Fast Aerosol Sensing Tools for Natural Event Tracking
FASTNET

Project Synopsis

Haze levels should be reduced to the ‘natural conditions’ by 2064. The space, time, composition features of natural aerosols are not known. This long-term project goal is to better characterize the natural haze conditions. Focus is on detailed analysis of major natural events, e.g. forest fires and windblown dust. FASTNET is primarily a tools development project for data access, archiving and analysis. This, first year pilot project focuses on demonstrating the feasibility and utility of FASTNET.

NESCAUM
Tools in support of Inter-RPO Data Analysis Workgroup
Performed by
CAPITA & Sonoma Technology, Inc
Fast Aerosol Sensing Tools for Natural Event Tracking FASTNET

Analysts Console

Value-adding clients

Data Providers
Value-adders

Misc. Data
Weblinks
Comments

Event Console

Managers Console

Event Summary

Data Providers

Community Website
FASTNET Background

- Dallas RPO meeting Discussions of “Other Haze-Relevant Data”
- RPO Workgroup Presentations on Natural Sources & Events
- RPO Workgroup Proposal Recommendation for EPA funding
- MANE-VU (NESCAUM) Request for Proposals
- Inter-RPO “FASTEST” Technical Steering Group
- Top Proposal from CAPITA + Sonoma Technology Inc.
- FASTEST Recommended Modifications approved by CAPITA
- Contract Signed, Sealed & Delivered
- Ready, Set, Go!
FASTNET Contract Managers: **Gary Kleiman** & **Rich Poirot**

**FASTEST** (FAStnet Testing, Evaluation and Steering Team)

- **Melinda Hoskin** (CENRAP)
- **George Allen** & **Bill Gillespie** (MANE-VU)
- **Donna Kenski** (MWRPO)
- **Pat Brewer** (VISTAS)
- **Marc Pitchford** & **Tom Moore** (WRAP)
- **Jim Szykman** & **Fred Dimmick** (EPA)
- **Doreen Neil** (NASA)
- **Rick Artz** (NOAA)
- Others?
Scope of Work and Deliverables

Task 1: Prepare a long-term plan for RAW-FASTNET
The long-term plan for continued maintenance, operation and utilization of the FASTNET tools will include a specific focus on information technology requirements.
A final version of this long-term plan will be delivered after completion of Tasks 2, 3 and 4 and thus benefit from the experience and insight gained in carrying out these tasks.

Task 2: Prepare candidate real-time data list and demonstrate the archiving/processing
CAPITA will solicit input from, and document responses to, the FASTNET steering committee on which data sets should be given highest priority for inclusion in this 1-year project.

CAPITA will track and document three historical events (not one as proposed in). The specific events will be decided in concert with the FASTNET steering committee, and should be selected to reflect the different major causes of natural aerosols and impacts in the different RPO regions, preferably the modeling year 2002.
Each of the data sets identified in Task 2 (if available) will be used to develop some archived renderings, analyses or other data product for inclusion in the summary report and on the community website for each event tracked. The specific objective is to provide quantitative estimates of the magnitude of natural source contributions for IMPROVE sites and sample days, in terms of the species used to calculate reconstructed extinction at these sites.

Task 4: Real-time tracking and documentation for two current events
CAPITA will track and document two current events (not one as proposed). To the extent feasible, these future events should also be selected to reflect different natural sources and different regional impacts.
CAPITA is expected to work in concert with the FASTNET steering committee and user group to select specific events for analysis and to assist in the analysis activities undertaken by the RPO user group. On the basis of the prioritized data sets CAPITA will develop a mechanism for “large aerosol events” notification.
Natural Aerosol Features and Event Analysis

• Natural Aerosol Features:
  – **Intense** – natural event concentrations can be much higher than manmade emissions
  – **Large** – major natural events frequently have global-scale impacts
  – **Episodic** – the main impact is on the extreme, not on the average concentrations
  – **Seasonal** - dust and smoke events are strongly seasonal at any location
  – **Uncontrollable** –natural events can seldom be suppressed; they may also be extra-jurisdictional.

• Natural Aerosol Event Analysis:
  – Much understanding can be gained from the study of major natural aerosol events
  – Their features are easier to quantify due to the intense aerosol signal
  – Subsequently, smaller events can be evaluated utilizing the gained insights
Significant Natural Contributions to Haze by RPO
Judged qualitatively based on current surface and satellite data

- Natural forest fires and windblown dust are judged to be the key contributors to regional haze
- The dominant natural sources include locally produced and long-range transported smoke and dust
Scientific Challenge: Description of PM

Particulate matter is complex because of its multi-dimensionality
It takes at least 8 independent dimensions to describe the PM concentration pattern

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Abbr</th>
<th>Data Sources</th>
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<tbody>
<tr>
<td>Spatial dimensions</td>
<td>X, Y</td>
<td>Satellites, dense networks</td>
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<tr>
<td>Height</td>
<td>Z</td>
<td>Lidar, soundings</td>
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<tr>
<td>Time</td>
<td>T</td>
<td>Continuous monitoring</td>
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<td>Particle size</td>
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<td>Size-segregated sampling</td>
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<td>Particle Composition</td>
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<td>Speciated analysis</td>
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<td>Particle Shape/Form</td>
<td>F</td>
<td>Microscopy</td>
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<tr>
<td>Ext/Internal Mixture</td>
<td>M</td>
<td>Microscopy</td>
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</tbody>
</table>

- Gaseous concentration: $g (X, Y, Z, T)$
- Aerosol concentration: $a (X, Y, Z, T, D, C, F, M)$
- The ‘aerosol dimensions’ size $D$, composition $C$, shape $F$, and mixing $M$ determine the impact on health, and welfare.
Technical Challenge: Characterization

- PM characterization requires many different instruments and analysis tools.
- Each sensor/network covers only a limited fraction of the 8-D PM data space.
- Most of the 8D PM pattern is extrapolated from sparse measured data.
- Some devices (e.g. single particle electron microscopy) measure only a small subset of the PM; the challenge is extrapolation to larger space-time domains.
- Others, like satellites, integrate over height, size, composition, shape, and mixture dimensions; these data need de-convolution of the integral measures.
Real-Time Aerosol Watch (RAW)

RAW is an open communal facility to study non-industrial (e.g. dust and smoke) aerosol events, including detection, tracking and impact on PM and haze.

RAW output will be directly applicable, to public health protection, Regional Haze rule, SIP and model development as well as toward stimulating the scientific community.

The main asset of RAW is the community of data analysts, modelers, managers and others participating in the production of actionable knowledge from observations, models and human reasoning.

The RAW community will be supported by a networking infrastructure based on open Internet standards (web services) and a set of web-tools evolving under the umbrella of Fast Aerosol Sensing Tools for Natural Event Tracking (FASTNET).

Initially, FASTNET is composed of the Community Website for open community interaction, the Analysts Console for diverse data access and the Managers Console for AQ management decision support.
RAWNET: The Evolving Web system
Data integration, delivery and decision support

**Interactive Virtual Workgroup Website (NSF-EPA-NOAA, 2000-2003 ~$400K)**
This is an open facility to allow active participation of a diverse virtual community in the acquisition, interpretation and discussion of the on-line PM monitoring data.
Participants can contribute information sources relevant to the current events (e.g. special data, web cam images, news reports), insights on data quality and interpretation and collectively prepare summaries.
It is the ‘organizational memory’ of the community through via links to other analyses, external resources, etc

**Analysts Console (NSF-NASA-RPO, 2001-2005 ~$600K - CATT $50K)**
An array of web-pages for one-stop access to current PM monitoring data including surface PM monitoring, satellite monitoring, weather and forecast models etc.
Taps into the on-line data services of EPA and RPOs, NASA, and NOAA and provides the most comprehensive picture available of the current and recent multidimensional aerosol pattern.
The emphasis is on timeliness and inclusiveness. The degree of integration for some data may be limited.

**Air Quality Managers Console (STI-EPA, 2003- ~$25K ++?)**
The console helps PM managers make decisions during major aerosol events.
Delivers a subset of the PM data relevant to the AQ managers, which includes the event summary reports prepared by the Virtual workgroups.
The console manages the ‘watch’ assignments of human observers at the Analysts Dashboard and issues alerts to AQ managers and other interested parties.
Data Federation Concept and the FASNET Network

Schematic representation of data sharing in a federated information system.
Based on the premise that providers expose part of their data (green) to others

Schematics of the value-adding network proposed for FASTNET
Components embedded in the federated value network
Data Acquisition and Usage Value Chain

Monitor → Store → Data 1 → Monitor
Monitor → Store → Data 2 → Monitor
Monitor → Store → Data n → Monitor
Monitor → Store → Data m → Monitor

IntData 1
IntData 2
Virtual Int. Data
IntData n

Monitoring → Acquisition Activities → Data Repository → Integrated Database → Usage Activities → Assessment

Action
Information ‘Refinery’ Value Chain (Taylor, 1975)

- Organizing:
  - Grouping
  - Classifying
  - Formatting
  - Displaying

- Analyzing:
  - Separating
  - Evaluating
  - Interpreting
  - Synthesizing

- Judging:
  - Options
  - Quality
  - Advantages
  - Disadvantages

- Deciding:
  - Matching goals,
  - Compromising
  - Bargaining
  - Deciding

Data → Information → Informing Knowledge → Productive Knowledge → Action

- e.g. CIRA VIEWS
- e.g. Langley IDEA
- RAW System
  - e.g. WG Summary Rpt
- e.g. RPO Manager
Data Flow and Processing

Integration

Aerosol Data Integration
- NAM PM2.5
- NAM Species
- NAM Visibility

Met Data Integration
- NAM Meteorology

Emissions Data Integration
- NAM Emissions

Data from many sources, always changing

Beneficial to all applications
To be performed only once, well

Analysis

- Status and Trends
- Exposure Assess.
- Standard setting
- Exceedances
- Control policies
- Control Implement.
- Tracking progress

AQ management activities
Interactive Virtual Workgroup Websites

July 2002 Quebec Smoke

Focus: Quebec Smoke Pall Over the Northeastern US

On July 6 and 7, 2002, a smoke cloud from the fires in northern Quebec blanketed the northeastern U.S. and adjacent Canada. The smoke has produced record PM2.5 concentrations, disruption to road and aviation traffic, and yellow coloration of the sky.

Explore slide shows: The Big Smoke in New England, Quebec Smoke in the Northeast

Monitoring and Modeling Data On-line
Satellite Data: SeaWIFS, TOMS, AVHRR, OSET
Other Data: APROMET, NRL Surface, NRL Model, Weather Undergr.

Asian Dust Websites
ACE, AsiaHome, ACA-Asia Logistics, AP-NET Asian Dust Network, Lidar Data Exchange, Naval Research Lab, Annual Page, Pacific Modeling Links

NOTE: All images and data presented on this website are for research and educational use only. All conversion of SeaWIFS data must be coordinated with equipment.
AQAC is a set of web-pages for one-stop access to current PM monitoring data. It taps into the on-line data services of EPA and RPOs, NASA, and NOAA and other providers. AQAC emphasizes timeliness and inclusiveness with some data integration. Provides tools for dynamic data connections, space-time overlays and some analysis. AQAC is implemented using the CAPITA Distributed Voyager infrastructure and tools.
Real-time PM Monitoring Console
Example Views – Selected from Dozens of spatial, temporal, height cross-sections
Air Quality Managers Console, ACMC (STI, Prototype)

- Managers Console helps PM managers make decisions during aerosol events.
- AQMC delivers a subset of the relevant PM data through a simple interface
- It includes event summary reports prepared by the ACAC Virtual workgroups
- The Analysts and Managers Consoles will issue alerts and triggers
- The Manager Console will be developed by STI with links to AIRNow
Task 1. FASTNET: Long-term plan (Year 1 activity)

Near Real-time Natural Event Analysis

- Acquire and archive (the volatile) real-time data on PM/haze for current events (2004+). (ASOS, GOES)

- Determine real-time the space-time-composition-optics pattern of PM for events over North America (one future event)

- Estimate the origin (natural/manmade), PM2.5 fraction and visibility impairment by source type and aerosol species for class I areas (one recent event)

- Provide fast notification and characterization (space-time pattern, projected impacts) to a broad “user community” and solicit non-routine data, feedback and expertise from the community (prototype)

Retrospective Natural Event Analysis

- For major natural events, synthesize rapidly available information with slower data streams, e.g. aerosol chemistry; estimate the impact on Class I areas (one recent event)

- Quantify the contribution of smaller (more frequent) natural aerosol events and the “just discernable” natural/manmade distinction

- Statistically characterize the long-term natural aerosol composition and visibility impacts for Class I areas

- Extend these analyses to the baseline period (2000-2004) of the Regional Haze rule

- Provide natural aerosol emission estimates for selected aerosol/haze modeling periods
## Data Analysis and Decision Support

<table>
<thead>
<tr>
<th>Data Sources &amp; Types</th>
<th>Retrospective Anal.</th>
<th>Now Analysis</th>
<th>Predictive Analysis</th>
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<tr>
<td></td>
<td>Months-years</td>
<td>Days</td>
<td>Days-years</td>
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<tr>
<td>All the Real-Time data +</td>
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<td>NAAPS MODEL Forecast</td>
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<td>NPS IMPROVE Aer. Chem.</td>
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<td>NOAA/EPA CMAQ?</td>
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<td>EPA Speciation</td>
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<td>EPA PM10/PM2.5</td>
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<td>EPA CMAQ Full Chem. Model</td>
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<td>EPA PM2.5Mass</td>
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<td>NWS ASOS Visibility, WEBCAMs</td>
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<td>NASA MODIS, GOES, TOMS, MPL</td>
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<td>NOAA Fire, Weather &amp; Wind</td>
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<td>NAAPS MODEL Simulation</td>
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| Data Analysis Tools & Methods         | Full chemical model simulation | Spatio-temporal overlays | Emission and met. forecasts |
|                                       | Diagnostic & inverse modeling  | Multi-sensory data integration| Full chemical model |
|                                       | Chemical source apportionment  | Back & forward trajectories, CATT | Data assimilation |
|                                       | Multiple event statistics      | Pattern analysis            | Parcel tagging, tracking |

| Communication Collab. & Coord. Methods| Tech Reports for reg. support | Analyst and managers consoles | Open, public forecasts |
|                                       | Peer reviewed scientific papers| Open, inclusive communication| Model-data comparison |
|                                       | Science-AQ mgmt. interaction   | Data assimilation methods    | Modeler-data analyst comm. |
|                                       | Reconciliation of perspectives | Community data & idea sharing|                     |

| Analysis Products                     | Quantitative natural aer. concr. | Current Aerosol Pattern | Future natural emissions |
|                                       | Natural source attribution      | Evolving Event Summary  | Simulated conc. pattern |
|                                       | Comparison to manmade aer.     | Causality (dust, smoke, sulfate) | Future location of high conc. |

| Decision Support                      | Jurisdiction: nat./manmade     | Jurisdiction: nat./manmade | Statutory & policy changes |
|                                       | State Implementation Plans, (SIP) | Triggers for management action | Management action triggers |
|                                       | PM/Haze Crit. Documents, Regs  | Public information & decisions | Progress tracking |

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Task 1. Deliverables

1. Long-term (5-year) Plan for an comprehensive Natural Aerosol Event Analysis system consistent with the RPO vision statement and RPO funding of about $100K/year
2. Guidelines for fostering interaction among agencies, researchers and AQ managers
3. Long-term community website (5+ years), showing the long-term plan deliberations
Task 2. Prepare candidate real-time data list and demonstrate the archiving/processing of some raw data.

- **Prepare Candidate Data Lists**
  - Develop a list of haze-relevant real-time data sources
  - Describe the accessibility and other features of each dataset
  - Prioritize the dataset list by suitability for FASTNET
  - Expose the dataset list for community contributions and comments.
  - Identify real-time datasets that require archiving and ‘expert processing’

- **Illustrate the processing a raw datasets**
  - Implement real-time the processing of truncated ASOS visibility data using filters and correction factors for data quality and weather influence. For details see Evaluation of the ASOS Light Scattering Network.

- **Demonstration of a volatile dataset archiving.**
  - Implement an archival system for 1200 station, hourly, truncated but ‘expert processed’ ASOS visibility data.
  - The ASOS weather dataset will be archived continuously during the dust/smoke season of 2004
  - The ASOS data will be accessible through the Analyst Console
Task 2. Deliverables

1. Initial list of candidate real-time datasets for aerosol event analysis.
2. Procedures, tools and ‘expert data processing’ code for ASOS scattering data.
3. Archiving (incl. procedures) of hourly NWS ASOS data for period April-October 2004.
Task 3. Prepare a Full Documentation for three Past Natural Aerosol Event

- Select natural event: July 2002 Quebec Smoke
- Acquisition of multiple haze-relevant information sources
- Processing and integration of multi-sensory data
- Analyze the historical natural aerosol event (smoke or dust)
  - Establish the origins of the aerosol emission
  - Spatial and temporal aerosol concentrations patterns, incl. speciated mass
  - Estimate visibility impairment (reconstructed extinction) during the event
  - Estimate the absolute and contribution of the natural source.
July 2020 Quebec Smoke Event

Superposition of ASOS visibility data (NWS) and SeaWiFS reflectance data for July 7, 2002

- PM2.5 time series for New England sites. Note the high values at White Face Mtn.
- Micropulse Lidar data for July 6 and July 7, 2002 - intense smoke layer over D.C. at 2km altitude.
GLAS Satellite Lidar (Geoscience Laser Altimeter System)
First satellite lidar for continuous global observations of Earth

California Fires, Oct 7, 2003
2002 Quebec Smoke over the Northeast

Smoke (Organics) and Sulfate concentration data from VIEWS integrated database
DVoy overlay of sulfate and organics during the passage of the smoke plume
Task 3. Deliverables

1. Summary report prepared by the community on the analysis and interpretation of the selected event (2002 Quebec Smoke) (Additional peer reviewed papers will be contributed by the participating analysts).

2. Assessment of the successes and the failures of the community-based event analysis approach

3. Long-term community website (5+ years), showing the collaborative analysis process and access to key input datasets.
Task 4: Real-time aerosol event tracking demonstration

- Acquisition of multiple haze-relevant information sources
- Processing and integration of multi-sensory data
- Demonstrate a real-time data distribution through open web interface
- Analyze the natural aerosol event real time
  - Establish the origins of the aerosol emission
  - Spatial and temporal patterns of aerosol concentrations
  - Estimate visibility impairment during the event
  - Estimate the contribution of the natural source.
A Real-time Event Monitoring Action Scenario

1. **Set up AQ Analyst Console** is set up to monitor aerosol parameters as maps, time series, etc.
2. Designated/voluntary analysts **monitor the aerosol situation** in North America and beyond.
3. The ‘aerosol watch’ consists of scanning the satellite and point samplers for event signals.
4. Once an event appears, **explore peripheral data** to ascertain the emergence of an event.
5. Some **forecast models can predict** the onset of **dust events** (e.g. The NRL NAAPS model).
6. ‘Watchers’ interact through the **FASNET community website**, share ideas, data.
7. Decide to ‘start intensive’ issue **trigger messages** to groups to participate and act.
8. During the event, **chaos, uncertainty, many decisions and actions** including ‘stop intensive’
9. Throughout, the **Managers Console shows relevant data and summaries**, more triggers.
10. As the event evolves, the **analyst-workgroup summarizes event**: sources, transport, pattern.
11. The event is evaluated if it warrants detailed retrospective analysis analyses.
12. Conduct retrospective analysis (completed in 1-2 years after the event)
Task 4. Deliverables

1. Demonstration of the real-time data access-ingestion-analysis capabilities of the FASTNET web-based tools system to track natural aerosol events consisting of the (1) Community website; (2) Analysts Console and the (3) Managers Console.

2. Assessment report of the strengths and weaknesses of the real-time data tracking system

3. Community summary report on the initial analysis and interpretation of the selected event

4. Event data, organized and stored (5+years), suitable for subsequent detailed analysis.
Project Management and Schedule

- The PI, Rudolf Husar of CAPITA, will manage the FASNET project. He will be supported by Kari Hojarvi of CAPITA.

- The Air Quality Managers Console will be the responsibility of STI.

- The FASNET project Steering Committee will provide guidance.

- Other agency managers (NASA, NSF) may also influence the project.
Regional Haze Rule: Natural Aerosol

Natural haze is due to natural windblown dust, biomass smoke and other natural processes. Man-made haze is due to industrial activities AND man-perturbed smoke and dust emissions. A fraction of the man-perturbed smoke and dust is assigned to natural by policy decisions.

The goal is to attain natural conditions by 2064; the baseline is established during 2000-2004. The first SIP & Natural Condition estimate in 2008; SIP & Natural Condition Revisions every 10 yrs.
Summary of EPA Haze Rule on Natural Conditions

- The default annual natural visibility is 11-12 deciview for the East, 8 dv for the West.
- The **regional** natural visibility is to be derived from **sulfate, nitrate, organic carbon, elemental carbon**, and **crustal material** estimates using IMPROVE methodology.
- EPA along with States, tribes, and FLMs to develop and refine the **technical guidance** on estimating natural conditions (e.g. natural fire and dust)
- States, in turn, will work with the FLMs, tribes and EPA in **estimating their natural conditions** using these guidelines at each Class I area.