As just seen, the empirical line fit technique has the virtues that it works in principle for any atmosphere and no atmospheric measurements are needed. However, it has the disadvantage that it requires field measurements of $R_{\mathrm{rs}}(\lambda)$ to use in developing the ELF functions. These are often impossible to obtain and certainly are not practicable for routine observation of large areas. The ELF technique also does the same atmospheric correction for every image point, even though for airborne imaging the viewing geometry may be significantly different for different image pixels.

Radiative transfer techniques take the sophisticated approach of numerically computing the atmospheric path radiance for each pixel in an image. The virtue of this approach is that every image pixel can get a different atmospheric correction, which can account for differences in viewing geometry or even for differences in atmospheric conditions in various parts of the image. The disadvantage of this approach is that the *atmospheric conditions must be measured in the field at the time of image acquisition*, or perhaps obtained from atmospheric forecast models, in order to obtain the inputs needed to compute the atmospheric path radiance for each pixel.

A pioneering radiative transfer model developed for atmospheric correction of airborne hyperspectral images over water is the TAFKAA code developed by the U.S. Naval Research Laboratory (Gao et al. (2000), Montes and Gao (2004)). TAFKAA is based on the earlier ATREM (ATmospheric REMoval) code of Gao and Goetz (1990). (Indeed, TAFKAA stands for The Algorithm Formerly Known As ATREM.) Other such codes exist (e.g., ACORN and FLAASH; see comparison in San and Suzen (2010)), but they are used primarily for terrestrial remote sensing. TAFKAA is discussed here because one of its versions is designed for the particular problems of oceanic hyperspectral remote sensing. (One TAFKAA version is designed for terrestrial imagery and does not remove surface reflectance; the other version is designed for ocean imagery and can remove sea-surface reflectance.)

When using a radiative transfer code such as TAFKAA, the sun and viewing geometry for each pixel are known from the location, time, sensor altitude and heading, and pixel location in a georectified image. If atmospheric conditions such as sea-level pressure; aerosol type, altitude, and optical thickness; and humidity are known, the path radiance can be computed for each path from pixel to sensor. Knowing the wind speed allows for a estimate of the background sky reflectance by the sea surface to be computed. These path radiance calculations are performed with an atmospheric radiative transfer model, usually including polarization. Such calculations are computationally intensive, so one set of calculations is performed for a wide range of conditions to create a look-up table of path radiances (and other factors, such as atmospheric transmittances). Given the viewing geometry and atmospheric conditions for a pixel, interpolation in the look-up table is used to obtain the appropriate wavelength-dependent path radiance and surface reflectance to subtract from the at-sensor radiance or reflectance to obtain the water-leaving radiance or reflectance at the sea surface.

The original TAFKAA look-up table included path radiances and atmospheric transmittances for the following grid of values:

- 5 aerosol types (maritime, 2 coastal, tropospheric, and urban)
- 5 relative humidities (50, 70, 80, 90, and 98%)
- 10 aerosol altitudes from 0 to 84 km

- 10 aerosol optical depths from 0.0 to 2.0 (at 550 nm)
- 9 solar zenith angles from 1.5 to 72 deg.
- 17 off-nadir viewing angles from 0 to 88 deg
- 17 azimuthal viewing angles from 0 to 180 deg, relative to the sun
- 17 wavelengths from 390 nm to 2.25 μm
- 3 wind speeds of 2, 6, and $10\,\mathrm{m\,s^{-1}}$

This grid of inputs required about 332 million solutions of the vector radiative transfer equation. These calculations required many months of computer time, but they need be done only once.

When processing an image, the user inputs the image information (location, time, aircraft or satellite altitude and heading, georectification information) and atmospheric conditions. TAFKAA can then look up the appropriate value to subtract from each at-sensor spectrum, interpolating as necessary in the look-up table. If no aerosol information is available, then TAFKAA defaults to making a "black-pixel" assumption and estimating the aerosol type from wavelengths of 750 and 865 nm (if no wavelengths greater than 1000 nm are available in the image), as previously described. TAFKAA allows the user to input a file with the sensor wavelength responses for the different wavelength bands, so that TAFKAA output matches a particular sensor's wavelength response as closely as possible. Inputs to TAFKAA are made via an ENVI-format image header file. Applications of TAFKAA can be seen at Montes et al. (2003) and Goodman et al. (2003).

There are assumptions in the TAFKAA calculations that limit its applicability or accuracy. The water-leaving radiance is assumed to be Lambertian; this excludes modeling multiple scattering effects between the water-leaving radiance and the atmosphere. It is assumed that the viewing geometry avoids direct sun glint; thus TAFKAA cannot correct sun glint in an image. The surface reflectance calculations for background sky radiance cannot correct for swell effects. The code does not interpolate in wind speed. Nevertheless, given the needed atmospheric information, TAFKAA provides adequate atmospheric corrections for a wide range of imagery and environmental conditions. However, as with any such model, if the inputs do not describe the imaged environment, the TAFKAA corrections can be poor.