



The TEAMx Observational Campaign

A unique dataset for numerical model development over complex terrain

Manuela Lehner and Mathias W. Rotach

Thanks to the TOC participants and the TEAMx community

ICCARUS 2026

TEAMx

Multi-scale transport and exchange processes in the atmosphere over mountains—programme and experiment

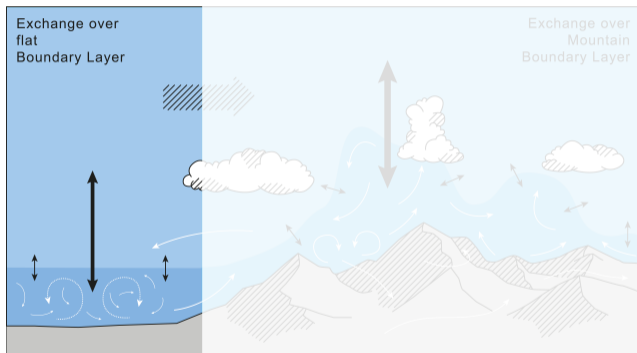
www.teamx-programme.org

... international research programme with > 40 signatories of the TEAMx Memorandum of Understanding

... endorsed by 

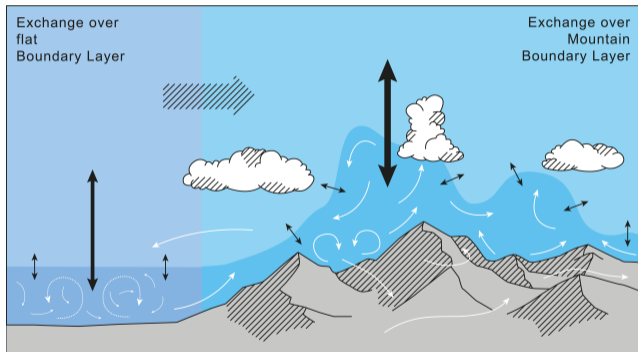
... a cross-cutting project of the  Hydroclimatology Panel

Mountain Boundary Layer (MoBL)



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

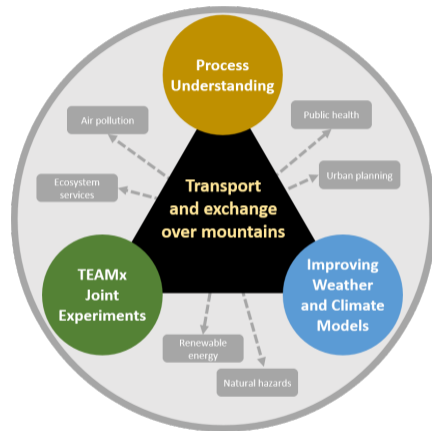
Mountain Boundary Layer (MoBL)



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

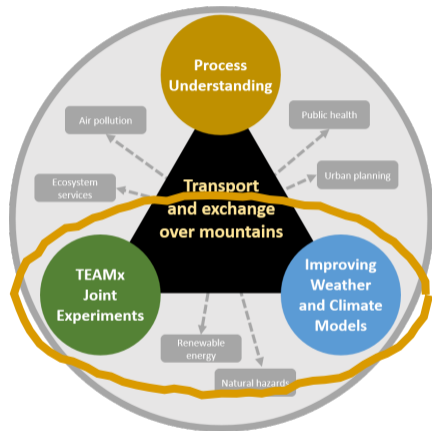
TEAMx Goals

- ▲ 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
- ▲ Supporting weather and climate service providers



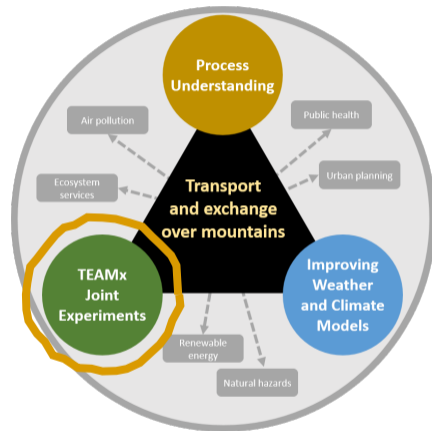
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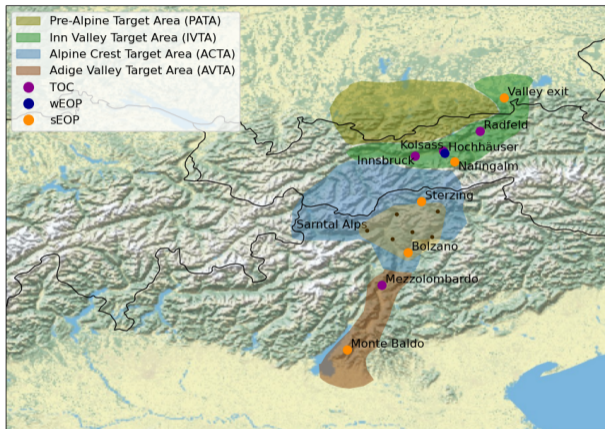


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TEAMx Observational Campaign (TOC)

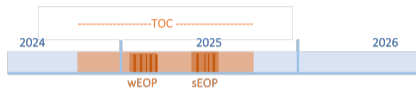


North-south transect through the Alps

- ▲ Pre-Alpine Target Area
- ▲ Inn Valley Target Area
- ▲ Alpine Crest Target Area
- ▲ Adige Valley Target Area

> 40 participating research groups

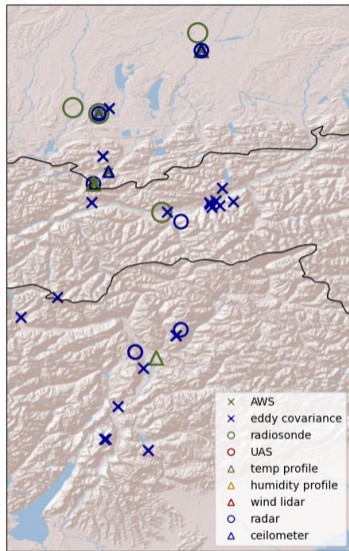
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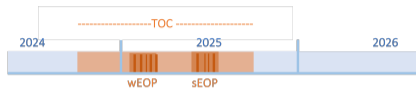
One-year long TOC

- ▲ Observations over a longer timescale than most field campaigns
- ▲ Increase the density of the existing observational infrastructure

operational sites excluding AWS networks

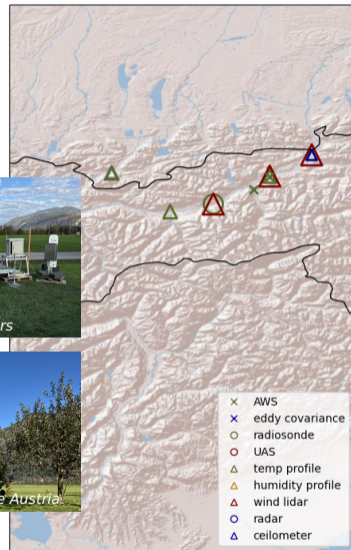


TEAMx Observational Campaign (TOC)



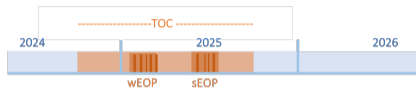
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instruments deployed for the TOC

TEAMx Observational Campaign (TOC)

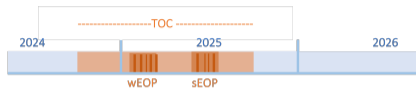


Extended Observational Periods

▲ Focus on individual processes

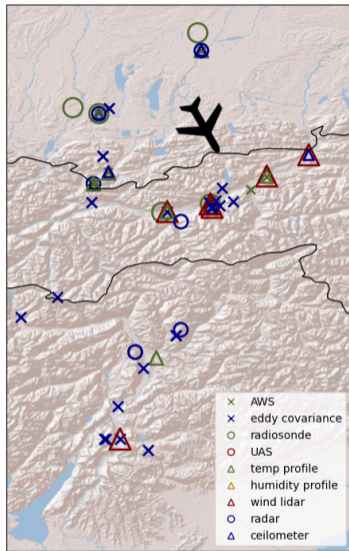


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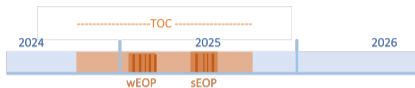


Extended Observational Periods

- ▲ Focus on individual processes
- ▲ Winter EOP (wEOP): 20 Jan–28 Feb

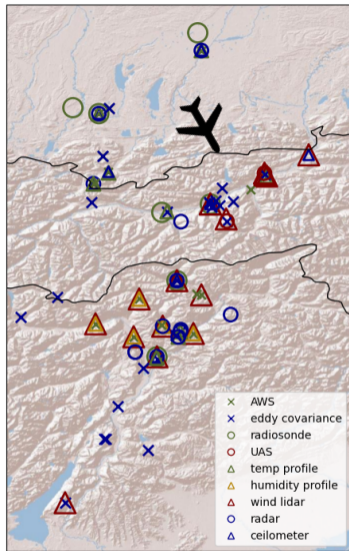


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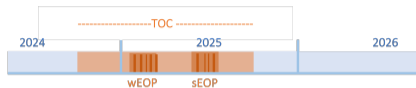


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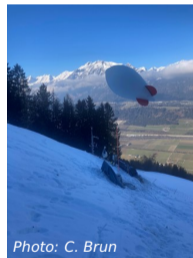


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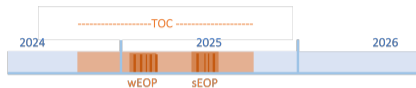


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- ▲ IOPs targeting specific weather conditions



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Extended Observational Periods

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3 research aircraft

- ▲ NCAS FAAM BAe146
- ▲ DLR Cessna Caravan
- ▲ TU Braunschweig Cessna F406



Aircraft observations

wEOP—DLR

▲ 6 flights (24 flight hours)

sEOP—DLR, TUBS, FAAM

▲ 3 weeks with all aircraft

▲ DLR: 18 flights (74 flight hours)

▲ TUBS: 35 flights (98 flight hours)

▲ FAAM: 27 flights (94 flight hours)

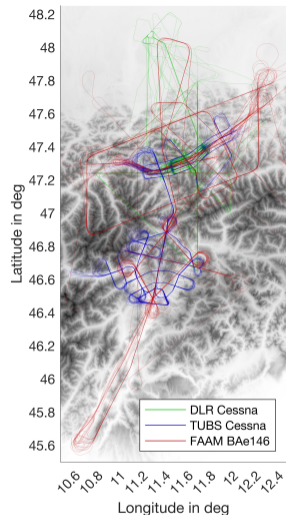


Figure: Philipp Gasch

Operations Center

- ▲ Daily meetings during the EOPs
- ▲ Weather briefings by four **student forecasters**
- ▲ **Scientists in Charge** leading the meetings and compiling IOP summaries and information on the status of field instrumentation



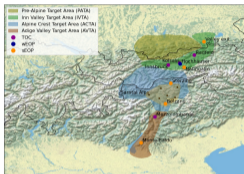
Photo: D. Anderson



Photo: M. Lehner

Multi-scale processes

Alpine scale



- ▲ Mountain waves
- ▲ Mountain-plain wind

Regional scale



- ▲ Orographic convection
- ▲ Foehn

Valley scale



- ▲ MoBL structure
- ▲ Valley winds
- ▲ Mountain venting
- ▲ Fog/low stratus

Local scale

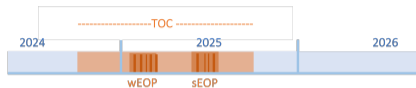


- ▲ Slope winds
- ▲ Turbulence

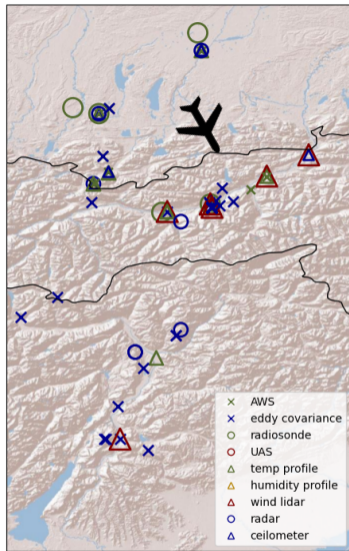
Observed processes

IOP type	wEOP	sEOP
Slope winds	6	2
Valley-exit jets	-	2
MoBL-thermal	2	14
MoBL-dynamic	1	1
Convection	-	7
Gravity waves	9	2
Synoptic	-	1
Total	17	24

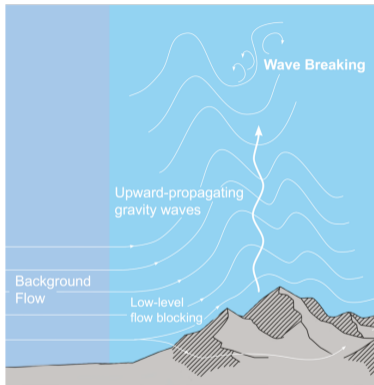
Winter EOP (wEOP)



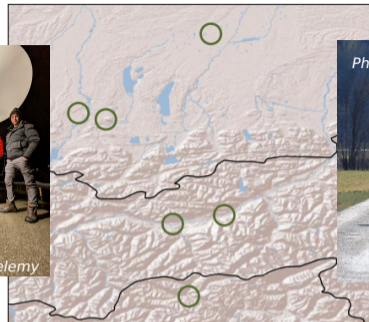
- ▲ 20 Jan–28 Feb
 - ▲ ≈ 10 profiling sites
 - ▲ ≈ 250 radiosonde launches
 - ▲ 1 research aircraft
- ▲ Main topics: Gravity waves, fog and low stratus, katabatic winds



Gravity waves



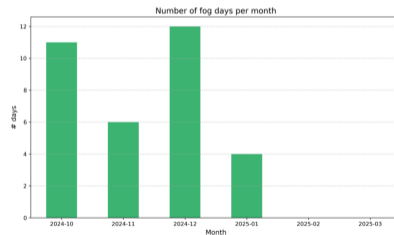
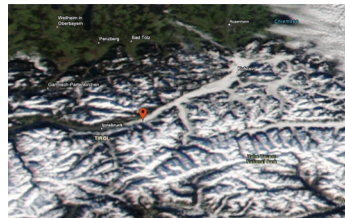
Credit: Andrew Orr



- ▲ Improve process understanding (especially gravity-wave drag)
- ▲ Improve understanding of how drag is resolved and parameterised in NWP and climate models at all scales

Fog and low stratus

Karlsruhe Low-Cloud Exploratory Platform (KLOCX): Life-cycle phases of **low-level stratiform clouds and fog**



Credit: Jutta Vüllers

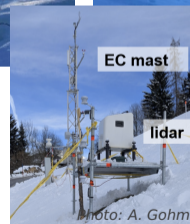
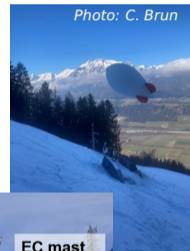
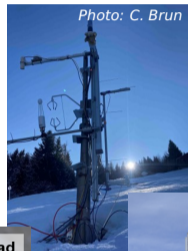
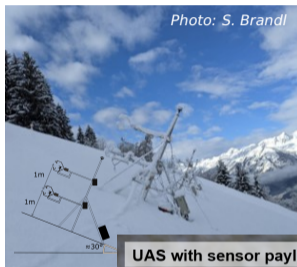
Downslope winds over a snow-covered slope

3D structure of **mean and turbulent flow properties**



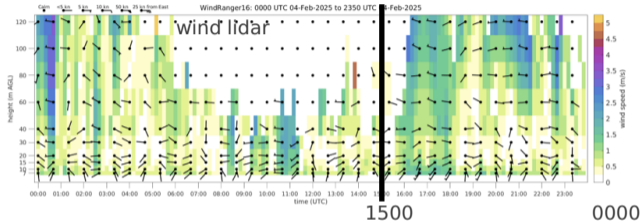
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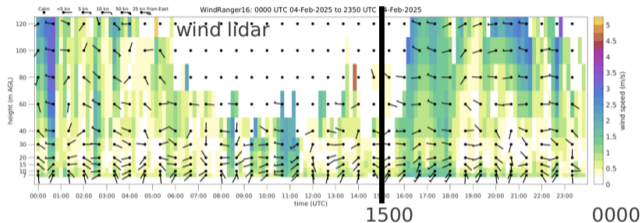


- ▲ Transition from downslope (S) to down-valley (W) winds
- ▲ Shallow southerly katabatic jet

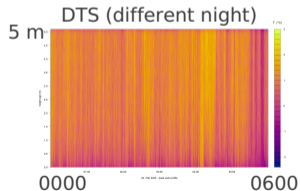
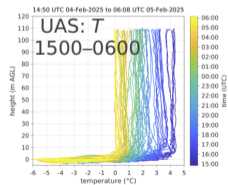
Credit: Alexander Gohm, Lena Pfister, Ivana Stiperski

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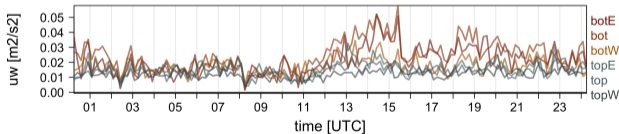
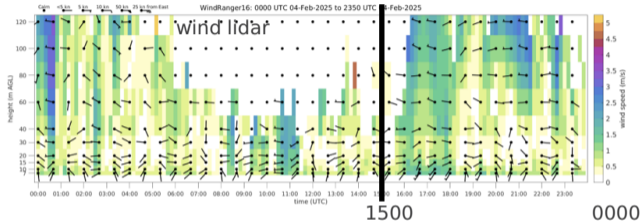
- ▲ Transition from downslope (S) to down-valley (W) winds
- ▲ Shallow southerly katabatic jet
- ▲ Shallow temperature inversion: 5–10 m



Credit: Alexander Gohm, Lena Pfister, Ivana Stiperski

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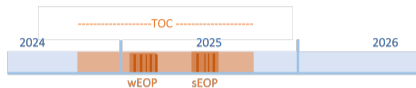
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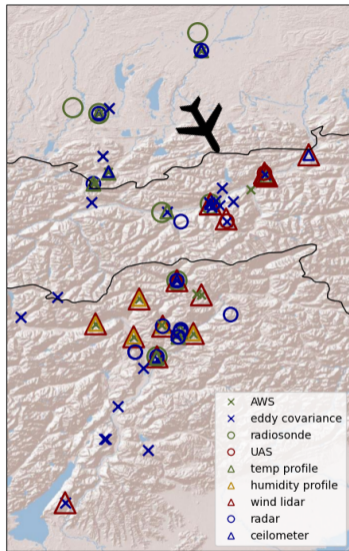
- ▲ Transition from downslope (S) to down-valley (W) winds
- ▲ Shallow southerly katabatic jet
- ▲ Shallow temperature inversion: 5–10 m
- ▲ Along-slope variations in turbulent fluxes

Credit: Alexander Gohm, Lena Pfister, Ivana Stiperski

Summer EOP (sEOP)

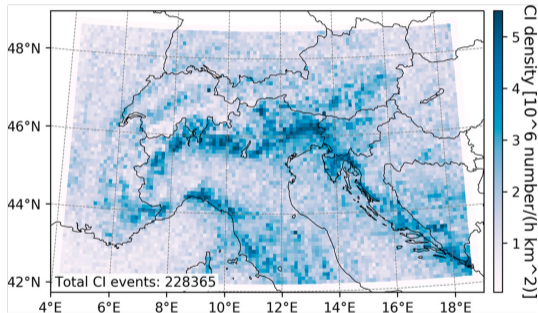


- ▲ 16 Jun–25 Jul
- ▲ ≈ 20 profiling sites
- ▲ ≈ 550 radiosonde launches
- ▲ 3 research aircraft
- ▲ Multiple UAS
- ▲ Main topics: convection, MoBL, thermal flows, turbulence



Convection

Sarntal Alps: Hotspot of convection initiation



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

Observed thunderstorms during the sEOP

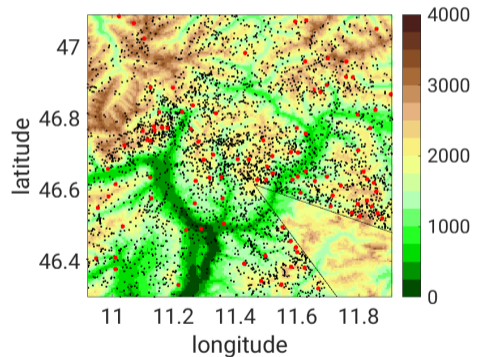
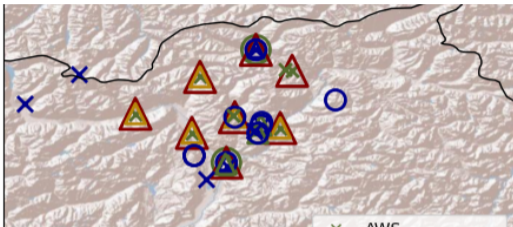


Figure: Jan Handwerker

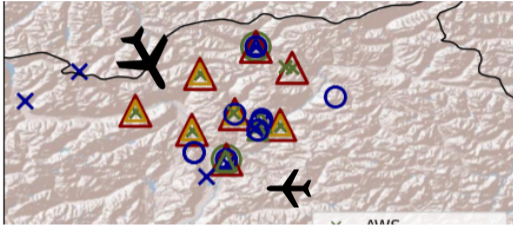
Convection



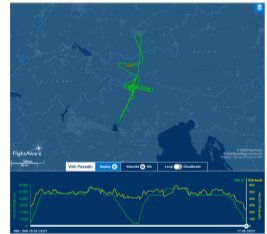
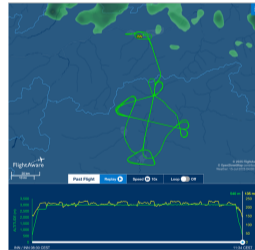
▲ Dense network of remote-sensing instrumentation + radiosoundings



Convection



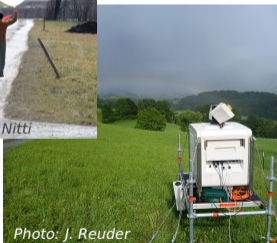
- ▲ Dense network of remote-sensing instrumentation + radiosoundings
- ▲ Aircraft: TU Braunschweig Cessna + NCAS FAAM



MoBL—Valley atmosphere

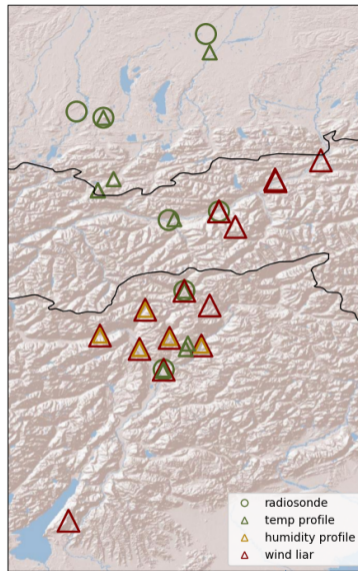
Spatially distributed vertical profiles

Radiosoundings

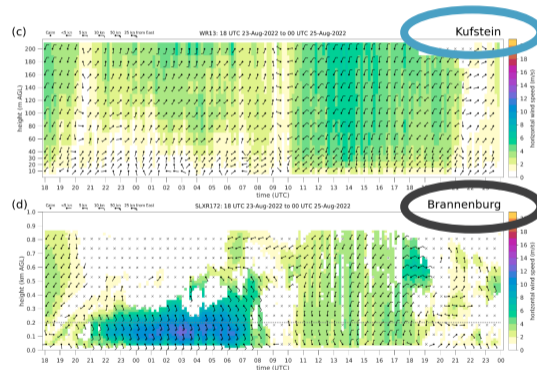
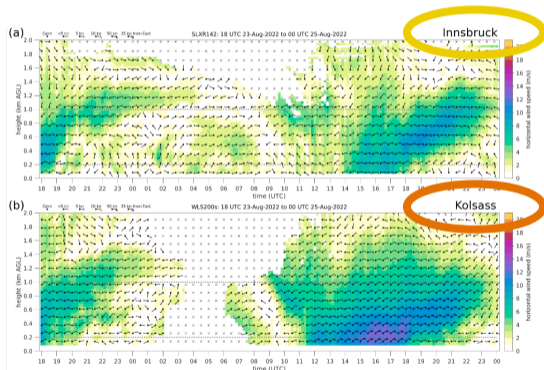
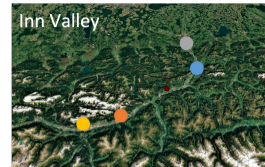


Wind lidars

T/RH profilers



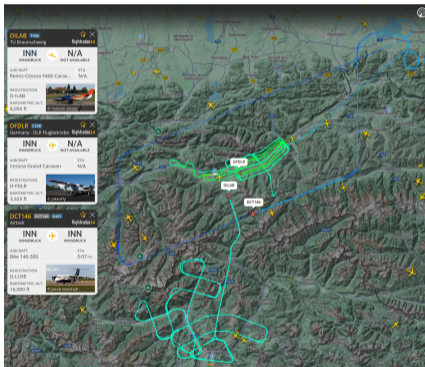
MoBL—Valley atmosphere



Pfister et al. (2024) : The TEAMx-PC22 Alpine field campaign—objectives, instrumentation, and observed phenomena. Met Z

MoBL—Valley atmosphere

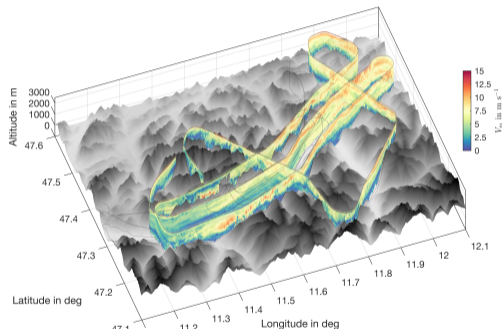
Airborne measurements



Source: flightradar24.com

Wind speed

TU Braunschweig Cessna, AIRflows

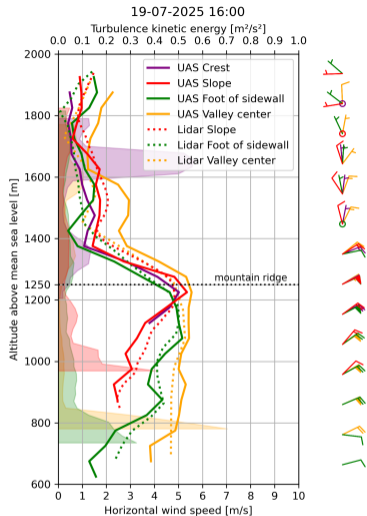


Credit: Philipp Gasch

MoBL—Valley atmosphere

Airborne measurements—UAS

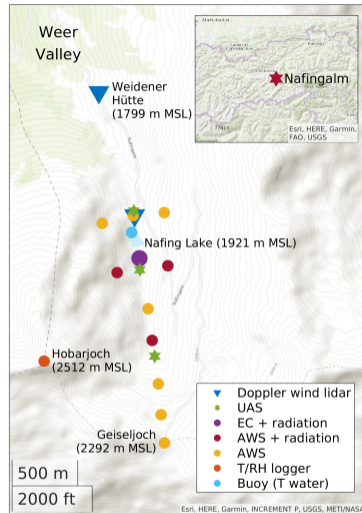
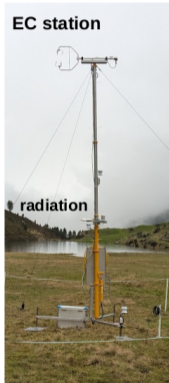
Vertical profiles + spatially distributed measurements



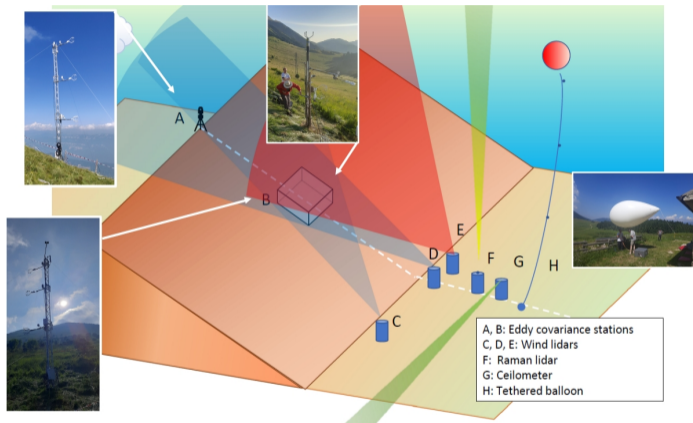
Credit: Andreas Platis

MoBL—Valley atmosphere

Photos and map: A. Gohm



MoBL—Slope winds

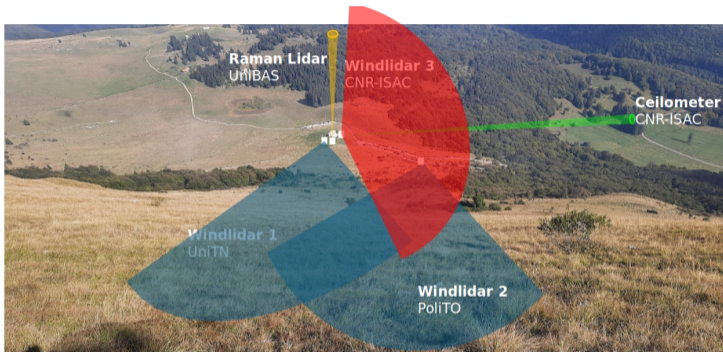


Monte Baldo



Credit: Dino Zardi, Lorenzo Giovannini, Giorgio Doglioni

MoBL—Slope winds



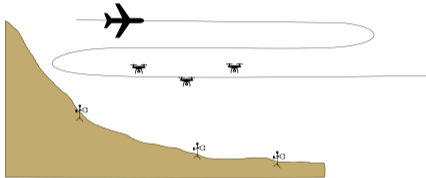
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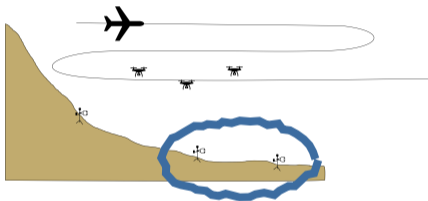
Turbulence in the MoBL

Observing turbulence throughout
the MoBL

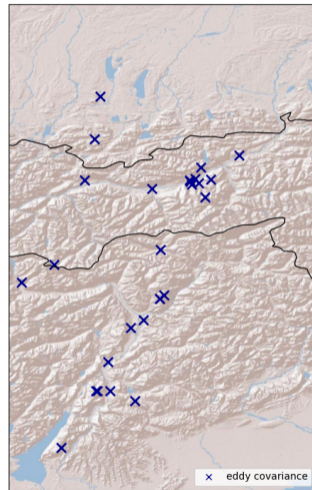


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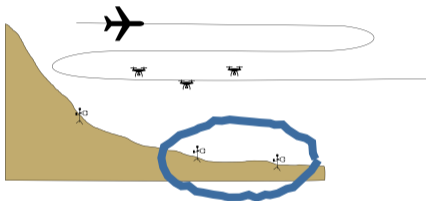


Surface layer: (networks of) eddy-covariance stations



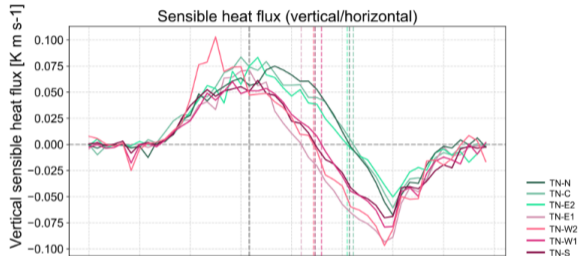
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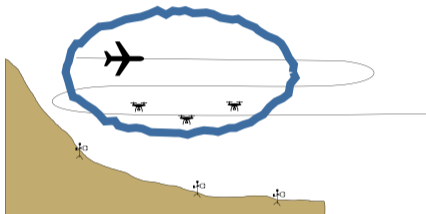
Network of EC stations (IVTA)



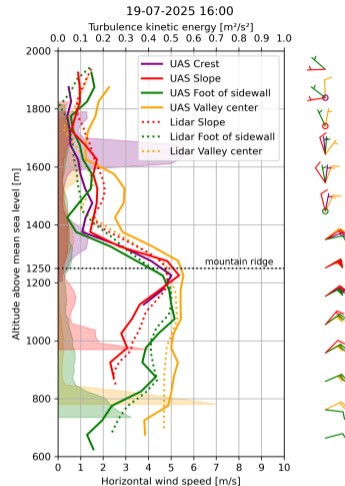
Credit: Jerome Gallet

Turbulence in the MoBL

Observing turbulence throughout the MoBL



Valley atmosphere: aircraft + (swarms of) UAS



Credit: Andreas Platis

Data availability

TOC data will be ...

- ▲ made publicly available one year after the TOC
- ▲ published in public repositories (e.g., PANGAEA, zenodo, ...)
- ▲ accessible through the **Earth Data Portal** (<https://earth-data.de>)

FEATURED DATA COLLECTIONS

Explore thematically grouped information



TEAMX OBSERVATIONAL CAMPAIGN

A one-year long atmospheric measurement campaign in a north-south transect through the Alps, including aircraft, UAS, remote-sensing instrumentation, eddy-covariance and automatic...

DATA 

WEBSITE 

EN
M.

Enl
tha
em



Photo: D. Anderson

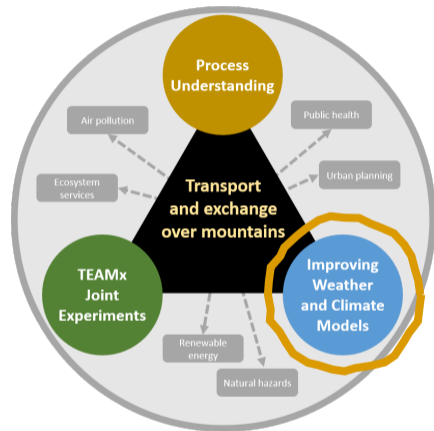


Photo: M. Lehner

Thank you to all TOC participants!

TEAMx Goals

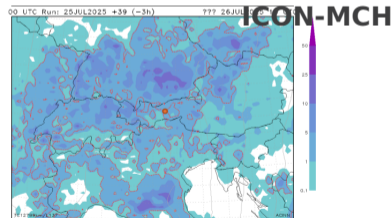
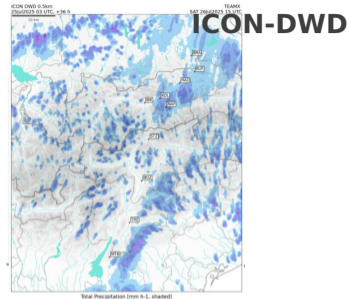
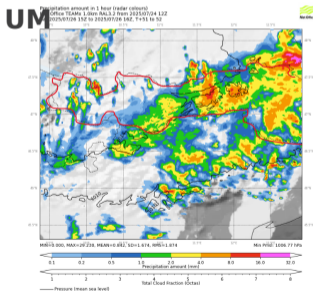
- ▲ Improving our understanding of transport and exchange processes between the surface and the atmosphere and within the atmosphere
- ▲ Evaluating and improving weather and climate models over complex terrain
- ▲ Collecting a unique dataset to study the transport and exchange processes
- ▲ Supporting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



High-resolution NWP forecasts

Daily forecasts supported by

- ▲ 500-m ICON runs from DWD
- ▲ 1-km ICON runs from Meteo Swiss
- ▲ 1-km UM runs from the Met Office

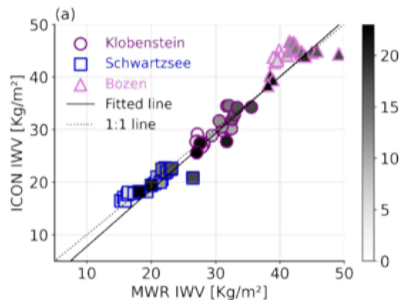


High-resolution NWP forecasts

Model evaluation and process studies, e.g.,

- ▲ Convection and precipitation over the Sarntal Alps
- ▲ MoBL and thermal flows
- ▲ Valley-exit jets in the Inn Valley

ICON vs observed integrated water vapor



Credit: Claudia Acquistapace

TEAMx analysis

GREAT (A GRey-zone Ensemble Analysis for TEAMx)

Lead PI: *Stefano Serafin (University of Vienna)*

- ▲ Goal: analysis integrating most TOC observations
- ▲ Forecast ensemble: ICON
- ▲ Data assimilation: KENDA
- ▲ Output 1: 1-km analysis for all IOPs (ICON-CH)
- ▲ Output 2: 125-m analysis for selected IOPs

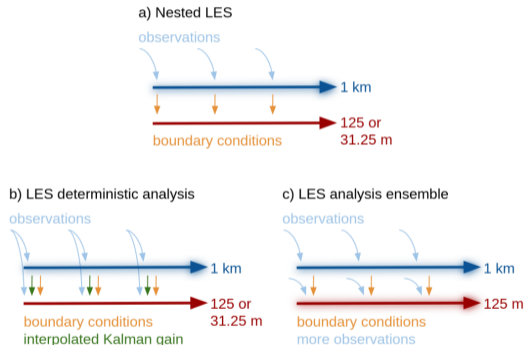


Figure: *Stefano Serafin*

Model intercomparison studies—Valley winds

Coordination: Lorenzo Giovannini (University of Trento)

- ▲ Representation of thermally driven winds
- ▲ CROSSINN campaign in the Inn Valley (PI: B. Adler)
- ▲ September case study
- ▲ 1-km grid spacing

Models: AROME, GRAMM-SCI, ICON, Meso-NH, WRF

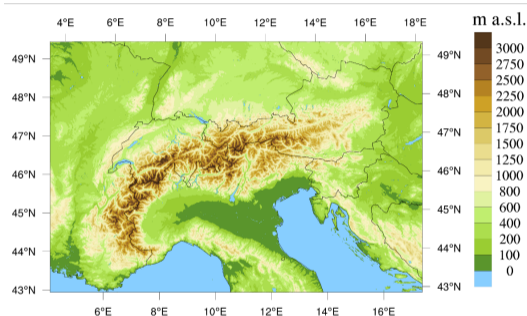
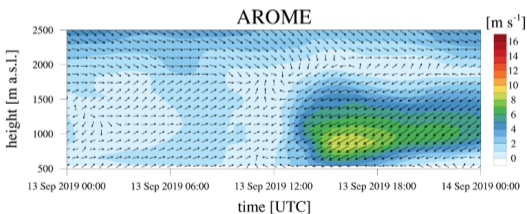
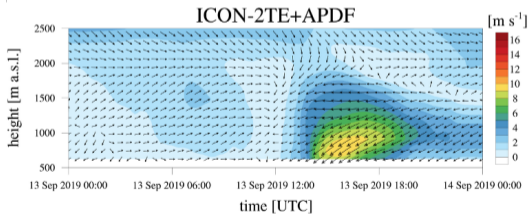
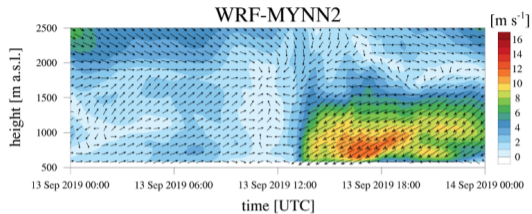
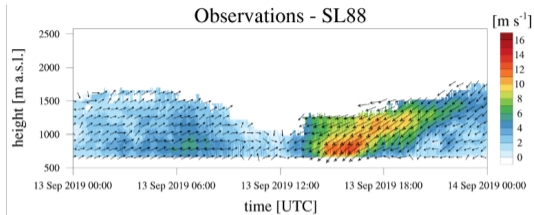


Figure: Lorenzo Giovannini

Model intercomparison studies—Valley winds



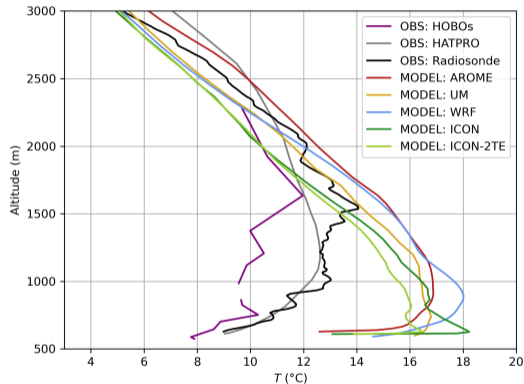
Figures: Lorenzo Giovannini

Model intercomparison studies—Cold-air pools

Coordination: Manuela Lehner

- Representation of the full CAP life cycle
- PIANO campaign in the Inn Valley (foehn-CAP interactions, *PI: A. Gohm*)
- Selected October night during a period of undisturbed conditions
- ≈500-m deep inversion at 0300 UTC
- 1-km grid spacing

Models: AROME, ICON, UM, WRF

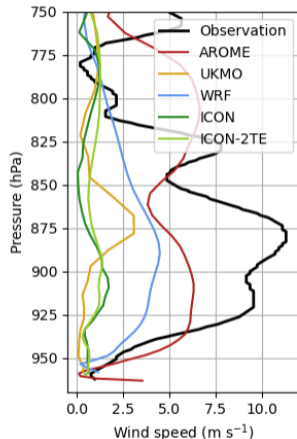


Model intercomparison studies—Cold-air pools

Coordination: Manuela Lehner

- ▲ Representation of the full CAP life cycle
- ▲ PIANO campaign in the Inn Valley (foehn-CAP interactions, *PI: A. Gohm*)
- ▲ Selected October night during a period of undisturbed conditions
- ▲ $\approx 500\text{-m}$ deep inversion at 0300 UTC
- ▲ 1-km grid spacing

Models: AROME, ICON, UM, WRF

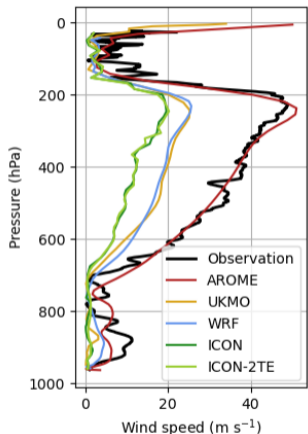


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Models: AROME, ICON, UM, WRF



Model intercomparison studies—LES

TABLES (Complex Terrain Atmospheric Boundary layer Large-Eddy Simulation model intercomparison) *Coordination: Ivana Stiperski (University of Innsbruck)*

- ▲ 7+ models (same initial and boundary conditions, similar grid)
- ▲ 6 simulations per model
 - ▲ 3 topographies (flat, 100-m mountain, 1000-m mountain)
 - ▲ Free convection + forced convection ($u = 10 \text{ m s}^{-1}$)

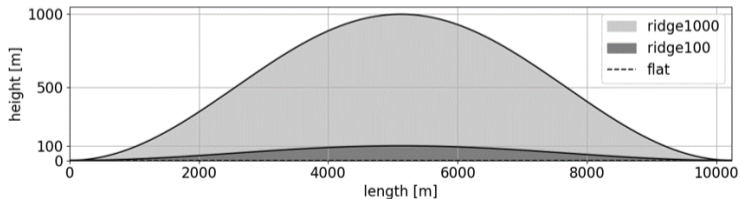


Figure: Andreas Rauchöcker

Model intercomparison studies—LES

First results from 4 models

Future analysis

- ▲ MoBL structure
- ▲ Reynolds stresses
- ▲ TKE budgets
- ▲ Coherent structures

u wind component

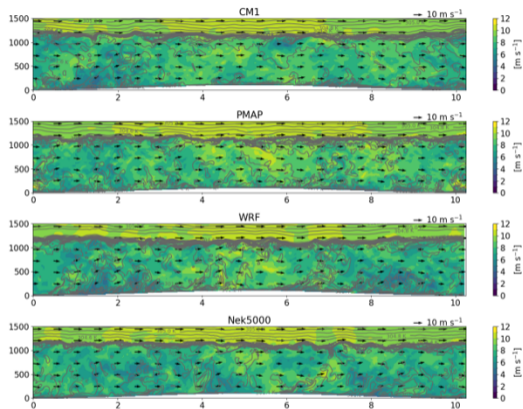


Figure: Andreas Rauchöcker

Model intercomparison studies—LES

First results from 4 models

Future analysis

- ▲ MoBL structure
- ▲ Reynolds stresses
- ▲ TKE budgets
- ▲ Coherent structures

Participating models: CM1, WRF, PMAP, DALES, ELMM, Jexpresso, Nek5000 (PALM, FastEddy, psNCAR, M. Calaf)

Missing: ICON

u wind component

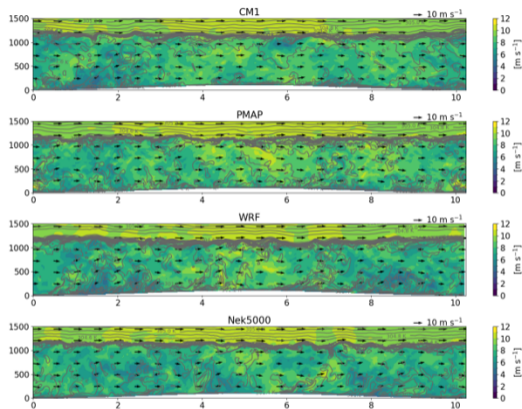


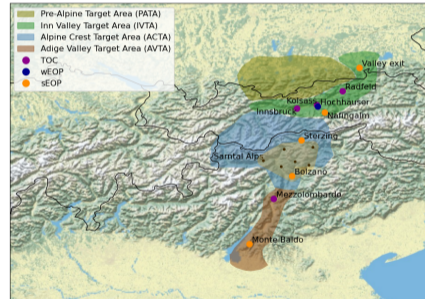
Figure: Andreas Rauchöcker

TEAMx Multi-scale transport and exchange processes in the atmosphere over mountains—programme and experiment

Web: www.teamx-programme.org

Contact: teamx-pco@uibk.ac.at

TEAMx Observational Campaign: one-year long campaign to collect a unique dataset to study transport and exchange processes over mountainous terrain



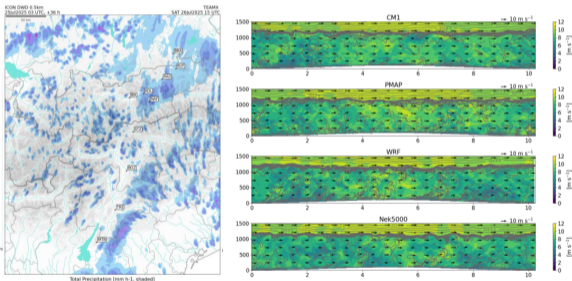
TEAMX

Multi-scale
transport and exchange
processes in the atmosphere
over mountains—programme
and experiment

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One of the four main TEAMx objectives is to **improve the representation of transport processes over mountains in weather and climate models.**



TEAMX Multi-scale
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TEAMX is welcoming new
collaborators.

Thank you!