Detection of Polar Stratospheric Clouds with IASI

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IASI 2024 Conference

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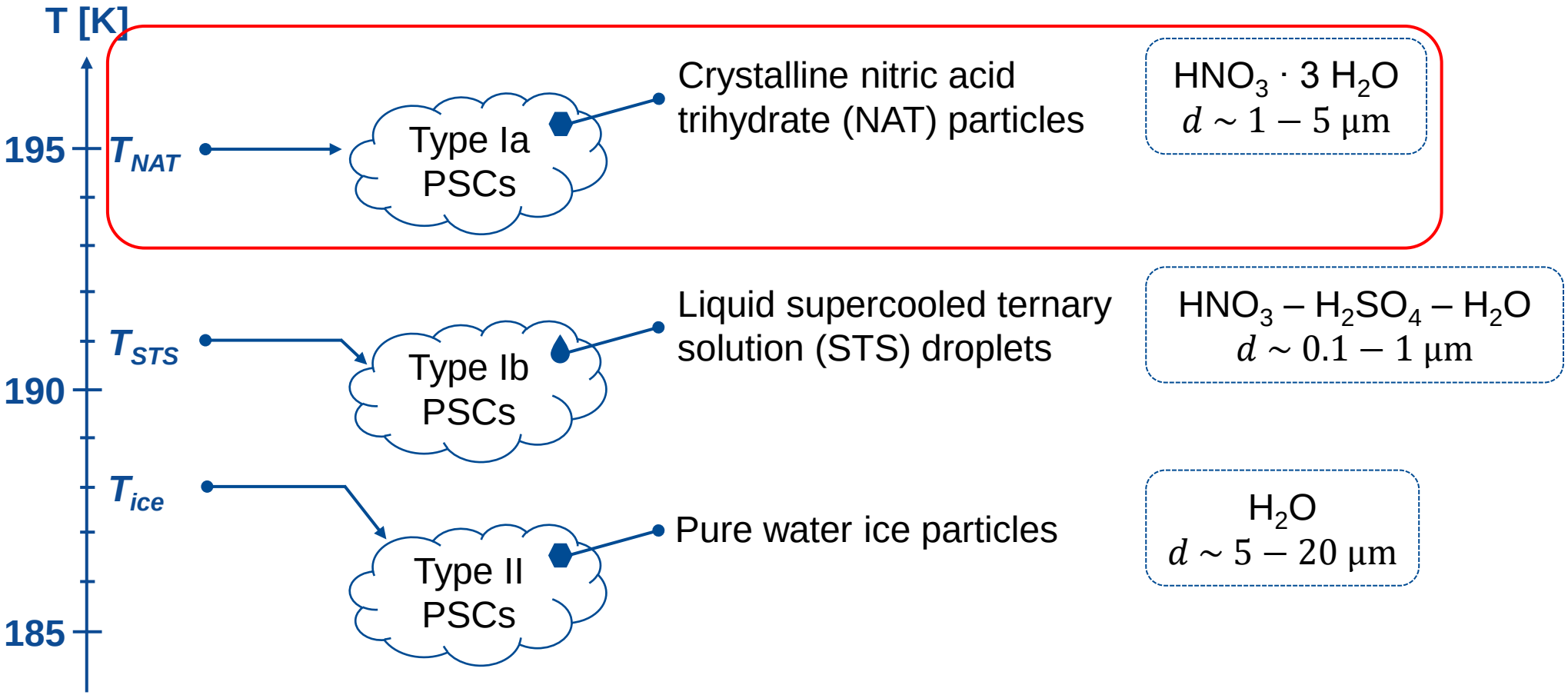
Polar Stratospheric Clouds (PSCs)

- **Extremely cold conditions**: only within the polar vortex in the lower stratosphere
- Particles/Droplets composed of **HNO_3**, **H_2SO_4** and **H_2O**: 3 types depending on composition



Key Roles of PSCs in Ozone Hole Formation

May

June

July

August

September

October

Polar vortex development

- Decrease in temperatures
- Separation of polar air masses

PSCs formation

- Activation of halogen species
- Denitrification/Dehydration of the stratosphere

Ozone hole development

- Catalytic cycles involving active halogen species

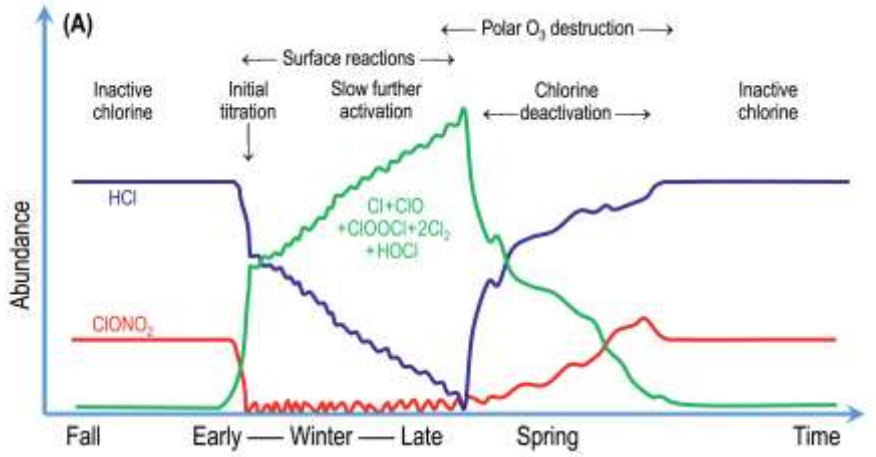


Figure from Tritscher et al. (2021).

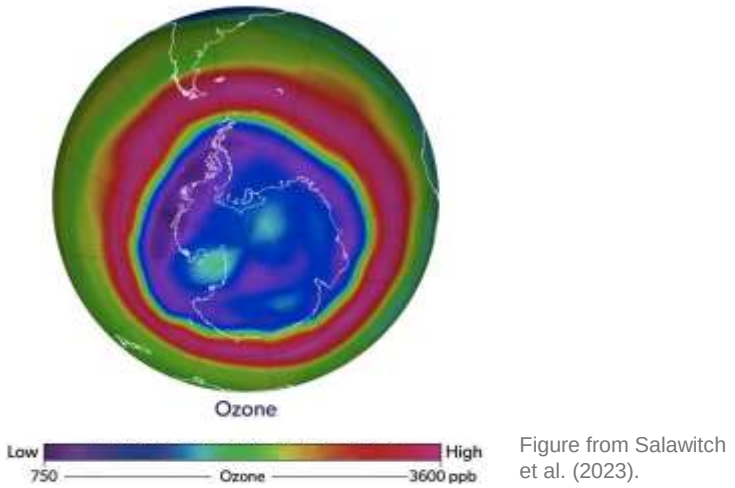


Figure from Salawitch et al. (2023).

September 15, 2021 – 18 km

Space-based Observations of PSCs

- **Limb** sounders (MIPAS, ACE)
- **Active** sounders (CALIOP)

Poor spatial coverage → **Lack of regular, large-scale observations**

MIPAS

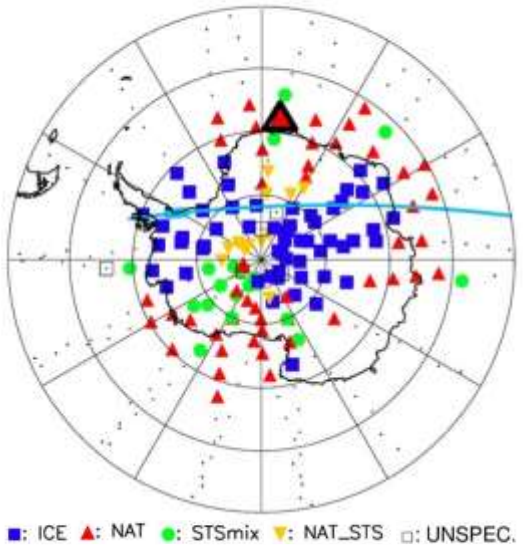


Figure from Tritscher, I. et al. (2021).

~ 250 measurements

CALIOP

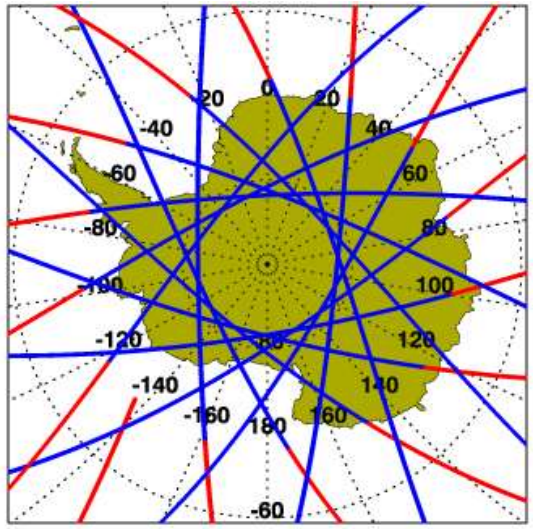
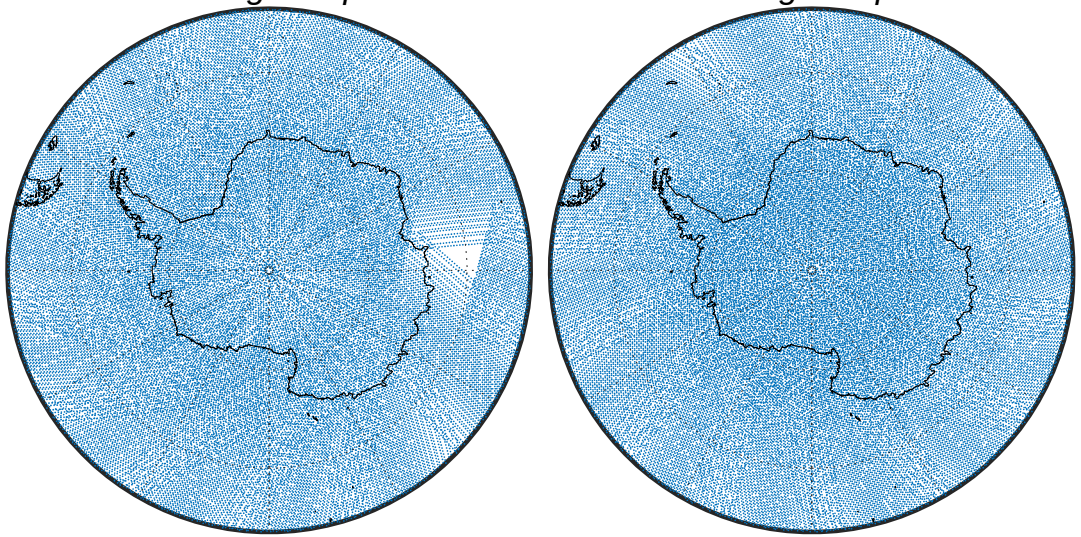


Figure from NASA (CALIPSO STANDARD Browse Images – V4.51).

IASI

Descending overpasses *Ascending overpasses*

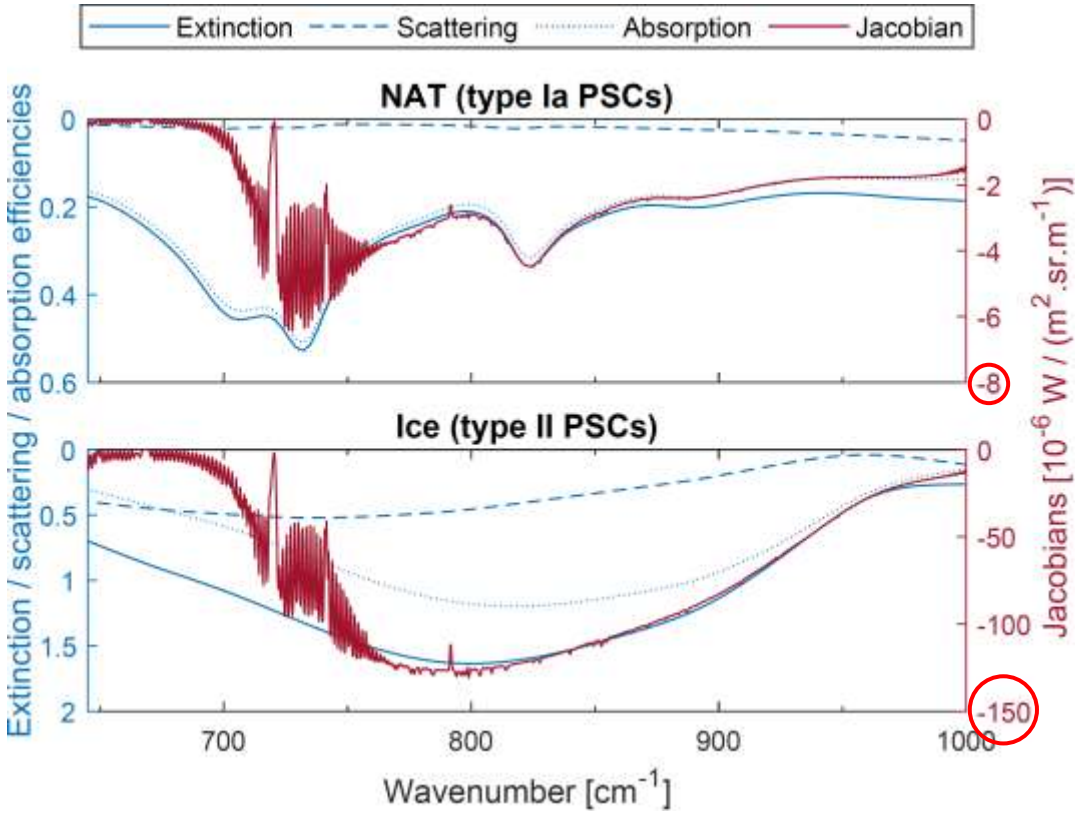


~ 138 000 measurements

Detection and Mapping

Challenge behind type Ia PSC detection with IASI

- Never identified in measurements from passive nadir-viewing sounders
- Broad and weak spectral signature



Detection and Mapping

Evidence of NAT spectral signature in IASI spectra

- Whitening transformation: based on the construction of a mean spectrum ($\bar{y}$) and an associated covariance matrix (S)

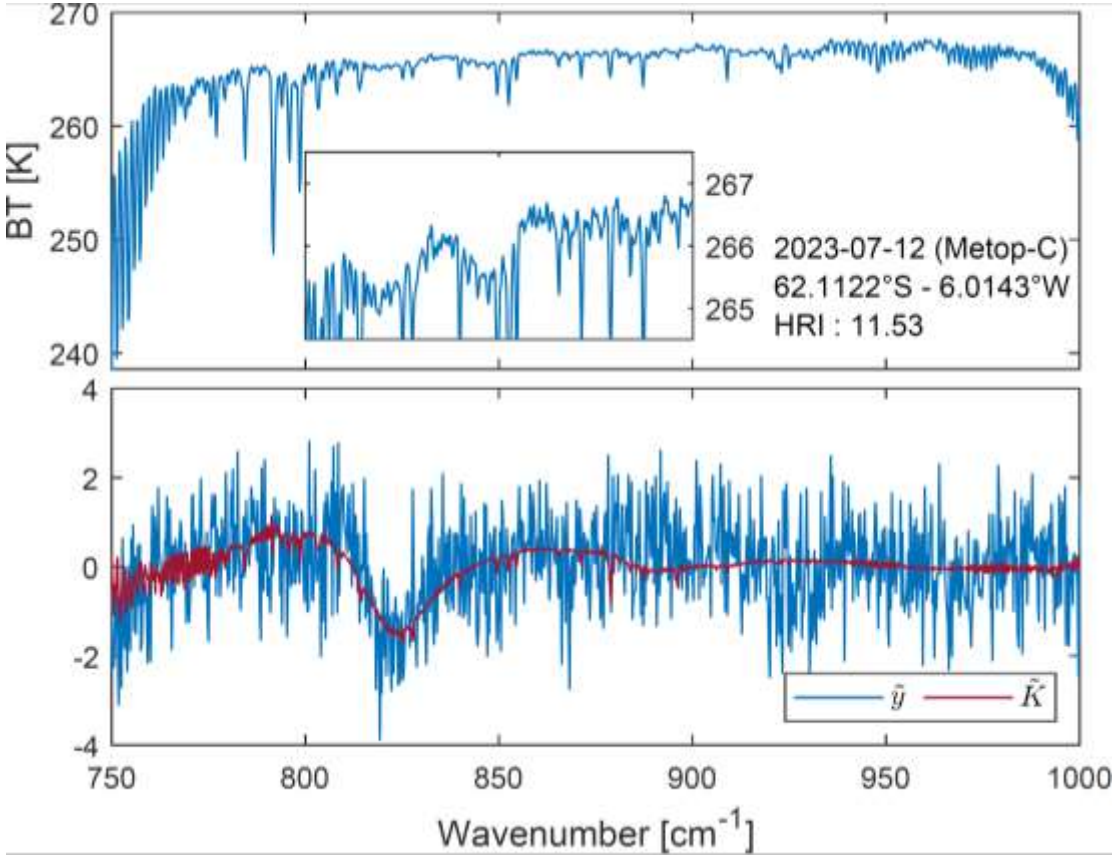
$$\tilde{y} = S^{-\frac{1}{2}}(y - \bar{y})$$
$$\tilde{K} = S^{-\frac{1}{2}}K$$

y: measured spectrum K: Jacobian of NAT particles

$\tilde{y}$: whitened spectrum $\tilde{K}$: whitened Jacobian

→ **Unambiguous identification** of NAT spectral signature in several IASI spectra

→ **First type Ia PSC observations** with a passive nadir-viewing sounder



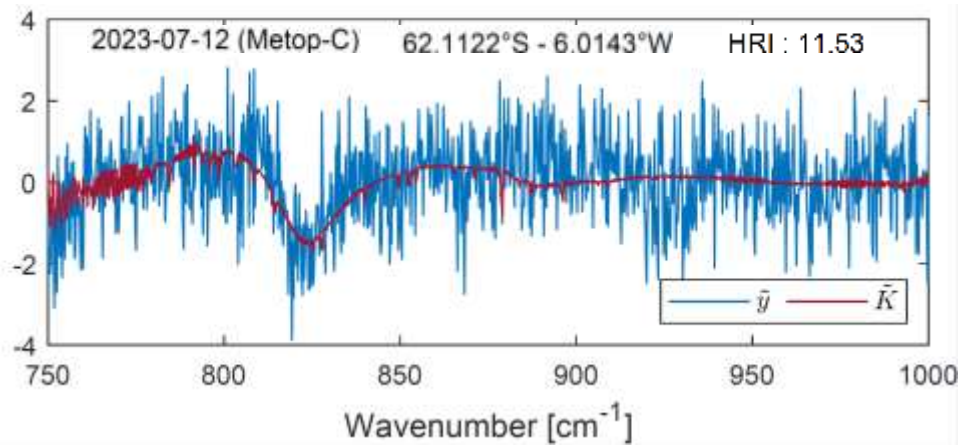
Detection and Mapping

Systematic observations of PSCs in the polar vortex

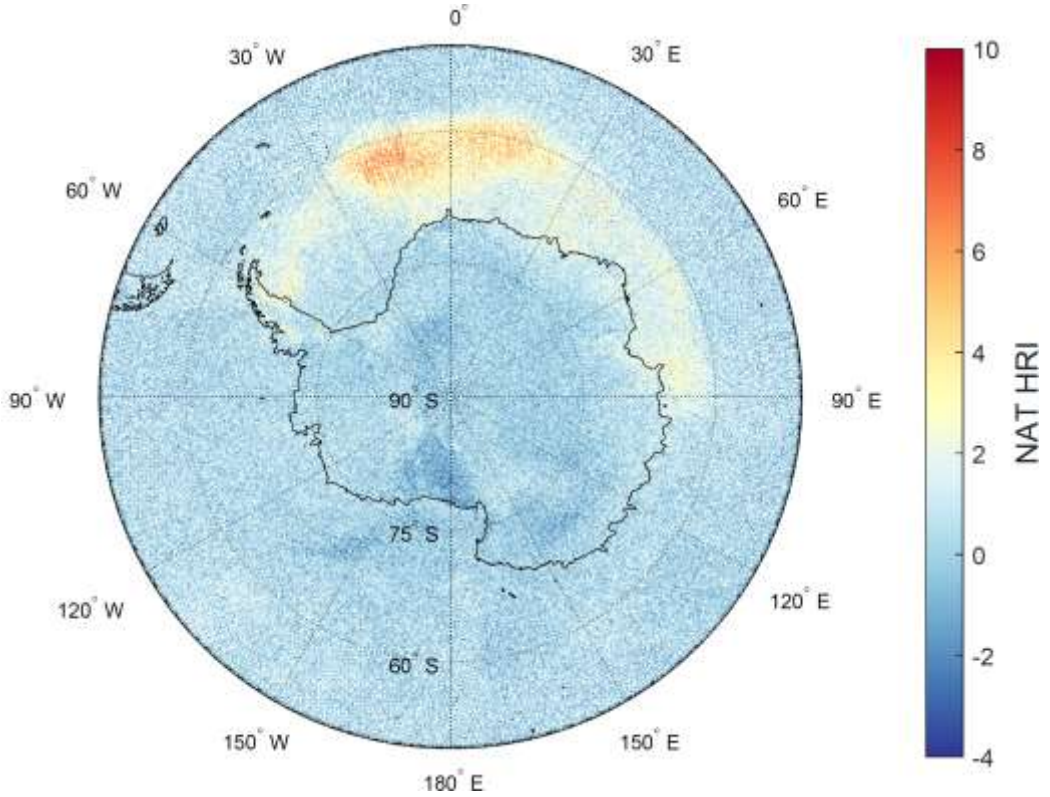
- Detection based on a hyperspectral range index (HRI): strength of the NAT spectral signature

$$\tilde{y} = S^{-\frac{1}{2}}(y - \bar{y})$$
$$\tilde{K} = S^{-\frac{1}{2}}K$$

$$\mathrm{HRI} = \frac{\tilde{K}^T \tilde{y}}{\|\tilde{K}\|}$$



→ **Daily detection maps**



July 12, 2023

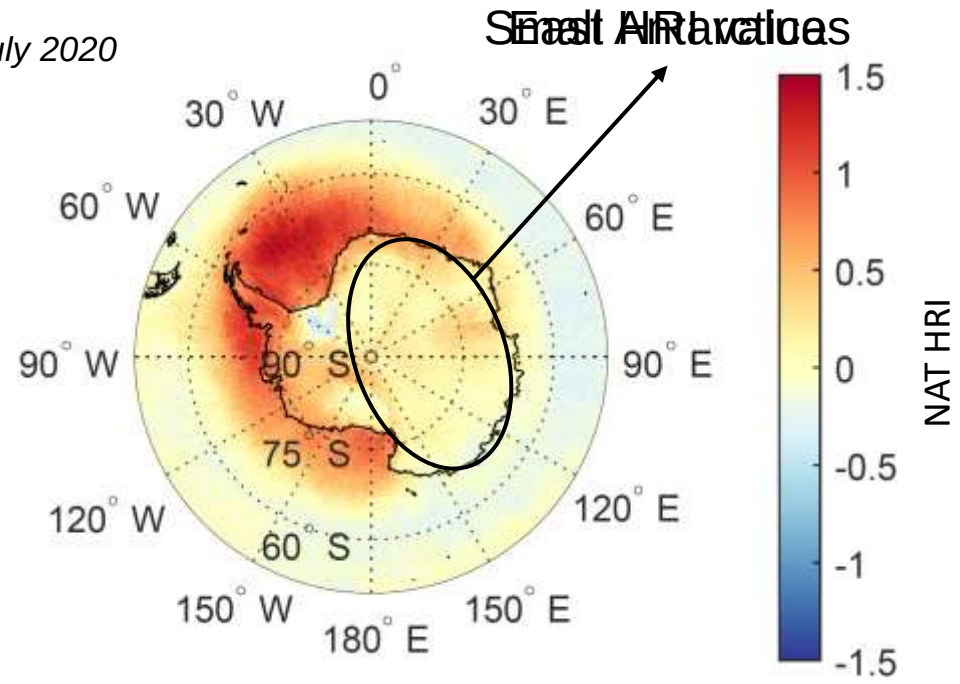
Detection and Mapping

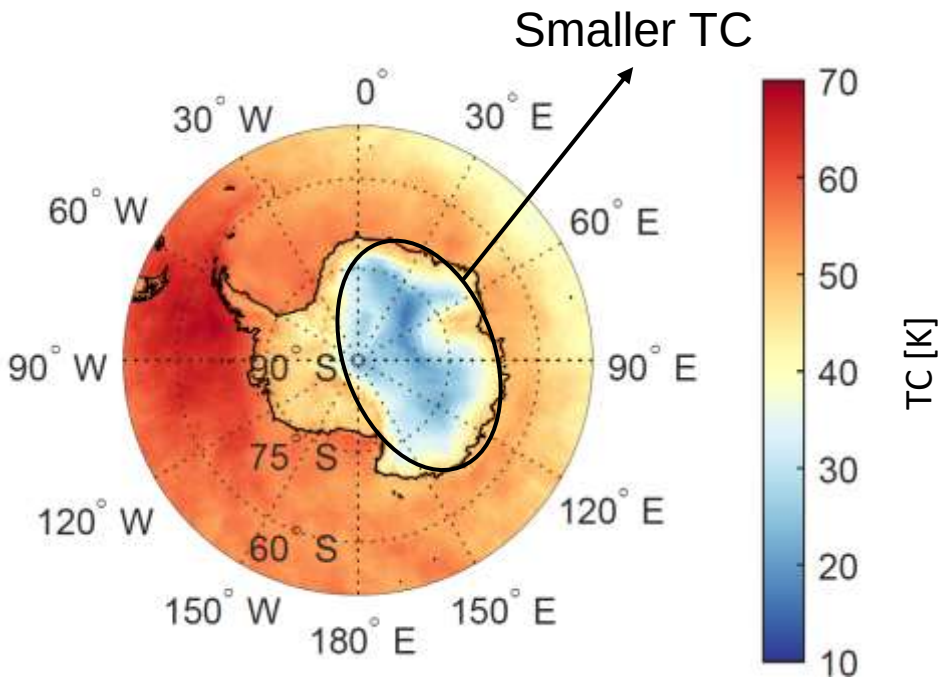
Application to the entire IASI dataset: 15-year PSC time series

- Reliable PSC detections over the ocean, but challenges over the continent

HRI ← Strength of the NAT spectral signature
- NAT particles abundance
- Thermal contrast

July 2020





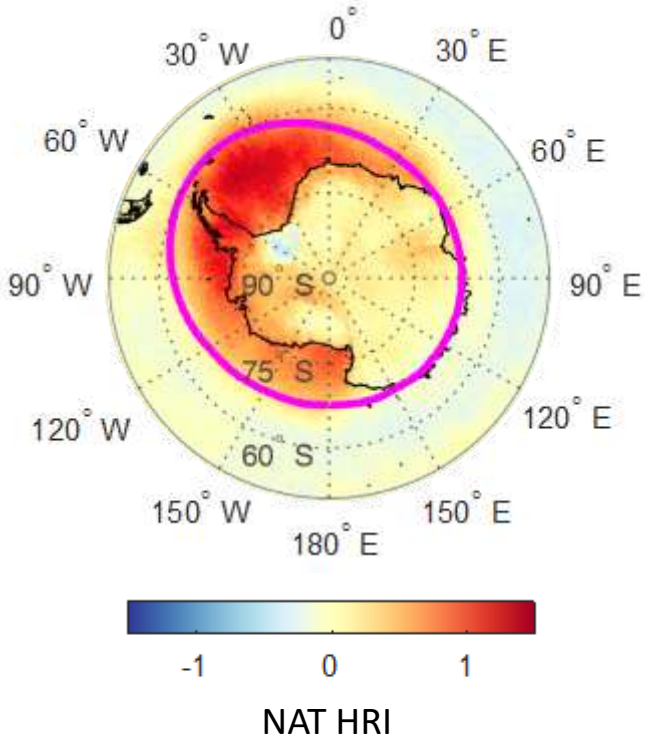
SPATIOTEMPORAL DISTRIBUTIONS

Study of the processes at play in the polar stratosphere

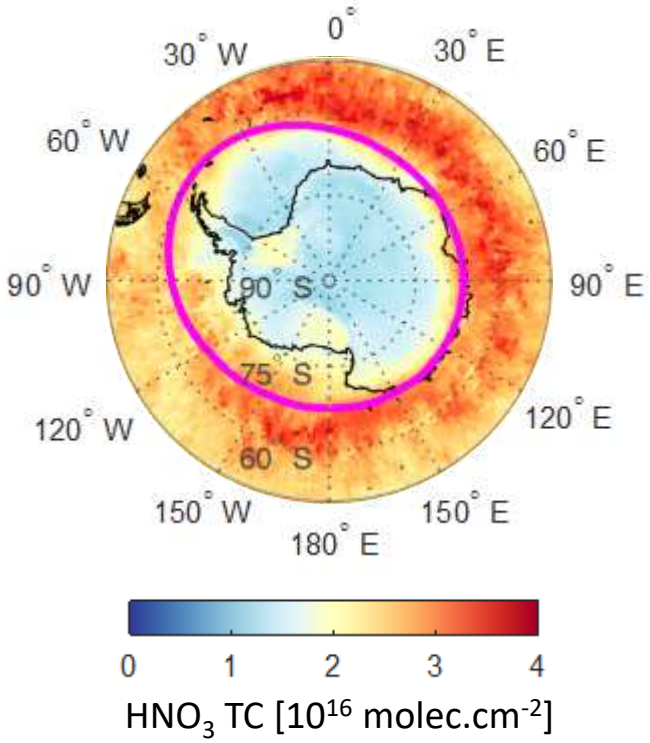
- Relations between PSCs detections (HRIs), HNO_3 total columns and stratospheric temperatures

JULY 2020

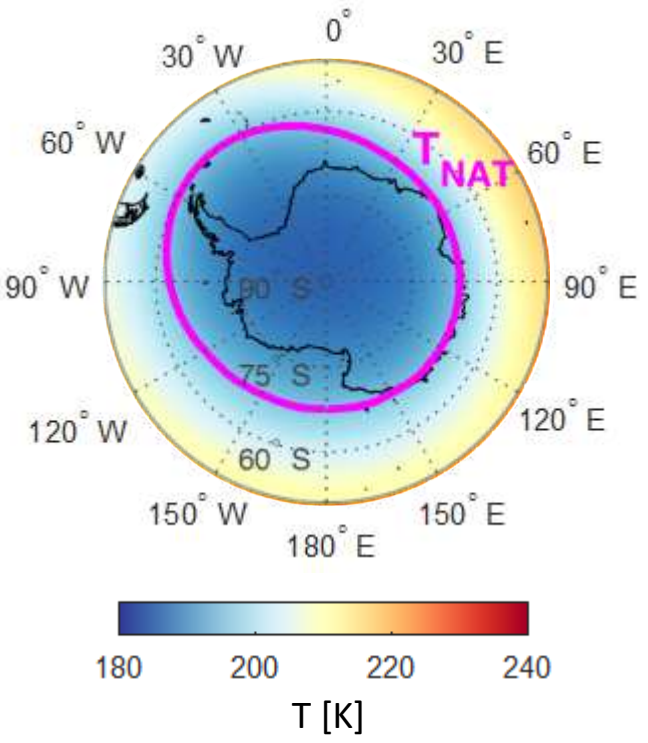
NAT HRI



HNO_3



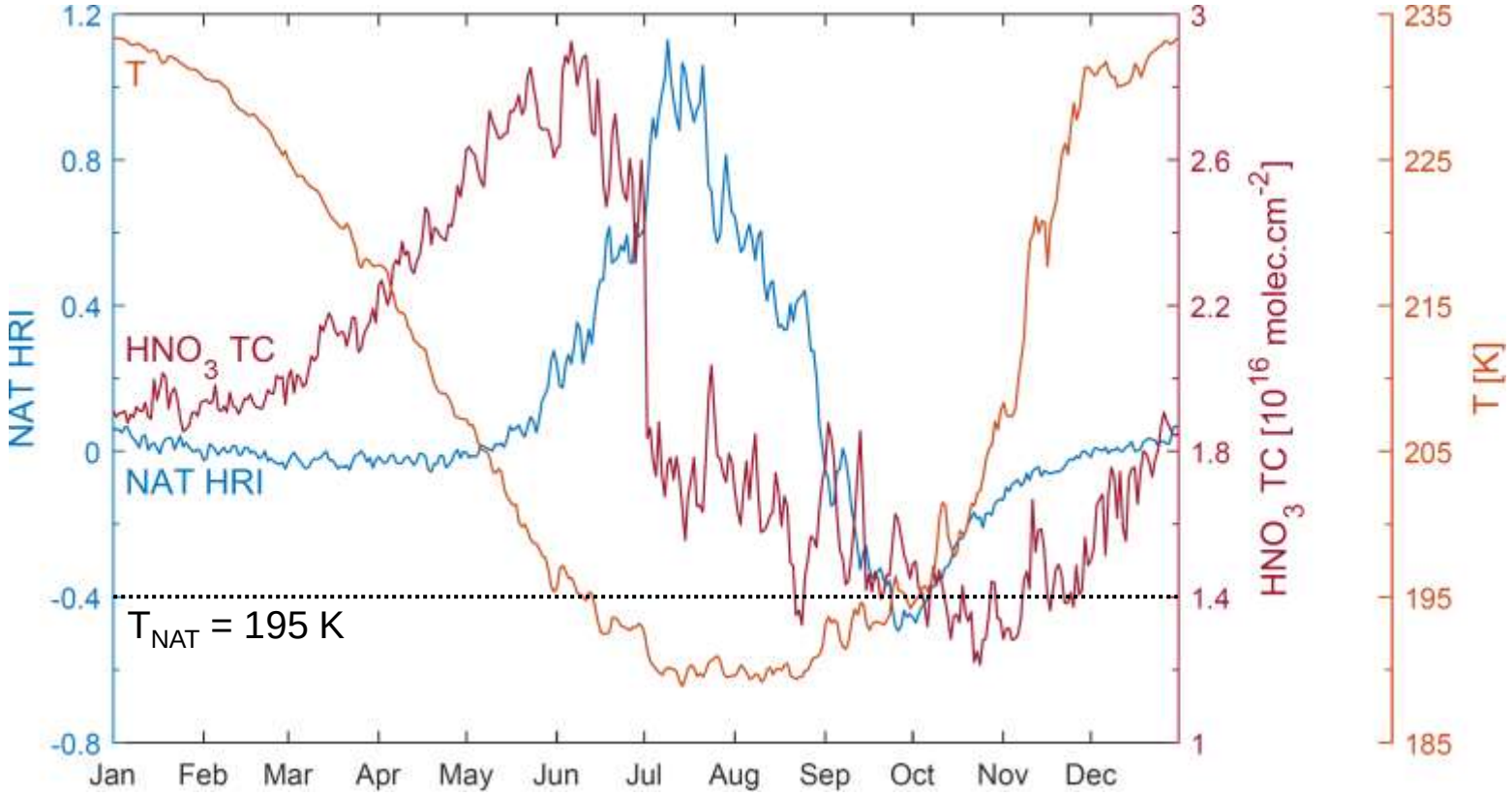
Temperatures



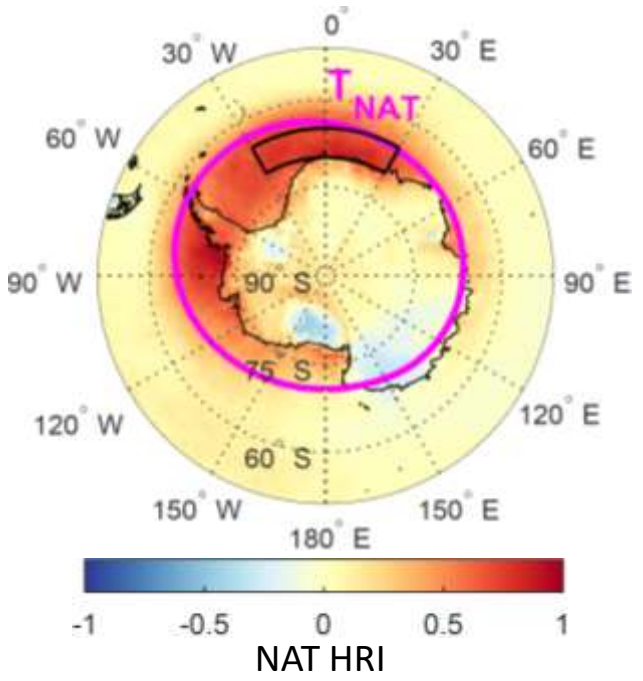
SPATIOTEMPORAL DISTRIBUTIONS

Study of the processes at play in the polar stratosphere

- Climatologies of HRIs, HNO_3 total columns and stratospheric temperatures



2008 – 2023 (-30° ≤ longitude ≤ 30° ; -70° ≤ latitude ≤ -65°)

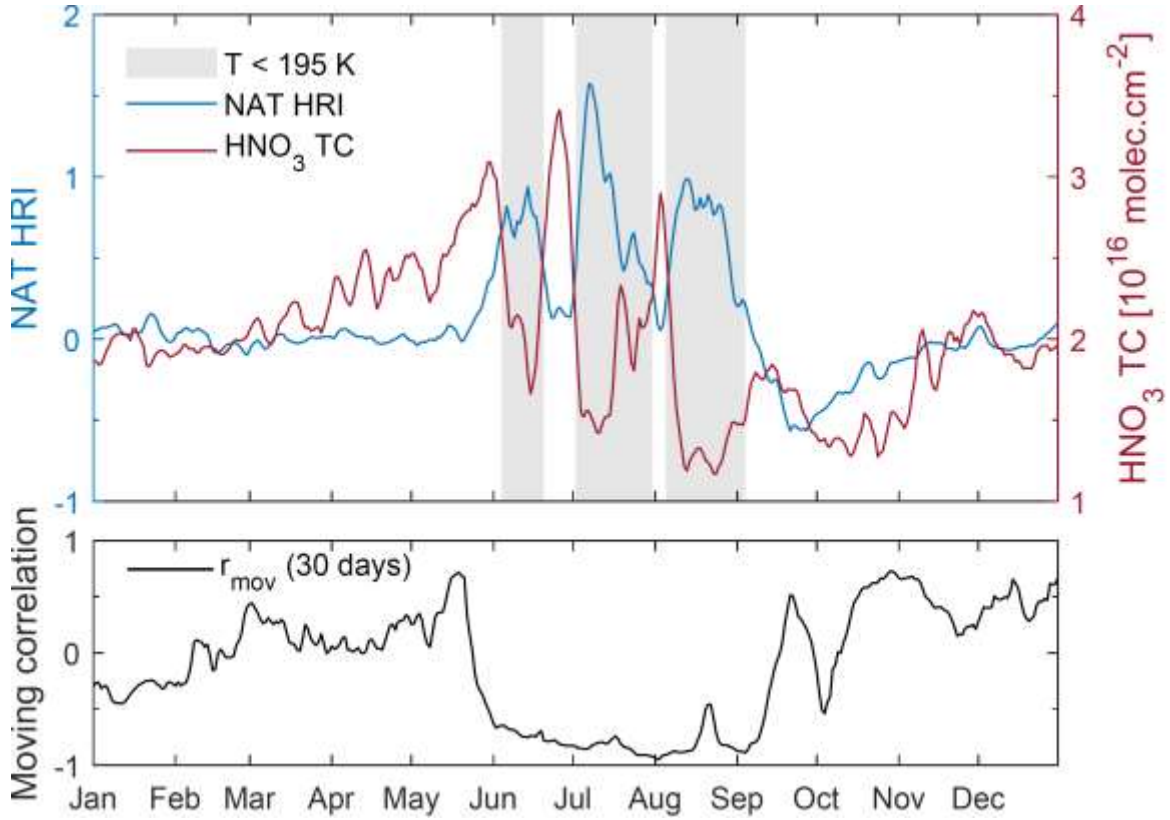


June – August 2023

SPATIOTEMPORAL DISTRIBUTIONS

Study of the processes at play in the polar stratosphere

- Clear anticorrelation between PSCs detections (HRIs) and HNO_3 total columns during winter

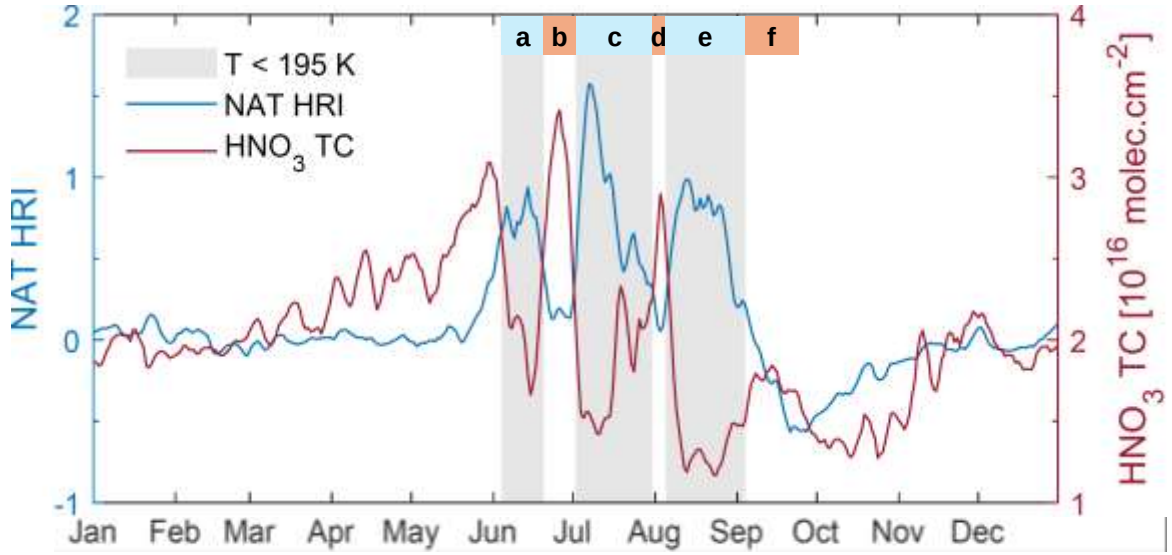


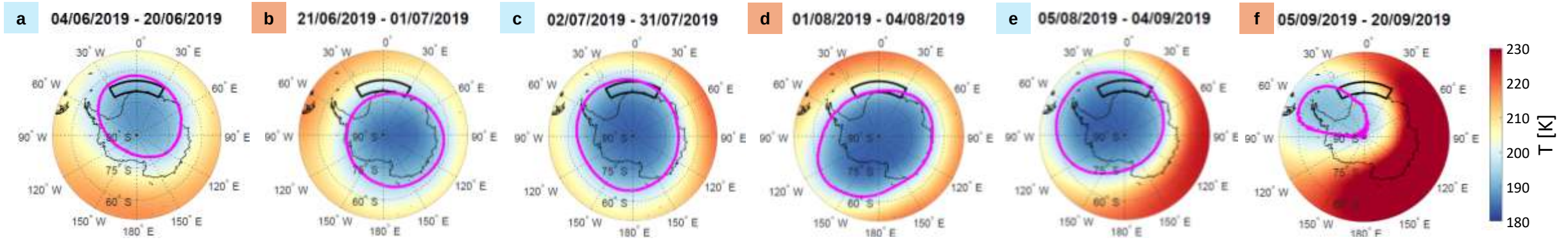
2019 (-30° ≤ longitude ≤ 30° ; -70° ≤ latitude ≤ -65°)

SPATIOTEMPORAL DISTRIBUTIONS

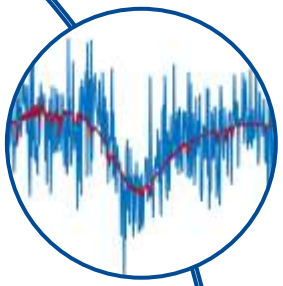
Study of the processes at play in the polar stratosphere

- Short-term patterns related to the dynamics of the polar vortex



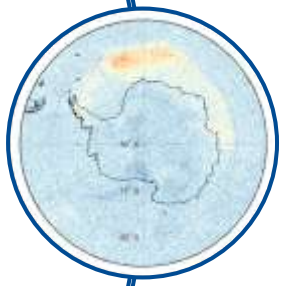


Conclusions



First observations of type Ia PSCs with a passive nadir-viewing sounder

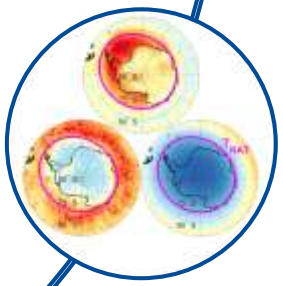
Identification of NAT spectral signature in several IASI spectra



Development of a detection method (HRI)

Systematic PSC detections in the polar vortex: daily detection maps

Application to the entire IASI dataset: unique PSC dataset



Study of the processes at play in the polar stratosphere

Relations between PSCs, HNO_3 and stratospheric temperatures

Anticorrelation between PSC detections and HNO_3 abundance

Capability of IASI to monitor the polar stratosphere

OUTLOOK

Quantitative product

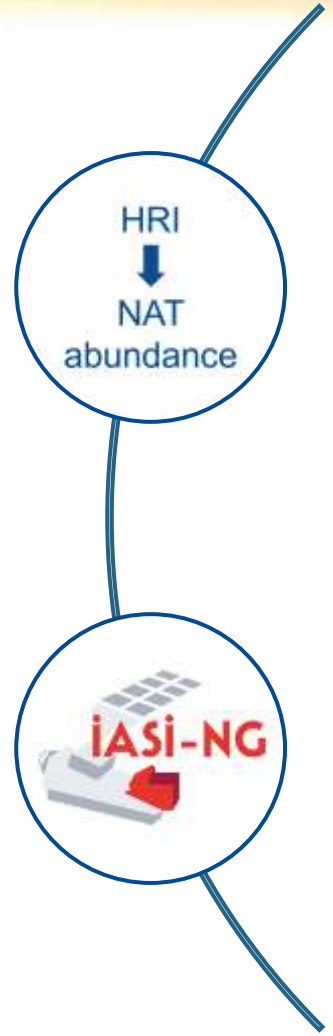
Retrieval of NAT particles abundance via look-up-tables

Representation of particles: size, shape

Future IASI-NG sounder

Better detection thanks to improved radiometric performances

Long-term continuity of measurements: evolution of PSCs with climate change

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