Introduction to Remote Sensing for Harmful Algal Blooms

Please type your questions in the Question Box. We will try and get to all your questions, but if we don't, feel free to email Sherry Palacios your question at sherry.l.palacios@nasa.gov

Session 2 Q&A Transcripts

Question 1: Can we monitor red tide daily?

Answer 1: You can monitor water quality from Terra/Aqua MODIS daily. Red tides aren't necessarily present every day, so whenever there is a large-scale HAB bloom with color change, then you can detect it using MODIS. You can detect if there's a bloom, but you will need to know a little more about the system to determine that it's a red tide in particular. At some concentration of chlorophyll there's a likelihood of discoloration. (If the water body is smaller than the satellite pixel, or if the bloom is smaller, it will be difficult.)

Question 2: Can we also determine the volume of algae?

Answer 2: Don't think so - **you can get at the concentration of chlorophyll in the water.** More recent algorithms are being determined that get at cell biovolume based on the backscattering. This is not operationally available, but it is available at the research level. The level of detail isn't at the species-level. (This isn't used as much for the HAB community, but rather for the ecosystem people.) If you want to know more about cell biovolume based on satellite data, we need to provide citations for that.

Question 3: In some literature I heard 8 days revisit is possible in Landsat OLI is it true?

Answer 3: Right now Landsat 7 & 8 are flying and while each provides data at 16 days, when you use both you can end up with an 8 day revisit by using 1 at a time. Caution: when using Landsat 7 ETM+, there's an artifact in the measurements that need to be corrected. There are some lines you'll see in images, and that needs to be corrected. Also keep in mind ETM+ and OLI - OLI has one more band than ETM+ but the other bands are similar. (Deep blue band in OLI)

Question 4: There are several websites for data download, e.g. LPDAAC, GLOVIS, EarthExplorer, etc. Do you know the reason for multiple, separate websites?

Answer 4: They were established at different times with slightly different features, so people have their own preferences. If you go to the ARSET website, especially for Landsat data in land webinars, there are demonstrations of how to use the sites for data. https://arset.gsfc.nasa.gov/about/models-tools for a list of tools and demonstrations/case studies using them, as available

Question 5: Could you talk a little bit more about using remote sensing to distinguish chlorophyll from CDOM from turbidity? The training materials indicated that this is possible, but Amita also implied that this is still difficult. Thanks!

Answer 5: When higher turbidity and CDOM is there, it's difficult to distinguish between the two. The signal is just from chlorophyll. But in research/literature, people have tried different spectral band combinations to work around this difficulty.

When you do SeaDAS, you have options for some of the models they use for how you want to separate the different materials in the water. There's different algorithms - one is referred to as QAA and another is GSM - and they're different approaches to tease apart these constituents. They're based on empirical methods and the physics of modeling these environments and being able to pull it apart analytically. (There are more methods, but those are some commonly used ones.)

Question 6: Is there a minimum or maximum area coverage for the best analysis? (SeaDAS)

Answer 6: Maximum/Minimum are something to consider, so any water body you're monitoring should have at least 3-5 satellite pixels of open water. It depends on satellite resolution, so for Landsat you should have at *least* 90 - 150 m^2 resolution and if it's MODIS, you should have 150-250 m^2 resolution. Any satellite you use - 3-5 pixels over open water.

Question 7: is there any link [http://optics.marine.usf.edu/index.html] for east Africa, Red Sea, and the Mediterranean?

Answer 7: It's mostly - there's some in East Asia - but most of them are focused on the U.S. Western Africa side of Atlantic

Question 8: Is there anyone doing processing on arabian sea and bay of bengal?

Answer 8: There is no operational system that focuses just on Bay of Bengal and Arabian sea, but if you look at OceanColorWeb and GIovanni you can get MODIS-based chlorophyll in those oceans because it's global coverage - both daily and monthly.

Question 9: Please, are these data contain wave heights ?

Answer 9: This is beyond the scope of this webinar, but if you look at altimeter data, and that will provide ocean surface height.

Question 10: Can we have chl-a data for any inland water body (lake), regardless of size?

Answer 10: From remote sensing, size is very important because it depends on satellite resolution. If the lake or pond is smaller than the satellite pixel, you cannot resolve it and can't use remote sensing to monitor it.

Question 11: How to differentiate between aquatic plants (lemna) and algae?

Answer 11: It is tricky as lemna is a floating plant, and may be conflated with floating cyanobacterial mats. If lemna is the only organism floating in the environment and floating algae are not a concern, then it may be possible to use RS for identifying and monitoring for it in a qualitative way.

Question 12: Will we be going over how to combine the raw data with our insitu measurements to produce data products that are similar to those seen in OceanColorWeb, GIOVANNI, SeaDAS, optics.marine.usf.edu, CyAN, Lake Erie HAB Tracker, NOAA Coast Watch, Copernicus Marine Env. Monitoring Service, or hab.nersc.no?

Answer 12: Because this is an introductory webinar, we won't cover that in particular. But we can provide you with some literature references on how it is done. That would be an advanced webinar topic, where we show you how to combine in situ data and remote sensing data - or how to develop your own algorithm.

Question 13: Which satellite product would you use for monitoring small lakes in Northern US? Are HAB predictions provided for small inland lakes as well?

Answer 13: The CyAN project addresses HAB predictions for small inland lakes, come back in week 4!

Question 14: Can you please provide additional information on utilizing Chlor data along shorelines with large sediment load? Often there are not in situ values available.

Answer 14: When you have large sediment loading occurring and you also want to see chlorophyll and there's no in situ data, it *is* going to be difficult. But if you send Amita an email, she'll try and look at some papers where multiple parameters are retrieved using remote sensing data. You really need some in situ measurements - you really need ground truthing and we've tried with RS data for remote areas, but you can only make qualitative assessments if we don't have ground truth to validate.

Question 15: for RS validations what is the possible ways ? In fact, we have in situ data but all the five algorithms overestimate in bay of bengal can anyone help me to sort out his issue in india

Answer 15: If you have in situ data and different algorithms overestimate - look at how you do atmospheric correction. Sometimes that may be a factor that's affecting your retrieval. One thing that might be helpful - but not as familiar with optical prop of the region - there are other ways to estimate chlorophyll. If there isn't a lot of sediment, you could take the fluorescence line height (normalized fluorescence line height approach) - we aren't talking about it much (if at all) in this series. But that might be one way to get around the problems. But if there's a high sediment load, it breaks down quickly.

Question 16: Where is the homework?

Answer 16: You can find the link to the first assignment on the webpage as well as in the Chat (see link). It will be **due by Oct. 1st** https://arset.gsfc.nasa.gov/water/webinars/HABs17

Question 17: In places with cloudiness like south of Chile. How can I get images? Can I make interpolations with SeaDAS?

Answer 17: Cloudiness is an issue for all optical measurements. Sometimes you can look at surrounding cloud-free or partially cloudy regions and gauge qualitatively what's going on. But cloudiness is a real issue.

Question 18: Can you talk about how to correct reflectance for accurate chl a estimation and if the data available on some of the tools discussed are corrected?

Answer 18: For a lot of the terrestrial RS, folks receive already computed products. Many of the portals Amita pointed you to is directing you to tools with chlorophyll a product, and this is done after pre-processing and corrections have taken place. You can get raw-er data and process it through SeaDAS (MODIS, VIIRS and some of the other satellites), and then you can process it with your own atmospheric correction parameters. We're not taking you through those steps as part of that, and we would love to do an advanced webinar on this if there's demand. But that's

where you would go into the data and do some of your own corrections. Will go from Level 1 B and then compute data products after correction.

For people that derive their own corrections start with raw data. There are programs - ACOLITE, for example - that many people use to correct data. USGS also has an atmospheric correction algorithm called SixS - there are 2 versions for this - they're used for MODIS as well as Landsat.

Question 19: Besides the given examples of satellites are there any other way to observe HAB, perhaps UAV Imagery?

Answer 19: Absolutely! Aircraft-based observations are also sometimes used, but UAV can definitely be used.

Question 20: Is it necessary to use a spectrometer to take samples?

Answer 20: If you're looking at optical observations from near-surface, for taking water samples: no. But if you're taking - you're trying to get optical measurements, then (Amita images) you need a spectrometer. Sherry: confirmed. You would need surface radiometry as well. You can reconstruct using those water measurements, if you want to filter the water and water optics, but the surface radiometer is going to provide that sea-truth measurement.

Question 21: How accurate are these products as shown in the websites you shown?

Answer 21: Depends on the region and would need to collect sea-truth to assess

Question 22: The algorithms are Tasson, Yugi sakuno, Chaugan, Hamilton, OC3. Can you please tell me why it overestimates in Bay of Bengal?

Answer 22: That is difficult to answer not knowing what the Bay of Bengal optical properties are and how the algorithms do the corrections. Maybe the best way is to start with raw data, do your own corrections, and try and derive an algorithm for yourself. There are other algorithms to consult. In last week's answers, there will be a link to a table for many of these algorithms. Many are empirically-based, they're regionally appropriate.

Question 23: Is it advisable to use modis chl-a data in place of in-situ measurements to validate your chl-a model results when you don't have field measured chl-a data?

Answer 23: If you don't have *any* in situ measurements, you will have to look at remote sensing data (such as MODIS chl-a), but really, in situ measurements are key for validation. This way -

Amita would say if you look at your model data and satellite data, you may not get an exact match. But if you look at anomalies, you'll get an idea of the variability the model is picking up.

Question 24: Is there available from Nasa a platform toolbox similar to the ESA SNAP toolbox for the scientific exploitation of satellite data?

Answer 24: NASA's SeaDAS is built on the same framework as SNAP (by the same company) and performs many similar operations. SeaDAS allows you to process and look for - visualize the images and data. There are other tools like we just saw - e.g., Giovanni - that will allow you to explore satellite data without downloading.

Question 25: What about other coloring agents, e.g. phycocyanin (blue) or phycoerythrin (red), can we have data on those?

Answer 25: There are algorithms that are out there that are trying to separate the phycocyanin from the spectrum as a way to ID if you see chl in the water, does it contain cyan. A lot of these algorithms ID if there's a bloom, and if it's cyanobacteria. In week 1's Q&A text, there are 2 links that will provide a starter to find where these algorithms are being developed. If you want to look for more recent references, you can look beyond those. But there are algorithms working on it.

Question 26: In response to Answer 12, are there plans to create an advanced webinar?

Answer 26: It depends on demand from the user community and if ARSET can put it together

Question 27: Now we know that not all HABs cause water discoloration. So, how and when do you decide to start monitoring potential HAB in a water body? What "triggers" do you look for in the field as well as from satellite imagery?

Answer 27: You can also look at SSTs along with - although the color's not changing, it will have some affect on your spectral radiance and the ratio of certain band reflectances. If you monitor that, you'll have some idea of when to start monitoring and go to the water body where a potential HAB might be.

Question 28: What is the most recent advancement in the remote sensing technology?

Answer 28: Hyperspectral measurements are something that can help in actually distinguishing between different parameters, such as CDOM or chlorophyll a - hyperspectral measurements EO was one satellite that had a hyperspectral instrument. There was HICO on the ISS (no longer operational). But Hyperion on EO had hyperspectral observations, and that can help.

Hyperspectral just provides so much more data you can use to tease apart different phytoplankton groups, and that goes a long way to figuring out what can be in the water. Using marine LIDAR is another advancement - using LIDAR, they started at 1 wavelength, they're starting to expand to have multispectral LIDAR. Using that you can get a lot more info about the groups, and what their absorbing and backscattering properties are. You can get down to cell biovolume more directly. Hopefully with upcoming missions, we'll get more multispectral imaging so that you can get more information out of the ocean.

Question 29: Satellite imagery works very well for ocean environments, but what happens with coastal environments, such as bays or coves?

Answer 29: That's where Amita would say many efforts are being undertaken - and Sherry is working on coastal remote sensing. in situ measurements + careful analysis of spectral bands (and if you have hyperspectral band data, that's even better). Analysis of in situ + RS data, something like Landsat with high resolution, and of course, now MSI from Sentinel-2 now has high resolution, can be used more effectively for coastal regions.

Question 30: If I want a NetCDF file of chlorophyll for a Great Lake, with as high of spatial/ temporal resolution as possible, what data source should I check out first? OceanColor Web? Thanks :)

Answer 30: the Coast Watch node for the Great Lakes - it's been in a NetCDF format - so look at the West coast node. Sherry will check and see if they provide that info, if you're looking for NetCDF - that's probably the quickest way to get that info. Feel free to send Sherry an email at sherry.l.palacios@nasa.gov

The Great Lakes node for CoastWatch serves GeoTIFF images of chlorophyll concentration for the various Great Lakes. They also serve other ocean color data products.

The node link is here: https://coastwatch.glerl.noaa.gov/

The link to the data products is here:
https://coastwatch.glerl.noaa.gov/ocean-color/ocean-color.html

Question 31: Glovis will be disappearing?

Answer 31: GloVIS has recently changed - not sure if it will go away, but there is a new version.

Question 32: IS Mod tran algorithm insufficient in atmospheric correction for Oli?

Answer 32: OLI correction - and if you email Amita, she'll send you the link - of how OLI atmospheric correction is done. But if you go to the USGS OLI webpage and the Landsat data webpage, you may find information about that there, too.

Question 33: is it also possible to retrieve turbidity maps from the online modis chl-a data and if so how?

Answer 33: Don't think so - you'll have to go to spectral radiances to get any turbidity also. There's a product call K490 that can be used for particle estimates in the water, and that will often be used.

Question 34 Can you talk more about how sea surface temperature (SST) was used for HABs detection?

Answer 34: SST can be used in a number of ways for HAB detection and forecasting. As light, nutrients, and temperature are the primary abiotic drivers of phytoplankton growth, SST and especially rising SST has been implicated as a factor in increased algal blooms, some of which are harmful. SST can also be used as a proxy, in some environments, for other environmental variables such as nutrients. SST can also be useful for helping to define physical barriers in the environment such as currents, fronts, and plumes which can act to dilute and concentrate algal blooms. As a result, SST is really useful as a variable in algal growth models, and is used in several HAB forecasting models.

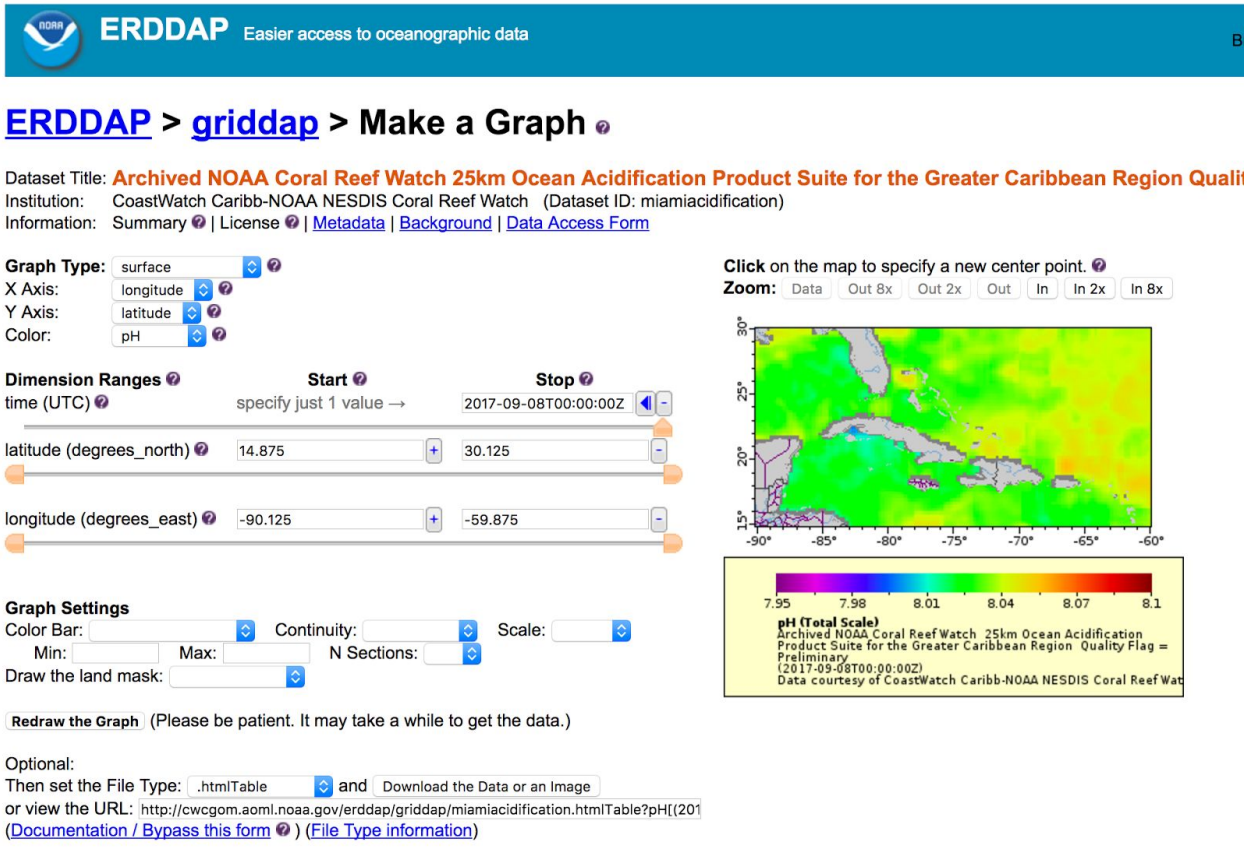
Question 35 Where do we get biological oxygen demand, dissolved salt concentration, pH value? Can these only be obtained from analytical methods?

Answer 35: At this time it is not possible to obtain biological oxygen demand from satellites.

It is possible to measure sea surface salinity (SSS) with the SMOS sensor. The short-lived Aquarius sensor also measured SSS. Both of these sensors have coarse spatial resolution on the order of tens of kilometers per pixel and so for applications in the coastal zone or inland lakes they are not practical.

There is an experimental product offered by NOAA that estimates pH, and other parameters related to seawater alkalinity, in the Caribbean. This is in support of NOAA's Coral Reef Watch program because of the impact of ocean acidification on corals. The link to see the data viewer for those data products is:

http://cwcgom.aoml.noaa.gov/erddap/griddap/miamiacidification.graph?pH[(2017-09-08T00:00:00Z)][(14.875):(30.125)][(-90.125):(-59.875)]&.draw=surface&.vars=longitude|latitude|pH&.colorBar=|||||



Question 36: I generally hear Landsat satellites talked about as the go-to for remote sensing because of its 30m resolution and its 16 days revisit time (8 if you include the 7 satellite, though it has the sensor errors that need to be dealt with), and I'm surprised I have not heard much about the Sentinel 2 satellites. With a 5 days revisit time and 10 m spatial resolution, I wonder why Sentinel would not be the go-to instead of Landsat. Are there drawbacks to using Sentinel 2 data over Landsat for monitoring HABs that may not be clear based solely on the satellite parameters?

Answer 36: Sentinel-2A and 2B satellites are recent satellites -- Landsat has been there for a number of years so the data have been used for developing algorithms.

Question 37: : Are there any in-situ databases available?

Answer 37: There are a number of in situ databases available. These are often managed at a regional scale (in the US) or for a particular discipline. For example, the ocean color algorithm

community uses NOMAD (formerly SeaBASS) for in situ observations to use in validating imagery and in algorithm development (https://seabass.gsfc.nasa.gov/wiki/NOMAD). Sherry (sherry.l.palacios@nasa.gov) will research more on HAB-specific in situ datasets and put into these notes

Question 38: What level products are usually already pre-corrected for clouds/atmospheric effects?

Answer 38: Typically Level 2 data have been atmospherically corrected. If you are interested in choosing the parameters for atmospheric correction, you can download Level 1 data and run the correction yourself (in SeaDAS, for example)

Question 39: Is there an assignment for this week?

Answer 39: Yes, Homework 1: (Due Oct. 1st)
https://docs.google.com/forms/d/e/1FAIpQLSdLLkIKA5MyIasebKPK_Oyxjff0EJCkP8FpD1cGpiKzqHJtPw/viewform?usp=sf_link

The link can be found on the training webpage as well as in the Chat window

Question 40: How can we assess which type of phytoplankton organism may cause the bloom in a specific region from remote sensing data?

Answer 40: Please see Week-1 Q/A.

Question 41: Can you please give an example about how to get the typical remote sensing data from a specific region?

Answer 41: This answer is really dependent on which sensor you wish to use as the data portals that serve the satellite data are specific to a sensor, or a small group of sensors. For example, if you wish to download Landsat data, https://earthexplorer.usgs.gov/ is one candidate website for downloading the data. After downloading the data, you could pull it into SeaDAS, Arc, ENVI, QGIS or a number of other image processing packages available for further analysis. As a user of data, it is a good practice to build a process flow that makes sense for the sensor you wish to use. Some data portals permit you to have a standing request for imagery and periodically the portal with ‘push’ the data to you. It depends on which sensor (e.g. MODIS) you are using and the policies for data dissemination by the organization that owns the sensor.