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Spatial scales of internal variability of annual mean all-sky and clear-sky surface solar radiation: quantitative estimates using CMIP6

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Internal variability, a natural source of uncertainty in climate projections, is important when one wants to distinguish between the forced signal and the random noise in the climate system. The downwelling surface solar radiation, a key climate variable, has been shown to exhibit unforced trends (i.e. trends exclusively due to internal variability) even on decadal timescales. These long-term unforced trends interfere with the forced signal and contribute to the decadal variations of SSR, known as global dimming and brightening. A common technique in observation analysis, which serves to reduce the contribution of internal variability and therefore give a better estimate of the forced signal, is the use of composite time series of multiple locations (averaging in space). We use annual mean data of 49 models from the pre-industrial control experiment of the Coupled Model Intercomparison Project – Phase 6 (CMIP6) to give a quantitative estimate of how much the system noise is reduced upon spatial averaging. We find that globally the standard deviation σ (which is proportional to the magnitudes of random trends) is reduced almost linearly with the horizontal grid increment Δx in the range 2 – 15 degrees. On coarser resolutions, deviations from a linear fit are observed, possibly because the patterns of ocean oscillations are not concentrated in compact forms in space. Comparing the rate of reduction of the noise with grid resolution ($d\sigma/d\Delta x$), we find that the noise in all-sky SSR is averaged out ~10 times faster (with increasing Δx) than the noise in clear-sky SSR. Numerical values estimated from the CMIP6 multi-model median and uncertainties estimated from the inter-model spread are $d\sigma/d\Delta x = -0.11 \pm 0.03$ Wm^{-2}/deg for all-sky SSR and $d\sigma/d\Delta x = -0.01 \pm 0.004$ Wm^{-2}/deg for clear-sky SSR. The all-sky SSR global mean σ for a 0.5 deg grid is 4.79Wm^{-2}, while for clear-sky it is 0.66 Wm^{-2}. Furthermore, $d\sigma/d\Delta x$ is strongly dependent on the geographical location, being more than twice as large in China, compared to Europe for both all-sky and clear-sky SSR.