Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

MIPAS discovers Antarctic nitric acid trihydrate (NAT) polar stratospheric cloud belt

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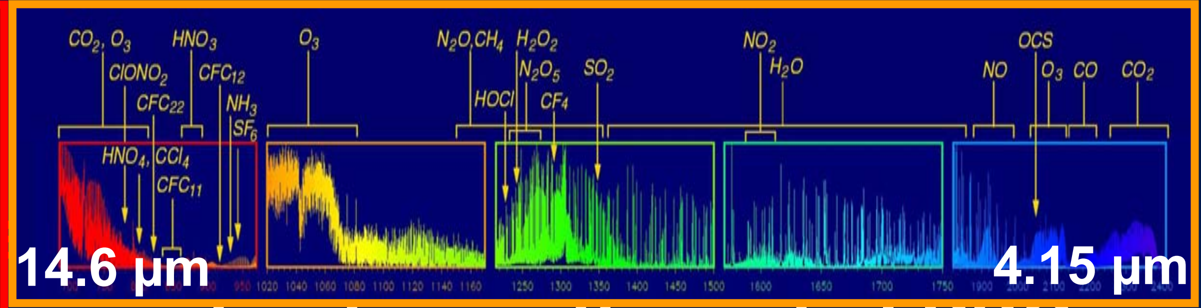
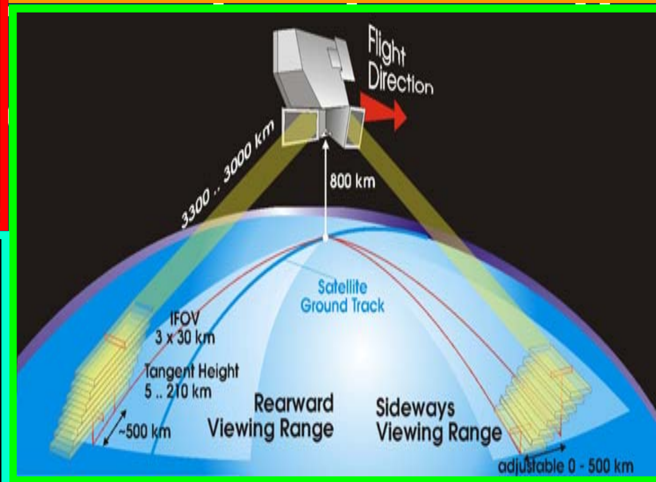
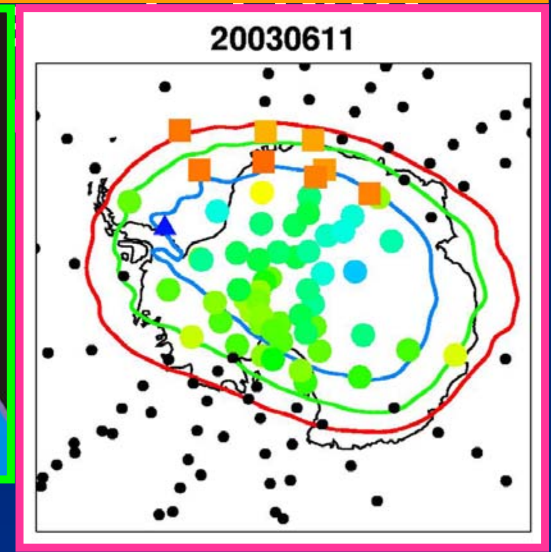
Questions

- What is the composition of solid nitric acid containing (Type 1a) PSCs?
- How do these particles nucleate?







Space borne → global view of PSC distribution

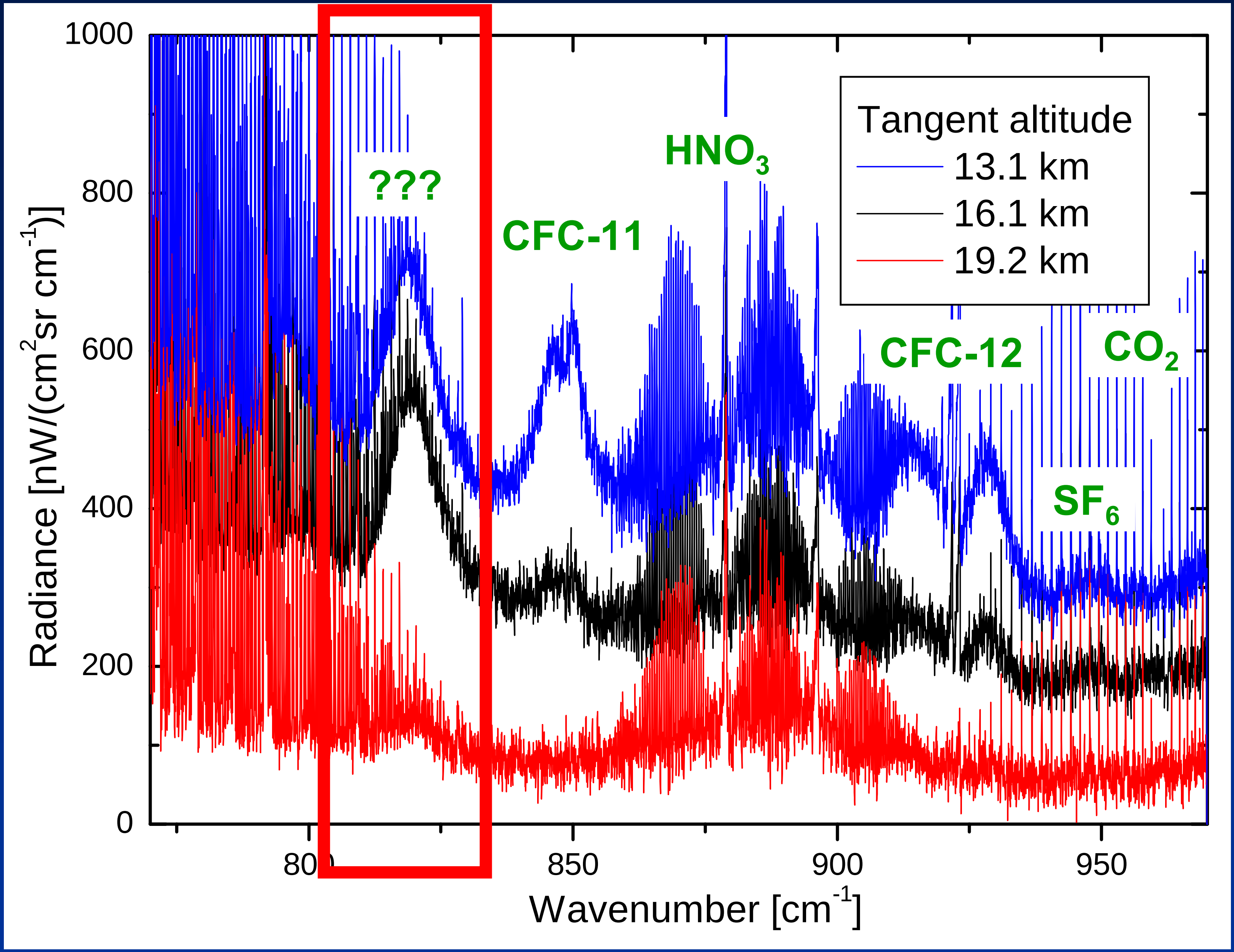
Mid-infrared → possibility to identify PSC composition through spectroscopic signatures

Limb → good sensitivity to thin clouds through long optical path

Emission → visibility of PSCs also during polar night

Antarctic stratosphere → ideal natural laboratory for PSC studies

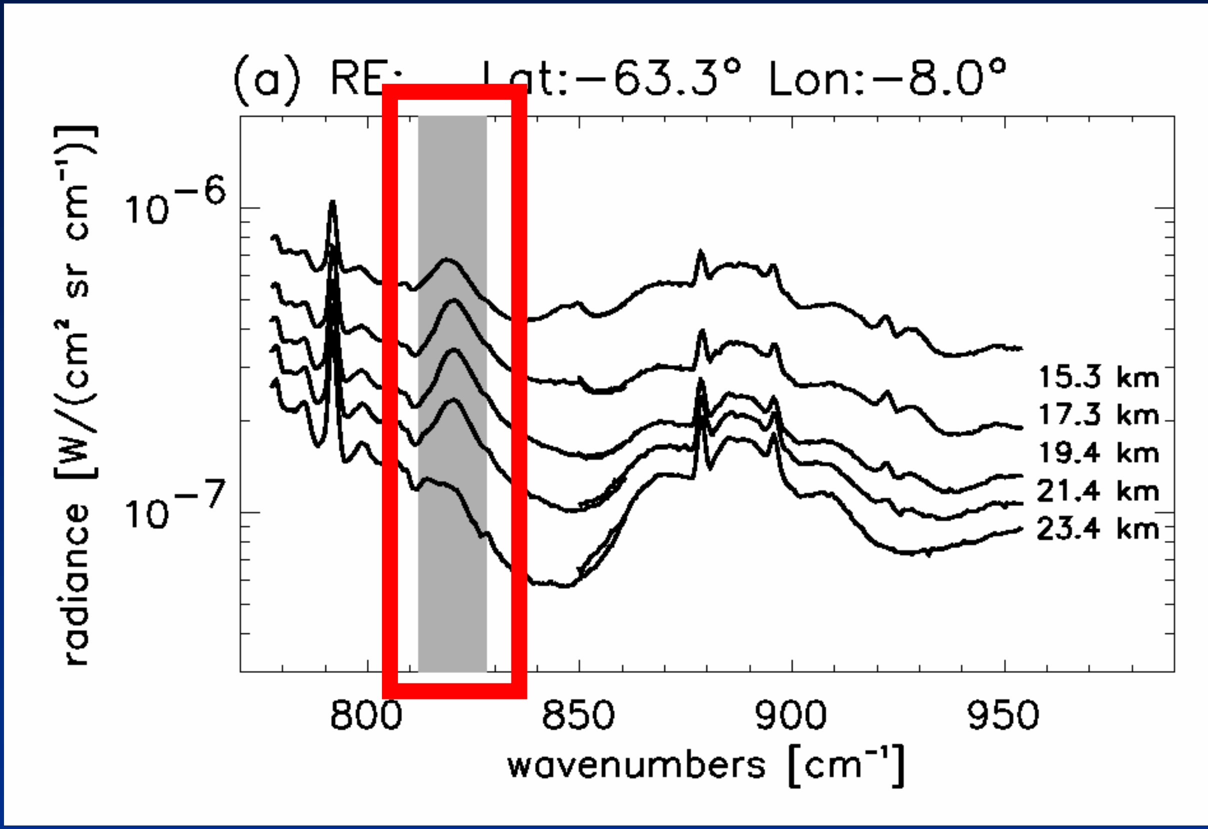
MIPAS PSC observations over McMurdo on 4 Aug 2003



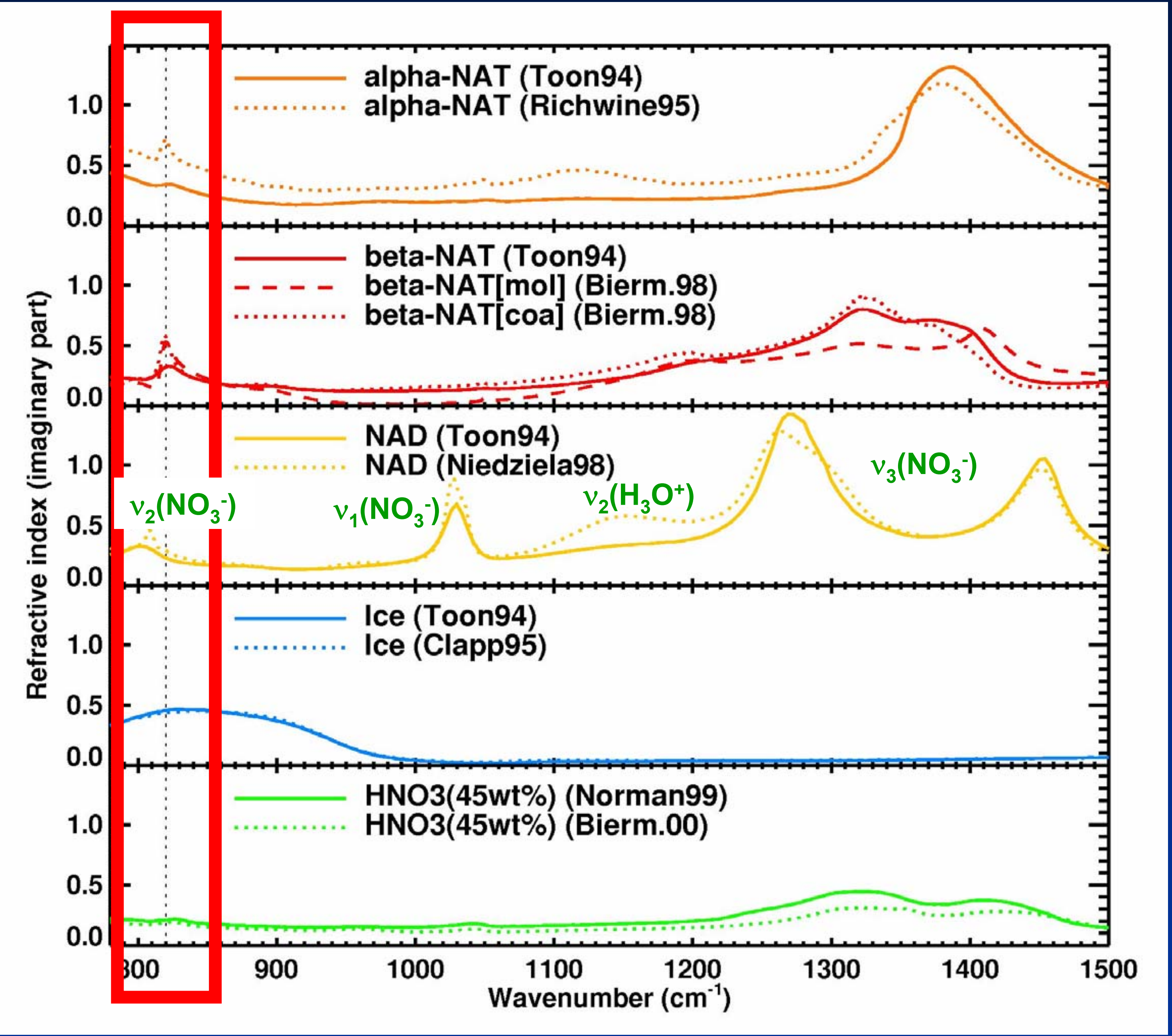
CRISTA PSC observations in August 1997

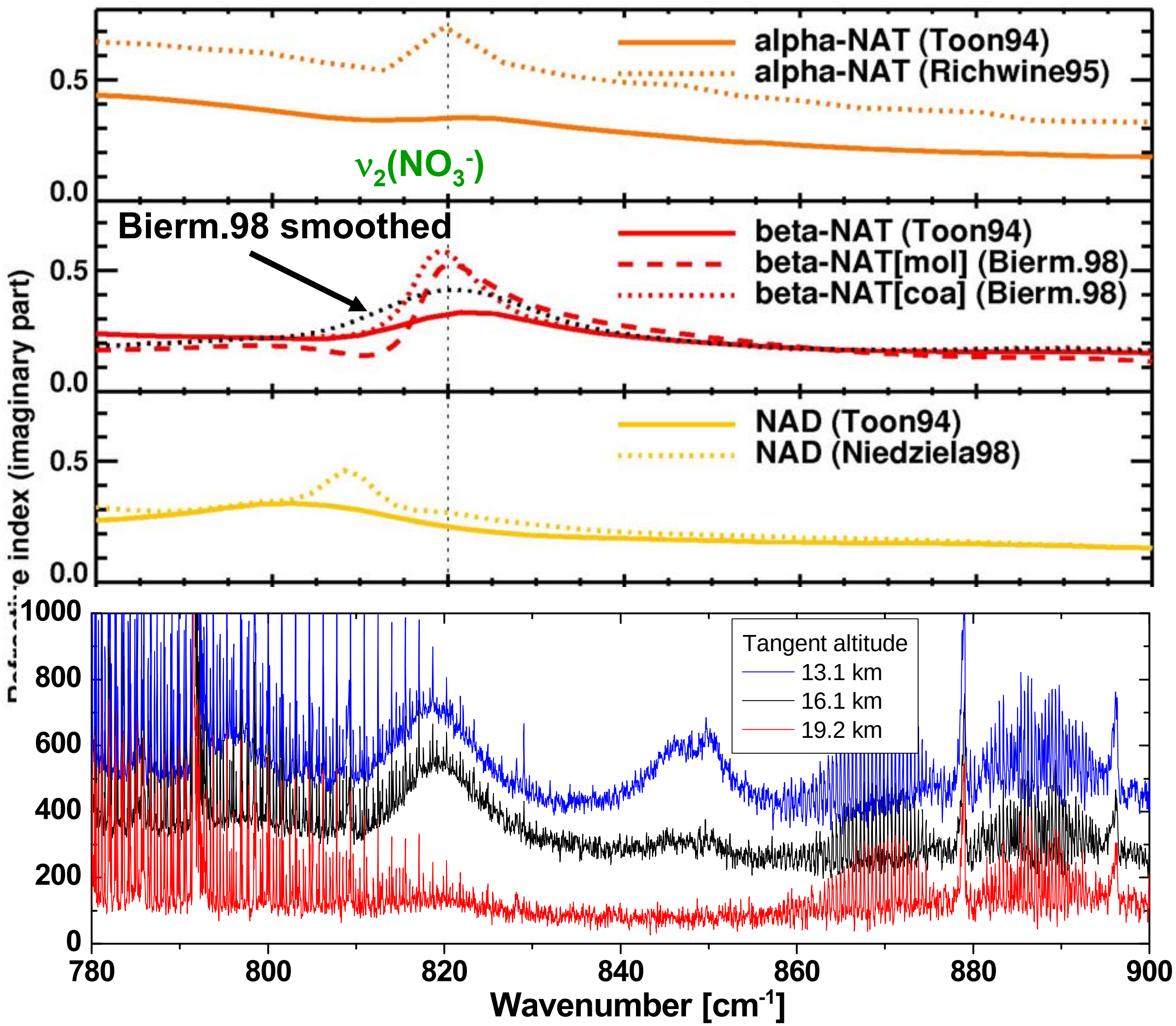
Spang and Remedios, 2003:

Spectral feature around 820 cm^{-1} attributed to NAT indirectly by HNO_3-temperature relationship and occurrence temperature of the band

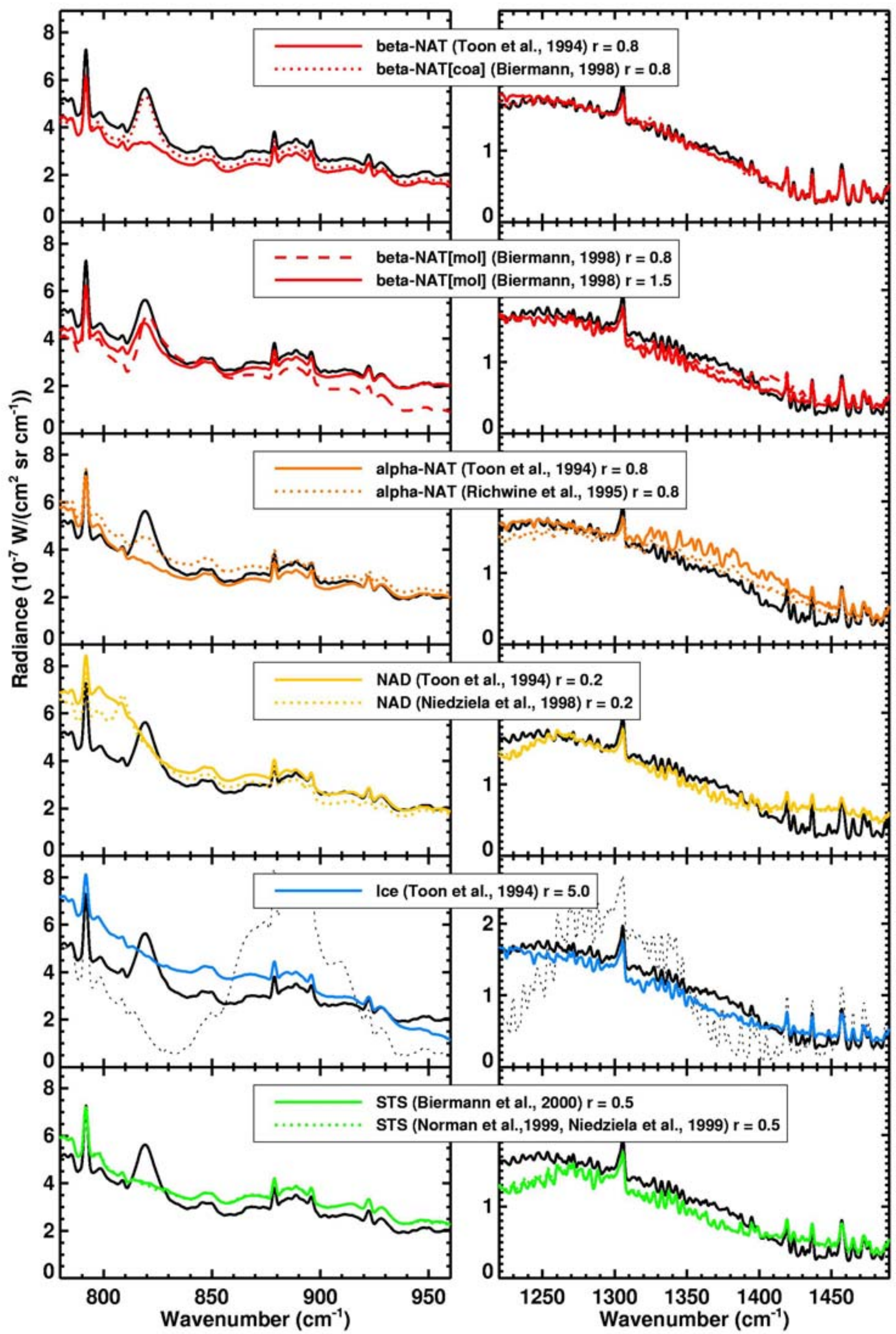


Refractive indices

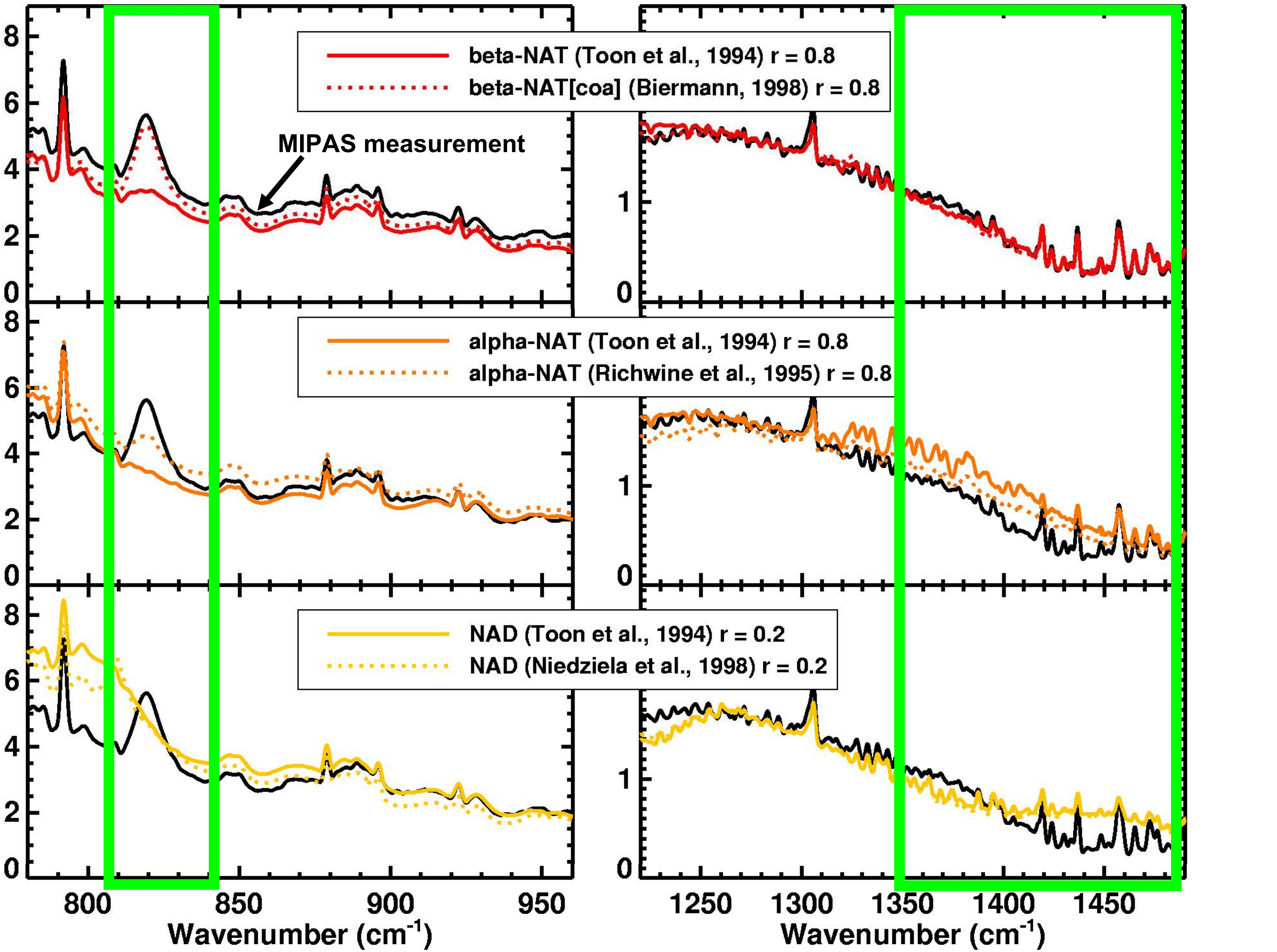



alpha-NAT (Toon94)
alpha-NAT (Richwine95)
$\nu_2(NO_3^-)$
Bierm.98 smoothed
beta-NAT (Toon94)
beta-NAT[mol] (Bierm.98)
beta-NAT[coa] (Bierm.98)
NAD (Toon94)
NAD (Niedziela98)
Refractive index (imaginary part)
0.0
0.5
Tangent altitude
13.1 km
16.1 km
19.2 km
0
200
400
600
800
1000
780
800
820
840
860
880
900
Wavenumber [cm^{-1}]

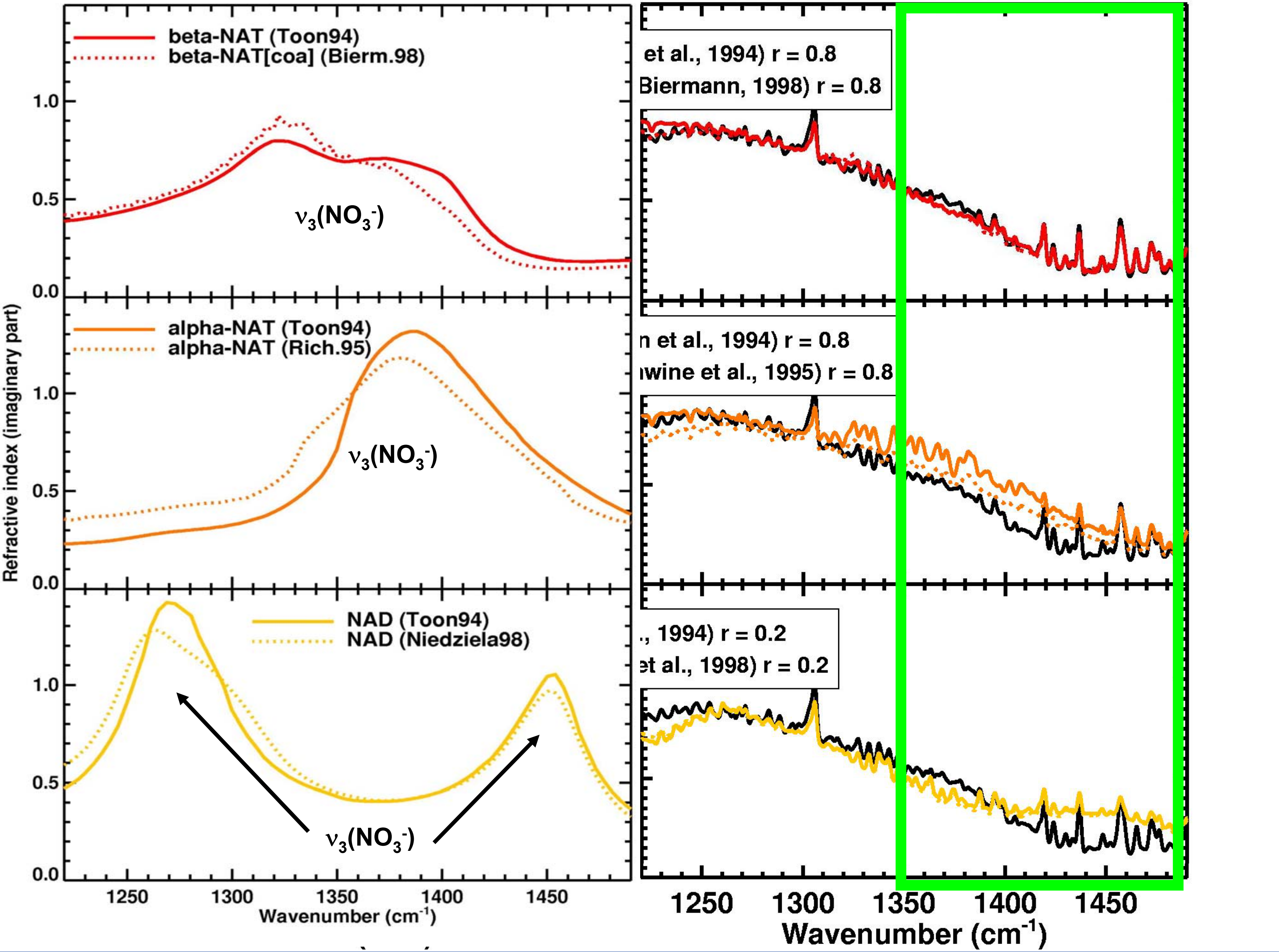
Spectral fit to the measurement



2006



beta-NAT (Toon et al., 1994) r = 0.8
beta-NAT[coa] (Biermann, 1998) r = 0.8
MIPAS measurement
alpha-NAT (Toon et al., 1994) r = 0.8
alpha-NAT (Richwine et al., 1995) r = 0.8
NAD (Toon et al., 1994) r = 0.2
NAD (Niedziela et al., 1998) r = 0.2
Wavenumber (cm^{-1})
Wavenumber (cm^{-1})



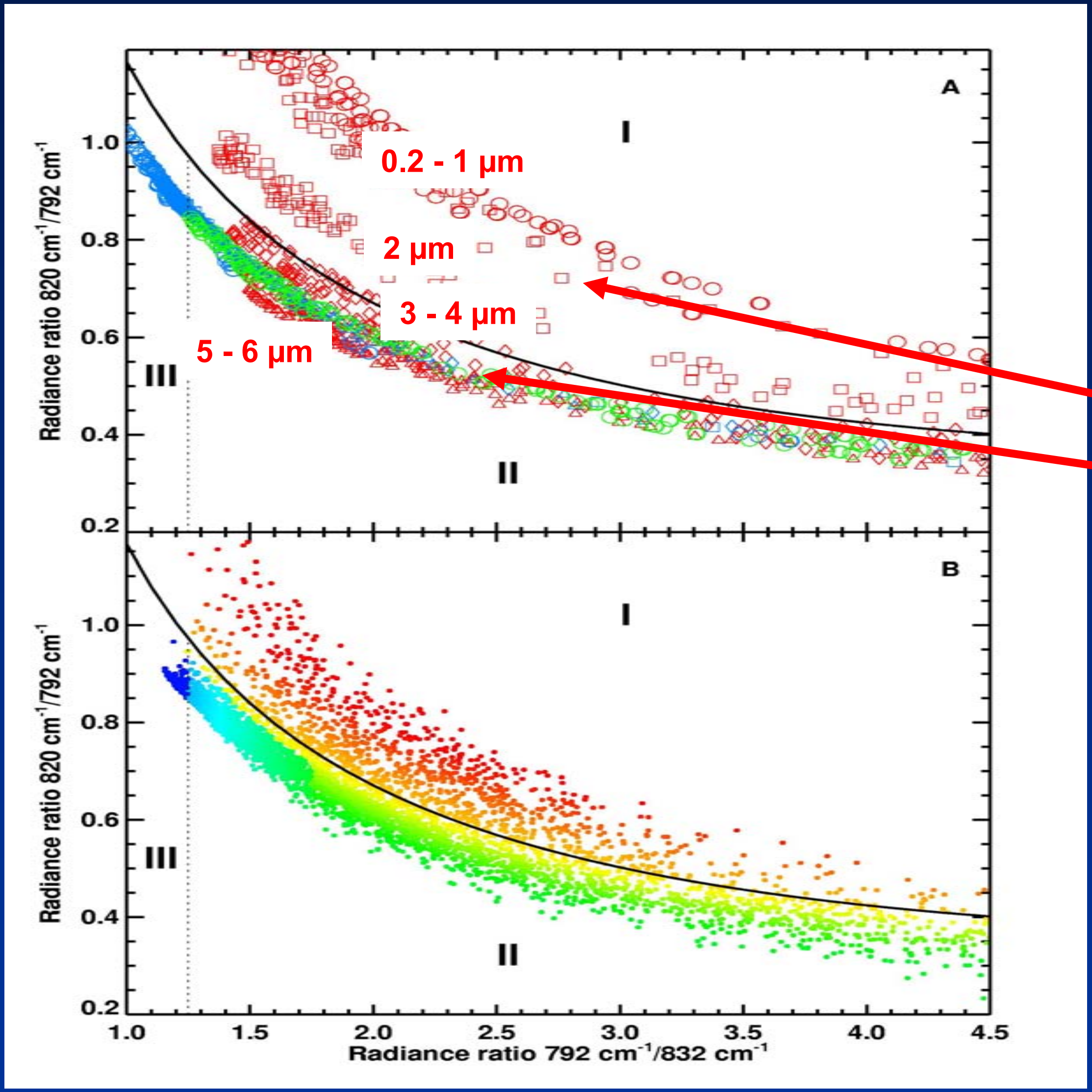
beta-NAT (Toon94)
beta-NAT[coa] (Bierm.98)
$\nu_3(NO_3^-)$
alpha-NAT (Toon94)
alpha-NAT (Rich.95)
$\nu_3(NO_3^-)$
NAD (Toon94)
NAD (Niedziela98)
$\nu_3(NO_3^-)$
Refractive index (imaginary part)
Wavenumber (cm^{-1})
et al., 1994) r = 0.8
Biermann, 1998) r = 0.8
n et al., 1994) r = 0.8
ıwine et al., 1995) r = 0.8
., 1994) r = 0.2
et al., 1998) r = 0.2
Wavenumber (cm^{-1})

Observed positions of the $\nu_2(NO_3^-)$-band of NAD and NAT

Reference	NAD	NAT
Biermann (1998)		$819\,cm^{-1}$ (β[coa]), $820\,cm^{-1}$ (β[mol])
Grothe et al. (2004)	$809\,cm^{-1}$ (α), $811\,cm^{-1}$ (β)	
Hudson et al. (2002)		$820\,cm^{-1}$ (α)
Koch et al. (1996)	$808\,cm^{-1}$ (RAIRS), $808\,cm^{-1}$ (trans)	$821\,cm^{-1}$ (RAIRS), $820\,cm^{-1}$ (trans)
Niedziela et al. (1998)	$808\,cm^{-1}$	
Richwine et al. (1995)		$820\,cm^{-1}$ (α)
Ritzhaupt and Devlin (1991)	$809\,cm^{-1}$	$820\,cm^{-1}$
Tisdale et al. (1999)		$820\,cm^{-1}$ (α)
Toon et al. (1994)	$802\,cm^{-1}$	$821\,cm^{-1}$ (α), $821\,cm^{-1}$ (β)

RAIRS: reflection/absorption infrared spectroscopy; trans: transmission spectra

Search for NAT in MIPAS observations



Simulation

β-NAT

STS

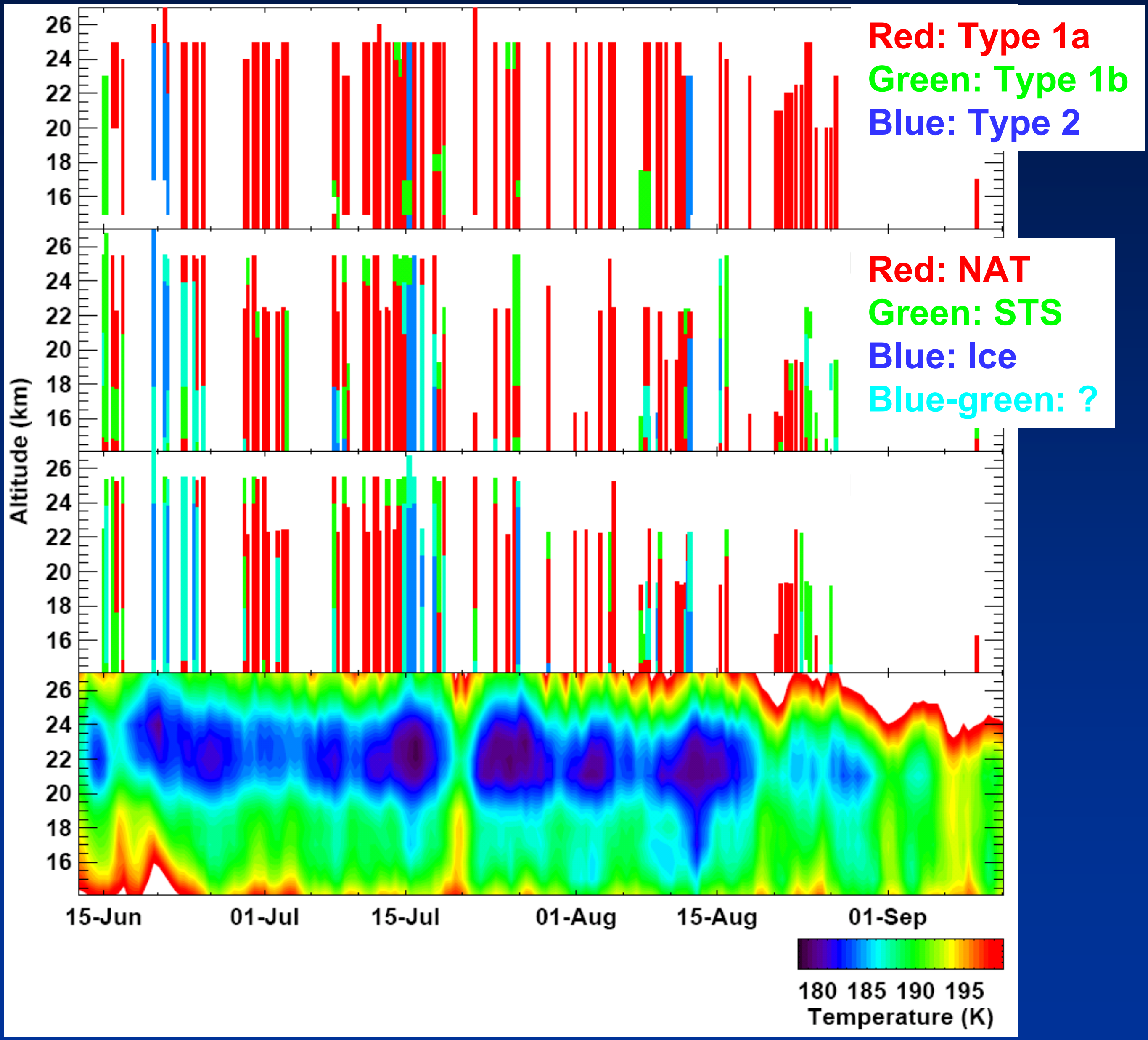
Ice

β-NAT: R < 3 µm

β-NAT: R > 3 µm

Observation

Comparison: MIPAS PSC composition ↔ Lidar PSC types



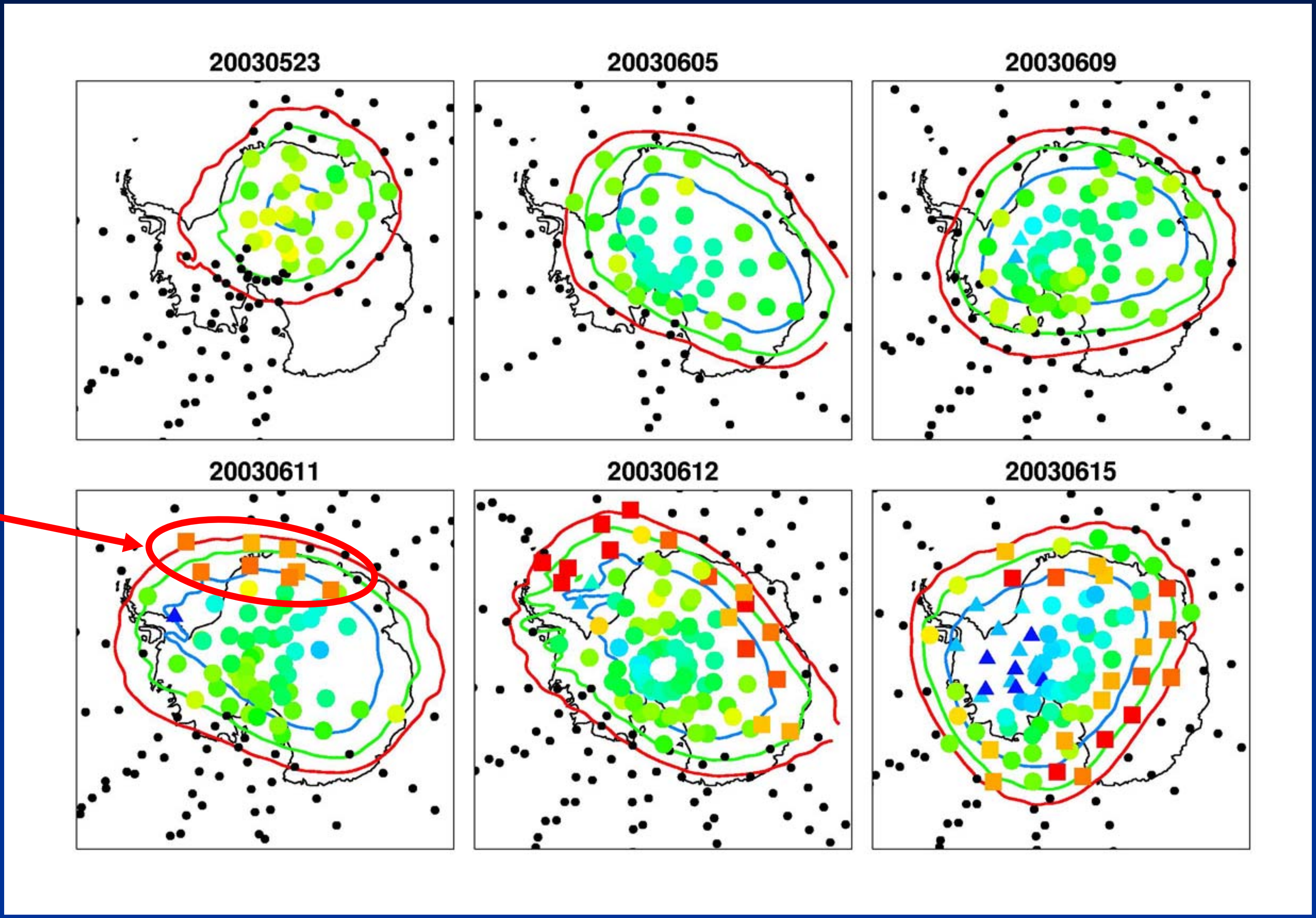
McMurdo Lidar

MIPAS closest match

MIPAS closest match but one

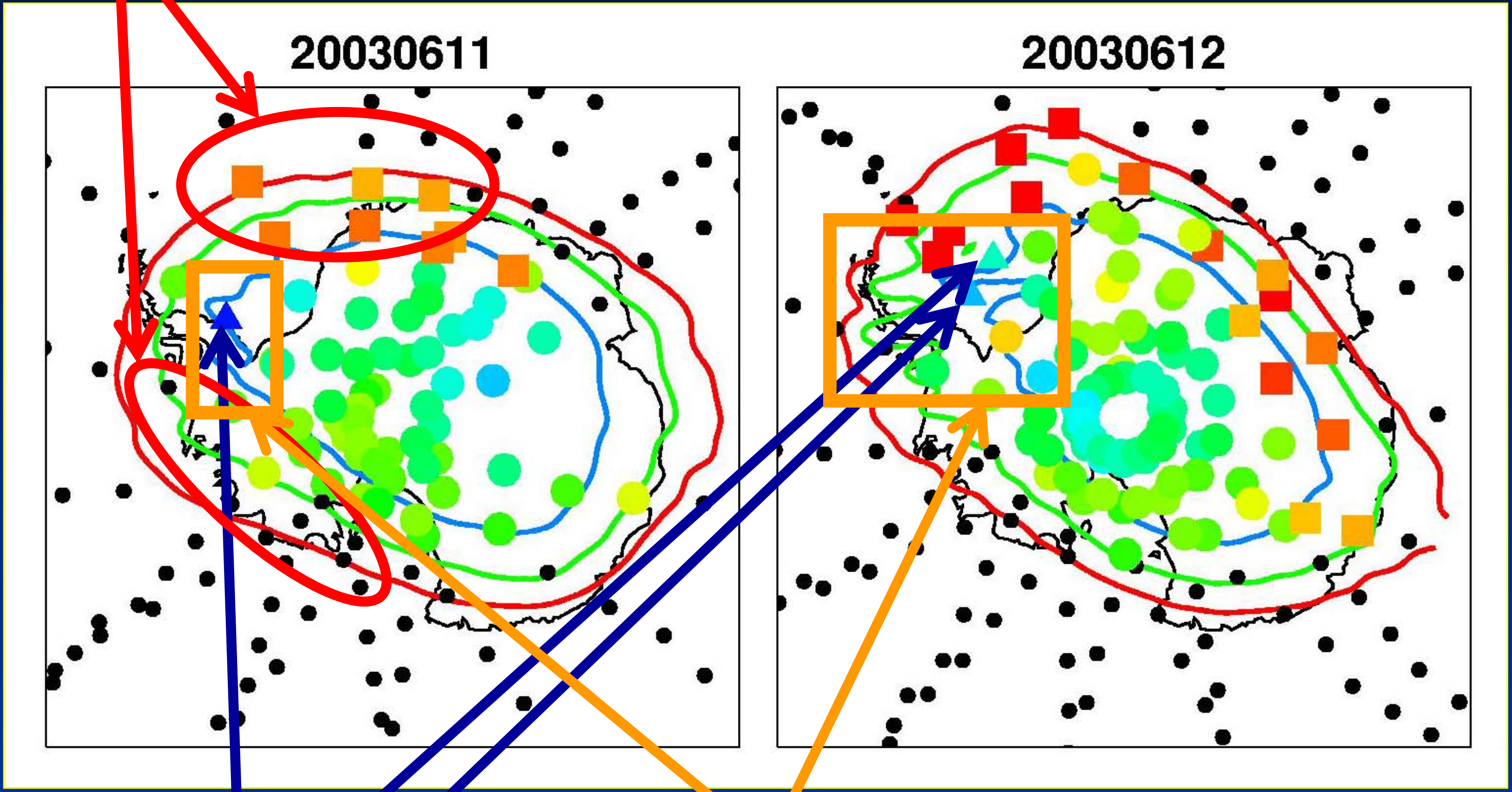
Temperature

Development of PSC Types over Antarctica



First NAT after ~20 days!

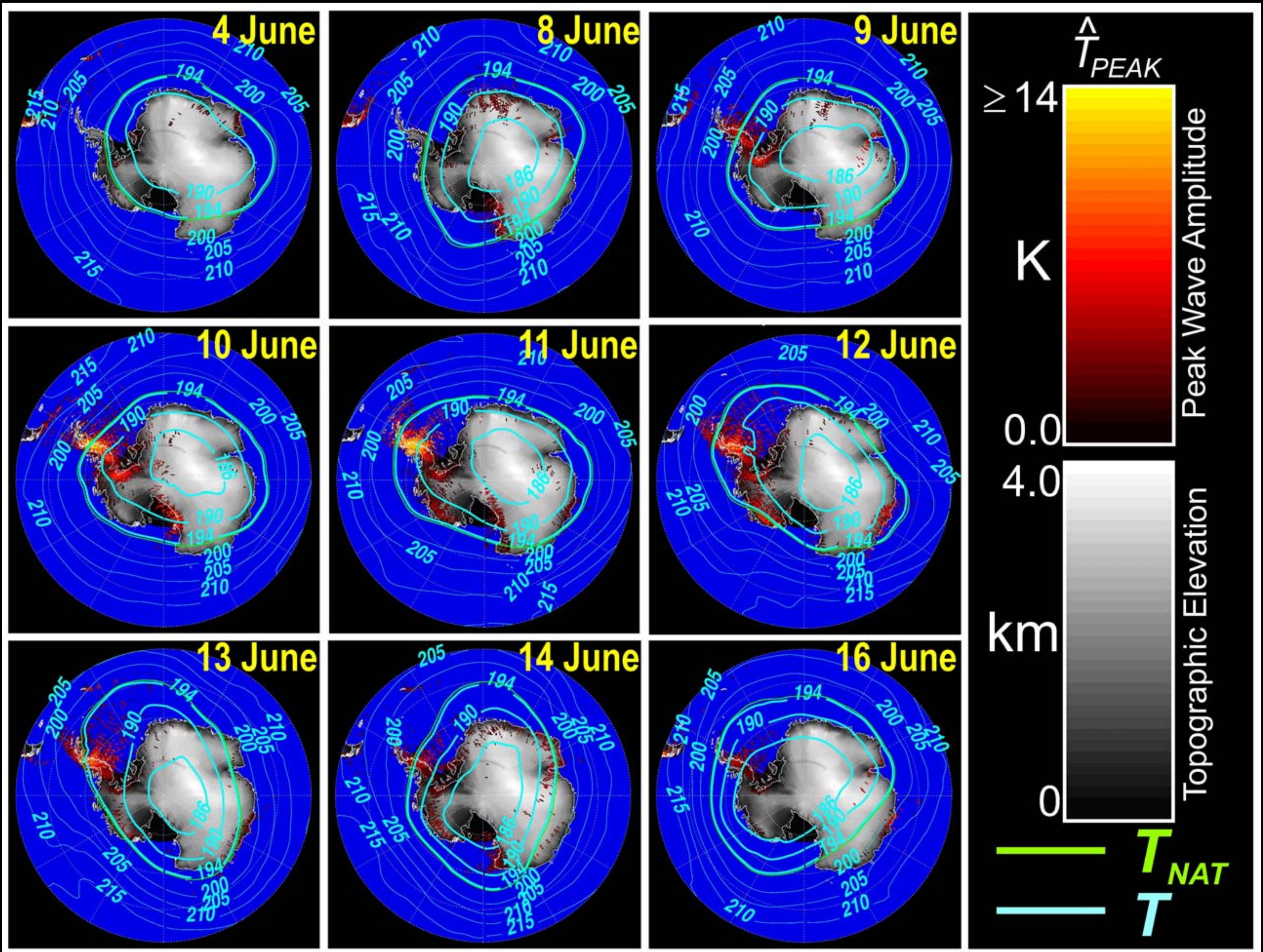
NAT only downwind the Antarctic Peninsula



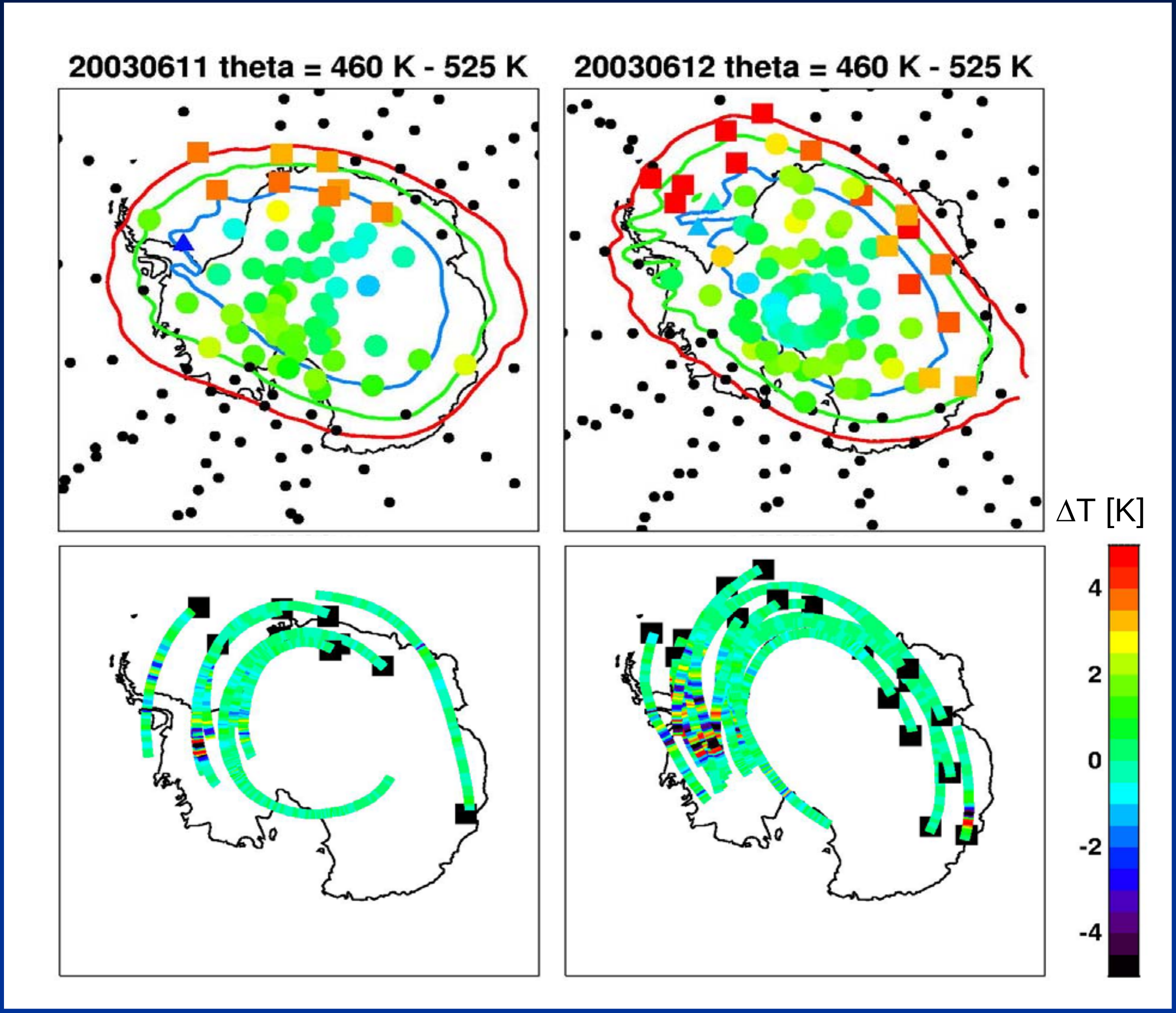
First ice observations

Oscillatory ECMWF temperature contours

Naval Research Laboratory Mountain Wave Forecast Model



Backward trajectories

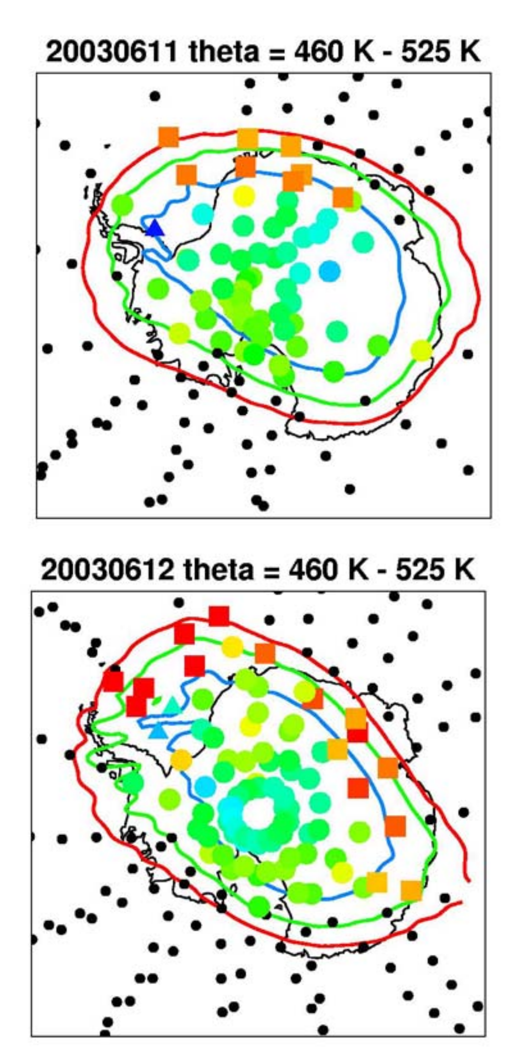


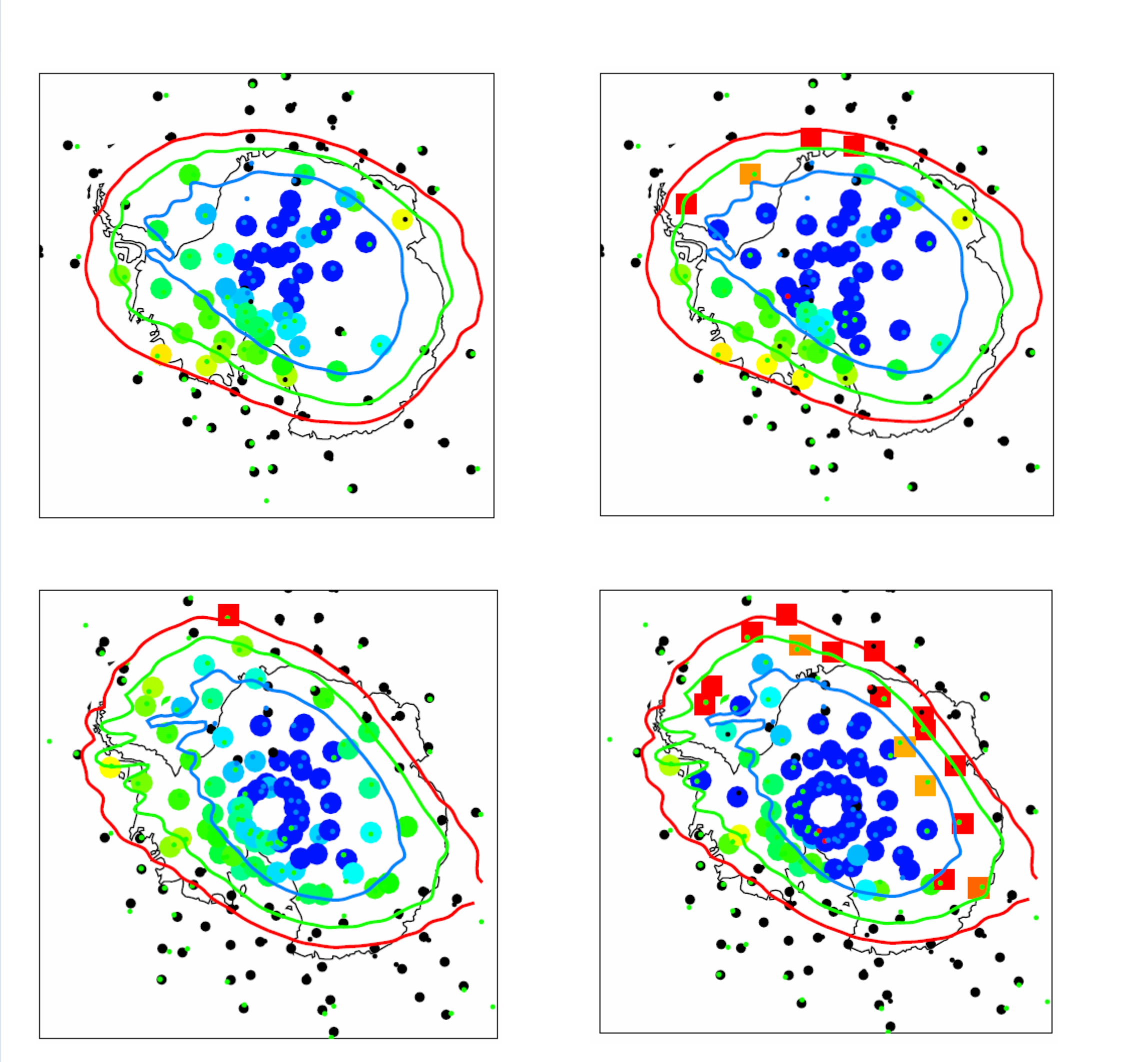
Microphysical PSC model runs

Measurement | Model

without | with

mountain waves





Summary

- **Spectroscopic evidence for β-NAT as constituent of Type 1a PSC**
- **No indication for NAD found in MIPAS PSC observations**
- **Detection of a NAT belt in the early Antarctic stratospheric vortex 2003: 20 days after first PSC observation**
- **Mountain wave activity over the Peninsula and the Ellsworth Mountains explains the sudden NAT formation**

→ Trigger for subsequent frequent vortex-wide NAT observations?

→ No freezing mechanism of NAT above the ice frost point necessary to explain the observed 'denitrification before dehydration' in the Antarctic vortex?

Spectroscopic Evidence for NAT, STS, and ice in MIPAS infrared limb emission measurements of polar stratospheric clouds
M. Höpfner, et al., Atmos. Chem. Phys., 6, 1201-1219, 2006.

MIPAS detects Antarctic stratospheric belt of NAT PSCs caused by mountain waves
M. Höpfner et al., Atmos. Chem. Phys., 6, 1221-1230, 2006.