Deep vertical propagation of internal gravity waves above New Zealand
German-Austrian contributions to DEEPWAVE-NZ

Photo: Sonja Gisinger

Photo: Petr Horalek
Outline

1. Status of Data Analysis
   (a) DLR Falcon
      - Flight level u, v, w, T, q
      - trace gases $\text{H}_2\text{O}$, CO, $\text{N}_2\text{O}$, O$_3$, SO$_2$, CH$_4$
      - wind lidar
   (b) Lauder Radiosondes
   (c) Lauder Rayleigh-Lidar
   (d) ECMWF T1297/L137 data

2. Ambient conditions for deep vertical wave propagation based on ECMWF analyses and forecasts
   (a) zonally averaged T, $V_H$, $\Theta$
   (b) altitude-time sections of T, $V_H$, $\Theta$ over NZ and GWPED at Lauder, NZ
1. Status of Data Analysis

(a) DLR Falcon

13 research flights in New Zealand, 10 flights coordinated with the NSF/NCAR GV

<table>
<thead>
<tr>
<th>Flight No</th>
<th>IOP</th>
<th>NSF/NCAR GV</th>
<th>Date</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF-F01, RF-F02</td>
<td>9</td>
<td>sequential Falcon and GV flights RF12 and RF13</td>
<td>30 June 1 July</td>
<td>GW event under transient forcing</td>
</tr>
<tr>
<td>RF-F03</td>
<td>no</td>
<td></td>
<td>2 July</td>
<td>tropopause fold</td>
</tr>
<tr>
<td>RF-F04, RF-F05</td>
<td>10</td>
<td>Falcon flights before and during RF16</td>
<td>4 July</td>
<td>GW event under WSW flow</td>
</tr>
<tr>
<td>RF-F06</td>
<td>10</td>
<td>RF20</td>
<td>10 July</td>
<td>intercomparison</td>
</tr>
<tr>
<td>RF-F07, RF-F08</td>
<td>13</td>
<td>Falcon flights before and during RF21</td>
<td>11 July</td>
<td>GW event under strong NW winds</td>
</tr>
<tr>
<td>RF-F09, RF-F10</td>
<td>13</td>
<td>Falcon flights after RF22</td>
<td>12 July 13 July</td>
<td>GW wave event with locally varying responses</td>
</tr>
<tr>
<td>RF-F11</td>
<td>no</td>
<td></td>
<td>14 July</td>
<td>volcano</td>
</tr>
<tr>
<td>RF-F12</td>
<td>15</td>
<td>no</td>
<td>17 July</td>
<td>critical level flow</td>
</tr>
<tr>
<td>RF-F13</td>
<td>16</td>
<td>Falcon flight after RF26</td>
<td>20 July</td>
<td>GWs in SW flow</td>
</tr>
</tbody>
</table>
1. Status of Data Analysis

(a) DLR Falcon

- Flight level u, v, w, T, q
- trace gases H$_2$O, CO, N$_2$O, O$_3$, SO$_2$, CH$_4$
- wind lidar

- noseboom 1 Hz data are delivered to EOL for all research flights RF-F01 to RF-F13

- data analysis should be checked carefully and the QC should be adjusted between EOL and DLR

for example:

- wind provided with only two decimals
- vertical wind set to NaN when aircraft exceeds certain ascent rate
1. **Status of Data Analysis**

   (a) DLR Falcon

   - Flight level u, v, w, T, q
   - trace gases H$_2$O, CO, N$_2$O, O$_3$, SO$_2$, CH$_4$
   - wind lidar

   - groups are working on data analysis

   - positive responses to keep deadlines for submitting data in time to EOL data catalog

Contacts:

H$_2$O data: Romy Schlage ([romy.schlage@dlr.de](mailto:romy.schlage@dlr.de))
CO, N$_2$O data: Stefan Müller ([stefan.mueller@uni-mainz.de](mailto:stefan.mueller@uni-mainz.de))
O$_3$, SO$_2$ data: Hans Schlager ([hans.schlager@dlr.de](mailto:hans.schlager@dlr.de))
Cirrus formation related to temperature fluctuations and moisture transport in mountain waves

RF-F01 29/30 June 2014

preliminary data, for quicklook use only

Ice clouds

$\lambda_1 \sim 12 \text{ km}$

$\lambda_2 \sim 28 \text{ km}$

$\lambda_3 \sim 120 \text{ km}$

Total water (WARAN)
Gas phase water (CR-2)
N\textsubscript{2}O is:
- Chemically inert in the troposphere.
- Homogenous distributed in the global troposphere.
- Has a long lifetime $> 100$ years in the stratosphere.

Ideal tropopause marker!

Correlation of both species!

Stratospheric air masses
DEEPWAVE

**Scientific focus:**
Trace gas fluxes and mixing of airmasses initiated by gravity wave activity!

**Short and long wavelengths**

**Interested in collaborations:**
Preliminary data already available on request!

S. Müller and P. Hoor
1. **Status of Data Analysis**

(b) **Lauder Radiosondes**
Operational from 13 June until 1 August 2014

Väisälä RS92-SGPL 68 launches

GRAW digital radiosonde DFM-09 30 launches

- Weight: 90 g; programmable frequency (400 - 406 MHz)
- With temperature and humidity sensor; pressure calculated by GPS height
- Programmable switch-off timer; windfinding with integrated GPS module

Totex balloons: 500 g and 600 g

Average max altitude: 31.2 km
Max altitude: 36.6 km
<table>
<thead>
<tr>
<th>IOP</th>
<th>Date</th>
<th># RS (Type)</th>
<th>Interval</th>
<th>Flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>13 - 14 June 2014</td>
<td>9 (V)</td>
<td>3 h</td>
<td>RF03, RF04</td>
</tr>
<tr>
<td>4</td>
<td>16 June 2014</td>
<td>4 (V)</td>
<td>3 h</td>
<td>RF05</td>
</tr>
<tr>
<td>5</td>
<td>18 June 2014</td>
<td>1 (V)</td>
<td></td>
<td>RF06</td>
</tr>
<tr>
<td>6</td>
<td>19 June 2014</td>
<td>5 (G)</td>
<td>3 h</td>
<td>RF07</td>
</tr>
<tr>
<td>8</td>
<td>24 - 25 June 2014</td>
<td>12 (G)</td>
<td>3 h</td>
<td>RF09, RF10</td>
</tr>
<tr>
<td>9</td>
<td>28 - 30 June 2014</td>
<td>15 (G, V)</td>
<td>3 h</td>
<td>RF11 – RF14, RF-F01, RF-F02</td>
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<tr>
<td>10</td>
<td>4 July 2014</td>
<td>13 (G, V)</td>
<td>1.5 h, 3 h</td>
<td>RF16, RF-F04, RF-F05</td>
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<tr>
<td>12</td>
<td>7 July 2014</td>
<td>1 (V)</td>
<td></td>
<td>RF18, RF19</td>
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<tr>
<td>13</td>
<td>10 - 13 July 2014</td>
<td>19 (G, V)</td>
<td>3 h</td>
<td>RF20 – RF22, RF-F06 - RF-F10</td>
</tr>
<tr>
<td>14</td>
<td>14 - 15 July 2014</td>
<td>1 (V)</td>
<td></td>
<td>RF23, RF24</td>
</tr>
<tr>
<td>15</td>
<td>16 - 17 July 2014</td>
<td>6 (G, V)</td>
<td>6 h</td>
<td>RF-F12</td>
</tr>
<tr>
<td>16</td>
<td>20 July 2014</td>
<td>4 (V)</td>
<td>6 h</td>
<td>RF25, RF26, RF-F13</td>
</tr>
<tr>
<td>17</td>
<td>31 July – 1 August</td>
<td>4 (V)</td>
<td>3 h</td>
<td></td>
</tr>
</tbody>
</table>
1. Status of Data Analysis

(c) DLR Rayleigh Lidar at Lauder

Photo: Bernd Kaifler
1. Status of Data Analysis

(c) DLR Rayleigh Lidar at Lauder

Total photons: 117133603150
709.9 hours
6.1 hours/day

Good Data:
486.6 hours

Resolutions

Raw profiles
Δz = 10 m
Δt = 10 ms

Results:
Δz = 1000 m
Δt = 600 s
Mean Temperature

Wave-like structures

Elevated stratopause
Data Analysis

10 min x 1 km T-profiles

Subtract background T (fit polynomial)

Temperature variance

Gravity wave potential energy density:

\[ E_p(z) = \frac{1}{2} \frac{g^2}{N^2(z,t)} \left( \frac{T'(z,t)}{T_0(z,t)} \right)^2 \]
Some Examples
Orographic Wave Event

Huge enhancement (log scale!)
Mean Gravity Wave Potential Energy Density

Orographic wave events
No deep propagation?
1. Status of Data Analysis

(d) ECMWF T1279/137 IFS data

(a) operational analyses 6 hourly at 00, 06, 12, and 18 UTC
operational forecasts 1 hourly data from 00 UTC and
12 UTC forecast runs (as IC and BC for mesoscale
numerical simulations)

available via DLR

(b) Interpolated data for specific locations and along flight
tracks of NSF/NCAR GV and DLR Falcon as input
for EOL data catalog

interest??
2. Ambient conditions for deep vertical wave propagation based on ECMWF analyses and forecasts
   (a) zonally averaged $T, V_{HOR}, \Theta$

   (b) altitude-time sections of $T, V_{HOR}, \Theta$ as area averages over the South Island and GWPED at Lauder, NZ
Zonal mean temperature (K) and horizontal wind (m/s)
Monthly mean July 2014      DEEPWAVE-NZ

ECMWF T1279/L137 operational analyses (6 h)
Zonal mean temperature (K) and potential temperature (K)
Monthly mean December 2013   GW-LCYCLE 1

ECMWF T1279/L137 operational analyses (6 h)
Zonal mean temperature (K) and horizontal wind (m/s)
Monthly mean December 2013
GW-LCYCLE 1

ECMWF T1279/L137 operational analyses (6 h)
Ambient conditions for deep vertical wave propagation based on ECMWF data

- altitude-time sections of $T$, $V_{\text{HOR}}$, $\Theta$ as area averages over 165° E .... 180° E and 40° S ... 50° S

- T1279/L137 IFS operational analyses 00, 06, 12, 18 UTC

T1279/L137 IFS high resolution forecasts initialized at 00 UTC and 12 UTC for intermediate time steps

+01, +02, +03, +04, +05, +07, +08, +09, +10, +11 h

- model level data interpolated vertically on a regular 500 m grid
ECMWF T1279/L137 operational analyses (6 h) and 1 hourly high-resolution IFS predictions

May 2014

T/K

South Island/NZ

$V_{\text{HOR}}/\text{ms}^{-1}$
ECMWF T1279/L137 operational analyses (6 h) and 1-hourly high-resolution IFS predictions in South Island/NZ for June 2014.
ECMWF T1279/L137 operational analyses (6 h) and 1 hourly high-resolution IFS predictions

T/K

$V_{\text{HOR}}/\text{ms}^{-1}$

Propagation funnels

IOP3,4, IOP6,7, IOP8, IOP9

South Island/NZ

June 2014
ECMWF T1279/L137 operational analyses (6 h) and 1 hourly high-resolution IFS predictions

South Island/NZ

July 2014

$V_{\text{HOR}}/\text{ms}^{-1}$
ECMWF T1279/L137 operational analyses (6 h) and 1 hourly high-resolution IFS predictions

South Island/NZ

$V_{\text{HOR}}/\text{ms}^{-1}$

Propagation funnels

IOP10  IOP13  IOP14  IOP16
ECMWF T1279/L137 operational analyses (6 h) and 1 hourly high-resolution IFS predictions

South Island/NZ

$T/K$

$V_{HOR}/\text{ms}^{-1}$

August 2014
Gravity Wave Potential Energy Density (2)

- altitude–time sections of GWEPED for Lauder, NZ for the 1 hourly data

\[
E_P = \frac{1}{2} \left( \frac{g^2}{N^2} \right) \left( \frac{T''^2}{T_0^2} \right)
\]

- calculation of ambient temperature profiles \( T_0 \) by means of stepwise polynomial fits to individual temperature profiles; fractional temperature variance is local difference \( T' = T - T_0 \) with \( T_0 \) as the smoothed and fitted profiles, buoyancy frequency computed from ambient profiles

- presentation in linear and logarithmic scalings
Gravity Wave Potential Energy Density (J/kg)

IOP 10 | IOP 13 | IOP 15

July 2014

1.0 1.6 2.7 4.5 7.4 12.2 20.1 33.1 54.6 90.0 148.4 244.7 403.4 665.1
Gravity Wave Potential Energy Density (J/kg)
Suggestions

(1) Generate merged files for all research flights stored in the EOL data catalog containing

(i) flight-level data from NSF/NCAR GV and DLR Falcon

(ii) interpolated numerical simulation results from ECMWF IFS, WRF, COAMPS, …. along the individual flight tracks

(2) Include post-campaign ground-based Lidar measurements as IOP‘s in data catalog
Thank you!