Public Health Applications in Remote Sensing

Environmental Surveillance for Public Health

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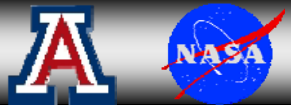
Earth Data Analysis Center

University of New Mexico



PHAiRS Research Team

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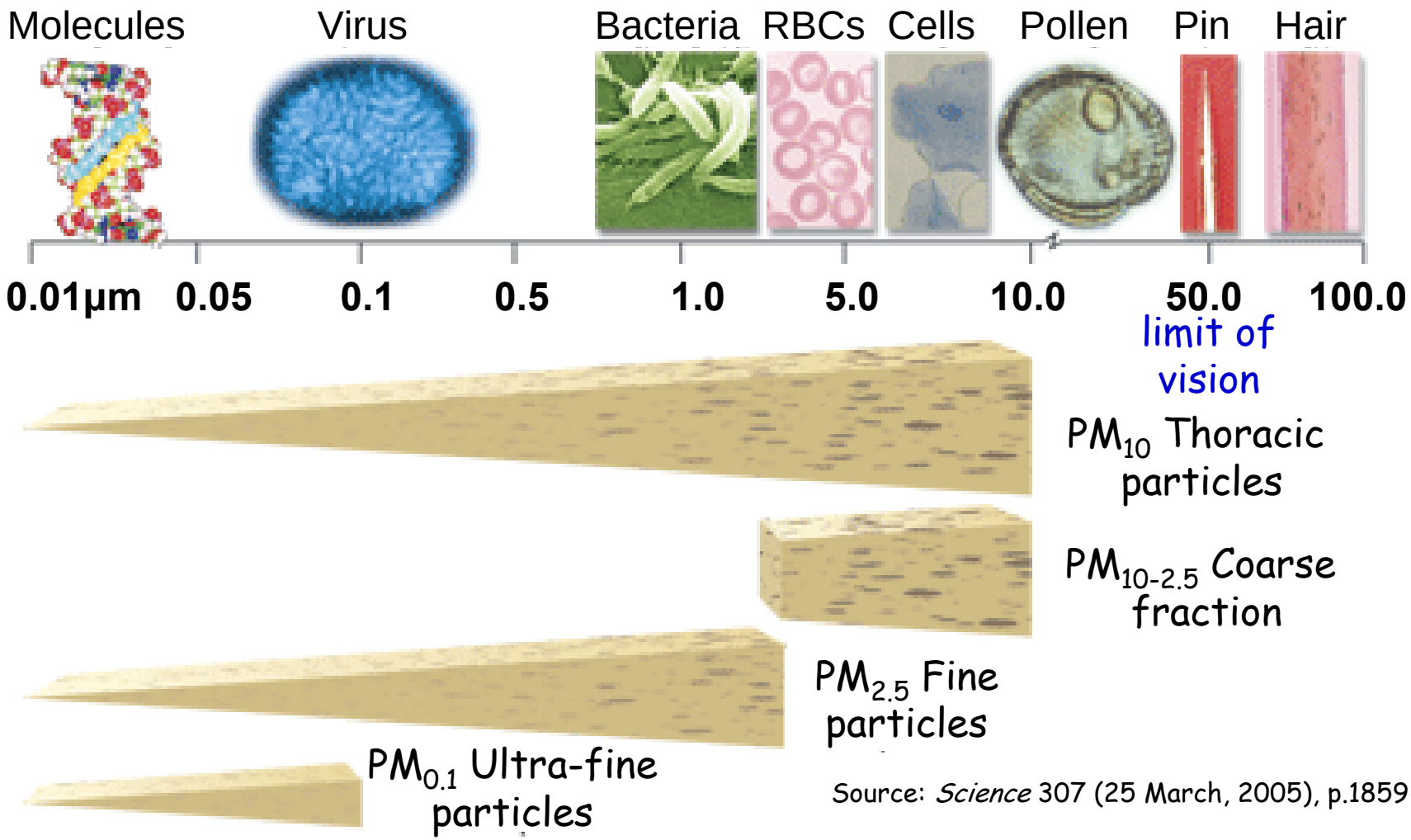
  - Pima County Dept of Environmental Quality
  - Arizona Dept of Health Services
  - NM Dept of Health
  - UNM Health Science Center
  - ARES Corporation
  - ABQ Air Quality Office

PHAiRS Aims and Goals

Addresses	Does Not Address
Quality of life	Lives saved
Public health	Individual health
Forecasting airborne dust episodes that could affect populations at risk	Forecasting public health *per se*
Syndromic surveillance (pre-diagnosis)	Disease diagnosis

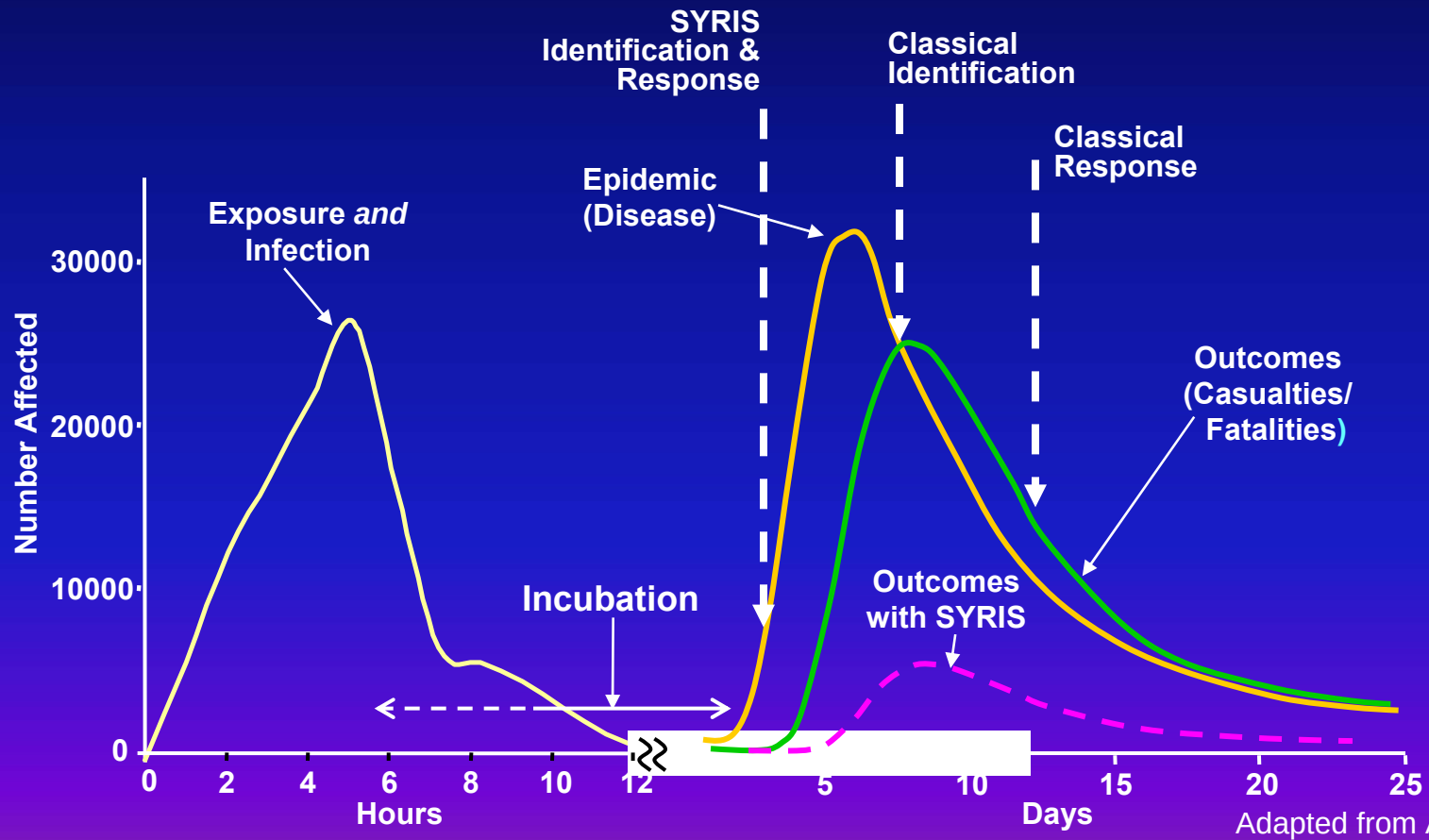
Particulate Matter Size Distribution & Related Biophysical Impacts



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

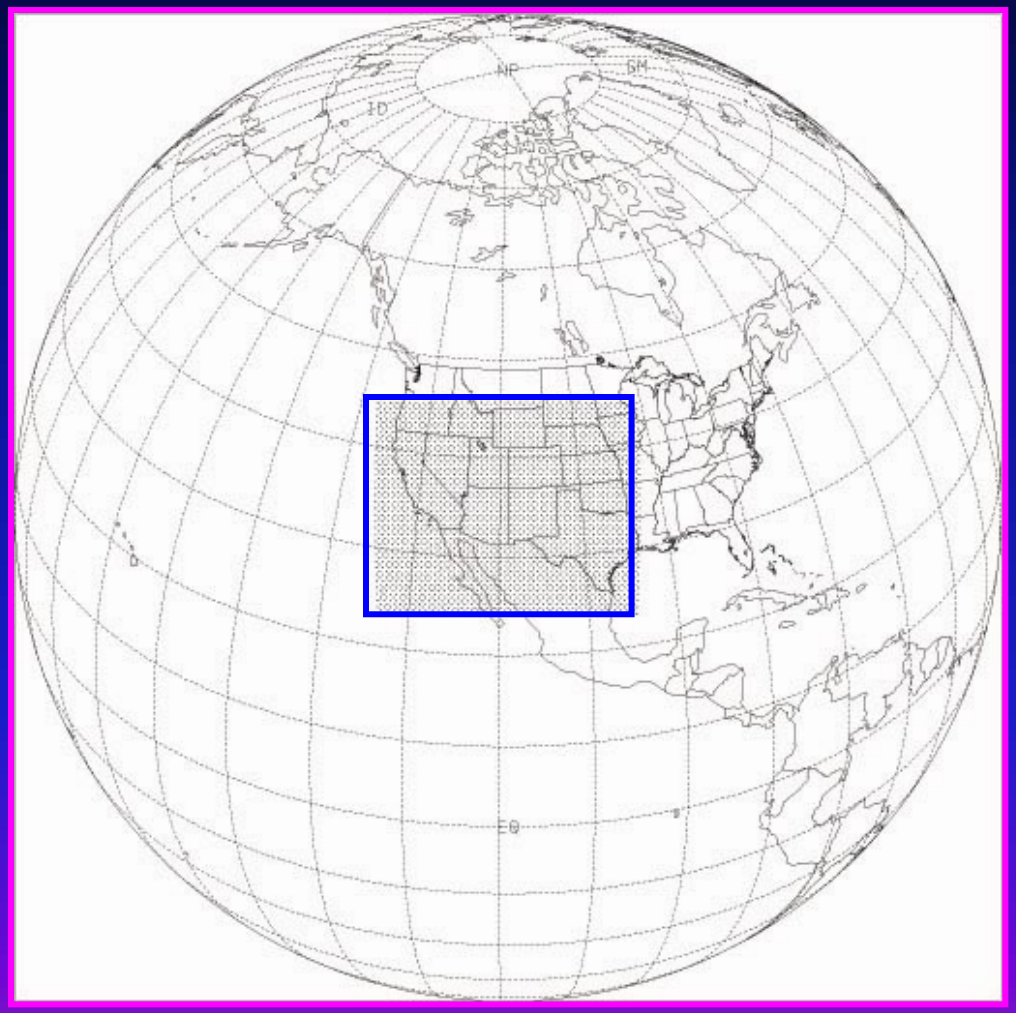
SYRIS = Earlier Detection and Immediate Response to Outbreaks

Exposure:	People/Animals are exposed to infectious agents
Epidemic:	People/Animals begin to show signs of infection
Outcome:	People/Animals begin to die or get very sick
SYRIS Outcome:	80% fewer People/Animals get sick or die



Adapted from ARES, 2007

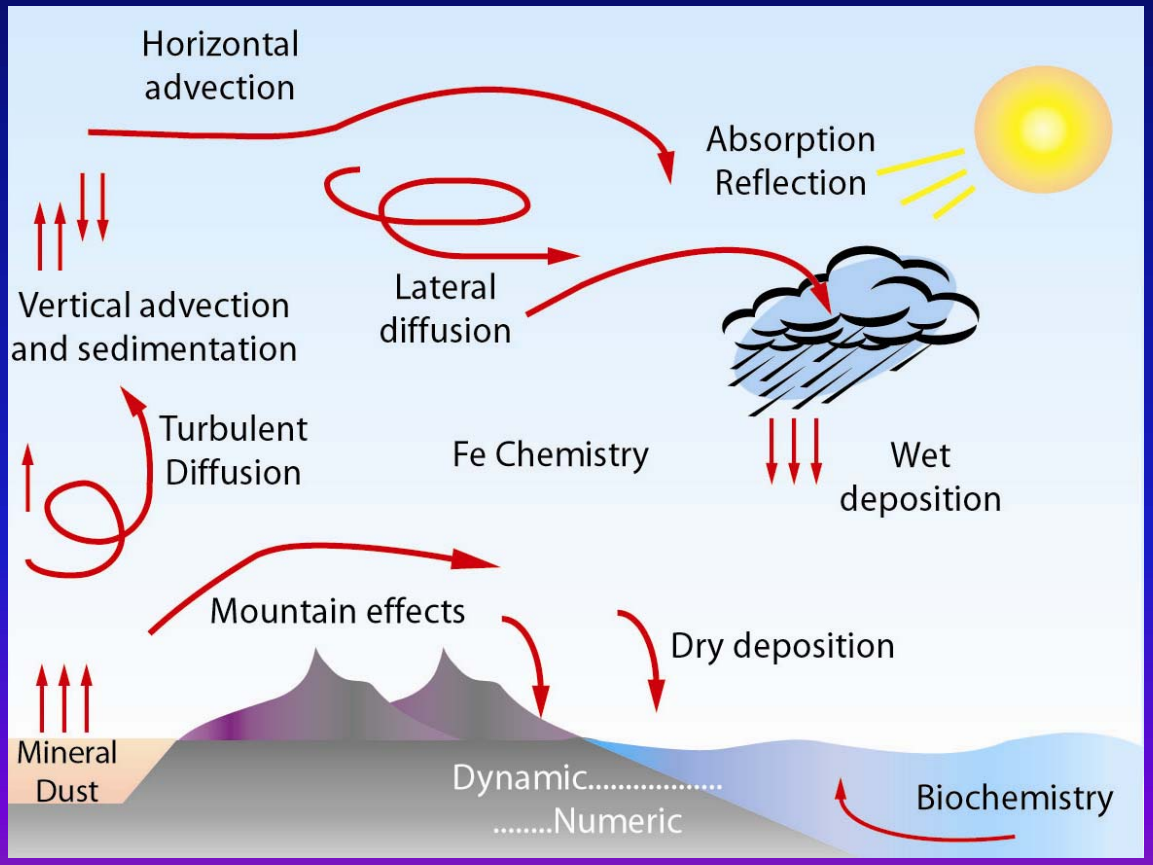
Model Domain



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

DREAM Equation

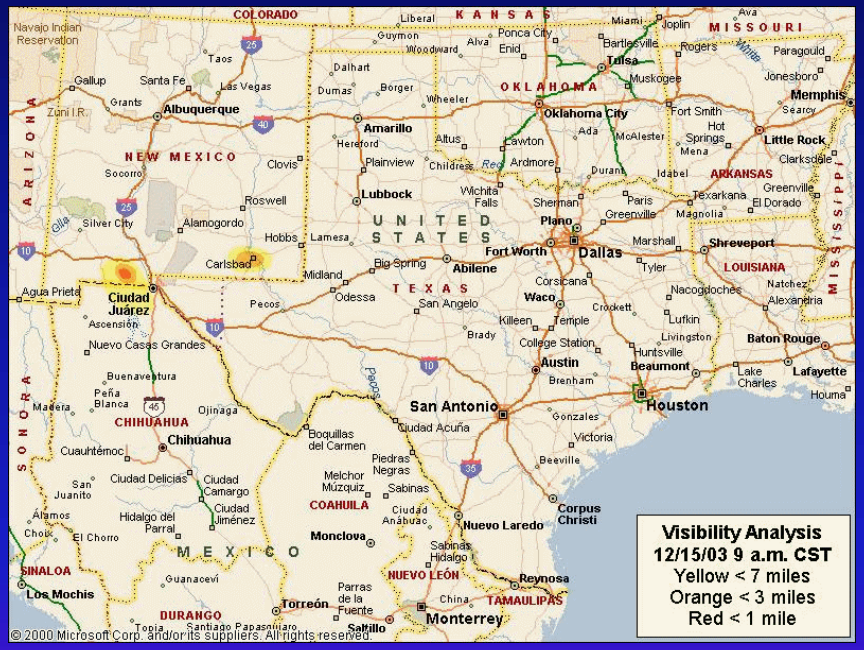
$$\frac{\partial C_k}{\partial t} = -u\frac{\partial C_k}{\partial x} - v\frac{\partial C_k}{\partial y} - (w - v_{gk})\frac{\partial C_k}{\partial z} - \nabla(K_H \nabla C_k) - \frac{\partial}{\partial z}\left(K_Z \frac{\partial C_k}{\partial z}\right) + \left(\frac{\partial C_k}{\partial t}\right)_{SOURCE}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



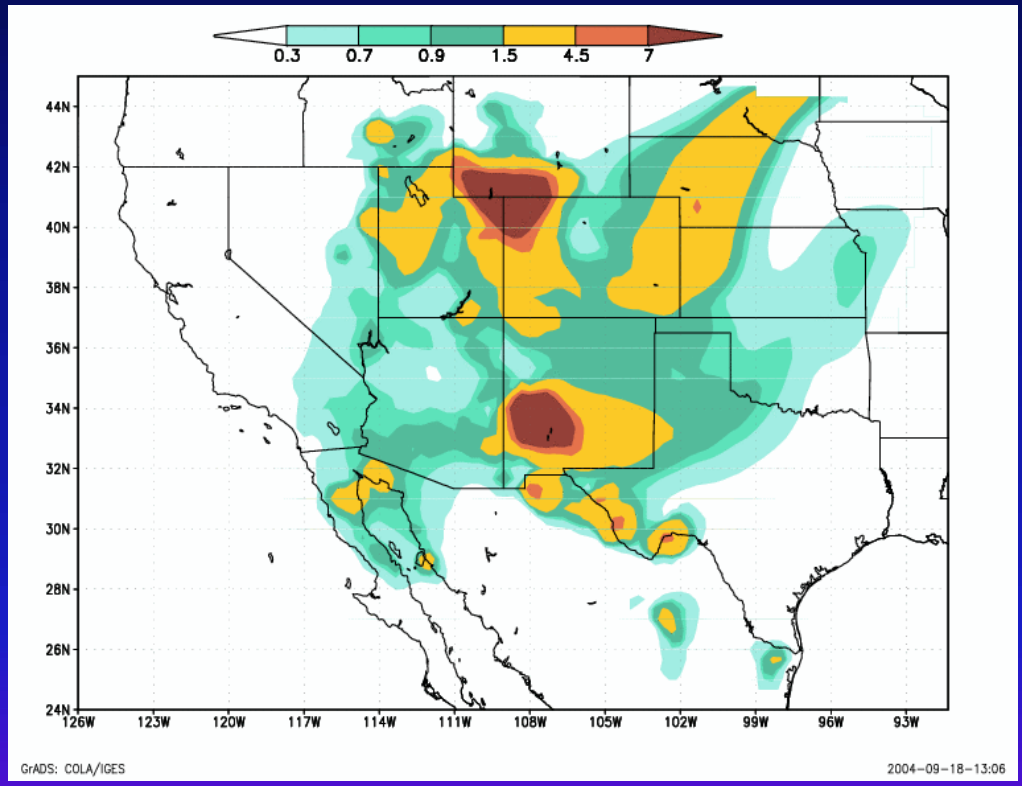
Baseline and Replacement Parameters

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

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



Texas
Continuous Air Monitoring Stations



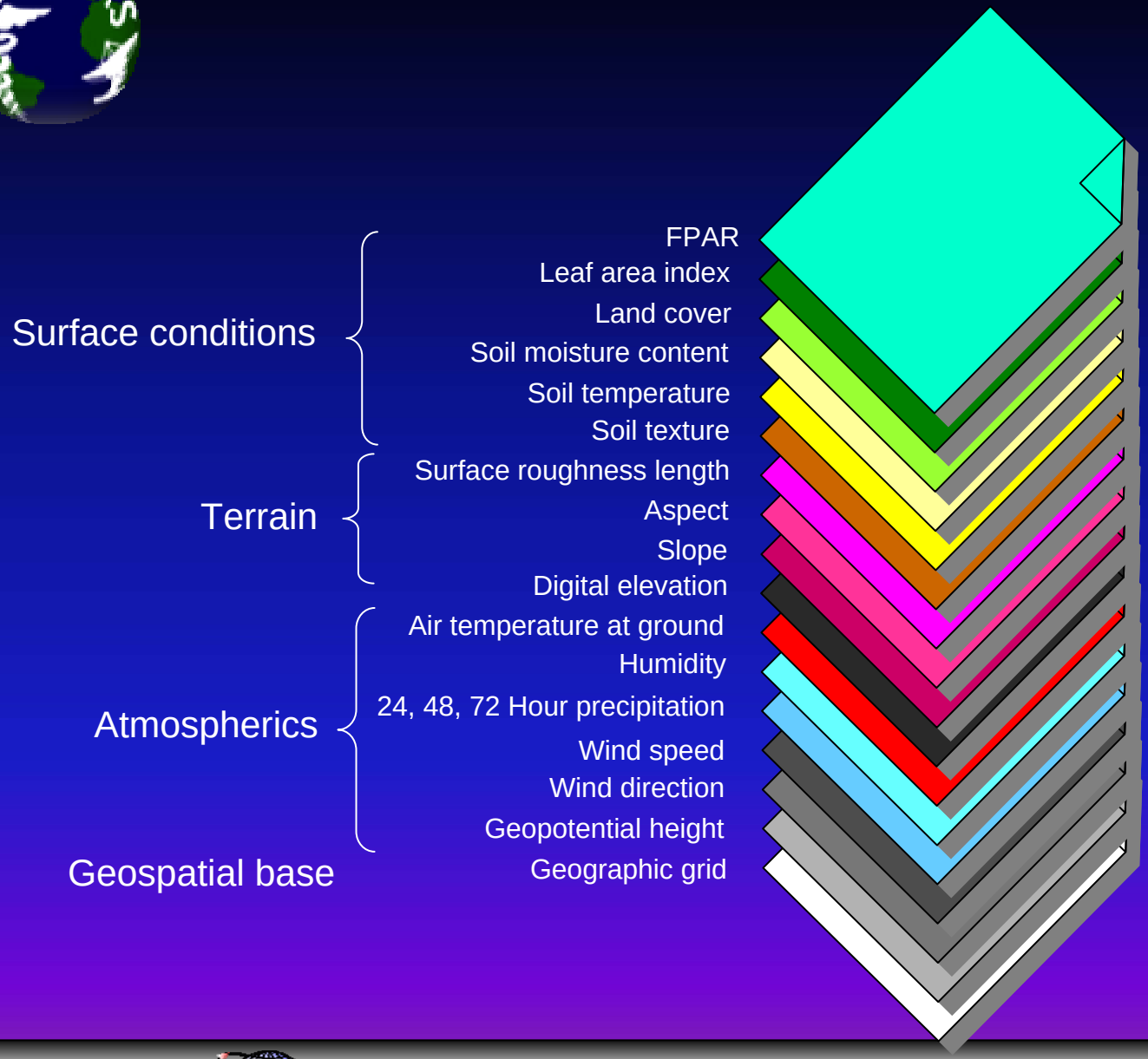
DREAM Baseline (no EO data included)

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.

The Baker's Rack

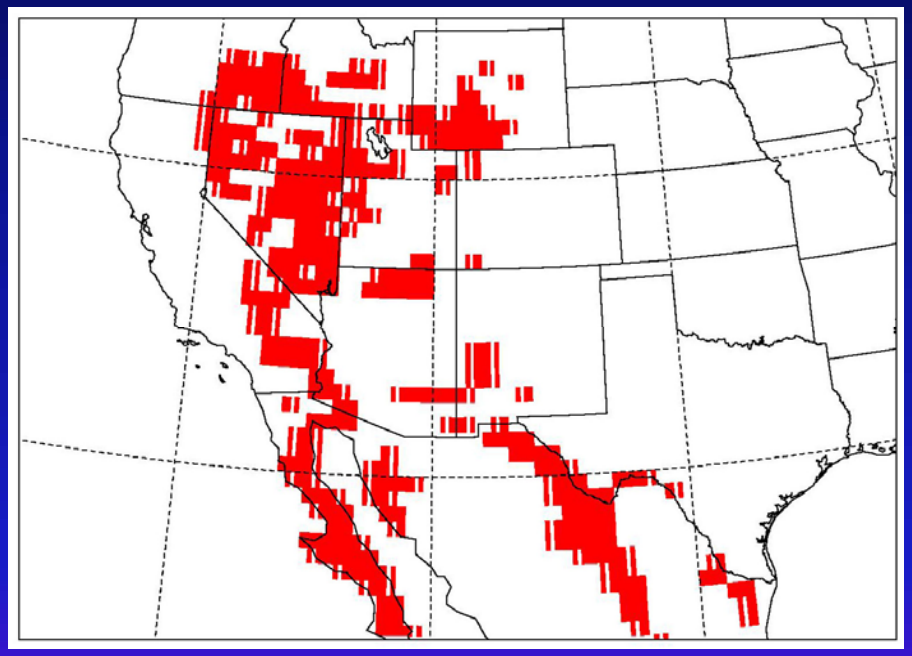


Aims are to: (1) replace selected trays in the rack with regularly refreshed EO digital data from the "terrain." "surface conditions," and "atmospheric" parameters that drive DREAM; (2) improve model output without altering the validity of the model's original function; and (3) convert the model to a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

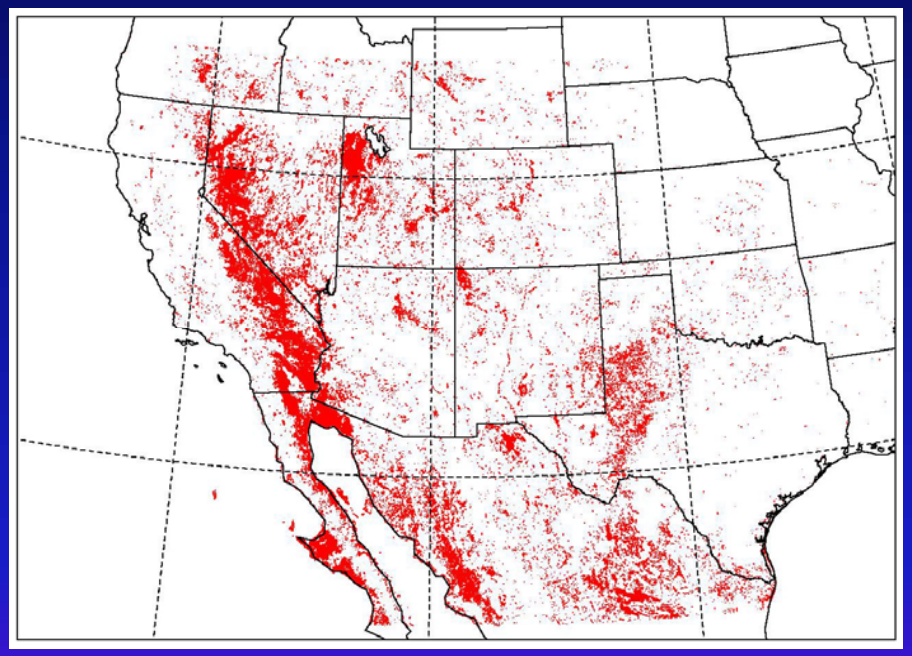
Steps in Assimilation

- 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

Barren Ground
(Potential Dust Sources)



Olson World Ecosystems

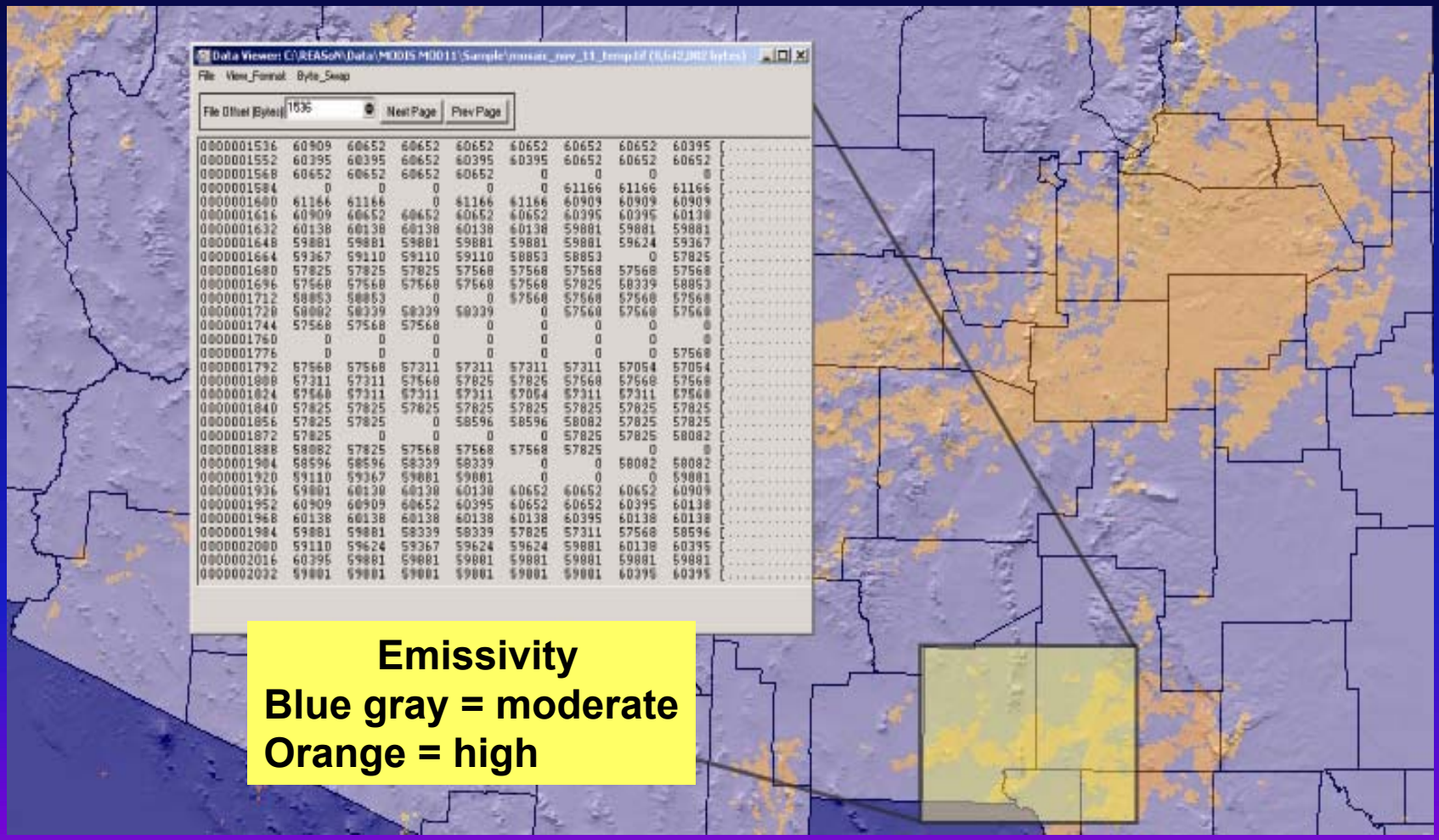


MOD12Q1 Land cover
reduced to binary format

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

TERRA/MODIS MOD11A1 Land Surface Temperature/Emissivity-Daily 1-km



Sample Model Runs of NCEP/eta + DREAM with and w/o Assimilated EO Data

Run #	*MOD12*	*SRTM*	*Surface roughness length*	*FPAR*	*AMSR-E*
Run 1a					
Run 2c	Y				
Run 4a	Y	Y			
Run 5a	Y	Y	Y		
Run 5b	Y	Y	Y		
Run 6a	Y			Y	
Run 15a	Y				Y
Run 10a	Y	Y	Y		Y

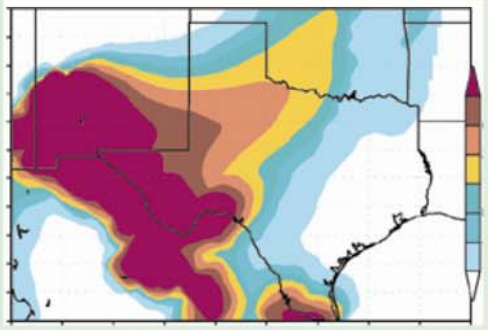
DREAM Performance
Before & After EO Data Assimilation

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**	$1-\frac{\sum_{i=1}^{N}(M_i - O_i)^2}{\sum_{i=1}^{N}(\lvert M_i - \overline{O}\rvert + \lvert O_i - \overline{O}\rvert)}$

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

Incremental Improvements to Model Performance

Baseline Model Performance



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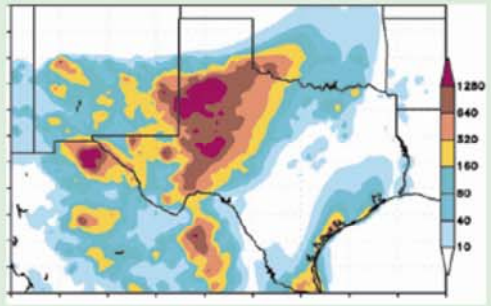
Model Performance After Assimilating Earth Observation Data



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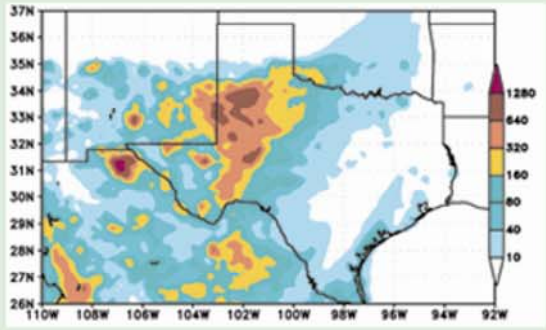
Model Performance Using NCEP/NMM Weather Forecast Model



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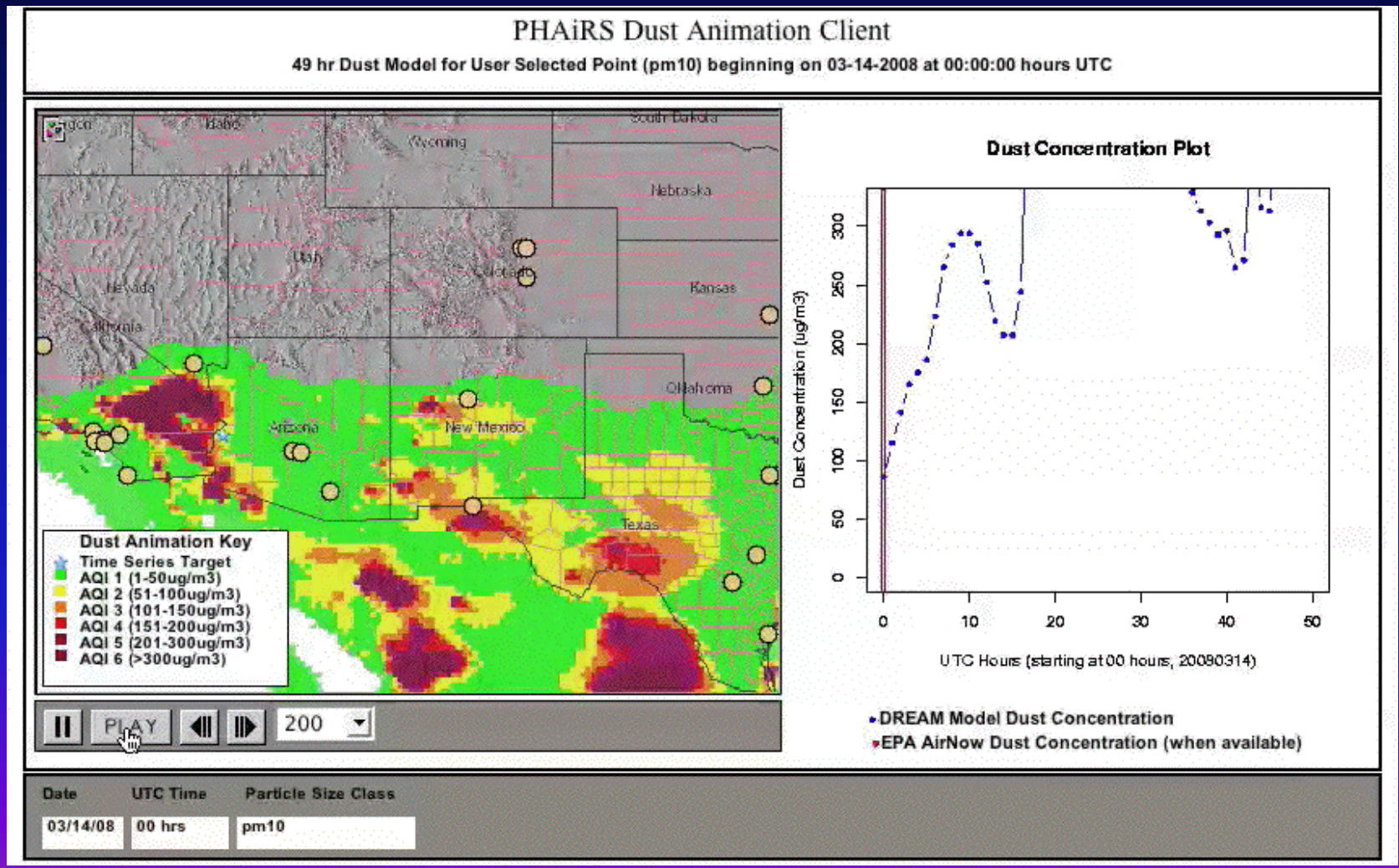
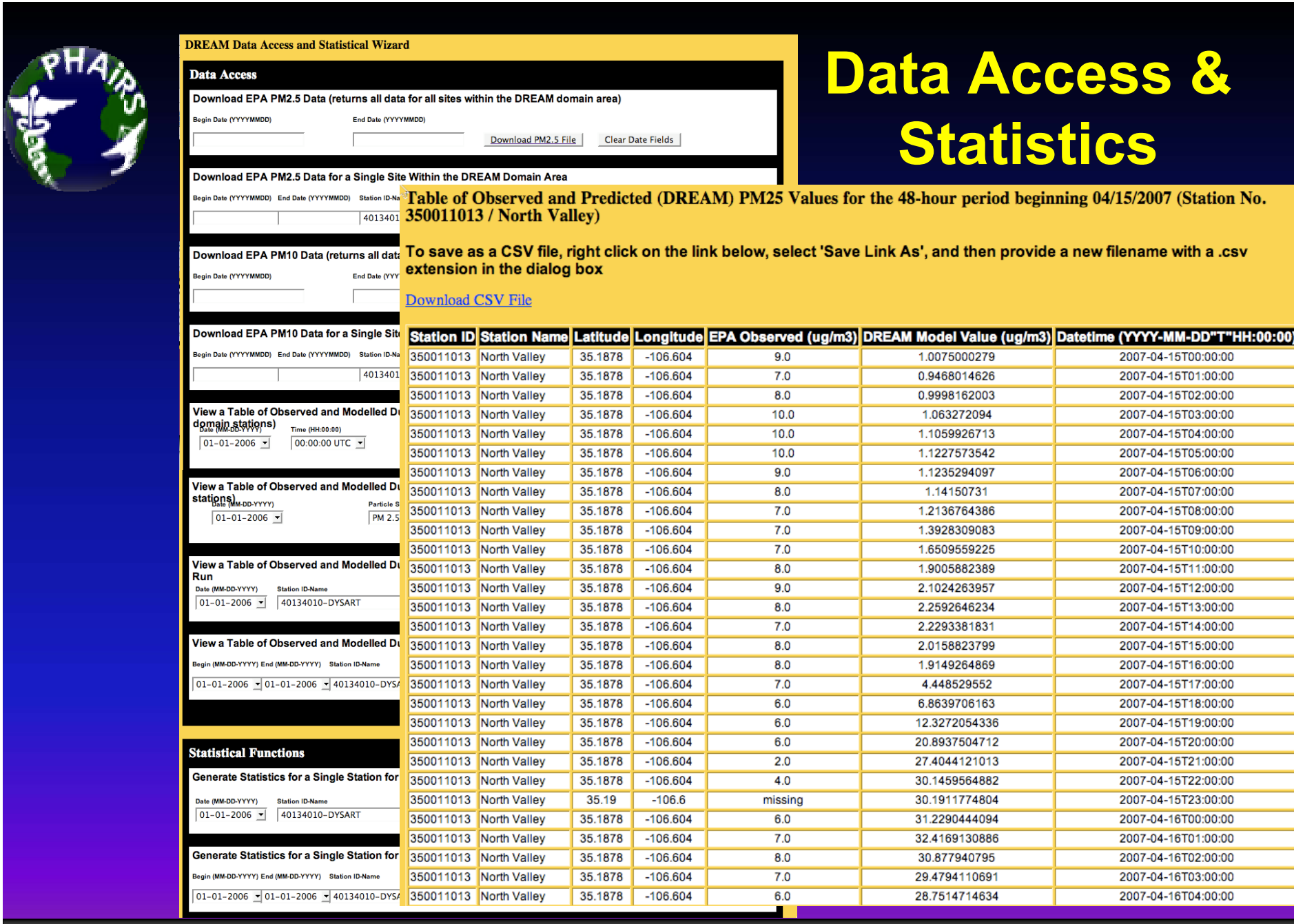
University of Arizona
World Meterological Organization

Enhancing DSS & Surveillance Tools

Dust Storm Animation (PM-10)
49 Hr Outlook for Yuma, AZ (14 Mar 08)



Data Access & Statistics



Station ID	Station Name	Latitude	Longitude	EPA Observed (ug/m3)	DREAM Model Value (ug/m3)	Datetime (YYYY-MM-DD"T"HH:00:00)
350011013	North Valley	35.1878	-106.604	9.0	1.0075000279	2007-04-15T00:00:00
350011013	North Valley	35.1878	-106.604	7.0	0.9468014626	2007-04-15T01:00:00
350011013	North Valley	35.1878	-106.604	8.0	0.9998162003	2007-04-15T02:00:00
350011013	North Valley	35.1878	-106.604	10.0	1.063272094	2007-04-15T03:00:00
350011013	North Valley	35.1878	-106.604	10.0	1.1059926713	2007-04-15T04:00:00
350011013	North Valley	35.1878	-106.604	10.0	1.1227573542	2007-04-15T05:00:00
350011013	North Valley	35.1878	-106.604	9.0	1.1235294097	2007-04-15T06:00:00
350011013	North Valley	35.1878	-106.604	8.0	1.14150731	2007-04-15T07:00:00
350011013	North Valley	35.1878	-106.604	7.0	1.2136764386	2007-04-15T08:00:00
350011013	North Valley	35.1878	-106.604	7.0	1.3928309083	2007-04-15T09:00:00
350011013	North Valley	35.1878	-106.604	7.0	1.6509559225	2007-04-15T10:00:00
350011013	North Valley	35.1878	-106.604	8.0	1.9005882389	2007-04-15T11:00:00
350011013	North Valley	35.1878	-106.604	9.0	2.1024263957	2007-04-15T12:00:00
350011013	North Valley	35.1878	-106.604	8.0	2.2592646234	2007-04-15T13:00:00
350011013	North Valley	35.1878	-106.604	7.0	2.2293381831	2007-04-15T14:00:00
350011013	North Valley	35.1878	-106.604	8.0	2.0158823799	2007-04-15T15:00:00
350011013	North Valley	35.1878	-106.604	8.0	1.9149264869	2007-04-15T16:00:00
350011013	North Valley	35.1878	-106.604	7.0	4.448529552	2007-04-15T17:00:00
350011013	North Valley	35.1878	-106.604	6.0	6.8639706163	2007-04-15T18:00:00
350011013	North Valley	35.1878	-106.604	6.0	12.3272054336	2007-04-15T19:00:00
350011013	North Valley	35.1878	-106.604	6.0	20.8937504712	2007-04-15T20:00:00
350011013	North Valley	35.1878	-106.604	2.0	27.4044121013	2007-04-15T21:00:00
350011013	North Valley	35.1878	-106.604	4.0	30.1459564882	2007-04-15T22:00:00
350011013	North Valley	35.19	-106.6	missing	30.1911774804	2007-04-15T23:00:00
350011013	North Valley	35.1878	-106.604	6.0	31.2290444094	2007-04-16T00:00:00
350011013	North Valley	35.1878	-106.604	7.0	32.4169130886	2007-04-16T01:00:00
350011013	North Valley	35.1878	-106.604	8.0	30.877940795	2007-04-16T02:00:00
350011013	North Valley	35.1878	-106.604	7.0	29.4794110691	2007-04-16T03:00:00
350011013	North Valley	35.1878	-106.604	6.0	28.7514714634	2007-04-16T04:00:00

New Directions

- Particle speciation of $PM_{2.5}$ using A-Train
- High Performance Computing-model runs
- Dust source updates – e.g. seasonal
- Vertical profile verification

Future Program Activities

- SDSWAS - WMO
- Rapid Prototyping for Pollen – MSFC, UA, UNM
- Interoperability – UA, UNM, GMU, GSFC
- SYRIS - AZ, NM, TX AQ Authorities & HSCs
- EPHTS & EPHTN – NMDOH, UNM, UA CDC
- EPA Workshop – Proposal stage, topic TBD
- ICSU 2008 Grant Proposal – ISPRS, UNM