Upwelling radiance distribution measurements and modeling during the SORTIE field work

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Abstract

During the SORTIE field work in Hawaii and San Diego, measurements of the upwelling spectral radiance distribution were made using the NuRADS radiance distribution sensor. In conjunction with these measurements, the VSF was measured using the new MASCOT sensor, along with other relevant inherent optical properties. The MASCOT sensor, as with all VSF scattering sensors, measures the volume scattering function for a small measurement volume, whereas the VSF sampled by the radiance distribution is from a much larger volume. Agreement between these two implies that, for this example, there was not a measurement scale problem.

Explanation

SORTIE is an effort to test both an alternative method to obtain vicarious calibration data, and to investigate the uncertainties and variance for single point calibration data sets. The overall idea is to collect a complete suite of radiometric data, with the most accurate and characterized instruments, along with as complete a set of inherent optical properties as possible. Many of these inherent optical properties (IOP's) are collected on a towed platform, so the subpixel variability of the IOP's can be determined and , through modeling, the effect of this variability on the radiometric data can be determined.

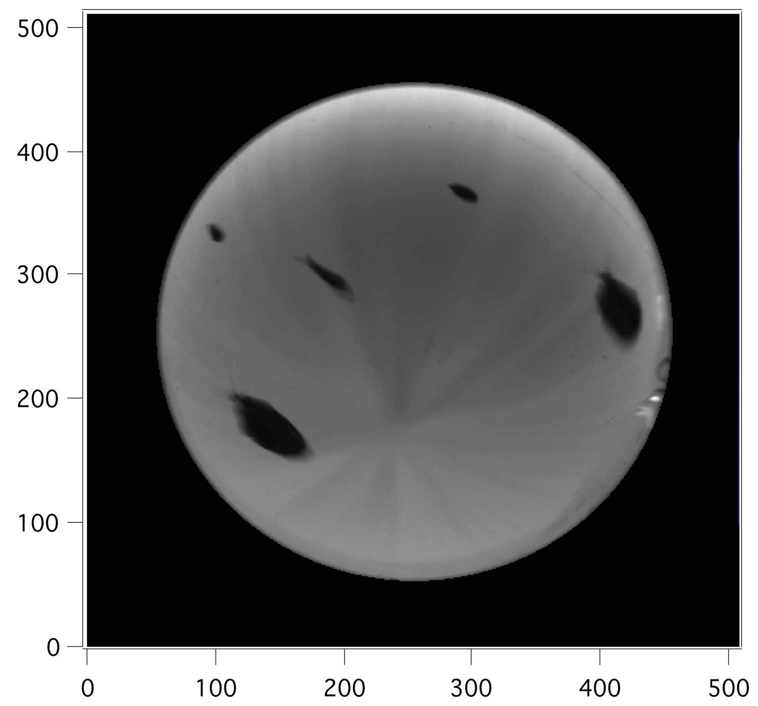
One aspect of this problem, which is important to understand, is how the measurement scale of the IOP's affects the extension of these measurements to the scale of the radiometric properties. For example, the volume scattering function is typically measured (when measured at all) with a sample volume on the order of a cm^3. This parameter is critical for predicting the radiance distribution, which is a fundamental parameter which describes the angular variation of the radiance. The radiance distribution, particularly in clear water, is determined by the volume scattering function for a very large volume of water. (>m3) Thus if there is a problem with measurement scales, it would be difficult to find agreement between the upwelling radiance distribution measurements, and the volume scattering function measurements (as tested through radiative transfer models). This SORTIE data set provides one of the best data sets, with which to test these ideas.

NuRADS

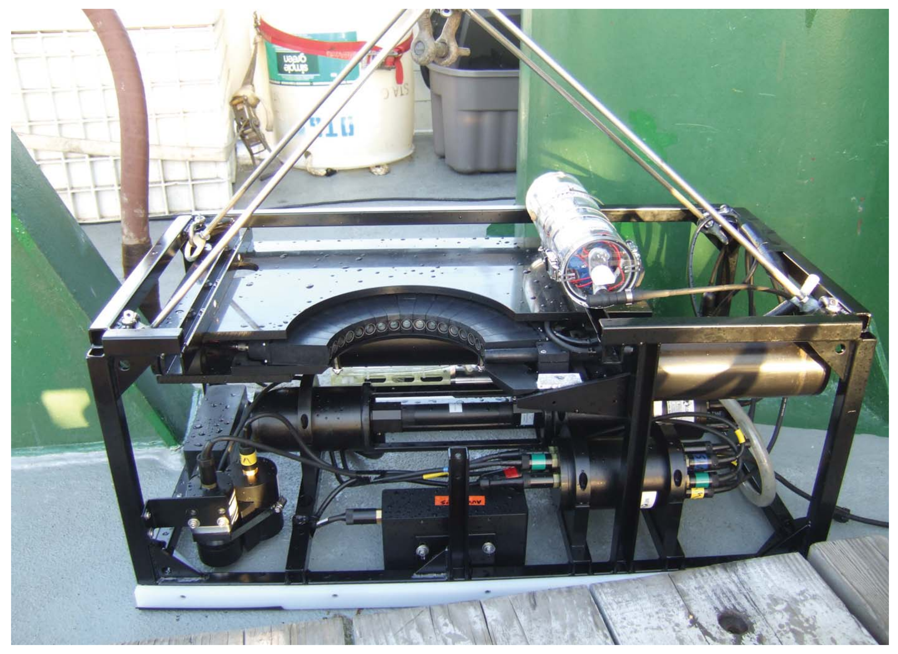
The NuRADS instrument has been described in many places (Voss and Chapin, 2005). The basic idea is that it is a fisheye camera system with spectral filters to select the wavelength, thus each image from the camera system collects an entire hemisphere of spectral radiance distribution data. There are 6 spectral filters in the system, thus a complete set of data is an image of the radiance distribution at each wavelength and an associated dark image. This system is set in the water, tethered to the ship by a communication and power cable, and allowed to float away from the ship to avoid shadowing issues. The instrument then runs continuously. Individual measurements contain natural artifacts (such as wave focusing, fish, etc) thus we average 10 minutes of data to get the average radiance distribution (effectively averaging 4-10 images).

NuRADS instrument shown on deck, with floats. Dome window is below instrument, and can't be seen.

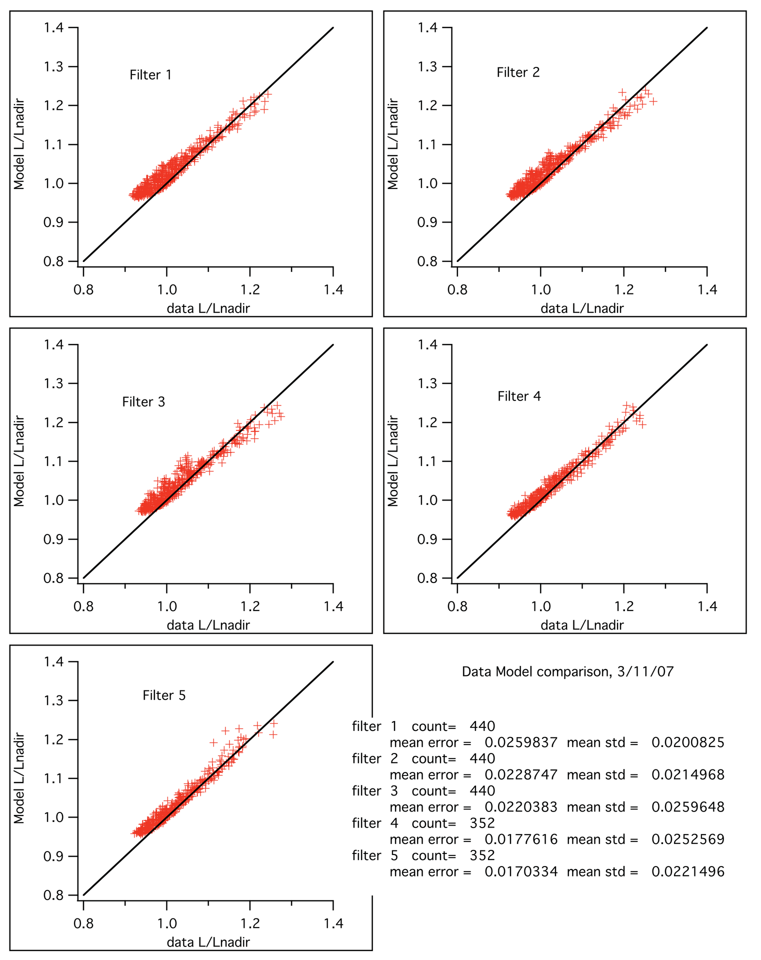
NuRADS instrument in water, making measurements. Typically instrument is floating 50m from ship, to avoid ship shadow.

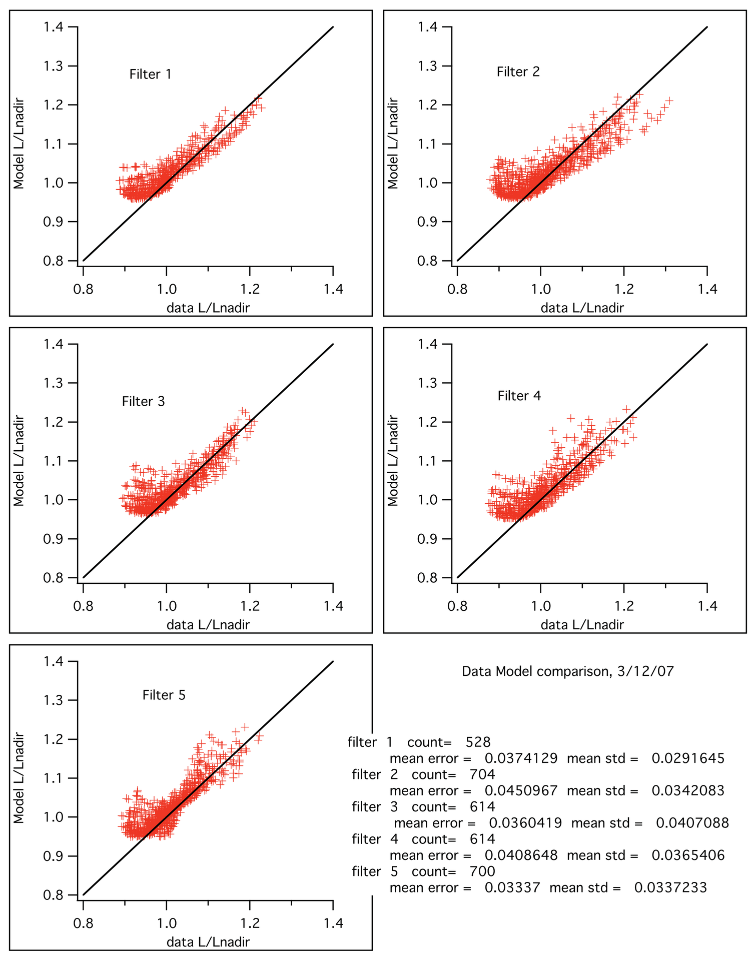


Example upwelling radiance distribution image. Illustrates natural variability caused by both "macro" bio-fouling and wave focusing. Anti solar point obvious towards the lower portion of the image.

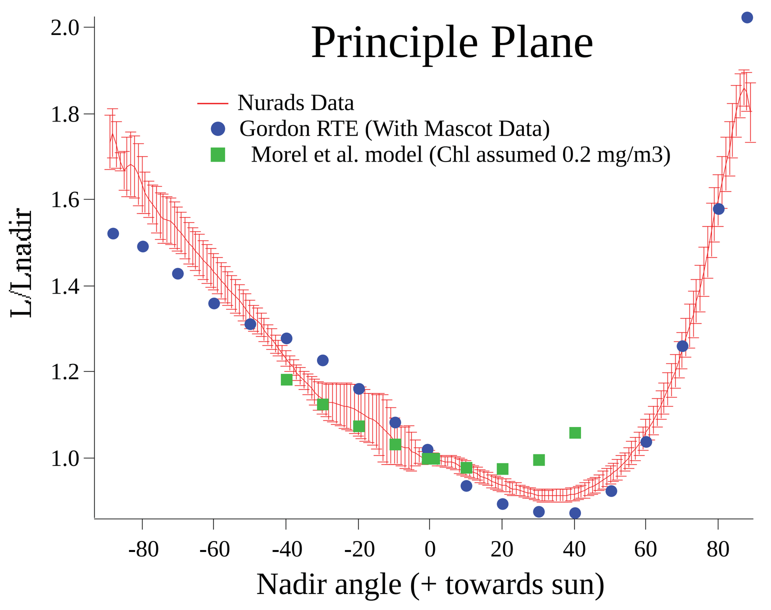


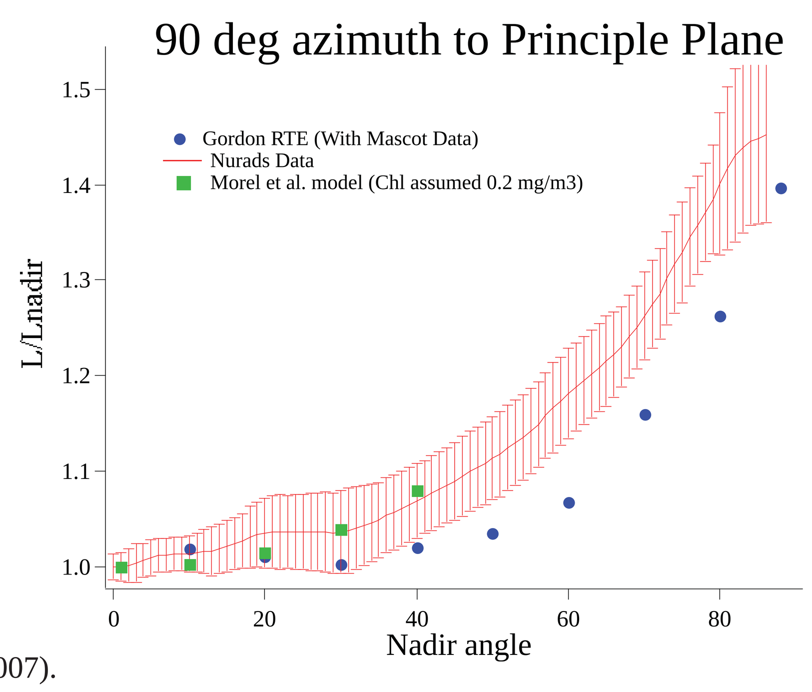
Mascot instrument on deck (Mascot is the ring of detectors at top of package). More details in Mike Twardowski's talk during the ocean color sessions.





It is useful to compare the radiance distribution measured with the commonly used model by Morel et al. This shows the comparison between the model and measurements performed on 3/11 (left) and 3/12 (right). The weather was better (less clouds) on 3/11 and the comparison worked out very well. This uses the measured Chl value as the index in Morel's model.





On the left we show a comparison between the radiance distribution measured with NuRADS and the radiance distribution derived from radiative transfer modeling and the MASCOT VSF (and other IOP measurements). We also show the comparison between the Morel model result (for the measured Chl) and the two others.

The whiskers on the data represent the std deviation of the data when averaged, and shows the natural variability or noise due to wave focusing. Notice that this increases in the anti solar direction (near -20 nadir angle) due to the instrument shadow in this direction and the stronger backscattering in the anti-solar direction.

We show the data along two axis, the principle plane (contains the anti-solar direction and the nadir) and 90 degrees to this plane. The RTE agrees very well in the forward direction, and reasonably well in the back direction at 90 to the principle plane. This comparison was done on 3/12, on which date there were some cirrus clouds, which could effect the results. We will also do this comparison for data from 3/11. It is interesting that the Morel model also did a good job fitting the experimental data in the backward direction, but did not do as well in the forward direction (where the Morel model is not used much as this would be in the glitter pattern).

Important references:

Voss, K. J. and A. L. Chapin, Upwelling radiance distribution camera system, NURADS, Optics Express, 2005, 13: 4250 – 4262.
Voss, K. J., A. Morel, and D. Antoine, "Detailed validation of the bidirectional effect in various Case 1 waters for application to ocean color imagery", Biogeosciences, 4, 781-789 (2007).
Morel, A., D. Antoine, and B. Gentilli, "Bidirectional reflectance of oceanic waters: accounting for rman emission and varying particle scattering phase function, Appl. Opt. 41: 6289-6306 (2002).

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