Influenza delle Parametrizzazioni della turbolenza e delle Interazioni Superficie-Atmosfera sulla Simulazione di Circolazioni Locali in una Valle Idealizzata

Andrea Zonato[1], Andrea Bisignano[1,2], Dario Di Santo[1], Dino Zardi[1], Lorenzo Giovannini[1]

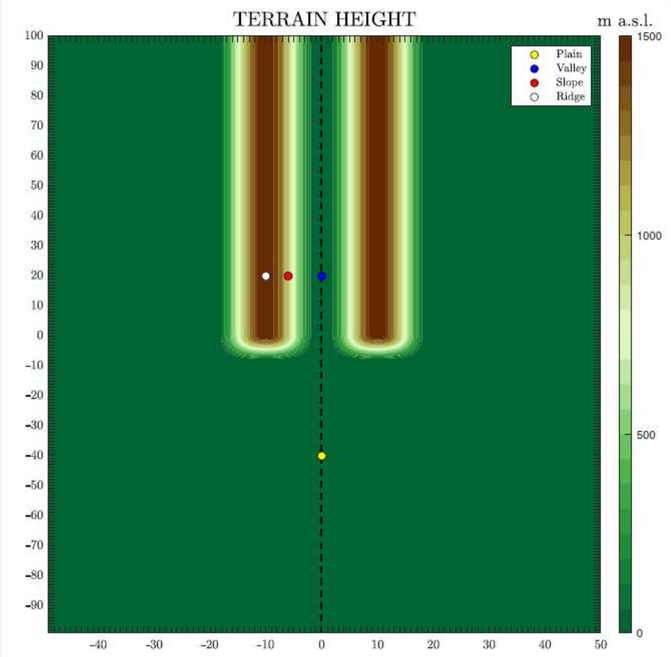
[1]Dipartimento di Ingegneria Civile, Ambientale e Meccanica, Università di Trento, [2]Agenzia Regionale per la Protezione dell'Ambiente Ligure

lorenzo.giovannini@unitn.it

Introduction

A set of Reynolds-averaged Navier-Stokes (RANS) simulations at 1 km horizontal resolution is performed in an idealized three-dimensional valley-plain topography, using typical geometrical features of a north-south Alpine valley, with ridges up to 1500 m above the valley floor and a distance of 20 km from crest to crest. The aim of the modeling experiment is to evaluate the sensitivity of model results to land surface models (LSMs) and planetary boundary layer (PBL) parameterizations, exploring all the schemes implemented in the Weather Research and Forecasting (WRF) model, including a newly developed k-ε closure. Results from the RANS simulations are compared against a large-eddy simulation (LES) with a resolution of 100 m, which is taken as the benchmark. The evaluation of numerical results focuses on the reproduction of along- and cross-valley thermally-driven circulations and on the associated thermal field both in the nighttime and in the daytime phases. The sensitivity of model results is assessed using as key metrics the strength and the timing of the thermally-driven circulations, as well as the vertical profiles of mean and turbulent quantities.

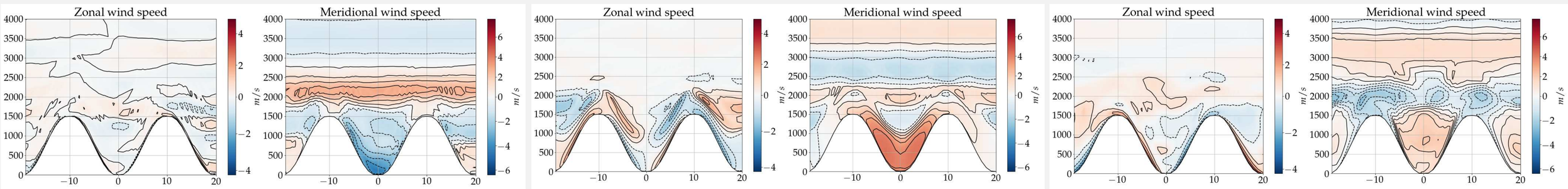
Modeling Set Up



Terrain height adopted in the simulations.

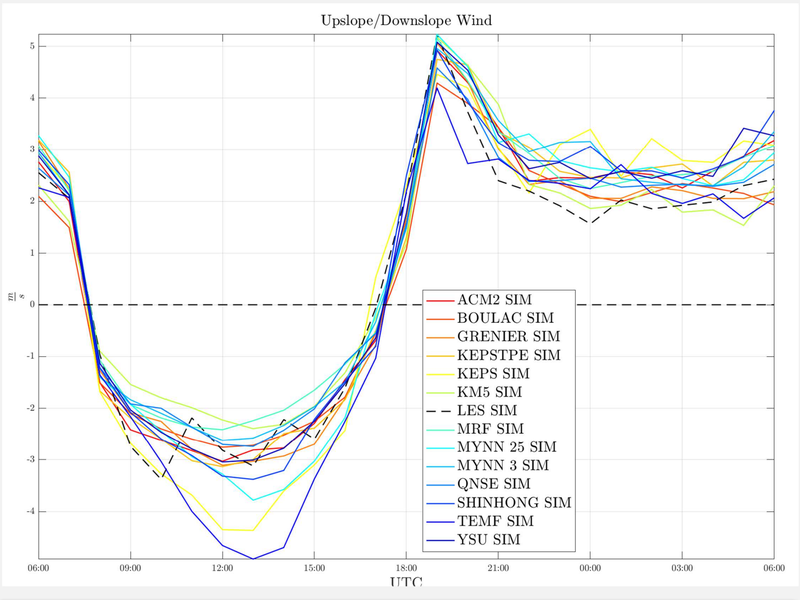
- $\Delta x = \Delta y = 1000$ m for RANS
- $\Delta x = \Delta y = 100$ m for LES
- Δz from 15 m close to the surface to 400 m at 12000 m AGL
- #x=100, #y=200, #z=65 for RANS
- #x=1000, #y=2000, #z=65 for LES
- Symmetric domain S-N and W-E
- Symmetric boundary conditions
- $U_0 = 0$ m s^{-1}, $V_0 = 0$ m s^{-1}
- $\theta_0 = \theta_s + \Gamma z + \Delta\theta[\exp(-\beta z)]$, $\theta_s = 280$ K, $\Gamma = 3.2$ K km^{-1}, $\Delta\theta = 5$ K, $\beta = 0.002$ m^{-1}
- $P_0 = 1000$ hPa
- No Coriolis force
- Lat = 46°N , Lon = 11°E
- 21st March

Modeling Results: Cross-Sections



Cross section of zonal (cross-valley) and meridional (along-valley) wind speed at 03 UTC (left), 12 UTC (center) and 21 UTC (right) from the RANS simulation with the BouLac turbulence parameterization and the NoahMP land surface model.

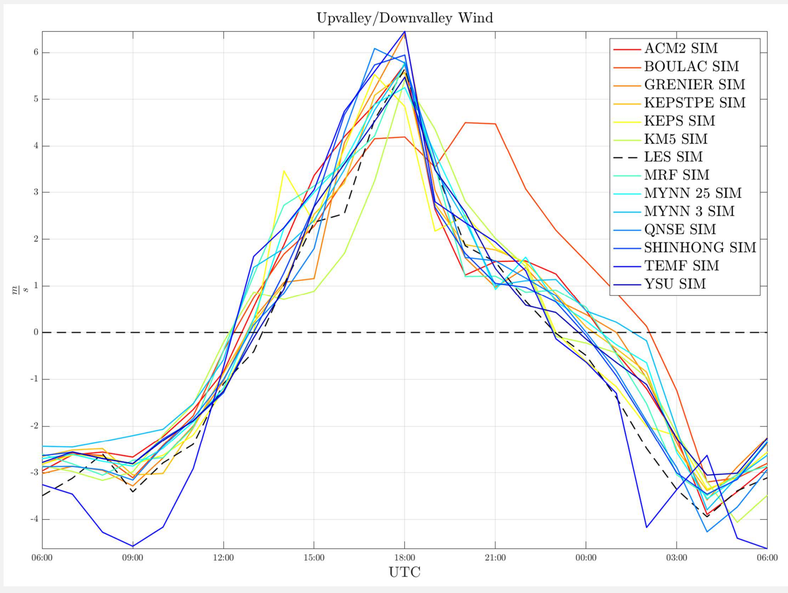
Cross-Valley Wind



Temporal evolution of the cross-valley wind in the slope point.

The transition between down- and up-slope wind and viceversa is similarly captured by all RANS simulations adopting different turbulence parameterizations, and well agrees with the LES. Significant differences are present in the simulation of the strength of the slope circulation, in particular for the upslope wind during daytime, with values ranging between 2 and 5 m s^{-1}.

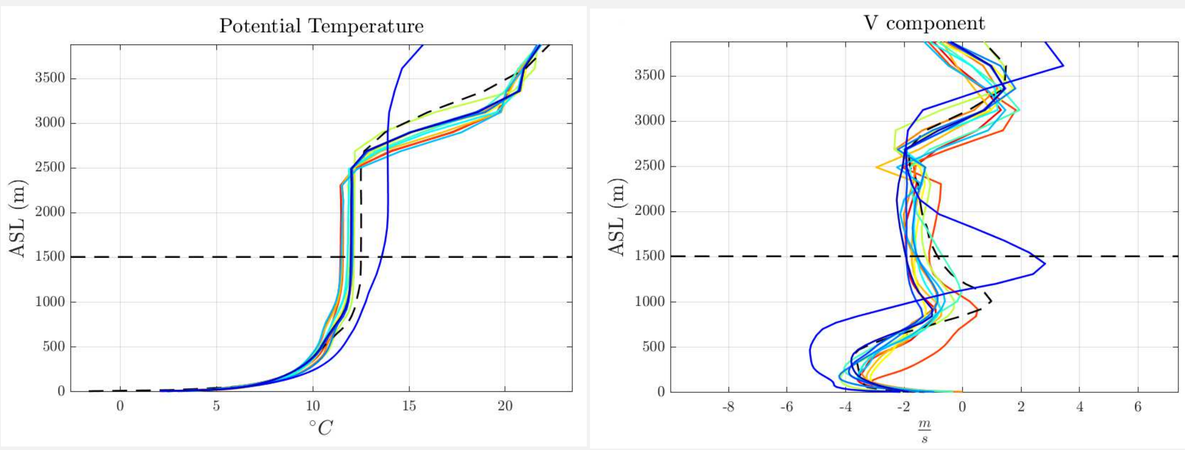
Along-Valley Wind



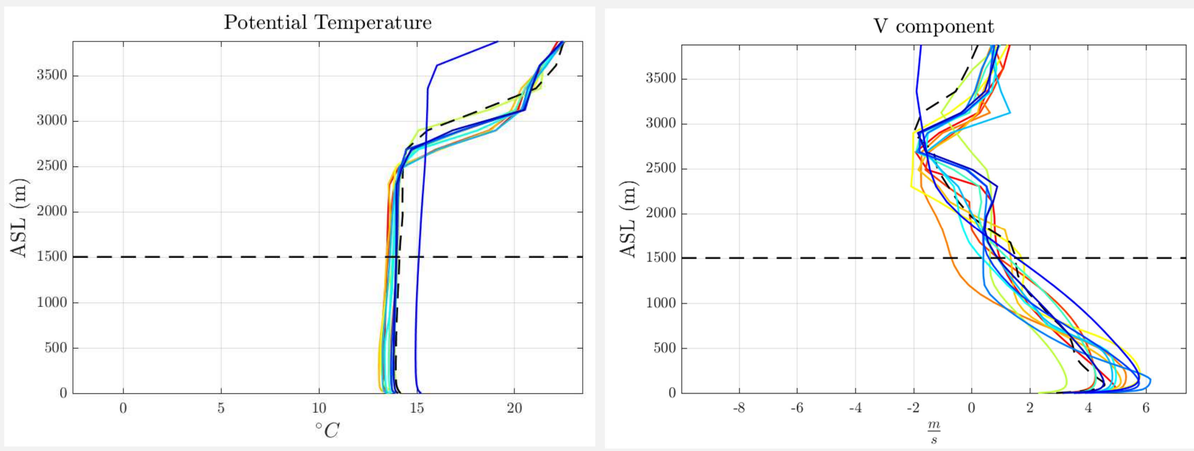
Temporal evolution of along-valley wind in the valley point.

The timing of the transition between down- and up-valley wind is similarly captured by all RANS simulations, while higher differences are present for the evening transition. The duration of the up-valley wind is overestimated by all RANS simulations, with an anticipation of its development and a delay of its cessation. On the other hand, the strength of both down- and up-valley wind is well-reproduced by most RANS simulations.

Modeling Results: Vertical Profiles



Vertical profiles of potential temperature (left) and along-valley wind (right) at 06 UTC from the RANS simulations and the LES.



Vertical profiles of potential temperature (left) and along-valley wind (right) at 18 UTC from the RANS simulations and the LES.

Project funded by the European Region Tyrol-South Tyrol-Trentino. Project IPN101 "Atmospheric boundary-layer modeling over complex terrain"