Multiscale Plume Transport from Collapse of the World Trade Center on September 11, 2001

Georgiy Stenchikov
Department of Environmental Sciences, Rutgers University

Nilesh Lahoti, Paul Lioy, Panos Georgopoulos
Environmental & Occupational Health Sciences Institute
a joint institute of UMDNJ-RWJ Medical School & Rutgers University

David Diner, and Ralph Kahn
Jet Propulsion Laboratory

***Objectives**: Reconstruction of the aerosol plume from the World Trade Center collapse and fire to better quantify its environmental and health impacts*

***Approach**:*
Observations
MISR
LANDSAT
Ground-based PM2.5 measurements
Modeling
Regional Atmospheric Modeling System (RAMS)
Hybrid particle and Concentration Transport (HYPACT) model

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CHEMICAL ANALYSIS OF A DISASTER

LOUISA DALTON, C&EN WASHINGTON

PLUMES OF SMOKE Fallout dust from the collapse of the WTC towers was composed mainly of construction materials. NYPD PHOTO

World Trade Center Fire Plume September 11, 15:01 EDT
As viewed from Newark, NJ|

Image courtesy of Praveen Amar of NESCAUM

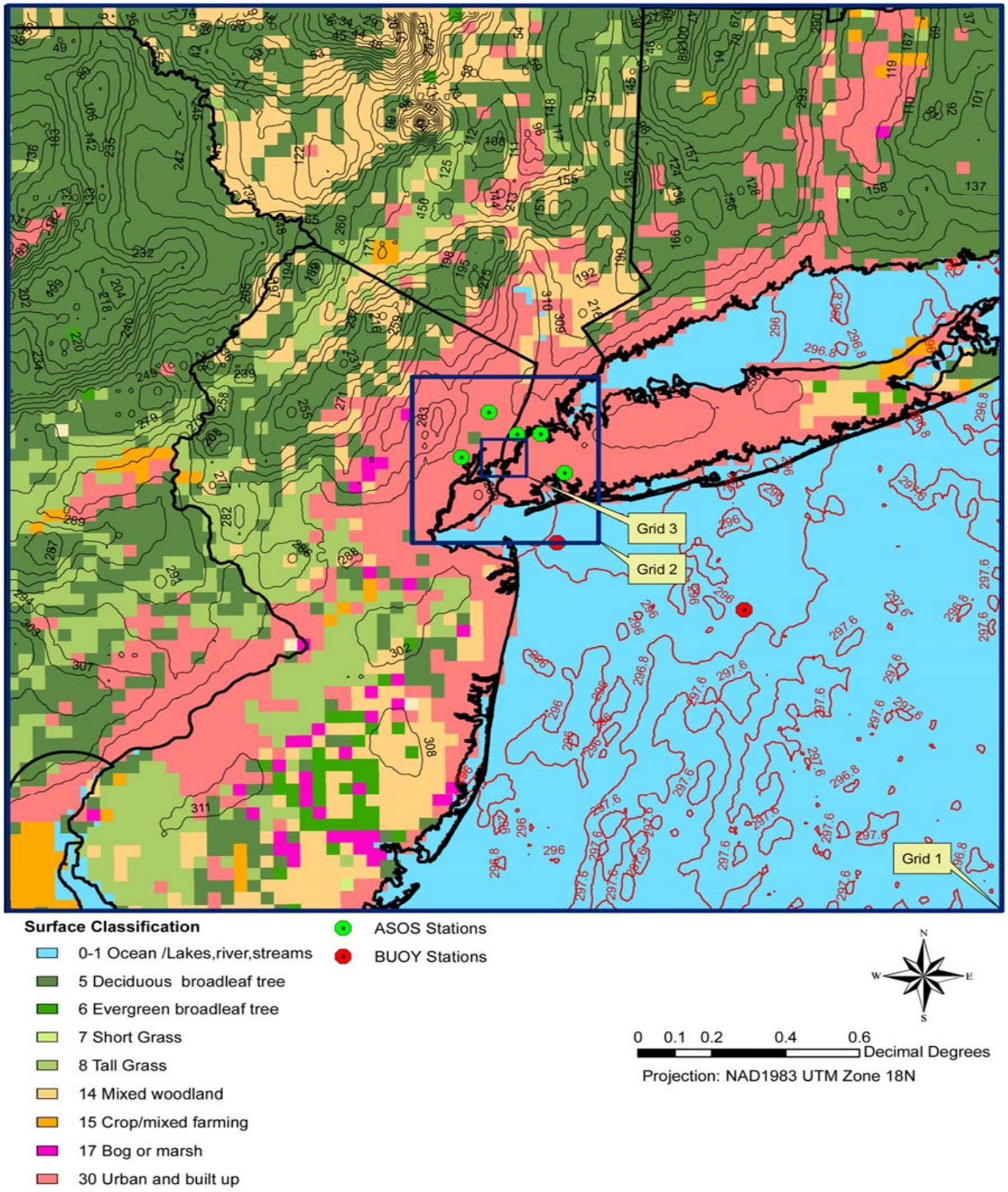
RAMS Model Domains and Boundary and Initial Conditions

Symbols show the location of the ASOS and BUOY stations.

Land elevation is shown with black contours.

Land cover classes from the USGS National Land Cover Dataset are distinguished by color over the land.

SST (red contours) was composited from AVHRR observations

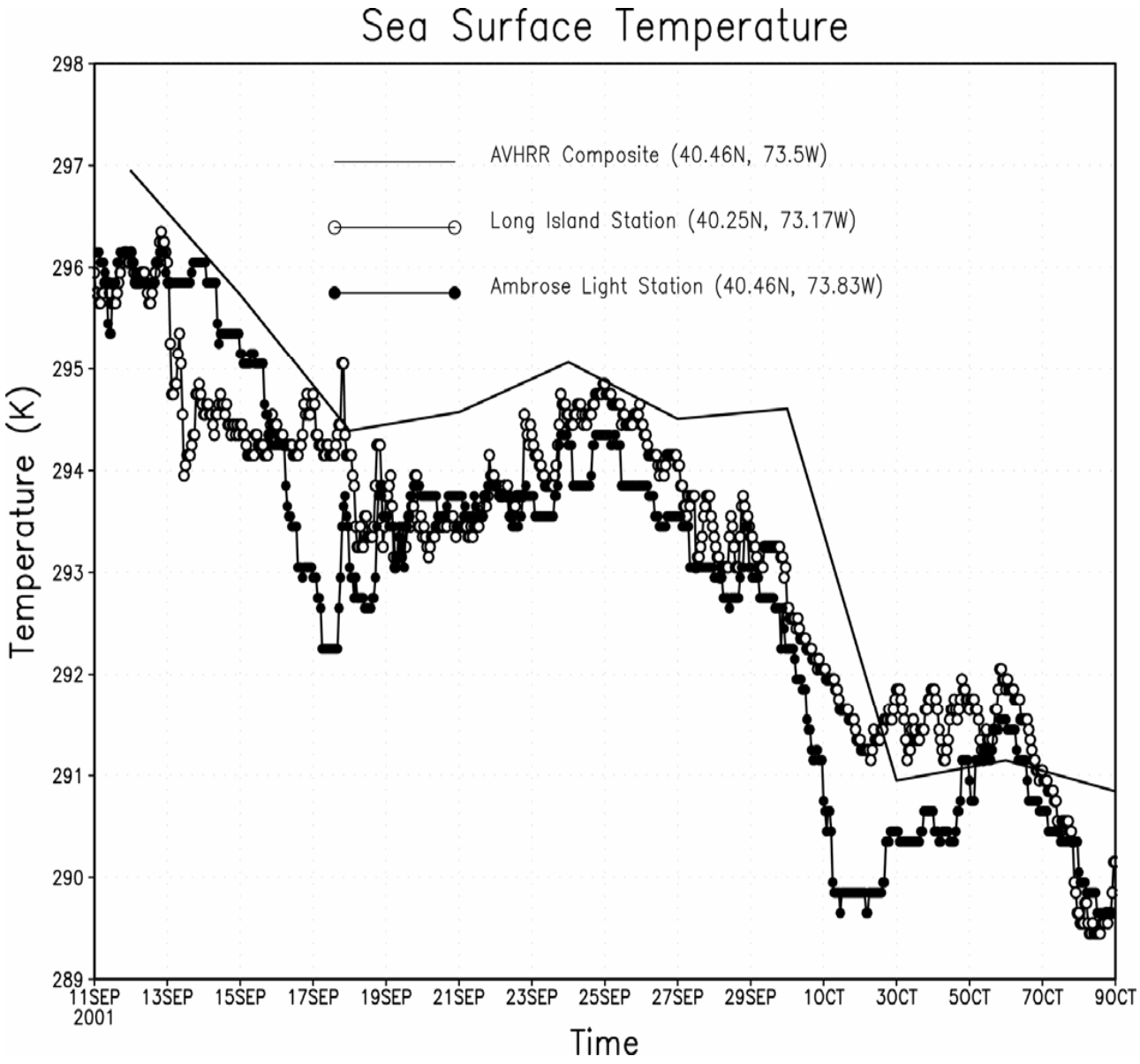


New Jersey Coast Sea Surface Temperature - AVHRR

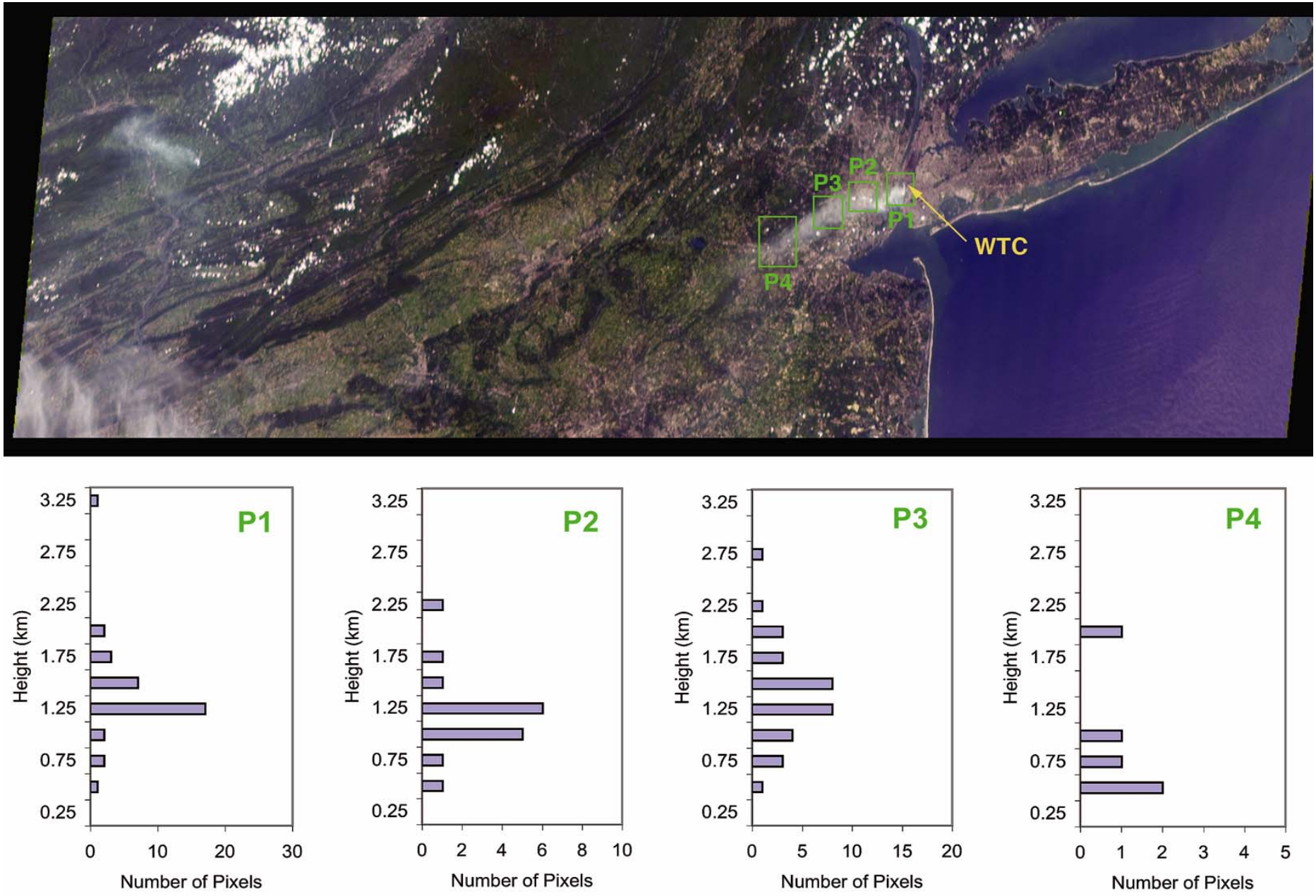
Three-day composited Sea Surface Temperature (K) at the New Jersey coast from the AVHRR retrieval at 40.46°N, 73.5°W.

and

Hourly observations from the Long Island (40.25°N, 73.17°W) and Ambrose Light (40.46°N, 73.83°W) buoy stations.



MISR Image and Plume Height Histograms



MISR stereo height analysis of the World Trade Center (WTC) smoke plume at 1603 UTC (1203 EDT) on September 12, 2001. The upper panel depicts MISR 70°-forward image of natural color reflectance for Terra orbit 9237. The lower panel shows histograms of height for the four patches.

World Trade Center Fire Plume September 12, 11:01 EDT
As viewed from Newark, NJ

Image courtesy of Praveen Amar of NESCAUM

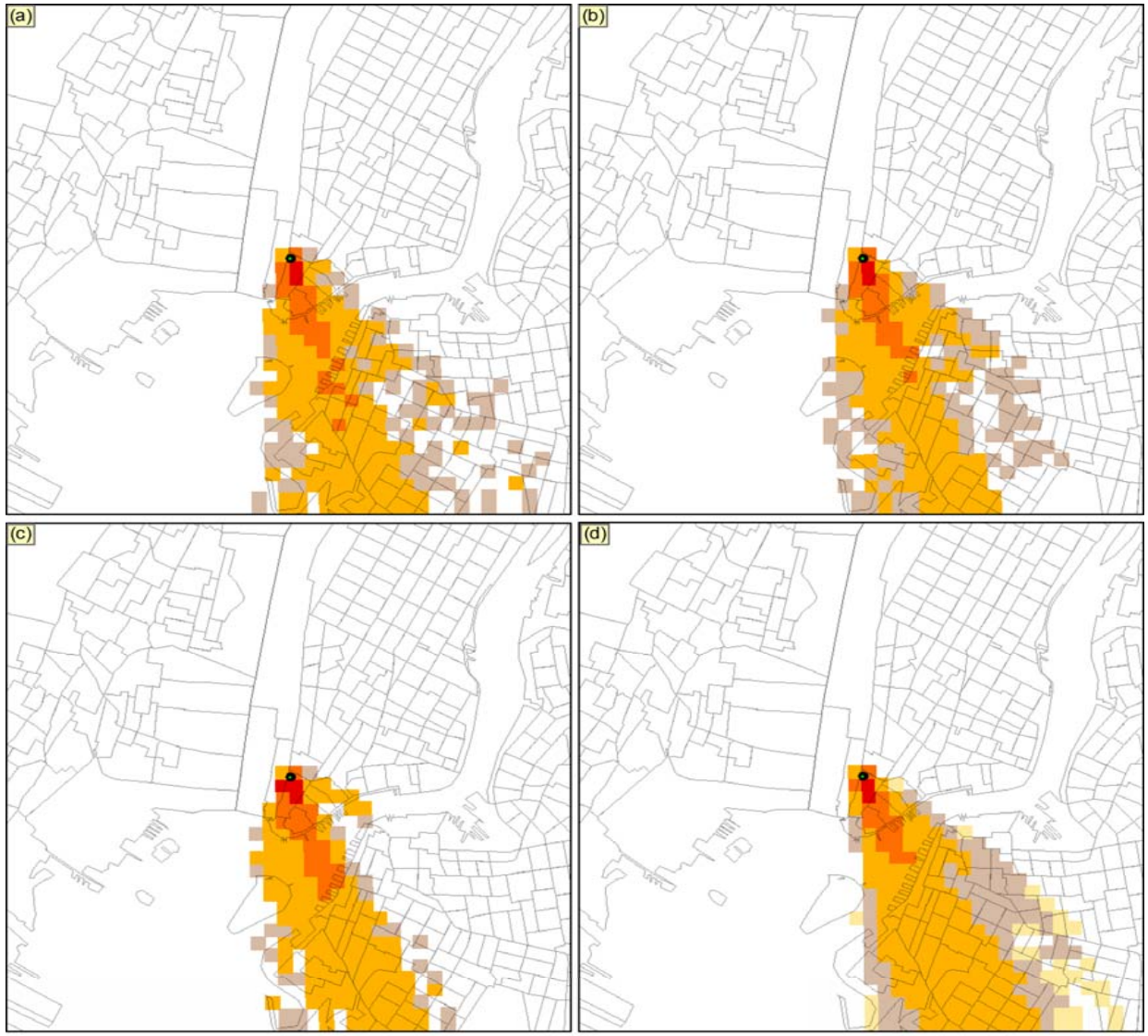
Low-level tracer concentrations simulation with 250m spatial and 30min time resolution, averaged over 8 hours from 0800 to 1600 EDT on September 11

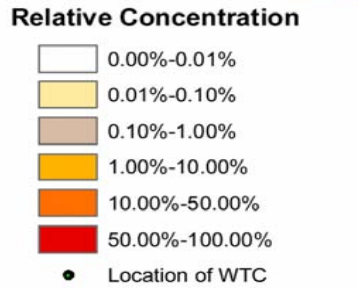
(a) Eta initialization with 100 particle/s release rate.

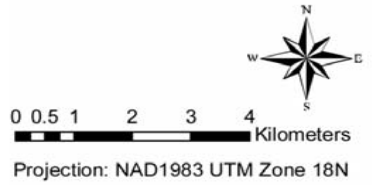
(b) Eta+ASOS itialization with 100 particle/s release rate.

(c) Eta+ASOS+NCEP nitialization with 100 particle/s release rate.

(d) Eta initialization with 1000 particle/s release rate.

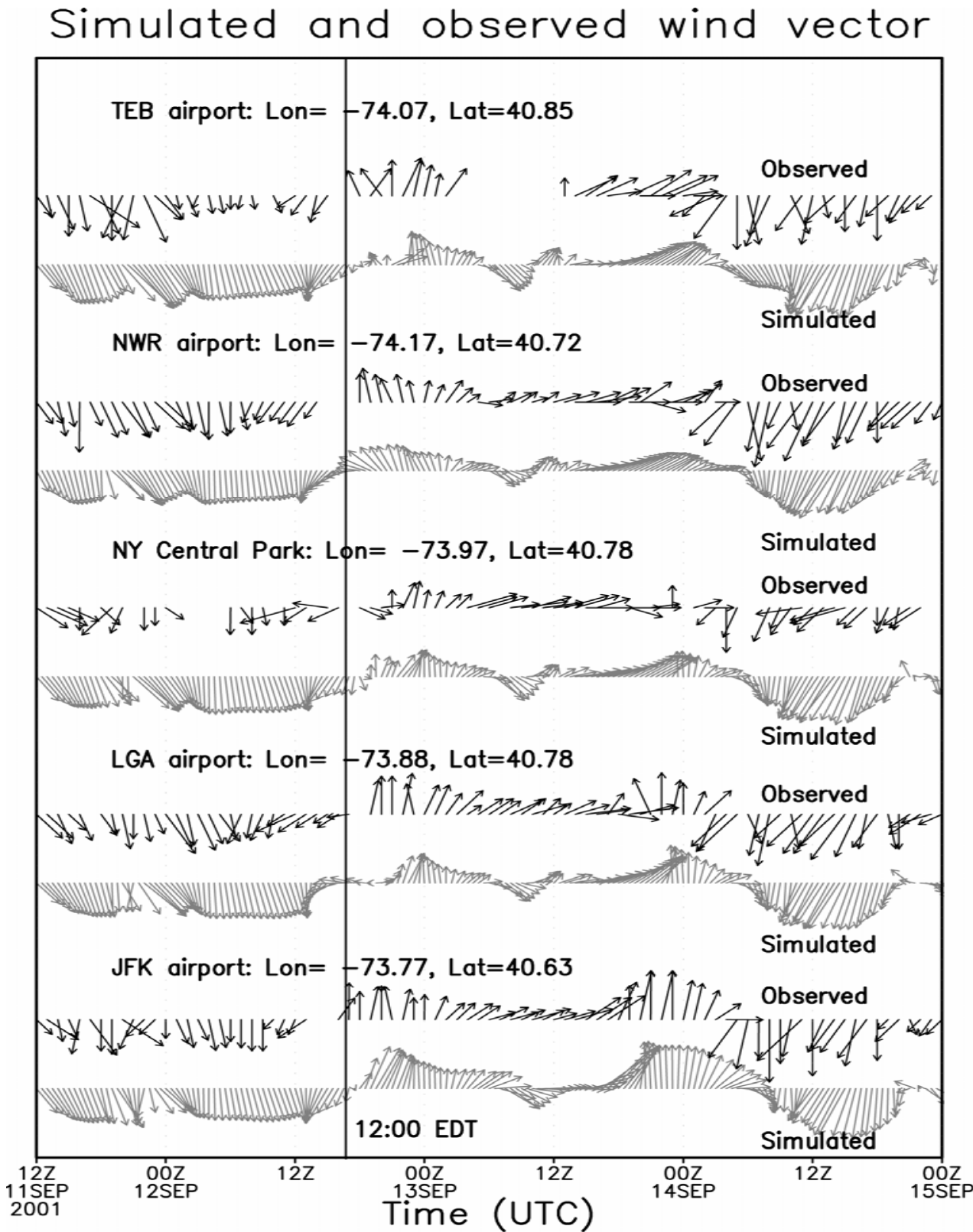






Simulated and observed surface wind vectors for ASOS station locations in the vicinity of the WTC.

Vertical solid line shows 1200 EDT, when the plume was observed by Landsat and MISR.

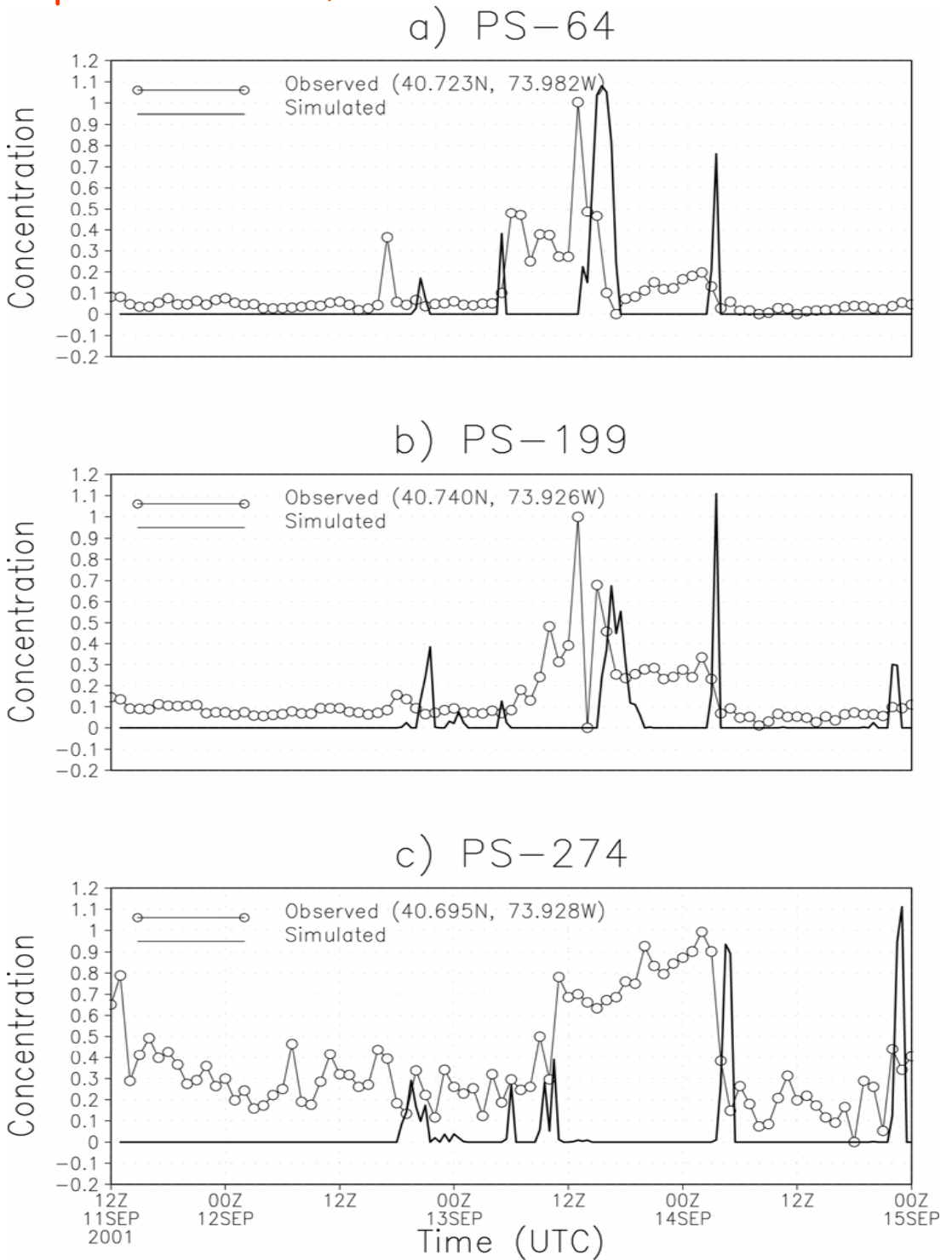


Modeled and Observed $PM_{2.5}$ Concentrations at 3 Locations
September 11-15, 2001

(a) Public School (PS)-64 in lower Manhattan, sampled at grid 3 resolution.

(b) PS-199 in Queens, sampled at grid 2 resolution.

(c) PS-274 in Brooklyn, sampled at grid 2 resolution.



~3km E

~7km E

~8km SE

Plume Simulations for September 12 at 11:30, 12:00, and 12:30 EDT

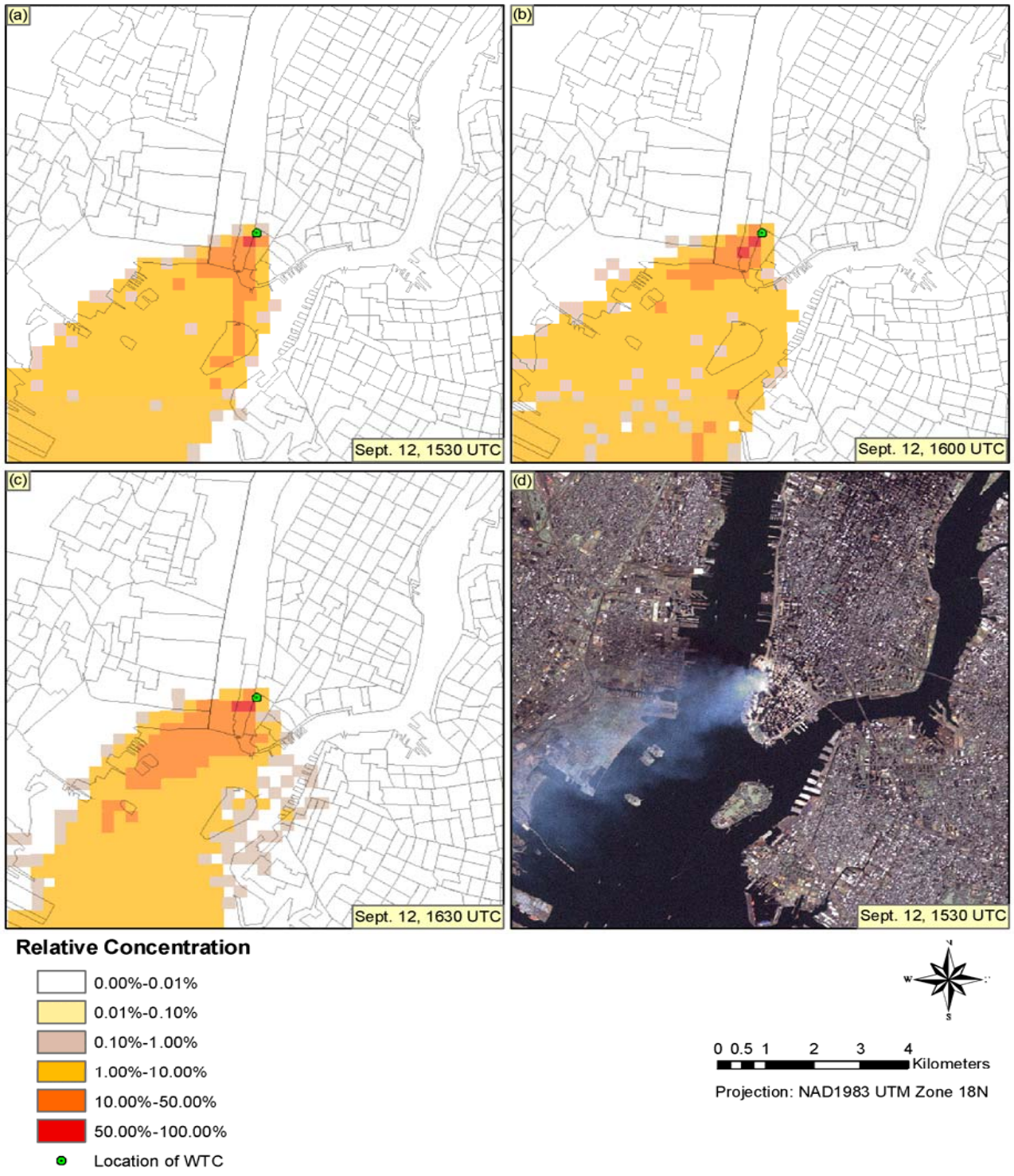
Normalized tracer concentrations averaged from 600m to 1000m on September 12, 2001:

(a) 1530 UTC (1130 EDT)

(b) 1600 UTC (1200 EDT)

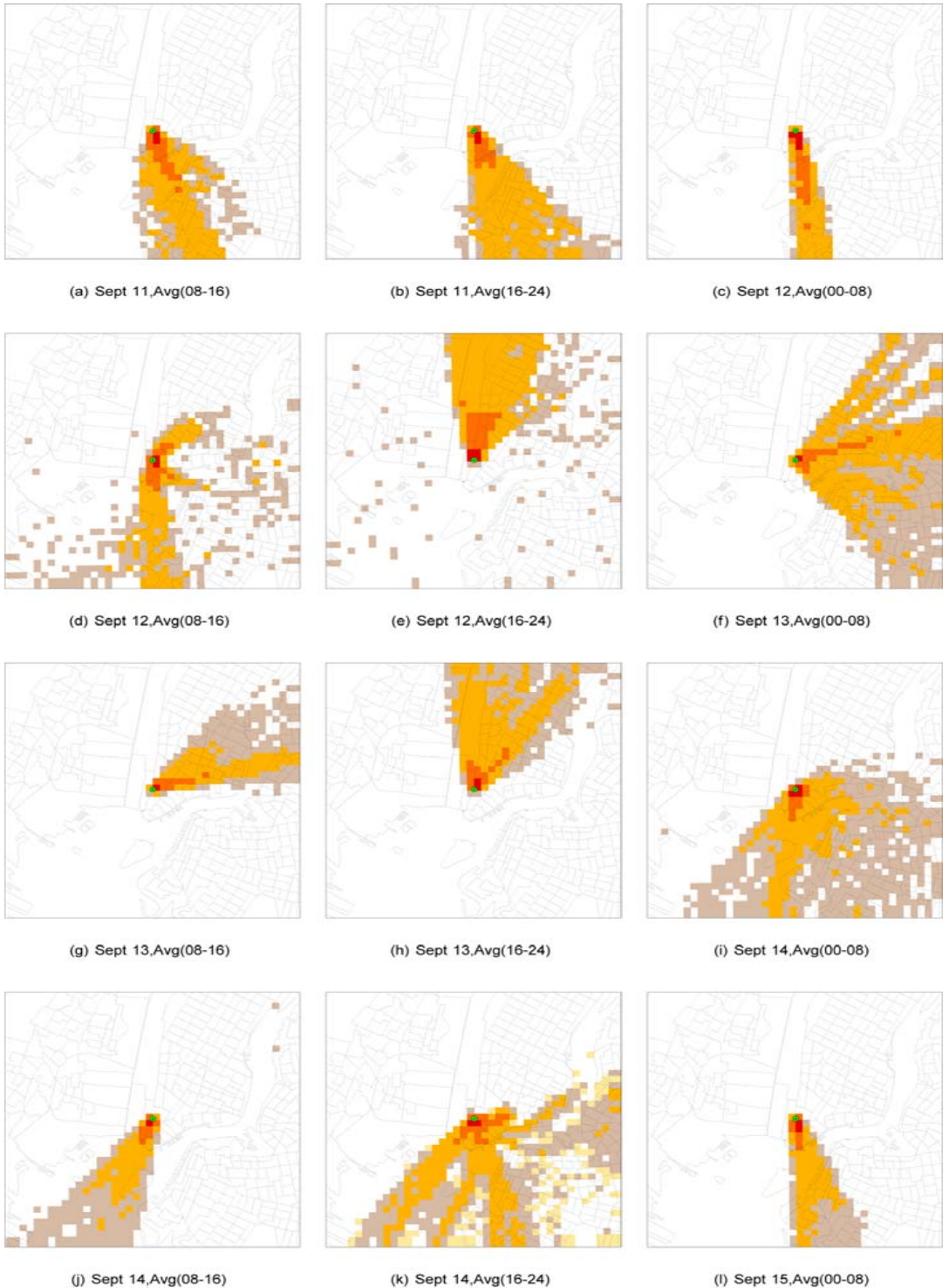
(c) 1630 UTC (1230 EDT)

(d) Landsat image at 1530 UTC (1130 EDT) on September 12 showing the plume blowing southwest.

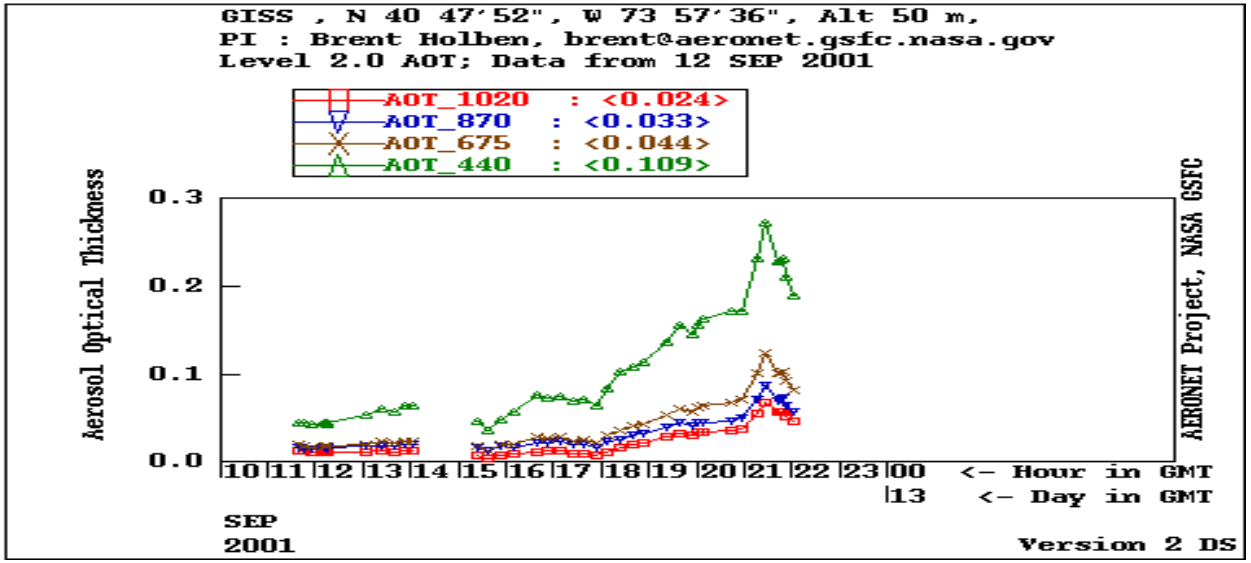


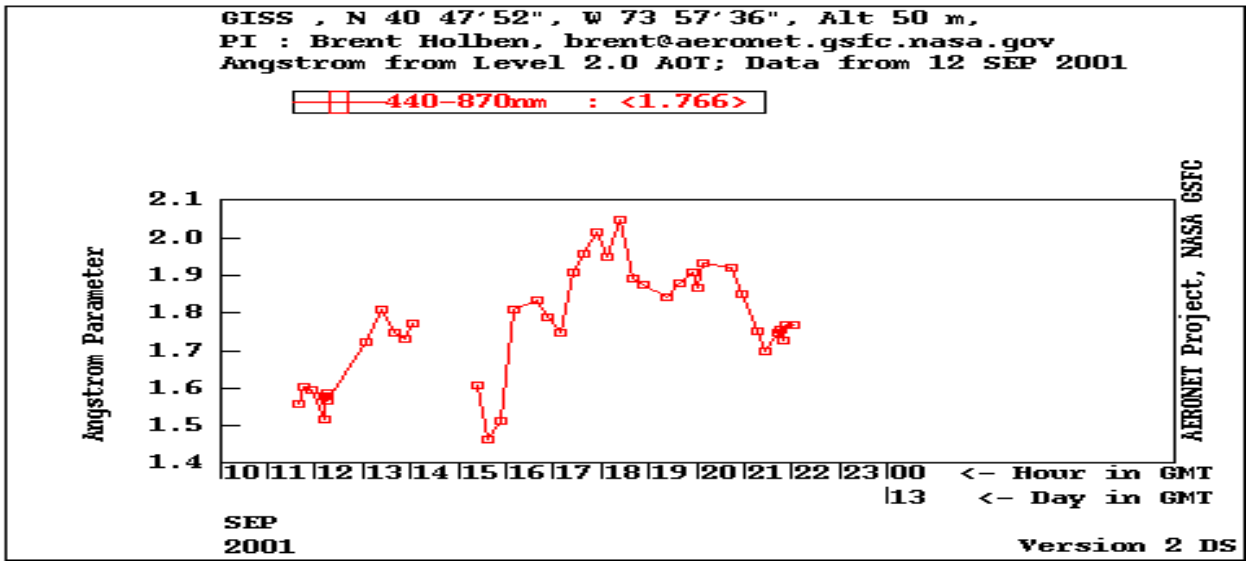
Simulated Tracer Concentrations at 10m Elevation
September 11-15

Simulated 8-hour average normalized low-level tracer concentrations for September 11-15 at the altitude of 10m.

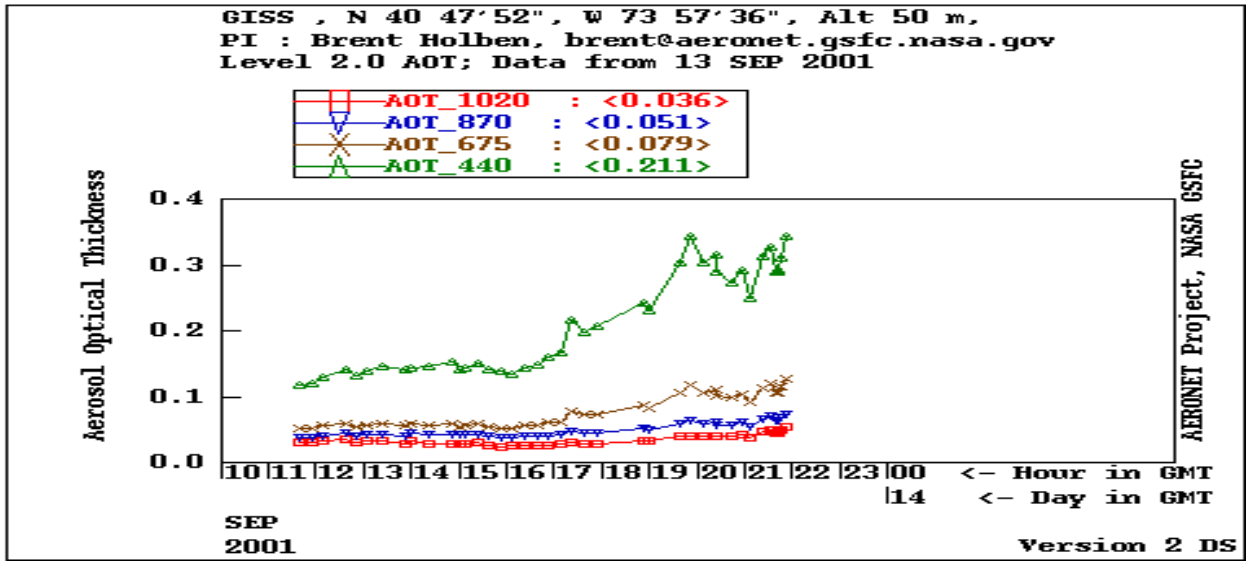


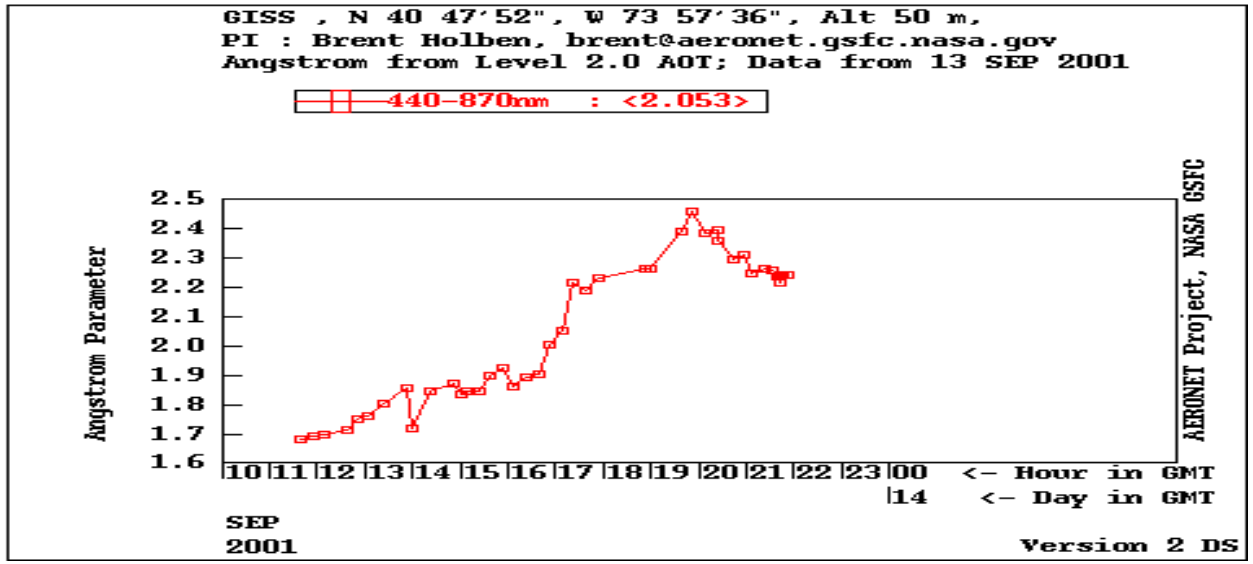
AERONET Observations for September 12, 2001





AERONET Observations for September 13, 2001





SUMMARY:

- This study demonstrates that the combination of numerical modeling and ground- and space-based observations allows reconstruction of the aerosol plume from the WTC site for the entire period of interest. The aerosol retrievals from ground- and space-based instruments provide important constrains for the plume simulations.

- The MISR retrievals allow better calibration of the surface estimates of plume altitude. The vertical structure of the fine-scale wind field also appears to be consistent with the MISR altitude estimates.

- AERONET observations are indicative of plume characteristics on September 12-13, when aerosol optical depth at the GISS site in the Upper Manhattan increased to about ~0.3 (at 440 nm). The angstrom exponent increased to 1.8 on September 12 and to 2.2 in the late afternoon on September 13 showing arrival of fine particles.

- The effective peak fine PM release rate from the fire at Ground Zero must be in the range 10-200g/s to be consistent with $PM_{2.5}$ concentrations observed in Manhattan, Brooklyn, and Queens during the 3 days following the collapse of the WTC.