Prediction of dust from dust storms: New Guidance in National Air Quality Forecast Capability

Operational Readiness Review

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Outline

- **Background**
  - *National Air Quality Forecast Capability*
  - *Prediction of dust from dust storms*
  - *Examples*
- **Review operational readiness**
  - *Readiness Criteria (OST)*
  - *Objective verification (NCEP)*
  - *Subjective feedback (OCWWS)*
  - *Production readiness (OPS)*
  - *Summary (OST)*
- **Recommendation**

Background

National Air Quality Forecast Capability

Vision

The National Air Quality Forecast Capability provides the US with ozone, particulate matter and other pollutant forecasts with enough accuracy and advance notice to take action to prevent or reduce adverse effects

Strategy

Work with EPA, US Forest Service, State and Local Air Quality agencies and private sector to develop end-to-end air quality forecast capability for the Nation

Prediction Capabilities, 1/17/12

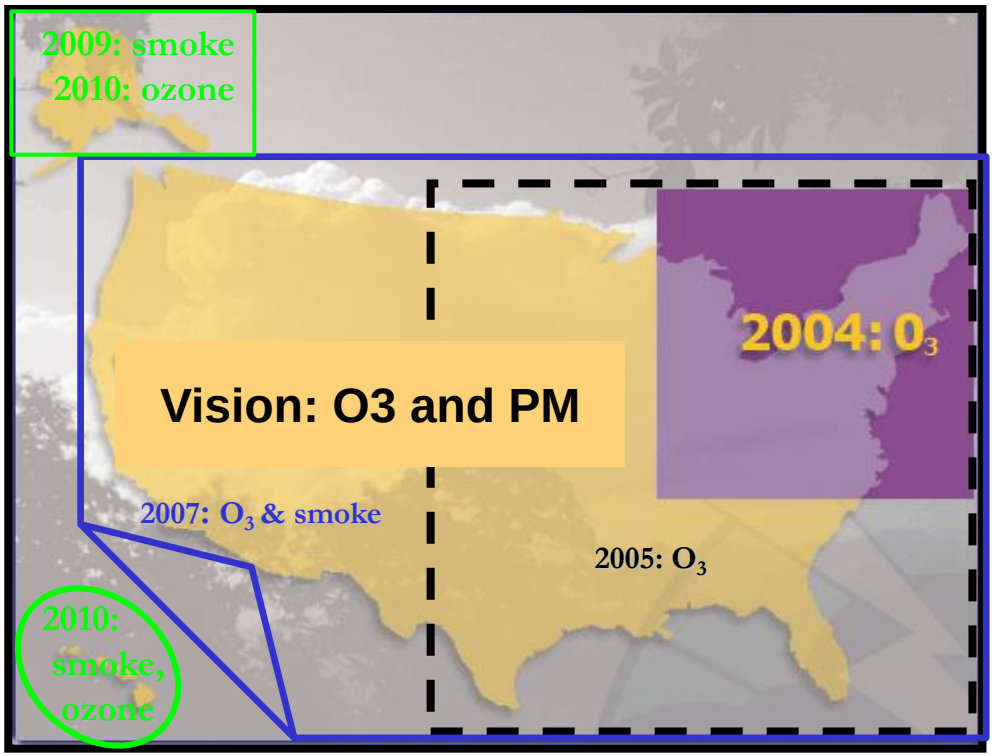
- Operations: Ozone and smoke nationwide

Near-term Operational Targets:

- Dust over CONUS

Longer range:

- Quantitative $PM_{2.5}$ prediction
- Extend air quality forecast range to 48-72 hours
- Include broader range of significant pollutants



Prediction of dust from dust storms over CONUS

- ***Critical for air quality forecasts of particulate matter (PM)***
  - *Windborne dust is a significant component of particle pollution*
  - *Dust emissions locally dominate PM (e.g. AZ and TX, 2011)*
  - *Challenges: when, how much and how far do dust emissions contribute to PM2.5?*

- ***Real-time information on dust emissions essential***
  - *Dust emissions depend on soil characteristics, wind velocity, soil moisture*

- ***Effectively leverages existing capabilities***
  - *NOAA/GFDL climatological map of dust sources from satellite observations*
  - *NOAA/NWS real-time information on soil moisture*
  - *NOAA/OAR expertise in dispersion prediction: HYSPLIT*

- ***Airborne dust impacts visibility, transportation safety, radiative forcing (and weather)***

Prediction of dust from dust storms over CONUS

End-to-End Capability

Model Components: Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

NCEP mesoscale NWP: NAM (NMMB, 12km resolution)

NOAA/OAR HYSPLIT dispersion for dust transport

Observational Input:

NWS real-time weather observations assimilated in NAM

Gridded forecast guidance products

On NWS Telecommunications Gateway and NDGD

Updated 2 times per day: 6z (available by 13z) and 12z (available by 17:30z)

Routine verification basis

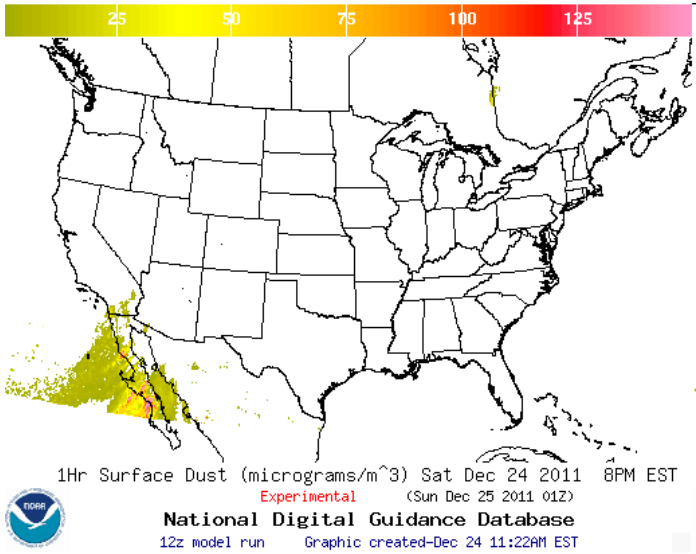
Near real-time NOAA/NESDIS dust-column product

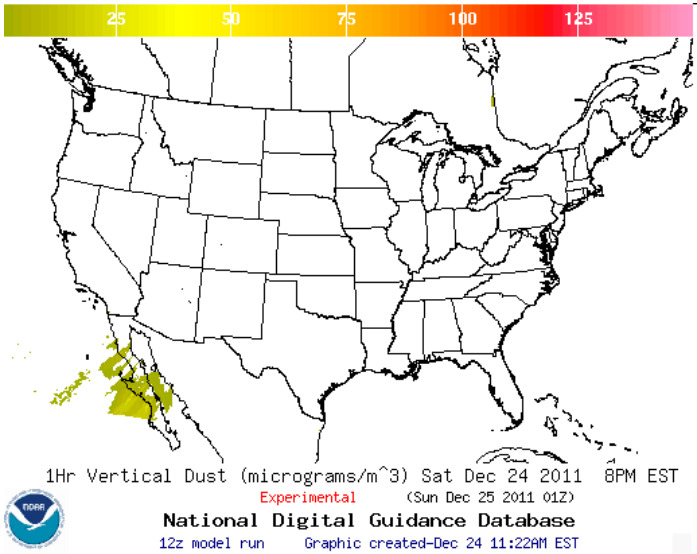
Customer outreach/feedback

NOAA/NWS field forecasters

State & Local AQ forecasters, coordinated with EPA

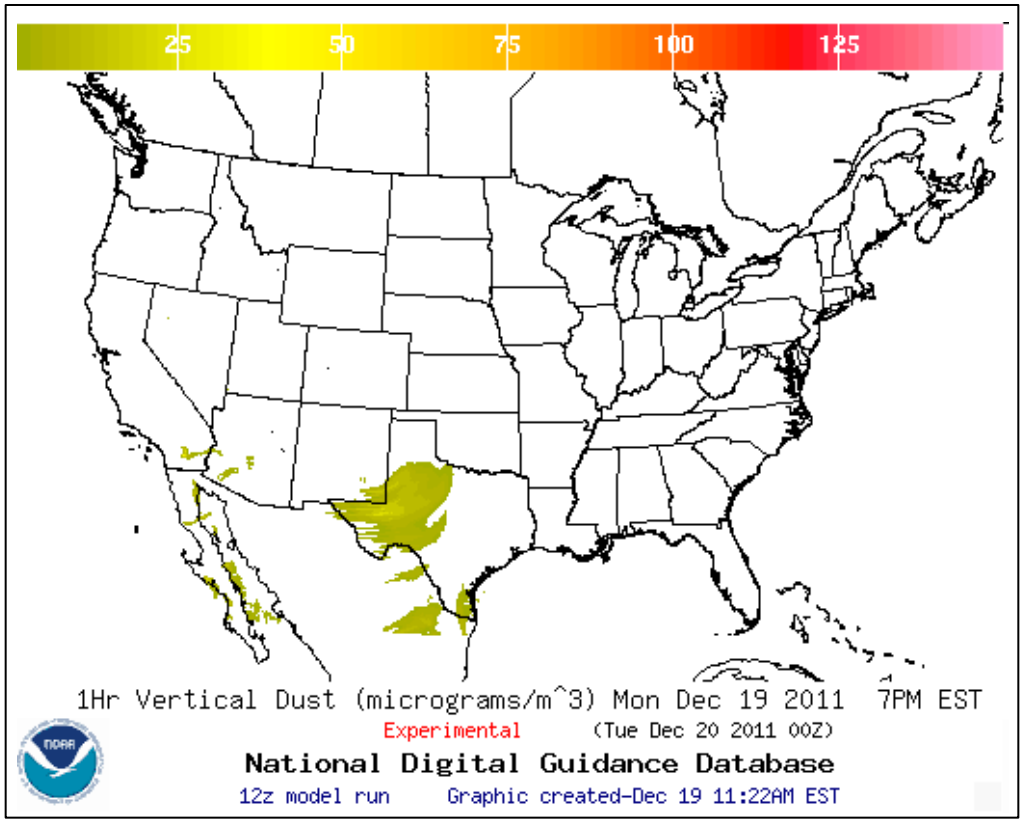
Public and Private Sector AQ constituents





CONUS dust forecast guidance:

December 19, 2011



- **Map of possible dust source locations and verification based on satellite observations**
- **Dust emissions depend on wind speed and real-time soil moisture**
- **HYSPLIT/NAM (NMMB) transport**

Publications in peer-reviewed literature:

Draxler, D, Paul Ginoux, and A F Stein, August 2010: An empirically derived emission algorithm for wind-blown dust. Journal of Geophysical Research, 115, D16212, doi:10.1029/2009JD013167.

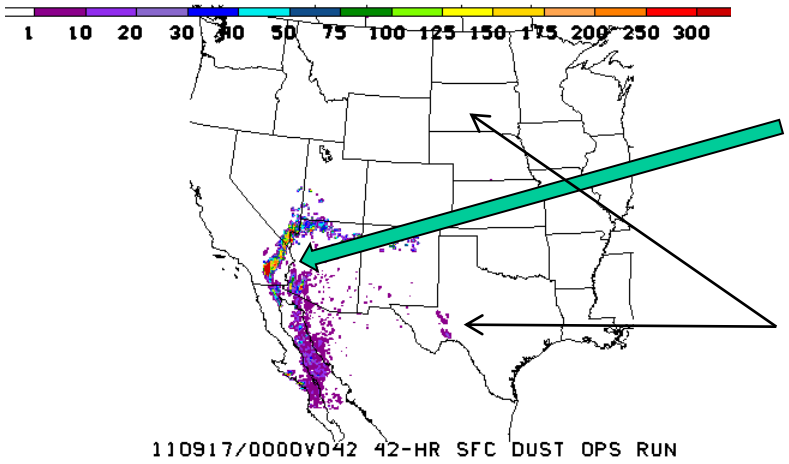
Ginoux, Paul, D Garbuzov, and N C Hsu, March 2010: Identification of anthropogenic and natural dust sources using Moderate Resolution Imaging Spectroradiometer (MODIS) Deep Blue level 2 data. Journal of Geophysical Research, 115, D05204, doi:10.1029/2009JD012398.

Draxler, R. R., and G. D. Hess (1998), An overview of the HYSPLIT_4 modelling system for trajectories, dispersion, and deposition, Aust. Meteorol. Mag., 47, 295–308.

Testing of dust predictions

- ***Initial NCO run started in May 2010. Product placed in experimental TOC directories and on the experimental directory on NWS web farm***
- ***Showed skill but often overestimated emissions in desert southwest and often missed emissions over the western plains (especially west Texas)***
- ***Current version includes modulation of emissions by soil moisture. It has been in real-time testing since May 2011, and running at NCO since November 2011. Shows improved prediction.***

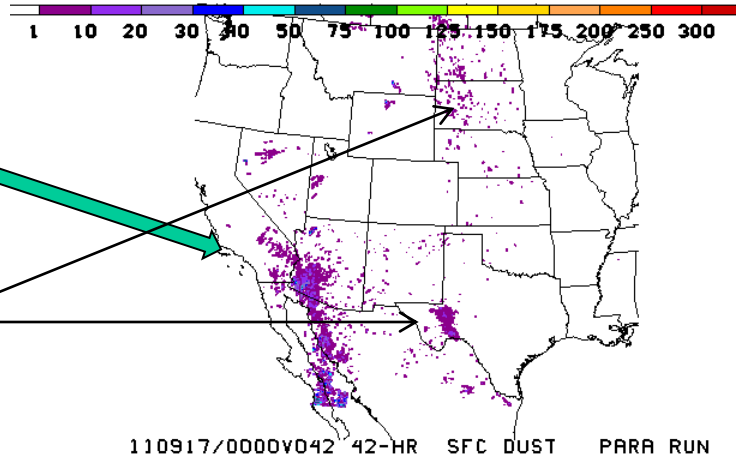
Initial model



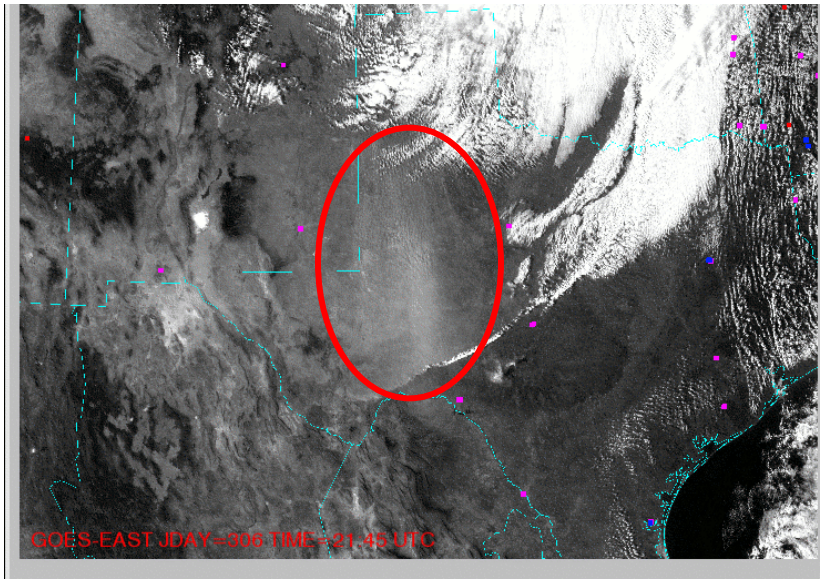
Reduced large concentrations in southwest

Capturing more smaller dust events

Current model

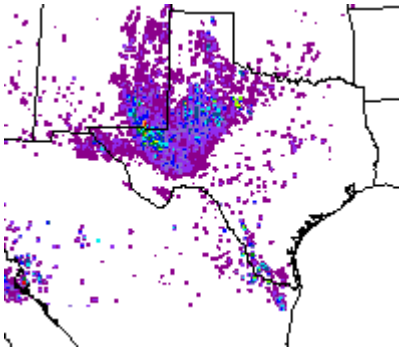


Texas dust event on November 2

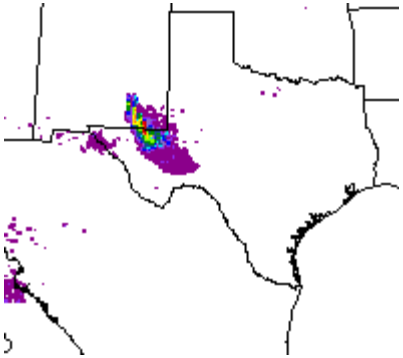


A widespread dust event occurred on Nov 2 beginning around 18Z in west central Texas. This event was the result of ~25kt synoptic scale winds ahead of a cold front. Through 0Z (Nov 3) the dust blew south covering all of west Texas and parts of southeast New Mexico.

Predicted dust concentration (ug/m3) at the surface

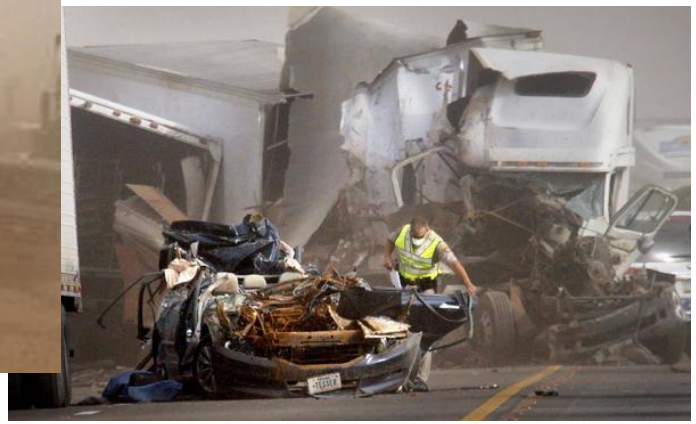


Current model: emissions modulated by soil moisture

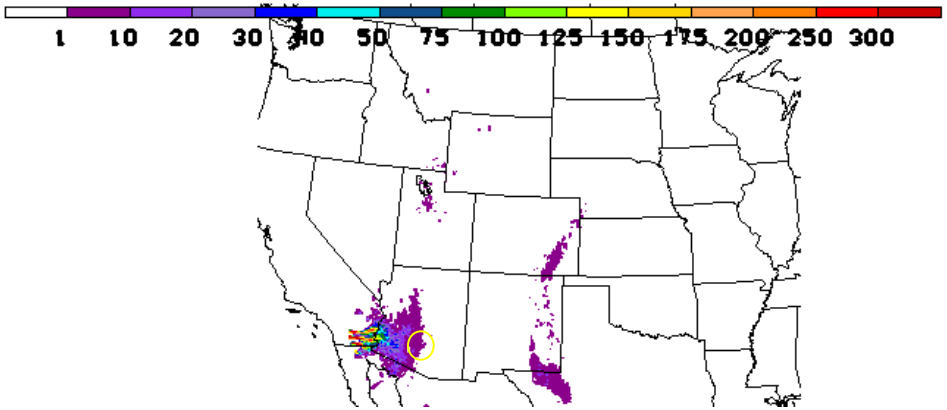


Initial model: emissions not modulated by soil moisture

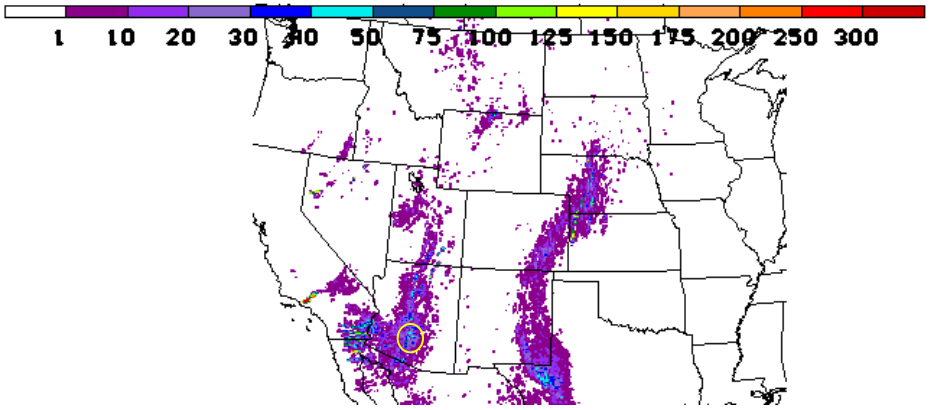
Arizona event on October 4



Initial model forecast from 12z on 10/3



Current experimental model forecast from 12z on 10/3



- ***3 serious crashes on I-10 between Phoenix and Tucson***
- ***Many injuries and 1 fatality***
- ***Southwest winds gusting to 35 kt with antecedent very dry conditions***

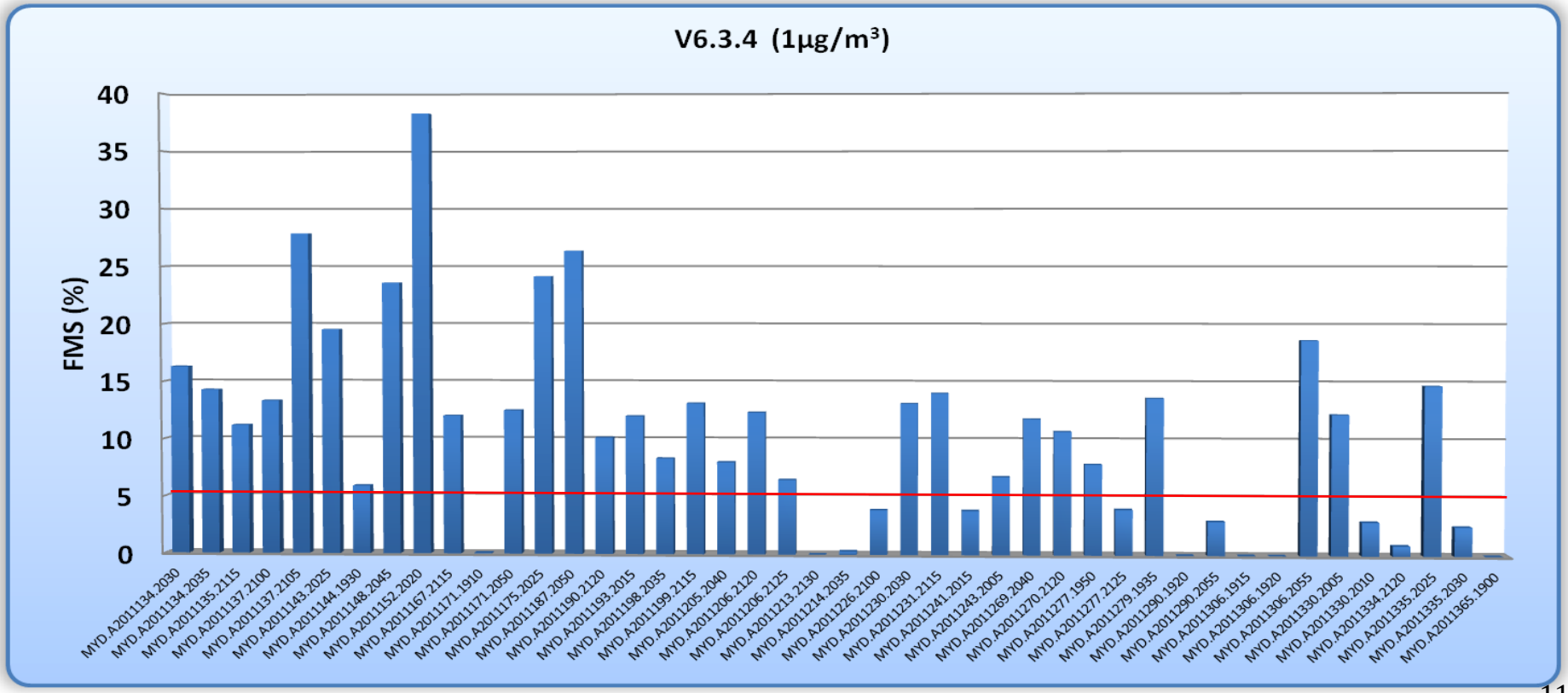
Source:http://www.deseretnews.com/article/700185387/I-10-reopened-after-dust-storm-causes-huge-pileup.html

CONUS Dust Forecast Guidance: *Verification Approach*

- **First real-time verification for dust from dust storms in daily use**
- **Based on NOAA/NESDIS Dust Mask Algorithm from MODIS imagery:**
  - *Product quality will be determined based on sunglint, solar zenith angle, dependence of thresholds used for detection on viewing geometry*
- **"Footprint" comparison for average column concentrations >1ug/m3:**
  - *Critical Success Index or figure-of-merit statistics:*

(Area Pred ∩ Area Obs) / (Area Pred. U Area Obs)

- **Initial skill target 0.05**



Review of Operational Readiness

CONUS dust forecast guidance:
Operational Readiness Criteria Summary

Criterion	Lead	Metric	Dates	Status 1/12
Objective Evaluation: CSI	*NCEP, NESDIS*	*> 0.05*	*5/11/11-1/15/12*	C
Subjective Feedback	*OCWWS*	*Positive on balance*	*6/22/10-12/31/11*	C
Production Readiness	*OPS, NCEP*			C
On-time delivery		*> 95 % (99%)*	*12/18/11-1/15/12*	C
Back-up		*In place*	*6/22/10-1/15/12*	C
Data retention		*In place*	*6/22/10-1/15/12*	C
Near-real time verification*	*NCEP, NESDIS*	*In place*	*1/31/12*	G

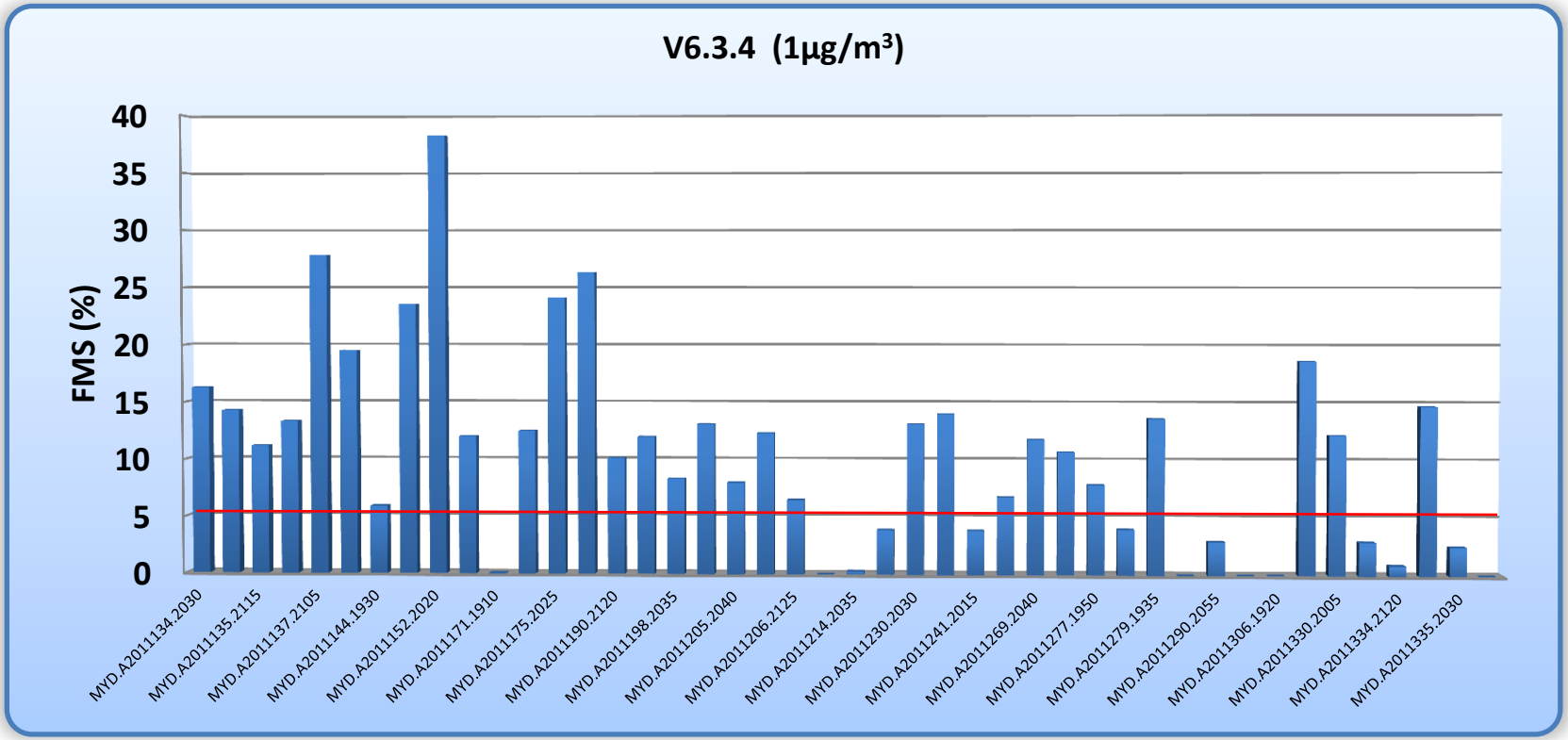
* = NESDIS automated (objective) product

Key	Complete	On schedule	At risk	Remedial Action Required

Objective Verification (NCEP, NESDIS)

Criterion	Metric	Dates	Status
Objective Evaluation: Accuracy	Prediction overlap (FMS) > 0.05 for 24-hr prediction that dust concentration ≥ 1 μg/m³ in total column	5/11/11-1/15/12	C

Summary Performance, based on new MODIS Dust Mask Product



Subjective Feedback (OCWWS)

Criterion	Metric	Dates	Status
Subjective Feedback	*External feedback from State/Local AQ forecasters support product as helpful.* *Other feedback: internal, constituent, general public: On Balance, positive*	*6/22/10-1/15/12*	C

Feedback Sources:

- **Feedback link from NDGD**
- **State and Local AQ forecasters**
- **NWS field forecasters**
- **Constituent group**
- **Other responses/comments on experimental products**

Example feedback: "NWS dust prediction is helpful for next day prediction of air quality." "The results you are getting are encouraging and well worth pursuing." – Bryan Lambeth, Texas Commission on Environmental Quality

Production Readiness (OOS, NCEP)

Criterion	Lead	Metric	Dates	Status 1/12
On-time delivery	OPS	Forecast guidance available by 1300 and 1730 UTC 95 %	12/18/11 – 1/15/12	99% C
Ftpserver	OPS	In place	6/22/10-1/15/12	C
NDGD server	OPS, MDL	In place	6/22/10-1/15/12	C
Back-up		Guidance and infrastructure backup in place	6/22/10-1/15/12	C
Data Retention		Archive at NCDC in place	6/22/10-1/15/12	C
Near-real time verification*	NCEP	In place	1/31/12	G

Notes: * NESDIS automated (objective) product

Key	Complete	On schedule	At risk	Remedial Action Required

Production Readiness (NCEP, NESDIS)

Near-real time verification

Criterion	*Metric*	*Dates*	*Status*
Near-real time verification	***Critical success index above 0.05 using 1 ug/m³ threshold***	***5/11/11-1/15/12 at NESDIS***	G

–***Verification Statistics:*** *Compiled and maintained by NESDIS STAR. Updated daily. Transitioning to NCEP 1/31/12.*

–***Availability:*** *Model developer group*

–***Seasonal summary:*** *Available on AQ program web site (public)*

–***Weekly verification:*** *Reports on operational performance measures provided by NCEP to OST PM*

–***NESDIS tailored***

MODIS Dust Mask Product: *Formatted as gridded WMO standard GRIB files Sent daily to NCEP for model verification*

–***Timeliness:*** *Daily; for 24 hour forecast interval by 48 hours after end of forecast interval*

Summary:
Experimental Production of dust forecast guidance for CONUS

- **January 2012 Status: ……general…**
  - *HYSPLIT predictions capture dust transport*
  - *Timing/location of plumes predicted; little quantitative concentration verification available other than column-wide*
- **Objective verification:** G
  - *Accuracy performance targets achieved*
- **Subjective feedback:** G
  - *Generally positive*
  - *Focus group forecasters providing additional feedback; additional feedback links posted on graphical display sites*
- **Production readiness:** G
  - *Forecast guidance available on time*
  - *Backup, data retention and verification demonstrated*

CONUS dust forecast guidance:
Operational Readiness Criteria Summary

Criterion	Lead	Metric	Dates	Status 1/12
Objective Evaluation: CSI	*NCEP, NESDIS*	*> 0.05*	*5/11/11-1/15/12*	C
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Near-real time verification*	*NCEP, NESDIS*	*In place*	*1/31/12*	G

* = NESDIS automated (objective) product

Key	Complete	On schedule	At risk	Remedial Action Required

Deployment Recommendation

Recommend:

NWS deploy dust forecast guidance for CONUS in the operational product suite

Backup

Phoenix, AZ dust event on July 5

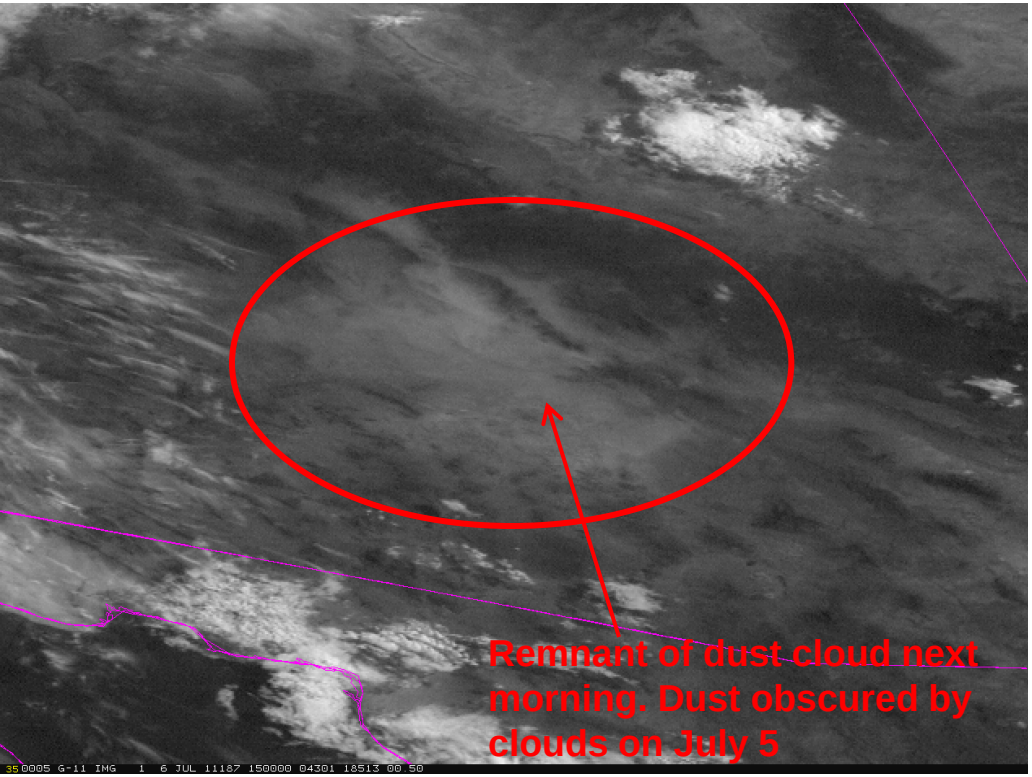
- Massive dust storm hit Phoenix, AZ in the evening on July 5, 2011
- Cloud was reported to be 5,000 feet when it hit, radar shows heights from 8,000-10,000 feet tall and 50 miles wide
- Originated from convection near Tucson
- Stopped air traffic for over an hour
- Arizona DEQ reported a PM10 concentration of 6,348 ug/m^3 during peak of storm at site in downtown Phoenix
- Storm moved through Phoenix at 30-40 mph

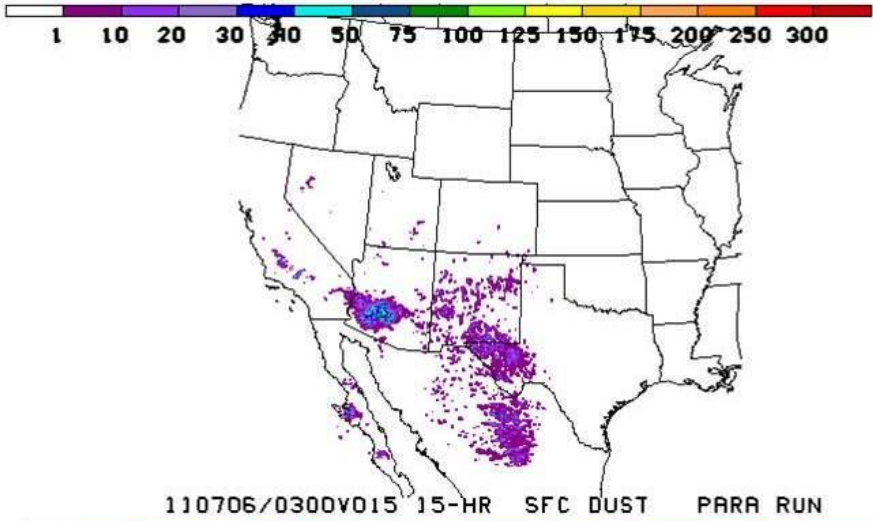

Source: http://www.wrh.noaa.gov/psr/pns/2011/July/DustStorm.php

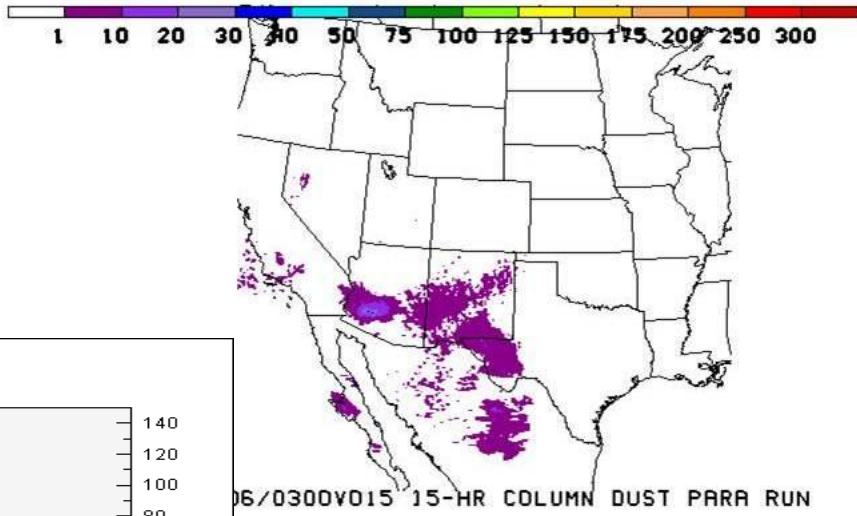

Source: http://www.huffingtonpost.com/2011/07/06/phoenix-dust-storm-photos-video_n_891157.html

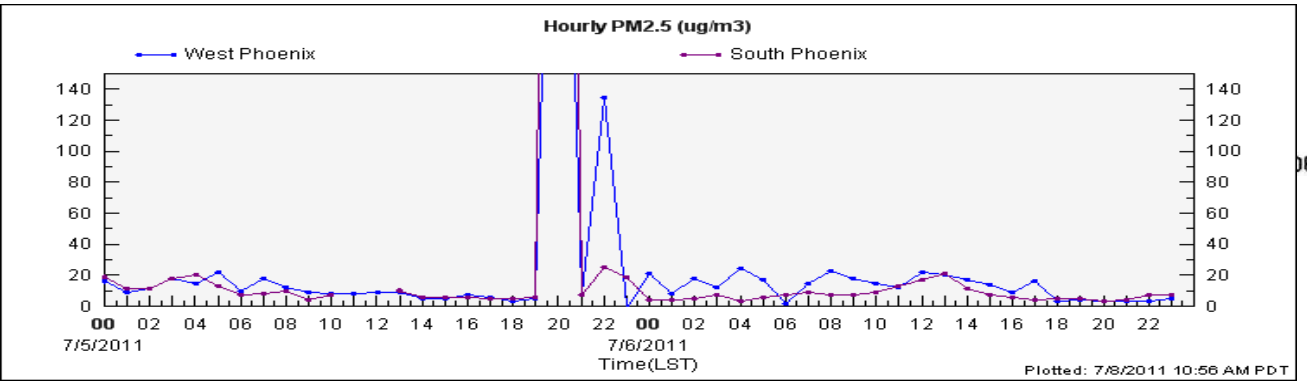
- Phoenix event generated by strong outflow MESOSCALE winds in common “dry” monsoon convective environment
- Dust emissions in previous two examples generated by SYNOPTIC wind field
- 12 km NAM background cannot resolve this type of convective outflow
- Regardless, the dust simulation CAN show an environment (based on soil moisture) favorable for significant dust emissions in the presence of strong surface winds

Phoenix, AZ dust event on July 5









Dust Forecast Tool for CONUS

Major Components

NWP Model

NMMB

NOAA/NWS

Weather Observations

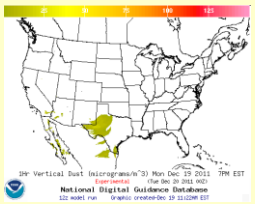
NWP Post-processors for AQ Modules

HYSPLIT Module:

NOAA/OAR

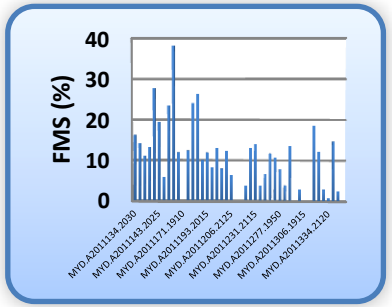
NOAA/GFDL

Map of possible dust sources

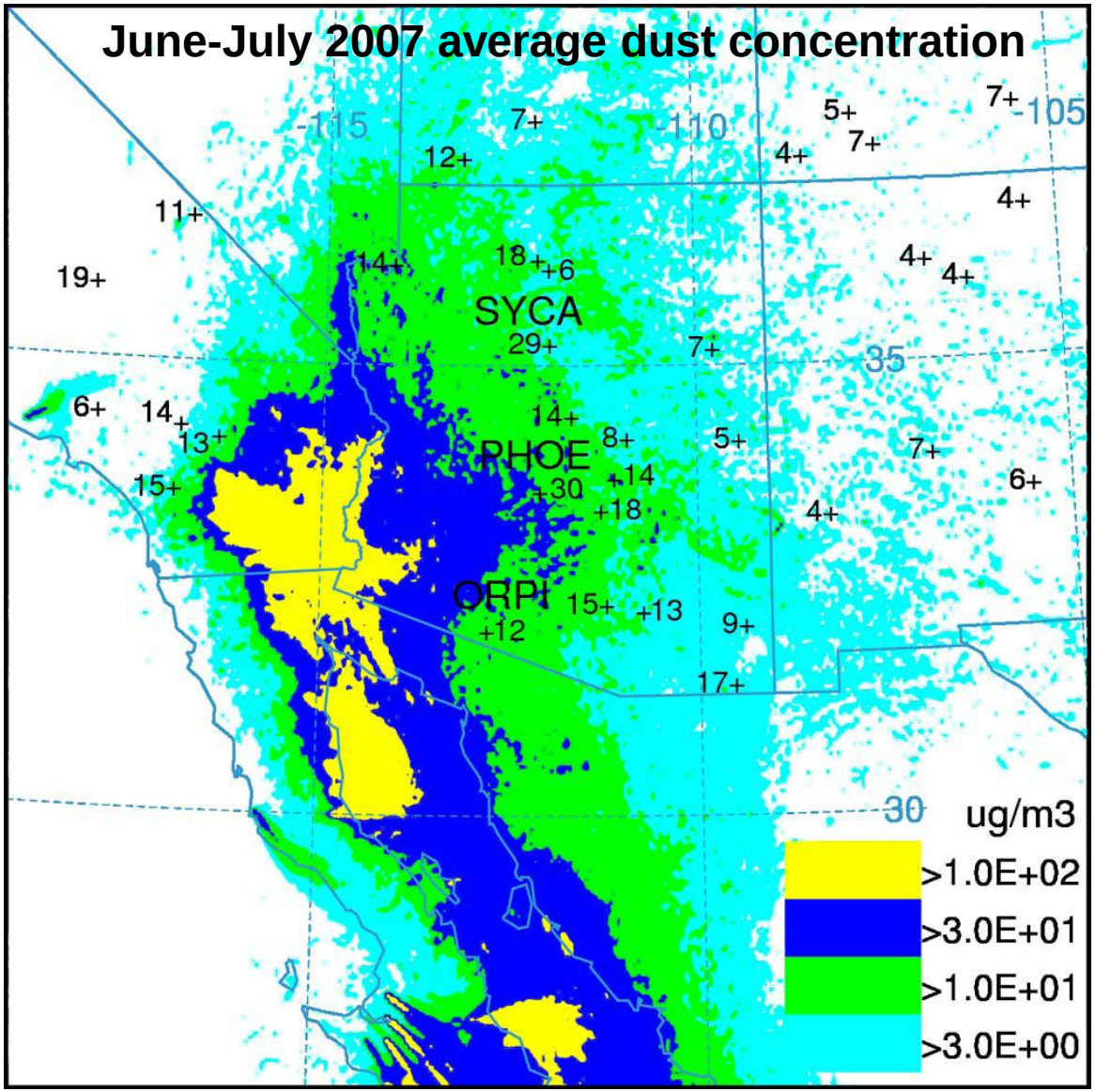


Verification:

NESDIS Dust



Dust simulation compared with IMPROVE data



Draxler et al. JGR 2010: HYSPLIT simulated air concentrations are compared with IMPROVE data in southern California and western Arizona:

- **Model simulations: contours**
- **IMPROVE dust concentration: numbers next to "+"**
- **Variability in model simulation**
- **Highest measured value in Phoenix**
- **Model and IMPROVE comparable in 3-10 ug/m^3 range**
- **Spotty pattern indicates under-prediction. Considering ways for improving representation of smaller dust emission sources.**
- **Dependence on soil moisture added in experimental testing**

Validation of MODIS Dust Mask Product (V6.3.4) using CALIPSO Vertical Feature Mask Product

MODIS dust mask product in a 5 X 5 km² around a CALIPSO observation are used for matchup. Table on this slide shows the summary of results. Formulae for Accuracy and POD are shown below the table.

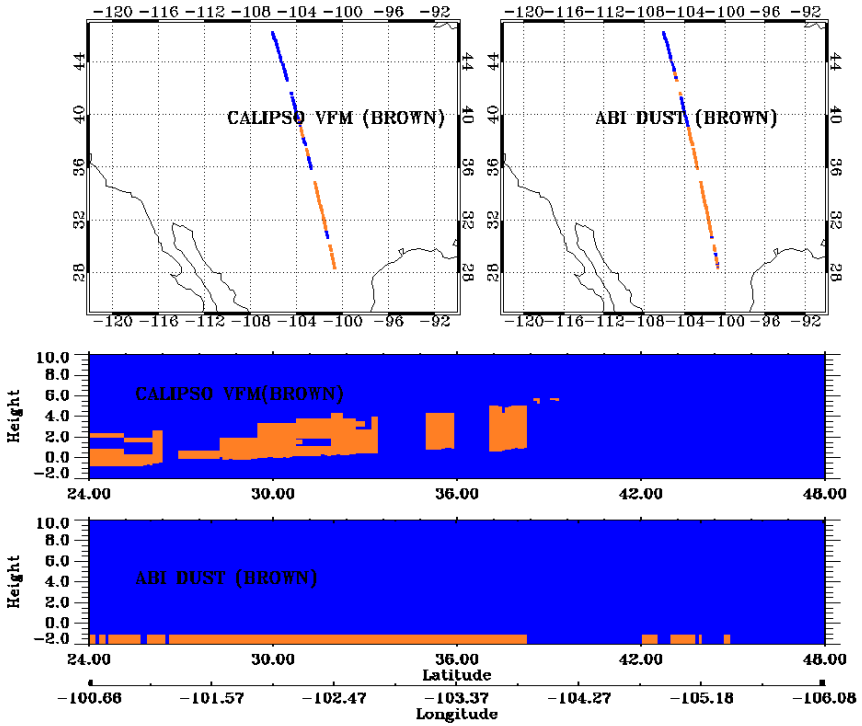
In 2010, 63 CALIPSO scan lines had dust cases. These scan lines over the US provided with thousands of pixels for comparison with MODIS dust mask product.

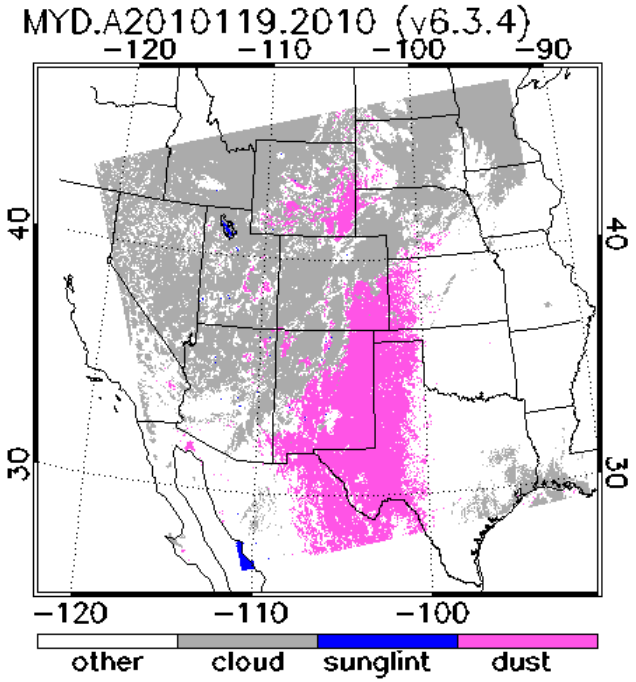
Examples of individual cases are shown in the following slides. Each slide has a CALIPSO scan line, MODIS dust mask product corresponding to the CALIPSO scan line, CALIPSO vertical profile, MODIS dust mask granule, MODIS deep blue and conventional AOD products (when two are available an average is taken). The table on the bottom left shows the agreement information and accuracy and POD are listed as well.

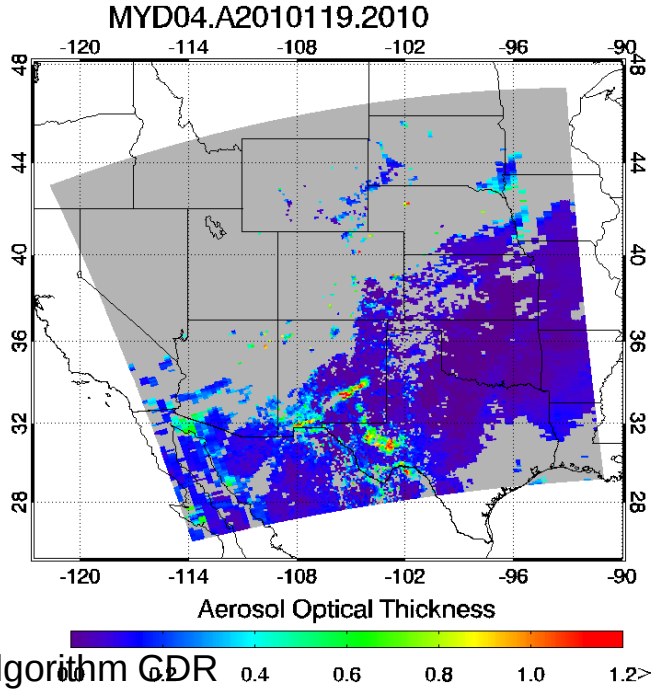
Cases	True Positive	False Negative	True Negative	False Positive	Accuracy (%)	POD (%)
63	564	476	9649	4422	67.59	54.23

True Positive (TP): MODIS and CALIPSO say dust
True Negative(TN): MODIS and CALIPSO say no dust
False Negative(FN): MODIS says no dust but CALIPSO says yes
False Positive(FP): MODIS says dust when CALIPSO says no

POD = TP/(TP+FN)
Accuracy = (TP+TN)/(TP+TN+FP+FN)







Detection	CALIPSO	MODIS	Samples
True positive	yes	yes	103
False negative	yes	no	9
True negative	no	no	74
False positive	no	yes	46

Accuracy=76.29
POD=91.96