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

**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
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

- 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**

- **HYSPLIT Module**
  - NOAA/OAR

- **USFS’s BlueSky Emissions Inventory**
  - USFS

- **NESDIS HMS Fire Locations**

- **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:
    \[
    \frac{(\text{Area Pred } \cap \text{ Area Obs})}{(\text{Area Pred. U Area Obs})}
    \]

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
Review of Operational Readiness
# Smoke Forecast Tool: Operational Readiness Criteria Summary

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Lead</th>
<th>Metric</th>
<th>Dates</th>
<th>Status 2/07</th>
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<tbody>
<tr>
<td><strong>Objective Evaluation: Accuracy</strong></td>
<td>NCEP</td>
<td>&gt; 8%</td>
<td>9/1/06 – 2/1/07</td>
<td>C</td>
</tr>
<tr>
<td><strong>Subjective Feedback</strong></td>
<td>OCWWS</td>
<td>Positive on balance</td>
<td>4/1/06 – 2/1/07</td>
<td>C</td>
</tr>
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<td><strong>Production Readiness</strong></td>
<td>OCIO, NCEP</td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>On-time delivery</td>
<td></td>
<td>&gt; 95 %</td>
<td>4/1/06 – 2/1/07</td>
<td>C</td>
</tr>
<tr>
<td>Back-up</td>
<td></td>
<td>In place</td>
<td>6/1/06</td>
<td>C</td>
</tr>
<tr>
<td>Data retention</td>
<td></td>
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<tr>
<td>Near-real time verification*</td>
<td>NCEP</td>
<td>In place</td>
<td>9/1/06 (at OAR)</td>
<td>C</td>
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<td></td>
<td></td>
<td></td>
<td>11/1/06 (at NCEP)</td>
<td>C</td>
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<tr>
<td><strong>Final go/no go decision</strong></td>
<td>NWS</td>
<td>Review date</td>
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* NESDIS automated (objective) product

**Key**
- **Complete**
- **On schedule**
- **At risk**
- **Remedial Action Required**
**Objective Verification (NCEP, OAR)**

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<tr>
<td><strong>Objective Evaluation: Accuracy</strong></td>
<td>Prediction overlap (FMS) &gt; 8% for 24-hr prediction that smoke concentration ≥ 1 μg/m³ in total column</td>
<td>9/1/06 – 2/1/07</td>
<td>C</td>
</tr>
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</table>

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

**Fire Season: 4/1/06 – 10/31/06**
- Exceeds target 96/184 days
- Cumulative FMS (>1 μg/m³) = 7.9%

**Full Test Season 4/1/06 – 12/31/06**
- Exceeds target 99/214 days
- Cumulative FMS (>1 μg/m³) = 7.7%

**Moving to new GASP product**
- Automated product provides objective basis for daily verification
- Comparison to HMS: slightly lower FMS, but higher during periods of active fires

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**HMS-based Verification**

**GASP Smoke-based Verification**

**September 1-15, 2006 (1 μg/m³ Forecast)**

**HYSLIT VS HMS Shapefiles (24h forecast)**

**GOES Daily TS (Grid to Grid)**
HYSPLIT vs. GASP (Sept 1-15, 2006)
Hourly and Daily Threat Scores for 1 and 5 ug/m^3 (forecast, unconditional)
# Subjective Feedback (OCWWS)

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<tr>
<td>Subjective Feedback</td>
<td>External feedback from State/Local AQ forecasters support product as helpful. Other feedback: internal, constituent, general public: On Balance, positive</td>
<td>4/1/06 – 2/1/07</td>
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**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

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<tr>
<td>On-time delivery</td>
<td>OCIO</td>
<td>Forecast guidance available by 1300 UTC (primary) &gt; 95%</td>
<td>4/1/06 – 2/1/07</td>
<td>C</td>
</tr>
<tr>
<td>Ftpserver</td>
<td>OCIO</td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>NDGD server</td>
<td>OCIO, MDL</td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Back-up</td>
<td>OCIO</td>
<td>In place</td>
<td>4/1/06</td>
<td>C</td>
</tr>
<tr>
<td>Product archiving</td>
<td>OCIO</td>
<td>In place</td>
<td>4/1/06</td>
<td>C</td>
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<td>Near-real time verification</td>
<td>NCEP</td>
<td>In place</td>
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# Production Readiness (OCIO, NCEP)

## On-time delivery

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

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<td>Daily; for 24-hour forecast interval 0700-0600 UTC by 48 hours after end of forecast interval.</td>
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- **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:**
  - HYPLIT 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:**
  - Accuracy performance targets achieved

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

- **Production readiness:**
  - 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
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* 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*