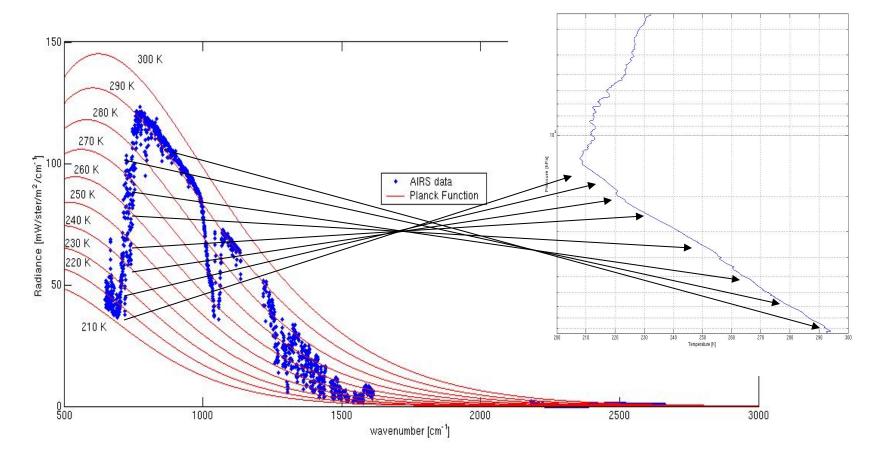


#### **Broad Band**





#### **High Spectral Resolution**

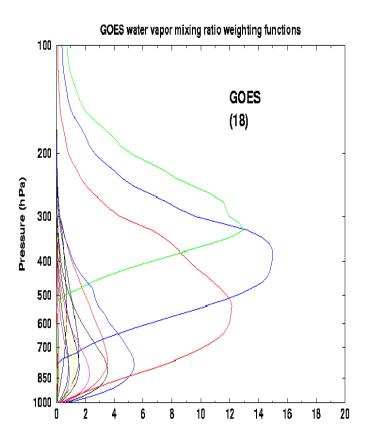


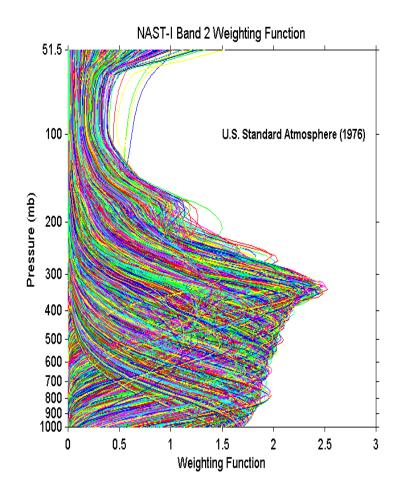
Samplig over rotational bands

### AIRS and MODIS (mt Etna, Sicily, 28 Oct 2002)

QuickTime<sup>™</sup> and a Microsoft Video 1 decompressor are needed to see this picture.

#### **Broad Band vs High Spectral**



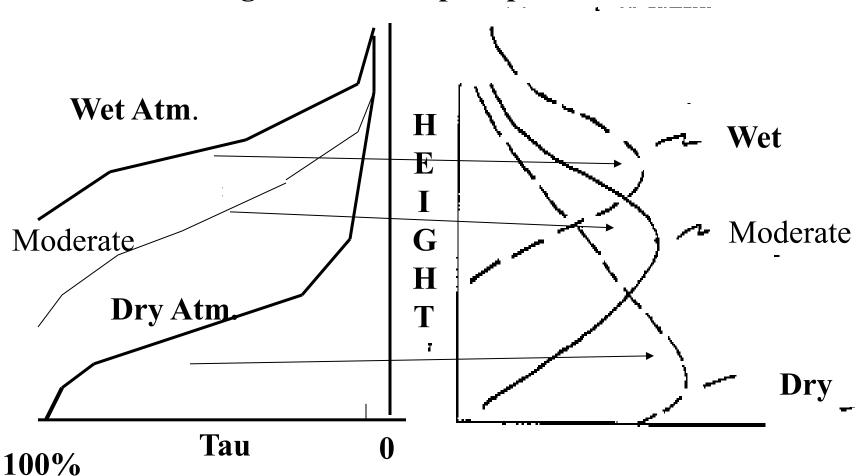


#### Questions

For a given water vapor line what happens to its weighting function When the amount of upper tropospheric water vapor increases?

#### Weighting Function

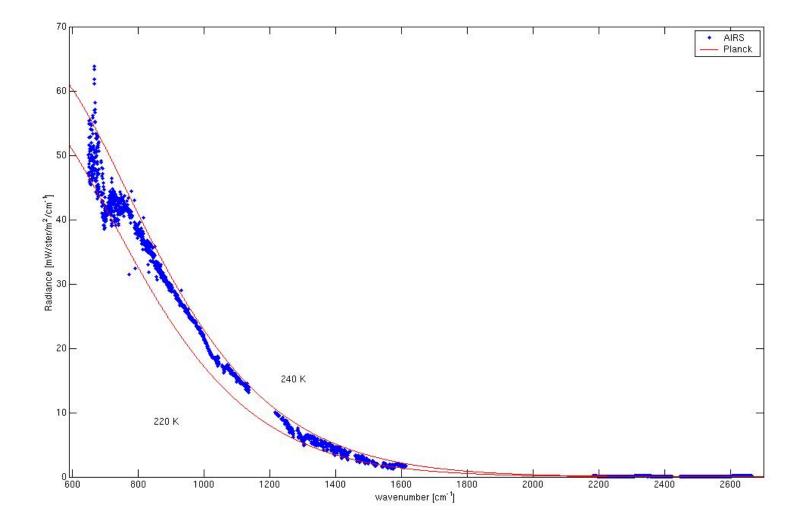
For a given water vapor spectral channel



#### Questions

How does it look the observed spectrum for high thick water vapor cloud ?

#### **Thick Cloud Opacity**

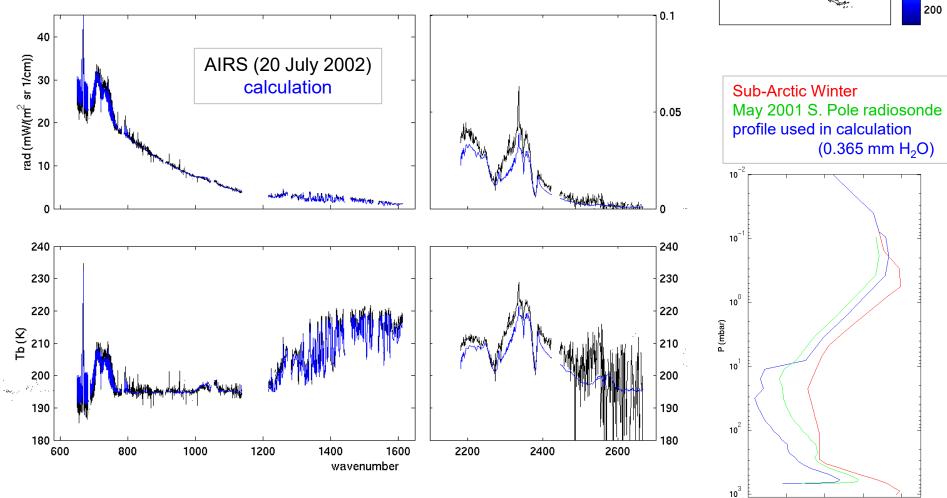


#### Questions

Moving deeper and deeper into an absorption line the observed BT tends do decrease, why?

Is it always true that the BT decreases going deeper into the absorption band?

#### **Temperature Inversions**



180 200 220 240 260 T (K)

AIRS (K)

250

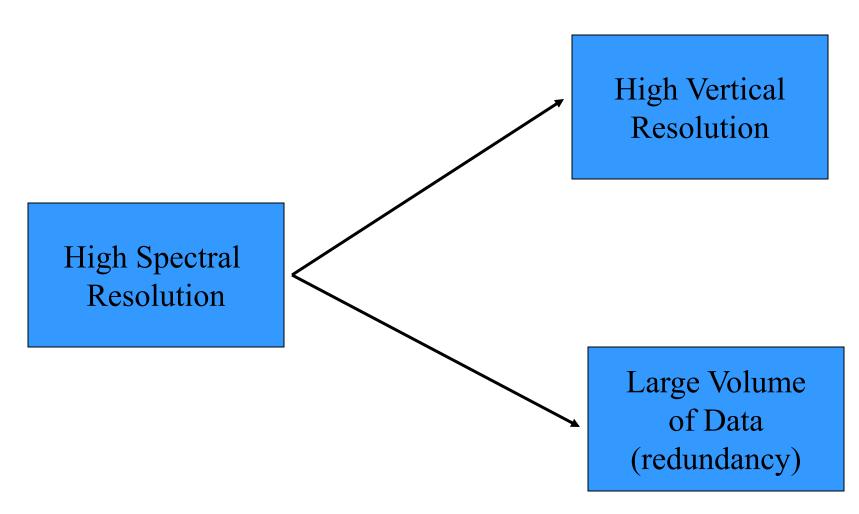
240

230

220

210

#### Conclusions



#### High Spectral Resolution: Products

- Sounding (T,WV) at high vertical resolution
- Surface Properties (Emissivity, T)
- Cloud properties (Top Pressure, Optical Thickness, Effective Emissivity)
- Wind Profiling
- Noise Filtered Observations

#### **Airborne Instruments**

- MAS: moderate spectral resolution, high spatial resolution
- NAST-I, S-HIS: high spectral resolution, lower spatial resolution

#### Airborne FTS Instruments



- <u>NPOESS Atmospheric Sounder Testbed</u> Interferometer (NAST-I) Microwave (NAST-M)
- Far-Infrared Sensor for Cirrus (FIRSC)

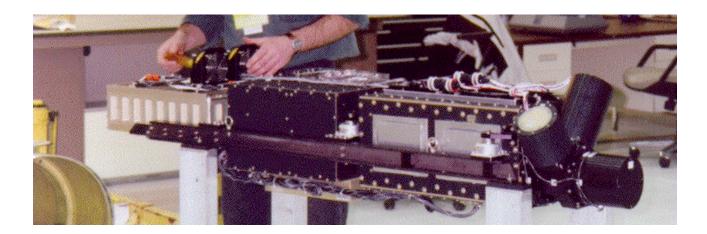


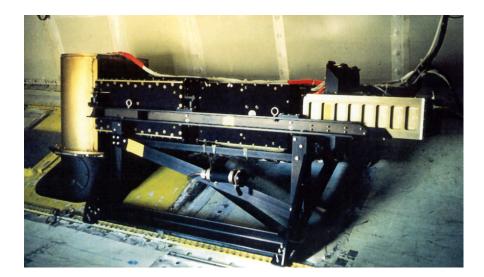


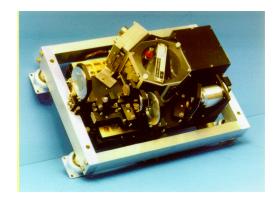


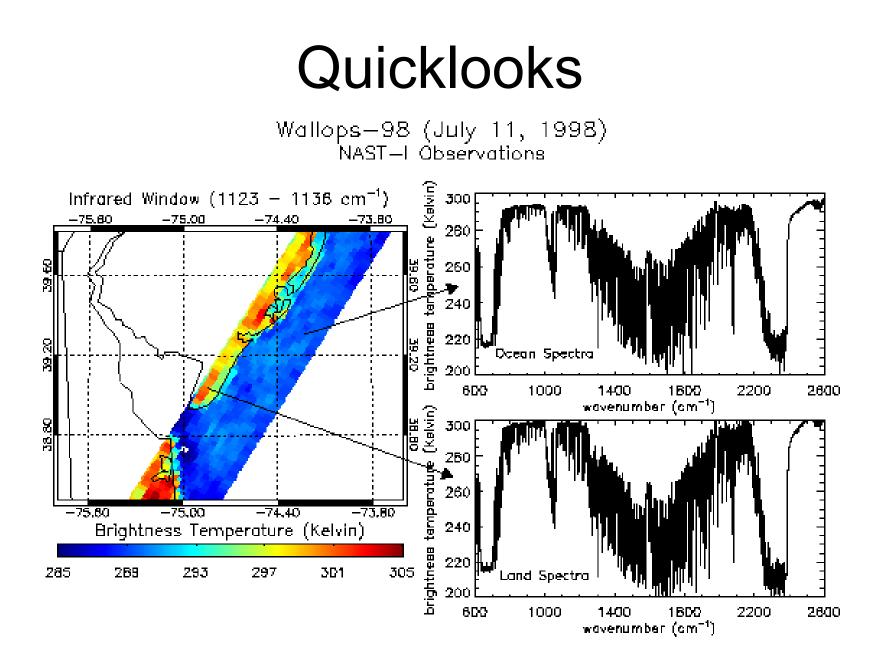


#### Scanning-HIS Aircraft Instrument

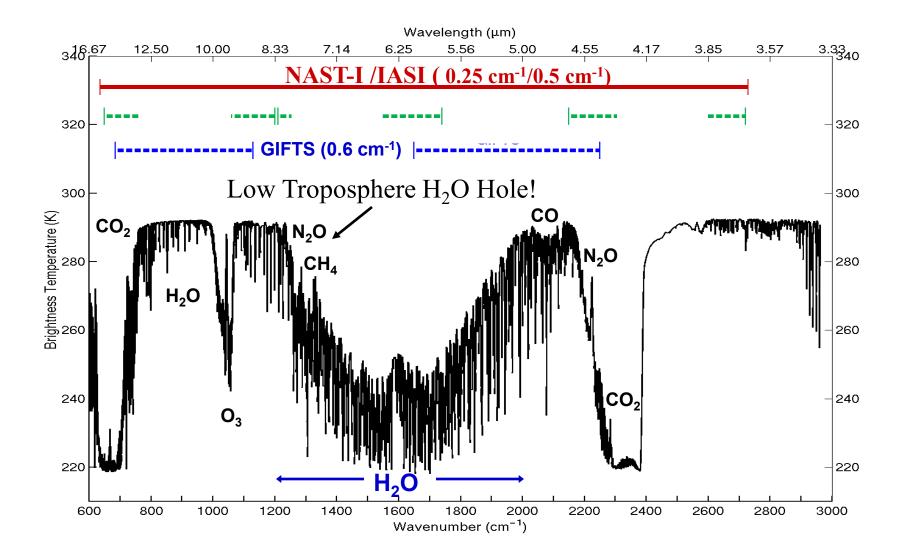


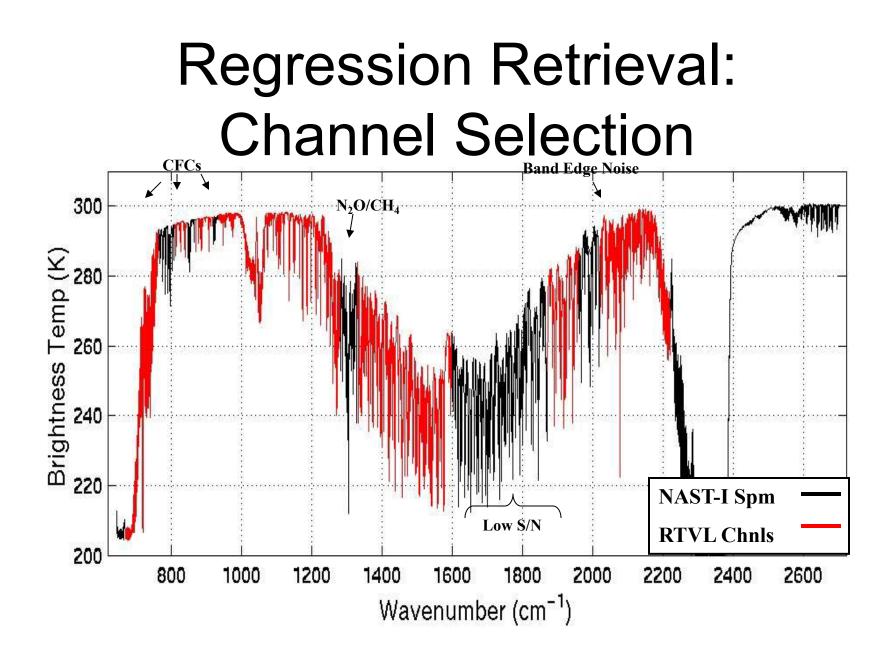






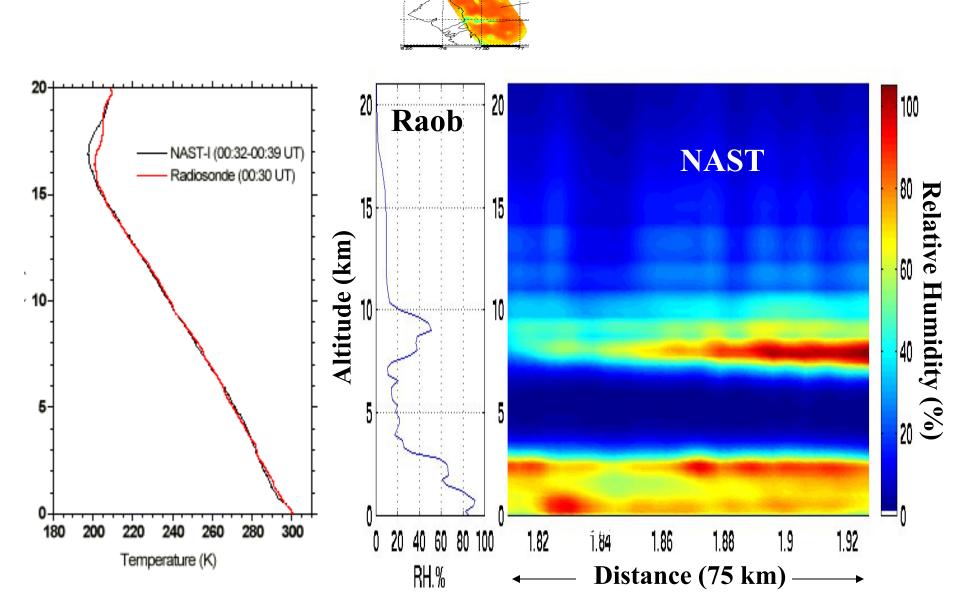
#### **Spectral Coverage**



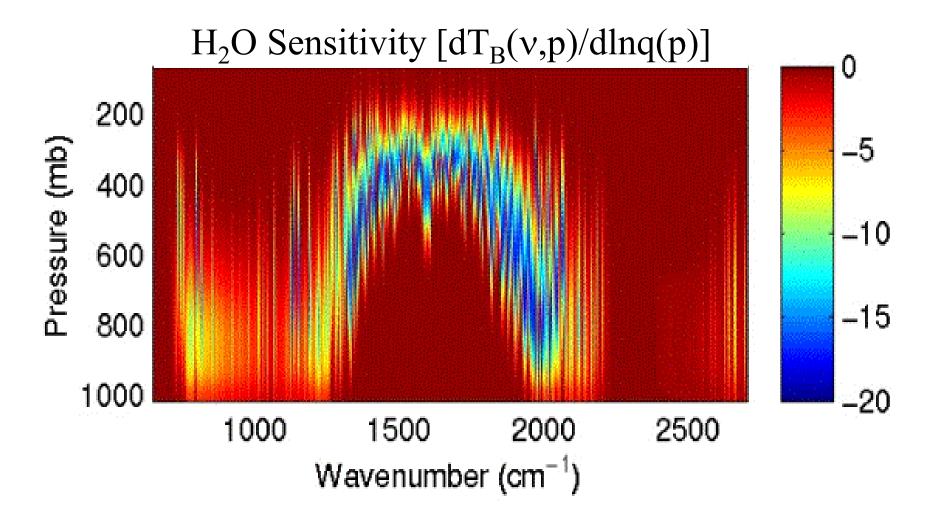


#### Water Vapor and Temperature **Retrievals** NASTI NASTI NASTI RAOB RAOB RAOB Altitude (km) **NOV 30 NOV 30 NOV 30** Temperature (K) H2O VMR (g/kg) RH (%) NASTI NASTI NASTI RAOB RAOB RAOB Altitude (km) **DEC 05 DEC 05 DEC 05** Temperature (K) H2O VMR (g/kg) RH (%)

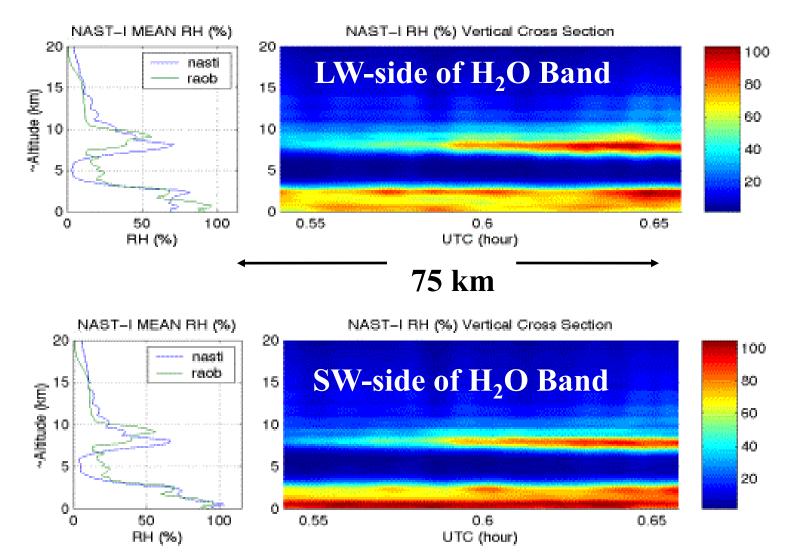
## <u>Sept 12,1998</u>



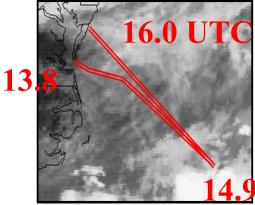
# Water Vapor Sensitivity



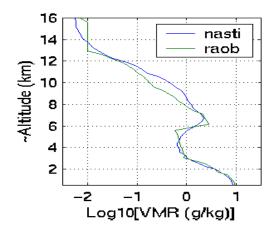
# Water Vapor Sensitivity



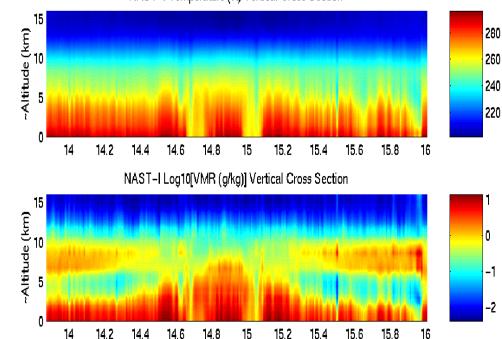
### Sounding in presence of thin clouds Proteus Flight Track (July 12, 2001)



GOES IR (1515 GMT)



NAST-I Temperature (K) Vertical Cross Section



This flight demonstrates the ability to observe the spatial moisture structure below a scattered and semitransparent Cirrus cloud cover

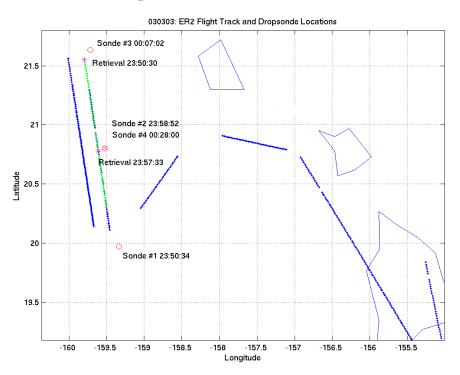
# THORPEX 2003

THORPEX objectives are:

- to improve the use of various in situ and space-based observation systems in operational weather predictions
- to evaluate model sensitivity studies and test the impact of targeted observations
- to begin to develop intelligent observing systems along with forecast models capable of dynamical interaction through data assimilation systems



# Soundings: 03 Mar 2003

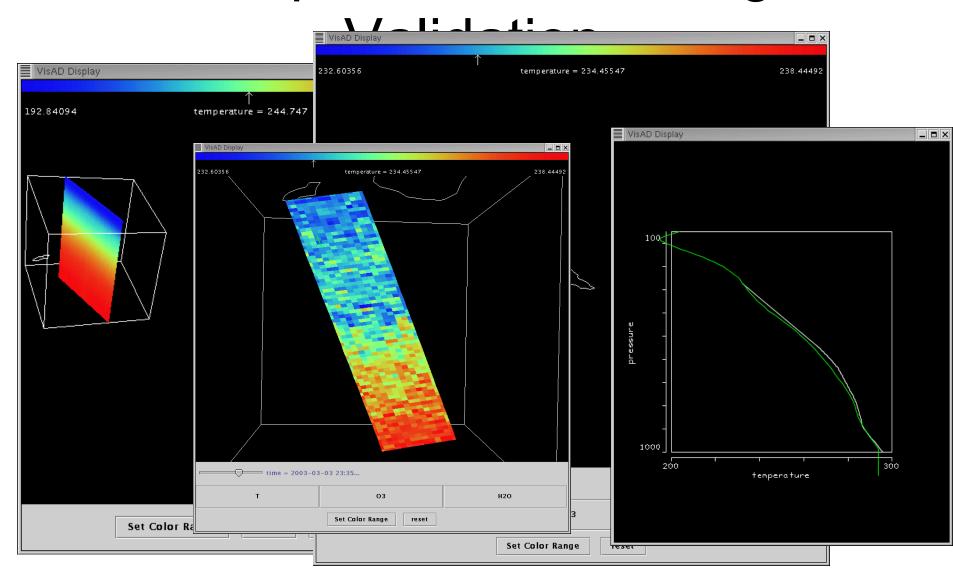


#### 23:49:00

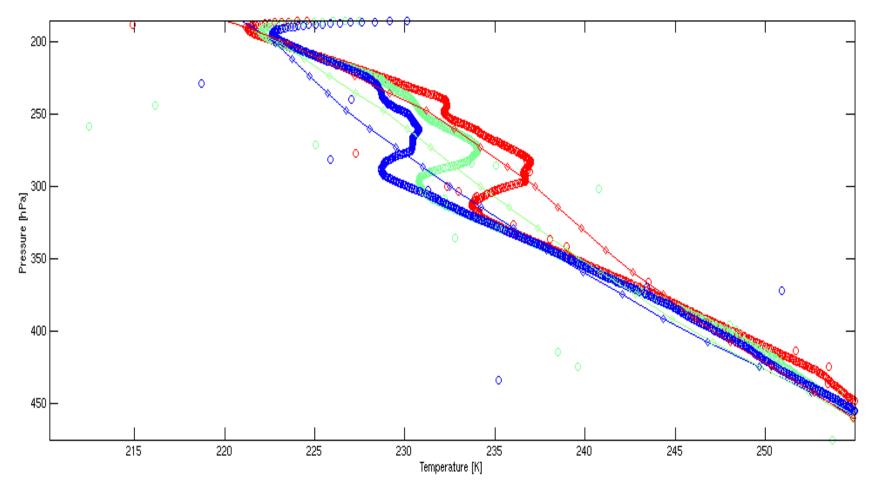


00:03:00

# **Temperature Sounding**

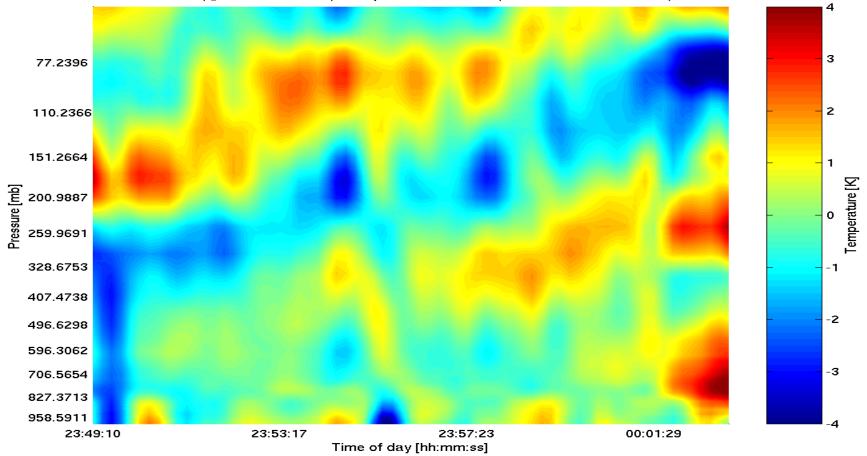


# Temperature Sounding Validation: Dropsondes



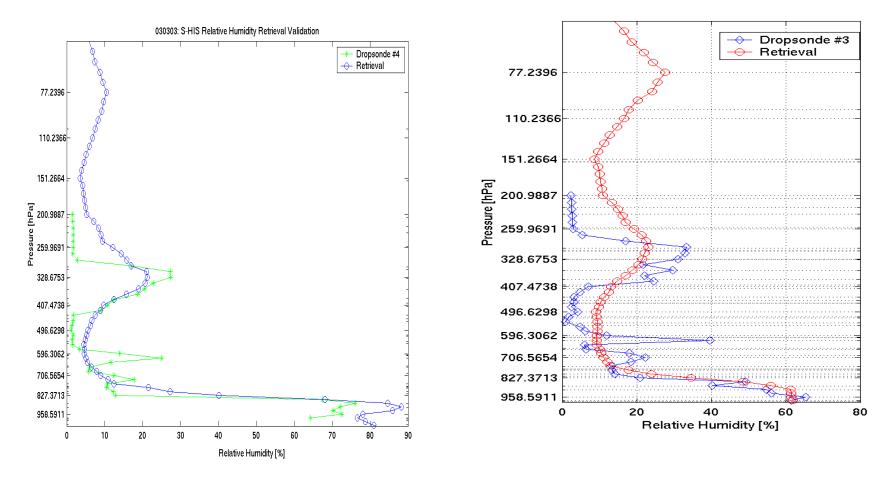
# Temperature Sounding Comparison:

030303: NASTI (@ SHIS resolution) Temperature Retrieval (Deviation from the mean) 30 PCs

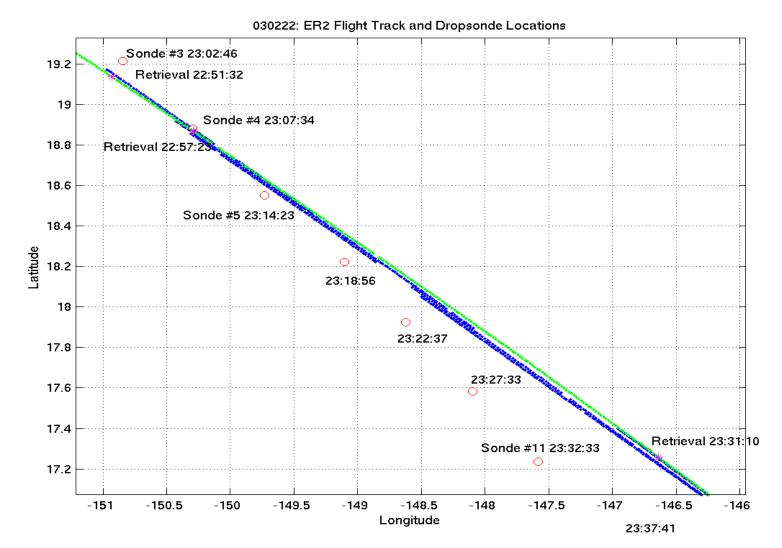


# **Relative Humidity Validation**

030303: S-HIS Relative Humidity Retrieval (T with 30 PCs, WV with 12 PCs)

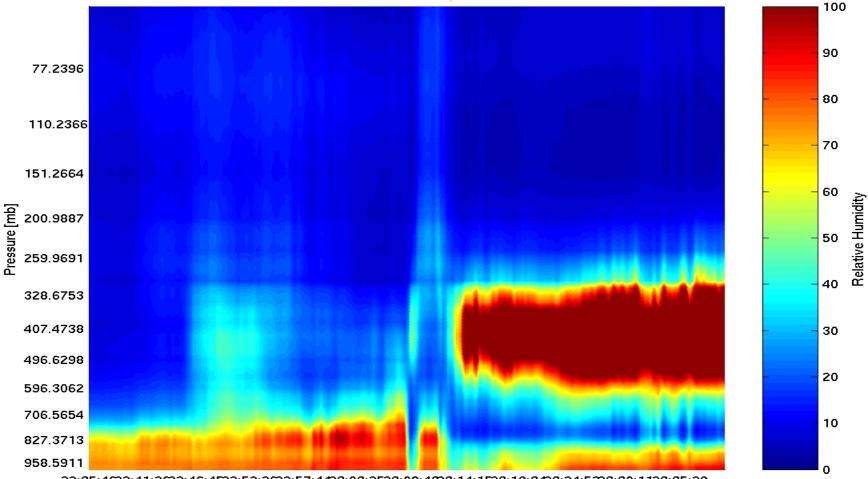


# Sounding: 22 Feb 2003



# S-HIS sounding

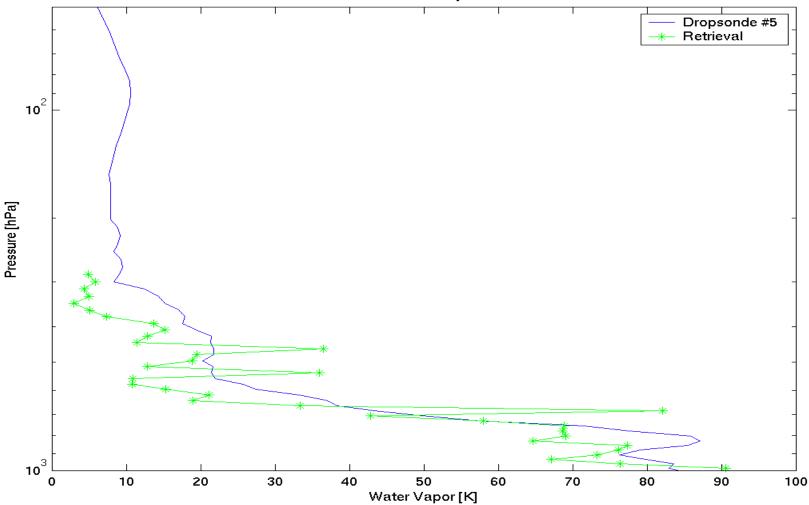
030222: SHIS Relative Humidity Retrieval 13 PCs



22:35:4622:41:2622:46:4522:52:2622:57:4423:03:2523:08:4323:14:1523:19:3423:24:5223:30:1123:35:29 Time of day [hh:mm:ss]

# **Relative Humidity Validation**

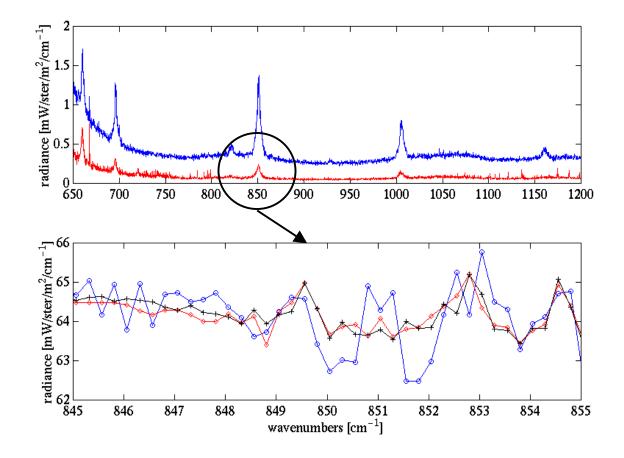
030222: S-HIS Relative Humidity Retrieval Validation



# Noise Reduction

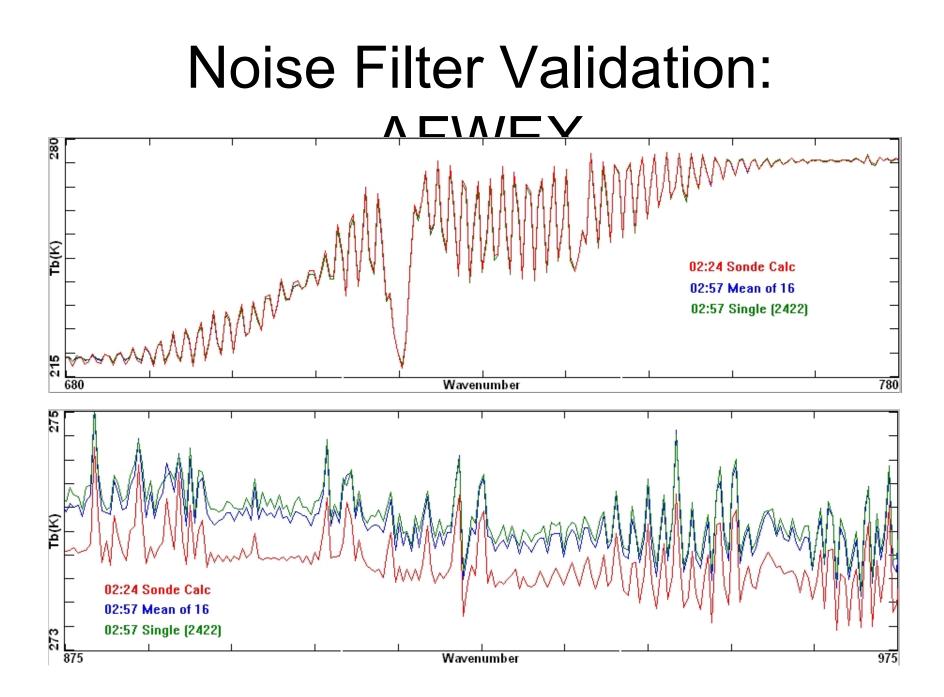
- High Spectral Resolution means high redundancy
- Reducing the instrument noise without compromising the spatial and spectral resolutions is very expensive
- We can take full advantage of the high redundancy, to filter out part of the instrument noise
- PCA has been chosen to build a noise filter
   that takes advantage of the high redundancy

### **Noise Reduction**

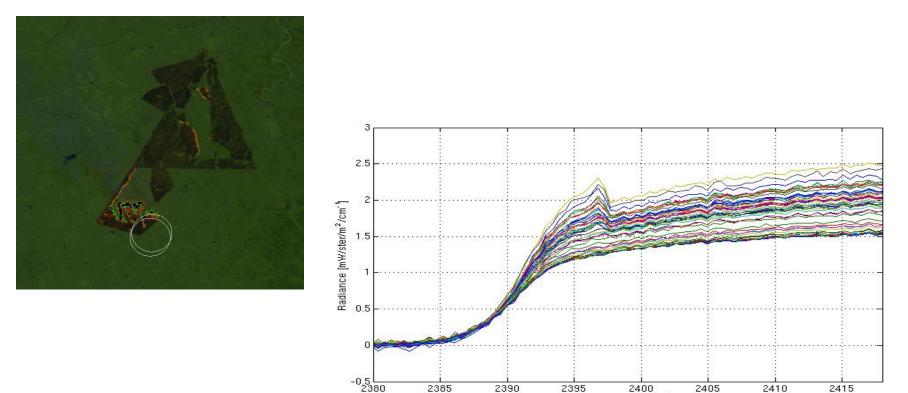


Uncorrelated Noise Before Compression After Compression

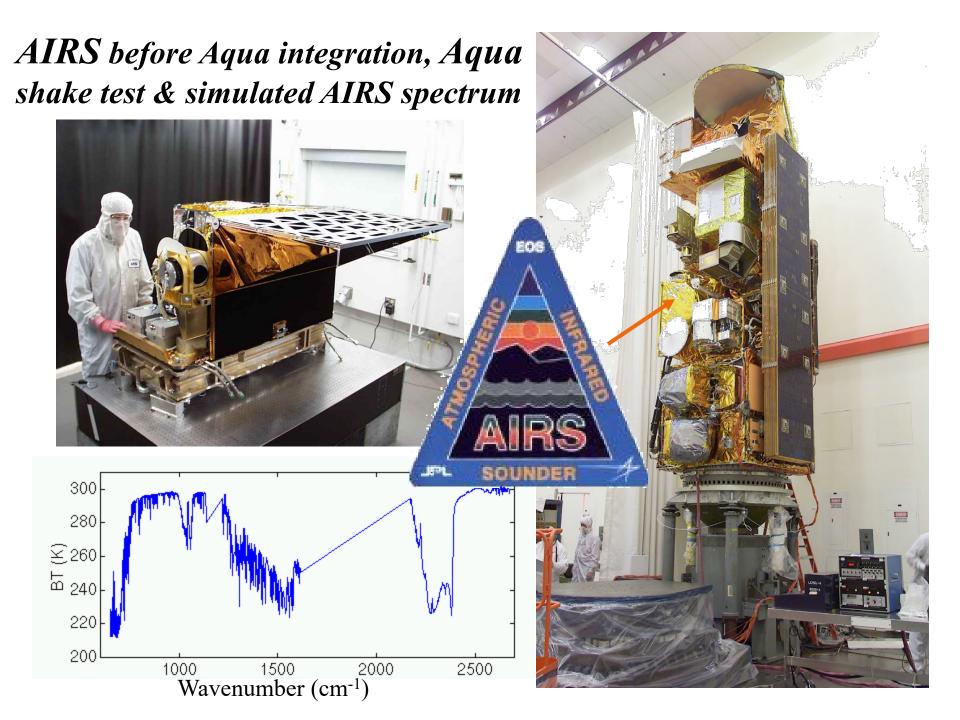
Single Recons. Spectrum Averaged Spectrum

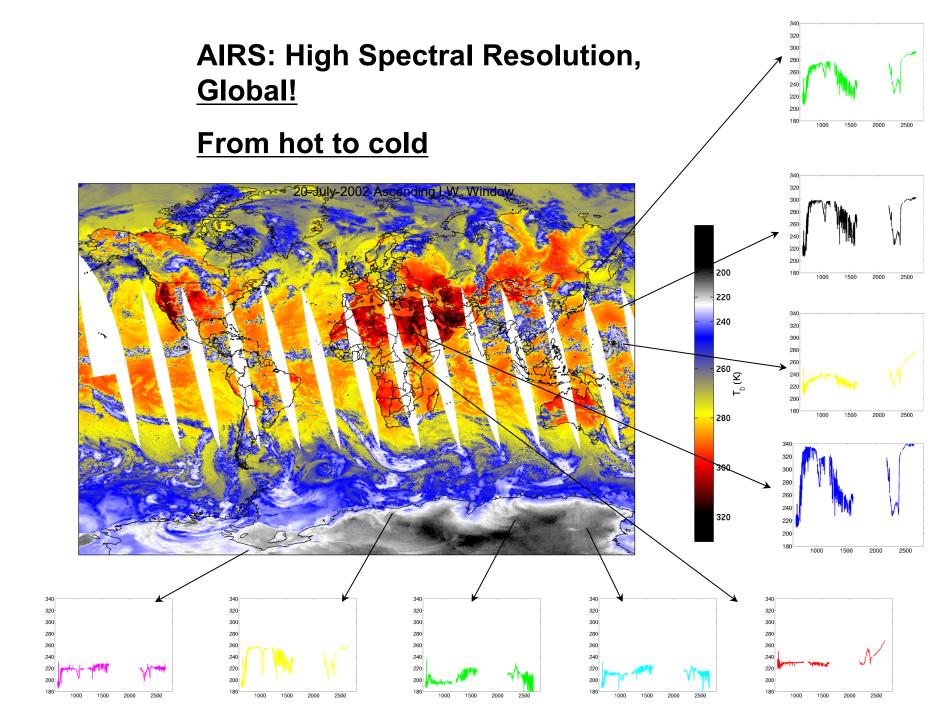


# **S-HIS: Noise Filter**

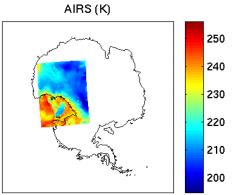


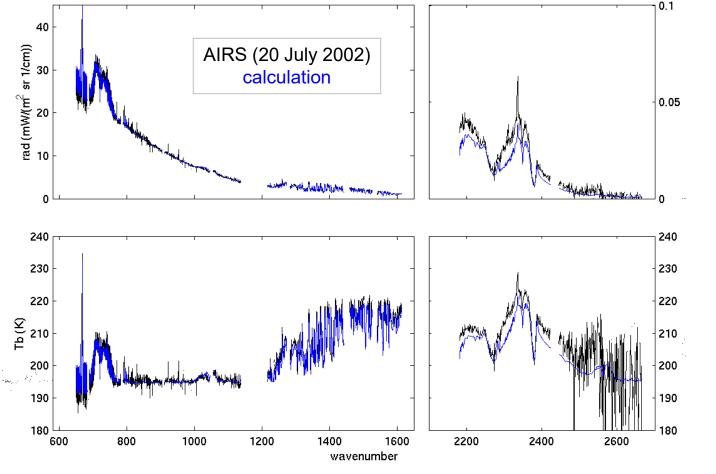
wavenumber [cm<sup>-1</sup>]



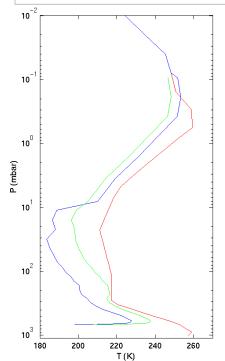


#### To Coldest ... Dome Concordia 20 July 2002 Obs-Calc

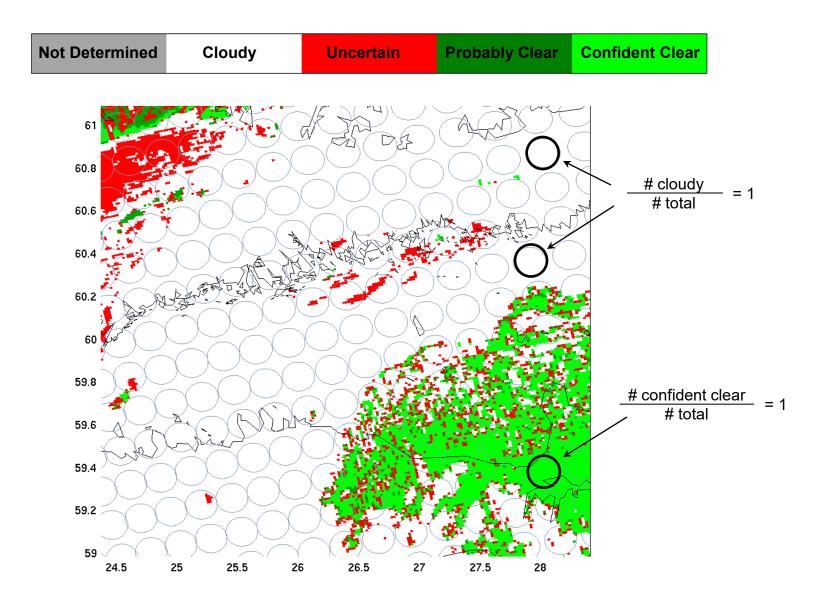


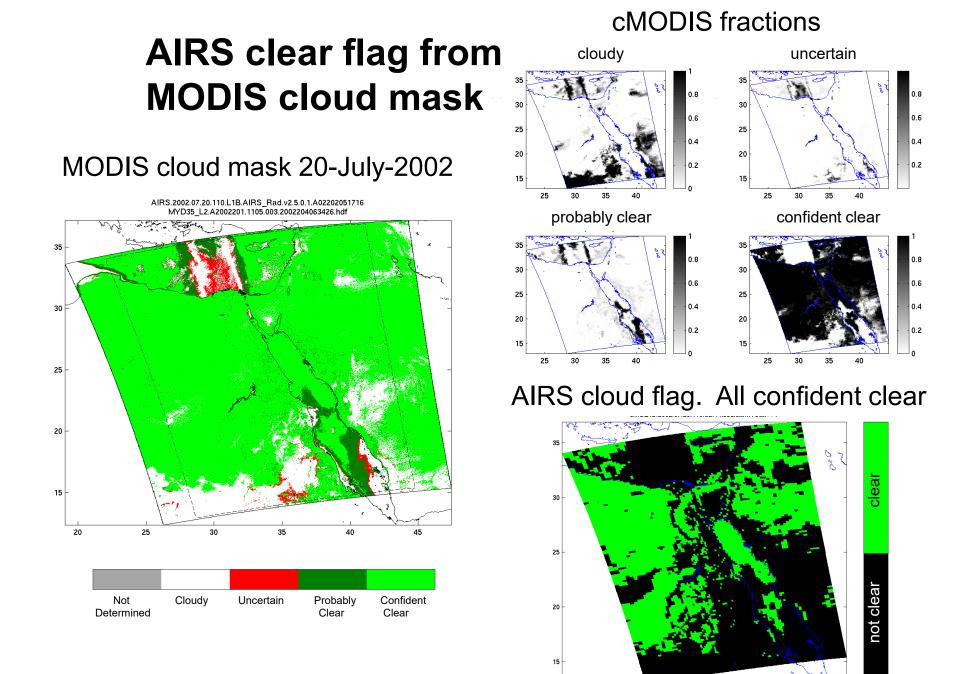


Sub-Arctic Winter May 2001 S. Pole radiosonde profile used in calculation  $(0.365 \text{ mm H}_2\text{O})$ 

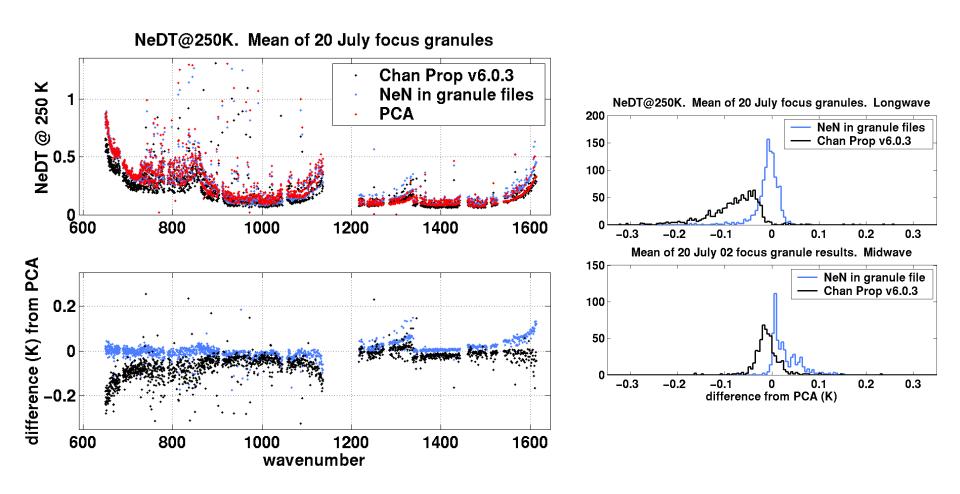


### Combining AIRS and MODIS for cloud mask

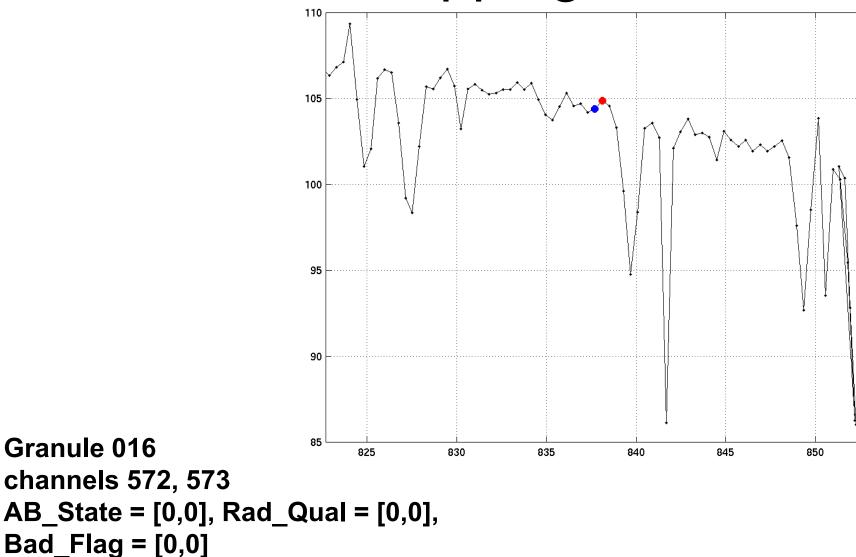




# Noise Characterization using PNF



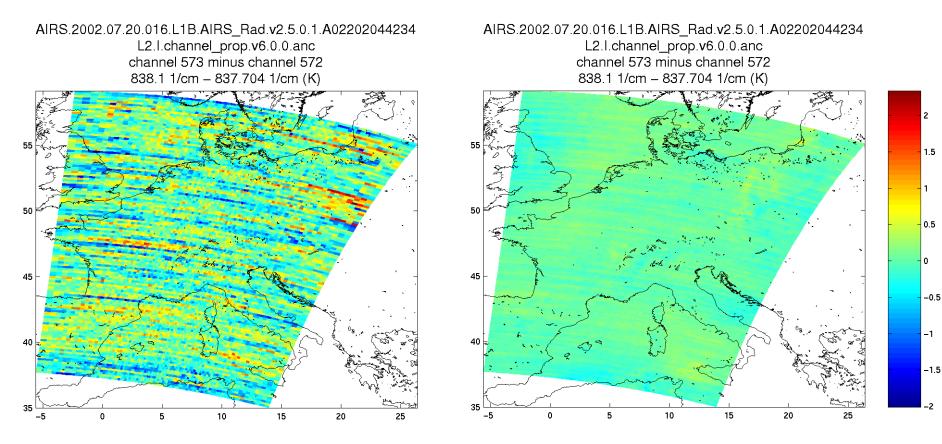
# **AIRS: Popping Noise**



# **AIRS: PCA Noise Filter**

#### Original

#### Filtered



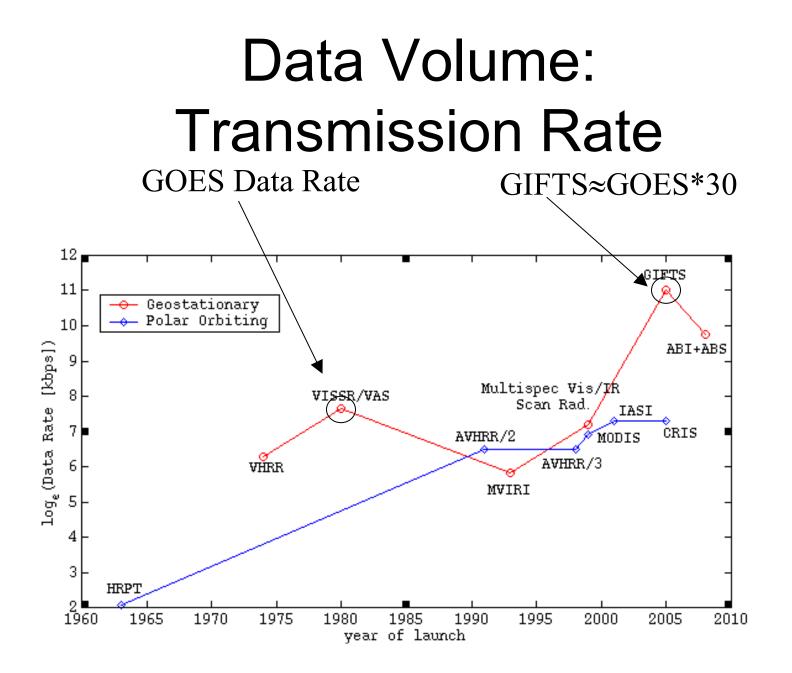
Channel 573 - Channel 572 Brightness Temperature Differences

# Main Challenges of High Spectral Resolution

- Data volume
  - data transmission
  - data storage
  - data processing (calibration, inversion)

# Data Volume

- The increased volume of data transmitted from the satellite to the ground, if not properly processed, will:
  - exceed the capacity of the current operational downlink technology
  - require expensive data systems to process the data on the ground



# **GIFTS** Data Volume

To download GIFTS data from home you would need 1000 modems





This CD can contain less than 1.5 minutes of GIFTS data ...24 hours data of GIFTS data would fill 925 CDs