**Copernicus Sentinel-6 measuring sea-levels using radar altimetry**

This November the newest member of the EU’s Copernicus programme, Sentinel-6 Michael Freilich, will take to the heavens from Vandenberg Air Force Base in California. The satellite is named after NASA’s former Director of Earth Observation and is a radar altimetry mission to monitor sea-level rise, wave-height and windspeed.

The mission is a collaboration between ESA, the European Commission, EUMETSAT, NASA and NOAA, with support from the French space agency CNES. It will continue a three-decade-long time-series of radar altimetry missions that started with the Topex-Poseidon mission and was then followed by the Jason missions.

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| Image | Text |
| 10:00:00:00 | **TITLE: Copernicus Sentinel-6****Subtitle: measuring sea-level using radar altimetry** |
| 10:00:08:00* Animation. Sentinel-6 launch with Falcon- 10/09/20 – SpaceX (2 shots)
* Animation. Sentinel-6 launch upper stage bringing satellite into orbit - 10/09/20 – SpaceX
* EXT. calm sea surface with waves – unknown date – stock footage, Storyblocks
* EXT. slow motion shot of wavy sea surface - unknown date – stock footage, Storyblocks
* Animation. Globe with mean sea-level rise – unknown date – ESA
* EXT. aerial-shot-of-ocean-waves-rolling-and-crashing-into-shore - – unknown date – stock footage, Storyblocks
 | **Soon Sentinel-6 Michael Freilich will be launched on top of a Falcon 9 from the Vandenberg Air Force Base in California, USA.** **Sentinel-6 will provide near-realtime operational measurements of sea-surface height, wave height and wind speed. These measurements allow scientists to monitor sea-level rise resulting from climate change, from regional to local scale.**  |
| 10:00:34:06* Interview: Craig Donlon, Sentinel-6 Mission Scientist, ESA - 21 October 2020 - Online from UK English
* EXT. aerial-of-the-ocean-waves-washing-up-on-rocks-slow-motion - unknown date – stock footage, Storyblocks
* EXT. waves-rolling-over-rocks - unknown date – stock footage, Storyblocks
 | **ITW Craig Donlon, Sentinel-6 Mission Scientist, ESA** the main instruments on board include a dual frequency radar altimeter and this is the primary instrument of the mission, and that's the one that's measuring sea surface height, significant wave height and wind speed over the ocean. From those measurements, we can actually have the superb measurements that we expect of sea level rise, but also the waves. //This is important for Marine operations and the altimeters provide perhaps some of them the best data sets that we have today over the global ocean. We have plenty of buoys in the ocean that measure waves, but they're often in the coastal zone. And it's only when you go to the altimetry that you can really have this this global coverage.[00:05:47][53.9] |
| 10:01:18:05* INT. Sentinel-6 in cleanroom – IAGB – Ottobrunn, Germany – nov 2019 – ESA
* Animation. Sentinel-6 operations graphic representation – 2020- ESA/ATG medialab
* Animation. Sentinel-6 instrument overview – 2020- ESA/ATG medialab
* Animation. Sentinel-6 operations in orbit with graphical representation – 2020- ESA/ATG medialab
* Animation. Globe with sea-surface height data – 2020 – ESA/ATG medialab
* Animation. Sentinel-3 meausring sea surface height with radar altimetry – unknown date – ESA
* Animation. Sentinel-6 launch solar panel deployment - 10/09/20 – SpaceX
* Animation. Jason-3 in orbit – unknwon date – NASA
* Animation. Sentinel-6 and Jason-3 measuring sea surface height from orbit – 2020 – ESA/NASA
* Animation. Sea-level rise data Topex-Jason missions – 2020 – NASA
* Ext. Aerial, Svalbard, Norway – Winter 2019 – ESA
* Combined animation. Mean sea-level rise evolution – 2019 – ESA
 | **This brand new radar altimeter is called Poseidon-4 and offers very precise high-resolution altimetry measurements. Other instruments are used together with the altimeter to improve it’s accuracy. With its high precision measurements Sentinel-6 will be the reference mission for all other altimetry missions. And measurements of other satellites will be compared to the data from Sentinel-6.** **At first Senitinel-6 will also fly in tandem with Jason 3 with only 30 seconds between both satellites. This is important to understand and homogenise the differences between successive missions and ensure that the time-series of sea-level measurements from space remains stable.****Long time-series are important to understand climate change and monitor a gradual process such as sea-level rise. They help scientists gauge exactly how much sea levels are rising and how fast they are rising.** |
| 10:02:22:24* Interview: Anny Cazenave, Senior Scientist, laboratoires d'etudes en Geophysique et Oceanographie Spaciale - 21 October 2020 - Online from France - English
 | **ITW Anny Cazenave, Senior Scientist, laboratoires d'etudes en Geophysique et Oceanographie Spaciale** With a long record we can precisely measure the acceleration we eventually can detect regional tipping points for example. If there is run away in the melting Greenland or Antarctica. Sea level will record this run away change because it is an integrator of all change that are occurring in the climate system. So we would be able to see some some change, big changes in the global climate. I would like to add also that a long record is very important to validate the climate models that are developed to simulate future change.[00:11:05][51.1] |
| 10:03:14:18* Still. Artists impression of Topex-Poseidon – 1992 – ESA
* Still. Artists impression of Topex-Jason missions – NASA
* Animation. Sentinel-6 360° view – 2020- ESA/ATG medialab
* Animation. Sentinel-6 fly-by – 2020- ESA/ATG medialab
* EXT. isigny-sur-mer-france-timelapse – stock footage, Storyblocks
* Animation. Sentinel-6 orbit with graphical representation – 2020- ESA/ATG medialab
* Animation. Globe with regional mean sea-level rise 1992 – 2019 – 2020 – ESA/ATG medialab
* Animation. Sentinel-6 360° view – 2019- ESA/ATG medialab
* Ext. Floating ice sheet, Svalbard, Norway – Winter 2019 – ESA
* EXT. aerial-mountain-river-waterfall-frozen-into-hundreds-of-white-icicles-in-winter – stock footage, Storyblocks
* EXT. icicles-melting-ice-spring-rain – stock footage, Storyblocks
* EXT. climate-change-effect-on-the-weather-crating-massive-sea-waves – stock footage, Storyblocks
* Still. Atlantic bed imprinted in gravity – unknown date – ESA
* EXT. mountain-river-in-norway – stock footage, Storyblocks
* Ext. beautiful-nature-norway-natural-landscape-aerial-footage-lovatnet-lake – stock footage, Storyblocks
* Animation. Sentinel-6 360° view – 2019- ESA/ATG medialab
* Animation. Sentinel-1 in orbit – unknown date – ESA
* Animation. Sentinel-5 in orbit – unknown date – ESA
* Animation. Sentinel-2 in orbit – unknown date – ESA
* Animation. Sentinel-3 in orbit – unknown date - ESA
 | **Sentinel-6 will extend and enhance a series of measurements started by the Topex-Poseidon mission in 1992. This mission was succeeded by the Jason 1, 2 and 3 missions, and now Sentinel-6 is taking us to the next level. The orbit in which Sentinel-6 will fly is optimised for limited interference from ocean tide changes, and after almost three decades of radar altimetry missions, is well known to scientists. By continuing and enhancing this timeseries with a new satellite design and high resolution instruments, Sentinel-6 will allow for further climate research and help scientists monitor the effects of climate change.** **Its data can also be used to improve ocean and weather forecasting, map seamounts and other tectonic features of the seafloor, and map rivers and lakes for hydrology purposes such as water and flood management.****Sentinel-6 is part of the European Copernicus programme and will complement the largest operational Earth observation programme in the world.**  |
| 10:04:28:09* Interview: Craig Donlon, Sentinel-6 Mission Scientist, ESA - 21 October 2020 - Online from UK English
 | **ITW Craig Donlon, Sentinel-6 Mission Scientist, ESA** if you think about how in an Earth system context, Copernicus spacecraft are providing more when they're used together. For example, Senintel-3 is providing the sea surface temperature and the ocean biology measurements. Sentinel-1 is providing radar imaging measurements of ocean swell waves, of sea ice. Sentinel-2 provides high-resolution measurements in the coastal zone. And when these are used together, a wonderful view of the Earth’s oceans can be achieved. It's almost like a painting. As you add more colour, you get a brilliant view of our wonderful planet.[00:37:09][33.5 |
| 10:05:01:13* INT. Sentinel-6 in cleanroom – IAGB – Ottobrunn, Germany – nov 2019 – ESA (5 shots)
* Ext. Seascape view evening sun, Italy – 2019 – ESA
* Ext. ishermen-with-fishing-boat-on-beach-in-thailand – stock footage, Storyblocks
* Ext. jakarta-indonesia-laborer-worker-people-life-at-the-old-port-of-sunda-kelapa - stock footage, Storyblocks
* Ext. time-lapse-of-ships-in-tokyo-bay-at-sunset- stock footage, Storyblocks
* Ext. miami-florida-skyline-coastal-view- stock footage, Storyblocks
* Ext. aerial-time-lapse-in-motion-on-a-sunny-day-down-the-coast-in-newport-beach - stock footage, Storyblocks
* Animation. Sentinel-6 launch 360°- 10/09/20 – SpaceX
 | **Sentinel-6 is a unique collaboration between the European Commission, ESA, EUMETSAT NASA and NOAA, with the support of the French space agency CNES. This teamwork underlines once more the satellite’s importance and the how the whole planet can both contribute and benefit from this vital mission. As sea level rises and our planet continues to change, the lives and livelihood of millions of people are at stake. With 10 percent of world population living in coastal zones less than 10 metres above sea level, we need accurate measurements to prepare and to mitigate the effects of sea-level rise and climate change.** |
| **10:05:46:08** | **B-ROLL** |
| Interview: Craig Donlon, Sentinel-6 Mission Scientist, ESA - 21 October 2020 - Online from UK English | **ITW Craig Donlon, Sentinel-6 Mission Scientist, ESA** * Well, the main instruments on board include a dual frequency radar altimeter. And this is the primary instrument of the mission. And that's the one that's measuring sea surface height, significant wave height and wind speed over the ocean. And from those measurements, we can actually have the superb measurements that we expect of sea level rise, but also the waves, the significant wave height, which is the top one third of the waves. If you were to look at them in time. So the biggest waves that you would see. This is important for Marine operations and the altimeters provide perhaps some of them the best data sets that we have today over the global ocean. We have plenty of buoys in the ocean that measure waves, but they're often in the coastal zone. And it's only when you go to the altimetry that you can really have this this global coverage. Now, the altimeter also measures the height of water over rivers and lakes and reservoirs on the land. And this is important for hydrology, for hydrology catchment, water catchment modelling. So from the height of the rivers and lakes, we can then deduce the discharge and the volume of water that's stored. That's important for sea level because the volume of water stored in reservoirs can act as a negative sea level rise. There are other instruments on board. There's a global navigation satellite system, radio occultation missions euh instrument. And this is used to determine vertical profiles of atmospheric temperature and humidity, which is very important for the numerical weather forecasting community, bringing our weather on a daily basis because the orbit and the orientation of the satellite are important for the altimeter measurements. The satellite is tracked by the GNSS the global navigation satellite system, and its velocity is measured using Doppler radio position and the GNSS satellites are exactly the same satellites that you and I both pick up on on our smartphones to know where we are. And using our apps on onboard the phones. All these instruments work together to provide some of the best quality measurements for climate research and the Sentinel-6.
* so Sentinel-6 also includes a microwave radiometer, an advanced microwave radiometer for climate, which is provided by NASA, JPL. And this instrument is used to determine the water vapour loading in the atmosphere. And this is important because water vapour slows the radar pulse travel time on the altimeter. And we need to make a correction for that. And that's what the microwave radiometer to the Sentinel six mission.
* Well, each satellite mission is carefully designed to fulfil a number of specific requirements. So let's take in past missions such as the enivisat mission. This provided a solution that addressed many different requirements using a single, pretty large satellite. Now, while this is great for research and development in an operational context, it's more efficient, it's more cost effective and more flexible to use a number of smaller missions that are optimised for specific tasks. Now, in copernicus, the altimetry constellation is an example where Sentinel-3 is optimised for mesocscale oceanography, where a Sentinel-6 is optimised more for climate related elements. In addition, if you think about how in an Earth system context, Copernicus spacecraft provided more when they used together. For example, Sentinel-3 is providing the sea surface temperature and the ocean biology measurements. Sentinel one is providing radar imaging measurements of ocean swell waves of Sea Ice Sentinel-2 provides high resolution measurements in the coastal zone. And when these are used together, a wonderful view of the ocean can be achieved. It's almost like a painting. As you add more colour, you get a brilliant view of our wonderful planet. And that's just not possible if you only have a few spacecraft. So diversity is really important. And that's what Copernicus is all about, is making sure we have the right spacecraft, the right instruments to paint that wonderful picture of planet Earth.
* Sentinel six is a new satellite mission which is designed to map and measure, monitor sea level rise, next acceleration. And it's part of the European Union Copernicus programme in support of climate change that will also measure wind waves over the ocean. But, of course, sea level rise being a key climate indicator because it integrates the Earth's system. Response to global warming is the core of its activities. And these measurements are going to help us to understand both the causes and the consequences of climate change, Central thinks, is thus a really fundamental component of the Copernicus altimetry constellation, together with Sentinel three, A and B launched a few years ago now.
* So the Times series on this particular orbit started at about 1992 with the topics beside that mission, and it's been continued by Jason Long. Jason, too. Now, Jason three and then sentence six will soon take over. And you need a long time series because you need a long enough record to be able to understand the trends that are occurring. If you only have a year's worth of data, it's very difficult to understand in an annual cycle which has seasons just like we see out of the window every day. Is very difficult to say. Well, you know, is this really a trend or is this just this year's worth of activity? And there's a critical length of data that you need to understand things like acceleration of sea level, because you need to be able to understand how modes of climate variability, such as El Nino or the Pacific Decadal Oscillation, how they map into the measurements that you make, because these are not really telling you much about the trend. What they're telling you about is the natural variability of the climate system. And so those need to be removed. When you when you're looking at linear trends today, what we see in the ultimate record is an acceleration of sea level rise. But superimposed on top of that, of course, is all the climate models. And so when you account for them, those trends aren't so strong. And this is an ongoing area of research that's been actively tapped by several several workers. So, indeed, making sure that we have a long time series is really, really important for the monitoring component. But it's also important if you're a climate modeller, if you're trying to make climate predictions into the future, how do we make sure that we believe those those diverse predictions? What can we do to actually say, well, look, you know, this is some validation? I mean, one way is you just wait and you collect measurements and then you say, okay, I told you. Here's my prediction and these are the measurements. And there you go. But that's not really what we want. That doesn't give you a predictive capability. So one way to do this is to configure your prediction system and run it backwards in time. And when you when you run it backwards in time, you have a whole series of measurements. And those measurements can be compared to the model output. And if there is good agreement, we have good reason to believe as long as the climate system doesn't shift gear into a tipping point and change dramatically. We have great confidence in the ability of our models than to predict forwards in time. And so a long time series helps you to build a robust appreciation of the performance of your climate prediction system.
* This is an important question. There's a big question and I could use many, many different examples to show how altimetry data are used in oceanography today. It's a real revolution. Altimetry has changed the way we view our oceans. But let's start with the top. Monitoring sea level to millimetre accuracy from thirteen hundred and thirty six kilometres in space is pretty good. If you think about it, three millimetres, it's smaller than your finger. This is quite an achievement. Sea surface heights so used to compute estimates of geostrophic ocean currents and ocean circulation patterns that are used together with ocean forecasting systems to give the forecasts that are used by many, many different services in an operational oceanography. People working in shipping, people working in the oil industry. People working in the coastal zones and the managers. This is all or coming from altimetry. Significant wave heights are used to monitor the global ocean-sea state. And this is important for mariners, but it's also important for the insurance industry and the ship designers. They want to know, okay, what is the sea state? What is the sea state? And what does it look like when I have a ship coming for insurance? And how do I design this ship for a particular part of the ocean? Because they're not all the same. Other applications include the study of ocean tides, the solid earth tides, the termination of the marine joyed, mapping of sea mouthes mapping of the heights of rivers and lakes for hydrology. If we think about the Genesis radio occultation measurements, these are used by weather prediction centres to improve weather forecasting, using vertical profiles of temperature and humidity and the microwave radiometer data. These can be used in their own right to estimate water vapour loads in the atmosphere for climate because of course, we have a very stable microwave radiometer on Central six. So the whole host of different activities that are underpinned by altimetry datasets such as the ones that we're going to get from Sentinel six. Michael Freilich.
* Well, in a nutshell, the Sentinel mission is the internationally agreed referenced satellite, which is making measurements to which all of the other satellite altimetry missions are making sea level measurements will be compared to. It means that if there are small differences between missions and different altimeters, then we can reconcile and homogenise those differences. One issue that perhaps people aren't aware of is calibrating an altimeter on the ground. It's quite difficult because we don't have a range on the ground, which is flat and is thirteen hundred and thirty six kilometres long. So there's always a little bit of uncertainty when we launches to the exact range biases that we may have onboard the spacecraft. And so we use a combination of techniques in the commissioning phase to verify and make sure we understand and correct for that in the Maidan database. Onboard the spacecraft, we can use transponders and we can use crossovers with other missions. And one of the things we do with Sentinel six and Jason three, Sentinel six will replace Jason. Three is we will fly back to back just 30 seconds apart to make sure that we have a very, very good understanding of any differences between the two missions. But there's more to it than just that. A reference mission provides a very well characterised measurement system with a very well specified and understood uncertainty, budget of metrological quality reference there almost to the standards organisations.
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| 10:18:55:18* Interview: Anny Cazenave, Senior Scientist, laboratoires d'etudes en Geophysique et Oceanographie Spaciale - 21 October 2020 - Online from France - English
 | **ITW Anny Cazenave, Senior Scientist, laboratoires d'etudes en Geophysique et Oceanographie Spaciale** * What is Radar Altimetry and how is it used?
* History of Satellite radar altimetry and time series and how what can you study with it?
* Sentinel-6 ensuring continuity of timeseries and why this is important.
* Contribution of Sentinel-6 to measuring sea-level rise in coastal areas
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| 10:25:43:01* Interview: Anny Cazenave, Senior Scientist, laboratoires d'etudes en Geophysique et Oceanographie Spaciale - 21 October 2020 - Online from France - French
 | **ITW Anny Cazenave, Senior Scientist, laboratoires d'etudes en Geophysique et Oceanographie Spaciale** * What is Radar Altimetry and how is it used?
* History of Satellite radar altimetry and time series and how what can you study with it?
* Contribution of Sentinel-6 to measuring sea-level rise in coastal areas
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| **10:30:32:05*** Animation. Sentinel-6 launch with Falcon- 10/09/20 – SpaceX
 | **Animation: Sentinel-6 launch****© SpaceX, September 2020** |
| **10:32:40:23*** Animation. Sentinel-6 – 2020 - ESA/ATG medialab
 | **Animation: Sentinel-6 operations and orbit****2020** |
| **10:34:17:00*** Animation. Sentinel-6 – 2020 - ESA/ATG medialab
 | **Animation: instruments and technical view****2020** |
| **10:35:02:00*** Animation. Sentinel-6 – 2020 - ESA/ATG medialab
 | **Animation: Sentinel-6 360°-view****2020** |
| **10:35:25:24** | **ESA OUTRO** |
| **10:35:37:24** | **END OF PROGRAMME** |