Presented at Pacific Ocean Remote Sensing Conference, Bali, 2002

Atmospheric Correction Near Hawaii: Clear Sky and Volcano Plumes

By JOHN PORTER and TORBEN NIELSEN
SOEST, University of Hawaii, 2525 Correa Rd, Honolulu, HI 96822
jporter@soest.hawaii.edu and torben@hawaii.edu

ABSTRACT

When aerosols from the Hawaii volcano plume are present then the water leaving radiance derived from the SeaWifs satellite using the SeaDas algorithm is too large. It is shown that this problem may be due to the use of an incorrect aerosol model. Furthermore, it is shown that using longer wavelengths may be needed to solve the atmospheric correction problem under Hawaii volcanic aerosols.

Key Words: Atmospheric Correction, Volcanic Aerosol, Ocean Color

INTRODUCTION

Atmospheric aerosol and molecules typically contribute a dominant part (70-90%) of the satellite-measured radiance over clean ocean waters (Gordon 1987). In order to obtain the water leaving radiance from satellite images, an atmospheric correction is required which removes aerosol and molecular scatter as a function of wavelength. While molecular scattering is easy to model, calculations of aerosol scatter are complicated by uncertainty in the aerosol size distribution and composition. The typical approach to solve this problem is to use near infrared wavelengths, where the water leaving radiance is near zero, to derive the aerosol type and optical concentration. Then the aerosol radiance is extrapolated to the visible wavelengths based on the aerosol type (Gordon and Wang, 1994). This general approach has been applied to the Coastal Zone Color Scanner (CZCS) and the SeaWifs sensor (McClain et al., 1998).

ATMOSPHERIC CORRECTION NEAR HAWAII

While the current approach to atmospheric correction has proved to be successful in many cases (McClain et al., 1998), we have found specific conditions where further improvements are needed. Figure 1 shows a SeaWifs image collected over Hawaii and processed to obtain aerosol optical depths with the NASA SeaDas software (Gordon and Wang, 1994). Clear areas with low aerosol optical depths are visible as well as areas with large loading of volcanic aerosol. During this time period, the winds were light and variable with a ridge present over the northern part of the Hawaiian Islands. Near the southern part of the islands, the northeast trade winds are beginning to blow again causing a clear volcano plume coming off the island of Hawaii. A remnant of the past volcano plume is present north of the Oahu. Clean regions appear in a cloud free band to the east of the islands as well as to the far west part of the image. Figure 2 shows the water leaving radiance calculated from this same image. Under the volcano plume, the calculated water leaving radiance (upwelling radiance from the ocean just above the surface) is higher than regions with cleaner air. Other wavelengths also showed higher water leaving radiance under the volcano plume (discussed below). The SeaWiFS images processed on other days showed a similar relationship between the high aerosol optical depths and high anomalously high water leaving radiances.

For the SeaDas calculations shown in Fig. 2-4, synoptic wind fields were used (1 degree resolution). Near the islands these winds are known to be wrong due to small-scale orographic effects but should be correct over the open ocean regions. In addition, this image was collected in January when the sun is near furthest south and sun glint is small. During the time of this image a Hawaii Ocean Time Series (HOTS) cruise was taking place (100 km north of Oahu) and visual observations reported hazy conditions with light winds (<3 m/s) and no whitecaps.

Therefore this suggests the problem may be due to incorrect aerosol models.

Aerosol optical depths were measured on the HOT cruise, which had a strong spectral dependence suggesting non-sea salt aerosol. Genetic inversion of the sun photometer measurements also supported the dominance of volcanic aerosol (accumulation mode aerosol) dominated.

In order to carry out atmospheric corrections realistic aerosol models are needed which capture the range of aerosol possibilities. One model, which has been used frequently, is the Shettle and Fenn (1979) aerosol model. This model (with diff. relative humidity conditions) was used for the SeaWifs and MODIS ocean color algorithms (Gordon and Wang, 1994) as well as others. The Shettle and Finn (1979) model assumes a fixed distribution for the accumulation mode and another fixed mode for the coarse mode. More recently various investigators have found that both the accumulation and coarse mode shift to larger sizes as the concentration increases. These aerosol features are captured in the aerosol models proposed by the Navy Aerosol Model (Garthman, 1984) , by Remer et; al., (1996) and by Porter and Clarke (1997). The Remer et al. (1996) model is currently being used by the MODIS aerosol team in their aerosol lookup tables.

Based on Mie calculations we have calculated the aerosol single scatter (aerosol optical depth times single scatter albedo times the aerosol phase function) for a range of aerosol models. Figure 3 shows the aerosol single scatter divided by the aerosol single scatter at 870 nm. This ratio is commonly referred to as epsilon, ε (Gordon and Wang, 1994). In this figure the Cox and Munk model is shown in pink, the Porter and Clarke model is shown in blue (for the coarse mode) and in red (for the accumulation mode). It can be seen that the sea salt scatter is spectrally flat while the accumulation mode has stronger wavelength dependence. In fact the largest accumulation mode aerosol cases (two bottom red line) are spectrally flat at larger wavelengths and are wavelength dependent at shorter wavelengths. The fact that the largest accumulation mode aerosol and the sea salt aerosol have similar spectral shape at the longest wavelengths means they cannot be distinguished from each other when normalized at 870 nm.

In contrast to these results, the Cox and Munk model (pink lines in Fig. 3), which is used by the SeaWifs algorithm, is typically very smooth with approximately the same slope at the larger and shorter wavelengths for all aerosol cases. Presumably this difference is due to the different aerosol models being employed. Based on the differences seen in Figure 2, we expect the SeaWiFS algorithm would not remove all the aerosol-scattered light at shorter wavelengths when large accumulation mode aerosol cases occur. This would cause the water leaving radiance to be too large and is consistent with what we are seeing under the volcano plume in Figures 1 and 2.

We now investigate the possibility of normalizing at longer wavelengths to see if the sea salt and accumulation modes can be better separated. Figure 4 shows the same epsilon calculations normalized at 1600 nm. When the aerosol scatter is normalized at 1600 nm fortunately the two aerosol modes are separated. This result suggest that atmospheric correction algorithms need to have one channel out at 1600 nm. The other channel can be either at 870 or 1045 nm.

DISCUSSION

The largest accumulation mode aerosols occur in volcano plumes or anthropogenic pollution. Interestingly Howard Gordon (personal communication) points out that they often find negative water leaving radiances under the US east coast aerosol plume, which is the opposite of what we find here! He suggest that aerosol absorption can reduce the satellite radiance at shorter wavelengths due to the increased multiple scatter at shorter wavelength (aerosol-molecular interaction). The Hawaii volcano plume is unique in that the accumulation mode aerosols have little absorption and are composed on sulfuric acid and associated water. Clearly the results we find here may not be applicable throughout the world, but for Hawaii volcanic aerosol it appears to provide hope for improved atmospheric correction algorithms.

REFERENCES

Garthman, S. G., Navy Hygroscopic Aerosol Model: Hygroscopic Aerosol. A. Deepak, Hampton, Va. 1984.

Gordon, H.R. and M. Wang, 1994, Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: a preliminary algorithm. Appl. Opt. 33, 443-452.

McClain, C. R., M.L. Cleave, G.C. Feldman, W. W. Greg, S. B. Hooker, 1998, Science quality SeaWiFS data for global biosphere research. Sea Technology, September.

Porter, J., Clarke, A., An Aerosol Size Distribution Model Based on In-Situ Measurements. J. Geophy. Res., 102, 6035-6045, 1997.

Remer, L.A., Y.L. Kaufman, and B.N. Holben, The size distribution of ambient aerosol particles. in Biomass Burning and Global Change, edited by J.S. Levine, MIT Press, Cambridge, Mass., 1996.

Shettle, E.P., and R.W. Fenn, Models for the aerosols of the lower atmosphere and the effects of humidity variations on their optical properties, Rep. AFGL TR-79-0214, AD-A085951, 94 pp., Air Force Geophys. Lab., Bedford, Mass., 1979. (Available as AD-A197945 from Natl. Tech. Inf. Serv., Springfield, Va.).

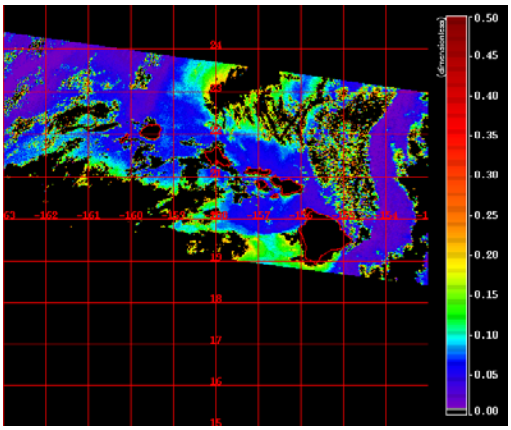

Figure 1. Aerosol optical depth (870 nm) calculated from a SeaWiFS image using the SeaDas software.

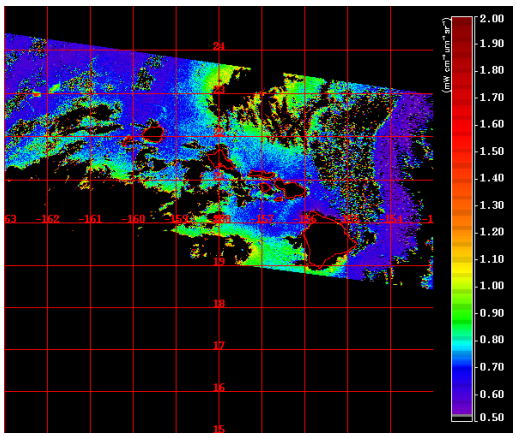

Figure 2. Water leaving radiance (510 nm) calculated from a SeaWifs image using the SeaDas algorithm (from same image as Fig. 1).

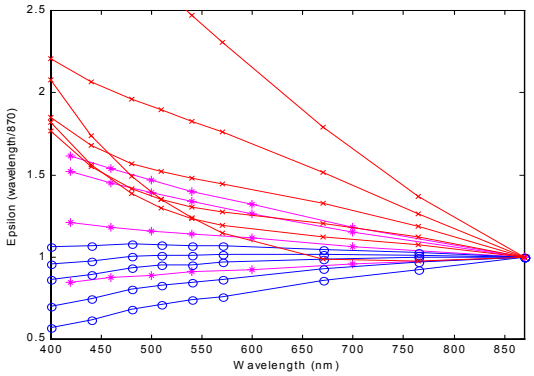

Figure 3. Aerosol single scattered radiance (at 135 degrees scattering angle) normalized by the aerosol single scattered radiance at 870 nm.

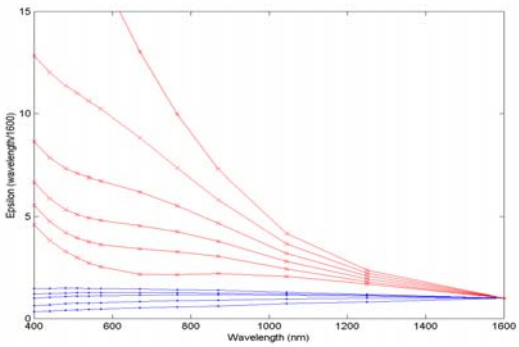

Figure 4. Aerosol single scattered radiance (at 135 degrees scattering angle) normalized by the aerosol single scatter radiance at 1600 nm.