$PM_{2.5}$ concentrations observed and modeled for the 2016 southern Appalachian wildfire event

United States Environmental Protection Agency

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Introduction

Fig. 1. *Fires outside of Gatlinburg, TN in late November 2016 (a,c). The wildfires resulted in 2,500 damaged structures as well as 14 fatalities. $PM_{2.5}$ from the fire emissions caused significant haze throughout the region (b), resulting in air quality warnings throughout the southeastern U.S.*

- Wildfires during Fall 2016 in the southern Appalachian region of the United States burned over 50,600 hectares leading to a widespread outbreak of elevated levels of fine particulate matter ($PM_{2.5}$).
- Ignitions occurred in areas stressed by record heat and a historical drought.[1,2,3]
  - Nearly 50% of the southeastern U.S. experienced "extreme" or "exceptional" drought from 25% to 50% by late November 2016 (Fig. 2).[3]
  - Several weather stations in the region reported precipitation totals of 10 inches or more below average.[4]

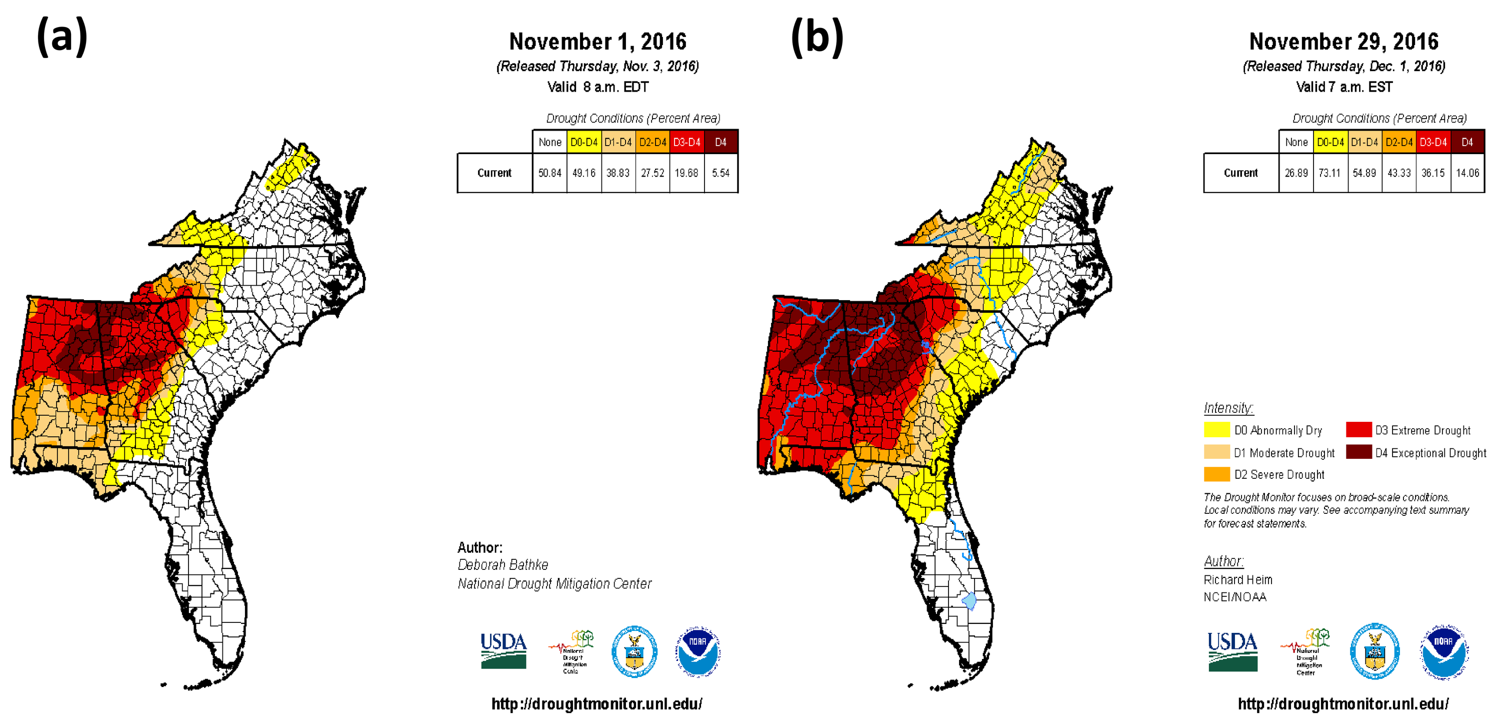

Fig. 2. *U.S. Drought Monitor for the Southeast region from (a) November 1 to (b) November 29.[3] The area experiencing drought conditions during November rose from 49% to 73%.*

Local Impacts:

The wildfires impacted local communities in the following ways:

1. **Air Quality:** AirNow sensors recorded average PM Air Quality Indexes (AQI) of 100-201 (categorized as "Unhealthy") in areas across the southern Appalachian region for 15 days during the study period of November 12 – 30, including Knoxville, TN; Chatanooga, TN; Atlanta, GA; and Asheville, NC.[5]
2. **Economics:** The National Oceanic and Atmospheric Association (NOAA) reported that the fires near Gatlinburg, TN, destroyed 2,500 structures alone. The total estimated cost of the all wildfires in the Southeast combined with those in California for the Fall of 2016 was $2.4 billion.[6]
3. **Mortality:** The Chimney Tops 2 fire near Gatlinburg resulted in 14 deaths.[6]

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Objective

- Wildfire prevalence may continue to increase in the future – due to changes in climate and the growing abundance of fire-prone forest biomass.
- Models like the Community Multiscale Air Quality (CMAQ) modeling system can be useful for estimating whether fires may produce harmful levels of $PM_{2.5}$.
- This study aims to evaluate the utility of a near-real-time version of CMAQ in simulating $PM_{2.5}$ from a significant fire event by comparing model output with observational data.

Study Design

- A near-real-time version of the coupled WRF-CMAQ model was used to simulate the impact of wildfire events.
  - Simulation period: November 7-17, 2016
  - CMAQ version 5.2 with CB05E51 chemical mechanism
  - WRF version 3.8
  - Boundary conditions derived from a hemispheric WRF-CMAQ simulation
- Wildfires actively burning in the southern Appalachians during November were identified using the National Wildfire Coordinating Group's Incident Information System.[7]
- Coupled WRF-CMAQ simulations with and without Fire INventory from NCAR (FINN) fire emissions were performed.
  - Downloaded SAPRC 99 FINN global emission dataset.
  - Converted data to SMOKE FF10 format.
    - No fuel loading or heat release in FINN data
    - Scaled heat flux using constant emission factor for all fires (0.13976 kg fuel per gram of $PM_{2.5}$ emission)
    - Added FIPS codes to each fire
    - Summed VOC and CH_4 to get total organic gases (TOG) and applied wildfire TOG profile to get CB05E51 (or CB6) emissions
  - Merged emissions with crop residue burn estimates (which exclude MODIS detections).
  - Used SMOKE to process fire emissions for CMAQ.
- Selected $PM_{2.5}$ monitors in EPA's AirNow sensor network in close proximity to the wildfires were compared to the model simulations.[5]
- Daily results were examined in connection with NASA's EOSDIS Worldview images. Fires and thermal anomalies were identified by Aqua (MODIS) and the base map is a corrected reflectance (true color) image by Suomi NPP (VIIRS).[8]

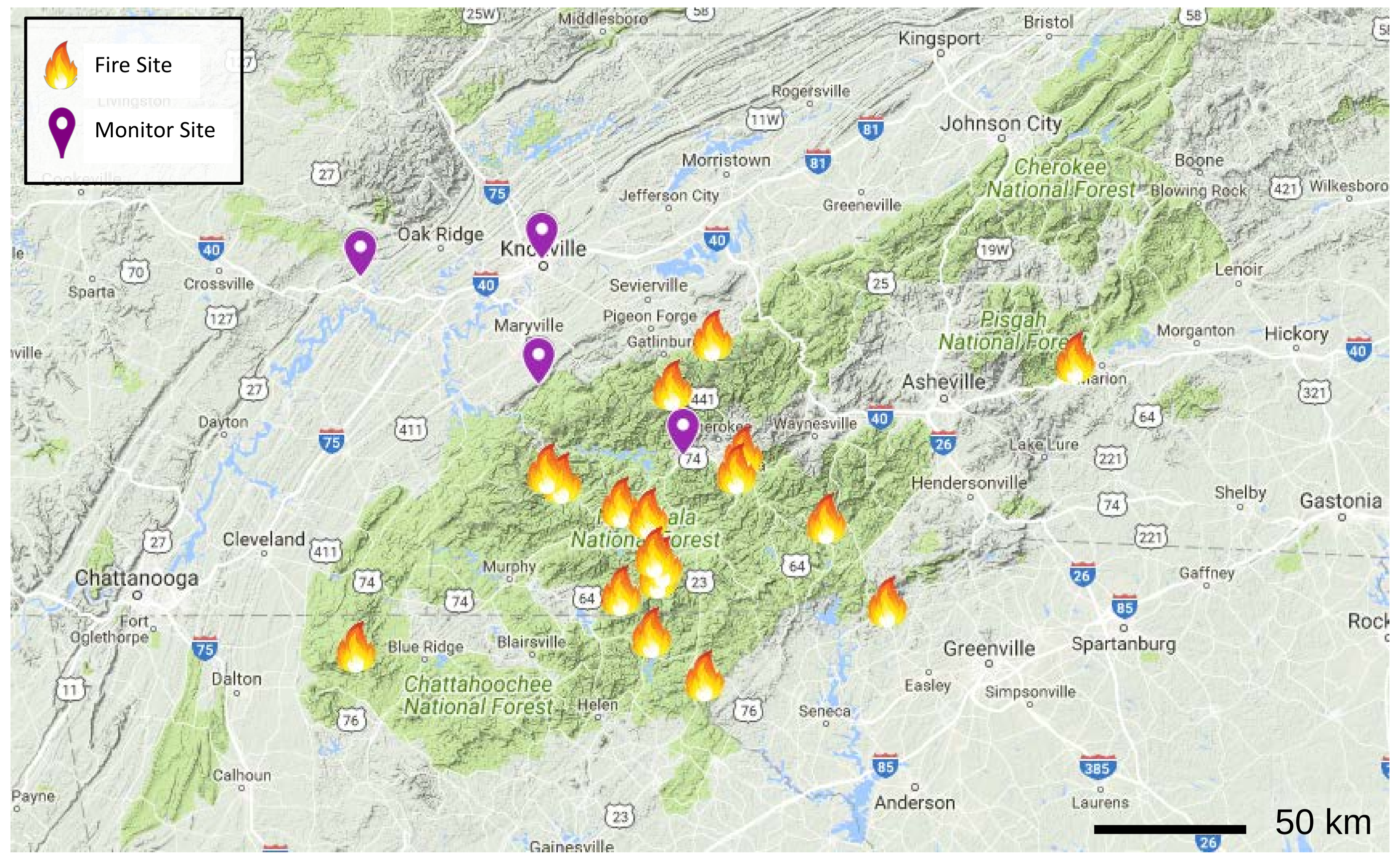

Fig 3. Sites with active fires during November 2016. Monitor site locations are noted in purple to emphasize their proximity.

Evaluation of CMAQ Model Runs

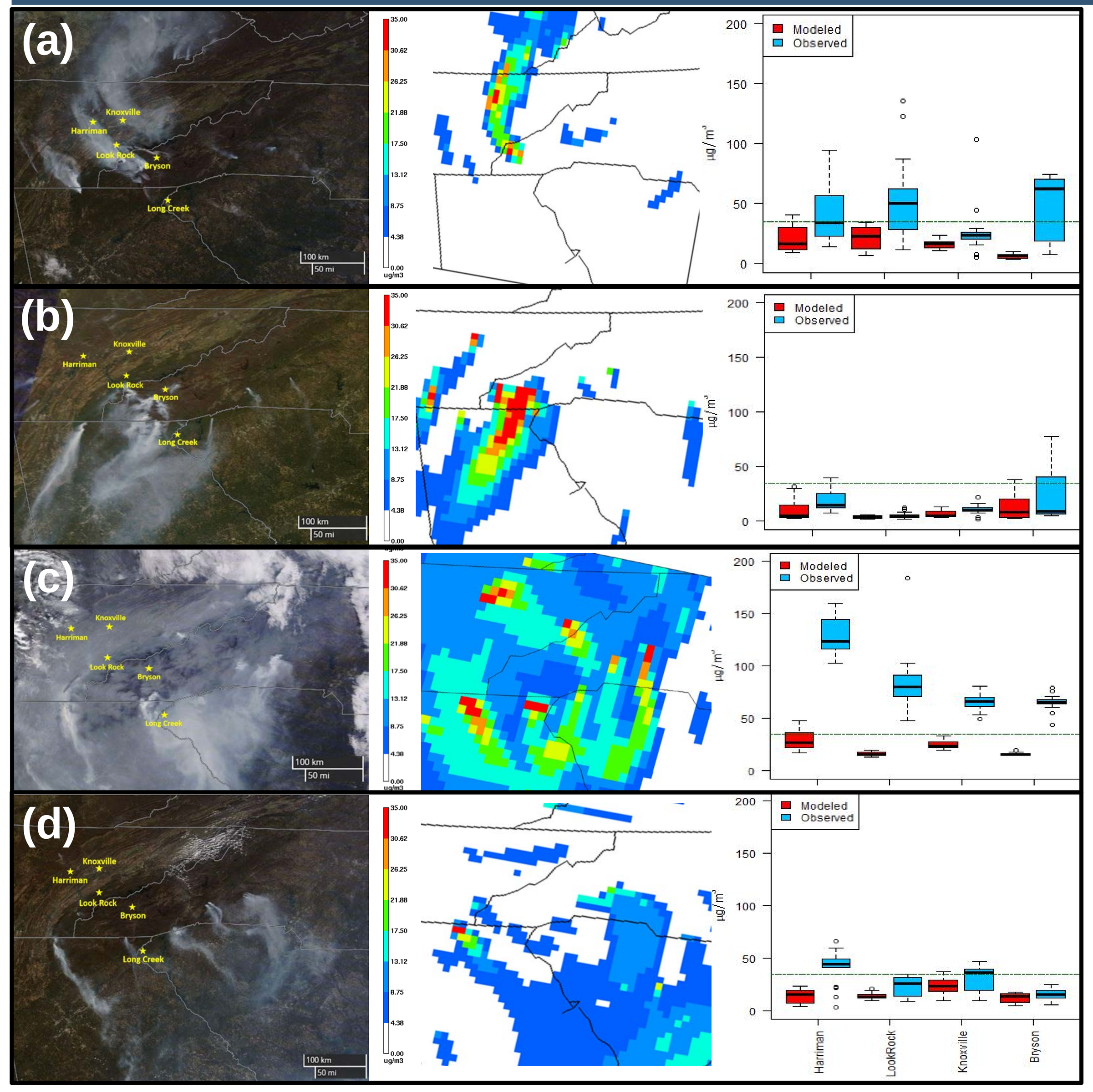

Fig. 4. *MODIS images of observed smoke plumes and monitor sites (left) compared to model predicted $PM_{2.5}$ concentrations (center) and box and whisker plots of both modeled and observed daily $PM_{2.5}$ concentrations (right) for (a) November 7, (b) November 10, (c) November 14, and (d) November 16.*

- MODIS-derived smoke plumes and CMAQ output agree qualitatively, often having similar shapes and geographic distributions.
- CMAQ simulation with FINN data, however, did not capture elevated surface concentrations observed at nearby AQS sites.
  - During the study period, more than 30 site days had average $PM_{2.5}$ concentrations exceeding 35 ug·m^{-3}, but CMAQ captured only one exceedance.

Discussion

- Air quality models such as CMAQ can be used to characterize the air quality impacts of wildland fires.
- Evaluation of the 2016 TN fire event suggests estimated smoke emission rates for this study may be underestimated.
- Evaluation of model predicted smoke transport and dispersion from wildland fires is complicated by the fact that satellite imagery may miss fires that are too weak to be detected by thermal imagery, occur at times that do not correspond to the satellite overpass, or are hidden by clouds.
- Field study data are needed to improve the temporal and vertical allocation of smoke emission rates in order to increase the accuracy of model-predicted smoke plumes.

References

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