AIRCRAFT AND IN SITU SALINITY AND OCEAN COLOR MEASUREMENTS: BRIDGING THE SATELLITE SALINITY COASTAL GAP

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1. INTRODUCTION

New microwave salinity measuring satellites (SMOS, launched Nov, 2009 and AQUARIUS, to be launched spring 2010) have relatively large pixel size (35-80 km). This does affect their primary ocean mission- global open ocean salinity measurements on a monthly time scale, to a limited extent. However, the large pixel size has a dramatic effect on measurements near the coast. It requires a large coastal gap in the observed salinity field, since land brightness temperatures bias the salinity (derived from brightness temperature) for nearshore pixels. One approach to reducing the coastal gap is using optical ocean color as a proxy for salinity. Rivers flowing into the coastal ocean carry freshwater as well as CDOM (Colored Dissolved Organic Matter). To the extent that CDOM, like freshwater, is conserved, CDOM concentration changes can serve as a proxy for freshwater dilution by mixing, and hence determine near-surface salinity in coastal waters. However, because CDOM characteristics are determined by unique conditions in each watershed, the relationship of CDOM to salinity can vary for different rivers. We have reported earlier [1] results using STARRS (Salinity, Temperature, and Roughness Remote Scanner airborne instrument) and ocean color from SeaWiFS simulator optical instruments, to estimate salinity in the nearshore region. In this study we will show an aerially derived Ocean Color Salinity algorithm as applied using the SeaWiFS level 1 & 2 normalized water leaving radiance (nwr) data products. In order to retrieve the remote sensing reflectance ($\mathrm{R_{rs}}$), normalized water leaving radiances are divided by the mean incoming irradiances. To the extent this is successful, it may provide the means to produce a coastal image of SSS with a 4 km resolution. This will show the capability of using ocean color to estimate salinity via optical satellite to a broader coastal zone of the Louisiana Shelf. We address the confounding factors of seasonal and river specific variation of fresh water sources by applying these results to observations at multiple seasons and locations. We have made multiple STARRS flights, primarily over the northern Gulf of Mexico, and also over the Atlantic Ocean (flying southeast from Newport News, VA). We apply the methods in [1] to multiple flights and survey regions.

2. OBSERVATIONS

The STARRS instrument has passive L-Band and C-Band microwave radiometers, for salinity and roughness detection, and IR radiometers for measuring SST. STARRS is mounted on a small twin engine aircraft (Piper Navajo). At a typical operating altitude of 2700 m, the swath of its six L-band beams is approximately 5 km. The swath lies across the airplane flight path and the six beams are oriented at ± 7, ± 22, ± 37 degrees from the vertical. C-band and IR instruments are nadir viewing. The L-Band radiometer determines salinity from the variation of ocean brightness temperature $\mathrm{T_b}$, with temperature and conductivity.

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Brightness temperature is proportional to emissivity, which is related to the complex index of refraction of the seawater and determined by the conductivity, hence indirectly the salinity. (See [2] for more information.) Further information on the STARRS instrument and data processing can be found at [3] and [4].

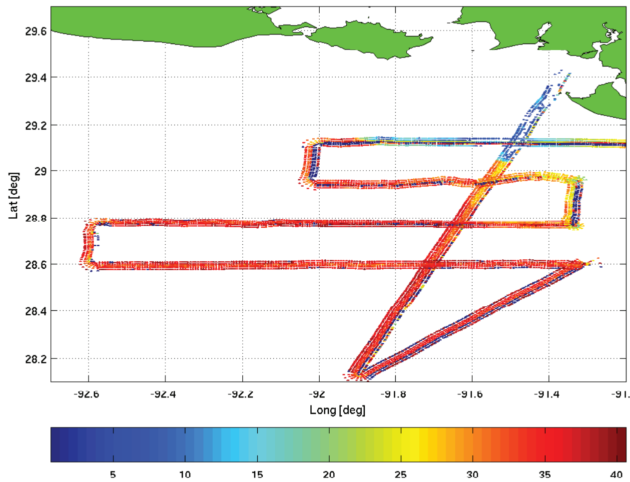

Fig. 1. Salinity map from morning flight on May 10, 2007. Noise from sun-glint is evident on the east side of the outbound leg. These scans were removed in subsequent processing.

Daytime flights necessary for the optical measurements are non-optimal for STARRS L-band measurements since sun-glint can produce errors in the SSS measurement. Data from any beams contaminated from sun-glint were either discarded, or a correction based on [5] was applied, depending on the severity of the sun-glint. At worst, only two of the six beams were adversely affected by sun-glint. The optical sensors mounted on the top and bottom of the aircraft are multi-wavelength radiance and irradiance sensors (Satlantic OCR-507 with SEAWIFS wavelength bands: 412, 445, 492, 554, 670, 780, 864nm). The ratio of downward viewing to upward viewing (irradiance/radiance) optical response, at each wavelength, provides a rough measure of ocean reflectance in that band. Data for all channels was sampled at approximately 5 Hz and averaged to a 2 second sample interval. The optical data from each flight was processed using the ProSoft package from Satlantic, the instruments' manufacturer. Level 3a processing was used, which provides a value at each wavelength band of water leaving radiance (downward view, LT) and a value for reference downwelling plane irradiance (upward view, ES). (For more information on these terms, see the Prosoft 7.7 manual [6].) No atmospheric corrections have been applied to the data. The results we will show indicate that omitting such correction is not crucial to the analysis.

Two flights of 3 and 3.5 hours were made on May 10, 2007 while a ship (RV Pelican) was on the outbound leg of the flights. A map of salinity from the morning STARRS flight is shown in Figure 1. To verify the quality of the STARRS salinity we compared it to the in situ salinity from the R/V Pelican. The STARRS system has significantly higher noise than the ship's thermosalinograph and various corrections are applied in order to calculate salinity. For more details see [1]. In spite of the noise in the STARRS data, the agreement between ship's thermosalinograph and STARRS salinity is good. Many features, if not exact magnitudes, of the salinity along this leg match between the thermosalinograph and STARRS. Given the quality of the STARRS salinity measurements, we will proceed to use the STARRS salinity to analyze the optical data and our ability to predict salinity from it.

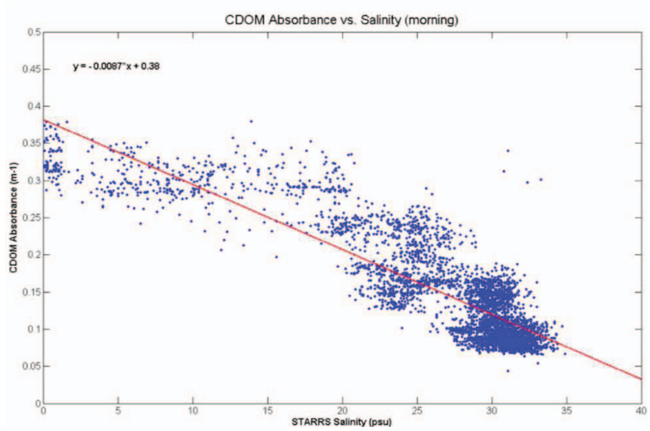

Fig. 2. Regression results for salinity versus absorbance from D' Sa for the outbound leg of the STARRS morning flight.

3. RESULTS

The empirical relation for CDOM, from D'Sa, is used to relate the optical measurements to salinity. [7]

$$\mathrm{A_{cdom}} = 0.227 \times (\mathrm{R_{rs}}510/\mathrm{R_{rs}}555)^{-2.022} \quad (1)$$

Where $\mathrm{R_{rs}}$ is the remote sensing reflectance, which is Radiance $\mathrm{Lu}(\lambda)$ / Irradiance $\mathrm{Ed}(\lambda)$. Thus, for the case of the morning flight (Figure 2), a fit between CDOM absorbance and STARRS salinity gives:

$$\text{Salinity} = \frac{0.227 \times (\mathrm{R_{rs}}510/\mathrm{R_{rs}}555)^{-2.022} - 0.34}{-0.0082} \quad (2)$$

4. CONCLUSIONS

We have used the shipboard thermosalinograph to validate the STARRS salinity measurements and then the STARRS salinity data to generate a regression for salinity Thus, we have demonstrated that the combination of STARRS and optical SEAWIFS observations can predict salinity in the nearshore region. This may also be a best case: the weather was clear, the salinity contrast in the region was very high, and the two flights presently examined were separated by only a few hours. In cases of different rivers as the source of fresh water, or even the same river at different times, more sophistcated analysis may be necessary to determine salinity over aircraft survey scales using optical data.

We will apply these methods to flights from different seasons and locations to evaluate the effectiveness of using airborne or satellite optical measurements as a proxy for salinity in the near coastal region. We will provide estimates of the errors due to seasonal variation of a particular river (Mississippi and Atchafalaya) and also provide estimates of errors to be expected for different regions.

5. REFERENCES

6. REFERENCES

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