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Delta-X: In Situ Water Surface Reflectance across MRD, LA, USA, 2021, Version 2

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Documentation Revision Date: 2022-09-23

Dataset Version: 2

Summary

This dataset includes above water measurements of remote-sensing reflectance measured in situ at field sampling stations during the Delta-X 2021 field efforts. Measurements were collected in the Atchafalaya River and Terrebonne Basins on the southern coast of Louisiana from 2021-03-25 to 2021-04-22 (spring) and from 2021-08-14 to 2021-09-24 (fall). Field sampling was paused on 2021-08-25 and resumed on 2021-09-13 due to the landfall of Hurricane Ida on 2021-08-26 approximately 70 km east of the study site. Water quality changes caused by the hurricane were expected to be minimal. Reflectance was measured near-simultaneously with collection of field samples and in-water sediment parameters in multiple channels of varying width (from a few meters to >100 m), near Delta-X intensive study sites, in open bays and lakes, and at a few locations in the nearshore Gulf of Mexico. For each in situ collection, a handheld Portable SpectroRadiometer (PSR-1100f, Spectral Evolution) was used to measure radiance from: (a) a highly reflective (>99% reflectance) Lambertian Spectralon panel (b) from the sky, measured at 40 degrees from the solar zenith and at 135 degrees from the sun azimuthal plane, (c) from the water, measured at 40 degrees from nadir and at 135 degrees from the sun azimuthal plane. These measurements were used to calculate remote-sensing reflectance and the water-leaving radiance relative to downwelling irradiance, including a correction for the influence of reflected skylight. These data are provided in comma-separated values (CSV) format.

There are two data files in comma separated values (CSV) format.



Figure 1: Collection of water-leaving radiance measurement using the Portable SpectroRadiometer (PSR).

Citation

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1. Dataset Overview

This dataset includes above water measurements of remote-sensing reflectance (R_{rs}) measured in situ at field sampling stations during the Delta-X 2021 field efforts. Measurements were collected in the Atchafalaya River and Terrebonne Basins on the southern coast of Louisiana from 2021-03-25 to 2021-04-22 (spring) and from 2021-08-14 to 2021-09-24 (fall). Field sampling was paused on 2021-08-25 and resumed on 2021-09-13 due to the landfall of Hurricane Ida on 2021-08-26 approximately 70 km east of the study site. Water quality changes caused by the hurricane were expected to be minimal. Reflectance was measured near-simultaneously with collection of field samples and in-water sediment parameters in multiple channels of varying width (from a few meters to >100 m), near Delta-X intensive study sites, in open bays and lakes, and at a few locations in the nearshore Gulf of Mexico. For each in situ collection, a handheld Portable SpectroRadiometer (PSR-1100f, Spectral Evolution) was used to measure radiance from: (a) a highly reflective (>99% reflectance) Lambertian Spectralon panel (b) from the sky, measured at 40 degrees from the solar zenith and at 135 degrees from the sun azimuthal plane, (c) from the water, measured at 40 degrees from nadir and at 135 degrees from the sun azimuthal plane. These measurements were used to calculate remote-sensing reflectance and the water-leaving radiance relative to downwelling irradiance, including a correction for the influence of reflected skylight.

Project: [Delta-X](#)

The Delta-X mission is a 5-year NASA Earth Venture Suborbital-3 mission to study the Mississippi River Delta in the United States, which is growing and sinking in different areas. River deltas and their wetlands are drowning as a result of sea level rise and reduced sediment inputs. The Delta-X mission will determine which parts will survive and continue to grow, and which parts will be lost. Delta-X begins with airborne and in situ data acquisition and carries through data analysis, model integration, and validation to predict the extent and spatial patterns of future deltaic land loss or gain.

Related Dataset:

Jensen, D.J., T.M. Pavelsky, and C. Lion. 2020. Pre-Delta-X: Spectral Reflectance of Water Surface, Atchafalaya Basin, LA, USA, 2016. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1804>

- Remote-sensing reflectance measurements made using a hand-held spectrometer from the Atchafalaya River Basin during the Pre-Delta-X Fall 2016 campaign.

Acknowledgement

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2. Data Characteristics

Spatial Coverage: Atchafalaya and Terrebonne Basins, Mississippi River Delta (MRD) floodplain, southern coast of Louisiana, USA

Spatial Resolution: Points

Temporal Coverage: 2021-03-25 to 2021-04-22 (spring) and 2021-08-14 to 2021-09-24 (fall)

Temporal Resolution: One-time measurements

Site Boundaries: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Atchafalaya and Terrebonne Basins	-91.4628	-90.5715	29.7546	28.7913

Data File Information

This dataset contains two files in .csv format: *DeltaX_WaterReflectance_PSR_Spring2021.csv* and *DeltaX_WaterReflectance_PSR_Fall2021.csv*.

These files contain measurements of remote-sensing reflectance (R_{rs}) measured in situ at field sampling stations on the southern coast of Louisiana. Reflectance is reported in the dataset as remote sensing reflectance at 1-nm intervals in the range 360 nm-900 nm, with uncertainty reported for each wavelength. Missing values are indicated by -9999.

Table 1. Data dictionary for *DeltaX_WaterReflectance_PSR_Spring2021.csv* and *DeltaX_WaterReflectance_PSR_Fall2021.csv*.

Variable	Units	Description	Collected during Pre-Delta-X campaign?
basin		Basin name: "Atchafalaya" or "Terrebonne"	Yes
site_id		Site identifier with format <basin>_<mmdd>_<station type> <station number>, where mm = month and dd = day. See Table 2 for basin and station type abbreviations	Yes
campaign		Field campaign: "Spring 2021" or "Fall 2021"	Yes
latitude	degrees north	Latitude of measurement station	Yes
longitude	degrees east	Longitude of measurement station	Yes
date	YYYY-MM-DD	Date of sampling and measurement	Yes
time	hh:mm:ss	UTC time of measurement	Yes

Rrs###, where ### is wavelength	sr ⁻¹	Remote sensing reflectance at a given wavelength per steradian (sr ⁻¹) measured above the surface of the water at 1-nm intervals from 360 nm to 900 nm	Yes. Note radiometric resolution of this dataset is 1-nm from 360-900 nm. Radiometric resolution from Pre- Delta-X Fall 2016 measurements is 5-nm from 446.5-1002.5 nm.
uncertainty_of_Rrs###, where ### is wavelength	sr ⁻¹	Uncertainty in the remote sensing reflectance at a given wavelength representing the propagated error from variability in measured radiance (DN) values as well as uncertainty in viewing geometry, and wind speed	No

Table 2. Abbreviations encoded in *site_id* variable.

Abbreviation	Description
Basin names	
WLD	Atchafalaya Basin (including Wax Lake Delta)
TB	Terrebonne Basin
Type of sampling station	
S	Full station: Water samples for total suspended solids (TSS) and Particulate Organic Carbon (POC) were collected along with water reflectance, measurements from the Sequoia Scientific® LISST-200X instrument (LISST), and water-quality indicators from ProDSS probe.
D	Dry stations: No water samples for TSS were collected. Measurements of water reflectance, from the LISST, and water-quality indicators from ProDSS probe were collected.
B	Basic station: Only measurements of LISST, and water-quality indicators from ProDSS probe were collected.

3. Application and Derivation

During the Delta-X project, above-water measurements of remote-sensing reflectance (Rrs) were collected at a number of sites across the Atchafalaya and Terrebonne basins. These sampling sites spanned large and small channels at locations chosen to cover a representative range of suspended solids concentration from a variety of hydrodynamic and physical settings typically encountered across the Atchafalaya and Terrebonne basins.

This dataset is used to calibrate and validate Delta-X's algorithms used for the retrieval of total suspended solids concentration from AVIRIS-NG imagery and to inform and validate Delta-X's sediment transport models. These in situ measurements of reflectance offer direct validation of the reflectance measured by AVIRIS-NG to assess the performance of the instrument for retrieving surface reflectance. In situ reflectance measurements are paired with concurrent measurements of TSS concentrations and other in situ water-quality indicators (water temperature, salinity, turbidity, chlorophyll-a fluorescence) and in situ measurements of beam attenuation coefficient at 670 nm, average suspended particle size, and suspended particle size distributions (all provided as separate data sets).

These location- and time-specific reflectance measurements were used to calibrate local empirical algorithms relating remote-sensing reflectance to sediment content, thereby permitting remote estimation of suspended sediment from airborne images.

Remote-sensing-derived maps of suspended sediment distribution were compared to numerical models to calibrate and validate its parameters. The models quantify the mesoscale (i.e., on the order of 1 ha) patterns of soil accretion that control land loss and gain and predict the resilience of deltaic floodplains under projected relative sea-level rise. Understanding and mitigating the impact of the relative sea-level rise on coastal deltas is urgent. If ignored, relative sea-level rise will very soon have devastating consequences on the livelihood of the half-billion people that live in these low-lying coastal regions.

4. Quality Assessment

Uncertainty was estimated from variability between multiple measurement spectra of the same target (differences between 8-24 spectra measuring panel, sky, or water irradiance) and from uncertainty associated with viewing geometry and wind speed. To avoid potential mismatch between in radiance spectra, spectra were collected over as short a time as possible and measurements of $R_{rs}(\lambda)$ were avoided during rapidly changing optical conditions (e.g., highly variable cloud conditions), and during very windy conditions. For each median radiance spectrum within a measurement series, variation in the measured set of 4-6 spectra was used to calculate a standard error. The error from the panel, sky, and water irradiance was then propagated through the calculation of R_{rs} to estimate uncertainty in R_{rs} contributed by variability between radiance spectra. Uncertainty in R_{rs} associated with viewing geometry and windspeed was estimated by varying these parameters and applying these variations to the calculation of ρ (surface reflectance factor): varying view zenith angle by +/- 10 degrees, varying view azimuth angle by +/- 20 degrees, and varying wind speed from zero m s⁻¹ to the wind speed measured at the station. Varying these parameters resulted in different ρ values calculated from the Mobley (2015) lookup tables, and this variability in ρ was used to calculate standard error. Uncertainty in the radiance spectra, uncertainty in ρ , and uncertainty in R (derived from the panel calibration specifications) were then propagated through the R_{rs} calculation creating an overall uncertainty estimate, which is reported in the table as the standard deviation of the resulting R_{rs} spectra.

5. Data Acquisition, Materials, and Methods

Remote sensing reflectance (R_{rs}) was measured from surface waters at locations across the Atchafalaya and Terrebonne Basins, portions of the Mississippi River Delta in coastal Louisiana. Sampling sites were located in multiple channels of varying width (from a few meters to >100 m), near Delta-X intensive study sites, and in open bays and lakes, and a few locations in the nearshore Gulf of Mexico. These locations represent a variety of hydrodynamic conditions within this wetland ecosystem (Figure 2).

Sites included three types of sampling stations:

- Full stations, where water samples for TSS were collected along with in-water measurements of water quality and sediment size distribution from the LISST and the ProDSS probe.
- Dry stations, where no water samples for TSS were collected. Measurements of water reflectance from the LISST and water-quality indicators from the ProDSS probe were collected.
- Basic stations, where only measurements of LISST, and water-quality indicators from the ProDSS probe were collected.

Reflectance measurements were attempted at all full and dry stations during the spring (2021-03-25 to 2021-04-22) and fall (2021-08-14 to 2021-09-24) field efforts by the Delta-X project. Field sampling was paused on August 25 and resumed on September 13, 2021, due to the landfall of Hurricane Ida on 2021-08-26 approximately 70 km east of the study site. Water quality changes caused by the hurricane were expected to have minimal effects on these surface reflectance measurements.

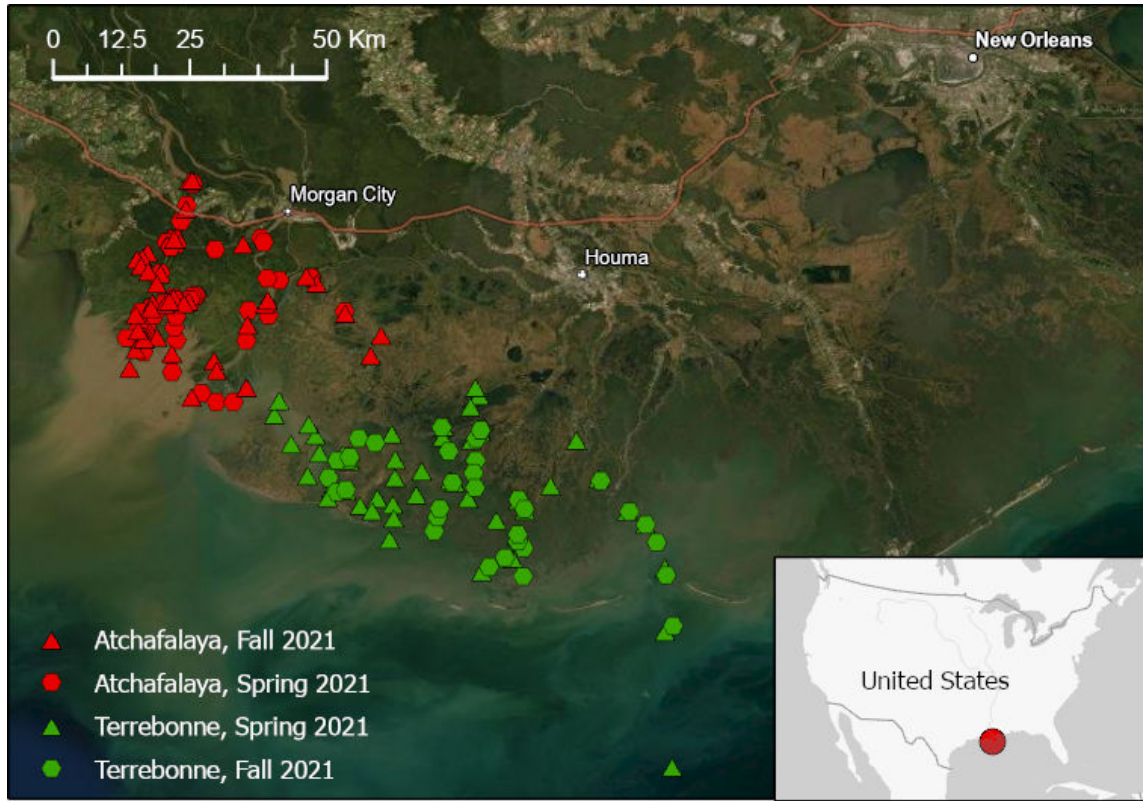


Figure 2. Delta-X 2021 sampling sites for water quality studies labeled by basin and field season.

Measurement Procedure

For each in situ collection, a handheld Portable SpectroRadiometer (PSR-1100f), manufactured by Spectral Evolution, was used to measure radiance from a series of targets:

1. from a highly reflective (>99% reflectance) Lambertian Spectralon panel,
2. from the sky, measured at 40 degrees from the solar zenith and at 135 degrees from the sun azimuthal plane, and
3. from the water, measured at 40 degrees from nadir and at 135 degrees from the sun azimuthal plane.

Measurement of each target was repeated 4-6 times, and the sequence of measuring each target was repeated 2-3 times to maximize the number of total measurements, while minimizing the time between measurement of different targets within a series. These radiance measurements were used to calculate the water-leaving reflectance corrected for specular reflection of skylight at the air-water interface for each series. Care was taken during measurement collection to maintain viewing geometry (135 degrees away from the sun direction, and 40 degrees off-nadir/azimuth) and to minimize the influence of shading or light reflected from the boat. Measurements of solar zenith angle (calculated from latitude, date and time of day) and wind speed were also collected coincidentally in order to estimate the fraction of skylight reflected at the air-sea interface from the tables compiled by Mobley (2015). Care was also taken to avoid measurements during variable illumination conditions (e.g., moving clouds) so that all measurements were made during short windows of time (1 to 2 minutes) when illumination conditions were stable.

In situ, hyperspectral, R_{rs} (360-900 nm), spectra were estimated from the above-water measurements as follows:

$$R_{rs}(\lambda) = (DN_{water+sky} - DN_{sky} * p) / (\pi * DN_{panel} * R^{-1}),$$

where $DN_{water+sky}$ is the measured radiance signal from the water and includes both the water-leaving signal and the signal of skylight reflected at the air-water interface. DN_{sky} is the measured signal from the sky, DN_{panel} is the measured signal from the white Spectralon panel, and R is the reflectivity of the plaque (approximately 99%; actual measured spectral values used in the calculation). Here, the factor π allows for the integration of the signal reflected off the Spectralon panel (Lambertian diffuser) to convert it from a radiance to an equivalent of an irradiance. The measured sky signal DN_{sky} is also multiplied by p a reflectance factor relating the relative signal measured when the detector views the sky to the reflected sky signal actually measured when the detector views the sea surface (the fraction of skylight reflected at the water's surface). This factor p varies substantially with wind speed, solar zenith angle, and viewing geometry, and was estimated for each station from lookup tables compiled in Mobley (2015) using field measurements of wind speed and calculated solar zenith angle.

Within each series of all three types of measurements, multiple measurement spectra of a single target (water, reflectance panel, or sky) were combined through the use of a median filter to create a single representative radiance measurement for the target from multiple spectra. Outlier spectra, defined as spectra differing from the median spectrum by more than 3 median absolute deviations at more than one third of wavelengths, were also removed from the analysis in this step. Median spectra for a target (water, reflectance panel, or sky) within a single series of measurements were then used to calculate remote sensing reflectance for each series following the approach (Mobley 2015) described above. This resulted in 2-3 R_{rs} spectra, one for each series of measurements collected at station. A representative R_{rs} spectrum for the station was then calculated by taking the mean of the R_{rs} spectra at each

wavelength across the different series of wavelengths.

Finally, an empirical correction was applied to remove any residual sun glint from reflectance measurements. This correction utilized an empirical relationship demonstrated between a shoulder in the absorption spectrum of pure water between 780 nm and 840 nm and the magnitude of remote sensing reflectance at 810 nm (Jiang et al., 2020). The empirical relationship between water spectral shape and the magnitude of glint-free reflectance at 810 nm allowed for the calculation of a scalar correction factor that was subtracted from all wavelengths to remove the influence of glint.

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

[Delta-X: In Situ Water Surface Reflectance across MRD, LA, USA, 2021, Version 2](#)

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
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7. References

Jiang, D., B. Matsushita, and W. Yang. 2020. A simple and effective method for removing residual reflected skylight in above-water remote sensing reflectance measurements. *ISPRS Journal of Photogrammetry and Remote Sensing* 165:16-27. <https://doi.org/10.1016/j.isprsjprs.2020.05.003>

Mobley, C. D. 2015. Polarized reflectance and transmittance properties of windblown sea surfaces. *Applied Optics* 54:4828-4849. <https://doi.org/10.1364/ao.54.004828>

8. Dataset Revisions

Version	Release Date	Revision Notes
2	2022-09-23	Fall 2021 data added. Spring 2021 data updated.
1	2022-05-02	Original release holding Spring 2021 data



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