Gustiness of the Novorossiysk Bora

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Received July 1, 2013

Abstract—The development of the Novorossiysk bora on February 5–6, 2010 is simulated with high spatial and temporal resolution using the regional model of atmospheric circulation. Considered are typical features of the wind speed and air temperature fields. Singled out are two regimes defining the type of the air flowing around the mountain ridge and the temporal variability (gustiness) of the surface wind speed.

DOI: 10.3103/S1068373913120054

The bora is traditionally defined as a strong, cold, and gusty wind blowing from coastal mountain ridges towards the sea. In the Black Sea basin, such wind is observed in the area of the Crimean Mountains and especially often in the environs of Novorossiysk (46 days per year on average) [2]. As a rule, the strong bora is accompanied by the significant temperature drop (sometimes to –25°C) and the wind speed increase up to 30–35 m/s and more that results in numerous destructions [2].

A distinctive feature of the bora wind is a high spatiotemporal variability associated both with local inhomogeneities of orography and the coastline and with the peculiarities of the way the air flows around the mountains [5, 6]. It is demonstrated in [3] that numerically simulates the bora observed in early February 2012, that the change in the hydrodynamic regime of the air flowing around the mountains from critical to supercritical occurs in the process of the bora development. These two regimes differ principally in characteristics of the wind speed and air temperature fields and especially in the structure of the surface jet stream [7].

In the present paper, the strong Novorossiysk bora observed on February 5–6, 2010 is considered. The WRF-ARW 3.3 regional model of atmospheric circulation with the spatial resolution in the internal domain of 333 × 333 m was used for the numerical modeling. The WRF model is described rather well; therefore, let us enumerate briefly the selected schemes of parameterization of subgrid processes and some other parameters [8].

Thirty seven unevenly located vertical σ-levels with the increased resolution were specified in the planetary boundary layer. To compute the radiation balance of long- and short-wave radiation, the RRTM (Rapid Radiative Transfer Model) and Dudhia’s parameterization schemes, respectively, are used; to compute the cumulus convection in the domains with the resolution of 9 and 3 km, the Kain–Fritsch parameterization is used; in the domain with the resolution of 1 and 0.3 km, the cumulus convection is computed explicitly and parameterization is not applied. To describe phase transitions in the atmosphere (microphysical processes), the Single-Moment 3-class scheme is used, and the MM5 similarity scheme is used for the parameterization of the surface boundary friction layer. The planetary boundary layer is parameterized using the 2.5-level Mellor–Yamada–Janjic scheme, where the kinetic energy of turbulence is one of the prognostic variables [8].

The data of FNL (Global Final Analysis) operational analysis with the resolution of 0.5° × 0.5° being updated every six hours were used as the input data for the external domain. After the adaptation of the model to the specified initial conditions, the development of atmospheric processes in all four domains was defined only by the periodically updating boundary conditions in the external domain.

The discreteness of model computations is ~60 s, and the output data were saved with the discreteness of 10 minutes. The horizontal step of the grid Δx = 0.3 km enabled to resolve efficiently the spatial inhomogeneities with the size of 7 × Δx ~ 2 km [8]. The SRTM terrain database with the discreteness of 3" (about 90 m) is used, where significant altitude drops are observed at some points on steep mountain slopes.
Therefore, a smoothing procedure was applied in the vicinity of such points in order to provide the stability of WRF numerical scheme in $\sigma$-coordinates. Besides, the database on the soil characteristics with the lower spatial resolution is interpolated to the points of the internal domain with the correct taking account of the coastline.

Figure 1 demonstrates computed fields of the wind speed at the height of 10 m referred to two time moments: 12:00 UTC on February 5, 2010, when the bora did not reach the maximum development stage, and 06:30 UTC on February 6, 2010 for the stage of the most developed bora (hereinafter, the Coordinated Universal Time is given in the text and figures). A significant difference should be noted between the wind speed fields for these two time moments. In the first case, the wind speed is maximal in the southern part of the Tsemes Bay area as well as in the north-western and south-eastern coastal part of the land area. The wind speed is insignificant over the lee slope of the mountain ridge. In the second case, on the contrary, the maximum wind speed (up to 30 m/s) is registered on the lee slope of the ridge and in the whole area of the