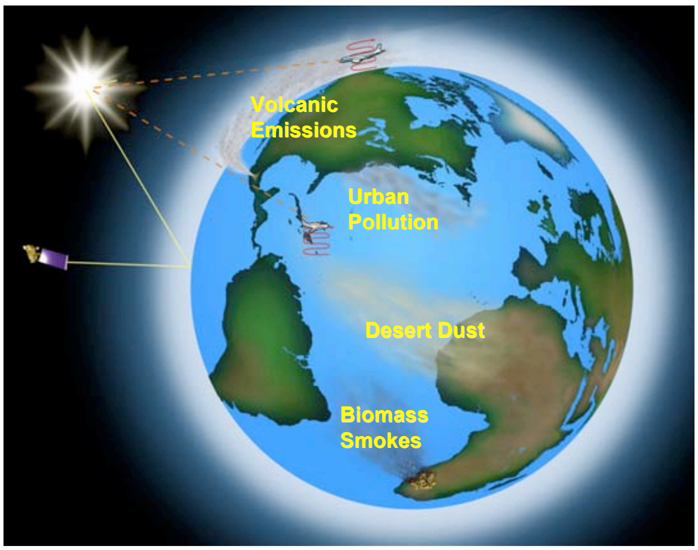
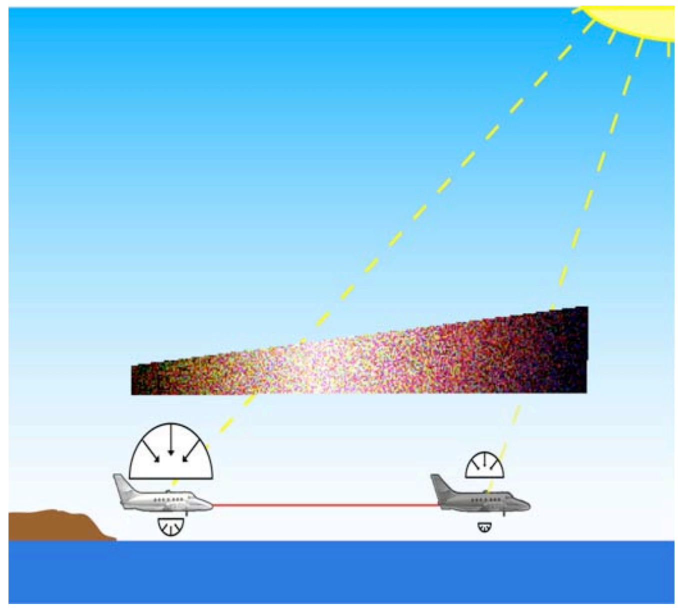
# Measuring Aerosol Effects on the Solar Energy that Drives Climate

## How do aerosol particles affect climate?

Aerosol particles (haze particles suspended in the atmosphere, generally smaller than cloud droplets) affect climate by changing the flow of radiant energy from the sun to the Earth's surfaces and within the atmosphere. They do this both directly, by scattering and absorbing solar radiation, and indirectly, by changing cloud properties, rain, snow, and atmospheric mixing. Aerosol particles are extremely varied, in part because they have very many sources, both manmade and natural (e.g., car exhaust, power plants, forest fires, evaporation from petroleum products, agriculture, natural living plants, dust storms, breaking ocean waves, volcanoes). Understanding how these aerosol particles affect climate is one of the most important and difficult challenges facing atmospheric science today.



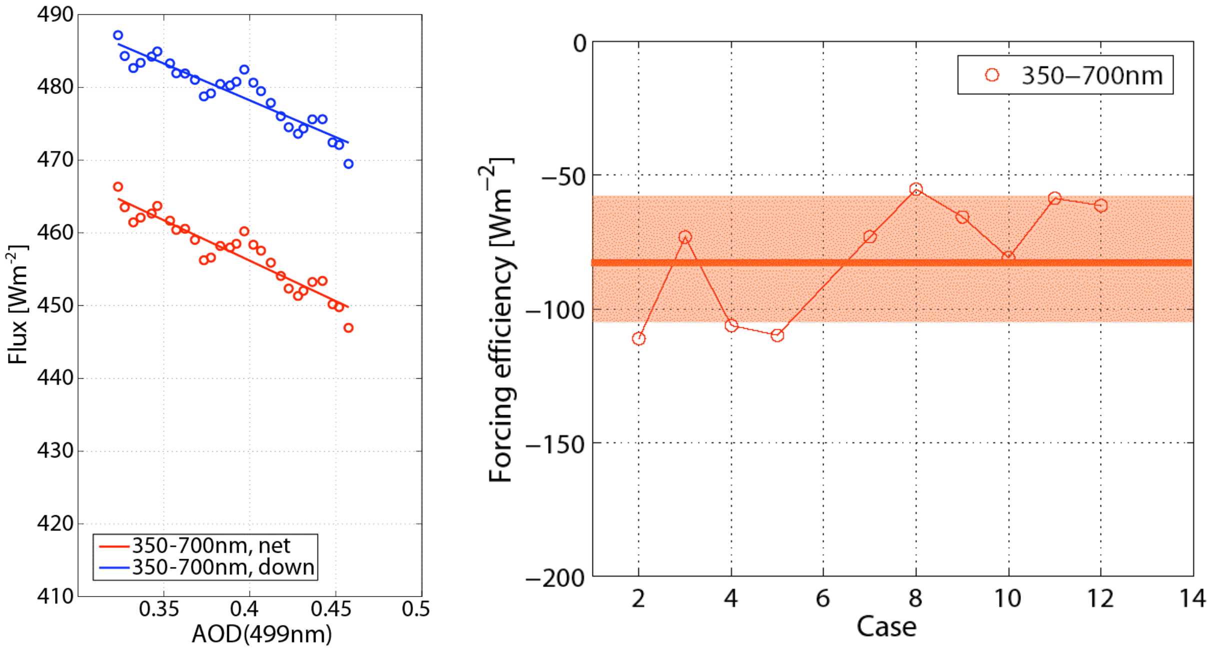



## What did we do during ICARTT?

- Modified a Jetstream 31 (J31) aircraft to accommodate two proven instruments that measure aerosol properties and solar radiation.
- Flew the instruments in a variety of aerosol conditions, including flight paths under differing amounts of aerosols.
- One instrument, the NASA Ames Airborne Tracking Sunphotometer (AATS-14), measured the transmission of the direct solar beam, yielding a measurement of the overlying aerosol column amount, called Aerosol Optical Depth (AOD).
- The other instrument, the Solar Spectral Flux Radiometer (SSFR), simultaneously measured the solar energy flowing from all directions above or below a horizontal plane (i.e., the solar energy flux), including its dependence on the wavelength (or color) of sunlight, from ultraviolet, through the visible, and into the near-infrared


- The change in solar energy flux per change in AOD is an important measure of an aerosol's climatic effect, called the <u>radiative forcing efficiency.</u>

## Reduction in solar energy at ocean surface caused by aerosol




**Left frame:** Solar radiative flux measured in Case 2 (21 July 2004) on the J31, plotted versus measured AOD. Blue: downwelling flux. Red: net (downwelling minus upwelling) flux. Flux is for the wavelength range 350-700 nm (roughly the visible range of solar wavelengths). AOD is for the midvisible wavelength 499 nm. **Right Frame:** Instantaneous aerosol radiative forcing efficiency for the 10 cases (of 14 measured) best suited for this analysis (because sun angle effects are small compared to aerosol effects).

## What did we learn?

1. The gradients (spatial variations) in AOD that occur frequently off the US East coast provide a natural laboratory for studying effects of aerosol particles on solar energy, and hence on climate.
2. For the average aerosol optical depth of ~0.5 in the 10 cases shown above, aerosols on average reduced the incident visible radiation (near midday) by the amount of energy it would take to power one 40 W light bulb for every square meter of ocean surface (0.5 x -80 W m-2 = -40 W m-2; see right frame above).
3. The radiative forcing efficiencies measured on the Jetstream 31 in ICARTT varied considerably from case to case. This probably reflects the variations in aerosol type present during ICARTT 2004, which included forest fire smoke, urban pollution, power plant plumes, and seasalt.

## What does it mean?

The J31 ICARTT results for radiative forcing efficiency can be used to test climate models that predict solar energy flux changes for given aerosol types and amounts (AODs). They also provide empirical factors for scaling solar flux changes as AOD changes because of increasing emissions or controls.

The radiative forcing efficiency results are just a small subset of the results from the J31 ICARTT measurements. Other J31 ICARTT measurements are being used to validate satellites, measure water vapor (a greenhouse gas), determine cloud and surface radiative properties, and test measurements by laser radars and particle samplers.

**For more information contact: Phil Russell (Philip.B.Russell@nasa.gov), Jens Redemann (jredemann@mail.arc.nasa.gov), or Peter Pilewskie (peter.pilewskie@lasp.colorado.edu)**

*The multi-agency ICARTT <http://www.al.noaa.gov/ICARTT/> was formed to study the sources, sinks, chemical transformations and transport of ozone, aerosols and their precursors to and over the North Atlantic Ocean. ICARTT Fact Sheets are designed to present important new science results and findings of high societal relevance to technical non-experts in the community and have been reviewed by an internal committee of peers.*