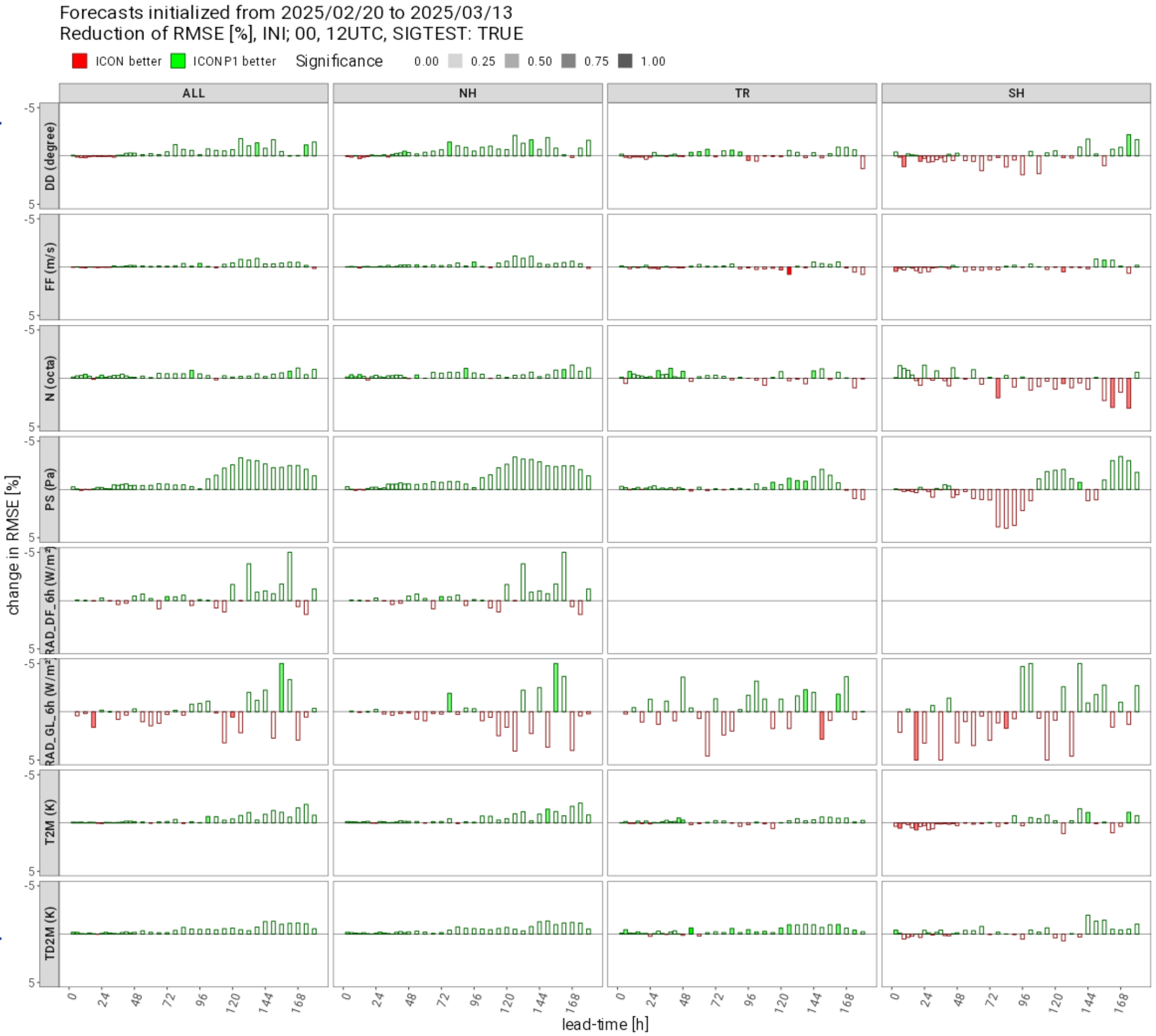
Making use of supplementary observations for the development of physical parameterizations

Linda Schlemmer, Maike Ahlgrimm , Sophie Löbel, Alberto de Lozar, Daniela Littmann

Standard Verification

- Verification against observations in standardised way
- Very useful and very efficient
- Sometimes it can be hard to learn something about individual processes and thus parametrizations

→ Need additional (auxiliary) observations



Outline

- Ground-based remote sensing
  - FESSTVaL
  - TEAMx - PIANO
- Crowd-sourced observations
- Satellite-based evaluations

NWP Model-Chain 03/2025 – the ICON family

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

ICON
(Icosahedral Nonhydrostatic) Model

Global (coarse) and
regional (high-resolution) applications

C2SM Center for Climate Systems Modeling

DKRZ

CONSORTIUM FOR SMALL SCALE MODELING COSMO

Max-Planck-Institut für Meteorologie

KIT Karlsruhe Institute of Technology

Outline

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  - FESSTVaL
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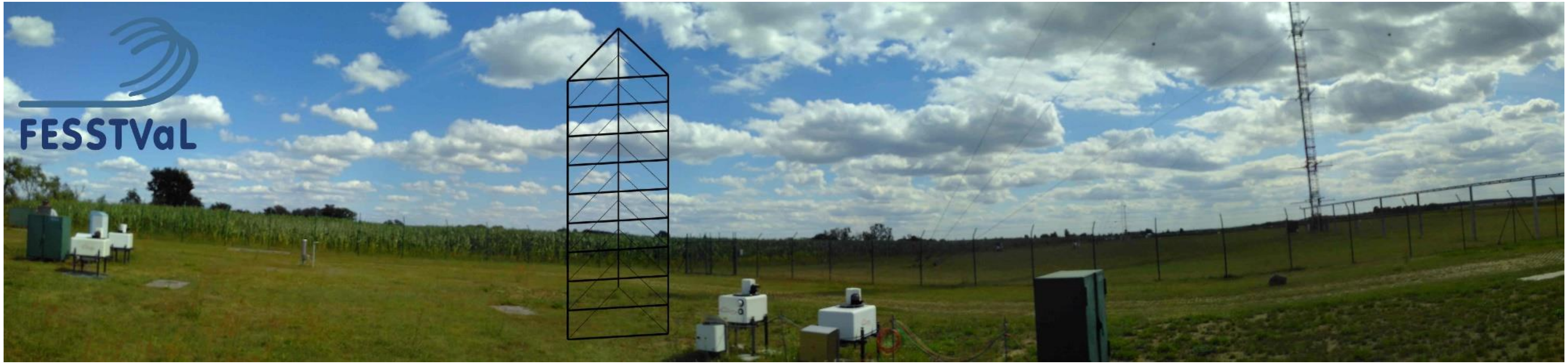

Cathy Hohenegger, Daniel Klocke, Felix Ament, Bastian Kirsch, Sarah Wiesner, Finn Burgemeister, Marco Clemens, Ingo Lange, Ulrich Loehnert, Julian Steinheuer, Tobias Böck, Stephanie Fiedler, Frank.Beyrich, Carola Detring, Ronny Leinweber, Matthieu Masbou, Linda Schlemmer, Volker Lehmann, Igor Kroener, Eileen Paeschke, Christine Knist, Henning Rust, Martin Göber, Mirjana Sakradzija, Noviana Dewani, Ivan Bastak Duran, Jürg Schmidli, Andreas Platis, Jakob Boventer, Jens Bange, Chiel van Heerwaarden, Wouter Mol, Nima Shokri, Hannes Nevermann, Kevin Wolz, Johannes Speidel, vogelmann, Norman Wildmann, Luc Rochette, Dave Turner, …

FESSTVaL

Field Experiment on Submesoscale Spatio-Temporal Variability in Lindenberg

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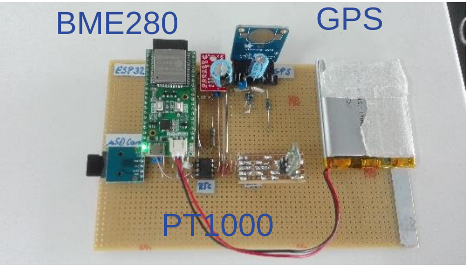
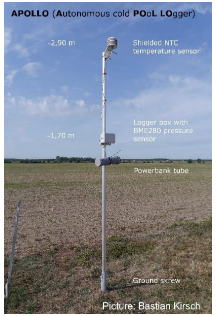
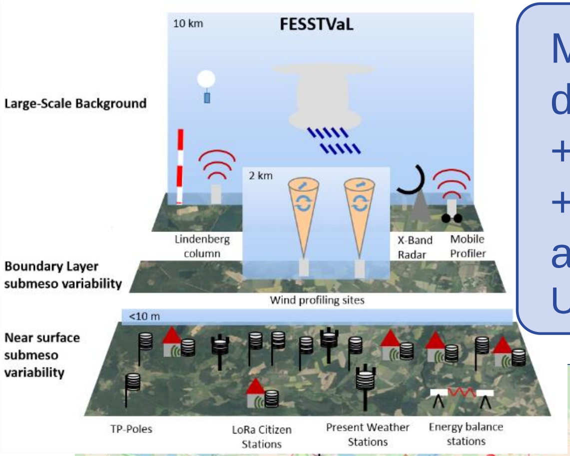
APOLLO

TP-pole: temperature and pressure (University Hamburg)

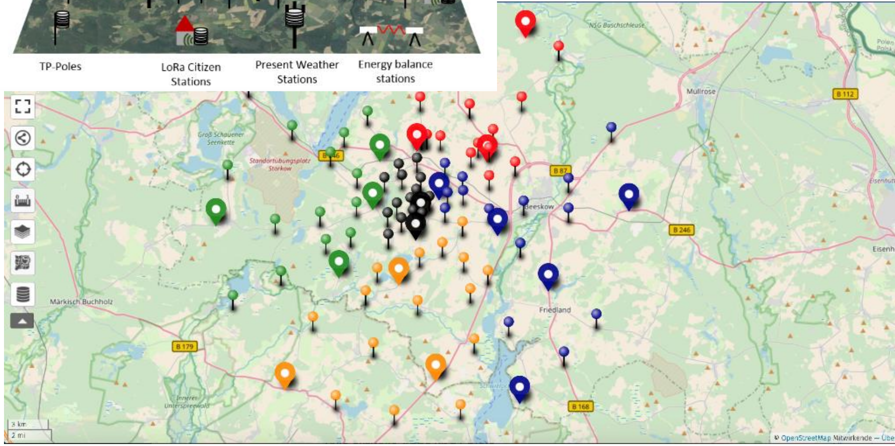




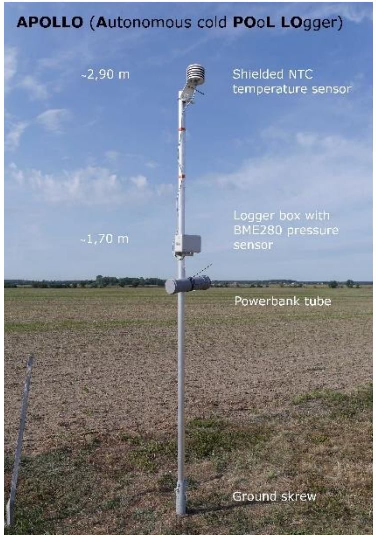
Cheap radiation sensors (University Wageningen)



Measurements distributed in space + vertical profiling + UAS (unmanned aerial systems), University Tübingen



Impressions



Picture: Bastian Kirsch

Comparison of vertical velocity variance to observations

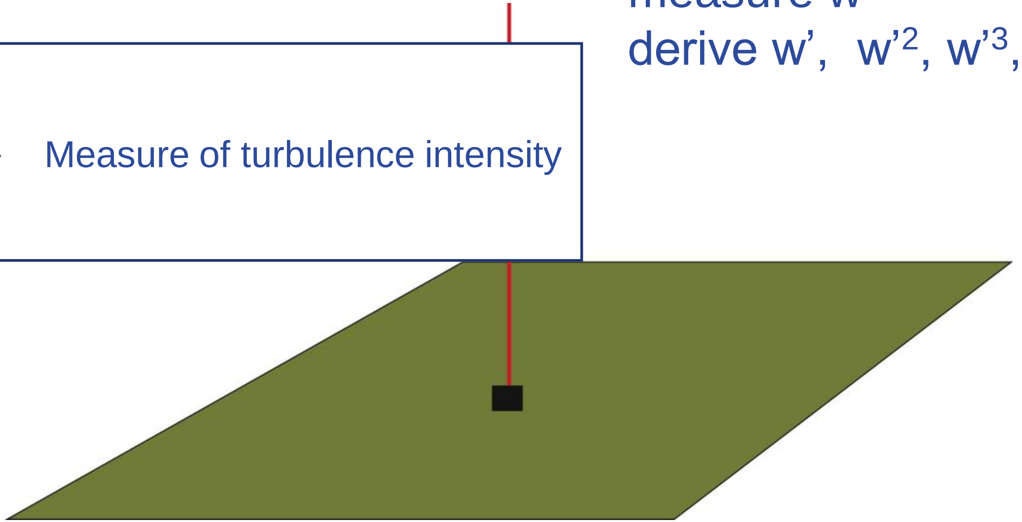
The variance of vertical velocity is retrieved using Doppler wind lidar operated in vertical stare mode

Measurement location in Falkenberg, MOL-RAO

$$\frac{\sigma_w^2}{w_*^2}$$ Measure of turbulence intensity

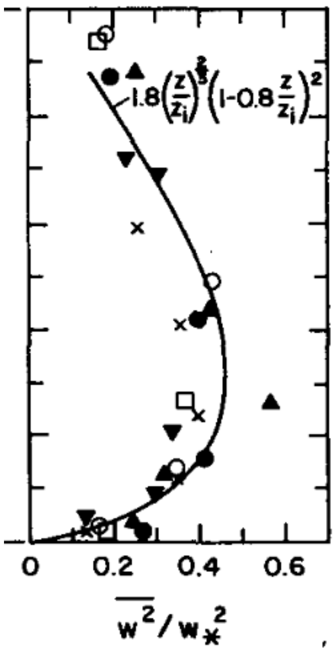
measure w

derive w’, w'^2, w'^3,…

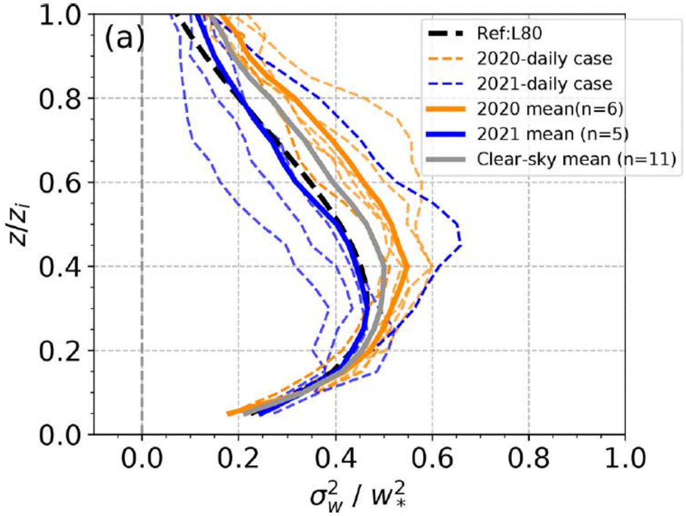


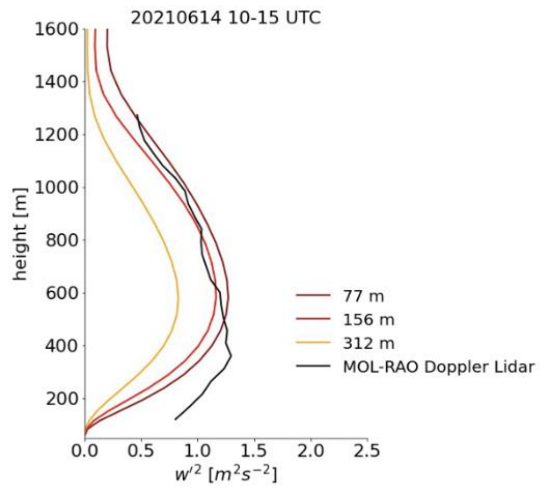
Dewani et al, 2023

Boundary Layer Turbulence



Clear-sky days





$$\frac{\overline{w^2}}{w_*{}^2} = 1.8(z/z_i)^{2/3}(1 - 0.8z/z_i)^2,$$

Lenschow, D. H., Wyngaard, J. C., & Pennell, W. T. (1980).

This suggests that moisture content and moisture transport are limiting factors for the intensity of turbulence in the convective boundary layer

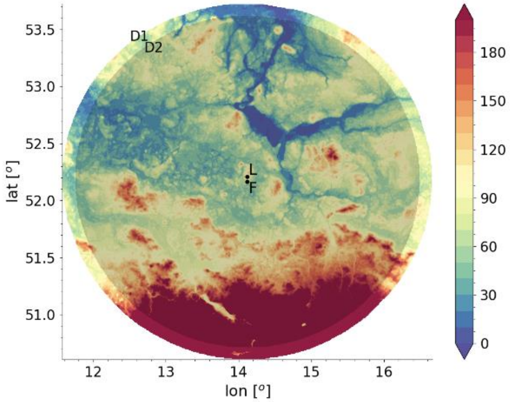
Dewani et al., 2023

Comparison model ↔ observations

ICON-nwp

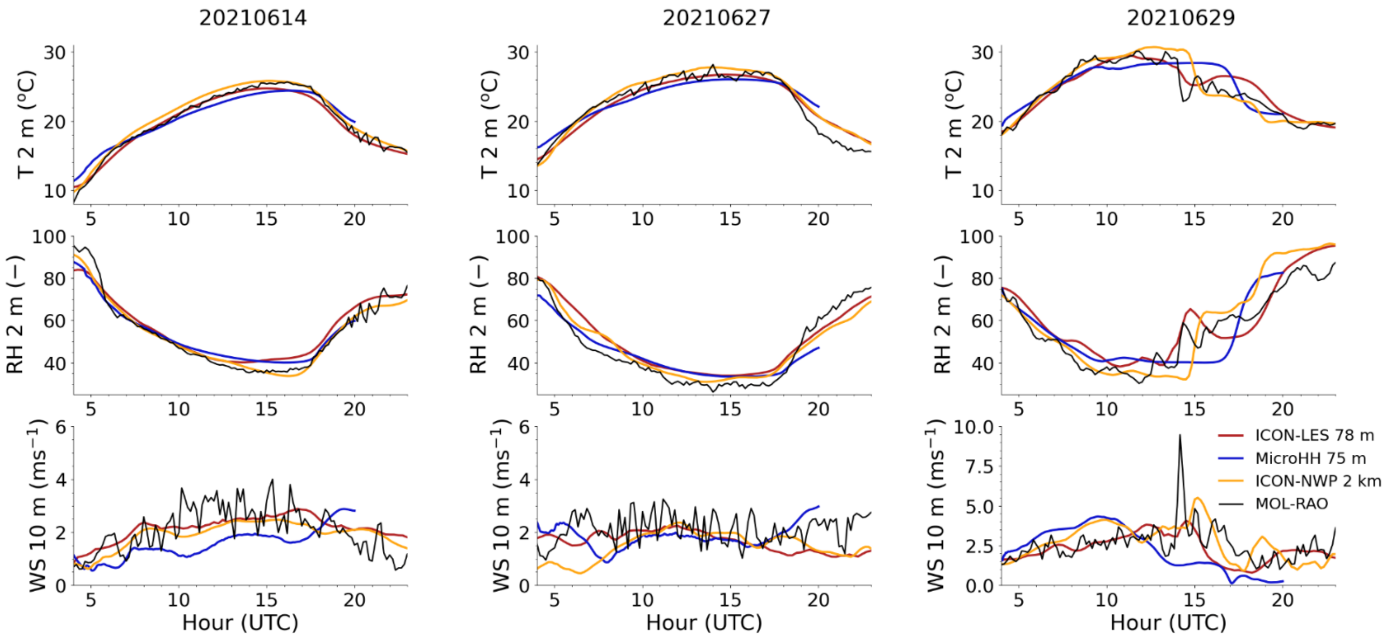
ICON-LES

Domain abbreviation	Grid spacing (m)	Domain size/diameter (approx. km)
ICON-LES		
DOM1	626	114
DOM2	313	63
DOM3	156	36
DOM4	78	23
ICON-LES - cold pool		
D1	525	348
D2	260	324
MicroHH-LES		
D1	75	19.2
D2	37.5	19.2
ICON-NWP		
DOM1	5 000	610
DOM2	2 500	382
DOM3	1 200	272



Sakradzija et al., 2025, submitted

Near-surface quantities fit well with observations



Sakradzija et al., 2025, submitted

TKE: model ↔ observations

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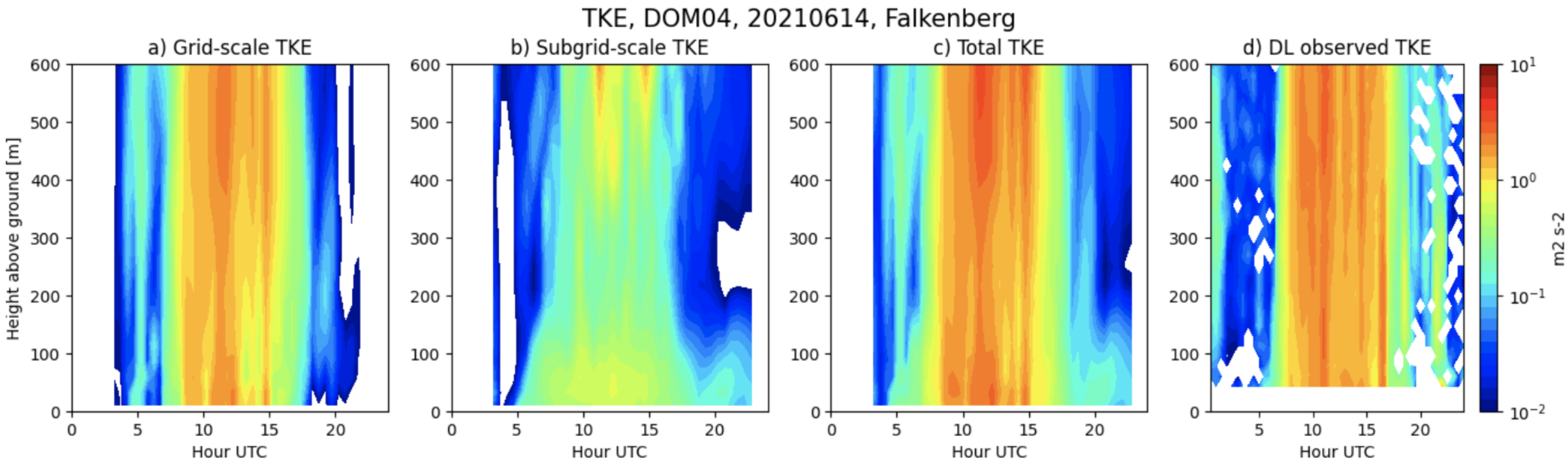
(Domain 04 Δx=78 m)

TKE: turbulent kinetic energy



Sakradzija et al., 2025, submitted

- At Δx=78 m still a lot of TKE at the sub-grid scale
- TKE well approximated during the daytime

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- Ground-based remote sensing
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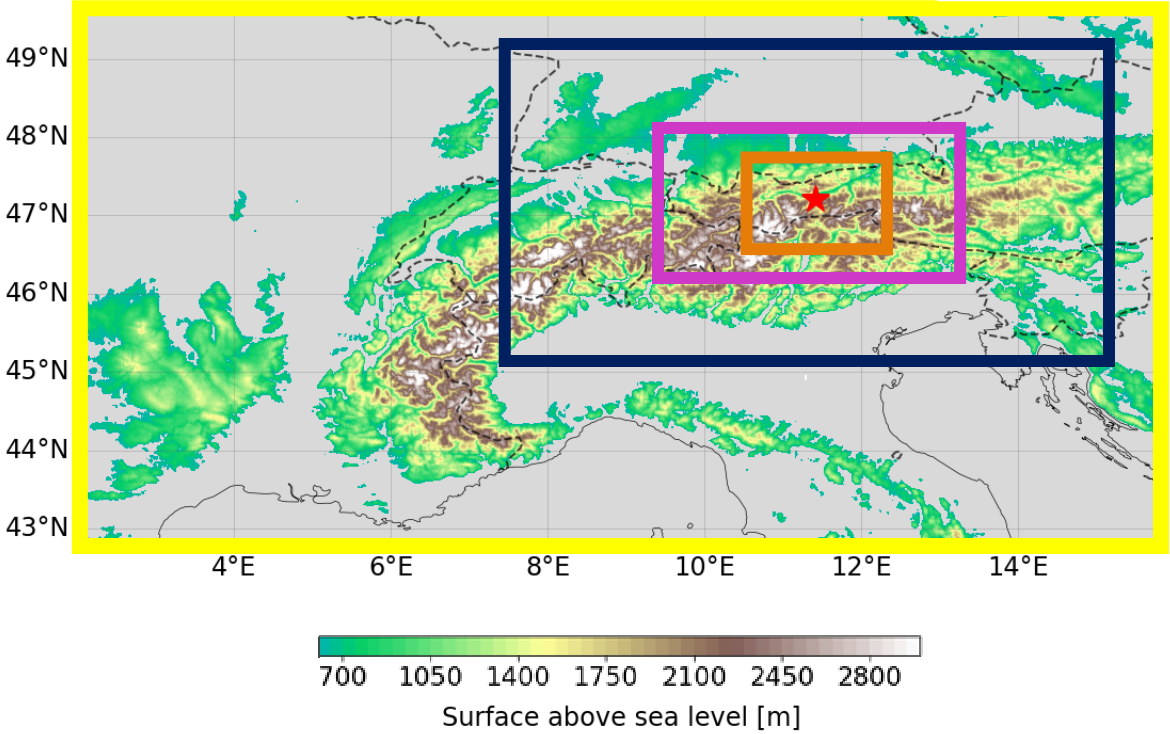
2. Experimental Setup around the Measurement Campaign PIANO

cold air pool case, October 2017

Experimental Setup around the Measurement Campaign PIANO



Δx

2 km

1 km

500 m

250 m

★ Station site

Model Setup of ICON-LAM*

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Wetter und Klima aus einer Hand

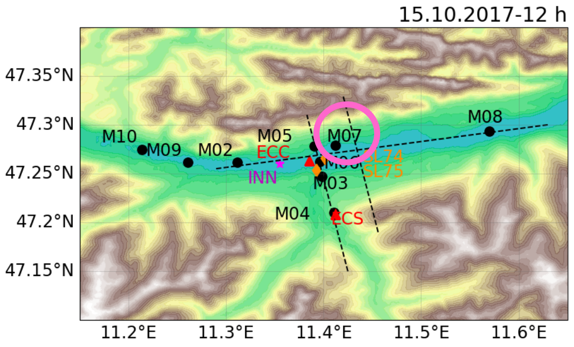
Physics Configuration	
Orography	Orographic gravity wave drag [1.]
Mircrophysics	Two-moment [2.]
Turbulence	TKE closure [3.] (/ Smagorinsky) [4.]
Sfc Transfer	TKE-STC (/ Louis) [5.]
Convection	Shallow convection [6.]
Land Surface	TERRA [7.]

1. *Lott an Miller (1997)*
2. *Seifert and Beheng (2006)*
3. *Mellor and Yamada (1982), and Raschendorfer (2001)*
4. *Smagorinsky (1963), Lilly (1962), and Dipankhar (2015)*
5. *Louis (1979)*
6. *Tiedke (1989), and Bechthold et al. (2008)*
7. *Schrodin and Heise (2001), and Schulz et al. (2016)*

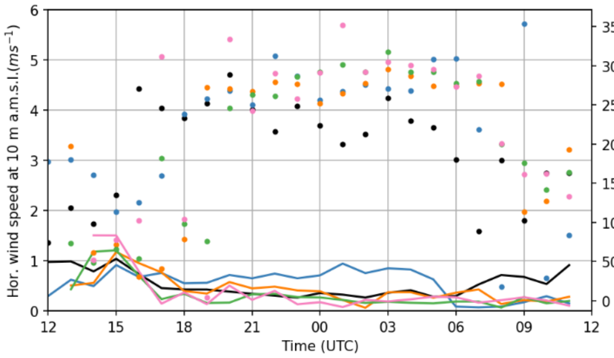
Model top	22 km
Vertical level	65 full (66 half)
Hor. grid scale	2 km, 1 km, 500 m, 250m
LATBC (at start)	Forecast (IFS)
Forecast restart	0 h
Duration	36 h
1-way-Nesting	
Model version icon-2024.10	

* Limited Area Mode (LAM)

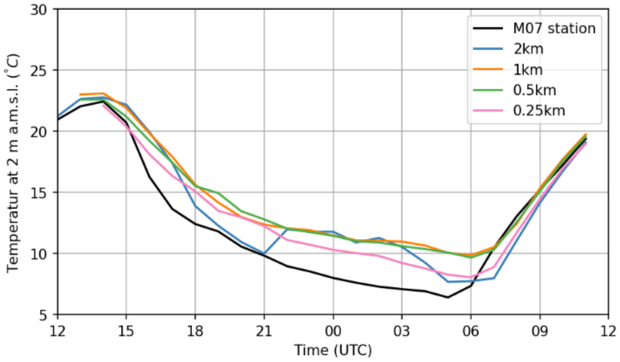
M07- Mid-Section

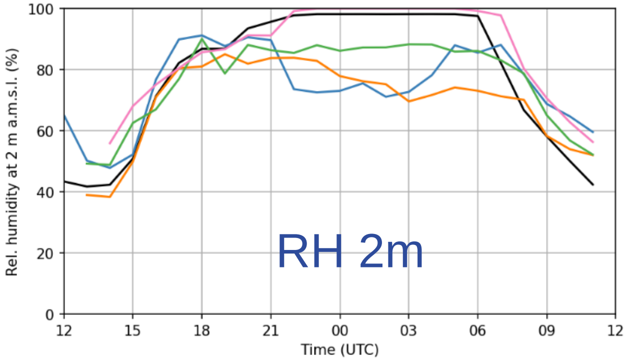


Wind speed and dir.



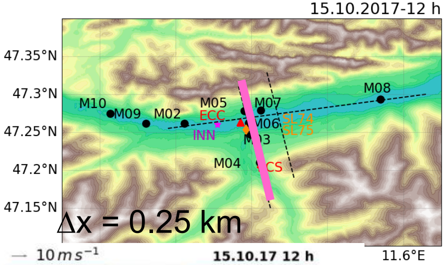
T 2m

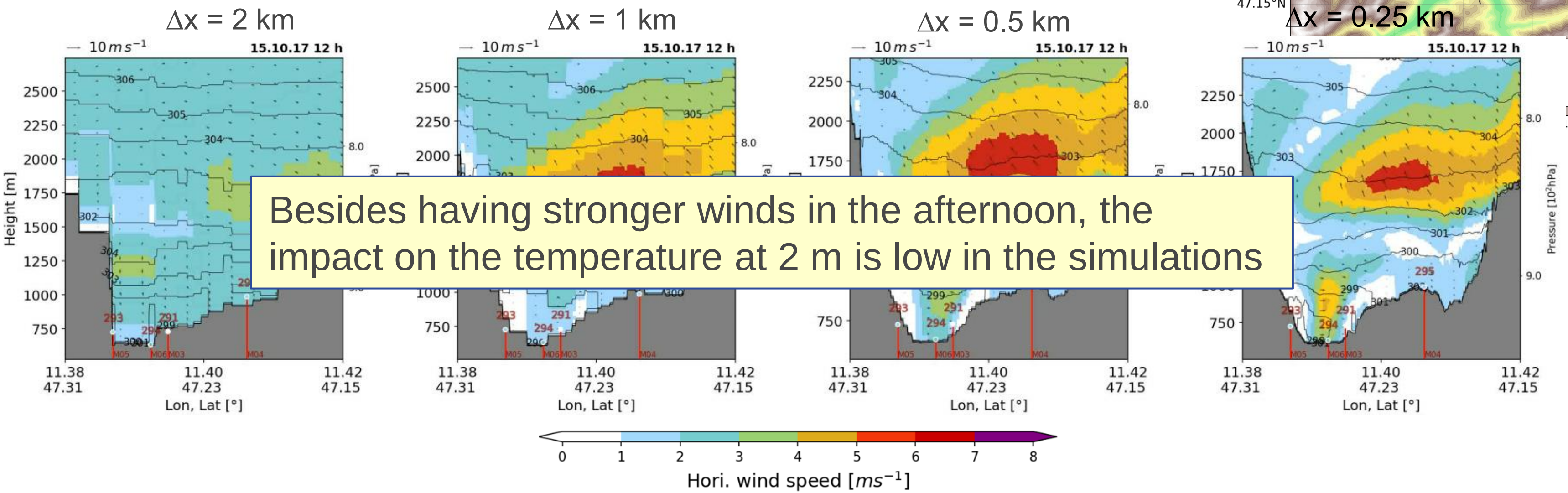




<u>Figure:</u> Temporal evolution of 10 m horizontal wind speed (left), 2 m temperature (middle), and 2 m relative humidity (right), averaged over the nearest neighbouring grid cell from simulations with horizontal grid spacings of 2 km (blue), 1 km (yellow), 0.5 km (green), 0.25 km (rosa), and observations from the Weather station **M07** (black) for the night between 15.10.2017, 12 h and 16.10.2017, 12 h.

Wind circulation at higher resolution

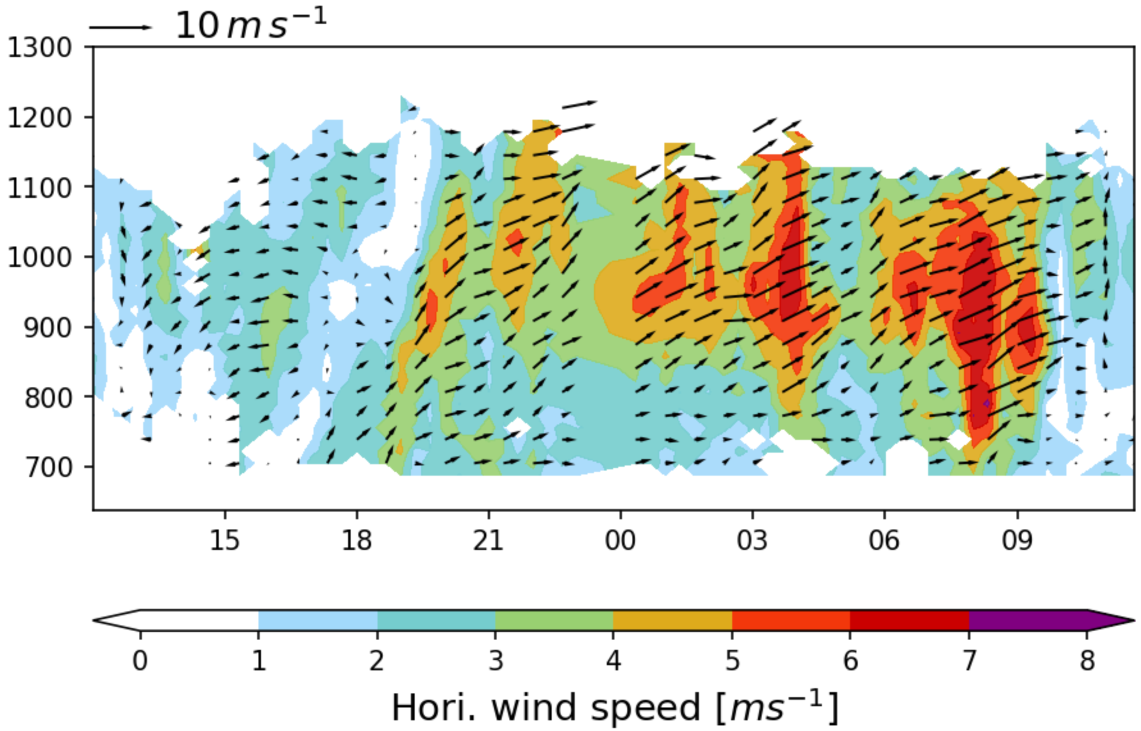




Besides having stronger winds in the afternoon, the impact on the temperature at 2 m is low in the simulations

Figures: Vertical cross sections in the Inn Valley for horizontal grid scales of 2 km, 1 km, 500 m, and 250 m (left to right). Contours represent the averaged horizontal wind speed, arrows indicate the wind direction, contour lines show the potential temperature for a cold air pool case during the night of 15.-16. October 2017. Measurements are marked as lines (red). **A strong jet is resolved by higher resolutions**

Observed wind speed



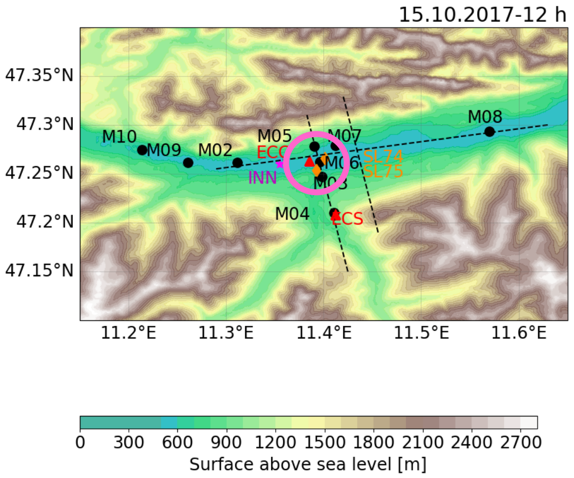
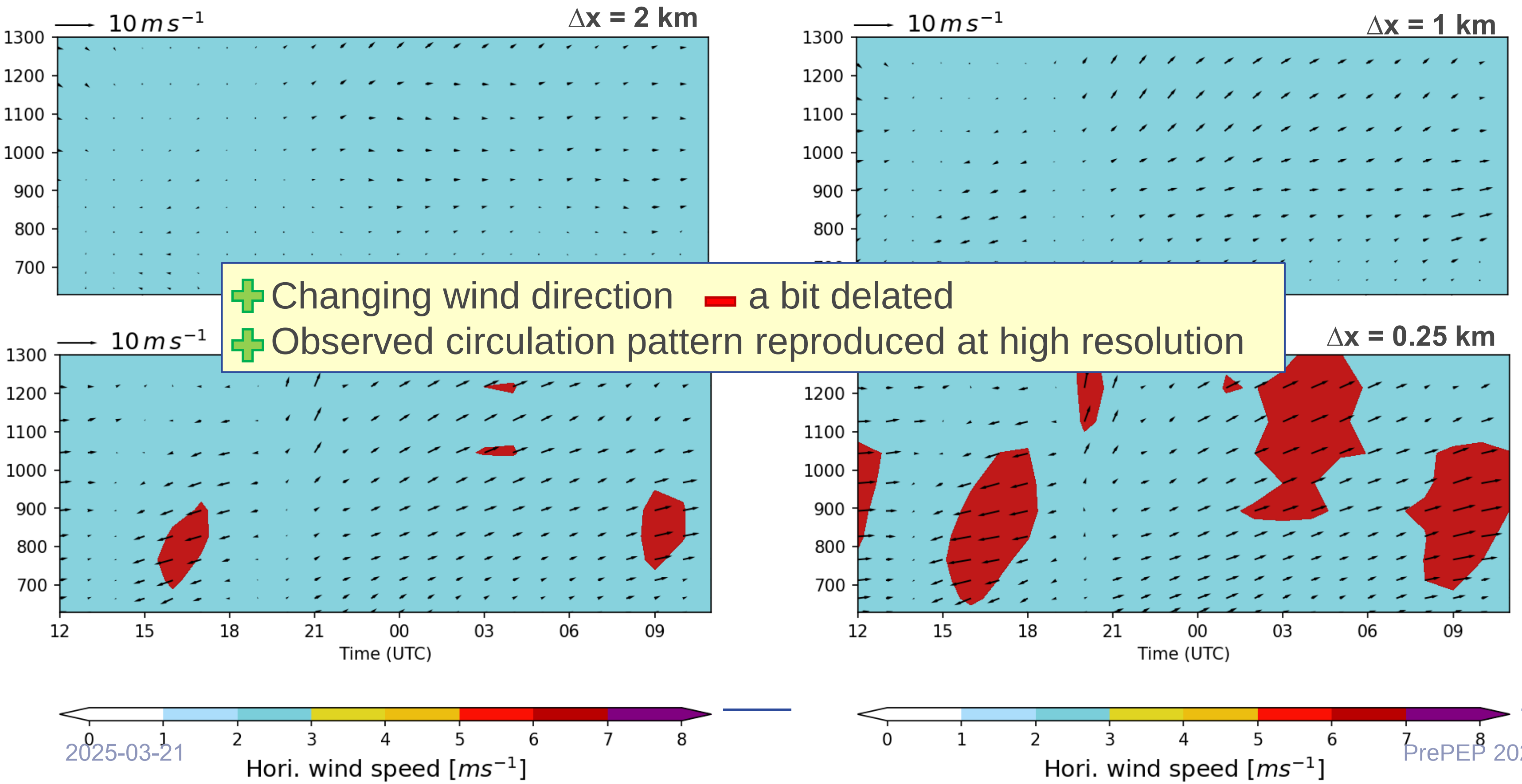


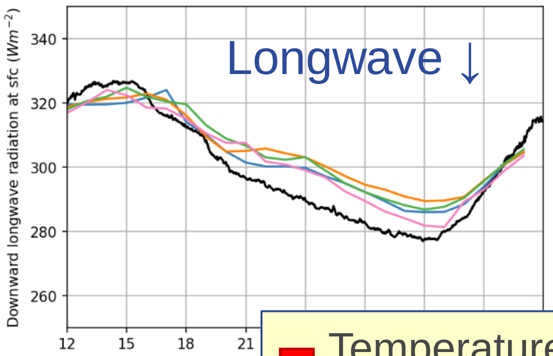
Figure: Temporal evolution of horizontal wind speed (contour) and wind direction (arrows) from LIDAR observation.

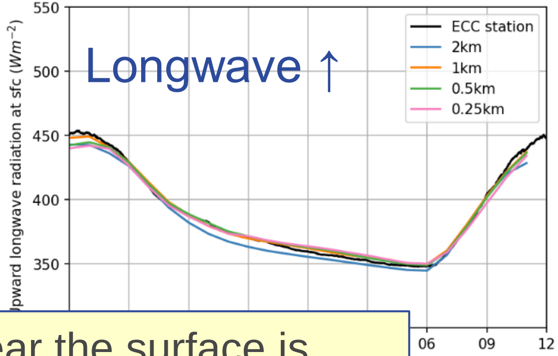
Simulated temporal wind speed



- ✚ Changing wind direction ▬ a bit delated
- ✚ Observed circulation pattern reproduced at high resolution

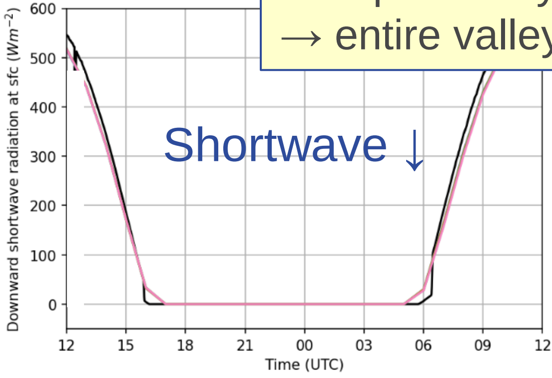
Radiation

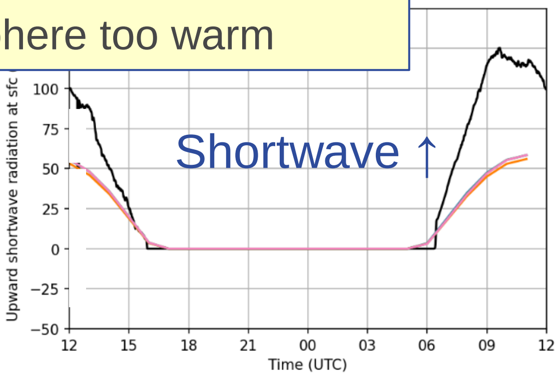




- Temperature bias near the surface is impacted by bias in the radiation

→ entire valley atmosphere too warm





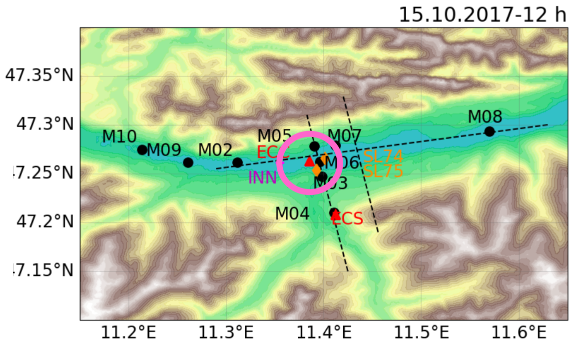


Figure: Temporal evolution of downward longwave radiation (left top), upward longwave radiation (right top), downward shortwave radiation (left bellow), and upward shortwave radiation (right below) from simulations with different horizontal grid scales (colored) and observation (black).

Outline

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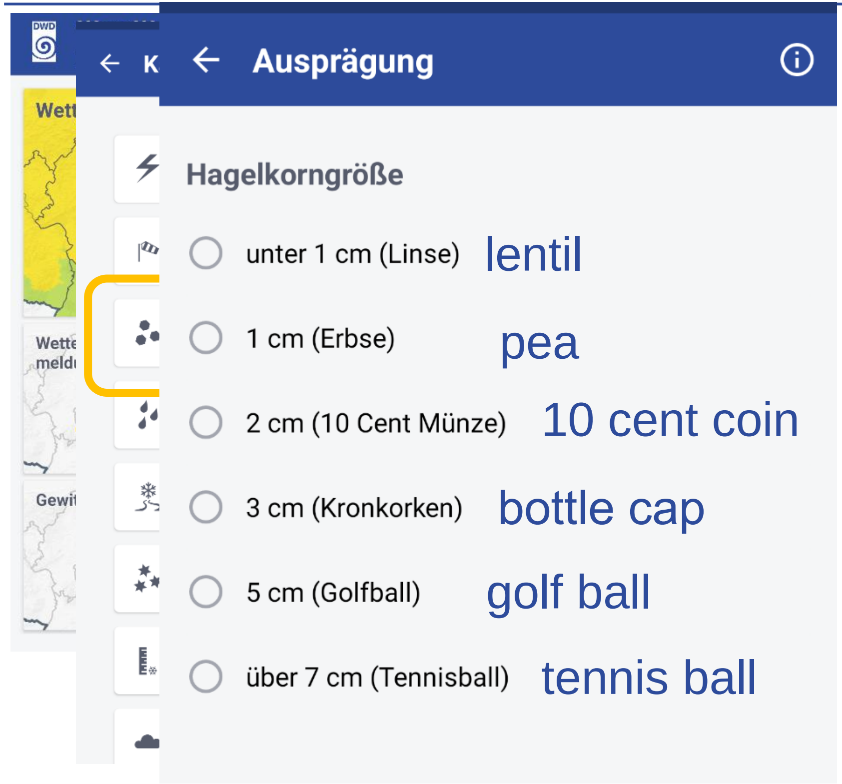
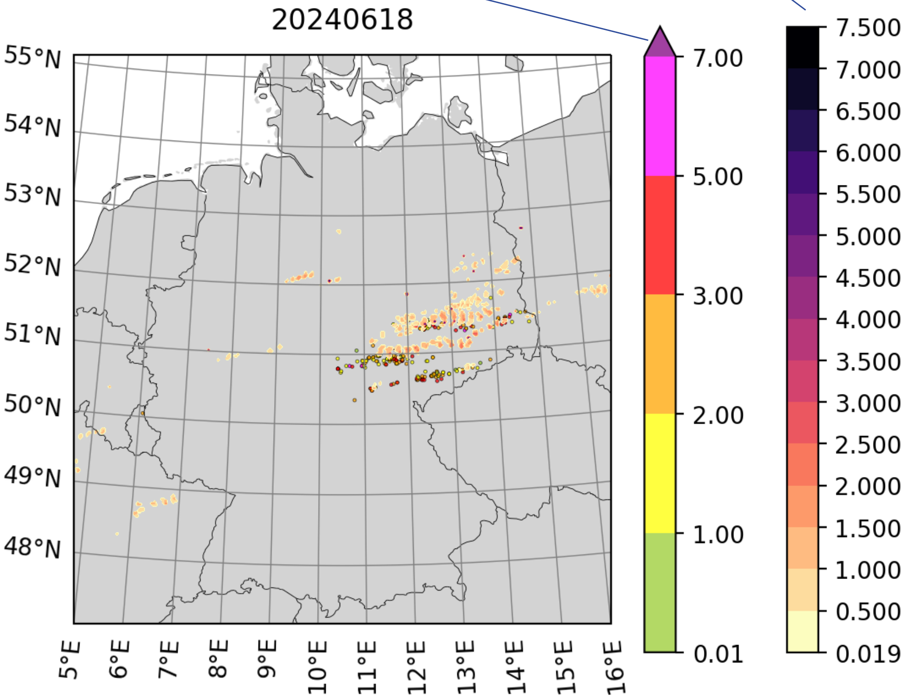
Making use of hail reports - hail size

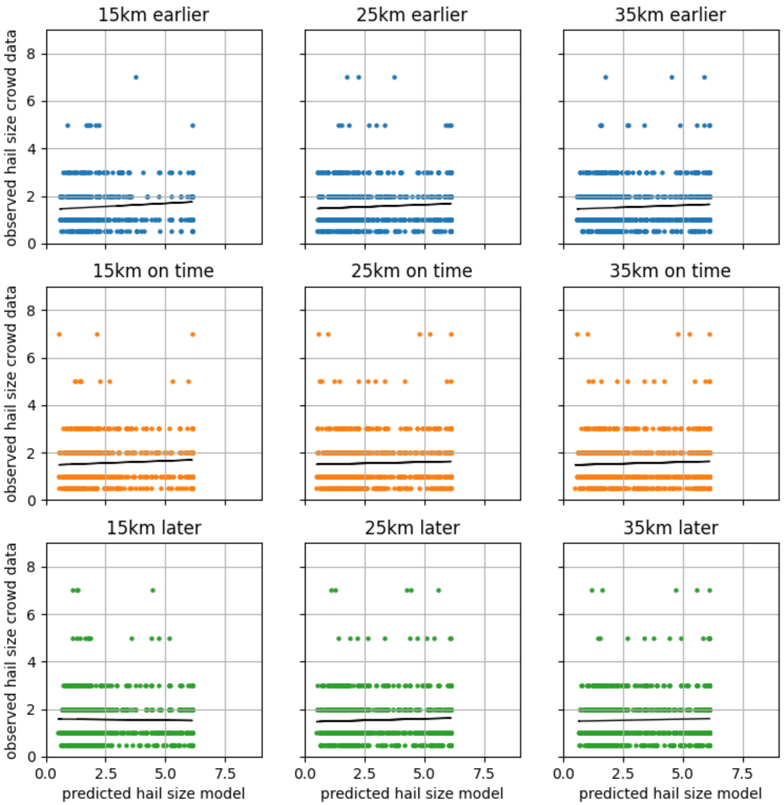


lentil
pea
10 cent coin
bottle cap
golf ball
tennis ball



Sophie Löbel, Alberto de Lozar, Uli Blahak

Making use of hail reports - hail size



For the specific case of hail size reports:

- The location can be used as a guide to judge if the model produced hail at the right place
- The quantitative comparison of reported and predicted hail size is difficult, probably due to a non-standardized reporting procedure
- Changed maximum value for median diameter for hail in the parametri-zation as a result
- Next step: add information from radar

Sophie Löbel, Alberto de Lozar, Uli Blahak

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- ➔ Ground-based remote sensing
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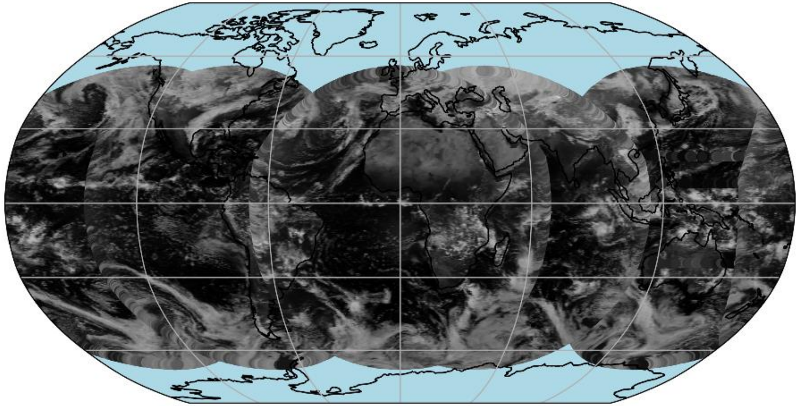
Intercomparison setup - observations

- Visible reflectances from **0.6µm channel**
  - SEVIRI: Met-9 & Met-10
    (updated calibration; A. Mousivand, Eumetsat)
  - AHI: Him-9
  - ABI: Goes-16 & Goes-18
- Experimental period
  - January 2024
  - Time resolution: 3-hourly data at 0, 3, 6, … UTC
- Observation data processing
  - DWD: Observations averaged onto model grid cells (here at 26km resolution)
  - ECMWF: Observation superobbing to ~29km resolution

ABI, SEVIRI and AHI 0.6µm reflectances
15 January 2024 (21,18,12,9,3 UTC)



Intercomparison setup – Global NWP models ICON & IFS

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Wetter und Klima aus einer Hand

- **Similar resolutions**: ICON @ 26km, IFS @ 29km
- Sub-grid cloud parameterizations
- **ICON model physics setups**:
  - **1M**: 1-mom. scheme – operational
  - **2Mi**: 2-mom. ice scheme with MODIS CDNC
  - **2Mi, CLC**: 2-mom. ice scheme with MODIS CDNC and ad hoc modification of cloud cover over sea by A. Seifert
- Effective **cloud particle radii**:
  - ICON: radiation scheme (1M), microphysics (2Mi & 2Mi, CLC) or RTTOV param. (Martin & Wyser)
  - IFS: RTTOV param. (Martin & McFarquhar)

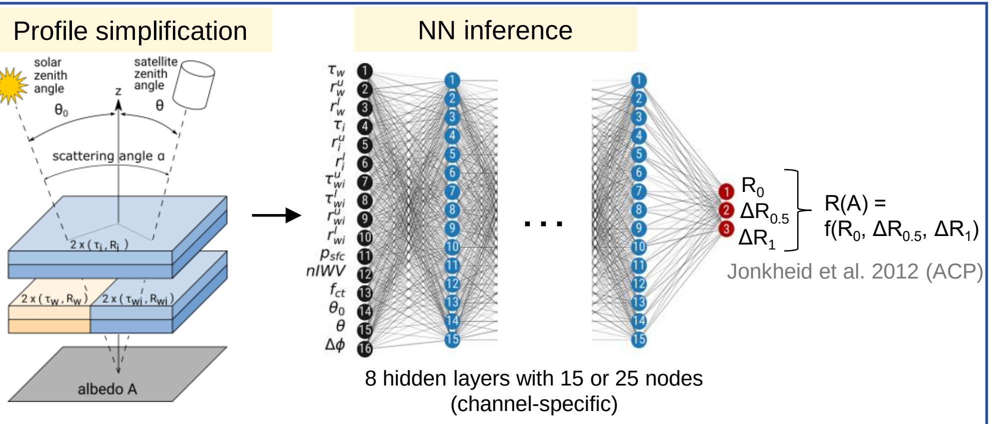
Intercomparison setup – Radiative Transfer

➔ **MFASIS-NN** in RTTOV-13.2: Fast RT model for visible satellite images

- NN-based approach with limited set of input parameters per atmospheric model column
- Trained on RTTOV-DOM (radiative transfer DISORT, 1 dim.)

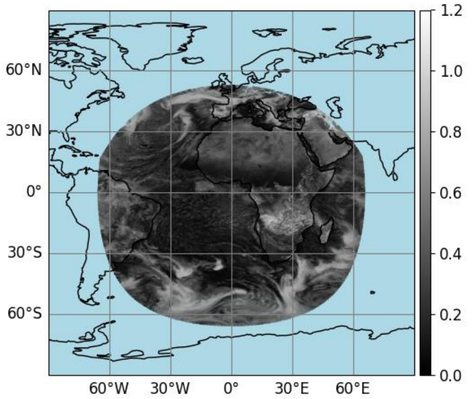
RTTOV / MFASIS-NN

NWP model profiles →



Refs.: Scheck 2021 (JQSRT), Baur et al. 2023 (AMT), RTTOV-14 Science and Validation Report

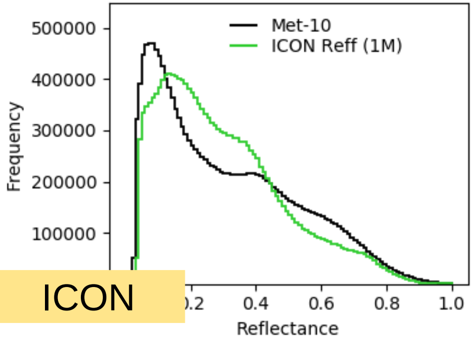
→



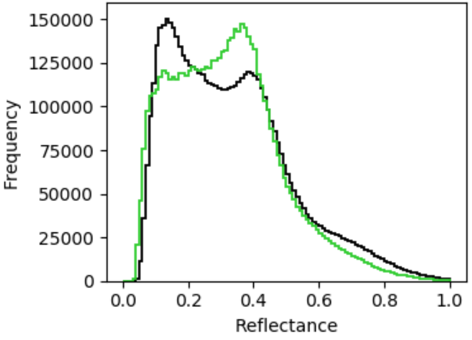
➔ **BRDF land atlas**: based on Jan. 2024 MODIS collection 6 data (J. Vidot)

Refl. histograms for SEVIRI: ICON vs. IFS

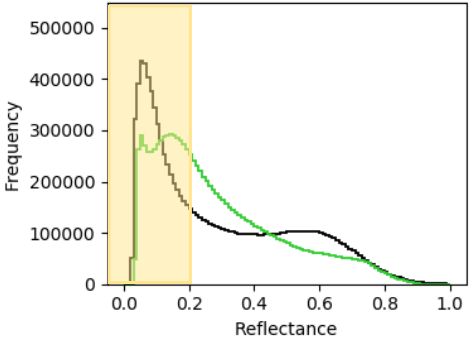
Full disk



Land surfaces

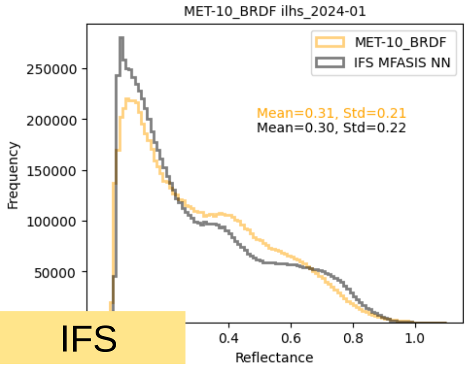


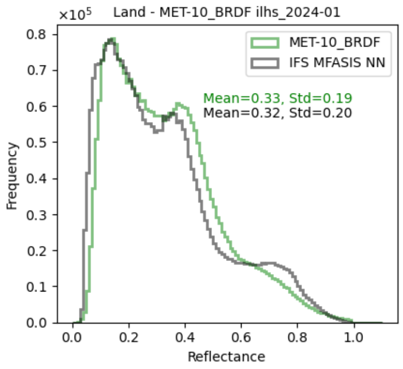
Sea surfaces

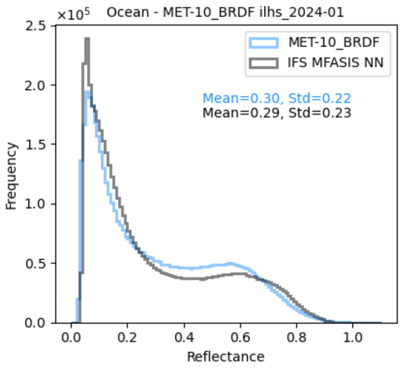


Overall structure of refl. histograms reproduced in sim.

Main difference: Peak at low reflectances due to too many thin model clouds in ICON (mainly oceans)







Refl. histograms for SEVIRI: ICON vs. IFS

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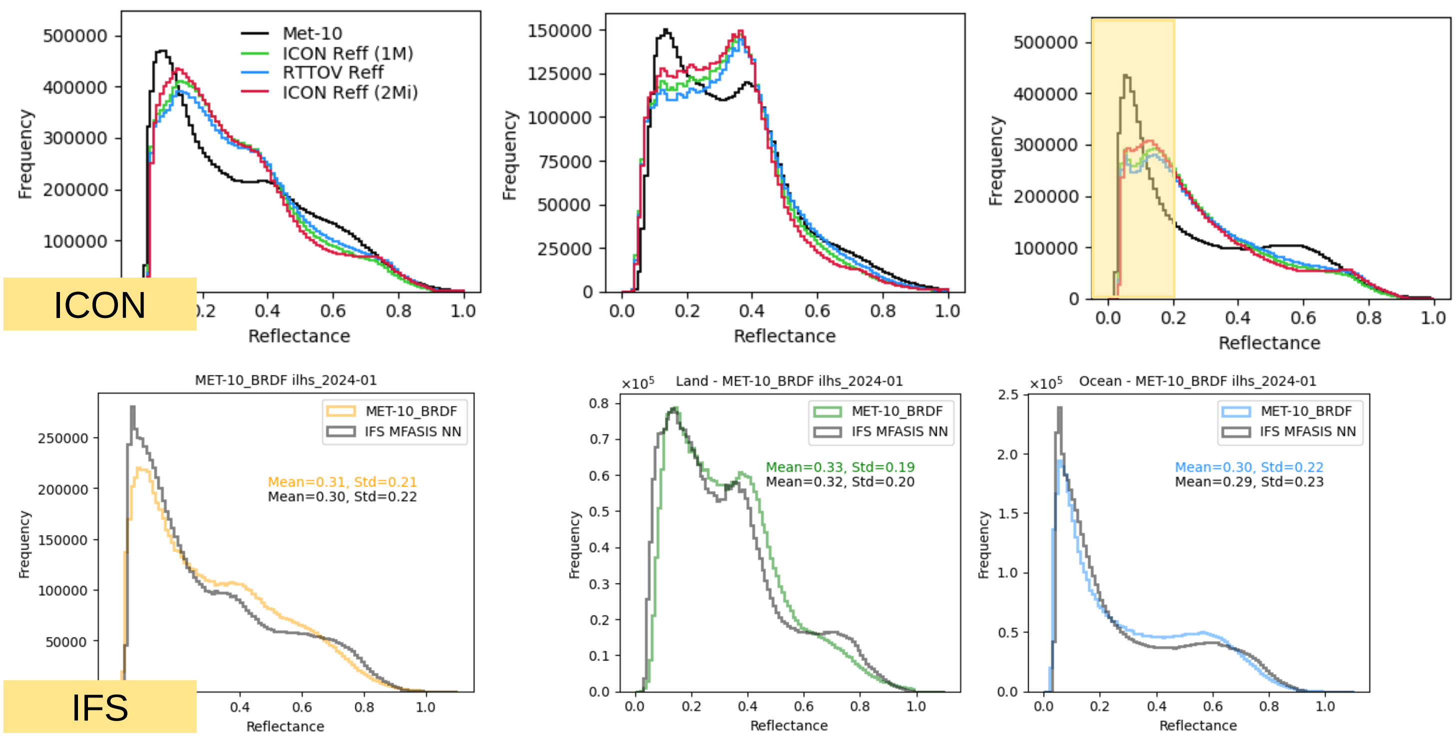
Wetter und Klima aus einer Hand

Full disk | Land surfaces | Sea surfaces



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Main difference: Peak at low reflectances due to too many thin model clouds in ICON (mainly oceans)

Little dependence on diff. radius param.s

Refl. histograms for SEVIRI: ICON vs. IFS

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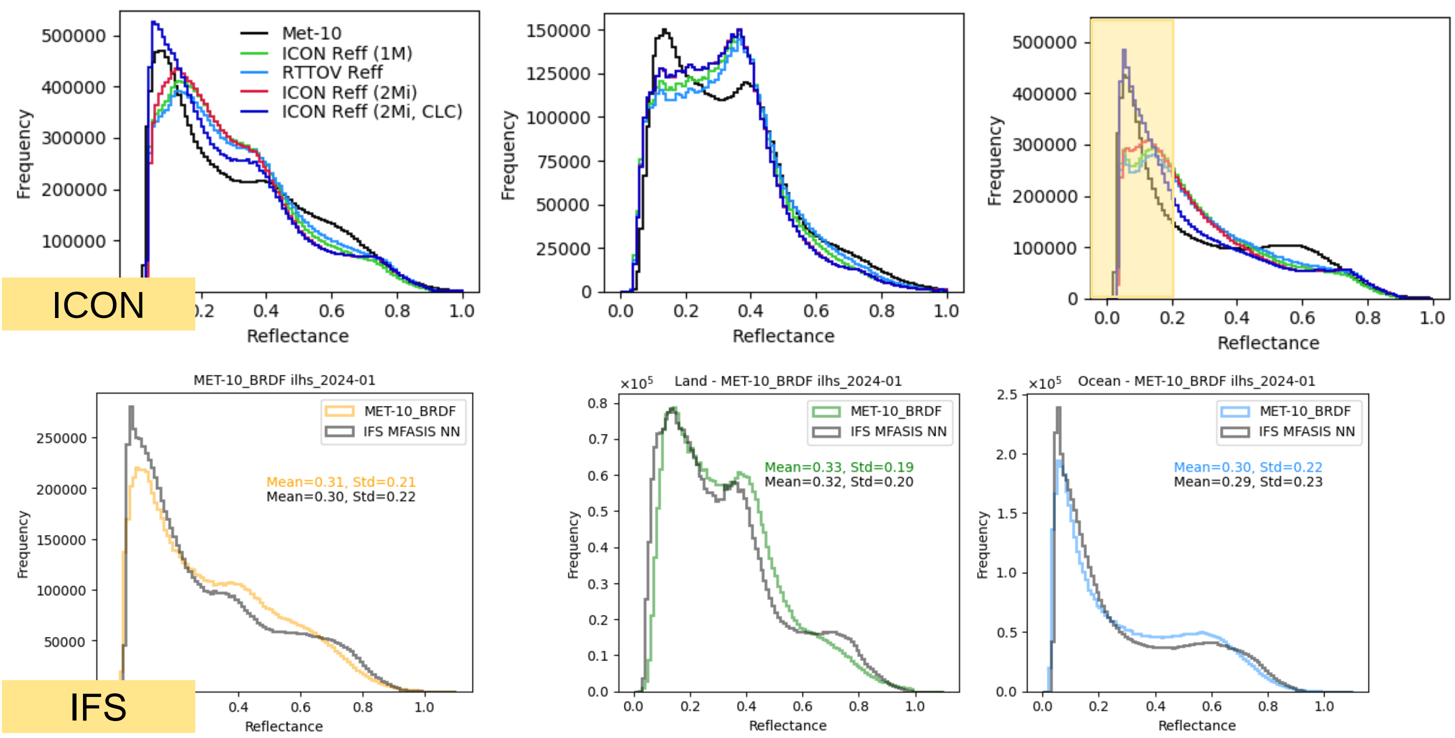

Overall structure of refl. histograms reproduced in sim.

Main difference: Peak at low reflectances due to too many thin model clouds in ICON (mainly oceans)

Little dependence on diff. radius param.s

Cloud cover scheme modifications largely reduce diff.s at low reflectances (ICON)

Summary

- (Novel) observations, in addition to standard verification, can help in the development of parametrizations
  - Process understanding
  - Fine-tuning, callibration
  - Identification of missing processes
- Each observational data set is different, need to understand how the measurement was taken and processed
- Quick availability of data is an advantage – easier to work on recent episodes