Evidence of Clear-Sky Daylight Whitening: Are we already conducting geoengineering?

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Are we already conducting geoengineering?

- We think so, in a way.
- With aircraft.
- I'm here to explain why we think so…

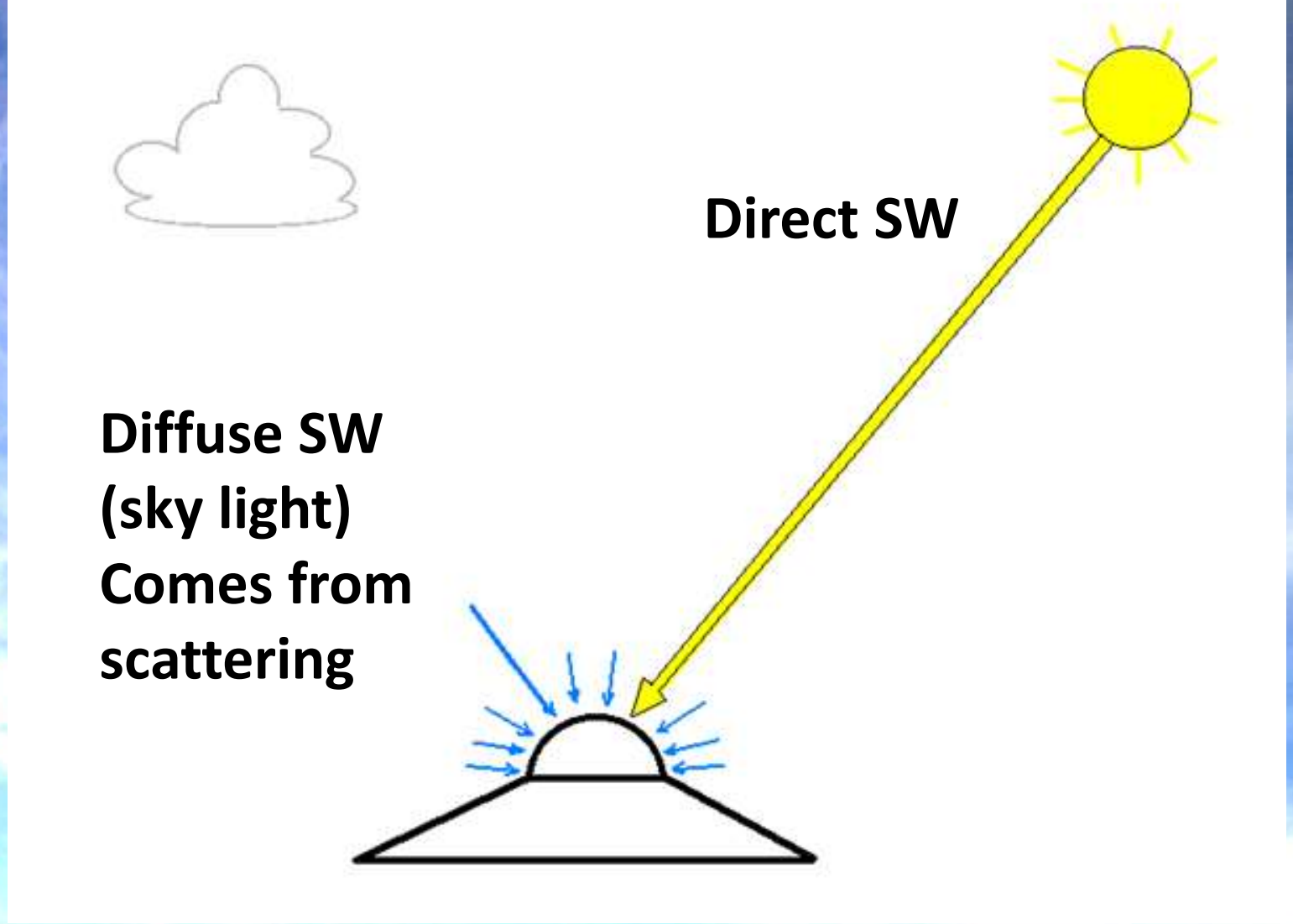
What is a Cloud?

We allow some amount of condensed water in the column (liquid or ice) to be classified as "clear sky."

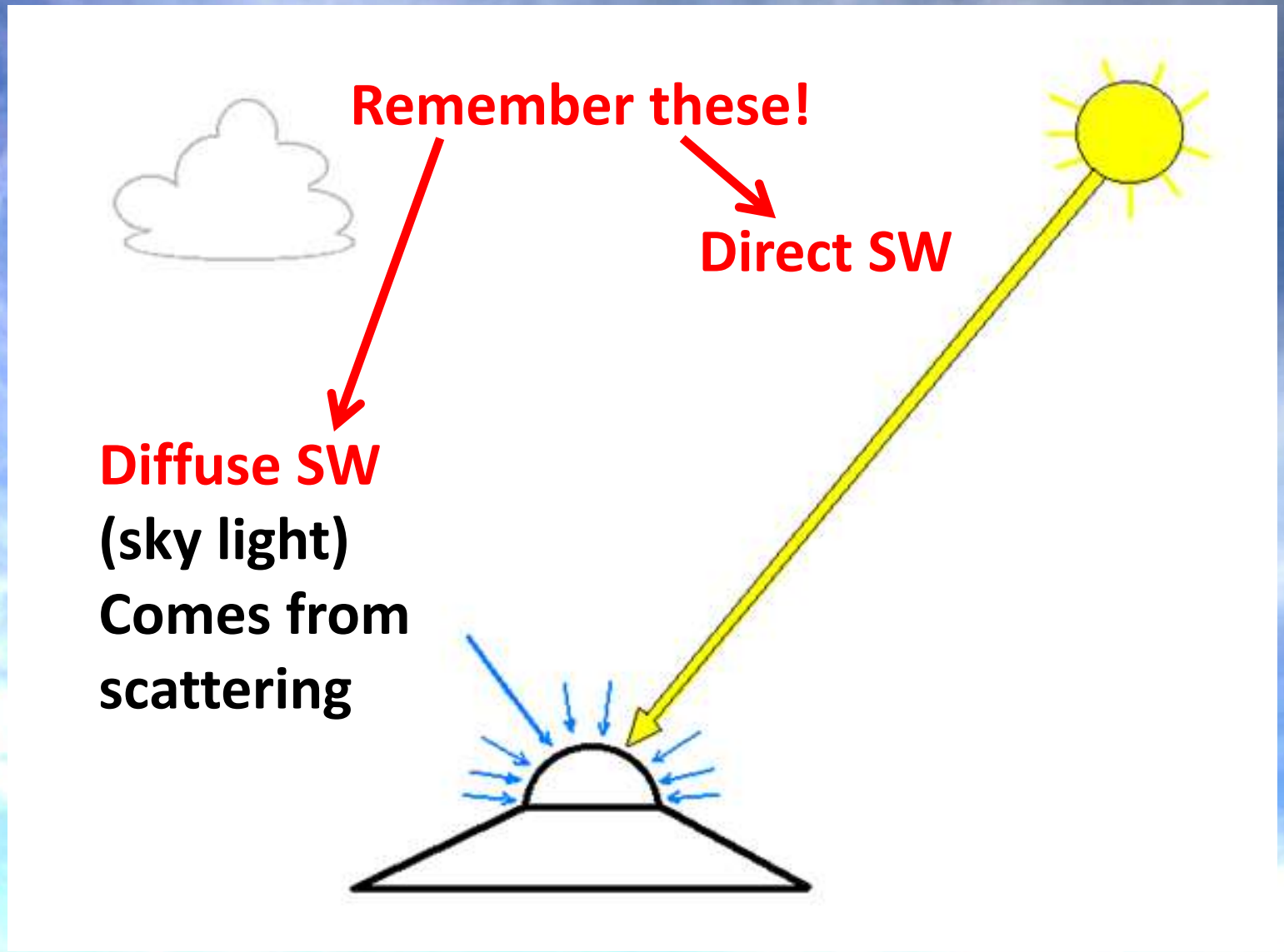
The overall clear-sky average "whiteness" seems to have increased.

Why?

Shortwave Radiation Components



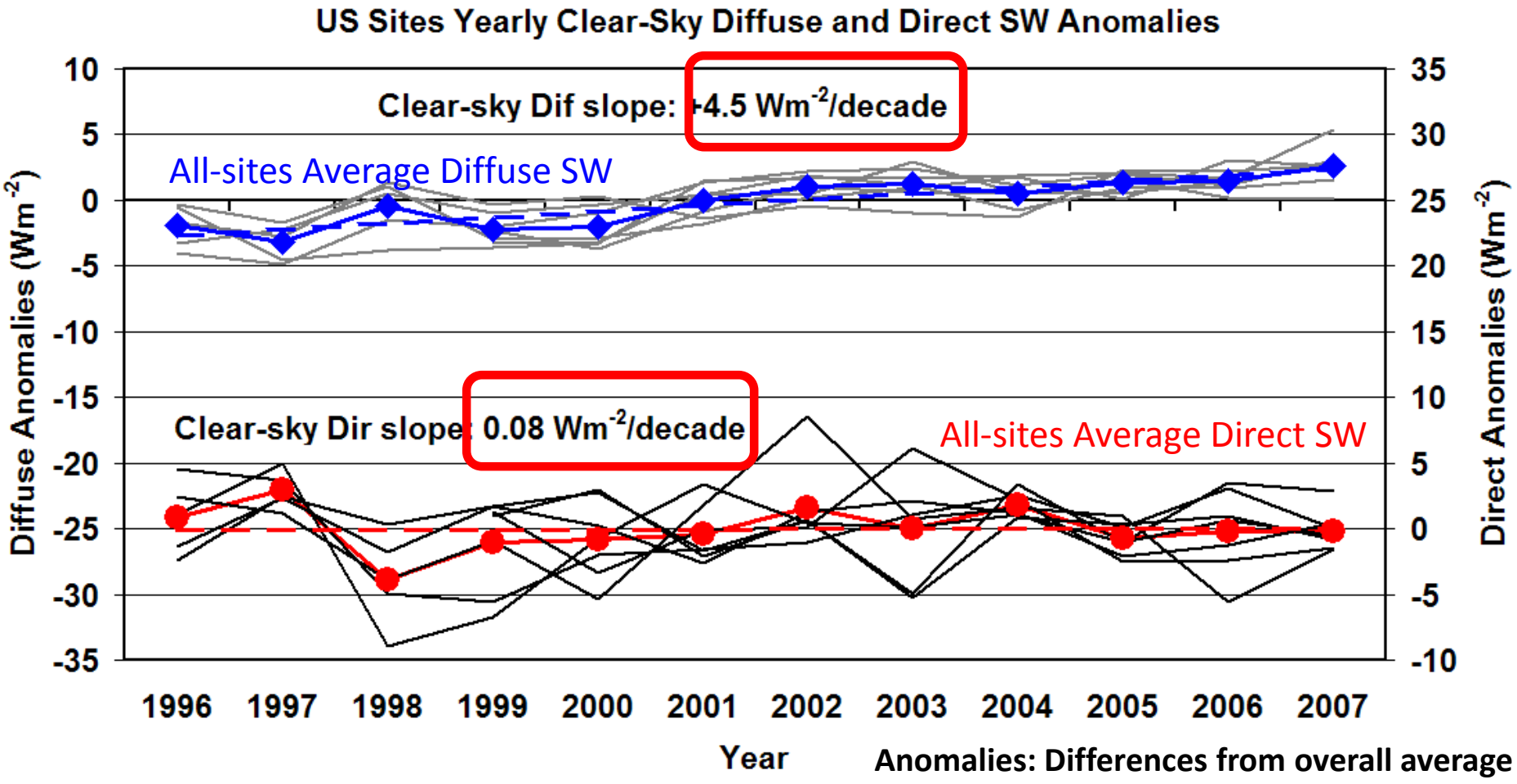
Shortwave Radiation Components



US Clear-Sky Brightening

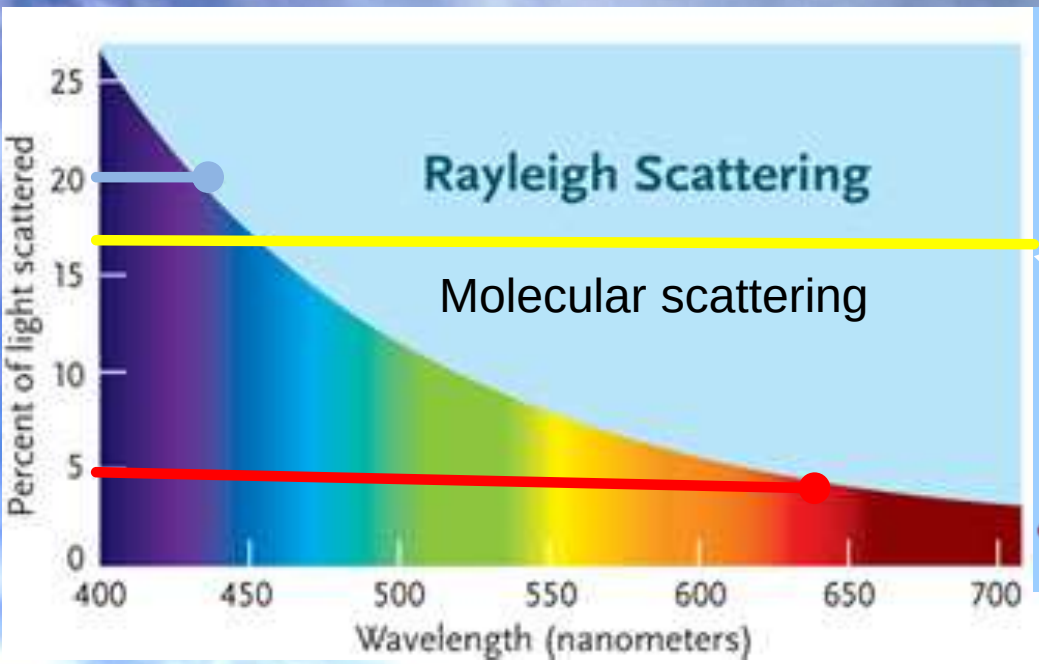
- **US average clear-sky SW increase**
  - **+ 4.6 Wm^{-2}/decade**
  - Long et al., (2009), doi:10.1029/2008JD011263.
- **Documented aerosol optical depth decrease**
  - Augustine, et al. (2008), doi:10.1029/2007JD009504.
- **For aerosol direct effect with decreasing ↓ aerosols**
  - **Expect increase ↑ in direct SW (less stuff in the way), decrease ↓ in diffuse SW (less scatterers)**
- **Study data shows:**
  - **Direct SW … no trend, didn't change!**
  - **Increase all in the Diffuse SW**
- **Just what scientists love: A mystery!**

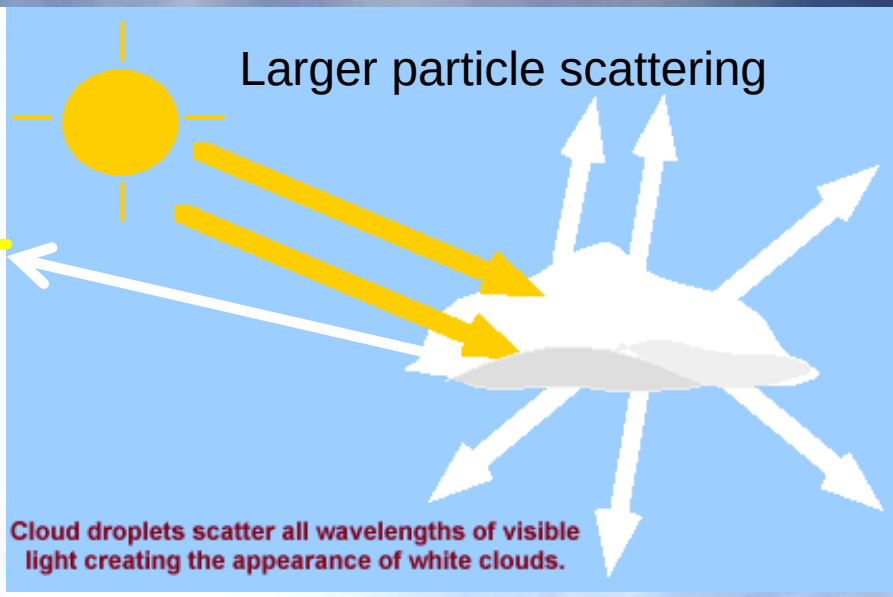
Clear-Sky SW Components



Long et al., (2009), doi:10.1029/2008JD011263

Clue 1: Why is the sky blue and a cloud white?



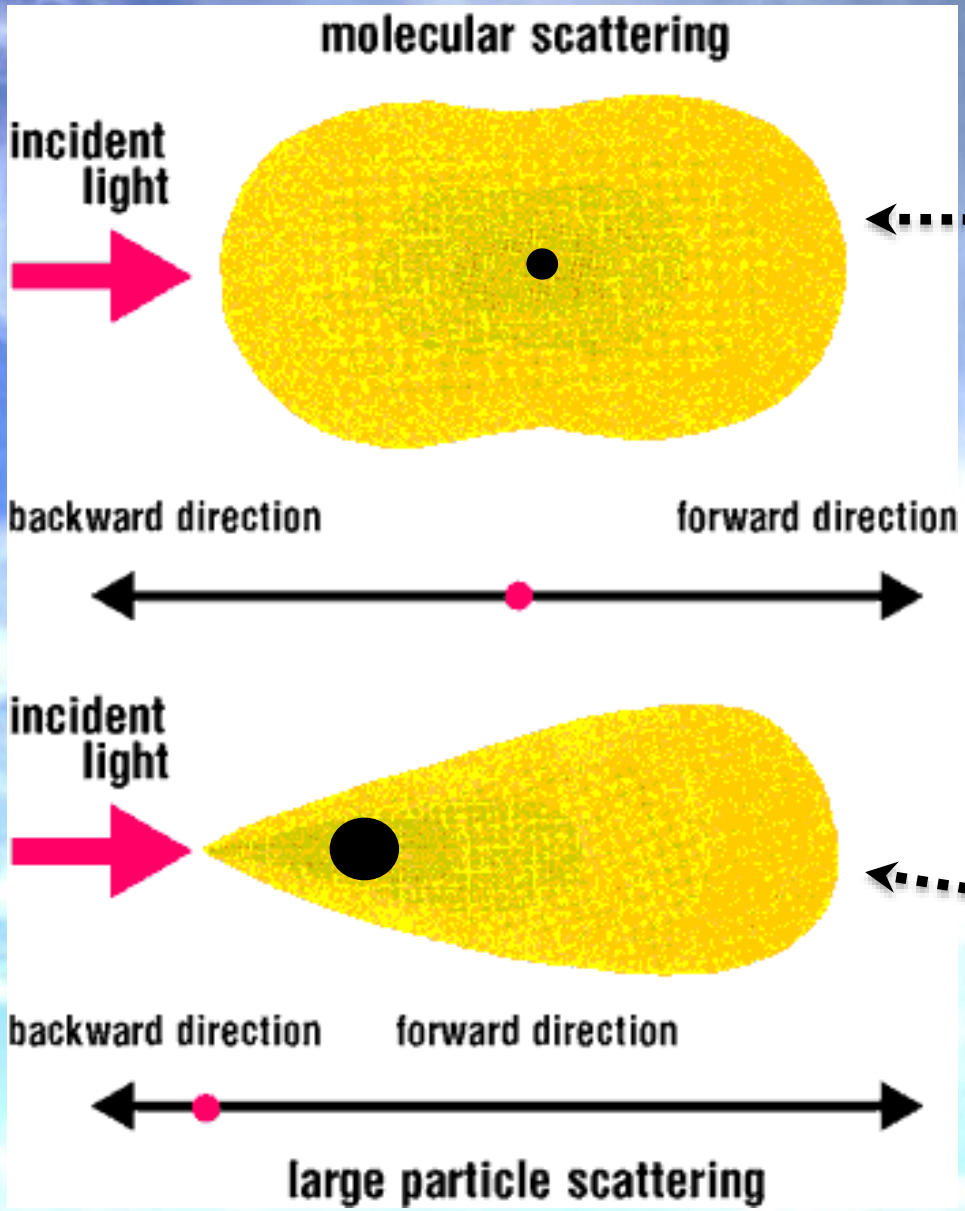


Blue light scattered 4X more than red light

Visible light scattered about equally

- **Use a ratio of red over blue spectral diffuse SW measurements:**
- **Ratio is small for blue sky, but approaches 1 for cloud.**
- **<u>So the red/blue ratio increases for increasing “whiteness”…</u>**

Clue 2: How particles scatter light

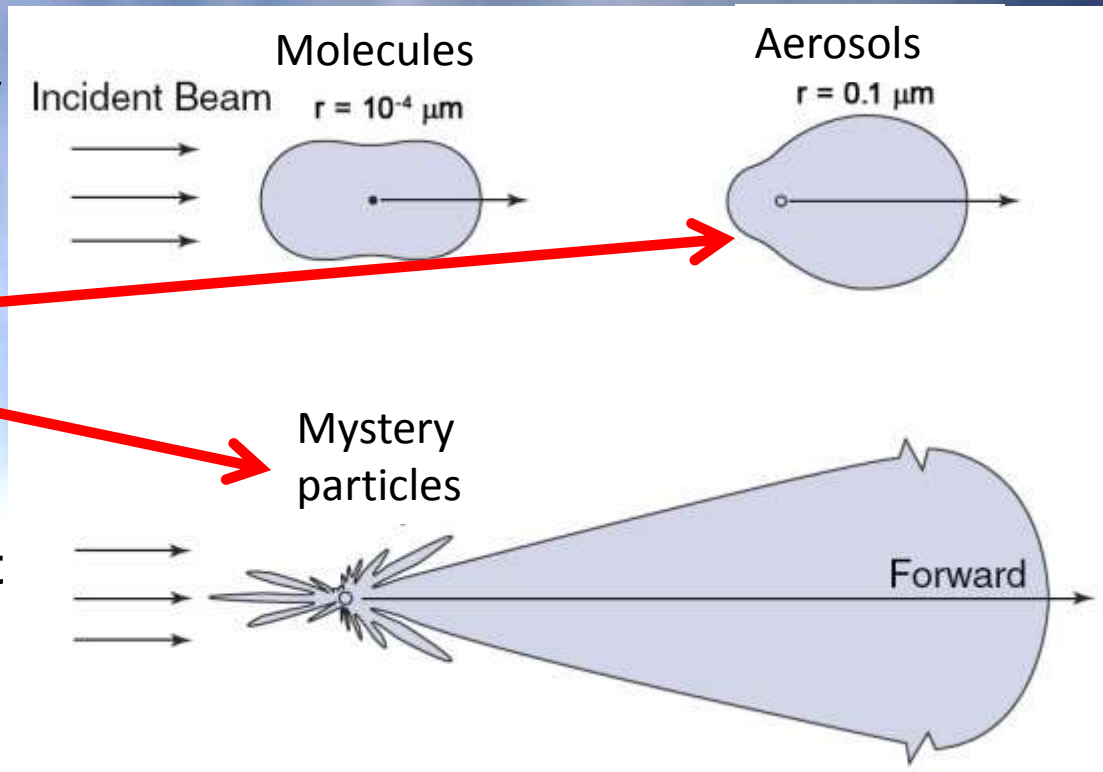


Molecules are small and scatter equally forward and backward

Larger particles scatter more in forward direction

The Hypothesis

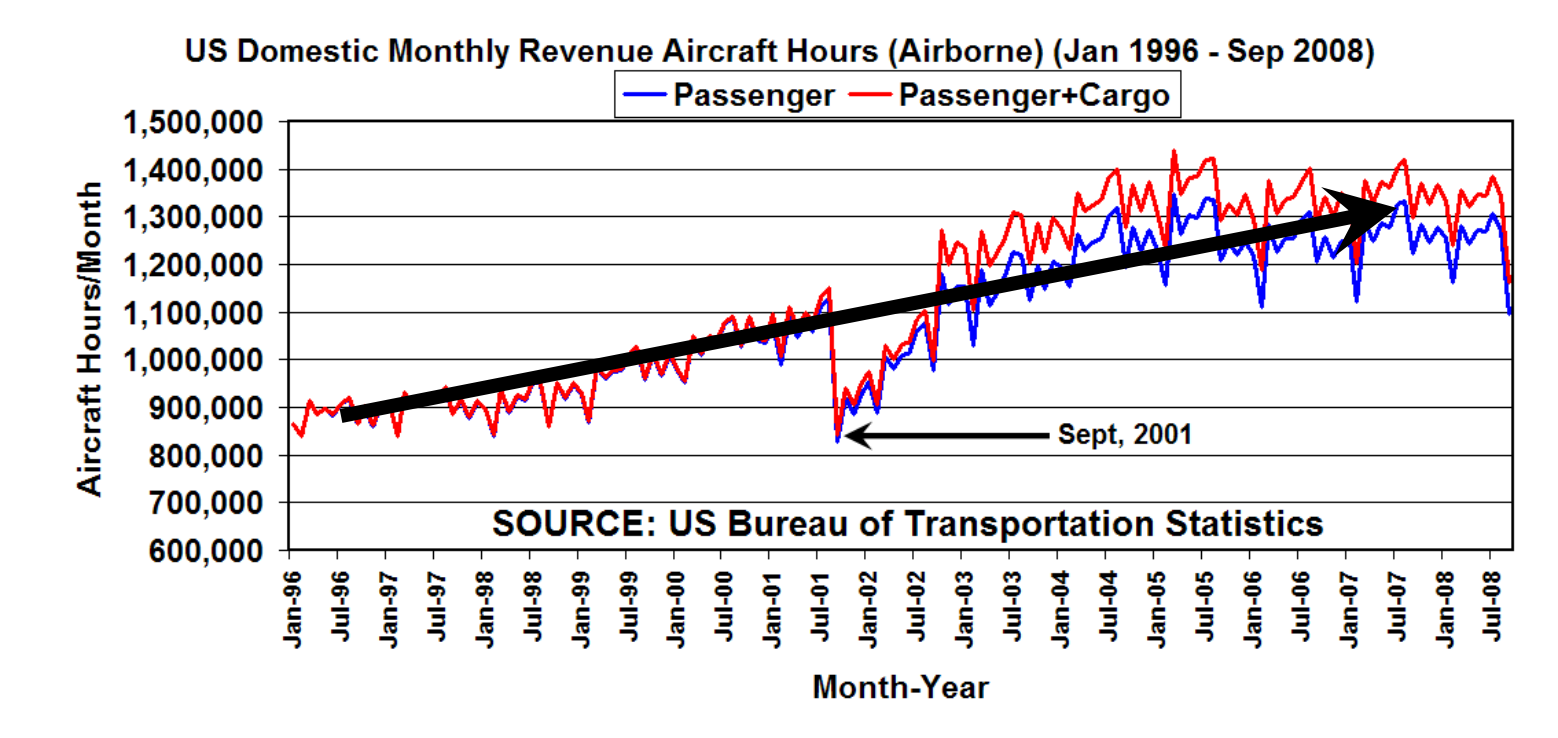
- Fewer aerosols so clear-sky SW increases
- But at the same time there was a shift from smaller scatterers to larger scatterers
- Result: increased direct SW is scattered out of the direct component into the diffuse
  - Large particle scattering more in forward direction, less backward
  - More SW reaches the surface per scatterer



What are these mysterious larger particles?

So where did the larger particles come from?

- Modeling shows the hypothesis works for less dry aerosol and more small ice crystals
- US commercial air traffic increased over the study period
- Jet exhaust results in aerosol particles and water vapor → contrails → moistening → contrail cirrus → cirrus haze
- Clear-sky whitening!



MFRSR diffuse spectral SW Measurements

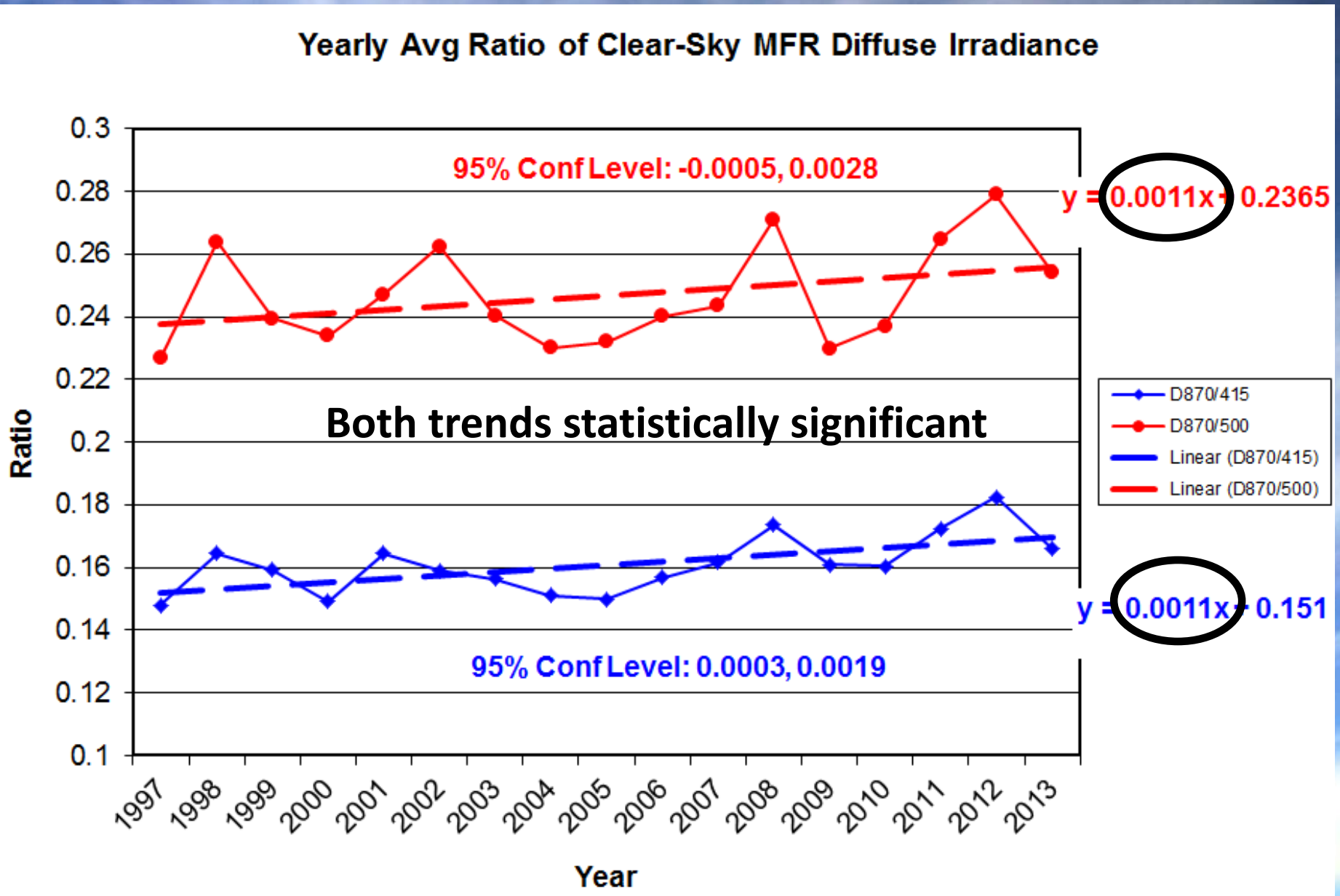
- The SURFRAD and ARM sites all have collocated Multi-Frequency Rotating Shadowband Radiometers (MFRSRs)
  - Include spectral channels at 415, 500, 615, 673, 870, 940 nm

MFRSR provides long-term measurements of "blue" and "red" spectral diffuse light we can use for a "red/blue" ratio.

  - Use SW detected clear-sky periods and fit functions for the MFRSR spectral channels, interpolate coefficients for cloudy periods same as broadband in original study
  - Produce yearly averages of clear-sky diffuse 870, 500, and 415 nm using same averaging methodology as original study

- If clear-sky whitening is occurring, there should be an increasing tendency in the 870/415 nm and 870/500 nm ratio (red/blue like TSI) through the study years

Yearly Red/Blue Ratio for ARM Southern Great Plains



Clear-sky Whitening

- Dry aerosols associated with pollution have decreased over the continental US
  - This cannot explain observed trends in clear-sky direct and diffuse SW
  - To explain trends, we need larger scatterers, such as small ice crystals
- Air traffic over the US (and elsewhere) increased
  - This can produce ice haze
- Air traffic appears to be making clear skies "whiter," on average
  - This redistributes incoming SW from direct to diffuse
  - Plants like diffuse SW lighting more than direct…less shadowing of lower leaves
  - Possible slight increase due to enhanced forward scattering
  - Climate change: changing the components of the climate by an activity of human industrial civilization

Unintentional Geoengineering?

Geoengineering: large-scale manipulation of an environmental process that affects the earth's climate

“Ice haze” from jet air traffic?

Thank You…

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This afternoon

Session A23K: Improved Understanding of the Surface Energy Balance and the Spatiotemporal Variation of Its Components I

Martin Wild 2:10-2:25pm: "The global mean energy balance under cloud-free conditions: an assessment based on direct observations and CMIP5 models"

Chuck Long 2:25-2:40pm: "Evidence of Clear-Sky Daylight Whitening: Are we already conducting geoengineering?"

Thank You…

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Questions!

- Tendency of Diffuse/Direct and 870/415 and 870/500 nm ratios compatible with hypothesis of clear-sky whitening…for SGP
  - Is this due to increased "ice haze" from increased jet air traffic?
  - Are the results the same for other (SURFRAD) sites? Are the 870/415 nm ratio slopes greater for the sites with greater clear-sky trends as one would expect?
  - Is the "whitening" occurring with same magnitude but more frequently, or same frequency but greater whitening?
- Long et al. (2009) study showed greater SGP clear-sky brightening Summer and Fall, very little for Winter and Spring
  - Are these seasonal trends the same for other geographic areas?
  - What are the seasonal differences causing these trend differences?
- If indeed caused by air traffic moistening and adding IN to the upper troposphere, then there should be a diurnal signature with increased whitening in the afternoon. Is there?

Extra info

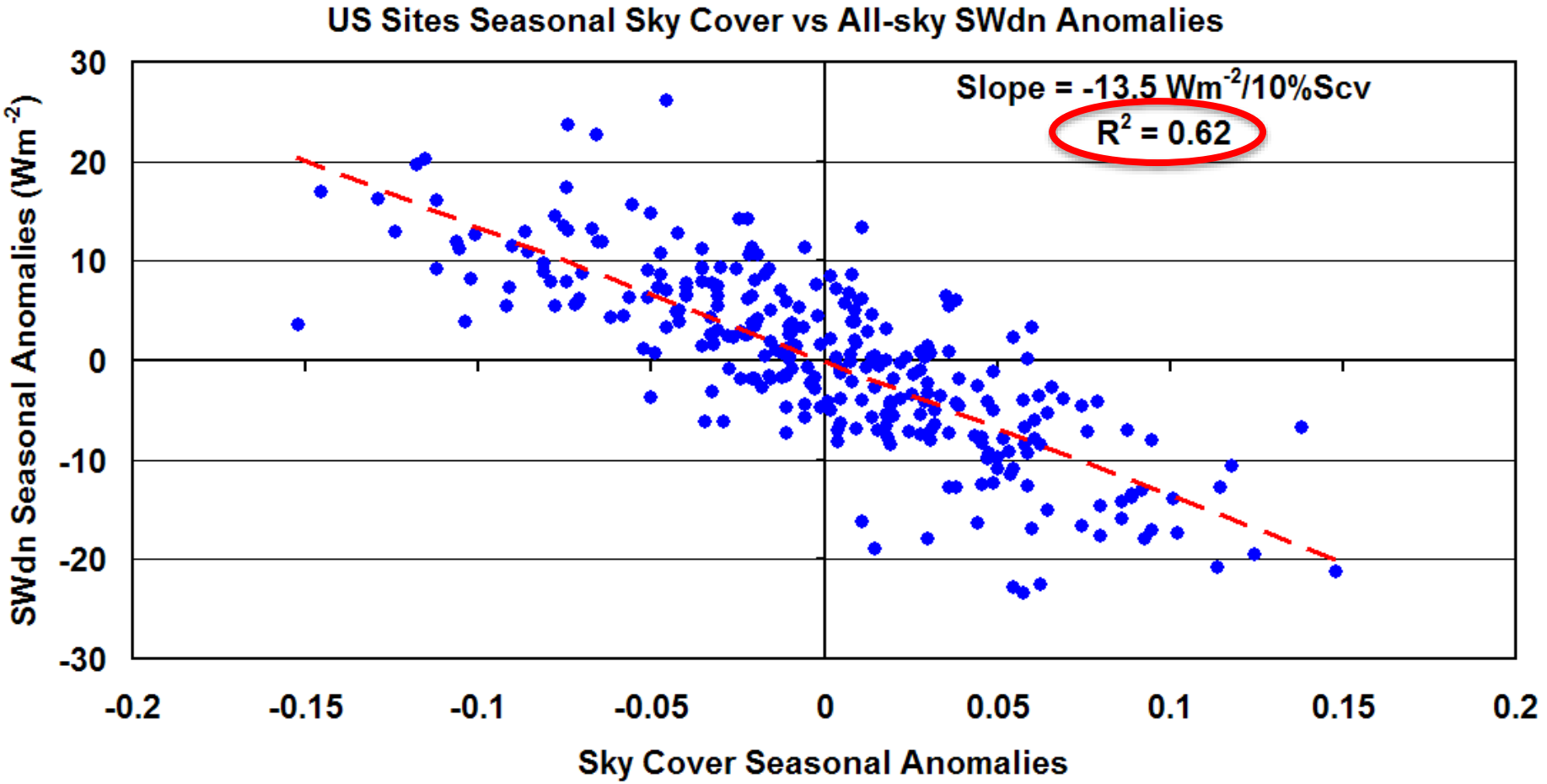
- SGP 1996-2007 clear-sky SW slope 3 W/m^2/decade
  - Clear-sky direct SW slope -0.3 W/m^2/decade
  - Clear-sky diffuse SW slope 3.2 W/m^2/decade

- Model sensitivity test: SHDOM radiative transfer model [Evans, 1998] in 1D mode, and average the SW over a 24-h period

- Hofmann et al (1998) Wyoming study of thin aerosol layers from jet exhaust, not spread over 1-2 km model layers!
  - 8.6 - 12.7 km (29 to 41 kft), 1973-1997
  - Thin layers of highly concentrated CN.
  - Frequency of occurrence of the CN layers approximately doubled from 1980 to 1992.

Hofmann, DJ, R. Stone, ME Wood, T Deshler, and JM Harris (1998): An analysis of 25 years of balloon borne aerosol data in search of a signature of the subsonic commercial aircraft fleet. GEOPHYSICAL RESEARCH LETTERS, VOL. 25, NO.13, PAGES 2433-2436.

Correlation of All-Sky Brightening with Sky Cover Anomalies



Ice crystals are not spherical…