UTILIZING A NUMERICAL WEATHER PREDICTION MODEL FOR DUST FORECASTING

Mike Leuthold
Department of Atmospheric Sciences
University of Arizona

Previous Dust Modeling Efforts

Dust Modelling and its Applications to the Border Region

Dazhong Yin, William A. Sprigg, Brian Barbaris and Patrick Shaw
Institute of Atmospheric Physics
The University of Arizona

THE UNIVERSITY OF ARIZONA. Arizona's First University.

THE UNIVERSITY OF ARIZONA. Atmospheric Sciences

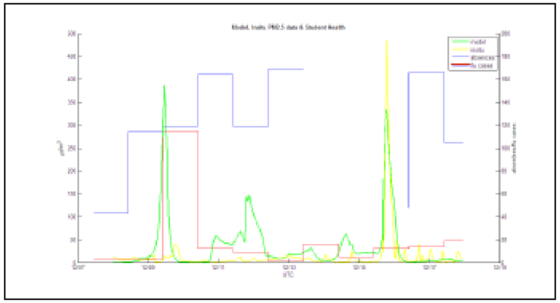
Public Health Applications in Remote Sensing

Introduction

Windblown dust composes a significant portion of atmospheric particulate matter (PM) along the U.S. Mexico border and is known to have adverse effects on human health and transportation. Prediction of high PM events associated with windblown soil would be beneficial to these areas of human welfare. Work is under way at the University of Arizona to model such events. The goal of this project is to accurately predict dust concentrations in space and time by incorporating NASA earth science observations with the models. Findings of the research include improved model results with updated finer resolution NASA earth observations and the association of high air-borne dust concentrations with the peak of student absentees (see figure below). Once validated, these models can serve as powerful tools in the forecast of dust episodes in the border region of the southwest U.S. and Northern Mexico.

Dust Modelling

The Dust REgional Atmosphere Model (DREAM), developed by Nickovic et al. (2001), is the model of this study. It is a transport module coupled with the NCEP Eta weather forecasting model. The dust module incorporates dust production, advection, diffusion and deposition into the weather model. The amount and location of dust particles lifted into the atmosphere are determined from land cover, soil texture, soil moisture and surface wind drag. Dust source regions are obtained primarily from NASA MODIS land cover data.

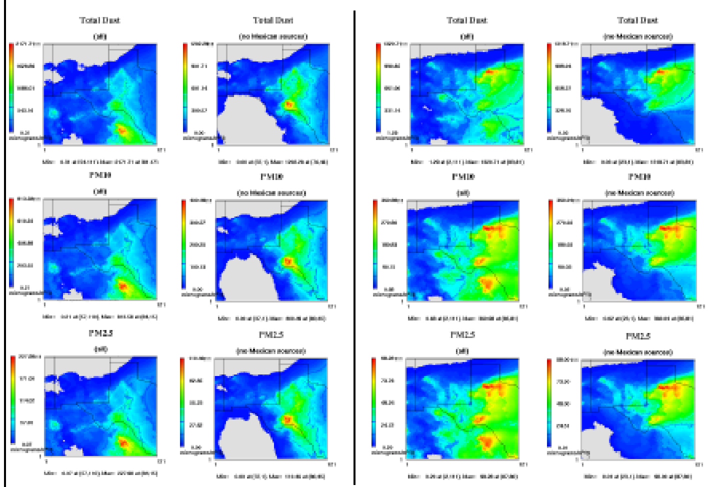


Health statistics from 2003 Lubbock, TX test case are plotted with dust storm model and in-situ data. Student absentees peak after observed and modelled peaks in the dust concentrations, but there appears to be little correlation with influenza. Providing schools with an advanced warning of a dust event could reduce the number of absences.

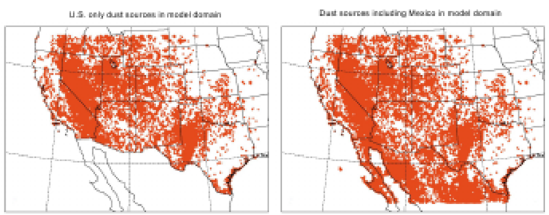
Border Experiment

An experiment was carried out to determine the contribution of Mexican source regions to border dust storms. Two dust storm cases from December 2003 were simulated using the DREAM model. Each case was examined with two sets of desert dust sources. The first used desert dust sources in the the whole U.S. Mexico domain, while the second used desert dust sources in the U.S. only.

The two 2003 dust storms (December 8-10 and December 15-17) were caused by synoptic forcing and affected Southern New Mexico, West Texas and Northern Mexico. Sustained winds as high as 20 m/s triggered the saltation and suspension of dust particles into the atmosphere and allowed for long range transport. Each case was simulated with and without Mexico source regions. Validation was performed by comparison with observed weather maps and statistics based on in-situ weather and PM concentration data.



Model surface concentrations ($\mu g/m^3$) for two 2003 test cases: average concentrations of case 1 with (column 1) and without (column 2) Mexican source regions. Average concentrations of case 2 with (column 3) and without (column 4) Mexican source regions. Modelled statistics show that as much as 40% of dust concentrations can be attributed to Mexican source regions.



Conclusions

Two December 2003 dust storms were simulated using a dust transport model. Each was operated using U.S. plus Mexico desert dust sources and U.S. only sources. It was found that northern Mexico contributes to the dust loading and concentrations by as much as 40%. These results show a coordinated effort in ecosystem protection and resource management by the U.S. and Mexico is necessary to control dust pollution in this region. Dust modelling can identify key sources and contribute significantly to dust control strategies.

References

Yin, D. and W.A.Sprigg. (In press). Modelling airborne dust pollution in the southwest united states: A trans-boundary perspective. In Papers from the 6th Conference on Research & Resource Management in Southwestern Deserts; Sky Alliance, Tucson. 32 pp.

Yin, D., S. Nickovic, B. Barbaris, B. Chandy, W. A. Sprigg; 2005; Modeling wind-blown desert dust in the southwestern United States for public health warning: a case study; Atmospheric Environment, 39, 6243-6254

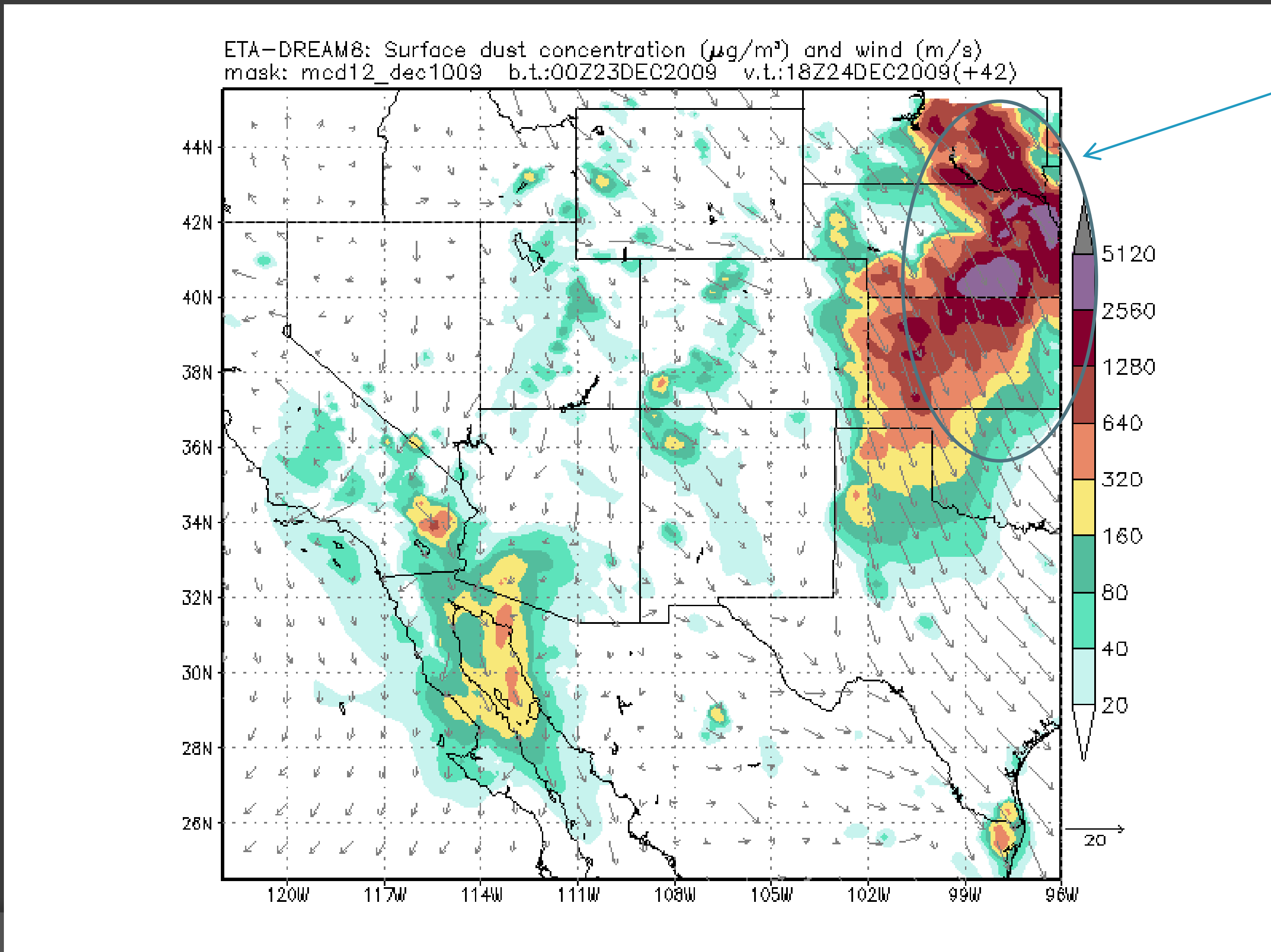
Acknowledgements

This work was funded by the NASA REASON project, in collaboration with the University of New Mexico (CA#NN504AA19A), through the University of Arizona department of Atmospheric Sciences and Institute of Atmospheric Physics. Dr. S. Caskey of Sandia National laboratories and Dr. K. Benedict of University of New Mexico provided student absentee data and MODIS 12 data.

Project Website:

http://www.atmo.arizona.edu/faculty/research/dust/dust.html

Dust Concentration Forecast from DREAM



Dust concentration too high. Soil moisture wrong?

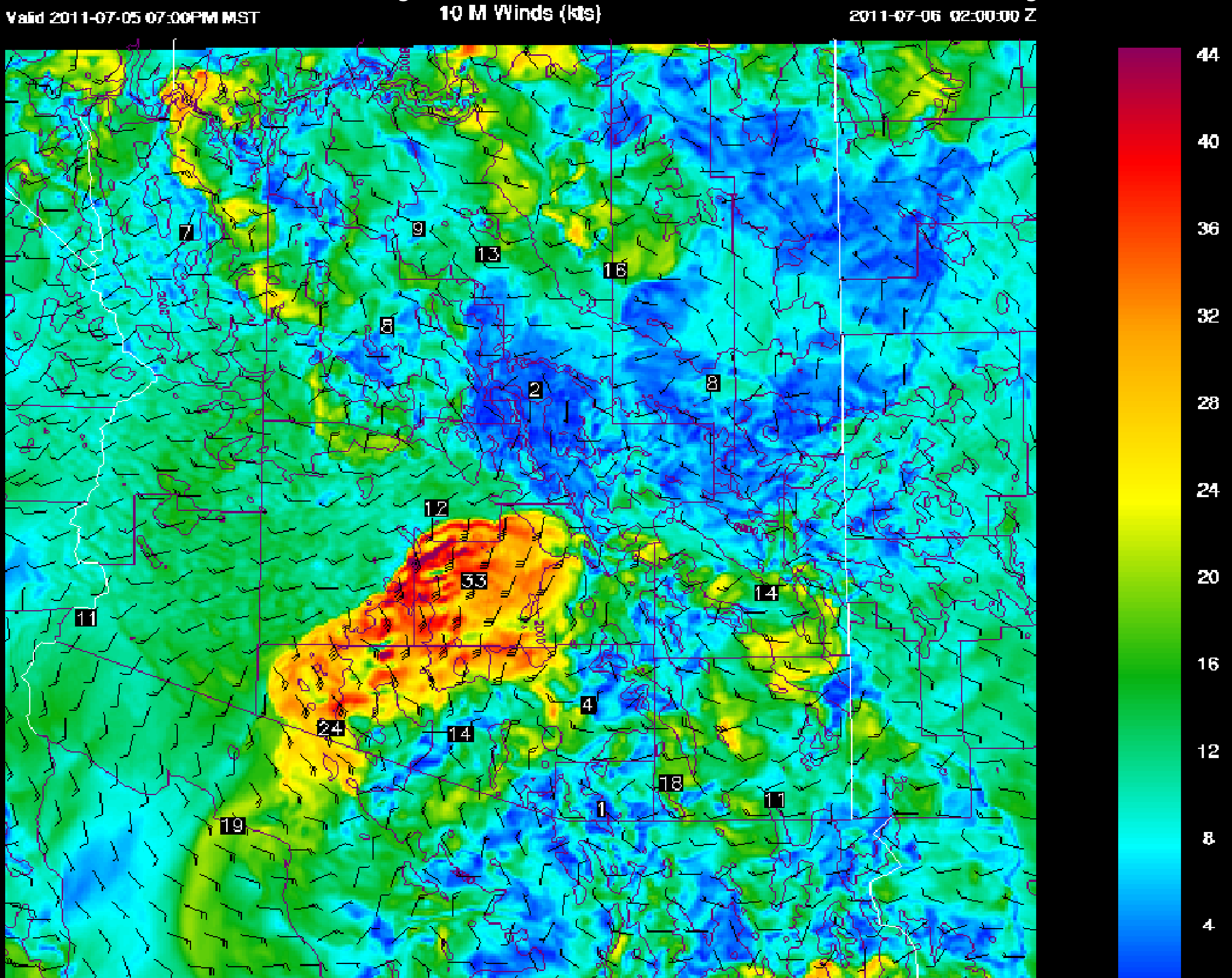
Did not resolve Summer convective winds

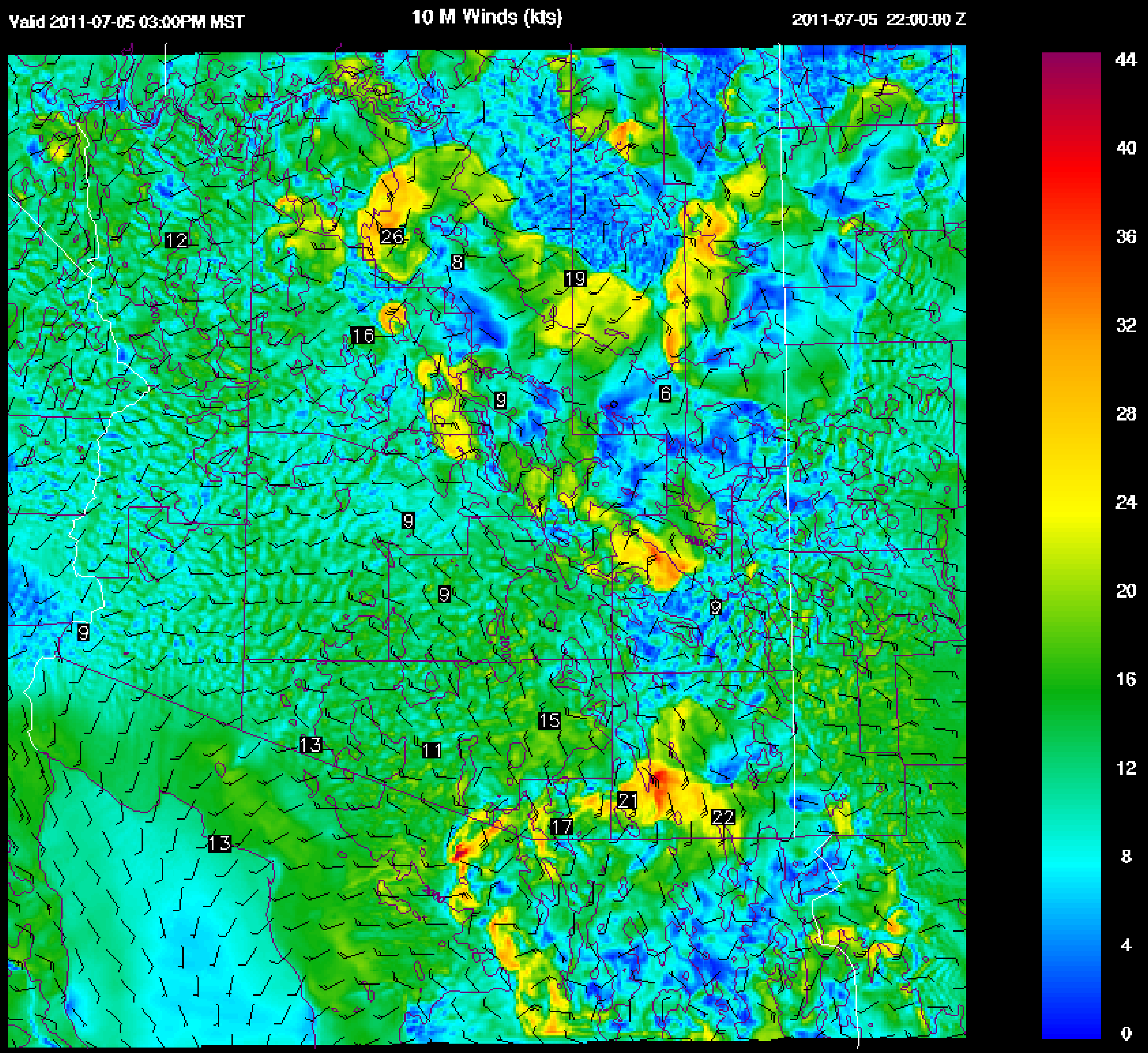
Took too long to run.

Difficult to upgrade

Sprigg (2009)

Convectively Generated Wind: 5 July 2011





Valid 2011-07-05 03:00PM MST
10 M Winds (kts)
2011-07-05 22:00:00 Z
44
40
36
32
28
24
20
16
12
8
4
0
12
26
8
19
16
9
6
9
9
9
9
15
13
11
21
22
17
13

Forecast Results for Dust Storm Days, .5 mi visibility or less at PHX

July 2	3	4	5	8	9	10	18	20
No	Yes	Yes	Yes	False Positive	Yes	Yes	Yes	No

Aug 18	27	Sept 9	11	12	27
No	No	Yes	Yes	Yes	?

Oct 4	Nov 4
Yes	Yes

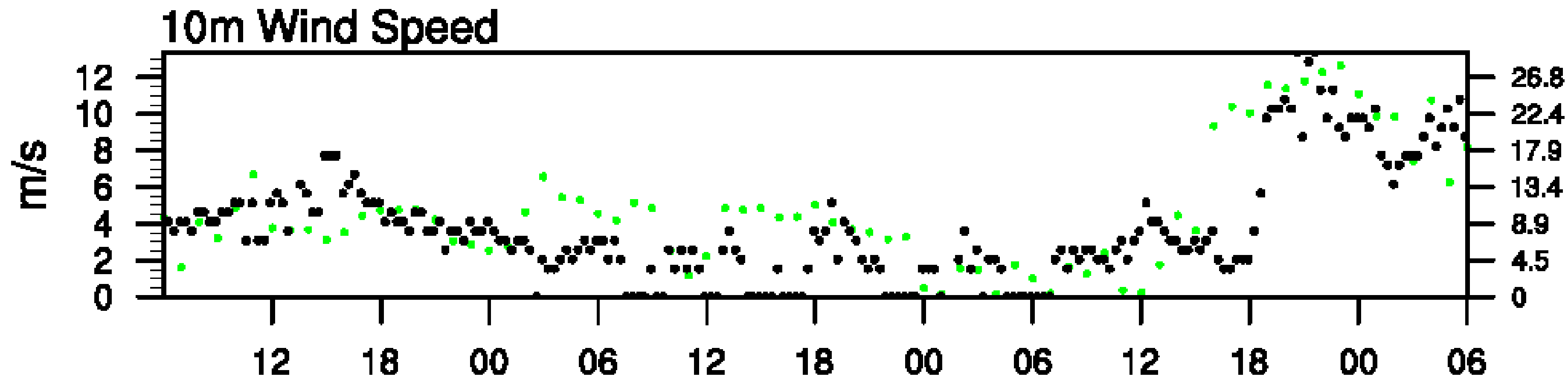
Criteria for convection verification: winds >10 m/s and/or rapid temperature drop. Sites include KPHX, KIWA, KLUF, KDVT.

Dust storm days courtesy of JJ Brost, NWS Tucson

Day 2 to 3 Forecast Skill

- WRF can provide accurate non-convective wind forecasts up to 72 hours in advance.
- Monsoon season forecasts are less accurate due to the chaotic nature of convection. Over the past few years, accuracy has improved for day 2 forecasts.

3 Day Wind Forecast for Casa Grande



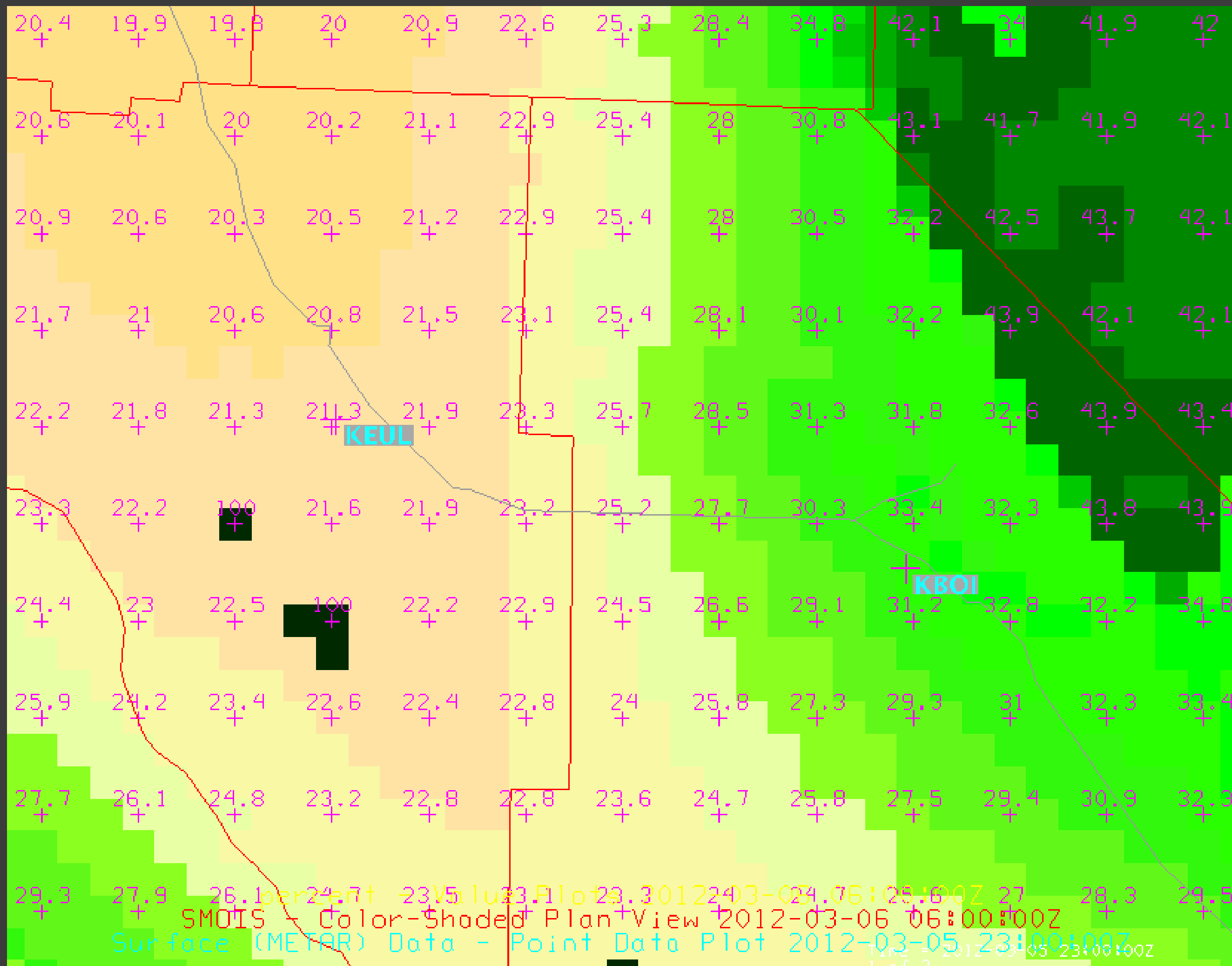
Day 1 Day 2 Day 3

Observed=Black, Forecast=Green

Model Deficiencies

- High resolution land surface cover data errors common: incorrect classifications, incorrect locations, out of date.
- Soil moisture poorly represented as large errors can exist both spatially and temporally.
- Model does not explicitly forecast wind gusts.
- Does not forecast dust.

Initialized 5cm Soil Moisture(%) at KBOI

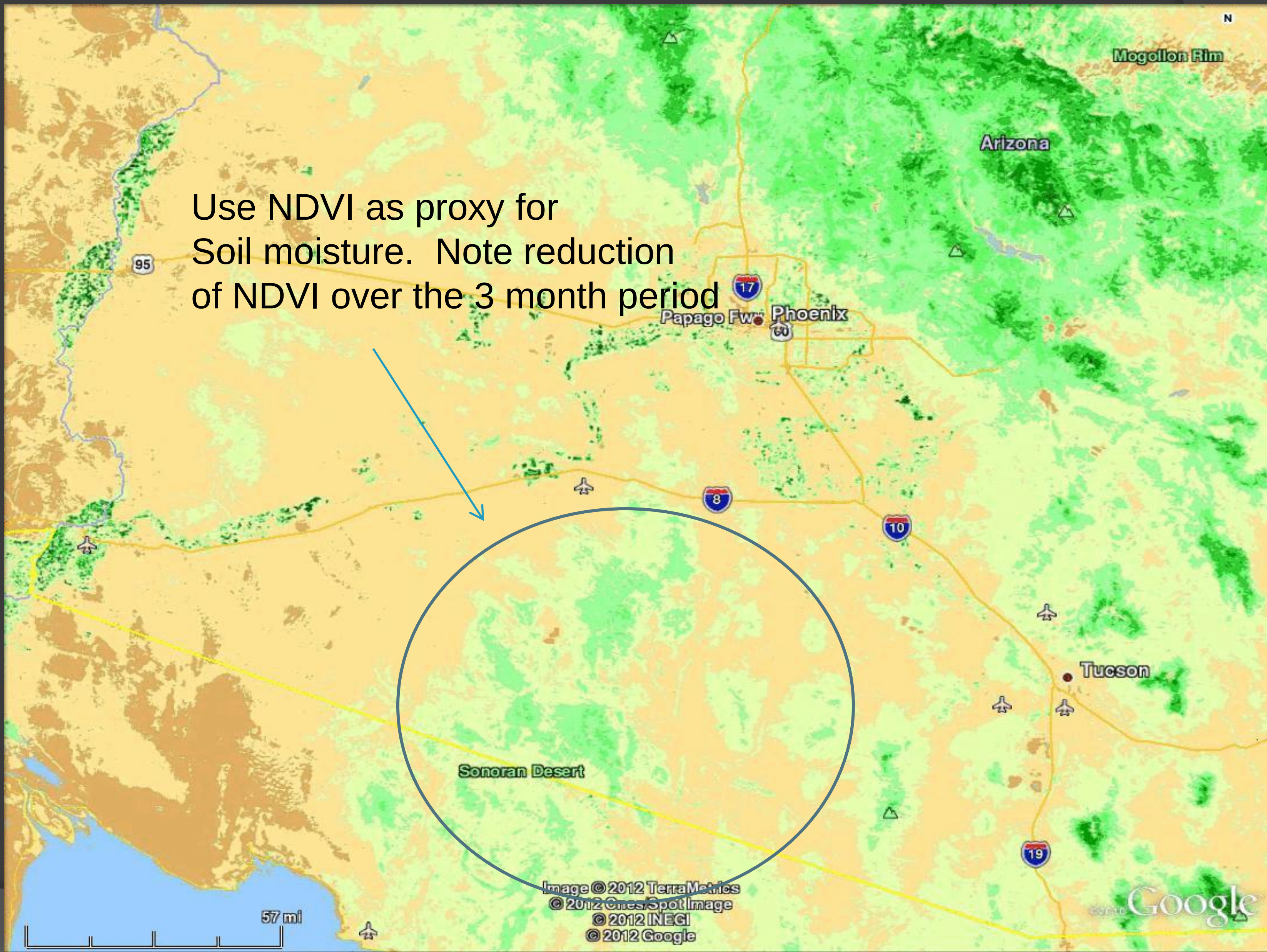


Solutions

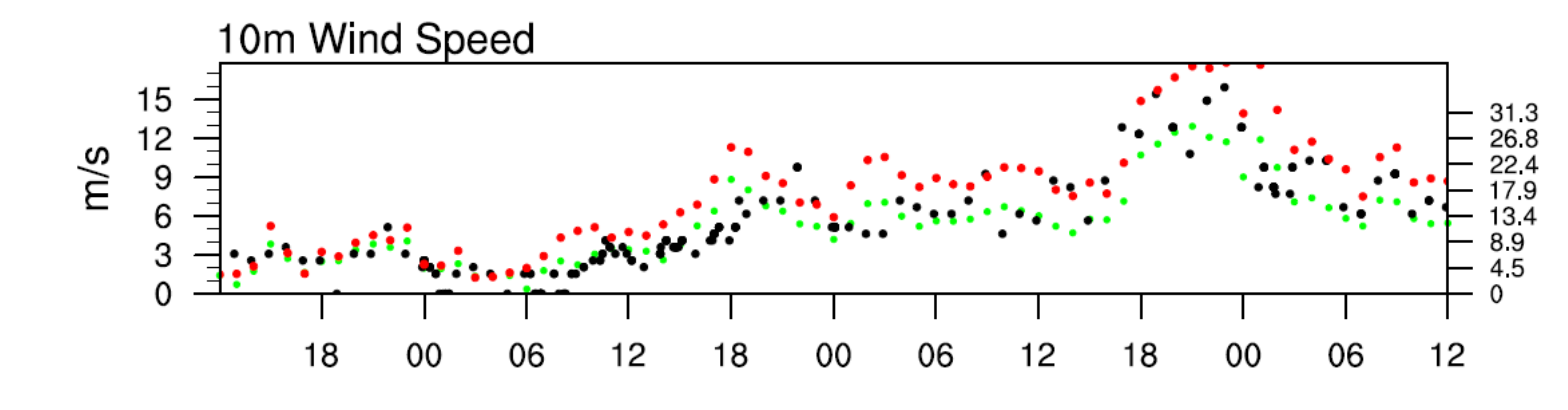
- Update land use data with corrected and/or more recent data. Yuma county and urban/suburban land use data has been corrected/replaced.
- Assimilate soil moisture directly from a network of sensors and/or use MODIS NDVI data to infer soil moisture.
- Develop gust forecast product using a blend of 10m/80m winds and/or alternative PBL options and add a DCAPE forecast for the convective season.
- WRF-Chem can be used to model dust creation and advection. Must turn off chemistry for operational use due to extreme computational requirements.

NDVI 3 Month Change: Jan 1- March 1

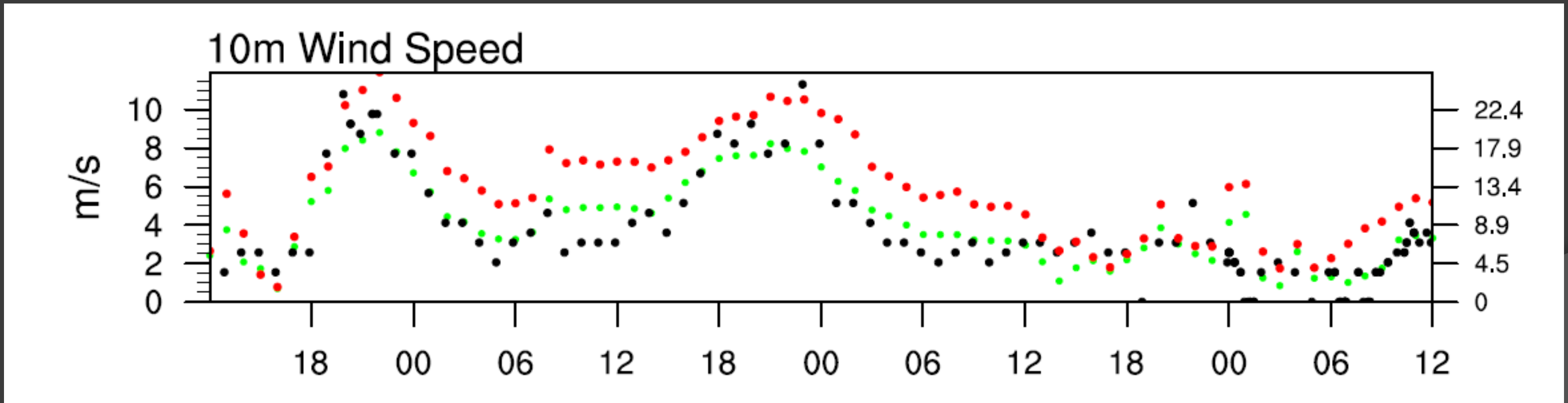
Use NDVI as proxy for
Soil moisture. Note reduction
of NDVI over the 3 month period



10/80m Wind Forecast



Time (GMT)



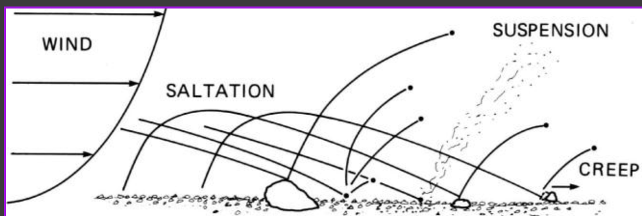
Time (GMT)

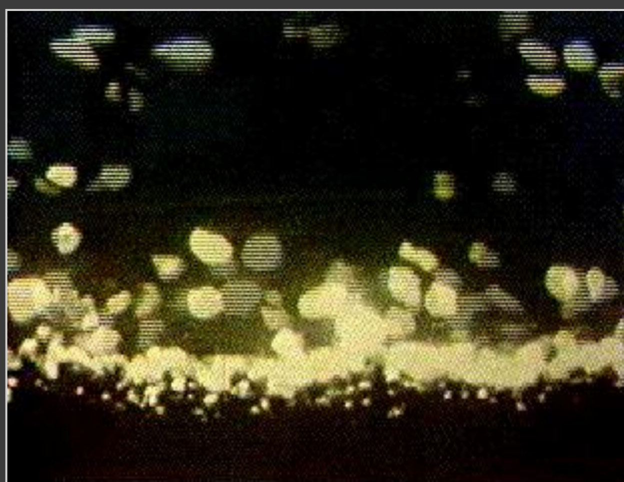
Black=Observed, Red=80m Forecast, Green=10m Forecast

Department of Atmospheric Sciences/UofA Expertise

- Eric Betterton: physics of dust transport, air quality, chemistry
- Ave Arellano: data assimilation, WRF Chem
- Chris Castro: NWP, regional climate
- Paul Brown (Ag): meteorological measurements
- Mike Leuthold: operational modeling

Wind Erosion Modeling



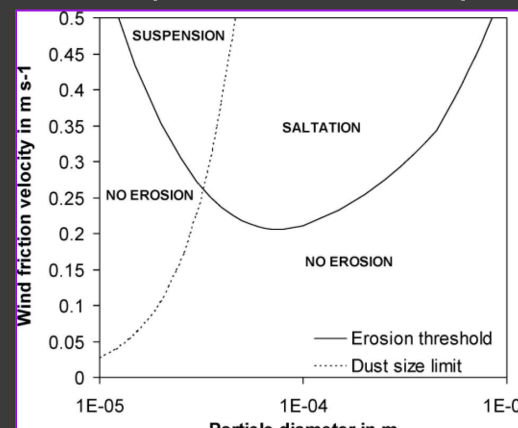


Saltating sand dune particles in wind tunnel

Kansas State University http://www.weru.ksu.edu/new_weru/multimedia/movies/dust003.mpg

Mass flux:

- Creep (rolling): 800-2000 μm D_p
- Saltation (hopping): 100-800 μm D_p
- Suspension (wind blown dust): <100 μm D_p



Greeley-Iversen erosion threshold curve

Kon *et al.*, *Int. J. Min. Reclamation & Env*. **21**, 198 (2007)

THE UNIVERSITY OF ARIZONA®

Arizona Cooperative Extension

AZMET

The Arizona Meteorological Network