Limitations in Forecasting Middle Eastern Dust Storms with Weather Models

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Hypothesis: A significant amount of Middle Eastern dust is generated by storms and missed by current weather forecast models

Conclusion: Storms not explicitly resolved in forecast models can alter dust concentrations by more than 250%

Motivations

Dust Storms Cause:

Reduced Visibility and Agricultural Productivity

Respiratory, Ocular, and Circulatory Damage

Spread of Disease

Ecosystem Fertilization

Fig. 1) Dust storm in Sudan (credit: Obaya Salkini)

- Severe dust outbreaks are common in the Middle East
- Large-scale dust sources can be captured in weather forecasting models, but dust lofted by small-scale storms is not explicitly predicted
- To improve dust forecasts, should we put resources into resolving the large-scale processes or small-scale storms?

Hypothesis

The amount of Middle Eastern dust lofted by storms is non-negligible relative to dust produced by large-scale flow

How do storms influence dust concentrations?

Methodology & Case Study

- Employ a numerical weather forecasting model as a laboratory to simulate a representative dust case study

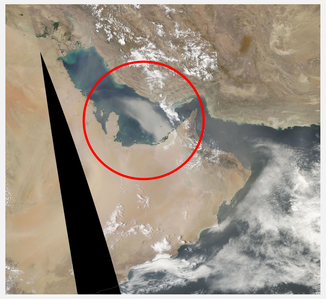

Fig. 2) AQUA true color image: 04-Aug-2016 / 9:30 UTC

Middle East:
04-Aug-2016

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Control Simulation
Include Storms

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Perturbed Simulation
No Storms

The amount of dust lofted scales superlinearly with surface wind speed

- Weather Research and Forecasting Model coupled with Chemistry (WRF-Chem 3.9.1.1) combined with the GOCART aerosol model

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Model Setup

- Model: WRF-Chem 3.9.1.1
- Dust Scheme: GOCART
- 15-km grid spacing – typical of global dust forecast models (Figure 3)
- Start: 02-Aug-2016-00Z
- End: 05-Aug-2016-00Z
- Initialization: FNL-GDAS (0.25°x0.25°)

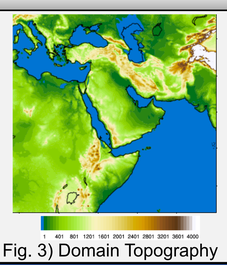

Fig. 3) Domain Topography

Conclusions

- Including storms in the simulation changes the spatial distribution and concentration of mineral dust (Fig. 4&5)
- More dust is lofted with storms in coastal regions
- Inland regions respond more strongly and loft less dust as the large-scale flow is punctuated by storms
- Storms move dust from the surface to higher levels of the atmosphere

Simulation Results

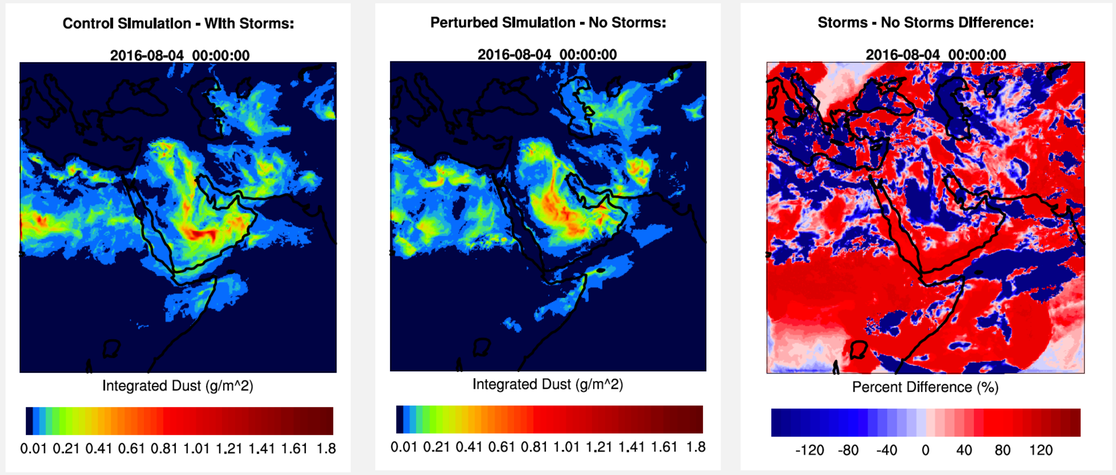

Fig. 4) Integrated dust for the control simulation (left) with storms, the no storm case (middle), and the percent difference (right)

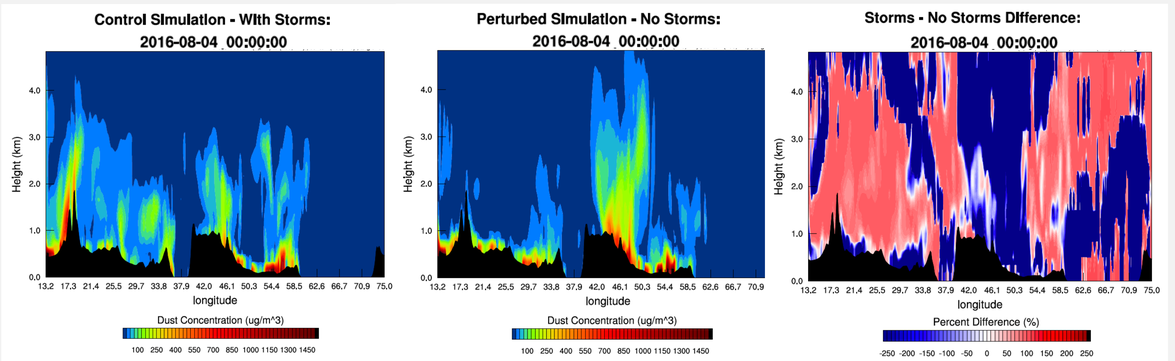

Fig. 5) Vertical E-W cross section of dust concentrations at 26°N for the control simulation with storms (left), the no storm case (middle), and the percent difference between the two (right). Terrain is contoured in black.

Coastal Areas

High moisture content

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More prone to generating storms

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Storms increase dust lofting

Inland Areas

Low moisture content

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Few storms

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Storms decrease dust lofting by interrupting large-scale flow

Storms redistribute dust from the surface to higher levels of the atmosphere compared to large-scale flow

The loss of dust inland outweighs the addition of dust along the coasts. There is a strong interference between the two

Future Work

- Regional convective vs non-convective dust lofting & convective parameterizations (2018 AMS meeting)
- Regional climatology & haboob climatology – frequency of this type of meteorological setup and dust outbreak
- Sensitivity to sea surface temperatures
- Dust scheme sensitivities

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