

The Modified Near-IR Correction Algorithm

Introduction

The Siegel near-infrared (NIR) approximation for high chlorophyll water (Siegel et al., 2000) significantly improved chlorophyll estimates in coastal waters using data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS).

- **3rd Reprocessing:** The Siegel algorithm was initially implemented during the third SeaWiFS reprocessing (Robinson et al., 2000).
- **4th Reprocessing:** A near-IR correction algorithm based on reflectance in the 670 nm band (Arnone, 1998) was adopted to perform a similar correction.

While the near-IR algorithm performed well overall, minor issues arose regarding how it handled **low chlorophyll waters**. This document outlines these problems and the modifications made to resolve them.

The Challenge: Near-IR Algorithm Problems

The NIR algorithm uses an iterative process during aerosol determination to account for non-zero water-leaving radiance in the NIR bands. This iteration is necessary because $L_w(670)$ —a product of aerosol-corrected radiances—is used to determine the NIR water-leaving radiance.

The Original Time-Saving Assumption:

To keep processing times efficient, the original near-IR method assumed an initial chlorophyll of 0.3 mg m^{-3} . For the majority of low chlorophyll water, this bypassed the computationally expensive aerosol determination iterations. The 0.3 threshold was chosen to ensure a smooth data distribution when iterations finally kicked in at higher chlorophyll levels.

While vicarious calibration to the MOBY site removed significant bias, this assumption caused two main problems:

1. **Unexpected Changes in Low Chlorophyll:** Normalized water-leaving radiance (L_{wn}) and chlorophyll values changed even in low or no-chlorophyll waters when the near-IR algorithm was turned on. This contradicted the expectation that NIR L_{wn} should be zero at low chlorophyll, which unsettled some SeaWiFS users.

2. **Calibration Bottlenecks:** The iterative vicarious calibration process became too time-consuming as the dataset grew. A new, faster calibration method was developed (calculating the gain factor directly without iteration), but this new method could not easily accommodate the near-IR algorithm's iterations.

The Complication:

Simply starting the aerosol determination with a NIR of 0 (instead of the 0.3 chlorophyll assumption) causes a sharp, unnatural discontinuity in the chlorophyll distribution when transitioning to higher values.

Requirements for a New Solution

Any modified algorithm needed to satisfy three strict conditions:

1. **No effect on low chlorophyll:** It must not affect L_wn and chlorophyll for low chlorophyll waters (< 0.3) or the majority of values at the vicarious calibration site (where average chlorophyll is ~0.08).
2. **No artifacts:** It must not introduce significant artificial spikes or drops in the chlorophyll distribution.
3. **Efficiency:** It must not significantly slow down processing speed.

The Solution: The Modified Near-IR Method

To ensure the algorithm has no effect at low chlorophyll levels but still works for higher levels (where it is needed), the OBPG implemented a **smooth transition system**.

Instead of abruptly turning the NIR correction on at a single chlorophyll value (which causes artifacts), the modified algorithm uses a NIR value that *smoothly transitions* from zero at a low chlorophyll bound to the standard Siegel NIR at a high chlorophyll bound.

The Transition Zone (0.7 to 1.3 mg m⁻³):

- Tests of the OC4v4 algorithm showed that the difference between using the Siegel correction and not using it is smallest near 1.0 mg m⁻³ (less than a 2% effect on chlorophyll).
- Therefore, the transition range was set between **0.7 and 1.3 mg m⁻³**.
- This relatively broad transition minimizes artifacts, and starting at 0.7 allows a wider range of water conditions to be used for vicarious calibration.

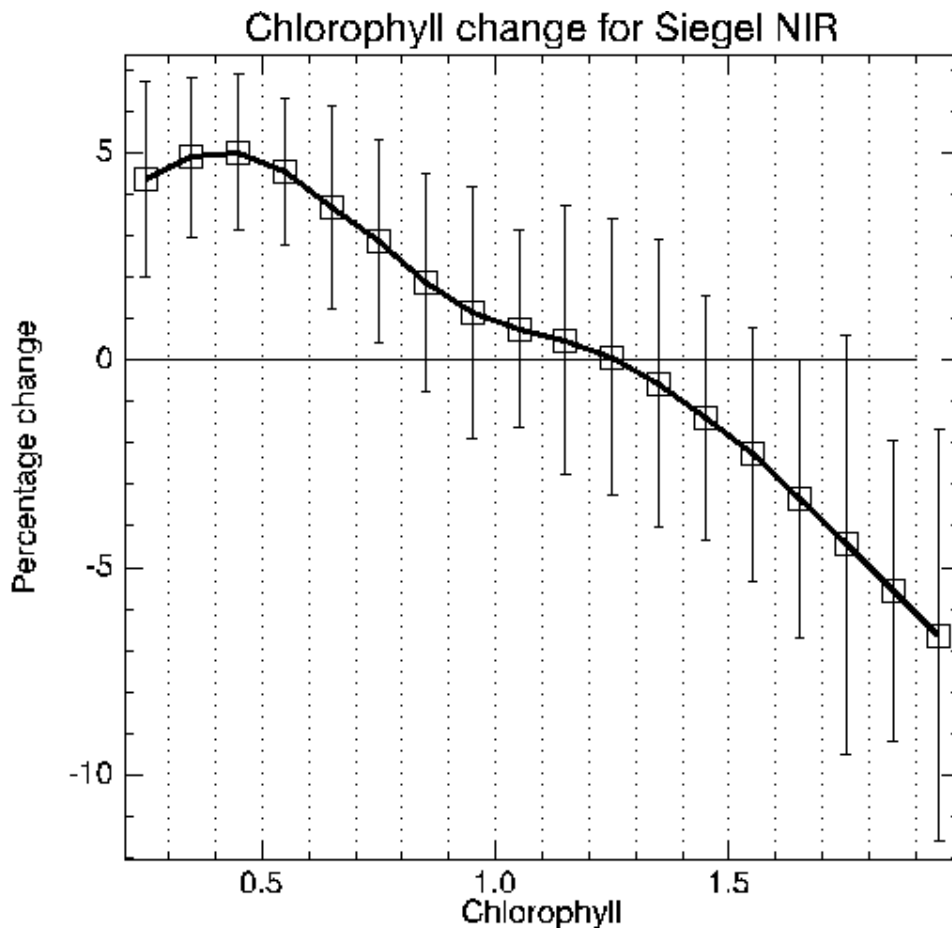


Figure 1: Average (boxes along the solid curve) and standard deviation (error bars) of the percent change of the chlorophyll between the Siegel with iterations and no Siegel in use. The ranges are 0.1 mg m⁻³ chlorophyll ranges from 0.2 mg m⁻³ to 2.0 mg m⁻³. The Siegel closely matches the no Siegel around 1 mg m⁻³.

Results and Performance

The modified algorithm was tested using 1 to 3 days of global GAC data (July 12-14, 1998) and compared to the operational program. The results were highly successful:

- **Smooth Distributions:** The modified method produced smooth chlorophyll distributions with zero artifacts at the 0.7 and 1.3 transition points. (See Figure 2).

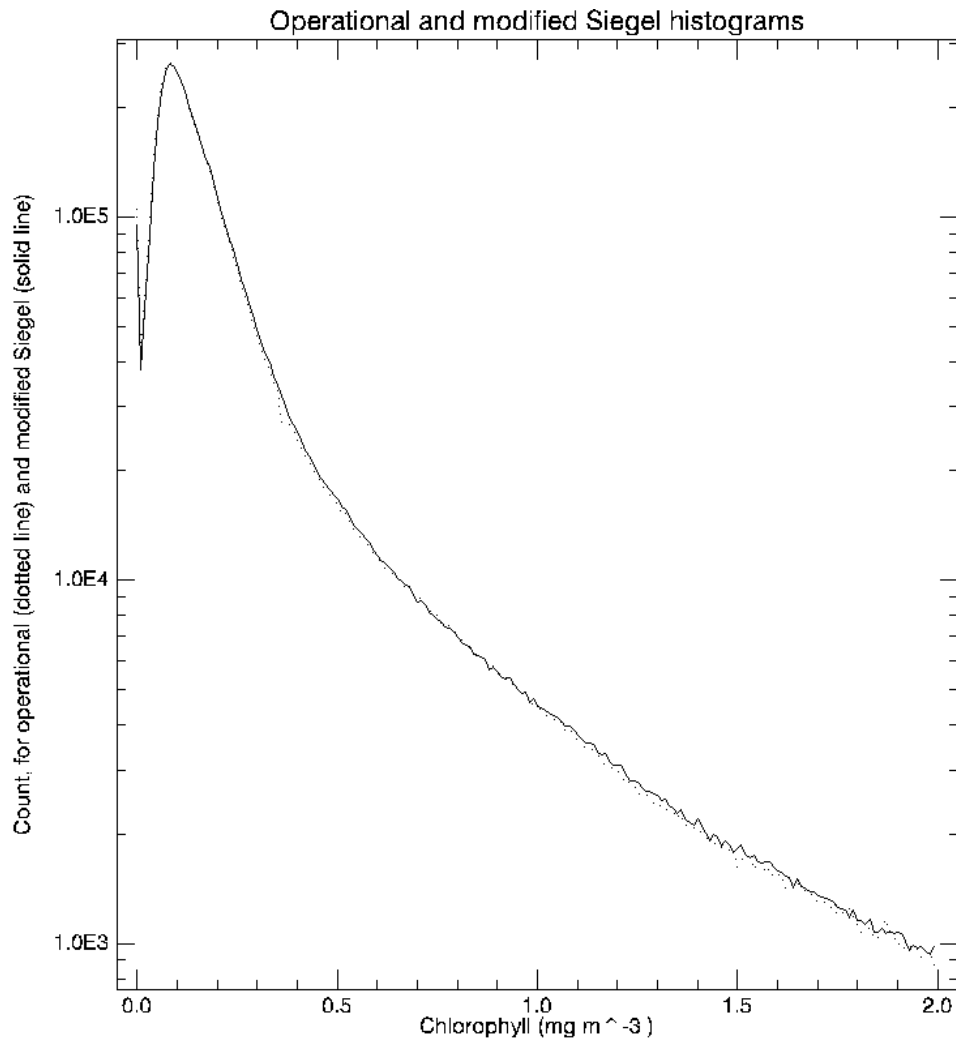


Figure 2: Chlorophyll distributions for the modified Siegel (solid line) and the current Siegel (dotted line) algorithms. Chlorophyll is taken from 46 level-2 files with global coverage for 12 - 14 July, 1998.

● **Minor Chlorophyll Adjustments:**

- *Low/Moderate Chlorophyll* (< 1.0): Increased by roughly 2% (up to 20% for extremely low values < 0.02).
- *High Chlorophyll*: Decreased by up to 18.5%.
- *Overall Average*: A very small overall increase of about **1.6%**. (See Figure 3).

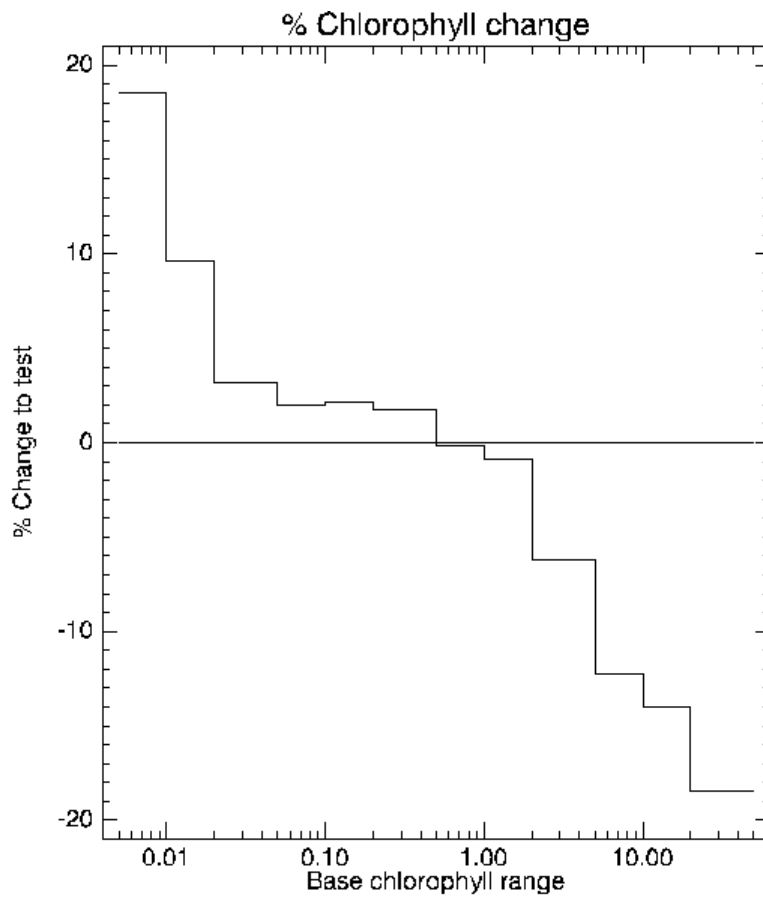


Figure 3: Average of the chlorophyll change from the standard Siegel method to the modified Siegel method as a function of the initial chlorophyll. The difference is compiled from 16 GAC files for the 12th of July, 1998.

- Minor Reflectance Changes:** The maximum average reflectance change occurred in the 2-5 mg m⁻³ range. The highest relative change was at 555 nm (8%, primarily because average reflectance here is naturally lower). Overall average reflectance change was minimal (< 1.8%). (See Figure 4).

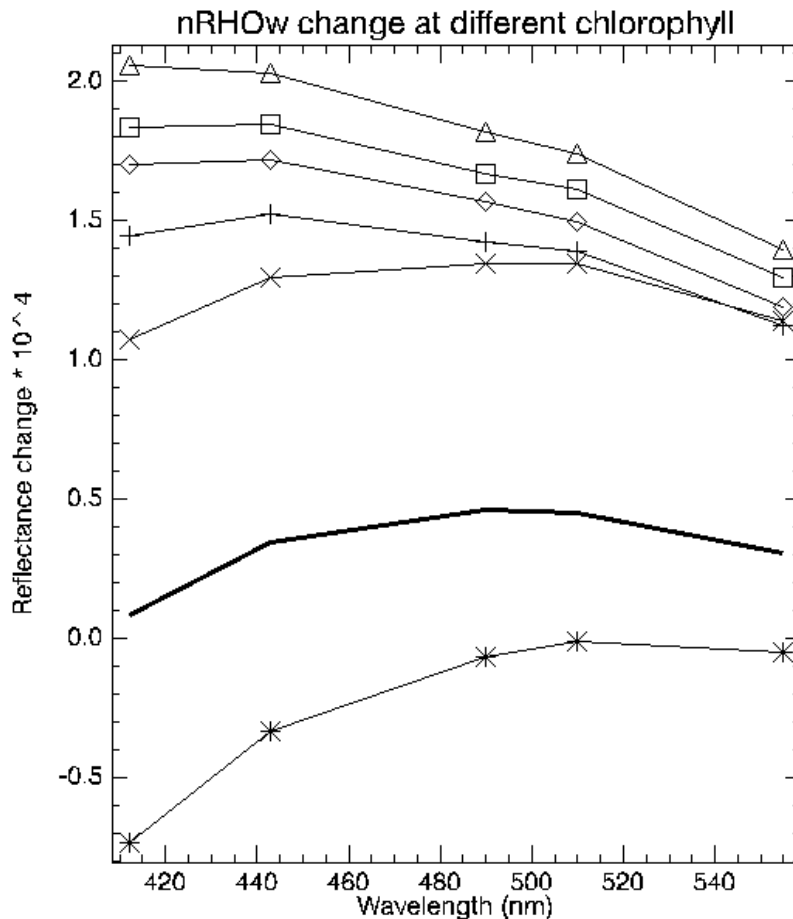


Figure 4: Change in the normalized water-leaving reflectance as a function of wavelength for various ranges of SeaWiFS chlorophyll. Ranges are: .5 - 1 mg m⁻³ (astrisk), 1 - 2 mg m⁻³ (diamond), 2 - 5 mg m⁻³ (triangle), 5 - 10 mg m⁻³ (square), 10 - 20 mg m⁻³ (square), 5 - 10 mg m⁻³ (square), 10 - 20 mg m⁻³ (plus sign), and 20 - 50 mg m⁻³ (x sign). The heavy line is the average reflectance change for all chlorophyll data. Average reflectances for the 5 wavelengths are (using this scale): 68., 63., 50., 34., and 17.

- **Negative Radiances:** The modification had little to no negative impact on the frequency of negative water-leaving radiances at 412 and 443 nm.

Conclusion

The modified Siegel algorithm successfully meets all required goals: it fixes the low-chlorophyll issues, introduces no data artifacts, maintains fast processing speeds, and works equally well with the Arnone implementation of the near-IR correction. It was successfully validated for use in the fourth SeaWiFS reprocessing.

References

1. **Arnone, R. A., et al. (1998).** "Coastal Optical Properties using SeaWiFS", (personal communication).
2. **Robinson, W.D., et al. (2000).** "Changes Made in the Operational SeaWiFS Processing." In: *SeaWiFS Postlaunch Calibration and Validation Analyses, Part 2*. NASA Tech. Memo. 2000-206892, Vol. 10.
3. **Siegel, D.A., et al. (2000).** "Atmospheric correction of satellite ocean color imagery: the black pixel assumption", *Appl. Opt.*, 39, pp 3582-3591.