First Climatology of Polar Mesospheric Clouds from GOMOS / ENVISAT stellar occultation instrument

Kristell Pérot,
Alain Hauchecorne, Franck Montmessin, Jean-Loup Bertaux

LATMOS
Laboratoire ATmosphères, Milieux et Observation Spatiale
Verrières Le Buisson - France

ESA Atmospheric Science Conference
Barcelona, Spain, 7-11 September 2009
Basic knowledge on Polar Mesospheric Clouds

PMC detection algorithm

First results
Polar Mesospheric Clouds (PMC): Clouds at the edge of space

Location: high latitude summer mesopause, the coldest region of the atmosphere: \( T \leq 140K \)

Average altitude = ~83 km → the highest clouds in the Earth’s atmosphere

Composed primarily of water ice particles

Also called noctilucent clouds (NLC), when observed from the ground

Extremely small optical depth, of only \( 10^{-6} \) to \( 10^{-4} \)

More and more frequent and bright

Occurrence at lower latitudes than ever before

→ link to the long-term global change in the mesosphere?
GOMOS Fast Photometers

PMC analysed using exclusively the **2 fast photometers** for the moment:

- Sampling frequency = 1 kHz
- Spectral bands : **470-520 nm** and **650-700 nm**
- Vertical resolution < 1 km
- Measurement during day time:

![Diagram showing GOMOS pointing direction, star direction, tangent point, and polar orbit.](image)
Signal measured by GOMOS photometers
(on the day side only)

Without PMC:

\[ S_{meas}(z) = S_{star}(z) + S_{molec}(z) \]

With a PMC along the line-of-sight:

\[ S_{meas}(z) = S_{star}(z) + S_{molec}(z) + S_{PMC}(z) \]
PMC detection algorithm

Goal: to isolate any PMC signature

Main detection criterion:
\[ \chi^2 > \chi^2_{\text{threshold}} \] (for the 2 photometers)

Algorithm applied to all GOMOS measurements from 26/08/2002 to 04/07/2006:

\[ \sim 200,000 \text{ events} \] processed

Verification of a great number of detections, and correction if necessary

In the end: Very accurate method

→ Almost 10,000 PMCs detected!

Very rich data set for further studies
Global PMC maps: Example of 2 PMC seasons in 2003 and 2004

- All GOMOS measurements
- PMC observations

Very good spatial and temporal resolution,
but important interhemispheric difference in the observation distribution
Results of GOMOS data set analysis: General representation

**Observations distribution**

**PMCs location**

- PMC location:
  - At High latitudes
  - During local summer

- Very good visualization of the geographical and temporal coverage

- 2003 and 2005:
  - Instrument problems → Data loss

**PMC Frequency**:

- Frequency of occurrence calculated on a local level:
  - In each square of 5 days by 5° lat

- Very quick variation

- At first glance:
  - PMCs more numerous in the North than in the South
 PMC detection frequency as a function of time

- Frequency calculation:
  - 2 weeks time bins
  - throughout 4 years
  - considered latitudes: ± [65;75]°

- A PMC season:
  - ~ 3 months period during local summer

- A great deal of interannual variability

- PMCs more frequent in the North, but interhemispheric differences are strongly dependent on observation distribution
PMC altitude

**Determination:**

- Cloud height defined as the tangent altitude corresponding to the highest peak of the PMC signature in the signal

**Distribution of output values:**

- for ~ 95% of the observations:
  
  \[ 80 \text{ km} < z_{\text{PMC}} < 86 \text{ km} \]

- Median value:
  
  = **82.7 km** in the North
  = **83.2 km** in the South

- Clouds slightly higher in the southern hemisphere (~ 500 m)
Latitudinal variation of PMC altitude:
Comparison to LIMA

**LIMA model**
- SH altitude > NH altitude
  - difference ~ 1km
- increase with latitude
  - with a slope ~40m/deg for both hemispheres
  - smaller at high latitude

**GOMOS**
- SH altitude > NH altitude
  - difference ~ 500m
- increase with latitude
  - with a slope ~48m/deg in the NH
  - ~20m/deg in the SH
  - independent on latitude

*Lübken et Berger, 2007*
Seasonal variation of PMC occurrence: Comparison to ALOMAR

ALOMAR RMR lidar

11 years of data: 1997 → 2007

maximum occurrence frequency:

52 %
23 days after solstice

GOMOS

4 years of data: 2002 → 2006

maximum occurrence frequency:

82 %
23 days after solstice

Fiedler et al., 2009
Seasonal variation of PMC altitude: Comparison to ALOMAR

<table>
<thead>
<tr>
<th>ALOMAR RMR lidar</th>
<th>GOMOS</th>
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<tbody>
<tr>
<td>Minimum altitude: 83 km 30 days after solstice) but polynomial shape less marked</td>
<td>Minimum altitude: 82.3 km 17 days after solstice</td>
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<tr>
<td>Mean seasonal variation &lt; 1 km</td>
<td>Mean seasonal variation ~1.4 km</td>
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Fiedler et al., 2009
GOMOS: Very accurate PMC detection algorithm and very rich PMC data set, but still scarcely exploited.

**Outlook: a Comprehensive Study of Noctilucent Clouds**

To perform the vertical inversion:
- more accurate altitude values
- Vertical thickness
- Geometric extent of clouds

To use GOMOS spectrometers:
- Size of cloud particles

To extend these results to today and in the future:
- Long term PMC data record:
  - Long term trend in cloud frequency?
  - Dependance on solar activity?

Project for a comparative study: GOMOS / LIMA and GOMOS / ALOMAR