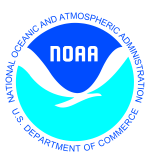# Smoke Forecast Tool:
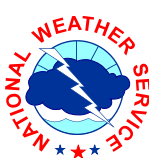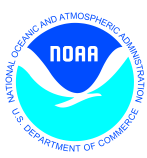# New Guidance in National Air Quality Forecast Capability

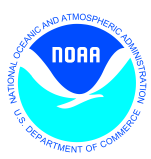Operational Readiness Review

NWS Director

February 22, 2007

Purpose of Readiness Review

Obtain Corporate approval for operational deployment of the smoke forecast tool as new forecast guidance in the Air Quality Forecast Capability
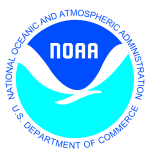
Outline

- **Background**
  - *Air Quality Forecast Program Goals, Planned Capabilities*
  - *Implementation Schedule*
- **Review operational readiness**
  - *Readiness Criteria (OST)*
  - *Objective verification (NCEP)*
  - *Subjective feedback (OCWWS)*
  - *Production readiness (OCIO)*
  - *Summary (OST)*
- **Polling of Senior Leadership**
- **Recommendation**

Background

National Air Quality Forecast Capability
Vision and Strategy

Vision

National Air Quality Forecast Capability which provides the US with ozone, particulate matter and other pollutant forecasts with enough accuracy and advance notice to take action to prevent or reduce adverse effects

Strategy

Work with EPA, State and Local Air Quality agencies and private sector to develop end-to-end air quality forecast capability for the Nation

National Air Quality Forecast Capability
Planned Capabilities

Near-term: 1-day forecast guidance for ozone

- **Operational for Eastern US as of August, 2005**

- **Extend to CONUS in FY07; Nationwide by FY10**

Vision: O_3 & PM in 10 Years
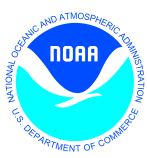
2004: O_3

2005: O_3
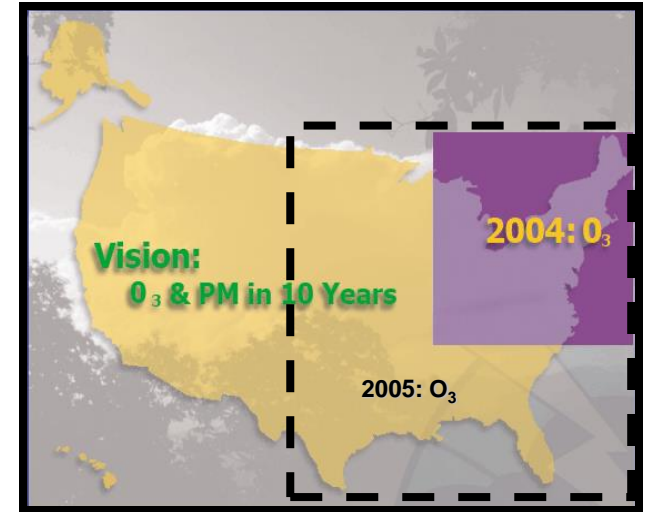
Intermediate (5-7 years):

- **Implement quantitative capability to forecast particulate matter concentration**

  - *Particulate size $\leq$ 2.5 microns*

Longer range (within 10 years):

- **Extend air quality forecast range to 48-72 hours**

- **Include broader range of significant pollutants**

Smoke Forecast Tool:
A step toward quantitative PM predictions

- *Required for particulate matter (PM) forecasts*
  - Fire emissions significant source of fine particle pollution (PM2.5)
  - Direct (e.g. soot) and indirect (from secondary reactions) contributions
  - Large fires locally dominate PM
  - Challenges: how much and how far do fire emissions contribute to PM2.5?
- *Real-time information on fire emissions essential*
  - Inventory-based aerosol component tests for PM forecasting consistently underpredict: errors ~ 2-5 X
  - Wildfire smoke sources too large and variable for success with inventory-based, climatological approximations
- *Effectively leverages existing capabilities*
  - NOAA/NESDIS observations of fire locations, extent
  - USFS estimates for wildfire smoke emissions based on vegetation cover
  - NOAA/OAR expertise in dispersion prediction: HYSPLIT
  - Scalable for CONUS, North American and global domains as needed

Smoke Forecast Tool
End-to-End Capability

Model Components: Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

NCEP mesoscale NWP: WRF-NMM

NOAA/OAR HYSPLIT dispersion for smoke transport

Observational Input:

NWS real-time weather observations

NESDIS fire locations/extent

Gridded forecast guidance products

On NWS Telecommunications Gateway and NDGD

Updated each day, 6Z cycle, available by 13Z

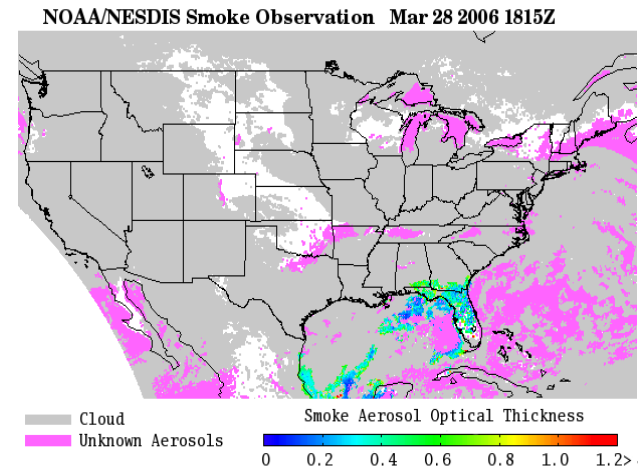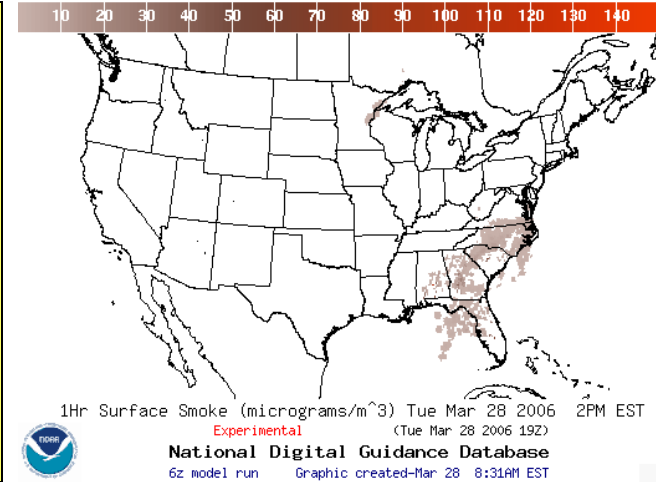### *Routine verification basis*

Near real-time NOAA/NESDIS smoke-column product
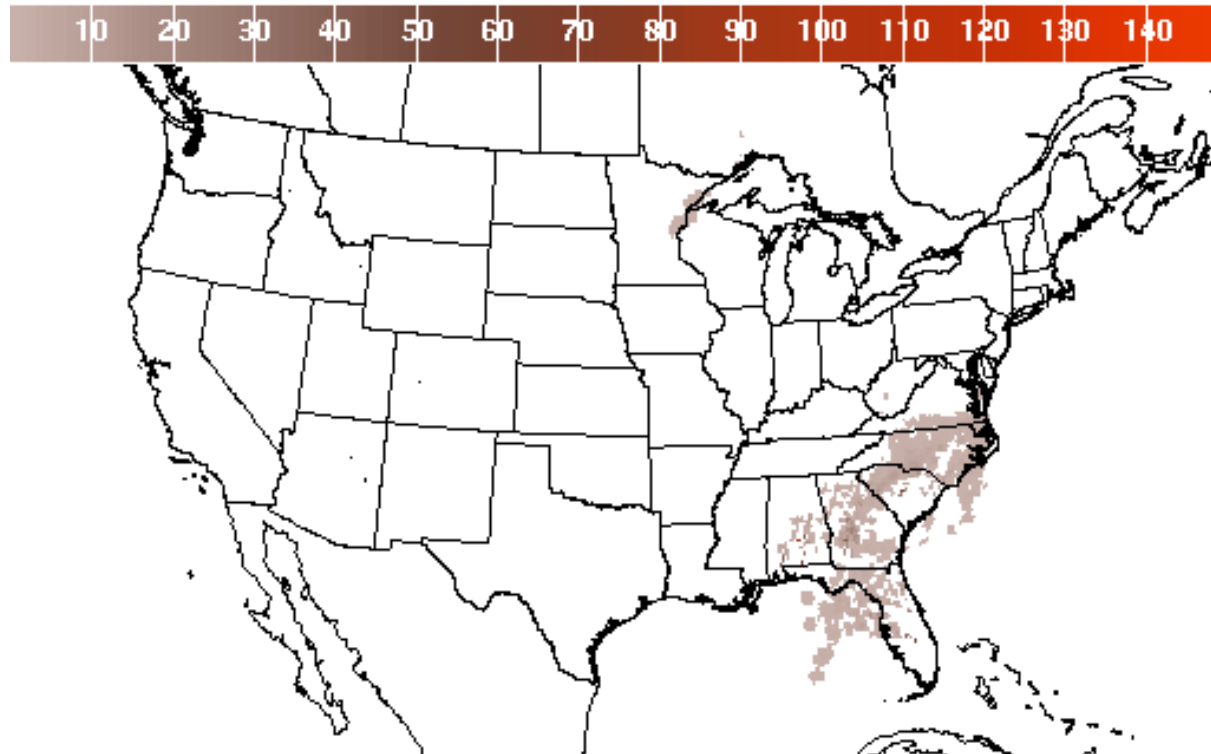
Customer outreach/feedback

NOAA/NWS field forecasters

State&Local AQ forecasters, coordinated with EPA

Public and Private Sector AQ constituents

Sample smoke forecast guidance

1Hr Surface Smoke (micrograms/m^3) Tue Mar 28 2006 2PM EST
Experimental (Tue Mar 28 2006 19Z)
National Digital Guidance Database
6z model run   Graphic created-Mar 28 8:31AM EST

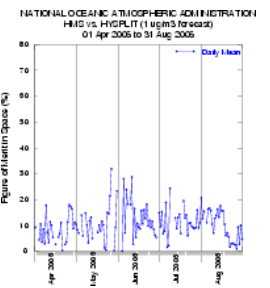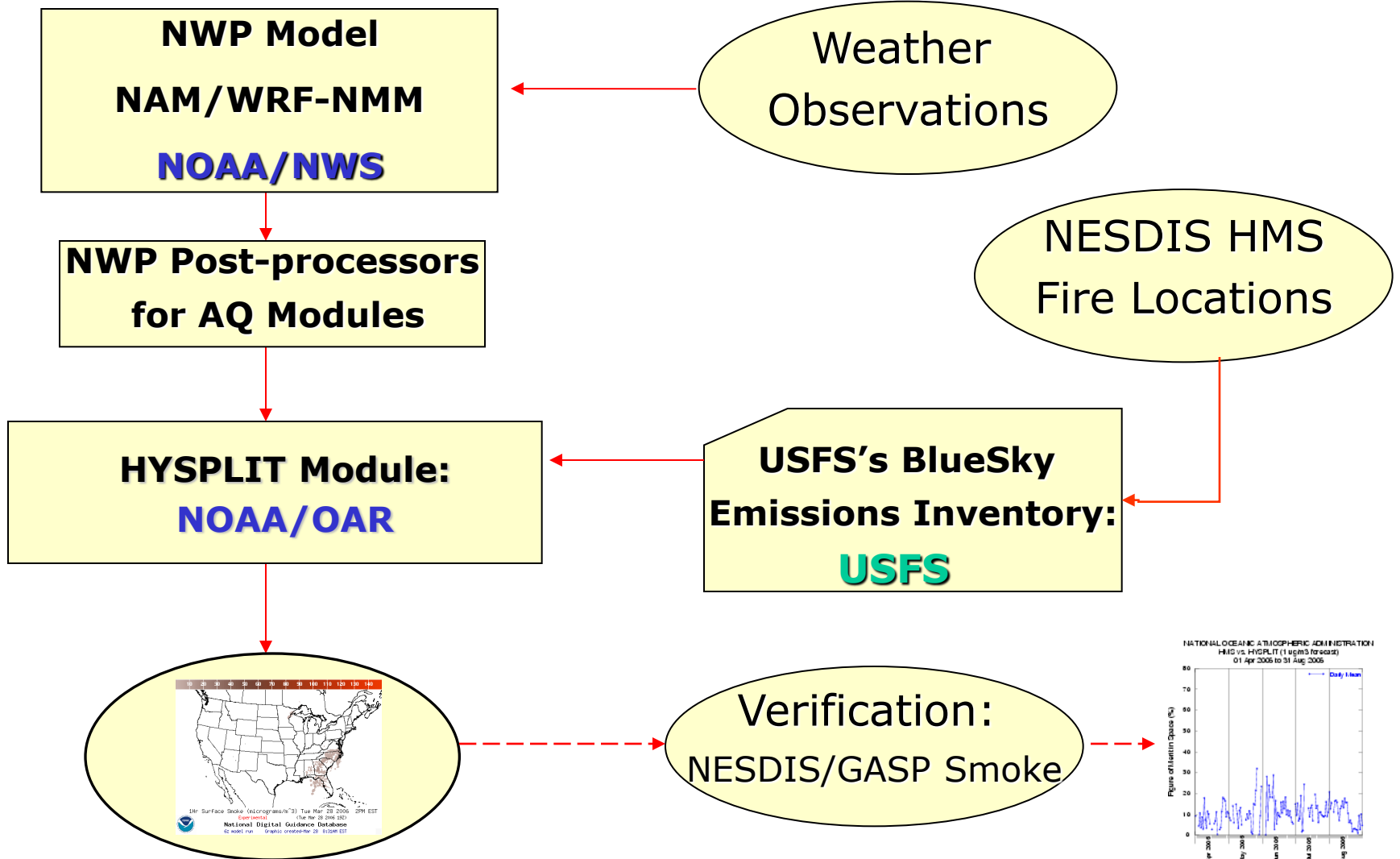- **Experimental Testing: from March, 2006**

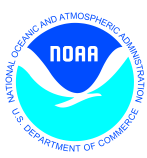- **Fire Locations and verification based on satellite observations**

- **Fire emissions estimates from USFS (BlueSky)**

- **HYSPLIT/WRF-NMM transport**

Smoke Forecast Tool
Major Components

NWP Model

NAM/WRF-NMM

NOAA/NWS

Weather Observations

NWP Post-processors for AQ Modules

NESDIS HMS Fire Locations

HYSPLIT Module: NOAA/OAR

USFS's BlueSky Emissions Inventory: USFS

Verification: NESDIS/GASP Smoke

Verification Approach: Smoke

Objective verification product developed for NWS:

- **First real-time verification for wildfire smoke in daily use**
- **Based on NOAA/NESDIS satellite imagery:**
  - *GOES Aerosol Smoke Product (GASP)*
  - *Smoke from identified fires only*
- **Filtered for interference:**
  - *Clouds, surface reflectance, solar angle, other aerosol*
- **"Footprint" comparison:**
  - *Threshold concentration ($1~\mu g/m^3$) for average smoke in the column*
  - *Tracking Threat scores, or Figure-of-merit statistics:*

    (Area Pred $\cap$ Area Obs) / (Area Pred. U Area Obs)

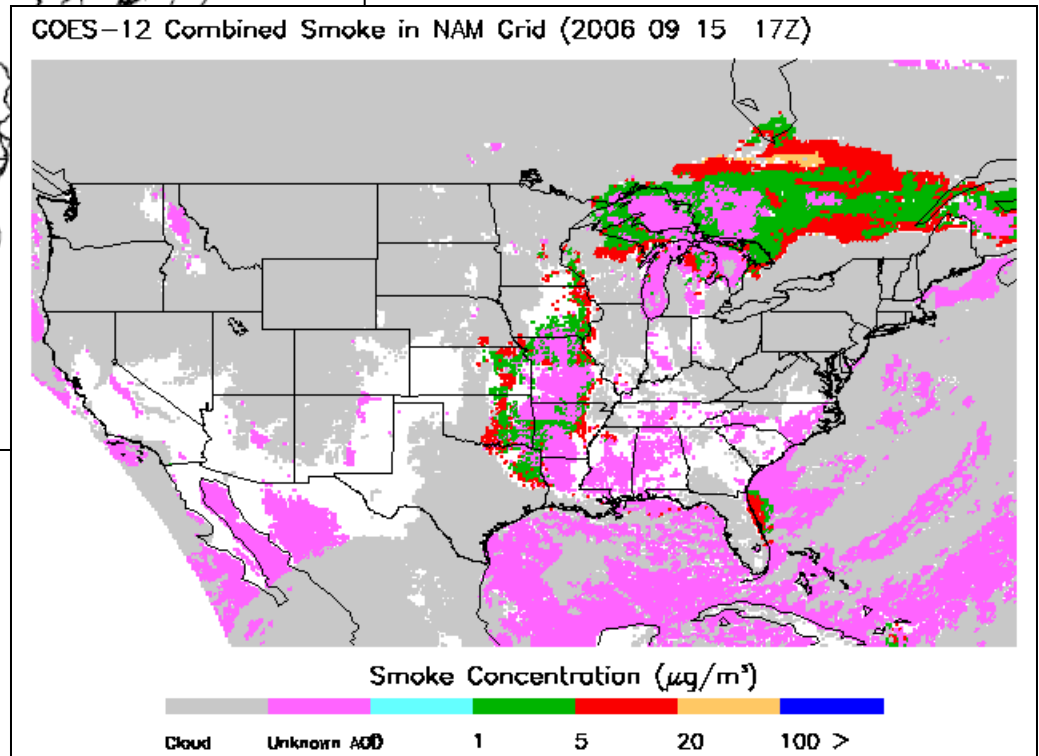## *Initial skill target set at 8%, checked with independent analysis in earlier methods:*

  - *Analysts isolate smoke in GOES-based NESDIS Hazards Mapping System (HMS)*
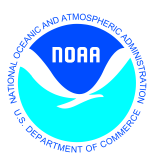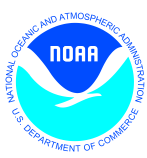
Sample Smoke Verification:
September 15, 2006
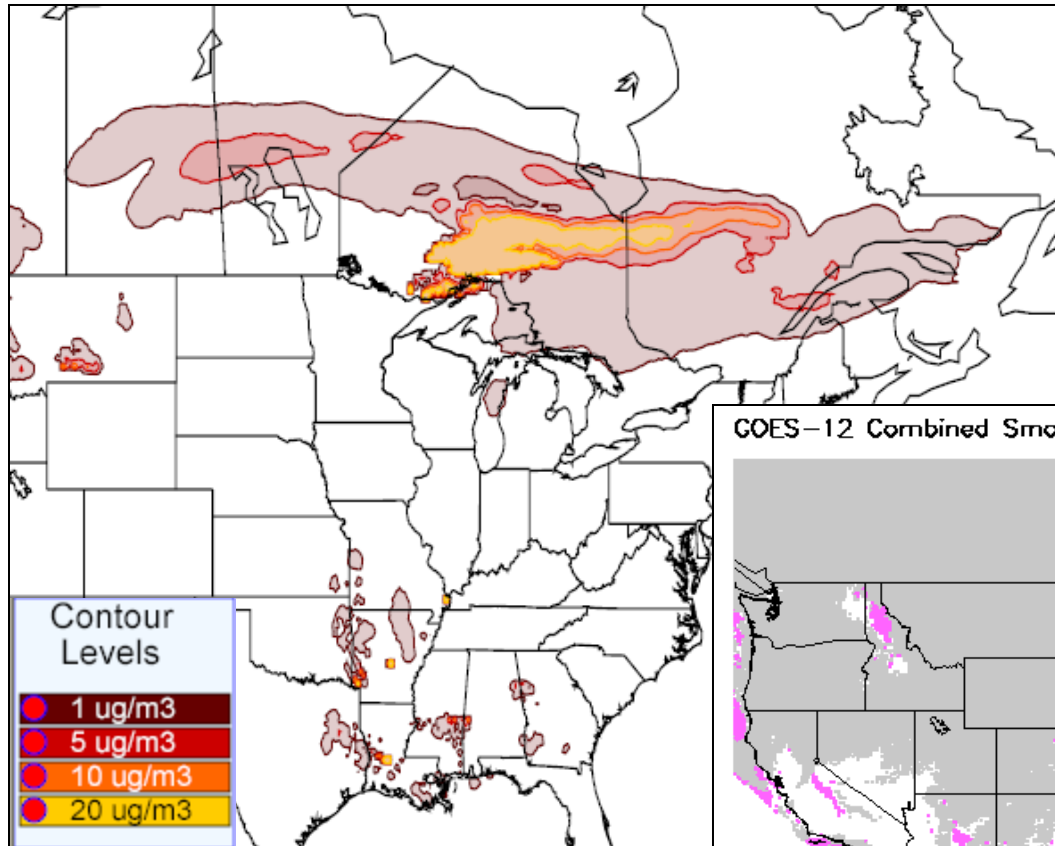
9/15/06, 17Z: high FMS (45%)

- **GOES smoke captures peak concentrations identified by HYSPLIT**

- **Cloud cover limits available observations in northern and western portion of plume**

Contour Levels

- 1 ug/m3
- 5 ug/m3
- 10 ug/m3
- 20 ug/m3

GOES-12 Combined Smoke in NAM Grid (2006 09 15 17Z)

Smoke Concentration ($\mu g/m^3$)

| Cloud | Unknown AOD | 1 | 5 | 20 | 100 > |

Review of Operational Readiness

Smoke Forecast Tool:
Operational Readiness Criteria Summary

Criterion	Lead	Metric	Dates	Status 2/07
Objective Evaluation: Accuracy	NCEP	> 8%	9/1/06 – 2/1/07	C
Subjective Feedback	OCWWS	Positive on balance	4/1/06 – 2/1/07	C
Production Readiness	OCIO, NCEP			C
On-time delivery		> 95 %	4/1/06 – 2/1/07	C
Back-up		In place	6/1/06	C
Data retention		In place	6/1/06	C
Near-real time verification*	NCEP	In place	9/1/06 (at OAR) 11/1/06 (at NCEP)	C
Final go/no go decision	NWS		**Review date**	G

* NESDIS automated (objective) product

Key	Complete	On schedule	At risk	Remedial Action Required

Objective Verification (NCEP, OAR)

Criterion	Metric	Dates	Status
Objective Evaluation: Accuracy	*Prediction overlap (FMS) > 8 % for 24-hr prediction that smoke concentration ≥ 1 µg/m³ in total column*	*9/1/06 – 2/1/07*	C

Summary Performance, based on, HMS Product (independent analysis)

Fire Season: 4/1/06 – 10/31/06

- **Exceeds target 96/184 days**
- **Cumulative FMS (>1 ug/m³)= 7.9%**

Moving to new GASP product

Full Test Season 4/1/06 – 12/31/06

- **Exceeds target 99/214 days**
- **Cumulative FMS (>1 ug/m³)= 7.7%**
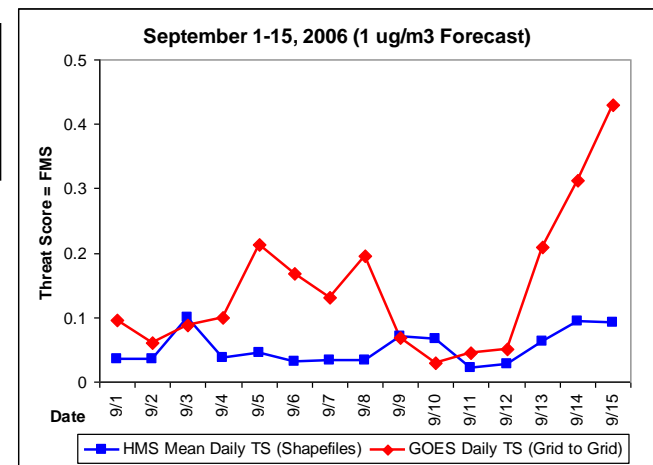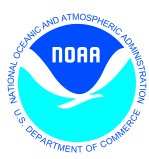
- **Automated product provides objective basis for daily verification**
- **Comparison to HMS: slightly lower FMS, but higher during periods of active fires**
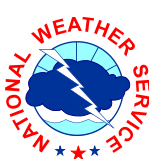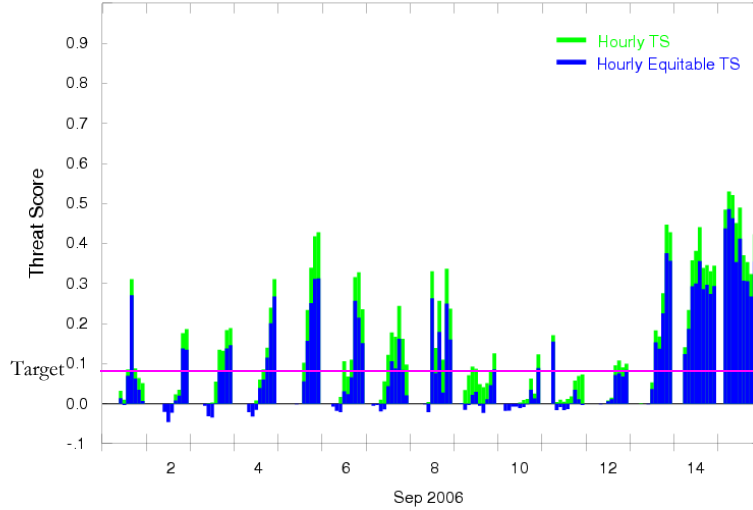
HMS-based Verification

HYSPLIT VS HMS Shapefiles (24h forecast)
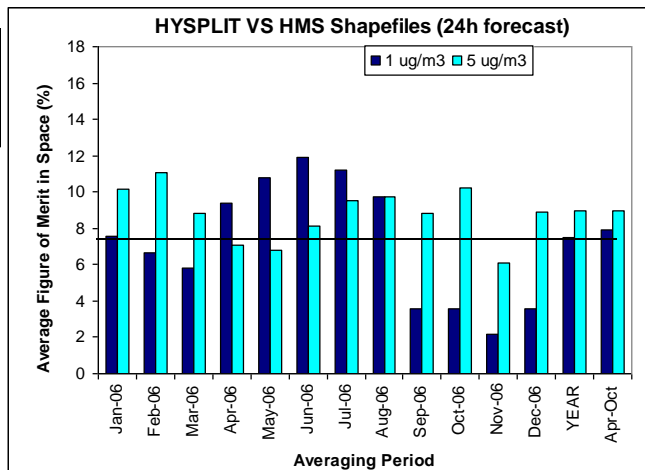
GASP Smoke-based Verification

September 1-15, 2006 (1 ug/m3 Forecast)

HYSPLIT vs. GASP (Sept 1-15, 2006)

Hourly and Daily Threat Scores for 1 and 5 ug/m3 (forecast, uncondtional)
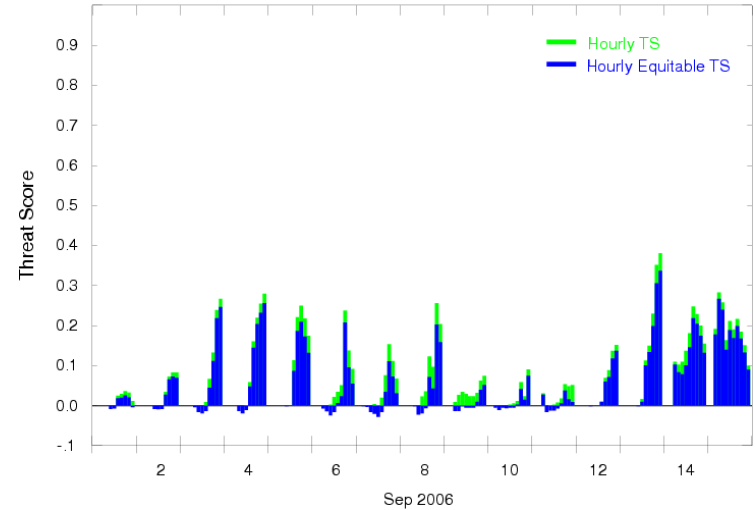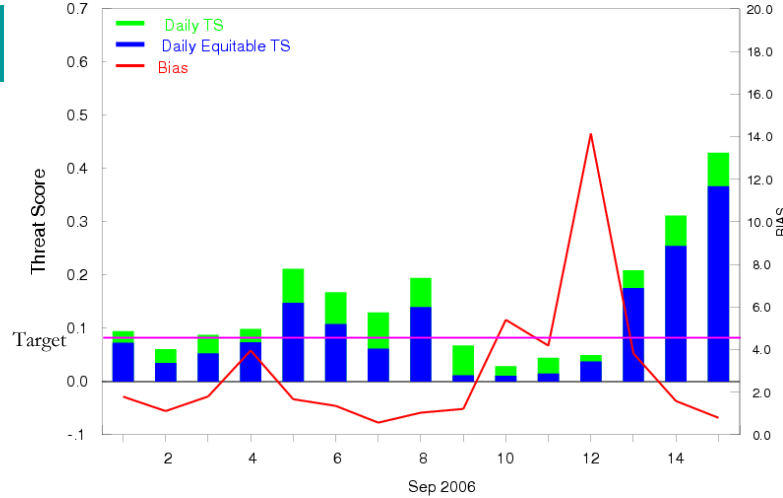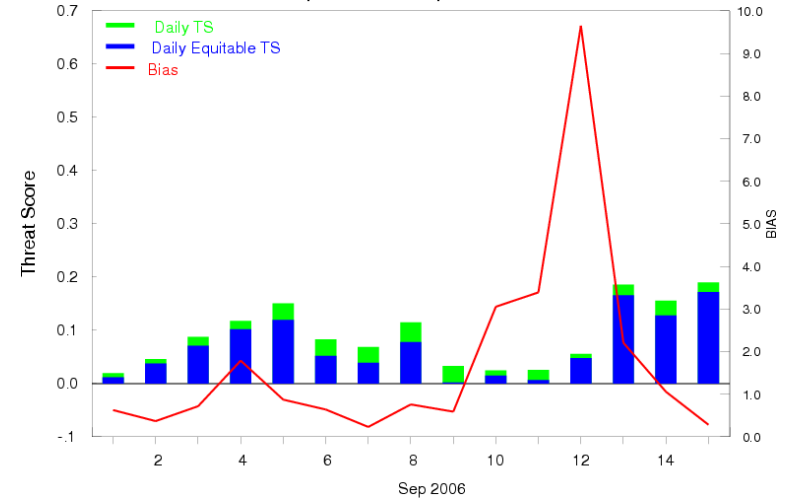
Hourly

Daily

1 ug/m³

5 ug/m³
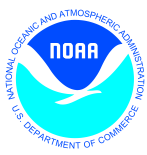
Subjective Feedback (OCWWS)

Criterion	Metric	Dates	Status
Subjective Feedback	*External feedback from State/Local AQ forecasters support product as helpful.* *Other feedback: internal, constituent, general public: On Balance, positive*	*4/1/06 – 2/1/07*	C

Feedback Sources:

- **Feedback link from NDGD**
- **State and Local AQ forecasters**
- **NWS field forecasters**
- **Constituent group**
- **Other responses/comments on experimental products**

Subjective Feedback:
Other responses/comments on experimental products

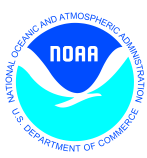**Responders represented a mix of public, AQ forecasters, and researchers from a dozen states including all NWS CONUS Regions.**

Sample Comments:

- **"Very useful for visualizing transport of …smoke. This is a superb product.   The smoke feature is very important."**
  - *AQ researcher and consultant; member of two government air quality committees*

- **"Fire emission important in SJV/CA in general… Important to incorporate real-time fire emissions"**
  - *AQF focus group member, California*

No negative comments received

Production Readiness

Criterion	Lead	Metric	Dates	Status 2/07
On-time delivery	OCIO	Forecast guidance available by 1300 UTC (primary) > 95%	4/1/06 – 2/1/07	C
Ftpserver	OCIO			C
NDGD server	OCIO, MDL			C
Back-up	OCIO	In place	4/1/06	C
Product archiving	OCIO	In place	4/1/06	C
Near-real time verification	NCEP	In place	11/1/06	C
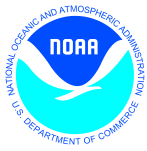
Production Readiness (OCIO, NCEP)
On-time delivery

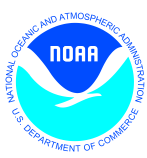| Criterion	Metric	Dates	Status
On-time delivery	*Forecast guidance available by 1255 UTC > 95%*	*4/1/06 – 2/1/07*	C
Guidance availability on NDGD	*Forecast guidance available on NDGD by 1300 UTC > 95%*	*4/1/06 – 2/1/07*	C
Guidance Back-up	*NCEP backs up as part of NCEP model backup*	*4/1/06*	C
NESDIS fire locations product delivered on time	*Delivered to NCEP/NCO daily: target 10 UTC*	*4/1/06*	C
NESDIS GASP observation product delivered on time	*Delivered to NCEP/NCO in near real-time: target within 1 hr of satellite pass*	*9/1/06*	C
IT infrastructure Back-up	*NESDIS ,CCS, TOC and interfacility communications links fully backed up. Reliability of comms links > 99.99%.*	*9/1/06*	C
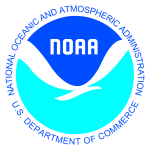
Experimental Smoke Data Availability

- **Monitored Data Flow Receipt from the TOC To NWS Web Farm**

  - *Data flow tracked from 4/1/06 – 2/1/07*

  - *Reviewed forecast guidance availability from system logs, graphical interface displays*

- **Availability must meet program criteria: Forecast guidance available by 1300 UTC > 95%**

  STATUS

  - *Availability at TOC FTP Server:* **GREEN**

  - *Data Archive at NCDC:* **GREEN**

  - *Guidance Availability at NDGD:* **GREEN**
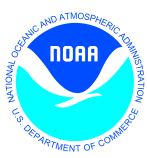
  - *Timely Display on the NWS Web Farm:* **GREEN**

Production Readiness (NCEP)
Near-real time verification

| Criterion	Metric	Dates	Status
Near-real time verification	*Daily; for 24-hour forecast interval 0700-0600 UTC by 48 hours after end of forecast interval.*	*11/1/06*	C

– **Verification Statistics:**   *Compiled and maintained by NCEP. Updated daily*

– **Availability:**   *Model developer group*

– **Seasonal summary**:   *Available on AQ program web site (public)*

– **Weekly verification**:   *Reports on operational performance measures provided by NCEP to OST PM*

– **NESDIS tailored**

   GASP product: *Formatted as gridded WMO standard GRIB files*

   Sent daily to NCEP for model verification; future assimilation

Summary:
Experimental Production of AQ forecast guidance for IOC

- **February 2007 Status: ……general…**
  - *HYSPLIT predictions capture smoke transport from fires -- especially for agricultural, prescribed and large wildfires*
  - *Timing/location of plumes predicted; little quantitative concentration verification available other than column-wide*

- **Objective verification:** **G**
  - *Accuracy performance targets achieved*

- **Subjective feedback:** **G**
  - *Generally positive*
  - *Focus group forecasters providing additional feedback; additional feedback links posted on graphical display sites*

- **Production readiness:** **G**
  - *Forecast guidance available on time*
  - *Backup, data retention and verification demonstrated*
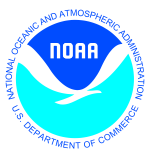
Future Science Infusion

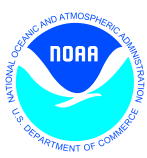## *NOAA planning for improvements to the smoke forecast capability*

- Addition of reactive transport of all estimated fire species within particulates forecast testing
- Global inputs from fires to be incorporated in GFS

Continuing R&D required

- OAR and EPA working actively with NWS to provide prototype capabilities for pre-operational development, testing experimental production, and implementation
- USFS improvements to operational fire emissions estimates (Bluesky) ongoing

Assuring quality with science peer reviews:

- Design review of major system upgrades (initial, yearly upgrades)
- Diagnostic evaluations with field campaigns and evaluations
- Publication of T&E in peer-reviewed literature
  - *Prados et al., Journal of Geophysical Research, in press, 1/07*
  - *Kondragunta et al., submitted for publication, 1/07*
  - *Zeng and Kondragunta, ms. in preparation, 1/07*
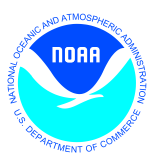 - *Ruminski, Kondragunta, Draxler and Zeng, in preparation, 1/07*

Smoke Forecast Tool:
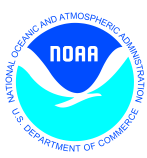## *Operational Readiness Criteria Summary*

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Final go/no go decision	NWS		Review date	G

* NESDIS automated (objective) product

Key | **Complete** | **On schedule** | **At risk** | **Remedial Action Required**
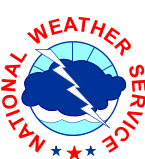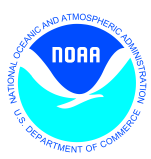
Polling of Senior Leadership

Polling of Senior Leadership

- **NCEP: Product quality, production readiness**
- **CIO: Production readiness**
- **OCWWS: Service readiness**
- **OST: Overall readiness for S&T Upgrade**
- **NOAA AQ PM: Program Manager's Assessment**

Deployment Recommendation

Recommend:

NWS deploy smoke forecast guidance as a new air quality component of operational product suite