Environmental Sensing: Air Quality and Human Health

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Xiangshan Conference

Beijing

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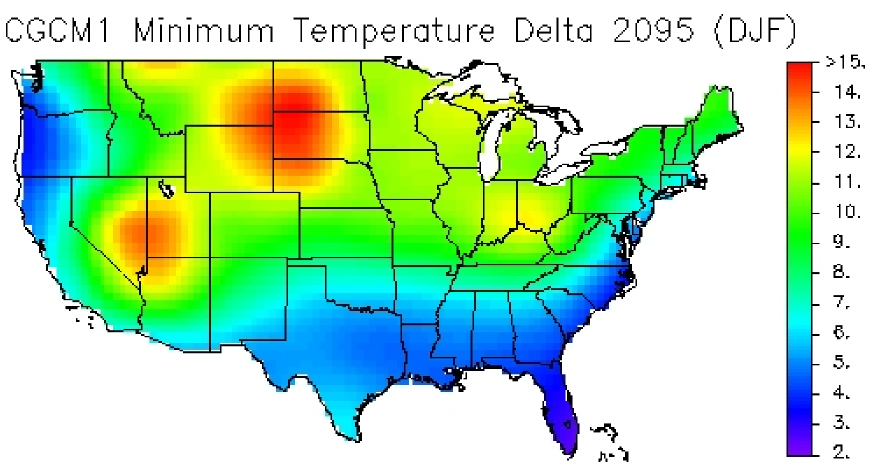
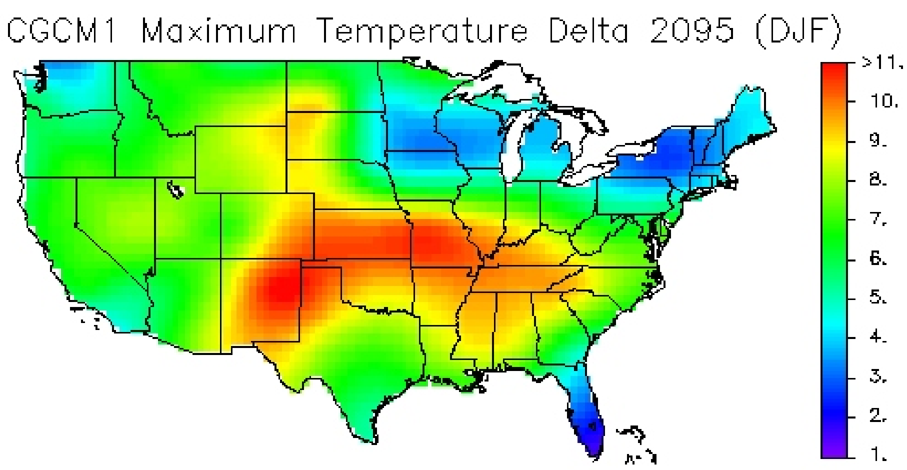
Modeled Results
National Picture

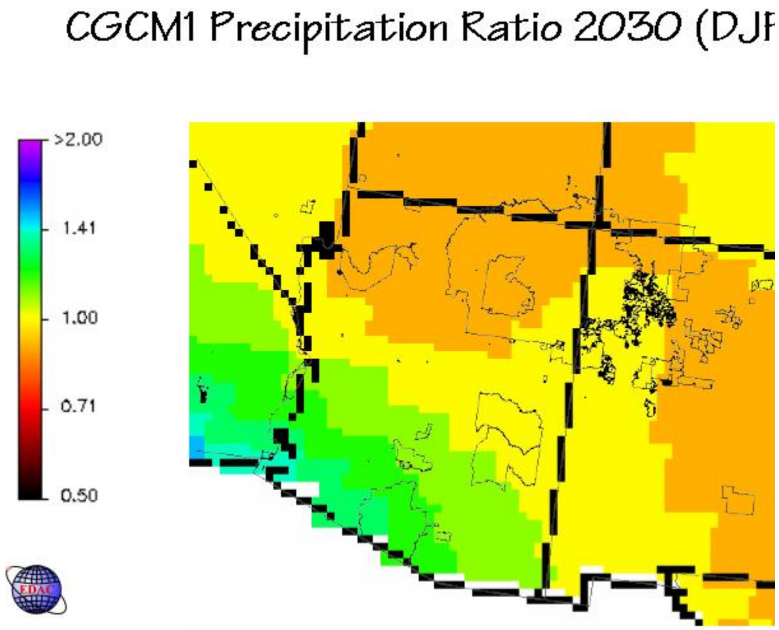
The 20th Century may have been comparatively mild. It is reported that 8 of the 10 warmest years in the global record occurred in the 1990s. Since 1900, temperatures in most of the western USA have increased 1-3°C, and ppt. has increased 10-40%.

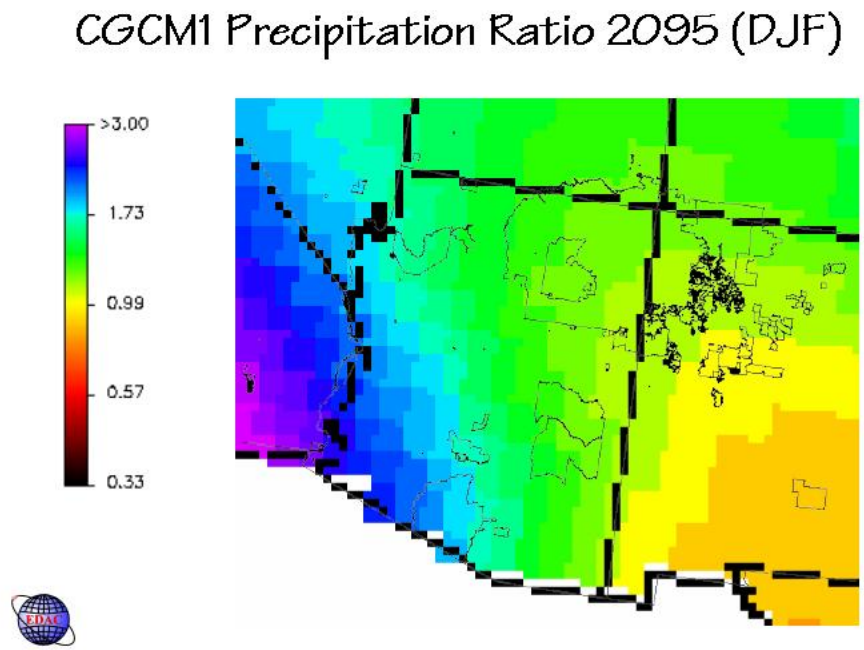
Although specific years are cited, the maps are averages of 10 years of simulated data. The 2095 Canadian model shows minimum differences ranging from 2-15°C; while the maximum changes range from 1-11°C.





Modeled Results
2030 & 2095 Winter Precipitation Ratios

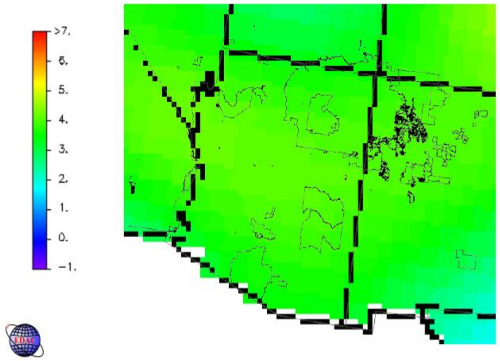




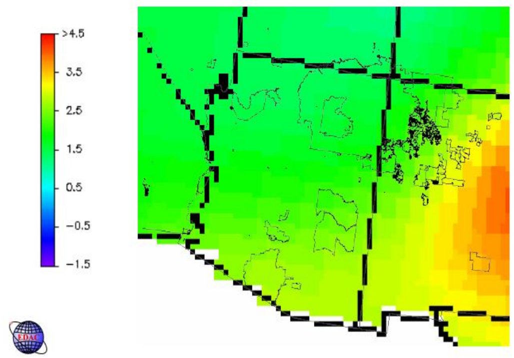
Precipitation ratios for 2030 suggest a 25-50% increase in SW AZ and SE CA; with nearly normal or slight decreases over the Colorado Plateau and central New Mexico. By 2095, ppt. is modeled to increase as much as 3X In SE CA and SW AZ; increase by 10-40% over the Colorado Plateau; but decrease slightly in southern NM.

Modeled Results
Canadian Model 2030

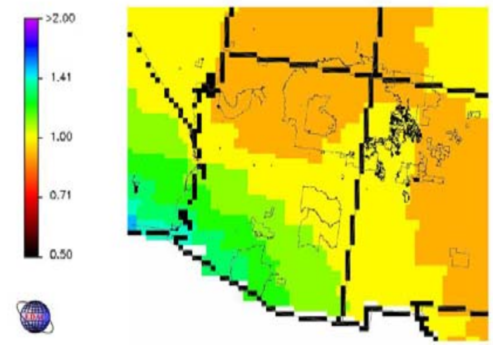
CGCM1 Minimum Temperature Delta 2030 (DJF)



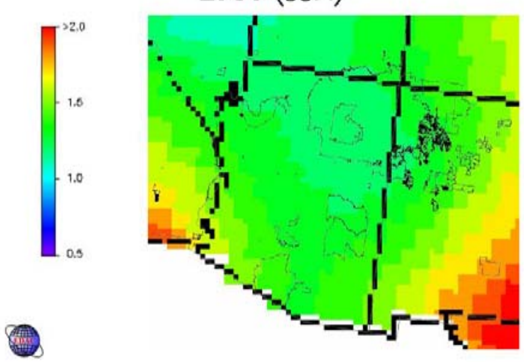
CGCM1 Maximum Temperature Delta 2030 (DJF)



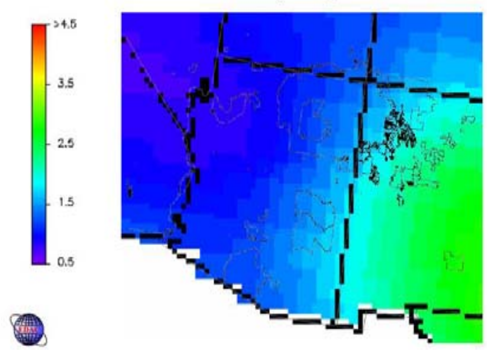
CGCM1 Precipitation Ratio 2030 (DJF)



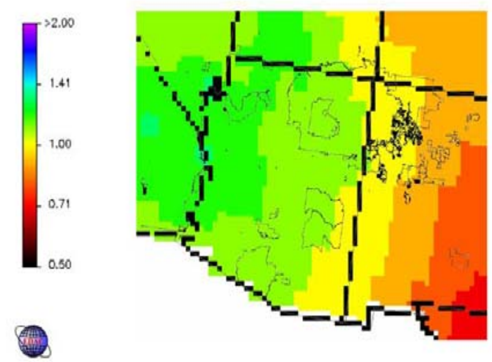
CGCM1 Minimum Temperature Delta 2030 (JJA)



CGCM1 Maximum Temperature Delta 2030 (JJA)

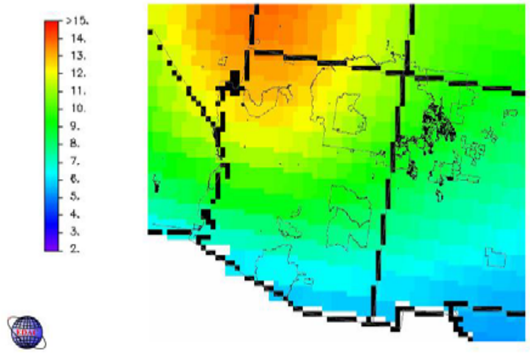


CGCM1 Precipitation Ratio 2030 (JJA)

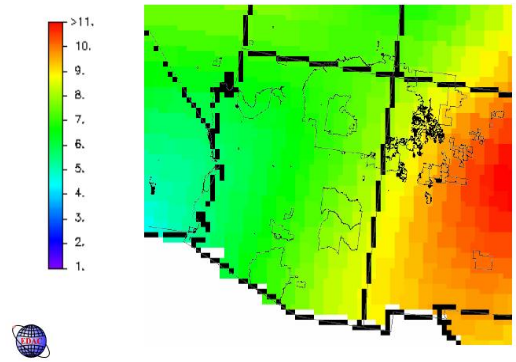


Modeled Results
Canadian Model 2095

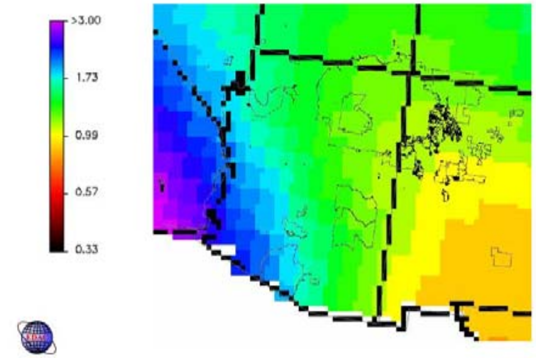
CGCM1 Minimum Temperature Delta 2095 (DJF)



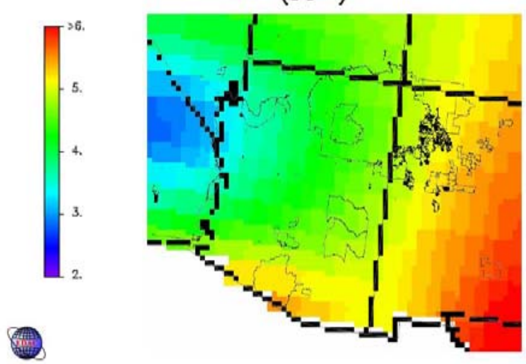
CGCM1 Maximum Temperature Delta 2095 (DJF)



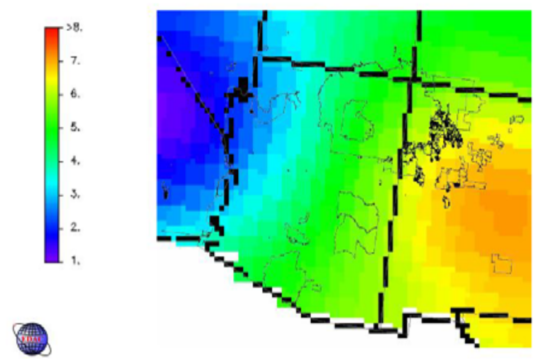
CGCM1 Precipitation Ratio 2095 (DJF)



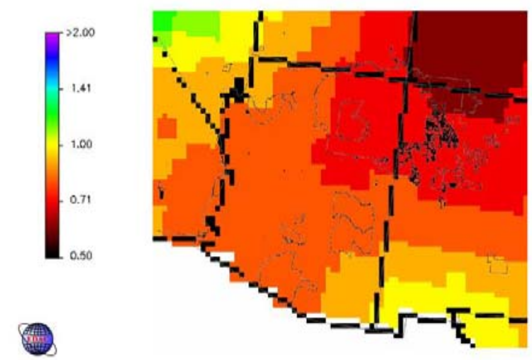
CGCM1 Minimum Temperature Delta 2095 (JJA)



CGCM1 Maximum Temperature Delta 2095 (JJA)

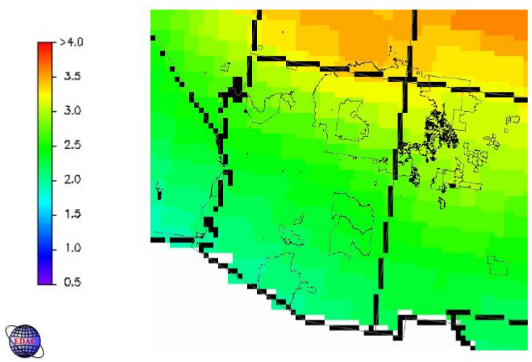


CGCM1 Precipitation Ratio 2095 (JJA)

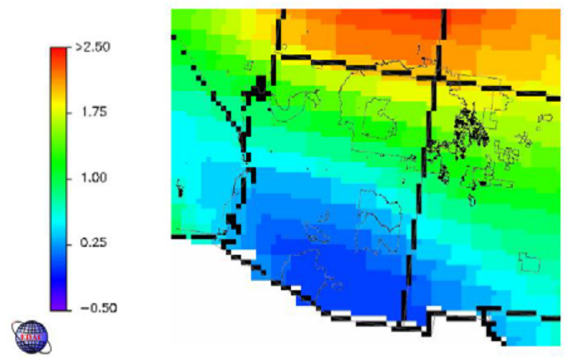


Modeled Results
Hadley Model-2030

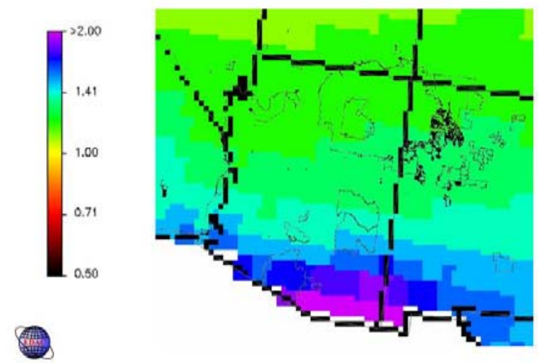
HADCM2 Minimum Temperature Delta 2030 (DJF)



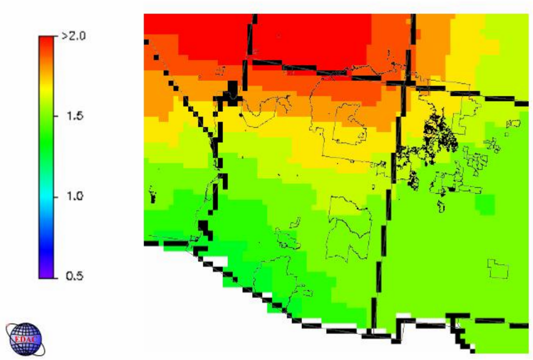
HADCM2 Maximum Temperature Delta 2030 (DJF)



HADCM2 Precipitation Ratio 2030 (DJF)



HADCM2 Minimum Temperature Delta 2030 (JJA)



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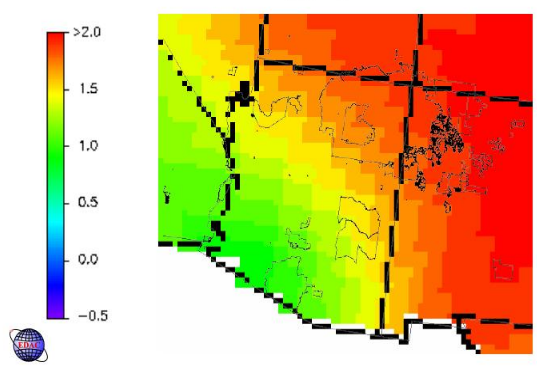
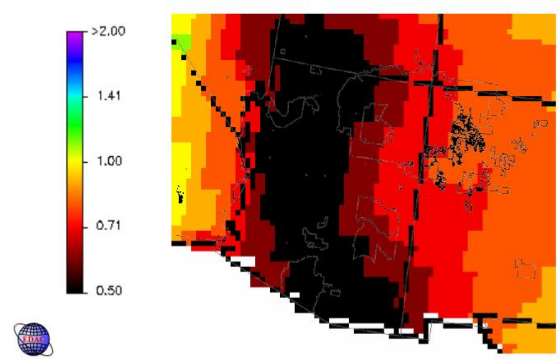
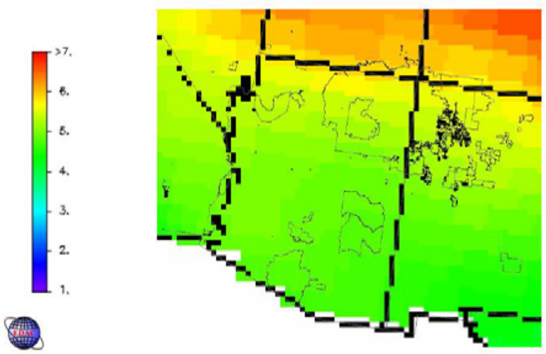


HADCM2 Precipitation Ratio 2030 (JJA)

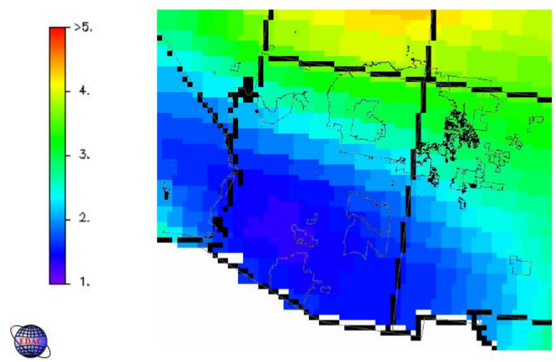


Modeled Results
Hadley Model 2095

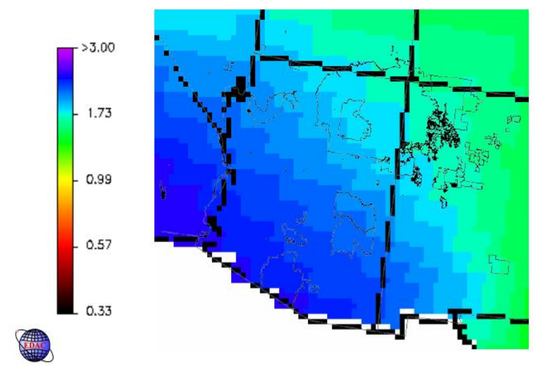
HADCM2 Minimum Temperature Delta
2095 (DJF)



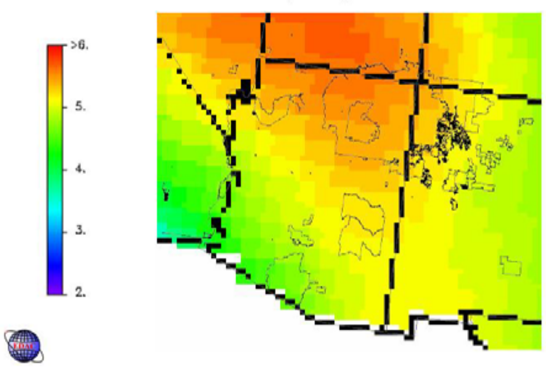
HADCM2 Maximum Temperature Delta
2095 (DJF)



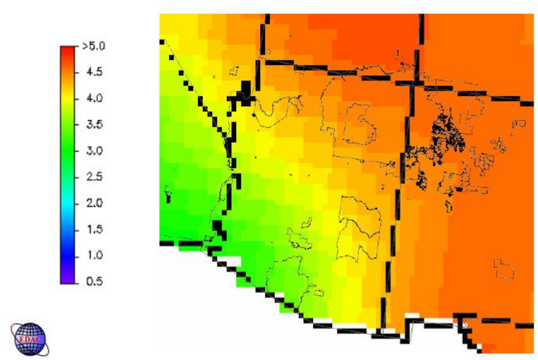
HADCM2 Precipitation Ratio 2095 (DJF)



HADCM2 Minimum Temperature Delta
2095 (JJA)



HADCM2 Maximum Temperature Delta
2095 (JJA)



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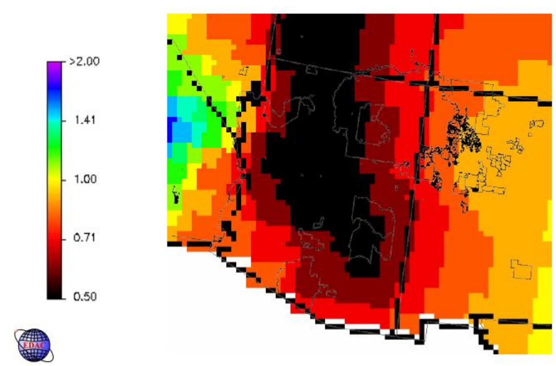
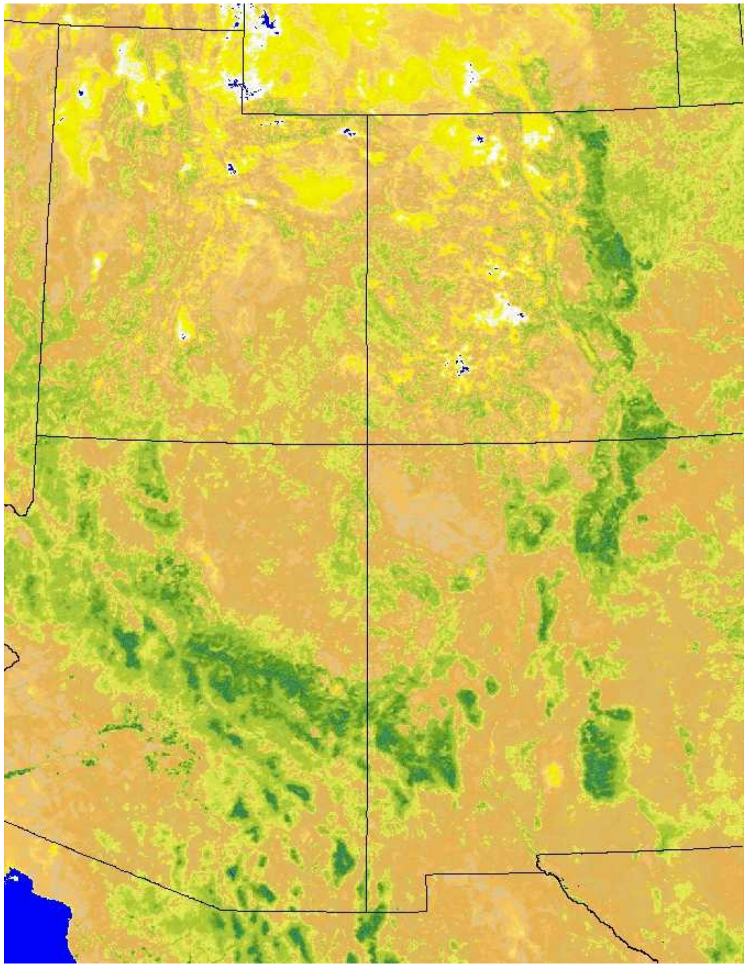
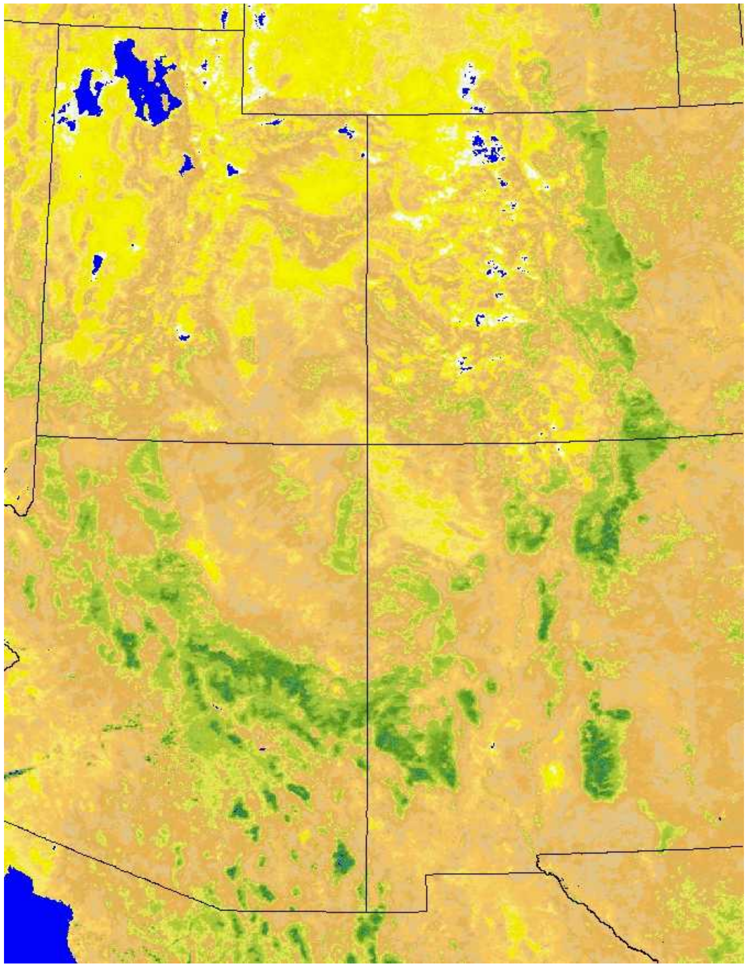


Observed Record
AVHRR Winter ’91 &’97

‘91

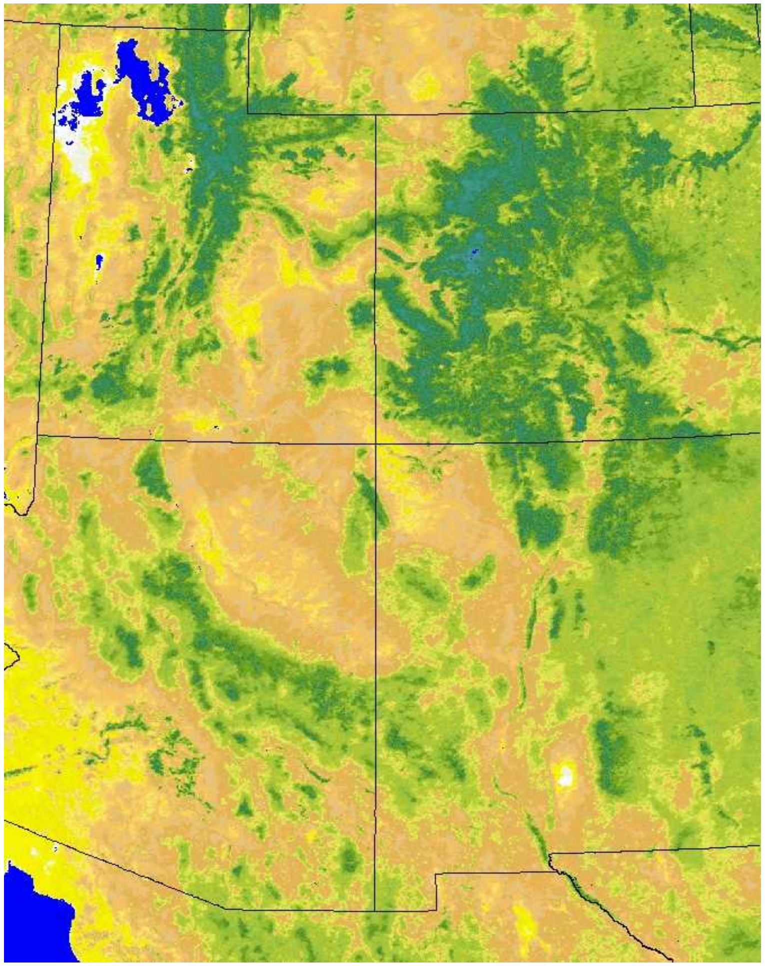


‘97

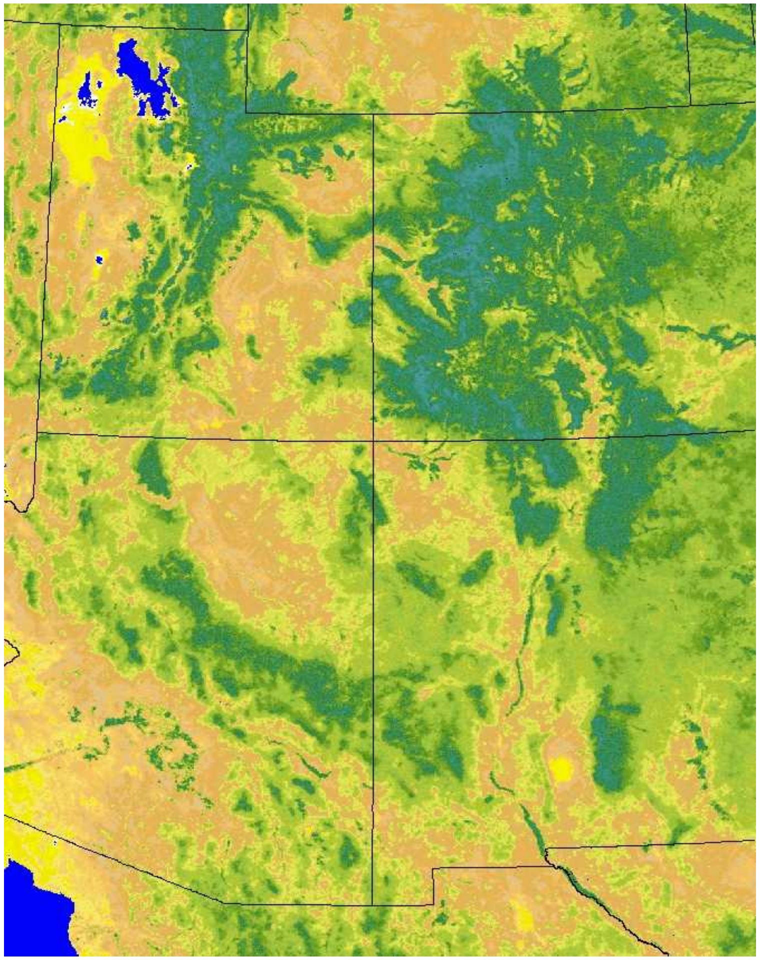


Observed Record
AVHRR-Summer ’91 & ‘97

‘91



‘97



Canadian Model 2030 & 2095

- The CCGM1 model suggests minimum winter warming of 1-2°C, with changes in winter maxima in the 3-6°C throughout most of the Southwest.
- Summer temperatures might increase 1-2°C, and perhaps as much as 3°C.
- By the 2090s, winter minimums could increase from 4-10°C and the maxima from 5-14°C
- By 2030, winter precip. is modeled to increase slightly across southern Arizona, but remain static throughout most of the SW.
- Summer precip. ratios could increase in California and Arizona, but decrease in New Mexico by 25-50%.

Hadley Model 2030 & 2095

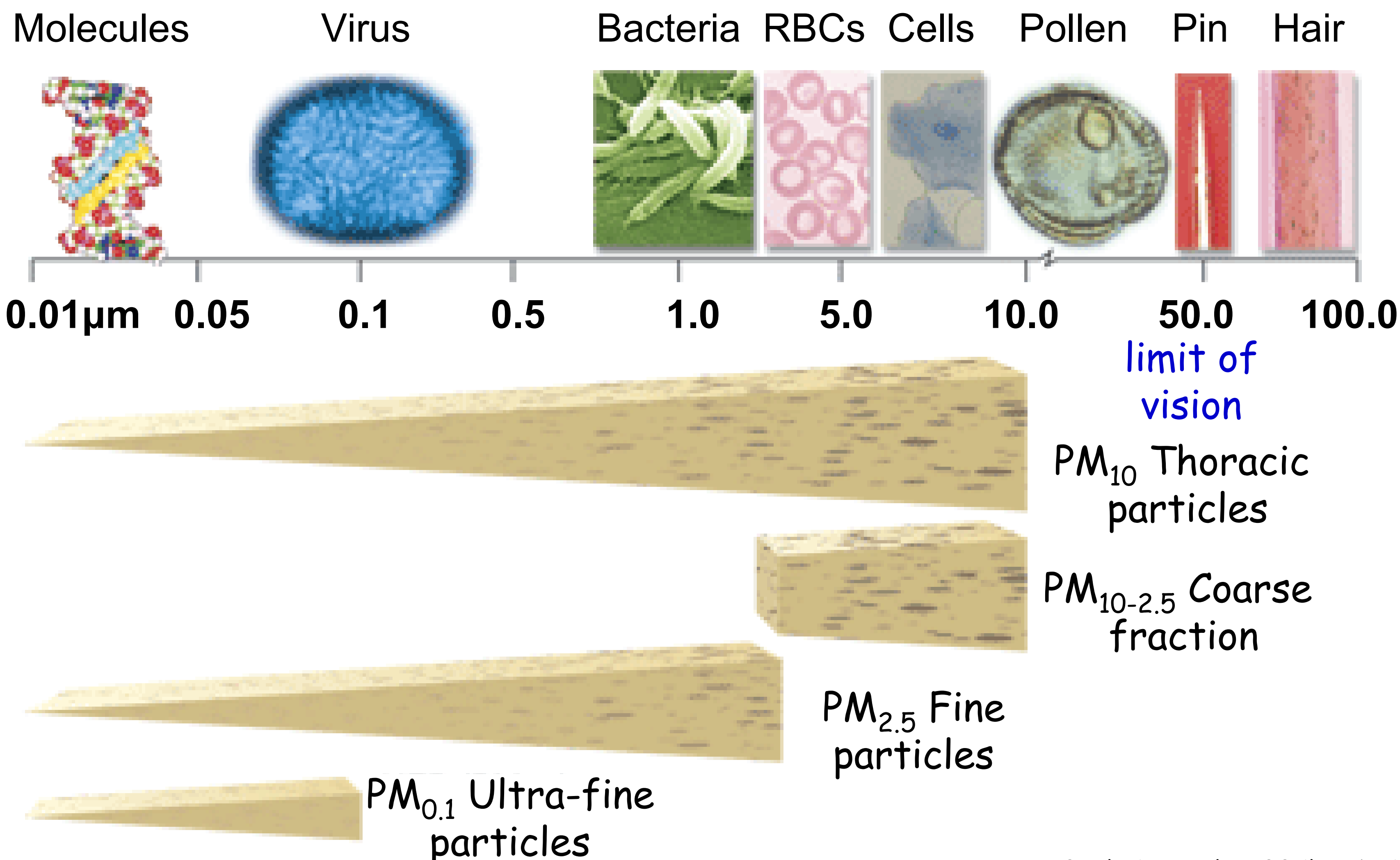
- In 2030, the Hadley model suggest winter minimum temperature increases of 1-3°C, with changes in the maxima of from 1-4°C.
- Summer minimum increases for 2030 are modeled at 1-2°C, while maxima may increase from >1 to >2°C.
- Winter precip. ratios for 2030 suggest double the current rate in the south, grading to a 25% increase in the north. Summers are modeled to be quite dry (with only half the current rate in central AZ, and only 75% of the current precip. in New Mexico)
- By the 2090s, winter minimum temperatures could increase from 1->5°C with an increase in the winter maxima of >6°C.
- Summer minimum increases range from 2-5°C, and the summer maxima might increase from 4->6°C
- Winter precip. ratios show increases throughout the region (1.5X to 2X), but summer ratios show significant deficits (ca. 0.4X to 0.75X), at least in the AZ and NM areas.

Observed Modern Changes

High elevation Spruce/Fir forest and low elevation Grass/shrubland in the Chiricahua Mtns

Encroachment of Piñon/juniper woodlands into foothills and riparian stringers

Particulate Matter Size Distribution & Their Related Biophysical Impacts

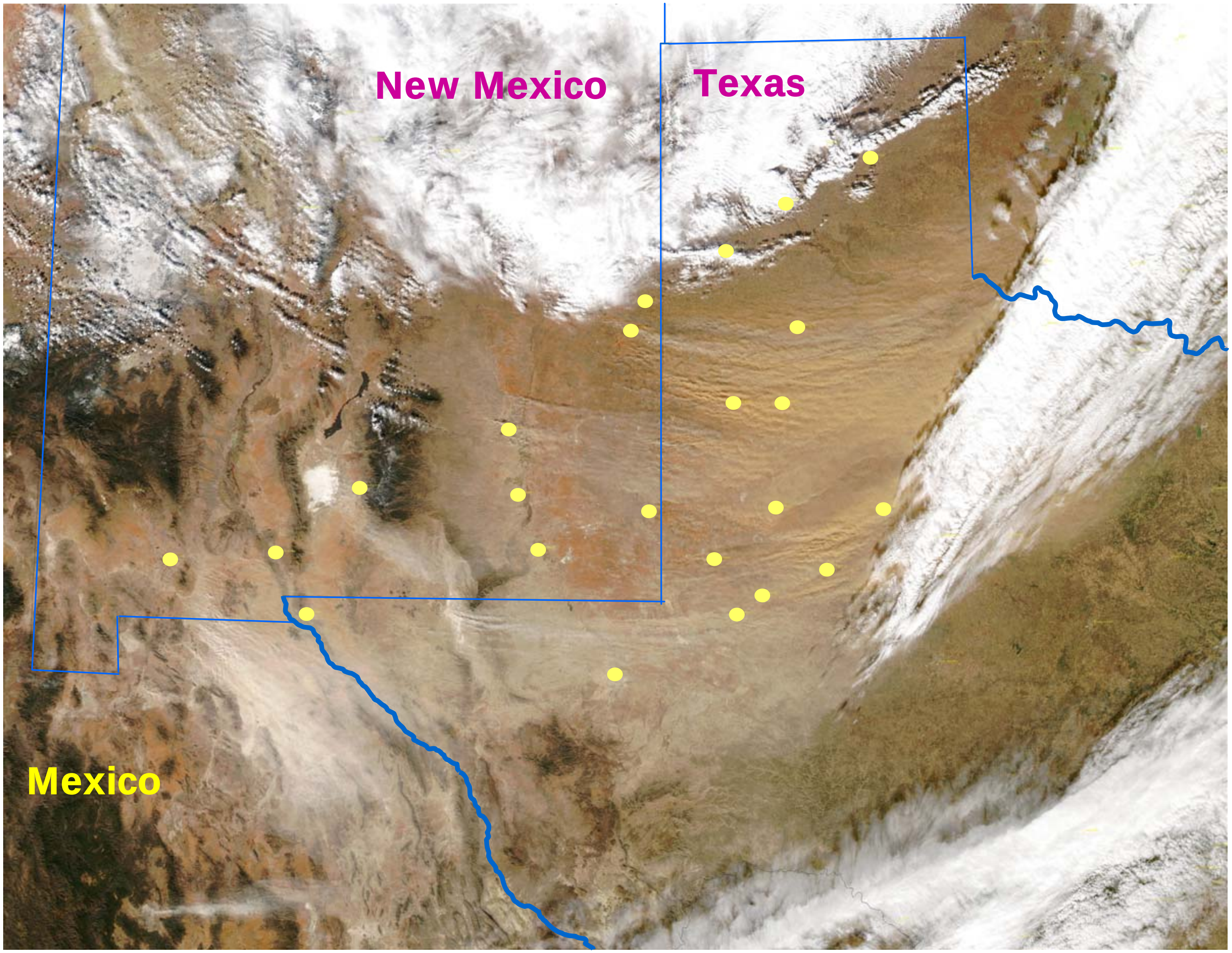


Source: *Science* 307 (25 March, 2005), p.1859

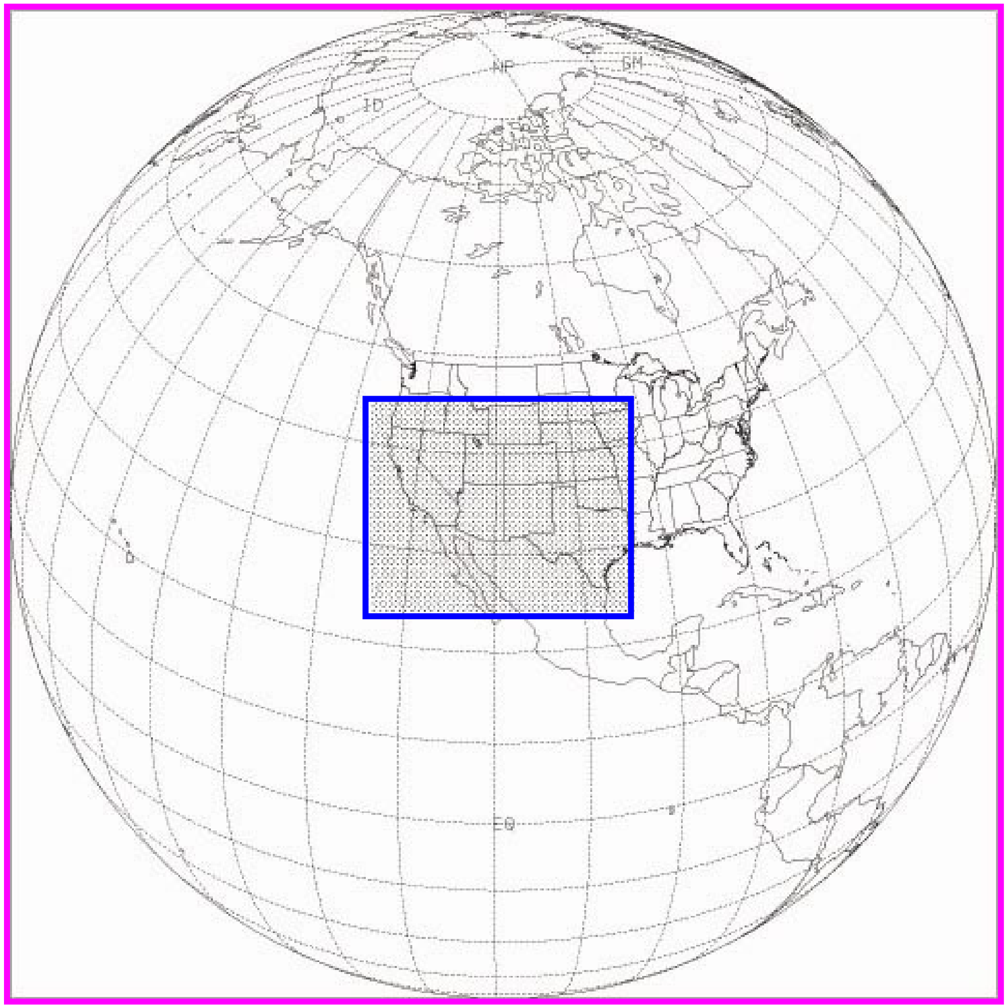
Aims and Goals

- 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

New Mexico/Texas Dust Storm – Dec 2003



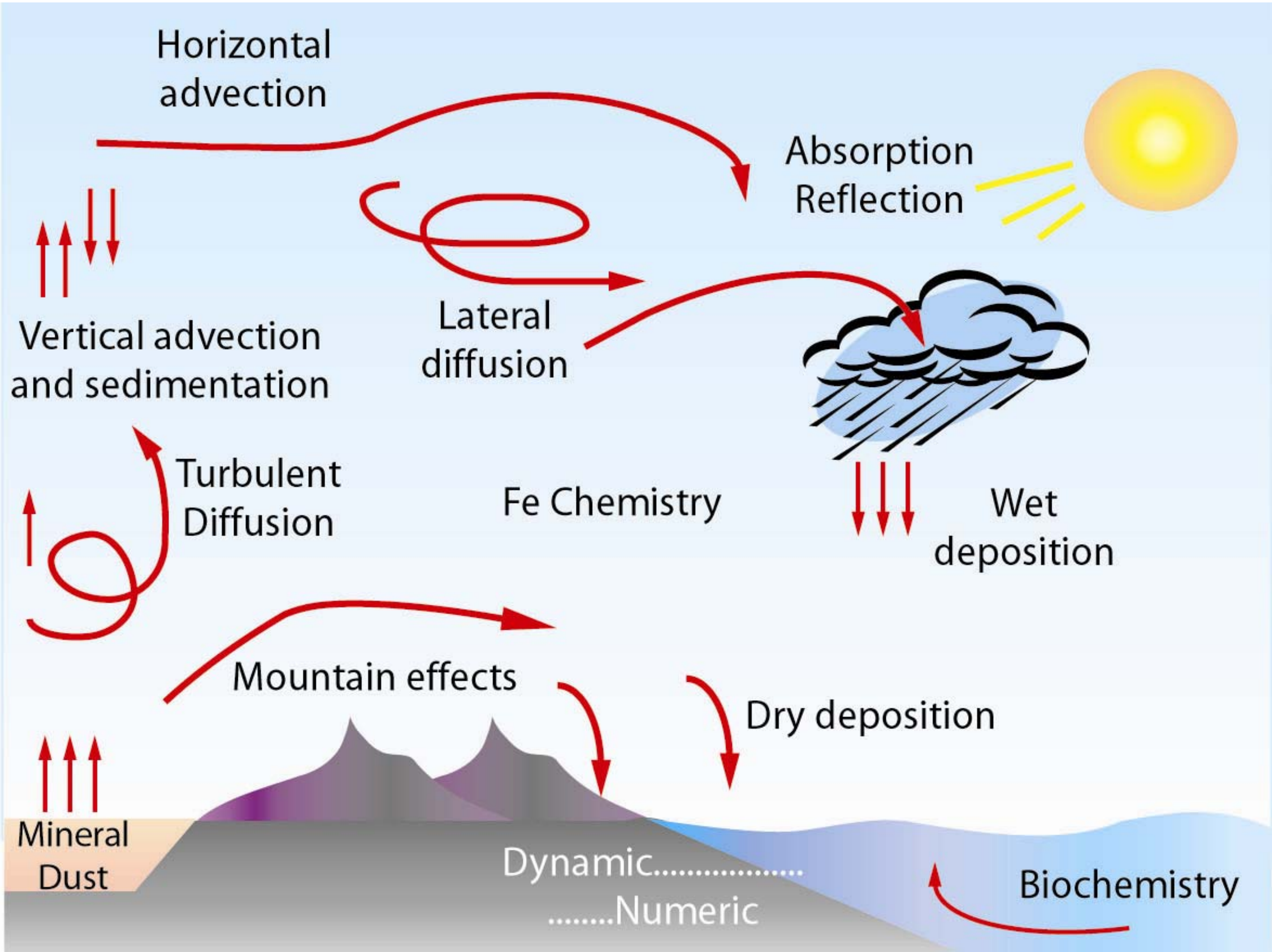
Model Domain



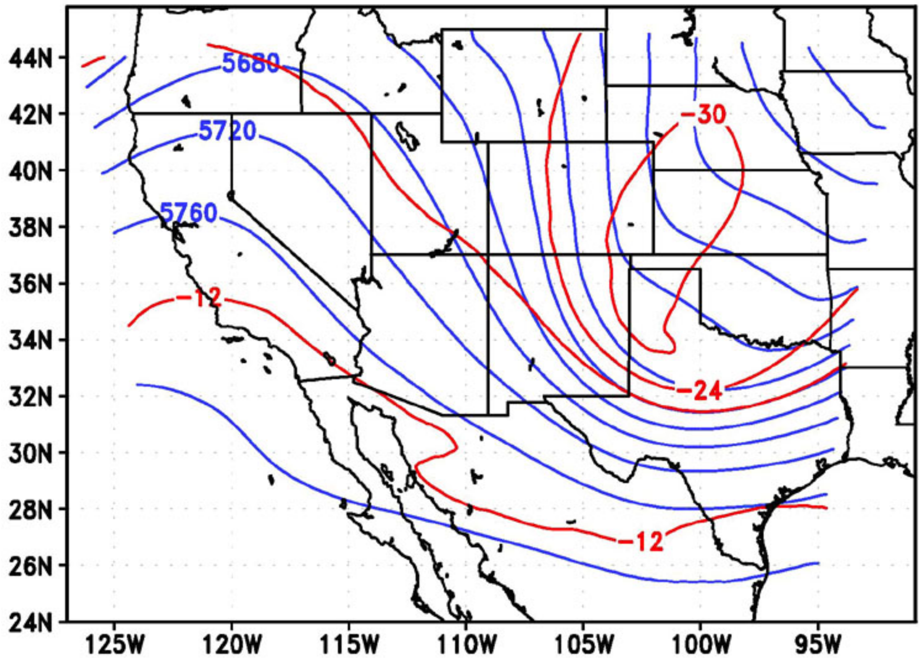
- Domain center at (109°W, 35°N)
- Horizontal semi-staggered Arakawa E grid
- Horizontal grid spacing 1/3 degree

DREAM EQUATION

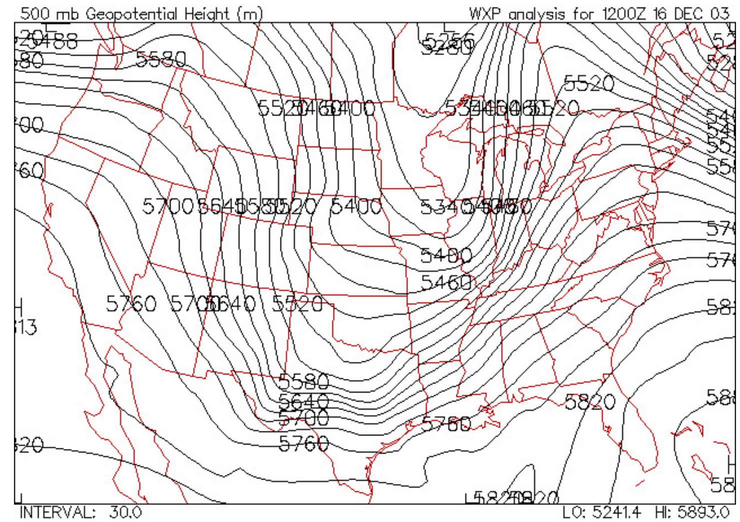
$$\frac{\partial C_k}{\partial t} = -u\frac{\partial C_k}{\partial x} - v\frac{\partial C_k}{\partial y} - (w - v_{gk})\frac{\partial C_k}{\partial z} - \nabla(K_H \nabla C_k) - \frac{\partial}{\partial z}\left(K_Z \frac{\partial C_k}{\partial z}\right) + \left(\frac{\partial C_k}{\partial t}\right)_{SOURCE}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



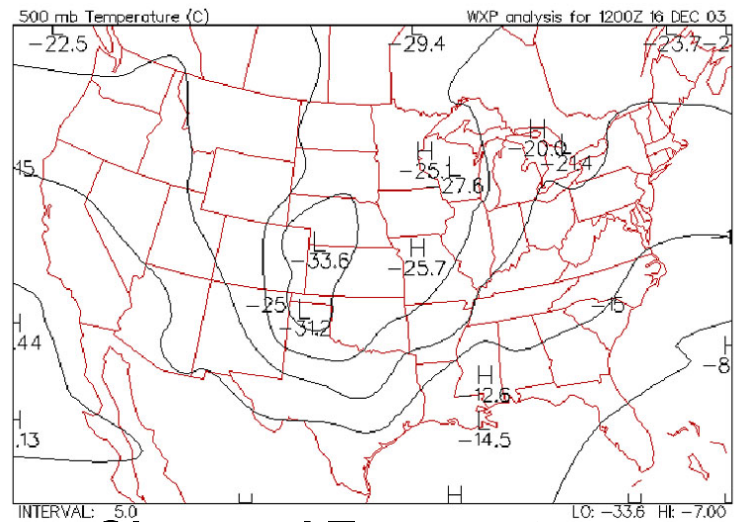
Modeled vs Observed Synoptic Patterns 12Z 16 Dec 03



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

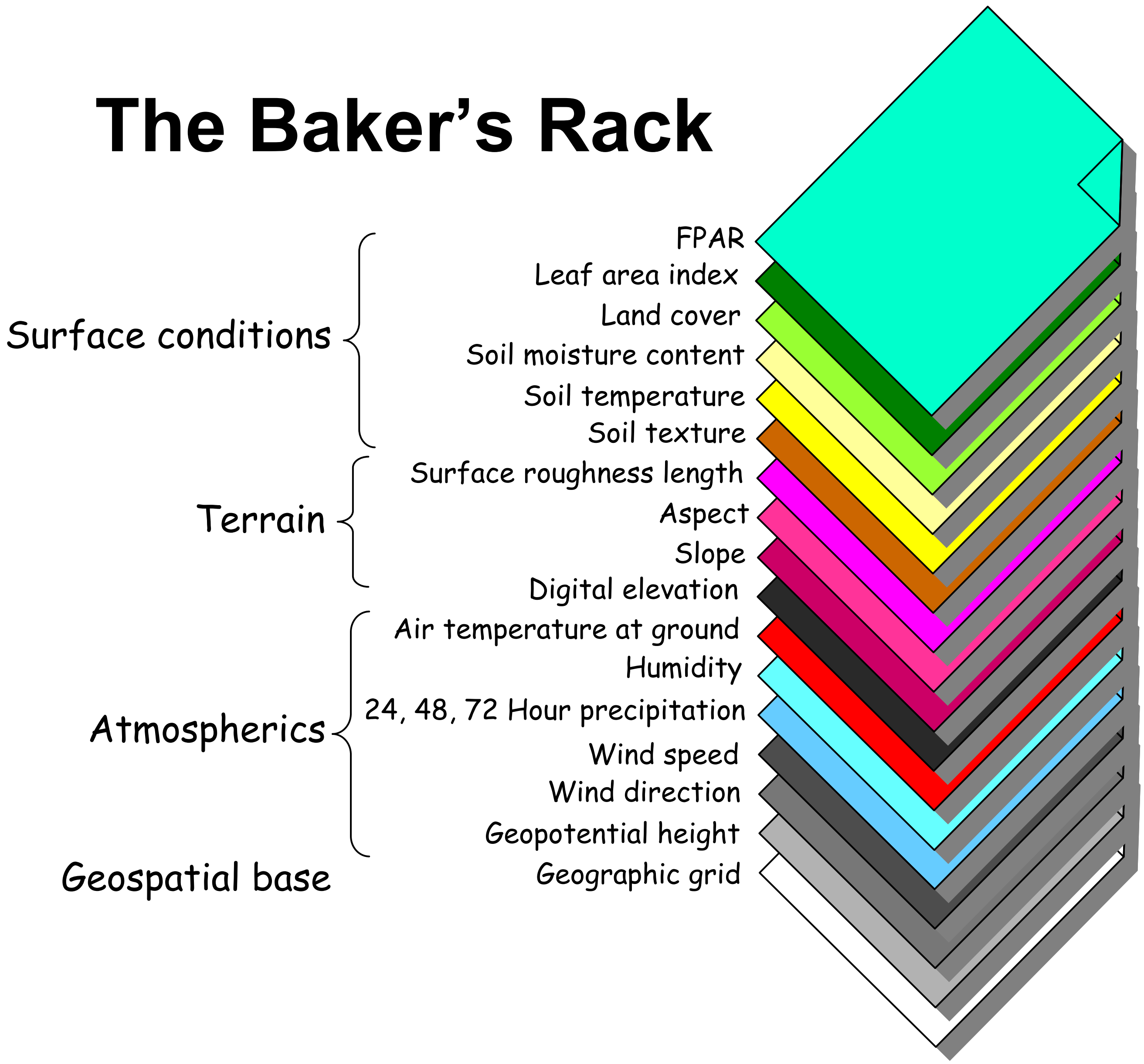
Assimilation: The process of replacing selected static parameters in an Earth system model with digital pixel values from Earth observation data sets to improve the model's performance and convert it into a more dynamic (forecasting) form without changing the model's intended purpose.

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

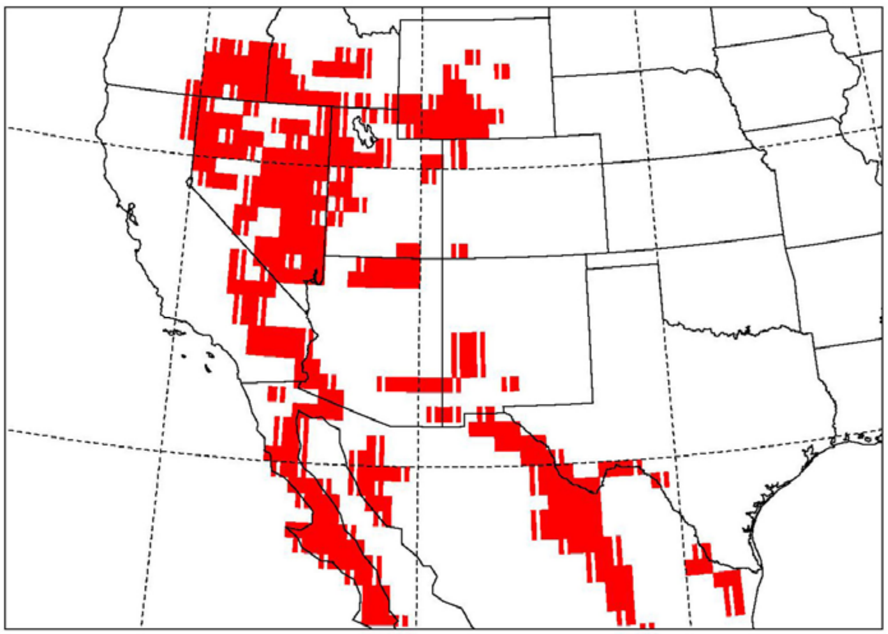
- Assess metadata & attributes of current model inputs and of possible EO inputs
  - Measurement units
  - x,y,z Resolution
  - Temporal frequency
  - Projection
  - File formats
  - Validity & accuracy
  - Error & error propagation
- Select EO inputs based on highest perceived benefit for enhancing 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

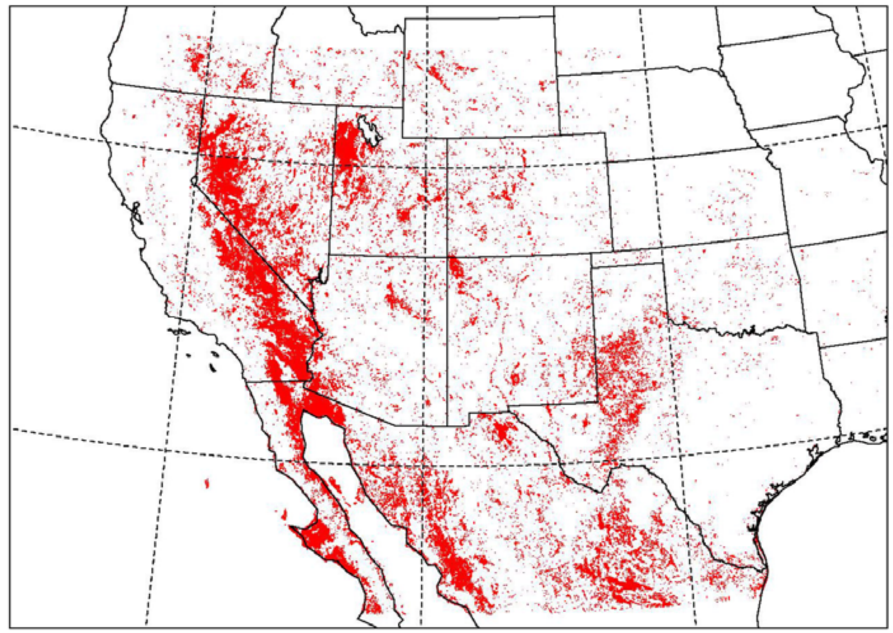


Aims are to: (1) replace selected trays in the rack with regularly refreshed EO digital data from the "terrain." "surface conditions," and "atmospheric" parameters that drive DREAM; (2) improve model output without altering the validity of the model's original function; and (3) convert the model to a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

Barren ground (Potential Dust sources)



Olson World Ecosystems

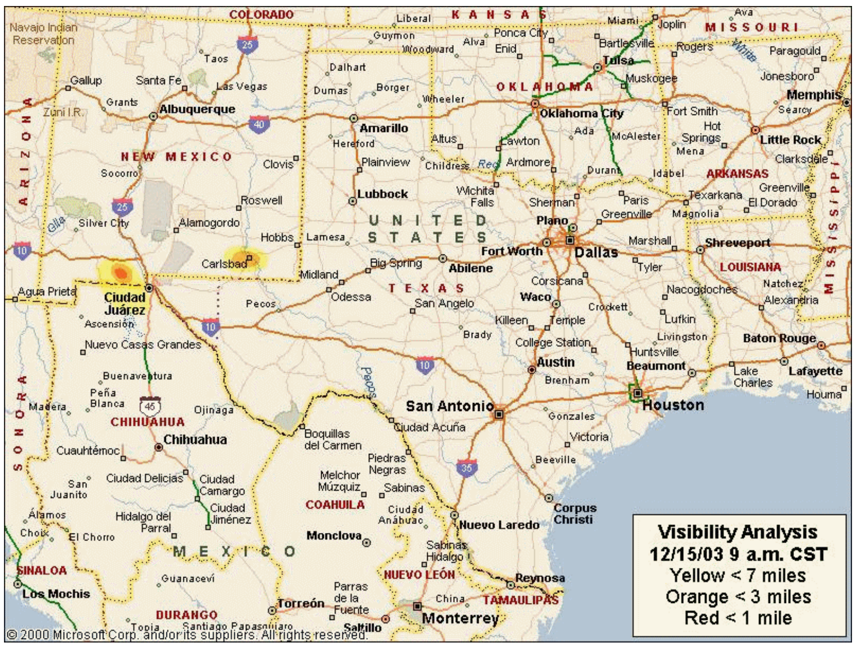


MOD12Q1 Land cover reduced to Binary format

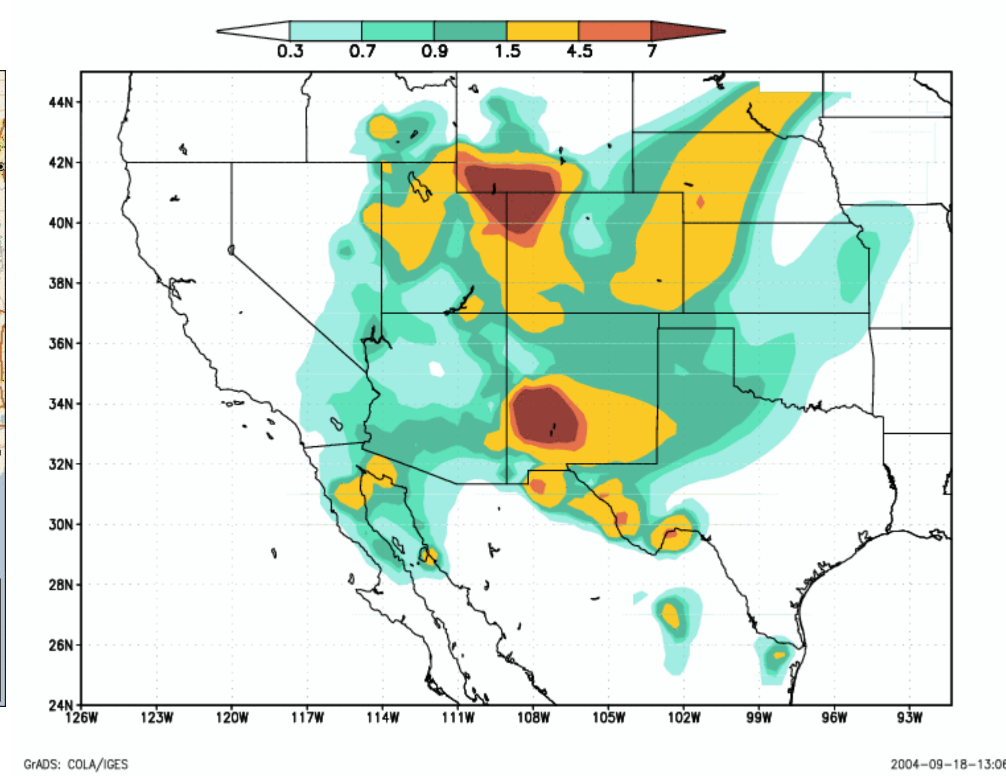
Aerodynamic Surface Roughness (z_0) controls dust entrainment

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)

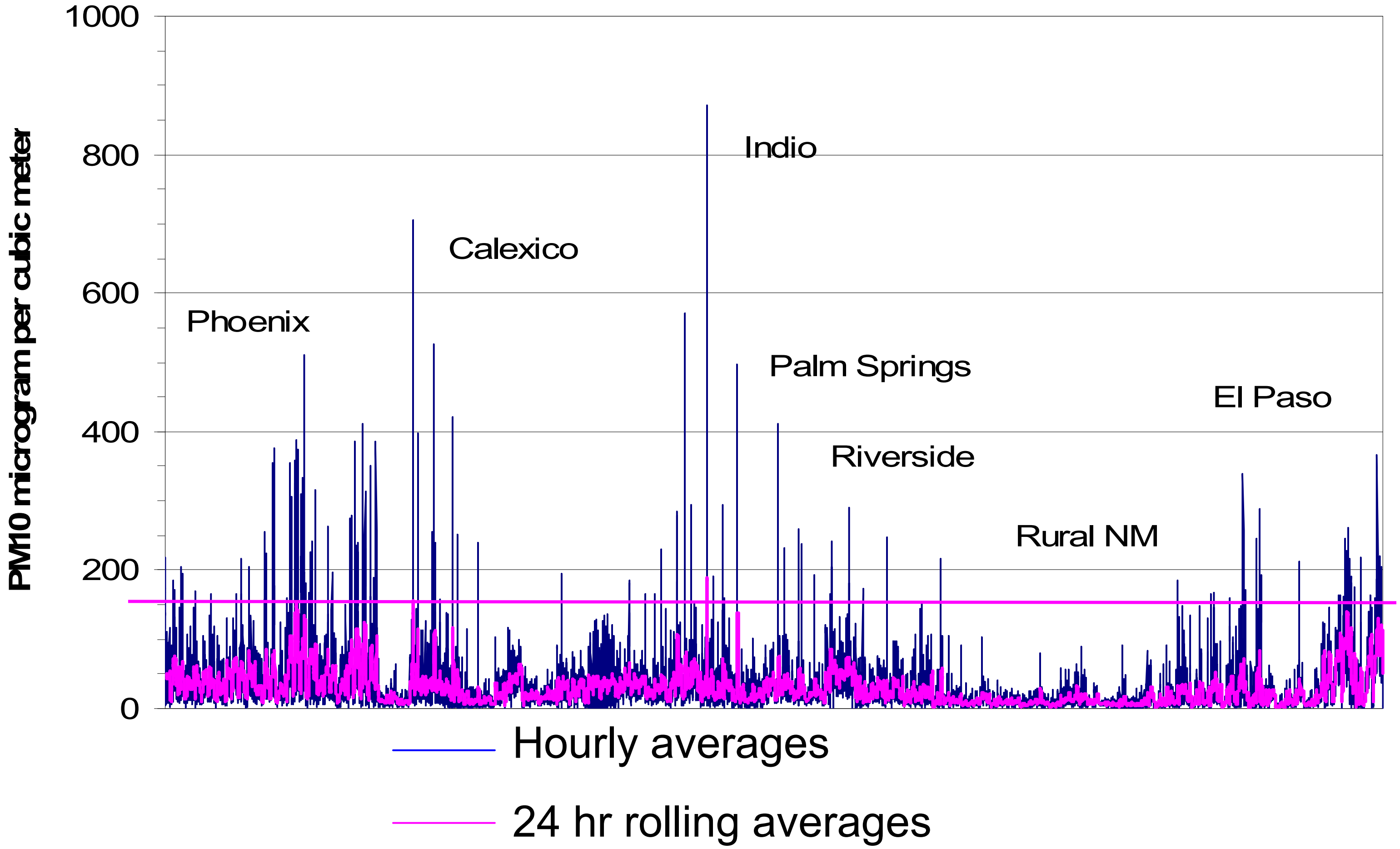
DREAM Performance
Before & After EO Data Assimilation

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

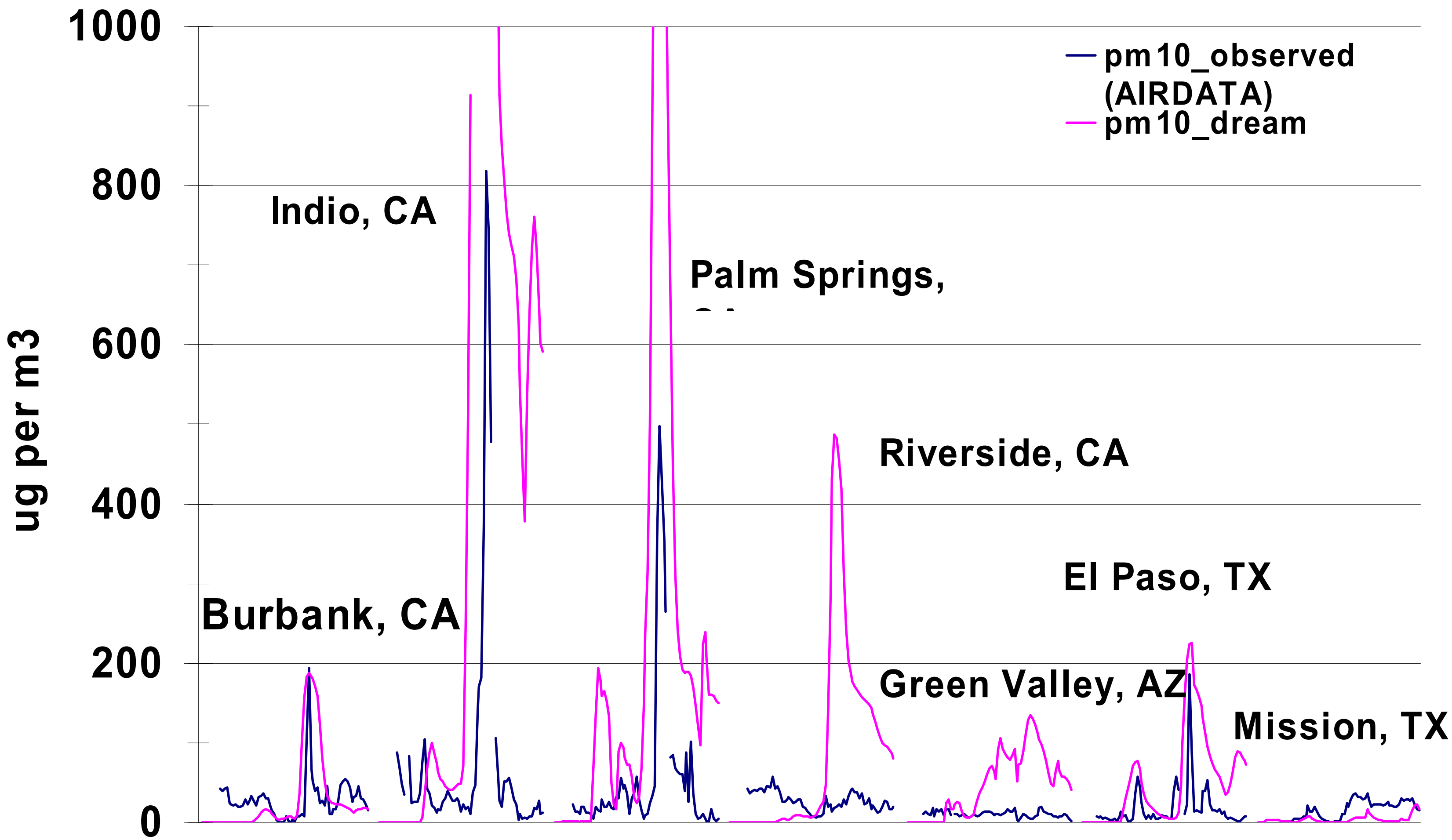
Blue = before EO Data Assimilation
Red = after EO Data Assimilation

January 2007 AIRNow Data

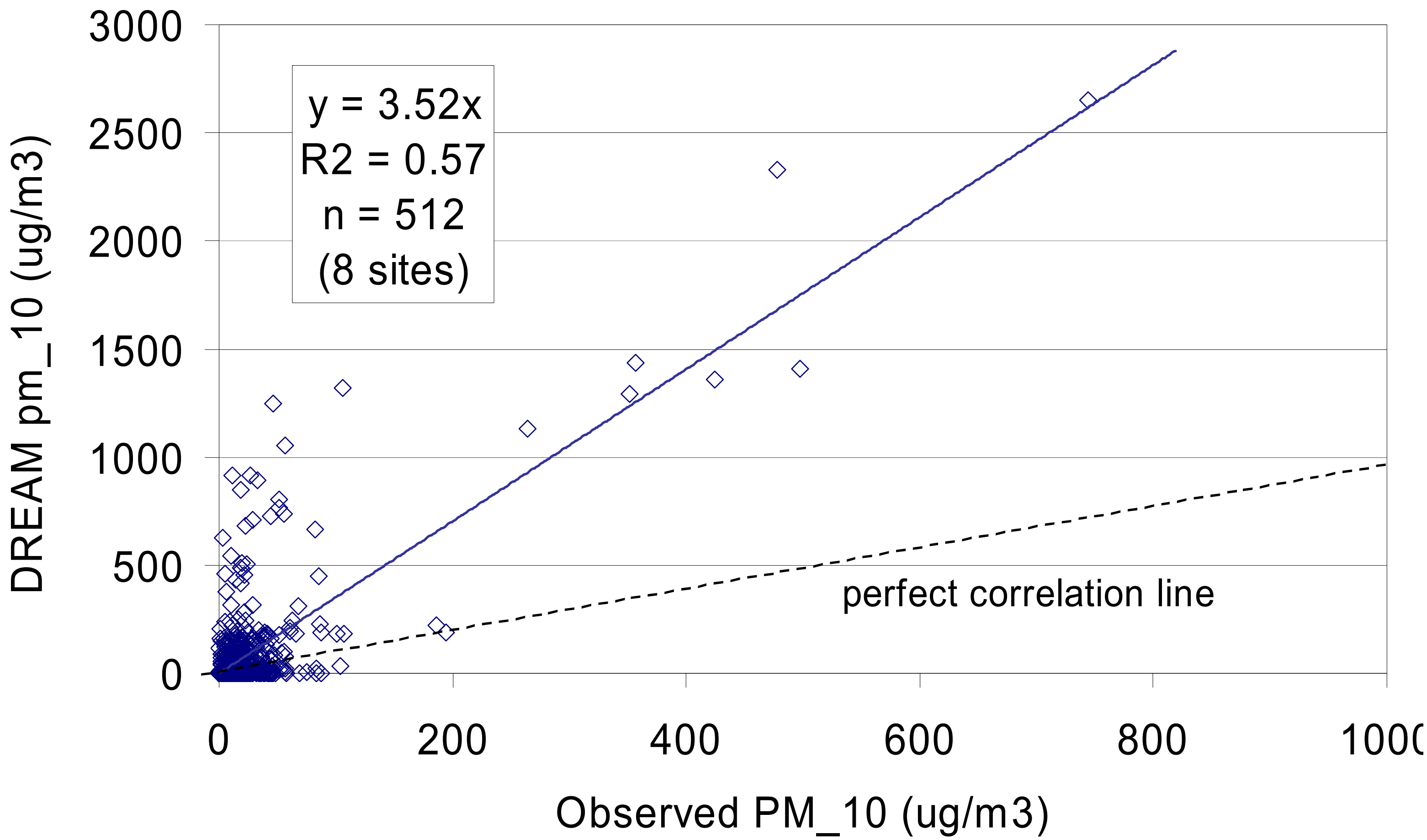
N ≈ 29K data points from 40 sites in the model domain



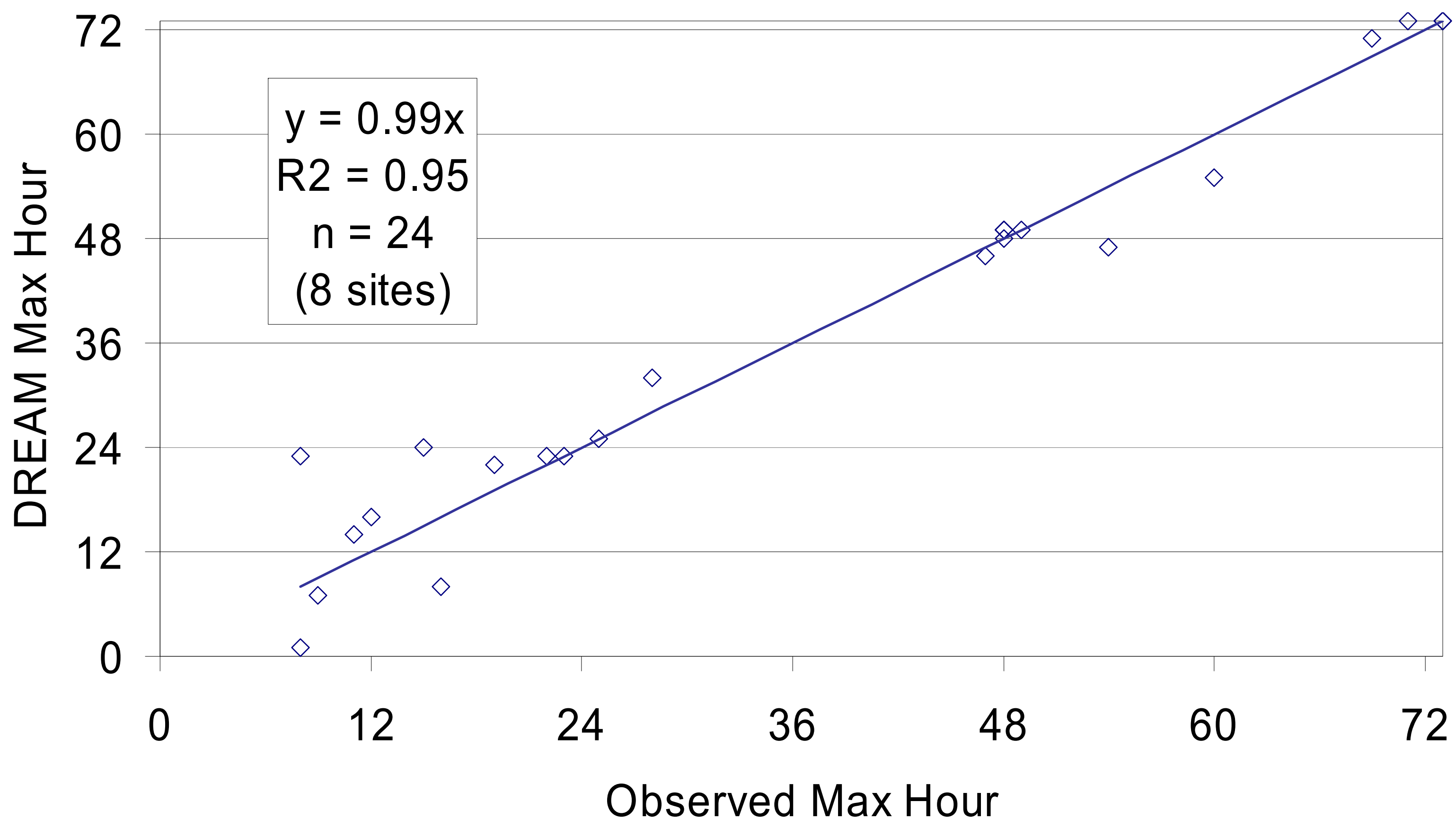
Dust Storm of January 4-6, 2007



Magnitude Correlation, Jan 4-6, 2007

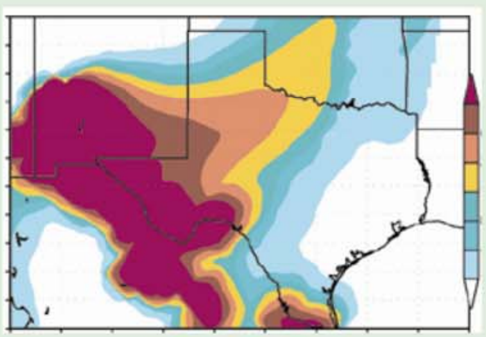


Timing Correlation, Jan 4-6, 2007



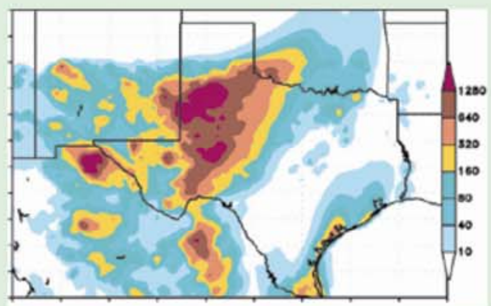
Incremental Improvements to Model Performance

Baseline Model Performance



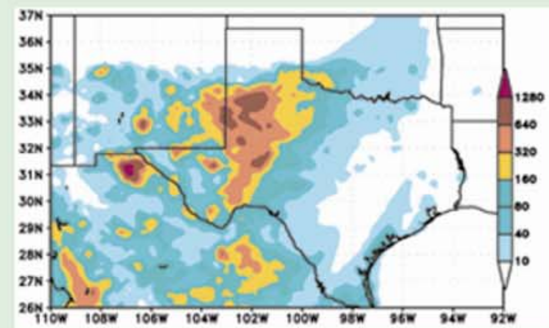
University of Malta
University of New Mexico
University of Arizona

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



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

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