libRadtran user course, lecture # 7

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Radiation quantities

Solution of the radiative transfer equation generally yields the **diffuse radiance**

$$L(\tau, \mu, \phi)$$

and the **direct radiance**

$$L^{dir}(\tau, \mu_0, \phi_0).$$

For polarization above quantities are vectors. From the radiances the upward, $E^{\uparrow}(\tau)$, and downward, $E^{\downarrow}(\tau)$, fluxes, or **irradiances** [W m^{-2} nm^{-1}], are calculated

$$\begin{aligned} E^{\uparrow}(\tau) &= \int_0^{2\pi} d\phi \int_0^1 \mu L(\tau, \mu, \phi) d\mu \\ E^{\downarrow}(\tau) &= \mu_0 L_0 e^{-\tau/\mu_0} + \int_0^{2\pi} d\phi \int_0^1 \mu L(\tau, -\mu, \phi) d\mu. \end{aligned}$$

Radiation quantities cont'd

Furthermore, the mean intensity

$$\overline{L(\tau)} = \frac{1}{2\pi}\left[L_0 e^{-\tau/\mu_0} + \int_0^{2\pi} d\phi \int_0^1 L(\tau,-\mu,\phi)d\mu + \int_0^{2\pi} d\phi \int_0^1 L(\tau,\mu,\phi)d\mu\right],$$

is related to the actinic flux (Madronich, 1987), F, used for the calculation of photolysis (or photodissociation) rates

$$F(\tau) = 4\pi\overline{L(\tau)}.$$

Finally, heating rates [K/day] may be calculated from either the flux differences or the mean intensity.

$$\frac{\partial T}{\partial t} = \frac{1}{c_p \rho_m}\frac{\partial E_{\mathrm{net}}}{\partial z} = \frac{4\pi}{c_p \rho_m}(1-\omega)(\overline{L}-B)\frac{\partial \tau}{\partial z}.$$

Note that the partial derivative of τ with respect to z is needed since optical properties and $\overline{L}$ are calculated as functions of τ.

Radiation quantities cont'd

Albedo:

$$A(\lambda) = \frac{E^{\uparrow}(\lambda)}{E^{\downarrow}(\lambda)}$$

Global albedo:

$$A_g = \frac{\int_0^\infty E^{\uparrow}(\lambda) d\lambda}{\int_0^\infty E^{\downarrow}(\lambda) d\lambda},$$

Radiative forcing (IPCC):

> *Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.*

Includes the calculation of the change in net (down minus up) irradiance (solar plus longwave [W m^{-2}]) due to the factor.

Brightness temperature T (Planck's law, black blody radiation)

$$L(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

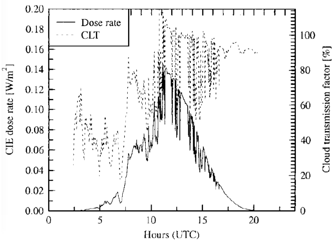
Measured quantities, NILU-UV

Measures irradiances in band i

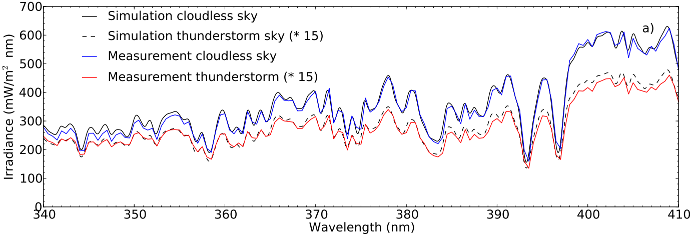
$$E_i^{\downarrow}(t) = \int_{\lambda_1}^{\lambda_2} E^{\downarrow}(\lambda, t)d\lambda$$

CIE UV dose for action spectrum A

$$E_{\text{CIE}}^{\downarrow}(t) = \int_0^{\infty} A_{\text{CIE}}(\lambda)E^{\downarrow}(\lambda, t)d\lambda$$



Measured quantities, UV spectrum



Surface based spectrometer measures downward irradiance as a function of wavelength.

$$E^{\downarrow}(\lambda, t) = \int_0^{2\pi} d\phi \int_0^1 \mu L(\lambda, \mu, \phi) d\mu$$

Measured quantities, AERONET

Surface-based radiance band measurements to deduce aerosol information.

$$L_i(\theta, \phi, t) = \int_{\lambda_1}^{\lambda_2} R(\lambda) L(\theta, \phi, \lambda, t) d\lambda$$

Measured quantities, SEVIRI

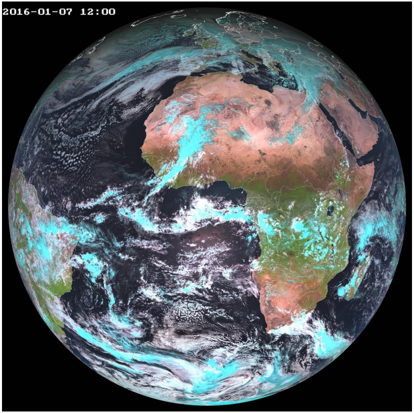
Spinning Enhanced Visible Infra-Red Imager (SEVIRI)

Measures radiances in band *i*

$$L_i(\theta, \phi, t) = \int_{\lambda_1}^{\lambda_2} R(\lambda) L(\theta, \phi, \lambda, t) d\lambda$$

Instruments like MODIS, VIIRS etc. measures similar quantities.

RGB composite



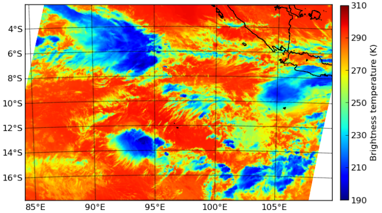
Measured quantities, IASI and AVHRR

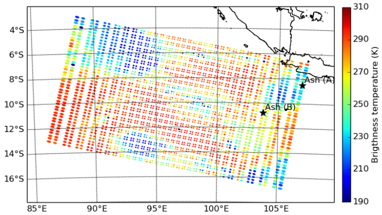
AVHRR

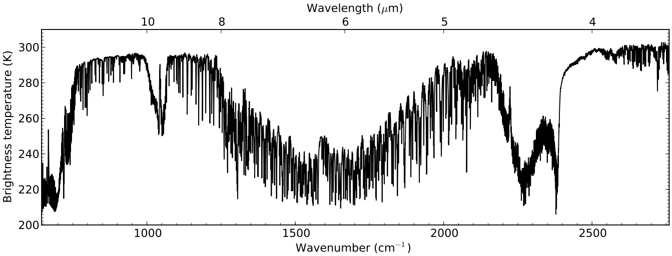
$$L_i(\theta, \phi, t) = \int_{\lambda_1}^{\lambda_2} R(\lambda) L(\theta, \phi, \lambda, t) d\lambda$$

IASI:

$$L(\theta, \phi, \lambda, t)$$





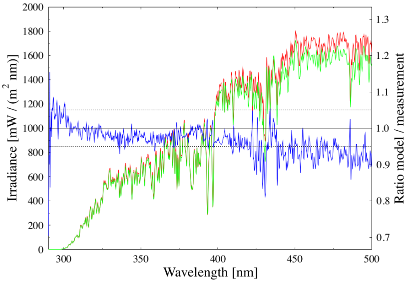


Validation

- Comparison with analytical solutions. DISORT has test code for this.
- Compare with other models
  - Need to agree on cross sections, atmospheric profile and layering.
  - What if all are wrong?
- Compare with measurements
  - Models do not compute what is being measured. Simulate instrument response.
  - Measurements do not precisely measure the wanted quantity. "Correct" measurements.
  - Models include approximations.
  - Measurements have uncertainties.
  - In atmospheric science measurements are generally not repeatable.
  - Closure experiments extremely difficult to make.

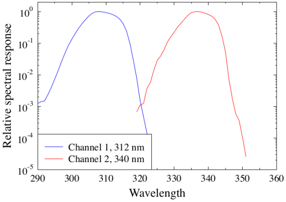
Validation: Surface irradiance

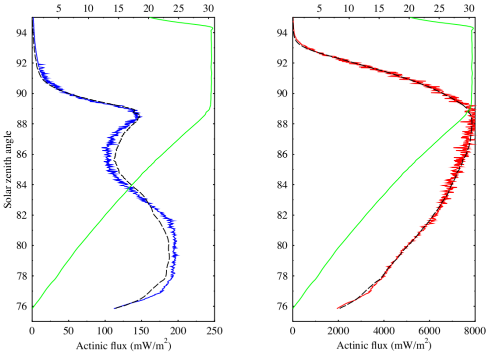
Numerous studies in the UV and visible of model-measurement comparisons of surface and airborne UV and visible irradiances and actinic fluxes (Kylling et al., 1993; Mayer et al., 1997; Kylling et al., 1998; Van Weele et al., 2000; Bais et al., 2003; Hofzumahaus et al., 2002; Kylling et al., 2003; Wendisch and Mayer, 2003).



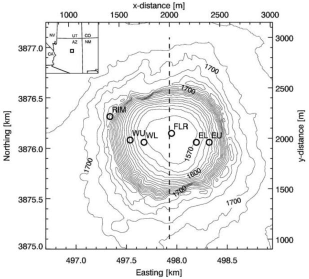
red line: measurements
green line: model
blue line: model/measurement ratio

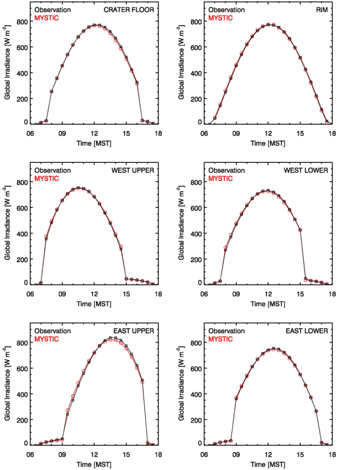
Validation: balloon measurements





Validation: 3D





From Mayer et al. (2010).

For 3D model intercomparison: `https://i3rc.gsfc.nasa.gov/I3RC-intro_new.php`

Today's exercises:

- Calculate solar spectrum, include filter function, integrate
- Calculate solar spectrum, include slit function
- Calculate thermal spectrum, include filter function, integrate
- Plot results

Hints:

- example input files: `UVSPEC_LOWTRAN_SOLAR.INP`
- options `filter_function_file`, `slit_function_file`

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