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Analysis of Temperature Distributions in Nighttime Inversions

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Adequate prediction of temperature inversion in the atmospheric boundary layer is one of prerequisites for successful forecasting of meteorological parameters and severe weather events. Examples include surface air temperature and precipitation forecasting as well as prediction of fog, frosts and smog with hazardous levels of atmospheric pollution. At the same time, reliable forecasting of temperature inversions remains an unsolved problem.

For prediction of nighttime inversions over some specific territory, it is important to study characteristic features of local circulation cells formation and to properly take local factors into account to develop custom modeling techniques for operational use.

The present study aims to investigate and analyze vertical temperature distributions in tropospheric inversions (isotherms) over the territory of Belarus. We study several specific cases of formation, evolution and decay of deep nighttime temperature inversions in Belarus by means of mesoscale numerical simulations with WRF model, considering basic mechanisms of isothermal and inverse temperature layers formation in the troposphere and impact of these layers on local circulation cells. Our primary goal is to assess the feasibility of advance prediction of inversions formation with WRF.

Modeling results reveal that all cases under consideration have characteristic features of radiative inversions (e.g., their formation times, development phases, inversion intensities, etc). Regions of “blocking” layers formation are extensive and often spread over the entire territory of Belarus. Inversions decay starts from the lowermost (near surface) layer (altitudes of 5 to 50 m). In all cases, one can observe formation of temperature gradients that substantially differ from the basic inversion gradient, i.e. the layer splits into smaller layers, each having a different temperature stratification (isothermal, adiabatic, etc). As opposed to various empirical techniques as well as theoretical approaches based on discriminant analysis, mesoscale modeling with WRF provides fairly successful forecasts of formation times and regions for all types of temperature inversions up to 3 days in advance.

Furthermore, we conclude that without proper adjustment for the presence of thin isothermal layers (adiabatic and/or inversion layers), temperature data can affect results of statistical climate studies. Provided there are regions where a long-term, constant inversion is present (e.g., Antarctica or regions with continental climate), these data can contribute an uncompensated systematic error of 2 to 10º C. We argue that this very fact may lead to inconsistencies in long-term temperature data interpretations (e.g., conclusions ranging from “global warming” to “global cooling” based on temperature observations for the same region and time period).

Due to the importance of this problem from the scientific as well as practical point of view, our plans for further studies include analysis of autumn and wintertime inversions and convective inversions. At the same time, it seems promising to develop an algorithm of automatic recognition of temperature inversions based on a combination of WRF modeling results, surface and satellite observations.