



# Predicting wildfire smoke

Photo by Liam Troobin-Smith 2021



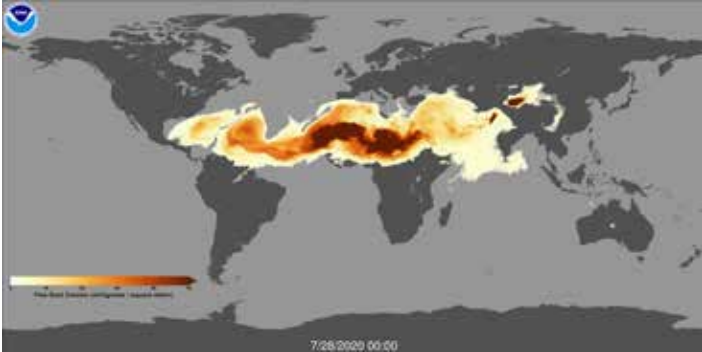
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### The Need

Atmospheric aerosols in wildfire smoke and air pollution kill an estimated 4.2 million people each year worldwide. Improved forecasts of air pollutants help the public avoid hospitalizations and premature deaths from respiratory, cardiovascular, and neurological diseases. Improved forecasts of visibility keep aircraft flying safely and efficiently by predicting ash from volcanic eruptions and smoke from wildfires.

### The Science

GSL led the development of the **Global Ensemble Forecast System - Aerosols (GEFS-Aerosols)**, an atmospheric composition model that integrates weather and air quality forecasting to produce week-long forecasts of aerosol components including wildfire smoke, soot, organic carbon,



A visualization of the GEFS-Aerosols forecast of Saharan dust carried across the Atlantic Ocean by wind in 2020.

particulate sulfate, dust, sea salt, and volcanic ash. This is NOAA's first operational global forecast that realistically accounts for the geographic distribution of atmospheric aerosols resulting from wildfires, dust storms, and human activity.



The HRRR-Smoke vertically integrated smoke forecast from July 20, 2021.

GSL also developed the hourly-updating **High-Resolution Rapid Refresh-Smoke (HRRR Smoke)** model that predicts the 3D transport of wildfire smoke plumes and the plumes' impact on visibility and weather over the U.S. The model ingests the most recent weather data combined with satellite fire detections from the past 24 hours and maps the information to the HRRR 3km grid. HRRR-Smoke then calculates the size of the fires and couples the information with weather simulations from HRRR to produce forecasts of near-surface smoke and vertically integrated smoke.



Smoke billows from the Beaver Creek Fire west of Walden, Colorado. Credit: Colorado State Forecast Service

## Applications

NOAA and other agencies use both HRRR Smoke and GEFS-Aerosols to make daily pollution and visibility forecasts for the U.S. and the globe. Stakeholders such as the EPA and state regulatory agencies use NOAA air quality forecast guidance to issue pollution alerts for sensitive populations. The FAA uses NOAA forecasts of visibility to keep aircraft flying safely.

Other users include:

- Firefighting operations
- Emergency management
- Railroad industry
- National Park Service
- USGS
- Vineyards
- Local and national media

## Transitions

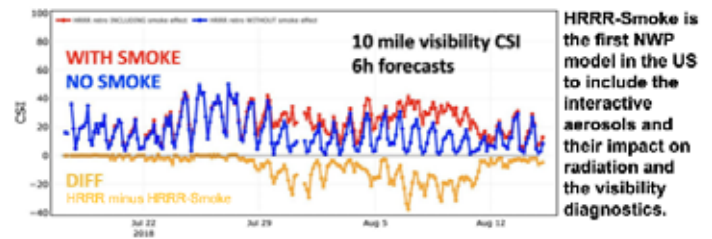
HRRR Smoke was implemented into NOAA National Weather Service operations on December 2, 2020. GEFS-Aerosols was transitioned into NWS operations on September 23, 2020.

## Metrics

The HRRR parent model has improved its short term (9-hour) forecasts of relative humidity and winds by 25% and 15% over the last decade. With the smoke module added to the HRRR, improvements were seen in both visibility and 2m temperature forecasts when smoke effects were included:

- Surface visibility < 3 miles showed 3% (a very rare event)
- Surface visibility < 5 miles showed 9% improvement
- Surface visibility < 10 miles showed 47% improvement (much more common)
- 2m temperature 12 hr forecasts over the western US were improved (as measured by decrease in RMSE) over a two week period in Aug 2018:
- 2mT showed 5% decrease in forecast error.

## Verification of the Surface Visibility Forecasting by HRRR-Smoke over Western US



CSI - critical success index (%)

The measurements from over 400 weather stations are included in this verification

Graph shows the surface visibility improvement by HRRR-Smoke over the regular HRRR (operational until December, 2020). The CSI plot shows that the regular HRRR shows less skill, when the visibility deteriorates due to dense smoke as expected.

## Future Work

GEFS-Aerosols is a collaborative effort between NOAA's GSL, Chemical Sciences Laboratory, Air Resources Laboratory, and the Environmental Modeling Center. Work is ongoing to add aerosol radiative feedback.

GSL scientists are now developing a new version of the HRRR for the NWS's next-generation model known as the Rapid Refresh Forecast System. RRFS is expected to be transitioned into operations in 2024. HRRR Smoke work is sponsored by the NOAA/NASA Joint Polar Satellite System Program, NOAA GSL, the FAA, the Cooperative Institute for Research in Environmental Sciences, and the Cooperative Institute for Research in the Atmosphere.

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