

Fundamentals of Aquatic Remote Sensing

Below is the script written out by the trainer for this program. It is not a word-for-word transcript of the recorded training, but will still give you all the highlights and information covered.

[SLIDE 1]

Hello! And welcome to ARSET's Fundamentals of Aquatic Remote Sensing webinar. This on-demand webinar is meant to serve as a foundation in aquatic remote sensing and as a prerequisite for future aquatic webinars and in-person trainings provided by ARSET. We appreciate your interest and participation in ARSET's programming.

[SLIDE 2]

So why take this course?

The objective of this course is to provide an overview of aquatic optics, the remote sensing of water targets, and NASA Earth observation resources available for aquatic applications

This image, captured by the Landsat-8 OLI satellite sensor, shows the view over Western Australia on May 12, 2013. The image shows the rich sediment, colored dissolved organic matter, and nutrient patterns in a tropical estuary and nearby vegetated areas. This type of information can help us infer the biogeochemistry of the system.

[SLIDE 3]

In this webinar, we will cover a broad range of information.

First will be an overview of light and how it interacts with the water column. Next, we will go over the fundamentals of remote sensing. Third we will discuss the types of data products we can derive from imagery and how those data products may be used. We will discuss NASA satellite imagery data sources as well as data processing tools.

This is a lot of material to cover in one session. There will be helpful links throughout the webinar that you can use to refer to online resources.

[SLIDE 4]

Why do we observe the ocean from space? To understand the Earth's processes on a global scale.

This animation shows a time series of chlorophyll from the SeaWiFS satellite sensor. If you look in the lower right you can see the month and year in the time series from 1997 to 2005.

Watch the animation for a moment. Focus on the ocean and notice patterns in the false color display of chlorophyll. Purple is low chlorophyll and green to red are high chlorophyll. Note the patterns that you see across the globe. For example in the south Pacific, the region is dark blue or even purple. This indicates low chlorophyll. Now look in the north Atlantic. Watch how it changes over time.

Notice how it 'greens up'? This occurs primarily during the spring bloom period and it slightly precedes the summer green up on land at the same latitudes.

Light, nutrients, and temperature drive phytoplankton productivity.

Satellite observations of ocean chlorophyll give us the ability to make global estimates of carbon uptake by phytoplankton. This information helps in our understanding of the global carbon budget.

[SLIDE 5]

What are some advantages of remote sensing of aquatic environments?

There is synoptic coverage, meaning remote sensing imagery can collect data over large area that would otherwise be impossible using ship or mooring observations alone.

Next, the ocean moves and so for many processes frequent satellite overpasses are needed to capture natural phenomenon. Many satellite sensors collect data on near-daily revisit rates and some of these processes can be observed.

Third, satellites can observe where ships cannot go.

[SLIDE 6]

To understand remote sensing, we must first have some knowledge of the water and its constituents.

[SLIDE 7]

In this section we will cover the nature of light and how it propagates through the atmosphere and water column, and back out to the sensor. We will also talk about the inherent optical properties of the constituents in the water and how they influence the color of light.

[SLIDE 8]

The first step in any discussion of remote sensing, requires an overview of the electromagnetic spectrum.

Energy is emitted from the sun and the photons travel at different wavelengths or energy levels.

For our purposes, we are mainly interested in the light in the visible range, or 400 to 700 nm, and in the thermal range. If you are familiar with terrestrial, or land, imaging the near and short-wave infrared regions are used, but because of the absorption of light by water at those wavelengths, we do not use those ranges for aquatic remote sensing.

[SLIDE 9]

Light from the sun passes through the atmosphere and if it reaches the sea surface it may reflect off of the surface or pass through it.

The fate of a photon is to be either scattered or absorbed.

If absorbed, phytoplankton, non-algal particles, colored dissolved organic matter, or water itself will absorb the light.

If scattered, it will do so in either the forward or backward direction. If in the backward direction, some of it will be re-emitted from the sea surface and will be detected by a sensor.

In aquatic remote sensing, we are interested in the radiometric unit, remote sensing reflectance, or R_{rs} .

Remote sensing reflectance is used in the ocean color algorithms to compute the data products of interest for ocean and aquatic science, like chlorophyll concentration.

R_{rs} can be defined as the ratio of backscattering to the total absorption and backscattering, as affected by the local sun and sky conditions.

Alternatively, it can be defined as the water leaving radiance (or light) just above the surface to the incoming or downwelling irradiance incident on the sea surface.

With this equation, we see the relationship of the inherent optical properties (absorption and scattering) of the material in the water to the quantity and quality of light in the underwater light field.

It is this R_{rs} quantity that is derived from satellite remote sensing measurements. Because of these relationships of what is in the water to the color of light emitted from it, we can infer concentrations of optically active constituents in the upper part of the water column that the satellite can 'see'

[SLIDE 10]

Here again is the equation for remote sensing reflectance.

Light absorption and backscattering by the different constituents in the water column govern the color of light the sensor detects.

The Landsat-8 OLI image to the right is of Rupert Bay in northern Canada.

Doesn't it look like a latte?

[SLIDE 11]

This image illustrates the effect of the different absorbing constituents in water.

This image shows the dark water characteristic of colored dissolved organic matter (or CDOM). This is coming from rivers flowing into the the bay from the south as well as from the east. CDOM-rich water tends to look black as it absorbs light strongly, but does not reflect much light backward.

In the middle part of Rupert Bay, tidal forces cause a re-suspension of sediments making for the light brown color.

Offshore of the mouth of the bay there are regions of blue-r water and regions that are slightly green, possibly due to phytoplankton.

If you are having a hard time seeing much of a difference among the chlorophyll, water, and CDOM examples, you're not alone. Part of the reason I used this example is to emphasize to you that water is a dark target. Remote sensing reflectance in the visible range is low for water, as compared to land, and so we must be very careful that instruments are sensitive enough for water targets, are calibrated in the visible range, and that we are careful not to over-correct for the atmospheric effects on light absorption and scattering.

[SLIDE 12]

What would the remote sensing reflectance spectra look like for these different water types?

In the figure on the right you see wavelength across the x-axis and remote sensing reflectance across the y-axis

Note how the remote sensing reflectance spectrum is very low for CDOM, but has a higher magnitude for sediments. This intuitively makes sense because the sediment imager looks light brown and brighter to our eye. The water appears blue. Chlorophyll reflects strongly in the green.

[SLIDE 13]

So to our eye chlorophyll looks green.

Look at the figure to the right. The gray vertical bars represent the wavelength ranges where a typical human eye detects light. Humans have color-detecting receptors that sense light in three ranges corresponding to blue, green, and red.

Our eyes typically can only sense three wavelengths, whereas satellite sensors can detect even more depending on the spectral resolution of the sensor.

So, let's learn more about satellite remote sensing

[SLIDE 15]

In this section we will discuss image resolution, Some of NASA's satellites and sensors for aquatic applications, imager correction, and satellite data processing levels.

[SLIDE 16]

When we talk about resolution, three types come to mind.

First is spatial resolution, or how the area on the ground translates to one pixel, the smallest unit measured by the sensor. For example, one Landsat 8 – OLI pixel can be 15 or 30 m in spatial resolution.

How often a sensor obtains an image of a particular part of the globe is referred to as temporal resolution. For example, Landsat-8 OLI returns only once every 16 days, but MODIS has a more frequent return rate at 1 – 2 times per day.

Spectral resolution refers to how many colors, or bands, an imager can collect. For example, the MODIS sensor has 36 spectral bands, whereas, Landsat-8 (OLI senses at just 9 spectral bands).

[SLIDE 17]

For the purposes of this webinar, we are most interested in passive satellite sensors that measure reflected solar radiation in the visible range to use in our ocean color algorithms. We are also interested in measuring the emitted infrared and microwave radiation in order to observe sea surface temperature. We call these sensors "passive" because they are detecting the reflected or emitted light energy from the sun.

For this webinar, we will only refer to passive remote sensing, although active remote sensing like lidar is gaining popularity for understanding particles in aquatic environments.

[SLIDE 18]

Satellite measurements can be used to infer characteristics of several Earth System spheres. Depending on the type of sensor, and which part of the electromagnetic spectrum is used, information can be gained about the atmosphere, including clouds, aerosols, and gases as well as the Earth's surface, including snow and ice, land vegetation, and water.

[SLIDE 19]

As mentioned before, the remote sensing of water bodies is used to derive the properties of optically-active water constituents. These include suspended sediments, algae, like this coccolithophore bloom near Norway, colored dissolved organic matter, and others.

We use passive sensors to measure the reflected solar radiation.

[SLIDE 20]

Sea surface temperature can be observed using sensors that detect emitted thermal radiation. Knowing sea surface temperature can give insight into the ocean heat budget, ocean current patterns and rates, the rate of photosynthesis in primary productivity models, among other information.

The image on the right shows an 8-day average of sea surface temperature along the east coast of the United States. The deep red color along the state of Florida and northward to North Carolina, where it detaches from the coastline is the Gulf Stream, a quick flowing western boundary current. After it detaches from the continent, turbulent flow encourages the formation of eddies that are evident on the eastern part of this image.

[SLIDE 22]

There are currently several US satellite that are used for the remote sensing of open ocean, coastal, and inland waters.

These include Landsat-7 and Landsat-8 and the Aqua and Terra satellites. The International Space Station also has also served as a 'satellite' for ocean imagery observations.

[SLIDE 23]

These next two slides provide a reference to the different NASA satellites and sensors that are used for ocean color remote sensing.

The Landsat Series, including the Thematic Mapper, Enhanced Thematic Mapper, and Operational Land Imager (or OLI) are used to observe water quality. These sensors provide high spatial resolution imagery, which is particularly valuable in coastal systems, where small scale processes can dominate and are otherwise neglected by coarser resolution imagery.

The Terra and Aqua satellites each host a MODerate resolution Imaging Spectrometer (or, MODIS) which senses both reflected visible radiance and emitted thermal energy.

MODIS is used for Land, Ocean, and Atmospheric applications and is used to infer several parameters (or data products) useful for understanding ocean biology, carbon dynamics, and circulation.

[SLIDE 24]

Other ocean color satellites include

- the Suomi- National Polar Partnership (or NPP) which hosts the Visible Infrared Imaging Radiometer Suite (or, VIIRS). This sensor is used for spectral reflectance and to infer chlorophyll concentration

- the International Space Station can be considered a satellite used for ocean color observations. The Hyperspectral Imager for the Coastal Ocean (or, HICO) rode aboard the ISS for five years from 2009 to 2014. This was a high spectral resolution sensor, sometimes referred to as an imaging spectrometer or 'hyperspectral' sensor.

- Finally, a satellite and sensor that is not yet launched, but is under development is the Plankton, Aerosols, Clouds, ocean Ecosystems (or, PACE). This proposed hyperspectral sensor is scheduled to launch sometime in 2022 or 2023.

[SLIDE 25]

The Landsat satellites have been collecting Earth observations since July 1972. The satellite has a near-polar orbit with a 10 am equator crossing time. The revisit rate is every 16 days. Spatial resolution varies by satellite, but it is typically possible to obtain 30 m resolution imagery. There is a commitment to continue with the Landsat program as it has been so successful in tracking land use and land change, and more recently with the launch of Landsat-8 with its broader use in aquatic systems.

Despite the relatively long revisit rate of 16 days, Landsat is still a useful imaging system to understand some applied science questions for aquatic systems including marsh subsidence and the effects of eutrophication in inland waters.

[SLIDE 26]

The Landsat-7 Enhanced Thematic Mapper launched in 1999 and has remained operational since. It has a 16 day revisit rate. Spectral bands include blue-green, green, red, panchromatic, and reflected and thermal IR.

Note in the figure that the reflectance of water is relatively lower than the reflectance of land. Recall me saying earlier, that water is a dark target. It also absorbs light strongly in the Near Infrared and beyond, so the number of useful bands for aquatic applications is limited to the visible range.

[SLIDE 27]

The development of Landsat-8's Operational Land Imager (or, OLI) included the addition of another spectral band to improve the remote sensing of aquatic systems. This satellite sensor also has a 16-day revisit rate, and with this, additional coastal band algorithms have been developed to derive chlorophyll, colored dissolved organic matter, and other water constituents.

The Sentinel-2a satellite from the European Space Agency was recently launched and observes at similar spectral bands to Landsat-8 OLI and at finer spatial and temporal resolution than Landsat-8. It may be of interest to some of you, but we will not be discussing it as a part of this webinar.

[SLIDE 28]

The work horse for much of ocean color remote sensing are the MODIS imagers on the Terra and Aqua satellites.

Both of these satellites are polar orbiting and have global coverage. They collect near-daily observations. Terra collects in the morning and Aqua collects in the afternoon. There are a number of other sensors on the Terra and Aqua satellites, but mostly for ocean color remote sensing, we are interested in the MODIS sensor.

[SLIDE 29]

What is MODIS?

MODIS is the Moderate Resolution Imaging Spectroradiometer.

It is designed for land, atmosphere, ocean, and cryosphere observations.

It has a spatial resolution of 1 km, but some of the bands sense at 250 m and 500 m. It is possible to interpolate the ocean color bands to the 250 m and 500 m spatial resolution using the image processing software SeaDAS. While this may introduce some error, this enables the use of the imagery in coastal waters where the finer spatial resolution is needed for the scale of processes occurring in these systems.

[SLIDE 30]

Another satellite is the National Polar Partnership also known as the Suomi-NPP.

This satellite was launched in 2011 and provides global coverage. It has a 1:30 pm equator crossing time on a near-daily revisit rate.

The VIIRS sensor is on this satellite and is used for ocean color remote sensing.

[SLIDE 31]

The VIIRS sensor is the Visible Infrared Imaging Radiometer Suite.

It is designed to collect measurements of ocean color, clouds, aerosols, surface temperature, fires, and albedo.

Between the MODIS and VIIRS sensors, we've got the ocean covered. But, satellites and their sensors do not operate indefinitely. Eventually they come to the end of their functional life.

This is why NASA and other space agencies are continuously investing effort in the development of new satellite sensors, and in the process changing the specifications of these sensors so that the data can be used to answer new questions in pure and applied science.

[SLIDE 32]

One example of an experimental sensor was the Hyperspectral Imager for the Coastal Ocean (or, HICO).

This was a partnership among the US Naval Research Lab, the Office of Naval Research, Oregon State University, and eventually NASA.

It was a high spectral resolution imager. This type of sensor is sometimes referred to as an Imaging Spectrometer or as a Hyperspectral Imager depending on the research community. HICO was designed and calibrated to collect over dark aquatic targets.

This sensor was only supposed to have an operational lifetime of one year. It was installed on the ISS in 2009 and was able to collect data for five years, way beyond its expected lifetime.

The imager was tasked to collect observations of specific targets defined by NRL and the scientific user community. These targets included open ocean, coastal, and inland waters.

More information about HICO can be found in the above links. HICO data are available through the NASA OceanColor Web Level 1 and 2 Browser.

An exciting aspect of this sensor is that it now provides a 5 year data set of hyperspectral remote sensing imagery that can be used for algorithm development for NASA's future hyperspectral satellite sensor.

[SLIDE 33]

The newest ocean color satellite sensor under development at NASA is the Ocean Color Imager on the Plankton, Aerosol, Clouds, ocean Ecosystems (or, PACE) satellite.

This will be a polar orbiting sensor with a 2-day revisit and 1 km ground sample distance.

The imagery will collect observations at high spectral resolution. On the right, you see an image showing the spectral resolution of legacy and current ocean color sensors. The PACE sensor will have much higher spectral resolution in the visible range, and will collect data in the short-wave infrared to improve on atmospheric correction.

An optional polarimeter is being considered for this satellite for cloud and aerosol studies and to aid in atmospheric correction of the ocean radiometry.

The proposed launch date is in the 2022 to 2023 time frame. I encourage you to visit the link on this page to learn more about the preparatory activities for this new sensor and to think about how it might be used in answering applied science questions in the future.

[SLIDE 34]

Radiometric observations of the Earth are made at some distance and at some angle relative to the Earth's surface. It can be as close as from a ship or dock, or as far away as from an airplane or satellite.

Along its path, light interacts with material in the atmosphere, such as dust, small particles, water vapor, and gasses, on its way to the water's surface. Once at the surface it can enter or bounce off, and then some will pass back out of the water column and upwards through the atmosphere. The material in the atmosphere absorbs and scatters light, changing the amount and spectral characteristics of the light.

In aquatic remote sensing, we work hard to remove the effects of the material in the atmosphere so we can obtain an image of the water's surface that is as close to accurate as possible. This can be really difficult because water is such a dark target and has low signal, and so mistakes in our correction can have a big impact.

[SLIDE 35]

As you have seen, water bodies dominated by phytoplankton, colored dissolved organic matter, suspended sediments, or detrital particles have distinctive water colors that are detectible in their remote sensing reflectances.

Like material in the water, material in the atmosphere also has spectrally distinct characteristics that influence what the satellite sensor sees.

[SLIDE 36]

Almost 90% of the reflectance signal detected by the satellite sensor is due to the atmosphere and only 10% is from the water's surface.

We use complex atmospheric correction algorithms that take into account the optical properties of atmospheric particles and gasses in order to subtract that signal from the light the sensor detects so that we can arrive at a surface reflectance.

Water is a dark target, so very little light is being emitted, compared to land or ice. So, the sensors used for aquatic remote sensing must have high signal to noise so that they have the sensitivity to detect the dark water surface even through the filter of the atmosphere

[SLIDE 37]

We work hard to measure light at the sea surface, in order to compare these so-called sea truth measurements to the results of our atmospheric correction algorithms.

How do we take these measurements? From a boat or a dock, using a hand held field spectroradiometer. We measure water leaving radiance and downwelling irradiance and use these measurements to derive remote sensing reflectance.

We consider these sea surface measurements to be the best estimate of the truth.

Airborne or satellite sensors also measure the water leaving radiance, but from much higher off of the water than a boat. We compare the sea-truth measurements to our atmospherically corrected imagery, which is a process also known as validation.

So how different is an image at the top of the atmosphere versus what we expect the surface to look like?

[SLIDE 38]

These images show the Narragansett Bay, Rhode Island, in the US.

On the left is an uncorrected image taken above the atmosphere.

On the right is the same image, but this time with the effects of atmospheric gas, aerosols, reflection off of the surface, water column vapor removed so that the only quantity that is represented is the water leaving radiance.

Because water is a dark target, a faulty atmospheric correction can introduce mistakes into the resulting image. The algorithms we use to estimate chlorophyll, colored dissolved organic matter, and suspended sediments are sensitive to variability in the remote sensing reflectance. If an image is improperly atmospherically corrected, then inaccurate estimates of these data products will result.

[SLIDE 39]

When we obtain satellite data, we can get it at different stages of processing depending on what our needs are. Some users prefer data that has already been atmospherically corrected and data products derived, whereas other users want the rawest data available so they can make choices about how to process the data, such as which atmospheric correction algorithm to use. In response, data providers serve the data at different processing levels.

[SLIDE 40]

Level 0 data are unprocessed instrument data at full resolution. Any artifacts of the of these data from the communication of the spacecraft to the ground station have been removed. These data are the most raw format available, and are only provided for a few of the mission.

Level 1A data are reconstructed, unprocessed instrument data at full resolution, time-referenced and annotated with ancillary information including radiometric and geometric calibration coefficients and georeferencing parameters computed and appended but *not* applied to the Level 0 data.

Level 1B data are Level 1A data that have had instrument and radiometric calibrations applied.

Level 2 data consist of derived geophysical variables at the same resolution as the source Level 1 data. These variables, also called data products, and include such data as chlorophyll, sea surface temperature, inherent optical properties, among others.

Level 3 data are derived geophysical variables that have been aggregated or projected onto a well-defined spatial grid over a well-defined time period.

Level 4 data are model output or results from analyses of lower level data

[SLIDE 41]

It is possible to obtain data at any one of these processing levels (Level 0 being the exception for some missions). The effort needed to work with the data is more difficult and requires more skill at lower levels, or where the data are the raw-est. Installed on a UNIX or LINUX based platform, NASA's image processing software SeaDAS enables the processing of data through these different levels.

So what kind of aquatic data products can a person obtain from satellite imagery?

[SLIDE 44]

Several ocean properties, or data products, can be derived from satellite remote sensing

- chlorophyll- a is contained in all eukaryotic phytoplankton and the cyanobacteria. It is used as a proxy for biomass of photoautotrophs at the water's surface. Because it is optically active we can estimate its concentration using remote sensing methods.

Other aquatic properties derived from remote sensing imagery include

- water turbidity
- CDOM
- Sea Surface Temperature
- and from other types of sensors, surface winds and salinity.

[SLIDE 45]

One of the most common questions I am asked about aquatic remote sensing is, "How is it possible to obtain chlorophyll- a from remote sensing imagery?" In the next few slides I hope to convey to you a high level understanding of how we derive this bio-physical data product from imagery.

[SLIDE 46]

Here is a schematic representation of the type of spectra one would obtain from waters with different chlorophyll concentrations. The four example spectra on the left, correspond to the images on the right. Spectrum 1 is from water with the highest chlorophyll concentration, each subsequent image has a decreasing chlorophyll concentration. This difference is also noted in the magnitudes of the spectra in the figure on the left. As chlorophyll concentration decreases, the peak height at around 550 nm decreases.

[SLIDE 47]

The chlorophyll-a algorithm is a fourth order polynomial relationship between a ratio of remote sensing reflectance at two wavelengths and chlorophyll-a. This type of algorithm was derived from empirical data (data collected at sea). There is more than one chlorophyll algorithm that can be used depending on the environment being studied (for example open ocean versus coastal) and which satellite sensor is being used. If you would like more details about the different chlorophyll algorithms, I suggest you follow the link to the algorithm description listed below the spectra.

Simply stated, the ratio of two remote sensing reflectance measures are used as inputs into the algorithm and the result is an estimate for chlorophyll. Validation of the chlorophyll algorithm is performed by collecting sea-truth measurements of chlorophyll within an hour of the satellite overpass. These in situ sea-truth chlorophyll-a measurements are then compared to the chlorophyll derived from satellite measurements and uncertainty is estimated.

It is a surprisingly straight-forward approach, developed in the 1970's and 1980's that continues to be refined and used today to estimate chlorophyll-a from space.

[SLIDE 48]

So now you have learned how chlorophyll is derived from first principles of aquatic optics and how it is possible to make quantitative estimates of global chlorophyll from space as you see in this image here. This is a composite of MODIS imagery from March-April-May 2014, or springtime in the northern hemisphere.

Note the chlorophyll concentration scale along the right and the patterns in the northern hemisphere. During spring, phytoplankton respond to increasing light, temperature, mixed layer depth, and the abundance of nutrients available to them. The north Atlantic in particular noticeably 'greens up' during this period.

[SLIDE 49]

Next, I will be going over how to obtain satellite data from a few of the data access tools commonly used by the research community and also I will introduce you to NASA's image processing software named SeaDAS.

This webinar series is focused on NASA and US-based satellite systems. There are other, international satellites and image processing tools available to the public, but those are not a part of this webinar.

[SLIDE 51]

Worldview is a web-based application for interactively browsing global, full-resolution satellite imagery and then downloading the underlying data. The

browse feature that lets you step through time is really useful if you want to search image scenes, without first having to go through the effort of processing the data to find features such as a phytoplankton bloom.

Worldview makes available over 100 data products and most of them are updated in near real time for the entire earth. This supports time-critical applications such as flood monitoring, air quality monitoring and wildfire management.

To start, I wanted to just browse satellite data to see if there was a recent period when there was a phytoplankton bloom in the Arabian Sea.

In the tool, I can click the red "Add Layers" button to call up a search window. From here I navigate to "other" where a window will open and give me the choice to add Chlorophyll a. for the Terra/MODIS and Aqua/MODIS sensors. I can see the chlorophyll data layer overlain on top of the true color image. If I click on the camera icon in the upper right corner of the webpage, I can define the region to save and save it in one of a number of formats including JPEG and GeoTIFF.

It looks like December 1st 2015 will be a good day to study because already I can see this swirl of chlorophyll just offshore of Muscat, Oman.

[SLIDE 52]

The NASA OceanColor Web is another data access resource. Here, you can obtain level 1 & 2 data from a number of satellite sensors including MODIS, VIIRS, and HICO.

[SLIDE 53]

Here is an example of the Level 1 & 2 Browser. You can select the sensor, month and year, date range and provide a location. It is possible to download image data from this search tool and then load it into NASA's image processing software for further processing and analysis.

[SLIDE 54]

There are other data portals out on the web. Three of them are listed here and I encourage you to look into them more. The NOAA tool has helpful regional information, but also provides global coverage data.

- The NOAA CoastWatch tool
- NASA Giovanni
- and the USGS Earth Explorer where you will learn to access Landsat data

[SLIDE 55]

So, how do you process the data after you download it?

In this next section I will introduce you to NASA's SeaDAS image processing tool which can be used to visualize and process the remote sensing data you just learned how to obtain.

[SLIDE 56]

You've already seen the Level 1 & 2 Browser from NASA OceanColor Web.

NASA's OceanColor Web is supported by the Ocean Biology Processing Group (OBPG) at NASA's Goddard Space Flight Center.

Think of it as a go – to resource for data, data processing tools, and an enthusiastic community of researchers.

The OBPG responsibilities include the collection, processing, calibration, validation, archive and distribution of ocean-related products from a large number of operational satellite-based remote-sensing missions providing ocean color, sea surface temperature and sea surface salinity data to the international research community since 1996.

When you explore the website, you will find information about the missions they support. The data access tools they have available, Documentation related to the data products and calibration and validation of data, and under the 'Services' tab you will find helpful links to the user forum and their image processing software SeaDAS.

This website provides a wealth of helpful information to becoming proficient at accessing, processing, and understanding ocean color satellite imagery. It is at this website that you can find the image processing software SeaDAS.

[SLIDE 57]

SeaDAS was originally developed for the SeaWiFS sensor and derives its name from the SeaWiFS Data Analysis System, but now it supports most US and international ocean color missions.

It is a comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.

It is freely available through the NASA Ocean Color Web website in the link at the top of this page.

SeaDAS is well supported with online tutorials, help pages, an active user community in the Ocean Color Forum, and an attentive and friendly support team based at NASA Goddard

[SLIDE 58]

The SeaDAS team at NASA Goddard has put together a suite of freely available on-demand tutorials and a webinar on how to install and use SeaDAS.

It is through these tutorials, webinar, and through your own use of the tool that you can learn the program.

SeaDAS is intuitive to use and does not take very long to learn. And since SeaDAS supports such a wide variety of satellite sensors, your time investment in learning it will be time well spent.

[SLIDE 59]

If you are interested in building your knowledge of in-water optics and the fundamentals of remote sensing beyond this fundamentals of aquatic remote sensing webinar, I highly recommend the Ocean Optics Web Book. This is a free online source that is perfect for beginners and advanced users alike. In my own research, I still refer back to this book when I need to clarify a concept.

And as noted previously, for more information on remote sensing, data access, and processing tools, the second link, the NASA Ocean Color Web has a wealth of information

[SLIDE 60]

So to re-cap this webinar...

In this webinar we have discussed the nature of light and how it propagates through the atmosphere and water column, and back out to the sensor. We have talked about the inherent optical properties of the constituents in the water and how they influence the color of light.

You've had an overview of the fundamentals of remote sensing, including spatial, temporal, and spectral resolution, we've talked about the different NASA satellites and sensors that can be used for aquatic applications, we've touched on the idea of atmospheric correction, and we have reviewed satellite processing levels and what they mean.

I've given an overview of data products used in aquatic remote sensing.

We've talked about a few of the data portals you can access to obtain remote sensing imagery for free.

And finally, I've directed you towards NASA's Ocean Biology Processing Group where you can obtain and learn more about the freely available image processing software named SeaDAS.

[SLIDE 61]

This concludes the Fundamentals of Aquatic Remote Sensing webinar. We thank you for your interest and participation in this ARSET webinar. I hope you will consider future ARSET webinars for your training needs.