2.4 WRF-Solar: Improvements to WRF for real-time solar energy forecasting applications and its evaluation

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WRF-Solar is a new version of the Weather Research and Forecasting (WRF) model that is augmented with new capabilities aimed at improving model components central to solar power forecasting (i.e. the aerosol-cloud-radiation system) and providing relevant solar parameters to enable better integration of solar power. Model developments use efficient numerical approaches to support operational forecasting and focus on four primary areas:

1) Developments to internally diagnose relevant atmospheric parameters required by the solar industry such as direct normal irradiance and diffuse irradiance, as well as high-frequency outputs of the irradiance limited only by the model time step.

2) Improved representation of the aerosol direct effect (aerosol-radiation feedback).

3) Incorporation of the aerosol indirect effects (cloud-aerosol interactions). The Thompson microphysics parameterization has been upgraded to include ambient water- and ice-nucleation aerosols.

4) Improved cloud-radiation feedback. A shallow cumulus parameterization was added to connect sub-grid fractional clouds to radiation schemes. In addition, the Thompson microphysics parameterization now provides the cloud droplet radius and ice crystal size to the RRTMG shortwave parameterization ensuring consistency between cloud particles and radiation.

Details of the upgraded model physics will be presented. An evaluation of the model performance under clear skies, and an assessment of the benefits of including the representation of the effects of unresolved clouds in the shortwave irradiance show the benefits of the upgrades. In a clear-sky assessment, the WRF-Solar simulations were compared against observations of the shortwave radiation components over the contiguous US (CONUS). Different representations of the atmospheric aerosols, including both a model-derived climatology of aerosol optical depth and temporally evolving aerosol optical properties from re-analysis products were examined. Models that explicitly solve atmospheric chemistry equations, and are initialized with an aerosol data assimilation process (i.e. GEOS-5) appear the most useful for clear-sky solar irradiance forecasting. Improvements of up to 58%, 76%, and 83% were found in global horizontal irradiance, direct normal irradiance, and diffuse irradiance, respectively, compared to a standard version of the WRF model. The effects of the unresolved clouds were analyzed using a set of WRF-Solar experiments with different representation of the sub-grid scale clouds. Given the high spatio-temporal variability of the clouds, each experiment consists of a 10 member WRF-Solar ensemble run at 9 km of horizontal resolution over the CONUS and using the Stochastic Kinetic-Energy Backscatter Scheme (SKEBS) in order to have a more statistically robust verification. The experiments span the year of 2014. Including the effects of the unresolved clouds reduced a positive bias (~ 50 W/m2) in the surface shortwave irradiance. The shallow cumulus feedbacks to radiation are responsible for the largest bias reduction.