OLYMPIC HARMONIE 2014 – Influence of the details of topography in a NWP model

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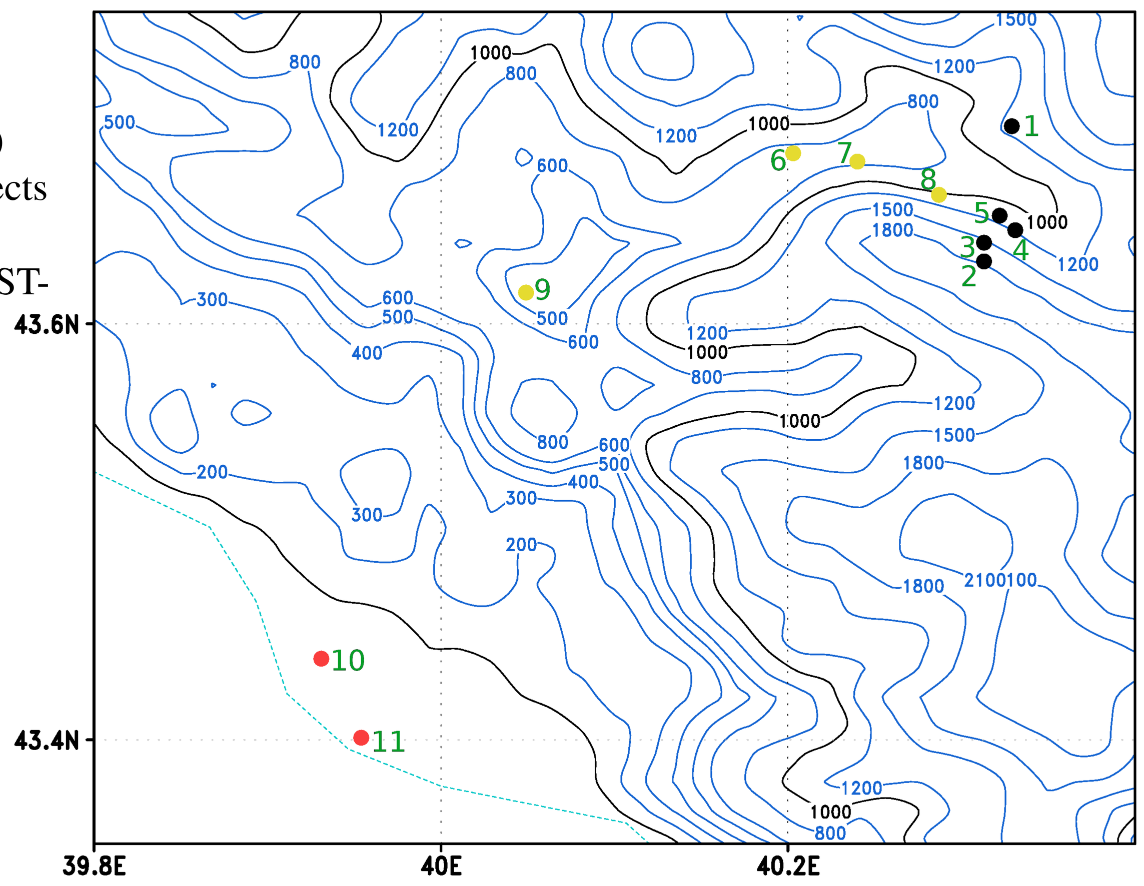
World Meteorological Organization (WMO) organized both Research Development Projects (RDP) and Forecast Demonstration Projects (FDP) during the Olympic games. The FROST-2014 (Forecast and Research: the Olympic Sochi Testbed) project focused in particular on the development/demonstration of modern short-term Numerical Weather Prediction (NWP) and nowcasting systems over mountainous region in winter-time conditions and on the assessment of practical use of this information. In order to do so, the project deployed several additional observation sites in the area. This new observation dataset was used in our study.



Location of the observation sites. Mountain, valley and coastal stations are marked with black, yellow and red dots, respectively. Surface elevation is represented by the HARMONIE 1.5 km resolution mean orography. Dashed cyan line on the lower left denotes the estimated coastline.

Orography and orovariables

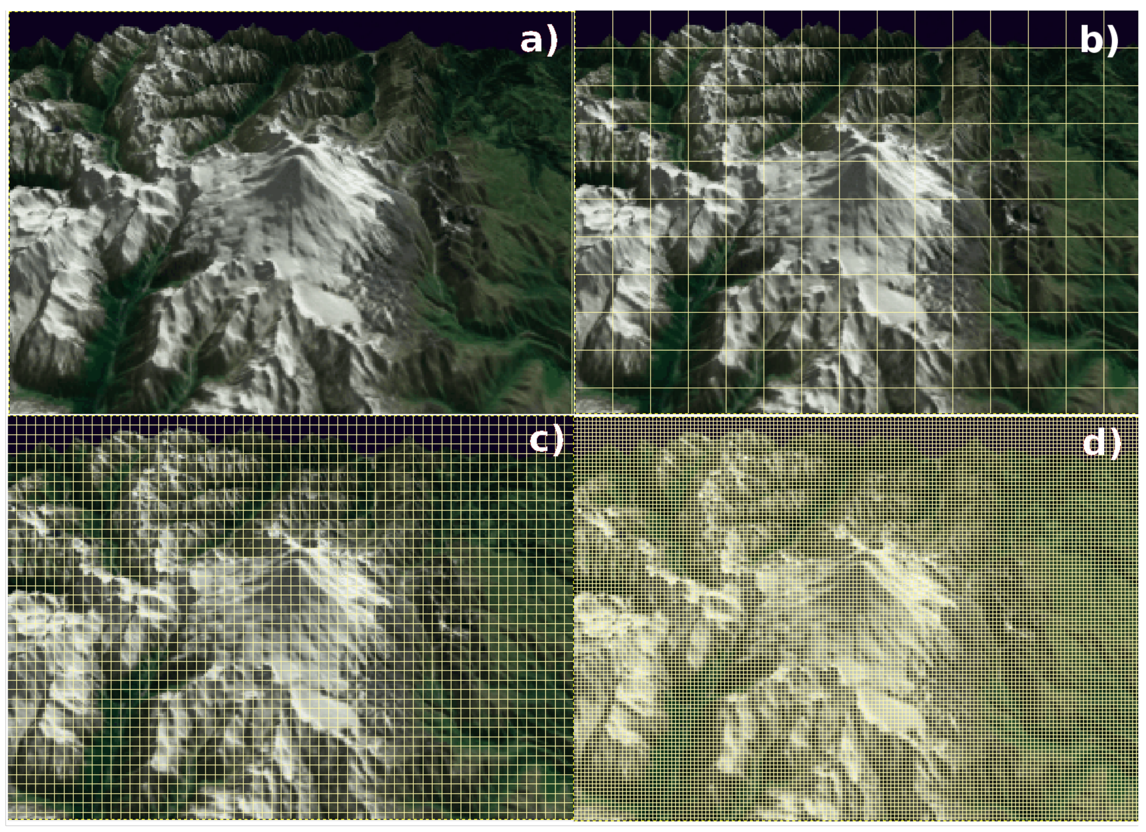


Illustration of different resolution grids laid over the highest peak of Europe Mt. Elbrus (43.355 N, 42.439 E, 5642 m), located on the Caucasian mountains. The picture of approximately 15 km width was picked from Google Earth. Grids shown: a) 15 km, b) 1 km, c) 250 m, d) 100 m. a) would represent a typical resolution of a synoptic scale NWP or model with one gridcell over the area. b) would correspond e.g. GTOPO30, c) and d) would represent e.g. the Global Multi-resolution Terrain Elevation Data 2010 7.5-arc-second and SRTM 3-arc-second resolutions, respectively. GTOPO30, SRTM and GMTED2010 are all used as fine-resolution source data in various NWP models.

Orography-related parameters derived for HARMONIE NWP from fine-resolution surface elevation

parameter	description	unit	usage	remarks
$H_{\Delta x}$	mean surface elevation	m	dynamics	smoothed
σ_{sso}	subgrid-scale standard deviation	m	momentum	
s_{sso}	mean subgrid-scale slope angle	rad	–	eigenvalue of gradient correlation tensor
$h_{m,i}$	slope angle in direction i	rad	radiation	
f_i	fraction of slope in direction i	-	radiation	
$h_{h,i}$	local horizon in direction i	rad	radiation	
δ_{sv}	sky view factor	-	radiation	derived, runtime
δ_{sl}	slope factor	-	radiation	derived, runtime
δ_{sh}	shadow factor	-	radiation	derived, runtime

In this study, these variables were derived from SRTM (Shuttle Radar Topography Mission, Jarvis et al. (2008)) 3" data within the SURFEX Physiography definition (PGD) subroutines. For radiation variables, preprocessing using GDAL (www.gdal.org) software and modification of PGD were needed. In PGD, even more variables are routinely calculated for the orographic momentum flux parametrizations but were not applied here.

Implementing new oroparametrizations to HARMONIE

A parametrization scheme for orographic effects on radiation was introduced to HARMONIE-AROME-SURFEX following Senkova et al. (2007). Slope (δ_{sl}) and shadow (δ_{sh}) factors are applied to modify downwelling direct shortwave radiation flux at the surface level. These factors allow to account for the different slope angles and directions with respect to the current solar position and estimate the relief shadows due to the neighbouring obstacles. Restricted visibility of sky is described by the sky-view factor (δ_{sv}), which is applied to modify the diffuse shortwave and downwelling longwave radiation fluxes.

A simplified version of the HIRLAM smallest-scale orographic turbulence parametrization (Rontu, 2006) was tried in HARMONIE instead of the default application of the concept of orographic roughness. The suggested scheme is another realization of the Wood et al. (2001) idea of handling the non-separated sheltering effect. The surface value of the subgrid-scale orographic stress $\vec{\tau}_{os}$ (horizontal momentum flux in the surface layer given in units of Pa) is related to the subgrid-scale orography variance σ^2_{sso}, multiplied by the turbulent stress $\vec{\tau}_{ts}$

$$\vec{\tau}_{os} = C_o \sigma^2_{sso} \vec{\tau}_{ts}, \qquad (1)$$

where C_o is the subgrid-scale orography drag coefficient and $\vec{\tau}_{ts}$ denotes the turbulent surface stress $\vec{\tau}_{ts}=\rho_s \overline{w' \vec{v}'}$. ρ_s stands for the air density at the surface, overline denotes average over a gridsquare and w' and $\vec{v}'$ are deviations of the vertical and horizontal wind components from the average, respectively.

References

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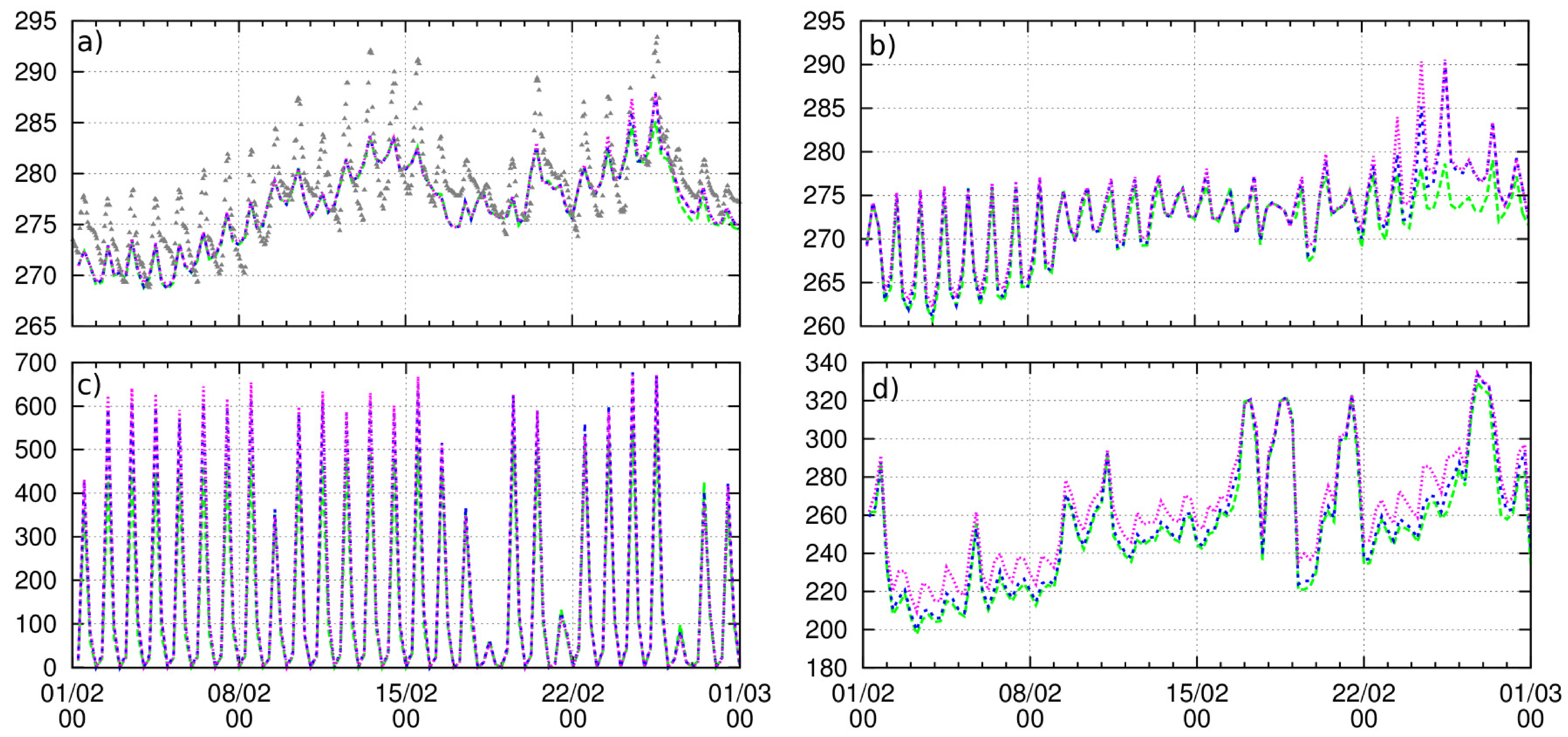
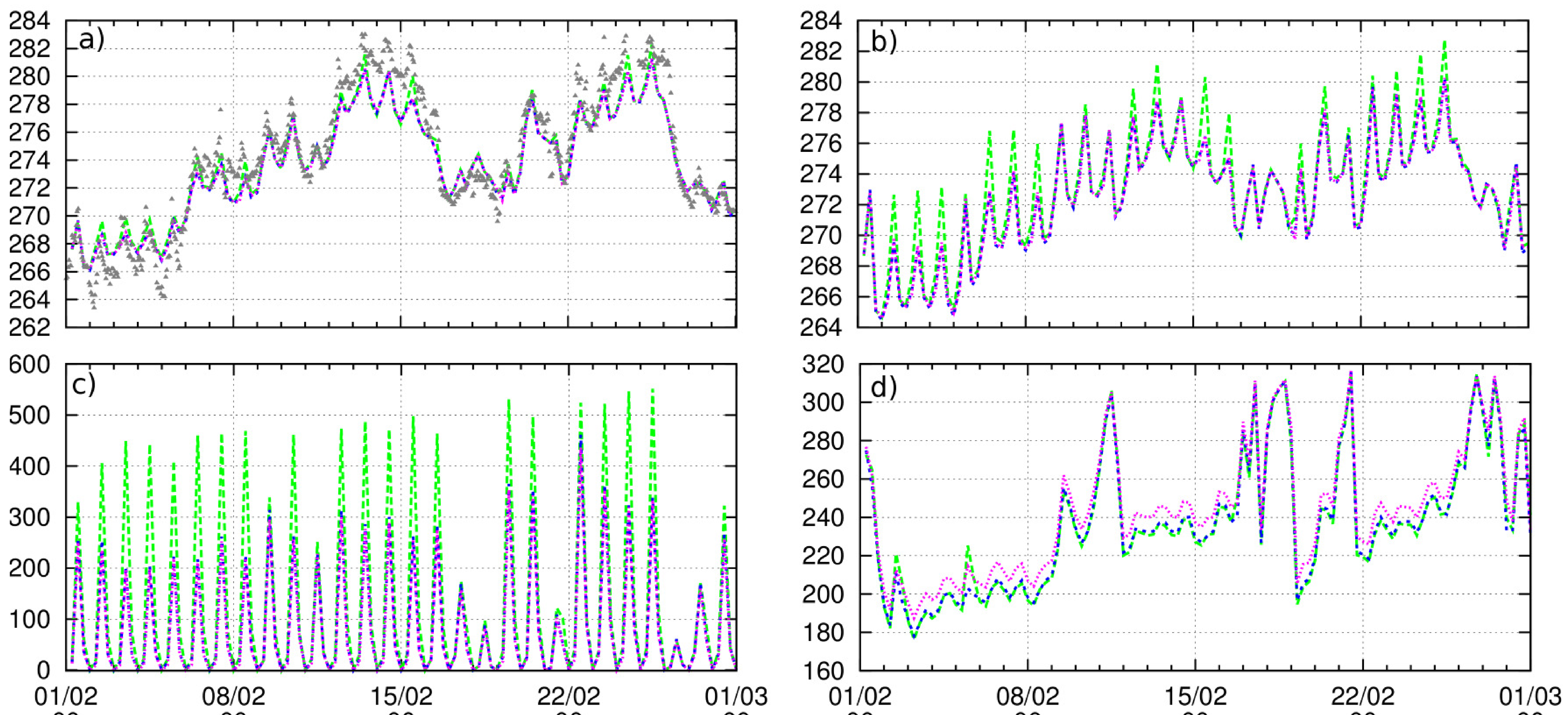
HARMONIE-AROME-SURFEX NWP system

We focus on development and testing of orographic radiation and momentum flux parametrizations in the framework of HIRLAM ALADIN Regional Mesoscale Operational NWP In Europe (HARMONIE) numerical weather prediction (NWP) system (Bénard et al., 2010; Seity et al., 2011). In this model, the surface-related parametrizations and data assimilation are treated by SURFEX (Masson et al., 2013). We implemented new schemes for parametrization of the orographic radiation and momentum fluxes into SURFEX and tested them in full HARMONIE system. The location of the study was choosen over Caucasian mountains near the city of Sochi, Russia, where the 2014 winter Olympic games were held on 8-23 February 2014.

Radiation and temperature results at mountain and valley stations



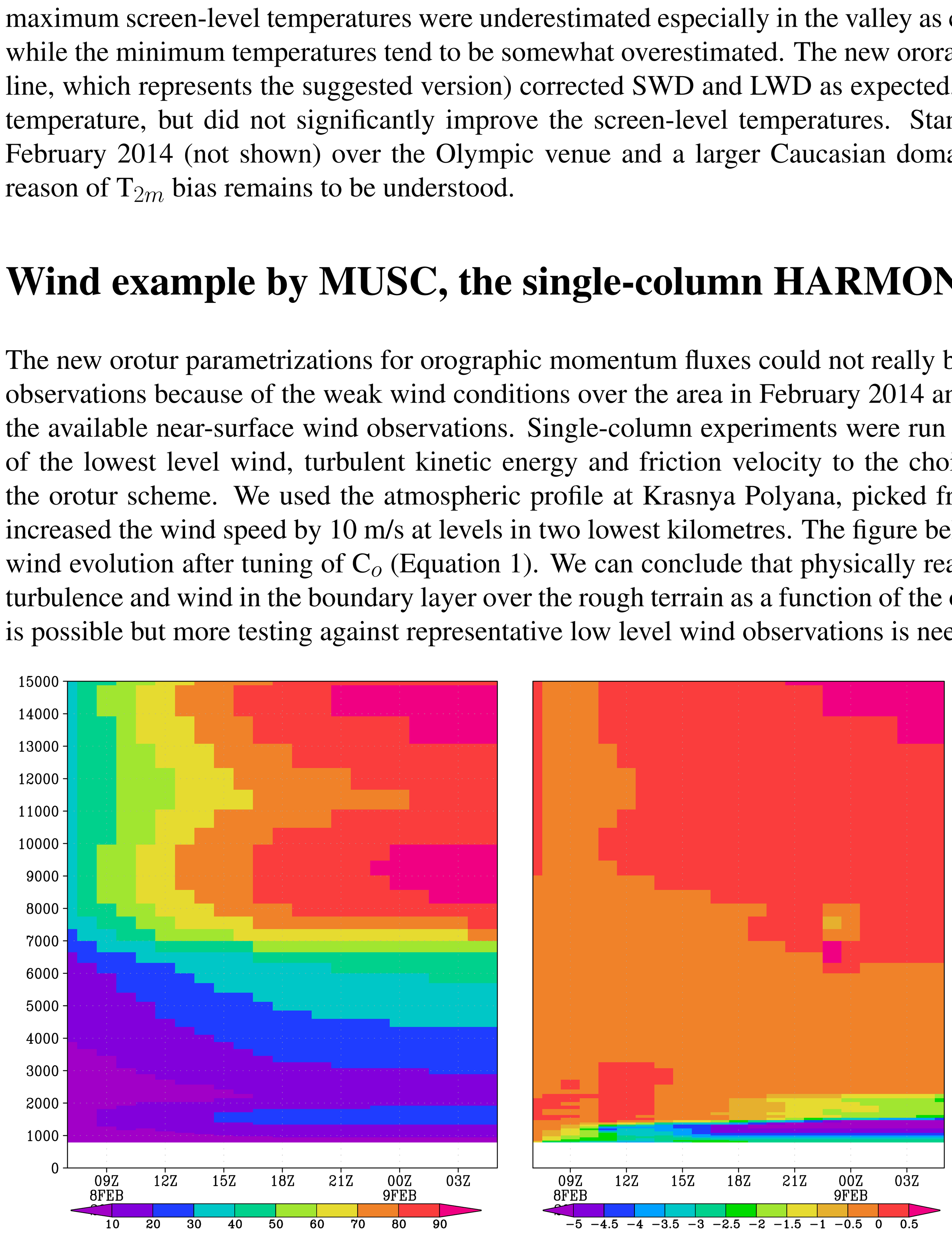
Predicted (a, lines) and hourly observed (a, grey triangles) T_{2m} (unit: K), T_{surf} (b), 6 - hourly average global SWD (c), 6 - hourly average LWD (d) radiation flux (unit: Wm^{-2}) picked from + 6h forecasts. Green: no oroparametrizations; blue: orotur + ororad with large δ_{sv}; magenta: orotur + ororad with reduced δ_{sv}, now suggested for implementation, starting at 00, 06, 12 and 18 UTC in February 2014 at Olympic valley station Krasnya Polyana (above, station marked with 6 in the map) and the mountain station 3 (below).



This example, picked from the full 3D HARMONIE experiments in February 2014, shows that the daytime maximum screen-level temperatures were underestimated especially in the valley as compared to the observations while the minimum temperatures tend to be somewhat overestimated. The new ororad parametrizations (magenta line, which represents the suggested version) corrected SWD and LWD as expected, thus influencing the surface temperature, but did not significantly improve the screen-level temperatures. Standard station verification for February 2014 (not shown) over the Olympic venue and a larger Caucasian domain confirms the result. The reason of T_{2m} bias remains to be understood.

Wind example by MUSC, the single-column HARMONIE

The new orotur parametrizations for orographic momentum fluxes could not really be tested against the Olympic observations because of the weak wind conditions over the area in February 2014 and the unknown properties of the available near-surface wind observations. Single-column experiments were run instead to test the sensitivity of the lowest level wind, turbulent kinetic energy and friction velocity to the choice of tunable parameters of the orotur scheme. We used the atmospheric profile at Krasnya Polyana, picked from the 3D experiments, but increased the wind speed by 10 m/s at levels in two lowest kilometres. The figure below shows an example of the wind evolution after tuning of C_o (Equation 1). We can conclude that physically reasonable tuning the low level turbulence and wind in the boundary layer over the rough terrain as a function of the orography standard deviation is possible but more testing against representative low level wind observations is needed.



Wind speed (m/s) as a function of height (m, y-axis) and time (x-axis) for Krasnya Polyana (station 6 in the map) from MUSC experiments initiated at 06 UTC the 8th of February 2014 with enhanced wind forcing. Values of the enhanced experiment on the left, difference from the reference (no orotur) on the right.

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