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

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Ocean Surface Topography Science Team Meeting
Over 30 Years of Sea Level Science
November 7–11, 2023
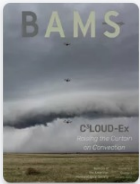SAN JUAN, PUERTO RICO, USA
NASA, CNES, NOAA, ESA, EUMETSAT

# References

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

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.
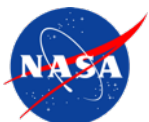
International Partnerships

> 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

31-year time series of data – A Climate Data Record
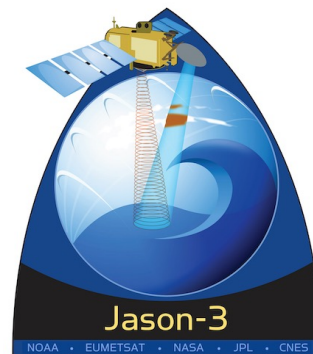
Key Applications Areas

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.

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Biological

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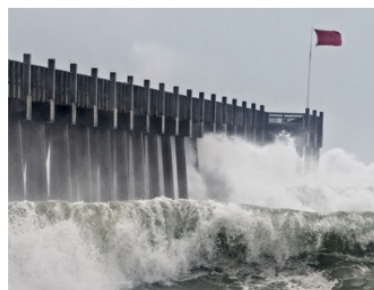
more ›
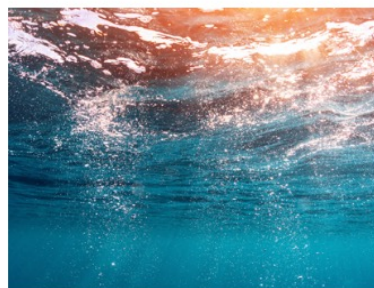
Climate

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 devasting 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
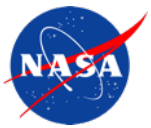
Altimetry Applications Topics

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

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.

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 Jason-3 missions comprise the along-track Sea Level Anomaly at 5 Hz (instead of 1 Hz) for two areas: North Atlantic and s. NetCDF format files are available. Additional information is available in the OSTM-Jason-2 and Jason-3 handbooks.

oducts are available at :

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
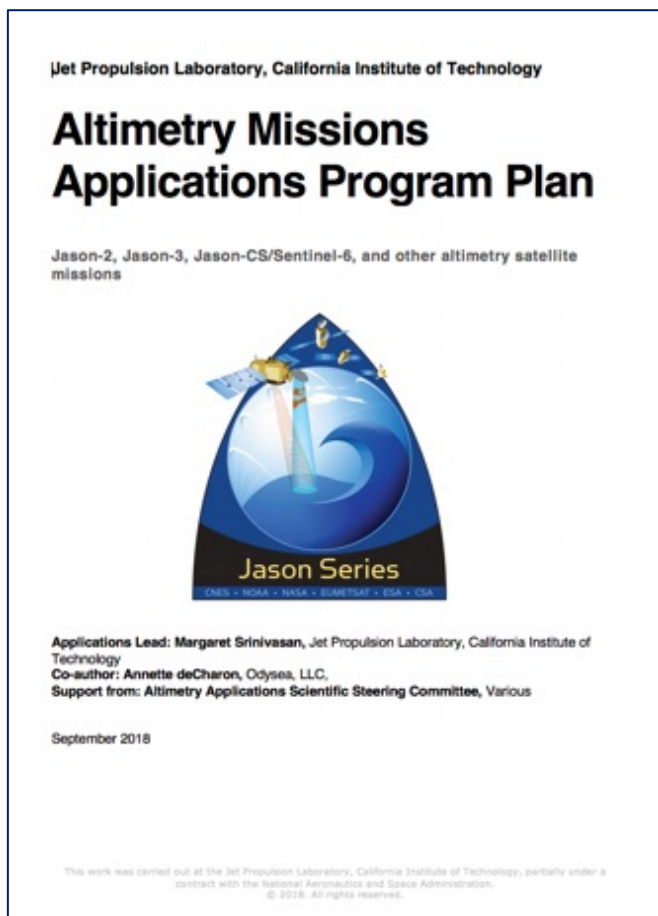
Users

- **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

Jet Propulsion Laboratory, California Institute of Technology

Altimetry Missions Applications Program Plan

Jason-2, Jason-3, Jason-CS/Sentinel-6, and other altimetry satellite missions

Jason Series
CNES · NOAA · NASA · EUMETSAT · ESA · CSA

Applications Lead: Margaret Srinivasan, Jet Propulsion Laboratory, California Institute of Technology
Co-author: Annette deCharon, Odysea, LLC,
Support from: Altimetry Applications Scientific Steering Committee, Various

September 2018

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NASA Earth Science Division
Applied Science Program
SWOT Mission

SWOT Applications Plan
D-79129, Ver. 1.0

September 2014

Edited by:
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swot.jpl.nasa.gov/applications

September 26, 2014
JPL D-79129

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

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sealevel.jpl.nasa.gov/applications   *swot.jpl.nasa.gov/applications*
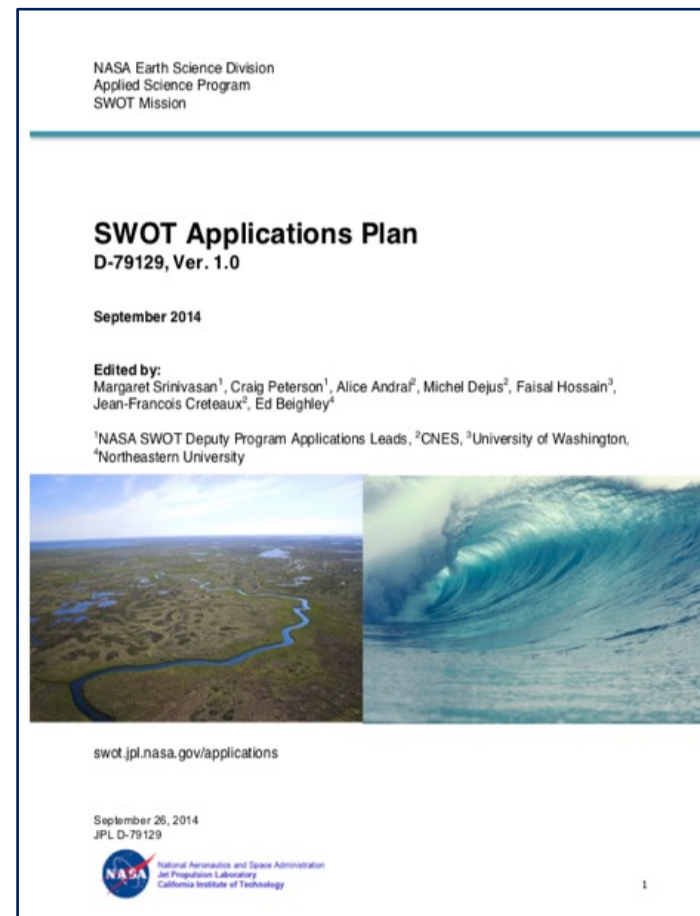
Coastal Applications of Altimetry

- **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 to 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
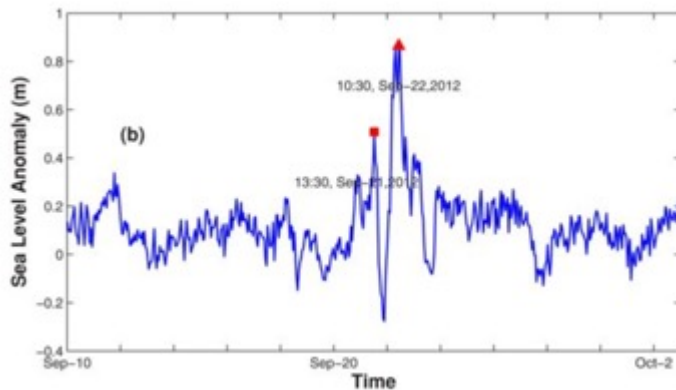
Image: Han, G., et al, 2012

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.

Source: www.myocean.eu

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.
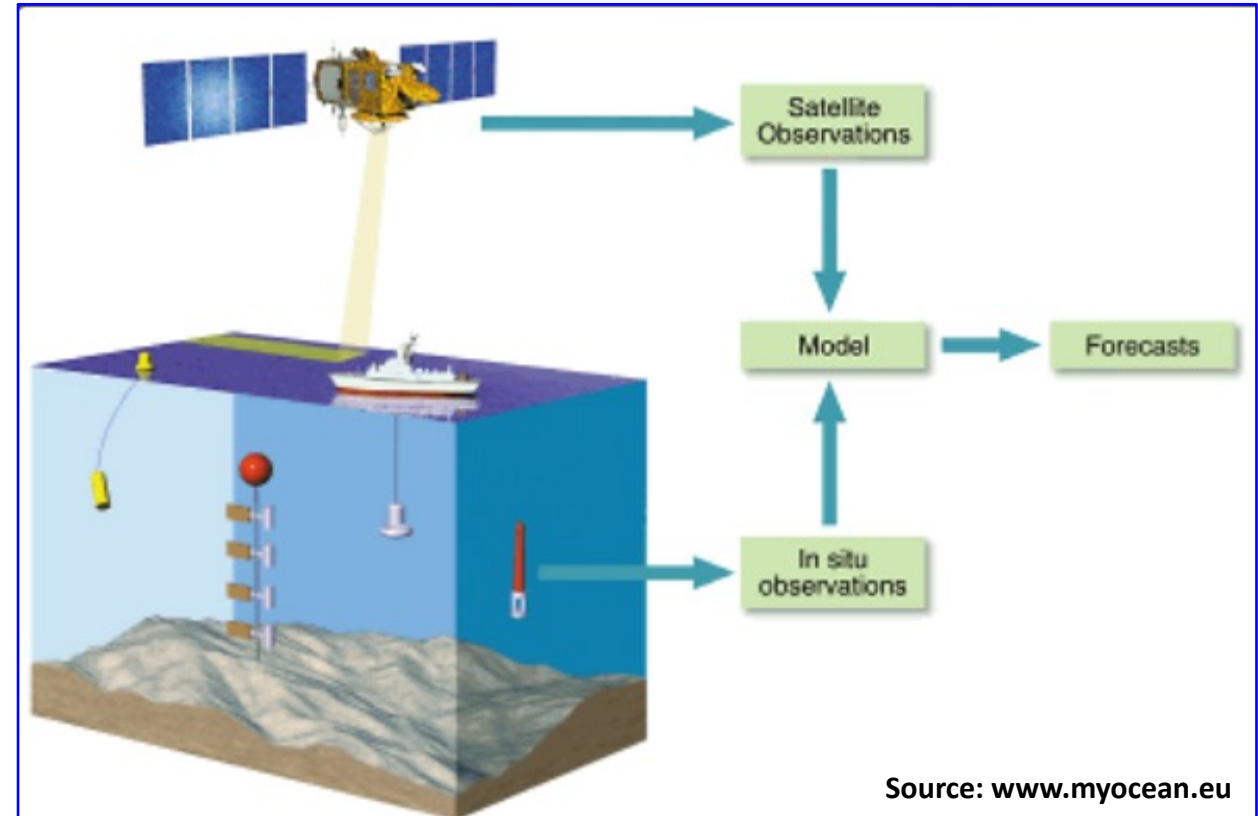
Ocean Navigation

Commercial Use Examples;

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

Blue SIROS
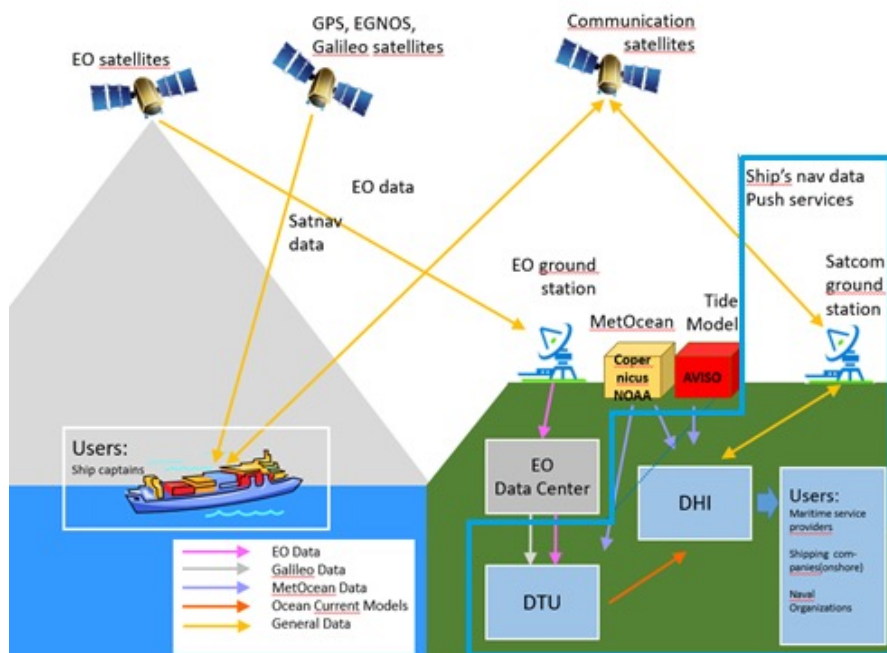
Merchant ship routes & marine pollution
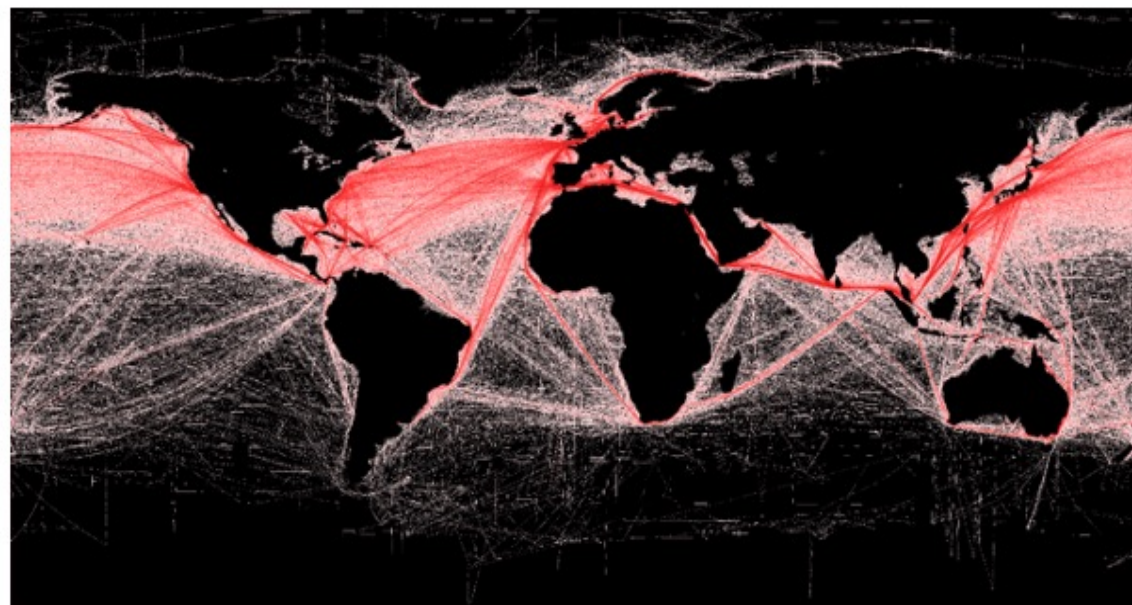
Merchant shipping traffic based on altimetry data (since 1992)

Fisheries Assessment & Management

Hilton's Realtime Navigator

FishTrack

Terra-Fin

Washington Regional - Oct 6, 2020 10:33 AM
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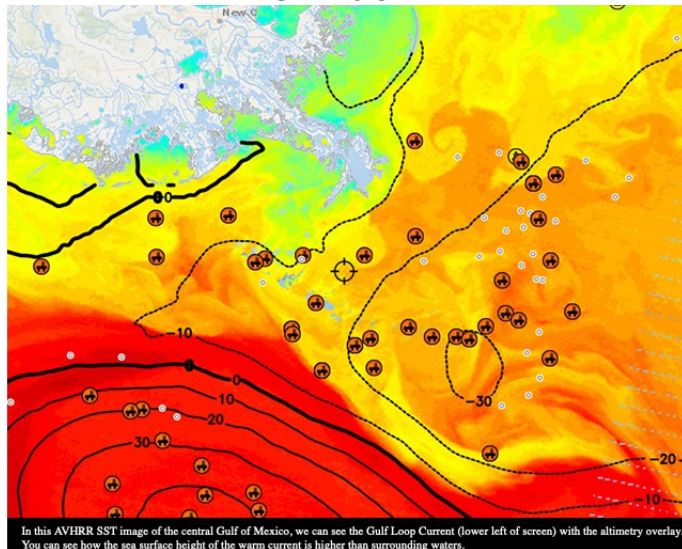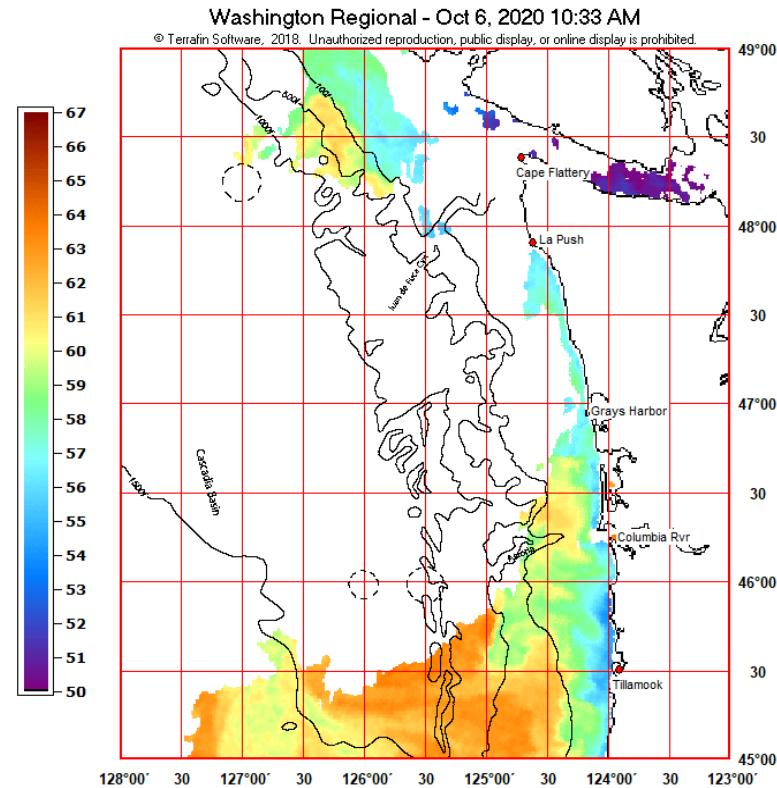
Commercial User Examples;
- Fish Track
- Hilton's Realtime Navigator
- Terra-Fin

Private Sector: Operational Ocean Forecasting

Source: jcgulfstream.com
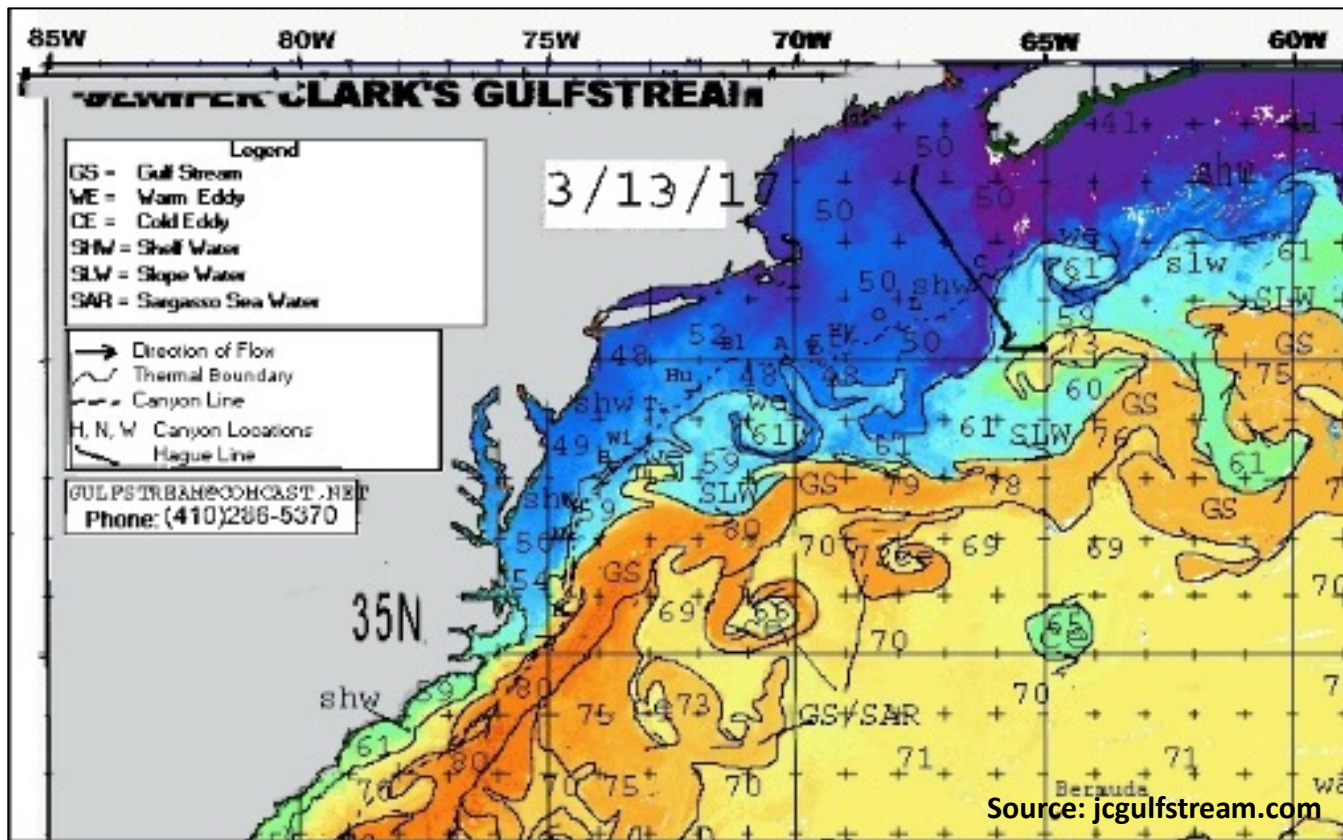
Jenifer Clark's GulfStream

- 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

Sea Surface Height

Sea Surface Temperature
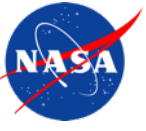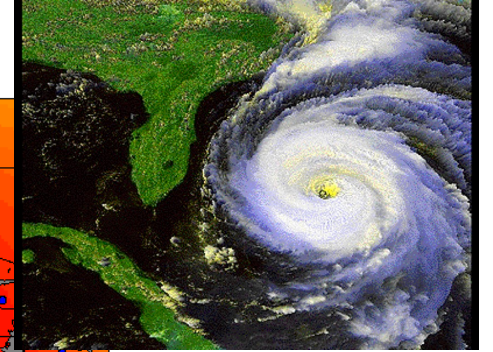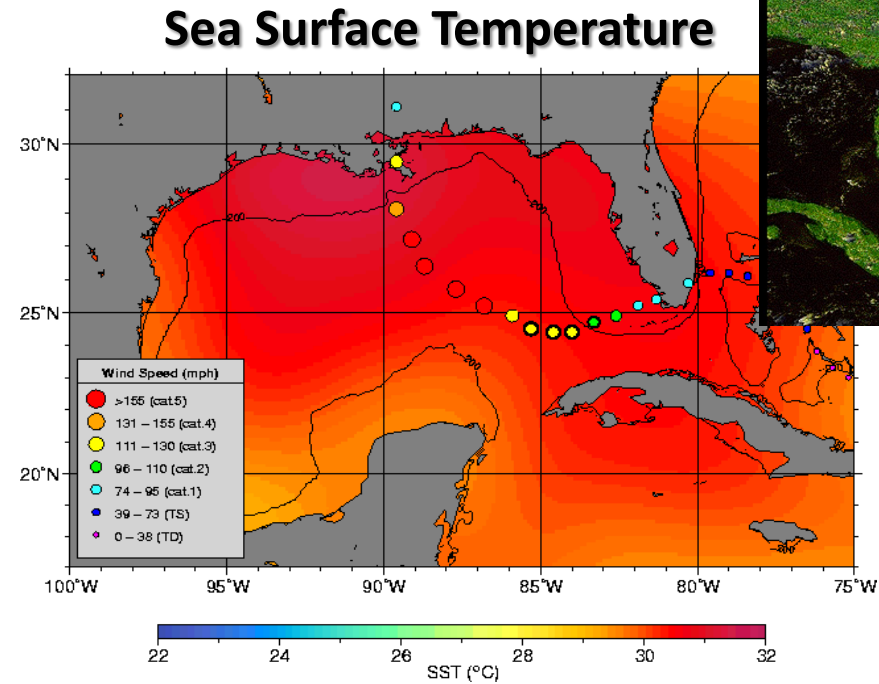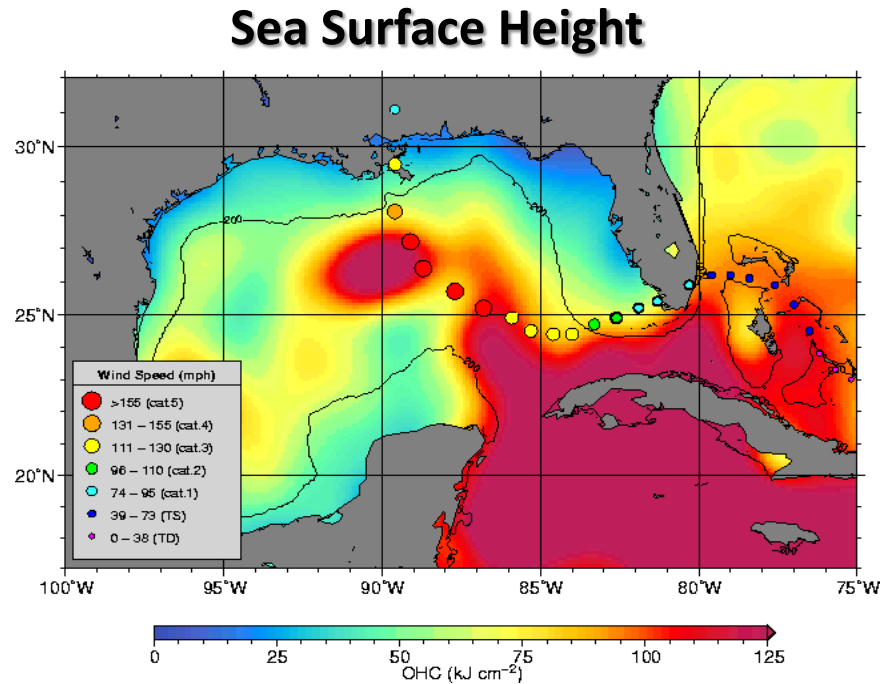
Source: NOAA/AOML

- 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.
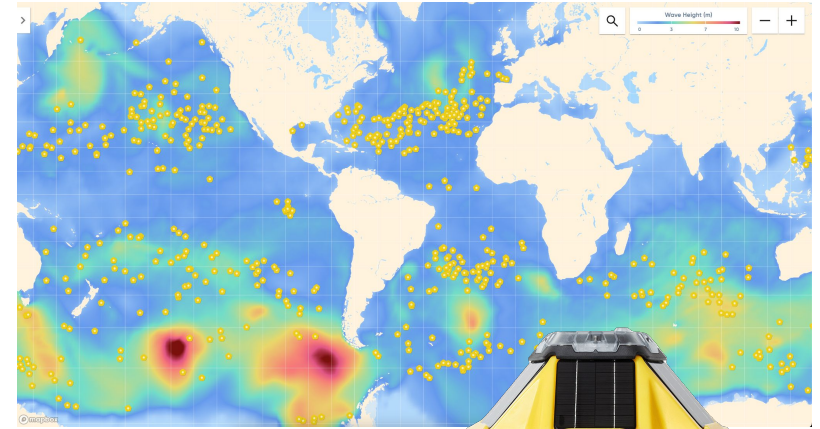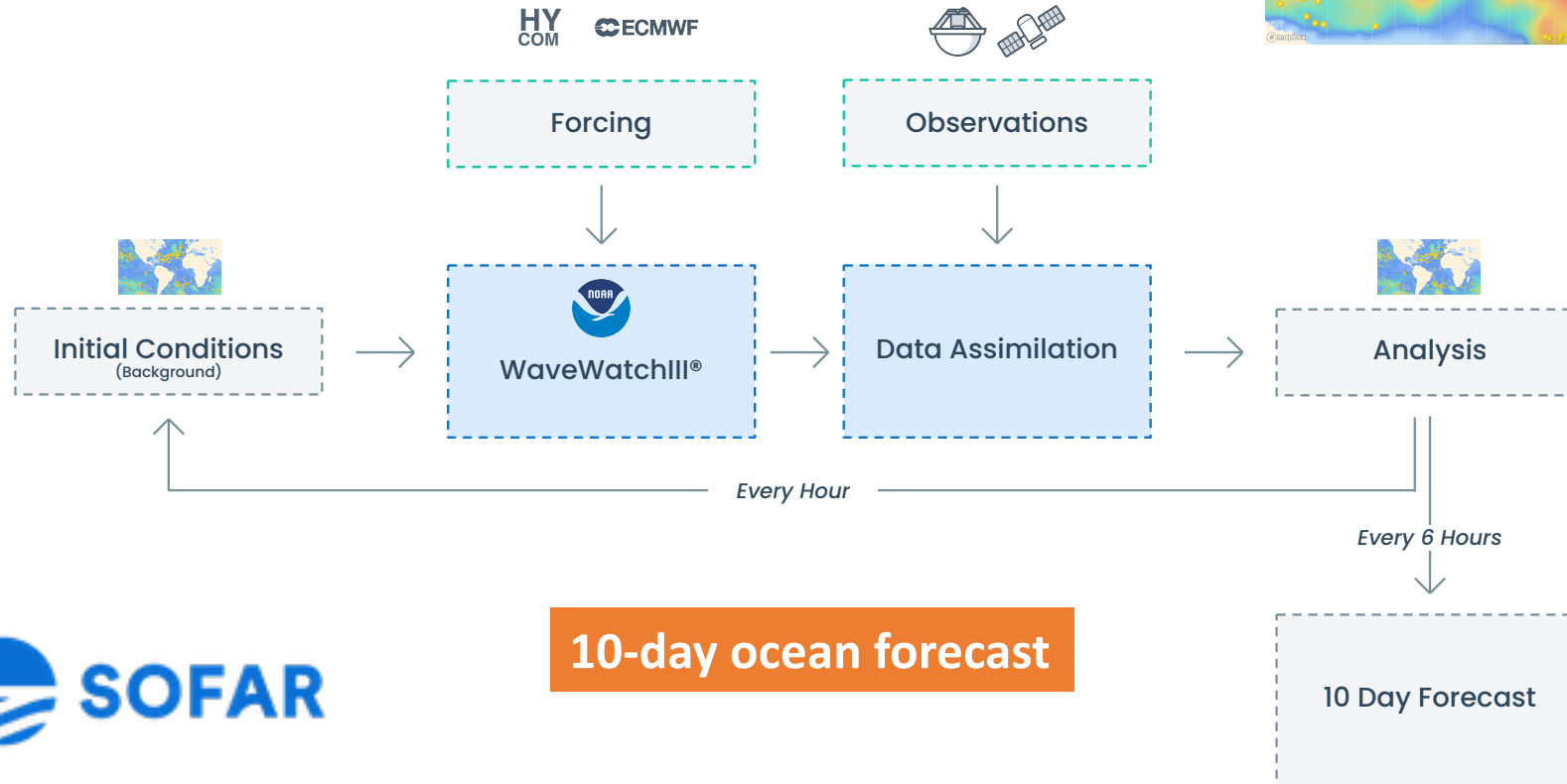
10-day ocean forecast

U.S. Navy – Naval Research Lab

All nadir altimeters
100 m temperature and currents
scv_reg swot
water_temp / currents 0100 m - 2023-04-12 0000 GMT

SWOT + all nadir altimeters
100 m temperature and currents
scv_ws swot
water_temp / currents 0100 m - 2023-04-12 0000 GMT

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 toprocess 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.
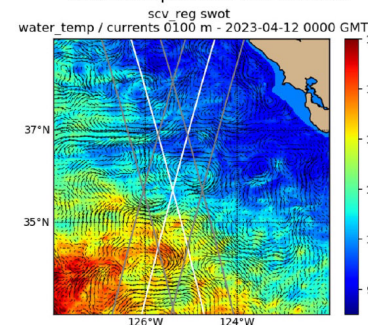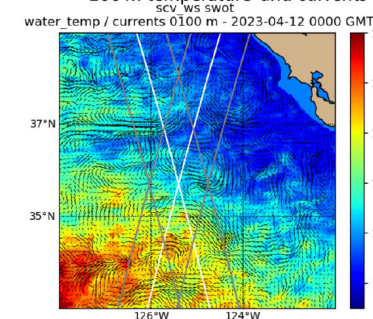
Numerical models to predict;
- **Ocean currents**
- **Temperatures**
- **Salinities**

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**
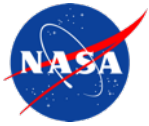
Global Reservoirs and Lakes Monitor - G-REALM

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
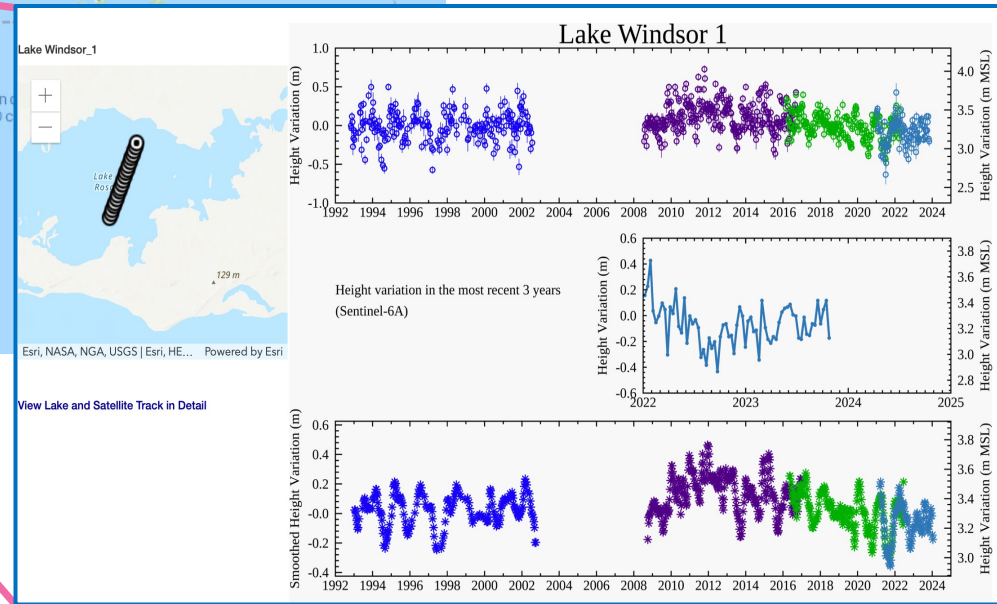
Source: C. Birkett, NASA

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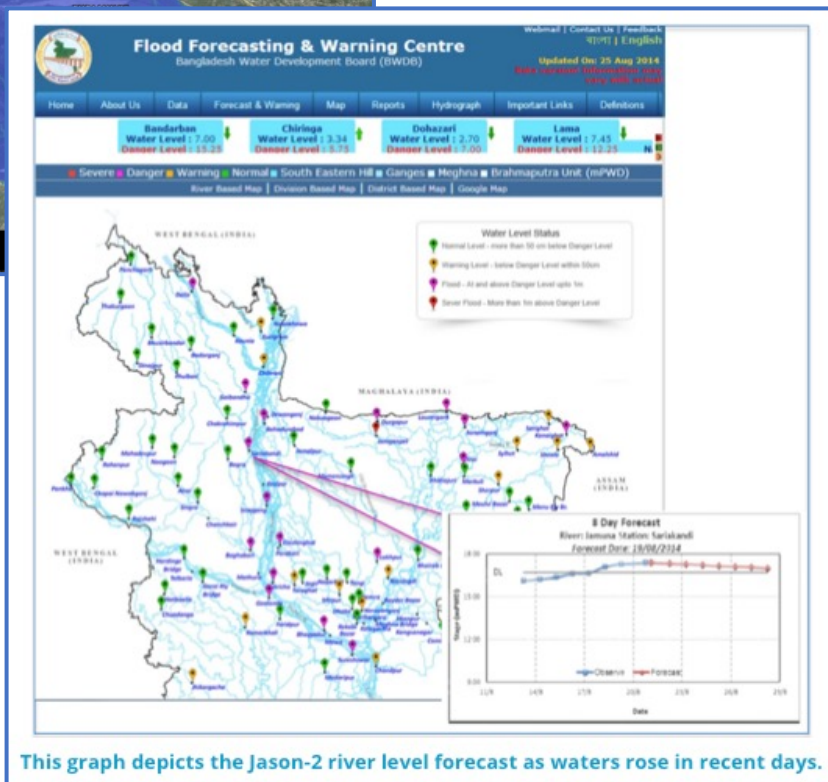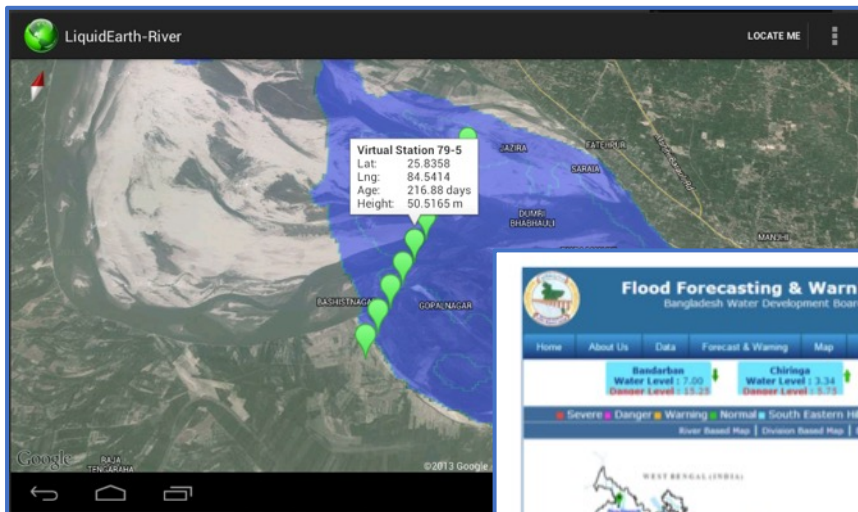
This graph depicts the Jason-2 river level forecast as waters rose in recent days.

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

Related Poster

'SWOT Applications Working Group (SAWG) Activities'

ODS Poster Sessions

Esperanza Beach Room (Lobby)

Wed, Nov 08 2023, 16:15 - 18:00 -

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