Climate Center Proposal April 2007

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Title: The Partitioning of Direct and Diffuse Solar Irradiance by Anthropogenic Aerosols and Possible Implications for the Carbon Cycle

Requested Amount $6,000

Background

Diffuse light and the carbon cycle

CO_2 concentrations experienced a sharp decline after the volcanic eruption of Mount Pinatubo in 1991. Roderick and Farquhar (*Oecologia 2001*) suggested that enhanced photosynthesis of plant canopies caused increased CO_2 uptake in the years of high volcanic aerosol concentrations due to increased diffuse light in spite of reduced total irradiance. A variety of plant canopies use diffuse irradiance more effectively than direct irradiance (Roderick and Farquhar *Oecologia* 2001 and Gu et al. *J. Geophys. Res.* 2002). The reason for this effectiveness is that enhanced diffuse light increases the actinic flux (light from all directions) within the canopy and more leaves contribute to photosynthesis. See figure 1. For example, enhanced photosynthesis was measured in deciduous forests (Harvard Forest) after the Pinatubo eruption of 1991. The increase was 23% in 1992 and 8% in 1993 (Gu et al. *Science* 2003).

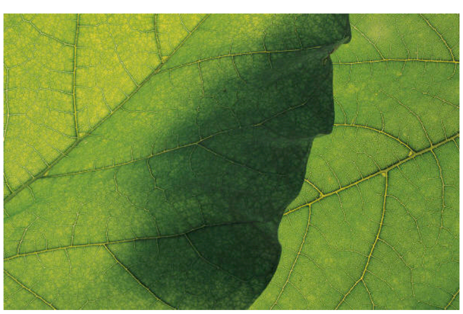
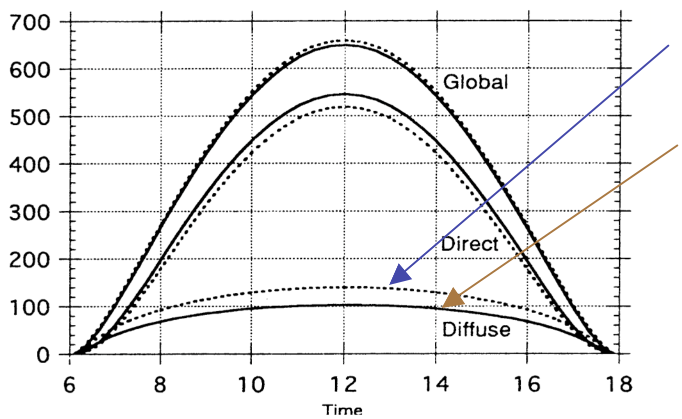


Figure 1: Actinic flux under direct light. Only top leaf receives enough direct sunlight for optimal photosynthesis. Leaf below is shaded and cannot reach optimal photosynthesis.

Light scattering versus light absorbing aerosols

Volcanic aerosol consists of light scattering sulfate particles. The increase in sulfate aerosol concentrations in the stratosphere led to increases in diffuse light, reduction in direct and a reduction in total sunlight. In contrast to volcanic aerosol however, anthropogenic aerosol consists of light scattering (e.g. sulfate, nitrate) AND light absorbing (e.g. soot) particulates. Light absorption increases with increasing path length of the sunray through the atmosphere. Hence the reduction is highest in the diffuse portion of the radiation and not as high in the direct portion.
With the same net reduction in total solar irradiance the partitioning of sunlight into direct and diffuse components can therefore vary significantly depending on the optical properties of the aerosol. See figure 2. Consequently, the 20th century dimming caused by anthropogenic aerosol increases may not have led to increased photosynthesis and hence decline in CO_2 as speculated before. In contrast it may have caused a weakening of the CO_2 biological sink.



•***Scattering*** aerosol of high optical depth
σ=0.9 and τ=0.15

Absorbing aerosol of lower optical depth:
σ=0.7 and τ=0.10

Figure 2:
Calculated diffuse and direct solar irradiance for absorbing and scattering aerosol for Hohenpeissenberg in March. (Liepert, 1996).

Proposed Research

I try to test this hypothesis with measurements of diffuse and direct sunlight above and below the canopy at Lamont under various aerosol concentrations. The light use efficiency of canopies can be calculated by models that take the radiative transfer through the canopy into account. Testing these models requires direct and diffuse light measurements at the top and bottom of the canopy that are very rarely performed. We currently measure direct and diffuse light on the roof of oceanography above the canopy with a rotating shadowband radiometer (http://www.ldeo.columbia.edu/~liepert/research/sunphotometer.html). I also possess a handheld sunphotometer that measures aerosol optical thickness of the atmosphere. Adding a pyranometer for direct / diffuse radiation measurements in the canopy would enable us to test the models and calculate the expected aerosol effect on ecosystem carbon uptake. Since NASA-GISS also operates a MFRSR these measurements can be reperated in Central Park.

The results of this proposed preliminary study would be a first step towards a more comprehensive proposal of studying the carbon fluxes in the urban to suburban to rural transect in collaboration with Kevin Griffin and Brendan Buckley.

Requested Budget

Total Amount $6000:

1. One Delta-T sunshine pyranometer for diffuse/direct solar radiation measurements: $4,500
2. Data logger, rechargeable batteries and supplies $500
3. Calibaration of the Microtops sunshotometer $500
4. Calibration of the MFRSR $500