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

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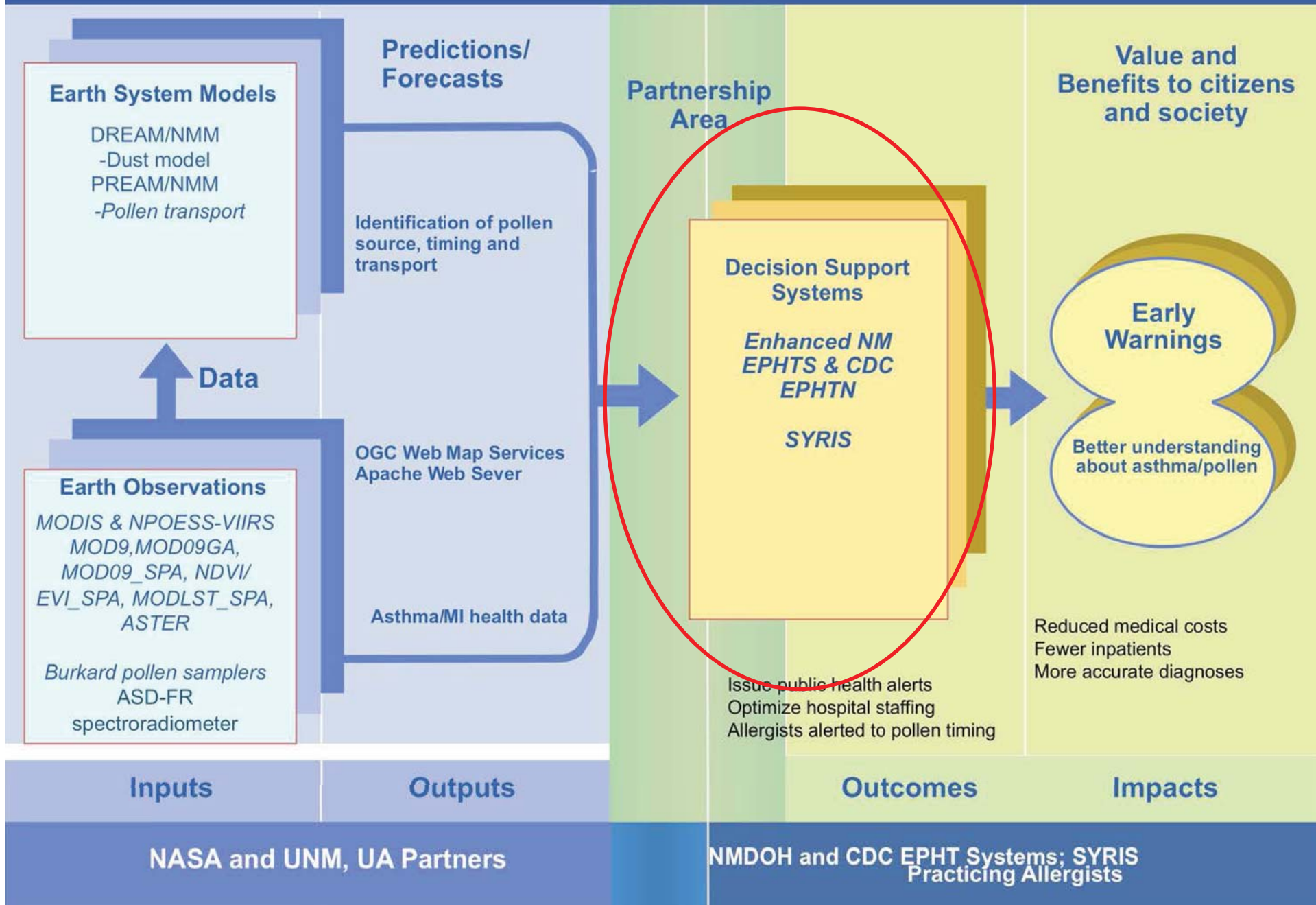
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Tracking Pollen for Asthma Alerts in Public Health DSS (Luvall)

Earth System Models

DREAM/NMM
-Dust model
PREAM/NMM
-*Pollen transport*

Predictions/ Forecasts

Identification of pollen source, timing and transport

Data

Earth Observations

MODIS & NPOESS-VIIRS MOD9,MOD09GA, MOD09_SPA, NDVI/ EVI_SPA, MODLST_SPA, ASTER

Burkard pollen samplers ASD-FR spectroradiometer

OGC Web Map Services
Apache Web Sever

Asthma/MI health data

Partnership Area

Value and Benefits to citizens and society

Decision Support Systems

Enhanced NM EPHTS & CDC EPHTN

SYRIS

Early Warnings

Better understanding about asthma/pollen

Reduced medical costs
Fewer inpatients
More accurate diagnoses

Issue public health alerts
Optimize hospital staffing
Allergists alerted to pollen timing

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.

March 2008

Moscow Birch Pollen

NE Alamos
SE Alamos   Santa Fe
Tijeras A   Palo Duro   SSWMA
Tijeras B   Copper   Crossbar   Classen

San Angelo
Sonora   Junction
Sonora   San Marcos
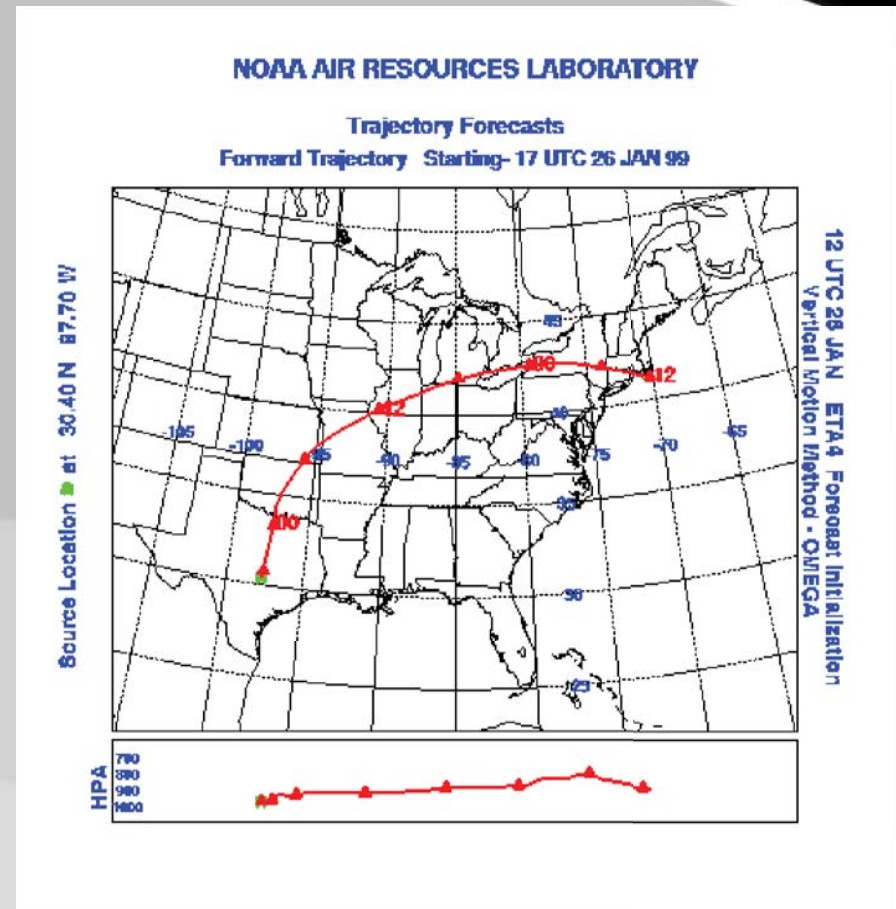
Chihuahuan Desert

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."

NOAA AIR RESOURCES LABORATORY

Trajectory Forecasts

Forward Trajectory   Starting- 17 UTC 26 JAN 99

Source Location ▶ at 30.40 N 87.70 W

12 UTC 26 JAN   ETA4 Forecast Initialization
Vertical Motion Method - OMEGA

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
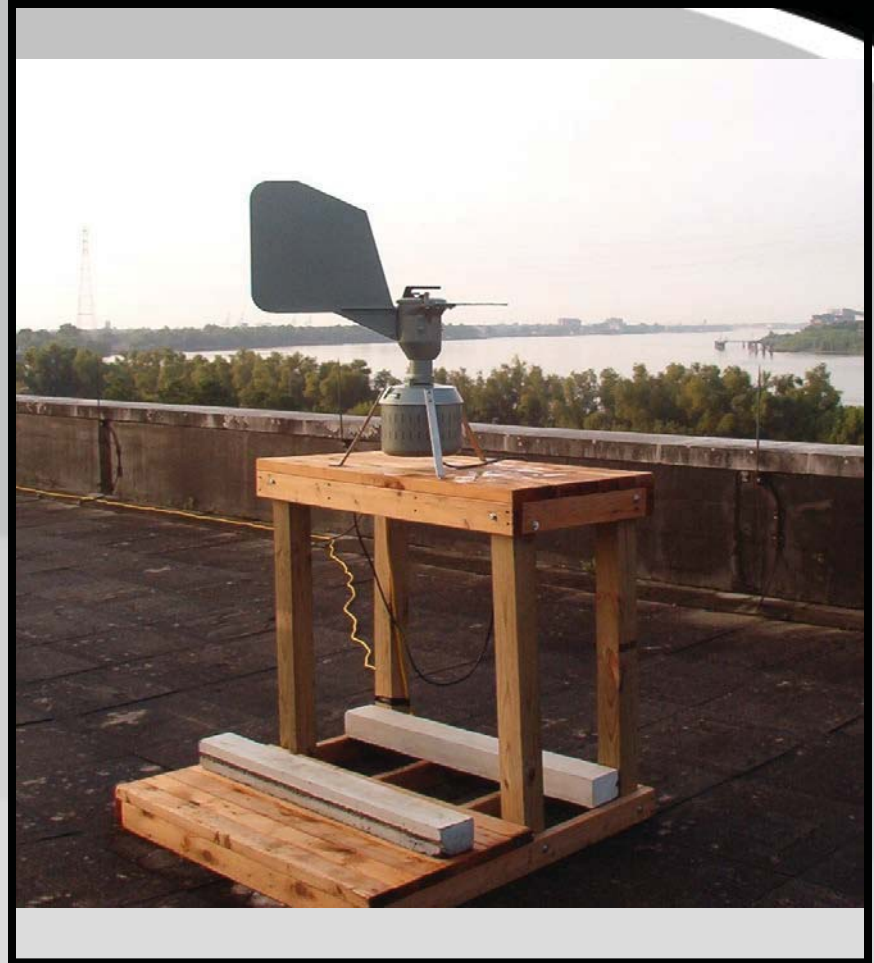
Limitations of Pollen Sampling

- 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
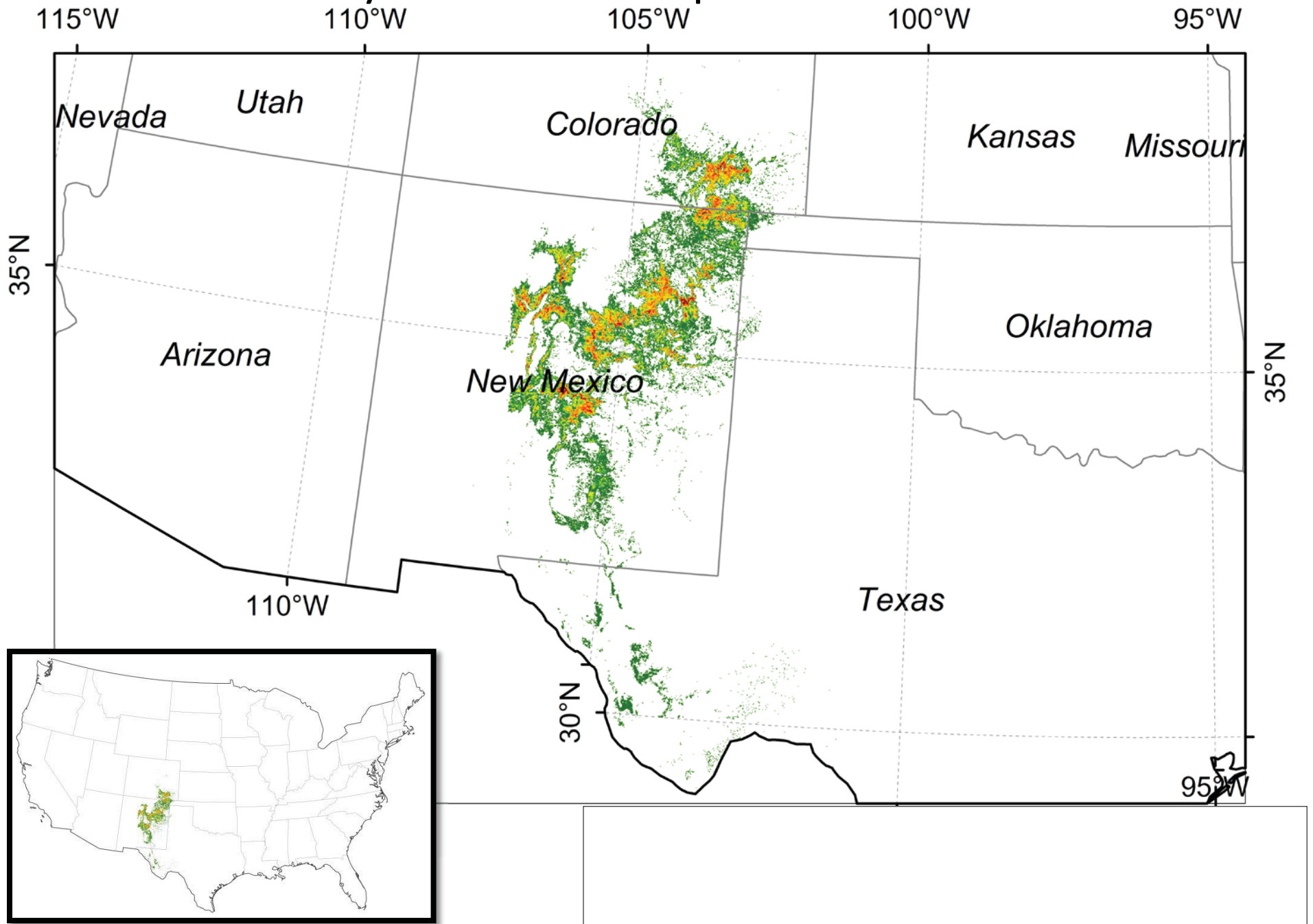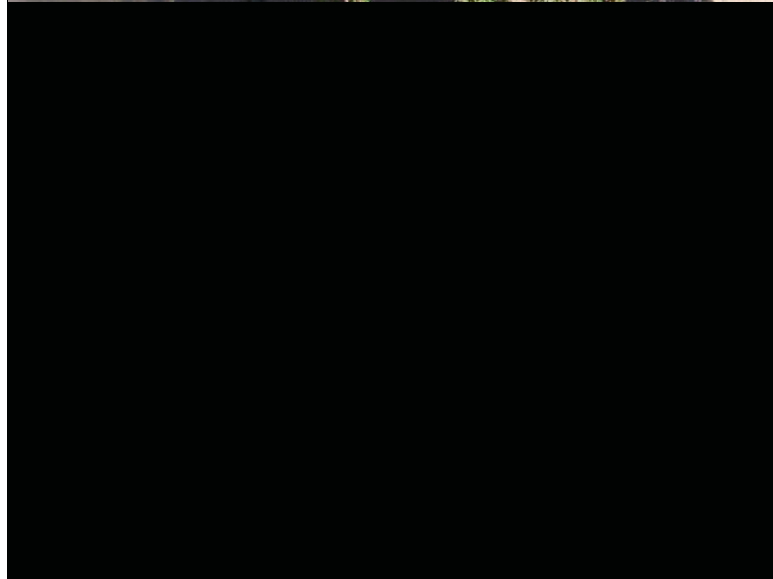
Spectral characteristics of male juniper canopies at different bud density levels

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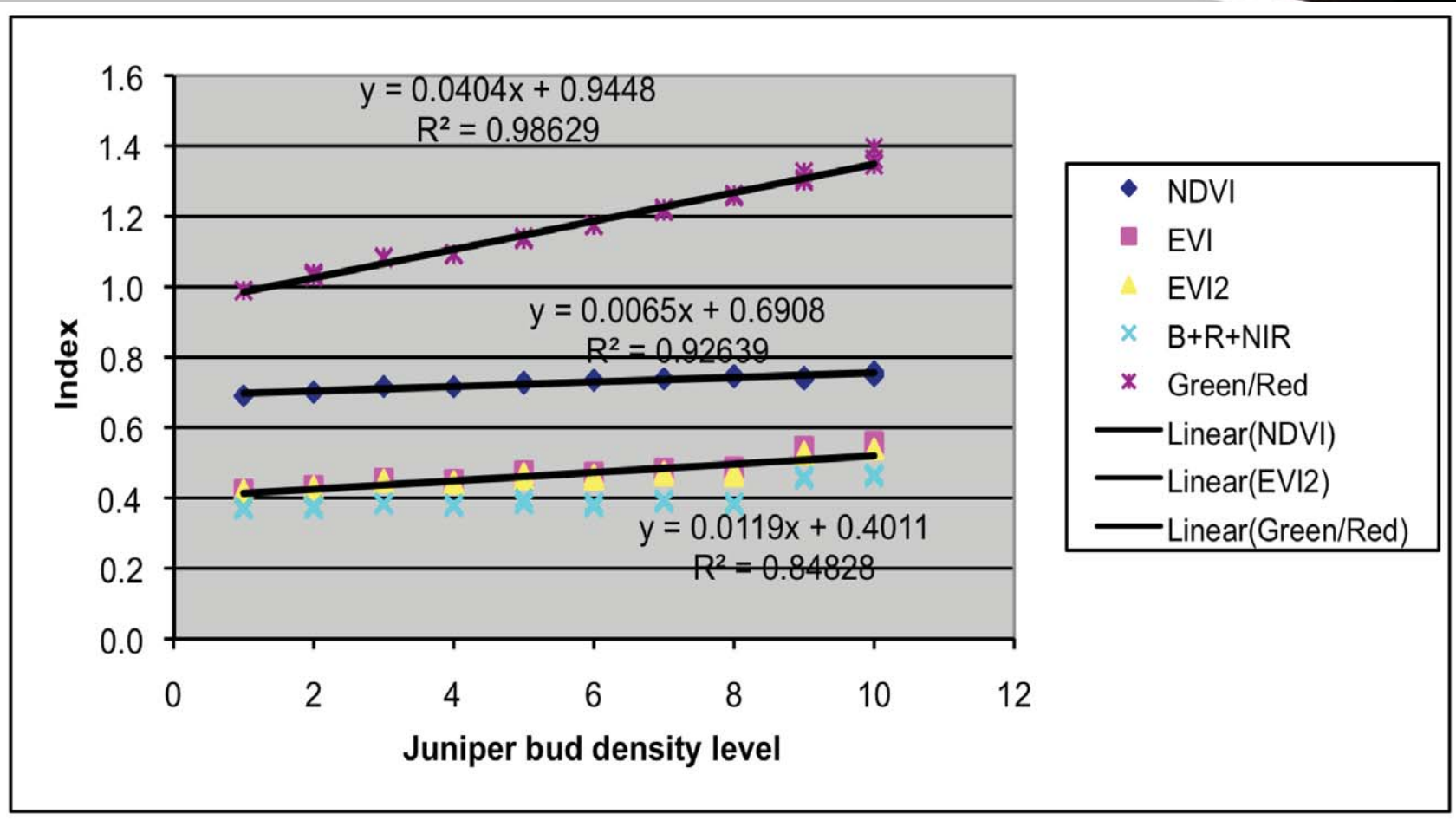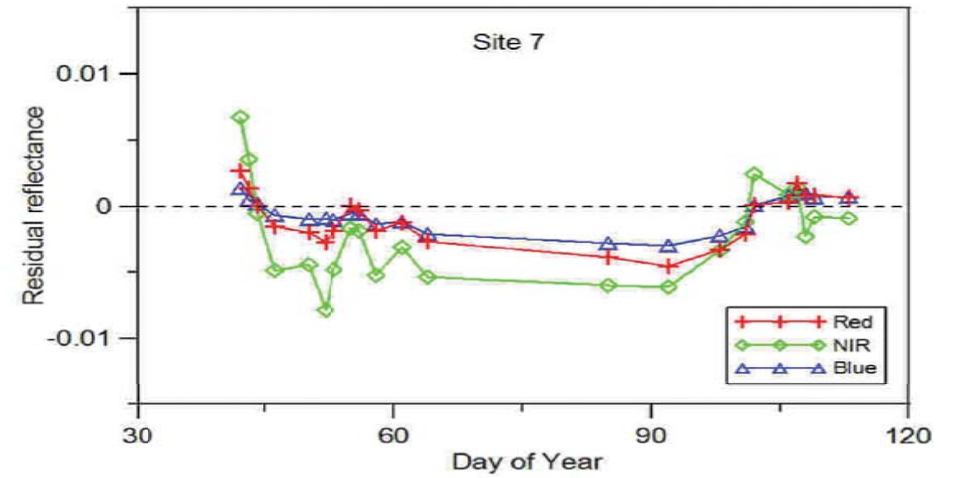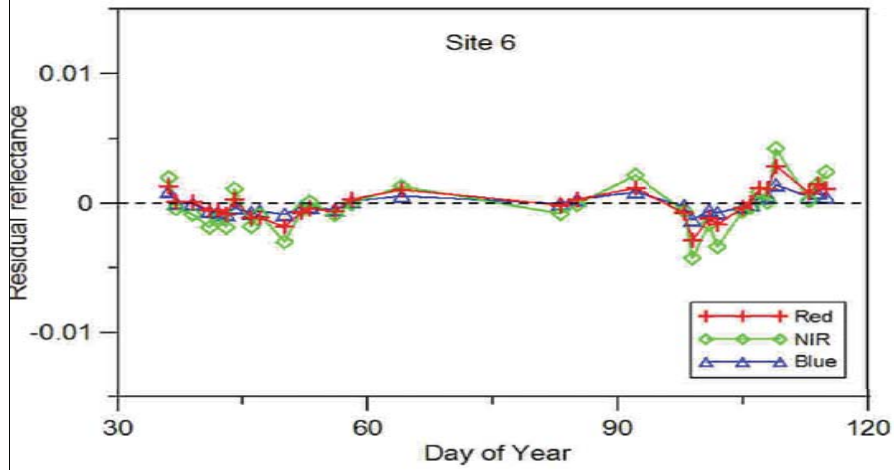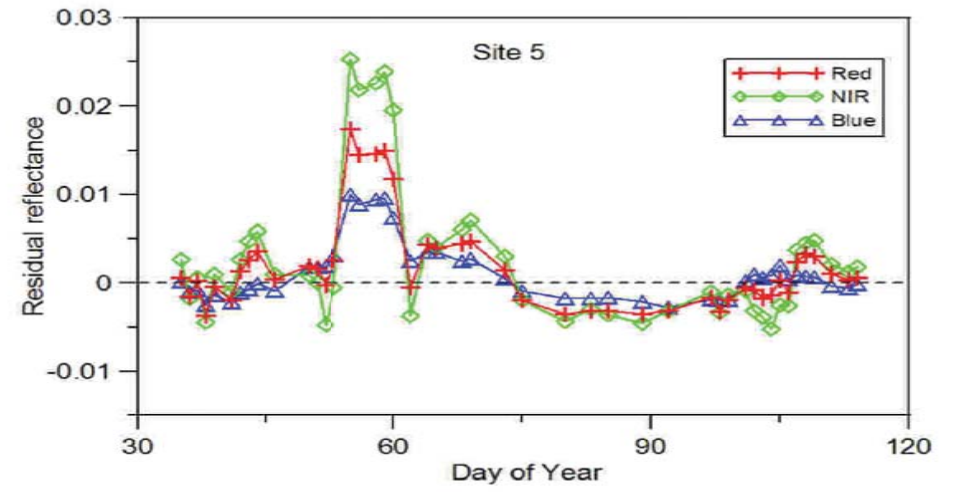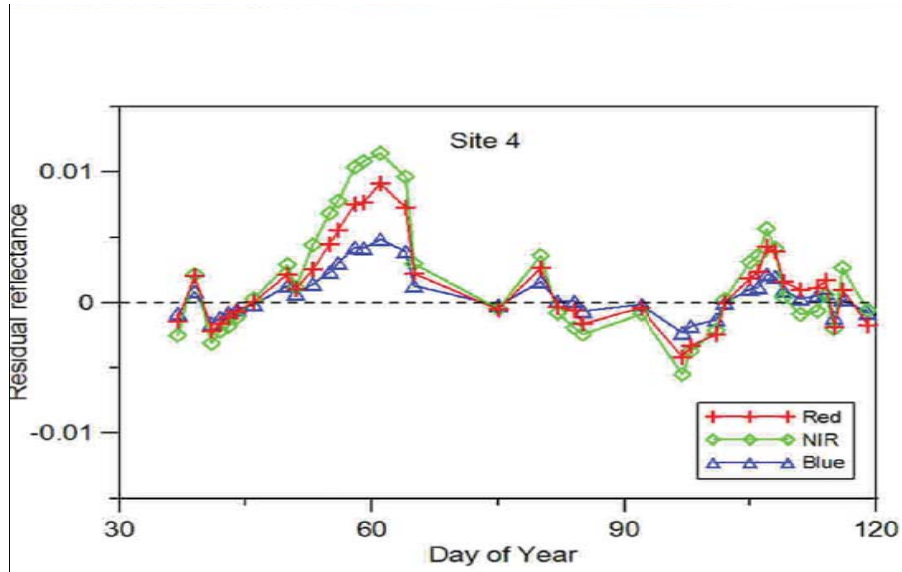
Temporal profiles of residual MODIS reflectances at the four study sites.

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 ($r = 0.4740$, $p = 0.035$)
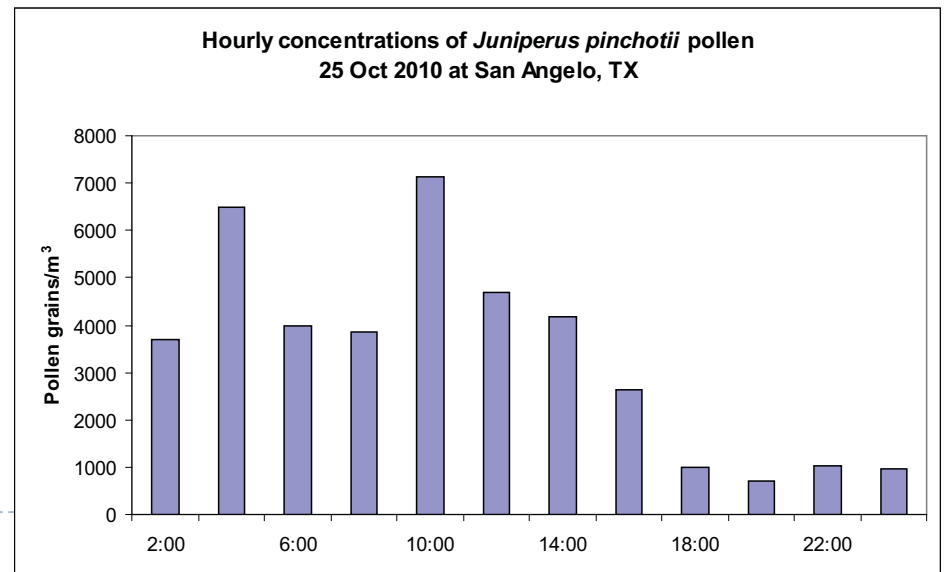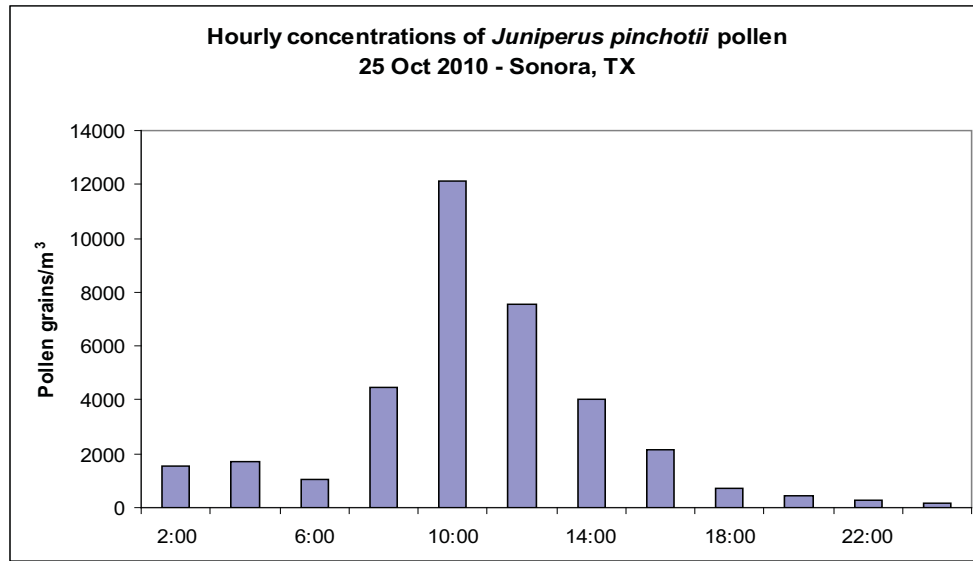
▸

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%
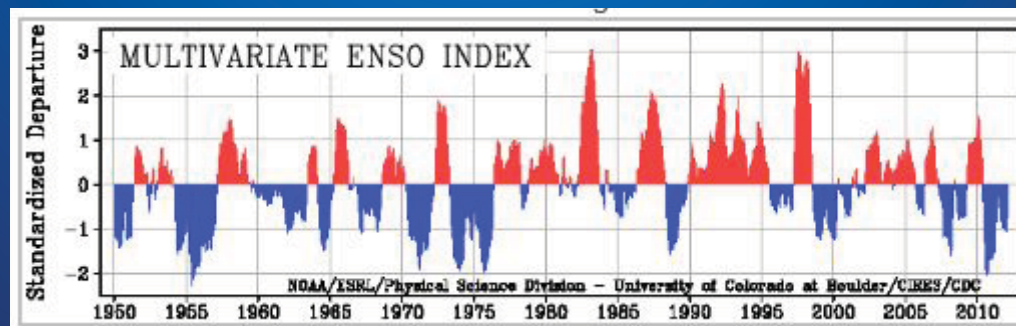
Trajectory analysis indicates the pollen originated in southwest Texas approximately 8 hours earlier
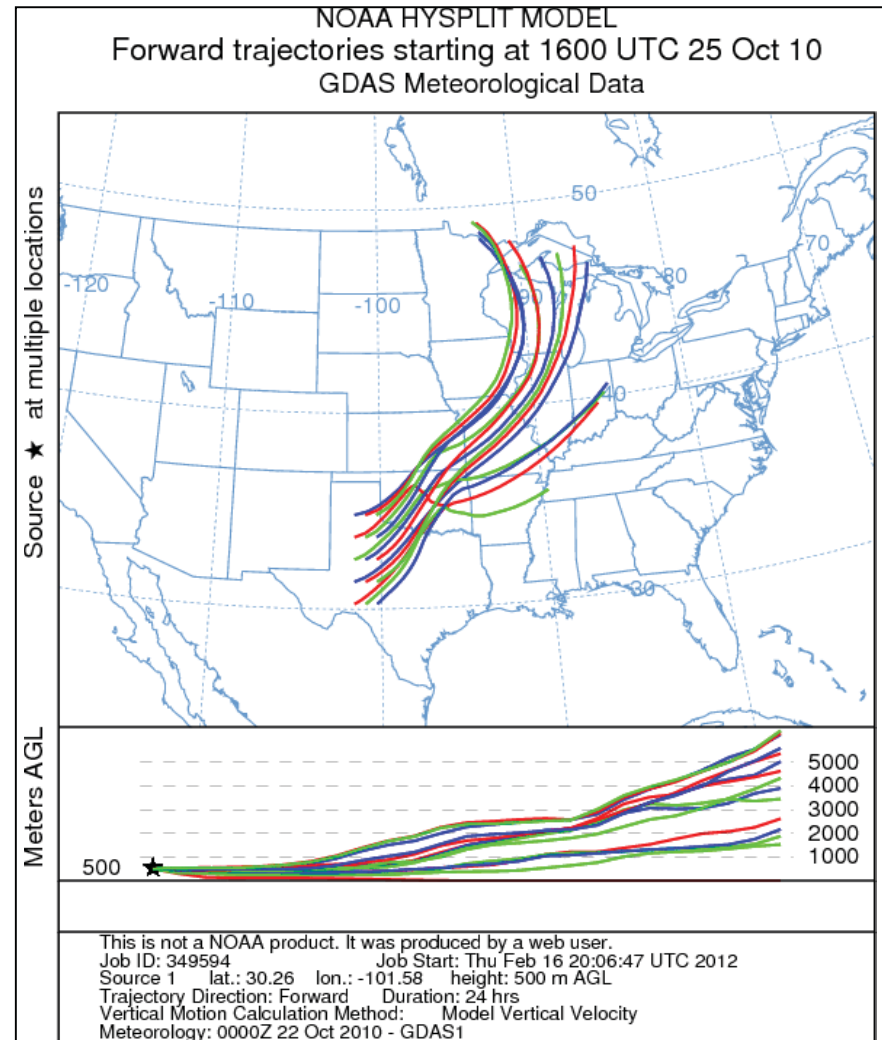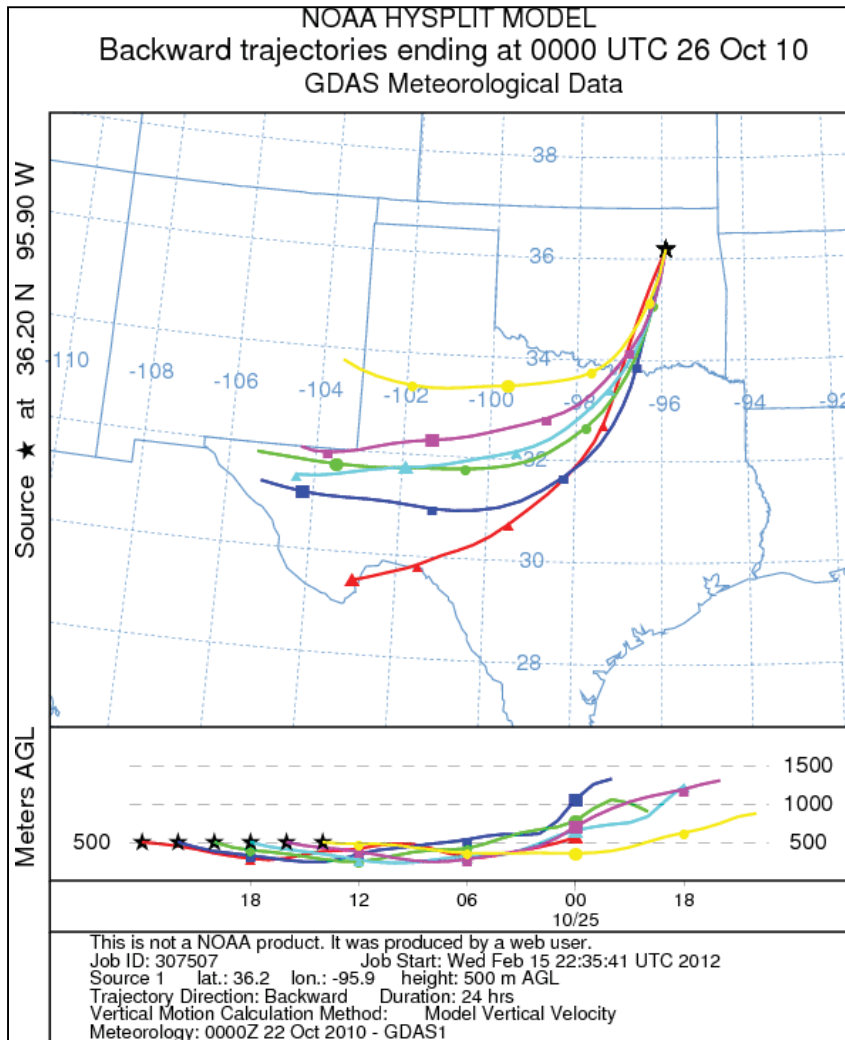
Juniperus pinchotii concentrations at Sonora and San Angelo confirm the trajectory model

Hourly concentrations of *Juniperus pinchotii* pollen
25 Oct 2010 - Sonora, TX

Hourly concentrations of *Juniperus pinchotii* pollen
25 Oct 2010 at San Angelo, TX

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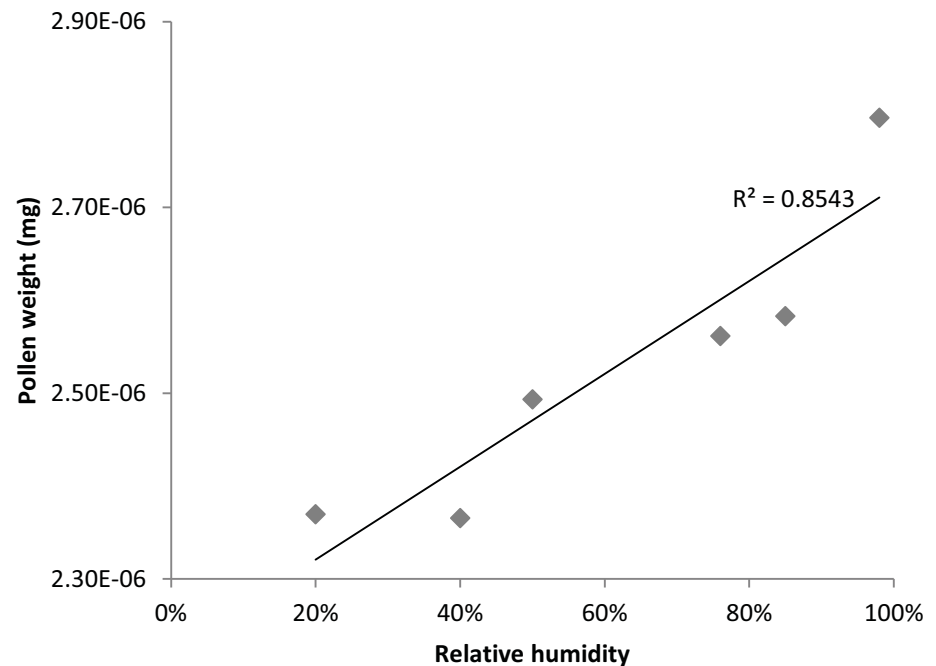
Estimated weight per pollen grain (*J. ashei*) after 2 hrs across the range of relative humidity levels at 20° C

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
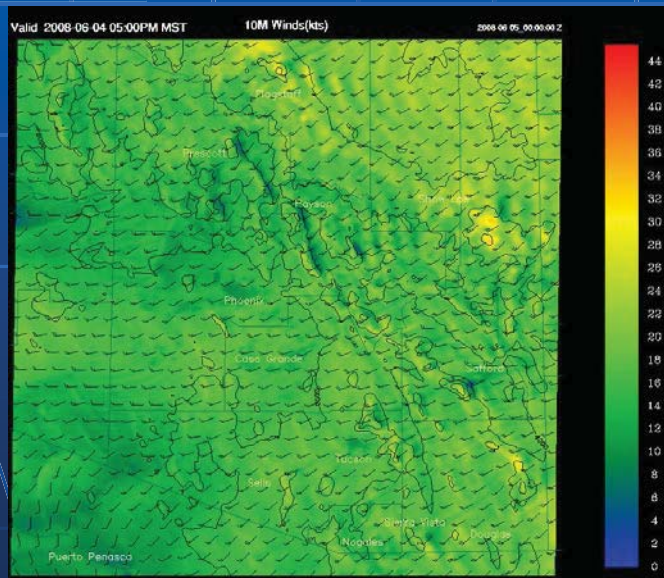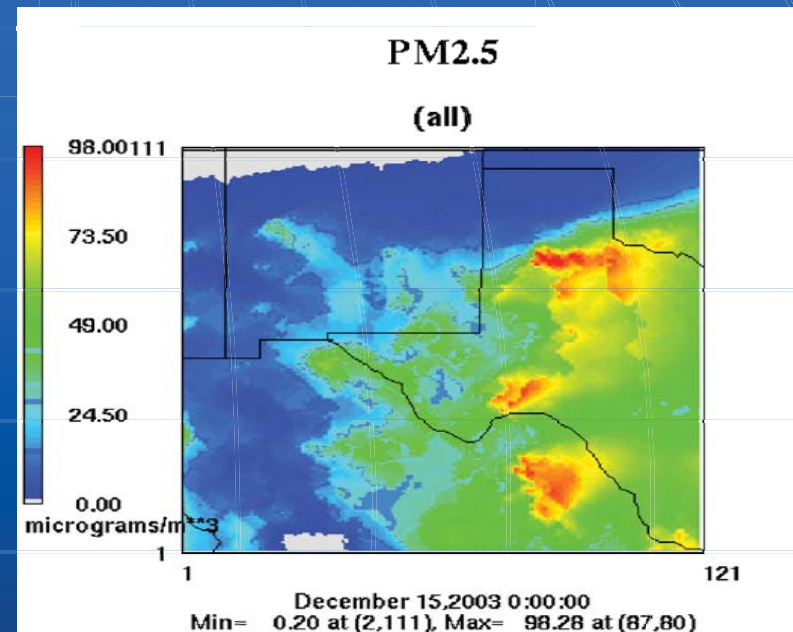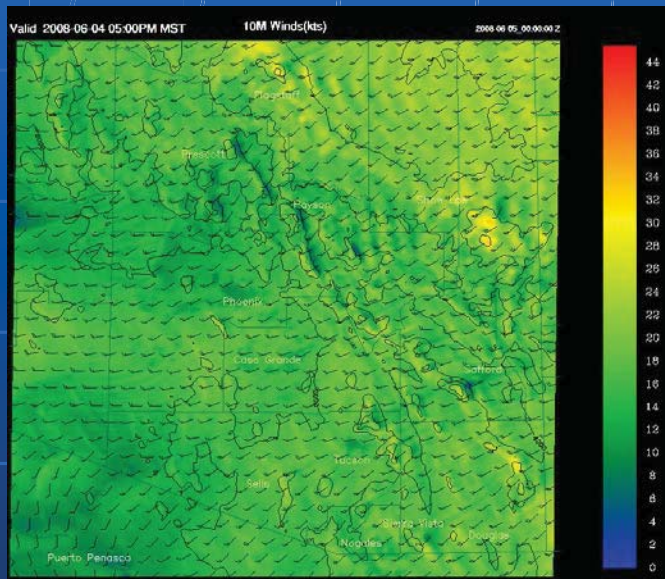
UA WRF 10-m wind forecast

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 → Pollen - PREAM

Dust REgional Atmospheric Modeling (DREAM) system

Pollen REgional Atmospheric Modeling (PREAM) system

- MM5
- WRF

UA WRF 10-m wind forecast

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
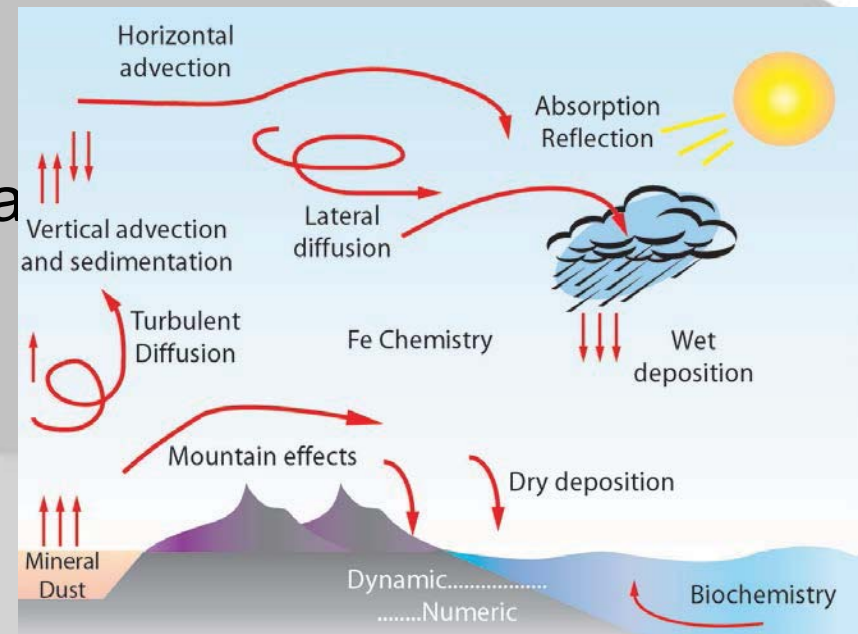A proposed test: mold spores

■ **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:

$$\textbf{PRPSM\_of\_J}_i = \textbf{T}_i \times \textbf{M}_i \times \textbf{H}_i \times \textbf{C}_i \times \textbf{P}_i$$

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

$$\textbf{T}_i = \textbf{GAP}_i \times \textbf{MODIS} \times \textbf{TC}$$

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
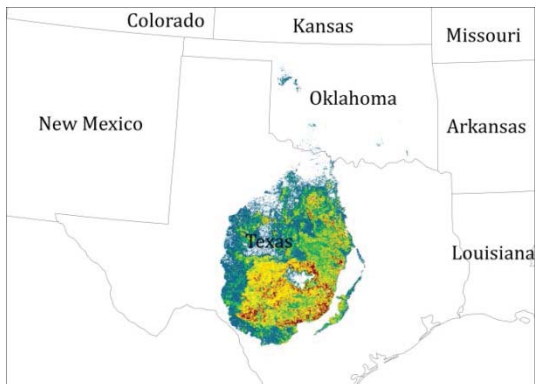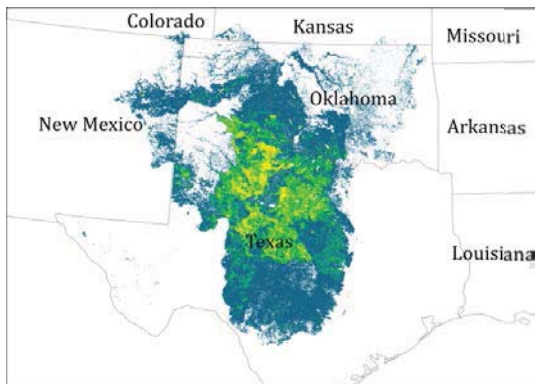
Pollen Count at Source
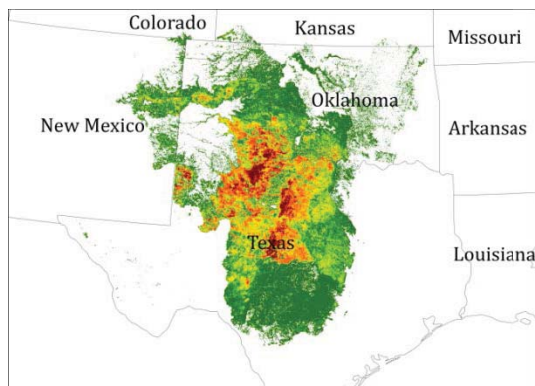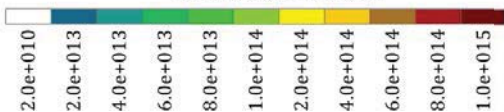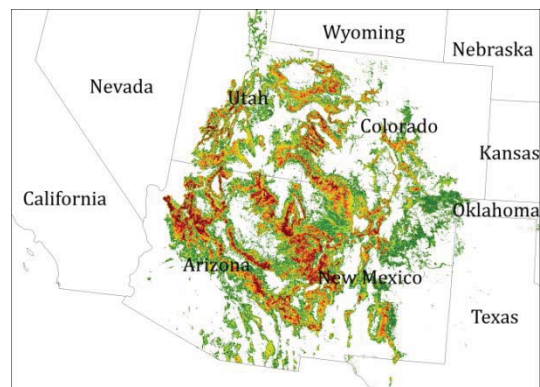
GAP derived Juniper distribution

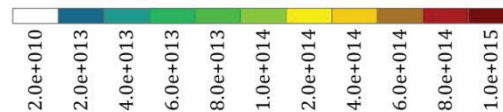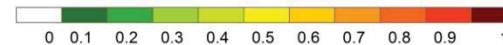*Spatial resolution: ~1 km (990 m)*

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
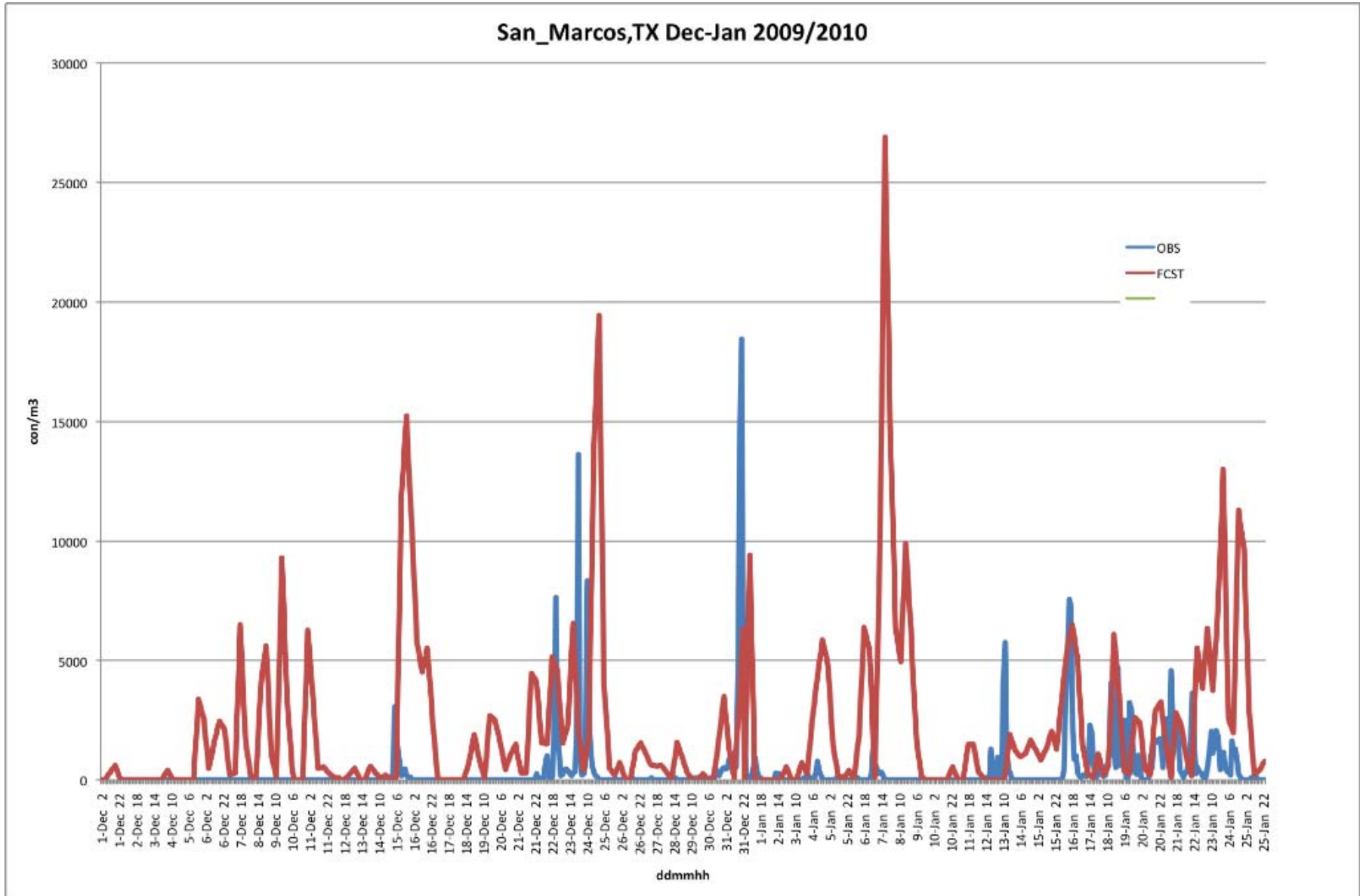

Pollen Count at Source
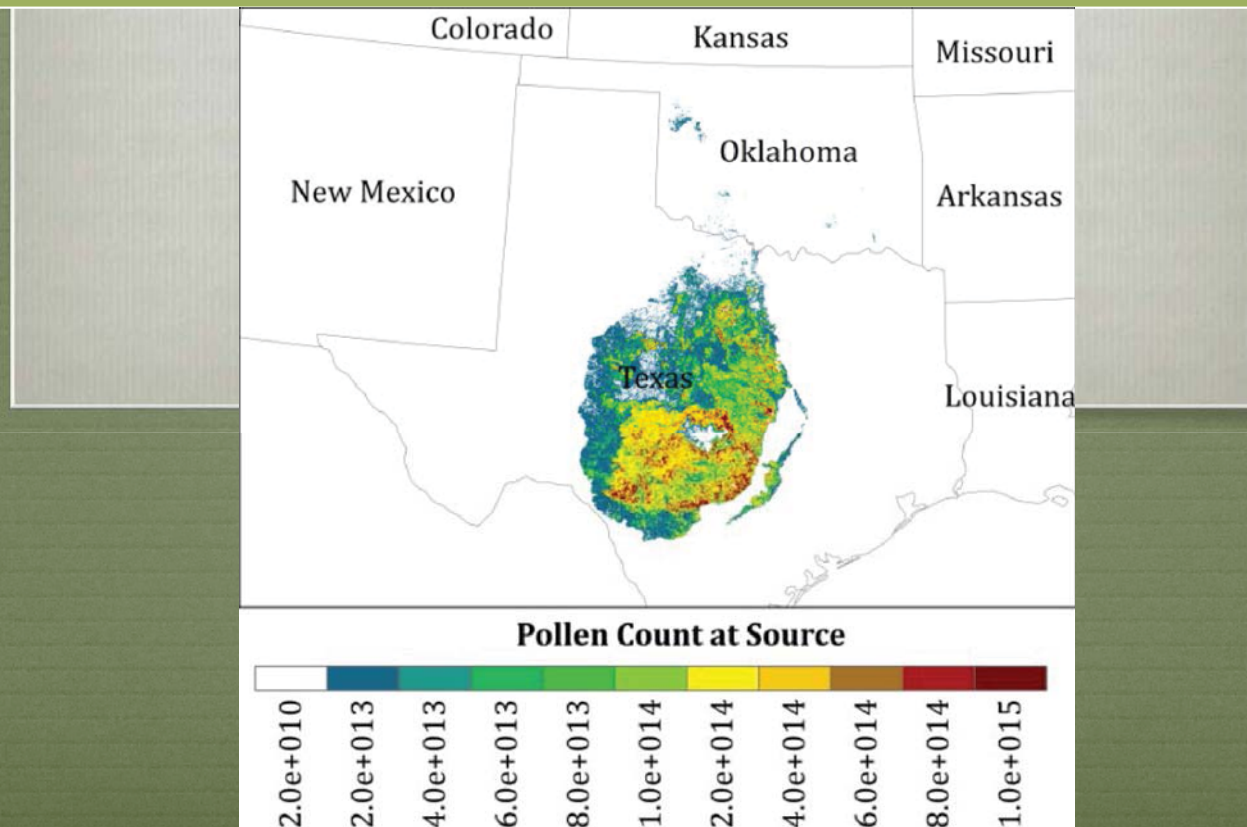
PREAM: Surface pollen concentration (#grains/m3)
Forecast base time: 00Z15DEC2009   valid time: 06Z15DEC2009 (+06)
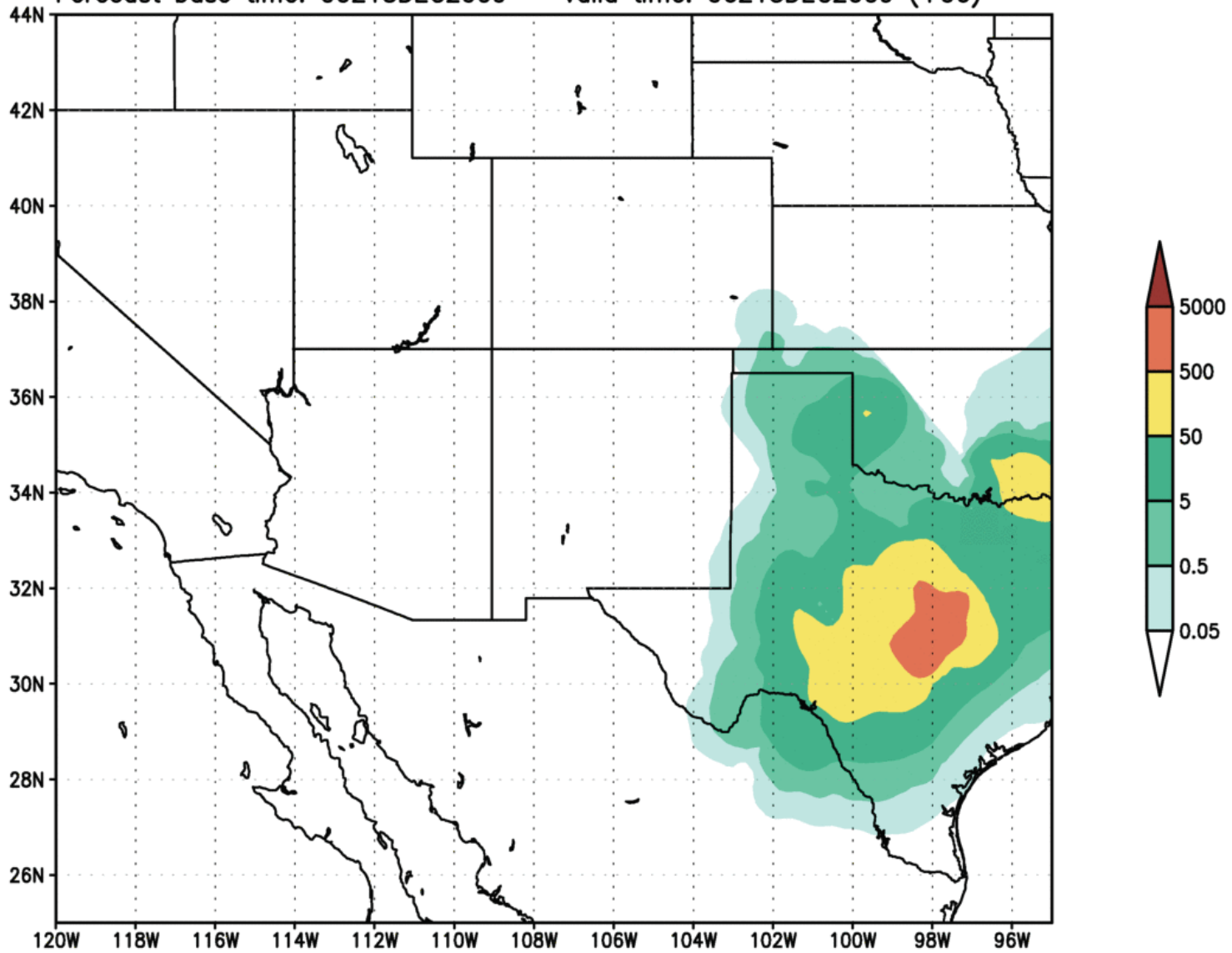
Model Validation (Juniper pollen count/ m^2)
Observed   Forecast

Demographics | **Syndrome Information**

Clinical Findings: Chronic Lung Disease Exacerbation

Symptoms (Reported by Patient)

Productive Cough? ( ) Yes ( ) No **Nasal Discharge?** ( ) Yes ( ) No

Sore Throat? ( ) Yes ( ) No **Wheezing?** ( ) Yes ( ) No

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

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Search Site [   ] **search**

western columbine
View All Species

Join Us!

We are looking for volunteers to help us monitor plant and animal species found across the United States. Click "Observe" to join us!

🔍 **Observe**

Featured Projects

Juniper Pollen Project

1 of 2   »

Sponsors

USA National Phenology Network

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.

Learn more about us

What is phenology?

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.

Why is phenology important?

USA-NPN News   **Phenology Feed**   **Join the Conversation**

▶ Phenoclimatology Position at UA

▶ Introducing the USA-NPN Video 🔗

▶ *Nature's Notebook:* "How to Observe" Handbook 📄 and Training Videos 🔗

▶ Phenology Special Issue in the Philosophical Transactions of the Royal Society

▶ USA-NPN Reports (including Strategic Plan and 2009 Annual Report) 📄

▶ Call for Papers: 4th Annual PROSE in Tucson, AZ, October 2010 📄

▶ Recent Media Reports

▶ Newsletter Archive

Are you...?

New to phenology?

Ready to start observing?

One of our partners?

Interested in creating a partnership?

An educator?

Interested in finding data to use?

A media outlet?

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.