Satellite Altimetry Observations Monitoring Changes in Ocean and Surface Water Systems: Applied Science in Support of User Communities

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Abstract

Ocean altimetry satellite missions have become invaluable for operational agencies, society, and decision-makers through their consistent, high-resolution measurements of the topography and surface height of both ocean and surface water bodies. Besides the critical research foci of the missions, they provide significant value in support of critical services such as safeguarding marine operations and navigation, coastal hazard assessment, fisheries, water resources planning, flood management, and disaster response, among many other uses. The data record spans more than 33 years beginning in 1992 with the launch of TOPEX/Poseidon, through the Jason series missions in the early and mid 2000s, Sentinel 6 Michael Freilich (2020), the the Surface Water and Ocean Topography (SWOT) mission (2022). Sentinel 6B will continue this valuable dataset, enabling tracking of sea level rise and ocean changes into the next decade and greatly informing climate adaptation strategies.

Collaborations between NASA, the French Space agency, CNES, NOAA, Eumetsat and the European Space Agency (ESA) has been crucial in developing an essential climate data record on land and ocean surface topography and has ensured broad and open access to the data that underpins resilience planning for vulnerable regions and assets. Engagement within these agencies and with industry has provided practical tools and tailored data products that expand ocean operations and water management efforts.

The continuation of this record in ESA's Copernicus program and the evolution of satellite technology, as with the SWOT high-resolution wide swath measurements, will continue to transform and expand the broad community of users—from operational agencies to the private sector—and will address current and emerging water challenges for long-term societal benefit. This work generally based on findings from Srinivasan & Tsontos (2023) and Eldardiry, et al (2022), presents select Applications demonstrating societal benefit and operational value of the NASA and partners satellite altimeter missions and highlights the importance of this time series and its contributions to operational and private sector users, particularly in addressing climate impacts on ocean and water resources.

Reference:

Srinivasan, M., Tsontos, V., 2023: Satellite Altimetry for Ocean and Coastal Applications. *Remote Sensing,* 15(16):3939, doi.org/10.3390/rs15163939

Eldardiry, H., Hossain, F., Srinivasan, M., Tsontos, V. 2022: Success Stories of Satellite Radar Altimeter Applications. BAMS, 103(1): doi.org/10.1175/BAMS-D-21-0065.1

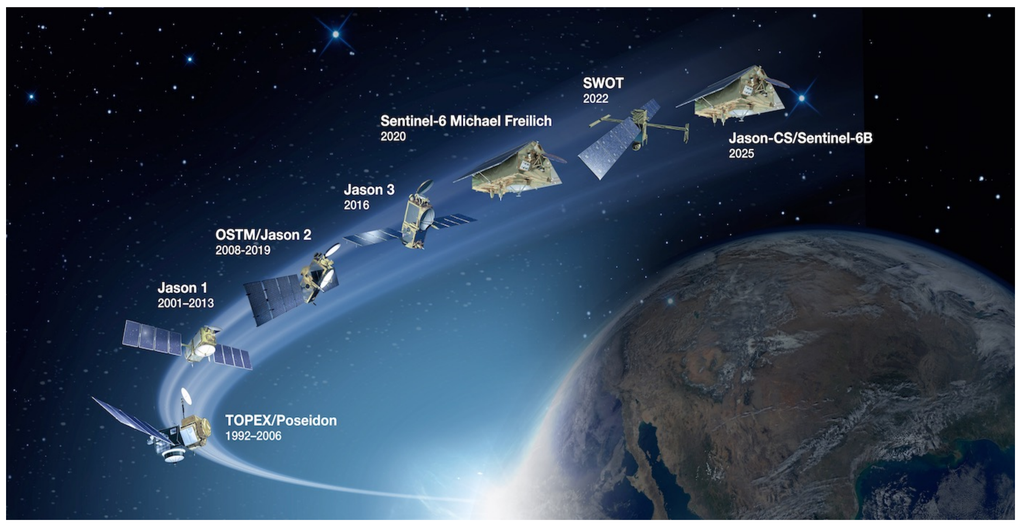
Altimeter measurements can estimate:

- water surface heights (over ocean & land)
- significant wave heights
- sea surface wind speeds
- topography of land, sea ice, and ice sheets

Earth Observation Applications for Societal Benefit

DATA → **Analysis** → **Information** → **DECISIONS**

- DATA: Satellite & In-situ Observation Integration
- Analysis: Models — *Process, Statistical, ML/AI*
- Information: Synthesis — *Products & Tools*
- DECISIONS: Operational Applications



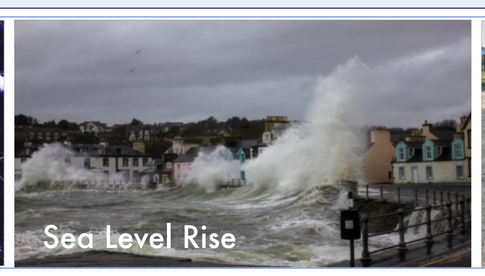
Continuity of NASA, CNES and partners Satellite Altimetry Missions

Applications User Communities

Over three decades of radar altimetry observations continue to provide key data enabling research discoveries and a broad spectrum of operational and user-driven applications. Two key user communities are 1) researchers and decision-makers who require reliable information for assessing climate and weather impacts to coastal and inland communities and, 2) operational and private sector users who rely on marine and weather forecasts for commerce, environmental, recreation, and public safety purposes. U.S. and European operational ocean, weather and climate agencies such as NOAA, EUMETSAT, ECMWF and Copernicus use radar altimeter products for a wide range of marine and weather applications. A growing number of private sector organizations use the data and information products from these satellites for a broad range of commercial and practical applications. New discoveries and advances in societally focused applications will be enabled by the increased spatial and temporal information in the newest and future missions from these international space agency collaborations. This growing body of knowledge and data enables assessments of storms, waves, and sea level rise impacts on coastal communities, and key information on hydrology and surface water applications and infrastructure along with other key contributions for societal benefit.

Select Altimetry Mission Applications

Success Story	User	Goal	Spatial Coverage	Operational or Commercial Application?
FishTrack	Surfline/Wavetrak	Fish Tracking	Global	Yes
EcoCast	NOAA	Fish Tracking	Pacific Ocean (West Coast)	Yes
NOAA Satellite-Derived Ocean Heat Content product	NOAA	Severe Storm Forecasting, Ocean Eddies	Global	Yes
NOAA Gulf of Mexico Monitoring (GOM)	NOAA	Oil Spill Response, Ship Routing	Gulf of Mexico	Yes
BlueSIROS	ESA and National Space Institute, Technical Univ. of Denmark (DTU)	Ship Routing	Global	Yes (thru DHIGroup)
ALTIBERG	CNES/CERSAT	Iceberg Detection	Global	No
MetOcean	Danish Hydraulic Institute (DHI)	Offshore Wind Farms	Global	Yes
GREALM	USDA-FAS/NASA/UMD	Reservoir Monitoring	Global	Yes
Virtual Rain and Stream Gauge Data Service (VRSG)	Asian Disaster Preparedness Center (ADPC)/ NASA Servir Project	Stream Gauge Height	Mekong River Basin	No
Coastal Flood Risk Warning	ECFAS (European Consortium)	Coastal Imacts, Coastal Resilience	Global	Yes
MetOcean	Danish Hydraulic Institute (DHI)	Offshore Wind Farms	Global	Yes



Jason 3, Sentinel 6-MF, Sentinel 6B & SWOT Missions: Enhanced Ocean, Coastal, Land Water Monitoring

Jason 3

- NOAA-led with partners NASA, CNES and EUMETSAT, an operational mission that supports commercial and practical applications related to sea level rise, ocean circulation, and climate change. Jason 3 provides continuity from the previous Jason-series satellites as the current reference altimetry mission.
- Enhanced coastal oceanography support via new techniques in radar altimetry developed to improve the performance of the mission in coastal areas (re-tracking & high-resolution wet tropospheric correction)

Mission: In extended mission phase, launched 17 Jan. 2016
Reference Orbit: 10-days, non sun-synchronous orbit, 1354 km, 66° inclination
Science instruments:
Poseidon-3B nadir altimeter, Multi-frequency Advanced Microwave Radiometer (AMR-C) for studying radar signal path delays & atmospheric phenomena, and GPS Receiver, DORIS, & LRA for positioning.

Sentinel 6-MF & Sentinel 6B

- Operational missions providing continuity of the reference altimetry record for sea level/climate studies and support for ocean forecasting and other applications.
- Enhanced coastal oceanography support via advanced techniques in radar altimetry developed to improve the performance of the missions in coastal areas (re-tracking & high-resolution wet tropospheric corrections).

Missions: **S6MF**--5.5 years (nominal), launched 21 Nov. 2020; **S6B**—5.5 years (planned), launch plan Nov. 2025
Reference Orbit: 10-days, non sun-synchronous orbit, 1336 km, 66° inclination
Science instruments:
Ku/C-band nadir SAR altimeter (Poseidon-4), Multi-frequency Advanced Microwave Radiometer (AMR-C) for studying radar signal path delays & atmospheric phenomena, High-Resolution Microwave Radiometer (HRMR) for enhanced atmospheric parameter measurement in coastal areas, GNSS-RO Antennas, DORIS, LRA.

Surface Water Ocean Topography (SWOT)

- Science mission monitoring Earth's surface water (oceanic & hydrological), near global coverage
- Enhanced resolution: detect 100m wide rivers, 250m^2 lakes & 1km^2 over ocean. (high-res. mode over land; low-res over ocean)
- Characterize ocean mesoscale and sub-mesoscale circulation
- Global inventory of terrestrial water bodies → estimate water body storage, river discharge change

Mission: 3 years (nominal), launched 15 Dec. 2022
Orbit: 21-days, non sun-synchronous, 890.6 km, 77.6° inclination
Science Instruments:
Ka-band SAR interferometric (KaRin) system with 2 x 50 km swaths, Jason-class altimeter provides nadir coverage, AMR-C Microwave radiometer measures atmospheric water vapor for signal correction.