

Evaluating the Turbulence Representation in a NWP Model over Mountainous Terrain

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The atmospheric boundary layer over mountains is very heterogeneous

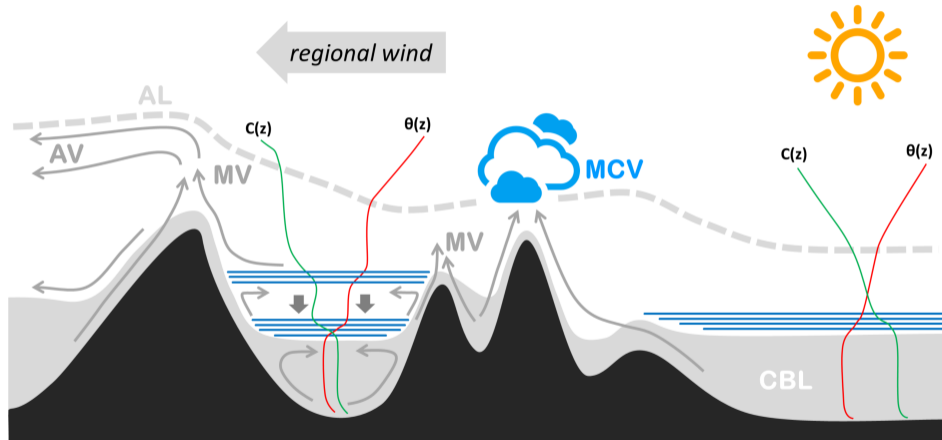


Image from Serafin et al. (2018)

Mountain Boundary Layers (MoBL) in NWP Models

MoBL in reality



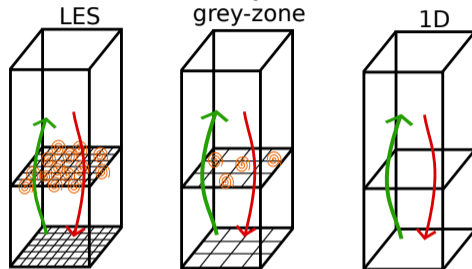
Representation in the
turbulence grey zone = ?

Representation in NWP model ($\Delta x = 1$ km)



Rotach and Zardi (2007)

Turbulence Representation



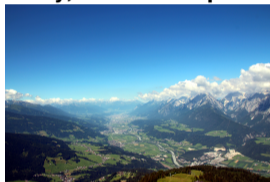
adapted from Honnert et al. (2011)

What is the added value of
increased resolution in
representing turbulence over
complex topography?

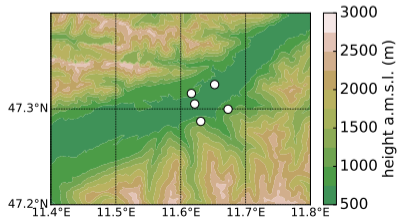
Location and Observations

Case studies: Valley winds days, where boundary layer processes dominate.

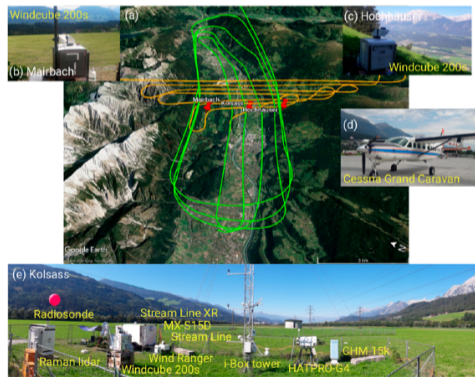
Inn Valley, Austrian Alps



i-Box Turbulence flux towers

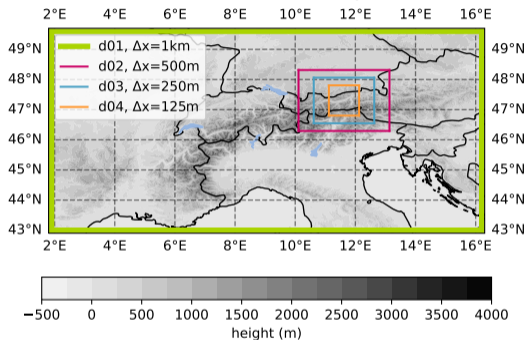


CROSSINN Campaign (Summer/autumn 2019) LIDAR, Temperature profilers, etc.



Model: ICON - Icosahedral Nonhydrostatic Model

Limited area set-up



Model Set-up

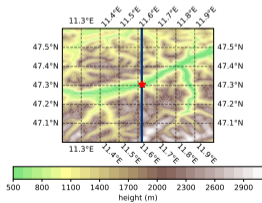
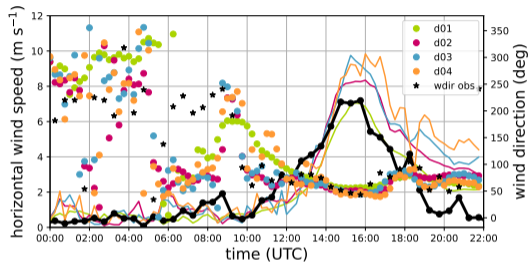
- Limited-area set-up, 4 domains
- BC: IFS-HRES ($\Delta x = 9\text{ km}$); IC: COSMO-1 Analysis ($\Delta x = 1\text{ km}$)
- model runtime 24 hours
- 80 vertical levels, lowest half level at 10 m a.g.
- **2 sensitivity runs for all domains:**
 1. 1D TKE scheme (after Mellor-Yamada)
 2. 3D Smagorinsky closure

How do the two turbulence schemes perform across resolutions?
At which Δx shall we switch to 3D?

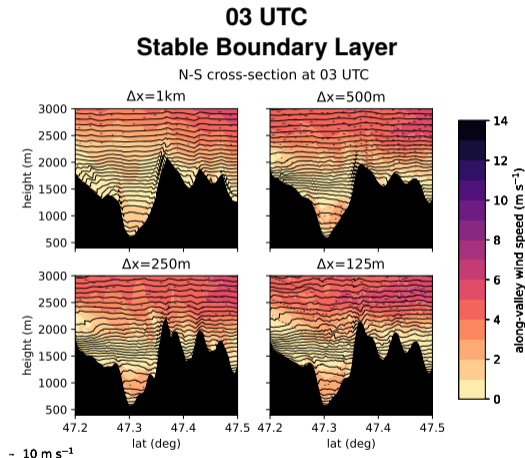
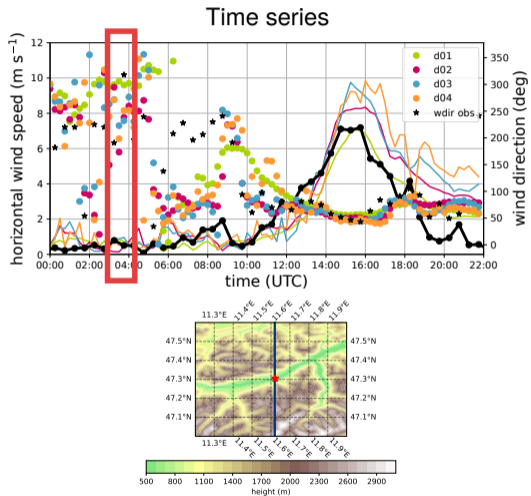
5 case studies: Aug 4 | Aug 14 | Aug 30 | Sept 13 | **Sept 14**

Case study: Typical diurnal cycle

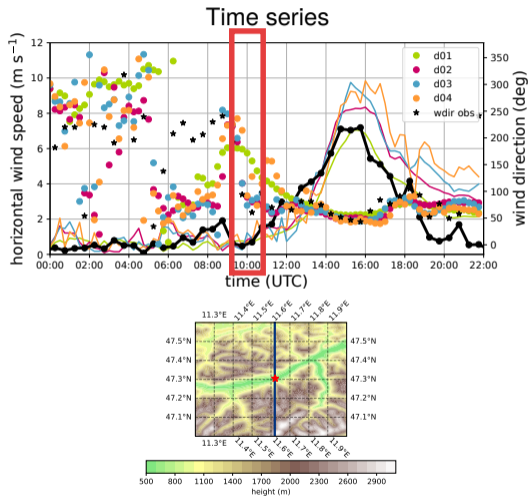
Time series



Case study: Typical diurnal cycle

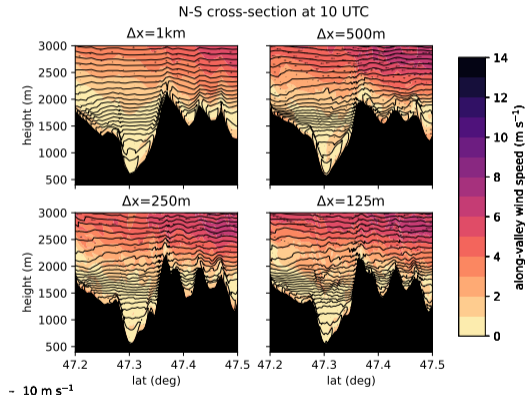


Case study: Typical diurnal cycle at the valley floor

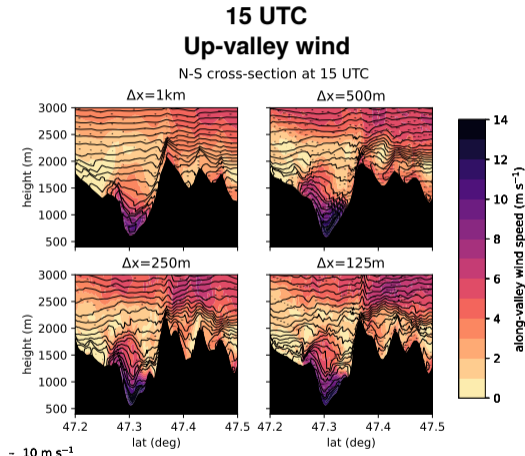
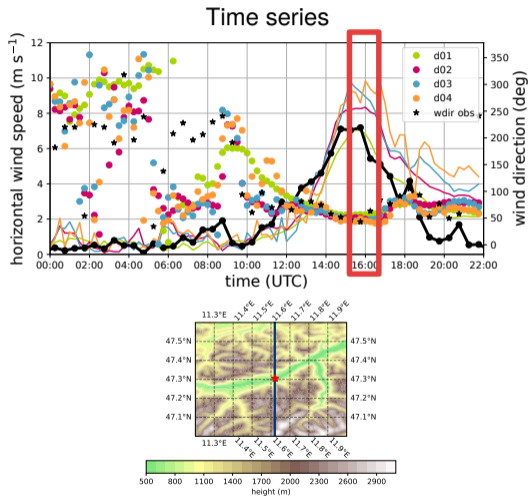


10 UTC

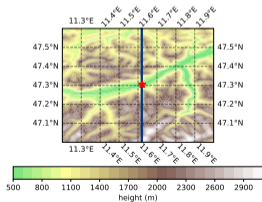
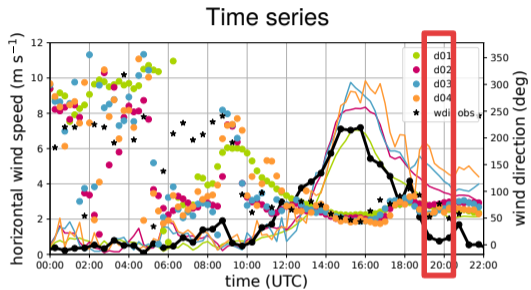
Slope Flows and Convective Boundary layer



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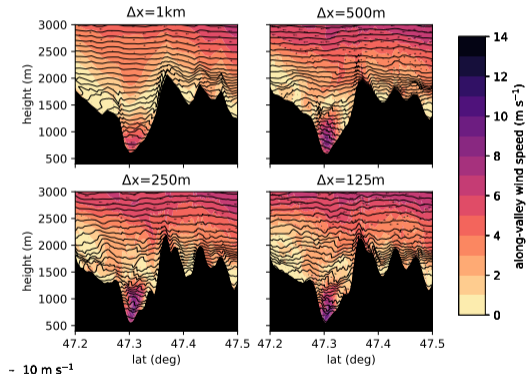


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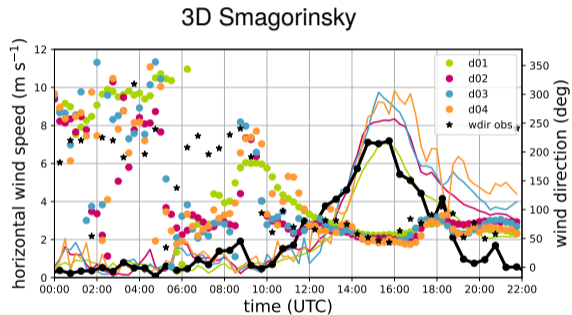
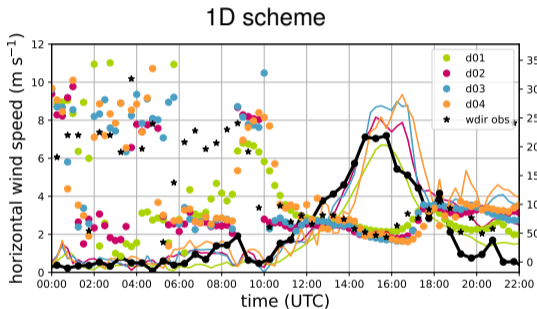


19 UTC Evening Transition

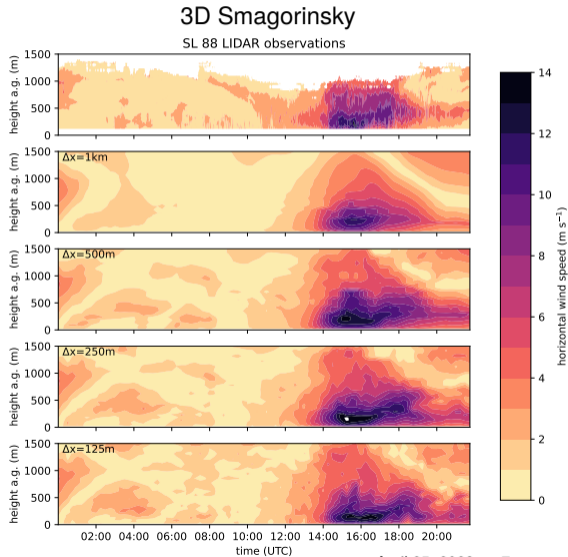
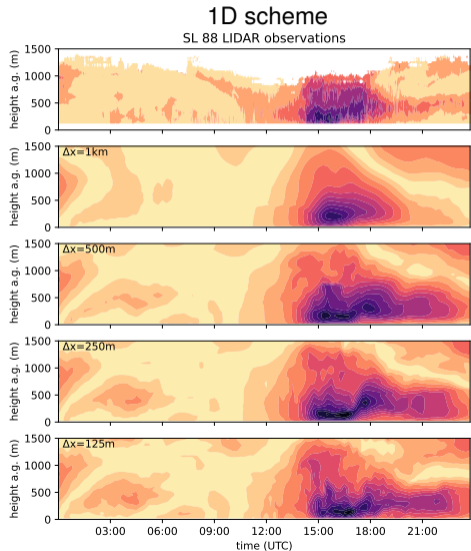
N-S cross-section at 19 UTC



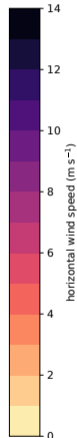
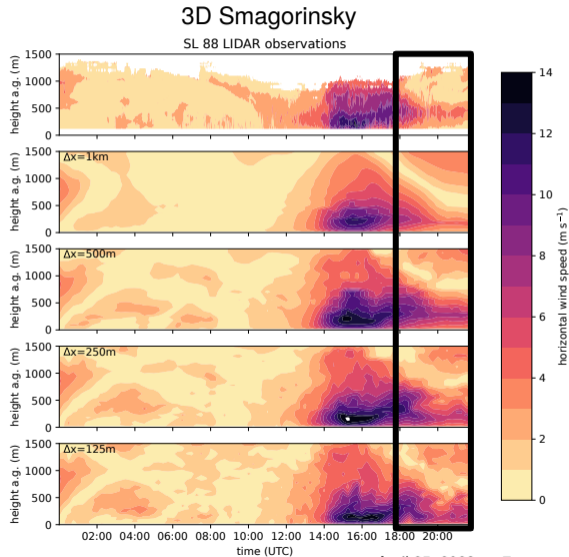
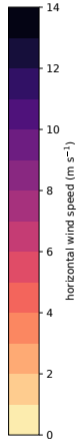
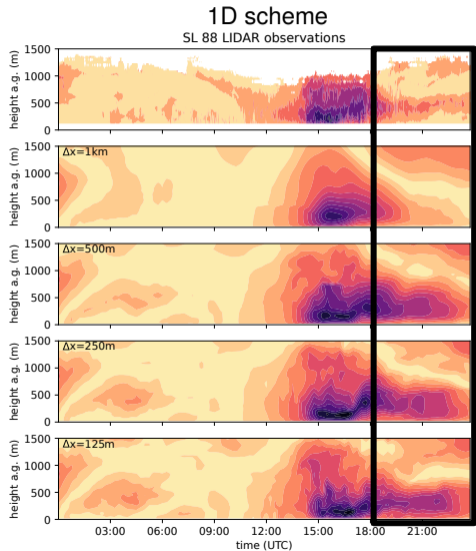
Case study: Typical diurnal cycle at the valley floor



Diurnal cycle at valley floor – LIDAR time series (vertical profiles)

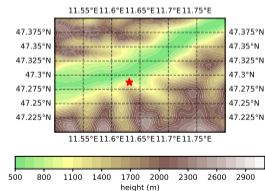
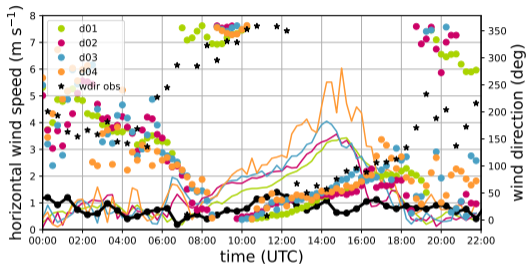


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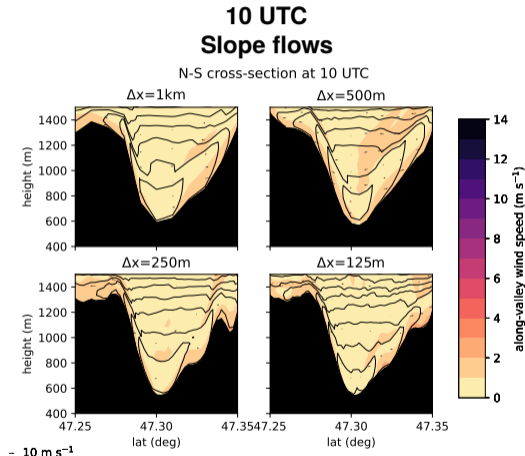
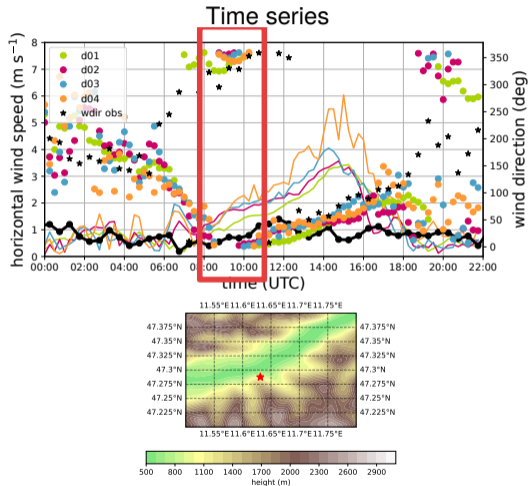


Is the valley floor representative for the entire valley?

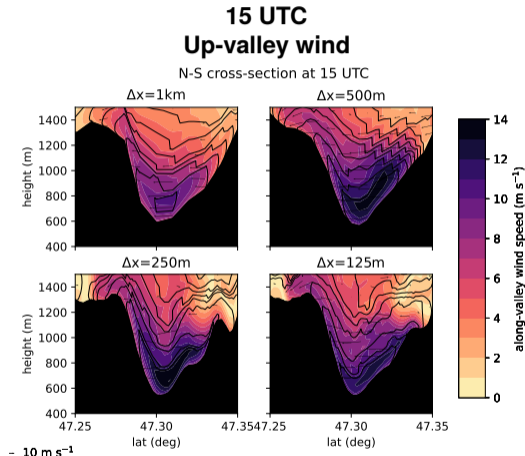
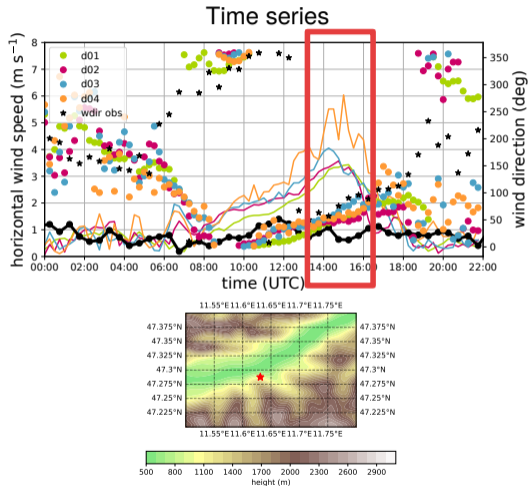
Time series at North-facing slope



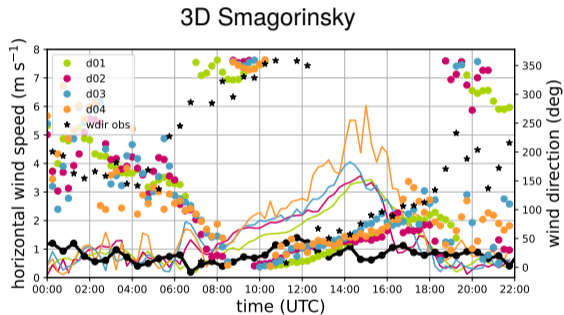
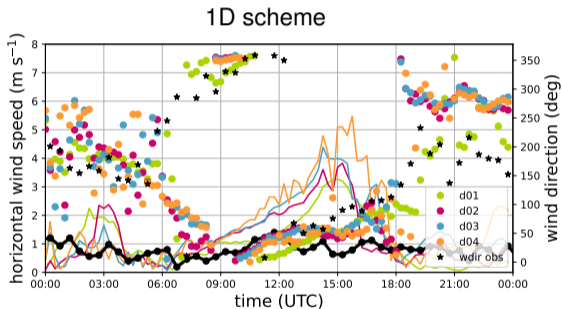
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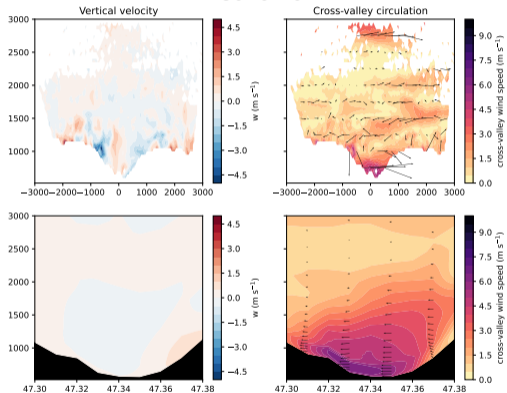


Diurnal cycle at the North-facing slope

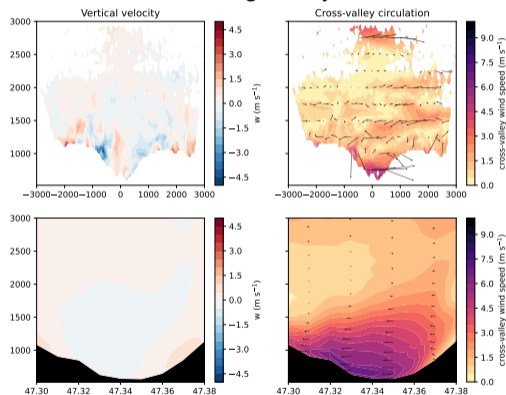


LIDAR cross-sections across the valley, 15 UTC, $\Delta x=1$ km

1D scheme

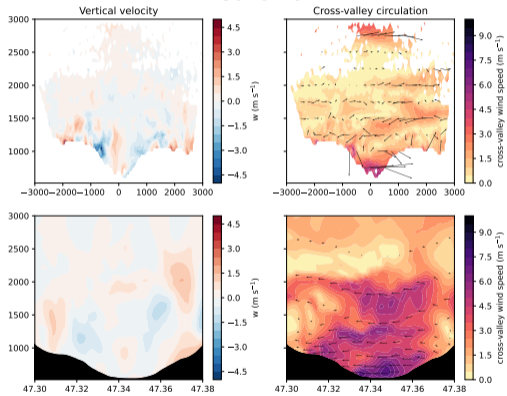


3D Smagorinsky

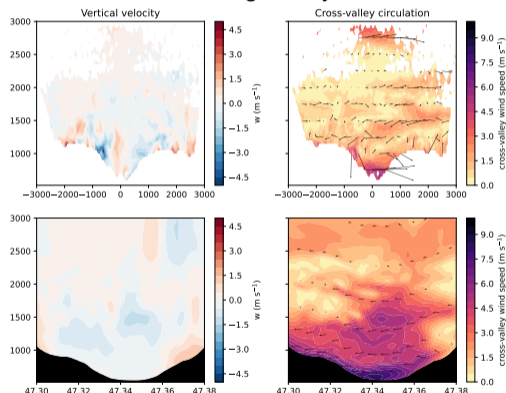


LIDAR cross-sections across the valley, 15 UTC, $\Delta x=125$ m

1D scheme

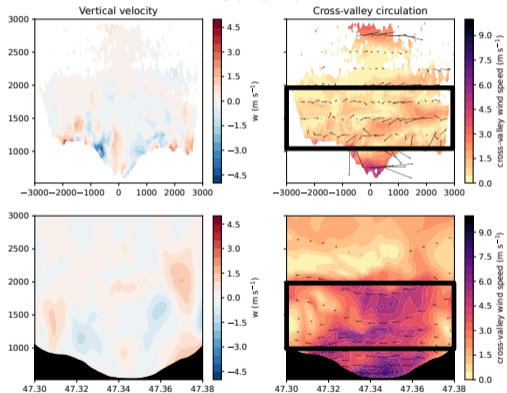


3D Smagorinsky



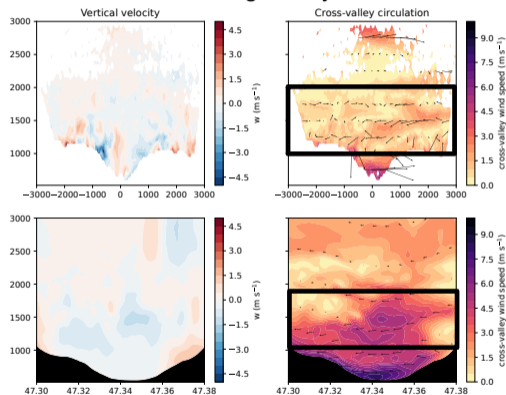
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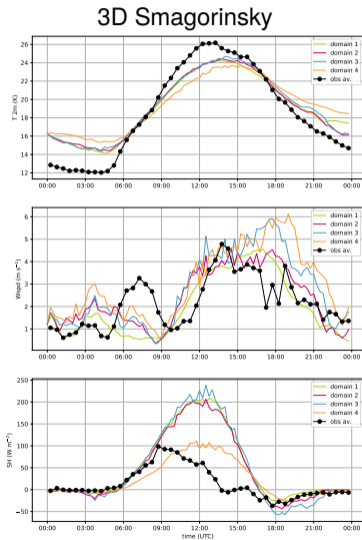
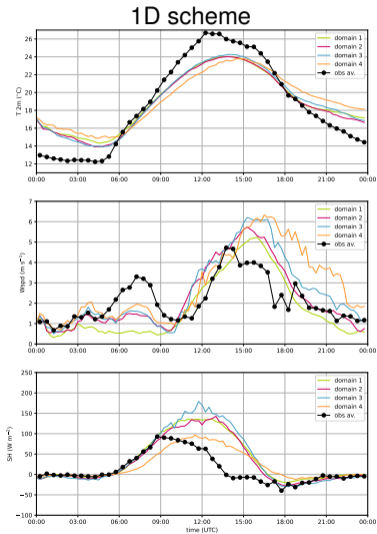
— 5 m s⁻¹ (cross-valley)

3D Smagorinsky

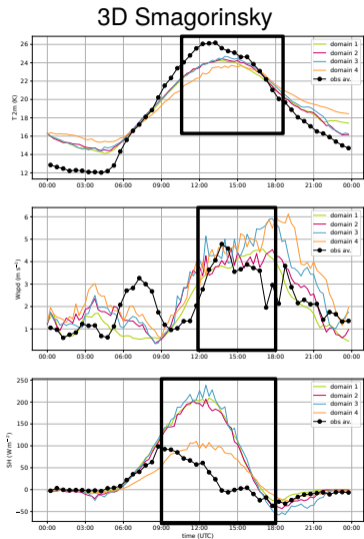
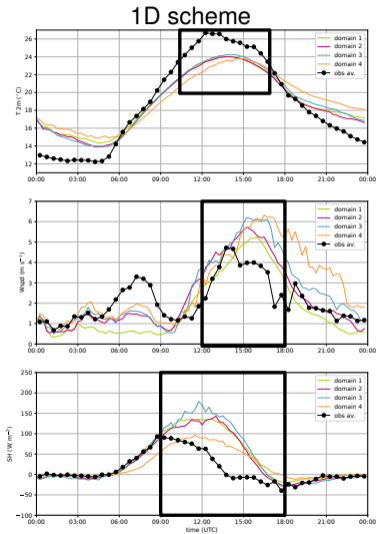


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All 5 case studies average - valley floor



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Summary and Conclusions

Model performance is ...

- Time-dependent (evening transition)
- Location-dependent (valley floor vs slope)
- Phenomenon-dependent (scale interactions, e.g. slope flows vs valley winds)

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- Vertical structure of the valley atmosphere (Δx smaller than 250 m)

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To-do...

- TKE representation – comparison with observations
- Turbulence grey zone analysis

Thank you! Questions?



Observations from



Simulations were performed within

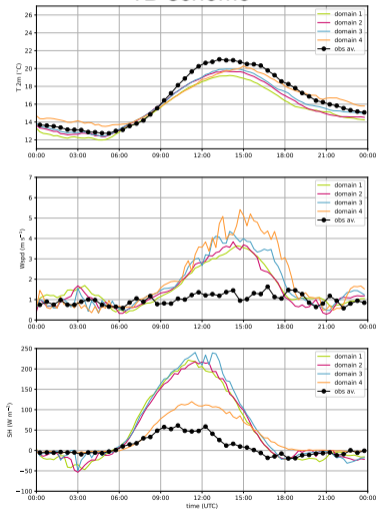


References

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All case studies validation - North-facing slope

1D scheme



3D Smagorinsky

