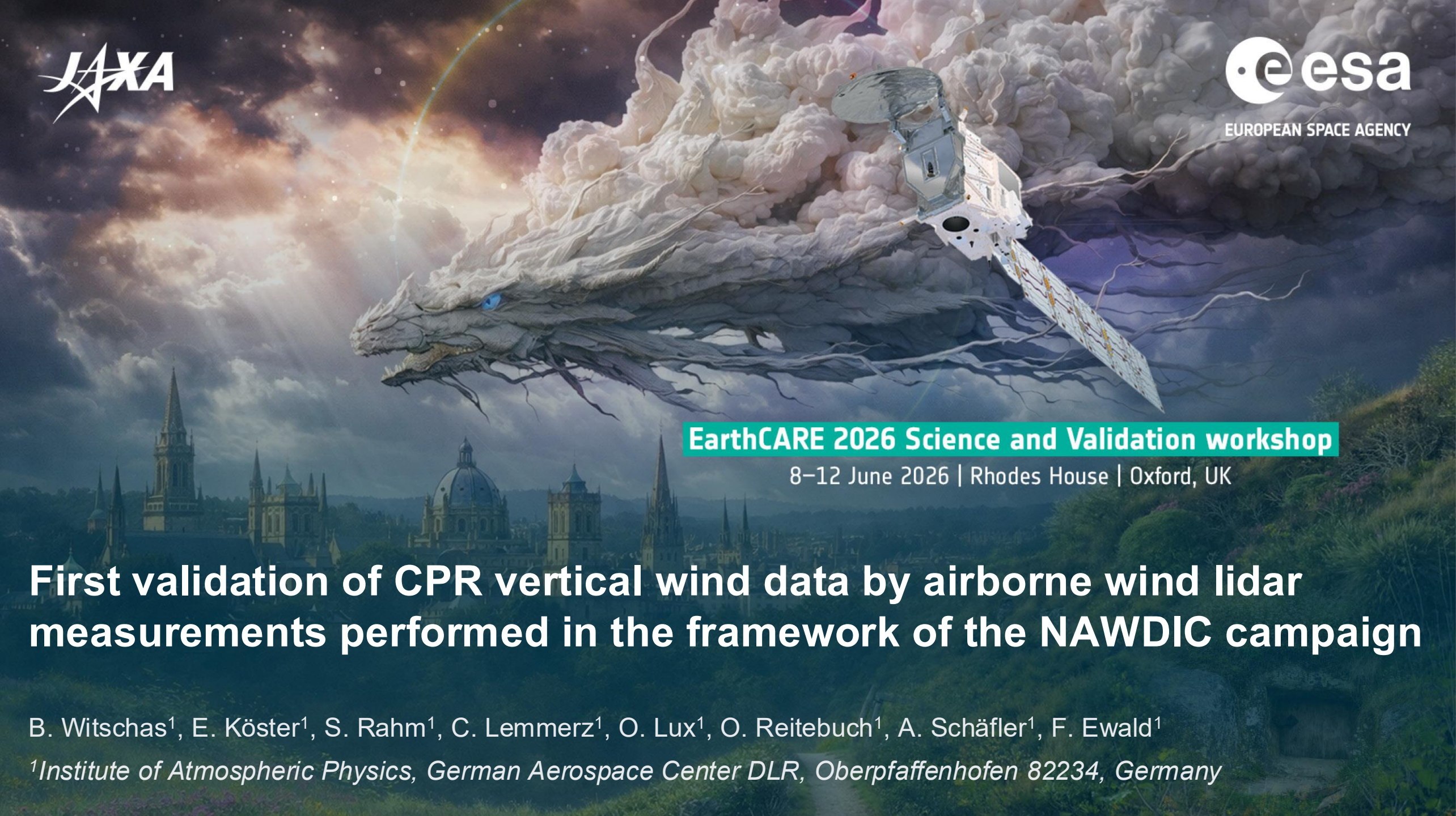

First validation of CPR vertical wind data by airborne wind lidar measurements performed in the framework of the NAWDIC campaign

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The airborne wind lidar HEDWIG

HEDWIG: The **HE**eterodyne **D**etection **W**ind L**I**dar **G**adget

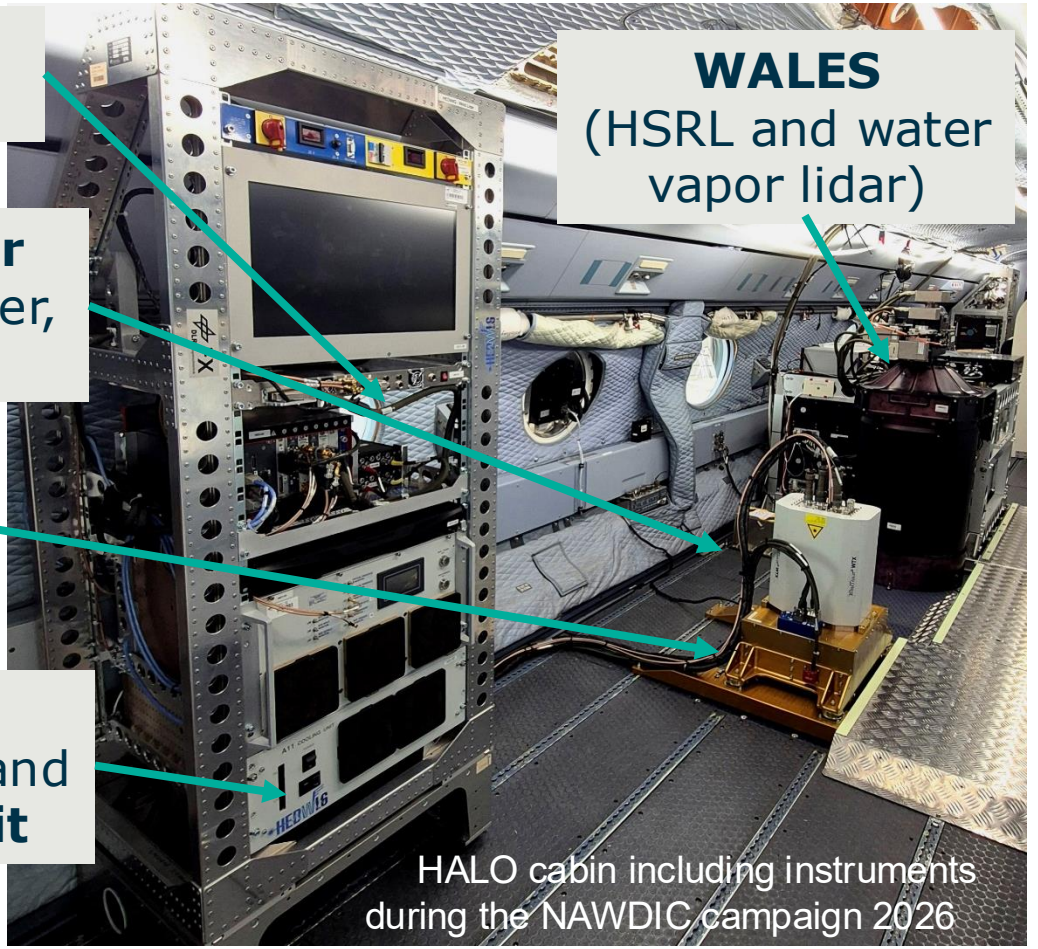
DAQ (incl. ARINC, GPS)

Transceiver (Laser, receiver, telescope)

Scanner

Laser electronics and **cooling unit**

WALES (HSRL and water vapor lidar)

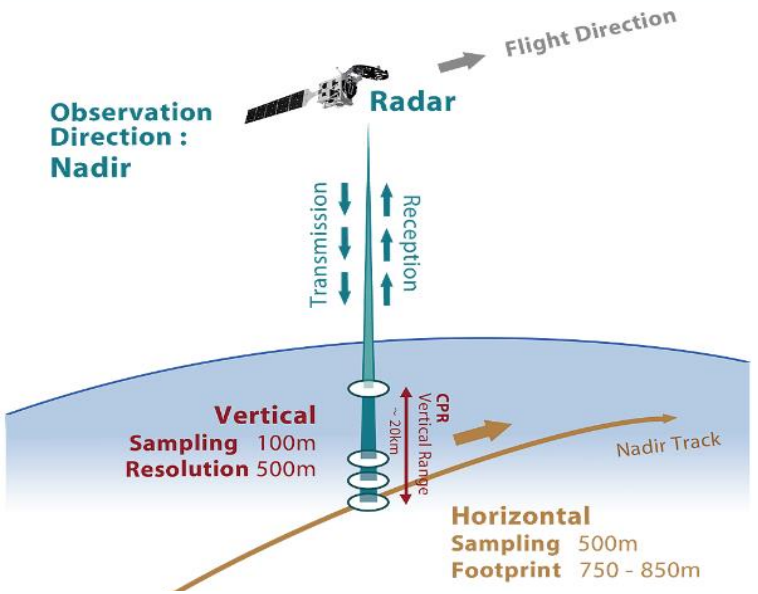


HALO cabin including instruments during the NAWDIC campaign 2026

Parameter	DLR 1.6-µm DWL
Detection principle	**Heterodyne detection**
Scanning	Double-wedge scanner
Wavelength	1617.25 nm (eye-safe)
Laser energy	**~2.0 mJ**
Pulse repetition rate	**750 Hz**
Pulse length	**(300 ± 20) ns (90 ± 6) m**
Telescope diameter	10 cm
Vertical resolution	100 m
Temporal averaging raw data (horizontal)	single shot = 1.33 ms
Temporal averaging product (horizontal)	1 s per LOS (750 shots), 5 s to 20 s (dep. on scan)
Horizontal resolution	~0.2 km LOS, 2 to 15 km
Precision (random error)	~0.2 m/s LOS

Comparison of CPR on EarthCARE and HEDWIG properties

CPR main objective: measuring **vertical structure of clouds** for the retrieval of their **microscopic** and **macroscopic properties**, and measuring the **vertical velocity of cloud particles**.



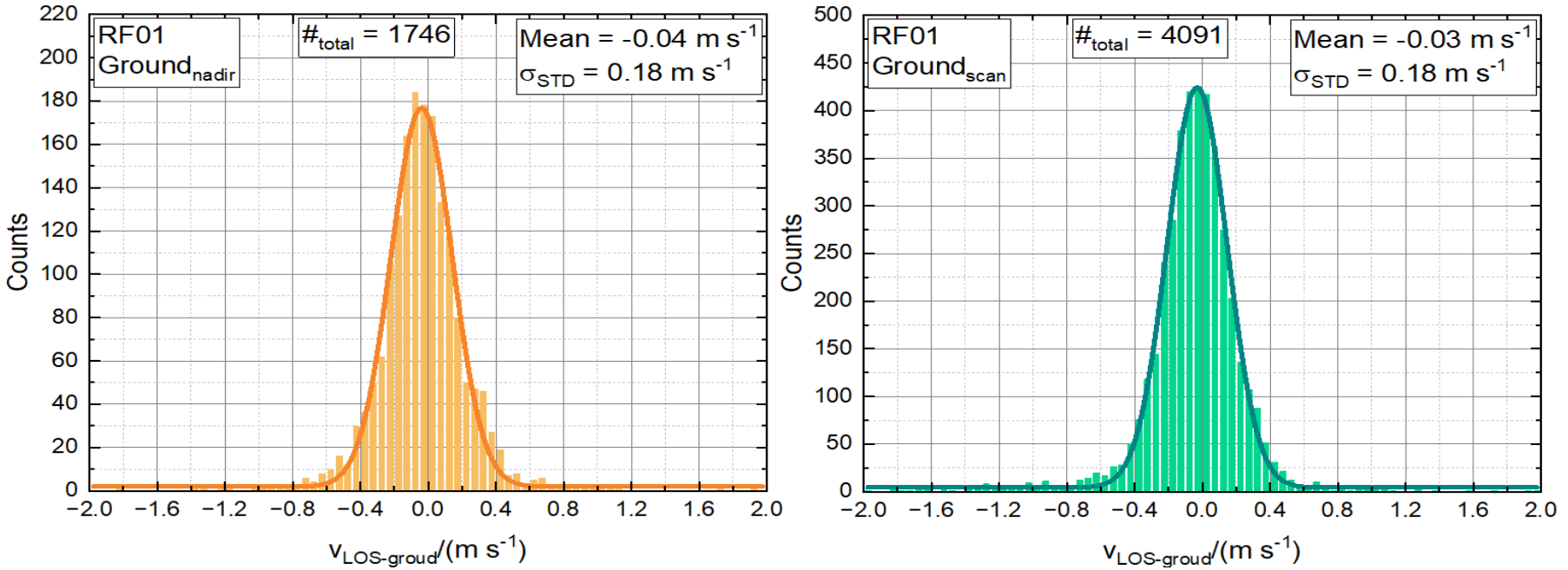
Parameter	CPR	HEDWIG lidar
Center frequency Wavelength	**94.05 GHz** **3.2 mm**	 **1.6 µm**
Height range	Up to 20 km	Up to 15.5 km (with HALO)
Vertical resolution	**500 m** (100 m sampling)	**100 m** (Laser pulse ~90 m FMWM)
Horizontal resolution	**750 m**	**200 m** to **1.2 km** (depending on scan mode)
Doppler accuracy	**1 m/s**	**<0.1 m/s** **~0.2 m/s** (precision)

Airborne HEDWIG wind lidar measurements are principally useful for CPR validation:

- Can **HEDWIG observations** provide an **independent reference or complementary** information (e.g. microscopic properties)?
  - Can **HEDWIG** measurements be used **to estimate** the **accuracy** and **precision** of CPR Doppler velocity observations?

Zero wind verification of HEDWIG

- The **installation geometry** of HEDWIG relative to the aircraft was precisely determined to enable an **adequate correction of the aircraft velocity in the line-of-sight measurements**.
- **Ground returns** are used for this purpose (available during four research flights).
- Both nadir and off-nadir observations indicate a **bias** (accuracy) between **–0.04 m/s** and **0.02 m/s** and a standard deviation (precision) of about **0.2 m/s**.

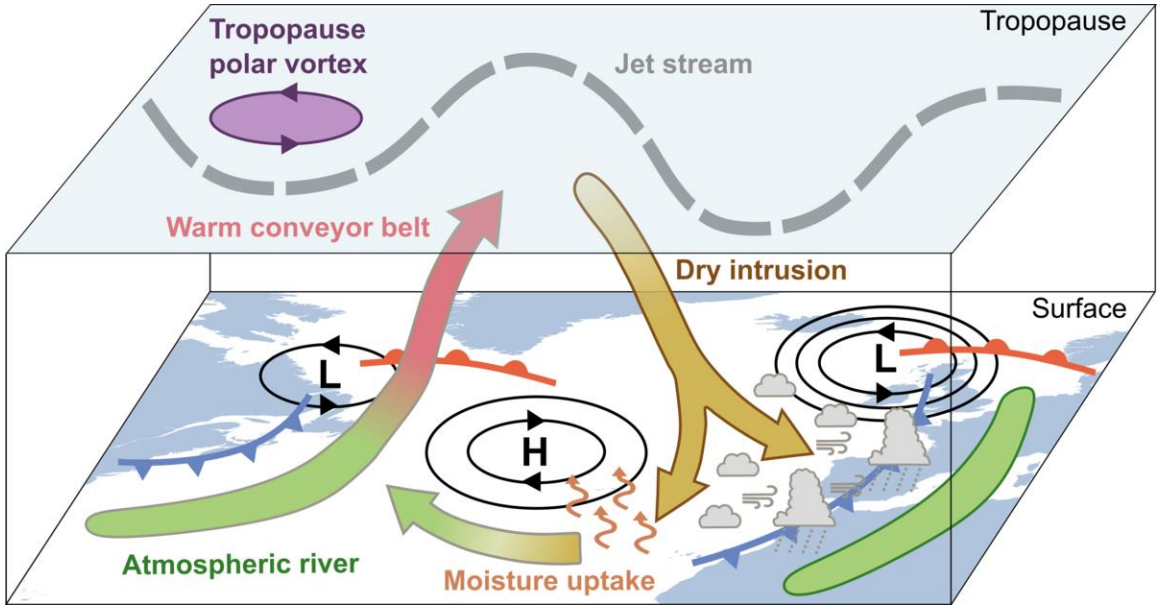


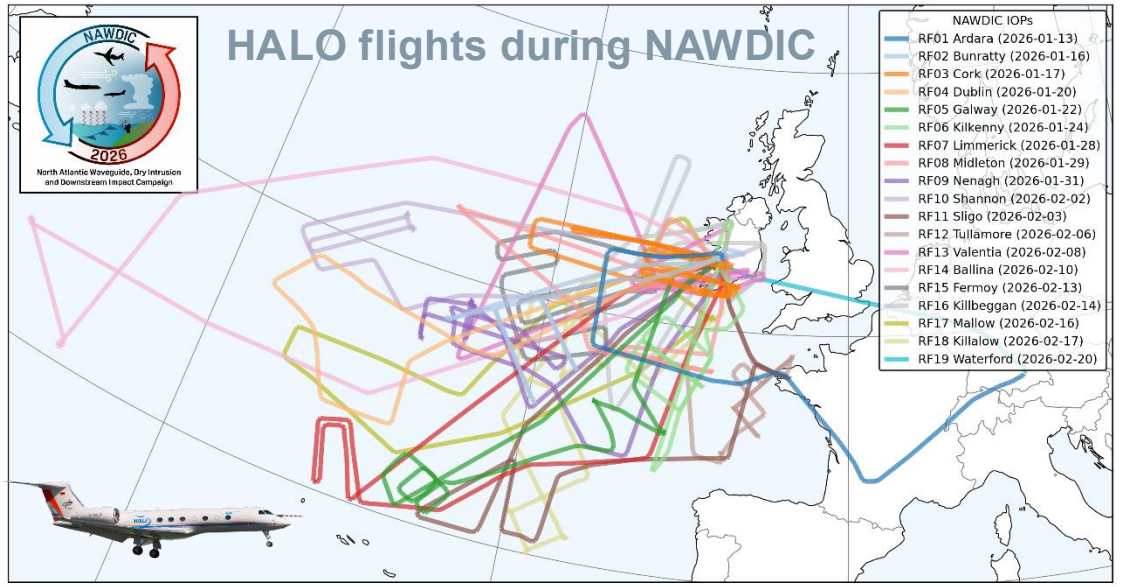
Sign convention: negative velocity means towards ground.

The NAWDIC campaign

Investigation of **dry intrusions** along **cold fronts** and their relation to **severe weather** in the **midlatitudes**

<u>International cooperation:</u>
KIT, DLR, LMU, ETH Zurich, Meteo France,
Weizmann-Institute of Technology,
NOAA, NCAR, NASA, and many more

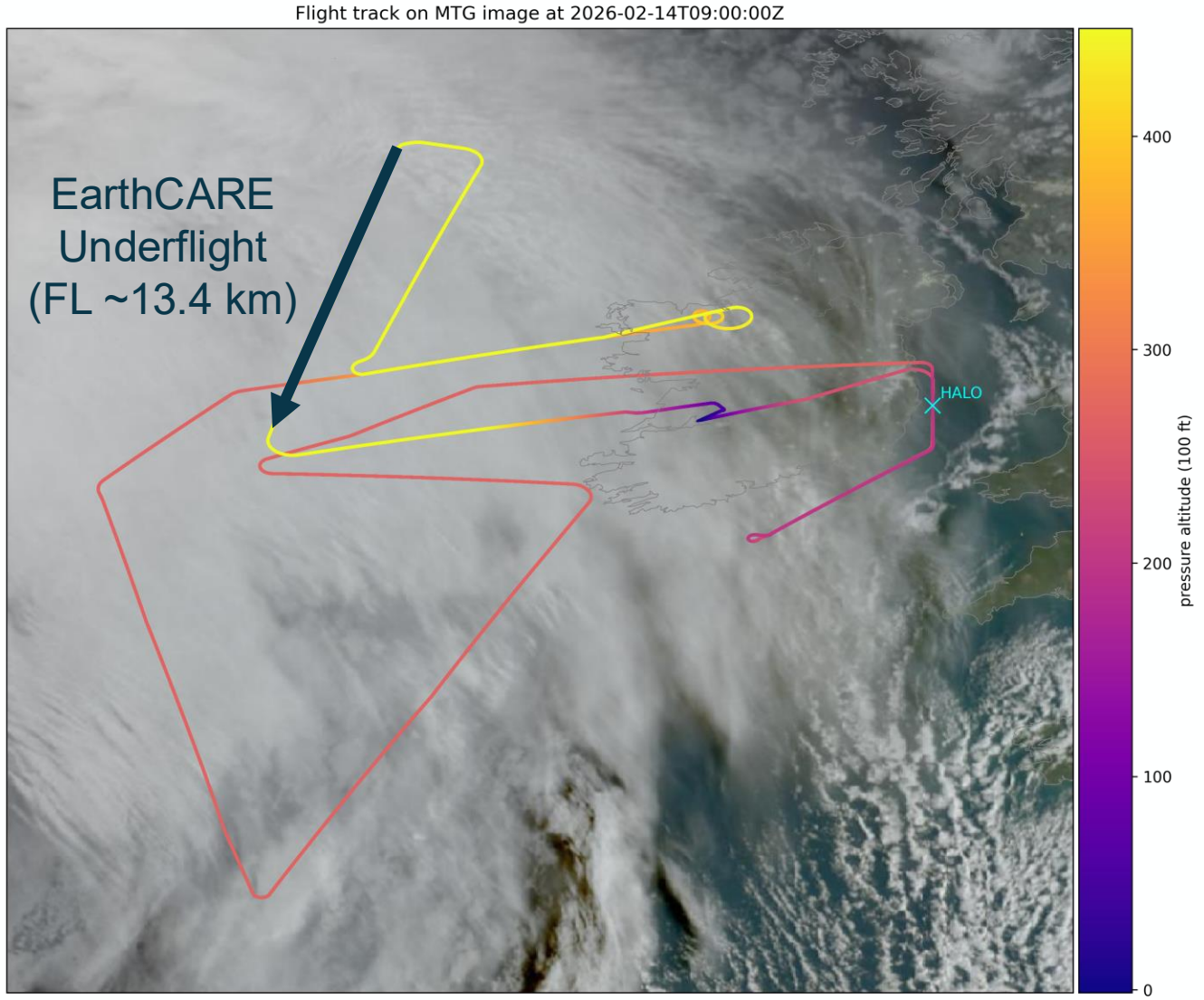




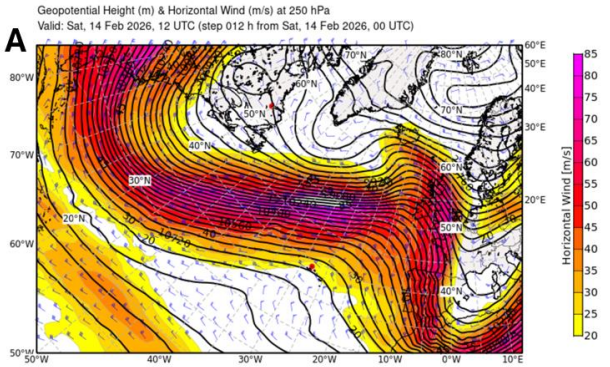
- 13 Jan to 20 Feb 26, Shannon, Ireland
- **19 research flights with HALO**
- ~150 flight hours (~100.000 km)
- Aircraft coordination of HALO with, French Safire ATR42, TU Braunschweig Cessna, NASA NURTURE G3 from Newfoundland
- **6 EarthCARE underflights**

More information: https://www.nawdic.kit.edu

NAWDIC EarthCARE underflights

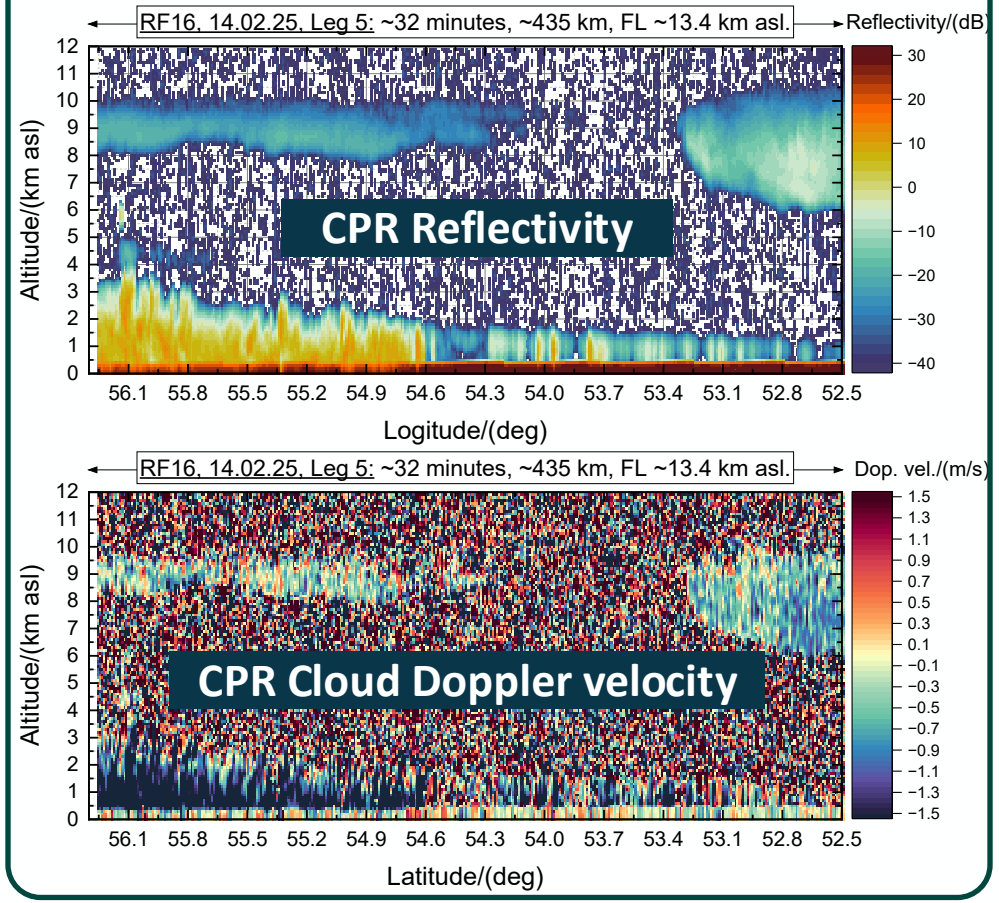


- All together, **six EarthCARE underflights** were performed during the NAWDIC campaign available for the **validation the CPR Doppler velocity** product.
- So far, one underflight has been analyzed (RF16, 14. Feb. 2026, **32 minutes, 435 km, FL ~ 13.4 km**) and is presented here.
- <u>RF16 synoptic situation:</u>
  Strong Atlantic jet stream, bringing the warm front of an cyclone towards Ireland. High cirrus clouds over the Atlantic and Ireland.

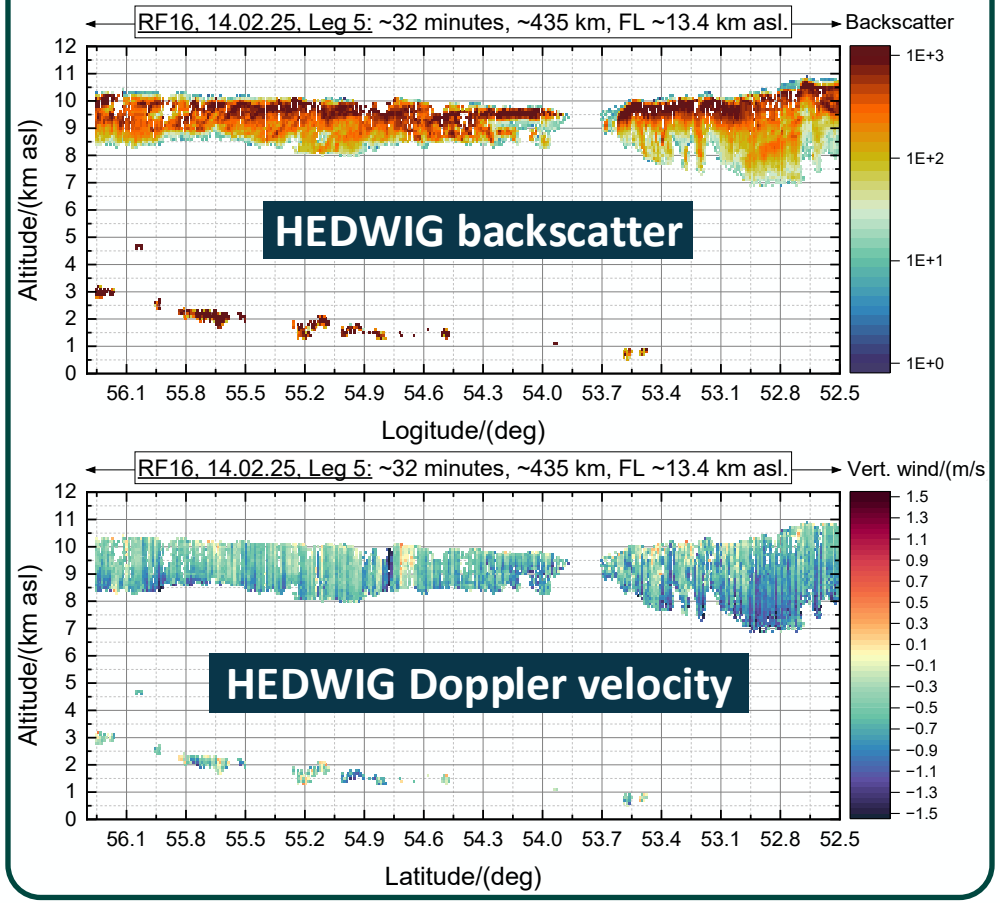


Comparison of HEDWIG and CPR (L1)

- **CPR L1 data:** ECA_JXDA_CPR_NOM_1B_20260214T152722Z_20260214T170838Z_09751D
- **Aerial average** to HEDWIG grid (~ half the resolution)
- **No additional QC**



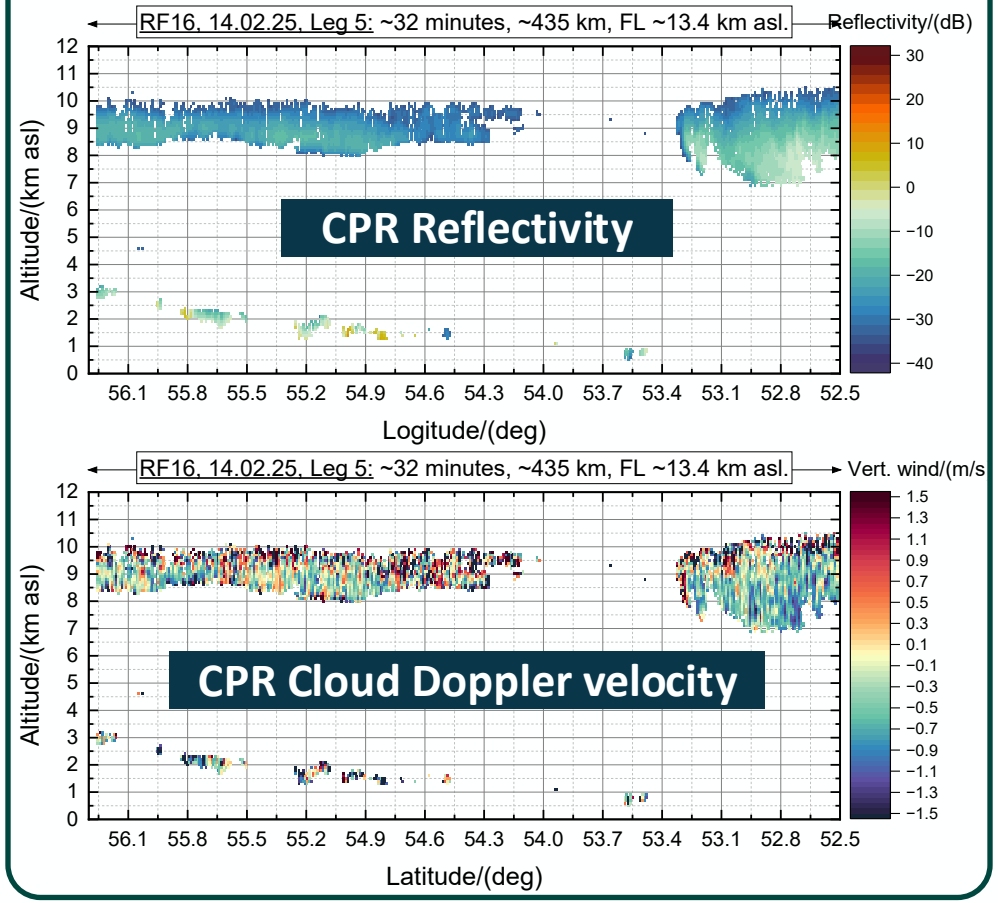
- **HEDWIG L1 data:** LOS measurements with nadir pointing, corrected for the aircraft velocity
- Backscatter is range corrected, but not “calibrated”



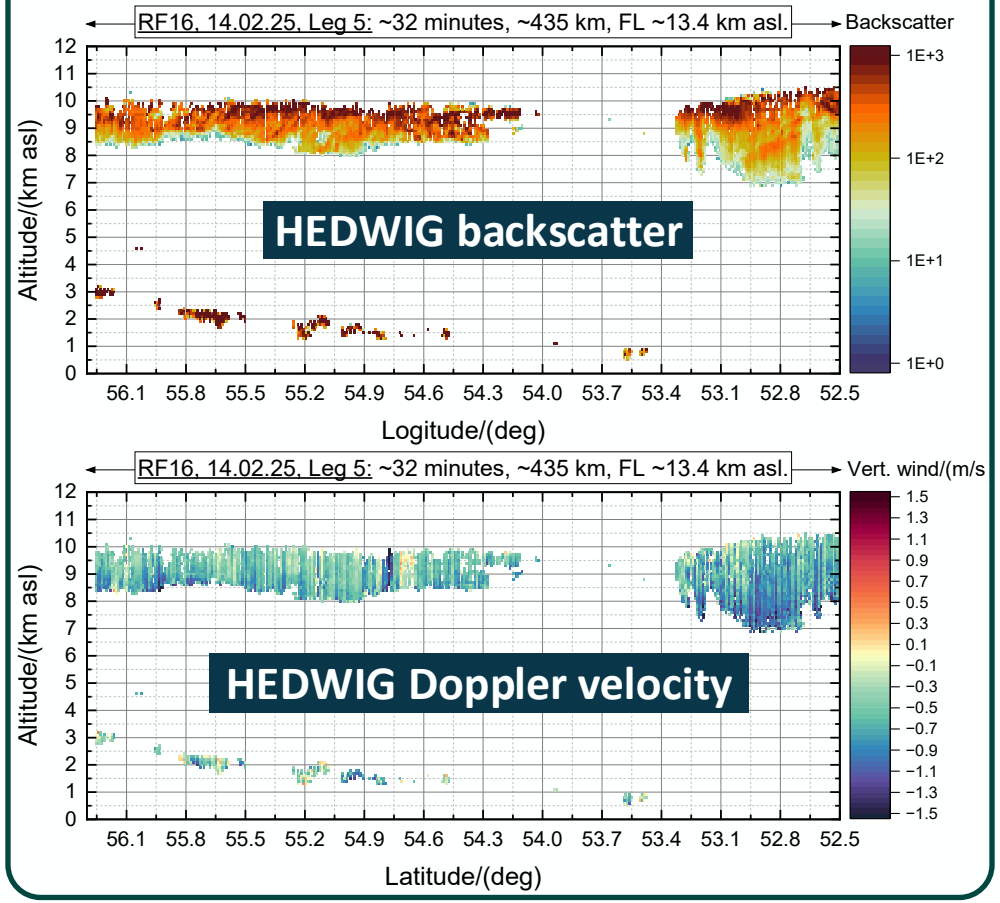
- **Excellent overlap** between CPR and HEDWIG, especially in the (cirrus) cloud.
- **CPR reflectivity** and **lidar backscatter** show different sensitivity.
- The **negative** (downwards) **Doppler velocity** is obvious in both datasets

Comparison of HEDWIG and CPR (L1)

- **CPR L1 data:** ECA_JXDA_CPR_NOM_1B_20260214T152722Z_20260214T170838Z_09751D
- **Aerial average** to HEDWIG grid (~ half the resolution)
- **QC:** **Ref. > -34 dBz, data only where valid HEDWIG**



- **HEDWIG L1 data:** LOS measurements with nadir pointing, corrected for the aircraft velocity
- Backscatter is range corrected, but not “calibrated”
- **QC:** **Data only where valid CPR data**



- **Excellent overlap** between CPR and HEDWIG, especially in the (cirrus) cloud.
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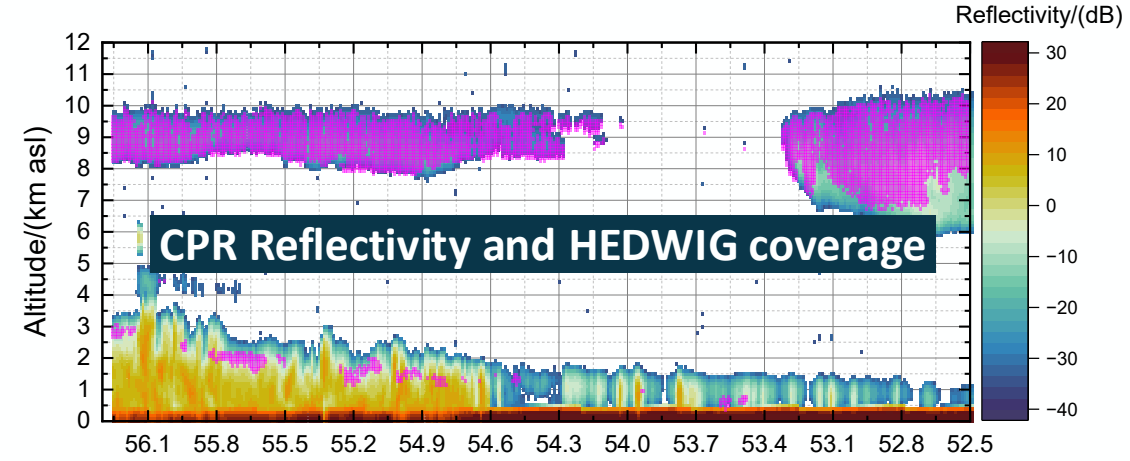
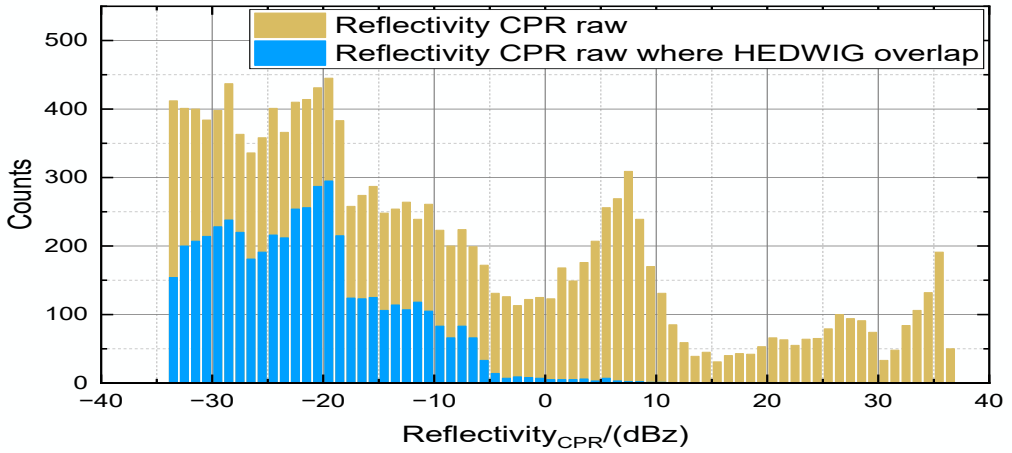
Comparison of HEDWIG and CPR (L1)

Data overlap between CPR and HEDWIG

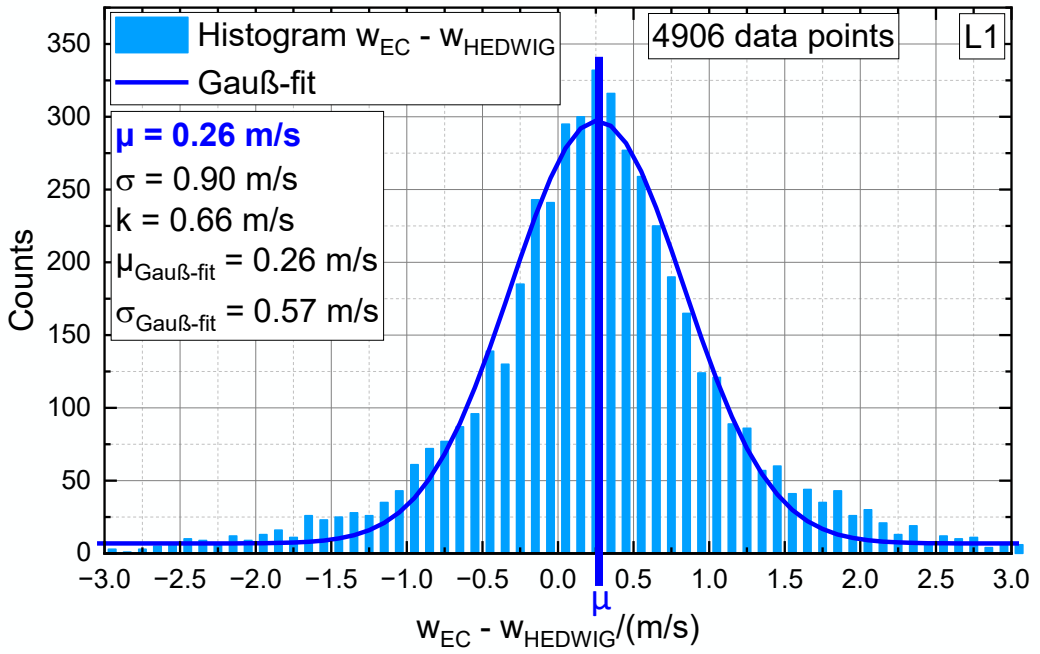




- **High data overlap (72%)** between CPR (colored) and HEDWIG (magenta) in the (cirrus) cloud.
- **Thick clouds and precipitation** in the boundary layer **are not detectable** by HEDWIG.
- **In total, the data overlap is 35% (4906 data points)** that could be used for validation (applying a reflectivity threshold of -34 dBz)
  → **statistically significant**
- The **data overlap** happens **mainly** for reflectivity values of **-34 dBz to -20 dBz,** but provides **valid data points down to -5 dBz.**

Data overlap and usefulness is scene/cloud dependent.

Comparison of HEDWIG and CPR (L1)



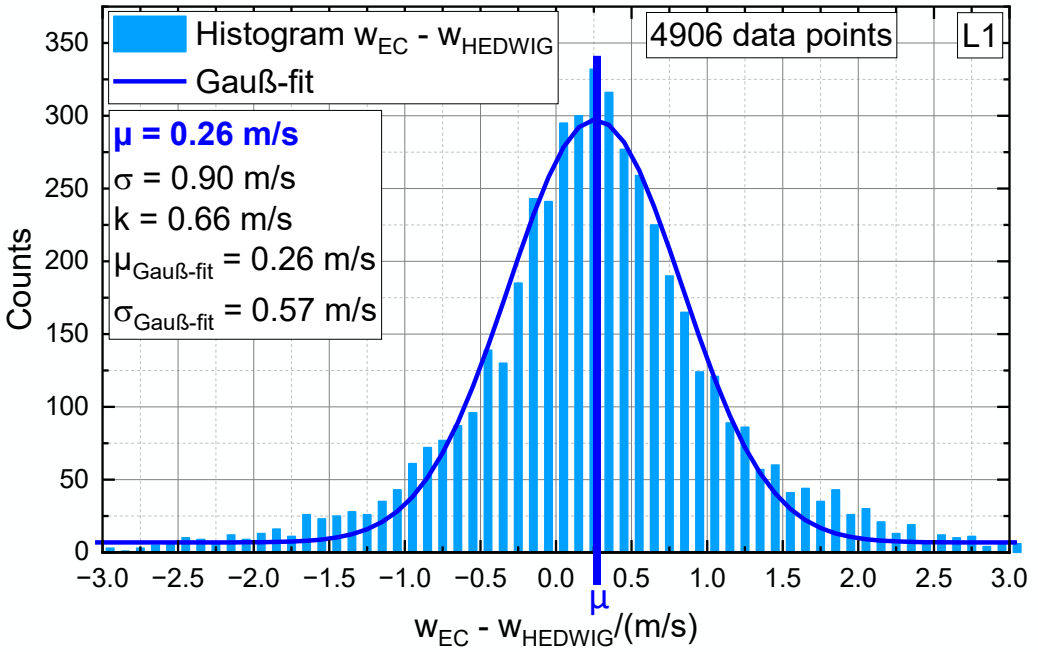
- Doppler velocity difference (CPR minus HEDWIG) is almost normally distributed ($r^2_{Gauß}$ = 0.98).
- On average, the CPR Doppler velocity differs by **(+0.26 ± 0.01) m/s** → Different fall velocities might be a **result of different sensitivity to different particle sizes.** However, CPR is expected to be more sensitive to larger particles with higher sedimentation velocity.
  → **further insights from the other underflights expected.**
- The **standard deviation** of this comparison is **0.66 m/s** (scaled MAD).

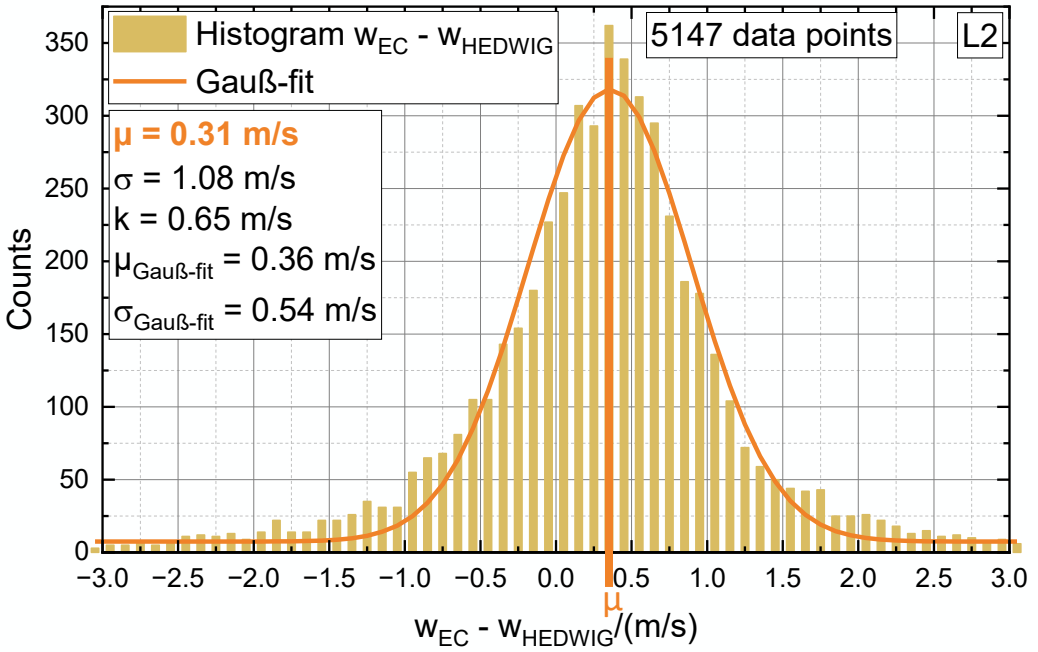
CPR averaged to HEDWIG grid (about half the resolution for this flight), and reflectivity threshold of -34 dBz used.

HEDWIG data: Nadir pointing observations
CPR L1 data: ECA_JXDA_CPR_NOM_1B_20260214T152722Z_20260214T170838Z_09751D.nc

Comparison of HEDWIG and CPR (L2)

- The analysis of **L2 data (JXCA)** differs only marginally, leading to an CPR difference of (+**0.31 ± 0.01**) **m/s** with respect to HEDWIG, and a standard deviation of **0.65 m/s** (scaled MAD).





HEDWIG data: Nadir pointing observations
CPR L1 data: ECA_JXDA_CPR_NOM_1B_20260214T152722Z_20260214T170838Z_09751D.nc
CPR L2 data: ECA_JXCA_CPR_CLP_2A_20260214T152722Z_20260214T172219Z_09751D.nc

Summary and conclusion

- DLR's novel wind lidar HEDWIG was deployed on the HALO aircraft for a first time during the NAWDIC campaign (Jan. to Feb. 2026, Shannon, Ireland).
- Ground returns are used to determine the **LOS accuracy and precision** to be ~**0.0 m/s** and **0.2 m/s**
  → well-suited for CPR Doppler velocity validation
- In total, **19 research flights** (~ 100000 km) were performed including **six dedicated EarthCARE underflights**.
- One underflight (RF16) analyzed so far (analysis of the other 5 underflights ongoing). Comparison to **L1 data** reveals:
  - A **mean difference** of (+**0.26 ± 0.01 m/s)** and a standard deviation (scaled-MAD) of **0.66 m/s**.
- Comparison to **L2 data** leads to similar results:
  - A **mean difference** of (+**0.31 ± 0.01 m/s)** and a standard deviation (scaled-MAD) of **0.65 m/s**.
- **This study indicates, that airborne wind lidar measurements are well-suited for validation of Doppler radar measurements from the EarthCARE CPR, but also from the upcoming WIVERN mission.**


HEDWIG
NAWDIC
2026
North Atlantic Waveguide, Dry Intrusion
and Downstream Impact Campaign