Statistical downscaling of wind speed time series data based on topographic variables

Wenxuan Hu, Yvonne Scholz, Madhura Yeligeti, Lüder von Bremen, and Marion Schroedter-Homscheidt
German Aerospace Center, Energy Systems Analysis, Köln, Germany (wenxuan.hu@dlr.de)

Renewable energy sources such as wind energy play a crucial role in most climate change mitigation scenarios because of their ability to significantly reduce energy-related carbon emissions. In order to understand and design future energy systems, detailed modeling of renewable energy sources is important. In the light of making energy system modelling possible at all variability scales of local weather conditions, renewable energy source information with high resolution in both space and time are required.

Nowadays, renewable energy resources data that are widely used among the energy modeling community are reanalysis data such as ERA5, COSMO REA6, and MERRA2. Taking wind speed as an example, reanalysis data can provide long term spatially resolved wind information on any desired height in a physically consistent way. However, their spatial resolution is coarse. In order to obtain a fine spatial resolution data focusing on wind speed, this paper proposes a statistical downscaling method based on reanalysis data, observation data, and the local topography.

While most statistical wind downscaling studies have focused on obtaining site specific data or downscaling probability density functions, this paper focuses on downscaling one-year hourly wind speed time series for Europe to 0.00833 degree X 0.00833 degree (approximately 1km X 1km) resolution. It has been proven by various studies that the local topography influences wind speed. The topographic structure in this study is determined by two metrics: TPI, a topographic position index that compares the elevation of each cell to the mean elevation of the neighborhood areas and Sx, a slope-based, direction-dependent parameter that describes the topography in the upwind direction. The observation data used in this study are MeteoSwiss measurement values which provide the hourly wind speed time series at the station heights. For each weather station with observation data, biases described by the local terrain features are introduced to minimize the root mean square error (RMS) and Kolmogorov-Smirnov D (KSD) statistic between the corrected and the observed wind speed. These biases are then assigned to grid points with the same terrain types as the weather station, which enables downscaling of the wind speed for whole Europe.

The results show that this downscaling method can improve the RMS and KSD for both ERA5 and COSMO REA6, especially at mountain ridges, which indicates that it can not only decrease the bias, but also provide a better match to the observed wind speed distributions.