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# The Diurnal Cycle of Precipitation: A Comparison of State-of-the-Art IMERG Observations, CMIP6 Models and ERA5 Reanalysis

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Simulations of the diurnal cycle of precipitation from CMIP6 models and the ERA5 reanalysis are evaluated against the observed diurnal cycle from NASA's IMERG observations. The IMERG observation product, which combines the GPM/TRMM microwave constellation, spaceborne infrared sensors and ground-based gauge measurements, provides 20+ years of gridded global precipitation estimates at 0.1˚ every half hour. Using IMERG's long precipitation record, the first multi-decade evaluation of the simulated diurnal cycle is conducted (IMERG and ERA5: 2000-2019; CMIP6: 1979-2008). After spatial and temporal matching of IMERG to the hourly CMIP6 (NCAR-CESM2, CNRM-CM6-1, CNRM-ESM2-1) and ERA5 simulations, the diurnal cycle for boreal summer is compared between products across the globe (60˚N-S). To avoid bias in the results, regions with yearly mean precipitation < 100 mm are excluded from all analyses, as well as regions with weak diurnal amplitudes when analysing the time of maximum precipitation. CMIP6 and ERA5 simulations underestimate the observed diurnal amplitude over ocean (14-66% of the precipitation mean, for the $5^{th}$-$95^{th}$ percentile range), with varying performance over land (26-134%). Maximum precipitation is observed to accumulate over land in the afternoon and at night (14-21 LST over flatter terrain, and 21-6 LST over mountainous regions), and in the morning over ocean (0-12 LST). CMIP6 and ERA5 are identified to better simulate the time of maximum over ocean than over land, though typically earlier in the day than observed. In particular, ERA5 and CMIP6 fail to capture the propagating night-time peaks in precipitation accumulation close to mountainous regions. Further analyses over CONUS, which include the ground-based radar network, highlight the improved performance of models in regions susceptible to convection (e.g. the Rocky Mountains). Furthermore, IMERG's skill in capturing the diurnal cycle over CONUS is demonstrated, and the current capability of the GPM Core Observatory's dual-frequency precipitation radar is assessed.