An optically thick PSC generated by gravity wave activity over Antarctica, and its potential for NAT belt seeding

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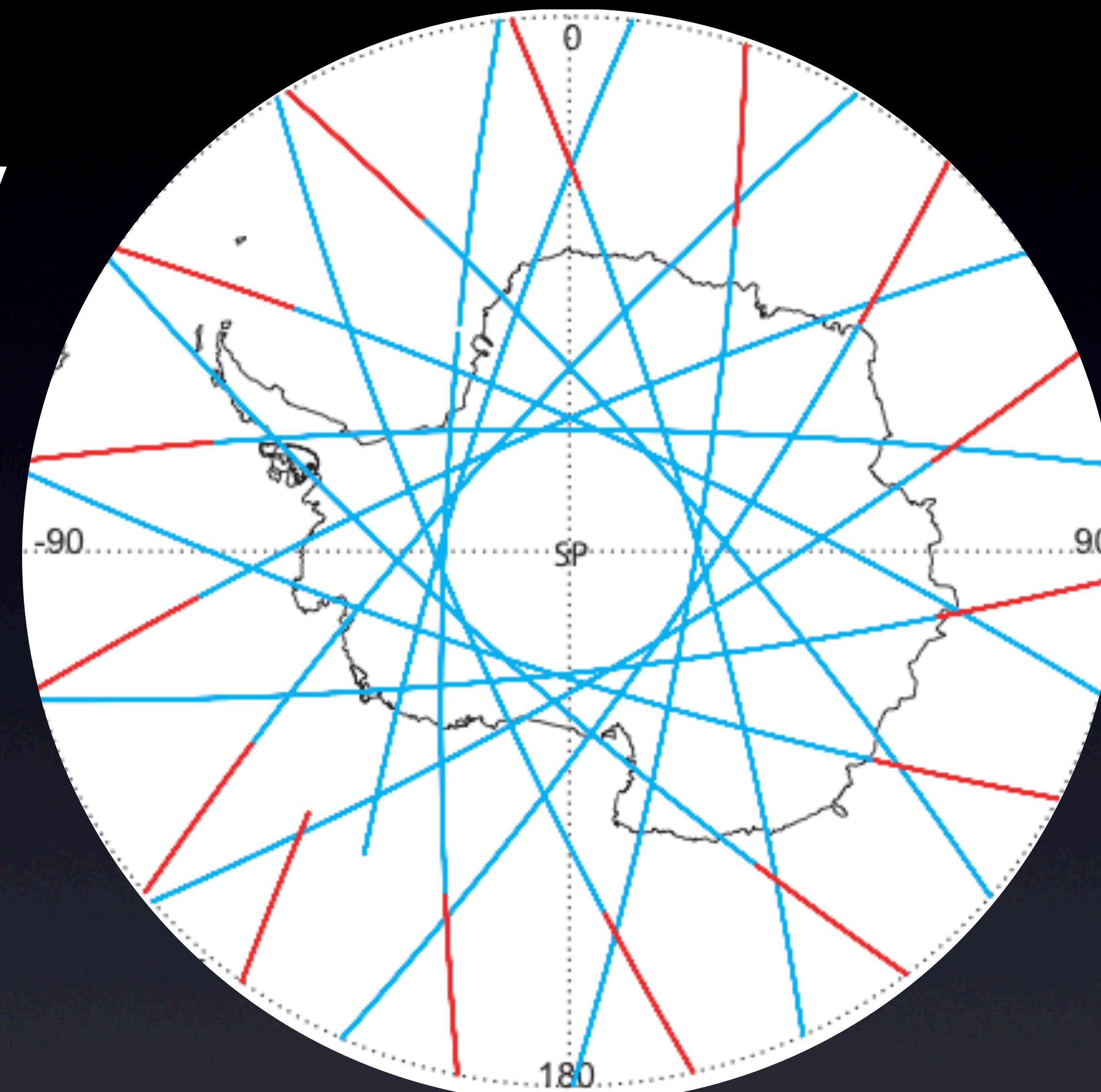
Polar Stratospheric Clouds

- form in the cold stratosphere during wintertime night conditions over the polar regions
- host heterogeneous chemical reactions that transform passive reservoir chlorine and bromine in their ozone-destroying forms
- scavenge nitric acid, slowing down the conversion of active species back into passive
- can be made of ice crystals, or $H_2O/HNO_3/H_2SO_4$ compound particles (NAT, NAD, STS...), depending on their formation environment (esp. temperature)
- are hard to monitor
  - passive occultation remote sensing is fine for cloud cover, but limited resolution

CALIPSO

- Platform launched in 2006
  - Orbits the earth ~14 time a day
  - ±82°
  - representative sampling of polar regions
- 3 instruments
  - WFC
  - IIR
  - CALIOP



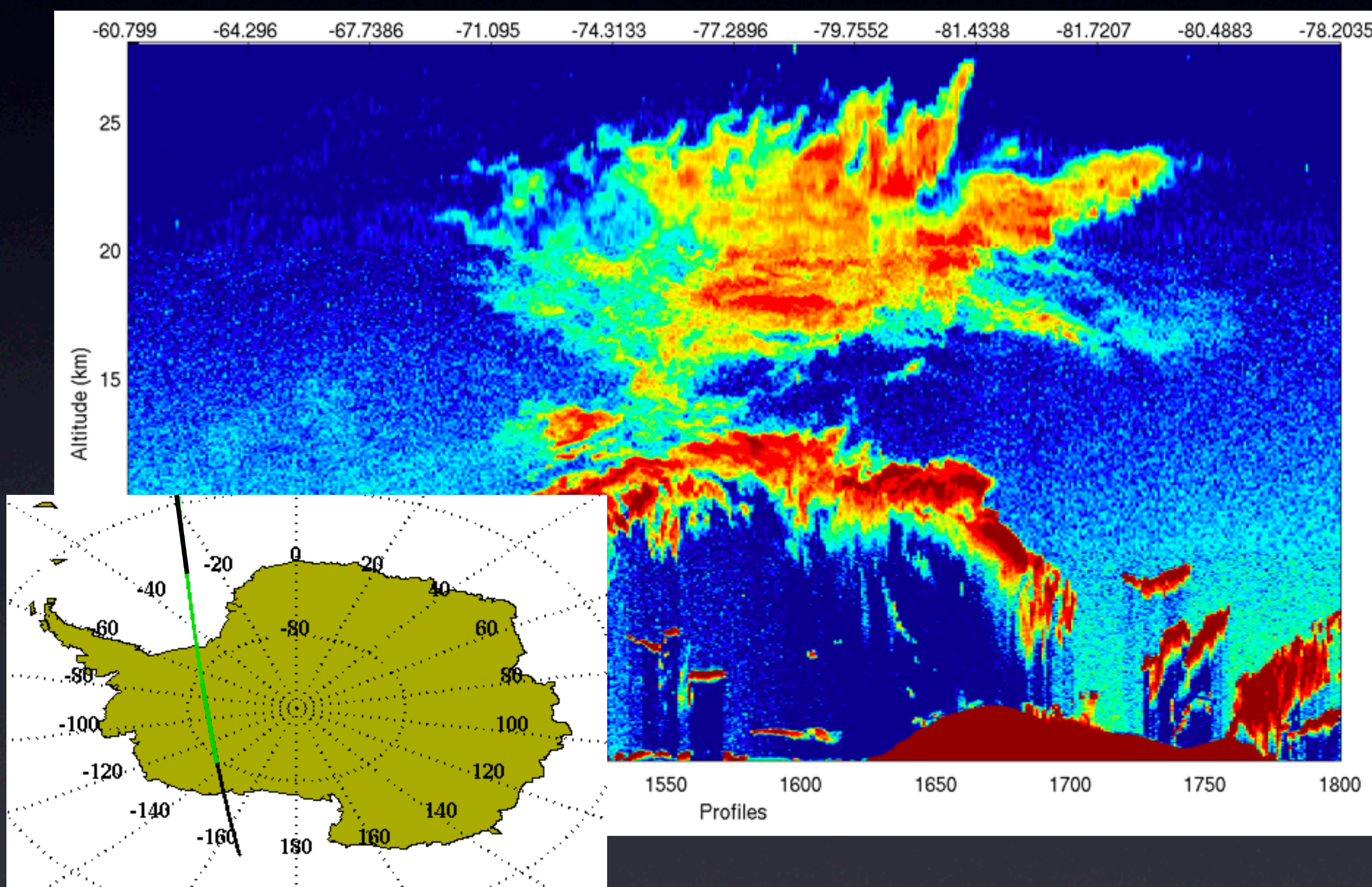
from *Pitts et al. 2007, ACP*

CALIOP: the CALIPSO lidar

- First operational spaceborne lidar
- two-wavelengths (532, 1064 nm), sensitive to light polarization
- documents vertical variability of backscatter, depolarization ratio, color ratio from ~40 km down to the ground
- retrieves the vertical distribution of macrophysical and optical properties for clouds, aerosols in a narrow atmospheric column below the satellite
- finest horizontal resolution 333 m
- vertical resolution is altitude-dependent : low tropo 30 m, upper tropo 60 m, low strato 180 m
- still going strong today - soon 4 years of data

PSCs from CALIOP (1)

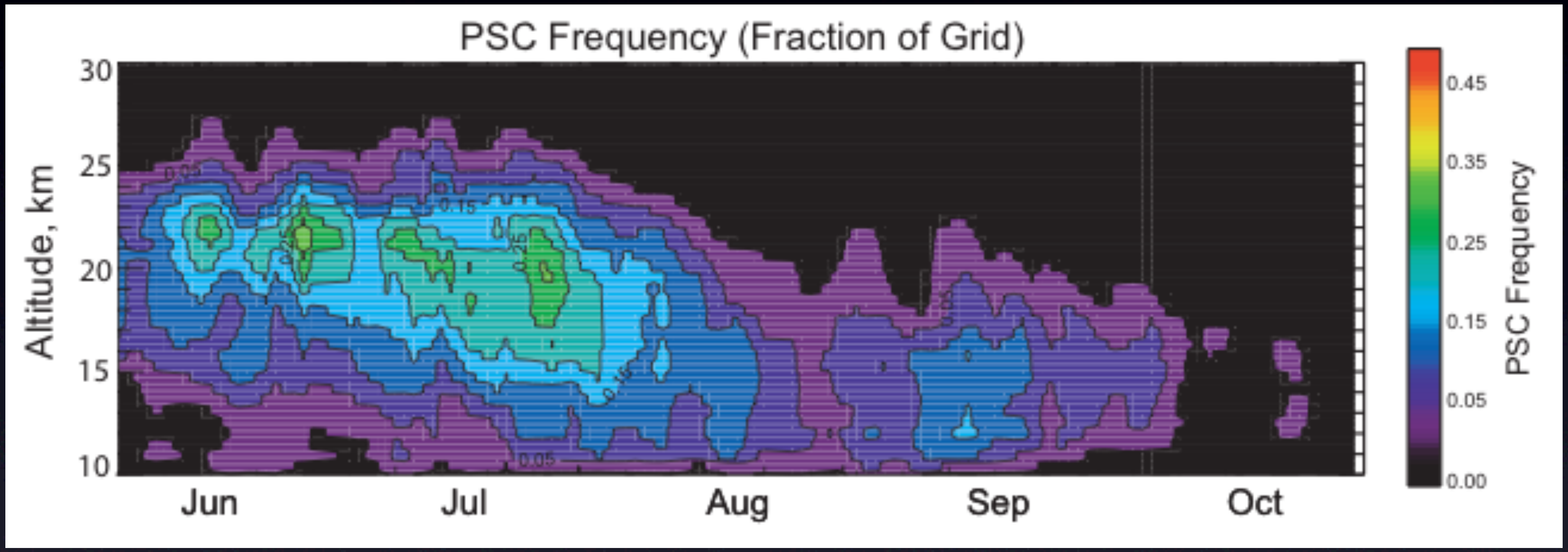
- Even though it was not part of the main objectives of the mission, CALIOP has provided unexpected insights into the distribution and composition of PSCs



- hi-res spatial localization
- depolarization informs about particle type (ice, NAT, STS)
- Individual PSC tracking (when lucky)

PSCs from CALIOP (2)

- Even though CALIOP observations describe a limited area, statistical inferences are possible through aggregation



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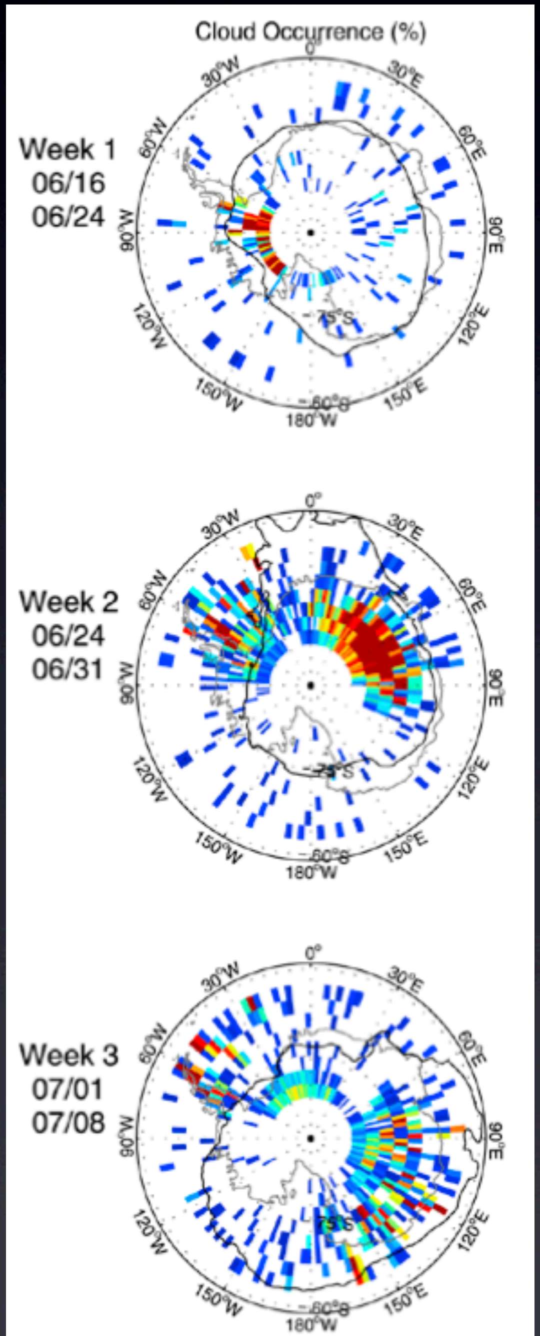
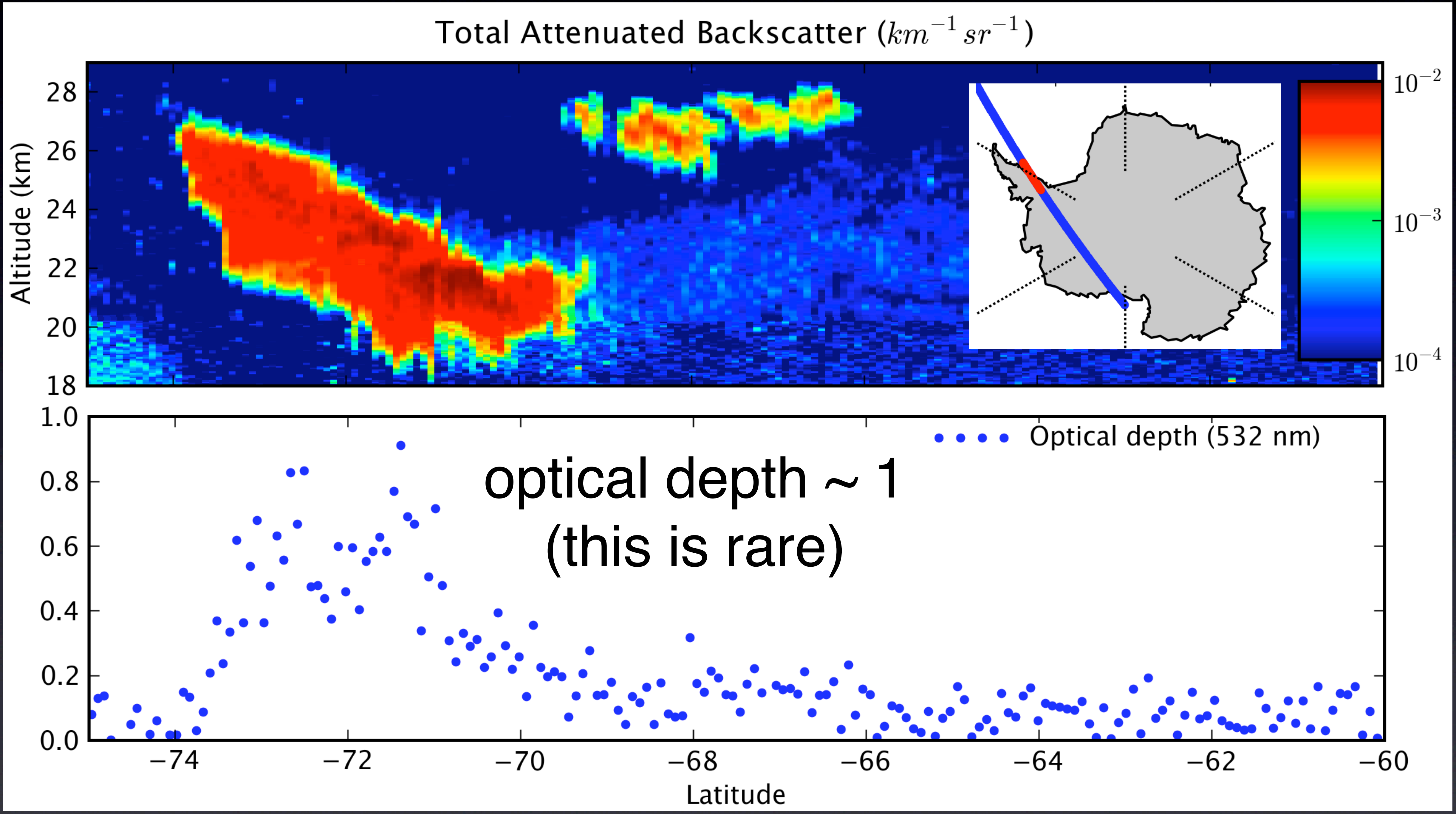


from *Noel et al. 2007, JGR*

An optically thick PSC (1)

- CALIOP overpass over the peninsula, june 2006

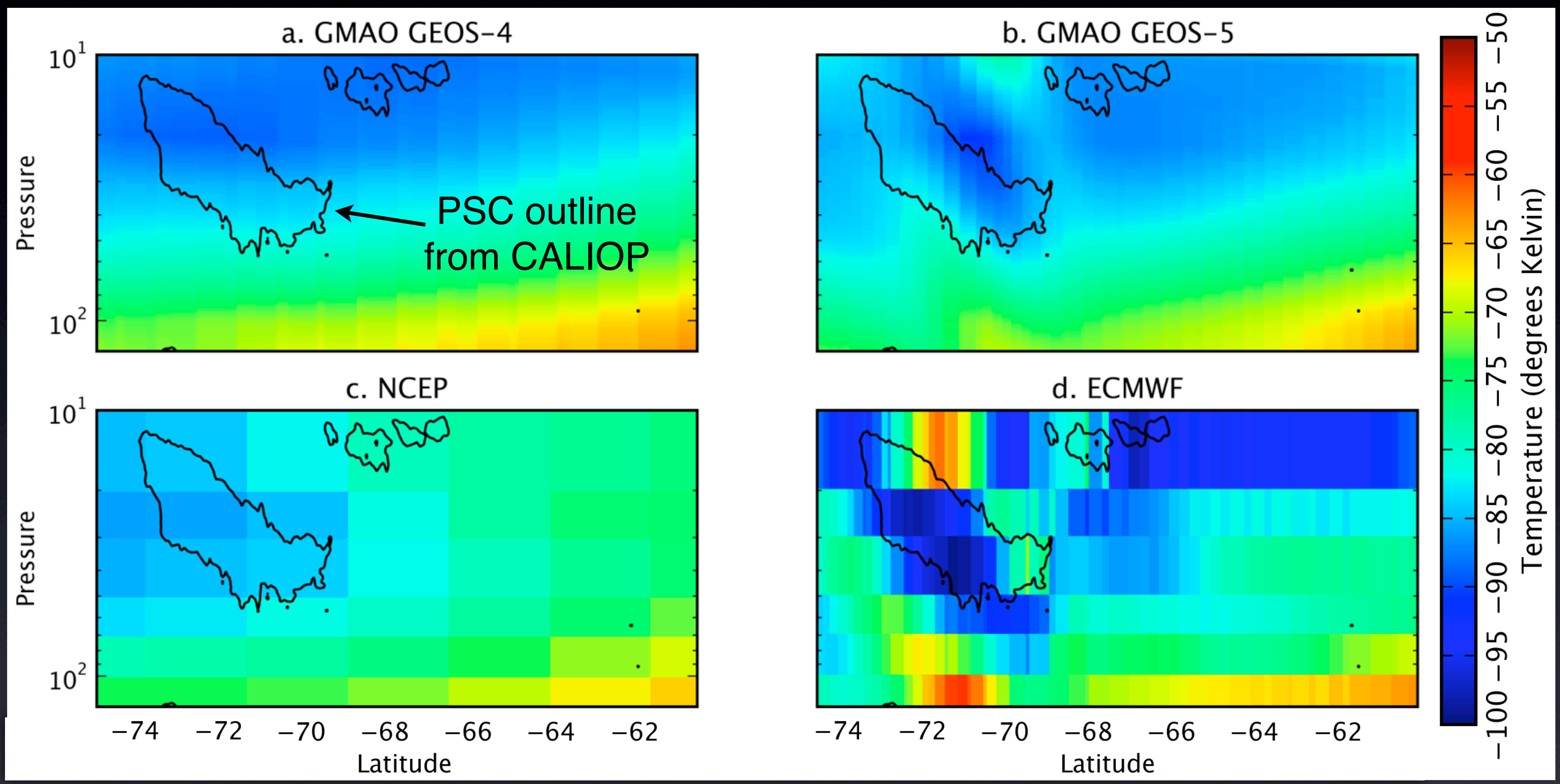


An optically thick PSC (2)

- According to its optical properties (depolarization, scattering ratio), this PSC is ice
- ice crystals nucleate at temperatures below ~188K or -85°C (considering common stratospheric water vapour concentrations) (*Alfred et al. 2007, ACP*)
- is this consistent with the PSC formation environment?

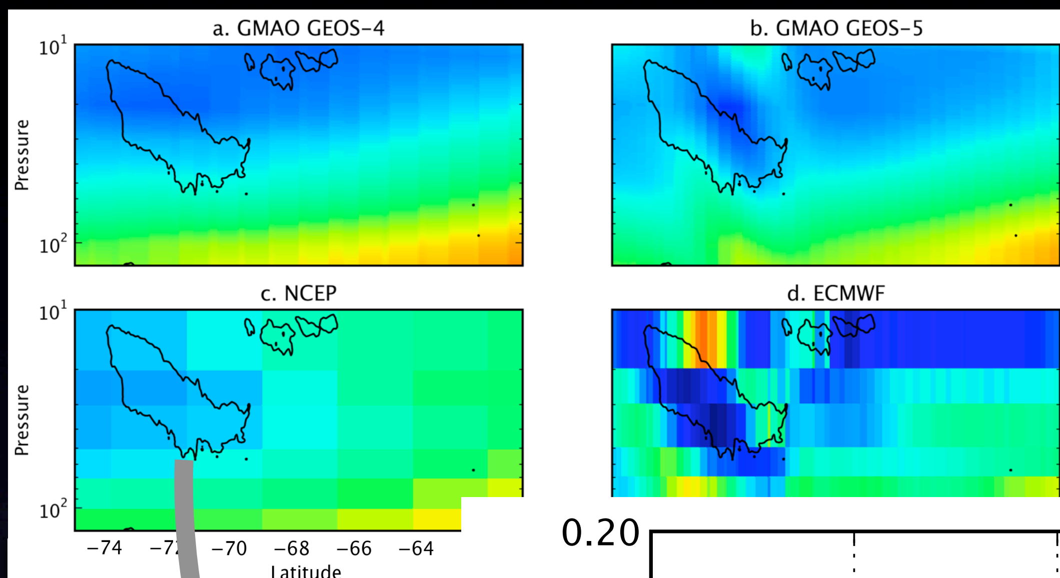
Temperature in the lower stratosphere

- We extracted GEOS4, GEOS5, NCEP, ECMWF temperatures along the CALIPSO trajectory and line of sight

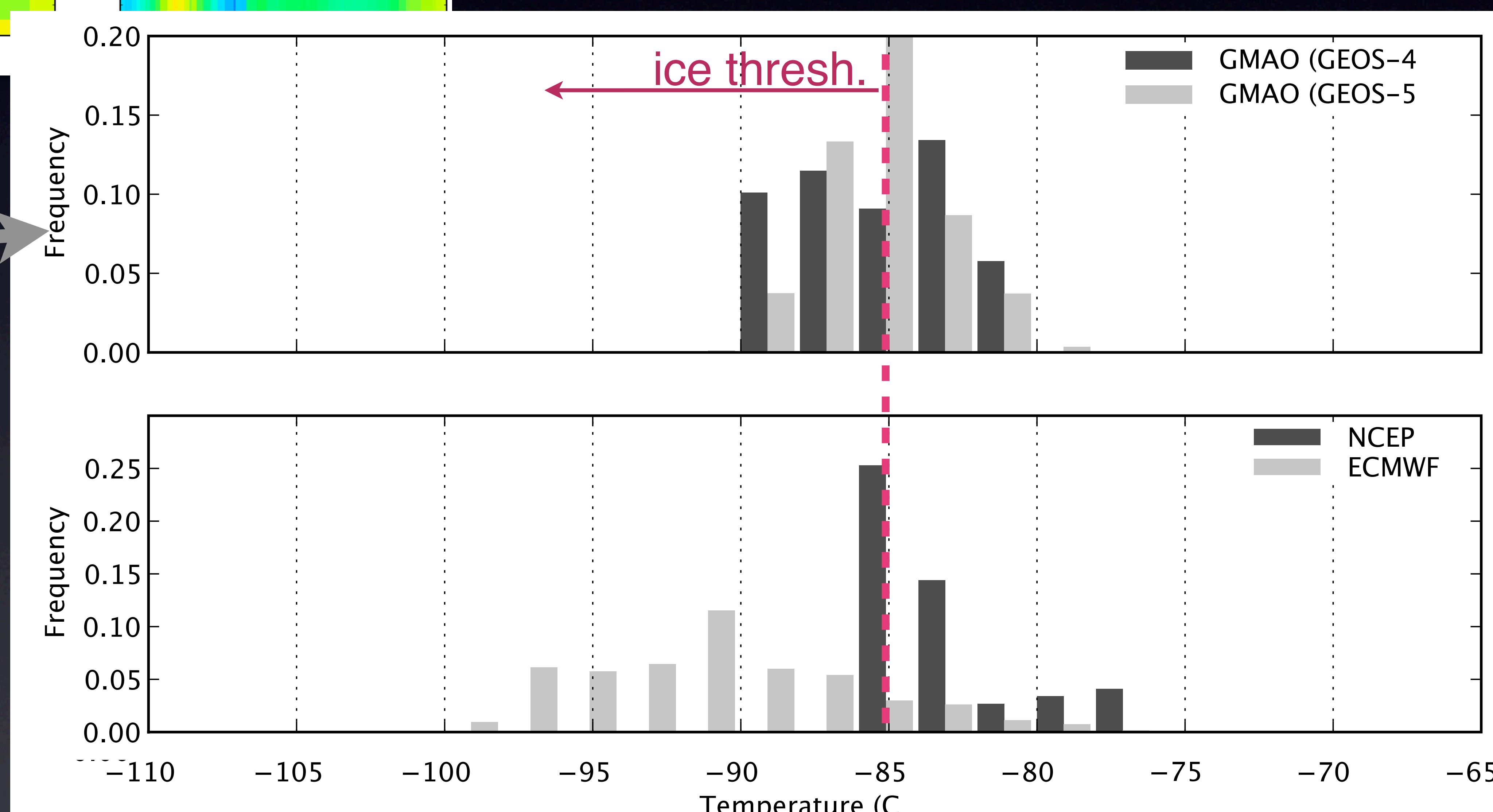


- Hints of a gravity wave event appear in NCEP, ECMWF, but are poorly resolved compared to CALIOP obs.

Temperatures within the PSC

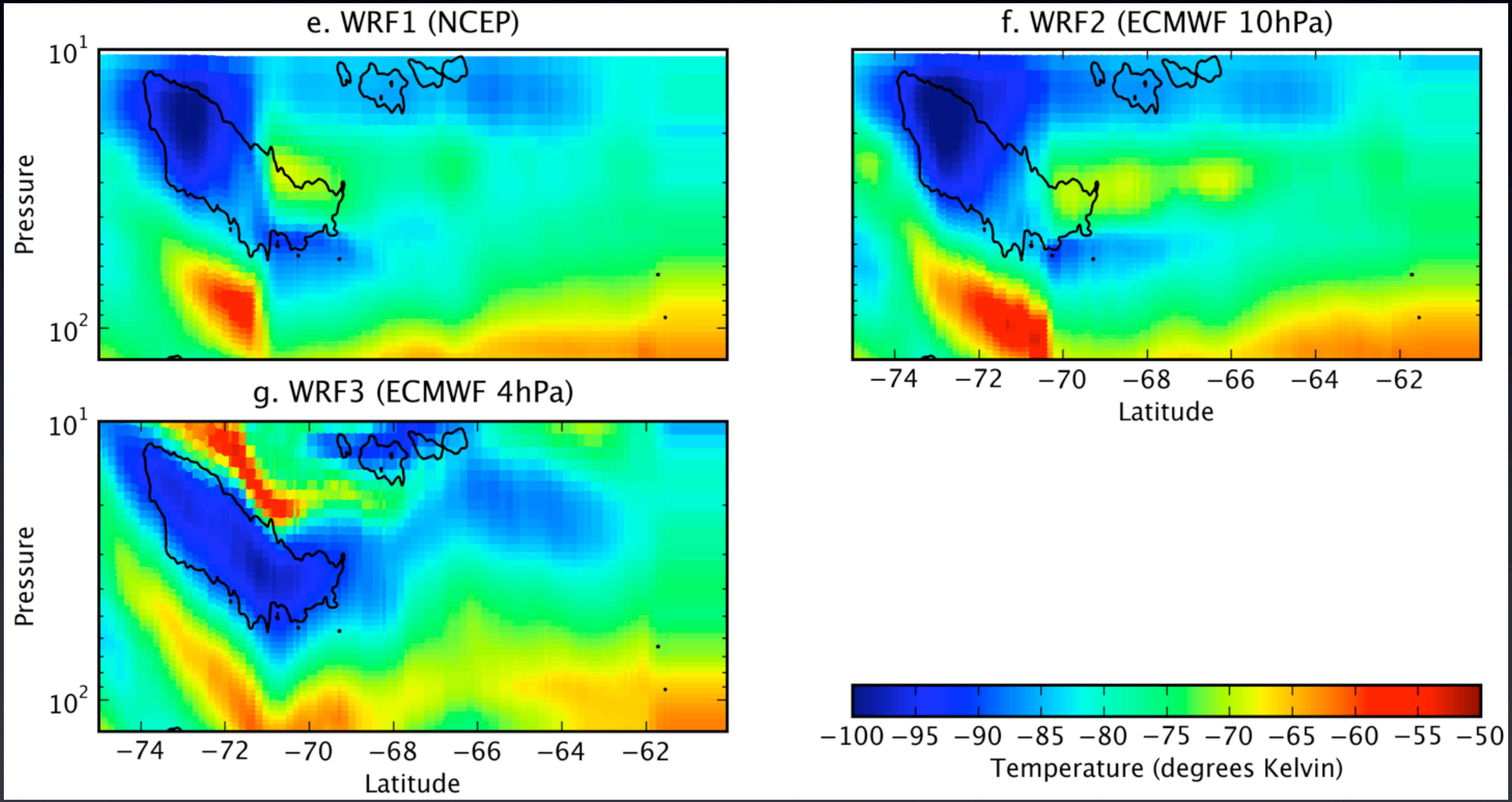


Temperature distributions within PSC are either too warm or scattered to explain its formation

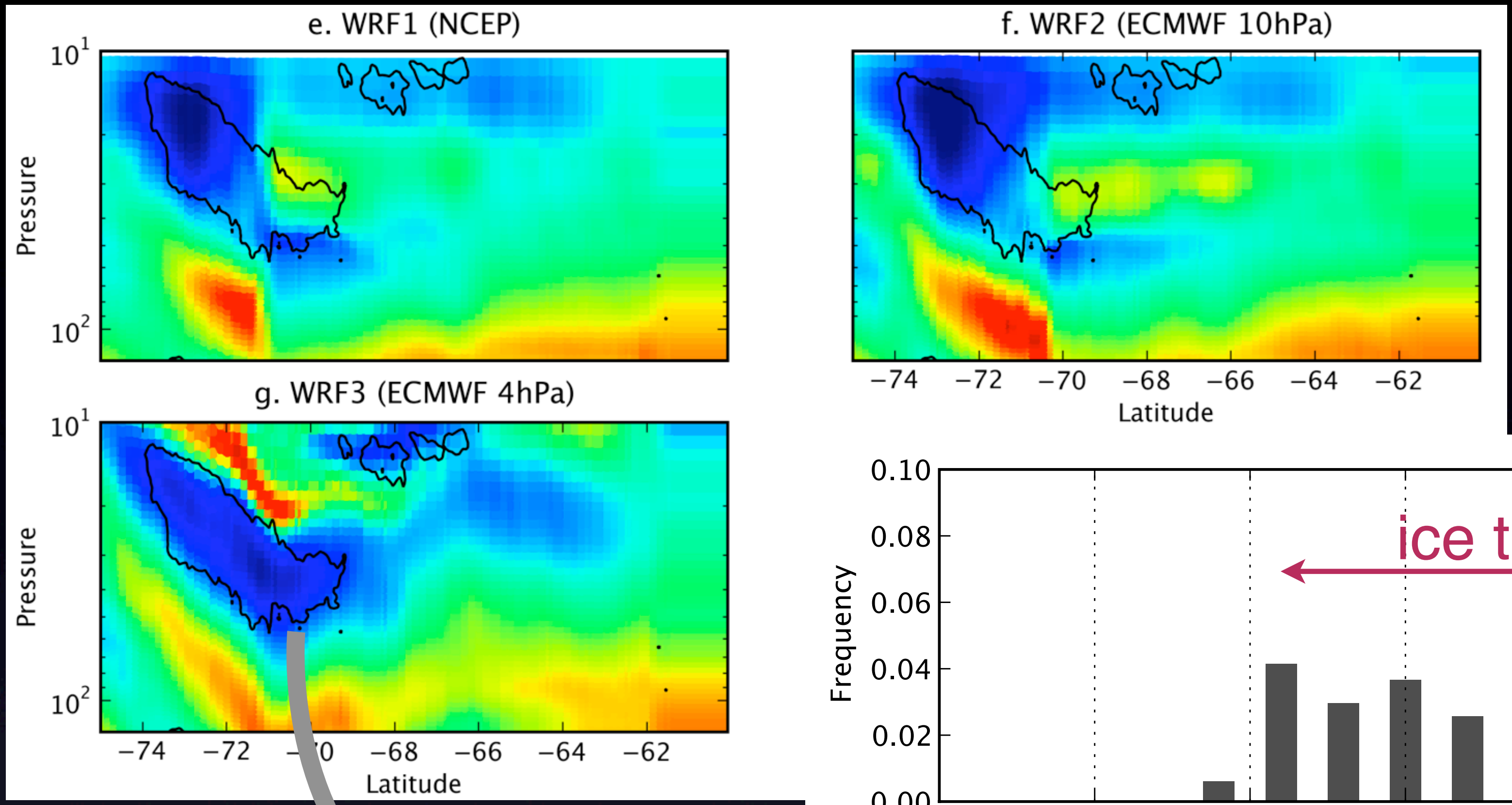


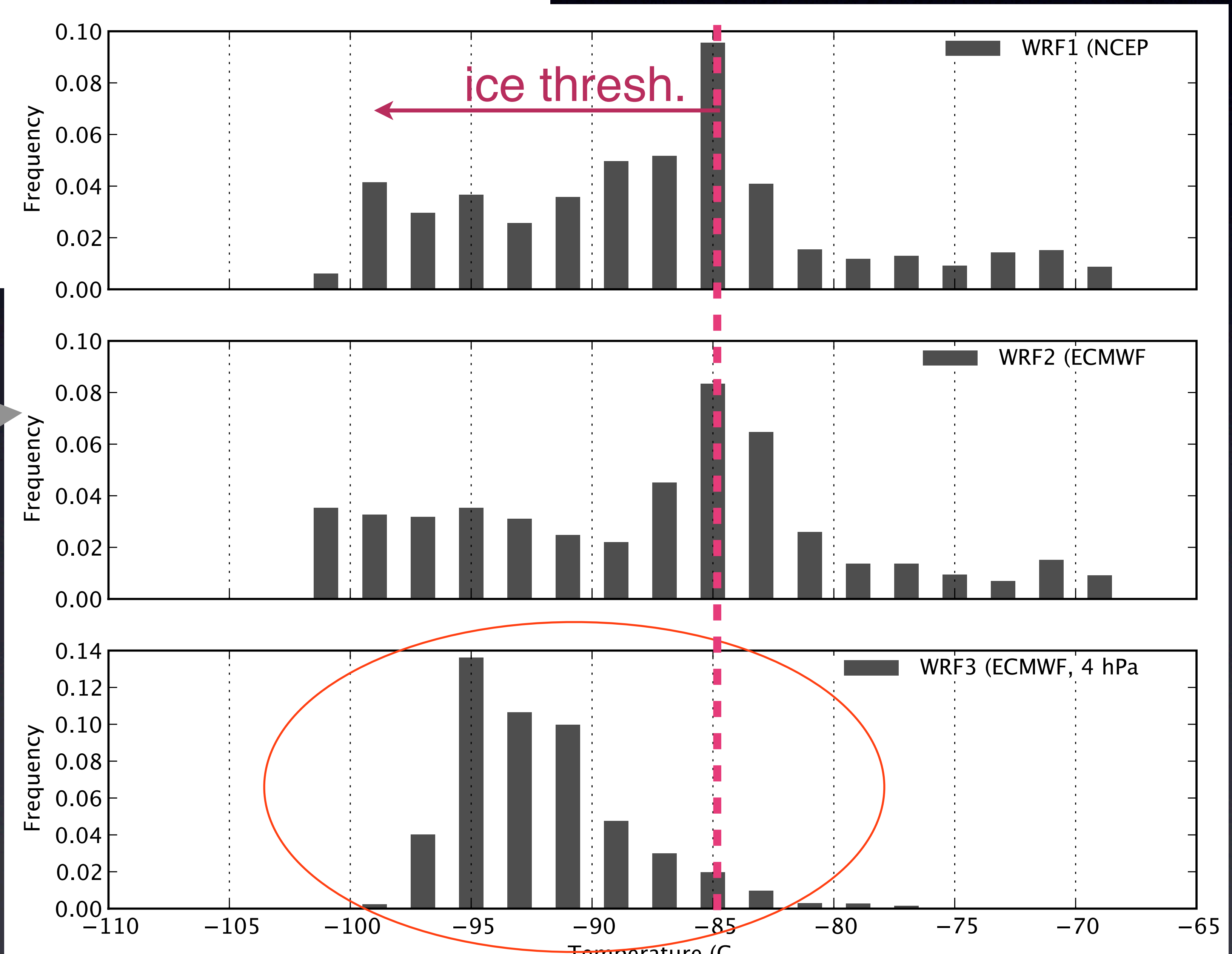
Mesoscale simulations

- WRF 2.2 - 100x100 grid @ 20 km res. centered on the peninsula, 120 levels, initialized with NCEP, ECMWF, ECMWF up to 4 hPa (~34 km)



PSC t° from mesoscale simulations



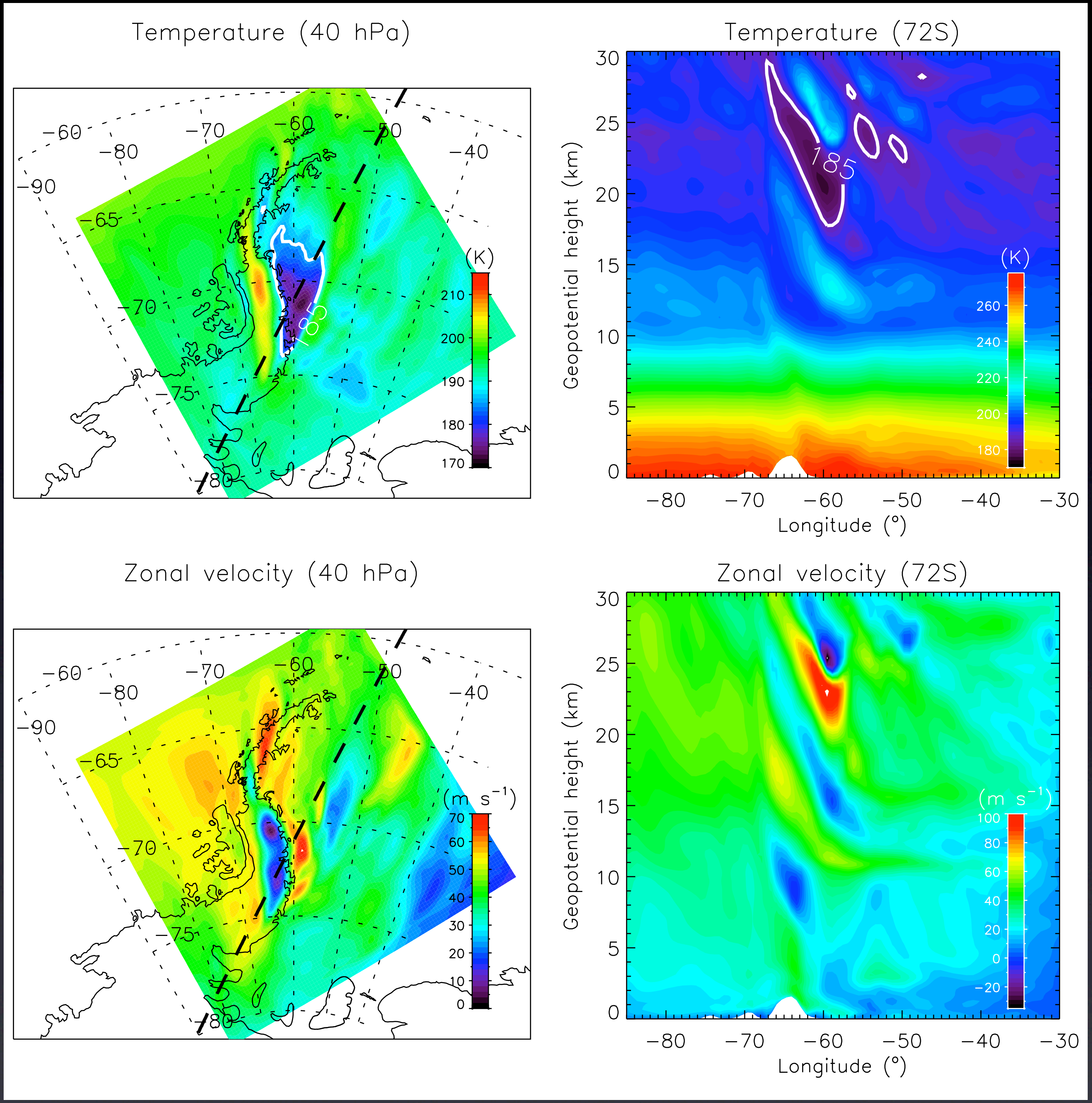


t° fluctuations from hi-res sim. follow very closely the PSC observed from CALIOP

PSC and gravity wave event

- The event created intense fluctuations of temperature (±15K) and zonal wind (120 m/s)
- High-resolution mesoscale simulations with high ceiling are required if we want to correctly compare temperatures with CALIPSO PSC observations
- Low-res temperature fields are off the mark by ~10-15 K
- Comparing modelled temperature fields with CALIPSO observations shows the PSC follows almost perfectly the area with $T < 188K$

The gravity wave event



Stratospheric surroundings

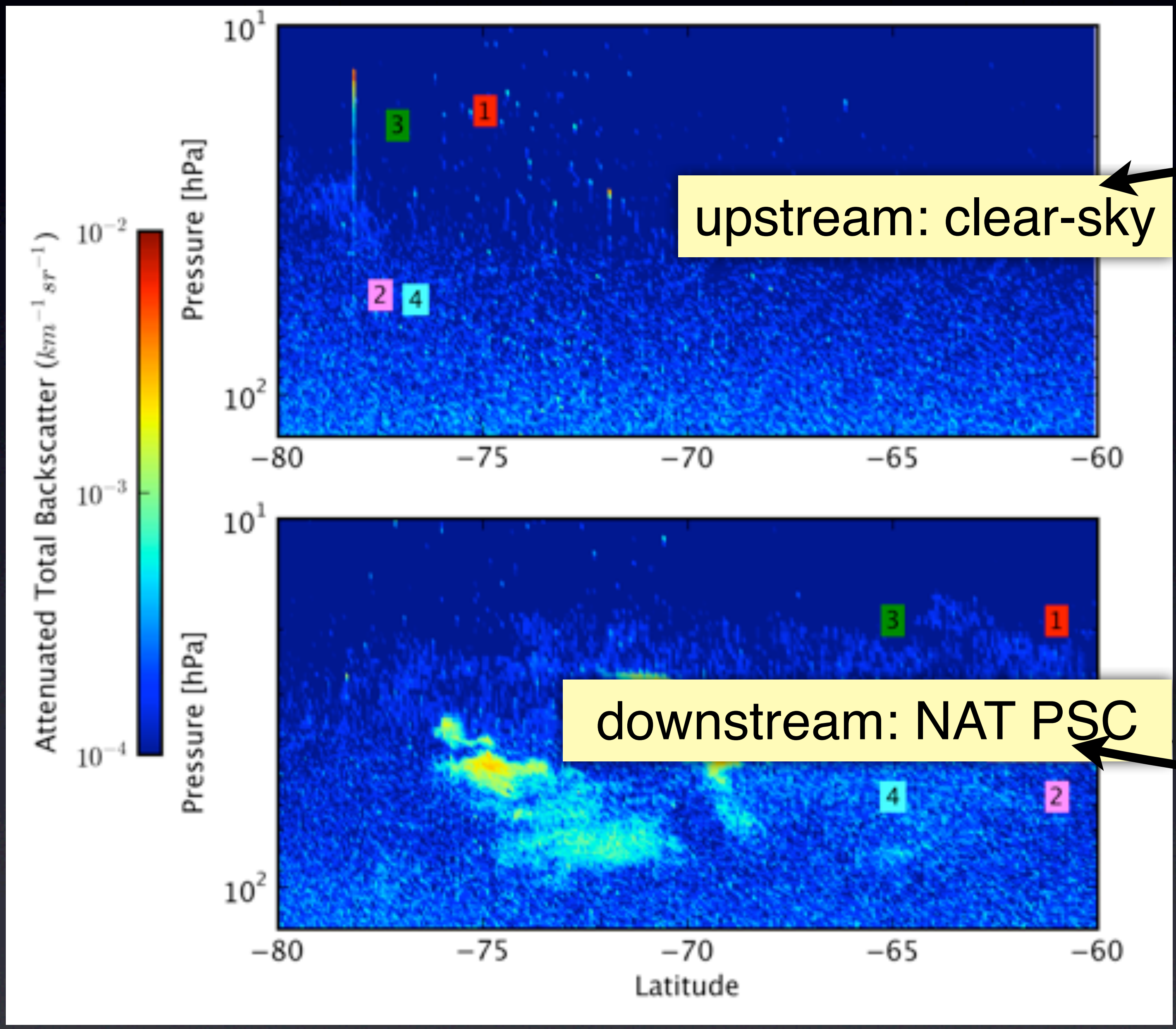
- Nearby CALIOP observations show:
- Upstream wrt the polar vortex: clear-sky
- Downstream wrt the polar vortex: a NAT-based PSC
  - NAT crystals (HNO_3 + H_2O) form at « warmer » temperatures (~195 K or -78°C vs. ~188K for ice) but their homogeneous nucleation is very inefficient
  - NAT PSCs are more common than ice PSCs, and cover a large part of Antarctica during JJA
  - It is traditionally assumed that stratospheric temperatures over Antarctica are cold enough to explain the large NAT PSC cover alone (not so clear in the Arctic)

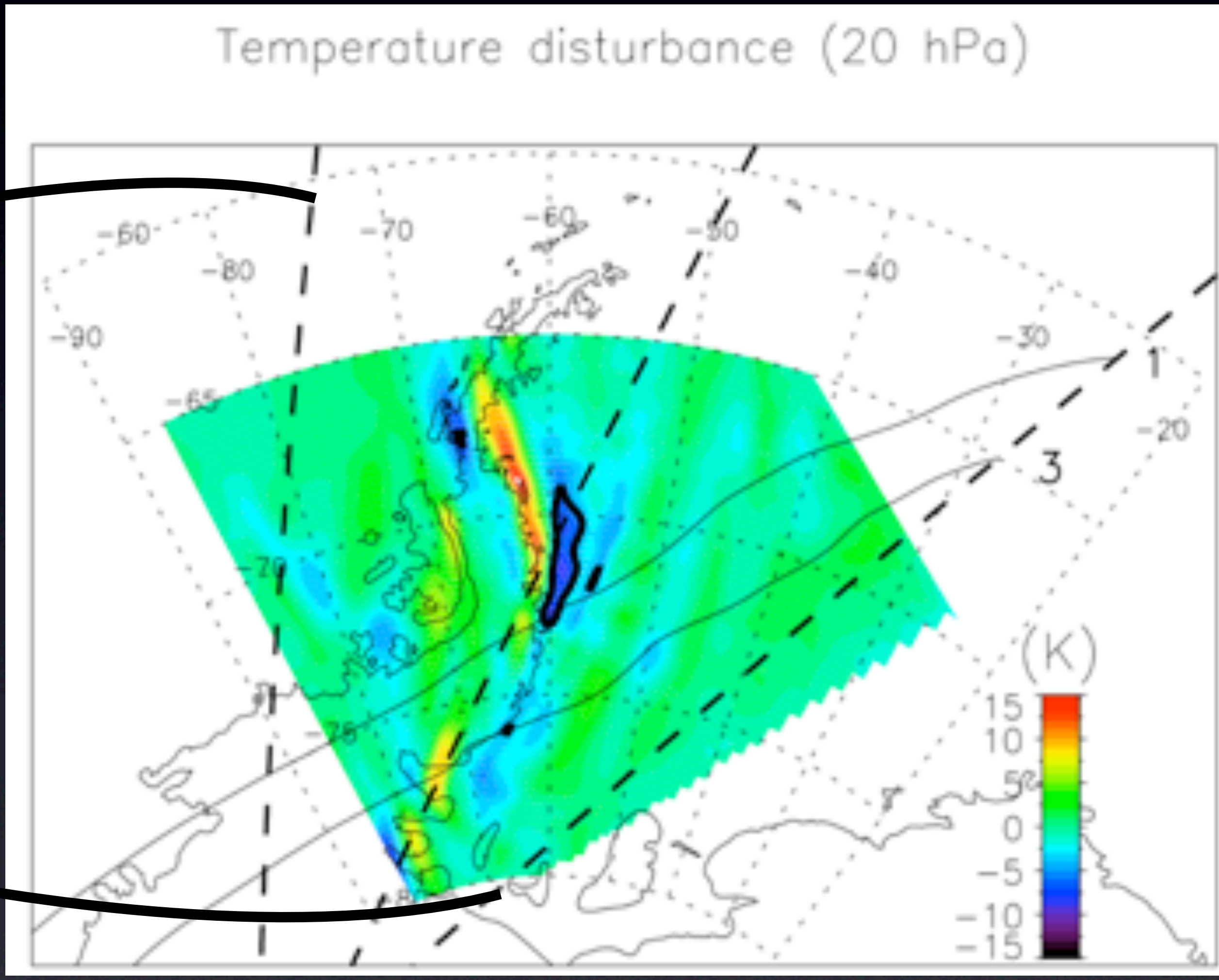
Mountain wave seeding hypothesis

- Term coined by Hopfner, Eckermann et al. (ACP, 2009)
- Mountain wave-induced perturbations bring stratospheric temperatures below ice formation threshold
- Ice PSC forms rapidly
- NAT crystals nucleate heterogeneously on ice during its cooling as it streams out of the mountain wave
- The generated NAT PSCs then grow and expand along the vortex in hospitable temperatures
- Are mountain waves key to the formation of NAT PSCs?
  - Over Antarctica, strato temperature may be cold enough
  - Not so clear in the Arctic

In the present case

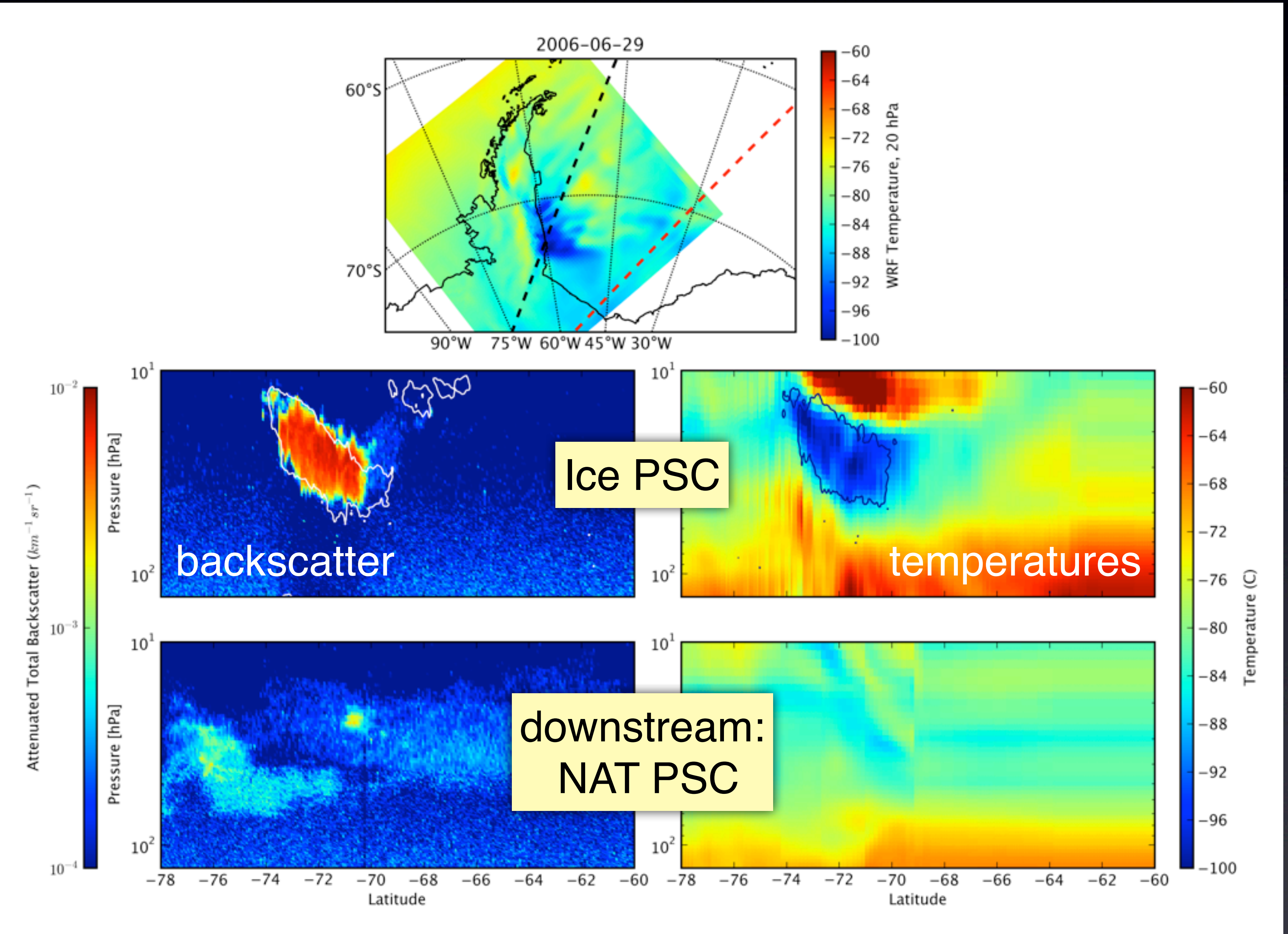
- Back-trajectories show that air holding the NAT-based PSC indeed travelled through the gravity wave perturbations





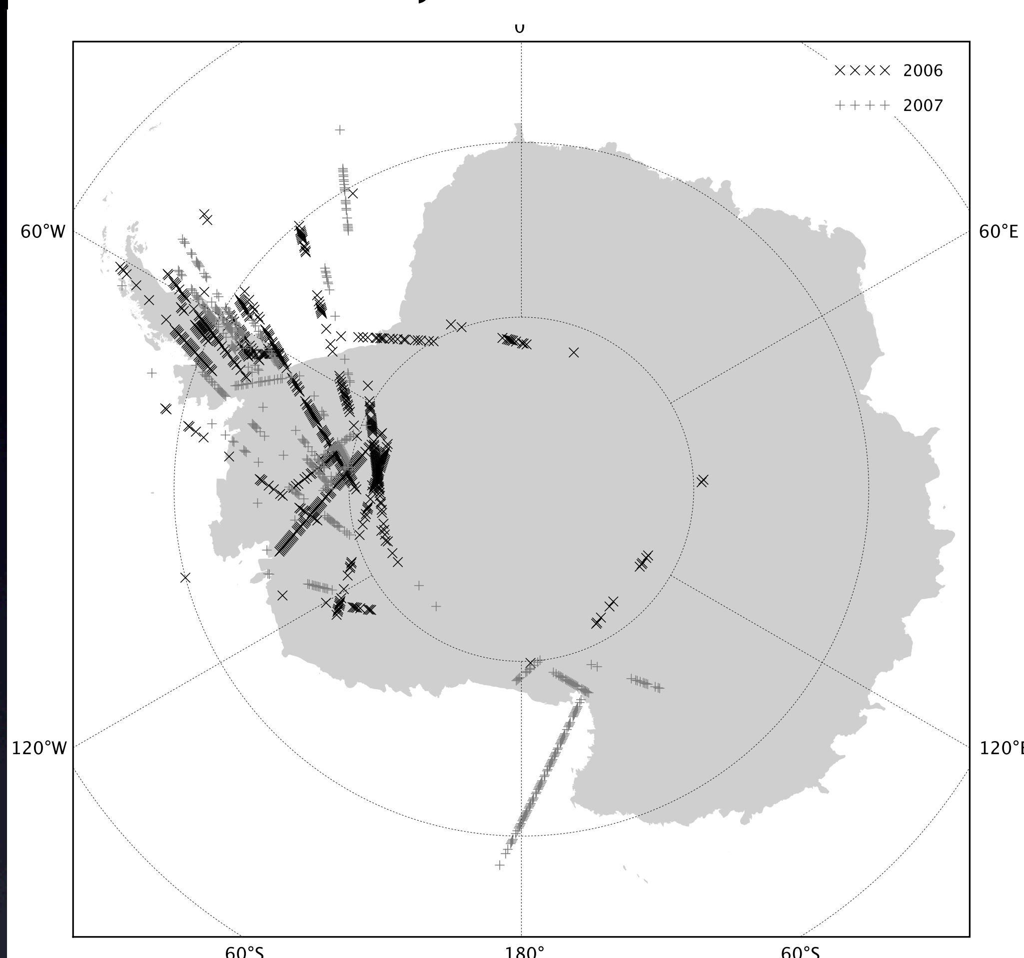
Gravity wave event lasted ~48 h

- During which both the ice-based PSC and the downstream NAT PSC stayed in place

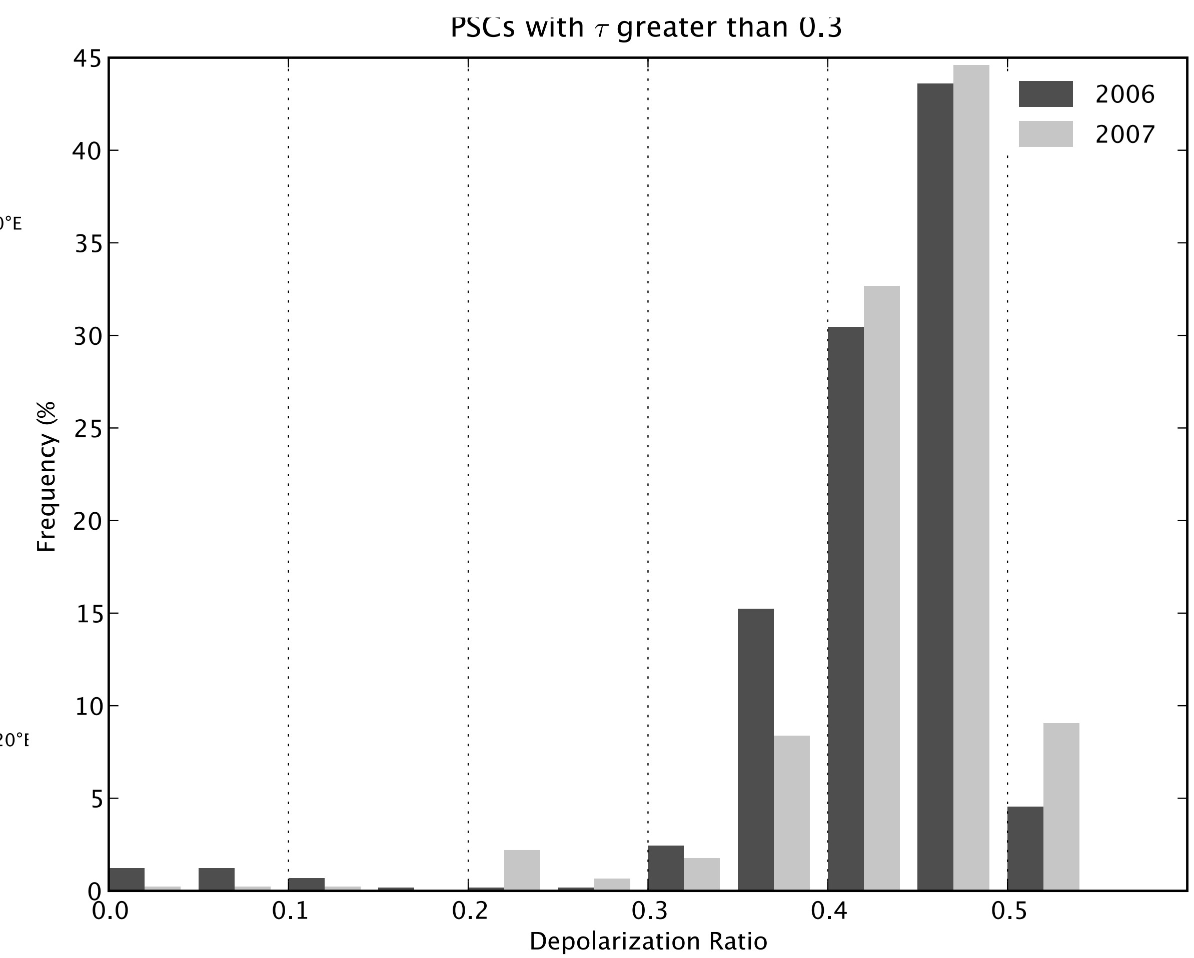


Optically thick PSCs 2006-2007

Rare, localized



All ice



Questions:

- Are all these ice PSCs linked to gravity wave events?
- Do they drive all or part of the NAT PSC population?
- What about the Arctic?

Concordiasi

- In-situ observations from Concordiasi could document conditions and fluctuations inside GW events (hopefully)
- Temperature, particle concentrations will be monitored as balloons are lifted in and out of waves
- Comparisons with PSC microphysical models will help us better understand PSC lifecycles and formation processes, maybe quantify the impact of the mountain wave seeding effect on the global PSC population