Questions & Answers Part 2

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Juan Torres-Perez (juan.l.torresperez@nasa.gov) or Britnay Beaudry (britnay.beaudry@nasa.gov).

Question 1: How can we plot a time series illustrating the trend, seasonality, and anomalies for NDVI, and a trend analysis of NDVI using Google Earth Engine?
Answer 1: Google Earth Engine has its own training on time series modeling and uses NDVI seasonality as the example. You can work through that here: https://developers.google.com/earth-engine/tutorials/community/time-series-modeling. I will also recommend you look at the 2021 ARSET training "Using Google Earth Engine for Land Monitoring Applications," as part 3 focuses on time series analysis and change detection. You can look at the course materials here: https://appliedsciences.nasa.gov/get-involved/training/english/arset-using-google-earth-engine-land-monitoring-applications.

Question 2: How do you observe salinity? Which sensor can I use for this? From what I know, optical sensors do not measure salinity.
Answer 2: Unfortunately, there are not many sensors that can retrieve salinity. Here's a paper that talks about some attempts to measure salinity with some airborne sensors: https://meridian.allenpress.com/jcr/article-abstract/27/5/830/145166/Remote-Sensing-of-Sea-Surface-Salinity-An-Overview.

Also, the Aquarius mission (a partnership between NASA and CONAE, the Argentinian Space Agency) was in orbit for a while (2011-2015). Some data can be found at: https://podaac.jpl.nasa.gov/dataset/AQUARIUS_L3_SSS_SMI_ANNUAL_V5.

Question 3: Could you please explain the differences between the following terms?
- **Remote sensing reflectance (Rrs)**
- **Water-leaving reflectance (= Pi*Rrs)**
- **Normalized water-leaving reflectance**

I have found equations on how each is derived, but they are too complicated. Could you explain their differences in simple terms? If an atmospheric correction processor is capable of generating all three from a Level-1 image, which one is preferred for use, for instance, in retrieving chlorophyll-a concentrations?
Answer 3: An excellent reference from Curtis Mobley about the differences of these parameters is: https://oceanopticsbook.info/view/introduction/overview. Usually, the Rrs is used for most of these calculations. The water leaving radiance is used to calculate Rrs. The normalized water-leaving reflectance is the reflectance corrected for atmospheric effects. This is usually done in the field by using a Spectralon diffuse surface panel which has an uniform surface usually 98% white.

Question 4: Is NDTI applicable at the global scale or is it specific for the region of study used by the author?
Answer 4: NDTI was originally developed for relatively small water bodies with sensors that have a high spatial resolution. As mentioned, it was originally developed for SPOT 10m data. We at DEVELOP have applied it to similar water bodies, but while using Landsat or Sentinel datasets. The applicability for global data will depend on the specific bands of the sensor. As always, if the pixel is coarse and if it is close to land masses, it might be influenced by land features so those pixels in particular cannot be used for analysis.

Question 5: What causes turbidity in ponds and lakes?
Answer 5: Usually these inland water bodies are affected mostly by watershed-related issues such as eutrophication and sedimentation as a result of changes in land use and land cover.

Question 6: What sensors allow me to know the temperature and salinity of the water?
Answer 6: For salinity, please refer to the Q2 above. For temperature, several satellite missions have been assessing this parameter for years. MODIS is one of them: https://modis.gsfc.nasa.gov/data/dataprod/ (shows all the products available for MODIS). Here's the link for VIIRS: https://podaac.jpl.nasa.gov/dataset/VIIRS_NPP-OSPO-L2P-v2.3.
Here's a recent paper on the use of Landsat data for sea surface temperatures: https://www.sciencedirect.com/science/article/pii/S0272771421004996.

Question 7: Is the NDCI useful to predict accurate concentrations, as its output will be between -1 and 1? Is it more a "ranger" than a precise estimator?
Answer 7: Many of these indices including the NDCI are used to get an idea of the concentration of specific parameters (such as chlorophyll in this case) and not necessarily accurate concentrations. Yet, the results can be correlated with in situ based data or concentrations calculated with other more robust algorithms to have an idea of the efficiency of the index to detect such parameters.

Question 8: How similar do band centers and bandwidths need to be between different satellite sensors to be able to derive the same indices? For example, the bands 708 and 665 were initially proposed for NDCI - what if I wanted to derive this index with a different satellite sensor with slightly different bands?
Answer 8: This is a very good question. Indeed, many of these indices have specific band ratios while others are more flexible and can be applied to different datasets.

Question 9: If using a cell phone camera (with only RGB), is it possible to determine the health status of submerged aquatic vegetation (podostemaceaes)?
Answer 9: No. An RGB camera is very limited in its spectral capabilities. Nonetheless, although not for aquatic vegetation, cell phone cameras have been used for citizen science approaches to calculate some water quality parameters using for example, the Hydrocolor app: https://misclab.umeoce.maine.edu/research/HydroColor.php.

Question 10: Does seasonality (winter/summer) affect detection of turbidity, chlorophyll?
Answer 10: Of course! Seasonality in any given system will affect the presence and detection of such parameters. Rainy years/seasons vs. drought years/seasons will show different values. Also, since we are using optical data, the presence of clouds will affect the detection as well.

Question 11: Will NDCI work for waters that are not turbid?
Answer 11: Yes, it can work. THe researcher will have to be careful in terms of being sure that there is no influence from bottom reflectance or submerged aquatic vegetation as these will create artifacts on your results.

Question 12: How accurate does the NDCI turn out to be? Is it also applicable globally or is it region specific?

Answer 12: Q4 and Q7 refer to this question.

Question 13: What is the best date/season for selecting images (Sentinel-2) to detect turbidity?
Answer 13: This will depend on your region of interest and the local conditions dominating your site (rain, clouds, depth of water body, etc).

Question 14: Can we estimate or map the nutrient (N, P, CDOM) status of shallow water (~8 cm thick) using NDCI or other indices for lowland flooded paddy fields?
Answer 14: No. NDCI is only used to have an idea of the amount of chlorophyll present in the water column.

Question 15: Is there a rule of thumb regarding the minimum depth of a water column to avoid issues with bottom reflectances? I've seen a general rule of moving '1 pixel inwards' to avoid shoreline contamination, but this is normally referring to ocean color sensors with pixel resolutions of 300m. How would this apply to higher-resolution multispectral sensors like Landsat?
Answer 15: This will also depend on the study site. Areas with typically clear coastal waters such as those in the tropics will have a much higher bottom reflectance influence than those with more turbid waters.

Question 16: How will the topography influence the spectral reflectance?
Answer 16: Topography does affect the spectral reflectance especially on land. This is where adding a digital elevation model (DEM) is particularly useful. In the water bathymetry and benthic reflectance have an additional effect which needs to be taken into account especially in shallow coastal clear waters such as those in the tropics. In this case, a bathymetric map will help. Here's a paper on topography influence on satellite datasets: https://www.tandfonline.com/doi/abs/10.1080/01431160210154029.

Question 17: Can the FAI or AFAI be applied to surface scums created by cyanobacteria, or is it only applied to floating macroalgae? Are there any other indices (or other methods) that can be used to derive surface scum from microalgae from optical sensors?
Answer 17: Can definitely be tried! Their usability will depend on the specific type of scum. Remember that cyanobacteria, for example, have phycocyanin (or sometimes phycoerythrin) as their main pigment and these absorb in different regions of the

electromagnetic spectrum. FAI and AFAI work very well for Sargassum as shown in the presentation.

Question 18: Do high values of NDCI indicate the presence of cyanobacteria as well?
Answer 18: Not necessarily. Remember that cyanobacteria have phycocyanin (or sometimes phycoerythrin) as their main pigment and these absorb in different regions of the electromagnetic spectrum.

Question 19: For spatial resolutions from cm to m, what alternatives can be applied other than the use of satellite images? I am studying aquatic plants submerged in an oligotrophic river with widths ranging from 3 to 23 meters and low depths. What methodology could I apply there to analyze the health status of this type of vegetation?
Answer 19: A drone-based hyperspectral or multispectral sensor may be tried. Nonetheless, these are costly and would require personnel skilled in drone flying. The processing of data, as with other airborne datasets, will require pre-processing as the data has to be corrected for aircraft-related issues (pitch, roll, yaw, for example).

Question 20: What spectral index can be used to determine dissolved heavy metals in river water?
Answer 20: We have no recollection of any index specifically designed for this purpose.

Question 21: If we have NDCI and in-situ Chl-a data for a site, how do we calibrate the NDCI for days without in situ data? Do we use the polynomial function from Mishra & Mishra (2012), or would we develop our own for our ROI?
Answer 21: Probably the best approach is to use the polynomial function described in their paper. There will always be an intrinsic error associated for non-in-situ data days as the water column typically changes through the day/week/month/etc.

Question 22: Are all these spectral indices in awesome spectral indices Python Github project? It is my go to source for spectral indices across different satellites. I can help bring them in, if some are not in this list: https://github.com/awesome-spectral-indices/awesome-spectral-indices.
Answer 22: Did not know about this! Thanks for sharing.

Question 23: For inland waters, are Level-2 data appropriate for calculating spectral indices in inland waters? Or would I need to work with Level-1 data to apply a Case 2 water-specific atmospheric correction?
Answer 23: These are usually calculated with L2 data which already have an atmospheric correction applied. Nonetheless, for aquatic bodies, applying an atmospheric correction model specifically designed for water bodies (such as ACOLITE, for example) and then applying the index might be more useful since many atmospheric correction models are usually developed for land purposes.

Question 24: Is there a way to relate dimensionless spectral indices to chl-a concentration?
Answer 24: Typically through a correlation analysis. Many of the papers that we referred to in the slides have such correlation analyses.

Question 25: In slide 37, could you show water levels? Is the decrease in the two dates from water depth changing (i.e., rising sea levels) as well?
Answer 26: I don't think so. Now, depending on when both images were collected during the day, there might be a tide-related effect but usually if images are from the same sensor, the acquisition times do not change significantly through the year.

Question 26: In terms of radiometric resolution, is Sentinel-3 a better sensor for water quality parameters than Sentinel-2 and Landsat 8/9 sensors?
Answer 27: I believe that is the case. The caveat is that Sentinel-3 has a coarser spatial resolution (~300m) than Sentinel-2 or Landsat.

Question 27: In line 59 of the GEE code, it's .median(). What is the difference if you use mean() instead?
Answer 28: By using .mean(), the image produced would be the mean value of the bands per pixel over the date range. You can read more about .mean in GEE here: https://developers.google.com/earth-engine/apidocs/ee-imagecollection-mean

Question 28: What is the programming language used in Google Earth Engine?
Answer 29: This is the Javascript version of Google Earth Engine.

Question 29: Can you please give your insight about the correction of bottom reflectance for shallow water bodies?

Answer 30: This is usually very challenging, especially in clear waters. Researchers usually collect spectral libraries of benthic components to help correct for this issue (for example, corals, seagrasses, sand, mud, etc.). In our previous Remote Sensing of Coastal Ecosystems webinar we covered some of these techniques. https://appliedsciences.nasa.gov/get-involved/training/english/arset-remote-sensing-coastal-ecosystems

Question 30: During the demo, B5 and B5 were selected for the calculation but both have different resolutions. Does it really not matter?
Answer 31: In the demo, we're using Bands 4 and 5. Band 4 has a 10-meter resolution and band 5 has a 20-meter resolution. When working with remote sensing data, you should always use the lowest resolution when performing calculations related to accuracy, scaling, etc. You'll see on line 83 we use a 20-meter resolution for the minmax scale specifically because of band 5's resolution.

Question 31: If I want to estimate chl-a using UAV derived images, can I still use the same NDCI formula, or does it depend on the sensor being used?
Answer 33: As long as your sensor collects the data within the same band center, it might be worth giving it a try. There are several models of multispectral or even hyperspectral cameras/sensors for UAVs out there yet, their applicability to remote sensing of water bodies is still pending.

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Question 1: Is there a particular bandwidth that we should be using to identify HABs (harmful algae blooms) particularly in remote bodies of water?
Answer 1: That depends on the type of HAB occurring at any given site. This is because, for example, a good reference for inland waters is the Kudela et al 2015 paper on detection of cyanobacteria using hyperspectral airborne data: https://www.sciencedirect.com/science/article/pii/S0034425715000437.

Another good reference is that of Anderson et al (2019): https://www.frontiersin.org/articles/10.3389/fmars.2019.00250/full?utm_medium=email&utm_source=govdelivery.

Also, please refer to previous ARSET webinars on water quality for additional references and valuable information.
https://appliedsciences.nasa.gov/get-involved/training/english/arset-remote-sensing-coastal-ecosystems

https://appliedsciences.nasa.gov/get-involved/training/english/arset-monitoring-coastal-and-estuarine-water-quality-using-remote

Question 2: What do you mean by 0+ in Remote Sensing Reflectance (Rrs)?
Answer 2: This is usually referred to for Rrs right at the water surface.

Question 3: Do you know any studies assessing GEE Sentinel-2 surface reflectance images for aquatic indices? Would it be better to apply other atmospheric correction methods, and if so, could it be done in GEE?
Answer 3: Here are a few studies that used Sentinel-2 in GEE to assess various aquatic indices.
Kislik et al (2022):
https://www.sciencedirect.com/science/article/pii/S1470160X2200512X

Yang et al (2020):
https://www.tandfonline.com/doi/full/10.1080/2150704X.2020.1757780
Sakti et al (2023):
https://www.nature.com/articles/s41598-023-32087-5
ARSET - Monitoring Water Quality of Inland Lakes using Remote Sensing:
https://appliedsciences.nasa.gov/get-involved/training/english/arset-monitoring-water-quality-inland-lakes-using-remote-sensing
Kwong et al (2022): https://www.frontiersin.org/articles/10.3389/fmars.2022.871470/full
Sherjah et al (2023):
https://iwaponline.com/jh/article/25/2/432/92983/Quality-monitoring-of-inland-water-bodies-using

Question 4: Do you know about any methodology that has derived pathogenic pollution from environmental factors such as spm or chl-a?
Answer 4: The papers mentioned earlier by Raphe Kudela et al (2015) (https://www.sciencedirect.com/science/article/pii/S0034425715000437) in inland lakes and Clarissa Anderson et al (2019) (https://www.frontiersin.org/articles/10.3389/fmars.2019.00250/full?utm_medium=email&utm_source=govdelivery) can be good references for this since the HABs studied by both groups can have very serious consequences on the local populations of not only humans but also marine mammals. The mentioned references also have an extensive list of previous works that can also be useful.

Question 5: How would one "unmix" the Landsat data at a specific pixel in the code (for showing the floating vegetation more clearly)?
Answer 5: If by “unmixing” you mean selecting a single band from the sensor, you can certainly do that! Here are some links that describe how to select and display information about bands in GEE:
https://developers.google.com/earth-engine/apidocs/ee-image-select
https://developers.google.com/earth-engine/tutorials/tutorial_api_02
You can see the values for a specific area by clicking on your area of interest while using the “Inspector” tab on the top right area of GEE’s user interface. When you do this with the code we used today, the only value that comes up is the NDCI value because that’s the only “band” we’re adding to the map below.

Question 6: Would it be possible to optimize some parameters derived from MODIS with higher spatial resolution images, such as Sentinel or Landsat?
Answer 6: You can apply similar approaches to Landsat or Sentinel datasets. Here's a paper by Brandon Smith et al (2021) who used Landsat data for this purpose: https://www.frontiersin.org/articles/10.3389/frsen.2020.623678/full, and another one from the same group but with Landsat and Sentinel datasets: https://www.sciencedirect.com/science/article/pii/S0034425721005800.

Question 7: Is there an indicator that measures the major oil spills in the sea?
Answer 7: Here's a fairly recent paper by Chuanmin Hu et al (2021) on what is really possible to detect with remote sensing in terms of oils spills: https://spj.science.org/doi/full/10.34133/2021/9141902?adobe_mc=MCMID%3D13000814905405683995335849378418609464%7CMCORGID%3D242B6472541199F70A4C98A6%2540AdobeOrg%7CTS%3D1688860800.

Question 8: When studying the evolution of a reservoir, we need to determine the volume occupied by sediment deposits at the bottom of the basin. How can we quantify the volume of these sediments or measure the depth of the water or the topographic level of the basin bottom?
Answer 8: You will need to use other techniques (not optical) to come up with a bathymetric map of the reservoir and then try to estimate the sediment concentration or volume with in situ collected data (g/l or similar), I think.

Question 9: Could you share the bibliographic reference of study done on suitable indices to map seagrass the presenter referred to?
Answer 9: The NDAVI paper by Villa et al (2014) in Remote Sensing of Environment is: https://www.sciencedirect.com/science/article/pii/S0034425715301711.

Question 10: Can AVW be used to describe wave action?
Answer 10: No. AVW is a measure of the color of the water.

Question 11: If a saltwater lagoon system in a highly developed (urban-residential) area has added a dye in an effort to minimize potential eutrophication (in this man-made lagoon, a in saltwater marsh ecosystem that spans 19.83 mi^2), how or what resolution and/or combination of indices would be appropriate to identify sources and areas of accumulation of certain pollution (i.e., waste matter

of animals vs. human sewage outlets)? I am concerned that the dye in combination with the small size of the sample area may be difficult to employ an appropriate algorithm due to the dye (blocking light, for eutrophication minimization). Any ideas on what to use/research to combine in order to address this?
Answer 11: I would think this type of assessment would require a very detailed in situ spectral data collection in different areas within the site to determine the spectral differences between areas with or without dye. Photosynthetic pigments such as chlorophyll or others have specific absorption in different parts of the spectrum as we saw in the webinar. The detection (or not) of phytoplankton in areas affected by the dye will depend on the absorption properties of the dye and whether those interfere with those of the photosynthetic pigments.

Question 12: What does the "QA60" in the cloud masking code come from?
Answer 12: QA60 is the bitmask band with cloud mask information. QA stands for "Quality" while 60 is the resolution in meters. You can learn more about how the QA60 band is created here:
https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-2-msi/level-1c/cloud-masks.

Question 13: In terms of index results, what are the differences of S2_SR with S2_SR_HARMONIZED collection data in GEE?
Answer 13: The HARMONIZED collection shifts data in newer scenes to be in the same range as in older scenes. You can read more about it here:
https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S2_HARMONIZED#:~:text=The%20HARMONIZED%20collection%20shifts%20data%20in%20newer%20scenes,as%20observation%20of%20inland%20waterways%20and%20coastal%20areas.

Question 14: In the GEE demo, why was the land around the lake not masked?
Answer 14: Since this is an introductory webinar, we didn't want to overwhelm the demonstration with any masking other than cloud masking. You can learn more about masking in GEE here:
https://developers.google.com/earth-engine/apidocs/ee-image-mask
https://developers.google.com/earth-engine/tutorials/tutorial_api_05.

Question 15: Why not use the Python language instead of Javascript in Google Earth Engine to calculate the indices?

Answer 15: Both are great! The process for calculating indices is the same, regardless of coding language, so I would suggest you use whatever is most comfortable for you.