POLSTRACC – A HALO Mission to Investigate the Polar Stratosphere in a Changing Climate

Hermann Oelhaf and Björn-Martin Sinnhuber (KIT) on behalf of the POLSTRACC team

WALES laser beam
Mid-latitude – high latitude and Upper Troposphere-Lower stratosphere coupling

Δ Radiative forcing: $T_{\text{Trop}} \downarrow$, $T_{\text{Strat}} \uparrow$
Δ Halogen loading $\downarrow$
POLSTRAACC + GW-LCYCLE + SALSA-1 → PGS

Polar Stratosphere in a Changing Climate +
The life cycle of gravity waves (GW-LCYCLE) +
Seasonality of airmass transport and origin in the lowermost stratosphere (SALSA-1)

Project Coordination:
H. Oelhaf & B.-M. Sinnhuber (POLSTRAACC)
KIT-IMK

Markus Rapp (GW-LCYCLE)
DLR-IPA

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Uni Frankfurt
## Combined in-situ/remote-sensing Multi-Instrument Payload

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Target Parameter</th>
<th>Technique</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLORIA</td>
<td>$N_2O$, $CH_4$, $H_2O$, HDO, SF$_6$, CFCs, $O_3$, ClONO$_2$, ...</td>
<td>Imaging IR Limb Sounder</td>
<td>KIT / FZ Jülich</td>
</tr>
<tr>
<td>WALES</td>
<td>Aerosol, $H_2O$, $O_3$</td>
<td>Lidar, upward looking</td>
<td>DLR-IPA</td>
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<tr>
<td>DOAS</td>
<td>BrO, OCIO, $O_3$, NO$_2$</td>
<td>UV/vis spectrometer</td>
<td>Uni Heidelberg</td>
</tr>
<tr>
<td>AIMS</td>
<td>HCl, HNO$_3$, ClONO$_2$, SO$_2$</td>
<td>Mass Spectrometer</td>
<td>DLR-IPA</td>
</tr>
<tr>
<td>BAHAMAS</td>
<td>meteorologic and avionic data</td>
<td>BAsic Measurement And Sensor System</td>
<td>DLR-FX</td>
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<tr>
<td>FAIRO</td>
<td>$O_3$</td>
<td>UV Photometer/Chemiluminescence</td>
<td>KIT</td>
</tr>
<tr>
<td>FISH / HAI</td>
<td>total/gas-phase $H_2O$</td>
<td>Lyman-Alpha Hygrometer</td>
<td>FZ Jülich / PTB</td>
</tr>
<tr>
<td>GhOST-MS</td>
<td>$CH_3Br$, CHBr$_3$, CHCl$_3$, CH$_3$I, CFCs, SF$_6$</td>
<td>GC-MS</td>
<td>University of Frankfurt</td>
</tr>
<tr>
<td>HAGAR-V</td>
<td>SF$_6$, $CH_4$, $H_2$, $N_2O$, CFCs, NMHCs, CO$_2$</td>
<td>GC-MS</td>
<td>University of Wuppertal</td>
</tr>
<tr>
<td>IPA-NOy</td>
<td>NO, NO$_y$</td>
<td>Chemiluminescence</td>
<td>DLR-IPA</td>
</tr>
<tr>
<td>Drop Sonde</td>
<td>$p$, $T$, humidity, wind</td>
<td>Drop Sonde System</td>
<td>DLR-IPA</td>
</tr>
<tr>
<td>TRIHOP</td>
<td>$CO$, $N_2O$, $CH_4$ and CO$_2$</td>
<td>Laser Spectrometer</td>
<td>University of Mainz</td>
</tr>
</tbody>
</table>
POLSTRACC / GW-LCYCLE / SALSA (PGS)

Facts & Figures

**POLSTRACC/GW-LCYCLE/SALSA**

December 2015 - March 2016

HALO flight tracks

Plot provided by A. Minikin, DLR-FX

- **3 mission phases:** within 8 Dec. 2015 and 18 March 2016
- **18 scient. flights**
- **~156 flight hrs**
- Northern/southernmost location
  - $+87^\circ$ N / $25^\circ$N
- **Payload**
  - $3.0$ t (incl. inlets + bellypod)
  - 3P staff + 5 scientists onboard
- **Max. flight altitude achieved**
  - $14.6$ km (FL480)
- **Max. range achieved**
  - $8060$ km/9332 km w/w.o. fuel stop
- **Coldest Temp. at flight level**
  - $-76^\circ$C
The Arctic winter 2015/16 from a meteor. perspective

Extreme cold and stable at the beginning (Nov/Dec 2015: coldest and strongest vortex for 68 years)

Cold and displaced in the middle

Warm and distorted at the end (major and final warming at the beginning of March)

Vivien Matthias et al., submitted to GRL, 2016
Winter 2015/2016 from CALIPSO perspective: widespread and vertically extended PSCs in mid-January

Michael Pitts & Lamont Poole, NASA, associate partners of POLSTRACC
PSCs and denitrification: Vertically and horizontally extended PSCs of different types set the scene for O3 loss

WALES
Airborne Lidar
PGS_F09
22 Jan 2016

Extended ice clouds embedded in NAT and STS

Voigt et al., to be submitted, 2016
Winter 2015/2016 from CLaMS perspective: rapid Ozone loss until mid-March (onset of stratospheric warming)
Selected Flights (2/18 scientific flights)

**Flight12**: 2016-01-31: WBC over Ireland, SZA=const. leg over Northern Scandinavia

**Flight14**: 2016-02-26: Subsided aged vortex air between Greenland and Canada
PGS #12: Highly resolved FAIRO-O3 as 'pathfinder' and tracer of UT/LS air

Very clean air in WCB

Jet region

Data: A. Zahn, KIT
PGS#12: Dynamical tracers, chlorine activation, BrO-CIO-OCIO kinetics

Preliminary data from FAIRO, AIMS, GHOST & miniDOAS

150hPa CLaMS forecast ClO_x

Plot provided by Dominique Lörks & Klaus Pfeilsticker
Flight14: 2016-02-26: Subsided aged vortex air between Greenland and Baffin bay
PGS#14: aged stratospheric air: subsidence and available chlorine

CLaMS simulations: Jens-Uwe Grooß, Jülich

TRIHOP observations: Peter Hoor and Jens Krause, University of Mainz

GHOST observations: Andreas Engel and Harald Bönisch, University of Frankfurt
Diagnosed Ozone depletion

Ozone depletion diagnosed from CLaMS active & passive ozone vs. observed ozone (F14)

Ozone depletion diagnosed from tracer-tracer relations using several flights (n.b.: any mixing still to be considered)

Jens-Uwe Groß  Andreas Zahn  Andreas Engel
GLORIA: providing the 2nd (or even 3rd) dimension

W. Woiwode and S. Johansson (KIT) and GLORIA team (FZJ&KIT)
**HNO₃ Overview**

- MW: 861-863 cm⁻¹ and: 866-870 cm⁻¹
- Fit parameters:
  - HNO₃
  - OCS
  - Shift
  - Offset
- Internal version: Retrieval_v00_sj/hno3_20
- Noise error: <0.07 ppbv
- Vertical resolution: 500-1000 m

ChemMode measurements/retrievals preliminary
GLORIA POLSTRACC Gravity Wave dedicated Flights
(mostly DynamicsMode (DM) measurements)
Jet stream induced GWs (modified by Greenland mountains) sampled by GLORIA-DM during PGS-18: up to ~4K T amplitude

GLORIA is capable of providing 2D and 3D distributions of trace gases and temperature, i.e. for gravity wave studies.
Summary of some first results from POLSTRACC

O3 loss of 500-1000ppbv observed at upper flight levels (400+/-10K)

Extended PSCs (ice, NAT, STS) observed by airborne LIDAR and CALIPSO in almost all flights until end of Feb., reaching sometimes even down to HALO flight levels 13-14 km and to top of Ci clouds

In situ observations of organic chlorine as well as in-situ and remotely probed HCl, ClONO2 and HNO3 indicate high amounts of inorganic chlorine up to about 2 ppbv, chlorine (de)activation in the lowermost stratosphere, redistribution of NOy and particulate NOy.

Capabilities of GLORIA to study GWs and highly resolved curtains of T and trace gases demonstrated

Reservoir of aged vortex air sampled up to 410 K in Theta several times (age of air up to 6 yrs at 390-410 K in March, O3 as high as 1800ppbv, N2O as low as ~180ppb)

Huge amount of tracer data of different lifetimes covering a large spread of theta levels allows to quantify mixing & transport pathways and to improve climatology
Many thanks to the whole team for the great engagement and team spirit !!!

Please note: work in progress, most results still preliminary

Outlook:
POLSTRACC Science meeting scheduled for 9-10 Nov. 2016
ACP special section in preparation

Further Info: POLSTRACC Wiki and White Book: https://www.polstracc.kit.edu/
POLSTRACC Objectives

- Structure, composition and dynamics of the Arctic winter lowermost stratosphere
- Chemical processes affecting ozone in the Arctic winter UTLS
- Polar stratospheric clouds and denitrification
- Cirrus clouds in the Arctic UTLS