Airborne remote sensing of clouds and precipitation using Ka- and W-band

Martin Hagen
DLR Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

Julien Delanoë (Laboratoire Atmosphères, Milieux, France)
Silke Groß (DLR, Oberpfaffenhofen, Germany)
Lutz Hirsch (MPI Meteorology, Hamburg, Germany)
and many others …
HAMP – HALO Microwave Package / NARVAL configuration

- METEK MIRA-35 cloud radar
- RPG microwave radiometers
- WALES / HRSL water vapour lidar
- drop sondes
- HALO-SR
- DOAS

Microwave radiometer
90/119  22/58  183 GHz

WALES / HRSL

Cloud radar
35 GHz
HALO Cloud Radar

- Modified MIRA-35 for aircraft use
- EMC compatibility
- Mitigation of electromagnetic radiation in cabin or to avionics
- Adapted clutter fence

Any technical modification requires paperwork, costs, delays, …

**Characteristics MIRA-35**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>35.2 GHz</td>
</tr>
<tr>
<td>Wavelength</td>
<td>8 mm</td>
</tr>
<tr>
<td>Tx power</td>
<td>30 kW</td>
</tr>
<tr>
<td>Pulse length</td>
<td>0.2 µs</td>
</tr>
<tr>
<td>PRF</td>
<td>5 kHz</td>
</tr>
<tr>
<td>Antenna dia.</td>
<td>1 m</td>
</tr>
<tr>
<td>Beam width</td>
<td>0.6°</td>
</tr>
<tr>
<td>Footprint @ 13km</td>
<td>136 m</td>
</tr>
<tr>
<td>Max. range</td>
<td>15 km</td>
</tr>
<tr>
<td>Range resolution</td>
<td>30 m</td>
</tr>
<tr>
<td>Integration time</td>
<td>1 s</td>
</tr>
<tr>
<td>Min. detect. signal</td>
<td>-38 dBz</td>
</tr>
</tbody>
</table>

Martin Hagen, 37th Conference on Radar Meteorology, Norman OK, 14 - 18 September 2015
Calibration Issues

Radar calibration

- Manufacturer calibration for trailer version
- Rearrangement of radar for aircraft usage (avoidance of leakages)
- Longer and bended wave guides (0.7 dB/m one-way)
- Losses by radome plate (1.2 dB one-way)
- Comparison during flights over ground-based MIRA-35, Cloudsat underpass, joint flight HALO – French Falcon (2013), or calibration using sea-scatter
NARVAL-South
North Atlantic trade wind clouds
PI: B. Stevens, F. Ament
10 – 21 December 2013
- 8 flights over tropical and subtropical Atlantic
- 7 A-train underpasses
- 75 drop-sondes released
- joined flight with French RASTA

NARVAL-North
post-frontal extra-tropics systems
PI: C. Klepp, S. Bakan
7 – 21 January 2014
- 5 flights over North Atlantic
- 2 transfer flights with 5 super-site overpasses
- 4 A-train underpasses
- 42 drop-sondes released
HALO Cloud Radar (Ka-band) – French RASTA (W-band)

Joint flight
during NARVAL
(19 Dec. 2013)
between
Lyon and Tarbes
Joint flight during NARVAL (19 Dec. 2013) between Lyon and Tarbes

HALO Cloud Radar (Ka-band) – French RASTA (W-band)

RASTA
(Radar aéroporté et sol de télédétection des propriétés nuageuses)
on-board French research aircraft Falcon F20
5 beam configuration for wind field estimation

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>95.04 GHz</td>
</tr>
<tr>
<td>Tx power</td>
<td>1.8 kW</td>
</tr>
<tr>
<td>Pulse length</td>
<td>0.4 µs</td>
</tr>
<tr>
<td>Max. range</td>
<td>18 km</td>
</tr>
<tr>
<td>Antenna diam.</td>
<td>0.3 m</td>
</tr>
<tr>
<td>Beam width</td>
<td>0.7°</td>
</tr>
<tr>
<td>Min. det. sig.</td>
<td>-23 dBz</td>
</tr>
<tr>
<td>@ 1 km 1 s integration</td>
<td></td>
</tr>
</tbody>
</table>
Joint flight during NARVAL (19 Dec. 2013) between Lyon and Tarbes

HALO Cloud Radar (Ka-band) – French RASTA (W-band)

- **HALO Mira35**: 35 GHz, Reflectivity [dBz]
- **F20 RASTA**: 95 GHz, Reflectivity [dBz]

![Map showing flight path from OPF to BGI](image)

Martin Hagen, 37th Conference on Radar Meteorology, Norman OK, 14 - 18 September 2015
Dual-Frequency Ratio MIRA (35 GHz) – RASTA (95 GHz) reflectivity (MIRA +8 dB calibration adjustment)

advection correction necessary (currently still ongoing)
wind at z = 5 km SW 30 kt
  10 km SW 70 kt
  12 km SW 50 kt
Ka-band Doppler velocity (corrected by pitch, TAS, and vertical aircraft motion)

remaining contribution of vertical gradient of horizontal wind
at z = 5 km SW 30 kt
10 km SW 70 kt
12 km SW 50 kt
HALO Cloud Radar (Ka-band) – French RASTA (W-band)

Z Ka-band

DFR Ka/W-band

vel_{cor} Ka-band

LDR Ka-band
HALO Cloud Radar (Ka-band) – French RASTA (W-band)

2.00 E – 2.15 E

3.70 E – 3.85 E
HALO Cloud Radar (Ka-band) – French RASTA (W-band)

3.70 E – 3.85 E

4.70 E – 4.85 E

Martin Hagen, 37th Conference on Radar Meteorology, Norman OK, 14 - 18 September 2015
Synergy of Radar, Lidar, and Radiometer

- **Cloud phase:**
  - Ice clouds, water clouds, super-cooled water clouds

- **Cloud properties**
  - IWC, LWC, eff. radius, ... in regions with overlap of radar and lidar, and regions with radar or lidar only
  - Vertical motion
    - Separation of vertical motion of air and fall velocity of particles feasible after phase classification and estimation of particle properties

- **Integrated properties**
  - Liquid water path, ice water path, integrated water vapour from microwave radiometers vs. intrinsic values from active instruments

[Graph showing data analysis with labels: HALO radiometer 20131212, trärde wind cumuli, IWV from dropsondes]
Summary and Outlook

- Co-ordinated flight provides unique case of dual-frequency observations of clouds and precipitation

- HALO Microwave Package:
  - combination of active and passive remote sensing
  - still in the learning phase of the HALO instruments

- Ongoing research within NARVAL data-set
  - radar calibration, Cloudsat and Calipso intercomparison
  - passive microwave retrievals
  - radar – radiometer – lidar synergy
  - ...

- NARVAL-2 to Barbados (summer 2016)
  NAWDEX from Iceland (fall 2016)