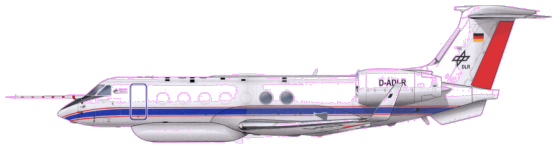
Airborne remote sensing activities using active and passive sensors

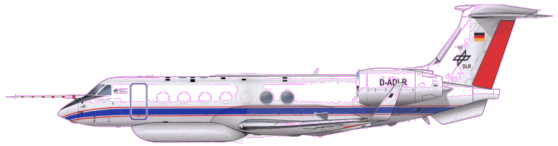


Susanne Crewell[1], Mario Mech[1], Max Maahn[1],
Emiliano Orlandi[1], Sabrina Schnitt[1]
Felix Ament[2], Andreas Fix[4], Martin Hagen[4], Akio Hansen[2],
Lutz Hirsch[3], Friedhelm Jansen[3], Christian Klepp[2], Heike Konow[2],
Bjorn Stevens[3], and Martin Wirth[4]

[1]Institute for Geophysics and Meteorology, University of Cologne
[2]Meteorological Institute, University of Hamburg
[3]Max-Planck Institute for Meteorology
[4]DLR Oberpfaffenhofen

ISMAR Workshop, Paris, 28-30 September 2015

Content



- HAMP: HALO Microwave Package
  - Instrument description
  - NARVAI campaigns 2013/2014

    Snow scattering

    SSMIS intercomparison
  - Future Campaigns

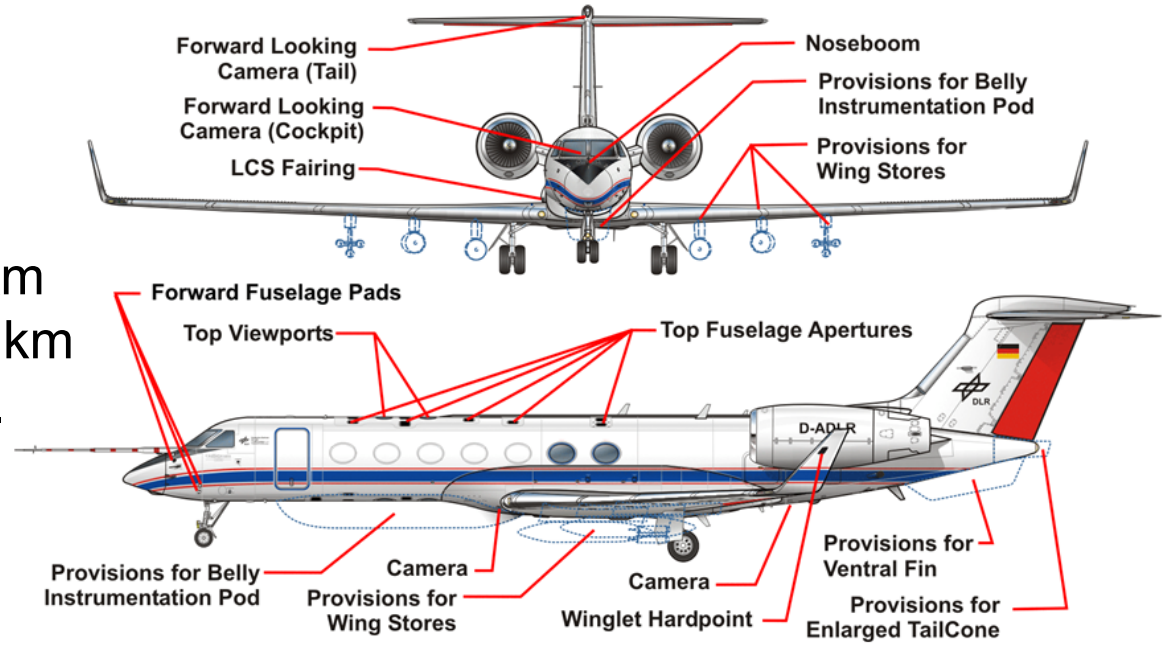
- MiRAC: Microwave Radar/radiometer for Arctic Research
  - Instrument description
  - Planned Campaigns 2017

High Altitude and LOng distance - HALO

Gulfstream G550

Distance: max. 9000 km
Flight altitude: max. 15.5 km
Duration: max. 11 Std.
Payload: max. 3 t

General Overview



Gulfstream

Bellypod instrumentation – NARVAL core

NARVAL – Next generation Aircraft
Remote sensing for VALidation studies

Microwave radiometers

Lidar window

Cloud radar

MIRA-36 cloud radar in ground operation

Parameter	MIRA-36
Frequency	35.563 GHz
Peak power	30 kW
Pulse length	200 ns
Pulse repetition	5 kHz
Integration time	1 s
Range resolution	30 m
Beam width	0.6°
Footprint	130 m @ 13 km
Expected sensitivity airborne operation	-38 dBZ (5 km), -30 dBZ (13 km)
Min. detectable LDR	-40 dB
Parameters	Z, V, spectral width, LDR

(Mech et al., AMT, 2014)

trailer for ground operation of the HAMP instruments during off duty times

Microwave radiometers

Table 2. HAMP passive bands with their noise equivalent delta temperature (NeDT), absolute accuracy (Acc.), beam width (Full Width at Half Maximum, FWHM), their main use in retrieving atmospheric variables, and corresponding satellite instruments. Upcoming missions (instruments) are given in italic letters.

Band	Frequencies [GHz]	NeDT [K]/Acc. [K]	FWHM	Application	Satellite
K H_2O	22.24,23.04, 23.84,25.44, 26.24,27.84, 31.40	0.1/0.5	5.0°	humidity profile, integrated water vapor, liquid water path rain	AMSU-A, SSM/I,AMSR-E, *GPM(GMI)* *MetOp-SG (MWS,MWI)*
V O_2	50.3,51.76, 52.8,53.75, 54.94,56.66, 58.00	0.2/0.5	3.5°	temperature profile, liquid water path, precipitating hydrometeors	AMSU-A, SSM/I(S) *MetOp-SG* *(MWS,MWI)*
W window channel	90.0	0.25/1.5	3.3°	liquid water path, snow water path	AMSU-B, SSM/I(S),AMSR-E, *GPM(GMI)*
F O_2	118.75±8.5,118.75±4.2, 118.75±2.3,118.75±1.4	0.6/1.5	3.3°	temperature profile precipitating hydrometeors	*MetOp-SG* *(MWS,MWI)*
G H_2O	183.31±12.5,183.31±7.5, 183.31±5.0,183.31±3.5, 183.31±2.5,183.31±1.5, 183.31±0.6	0.6/1.5	2.7°	humidity profile (upper troposphere), ice water path	AMSU-B, SSM/I(S), *GPM(GMI)*

(Mech et al., AMT, 2014)

Radiometer Physics GmbH

radiometer within trailer

Signal within the microwave region

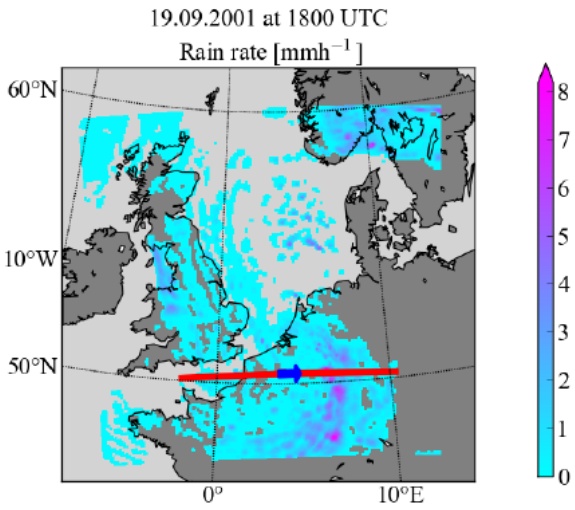
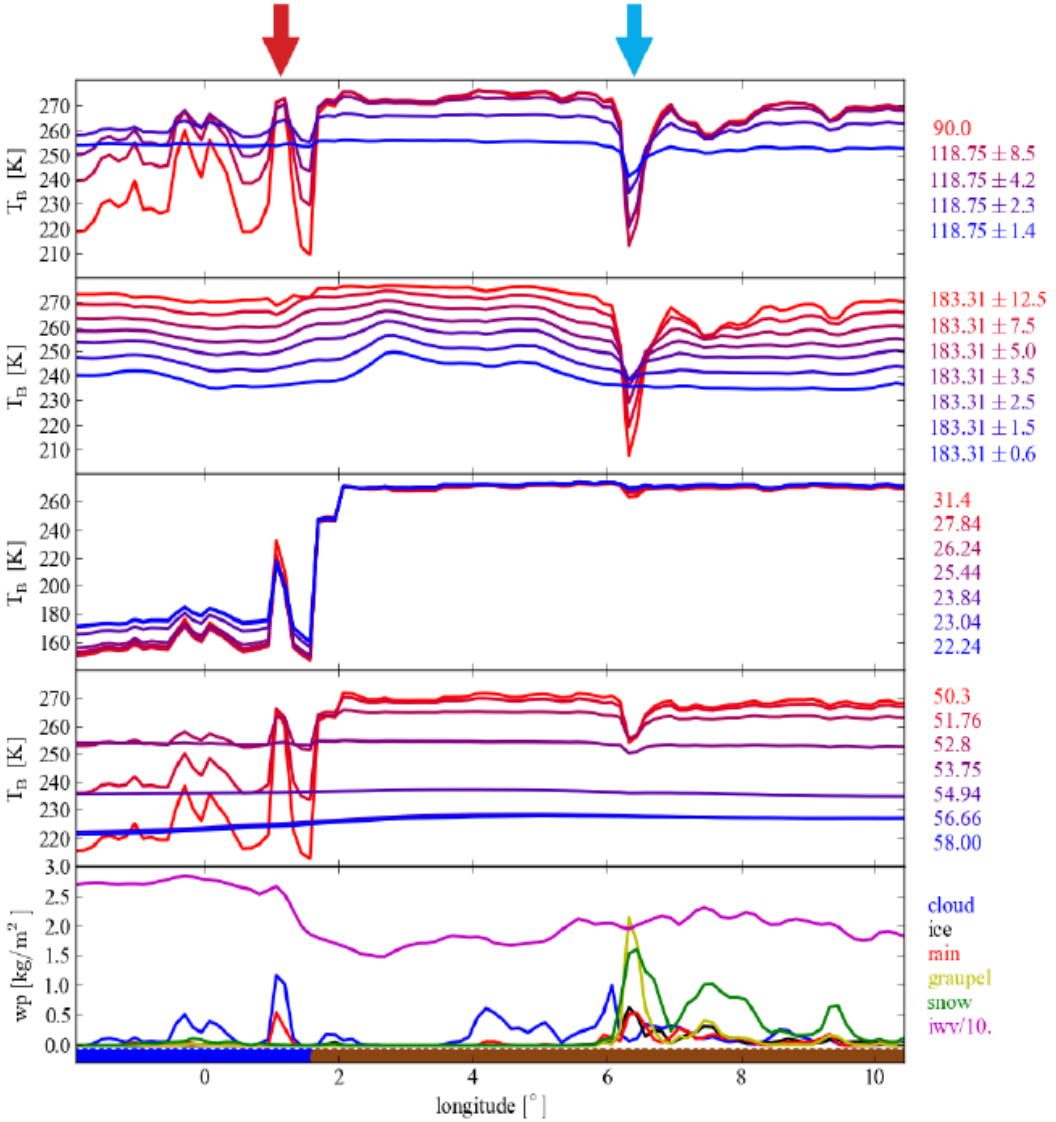


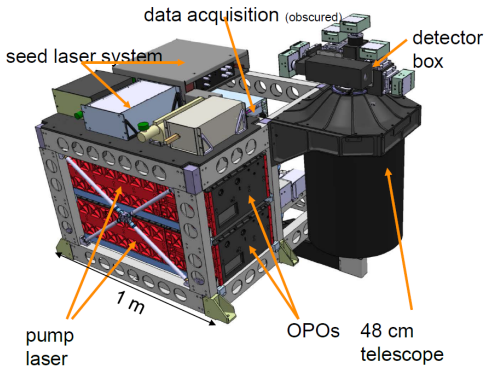
Fig. 4. Simulated rain rates in mmh^{-1} for the Hoek van Holland case on 19 September 2001 at 18 UTC. The red line and blue arrow indicate the artificial flight path show in Figs. 5 and 6.

Radiative transfer modelling based on MesoNH and the Passive and Active Microwave TRAnsfer simulator (PAMTRA)



NARVAL payload

DIAL – WALES

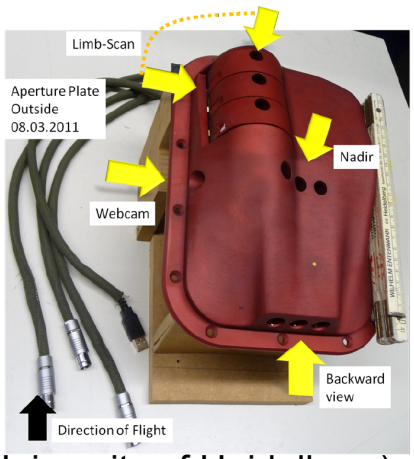


(DLR)

HALO-SR

(University of Leipzig, Research Center Juelich)

miniDOAS

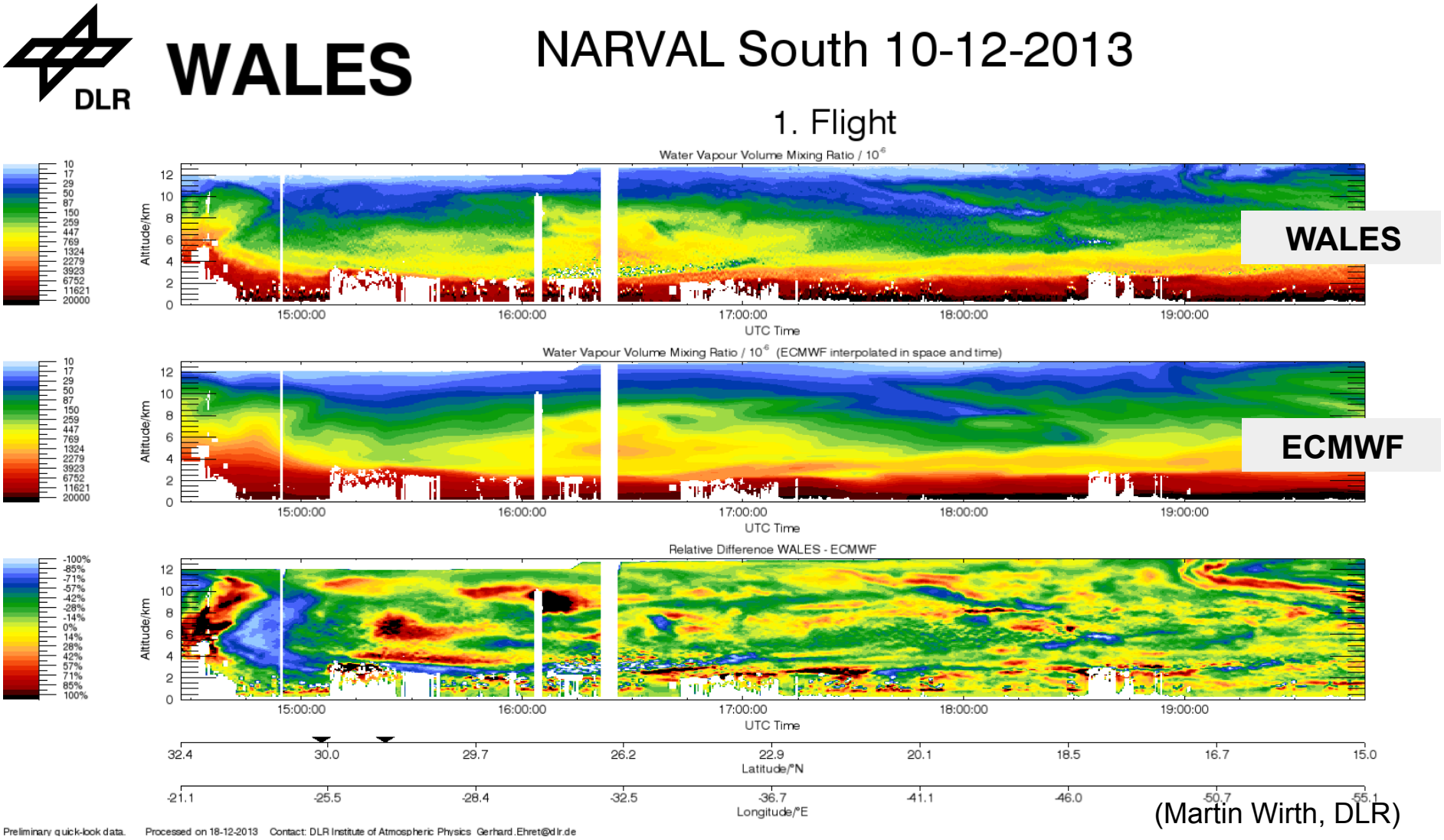


(University of Heidelberg)

Dropsondes

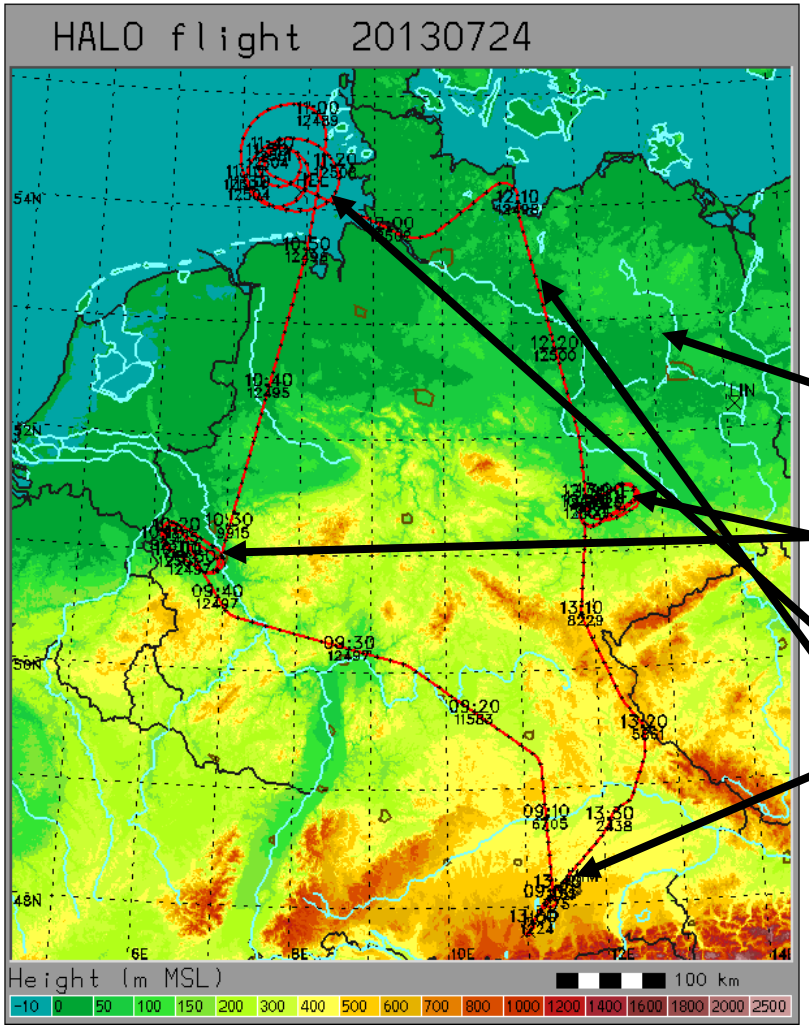
(DLR)

WALES versus ECMWF – water vapor profiles



(Martin Wirth, DLR)

NARVAL-DE



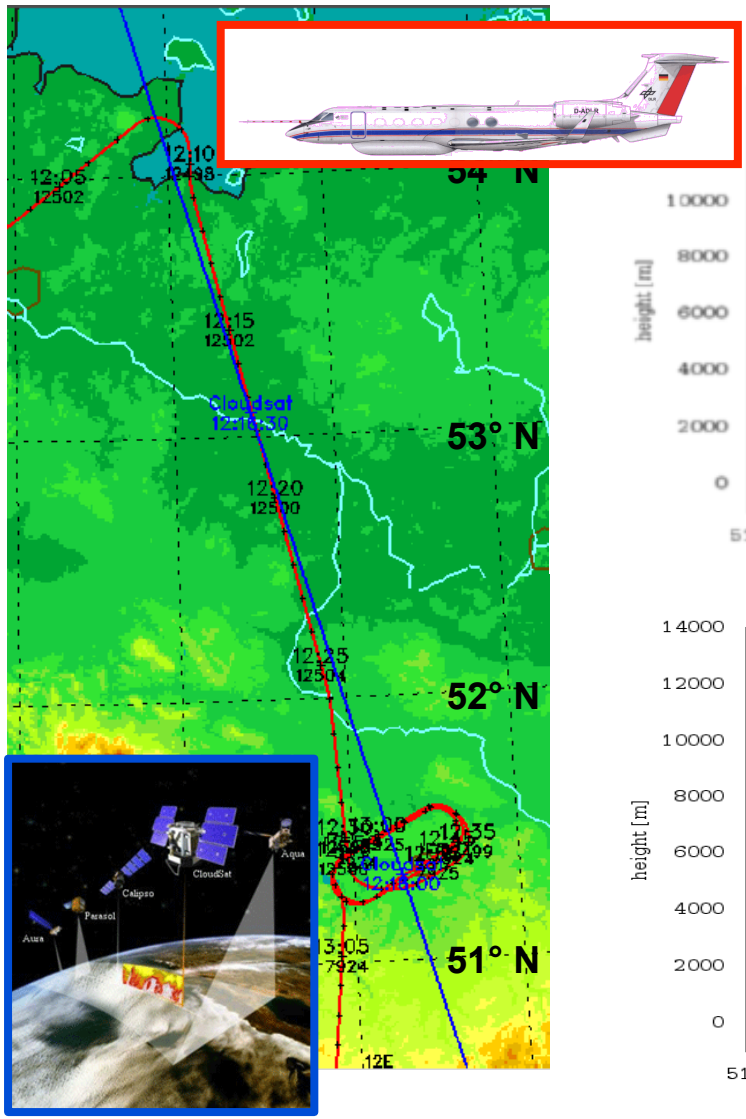
3 scientific test flights
- June 7, 2013
- June 11, 2013
- July 24, 2013

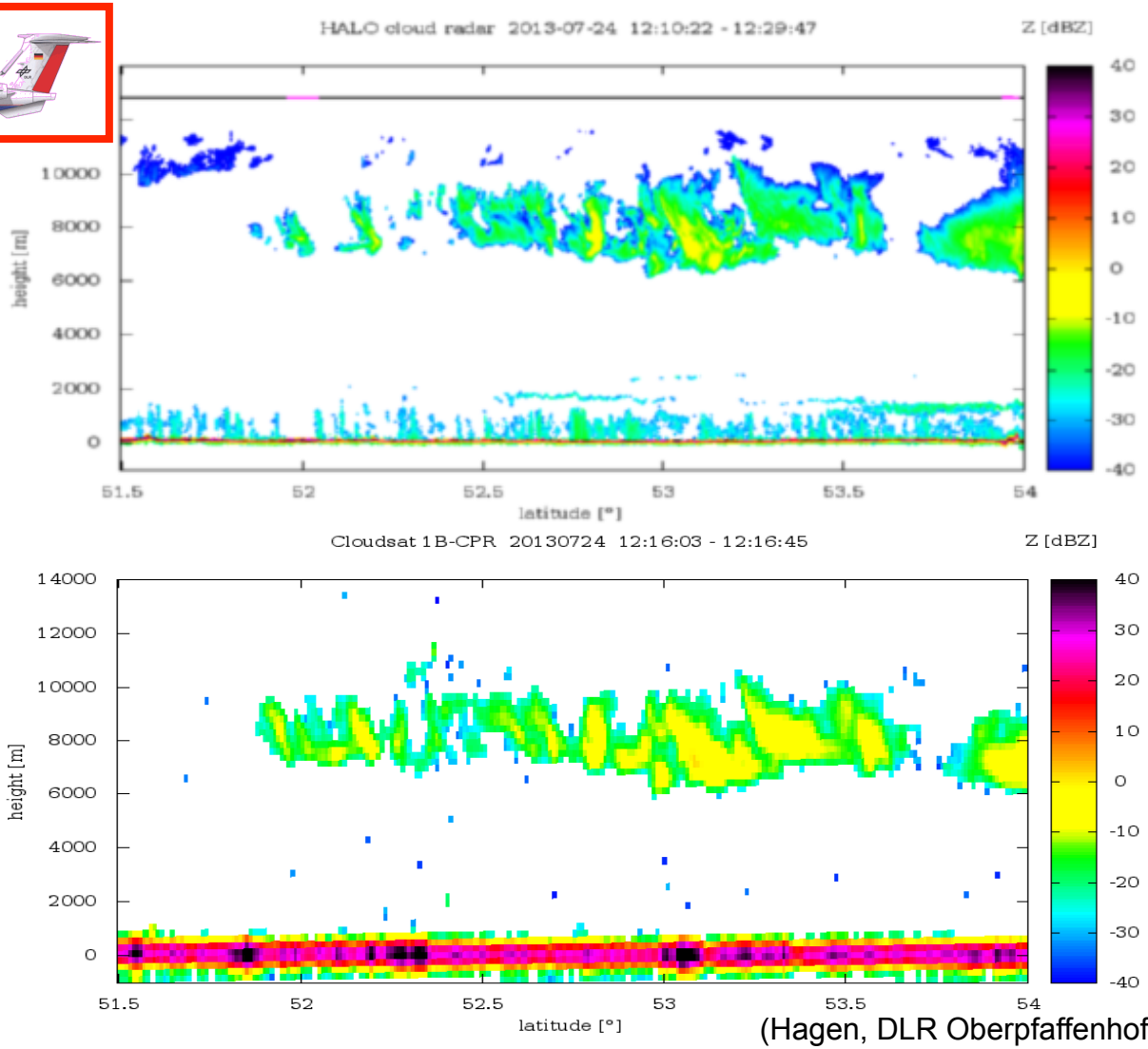
Overpasses over super sites
- Lindenberg (June 11)
- JOYCE (Jülich)
- Leipzig
- München

Radar calibration tests over Northern Sea

CloudSat underflight

Cloudsat under flight



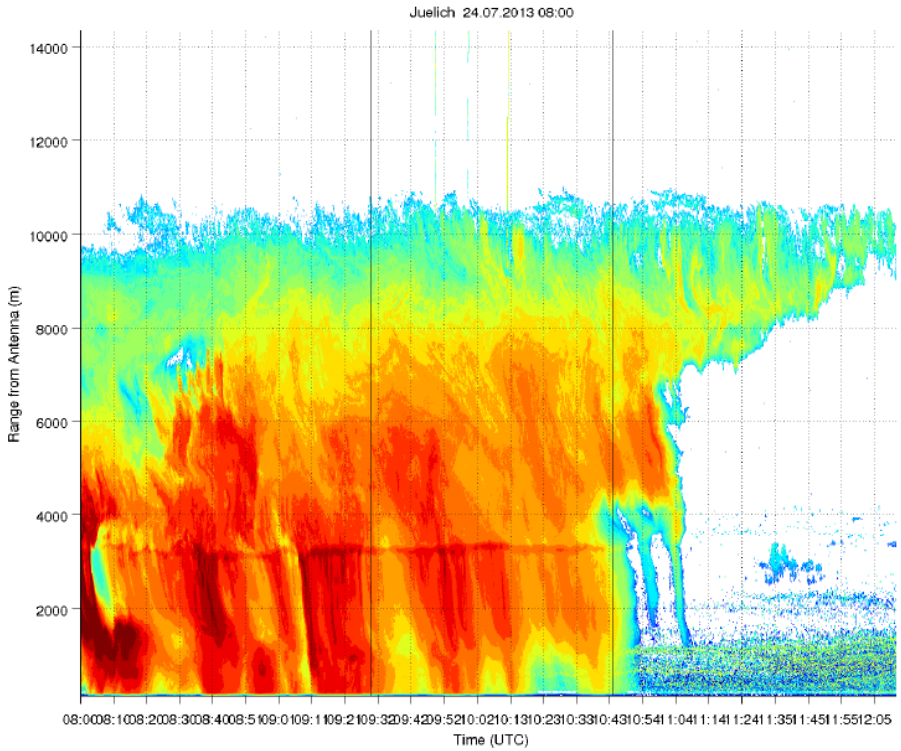


(Hagen, DLR Oberpfaffenhofen)

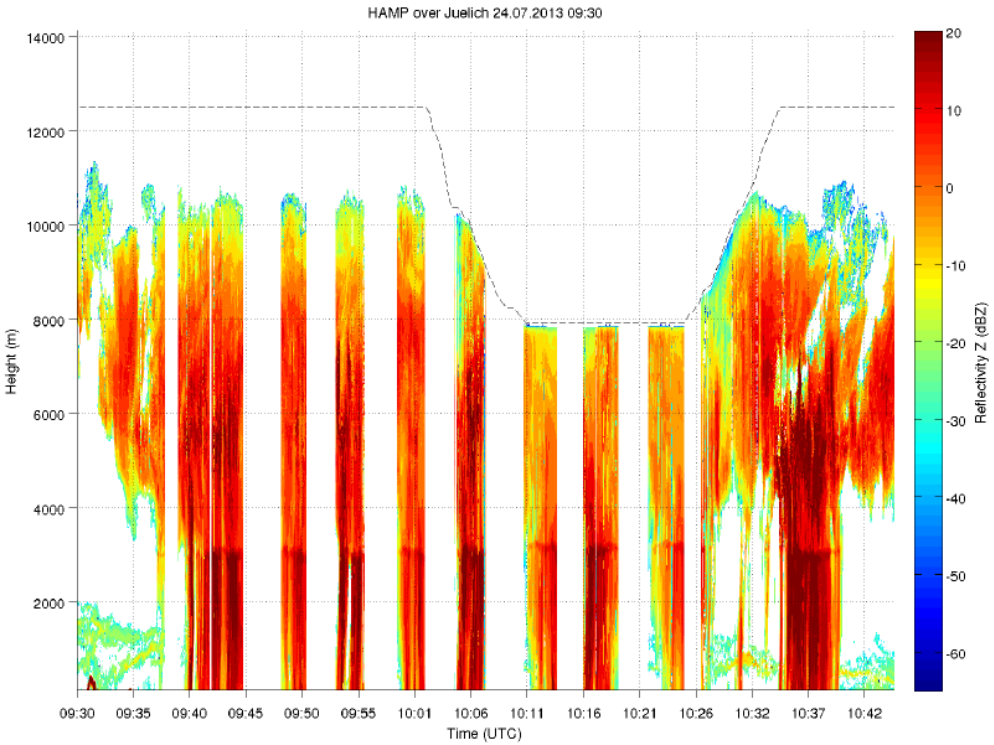
Super site JOYCE – Cloud radar

Jülich ObservatorY for Cloud Evolution (Loehnert et al. 2015), Jülich, Juli 24, 2013

JOYRAD-35



HAMP



(Heike Konow)

NARVAL

Two Names

Next Generation Aircraft Remote Sensing for Validation Studies
North Atlantic Rainfall Validation

Two Overarching Themes

Precipitation in shallow maritime convection (trade & post-frontal extra-tropics
The ability of HAMP-WALES to characterize the vertical structure of the Atmosphere

- Temperature
- Humidity
- Particles (Mostly Clouds, but also aerosols)

Two types of flights

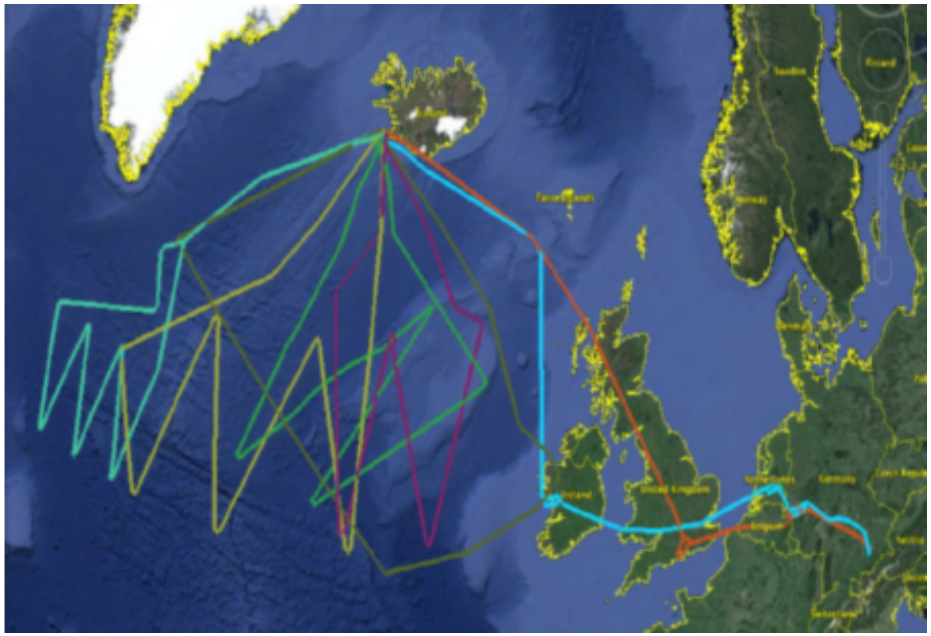
Post-frontal systems (NARVAL North)
North Atlantic Passat (NARVAL South)

But both names, and both themes will be asses on both types of flights – NARVAL north and south are two parts of a whole

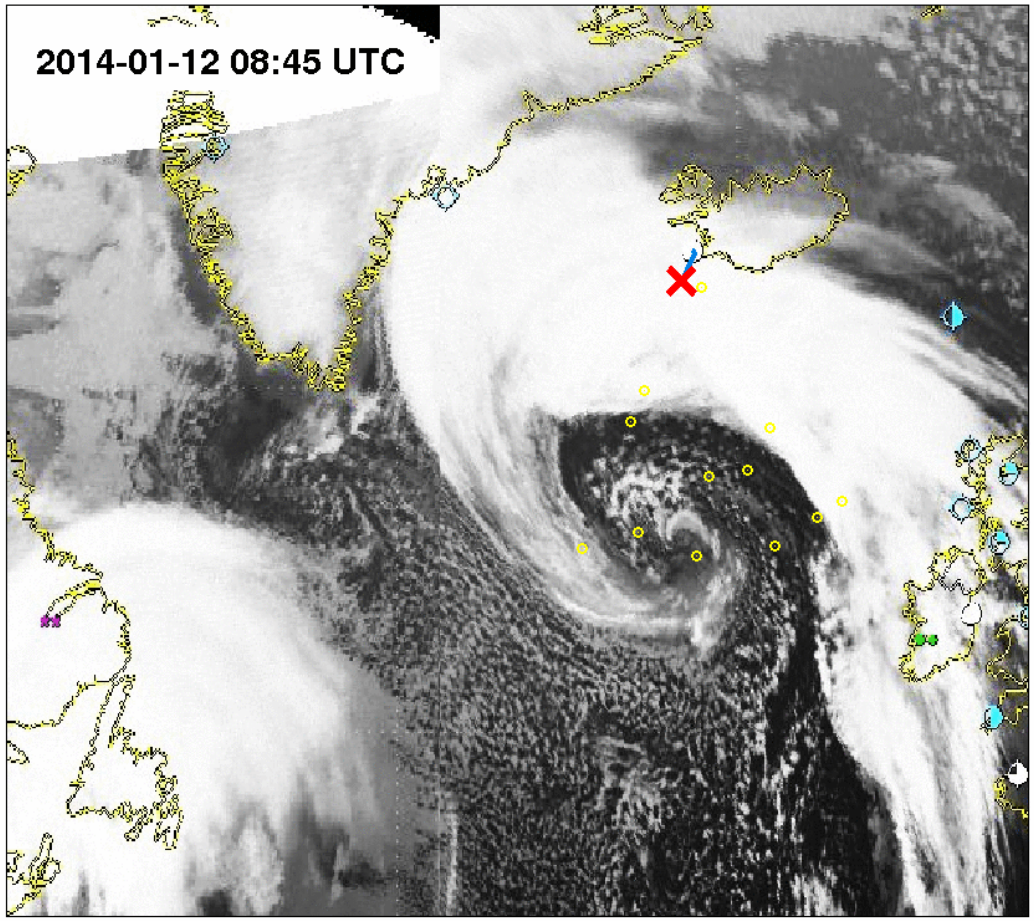
NARVAL flights

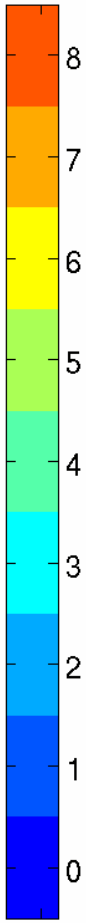
NARVAL-South
10 – 21 December 2013
- 4 transfer flight OP - Barbados
- 4 flights over tropical and subtropical Atlantic
- 75 dropsondes released

NARVAL-North
7 – 21 January 2014
- 5 flights over North Atlantic
- 2 transfer flights with several ground-based super-site overpasses
- 42 dropsondes released



Cloud regimes during single flight





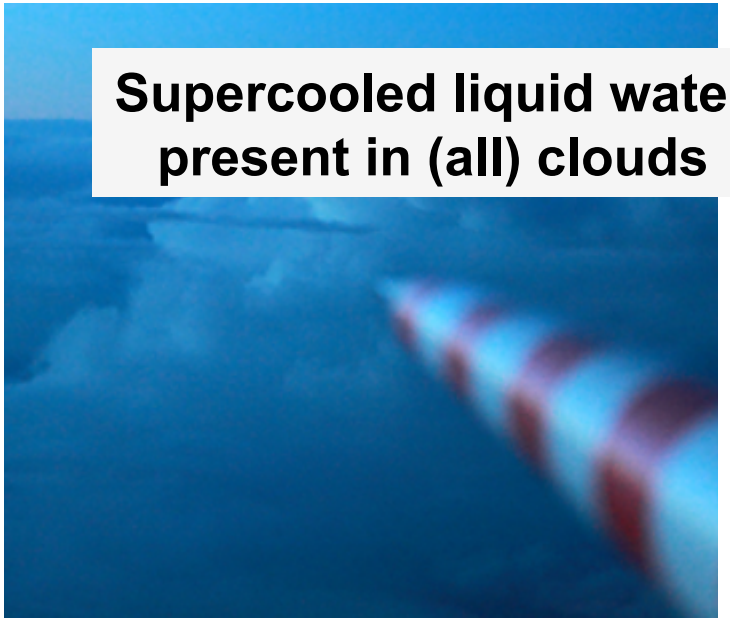
High ice clouds
Enhanced convection
Shallow convection
Postfrontal low
Spiral bands
Occlusion
Postfrontal subsidence
Cold front
Clear to low stratiform clouds

(Felix Erdmann, University of Hamburg)

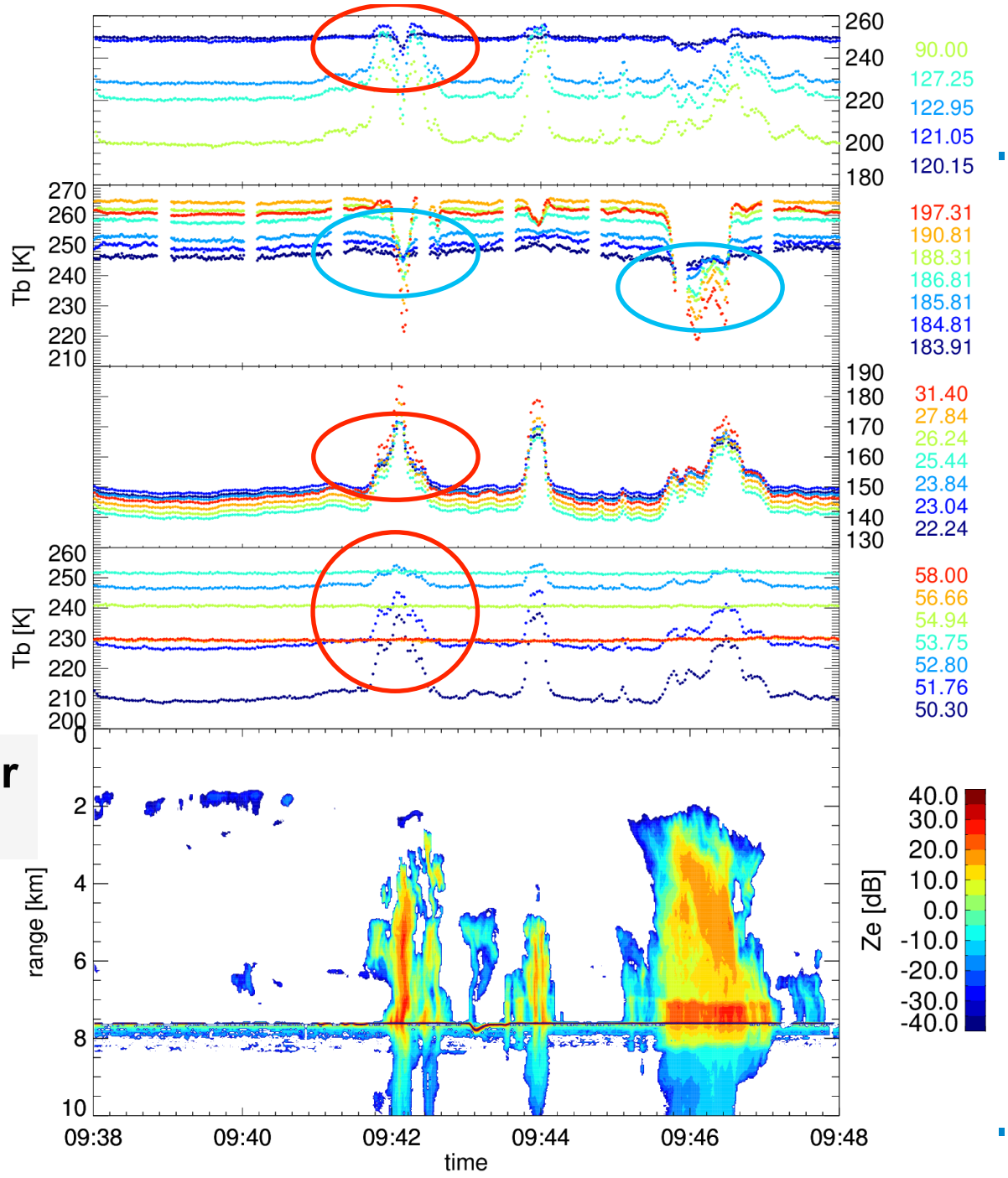
Cumulus Nimbus Northern Atlantic Jan 12, 2014

Near nadir measurements over ocean (cold background) with overlying emission and scattering signal

Sensing capabilities of channels along the wings clearly visible (warmer Tb close to line center)

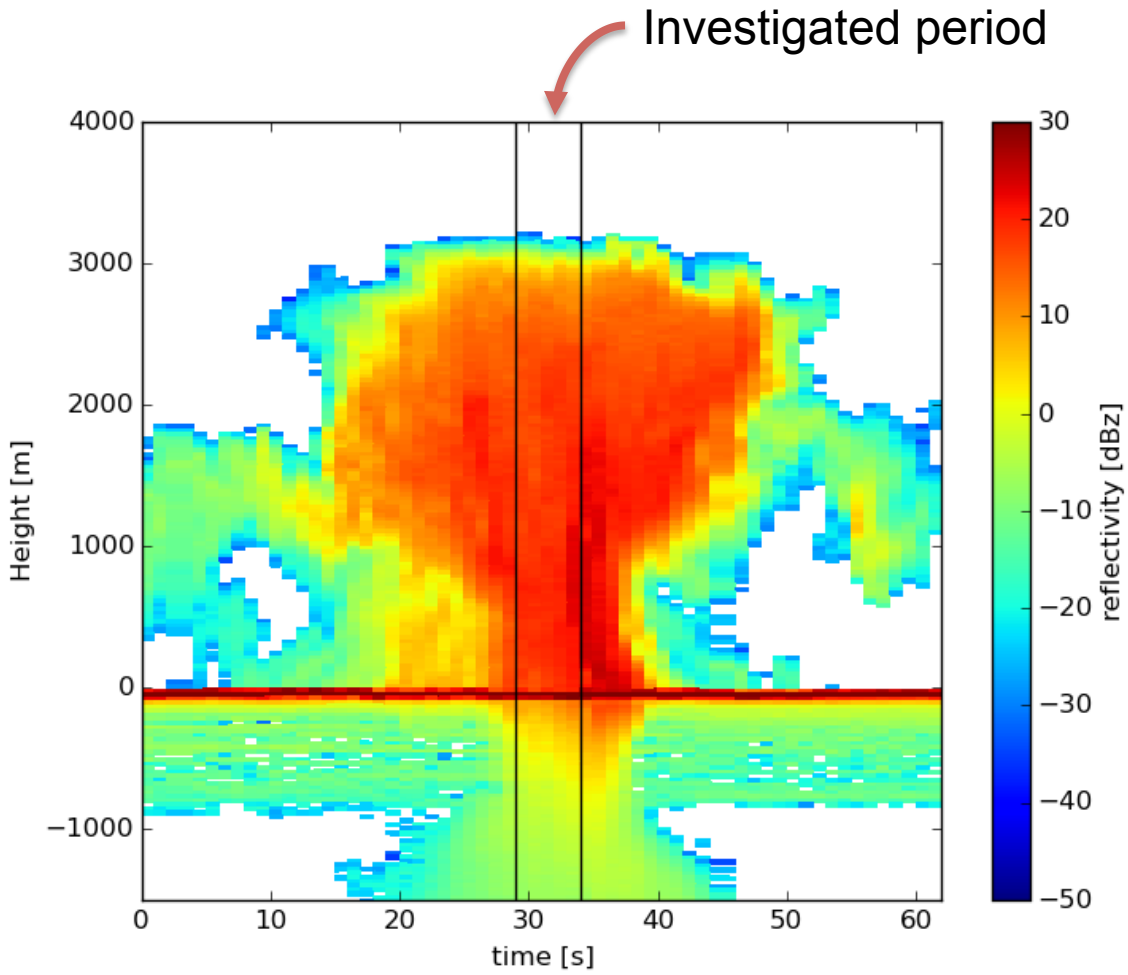


Supercooled liquid water present in (all) clouds



Closure study for snow scattering

NARVAL north flight #10, 9.1.14, ~15:30 UTC



Procedure

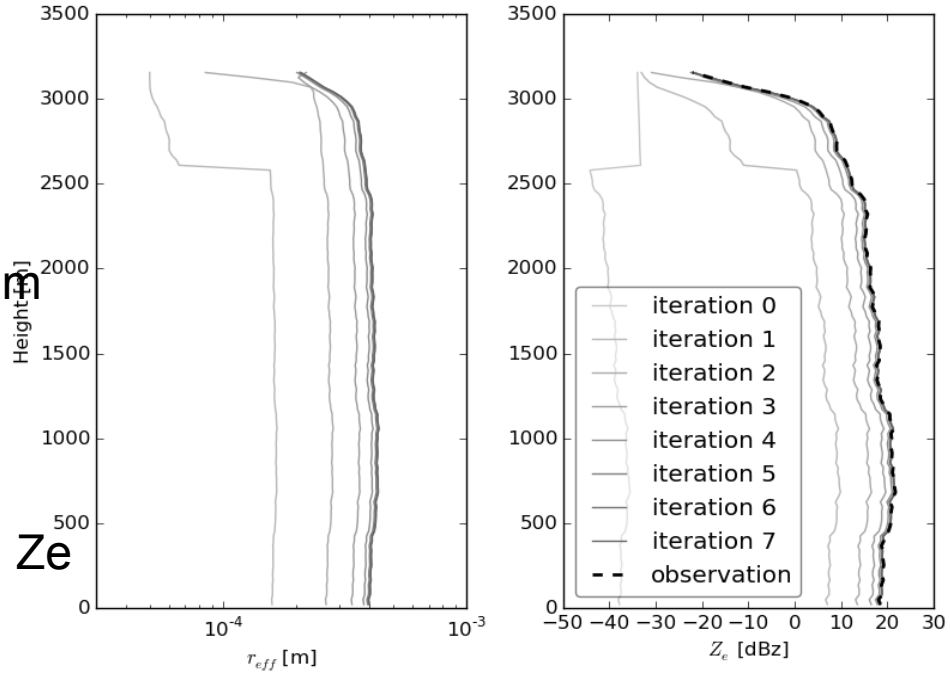
1) Generate atmospheric state from dropsonde and

- determine profiles of Ice water content (IWC) and effective radius (reff) from radar reflectivity
  - for all particles from hydrometeor list of Kulie et al (2010)
  - Include: s Mass-size and Ze-IWC relations

- use Liquid Water Path (LWP) retrieved from K-band radiometer.

- distribute either
  - equally in the whole cloud column
  - equally in the topmost 15/300/600 m of the cloud

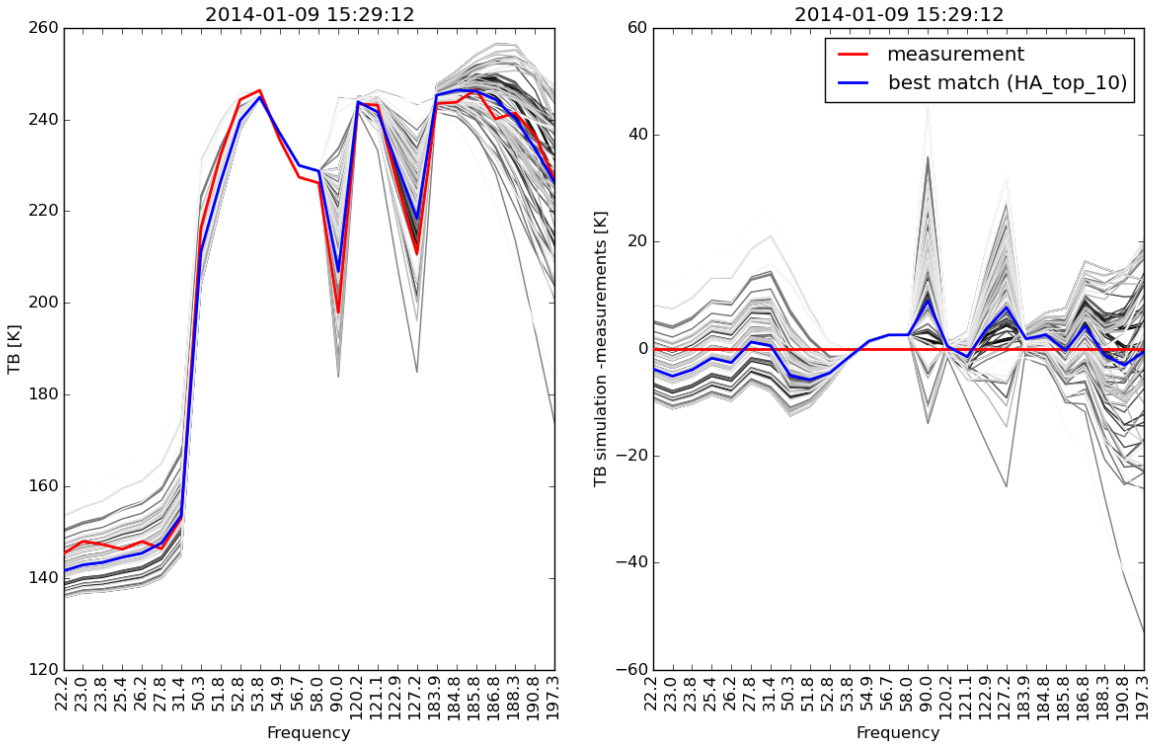
- for all particle types: use Optimal Estimation in order to find reff corresponding to observed Ze



Procedure

2) Simulate brightness temperatures

- Use IWC and reff (and LWC) profile to simulate TBs at all HALO HAMPs frequencies.
- Determine difference between measurements and simulations



Which particle type works best?

Try out all particle types of Kulie et al 2010 and combine with all LWC locations. Rank the simulations according to the measured TB and determine the mean rank of all investigated profiles:

1) HA_top_5 2.6
2) HA_top_10 3.2
3) HA_top_20 4.6
4) LP1_top_10 7.4
5) LP1_top_20 8.8
6) HC1_top_5 12.0
7) HC1_top_10 13.2
8) LSS_top_20 13.2
9) LSS_top_10 13.6
10) LSS_top_5 13.8
11) HC1_top_20 15.0
12) HC2_none 15.8
13) LDS_none 20.8
14) HP_top_5 21.0
15) LC2_top_20 21.0
16) HP_none 21.2
17) HR6_none 22.0
18) HP_top_10 23.2
19) LR3_none 26.2
20) LC3_equal 26.8

HA: Hong Aggregates work best when liquid is at the top

LP1: Liu thick hexagonal plate

HC1: Hong Hexagonal column

First configuration without SCLW at position 12

First configuration with equally distributed SCLW at position 20

Summary and next step

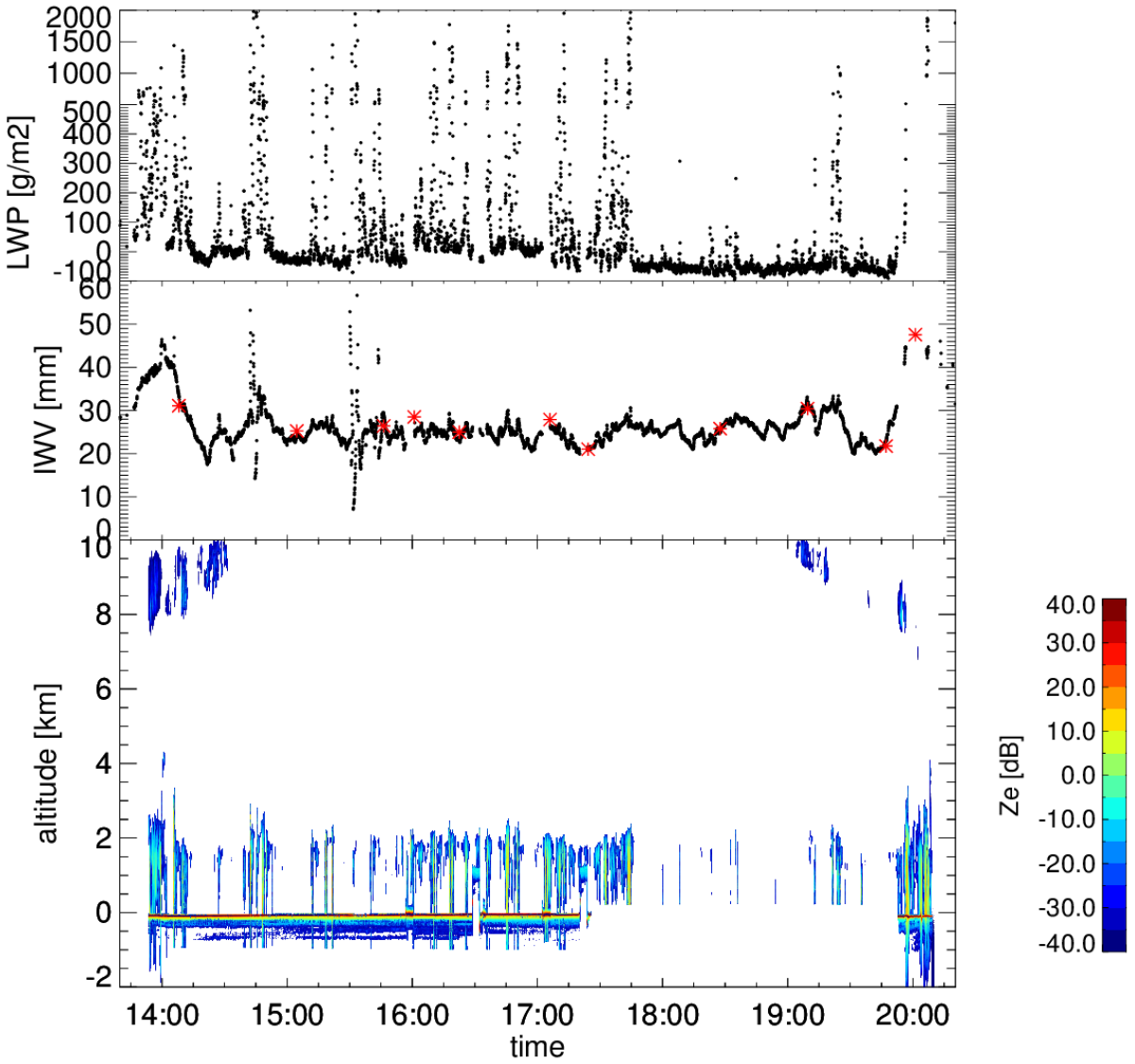
For the investigated cases (preliminary):

- Aggregates work best
- Whether the liquid is distributed in the uppermost 5, 10 or 20 radar levels is not of great importance
- Performance is worse when liquid is distributed equally or entirely omitted

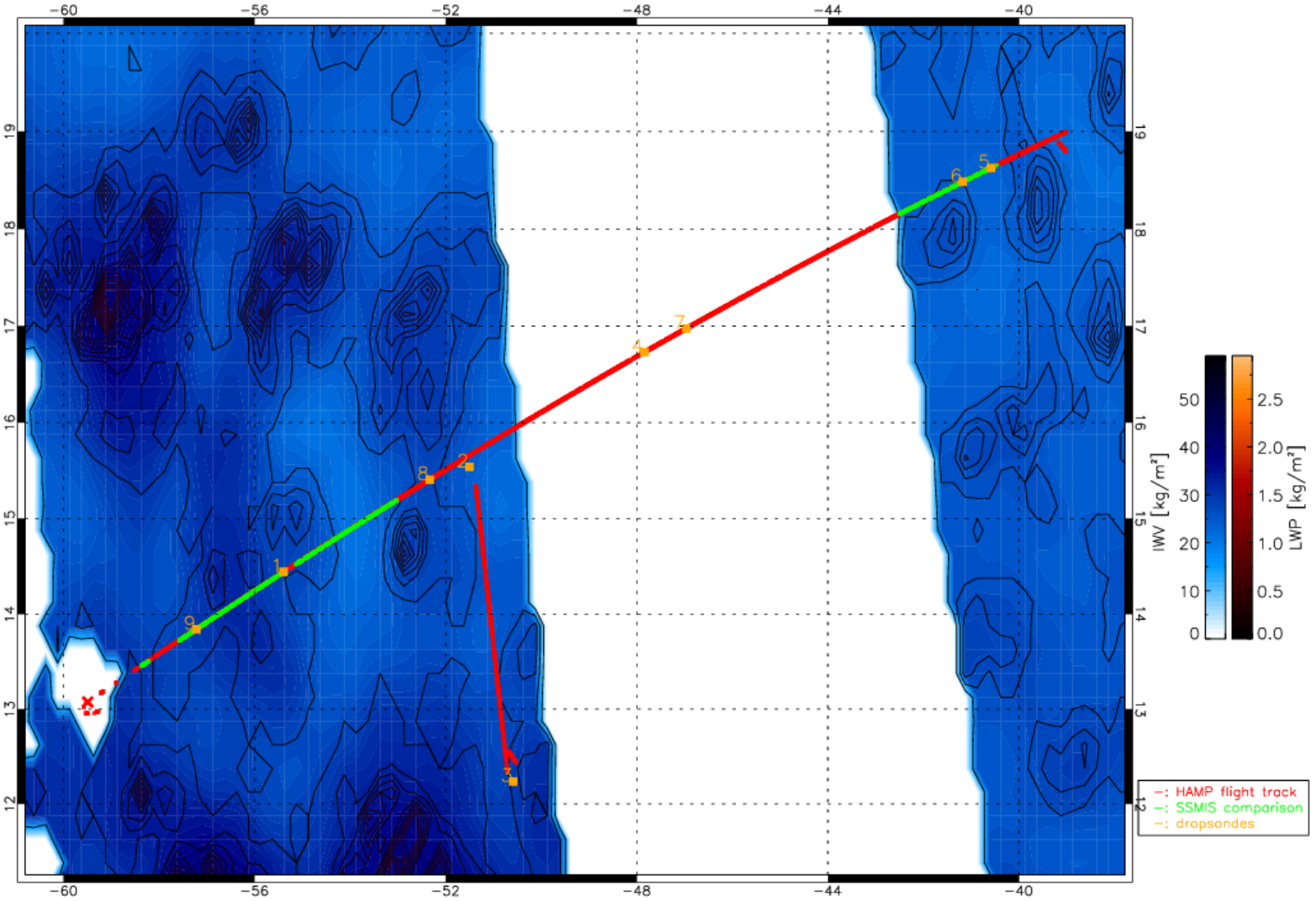
Next steps

- Use databases instead of Mie spheres for scattering estimation
- Consider different spatial/temporal resolution of radar and radiometer.
- Analyse more profiles
- Assess calibration errors

NARVAL South:



Comparison HAMP - SSMIS

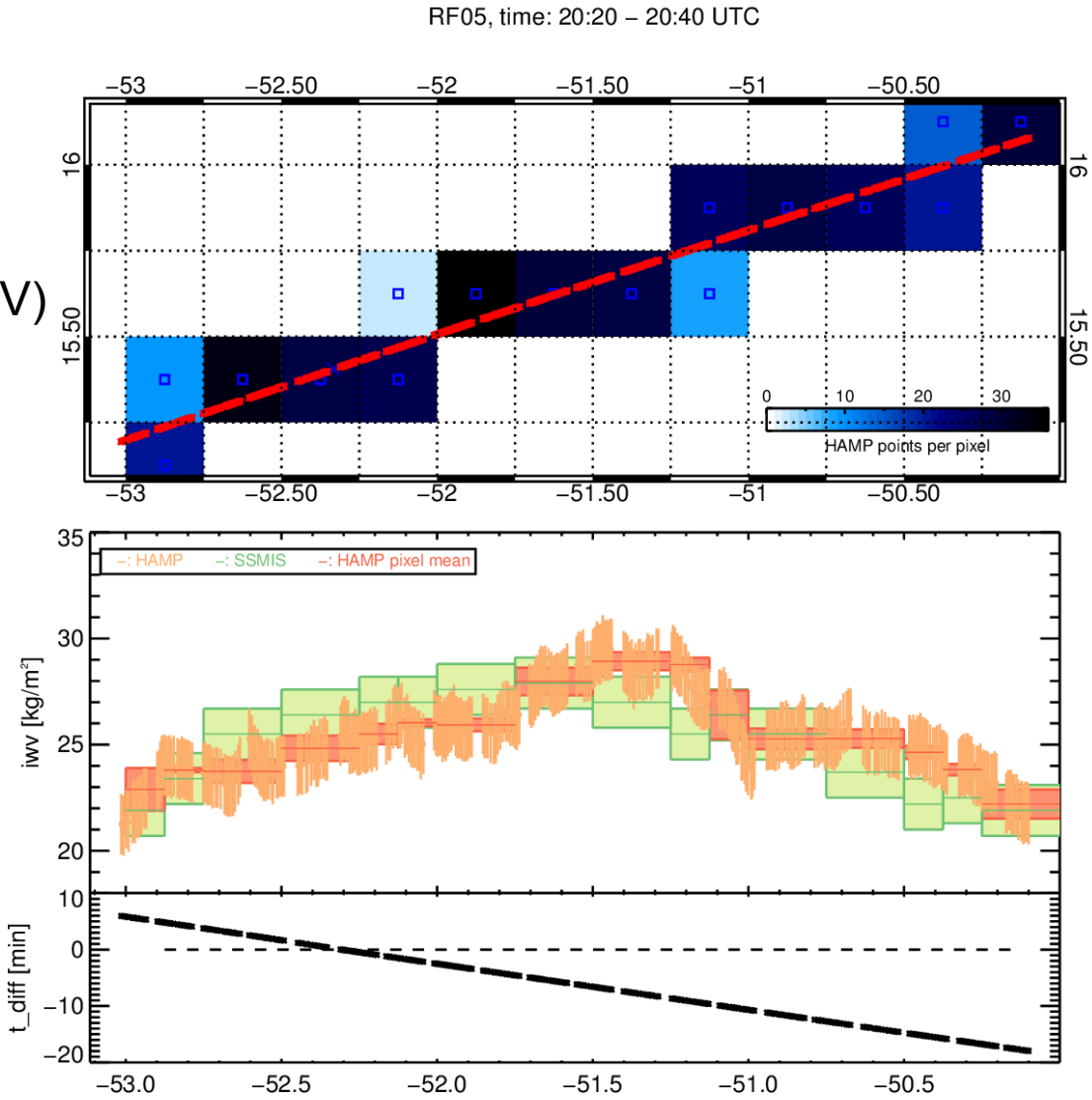


Comparisson HAMP - SSMIS

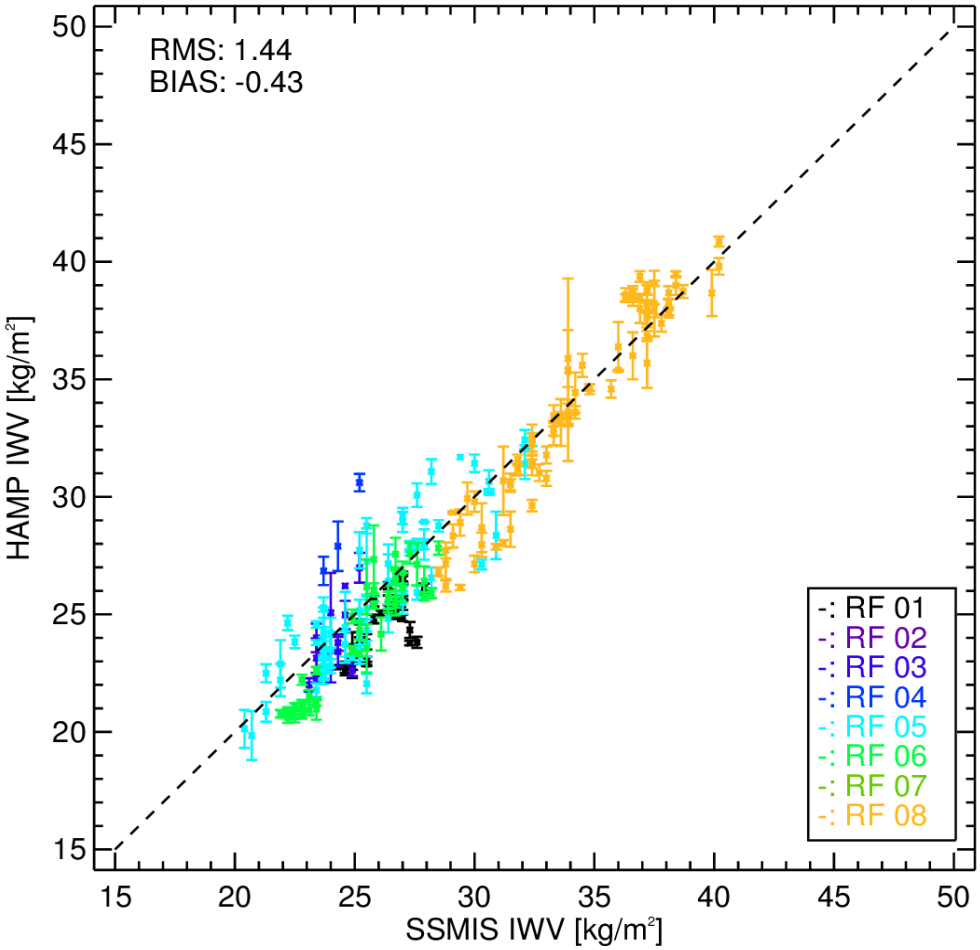
Statistical retrievals based on dropsondes, artificial clouds, and radiative transfer simulations:

HAMP Integrated water vapor (IWV) compared to 73 dropsondes
RMSE 1.4 kg /m^2

Matching HAMP to SSMIS pixel size for time difference < 20 min



Integrated Water vapor (IWV)

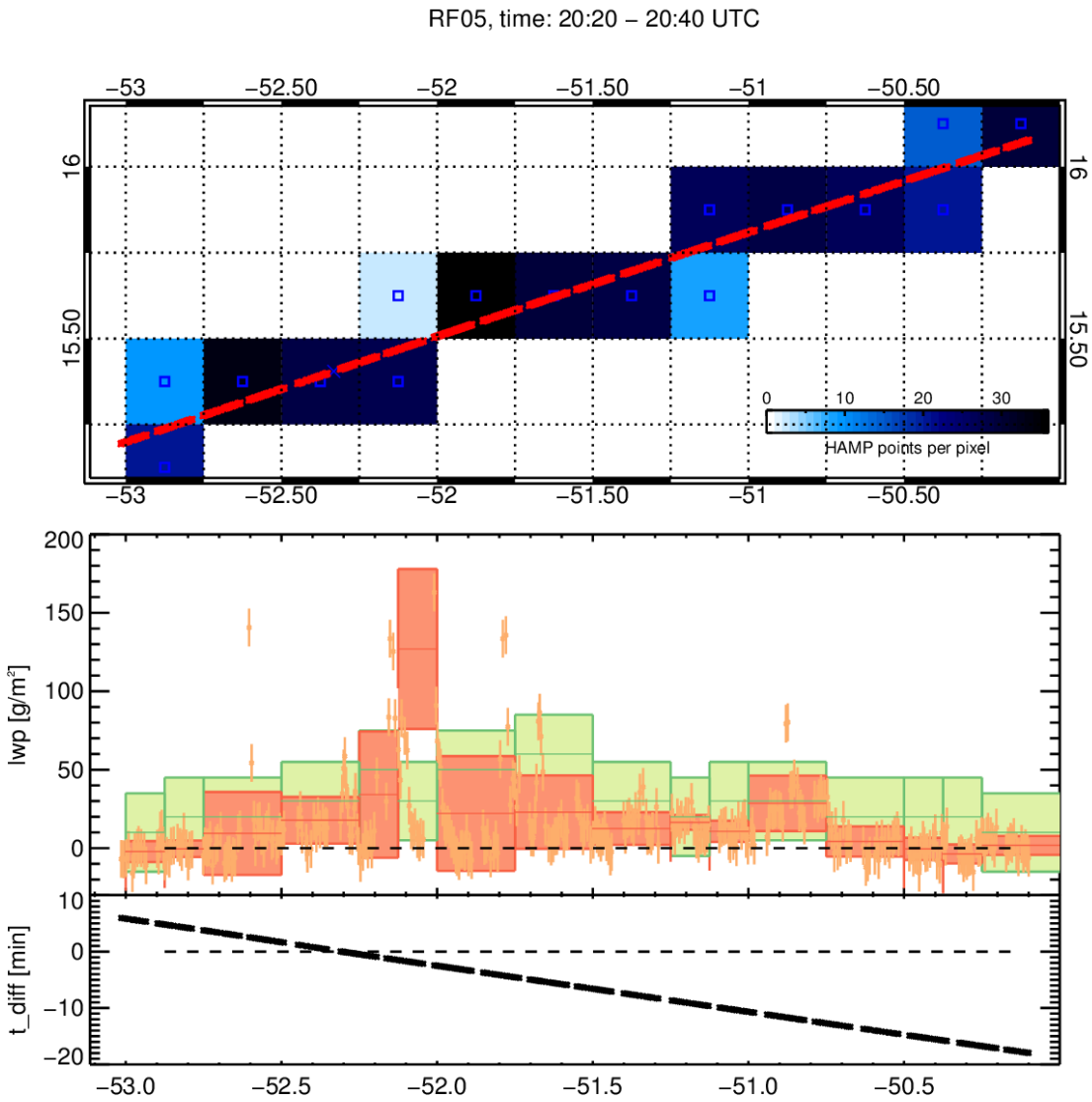


Statistical intercomparison over all research flights (RF)

Liquid Water Path (LWP)

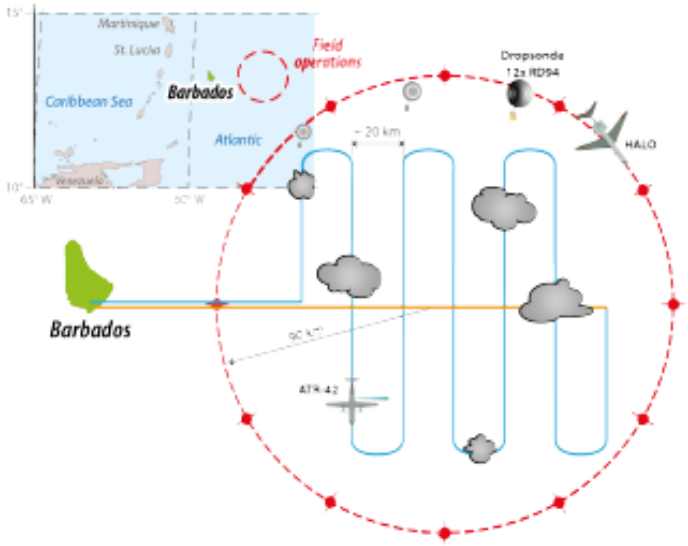
LWP standard deviation during clear sky cases 12 g/m^2

Due to coarse resolution SSMIS can not resolve smaller cloud structures



Upcoming HALO campaigns

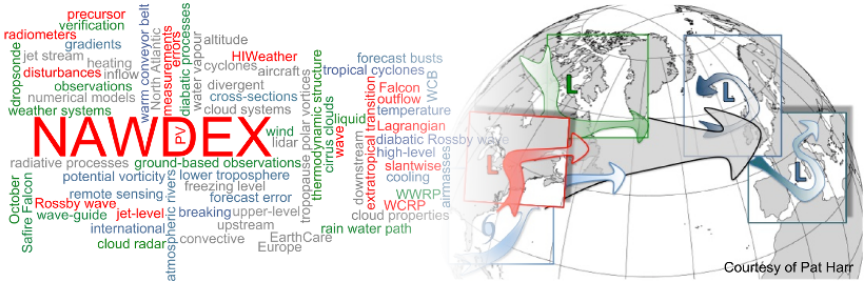
NARVAL II – Barbados (August 2016)



Aims:

- Characterize moisture around clouds
- Investigate in- and outflow
- Observe the structure of subtropical cumulus clouds

NAWDEX - North Atlantic Waveguide and Downstream Impact Experiment (Sep 2016)



Aims:

- Increase the physical understanding and quantify the effects of diabatic processes on disturbances to the jet stream near North America
- Investigate their influence on downstream propagation across the North Atlantic
- Estimate their consequences for high-impact weather in Europe

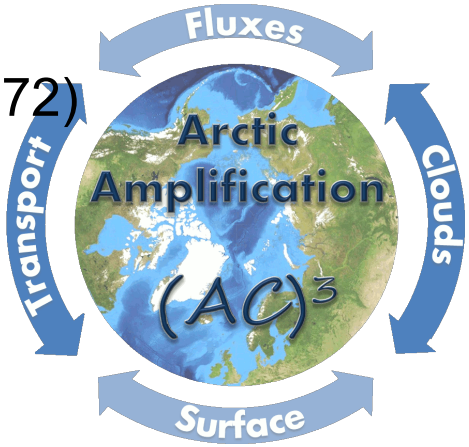
Summary & Outlook

- HALO aircraft equiped with remote sensing instrumentation successfully operated during 140 flight hours
- core instrumentation (radiometer, cloud radar, and lidar) worked reliable and shows good sensitivity
- (re-)calibration of the instruments and correction due to „moving“ aircraft is under way
- synergy potential will be further investigated

C. Klepp et al., NARVAL Campaign Report, Tech. Rep. 164, MPI-M Hamburg Germany

M. Mech, E. Orlandi, S. Crewell, F. Ament, L. Hirsch, M. Hagen, G. Peters, and B. Stevens: HAMP – the microwave package on the High Altitude and LOng range research aircraft (HALO), Atmos. Meas. Tech., 7, 4623-4657, 2014.

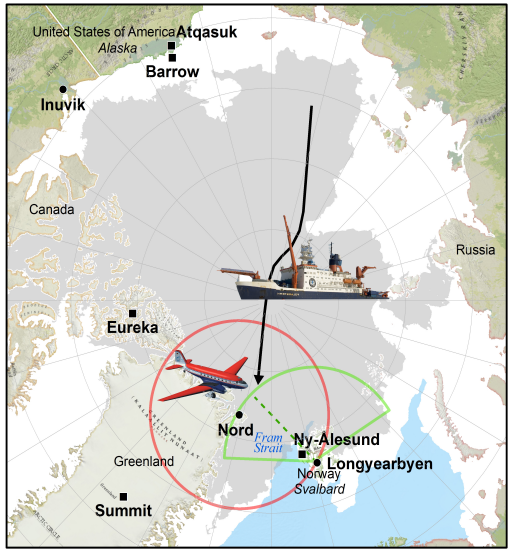
ArctiC Amplification:
Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms $(AC)^3$



Transregional Collaborative Research Center (TR172) proposed to German Science Foundation by

- University of Leipzig (M. Wendisch)
- University of Bremen
- University of Cologne
- Leibniz Institute for Tropospheric Research
- Alfred Wegener Institute (AWI)

Comprehensive observational and modeling effort to identify, investigate, and evaluate the key processes contributing to Arctic Amplification



Investigation of arctic mixed-phase clouds by airborne remote sensing within AC3

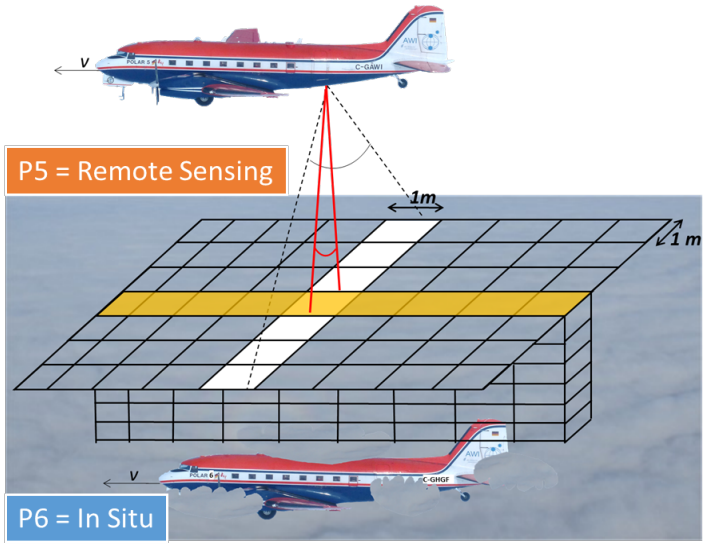
Arctic mixed-phase clouds play a significant role in Arctic energy budget, butare poorly understood and not well represented in climate models

investigations require **collocated airborne observations** providing simultaneous in-situ and remote sensing

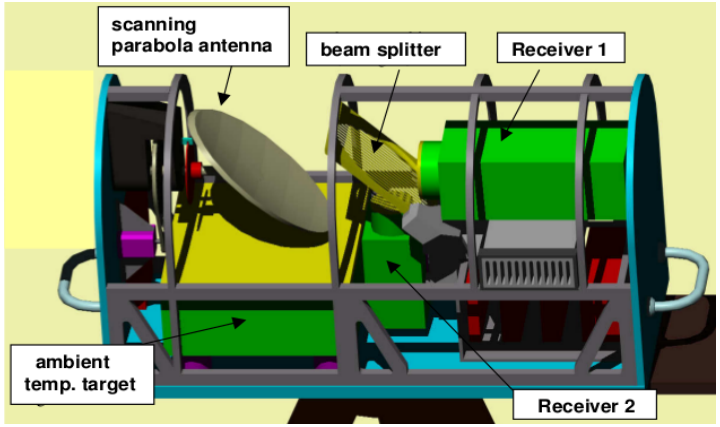
In-situ on Polar 6 (P6):
CVI + CPC, OPC, UHSAH, PSAP
- 0.06 to 10µm size range
- Characterize IN and CCN

Remote sensing on Polar 5 (P5):
Eagle/Hawk imaging spectrometer
- visual and infrared observations
- Maps of cloud phase, optical properties

Microwave Radar/rad. for Arctic Clouds (MiRAC)
- radar fo rhydrometeor profiling
- passive observations by radiometer for humidity
- profiles and integrated liquid and ice water contents

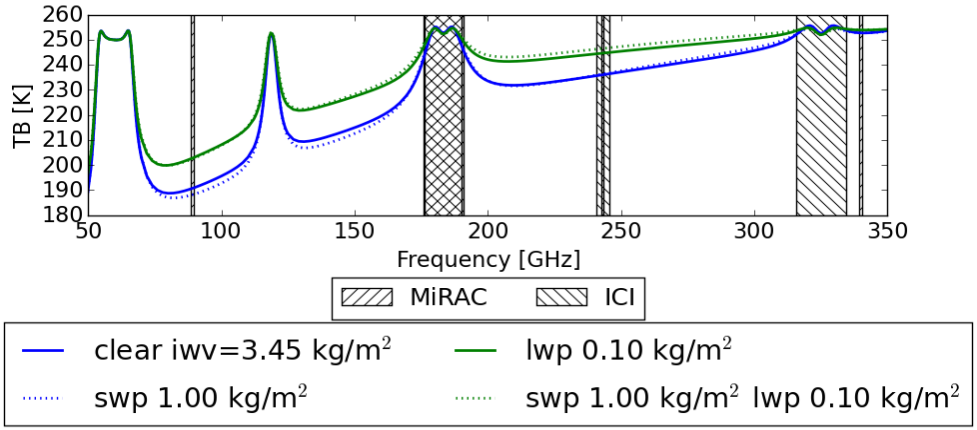


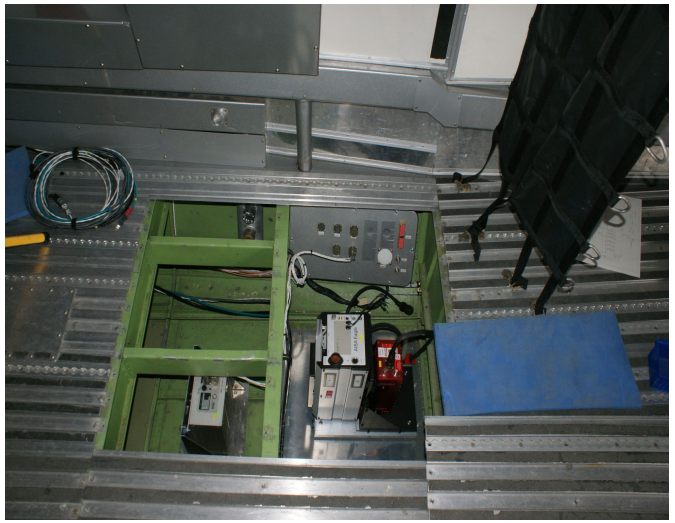
MiRAC - Radiometer



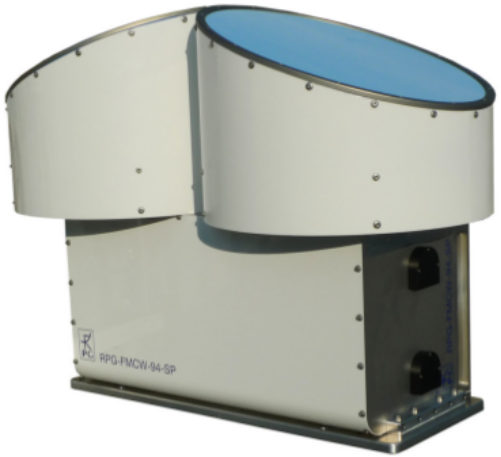
Specifications:

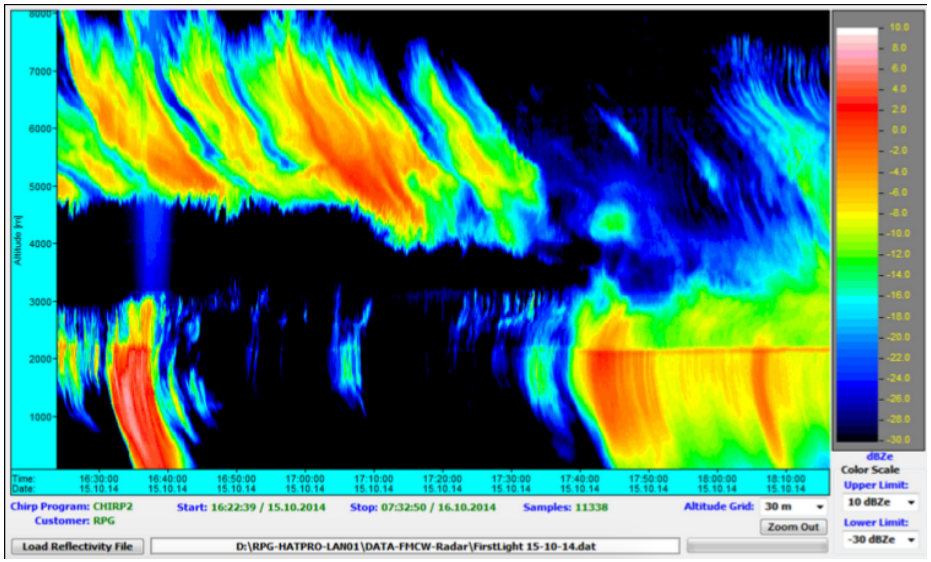
- Passive receivers at 183.31 (6 channels), 243, and 340 GHz
- Noise 1500 K for 183 GHz WV profiler
- HPBW 1.3°
- Humidity profiles and IWC
- Power consumption < 120 W average
- 60 kg without dew blower and stand





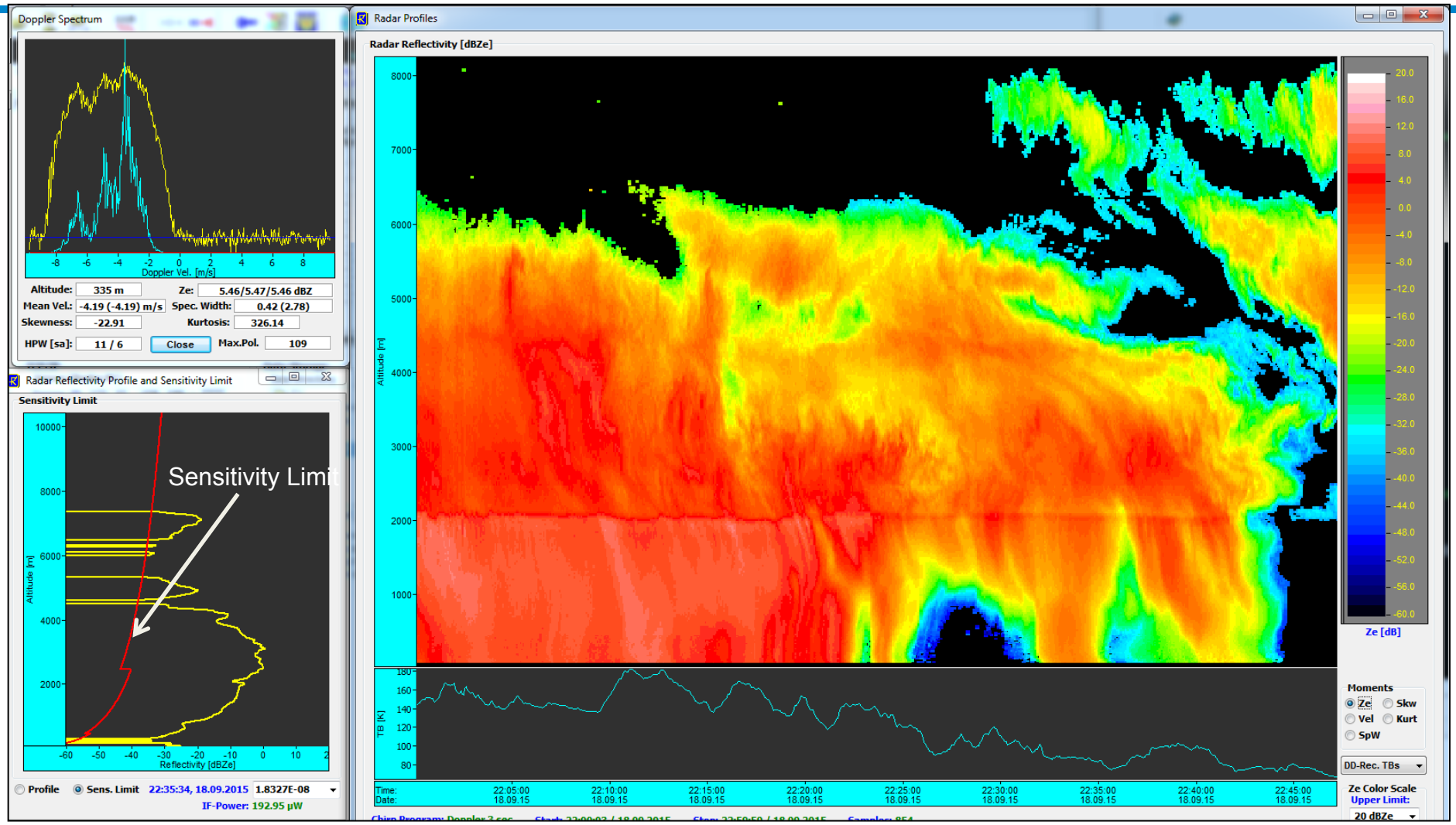
MiRAC - Radar



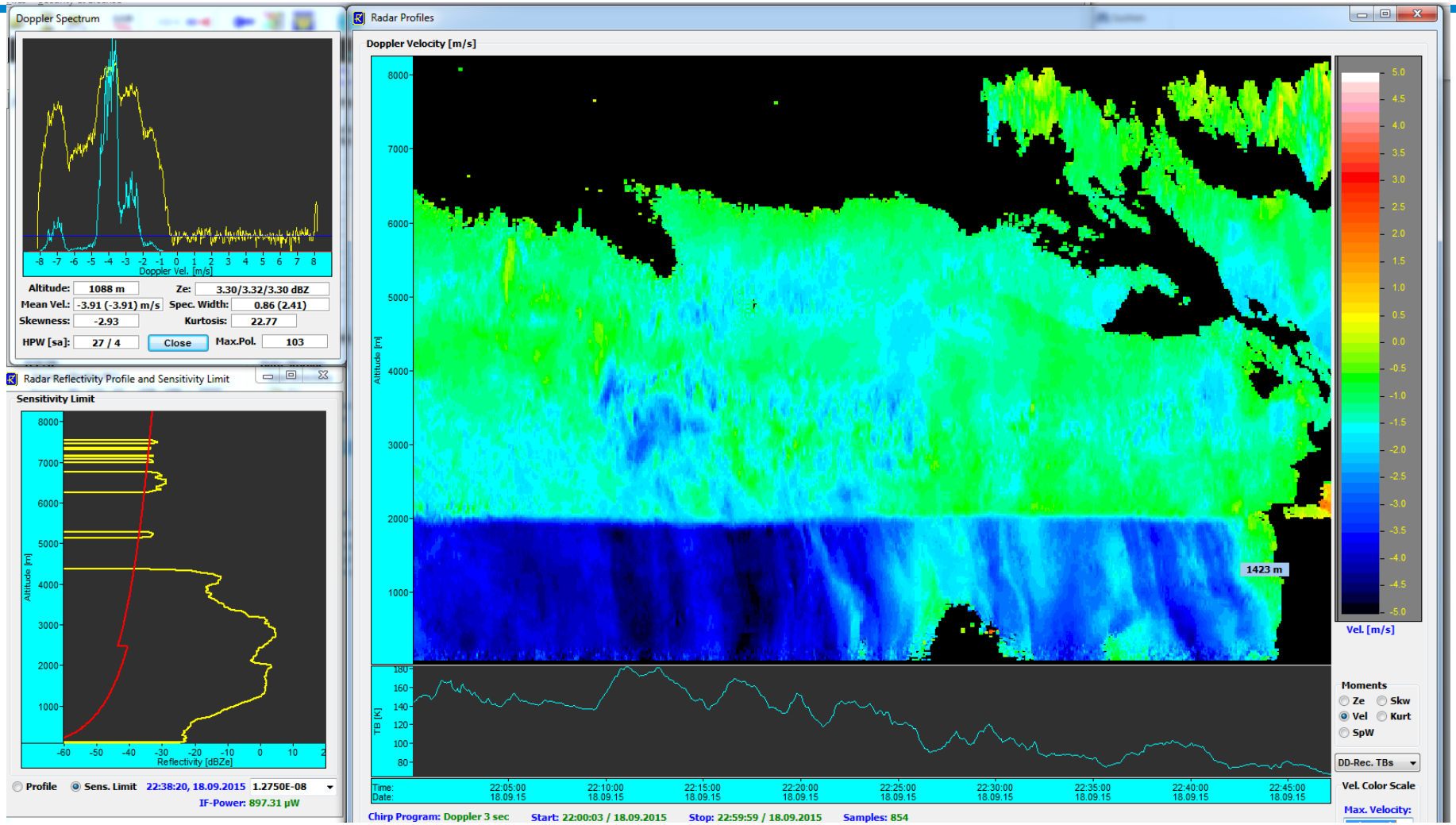


Specifications:

- 94 GHz Frequency Modulated Continuous Wave (FMCW) radar
- High-Power transmitter with 2 W
- Built-in 89 GHz passive radiometer
- High resolution profiles of hydrometeors and Doppler spectra
- Integrated liquid water
- 80 kg without stand, 80 x 50 x 60 cm



Doppler spectra are only calcuated for range bins of Ze > Sensitivity Limit


Doppler Spectrum
Doppler Vel. [m/s]
Altitude: 1088 m
Ze: 3.30/3.32/3.30 dBZ
Mean Vel.: -3.91 (-3.91) m/s
Spec. Width: 0.86 (2.41)
Skewness: -2.93
Kurtosis: 22.77
HPW [sa]: 27 / 4
Close
Max.Pol. 103
Radar Reflectivity Profile and Sensitivity Limit
Sensitivity Limit
Altitude [m]
Reflectivity [dBZe]
Profile
Sens. Limit
22:38:20, 18.09.2015
1.2750E-08
IF-Power: 897.31 µW
Radar Profiles
Doppler Velocity [m/s]
Altitude [m]
1423 m
Vel. [m/s]
TB [K]
Moments
Ze
Skw
Vel
Kurt
SpW
DD-Rec. TBs
Vel. Color Scale
Max. Velocity:
Time:
Date:
Chirp Program: Doppler 3 sec
Start: 22:00:03 / 18.09.2015
Stop: 22:59:59 / 18.09.2015
Samples: 854