Development of high school modules based on atmospheric physics research

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Objectives of this talk

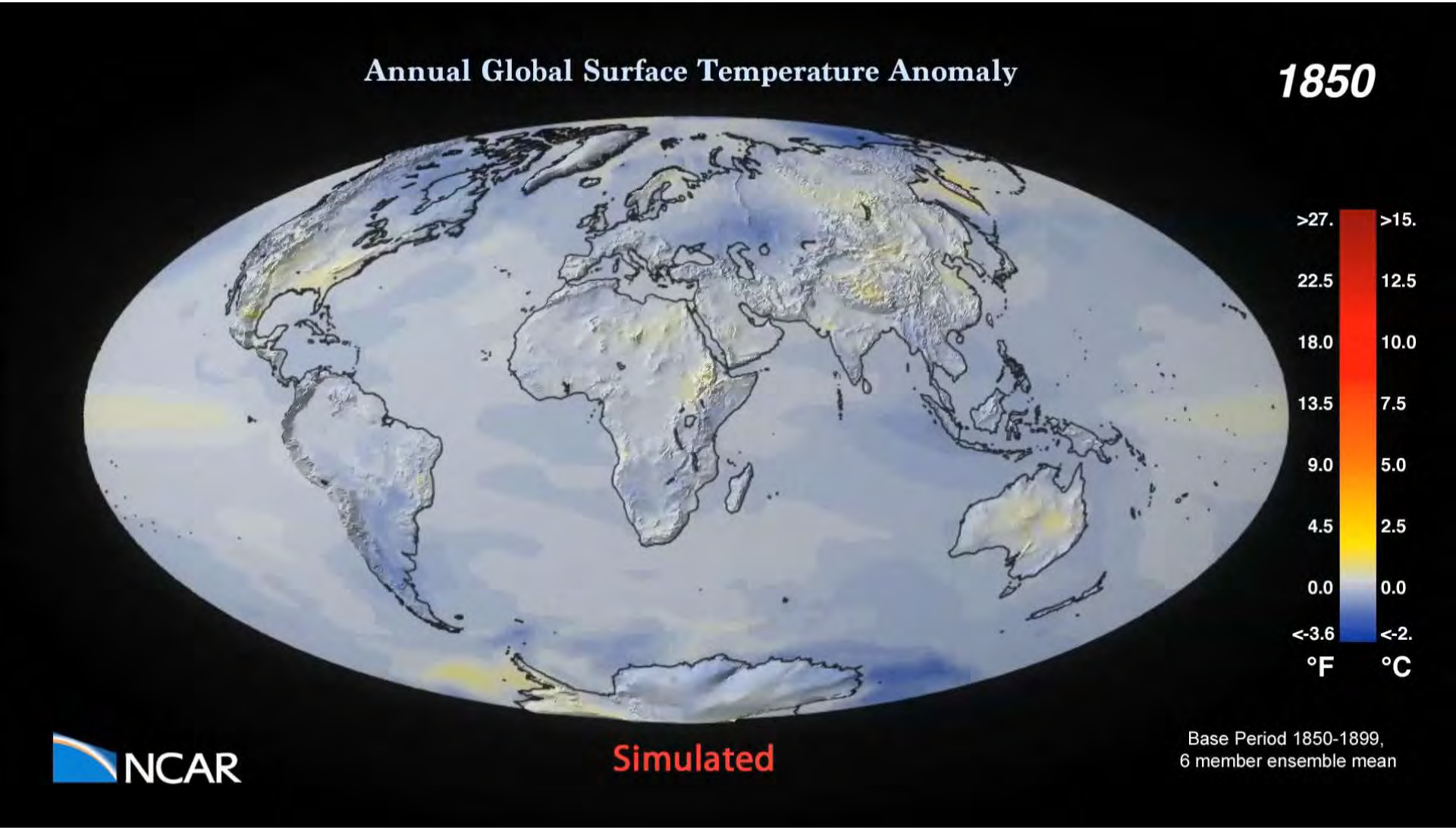
- Plan to develop module for high school physics classes
  - Based on research on **physics of dust storms and climate change**
  - Module would address several science standards

- 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**

Outline

- 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**

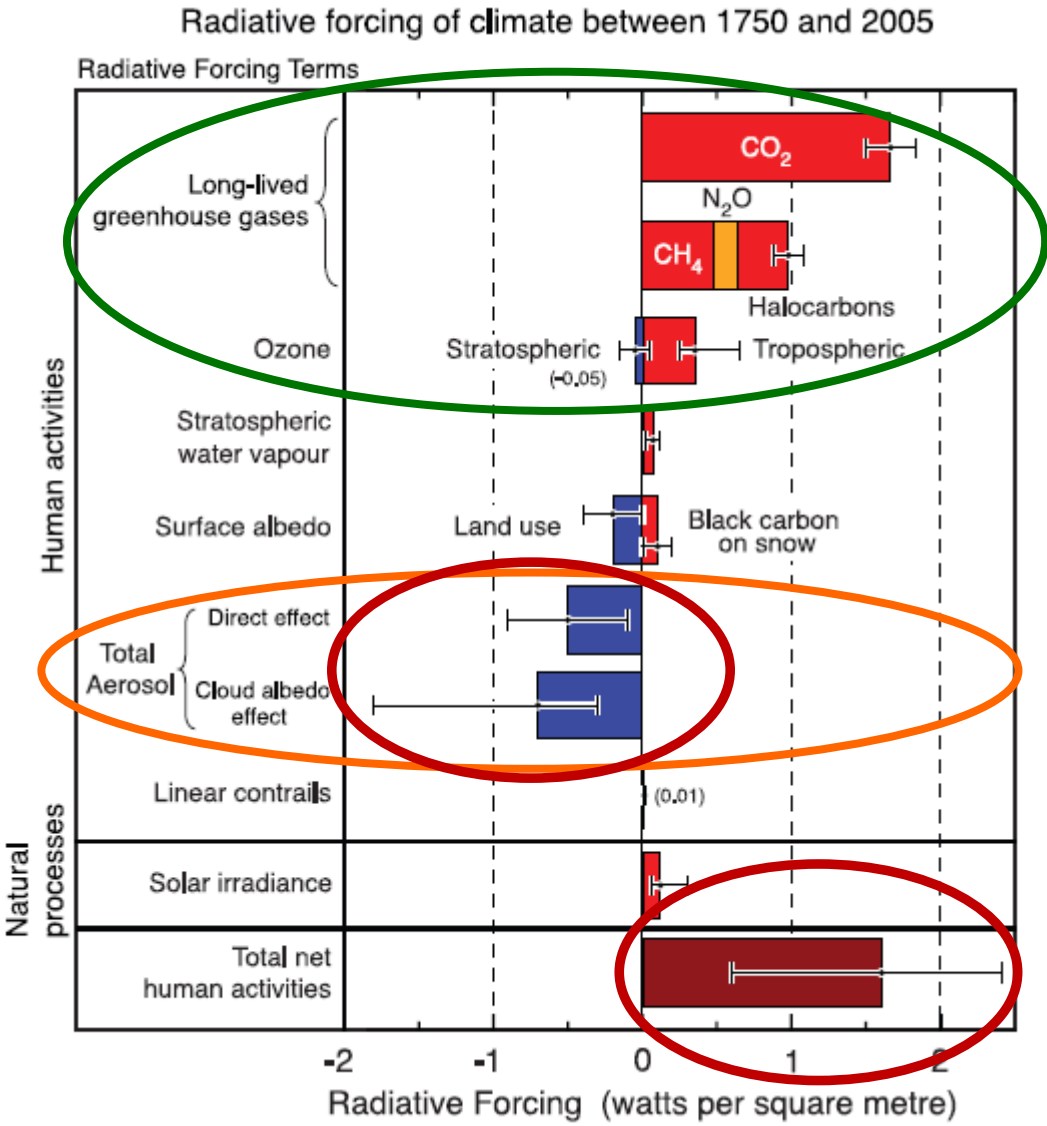
Movie of warming Earth



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

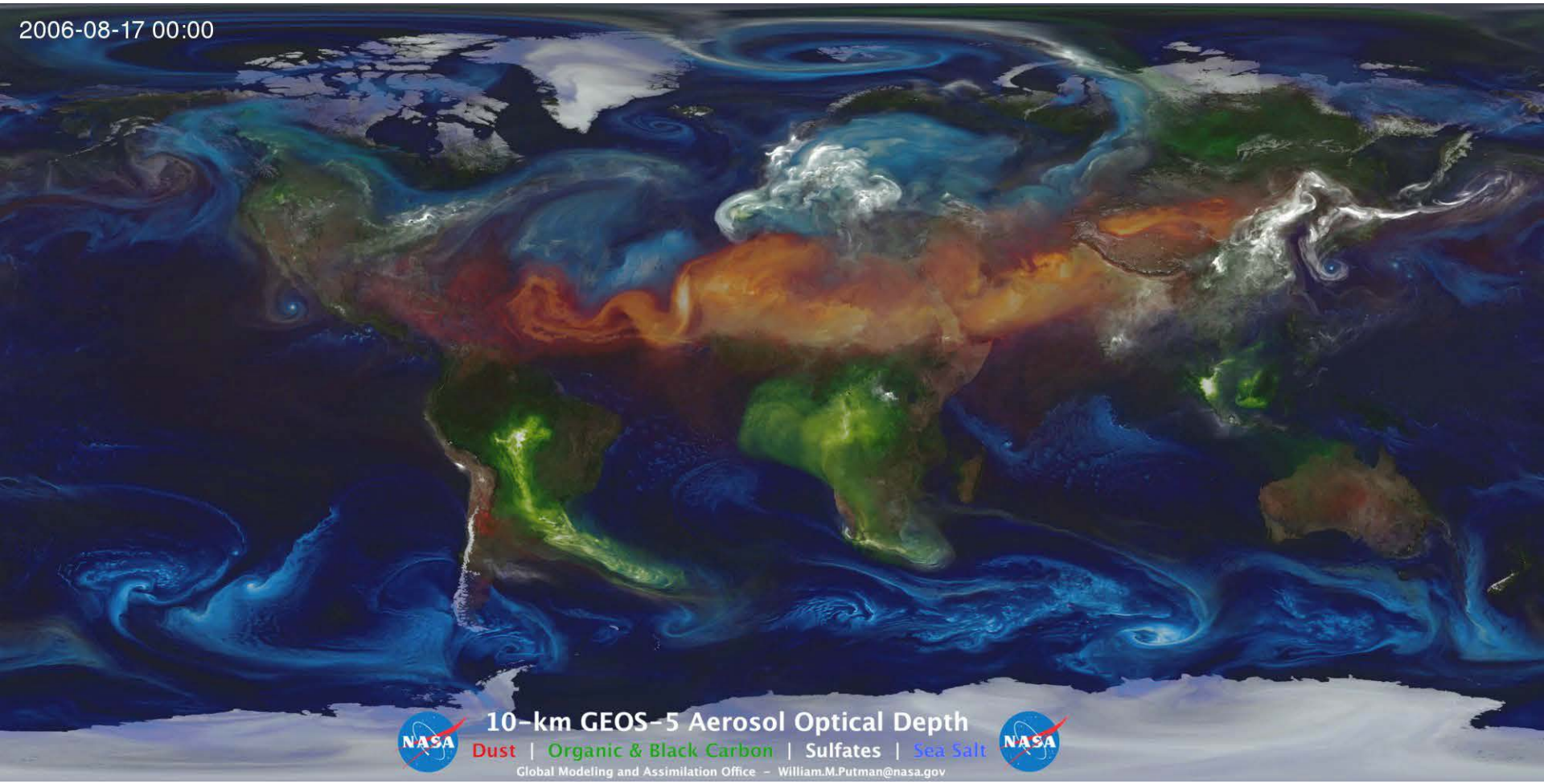
Physics of the climate problem

- 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



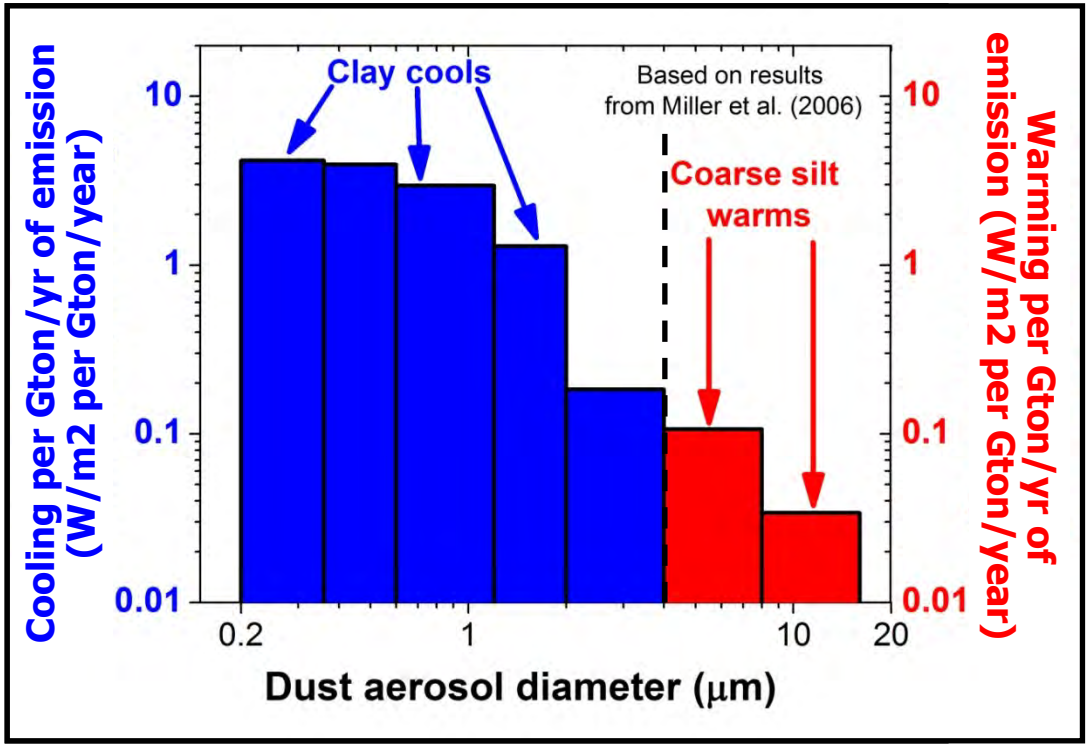
(Intergovernmental Panel on Climate Change, 2007)

Movie of different aerosol species



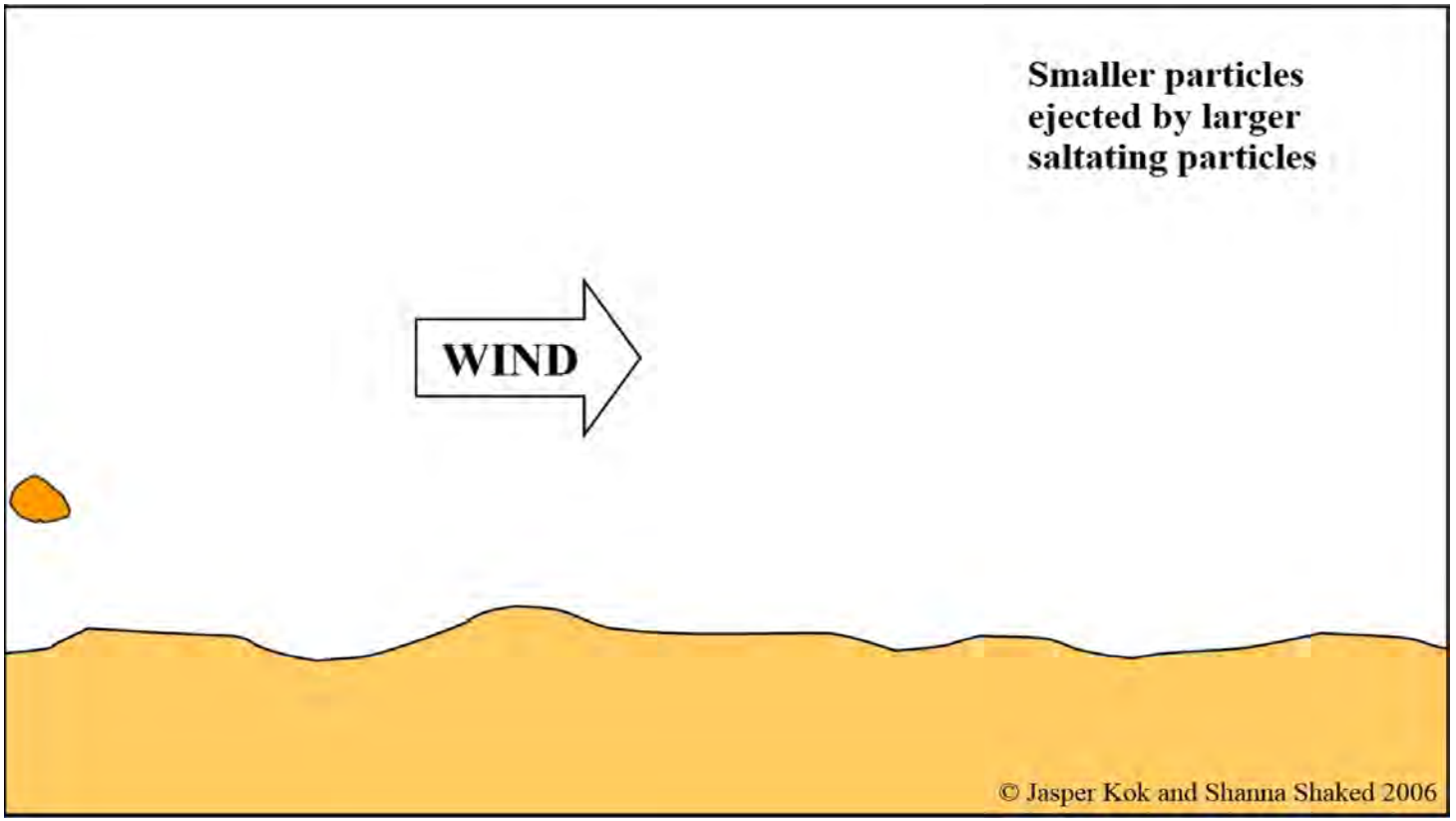
Opposing effects of dust on climate

- **Small "clay" dust (D_d < 2 µm) cools** by scattering solar radiation
- **Larger "silt" dust (D_d > 2 µm) 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**!



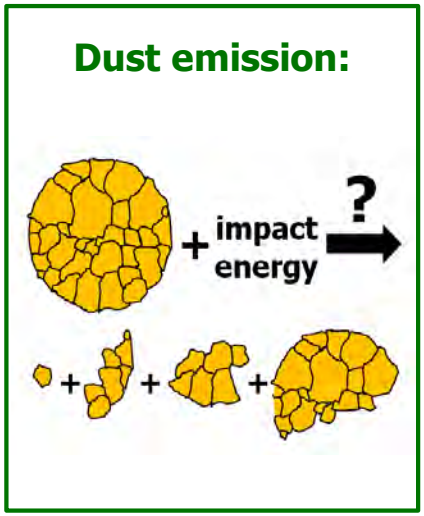
Physics of dust emission: blowing sand

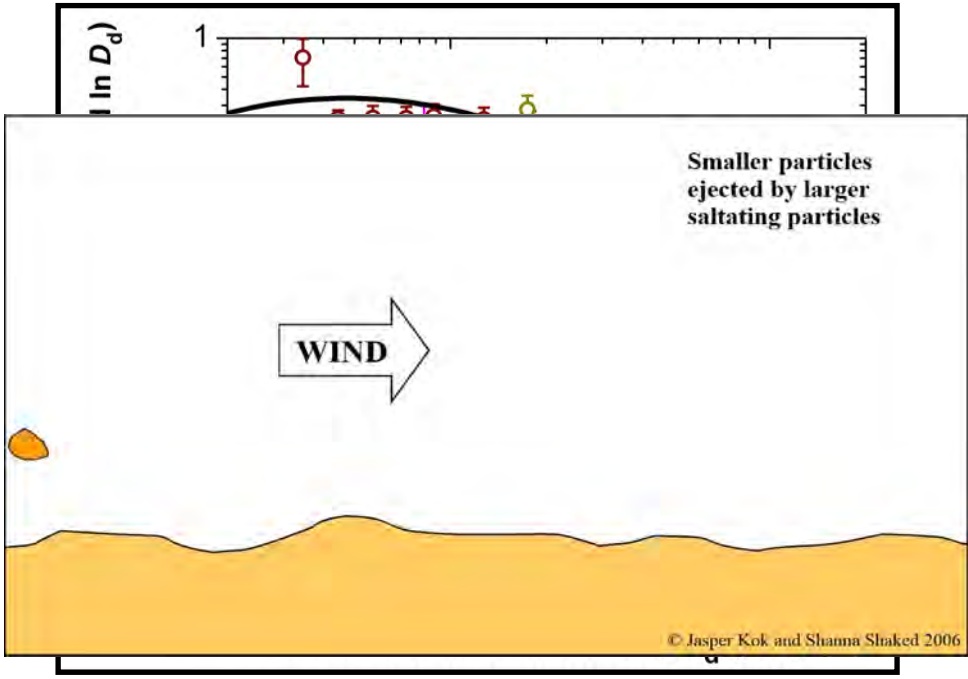
- Dust aerosols (~0.1-20 μm) are emitted by **impacts of blowing sand** (~200 μm)
  - Also forms **dunes and ripples**



Dust emission ≈ 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





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- Introduction to my research in atmospheric physics
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- 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**

- 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?

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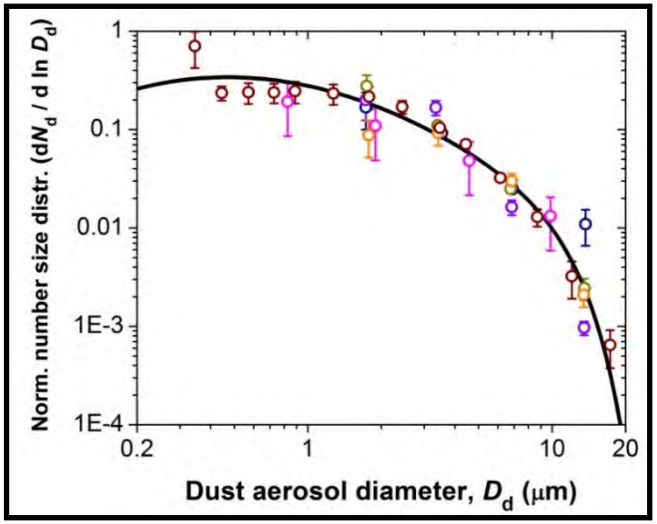
Proposed HS physics module on dust and climate change (2)

- 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:
#3
#2
#1

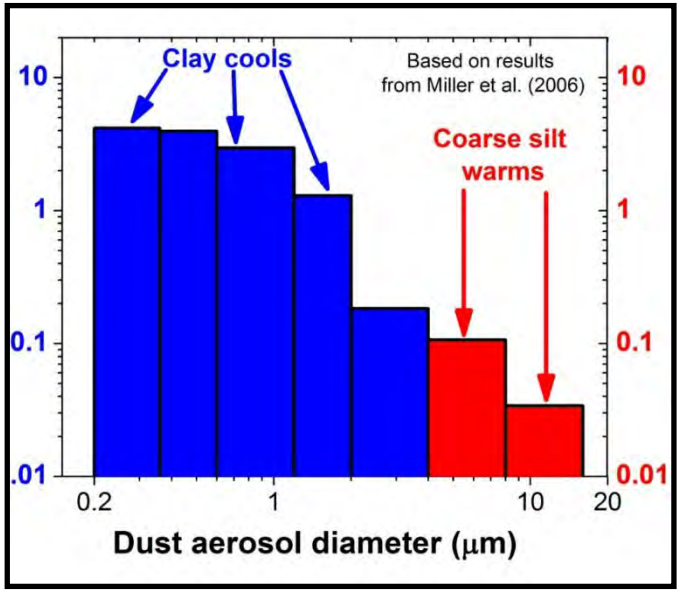
- Lesson #2: Large dust versus small dust
  - Given total desert area, and average sand impacts per unit area and year, what is total dust emission rate?
  - Provide measurements of dust size distribution
    - How many large dust particles are emitted for each small particle?
  - How much large and small dust is ejected into atmosphere per year?



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

- 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**

- 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



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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)

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.

Photo credit: Daniel Bryant