

Lecture 4.

Impact of aerosols and clouds on solar radiation at Earth's surface: dimming or brightening?

Outline:

1. Background materials.

2. Papers for class discussion:

Wild, M., et al., *From dimming to brightening: decadal changes in solar radiation at Earth's surface*, *Science*, vol.38, pp. 847- 850, 6 May 2005.

Alpert P., P. Kishcha, Y. J. Kaufman, and R. Schwazbard, *Global dimming or local dimming?: Effect of urbanization on sunlight availability*. *GEOPHYSICAL RESEARCH LETTERS*, VOL. 32, L17802, doi:10.1029/2005GL023320, 2005.

Background materials.

Surface energy budget is defined as the energy or heat budget at the earth's surface, considered in terms of the fluxes through a plane at the earth-atmosphere interface. The energy budget includes radiative, sensible, latent and ground heat fluxes.

$$F_{net,SW} = F_{net,LW} + F_{lat_heat} + F_{sens_heat} + F_{cond}$$

where $F_{net,SW}$ is the net shortwave (solar) radiation at the surface; $F_{net,LW}$ is the net longwave (thermal IR) radiation at the surface; F_{lat_heat} is the latent heat flux; F_{sens_heat} is the sensible heat flux, and F_{cond} is the conductive flux below the surface.

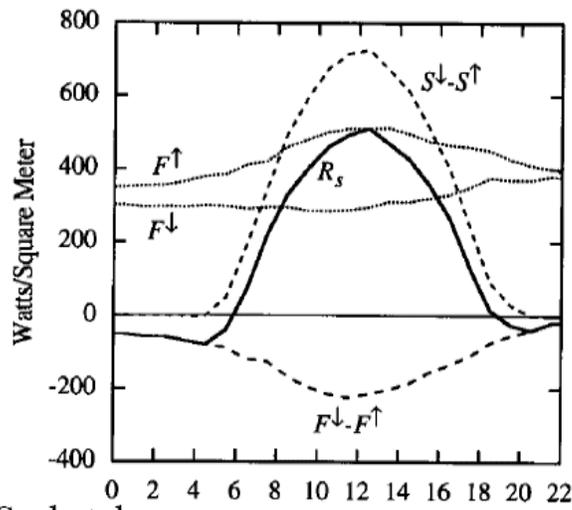


Figure 4.1 Example of the diurnal variation of net SW+LW radiation (R_s)

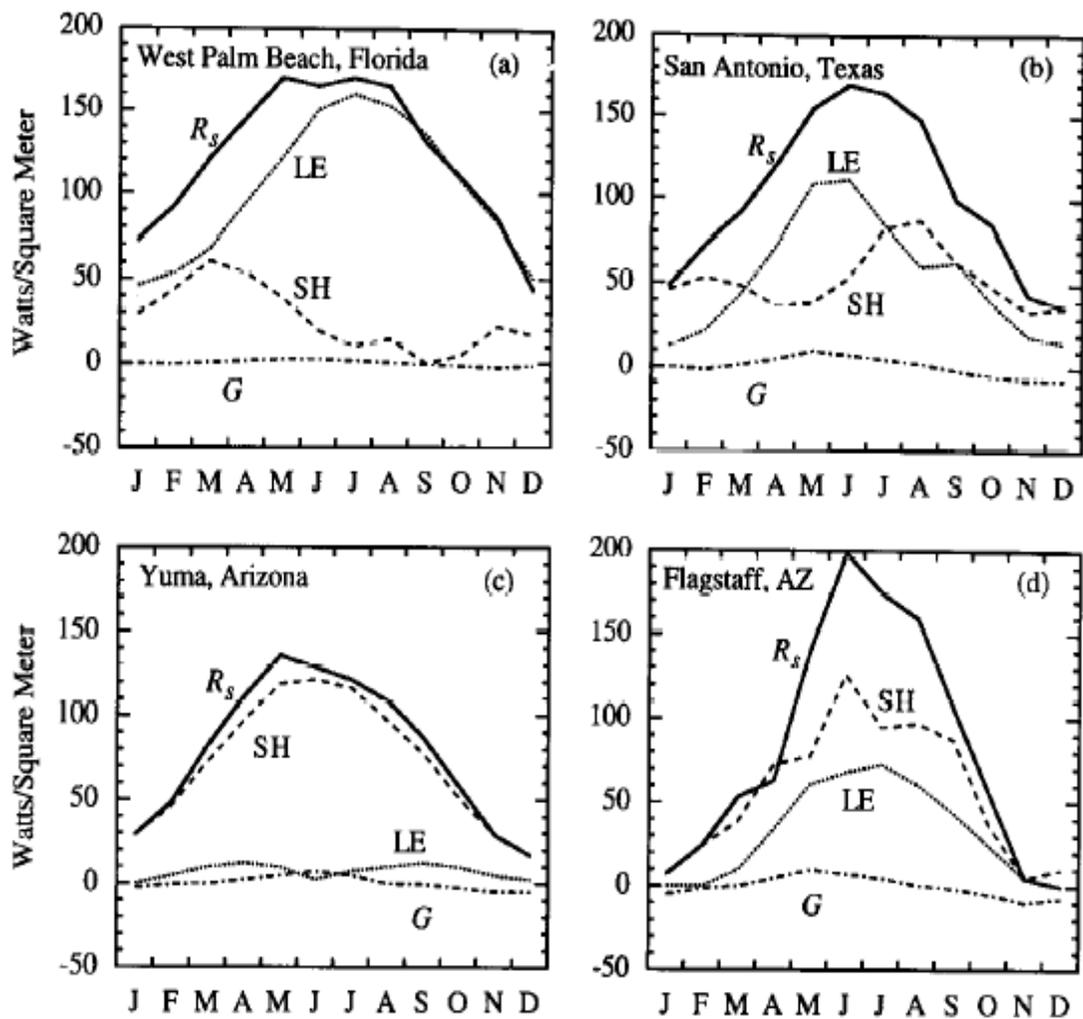


Figure 4.2 Example of seasonal variations in surface energy balance over the land.

NOTE:

- ✓ G (same as F_{cond}) is relatively small compared to other terms;
- ✓ The relative strengths of LE (latent heat) and SH (sensible heat) depends on the availability of soil moisture

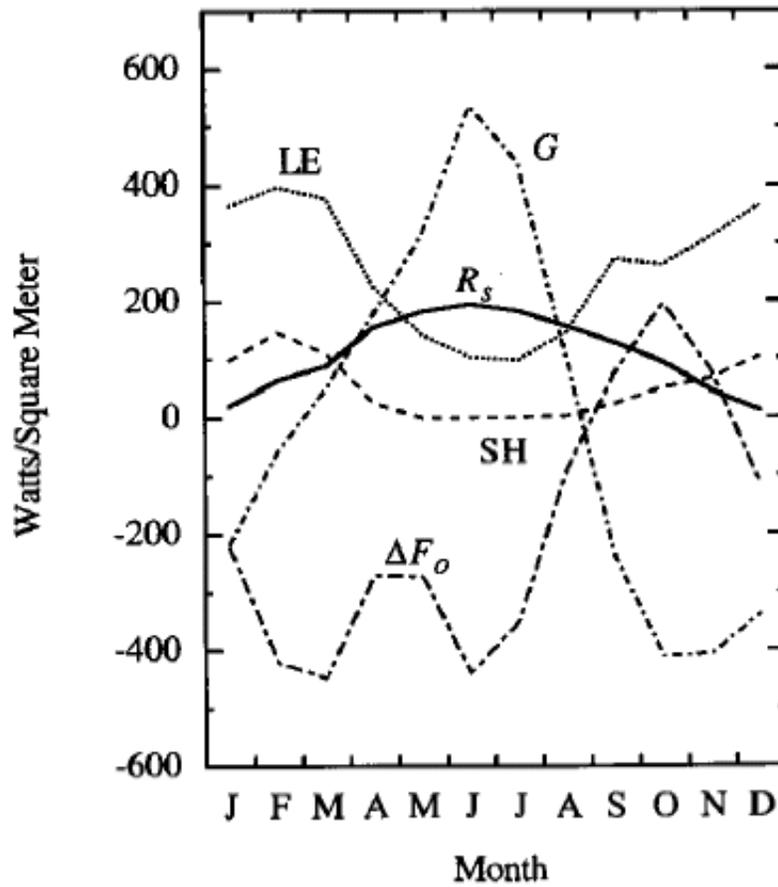


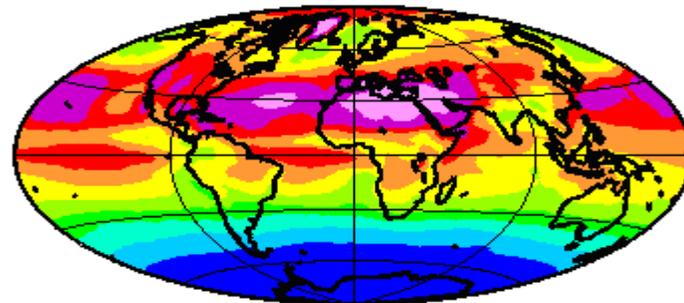
Figure 4.3 Example of seasonal surface balance over the ocean: annual cycle of heat budget component of the Gulf Stream (38N, 71 W).

NOTE:

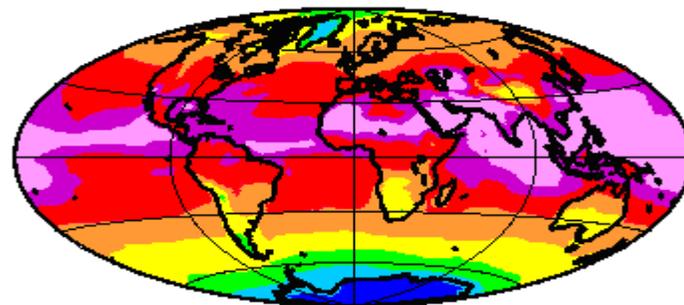
- ✓ G does not have to be negligible;
- ✓ Ocean heat transport (ΔF_o) can be (though not always) a significant contribution to the balance;
- ✓ Latent flux is not limited by availability of moisture

Radiation at the surface:

Figures below show the geographical distribution of 8-year averages of downward shortwave (SW or insolation) and downward longwave (LW) fluxes (DLF), respectively, for July based on satellite data. The insolation distribution is primarily zonal, modulated by the distribution of clouds. The maxima occur over the Arctic, Greenland, and subtropical regions of the Northern Hemisphere due to the high amount of incident solar radiation and the low amount of clouds. The maxima for DLF occur over broad regions in the tropics with a gradual decrease toward the poles. The highest values occur over areas that exhibit high surface temperatures such as the subtropical deserts, and over areas where the abundance of clouds and water vapor enhance the DLF such as along the inter-tropical convergence zone (ITCZ). The lowest values for July occur over Antarctica.



: Geographical distribution of 8-year average of downward SW flux for July. (W m^{-2})



Geographical distribution of 8-year average of downward LW flux for July. (W m^{-2})

Figure 4.4

Baseline Surface Radiation Network (BSRN) (<http://bsrn.ethz.ch/>) was established to provide a worldwide network to continuously measure radiative fluxes at the Earth's surface. At present, there are 35 BSRN stations in operation. These stations measure different sets of radiation values (e.g., direct and diffuse solar radiation, longwave radiation, etc).

BSRN Objectives

- To monitor the background (least influenced by immediate human activities which are regionally concentrated) shortwave and longwave radiative components and their changes with the best methods currently available.
- To provide data for the calibration of satellite-based estimates of the surface radiative fluxes.
- To produce high quality observational data to be used for validating the theoretical computations of radiative fluxes by models.

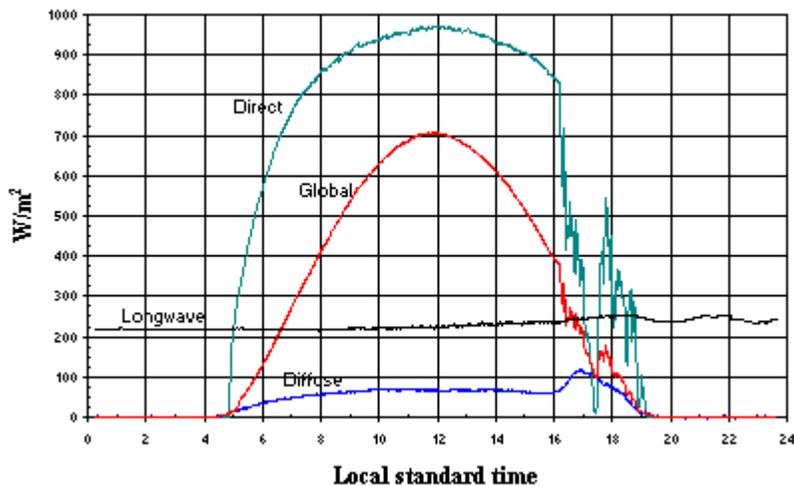


Figure 4.5 Example of measurements of direct, diffuse, global (direct +diffuse) and LW radiation at a BSRN site in Switzerland. Morning hours is the clear sky, where as variations in late afternoon are caused by intrusions of aerosols.