# Public Health Applications in Remote Sensing (PHAiRS)

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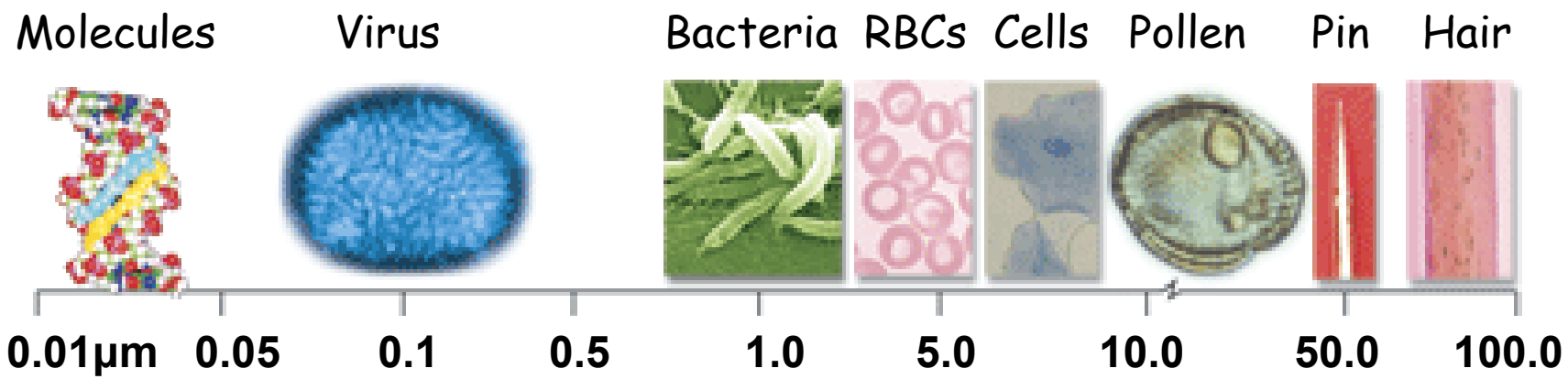
# Project Participants

| UNM EDAC | U of A Atmos. Sci. | Stake-holders |
|---|---|---|
| Stan Morain | Bill Sprigg | NM/AZ-DOH |
| Amy Budge | Brian Barbaris | NM/AZ-DEQ |
| Karl Benedict | Dazhong Yin | Hospitals |
| Bill Hudspeth | Slobodan Nikovick | AERES Corp. |
| Tom Budge | Patrick Shaw | Med Sci Ctr, TxTech |
| Gary Sanchez | | ABQ AQO |

# Talking Points

- Atmospheric contaminants
- The DREAM--Dust Regional Atmospheric Model
  - Concept and domain
  - Components
  - Performance and parameter replacements
- Earth observation data assimilation
  - Concept and definitions
  - Candidates
  - Why it's not so simple
- Sample model run, data sets and improvements

# Particulate Matter Size Distribution & Their Related Biophysical Impacts




limit of vision

$PM_{10}$ Thoracic particles

$PM_{10-2.5}$ Coarse fraction

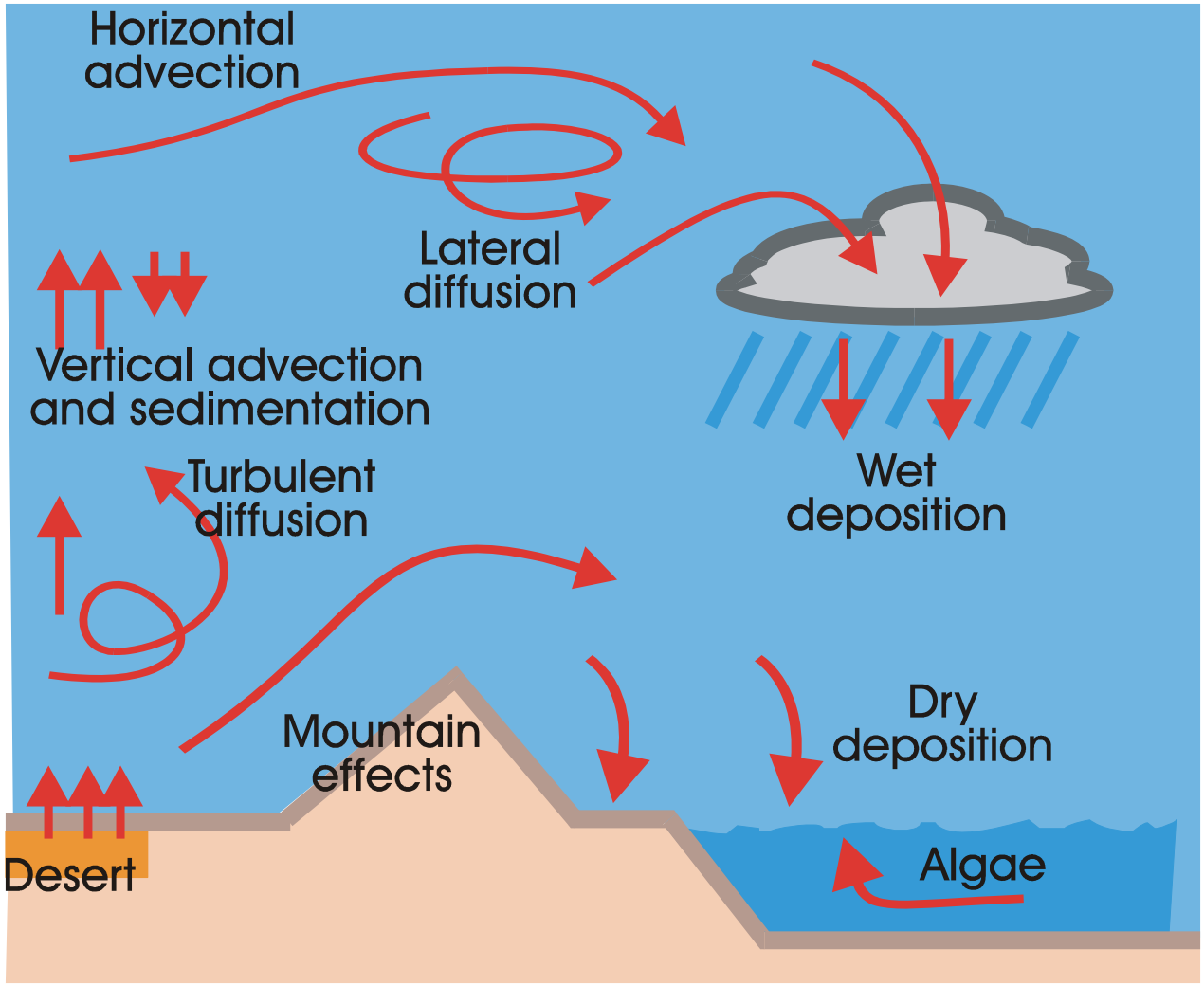
$PM_{2.5}$ Fine particles

$PM_{0.1}$ Ultra-fine particles

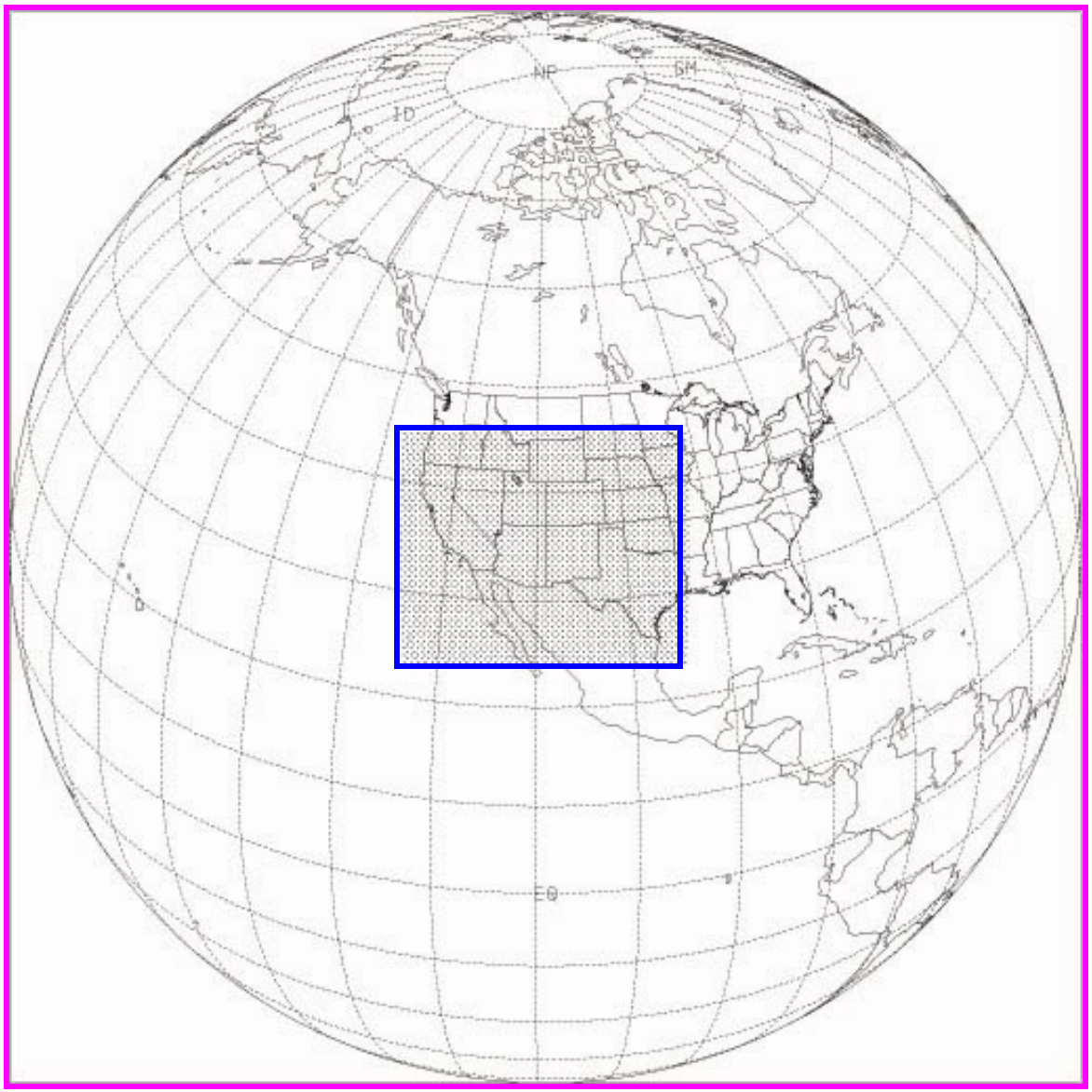
Source: *Science* 307 (25 March, 2005), p.1859

# DREAM's GOVERNING EQUATION

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



# Model Domain

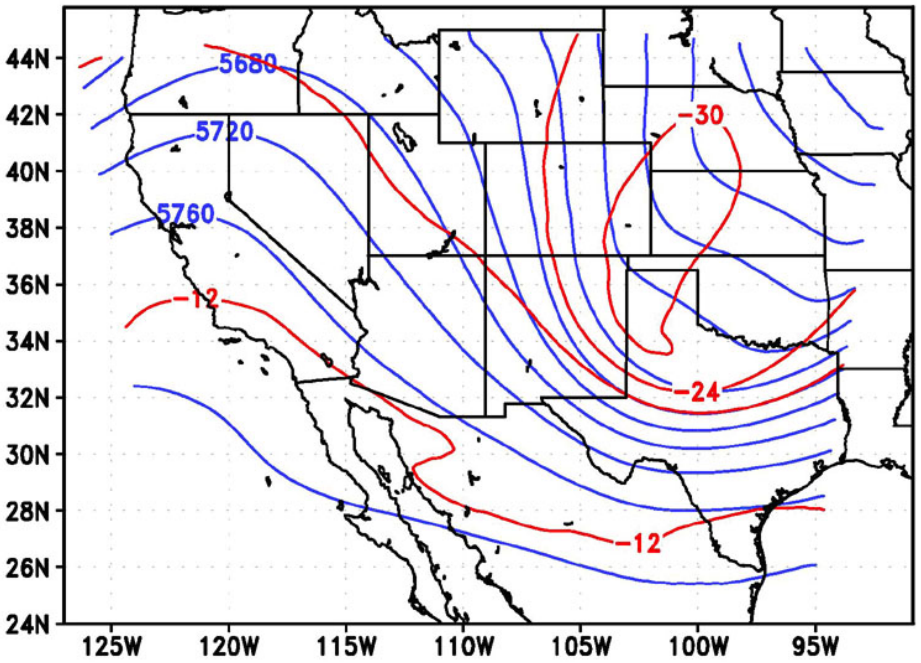



- Domain center at (109°W, 35°N)
- Horizontal semi-staggered Arakawa E grid
- Horizontal grid spacing 1/3 degree

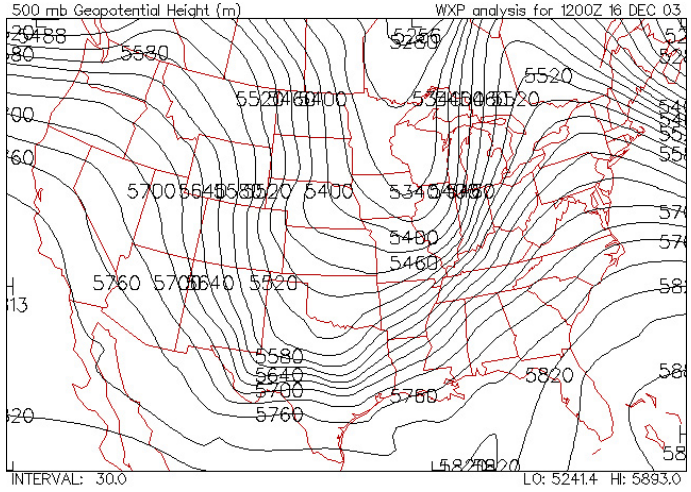
# DREAM Has Two Main Parts

- An atmospheric modeling system
  - 32 model layers extending from the Earth's surface to 100 hPa in the vertical
  - In the x,y dimensions resolutions range from 0.1 degree to 1.0 degree lat. / lon.
- A dust concentration module
  - parameterizes both wet and dry deposition
  - Soil textures are specified by the NCEP/Eta model using
    - ZOBLER seven textural classes @ 1° resolution
    - The UNCEP/GRIDDED FAO/UNESCO soil units @ 2′ res.
  - vegetation cover
  - Soil moisture
  - Surface atmospheric turbulence
  - Topography

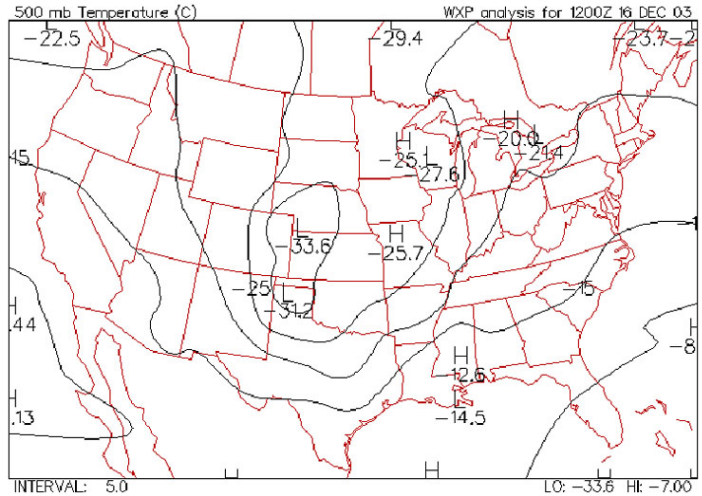
# Modeled vs Observed Synoptic Patterns
# 12 Z 16 Dec 03




DREAM Simulation

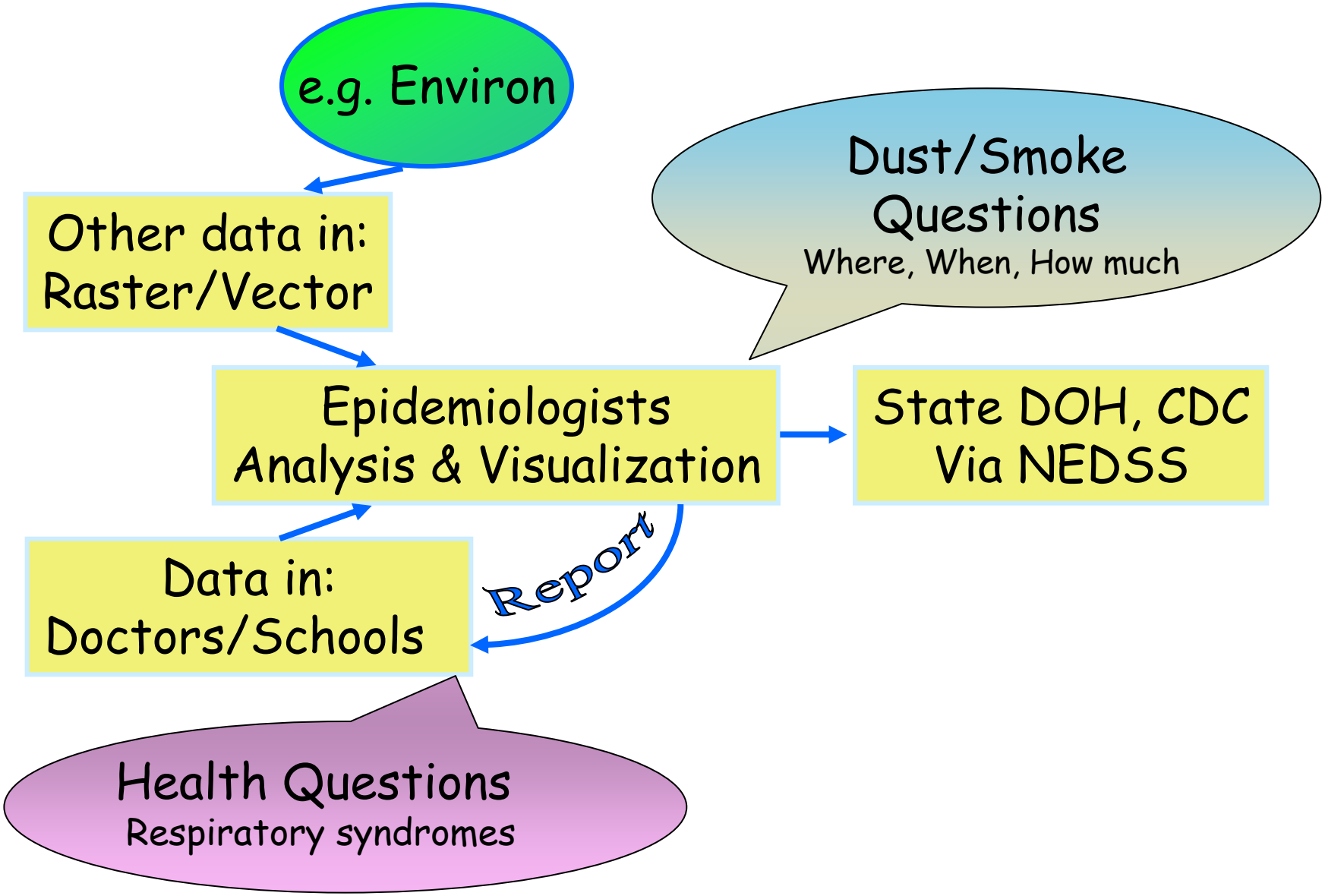



Observed Geopotential Height




Observed Temperature

# Data Assimilation Concept



# 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.

# DREAM Replacements as of April '06

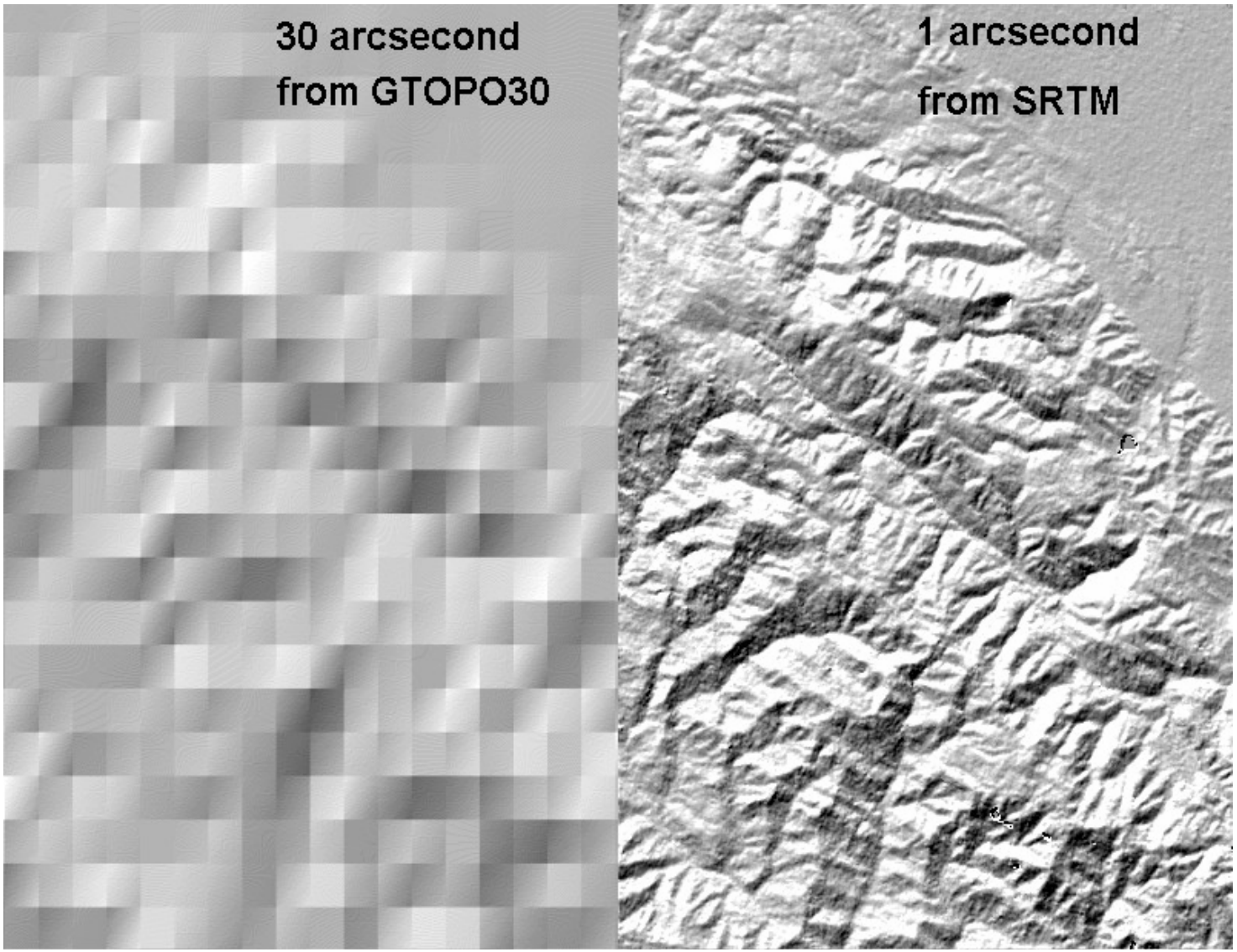
*Previously used data*

- Soil Moisture: simulated using a land surface model
- Elevation: USGS 1 km terrain data
- Vegetation: Olson World Ecosystems 10-minute, ± 19 km resolution
- Aerodynamic Roughness Length predicted using 12 SSiB land cover types

*Data being evaluated*

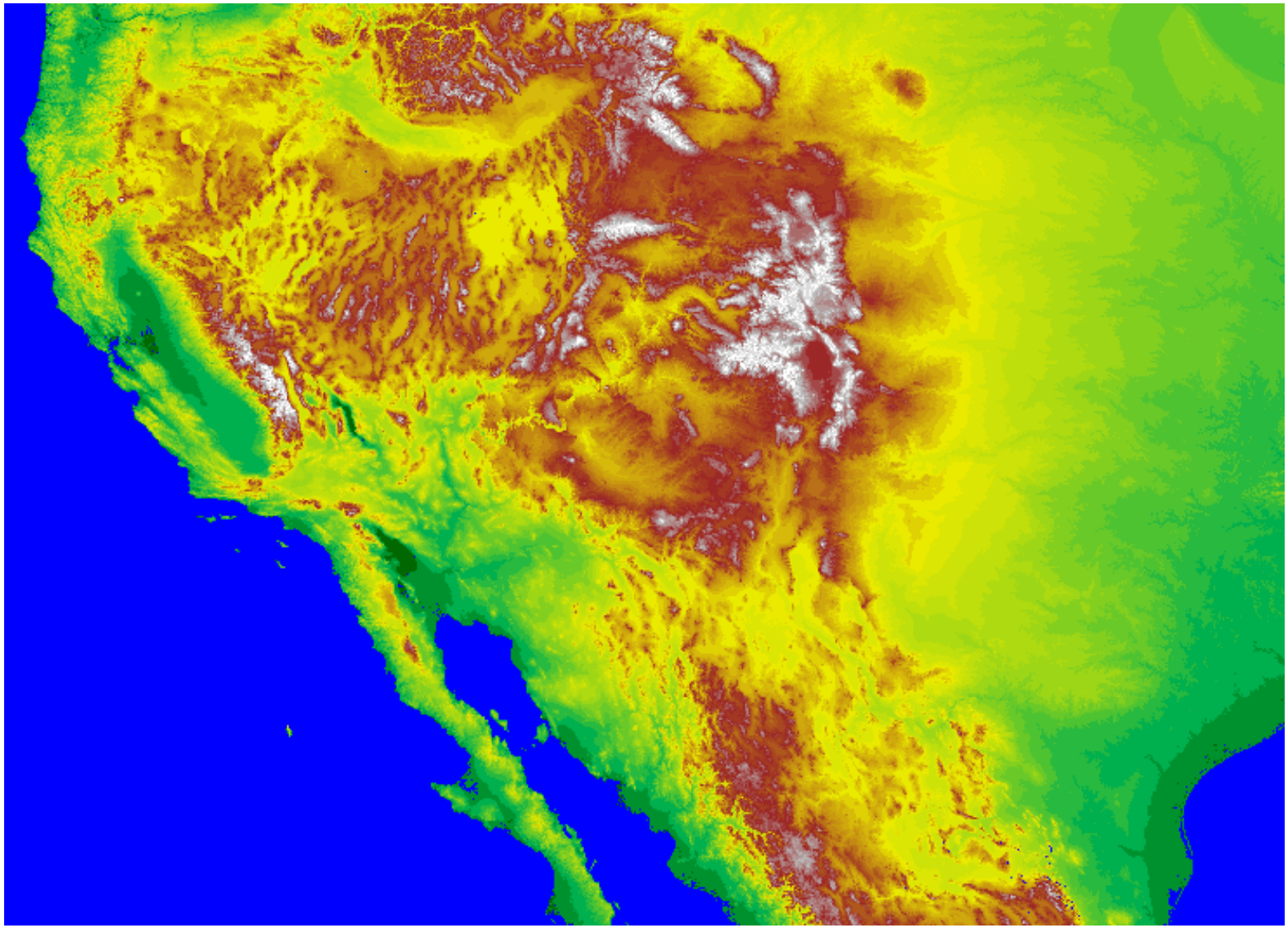
- AMSR-E soil moisture data
- SRTM 90 meter terrain data
- MOD12 Land Cover 1 km resolution
- Look-up table based on MOD12 land cover, 1 km resolution

# Replacing w/ Higher Resolution Elevation Data



# Level-1 (90m)SRTM Data for DREAM Domain

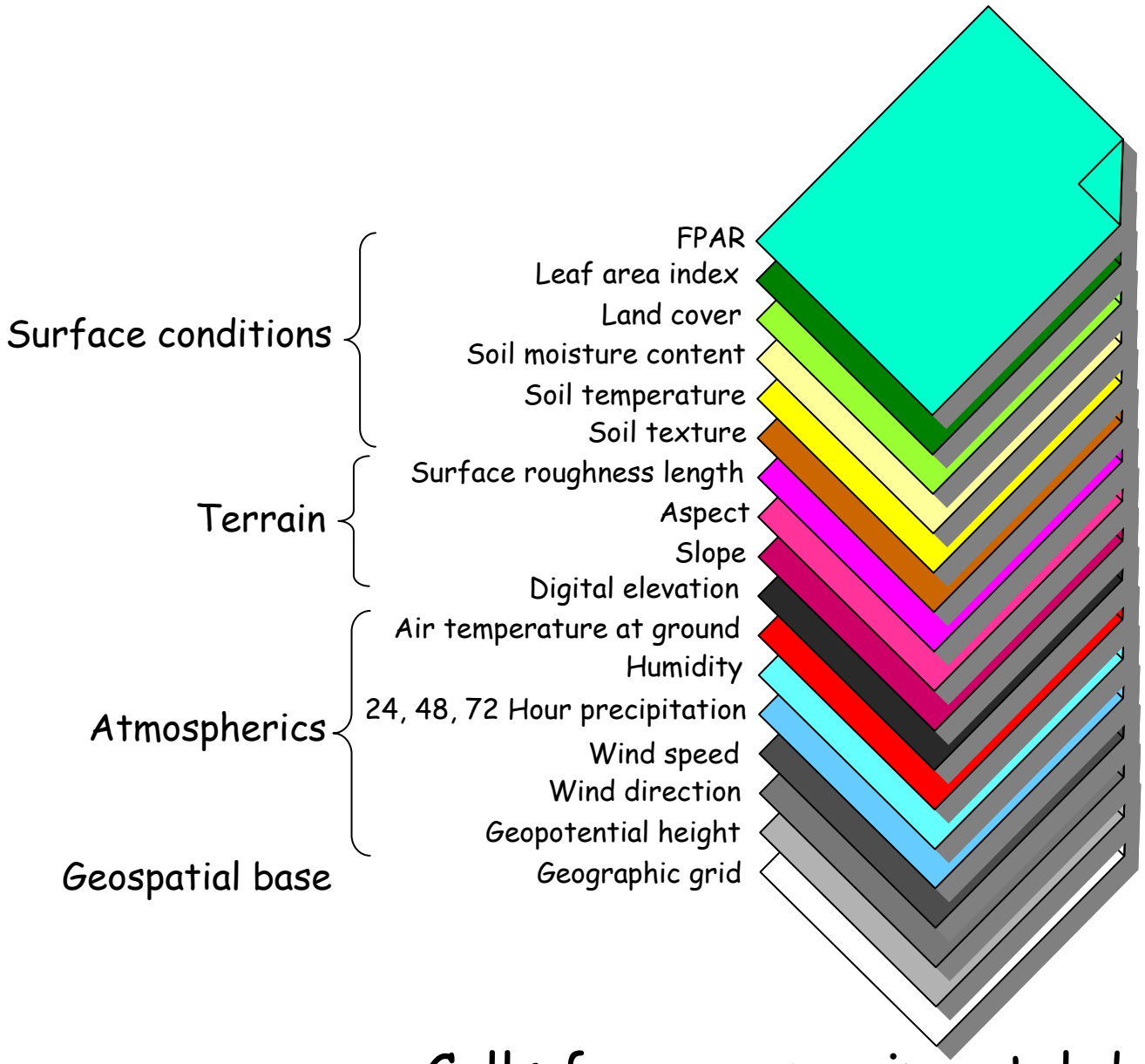
Large voids have been filled using GTOPO30 Data; small ones w/ a 5x5 filter



# 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.

Calls for an experimental design

# Possible Experimental Design
## V&V each model run in each iteration & Benchmark

- MOD 12 Land Cover
- SRTM Elevation
- AMSR-E Soil Moisture
- Surface Roughness Length from MOD12
- MOD11 Soil Temperature
- AMSU-A Humidity

Iteration III

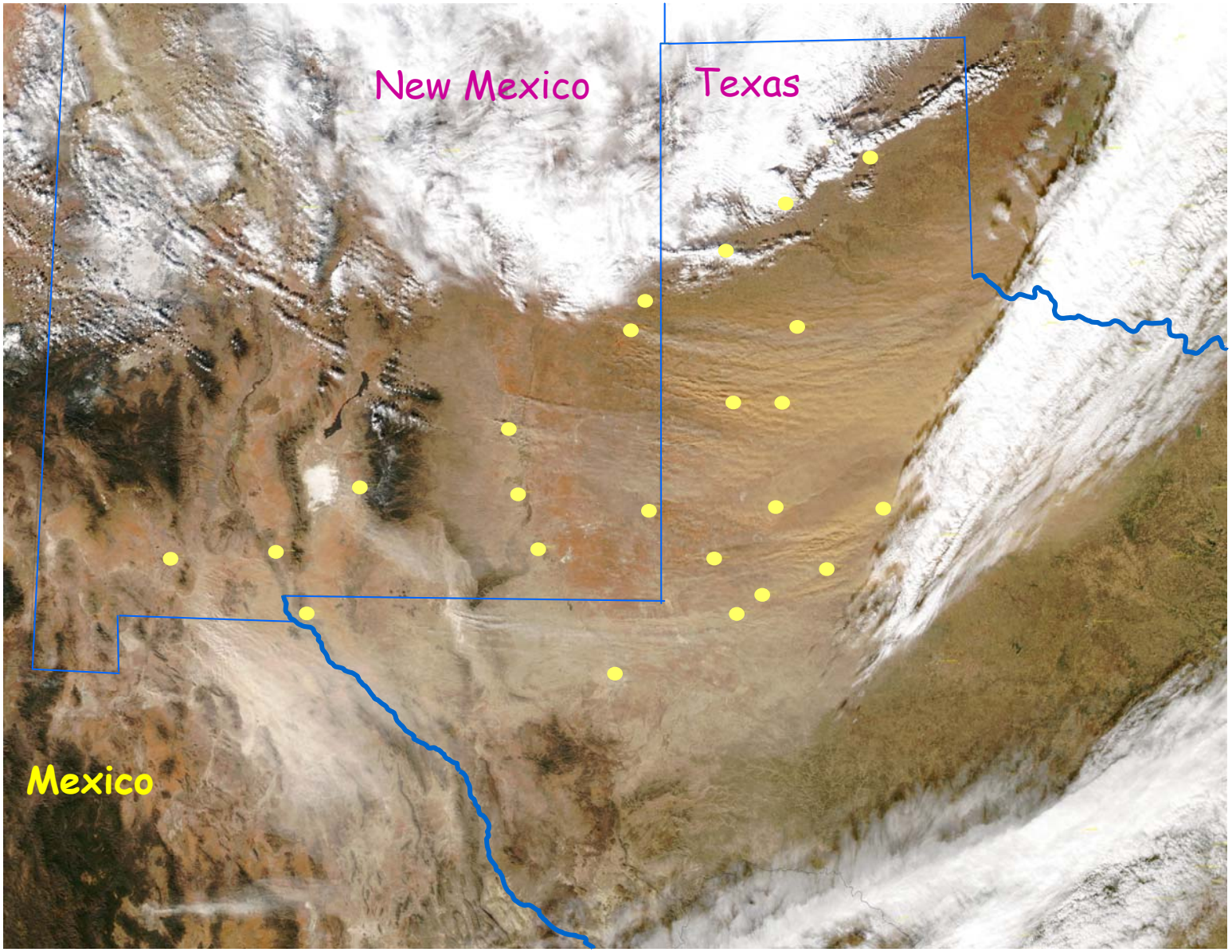
| | | | |
|---|---|---|---|
| 1,2,3 | 2,3,4 | 3,4,5 | 4,5,6 |
| 1,2,4 | 2,3,5 | 3,4,6 | |
| 1,2,5 | 2,3,6 | | |
| 1,2,6 | | | |

Altogether 41 model runs

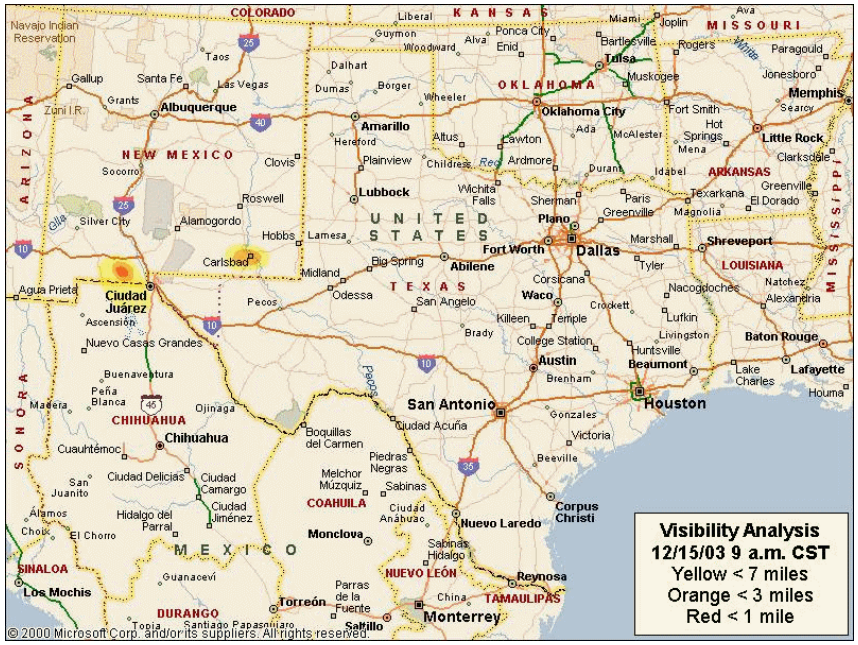
- Iteration I: Replace six parameters, 1 at a time (= 6)
- Iterations II: 2 parameters sequentially (= 15)
- Iteration III: 3 parameters sequentially (= 10)
- Iteration IV: 4 parameters sequentially (= 6)
- Iteration V: 5 parameters sequentially (= 3)
- Iteration VI: 6 parameters taken together (= 1)

Need to automate statistical analysis procedure

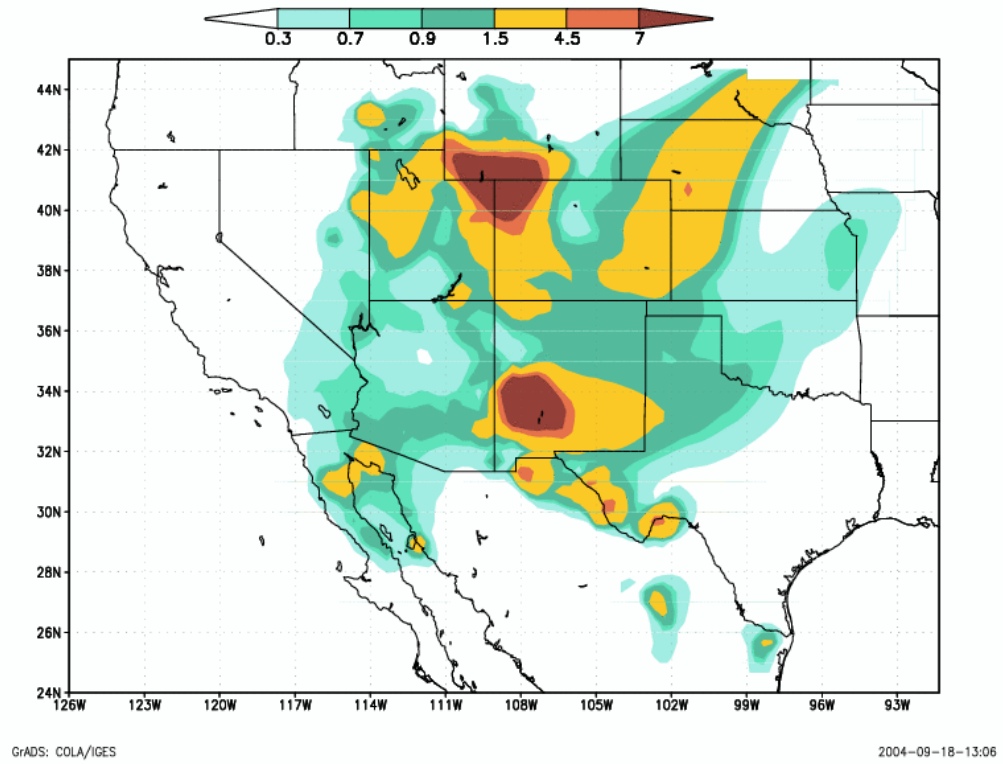
# New Mexico/Texas Dust Storm – Dec 2003



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




Texas
Continuous Air Monitoring Stations




DREAM Baseline (no EO data included)

# Planned Replacements & Refinements

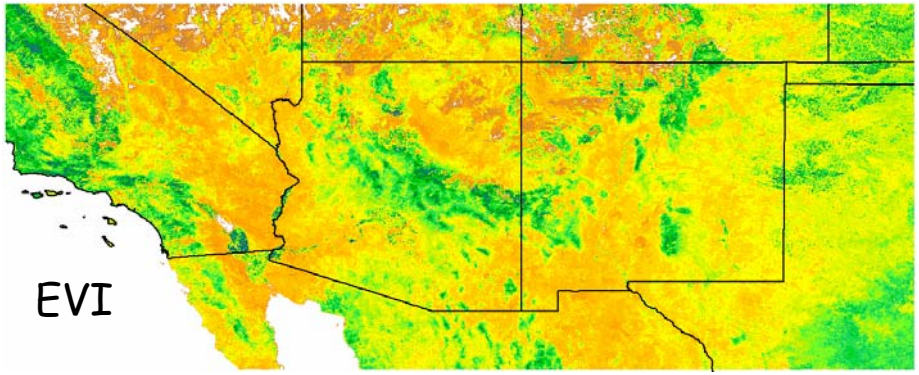
## Now

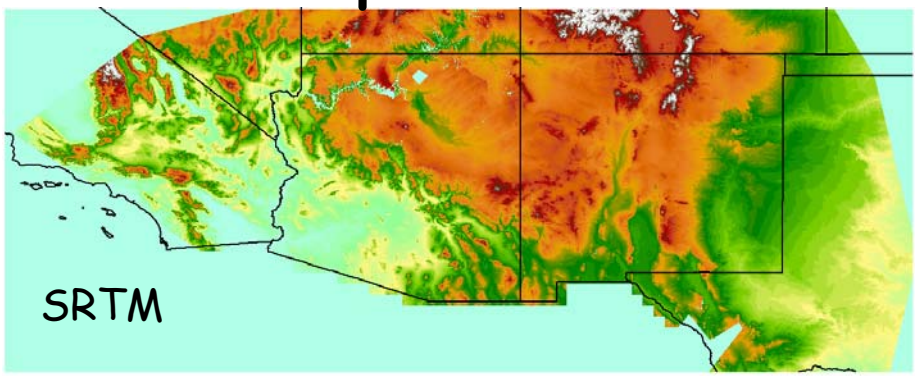
- SRTM Level-1 90m Elv
- MOD12 Land Cover
- NCEP/ETA Hydrostatic
- NWS Humidity
- Soil Temperature
- NCEP Precipitation
- Aerodynamic Roughness

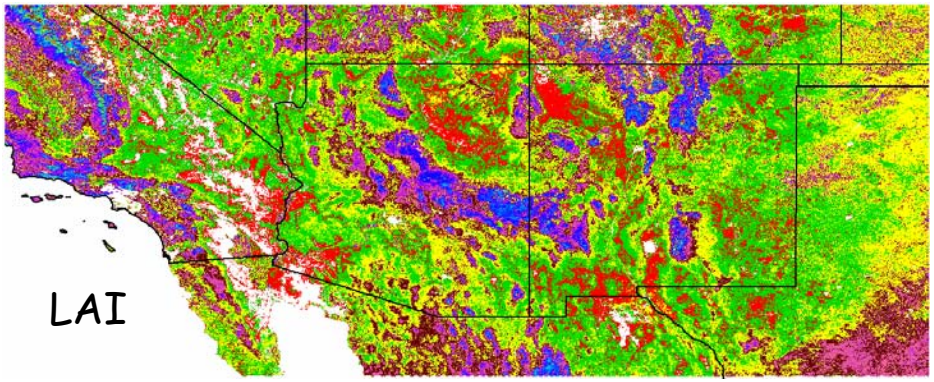
## Later

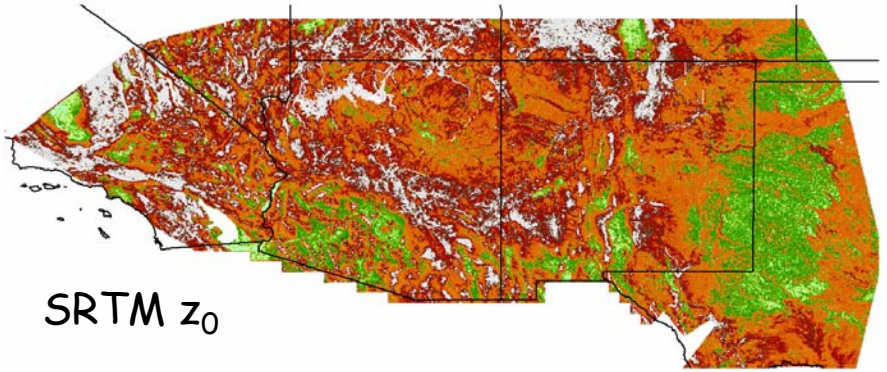
- ASTER AST14 Elevation
- MOD15 LAI and FPAR
- NCEP/NMM Non-Hydro
- AMSU-A Humidity
- MOD11 Soil Temp
- TRMM 5-day Rain Map
- ???

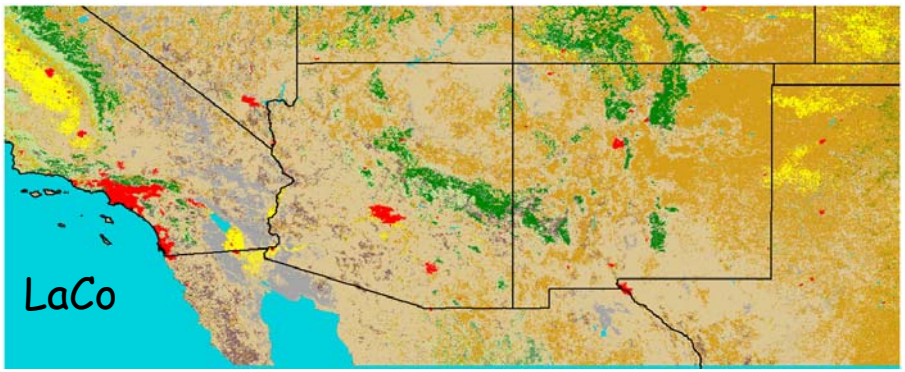
# Visualization of Candidate Replacements

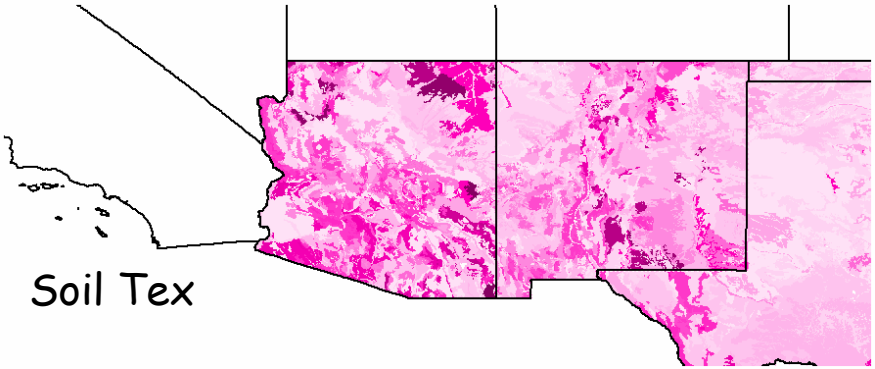


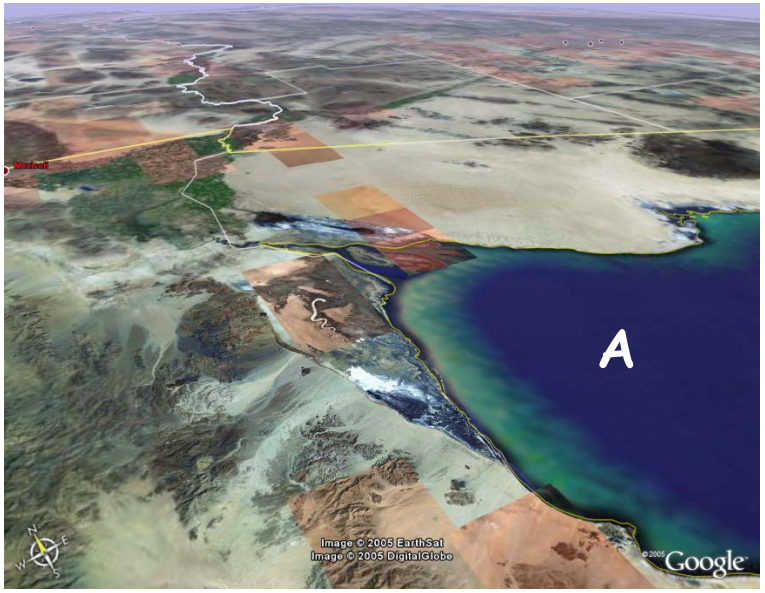



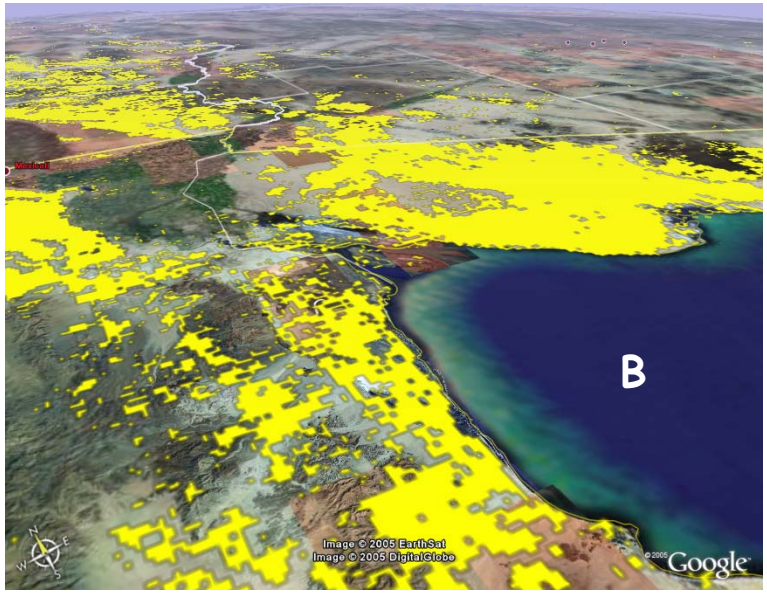



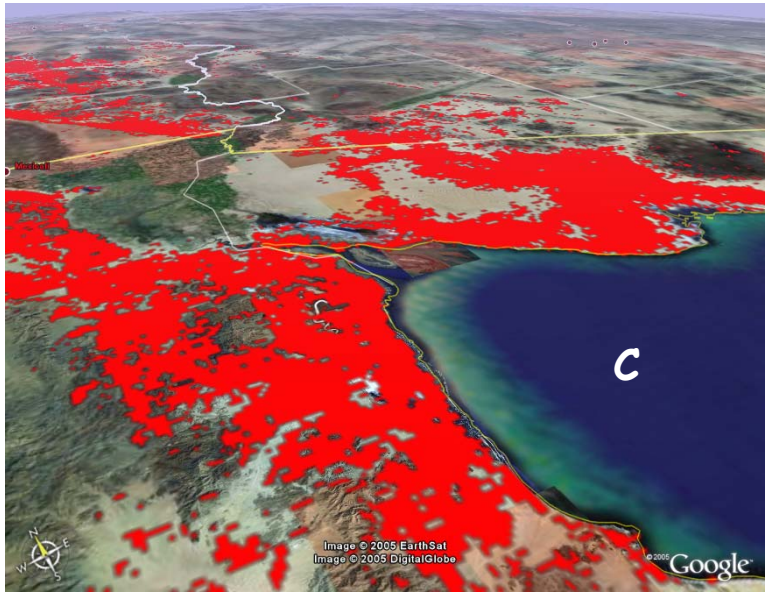



# Comparison of 3 EO Products. B and C are Fused with A

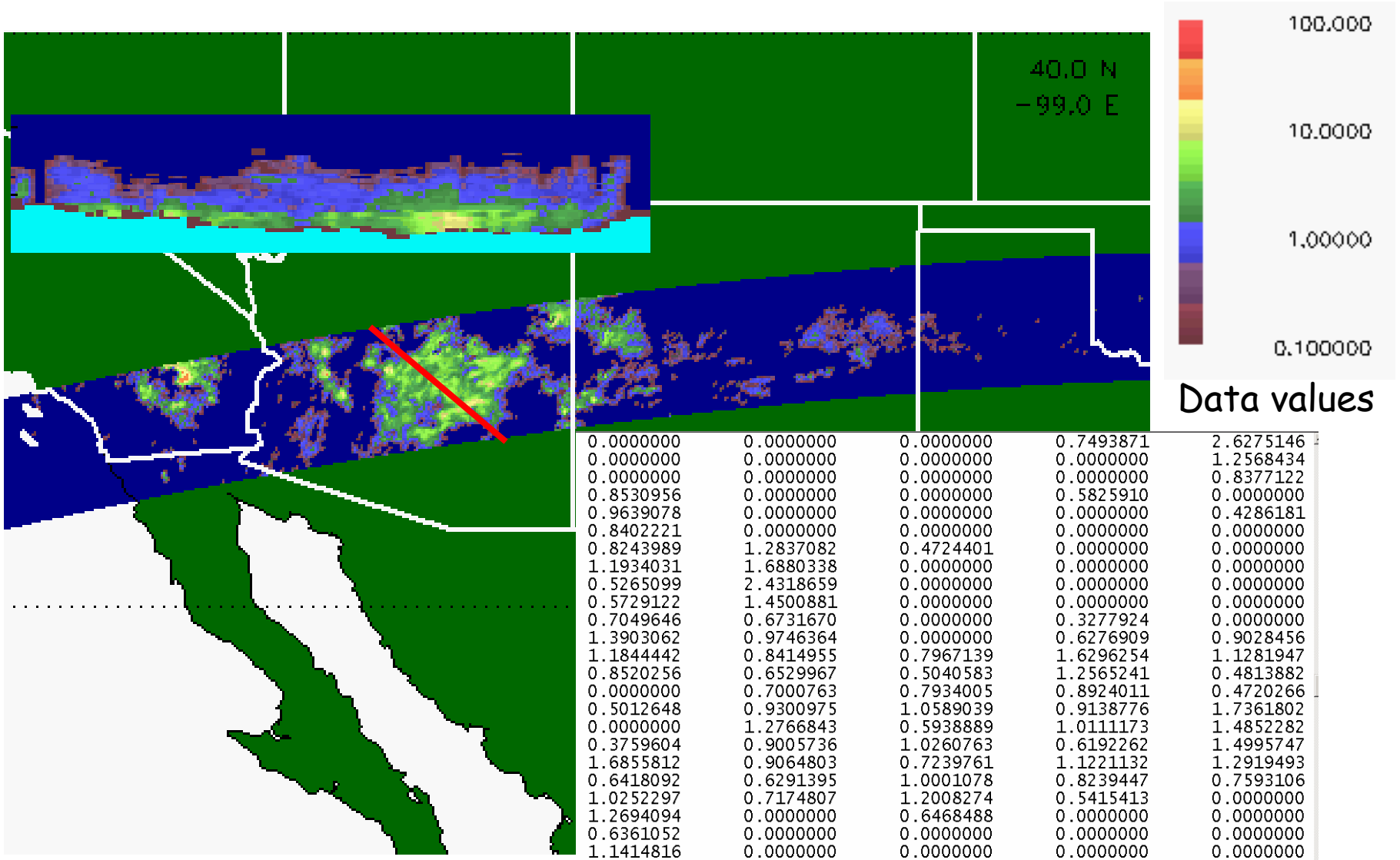



(A) Head, Sea of Cortez, ©DigitalGlobe; (B) MOD12 – Land Cover IGBP Class 16 – "Barren or Sparsely Vegetated; (C) MOD 15 – FPAR fill class 253 – "Barren, desert, or very sparsely vegetated".

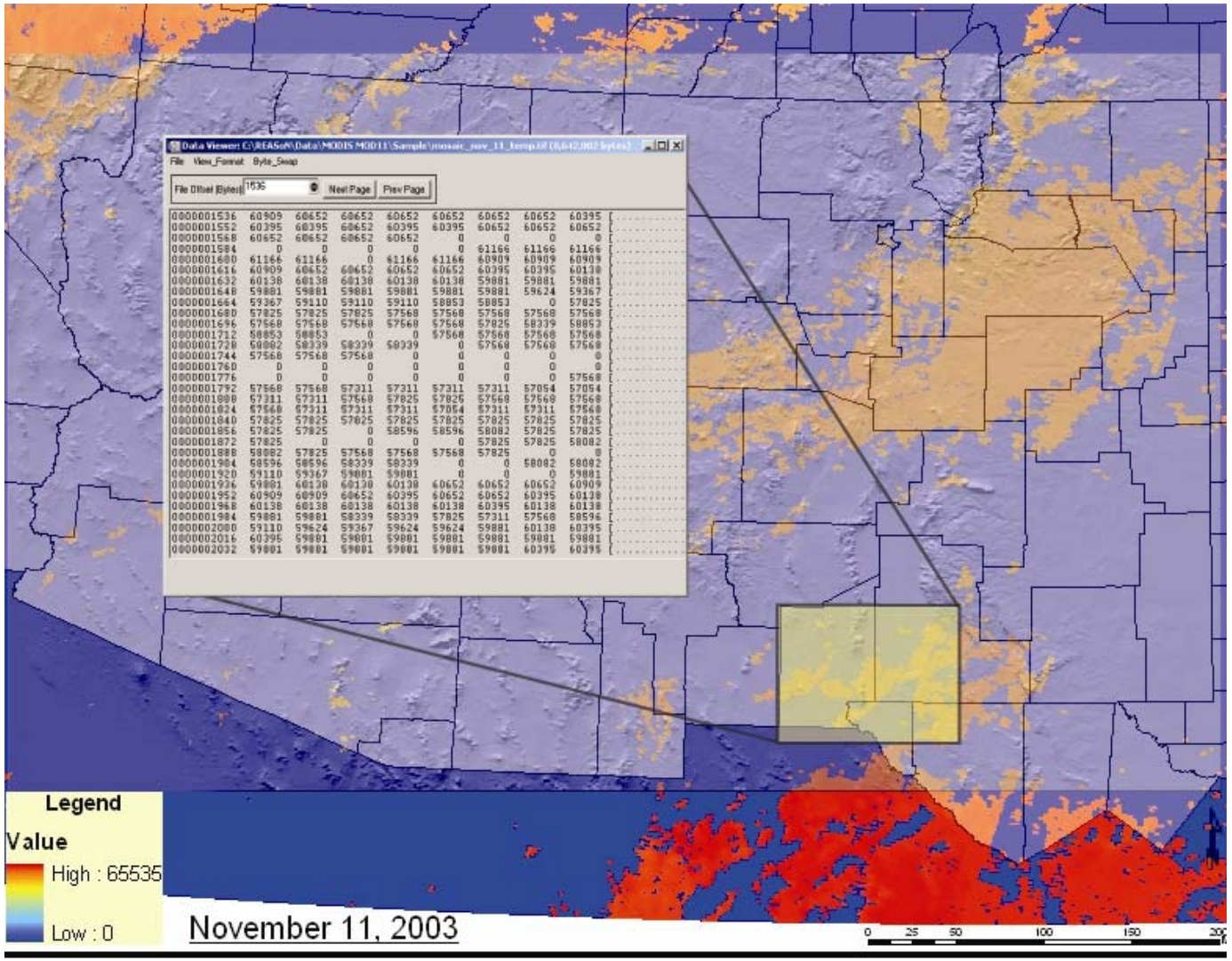
# TRMM PR 2A25 Surface Rain Rate 11/12/03



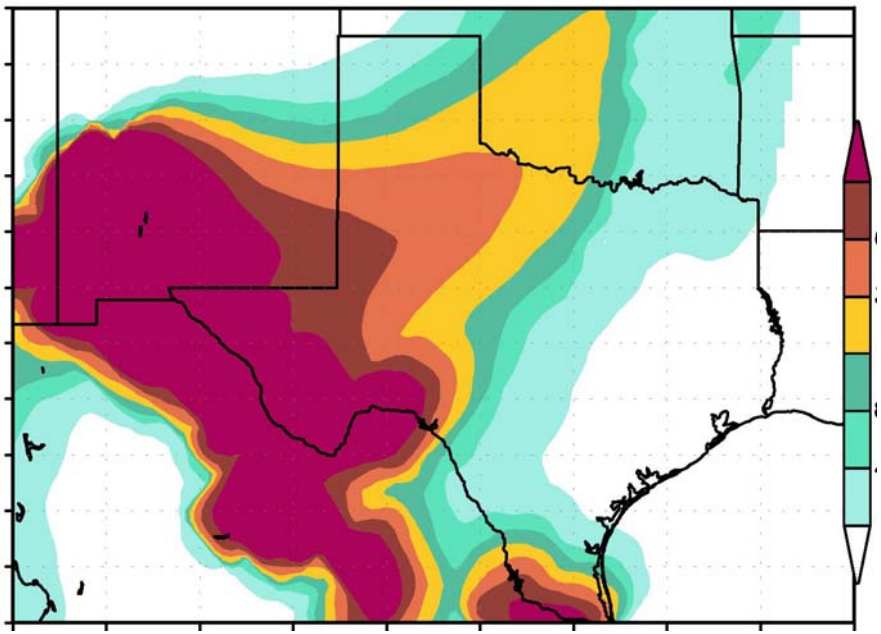

Data values

| | | | | |
|---|---|---|---|---|
| 0.0000000 | 0.0000000 | 0.0000000 | 0.7493871 | 2.6275146 |
| 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 1.2568434 |
| 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.8377122 |
| 0.8530956 | 0.0000000 | 0.0000000 | 0.5825910 | 0.0000000 |
| 0.9639078 | 0.0000000 | 0.0000000 | 0.0000000 | 0.4286181 |
| 0.8402221 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| 0.8243989 | 1.2837082 | 0.4724401 | 0.0000000 | 0.0000000 |
| 1.1934031 | 1.6880338 | 0.0000000 | 0.0000000 | 0.0000000 |
| 0.5265099 | 2.4318659 | 0.0000000 | 0.0000000 | 0.0000000 |
| 0.5729122 | 1.4500881 | 0.0000000 | 0.0000000 | 0.0000000 |
| 0.7049646 | 0.6731670 | 0.0000000 | 0.3277924 | 0.0000000 |
| 1.3903062 | 0.9746364 | 0.0000000 | 0.6276909 | 0.9028456 |
| 1.1844442 | 0.8414955 | 0.7967139 | 1.6296254 | 1.1281947 |
| 0.8520256 | 0.6529967 | 0.5040583 | 1.2565241 | 0.4813882 |
| 0.0000000 | 0.7000763 | 0.7934005 | 0.8924011 | 0.4720266 |
| 0.5012648 | 0.9300975 | 1.0589039 | 0.9138776 | 1.7361802 |
| 0.0000000 | 1.2766843 | 0.5938889 | 1.0111173 | 1.4852282 |
| 0.3759604 | 0.9005736 | 1.0260763 | 0.6192262 | 1.4995747 |
| 1.6855812 | 0.9064803 | 0.7239761 | 1.1221132 | 1.2919493 |
| 0.6418092 | 0.6291395 | 1.0001078 | 0.8239447 | 0.7593106 |
| 1.0252297 | 0.7174807 | 1.2008274 | 0.5415413 | 0.0000000 |
| 1.2694094 | 0.0000000 | 0.6468488 | 0.0000000 | 0.0000000 |
| 0.6361052 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| 1.1414816 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| 1.0768880 | 0.7671593 | 0.0000000 | 0.0000000 | 0.0000000 |
| 0.0000000 | 0.7284701 | 0.0000000 | 0.0000000 | 0.0000000 |
| 1.1762154 | 1.0518624 | 1.1717046 | 0.0000000 | 0.0000000 |

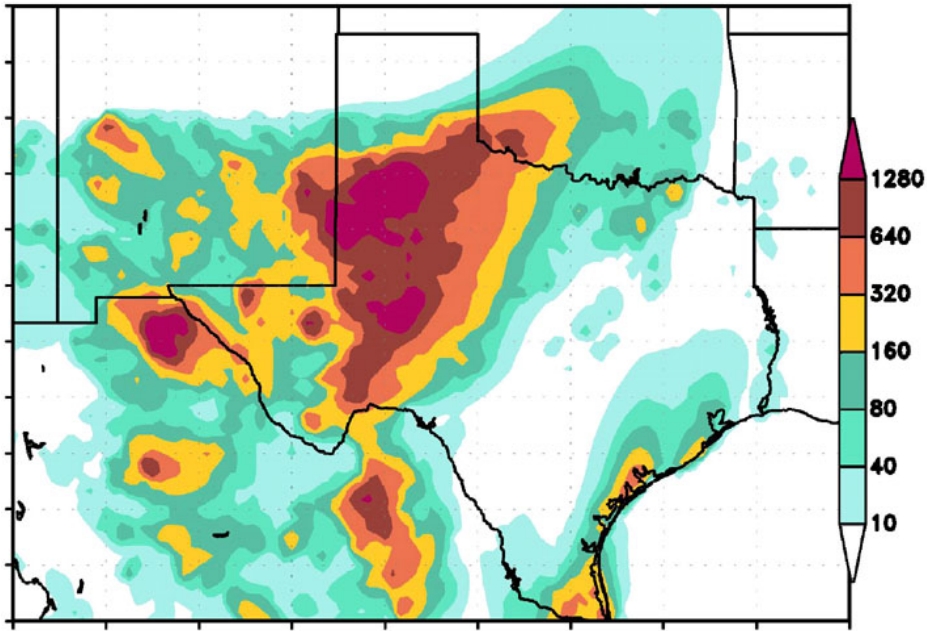
# TERRA/MODIS MOD11A1 Land Surface Temperature/Emissivity-Daily 1-km



# Comparison of DREAM Dust Concentrations at 20Z 15 Dec 03



Static Surface Inputs




EO Surface Inputs

# 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**<br>4.37 | **226.60**<br>230.38 | **275.56**<br>277.48 | $\frac{1}{N}\sum_{i=1}^{N} M_i$ |
| Mean bias | **-0.88**<br>-1.16 | **-4.80**<br>-1.02 | **-1.20**<br>0.72 | $\frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)$ |
| Mean error | **1.97**<br>2.03 | **51.76**<br>47.85 | **4.09**<br>2.67 | $\frac{1}{N}\sum_{i=1}^{N}\lvert M_i - O_i\rvert$ |
| Agreement index | **0.74**<br>0.75 | **0.74**<br>0.76 | **0.71**<br>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 values = before EO Data Assimilation
Red values = after EO Data Assimilation