Air Resources Laboratory

Conducting research and development in the fields of air quality, atmospheric dispersion, climate, and boundary layer

Towards an unified emission system for regional dust forecast in NOAA, USA

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Outline

- National dust forecasting service in the U.S.
- Upcoming NWP changes affect the service
- Multiple efforts in NOAA and other institutions
- Case studies and comparison
- Comparison of 4 emission scheme inlined in HRRR
- Summary and future work

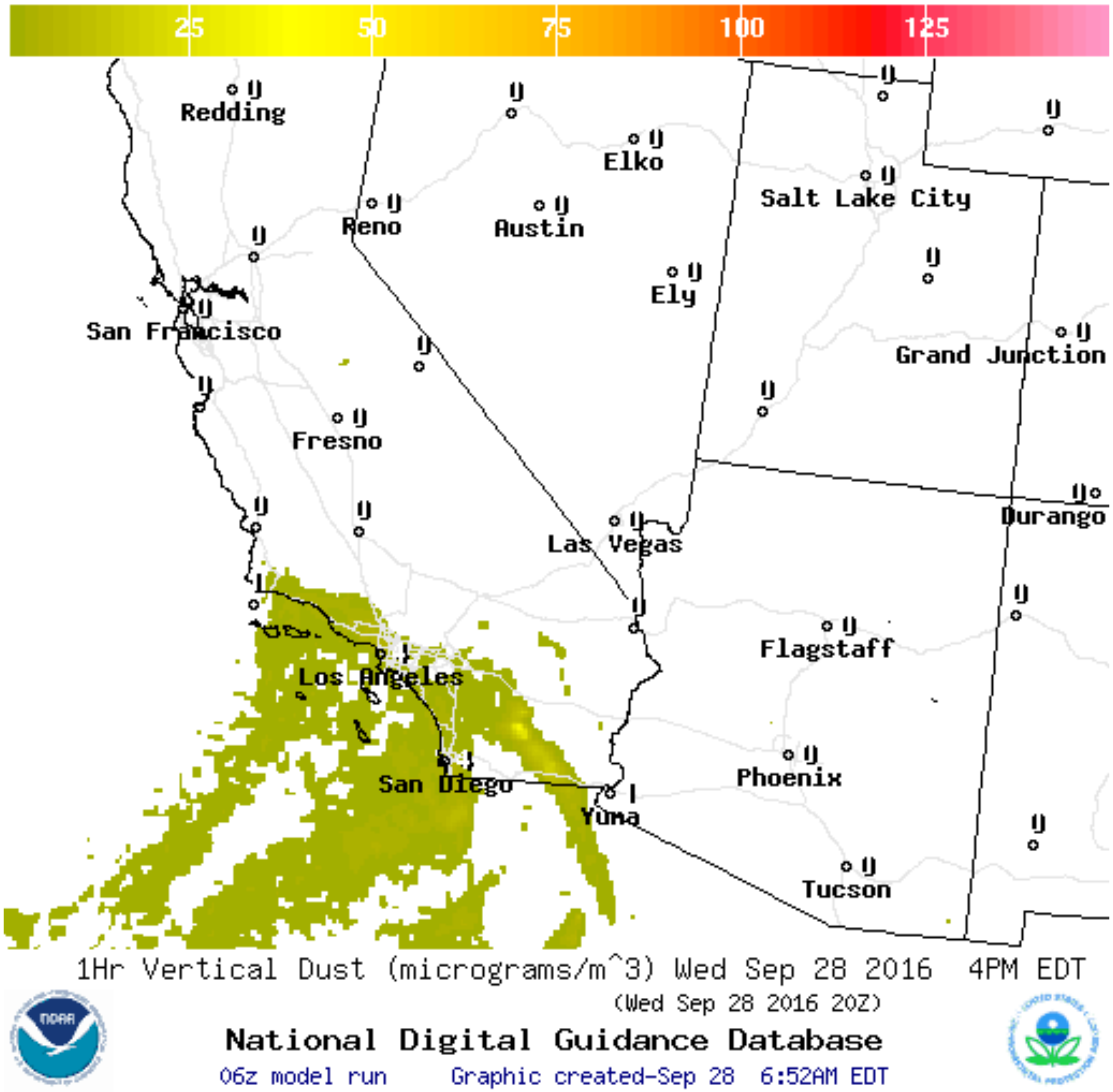
Dust Effects and Major Dust Sources

Dust Effects

1) Clouds and precipitation
2) Radiative energy balance
3) Atmospheric composition and chemistry
4) Major biogeochemical cycles
5) Ecosystem functioning
6) Socioeconomic systems and human well-being

Major Dust Sources

http://airquality.weather.gov/

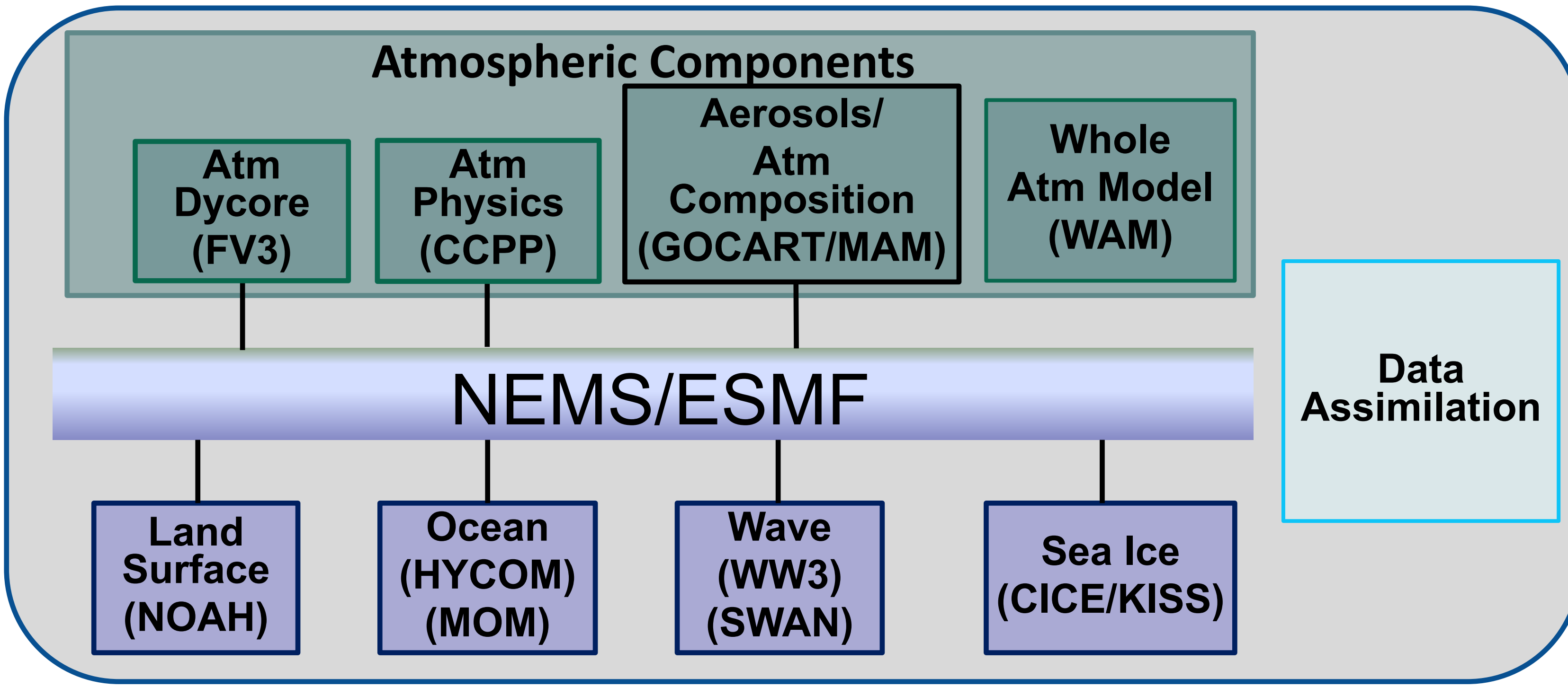


- Source regions with emission potential estimated from MODIS deep blue climatology for 2003-2006 (Ginoux et al. JGR 2010)
- Emissions modulated by real-time soil moisture.
- HYSPLIT model for transport, dispersion and deposition (Draxler et al., JGR, 2010)

Next Generation Global Prediction System (NGGPS)

- Global atmospheric prediction model with non-hydrostatic scalable dynamics
- Improve data assimilation and physics
- Position NWS for next generation high performance computing
- Engage community in model/components development
- Reduce implementation time
- Provide World's Best Global Forecast Guidance

- Fully coupled system
- Built using NEMS/Earth System Modeling Framework
- Each component model will be community code

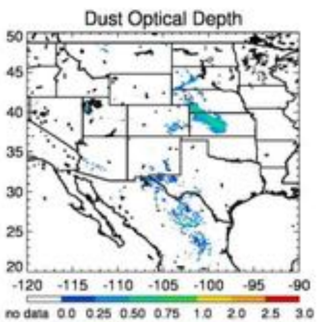


Contacts: Fred Toepfer and Ivanka Stajner

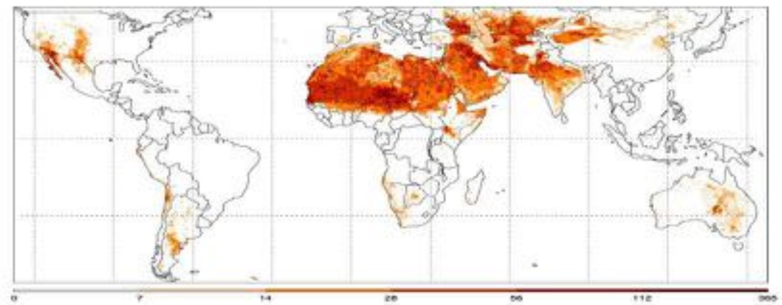
NOAA NGGPS project
PI: Paul Ginoux (NOAA GFDL)

1. Dust Sources Inventory

Dust detection using MODIS satellite at 0.1° resolution (~10 km) daily for 12 years (2003-2014). Dust source = location of the most frequent dust events (Ginoux et al., Rev. Geophys., 2012). Unique global high resolution dust sources inventory.



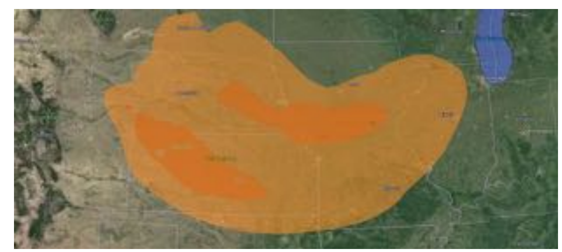
One granule of satellite pixels at a time from regional to global, daily and for 12 years of newly released MODIS data →



2. Dust Simulation/forecasting

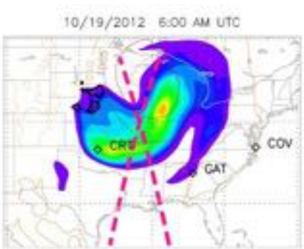
Dust simulation with NMMB for one year (2012), global and CONUS (high resolution)

Dust events are frequent in the High Plains, creating deadly accident, shutting Interstate Highways, such as in October 2012. →

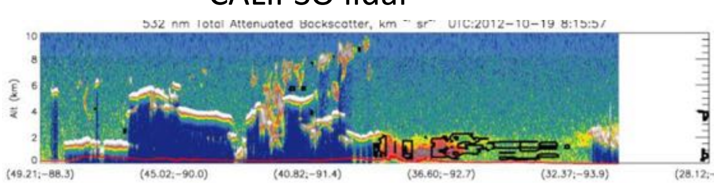


3. Model Evaluation

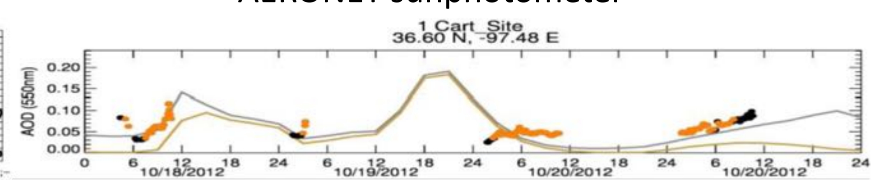
Evaluation and skill scores using ground-based and satellite data



CALIPSO lidar



AERONET sunphotometer

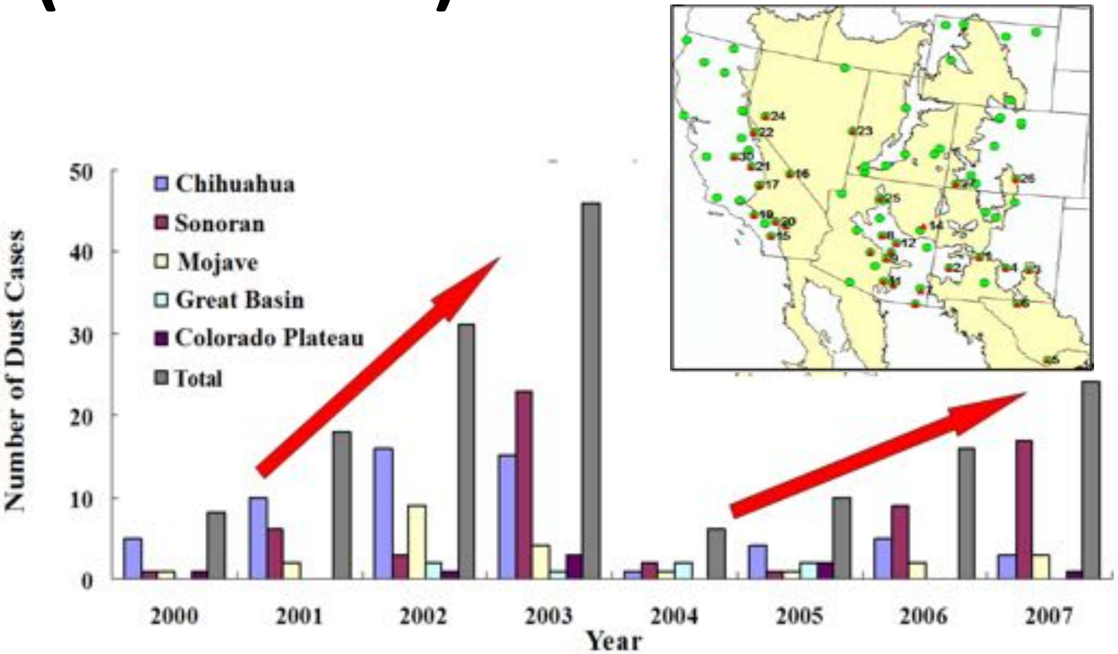


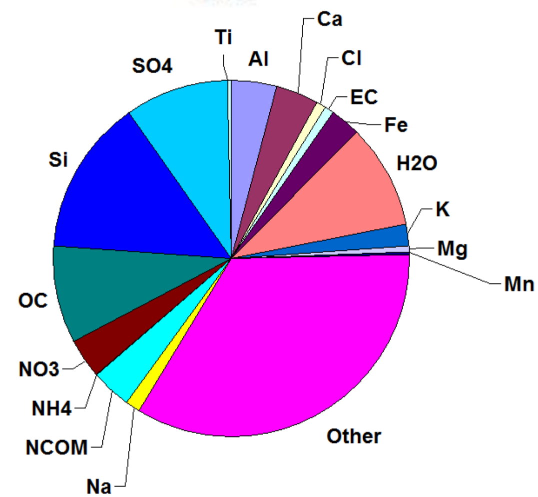
Dust Records over the western US (2000-2007)

Table 1. Identified local dust events from the IMPROVE monitoring network from 2000 to 2007. The concentrations and ratios listed in the table represent the mean values if there is more than one identified dust episode.

Site	SiteID	Longitude	Latitude	PM_{10} (mg m^{-3})	$PM_{2.5}$ (mg m^{-3})	$PM_{2.5}$/PM_{10} Ratio	Local Dust Events (YYMMDD)
1	BOAP1	−106,85	33,87	42,44	6,99	0,16	011016
2	GICL1	−108,24	33,22	35,59	7,71	0,22	070328
3	SACR1	−104,4	33,46	72,15	15,95	0,22	010410, 010925, 030415, 030602, 030601, 031226, 050311, 051203, 060312, 060619, 060622, 071114
4	WHIT1	−105,54	33,47	89,55	20,42	0,23	020426, 060216
5	BIBE1	−103,18	29,3	53,25	12,36	0,24	000322, 000422, 000921, 010309, 011124, 020216, 020308, 020312, 020330, 020402, 020616, 021110, 030328, 030406, 030413, 051127
6	GUMO1	−104,81	31,83	73,2	15,63	0,22	000422, 000517, 010422, 010603, 010624, 010713, 011016, 020309, 020420, 020502, 020511, 020528, 020610, 020613, 020618, 030202, 030304, 030415, 030418, 030515, 030723, 031208, 031226, 040608, 051127, 060318, 070223
7	CHIR1	−109,39	32,01	73,34	17,05	0,24	000408, 011109, 030521, 030717, 051127, 060601, 060714, 061222, 070328
8	IKBA1	−111,68	34,34	62,53	18,76	0,29	010621, 020314, 030515, 030521, 030530, 030726, 040603, 070412, 070720
9	QUVA1	−111,29	33,29	61,2	13,64	0,22	011016, 020426, 020514, 030302, 030515, 030521, 030617, 030620, 030714, 030717, 030908, 041021, 060216, 060414, 060716, 060725, 070418, 070708, 071018
10	SAGU1	−110,74	32,17	57,79	18,13	0,31	011109, 030521, 030717, 060625, 070328, 070412
11	SAWE1	−111,22	32,25	75,59	20,23	0,25	011108, 030521, 030711, 030717, 030908, 070328, 070412, 070415, 070523
12	SIAN1	−110,94	34,09	59,6	17,22	0,3	011016, 030515, 030530, 070412, 060716
13	TONT1	−111,11	33,65	61,6	13,89	0,23	060716, 070412, 070708, 070720, 071006
14	PEFO1	−109,769	35,07	55,4	13	0,24	030508, 050404,050419
15	AGTI1	−116,97	33,46	72,46	13,69	0,19	010817, 021125, 030106, 070412
16	DEVA1	−116,85	36,51	60,95	12	0,19	030508, 030613, 030520, 040903, 061228
17	DOME1	−118,14	35,73	65,6	6,86	0,1	31030
18	JOSH1	−116,39	34,07	69,58	15,97	0,27	000812, 011001, 020731, 030819, 050802, 060625
19	SAGA1	−118,03	34,3	45,12	6,43	0,14	21002
20	SAGO1	−116,91	34,19	71,09	10,97	0,16	021125, 070412, 070521
21	SEQU1	−118,83	36,49	78,61	10,06	0,16	020710, 031030
22	HOOV1	−119,18	38,09	140,29	45,76	0,31	20228
23	GRBA1	−114,22	39,01	104,62	18,85	0,18	20228
24	WARI1	−118,82	38,95	70,39	12,85	0,19	030821, 040310, 040903, 050916, 050922
25	DVOA1	−112,13	38,08	107,08	32,39	0,3	70720
26	GRSA1	−105,52	37,72	51,28	11,3	0,23	000517, 020511, 030503, 050603
27	MEVE1	−108,49	37,2	65,2	13,68	0,22	030202, 030415, 050419
28	DOUG1	−109,54	31,35	81,27	21,2	0,26	070328 ,071108
29	PHOE1	−112,1	33,5	78,82	15,93	0,21	011016, 020511, 020722, 030817, 030302, 030515, 030530, 030714, 030717, 030908, 060403, 060414, 060625, 070412, 070720
30	FRES1	−119,77	36,78	88,88	16,85	0,19	040815, 060814, 060929, 061026, 070912

Monitor-based Dust Records

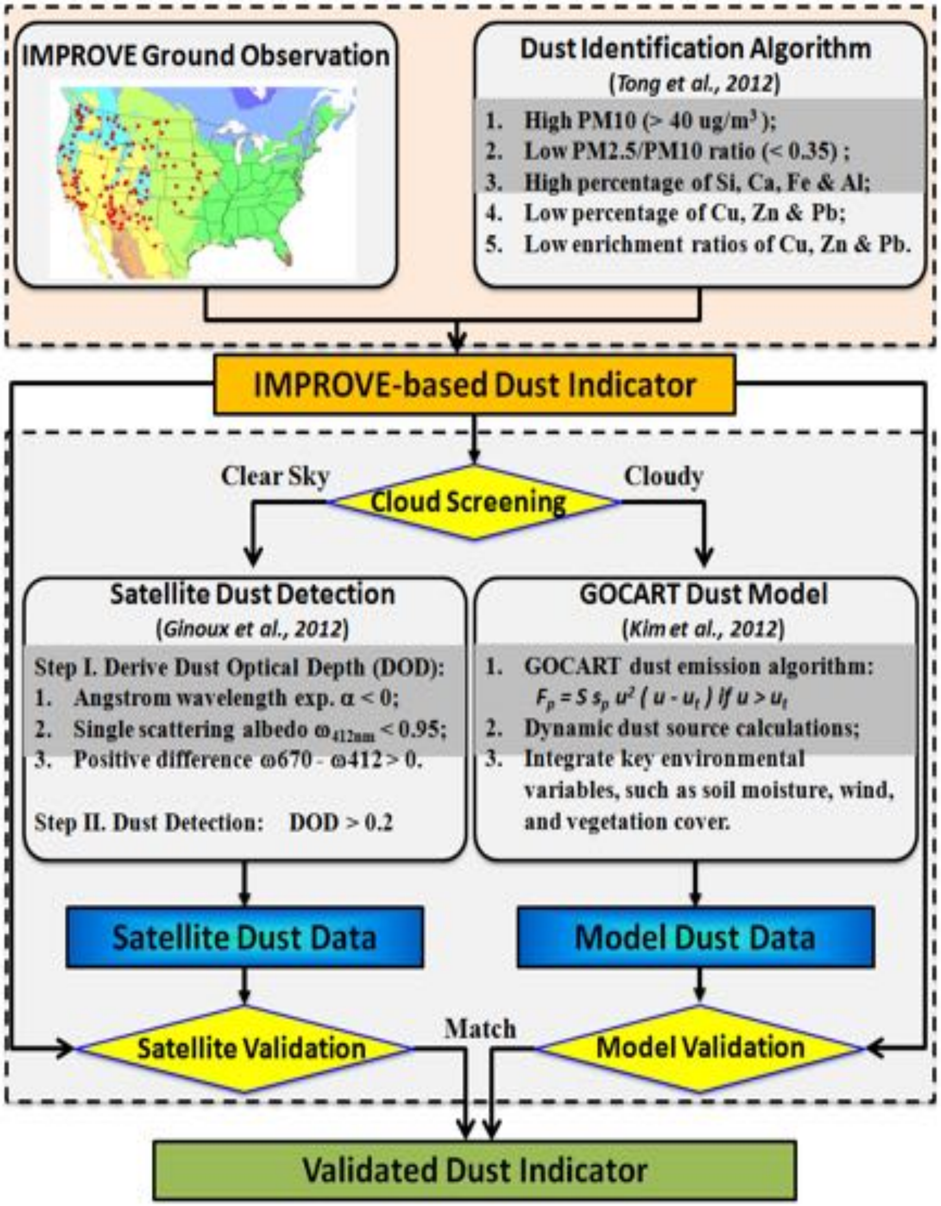




Dust Chemical Profile

(source: Tong et al., *ACP*, 2012)

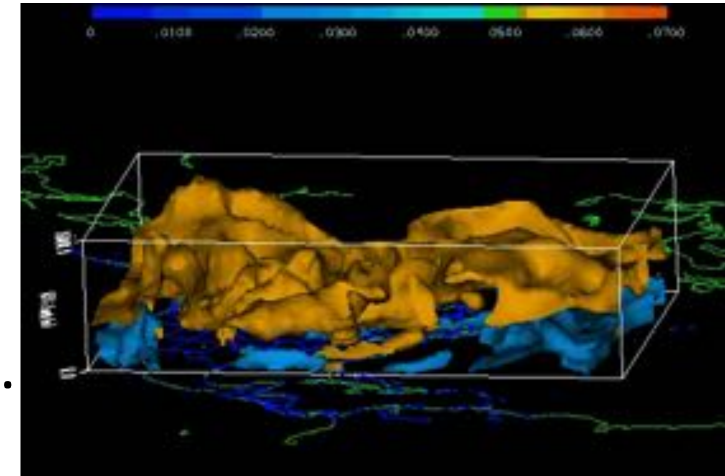
Dust indicator for climate assessment



- Collaboration between NOAA, NASA, UTEP and southwestern air quality districts.
- Extend Tong et al (2012) study to have a 30-year database of US dust activity
- Validation with more satellite products and model prediction.

Dust is sensitive to climate -- a good indicator of change.

CMAQ5.0.2 Windblown Dust Emission



(*http://www.cmaq-model.org*)

❖ **CMAQ (Community Multiscale Air Quality) model is the 3rd generation air quality model for EPA research and regulatory studies.**

❖ **> 1000 user groups world around.**

❖ **Dust is important for climate, air quality and more.**

❖ **CMAQ Dust module , based on a modified Owen's Equation (*source: Tong et al, 2012*):**

$$F = \sum_{i=1}^{M} \sum_{j=1}^{N} K \times A \times \frac{\rho}{g} \times S_i \times SEP \times u_* \times (u_*^2 - u_{*ti,j}^2)$$

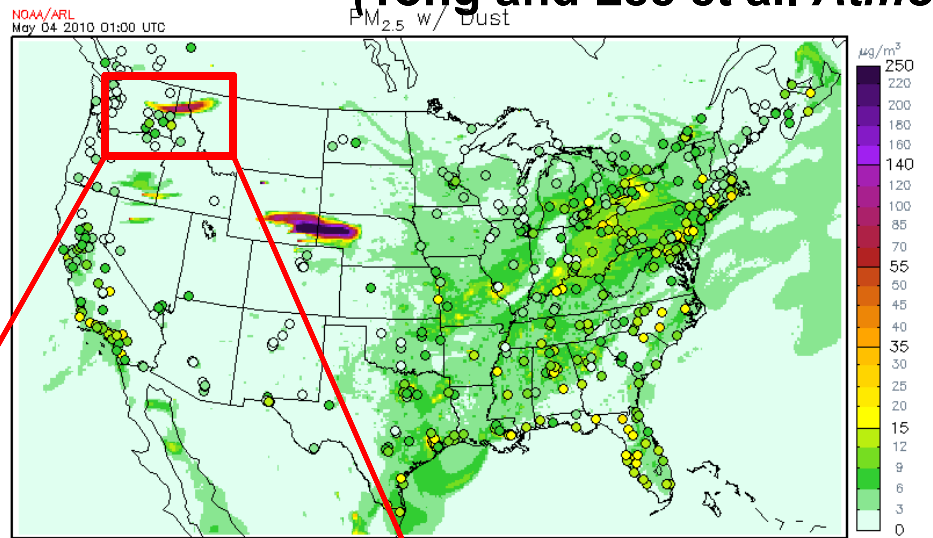
❖ **Effect of non-erodiable elements (Drag partition).**

❖ **Effects of rain and snow (*Fecan et al, 1999*):**

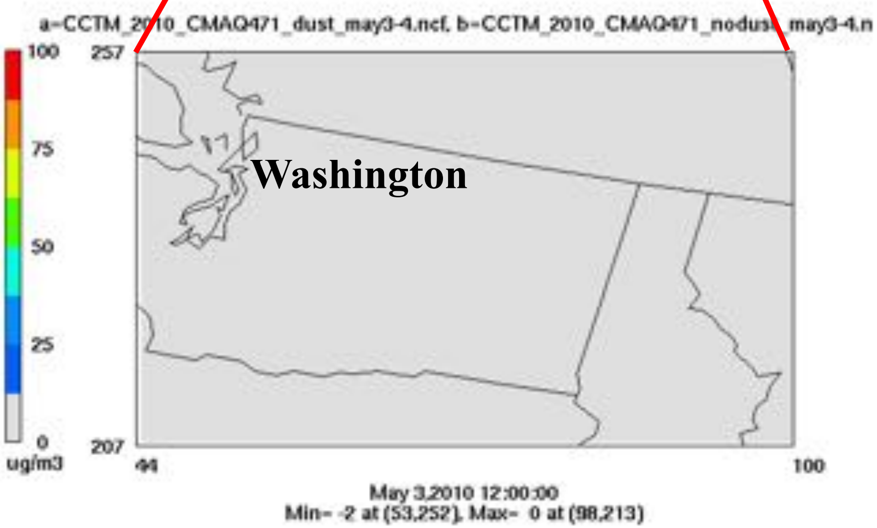
$$w' = 0.0014 * (\%clay)^2 + 0.17 * (\%clay)$$

CMAQ dust forecasting

(Tong and Lee et al. *Atmosphere* 2013)



Dust PM2.5 on May 3,2010



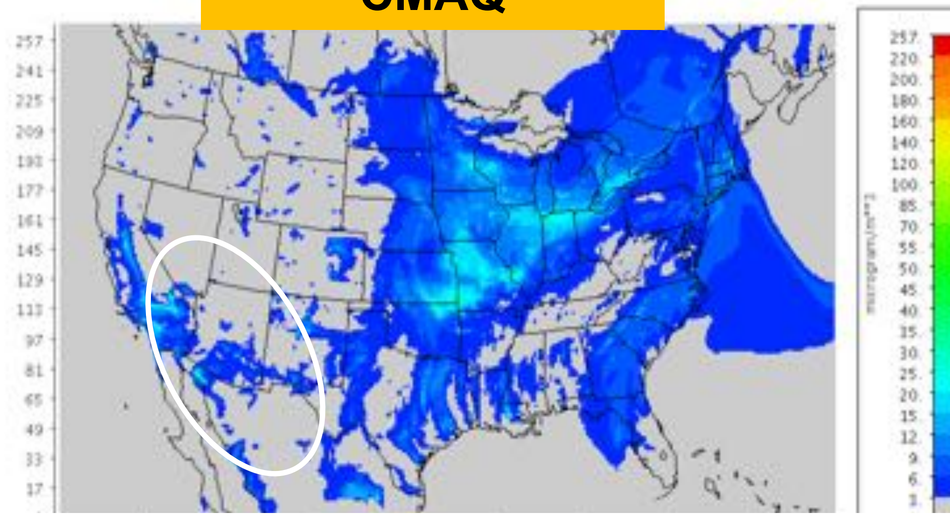
12:30 p.m, May 3,2010

--http://earthobservatory.nasa.gov/NaturalHazards

FENGSHA, CMAQ and MODIS on May 11, 2015

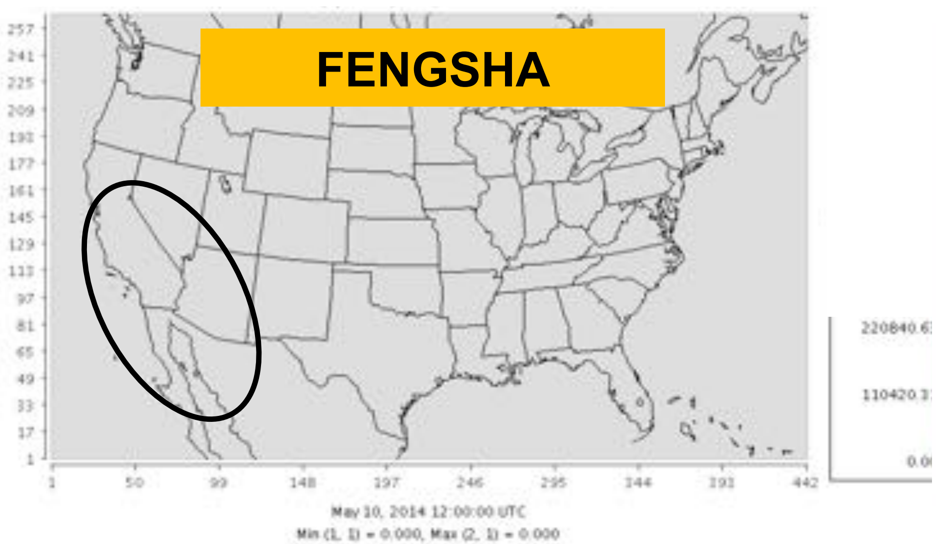
Satellite

CMAQ

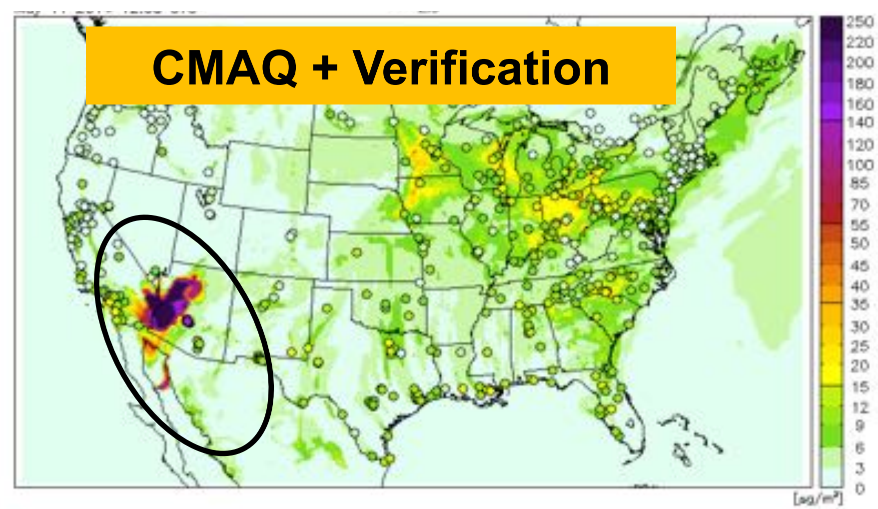


Modelled dust events are well consistent with satellite data.

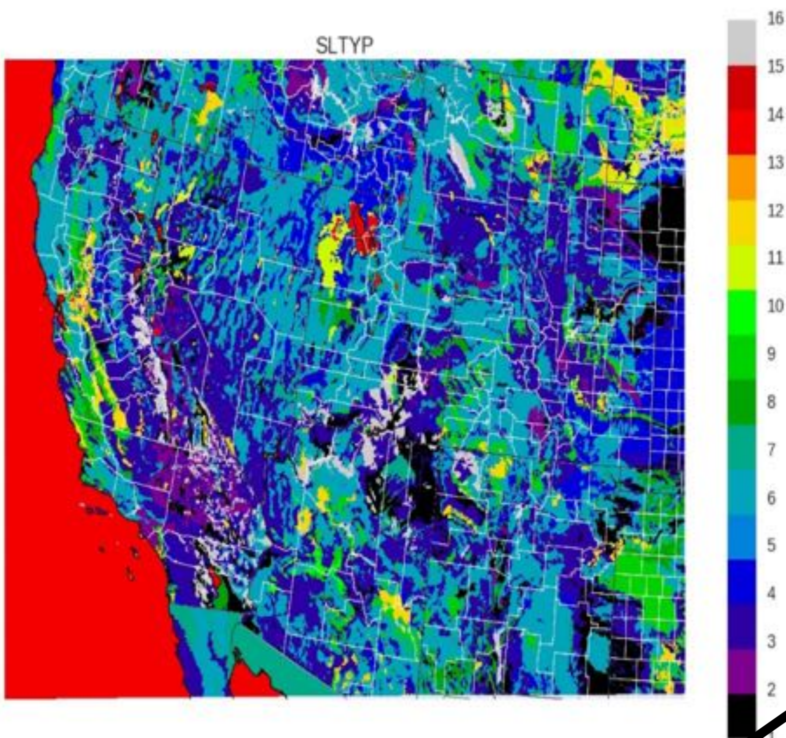
FENGSHA

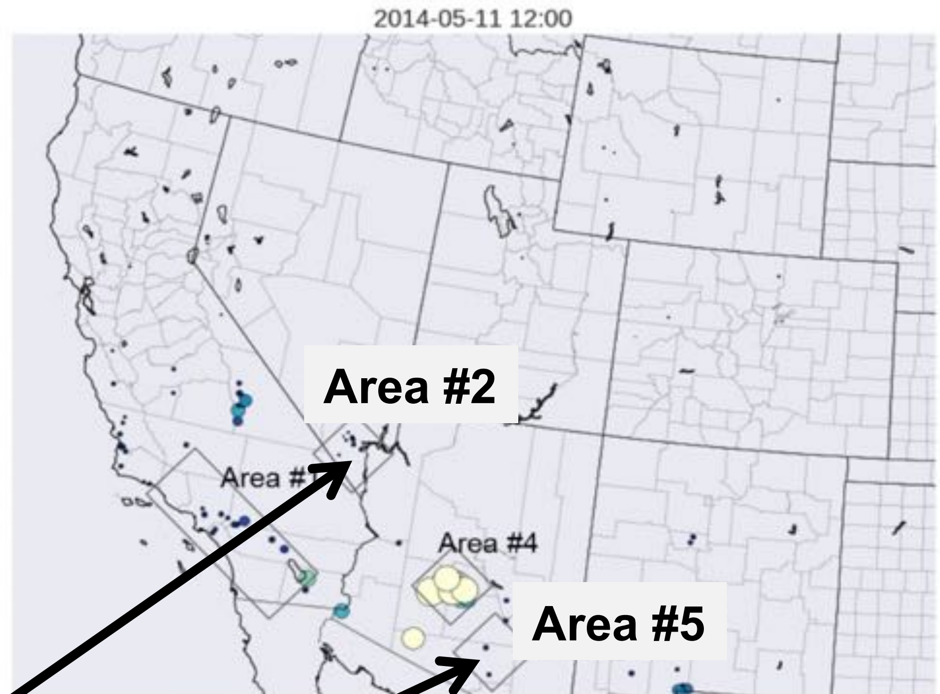


CMAQ + Verification



Option 1: HRRR meteorology with CMAQ5.0.2 dust model



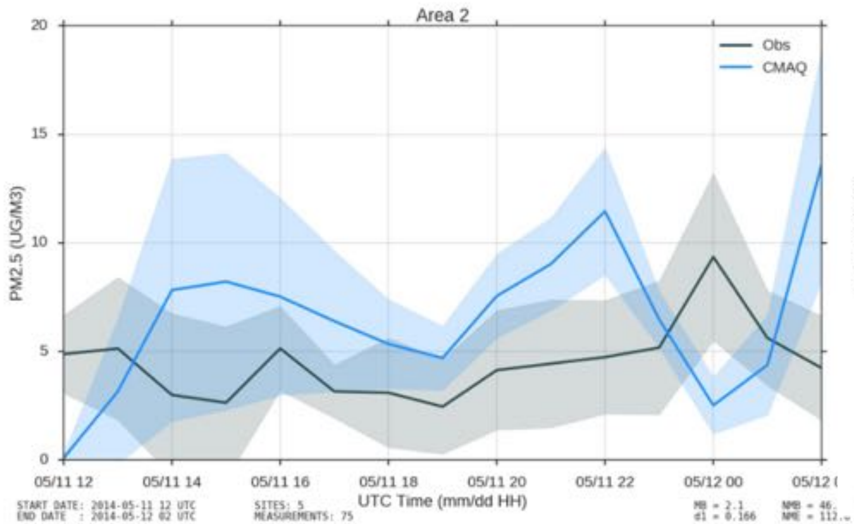


Soil type map used in HRRR

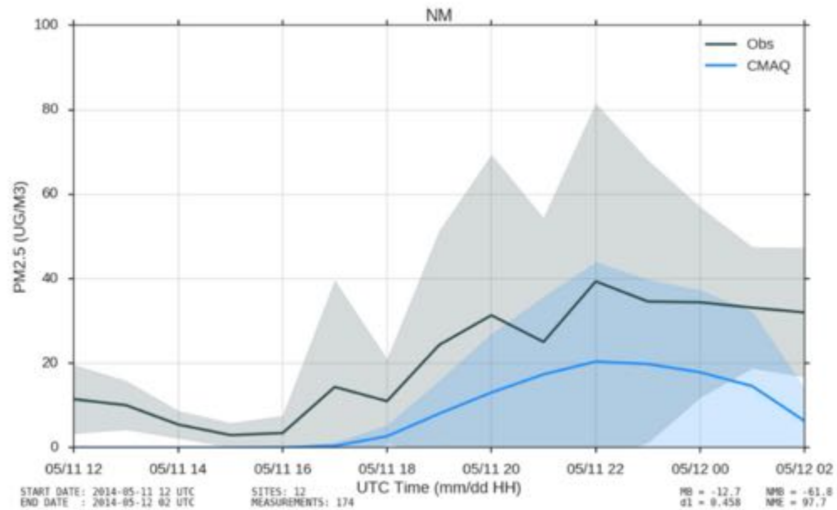
Attention is paid to **Area #2** where medium sized dust storm poses challenge for models. (**Area#5)** sees relatively larger storms on May 11 2015

Definition of areas characteristic of air-sheds and dust source regions that we used to evaluate the HRRR-CMAQ windblown dust model: (area#1) South Coast areas centered around L.A. CA; (area#2) Las Vegas and its vicinity; (area#4) Phoenix, AZ and its vicinity; and (area#5) Southern AZ across the NM border.

Area #2



Area #5

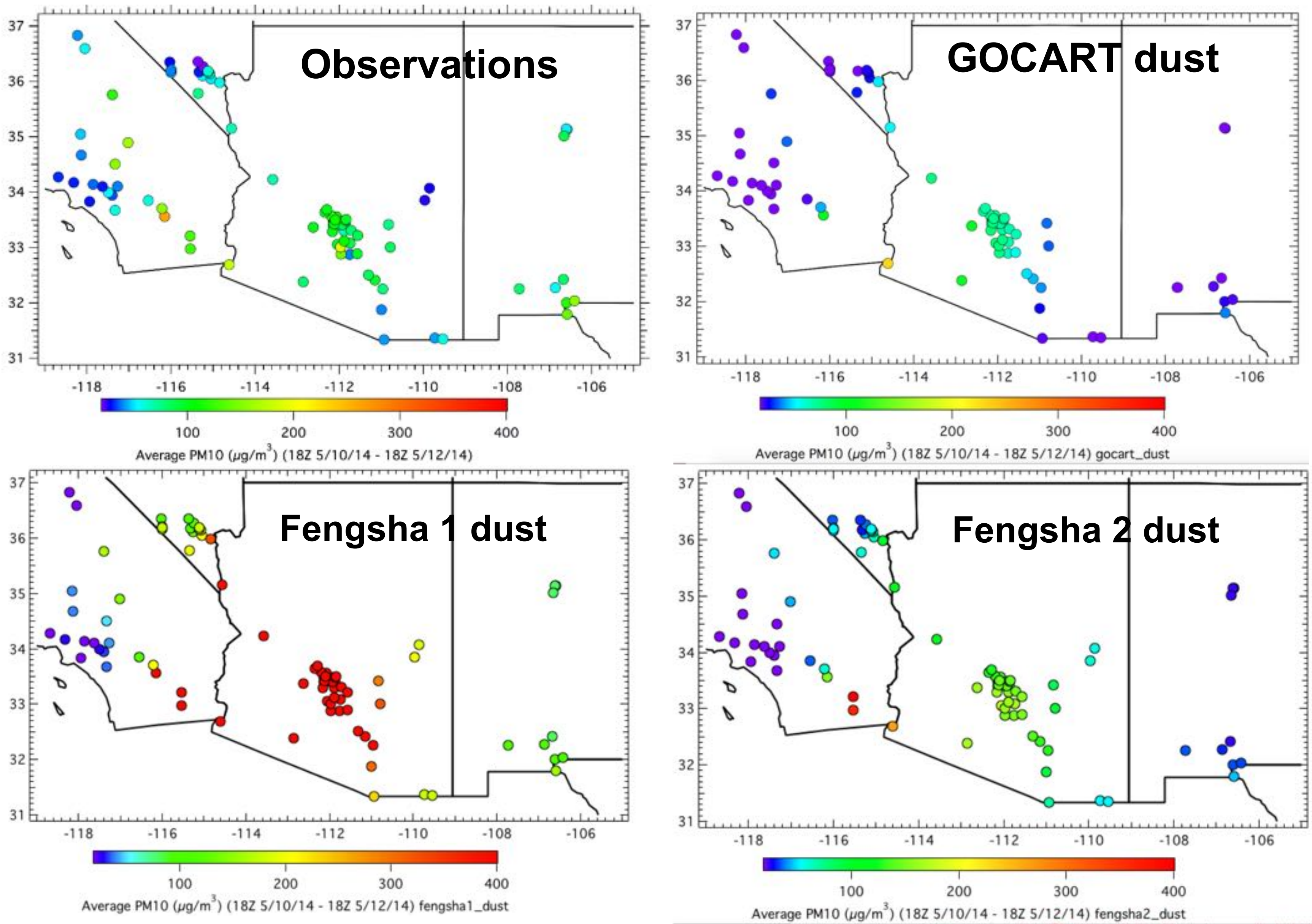


Evaluation time series for the HRRR-CMAQ windblown dust model for the May 11 2014 test case over regions depicted in previous slide for: (a) **Area#2** -- Las Vegas and its vicinity; and (b) **Area#5** -- Southern AZ across the NM border.

Evaluation of windblown dust emission scheme inlined into HRRR

Scheme	Govern Feature	Correlation coefficient	Median mod/obs	Median |timing error|
AFWA 4	α_{dust} =0.5 ; γ_{dust} =1.0	0.79	0.88	2.2 h
AFWA 7	α_{dust} =1.0 ; γ_{dust} =1.5	0.71	0.36	3.2 h
U Cologne (UoC2)	Dust scheme 1	0.63	1.48	2.3 h
fengsha1	USGS soil type	0.72	3.55	3.5 h
fengsha2	USDA 500m soil type	0.71	1.09	3.6 h
GOCART	Base physics (NASA)	0.67	0.50	2.8 h

Average PM10 for the 5/11/14 to 5/12/14 Dust Storm Event:
Comparing HRRR/Dust model results with EPA AQS monitor data



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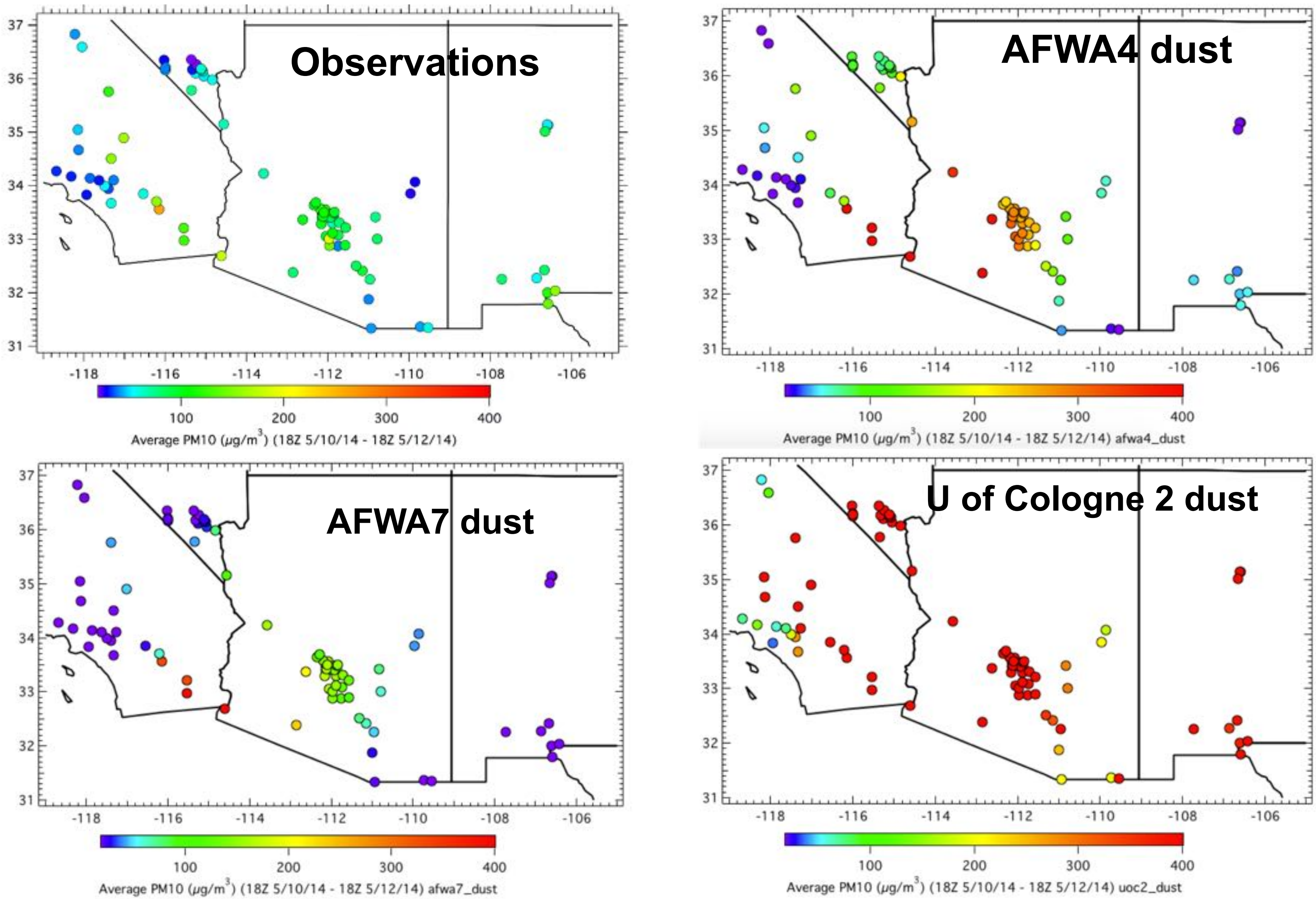
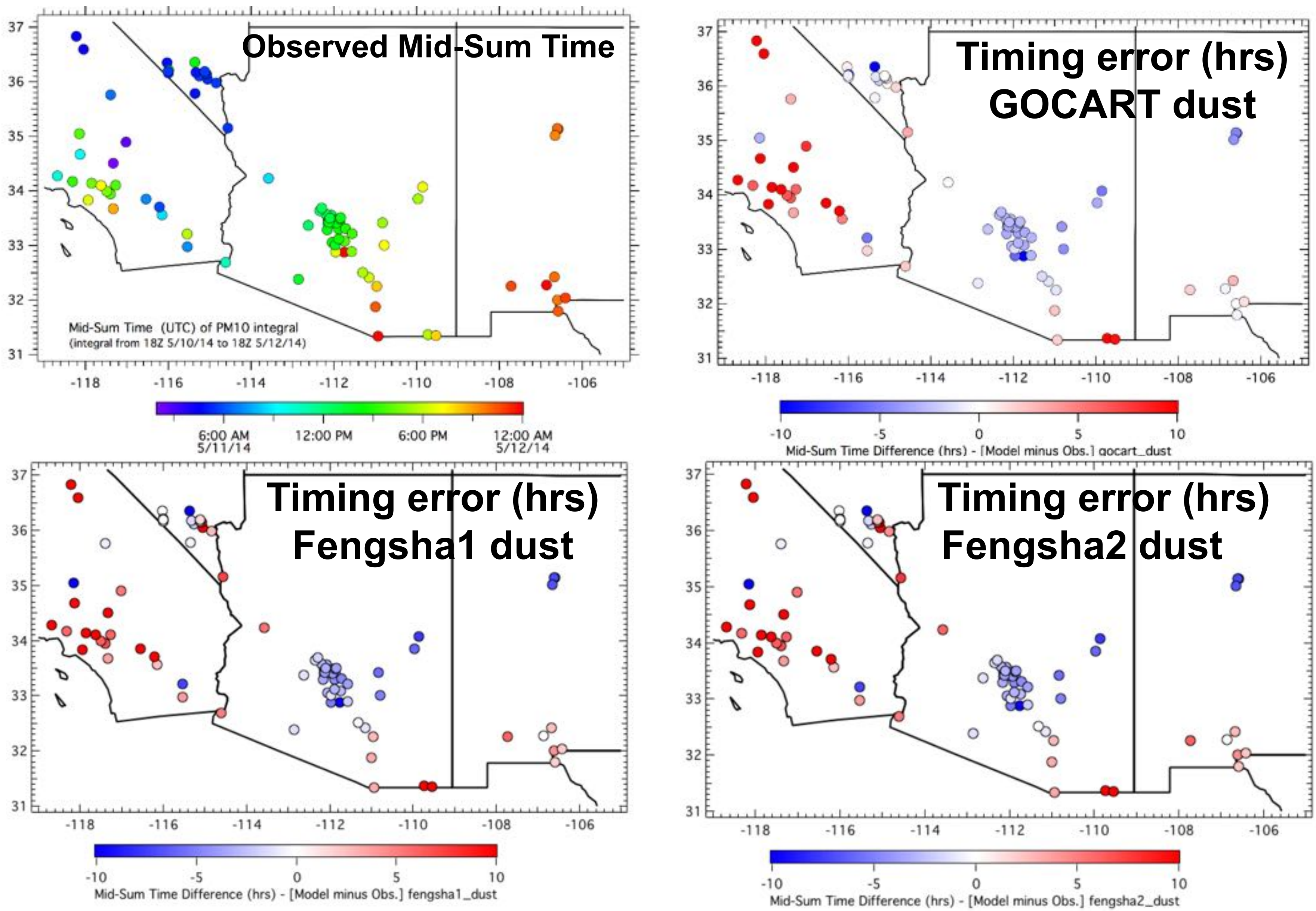


PM10 timing errors for the 5/11/14 to 5/12/14 Dust Storm Event:
Comparing HRRR/Dust model results with EPA AQS monitor data



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SUMMARY

- NOAA provides national dust forecasting service in the U.S.
- Upcoming NOAA NWP changes affect the dust forecasting service
- Multiple efforts in NOAA and other institutions pre-position for such changes
- NOAA OAR proposes 4 options of dust emission modules
  - Air Force Weather Agency (AFWA) – previously developed in MM5
  - Cologne U scheme
  - Fengsha as available in CMAQ5.0.2
  - Goddard Global Ozone Chemistry Aerosol Radiation and Transport (GOCART)
- The unification and selection task for the service is a working progress
- Preliminary results showed comparable skill by all these 4 options
- Results is sensitive to fine resolution soil data and real time moisture data

http://www.mdpi.com/journal/atmosphere/special_issues/air_monitoring

Air Quality Monitoring and Forecasting

Manuscripts on the topic due June 30 2017

Guest Editors: Pius Lee, Rick Saylor, Jeff McQueen