Forecast and Classification of Dust Events in the East Mediterranean using Machine Learning

Ron Sarafian, Dori Nissenbaum, Shira Raveh-Rubin & Yinon Rudich
Earth and Planetary Sciences, Weizmann Institute of Science, Israel

WEIZMANN INSTITUTE OF SCIENCE

Abstract

Dust events, presenting a health risk and an economic burden potentially exceeding hundreds of millions of dollars annually, necessitate a comprehensive understanding to facilitate precise and prompt forecasting. Such knowledge aids in impact mitigation and enhances societal safeguards. In this study, we offer an innovative climatological insight into the correlation between weather systems and dust transportation by methodically categorizing dust events. An 18-year compilation of ground PM_{10} measurements in Israel, coupled with atmospheric reanalysis data, form the basis of our novel, unsupervised classification method for dust events in the Eastern Mediterranean. Further, we introduce a meteorological deep multi-task learning strategy for dust event forecasting. This approach integrates both the forecasting of local PM_{10} (primary task) as observed in situ, and the simultaneous prediction of the satellite-assisted regional PM_{10} (auxiliary task), thereby leveraging correlated task information.

Deep Auxiliary-Task Learning Forecasting

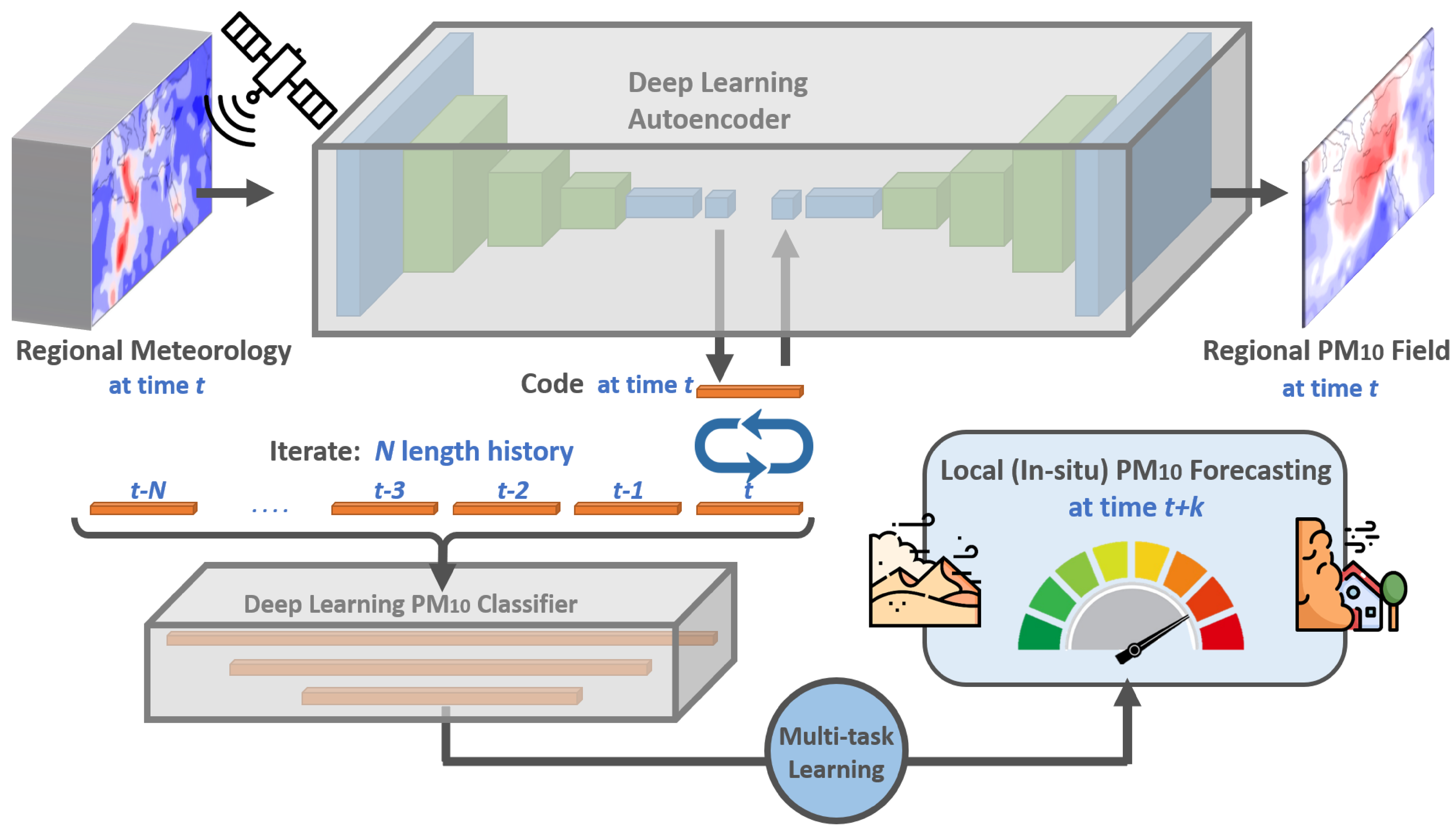

Figure 1. At each timestamp, a meteorological input tensor, time feature, and in-situ PM_{10} level are channeled into an encoder network, which consequently generates a code. These codes are then forwarded to the decoder network, yielding regional PM_{10} predictions. Simultaneously, the classifier network utilizes the codes to generate a local dust level forecast.

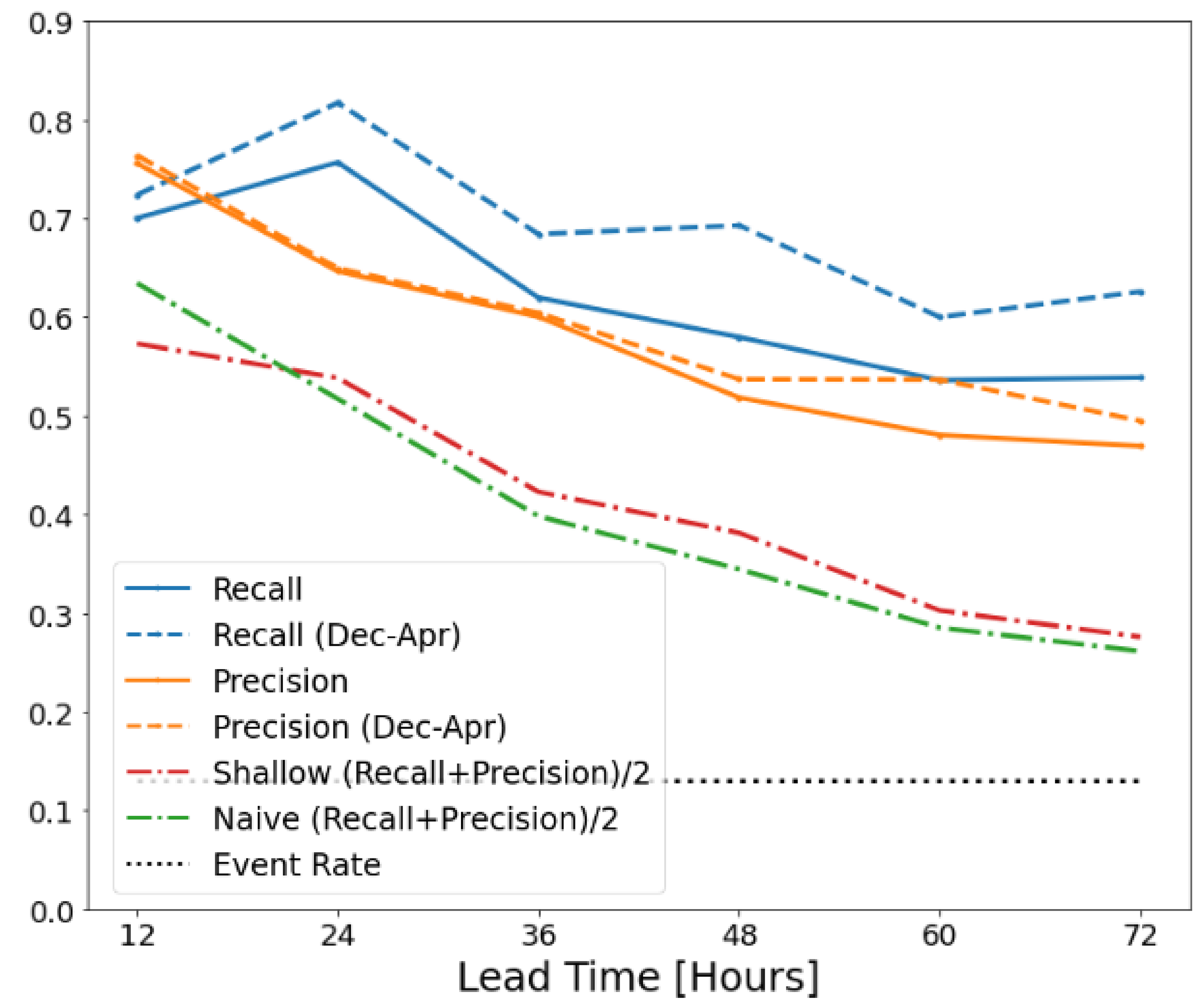

Figure 2. Recall and precision of local dust event (PM_{10}>65.2) forecast for increasing lead time.

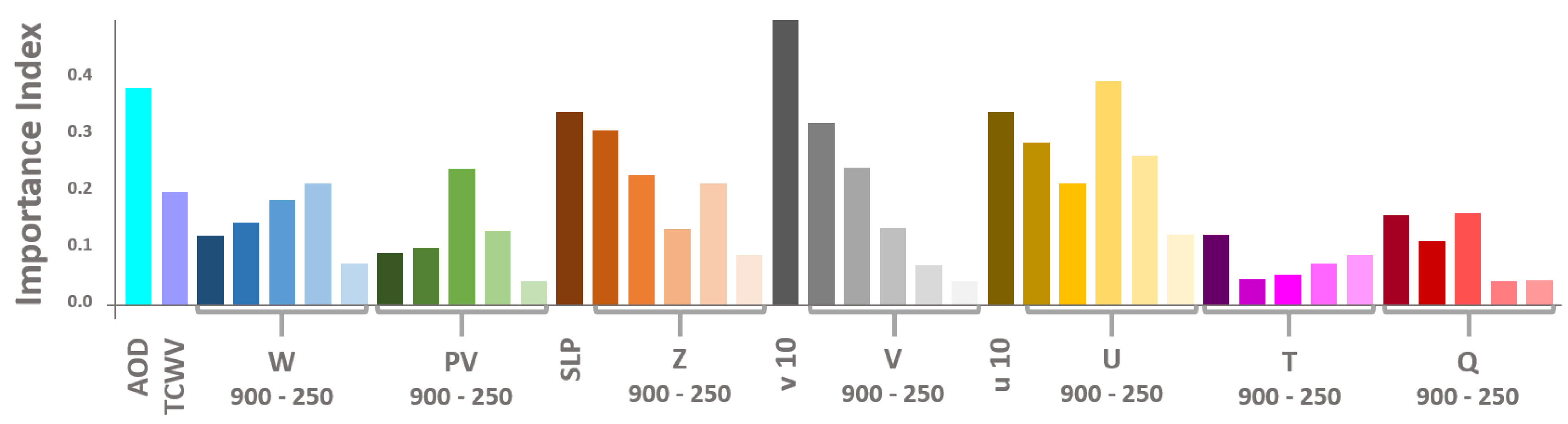

Figure 3. This is a Dust-Forecast Variable Importance Index, which is derived by integrating the meteorological attribution towards the model's dust event prediction over both time and space, thereby using integrated gradients.

Machine-Learning based Classification

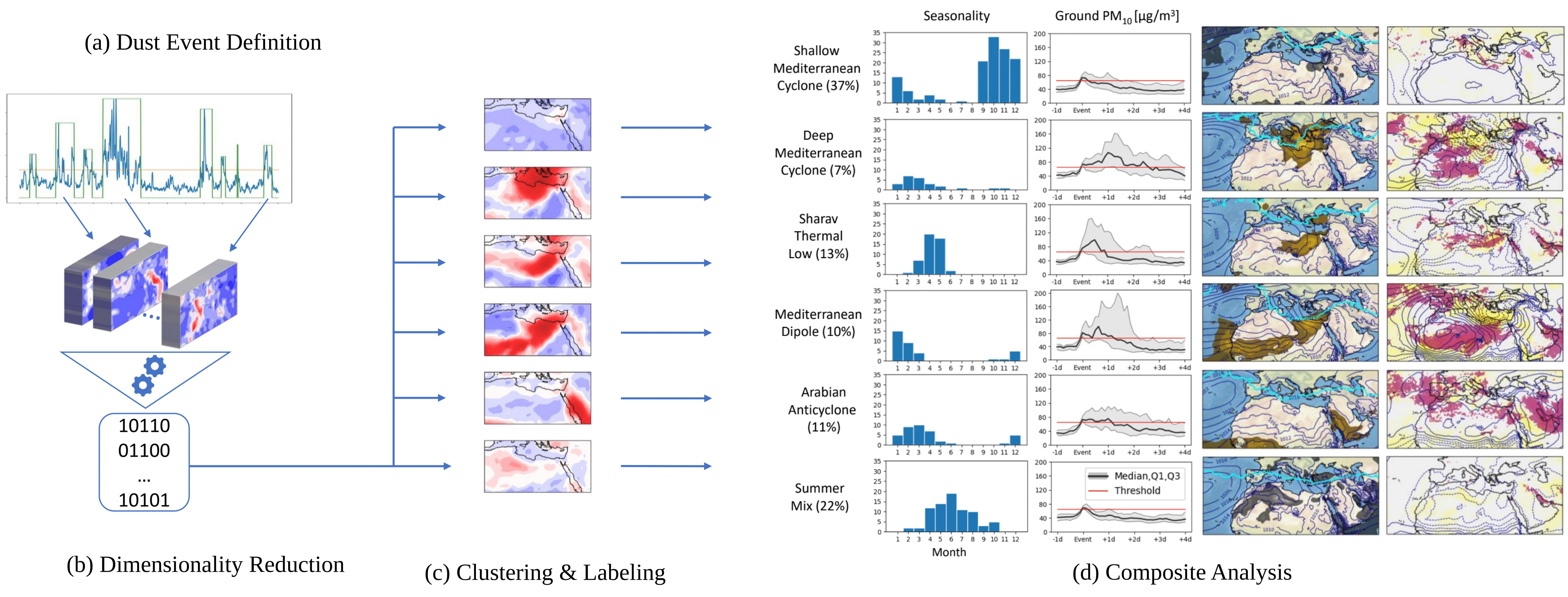

Figure 4. Unsupervised classification method's overview: A. dust event definition yielding 356 event; B. compression of the events' CAMS PM_{10} map timeseries; C. clustering and labeling of the compressed timeseries; and D. composite examination of the clustered events