A data-driven approach to exploit spatial and spectral structures in geostationary satellite data for remote sensing of fog tested for the Atacama Desert

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ABSTRACT

Accurate and efficient satellite-based fog detection is desired for various research and operational applications. However, conventional retrievals still suffer from limited detection skill and require expert knowledge to interpret available products. They typically rely on sequential thresholds tests applied to individual spectral bands or band combinations without considering all available spectral information from satellite observations. First approaches using more data-driven methodologies and adding hand-designed variables to consider spatial structures have shown promising improvements. Here, we apply a fully convolutional artificial neural network architecture to exploit available spatial and spectral information to segment satellite images into fog and no-fog pixels. We use cropped images from the Geostationary Operational Environmental Satellite - 3rd generation (GOES-16) with a focus on the Atacama Desert. By choosing this study region, algorithm development and testing benefit from a rather homogeneous surface in time and space, excluding substantial seasonal effects on reflection and emission due to a vegetation cycle. Additionally, the variety of fog types is limited and spatially constraint. The coastal region is affected by advected stratocumulus which forms fog when it intercepts with the coastal mountain range and sustains fog-dependent ecosystems whereas further inland conditions are more conducive to formation of radiation fog. On the eastern margin of the desert, orographic up-slope fog occurs when humid air is advected and cools upon forced ascent at the slope of the Andes. By investigating and explaining how the neural network derives its decision, we identify unique spatial and spectral fog signatures and relate them to the distribution of the specific fog types. This way, scientific consistency can be established and our understanding about specific fog structures and related mechanisms can be improved. For training and validation of the neural network, we created a novel ground-based reference fog data set which is based on in-situ leaf wetness sensor measurements refined with additional meteorological station data. These data were obtained from a station network deployed across the Atacama Desert by the Collaborative Research Center “Earth – Evolution at the Dry Limit” (https://sfb1211.uni-koeln.de/) of the German Science Foundation (DFG SFB1211).