Public Health Applications in Remote Sensing

Environmental Sensing: An Evolving Program for Air Quality and Human Health

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Program Elements

- PHAiRS
- SDSWAS
- NASA RPC - Pollen
- Interoperability
- SYRIS; Air Quality Authorities; Health Offices
- EPHTS & EPHTN
- EPA Workshop
- ICSU 2008 Grant Proposal

PHAiRS Research Team

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  - T. Budge (UNM)
  - D. Yin (UA)
  - B. Barbaris (UA)
  - S. Caskey (SNL)
  - D. Holland (NASA-SSC)
  - J. Speer (TTUHSC)
- Research Assistants
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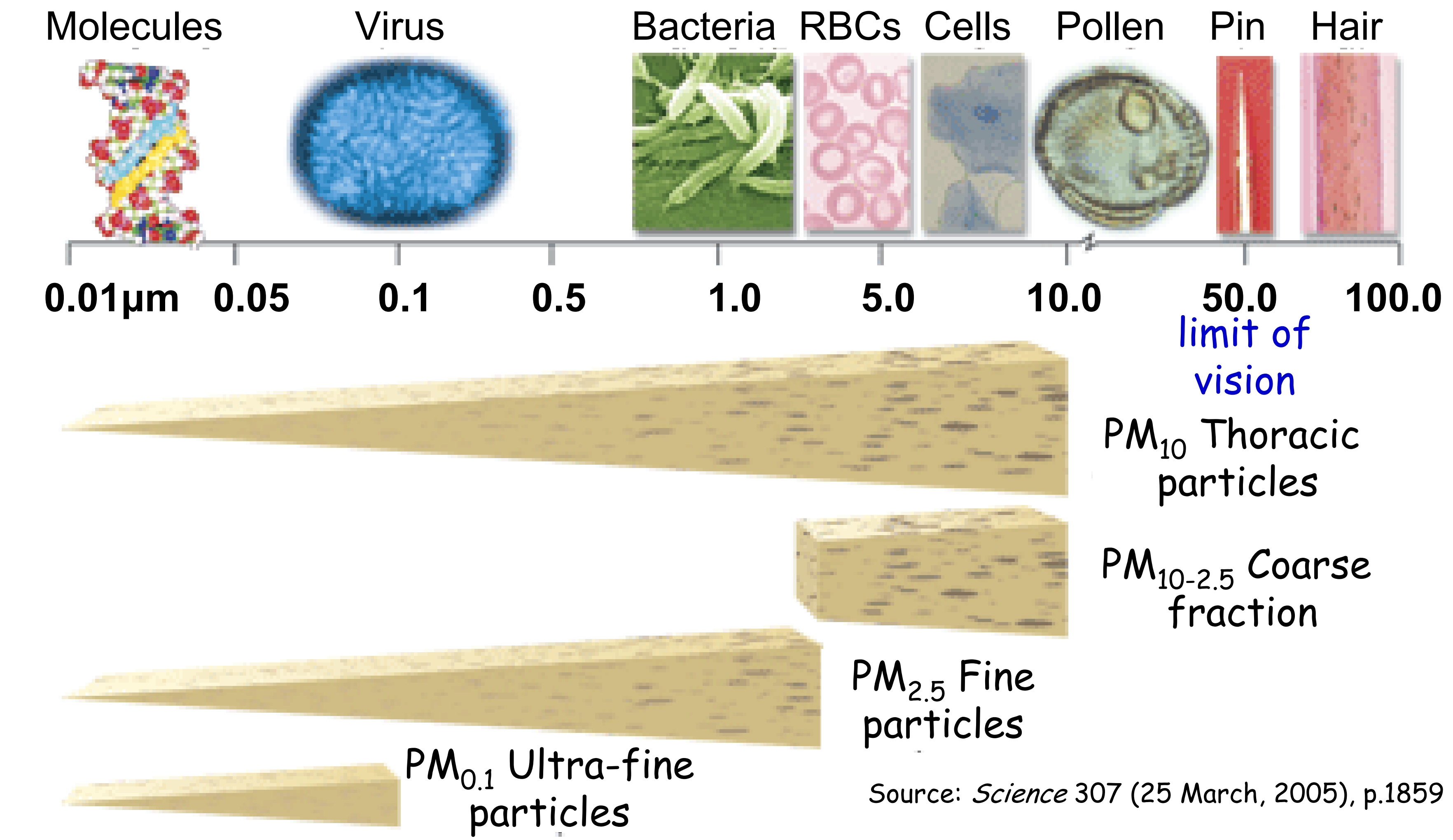
  - Beena Chandy (UA)
  - Chris Cattrall (UA)
  - Patrick Shaw (UA)
- Public Health Partners
  - City of Lubbock Dept of Health
  - Pima County Dept of Environmental Quality
  - Arizona Dept of Health Services
  - NM Dept of Health
  - UNM Health Science Center
  - ARES Corporation
  - ABQ Air Quality Office

Aims and Goals

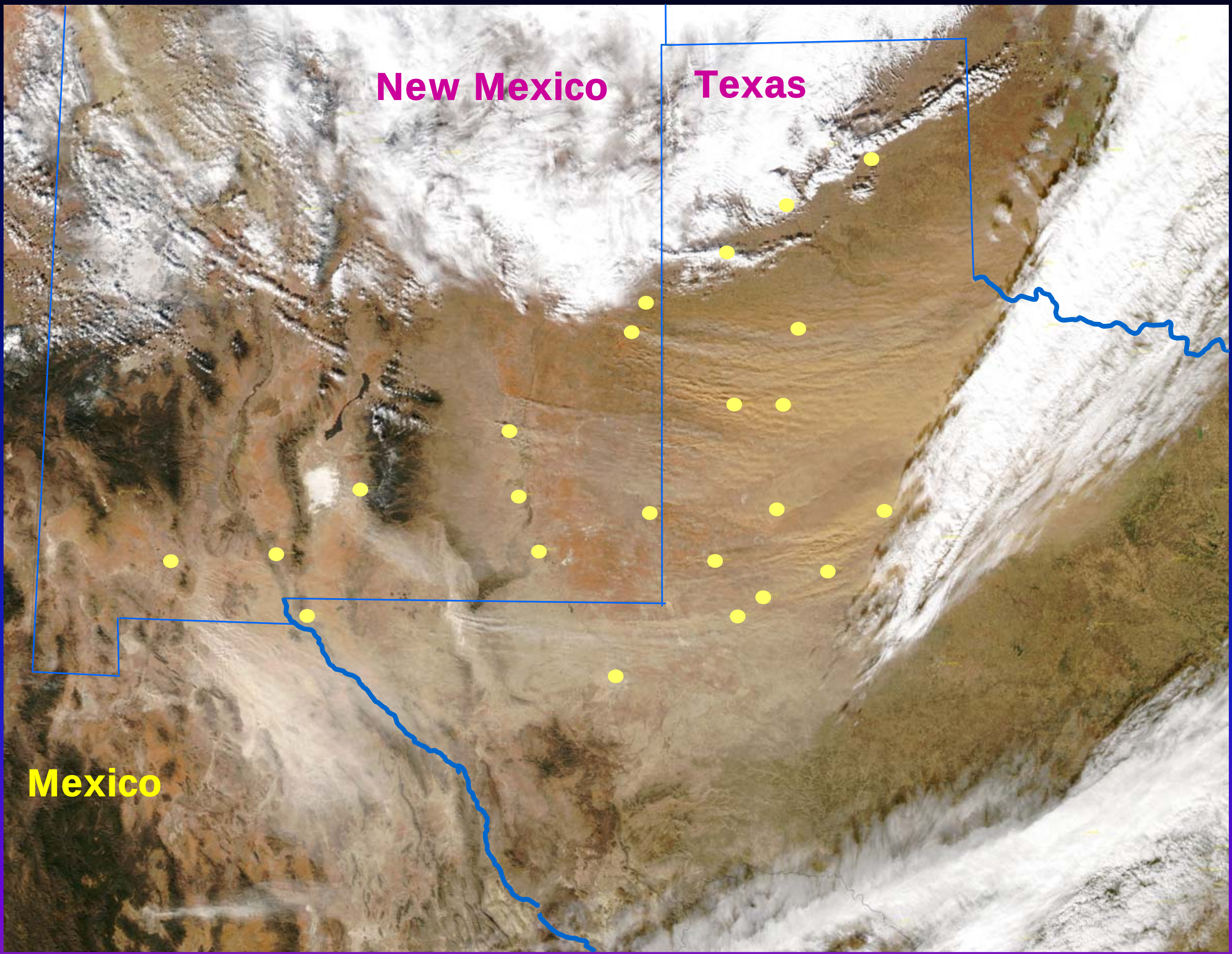
- Focus on SW, dust storms, respiratory diseases, and syndromic surveillance
- 3 thrusts
  - Assimilate EO data into DREAM as part of NCEP/eta forecasting system
  - Measure incremental improvements to DREAM outputs as inputs to RSVP/SYRIS
  - Create collaborations with public health authorities to validate relationships between dust episodes and respiratory complaints

Particulate Matter Size Distribution & Their Related Biophysical Impacts

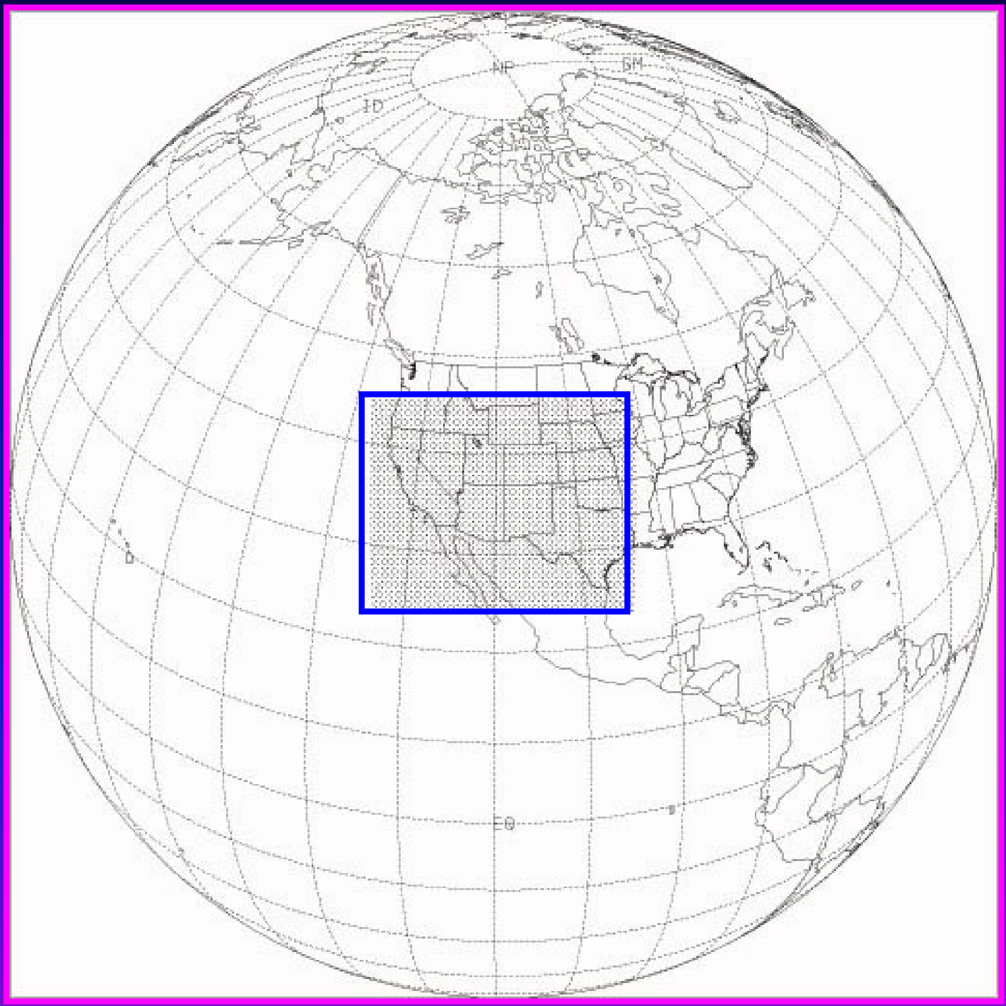


Source: *Science* 307 (25 March, 2005), p.1859

New Mexico/Texas Dust Storm – Dec 2003



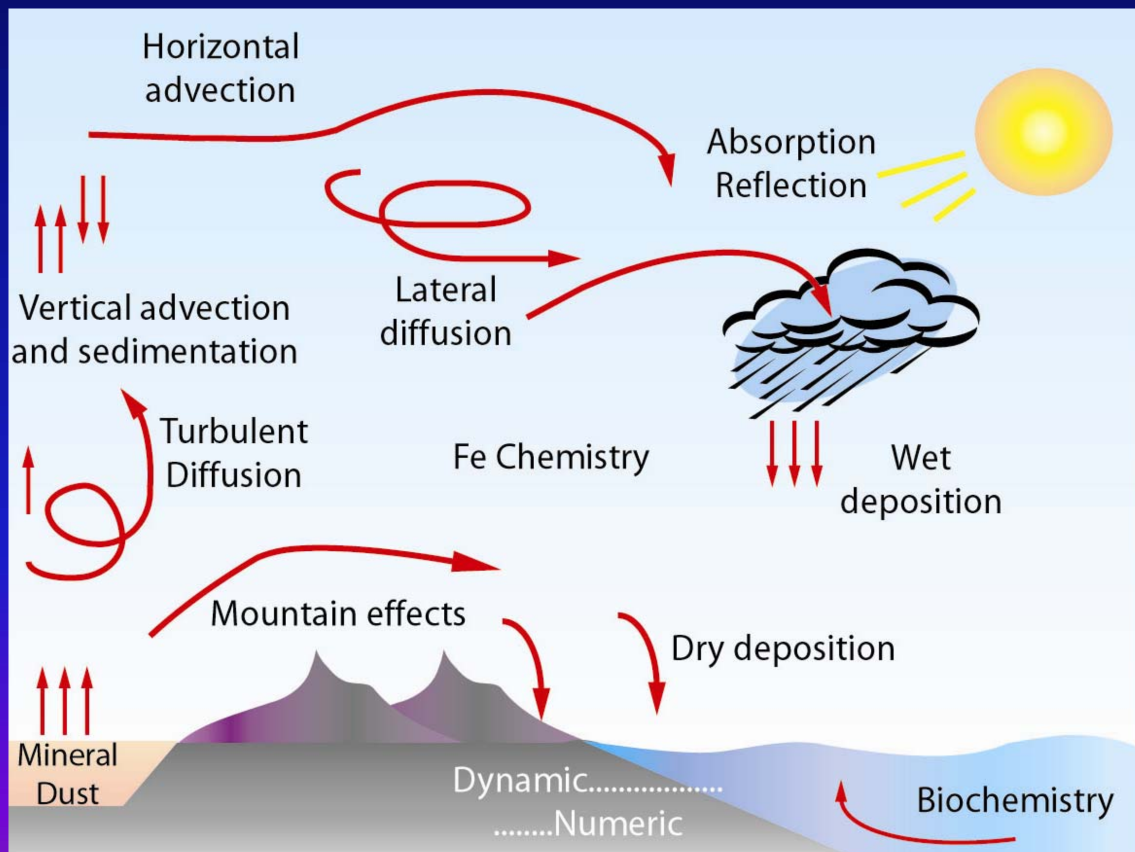
Model Domain



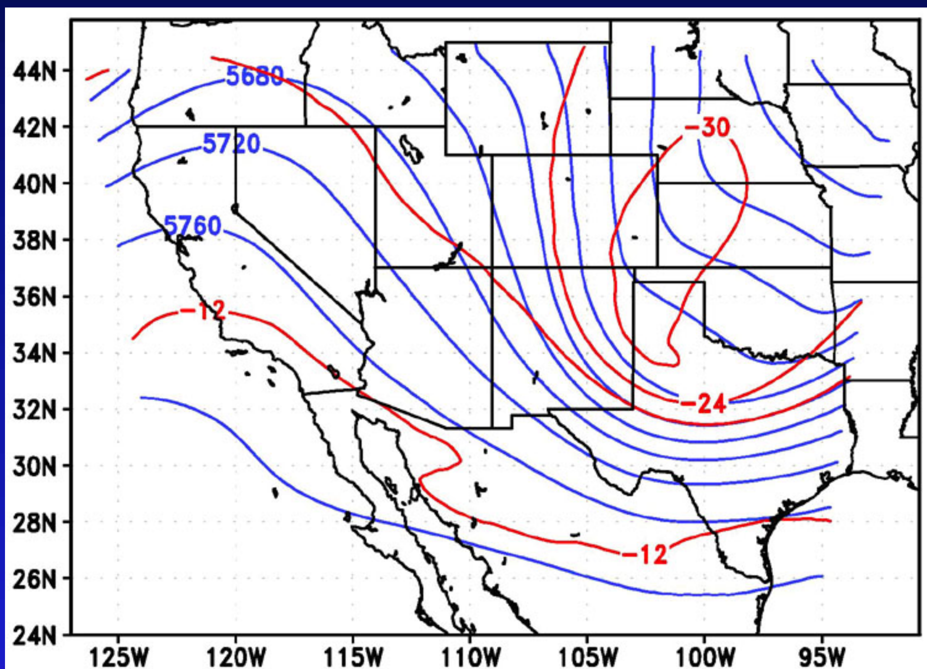
- Domain center at (109°W, 35°N)
- Horizontal semi-staggered Arakawa E grid
- Horizontal grid spacing 1/3 degree

DREAM Equation

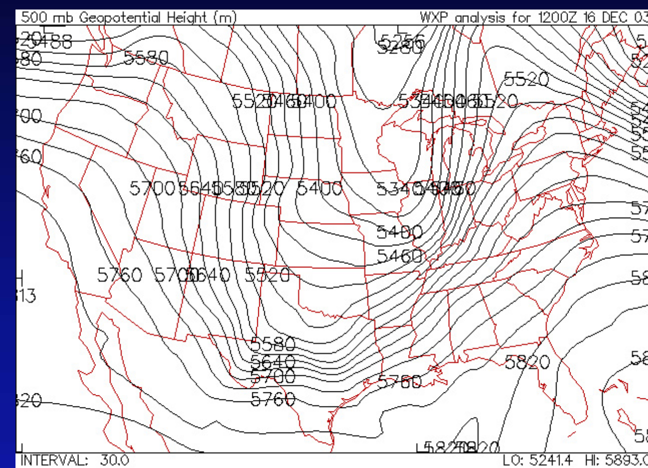
$$\frac{\partial C_k}{\partial t} = -u\frac{\partial C_k}{\partial x} - v\frac{\partial C_k}{\partial y} - (w - v_{gk})\frac{\partial C_k}{\partial z} - \nabla(K_H \nabla C_k) - \frac{\partial}{\partial z}\left(K_Z \frac{\partial C_k}{\partial z}\right) + \left(\frac{\partial C_k}{\partial t}\right)_{SOURCE} - \left(\frac{\partial C_k}{\partial t}\right)_{SINK}$$



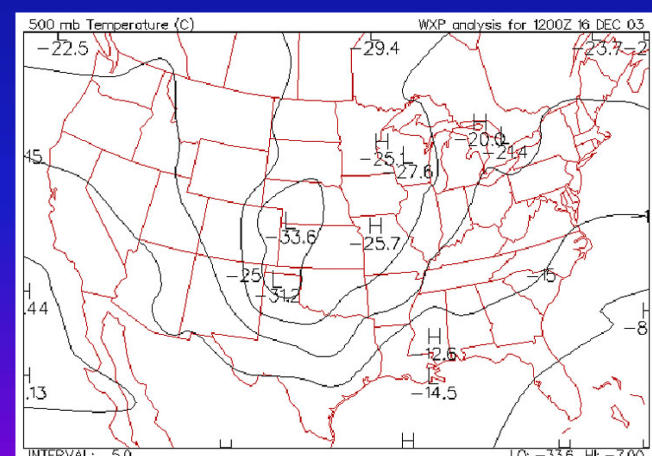
Modeled vs Observed Synoptic Patterns
12Z 16 Dec 03



DREAM Simulation
red isolines = temperature
blue isolines = geopotential height



Observed Geopotential Height



Observed Temperature

Baseline and Replacement Parameters

Baseline DREAM Parameters	Function/Purpose	EO Replacement Parameters
ECWMF medium-range weather forecast model	Initial & boundary conditions; Res. = 1°	NCEP/eta global forecast model
Olsen World Ecosystems	Land cover; Res. = 10min.	MOD-12 Res. = 1km
USGS terrain data	Res. = 1km	SRTM-30 Res. = 1km
Aerodynamic roughness length: predicted using 12 SSiB land cover types	Estimate dust entrainment potential	Look-up table linked to MOD-12 land cover
Soil Moisture: simulated using a land surface model	Res. = 2min.; categories reduced to texture categories	AMSR-E

Assimilation vs. Fusion

Assimilation: The process of replacing selected static parameters in an Earth system model with digital pixel values from Earth observation data sets to improve the model's performance and convert it into a more dynamic (forecasting) form without changing the model's intended purpose.

Fusion: The process of including EO image products (at any of several levels of processing) into a GIS architecture in such a way that the datasets, both vector and raster, are geospatially registered at a specified scale. This usually requires sub-setting, re-projection and rescaling of fused data.

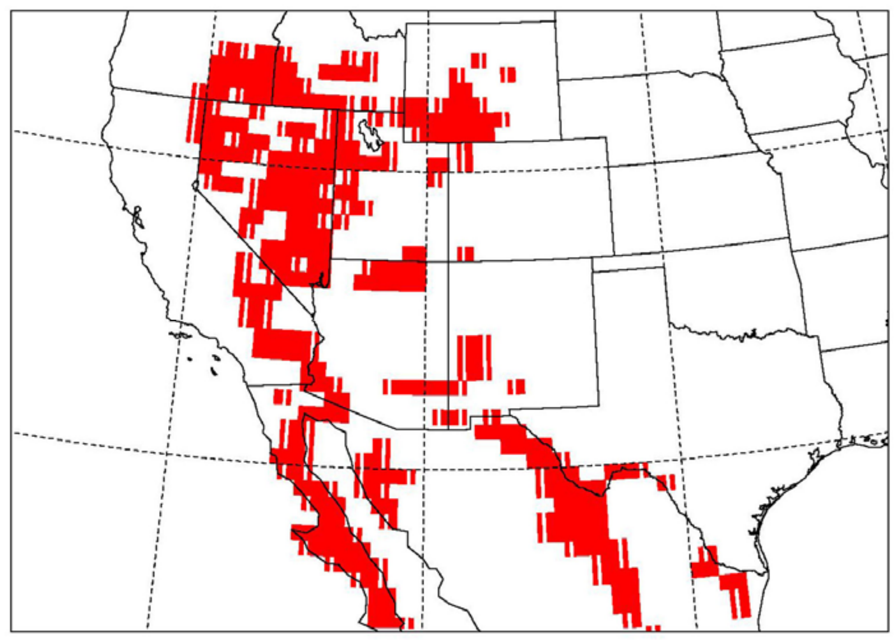
Steps in Assimilation

- Assess metadata & attributes of current model inputs and of possible EO inputs
  - Measurement units
  - x,y,z Resolution
  - Temporal frequency
  - Projection
  - File formats
  - Validity & accuracy
  - Error & error propagation
- Select EO inputs based on highest perceived benefit for enhancing model output
- Replace model input with EO data and compare model outputs
- Iterate with successive EO inputs
- Measure improvements at each stage and document overall performance improvements

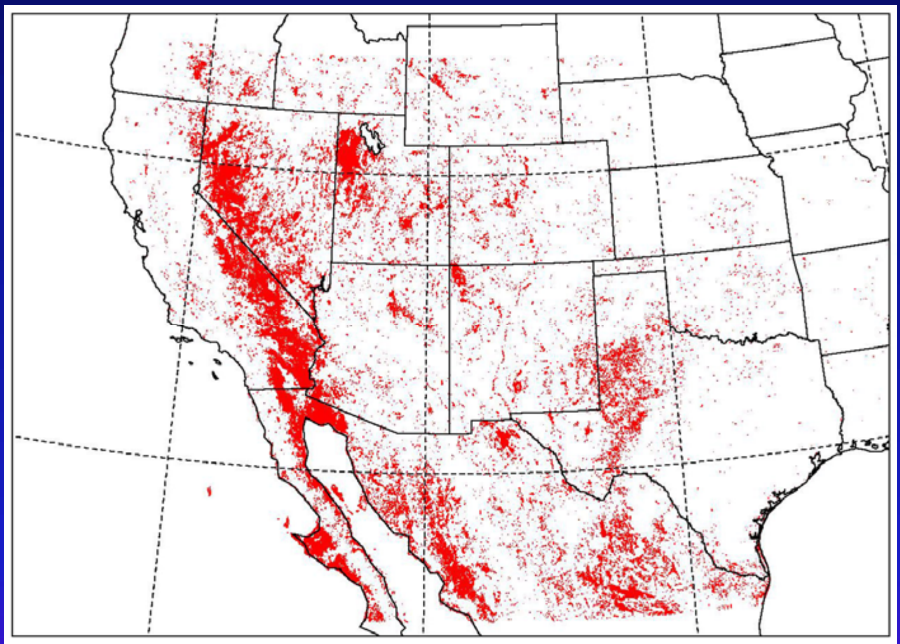
The Baker's Rack

Aims are to: (1) replace selected trays in the rack with regularly refreshed EO digital data from the "terrain." "surface conditions," and "atmospheric" parameters that drive DREAM; (2) improve model output without altering the validity of the model's original function; and (3) convert the model to a more dynamic forecast.

Barren Ground (Potential Dust Sources)



Olson World Ecosystems



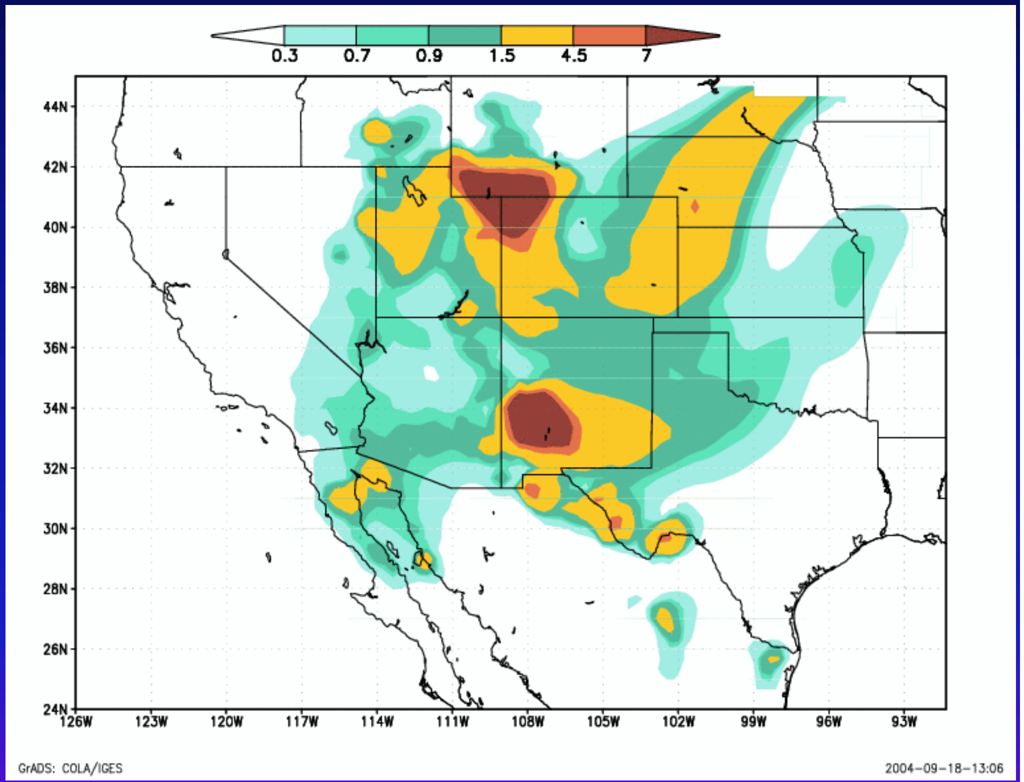
MOD12Q1 Land cover reduced to binary format

Aerodynamic Surface Roughness (z_0) Controls Dust Entrainment

DN	Land Cover Category	Z_0 Range (m)	Default z_0
8	Woody Savanna	0.10-0.20	0.15
9	Savanna	0.03-0.10	0.06
10	Grassland	0.03-0.07	0.05
12	Cropland	0.04-0.18	0.11
14	Crops/Natural Mosaic	0.10-0.30	0.20
16	Barren/Sparse	0.00-0.01	0.01
253	Fill	0.00	0.00

Observed Visibility vs. Modeled Dust Concentrations Dec. 15-16, 2003

Texas
Continuous Air Monitoring Stations



DREAM Baseline (no EO data included)

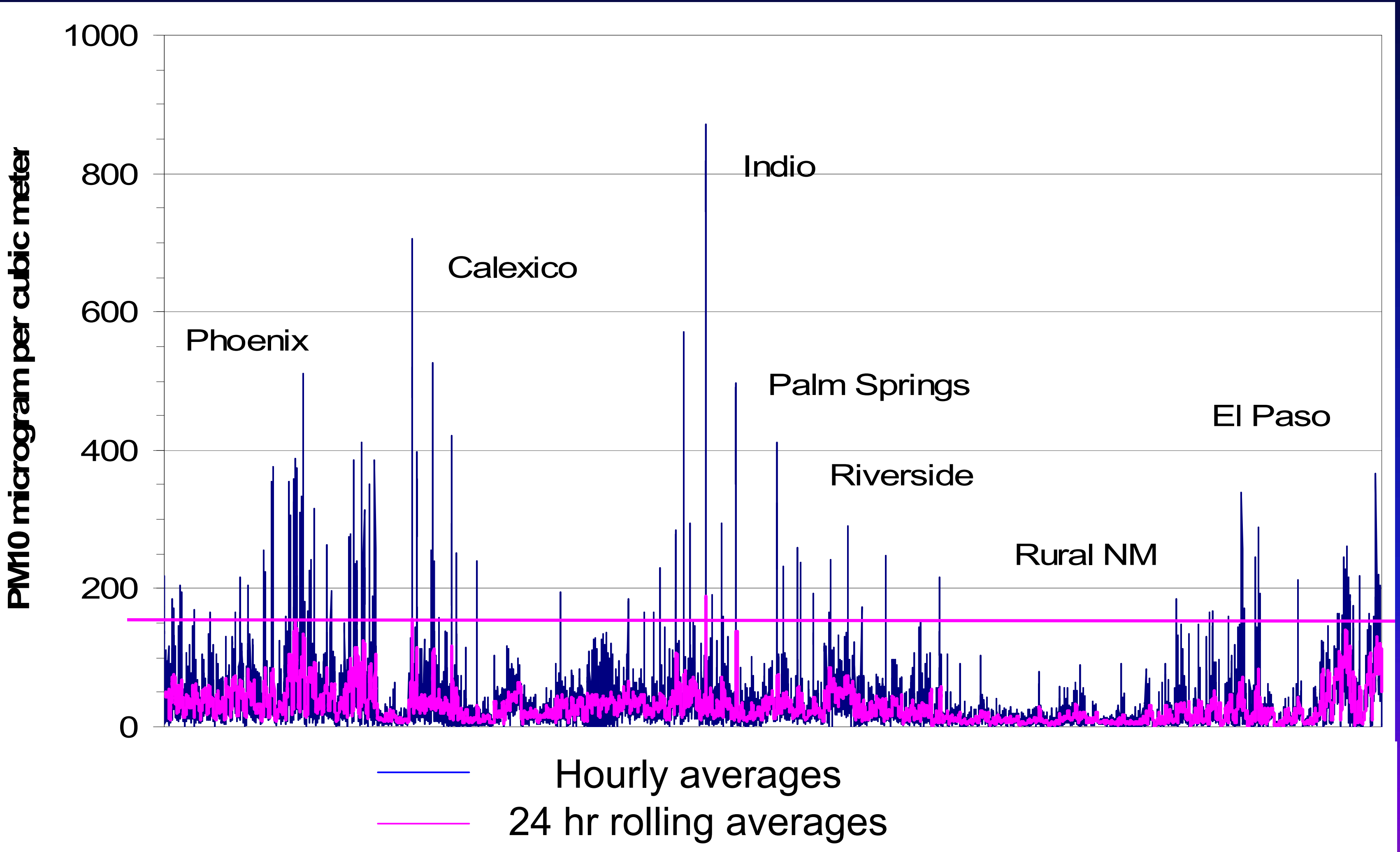
DREAM Performance
Before & After EO Data Assimilation

Metrics	Wind Speed (m/s)	Wind Direction (°)	Temp. (K)	Definition (M = modeled; O = observed)
Mean observed	**5.53**	**231.40**	**276.74**	$\frac{1}{N}\sum_{i=1}^{N} O_i$
Mean modeled	**4.65** **4.37**	**226.60** **230.38**	**275.56** **277.48**	$\frac{1}{N}\sum_{i=1}^{N} M_i$
Mean bias	**-0.88** **-1.16**	**-4.80** **-1.02**	**-1.20** **0.72**	$\frac{1}{N}\sum_{i=1}^{N} (M_i - O_i)$
Mean error	**1.97** **2.03**	**51.76** **47.85**	**4.09** **2.67**	$\frac{1}{N}\sum_{i=1}^{N} \lvert M_i - O_i \rvert$
Agreement index	**0.74** **0.75**	**0.74** **0.76**	**0.71** **0.95**	$1 - \frac{\sum_{i=1}^{N} (M_i - O_i)^2}{\sum_{i=1}^{N} \left(\lvert M_i - \overline{O} \rvert + \lvert O_i - \overline{O} \rvert \right)}$

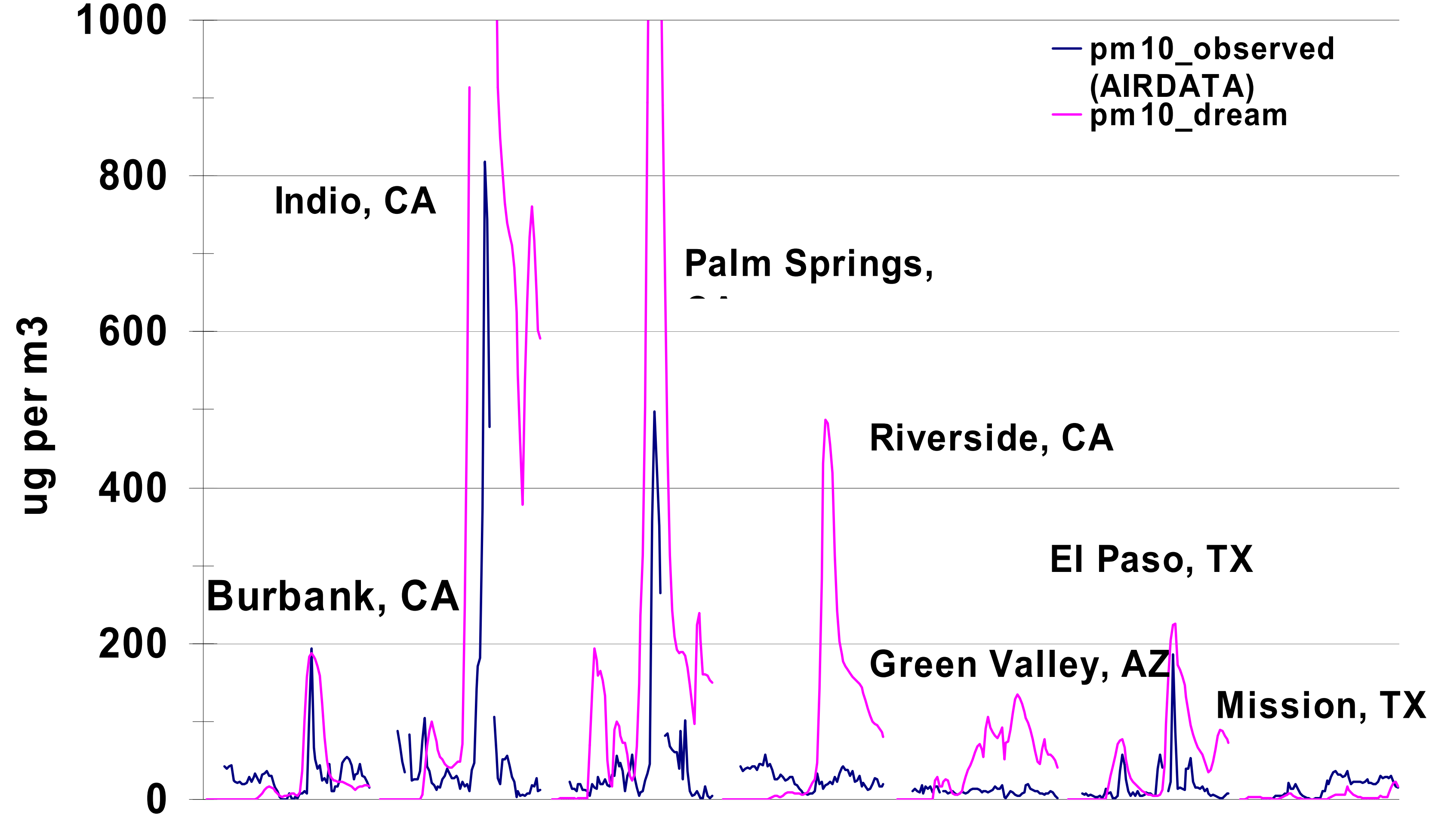
Blue = before EO Data Assimilation
Red = after EO Data Assimilation

January 2007 AIRNow Data

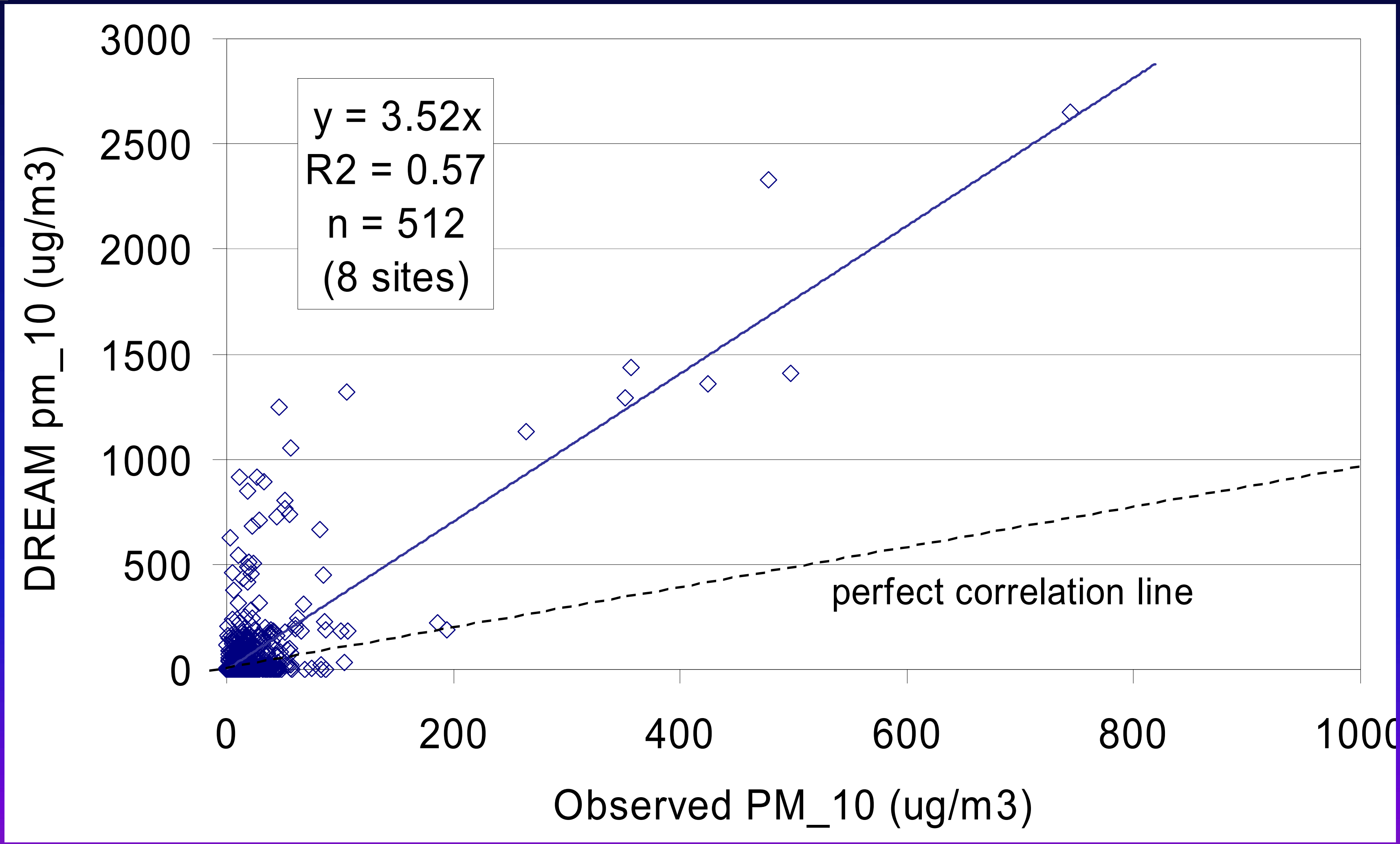
N ≈ 29K data points from 40 sites in the model domain



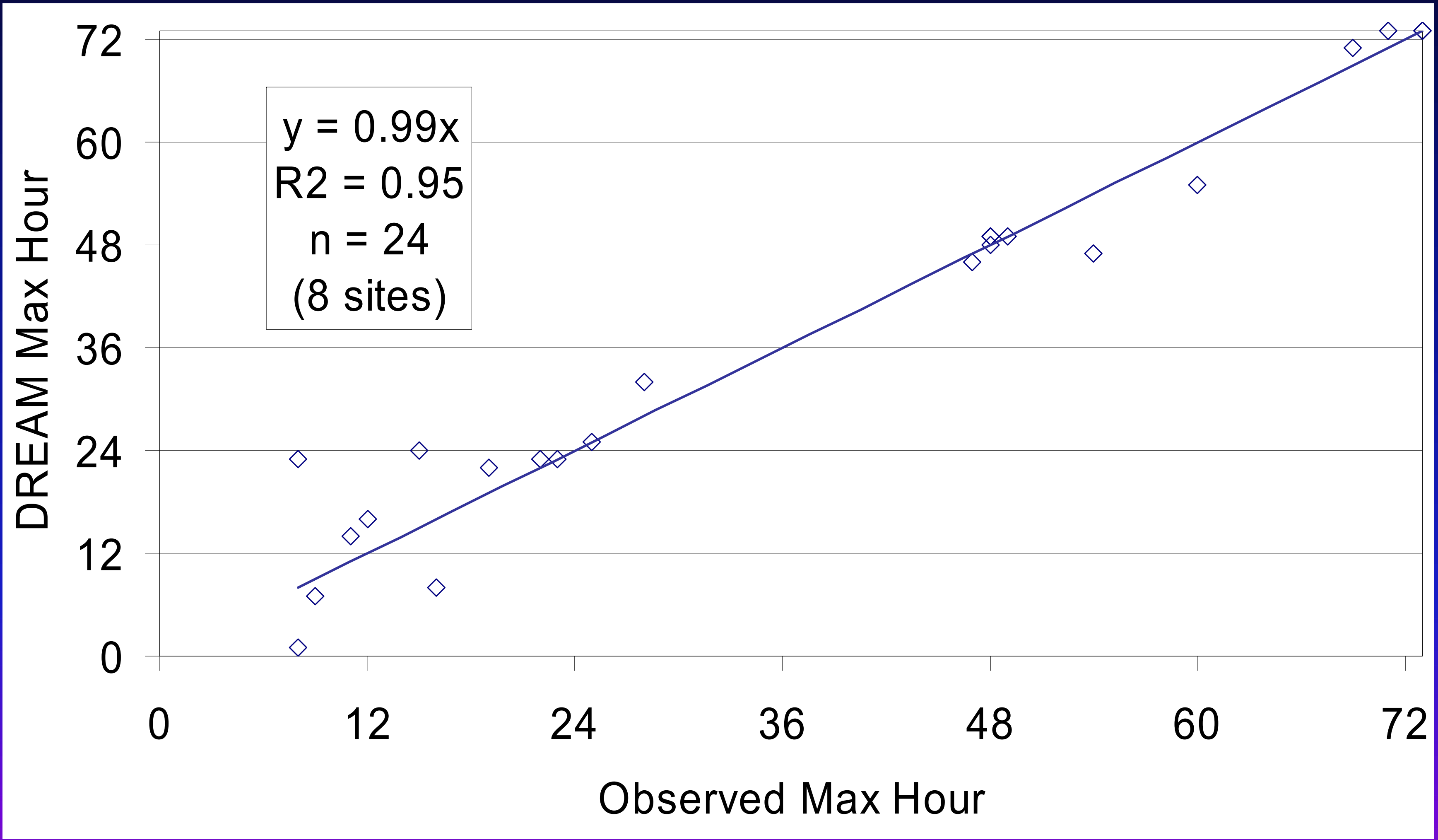
Dust Storm of January 4-6, 2007



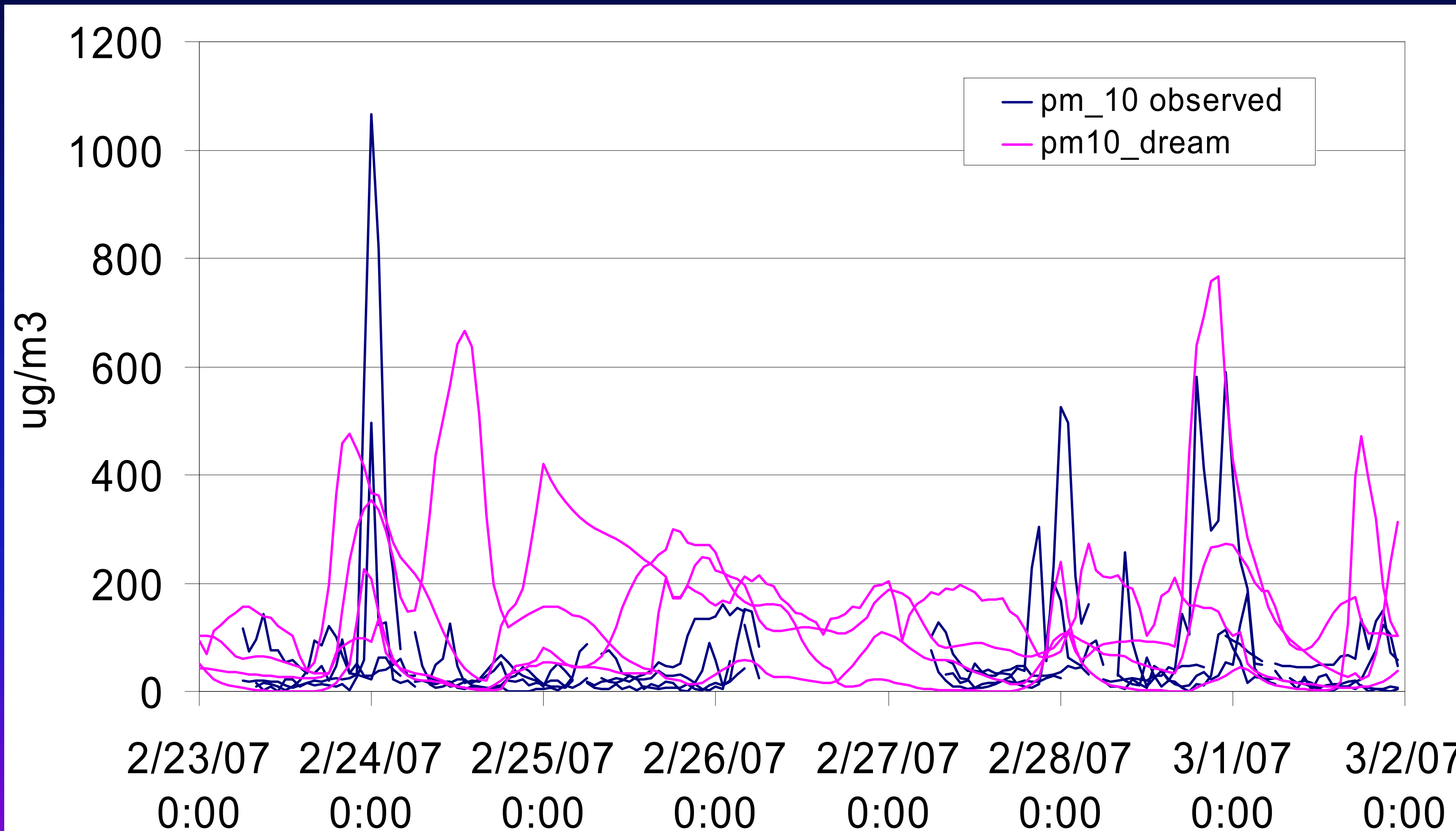
Magnitude Correlation - Jan 4-6, 2007



Timing Correlation - Jan 4-6, 2007

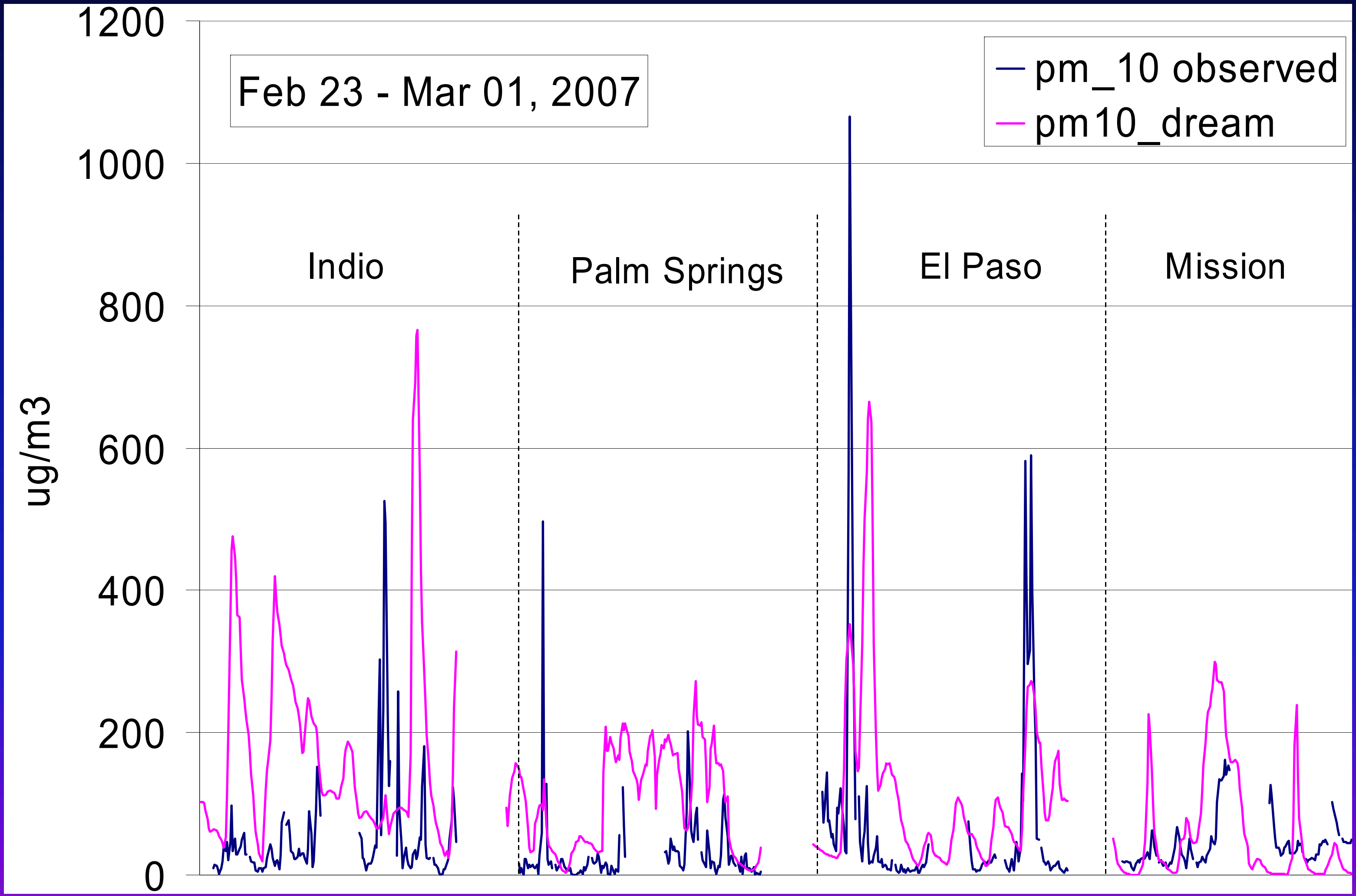


Indio, Palm Springs, El Paso, Mission AIRNow and DREAM Data

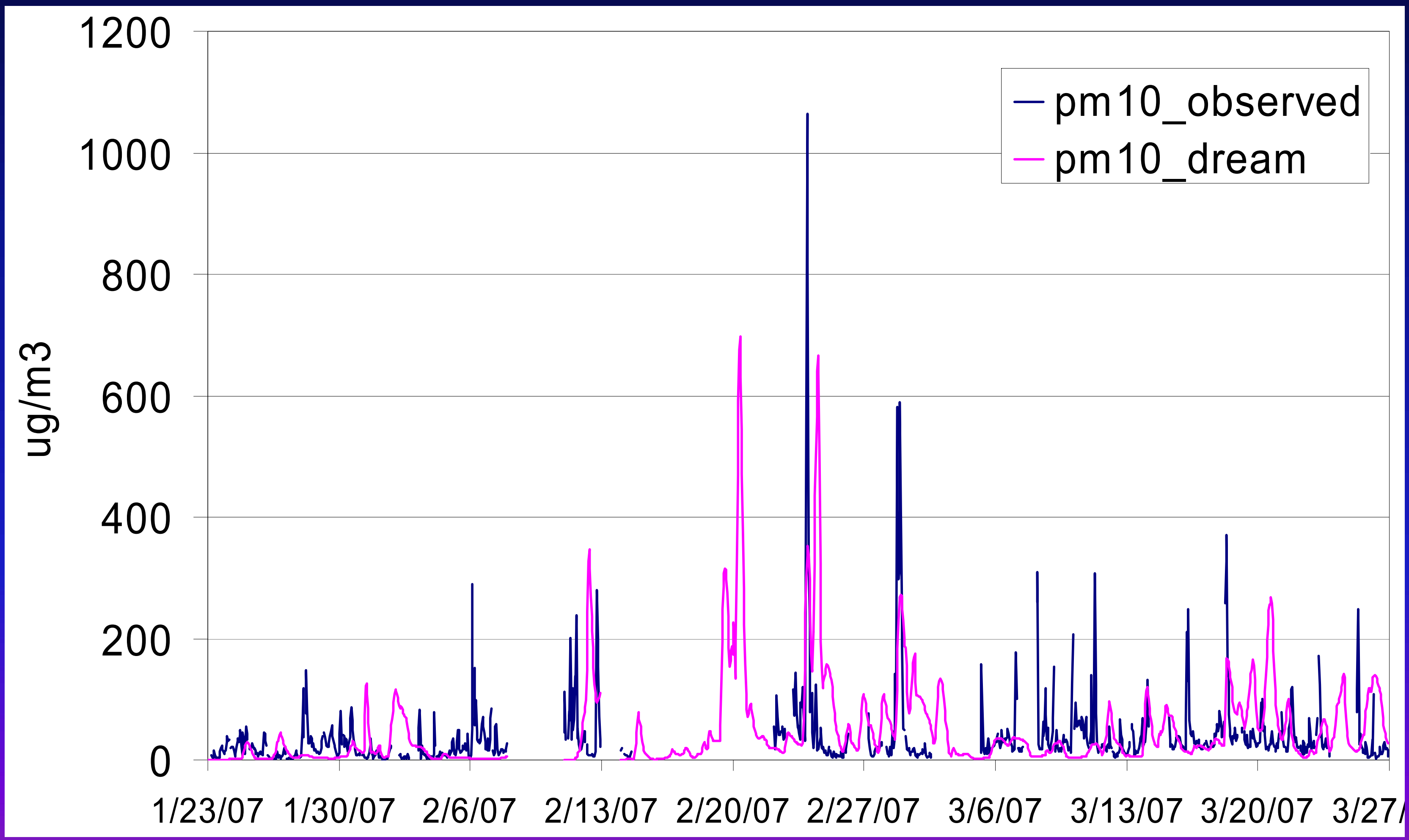


UNM EDAC NASA

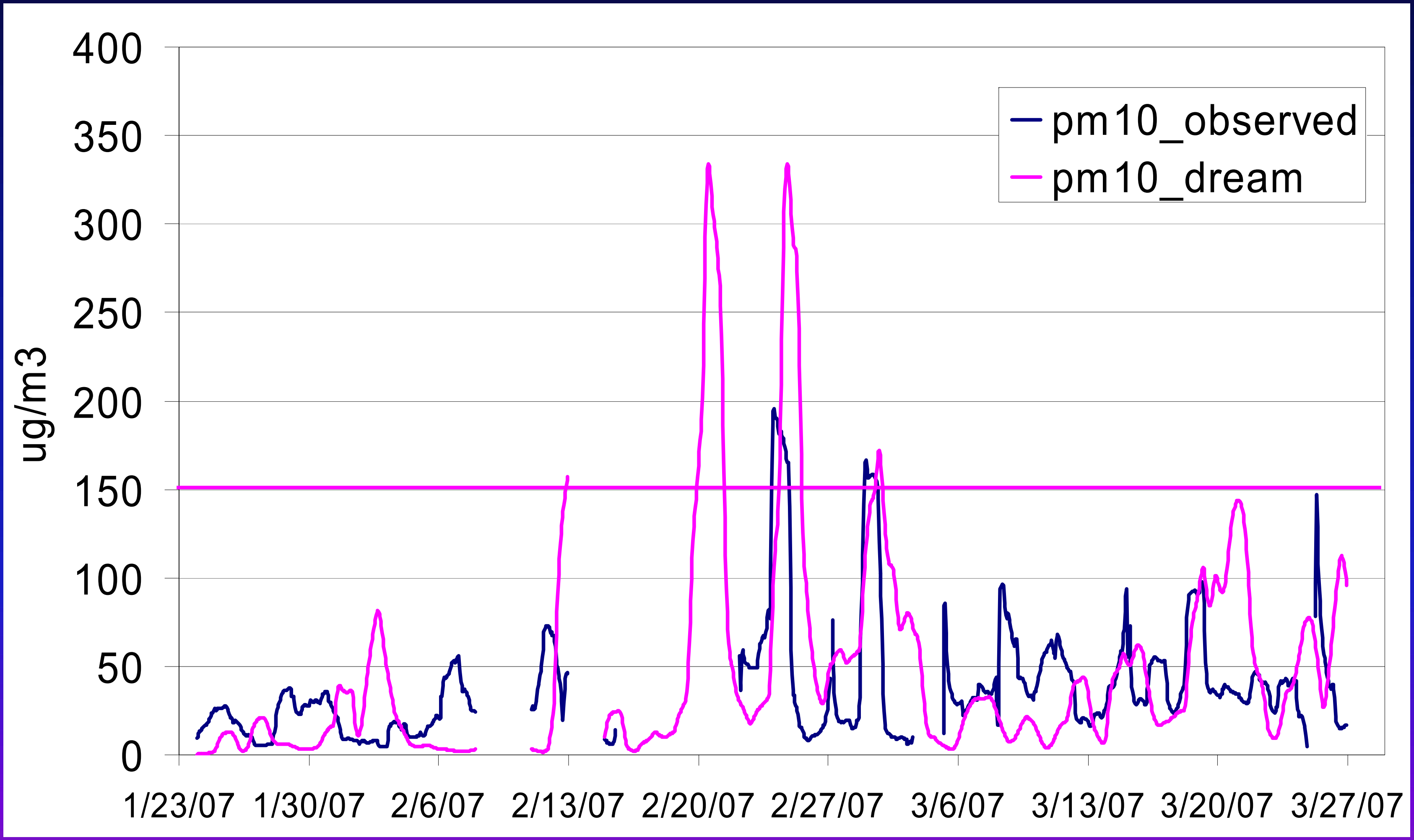
Indio, Palm Springs, El Paso, Mission AIRNow and DREAM Data



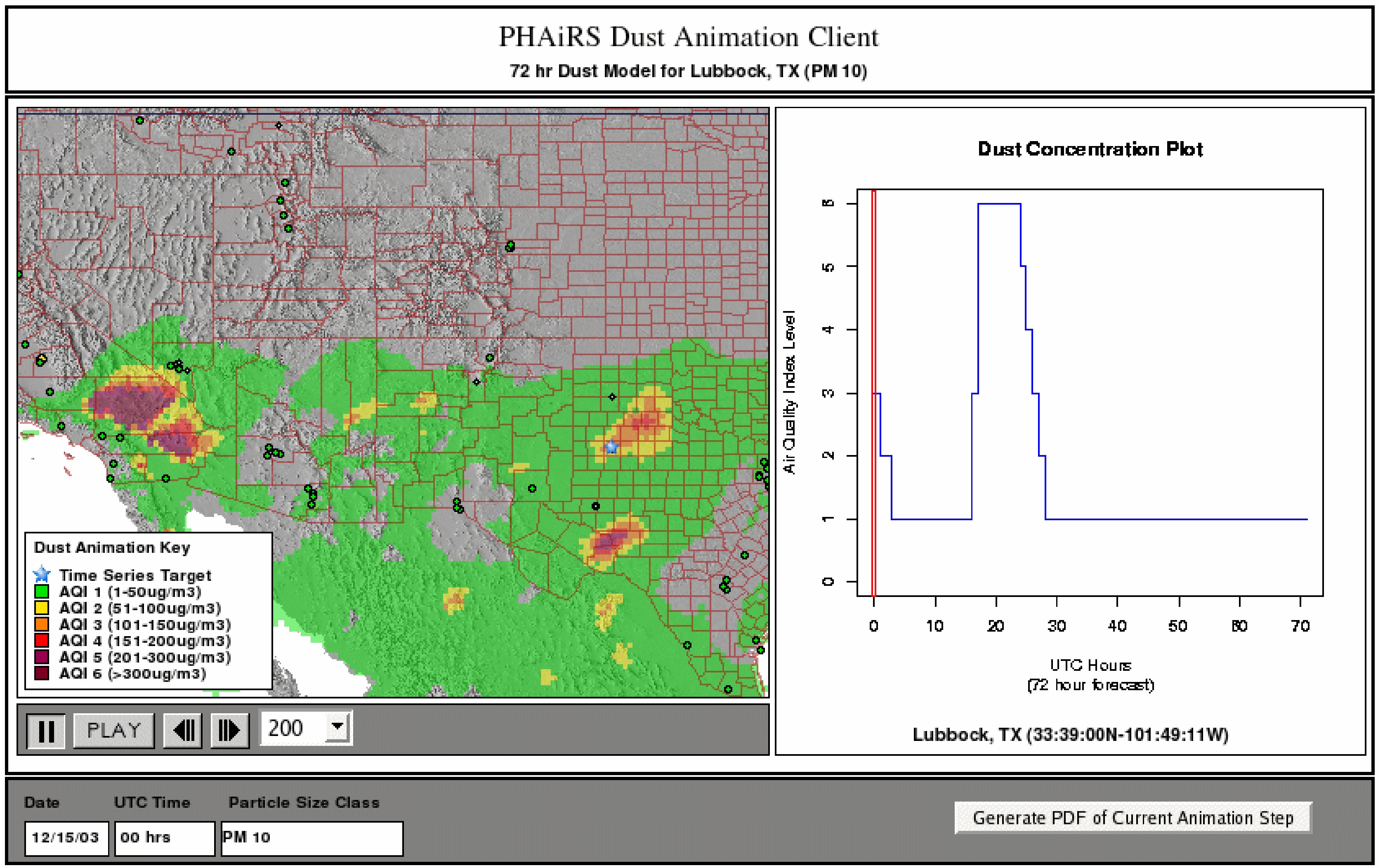
University of Texas-El Paso Station
n = 970



University of Texas-El Paso Station—24 hour rolling average

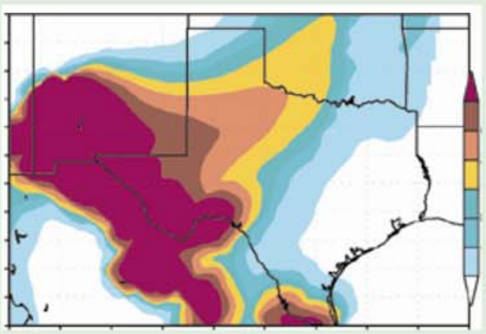


Dust Animation (PM-10)
72 Hr Outlook for Lubbock, TX



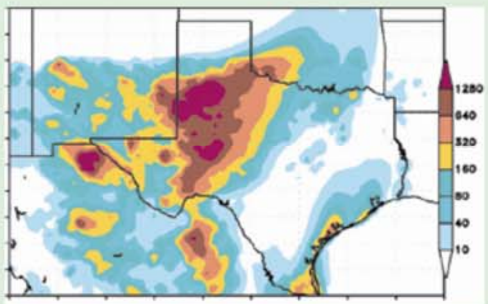
Incremental Improvements to Model Performance

Baseline Model Performance



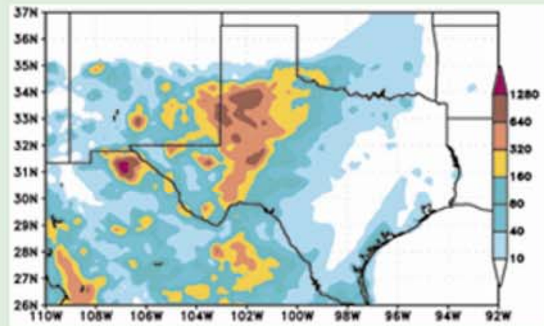
University of Malta
University of New Mexico
University of Arizona

Model Performance After Assimilating Earth Observation Data



NASA / University of New Mexico
University of Arizona
World Meterological Organization

Model Performance Using NCEP/NMM Weather Forecast Model



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