Questions & Answers Part 1

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 Amita Mehta (amita.v.mehta@nasa.gov) or Sean McCartney (sean.mccartney@nasa.gov).

Question 1: On Global Water Measurements portal, what is the criteria to include lakes in the dataset? There are some lakes that do not have data from specific satellites (e.g., Lake Velasco Ibarra does not have SWOT data), does the website pick only one satellite source? If it does, how does it make the selection? Can one access the data for smaller lakes not visible on GWM website?
Answer 1: That depends on the lake size. Many lakes < 100 km2 are not included. The resolution of the altimeter determines what lakes get included.

Question 2: Can you elaborate more on the understanding of high resolution measurement (~200 m) of SWOT?
Answer 2: The actual resolution of the SWOT depends on the data product being leveraged. Over inland water bodies the satellite samples and returns data at a higher rate than over the ocean. This is considered "high rate" data, which is then further processed on the ground to provide user's data products, such as a raster image, which can have a gridding on the order of ~100 m. That is derived from higher resolution products such as the pixel cloud mask.

Question 3: Can we measure the lake level of any lake from the world or specific lakes? Is the data available just for the specific lakes? Is there a way to get the raw data from the satellite with all its spatial extents?
Answer 3: For SWOT: There is some a priori information that informs the raw data processing. This information can determine where the lake products are processed. If a lake is in that database, then there should be lake elevation data available. The "raw" data would be the level 1 interferogram products. This would require significant processing to turn into elevation of a lake. It is not recommended for a typical user to start from the L1 data. We recommend instead using the pixel cloud product to generate your own water surface elevation estimates.

Question 4: Can GEDI mission data be used similar to the ICESAT-2? The wavelength for GEDI is in Infrared unlike ICESAT, does that matter for water altitude calculation?
Answer 4: Yes, it is possible. Please see https://doi.org/10.1016/j.rsase.2024.101213 for example.

Question 5: Are river cross sections/bathymetry generated?
Answer 5: Bathymetry is not a variable provided in the current SWOT data products. With many repeat observations of river width and WSE, a portion of river bathymetry could be derived. This is an active area of research.

Question 6: Why is WISP limited to the US?
Answer 6: WISP is developed by the US Geological Survey (USGS), a federal agency within the US. This partnership between NASA and USGS focuses on serving the US water information needs. We will address this in Part-2 when the use of WISP will be demonstrated.

Question 7: For SWOT data, when looking at the SWOT_L2_HR_Raster_100m raster product, what metrics would you use to filter for high confidence since elevation, area, etc. components have their own confidence and uncertainty components?
Answer 7: There are a variety of variables in the SWOT raster product you can use to filter. Some good starting points are:

- Wse_qual and water_area_qual: quality flag of the wse and area measurements
- Wse_uncert and water_area_uncert: uncertainty of wse and area measurements
- Water_frac: the fraction of each pixel that is identified as water (removing low water_frac pixels can significantly reduce noise)

See the product documentation for all variable fields:
https://search.earthdata.nasa.gov/search/granules/collection-details?p=C2799438271-POCLOUD&pg[0][v]=f&pg[0][gsk]=-start_date&q=swot%20raster

Question 8: How can ICESat-2 and SWOT data be related from their different spatial resolutions (e.g. 11 m footprint vs ~100 m?
Answer 8: The comparisons would need to be done over similar water bodies and then sampled to similar time and space resolutions. This process is typically done by taking the higher resolution product and manipulating (e.g., averaging) to a lower resolution.

Question 9: For Global Water Measurements dataset, height variations are relative to what? Geoid, ellipsoid, initial water level, etc.
Answer 9: With respect to a Geoid. Please refer to https://blueice.gsfc.nasa.gov/gwm/html/WATER-MONITOR.faq.pdf for specific information.

Question 10: When we saw the name of different satellites on GWM website, there were 10 Hz or 20 Hz given. What do they point at?
Answer 10: These frequencies show tracking rates. As we saw, satellite position is important to derive water surface heights. These are the frequencies used for tracking satellite position.

Question 11: If we want to operationalize the data acquisition in order to provide an EO service, will we be dealing with any kind of quotas? e.g., limited bandwidth after too many downloads per month etc. (similar to the copernicus dataspace ecosystem)
Answer 11: We are not aware of any NASA Earth Data download or access quotas. If you are using some of the larger SWOT data products (e.g. high rate pixel cloud) over large spatial/temporal domains, you may be limited by your own internet bandwidth, storage, and computing power.

Question 12: How long will SWOT continue to make measurements? At one point, I recall it was planned for about three years. How accurate are SWOT measurements of river/lake height, width, and slope?
Answer 12: SWOT's planned science mission is 3 years, but that doesn't mean it will stop measuring after 3 years. Historically, altimetry missions have outlasted their initial mission design length. In regards to accuracy of SWOT measurements, numbers say that we are measuring past the minimum requirements. We will include numbers in the final document. 1.7 cm/1km for 10km length reach of rivers larger than 100m wide https://swot.jpl.nasa.gov/system/documents/files/2176_2176_D-61923_SRD_Rev_B_20181113.pdf

- Lakes:
    - WSE 10 cm error or better for water bodies larger than 1 km^2 and 25 cm error or better for water bodies between $(250m)^2$ and 1 km^2
- Rivers:
    - WSE 10 cm error or better for river reaches with surface area larger than 1km^2 and 25 cm error or better for river reaches with surface area between $(250\ m)^2$ and 1 km^2

    - Slope 1.7 cm/1 km for 10 km length reach of rivers larger than 100 m wide
- Surface Area: Relative error smaller than 15% of total water body area for lakes larger than (250 m)^2 or for 10 km river reaches wider than 100 m.

Question 13: What is the main difference between the acquisition technique used with SAR and that used with altimetry satellites?
Answer 13: SAR has 'moving' or synthetic antennas that create images, generally with high resolution. Altimeters through a pulse and and measure time of echo and convert that to surface elevation. We will provide references with details.
Conventional Nadir Radar Altimetry: This technique operates by transmitting radar pulses directly downwards (at nadir) and measuring the time it takes for the pulse to reflect off the surface and return to the satellite. It essentially measures the range to the closest point on the surface within a relatively large footprint. Data is collected along a narrow strip directly beneath the satellite.
SAR Altimetry: In contrast, SAR altimetry utilizes the Doppler effect by processing a series of radar pulses transmitted as the satellite moves along its track. By coherently processing the echoes from multiple pulses over a synthetic aperture, SAR altimetry can synthesize a much longer antenna. This allows for a significant improvement in along-track spatial resolution, effectively "focusing" the radar beam and reducing the footprint size in the along-track direction.

Question 14: Can I use "suspect" data quality points? they are the only ones available in my case.
Answer 14: There is an ongoing reprocessing campaign right now that is transitioning the products to Version D. You may want to check the new dataset when it becomes available since the suspect data may be changed based on updates to the algorithms. If the data remains flagged as suspect, then it is likely questionable and should be treated with caution.

Question 15: SWOT measures water surface height, but can we get depth from it?
Answer 15: SWOT provides data relative to a terrestrial reference frame. More on the reference frame can be found here. SWOT does not penetrate the water surface, so depth information must be derived by bringing in additional data sources (e.g. DEM or bathymetry).

Question 16: I have found some SWOT WSE, and slope observations (from vector products) in Missouri Basin, having width less than 100m (quality flag between

1-2), why is that if it can see rivers more than 100m width? Should we request data processing for better quality or higher resolution, or is it available on demand—particularly for river level data?
Answer 16: Certain high priority reservoirs/rivers have been added to the database that SWOT processing leverages to transform the interferograms to WSE. This is possible because the KaRIn instrument is doing better than mission requirements and we can successfully resolve many water bodies smaller than 100 m. However, we cannot process all of them. The determination comes from the a priori database: http://gaia.geosci.unc.edu/SWORD/

Question 17: Is there a way of processing this data in the cloud, I guess they might have very high memory requirements?
Answer 17: SWOT data is available in the AWS cloud. Here is a tutorial: https://podaac.github.io/tutorials/notebooks/datasets/SWOTHR_s3Access.html

Question 18: I am particularly interested in the variations in water levels of small lakes (there are about 300,000 lakes in Finland). Did I understand correctly that the resolution extends to water bodies as small as 250 m^2?
Answer 18: The specification is actually $(250\ m)^2$, or about 62,500 m^2. The prior lake database has water bodies as small as 10000 m^2. More information on the prior lake database can be found here:
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023WR036896
The database itself can be downloaded from CNES's hydrology data portal:
https://hydroweb.next.theia-land.fr/

Question 19: Is land area filtered out/not measured so only water pixels are represented?
Answer 19: The pixel cloud contains both water and land pixels and requires filtering by classification to get only water detections. The raster product contains only water pixels, but contains a field for the fraction of water within each grid cell, so some grids are a mixture of land and water. The lake and river products both represent only the water surface.

Question 20: If I wanted to look at a river from source to mouth, and it crosses swaths, would I need to locate all the swaths (or tiles or scenes) that the river crosses and stitch it all together?
Answer 20: We will have more information about this in Part-2 with a demonstration of SWOTViz and WISP. You generally will need to stitch the tiles together along the length

of a river. Here is a tutorial that shows how to get river data for all reaches associated with a given river:
https://podaac.github.io/tutorials/notebooks/DataStories/SWOTHR_Science_Application_localmachine.html

Question 21: How do snow and aquatic vegetation growth affect the quality of SWOT products?
Answer 21: Aquatic vegetation does not strongly affect the returns. Over land, such as in wetland areas, SWOT is performing quite well. Please see the recent publication: Kica, S., Pavelsky, T. M., Fayne, J. V., & Williams, B. A. (2025). SWOT Water Surface Elevation in Herbaceous Wetlands of Florida's Everglades. Geophysical Research Letters, 52, e2025GL114956. https://doi.org/10.1029/2025GL114956

Question 22: Does SWOT provide simulations of rivers and lakes in which their measurements lengths and volume changes according to the position we move it to?
Answer 22: None of the current standard SWOT products includes simulations and are based solely on observations and a priori information.

Question 23: What is the accuracy of water elevation observation? +-1 cm 1+10 cm, +-5 cm? Or does it vary?
Answer 23: Yes, the accuracy varies with satellites from 3-5 cms. As referenced before, SWOT is currently exceeding the minimum requirements. See question 12.

Question 24: Can you explain the parameters under SWOT Level-2 HR Raster-100m?
Answer 24: Related on how to filter the raster product. The main features are the WSE and Water area estimates (variables). Refer to Q7.

Question 25: To clarify- one SWOT image is a radar image and we need two images to make an interferogram? Or is it an interferogram itself? If the second is correct, what images are being used to create the interferograms? I have downloaded a couple of images and each file has several raster layers.
Answer 25: The SWOT satellite has two radar antennas and with each observation, generates an interferogram between these two antennas. We recommend using higher level products than the level 1 interferograms as considerable processing is needed to turn these into water surface elevation and extent data. For more detailed explanation of how the sensor works, see the user handbook:

https://deotb6e7tfubr.cloudfront.net/s3-edaf5da92e0ce48fb61175c28b67e95d/podaac-ops-cumulus-docs.s3.us-west-2.amazonaws.com/web-misc/swot_mission_docs/D-109532_SWOT_UserHandbook_RevA_20250311_sig-final.pdf?A-userid=None&Expires=1747255766&Signature=H61f4RpN~7mhO~dQ5B-il0Zmsb3cszkRAxsvewfp6AEAwWbnvuar2SiQL8AmbSeZhgP6B9IV4aHoq8Dt-XIaNimdOCZx2qs2bcjd4jqK-BS929cFdPqMRzUt1ItOutBEXo1bjHyrRLAseLpQBMdNqhCV7rhQ7l5M7tiwMBFLH4M~1izDJj-94QstOJWm3TW1r~i-PIxl2eEPmwAV9jexts1YxwiPRnfG-cMXD752qhI2ZAHoUWaskm5jC8aFPILJNh~xz91mEyx-AP9hIJ4wHubgRy7n53MX4Y36laGDJzmGnNwK7kwqeOlies4RaI2JcPFP~yM1Z8~h~N42qRAGaw__&Key-Pair-Id=K2X9OXGALFC0Q2

Question 26: What is the difference between Obs Unassigned and Prior?
Answer 26: For every lake observation, you will get 3 types of products. Observed (Obs), Unassigned and Prior.
Prior is referenced directly to the database with one water body in the database equating to one water body in the product. Obs is also in reference to the database, but allows lakes to split and join. Unassigned captures all detected water bodies that do not have entries in the prior database. More information can be found here: https://deotb6e7tfubr.cloudfront.net/s3-edaf5da92e0ce48fb61175c28b67e95d/podaac-ops-cumulus-docs.s3.us-west-2.amazonaws.com/web-misc/swot_mission_docs/pdd/SWOT-TN-CDM-0673-CNES_Product_Description_L2_HR_LakeSP_20250307_RevC_signed.pdf?A-userid=None&Expires=1747255726&Signature=QltSV5ucQhv3WNfrKFGtORASPu3rdK5UYyaWsE1b4ivPIcmaGC0aJkga91JhC~QGFWmedQBaRB1g-AKyysGTL0OzyCzC1Jwv8GJq9mS9ogdopKxDtZvxKZQe87degwELIUocdtmxn3VNc8gyeN2vkRaM2yrnSqTNsmHeKVK7JrxoJcSHcziB2S1CVU50f86-JXUtgg2k1iAiDD9BeEy2mOUkvd1hhl7nOjiLg71yevbJH-LSmmIDbRBtDTe56zKQRNQPKAN-FSX4wFKyMxPhjAo4JlAPX05uvXy5TolHS3C5~zEnf-iPs0JshppQgiJTA90QKd-DLZ9Lm0ReSwClQg__&Key-Pair-Id=K2X9OXGALFC0Q2

Question 27: All satellite-derived products come with certain limitations or inherent errors, even after processing and filtering. In the case of SWOT, particularly for elevation, river, and lake products, what types of errors or uncertainties should we be aware of?
Answer 27: See Chapter 10 of the users handbook for a comprehensive list of SWOT phenomenology:
https://deotb6e7tfubr.cloudfront.net/s3-edaf5da92e0ce48fb61175c28b67e95d/podaac-ops-cumulus-docs.s3.us-west-2.amazonaws.com/web-misc/swot_mission_docs/D-109532_SWOT_UserHandbook_RevA_20250311_sig-final.pdf?A-userid=None&Expires=1747255766&Signature=H61f4RpN~7mhO~dQ5B-il0Zmsb3cszkRAxsvewfp6AEAwWb

nvuar2SiQL8AmbSeZhgP6B9IV4aHoq8Dt-XIaNimdOCZx2qs2bcjd4jqK-BS929cFdPqMRzUt1ItOutBEXo1bjHyrRLAseLpQBMdNqhCV7rhQ7I5M7tiwMBFLH4M~1izDJj-94QstOJWm3TW1r~i-PIxI2eEPmwAV9jexts1YxwiPRnfG-cMXD752qhI2ZAHoUWaskm5jC8aFPILJNh~xz91mEyx-AP9hIJ4wHubgRy7n53MX4Y36IaGDJzmGnNwK7kwqeOlies4RaI2JcPFP~yM1Z8~h~N42qRAGaw__&Key-Pair-Id=K2X9OXGALFC0Q2

Question 28: Are there any indexes for IDs containing the particular reservoir or continent?
Answer 28: You can get the lake or reservoir ID's from the prior lake database, which is available from CNES's hydrology portal: https://hydroweb.next.theia-land.fr/

Similarly, you can river reach ID's from the prior river database (SWORD): https://www.swordexplorer.com/

Swath oriented products are broken down by continent. For more information about spatial organization of the SWOT products, see this tutorial: https://podaac.github.io/tutorials/quarto_text/SWOT.html#tips-for-swot-spatial-search

Question 29: Can we use this data to estimate water quality parameters?
Answer 29: SWOT only provides water surface elevation data, so nothing about quality (i.e. spectral content). Refer to previous ARSET trainings relating to water quality measurements.

Question 30: How does high relief topography near water bodies impact measurements? For example, the Grand Canyon, Arizona.
Answer 30: High relief topography can have an impact on SWOT observations. The degree of impact is highly dependent on observation geometry.

Question 31: Where can we get data for river flooding for much smaller rivers (<100m) and especially monitoring river levels even if it is cloudy?
Answer 31: SWOT observations are not inhibited by clouds. All of the rivers included in the SWOT processing are in the SWORD database: http://gaia.geosci.unc.edu/SWORD/, as referenced above.

Question 32: How precise is the water extent mapping with SWOT for floodplains, specially for shallow waters in the floodplains? As its Ka band radar and floodplains are covered with vegetation, I wanted to know how precise the inundation mapping (for shallow floods) in the floodplain is.

Answer 32: We refer you to recent publications, as this is an ongoing area of research and results may vary by environment:
Simoes-Sousa, I. T., Camargo, C. M. L., Tavora, J., Piffer-Braga, A., Farrar, J. T., & Pavelsky, T. M. (2025). The May 2024 flood disaster in southern Brazil: Causes, impacts, and SWOT-based volume estimation. Geophysical Research Letters, 52, e2024GL112442. https://doi.org/10.1029/2024GL112442
Kica, S., Pavelsky, T. M., Fayne, J. V., & Williams, B. A. (2025). SWOT Water Surface Elevation in Herbaceous Wetlands of Florida's Everglades. Geophysical Research Letters, 52, e2025GL114956. https://doi.org/10.1029/2025GL114956

Question 33: Can you please elaborate more on how SWOT data can be used for volumetric evaporation study?
Answer 33: In the example presented, the Texas Water Development Board is using SWOT in two ways. First, SWOT observations of lake storage anomaly of unmonitored lakes are used to fill in state-wide reservoir storage budget. Second, surface area from SWOT is used alongside other parameters (e.g. air temperature, humidity, etc.) to estimate evaporative losses.

Question 34: I am interested in hearing more on your research on SWOT analysis and dams. Given the growing trend of dam removals in the U.S., particularly in the West. I'm curious to hear your thoughts on how this might shape the future of water supply planning in the region. Have you observed any key challenges or opportunities emerging from this shift?
Answer 34: A key novelty of SWOT observations within the U.S. is its ability to track storage of small, unmonitored reservoirs. This can provide a more holistic view of regional water resources that can better inform planning.

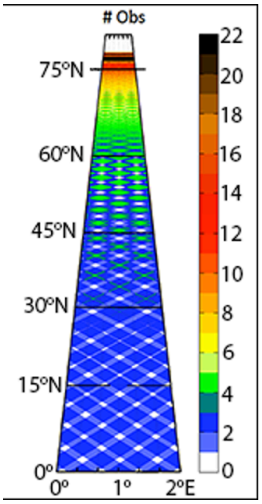
Question 35: With SWOT's 21-day temporal resolution, short-duration floods might be missed if they occur between satellite returns to the same location, right?
Answer 35: Correct.

Question 36: Is there a land topography product if we want to know water_level = wse-topography?
Answer 36: Many locations will have their own regional digital elevation model (DEM).

Question 37: Can we access data on Google Earth Engine?

Answer 37: As of this training, no SWOT products are available in GEE. GEE determines which datasets they bring into their system. You can make requests to GEE directly to provide SWOT data. This is not something that NASA facilitates.

Question 38: Is it 21 repeating cycles for SWOT dataset? If we need a more frequent repeating cycle, what would be the solution?



Answer 38: Some locations have data at higher temporal resolution because the location may be observed by more than one pass of the SWOT satellite. This is a function of latitude. The figure to the right shows the number of observations as a function of latitude. As indicated, higher latitudes will have more revisits than lower latitudes. So while an individual pass will occur every 21 days, there may be multiple passes over a given geographic point.
https://swot.jpl.nasa.gov/resources/89/swot-science-orbit/

Question 39: How can we precisely measure ocean and river tidal variations over mangrove regions in the Bay of Bengal using the altimetry principles of the SWOT mission? Specifically, how does SWOT's Ka-band radar interferometry improve our understanding of tidal propagation and water surface dynamics in complex deltaic environments like the Sundarbans?

Answer 39: SWOT HR data products are not corrected for ocean tides, and therefore, some of the oceanward river elevations do exhibit tidal influence. This is also true for the pixel cloud products. The LR (ocean) data products are distributed with tidal corrections derived from the FES global tide models (differing model versions depending on which SWOT data version you access - see the product description documentation for details). Regarding deriving tidal constituents from SWOT data, this has been done in several locations using the 1-day repeat data of the calibration and validation orbit. Please see the following publications:

Hart-Davis, M. G., Andersen, O. B., Ray, R. D., Zaron, E. D., Schwatke, C., Arildsen, R. L., et al. (2024). Tides in complex coastal regions: Early case studies from wide-swath SWOT measurements. Geophysical Research Letters, 51, e2024GL109983. https://doi.org/10.1029/2024GL109983

Kica, S., Pavelsky, T. M., Fayne, J. V., & Williams, B. A. (2025). SWOT Water Surface Elevation in Herbaceous Wetlands of Florida's Everglades. Geophysical Research Letters, 52, e2025GL114956. https://doi.org/10.1029/2025GL114956

Question 40: Are bad quality flag SWOT lake water pixel cloud data filtered before generating SWOT_L2_HR_LakeSP?
Answer 40: Yes. The Lake SP product quality flags inherit aggregate quality flags from source pixel cloud.

Question 41: Will this data, including the raw NetCDF file, be available on the Earthdata portal (Giovanni) as part of the migration by the end of 2026?
Answer 41: This is a question for the Giovanni team.

Question 42: What is the current processing time for SWOT L2 products?
Answer 42: They have approximately a 3 day latency.

Question 43: Given that SWOT_L2_LR_SSH data has a native spatial resolution of approximately 2 km, what would be an appropriate interpolation resolution for effective visualization and analysis, especially in coastal regions?
Answer 43: The L2 LR SSH data product provides along track sea surface height, sea surface height anomaly, wind speed, significant waveheight, on a geographically fixed, swath-aligned 2x2 km^2 grid, as well as sea surface height on a 250x250 m^2 native grid.
https://podaac.jpl.nasa.gov/SWOT?tab=datasets-information&sections=about%2Bdata
Additionally, Level 3 2 km products can be accessed from AVISO:
https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/swot-l3-ocean-products.html

Question 44: You have mentioned the lake extents will be taken as the average of observed extents in the 21 days will be recorded. But the extent can vary over 21 days, so taking average would not be accurate, right? How do I address these issues?
Answer 44: This is for the cycle averaged product only. You are correct that averaging lake variables within this time may lead to errors. In such cases, the single pass product is more suitable.

Question 45: I have a question about water_frac band in HR_raster, for some pixels water_frac goes beyond 1, how is it possible to have water more than 1 fraction of the pixel? this also happens for the water_area which some pixels have water_area more than the total area of the pixel which is 100*100 or 250*250

Answer 45: This is a known issue with the water fraction estimate that stems from pixel cloud level noise. In practical use, when the water fraction of a raster pixel exceeds 1, then this can be interpreted to be equivalent to a value of 1 for that pixel.

Question 46: If I understood correctly, you advised against using raw pixel values and recommended aggregating the data instead. Could you explain the limitations of relying on raw pixel values and why data aggregation is preferable?
Answer 46: The variables of individual pixel cloud pixels can exhibit higher noise than may be useful. By aggregating these variables over a water surface area, the noise is reduced.