4th ACCORD All Staff Workshop - Norrköping

Evaluation of AROME model Valley Wind Simulations in the Inn Valley, Austria

Sensitivity to Horizontal Grid Resolution

NWP Group GeoSphere Austria – ACINN
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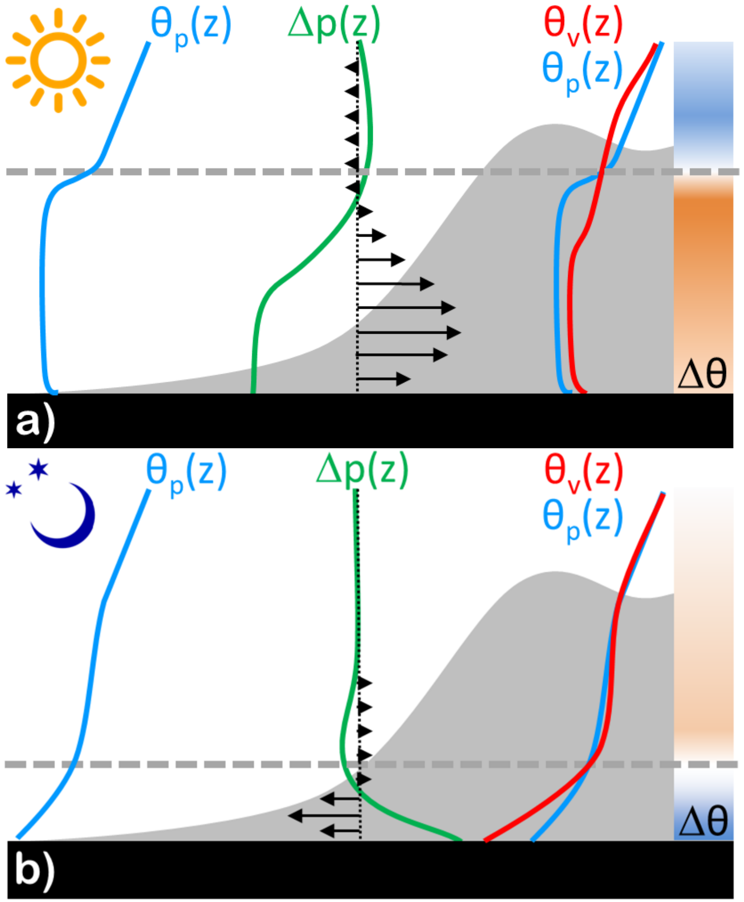
Outline

- Introduction to topic
- Research site – CROSSINN field campaign
- Setup AROME-Aut
- Case study – IOP8
  - challenges valley wind simulations
  - impact horizontal grid resolution
- Summary

Motivation – valley wind simulations

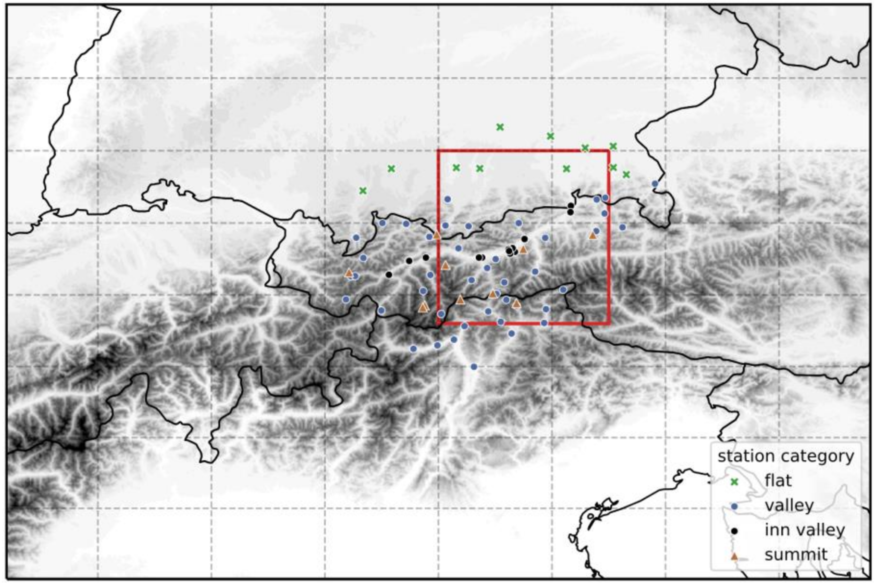
- common local aspect in Inn Valley, Austria
  - intensively studied in past
    (e.g., Vergeiner and Dreiseitl 1987; Zängl 2004, 2009; Gohm et al. 2009)
  - thermal forcing, pressure-driven channelling, forced-channelling
  - local weather conditions, air pollutant transport, clouds, precipitation
- lack of detailed three-dimensional evaluations for NWP models
- influence grid resolution
  - weak response mean wind flow characteristics $\Delta x < 1.0$ km
    (e.g., Umek et al. 2022, Fritz 2023)
  - potential to further enhance prediction
- performance and sensitivity to Δx for AROME-Aut simulations
  - case study CROSSINN field campaign

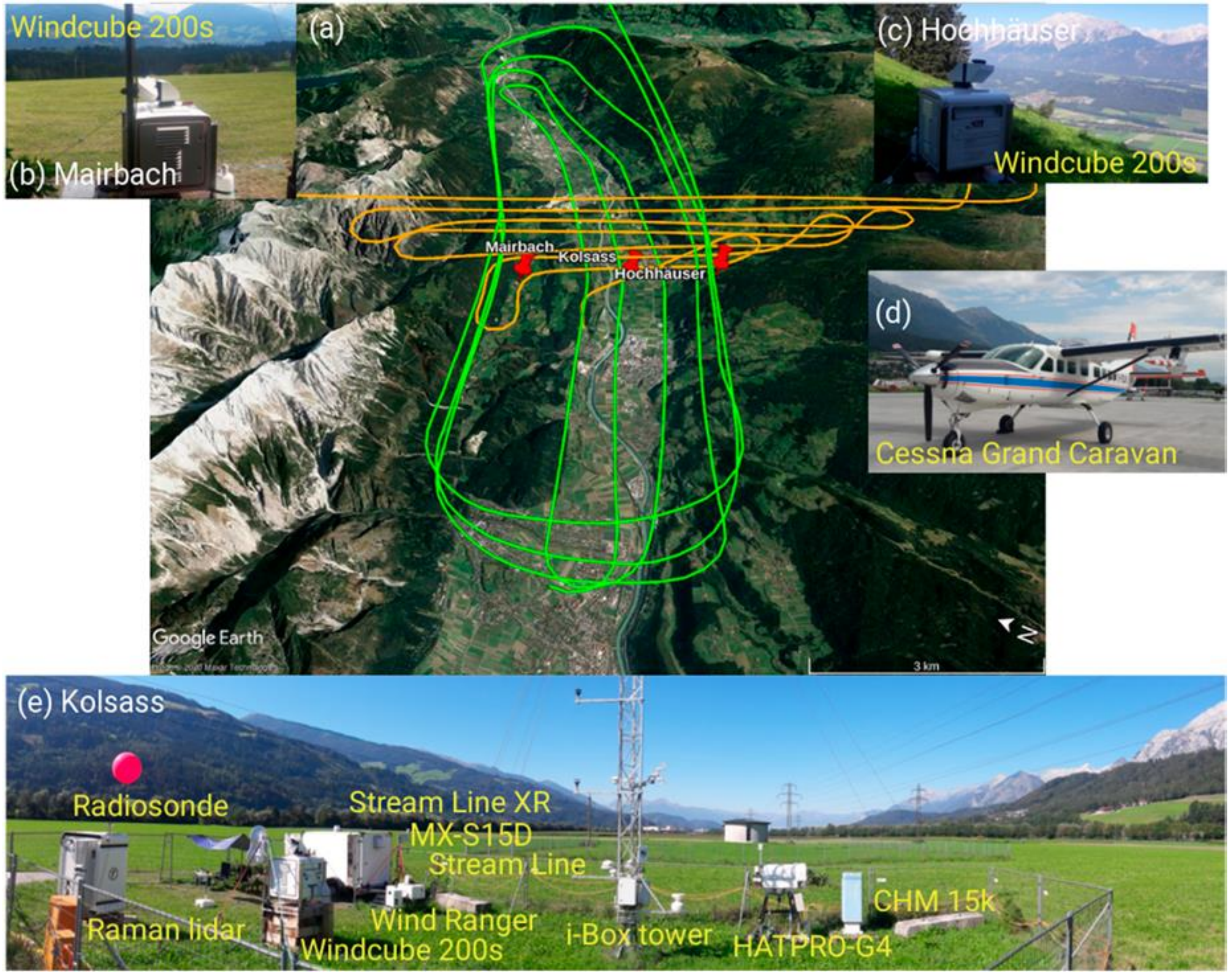


(Serafin et al. 2018)

Research site - CROSSINN

- Field experiment to study 3D flow structure in Inn Valley (Adler et al. 2021)
  - August to October 2019
  - IOP8: 13 – 14 September 2019
- in situ and remote sensing observations
  - Lidars, Radiosondes
- AWS stations

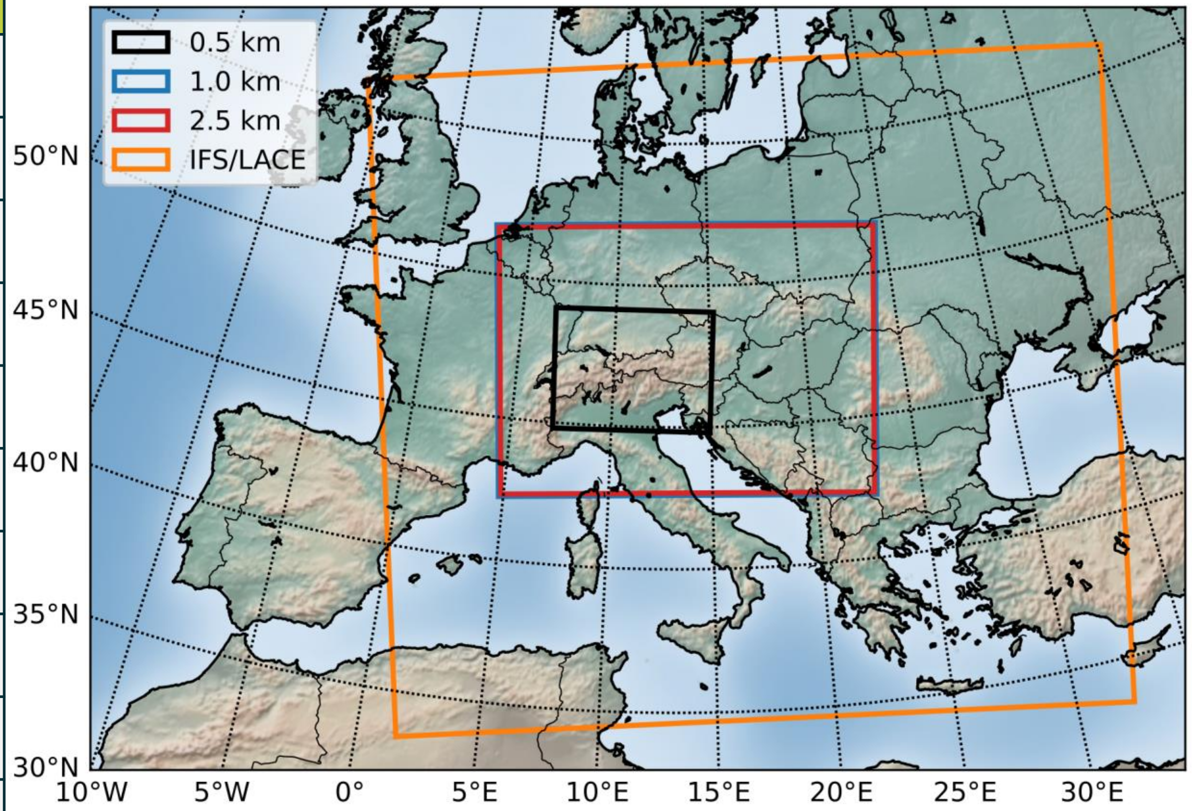




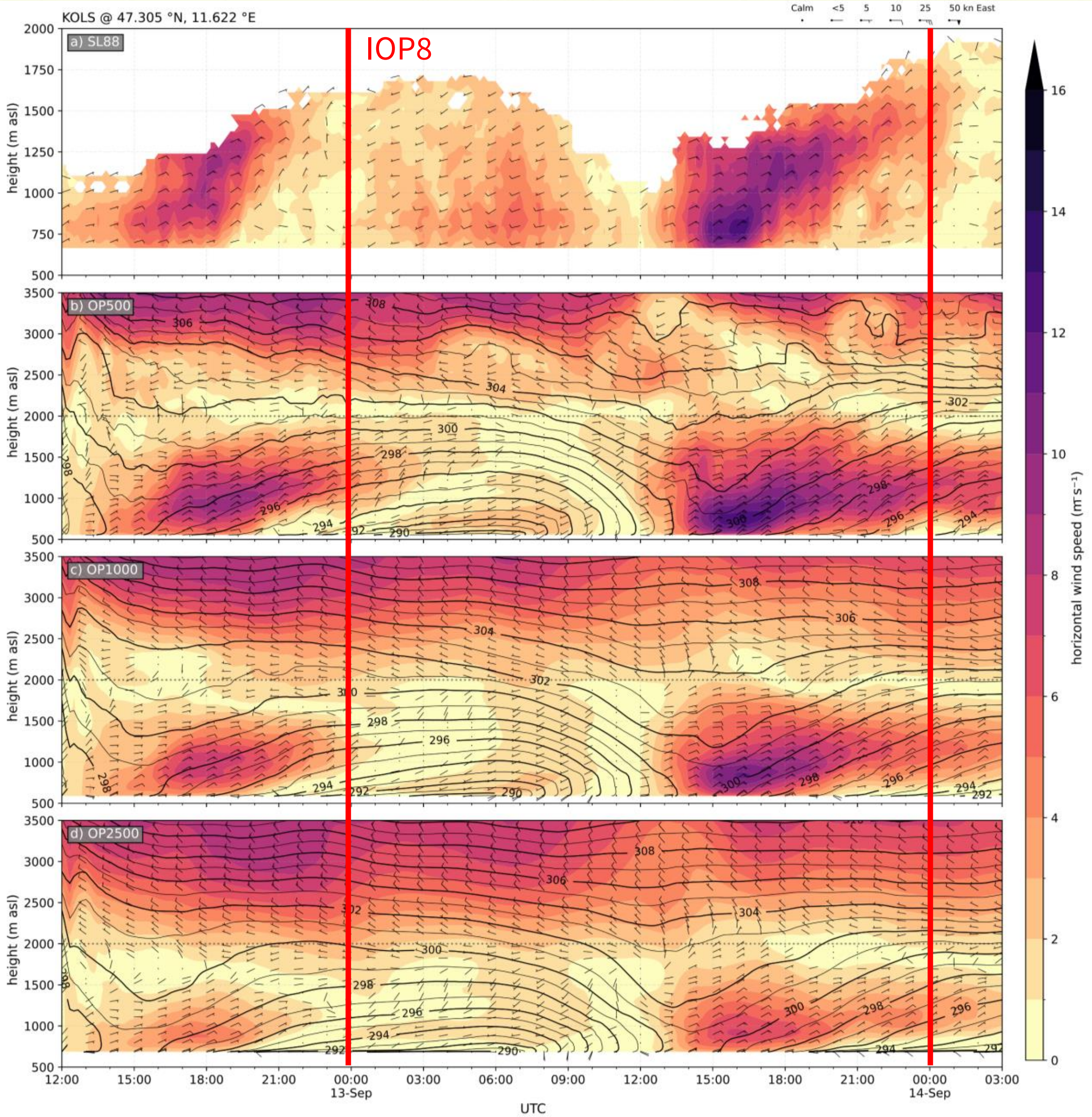
(Adler et al. 2021)

Model setup – AROME-Aut

	OP2500	*OP1000*	*OP500*
Model version	CY46t1		
Horizontal resolution	2.5 km	1.0 km	0.5 km
Number grid points	600 x 432	1500 x 1080	1250 x 960
Time step	60 s	40 s	20 s
Vertical levels	90		
Initialization atmosphere	3DVAR - IFS		
Initialization surface	surface OI	downscaling 2.5 km	
Initialization time	12 UTC, 12 Sep 2019		
Coupling model	IFS (1 h)		
Lead time	39 h (10 min output)		
Physics	AROME		

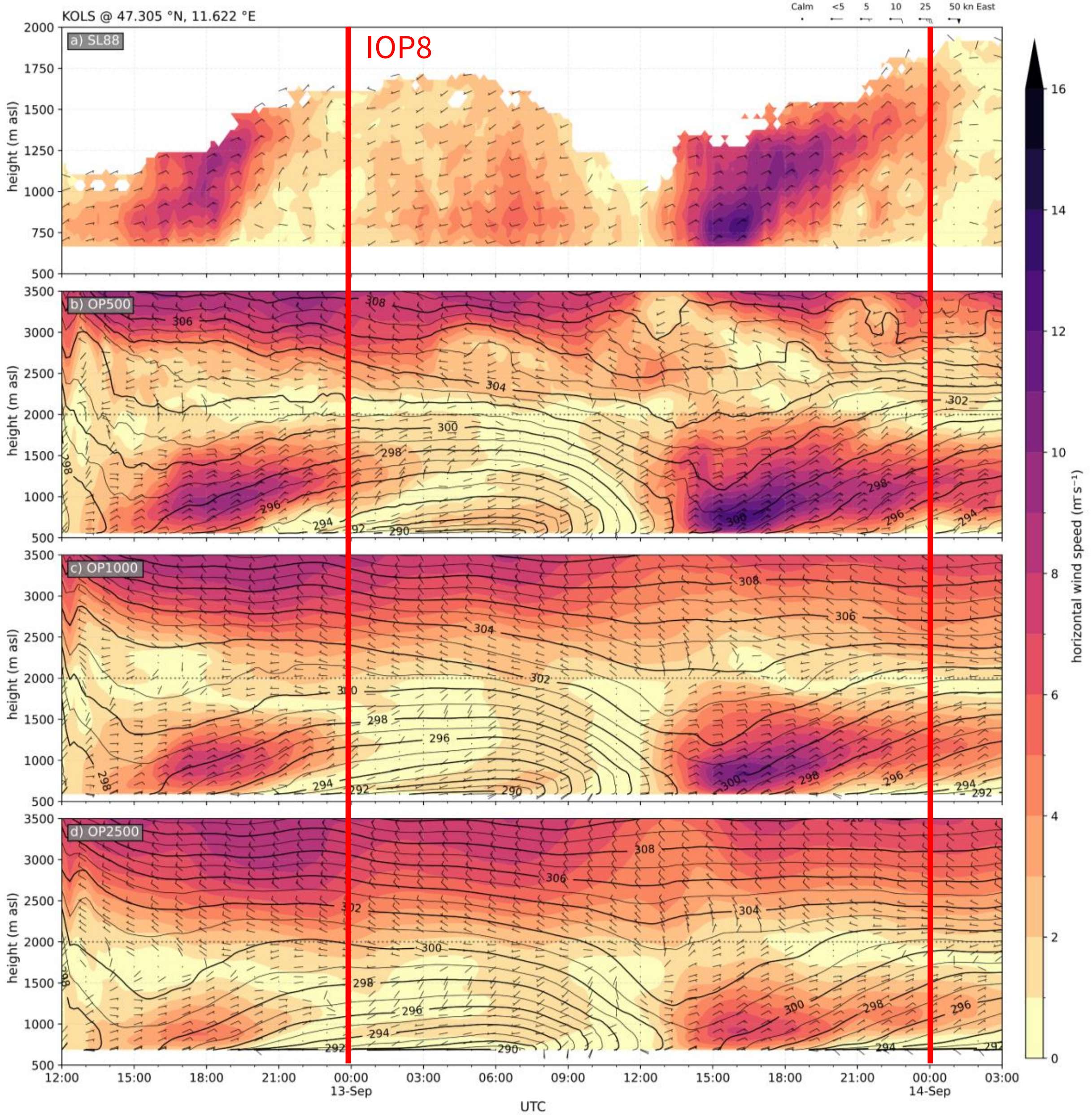


Case study IOP8



- mean flow structure well captured
- 2 major challenges:
  - downvalley wind phase underestimated
  - persistent upvalley wind layer @ ~ 1000 m asl

Case study IOP8



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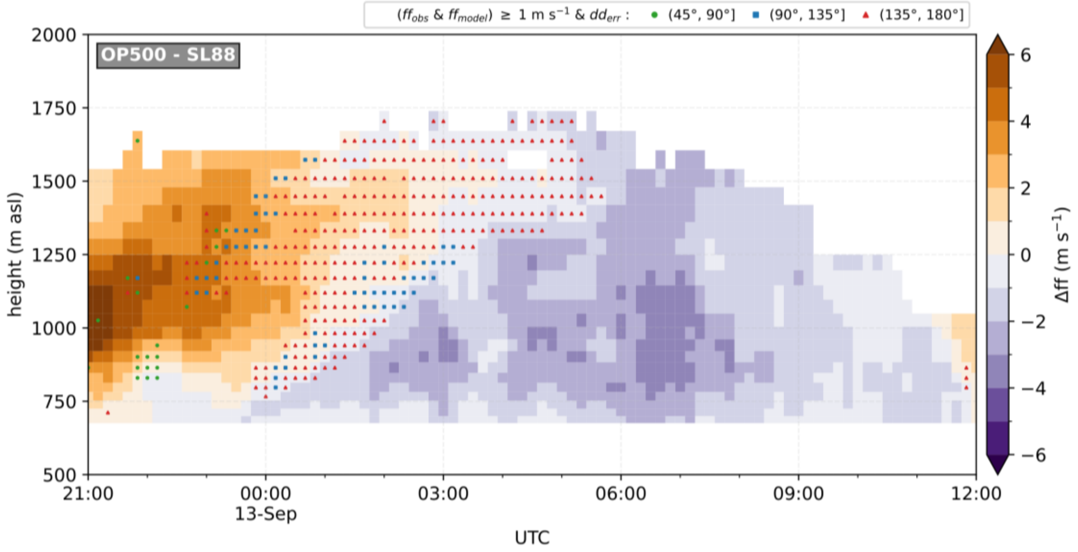
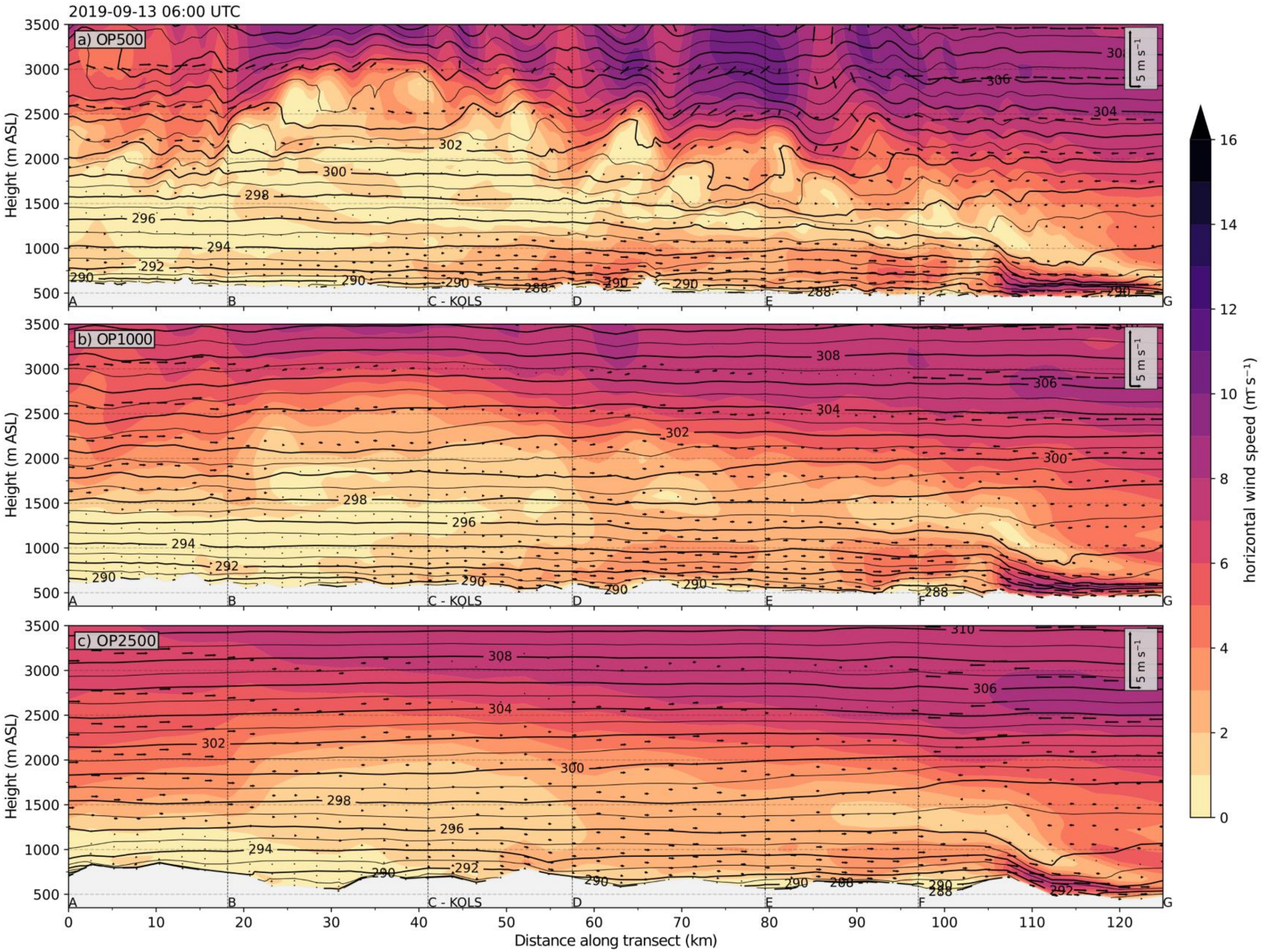
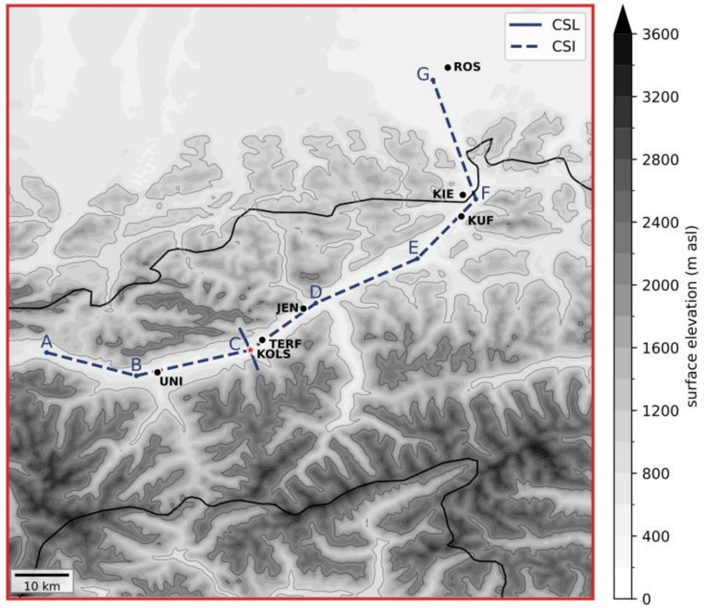


- peak downvalley winds around 07 UTC (low-level jet)
- downvalley wind speeds underestimated by all AROME-Aut simulations
  - e.g., OP500: ~ 3 m/s, OP2500: ~ 4 m/s

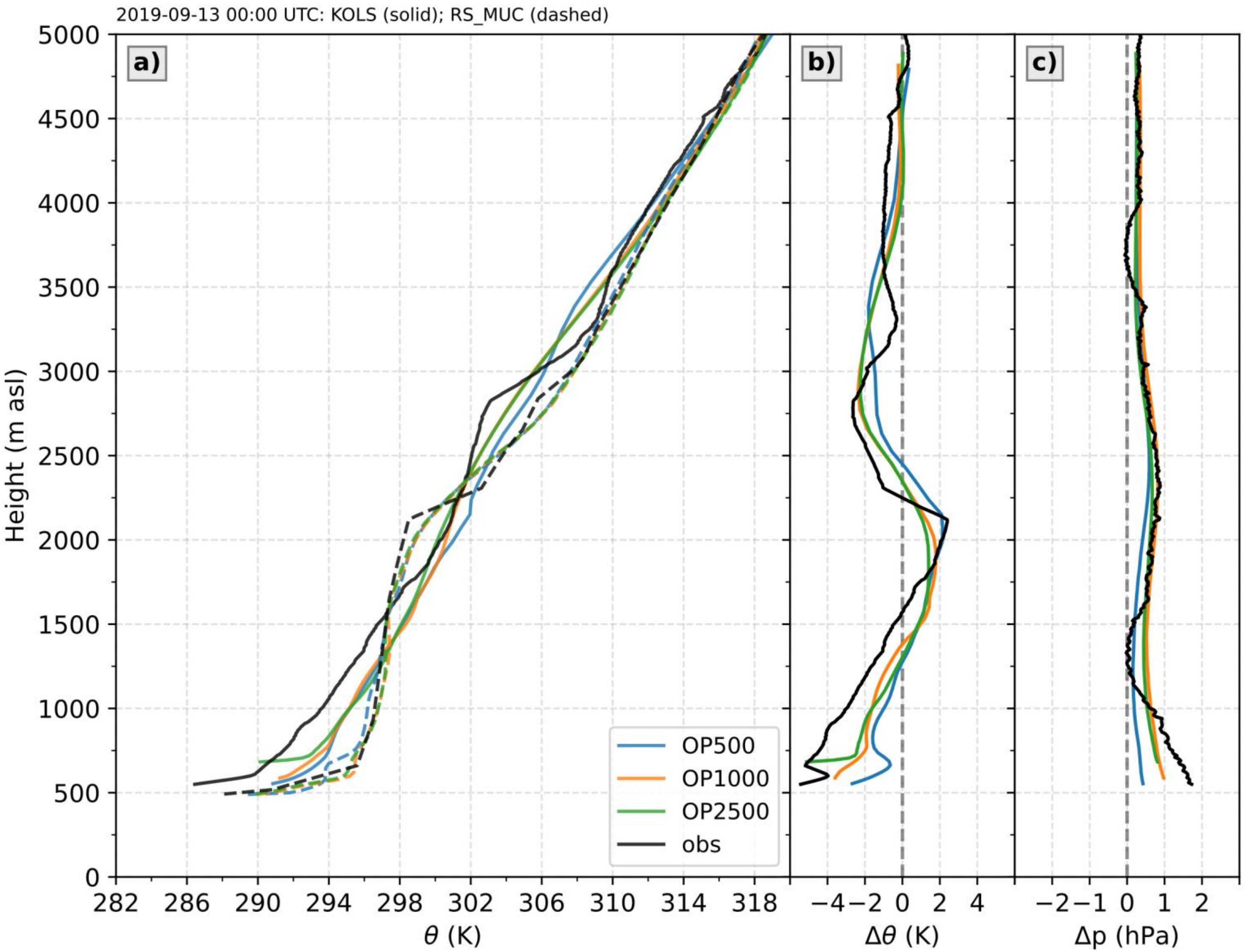
Case study IOP8 – Challenge downvalley winds





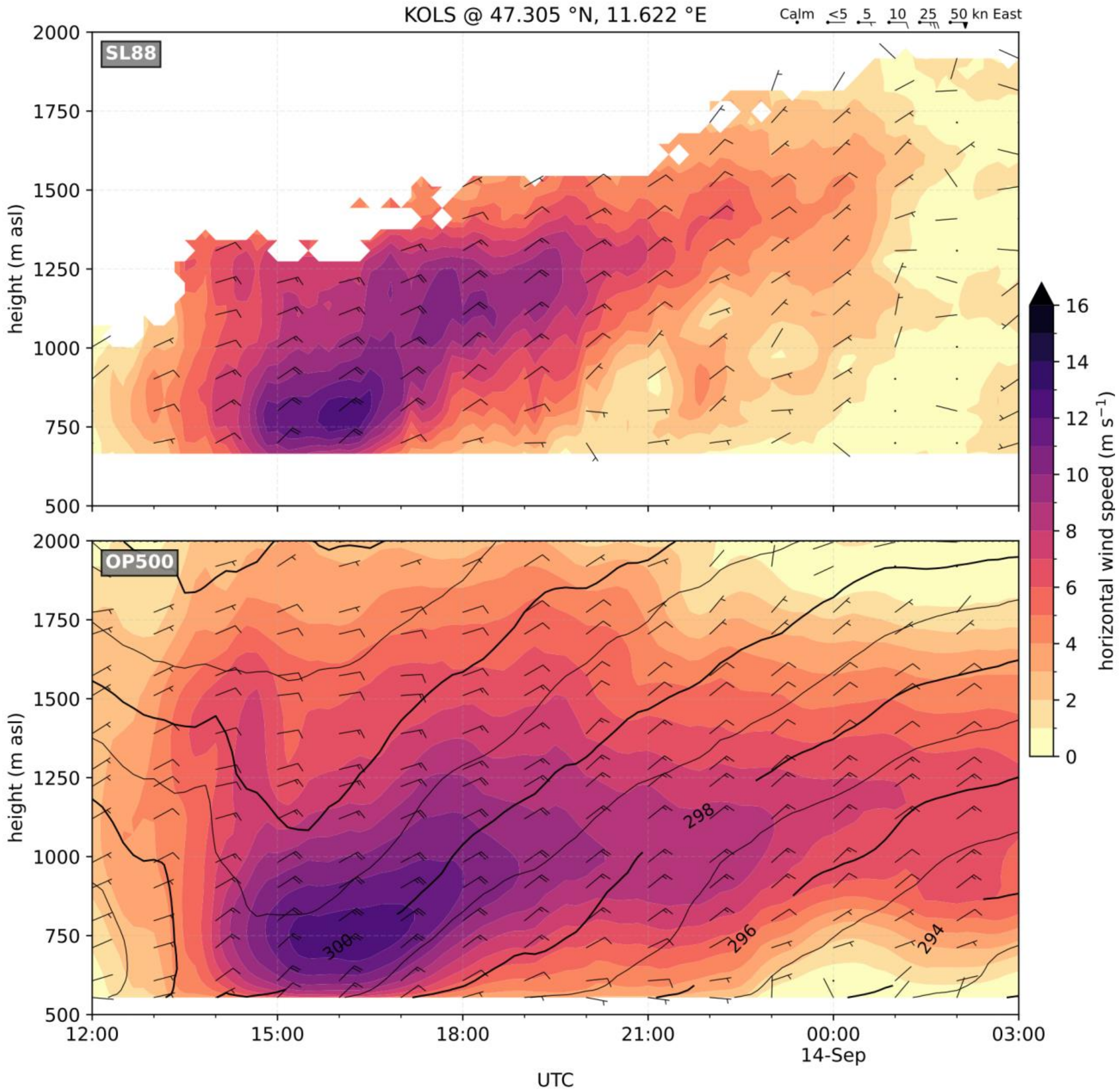
- downvalley wind concentrated towards lower Inn Valley
- Inn Valley exit jet
- OP500:
  - decoupled from synoptic flow
  - quasi-stationary gravity waves
- OP1000, OP2500:
  - forced channeling effects exit region

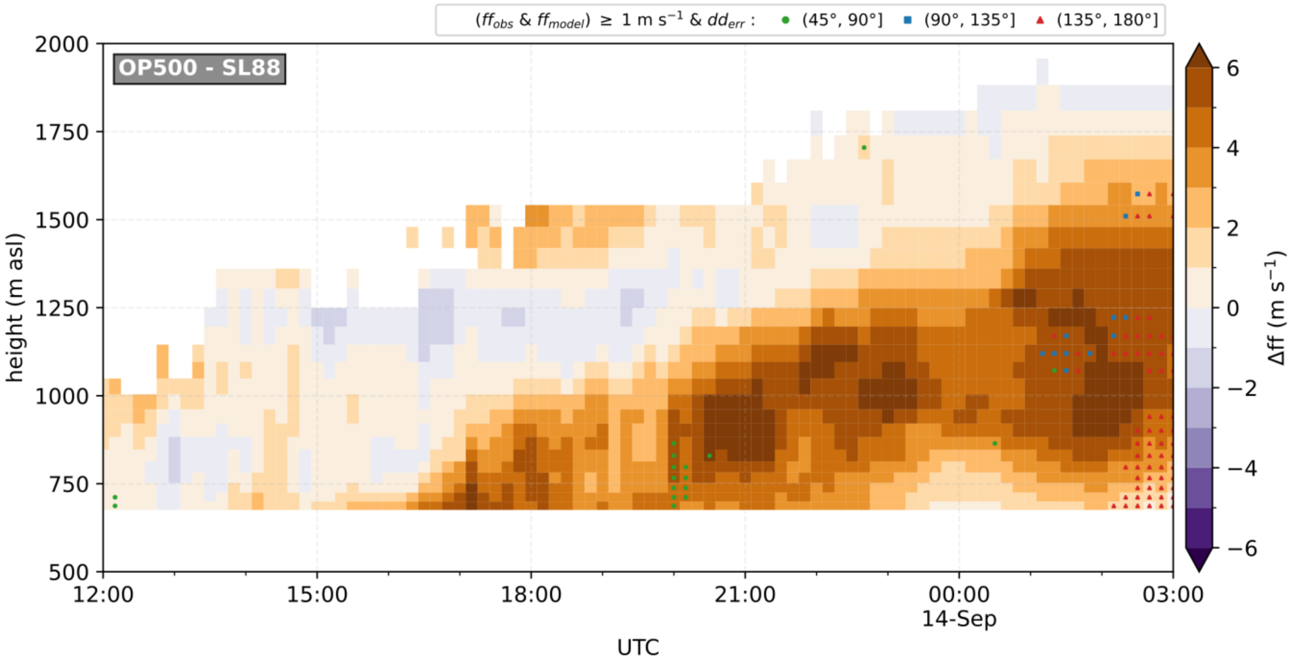
Case study IOP8 – Challenge downvalley winds



- warm and dry bias over whole valley atmosphere
- quite well approximated over Alpine Foreland
- all simulation able to capture two-folded sign change Δθ
- similar evolution during morning hours
- underestimated thermal forcing
  - reduced pressure difference to Alpine Foreland

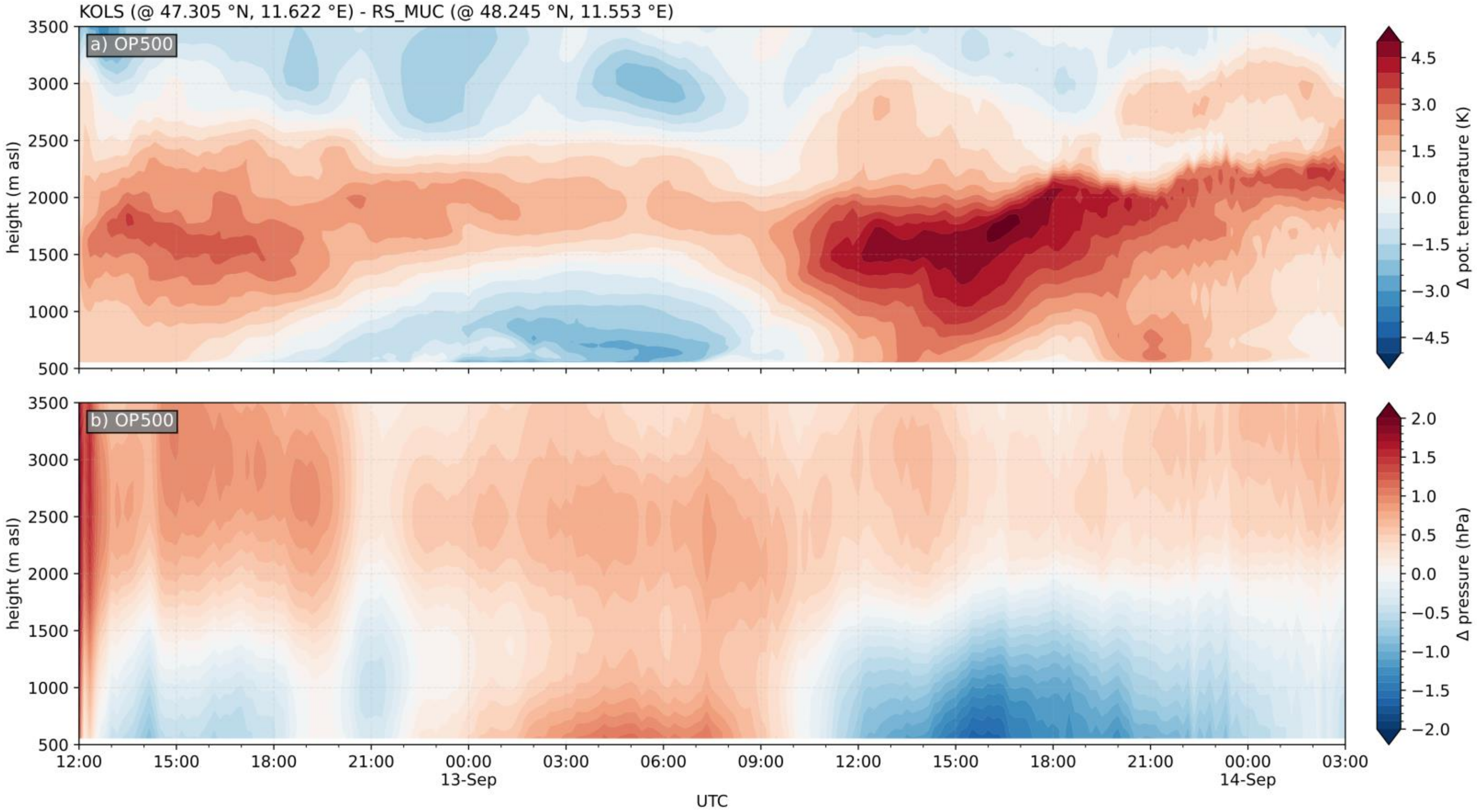
Case study IOP8 – Challenge upvalley winds

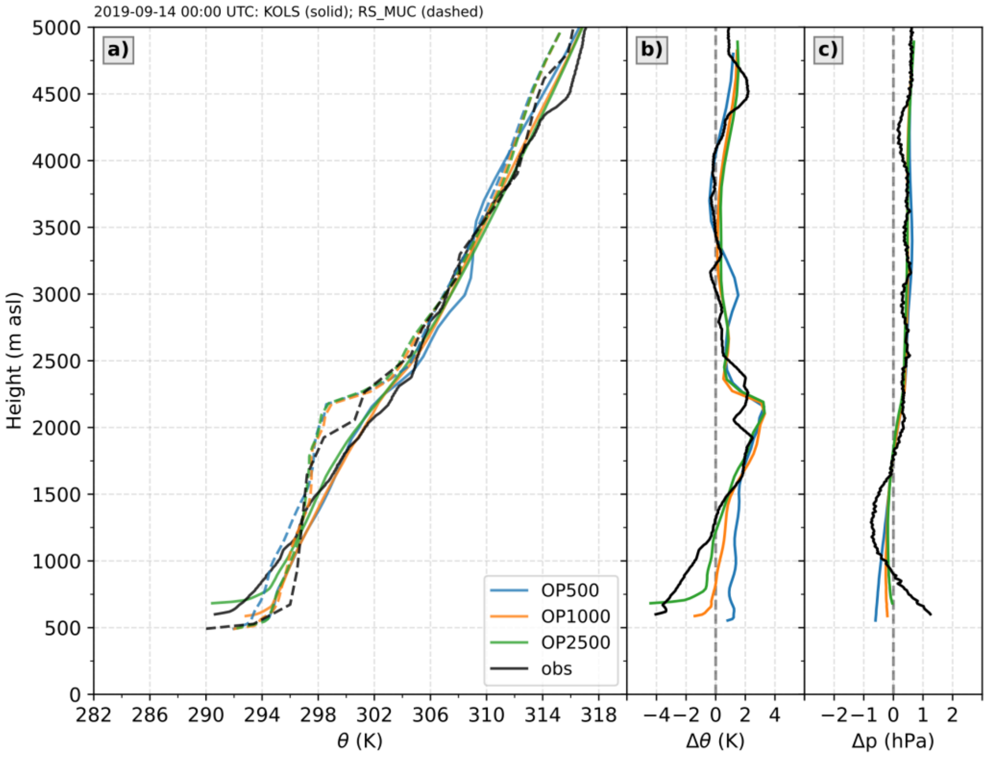




- onset and maximum magnitude well captured
- lifting upvalley wind layer too weak
- persistent upvalley winds in layer around 1000 m asl
- similar but weaker in OP1000 and OP2500

Case study IOP8 – Challenge upvalley winds

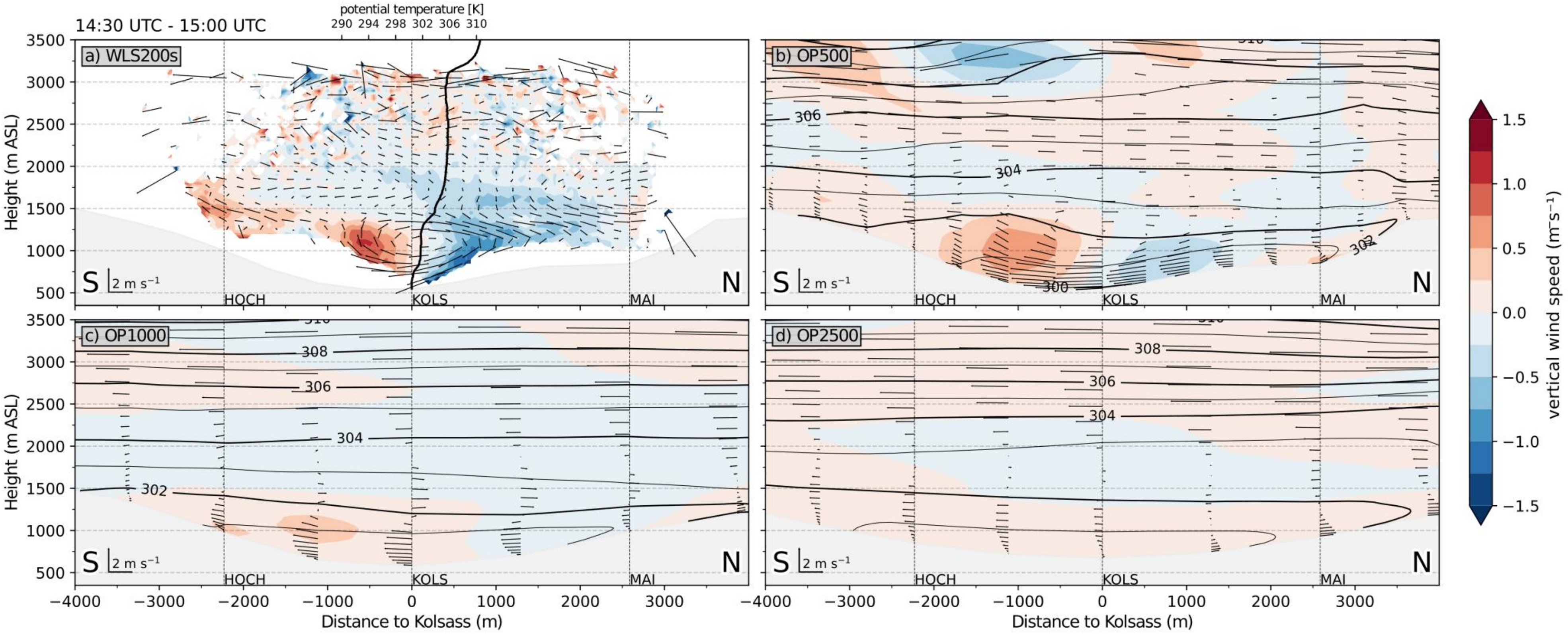


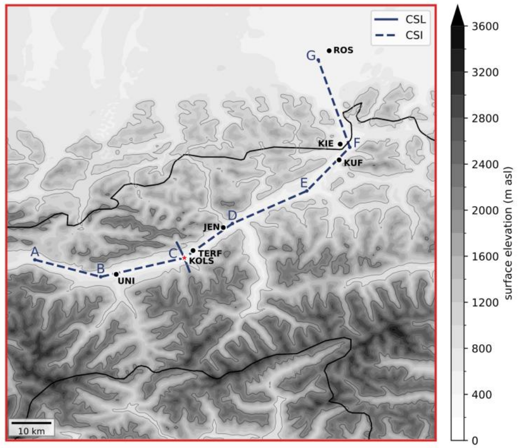


- no thermal forcing for downvalley winds second night
  - valley atmosphere remains warmer; reddish colors in a)
  - pressure difference remains negative; blueish colors in b)

- difference to first night
  - relatively warmer valley BL
  - simulated cold air advection in Alpine Foreland

Case study IOP8 – impact Δx





- cross-valley vortex along VCS Inn Valley
  - subsiding northerly flow, updrafts south of Kolsass, return flow between 1250 to 1500 m asl
- investigated in e.g., Babic et al. (2021)
- OP500 able to capture small-scale feature → enough grid points
- gravity waves

Summary

Challenge 1: nocturnal downvalley wind phase

- insufficient thermal forcing
- forced channeling effects in central Inn Valley might be underestimated
- only slight improvements with smaller Δx

Challenge 2: persistent upvalley wind second night

- thermal forcing does not change sign
  - valley atmosphere warmer, slightly colder airmass Alpine Foreland
- forced channeling effects with NE directed flow towards Inn Valley entrance region
- not shown: sign of lateral boundary domain forcing in 0.5 km simulations (smaller model domain)

Influence higher horizontal grid resolution (i.e., 0.5 km)

- mean flow characteristics show only weak influence (i.e., flow structure)
- improvements for small-scale features
  - gravity waves, cross-valley vortex, local channeling effects, (more detailed topography)
- smaller biases and higher Hit rates in representation of surface near winds (AWS-stations)
- magnitudes, structure upvalley low-level jet better captured

References

Adler, B., and Coauthors, 2021: CROSSINN: A Field Experiment to Study the Three-Dimensional Flow Structure in the Inn Valley, Austria. Bull. Amer. Meteor. Soc., **102 (1)**, E38–E60, https://doi.org/10.1175/bams-d-19-0283.1.

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Zängl, G., 2009: The impact of weak synoptic forcing on the valley-wind circulation in the Alpine Inn Valley. Meteor. Atmos. Phys., **105 (1-2)**, 37–53, https://doi.org/10.1007/s00703-009-0030-y.

ADDITIONAL FIGURES

Benedikt Wibmer

Case study IOP8 – Meteorological conditions (ERA5)

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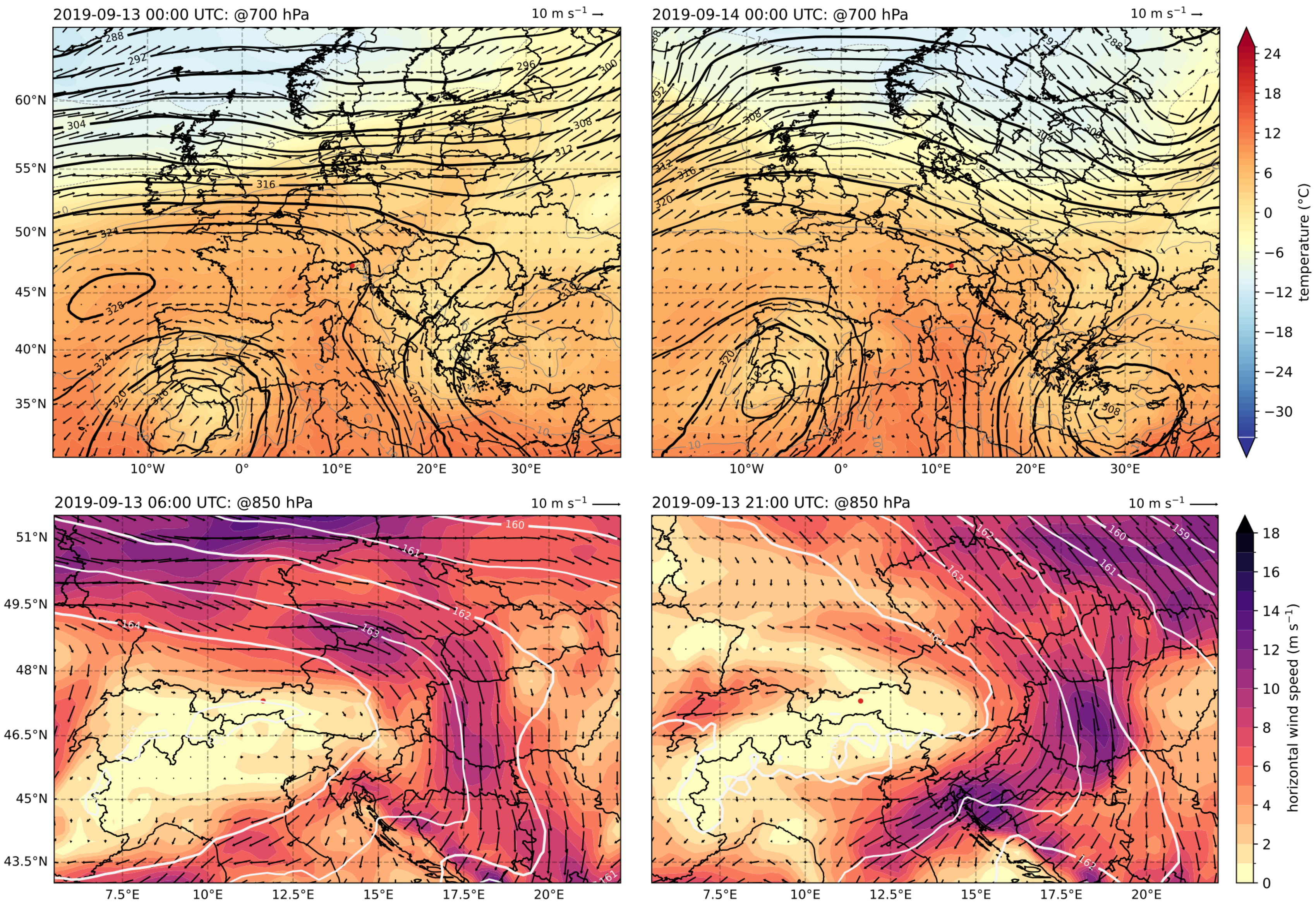
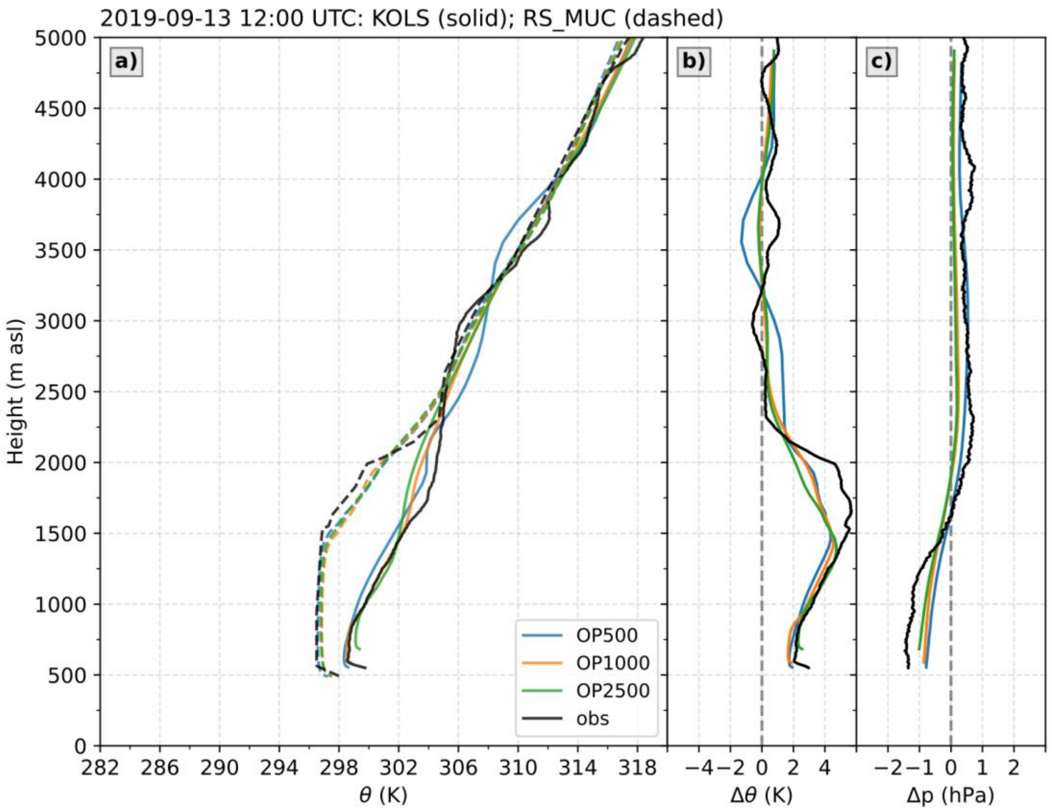
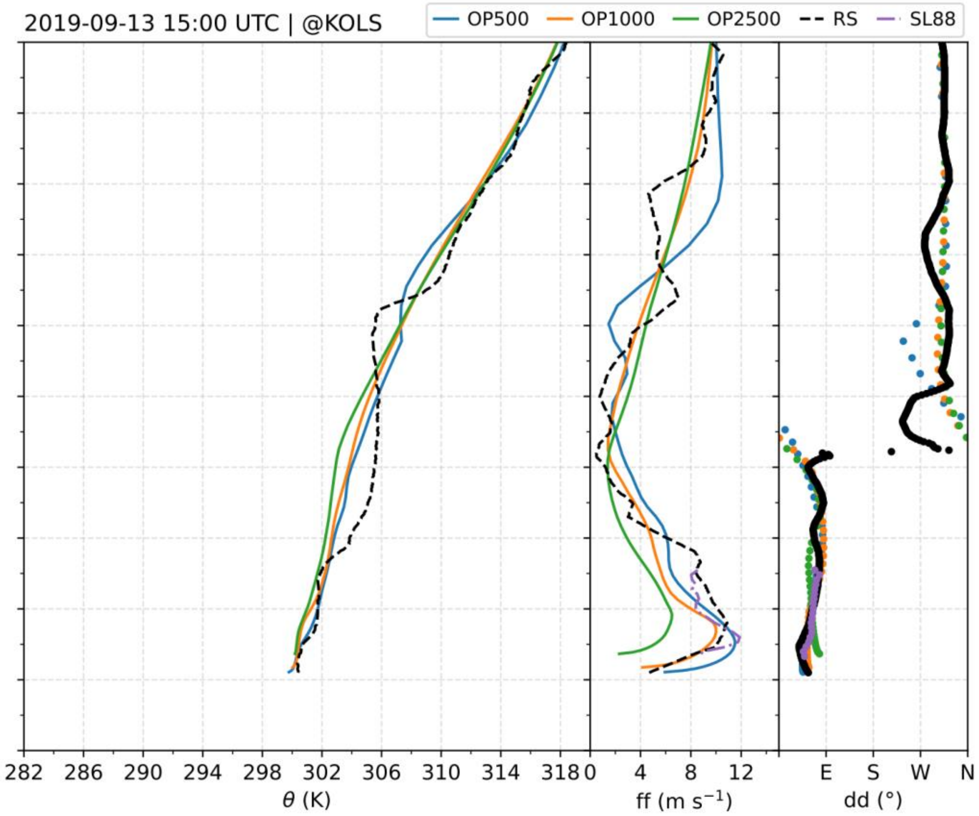
- High-pressure region over central parts of Europe
- ridge axis gets pushed further south during IOP8

- 850 hPa:
  - split-up of wind field around Alps
  - shift W → NW directions in Alpine Foreland
  - calm inn valley entrance region



Case study IOP8 – afternoon hours

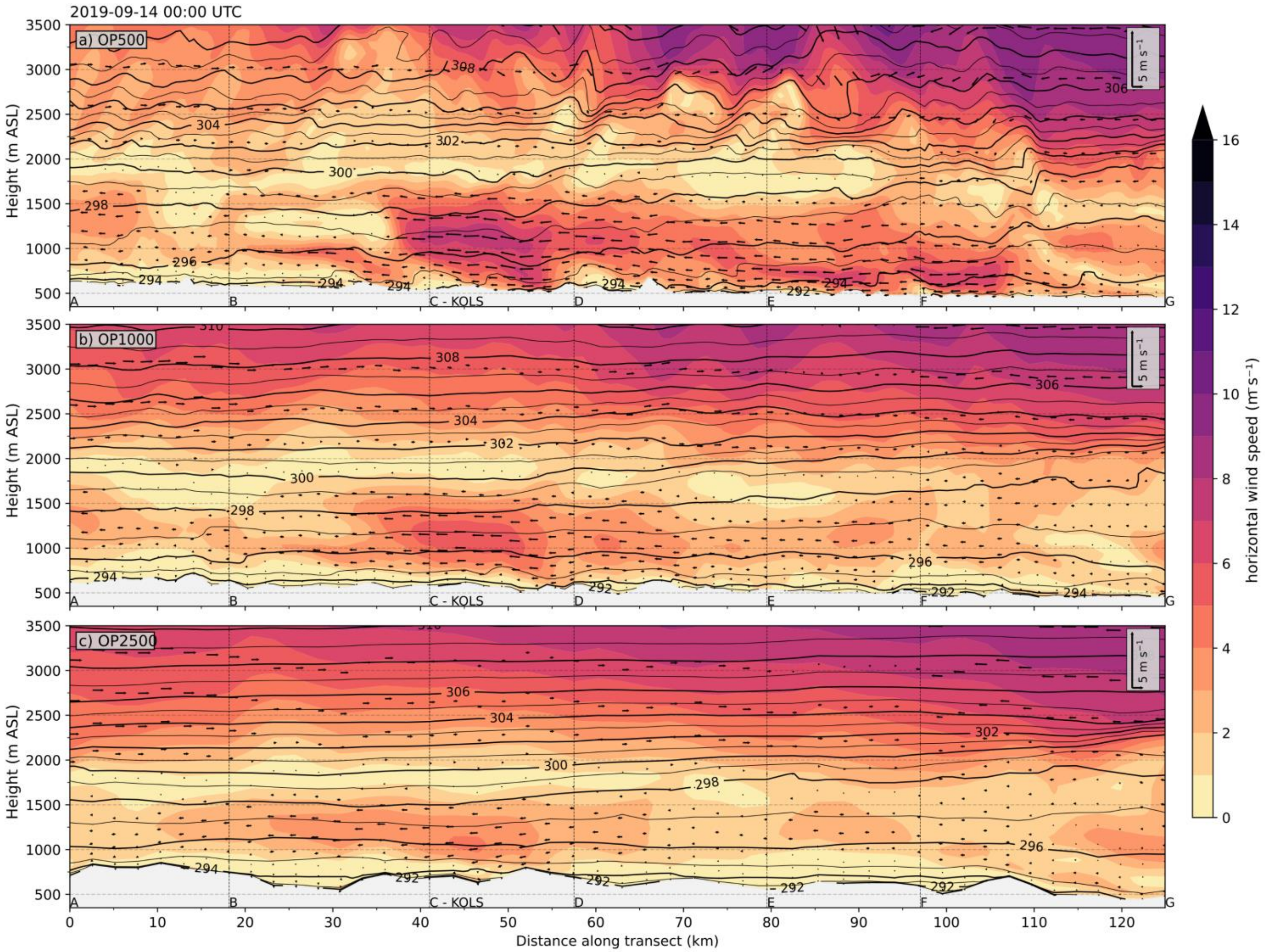


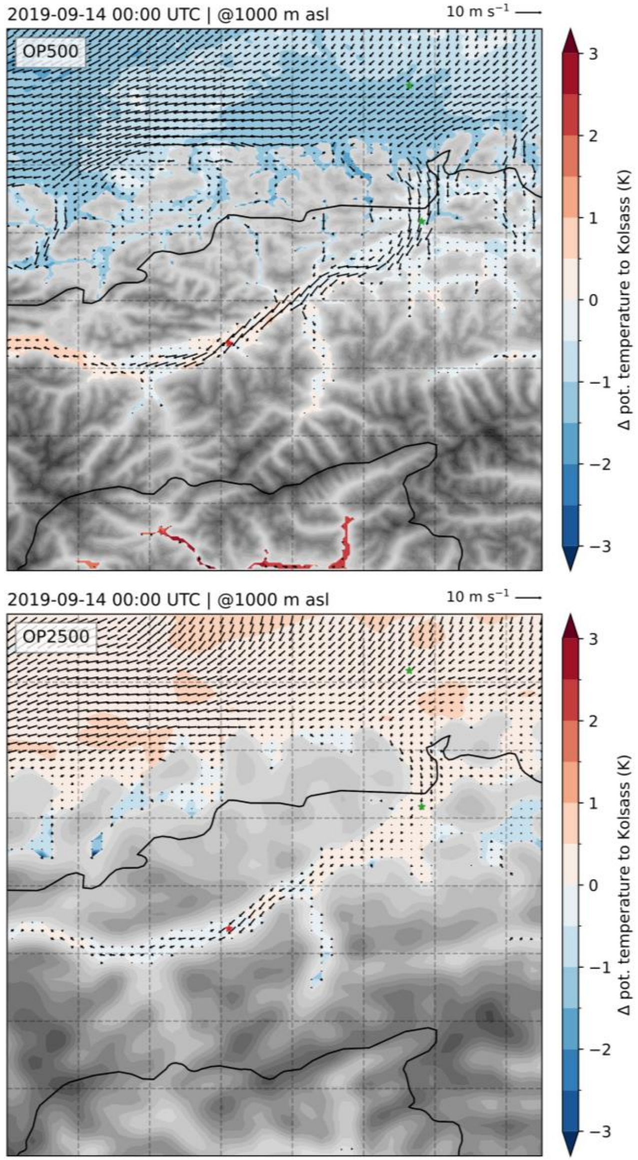


- warm bias vanished in valley BL
- valley atmosphere warmer than adjacent plain (2-4 K) below 1500 m asl
- thermal forcing better captured

- rapid increase upvalley winds until 15 UTC (~12 m/s - @750 m asl)

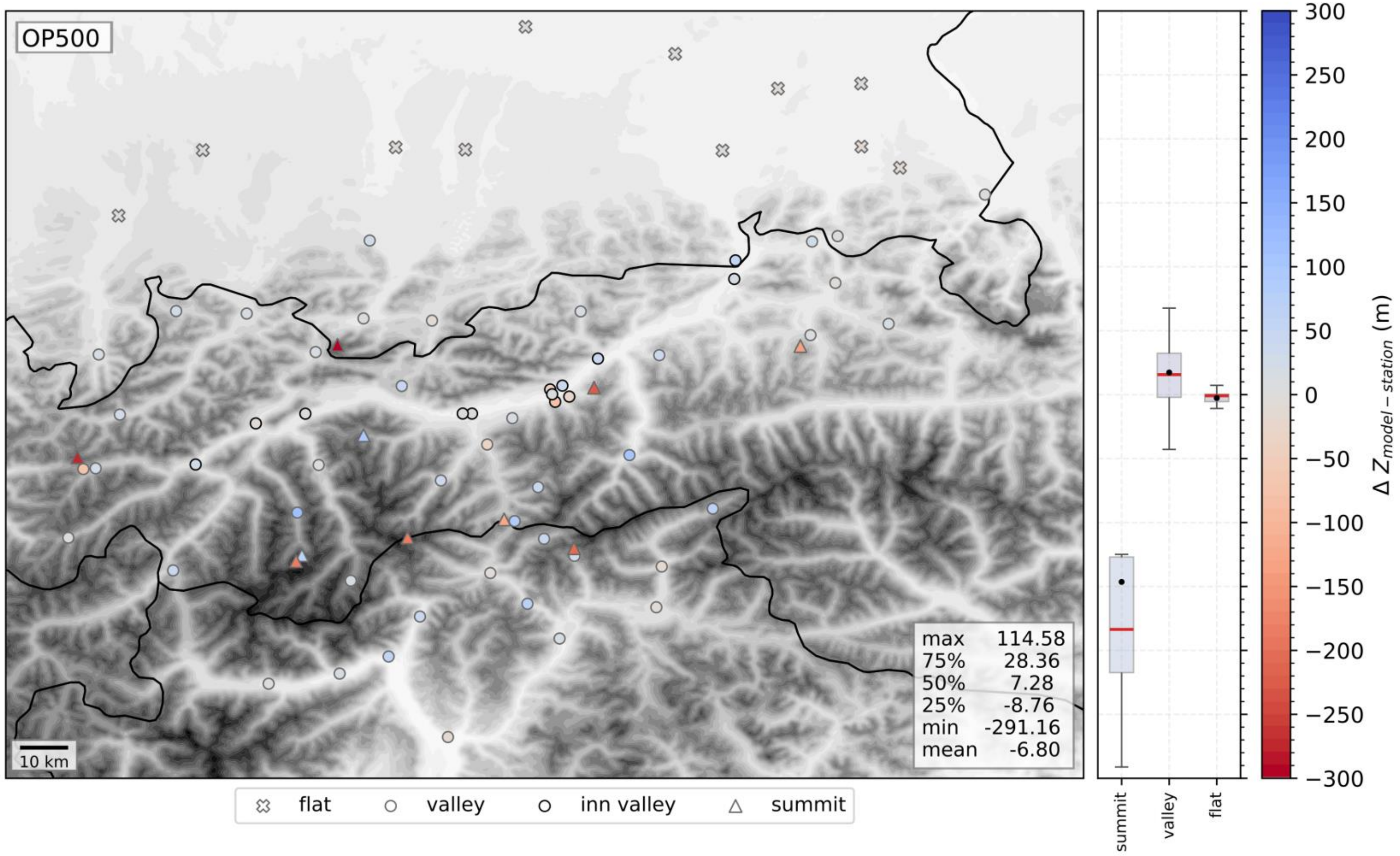
Case study IOP8 – Challenge upvalley winds





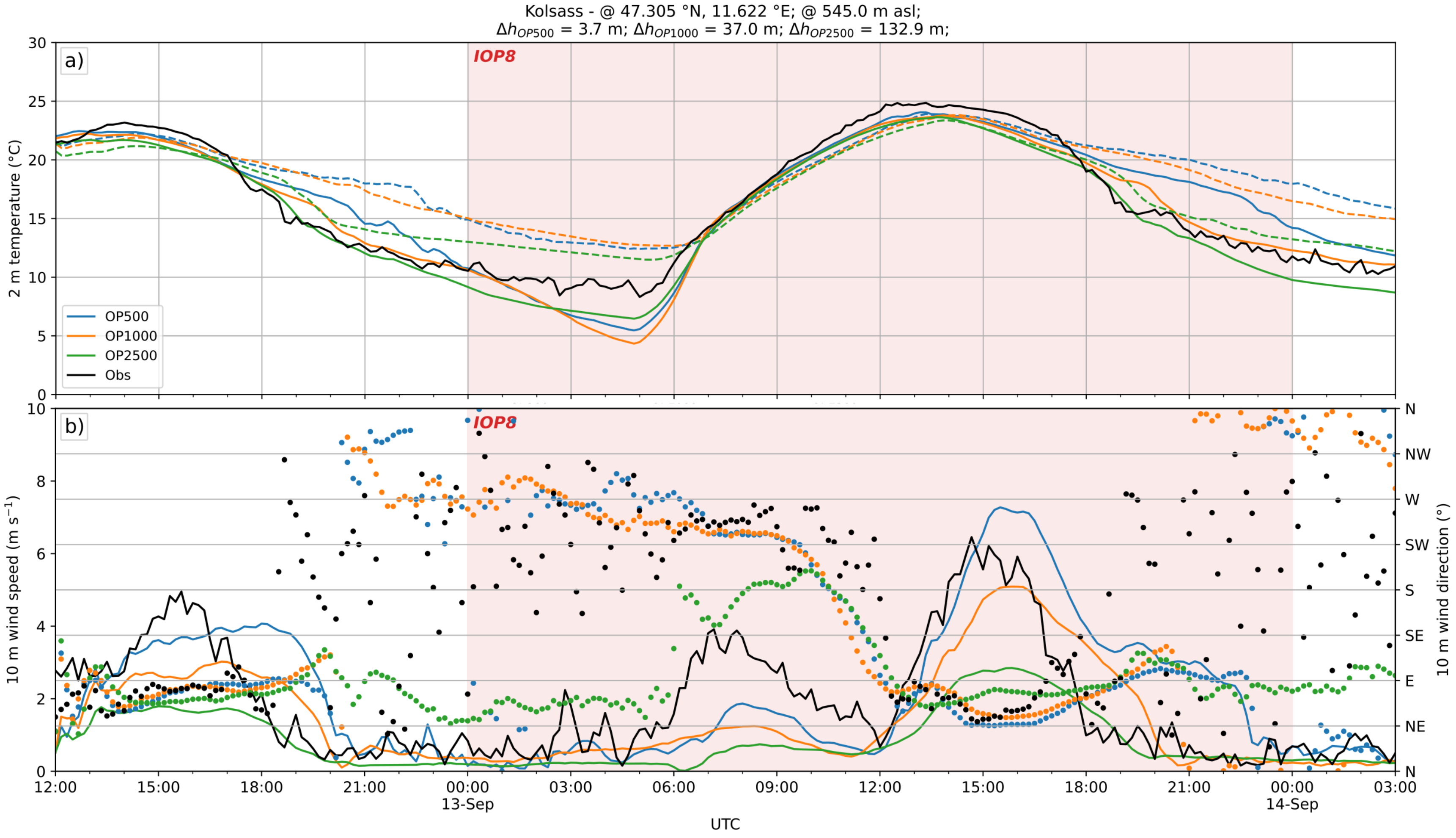
- NE flow near Inn Valle entrance indicates forced channeling effects

Case study IOP8 – impact Δx (topography)



- large improvements due more realistic topography
- Median bias to AWS-stations:
  - OP500: 7 m
  - OP1000: 30 m
  - OP2500: 140 m
- improved valley representation
- summit stations too low

Case study IOP8 – impact Δx (time series Kolsass)



- diagnostic adaption T2m (Meier et al. 2021)
  - tuned towards 1 m during nighttime
  - warm bias reduction
  - overestimated cooling first night
  - suppressed cold pool formation OP500 → upvalley winds

- 10 m wind:
  - underestimated downvalley winds i.e., OP2500

Case study IOP8 – impact Δx (10 m winds)

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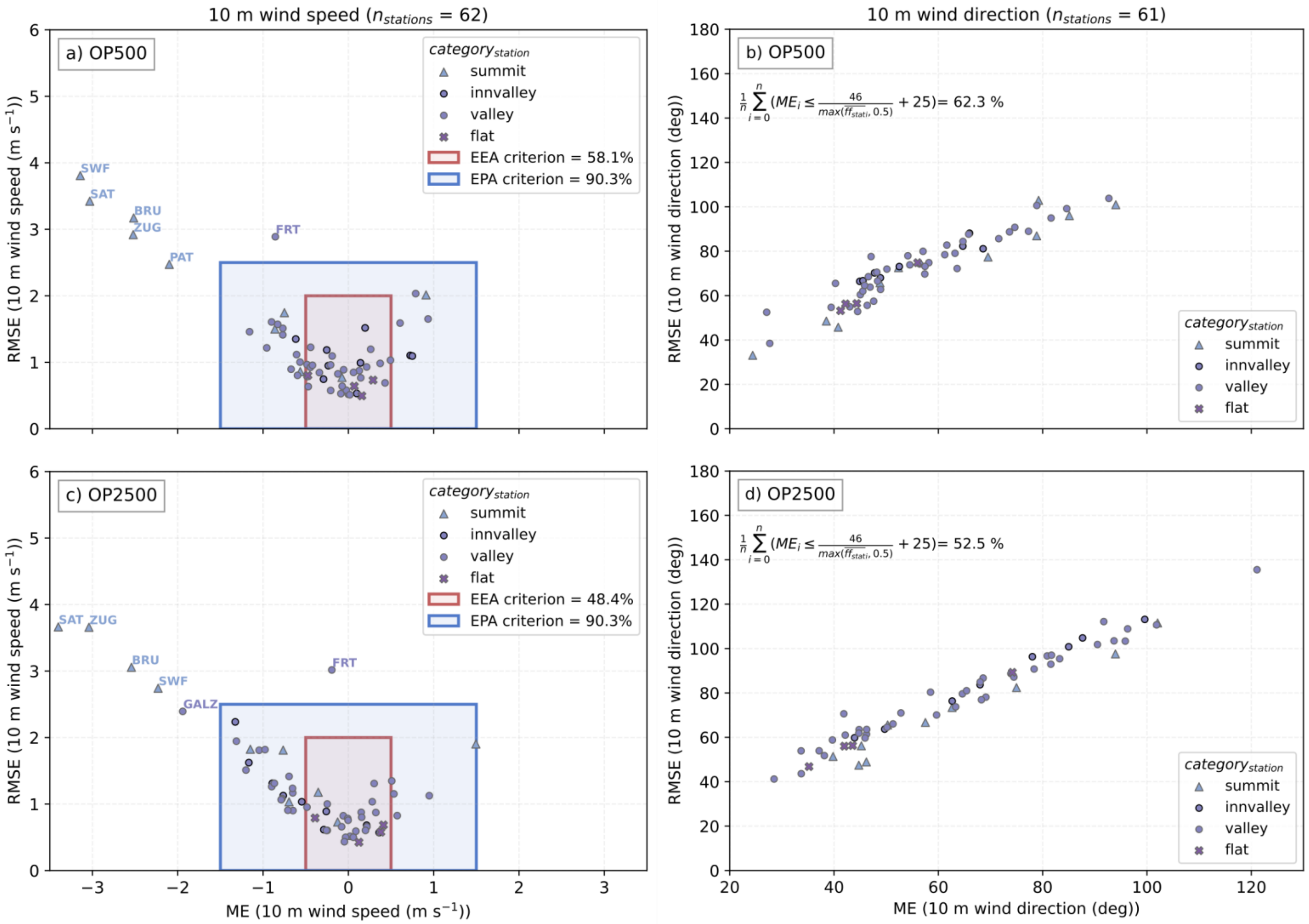
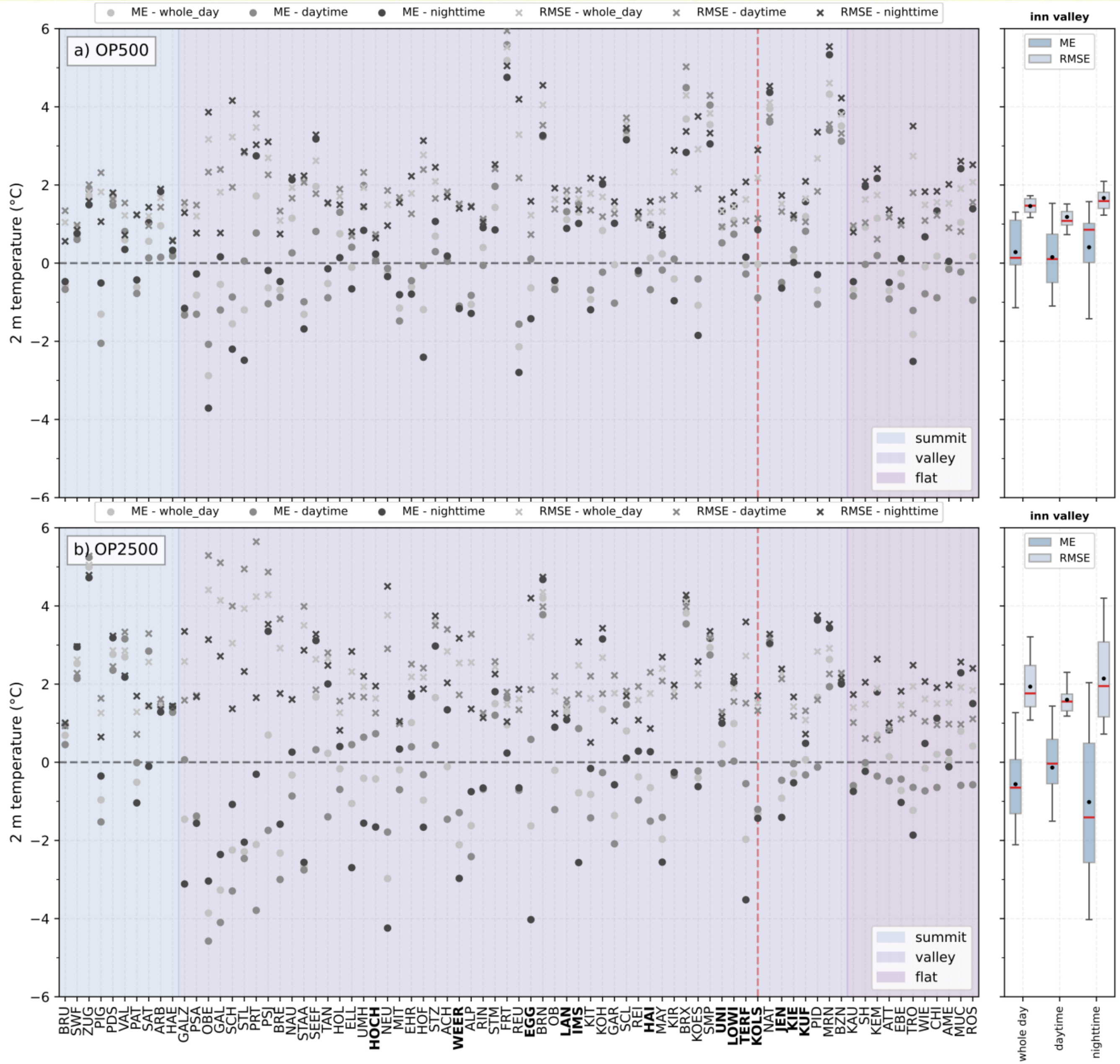


All stations ($n_{ff}=62$; $n_{dd}=61$)	ME		RMSE		Hit rates [%]		
	ff [m s^{-1}]	dd [°]	ff [m s^{-1}]	dd [°]	ff_{EEA}	ff_{US-EPA}	dd
OP500	**-0.36**	**56**	1.23	73	**58**	90	**62**
OP1000	-0.42	57	**1.16**	**71**	55	89	59
OP2500	-0.44	64	1.23	78	48	90	52

Inn Valley stations ($n_{ff}=9$; $n_{dd}=8$)	ff [m s^{-1}]	dd [°]	ff [m s^{-1}]	dd [°]	ff_{EEA}	ff_{US-EPA}	dd
OP500	**0.06**	55	1.05	74	**67**	100	50
OP1000	-0.20	**52**	**0.95**	**69**	67	100	**87.5**
OP2500	-0.52	72	1.12	87	44	100	25

- Higher grid resolution:
  - smaller station averaged ME (ff + dd)
  - improvements EEA benchmark (ff) and Hit rates dd (Oettl and Veratti 2021)
- largest disagreement for summit stations (sensitive to grid point selection)

Case study IOP8 – impact Δx (2 m temperature)



- diagnostic T2m adaption (Meier et al. 2021)
- all 77 AWS stations:
  - tendency warm bias
  - reduction RMSE (OP500: 2.0 K; OP2500: 2.31 K)

- Inn Valley stations (boxplot):
  - nighttime ME: 0.41 K (OP500); -1.02 K (OP2500)
  - daytime quite similar
  - less spread between stations observable with higher resolution (ME and RMSE)