High-resolution dust source function and a case study in the NU-WRF model

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Introduction

- While permanent deserts are major source of mineral dust, semi-arid dust source regions account for 12-20 % of the global dust emission (Ginoux et al., 2012; Kim et al., 2013). The semi-arid source dust is even more important in local-scale and regional-scale.
- The current GOCART dust emission parameterization in the community WRF-chem model uses the source function in 0.25° resolution and static.

$$F_p = C\,S\,s_p\,u^2_{10\mathrm{m}}(u_{10\mathrm{m}} - u_t),\ \text{if}\ u_{10\mathrm{m}} > u_t$$

$$\boldsymbol{S = H \times B}$$

H=Topographic depression (0.25°)

B= Bareness (Static)

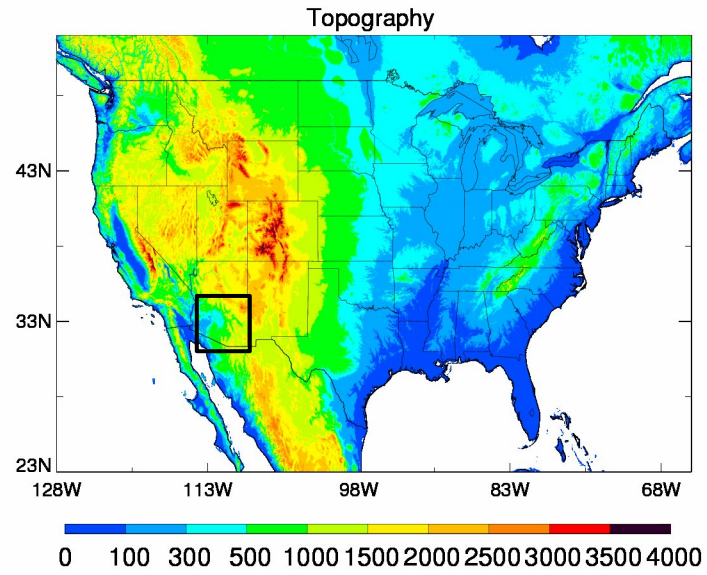
S (Dyn)

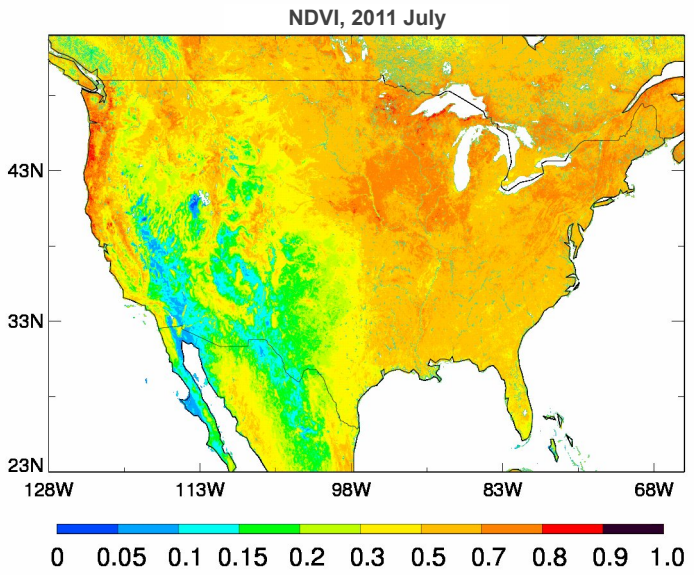
H: 1-km

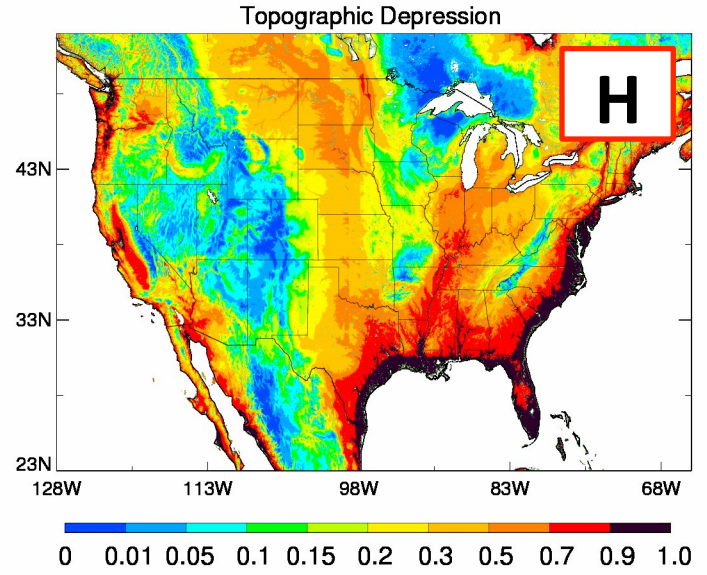
B: Dynamic

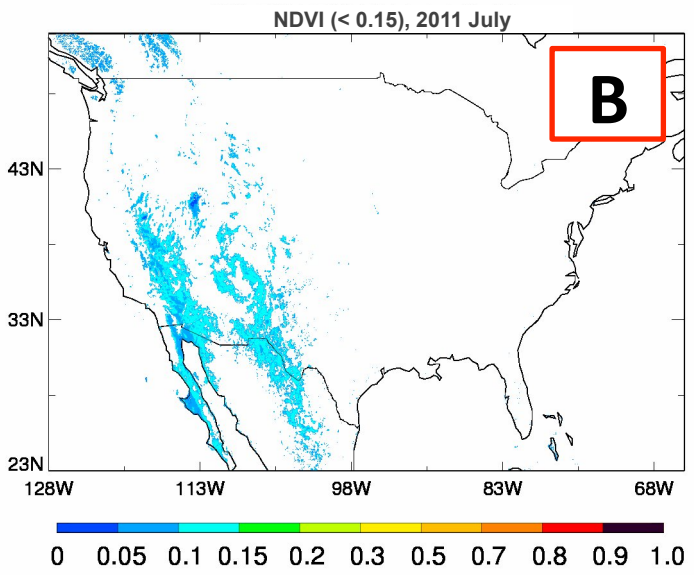
- We have developed a dust source function in 1-km resolution and bareness uses the surface vegetation from the MODIS satellite.
- We have conducted a case study with an extreme dust storm that occurred in Phoenix Arizona in July 5 2011, using NASA Unified-WRF (NU-WRF).

New Dust Source Map: (1km, July 2011)





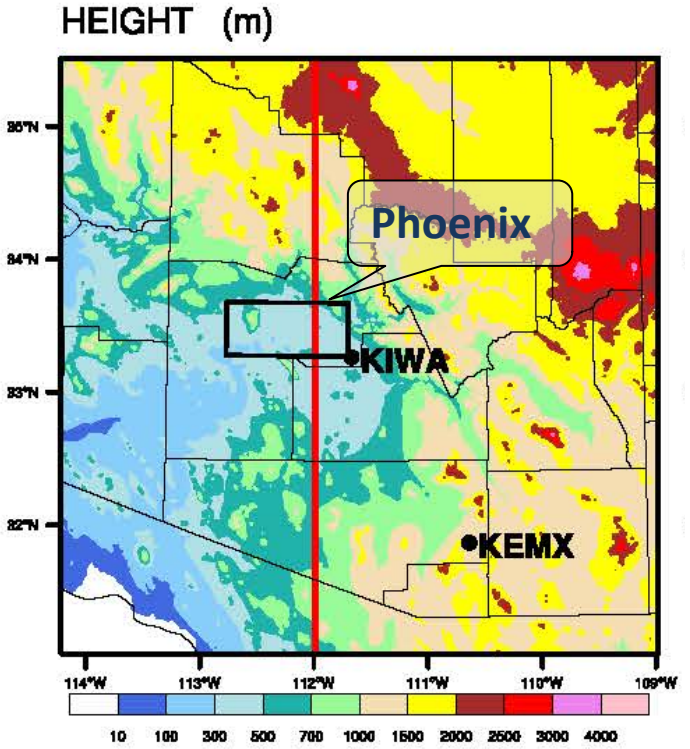




A Case Study with the Phoenix Dust Storm (July 5, 2011)

- Goal: To test the NU-WRF's ability with the new 1-km dust source function to simulate the extreme dust storm case.

Looking south, 7:45PM, 5 July 2011
from the US National Weather Service Phoenix Office



Why did we choose this storm?

1. One of the strongest cases that is observed in US Cities.
2. Limited but useful observations are available.
3. The case is well studied using model and observations.
   - Raman et al., 2014; Vukovic et al.,2014; Sprigg et al., 2014

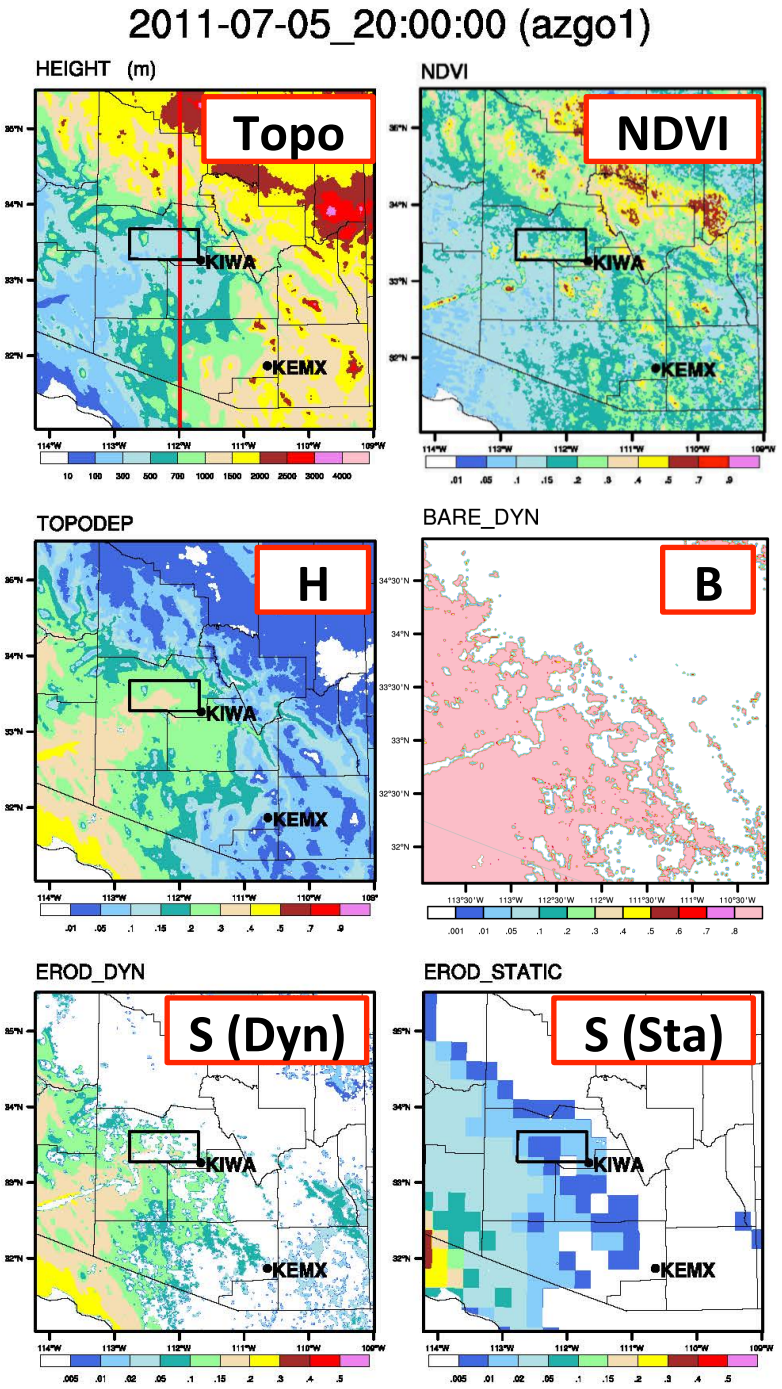
NU-WRF Case Study

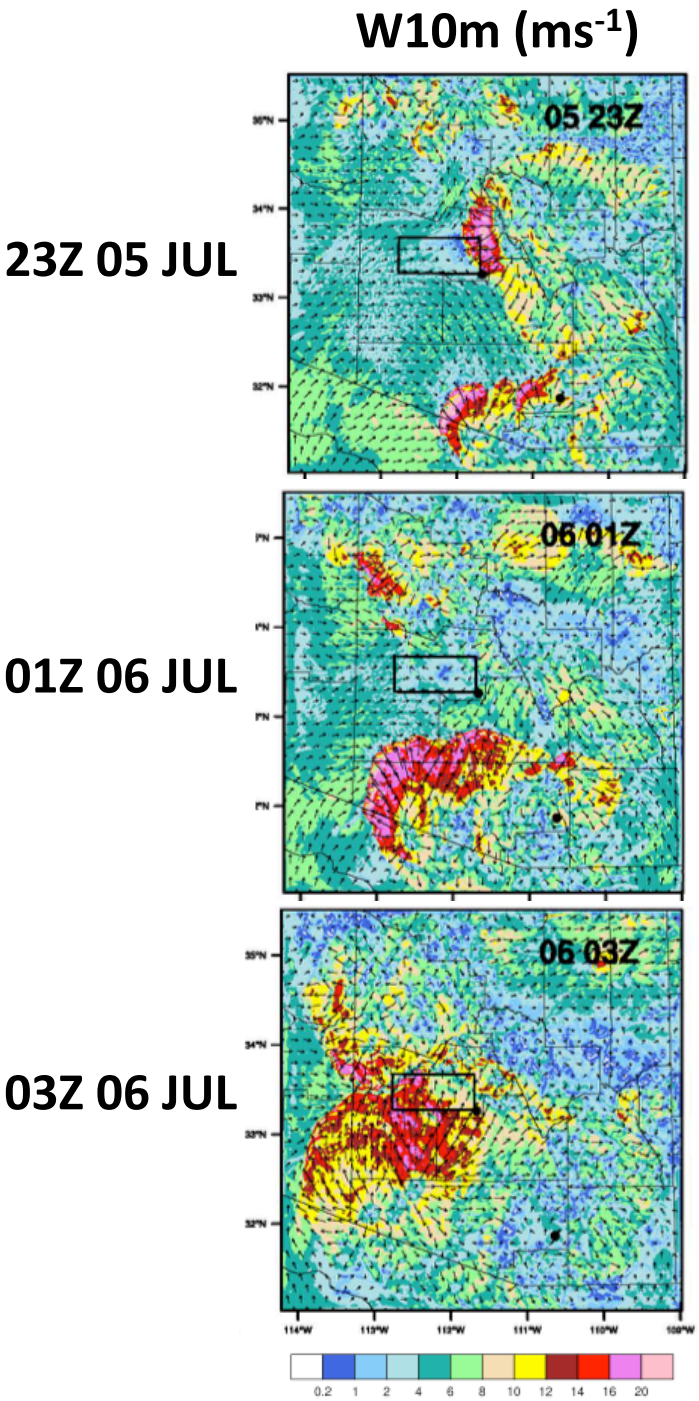
NU-WRF Simulation Setup

Time: 00z July 5 - 00z July 7, 2011
Horizontal : 500x500 (1 km)
Vertical : 30 layers (~50mb)
Initial Condition: GFS
Aerosol scheme: GOCART

Physics

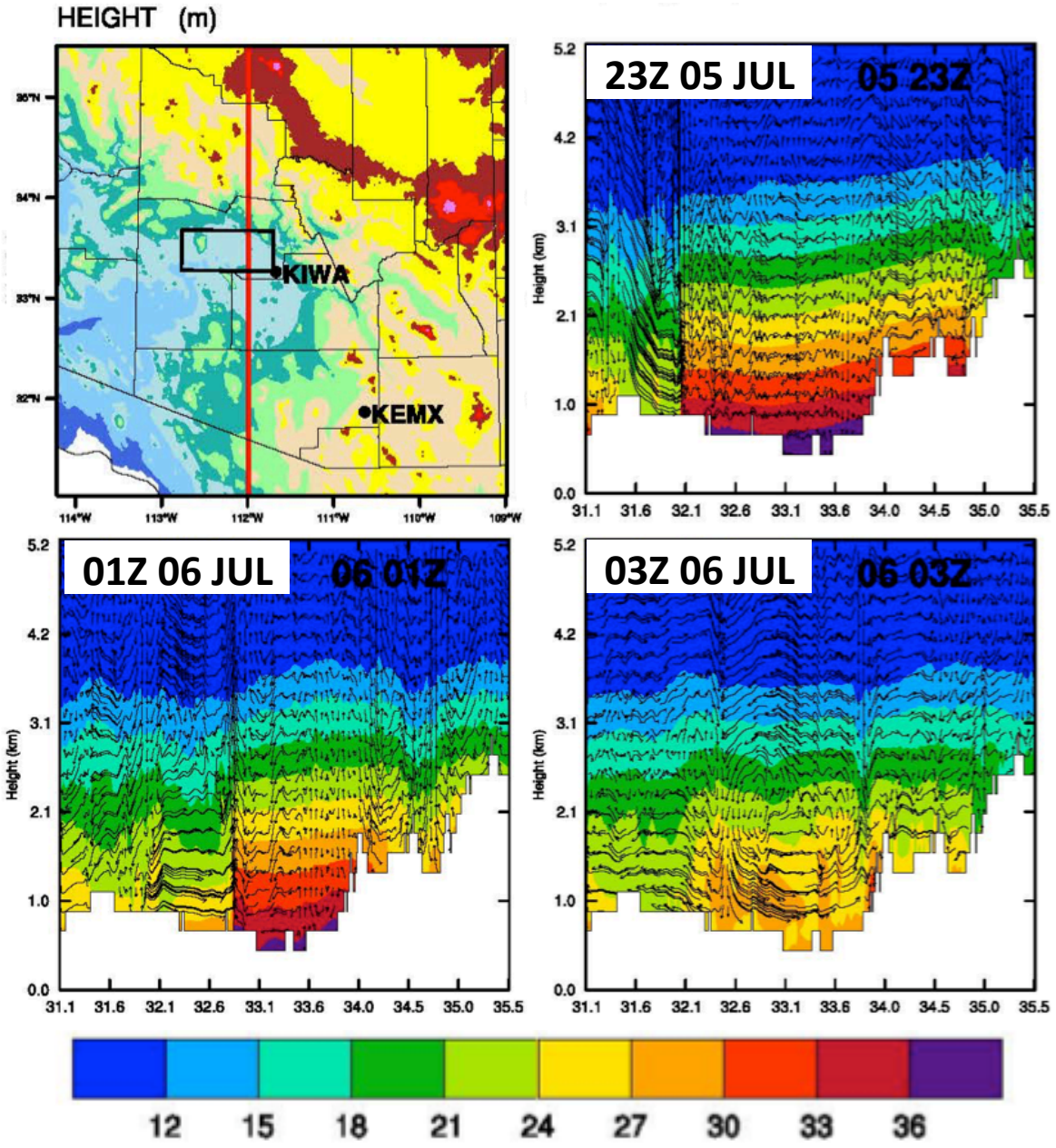
Processes Name	Setup
Longwave radiation	Goddard
Shortwave radiation	Goddard
Surface layer	Monin-Obukhov
Land surface	Noah LSM
Boundary layer	YSU
Cumulus clouds	Explicit



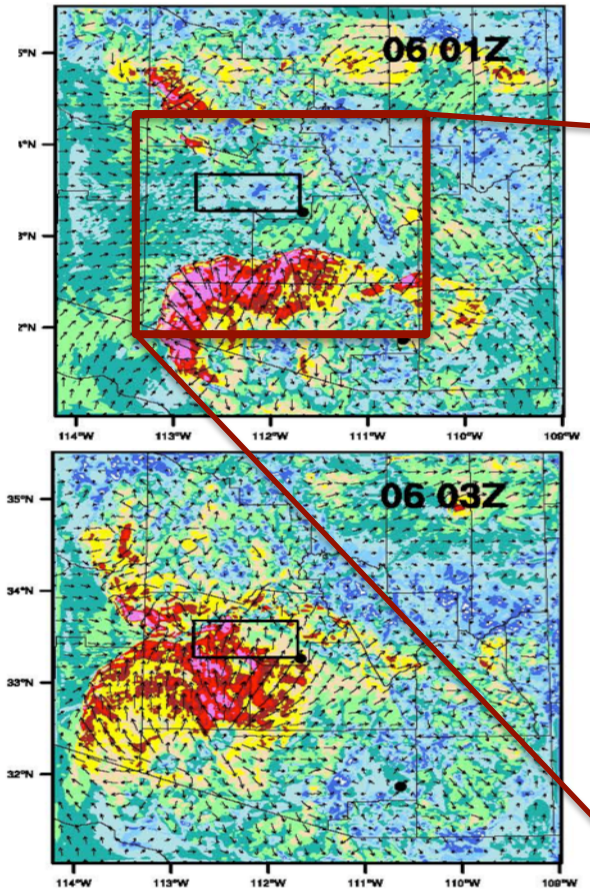


- A well defined front is located in southern region of the domain.
- The front is moving fast toward northwest.
- The strong wind field covers the Phoenix area.

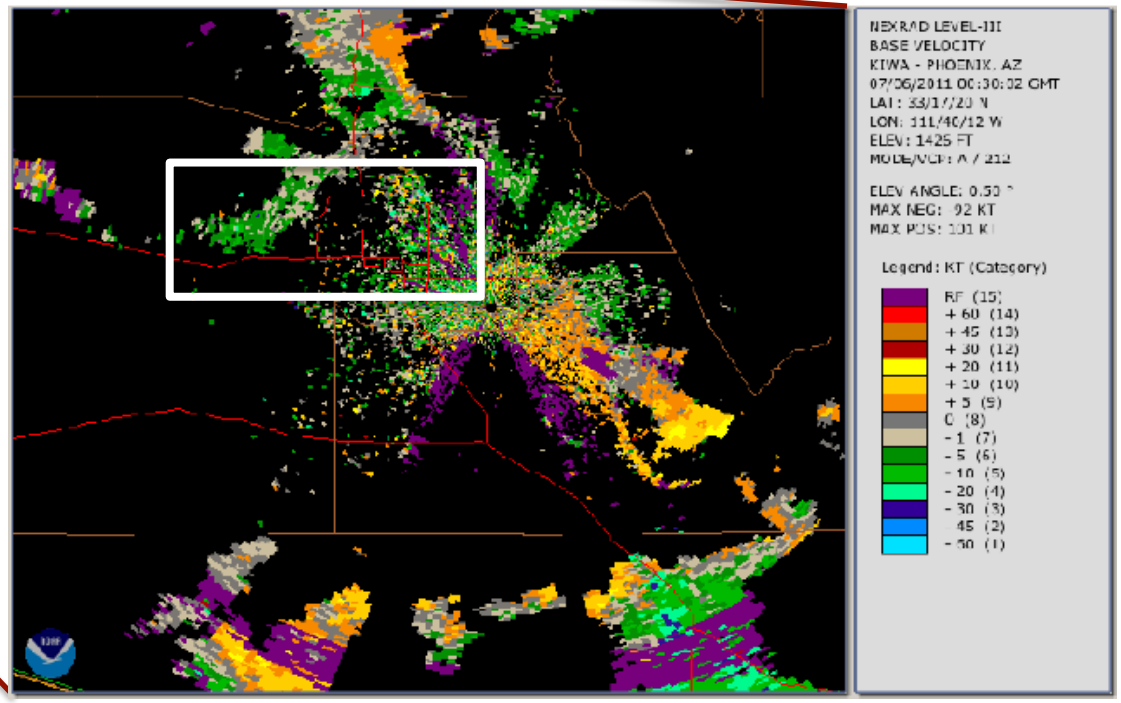
Cross Section of Temperature



Horizontal Wind Field



NEXRAD BASE VELOCITY (KIWA)



00:30Z ~ 04:00Z with 15min interval

1. WRF captures location, area and time of dust storm in general.
2. However, wind fields by WRF showed slight offset from the radar observation.
3. While dust emission is highly sensitive to wind field, matching model dust with observation is more challenging.

NU-WRF Experiments (29+ cases)

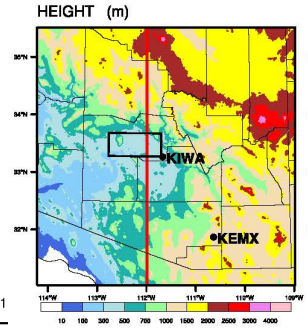
Met related 16 runs

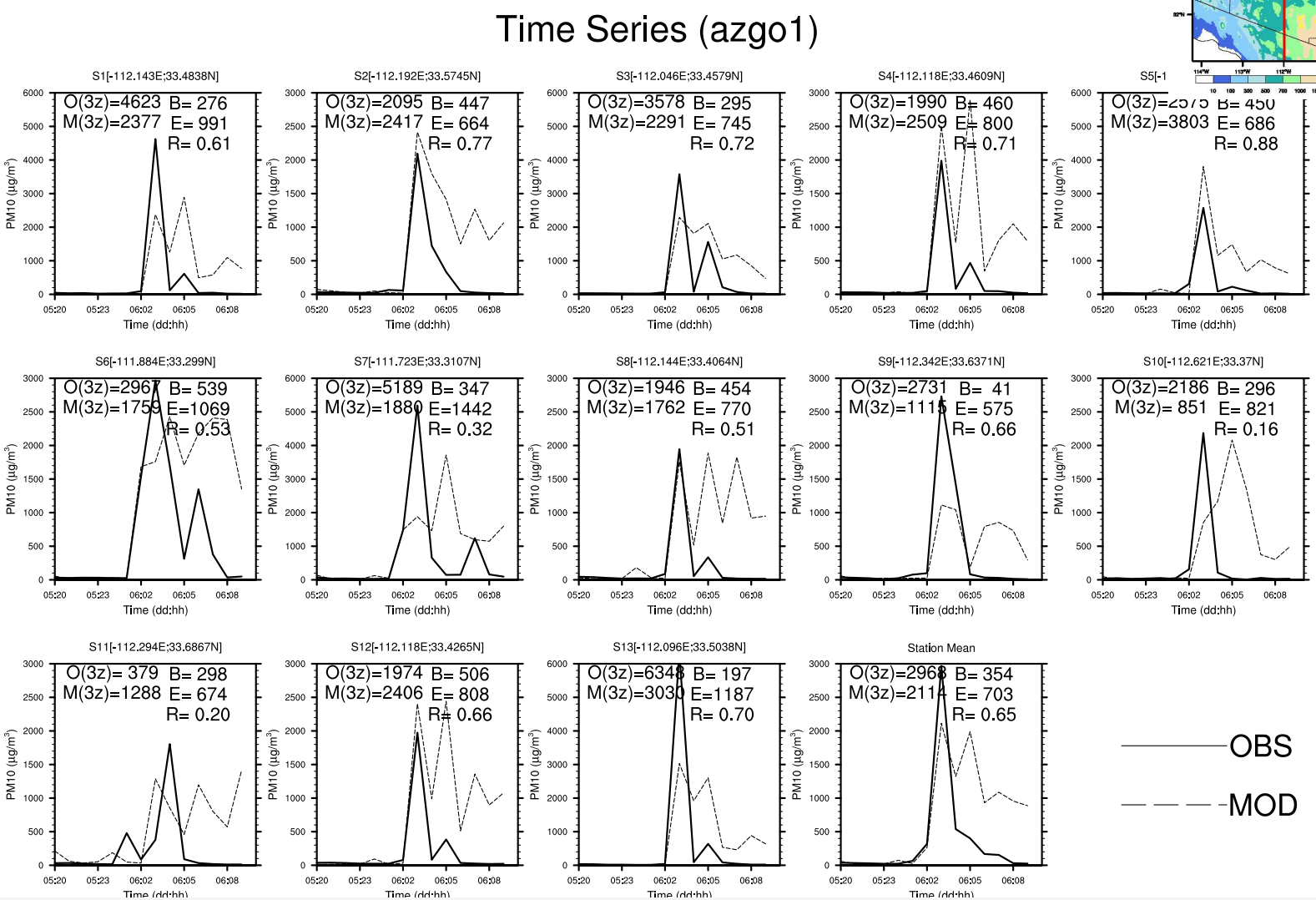
Exp. Name	PBL	LW/SW	Landcover	LIS	Layer	Initial time	Domain	Met Input	Testing param.
azgo1	YSU	55/55	MODIS	No	30	2011-07-05:00	1	GFS	Reference
azgo1pbl	**MYJ**	55/55	MODIS	No	30	2011-07-05:00	1	GFS	PBL(=2)
azgo1p1	YSU	**5/5**	MODIS	No	30	2011-07-05:00	1	GFS	Radiation Scheme
azgo1p2	YSU	**5/5**	**USGS**	No	30	2011-07-05:00	1	GFS	Radiation+ Landcover
azgo1lis	YSU	55/55	MODIS	**Yes**	30	2011-07-05:00	1	GFS	**LIS**
azgo1lay	YSU	55/55	MODIS	No	**60**	2011-07-05:00	1	GFS	Layer
azgo1layp	YSU	**5/5**	MODIS	No	**60**	2011-07-05:00	1	GFS	Layer+Rad
azgo1layli s	YSU	55/55	MODIS	**Yes**	**60**	2011-07-05:00	1	GFS	**Layer+LIS**
azgo1it1	YSU	55/55	MODIS	No	30	**2011-07-04:12**	1	GFS	Initial time
azgo1nest	YSU	55/55	MODIS	No	30	2011-07-05:00	**3**	GFS	Larger D03
azgo1nest 2	YSU	55/55	MODIS	No	30	2011-07-05:00	**3**	GFS	Smaller D03
azgo1fdda	YSU	55/55	MODIS	No	30	2011-07-05:00	1	GFS	**FDDA_grid**
azgo1narr	YSU	55/55	MODIS	No	30	2011-07-05:00	1	**NARR**	Met input
azgo1nam anl	YSU	55/55	MODIS	No	60	2011-07-05:00	1	**NAManal**	Smaller D03
azgo1p56	YSU	**56/56**	MODIS	No	30	2011-07-05:00	1	GFS	**Radiation +No_Rad_feedbk**
azgo1pfb	YSU	**56/56**	MODIS	No	30	2011-07-05:00	1	GFS	**Radiation +Rad_feedbk (**

Dust related 13 runs

Exp. Name	GWET	Resolution Factor	Emission	k(duemi)	no emi time
azgo1	0.5	0.2	GOCART	1 (~60m)	none
azgogw1	**0.35**	0.2	GOCART	1 (~60m)	none
azgogw2	**0.3**	0.2	GOCART	1 (~60m)	none
azgo1resf	0.5	**1**	GOCART	1 (~60m)	none
azgo1afwa	0.5	0.2	**AFWA**	1 (~60m)	none
azgo1sta	0.5	0.2	**Static**	1 (~60m)	none
azgo2k3	0.5	**1**	GOCART	**3 (~250m)**	none
azgo2k3resf02	0.5	0.2	GOCART	**3 (~250m)**	none
azgo2k5resf02	0.5	0.2	GOCART	**5 (~500m)**	none
azgo2k5resf03	0.5	**0.3**	GOCART	**5 (~500m)**	none
azgo2k5resf02emi03	**0.35**	0.2	GOCART	**5 (~500m)**	**0300z-0500z**
azgo2k8resf02emi03	**0.35**	**0.2**	GOCART	**8 (~1300m)**	**0300z-0500z**
azgo2k8resf03emi03	**0.35**	**0.3**	GOCART	**8 (~1300m)**	**0300z-0500z**

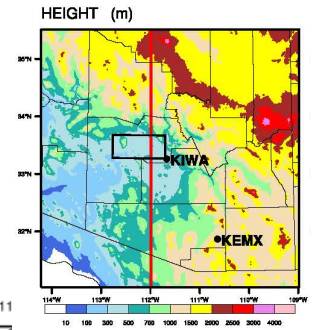
Surface Dust: Without Optimization

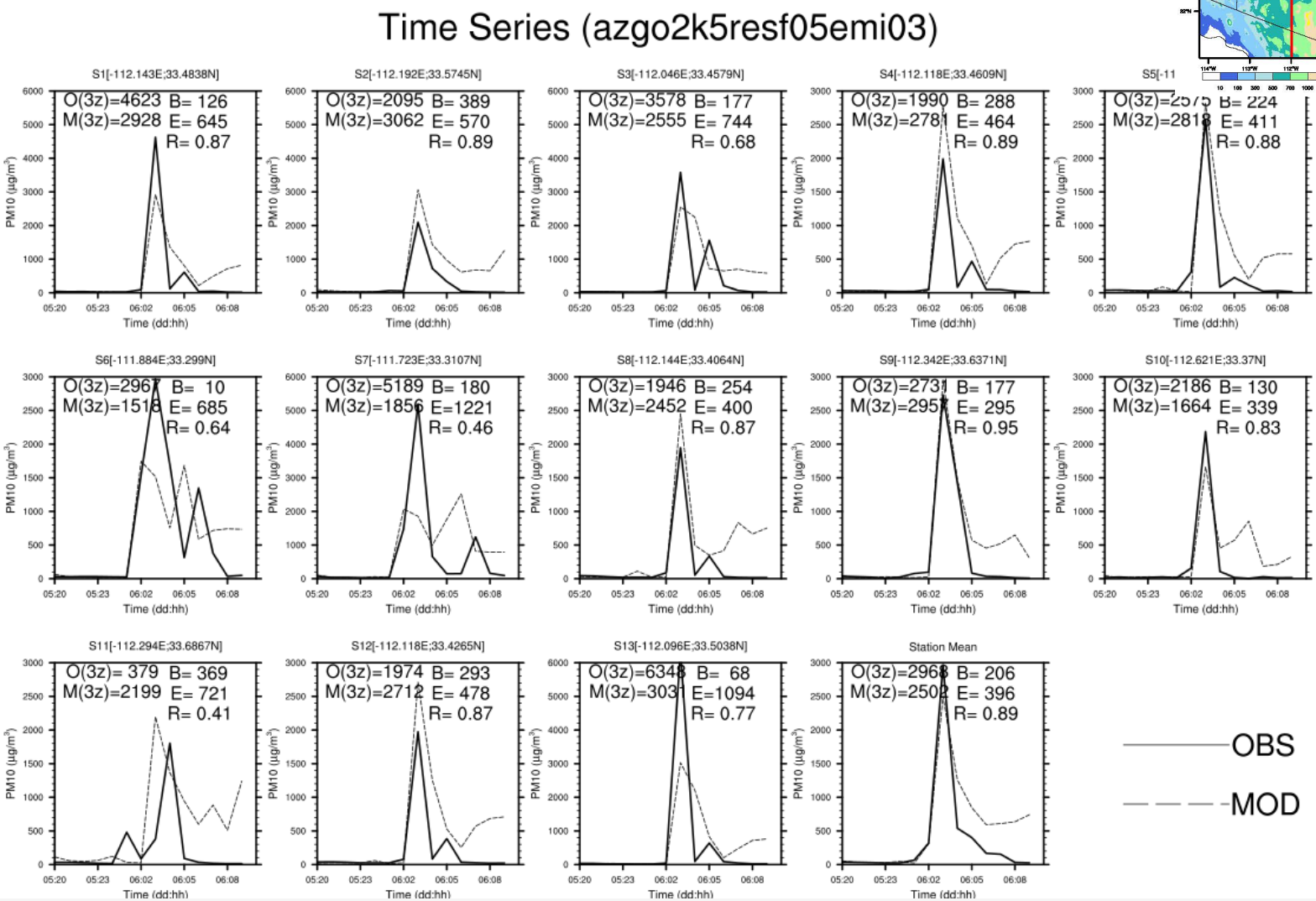




- Without optimization, model simulates dust storm arrival time and magnitude, but it shows large residual dust after the storm.

Surface Dust: With Optimization





- Parameters that affect the optimized dust simulation are:
  - Emission tuning factor, Vertical distribution, Emission time, and Soil moisture

Summary

1. An 1-km dynamic dust source function has been developed in NU-WRF.
2. NU-WRF was successful in simulating the magnitude of the Phoenix July 2011 dust storm with the new source function.
3. However capturing accurate location, area, and timing of dust storm, and matching the model with observation is still challenging in NU-WRF, mainly due to the inaccurate winds and slow dust removal.
4. Further adjustments helpful to improve model performance are:
   - Emission tuning factor, Vertical distribution, Emission time, and Soil moisture.

Thank You!

Aerosol Optical Depth