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Dispersion conditions in complex terrain - a case study of the January 2010 air pollution episode in Norway

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A period with poor dispersion conditions was responsible for high NO_2 concentrations in Norway, cities of Bergen and Oslo in first two weeks of January 2010. The meteorological conditions during these episodes are studied by standard meteorological observations, supplementary elevated temperature observations and the met.no operational NWP simulations with the UK Met Office Unified Model (UM) for air quality forecasting in Bergen and Oslo. The episode in Oslo is also simulated with an experimental high resolution version of UM (0.333 km).
Due to lack of radio soundings the inversion is diagnosed from surface observations at sites with different elevations, and from temperature observations in 2, 8, 10, 25 and 40 meter above ground in the cities. The observations indicate that the episodes are characterized by both a near surface inversion limited to 8 - 10 meters above ground level during the whole period and a deep inversion of a few hundred meters during the last 5 days. The pollution level increases, also during night time, when the inversion extends to higher levels.
The operational model reproduces both the near surface and the deep inversion. Moreover it maintains the inversion over several days from one run through the next with subsequent data assimilation and forecasting. The confidence in the realism of the simulated inversion build up is due the link to the observed atmosphere through the data assimilation.
Both cities are located in topographic basins surrounded by hills and mountains. Temperature isolines following the surface along the slopes from elevated areas are signals that the drainage flow is simulated with the model. When the surface layer is cooled in its full depth, it will experience a higher density than the air in the free atmosphere at the same level, and flow along the surface down to lower elevations. Moreover the near surface air at the elevated stations is continuously replaced by the air from the free atmosphere thus representing the temperature of the free atmosphere.
There is a large scale northerly flow over Eastern Norway during the episode due to the location of the high pressure center over Western Norway, Bergen. The orographic influence leaves the western part of Oslo in the lee of the hills to the north while the wind turns easterly in the valley east of the city. In the experiments with very high model resolution, the local circulation is clearly improved as compared to observations, most likely due to resolved orographic roughness.
The model resolution is to low to capture the main features of the orography in Bergen which are more small scale than in Oslo. There are also less observations. However the calculated two dimensional trajectories in lowest model level are kept well within the limited area of Bergen. The northerly winds in the fjord act as a wall against the outflow from Bergen city, and the vertical flow is effectively prevented by the inversion. This success in simulating the local wind is probably due to the large scale forcing.