Detection of Antarctic ice polar stratospheric clouds from AIRS assimilation

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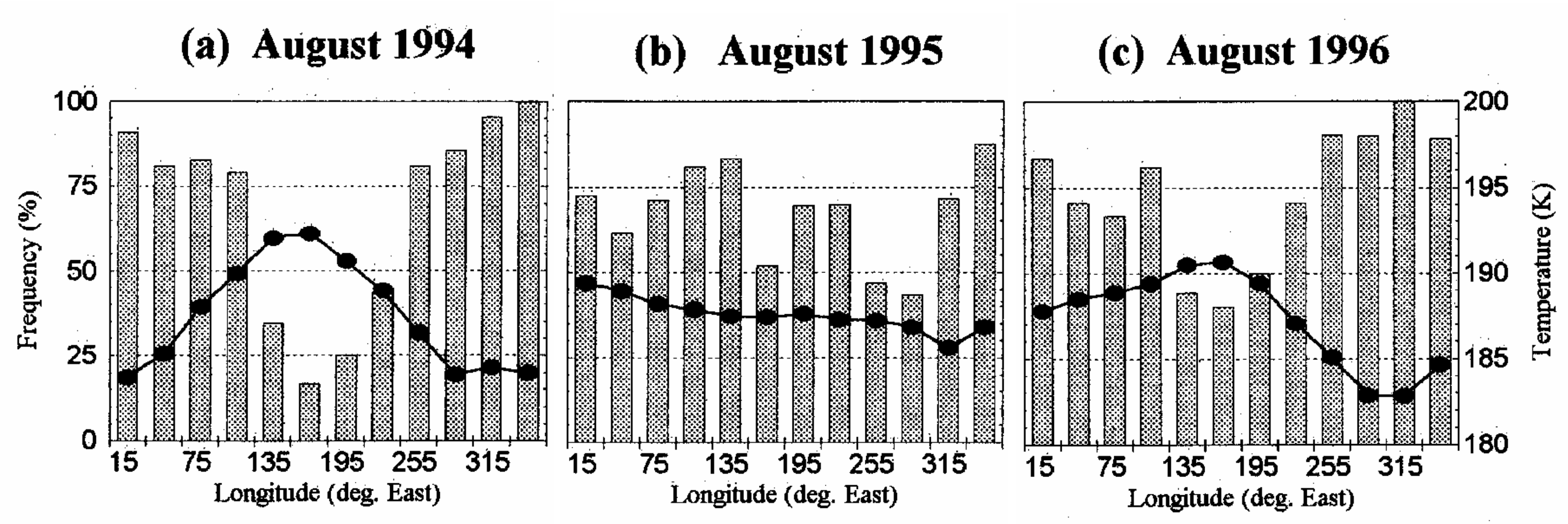
FIELDS

Overview

Hypothesis: AIRS observed-forecast (O-F) residuals can be used to detect ice polar stratospheric clouds

- Instrumentation overview (POAM, AIRS)
- PSC detection theory
- Model support (MODTRAN/IMPACT)
- Observational support (POAM III)
- Applications (climatology, NH cloud detection)

POAM II comparison

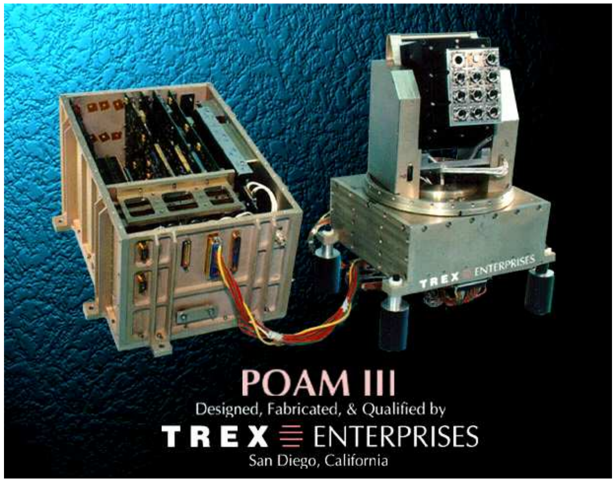


- POAM II ice and layer (STS/NAT) PSC frequency distributions
- Longitudinal dependence of PSC frequency annually variable
- Peak frequency typically downwind of peninsula
- August 1995 shows bimodal distribution, as in 2004

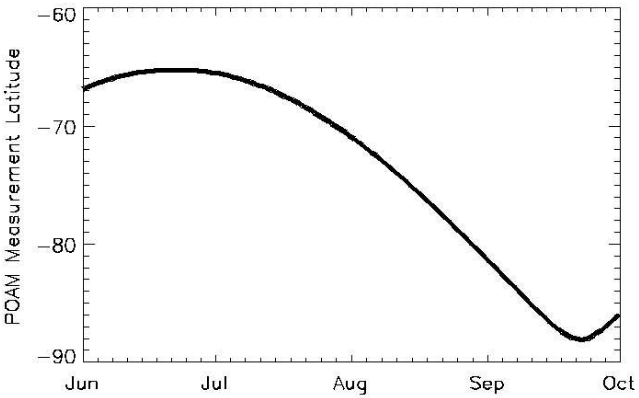
Figures from Fromm et al., JGR, 102(D19), 23,659-23,672, 1997.

POAM III

POAM III is a 9-channel visible/near infrared photometer for making measurements of stratospheric constituents using solar occultation.

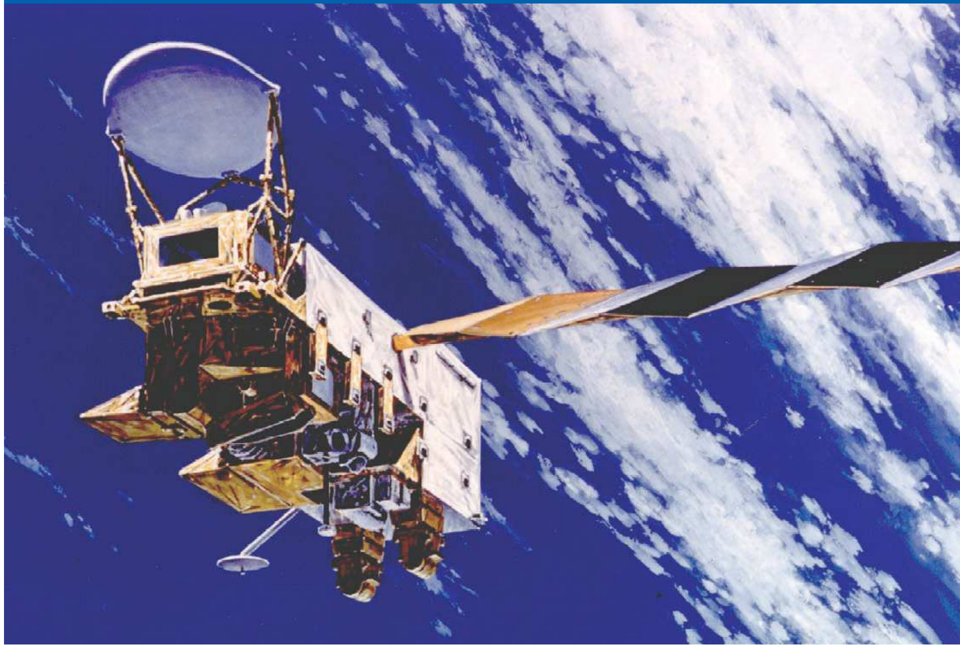


- The POAM instrument observes polar stratospheric clouds via two methods:
  - Aerosol extinction greater than 4σ over background level (NAT/STS)
  - Measurement cutoff at least 3 km above tropopause due to high extinction levels (ice)



- POAM III was launched on the SPOT 4 spacecraft on 23 March 1998 into a polar sun synchronous orbit (833 km, 98.7° inclination, 10:30 equatorial crossing). The instrument remained operational until 5 December 2005.

AIRS instrument

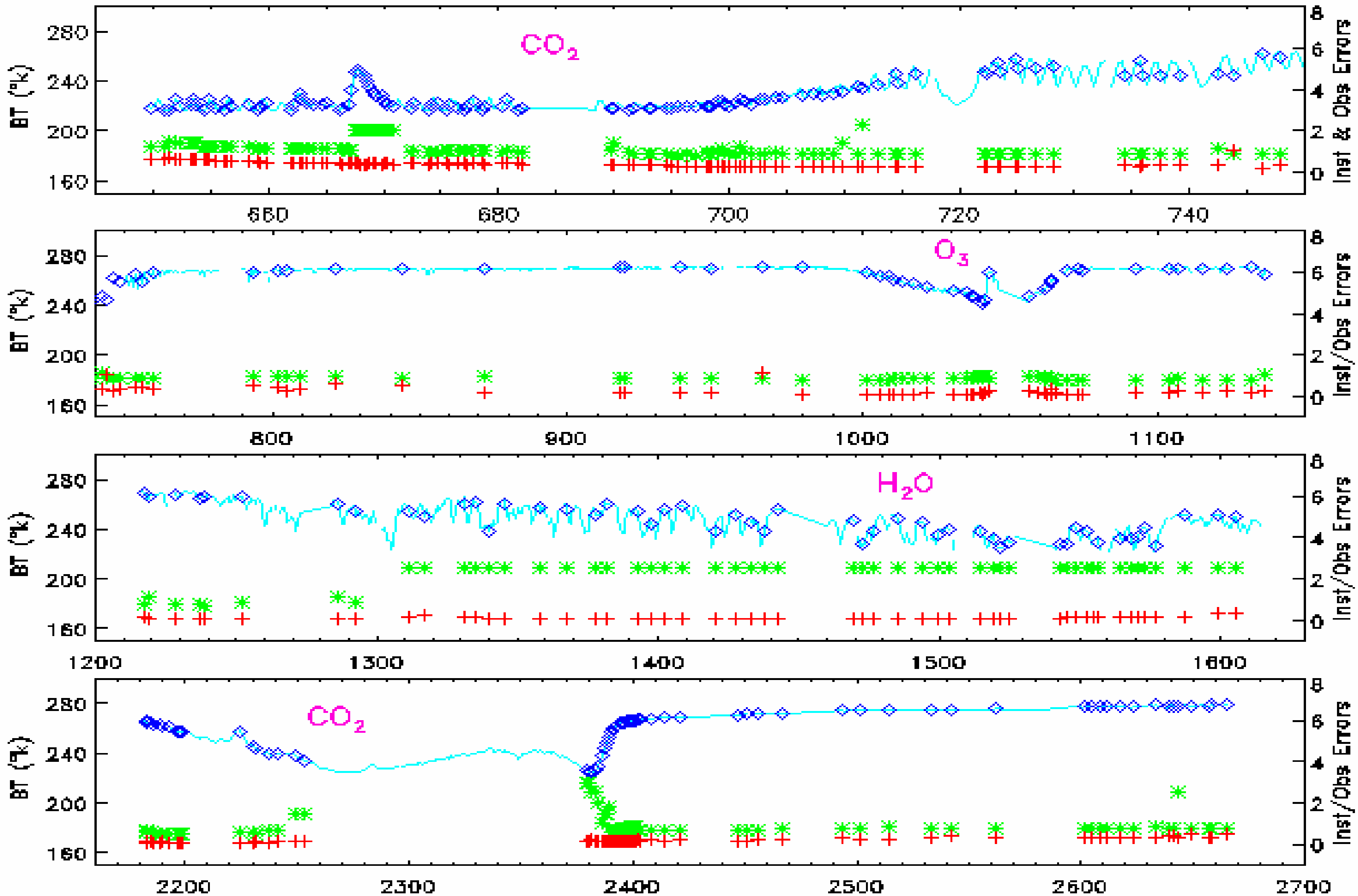


"This AIRS instrument has provided the most significant increase in forecast improvement in this time range of any other single instrument."

- Retired Navy Vice Adm. Conrad C. Lautenbacher, Jr., Ph.D. Under Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration (NOAA)

- Atmospheric Infrared Sounder flies on the Aqua spacecraft, part of NASA's A-Train
- Measures infrared emission over 2378 spectral channels; differing altitude sensitivities of each wavelength leads to a full atmospheric sounding
- Major operational products include sea, land, and profile temperatures, moisture, and ozone
- Accurate to +/-1 K over 1-km resolution
- 281 AIRS channels are assimilated into GEOS-5

AIRS channel selection



◇ 281 channels assimilated into GEOS-5 + instrument errors * observation errors

GEOS-5: 3D-Var analyses using IAU

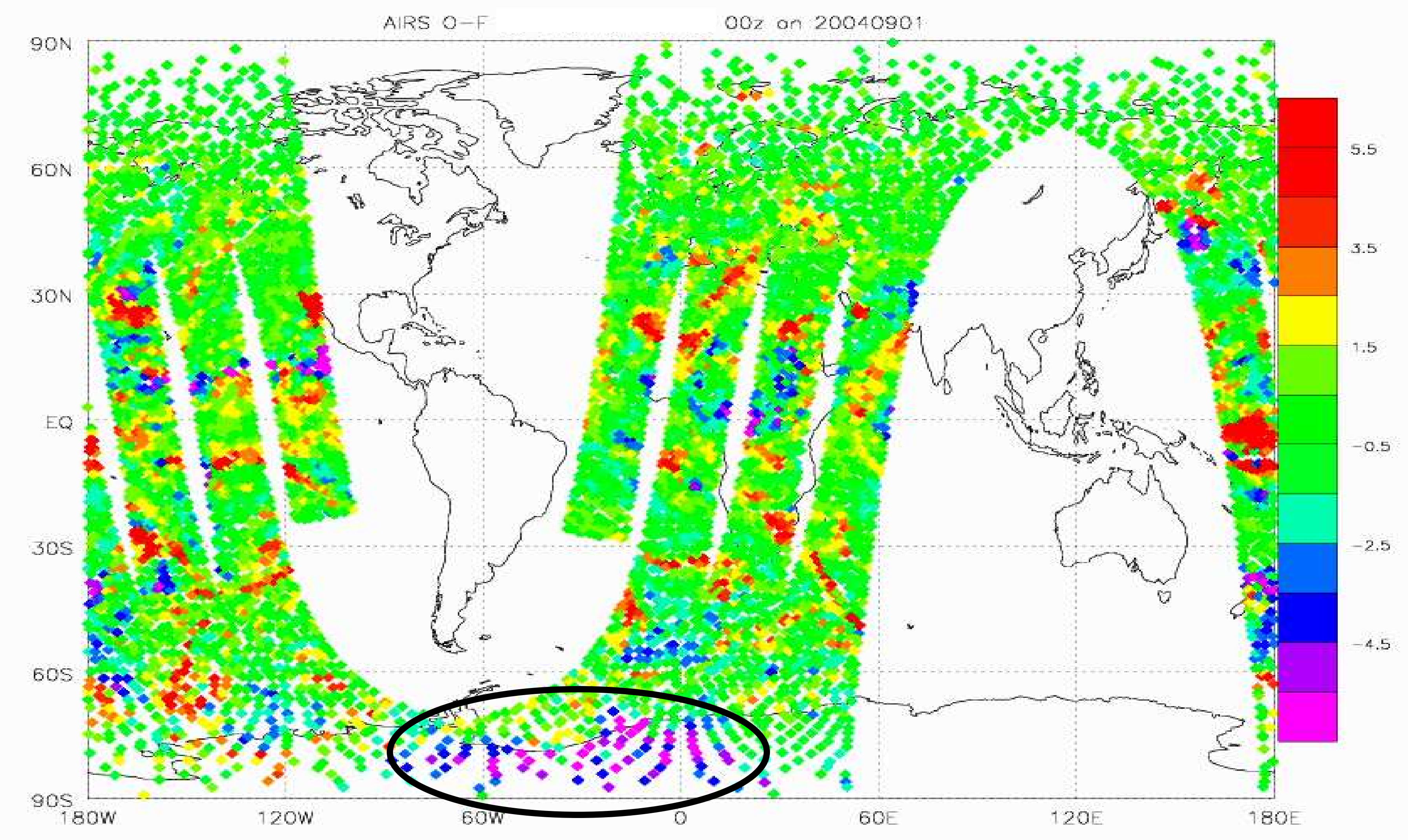
Gridpoint Statistical Interpolation (GSI) analysis scheme, developed by NCEP and adapted by GMAO

Data: conventional (e.g.,sondes, aircraft); IR and microwave radiances from NOAA platforms and EOS-Aqua; SBUV ozone retrievals

Gridpoint GCM developed in GMAO, with "finite volume" dynamical core (Lin) and GSFC physics package (Suarez, Bacmeister). Radiation code from Chou and Suarez; GWD from Garcia and Boville

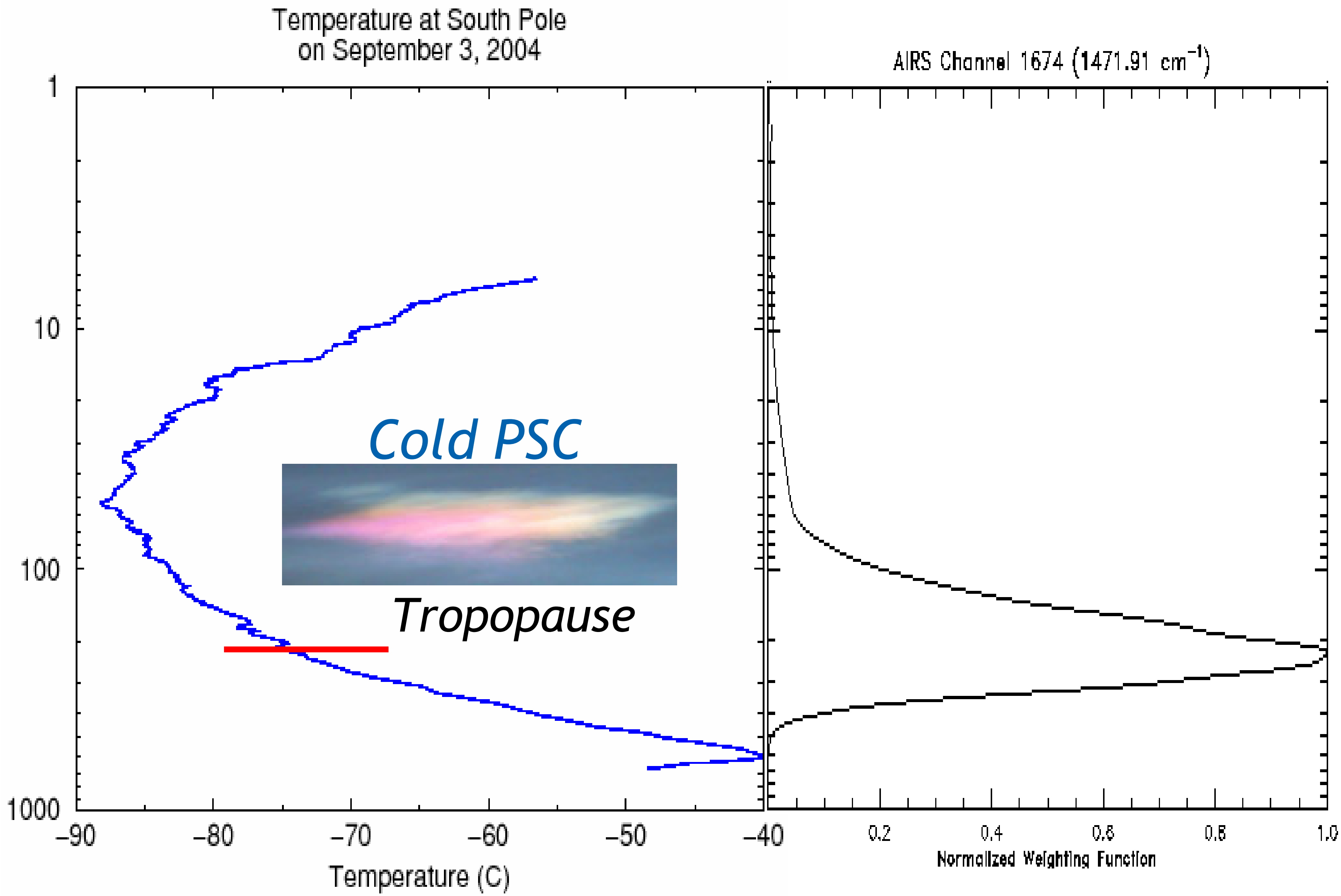
Assimilated analyses produced using "Incremental Analysis Update" technique, via "forcing terms" in the GCM

AIRS observed-forecast residuals



Thinned AIRS channel 1674 (1472 cm-1) O-F residuals, 6-hr timeframe

PSC sensitivity



MODTRAN

The MODerate spectral resolution atmospheric TRANsmission code was developed by AFRL/VSBT in collaboration with Spectral Sciences, Inc.

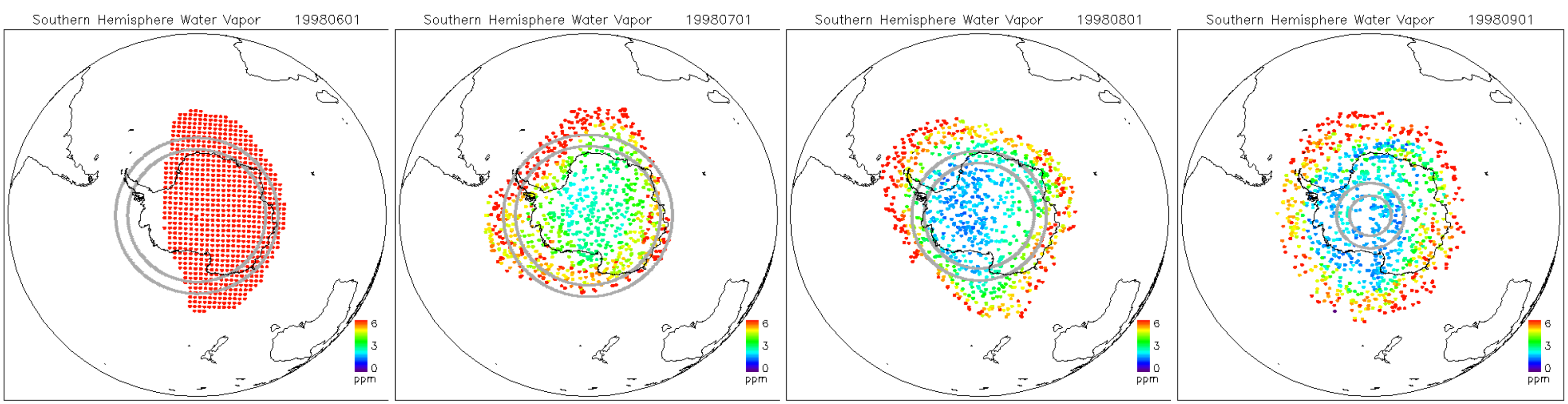
Models atmospheric propagation of electromagnetic radiation from the far-infrared (100 cm-1) to the deep ultraviolet (50000 cm-1) with a spectral resolution of 1 cm-1.

Capabilities include molecular band model parameterization, spherical refractive geometry, solar and lunar source functions, and scattering (Rayleigh, Mie, single and multiple), and default profiles (gases, aerosols, clouds, fogs, and rain).

Atmospheric profiles can be user-defined, including the inclusion of wavelength-dependent aerosol extinctions for cloud layers.

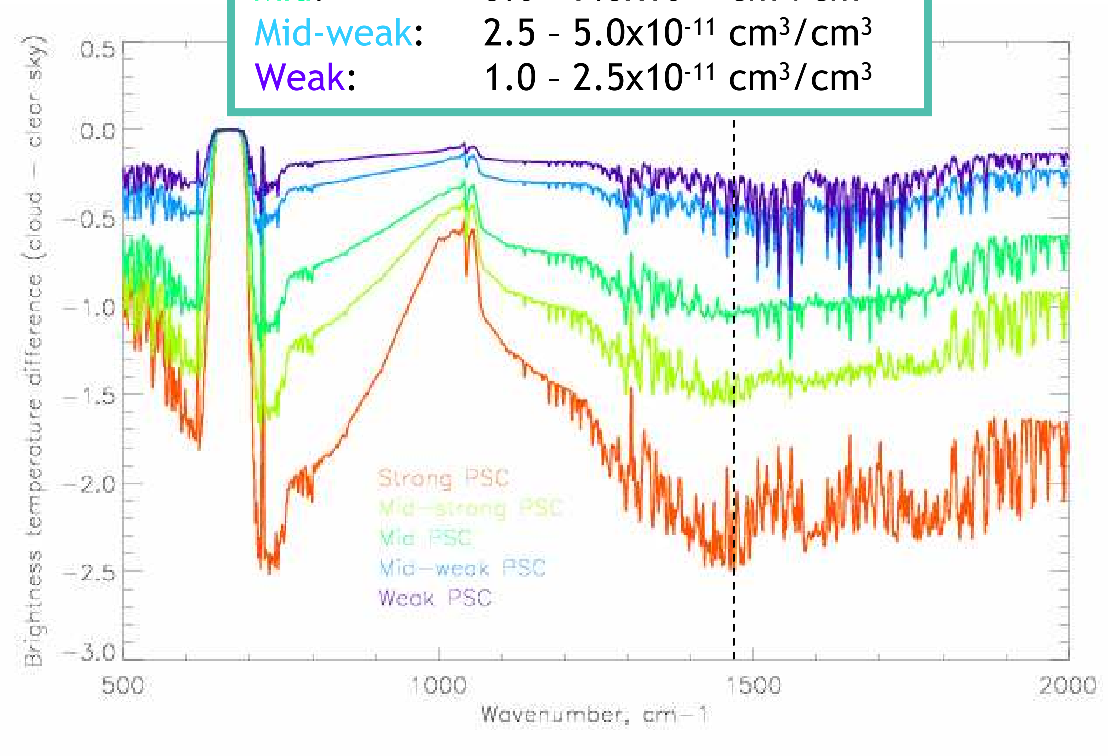
IMPACT

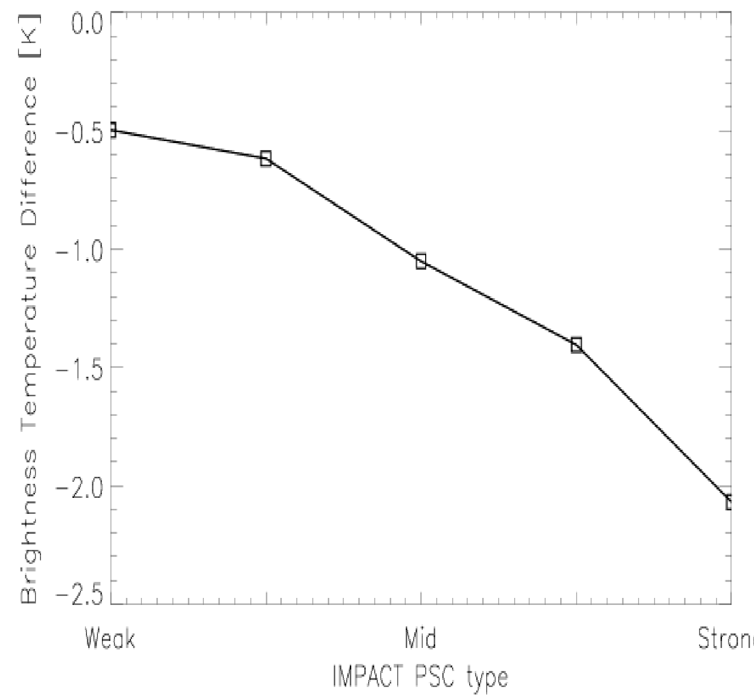
- Integrated MicroPhysics And Chemistry on Trajectories code calculates gas and aerosol mixing ratios and wavelength-dependent aerosol extinction in a single air parcel using microphysics, heterogeneous chemistry, and photochemistry.
- Calculations are performed for approximately 2000 parcels initialized on the 500 K isentrope and descend during the 1998 SH winter season (1 June – 30 September).
- Microphysical parameters are tuned using POAM III observations.
- Ice PSCs are categorized according to ice particle density, with the corresponding aerosol extinctions used in the MODTRAN code.



IMPACT/MODTRAN results

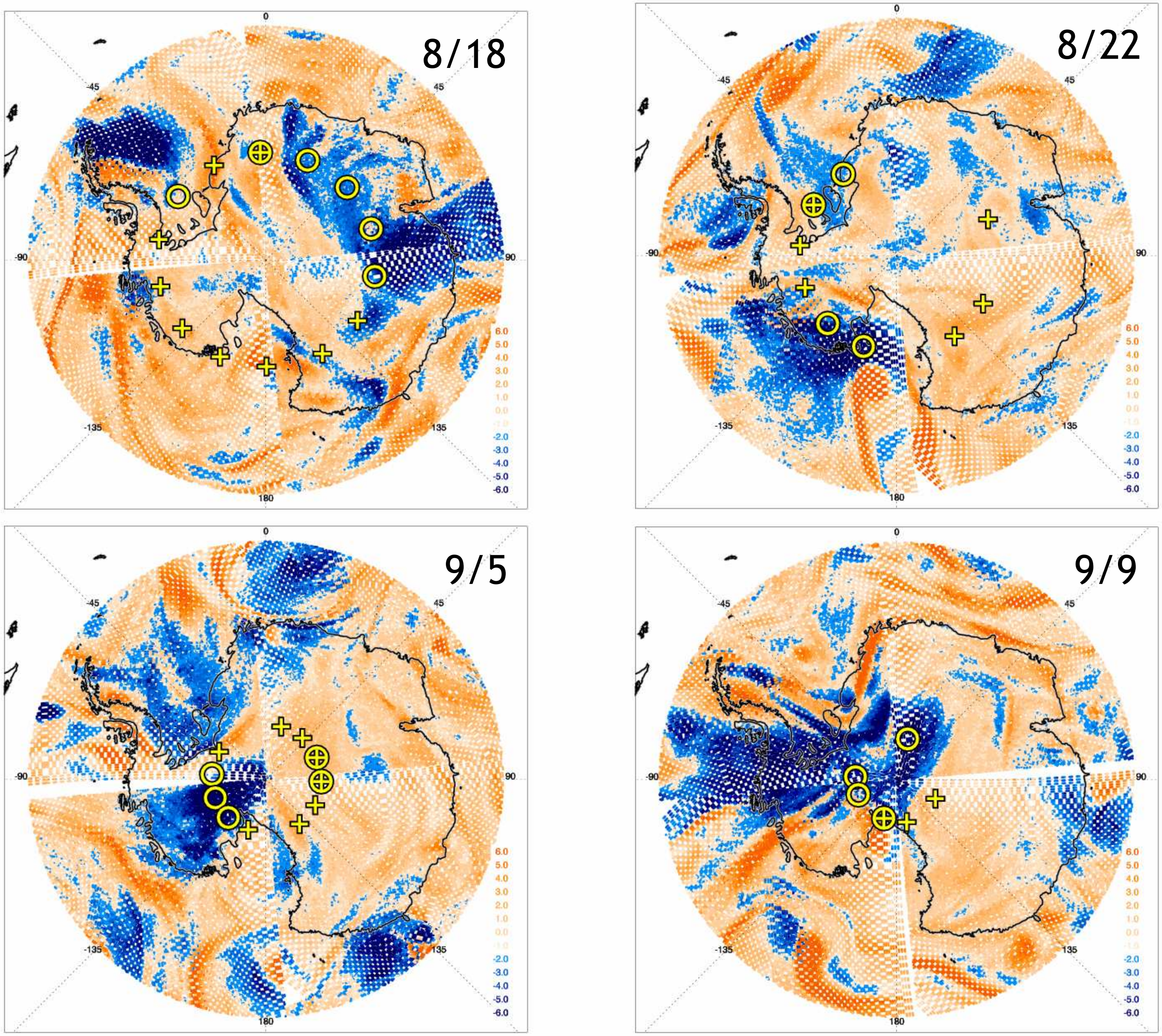
Strong:	>1.0×10^{-10} cm^3/cm^3
Mid-strong:	7.5 – 10.0×10^{-11} cm^3/cm^3
Mid:	5.0 – 7.5×10^{-11} cm^3/cm^3
Mid-weak:	2.5 – 5.0×10^{-11} cm^3/cm^3
Weak:	1.0 – 2.5×10^{-11} cm^3/cm^3





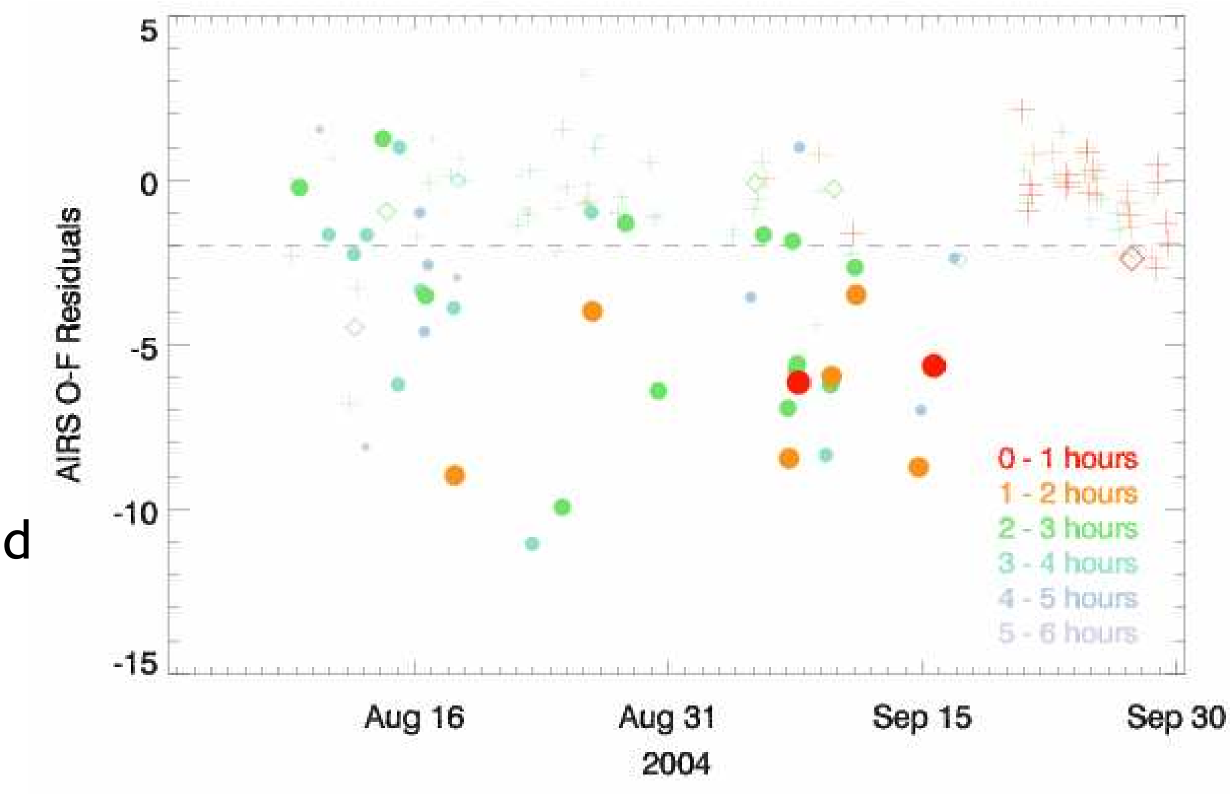
- Combined MODTRAN/IMPACT results indicate decrease in brightness temperature upon introduction of ice PSCs.
- Differences from clear sky conditions are shown.

POAM/AIRS comparison



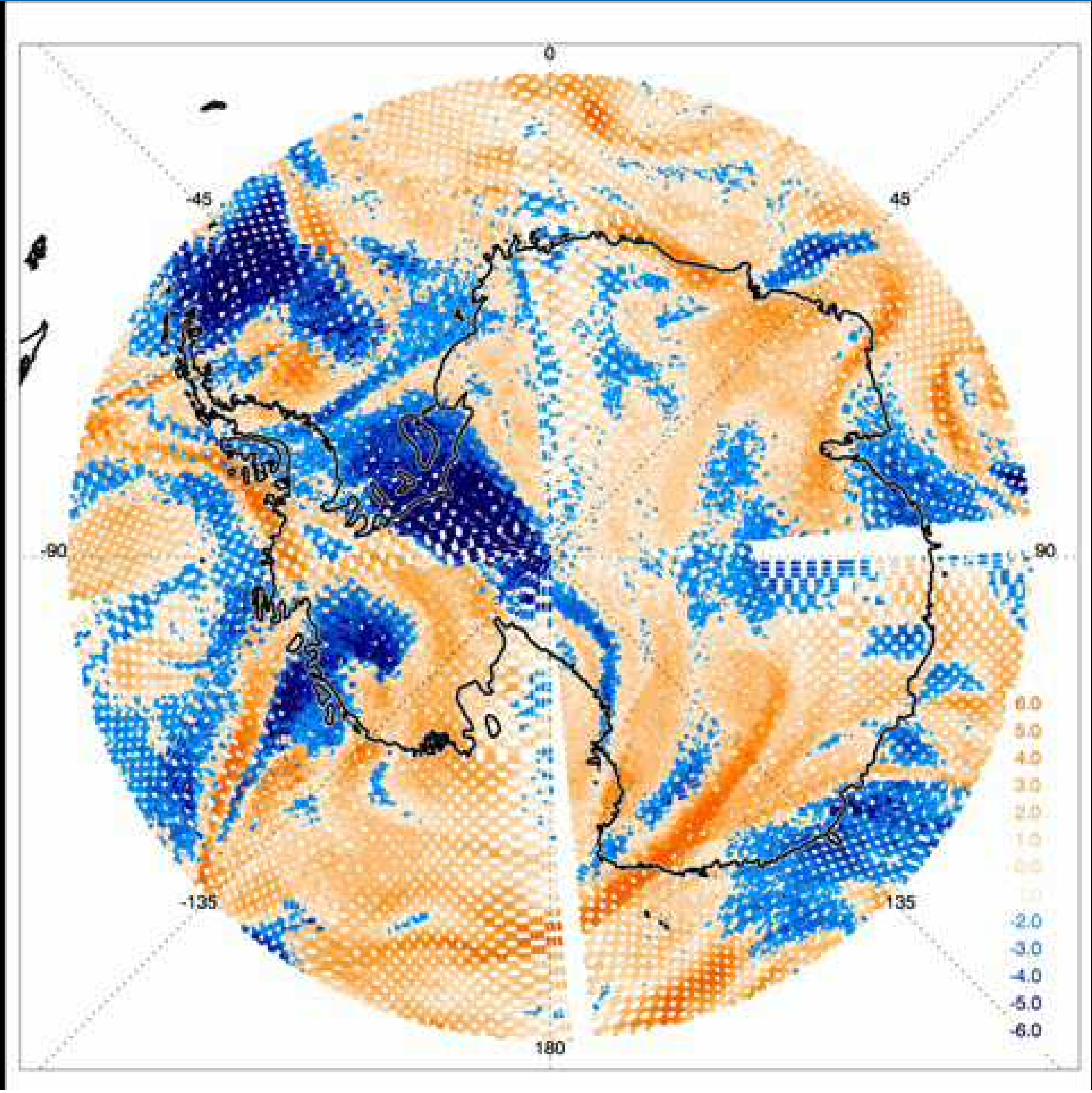
Time series

- Time series shows unthinned AIRS O-F residuals at locations and times of POAM measurements
- Due to differing measurement characteristics, AIRS and POAM measurements may be several hours apart, and so will not measure same air mass

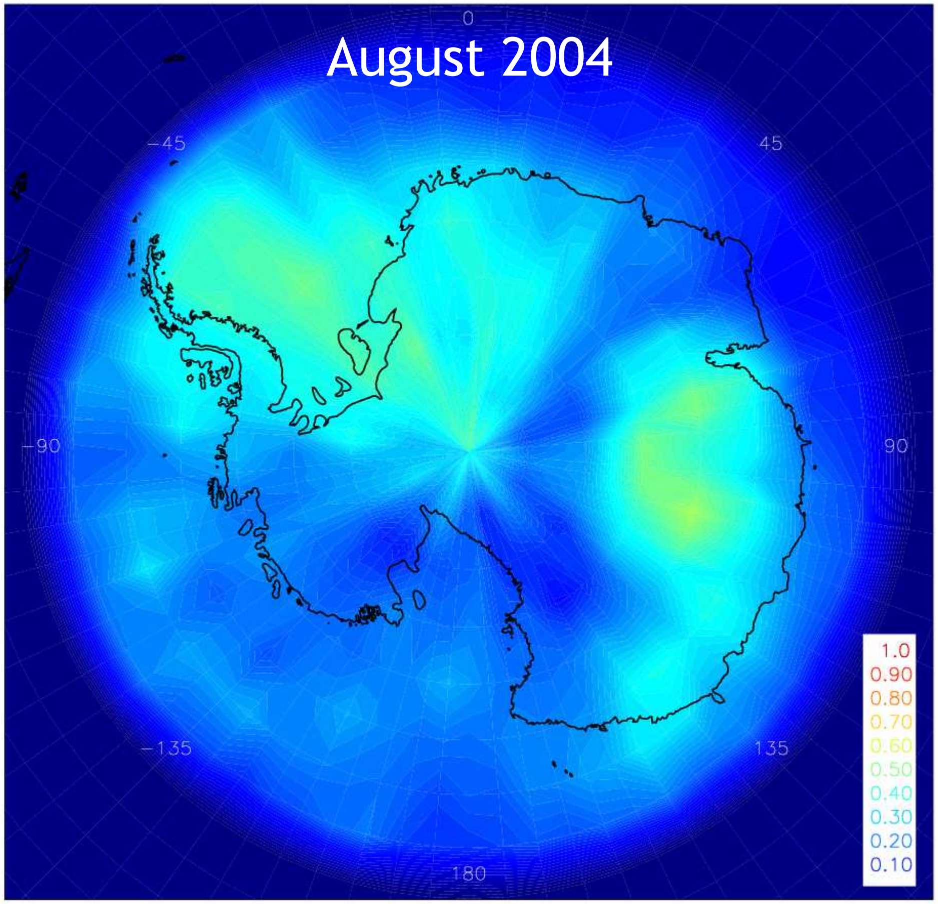


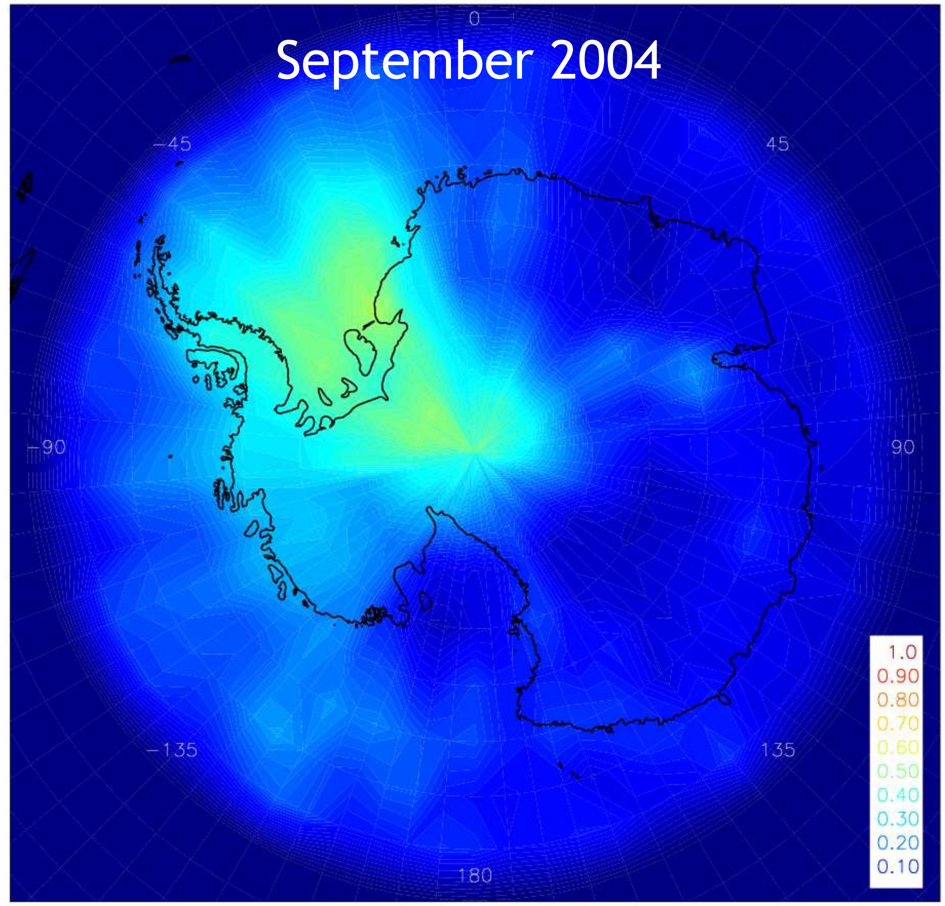
- For measurements coincident within ~2 hours, there is a high degree of correlation between O-Fs below -2 K and ice clouds
- Almost no clear-sky measurements have O-Fs below -2 K

August/September 2004



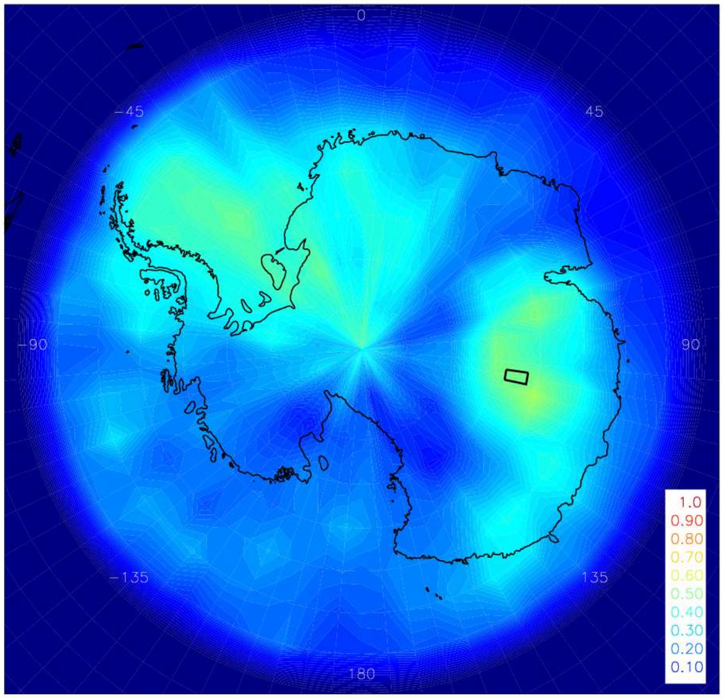
PSC frequency

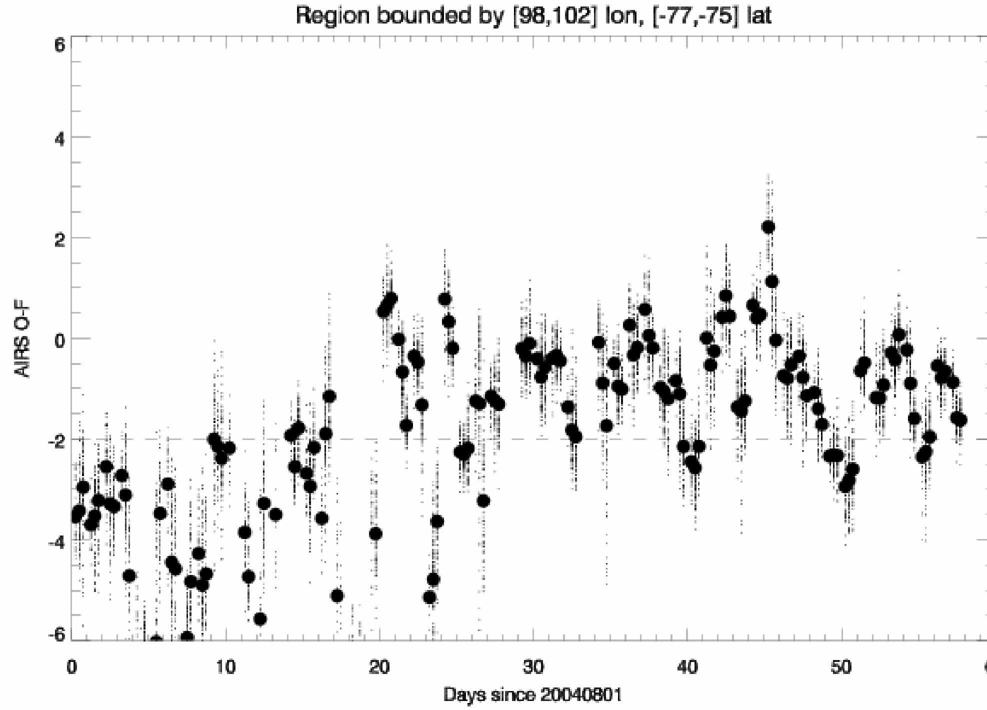


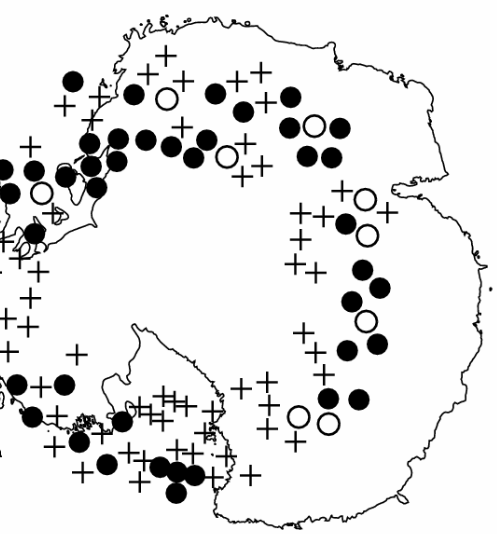


- O-F residuals over a full month can be used to estimate the frequency of occurrence of ice PSCs.
- PSCs frequently appear downwind of Antarctic Peninsula, but also close to 90° E in August.

August PSCs



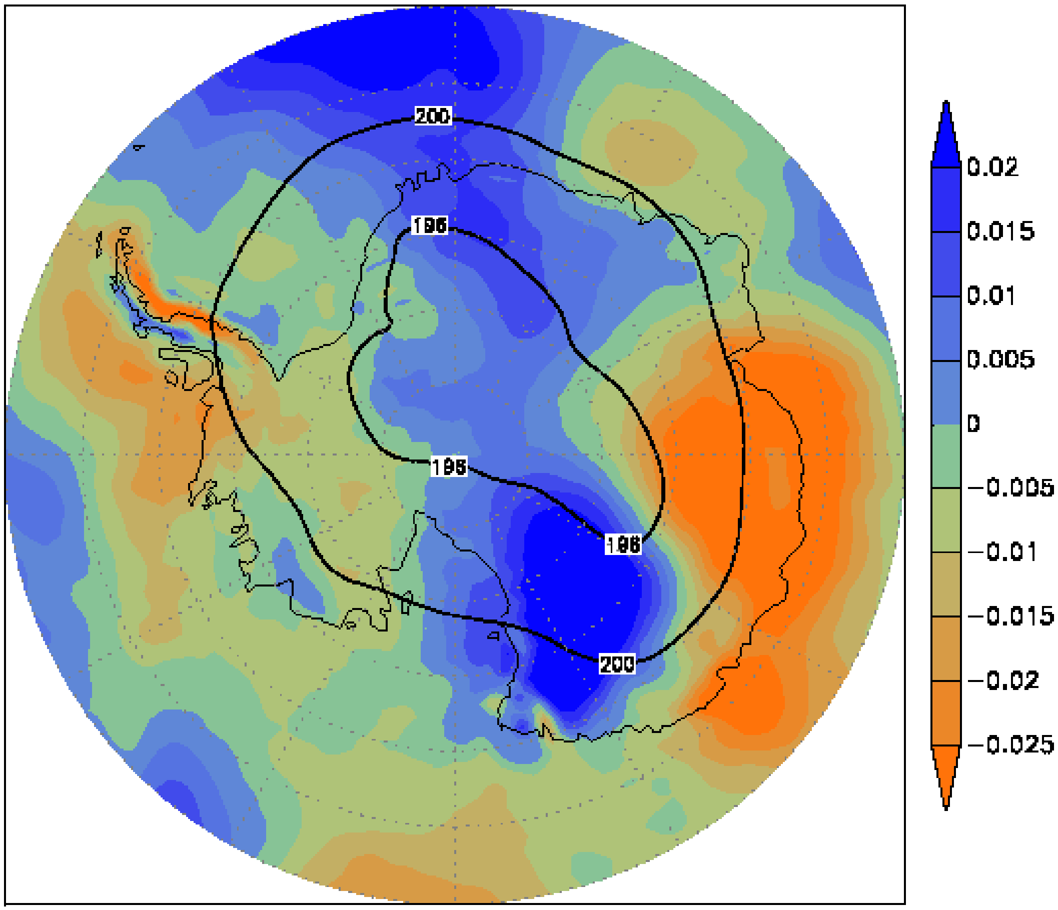




POAM

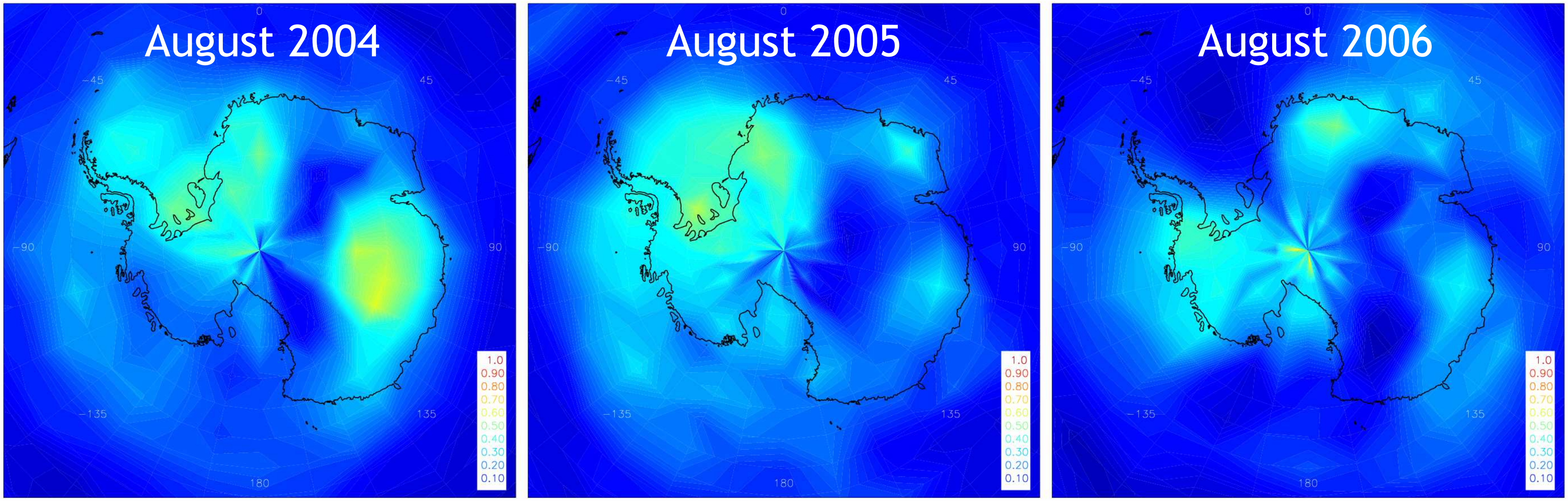
- Frequent PSCs in early August downwind of 90^o E.
- Cannot be resolved by POAM

Upwelling



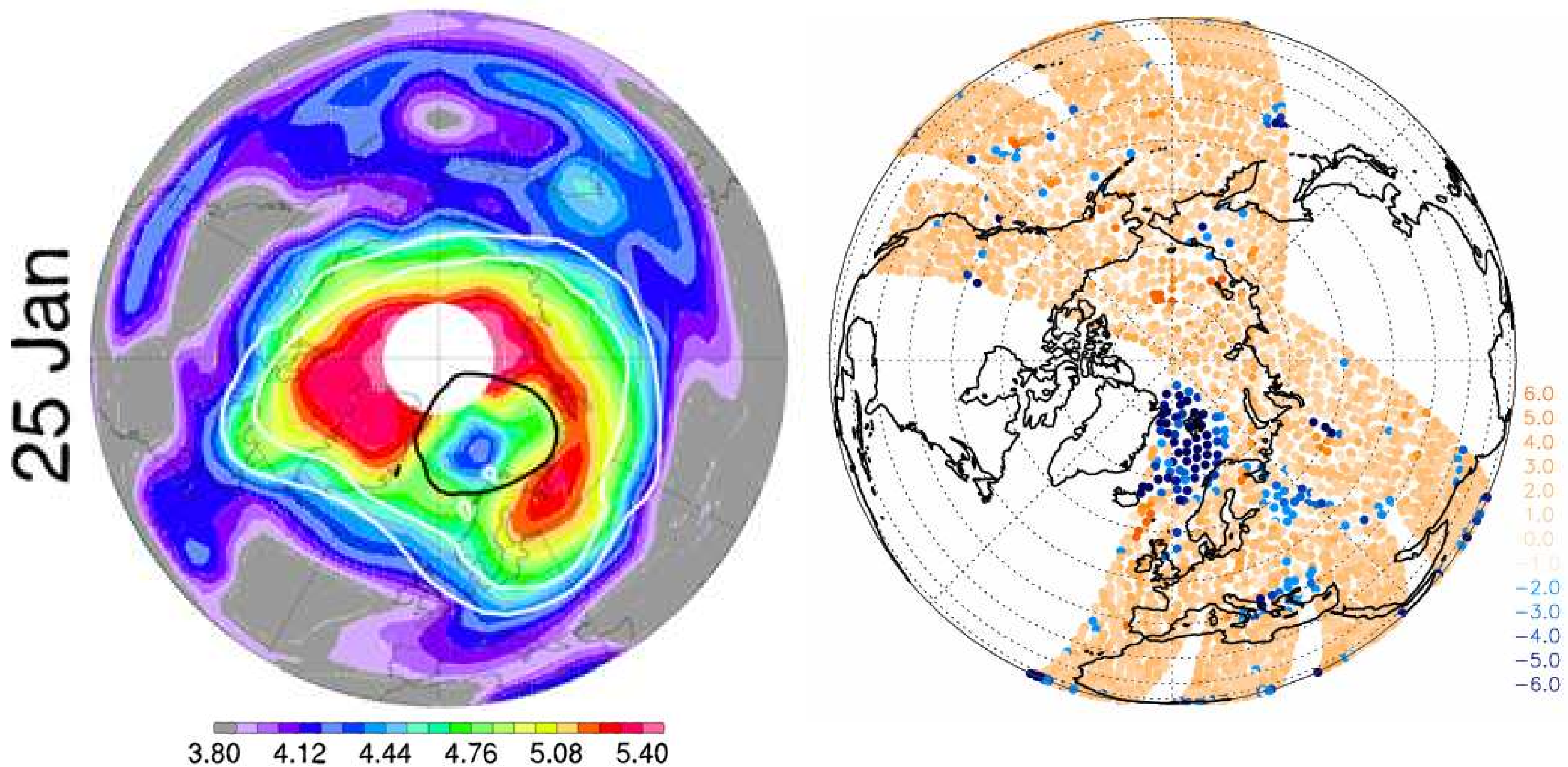
- Map of mean vertical velocity ω (Pa/s), temperature contours for August 2004 at 200 mb
- Significant upwelling is present around 100° E, in region of high PSC activity
- Moist tropospheric air may be upwelling into the stratosphere where PSCs form
- Also note the presence of wave activity at the Antarctic Peninsula, a possible PSC formation trigger

Thinned annual PSC frequencies



- Annual changes in PSC frequency distribution evident from thinned AIRS O-F residuals
- High degree of variability in longitudinal dependence of PSCs
- Data can lead to a detailed climatology, insight into PSC formation when coupled with wind and temperature fields

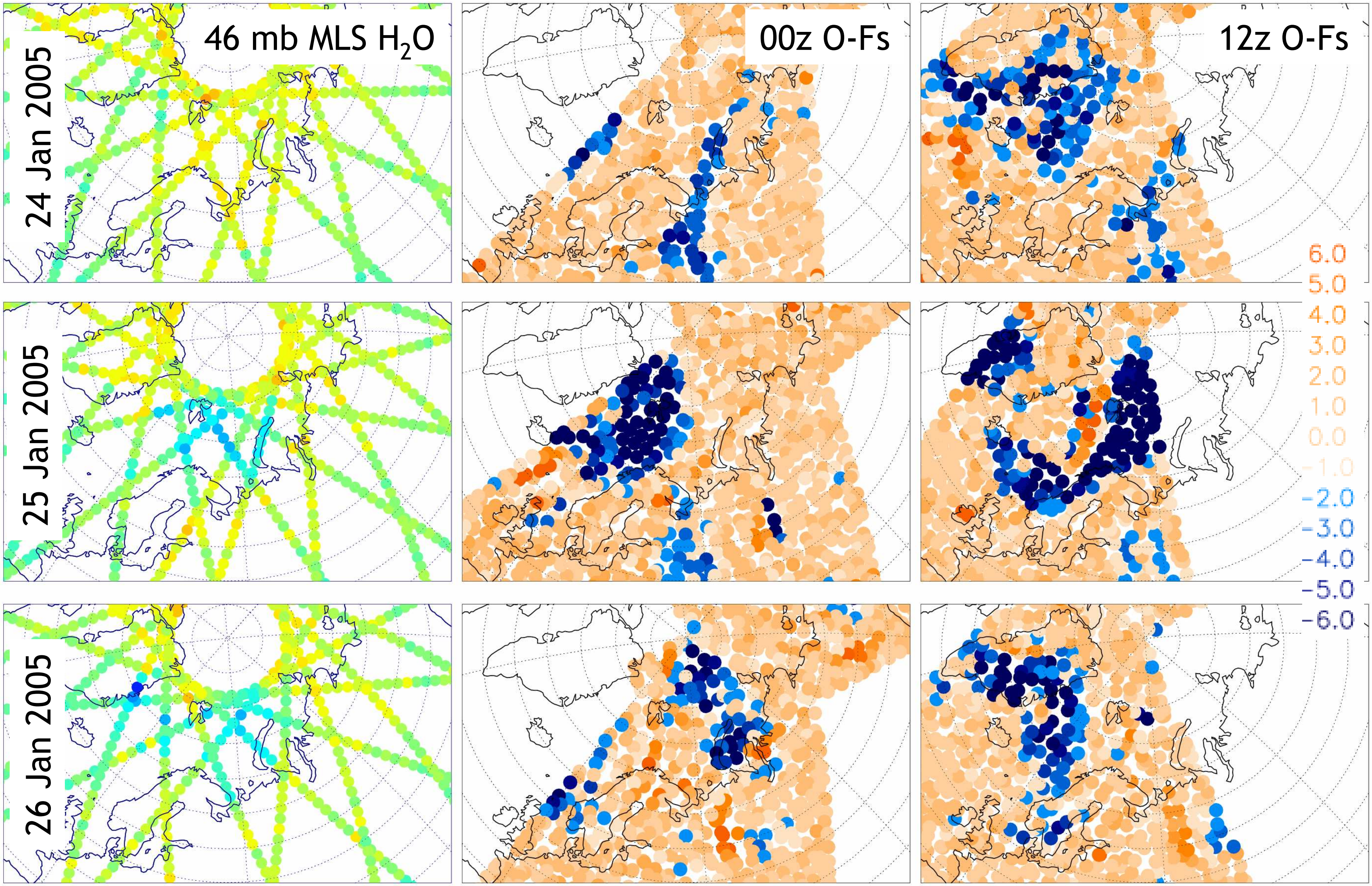
Northern hemisphere ice cloud



- Ice PSC inferred by MLS water vapor measurements at 480 K on 25 Jan 2005[1]
- Corresponds to region of very low O-Fs

[1]Jimenez et al. GRL, 33, L16806, doi:10.1029/2006GL025926, 2006.

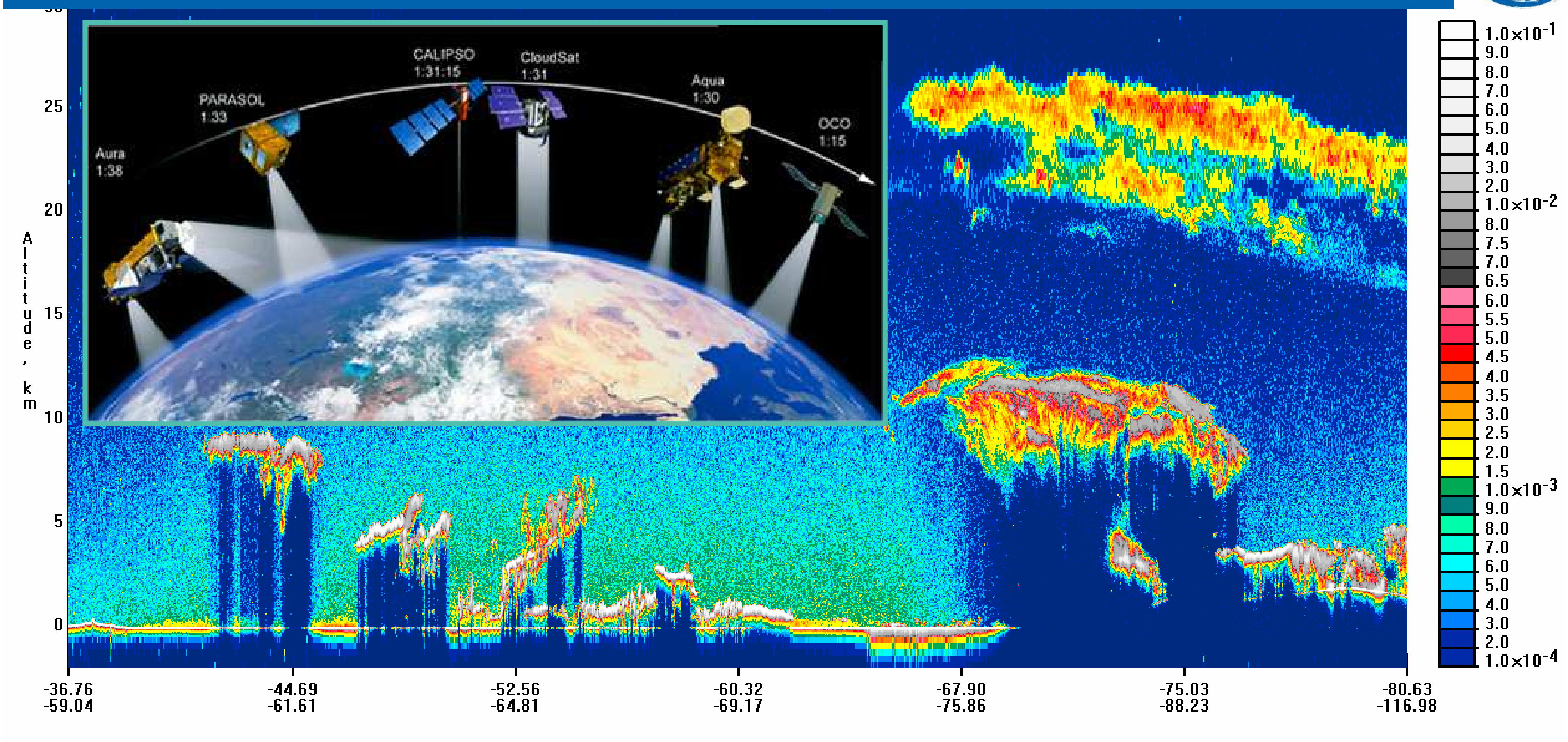
MLS comparisons



Conclusions

- AIRS observed-forecast residuals frequently highly negative in Antarctic winter
- Combined MODTRAN and IMPACT results indicate that the presence of ice PSCs may lead to negative AIRS O-Fs
- High degree of correlation exists between negative AIRS O-Fs and POAM observations of Antarctic ice PSCs
- MLS observations of a Northern hemisphere ice cloud also corresponds to region of negative AIRS O-Fs
- Longitudinal dependence of PSC formation highly variable from year to year
- Unusual region of high PSC occurrence in August 2004 corresponds to upwelling of moist tropospheric air into stratosphere

Future studies: CALIPSO



- CALIPSO observes vertically-resolved extinction with high resolution
- Launched in 2006 as part of NASA's A-Train, leading to measurements nearly coincident with AIRS

IAU implementation