TEAMx

Welcome to the

First TEAMx Workshop

Hosting Institutions

UNIVERSITY OF TRENTO - Italy

AISAM Associazione Italiana di Scienze dell'Atmosfera e Meteorologia

universität innsbruck

Funding Institutions

IUGG

IAMAS International Association of Meteorology and Atmospheric Sciences

universität innsbruck

TEAMx

First TEAMx Workshop

Setting the Scene

Motivation and Goals of the Workshop

Mathias Rotach, University of Innsbruck (A)
Stephen Mobbs, NCAS (UK)

…with plenty of input from
Marco Arpagaus, Joan Cuxart, Stephan De Wekker, Vanda Grubišić, Norbert Kalthoff, Dan Kirshbaum, Manuela Lehner, Alexandre Paci, Elisa Palazzi, Jürg Schmidli, Stefano Serafin, Georg Wohlfahrt, Dino Zardi

It is about time.....

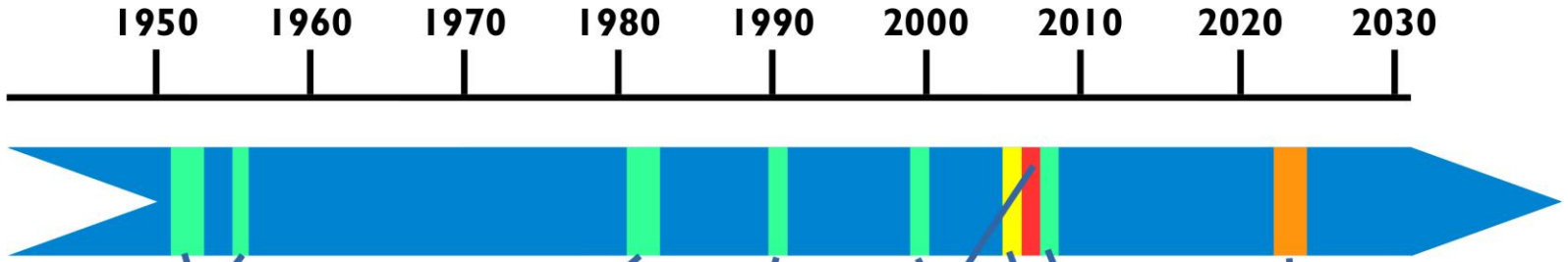
... to make Mountain Meteorology great again?

… to let mountain areas have their place in weather and climate science equally as ‘urban areas‘, ‘tropical regions‘ or ‚coastal regions‘

... to make the next internationally coordinated step in understanding and predicting the interactions between mountains and the atmosphere

for.....

Following a Long Tradition ….



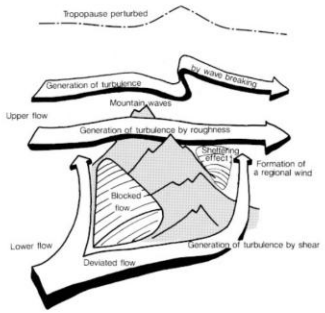
THE ALPINE EXPERIMENT alpex 1981-1982

MESOSCALE ALPINE PROGRAMME MAP

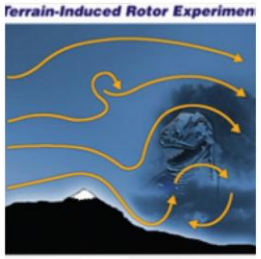
TEAMx

COPS

Sierra Wave



PYREX Experiment



T-REX Experiment

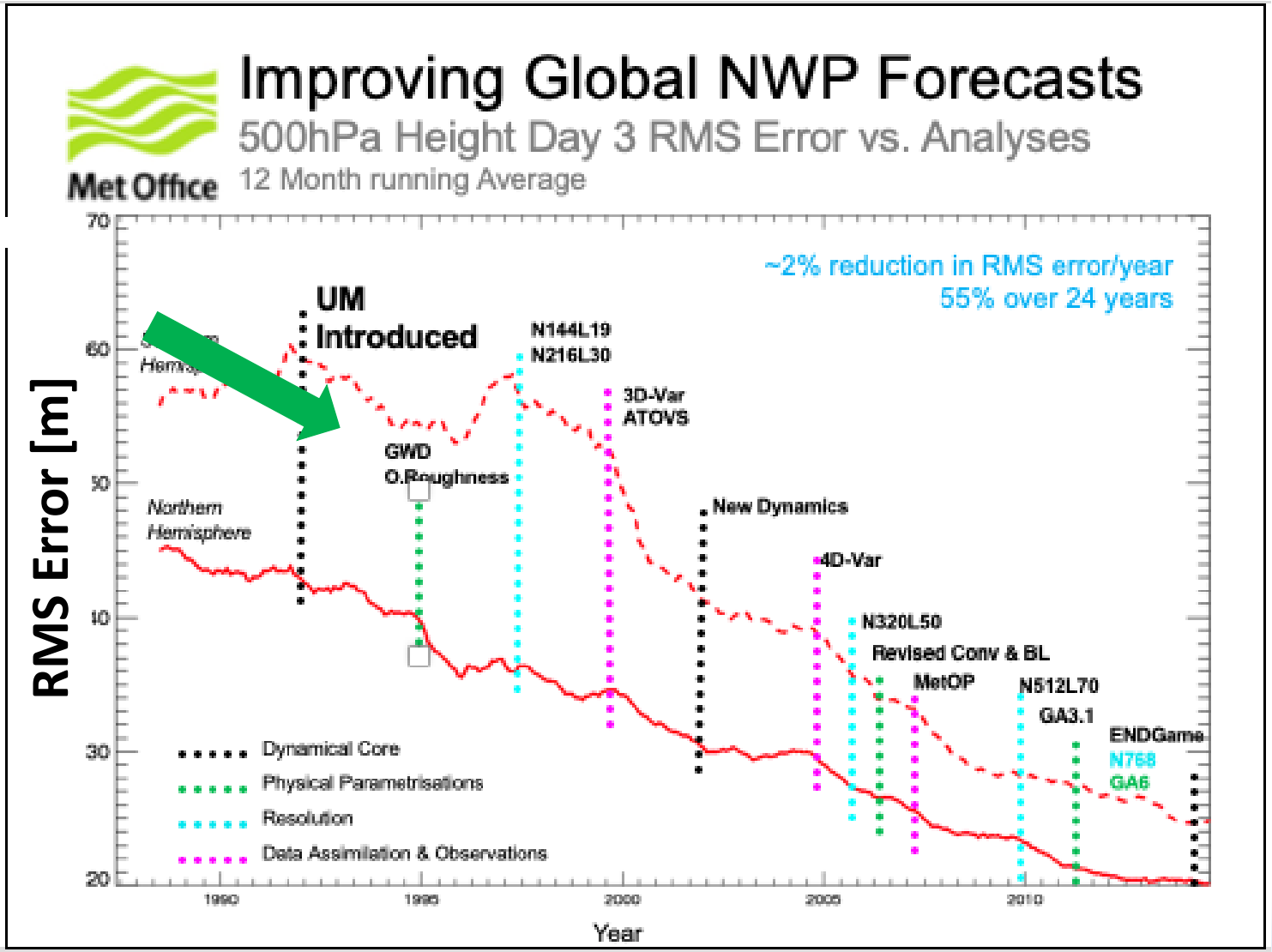
Is mountain weather and climate relevant?

- 20 years ago, ‚weather & climate' with rather narrow focus
- Now, we understand it to be much broader
  → composition & air quality
  → hydrology & flooding
  → ....

Example 1: Gravity Wave Drag

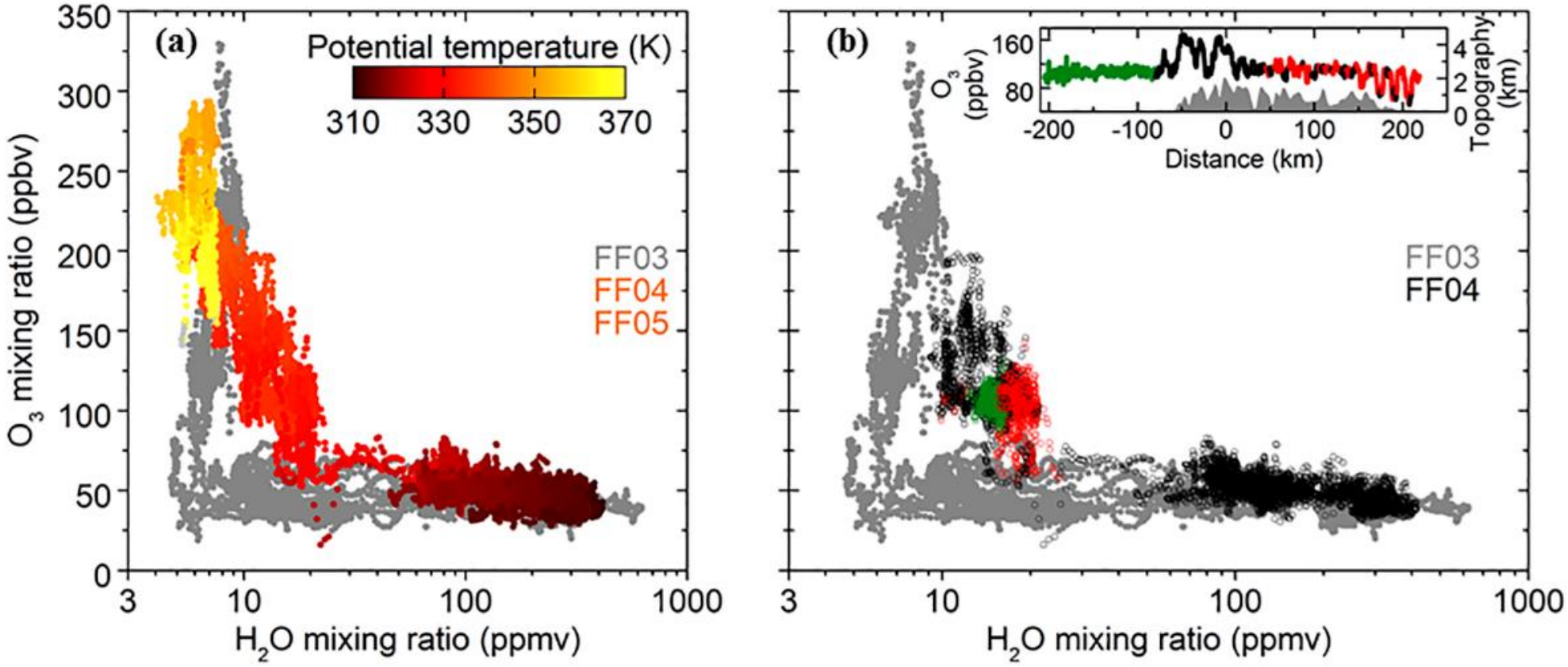
- Despite major advances in GWD representation and observation (e.g. DEEPWAVE 2014), there remain significant areas of uncertainty
- Scientific uncertainties
  - Role in transport of water vapour and constituents
  - Tropospheric response to stratospheric gravity wave breaking, e.g. downslope wind/Föhn predictability
- Technological uncertainties
  - Representation of partially resolved gravity waves in global and regional NWP (climate models)

Momentum exchange



Courtesy A Brown (ECMWF)

Gravity Wave Drag



Heller *et al* 2017 ACP
From DEEPWAVE

Evidence that GW breaking is modulating the UTLS water vapour

Example 2: Air Chemistry

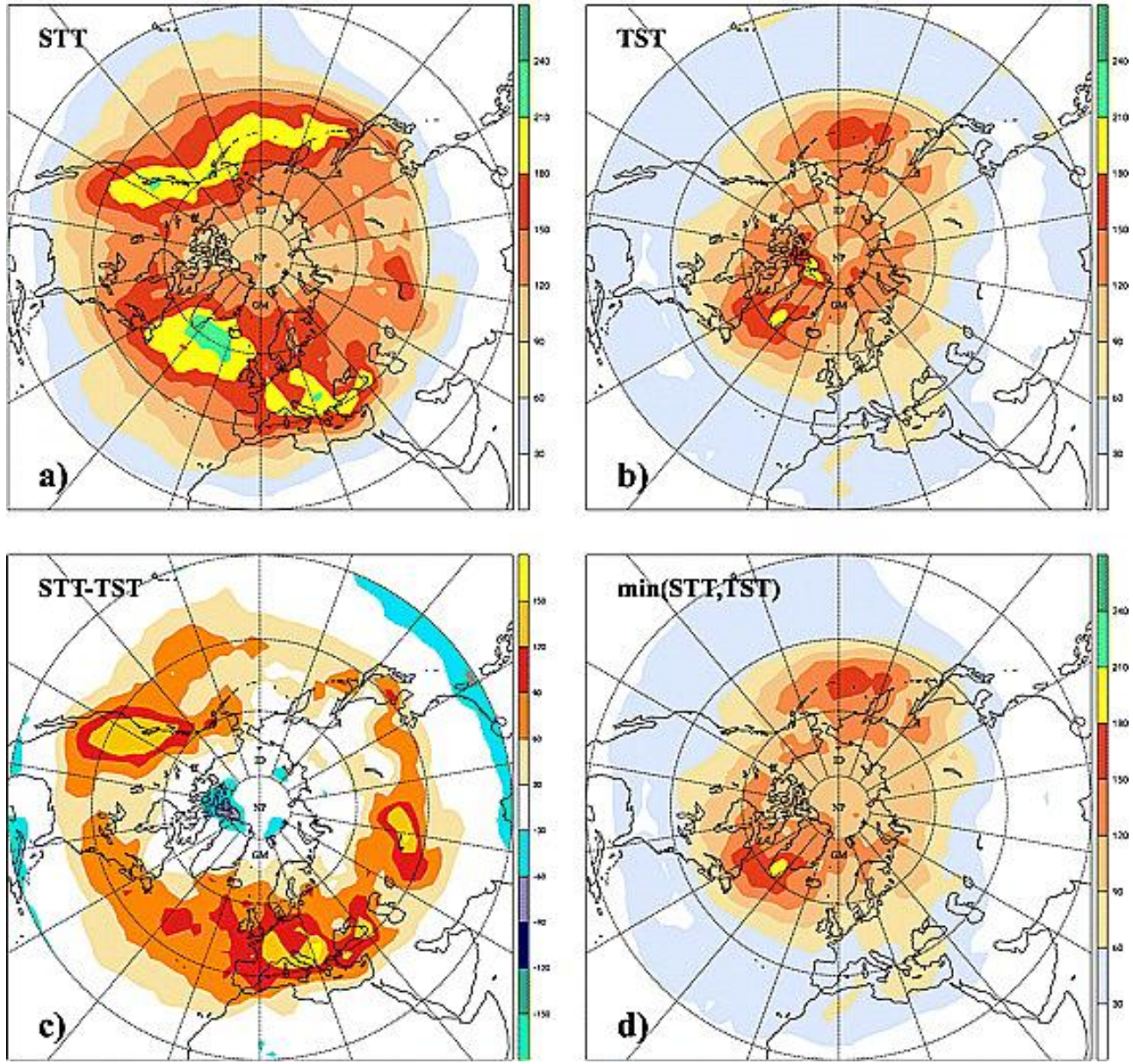
- Possible focus on two areas representing significant scientific and impact uncertainty/relevance
  - Atmospheric boundary-layer pollution in mountainous terrain, e.g. cold pooling, boundary-layer venting
  - The role of mesoscale mountain flows in troposphere-stratosphere exchange
- Previous mountain meteorology experiments have tended to be motivated by challenges in weather and to a lesser extent climate impacts – these remain current and relevant but air quality has at least equal societal relevance.

Air Chemistry

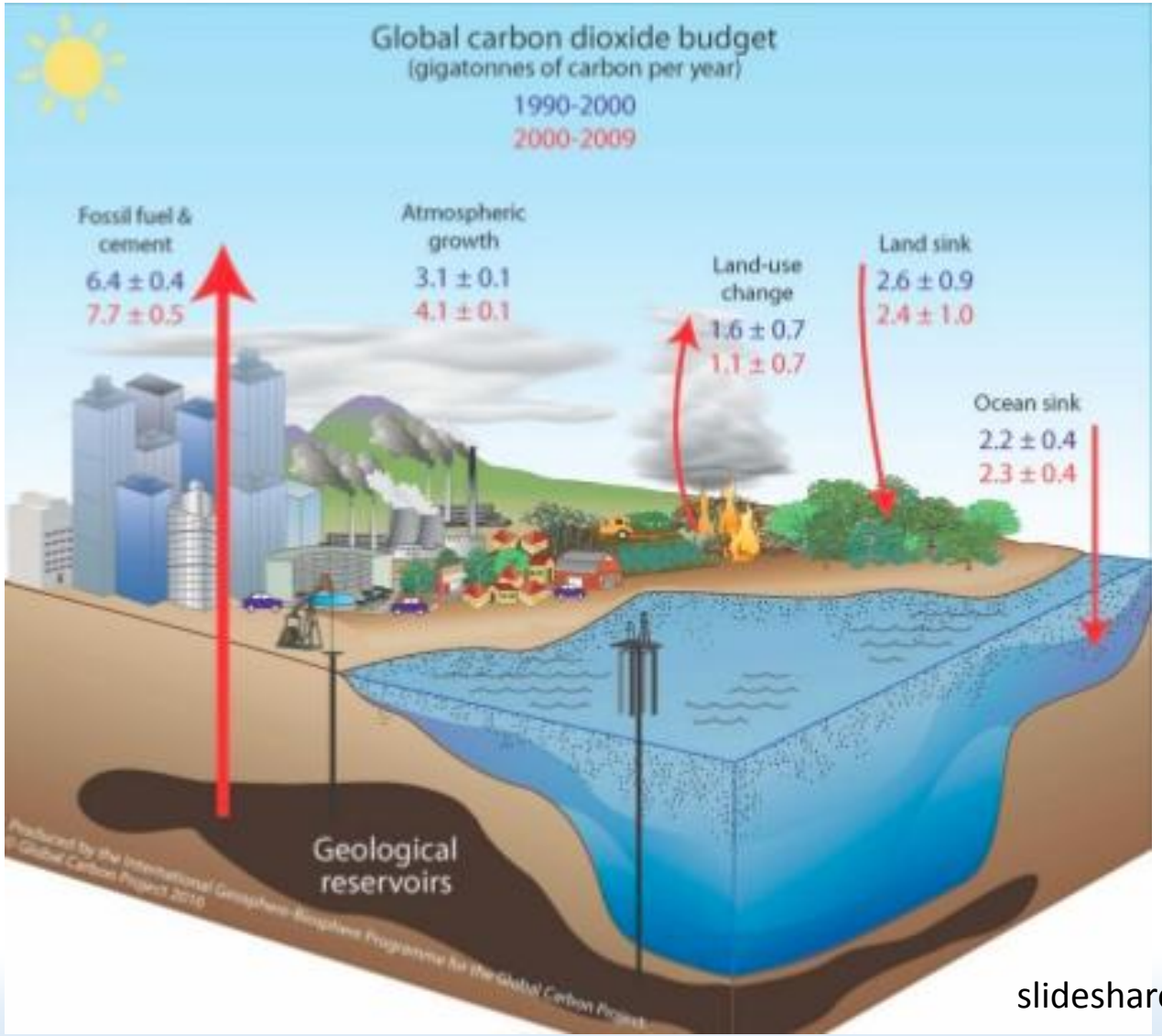
From Sprenger & Wernli
JGR 2003

Troposphere-Stratosphere
Mass fluxes from ERA15

Net flux correlated with
Mid-latitude mountains?



Example 3 – global Carbon budget



slideshare.net

Fate of Anthropogenic CO_2 Emissions

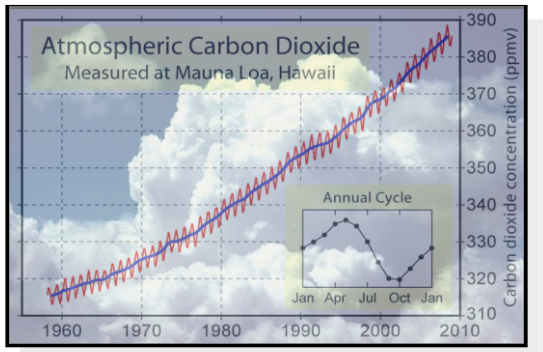
9.3 ± 0.5 PgC y^{-1}

+

1.0 ± 0.5 PgC y^{-1}

4.5 ± 0.1 PgC y^{-1}

45%



3.1 ± 0.9 PgC y^{-1}

30%

Calculated as the residual of all other flux components

26%

2.6 ± 0.5 PgC y^{-1}

Average of 5 models

Global Carbon Project 2010; Updated from Le Quéré et al. 2016 – budget: 2006-2015

Land surface Carbon uptake

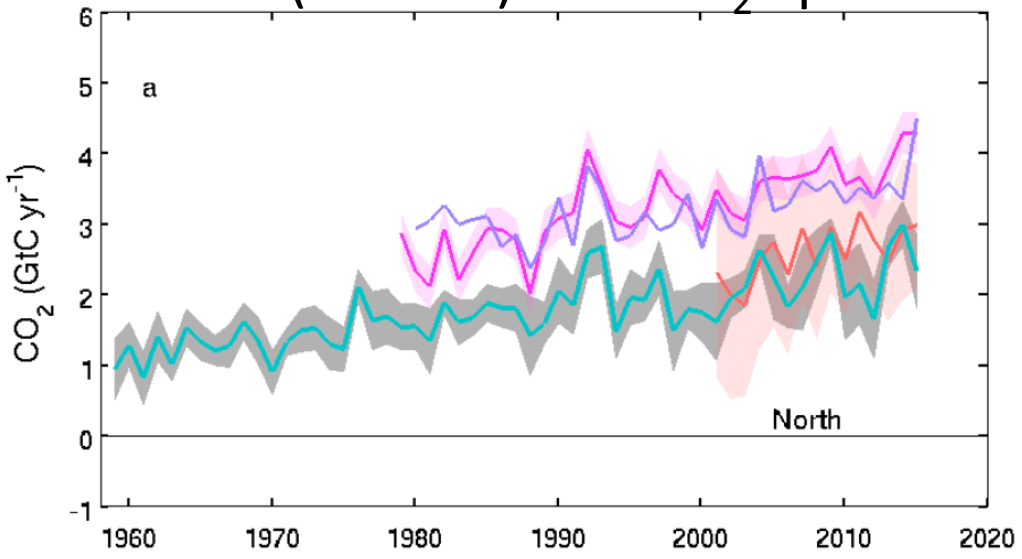
Overall:

⟶ uncertainty of land uptake the largest

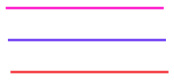
⟶ land uptake modelled depends on method
(2.3 vs. 2.7/3.8/3.8 PgC y^{-1} for 2006-2015)

⟶ *modelled*: does not take into account terrain

NH (> 30° N) land CO_2 uptake



Dynamic veg models



atmospheric inversions

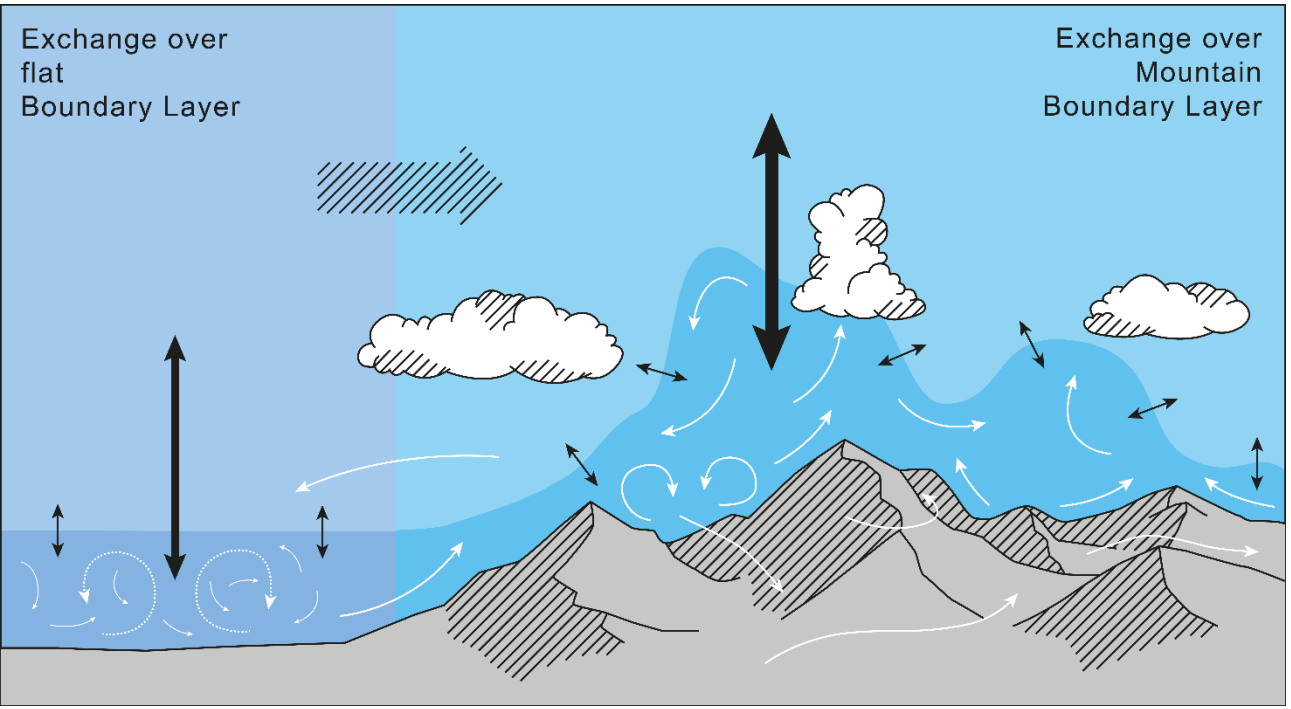
(Le Quere et al. 2016)

Modeled land surface uptake

Model approaches:

- ➢ atmospheric inverse modeling
- ➢ dynamic global vegetation models

} → rely on 'boundary layer exchange'



→ Is the near-surface exchange parameterized appropriately?

→ In 10 km grid-spacing climate models? (in 1 km grid spacingn NWP models?)

→ is the Mountain Boundary Layer correctly reproduced?

Example 4 – flash flood modelling

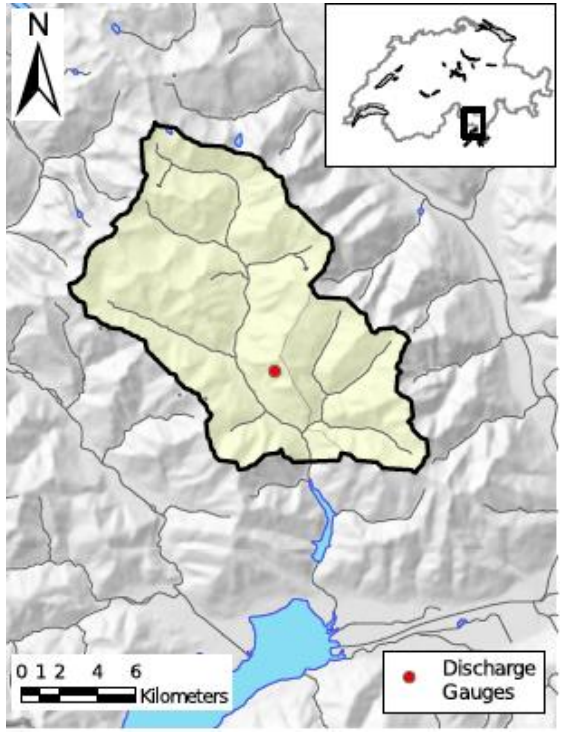
Verzasca Valley
7-8 August 1978

Picture from Antonio Giordani

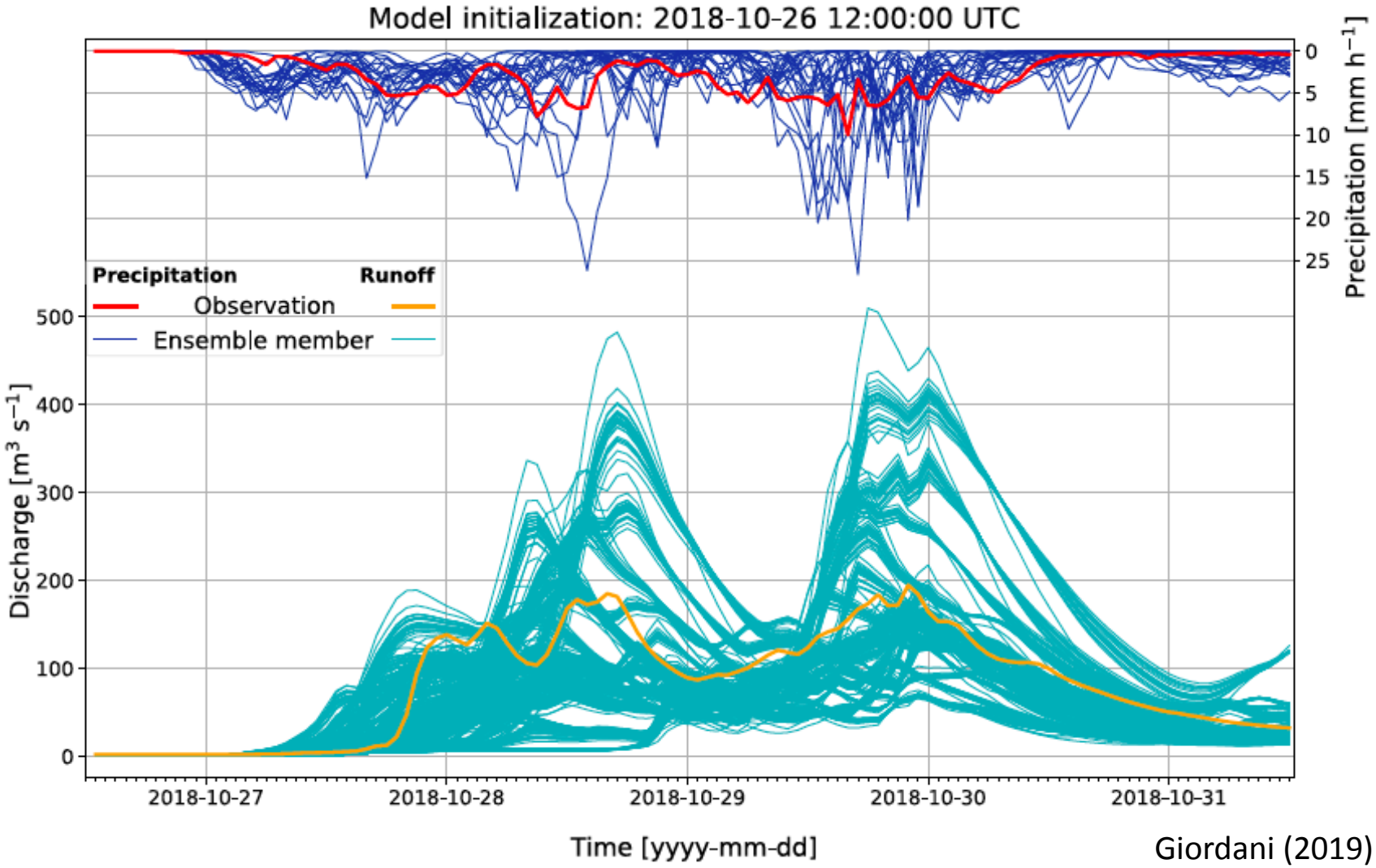
Hydrological Ensemble forecast

(based on Antonio Giordani (2019), MSc Thesis, UIBK, in collaboration with Massimiliano Zappa, WSL)

- Small catchment in southern Switzerland: Verzasca (186 km^2)
- Atmospheric EPS: COSMO-E (Klasa et al. 2018)
  → 2.2 km horizontal grid spacing
  → 21 members (clustered from IFS EPS)
- Hydrological model: PREVAH (Viviroli et al 2009)
  → semi-distributed
  → 25 physical parameter combinations
- A total of 21x25=525 simulations per initiation time
- Example: October 26-31, 2018



Hydrological Ensemble forecast

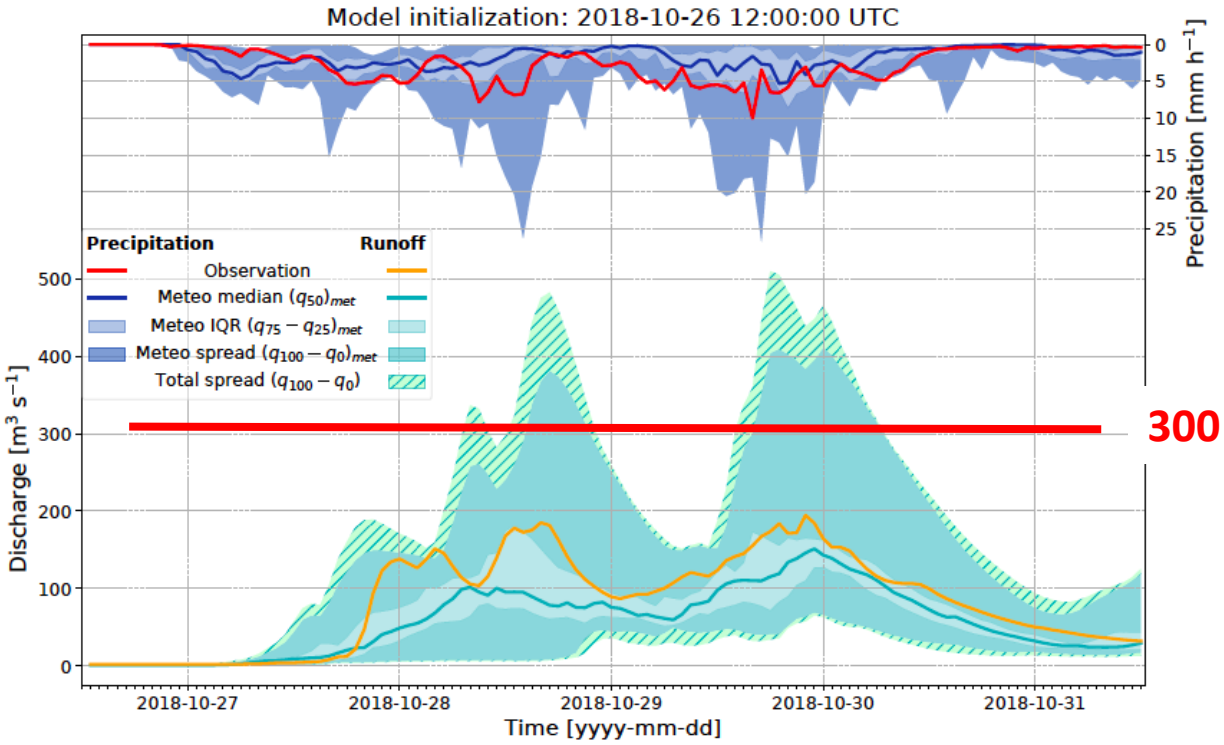


Giordani (2019)

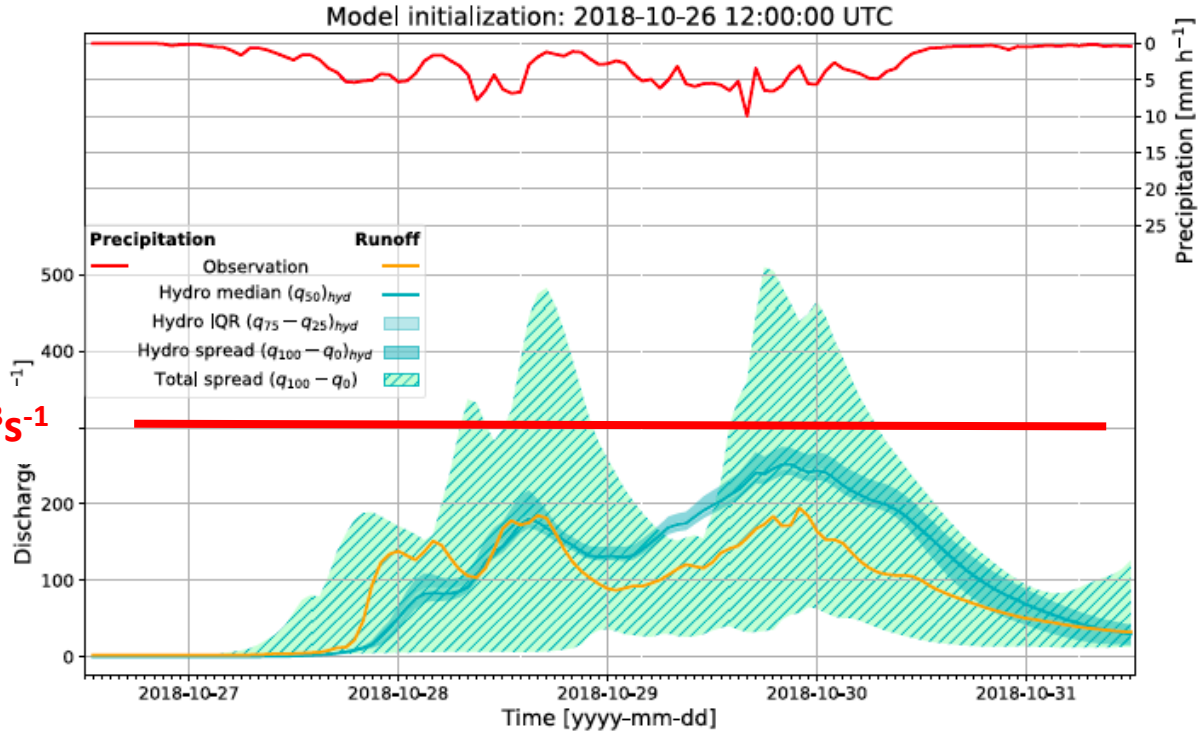
Hydrological Ensemble forecast

Uncertainty from meteorological ensemble

Uncertainty from hydrological ensemble



300 m^{3}s^{-1}



Giordani (2019)

Hydrological Ensemble forecast

- dominant contribution to uncertainty: meteorological input
- Example for small catchment → quite general result
- Impact-oriented modelling (like hydrology)
  → needs realistic meteorological input
- In many ways related to exchange processes in the MoBL
  → convection & CI
  → moisture abundance
  → dynamic flow modification
- Similar for many other types of impact-oriented forecast models

Technological Drivers

- There have been huge technological advances in observational and computational technology since previous intensive observational campaigns
- Ground-based remote sensing:
  - Radar, lidar, boundary-layer profiling, tomographic
- Satellite-based remote sensing:
  - Resolution, parameters retrieved
- Airborne sampling and remote sensing
- Large sensor networks

Technological Drivers

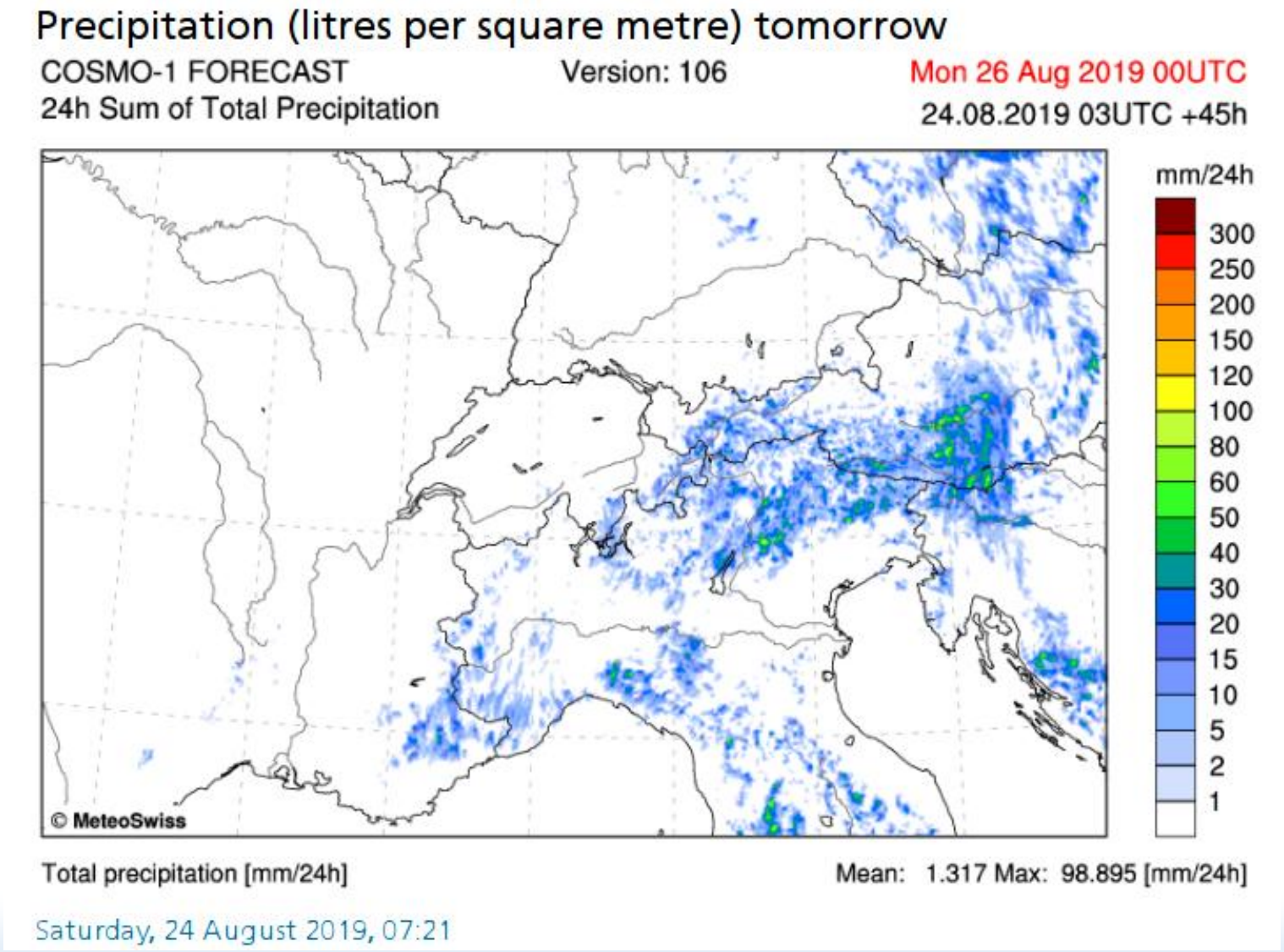
- Model advances:
  - Unprecedented resolutions made possible by advances in computer hardware and software
  - These resolutions raise many new questions concerning the representation of physical and other processes
  - New challenges for model initialisation and evaluation arise: acquisition of observational data, data assimilation techniques
  - The days of getting more power for less money as a result of computer advances are almost over – Moore's law is over. In the future we will depend on innovative algorithms, better models, better data

Technological Drivers

Extreme resolution forecasting

e.g. COSMO-1 @ 1.1 km

Such high resolutions challenge not only the computational science and physical model formulation but also DA and model evaluation



TEAMx

Multi-scale **T**ransport and
Exchange Processes in the
Atmosphere over
Mountains
Programme and e**x**periment

- discussion started: after ICAM-2015
- meetings aside conferences
- Coordination and Implementation Group established (9/2017)

Coordination and Implementation Group

- Marco Arpagaus, MeteoSwiss
- Joan Cuxart, Universitat de les Illes Balears
- Stefan De Wekker, University of Virginia
- Vanda Grubišić, NCAR
- Norbert Kalthoff, Karlsruhe Institute of Technology (KIT)
- Daniel Kirshbaum, Mc Gill University
- Manuela Lehner, University of Innsbruck
- Stephen Mobbs, University of Leeds (NCAS)
- Alexandre Paci, Meteo France (CNRS)
- Elisa Palazzi, ISAC CNR
- Mathias Rotach, University of Innsbruck (chair)
- Stefano Serafin, University of Innsbruck (project coordinator)
- Dino Zardi, University of Trento

Coordination and Implementation Group

What did we do?

- Memorandum of Understanding
  → document to express common understanding of the importance of Mountain Weather & Climate, the need for research and collaboration

TEAMx

The TEAMx Programme Coordination Office is hosted at the University of Innsbruck, Austria

Contact

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

Memorandum of Understanding signed on:

- University of Virginia: 15 May 2018
- Meteo France: 17 May 2018
- University of Trento: 18 May 2018
- University of Innsbruck: 23 May 2018
- MeteoSwiss: 28 May 2018
- Center for Climate Systems Modeling: 1 June 2018
- McGill University: 11 June 2018
- Karlsruhe Institute of Technology: 26 September 2018
- National Centre for Atmospheric Science (UK): 8 November 2018

- Signatories as ‚founding institutions'
- New signatories welcome (and underway)

Coordination and Implementation Group

What did we do?

- Memorandum of Understanding
- Establish a Programme Coordination Office (PCO)
  → ‘crowd funding’ among founding institutions
  → sponsors: Karlsruhe Institute of Technology KIT, Météo France, MeteoSwiss, National Center for Atmospheric Science (NCAS), University of Innsbruck, University of Trento, ZAMG, *C2SM (pending*)
  → Progamme Coordinator: Stefano Serafin (UIBK)

Coordination and Implementation Group

What did we do?

- Memorandum of Understanding
- Establish a Programme Coordination Office
- Special Issue on Special Issue **"Atmospheric Processes over Complex Terrain“** in ‘Atmosphere’
  → guest editors Rotach & Zardi

Special Issue ‚Atmosphere‘

Atmospheric Processes over Complex Terrain

- De Wekker, S.F.J., Kossmann, M., Knievel, J.C., Giovannini, L., Gutmann, E.D., Zardi, D. (2018): Meteorological Applications Benefiting from an Improved Understanding of Atmospheric Exchange Processes over Mountains. *Atmosphere*, **9**, 371.

- Emeis, S., Kalthoff, N., Adler, B., Pardyjak, E., Paci, A., Junkermann, W. (2018): High-Resolution Observations of Transport and Exchange Processes in Mountainous Terrain. *Atmosphere*, **9**, 457.

- Hacker, J., C. Draper, and L. Madaus (2018): Challenges and Opportunities for Data Assimilation in Mountainous Environments. *Atmosphere*, **9**, 127.

- Katopodes Chow, F., Schär, C., Ban, N., Lundquist, K.A., Schlemmer, L., Shi X. (2019): Crossing Multiple Gray Zones in the Transition from Mesoscale to Microscale Simulation over Complex Terrain. *Atmosphere*, **10**, 274.

- Kirshbaum, D.J., B. Adler, N. Kalthoff, C. Barthlott and S. Serafin (2018): Moist Orographic Convection: Physical Mechanisms and Links to Surface-Exchange Processes. *Atmosphere*, **9**, 80.

- Lehner, M. and M.W. Rotach (2018): Current Challenges in Understanding and Predicting Transport and Exchange in the Atmosphere over Mountainous Terrain *Atmosphere*, **9**, 276.

- Serafin, S., B. Adler, J. Cuxart, S.F.J. De Wekker, A. Gohm, B. Grisogono, N. Kalthoff, D.J. Kirshbaum, M.W. Rotach, J. Schmidli, I. Stiperski, Ž. Večenaj and D. Zardi (2018): Exchange Processes in the Atmospheric Boundary Layer Over Mountainous Terrain. *Atmosphere*, **9**, 102.

- Vosper, S.B., Ross, A.N., Renfrew, I.A., Sheridan, P., Elvidge, A.D., Grubišić, V. (2018): Current Challenges in Orographic Flow Dynamics: Turbulent Exchange Due to Low-Level Gravity-Wave Processes. *Atmosphere*, **9**, 361.

- Giovannini et al: Atmospheric pollutant transport over complex terrain, in preparation

Goal:

- Solicit review articles on topics relevant for the TEAMx
- Basis for TEAMx White Paper

Coordination and Implementation Group

What did we do?

- Memorandum of Understanding
- Establish a Programme Coordination Office
- Special Issue on Special Issue **"Atmospheric Processes over Complex Terrain“**
- TEAMx White Paper
  → Science Plan for TEAMx
  → largely based on ‘special issue papers’
  → subject of this workshop

Coordination and Implementation Group

What did we do?

- Memorandum of Understanding
- Establish a Programme Coordination Office
- Special Issue on Special Issue **"Atmospheric Processes over Complex Terrain“**
- TEAMx White Paper
- Funding opportunities
  → coordinate efforts
  → enable collaboration

Funding opportunities

- TEAMx is **bottom-up financed**
  → no ‘big pot of money’
  → *your project* – if it conforms to the scientific goals of TEAMx – contributes to the scientific achievements of TEAMx
- Projects can be stand-alone projects / bi- (multi) lateral / programmes
- CIG / PCO supports coordination / initiation of new collaborative projects
  → more in the wrap up session

TEAMx Science plan – White Paper

TEAMx Science plan – White Paper

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.

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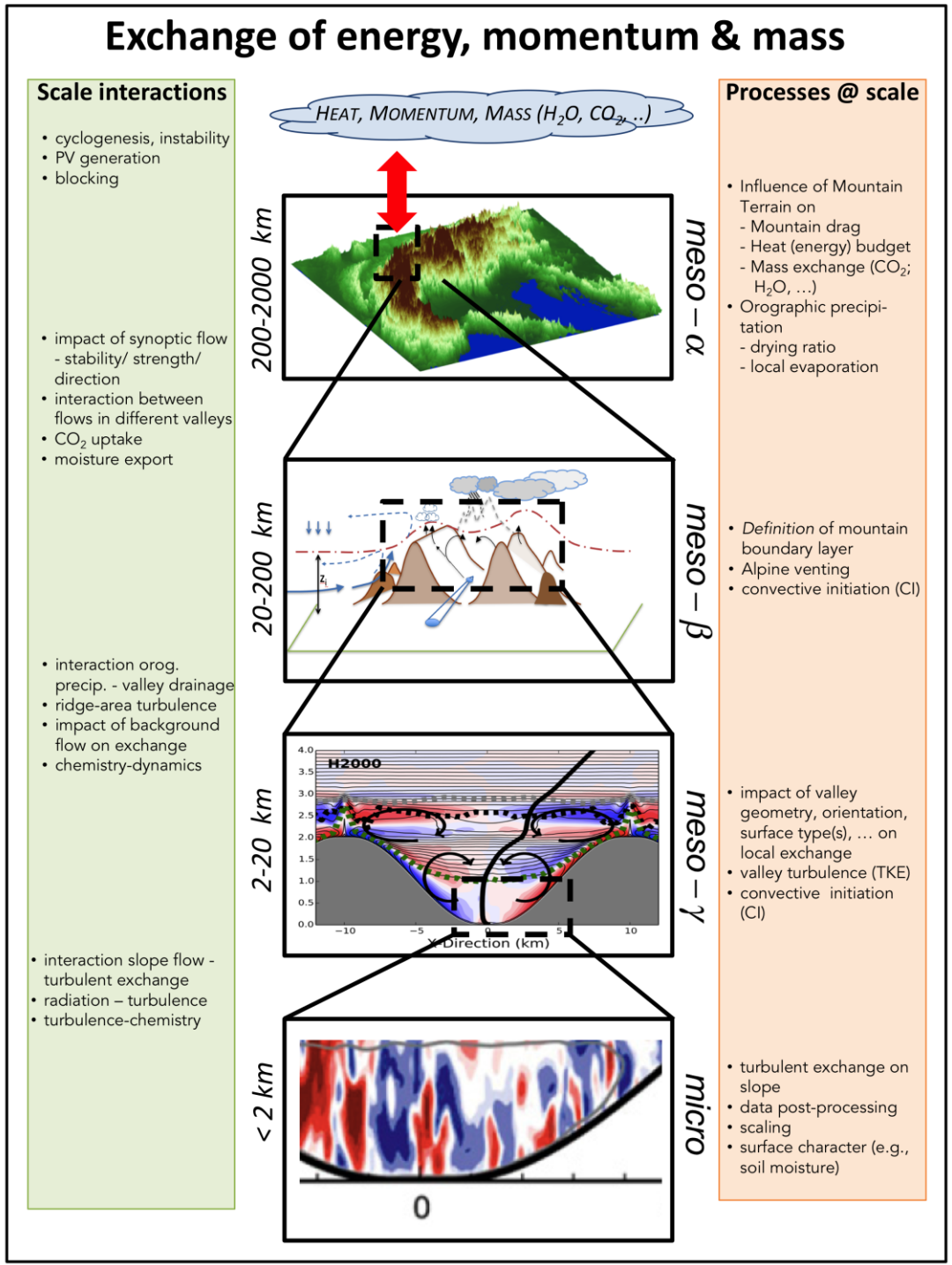
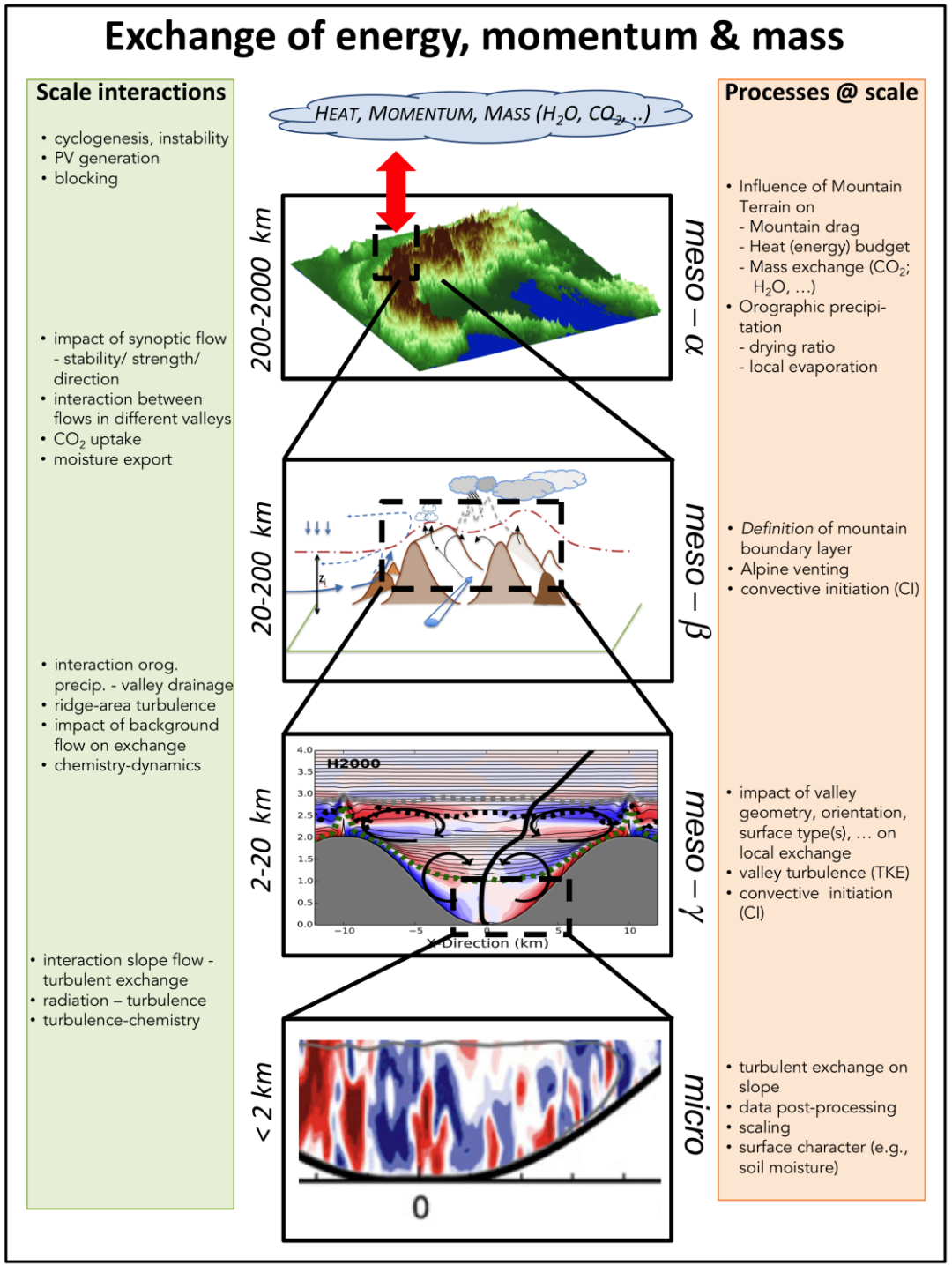
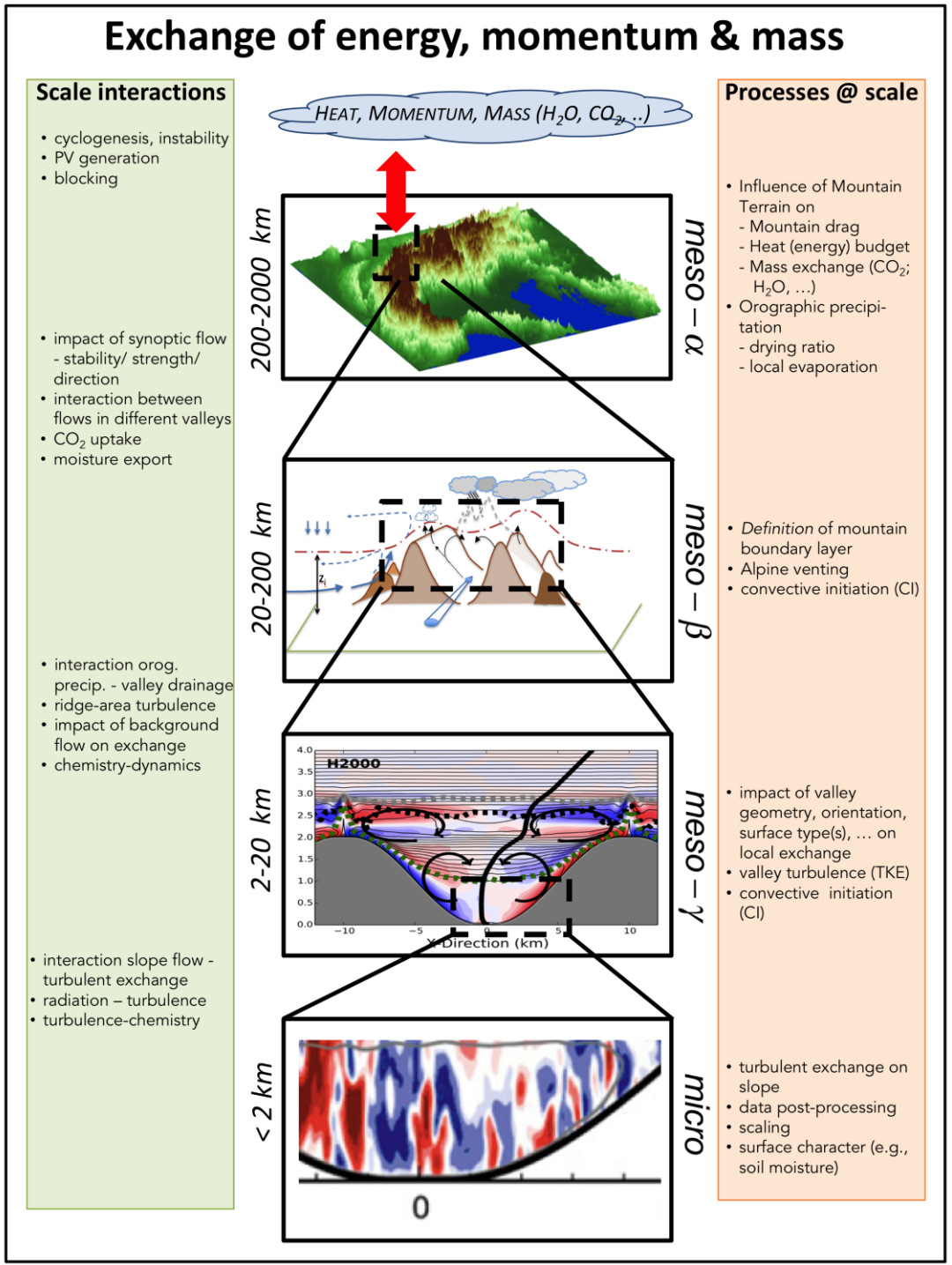
… and their interactions



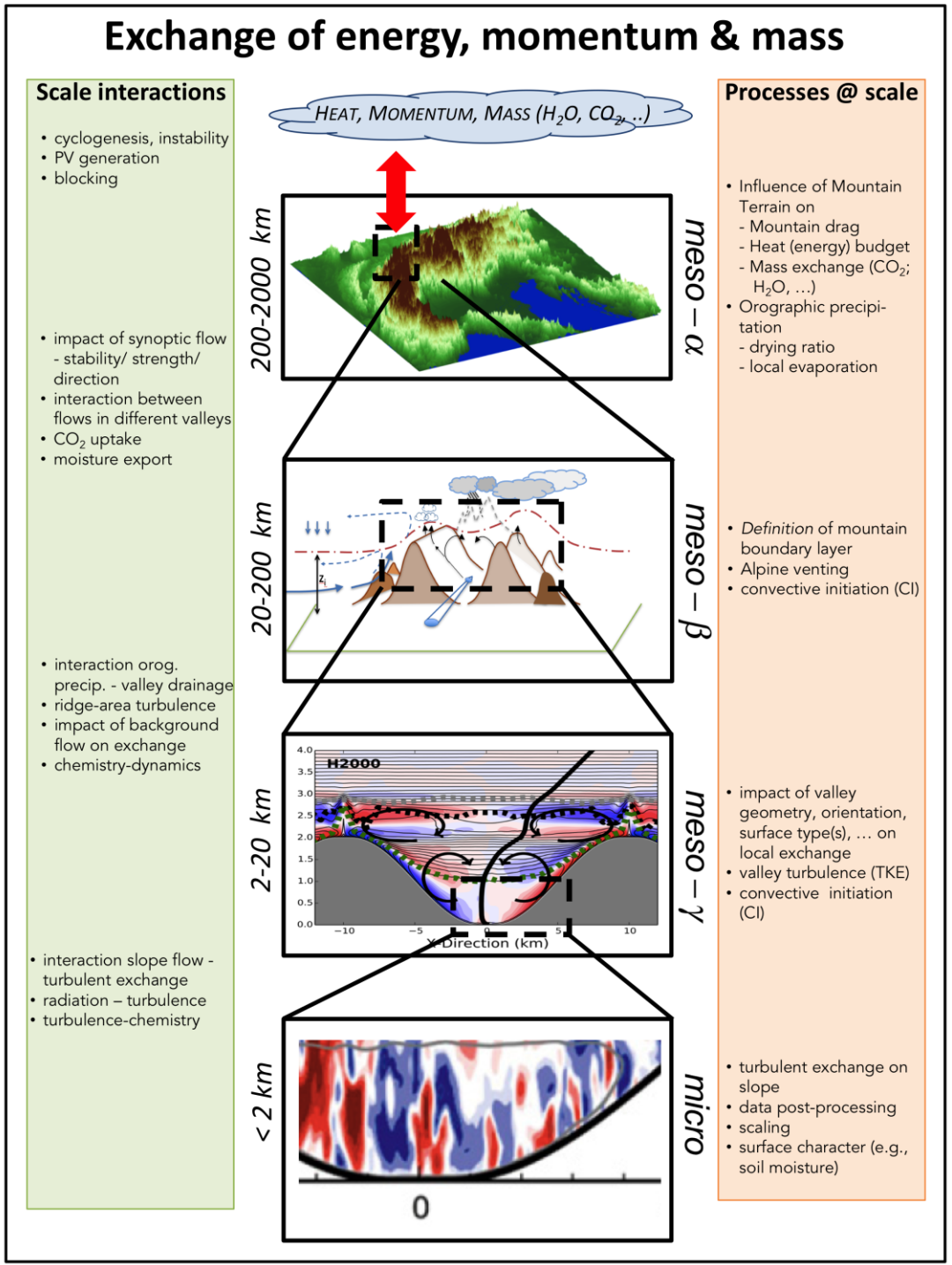
Processes at various spatial scales …



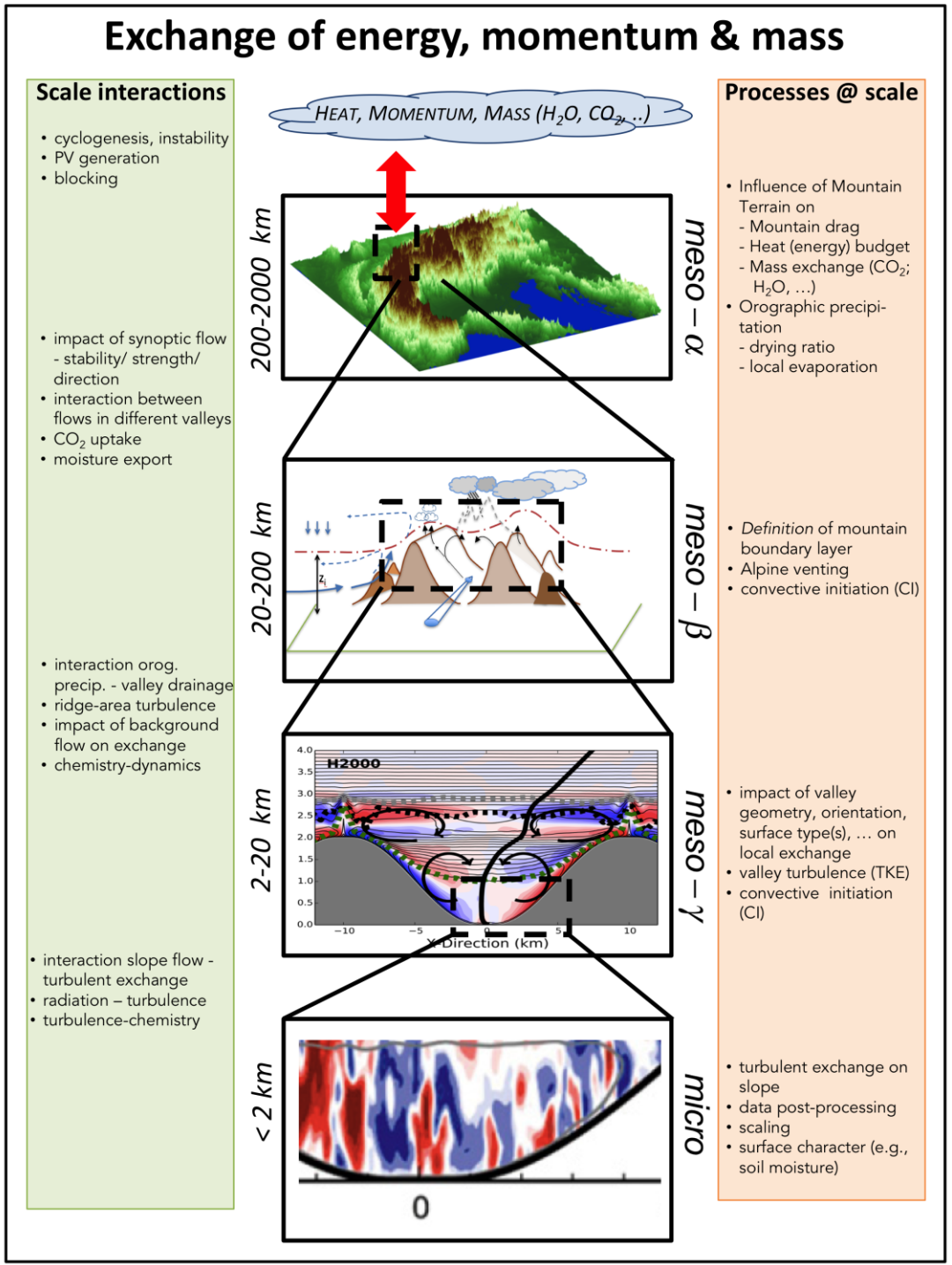
- Influence of mountain terrain on
  - mountain drag
  - heat (energy) budget
  - mass exchange (CO_2; H_2O, …)
- orographic precipitation
  - drying ratio
  - local evaporation



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

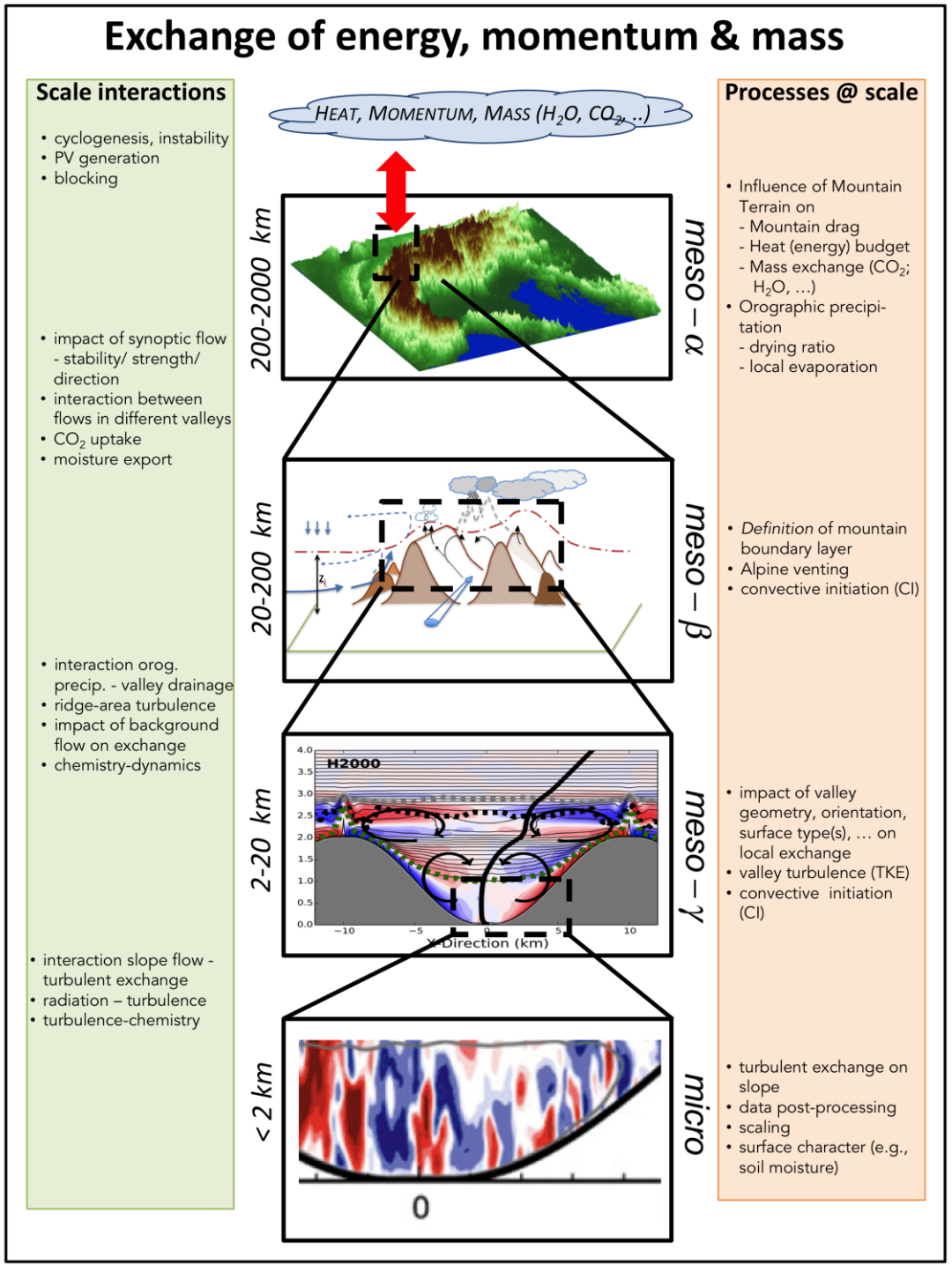


- impact of valley geometry, orientation, surface type(s), … on local exchange
- valley turbulence (TKE)
- convection initiation (CI)

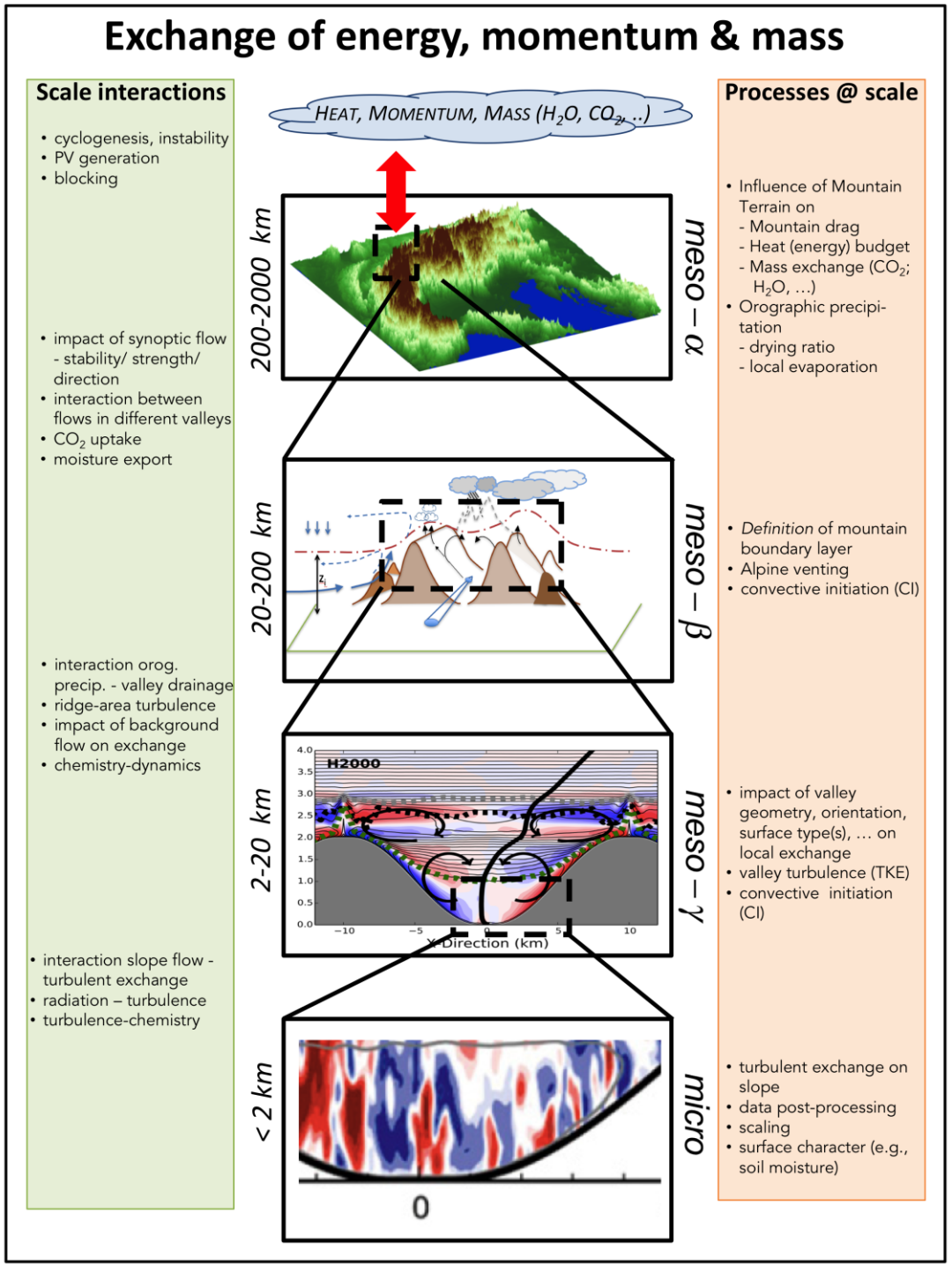


- turbulent exchange on slope
- data post-processing
- scaling
- surface character (e.g., soil moisture)

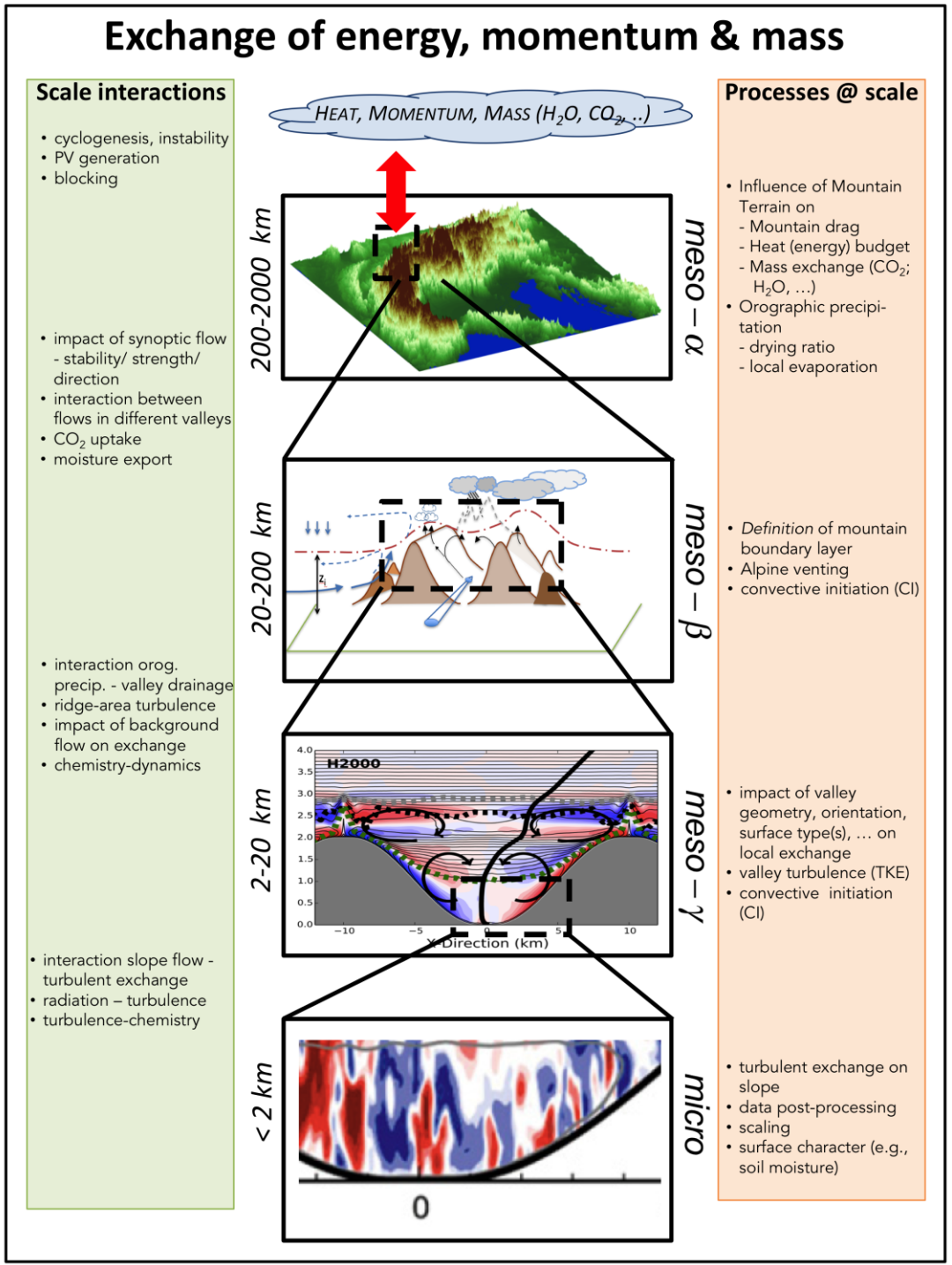
- cyclogenesis, instability
- PV generation
- blocking



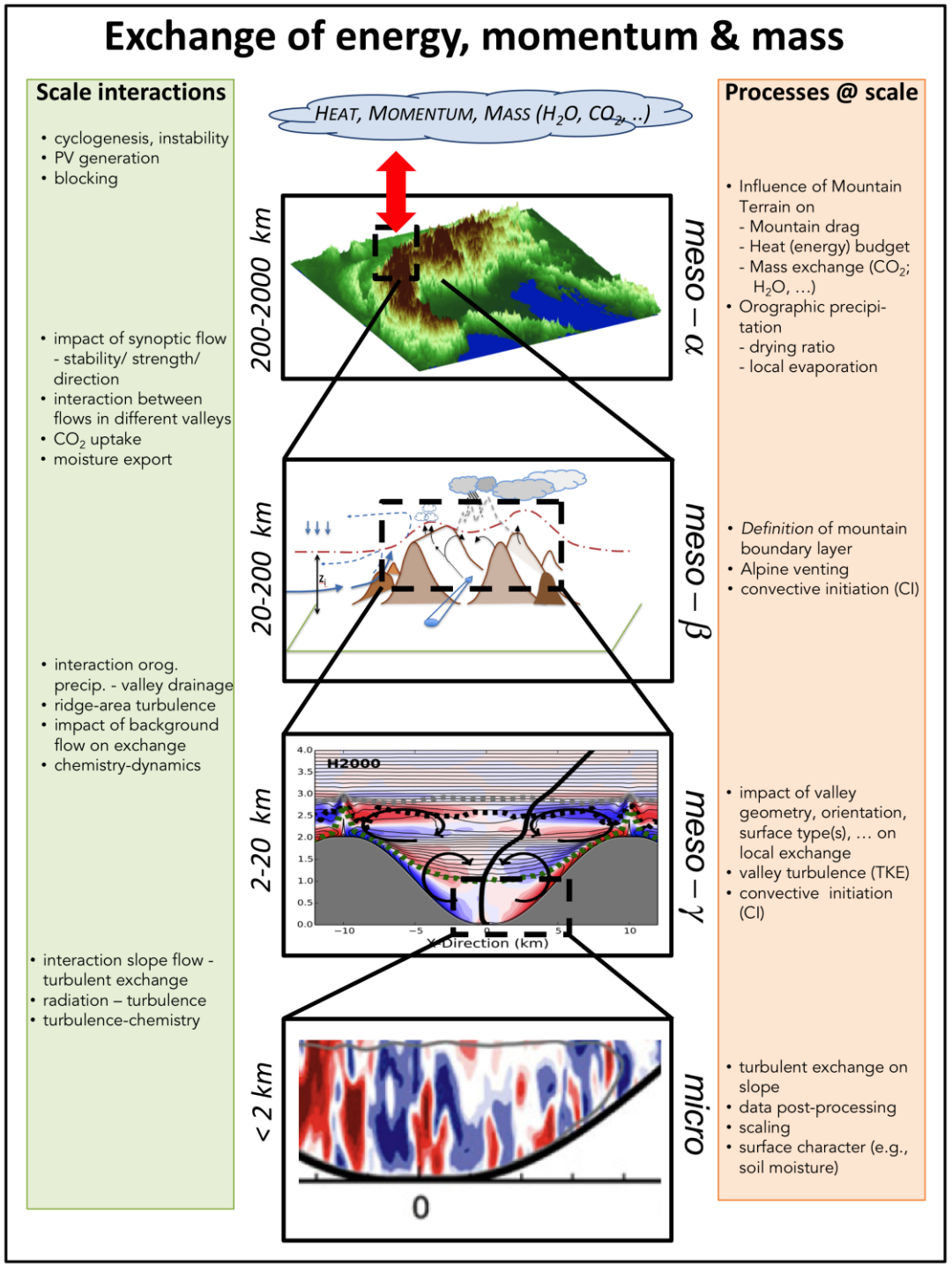
- impact of synoptic flow
  - stability/ strength/ direction
- interaction between flows in different valleys
- CO_2 uptake
- moisture export



- 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

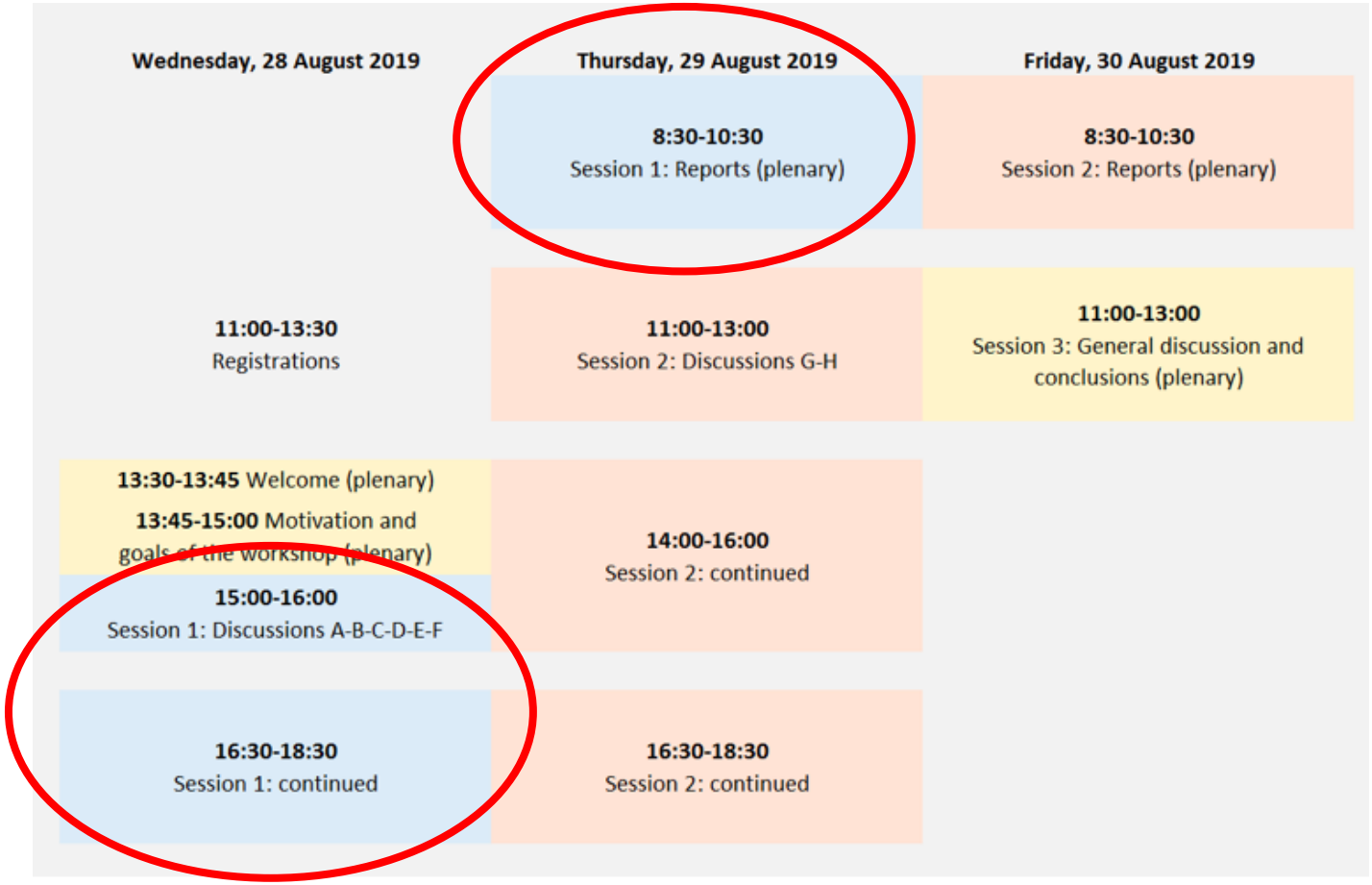


Overall Scientific Goals

- Understand the **processes** contributing to exchange over mountains
- Joint **field experiment**
  → many of the objectives cannot be addressed by one group alone
  → what must be coordinated?
  → how to produce ‘more than the sum’ in terms of exp facilities?
- Numerical **modelling**
  → needs for preparation of field experiment
  → lack of reference case (‘theoretical solution’) as benchmark: GABLS-ct?
- Relation to **service providers** (*impact-oriented modeller’s needs*)
  → how to address these in field and numerical modelling experiments?
  → any requirements (variables) more important / more general / more ...?

Aims and organisation of the Workshop

- Today (Wed afternoon)
  - → Discussions A-F
  - → *processes*
- Goal:
  - → content of WP complete?
  - → experimental needs?
  - → numerical modelling needs?
- Each dicussion
  - → produces summary
  - → will be reported Thu morning



Wednesday, 28 August 2019	Thursday, 29 August 2019	Friday, 30 August 2019
	8:30-10:30 Session 1: Reports (plenary)	**8:30-10:30** Session 2: Reports (plenary)
11:00-13:30 Registrations	**11:00-13:00** Session 2: Discussions G-H	**11:00-13:00** Session 3: General discussion and conclusions (plenary)
13:30-13:45 Welcome (plenary) **13:45-15:00** Motivation and goals of the workshop (plenary)	**14:00-16:00** Session 2: continued	
15:00-16:00 Session 1: Discussions A-B-C-D-E-F		
16:30-18:30 Session 1: continued	**16:30-18:30** Session 2: continued	

TEAMx Science plan – Processes

Discussion F: Mountain boundary layer flows

Discussion E: Land-atmosphere exchange

Discussion D: Orographic flow dynamics

Discussion C: Orographic convection

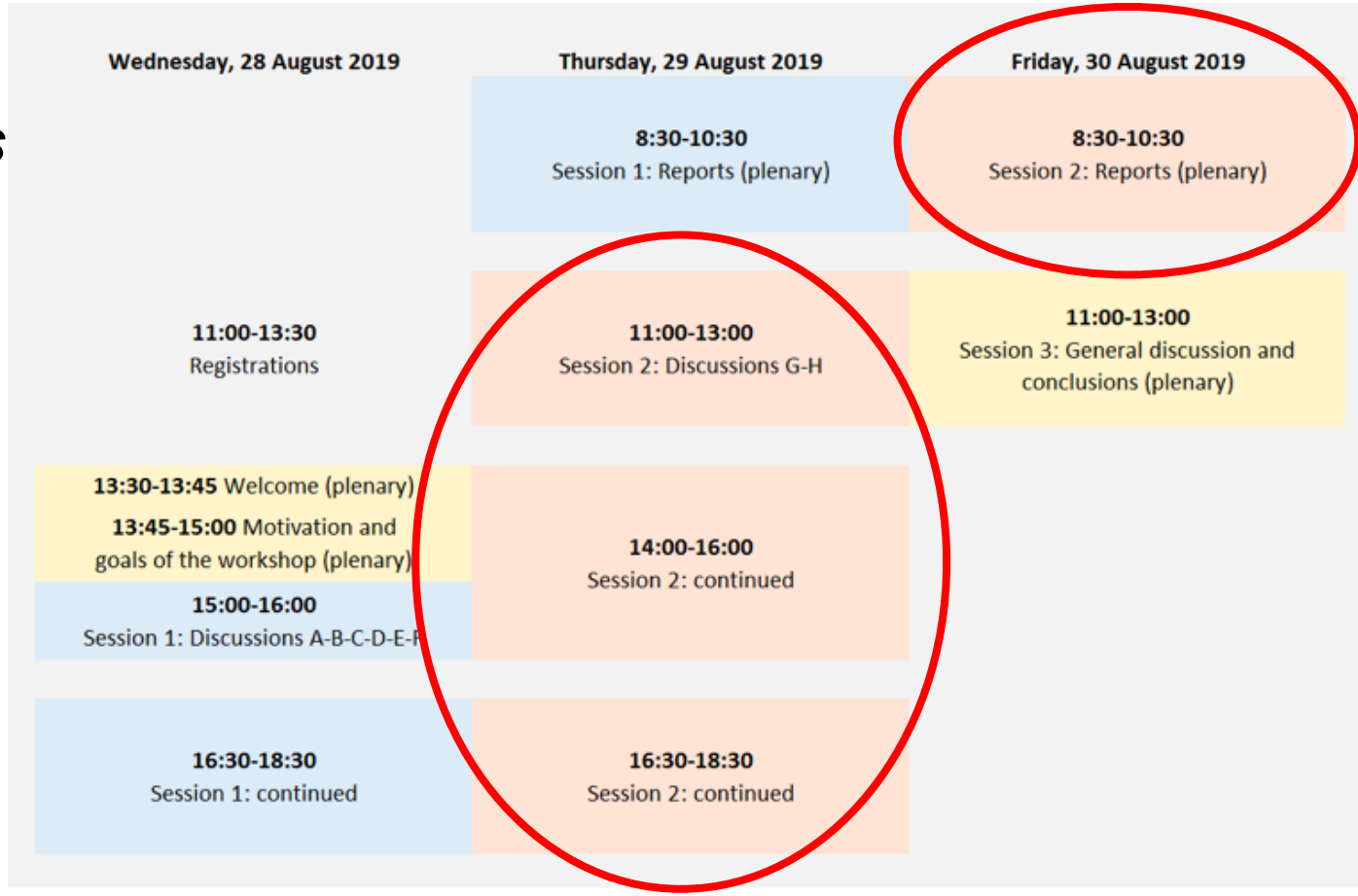
Discussion D: Orographic flow dynamics

Discussion B: Climate processes /changes in mtns

Discussion A: Air chemistry and atmospheric dispersion modelling

Aims and organisation of the Workshop

- Thursday
  - → Discussions G, H
  - → *strategy for field experiments*
  - → *strategy for numerical modelling experiments*
- Goal:
  - → content of WP complete?
  - → joint field experiment: what, when, where, ...
  - → joint numerical modelling activities: what, how, …
- Each dicussion
  - → produces summary
  - → will be reported Fr morning



TEAMx Science plan – Observations

Corresponding Discussions A-F

Discussion G: Strategy for field experiments

TEAMx Science plan – num. Modelling

Corresponding Discussions A-F

Discussion G: Strategy for field experiments

Aims and organisation of the Workshop

- Friday
  - → summary
  - → wrap up

- Goal:
  - → WP2.0
  - → establishment of working groups
  - → ...

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TEAMx

...any questions on

First TEAMx Workshop

Hosting Institutions

UNIVERSITY OF TRENTO - Italy

AISAM Associazione Italiana di Scienze dell'Atmosfera e Meteorologia

universität innsbruck

Funding Institutions

IUGG

IAMAS International Association of Meteorology and Atmospheric Sciences

universität innsbruck

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