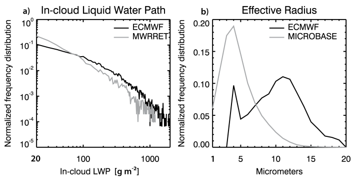
ARM Observations Guide Low-Cloud Parameterization Development in the ECMWF Model

Research Highlight

The long-term measurement records from the Atmospheric Radiation Measurement site on the Southern Great Plains (SGP) show evidence of a surface irradiance bias in the global Numerical Weather Prediction model from the European Centre for Medium-range Weather Forecasts (ECMWF). This has been a long-standing problem in the model and previous studies have suggested that low clouds may contribute. In order to guide improvements to the model's cloud and radiation parametrizations, the origin of the bias is explored for different cloud regimes in order to highlight the particular cloud processes that are contributing to the error. Observed and modeled cloud fraction profiles over six years at the SGP site are classified and sorted based on the surface irradiance bias associated with each sample pair.

By breaking down the components of the surface irradiance bias by cloud regime, a number of partially compensating errors are uncovered. The cloud radiative forcing of shallow cumulus cloud is found to be overestimated, but the radiative bias is compensated by too little occurrence of this regime. In contrast, overcast low-cloud conditions underestimate the cloud radiative forcing and are identified as a major contributor to the overall surface irradiance bias. These opposing surface irradiance biases for broken and overcast cloud cover conditions are at least partially explained by an overestimate and underestimate of liquid water path respectively. To improve agreement with the observed liquid water path distribution would require a reduction of cloud liquid to a third for broken low clouds and an increase by a factor of 1.5 in overcast situations. The model also overestimates the effective radius for all cloud, but this effect is secondary to the error in cloud liquid water.

The opposing biases produced by broken and overcast low-cloud samples explain why recent changes and qualitative improvements to the ECMWF's shallow convection scheme were not reflected in the surface shortwave radiation fields: reducing the bias for broken cloud conditions addresses only part of the problem. Unless the bias observed during overcast conditions is addressed at the same time, the lack of compensation will lead to an overall increase in the radiation bias. Future developments to the shallow convection, boundary layer, and cloud microphysics parameterizations will target a reduction in the shortwave cloud forcing and liquid water path for shallow convective clouds over land while at the same time increase cloud cover and liquid water path for overcast stratiform cloud. The combination of a simple cloud classification using ARM cloud and radiation observations with the ECMWF model surface irradiance bias has proved to be a valuable tool for model assessment to discover compensating errors and is a necessary step to guide future parameterization improvements.



Left: Normalized frequency distribution of (grey) observed and (black) modeled in-cloud liquid water path for 146 fair-weather cumulus days at ARM SGP. Right: Normalized frequency distribution of (grey) observed and (black) modeled liquid effective radius for fair-weather cumulus days.

Reference(s)

Ahlgrimm M and R Forbes. 2012. "The impact of low clouds on surface shortwave radiation in the ECMWF model." Monthly Weather Review, , . ACCEPTED.

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Cloud Life Cycle