Evaluation of the Performance of COSMO-1 in Truly Complex Terrain

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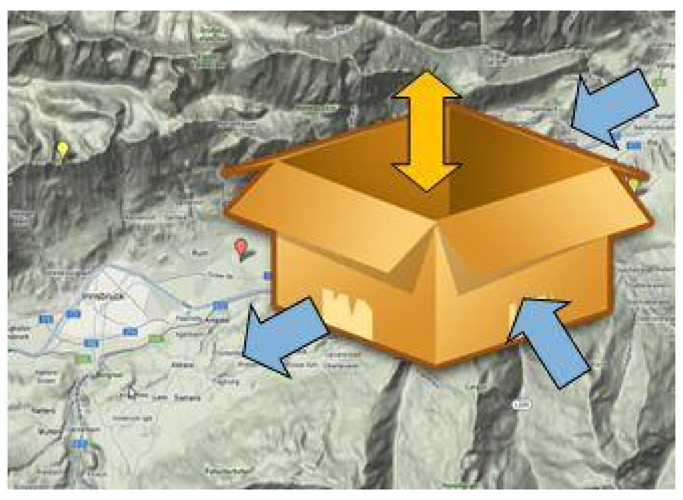
The Project "Turb-i-Box"

Motivation

Operational numerical weather prediction has gone through significant improvements in the last years, using horizontal grid resolutions up to Δx=1 km. However, there are still some model deficiencies, especially in mountainous areas. We want to explore the performance of COSMO-1 in the Inn Valley, Austria, by evaluating the model's terrain representation and parameterizations.

Main Questions:

- How does COSMO-1 perform in complex terrain?
- Does the model produce the *right* fields for the *right* reasons?
- Why does the model produce the right/wrong output?



Test Location and Data:

- Inn Valley, Tyrol, Austria
- Measurement data from the i-Box dataset

The i-Box Data

Six measurement sites on locations representative for complex terrain, such as

- Valley bottom
- Slope
- Mountain top

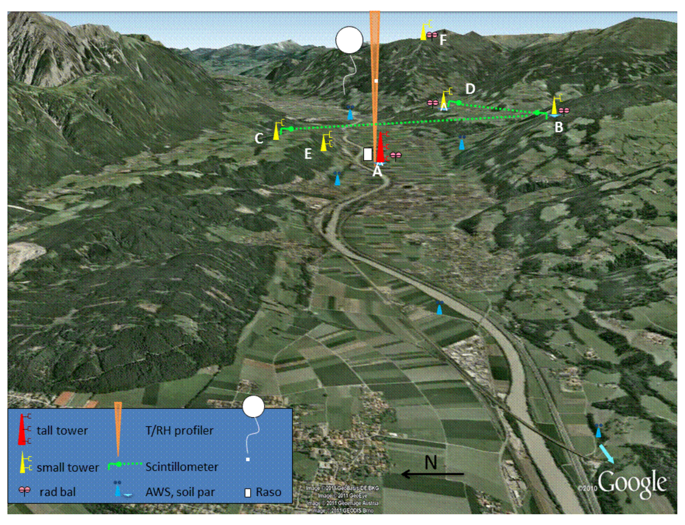


Figure 1 : A view from the West into the Inn Valley and the measurement sites.

Figure 2 : One of the slope stations, Hochhäuser.

Flux Towers: Long-term measurements

- Usual meteorological parameters
- Turbulent fluxes
- Radiation
- Turbulence Kinetic Energy (TKE)

Remote sensing

- HATPRO (Passive Microwave Temperature & Humidity Profiler)
- Doppler Lidar (HALO)
- Scintillometer

The COSMO Model in Complex Terrain

Model Setup:

- Similar to MeteoSwiss pre-operational setup
- Δx=1.1 km, 80 vertical levels
- Domain (Fig. 3) spans main Alpine Range (to be extended)
- Initialization: COSMO-1 analysis, with COSMO-7 fields as boundary data

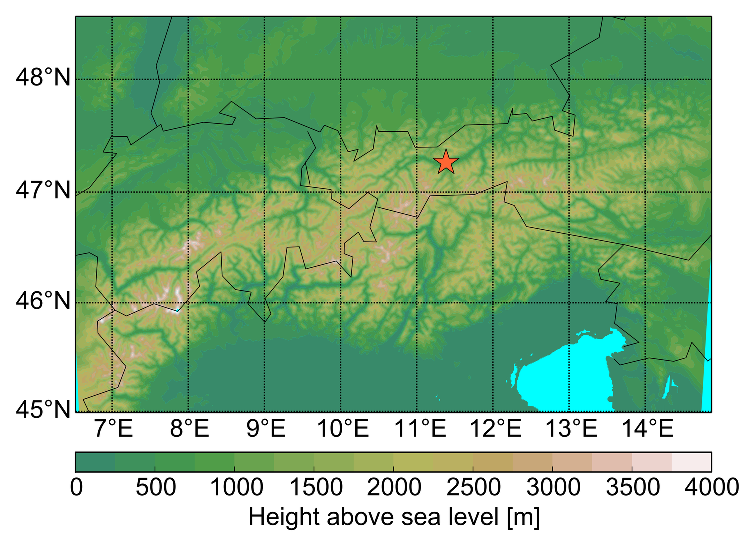


Figure 3 : The domain used for simulations.

Challenges in high-resolution modeling in complex terrain

1. **'Gray zone' turbulence**
   Boundary-layer schemes still apply for Δx=1 km, but a resolved part of the processes is already present.
2. **Input Data**
   The input data (e.g, soil moisture) should have a high resolution to fully exploit the potential advantages of model resolution.
3. **Parameterizations (radiation & turbulence)**
   Developed for horizontally homogeneous and flat surroundings, hence maybe not suitable for complex terrain.
4. **Terrain Representation**
   Mountain peaks and steep slopes are challenges for numerical stability and representation on the grid.

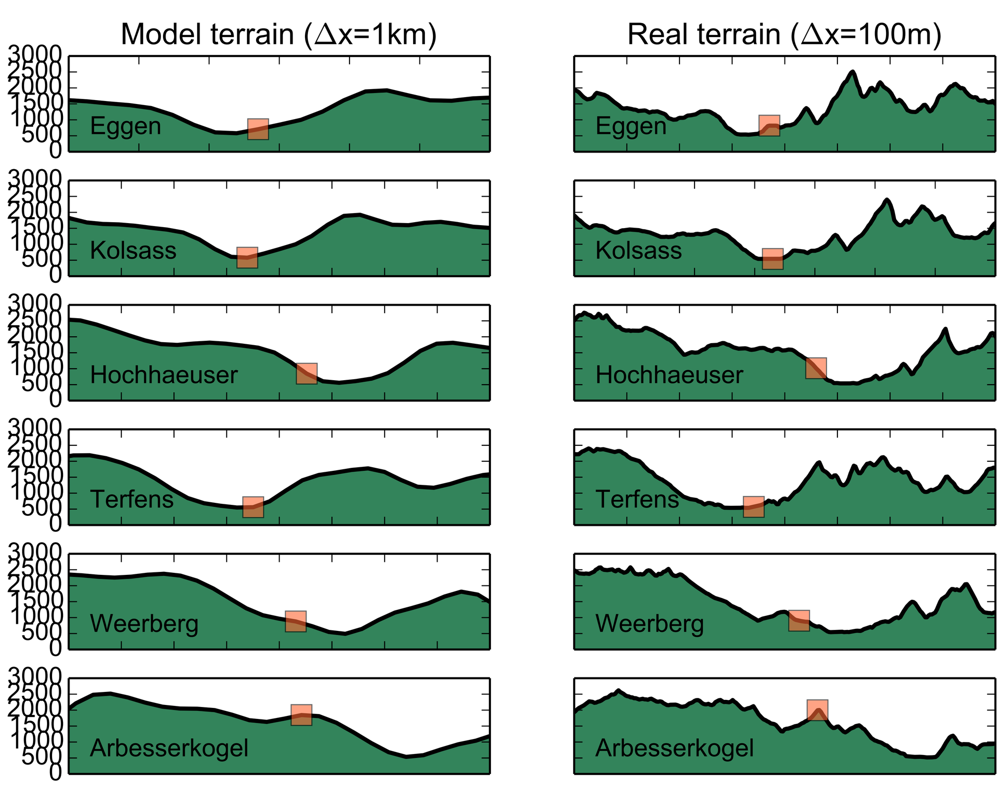


Figure 4 : South-north cross-sections (x=8 km) of the six i-Box stations and their representation on the model grid.

Methods: Case Studies

Weather situations representative for processes in complex terrain:

- Valley wind day
- Stable boundary layer
- Foehn wind events
- Synoptic influence on the valley (e.g. channeling)

→ Simulations are either initialized at 00 UTC or 12 UTC and run for 24 hours.

Results: Valley Wind Day

Daytime: June 11, 2014

- Up-valley wind is well represented by the model (fig. 5 & 6)
- Discrepancies in morning/evening transitions (fig. 7, left)
- Slope station: Larger differences, especially in wind speed magnitude (fig. 8, right)

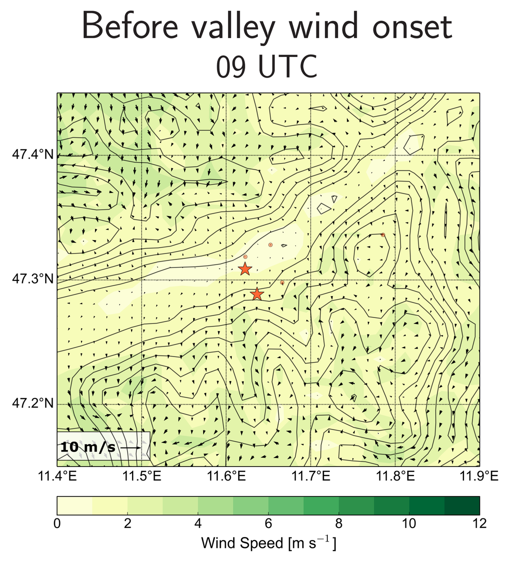


Figure 5

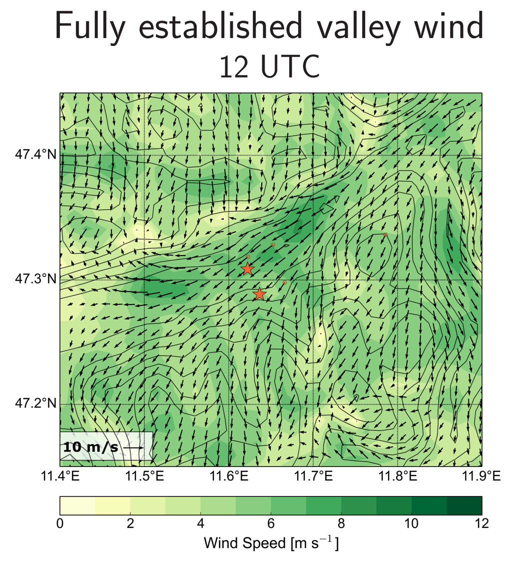


Figure 6

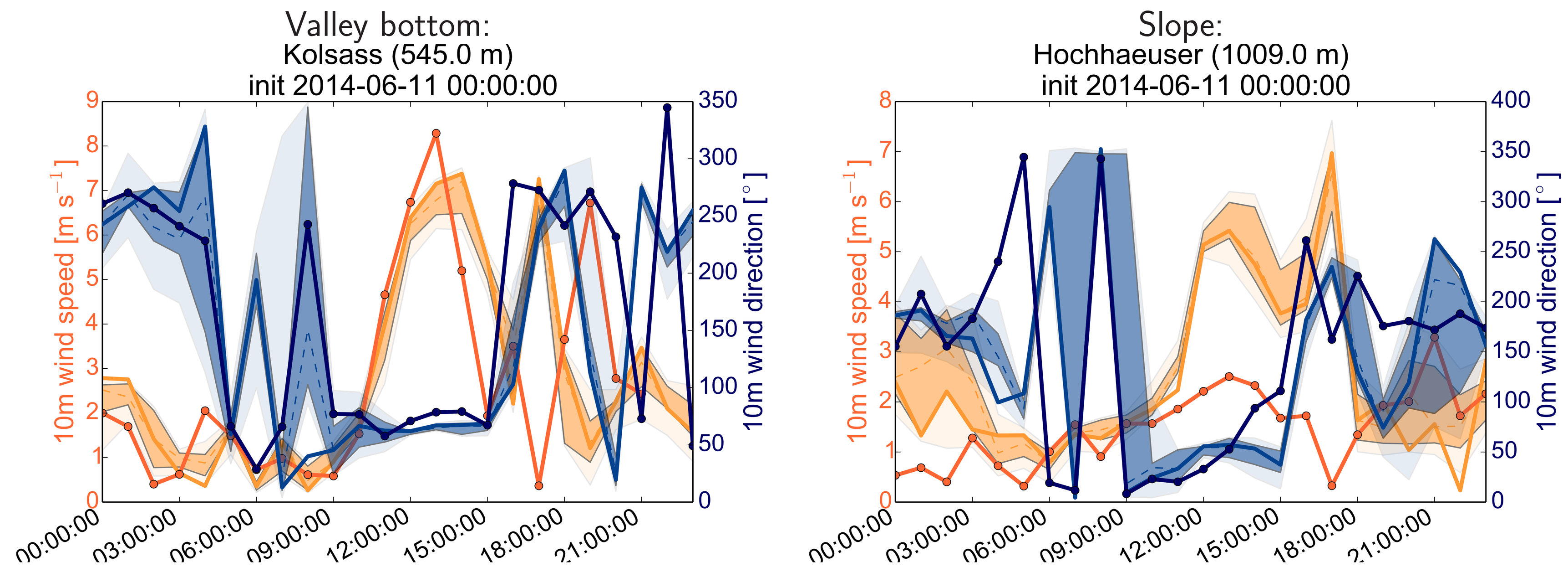


Figure 7 : Time series of 10 m **wind speed** and **wind direction** of the valley station, Kolsass (left) and the slope station Hochhäuser (right). Lines with dots indicate the observations (●—●), while full lines show the model output (—).

Results: Stable Boundary Layer

Nighttime: June 11, 2014

- Valley-wind circulation reverses during evening transition. Down-valley flows are much weaker (fig. 8 & 9)
- Day: Good agreement between model and observations in TKE values (fig. 10)
- Night: Model underestimates the TKE magnitude, with an even larger difference on the slope station (fig. 10, left)

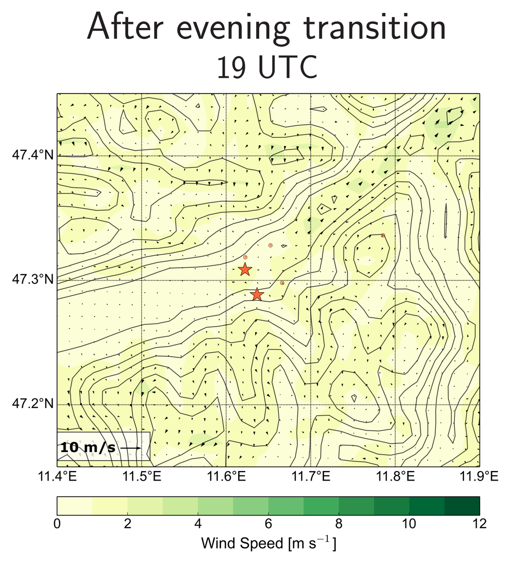


Figure 8

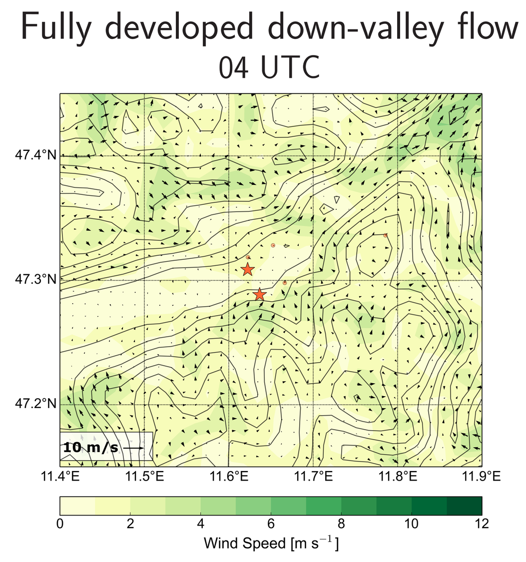


Figure 9

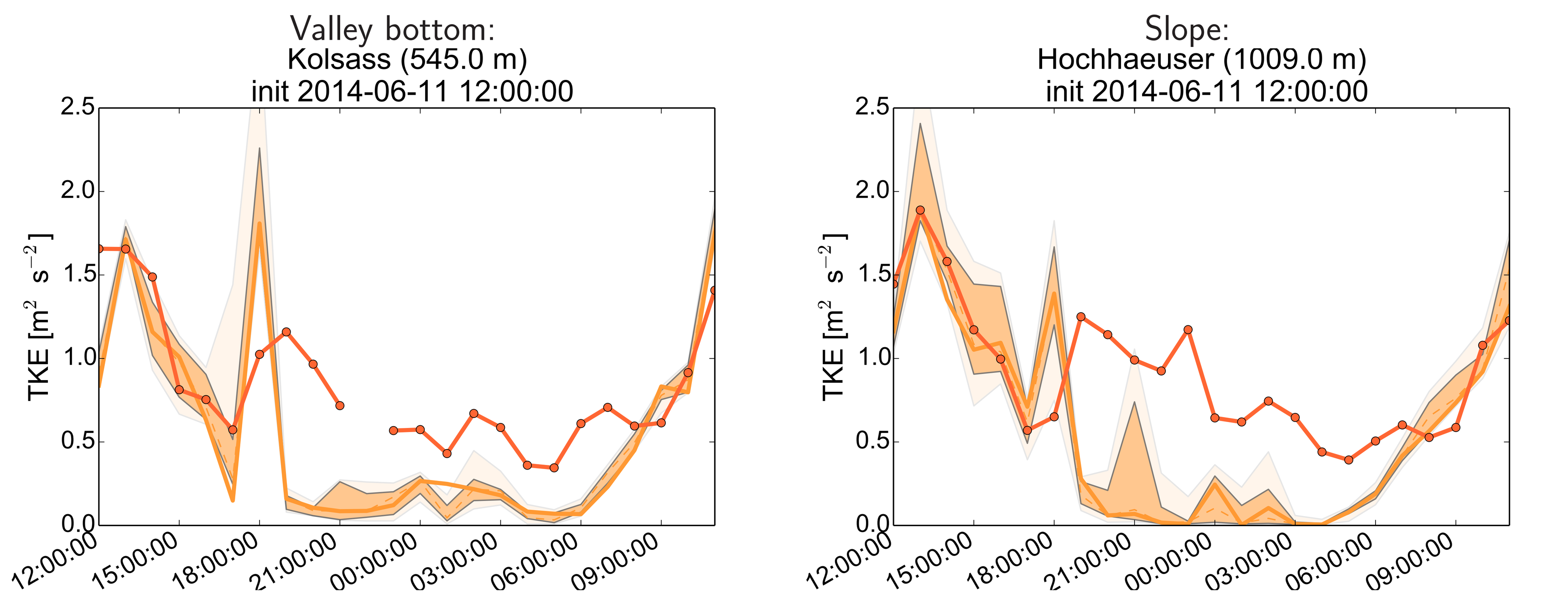


Figure 10 : Time series of **turbulence kinetic energy (TKE)** of the valley station, Kolsass (left) and the slope station Hochhäuser (right). Lines with dots indicate the observations (●—●), while full lines show the model output (—).

Conclusions and Outlook

- Correct terrain representation plays a crucial role for numerical weather prediction in mountainous areas
- The processes on the valley floor are generally better represented than on the slope
- Better model performance during daytime than during nighttime
- Continue with data analysis including a special focus on terrain representation
- Evaluate the components of the parameterizations with the i-Box data for complex terrain (Inn Valley) and data for "rolling terrain" (Payerne, Switzerland)

Acknowledgements

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