Integration of Airborne Aerosol Prediction Systems and Vegetation Phenology to Track Pollen for Asthma Alerts in Public Health Decision Support Systems

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Tracking Pollen for Asthma Alerts in Public Health DSS (Luvall)

**Earth System Models**
- DREAM/NMM
  - Dust model
- PREAM/NMM
  - Pollen transport

**Earth Observations**
- MODIS & NPOESS-VIIRS
  - MOD9, MOD09GA, MOD09_SPA, NDVI/
  - EVI_SPA, MODLST_SPA, ASTER
- Burkard pollen samplers
- ASD-FR spectroradiometer

**Data**
- OGC Web Map Services
- Apache Web Server
- Asthma/MI health data

**Predictions/Forecasts**
- Identification of pollen source, timing and transport

**Decision Support Systems**
- Enhanced NM EPHTS & CDC EPHTN
- SYRIS

**Partnership Area**
- Issue public health alerts
- Optimize hospital staffing
- Allergists alerted to pollen timing

**Value and Benefits to citizens and society**
- Early Warnings
  - Better understanding about asthma/pollen
  - Reduced medical costs
  - Fewer inpatients
  - More accurate diagnoses

**Inputs**
- NASA and UNM, UA Partners

**Outputs**
- NMDOH and CDC EPHT Systems; SYRIS
  - Practicing Allergists
### Top pollen-producing species

<table>
<thead>
<tr>
<th>Los Alamos</th>
<th>Albuquerque</th>
</tr>
</thead>
<tbody>
<tr>
<td>juniper</td>
<td>mulberry</td>
</tr>
<tr>
<td>sagebrush</td>
<td>juniper</td>
</tr>
<tr>
<td>pine</td>
<td>ash</td>
</tr>
<tr>
<td>Alternaria*</td>
<td>goosefoot</td>
</tr>
<tr>
<td>oak</td>
<td>cottonwood</td>
</tr>
<tr>
<td>grass</td>
<td>grass</td>
</tr>
<tr>
<td>ragweed</td>
<td>sagebrush</td>
</tr>
<tr>
<td>goosefoot</td>
<td>pine</td>
</tr>
<tr>
<td>Cladosporium*</td>
<td>elm</td>
</tr>
<tr>
<td>Myxomycete*</td>
<td>aster</td>
</tr>
<tr>
<td>cottonwood</td>
<td>ragweed</td>
</tr>
<tr>
<td>mulberry</td>
<td>sycamore</td>
</tr>
<tr>
<td>aster</td>
<td>oak</td>
</tr>
<tr>
<td>elm</td>
<td>willow</td>
</tr>
</tbody>
</table>

* fungal / slime mold spores
• High concentrations of pollen allergens have also been shown to occur in thoracic particles (<10 microns in diameter) and respirable particles (<2.5 microns in diameter) and these correlated well in time with airborne pollen concentrations. ... airborne pollen results in exposure of the lower airways and lung to pollen allergens.

• The association between air pollution and the number of daily deaths may be related to the inflammatory potential of very small particles

• ...suggests that high airborne pollen concentrations, which nowadays are mainly seen as triggers of allergic symptoms, may have far more serious effects than previously thought.

27 Jan 99, Jim Anderson in London, Ontario reported atmospheric *Juniperus* pollen - 58 pollen grains/m$^3$

Trajectories show that the source of this pollen was Texas population of *Juniperus ashei*

Our Jan 26 forecast indicated that the “pollen has the potential to travel very long distances.”
Burkard Spore Trap
PollenCast for Tucson, Arizona

Reported Levels

Tree pollen count for today, 03/31/08:

Moderate

See past pollen counts for Tucson, Arizona

Forecasted Levels

- Very High
- High
- Medium
- Low
- No Activity

Forecast not available
Limitations of Pollen Sampling

- Lack of stations
- Count frequency & reporting lag time
- Different sampling instruments Rotorod Sampler/Burkard Spore Trap
- Only indentifiable pollen “grains”
- Expertise in counting/identification
- Refusal to release sampling information—”We do not reveal the sources for our data for privacy and proprietary, competitive reasons. Some pollen counts are conducted privately, and are not meant to be broadcast to the public”
Pollen Timing

- *Growing Degree Days* - the average of the daily maximum and minimum temperatures compared to a base temperature, $T_{\text{base}}$, (usually 10 °C)
- Response to length of day
- Species differences
- Climate – Variability in Precipitation
- Weather
Juniper species

Juniperus ashei (TX, OK)
Juniperus monosperma (NM)
Juniperus scopulorum (NM)
Juniperus pinchotii (TX, OK)
Juniper density* distribution over USA

(1 km grid resolution)
Juniperus monosperma

http://www.conifers.org/cu/Juniperus_monosperma.php
Pollen production

- Size of tree, cones per unit area, %veg.
- Cones per tree
- Pollen per cone
  - Preliminary pollen count for *J. ashei* = 381,000 pollen grains/cone
Y intercept = 1.76
$10^b = 57.5 = k$
n = $kh^b$
n = $57.5(3^3.39)$
n*8 = **19,060 cones**
n = $57.5(4^3.39)$
n*8 = **50,550 cones**

Y intercept = 2.71
$10^b = 513.2 = k$
n = $kh^b$
n = $513.2(3^3.73)$
n*8 = **247,200 cones**
n = $513.2(4^3.73)$
n*8 = **722,870 cones**
Mean Daily Concentration* of Airborne *Juniperus ashei* Pollen at Sonora, TX

*Concentration for each day is the mean of 12 bihourly concentrations*
2003 Los Alamos daily pollen

Daily pollen counts (grains/m³)

- **juniper**
- **Cladosporum**
- **sagebrush**
2006 Los Alamos daily pollen

Juniper

Sagebrush

daily pollen counts (grains/m^3)
date
Spectral characteristics of male juniper canopies at different bud density levels

<table>
<thead>
<tr>
<th>Density level</th>
<th>Bud density (g/m^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>204.2</td>
</tr>
<tr>
<td>2</td>
<td>190.0</td>
</tr>
<tr>
<td>3</td>
<td>176.9</td>
</tr>
<tr>
<td>4</td>
<td>164.9</td>
</tr>
<tr>
<td>5</td>
<td>151.1</td>
</tr>
<tr>
<td>6</td>
<td>136.2</td>
</tr>
<tr>
<td>7</td>
<td>115.8</td>
</tr>
<tr>
<td>8</td>
<td>92.9</td>
</tr>
<tr>
<td>9</td>
<td>45.9</td>
</tr>
<tr>
<td>10</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Relationships between spectral indices and juniper bud density levels

- NDVI: $y = 0.0404x + 0.9448$, $R^2 = 0.98629$
- EVI: $y = 0.0065x + 0.6908$, $R^2 = 0.92639$
- EVI2: $y = 0.0119x + 0.4011$, $R^2 = 0.84828$
MODIS Juniper Time Series

Enhanced Vegetation Index

70-90% density
Juniper Site 2

Pollinating period

DOY, 2006
Temporal profiles of residual MODIS reflectances at the four study sites.
S038-SOUTHERN ROCKY MOUNTAIN PINYON-JUNIPER
During pollen eruption (Top) and seen from space (Bottom)
Many challenges

• Residual signals and reference baselines
• Landscape vs species level phenology & signals (disaggregate woody from herbaceous)
• Surface heterogeneity and spatial characterization of landscape
• Future sensors & fusion (Lidar, VIIRS, HyspIRI)
• BRDF & surface aerodynamics
• Modeling (vegetation dynamics, phenology)
Weather - DREAM

Dust REgional Atmospheric Modeling (DREAM) system

- MM5
- WRF


Yin et al., The impact of using different land cover data on wind-blown desert dust modeling results in the southwestern United States *Atmos. Environ.*, **41**, 2214-2224 (2007).

Adapted from Betterton ppt
Applications Have Included:
- Dust Storms & Airborne Mineral Dust Concentrations in the Middle East, Africa and the Southwest US
- Pollen in Colorado, New Mexico & Texas
- Volcanic Ash in the Mediterranean
- Soybean Rust in South America

A new test: Forest fire ash and smoke plumes
A proposed test: mold spores
Model predictions (72-h):
- Horizontal distribution
  - Surface concentration
  - Total column mass (dust load)
  - Wet, dry, total deposition
  - Meteorological variables
- Vertical distribution
  - Concentration
  - Cross sections
  - Fixed point/time profiles
- Fixed point (selected sites/cities)
Pollen Strategy

- Select Pollen of Interest
- Map Pollen Source
- Estimate Emission on Test Date
- Prepare Model
  - Insert Terrain & Pollen Aerodynamic Characteristics
  - Insert Source Emission
  - Insert Meteorology
- Simulate Downwind Pollen Dispersal
- Evaluate
Juniper Pollen

Good News for Modeling

- Pollination Dec-March, little confusion with other pollinating plants
- *Juniperus* pollens are (mostly) spherical, 18-30 μm size

*Juniperus virginiana*
Phenology and Pollen Transport

Pollen sources derived from phenological maps

DREAM - UofA numerical meteorological particulate transport model

Final Product – predicted concentrations of pollen in time and space

NASA MODIS data

http://www.atmo.arizona.edu/research/dust/dust.html
Pre-PREAM Test

- Single-particle (size) Pre-PREAM
- Simultaneous transport from 4 sources
- Result: sum of transported particles coming from the 4 sources
Preparing Source for Model

- Model requires juniper density (pixel fraction): percent juniper pixels (30m resolution) present in 2-km cell
  - Each 2km cell has 66 x 66 (4,356) pixels
  - Count juniper pixels
  - $(\#\text{Juniper Pixels})/4,356 = \text{juniper pixel fraction} = \text{juniper density}$
Juniper Type Filter

CO Piñon-
Juniper Density

Class S039, Colorado Plateau, Piñon-Juniper Woodland

Density (%)

High : 100
Low : 6

Juniper Density value was estimated from the aggregation of 30-m pixels into 2-km pixels. This value indicates what percentage of the original 30-m pixels corresponds to the new 2-km pixel labeling class.
Juniper Pollen
Near-surface concentration (Nm3)

6 March 2006
9 March 2006
11 March 2006
Los Alamos:
Pollen concentration: 24 Feb – 19 March 2006

Model integration time
Status of Transitioning Pollen Data Into NM EPHT

- Progress in year 1 (green oval):
  - Prepare interface for health client server
  - Prepare server for pollen data output
- Test server functions: (yellow oval):
  - Dependent upon receiving sample data from modeling team
- Activities for out years: (blue boxes)
Welcome to the New Mexico EPHT Mapping Applications Page

How to use this map

The layers that you have requested to map are listed below. To add them to the map click 'add to map'. When you first add your EPHT query layer it will appear above the other layers in your map. You can use the arrowed buttons beside each layer in the table of contents to move layers up and down in the list for viewing. Navigation controls for the map are just below the map. Hovering over any of the controls gives you directions for their use. You must have popups enabled in your web browser in order to be able to query features in the map. You can use the small locator map above to zoom on the map in addition to using the zoom button below the map, just click and drag.

Map Layers from: your EPHT data search

DREAM dust output PM2.5 - Classified 24-Hr Mean 2009-04-11T00:00:00Z

add to map

Table of Contents

1. DREAM dust output PM2.5 - Classified 24-Hr Mean 2009-04-11T00:00:00Z

   - Excellent
   - Good
   - Moderate
   - Unhealthy For Sensitive Groups
   - Unhealthy
   - Very Unhealthy
   - Hazardous

2. Water System Boundaries
Syndrome Reporting Information System™
The SYRIS system provides:

- Real-time, Syndrome-Based Reporting Tool
- 2-Way Real-time Communication System - 24/7
- Automated, Immediate 'Alerts' to Public Health Officials (PHO's)
- Health 'Alerts' to Vets, Doctors, Hospitals, & Schools
- Web-Based Tool for Easy Syndrome Entry and Communication
- Geographic Mapping of Disease Outbreaks
- Connects All Health Care Providers to a Common Database
- Instantaneous Geographic Mapping of Disease Outbreaks
- Full compliance with the requirements of Public Law 109-417 (the Pandemic and All-Hazards Preparedness Act)
RIS will be used by Public Health Officials for interactive display of PREAM pollen maps, syndrome porting and alerts
Conclusions

- The residual signal indicates that the pollen event may influence the seasonal signal to an extent that would allow detection, given accurate QA filtering and BRDF corrections. MODIS daily reflectances increased during the pollen season.

- The DREAM model (PREAM) was successfully modified for use with pollen and may provide 24-36 hour running pollen forecasts.

- Publicly available pollen forecasts are linked to general weather patterns and roughly-known species’ phenologies. These are too coarse for timely health interventions. PREAM addresses this key data gap so that targeting intervention measures can be determined temporally and geospatially.

- The New Mexico Department of Health (NMDOH) as part of its Environmental Public Health Tracking Network (EPHTN) would use PREAM a tool for alerting the public in advance of pollen bursts to intervene and reduce the health impact on asthma populations at risk.

- SYRIS provides direct feedback from and to the health community.