The Influence of Meteorological Phenomena on Midwest $PM_{2.5}$ Concentrations: A Case Study Analysis

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Acknowledgments

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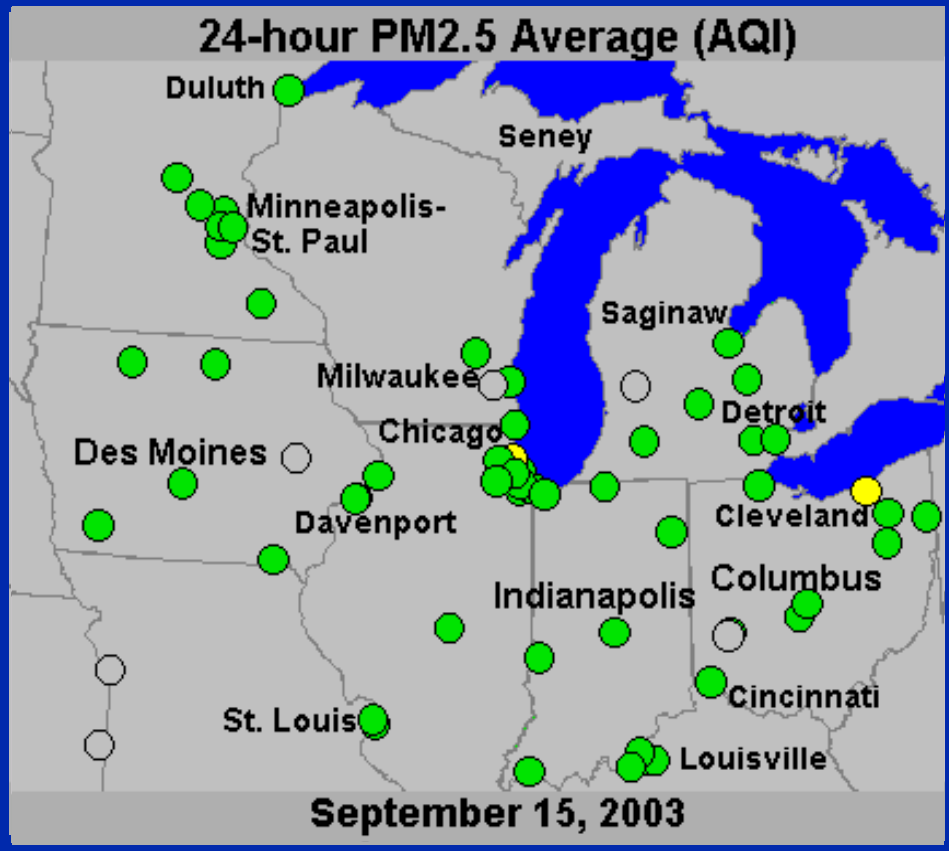
Introduction

- Starting in October 2003, current- and next-day forecasts for $PM_{2.5}$ were issued for over 150 cities throughout the United States.
- A better understanding of the processes, especially fronts and unusual events, that impact $PM_{2.5}$ is needed.
- As part of the effort to better understand the influence of meteorological phenomena and unusual events on $PM_{2.5}$, a case study was performed for the Midwest for September 7-14, 2003.

Overview of Case Study (1 of 3)

Key Issue –
Forecasts predicted quick frontal passage to clean out Midwest

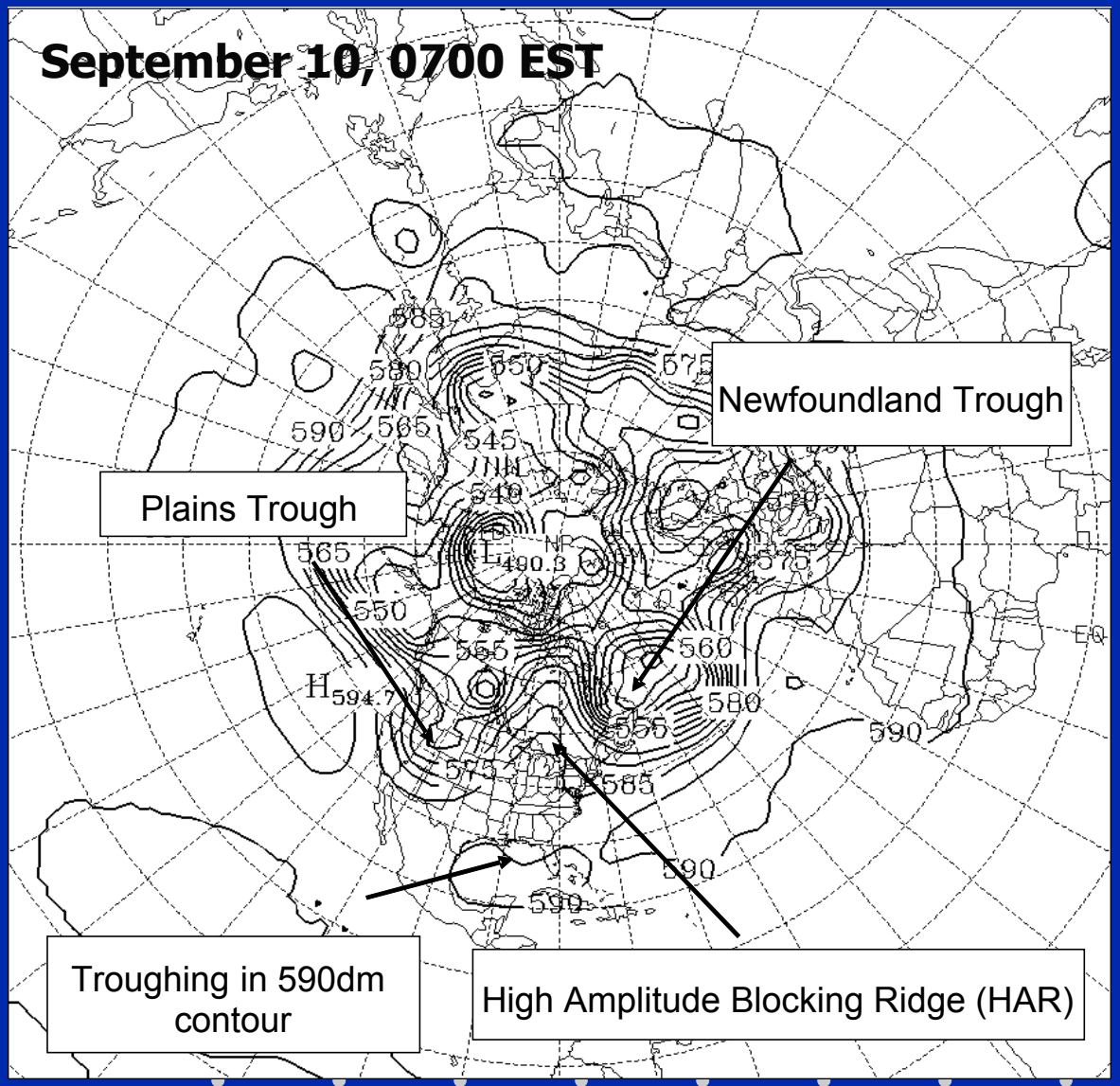
Smoke from wildfires may have contributed to local $PM_{2.5}$ (Kittaka et al., 2004)



$PM_{2.5}$ levels were high throughout the midwestern United States with Moderate and Unhealthy for Sensitive Groups levels

Overview of Case Study (2 of 3)

- Synoptic blocking feature influenced smaller scale features by deflecting aloft short waves.
- Movement of upper-level features influenced the motion of surface cyclones and associated frontal boundaries.
- Frontal movement during the episode had a dramatic influence on local weather and air quality conditions.

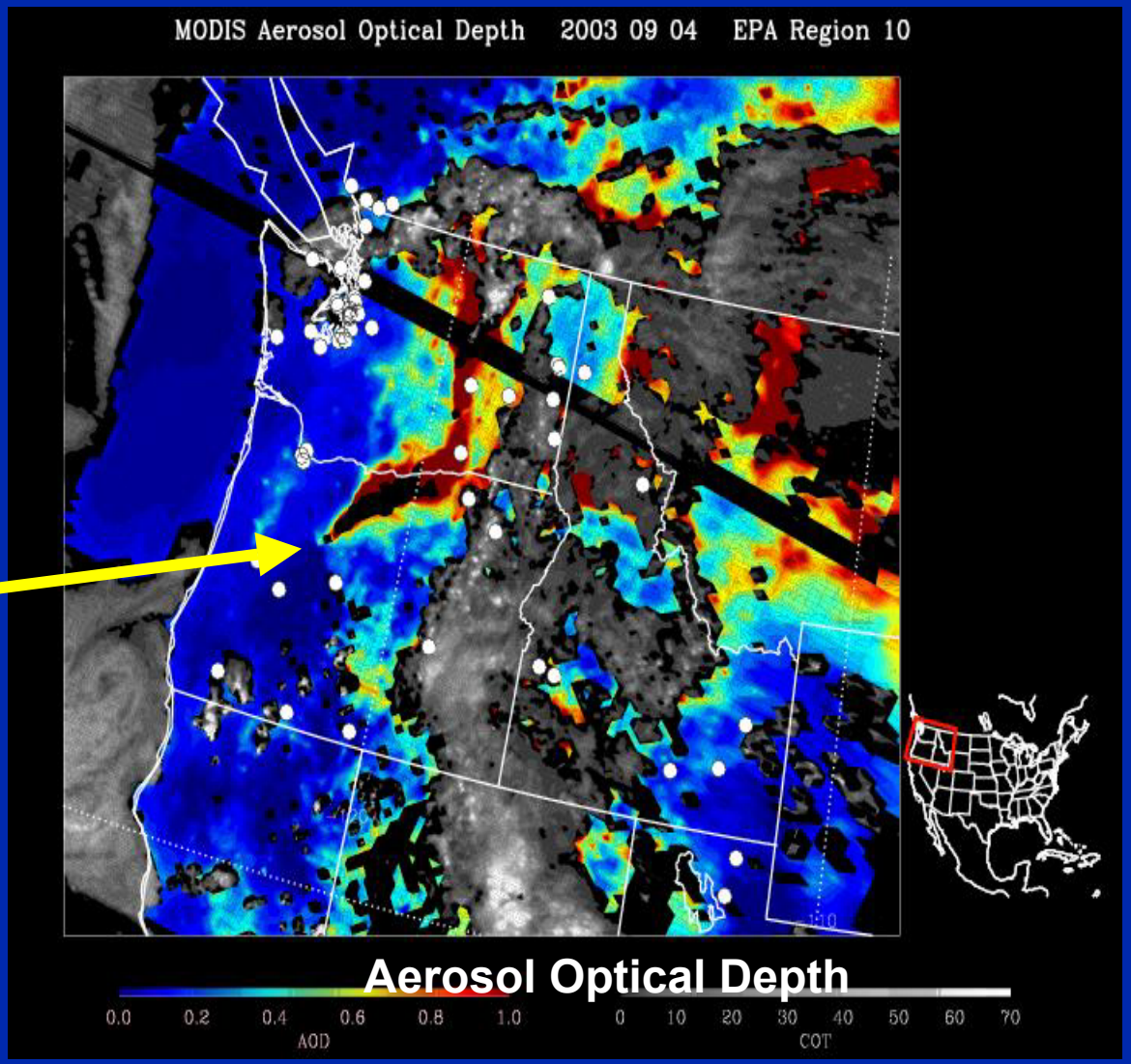


Overview of Case Study (3 of 3)

MODIS observations of Pacific NW wildfires on September 4, 2003

Bear Butte Fire & Booth Fire wildfire complex
Northwest Oregon on September 4, 2003

MODIS imagery from Kittaka et al., 2004

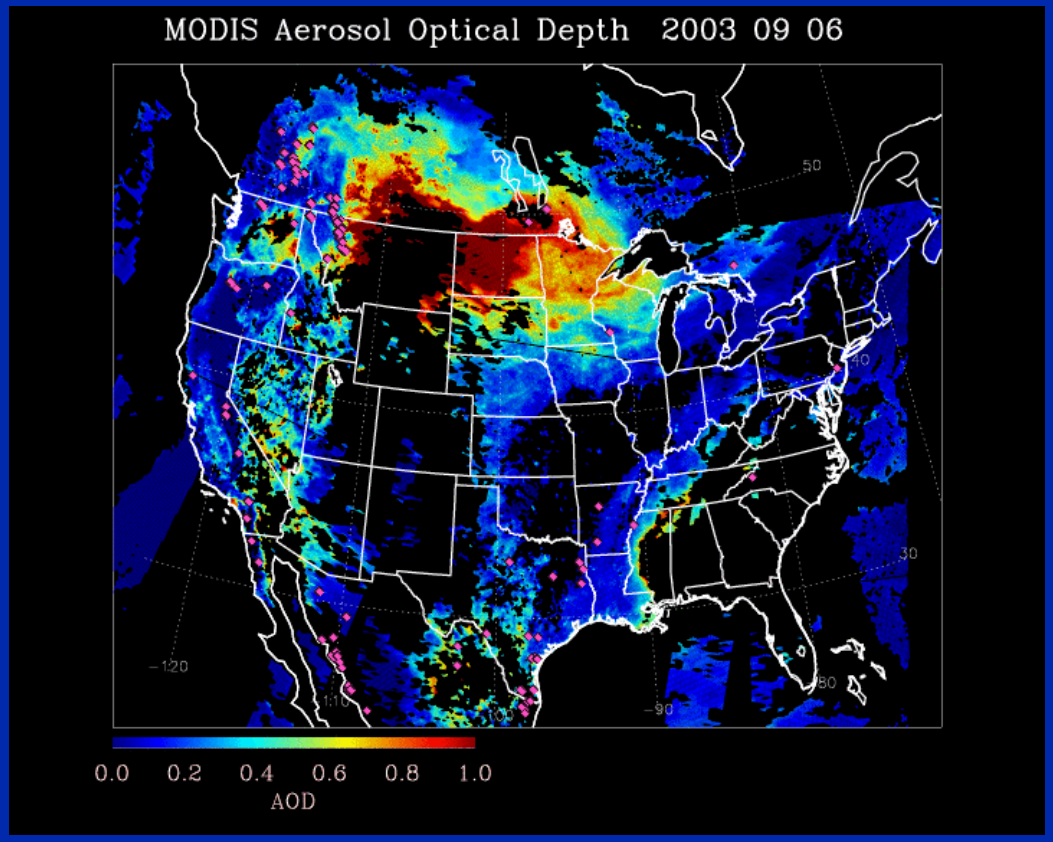


NASA MODIS and AOD

- NASA has two high resolution polar orbiting satellites (MODIS)
- Satellites pass over areas around local noon
- Satellites measure aerosol optical depth (AOD), or total aerosols in the column

September 6, 2003

Smoke over Dakotas and Minnesota, headed toward western Great Lakes



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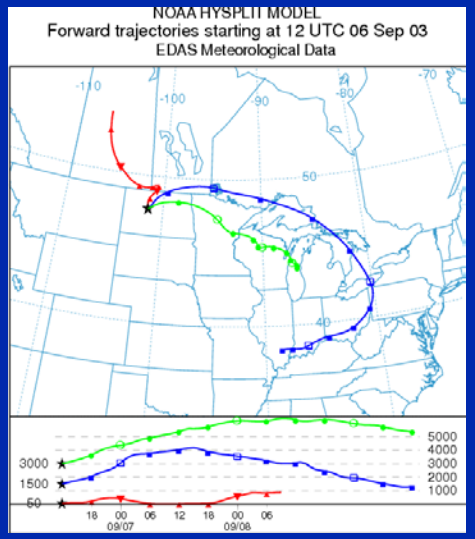
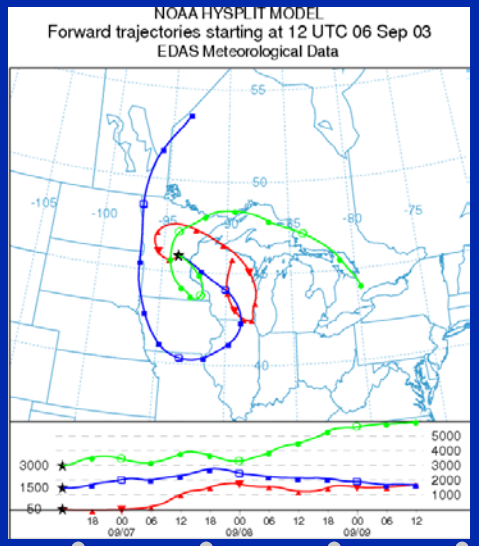
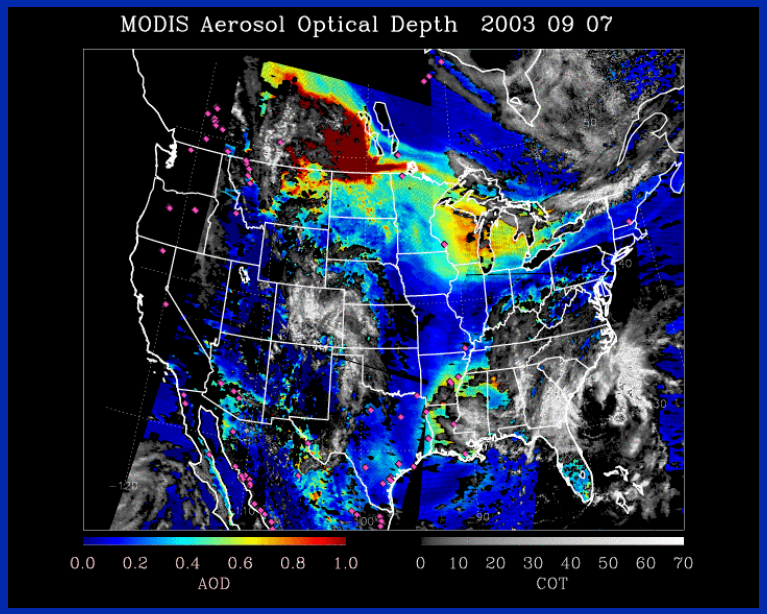




September 7, 2003

- Aerosols and/or smoke over the western Great Lakes
- Surface decoupled from upper-air all day



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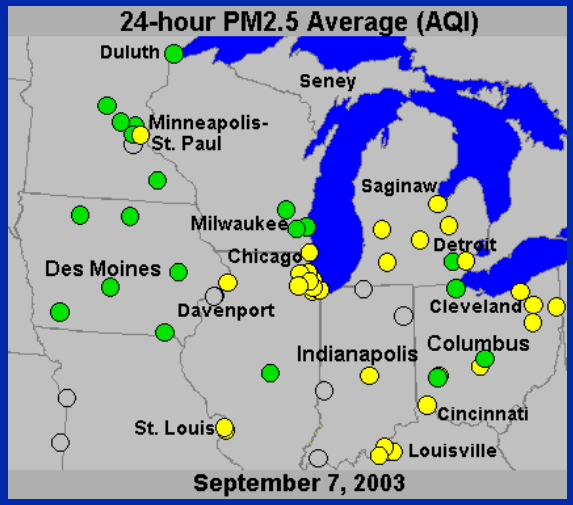
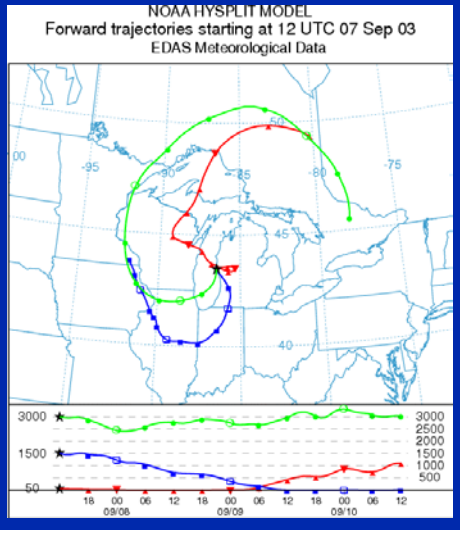
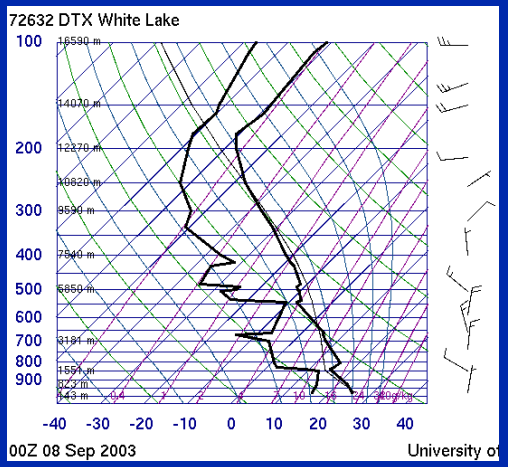
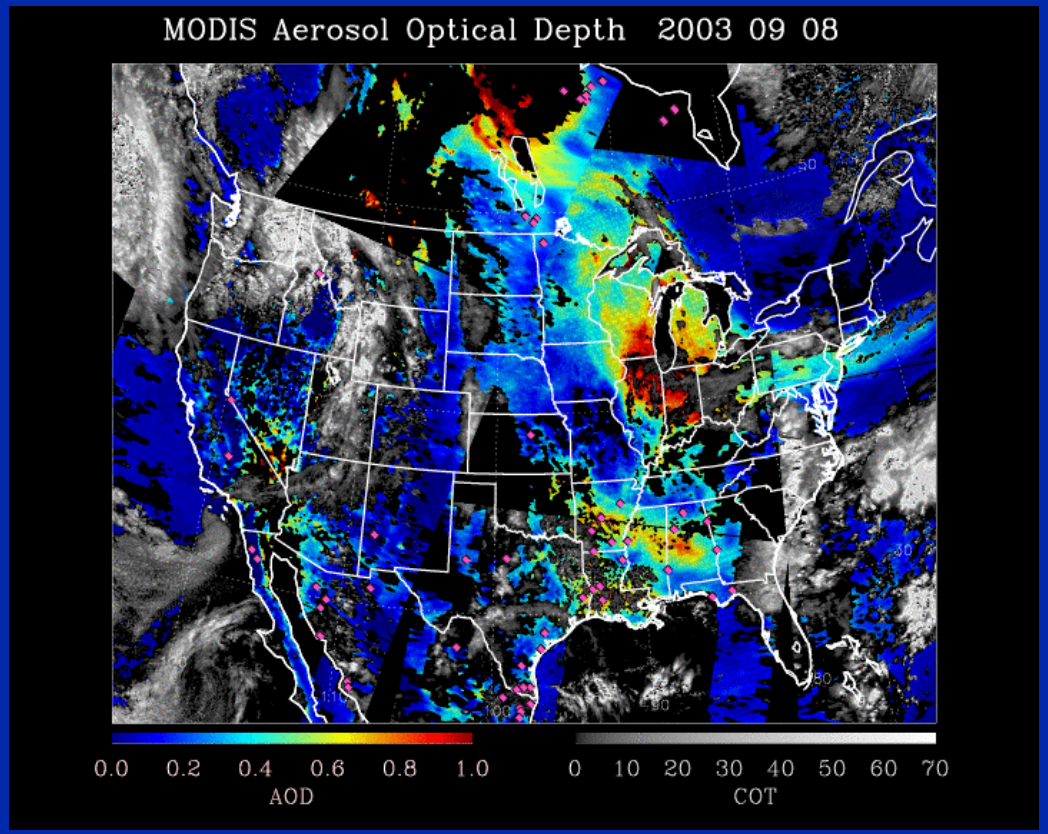






September 8, 2003

- Aerosols remained over Midwest
- Surface remained decoupled



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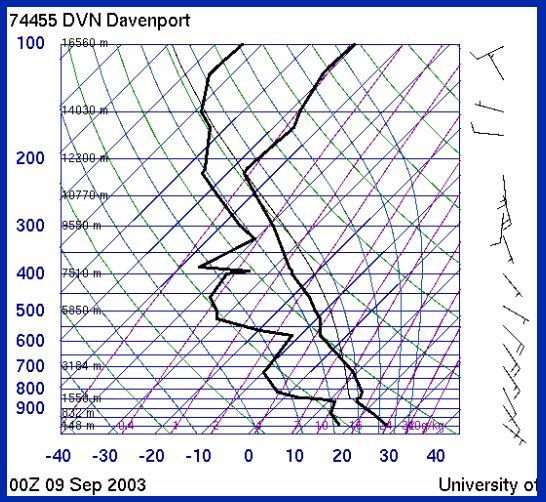
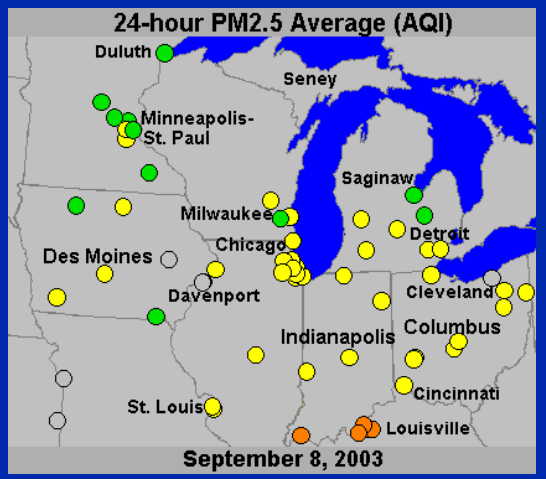
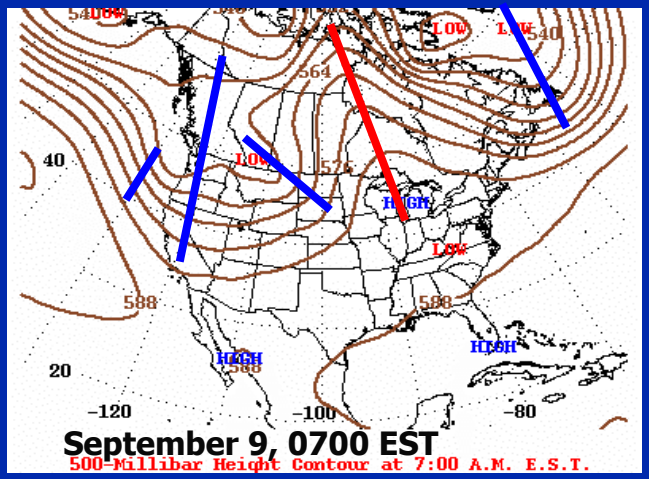
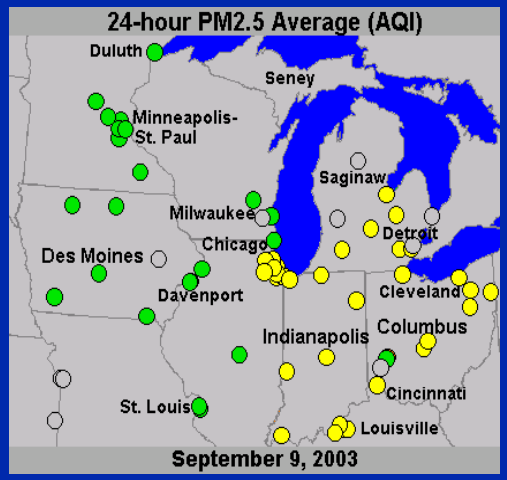


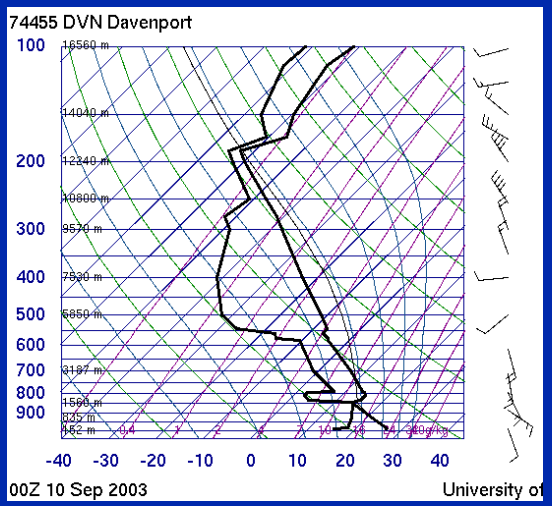


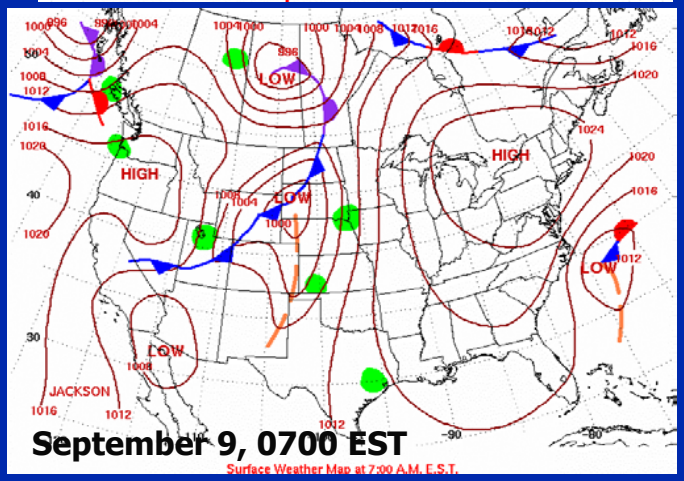
September 9, 2003

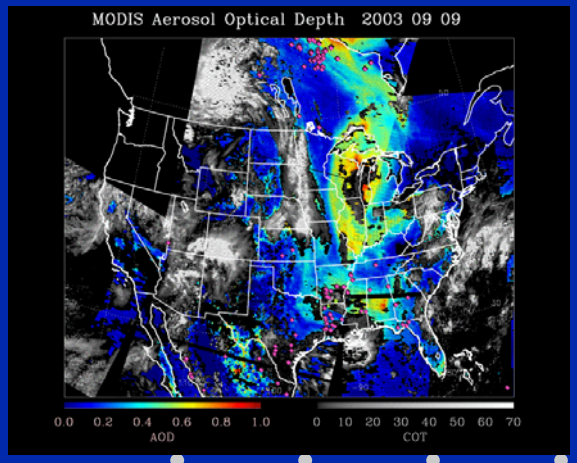
- Blocking by a high amplitude ridge (HAR) kept short-wave troughs from reaching the Midwest. Surface remained decoupled from upper-air.









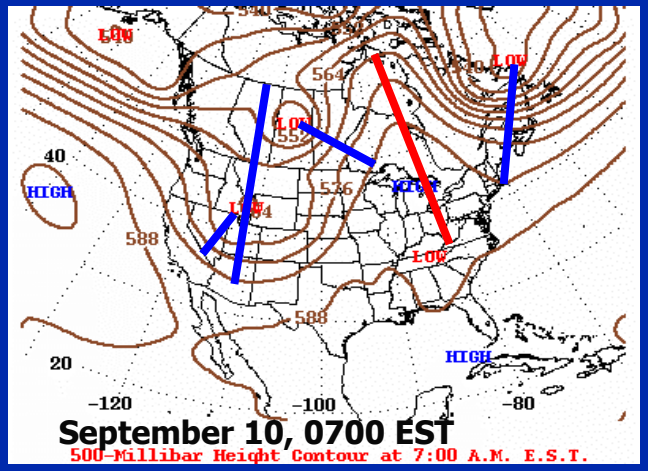


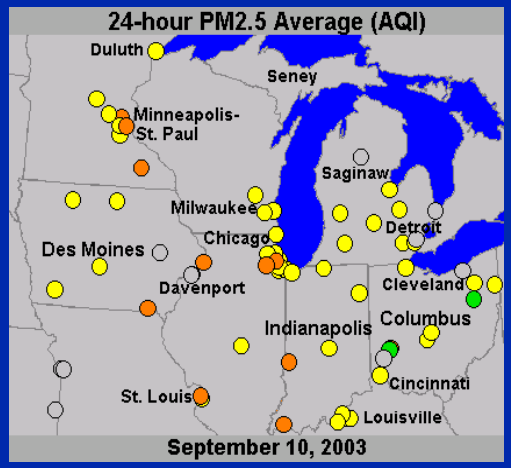
Aerosols remained over Midwest.

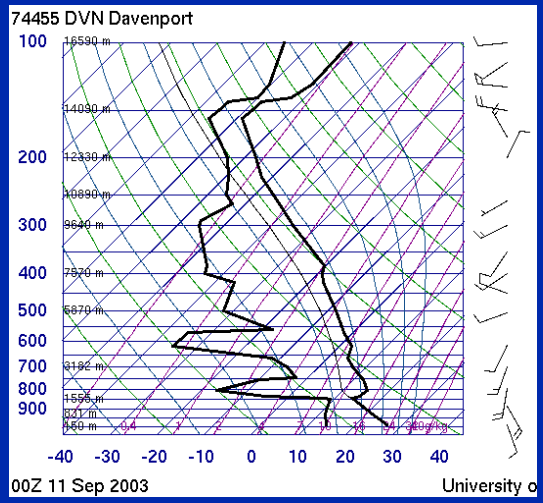
Image from NASA

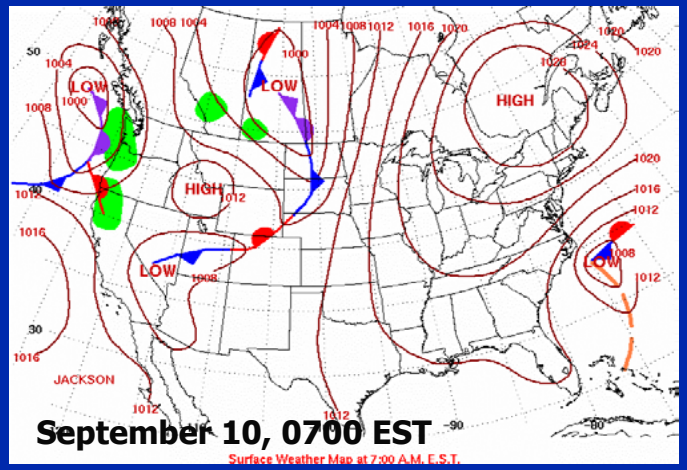
September 10, 2003

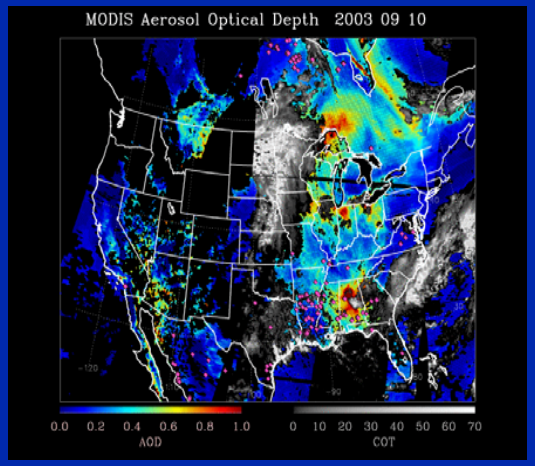
Blocking by a HAR kept short-wave troughs from reaching the Midwest. Surface and upper-air remained decoupled.









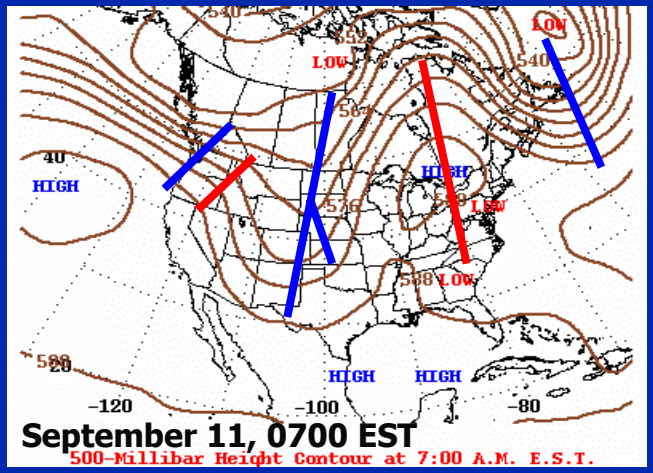


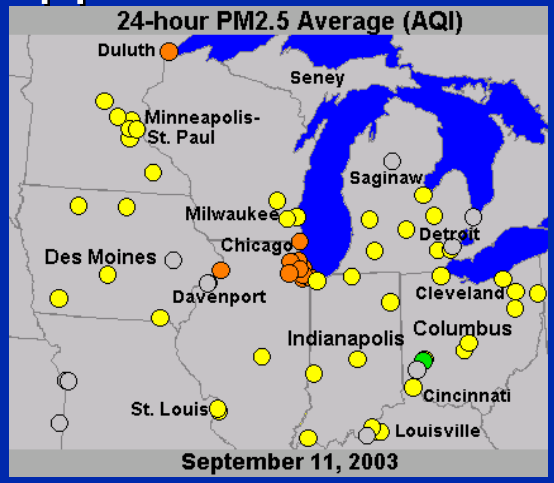
Smaller area of high aerosol concentrations

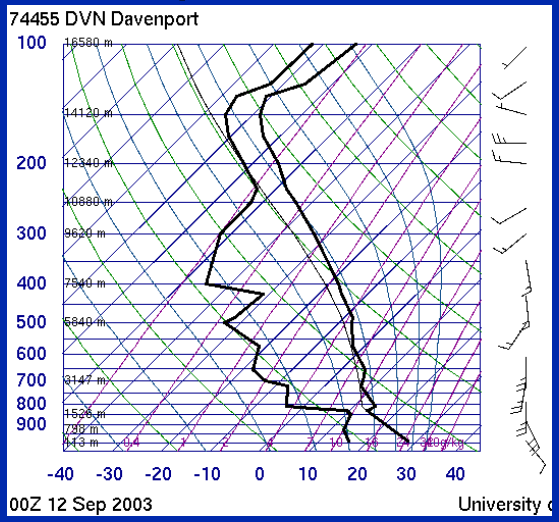
Image from NASA

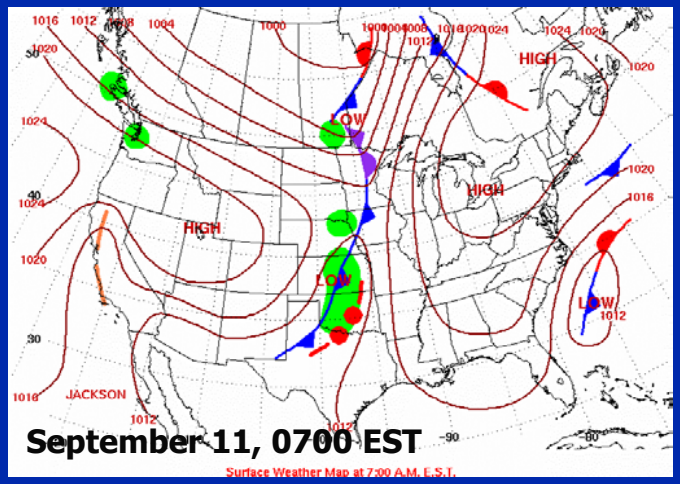
September 11, 2003

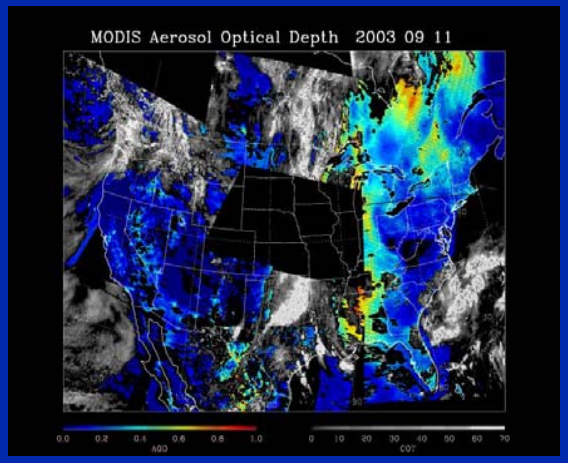
- HAR slid east but surface cyclogenesis behind the initial frontal boundary and low pressure center retarded front motion. Surface and upper-air remained decoupled.









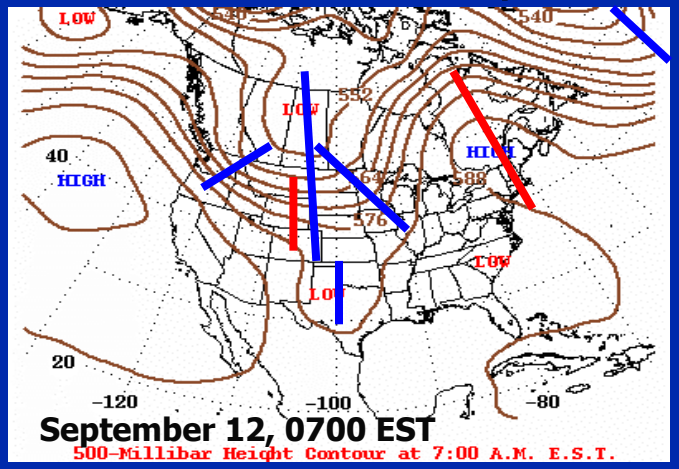


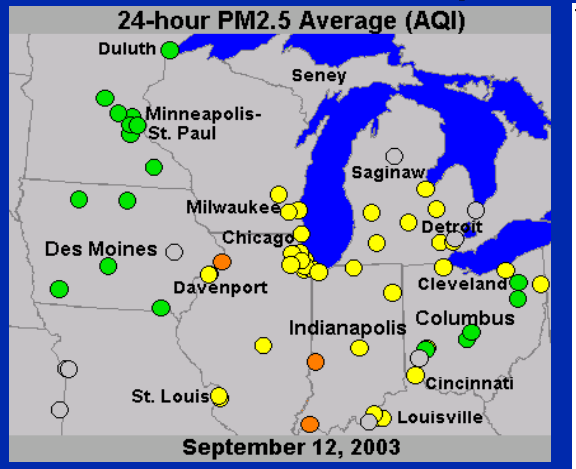
AOD not available for large portion of Midwest

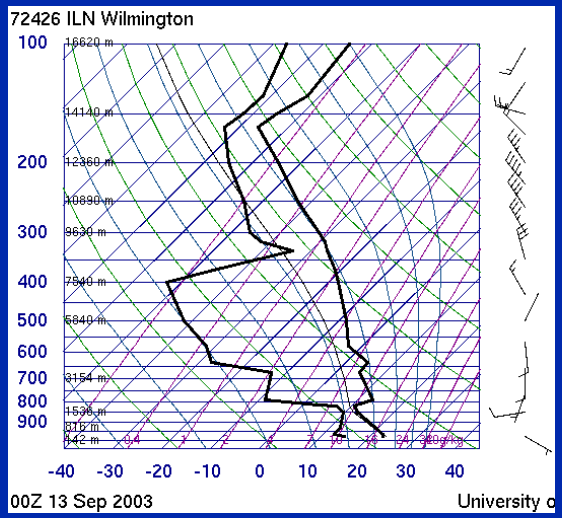
Image from NASA

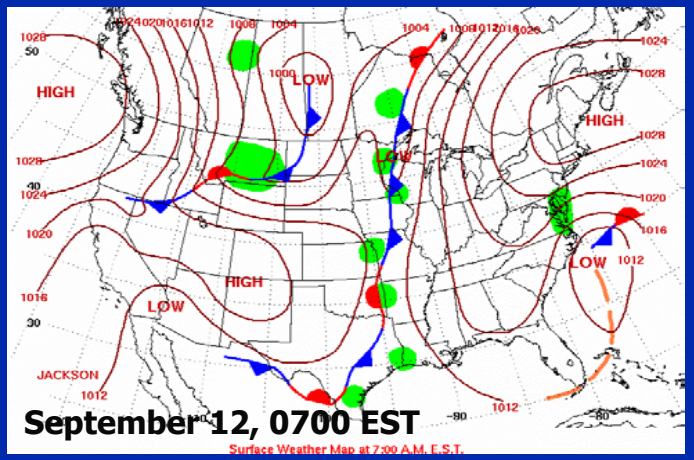
September 12 , 2003

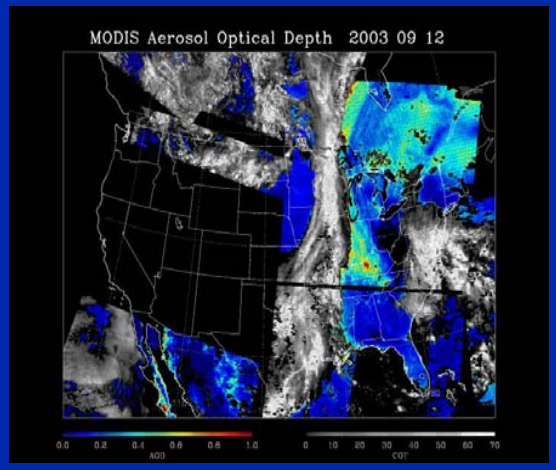
- HAR slid east, but surface cyclogenesis behind the initial frontal boundary and low pressure center retarded front motion. Atmosphere remained decoupled.









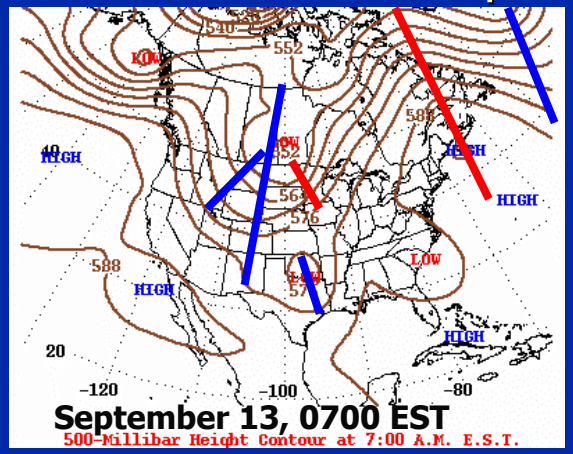


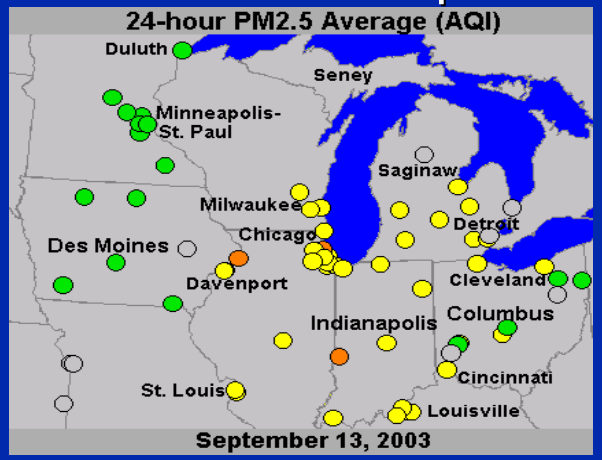
- Front evident as band of clouds
- Area of high AOD pushed south

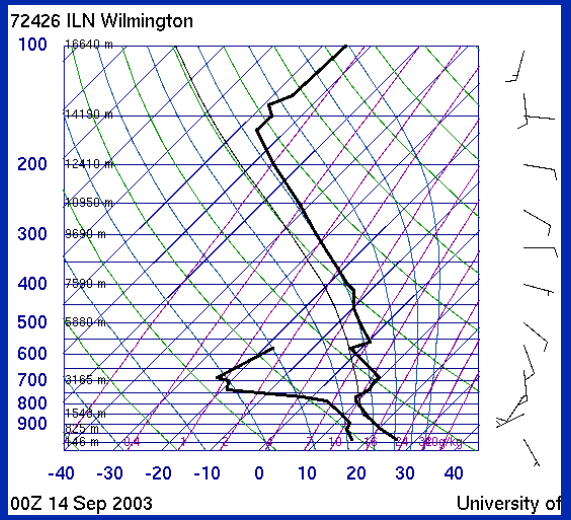
Image from NASA

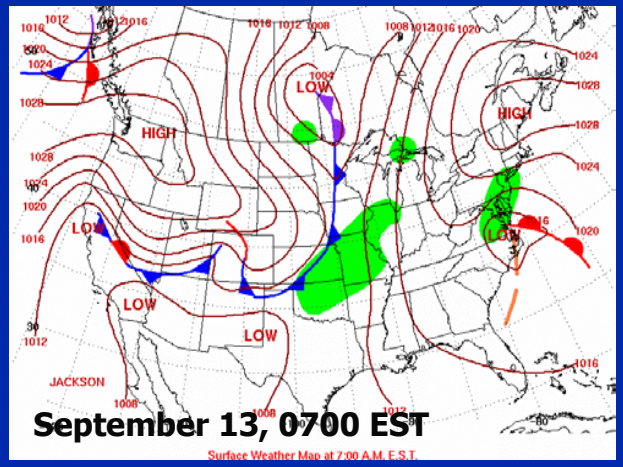
September 13, 2003

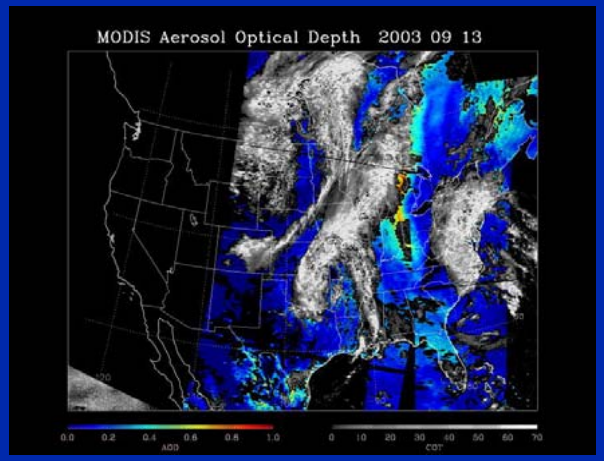
Short wave intensified larger-scale atmospheric wave and was responsible for pattern progression. This caused the surface features to progress which was ultimately responsible for changes in air quality conditions. Atmosphere remained decoupled.









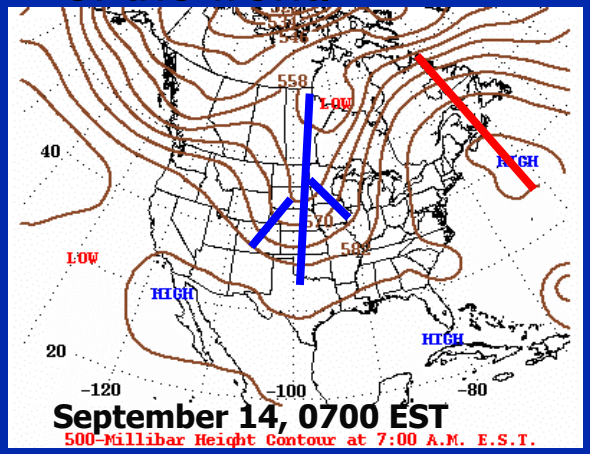


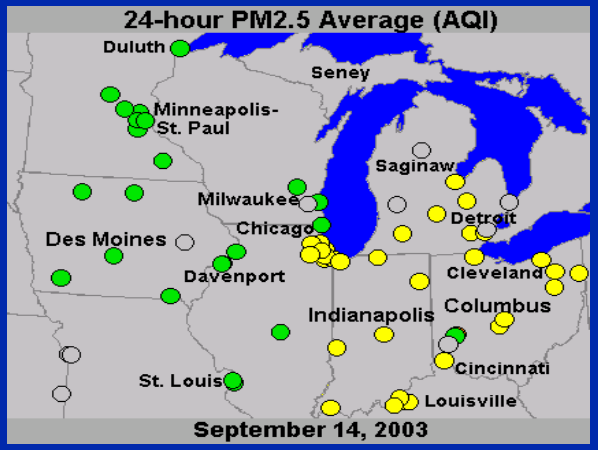
Clouds obscure AOD over Midwest

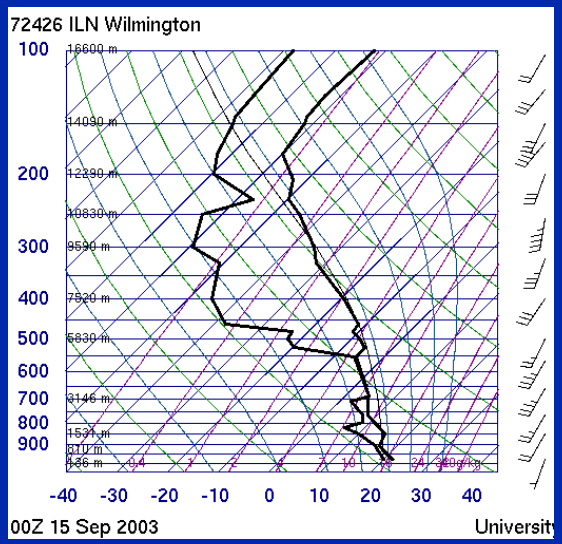
Image from NASA

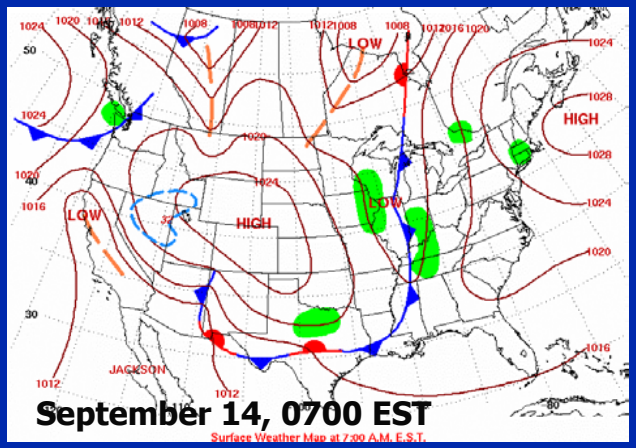
September 14, 2003

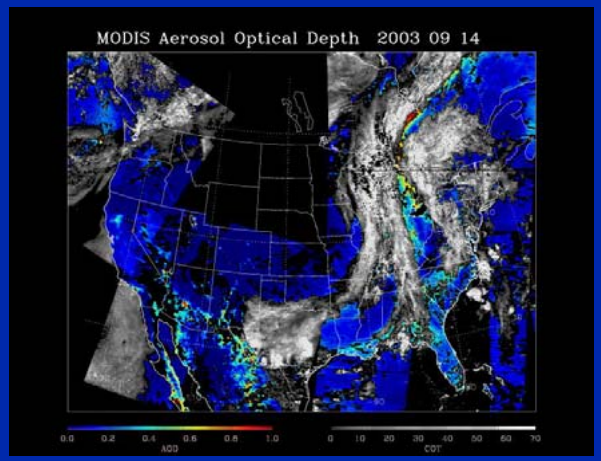
Short wave intensified larger scale atmospheric wave and was responsible for pattern progression. This caused the surface features to progress which was ultimately responsible for changes in air quality conditions. Atmosphere remained decoupled in eastern Midwest ahead of the front.









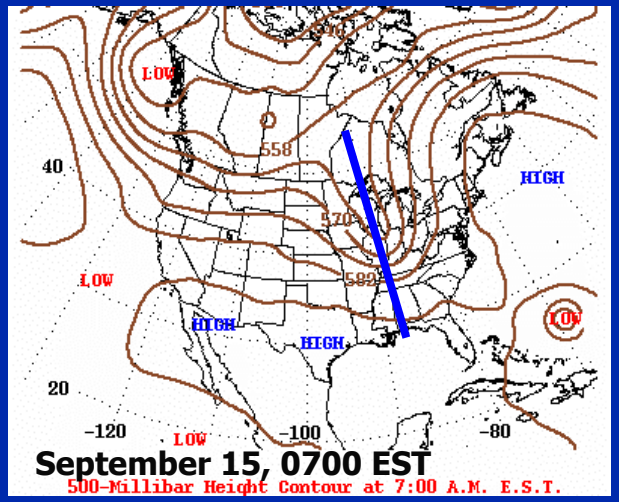


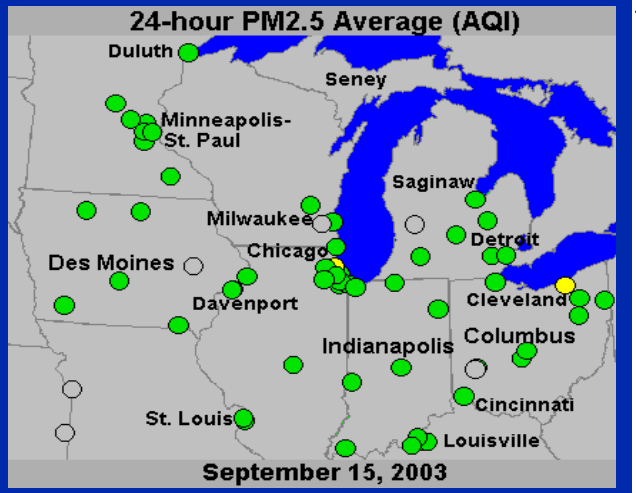
Clouds obscure AOD over Midwest

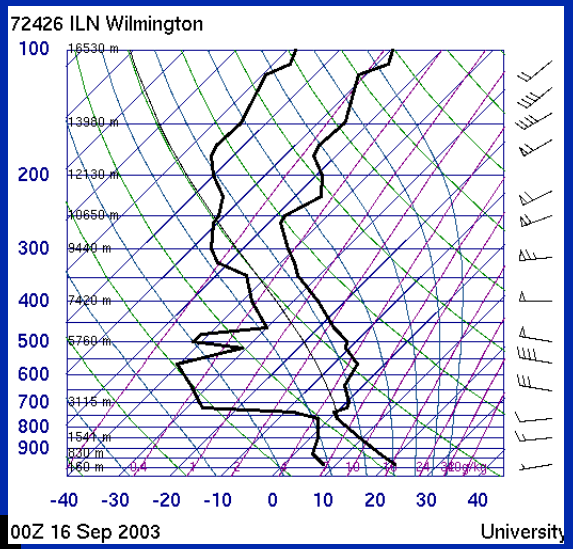
Image from NASA

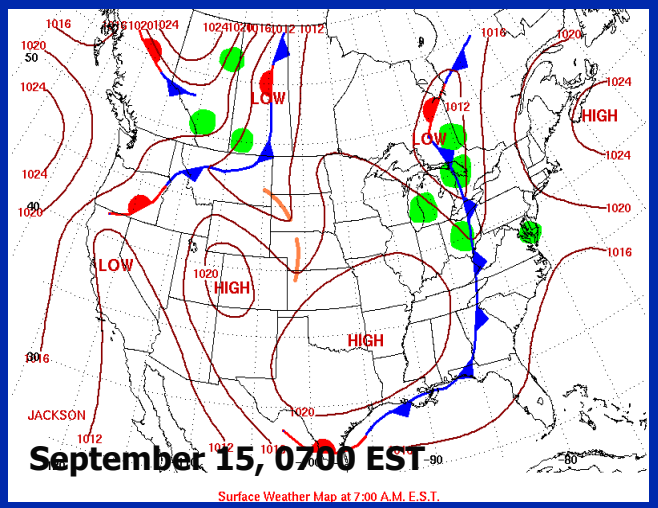
September 15, 2003

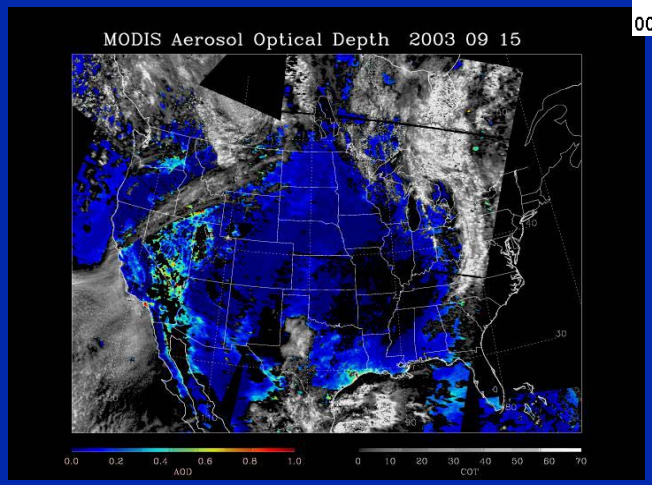
Upper-air trough and surface front passed through the area. Atmosphere mixed up to 700 mb.









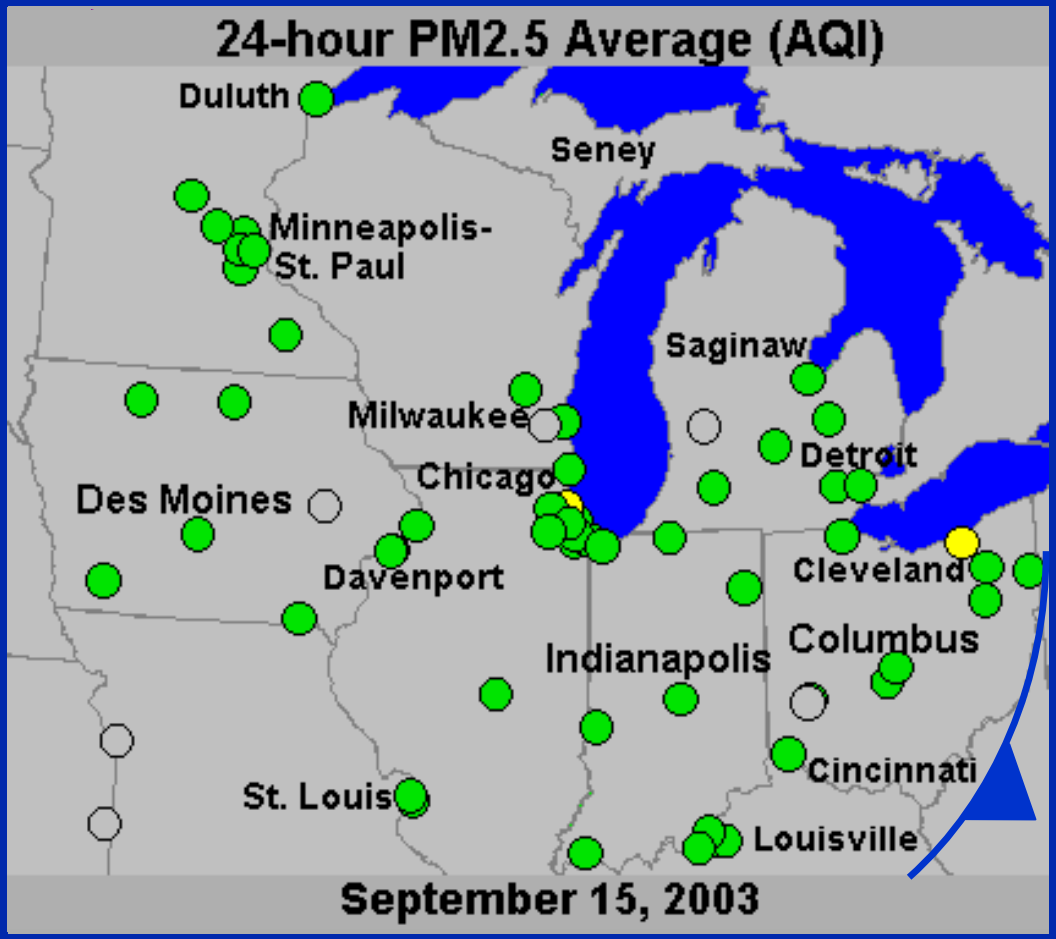


Low AOD throughout the region behind the front

Image from NASA

Fronts and $PM_{2.5}$ Concentrations

Distinct difference between pre- and post-frontal air masses



Conclusions (1 of 2)

Synoptic Weather

- Upper-level weather strongly influences the development and movement of surface weather features such as surface cyclones.
- Surface cyclogenesis can cause large variations in frontal motion.

Regional Weather

- Determination of frontal passage is critical.
- Frontal stagnation can cause regional $PM_{2.5}$ concentrations to remain high for extended periods.
- Regional stagnation associated with surface and aloft high pressure tends to produce the best conditions for regional build-up of $PM_{2.5}$.

Conclusions (2 of 2)

Influence of Smoke

- MODIS AOD indicated smoke from northwestern wildfires moved over the Midwest.
- More information needed to determine if smoke mixed down to the surface
  - Temperature sounding data indicate that it may not have
  - Descending trajectories indicate otherwise (Kittaka et al., 2004).
- Additional analysis
  - $PM_{2.5}$ composition (potassium ion and OC/EC ratio)
  - Total Ozone Mapping Spectrometer (TOMS) aerosol index (shows aerosols present aloft)

Reference

Kittaka C., Szykman J., Pierce B., Al-Saadi J., Neil D., Chu A., Prins E., and Holdzkom J. (2004) Utilizing MODIS satellite observations to monitor and analyze fine particulate matter ($PM_{2.5}$) transport event. Paper no. 1.3 presented at the *84th Annual AMS Meeting in Seattle, WA, January 11-15, 2004*.