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Machine learning methods have shown to be a powerful approach to modeling coastal systems including combining the nonlinear combinations of atmosphere, ocean, and land forcings. One of the foci of the NSF AI Institute for Research on Trustworthy AI in Weather, Climate, and Coastal Oceanography (AI2ES) is the development of ML based methods to predict visibility and onset and duration of coastal fog events. Improving such predictions is of great importance for coastal area management particularly for air and sea transportation. The reliable prediction of fog with machine learning is however challenging due to the infrequency of the target event, and the spatiotemporal and variable inter-dependency of the inputs, along with data non-stationarity. 3D CNN-based models are able to learn not only 2D spatial patterns and correlations between groups of pixels and a target but also learn spectral correlations between bands or temporal correlations between input variables. FogNet is a 3D CNN-based model taking advantage of the combination of an atmospheric numerical model output, sea surface temperature satellite imagery and derived air-sea interaction features. The input to FogNet consists of up to 384 ordered variable maps organized in five data cubes organized based on the physics of the problem (1) wind, (2) turbulence, kinetic energy and humidity, (3) lower atmospheric thermodynamic profile, (4) surface atmospheric moisture and microphysics and (5) sea surface inputs. A more granular physics grouping will also be tested. The model predicts fog and mist visibility categories below 1600m, 3200m and 6400m for 6-, 12- and 24-hr lead times with performance comparable or superior to existing operational models.

As performance continues to improve, often through the use of novel and/or more complex models, it is important to study and quantify the relative importance of the components and the inputs of these models. Along with the development of the model, explainable AI (XAI) methods were applied and adapted for FogNet. Results show that the 3D architecture indeed outperforms several 2D kernels, that the physics-based grouping of input meteorological variables leads to better performance. XAI also allowed to evaluate the benefits of different auxiliary modules, the multiscale feature learning and the parallel and separate spatial-variable-wise feature learning.

Ongoing further developments include a new version of FogNet based on a Vision-Transformer architecture. The new architecture introduces a multi-view attention method to model more explicitly nonlinearly correlated inputs and help better understand their interactions, particularly in the spatial, temporal, and variable dimensions. While the 3D CNN FogNet model and its new transformer-based architecture have shown significant improvements over present operational models, they would be challenging to implement operationally. Based on XAI results emphasizing the importance of atmospheric predictions for the target location, a Variational AutoEncoder (VAE) that would be easier to implement broadly is being developed. The model inputs are the High-Resolution Rapid Refresh (HRRR) predictions for the target location and the same calibration for 14 locations along the Texas coast.

As many organizations are working on harnessing the power of Artificial Intelligence to better predict and manage our environment, we need many more young scientists ready to contribute to this discovery and operational implementation process. AI2ES trains dozens of scientists from Community Colleges, to 4-year universities, MS, PhD and a robust cohort of Post Doctoral students. Thanks to partners at universities, national laboratories, including a Naval Research Laboratory, private industry an ecosystem is being developed to give a chance for young ML geoscientists to develop withing diverse environments and be ready to tackle important and pressing challenges as part of convergent teams.

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