Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

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Federal Ministry
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by the German Bundestag



Regulation for Wind Energy

Compatibility of Doppler VHF omnidirectional radio range (DVOR) and wind turbines

Metrology for Energy Regulation - Open Public Consultation

Dr. Thorsten Schrader

June 24, 2024 (Online)

Agenda

- Background
- Modernized evaluation method for interaction DVOR / wind turbines – Reduced costs
- Validation measurements and simulations
- Reduced Costs of Regulation - Reduction of the building restricted area for DVOR
- Summary

Background: Transition towards Renewable Energy

- Many new construction projects of wind turbines in Germany
- Air Navigation Service Provider (ANSP) (Deutsche Flugsicherung DFS GmbH)

  must ensure availability and safe functioning of its systems and services

  such as terrestrial navigation services and Radar systems.





- ICAO EUR DOC 015 recommends building restricted area within radius of 15 km (check for wind turbines),

  but: tall buildings are not considered at all after a distance of 3 km. contradiction

- Supreme court decision in the Federal Administrative Court:

  Old method is valid as long as it has not been proven wrong or new scientific findings are available.

Research focus arcass: On-site Measurement Technology for Navigation and Radar Systems

Non-directional beacon (NDB) and direction finder (ADF)	500 kHz
Instrument landing system Localizer (ILS-LLZ)	110 MHz
(CVOR, DVOR)	113 MHz
Maritime Radio Service (external)	160 MHz
Instrument landing system Glide Path (ILS-GP)	330 MHz
DWD UHF Windprofiler	482 MHz
Airport surveillance radar (ASR)	2.7 GHz
Air defense radar (LVR)	some GHz
DWD precipitation radar (C-Band)	5.6 GHz
X-Band naval radar (external)	9.375 GHz

arcass: Advanced remote-controlled airborne sensor systems

Bearing Angle Error of Doppler-VOR (DVOR)

Quelle: LUH





Magnetic North

AM reference signal

Radial

FM course signal

$+\Delta\varphi_{WT}$



$$\varphi_{bearing} \cong \left(\varphi_{AM} - \varphi_{FM}\right) + \Delta\varphi_{WT}$$

Bearing angle error

$$\Delta\varphi_{WT} \cong \left(\Delta\varphi_{AM} + \Delta\varphi_{FM}\right)$$

Evaluation of Interaction of WT with DVOR Signals → Bearing Angle Error

Old

$$\Delta\varphi = \Delta\varphi_{Anlage} + \sqrt{\Delta\varphi_{FI}{}^2 + \Delta\varphi_{WEA}{}^2}$$

$$3° = 2° + 1°$$

Radius of building restricted area around DVOR was 15 km

→ area 707 km²

Now

Max. Angular error according to ICAO
System internal error
Preload from cross bear.
Forecast new WT

$$\Delta\varphi_{ICAO} = \Delta\varphi_{Anlage,\ red} + \sqrt{\Delta\varphi_{DK}{}^2 + \Delta\varphi_{WEA\text{-}neu}{}^2}$$

$$3.5° = 1.5° + \sqrt{(1°)^2 + (1.7°)^2}$$

By end of 2022: Building restricted area around DVOR was reviewed again and often reduced to 7 km radius

→ area 154 km²

Improved data through advanced technology from WERAN projects.
Allow for more opportunities for wind energy without compromising flight safety.

Signal Integrity Assessment of DVOR

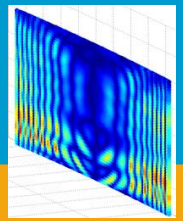
project WERAN

1 km

On-Site-Measurements (time stamp, locus, data)

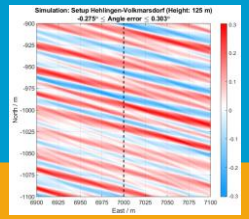


Full-wave simulation in time- and frequency domain



project WERAN plus

New forecast tools: DFSM AFIS



100 km

Converting drone VTOL



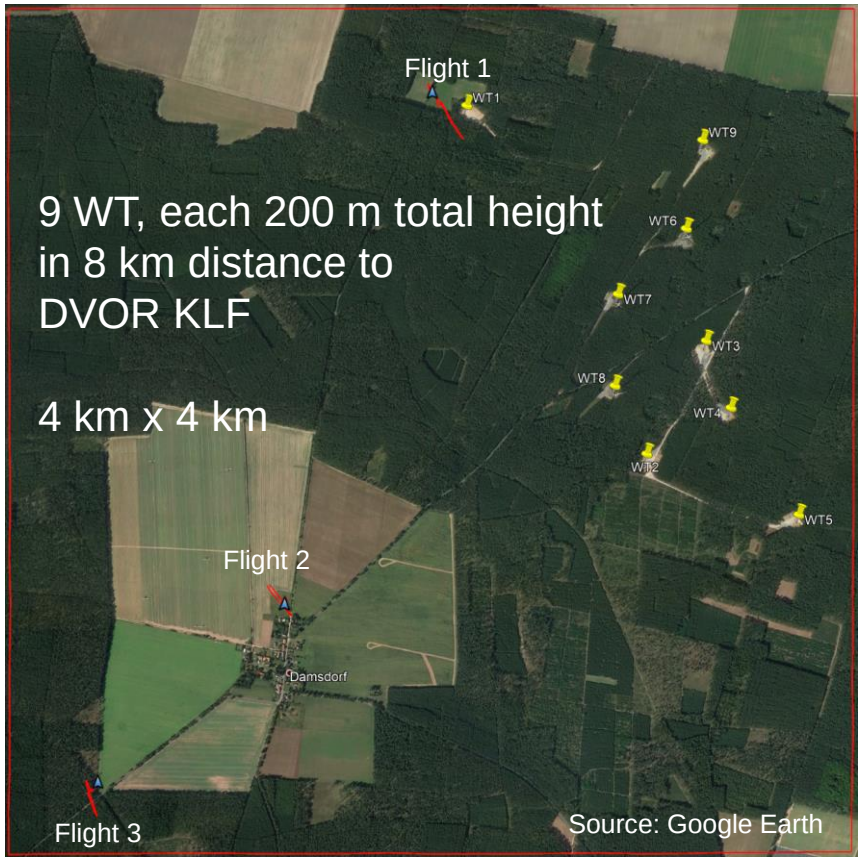
1000 km

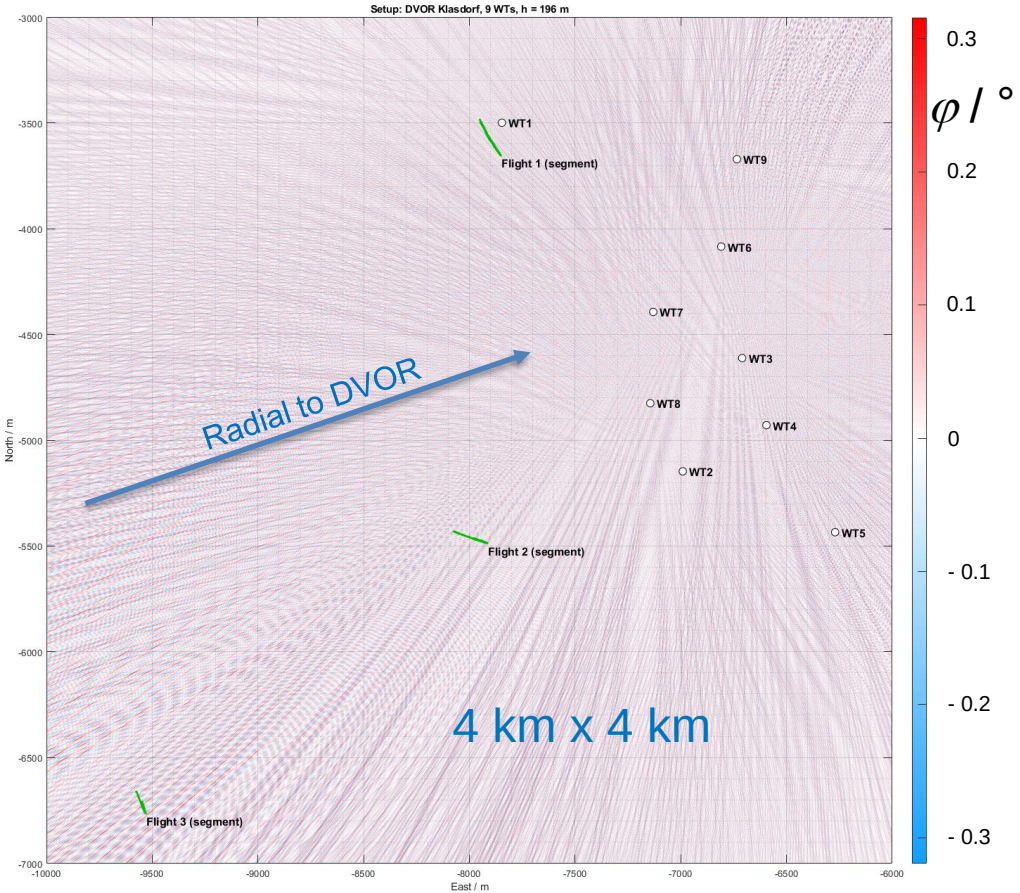
Research aircraft Jade One



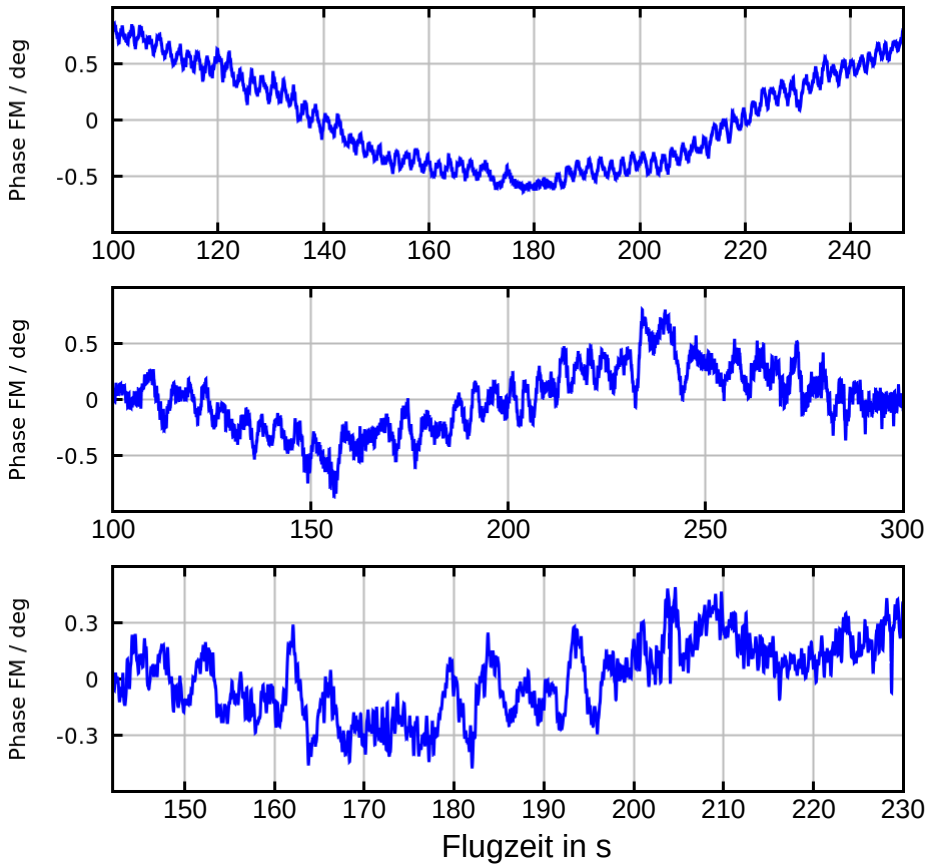
Validation: Compare all against each other, independent methods

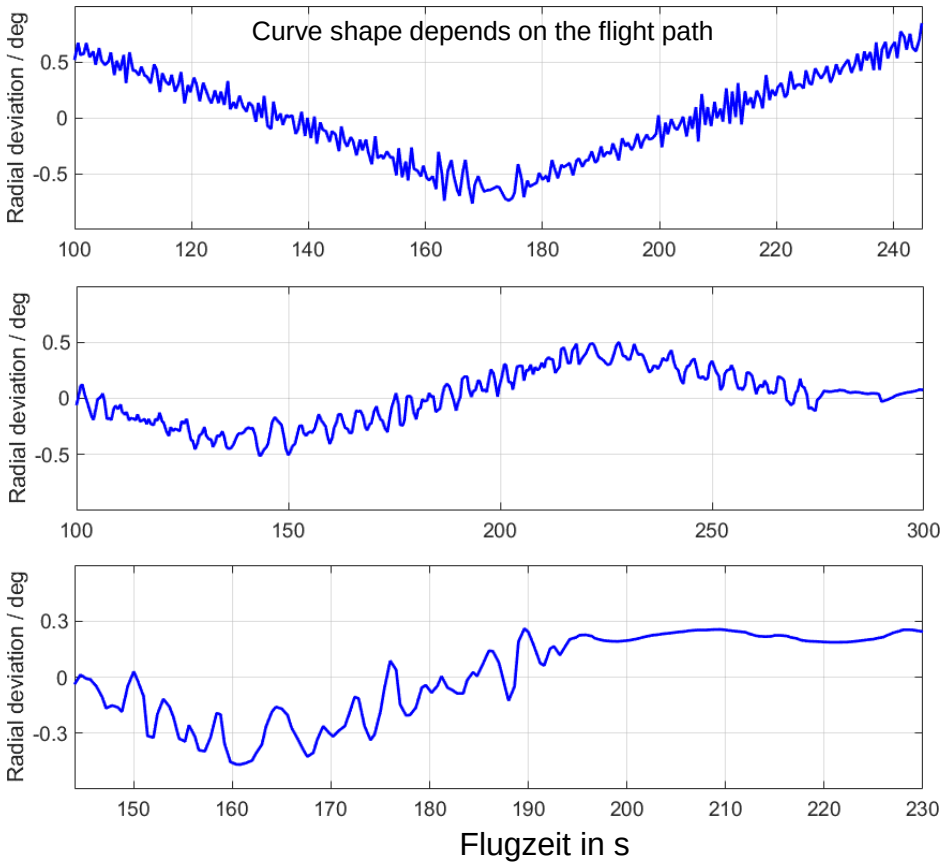
Real Wind Farm as Test Scenario





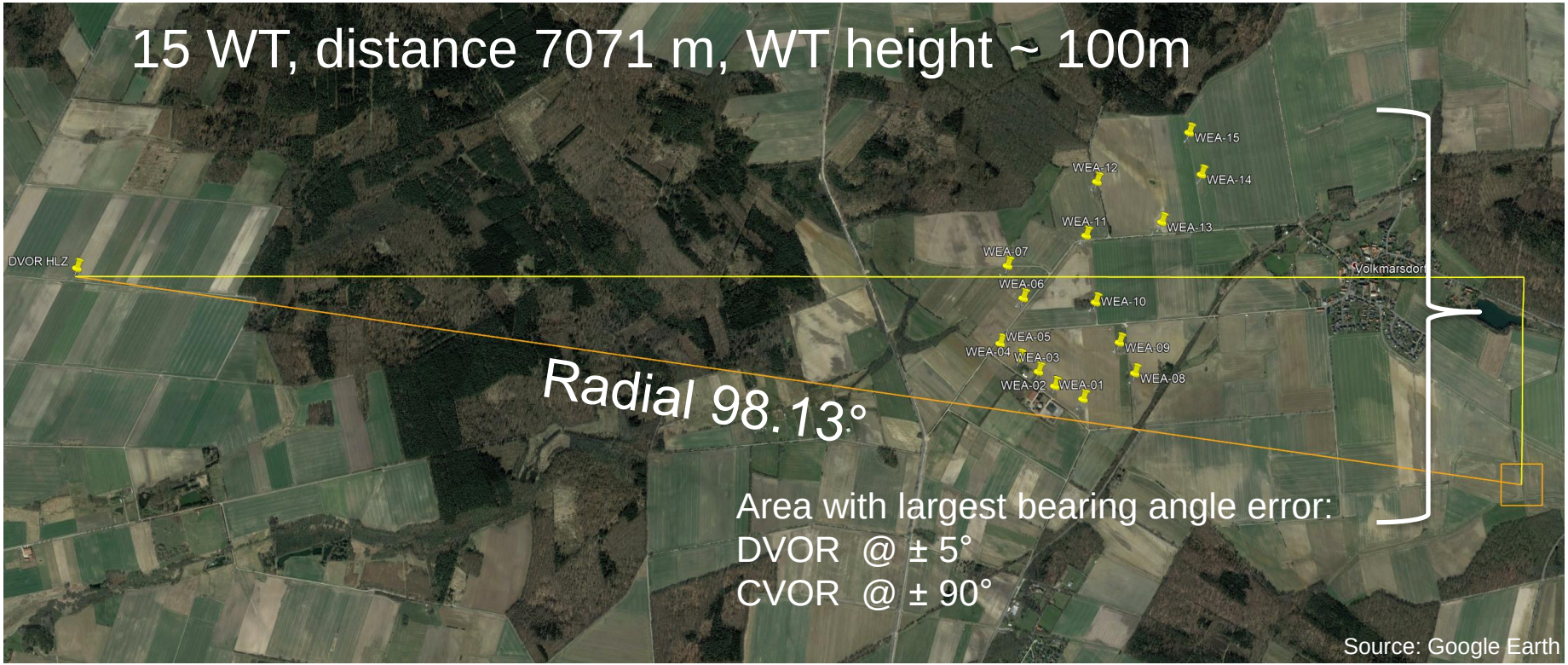
Comparison of On-site Measurement and Forecast





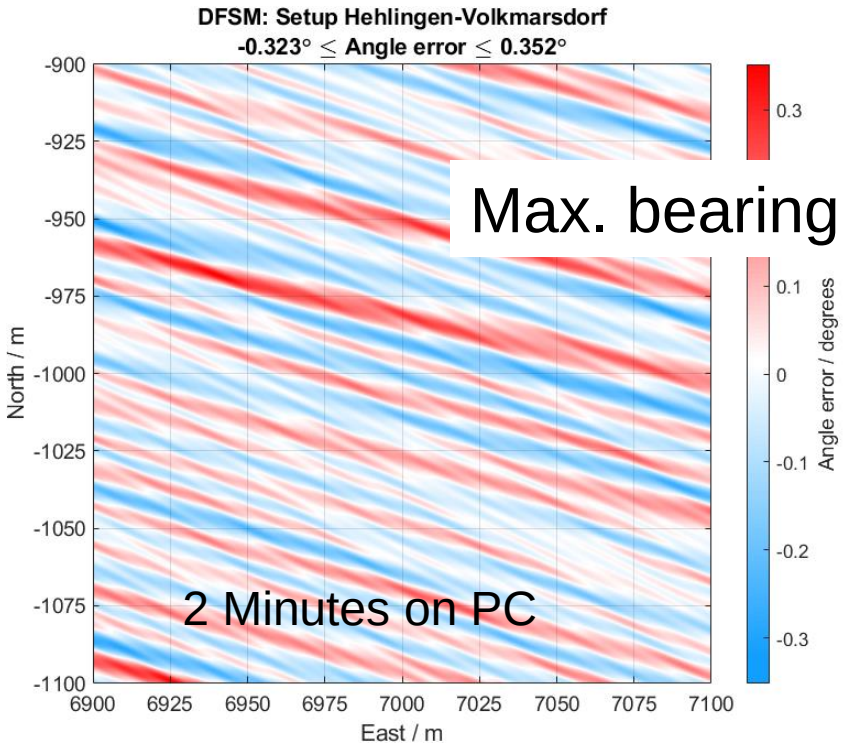
Validation of Forecast DVOR Hehlingen

Setup

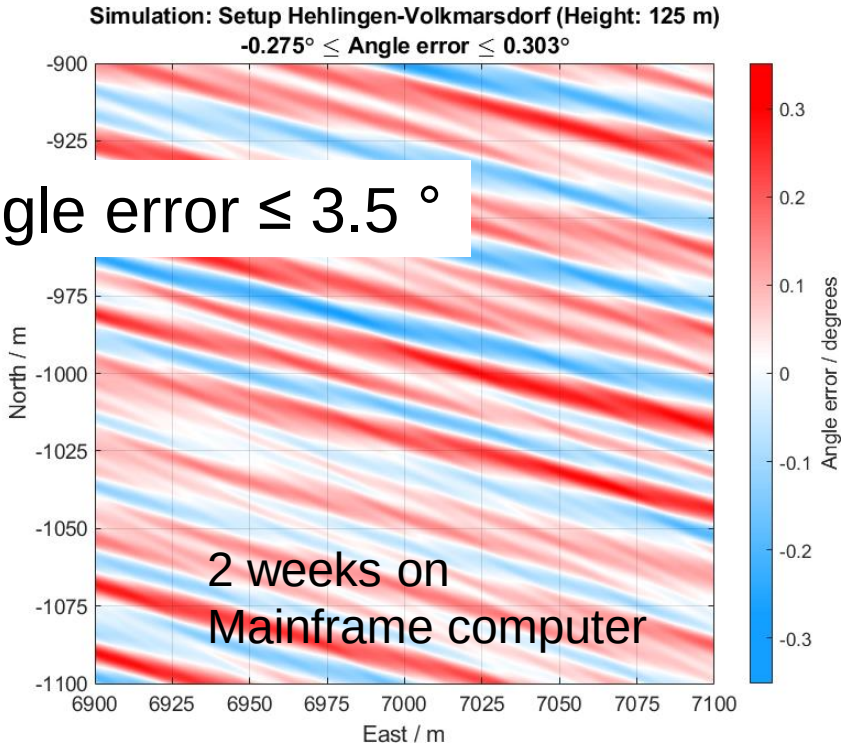


Validation of Forecast DVOR Hehlingen

Comparison: DFSM forecast / full wave EM simulation (Feko + own math).

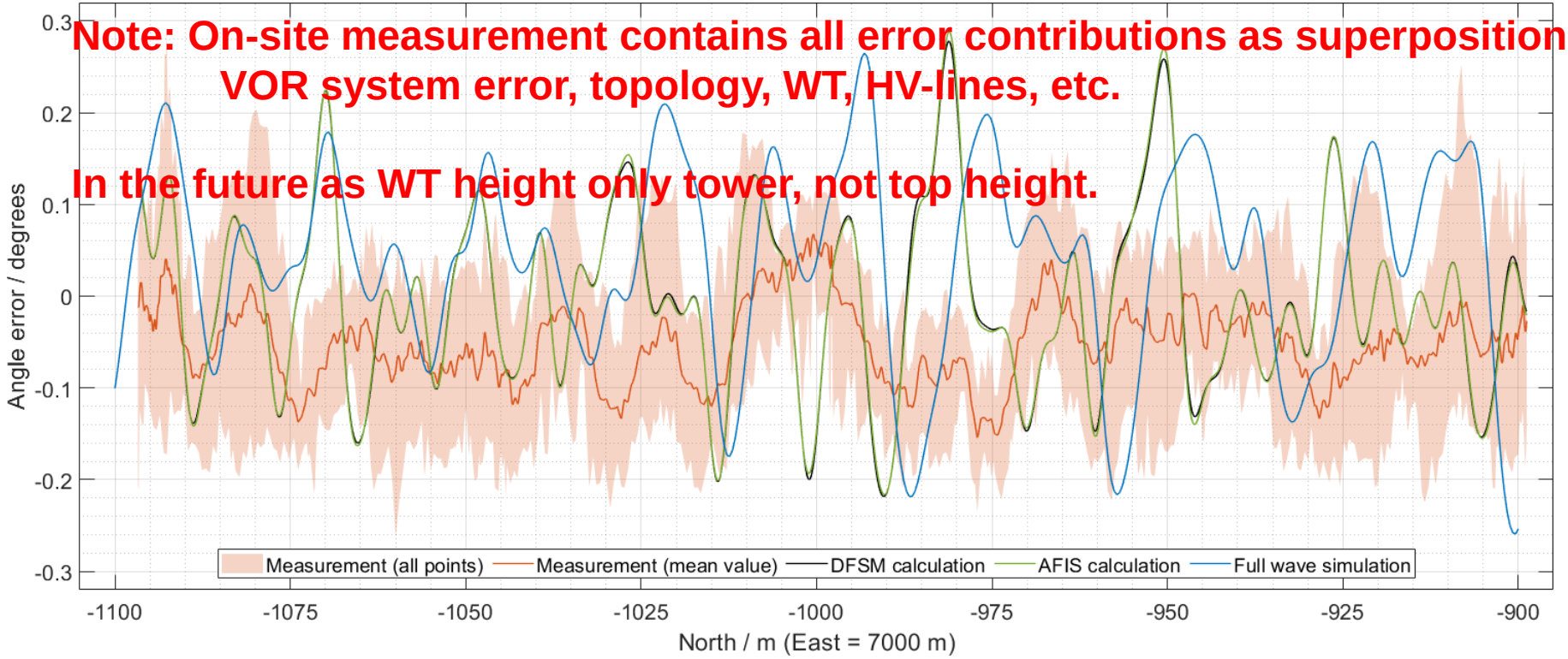


Max. bearing angle error ≤ 3.5 °



Validation of Forecast DVOR Hehlingen

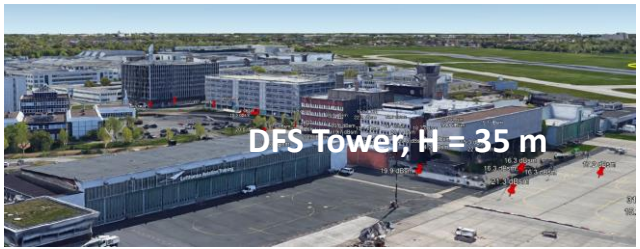
Comparison: DFSM / AFIS / EM Fullwave Simulation / on-site-meas

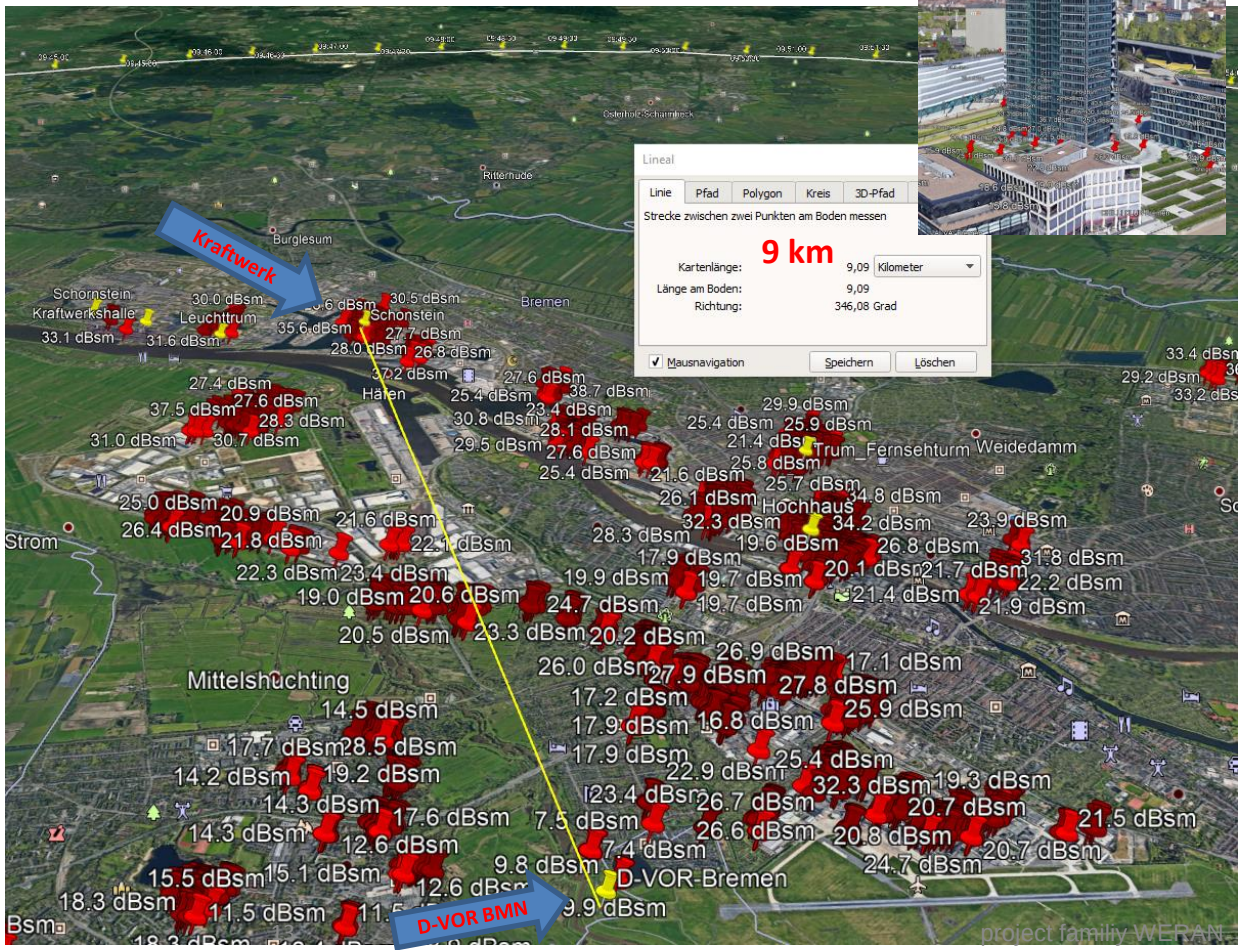


DVOR Doppler Cross Bearing

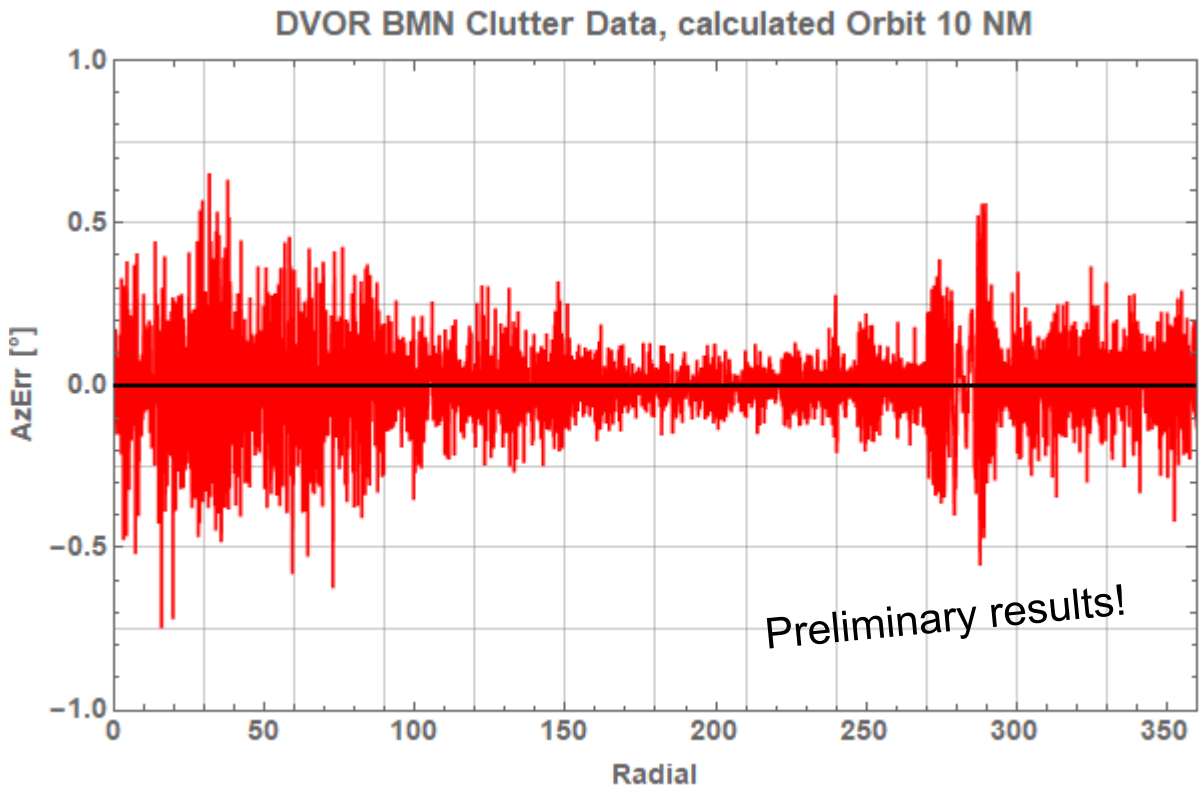
- Flight track
- DVOR Bremen
- Clutter data map (place and disturbance effect): Airport, power plant, high-rise buildings, industrial plants, ...
- Relative disturbances

- Inherent validation by comparison of the location in maps





From Clutter Data Map to Preload of AzError



More areas for onshore wind energy: Air traffic control reduces protection areas of its Doppler omnidirectional radio ranges DVOR

New calculation formula makes significant contribution to energy transition
Joint press release by DFS, BAF, BMDV, BMWK, PTB
01.08.2022

As of 1 August 2022, DFS Deutsche Flugsicherung GmbH will reduce the size of its building restricted area around Doppler omnidirectional radio ranges (DVOR). This creates further potential for more areas for wind turbines in Germany and makes a significant contribution to the energy transition. This was made possible by the intensive cooperation between BMDV, BMWK, BAF, PTB and DFS.



https://doi.org/10.7795/120.20220401

Summary

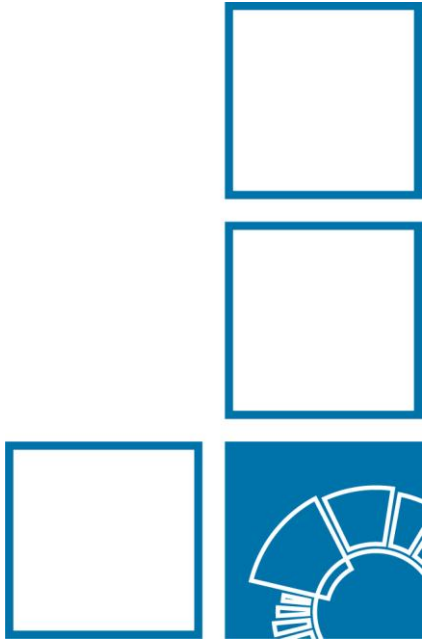
- Completely modernized assessment methodology DVOR and CVOR / WT interaction
- On-site measurements (with drones / research aircraft) and full wi
- Simple forecasting software, e
- Now: Doppler cross bearing pr ers, flight safety greatly improved
- ***Building restricted area around DVOR could be reduced from 15 km to 7 km***

Local communities, planning offices, and approval authorities use identical data.

Due to better insight at system level and scientific data:

Metrology greatly helped to reduce cost of regulation.

Free 1100 WT (2023: 28700 WT total), 5 GW electric power, 4 Billion € investment



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