

WEATHER CLIMATE WATER



WORLD
METEOROLOGICAL
ORGANIZATION

8th WMO Workshop

on the Impact of Various Observing Systems on
Numerical Weather Prediction and Earth System Prediction

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SMHI



Observations Impact in Complex Mountainous Terrain

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Conclusions

- ▲ there will be a yearlong field campaign
 - EOPs
 - IOPs
- ▲ many additional surface based remote sensing instruments
- ▲ data openly available

Hypothesis

 Weather forecast in **mountainous terrain** is worse than in the flat lands

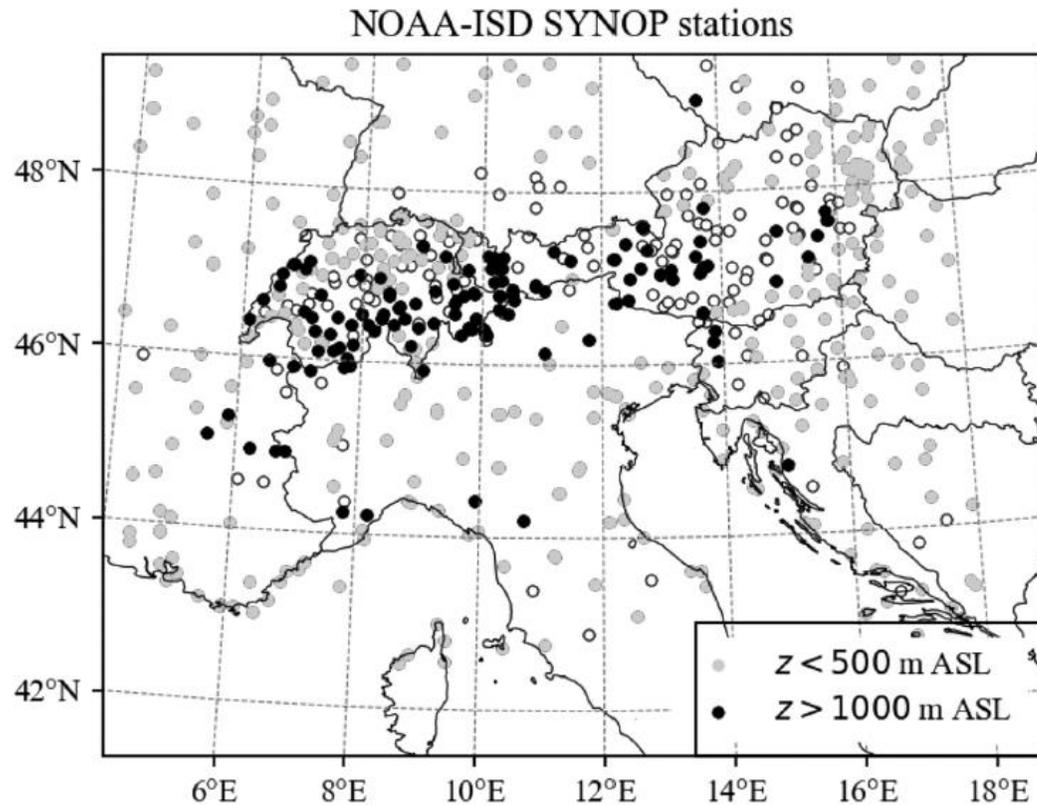
Hypothesis

 Weather forecast in **mountainous terrain** is ~~worse~~ *more challenging* than in the flat lands

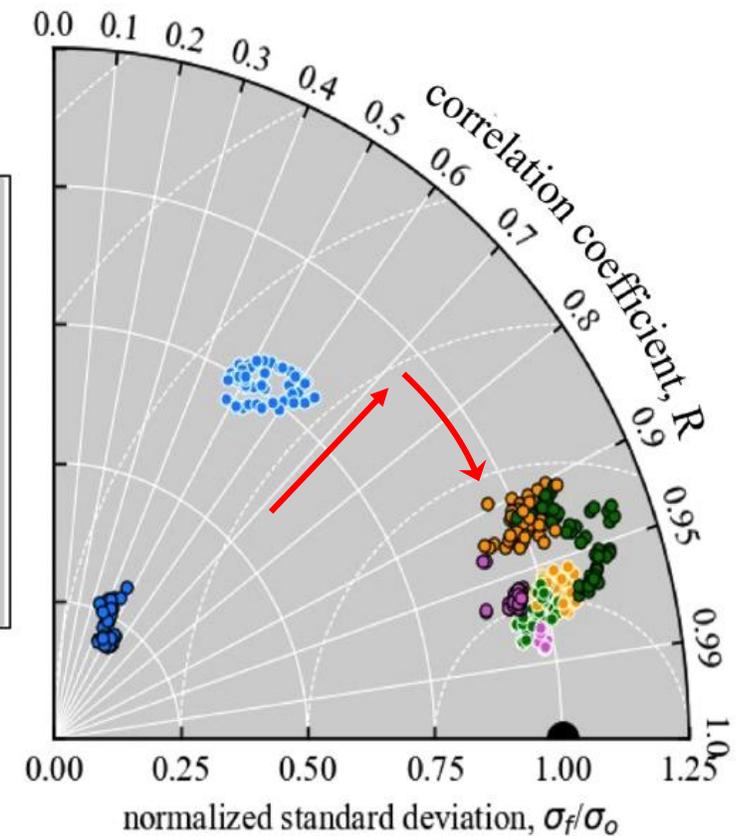
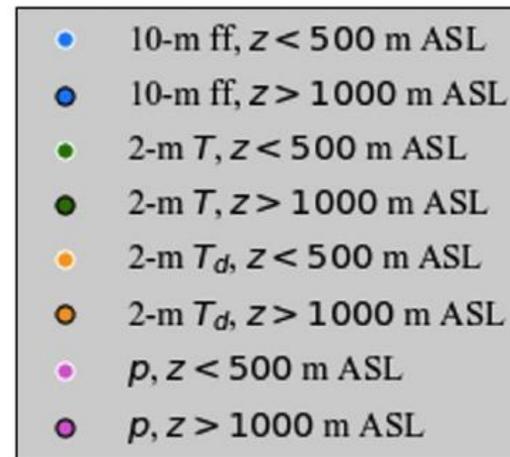
Mountain vs flatland stations

1 hr averages, mountain vs flat lands

IFS, 2016-2019, 0-48 hr forecast



- station height > 1000 asl
- station height < 500 asl



Hypothesis

- ▲ Weather forecast in mountainous terrain is ~~worse~~ *more challenging* than in the flat lands
- ▲ due to
 - mountain-specific processes (and our missing understanding)
 - lower density in observations – also observational challenges
 - larger challenges in DA ...
- ▲ three out of four pillars in TEAMx

TEAMx Science Plan

Objective	Primary Focus	Target
Process understanding	Micro- and meso-scale processes within and above the <i>mountain boundary layer</i> (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	<i>Models right for the right reason</i> , 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 climate change).	Smaller uncertainty of impact models, due to reduced errors in weather and climate information.

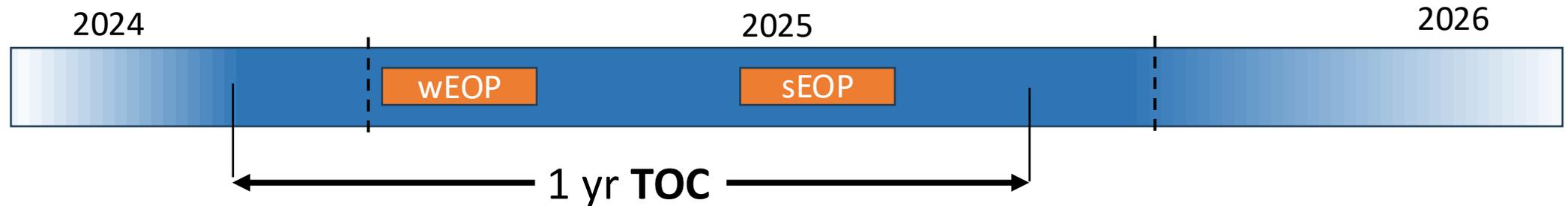
**Multi-scale Transport and
Exchange Processes in the
Atmosphere over
Mountains
Programme and experiment**

- ...a bottom-up financed research program on weather, climate & air pollution in mountain areas
- in the 'tradition' of international mountain meteorology programs (ALPEX, PYREX, MAP → **TEAMx**)
- Institutional 'crowd funding' for a Programme Coordination Office (*PCO* - @ UIBK)
- endorsed by the World Weather Research Programme (WWRP) of WMO cross-cut project of the GEWEX Hydroclimate Panel (WCRP)



TEAMx Observational Campaign (TOC)

Autumn 2024 - autumn 2025 (EOPs and IOPs):

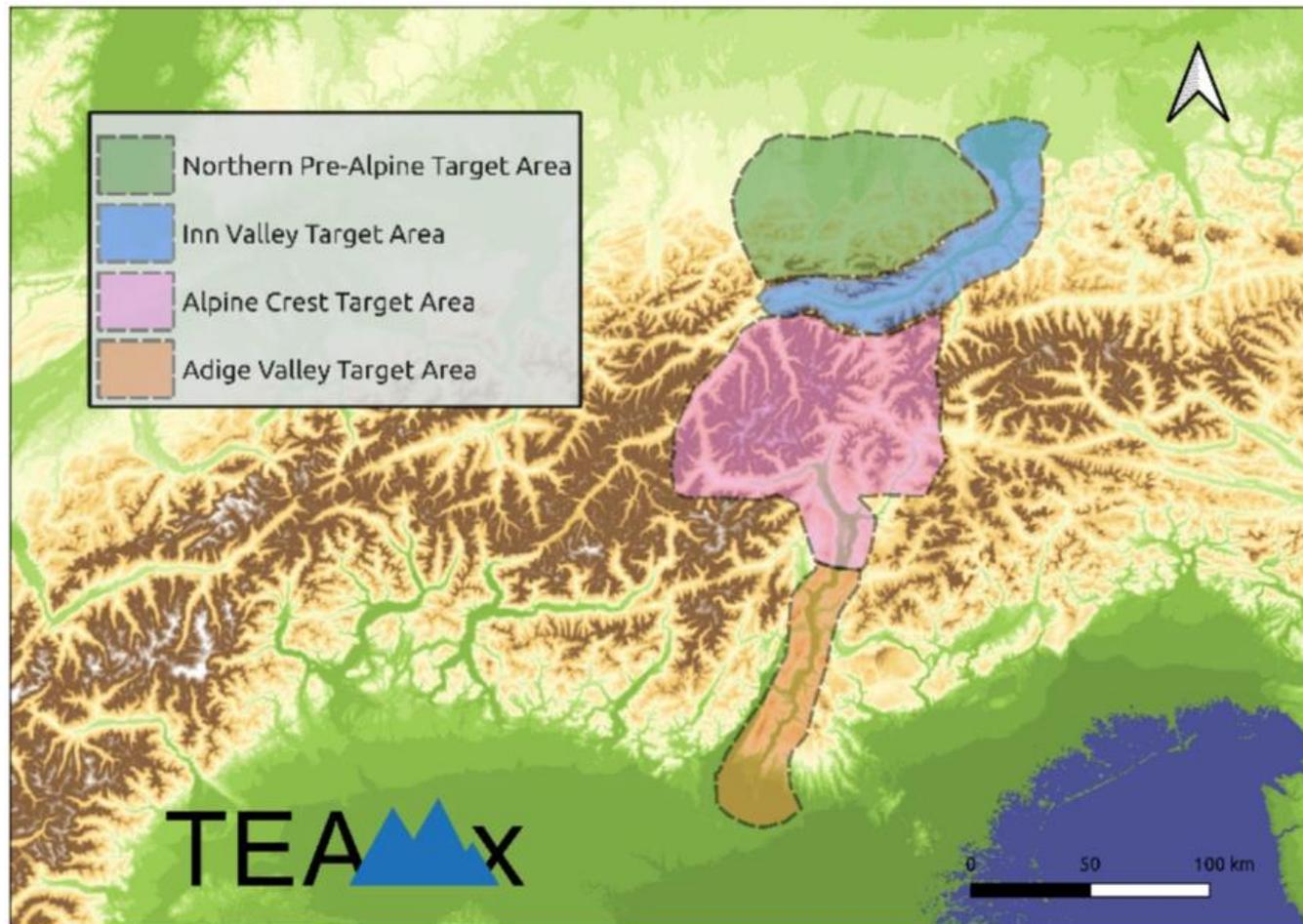


TOC: 1 year duration - operational plus semi-operational networks
- additional deployments (> 'an additional AWS')

Extended Operations period Winter (**wEOP**): 6 weeks
- additional deployments - project based
- IOPs (airborne observations, RaSo, ...)

Extended Operations period Summer (**sEOP**): 6 weeks
- additional deployments – project
- IOPs (airborne observations, RaSo, ...)

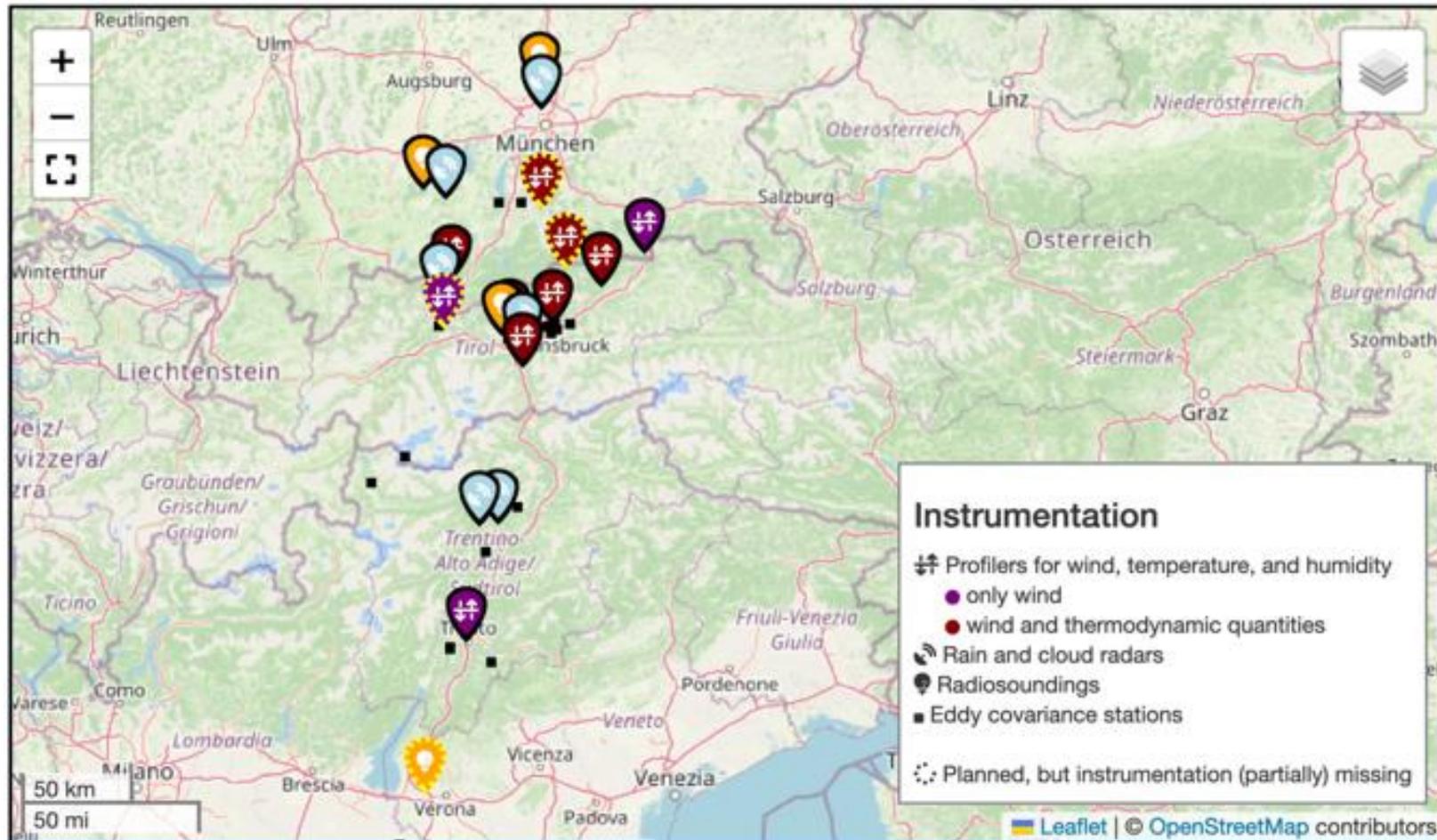
TOC



4 target areas

-  in an area of *relatively* dense AWS coverage
-  accessibility of sites
-  steep gradients

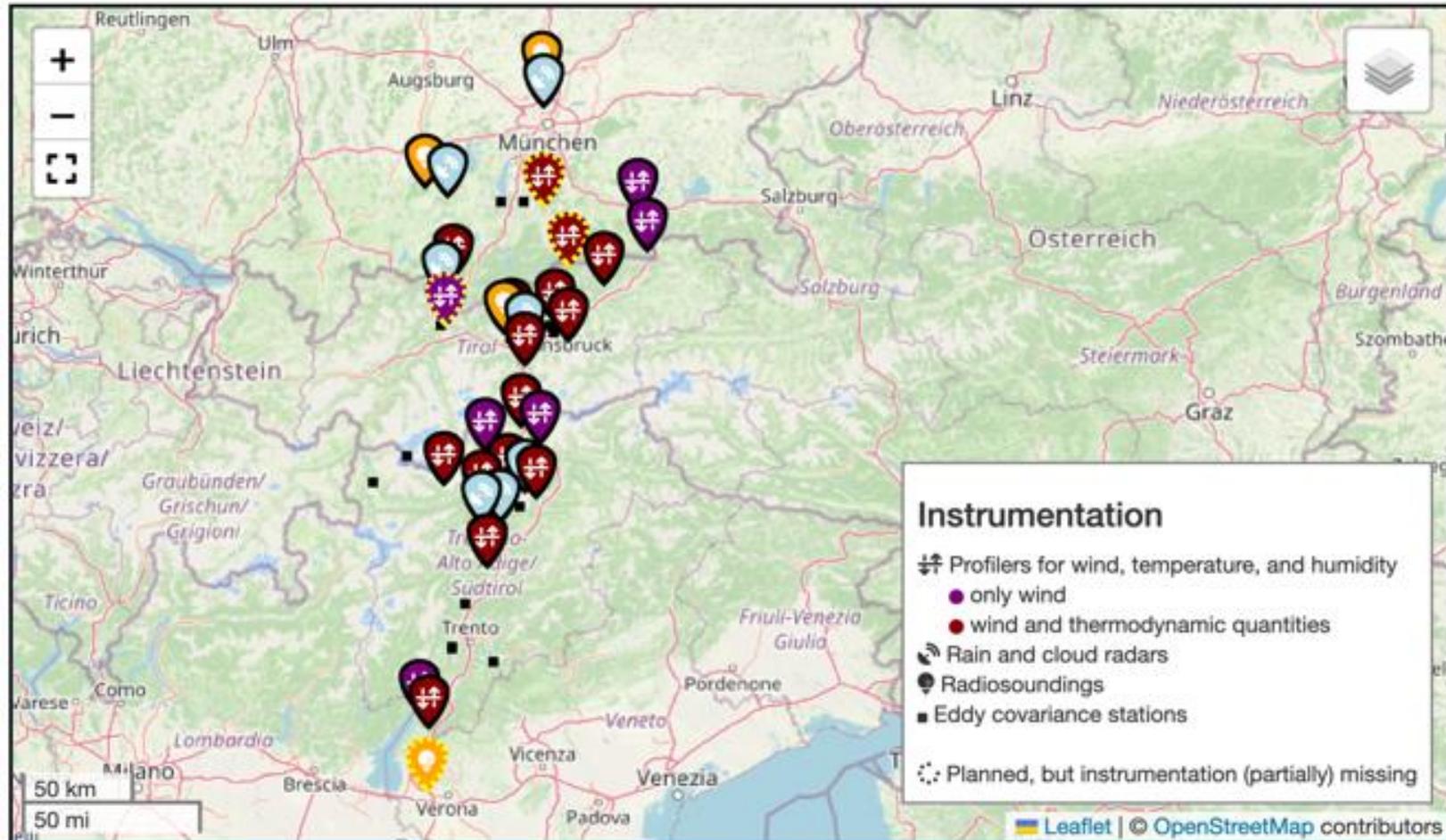
EOPs



Winter EOP

-  additional DWL / T&RH 
-  existing RaSo 
-  existing sfc flux sites 

EOPs



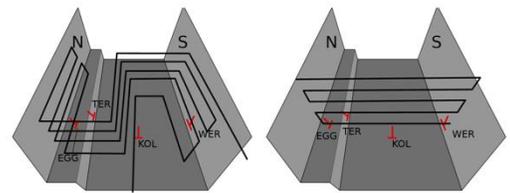
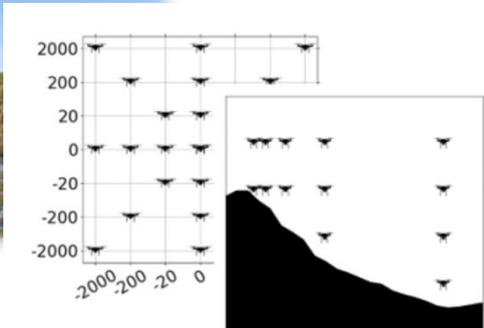
Summer EOP

- ▲ additional DWL / T&RH
- ▲ existing & add. RaSo
- ▲ existing sfc flux sites

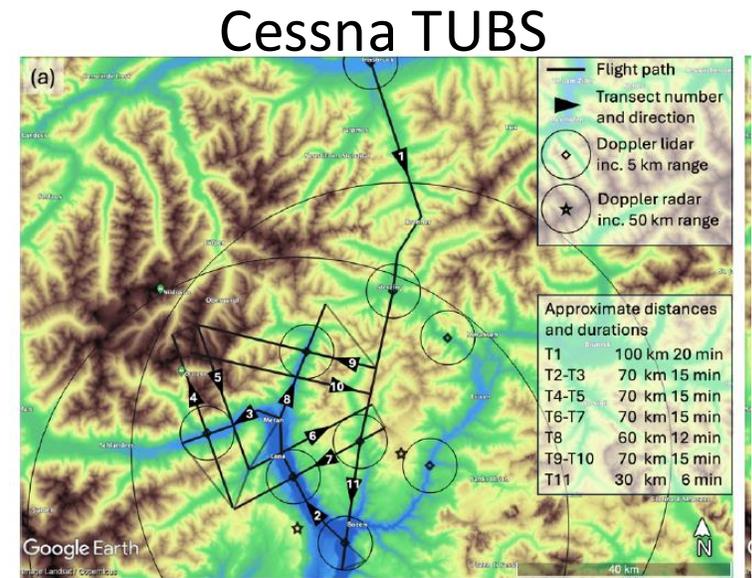


IOPs

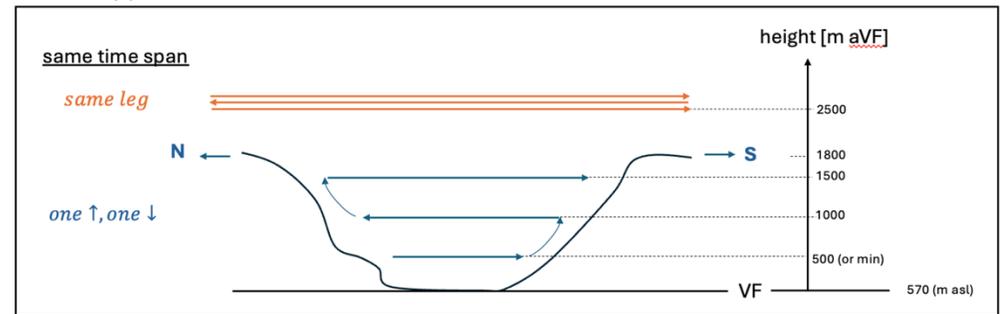
- ▲ airborne observations
- ▲ add. RaSo
- ▲ existing sfc flux sites
- ▲ uncrewed aerial systems



Cross-valley patterns



Cessna GC-DLR



Assimilation

- ▲ 'standard observations' (additional DWL / MWR, RaSo) during EOP
 - 500 m ICON simulations @DWD and MCH
 - in the framework of GLORI-A project (digital twin over the alpine region)
 - possibly other digital earth contributions
 - used for IOP planning (dedicated forecasts)
- ▲ high-resolution reanalysis
 - target grid spacing: 125 m
 - for the IOPs
 - project GREAT (U Vienna, U Innsbruck, KIT, DWD, MCH)



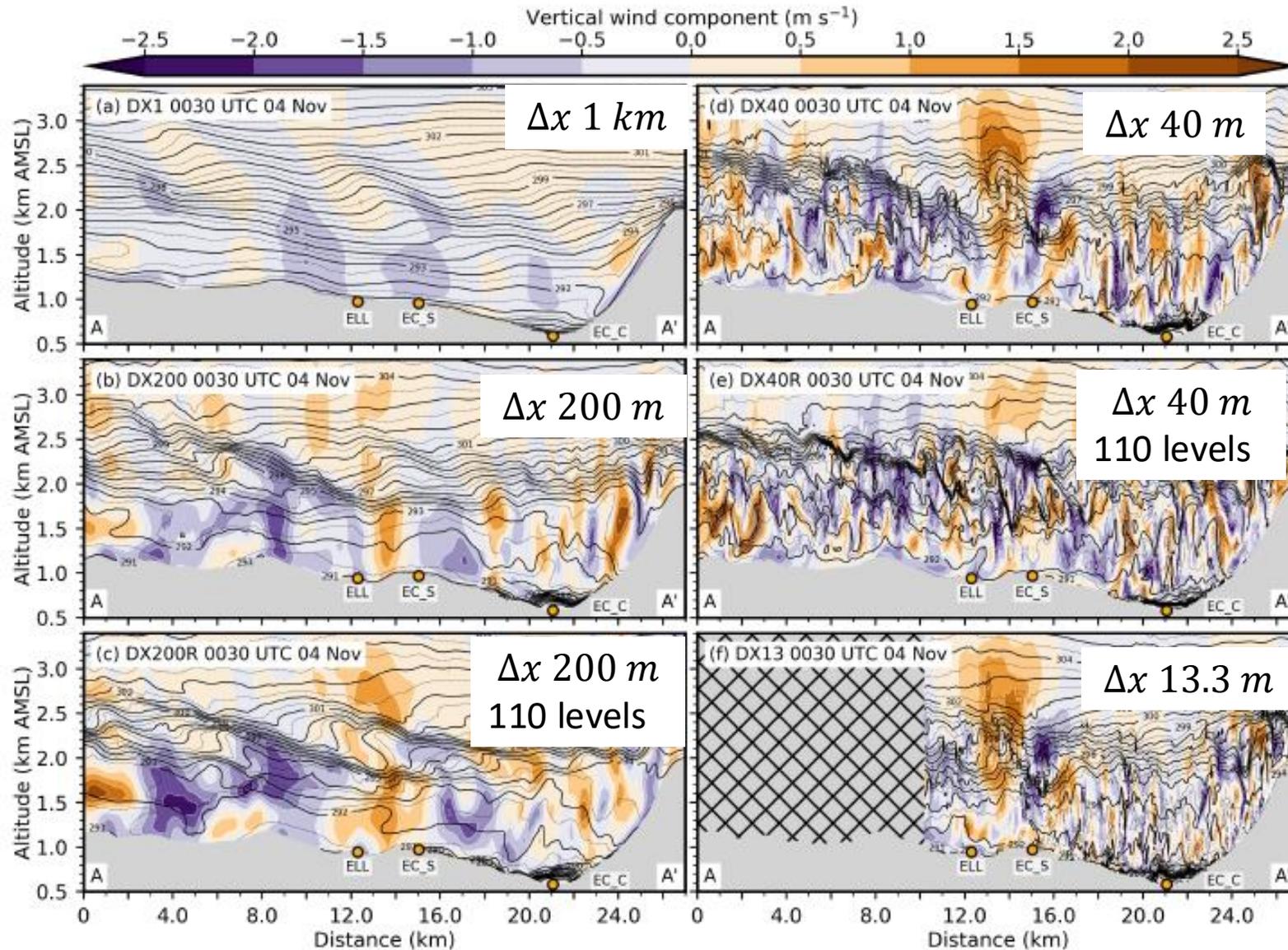
GREAT plans

- ▲ A **GR**ey-zone **E**nsemble **A**nalysis for TEAMx: GREAT
→ under review
- ▲ KENDA
→ Localized Ensemble Transform Kalman Filter (LETKF)
→ presently implemented in the Kilometer-scale Ensemble Data Assimilation system KENDA (of ICON) [Schraff et al. 2016]
- ▲ Background error models
→ for high-resolution ensemble perturbations in complex terrain
→ different error sources
→ uses TOC (and i-Box) observations for reference
- ▲ Terra incognita

GREAT plans

- ▲ Background error models
 - using LES & available obs (existing DWL/MWR and i-Box sites)
- ▲ different error sources
 - turbulence model (e.g., Goger et al. 2018/19)
 - large scale IC & BC
 - local IC & BC (SEB and surface exchange)
 - internal errors
- ▲ modeling challenges ...

LES in complex terrain ...



- WRF simulations:
- vertical wind
 - quite tricky smoothing of topo
 - also requires input (sfc character, SM, ...) at similar resolution

Conclusions

- ▲ there will be a yearlong field campaign
 - EOPs
 - IOPs
- ▲ many additional surface based remote sensing instruments
- ▲ data openly available
- ▲ DA in complex terrain requires special efforts
 - data availability
 - representativeness
 - modeling challenges
- ▲ TEAMx provides a step forward

TEAMXX



Thank you!

References

- Goger B, Rotach MW, Gohm A, Fuhrer O, Stiperski I, Holtslag AAM: 2018, The Impact of 3D Effects on the Simulation of Turbulence Kinetic Energy Structure in a Major Alpine Valley, *Boundary-Layer Meteorol*, **168** (1), 1-27, <https://doi.org/10.1007/s10546-018-0341>
- Goger B, Rotach MW, Gohm A, Stiperski I, Fuhrer O, de Morsier G: 2019, A New Horizontal Length Scale for a Three-dimensional Turbulence Parameterization in Meso-scale Atmospheric Modeling over Highly Complex Terrain, *J Appl Meteorol Climatol*, **58**, 2087-2102, DOI: 10.1175/JAMC-D-18-0328.1
- Rotach MW, Serafin S, Ward HC, Arpagaus M, Colfescu I, Cuxart J, De Wekker SFJ, Grubišić V, Kalthoff N, Karl T, Kirshbaum DJ, Lehner M, Mobbs S, Paci A, Palazzi E, Bailey A, Schmidli J, Wittmann C, Wohlfahrt G, Zardi D: 2022, A collaborative effort to better understand, measure and model atmospheric exchange processes over mountains, *Bulletin American Meteorol Soc*, E1282–E1295, <https://doi.org/10.1175/BAMS-D-21-0232.1>
- Schraff, C., H. Reich, A. Rhodin, A. Schomburg, K. Stephan, A. Periañez, and R. Potthast, 2016: Kilometre-scale ensemble data assimilation for the COSMO model (KENDA). *Quart. J. Roy. Meteor. Soc.*, **142**, 1453–1472, <https://doi.org/10.1002/qj.2748>.
- Serafin S, Rotach MW, Arpagaus M, Colfescu I, Cuxart J, De Wekker SFJ, Evans M, Grubišić V, Kalthoff N, Karl T, Kirshbaum DJ, Lehner M, Mobbs S, Paci A, Palazzi E, Raudzens Bailey A, Schmidli J, Wohlfahrt G, Zardi D: 2020, Multi-scale transport and exchange processes in the atmosphere over mountains. Programme and experiment, Innsbruck university press, 1st Edition, ISBN 978-3-99106-003-1, DOI 10.15203/99106-003-1, 48pp.
- Umek L, Gohm A, Haid M, Ward HC, Rotach MW: 2022, Influence of grid resolution of large-eddy simulations on foehn-cold pool interaction, *Q J R Meteorol Soc*, **148**, 1840–1863, doi: <https://doi.org/10.1002/qj.4281>