<u>**Title:**</u> **Self-supervised cloud classification using infrared imagery to character extreme precipitation events over the Alps**

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<u>Abstract</u>:

Climate change is intensifying and increasing the frequency of storms in the Alpine region. However, accurately capturing these events remains a challenge for current weather models due to the complexity of atmospheric processes over mountainous terrain. Realistic rainfall predictions require precise cloud representation, especially for deep convective systems that cause extreme precipitation.

We present a framework for classifying cloud structures observed by the Meteosat Second Generation (MSG) geostationary satellite. Leveraging its good spatio-temporal resolution and extensive historical data, our approach exploits 10.8 µm infrared channel alone and in combination with the 6.2 µm water vapor channel. This synergy enables a better representation of diurnal cycles and cloud top heights. Our classification framework employs a self-supervised deep learning (DL) model to generate a feature space where cloud structures group together based on their semantic similarity.

We characterize the identified cloud classes using a range of physical parameters, including cloud properties, precipitation amounts, lightning activity, and morphological indices. Additionally, their diurnal and seasonal variability to determine whether some cloud types are most likely to occur. Once the classes are physically described, cloud development in the feature space associated with extreme convective rainfall and hailstorms in the Alps, as recorded in the European Severe Storms Laboratory (ESSL) database. We study the transition of convective systems to extreme precipitation across space and assess the associated environmental conditions.

Ultimately, this framework can enhance the evaluation of numerical weather prediction models by analyzing how simulated cloud evolution aligns with observed transitions in extreme events. Furthermore, it can be used to improve nowcasting and early warning systems for extreme precipitation by leveraging observation-based transition probabilities derived from past severe weather events.