
# Five Years after: Insights from the Field Experiment on Sub-Mesoscale Spatio-Temporal Variability in Lindenberg

**Bastian Kirsch (1)*, Maike Ahlgrimm (2), Felix Ament (1), Frank Beyrich (3), Carola Detring (3), Cathy Hohenegger (4), Daniel Klocke (4), Ronny Leinweber (3), Ulrich Löhnert (5), Annika Obermann-Hellhund (2), Eileen Päschke (3), Andreas Platis (6), Anja Rapmund (1), Henning Rust (7), Mirjana Sakradzija (8), Linda Schlemmer (2), Julian Steinheuer (5)**

Hans-Ertel-Zentrum für Wetterforschung (HErZ) sowie (1) Universität Hamburg, (2) Deutscher Wetterdienst, Offenbach am Main, (3) Deutscher Wetterdienst, Meteorologisches Observatorium Lindenberg, (4) Max Planck Institut für Meteorologie, Hamburg, (5) Universität Bonn / Universität zu Köln, (6) Eberhard Karls Universität Tübingen (7) Freie Universität Berlin, (8) Ludwig Maximilians Universität München

*now at Karlsruhe Institute of Technology

# Five Years after: Insights from the Field Experiment on Sub-Mesoscale Spatio-Temporal Variability in Lindenberg

1. FESSTVaL: Idea and Concept
2. Measurements and Data
3. Analysis of Measurements
4. Modelling
5. Perspectives

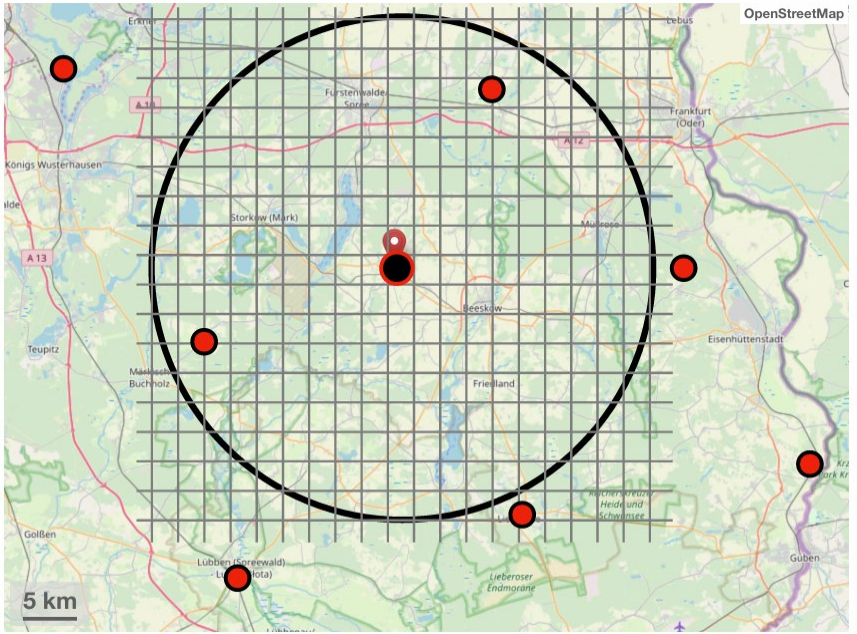
# 1. FESSTVaL: Idea and Concept



## FESSTVaL …

**… a campaign to study sub-mesoscale phenomena** (500 m – 5 km)

- ➔ NWP models (Δx ~ 2 km) explicitly simulate deep convection, but cannot resolve **small-scale phenomena** (shallow convection, turbulence)
- ➔ modern Large-Eddy Simulation (LES) models have a much finer grid (grid spacing < 100 m), but rely on **parametrizations** (turbulence, micro physics)
- → **Existing observing networks are too coarse to validate model simulations at the micro-α / meso- γ scale**




FESSTVaL study area around Lindenberg Meteorological Observatory (black dot) with stations of the operational DWD network (red dots) and the ICON-D2 grid

# 1. FESSTVaL: Idea and Concept



Three topics related to sub-mesoscale variability:

1. **Boundary layer structures**
2. **Cold pools**
3. **Wind gusts**

Plus a new methodical approach:

4. **Citizen science**

Supplemented by:

5. **Modelling**

**Goals of the field campaign:**

→ Improved understanding of sub-mesoscale processes and structures

→ Validation of convection-permitting NWP models

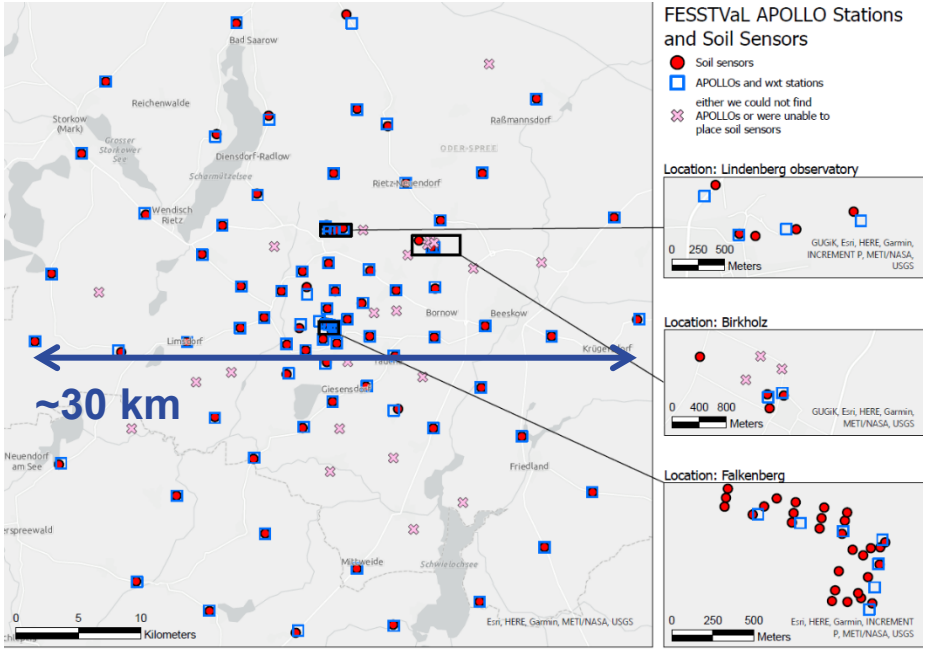
→ Tests of new instruments and measurement strategies for future observing networks

**The idea and concept of FESSTVaL was presented at the 1st Workshop on Observational Campaigns for Better Weather Forecasts at ECMWF in June 2019**



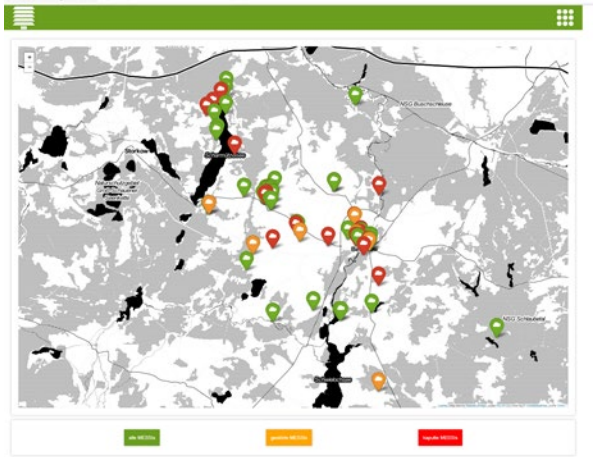
Overview Paper: Hohenegger et al. (2023), BAMS,
DOI: 10.1175/BAMS-D-21-0330.1

## Networks and Supersites (Jun–Aug 2021)




*Station network and supersites Falkenberg, Lindenberg, Birkholz*

Lindenberg Observatory (MOL-RAO)

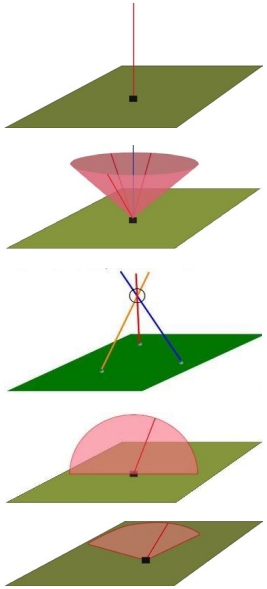


*MESSI network*

## Boundary layer structures

- Doppler-LiDARs in different scan modes and at different sites
- Coupling Doppler-Lidar – DIAL – Raman-Lidar
- In-situ turbulence profiles (99-m tower Falkenberg)
- Near-surface turbulent fluxes from energy-budget stations and scintillometry
- Airborne ABL measurements with UAS

Lidar scan patterns:



Vertical stare

Velocity azimuth display (VAD)

Virtual tower

Range-height indicator (RHI)

Plan-position indicator (PPI)

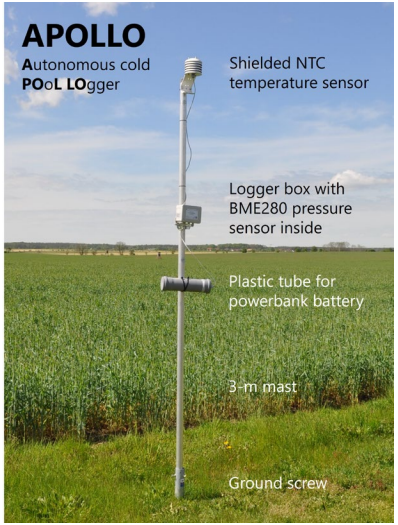
## Cold pools

- Three profiling stations
- X-band rain radar
- radiosoundings
- Dense network of simple autonomous measurement stations
  - 80 non-commercial „APOLLO“ stations
  - 19 WXT weather stations
  - 80 soil moisture measurement points

1x

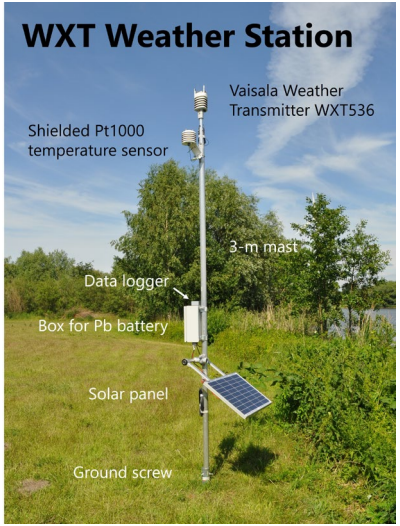

*RR within 20-km range @ 30 s*

80 x




*T, p @ 1 s*

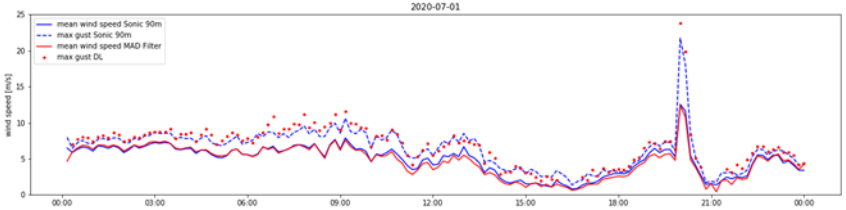
19 x

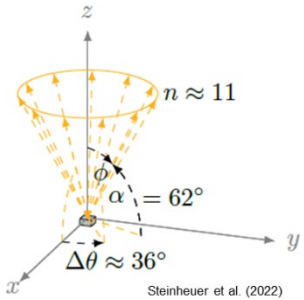



*T, p, RH, wind, RR @ 10 s*

## Wind gusts

- Doppler-LiDAR in special scan modes at three different sites
- Wind- and turbulence profile measurements at the Falkenberg 99-m tower

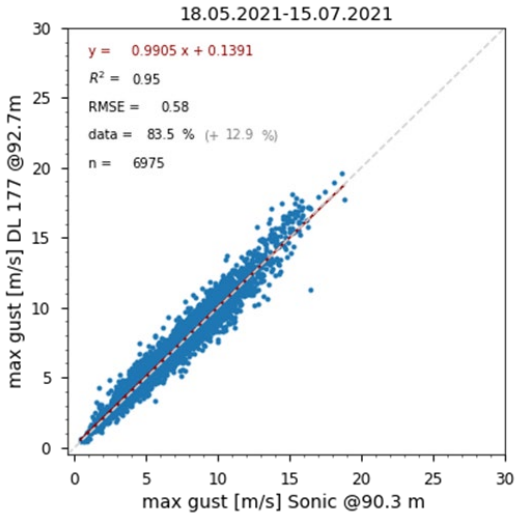



Steinheuer et al. (2022)

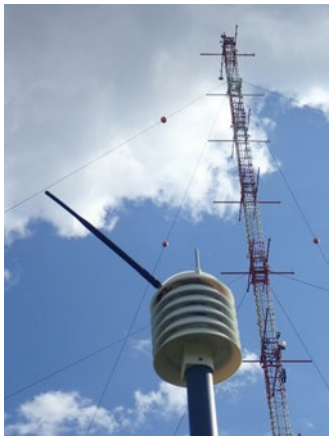
3.000 pulses/ray

~3.4 s scan duration



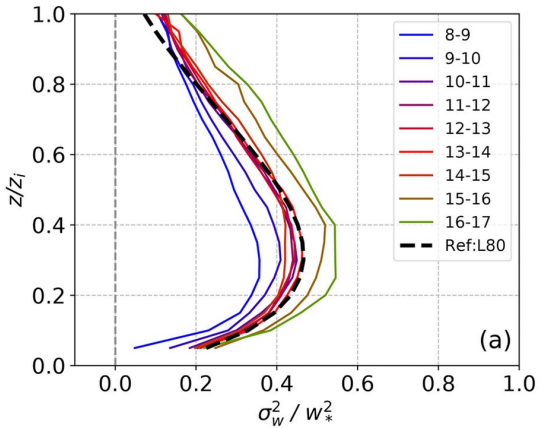
## Citizen Science

- ➔ Distribution of ~ 70 Arduino-based meteorological data loggers (so-called „MESSI“) to local citizens in Lindenberg and surroundings
- ➔ workshops / web tutorials for the assembly of the instruments and for project information
- ➔ 3D-printed housings (of special interest for pupils)
- ➔ data transmission to central servers via LoRaWAN (range < 5 km)

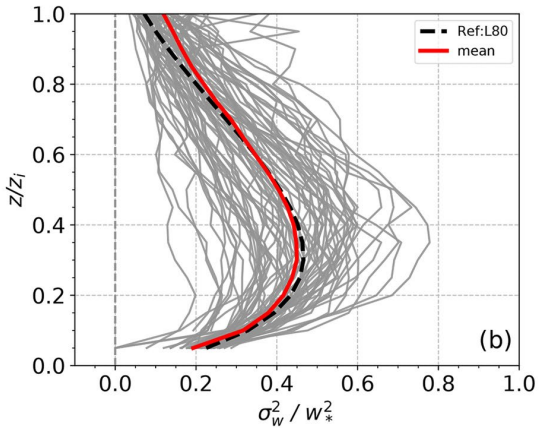


# Boundary Layer Structure

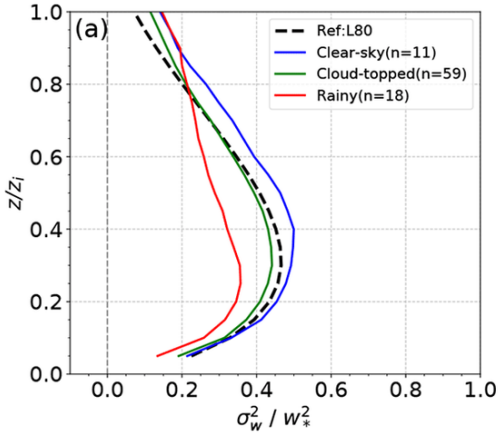
**Scaled vertical velocity variance from Doppler wind lidars dependent on meteorological conditions**
Dewani et al. (ACP, 2023 - https://doi.org/10.5194/acp-23-4045-2023)




*Diurnal Variation*



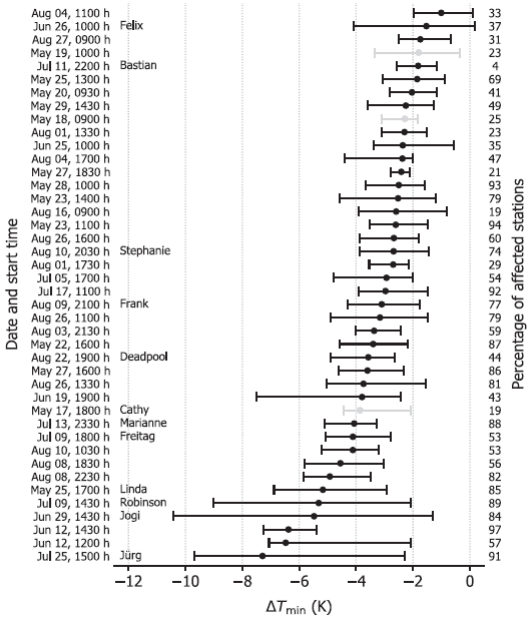

*All days*



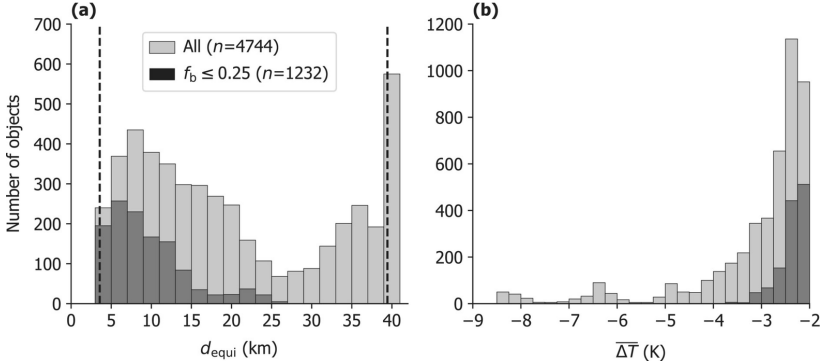

*Different sky conditions*

## Cold Pools

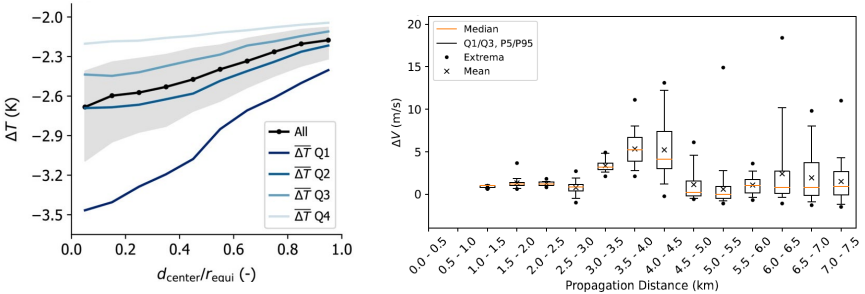
42 cold pool events observed during 113 days




*Diameter and mean ΔT of all cold pool objects*

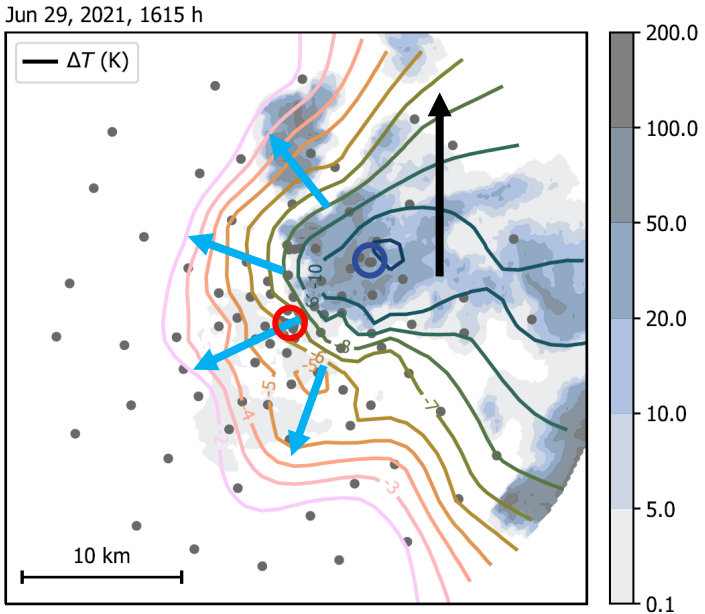



*ΔT and wind gusts dependent on distance to cold pool centre*

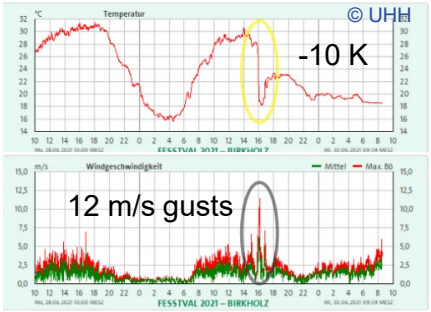


## Cold Pools

### Golden case „Jogi“ (29 June 2021)

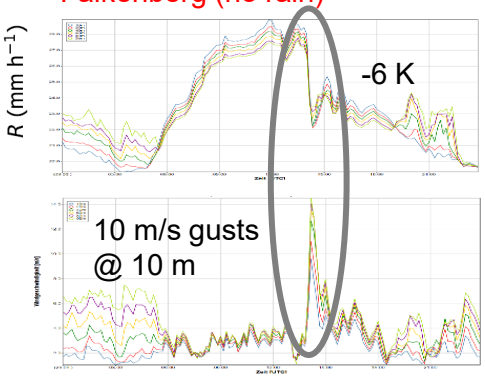



Birkholz (heavy rain)

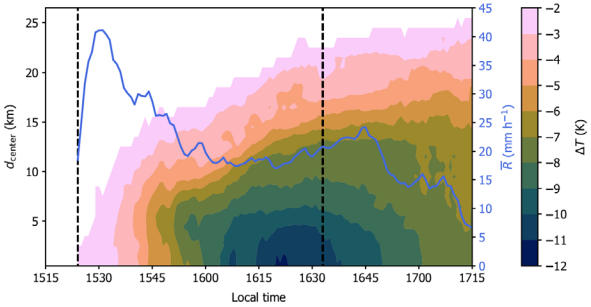



© W. Mol (Wageningen UR)

Falkenberg (no rain)




Evolution of radial ΔT





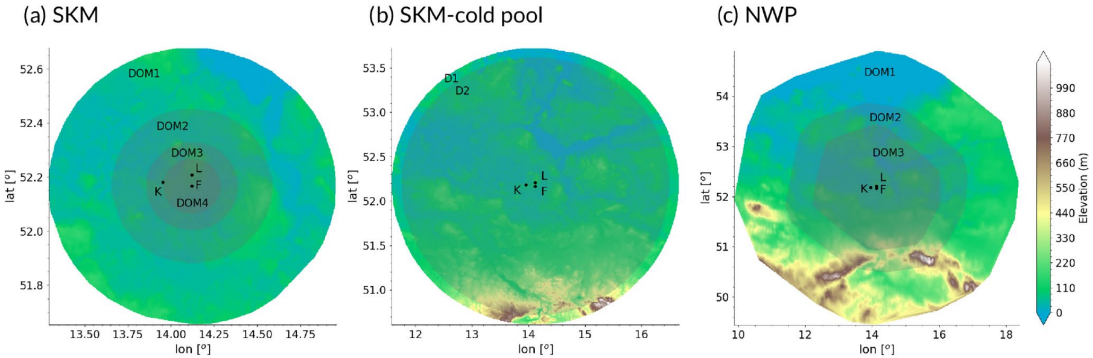

Kirsch et al. (2023), QJRMS, DOI: 10.1002/qj.4626

# 4. Modelling



- FESSTVaL campaign observations provide a great opportunity for model evaluation.
- First modelling paper published, illustrating some examples of topics that can be explored with FESSTVaL dataset
- Exploring ICON at km-scale and sub-km-scale resolutions, with MicroHH as an LES reference

ICON sub-km model (SKM) domains




ΔX = 626 to 78 m

ΔX = 525 to 260 m

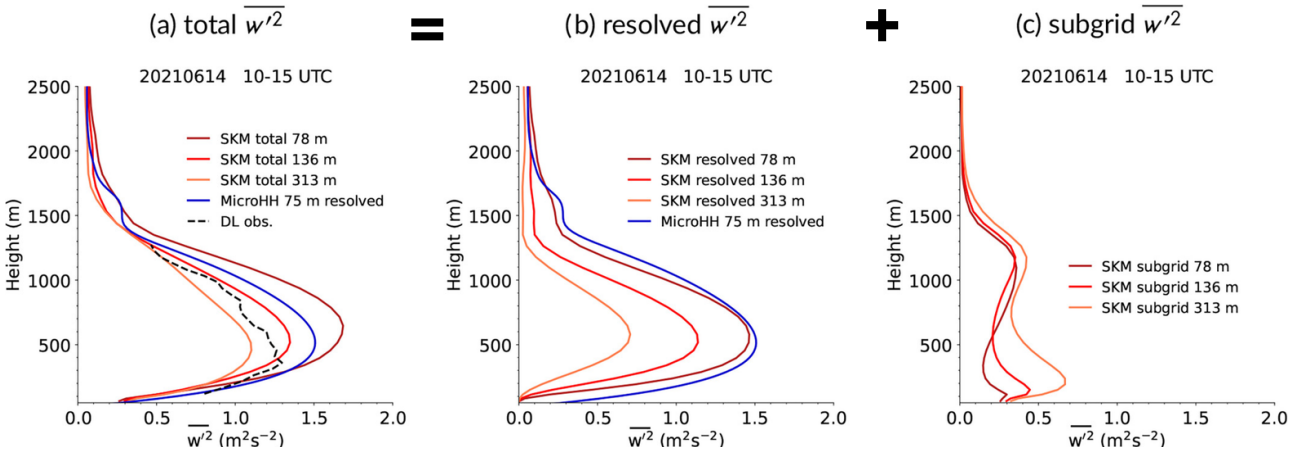
ΔX = 5000 to 1200 m

Sakradzija et al. (2026), QJRMS, DOI: 10.1002/qj.70037

# Model evaluation, topic 1: Turbulent transport in the ABL at gray-zone resolutions

## Partitioning of vertical velocity variance between resolved vs. subgrid-scale contributions across sub-km-resolutions

Use of Doppler lidar retrievals for the evaluation of turbulence schemes



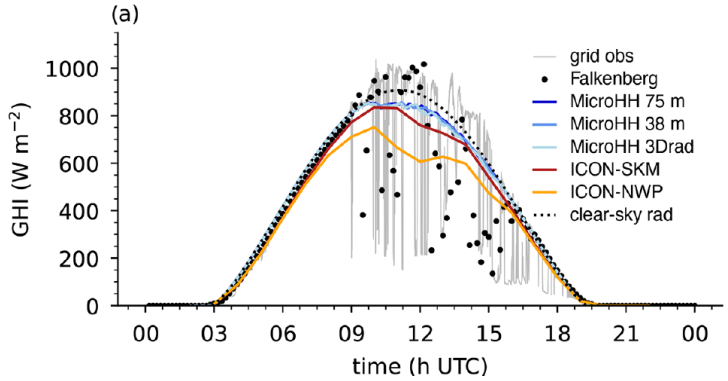

Total VVV in ICON is not scale-invariant!

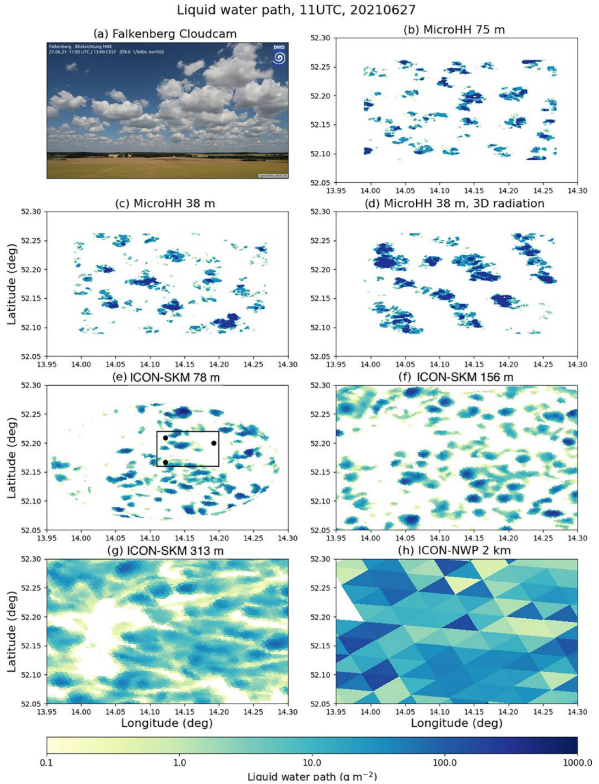
Re-partitioning between resolved and parametrized contributions

## Model evaluation, topic 2: Clouds and Radiation

Study the effect of **cloud shadows** and **3D effects** in cumulus cloud fields using **distributed network** of SW sensors

Global Horizontal Irradiance (GHI)






Sakradzija et al. (2026), QJRMS, DOI: 10.1002/qj.70037

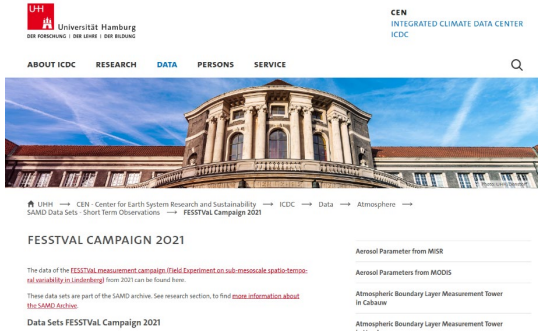
# 5. Perspectives

→ FESSTVaL provides a unique data set on the temporal and spatial structure of the ABL, cold pools, and wind gusts at the sub-mesoscale.

→ First modelling studies have demonstrated versatility of data set for validation of many processes (turbulence/clouds/radiation/cold pools)

→ All data are available via the Integrated Climate Data Centre (ICDC) @ University of Hamburg

https://www.cen.uni-hamburg.de/en/icdc/data/atmosphere/samd-st-datasets/samd-st-fesstval.html



# Follow-up field experiment by HErZ: VITAL-II (June – August 2026)

# Thank you for your attention!