OceanColor BRDF Evaluation

Notes on the problem

The problem in four sentences: Normalized water-leaving radiances (nLw) are inexact so long as the observations are collected under non-ideal conditions, for example, high sensor zenith angles. Exact nLw's are desirable when comparing radiances collected by different sensors at different times of day. Fresnel corrections partially account for variations in sensor and solar geometry. Morel and others postulate that the nLw's need to be adjusted further because the sea surface is non-Lambertian, in part, due to the nonisotropic subsurface light field. Below describes various steps that have been implemented, or may adopted in the future, to address these issues.

(1) Water-incident Fresnel correction suggested by M. Wang and introduced into SeaWiFS operational processing during Reprocessing 4: Spectrally independent correction that accounts for the reflection and refraction effects that occur when Lu(0-) propagates upward through a flat surface. Depends entirely on sensor zenith angle. Applied in operational processing as an on-the-fly-calculated correction factor.

(2) Air-incident Fresnel correction suggested by M. Wang and slated for inclusion in the next SeaWIFS and MODIS-Aqua reprocessings. Spectrally dependent correction that accounts for the reflection and refraction effects that occur when Ed(0+) propagates downward through a wind-roughened surface. Depends on solar zenith angle and wind speed. To be applied in operational processing as an on-the-fly-calculated correction factor.

* Note that the combination of (1) and (2) is conceptually equivalent to the Gothic-R term proposed by Morel and others .

(3) f/Q correction developed by Morel and others : Accounts for the spectrally dependant, nonisotropic (bidirectional structure of the) subsurface light field, which is not addressed in (1) or (2). Depends on sensor zenith angle, relative azimith angle, illumination conditions (solar zenith angle and AOT), sea state (wind speed), and in-water constituents (inherent optical properties, IOP's). Through Monte Carlo simulations, the authors built a lookup table for:

- 7 wavelengths (412.5, 442.5, 490, 510, 560, 620, 660)
- 6 [chl] (0.03, 0.1, 0.3, 1.0, 3.0, 10.0)
- 6 solar zenith angles (0, 15, 30, 45, 60, 75)
- 13 relative azimuth angles (every 15 deg from 0 to 180)
- 17 nadir angles (1.078 to 48.830 deg)

The sensor zenith angle is related to the nadir angle via Snell's Law using the index of refraction for water (1.34). Correction factor is the ratio of f/Q for nadir and solar zenith angles (and thus, relative azimuth angle) = 0 to f/Q for actual viewing geometry. Both are estimated by weighting and interpolating the boundary conditions provided in the lookup table. The chl input is used to account for the IOP's (specifically, backscattering and absorption). See Morel and Maritorena (2001) and references therein for a description of these chl->IOP models.

* Note that the full Morel and others correction applies both the Gothic-R term and (3).

Questions on the table regarding f/Q

Recognizing the need for a BRDF correction, the following application-related questions are currently under consideration:

Is the existing suite of wavelengths with which the f/Q model was derived (MERIS) sufficient for application to SeaWiFS and MODIS? Would interpolating between neighboring wavelengths be sufficient?

Is the [chl] range with which the f/Q model was derived appropriate for global application? How does the model perform in Case 2 waters? How well does the model interact with the current NIR correction?

Are the satellite-derived [chl] values retrieved at the scan edge (most extreme geometry) sufficiently accurate to correct the satellite radiances?

At what level does the f/Q correction propagate through Level-3 binning (daily, weekly, monthly, yearly)? Are the data products at higher binning levels significantly different after applying the correction to the input Level-2 data?

Even if applying the correction improves comparisons between satellites at Level-3, does the community want the correction applied full time (e.g., at Level-2)?

Hypothetical studies of f/Q

For the following, the correction is defined as:

- f/Q correction = f/Q(hypothetical) / f/Q(observed)

What is the magnitude of the correction for a given scenario?

- Plot of various geometries and wavelengths as a function of chl versus solar zenith angle
- Plot of various geometries as a function of wavelength versus chl

- Created via:
  ° calculate f/Q correction using the following as inputs
  ° 3 wavelengths (443, 490, and 555)
  ° 3 [chl] (0.05, 0.2, 1.0)
  ° 4 sensor zenith angles (15, 30, 45, 60)
  ° 4 solar zenith angles (15, 30, 45, 60)
  ° 3 relative azimuth angles (0, 90, 180)

How does the f/Q correction modify MOBY field data?

- Plot of correction for MOBY at three times of day for a calendar year

- Created via:
  ° fix latitude at 20.8, longitude at -157.2, and [chl] at 0.08 mg/m3
  ° calculate solar zenith angle for 365 days of year at 20:30, 22:00, and 23:30 GMT
  ° fix sensor zenith at 0.0 and relative azimuth at 0.0 (MOBY viewing angles)
  ° calculate f/Q correction at three times of day for 365 days of year

How do the corrections modify satellite data?

- SeaWiFS f/Q correction at MOBY for 2003 (geometry)
- MODIS-Aqua f/Q correction at MOBY for 2003 (geometry)

- SeaWiFS f/Q correction in South Pacific for 2003 (geometry)
- MODIS-Aqua f/Q correction in South Pacific for 2003 (geometry)

- Created via:
  ° run overflight predictions for both sensors at fixed coordinates for all of 2003
  ° fix latitude at 20.8, longitude at -157.2, and [chl] at 0.08 mg/m3 for MOBY
  ° fix latitude at -42.0, longitude at -90.0, and [chl] at 0.10 mg/m3 for South Pacific
  ° use the zenith and azimuth angles provided in the overflight predictions to calculate corrections for each observation

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Level-3 studies of f/Q

How do the corrections alter SeaWiFS and MODIS-Aqua time series?

Comparative time-series analyses of oceanic optical properties are currently being performed for both SeaWiFS and MODIS-Aqua. Several of these analyses address BRDF-related issues.

- SeaWiFS Calibration and Algorithm Testing
- MODIS-Aqua Calibration and Algorithm Testing

References

Morel, A., and B. Gentilli, 1991: Diffuse reflectance of oceanic waters: its dependence on Sun angle as influenced by the molecular scattering contribution. Appl. Opt., 30, 4427-4438

Morel, A., and B. Gentilli, 1993: Diffuse reflectance of oceanic waters. II. Bidirectional aspects. Appl. Opt., 32, 6864-6879

Morel, A., and B. Gentilli, 1996: Diffuse reflectance of oceanic waters. III. Implication of bidirectionality for the remote-sensing problem. Appl. Opt., 35, 4850-4862

Morel, A., and S. Maritorena, 2001: Bio-optical properties of oceanic waters: A reappraisal. J. Geophys. Res., 106, 7163-7180

Morel, A., D. Antoine, and B. Gentilli, 2002: Bidirectional reflectance of oceanic waters: accounting for Raman emission and varying particle scattering phase function. Appl. Opt., 41, 6289-6306

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