Representation of Mixing Height Climatology over Europe and US in ERA-Interim

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Motivation:

Understanding and predicting weather, climate, and air quality depend on reasonably accurate characterization of vertical exchange of heat, moisture, trace gases, aerosols, and air pollutants between the surface and the free atmosphere through the planetary boundary layer. The convective and turbulent processes controlling mixing are complex, non-linear, and chaotic, and they vary on a wide range of space and time scales. A common characterization of these processes employs the concept of mixing height (MH), loosely interpreted as the height of a layer within which a substance will be fully mixed, given a particular set of atmospheric and surface conditions and given sufficient time for the mixing to occur. Because reanalysis MH information is used for practical problems such as development of air pollution control policies and evaluation of carbon dioxide sources and sinks, it is important to evaluate (and if necessary improve) the reliability of the representation of MH in reanalyses.

Methods:

As a first attempt to evaluate reanalysis MH information, we compared MH from the ECMWF Reanalysis Interim (ERA-Interim) product with MH derived from radiosonde observations over the continental U.S. (~25-50°N, 65-125°W) and Europe (including portions of North Africa and the Mediterranean ~35-60°N, 10°W-30°E). After an evaluation of numerous methods of calculating MH, we used a bulk Richardson (Ri) number formulation, which involves computing the vertical profile of Ri from virtual potential temperature and wind profiles. The MH is located at the first level above the surface at which Ri reaches the threshold value of 0.25.

These calculations were made using radiosonde and ERA-Interim daily data for the period 1981-2005. In ERA-Interim, the boundary layer is fairly well resolved with the lowest model levels at about 10, 30, 60, 100, 160, 240 m above the model surface. The level spacing increases gradually with height with a vertical resolution of about 200 m at 900 hPa and 500 m at 500 hPa. ERA-Interim data products, initially available publically at a more limited set of pressure levels at a lower horizontal resolution of 1.5 degrees, include boundary layer height estimates. However, we do not employ those estimates because they are computed using an algorithm that is not applicable to radiosonde data because turbulence parameters are required. For consistency, and to take advantage of the full resolution of ERA-Interim, the model level data were re-processed at the original resolution with the same algorithm that is applied to the radiosonde data.

Radiosonde data, from the NOAA National Climatic Data Center's Integrated Global Radiosonde Archive, are from 69 U.S. and 53 European stations that met the following sampling requirements: at least 300 soundings per season during 1981-2005, with at least 7 reported data levels between the surface and 500 hPa. Soundings from low-elevation (< 500 m) stations typically had 10 to 30 lower-tropospheric data levels.

Climatological MH statistics were computed for annual and seasonal conditions at each station or grid, separately for 0000 and 1200 UTC. Comparisons of ERA-Interim and radiosonde results were made to identify biases and patterns of spatial and temporal co-variability.

Results:

Our main findings are:

1. Several factors contribute to uncertainties in MH estimated using the bulk Richardson number method. Overall relative uncertainty can exceed 50 % for MH < 1 km, but is generally < 20 % for MH > 1 km.

2. Climatological MHs are generally < 1 km during daytime and < 0.5 km at night over both Europe and the U.S.

3. During daytime, summertime MHs are deeper than in wintertime, but at night winter MHs exceed summer values.

4. ERA-Interim MH tends to underestimate MH observed by radiosondes and show a smaller range of values, despite assimilation of radiosonde data.

5. The ERA-Interim MH product shows higher MH, especially over high elevation regions, than the algorithm used in this study. The difference is larger over ocean than over land. Differences are < 100 at night and several 100 m during daytime.

6. ERA-Interim provides MH over ocean areas not sampled by radiosondes. Oceanic MH shows much smaller seasonal and diurnal variability than over land.

7. Spatial correlations between radiosonde and ERA-Interim values of annual median MH are 0.85 over the U.S. and 0.56 over Europe for daytime observations, and 0.75 over the U.S. and 0.82 over Europe for nighttime observations.

Plans:

We intend to conduct similar comparisons with MH calculations from several other reanalyses in advance of the Conference and to present those results in addition the ERA-Interim results discussed above.

We also examined MH climatology in two contemporary free-running climate models; those results will not be presented at this conference. The climatological MH datasets developed for this study will be made available to interested researchers for evaluation of MH representations in other reanalyses and climate, air quality and weather forecasting models.

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