Capturing boundary layer cloud variability using regularized self-supervision for short-term solar energy applications

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Boundary layer clouds have a strong influence on solar radiation and introduce high variability, which poses a major challenge for short-term solar energy (STSE) power production. The resolution of present-day satellite observations cannot fully resolve the spatio-temporal dimensions of these clouds, which are often organized into larger cloud systems (structure and distribution). Therefore the inherent uncertainty in observation-based analysis approaches is often attributed to the limitation of coarse satellite resolution. The increase in spatio-temporal resolution in Earth observations offered by next-generation satellites such as Meteosat Third Generation (MTG) promises to better capture the high variability of boundary layer clouds. It also challenges us to investigate the strong fluctuations or ramps in STSE production and its association with cloud system temporal variability.

In this work, we build on Chatterjee et al., 2023 (submitted to the journal AI4ES), where a self-supervised neural network has been developed and used to identify distinct cloud systems over central Europe in support of their physical interpretation. The reason behind using self-supervision is that we want the network to evolve its understanding, which fully captures the complex relations in cloud systems without human interference. Using an enhanced cloud optical depth (COD) product at a resolution of 2 x 1 km^2 and 5 minutes, the network has learned the representation of cloud systems and identified the distinct spatial pattern and distribution of cloud systems over central Europe. Here we extend the capacity of the trained neural network to exploit its usage for STSE power production.

We use the transfer learning capacity of the trained network (trained with random crops all over central Europe) over ground-based measurements at the supersite JOYCE in Juelich, Germany, and extend results to wider Germany using a ceilometer network (SYNOP stations). We study the persistency and transition of cloud systems from one class to the next as identified by the network. With the given 5-minute temporal resolution of satellite observations, we first establish the variability in power production for different classes. We also evaluate how the neighboring tiles' cloud systems influence the probability of state transitions. Ultimately our goal is to exploit the structural information of cloud systems for short-term solar energy nowcasting.