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Scale-dependent Temporal Variability of the Clear-Sky Index and its Relevance for Solar Radiation Forecasts

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Solar radiation forecasting is essential for the efficient operation of solar energy plants. Accurate forecasting models can help optimize solar energy use, reduce costs, and minimize environmental impacts. The clear-sky index (CSI) is a common parameter used in forecasting models to estimate the amount of solar radiation reaching the Earth's surface. CSI is the ratio between surface solar radiation (SSR) and surface solar radiation in a clear sky situation (SSR_{cs}). The temporal variability of CSI is scale-dependent, meaning that the evolution of CSI is less predictable at smaller spatial scales than at larger scales. This variability can strongly impact the accuracy and quality of solar radiation forecasts.

Our study aims to investigate the temporal variability of CSI at different spatial scales (from 0.02˚ to 2˚) and its possible application to SSR forecasting models. The study uses cloudiness maps estimated from Meteosat SEVIRI Level 1.5 data by the HelioMont algorithm (Castelli et al., 2014) with a spatial resolution of 0.02˚ and a temporal resolution of 15 minutes over Switzerland. To quantify the temporal variability of CSI as a function of spatial scale, we draw on methods used by Venugopal et al., 1999 and Pulkkinen et al., 2019 for precipitation analysis.

We show that the temporal variability of CSI is indeed scale-dependent, with smaller spatial scales (down to ~0.02˚) exhibiting higher temporal variability than larger scales (up to ~2˚). We also show that Fourier decomposing the CSI field in space can help to track the different temporal evolutions for the different spatial scales. This finding is particularly important for the development of more accurate forecasting models, as it suggests that different models (or at least scale-dependent parameter values) may be required for different spatial scales.

In conclusion, this study provides valuable insights into the temporal variability of CSI at different spatial scales providing experimental correlation between the spatial scale and the variability of CSI's temporal evolution. The findings of this study have important implications for the development of more accurate forecasting models, which can ultimately contribute to the increased use of solar energy sources.