

THE HAZARD MAPPING SYSTEM AND THE TRANSFER OF THIS TECHNOLOGY FOR GLOBAL FIRE AND SMOKE EMISSIONS

California

LOS ANGELES ●

SAN DIEGO ●

*Pacific
Ocean*

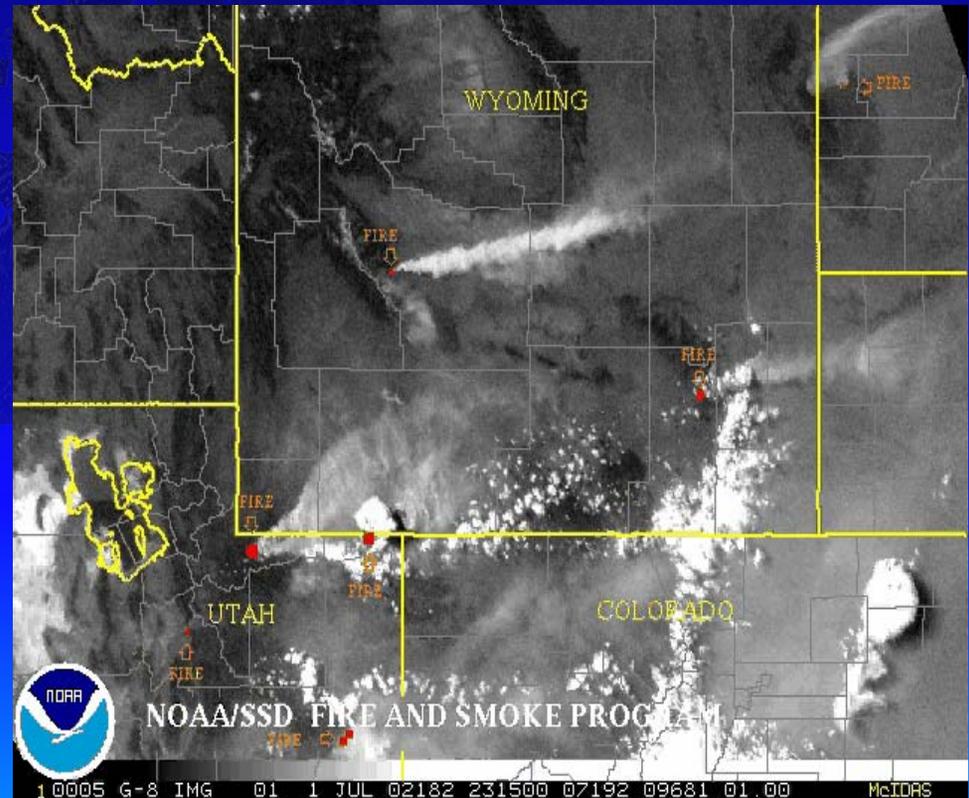
**Jamie Kibler, Mark Ruminski, John Simko,
Wilfred Schroeder**

GOFC/Gold Fire Monitoring and Mapping Implementation Team
2nd Workshop on Geostationary Fire Monitoring and Applications
December 4-6, 2006, EUMETSAT, Darmstadt, Germany



MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

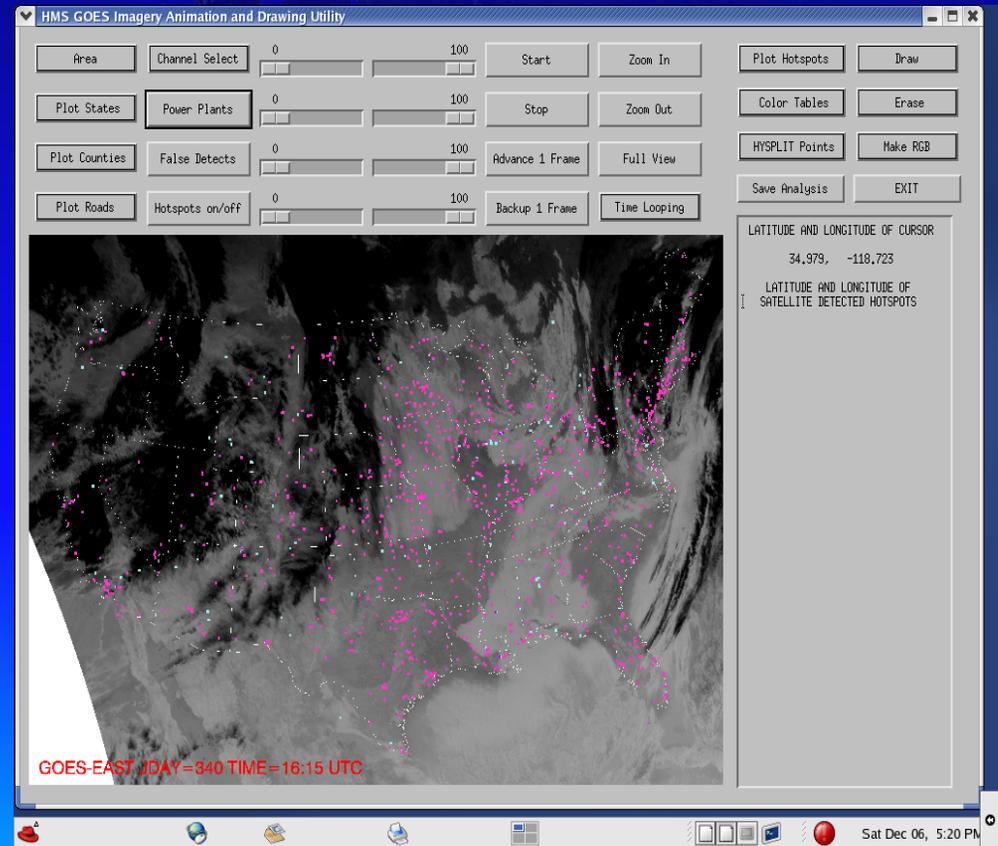
In 1998 NOAA/NESDIS began a fire and smoke analysis as smoke from Mexico began moving into the southern US and affecting health, transportation and other forms of industry. The analysis at the time was done in the format of individual sectors.





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

- In July 2002 the fire and smoke analysis began on the Hazard Mapping System (HMS) for the continental US and eventually Alaska, Hawaii, Canada and Mexico/Central America.





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

The HMS GUI

The screenshot displays the HMS GUI interface, which is organized into several functional sections:

- Control Panels:** Located at the top, these include:
 - Area:** A button to select the geographic area.
 - Channel Select:** A slider control ranging from 0 to 100.
 - Plot States:** A button to toggle state-related data.
 - Power Plants:** A slider control ranging from 0 to 100.
 - Plot Counties:** A button to toggle county-level data.
 - False Detects:** A slider control ranging from 0 to 100.
 - Roads/Light:** A button to toggle road and light data.
 - Hotspots on/off:** A slider control ranging from 0 to 100.
- Action Buttons:** A central cluster of buttons for navigation and processing:
 - Start** and **Stop**
 - Zoom In** and **Zoom Out**
 - Advance 1 Frame** and **Backup 1 Frame**
 - Full View** and **Time Looping**
- Display and Analysis Tools:** A right-hand panel containing:
 - Plot Hotspots** and **Draw**
 - Color Tables** and **Erase**
 - HYSPLIT Points** and **Make RGB**
 - Save Analysis** and **EXIT**
- Data Display:** A large central black area for the main map, and a text display area on the right showing:
 - LATITUDE AND LONGITUDE OF CURSOR:** 24.607, -98.939
 - LATITUDE AND LONGITUDE OF SATELLITE DETECTED HOTSPOTS:** (This section is currently empty)



MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

AUTOMATED FIRE DETECTION ALGORITHMS USED IN THE HMS

- **Wildfire – Automated Biomass Burning Algorithm (WF-ABBA) for GOES**
- **Fire Identification, Mapping and Monitoring Algorithm (FIMMA) for NOAA AVHRR**
- **MODIS MOD14 for MODIS (Terra and Aqua)**





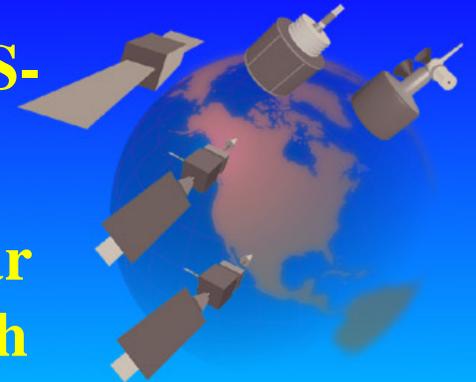
MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

SATELLITES CURRENTLY USED FOR FIRE AND SMOKE DETECTION

- **GOES 12 and GOES 11**
- **NOAA 15, 17 and 18**
- **MODIS AQUA AND TERRA**
- **Future: OMI and METOP**

Over 100 looks per day in areas of GOES-East and GOES-West overlap.

Two looks per satellite per day with Polar spacecraft in mid latitudes – more at high latitudes





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

THE FIRE AND SMOKE ANALYST THEIR JOB

- **Quality checks the fire points produced by the ABBA, FIMMA and MODIS algorithms by looking at the associated satellite data.**
- **Draws in the smoke produced by the fires. The analyst can identify the smoke as light, moderate or thick with an assigned numerical value for each plume.**
- **Provides locations of significant smoke producing fires as input to the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model which provides a 48 hour forecast of the smoke.**





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

WHY DO WE NEED INPUT FROM FIRE AND SMOKE ANALYST AND ARE NOT THE ALGORITHMS GOOD ENOUGH?

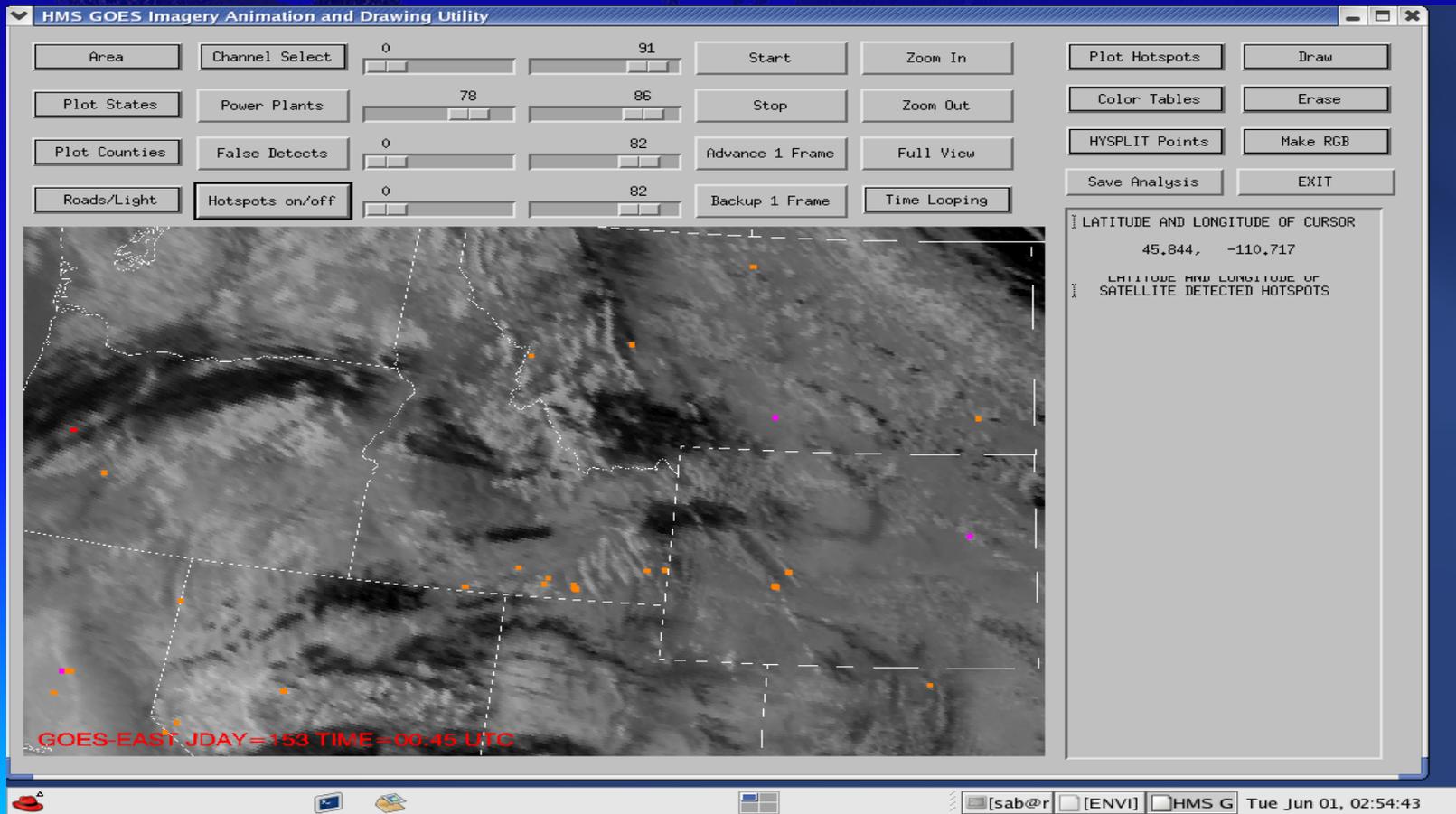
1. The reflectivity from the edge of cloud bands can be mistaken for fires by the algorithms.
2. Sun glint off water surfaces at high sun angles can generate false detects by the algorithm.
3. Urban Heat Islands and certain land types can cause the algorithm to identify false detects as fires.
4. The algorithms do not pick up all fires due to a number of reasons.
 - A. Fire does not burn hot enough or fire duration is too short
 - B. Screens are inserted into the algorithm to eliminate false detects, but sometimes they actually eliminate real fires.
 - C. Canopy issues – fires in a heavily forested area.
 - D. Many more.....





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

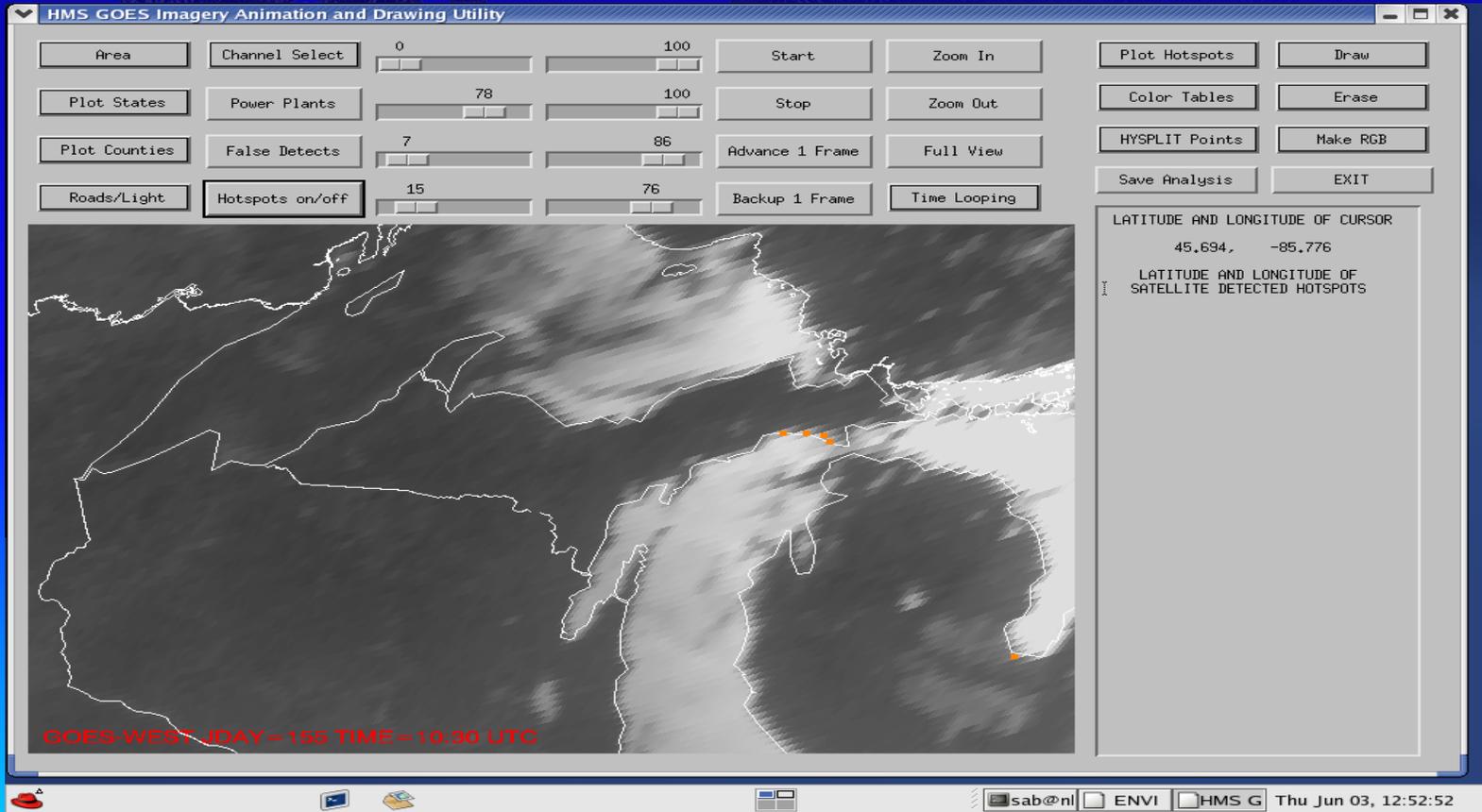
HIGHLY REFLECTIVE CLOUDS IDENTIFIED AS FIRES





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

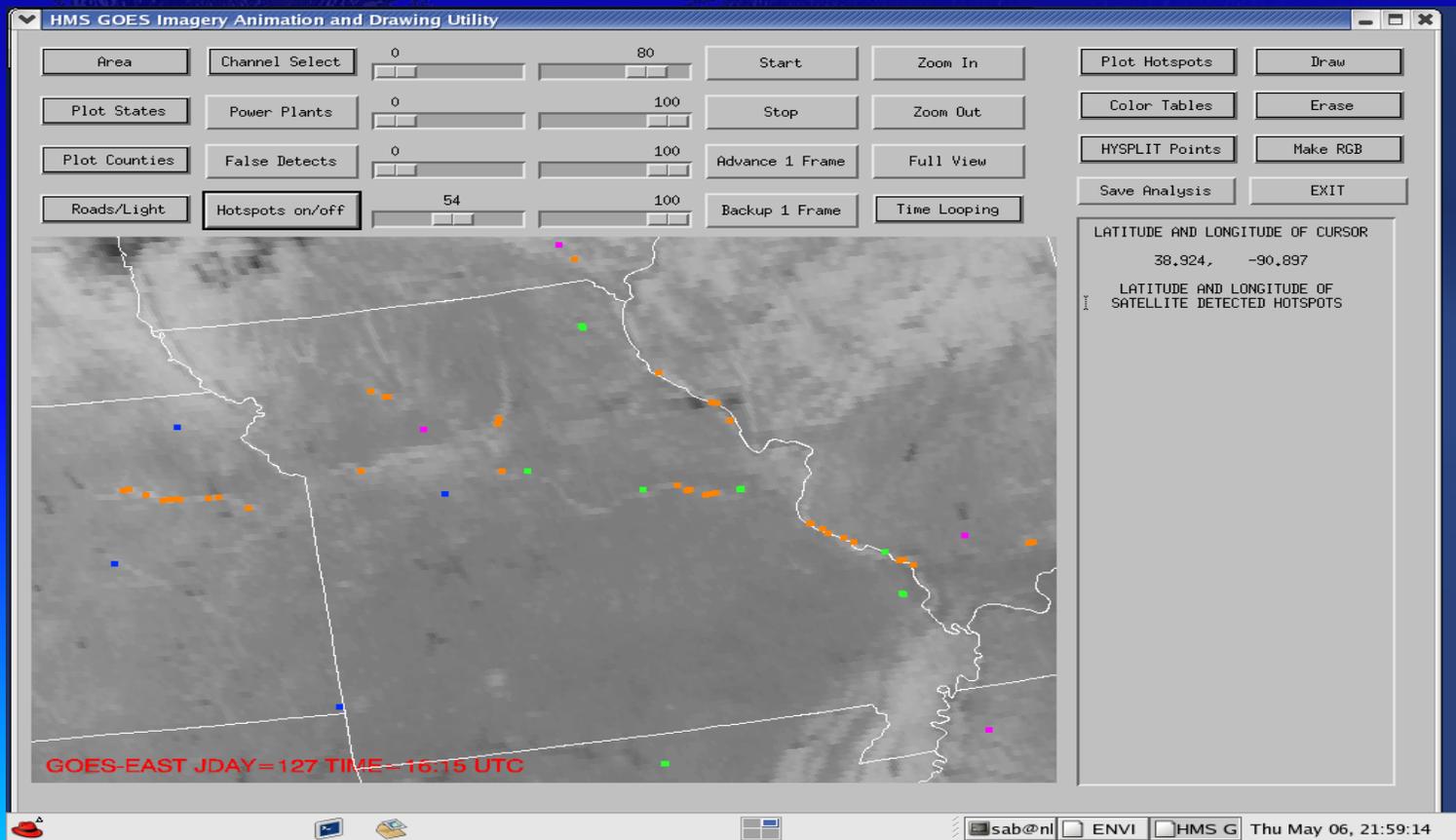
SUN GLINT OFF WATER SURFACES AT HIGH SUN ANGLES





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

URBAN HEAT ISLANDS AND LAND TYPES CAN CAUSE FALSE DETECTS





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

SHORT DURATION AGRICULTURAL/PREScribed





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

HMS GUI WITH POWER PLANTS AND KNOW FALSE ALARM LOCATIONS

The screenshot displays the HMS GUI interface. The main window is titled "HMS GOES Imagery Animation and Drawing Utility". It features a central satellite image of the United States with various data overlays, including a grid of pink dots representing hotspots and a grid of white dots representing power plants. The interface includes several control panels:

- Area:** Channel Select (0 to 100), Start, Zoom In, Plot Hotspots, Draw
- Plot States:** Power Plants (0 to 100), Stop, Zoom Out, Color Tables, Erase
- Plot Counties:** False Detects (0 to 100), Advance 1 Frame, Full View, HYSPLIT Points, Make RGB
- Plot Roads:** Hotspots on/off (0 to 100), Backup 1 Frame, Time Looping, Save Analysis, EXIT

On the right side, there is a text box displaying the following information:

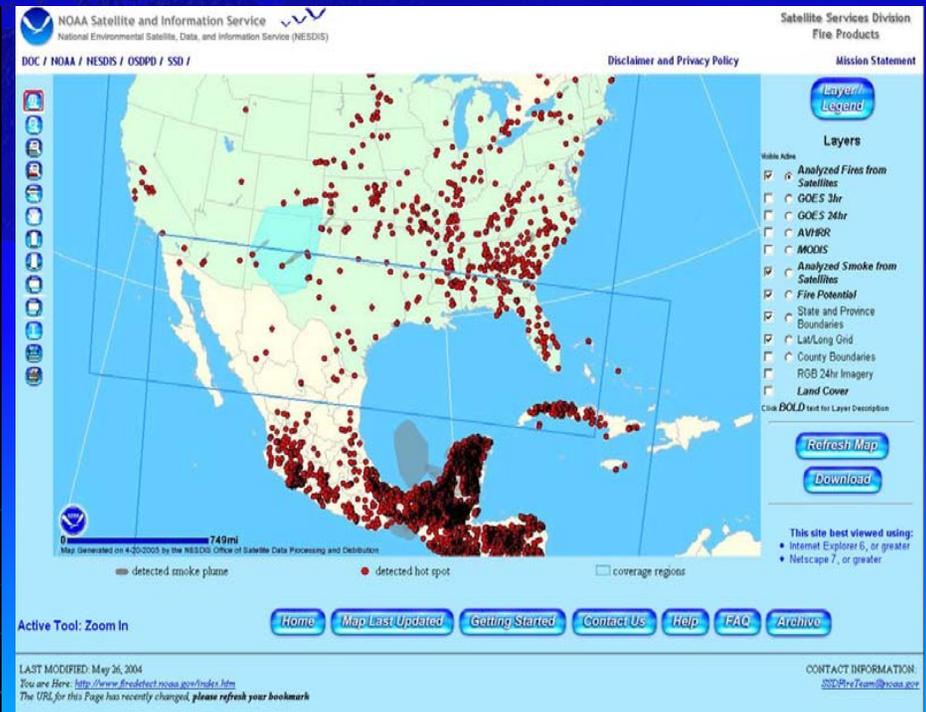
```
LATITUDE AND LONGITUDE OF CURSOR  
34.979, -118.723  
LATITUDE AND LONGITUDE OF  
SATELLITE DETECTED HOTSPOTS
```

At the bottom left of the satellite image, the text "GOES-EAST JDAY=340 TIME=16:15 UTC" is displayed in red. The Windows taskbar at the bottom shows the date and time as "Sat Dec 06, 5:20 PM".



MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

HMS GRAPHICAL OUTPUT IN A STATIC JPG AND GIS





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

What is done with the smoke after analyzing it.

- 1. The analyst provides input to the HYSPLIT in the following ways:**
 - A. Identifies the duration of the smoke being produced by the fire.**
 - B. Number of HYSPLIT points determined by the amount of smoke and/or areal extent of the fire**
 - C. Each Point represents 1 square km.**
- 2. Text product describing smoke and blowing dust. The analyst will describe the location of the fire, how thick the smoke is and where the smoke is moving by mentioning states, regions counties, roads, national forest, and etc.**

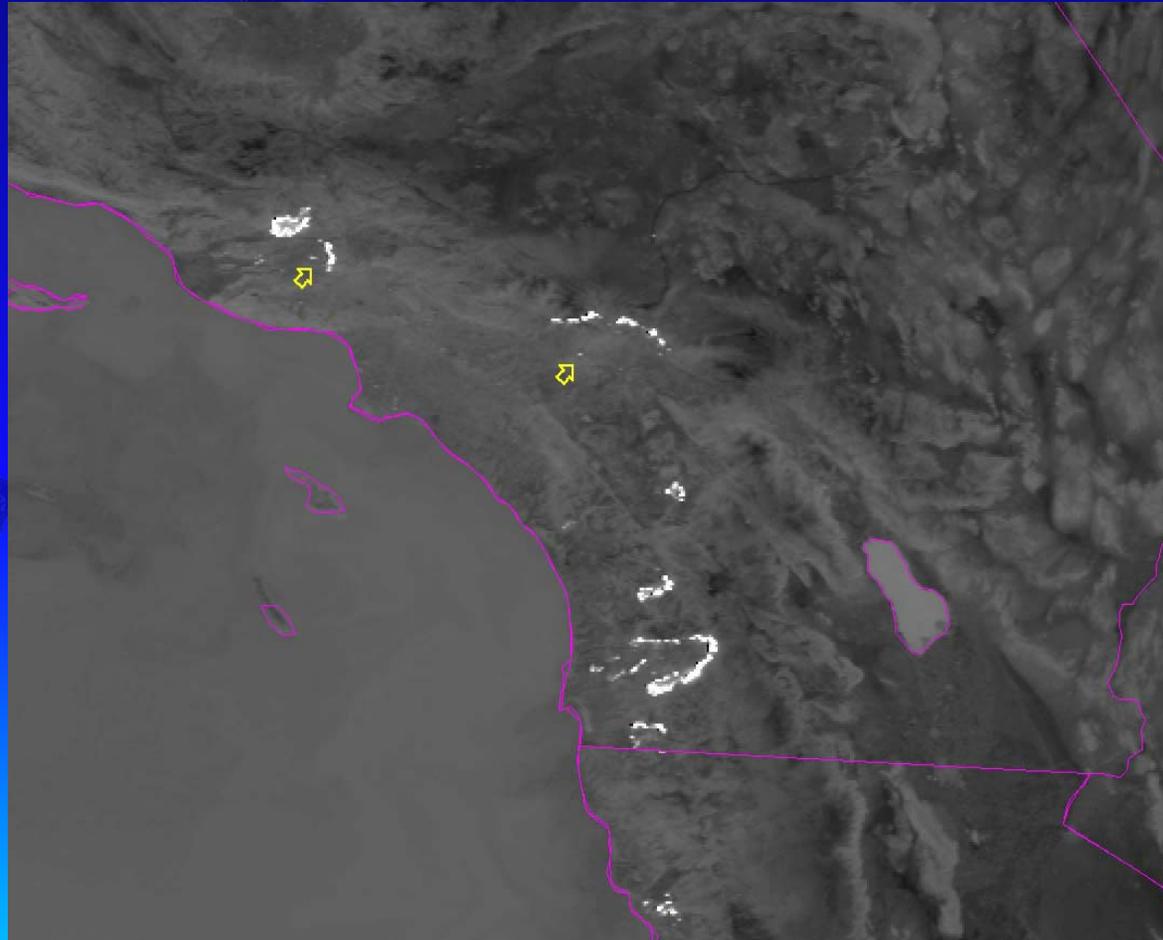




MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Arrows pointing to single
pixel ($\sim 1\text{km}^2$) hotspots.

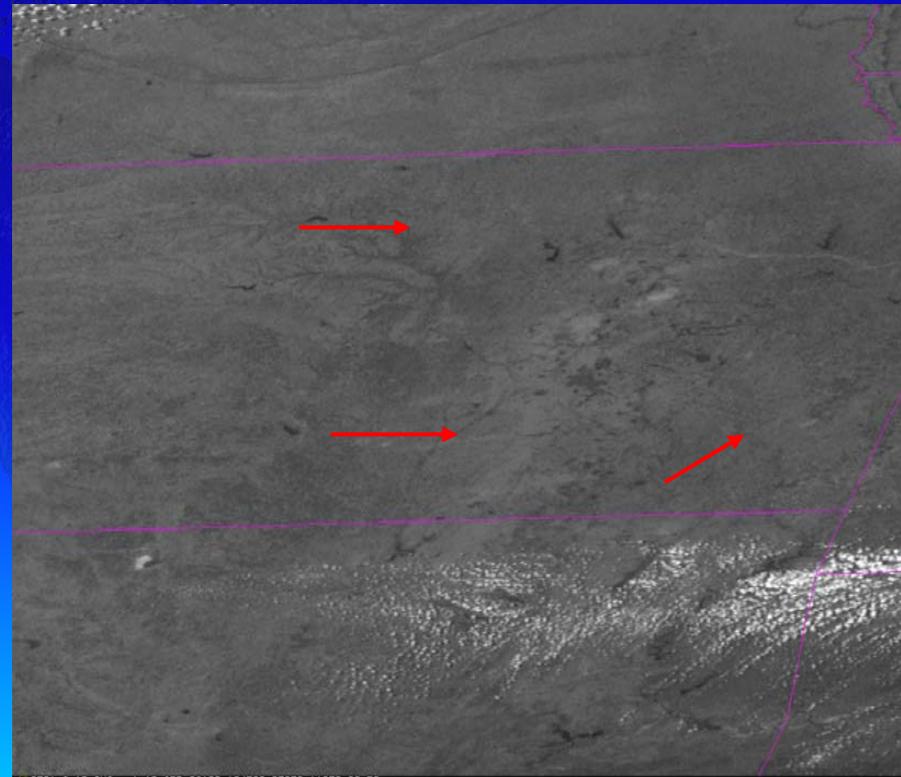
Each of the large fires would
be represented by 20-30 or
more points as input to an
emission model





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Analyst can determine the duration of the smoke being produced by the fire





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Recent Changes to the HYSPLIT INPUT

- 1. HYSPLIT switched from using constant emission rate for all input locations to using BlueSky framework in 2005
BlueSky emissions are variable and dependent on land use/vegetation type, fuel loading, moisture, consumption, etc.**
- 2. In May 2006 analyst began supplying start/end times for smoke emitting fires.**

This allows for specification of short duration agricultural and prescribed burns as well as replicating the diurnal variations observed in wildfires (seen in previous slides).

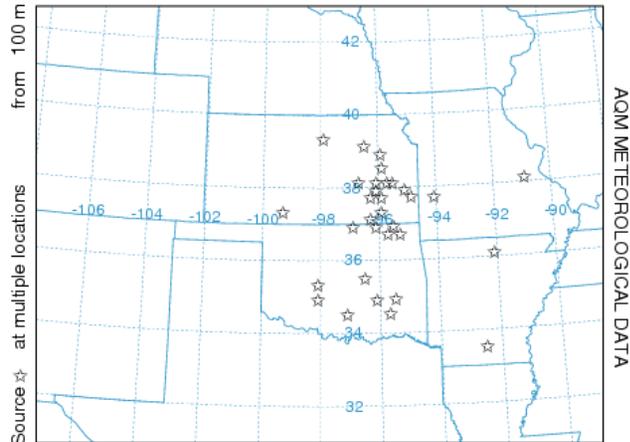




MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

VARIABLE FIRE SIMULATION

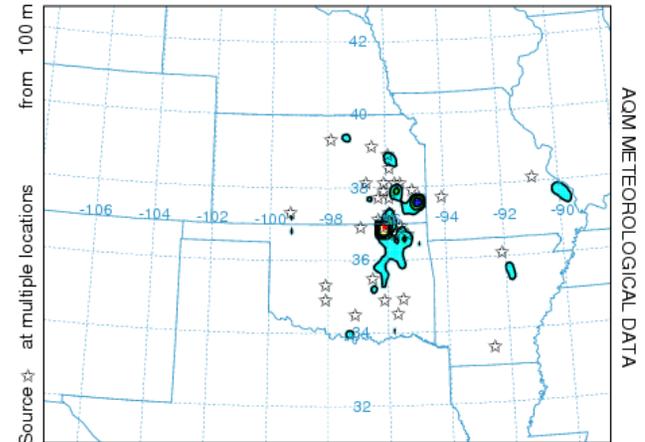
Concentration ($\mu\text{g}/\text{m}^3$) averaged between 0 m and 5000 m
Integrated from 1100 19 Apr to 1200 19 Apr (UTC)
PM25 Release started at 0600 19 Apr 06 (UTC)



1.0E+01 5.0E+00 2.0E+00 1.0E+00
1.0E+00 Maximum at square
2.1E-17 Minimum

CONSTANT FIRE SIMULATION

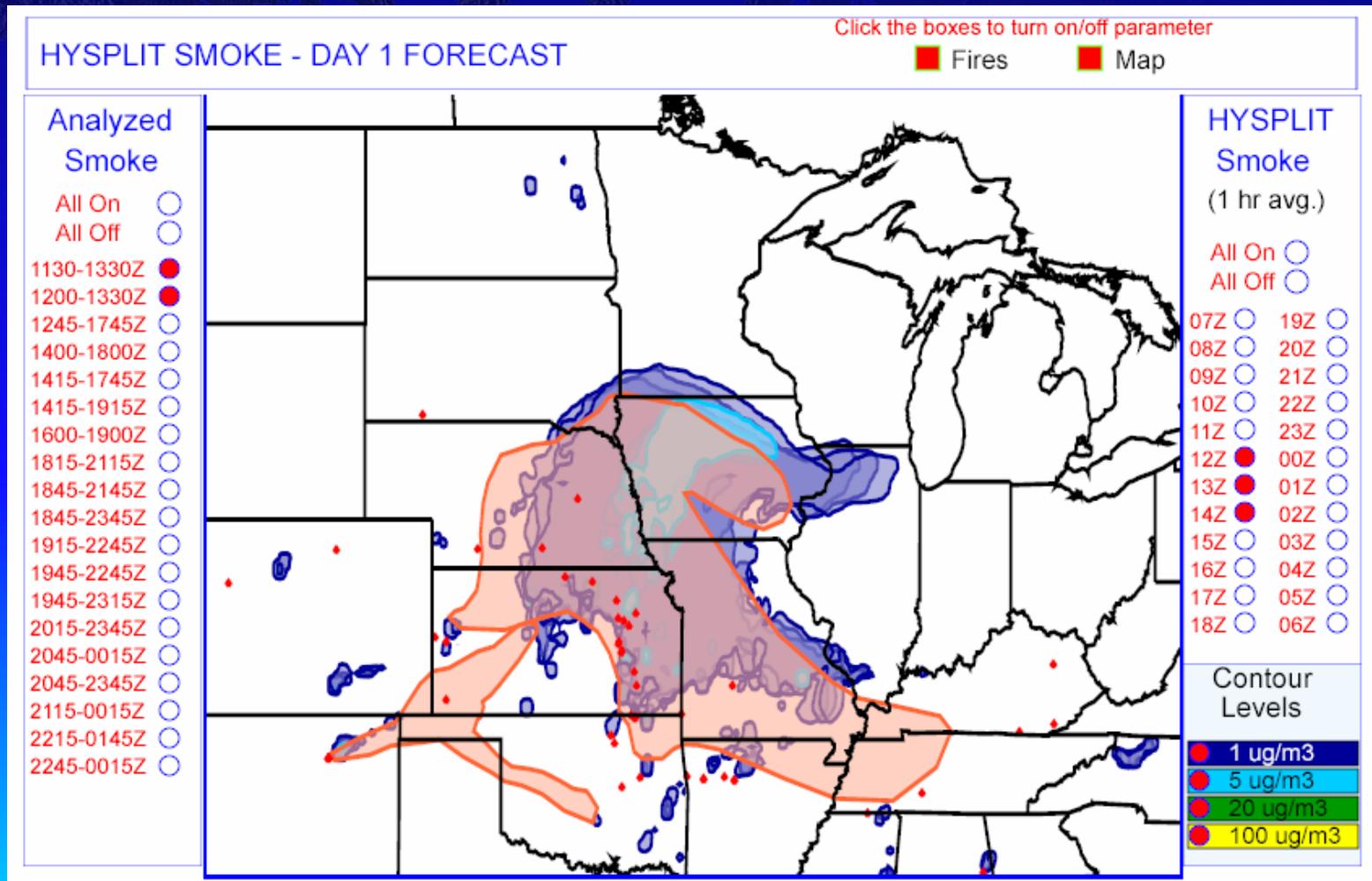
Concentration ($\mu\text{g}/\text{m}^3$) averaged between 0 m and 5000 m
Integrated from 1100 19 Apr to 1200 19 Apr (UTC)
PM25 Release started at 0600 19 Apr 06 (UTC)



1.0E+01 5.0E+00 2.0E+00 1.0E+00
1.8E+01 Maximum at square
2.7E-17 Minimum



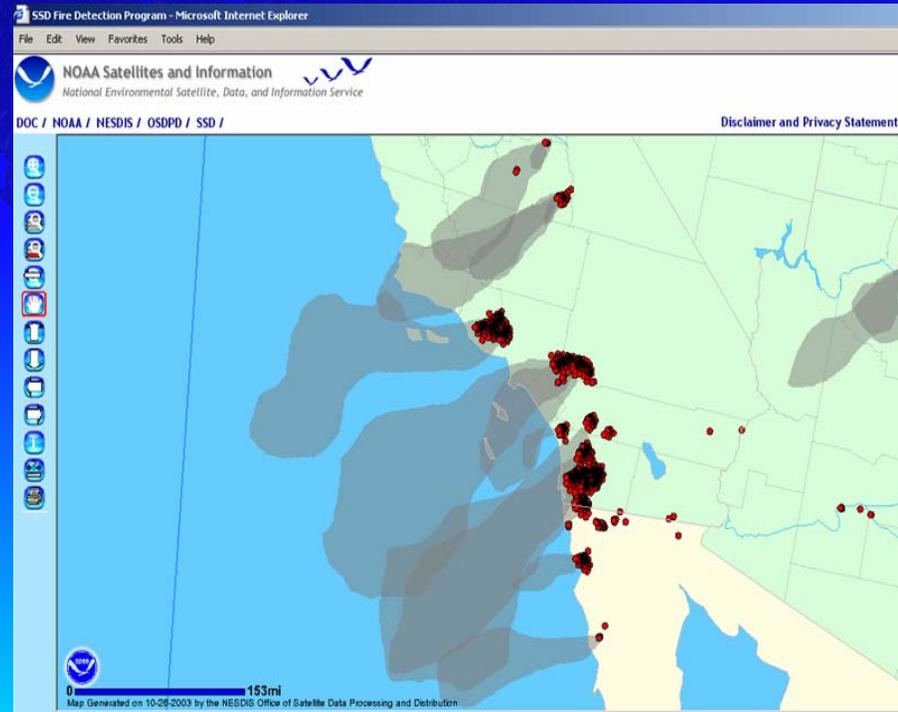
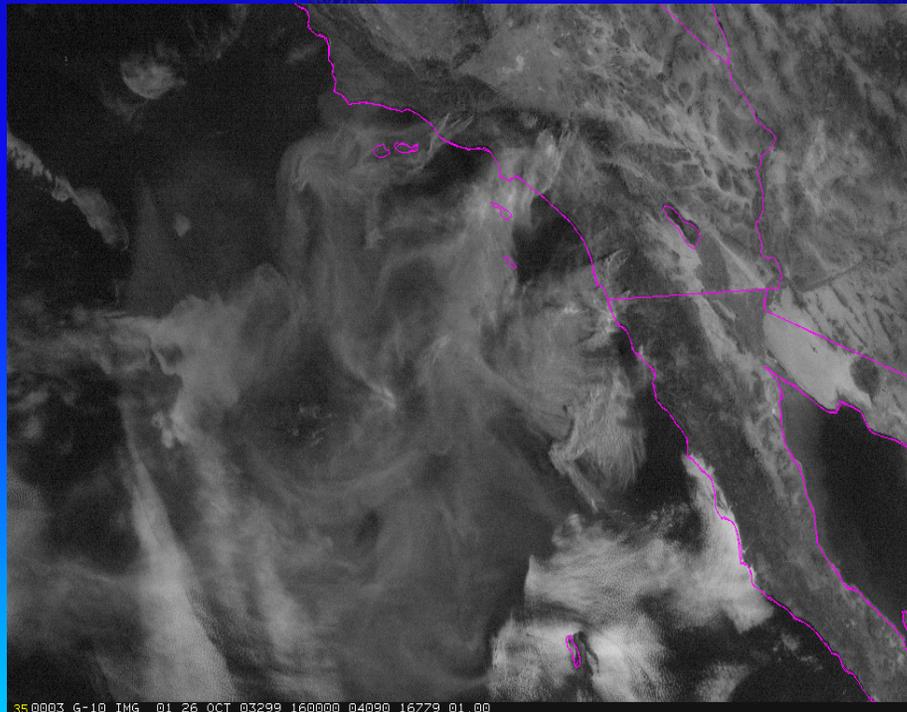
MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Individual GIS smoke plume shapefiles are tagged with
observation start/end times





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

SMOKE TEXT PRODUCT

Tuesday October 24, 2006 DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY THROUGH 0130Z October 25, 2006

California: A wildfire burning in the Sequoia National Park (Tulare county) is producing an area of moderately dense smoke moving south across southeastern California. In the Lassen National Park (Tehama county), a fire is emitting an area of moderately dense smoke moving east SE into Lassen and Plumas counties. Oregon: Multiple fires burning across Klamath counties are producing areas of moderately dense smoke moving east SE. The two fires in the northern part of the county are burning in the Winema National Forest. Another fire in Curry county is emitting moderately dense smoke moving south SW into the Pacific. In Josephine county a fire is emitting a smoke plume moving south SW into northwestern California before reaching the Pacific Coast.

North Dakota/Saskatchewan/Manitoba/Northern Plains: Hundreds of most likely agricultural fires are burning across southern Saskatchewan/Manitoba and North Dakota. There are some fires in the surrounding states. The numerous fires are producing an area of thin smoke across eastern North Dakota and southwest Manitoba and southeast Saskatchewan. There are so many fires trying to find the point source of the smoke is very difficult.

J Kibler

Unless otherwise indicated:

Areas of smoke are analyzed using GOES-EAST and GOES-WEST Visible satellite imagery.

Only a general description of areas of smoke or significant smoke plumes will be analyzed.

A quantitative assessment of the density/amount of particulate or the vertical distribution is not included.

Widespread cloudiness may prevent the detection of smoke even from significant fires.





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

**Currently we are just drawing smoke outlines of
smoke extent**

**Very soon analysts will begin drawing contours of
smoke concentrations.**

**Contours will be largely influenced by the GOES
Aerosol and Smoke Product (GASP)**





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Properties of GASP:

Produced $\frac{1}{2}$ hourly from GOES EAST/WEST

Fully automated

Utilizes GOES visible band brightness values

Aerosol Optical Depth (AOD) is converted to
concentration using a mass extinction coefficient of 7.9
 $\pm 4.5 \text{ m}^2/\text{g}$





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Limitations of GASP (and analyst drawn contours):

There is no vertical structure

Due to dependence on visible imagery, only available during daylight

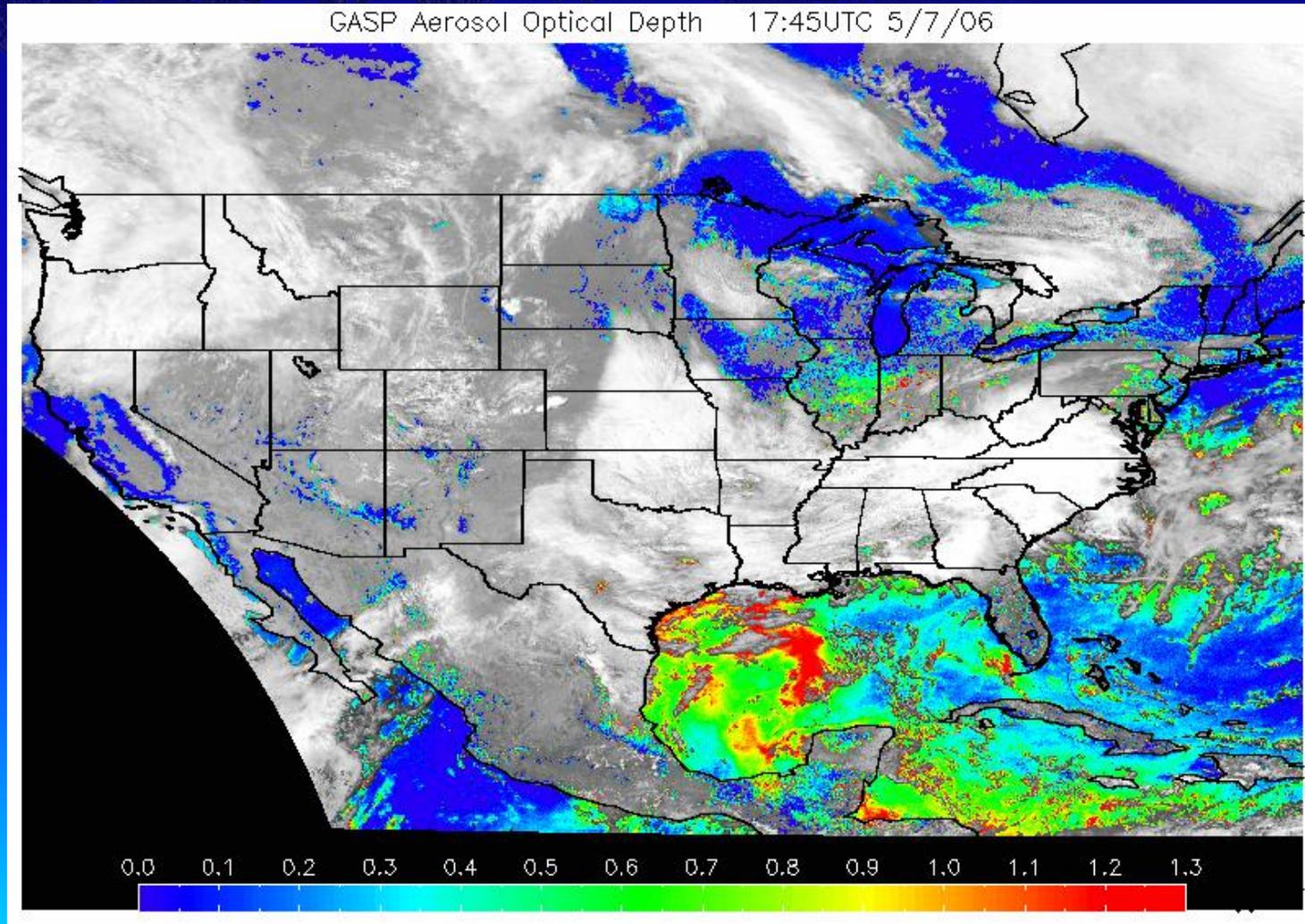
Clouds hinder detection

GASP does not distinguish between aerosol types – analysts attempt to





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

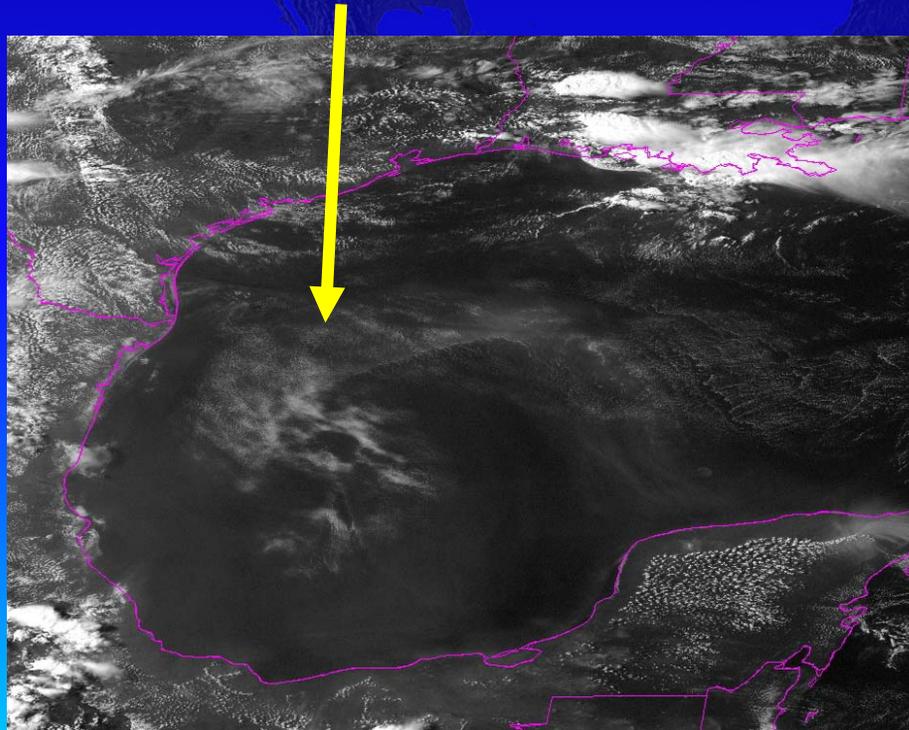




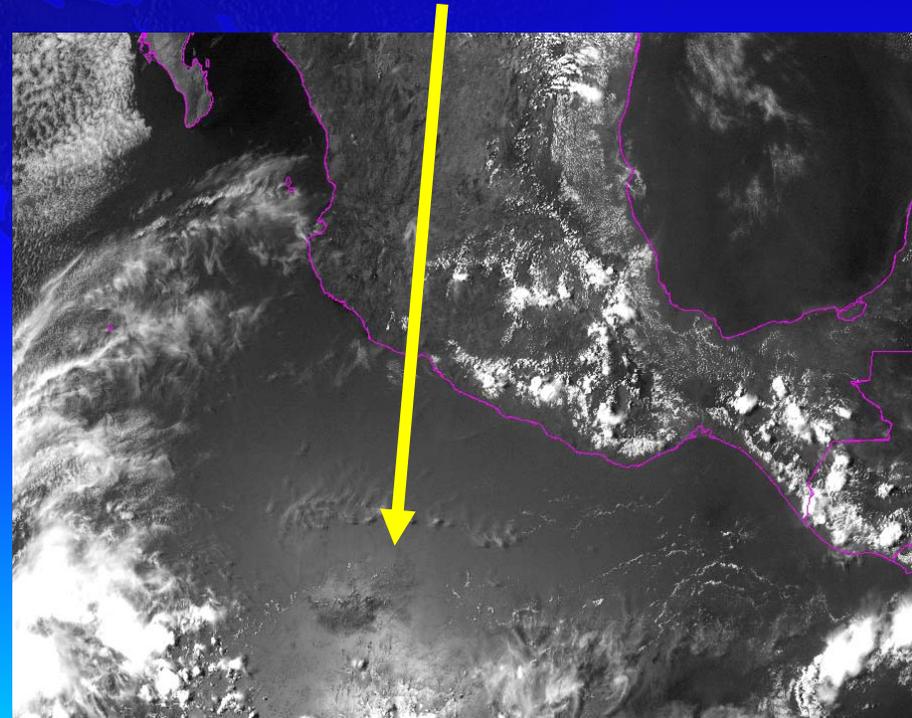
MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Clouds and sun glint are difficult for GASP to resolve

Clouds mixed with smoke



Sun glint





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Long range transport of smoke does not adhere to political or geographic boundaries

HMS analysis includes Central America during Spring and Alaska/Canada from late Spring into the Fall during each region's peak burn season

Responsibility for Central American analysis was transferred to the Mexican National Weather Service in Spring 2006

By mid to late 2007 the goal is to have a HMS installed for the Thailand region in the detection of fires and associated smoke.





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Reasons for the Technology Transfer of the HMS to Mexico and Thailand

- **Global Air Quality Forecast/Initiatives**
- **To be used as a tool to combat illegal burning in Central America and Thailand.**
- **To alert emergency crews of the presence of wildfires across Mexico.**
- **To have a full integrated North American fire and smoke product.**
- **Each office produces an analysis for the region they are most familiar with**





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

WHAT TOOK PLACE IN THE TRANSFER OF THE HMS TO MEXICO/CENTRAL AMERICA

- **In 2004 and 2005 the Partners of the Americas, through the State Department funded The American Fellows Program. This allowed analyst from Mexico and Guatemala to be trained on the HMS and provide analysis for Central America during the Spring fire season in 2004/2005.**
- **In February – April 2006 the HMS was installed in Mexico in the Servicio Meteorológico Nacional (SMN) environment. The ability to run the HYSPLIT to track smoke emissions was acquired. The analysis from Mexico is transferred and merged with that from NESDIS to produce a coherent analysis for North America.**
- **Future: Provide the framework for the continuation of the program, possibly through a Memorandum of Agreement (MOA) or Memorandum of Understanding (MOU)**
- **Updates and modifications of the HMS in Mexico**



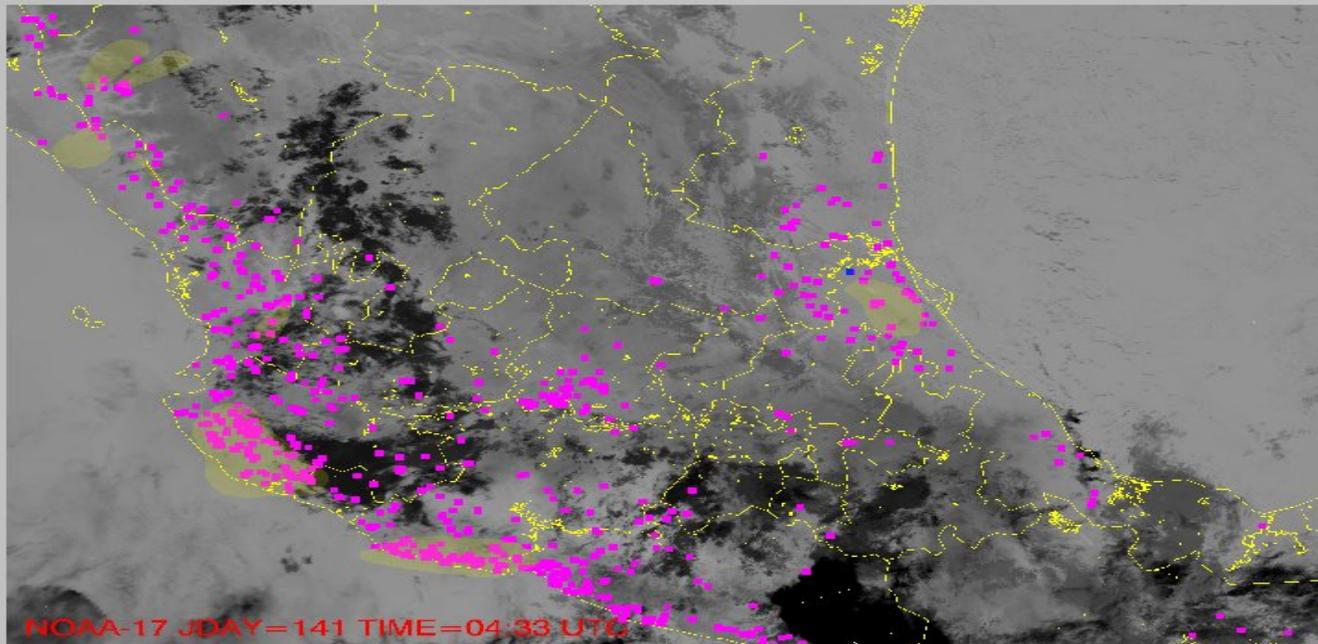


MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

CENTRAL AMERICA HMS GUI

Area	Channel Select	0	100	Start	Zoom In
Plot States	Power Plants	0	100	Stop	Zoom Out
Plot Counties	False Detects	0	100	Advance 1 Frame	Full View
Roads/Light	Hotspots on/off	0	100	Backup 1 Frame	Time Looping

Plot Hotspots	Draw
Color Tables	Erase
HYSPLIT Points	Make RGB
Save Analysis	EXIT



LATITUDE AND LONGITUDE OF CURSOR
25.488, -99.718

LATITUDE AND LONGITUDE OF
SATELLITE DETECTED HOTSPOTS



MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

THAILAND HMS GUI: MID/LATE 2007

The screenshot displays the Hazard Mapping System (HMS) interface for Thailand, featuring a central satellite map and a control panel. The control panel includes several sections:

- Plot Countries:** Channel Select (0 to 100), Start, Zoom In
- Plot Provinces:** Power Plants (0 to 100), Stop, Zoom Out
- Land Cover:** False Detects (0 to 100), Advance 1 Frame, Full View
- Roads/Light:** Hotspots on/off (0 to 100), Backup 1 Frame, Time Looping

Additional controls on the right side include:

- Plot Hotspots, Draw
- Color Tables, Erase
- HYSPLIT Points, HOLD
- Save Analysis, EXIT

The central map shows a satellite view of Thailand with cyan outlines of provinces and various colored dots (red, blue, green) representing hotspots. A cursor is positioned over the map, and the right panel displays the following coordinates:

LATITUDE AND LONGITUDE OF CURSOR
27.498, 99.997

LATITUDE AND LONGITUDE OF SATELLITE DETECTED HOTSPOTS



MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Validation of the HMS

- **Primary objective was to verify manual and automated fire points from the MODIS TERRA satellite and near simultaneous GOES images.**
- **Validation used high resolution imagery from the Advance Spaceborne Thermal emission and Reflection Radiometer (ASTER)**
- **Due to the availability of ASTER data, study limited to mid to late morning observation hours near center of MODIS images suborbital track.**
- **AVHRR sensor and MODIS AQUA not included in the study due to the above limitation.**





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Results of the MODIS Validation

- Among the 659 MODIS automated detections obtained, ASTER did not detect 28 of them, an indication of a commission error.
- The ASTER scenes verified 9 of the MODIS pixels were adjacent to a ASTER pixel showing an active fire.
- 8 pixels were found to be associated with various types of industrial plants.
- The remaining 11 pixels without an accompanying fire or heat source to explain the detection resulted in a reasonably low commission error of less than 2%





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Results of the GOES Validation

- Among the 103 GOES automated detections obtained, ASTER did not detect 19 of them, an indication of a commission error.
- Visual inspection of the location of the fires confirmed only two pixels as true commission errors.
- Of the remaining 17 detections, 16 pixels were found to have active ASTER fire pixels in the immediate vicinity of the GOES pixel and 1 within two GOES pixels.
- The result was a commission rate of less low commission error of less than 2%.....similar to MODIS



MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Validation Conclusion

The automated fire products derived from MODIS (MOD14) and GOES (ABBA) are performing reasonably well for the region and time of day studied. Commission errors were relatively small for both products (less than 2%)





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

- All products available on the Web at:
www.ssd.noaa.gov/PS/FIRE/

- Includes links to

archived products

automated fire algorithms

GIS page

HYSPLIT smoke forecasts

near real time imagery

GASP imagery

manual quality controlled analysis





MONITORING FIRE AND SMOKE EMISSIONS WITH THE HAZARD MAPPING SYSTEM

Additional contributors who have made the system possible

**Donna Mcnamara
George Stephens
John Simko
Jamie Kibler
Tim Kasheta
Po Li**

**UMd/NASA MODIS fire team
CIMMS GOES fire team
Yi Song
Ivan Csiszar
Rob Fennimore
Tad Franson**

