

Altimetry Missions Applications Support: An international collaboration for the Jason-series, Sentinel 6 & SWOT

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Acknowledgements: Jason 3 & S6MF Projects, OSTST, NASA Applied Sciences, CNES/FIP, SWOT Project, SWOT ST



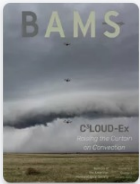


References



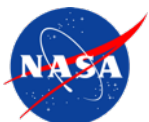
remote sensing

Srinivasan, M.; Tsontos, V. Satellite Altimetry for Ocean and Coastal Applications: A Review. *Remote Sens.* **2023**, *15*, 3939. <https://doi.org/10.3390/rs15163939>



**Bulletin of the
American
Meteorological
Society**

Eldardiry, H., Hossain, F., Srinivasan, M., and Tsontos, V. Success Stories of Satellite Radar Altimeter Applications. *Bulletin of the American Meteorological Society*, **2022**. 1-49. <https://journals.ametsoc.org/view/journals/bams/103/1/BAMS-D-21-0065.1.xml>.



International Partnerships

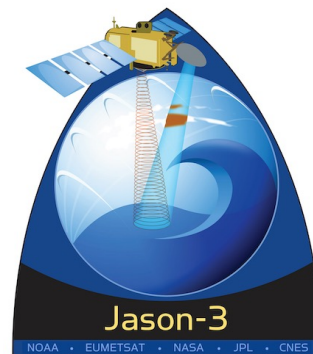
- NASA and the French Space Agency (CNES)
- 31+ year U.S./French partnership of the highly successful TOPEX/Poseidon, Jason-1, and Jason-2 missions

Current mission partners;

- Jason-3: *CNES, NOAA, EUMETSAT*
- Sentinel-6 Michael Freilich: *CNES, ESA, EUMETSAT, NOAA*
- Surface Water & Ocean Topography (SWOT): *CNES, CSA, UKSA*

Future missions;

- Sentinel-6B 2025, NASA/CNES/ESA
- Sentinel-6C 2030s





Key Applications Areas



Water Cycle

Although Earth's water cycle is dominated by the ocean, understanding its land-based component is vitally important.

[more >](#)



Operational

Over the past 28 years, the simultaneous operation of several satellite altimeter missions – along with the development of data merging techniques – have provided unique capabilities to observe the ocean in an operational manner.

[more >](#)



Coastal

Satellite altimetry over the open ocean is reasonably well understood and data are routinely utilized for a variety of ocean applications.

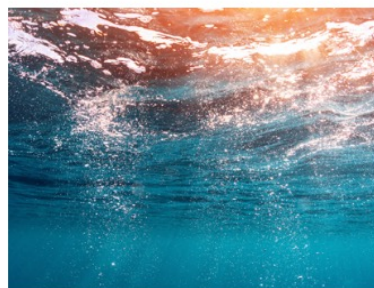
[more >](#)



Biological

Altimetry data have been used to understand biology at large and small scales.

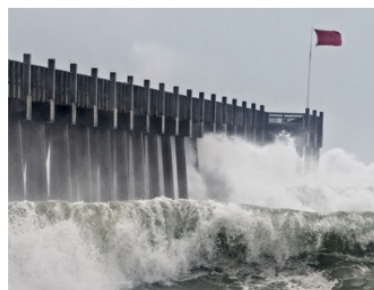
[more >](#)



Climate

Global sea level rise is an obvious indicator of climate change in the ocean, a trend that is impacting many coastal populations.

[more >](#)



Hazards

Coastal storms, hurricanes, and tsunamis are among the most devastating natural hazards in terms of property damage and loss of human life.

[more >](#)



Applications Areas Users

Ocean

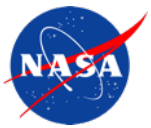
- [Operational ocean forecasting](#); naval operations, safety at sea, environmental monitoring
- [Marine operations](#); sea state for ship routing, offshore infrastructure, hazards assessment
- [Environmental tracking](#); marine debris, [oil spill discharge forecast](#) (ocean currents)

Surface Water

- [Global lake & reservoir monitoring](#); i.e., water resource managers, USDA Foreign Agricultural Service (FAS); SWOT EAs
- [River heights](#) (real and “virtual”); i.e., water resource managers, Bangladesh Water Development Board, flood forecasters
- [Hydropower](#); operations, transboundary water information

Coastal

- Coastal impacts of [sea level rise](#); coastal water managers, coastal infrastructure, communities
- [Storm surge forecasting](#); coastal managers, coastal communities
- Hurricanes; coastal [impacts of wind & waves](#), [intensity monitoring and forecast](#)




Altimetry Applications Topics

| Categories | Title | Titles |
|-------------|---|--|
| Biological | 1. Fish and Mammals | Tracking Populations of Fish and Mammals + Fish Larvae Transport |
| | 1. Coral and Submerged Reefs | Coral Reefs + Mapping Submerged Reefs (Costal) |
| | 1. Primary Production | Primary Production |
| Climate | 1. Global Sea Level Rise and Ocean Warming | Sea Level Rise + Global Ocean Warming |
| Coastal | 1. Hurricane Forecasting | Forecasting Hurricane Impacts + Hurricanes (Hazard) + Maybe Tsunamis (Hazard) |
| | 1. Storm Forecasting and Impacts on Communities | Storm Surges Forecasting + Impacts of coastal Erosion on Communities + Coastal Storm Modeling (Hazard) |
| Operational | 1. Ocean Forecasting | Operational Ocean Forecasting + Assessment of Shipping Risks |
| | 1. Tracking Marine Debris | Tracking Marine Debris |
| | 1. Oil Spill Tracking | Oil Spill Tracking |
| Water cycle | 10. Monitoring Climate-Sensitive Lakes | Monitoring Climate-Sensitive Lakes |
| | 11. Flood Forecasting | Studying Factors that Affect Water Availability + Observing Rivers in Poorly Instrument Regions + Impact of Dams |



Communication Products

**Jet Propulsion Laboratory**
California Institute of Technology

Ocean Surface Topography from Space

[Home](#) [Ocean Observation](#) [Science](#) [Applications](#) [Data](#) [Missions](#) [News](#) [Resources](#)

APPLICATIONS

Overview

Since 1993 ocean altimetry data has provided researchers and operational users like NOAA's extreme weather units with valuable data to answer questions about ocean circulation, ocean dynamics, sea level rise, and hurricane intensities. Data and images are available in near real-time for some uses, and are used for a wide range of scientific as well as commercial and practical applications.

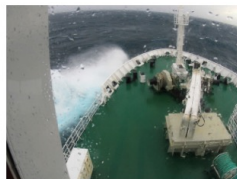
Click on the categories below to discover more about the valuable applications that derive from these important satellite missions.



Water Cycle

Although Earth's water cycle is dominated by the ocean, understanding its land-based component is vitally important.

[more >](#)



Operational

Over the past 28 years, the simultaneous operation of several satellite altimeter missions – along with the development of data merging techniques – have provided unique capabilities to observe the ocean in an operational manner.



Image: JPL/NASA

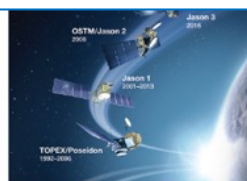


Image: JPL/NASA



Image: JPL/NASA

from these missions allowed scientists to monitor changes in the sea level, as well as providing the TOPEX/Poseidon and the Jason-1 were cooperative space agency. The TOPEX/Poseidon mission ended in 2006. The Jason-1 mission ended in 2013 and delivered the Ocean Surface Topography Mission on the mission included NOAA and Eumetsat.

The Jason Continuity of Service (Jason-CS) mission on the U.S. and Europe. Two identical satellites, Sentinel-6A and S

Products

Level 2 products from both OSTM/Jason-2 and Jason-3 missions comprise a family of nine different types of geophysical records (GDRs): Operational GDR (OGDR), Interim GDR (IGDR), and final GDRs. All nine sets contain sea surface height, ocean wind speed, significant wave height information and all required corrections. The Level 3 products from both OSTM/Jason-2 and Jason-3 missions comprise the along-track Sea Level Anomaly at 5 Hz (instead of 1 Hz) for two areas: North Atlantic and Pacific. NetCDF format files are available. Additional information is available in the OSTM-Jason-2 and Jason-3 handbooks.

Products are available at :

<https://loaders.jpl.nasa.gov/Altimetry/Data-Information/Coasts/Altimetry>

**Jet Propulsion Laboratory**
California Institute of Technology

SWOT SURFACE WATER AND OCEAN TOPOGRAPHY

[Home](#) [Mission](#) [Science](#) [Applications](#) [News & Events](#) [Resources](#)

APPLICATIONS

Applications Areas

Hydrology Applications



Floods

Flooding hydraulics are well modeled but poorly measured by current methods. Floodplain water levels, for example, are rarely measured during the passage of a flood wave. Instead "wrack marks" are measured after the event has occurred, and the marks, which indicate some water level during the flood, are often considered to be the high water mark. Any dynamics (rising and falling of water) during the flood event are lost. SWOT aims to provide water level records for any flooding events that underlay a given satellite overpass. SWOT scientists will also be able to look at synergistic combinations of SWOT and other satellite datasets, modeling, and in situ observations to improve capabilities.



Drought

Model predictions (and hence drought monitoring) can be greatly enhanced through assimilation of space-based surface water observations such as those from the future AirSWOT and SWOT missions. There may be opportunities to combine surface water measurements from AirSWOT and SWOT with other satellite data and

Featured Resources



[CNES - First SWOT Images Video Gallery](#)



[Water-Monitoring Satellite Moves Closer to Launch](#)



[Surface Water and Ocean Topography \(SWOT\) Science Talk](#)

[more resources >](#)



Applications Program for User Communities

- Understand the requirements of decision makers
- Communicate the value of available data and information resources
- Clarify and quantify uncertainties with respect to attribution of drivers for global climate change and the implications for regional affects
- Target audience identification: water managers, local government agencies, operational agencies

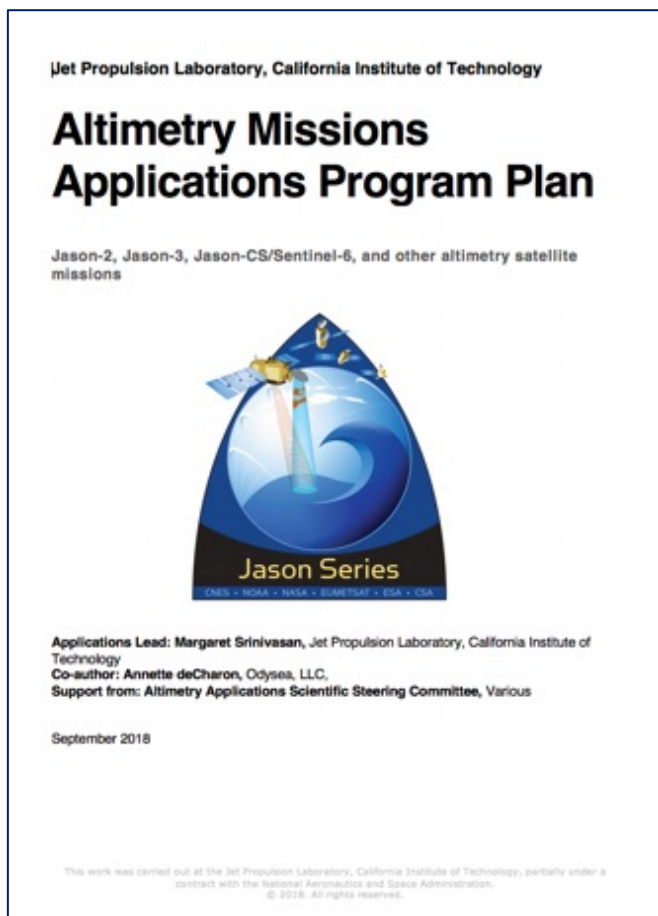
Users

- **Marine environment monitoring** – marine debris, oil spills; Coastal managers, ocean biologist, marine mammal monitoring organizations
- **Weather & event forecasting, seasonal and climate prediction;** NOAA (CoastWatch, OceanWatch, National Hurricane Center)
- **Maritime safety and pollution forecasting, national security, the oil and gas industry, fisheries management and coastal and shelf-sea forecasting.**

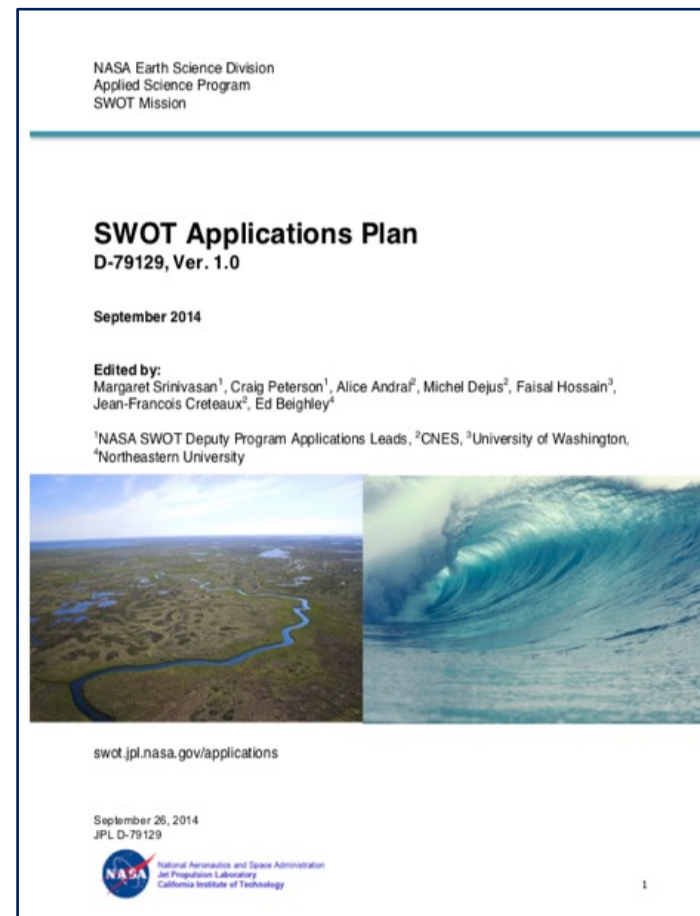


Applied Science Approach & Planning

- Jason 2 & 3, Sentinel-6 Michael Freilich Missions – Project-funded
- SWOT – NASA Applied Sciences Program + Project-funded



sealevel.jpl.nasa.gov/applications



swot.jpl.nasa.gov/applications



Coastal Applications of Altimetry

- **Coastal Ocean Dynamics –**
 - Observe coastal currents and storm surges (ground track/swath-dependent)
 - Navigation in the coastal ocean
 - Decision support of coastal managers: knowledge of currents to accurately determine pathways for spills of toxic materials, movement of blooms of toxic algae or anoxic water conditions, most probable search areas for missing persons or disabled boats, originating locations for material discharged from ships or shore
 - SWOT will provide spatial structure of coastal dynamics with global high res observations
- **Storm Surge Forecasting**
- **Impacts of Coastal Erosion on Communities**
- **Modeling Hurricane Winds and Waves Along Coasts**

**See Vardis's talk Thurs. 9 am,
Coastal Splinter**

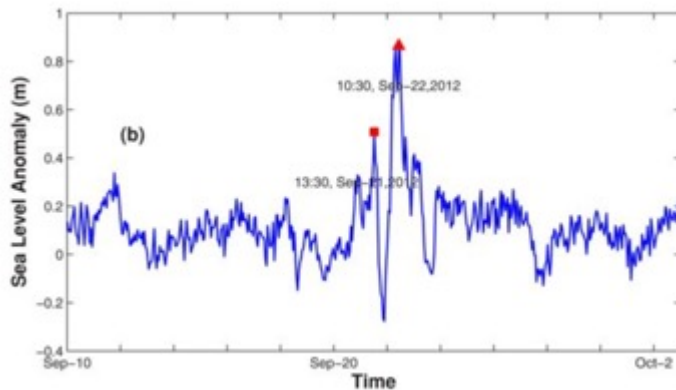


Image: Han, G., et al, 2012





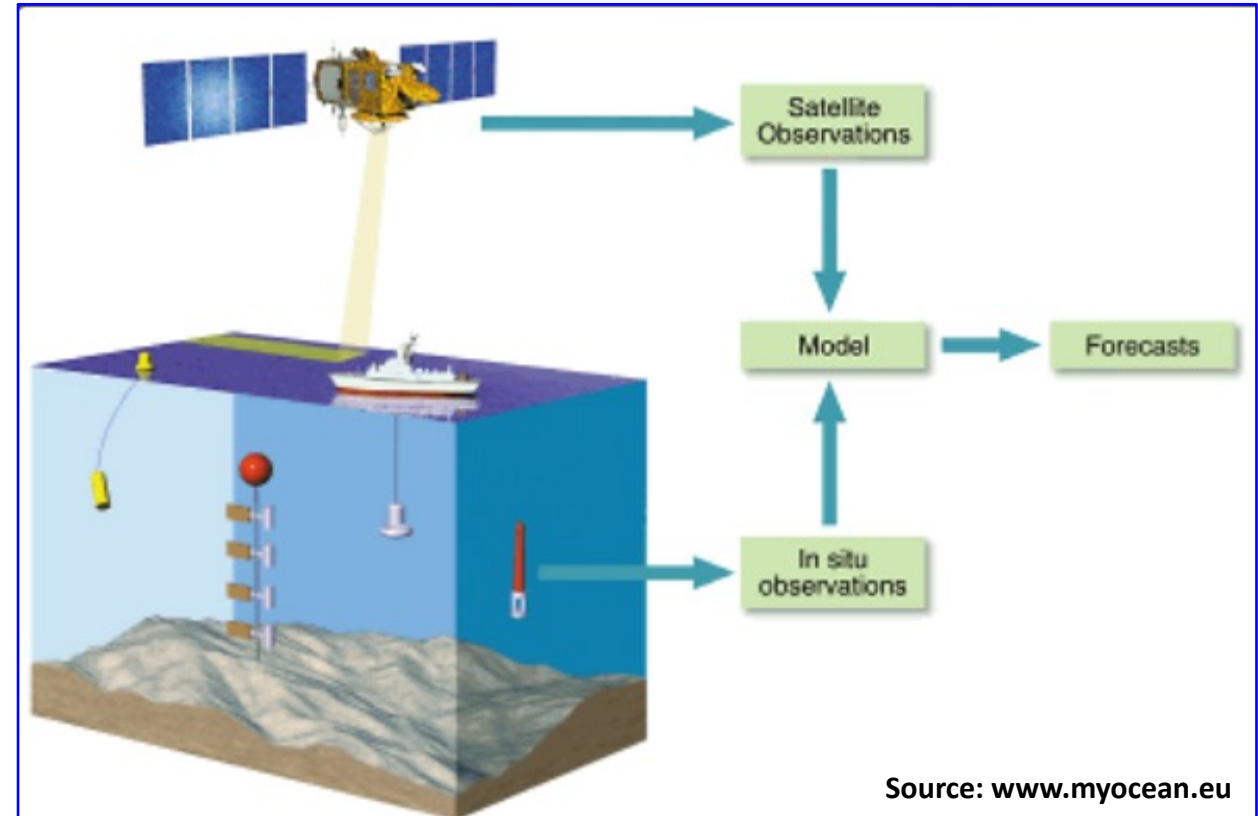
Operational Ocean Forecasting

Summary: Multiple satellite altimeters over 28 years and data merging techniques → unique capabilities to observe the dynamic oceanography

- NRT high-res global sea level anomaly maps ([SSALTO/DUACS](#) system).
- Altimetry + in situ ocean observation systems ([Argo](#)) provide measurements of global SLR (~3 mm/yr).
- Mercator - Ocean Monitoring Indicators (OMI), analysis and forecasting models are strongly dependent on multiple altimeter data and Argo observations.

Users: Products & services for a wide range of applications:

- Marine environment monitoring – marine debris, oil spills
- Coastal managers, ocean biologist, marine mammal monitoring organizations
- Weather & event forecasting, seasonal and climate prediction; NOAA (CoastWatch, OceanWatch, National Hurricane Center)
- Maritime safety and pollution forecasting, national security, the oil and gas industry, fisheries management and coastal and shelf-sea forecasting.



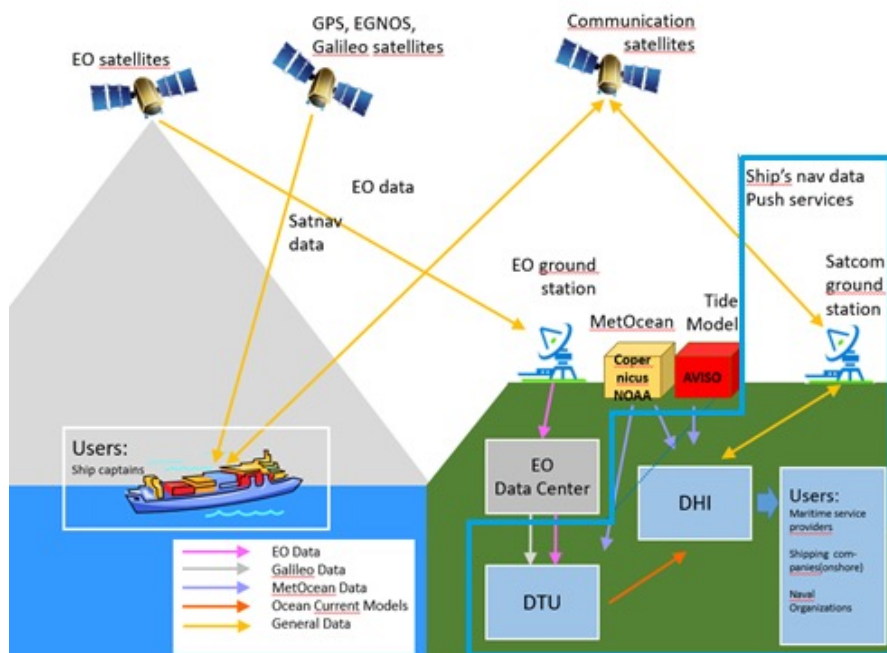


Ocean Navigation

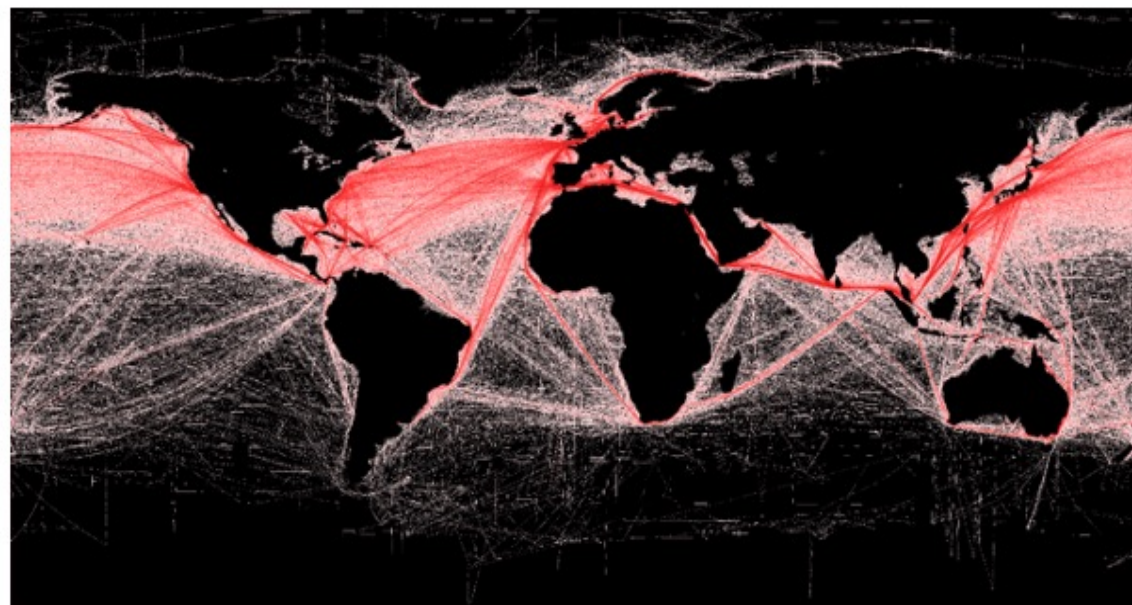
Commercial Use Examples;

- Blue SIROS – marine route optimization
- Monitoring merchant ship traffic and ocean pollution monitoring

Blue SIROS



Merchant ship routes & marine pollution



Merchant shipping traffic based on altimetry data (since 1992)

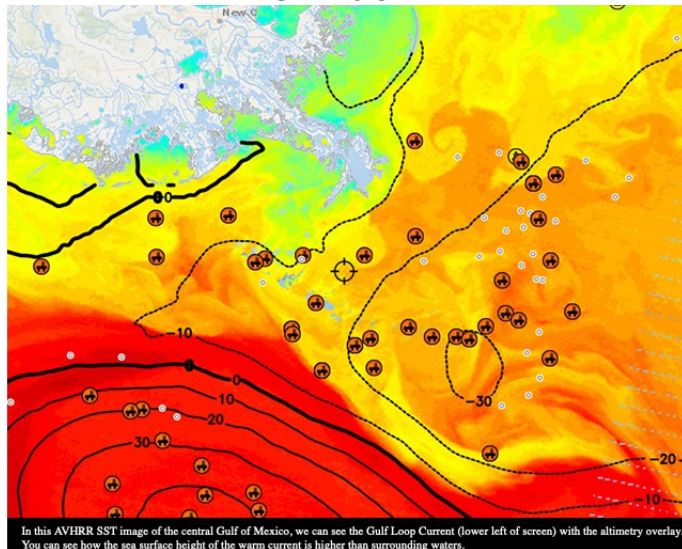


Fisheries Assessment & Management

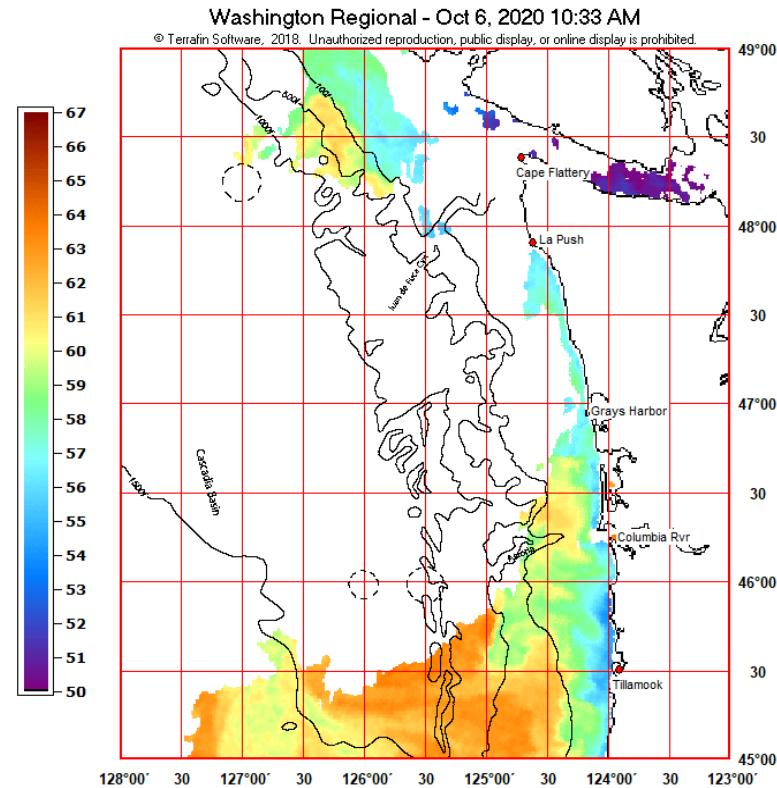
Hilton's Realtime Navigator



FishTrack



Terra-Fin

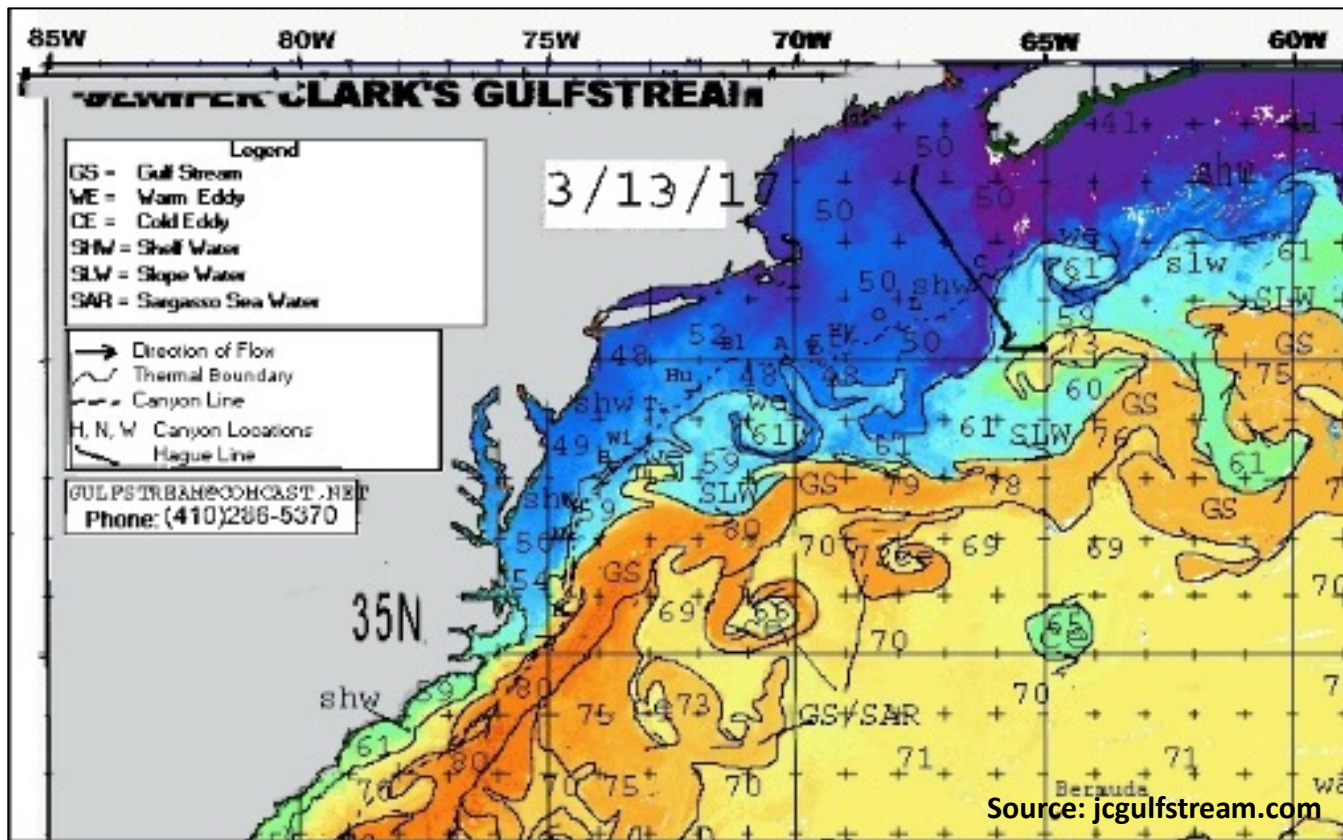


Commercial User Examples;

- Fish Track
- Hilton's Realtime Navigator
- Terra-Fin



Private Sector: Operational Ocean Forecasting

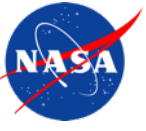


Jenifer Clark's GulfStream

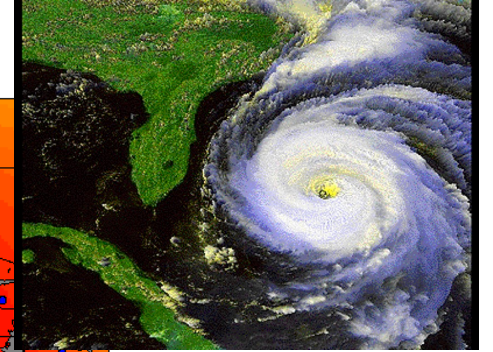
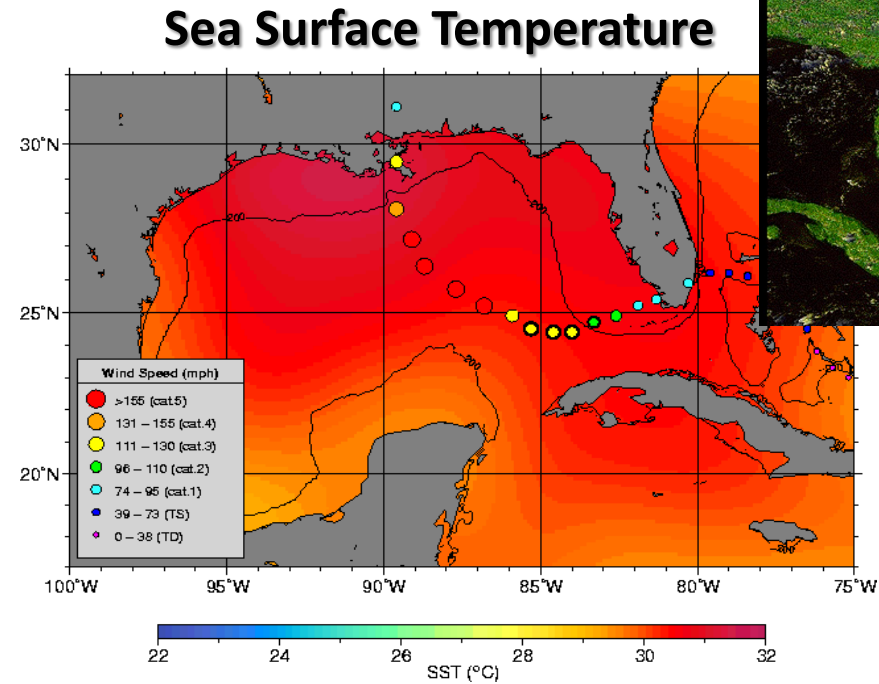
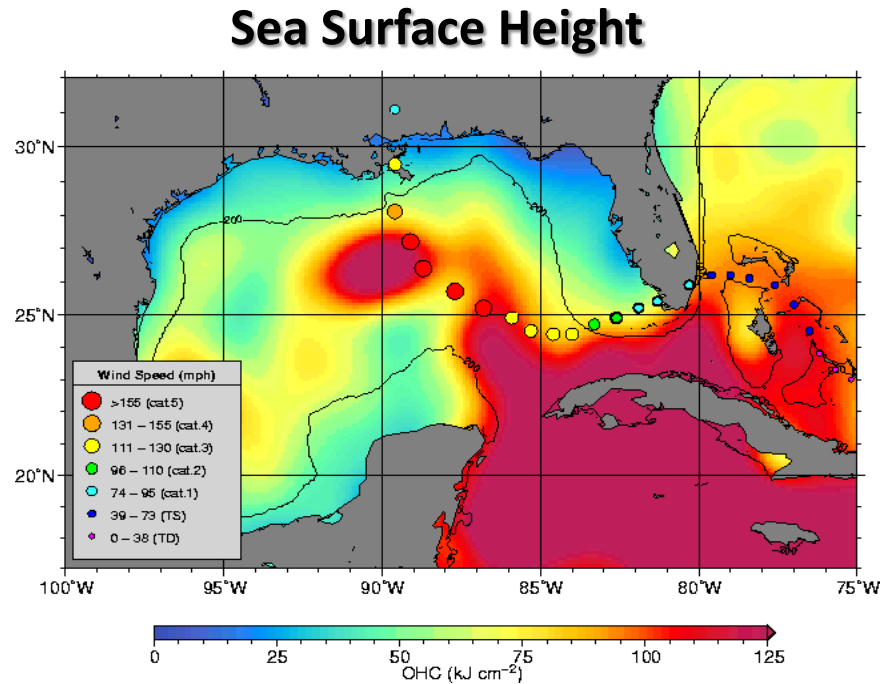
- Charts of surface height
- Eddies and swift moving currents can be identified
- Transatlantic ship routing, cable laying, and oil exploration use these maps to increase safety and economic return.
- Recreational boating

Application: Realtime ocean charts for general marine consulting using infrared, satellite altimetry, and surface isotherm data. Oceanographic analyses are produced and available for the Gulf Stream area and all major global currents.

Operation: Using near real-time altimeter data with sea surface temperature imagery to evaluate currents affecting offshore operations. Waypoints are also provided for taking advantage of favorable currents and for avoiding unfavorable ones.



Hurricane Forecasting



Source: NOAA/AOML

- NOAA National Hurricane Center
- Ocean heat content shows heat available over to increase intensity of tropical cyclones.
- Long-term seasonal forecasts of the numbers and strengths of hurricanes expected in a given hurricane season
- Short term forecasts of the strength of individual hurricanes

**Ocean heat content
Forecast – hurricane strength**



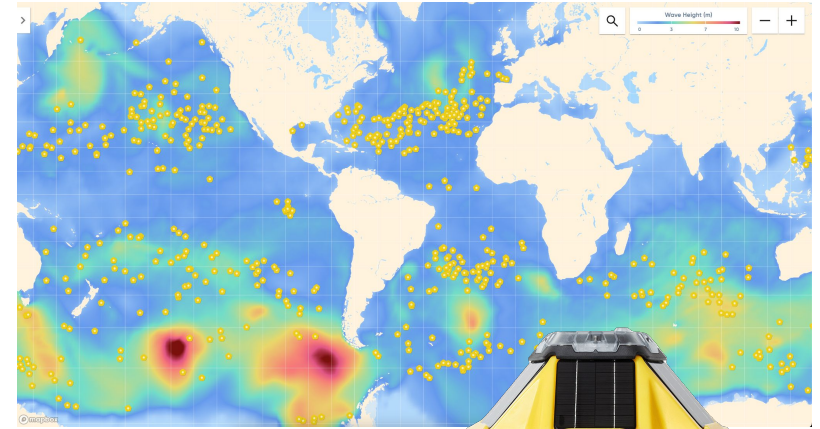
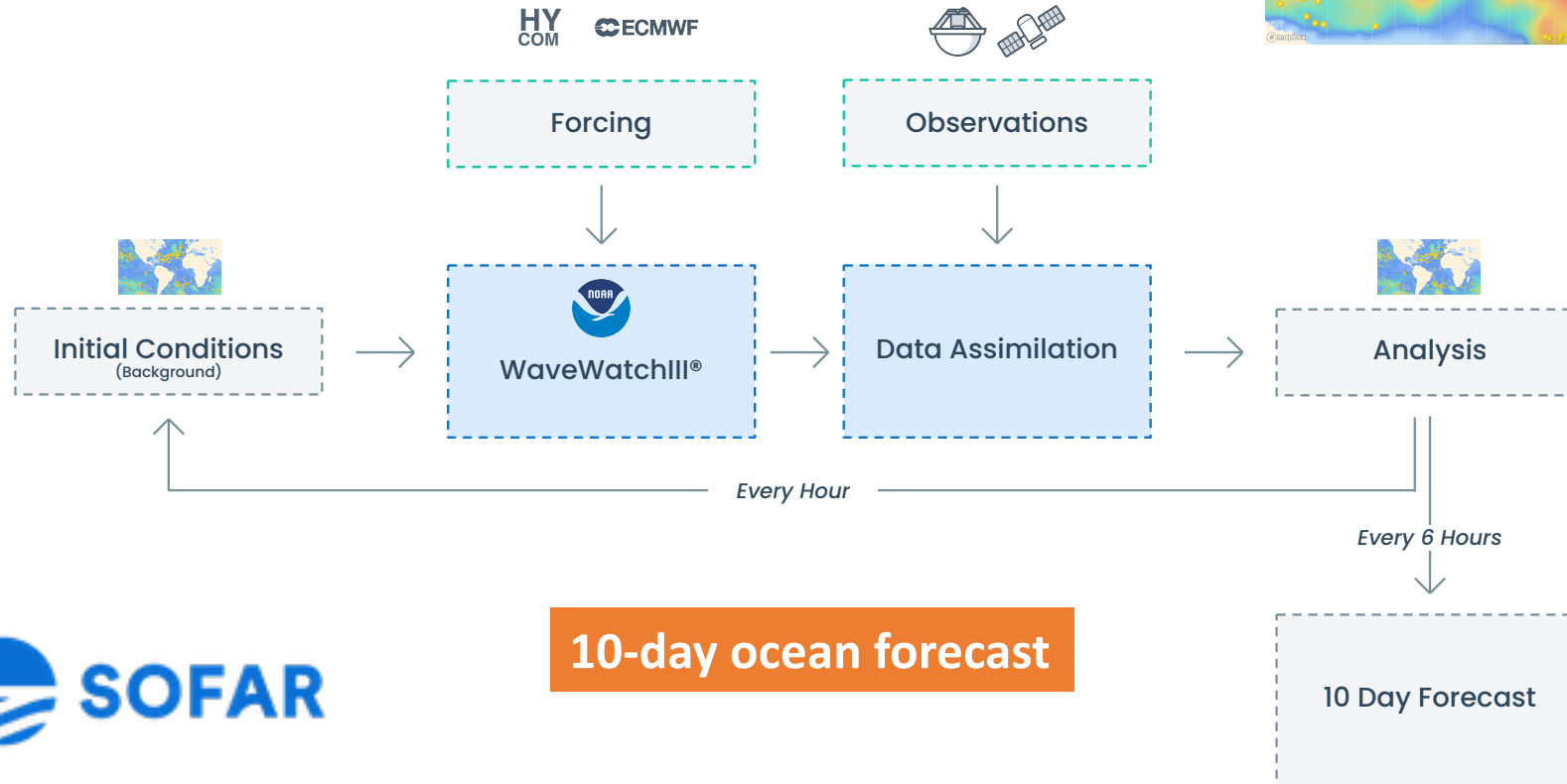
Private Sector: Sofar Ocean



SWOT EA Introduction

Assimilation of the Sofar Spotter Network

Data incorporated into WW3 model hourly to improve forecast skill.



10-day ocean forecast

10 Day Forecast



U.S. Navy – Naval Research Lab



Title: SWOT Ocean Prediction

Organization: U.S. Navy, Naval Research Lab

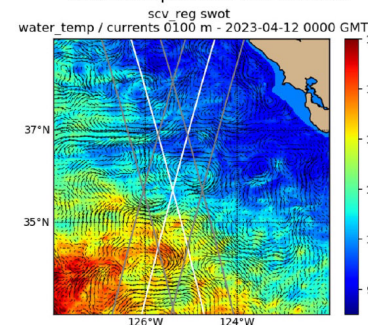
Leads: Gregg Jacobs; Joseph D'Addezio

Summary

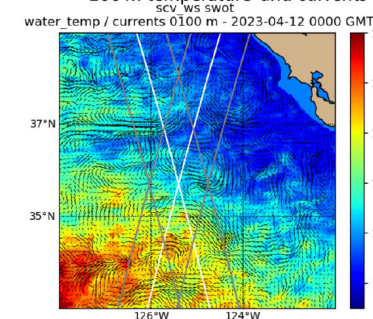
The U.S. Navy uses sea surface height observations with numerical ocean models to predict the future ocean currents, temperatures, and salinities. The models span global coupled ocean / atmosphere / ice / wave models to nested coupled models with resolutions down to 100 m and less. The systems utilize all available satellite sea surface height, sea surface temperature, ice concentration, wave heights, and in situ profile and surface observations.

Computing ocean predictions requires correcting ocean models with recent observations. The first challenge is to process SWOT rapidly, removing systematic errors without damaging the ocean signal, and bringing the processed data to the ocean forecast systems. SWOT observations resolve features at much higher resolutions than prior observing systems, and many prior assumptions of data distribution and ocean features are no longer valid. We must address these prior assumptions and the manner in which observations correct the ocean forecasts changes.

All nadir altimeters
100 m temperature and currents



SWOT + all nadir altimeters
100 m temperature and currents



Numerical models to predict;

- Ocean currents
- Temperatures
- Salinities



Private Sector: Offshore oilfield operational support



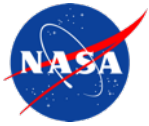
Data User: Capt. Karl Greig, captain of an Edison Chouest Offshore tugboat used NRT Jason data from CCAR to optimize routes while towing semi-submersible drilling rigs used in deep water oil and gas exploration between lease blocks.

Example Operation: Moving a rig from Mississippi Canyon block 68 to Mustang Island block 68, a total of 425 nautical miles. Typical towing speeds are 3 to 4 knots so avoiding and/or using eddy currents significantly reduces transit times, in this case by over 50 hours.

Altimeter Product Used: Overlays of geostrophic velocity vector on colored magnitudes values accessed on CCAR website by satellite phone.

Estimated Savings: \$650,000 in rig downtime and towing costs for one event.

- Commercial marine operations
- Route optimization
- Cost savings



Global Reservoirs and Lakes Monitor - G-REALM

10-day Resolution Products

Lakes 301 Date 2020-10-18



Time series of water levels for rivers
& lakes from altimetry

| | | | |
|-------------|------|-------------|-----|
| Rivers | 1490 | Lakes | 155 |
| Operational | 260 | Operational | 64 |
| Research | 1290 | Research | 91 |

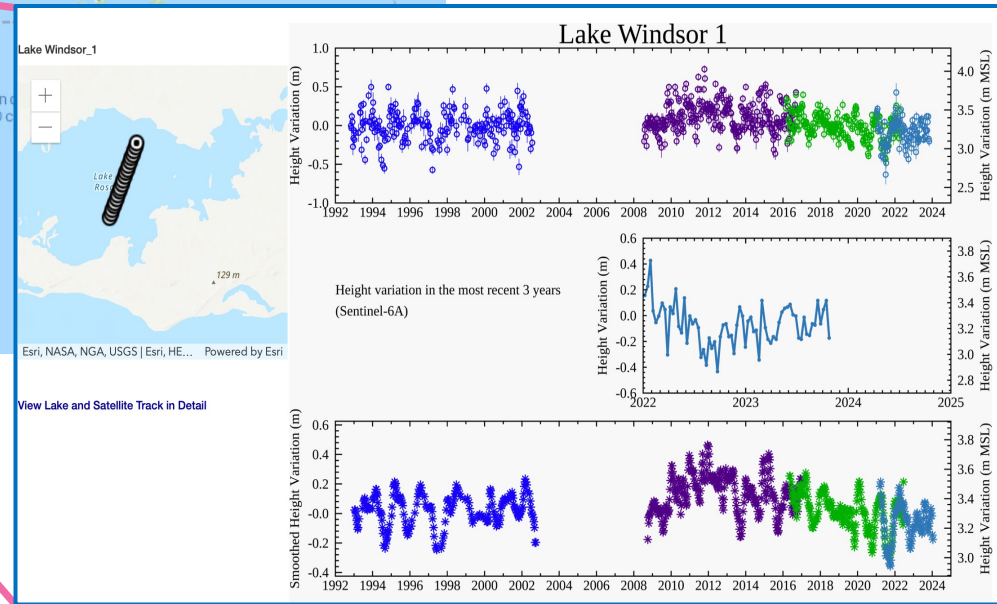
Host: USDA FAS

Resources:

<https://water-monitor.sgt-inc.com/lake/Index>

https://ipad.fas.usda.gov/cropexplorer/global_reservoir/

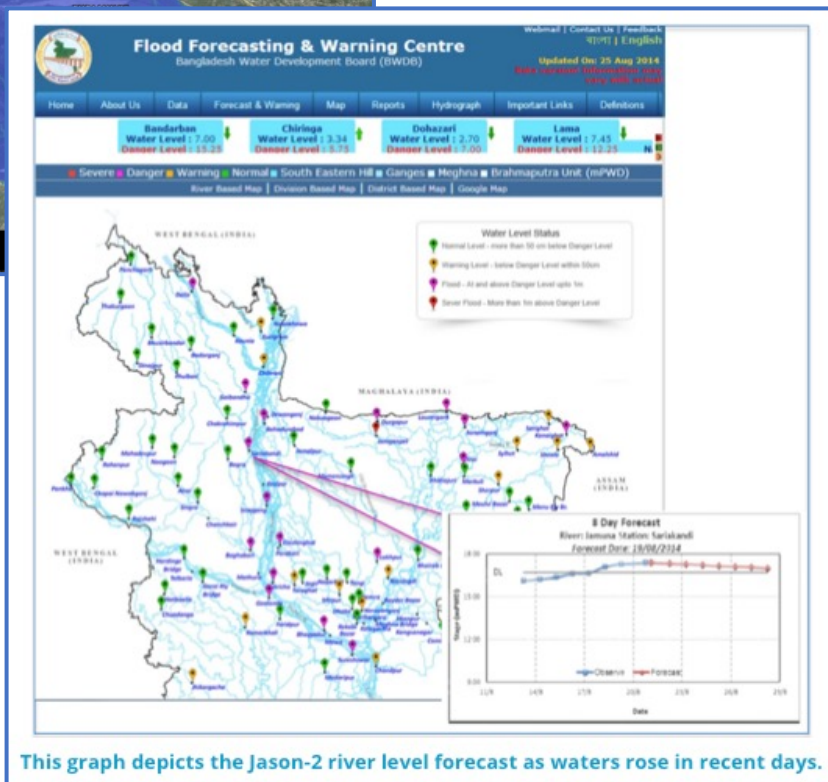
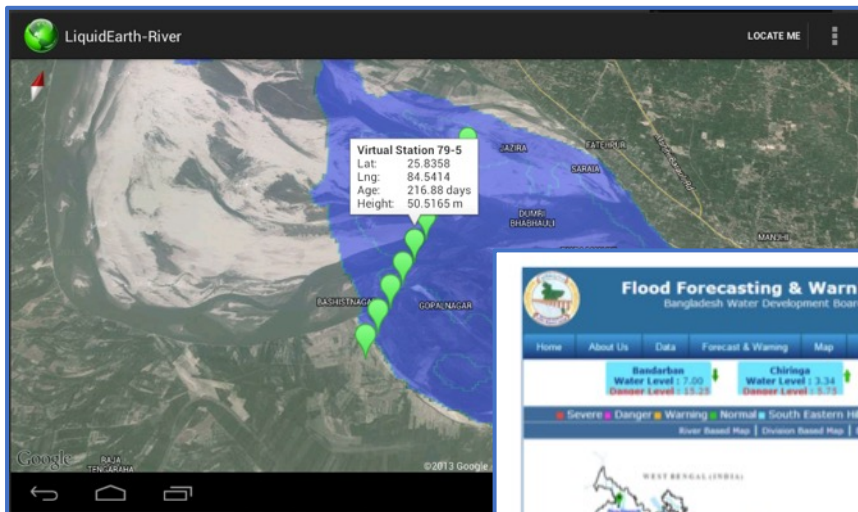
<http://www.theia-land.fr/en/products/water-levels-rivers-and-lakes-hydroweb-0>



Source: C. Birkett, NASA



Flood Risk Assessment



This graph depicts the Jason-2 river level forecast as waters rose in recent days.

Summary: U. Washington developed a [mobile platform for the dissemination of flood risk](#) in developing nations.

- Uses multiple altimeter inputs (Jason 2, ICESat-2, Sentinel 3, Cryosat-2).
- River levels used to model downstream virtual stream gauge levels.
- Flood forecast times increased (5 to 8 days)

Users:

- Flood Forecasting and Warning Center (FFWC), Bangladesh Water Development Board
- NASA's SERVIR

Link; NASA's SERVIR Program; <https://www.servirglobal.net/Global/Articles/Article/1334/servirs-flood-forecasting-system-proving-itself-in-bangladesh>



Related talk

Coastal Altimetry Splinter, Thurs. 9 am - Vardis Tsontos

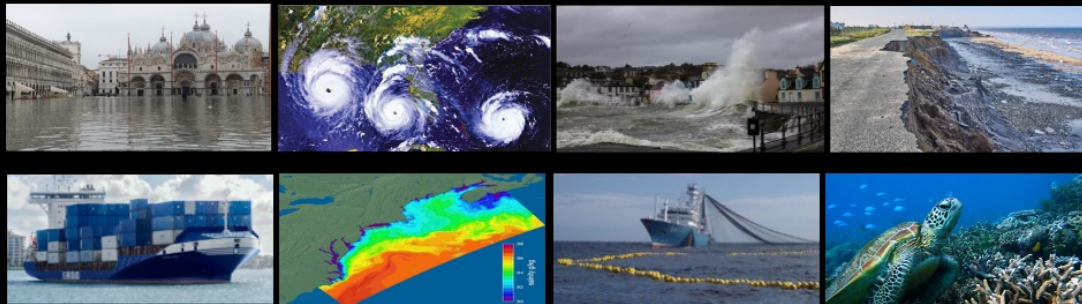


Satellite Altimetry for Ocean and Coastal Applications for Societal Benefit

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OSTST 2023



San Juan, Puerto Rico

7-11 October 2023



Thu, Nov 09 2023, 14:00 - 15:45



2023 – OSTST – San Juan, Puerto Rico – 7-11 November 2023

SWOT APPLICATIONS WORKING GROUP (SAWG) REPORT (2022-2023)

V. Tsontos¹, M. Srinivasan¹, M. Bonnema¹, S. Peña-Luque², N. Picot²

¹Jet Propulsion Laboratory, California Institute of Technology
²Centre National d'Etudes Spatiales





Abstract

Building upon successful partnerships that have ensured continuity in satellite altimetry missions for over 30 years, SWOT will demonstrate the very high potential of satellite remote sensing for operational and practical applications and will provide a key assessment of value of the considerable investments made by the international partner space agencies in satellite systems for Earth observations and societal benefit. The SWOT Applications Team has spent roughly a decade developing and implementing activities to identify, evaluate, and enhance the future user communities of SWOT data. We have developed meaningful engagement with the SWOT Early Adopters (EA) community by illuminating the path forward to using SWOT data in their systems and operations and by providing applied research in the relevant hydrology and oceanography capacities that SWOT will provide.


Our goal has been to maximize user readiness of SWOT data post launch. We have provided a venue for EAs to share their Applications projects with our community and look ahead to the use of SWOT in their decision-making capacities. We have of how they plan to use SWOT in their workflow, what questions they need SWOT to answer, and questions of what support users require in order to be successful in their use of SWOT.

The support of the CNES and NASA SWOT Working Group has been key to the success of the SWOT EA community. Over the next two years, our community will transition to active adoption of SWOT data as an important tool in their applications and decision support systems. Here summarize the goals, activities and plans of the SWOT Applications Team, highlighting efforts within the SWOT Early Adopters program and participating agency projects across hydrology, coastal and ocean application domains.



Continuity of Satellite Altimetry Missions over 30+ years

Timeline showing missions from 1960 to 2030: SEINTALE-4, SWOT, SEINTALE-4-M, SEINTALE-4-B, JASON-2, SARAL, OCEANOST-2, JASON-2, OCEANOST-2, TOPEX/Poseidon, GEOSAT, JASON-1, OCEANOST-1, TOPEX/Poseidon, GEOSAT.



Applications & Early Adopters Program

Goals


- Engage and promote improved understanding of the SWOT mission and the use of SWOT products to a community of end-users and decision makers interested in using SWOT data in applications with an applied science and operational focus.
- Cultivate a "community of practice" comprised of agencies and users with a series of decision support application use cases to jump-start the usage of SWOT mission data in operations
- Facilitate feedback between user communities and the SWOT project.
- Provide information and a collaborative forum for different types of users and communities
- Design communication strategies to target and support requirements of the user community.

Activities

- Active engagement and outreach on SWOT to the applications community.
- Development of the SWOT Early Adopters (EA) group
- Quarterly telecons with the SWOT EA community, providing: updates on mission status, data availability/access, and an open forum for information exchange with EAs, highlighting of EA project efforts
- Annual SWOT Applications Early Adopter Workshop (next: December 2023 Hybrid Online & Caltech, Pasadena CA)
- Quarterly newsletter.
- SWOT Applications website <https://swot.jpl.nasa.gov/applications/>
- Regular presentations at relevant conferences & meetings
- Journal and other publications
- Maintenance of SWOT and Altimetry publications list

SWOT Early Adopters (32 organizations & projects)

- Alexandria University, Egypt
- ANA Brazil (Brazil National Water Agency)
- Asian Disaster Preparedness Center (ADPC)/SERVIR-Mekong
- BRL Ingénierie (BRL)
- Centre for Water Resources Development and Management (CWRDM), Kerala, India
- Cleveland Water Alliance (CWA)
- CLIA
- Compagnie Nationale du Rhône (CNR)
- Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)
- Environment and Climate Change Canada (ECCC)
- ESRI
- EMA Global
- French National Research Institute (IRD)
- FLUNGEME
- Geological Survey of Brazil (SGB)
- ICUBE SERVIT
- Indian Institute of Technology Bombay
- Indian Institute of Technology Delhi
- Magellum
- Mercator Ocean
- NASA Short-term Prediction Research and Transition (SPoRT) Center, Univ. Alabama
- NOAA/CIRES University of Colorado Boulder
- Northeastern University
- Ohio State University
- Pakistan Council of Research in Water Resources (PCRWR)
- Stantec Consulting Services Inc. (Stantec)
- Texas Water Development Board (TWDB), Austin, TX
- U.S. Air Force Weather's Land Information System (LIS), Offutt
- US Geological Survey (USGS)
- University of Bonn and Helmholtz-Zentrum Geesthacht
- Worlex Inc.
- Water in Sight

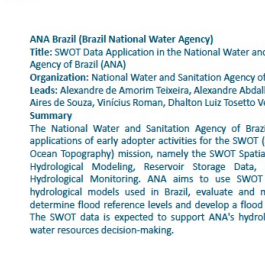
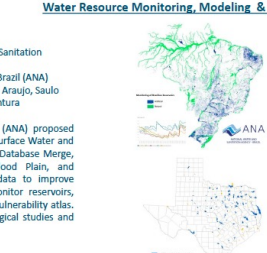


Early Adopter Application Spotlight

Water Resource Monitoring, Modeling & Management

ANA Brazil (Brazil National Water Agency)
Title: SWOT Data Application in the National Water and Sanitation Agency of Brazil (ANA)
Organization: National Water and Sanitation Agency of Brazil (ANA)
Leads: Alexandre de Amorim Teixeira, Alexandre Abdalla Araujo, Saulo Aires de Souza, Vinícius Romão, Dhalton Luiz Tosetto Ventura

Summary
The National Water and Sanitation Agency of Brazil (ANA) proposed applications of early adopter activities for the SWOT (Surface Water and Ocean Topography) mission, namely the SWOT Spatial Database Merge, Hydrological Modeling, Reservoir Storage Data, Flood Plain, and Hydrological Monitoring. ANA aims to use SWOT data to improve hydrological models used in Brazil, evaluate and monitor reservoirs, determine flood reference levels and develop a flood vulnerability atlas. The SWOT data is expected to support ANA's hydrological studies and water resources decision-making.

Texas Water Development Board (TWDB), Austin, TX
Title: Estimation of Volumetric Evaporative Water Loss from Unmonitored Reservoirs in Texas
Organization: Texas Water Development Board (TWDB), Austin, TX
Leads: Nelson Fernando, PhD, Manager; John Zhu, PhD, PG, Hydrologist

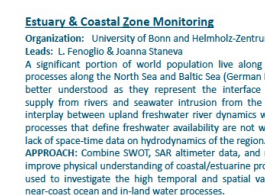
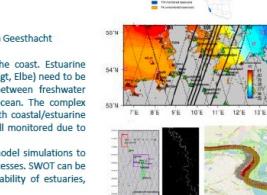
Summary
Of the over 7,000+ dams (lakes/reservoirs) in Texas, only 119 are gauged for water level monitoring. Evaporative loss from reservoirs is significant and often exceeds the water usage from reservoir. Being able to monitor evaporative water loss from all unmonitored reservoirs would lead to improved assessments of surface water availability in the state. SWOT's ability to track water elevation and area/extent over global inland water bodies will equip TWDB with a monitoring capability that covers all other unmonitored water bodies that are greater than 250 m x 250 m. SWOT's storage change data will also help improve forecasts of water availability. TWDB plans to use SWOT lake surface elevation and area datasets, along with TWDB's gridded lake evaporation rate dataset to compute the volumetric lake evaporation loss for all lakes that are detected by SWOT on a monthly basis.

Estuary & Coastal Zone Monitoring

Organization: University of Bonn and Helmholtz-Zentrum Geesthacht
Leads: L. Fenoglio & Joanna Staneva

A significant portion of world population live along the coast. Estuarine processes along the North Sea and Baltic Sea (German Bight, Elbe) need to be better understood as they represent the interface between freshwater supply from rivers and seawater intrusion from the ocean. The complex interplay between upland freshwater river dynamics with coastal/estuarine processes that define freshwater availability are not well monitored due to lack of space-time data on hydrodynamics of the region.

APPROACH: Combine SWOT, SAR altimeter data, and model simulations to improve physical understanding of coastal/estuarine processes. SWOT can be used to investigate the high temporal and spatial variability of estuaries, near-coast ocean and in-land water processes.

Assimilation in Ocean Analysis & Forecasting systems

Organization: Mercator Ocean
Lead: Pierre-Yves Le Traon

Mercator Ocean implements the operational "Mercator System" for ocean analysis and forecasting on behalf of the Copernicus Marine Environment Monitoring Service.

SWOT data will be:

- assimilated in the Mercator ocean analysis & forecasting systems
- combined nadir altimeter, other satellite data (SST, Ocean Color, ...)
- in-situ data and high resolution global models
- used to produce L4 SWOT SSH/A data products at higher resolution with global coverage in support of coastal and ocean applications