

PHAIRS

A Public Health Decision Support System: Initial Results

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Goal of Current Research

- Develop baseline of DREAM dust model performance against which improvements resulting from substitution of NASA-derived satellite data inputs.



Atmospheric Modeling System Module

- Uses outputs from the European Center for Medium Range Forecasts (ECMWF)
- Models standard climatic phenomena (specific humidity, temperature U-velocity, and V-velocity)
- DREAM uses gridded analysis or forecasting fields from ECMWF model for initial and boundary conditions

Dust Concentration Module

- Simulates/predicts all major phases of the atmospheric dust cycle (dust production, turbulent mixing, long-range transport, and deposition)
- Four dust particle size classes are modeled (0.73, 6.1, 18, and 38 μm radius)
- Dust source modeling uses gridded array of land surface conditions



Static Surface Data for Dust Model

- United States Geological Survey Terrain Height Data (USGS) – 30 second resolution – used to define model topography
- Olson World Ecosystem 10-minute resolution vegetation data – used to define dust productive areas
- FAO/UNESCO 2-minute soil texture data used in both the atmospheric and dust production modules



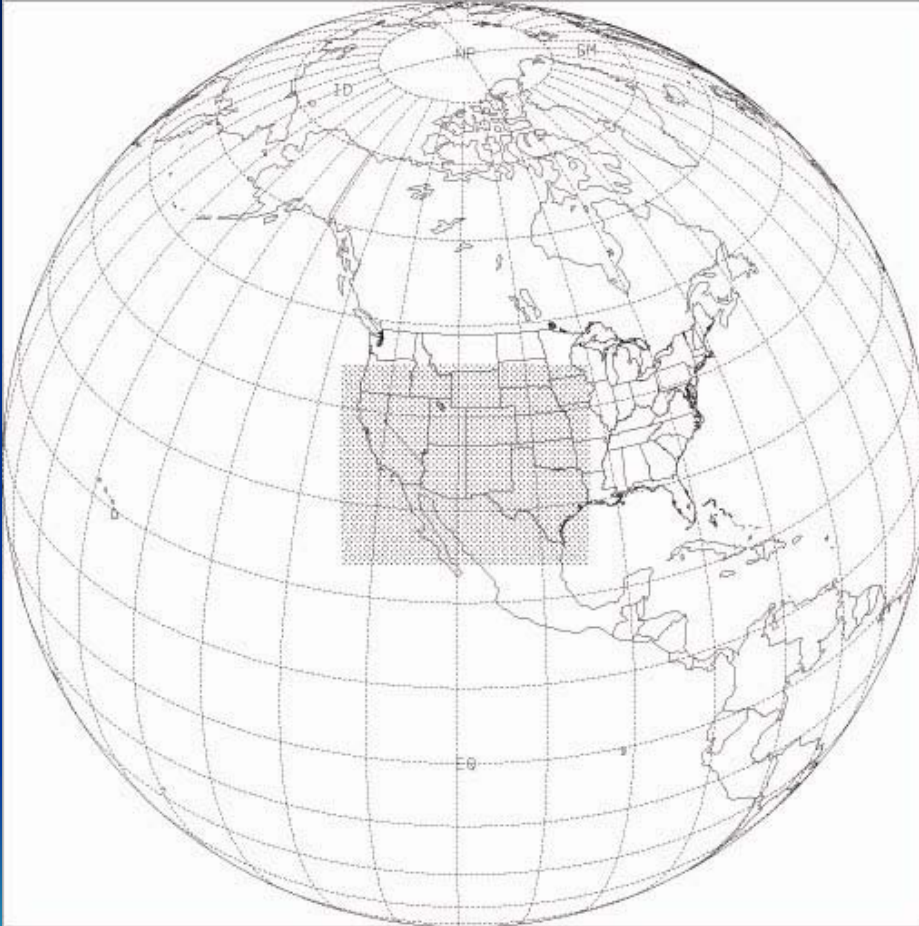
Model setup

Vertical eta levels			
Full eta level	Height(m ABS)	Half eta level	Height(m ABS)
1	15797.04	1	15022.83
2	14248.62	2	13561.76
3	12874.90	3	12257.34
4	11639.78	4	11079.29
5	10518.81	5	10006.64
6	9494.47	6	9024.08
7	8553.70	7	8120.08
8	7686.46	8	7285.66
9	6884.85	9	6513.69
10	6142.52	10	5798.42
11	5454.31	11	5135.13
12	4815.95	12	4519.92
13	4223.89	13	3949.52
14	3675.15	14	3421.18
15	3167.21	15	2932.59
16	2697.98	16	2481.81
17	2265.64	17	2067.16
18	1868.69	18	1687.28
19	1505.87	19	1341.00
20	1176.13	20	1027.38
21	878.63	21	745.65
22	612.68	22	495.24
23	377.80	23	275.71
24	173.63	24	86.82
25	0.00		

- 24 vertical layers comprising the full complement of 25 Eta levels



Test Case



- Pacific cold front
- December 15-17, 2003
- New Mexico and West Texas
- Domain center at (109°W, 35°N)
- Horizontal semi-staggered Arakawa E grid with 41×65 cells
- Horizontal grid spacing 1/3 degree (20 arc minutes)
- Boundary conditions refreshed at 6 hour intervals



Model Validation

- 1. DREAM Model meteorological outputs are verified against in-situ measurements (e.g. surface and upper-air meteorological data, weather radar observations, and satellite images).
- 2. DREAM Model dust concentration fields are verified against surface *in-situ* particulate matter data measured at PM2.5 Air Quality System (AQS) sites.



Statistical Tests to Measure Association Between Modeled and Observed Dust Concentration Values

Mean modeled	$\frac{1}{N} \sum_{i=1}^N M_i$	M_i modeled value at each site
Mean observed	$\frac{1}{N} \sum_{i=1}^N O_i$	O_i observed value at each site
Mean Bias	$\frac{1}{N} \sum_{i=1}^N (M_i - O_i)$	0 if perfect
Mean error	$\frac{1}{N} \sum_{i=1}^N M_i - O_i $	0 if perfect
Normalized mean bias	$\frac{\sum_{i=1}^N (M_i - O_i)}{\sum_{i=1}^N O_i} * 100\%$	0 if perfect
Normalized mean error	$\frac{\sum_{i=1}^N M_i - O_i }{\sum_{i=1}^N O_i} * 100\%$	0% if perfect
Fractional bias	$\frac{1}{N} \sum_{i=1}^N \frac{M_i - O_i}{(M_i + O_i)/2} * 100\%$	0% if perfect
Fractional error	$\frac{1}{N} \sum_{i=1}^N \frac{ M_i - O_i }{(M_i + O_i)/2} * 100\%$	0% if perfect
Index of agreement	$1 - \frac{\sum_{i=1}^N (M_i - O_i)^2}{\sum_{i=1}^N (M_i - \bar{O} + O_i - \bar{O})}$	1 if perfect



Measurement data used in evaluation

- Meteorological data
 - 95 surface synoptic sites
 - 663 surface METAR sites (Aviation hourly surface weather data)
 - 77 upper-air sites (radiosonde)
- Air Quality Service data
 - 58 PM10 ground sites
 - 75 PM2.5 ground sites
- Satellite images



Model Validation 1

Dazhong Yin – Department of Atmospheric Sciences, University of Arizona

DREAM Model meteorological outputs are verified against *in-situ* measurements

- surface and upper-air meteorological data
- weather radar observations



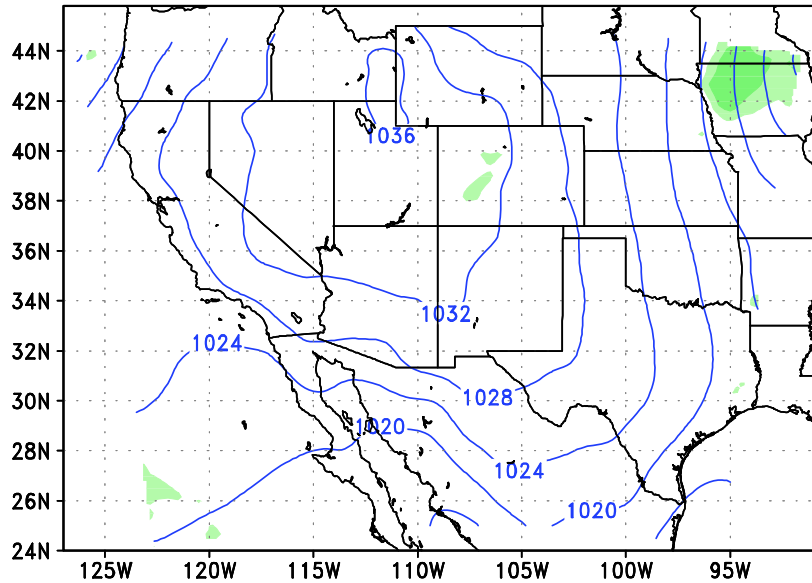
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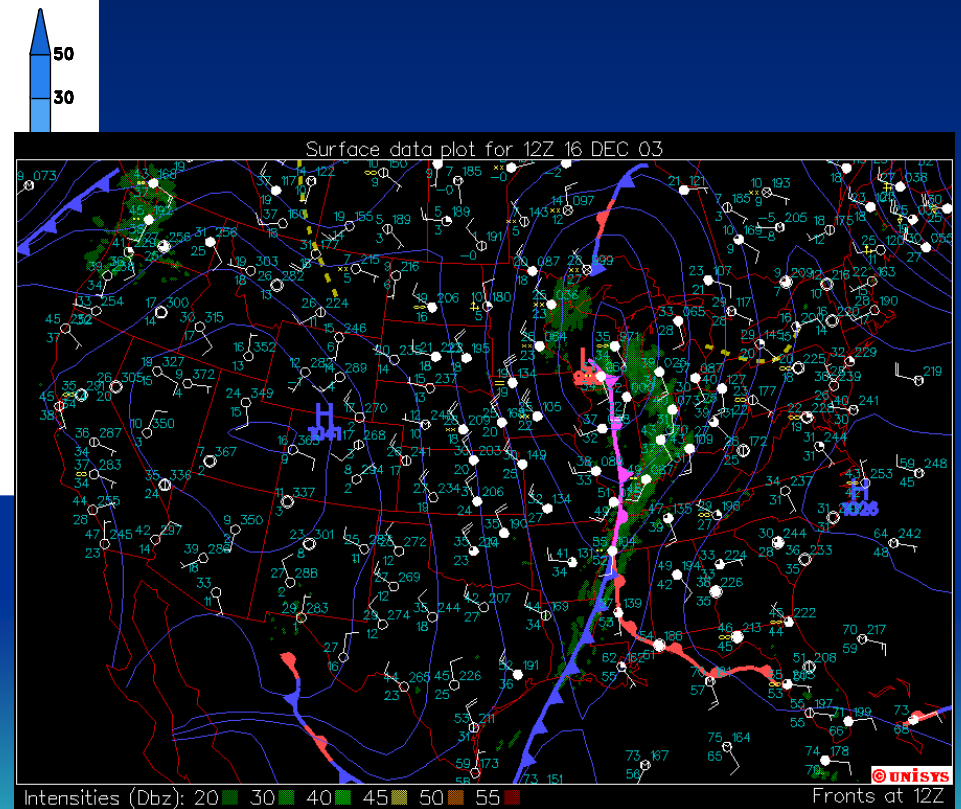
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Surface Map – Precipitation and Pressure

12h acc. Precipitation and MSL Pressure
12z 16 DEC 03



DREAM Model Output



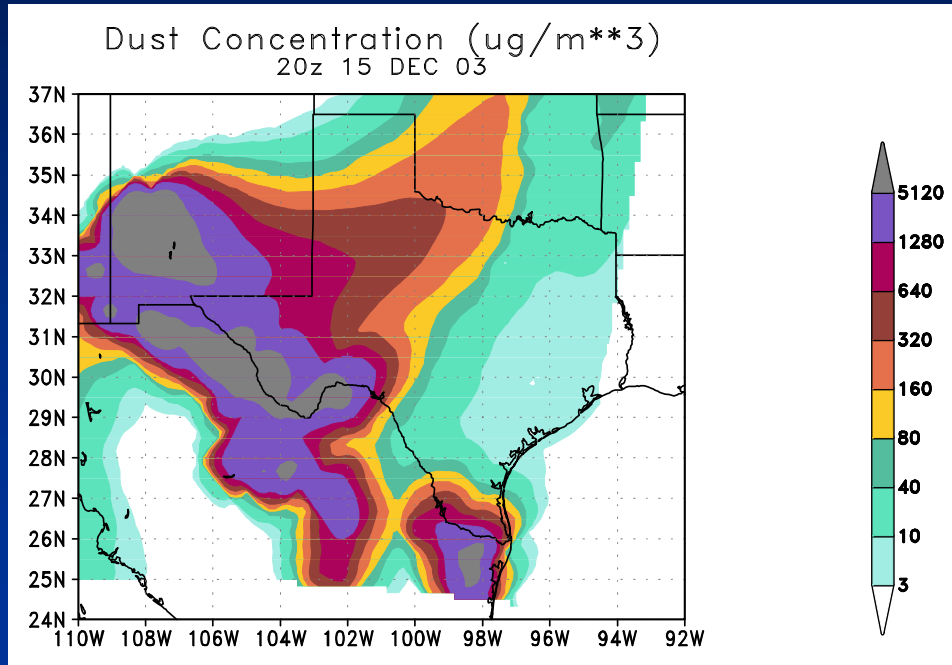
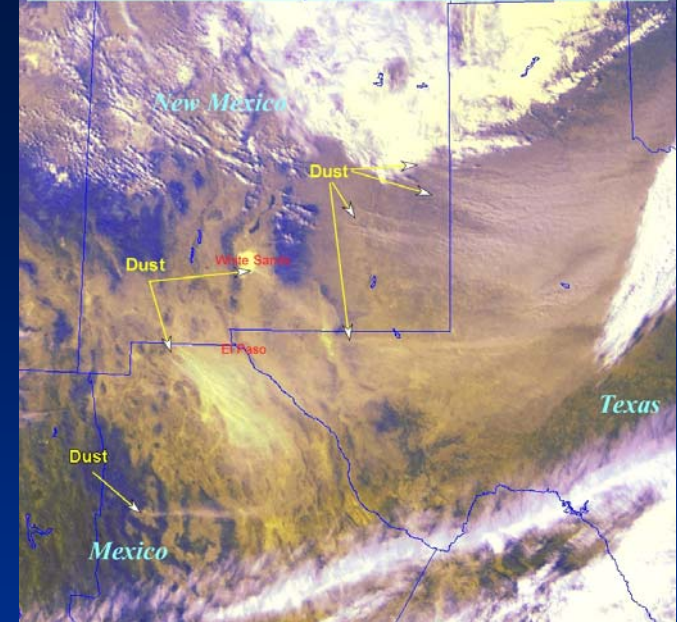
Plymouth State Weather Center
Meteorological Observations



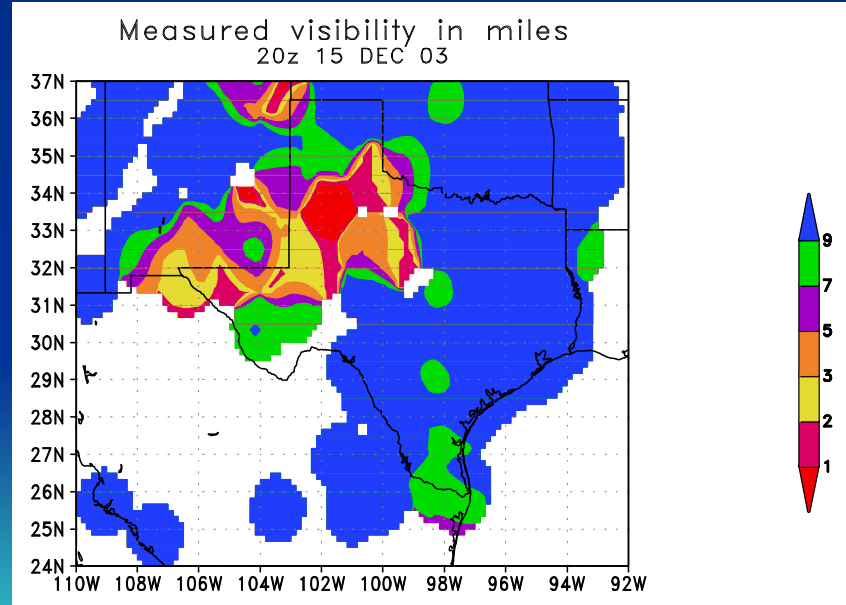
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Dust Map – GOES 12 Vis/IR Composite

GOES 12 - Vis/IR Composite 12/15/03 2:26 p.m. CST



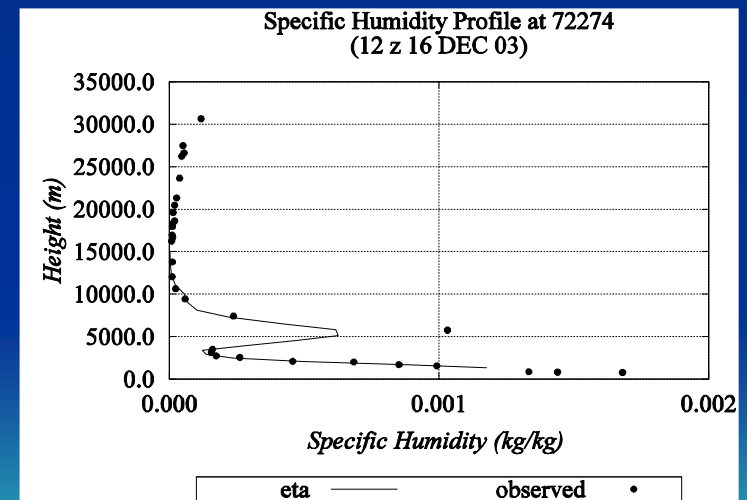
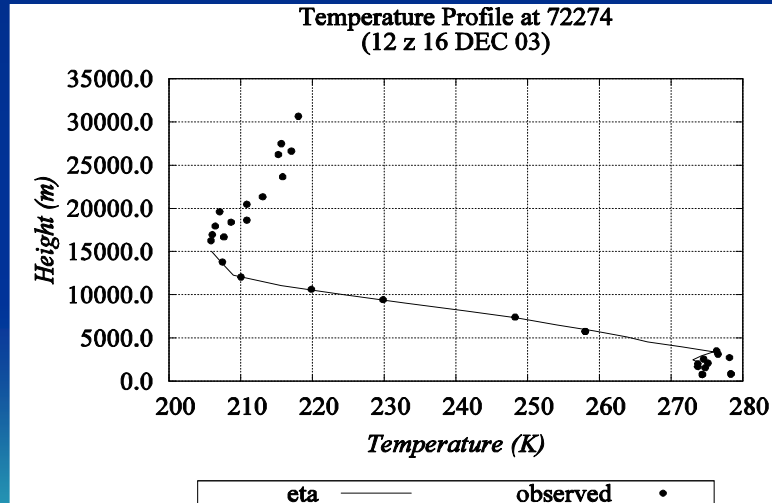
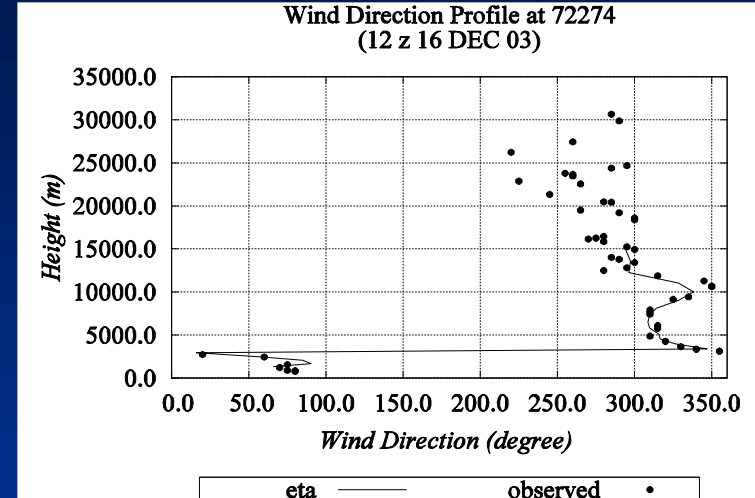
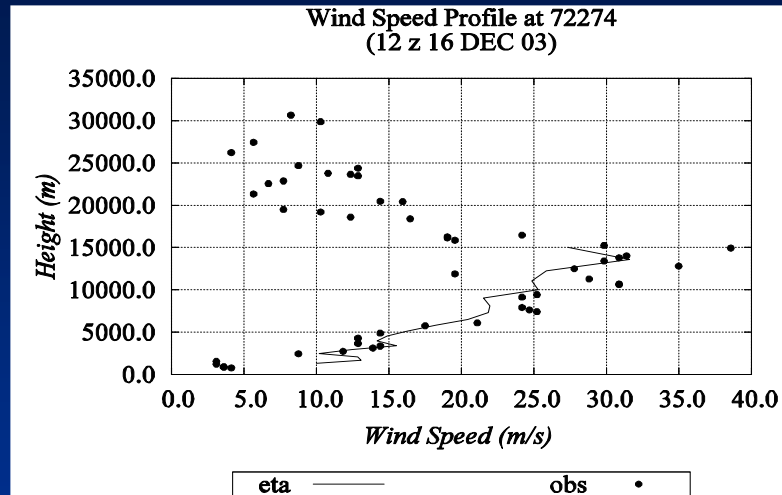
DREAM Model Output



Visibility

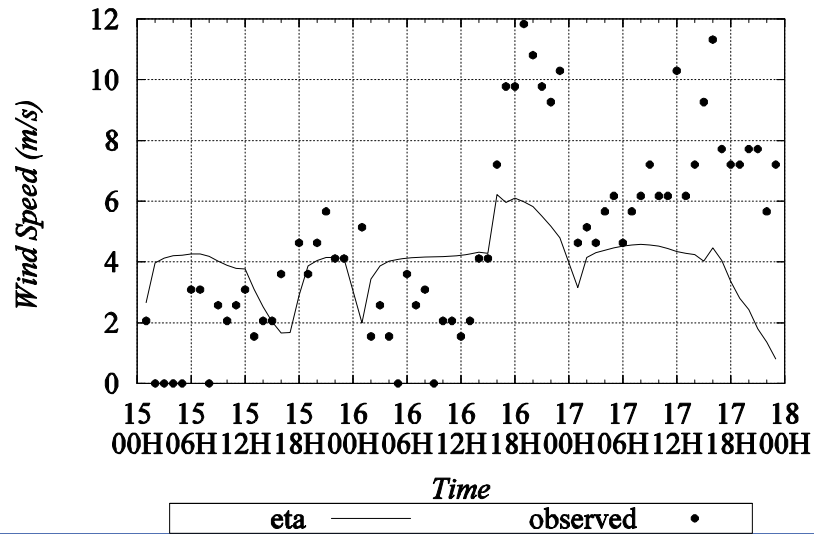


Vertical profile (wind speed, wind direction, temperature, specific humidity) Tucson, Arizona

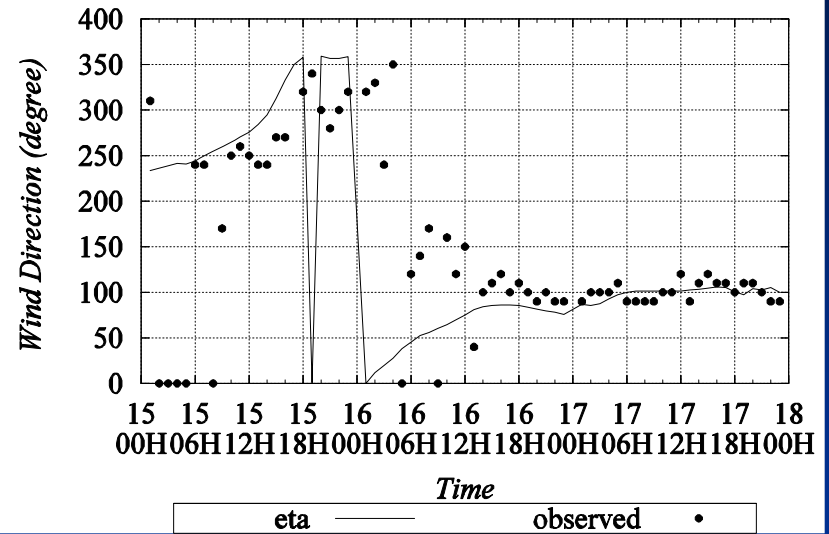


Time series (wind speed, wind direction, temperature) Tucson International Airport

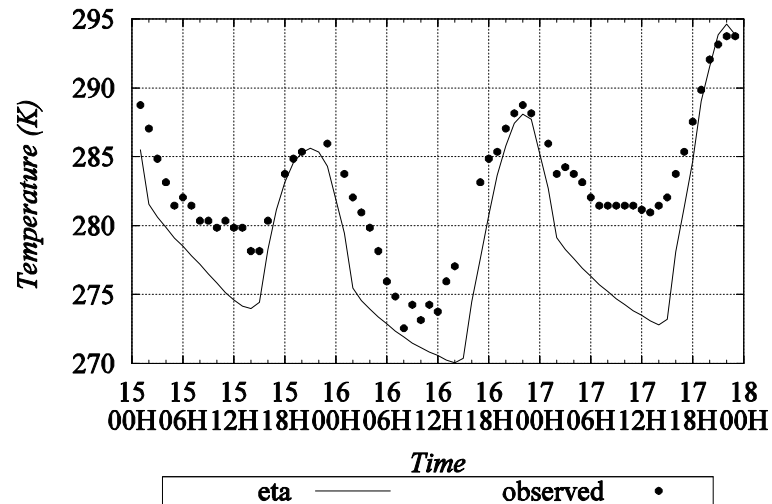
Wind Speed at KTUS



Wind Direction at KTUS



Temperature at KTUS



Model Validation 1 - Summary Results

- DREAM successfully predicted meteorological fields for the dust event in December 2003, with respect to both field patterns and values at individual sites. Statistically, the agreement indices for basic elements such wind and temperature are above 0.7.
- Model predicted dust patterns quite well, compared to the satellite images and measured visibility distributions.



Model Validation 2

Beeny Chandy and Brian Barbaris

Department of Atmospheric Sciences, University of Arizona

Point-by-point comparison between model output and in-situ data

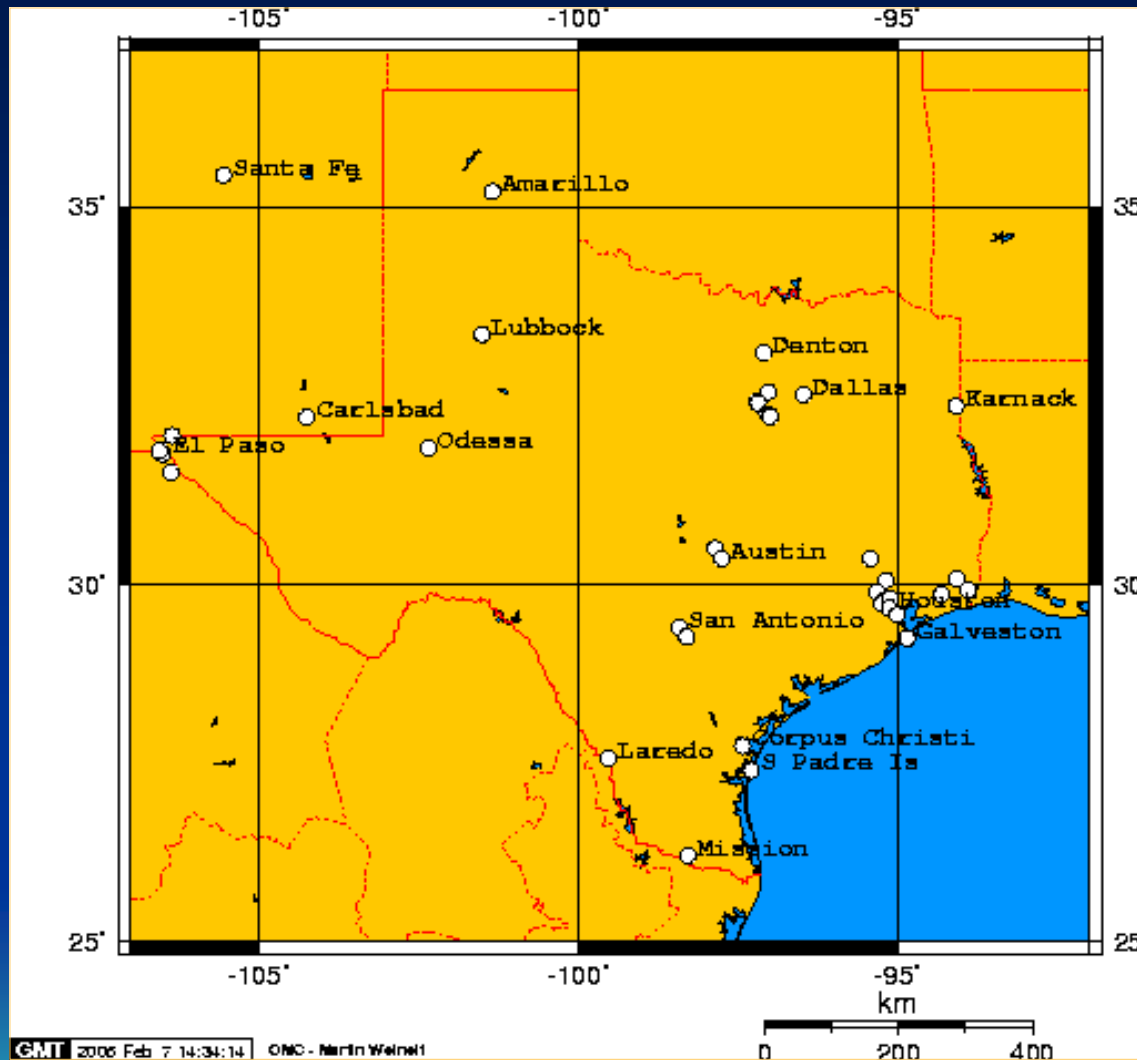
- **Peak Hour** - the UTC time of day that the one-hour PM_{2.5} maximum occurred
- **Event Duration** - the length of time the local population may have been exposed to unhealthy dust levels ($65 \mu\text{g}/\text{m}^3$, daily average)
- **Magnitude** - the highest one-hour mean PM_{2.5} ($\mu\text{g}/\text{m}^3$) observed during the event (15-16 December 2003)



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Ambient Air Monitoring

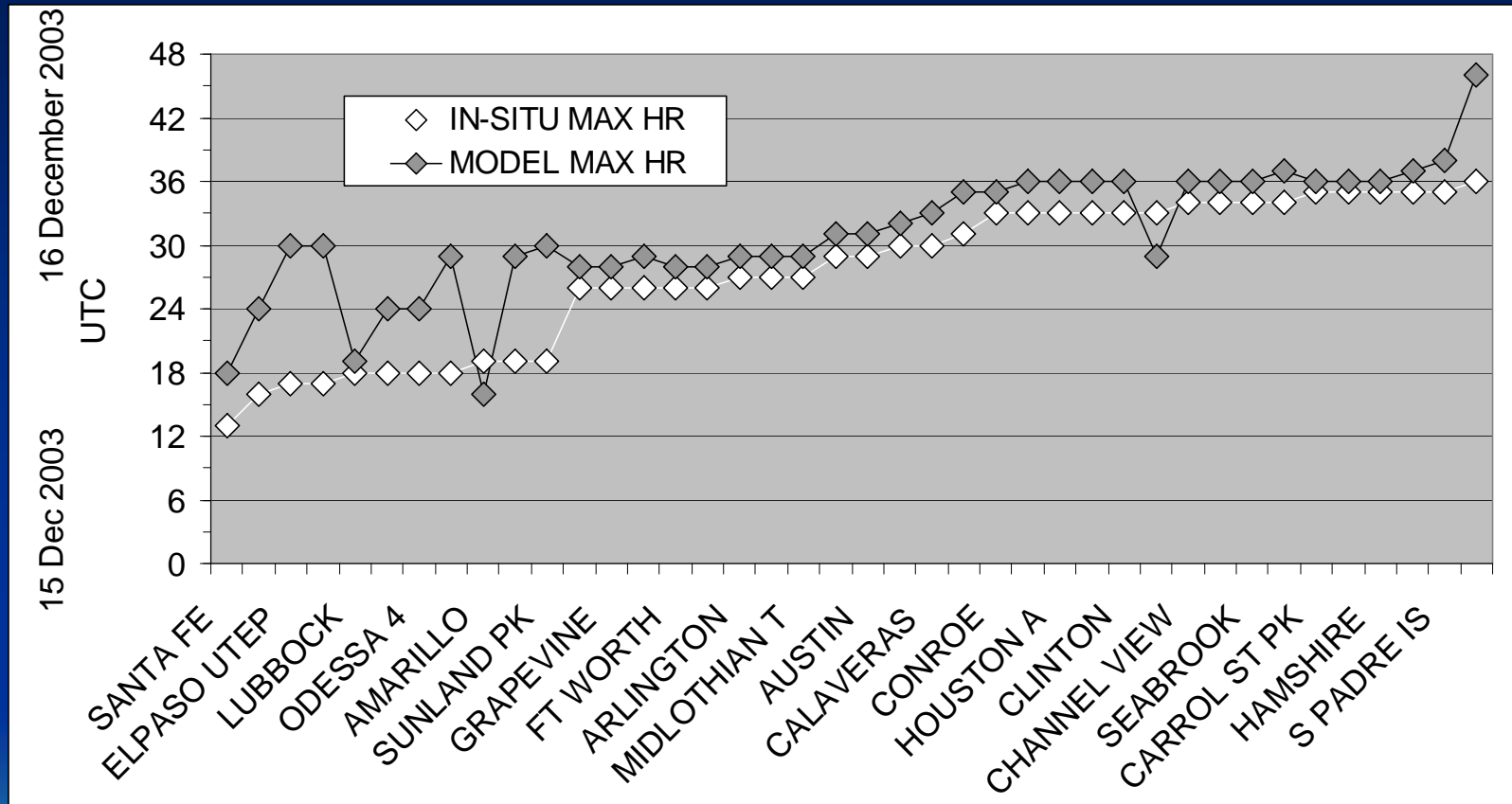


During the December 15-16th 2003 test case, forty air monitoring stations in NM, TX continuously measured the fine fraction (PM_{2.5}) of aerosol dust.

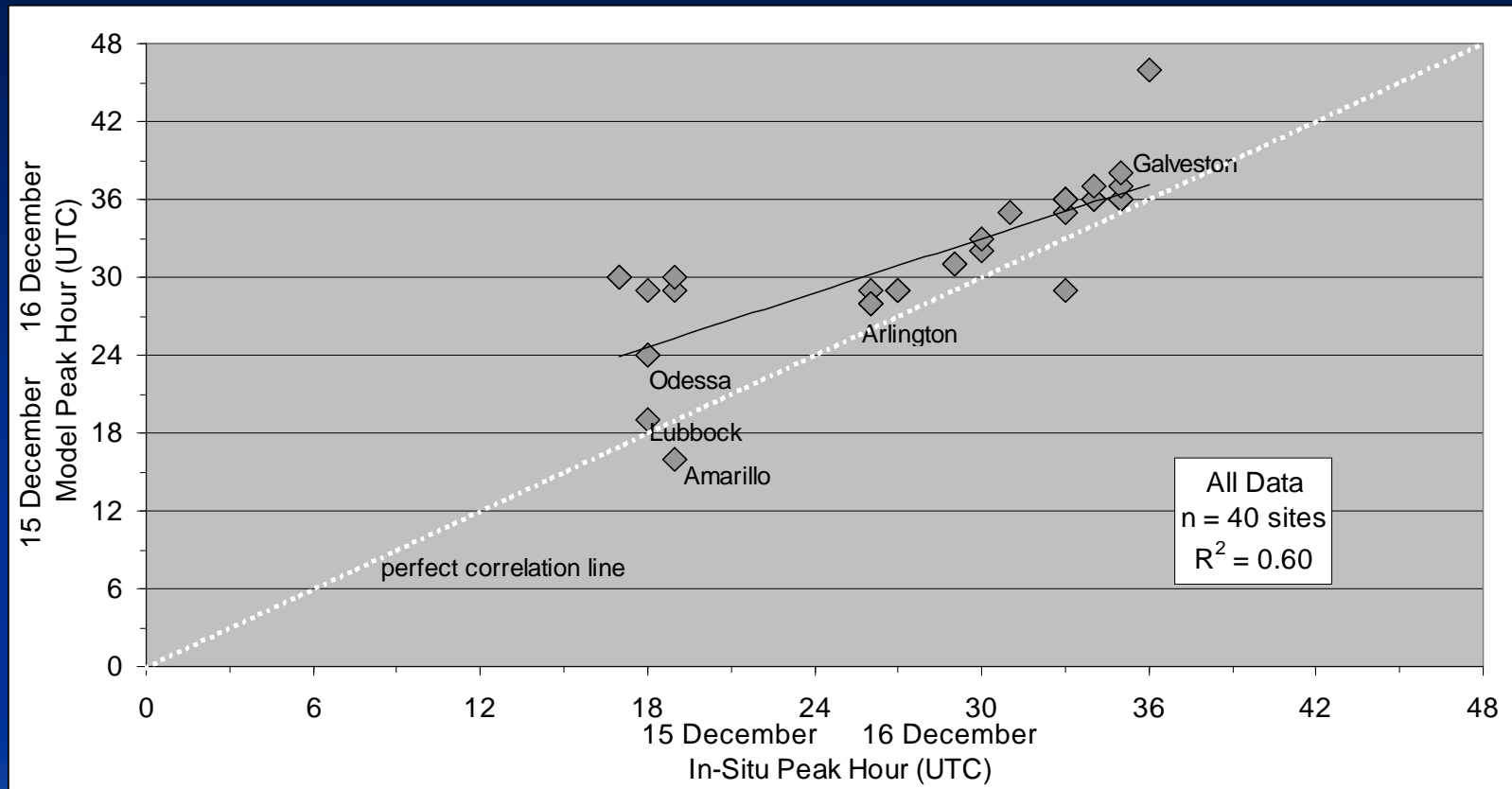
How well did the DREAM model perform in predicting the timing, duration and magnitude of the event at each of these stations?



Peak Hour PM2.5 Fraction



Peak Hour PM2.5 Fraction All sites (n=40)



Moderate correlation ($R^2 = 0.60$) between the model and in-situ peak hour over the entire 2-day event.

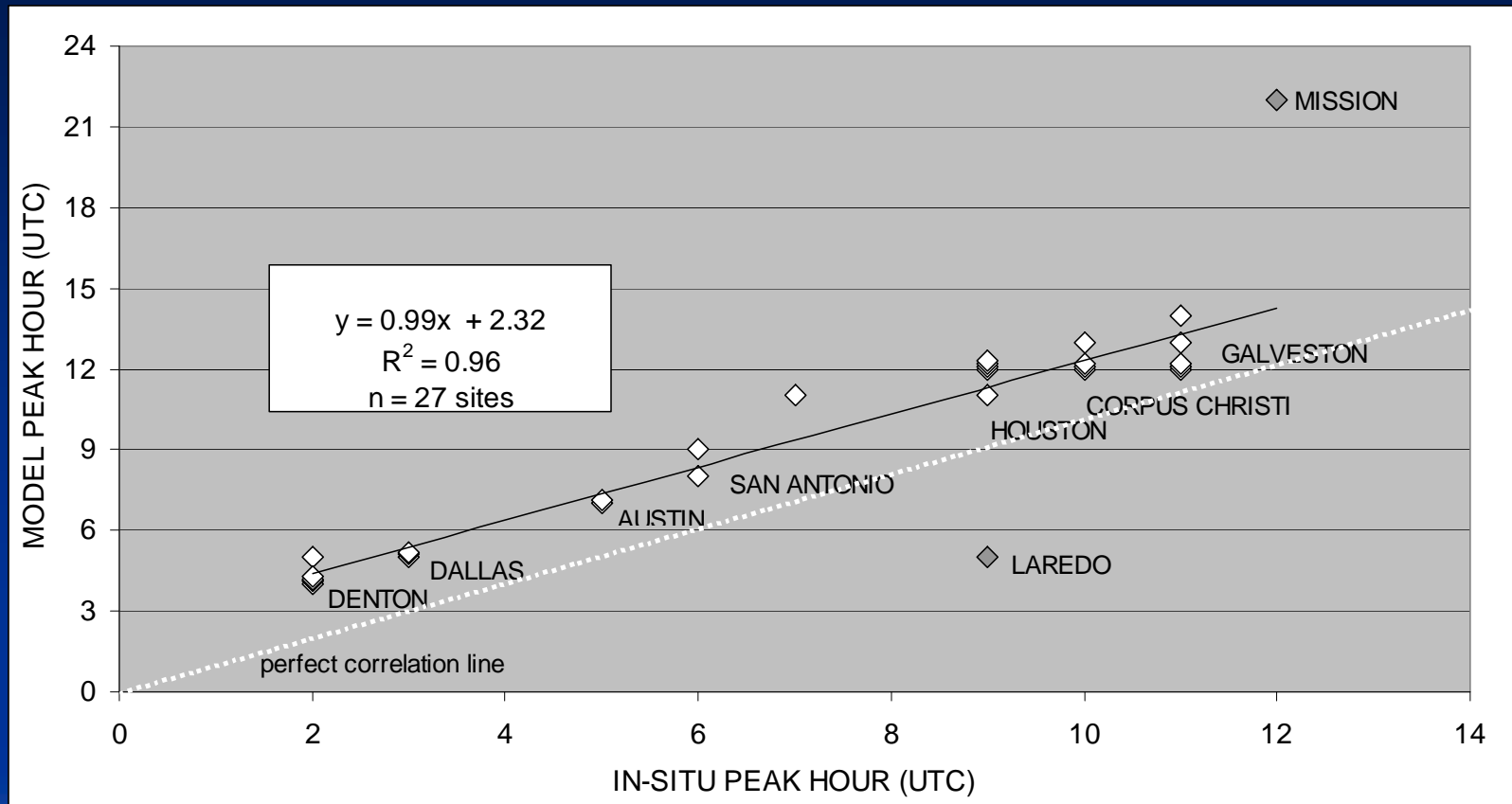


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Peak Hour PM2.5 Fraction Central and East Texas sites (n=27)



Excellent correlation ($r^2 = 0.96$, $n = 27$) over central and east Texas on the second day.



Event Duration

EPA National Ambient Air Quality Standard for PM_{2.5}:

Primary: 65 $\mu\text{g}/\text{m}^3$ average exposure over a 24-hour period.

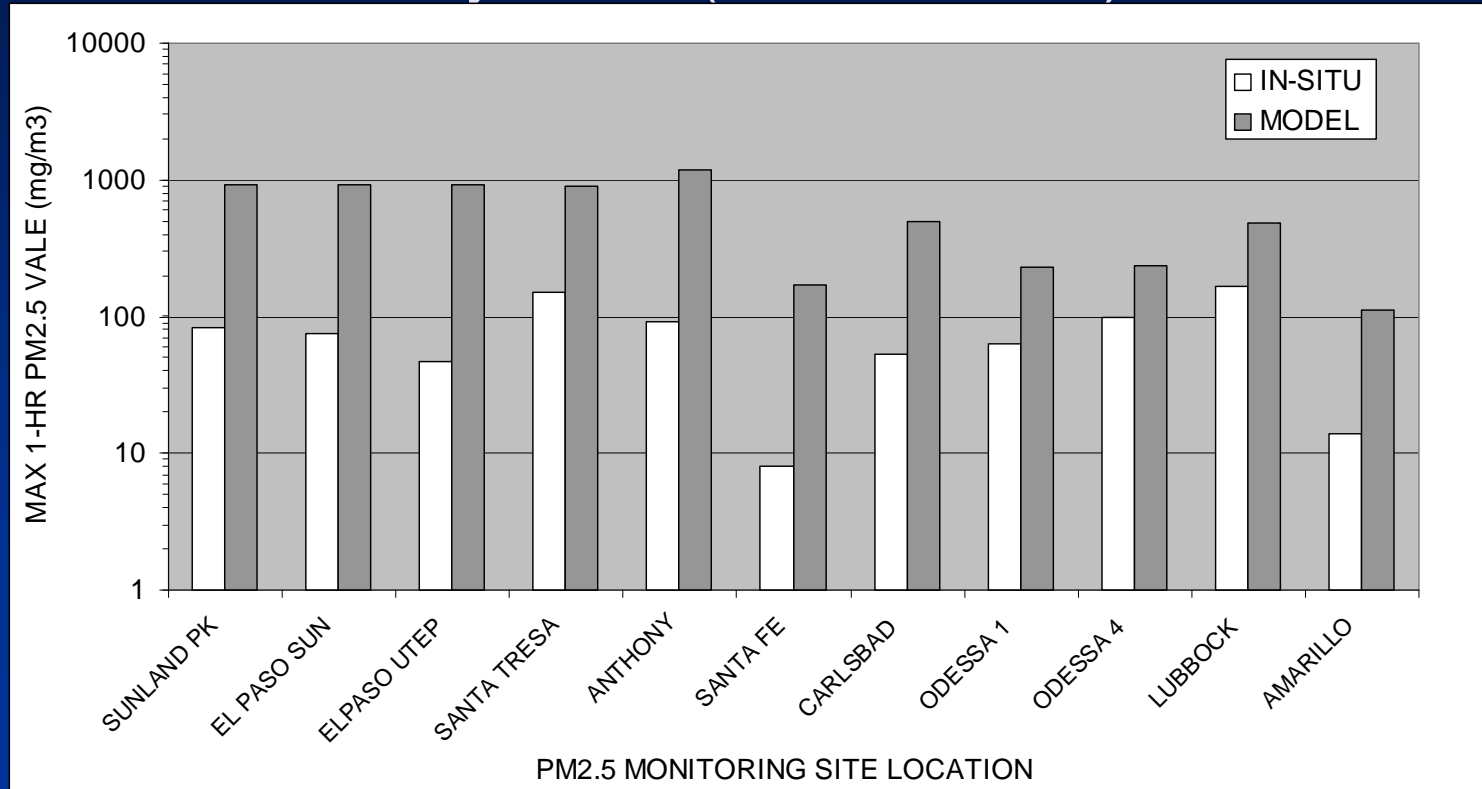
Lubbock, TX, based on observed, *in-situ* values, was the only reported exceedance during the event with a measured daily average of 76.7 $\mu\text{g}/\text{m}^3$.

Lubbock was among eight sites where the DREAM dust model predicted exceedances of the primary standard (all in New Mexico and West Texas).



Magnitude

Comparison of the Highest One-Hour PM 2.5 Averages Early Event (15 December)

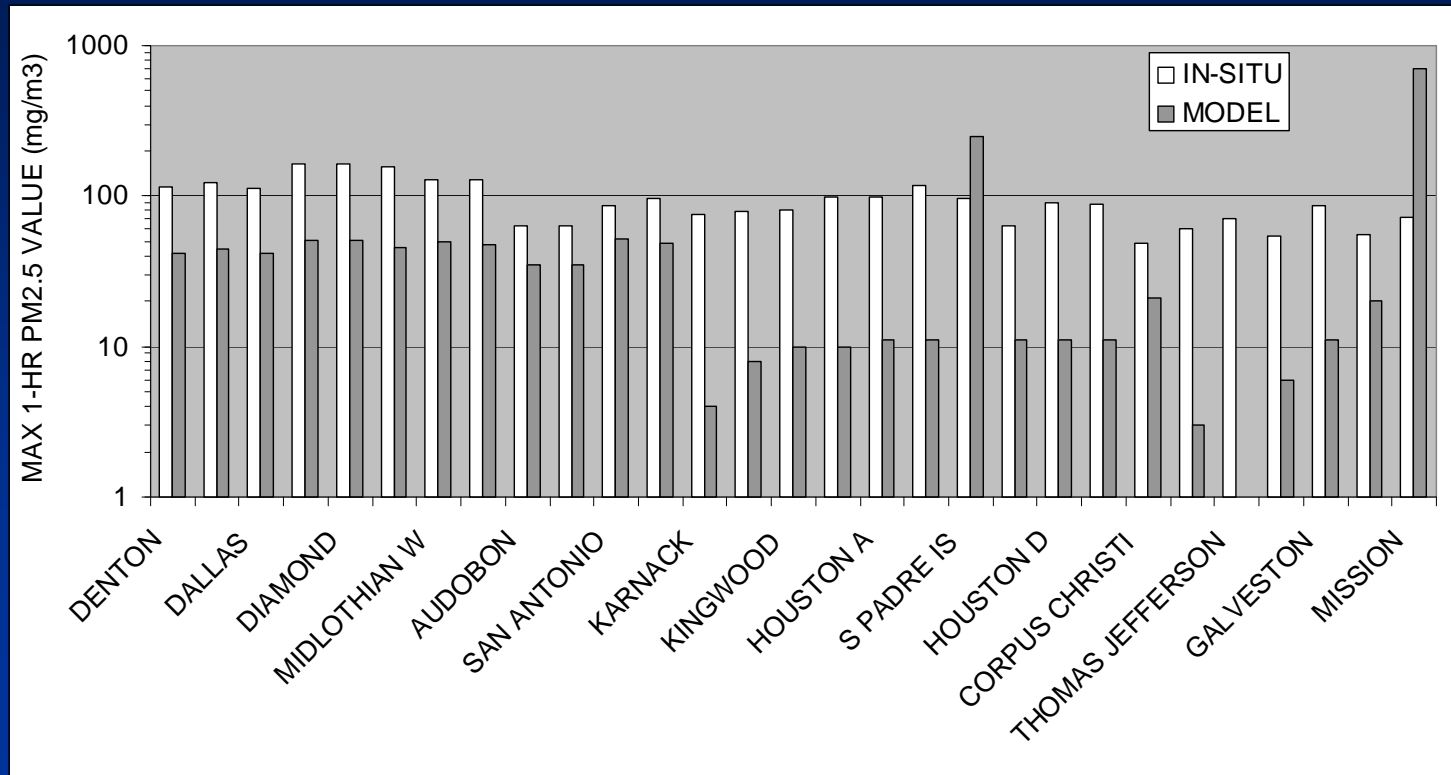


DREAM model *over-predicted* concentrations by an order of magnitude during the early stages of the event in the western part of the study unit.



Magnitude

Comparison of the Highest One-Hour PM 2.5 Averages Early Event (15 December)

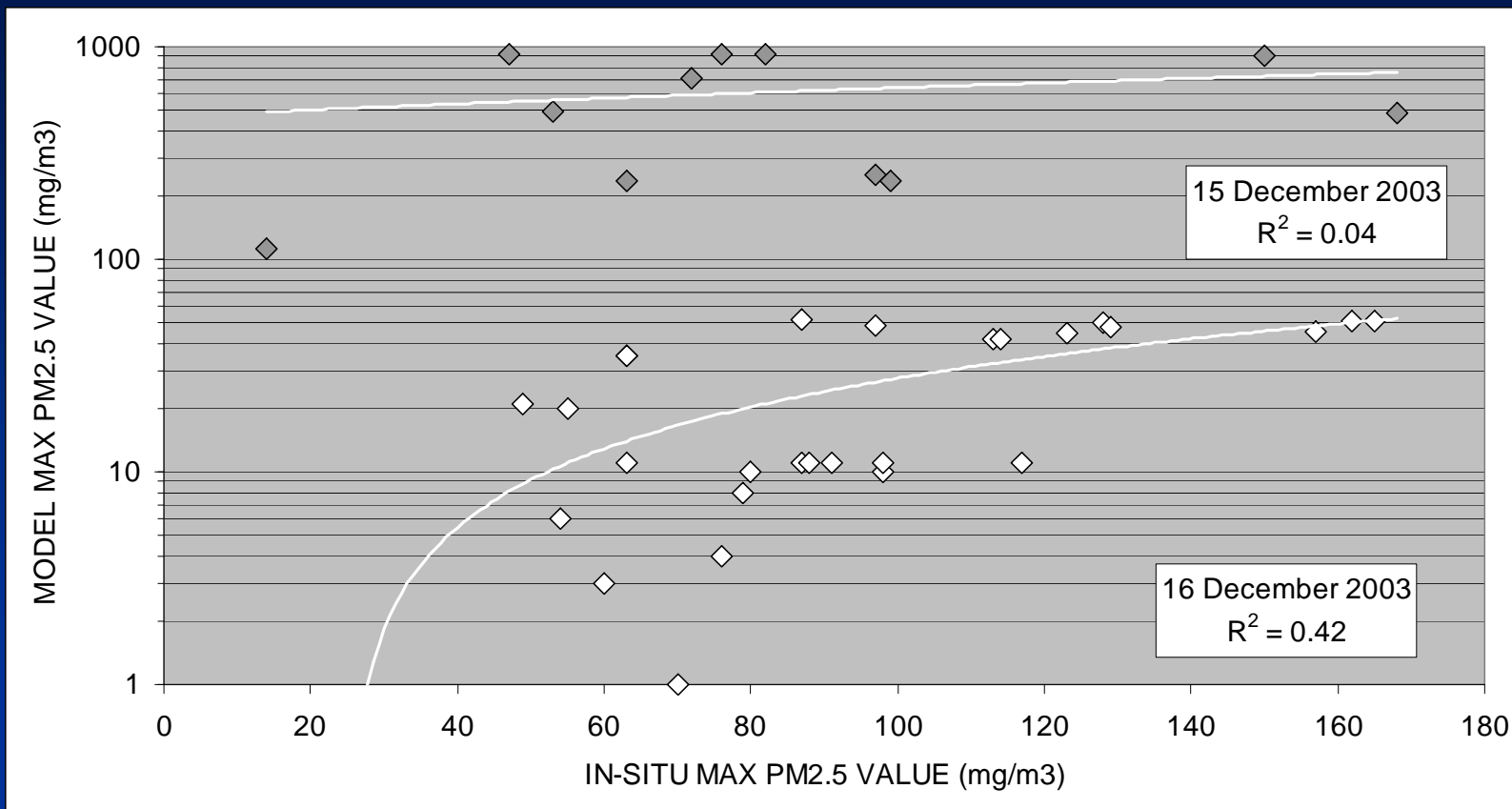


DREAM model *under-estimated* concentrations by as much as an order of magnitude in the later stages in the eastern part of the study unit.



Magnitude

Scatter plot of all Max 1-Hour Observations (40 sites)



Scatter plot of maximum one-hour values indicates no correlation ($r^2 = 0.04$, $n=11$ sites) on the first day and poor correlation ($r^2 = 0.42$, $n=29$ sites) on the second day.



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Future Work

NASA-derived satellite data

- Use higher resolution data, including land cover, soil texture, to refine dust source modeling in SW
- Increase in resolution of model horizontal grid to 1/9 degree (~6.7 arc minutes).



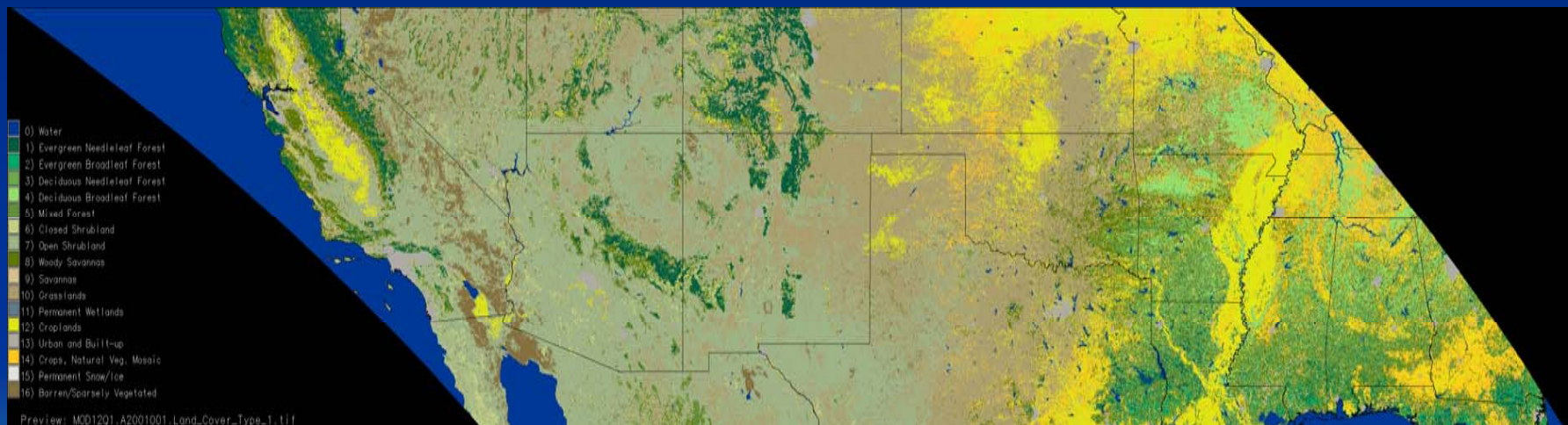
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MODIS 12 Land Cover Product

- 1 km grid resolution
- 16 Land Cover classes



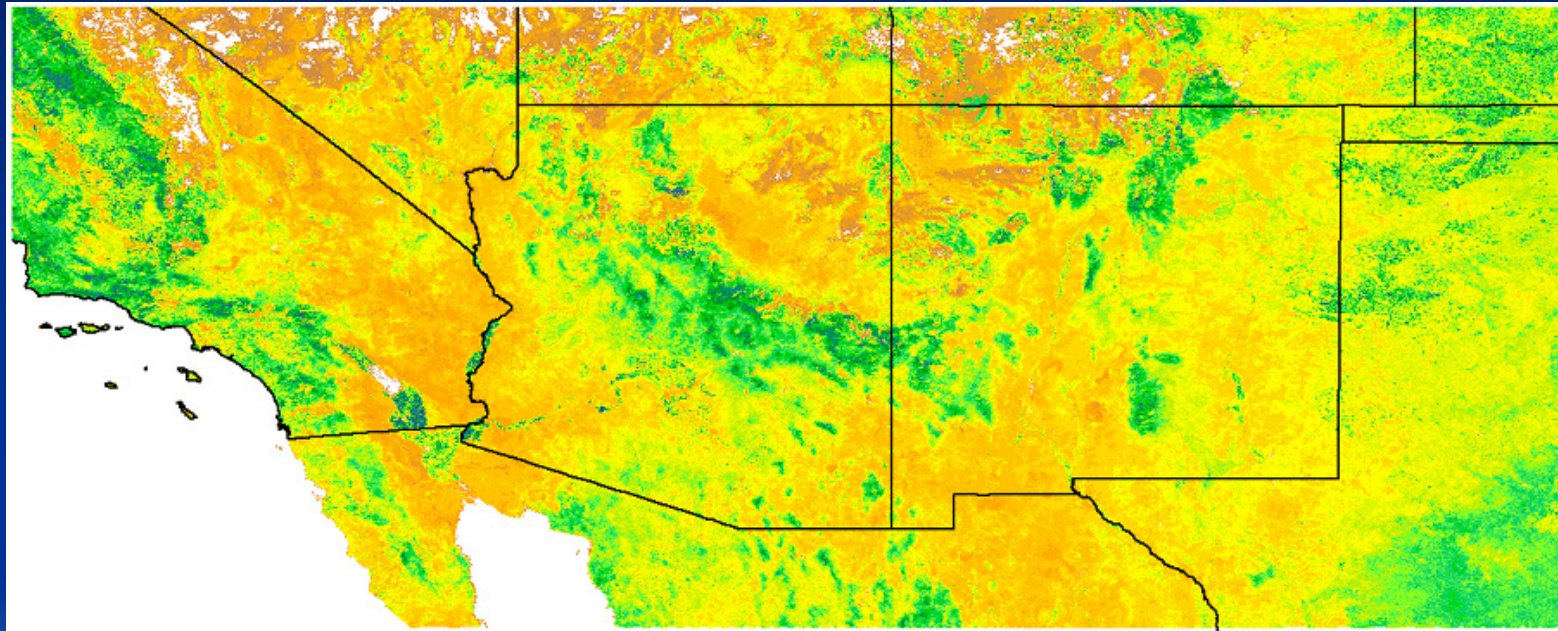
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Enhanced Vegetation Index – MODIS 13

- measures photosynthetic vegetation activity
- 1 km resolution



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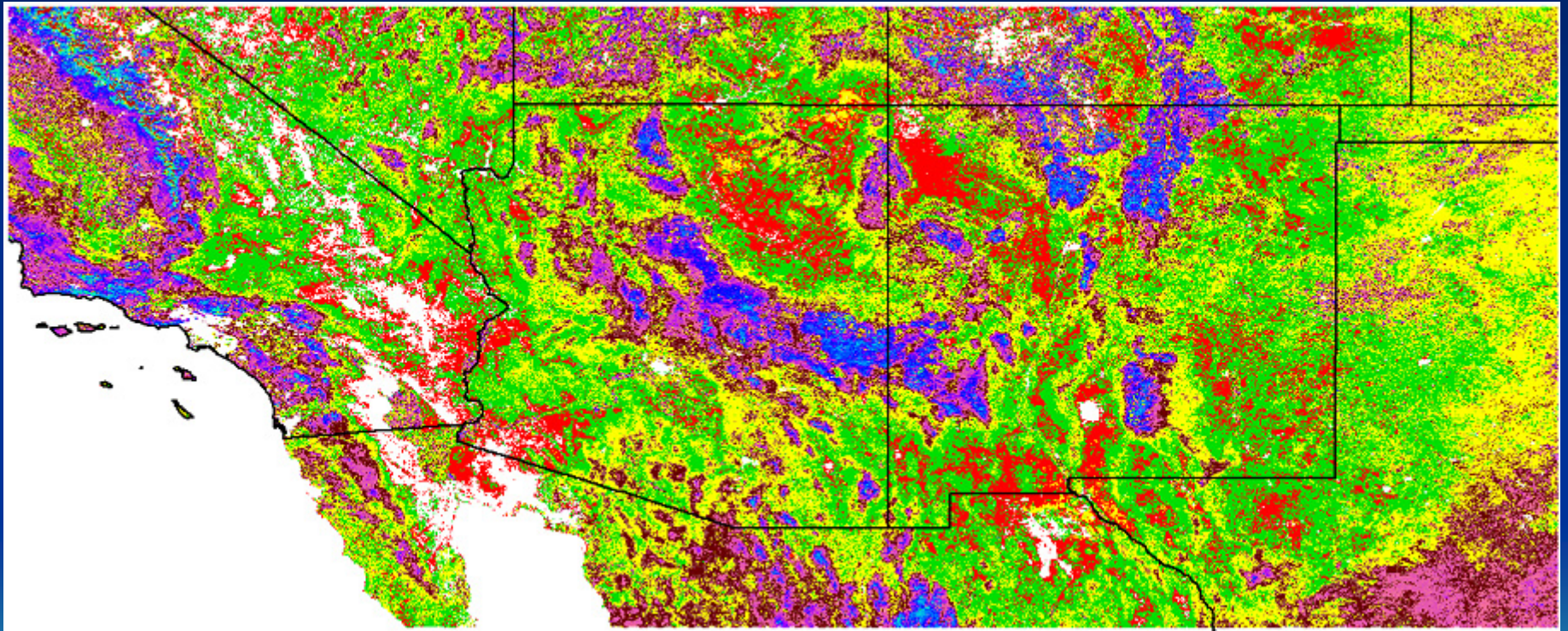


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Leaf Area Index – MODIS 15

-1km resolution

-measures leaf area per unit ground area



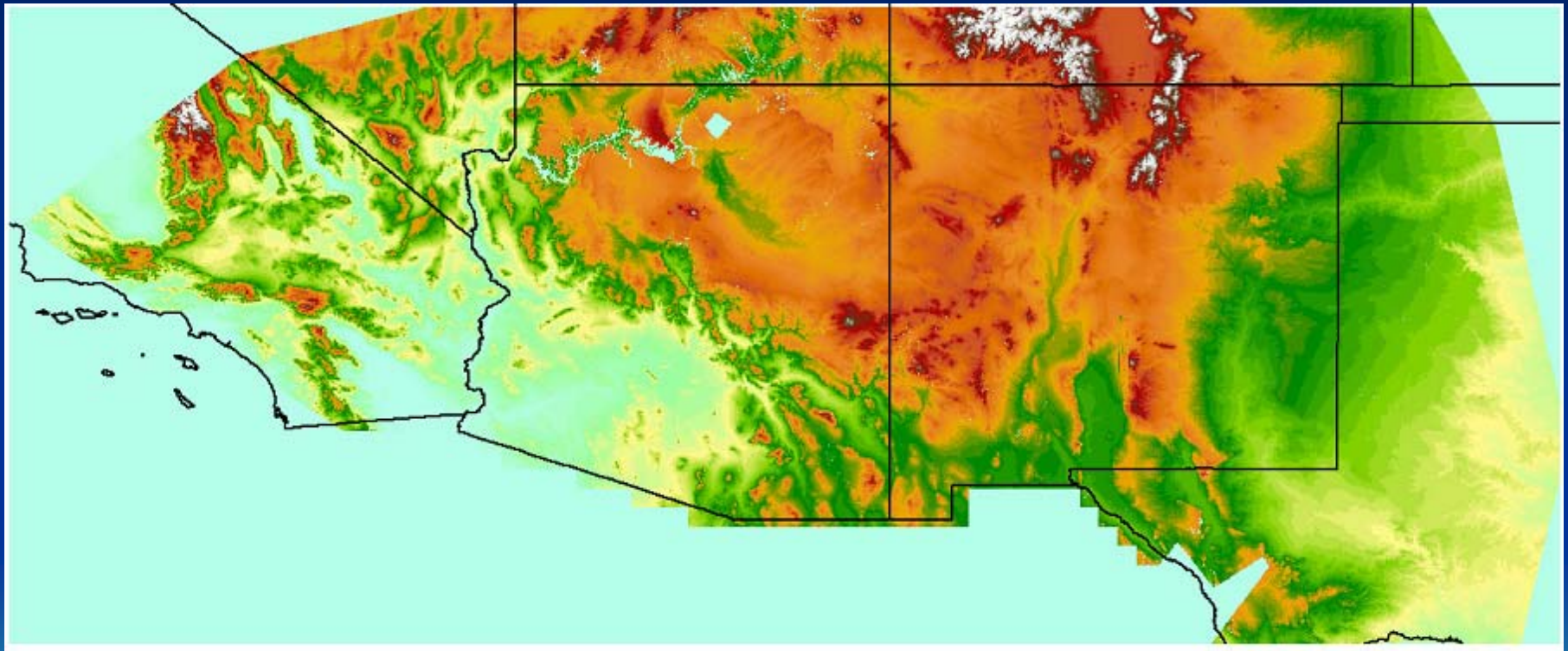
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Shuttle Radar Topographic Mission (SRTM)

-Level 2 data at 1 arc-second (~30m) resolution



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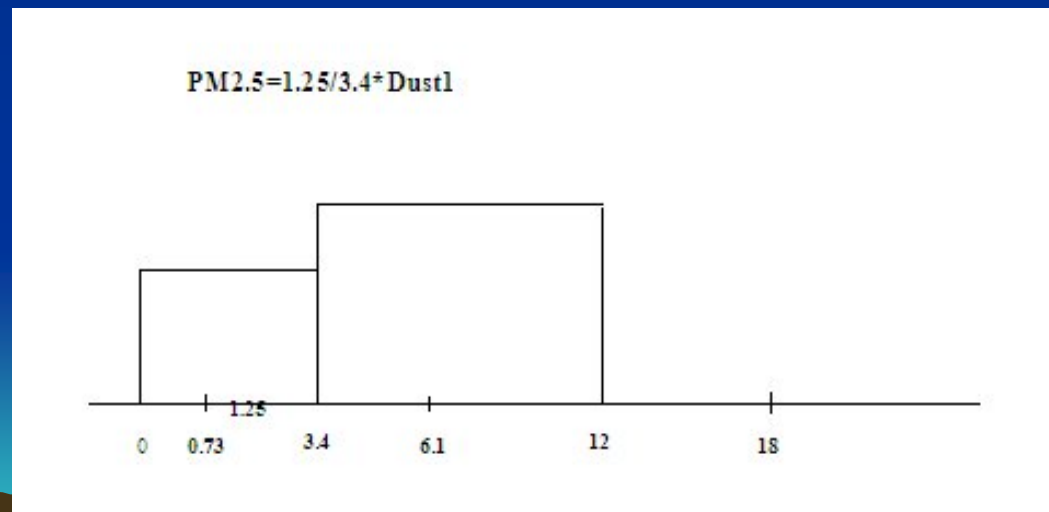
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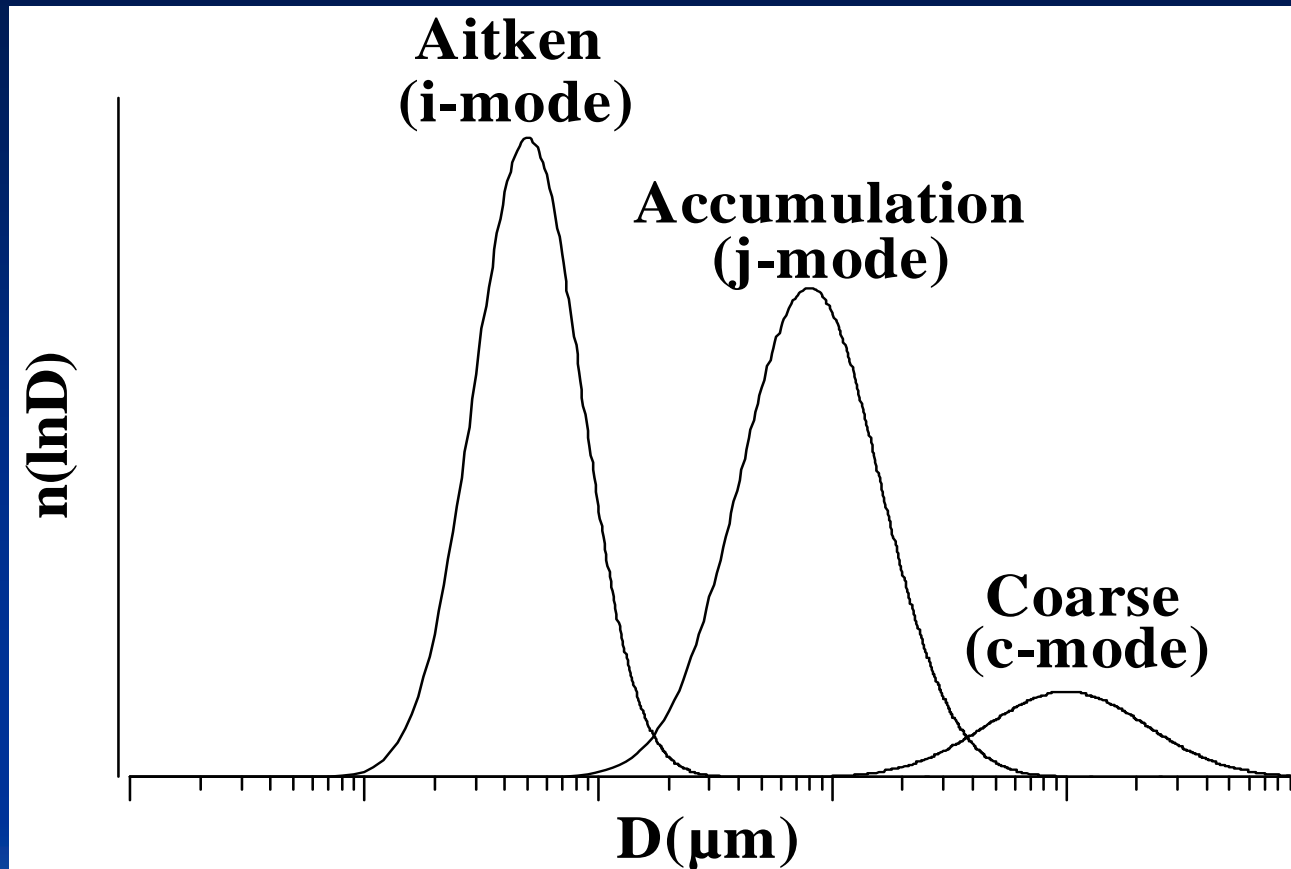
Future work

Particle-size distributions

- Enhancements to the current dust production model to give detailed particle size distribution

Category	Radius (μm)	Diameter(μm)
Dust 1	0.73	1.46
Dust 2	6.1	12.2
Dust 3	18	36
Dust 4	38	76





Future work

Client Development

- Automated data acquisition, processing, and integration technologies that streamline the ingestion of NASA data and the transfer of Dust Model outputs into an online client.
- Open source tools (GRASS GIS, Minnesota Mapserver, R Statistical Package, PostGIS Spatial Database)
- A variety of query functions for assessing descriptive statistics, time-series analysis, and the spatial distribution of dust concentrations.



PHAIRS Time-Series Forecasting

Applications Actions Mon Jun 13, 11:18 AM

PHAIRS Mapping Client - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://falstaff.unm.edu/cgi-bin/reason/dust_client.py

Red Hat, Inc. Red Hat Network Support Shop Products Training

Public Health Applications of Remo

Time Series of PM2.5 (ug/m³)-Lubbock Texas

Dust Concentration (ug/m³)

Hours UTC

U.S. Counties
 U.S. Zip Codes
 U.S. Rivers

Background Raster Layers

Dust 1 22UTC - Level 1

	0-50ug/m ³
	51-100ug/m ³
	101-150ug/m ³
	151-200ug/m ³
	201-250ug/m ³
	251-300ug/m ³
	301-350ug/m ³
	351-400ug/m ³
	401-450ug/m ³
	451-500ug/m ³
	4001-5000ug/m ³
	5001-6000ug/m ³

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firefox-bin (3) Evolution - A [wilbur@dim] [R_dem_der] R Graphics: [RealPlayer] [The GIMP] Plots and G GRASS 5.3

Future Work

Public Health Data

- Goal is to connect the modeling of dust distributions and trends with epidemiological studies based on West Texas health data.
- Integrated data from hospitals and clinics, from physicians, from schools, and from data sets maintained by state and federal agencies.
- Assembled approximately 100,000 records concerning children and adults (and pertaining to respiratory illnesses in West Texas).
- Records include detail on asthma, influenza, associated mortality information, behavioral and risk-factor surveys, clinic files, and hospital discharge data.



Acknowledgements

- Marvin Landis –visualization
- Jim Koermer of Plymouth State University-met observational data and met analysis products
- weather.unisys.com-surface weather maps
- www.rnrcc.tx.us- satellite images
- US EPA-AQS PM data



Working for public health!

