Insights from ceilometer and scintillometer measurements in the Inn Valley

An overview of IWCR projects **CELINE** and **SASHIMI**

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CELINE Spatial and temporal patterns in ceilometer observations along the Inn Valley

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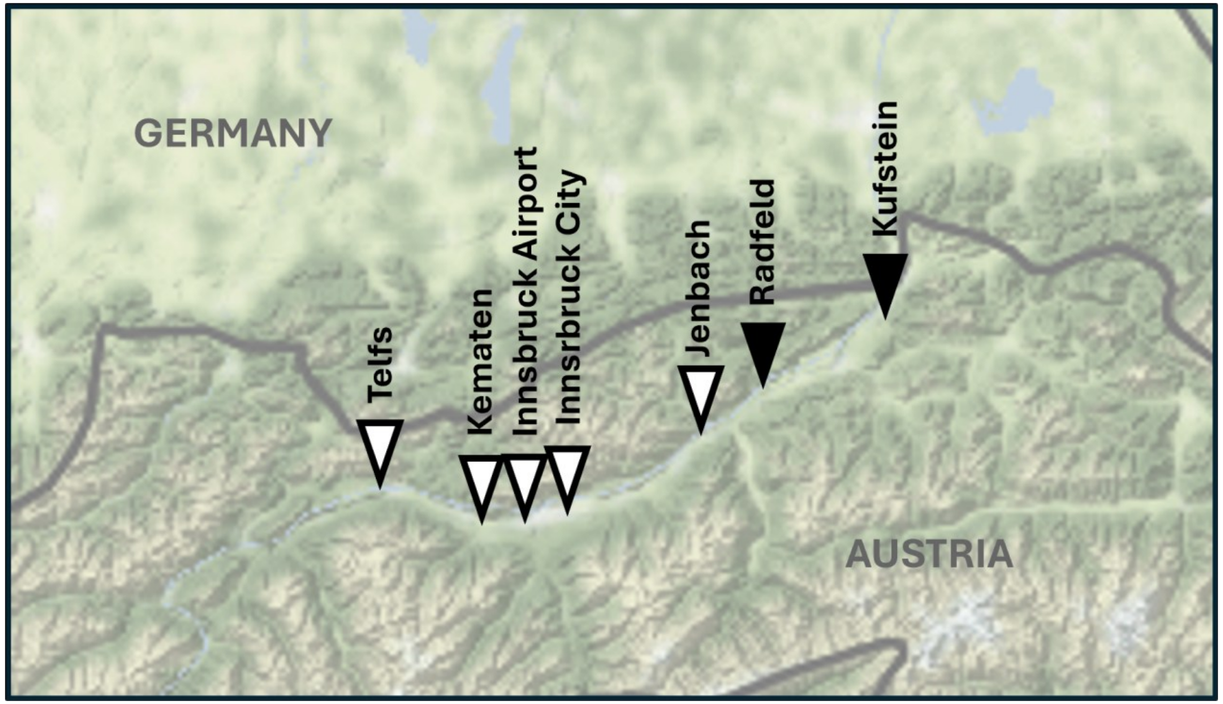
6-month project (March-August 2025)

Research objectives:

1. Do the ceilometers provide reliable estimates of **boundary layer height** compared to other methods?
2. How does boundary layer height **vary with location** along the Inn Valley? Can consistent differences be identified and related to **orography** or **land cover**?
3. Do the observations provide evidence for increased boundary layer heights over **urban areas** (i.e. Innsbruck)?



Ceilometer locations along the Inn Valley.
Ceilometers at Telfs, Kematen, Innsbruck Airport, Innsbruck City and Jenbach are operated by Austro Control (CL31, white triangles). Ceilometers at Radfeld and Kufstein are operated by GeoSphere Austria (CL51, black triangles). Background OpenStreetMap ©

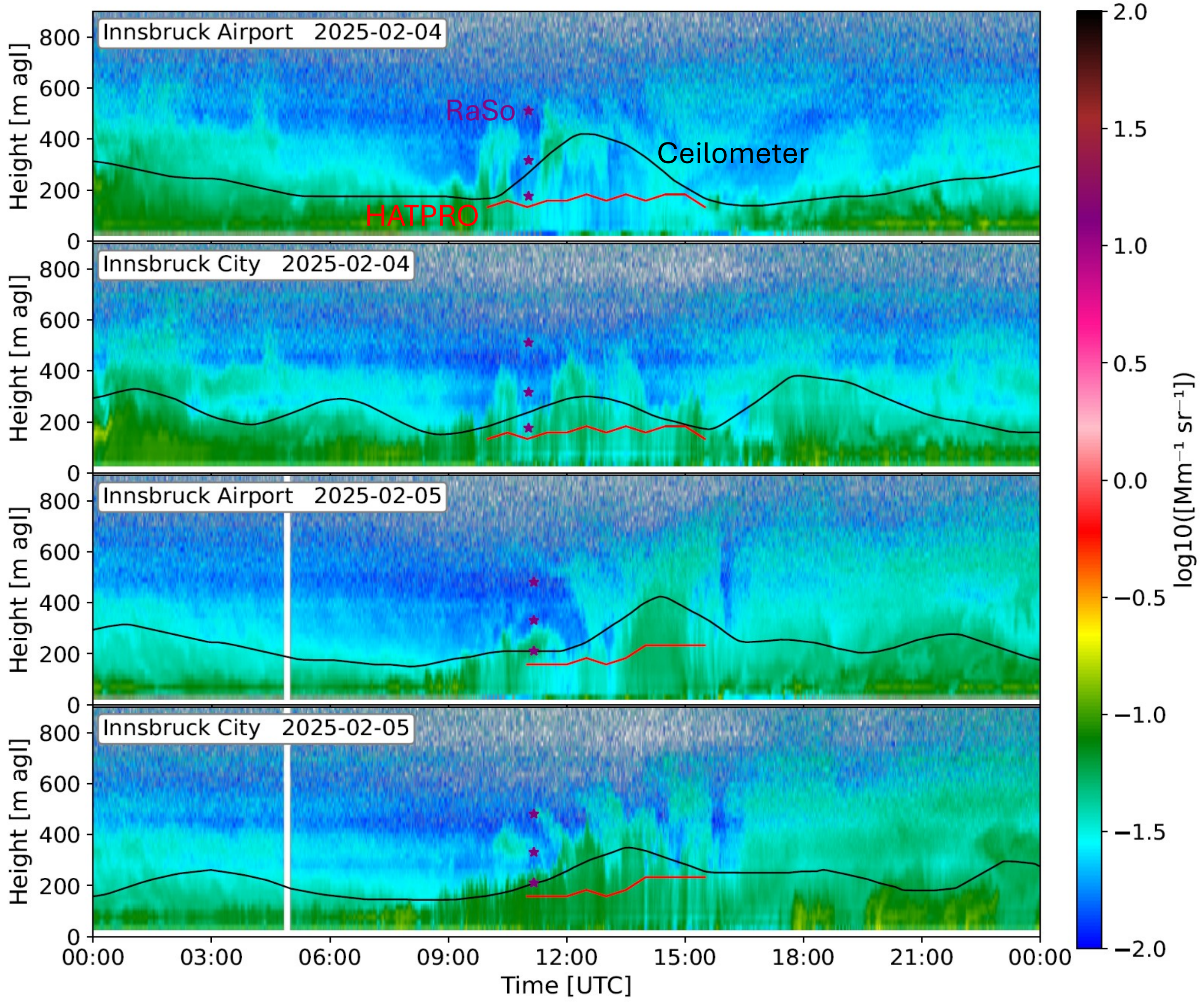
Approach

- Ceilometers provide continuous backscatter profiles which are related to the vertical distribution of aerosols.
- By looking at changes in the backscatter profiles, mixing layer height (MLH) can be estimated.

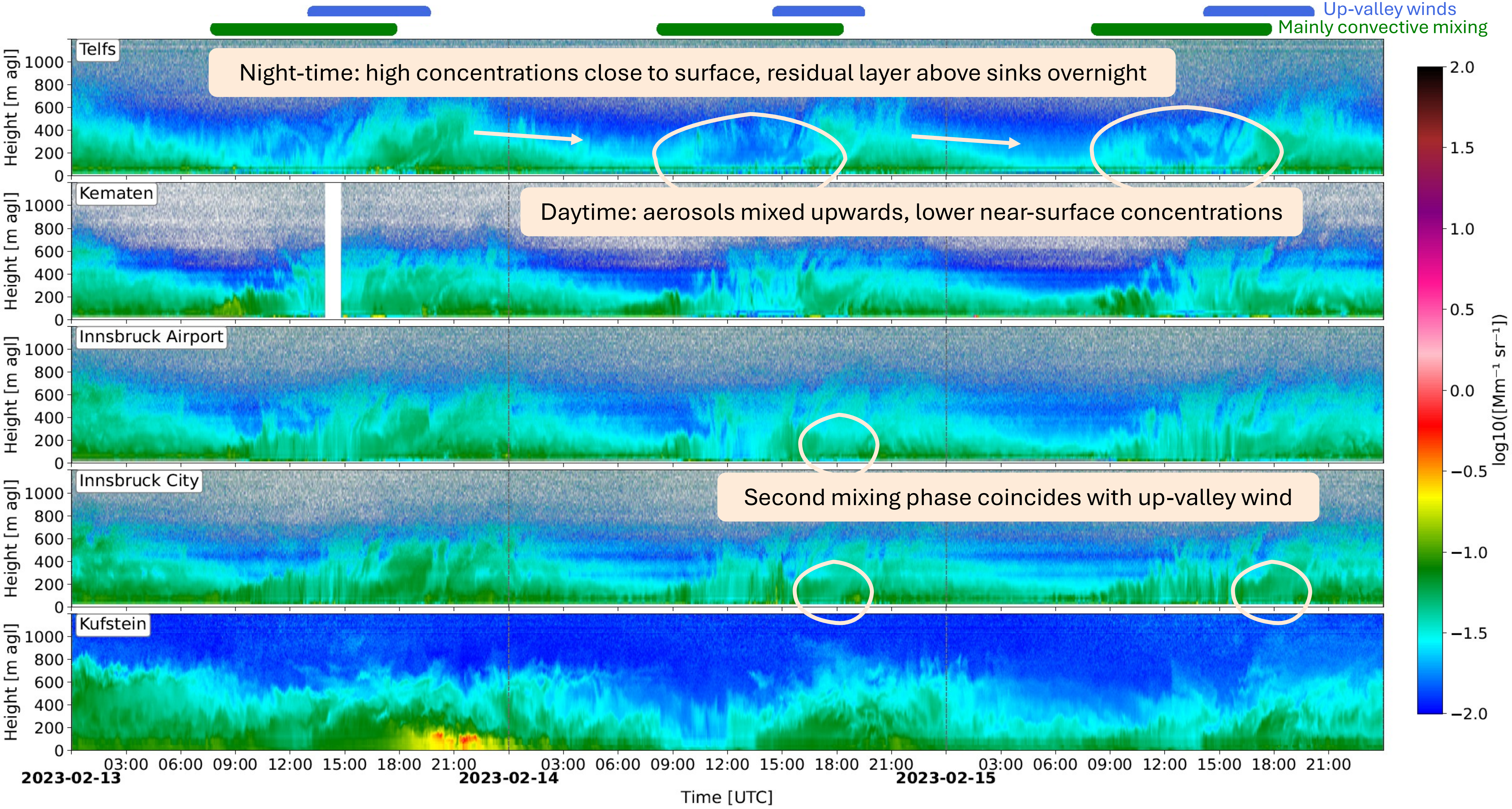
- In mountainous terrain:
  - the structure and evolution of the boundary layer are far more complex (e.g. Lehner and Rotach 2018),
  - orographic circulations (slope/valley winds) affect boundary layer structure and can lead to elevated pollutant layers,
  - downslope windstorms can have a dramatic impact on atmospheric conditions.

→ Study focuses on case studies of two different flow regimes (valley winds, foehn), and how these influence the **backscatter profiles** measured by the ceilometers.

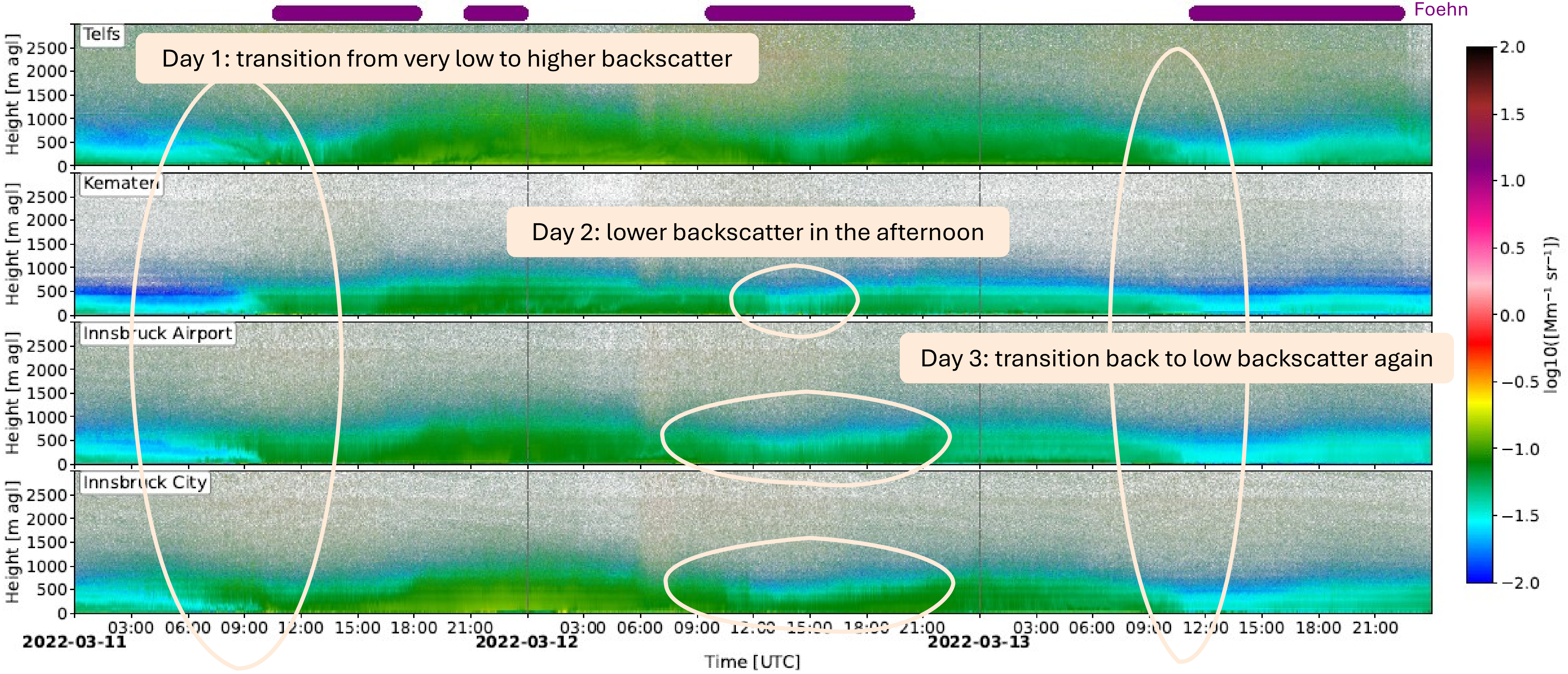
→ Mainly **cool-season case studies** (generally lower MLH, better vertical coverage, important for air quality).



Valley wind case study (13-15 Feb 2023)

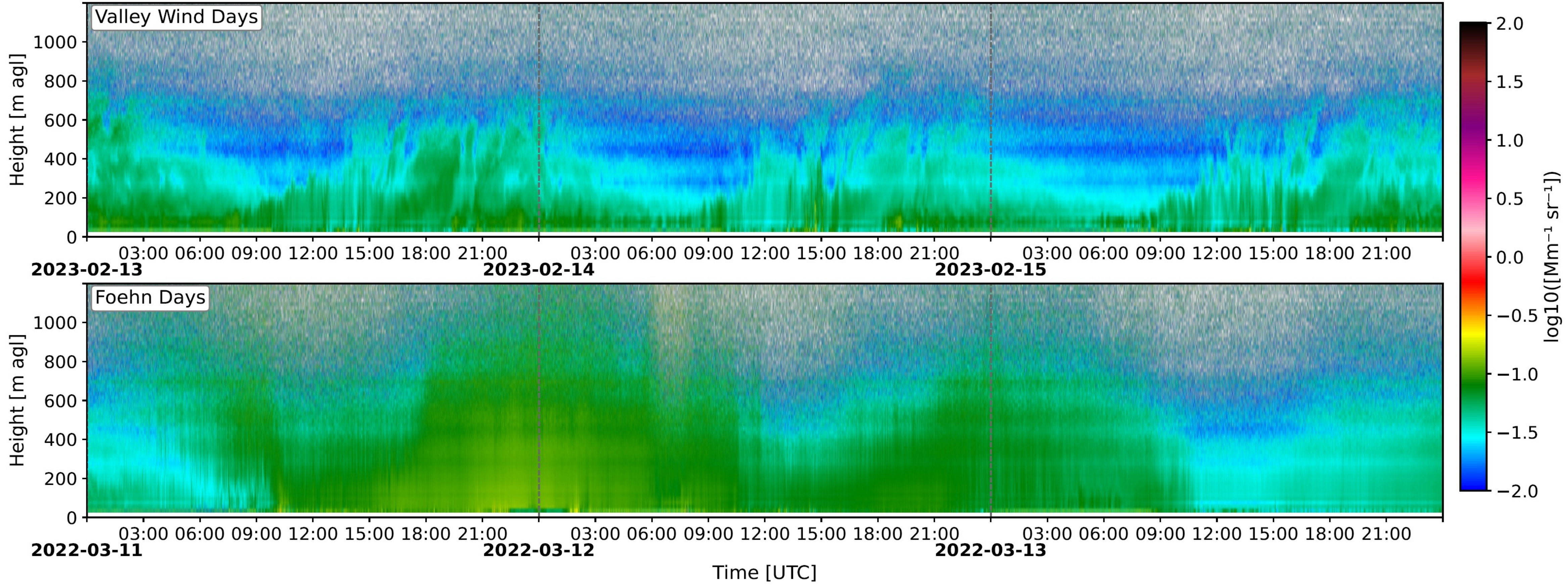


South foehn case study (11-13 Mar 2022)



Backscatter profiles from Innsbruck City

- Very different structure and diurnal evolution to ideal cases over flat terrain.
- Aerosols are more uniformly distributed on foehn days; mixing occurs from the top down as foehn air enters the valley.
- On valley wind days mixing is driven mainly by convection from surface heating; there is fine-scale variability over short time intervals.



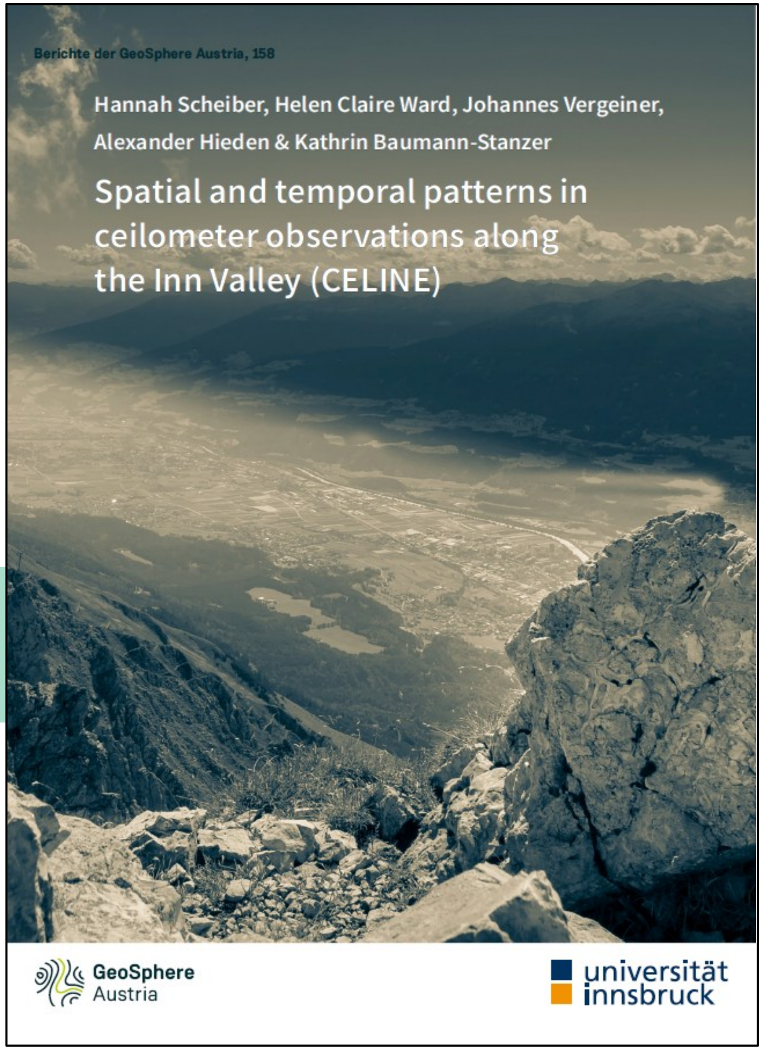
Summary

Conclusions

- Backscatter profiles differ from idealised cases over flat terrain. This precludes successful automatic detection of MLH.
- Profiles are very different on valley wind and foehn days. There is also variation within each type of flow.
- Small differences in MLH due to a potential UHI effect of Innsbruck seem to be overshadowed by the complexity of the valley atmosphere.
- Further work could include numerical modelling to better study mechanisms at different locations in the valley and to aid interpretation of the backscatter signals.

For more details, please see the published project report:

Scheiber H, Ward HC, Vergeiner J, Hieden A, Baumann-Stanzer K (2025)
Spatial and temporal patterns in ceilometer observations along the Inn Valley (CELINE).
Berichte der GeoSphere Austria, 158, 55p., GeoSphere Austria, Wien, ISSN: 2960-4486



SASHIMI Spatially averaged sensible heat fluxes in mountainous terrain for model evaluation

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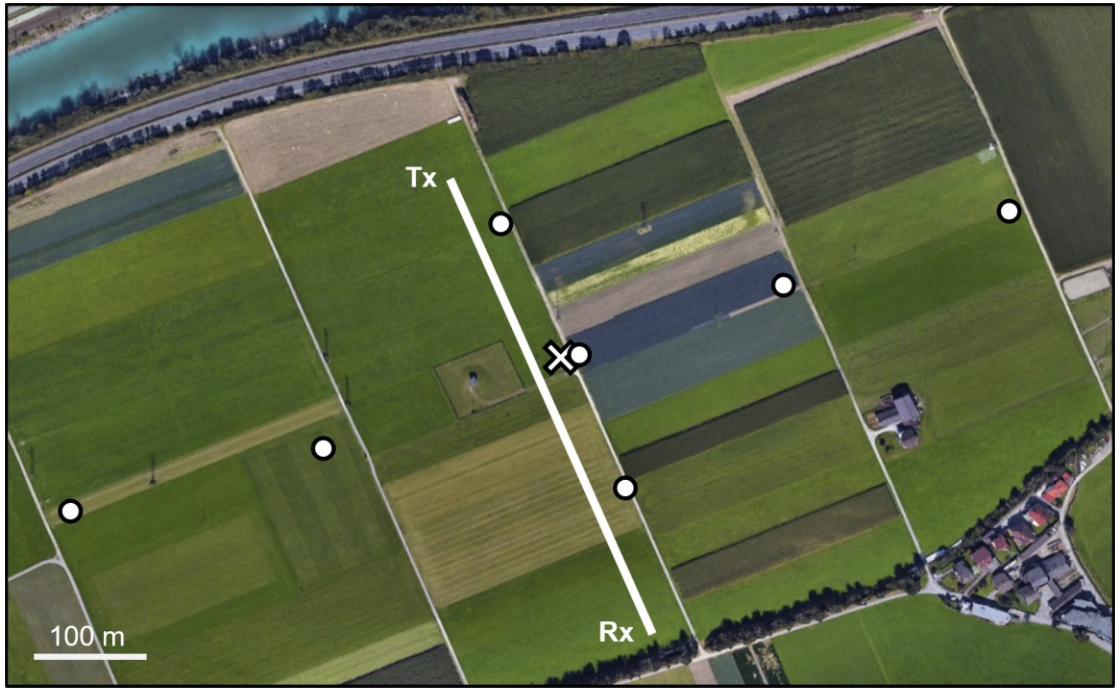
Clemens Wastl, Daniel Deacu (GeoSphere Austria)

6-month project (May-November 2025)

Research objectives:

1. Use scintillometry to obtain **area-averaged sensible heat fluxes** during the summer Extensive Observation Period (EOP) of the TEAMx campaign.
2. Investigate how sensible heat fluxes from the scintillometer **compare to eddy covariance** measurements.
3. Assess **whether scintillometry can be used** at a valley floor site in mountainous terrain.
4. Evaluate **AROME model** output against the observed fluxes, with particular attention given to differences in spatial representativeness and processes captured by the different techniques.



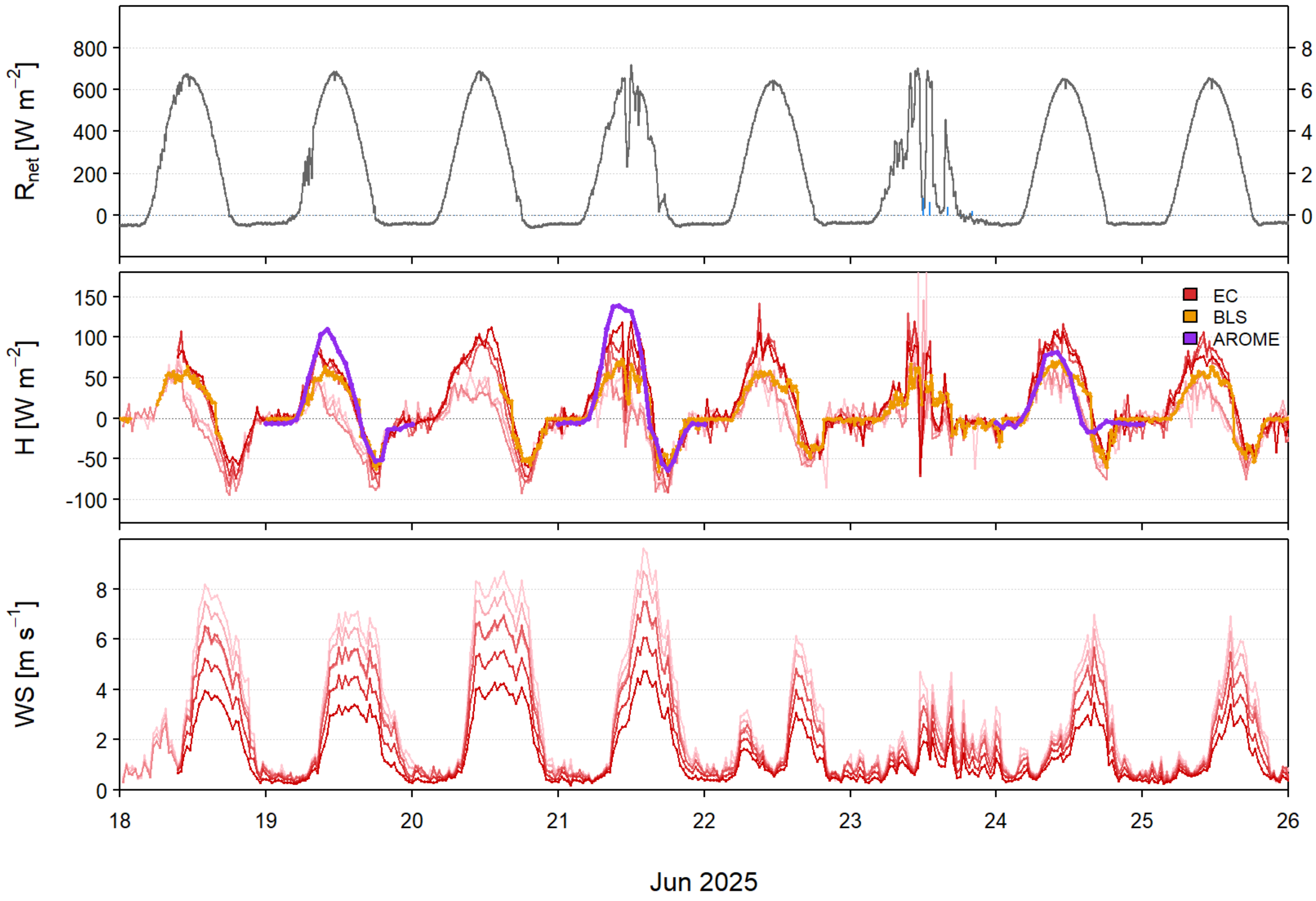
Scintillometer path (line), Kolsass i-Box station (cross) and additional eddy covariance stations (circles) during the TEAMx summer EOP.
Aerial imagery from Google Earth.

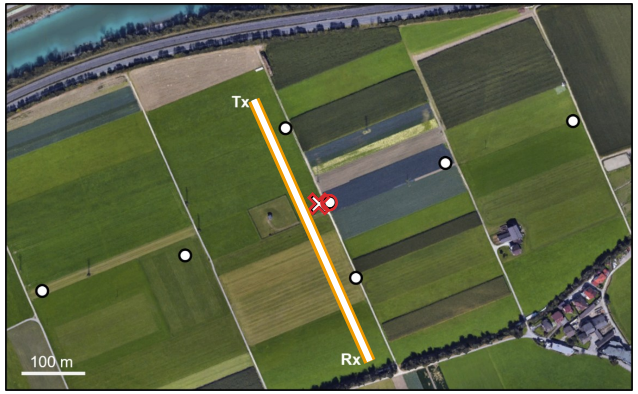
Field measurements and data processing

- BLS900 large aperture scintillometer deployed from 10 June-22 July 2025.
- Good data coverage from 15 June-16 July 2025 (due to power issues and height of crops).
- Quality control includes removing times of low signal strength (e.g. rain, condensation, misalignment).
- Scintillometer data processing requires additional information including displacement height (0.35 m), roughness length (0.05 m), approximate Bowen ratio (0.25) and the sign of the sensible heat flux. Sensitivity to these variables was investigated.

Photos: Lena Zelger

Comparison of sensible heat fluxes from BLS and EC





18-25 Jun: mostly clear valley wind days

Central EC tower with 6 levels (1 - 17 m)

Sensible heat flux peaks before noon and turns negative long before sunset
(Lehner et al. 2021)

Scintillometer is in good agreement with central EC measurement at similar height

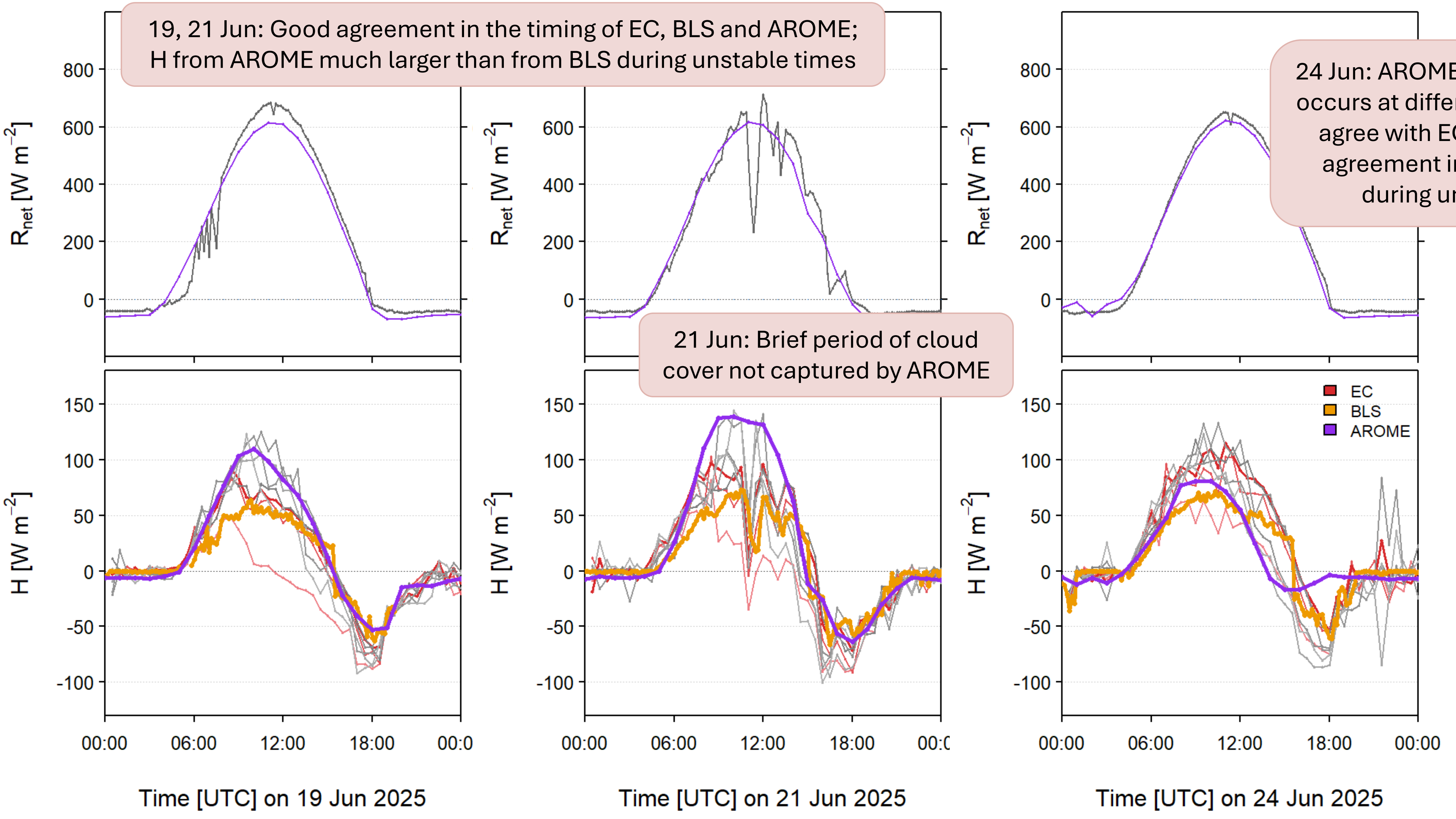
✓ → scintillometry can be used at a valley floor site in complex terrain

Comparison of observed fluxes with AROME model output

19, 21 Jun: Good agreement in the timing of EC, BLS and AROME; H from AROME much larger than from BLS during unstable times

21 Jun: Brief period of cloud cover not captured by AROME

24 Jun: AROME and BLS transition occurs at different times, yet both agree with EC stations; closer agreement in magnitude of H during unstable times



Summary

- Dataset of area-averaged sensible heat fluxes from the scintillometer collected for comparison with EC and model.
- Scintillometer fluxes consistent with EC, suggesting that scintillometry can be used even in this complex environment.
- All approaches (EC, BLS, AROME) capture the early change in sign of the sensible heat flux.
- Further work will include:
    - exploration of similarities and differences using data from the EC network and footprint analysis,
    - extension of model comparison to include more days and consider spatial representativity.

Photos: Lena Zelger

Acknowledgements

- We thank IWCR for providing the funding to make these two projects possible.
- We are grateful to everyone who assisted with fieldwork or provided data.