

Measuring Coastal Sea-Surface Salinity of the Louisiana Shelf from Aerially Observed Ocean Color

V.J. Maisonet¹, J. Wesson², D. Burrage² & S. Howden¹

1-USM, Department of Marine Science
1020 Balch Blvd

Stennis Space Center, MS 39529 USA

2- Naval Research Laboratory
Bldg 1009

Stennis Space Center, MS 39529 USA

Abstract- We have demonstrated the ability of airborne radiance and irradiance sensors to detect the persistent salinity gradient of the Atchafalaya plume and corresponding color fronts as observed by in-situ shipboard measurements as well as STARRS. We used an empirical algorithm

$$A_{cdom}(412) = 0.227 \times (R_{rs510}/R_{rs555})^{2.022} \quad (1)$$

for CDOM from D'Sa *et al.* 2006. Their study was conducted in the same region (Louisiana Shelf) and time of year (March) as our study and it was performed with similar optical equipment.

This study resulted in an Ocean Color Salinity model that can measure with ~88% accuracy the Sea-Surface Salinity of the Louisiana shelf. A multi-linear regression for salinity, based on two of the optical channels, provides an excellent qualitative proxy for large scale coastal salinity in the Atchafalaya plume region ($y = -0.0082x + 0.34, R^2 = 0.90, n = 5220$). We then developed two algorithms from the May and November data. This was done to create two seasonal equations for salinity.

I. INTRODUCTION

In the next year both NASA and the European Space Agency have missions to deploy the Aquarius and SMOS satellites, each of which are equipped with L-Band Radiometer's with resolutions of 100km and 35-80 km, respectively [1]. These sensors are capable of measuring Sea Surface Salinity (SSS) in the open ocean but due to coarse horizontal resolution and issues with thermal emission from the coastal land, they will likely be unable to measure the coastal zone SSS. However, SSS in the inner coastal region can be retrieved at the several PSU level using hyper spectral data (e.g., D'Sa *et al.* 2006 [2]) which is being measured from by various satellites. This technique uses remote sensing of Colored Dissolved Organic Matter (CDOM) and the conservative mixing of CDOM in many of the inner coastal regions to estimate salinity.

Taking advantage of a colleague's cruise on the R/V Pelican that was planned to cross the Atchafalaya river plume, we scheduled over flights of the Pelican cruise track with the NRL STARRS (Salinity, Temperature and Roughness Remote Scanner), and optical multi-wavelength radiance and irradiance sensors (Satlantic OCR-507 at SeaWiFS wavelength bands) on a Piper Navaho aircraft. The data collected from the R/V Pelican included SSS, ocean color, and fluorescence. Simultaneous airborne optical and microwave sensor data are analyzed to arrive at a relationship between

CDOM and SSS. CDOM is the optically measurable component of the dissolved organic matter in water. It is a naturally occurring substance that occurs when organic matter (plant tissue) is broken down by microbes either in the soil or in a body of water [3,4]. The color of water ranges between green, yellow-green, and brown with increased CDOM. We report here on the measurements made in May 2007.

II. OBSERVATIONS

Two flights of 3 and 3.5 hours were made on May 10, 2007 while the R/V Pelican was on the outbound leg of the flights Fig 1. During the day of the 10th the Pelican was moving toward shore. The STARRS instrument has passive L-Band and C-Band microwave radiometers, for salinity and roughness detection, and IR radiometers for measuring SST. 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)[5]. The ratio of downward viewing to upward viewing (irradiance/radiance) optical response, at each wavelength, provides a rough measure of ocean reflectance (R_{rs}) in that band. 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).

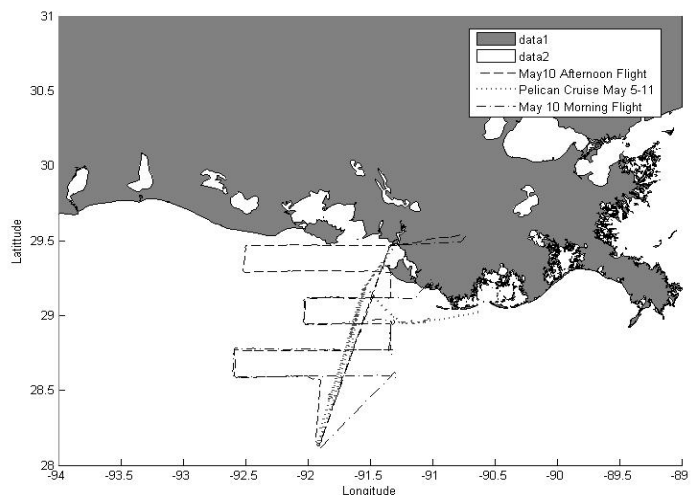


Figure 1. Entire flight tracks of aircraft and R/V Pelican May 2007

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14. ABSTRACT We have demonstrated the ability of airborne radiance and irradiance sensors to detect the persistent salinity gradient of the Atchafalaya plume and corresponding color fronts as observed by in-situ shipboard measurements as well as STARRS. We used an empirical algorithm $A_{cdm}(412) = 0.227 \times (R_{rs510}/R_{rs555}) - 2.022$ (1) for CDOM from DSa et al. 2006. Their study was conducted in the same region (Louisiana Shelf) and time of year (March) as our study and it was performed with similar optical equipment. This study resulted in an Ocean Color Salinity model that can measure with ~88% accuracy the Sea-Surface Salinity of the Louisiana shelf. A multi-linear regression for salinity, based on two of the optical channels, provides an excellent qualitative proxy for large scale coastal salinity in the Atchafalaya plume region ($y = -0.0082 \times x + 0.34, R^2 = 0.90, n = 5220$). We then developed two algorithms from the May and November data. This was done to create two seasonal equations for salinity.					
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To best view the Atchafalaya outflow only the onshore-offshore flights and transects are considered (Fig 2). In this figure are the two flight tracks taken in the morning and afternoon of the 10th of May, the duration between the endpoint is about 45 min. The two ship transects were taken on May 7-8 & May 8-9 each taking about 10 hours endpoint to endpoint.

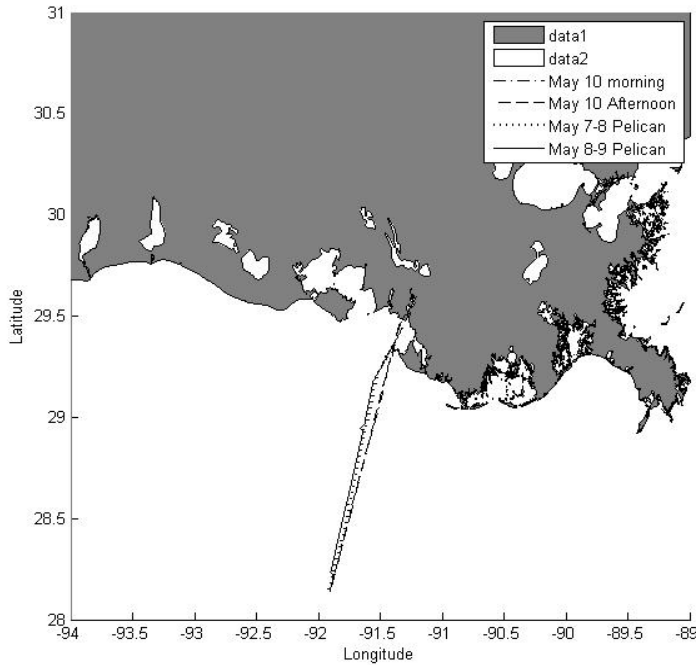


Figure 2. Outbound Flight transects of aircraft and R/V Pelican May 2007

The STARRS data was compared to the in situ data of the R/V Pelican for validation. The salinity samples were taken from the flow through system onboard which sampled the conductivity of the water every 10 seconds. The STARRS system using the L-band radiometer sampled at approximately 2 second intervals [6]. In Fig 3 is the comparisons between the two flights and 2 selected ships transects. The STARRS salinity data followed the general salinity trends seen in the Pelican data, but they do not overlay. The Pelican data indicate that the near-shore salinity gradient migrated offshore between the May 7-8 transect and the May 8-9 transect. The further offshore migration seen in the STARRS data taken an additional two days later is consistent with this advection continuing. The approximately 3 psu offset between the offshore SSS data from the Pelican and the STARRS may be due to a sampling problem. The microwave thermal emission from the sea surface comes from the upper several cm of the sea surface. The intake for the flow-through system on the R/V Pelican is at 1m below the surface. Depending upon meteorological conditions, river plumes in the northern Gulf can result in strong stratification within the upper 1 m of the water column. The approximately 3 psu difference between the in situ and aircraft data could very well be due to such

stratification. This confirmed the accuracy of the STARRS salinity samples.

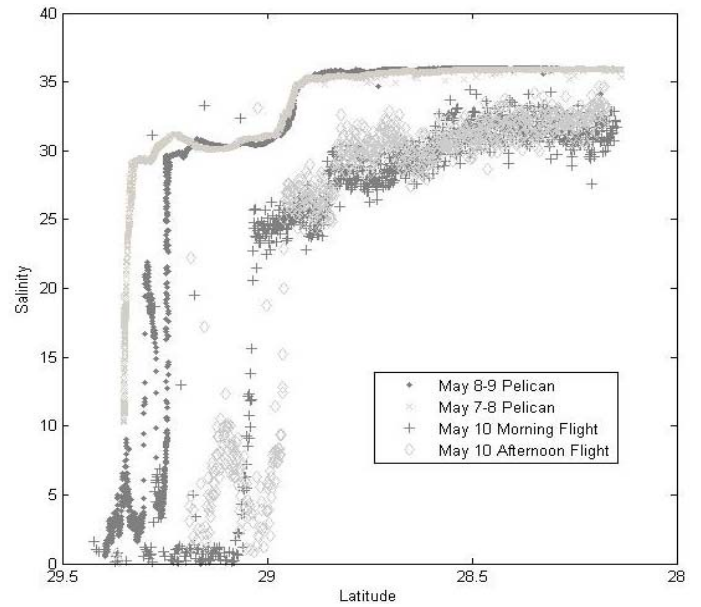


Figure 3. Salinity samples plotted against its latitude (distance from shore) for the aircraft and Pelican outbound transects.

The optical sensor onboard the aircraft has a sampling rate of ~.17s. This yielded a sampling ratio between the OCR and STARRS to 11:1 [7]. Meaning that one beam spot of the radiometer was integrated as 11 smaller beam spots of the optical sensor was integrated. In order to directly compare the optical sensor to the radiometer the optical data was 'averaged down' to the level of the STARRS data. This was done by determining the center of the STARRS beam spot and finding the corresponding center beam spot in the optical data set and averaging that spot with the 5 before and after the center spot.

To determine if CDOM holds as a conservative tracer of freshwater in this region it is necessary to plot CDOM against salinity to confirm this relationship. For ease of computation an empirical algorithm (1) for CDOM was used from D'sa *et al.* 2006 [2].

$$A_{\text{cdom}}(412) = 0.227 \times (R_{\text{rs}510}/R_{\text{rs}555})^{-2.022} \quad (1),$$

Where the R_{rs} is the remote sensing reflectance which is the Radiance $Lu(\lambda)/\text{Irradiance } Ed(\lambda)$. This algorithm was created using data collected off of the Eastern Louisiana shelf in March 2004. The utilization of this equation was in the best interest of the study since it was developed in the same region and season. Also, the optical instrument used to collect the data was the older model of the sensor used in this study.

Fig. 4 is CDOM absorbance using the D'sa algorithm and plotted against STARRS salinity.

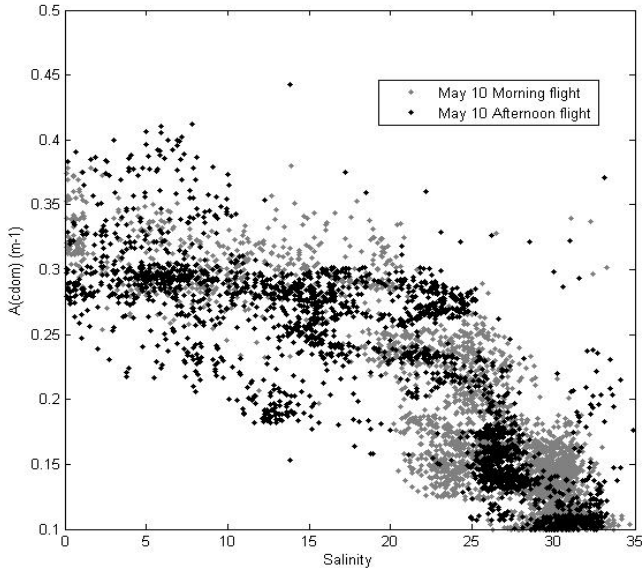


Figure 4. CDOM absorbance vs. STARRS salinity for both entire flights

III. RESULTS

In fig 4 where D'sa CDOM is plotted against salinity shows that the relationship between CDOM and Salinity holds true for this region. Below in figure 5, is the regression of the morning flight with that of STARRS, yielding the linear equation (2).

$$y = -0.0082x + 0.34, n=1100, r^2 = 0.90 \quad (2)$$

This equation (2) was combined with equation (1) to create equation (3)

$$\text{Salinity} = \frac{0.227 (R_{rs\ 510}/R_{rs\ 555})^{-2.022} - 0.34}{-0.0082} \quad (3)$$

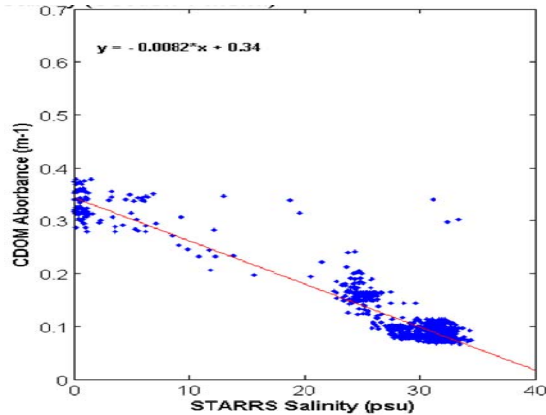


Figure 5. Regression of CDOM and Salinity from morning flight

This equation was then applied to the aircraft afternoon data set for validation which can be seen in figure 6. The modeled salinity from CDOM yielded a R^2 value of 0.88 for the afternoon data set.

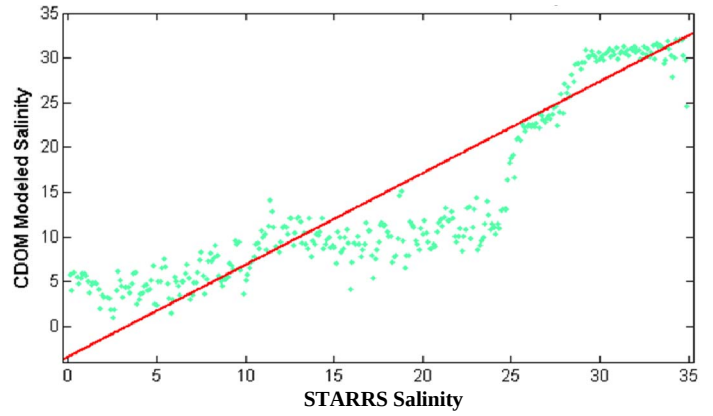


Figure 6. Modeled Salinity from CDOM plotted against STARRS salinity

IV. CONCLUSIONS

This study so far has shown that CDOM does indeed behave conservatively in the region of the Western Louisiana shelf where influenced by the Atchafalaya River. The CDOM estimated by the aircraft optical measurements yielded a SSS with a accuracy of ~88%. These results do come with a few caveats: this study occurred in the spring-early summer and the CDOM-SSS relationship may differ in other seasons, although some have shown that this relationship hold year round [4]. Also, this model effective in the near Coastal zone and assumes non-conservative processes, such as photo-degradation, are low in the near coastal waters. Further offshore this assumption does not hold. Further investigation needs to be done since the retrieved CDOM from the aircraft measurements in this study had unusually low concentrations as compared to others studies in the same region [2,3,4]. Our ultimate goal is to develop interpolation methods that use inner coastal SSS from hyper spectral satellite data and offshore SSS from L-band satellite data to fill in the SSS data gap from the inner shelf to the open ocean that will exist.

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