Inversion of Remote Sensing Reflectance to Obtain Phytoplankton Community Size Structure

I. Introduction
Size distribution is a major biological factor that governs the functioning of pelagic ecosystems. Despite the physiological and taxonomic variability in a phytoplankton assemblage, Ciotti et al. (2002) described a strong correlation of the size of the dominant organism and several factors controlling the spectral shape of the absorption coefficient of phytoplankton (eqn. 1). In this way, the phytoplankton size parameter (S, percentage of picoplankton) can be retrieved from remotely sensed reflectance (\(R_p, a_w^r\)) through its relation to absorption (\(a_p\)).

\[
\alpha_p(\lambda) = [S \cdot a_p(\lambda) + (1 - S) \cdot a_m(\lambda)]
\]

II. Theory of Inversion
The inversion relates reflectance spectra (\(R_p(\lambda)\)) to the inherent optical properties (IOPs) of water, in particular total absorption (\(a\)) and backscattering (\(b\)) coefficients. The inversion of \(R_p(\lambda)\) to obtain \(S\) is done by fitting the modeled IOPs to \(R_p(\lambda)\) by non-linear least-squares optimization according to a modified Harvey-Siegel-Marinova 2001 inversion model (Marinova et al. 2002).

III. Feasibility - Forward Modeling
Radiometer Sensitivity and Detection
The difference between pico- and microplankton \(R_p(\lambda)\) (\(AR_p(\lambda)\)) were calculated and reduced to 10% of the original signal to account for atmospheric loss (degraded mean \(AR\) = 2.3x10^{-4} \(\text{sr}^{-1}\)). The least sensitive channel of SeaWiFS (412 nm, \(NEAR_p = 5.4 \times 10^{-4} \text{sr}^{-1}\)) is an order of magnitude more sensitive than \(AR_p\), indicating the inversion methodology to obtain \(S\) can be successful with current satellite instrument specifications.

IV. Preliminary Validation
Relative biomass proportions of pico-, nano-, and microplankton can be estimated from the concentrations of taxonomically significant pigments (Bricaud et al. 2004). HPLC pigments collected from the Atlantic Meridional Transect (AMT) (Wendt and Bailey 2002; Wendt et al. 2003) are used to characterize in situ percentage of picoplankton across diverse ecological regions. Phytoplankton size estimated from AMT pigments are compared to \(S\) satellite inversion estimates.

V. Application to Satellite Imagery
SeaWiFS high-resolution level 1a \(R_p(\lambda)\) imagery corresponding to the date and location of the AMT in situ stations were processed to level 2 and inverted to obtain an estimate of \(S\).

VI. Conclusions
Initial results are promising but significant improvement is still needed. The inversion scheme is yielding noisy estimates of \(S\) in comparison to the in situ AMT HPLC pigment estimate of picoplankton. The imagery inversion estimate of \(S\) displays better retrieval at higher percentage of picoplankton in a given community. The spatial pattern in the imagery are reasonable, however, the estimate of the size parameter still needs improvement. Further tuning of the \(\alpha_{\text{meas}}(S)\) and \(b_p(\lambda)\) shape coefficients and the overall inversion approach may be required. The methodology has implications for new production models and carbon cycling investigations.

References

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