Integrating Airborne Dust Forecasting and Remote Sensing into Air Quality and Public Health Decision Support Services

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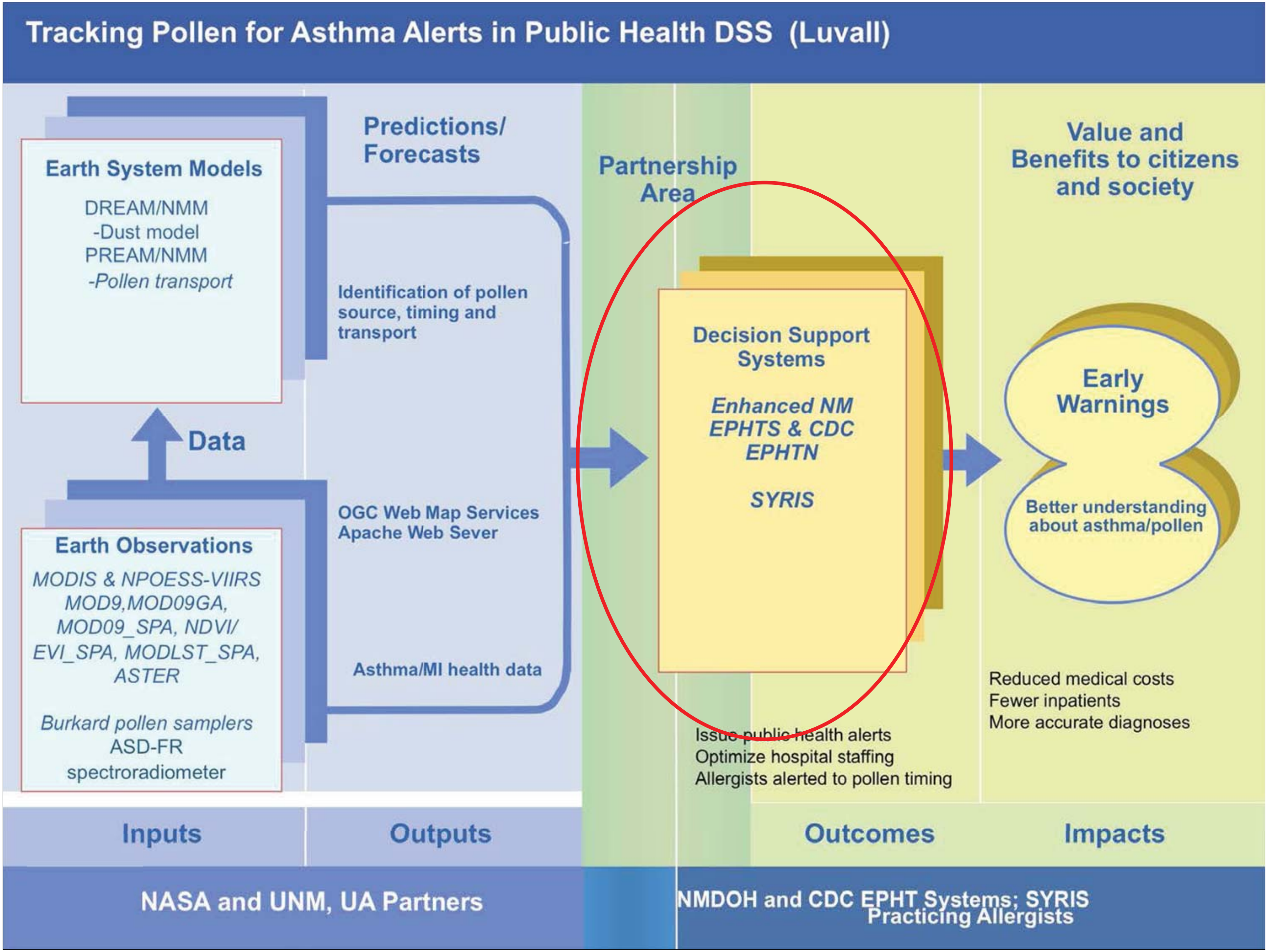

Tracking Pollen for Asthma Alerts in Public Health DSS (Luvall)
Earth System Models
DREAM/NMM
-Dust model
PREAM/NMM
-Pollen transport
Data
Earth Observations
MODIS & NPOESS-VIIRS
MOD9,MOD09GA,
MOD09_SPA, NDVI/
EVI_SPA, MODLST_SPA,
ASTER
Burkard pollen samplers
ASD-FR
spectroradiometer
Predictions/
Forecasts
Identification of pollen source, timing and transport
OGC Web Map Services
Apache Web Sever
Asthma/MI health data
Partnership
Area
Decision Support
Systems
Enhanced NM
EPHTS & CDC
EPHTN
SYRIS
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
Outputs
Outcomes
Impacts
NASA and UNM, UA Partners
NMDOH and CDC EPHT Systems; SYRIS
Practicing Allergists

Pollen and Respiratory Disease: What little is known[2]

Increase in mortality of these disorders:

	Poaceae pollen concentrations (grains per m³ air)			
	<22	22–77	78–135	>135
	Relative risk	Relative risk (95% CI)	Relative risk (95% CI)	Relative risk (95% CI)
Cardiovascular disease	1·000	1·015 (1·002–1·029)	1·012 (0·994–1·029)	1·061 (1·038–1·084)
Chronic obstructive pulmonary disease	1·000	1·095 (1·053–1·139)	1·124 (1·069–1·181)	1·150 (1·079–1·225)
Pneumonia	1·000	1·104 (1·049–1·163)	1·093 (1·023–1·168)	1·168 (1·077–1·266)
Total	1·000	1·019 (1·010–1·028)	1·019 (1·008–1·031)	1·043 (1·028–1·058)

- High concentrations of pollen allergens have also been shown to occur in thoracic particles (<10 microns in diameter) and respirable particles (<2·5 microns 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."

[2] Bert Brunekreef, Gerard Hoek, Paul Fischer, Frits Th M Spieksma. Relation between airborne pollen concentrations and daily cardiovascular and respiratory-disease mortality. Lancet Vol 355 (2000): 1517-8.

Moscow Birch Pollen


NE Alamos
SE Alamos
Santa Fe
Tijeras A
Tijeras B
Palo Duro
SSWMA
Crossbar
Classen
Copper
San Angelo
Junction
Sonora
Sonora
San Marcos
Chihuahuan Desert
Gulf of California

Juniper Species and Pollination Season

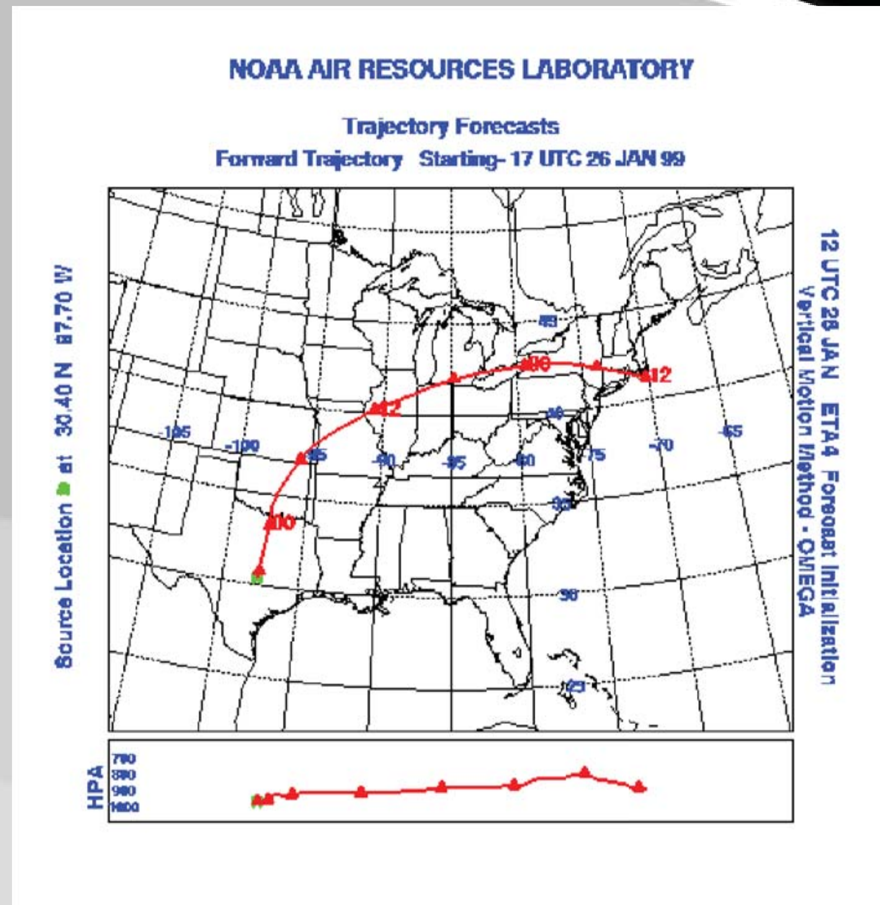
- **Juniper Ashei (J_a)** is mostly found to be distributed over Texas and Oklahoma and pollinates during **December to January**. Thus, the dispersion of juniper pollens during December-January is mostly restricted to J_a type..

- **Juiper Pinchotti (J_p)** is mostly distributed over Texas and pollinated during **October-November**. Thus, the dispersion of juniper pollens during this period is mostly restricted to J_p type.

- **Juniper monosperma (J_m) and Juniper scopulurum (J_s)** are prevalent in New Mexico and pollinates during **March-April** period. Thus, the dispersion of juniper pollens during this period is mostly restricted to J_m and J_s type.

Continental transport

- 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.”



Van de Water et. al 2003

Pollen per cone

Sonora	472,000 pollen grains/cone
Dallas	402,000 pollen grains/cone
San Marcos	374,000 pollen grains/cone
Junction	363,000 pollen grains/cone

269,946 to 946,646
cones per tree

160 to 1500
Trees/Ha

Pollen Release

Burkard Spore Trap

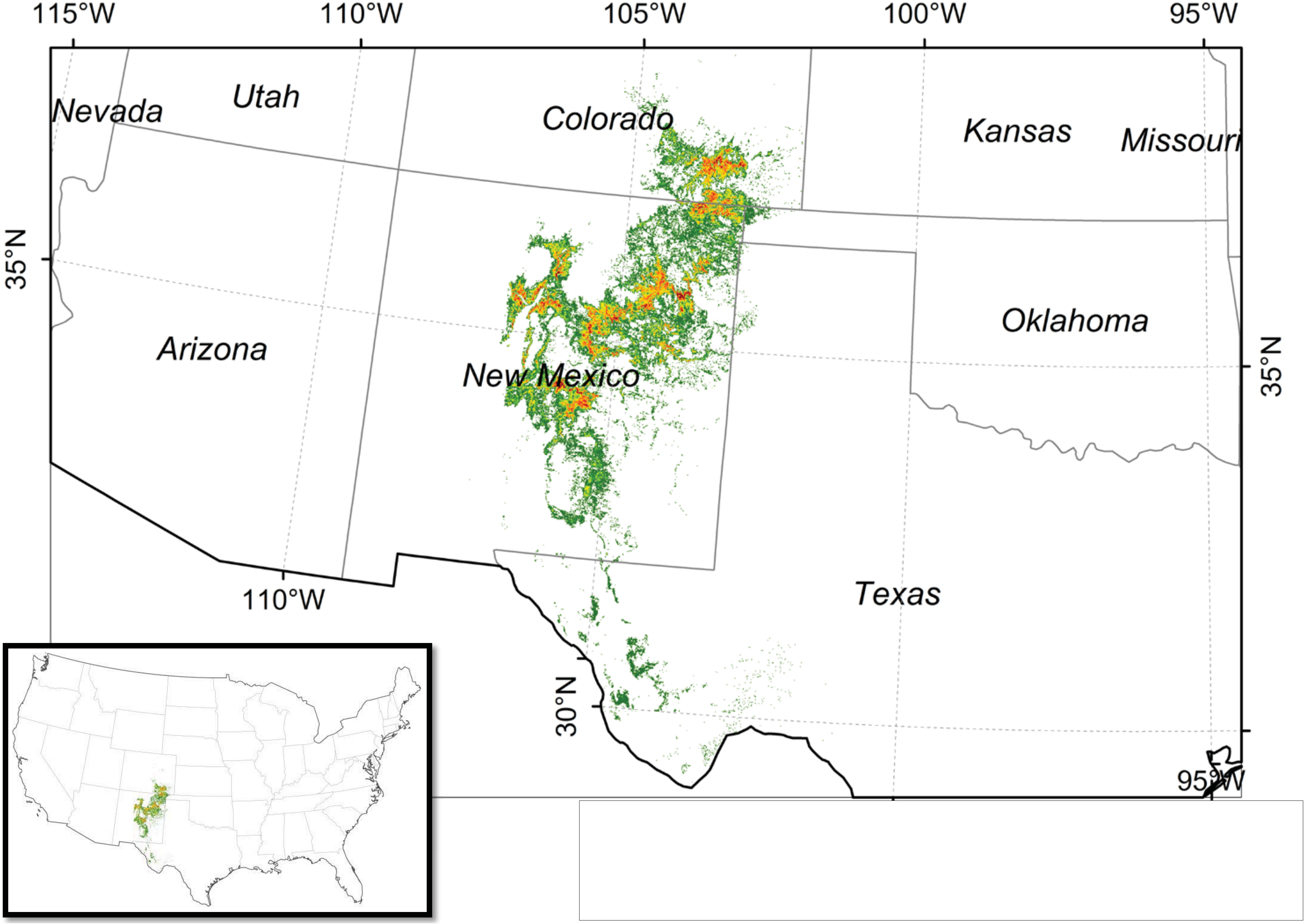
Limitations of Pollen Sampling

- Lack of stations
- Count frequency & reporting lag time
- Different sampling instruments Rotorod Sampler/Burkard Spore Trap
- Only indentifiable pollen “grains”
- Expertise in counting/indentification
- 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_{base}, (usually 10 ° C)
- Response to length of day
- Species differences
- Climate – Variability in Precipatation
- Weather

Southern Rocky Mountain Juniper Woodland and Savanna



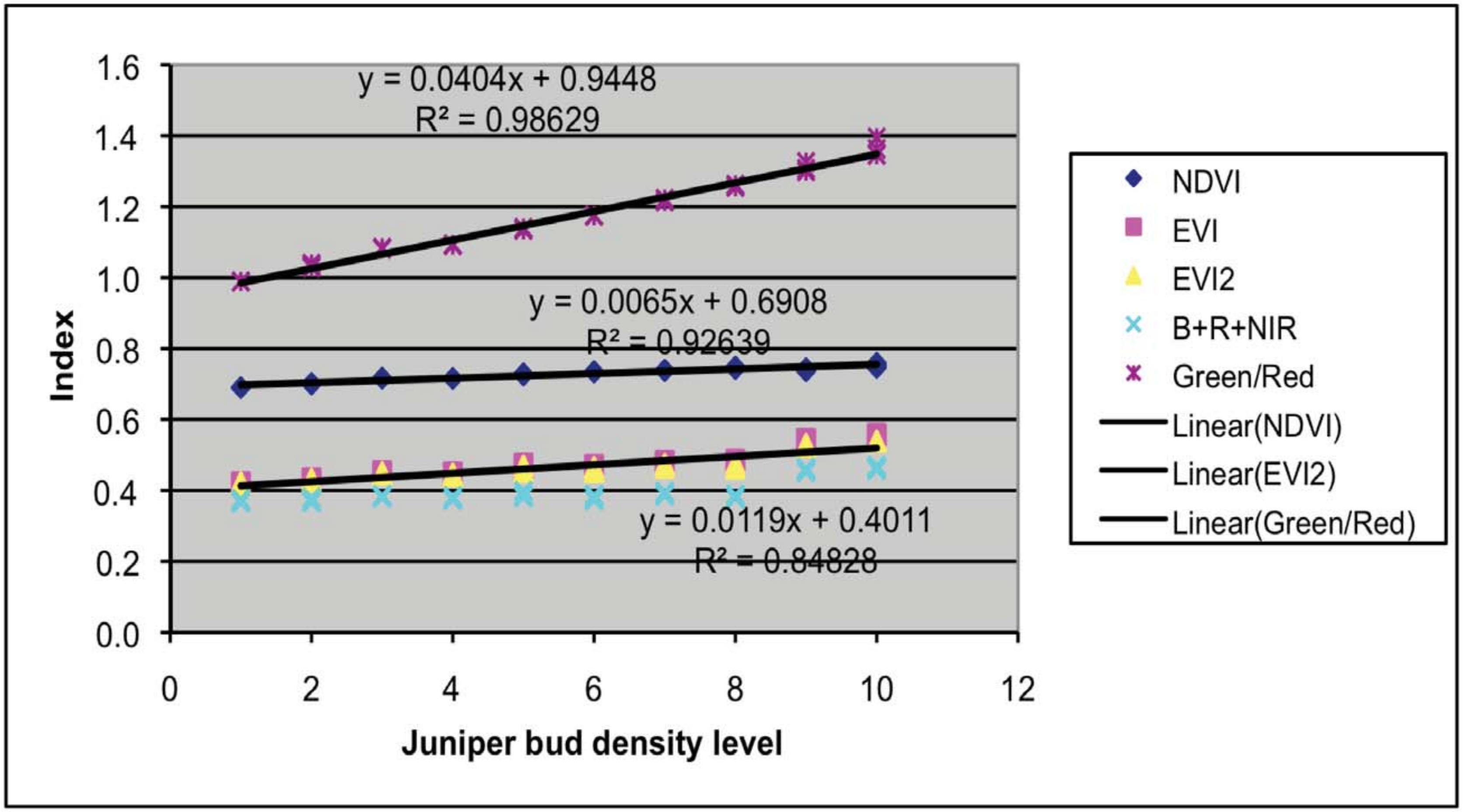

04/13/2009 14:11

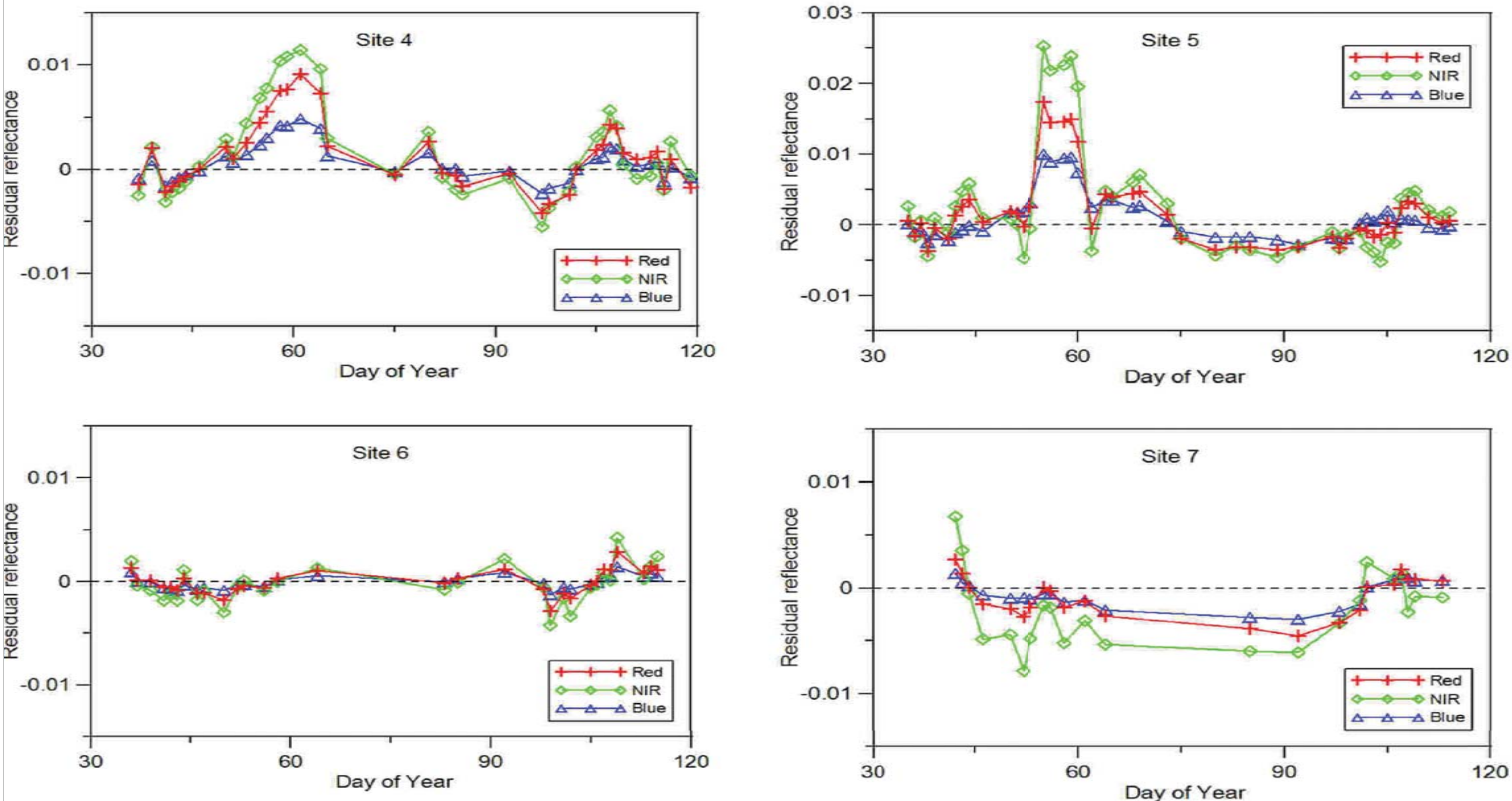

04/13/2009 15:05

Spectral characteristics of male juniper canopies at different bud density levels

Density level	Bud density (g/m^2)
1	204.2
2	190.0
3	176.9
4	164.9
5	151.1
6	136.2
7	115.8
8	92.9
9	45.9
10	0.0

Relationships between spectral indices and juniper bud density levels





Temporal profiles of residual MODIS reflectances at the four study sites.

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)

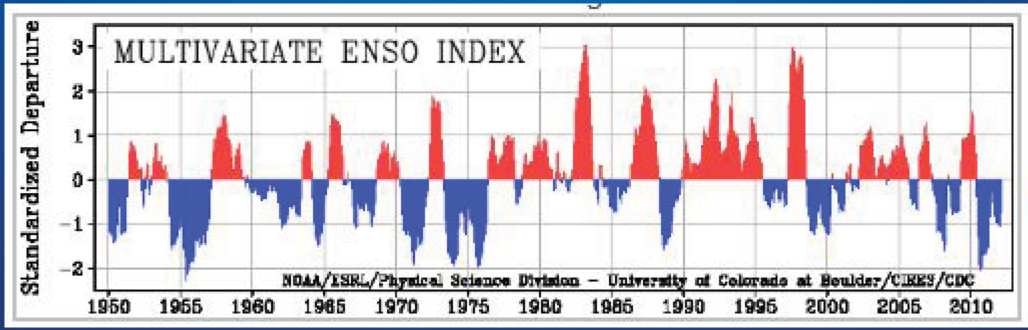
Summary Statistics for 2010 and 2011 *Juniperus pinchotii* pollen seasons at source

Location	Average daily concentration Pollen grains/m3	Peak daily concentration Pollen grains/m3	Date of peak	Peak hourly concentration Pollen grains/m3	Time of peak hour	Date of peak hour
2010						
Erick, OK	337	5,563	25-Oct	15,898	10:00 AM	25-Oct
Sonora, TX	286	3,019	25-Oct	12,152	10:00 AM	25-Oct
San Angelo, TX	653	5,542	1-Nov	10,195	Noon	1-Nov
2011						
Erick, OK	12	214	16-Oct	800	10:00 AM	16-Oct
Sonora, TX	64	428	26-Oct	2,422	10:00 AM	31-Oct
San Angelo, TX	60	493	26-Oct	2,747	4:00 AM	26-Oct
Quanah, TX	22	190	19-Oct	703	8:00 PM	19-Oct

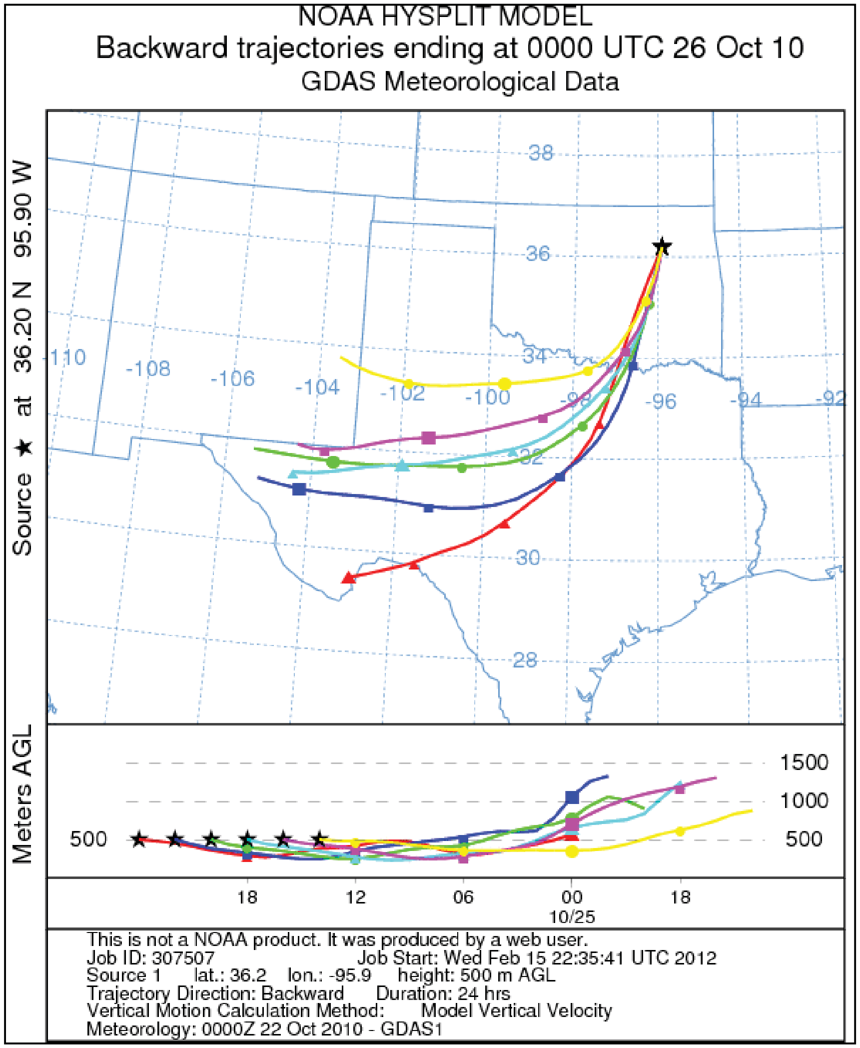
Influence of preseason meteorological variables for *Juniperus ashei*

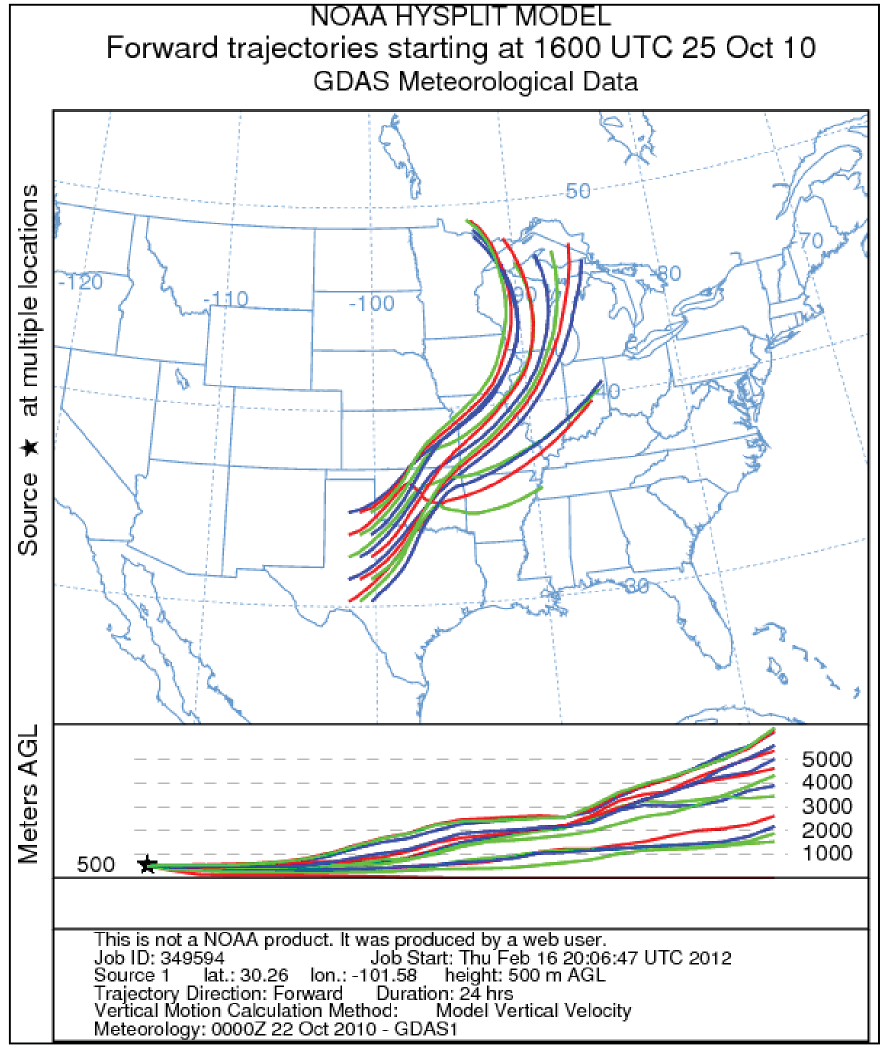
- Start date
  - Significantly correlated with mean monthly temperature in December ($r = 0.467$, $p = 0.038$) and November rainfall ($r = 0.468$, $p = 0.038$)
- Cumulative Season Total (CST)
  - Significantly correlated with mean maximum temperature in December ($r = 0.4740$, $p = 0.035$)

Trajectory Wind Directions				
	Southerly	Northerly	Within TX	Other
2007 to 2008 Pollen Year				
	17%	54%	24%	5%
2008 to 2009 Pollen Year				
	12%	68%	7%	12%
2009 to 2010 Pollen Year				
	31%	50%	7%	11%
2010 to 2011 Pollen Year				
	26%	41%	30%	4%
2011 to 2012 Pollen Year				
	18%	54%	16%	13%

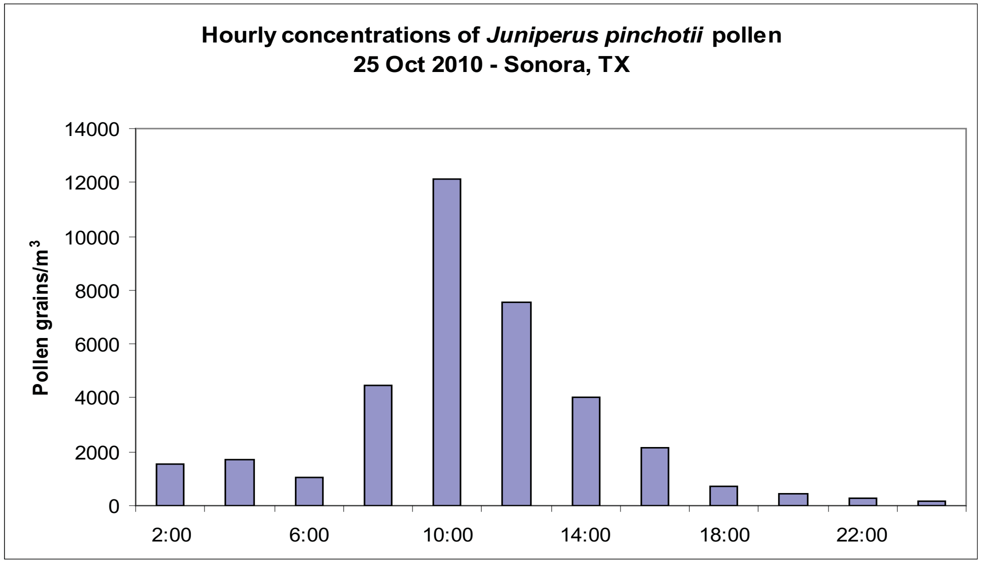


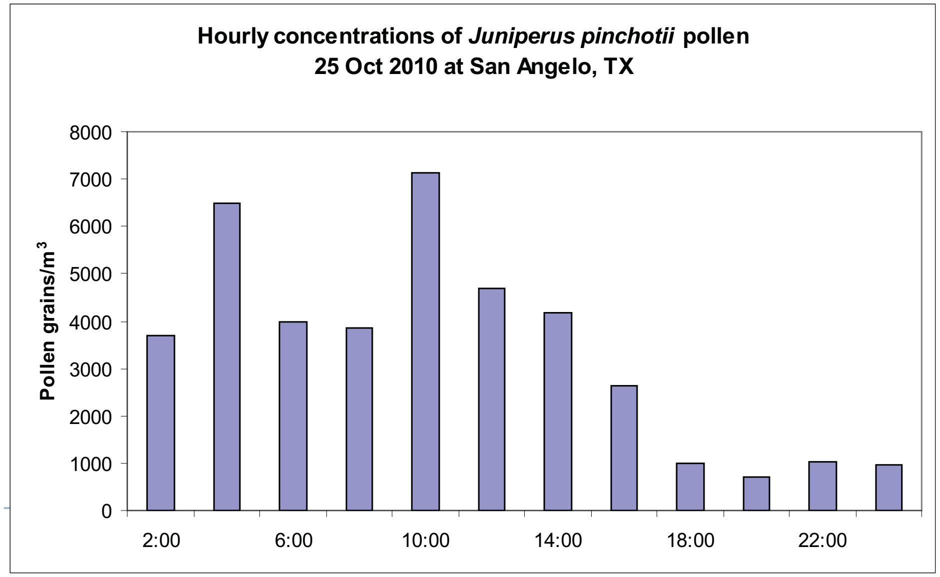
Trajectory analysis indicates the pollen originated in southwest Texas approximately 8 hours earlier





Juniperus pinchotii concentrations at Sonora and San Angelo confirm the trajectory model



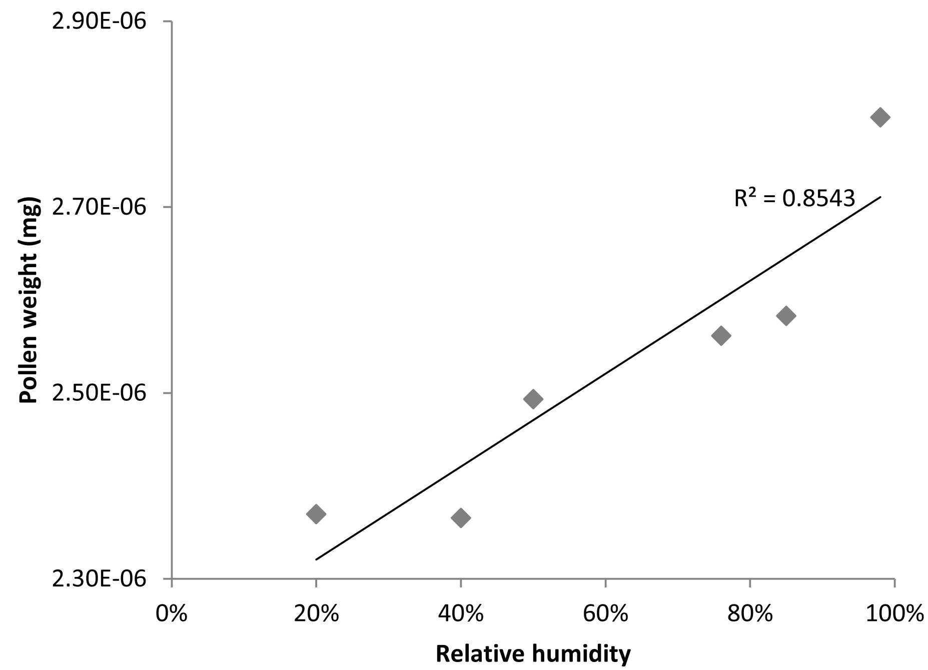


Hygroscopic Weight Gain of *Juniperus* Pollen

- *Juniperus ashei, J. monosperma*, and *J. pinchotii* were dusted on greased slides and exposed to a range of temperatures and humidity levels and weighed at 2 hrs and 6 hrs.

- *J. ashei* was weighed at temperatures 4° C, 15° C, and 20° C at relative humidity levels; 20%, 40%, 50%, 75%, 86%, 97%.

- Weight was not significantly affected by temperature or time.



Estimated weight per pollen grain (*J. ashei*) after 2 hrs across the range of relative humidity levels at 20° C

Airborne Dust Simulations and Forecasts

University of Arizona
With NASA Earth System Science & University of New Mexico

Phoenix dust storm – 7 June 2006
Photo by Robb Schumacher Arizona Republic

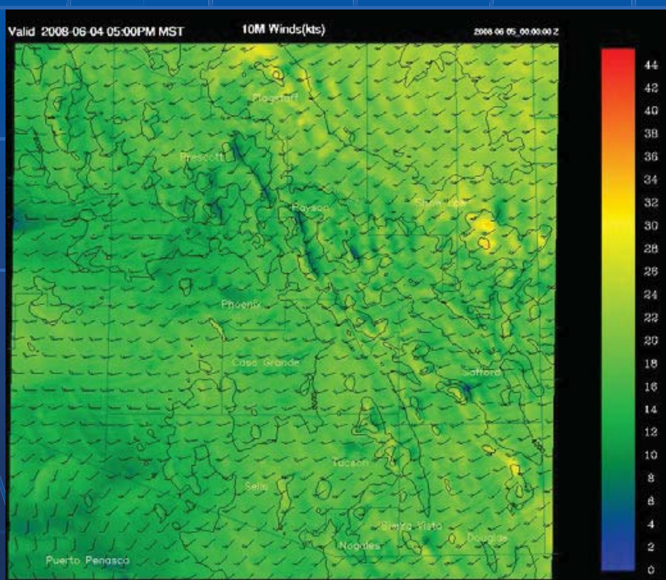
Department of Atmospheric Sciences

http://www.atmo.arizona.edu/faculty/research/dust/dust.html

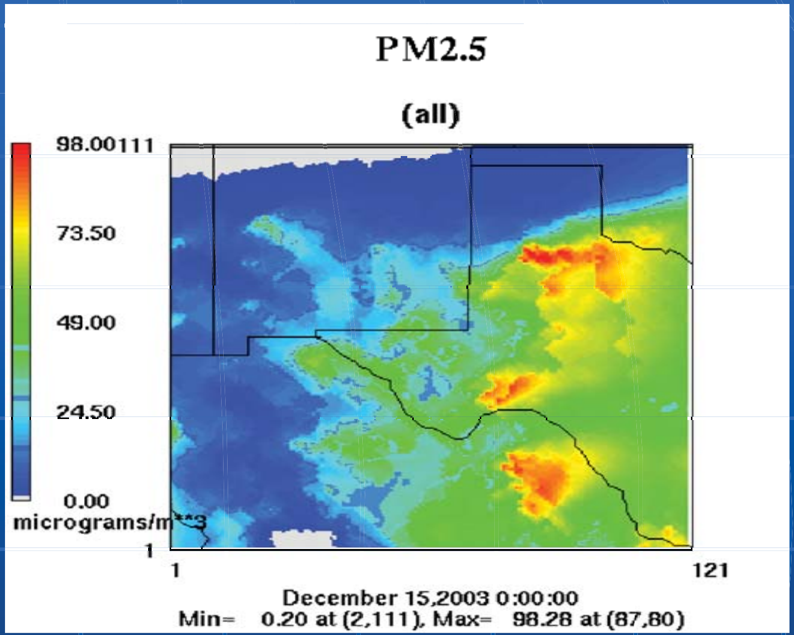
Weather - DREAM

Dust REgional Atmospheric Modeling (DREAM) system

- MM5
- WRF



UA WRF 10-m wind forecast



S. Nickovic et al., A model for prediction of desert dust cycle in the atmosphere, *JGR* **106**, 18113–18129 (2001) .

Yin et al., Modeling wind-blown desert dust in the southwestern United States for public health warning: A case study, *Atmos. Environ*. **39**, 6243-6254 (2005).

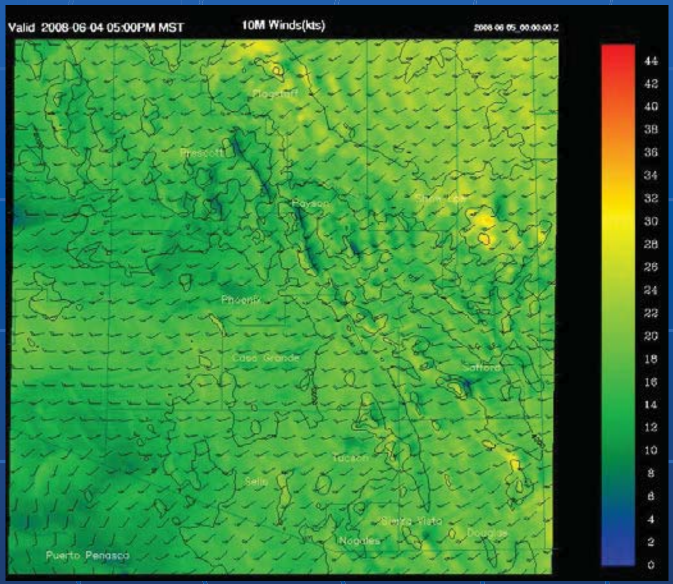
Yin et al.,The impact of using different land cover data on wind-blown desert dust modeling results in the southwestern United States *Atmos. Environ*., **41**, 2214-2224 (2007).

Adapted from Betterton ppt

Weather - DREAM

Dust REgional Atmospheric Modeling (DREAM) system

- MM5
- WRF



UA WRF 10-m wind forecast

Pollen - PREAM

Pollen REgional Atmospheric Modeling (PREAM) system

Model horizontal domain: Southwest US
Model resolution: ~19 to 40 km
Bins: 4, sized by pollen gain size distributions
Boundary conditions: driven by the NCEP/WRF 1 degree global forecasts used to refresh; initial conditions every 24 hours, boundary conditions every 6 hours
Model Output: Every 3 hr maps of pollen surface concentrations (grains/m^3) out to 48 hrs.

S. Nickovic et al., A model for prediction of desert dust cycle in the atmosphere, *JGR* **106**, 18113–18129 (2001) .
Yin et al., Modeling wind-blown desert dust in the southwestern United States for public health warning: A case study, *Atmos. Environ*. **39**, 6243-6254 (2005).
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).

VERSATILE DREAM

Applications Have Included:

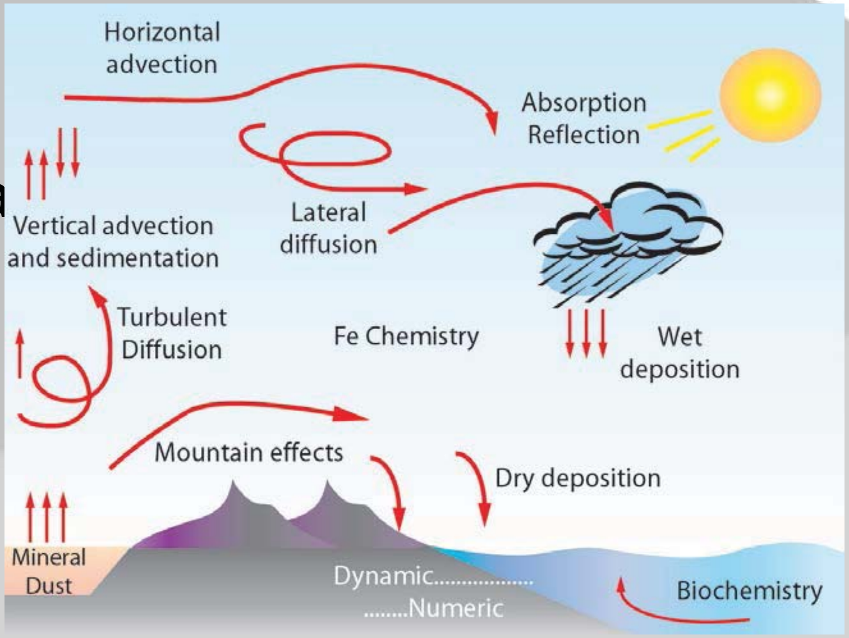
- Dust Storms & Airborne Mineral Dust Concentrations in the Middle East, Africa and the Southwest US
- Pollen in Colorado, New Mexico & Texas
- Volcanic Ash in the Mediterranean
- Soybean Rust in South America

A new test: Forest fire ash and smoke plumes

A proposed test: mold spores

DREAM 4-8 particle bins

- **Model predictions (72-h):**
- Horizontal distribution
  - Surface concentration
  - Total column mass (dust loa
  - 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

Pollen release potential Source Map/Mask

($PRPSM\_of\_J_i$) of a Juniper species "*i*" is calculated as:

$$\mathbf{PRPSM\_of\_J_i = T_i \times M_i \times H_i \times C_i \times P_i}$$

Where
T_i = Number of J_i trees
M_i = Male/Female ratio of J_i
H_i = HCP_LCP/All ratio for J_i
C_i = Cones per J_i tree
P_i = Pollens per cone for J_i

The number of trees of a Juniper species "i" per grid cell is calculated as

$$\mathbf{T_i = GAP_i \times MODIS \times TC}$$

Where
GAP_i = Fraction of J_i at 1 km grid (range 0-1)
MODIS = MODIS derived percent tree cover per 1 km^2 grid cell (in fraction, range 0-1)
TC = Tree count or number of trees.

Ground truth (transect data)

(a) Male to Female ratio

(b) HCP_LCP to All ratio

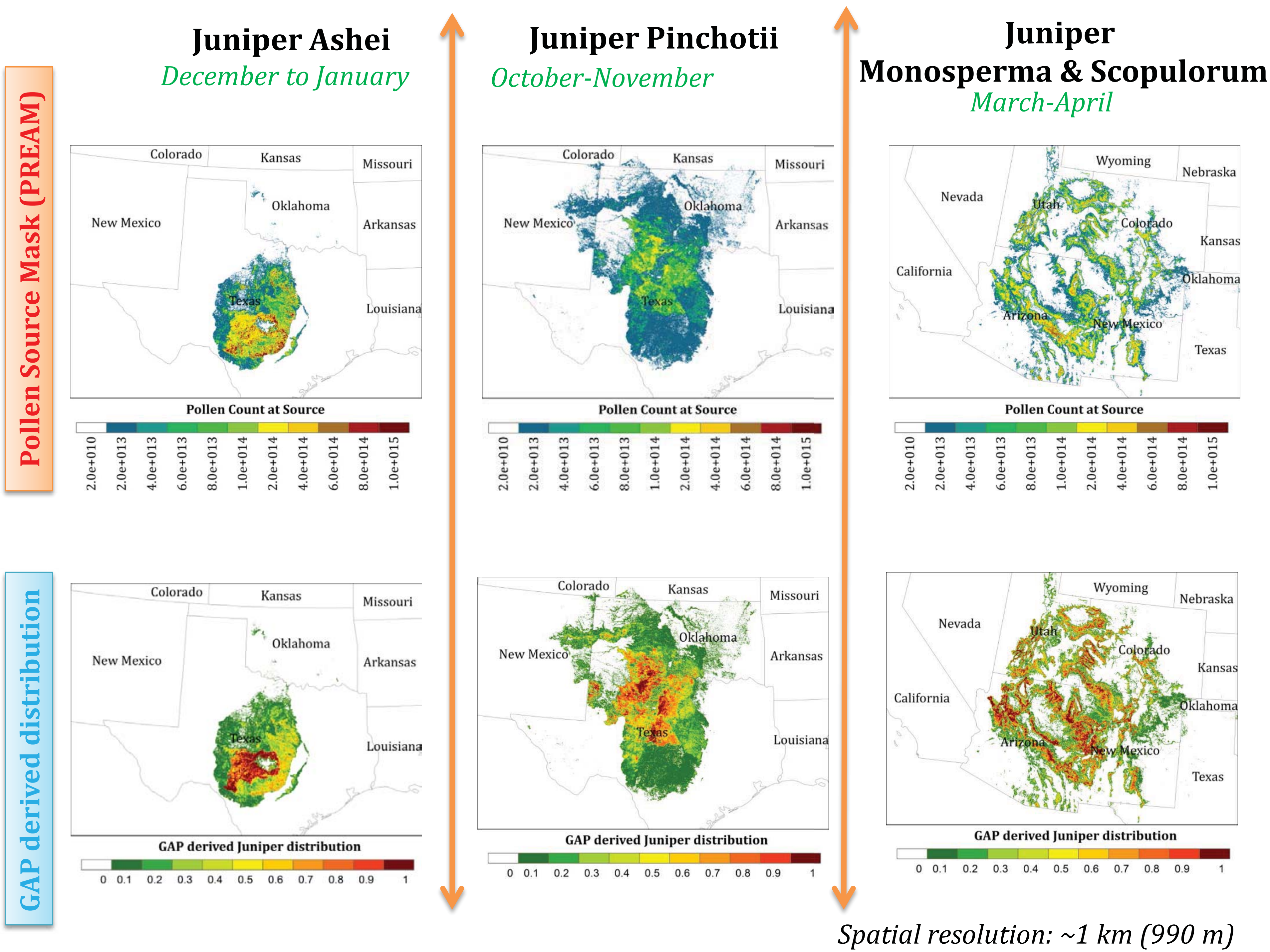
- 0 – Only enough cones to determine gender
- 1 – Low Cone Production (LCP) tree
- 2 – High Cone Production (HCP) tree

(c) Cones per tree

(d) Pollen grains per cone

(d) Age

(Height & edge effect)


Juniper Ashei
December to January
Juniper Pinchotii
October-November
Juniper Monosperma & Scopulorum
March-April
Pollen Source Mask (PREAM)
GAP derived distribution
Colorado
Kansas
Missouri
New Mexico
Oklahoma
Arkansas
Texas
Louisiana
Nevada
Utah
Wyoming
Nebraska
California
Arizona
Pollen Count at Source
2.0e+010
2.0e+013
4.0e+013
6.0e+013
8.0e+013
1.0e+014
2.0e+014
4.0e+014
6.0e+014
8.0e+014
1.0e+015
GAP derived Juniper distribution
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Spatial resolution: ~1 km (990 m)

PREAM

Pollen Plume Simulation for Juniper Emissions
For the period 15 December 2009 – 1 January 2010
Run by Slobodan Nickovic, September 2012

Atmosphere Model Setup

Model horizontal domain: Southwest US

Model resolution: ~40 km

Simulation period:
15 December 2009 – 1 January 2010

Boundary conditions: 1 degree global forecasts used to refresh

- initial conditions every 24 hours
- boundary conditions every 6 hours

PREAM

Pollen Plume Simulation for Juniper Emissions
For the period 15 December 2009 – 1 January 2010

PREAM – Pollen Regional Atmospheric Model

Derived from DREAM (dust), modified to simulate pollen

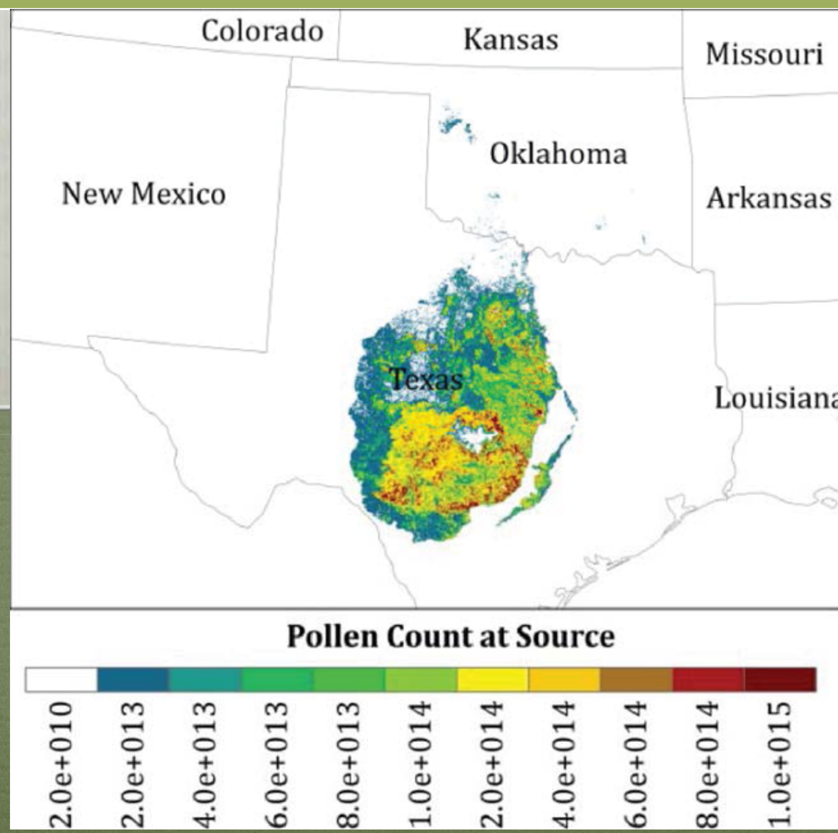
- 4 particles bins

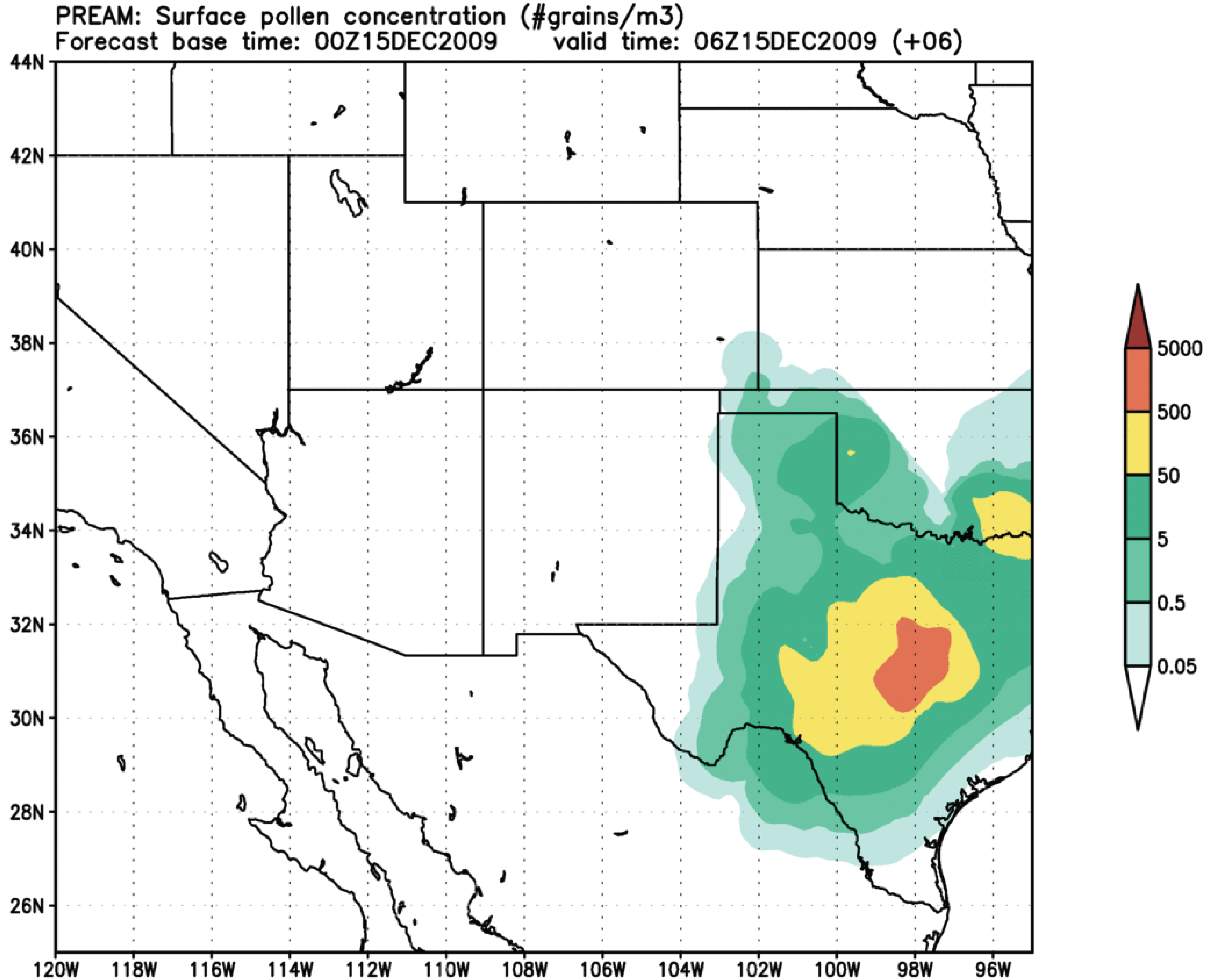
- PREAM is online driven by the NCEP/ETA

Emission:
- Viscous-sublayer parameterization
- Emission dependent on friction velocity

The PREAM 15 December 2009– 1 January 2010 Run

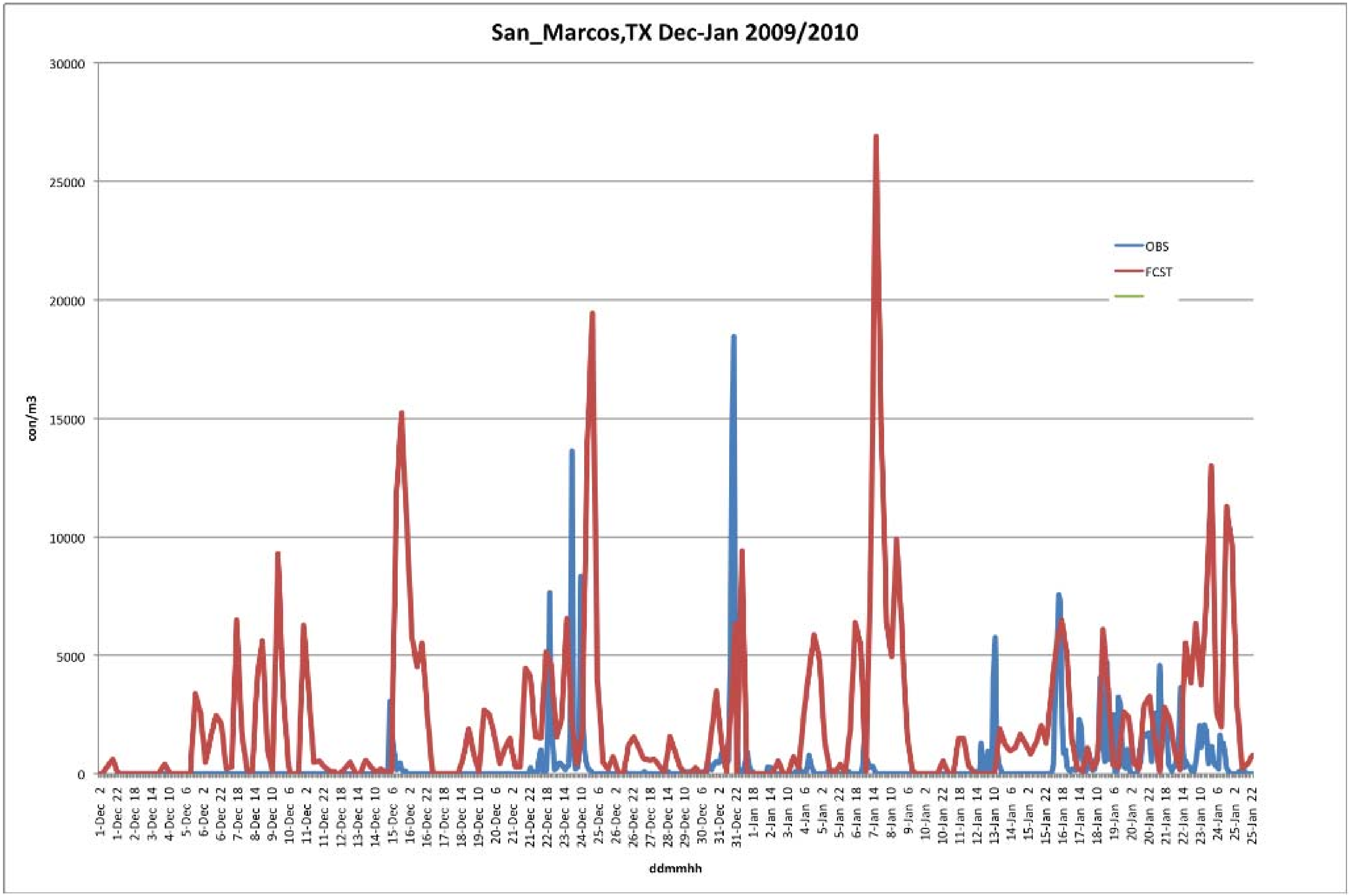
- “cold start” used for the very first day
- simulated 3D concentration from the previous day is the initial condition for the next day simulation

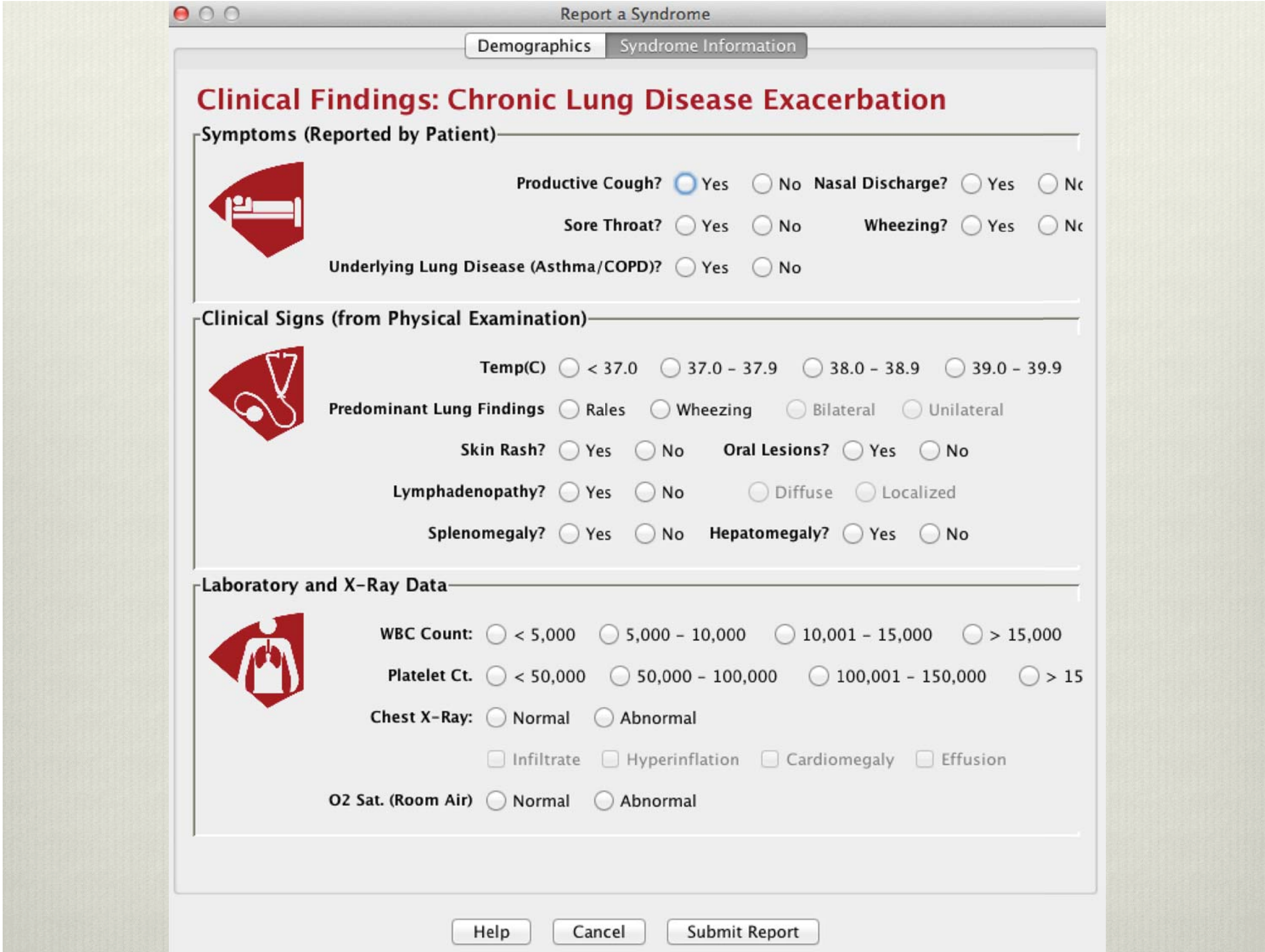


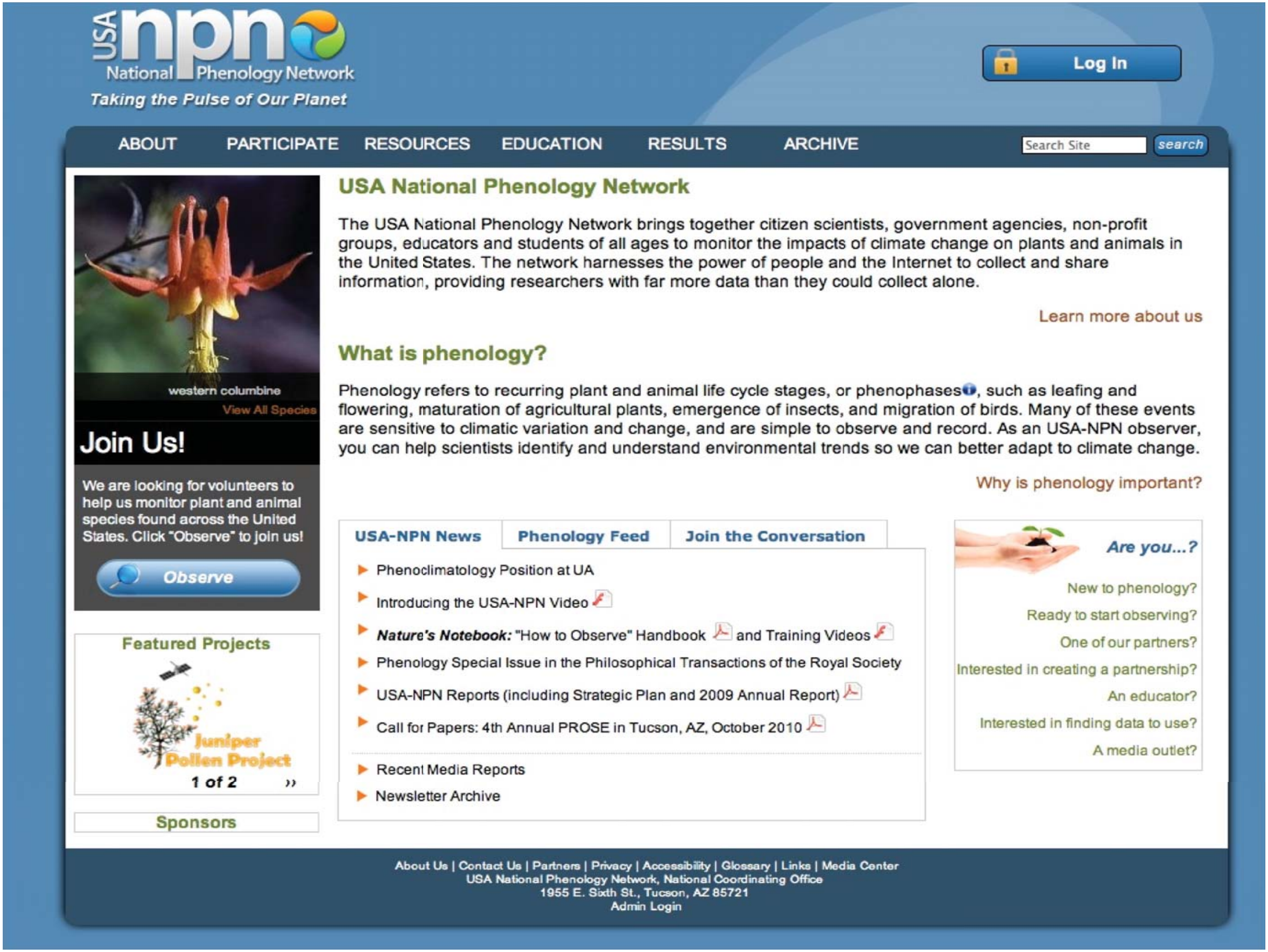

PREAM: Surface pollen concentration (#grains/m3)
Forecast base time: 00Z15DEC2009 valid time: 06Z15DEC2009 (+06)
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
120W
118W
116W
114W
112W
110W
108W
106W
104W
102W
100W
98W
96W
5000
500
50
5
0.5
0.05

Model Validation (Juniper pollen count/ m^2)

Observed Forecast




Report a Syndrome
Demographics
Syndrome Information
Clinical Findings: Chronic Lung Disease Exacerbation
Symptoms (Reported by Patient)
Productive Cough? Yes No
Nasal Discharge? Yes Nc
Sore Throat? Yes No
Wheezing? Yes Nc
Underlying Lung Disease (Asthma/COPD)? Yes No
Clinical Signs (from Physical Examination)
Temp(C) < 37.0 37.0 – 37.9 38.0 – 38.9 39.0 – 39.9
Predominant Lung Findings Rales Wheezing Bilateral Unilateral
Skin Rash? Yes No
Oral Lesions? Yes No
Lymphadenopathy? Yes No Diffuse Localized
Splenomegaly? Yes No
Hepatomegaly? Yes No
Laboratory and X-Ray Data
WBC Count: < 5,000 5,000 – 10,000 10,001 – 15,000 > 15,000
Platelet Ct. < 50,000 50,000 – 100,000 100,001 – 150,000 > 15
Chest X-Ray: Normal Abnormal
Infiltrate Hyperinflation Cardiomegaly Effusion
O2 Sat. (Room Air) Normal Abnormal
Help
Cancel
Submit Report


USA npn
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Juniper Pollen Project
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The USA National Phenology Network brings together citizen scientists, government agencies, non-profit groups, educators and students of all ages to monitor the impacts of climate change on plants and animals in the United States. The network harnesses the power of people and the Internet to collect and share information, providing researchers with far more data than they could collect alone.
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Phenology refers to recurring plant and animal life cycle stages, or phenophases, such as leafing and flowering, maturation of agricultural plants, emergence of insects, and migration of birds. Many of these events are sensitive to climatic variation and change, and are simple to observe and record. As an USA-NPN observer, you can help scientists identify and understand environmental trends so we can better adapt to climate change.
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Phenology Special Issue in the Philosophical Transactions of the Royal Society
USA-NPN Reports (including Strategic Plan and 2009 Annual Report)
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USA National Phenology Network, National Coordinating Office
1955 E. Sixth St., Tucson, AZ 85721
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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 sucessfully modified for use with pollen and may provide 24-36 hour running pollen forcasts.

✓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.