



Multi-scale **t**ransport and **e**xchange processes in the **a**tmosphere
over **m**ountains – programme and **e**xperiment

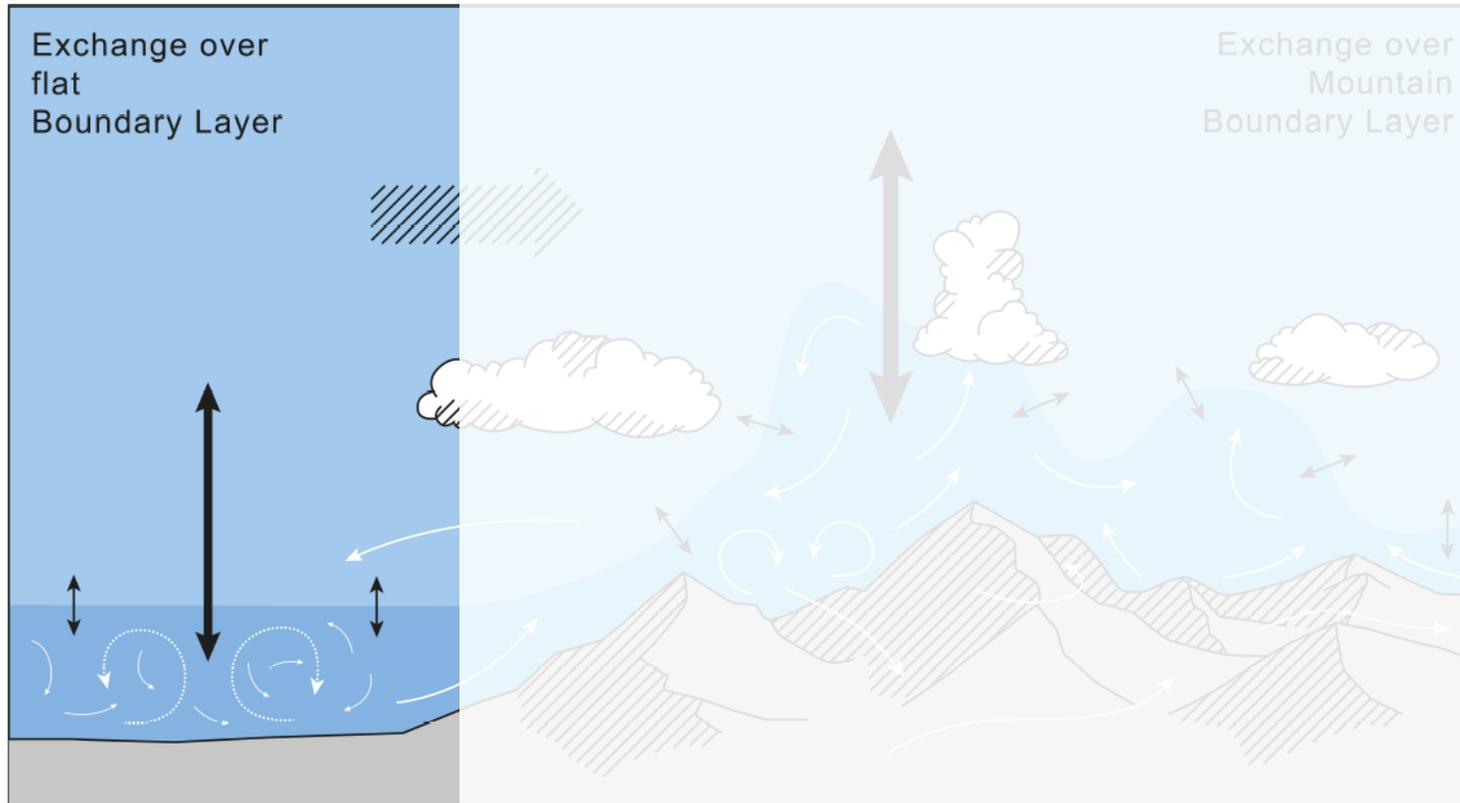
The TEAMx Observational Campaign

Manuela Lehner (University of Innsbruck)

... and the TEAMx Coordination and Implementation Group, Task Teams, Working Groups,
Committees, Target Area Representatives, and the whole TEAMx community

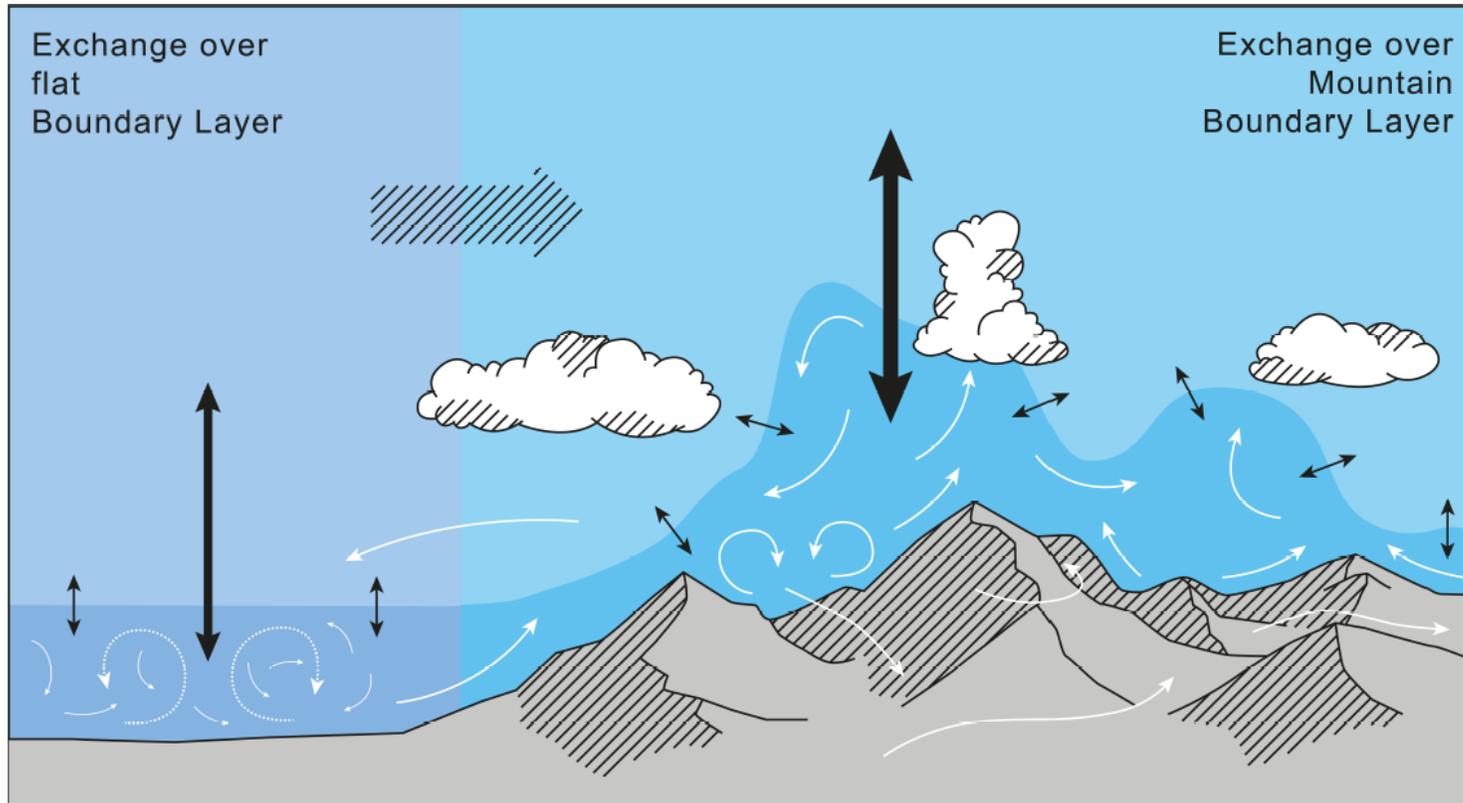


Mountain Boundary Layer (MoBL)



- ▲ Horizontally homogeneous conditions
- ▲ Exchange due to vertical turbulent transport
- ▲ Turbulence parameterizations based on observations for flat terrain and homogeneous terrain

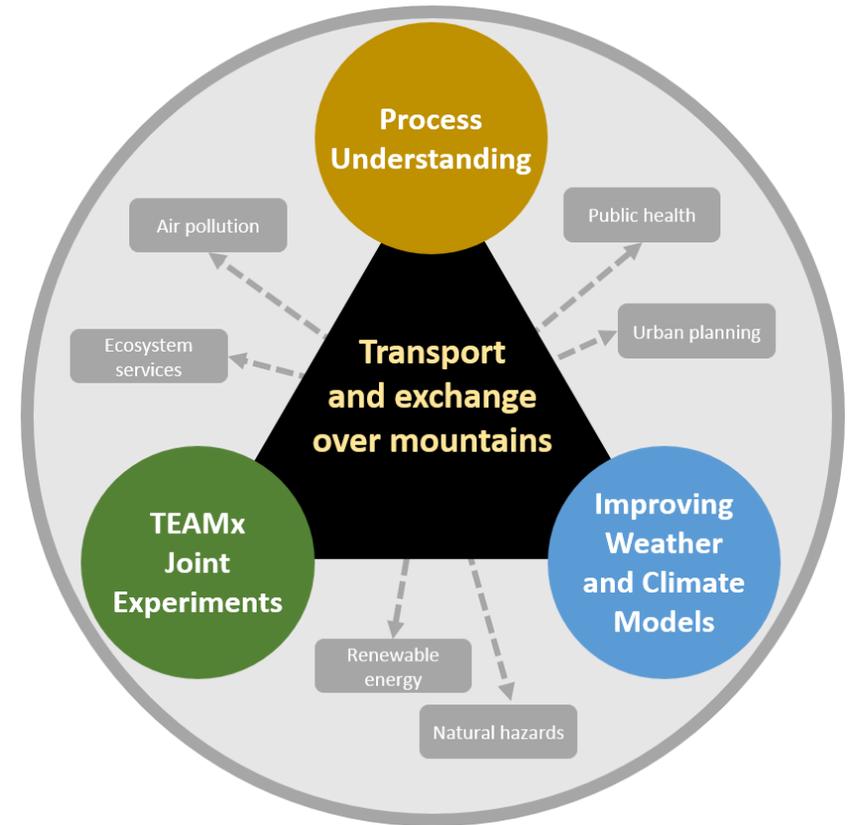
Mountain Boundary Layer (MoBL)



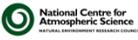
- ▲ Wide range of scales
- ▲ Interacting processes
- ▲ 3D spatial variability
- ▲ Processes that are difficult to measure/model
- ▲ Questionable applicability of measurement/modelling techniques

TEAMx Goals

- ▲ Improving our understanding of transport and exchange processes between the surface and the atmosphere and within the atmosphere
- ▲ Evaluating and improving weather and climate models over complex terrain
- ▲ Collecting a unique dataset to study the transport and exchange processes
- ▲ Reducing errors in impact models



TEAMx Community

| | | | |
|---|---|--|---|
|  UNIVERSITY OF VIRGINIA |  METEO FRANCE |  UNIVERSITY OF TRENTO - Italy |  universität innsbruck |
|  MeteoSwiss |  C2SM Center for Climate Systems Modeling |  McGill UNIVERSITY |  KIT Karlsruher Institut für Technologie |
|  National Centre for Atmospheric Science |  ISAC |  ARPAL Agenzia regionale per la protezione dell'ambiente |  Met Office |
|  GeoSphere Austria |  Icelandic Met Office |  University of Colorado Boulder |  arpa FVG meteo |
|  ETEMPS Center of Excellence Translating of Environment and Model Prediction of Severe events |  University of Reading |  Wegener Center |  UNI GRAZ |
|  DLR |  WSL |  SLF |  EMBRY-RIDDLE Aeronautical University |
| | | |  Deutscher Wetterdienst Wetter und Klima aus einer Hand |

| | | | |
|---|---|--|--|
|  UNIVERSITY OF ICELAND |  UEA University of East Anglia |  universität wien |  BOKU Universität für Bodenkultur Wien |
|  arpav Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto |  MOUNTAIN RESEARCH INITIATIVE |  CHARLES UNIVERSITY |  CONICET |
|  HUMBOLDT-UNIVERSITÄT ZU BERLIN |  Universität Basel |  LMU MIM |  UNIVERSITY OF BERGEN |
|  FSSL European Severe Storms Laboratory |  BEWÄHRUNGSSCHUTZ PROTEKTIONSKOMITEE |  Consiglio Nazionale delle Ricerche |  UGA Université Grenoble Alpes |
|  UNIVERSITÄT ZU KÖLN |  UNIVERSITÀ CATTOLICA del Sacro Cuore | | |

Signatories of the Memorandum of Understanding

TEAMx Community

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Signatories of the Memorandum of Understanding

TEAMx is ...
 ... endorsed by

 ... a cross-cutting project of the

 Hydroclimate Panel

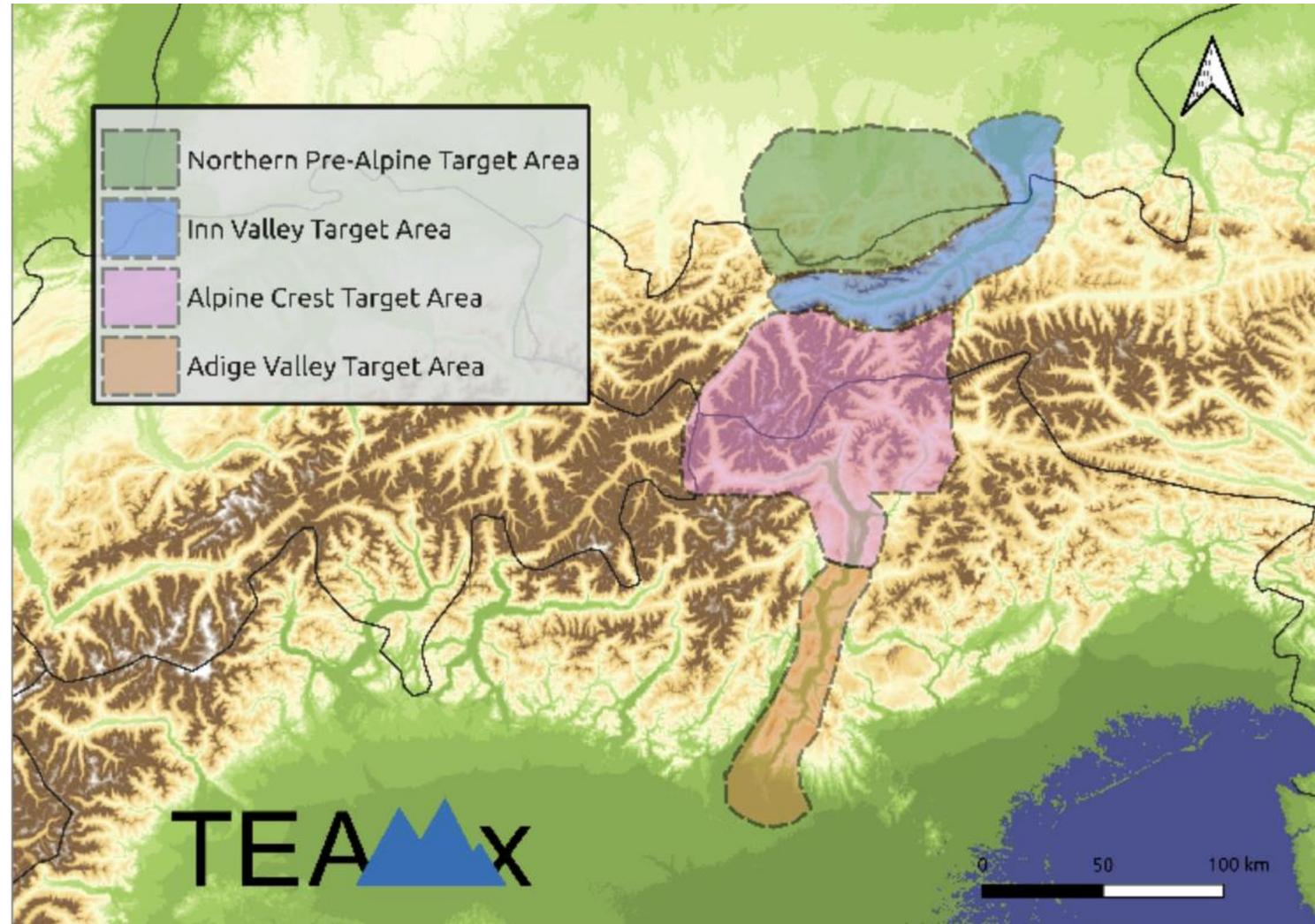


TEAMx Community

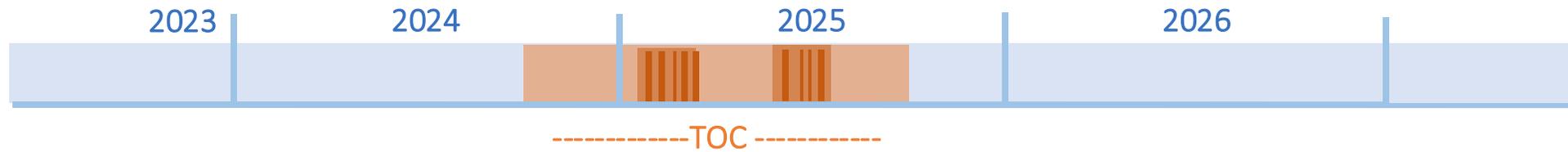


4th TEAMx Workshop (19–20 November 2024)

TEAMx Observational Campaign (TOC)



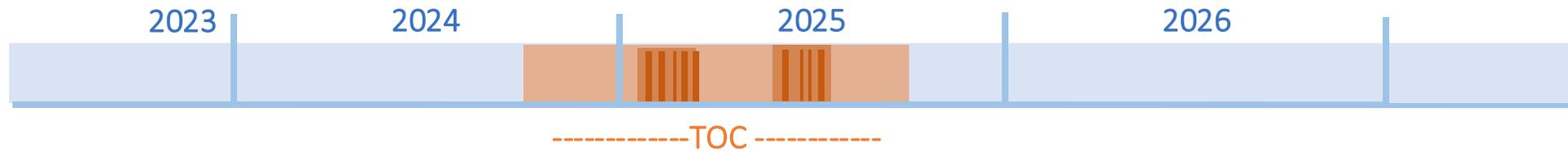
TEAMx Observational Campaign (TOC)



▲ One-year long TOC: Sep 2024 – Sep 2025



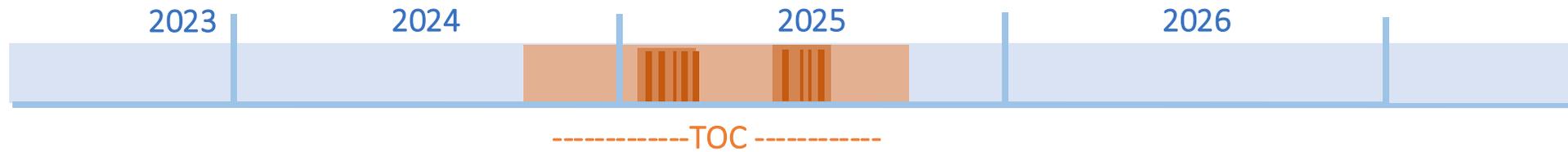
TEAMx Observational Campaign (TOC)



- ▲ One-year long TOC: Sep 2024 – Sep 2025
- ▲ Winter EOP (wEOP): Jan/Feb 2025
- ▲ Summer EOP (sEOP): Jun/Jul 2025



TEAMx Observational Campaign (TOC)



- ▲ One-year long TOC: Sep 2024 – Sep 2025
- ▲ Winter EOP (wEOP): Jan/Feb 2025
- ▲ Summer EOP (sEOP): Jun/Jul 2025
- ▲ IOPs targeting specific weather conditions



Aircraft activities

Coordinated flights in ACTA desired, vertically stacked?

Coordinated flights in IVTA, vertically stacked



Low level
Cessna Caravan



Credit: DLR (CC BY-NC-ND 3.0)





Technische
Universität
Braunschweig

Low-mid level
Cessna F406



Credit: Florian Szczepanek, AviationMedia.com




FAAM  Mid-up level
BAe146



Credit: FAAM (CC BY-NC-SA 2.0)



National Centre for
Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

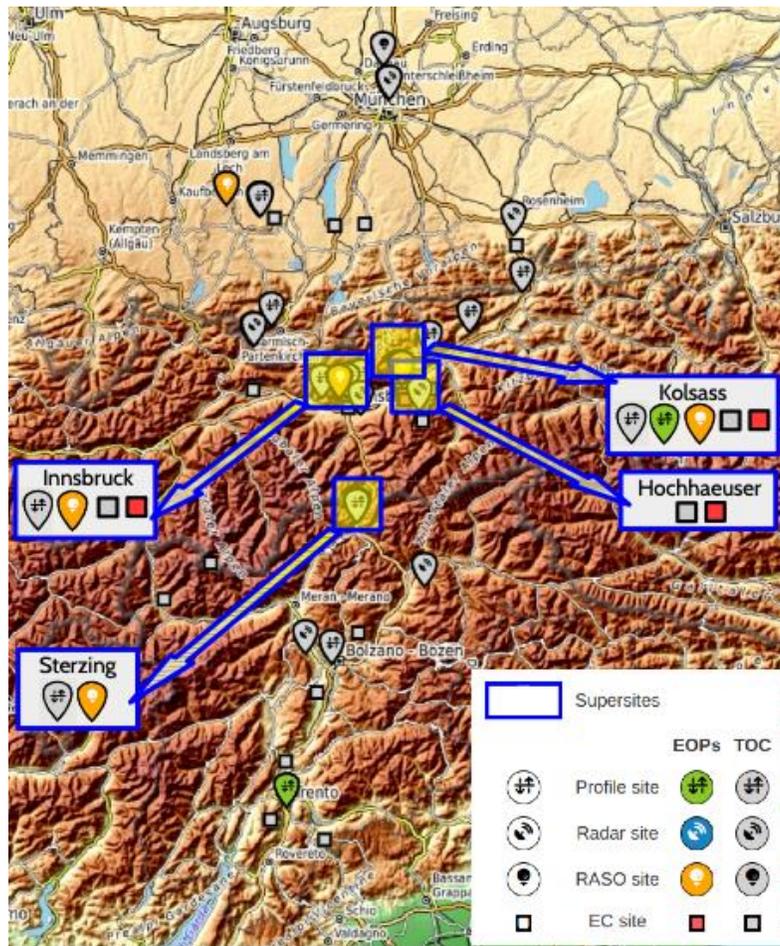
IVTA, PATA

IVTA, ACTA

ACTA

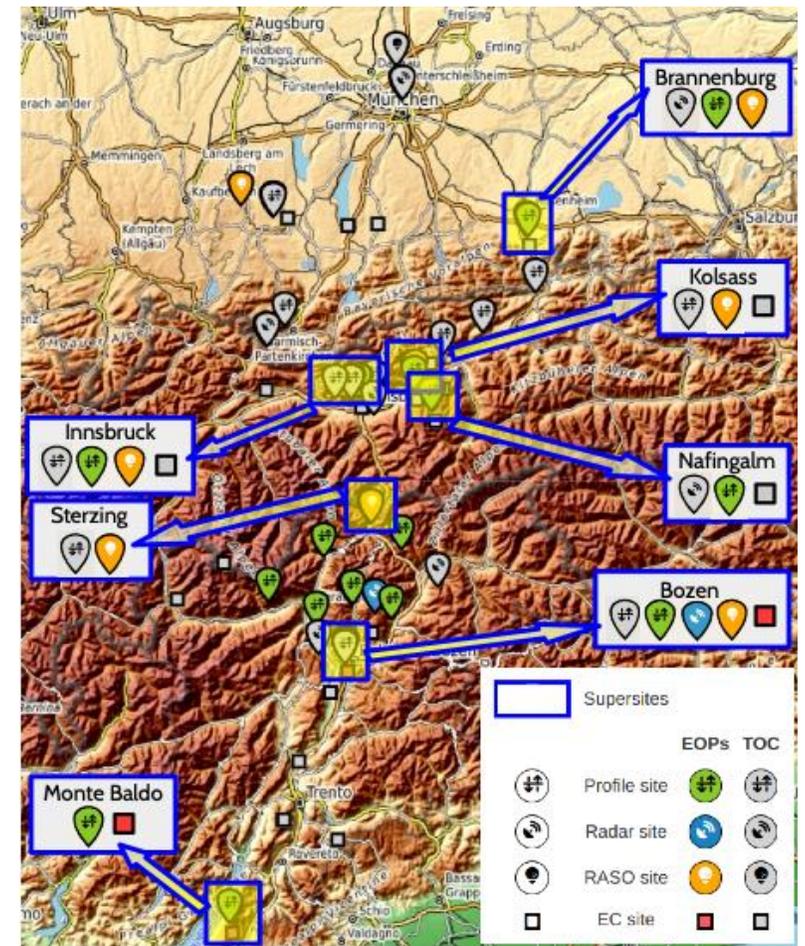
Slide credit: Philipp Gasch (KIT)

TEAMx Observational Campaign (TOC)



Instrumentation during the

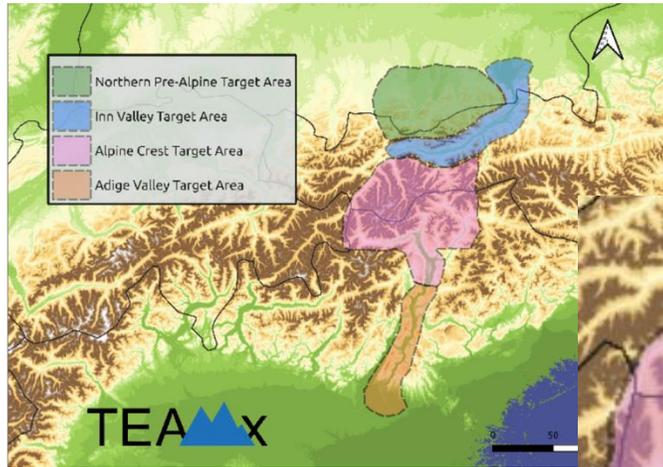
WEOP



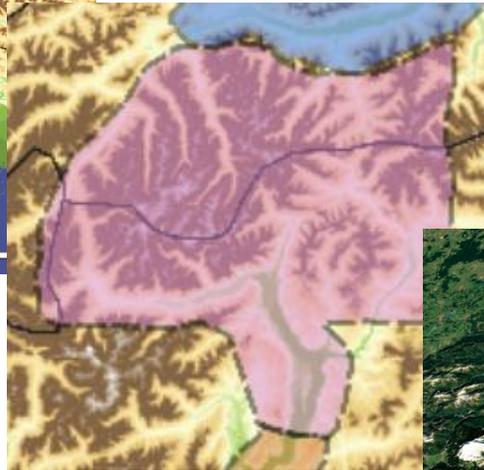
sEOP

Multi-scale processes

Alpine scale



Regional/target-area scale



Valley scale

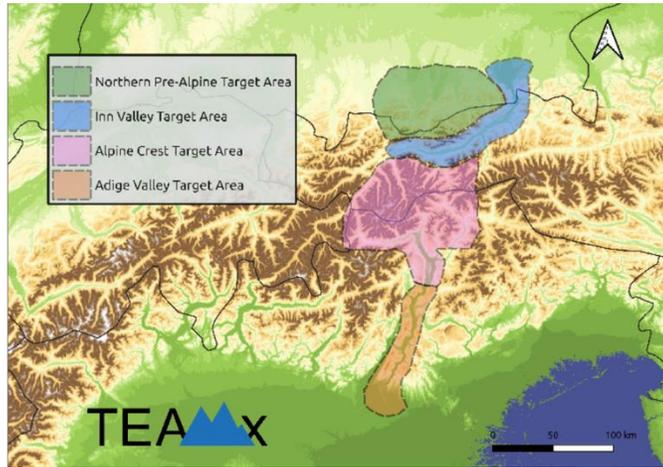


Local scale

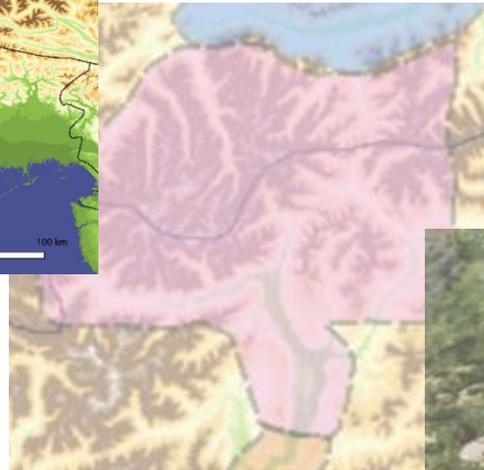


Alpine scale

Alpine scale



Regional/target-area scale



Valley scale

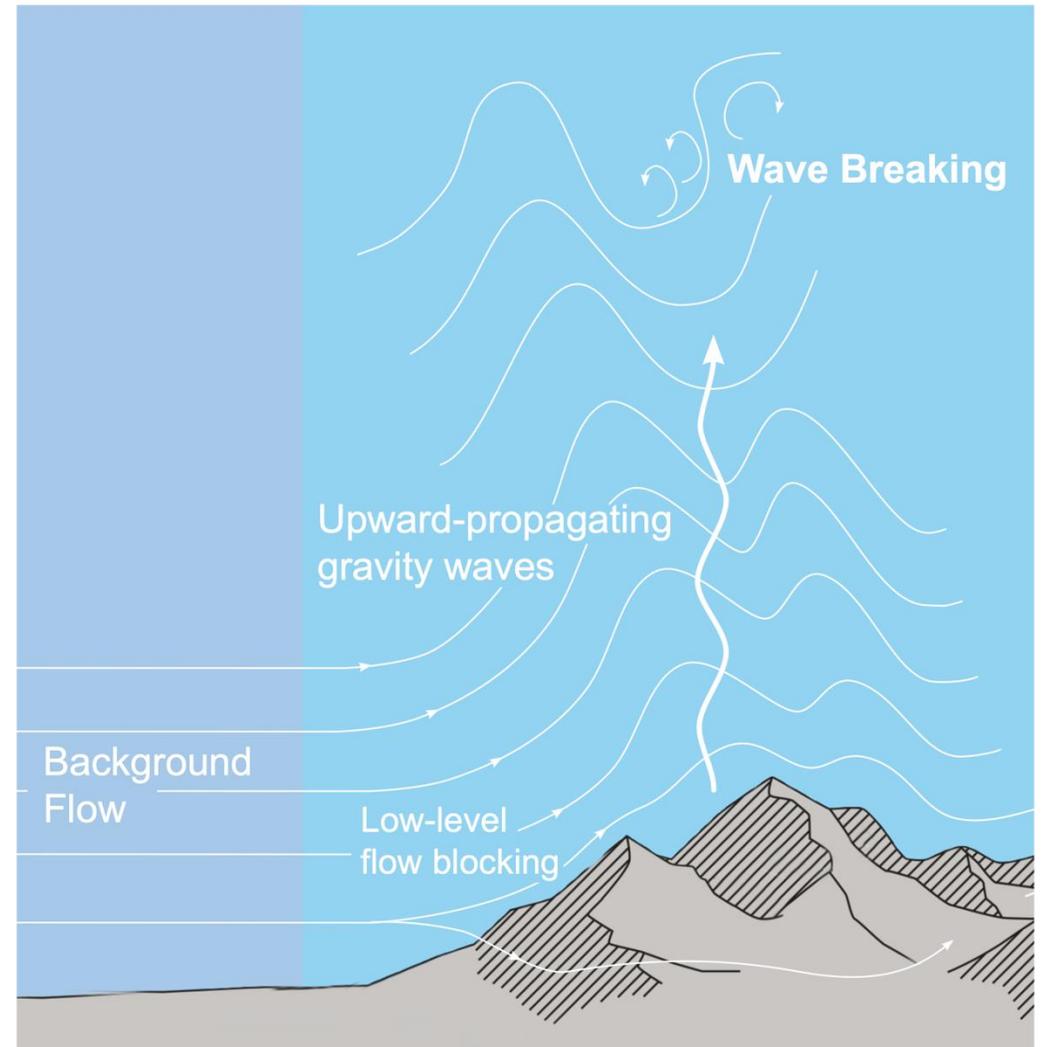


Local scale



Mountain waves

- ▲ Orographic blocking
- ▲ Gravity wave breaking and turbulence production
- ▲ Orographic drag parameterizations

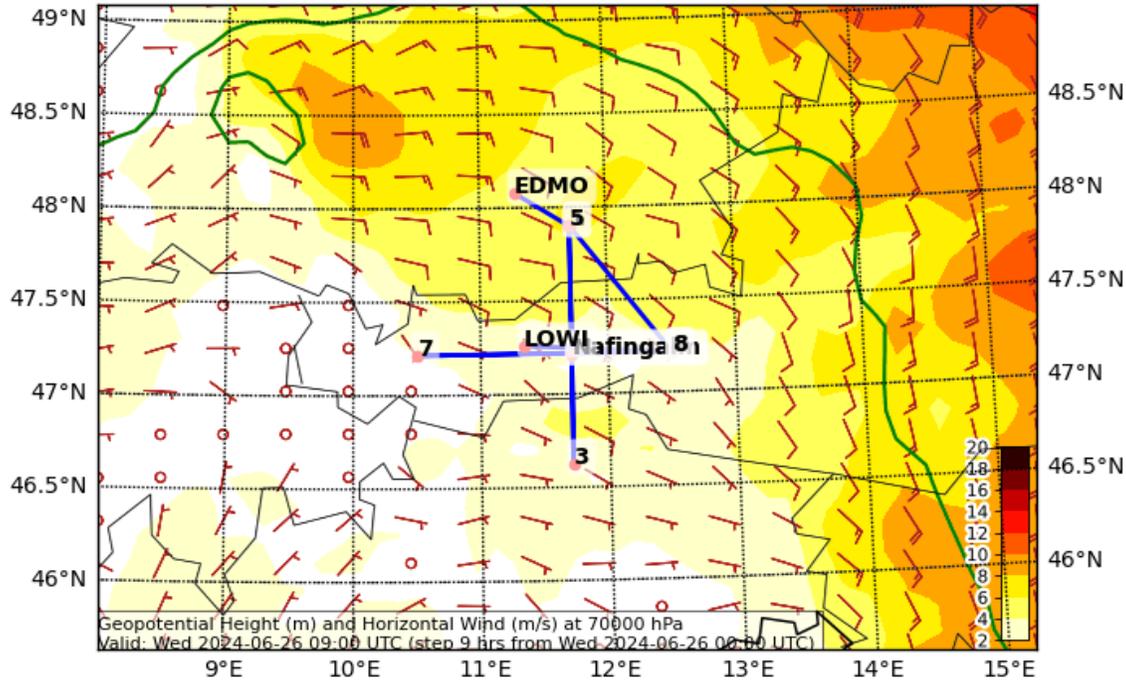


Credit: Andrew Orr (British Antarctic Survey)

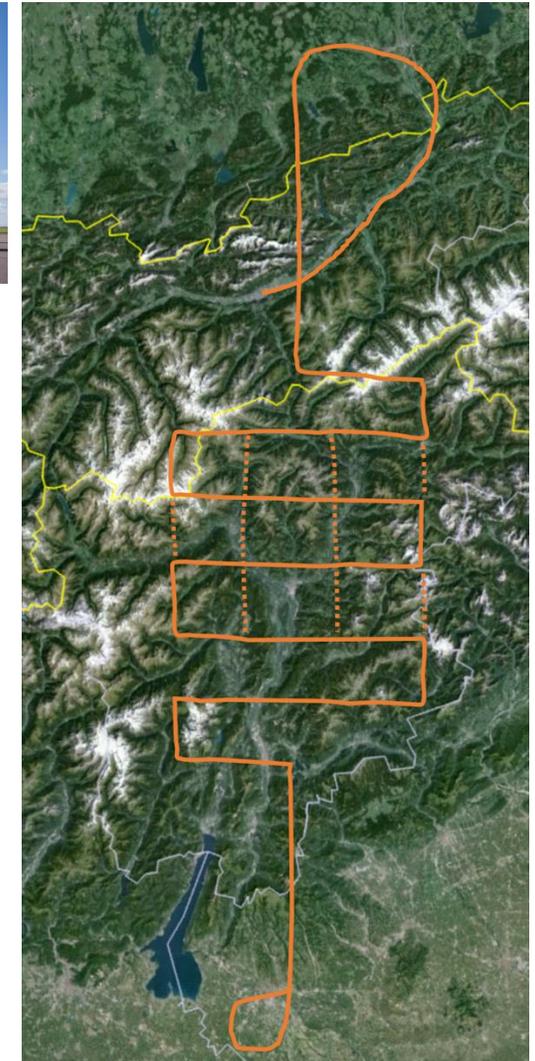
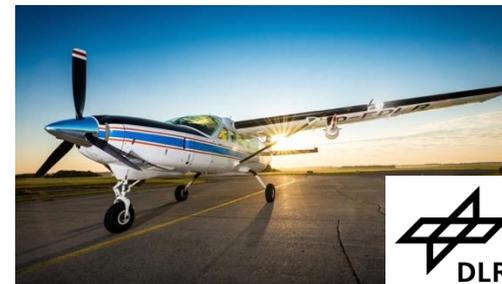
Mountain waves



Geopotential Height (m) and Horizontal Wind (m/s) (wind_2_20) at 70000.0 (Pa)
Valid: 2024-06-26T09:00:00Z (initialisation: 2024-06-26T00:00:00Z)



Credit: Sonja Gisinger (DLR), Philipp Gasch (KIT)



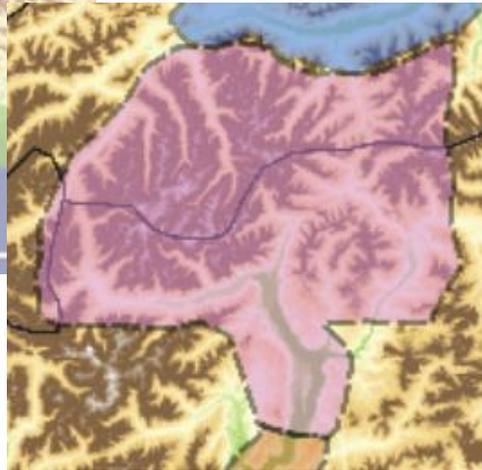
Credit: Philipp Gasch (KIT)

Regional/target-area scale

Alpine scale



Regional/target-area scale



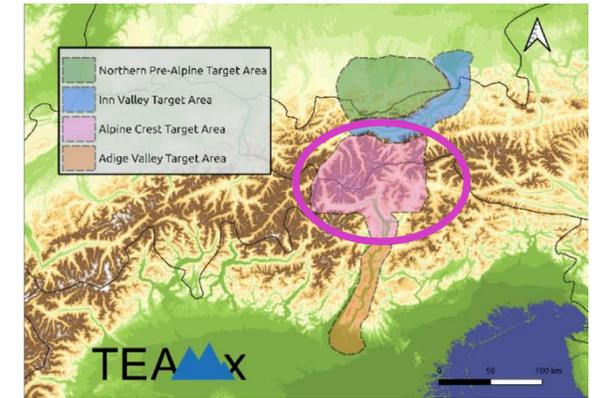
Valley scale



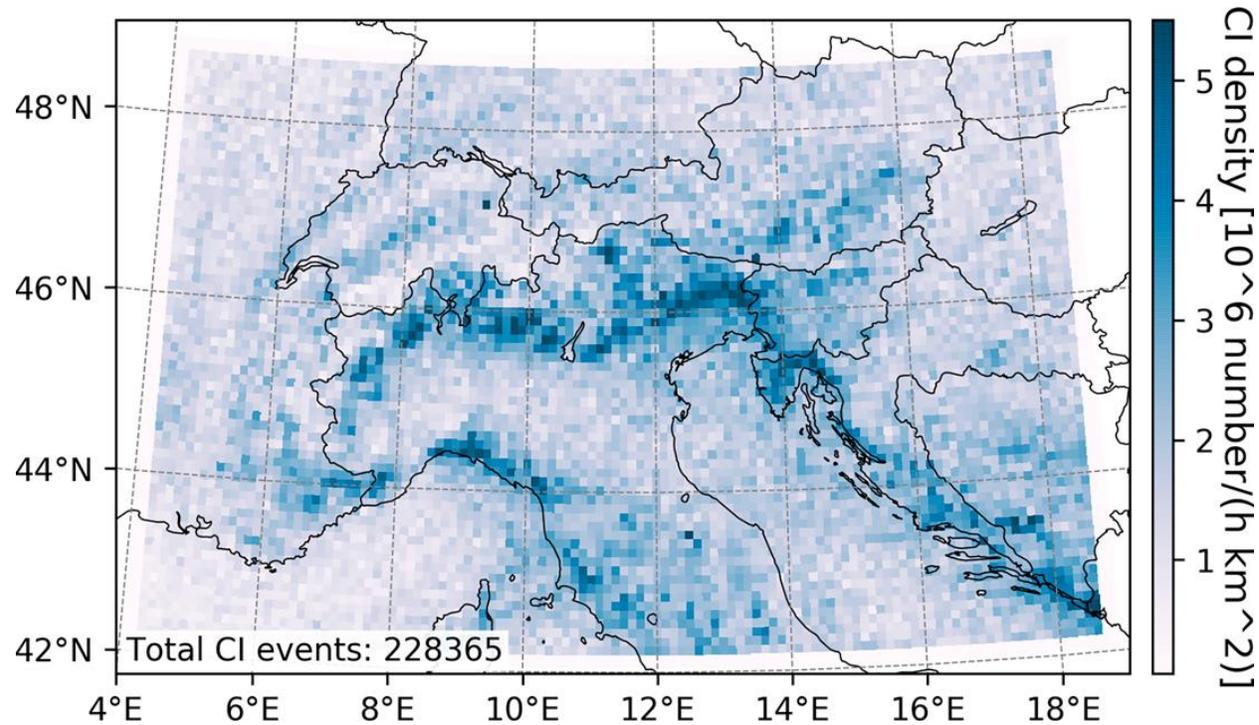
Local scale



Convection initiation and development

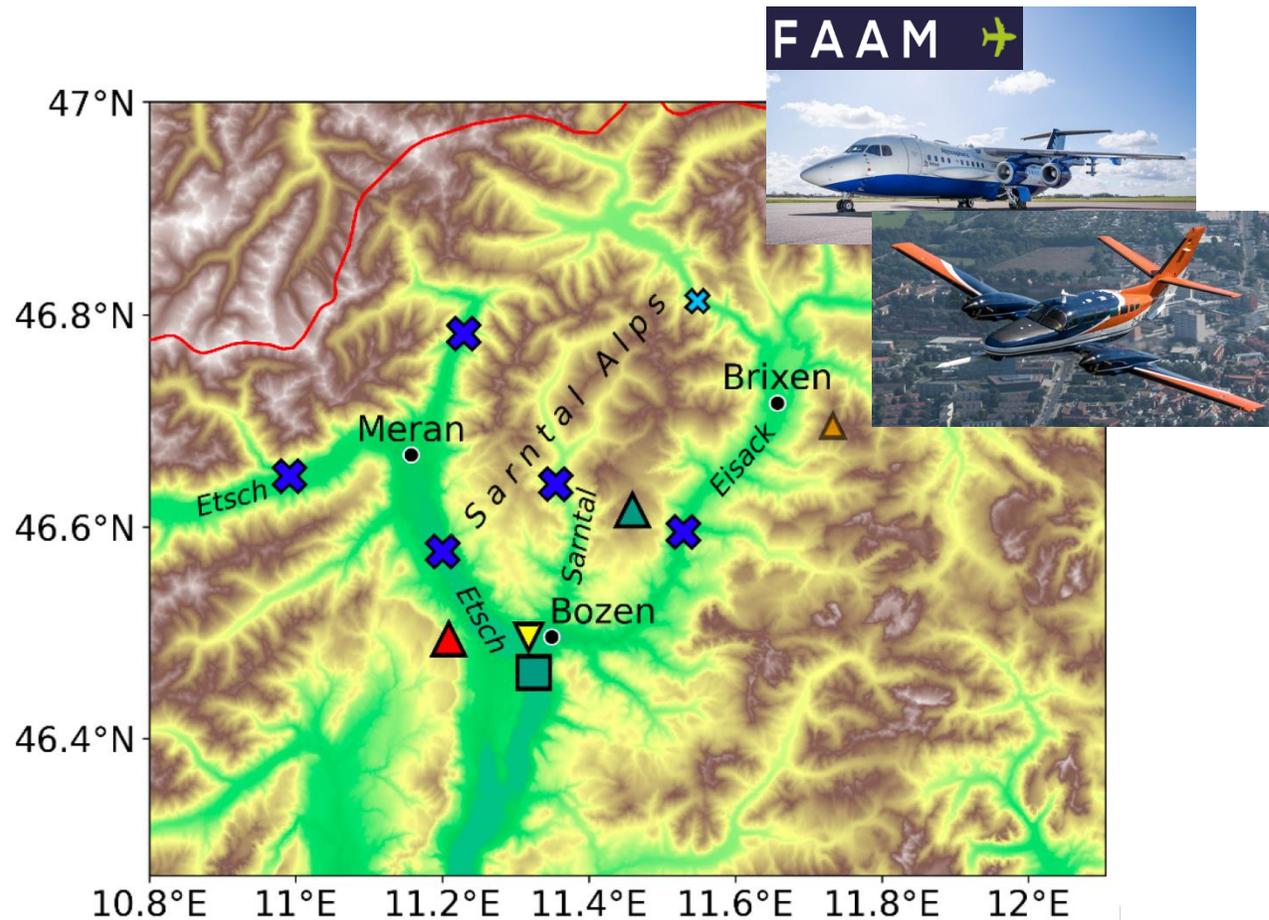
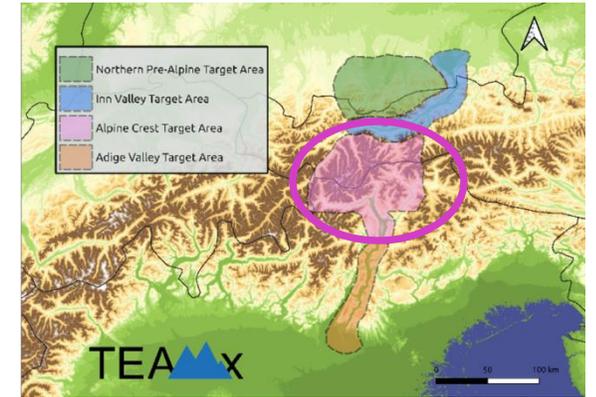


▲ Sarntal Alps: hotspot of convection initiation



Manzato et al. (2022) : A pan-Alpine climatology of lightning and convection initiation. Monthly Weather Review.

Convection initiation and development



- ▲ Sarntal Alps: hotspot of convection initiation
- ▲ Terrain influence on location, timing, and strength of convection
- ▲ Network of radars, wind lidars, and DIAL
- ▲ KIT, NCAS, University of Cologne, University of Vienna

Credit: Jan Handwerker (KIT)

Valley scale

Alpine scale



Regional/target-area scale



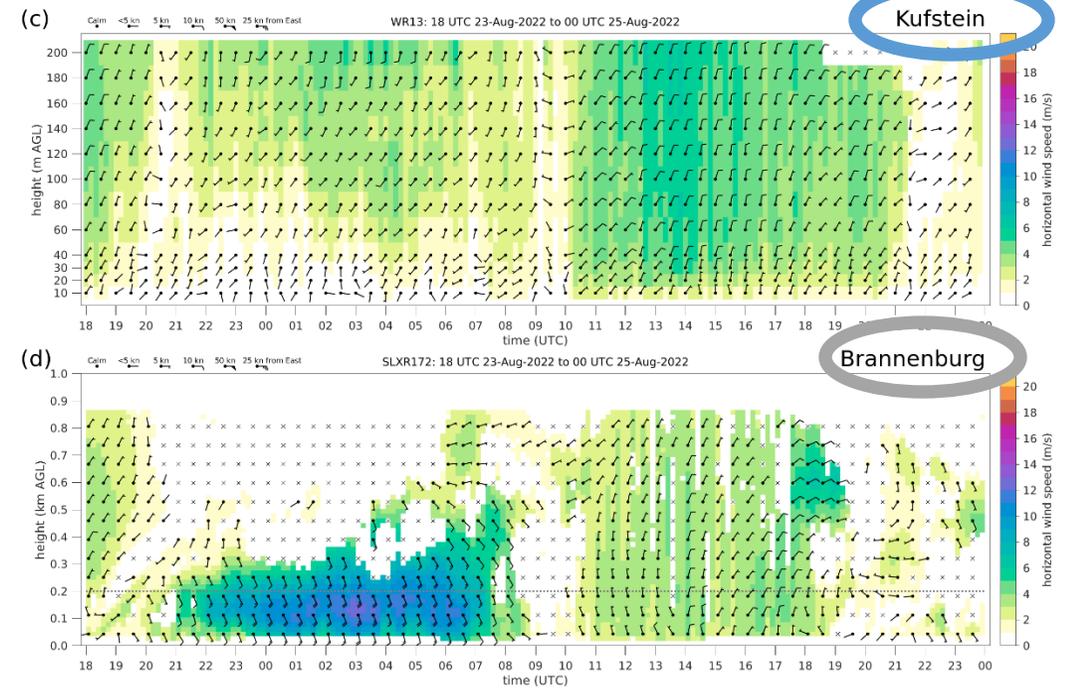
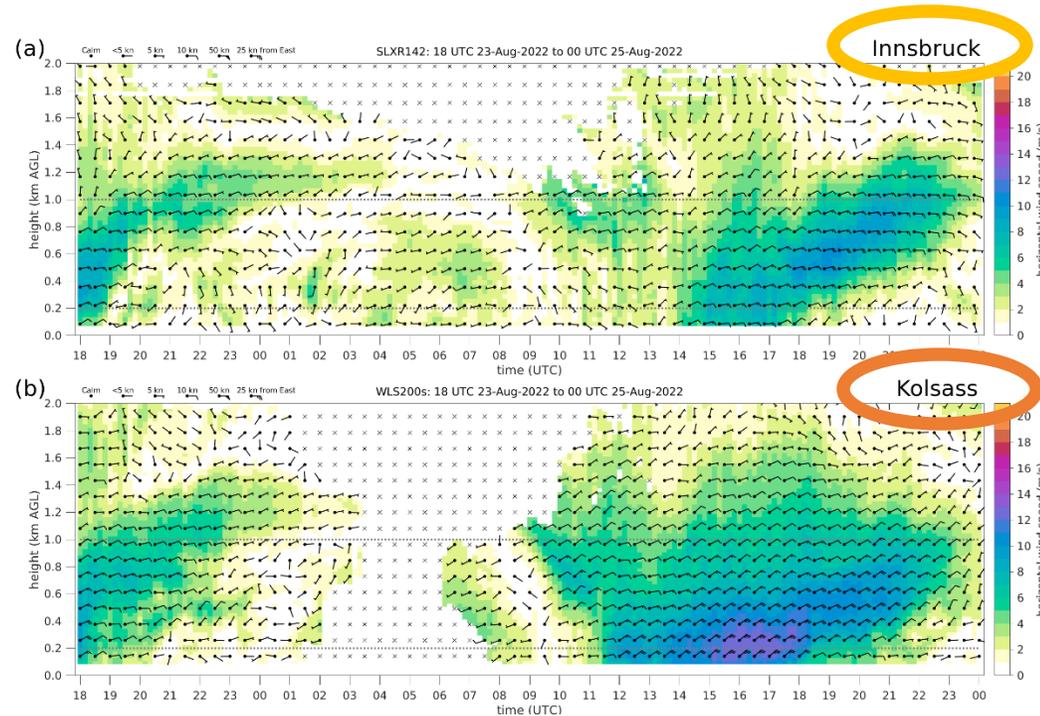
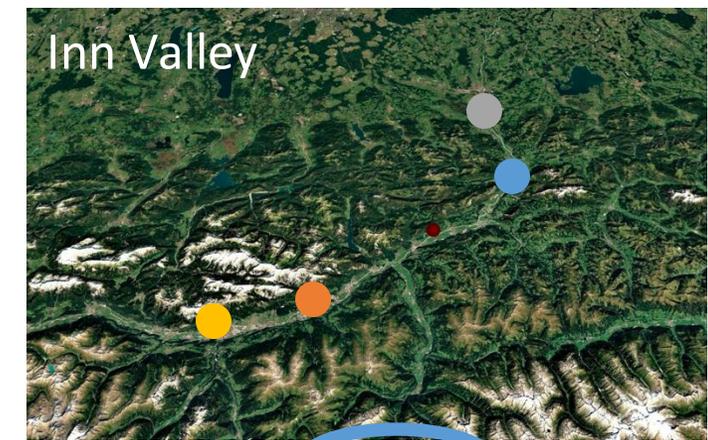
Valley scale



Local scale

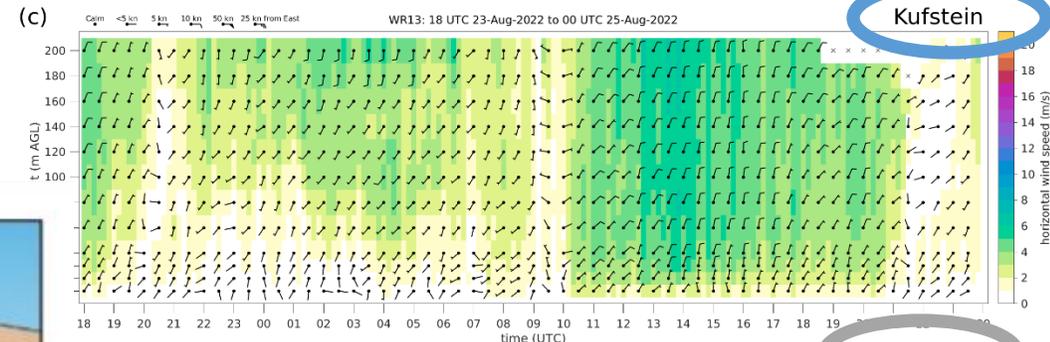
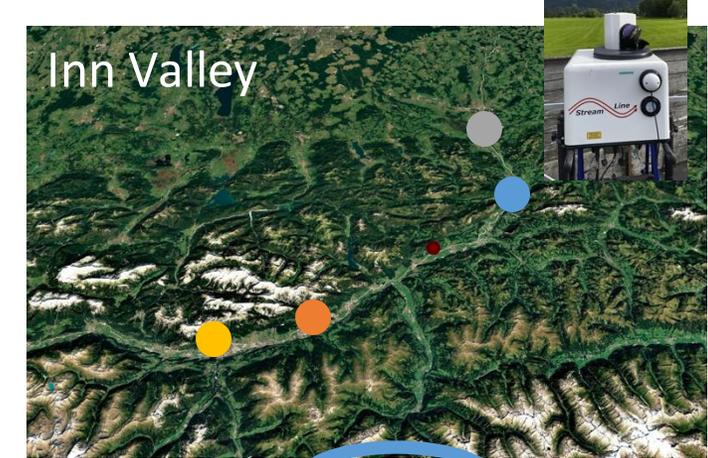


MoBL structure

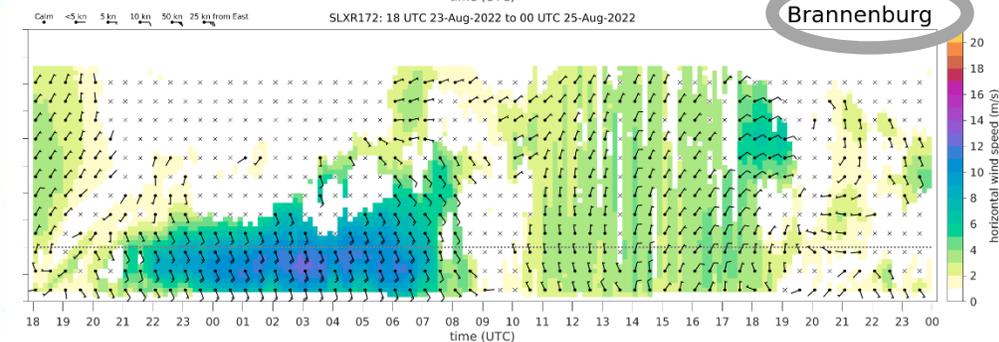
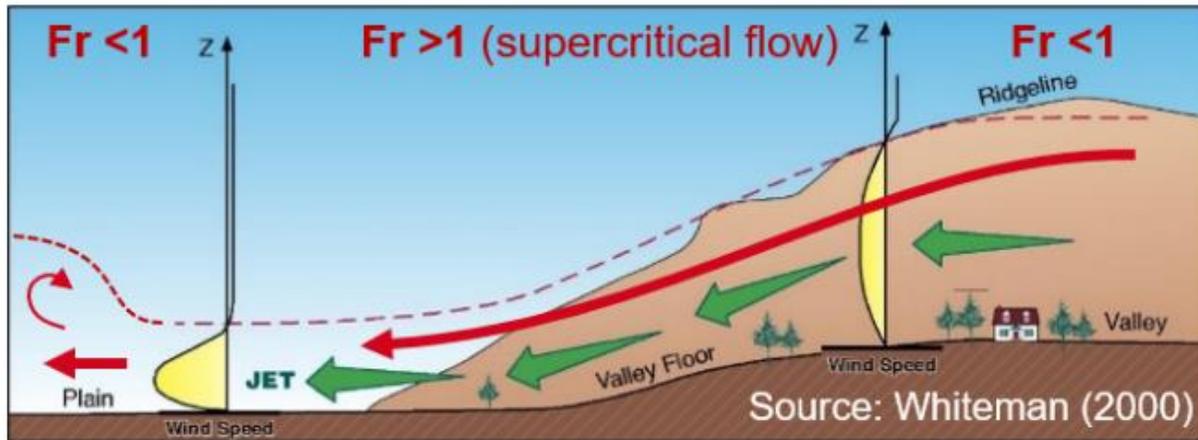


Pfister et al. (2024): The TEAMx-PC22 Alpine field campaign – objectives, instrumentation, and observed phenomena. Meteorologische Zeitschrift

MoBL structure



Valley-exit jet



Pfister et al. (2024): The TEAMx-PC22 Alpine field campaign – objectives, instrumentation, and observed phenomena. Meteorologische Zeitschrift

MoBL structure

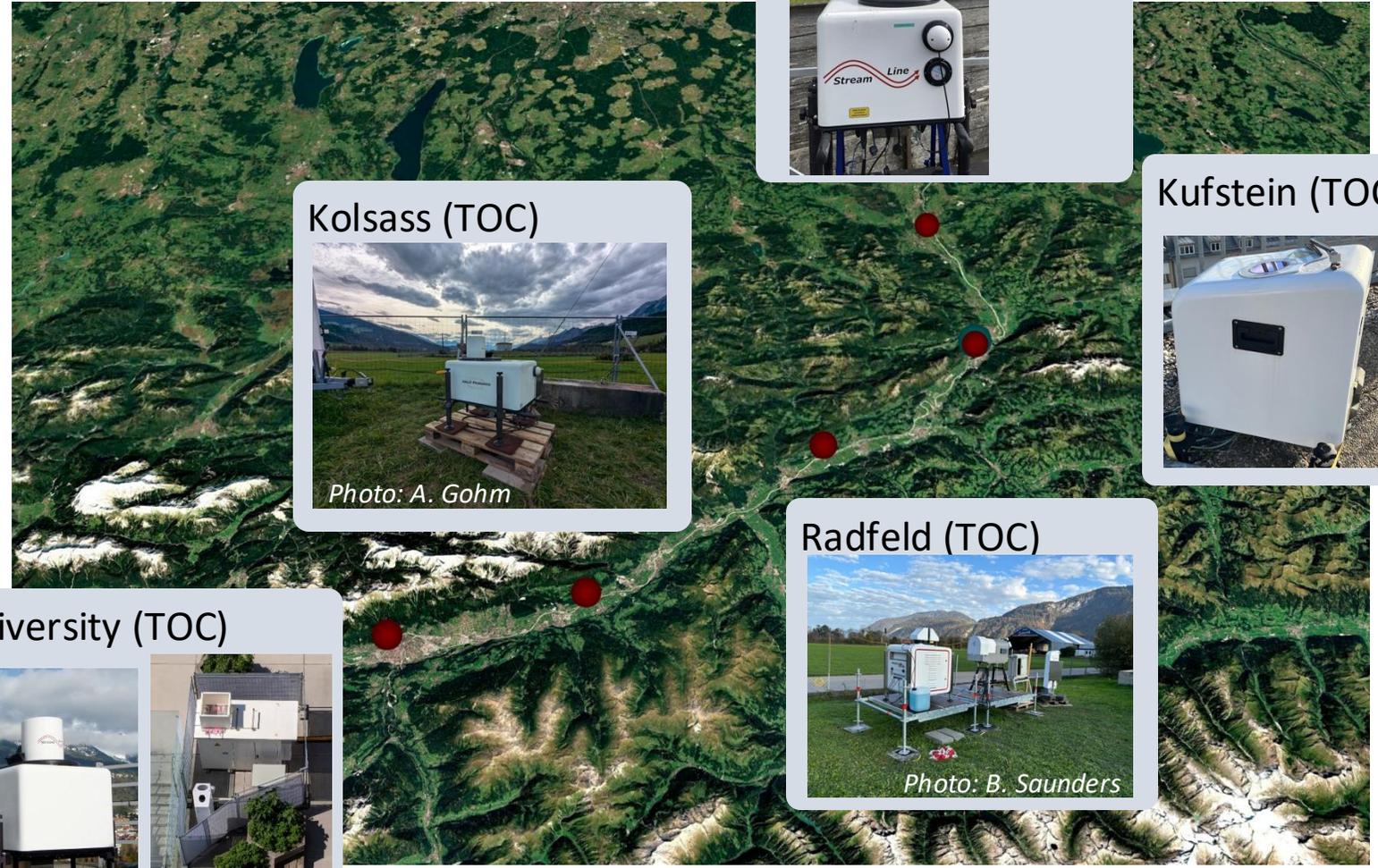
University of Innsbruck

KIT

Meteo Swiss

GeoSphere Austria

DWD



Brannenburg (sEOP)



Kolsass (TOC)



Kufstein (TOC)



Radfeld (TOC)



Innsbruck University (TOC)



MoBL structure (IOPs)

University of Innsbruck

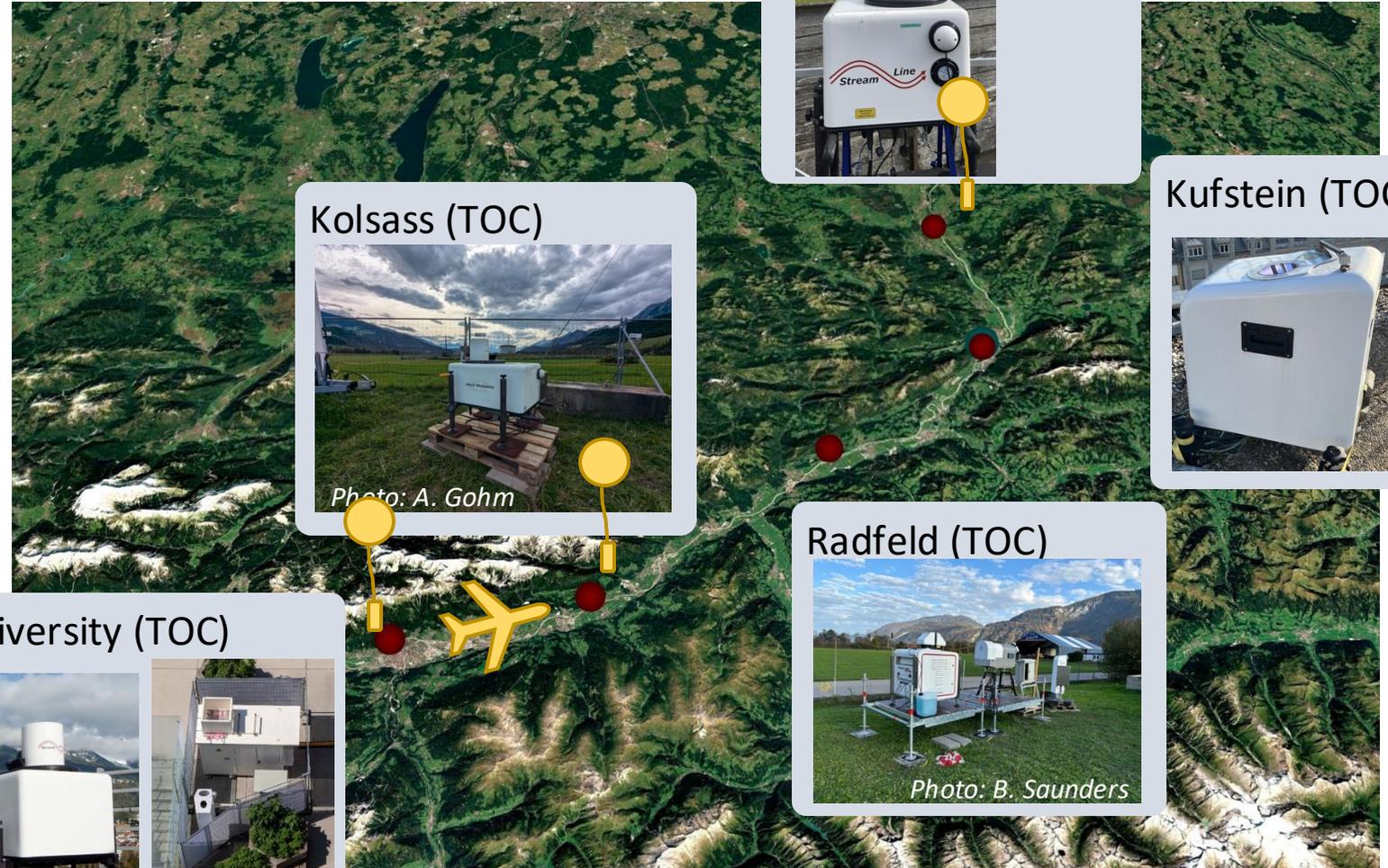
KIT

Meteo Swiss

GeoSphere Austria,

DWD

DLR



Brannenburg (sEOP)



Kolsass (TOC)



Photo: A. Gohm

Kufstein (TOC)



Radfeld (TOC)



Photo: B. Saunders

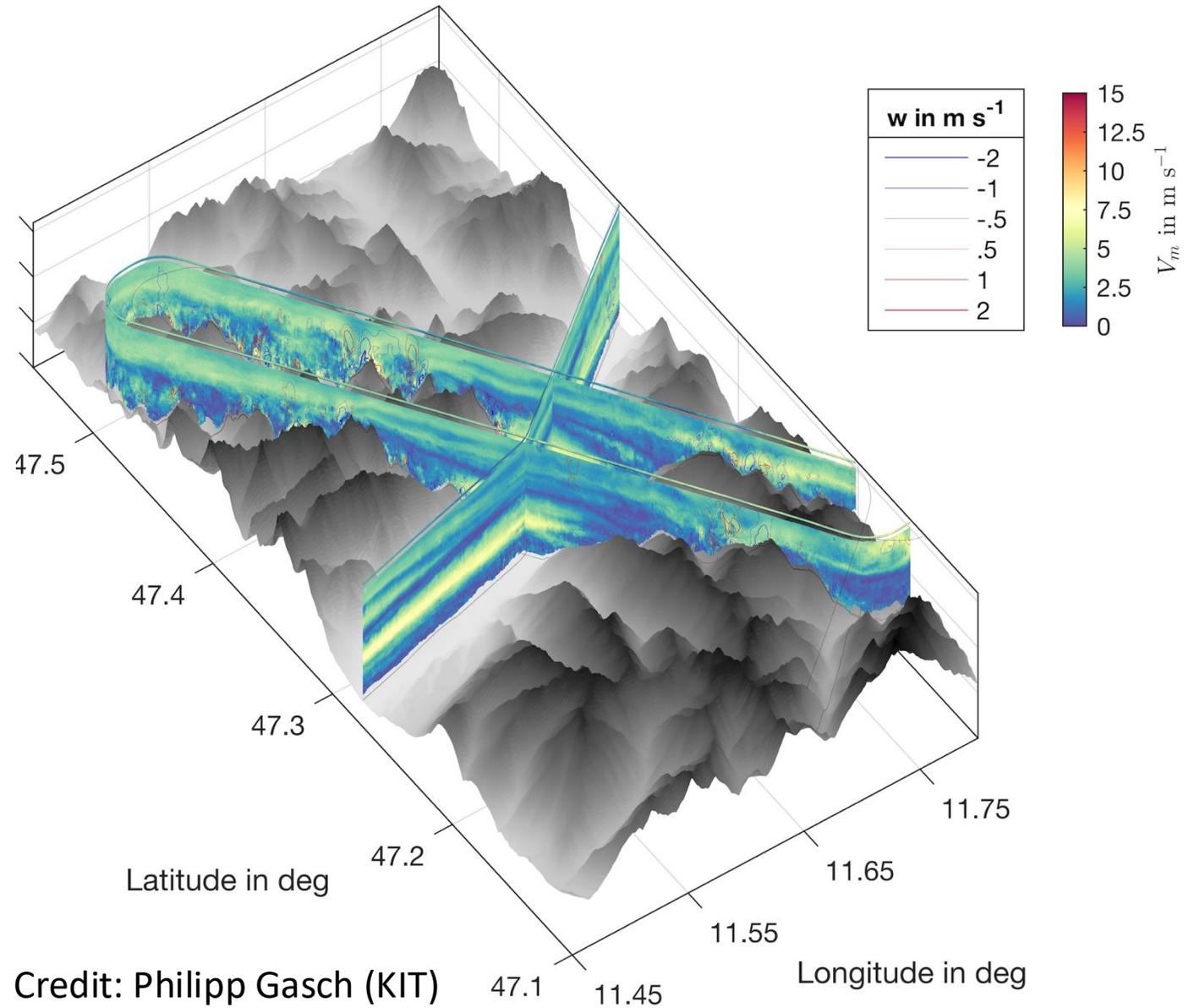
Innsbruck University (TOC)



Photos: A. Gohm

MoBL structure (IOPs)

- ▲ AIRflows: Novel 5-beam lidar onboard the TUBS Cessna F406
- ▲ Developed by KIT
- ▲ 3D wind field at 100-m resolution



Local scale

Alpine scale



Regional/target-area scale



Valley scale

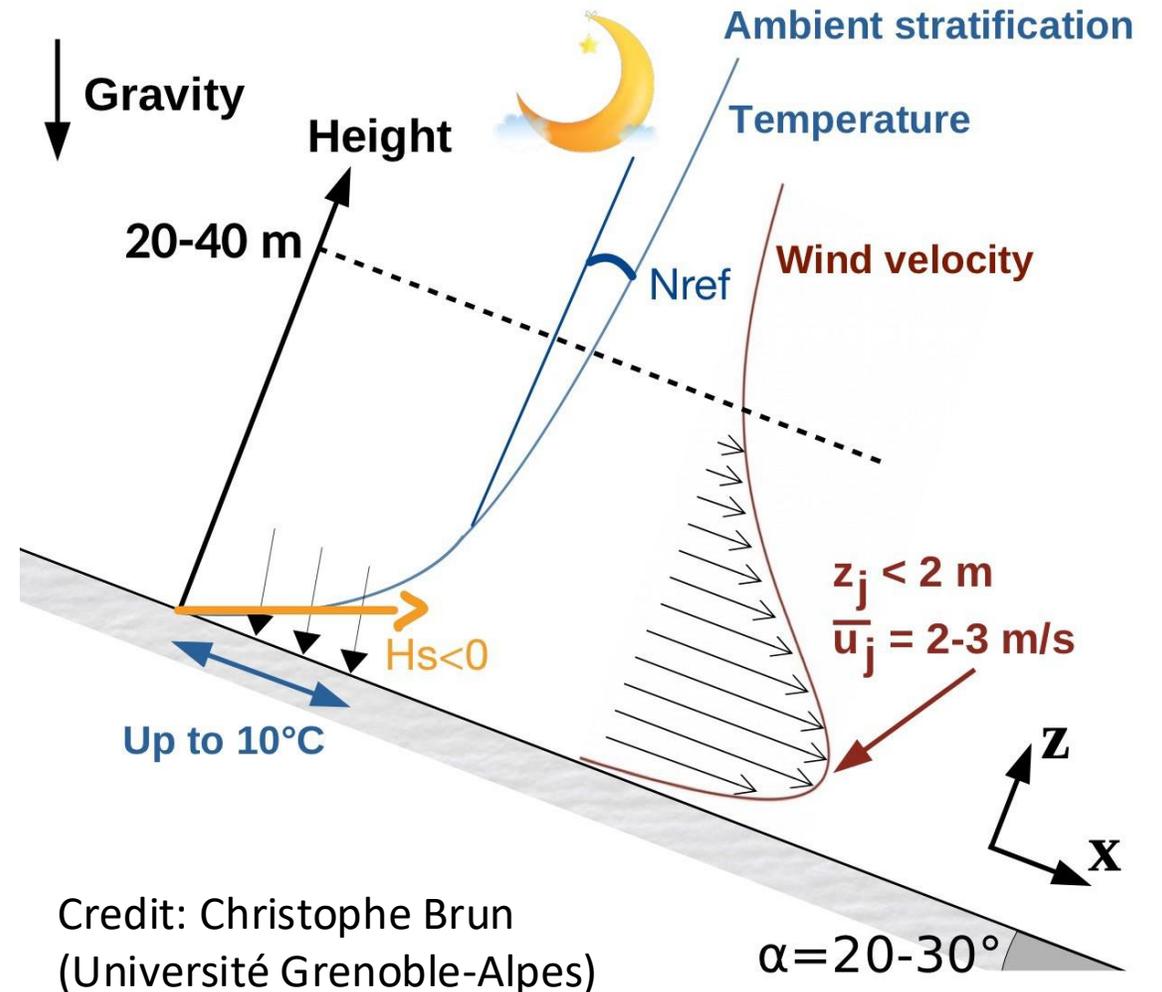


Local scale



Slope winds

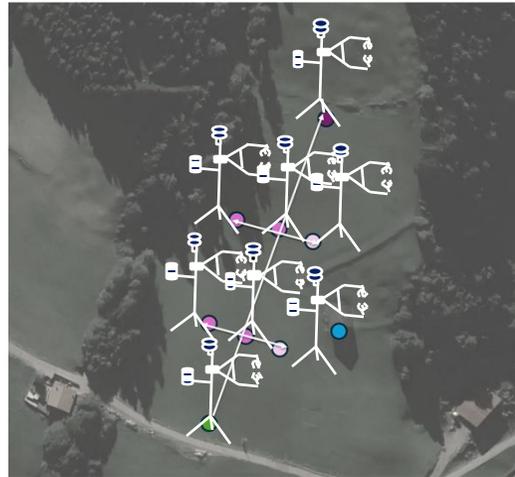
- ▲ Diurnal evolution of mean and turbulent slope-flow properties
- ▲ Turbulent properties of katabatic flows below and above the jet maximum
- ▲ Small-scale spatial variability of mean and turbulent properties
- ▲ Impact of small-scale terrain features and interactions with other flows



Slope-wind experiments

wEOP: i-Box site Hochhäuser (IVTA)

- ▲ Turbulence station network
- ▲ Distributed temperature sensing
- ▲ Wind lidar, tethered sonde, UAS
- ▲ UIBK, Université Grenoble Alpes

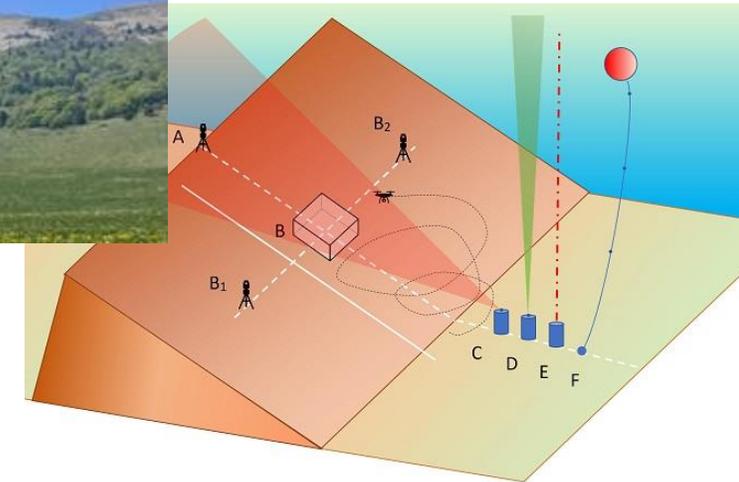


sEOP: Monte Baldo (AVTA)

- ▲ Turbulence tower
- ▲ Along-slope temperature profile
- ▲ Wind lidar, Raman lidar, ceilometer
- ▲ University of Trento, CNR, University of Bologna



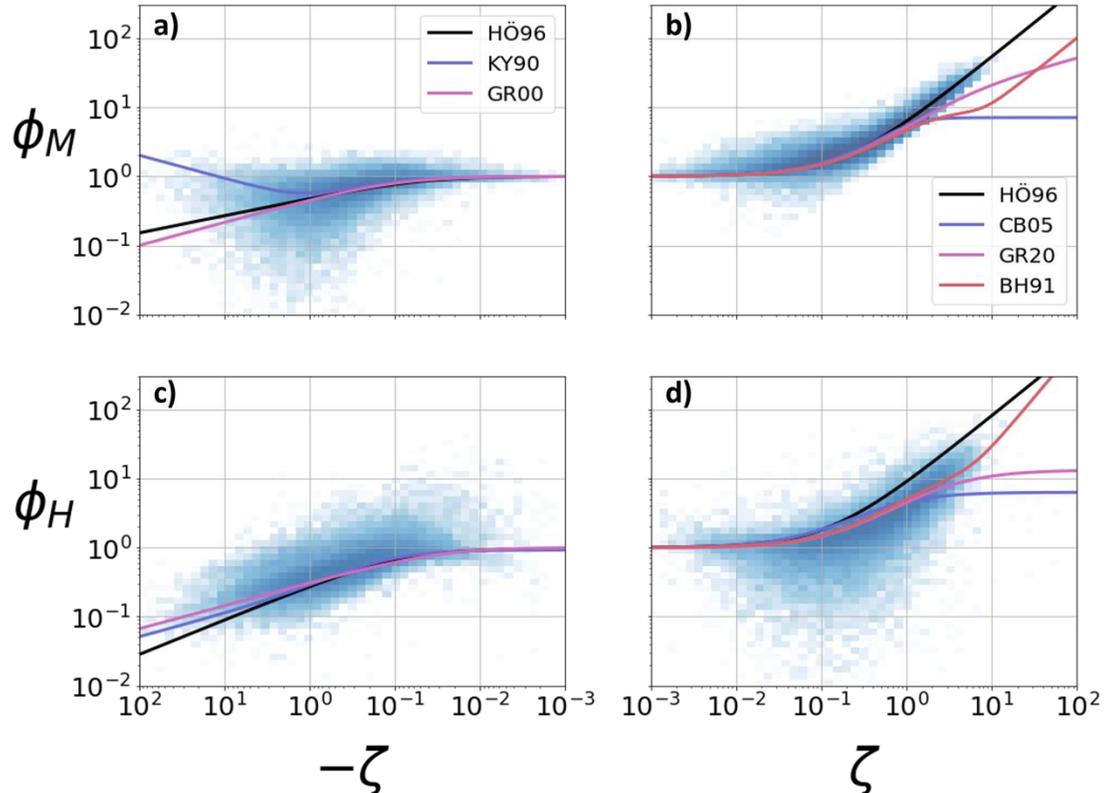
Credit: Dino Zardi



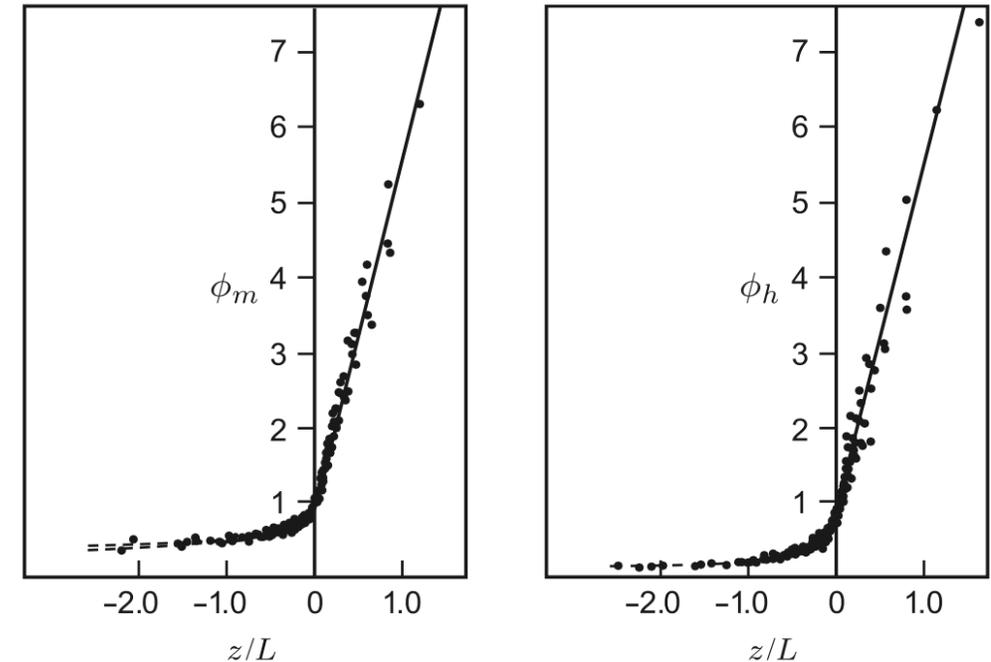
Turbulence scaling

$$\phi_M = \frac{\kappa z}{u_*} \frac{d\bar{u}}{dz}, \quad \phi_H = \frac{\kappa z}{\theta_*} \frac{d\bar{\theta}}{dz}$$

Complex terrain



Flat terrain

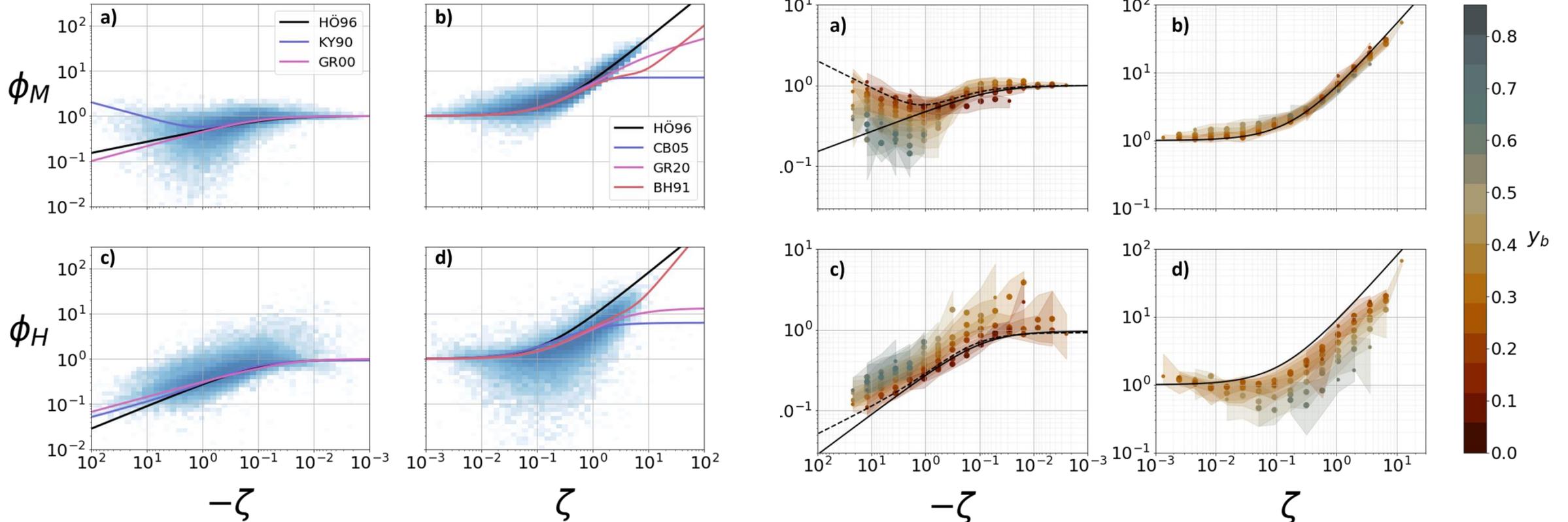


Mosso et al. (2024) : Flux-gradient relations and their dependence on turbulence anisotropy. Quarterly Journal of the Royal Meteorological Society

Credit: Ivana Stiperski (UIBK)

Turbulence scaling

$$\phi_M = \frac{\kappa z d\bar{u}}{u_* dz}, \quad \phi_H = \frac{\kappa z d\bar{\theta}}{\theta_* dz}$$

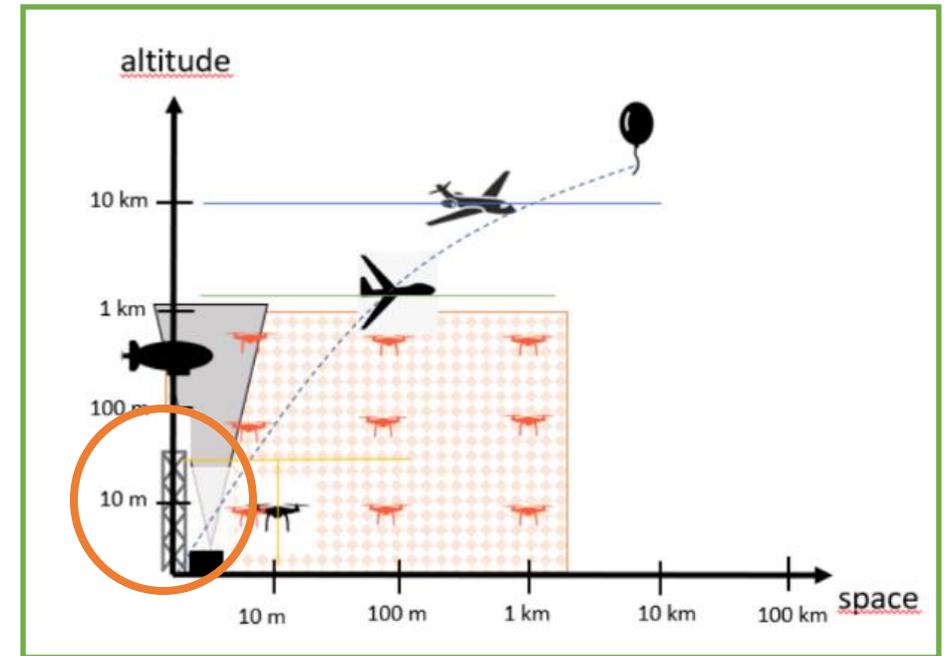
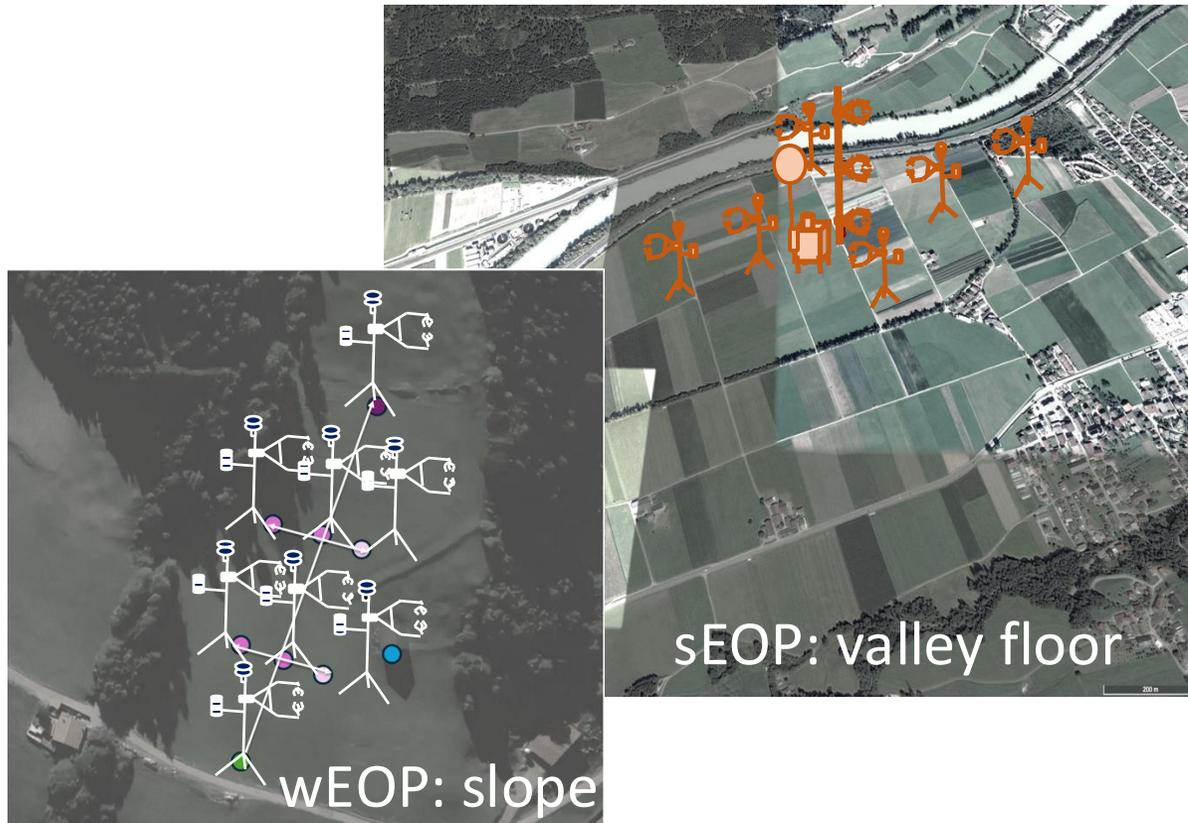


Mosso et al. (2024) : Flux-gradient relations and their dependence on turbulence anisotropy. Quarterly Journal of the Royal Meteorological Society

Credit: Ivana Stiperski (UIBK)

Turbulence measurements

Turbulence station networks (UIBK and others)



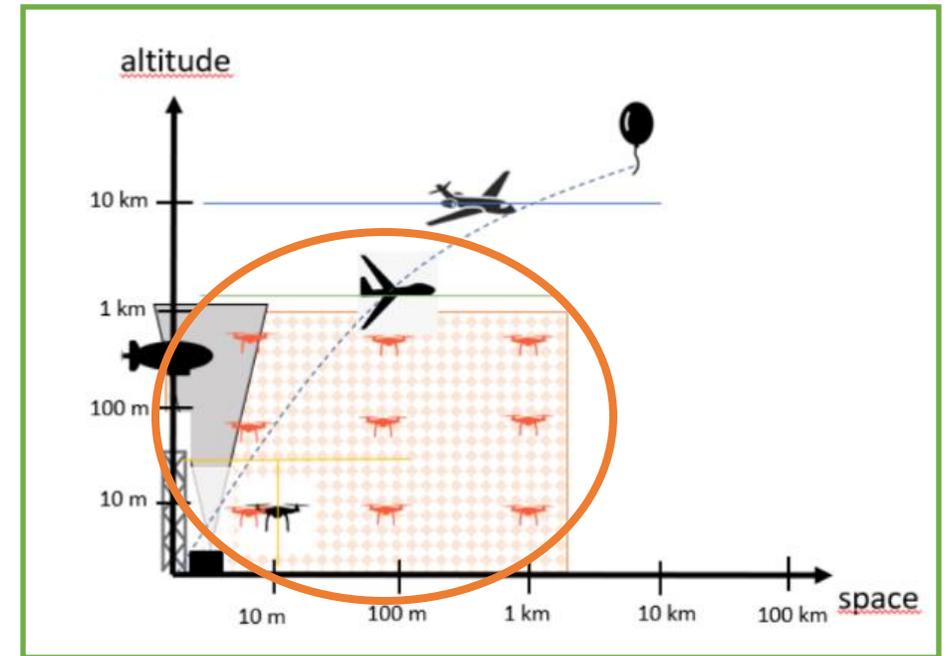
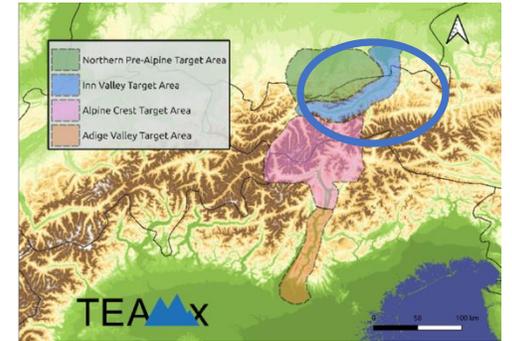
Credit: Norman Wildmann (DLR)

Turbulence measurements

Fleet of UAS (DLR and others)



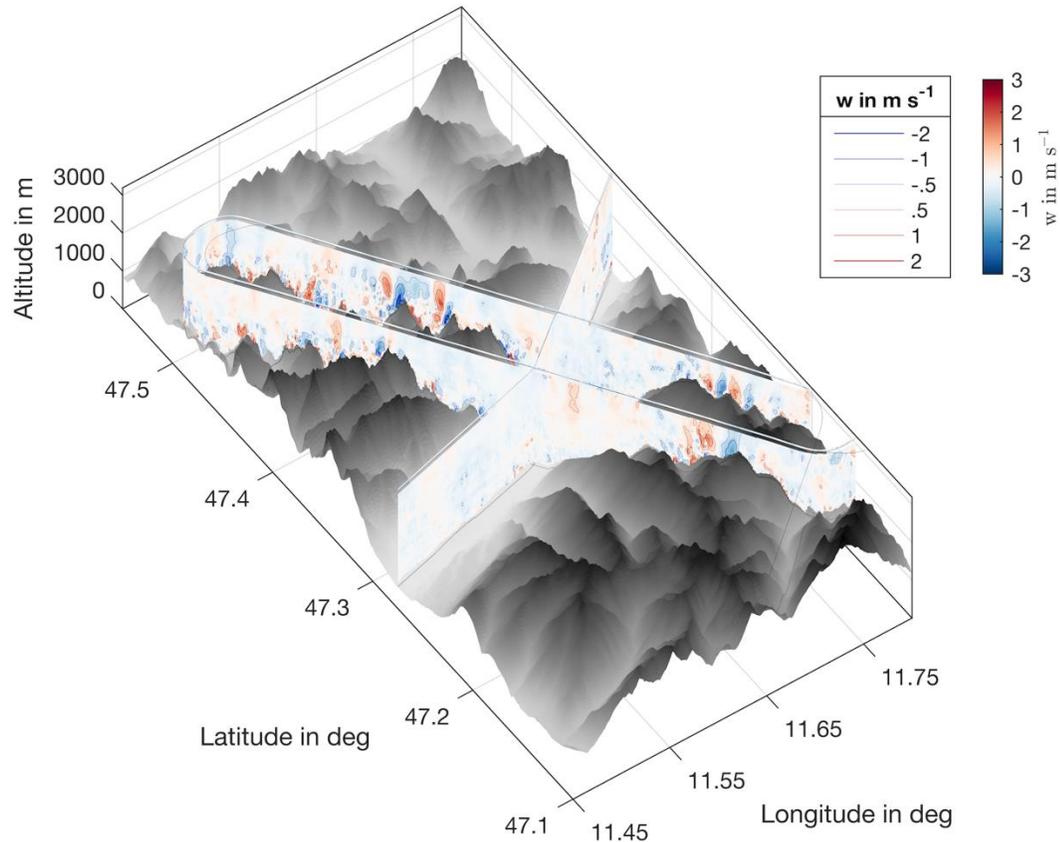
Credit: Norman Wildmann (DLR)



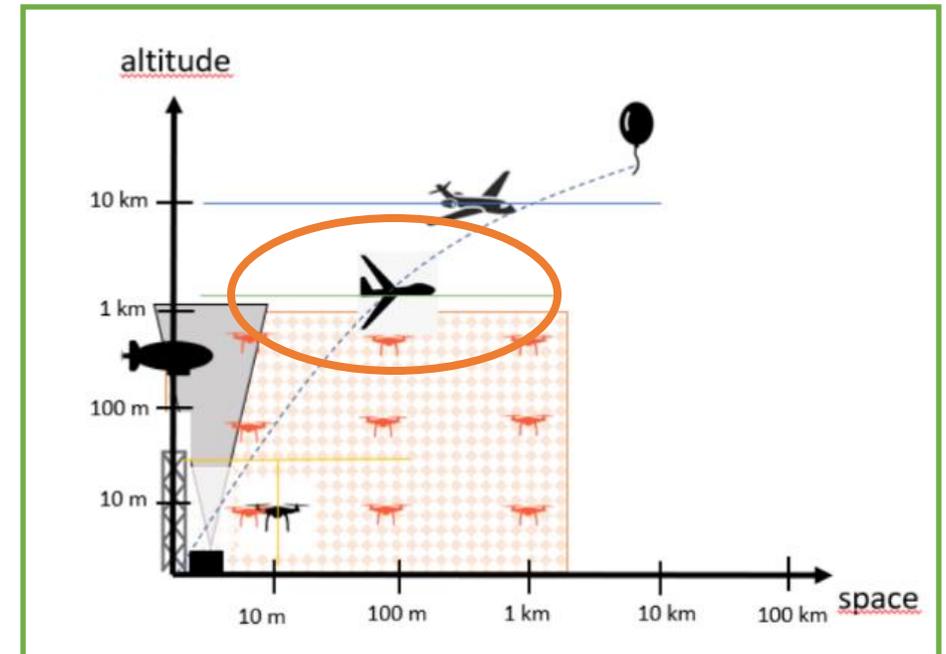
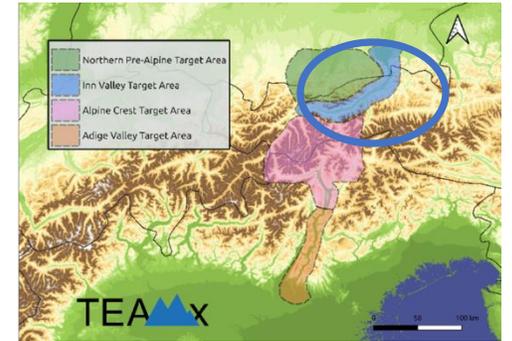
Credit: Norman Wildmann (DLR)

Turbulence measurements

Aircraft flights (UIBK, DLR, ...)

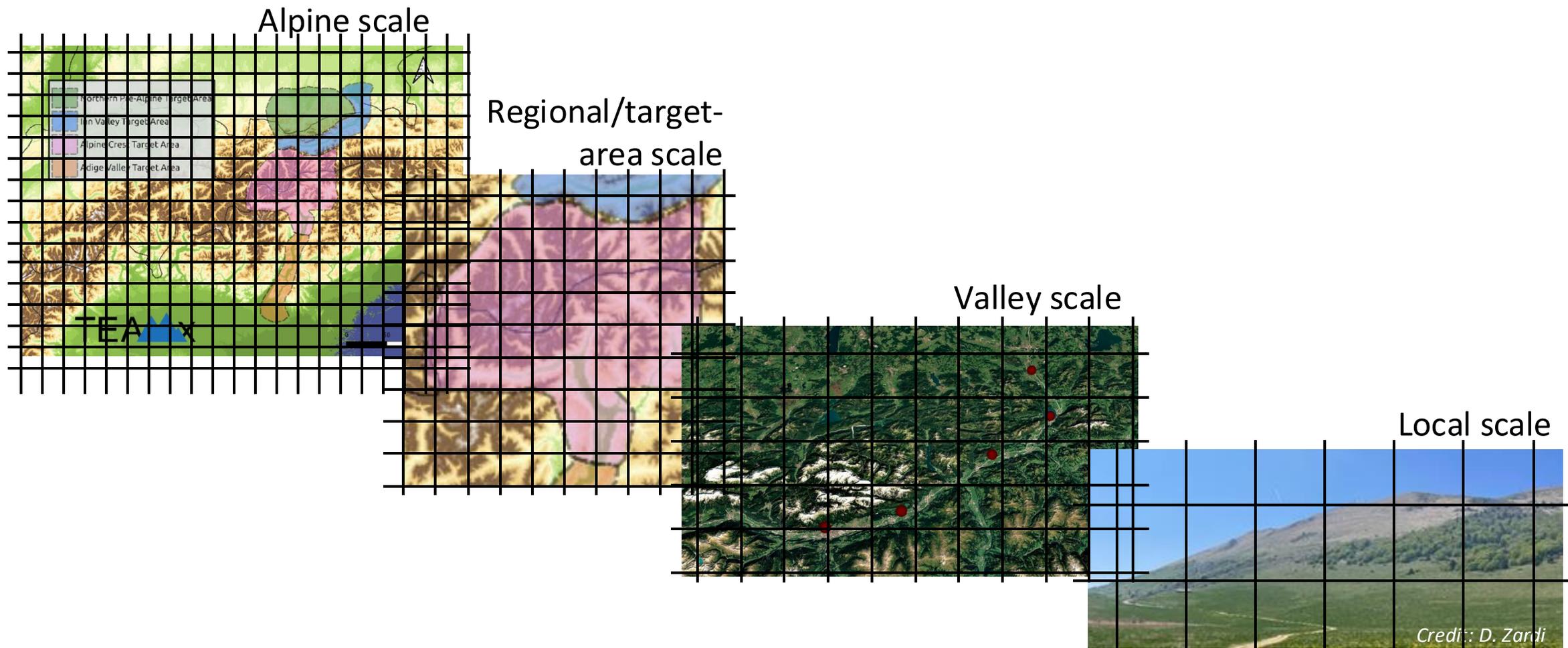


Credit: Philipp Gasch (KIT)



Credit: Norman Wildmann (DLR)

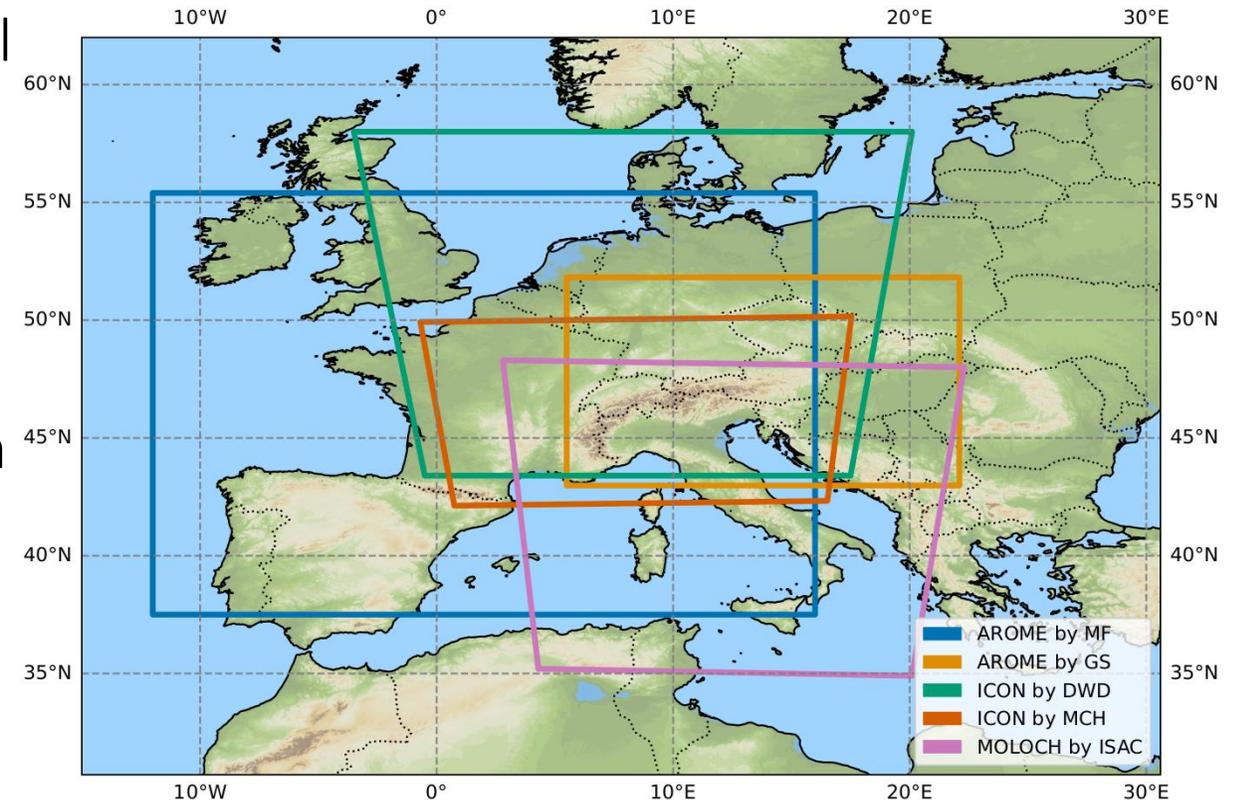
Numerical Weather Prediction



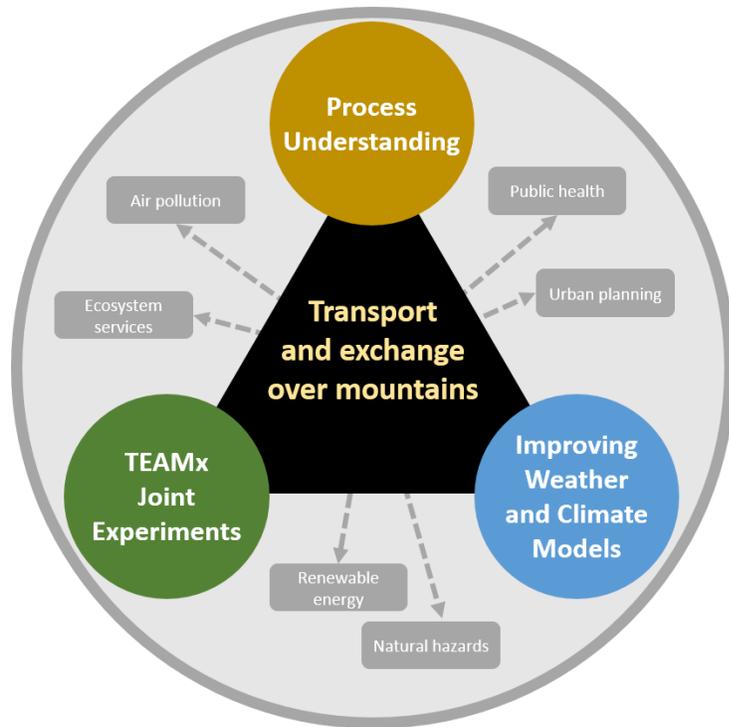
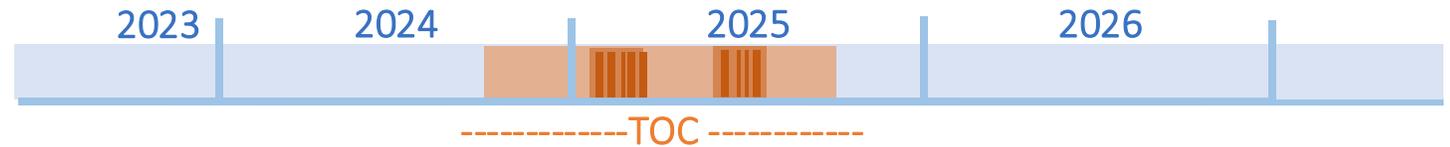
High-resolution forecast runs

High-resolution **NWP forecast runs** will be provided to guide IOP planning and for model development.

- ▲ ICON (DWD) – 2.2/0.5 km
- ▲ ICON (MeteoSwiss) – 1.1/0.5 km
- ▲ AROME (GeoSphere Austria) – 2.5/1.0 km
- ▲ AROME (Météo-France) – 1.3/0.5 km
- ▲ MOLOCH (CNR ISAC) – 1.25 km
- ▲ UM (UK Met Office) – 1.0 km
- ▲ ALARO (DHMZ) – 4.0/1.3 km



... Multi-scale transport and exchange processes in the atmosphere over mountains – programme and **experiment**



- ▲ International research program
- ▲ Research institutions and weather services
- ▲ Ongoing one-year long measurement campaign
- ▲ Four target areas along a transect through the Alps
- ▲ Observations targeting a wide range of processes and spatial scales