# Questions & Answers Session 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 Erika Podest (erika.podest@jpl.nasa.gov), Amita Mehta (amita.v.mehta@nasa.gov) or Sean McCartney (sean.mccartney@nasa.gov).

**Question 1: Between thermal expansion and ice melting, which one is the biggest driving factor for sea level rise?**

Answer 1: This depends on the time period we're looking at. During the satellite record (~2005 to now), about ⅔ (2 mm) of global sea-level rise is from ice melting, and the other ⅓ (1 mm) is from thermal expansion. If you go back further, the relative contribution does change a bit.

**Question 2: Is there satellite imagery on sea level rise changes for the different Islands in the Caribbean? How do we access this data?**

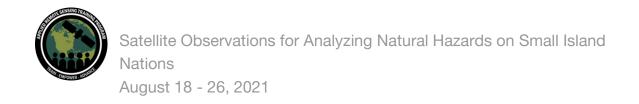Answer 2: Yes! You can access the data for any location across the globe here: https://sealevel.nasa.gov/data_tools/1. The recording for this session includes a discussion of this data access tool. Some of the tools showcased are US centric, but we are working on expanding availability.

**Question 3: It is very interesting - the graph showing the global mean sea level, and I'm wondering how one can get this data?**

Answer 3: This data can be downloaded from a few different spots. One of the easiest is here: https://sealevel.nasa.gov/understanding-sea-level/key-indicators/global-mean-sea-level.

**Question 4: "Mean Sea Level" is meaningless without a Datum. What is the Datum that you are using?**

Answer 4: In the case of the satellites, ocean height measurements are made relative to the geoid. Mean sea level at a tide gauge means something different than the "global mean sea level" (GMSL) from altimetry. GMSL can be viewed as the globally averaged sea level measured by altimeters.

**Question 5: Satellite-derived mean sea level is a global, "ensemble" statistic. Sea level measurements are dynamic and, in any given sample, must be higher in some places and lower, in others. How much variability [Std Dev] is there? Are there locations where SL is consistently high or low?**

Answer 5: Yes, there is a great deal of spatial variability on a range of timescales. In terms of sea-level rise, there are locations that are persistently higher than the global average. On shorter timescales, there can be very large departures (both positive and negative) from the global average. The "standard deviation" from the global average will be very dependent on the timescale you are looking at.

**Question 6: Are there significant changes in areas where there are tectonic plates under the sea?**

Answer 6: Changes in the ocean basins will impact the sea-level change that we measure. While not directly related to this question, a big effect we see in global sea level rise is from glacial isostatic adjustment (GIA). The ocean is actually getting a bit bigger as a result of GIA.
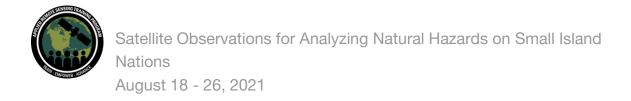
**Question 7: Does El Niño make sea level higher because the East Pacific Ocean is warmer at this phase?**

Answer 7: Yes, during El Niño, the thermal expansion of the warming water in the eastern Pacific Ocean does lead to higher sea levels.

**Question 8: Are global warming and El Niño different things? Is there any connection between them?**

Answer 8: Yes, they are considered two different things. There are two easy ways to explain this: 1) the underlying processes are different, and 2) the timescales are very different. Global warming is a result of increased greenhouse gases that then causes sea-level rise. This is persistent and happens over long time periods. El Niño on the other hand is a natural climate pattern that works on roughly 2-7 year time periods. Now, there is some research that El Niño will change as a result of global warming, so there is potentially a connection between the two!

**Question 9: Is it also possible that sea level can increase due to waste deposits (plastics, etc) at the bottom of the sea?**

Answer 9: The amount of water going into the ocean as a result of melting ice is huge, as is the amount of energy/heat being absorbed by the ocean. The increase in sea level as a result of these processes is much, much larger than anything that could result from waste deposits. But...we definitely shouldn't be putting any extra heat, melted ice, or waste into the ocean!

**Question 10: Can you please explain the mechanism behind loss of ice and its impact on sea level decrease around it.**
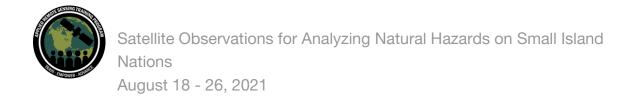Answer 10: When the ice-covered portions of Earth warmed, the ice melts. This meltwater then goes into the ocean. The amount of ice being lost by the ice sheets over time is really very large. So large that losing this ice/water mass changes the gravitational pull of the ice sheets. When there is a lot of ice, these ice sheets actually pull water in the ocean towards them. When the ice sheets lose mass, this pull gets weaker and less water is pulled towards them. So the melt water from the ice sheets gets distributed throughout the global ocean, while the water in the immediate vicinity of the ice sheets falls.

**Question 11: Many countries have established a vertical datum database of points that are used for various applications including planning of engineering structures. The datums are based on mean sea levels that are basically changing due to global sea-level changes as articulated by the training. What happens to these already established datums?**
Answer 11: In the U.S., these datums are evaluated and can be updated. As you note, mean sea level is changing as a result of global warming. NOAA updates tidal datums every 20-25 years as a result of global sea level rise.

**Question 12: To what degree is the observed increase also a result of increased amount of data and/or frequency of recording/analysis? Not debating the result ... just wondering what is the impact of additional and more refined data?**
Answer 12: Because of the satellite measurements, we have much more definitive and statistically certain estimates of global sea level rise. That said, there is a great deal of work and research that goes into looking at past sea level changes and comparing them to present changes. We understand sea level change that has occurred quite well both in the past and in the present.

**Question 13: If sea level changes have a negative global impact, how can we prevent these negative impacts at local, regional and global scales?**

Answer 13: On a global scale, the key is to limit and reduce emissions as much as possible. This is the best way to limit future sea-level rise. On a local scale, there are strategies that can be implemented to mitigate or adapt to the impacts that are being seen. This combination of adaptation and emission reduction is really the best strategy for dealing with sea-level rise.

**Question 14: Would you say that the contributions from ice sheets melting are higher than from water thermal expansion?**

Answer 14: Since 2005, the contribution from ice sheets to global sea level rise has been larger than the contribution from thermal expansion.
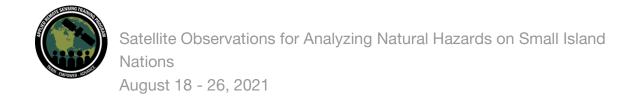
**Question 15: What is the best adaptation & mitigation approach for Indonesia to sea level rising at the regional to local scale as Islands Nation?**

Answer 15: Adaptation and mitigation strategies vary so much from region to region. This is a difficult question to answer, although understanding the processes that are contributing to the sea-level rise problem is an important first step towards designing and implementing adaptation and mitigation strategies.

**Question 16: If dams and reservoirs have affected sea level, how do droughts affect it? Where is all the water going in the global water balance?**

Answer 16: When there is a significant movement of water between ocean and land, this does get seen in global mean sea level. One drought in a particular region may not show up strongly in global mean sea level, but something on global scales will. Actually, during a La Niña, there is an increased movement of water from ocean to land that results in a drop in global mean sea level.

**Question 17: Can the tools at the NASA sea level portal be used to assess sea level change and rise in other countries as well, or is it only for US territories?**

Answer 17: Our goal is to provide the tools for the entire globe, but some of these are a work in progress. All the tools discussed in this training should be global in scope within the next month or two.

**Question 18: Can I use these tools to project flooding along the shores of an inland lake like Lake Victoria?**

Answer 18: We do not have projections for inland lakes at this time. Other data would be needed to make this assessment. To learn more about how NASA monitors surface height of inland waters, refer to the ARSET training below:

https://appliedsciences.nasa.gov/join-mission/training/english/arset-mapping-and-monitoring-lakes-and-reservoirs-satellite

**Question 19: Is it possible to download different satellite data for individual sites as a csv file?**

Answer 19: We are working to make the data more accessible. This is on the list of things to do! Currently, the IPCC projections in our tool are available as a csv file. We're working to implement this across tools.

**Question 20: Can the NASA tool be used to model or simulate inundation due to sea level rise or high tide flooding at a local scale?**

Answer 20: We don't have this available for the IPCC projections shown in this webinar. Other organizations such as Climate Central do have such tools.

**Question 21: Does natural sea level variability have to do with astronomical gravitational changes?**

Answer 21: Yes, as an example, the moon drives changes in our tides over a range of timescales. The moon wobble discussed will also be a significant factor in increased flooding in the future.
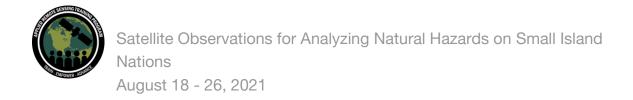
**Question 22: Do we have access to this platform?**

Answer 22: The NASA sea level portal can be found here: https://sealevel.nasa.gov. The tools discussed are here: https://sealevel.nasa.gov/data/tools.

**Question 23: How do SAR polarizations VV, VH affect our observations?**

Answer 23: They don't really affect our ability to assess subsidence. Below are links to previous ARSET SAR trainings to learn more.

1. https://appliedsciences.nasa.gov/join-mission/training/english/arset-introduction-synthetic-aperture-radar

2. https://appliedsciences.nasa.gov/join-mission/training/english/arset-radar-remote-sensing-land-water-disaster-applications
3. https://appliedsciences.nasa.gov/join-mission/training/english/arset-sar-disasters-and-hydrological-applications

**Question 24: What DEM are you using when analyzing flooding, and how is accuracy of the DEM taken into consideration in the flooding extent, depth and recurrence?**

Answer 24: We are not using any DEM in our flooding analysis. The high tide flooding is a user defined (NOAA) threshold and someone with knowledge of the local area can adjust the threshold.

To do flooding simulations you would need very accurate DEMs.

**Question 25: Is there a relationship between sea level rise and solar cycles?**

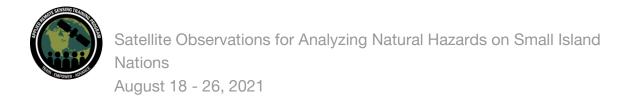Answer 25: No, long term sea level rise does not correlate with solar cycles.

**Question 26: When comparing Small Island Developing States in the Pacific and in the Caribbean, we often hear more about sea-level rise impacts in Pacific Island States, and not much in the Caribbean. Can you confirm with this space-based data that one can see such trends?**

Answer 26: With the satellite data and understanding of sea level rise, we do see these increases in sea level in the Caribbean. Part of this is the difference in drivers of sea level rise and the signals that are observed. Hurricanes are a bigger factor in some of the Pacific Island States.

**Question 27: What tools and layers would be the ones to use in order to build scenarios for Sea Level Rise for projections showing inventories of building structures?**

Answer 27: You would need several layers. The long term projections from the IPCC and an accurate and high resolution DEM would be important. The high tide flooding tool would be important as well. A number of tools and layers would be needed, including the ones shown in the presentation in order to build such scenarios.

**Question 28: Does your team have social scientists that develop planning strategies for island nations with this data? Is there a link to their work?**

Answer 28: I don't currently work with social scientists, but the connections are there.

**Question 29: Philippines is on a small plate. Do you have any recent data that shows the mean global sea level of the Philippines?**
Answer 29: We have very good estimates of sea level rise off the coast of the Philippines using satellite altimetry from 1993 through present. The data is available through the data analysis tool.
Interestingly, sea level rise off the coast of the Philippines has been amongst the highest in the world.

**Question 30: How does one acquire data and perform an analysis for sea level rise projections for areas where there are no tidal gauges installed? For example, I am not seeing on the tidal gauge map any gauge installed on the coast of Sierra Leone.**
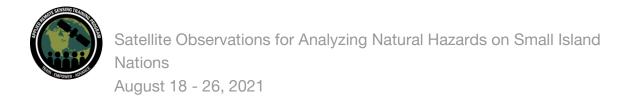Answer 30: Using the IPCC projection tool you can click on any part of the ocean, even if there is no tide gauge, and get an estimate of sea level rise regardless of the location in the ocean. The high tide flood analysis tool however, relies on statistics from a tide gauge and we are therefore limited in the analysis done in areas where there is no tide gauge.

**Question 31: Mean Sea Level has already been adopted as a vertical datum for measuring the heights of various resources. When it is changing with time as has been discussed, how does one deal with the changes when we are measuring heights?**
Answer 31: There needs to be careful and well documented communication between those assessing mean sea level at a local or national level and those that are trying to implement it for planning or infrastructure.

**Question 32: Is there any interlink between inland wetlands with local mean sea level?**
Answer 32: Local sea level and inland wetlands are going to be connected. If sea level increases at the coast then that somehow affects wetland areas. They are closely connected because they are geographically connected.

**Question 33: Can we use SAR data to assess changes in coastlines (coastal displacement)?**
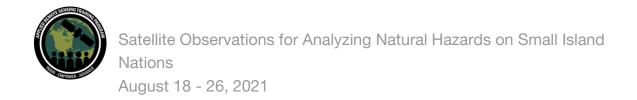Answer 33: Yes, there is SAR data looking at this application such as water extent and coastal changes.

**Question 34: The question about past vs current and high precision data was aimed to get at methods that are being used to reconcile differences in accuracy and precision as well as data collection methods in addition to a number of data points now vs. in the past and how that variance is accounted for in the models and methods.**
Response 34: There are a lot of different in situ observations that we rely on in the past before the satellite record. The strategy in trying to piece out the global or regional sea level contributions vary a great deal between those different observing systems. If we focus specifically on the tide gauges - the maps shown at the beginning of the presentation indicate that there is a geographical distribution and hemispheric bias to those tide gauges. For example, there are more tide gauges in the northern than in the southern hemisphere. There are also more tide gauges located off the coast of North America, Japan and Europe than in other locations. The strategy to make sense of these observations is to account for those regional differences that we have and then still come up with an assessment of global sea level rise. An important piece is how to estimate the uncertainty in the estimate. There is a wealth of literature on how to do this type of analysis using the tide gauges and a wide range of strategies even for the example I showed. There is a lot of careful work being done and we are able to get estimates from that past record with an uncertainty that is small enough that you can assess the change between what we see in the tide gauges in the past and what we see with the altimetry right now. Our estimates are good enough that we can see these changes that are happening through time.
Note that this question and the previous one address a very important topic and there is an enormous amount of work trying to make sense of the observations prior to the satellite record.

**Question 34: Is coastal subsidence more likely in small islands specifically considering decreased freshwater availability and increased ground water extraction (in addition to earthquakes)? Is there a way to predict subsidence based on ground water extraction scenarios via remote sensing?**

Answer 34: I would not say that small islands are more prone to subsidence. I will say that a small island that is doing a lot of ground water extraction - that is going to be a driver of subsidence. We have seen in certain parts of the US coastline that when you reduce the groundwater extraction you reduce the rate of subsidence occurring. In that sense if you alleviate or reduce that cause then you will see an effect. In terms of projecting, it is difficult to say the direct relationship between the rate of groundwater extraction and the rate of subsidence. That needs to be done at a local level. You would however, expect to see a change in the amount of subsidence if you reduce groundwater extraction.

**Question 35: What is the accuracy of the altitudes calculated by space altimeters at the coastal level?**
Answer 35: We are able to get estimates of sea level down to about 1inch or 2.5 cm of accuracy. There are a number of corrections that go into making that assessment such as atmospheric corrections, understanding where the spacecraft is, and correcting when the radar pulse interacts with the surface of the ocean. Once you do that for the spot size, you get about a 2cm accuracy of sea level for that area from space.

**Question 36: ENSO cycles have some interesting teleconnections on precipitation patterns, for example tropical America is becoming more dry during La Niña and the southeast is becoming more wet with exceptional precipitation associated with northeast monsoons. You just mentioned that La Niña results in a drop of global mean sea level. Would the amount of water that is taken up into the atmosphere as water vapour take away their 'volume'?**
Answer 36: Yes. Basically it is a matter of how that water gets taken out of the ocean, the time it spends in the atmosphere, and where it gets dumped on land. There are a wide variety of calculations to make in order to assess where that water sits at any given time. There is a lag for instance between global mean sea level and then changes in precipitation on land or changes in the water mass on land as measured by GRACE. I will note that it is a really good question, which is important to consider. It is not always obvious how an El Niño will affect different parts of the world. Some areas will see increased rainfall and others a decrease in rainfall and it varies from event to event. Every El Niño is going to be different with a different regional response. That is something we are looking at very closely. The satellites play a large role in trying to understand that interplay between the ocean and the atmosphere and the land.