Polar Mesospheric Cloud Particle Size Retrieval from GOMOS / ENVISAT Observations

Kristell Pérot[1], Alain Hauchecorne[2], Franck Montmessin[2], Jean-Loup Bertaux[2]

1. Chalmers University of Technology, Gothenburg, Sweden
2. LATMOS, Guyancourt, France

CHALMERS

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LATMOS

Polar Mesospheric Clouds (PMCs), or Noctilucent clouds (NLCs)

- Location:
  High latitude summertime mesopause region (HLSM)
  (80 < altitude < 86 km, latitude > 55°)

- Composition:
  Water ice – meteoric smoke mixture (H_2O > 97% by volume, Hervig et al., 2012)

- Why do we care?
  - Very sensitive to changes in their environment →
    Important tracers for the complex processes that control the mesosphere
    (wave activity, dynamical coupling mechanisms)
  - **Possible indicators of long-term climate change in the Mesosphere**

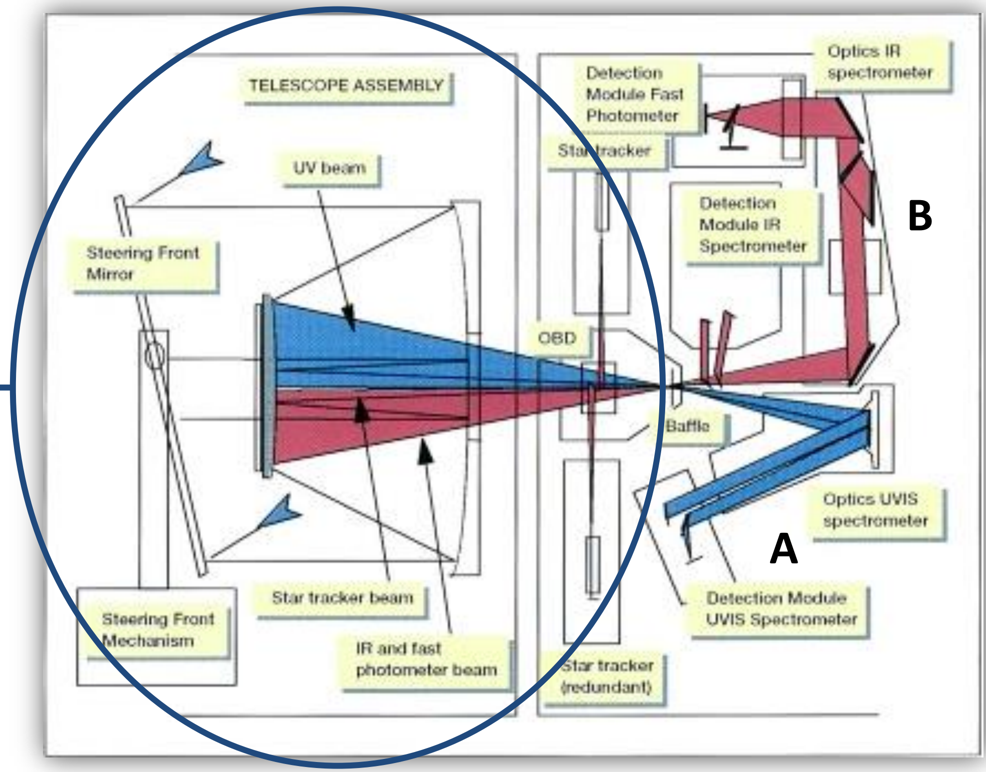
GOMOS: Global Ozone Monitoring by Occultation of Stars

Part of the **ENVISAT** mission, developed by the european space agency, Launched in 2002 by Ariane 5 in Kourou (French Guyana)

Sun-synchronous orbit:
Average altitude ≈ 800km, inclination = 98,6°, orbital period = 100.6min, equator descending crossing-time = 10:00 local time

Stellar occultation technique:
- very accurate altitude retrieval
- very good geographical and temporal coverage
- observations at various local times
- self-calibrated data

Pointing system



(ESA)

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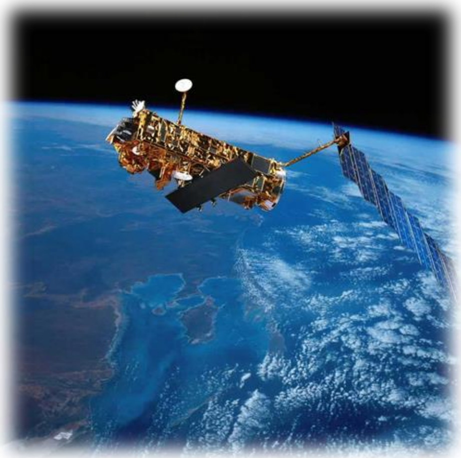

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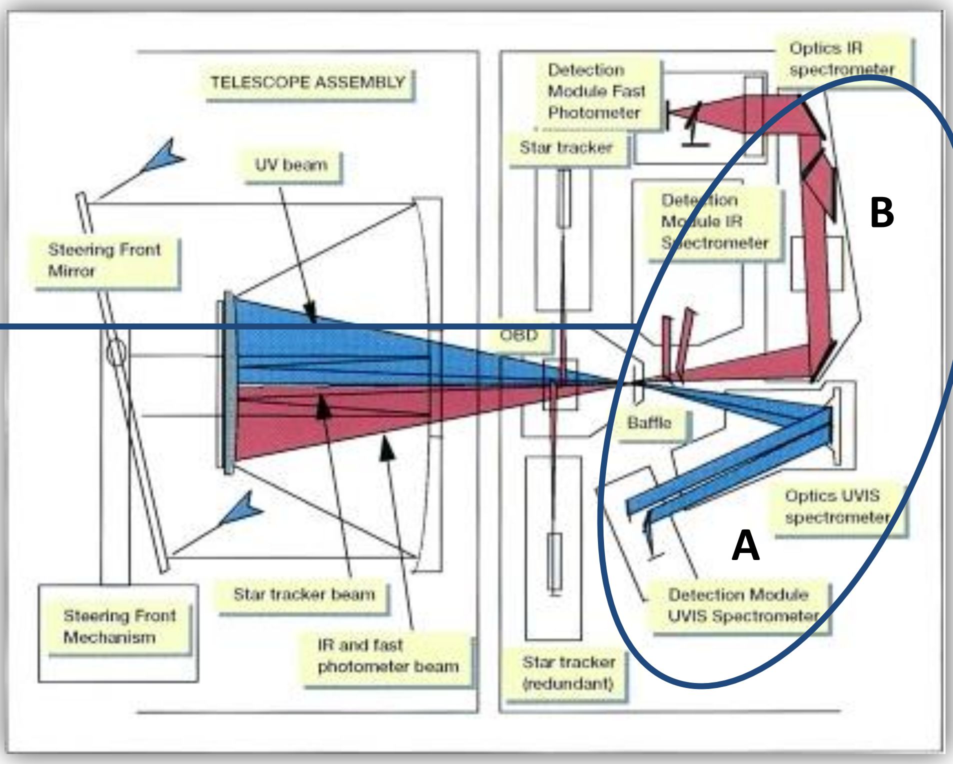
<u>4 spectrometers UV-vis-NIR:</u>
- **Spectral region**:
  248-955 nm (UV – vis – NIR)
- **Spectral resolution**:
  0.8 nm (A) and 0.13 nm (B)
- **Vertical resolution**:
  1 to 1.7 km



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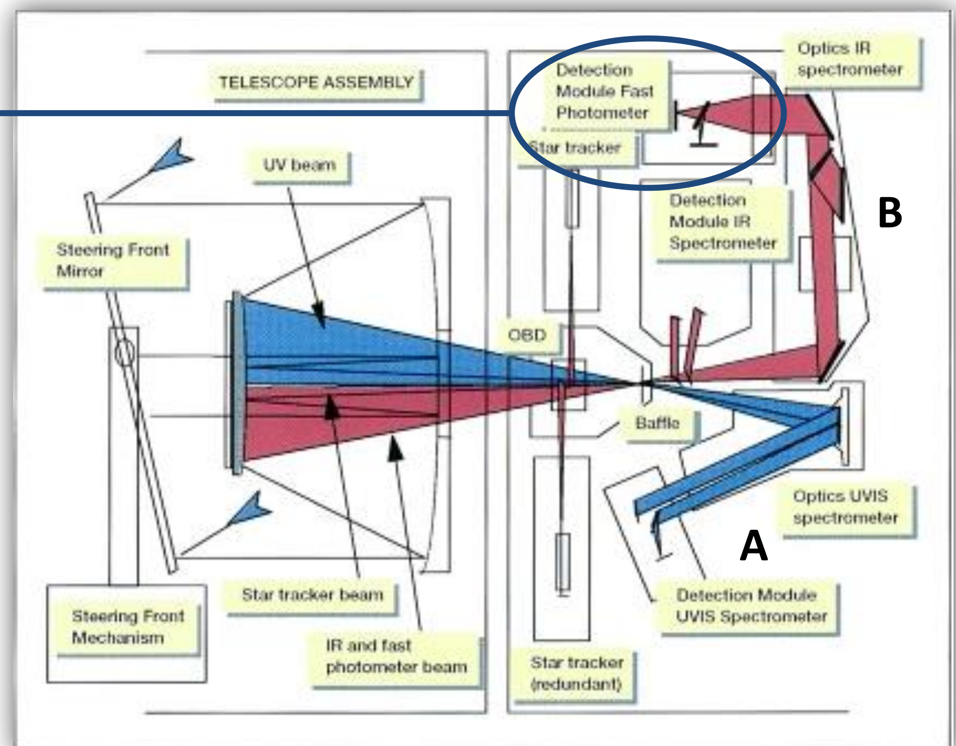
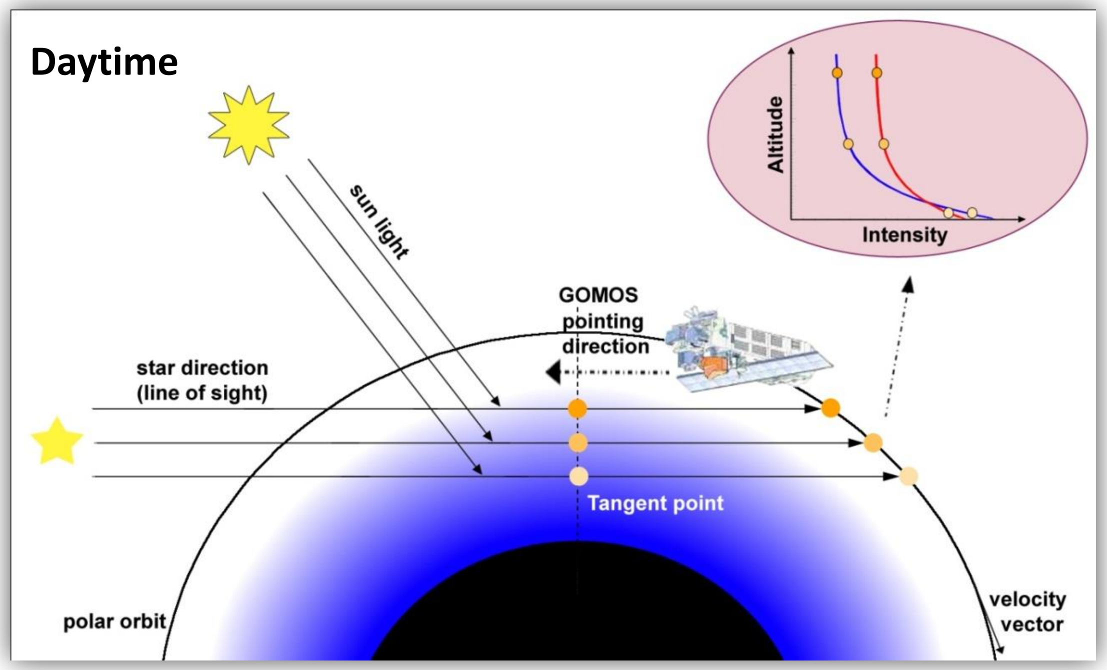


2 fast photometers

(ESA)

PMC detection from GOMOS observations

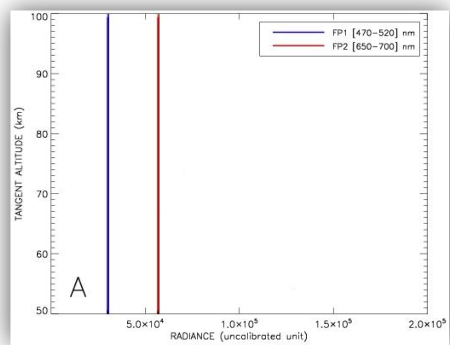


2 fast photometers:

- Spectral bands:
  FP1: ~470 – 520 nm
  FP2: ~650 – 700 nm
- Sampling frequency = 1 kHz
- **Vertical resolution < 1 km**

Dark limb:

$$F(z_t) = F_{star}(z_t)$$



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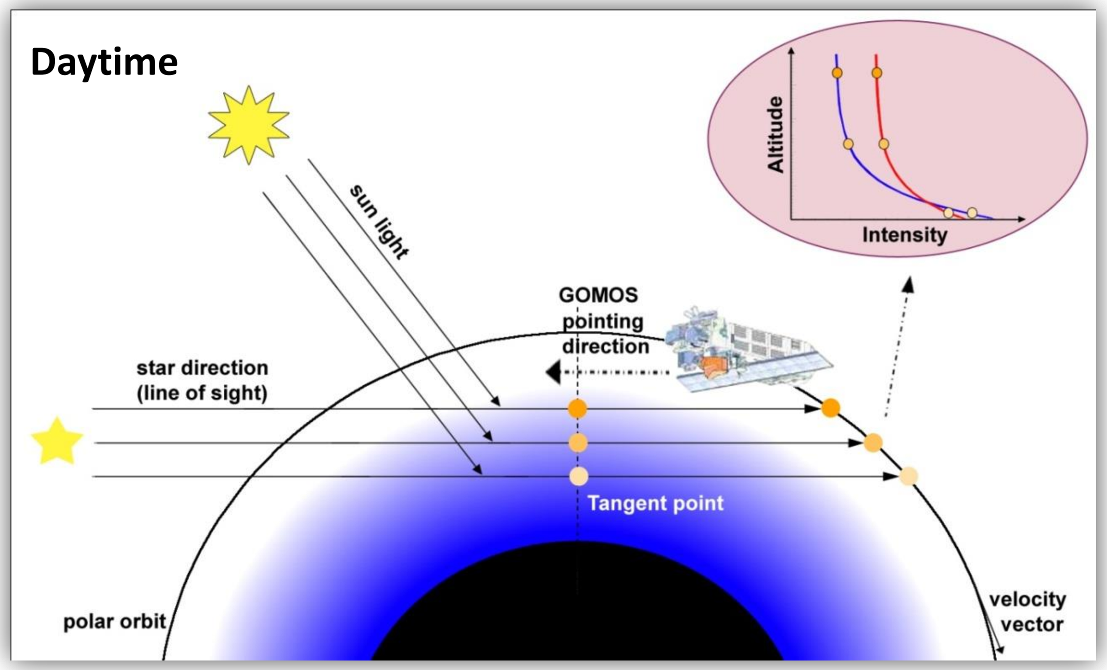

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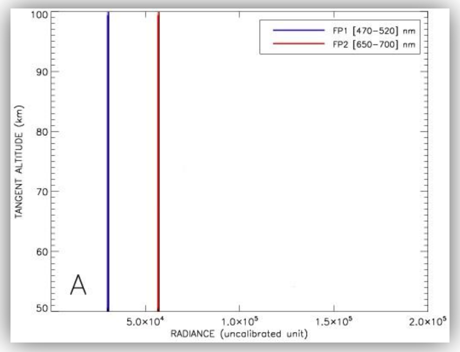
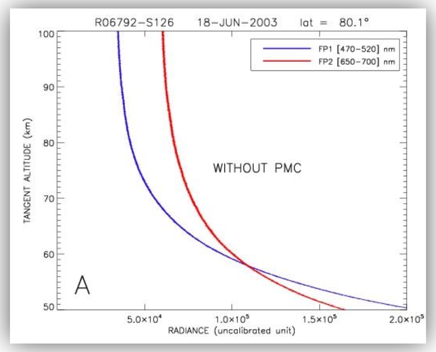
Bright limb without PMC along the line of sight:

$$F(z_t) = F_{star}(z_t) + F_{Ray}(z_t) + F_{straylight}(z_t)$$





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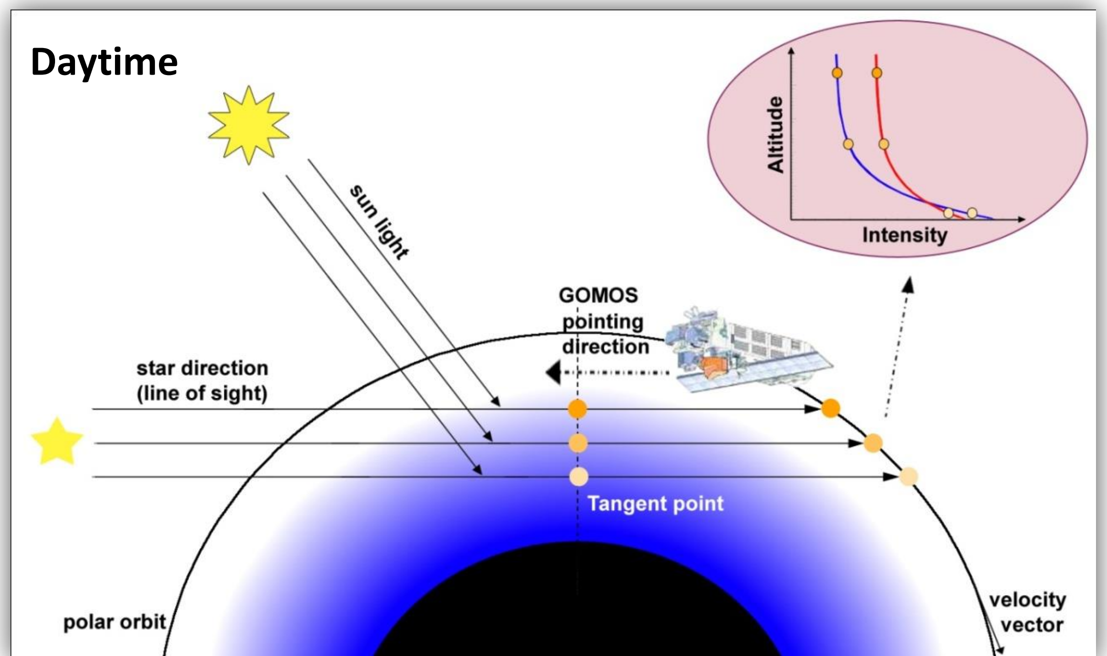

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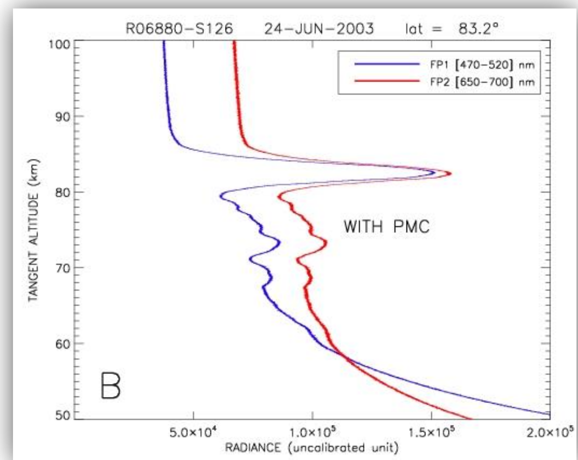
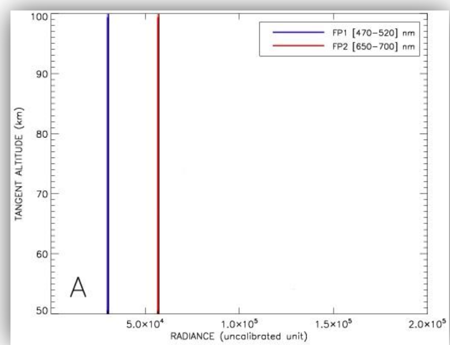
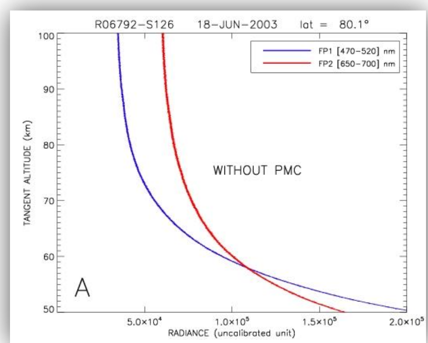


Bright limb with PMC along the line of sight:

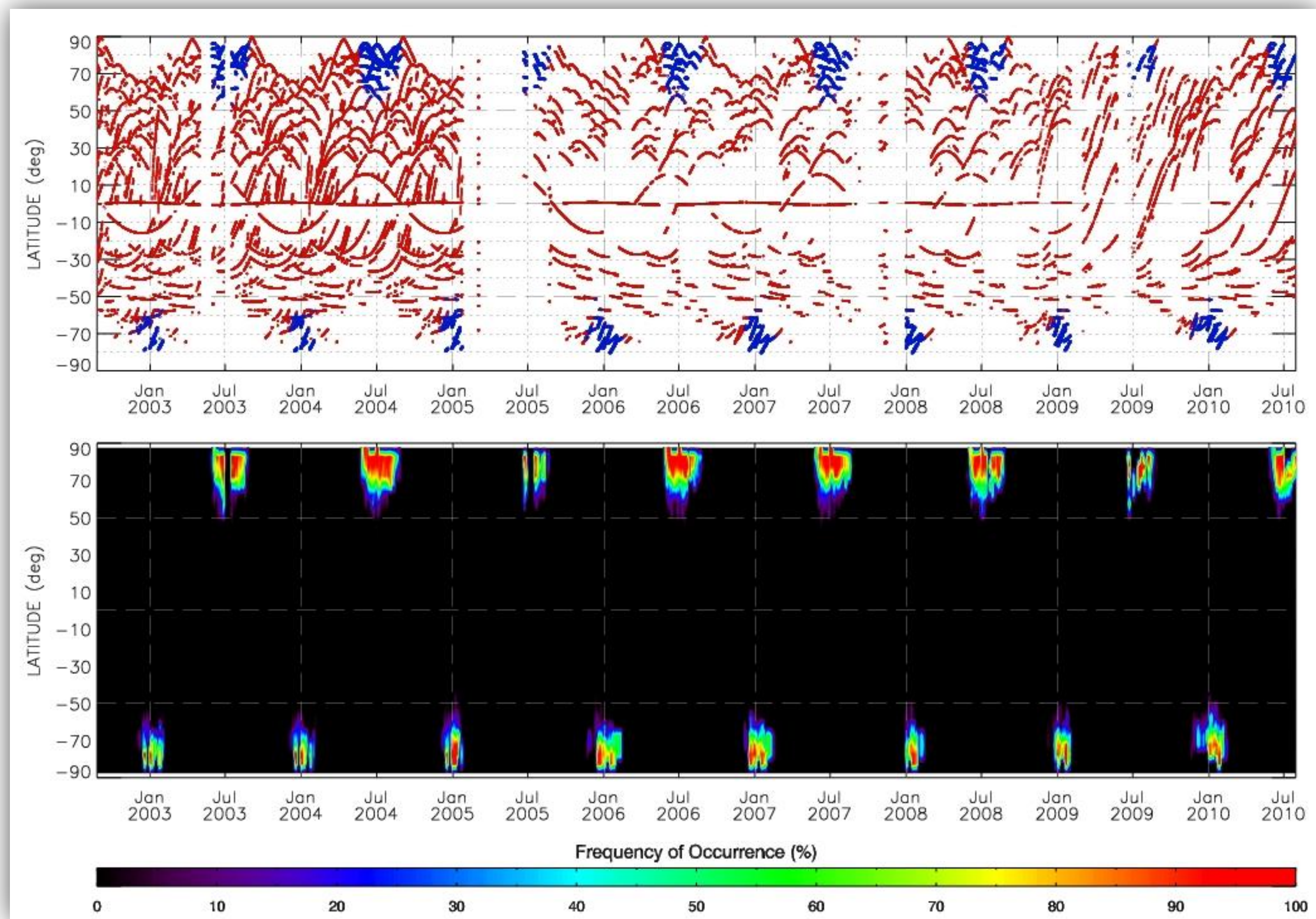
$$F(z_t) = F_{PMC}(z_t) + F_{star}(z_t) + F_{Ray}(z_t) + F_{straylight}(z_t)$$





→ **PMC detection** algorithm, and retrieval of their main properties (peak altitude, radiance)

GOMOS PMC data set



(Pérot et al., ACP, 2010)

● PMC detection

● No PMC detection

Detection algorithm applied to all GOMOS measurements

From **August 2002**

to **July 2010**:

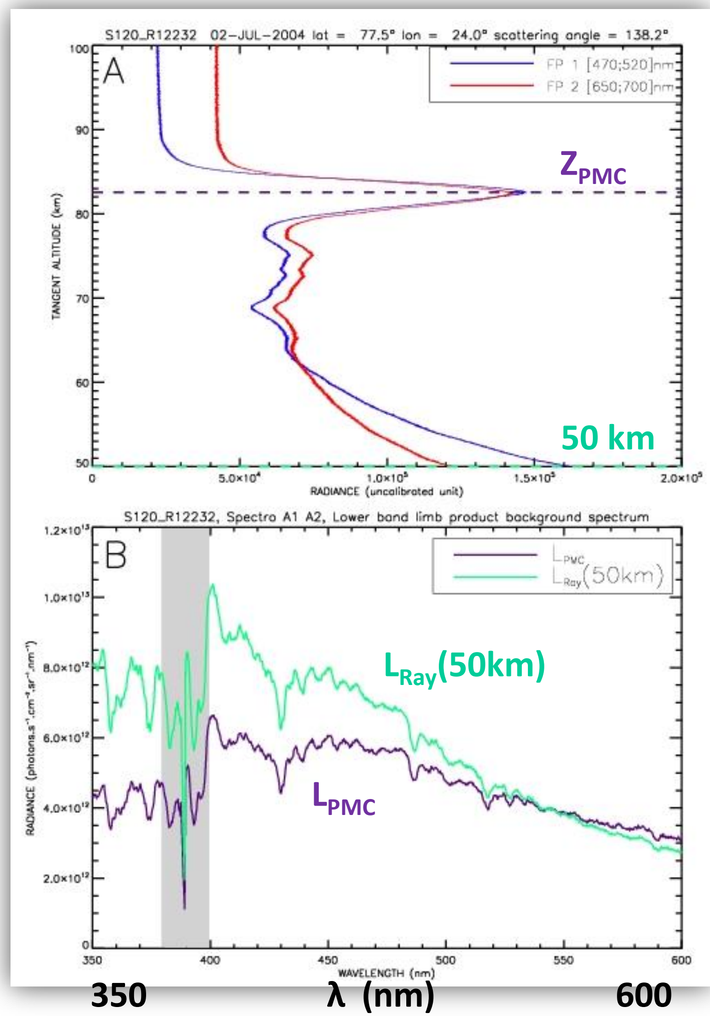
> 300 000 profiles analysed

→ **> 21 000 PMCs** detected

Extension of this data set until the end of GOMOS operational life (April 2012):

in progress at LATMOS in the framework of the **ESA project mesosphEO** (exploitation of the mesosphere).

PMC particle size retrieval: Determination of the Ångström exponent



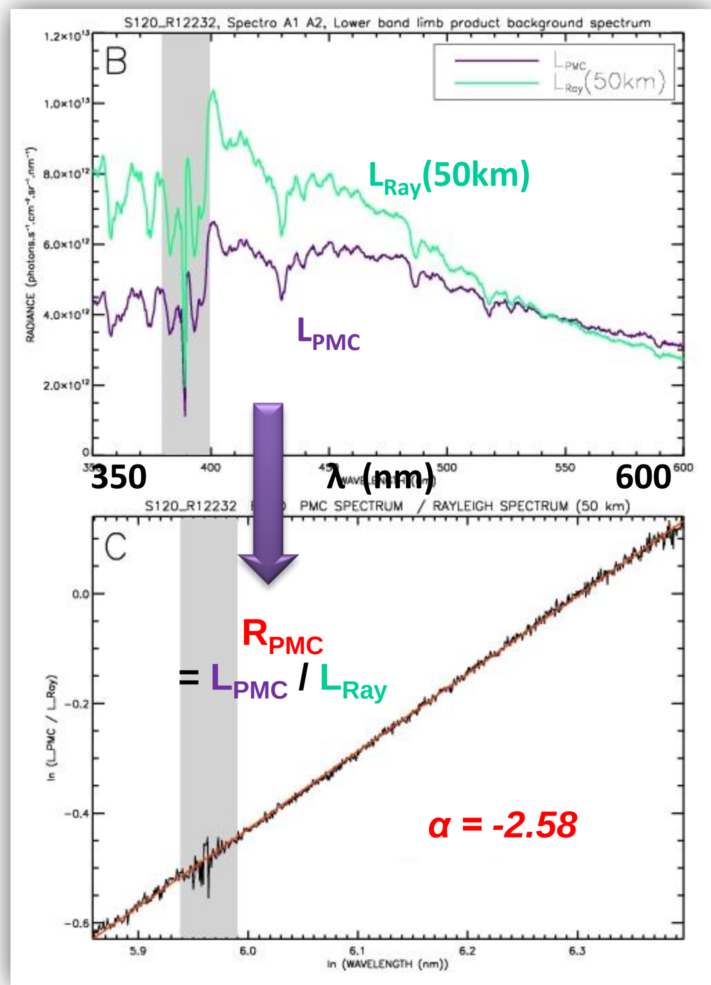
Knowledge of the size distribution of PMC ice particles:
Essential for a correct modeling

Ångström exponent α: characteristic parameter of the spectral dependence of light scattering by small particles.

- **Background bands** of GOMOS spectrometers CCD
- Spectral range: **[350-600]nm**
- For each detected PMC:

1. External stray light correction
2. **Rayleigh radiance** spectrum (reference): $L_{Ray} \propto \lambda^{-4}$
3. **PMC radiance** spectrum: $L_{PMC} \propto \lambda^{\alpha}$

PMC particle size retrieval: Determination of the Ångström exponent



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Ångström exponent α : characteristic parameter of the spectral dependence of light scattering by small particles.

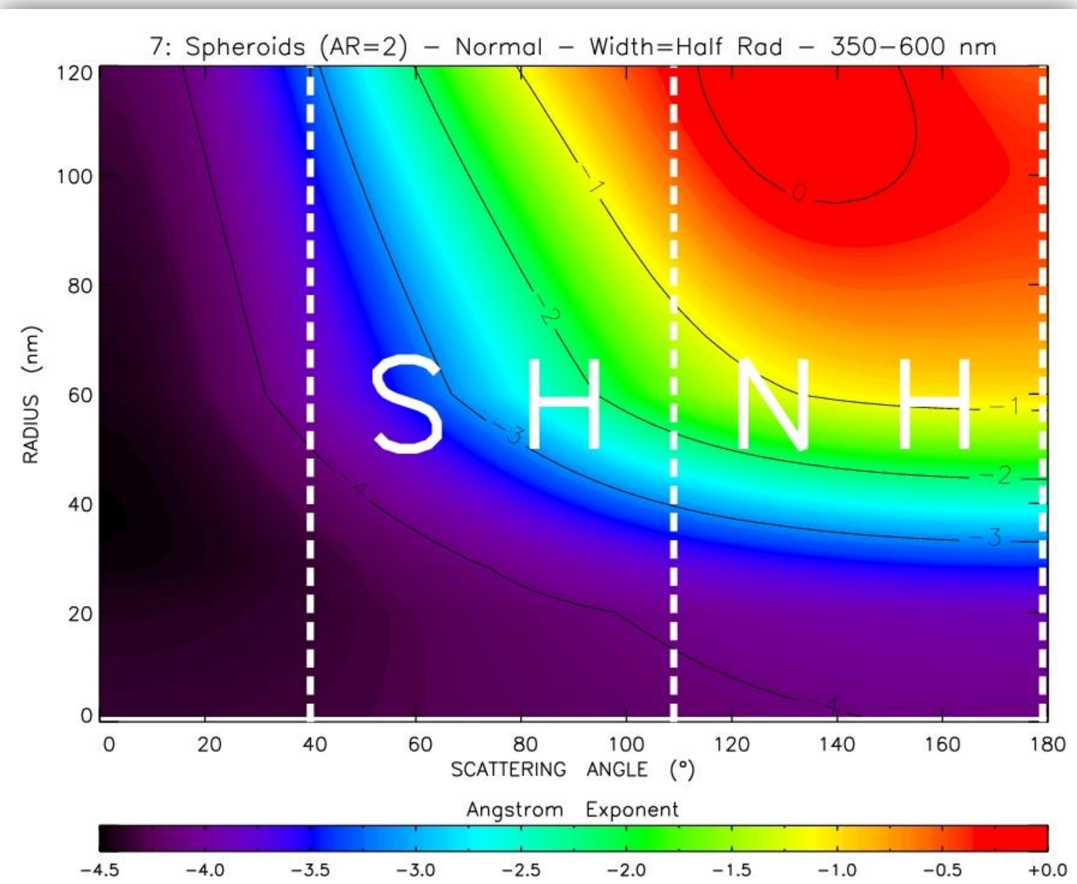
- **Background bands** of GOMOS spectrometers CCD
- Spectral range: **[350-600]nm**
- For each detected PMC:

4. Ratio: $$R_{PMC} = \frac{L_{PMC}}{L_{Ray}} \propto \frac{\lambda^{\alpha}}{\lambda^{-4}} = \lambda^{x}$$

logarithmic form: $$ln(R_{PMC}) = x \, . \, ln(\lambda) + C$$

with: $$\alpha = x - 4$$

PMC particle size retrieval: From Ångström exponent to particle size



- Assumptions:
  - **Spheroïds (AR = 2)**
  - **Normal distribution**:

  σ = 10nm if r ≤ 20nm

  σ = r / 2 if 20nm < r < 60nm

  σ = 30nm if r ≥ 60nm
  - **Pure ice particles**

- Modelling: **T-matrix method** (calculations by Gerd Baumgarten, IAP Kühlungsborn)

Note: median radius of a Gaussian distribution

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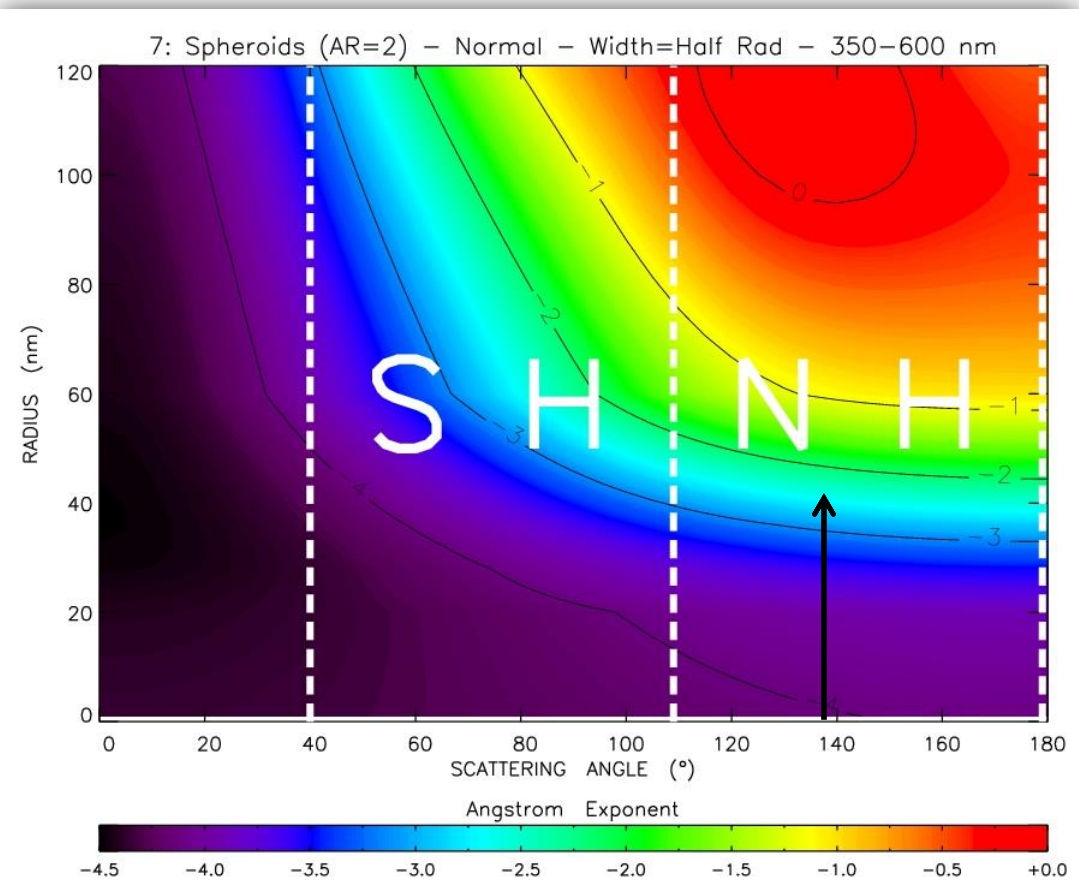

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- Example:
  α = -2.58 and θ = 138.2°

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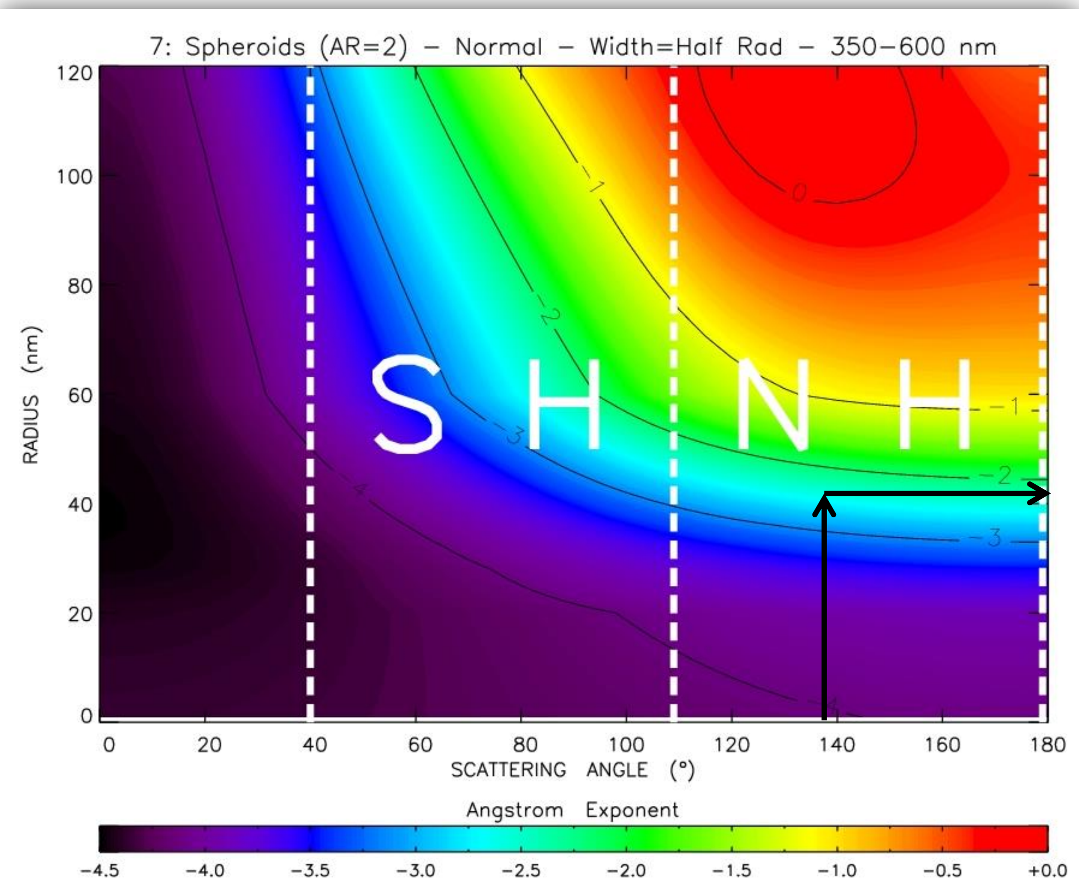

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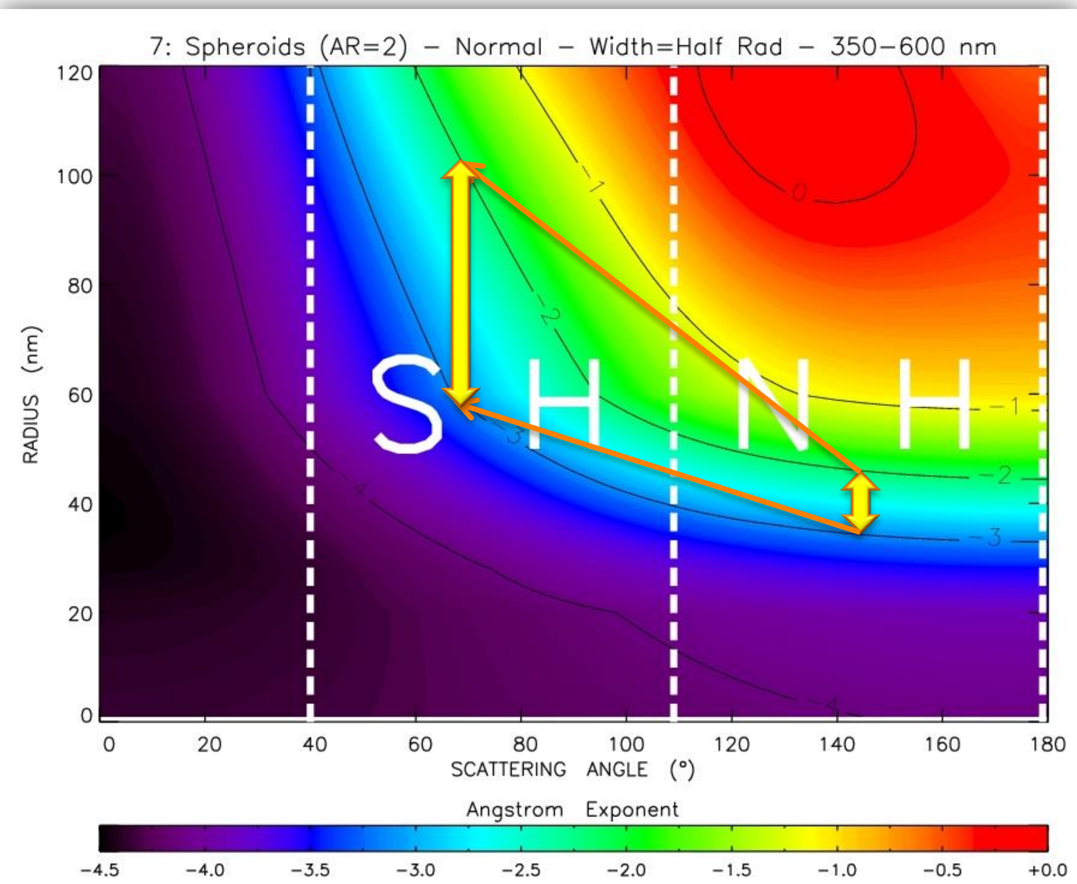

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- Example:
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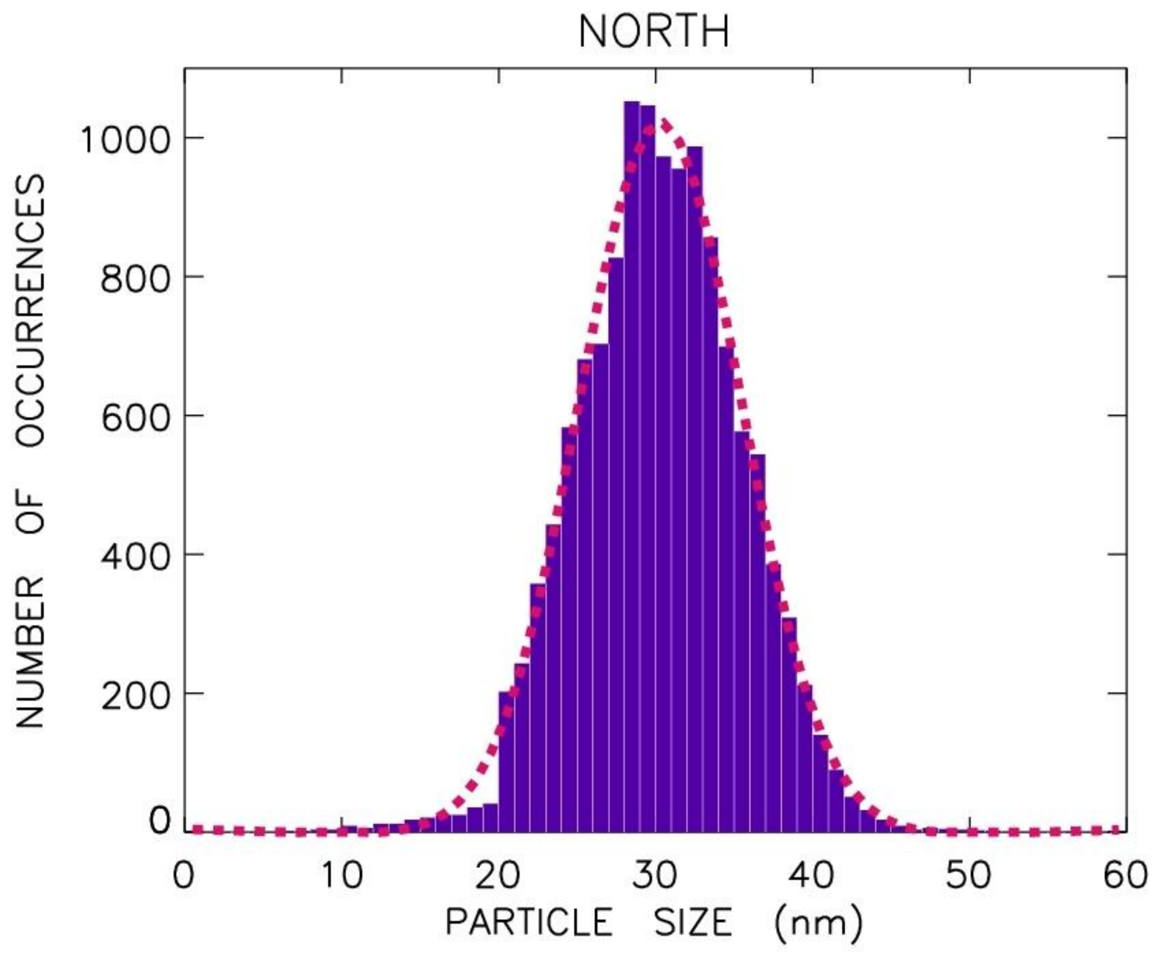
  → r = 40.01 nm
- **More uncertain retrieval for the Southern hemisphere**

PMC particle size retrieval:
Results for the northern hemisphere



- Algorithm applied to all clouds detected between 2002 and 2010:

  ~14 000 PMCs
  in the northern hemisphere

- Output values:

  20 nm < r < 45 nm

  Mean radius = 30.3 nm
  Standard deviation = 5.2 nm

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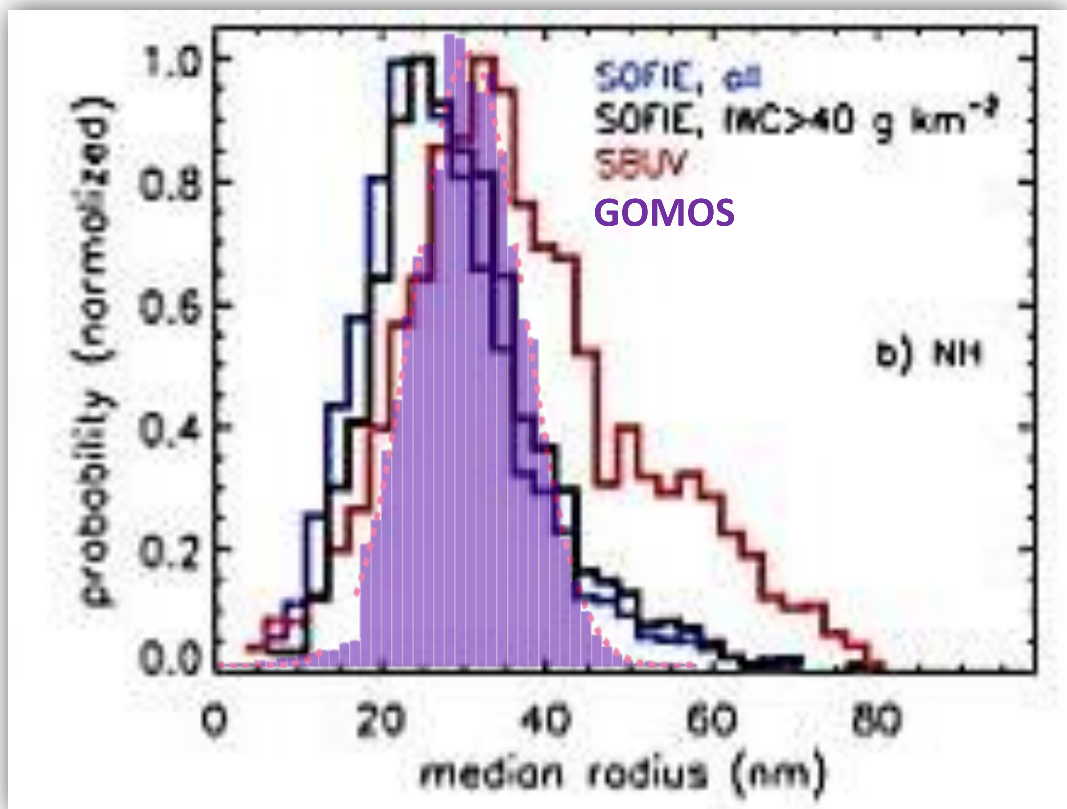

From Hervig and Stevens (2014)

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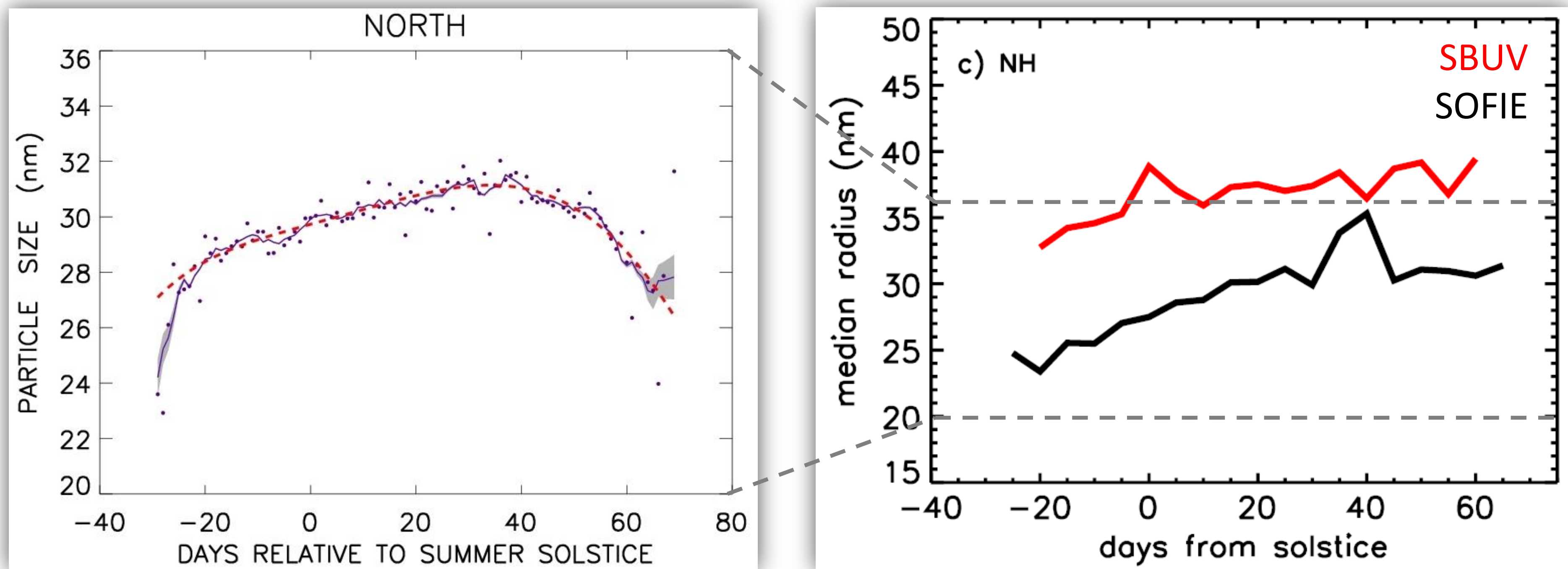
- **Good consistency** with other instruments:

For example, SOFIE and SBUV:
Observations in the Northern Hemisphere, between 2007 and 2013,
Similar assumptions on the shape of the particles and on the particle size distribution:
SOFIE mean radius = 30 nm, SBUV mean radius = 37 nm.

Seasonal variation



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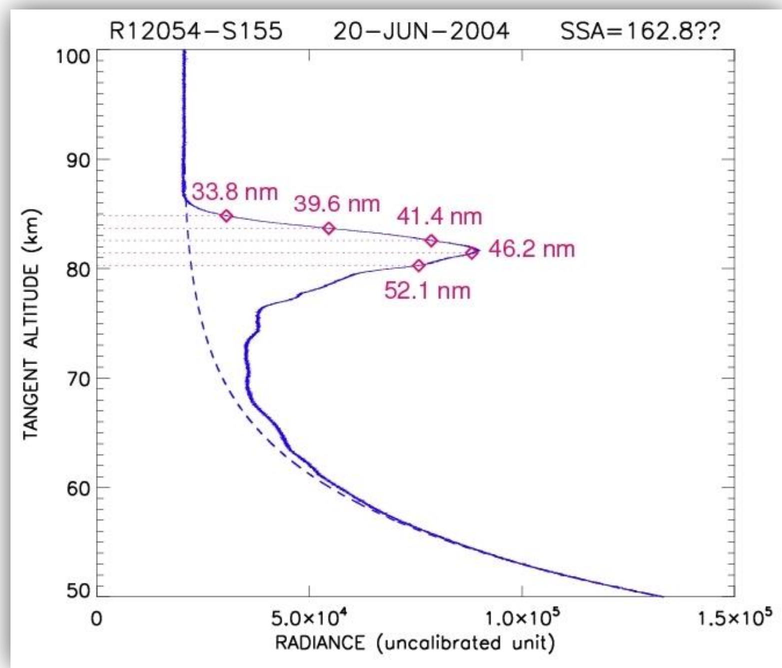
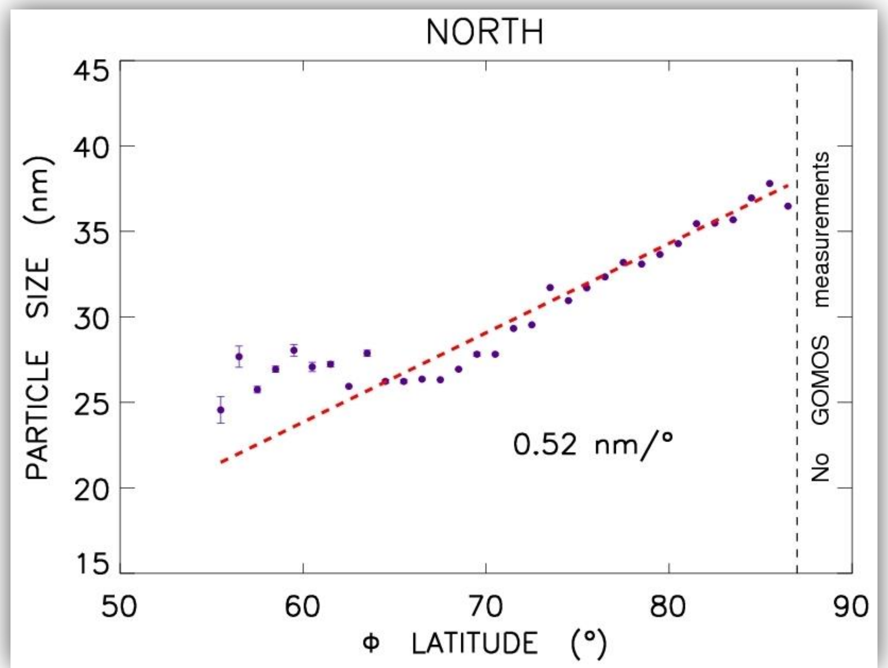
- Seasonal features:
  correlated with peak radiance

- Consistent with seasonal evolution of the mesopause region:
  Saturation level higher in mid-season

Vertical and latitudinal variations





Anticorrelation between altitude and particle size:

1. PMC particles form near the mesopause where saturation ratios are largest.
2. Particles fall within the saturated layer and keep growing.
3. The deepest the layer, the larger the particles.

Clear **linear increase towards the poles:**

The vertical extent of the saturated region increases with latitude

→ Particle growth favored

Summary

PMCs:
Tracers for the **physical processes** that control the **mesosphere**.

Particle size:
Important parameter to look at, **essential for a correct modelling** of their formation, their growth and their lifetime.

GOMOS:
8-year data set (extension to 10 years in the framework of the ESA mesosphEO project)
Paper in preparation.