$$L_{WN}(\lambda) = \frac{L_W(\lambda)}{t(\lambda, \theta_o)\cos\theta_o \left(\frac{d_o}{d}\right)^2}, \tag{2.13}$$

where d_o is the mean earth-sun distance, and $t(\lambda, \theta_o)$ is the diffuse atmospheric transmittance computed as

$$t(\lambda, \theta_o) = e^{-\frac{\frac{1}{2}\tau_R(\lambda) + \tau_{O_3}(\lambda)}{\cos\theta_o}}. \tag{2.14}$$

The Rayleigh optical thickness $\tau_R(\lambda)$ is taken for mean atmospheric pressure (Penndorf 1957), and the ozone optical thickness $\tau_{O_3}(\lambda)$ is computed for an atmospheric ozone concentration of 350 Dobson units. The ratio of average to actual earth sun distances is approximated as

$$\frac{d_o}{d} = 1 + 0.0167\cos\left[\frac{2\pi(J-3)}{365}\right], \tag{2.15}$$

where J is the sequential day of the year.

The *normalized water-leaving radiances* $L_{WN}(\lambda)$ computed with Equations (2.13) through (2.15) are still dependent on the bidirectionality of the ocean's reflectance, as determined by the local inherent optical properties of the water and the solar zenith angle θ_o (Morel and Gentili 1996). To remove the bidirectional reflectance effects, it is necessary to convert the above $L_{WN}(\lambda)$ to *exact normalized water-leaving radiance* $L_{WN}^{ex}(\lambda)$ following the protocols in Vol III, Chapter 4.

Spectral Band Averaging

The water leaving radiance corresponding to each wavelength band of a satellite ocean color sensor is determined from the MOBY solar-normalized water leaving radiances $L_{WN}(\lambda)$ as

$$L_{WN}^{MS}(\bar{\lambda}_i) = \frac{\int_0^\infty r_n^S(\lambda, \bar{\lambda}_i) L_{WN}(\lambda)\, d\lambda}{\int_0^\infty r_n^S(\lambda, \bar{\lambda}_i)\, d\lambda}, \tag{2.16}$$

where the superscripts S and MS denote a particular satellite ocean color sensor and a MOBY derived estimate for that satellite, respectively, $\bar{\lambda}_i$ is the effective wavelength of the i^{th} band of that sensor, and $r_n^S(\lambda, \bar{\lambda}_i)$ is the normalized relative spectral response function of that channel. In practice, (2.16) is approximated numerically.

An example MOBY water-leaving radiance spectrum is compared to the shapes of the spectral response function of MODIS ocean bands in Fig. 2.15. Note that $L_{WN}(\lambda)$ must be transformed to $L_{WN}^{ex}(\lambda)$ (Vol. III, Chapter 4) prior to match-up comparisons between MOBY and satellite water-leaving radiances.