New model provides improved air-quality predictions in fire-prone areas

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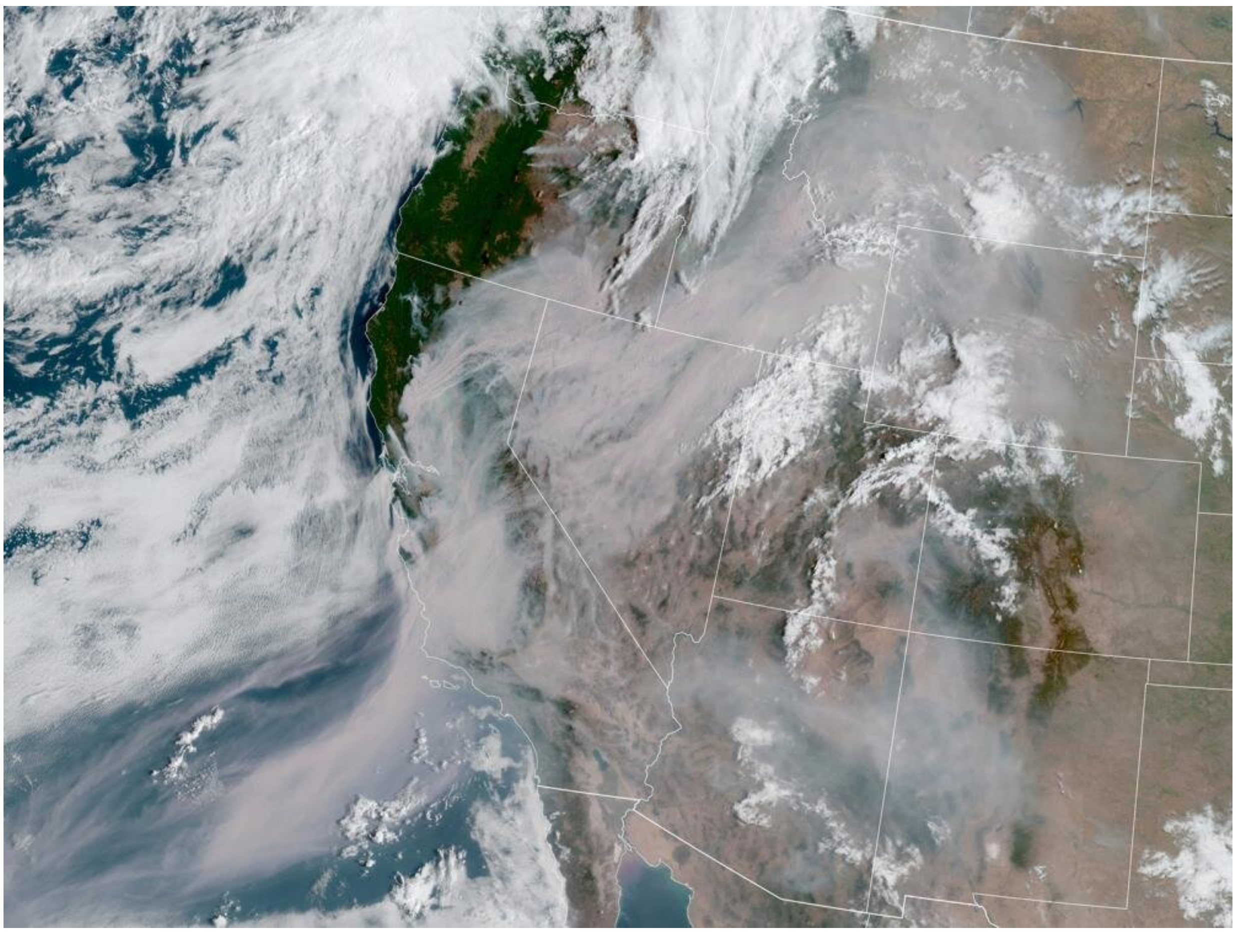


An August 2020 satellite image from the National Oceanic and Atmospheric Administration (NOAA) captured an image of wildfire smoke covering a portion of the west coast. Credit: National Oceanic and Atmospheric Administration

Globally, wildfires are becoming more frequent and destructive, generating a significant amount of smoke that can be transported thousands of miles, driving the need for more accurate air pollution forecasts. A team of Penn State researchers has developed a deep learning model that provides improved predictions of air quality in wildfire-prone areas and can differentiate between wildfires and non-wildfires.

"As climate change continues to cause ecological changes and challenges, it is likely that wildfire activities will continue to rise," said Manzhu Yu, assistant professor of geography at Penn State and lead investigator on the project. "Because of this, it is an urgent research priority to accurately predict the concentration of air pollutants induced by wildfire smoke, especially in wildfire-prone areas."

Wildfire smoke contains a combination of particulate matter and many gaseous pollutants. Fine particulate matter, referred to as PM2.5, has been associated with significant risks to human health and is regulated by the U.S. EPA.

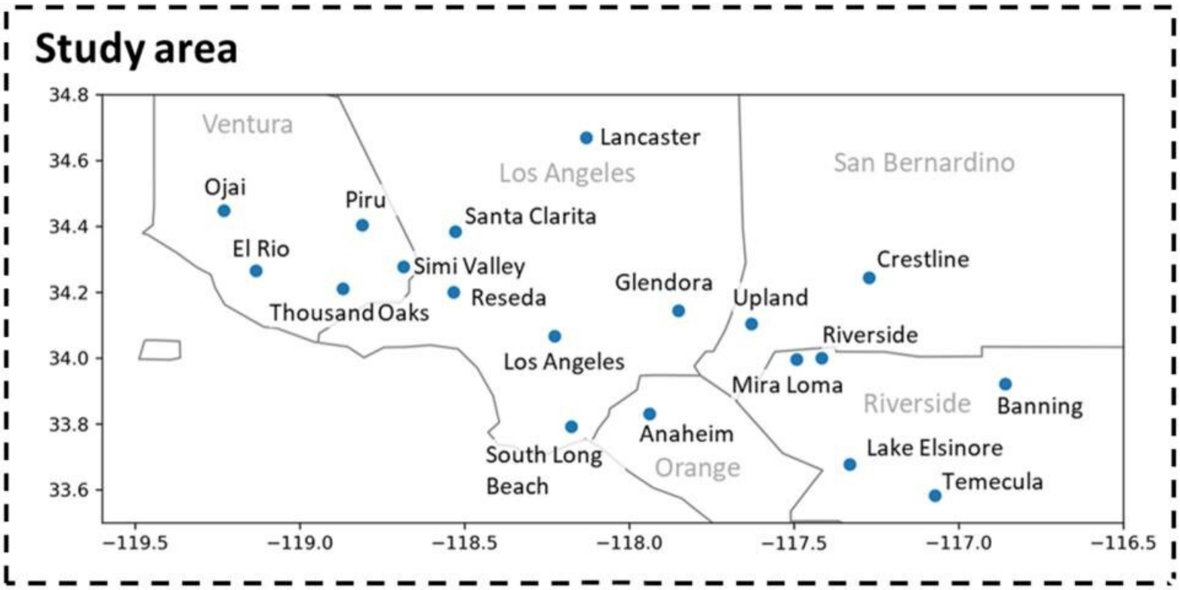
"The fine particulate matter in wildfire smoke can adversely impact human health when the levels are high," said Yu. "Air quality predictions for fire-prone areas can significantly help emergency managers and public health officials mitigate potentially adverse environmental and public health impacts from air pollution events."

According to Yu, the team's new model would be able to warn people sooner about hazardous air quality. The team reported their findings in the journal *Science of the Total Environment*.

Accurate prediction of air quality, especially for pollutants derived from wildfires, is challenging since it is highly related to the characteristics of the wildfire, such as atmospheric conditions, topography, fuel and moisture, according to the researchers.

"The advantage of this model is that it is able to produce better predictions that can capture the abrupt changes of PM2.5 when wildfire occur, while not underestimating the amount of PM2.5 that is present, which other models tend to underestimate," said Yu. "Likewise, the model does not overestimate PM2.5 when there is no fire."

The model the team developed is an iteration of an existing deep learning model called "Transformer," which is a sequence-to-sequence model originally proposed for language translation and has been successfully used for time series forecasting. The new model, called ST-Transformer, uses a novel framework that can determine trends associated with wildfires.



The research team used data from U.S. Environmental Protection Agency air quality stations in the greater Los Angeles area. Credit: Manzhu Yu

Using data from U.S. EPA air quality stations in the greater Los Angeles area, the model was trained to conduct time series forecasting on PM2.5 concentrations. Because air quality stations are sparsely located across large areas and collect data throughout the day, ST-Transformer must consider time and space variables as well as variable-wise dependencies, which are variables that impact each other.

"To train the ST-Transformer model, we included spatial, temporal and variable-wise dependencies of wildfire, smoke and air pollutants," Yu said. "We also switched Transformer's full attention mechanism to sparse attention, which can be trained to prioritize and capture the most relevant information. This allows the model to focus on only wildfire-related PM2.5."

The traditional way to perform this kind of model work for time series forecasting is to train models separately for no-smoke or baseline scenarios as well as smoke scenarios. Then baseline models can be used to predict air pollution for days without wildfire smoke, and the smoke model to predict for days with wildfire smoke, according to the team. But Yu and her team merged these inputs into one model.

"That's where sparse attention comes into play because with sparse attention, you know which inputs will better provide an accurate forecast," she said. "Sparse attention also provides better estimations of PM2.5, reducing overestimations during baseline times and underestimations when there is a fire."

Yu said ST-Transformer could also be used to improve predictions in other fields, such as water quality, precipitation and solar radiation.

"ST-Transformer could be helpful to predict water quality issues where you have stations in the water, but you cannot control where you can place them," Yu said. "For example, the nitrogen or phosphorus in runoff that can cause algal blooms are like wildfires because they are fluid and dynamically changing all the time. Your sensors may or may not capture that."

More information: Manzhu Yu et al, Predicting hourly PM2.5 concentrations in wildfire-prone areas using a SpatioTemporal Transformer model, *Science of The Total Environment* (2022). DOI: 10.1016/j.scitotenv.2022.160446

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