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 Kelly Luis (kelly.m.luis@jpl.nasa.gov), Anthony Campbell (anthony.d.campbell@nasa.gov), or Cheryl Doughty (cheryl.l.doughty@nasa.gov).

Question 1: Are there libraries of spectral signatures of saltmarsh species?
Answer 1: Yes, the USGS spectral library includes salt marsh species. It can be found at the doi below.

Kokaly, R.F., Clark, R.N., Swayze, G.A., Livo, K.E., Hoefen, T.M., Pearson, N.C., Wise, R.A., Benzel, W.M., Lowers, H.A., Driscoll, R.L., and Klein, A.J., 2017, USGS Spectral Library Version 7: U.S. Geological Survey Data Series 1035, 61 p., https://doi.org/10.3133/ds1035.

Question 2: I am trying to run a code of forest extent mapping over the entire area of Cote d'Ivoire, but GEE keeps returning the following error messages: user memory limit exceeded. Could anyone kindly guide me on how to resolve this?
Answer 2: I would suggest running the code for sections of your study area. Chunking your code may help.

Question 3: Can you share more information about methodology validation for historical images? Please link some of the research articles.
Answer 3: Check out Olofsson et al 2014 for suggested practices in accuracy/validation of landcover changes. Your validation analysis will depend on what historical data and imagery are available.
https://www.sciencedirect.com/science/article/pii/S0034425714000704

Question 4: Is it possible for salt marsh, seagrass, and mangrove to overlap in a single map?
Answer 4: Yes! In the section on co-occurring blue carbon ecosystems, we covered one example from Florida where these 3 ecosystems meet. There are many places globally where salt marsh, seagrass, and mangrove co-exist, but may or may not be currently mapped in global datasets.

Question 5: Is there any index to identify salt marshes?
Answer 5: There are many indices used in mapping salt marshes including many of the most common such as NDVI and NDWI. In general what index performs best would depend on your study question and study site.

Question 6: How can we estimate carbon in soil that you explain in the last slide (slide #soil organic carbon map)?
Answer 6: The full methods that went into spatially predicting soil organic carbon in tidal marshes are available in the related paper by Maxwell et al. (2024 https://www.nature.com/articles/s41467-024-54572-9). Their model uses a variety of parameters including satellite derived (NDVI), landform (slope, elevation), modeled (tidal amplitude) and others.

Question 7: For salt marsh and seagrass mapping, how can temporal variability (e.g., tidal cycles and vegetation seasonality) be accounted for in classification models to minimize misclassification errors?
Answer 7: There are many approaches to account for the seasonality and tidal cycles including the DECODE algorithm targeted at mapping by including tides and seasonality as parameters in the time series analysis. Other approaches seek to filter and quantify inundated data such as the FLATS algorithm.

Xiucheng Yang, Zhe Zhu, Shi Qiu, Kevin D. Kroeger, Zhiliang Zhu, and Scott Covington. "Detection and characterization of coastal tidal wetland change in the northeastern US using Landsat time series." Remote Sensing of Environment 276 (2022): 113047. https://doi.org/10.1016/j.rse.2022.113047. [DECODE v1]

Narron, C.R., O'Connell, J.L., Mishra, D.R., Cotten, D.L., Hawman, P.A. and Mao, L., 2022. Flooding in Landsat across tidal systems (FLATS): An index for intermittent tidal filtering and frequency detection in salt marsh environments. Ecological Indicators, 141, p.109045.

Question 8: What specific challenges arise when distinguishing salt marsh and seagrass ecosystems in areas with overlapping vegetation types or high turbidity, and how can remote sensing tools address these issues?
Answer 8: Discrete habitat boundaries are one of the largest challenges in creating these maps, approaches that allow for overlap (fuzzy boundaries, etc) between

ecosystems can provide insight but complicate the carbon monitoring aspect of mapping blue carbon.
Satellite data with frequent revisits is critical for mapping seagrass in high turbidity regions. There is no guarantee that a clear image will be acquired by the higher revisit time increases the likelihood of acquiring such an image.

Question 9: Are there any examples of seagrass mapping by sourcing images from PlanetScope's Dove satellites?
Answer 9: Yes, there is great work being done mapping seagrass with PlanetScope data. Including work in the Chesapeake Bay and Seychelles.

Hill, V.J., Zimmerman, R.C., Byron, D.A. and Heck Jr, K.L., 2024. Mapping Seagrass Distribution and Abundance: Comparing Areal Cover and Biomass Estimates Between Space-Based and Airborne Imagery. *Remote Sensing*, *16*(23), p.4351.
Lee, C.B., Martin, L., Traganos, D., Antat, S., Baez, S.K., Cupidon, A., Faure, A., Harlay, J., Morgan, M., Mortimer, J.A. and Reinartz, P., 2023. Mapping the national seagrass extent in Seychelles using PlanetScope NICFI data. *Remote Sensing*, *15*(18), p.4500.

- Planet images are available for free through ESA but require a proposal https://earth.esa.int/eogateway/missions/planetscope#data-section. Planet also provides access to students and academics: Education and Research Program | Planet. The example scripts in this training do not utilize planet and demonstrate methods for mapping blue carbon that are completely free and open source.
- You can also access some composites of Planet imagery for free through the NICFI program: https://www.planet.com/nicfi/; https://www.nicfi.no/2024/09/17/nicfi-prolongs-public-access-to-high-resolution-rainforest-satellite-images/

Question 10: How can uncertainty in carbon stock estimates from global datasets be reduced to align better with localized management practices and reporting requirements under frameworks like the Paris Agreement?
Answer 10: Wetlands, especially coastal ones, like the blue carbon systems discussed today represent a lot of uncertainty in global carbon budgets. That is because wetlands across the world are diverse and responding to diverse drivers of change. We need to map at scales that capture the relevant variability for reporting.

Question 11: In areas with overlapping blue carbon ecosystems, such as salt marsh-mangrove ecotones, what methods can be used to accurately delineate boundaries and ensure correct carbon accounting?

Answer 11: These regions would benefit from mapping at higher spatial, temporal, and spectral resolutions.

Question 12: The demonstration highlighted the use of Google Earth Engine for mapping and carbon accounting. Are there specific recommendations for enhancing model accuracy when applying these tools in regions with sparse in-situ data?
Answer 12: Check out Olofsson et al 2014 for suggested practices in accuracy/validation of landcover changes. Your validation analysis will depend on what historical data and imagery are available.
https://www.sciencedirect.com/science/article/pii/S0034425714000704

Question 13: How can EO tools be used to monitor fine-scale changes in salt marsh and seagrass dynamics that are sensitive to climate and anthropogenic stressors?
Answer 13: The trick to monitoring is having satellite imagery over time, the trick to monitoring fine-scale changes is to have higher resolution imagery. We are limited by what data is available to us. Check out Planet imagery for its high spatial and temporal resolution. Check out Bullocke et al. for an example of monitoring landcover change using high density time series data:
https://www.sciencedirect.com/science/article/pii/S0034425719301634#f0025

Question 14: How is L band data from the upcoming NISAR going to help in the estimation of blue carbon stock? Will it be polarimetry or interferometry that will be the game changer? Also, the S-band data will mostly get bounced by the top of the canopy, I guess, so what information on biomass can we get from it?

Answer 14: NISAR will be most useful for estimating biomass in mangrove environments but could also be informative for mapping inundation extent in salt marshes. The top of canopy measurement from the S-band will likely be very useful for developing global models of canopy height and in turn biomass. This approach has been done previously using both SRTM and TanDEM-X data.

Simard, M., Fatoyinbo, L., Smetanka, C., Rivera-Monroy, V.H., Castañeda-Moya, E., Thomas, N. and Van der Stocken, T., 2019. Mangrove canopy height globally related to precipitation, temperature and cyclone frequency. *Nature Geoscience*, *12*(1), pp.40-45.

TanDEM-X data: https://daac.ornl.gov/CMS/guides/CMS_Global_Mangrove_Forest_Ht.html

Question 15: Why don't you check the heterotrophic activity in the salt marsh? Is there a GEE function for that?
Answer 15: We may be able to look at heterotrophic activity, using similar approaches to what we've seen today, by pairing data from the field with the images we capture with satellites. The first step is to develop algorithms that relate your metric of heterotrophic activity to the satellite data. Conversely, you can measure the impacts of heterotrophic activity if it causes a detectable change in the landscape. For example, crab burrowing can change saltmarsh cover and alter carbon storage.

Question 16: In the last portion by Cheryl, are we calculating a blue carbon capacity zone or blue carbon storage (unit) for each ecosystem?
Answer 16: We are estimating carbon stocks based on the best available information available on ecosystem extents.

Question 17: Are there tools to measure and monitor carbon fixation and fluxes in the ocean ecosystems on a global and regional scale for carbon accounting?
Answer 17: This is an area of active research, but relies on similar "upscaling" approaches we've discussed today where data from the field are paired with remotely sensed imagery to "upscale" our ground estimates to predict over a larger area. In terms of fluxes, in coastal areas we are looking to take flux data and upscale.

Question 18: In the protocols for measurement, monitoring, and reporting of structure, biomass and carbon stocks in mangrove forests, Kauffman and Donato highlight approaches for quantifying uncertainty from carbon pools. There have also been training sessions on performing this using field data. However, I am interested in estimating uncertainties from carbon pools estimated using earth observation techniques. The verra methodology recommends robust uncertainty estimation techniques. How is this done?
Answer 18: This training is focused on mapping ecosystem extents. Robust uncertainty for spatial data can be quantified using accuracy assessment approaches such as those from Olofsson et al 2014.
https://www.sciencedirect.com/science/article/pii/S0034425714000704.

Question 19: Landsat seems to struggle to detect saltmarshes. Is that related to its spatial resolution?

Answer 19: Partly, but this example highlights the tradeoffs between spatial and temporal resolution. In order to compare to high resolution data, we opted for one image in time from each of the four sensors, which were taken at different dates.

Question 20: We are working on seagrass mapping for a remote area in Indonesia. It is a fairly large area, and we can only collect a small part of the seagrass field data. How can we estimate carbon for such a situation?
Answer 20: Yes, remote sensing is ideal for just this type of carbon estimation. You can utilize your field data along with extent to get an estimate of the carbon for the larger region.

Question 21: Does SAR (microwave) have any role / application in mapping blue carbon?
Answer 21: Yes, SAR has many applications in mapping blue carbon ecosystems. Global Mangrove Watch (https://www.globalmangrovewatch.org/) utilizes SAR for mapping mangrove extent

Question 22: Considering the impact of climate change on vegetation traits and carbon sequestration....is it important to take field data like DBH and other or is the SAR data good? How much accuracy between them on GEE on specifically arid and semi arid regions?
Answer 22: In many cases we would want to compare what we measure in the field against what we measure with remote sensing to check that the remotely sensed data is accurate in our region. This is especially true if arid and semi arid mangroves are not well represented by global data. Again, this is determined by what data may be available, and using the best available data whether from the field or GEE.

Question 23: What strategies can be employed to align blue carbon ecosystem datasets with national adaptation and mitigation plans, ensuring they are accessible and actionable for policymakers at both local and global levels?
Answer 23: Standard methods and units for reporting blue carbon datasets are helpful to align local to global levels. We have highlighted the International Panel for Climate Change (IPCC) Global Protocol for Community-scale greenhouse gas emissions (GPC) need for tier 3 data that captures local carbon emissions for which remote sensing of blue carbon can benefit.

Question 24: What is the throughput of gas impurities?

Answer 24: This is a great question that goes beyond the topics covered today. Today we covered how to improve estimates of mapping extents and stocks of Blue C ecosystems from which change in blue carbon have been estimated. This question pertains to fluxes, another way to describe throughputs (a volume of gas moving through a plane per unit time). Quantifying gas fluxes in wetlands is being measure across the globe with FLUXNET (https://fluxnet.org/) and using this info with remote sensing is an active area of blue carbon research (e.g., https://earth.gsfc.nasa.gov/acd/campaigns/nasa-carbon-monitoring-system-blueflux).

Question 25: I am interested in looking at elevation/depth of sea grass etc. I am aware at a high level that sea level contours can be derived from time-series images. Can you tell us more about this and provide some resources/references.
Answer 25: Pairing optical and lidar data can be used to map shallow coastal regions with high accuracy. See this paper from Thomas et al. 2022. “A Purely Spaceborne Open Source Approach for Regional Bathymetry Mapping” https://ieeexplore.ieee.org/abstract/document/9834969