

# Development of high school modules based on atmospheric physics research

**SCAAPT 2015 Spring meeting**  
**UCLA**  
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**Jasper Kok**

Assistant professor

Atmospheric & Oceanic Sciences

UCLA

[jfkok@ucla.edu](mailto:jfkok@ucla.edu)

**&**

**Shanna Shaked**

Lecturer

Physics department

UCLA

[shaked@physics.ucla.edu](mailto:shaked@physics.ucla.edu)

# Objectives of this talk

- Plan to develop module for high school physics classes
  - Based on research on **physics of dust storms and climate change**
  - Module would address several science standards
- Hope to **find one or more partners** for developing and implementing high school physics module
  - Applying for funding for high school teacher to jointly develop lesson plans in summer
  - Interested? → **[jfkok@ucla.edu](mailto:jfkok@ucla.edu)**

# Outline

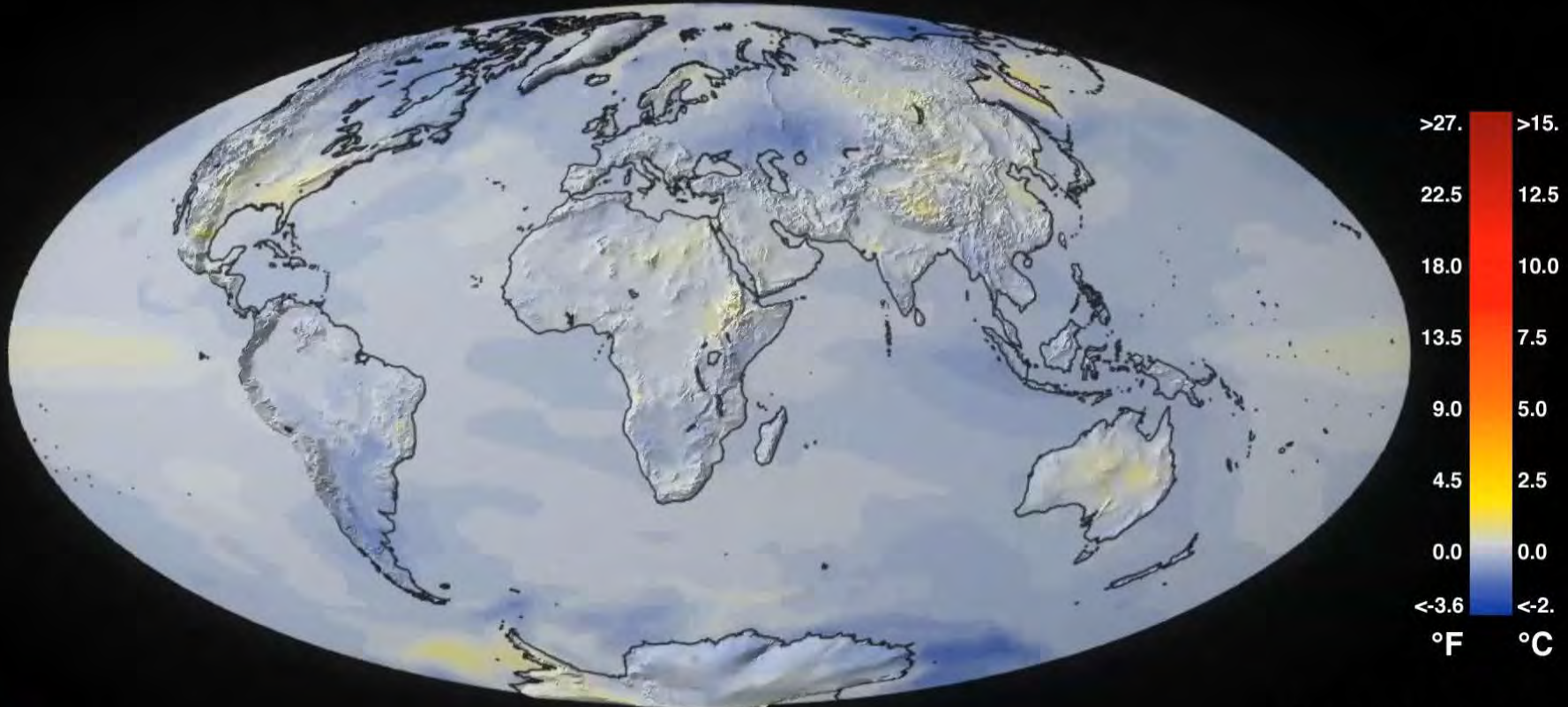
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- Introduction to my **research in atmospheric physics**
  - Relation to **climate change**
- Proposed **high school physics module**
  - Does atmospheric dust warm or cool the planet?
- **Feedback and discussion**

# Movie of warming Earth

Annual Global Surface Temperature Anomaly

1850



Simulated

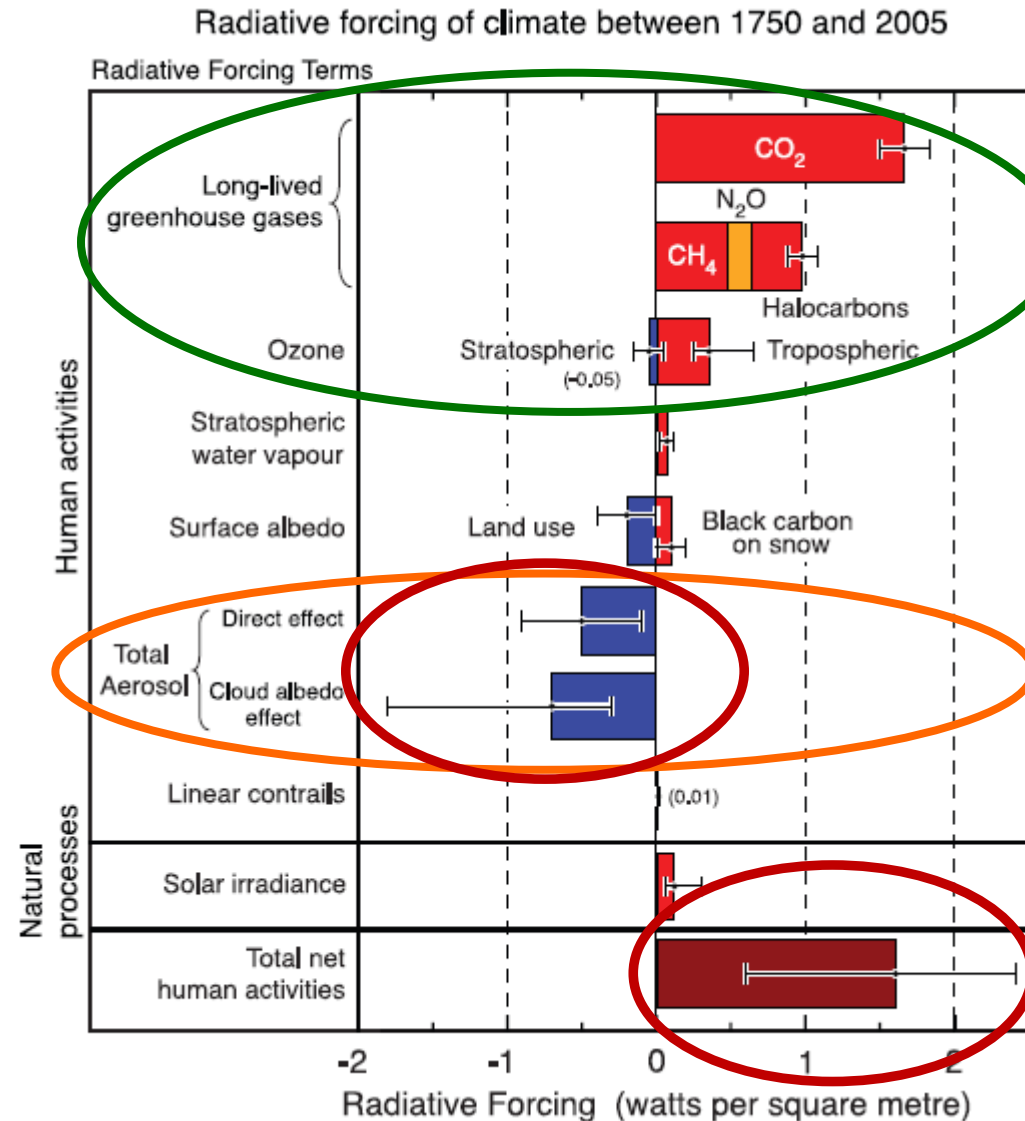
Base Period 1850-1899,  
6 member ensemble mean

<http://opensky.library.ucar.edu/collections/OSGC-000-000-020-047>

Jasper Kok (jfkok@ucla.edu) – Dept of Atmospheric & Oceanic Sciences - UCLA

# Physics of the climate problem

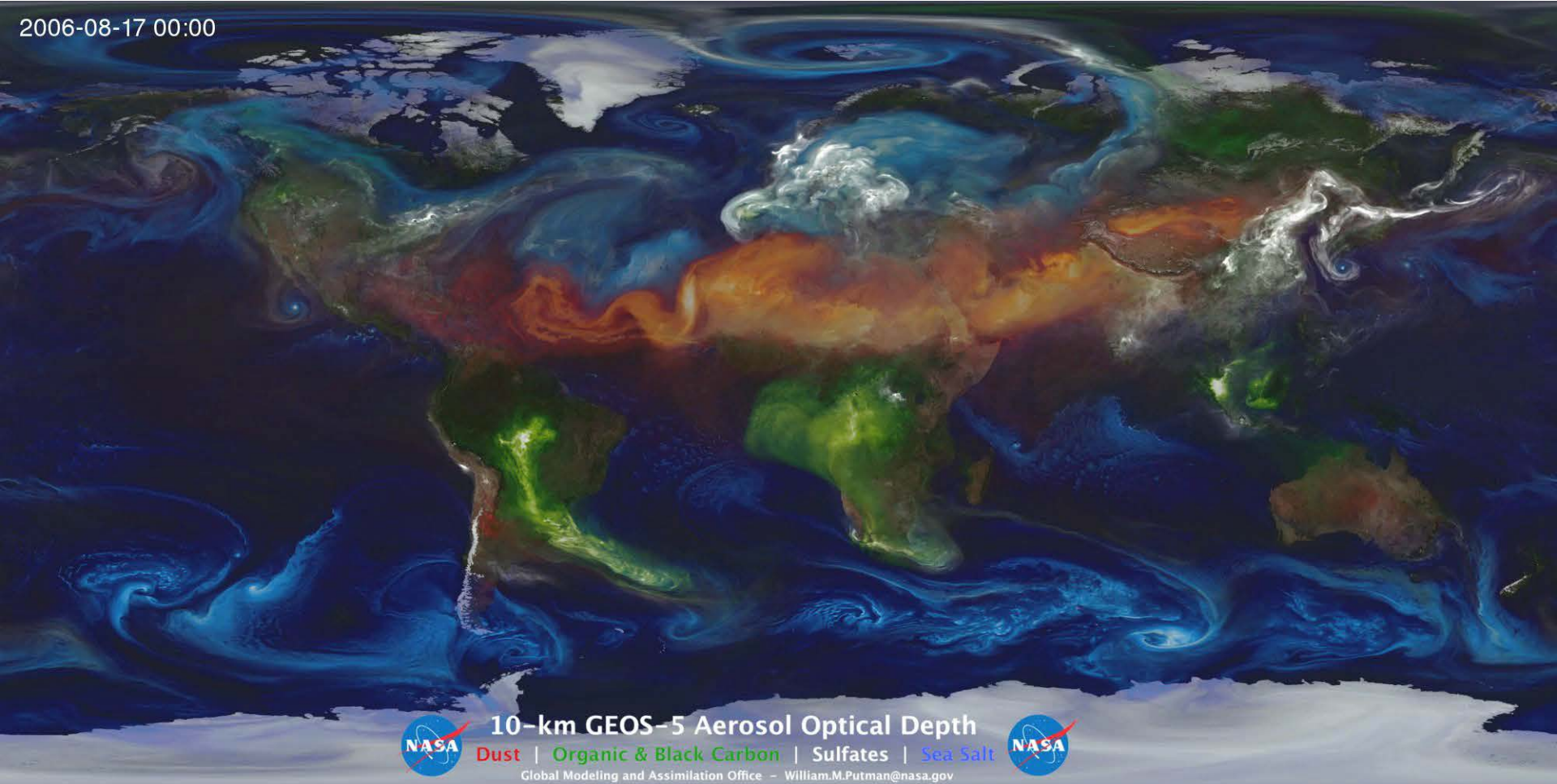
- Human activities have **increased greenhouse gas concentration**
  - Their effect is relatively well understood
- Humans also emitted particulate matter ("**aerosols**")
  - Very diverse, and variable in time and space
  - Impact climate through **poorly understood** interactions with clouds and radiation
- Impact of aerosols is **leading source of uncertainty** in climate projections



(Intergovernmental Panel on Climate Change, 2007)

# Movie of different aerosol species

2006-08-17 00:00



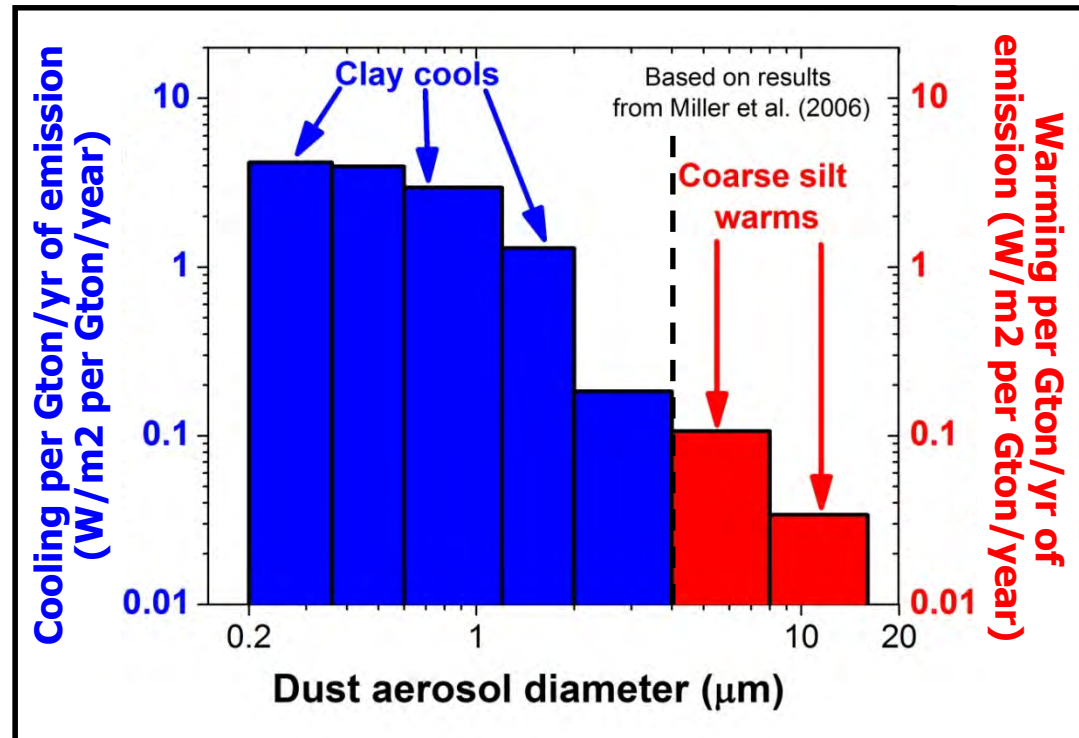


# Opposing effects of dust on climate

- **Small “clay” dust ( $D_d < 2 \mu\text{m}$ ) cools** by scattering solar radiation
- **Larger “silt” dust ( $D_d > 2 \mu\text{m}$ ) also absorbs** solar radiation, as well as terrestrial radiation
  - Globally-averaged effect is **probably warming**

- So does dust **warm or cool** the planet?
  - Depends on the **distribution of sizes** of dust

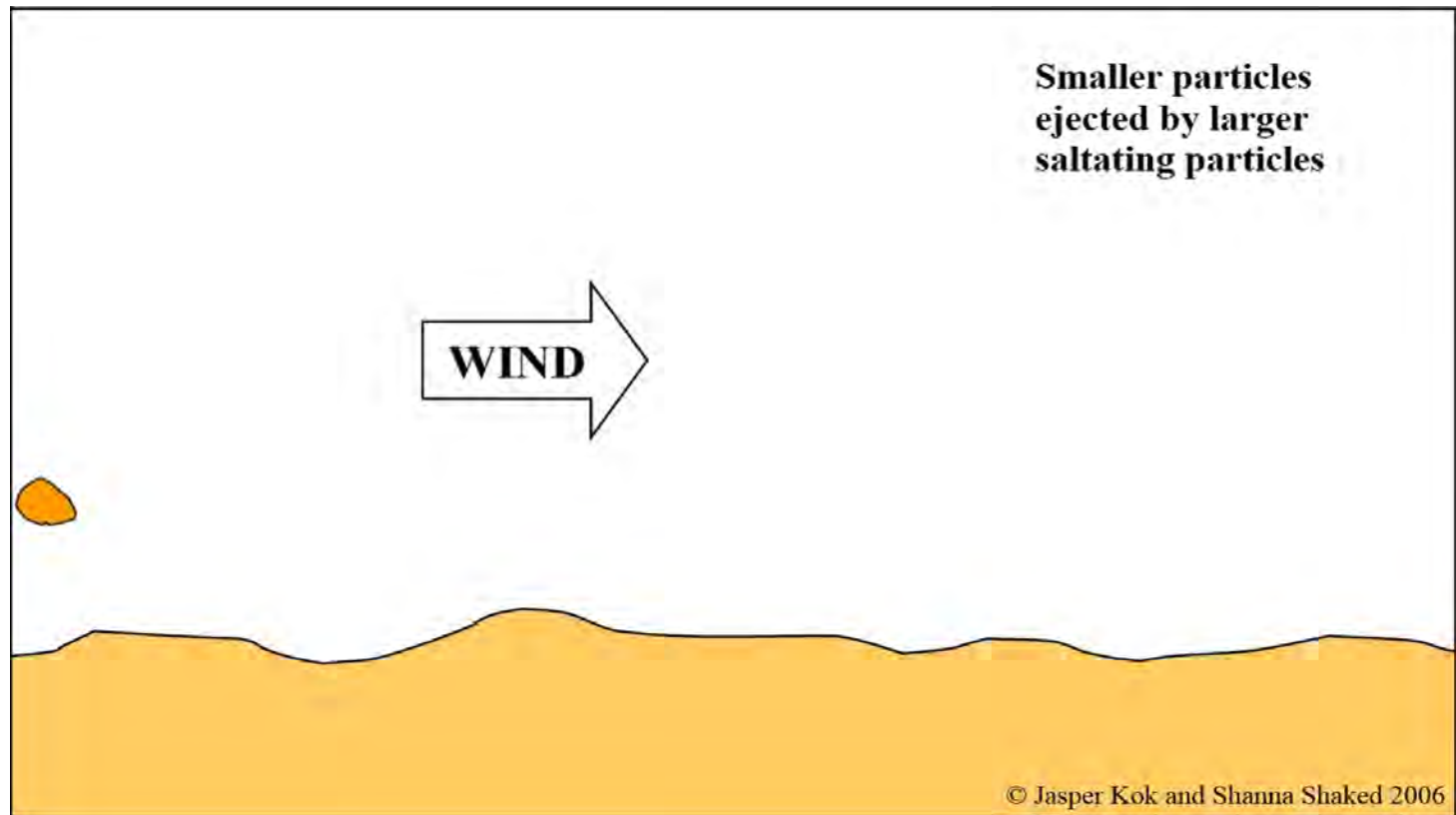
- What determines size distribution of dust?
  - The **physics of dust emission!**





# Physics of dust emission: blowing sand

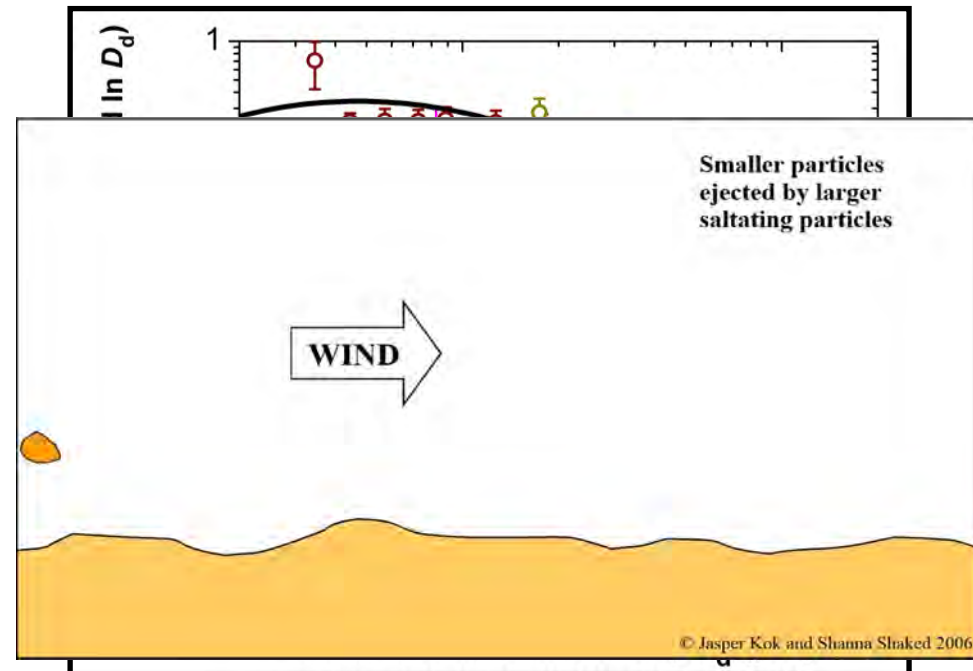
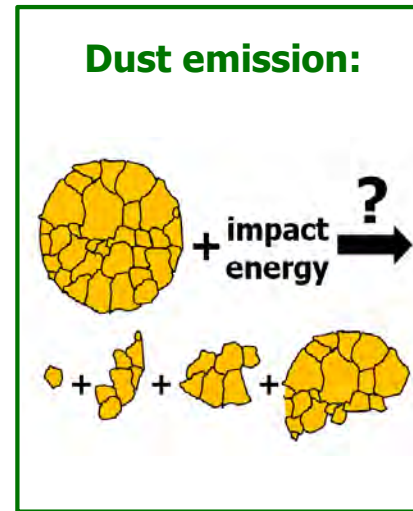
- Dust aerosols ( $\sim 0.1\text{-}20\ \mu\text{m}$ ) are emitted by **impacts of blowing sand** ( $\sim 200\ \mu\text{m}$ )
  - Also forms **dunes and ripples**





# Dust emission $\approx$ breaking glass

- Dust emission is like **breaking glass**
  - Bouncing sand "**cracks**" soil
  - **Similar to drinking glass cracking** on kitchen floor
- Used analogy to **derive dust size distribution** at emission
  - Matches measurements



# Outline

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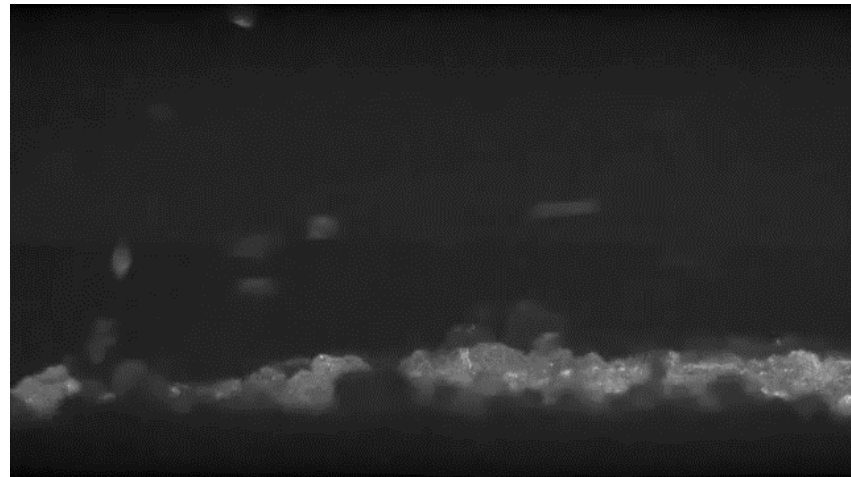
- Introduction to my research in atmospheric physics
  - Relation to climate change
- Proposed **high school physics module**
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# Proposed HS physics module on dust and climate change (1)

- Guiding question: Lesson:
  - Does dust warm or cool the planet? **#3**
  - How much big dust and small dust gets into atmosphere? **#2**
  - How does dust get into atmosphere? **#1**

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- Potential lesson #1: Physics of dust emission
  - Use video analysis of sand trajectories to calculate wind acceleration (HS-PS2-1: Newton's second law)
    - Calculate force of wind from mass of sand
  - Calculate sand impact energy from video analysis (HS-PS2-4: Energy conservation)
    - Given bonding energy of dust (J/kg) in soil, how much dust is ejected per sand impact?



# Proposed HS physics module on dust and climate change (2)

Lesson:

**#3**

**#2**

**#1**

- Guiding question:

- Does dust warm or cool the planet?

- How much big dust and small dust gets into atmosphere?

- How does dust get into atmosphere?

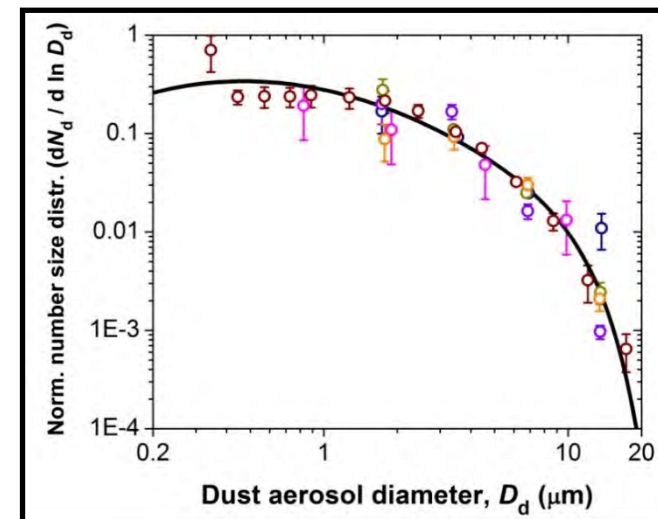
- Lesson #2: Large dust versus small dust

- Given total desert area, and average sand impacts per unit area and year, what is total dust emission rate?

- Provide measurements of dust size distribution

- How many large dust particles are emitted for each small particle?

- How much large and small dust is ejected into atmosphere per year?



# Proposed HS physics module on dust and climate change (3)

Lesson:

■ Does dust warm or cool the planet?

**#3**

■ How much big dust and small dust gets into atmosphere?

**#2**

■ How does dust get into atmosphere?

**#1**

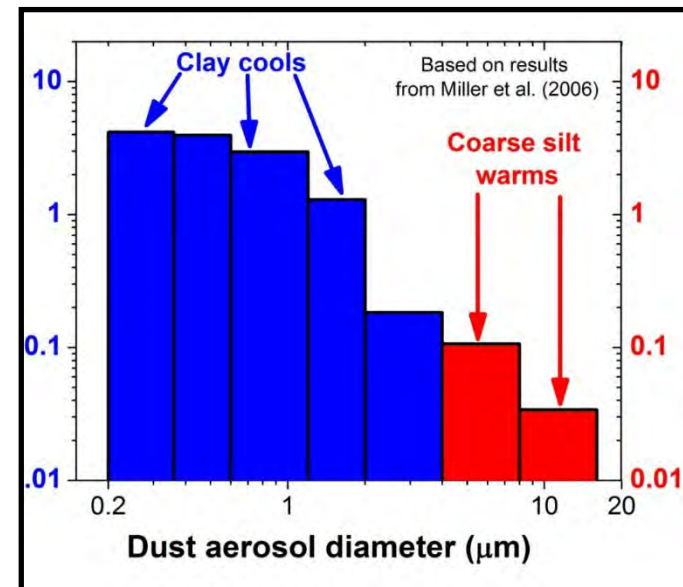
■ Lesson #3: Does dust warm or cool the planet?

■ Small dust cools, large dust warms

- What is net effect of dust on climate?
- Projected future dust changes: -20% to +30%. What is resulting change in Earth's energy budget?
- What would be resulting T change?

■ Combine in computational model for HS-PS3-1 (computational model of energy flows)

- Compare students results to range of scientific results



# Outline

- Introduction to my research in atmospheric physics
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- Proposed high school physics module
  - Does atmospheric dust warm or cool the planet?
- **Feedback and discussion**



# **Clicker questions to get your feedback**

**(Shanna made me do this)**

**Would you be interested in using my proposed module in your classroom?**

A. Yes, very interested

B. A little interested

C. Not interested

**Would covering several NGSS Earth Science standards make you more or less interested in using my module?**

A. More interested

B. Makes no difference

C. Less interested

**Would covering several Common Core mathematics standards make you more or less interested in using my module?**

A. More interested

B. Makes no difference

C. Less interested

**Would you be interested in jointly developing the proposed module in a funded collaboration?**

A. Yes, very interested

B. A little interested

C. Not interested

# Interested? Questions?

(You can reach me at [jfkok@ucla.edu](mailto:jfkok@ucla.edu))

## Relevant papers:

Kok, J. F. (2011), A scaling theory for the size distribution of emitted dust aerosols suggests climate models underestimate the size of the global dust cycle, *Proc. Natl. Acad. Sci. USA*, 108, 1016-21

Kok, J. F., E. J. R. Parteli, T. I. Michaels, and D. Bou Karam (2012), The physics of wind-blown sand and dust, *Reports on Progress in Physics*, 75, 106901

Kok, J. F., S. Albani, N. M. Mahowald, G. Fratini, J. A. Gillies, M. Ishizuka, J. Leys, M. Mikami, M.-S. Park, S.-U. Park, R. S. Van Pelt, and T. M. Zobeck (2014), An improved dust emission model. Part 1: Model description and comparison against measurements, *Atm. Chem. Phys.*, 14, 13023.

Kok, J. F., N. M. Mahowald, and D. S. Ward (2014), An improved dust emission model. Part 2: Evaluation in the Community Earth System Model, with implications for the use of dust source functions, *Atm. Chem. Phys.*, 14, 13043.