Airborne Coherent Wind Lidar measurements of vertical and horizontal wind speeds for the investigation of gravity waves

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Recent gravity waves campaigns
Overview and objectives

Campaigns objectives

- Study **dynamical coupling processes** by gravity waves from the **troposphere** into the **stratosphere** and **mesosphere** by characterizing their complete life cycle: Gravity wave excitation $\rightarrow$ propagation $\rightarrow$ dissipation
- Improve GW parameterizations for use in climate models

**GW-LCYCLE I (Kiruna, Sweden)**
- 2 - 14 Dec. 2013
- DLR Falcon (e.g. Wind Lidar)
- Radiosondes (Alomar, Esrange, Sodankylä)
- Ground-based lidar and radar observations (ALOMAR, Esrange)

**GW-LCYCLE II (Kiruna, Sweden)**
- Instruments as in GW-LCYCLE I + coordinated flights with HALO
- Rayleigh lidar in Sodankylä

**DEEPWAVE (Christchurch, NZ)** [1]
- NCAR GV (e.g. Rayleigh + Na-Lidar)
- DLR Falcon (29 Jun. – 21 Jul.)
- Ground-based instruments (e.g. Rayleigh lidar)

[1] Fritts et al., BAMS, 2016 – The Deep Propagating Gravity Wave Experiment
The 2μ airborne coherent Doppler Wind Lidar of DLR
Instrument description

- Wavelength: 2.022 µm
- Repetition rate: 500 Hz
- Pulse energy: 1.8 mJ
- Pulse length: 0.5 µs (150 m)
- Off-axis telescope: Aperture 10 cm

Resolution:
- Vertical: 100 m
- Horizontal (scan): ~6.7 km (32 s)
- Horizontal (Nadir): ~0.2 km (1 s)
- Double Wedge Scanner: Elevation ±30°
The 2µ airborne coherent Doppler Wind Lidar of DLR
Operation modes

**Scanning mode**
- 3 D wind vector
- Horizontal resolution ~ 6.7 km
- Vertical resolution = 100 m
- **forcing/inflow conditions**

**Fixed LOS-mode**
- LOS wind (vertical wind speed)
- Horizontal resolution ~ 200 m
- Vertical resolution = 100 m
- **GW amplitude and spectrum**
1. Determine the actual lidar installation position [1] → the actual laser beam pointing position can be calculated.

2. Using horizontal wind speed and direction from ECMWF re-analysis in order to calculate the projection in LOS direction.

3. Validate ECMWF data with lidar measurements

4. Correct LOS wind in order to retrieve vertical wind

Vertical wind retrieval and correction

Comparison of model and measurement (linear fit) yields:
- $r^2 = 0.85$
- Slope = 1.00
- Intercept = 0.01 m/s

$\rightarrow$ ECMWF data is suitable for a reliable wind correction
Vertical wind retrieval and correction
After correction, the bias of the vertical wind speed can be estimated to be less than 10 cm/s. The standard deviation (precision) is better than 0.5 m/s.
Horizontal structure well represented by WRF model calculations. However, the amplitudes are by a factor of 2 underestimated.
Results
GW-LCYCLE II – 2016-01-28a

300 hPa

Geopotential Height (m) & Horizontal Wind (m/s) at 300 hPa
Valid: Thu, 28 Jan 2016, 18 UTC (step 066 h from Tue, 26 Jan 2016, 00 UTC)

Scanning mode
Vertical wind mode
Results
GW-LCYCLE II – 2016-01-28a
Results
GW-LCYCLE II – 2016-01-28a

Wavelet analysis

Wave-breaking/secondary wave generation at the tropopause region
Results
GW-LCYCLE II – 2016-01-28a

6.7 - 7.2 km

8.7 - 9.2 km

9.7 km

power/(m²/s²)
Summary

• The DLR airborne coherent Doppler wind lidar was successfully deployed in three campaigns aiming to investigate the life cycle of gravity waves from excitation to dissipation.

• Vertical wind speeds were measured with an accuracy of better than 10 cm/s and a precision of better than 0.5 m/s.

• Both, the horizontal and the vertical wind measurements yield valuable data for characterizing gravity waves e.g., inflow/excitation conditions, wave excitation, breaking, dissipation, etc.

Outlook

• Combining measured vertical and horizontal wind profiles with other airborne and ground based data sets (currently performed).

• Implementing the possibility of determining the actual lidar installation position wrt. to the aircraft during flight → flight attitude offset correction can be adapted for each flight leg or rather altitude

• Adapt the scan pattern for horizontal wind retrieval in areas of strong gravity wave forcing