The DWD project for evaluating ground-based remote sensing systems for future network deployment

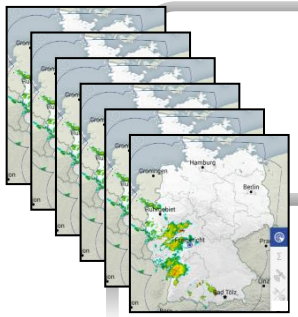
C. Knist, V. Lehmann and M. Kayser

Lindenberg Meteorological Observatory - Richard Aßmann Observatory
Deutscher Wetterdienst (DWD), Germany

Overarching goal

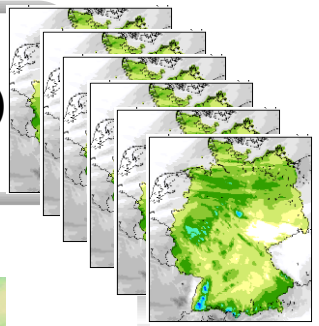
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Improving very short range convective-scale forecasting



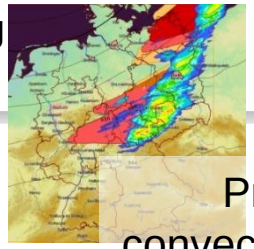
nowcasting
(0-2 h)
(NWC)

very-short range
forecasting (2-12 h)
(VSRF)



NWC+VSRF

SINFONY (0-12 h)
Seamless **IN**tegrated **FO**recasti**N**g s**Y**stem



Prediction of
convective phenomena
High Impact weather

→ requires more detailed and continuous boundary-layer profiles of **temperature**, **wind** and **humidity**

WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction, 2016

Qualitative extension of measurement network

Ground-based remote sensing








Which methods are fit for operational use?

What are the requirements for operational network deployment?

Requirements for operational network deployment

Theoretical and practical understanding

- sufficient knowledge of the „real-world“ measurement process
- well-defined measurand, known error statistic, well-tested algorithms (e.g. retrievals)

24/7 all weather operation

- fully automated operation
- rugged design

Availability

- commercially available
- sustainable operation over 10+ years (spare parts, software support)

Practicality

- radars: Available RF spectrum, compliance with regulations
- lidars: Eye-safety
- proven systems
- reliable and robust calibration methods (if necessary)

Usefulness

- „acceptable" cost-benefit relation, measurable positive impact in NWP

Instrument assessment for network deployment

Observing system testbeds

(1) Observatory Lindenberg:
reference station, initial tests

(2) Testbed site Aachen-Orsbach:
weather station**,** quasi-operational setting

Deployment

reliability

sustainability

operational costs

maintenance

system/data monitoring

…

Data Quality

(RMSE/Bias)

comparison with observations from other sources

comparison with NWP model output (O-B statistics)

…

NWP Impact

(NWC,SINFONY)

data integration to CIRRUS-DB: WMO-BUFR, netCDF (CF)

data assimilation impact

forecast skill

…

recommendations for network developing:
best methods, products, network design
…

DWD Working groups:
Observatory Lindenberg, Data Assimilation, Observing Networks/Data, Service and Logistics

Instruments for monitoring atmospheric profiles

Test and evaluation of following methods are in progress:

Technology	Variables measured
Water vapor DIAL (active optical)	water vapor mixing ratio
Microwave radiometer (passive radiowave)	brightness temperature, temperature, water vapor, liquid water path (LWP)
Raman lidar (active optical)	temperature, water vapor
Doppler lidar (active optical)	wind (u,v)
Cloud radar (active radiowave)	cloud properties (e.g. cloud base/top)

DIAL Differential Absorption Lidar (active, optical)

Wavelength: dual, submicron

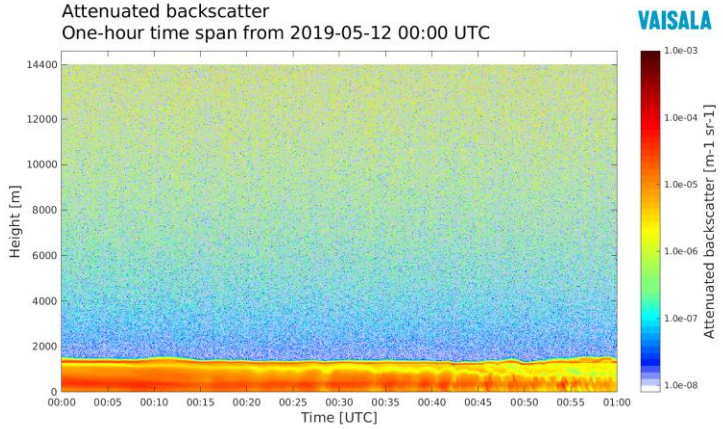
→ Water vapor mixing ratio profile
maximal height coverage: **3 km**
nominal vertical resolution: > **100 m**
Time resolution: **20 min**

Availability:
- beta-version operating since 22nd Jan 2019
- commercial version available soon

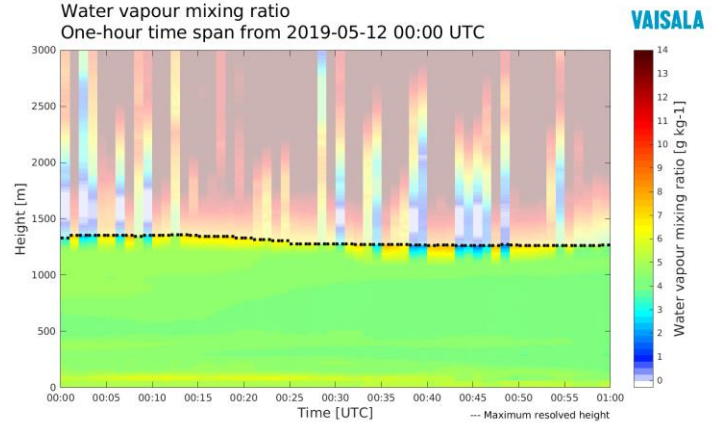
24/7 all weather operation:
- yes, limited availability in and above optically thick clouds
- rugged design

Practicality:
- easy to deploy, fully autonomous operation
- laser class 1M (eye safe)
- no calibration problem for DIAL method

Attenuated backscatter: dt=1 min, dh=1.4 m



Mixing ratio: dt=1 min (20-min averaging), dh=4.9 m



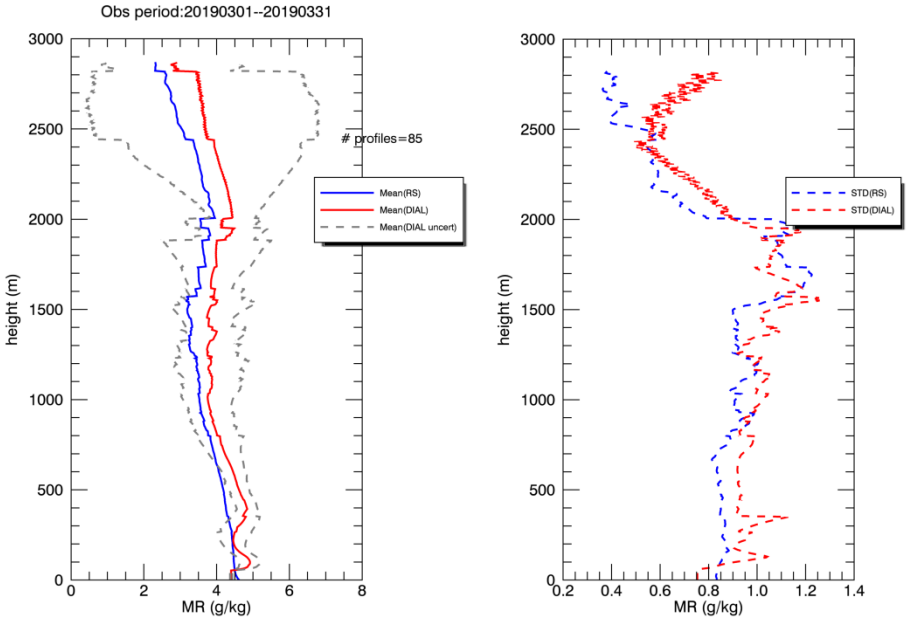
More details? Presentation **Session 3, R. LEHTINEN et al.**

DIAL Differential Absorption Lidar -- Evaluation

Performance aspects: e.g.

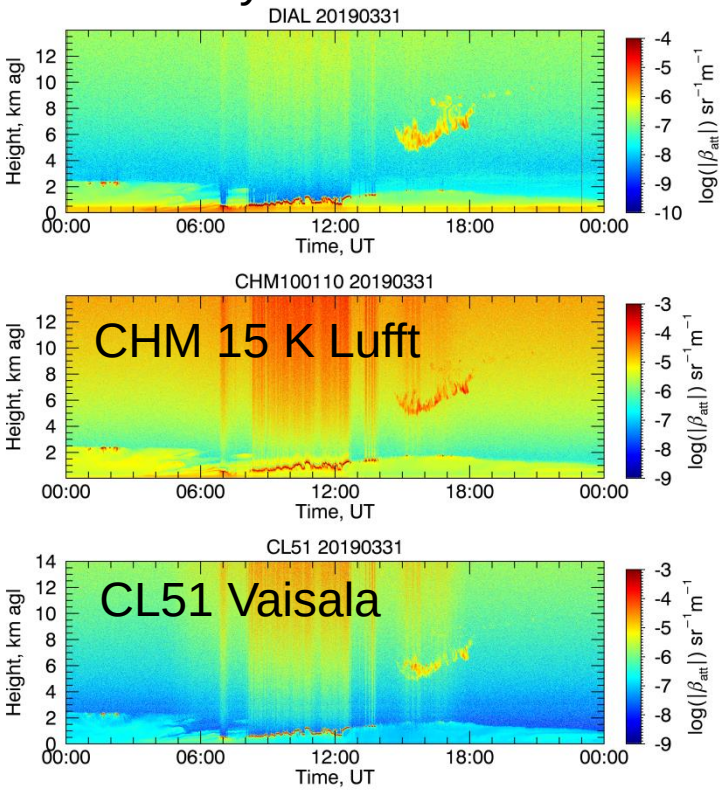
accuracy water vapor measurements:

- comparison with radiosonde ascents (4/day)
- comparison with Raman lidar RAMSES



attenuated backscatter profiles:

Preliminary results



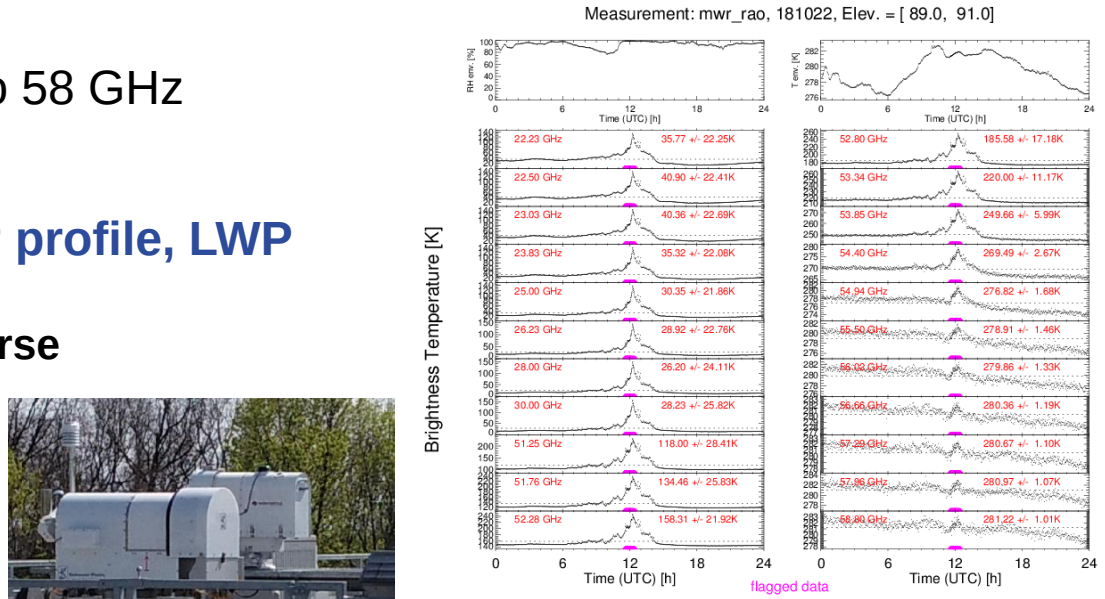
→ further evaluation: hardware/software reliability, robustness, operational sustainability, retrieval skill…

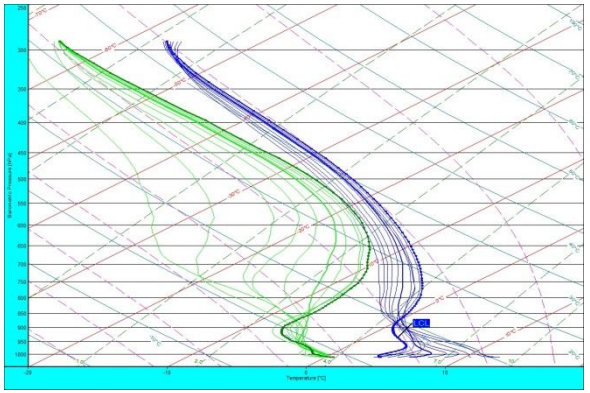
Microwave Radiometer (passive, radiowave)

14 to 22 channels:
k-band 22 to 31 GHz, v-band 51 to 58 GHz

→ Brightness temperatures (T_b)
→ Temperature and water vapor profile, LWP

maximal height coverage: **10 km**
nominal vertical resolution: **rather coarse**
time resolution: **< 1 min**





Availability:
- commercially available for decades

24/7 all weather operation:
- yes, except rain (wet radome)
- rugged design

Practicality:
- easy to deploy, fully autonomous operation
- regular calibration using LN2 – still issues !
- retrieval algorithm: Inverse problem (ill-posed)

Microwave Radiometer -- Evaluation

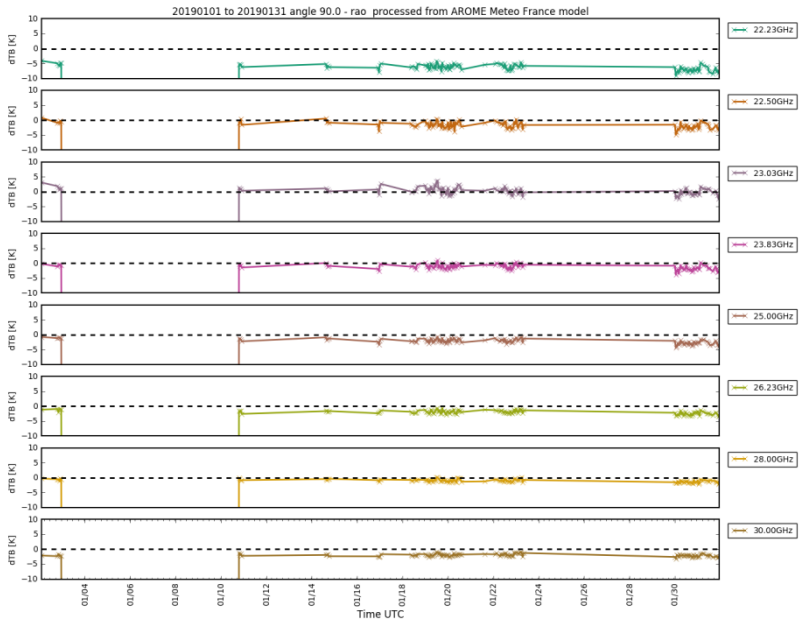
Performance aspects: e.g.

Stability of calibrations:

– Observation minus Background (O-B) statistics:

- TOPROF, P. Martinet: pauline.martinet@meteo.fr
- Background: Model:

AROME-France with 1h rapid update forward model:
RTTOV-ground-based (De Angelis et al. 2017, AMT)



Practicality of LN2 calibrations in a network?

Limitations, faulty calibration?

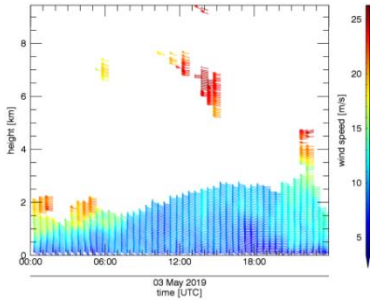
→ further evaluation:
hardware/software reliability, robustness, sustainability, retrieval skill…

O-B: Poster **Session 2, P. MARTINET et al.**

Doppler Lidar (active, optical)

Wavelength: 1,5 µm

→ Horizontal wind profile (u, v)
maximal height coverage: **10 km**
nominal vertical resolution: **20 - 50 m**
time resolution: **10 – 30 min**



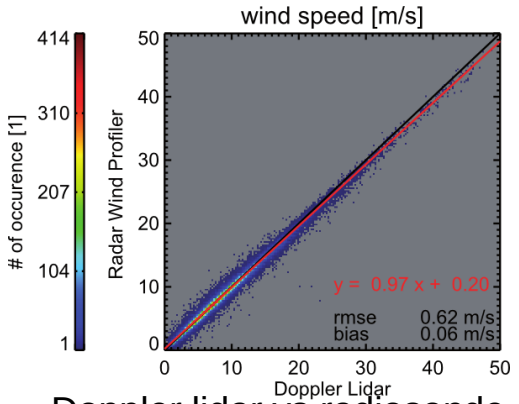
Availability:
- commercially available

24/7 all weather operation:
- yes, limited availability in and above thick clouds or particle-free atmosphere (no targets)
- rugged design

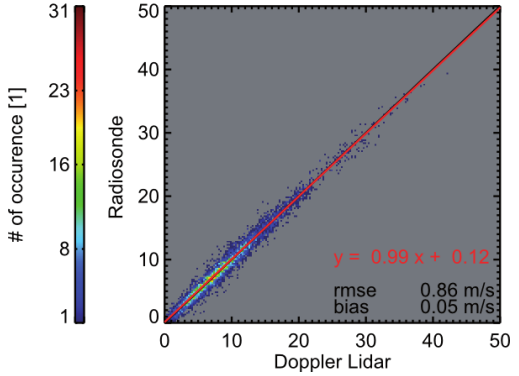
Practicality:
- easy to deploy, fully autonomous operation
- laser class 1M (eyesafe)
- no calibration problem

Performance aspects: e.g. accuracy wind speed:

Doppler lidar vs RWP (1-year)



Doppler lidar vs radiosonde



→ further evaluation: hardware/software reliability, robustness, sustainability, retrieval skill…

Päschke et al. [2015]

Summary and outlook

overarching goal is to improve nowcast and very-short range NWP

→ extension of the DWD observing network using ground-based remote sensing

2019
- instrument tests in **Lindenberg** (Doppler lidar, DIAL, MWRs)

2020
- testbed site preparation in **Aachen-Orsbach**: technical infrastructure

2022
- testbed deployment of Doppler lidar, MWR, DIAL and cloud radar in **Aachen-Orsbach** and **Lindenberg**

2024
- concept for network deployment of atmospheric profile sensors

2027
- testbed deployment of Raman lidar
- extended concept for future network deployment

Acknowledgements

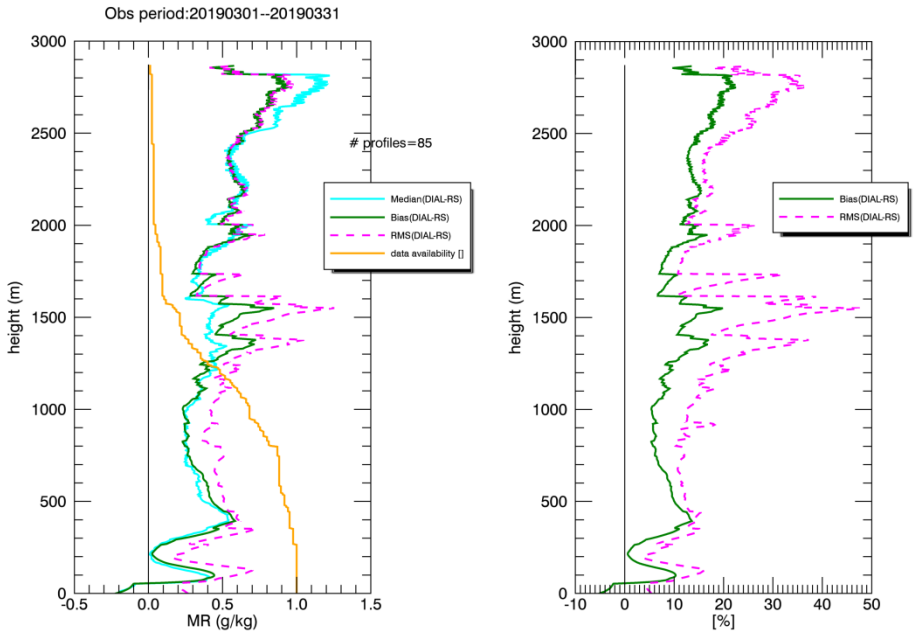
- Ronny Leinweber, Krispin Bisek - DWD Lindenberg
- Dr. Ulrich Blahak – DWD, Data Assimilation

DIAL Differential Absorption Lidar -- Evaluation

Performance aspects: e.g.

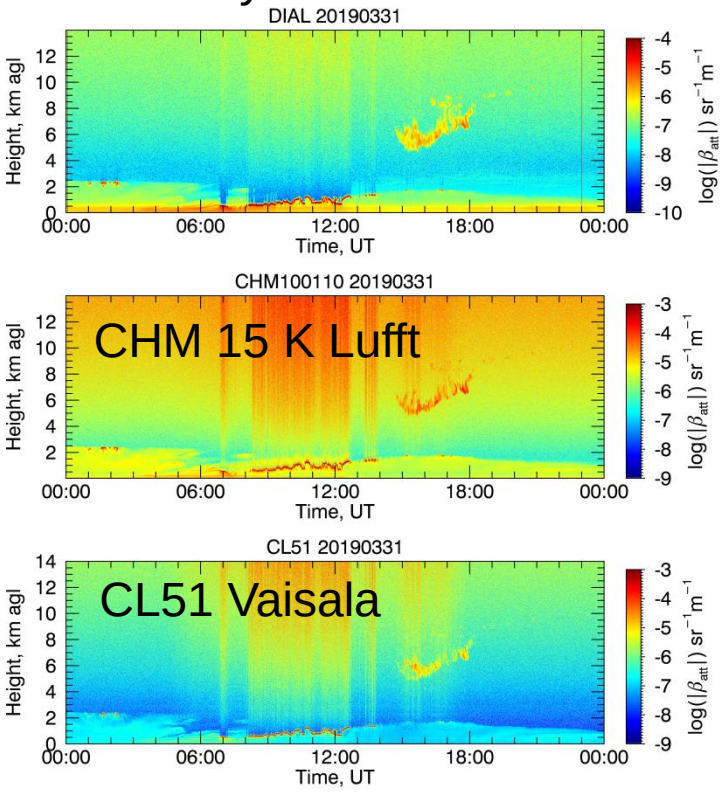
accuracy water vapor measurements:

- comparison with radiosonde ascents (4/day)
- comparison with Raman lidar RAMSES



attenuated backscatter profiles:

Preliminary results



→ further evaluation: hardware/software reliability, robustness, operational sustainability, retrieval skill…