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A case study on wintertime inversions in Interior Alaska with WRF

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ABSTRACT

The Weather Research and Forecasting (WRF) model is run in various configurations for a five day cold weather period with multi-day inversions over Interior Alaska. Comparison of the simulations with radiosonde data and surface observations shows that WRF's performance for these inversions strongly depends on the physical packages chosen. Simulated near-surface air temperatures as well as dew-point temperatures differ about 4 K on average depending on the physical packages used. All simulations have difficulties in capturing the full strength of the surface temperature inversion and in simulating strong variations of dew-point temperature profiles. The greatest discrepancies between simulated and observed vertical profiles of temperature and dew-point temperature occur around the levels of great wind shear. Out of the configurations tested the radiation schemes of the Community Atmosphere Model combined with the Rapid Update Cycle land surface model and modified versions of the Medium Range Forecast model's surface layer and atmospheric boundary layer schemes capture the inversion situation best most of the time.

1. Introduction

Interior Alaska (Fig. 1) is particularly susceptible to prolonged temperature inversions (hereafter called inversions) during winter. In the south and north, Interior Alaska experiences less than 3 h to 0 h of solar radiation in December with a slight increase in January. Snow fall often beginning in the 2nd half of September generates a snow cover that persists from the midst of October to the midst of April. Thus, the radiation flux balance is mainly negative and leads to the formation of near-surface inversions. In addition, calm winds accompanied by less shear production of turbulent kinetic energy (TKE) often prevail over Interior Alaska. Under such weather conditions, the stratification of the atmospheric layers in the vicinity of the earth's surface becomes extremely stable. Such weather situations typically lead to huge air quality problems. Air layers close to the ground are strongly polluted by gaseous and particulate matter (PM) released by the combustion of huge amounts of fossil fuel for heating and electricity production and of gasoline in the engines of cars required to safe life under extremely low air temperatures. Long-lasting inversions cap these air layers and strongly hinder the export of polluted air into unpolluted air layers aloft especially during the occurrence of calm winds. The emitted PM and gaseous compounds like carbon monoxide, sulfur dioxide, and nitrogen oxides accumulate under such extremely stable conditions and lead to frequent violations of Environmental Protection Agency (EPA) regulations in Fairbanks, the only city in Interior Alaska.

Since in Interior Alaska, inversion events result in serious air pollution problems during winter, it is important to forecast such inversion events with a sufficient degree of accuracy to get a reliable basis for warning the public to achieve a common behavior that prevents a further increase of air pollution. Therefore, we apply the Weather Research and Forecasting model (WRF; Skamarock et al., 2008) for a multi-day inversion event beginning in the 2nd half of January 2008 to examine WRF's feasibility to forecast and its performance in forecasting such events. Our model experiments apply alternatively two different model setups that have been chosen because of their ability to describe snow and permafrost as well as mixed phase cloud

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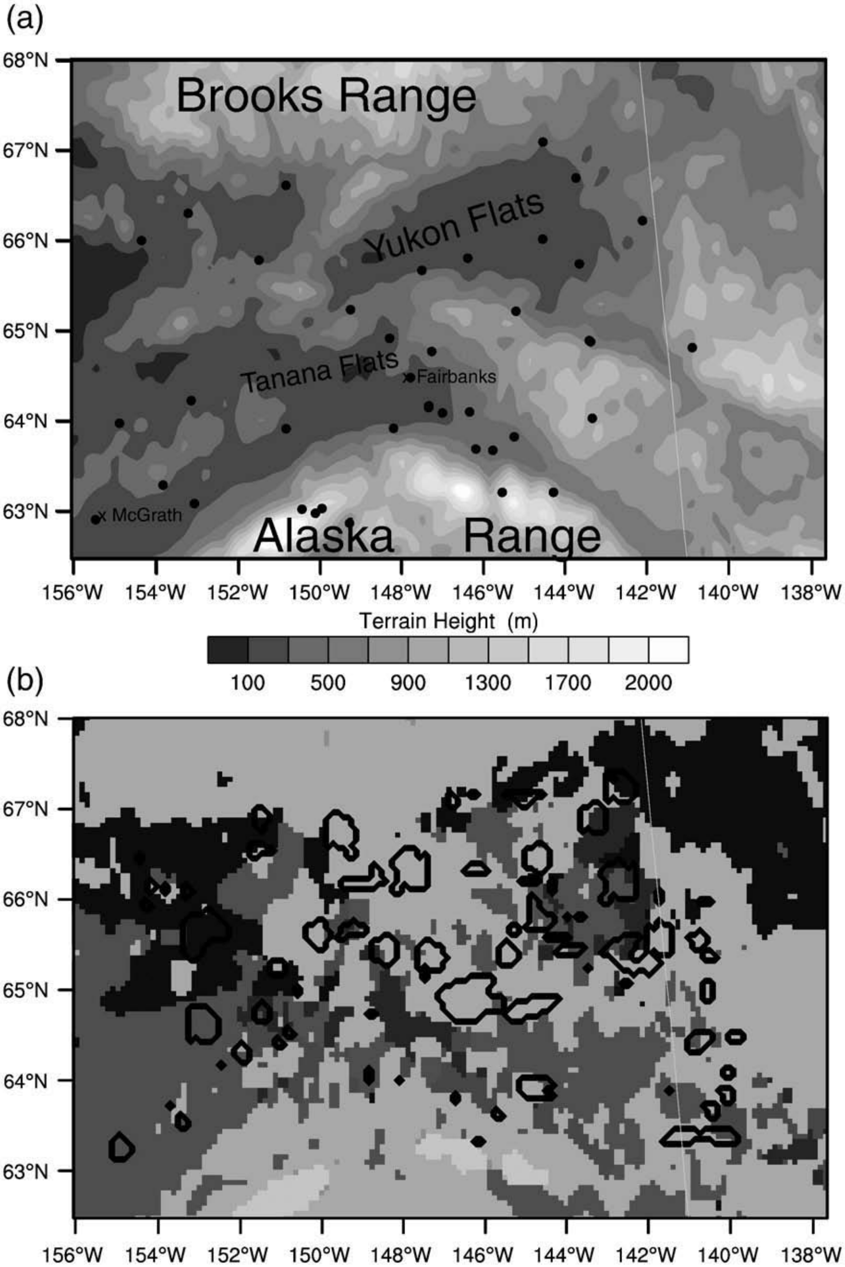

Fig. 1. Model domain used in this study. (a) Gray shades and contour lines give the terrain elevation as considered in WRF. Dots and crosses indicate the locations of surface observation sites and the radiosonde sites. (b) Land-use as assumed in the simulations except for the sensitivity studies on land-use. The latter assuming young fire scars in the areas indicated by the contour lines. Land-use from dark to light urban, grassland, shrubland, deciduous broadleaf and needleleaf forest, evergreen broadleaf and needleleaf forest, mixed forest, herbaceous and wooded wetland, barren or sparsely vegetated land, herbaceous, wooded, and mixed tundra. Interior Alaska encompasses the Yukon Flats, the Fairbanks area and Tanana Flats and the mountain range that connects these areas.

microphysical processes. Furthermore, various sensitivity studies are performed to further assess discrepancies between simulated and observed conditions. Simulation results are evaluated using the data of radiosonde and near-surface observations.

2. Case description and observational data

For our simulations, we consider the period January 27 0000UTC [January 26 1500 Alaska Standard Time (AST)] to February 2 0000 UTC [January 31 1500 AST].

2.1. Synoptic situation

At the beginning of the episode strong wind shear existed between the lower and mid-troposphere. From the surface to about 500 hPa the wind changed its direction by about 180°. On January 27, 2008 a cloud system moved into Alaska from southwest and covered western Alaska by the end of the day. Western Alaska remained cloudy for the next 2 days with some traces of snow in the southwestern part, still covered by the model domain, and western Alaska Range. On January 30,