# Comparison of results of polarimetric imaging and radiative transfer modeling of the atmosphere-ocean system

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Quantitative polarimetric imaging of the sky and ocean surfaces can drastically improve the knowledge of the remote sensing of the atmosphere and the retrieval of water parameters because of the obvious increase in information content carried in such measurement. However, technological difficulties have long challenged the design and assembly of polarimetric instruments capable of measuring a scene's Stokes vector with satisfactory accuracy. In addition to this, deploying such instruments (i.e.: polarization camera) in the field is often critical due to the rough environment to which they are exposed as well as the significant uncertainties in orientation from unstable platforms such ships. We present results from the calibration technique adopted for the commercially available, full-Stokes polarimetric camera (SALSA , Bossa Nova Technologies), together with the analysis of measurements acquired in the lab, and in the field on different ocean-water types. The images are validated against simultaneous and co-located measurements by a hyperspectral radiometric polarimeter (HyperSAS-POL). Camera measurements of the sky and the water surface for various viewing angles and atmospheric and oceanic conditions were successfully matched with results of modeling using a vector radiative transfer code for the atmosphere-ocean system.

# Impacts of water constituents on the TOA radiances for scalar and vector radiative transfer simulations


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## INTRODUCTION

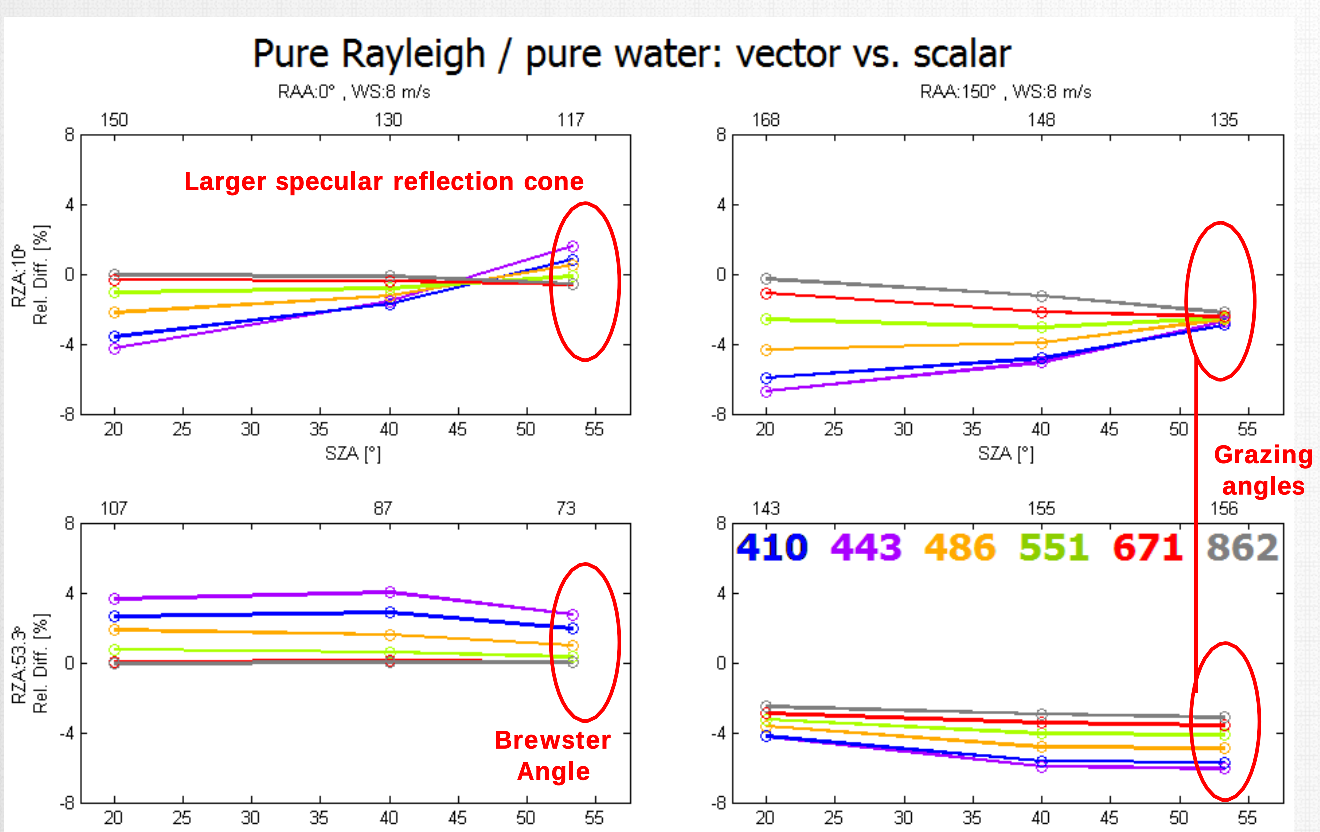
Modern satellites such as MODIS (*Moderate Resolution Imaging Spectroradiometer*) and VIIRS (*Visible Infrared Imaging Radiometer Suite*) collect daily datasets of Top of the Atmosphere (TOA) reflectances used to retrieve ocean and coastal waters Inherent Optical Properties (IOPs). These properties (IOPs) are then used to estimate Ocean Color (OC) products such as phytoplankton absorption and concentration, color dissolved organic matter (cdom), etc. These retrievals can be significantly improved if sensitivity to polarization (accounted for as much as 3% at the TOA reflectances) is properly evaluated and corrected.

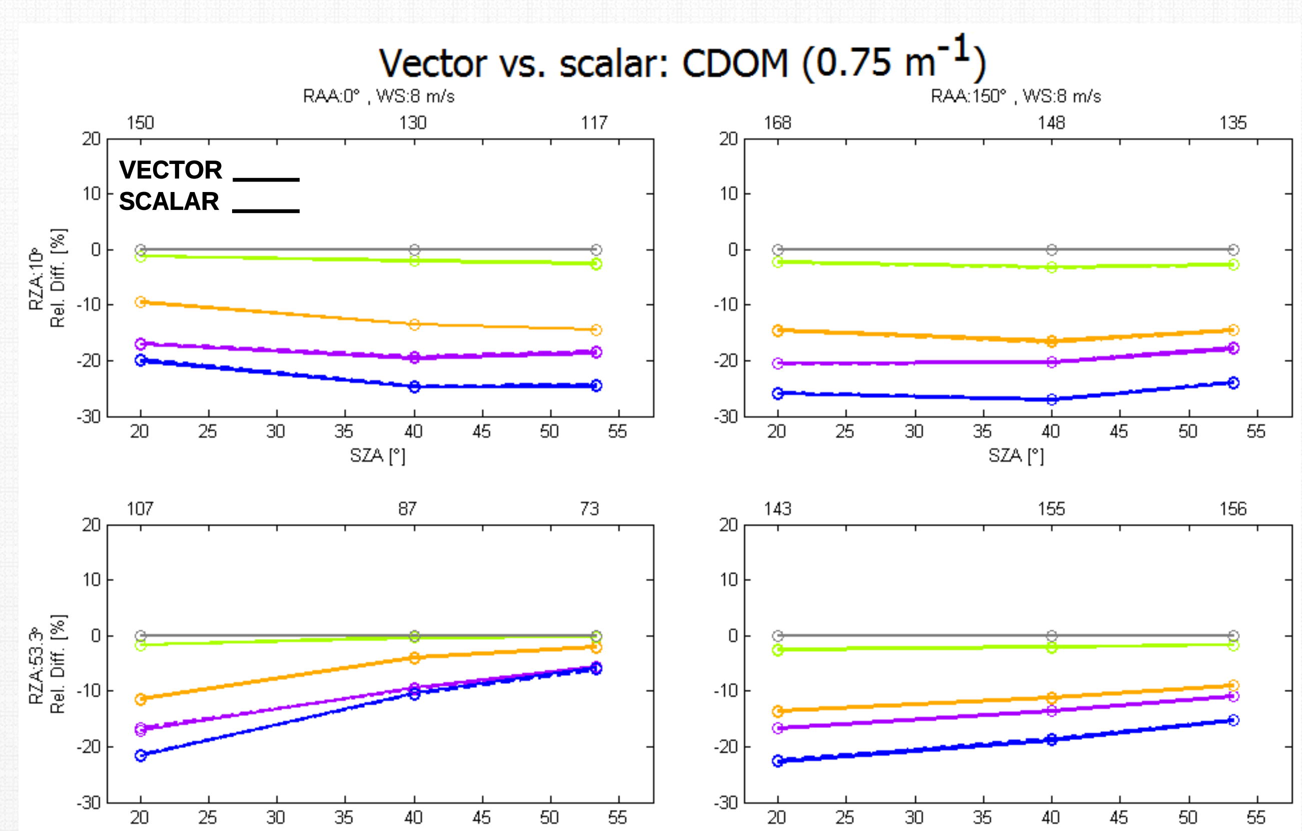
Knowledge of the typical solar-satellite geometries and the impacts of typical water constituents can help to better estimate TOA radiances over oceanic and coastal waters. Further analysis of this work is expected to include the impact of atmospheric aerosols and hydrosols more commonly found in coastal regions.

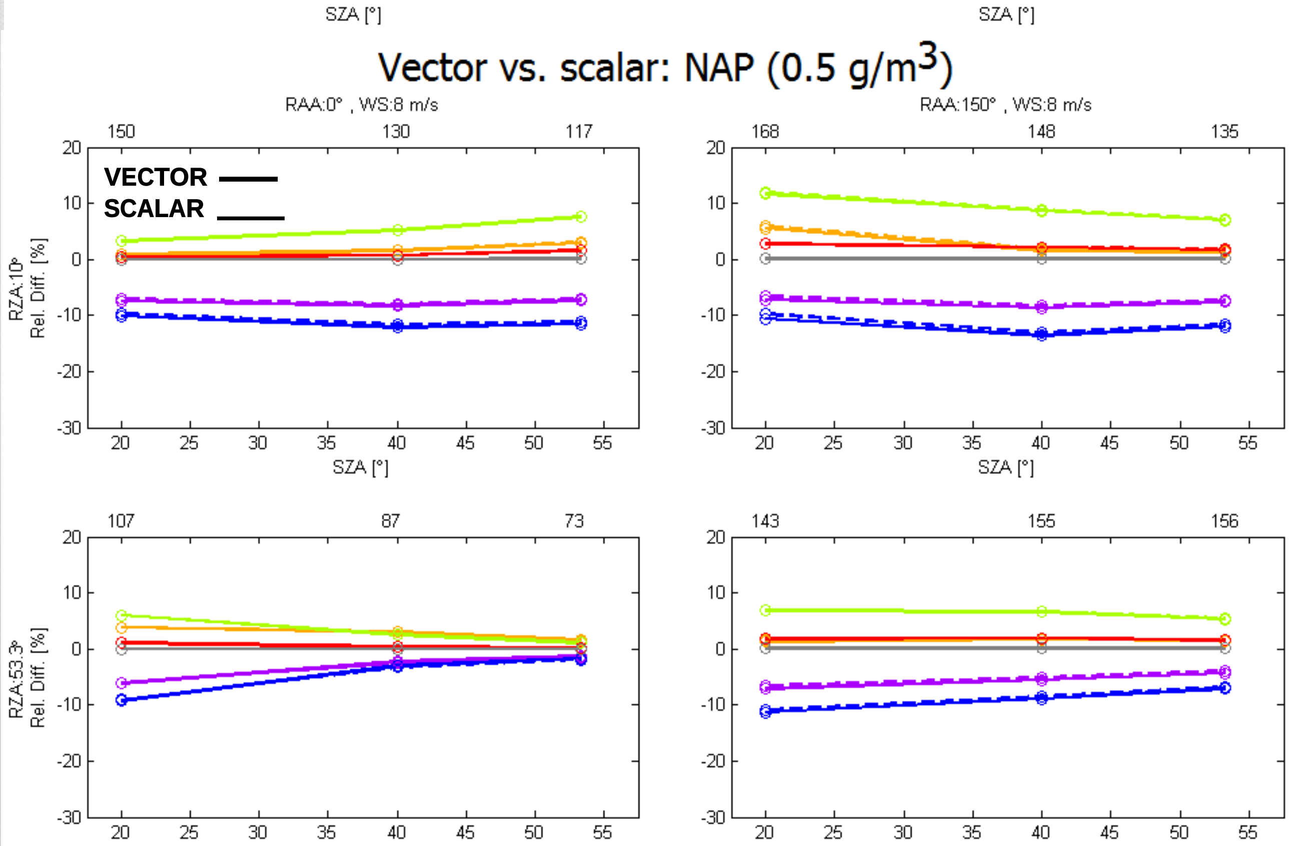
## CONCLUSIONS

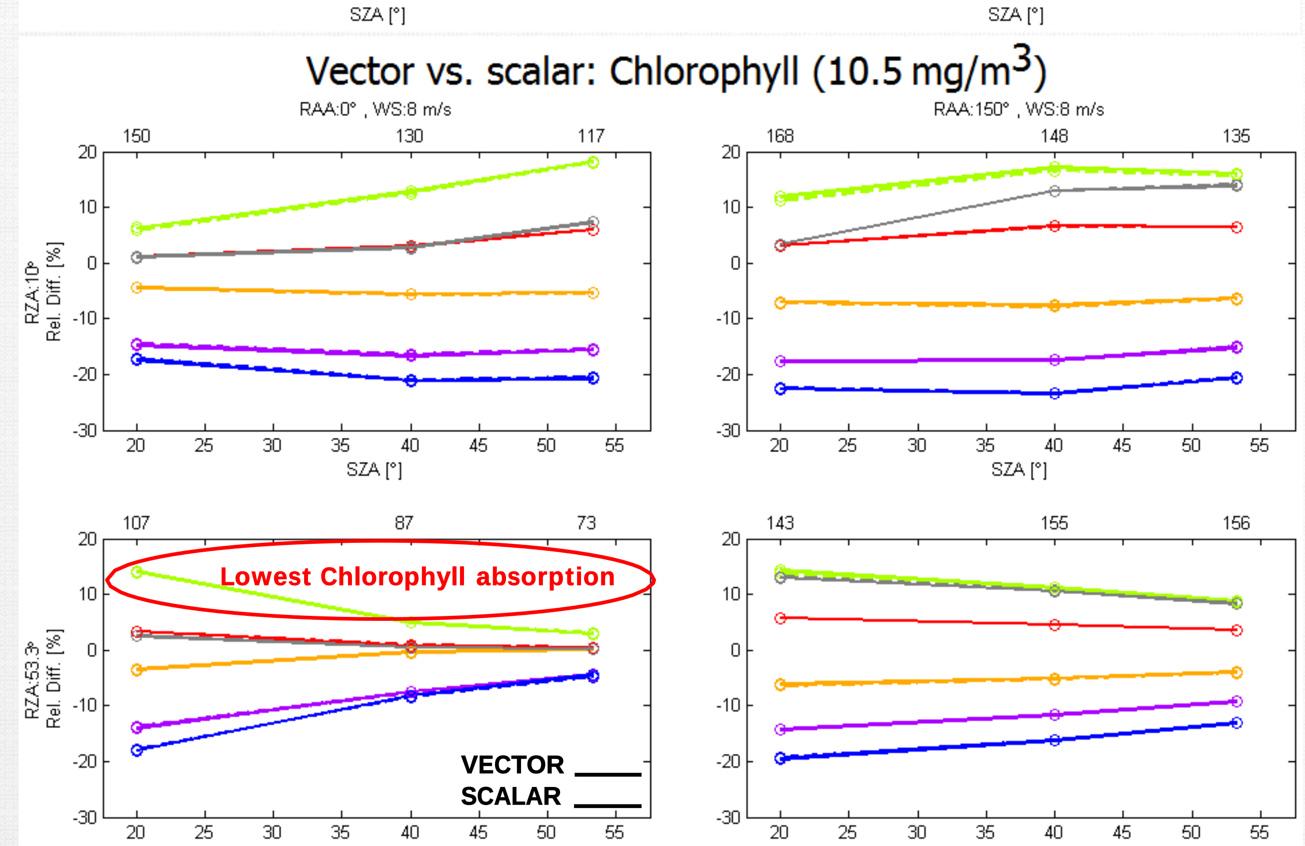
- **Scalar treatment underestimates the TOA radiance** with respect to more accurate vector radiative transfer (VRT) simulations.
- Relative differences higher than 10% are encountered at all modeled geometries when water constituents are added in excess (i.e. maximum concentration among typical values) and generally with higher values at shorter wavelengths.
- Negative relative differences in the mid-visible for large concentrations of Chlorophyll are explained by larger absorption.
- Decreasing absorption implies increasing scattering, which leads to depolarization.
- Negative relative differences for larger concentrations of CDOM and Chlorophyll in the blue-green are due to increased absorption and polarization.
- **Even small differences affect OC products**, see for example NAP (non-algal particles) in the green band.

## RESULTS



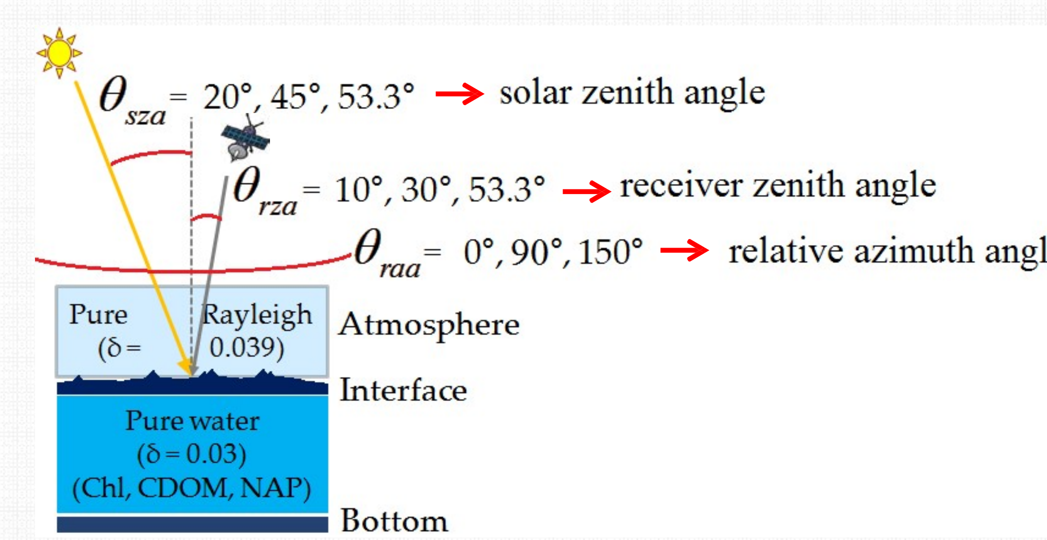




## METHODOLOGY

- A simplified air/water interface has been adopted to compare the results of radiative transfer (RT) simulations in scalar and vector modes using RayXP code. RayXP is a polarized, atmosphere/ocean coupled radiative transfer code which includes wind-roughened surface.
- This simplified model includes a pure Rayleigh atmosphere (no aerosols) and pure water (no hydrosols) with depolarization factors (δ) of 0.039 for sky and 0.03 for water.
- Relative differences are calculated as (**D1-D0**)/**D0** , where:
  - **D0** is the radiative transfer simulation (TOA normalized radiance) of Pure Rayleigh/ Pure water case (PRPW).
  - **D1** is the radiative transfer simulation (TOA normalized radiances) of PRPW + water constituent (i.e.: CDOM, Chlorophyll, NAP).
- The impact of CDOM to the TOA radiance is simulated by varying its absorption from 0.05 $m^{-1}$ to 0.75 $m^{-1}$.
- Contribution of Chlorophyll has been simulated for two concentrations: 2 $mg/m^3$ and 10.5 $mg/m^3$. Other parameters for Chlorophyll simulations include the refractive index (1.06 relative to water) and particle size distribution (ξ) of 2.995 and 4.0, respectively.
- NAP concentrations are taken as 0.5 $g/m^3$ and 7.55 $g/m^3$ with index of refraction 1.18 relative to water and particle size distribution (ξ) of 2.995 and 4.0.
- Both index of refraction and particle size distribution play a significant role in the polarization features of the scattering media, for this reason only typical values are being considered and studied.
- Different sun-receiver geometries are explored (SZA, RZA and RAA).
- Additional inputs such as Chlorophyll and NAP scattering matrices are obtained from well-known in-situ field measured data and Mie theory calculations
- Atmospheric aerosols are not considered (further analysis will be considered in future work).
- Optically semi-infinite waters. Bottom is black.

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THIS STUDY WAS SUPPORTED AND MONITORED BY NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) UNDER GRANT - CREST GRANT # NA11SEC4810004