Lessons Learned with the AIRS Hyperspectral Sensor

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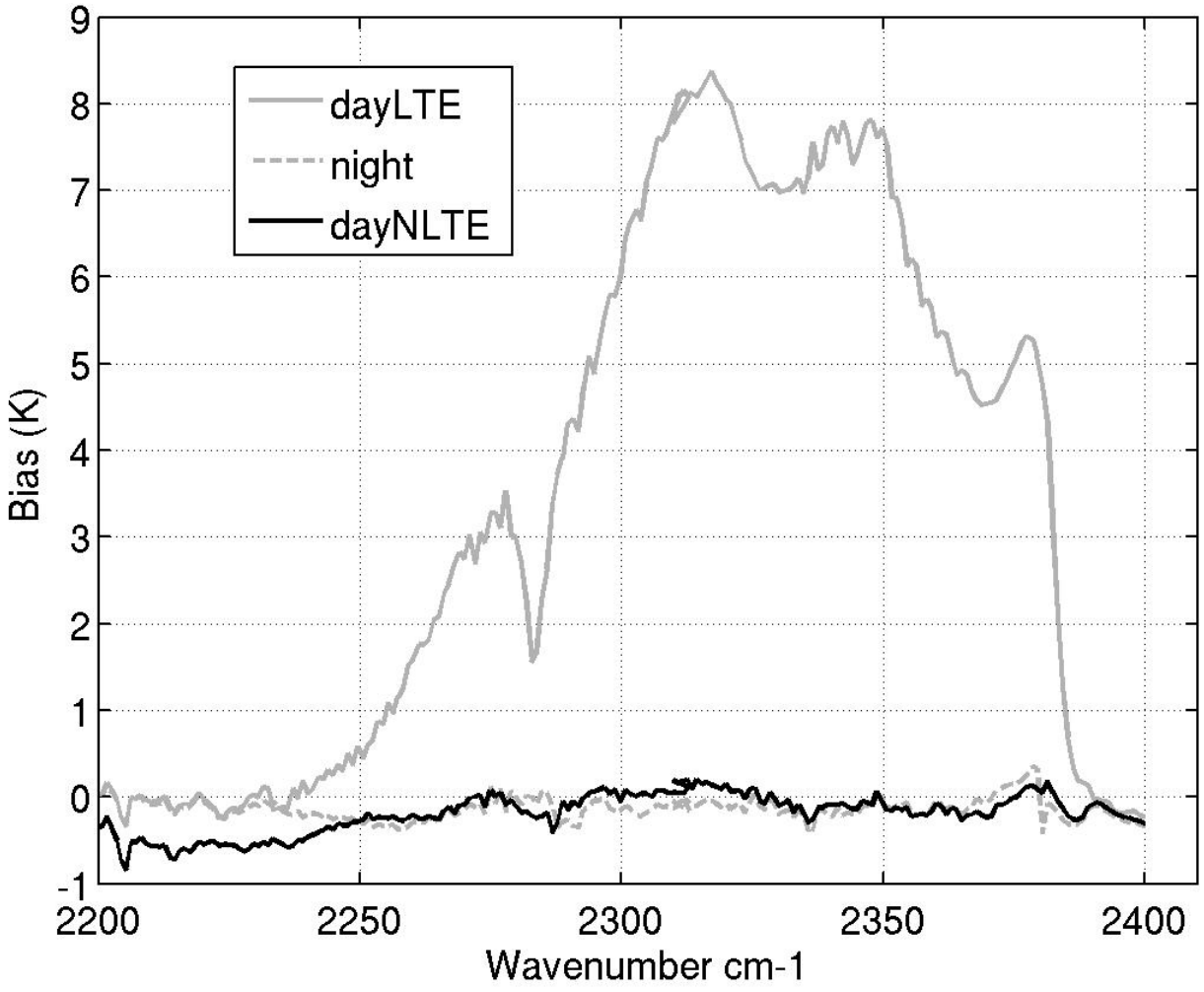
Thanks to: ASL Group Members: Scott Hannon, Sergio De Souza-Machado, and Howard Motteler.

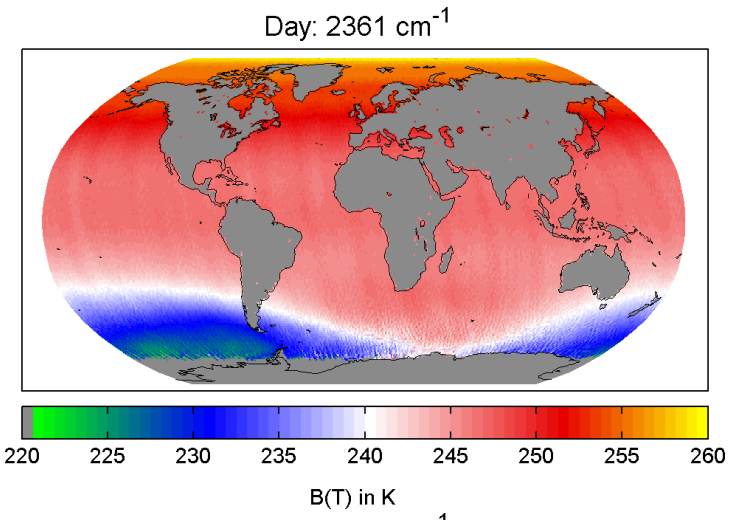
Overview

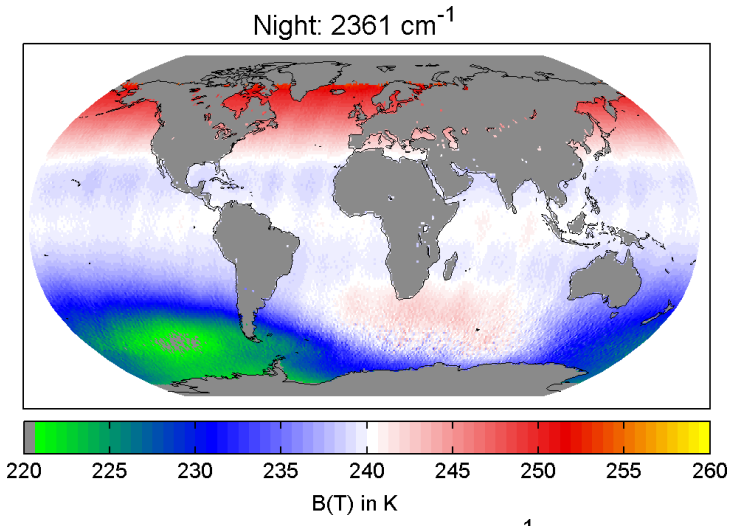
- RTA update (SARTA/kCARTA)
  - Non-LTE
  - Clear sky
- Minor gases
- Progress on detecting, modeling mineral dust with scattering RTA
- Doing climate with hyperspectral sensors

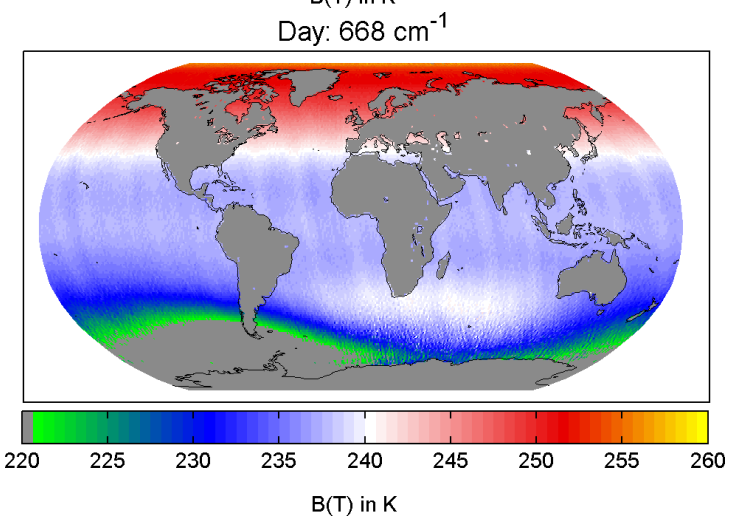
Bias summary of Non-LTE: Ignore black line

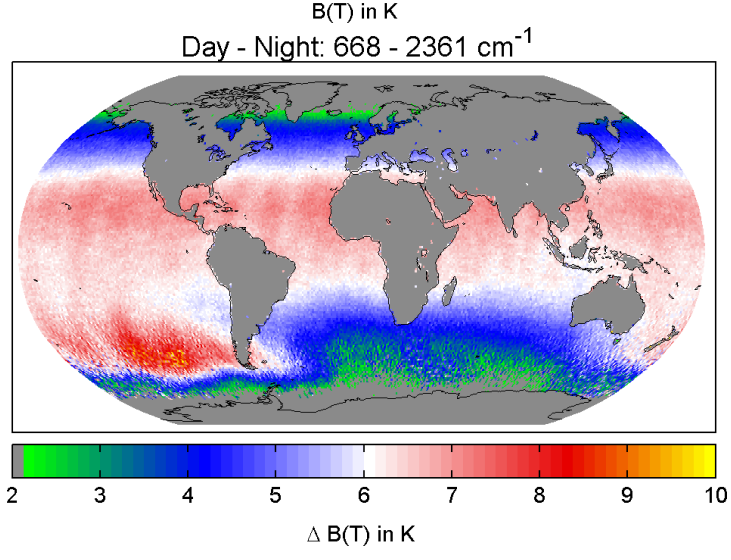


Global Behavior of Non-LTE (July 1-15)

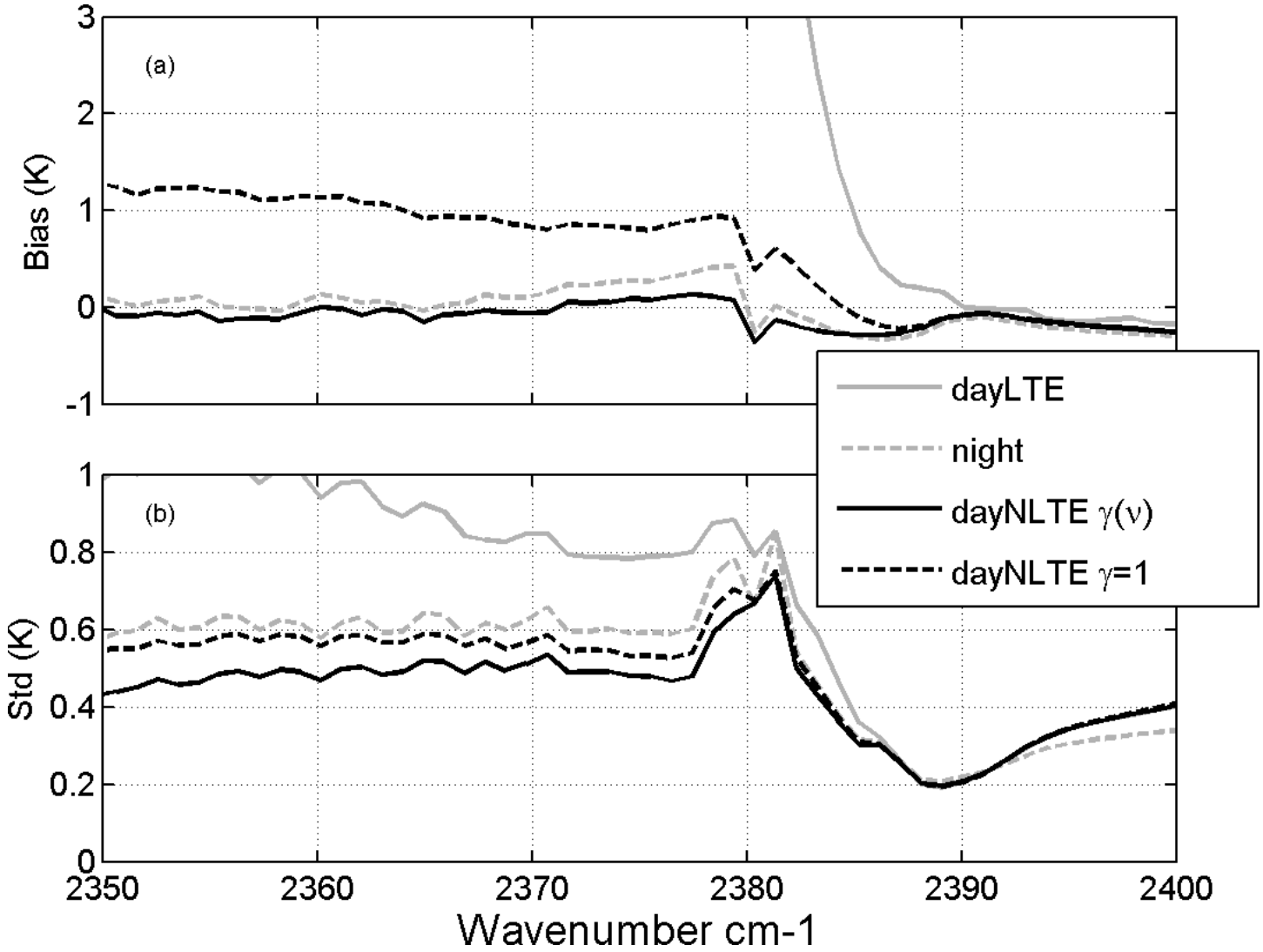




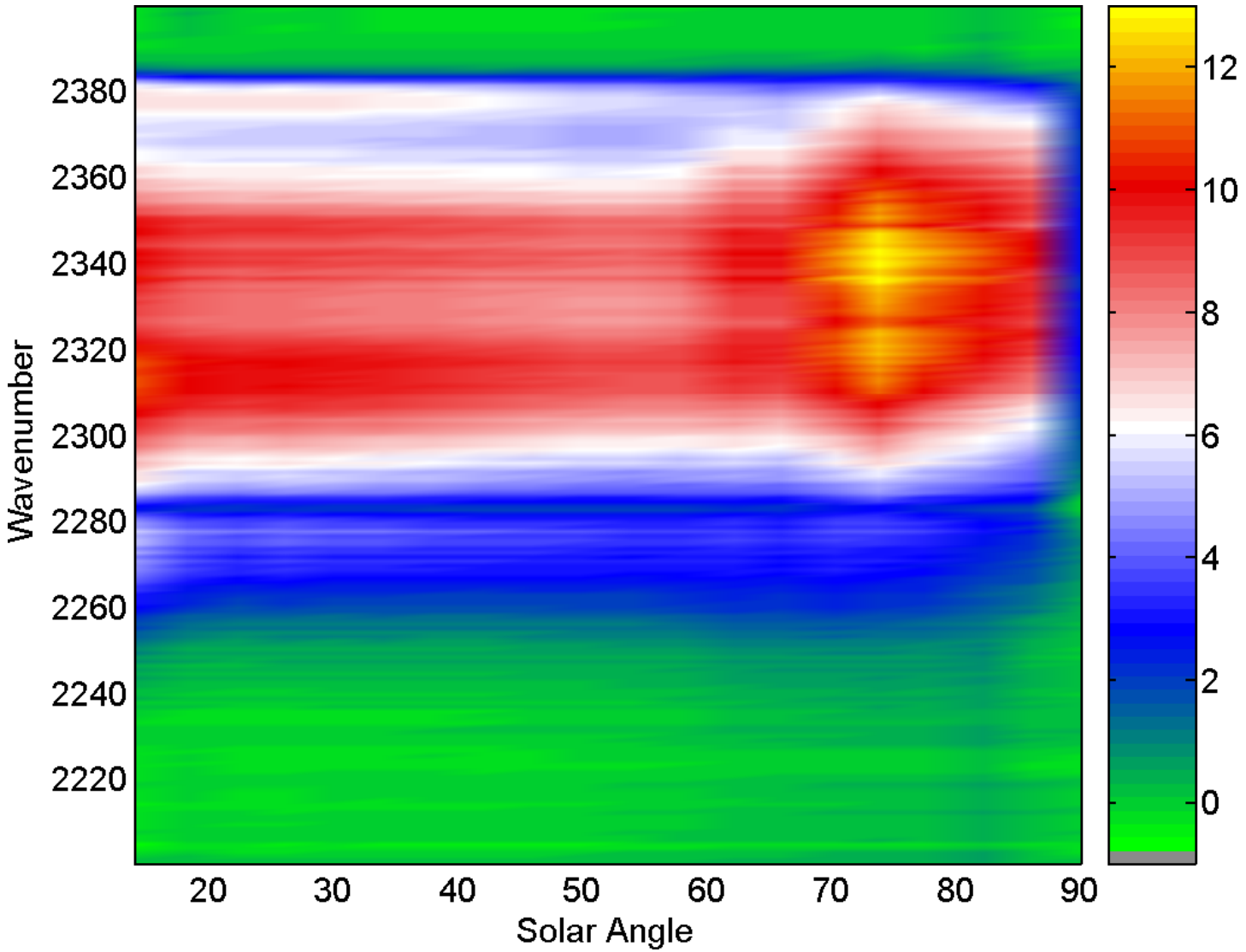




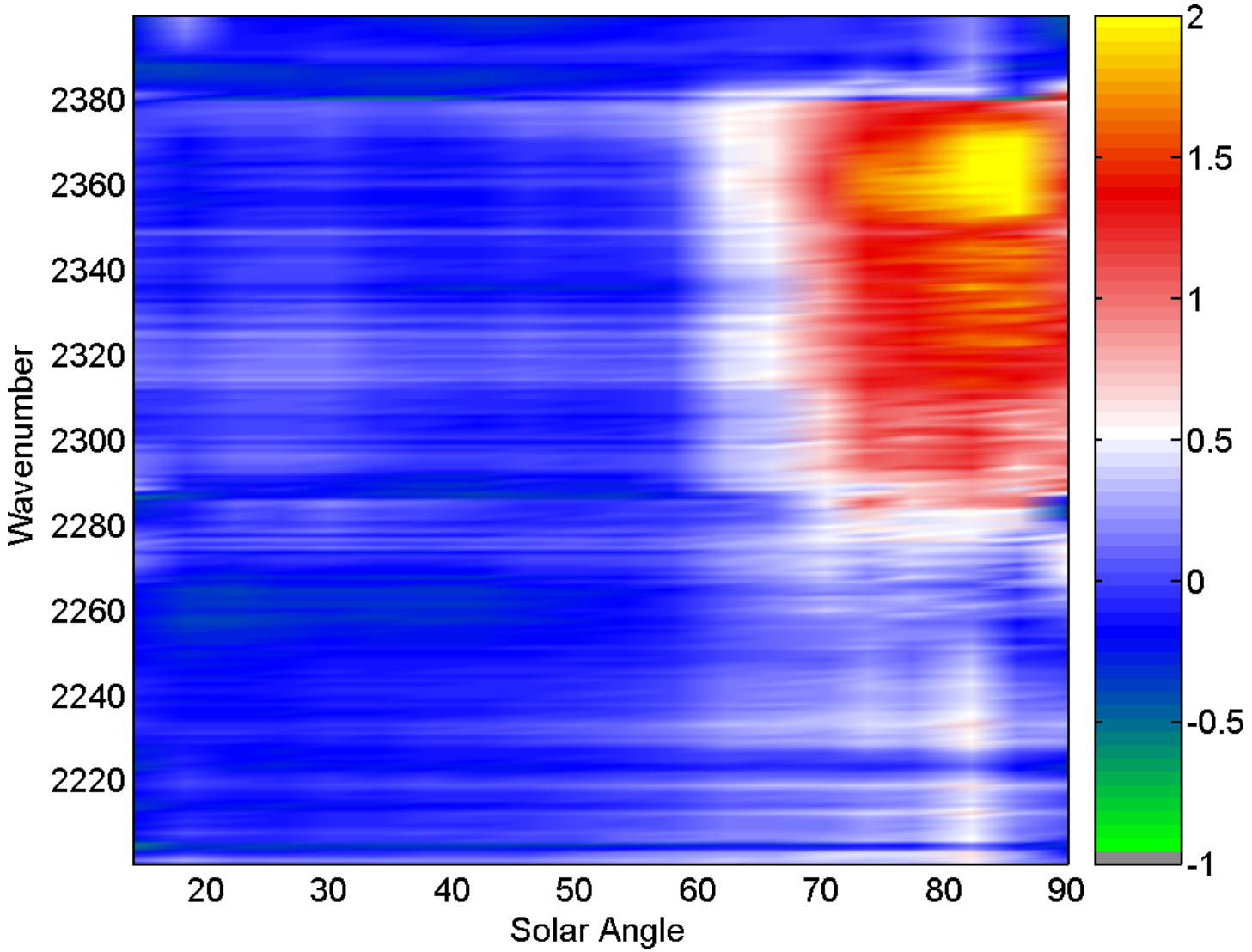
Zoom of Bias and Std's for Non-LTE



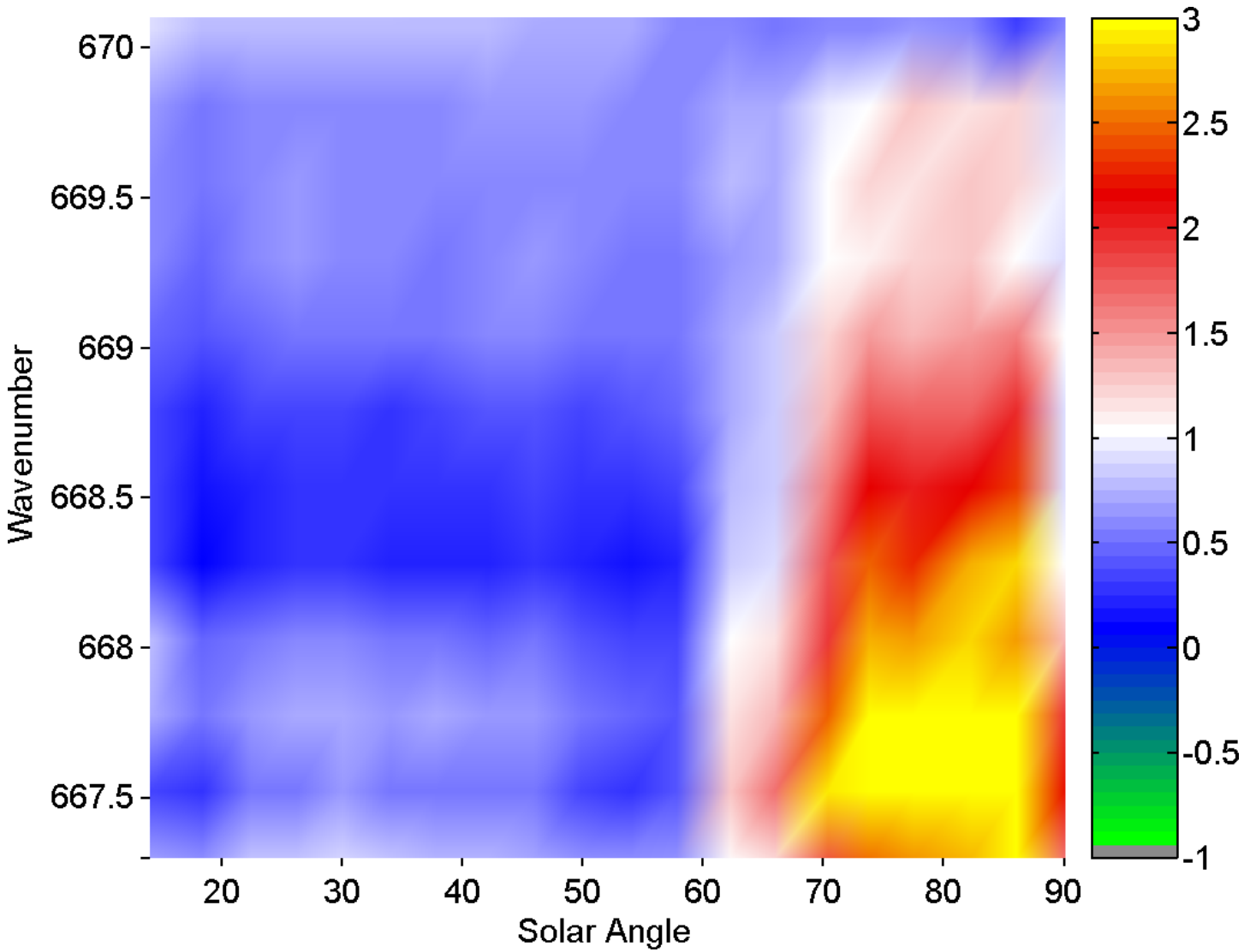
Bias vs Solar Angle: No Non-LTE Fix



Bias vs Solar Angle with Non-LTE Fix



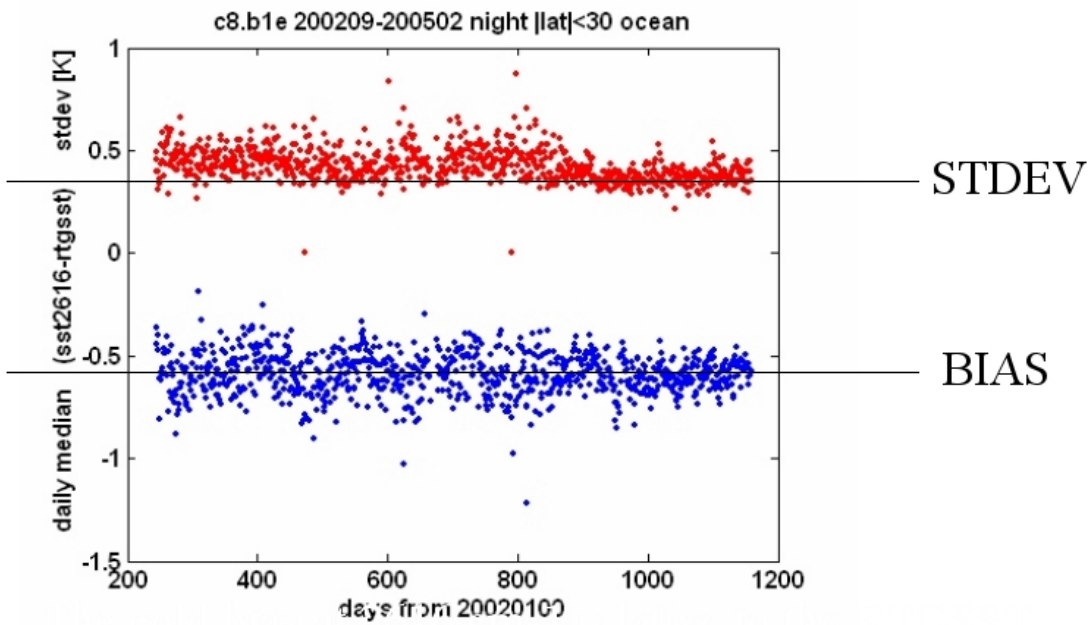
15 μm Bias vs Solar Angle, No Non-LTE Emission



RTA Validation: AIRS Radiometric Stability: <0.01K/year

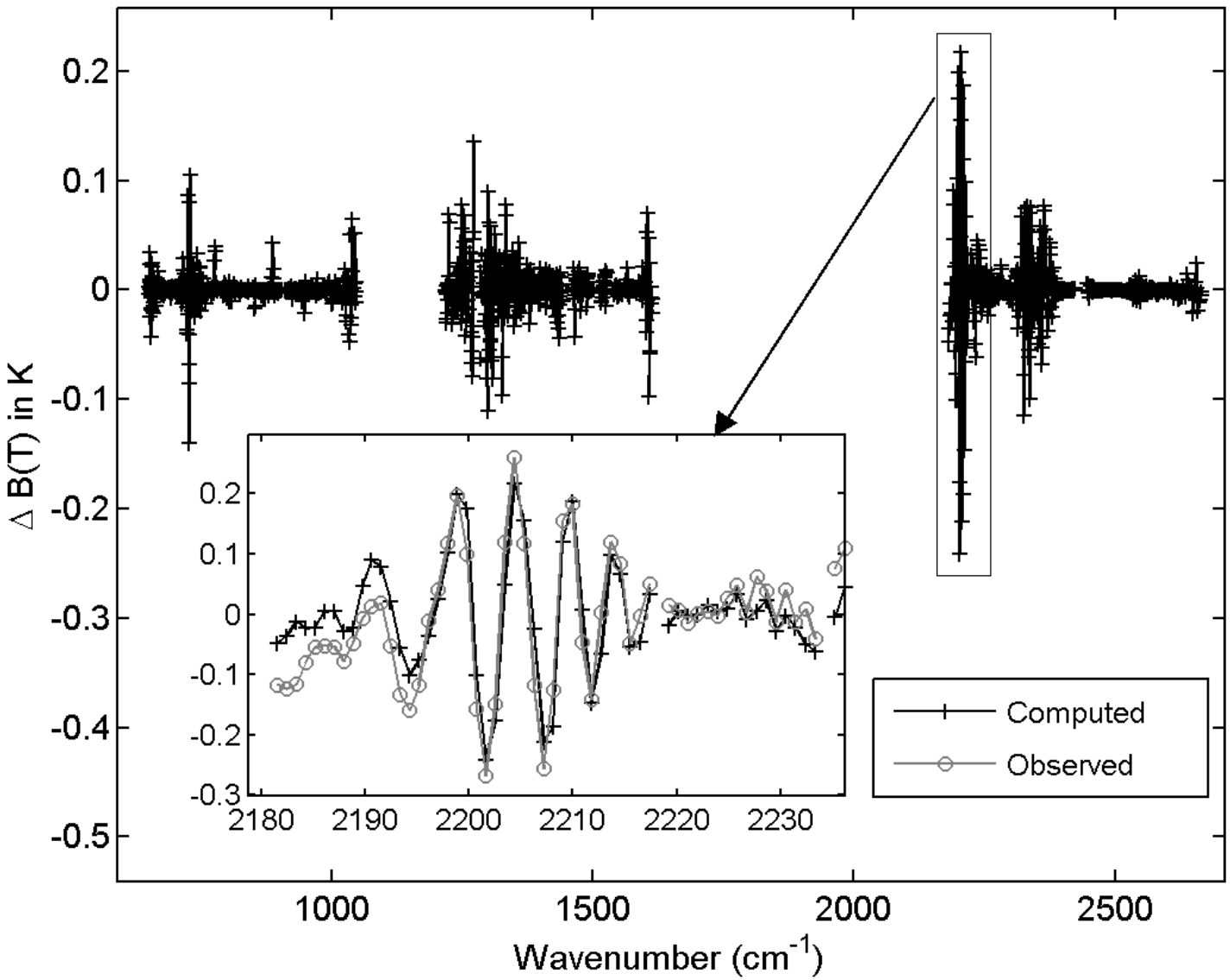
Work by H. Aumann (NASA/JPL)

The 600 mK cold bias is explained to 10 +/- 120 mK

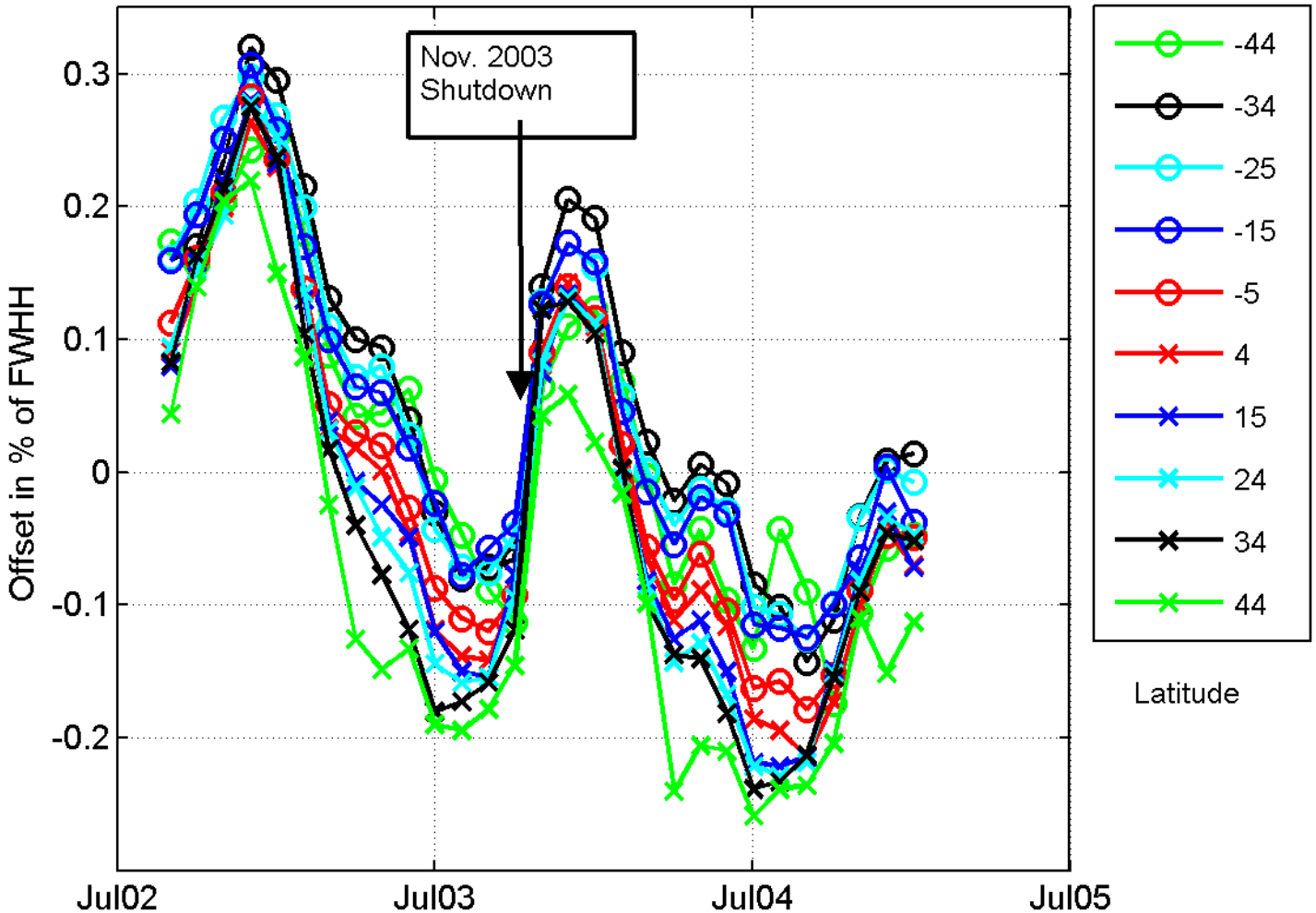


The accuracy at 2616 cm-1 in the 290-305 K range is 10+/-120 mK with stability of <16 mK/year for all data from 200209-200508 (JGR 2006)

SRF Shape (fringes) Introduce Bias: Understood, not fullly implemented



Slight frequency shifts: Important for climate



A great RTA validation dataset exists

Table: Number sonde launches, LIDAR observations, coincident with AIRS.

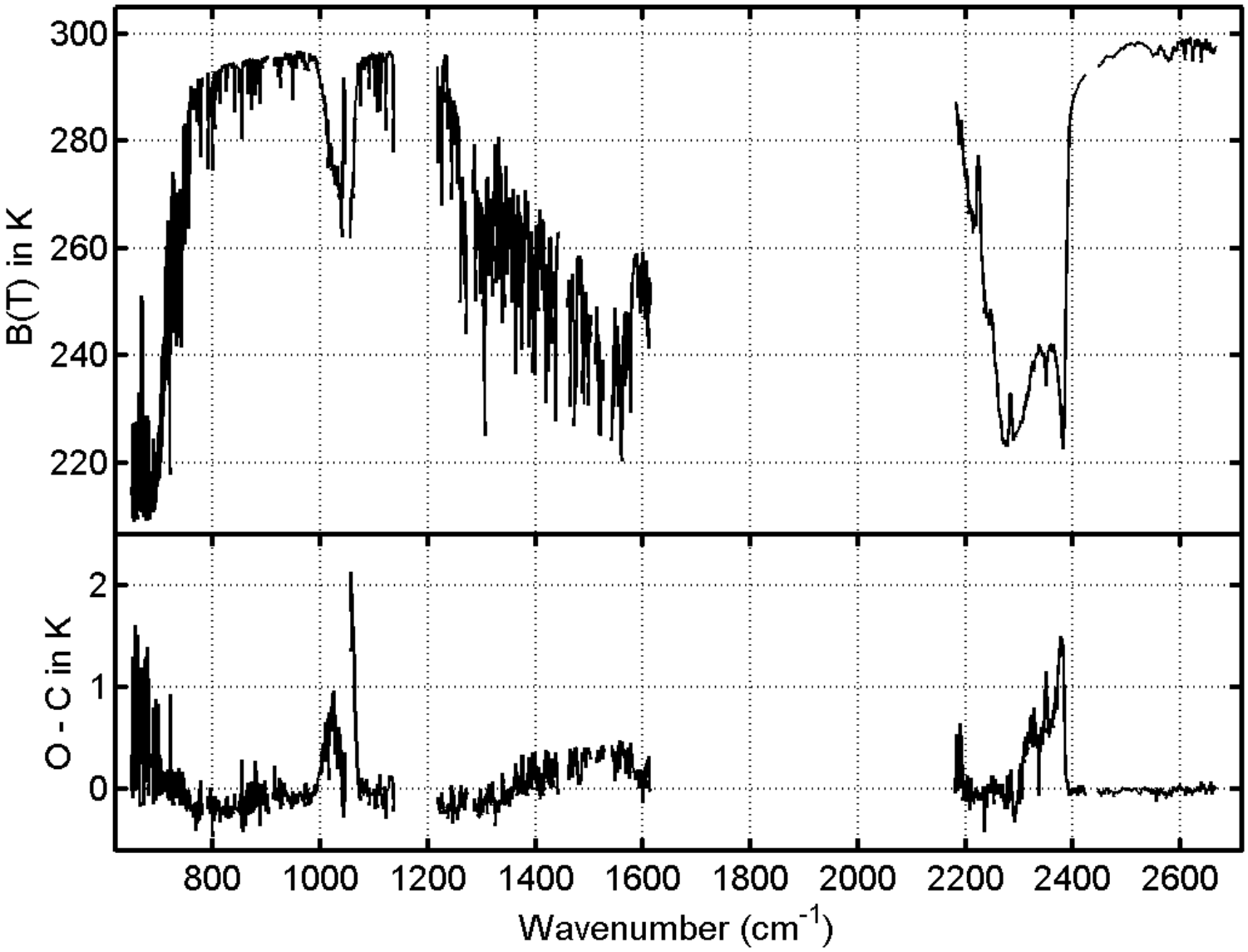
Name	Technique	# of Coincident Sondes
ARM TWP Phase1	RS-90	154
ARM TWP Phase2	RS-90	178
ARM TWP Phase3	RS-90	163
ARM SGP Phase1	RS-90	125
ARM SGP Phase2	RS-90	171
ARM SGP Phase3	RS-90	160
Mcmillan/ABOVE	RS-90	195
Minnett	RS-90	146a
Vömel	FP	29
Whiteman/LIDAR	SRL	23

a. Includes RS-80 sondes not used here.

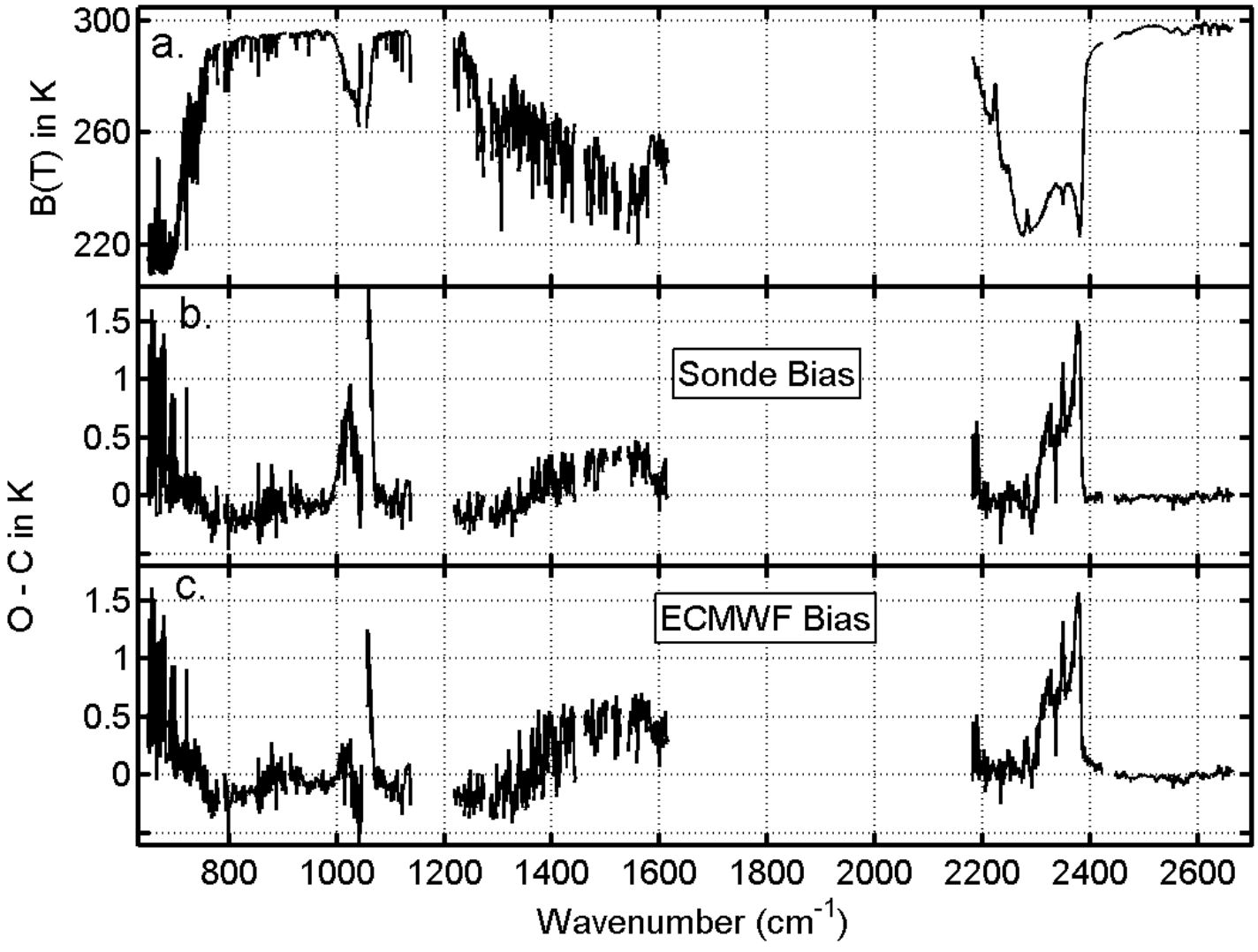
Table: Summary of number of clear observations over ocean at night.

Name	% Clear	# Sonde/Lidar Profiles
ARM TWP	15	38
Mcmillan/ABOVE	7	7
Minnett	25	23

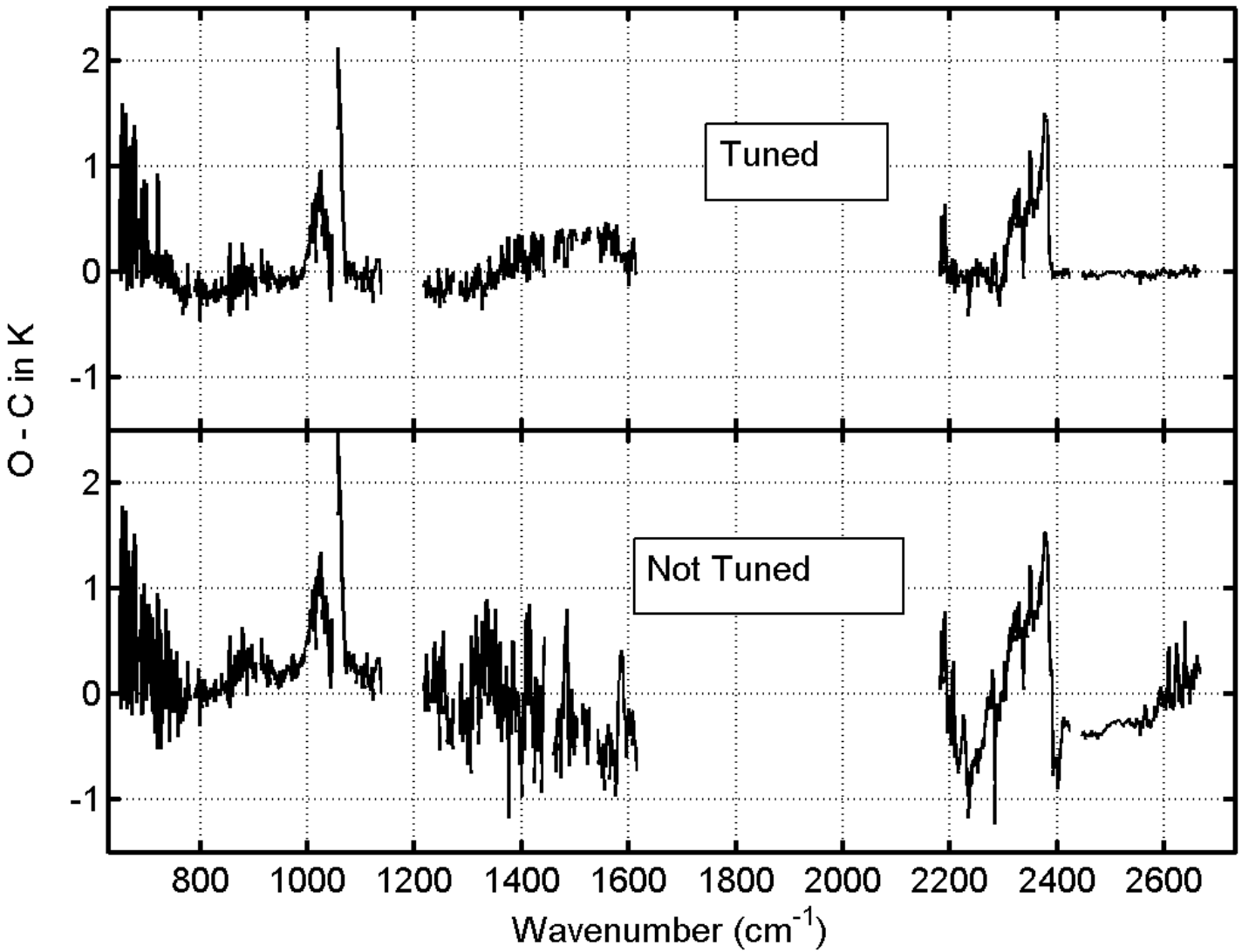
RS-90 Validation Campaign Bias Results



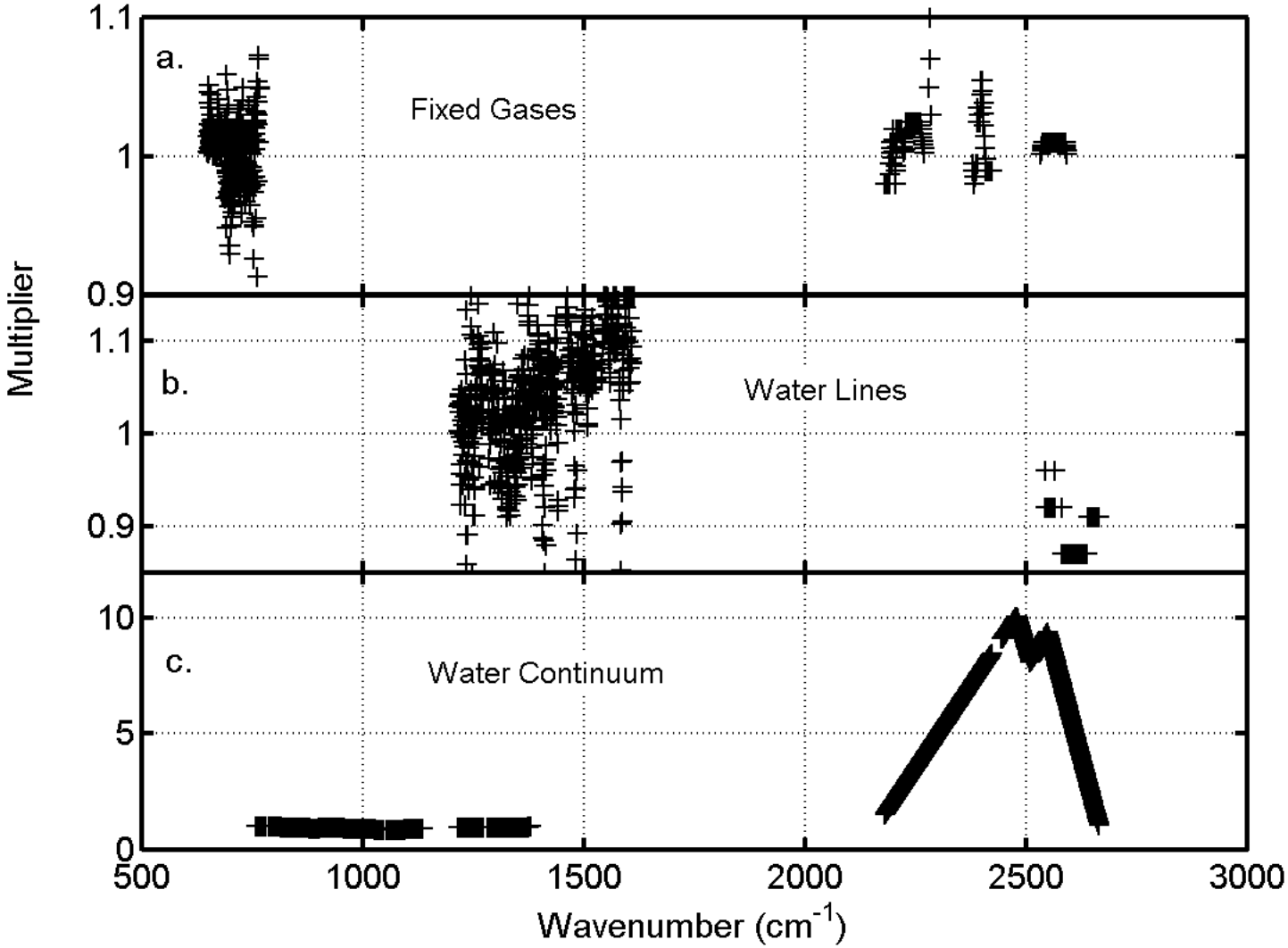
RS-90 vs ECMWF Biases: 24 Month Avg



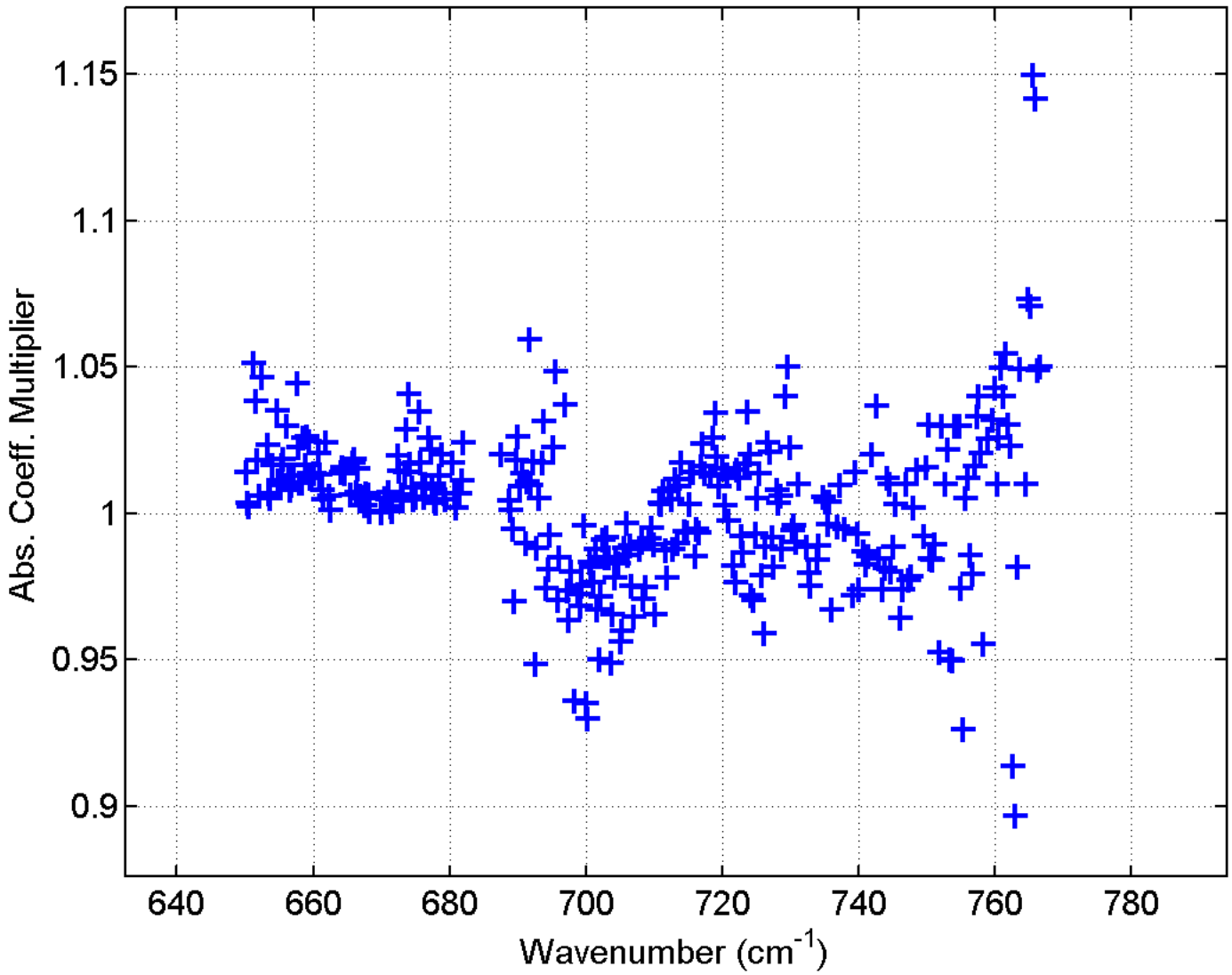
BUT (the bad news): We had to empirically adjust transmittances (using ARM-TWP 1)



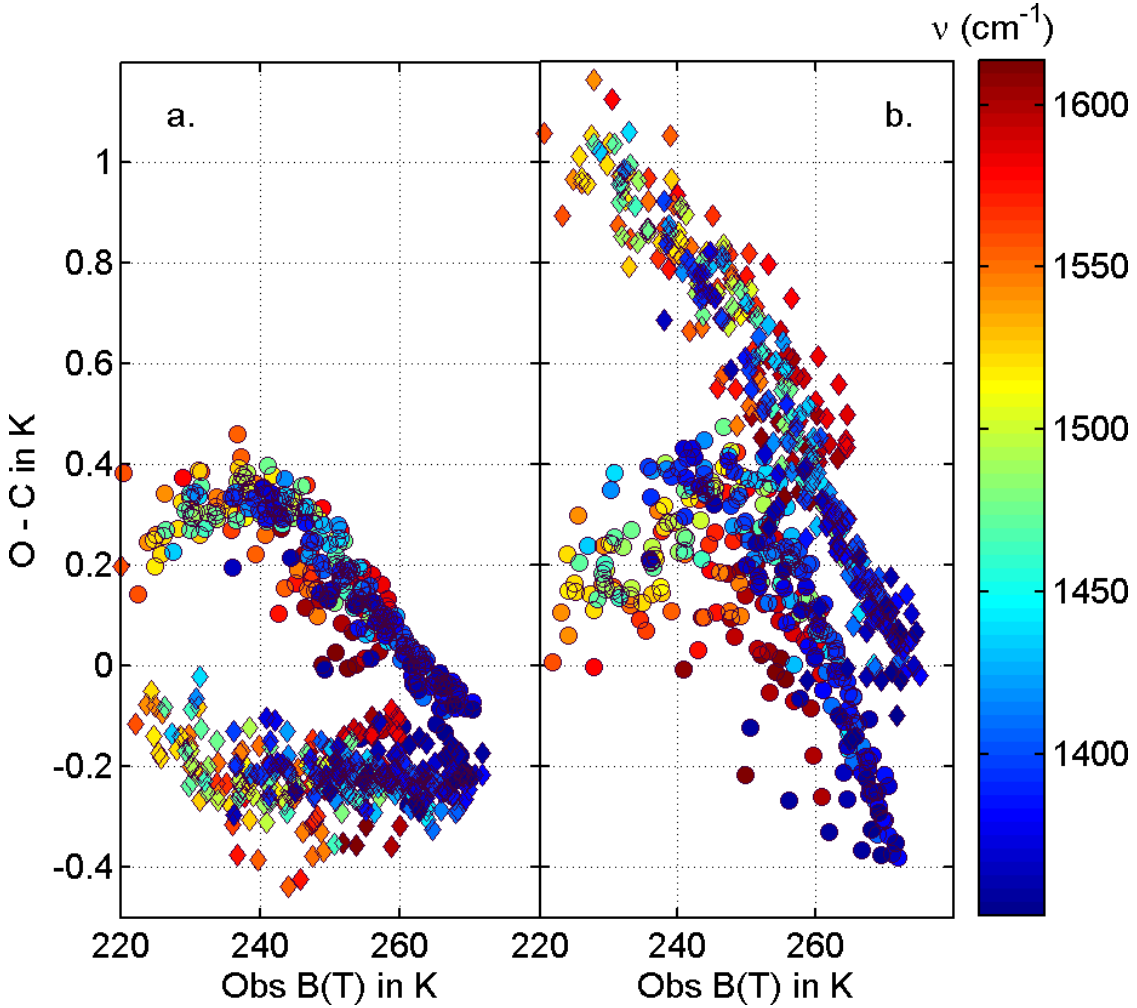
Adjustments in units of optical depths



Adjustments in units of optical depths: Zoom of Fixed Gases (CO_2)



Day/Night RS-90 and Frost-Point Differences



Mean night vs day biases for a. all RS-90 sondes, b. Vömel's (NOAA/CMDL) frost-point hygrometers

Minor Gases Impact RTA Validation

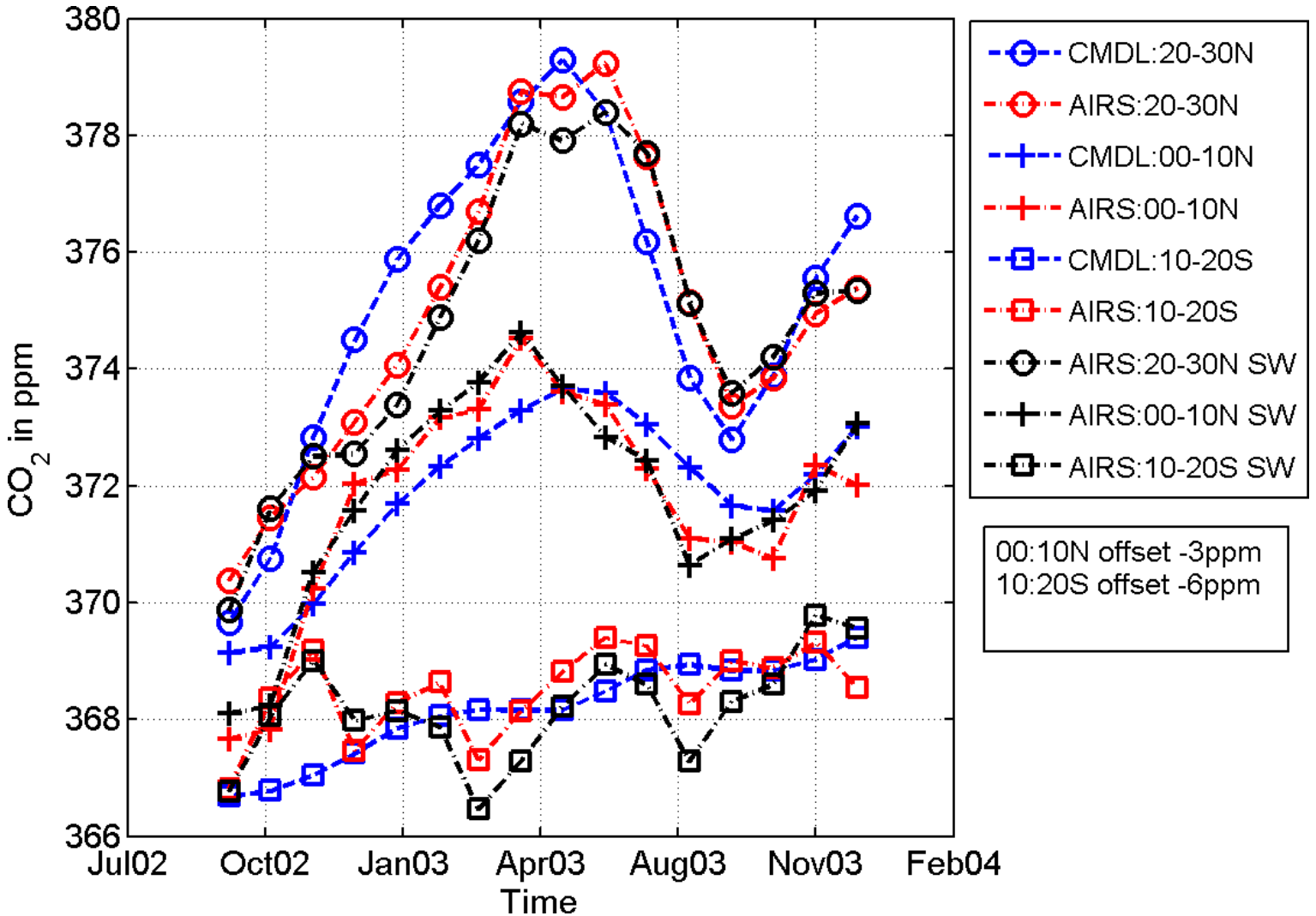
Minor gases need to be well understood to:

1. Validate the RTA
2. Use hyperspectral sensors for climate

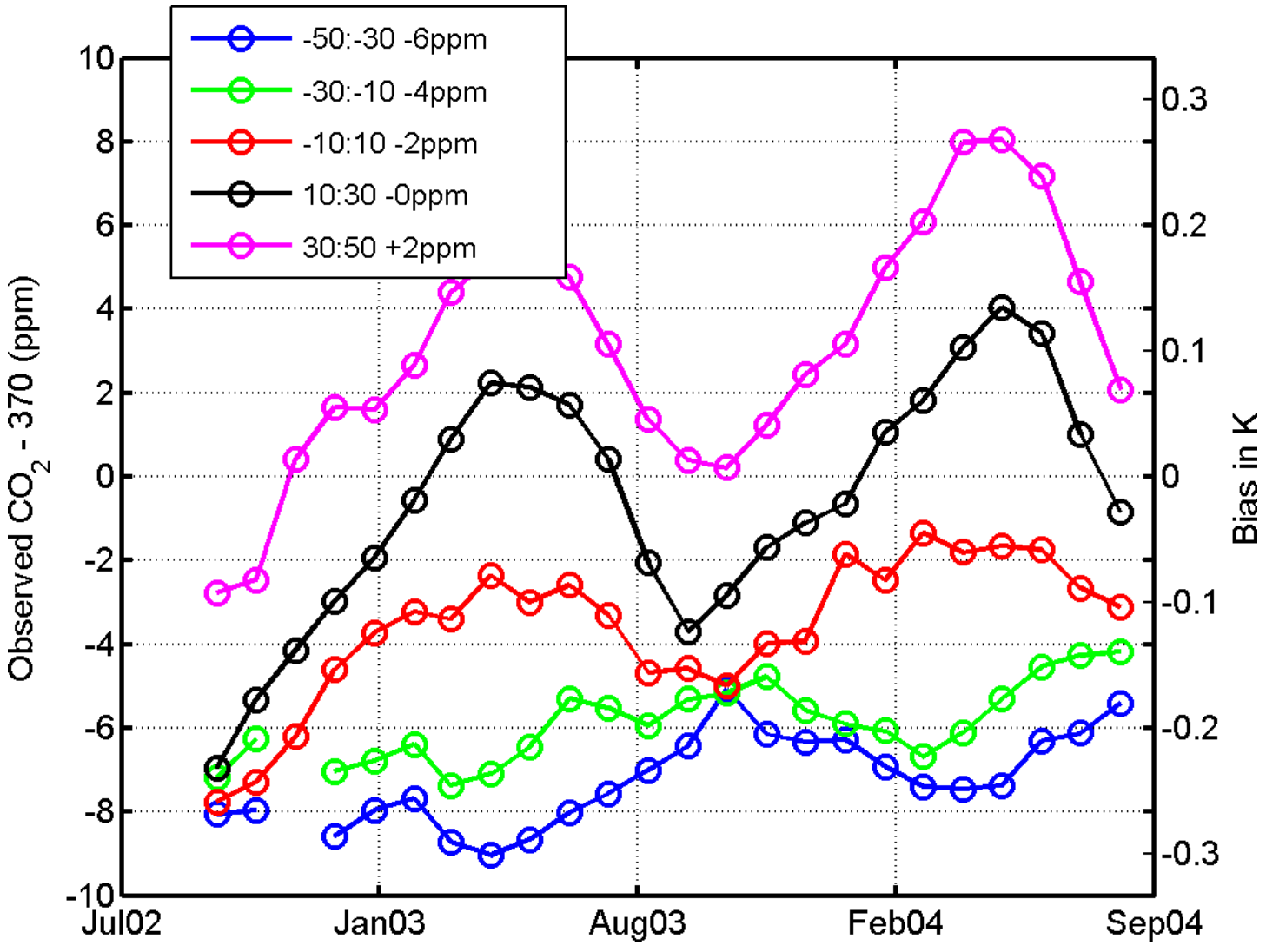
Plus, we might find something interesting.

Stratospheric "interference" a big problem? (Especially important for polar work with hyperspectral.)

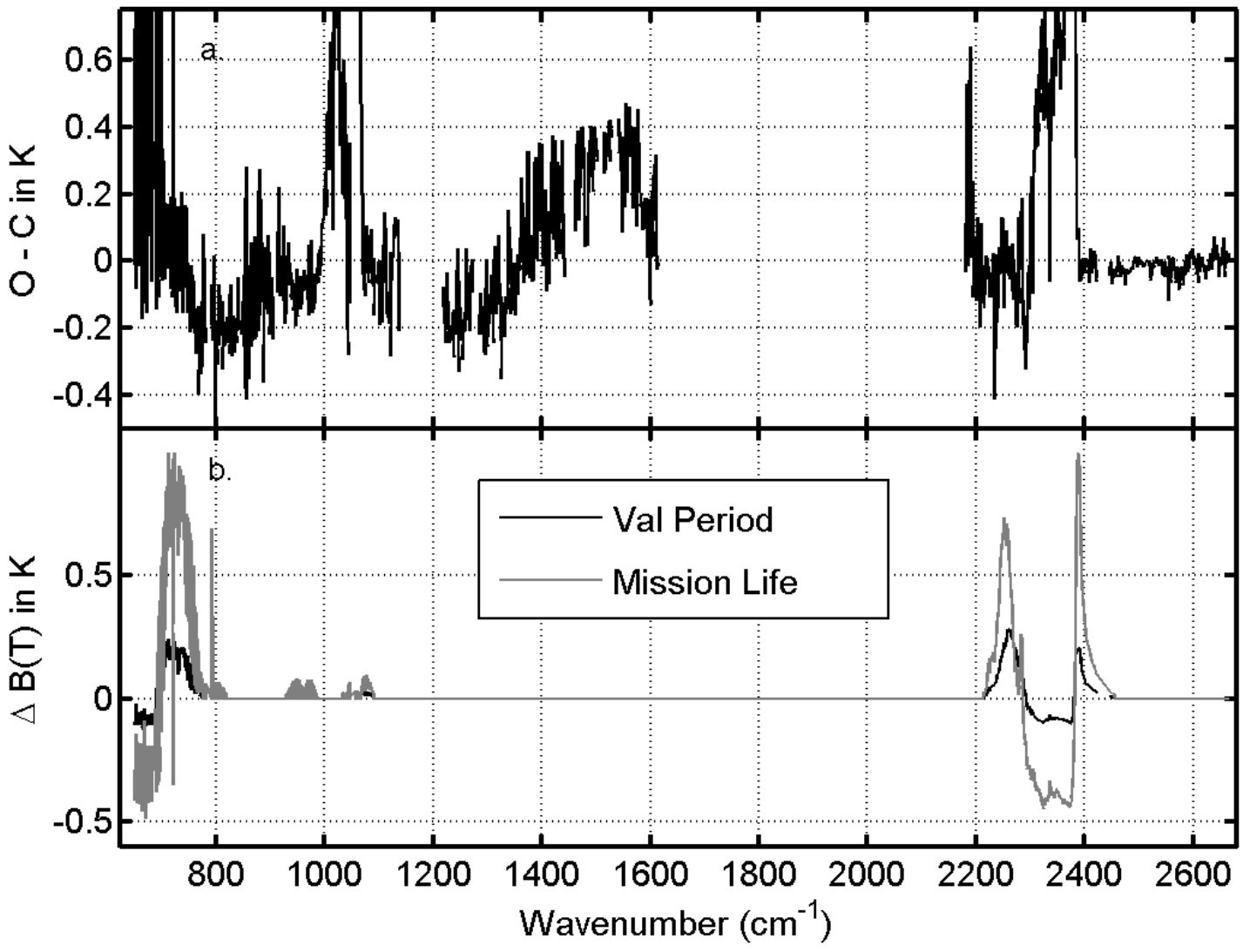
Variable CO_2: ECMWF for T(z)



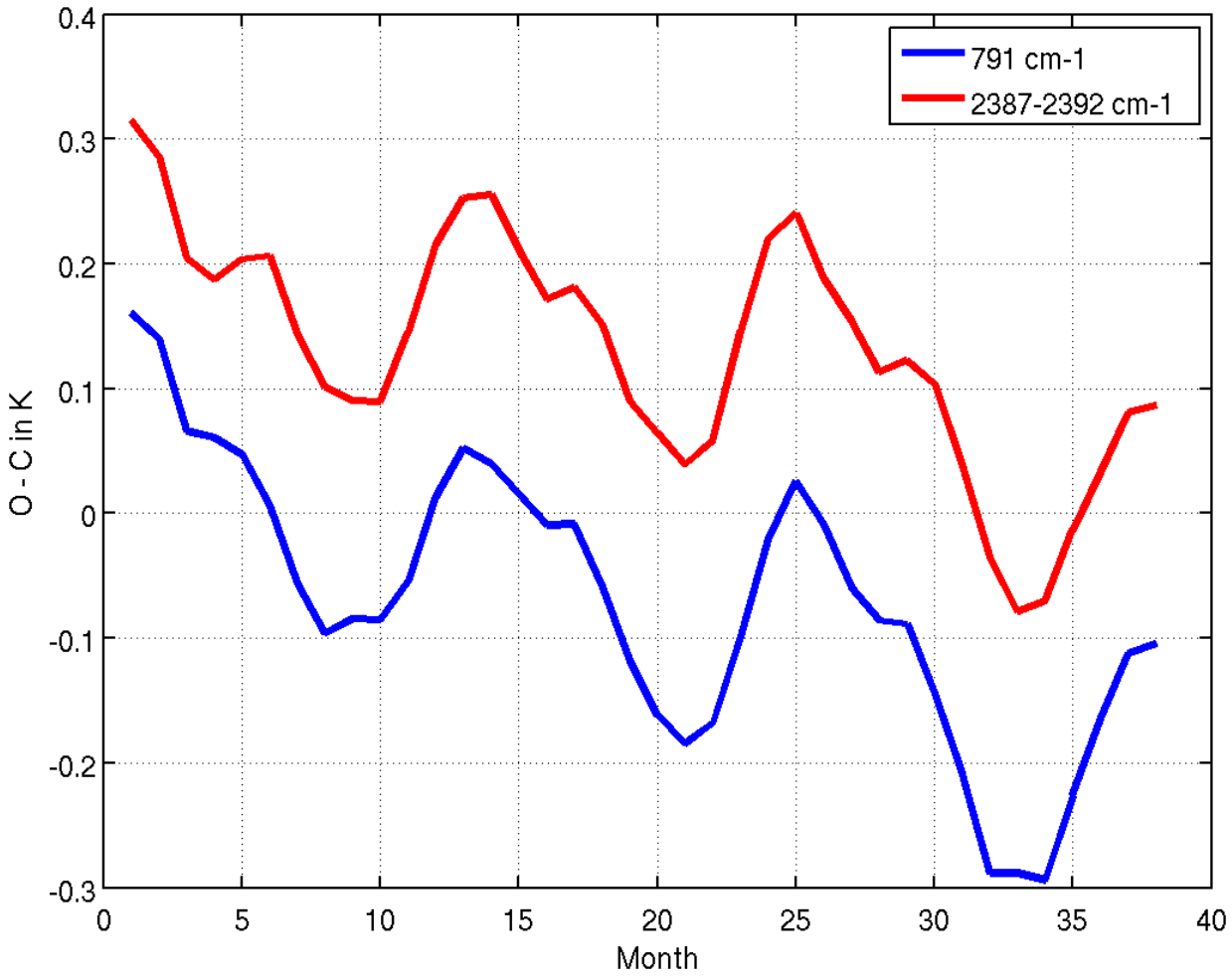
And it's global variation



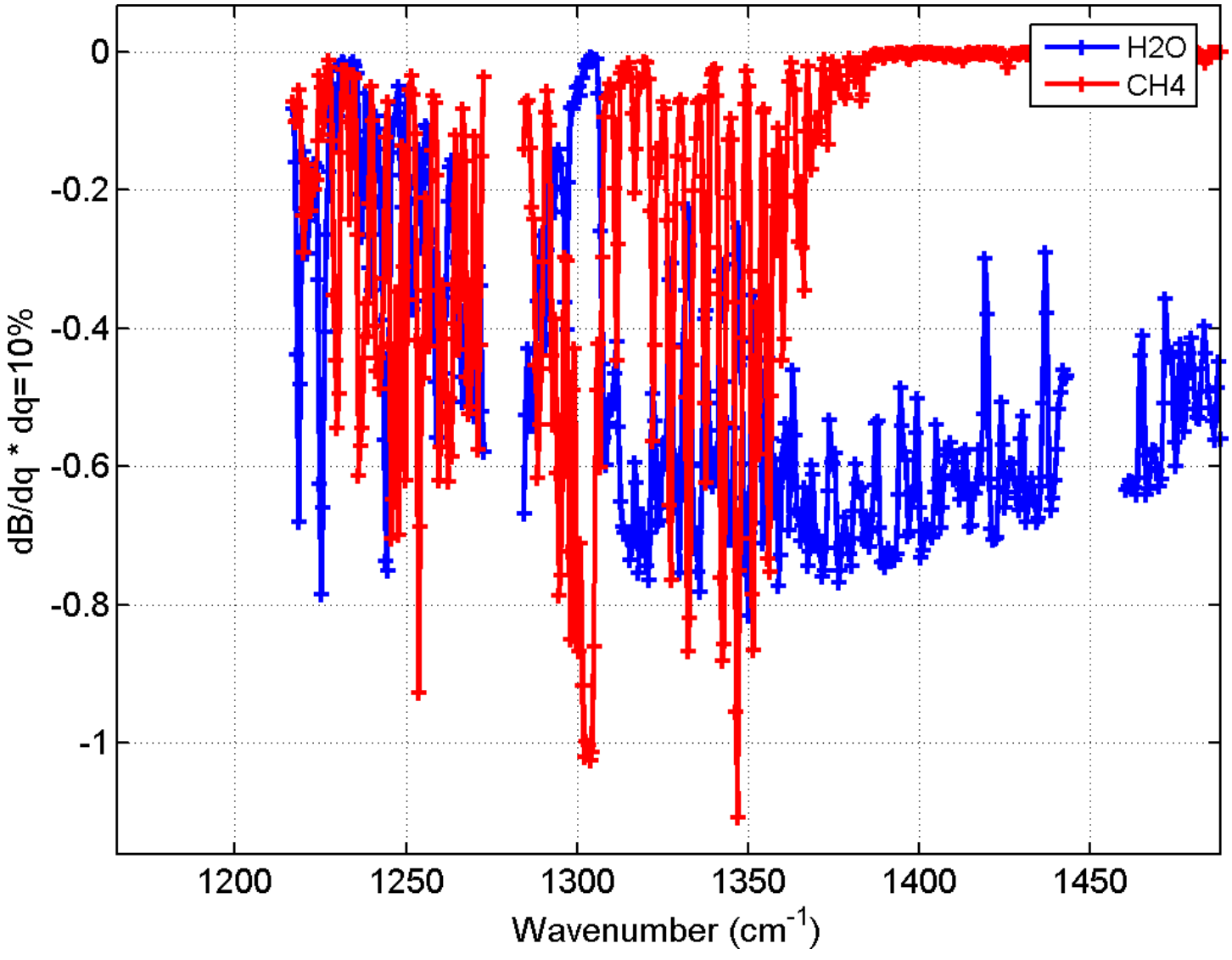
CO_2 Variability Important for Weather and Climate



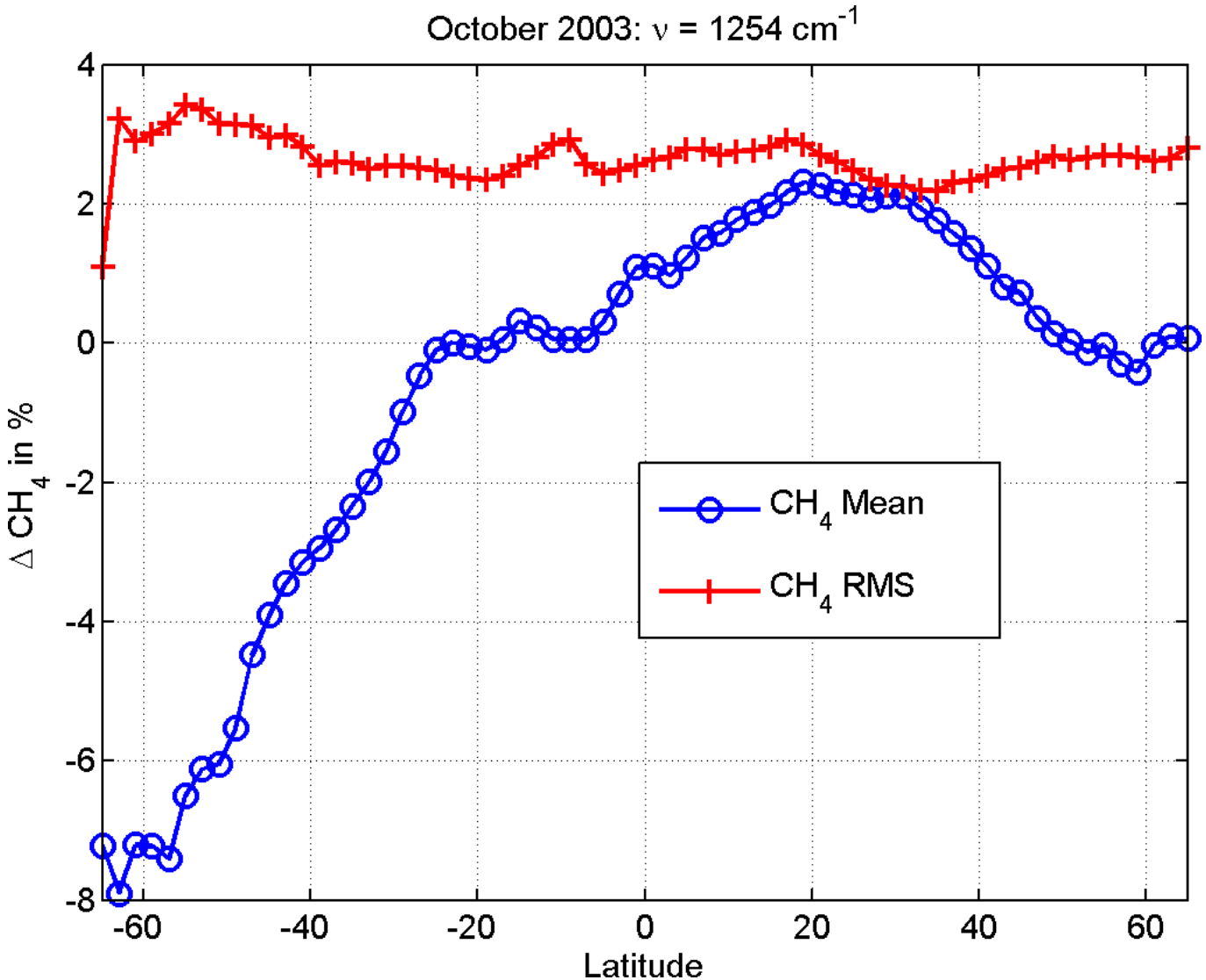
Latest CO_2 from AIRS, 38 Months: ~25-45 Deg



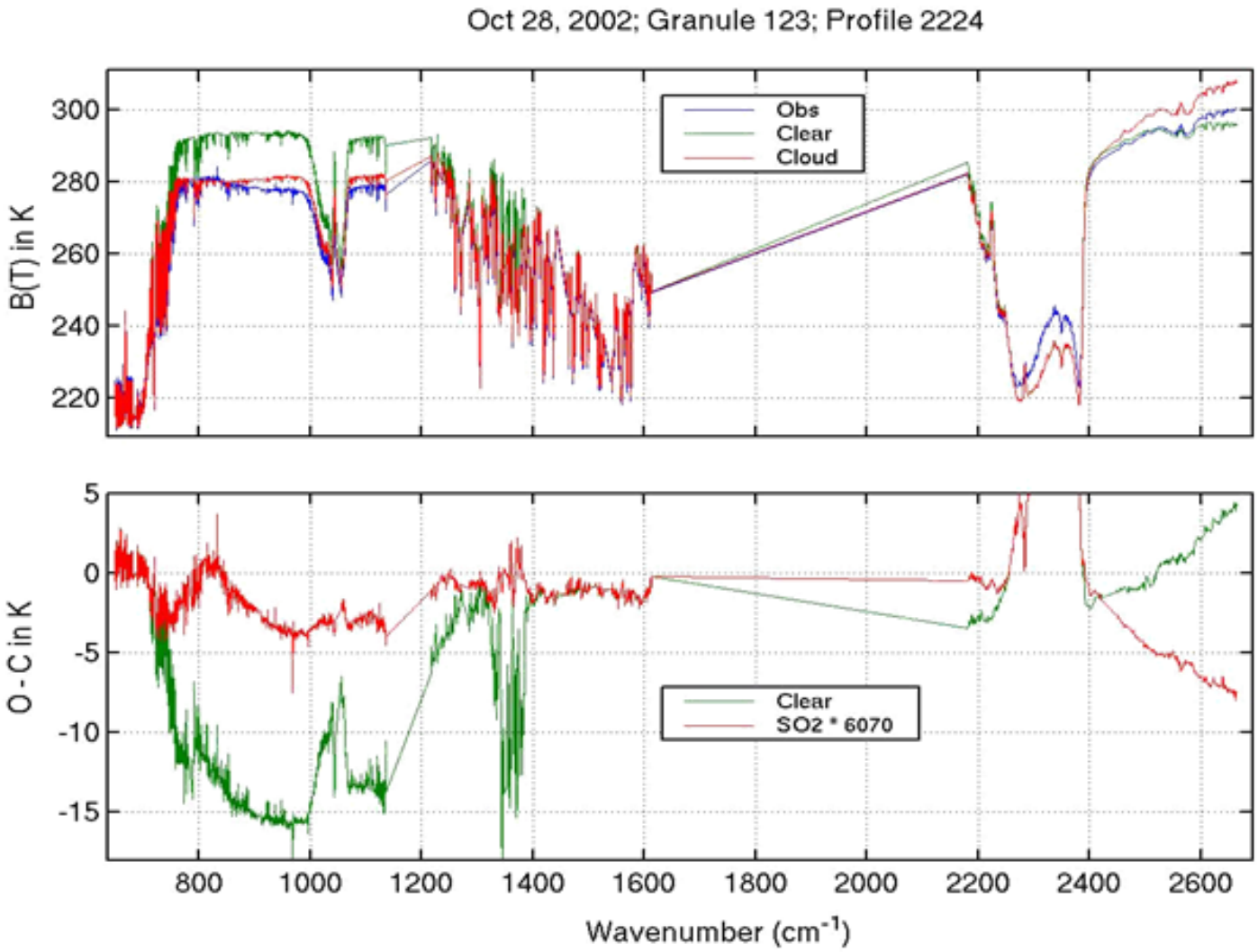
CH_4 Interferes with H_2O



CH_4

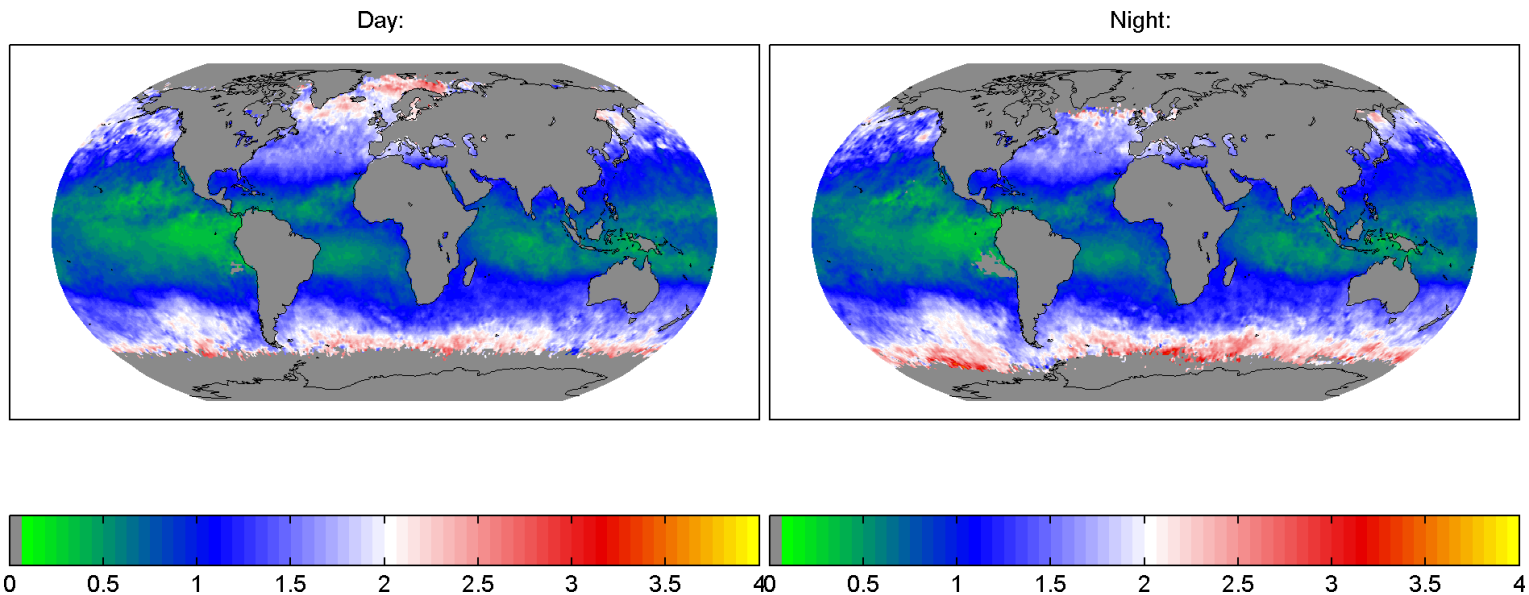


Volcanic SO_2 and Ash are seen

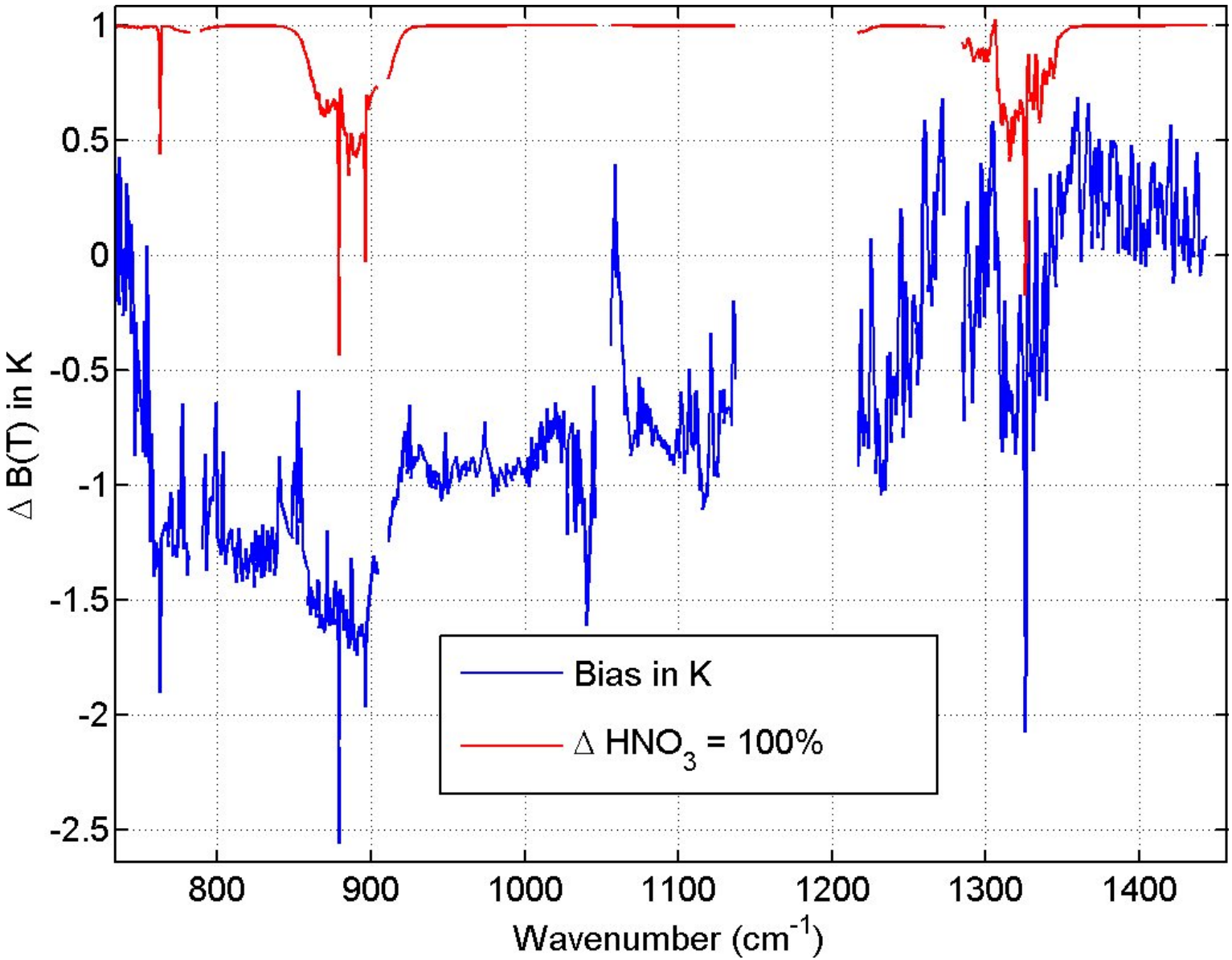


May 2004 Monthly Means of HNO_3

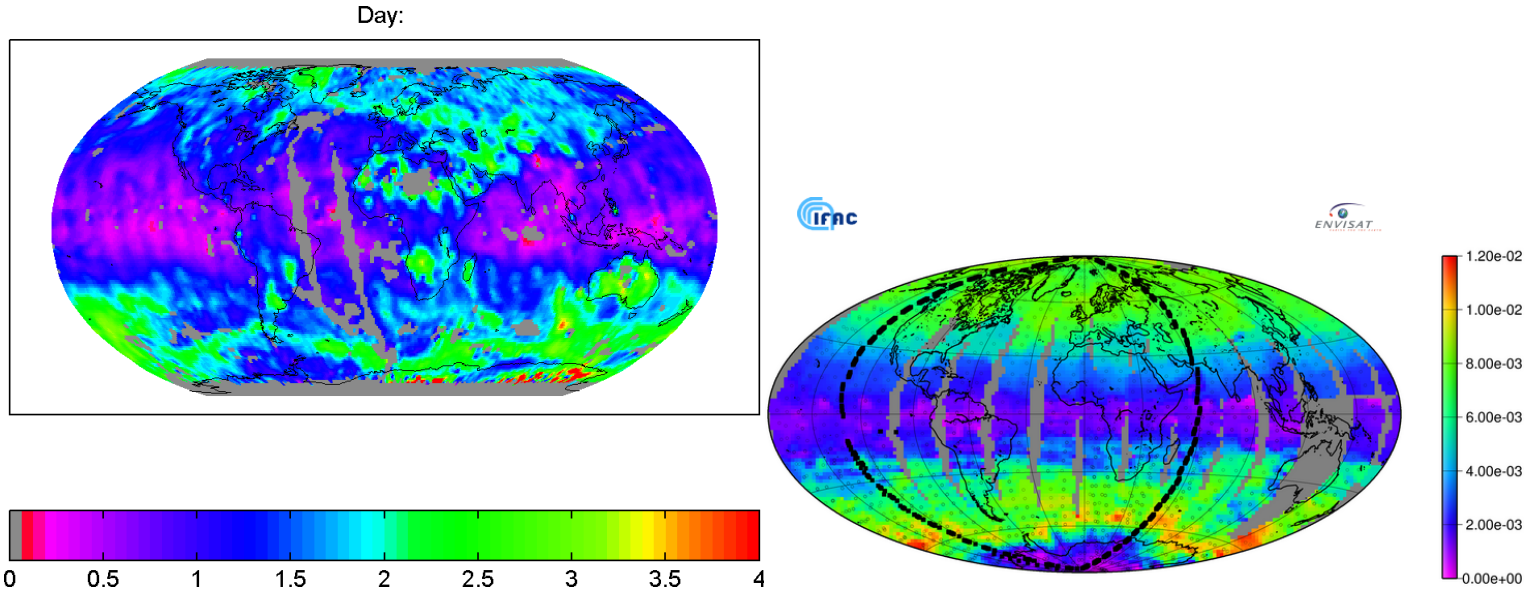
- RTA modified to include variable HNO_3
- Used L2 retrievals, just varied scalar multiplier of HNO_3 column
- HNO_3 unit is (observed column)/(reference column). Reference column is $\approx 10^{14}$ mol/cm^2
- Ocean only

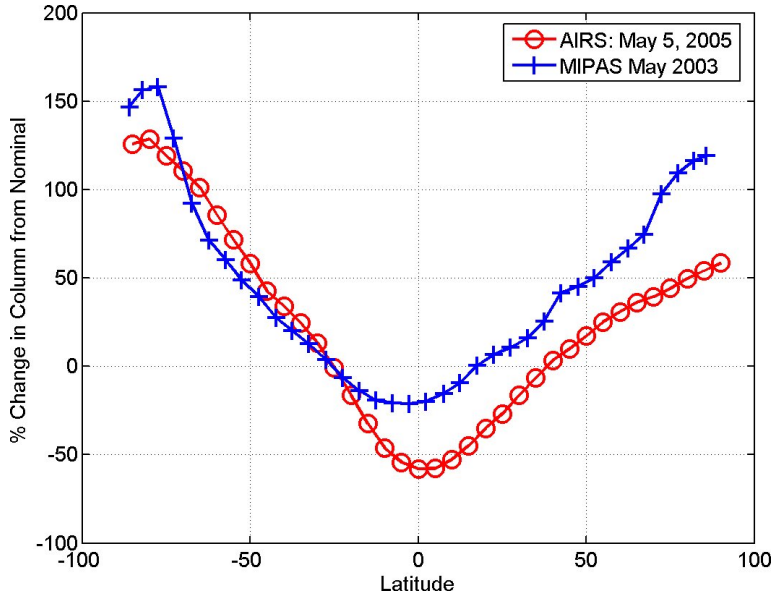


HNO_3 Signal in Polar Granule Residuals

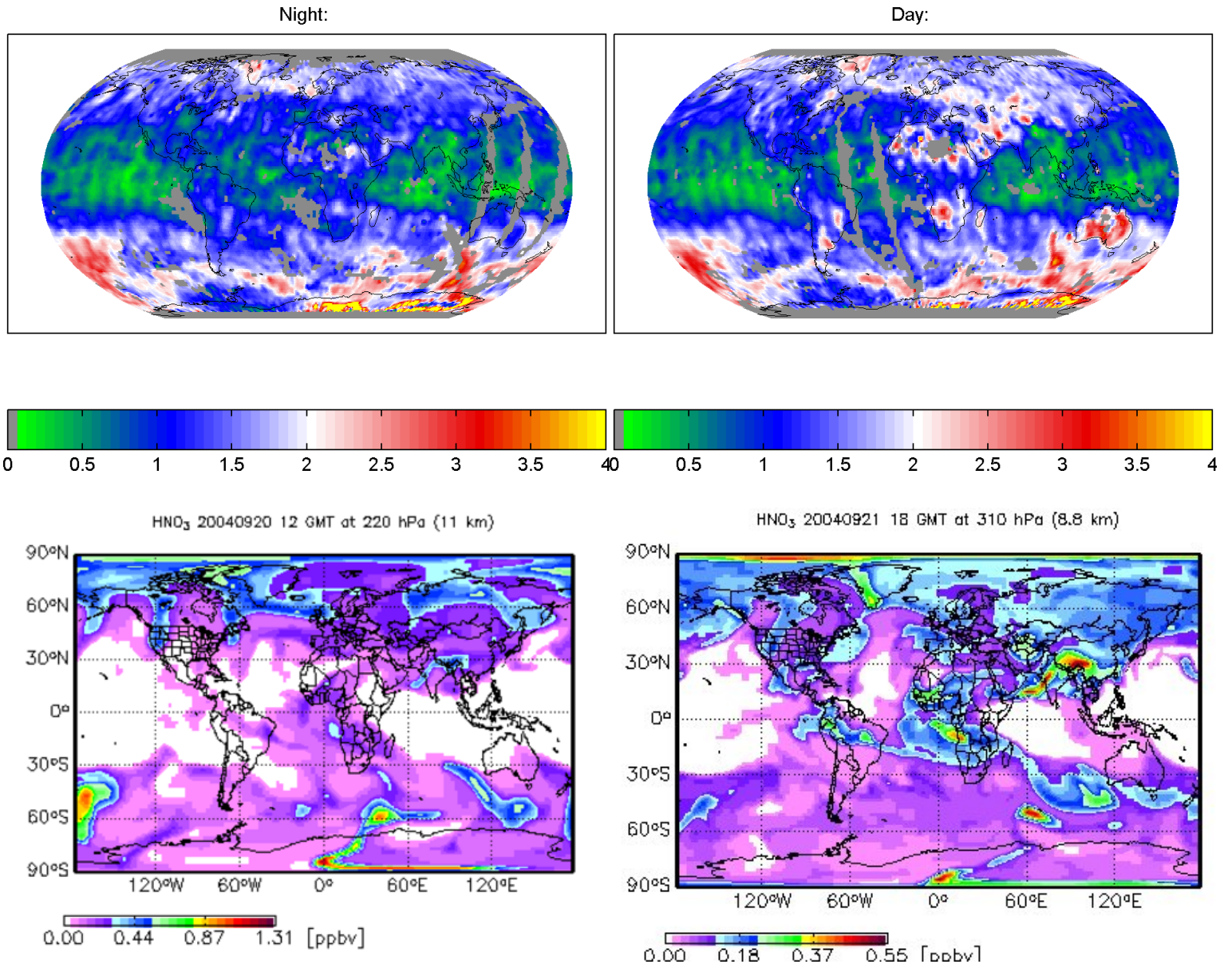


Very Rough Validation versus MIPAS

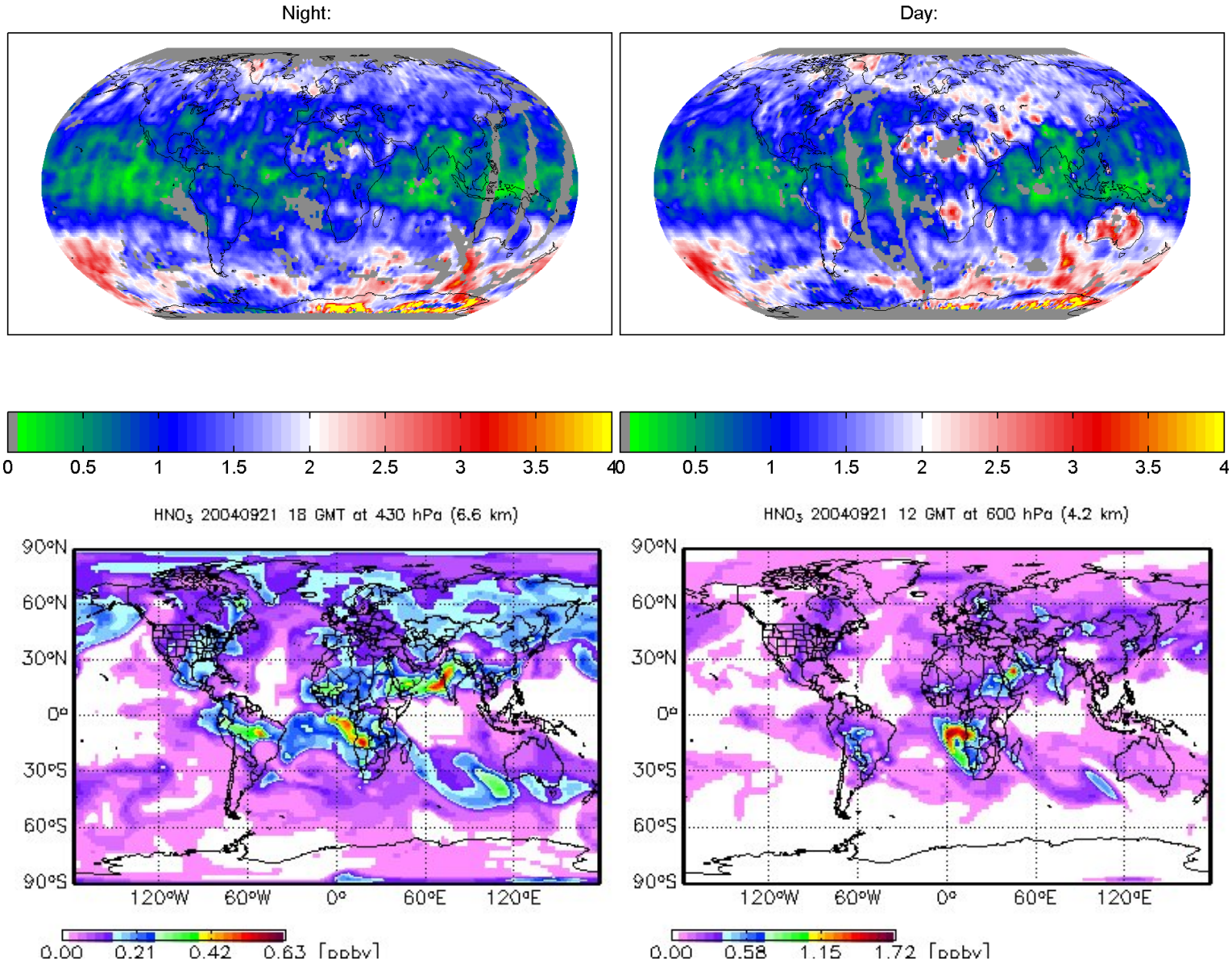




GEOS-CHEM: Sept. 20-21, 2004, 220 and 310 mbar

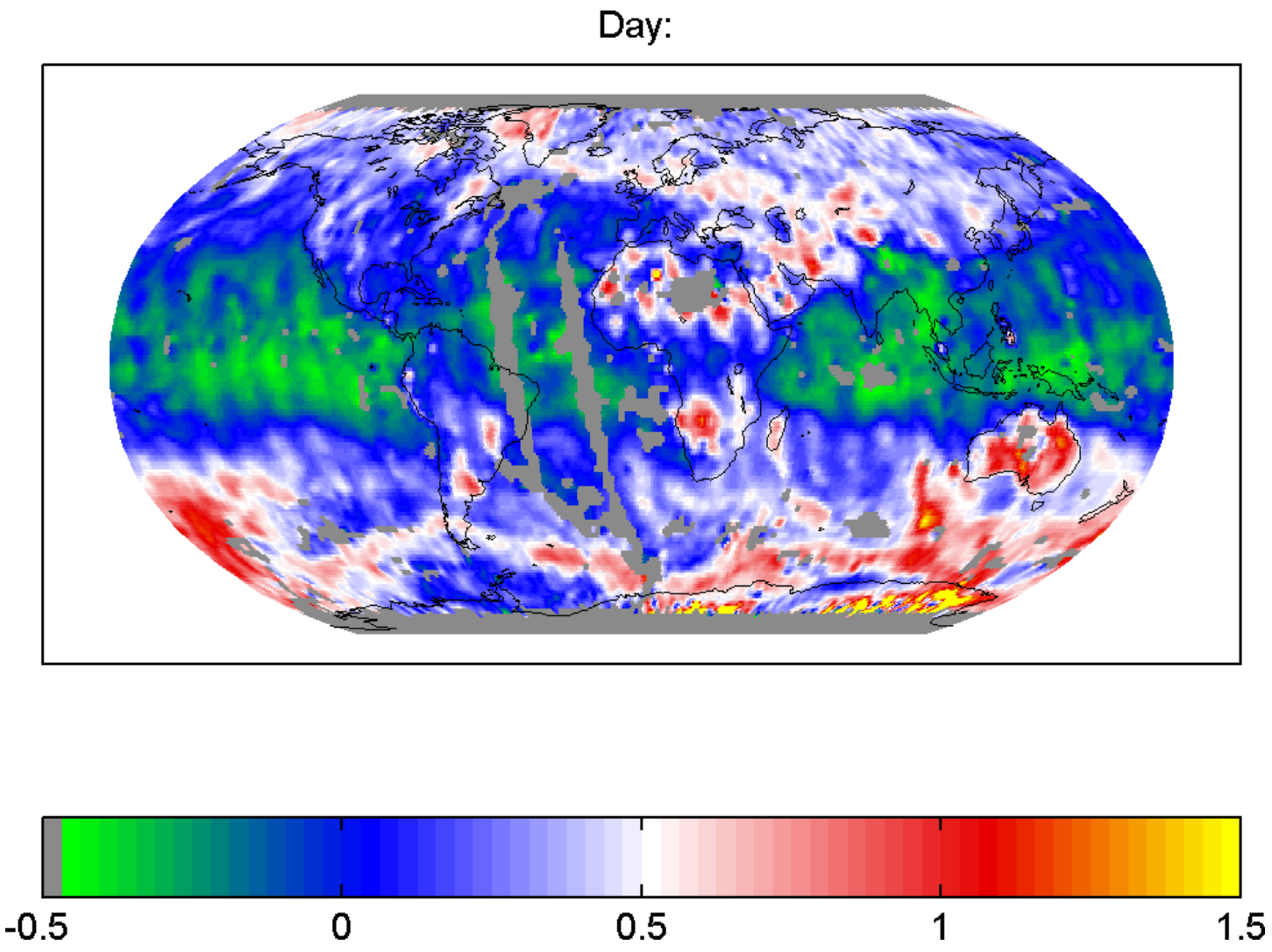


GEOS-CHEM: Sept. 20-21, 2004, 430 and 600 mbar



B(T) Influence for 1X Change in HNO_3, Channel 1440

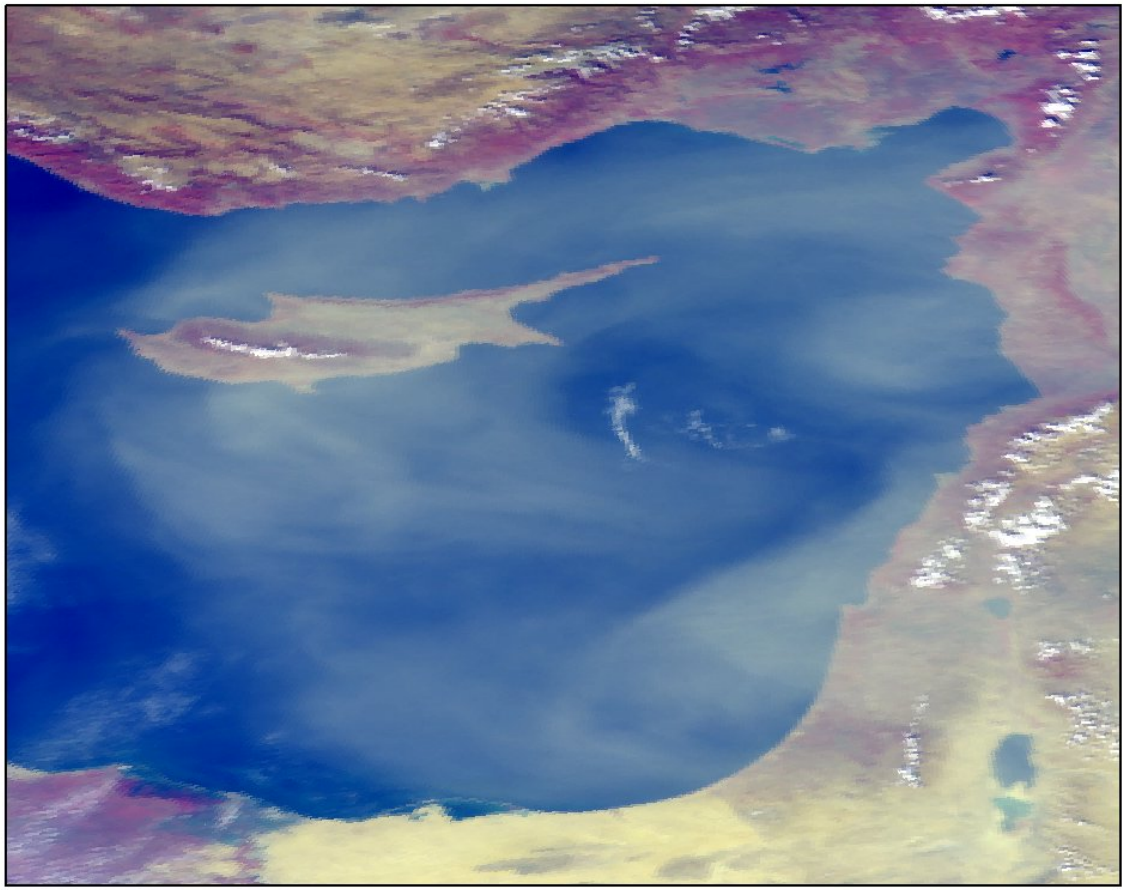
- About 5 channels this sensitive
- 189 AIRS channels have $dB(T)/d(HNO_3 = 1X) > 0.1K$



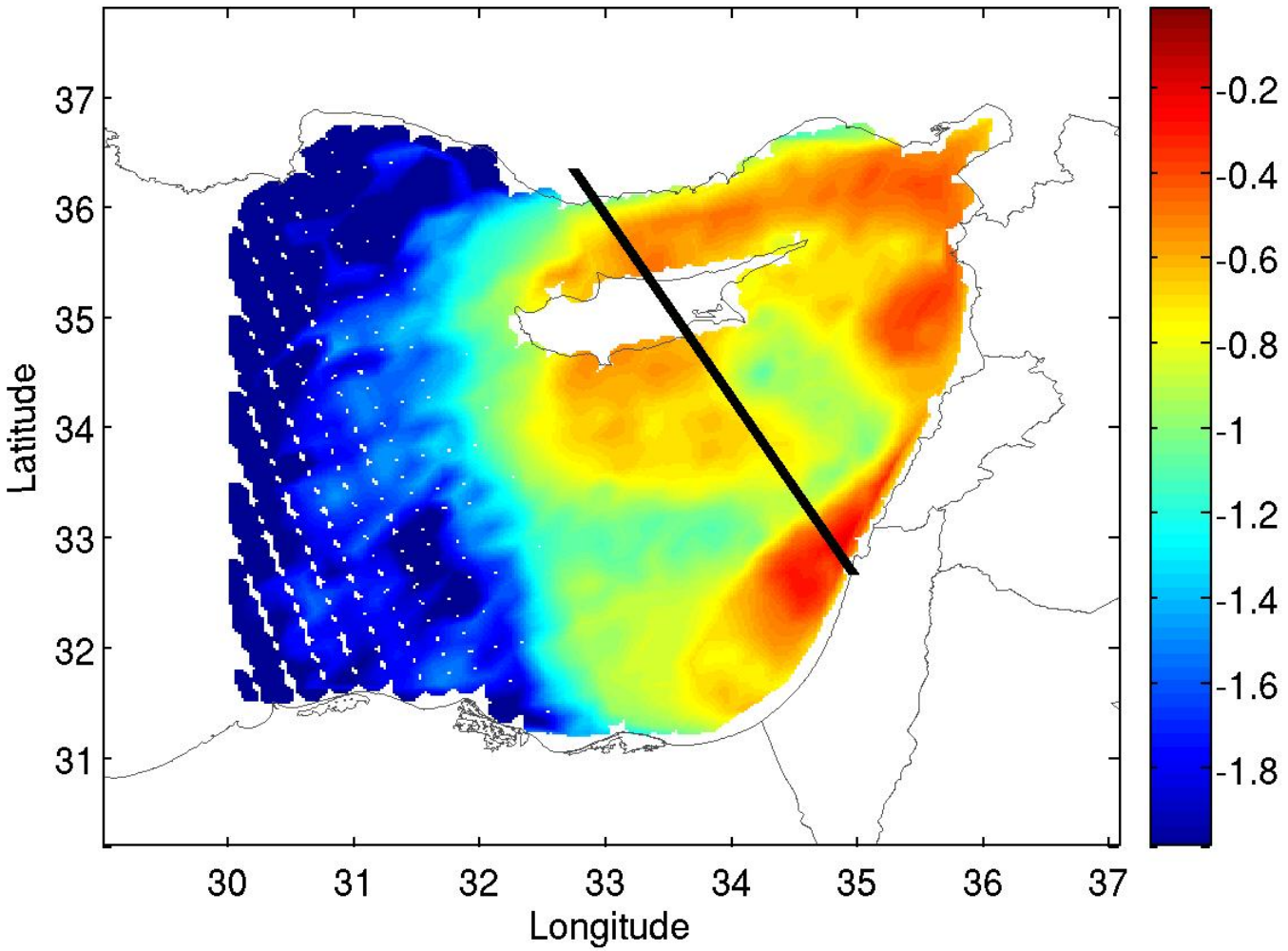
AIRS Dust Observations: Scattering SARTA

- We have observed many dust outbreaks, with quantitative analysis over oceans using SARTA-scattering
- Paper in GRL on Medit. case (comparisons to MODIS)
- Some differences in spectral structure (index of refraction)
- Observed volcanic ash clouds
- Hyperspectral IR sees dust througout tropical Atlantic in summer: *Important to include in assimilation/retrieval for hurricane applications?*
- Developing a dust flag for next AIRS processing cycle. Hopefully future reprocessing will include dust optical depth. More work needed on how to handle dust vertical structure and interfering clouds.
- SARTA/kCARTA now has scattering based on paper by Chou, Lee, Tsay, Fu; Parameterization for Cloud Longwave Scattering for use in Atmospheric Models in Journal of Climate, vol 12, pg 159 (January 1999)
- Two layer clouds possible, so can have water plus ice, or water plus dust. Very fast with analytic Jacobians.

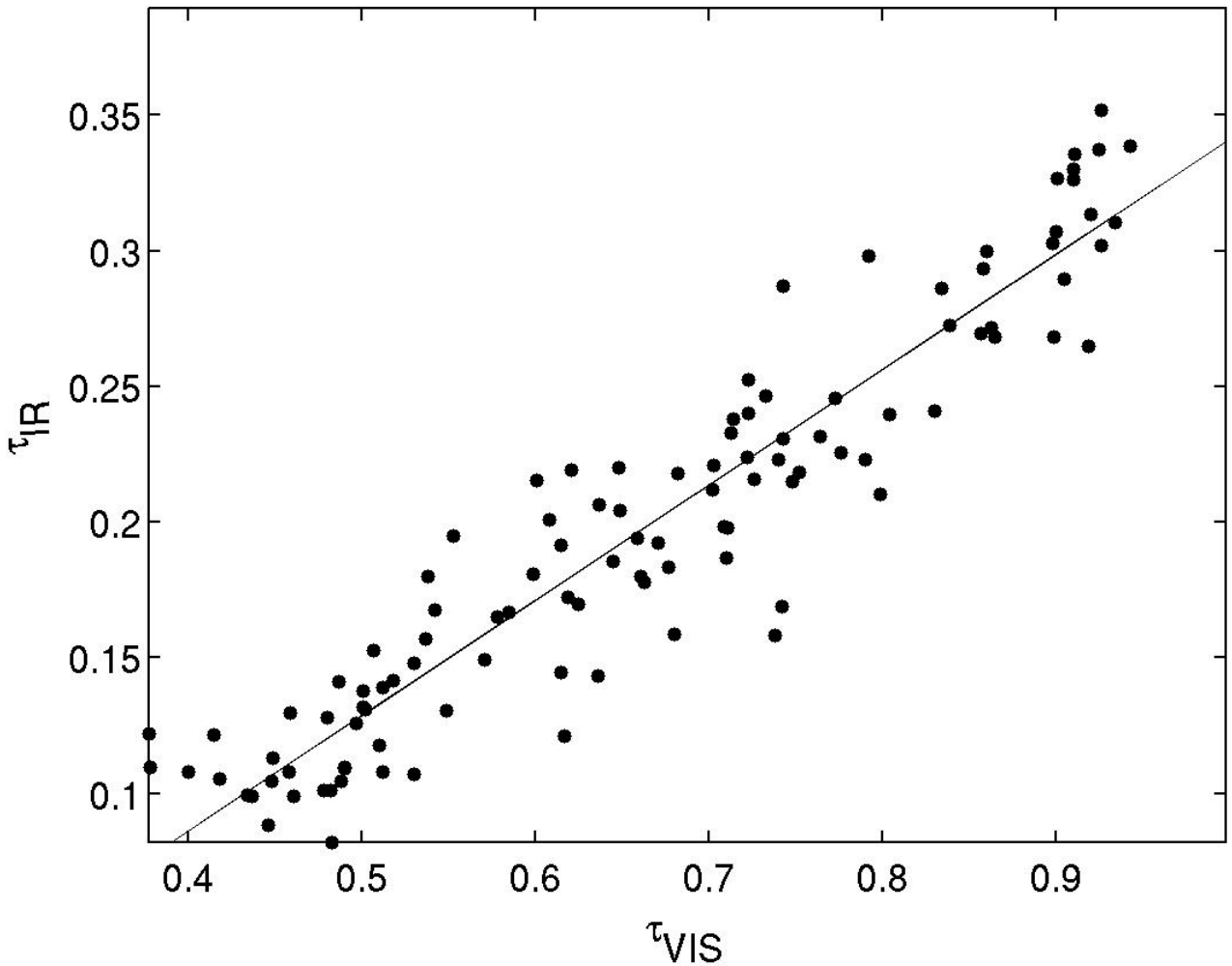
Mediterranean Dust Storm



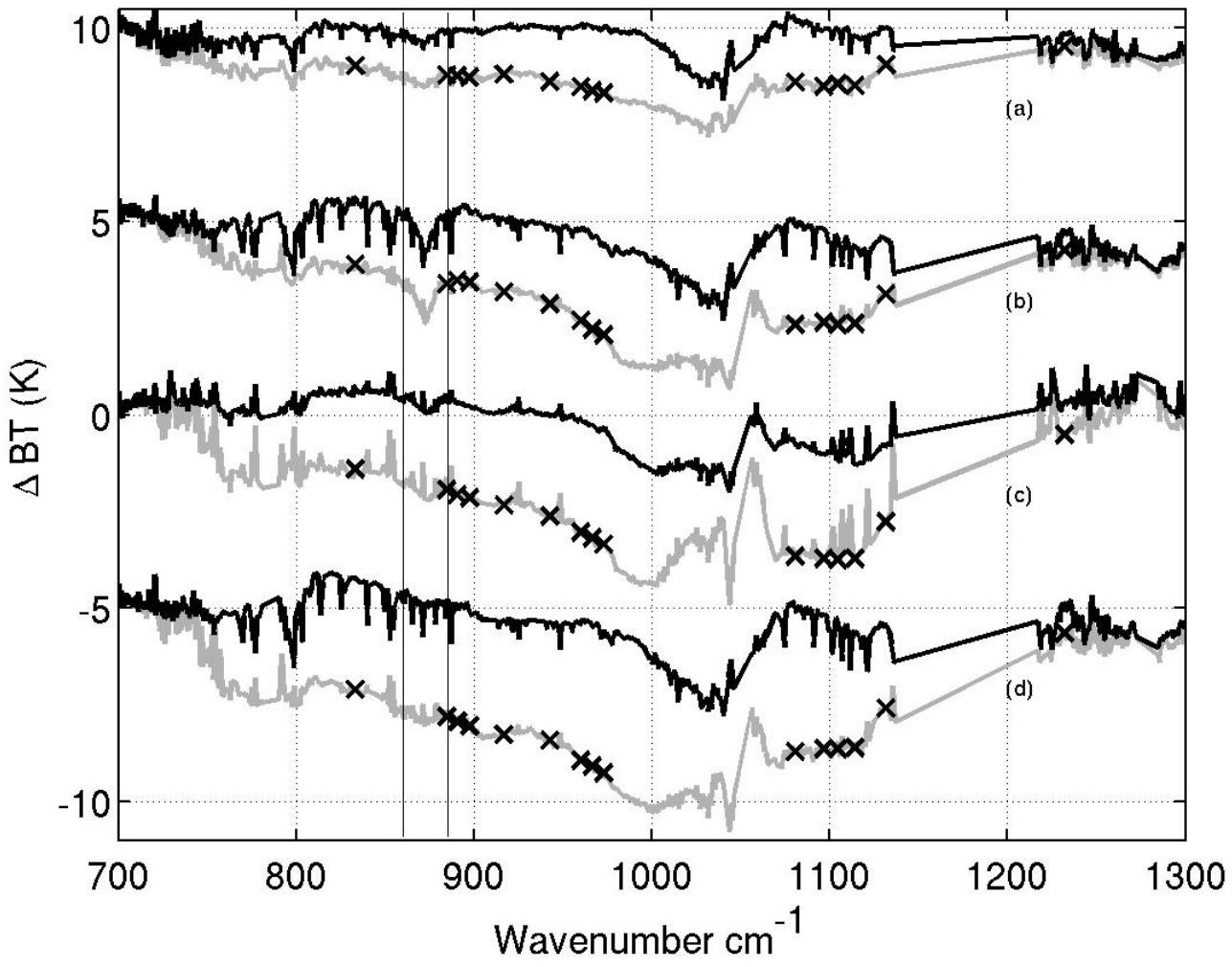
Derived Optical Depths at 900 cm^{-1}: Scattering SARTA



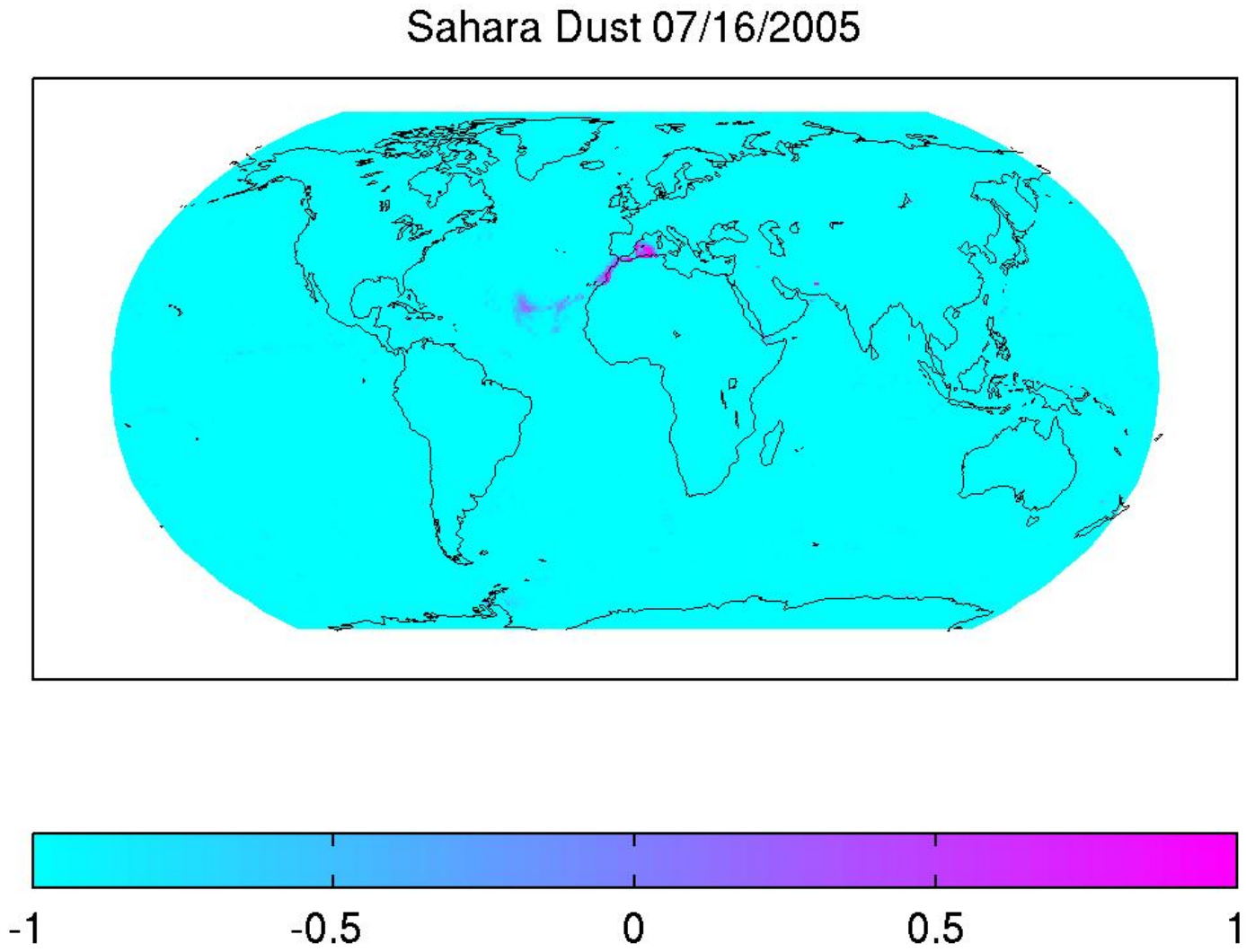
MODIS vs AIRS-derived Optical Depths



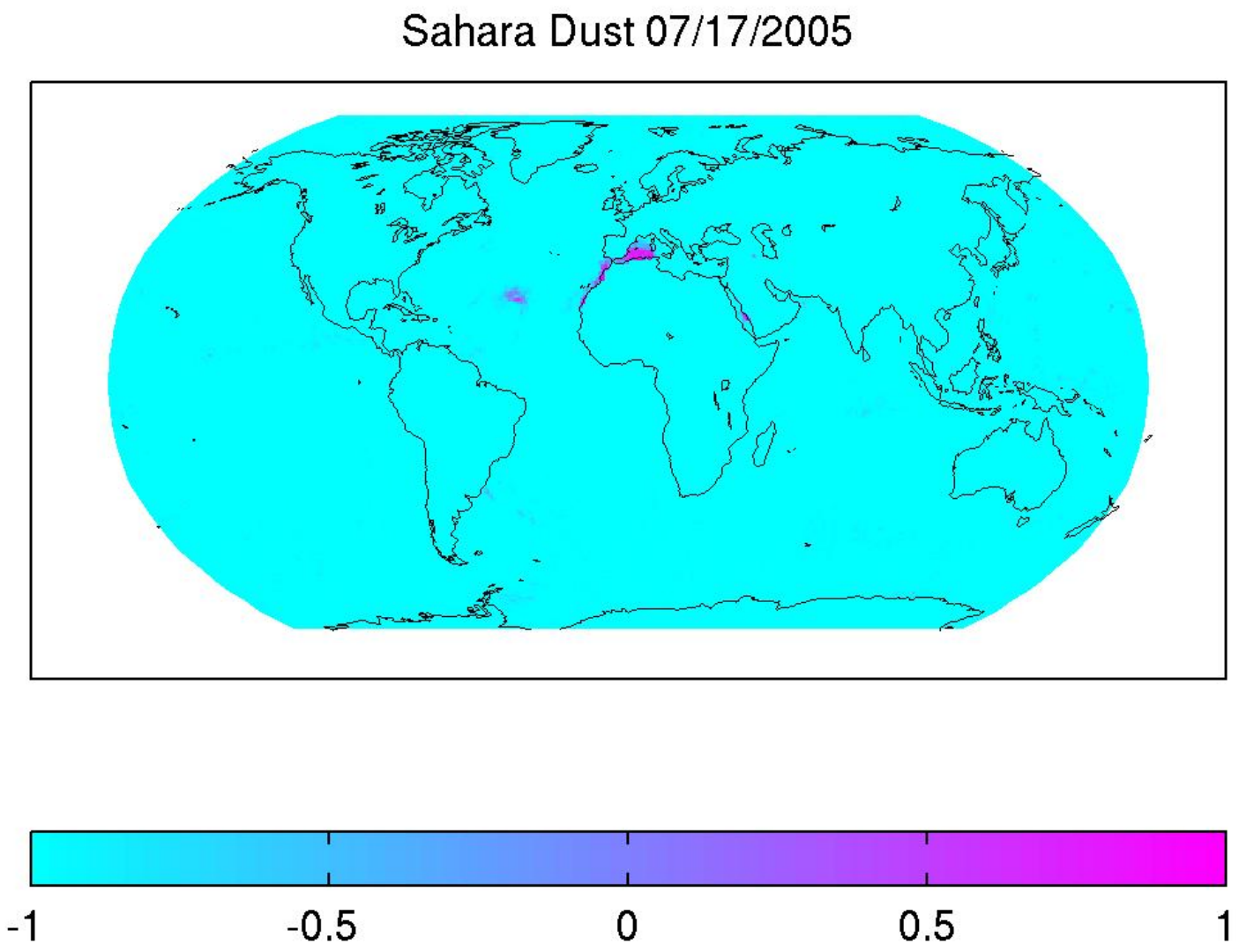
Spectral Effects of Dust



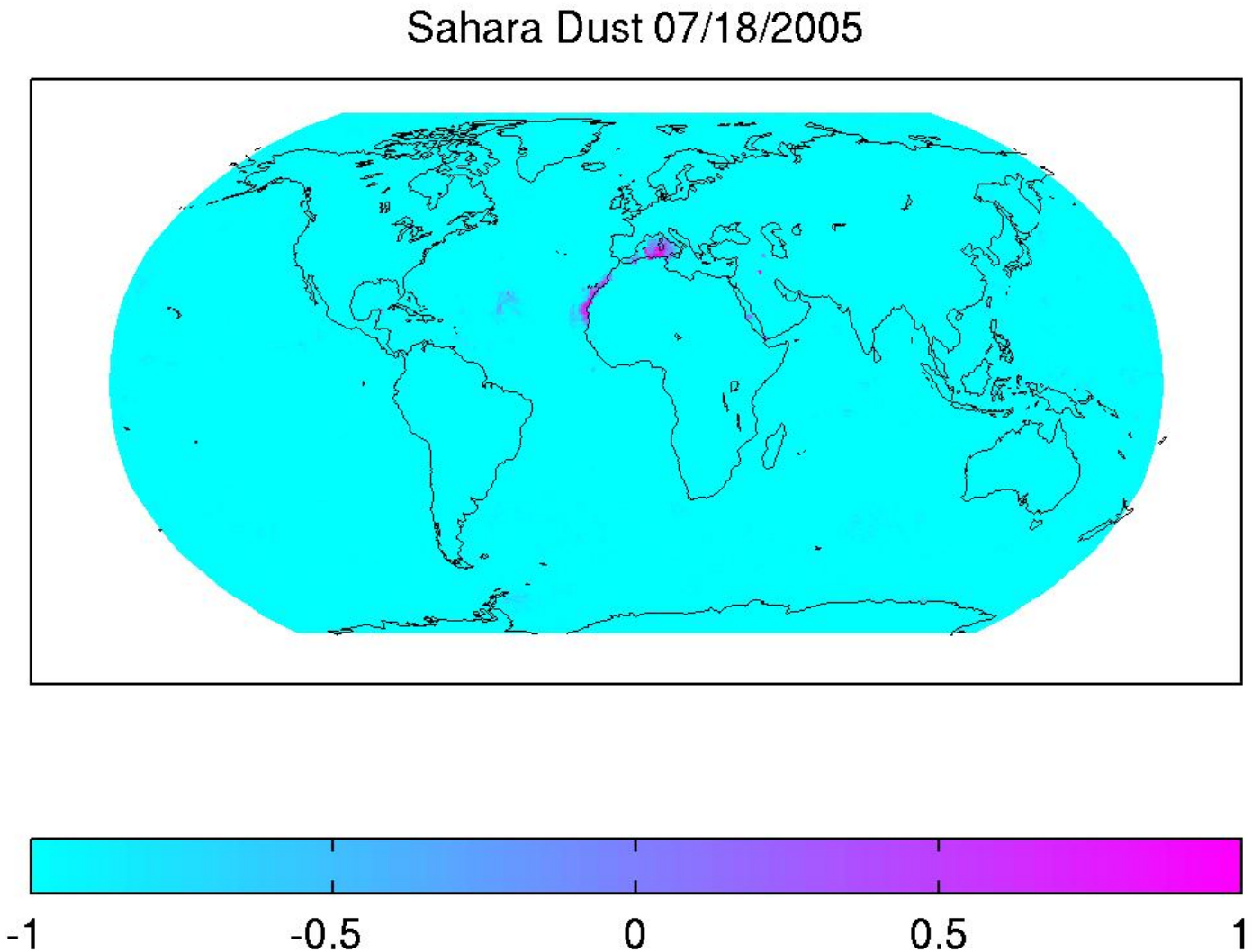
Day 1: Dust Flag



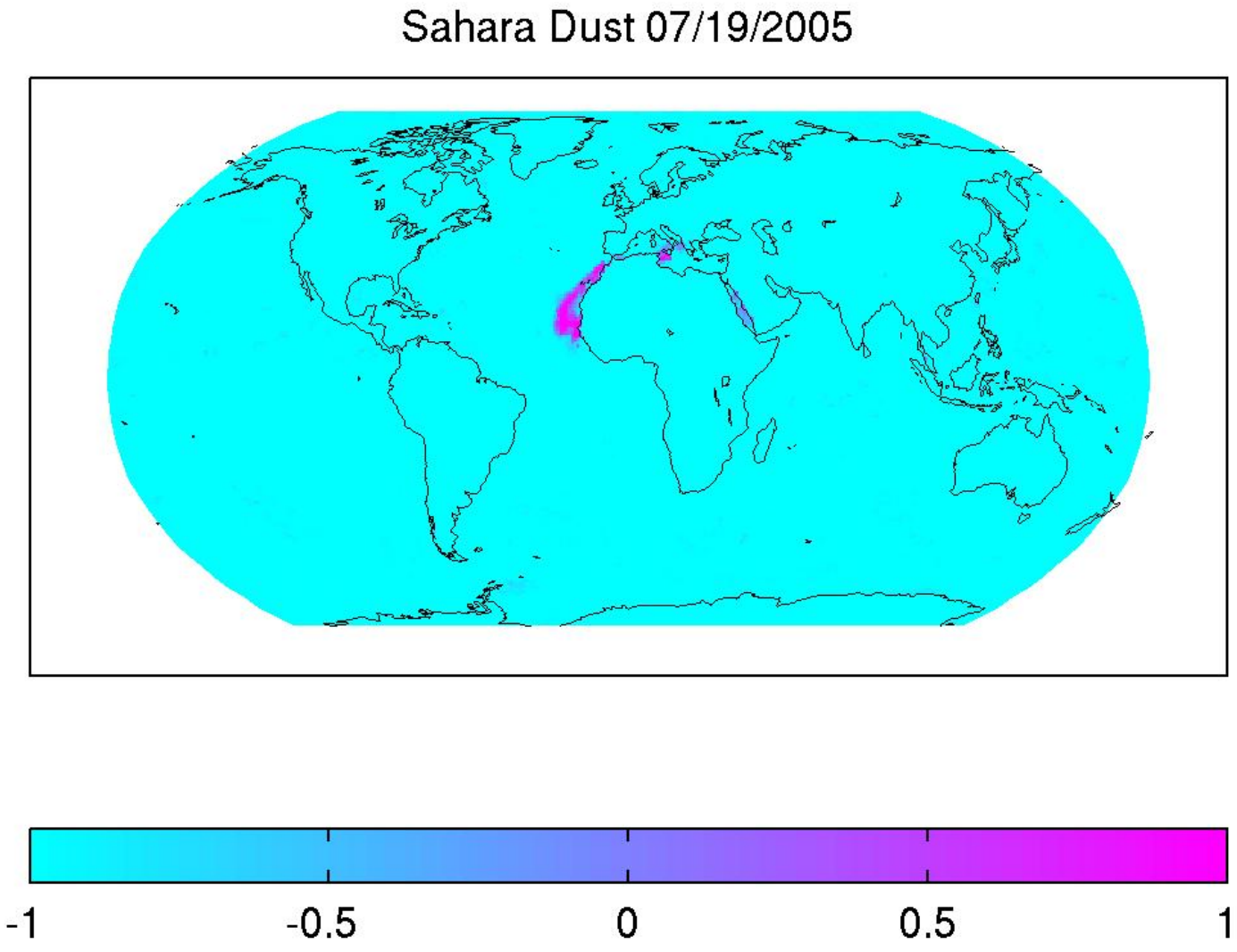
Day 2: Dust Flag



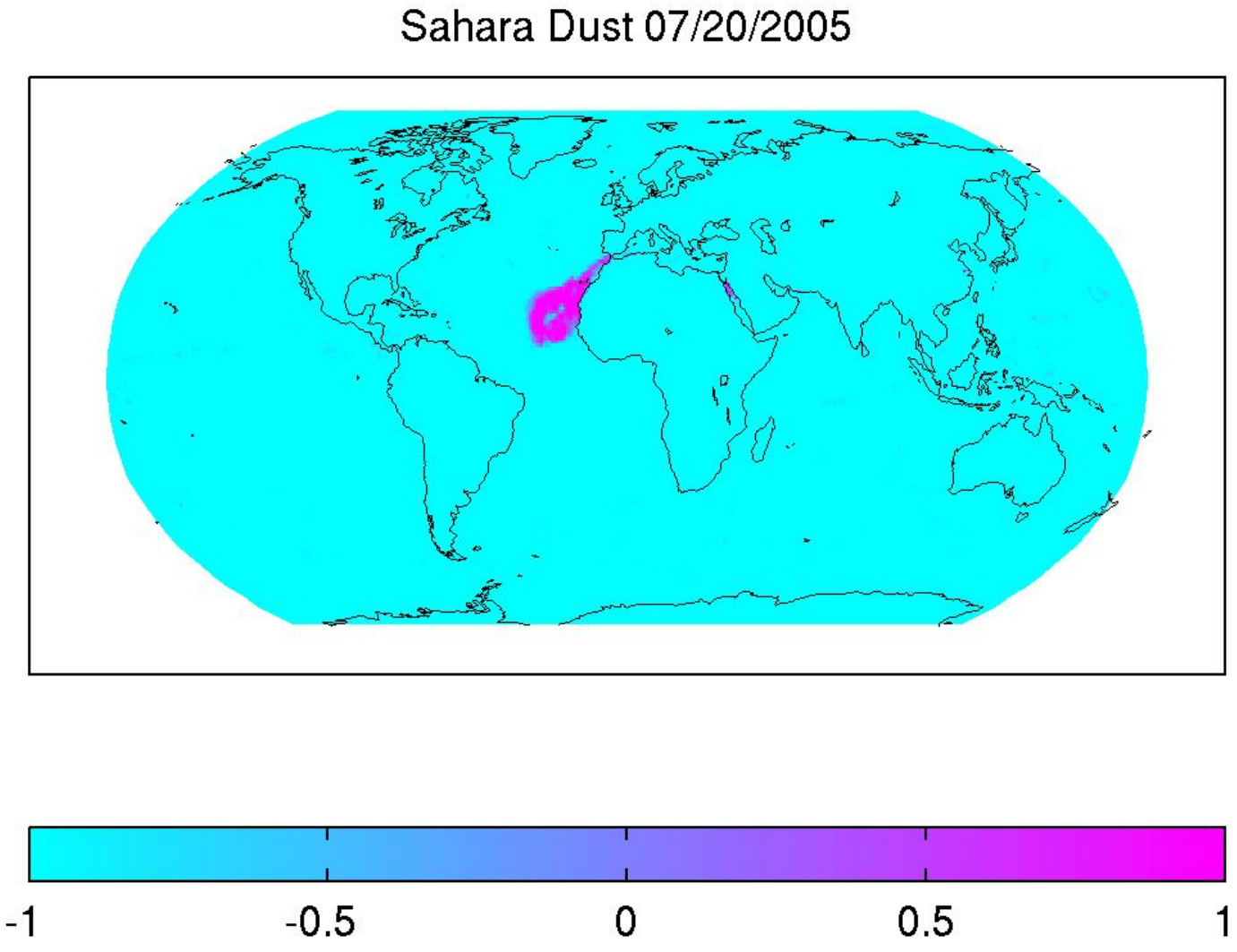
Day 3: Dust Flag



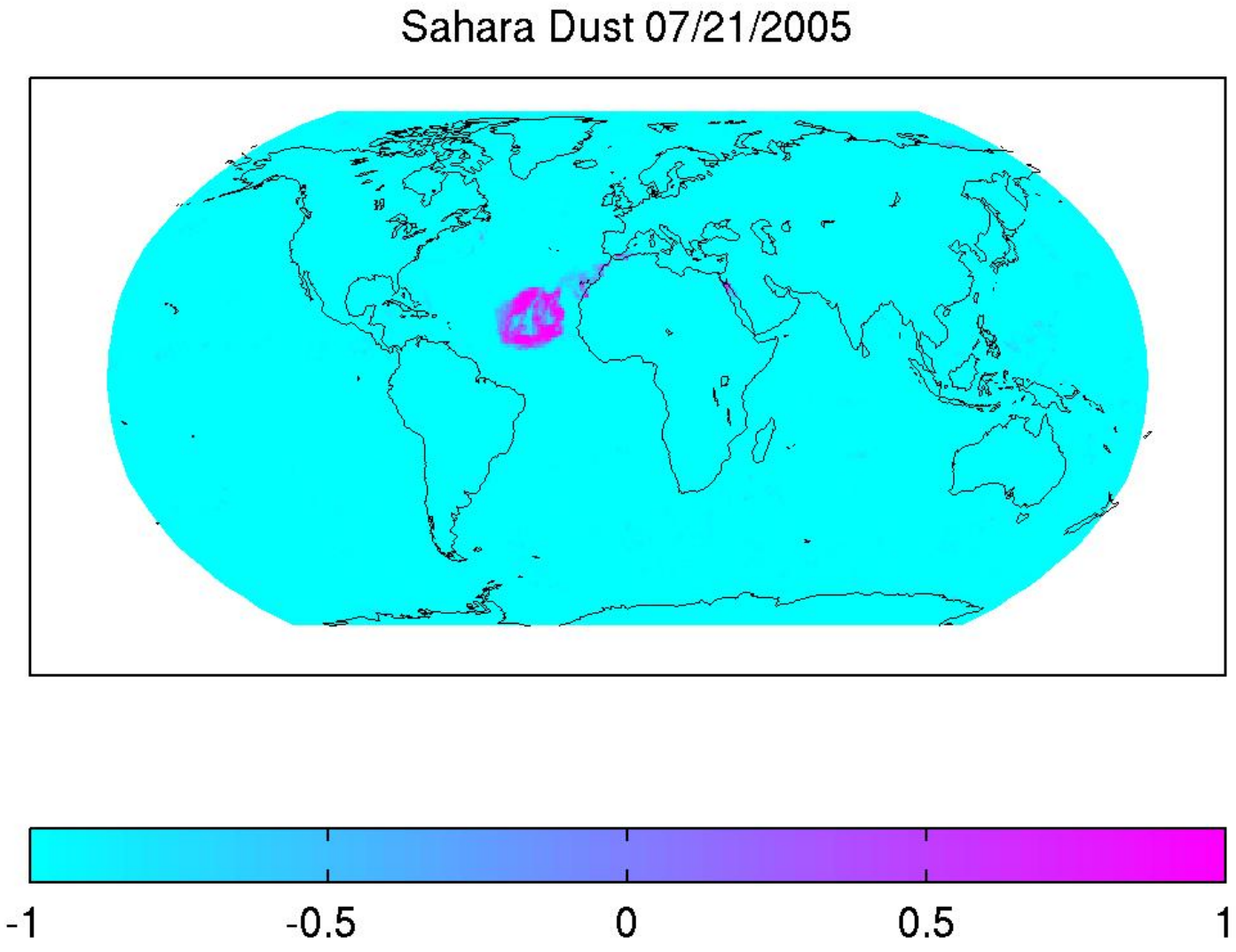
Day 4: Dust Flag



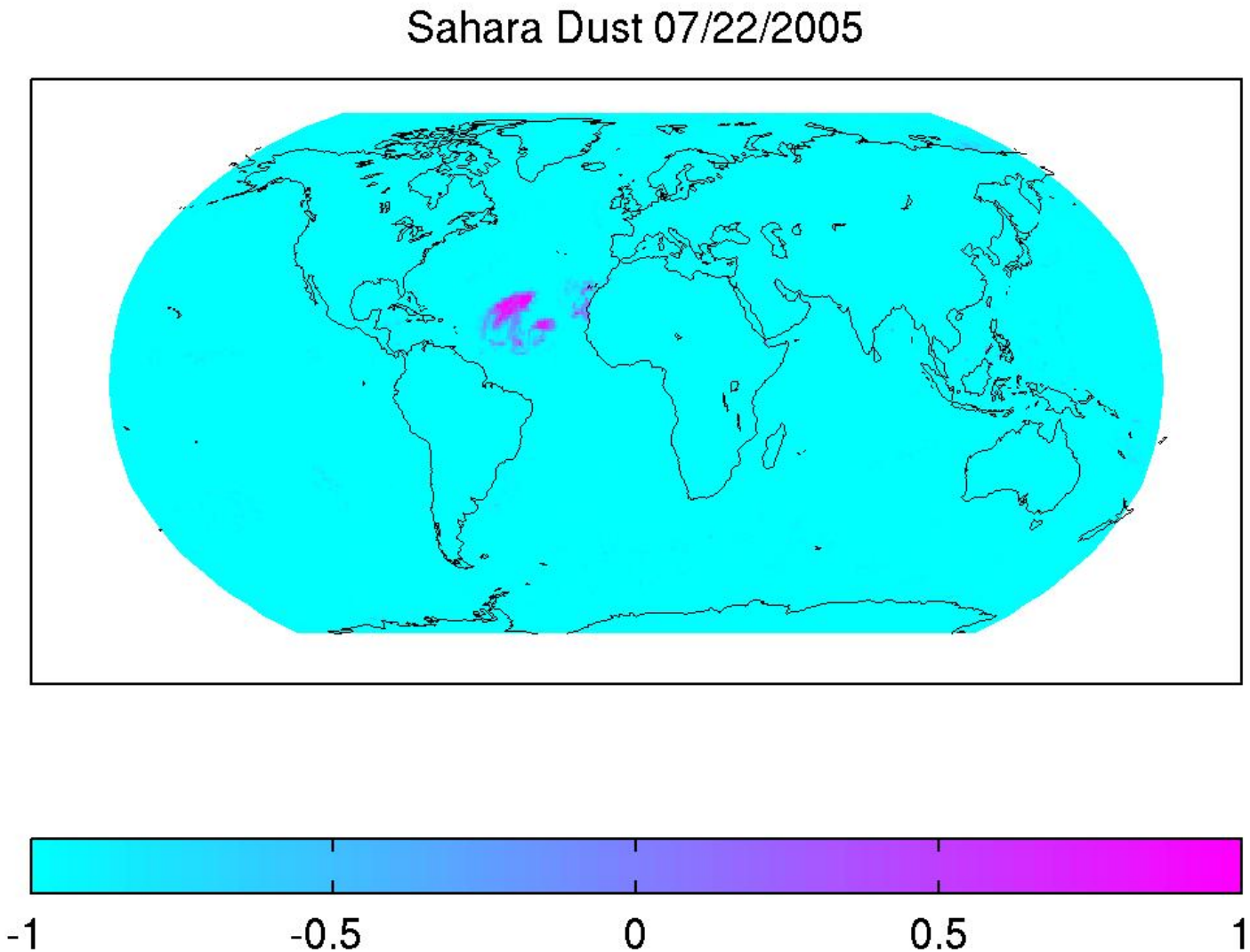
Day 5: Dust Flag



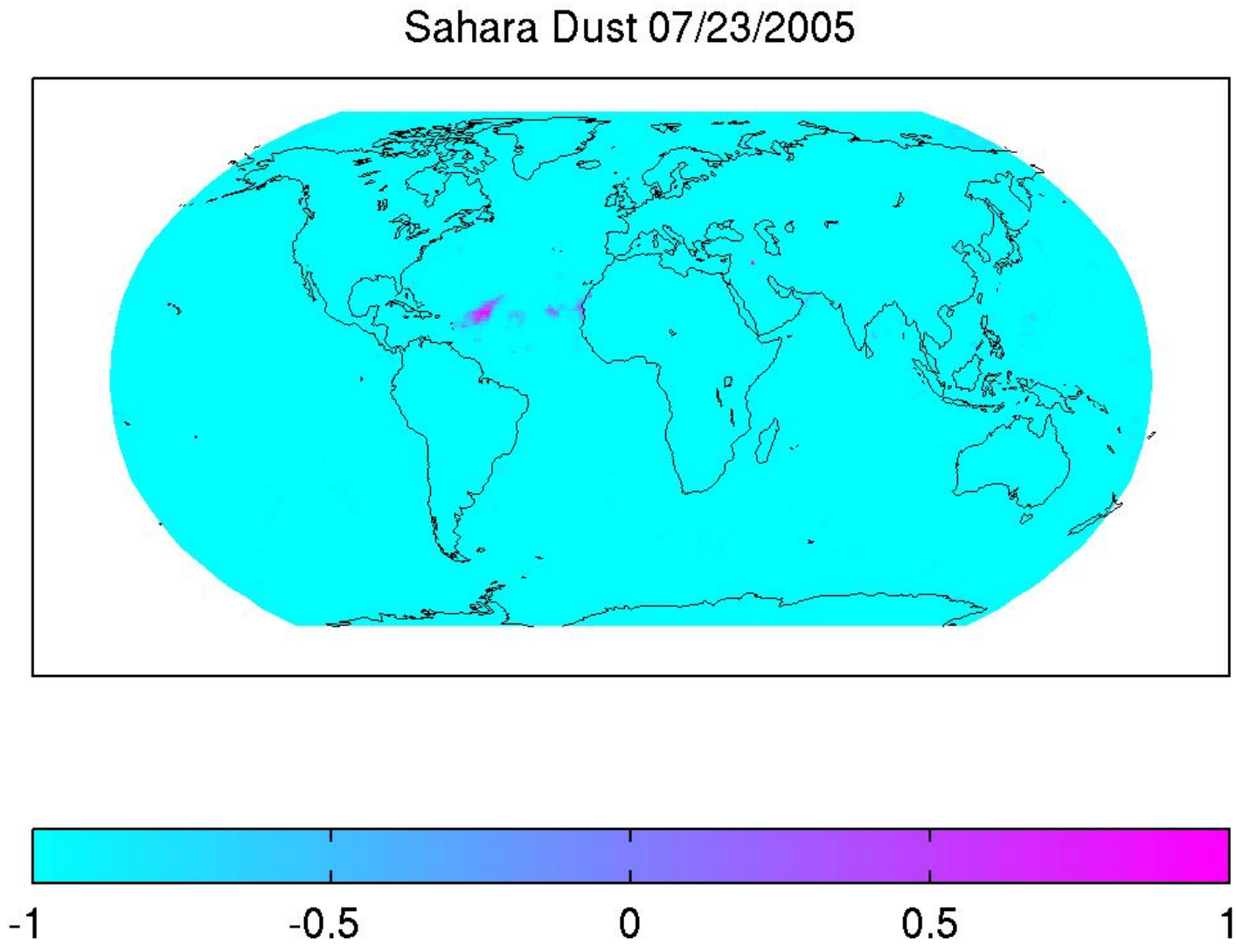
Day 6: Dust Flag



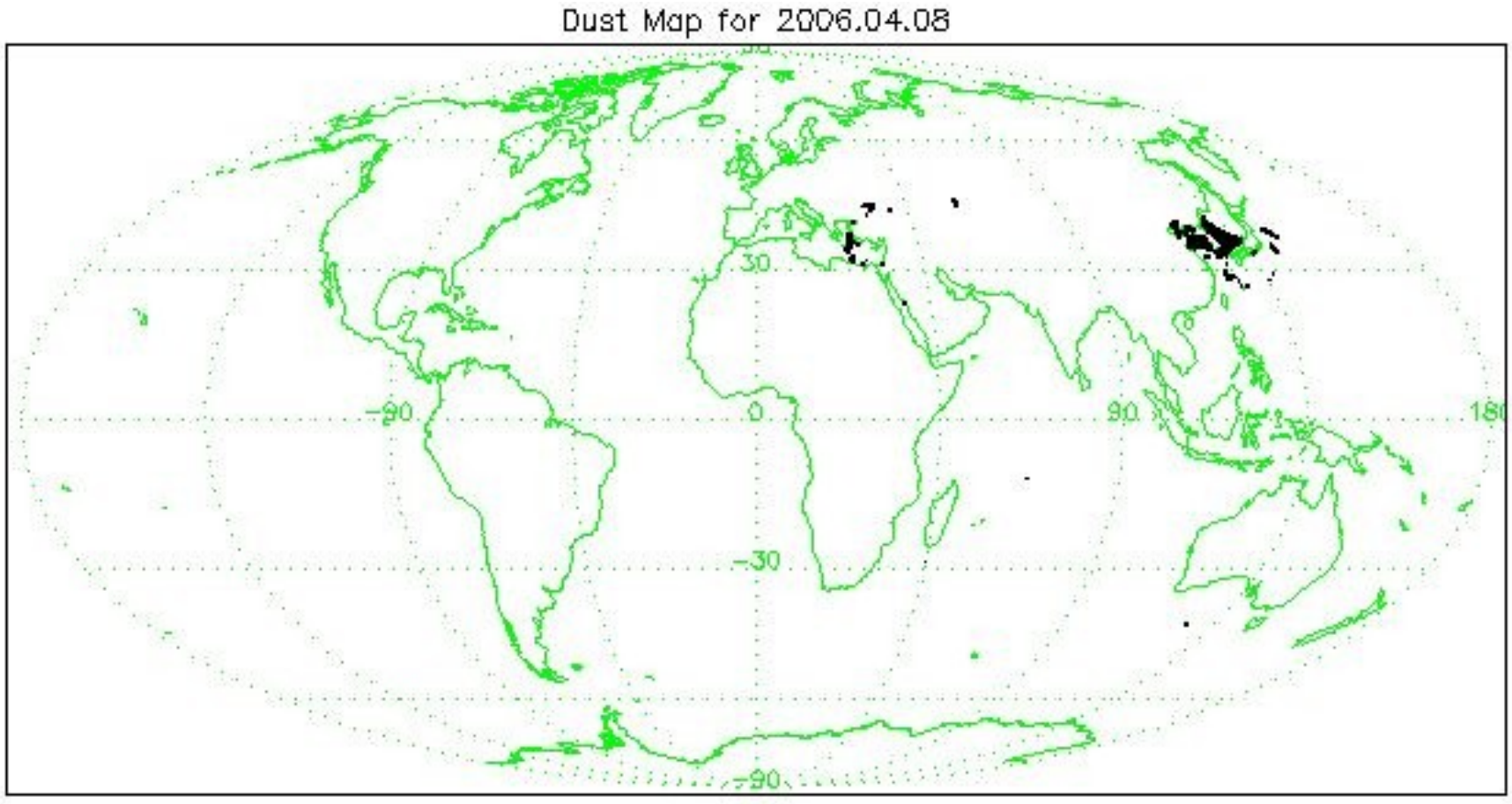
Day 7: Dust Flag



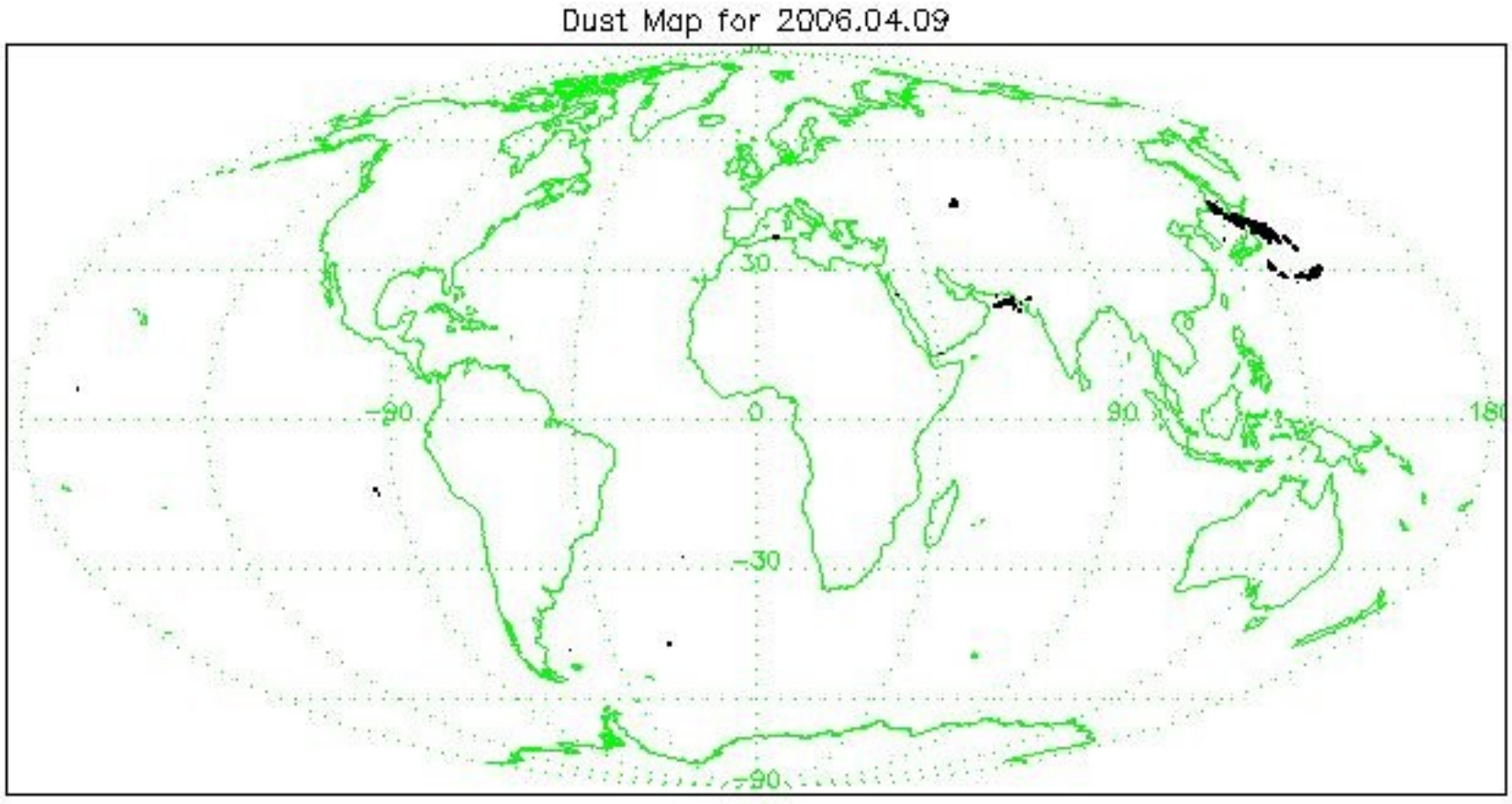
Day 8: Dust Flag



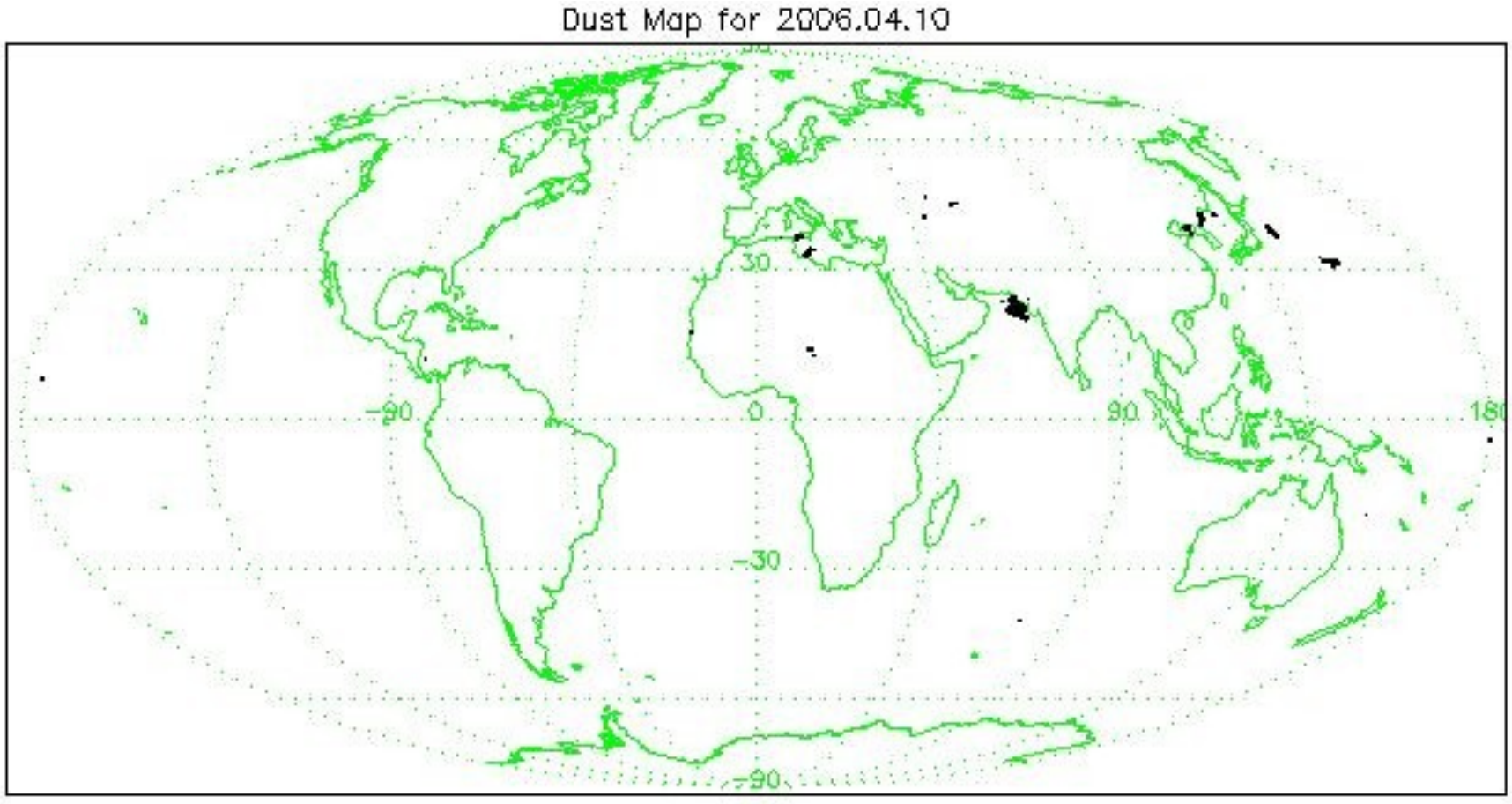
April 8, 2006



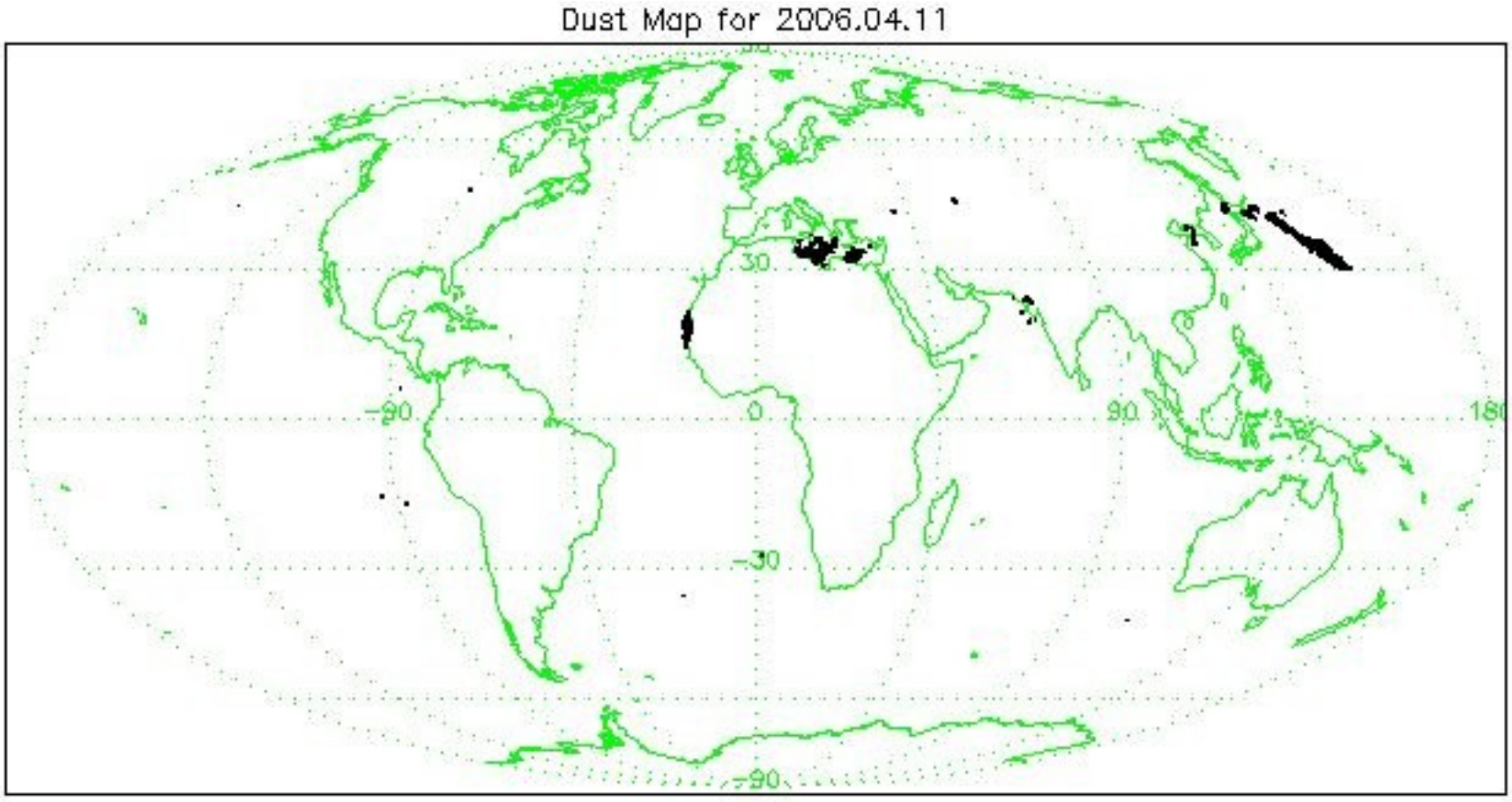
April 9, 2006



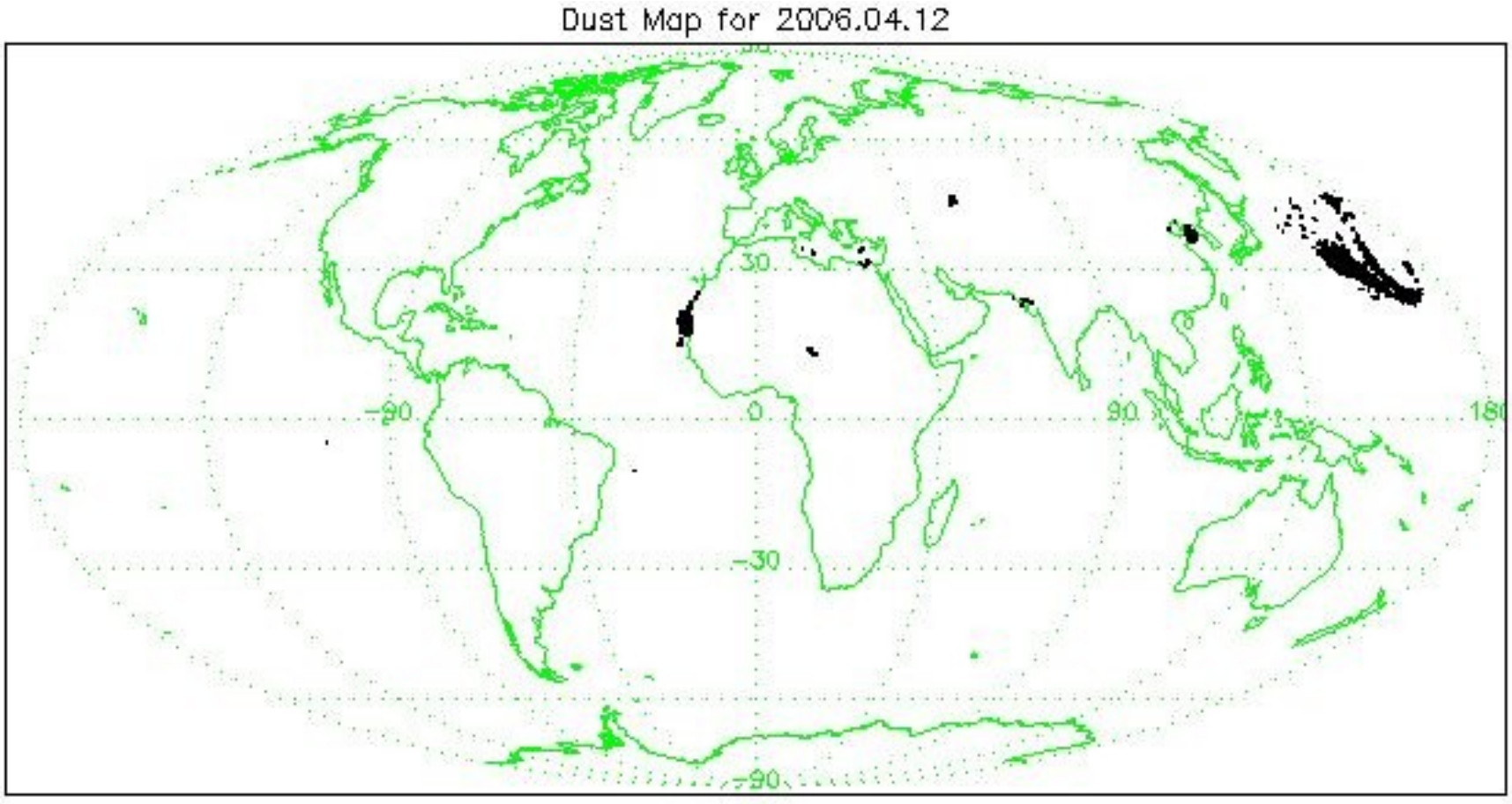
April 10, 2006



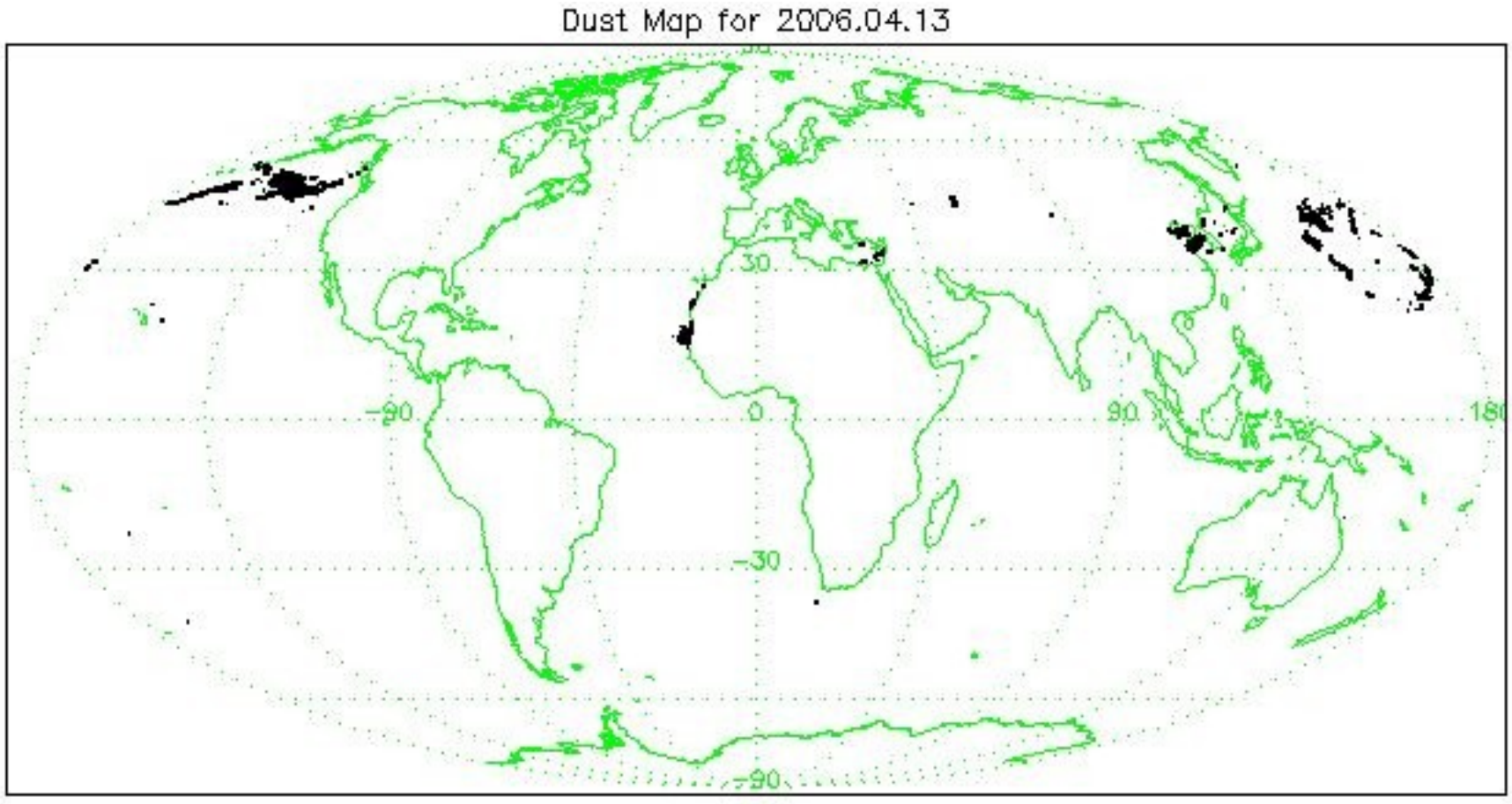
April 11, 2006



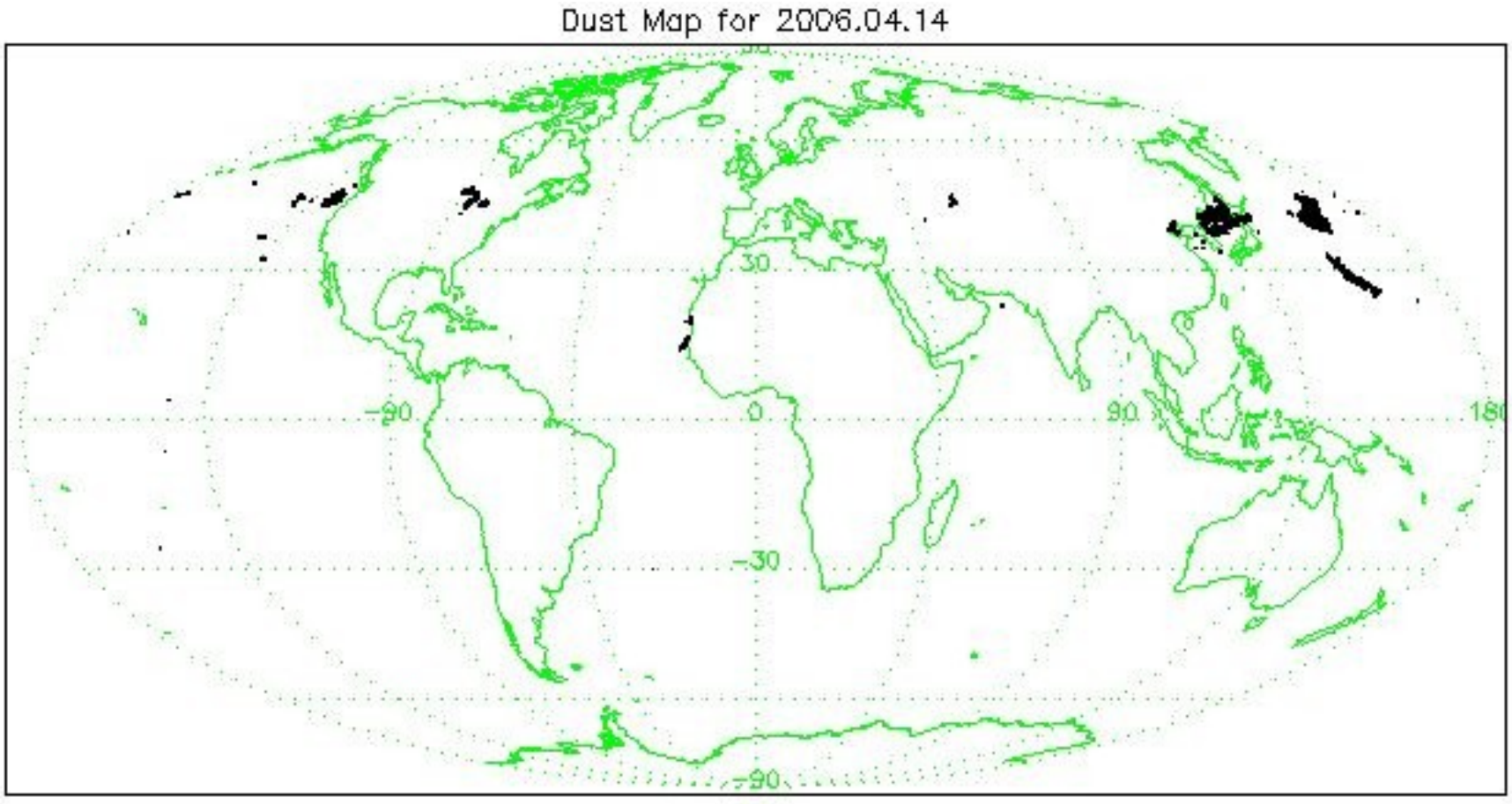
April 12, 2006



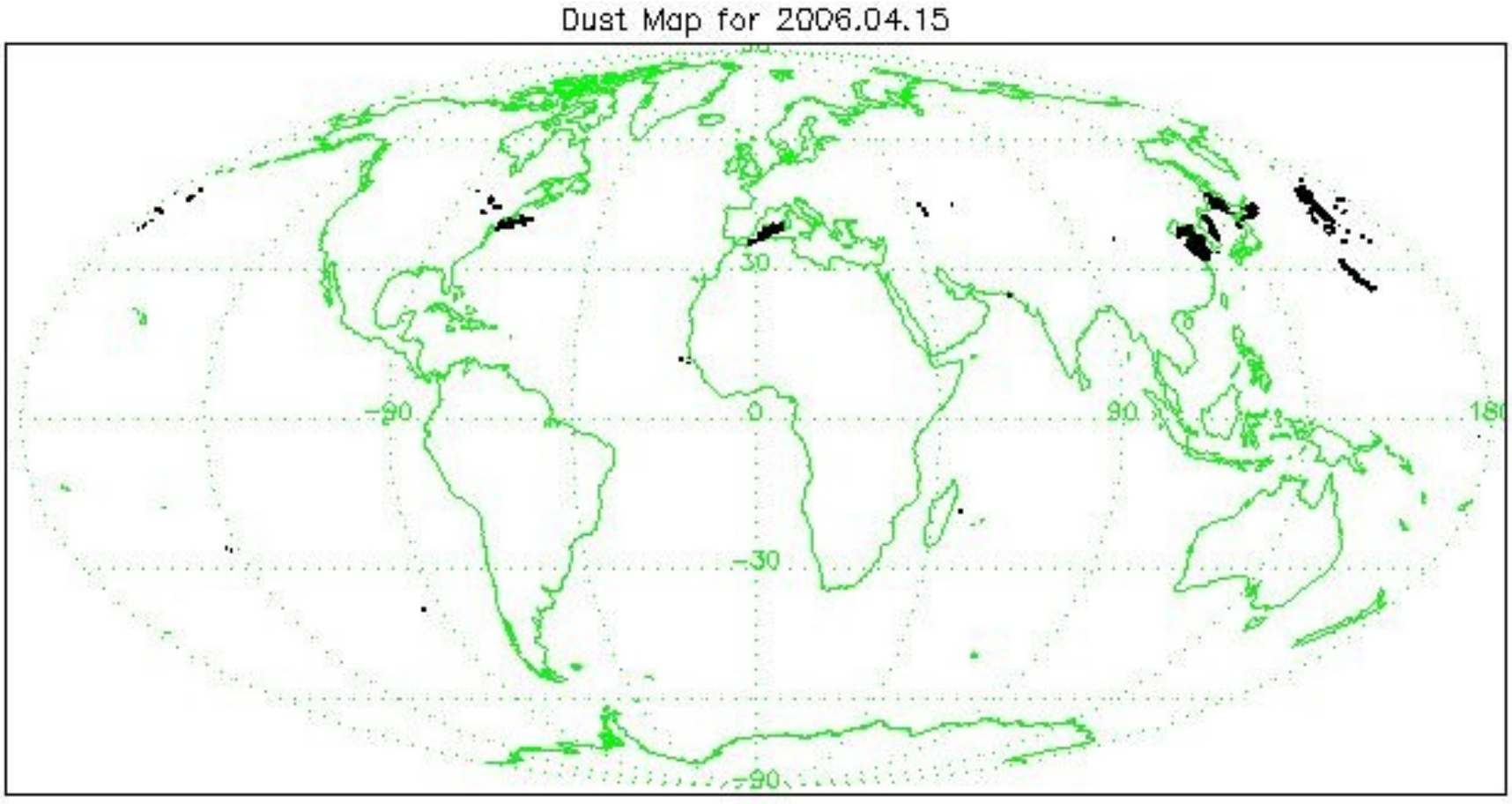
April 13, 2006



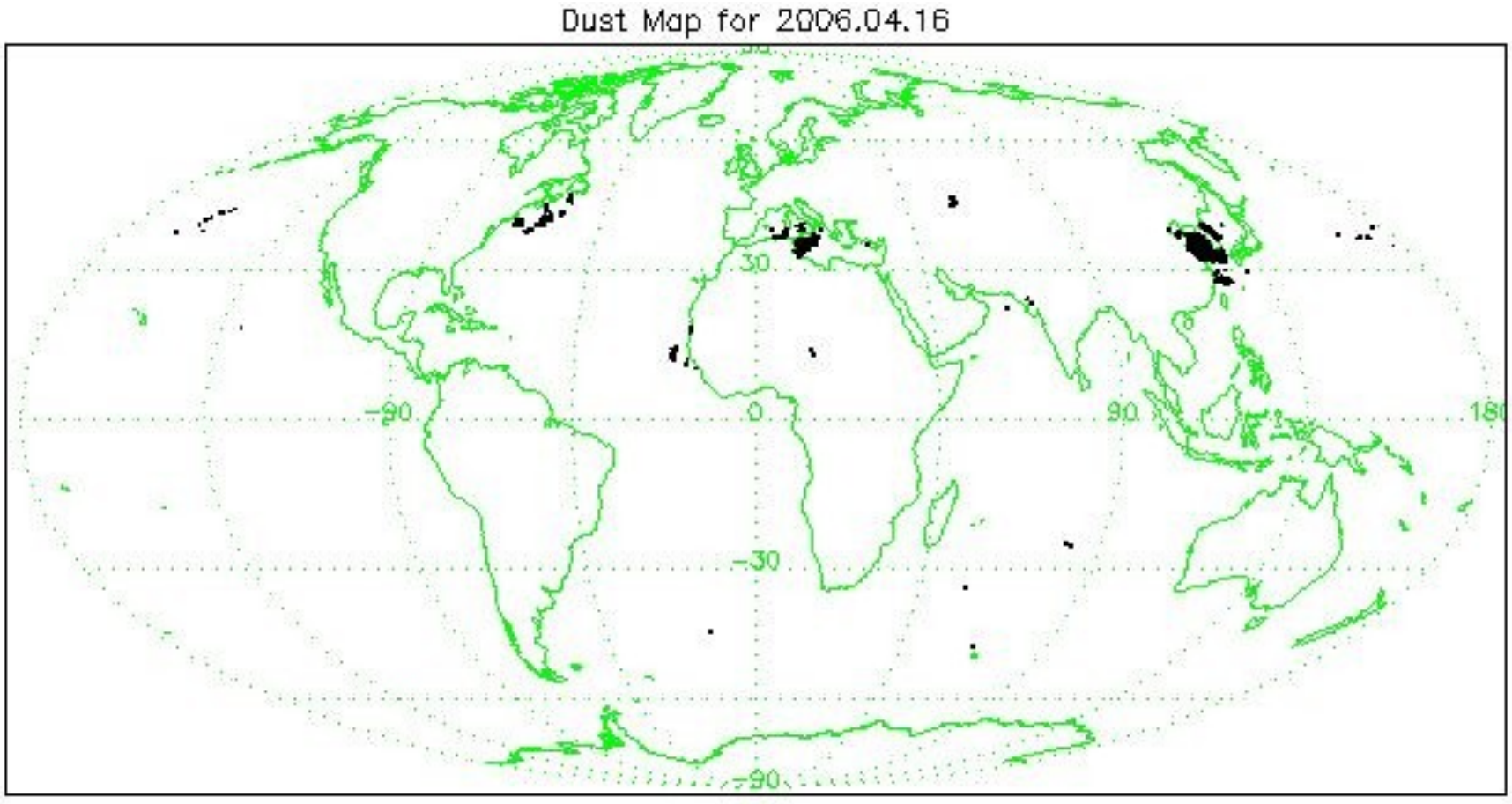
April 14, 2006



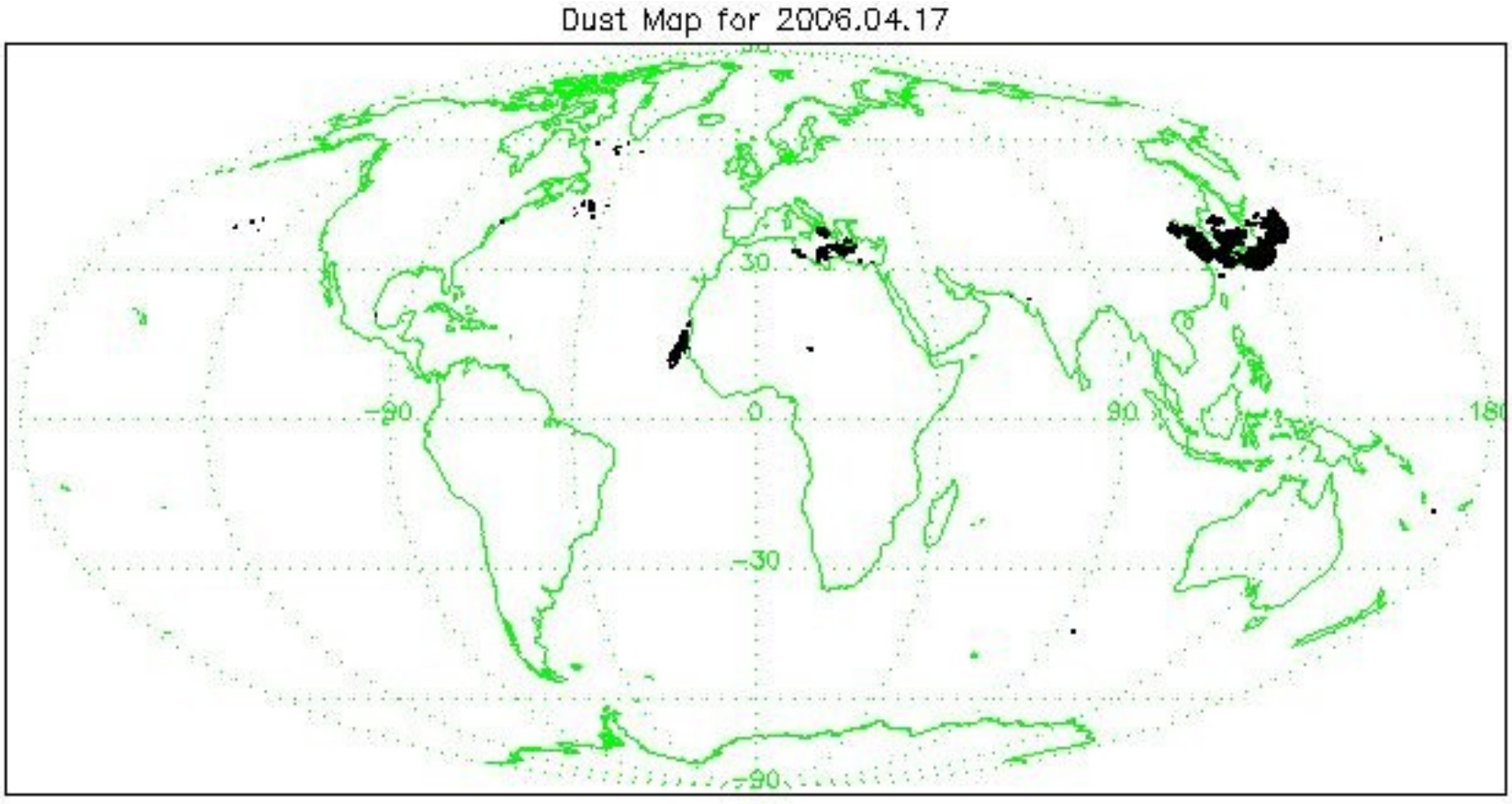
April 15, 2006



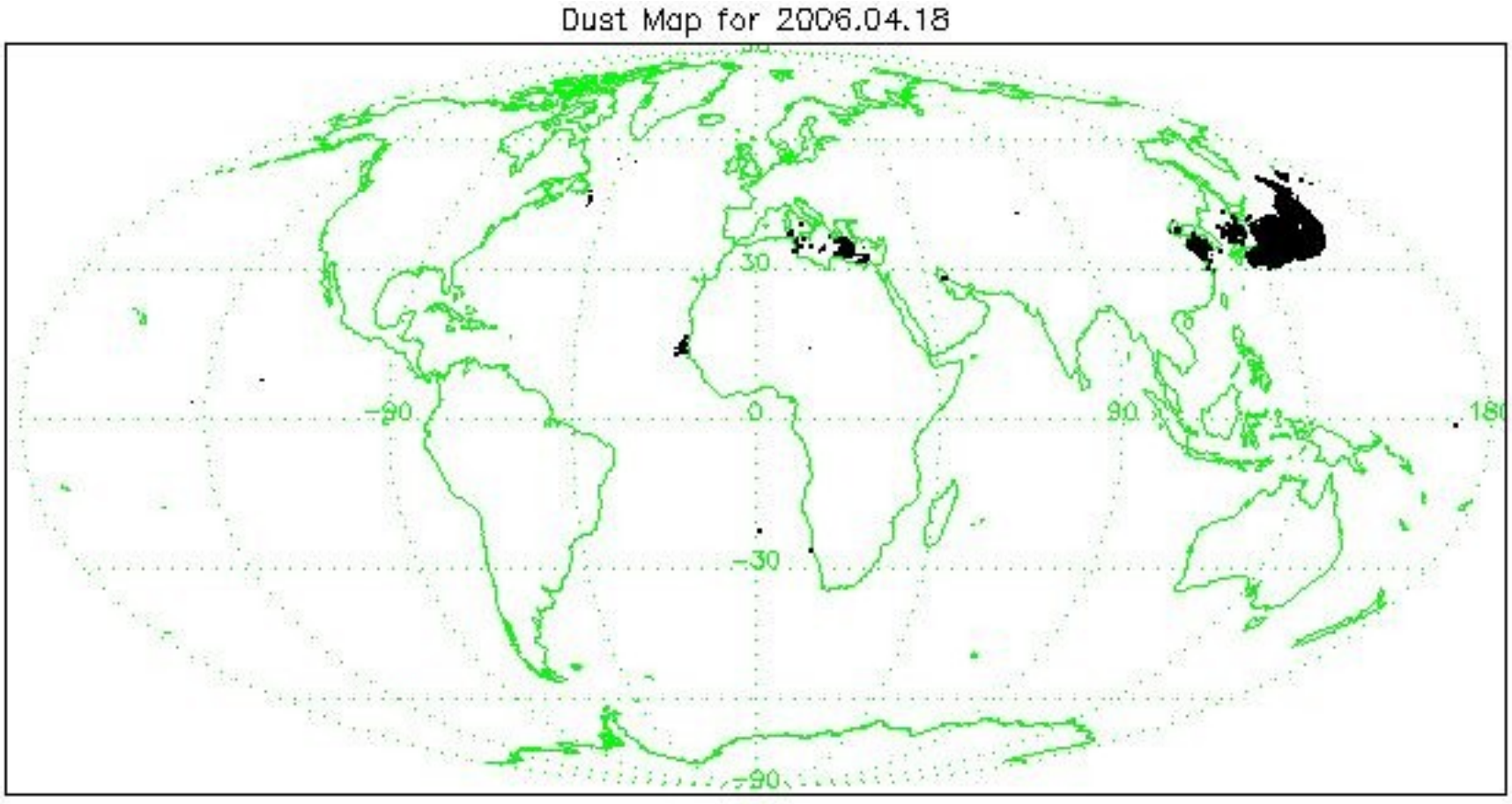
April 16, 2006



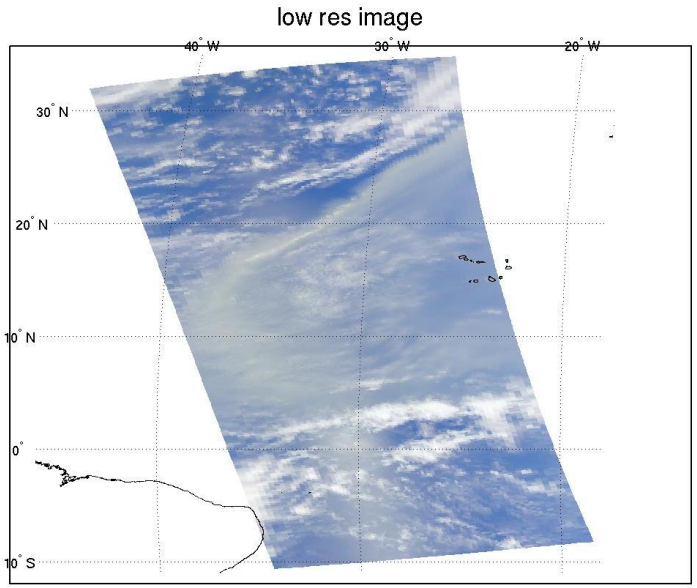
April 17, 2006

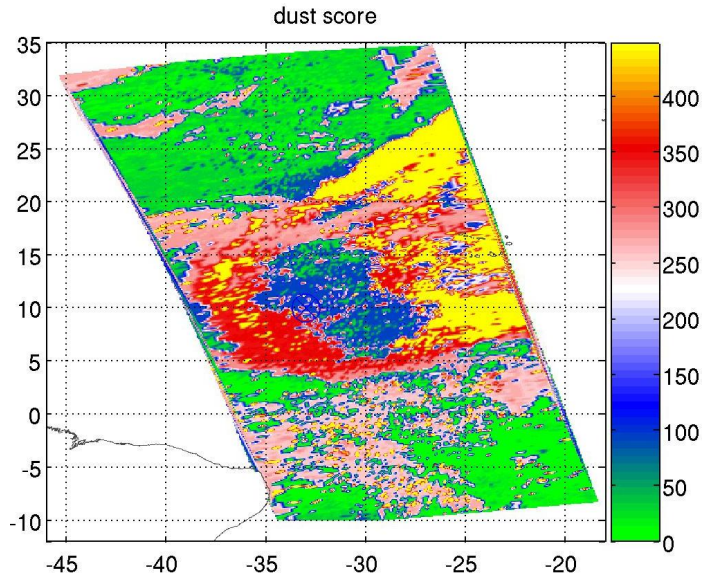


April 18, 2006

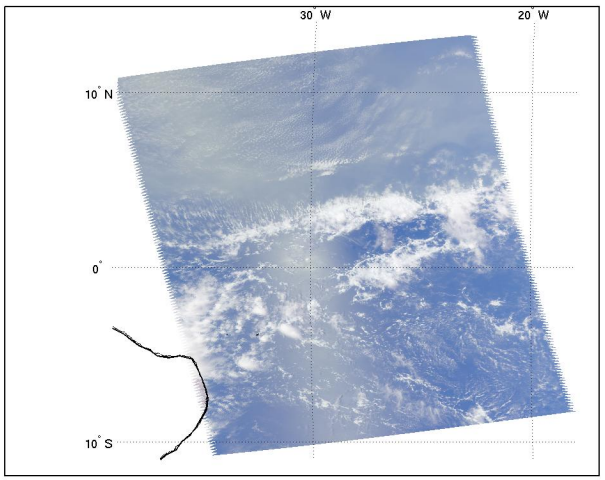


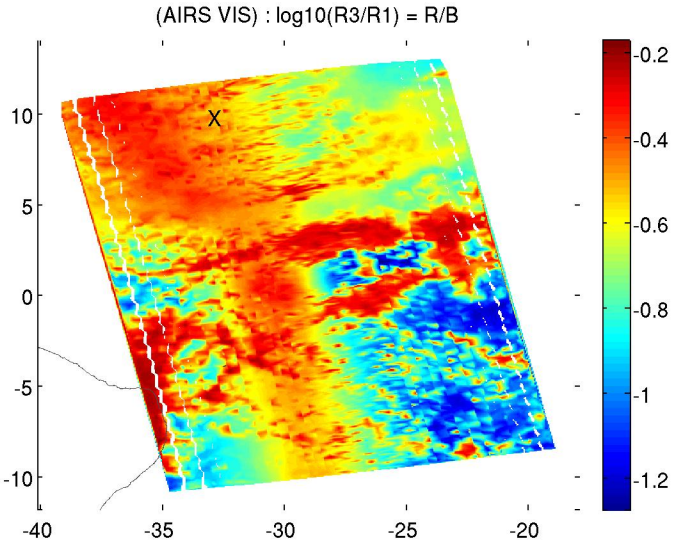
AEROSE Dust Study





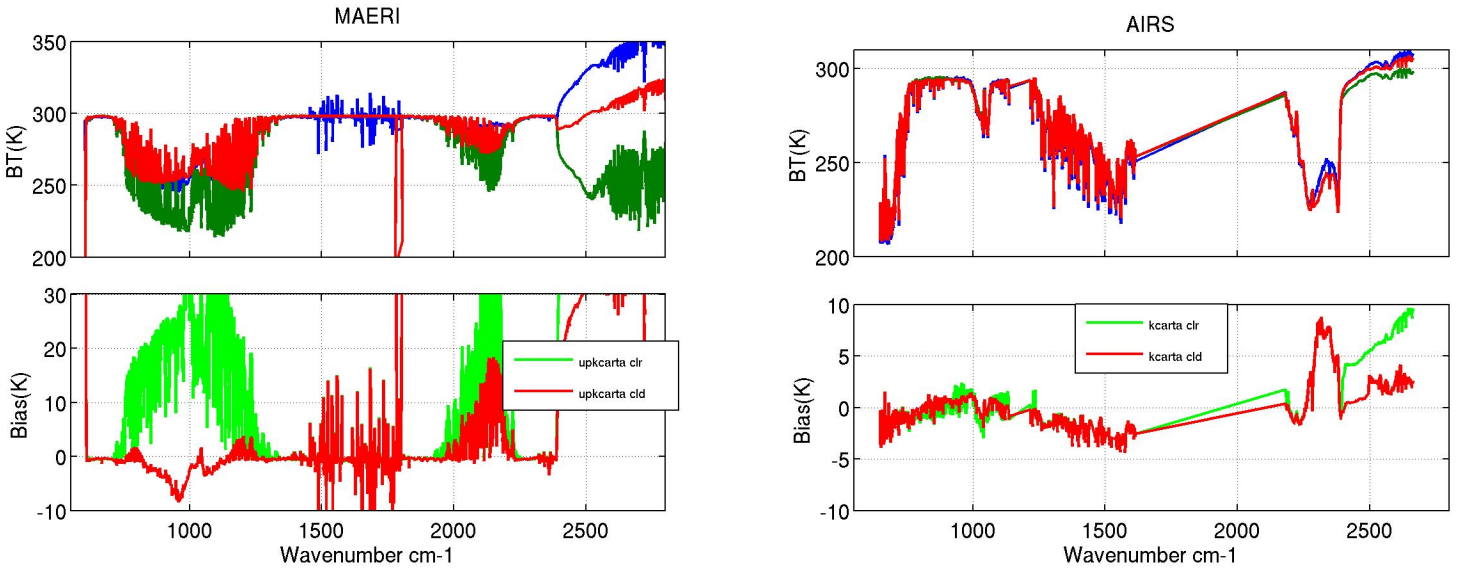
AEROSE March 07, 2004





- Left slide is false color visible image
- Right slide is $log_{10}(red/blue)$, so higher values imply AIRS is looking at something other than warm blue ocean!
- "X" marks position of ship

AEROSE March 07, 2004

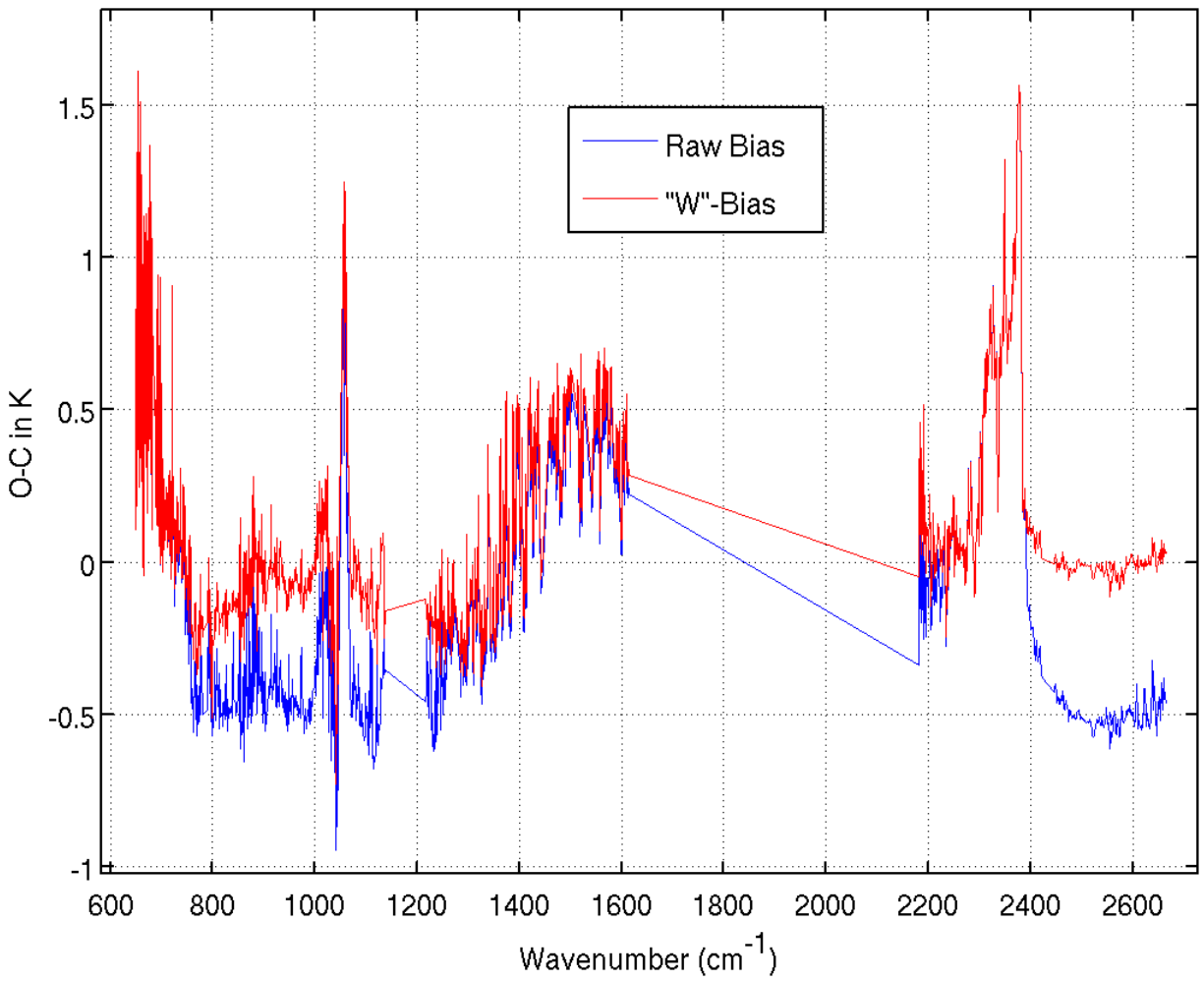


- Photometer indicates “dusty” sky
- Cannot simultaneously fit AIRS and MAERI data
- Also might have sunglint problems??
- blue = obs, green = clear calc, red = cloudy calc
- AIRS sim : dust from 900 mb down, $D \simeq 1.5$ um, $\tau(900 cm^{-1}) \simeq 1.02$
- MAERI sim : dust from 900 mb down, $D \simeq 2.5$ um, $\tau(900 cm^{-1}) \simeq 0.4$

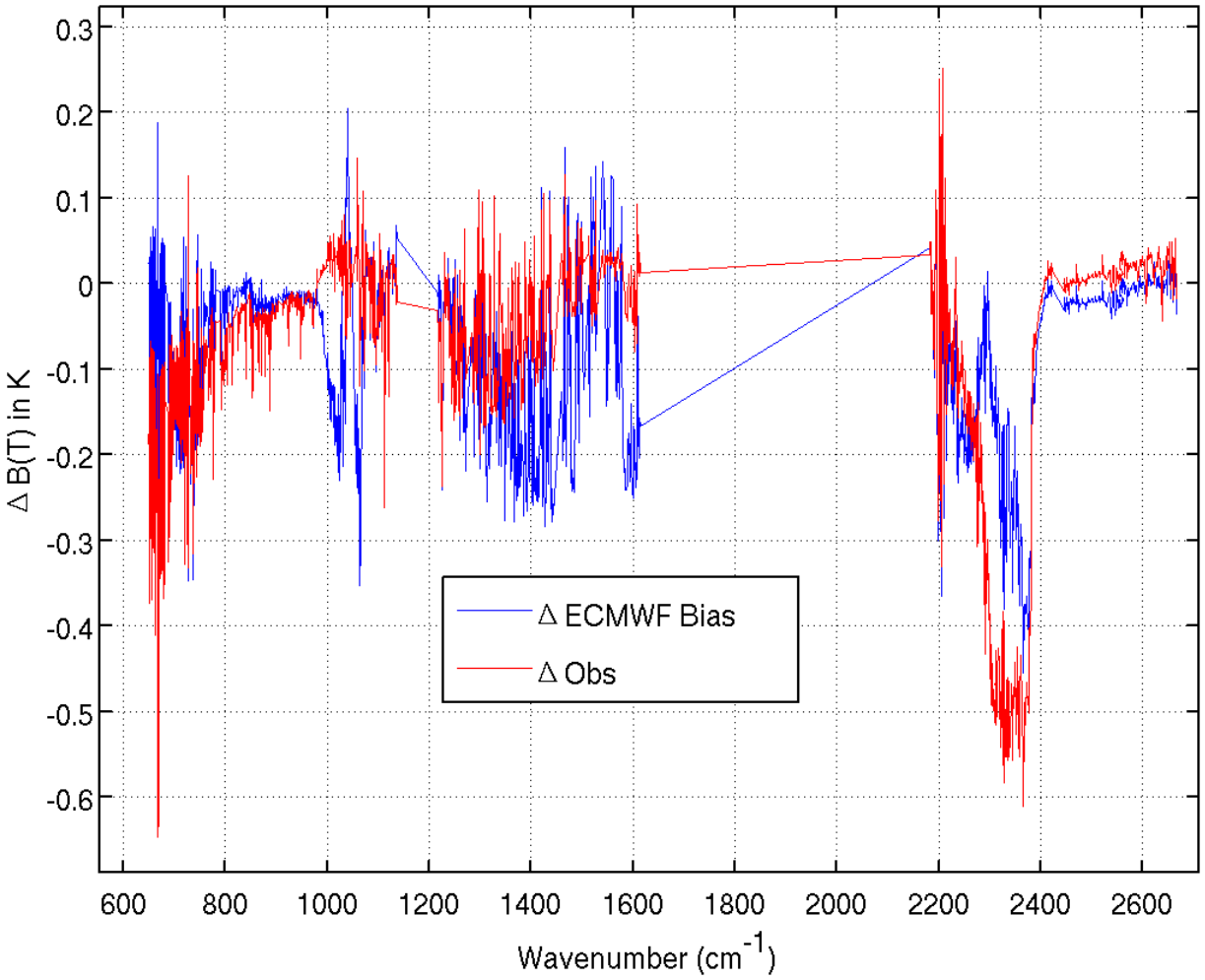
Climate with Hyperspectral IR

- Can we use hyperspectral IR sensors for climate studies
- Lot's of issues
  - Sampling errors with clear?
  - How do climate with cloudy FOVS?
  - Tie sensor's radiometric cal (AIRS to IASI to CrIS)
  - Minor gases
  - Different spectral response functions
- We have sub-setted "clear" ocean-only FOVS since AIRS started operation. Now have 38 month data set (always growing).
- A quick look at what this data set sees:

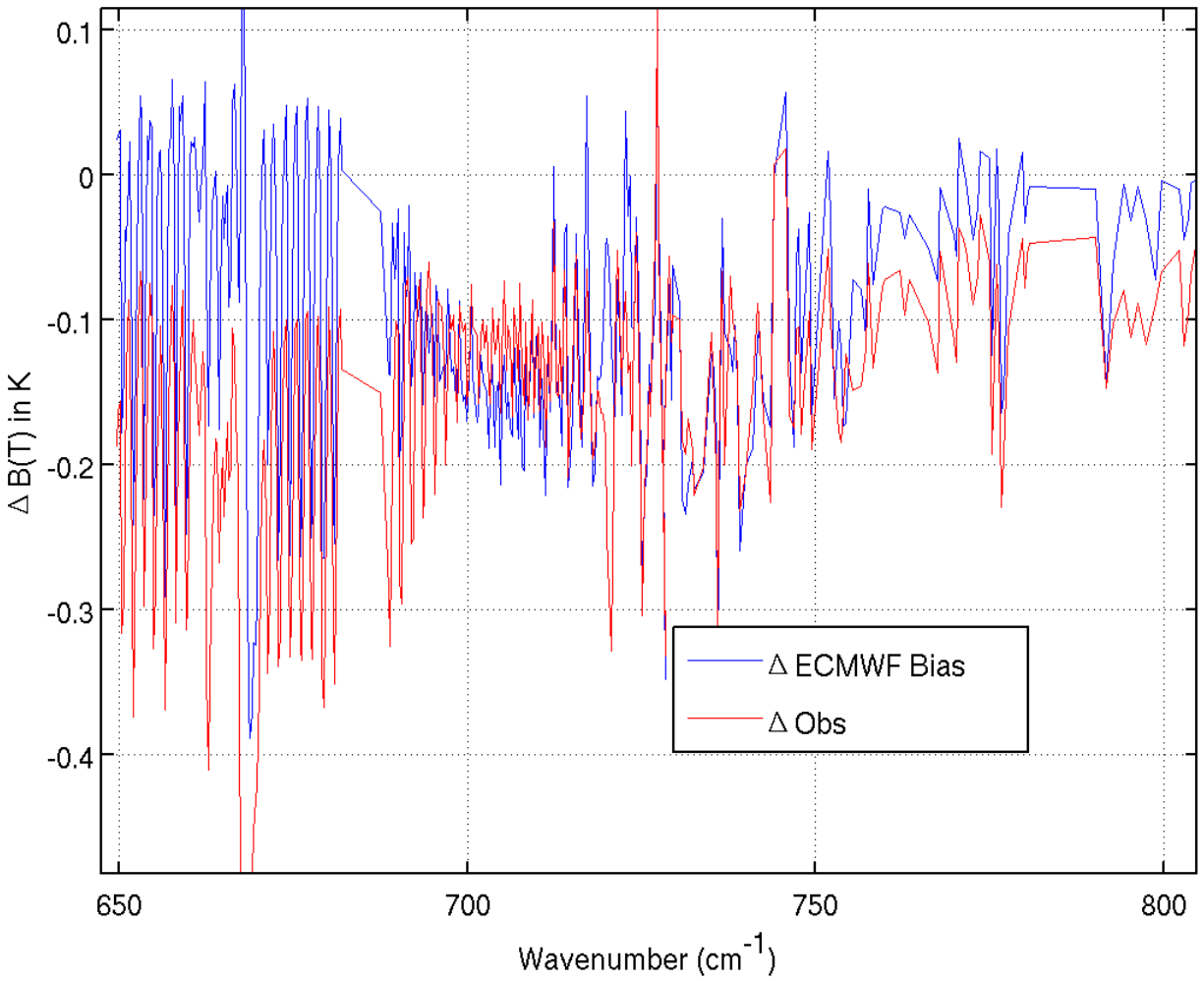
Biases versus ECMWF have SST and TCW "retrieved"



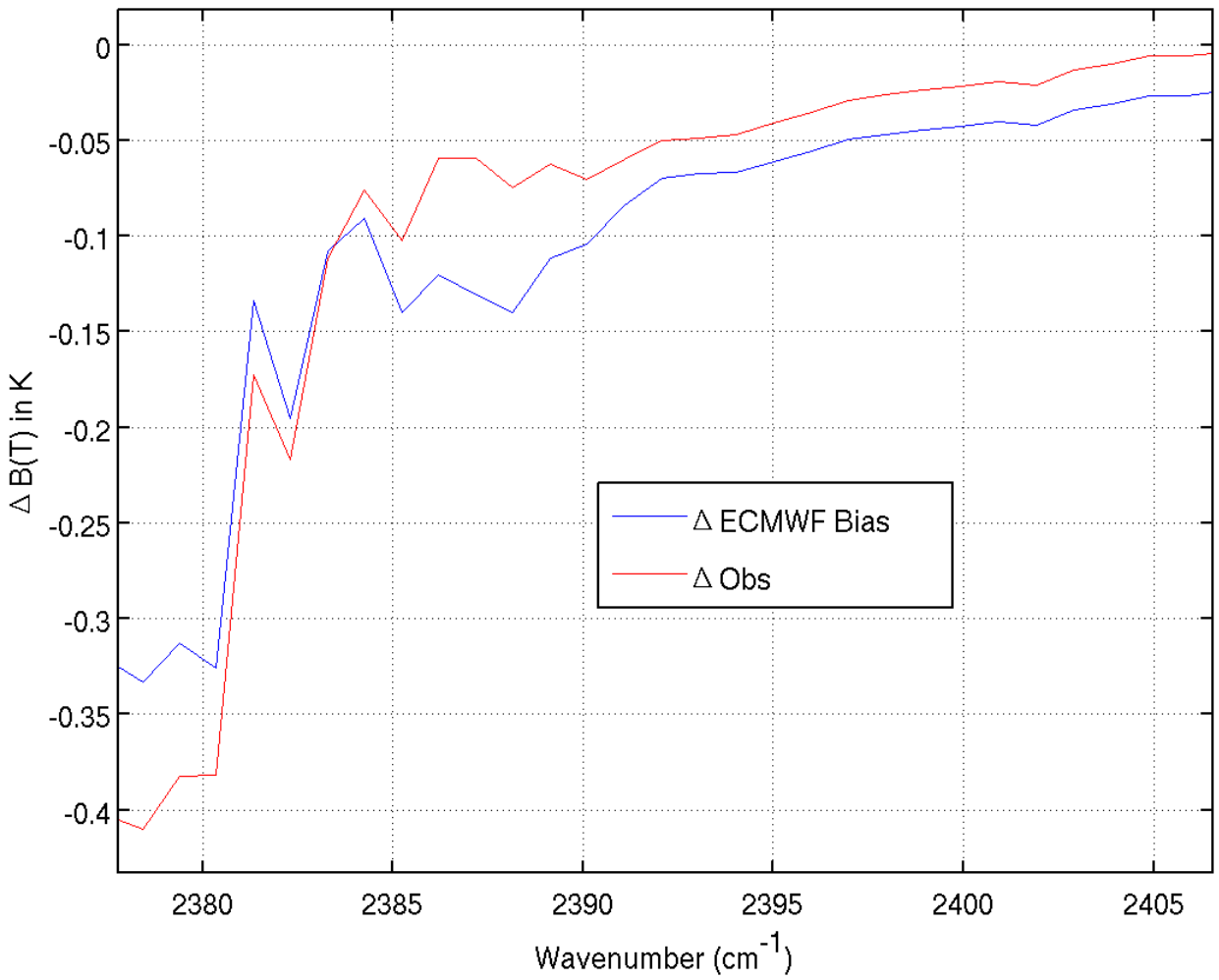
Bias/Obs Differences, Δt = 2 Years: Mid Lat



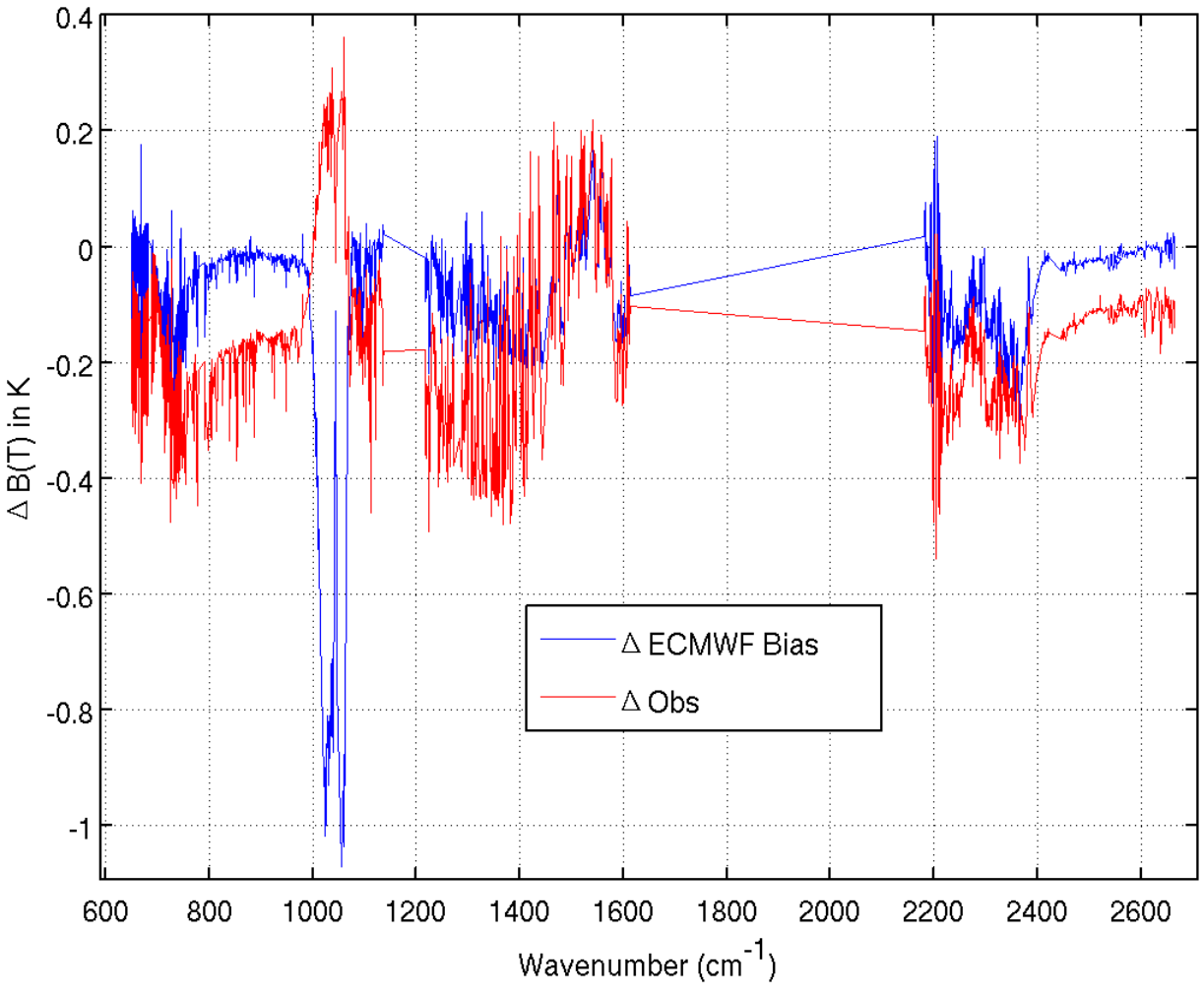
Bias/Obs Differences, Δt = 2 Years: Mid Lat:Zoom



Bias/Obs Differences, Δt = 2 Years: Mid Lat:Zoom



Bias/Obs Differences, Δt = 2 Years: High Lat



Conclusion

Doing climate with hyperspectral sensors will require a lot of work, but we have the capability to produce an excellent radiometric record with AIRS.