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TEAMx

The First TEAMx Workshop - a summary of achievements after a week-end of contemplation

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TEAMx

Multi-scale Transport and
Exchange Processes in the
Atmosphere over
Mountains
Programme and experiment

- ...a bottom-up financed research programme on weather, climate & air pollution in mountain areas
- 'crowd funding' for a Programme Coordination Office (PCO)

  → sponsors: Karlsruhe Institute of Technology KIT, Météo France, MeteoSwiss, National Center for Atmospheric Science (NCAS), University of Innsbruck, University of Trento, ZAMG, (Center for Climate Systems Modeling (C2SM)

  → Progamme Coordinator: Stefano Serafin (UIBK)

Overarching objectives

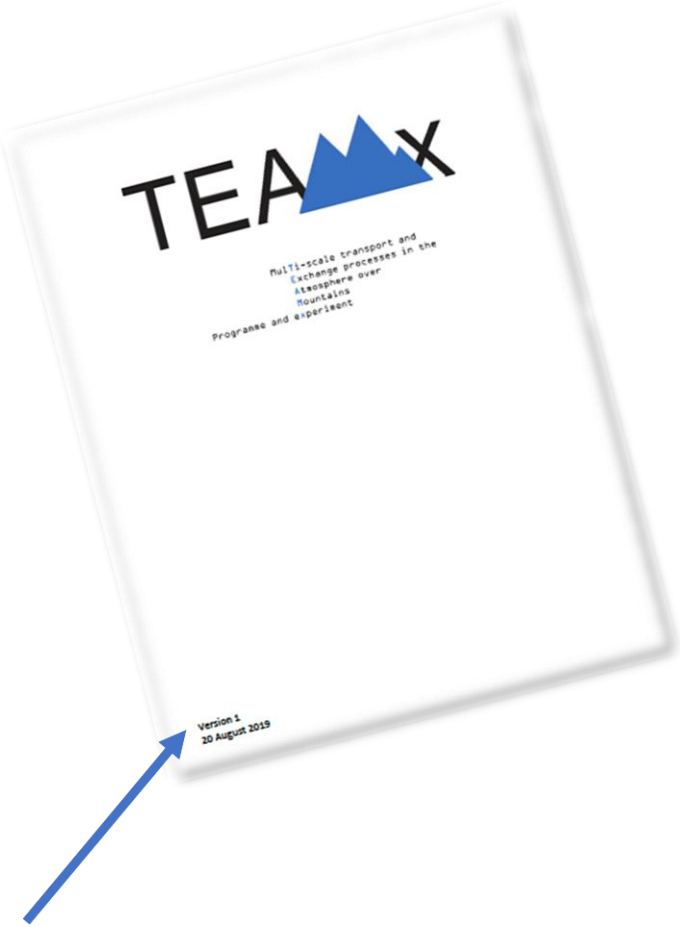
Objective	Primary Focus	Target
Process understanding	Micro- and meso-scale processes within and above the *mountain boundary layer* (MoBL); Interaction between scales.	Quantitative understanding of momentum, energy and mass exchange over mountainous terrain
TEAMx Joint Experiment(s)	Collaborative use of multi-platform instrumentation to sample the spatial heterogeneity of turbulence and mesoscale circulations over and near mountains	Quality-controlled observational data pool, available for process investigation, high-resolution model verification, parameterization development
Improving Weather and Climate Models	*Models right for the right reason*, i.e., identification and reduction of model biases and uncertainties over complex terrain	Weather forecasts and climate simulations over mountains as good as over flat terrain, and less reliant on model output post-processing
Support to Weather and Climate Service Providers	Air pollution, hydrology, climate change scenarios (e.g., elevation-dependent warming).	Smaller uncertainty of impact models, due to reduced errors in weather and climate information.

Workshop goals

- TEAMx Science plan is summarized in a White Paper

  → WP1.0

- *Work out [the basis for] TEAMx WP2.0*
- Work out requirements /availabilities for the joint experiment
- Work out possibilities for joint numerical modelling exercises



Topics

- Discussion A: ***Air chemistry and atmospheric dispersion modelling***
- Discussion B: ***Climate processes / climate change in mountains***
- Discussion C: ***Orographic convection***
- Discussion D: ***Orographic flow dynamics***
- Discussion E: **Land atmosphere exchange**
- Discussion F: **Mountain Boundary Layer Flows**

- Discussion G: **Strategy for field experiment**
- Discussion H: **Strategy for numerical modelling**

→ all in relation to and dependent on transport and exchange processes in the atmosphere over mountains

Overarching Science Gaps

- **Turbulence Theory** 'not applicable' in complex terrain
  → assumption: 'h*orizontally homogeneous* & flat' is violated ...
  → relevant in land atmosphere exchange
  → relevant in Mountain Bundary Layer flows
  → relevant in the interaction between turbulent boundary layer and meso-scale mountain-induced flows
  → relevant for air pollution in mountain terrain
  → relevant for climate diagnostics
- Joint experiment must produce data
- Joint numerical modelling efforts must be established to obtain a benchmark

Overarching Science Gaps

- **Processes behind 'elevation dependent warming' (EDW)** not understood
  → mountain areas usually with larger ΔT than other regions, warming is height dependent
  → other elevation dependent changes (beyond T)?
- understanding of land atmosphere exchange / MoBL flows essential ….
- *no data* available in mountain areas
  → here: data likely relevant to understand EDW
  → how can joint experiment produce 'climate data'?
- high-resolution climate modelling with focus on mountains missing

Overarching Science Gaps

- **Orographic precipitation**
  → large progress with respect to synoptically forced precipitation processes in projects like MAP
- Convection initiation
  → primary and secondary triggering
  → interaction with the MoBL / land atmosphere exchange
- predictability
  → shorter time scales (weather)
  → role of upstream conditions?
- Hot topic in climate community
  → regional: FPS CORDEX - not (yet) with a 'mountain focus'
  → global: address biases in conv parameterizations over mountains

Overarching Science Gaps

- ***Orographic flow dynamics***

  → possibly the most mature (i.e., oldest) topic - GWD parameterizations in global models to get the momentum balance right

  → but: Irina Sandu's presentation on Monday ...

Long list of open questions, some of which we start answering…:

- What causes inter-model differences? parameterizations, underlying subgrid orography ? filtering of resolved orography? *(Elvidge et al., 2019)*
- Is the transition between resolved and parametrized handled well? *(Van Niekerk et al. 2016, Vosper 2016, Kanehamaet al., submitted)*
- Can we learn from high resolution simulations whether the schemes well suited for complex mountain ranges? (*Vosper et al., 2015, 2016, Van Niekerk et al, 2018, Vosper et al, submitted*)
- How should the partition between different schemes done?
- How does small scale orography affects the large (planetary scales)?

Overarching Science Gaps

- ***Orographic flow dynamics***
  → possibly the most mature (i.e., oldest) topic - GWD parameterizations in global models to get the momentum balance right
  → but: Irina Sandu's presentation on Monday ...
- Recent advances extending into the stratosphere (e.g., DEEPWAVE)
  → Alps?
- Mass exchange (not only momentum)
  → alpine pumping
  → air chemistry and pollution
- Largely determined by (meso-to synoptic scale) upwind conditions

Overarching Science Gaps

- **Air chemistry and atmospheric dispersion modelling**
- Two distinctive scales
  → I: role of dynamic processes (e.g. GW) processes on mass transport through accross stroppopause largely unknown
  → II: local 'valley scale' ('CAP pollution')
- ad I) Interaction between chemical processes (various characteristic time scales) and 'mountain flows' (various characteristic time scales) largely unexplored
  → Largely determined by (meso-to synoptic scale) upwind conditions
- Ad II): sub-grid scale parameterization for pollutants missing
  → MoBL and land atmosphere exchange (dispersion models for steep terrain)
  → turbulence theory ....

TEAMx Joint Field Experiment

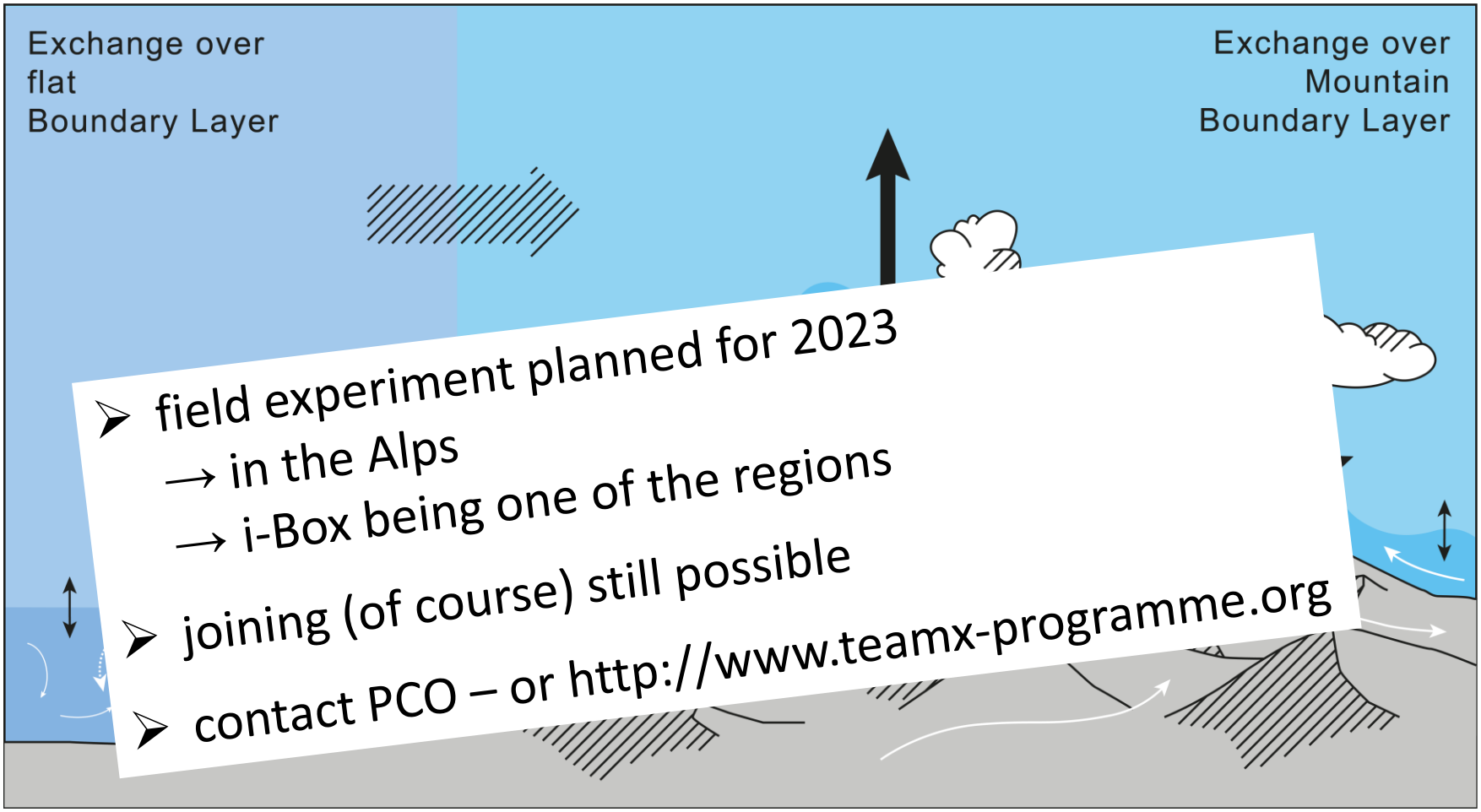
- Unique - with respect to earlier mountain meteorology projects - by combining
  → local forcing & meso-scale upwind conditions
  → what must be coordinated?
  → how to produce 'more than the sum' in terms of exp facilities?
- Unique – with respect to earlier BL experiments (Perdigao, Materhorn, ..) - by combining
  → different terrain elements & surface elements
  → slope / ridge etc. vs. alpine pasture / forest / glacier / urban
- Unique - with respect to earlier ‚mountain meteorology projects'
  → by including needs of climate modelling
  → by including air chemistry & atmospheric composition
- All these: TEAMx = Multi Scale ….

- Major next step: blueprint for the joint experiment

Joint numerical modelling

- Learn from the climate community
  → CMIP / CORDEX etc: define common modelling framework
- Lack of theoretical reference case
  → for transport and exchange over mountains
  → different strategies for an 'ideal → real' or 'real → ideal' modeling strategy
  → GABLS-ct
- A number of specific modelling issues
  → terrain representation
  → high-resolution re-analysis
  → CORDEX FSP on mountains

Exchange



- field experiment planned for 2023
  - → in the Alps
  - → i-Box being one of the regions
- joining (of course) still possible
- contact PCO – or http://www.teamx-programme.org

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Thank you for your attention!

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Exchange of energy, momentum & mass

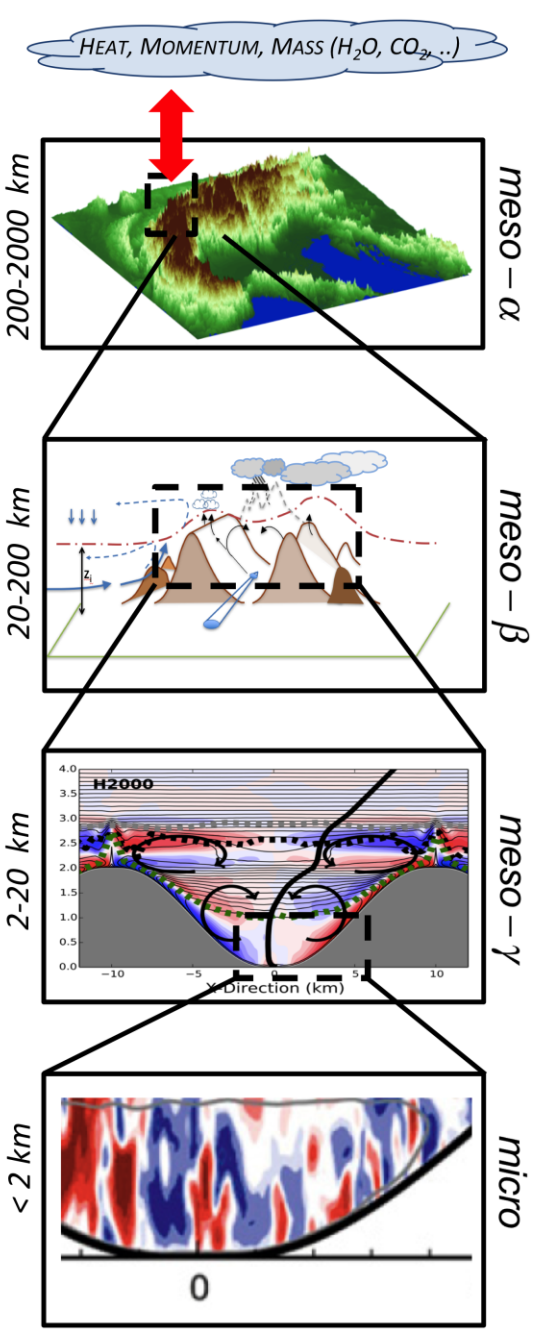
Scale interactions

- cyclogenesis, instability
- PV generation
- blocking

- impact of synoptic flow - stability/ strength/ direction
- interaction between flows in different valleys
- CO_2 uptake
- moisture export

- interaction orog. precip. - valley drainage
- ridge-area turbulence
- impact of background flow on exchange
- chemistry-dynamics

- interaction slope flow - turbulent exchange
- radiation – turbulence
- turbulence-chemistry



Processes @ scale

- Influence of Mountain Terrain on
  - Mountain drag
  - Heat (energy) budget
  - Mass exchange (CO_2; H_2O, …)
- Orographic precipitation
  - drying ratio
  - local evaporation

- *Definition* of mountain boundary layer
- Alpine venting
- convective initiation (CI)

- impact of valley geometry, orientation, surface type(s), … on local exchange
- valley turbulence (TKE)
- convective initiation (CI)

- turbulent exchange on slope
- data post-processing
- scaling
- surface character (e.g., soil moisture)