Special Symposium on Applications of Air Pollution Meteorology, Paper #843

Modeling Atmospheric Transport and Dispersion of Smoke from Wildland Fires

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Introduction

▪ Smoke transport and dispersion from wild fires is a critical health and safety issue.

▪ Grid resolution of current smoke dispersion modeling systems (e.g., Bluesky) hinders modeling of smoke dispersion at local scale and over areas of complex terrain.

▪ In this study, we simulate the transport and dispersion of smoke from the Oct. 2007 wildfire outbreak in Southern California using a coupled atmosphere/particle dispersion modeling system.

▪ The objectives of this study are:

- to evaluate the performance of the coupled Weather Research and Forecast (WRF) model –Lagrangian Particle Dispersion model (FLEXPART) to simulate smoke dispersion over complex terrain,
- to examine the pathways by which smoke is transported under different synoptic conditions,
- to understand the role of thermally driven flows and boundary layer structure in smoke transport and dispersion.

Model Configuration

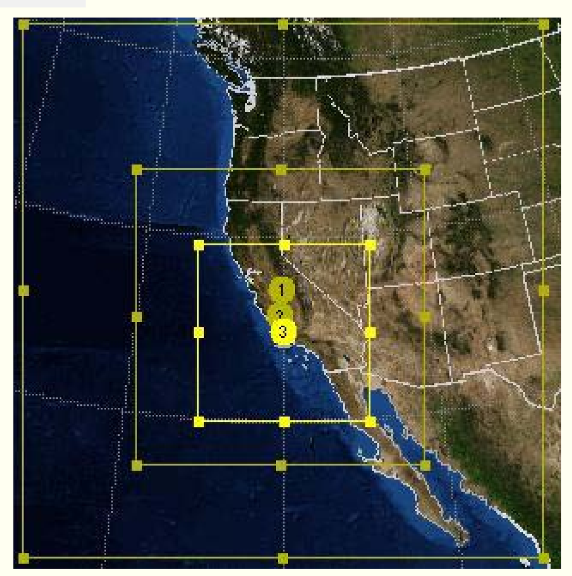
WRF- simulate meteorology fields

•Three nested domains at 36,12,4 km grid spacing and 49 vertical levels.

•Simulation period: 15-30 Oct. 2007.

•Initialization: NARR data.

•Physical parameterizations: MYJ PBL, NOAH LSM, RRTM radiation, Lin microphysics, Kain-Fritsch cumulus.



Wind speed and direction, temperature, moisture, and turbulence

Validation Using Observation

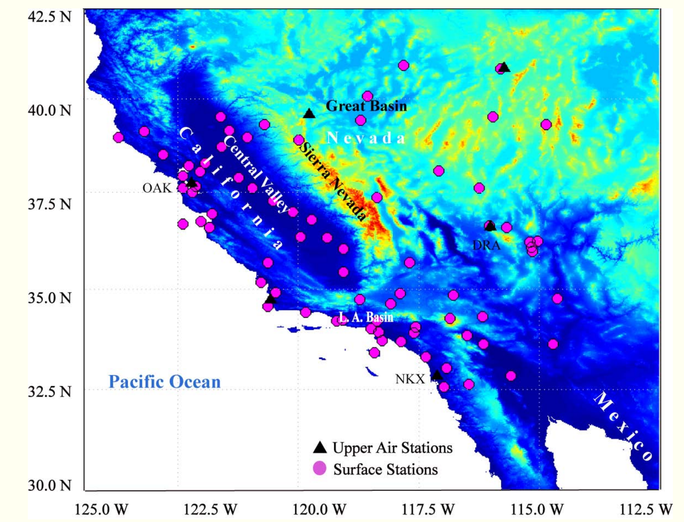
FLEXPART – simulate smoke particle concentration

•Passive tracer particles released at different times from multiple fire locations to mimic the spatially and temporally varying emission rates of particles from the October 2007 Southern California wildfires.

• The particles then tracked in space and time and concentration fields derived by counting particle numbers for given areas.

Observational Data

▪Surface meteorological stations (pink circles) and upper air stations (black triangles) in the study domain

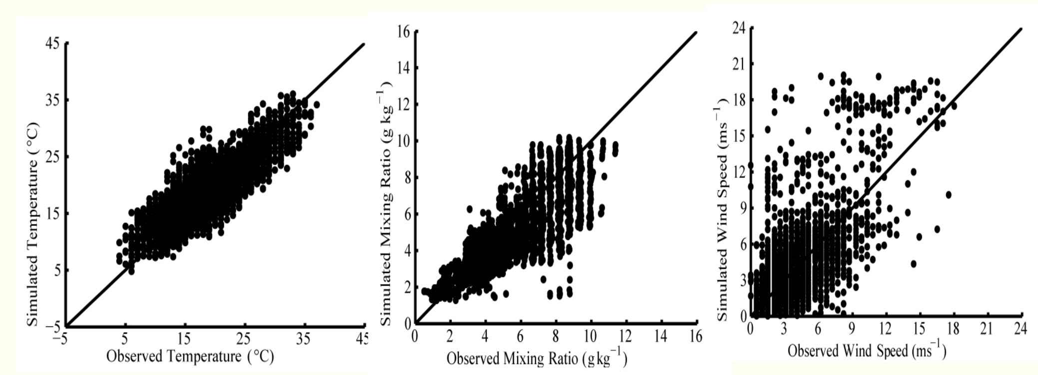


▪Total Ozone Mapping Spectrometer (TOMS) derived aerosol index

▪Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)

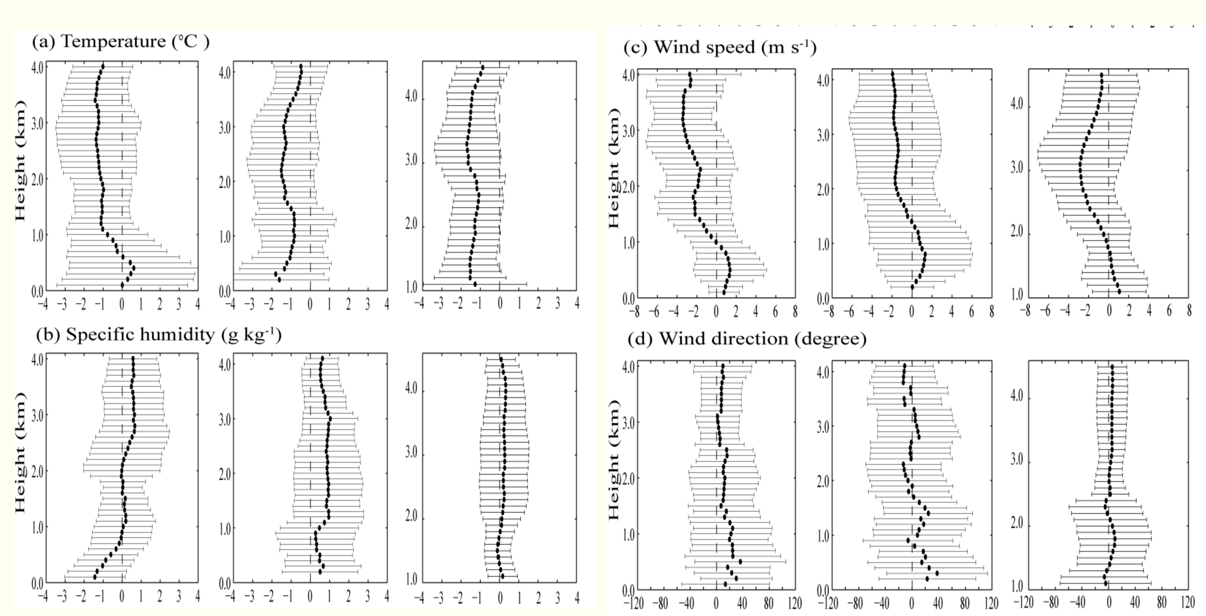
Validation of simulated meteorological fields

Surface meteorological fields

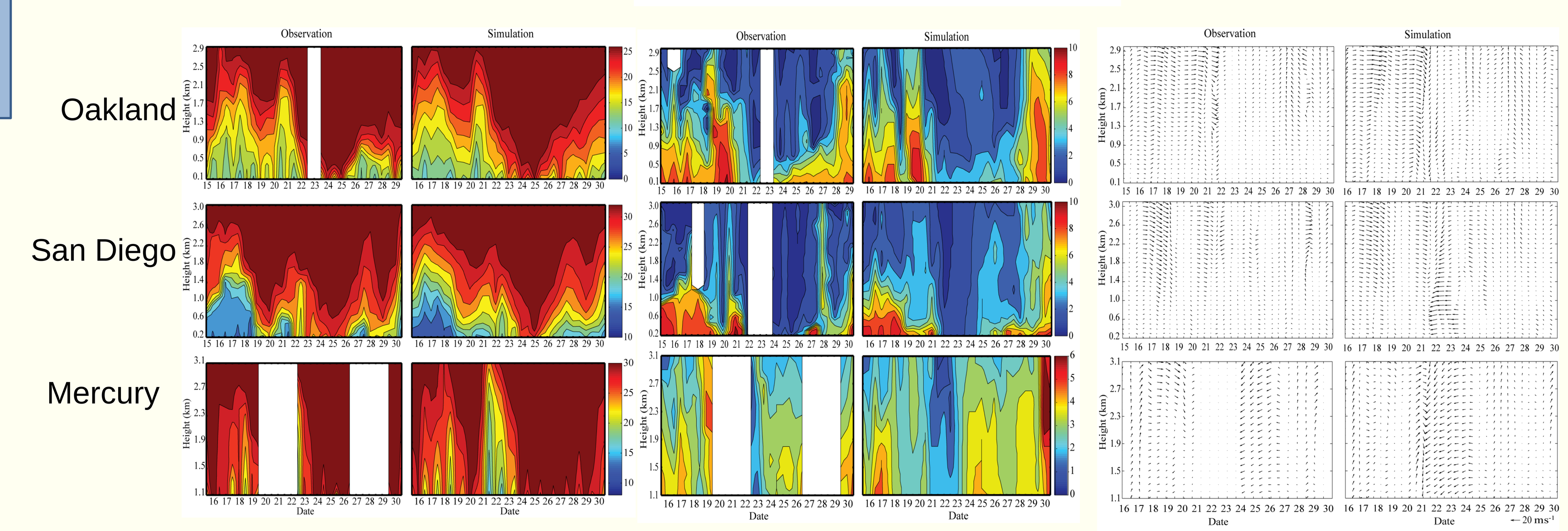


Simulated and observed hourly temperature (^oC) (left), mixing ratio (g kg^{-1}) (center), and wind speed (m s^{-1}) (right) at all surface meteorological stations for the entire simulation period.

Upper-level meteorological fields



The mean and standard deviation of the differences between simulated and observed vertical profiles of (a) temperature, (b) specific humidity, (c) wind speed, and (d) wind direction at three upper-air locations: Oakland (left), San Diego (middle) and Mercury (right).

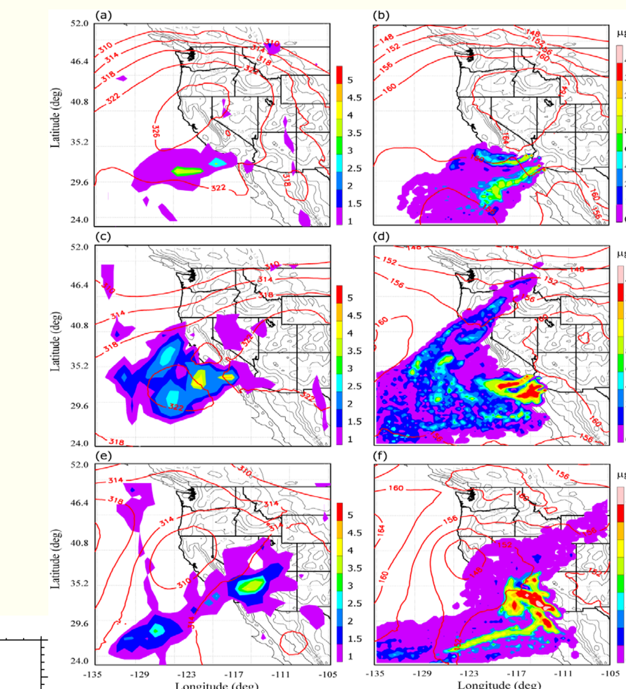


Time-height cross section of the observed and simulated potential temperature (°C) (left panel),specific humidity (gkg⁻¹) (middle panel) and vector winds (right panel).

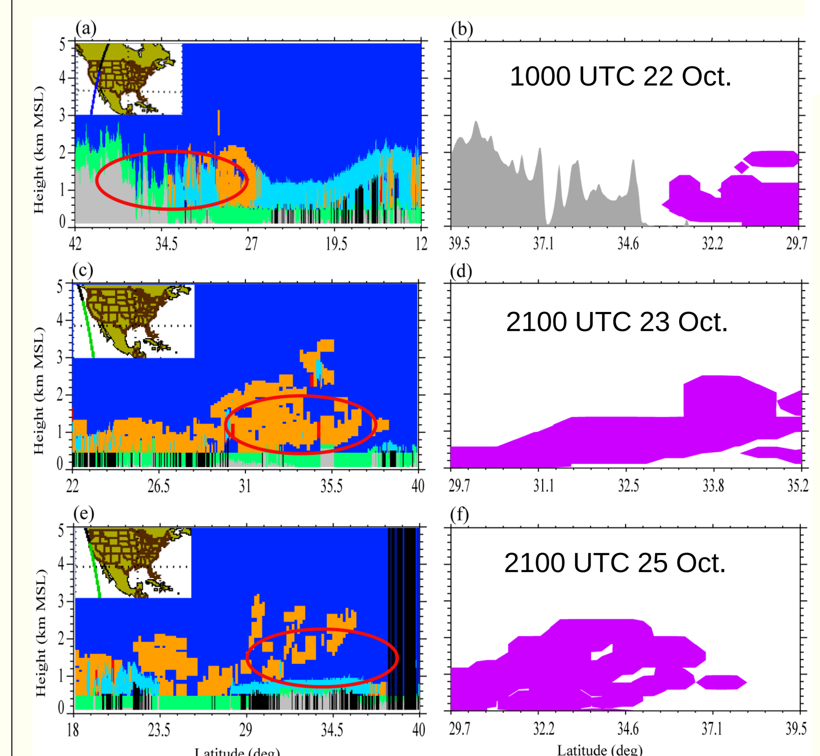
Smoke Transport and Dispersion

Horizontal distribution of smoke plumes

TOMS aerosol index (left) and FLEXPART CO tracer fields (right). Red contour lines are the geopotential heights (in 10 m interval) at 700 hPa (left) and 850 hPa (right).

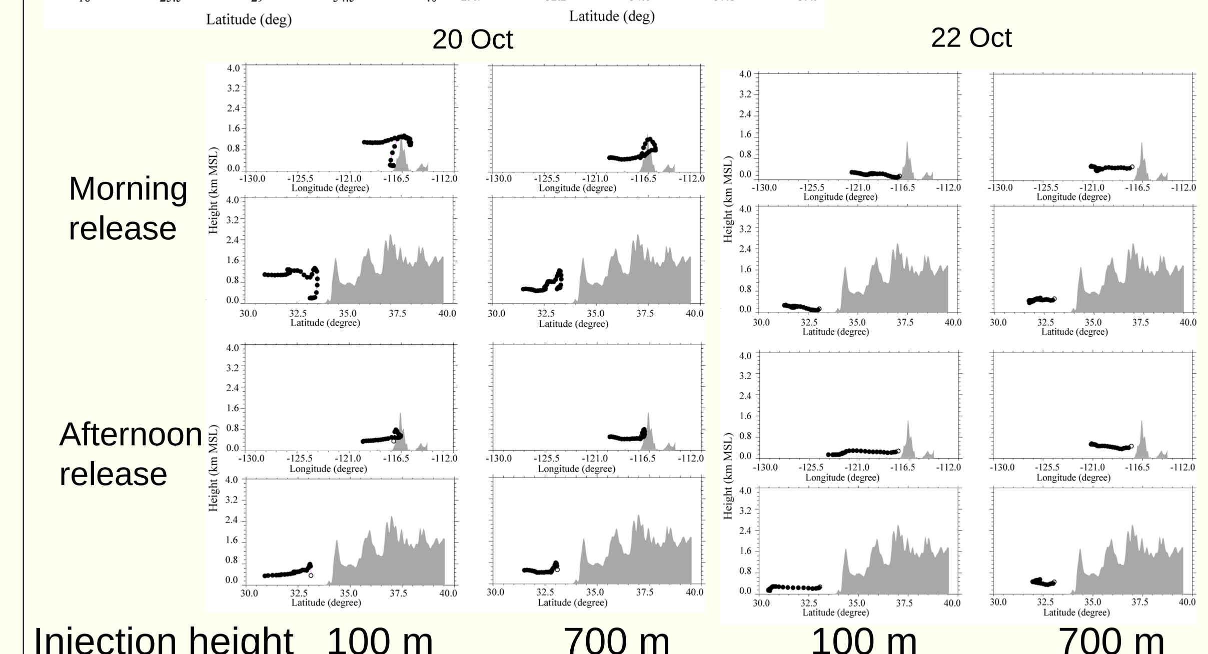


Vertical distribution of smoke plumes



Aerosol distribution (yellow color) from the CALIPSO vertical feature mask data (left column) and the corresponding vertical cross section of simulated CO concentration (right column) for different ground tracks.

The influence of releasing time and height on smoke transport



Simulated smoke trajectories

Conclusions

- The WRF model captured the flow patterns and boundary layer development over areas of complex terrain in Southern California. There was a warm and dry bias at coastal and valley locations and a cold and wet bias at mountainous sites, but the bias values were small (< 0.5 ^oC and 1 g kg^{-1}). The simulated surface winds were generally lower than the observed (<0.5 m s^{-1}).The simulation adequately captured the vertical structure of temperature, moisture, and wind, and the simulated mixed layer heights were also in good agreement with the observed.
- The coupled WRF-FLEXPART dispersion modeling system was capable of simulating the observed spatial distributions of smoke plumes from wildfires.
- The results highlight the important role of the region's complex topography in the determination of the smoke transport patterns and the need to accurately represent information such as plume rise in simulations of smoke transport and dispersion.

Acknowledgement:
Funding for this research was provided by Interagency Joint Fire Science Program (Project No: 9-1-04-1).