A New Dust Dataset from the IMPROVE Ground Network

Daniel Tong, Julian Wang, Hang Lei and Barry Baker
NOAA Air Resources Laboratory, College Park, MD

Thomas Gill
University of Texas at El Paso, TX

Binyu Wang
George Mason University, Fairfax, VA

(JPSS Science Meeting 2017, College Park, MD)
The “Dust Bowl” During the Great Depression (1930s)

◆ Dust Bowl: A period of severe dust storms during the 1930s;
◆ Causes: Extended droughts and poor land management;
  ✓ Homestead Acts: settlement over the Plains for agriculture;
  ✓ “Rain follows the plow”: unusually wet climate;
  ✓ New agricultural machinery: Deep plowing, eliminating native grass;
  ✓ Favorable dust storm conditions during 1930s drought;
The “Dust Bowl”

Impacts:

✓ Stripped 75% of top soils over thousands of farms;
✓ Destroyed agriculture and ecosystem (~1950s);
✓ > 500,000 lost homes and communities;

"And then the dispossessed were drawn west--from Kansas, Oklahoma, Texas, New Mexico; from Nevada and Arkansas, families, tribes, dusted out, tractored out... They streamed over the mountains, hungry and restless--restless as ants, scurrying to find work ... anything, any burden to bear, for food. The kids are hungry. We got no place to live…"

-- John Steinbeck in the Grapes of Wrath
Another “Dust Bowl”?

◆ Central U.S. plains saw severe droughts about once or twice a century over the past 400 years (Woodhouse & Overpeck, 1998).

◆ This recurring trend may be enhanced global climate change (Schubert et al., 2004).

◆ Global warming → Precipitation shift from subtropics, greater evaporation, less snow/ice, and earlier spring → amplify the effects of natural climatic variations → intensified droughts and “dust-bowlification” (Romm, 2011).

(Source: Romm, 2011)
How to Monitor Dust Storms

Chinese Sand and Dust Network

(Wang et al., 2008)

The US Aerosol Network IMPROVE

IMPROVE Samplers
Samples Analyzed at UC-Davis
Satellite-aided Algorithm Training

PM10: Particulate Matter < 10 μm
PM2.5: Particulate Matter < 2.5 μm

GUMO
Nov. 27, 2005

BIBE

DEVA
Apr. 12, 2007

SAGO1

Concentration (μg/m³)
Satellite-aided Algorithm Training

Crustal (μg/m³)

• GUMO
• GUMO
• BIBE
• DEVA
• SAGO1

Apr. 15, 2003
Nov. 27, 2005
Apr. 12, 2007

Si – Silicon; Ca – Calcium; K – Potassium; Fe – Iron
Satellite-aided Algorithm Training

PM2.5/PM10 Ratio

Apr. 15, 2003
- GUMO

Nov. 27, 2005
- GUMO
- BIBE

Apr. 12, 2007
- DEVA
- SAGO1

PM2.5/PM10
Dust Identification through Cluster Analysis

Five Dust Indicators:

- High PM$_{10}$, PM$_{2.5}$
- Low PM$_{2.5}$/PM$_{10}$ ratio
- High Crustal Fraction
- Low anthropogenic Fraction;
- Low Enrichment Factor;

Cu – Copper
Pb – Lead
Zn – Zinc
Detecting Dust Storms

Guadalupe Mountains National Park

This algorithm, combined with cluster analysis, can pin-point dust.

(Source: Mo Dan)
Locations of Dust Storms

Dust storms detected at 29 sites with continuous data records.
Long-term Dust Trend

20 Giant Storms in 1990s → 48 Storms in 2000s;
Seasonal Variation

Increase in Spring (mostly) and Fall;
Almost no change in Summer/Wet Season;
Decreasing Dust Trends in Asia and Africa

Global dust concentration decreased at 1.2%/yr from 1984 –2012

(Shao et al., 2013)
What Drives the Dust Trend?

(Contributed by Hang Lei)

<table>
<thead>
<tr>
<th></th>
<th>ENSO</th>
<th>PDO</th>
<th>NAO</th>
<th>PNA</th>
<th>AO</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL-dust</td>
<td>-0.44</td>
<td>-0.62</td>
<td>-0.41</td>
<td>-0.33</td>
<td>0.38</td>
</tr>
<tr>
<td>HL-dust</td>
<td>-0.32</td>
<td>-0.73</td>
<td>-0.40</td>
<td>-0.56</td>
<td>0.33</td>
</tr>
</tbody>
</table>

LL – Low Latitude North American deserts (Chihuahua, Mojave, and Sonoran);
HL – High Latitude Deserts (Great Basin and Colorado Plateau)
Changes in Sea Surface Temperature

(Contributed by Julian Wang)
Changes in Soil Moisture

(C的是tributed by Julian Wang)
What’s Next?

- Build community consensus on the long-term trend;
- Use ground data for satellite product validation.

IMPROVE vs MODIS Dust Frequency (MODIS data - Ginoux et al., 2012)

Ground networks

(source: Ciren and Kondragunta, 2014)
Summary

◆ We developed a new dust identification method for IMPROVE dataset for VIIRS Dust validation

◆ The frequency of dust storms more than doubled from 1990s to 2000s in the Southwest United States.

◆ The dust trend is likely driven by large-scale variations of sea surface temperature in the Pacific Ocean.

• Further information:
  Tong et al., Atmospheric Chemistry & Physics, 2012;
  Lei et al., Climate Dynamics, 2016;
  Tong et al., Geophysical Research Letter, 2017;
Acknowledgment & Data Access

• Funding Support: NASA ROSES and NOAA USWRP;
• Data: EPA, NOAA, NASA, CDC and Arizona DHS;
• Many colleagues for inspiring discussion.

• Data Access: Email qtong@gmu.edu
• Project Website: http://ws.laits.gmu.edu/nca