



# Surface Water and Ocean Topography (SWOT) Mission

1<sup>st</sup> Science Team Meeting

13-16 June 2016

## Applications

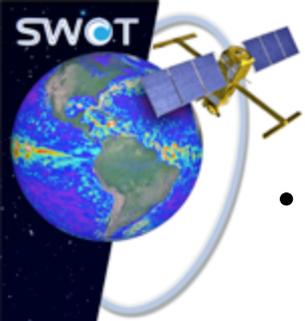
*Contributors:*

**Margaret Srinivasan, Craig Peterson: NASA Applications Leads**

**Alice Andral, Michel Dejus: CNES Applications Leads**

**Faisal Hossain, Ed Beighley: Applications Scientists**

**SWOT Applications Working Group**



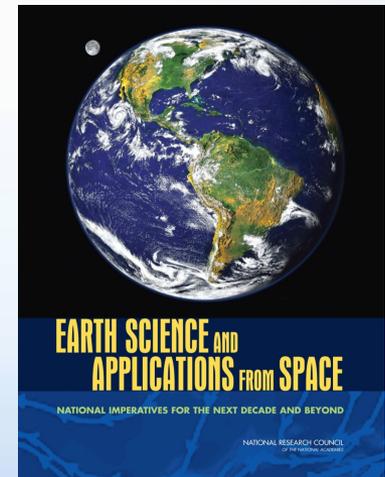
# Outline

- Overview of the SWOT Applications program, Objectives, Framework, ST & Project communication
- SWOT Applications Working Group (SAWG)
- Activities; User workshops, Tutorials, Early Adopters program
- Near-term plans & long-term goals

## **Bases of Applications programs;**

- NASA -- Earth Science Division, Applied Science Program, Decadal Survey
- CNES -- French Investment Program
- CSA, UKMO -- Collaborations

**SWOT mission is implementing an applications approach at the project level, supported by NASA, CNES, and the science leads.**





# Overview

- SWOT is a science mission, not an application mission.
- The SWOT mission will provide data products to facilitate the use of SWOT observations by users.
- Data availability (including latency) and access are critical to success.
- Close alignment with NASA & CNES data centers
- Partnership -- assumes and requires association, participation, and mutual interests; NASA, CNES, CSA, UKSA, Project, ST, operational agencies, university partners, industry/commerce, data centers





# SWOT Applications Program

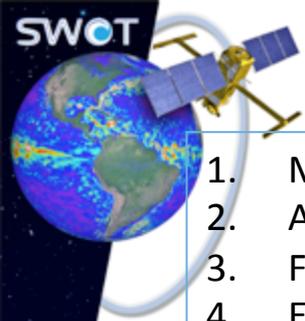
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## Goals;

- Partner with ST
- End user focus
- Facilitate feedback; SWOT user communities  $\leftrightarrow$  SWOT project
- Promote collaborations
- Design communication strategies
- Outcomes; user-driven inputs for SWOT mission/data

## Methods;

- Organization: ST members, applications collaborators, partners
- SWOT Applications Working Group
- Assess current benefits & requirements
- Outreach to broad user community
- Engage strategic partners
- “Early Adopters” & Research Early Adopters
- Workshops, science meetings, email list, web, personal interactions
- Funding -- Applications aspects of ST work (AS, ROSES, TOSCA, etc.)
- Capacity-building (i.e., SERVIR)

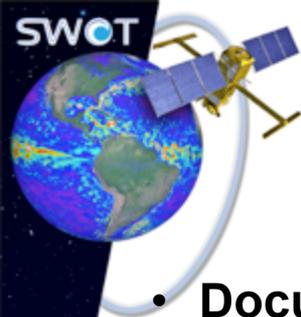


# SWOT Applications Working Group (SAWG)

1. Margaret Srinivasan, Craig Peterson, **NASA Applications Leads**
2. Alice Andral, Michel Dejus, **CNES Applications Leads**
3. Faisal Hossain, U. Washington, **U.S. SWOT Applications Scientist**
4. Ed Beighley, Northeastern University, **U.S. SWOT Applications Scientist**
5. Rosemary Morrow, LEGOS, **CNES Ocean Science Lead**
6. Jean-Francois Cretaux, LEGOS, **CNES Hydrology Science Lead**
7. Kostas Andreadis, JPL
8. Bob Arnone, U. Southern Mississippi at Stennis SC
9. Sylvain Biancamaria, LEGOS
10. Matt Bonnema, U. Washington
11. Emilie Bronner, CNES
12. Phil Callahan, JPL
13. Jennifer Cruz, JPL
14. Annette deCharon, U. Maine
15. Guy Schumann, RSS, Google
16. Jessica Hausman, PODAAC JPL
17. Nicolas Picot, CNES
18. Gregg Jacobs, Naval Research Laboratory
19. Alexander Kurapov, U. Oregon
20. Robert Leben, U. Colorado
21. Pierre-Yves Le Traon, Ifremer & Mercator Ocean
22. Dennis Lettenmaier, U. Washington
23. Steve Nerem, U. Colorado
24. Tamlin Pavelsky, University of North Carolina
25. Vinca Rosmorduc, CLS
26. Robert Saint-Jean, Canadian Space Agency
27. Guy Schumann, RSS, Google

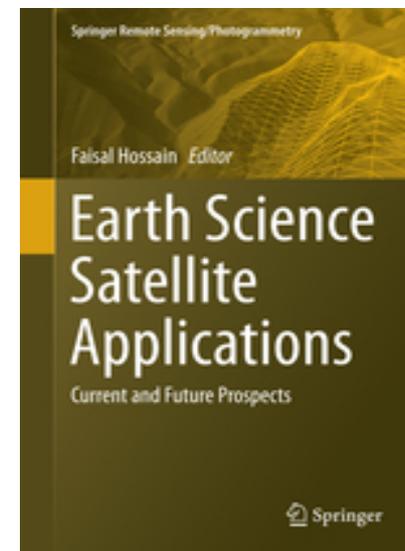
**Quarterly telecons**  
**ST meetings**  
**Email listserve**

**Wednesday, 6 pm,**  
**Westin San Gabriel Room**



# Applications: NASA-CNES Phase A/B Activities

- **Documents;** 1) *SWOT Applications Plan*, 2) *SWOT Early Adopters Program Guide*
- **Early Adopters Program;** 2015 implementation
- **1<sup>st</sup> User Workshop;** January 2015
- **SWOT Online User Survey;** assess needs, capabilities, scales, PO.DAAC 'Use Cases'
- **SWOT Applications Traceability matrix;** connecting applications to capabilities
- **SWOT User database;** user community
- **Publications/presentations;** Peer-reviewed journals, book chapter, BAMS article, posters, oral presentations



## **SWOT Applications Program – the only;**

- **Joint, international applications program for NASA Applied Sciences Program and for the CNES accompaniment program**
- **International working group (SAWG)**

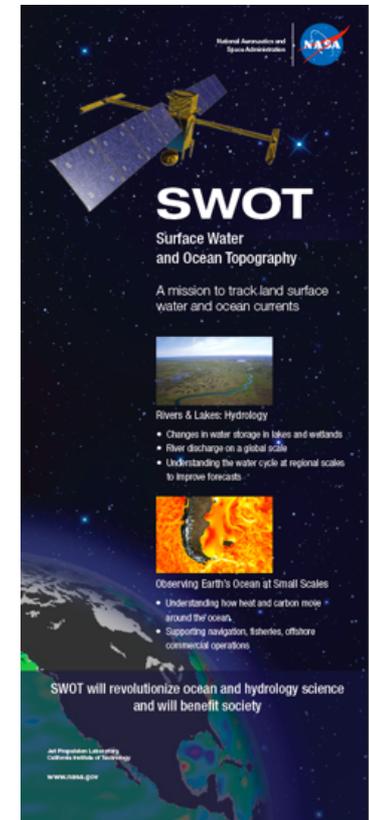


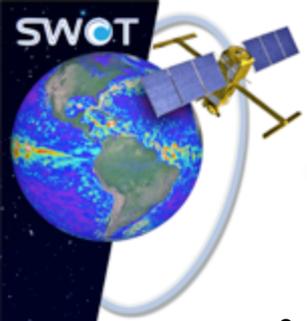
# SWOT Early Adopters Program

**Who:** Users/stakeholders who may have a direct or clearly defined need or use for information from SWOT mission data, and who, using their own resources (funding, personnel, facilities, etc.), can demonstrate the utility of mission data for their particular system or model.

**Tools:** User database, online survey, applications workshops, training, support/contact with SWOT ST, data center tools.

**Why:** Value-added demonstration for NASA mission, promote applied uses of mission information, international collaboration, expand capabilities for technologies bridging to societal benefits, Accelerate the use of mission products *post-launch* by providing specific and continuous support to Early Adopters.



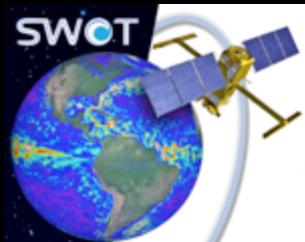


# Early Implementation of SWOT EAs

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- ‘Seed’ Early Adopters – Research Early Adopters
- Demonstrate utility and societal value of SWOT data through applied research
- ST/SAWG members with data sets for applied research
- Planned tutorial focused on available (simulated, proxy) data sets
- Leverage resources and build on existing efforts

**Research Early Adopters**



# Submesoscale Prediction of Eddies through Altimeter Retrieval (SPEAR)

Gregg Jacobs



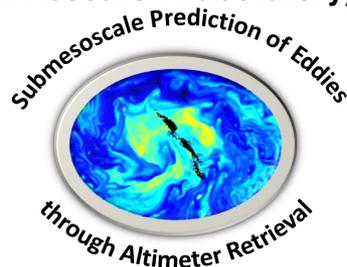
Naval Research Laboratory, Ocean Dynamics and Prediction

## Research Objectives

- Enable ocean forecasting into the submesoscale eddy domain
- Prepare to utilize SWOT high resolution satellite altimeter sea surface height
- Quantify SWOT submesoscale prediction skill

## Team Membership (Naval Research Laboratory)

Dr. Gregg Jacobs  
 Dr. Robert Helber  
 Dr. Clark Rowley  
 Dr. Scott Smith  
 Dr. Innocent Souopgui  
 Dr. Max Yaremchuk

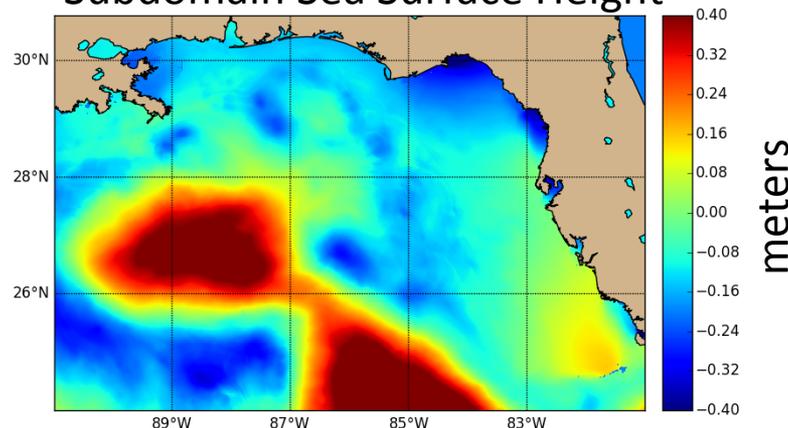


## Status

- Project extends FY17-FY19
- Experiments under way with CARTHE researchers



## Subdomain Sea Surface Height

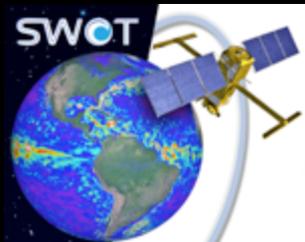


## Data product/Methodology

- Primitive equation numerical ocean models assimilating available satellite and in situ observations forcing by weather prediction systems
- 1 km resolution and finer to resolve submesoscale ageostrophic dynamics
- SWOT simulator to sample model sea surface height
- 1 km Gulf of Mexico 2012 to present
- 250 m northeastern Gulf of Mexico Jan 2016 – April 2016
- Other areas at 1 km and finer resolution planned for coming year
- Use SWOT simulator with multi-dynamic assimilation methods through 3DVar and 4DVar

## Schedule and Issues

- FY17: Build ageostrophic submesoscale covariances through semigeostrophic dynamics, verify against full model fields, generalize the assimilation process
- FY18: Incorporate submesoscale covariances into generalized assimilation, begin multi-dynamic assimilation with mesoscale geostrophic dynamics in first analysis and submesoscale ageostrophic dynamics in second analysis
- FY19: SWOT Observation System Simulation Experiments (OSSEs) to quantify the predictive capabilities of the submesoscale ageostrophic eddies



# SWOT FOR IMPROVING HYDRAULIC MODEL CALIBRATION FOR OPERATIONAL NOWCAST OF TRANSBOUNDARY RIVER FLOW -

Faisal Hossain

## Research Objectives

Assess the value of SWOT data (distributed water elevation and inundated area) for improving hydraulic model calibration and set up.

Assess the skill of the continental-scale hydraulic model in operational nowcast of transboundary streamflow, flood forecast and river heights

## Team Membership

- Faisal Hossain (UW),
- Safat Sikder (UW)
- Nishan Biswas (UW)
- Stakeholder – Institute of Water Modeling and FFWC, Bangladesh

## Status

- Current state: HEC RAS is set up over Ganges-Brahmaputra river basin. But stage-width relationship available at few places using altimeter and non-sync Landsat/MODIS
- Region: South Asia
- How available for sharing? – Model and Ensuing data will be available
- Qualifiers: SWOT Simulator with Rivwidth is needed
- We will test how the simultaneous availability of height and width (to set up stage-width and Q relationship improves our HEC RAS model).
- Eventually – we want to apply ALL platforms, SWOT and others (Landsat, MODIS, altimeters)

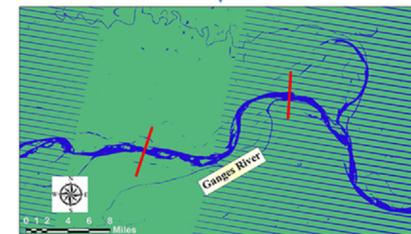
## Methodology



.Maswood\*, M., F. Hossain (2016). Advancing River Modeling in Ungauged River Basins using Remote Sensing: The Case of Ganges-Brahmaputra-Meghna Basins. *Journal of River Basin Management*, vol. 14(1), pp. 103-117, (doi:10.1080/15715124.2015.1089250).

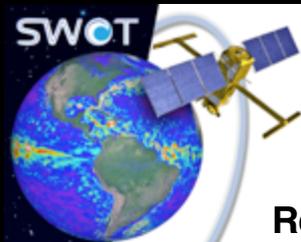


LANDSAT image classification



## Methodology, Schedule and Issues

- We'll corrupt a 'reference' HEC RAS water level with SWOT simulator and then derive stage-width and Q relationships. Next, we will insert into reference HEC RAS the 'SWOT' based river bathymetry data. We will repeat the same for reference HEC RAS using altimeter-Landsat based bathymetry (non-sync). Simulation of water level downstream in delta region (stakeholder agencies are interested in this) will be compared for the 3 options (reference, SWOT and altimeter-Landsat non-sync)
- Fall 2016 – start applying simulator on HEC RAS water DEM
- Fall 2017 – assessment of performance after replacing river bathymetry
- Fall 2018 – Report results and share with IWM/FFWC



# SWOT FOR IMPROVING RESERVOIR MANAGEMENT

Faisal Hossain, Bangladesh-IWM, Pakistan-PCRWR, Vietnam-NUCE

## Research Objectives

Assess the value of SWOT data (distributed water elevation and inundated area) for improving reservoir operations (outflow estimation, storage change and inferring rule curves

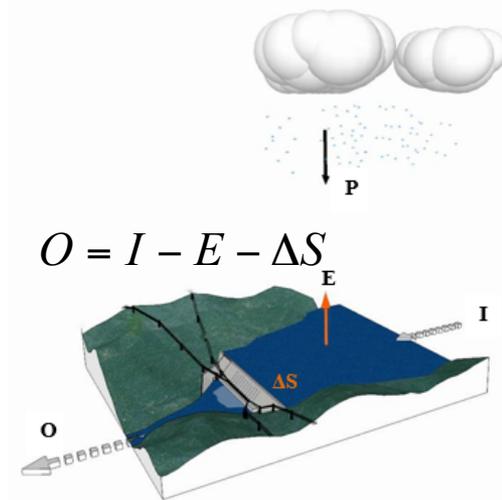
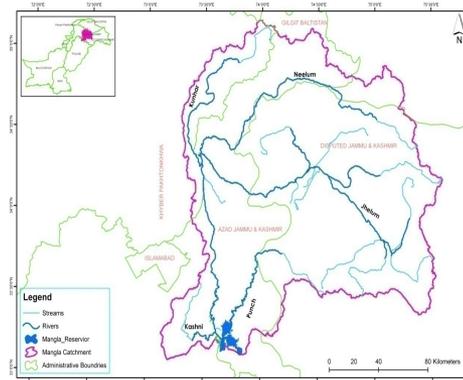
## Team Membership

- Faisal Hossain (UW),
- Matthew Bonnema (UW)
- Stakeholder – Institute of Water Modeling (Bangladesh),
- PCRWR (Pakistan) and NUCE (Vietnam)

## Data product/Methodology

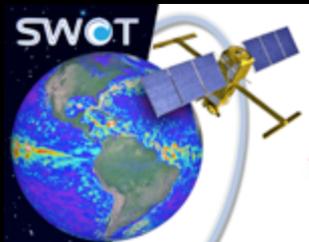
- We will apply the following mass-balance approach using SWOT simulator data outlined in Bonnema et al. (2016) –
- Bonnema\*, M., S. Sikder, Y. Mao, X. Chen and F. Hossain, I.A. Pervin, S.M. M. Rahman and H. Lee. (2016). Understanding Satellite-based Monthly-to-Seasonal Reservoir Outflow Estimation as a function of Hydrologic controls *Water Resources Res.*, (In revision) (doi: 10.1002/2015WR017830).
- SWOT simulator will be applied on reservoir surface area and height data (derived from altimeter, SRTM, MODIS/ Landsat). Three reservoirs are selected – Mangla or Tarbela (Pakistan), Kaptai (Bangladesh) and a reservoir on Red river (Vietnam)

## Status



## Schedule and Issues

- Fall 2016 –Spring 2017– start applying simulator on selected reservoirs after reservoir bathymetry is derived from in-situ or non-SWOT data
- Summer 2017-Spring 2018– assessment of performance of SWOT data in reservoir outflow and storage changes.
- Summer 2018-Spring 2019 – rule curve inference.
- Data and results will all be made available freely



# Fusion of SWOT with Coastal Ocean Weather and Ecological Processes

Robert Arnone

University of Southern MS, Dept Marine Science, Stennis Space Center

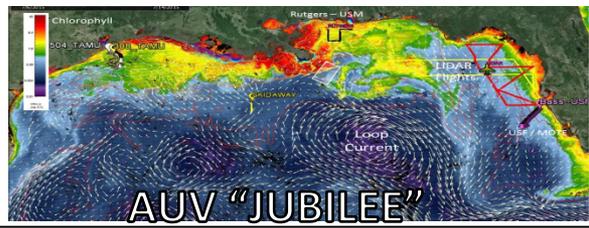


## Research Objectives

1. Integrate and fuse SWOT with ocean weather products for satellites and models in coastal regions.
2. Define if SWOT can be used for adaptive sampling with the Ocean Weather Laboratory.
3. Examine applications of SWOT to support coastal marine ecology.
4. Define SWOT detection of river plumes and estuary processes impact the ecosystem and bio-optical ecology.

### Team

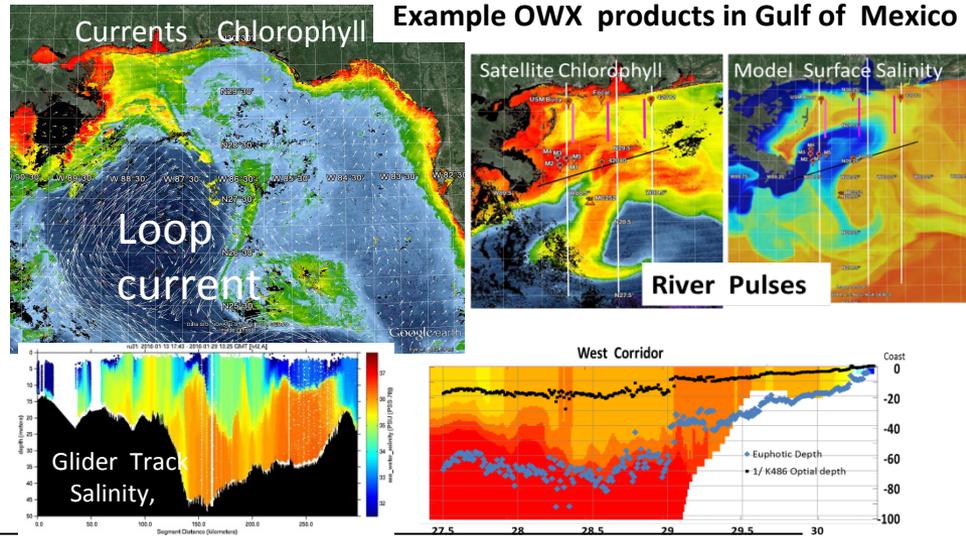
- Pro Robert Arnone
- Dr. Inia Soto
- Dr. K. Cambazoglu
- Dr. Jerry Wiggert
- Dr. Brook Jones



## Status - OWX Lab

<https://www.usm.edu/marine/research-owx>

### Example OWX products in Gulf of Mexico



## Data product/Methodology

- Ocean Weather Laboratory (OWX) products of models and satellites SST and color and bio-optics (VIIRS)
- Defining Uncertainty with different products (3 Circulation models and satellite bio-optical and observations)
- Gulf of Mexico and coastal estuaries
- Periodic data products available

## Ocean Weather Laboratory

### Satellite Products

- Biology - Chlorophyll
- Light attenuation
- Particles - Backscatter
- Absorption
- CDOM
- Detritus
- Phytoplankton
- Sea surface Temperature
- Sea surface Salinity

### Model Products

- Sea Surface Temperature
- Sea Surface Salinity
- Mixed Layer Depth
- Intensity of Mixed Layer
- Sea Surface Height
- Current Vectors
- Current Magnitude
- Model Differences
- Regional Cross Sections

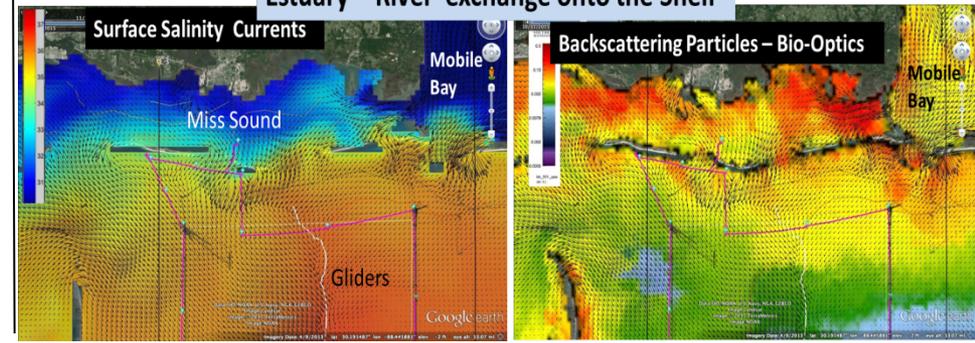


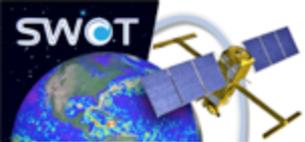
Add SWOT

## Schedule and Issues

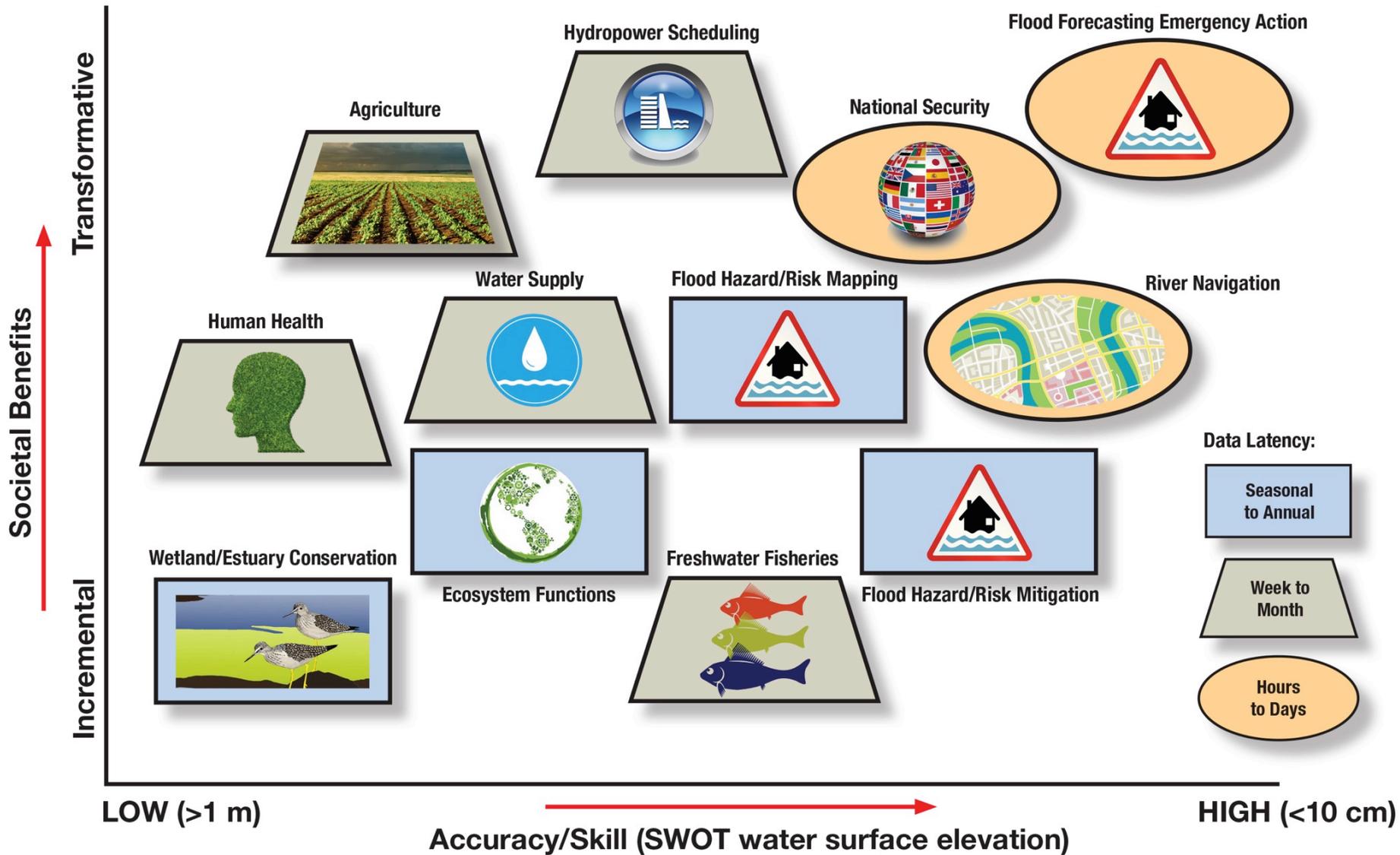
- a. Leveraging GOMRI - Concorde and Restore.
- b. 2017 Daily Nowcast of ocean weather Products for Gulf of Mexico
- c. Integrate SWOT into OWX requires address data availability and format

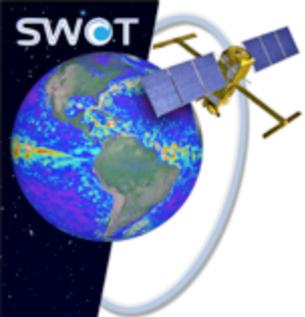
### Estuary - River exchange onto the Shelf





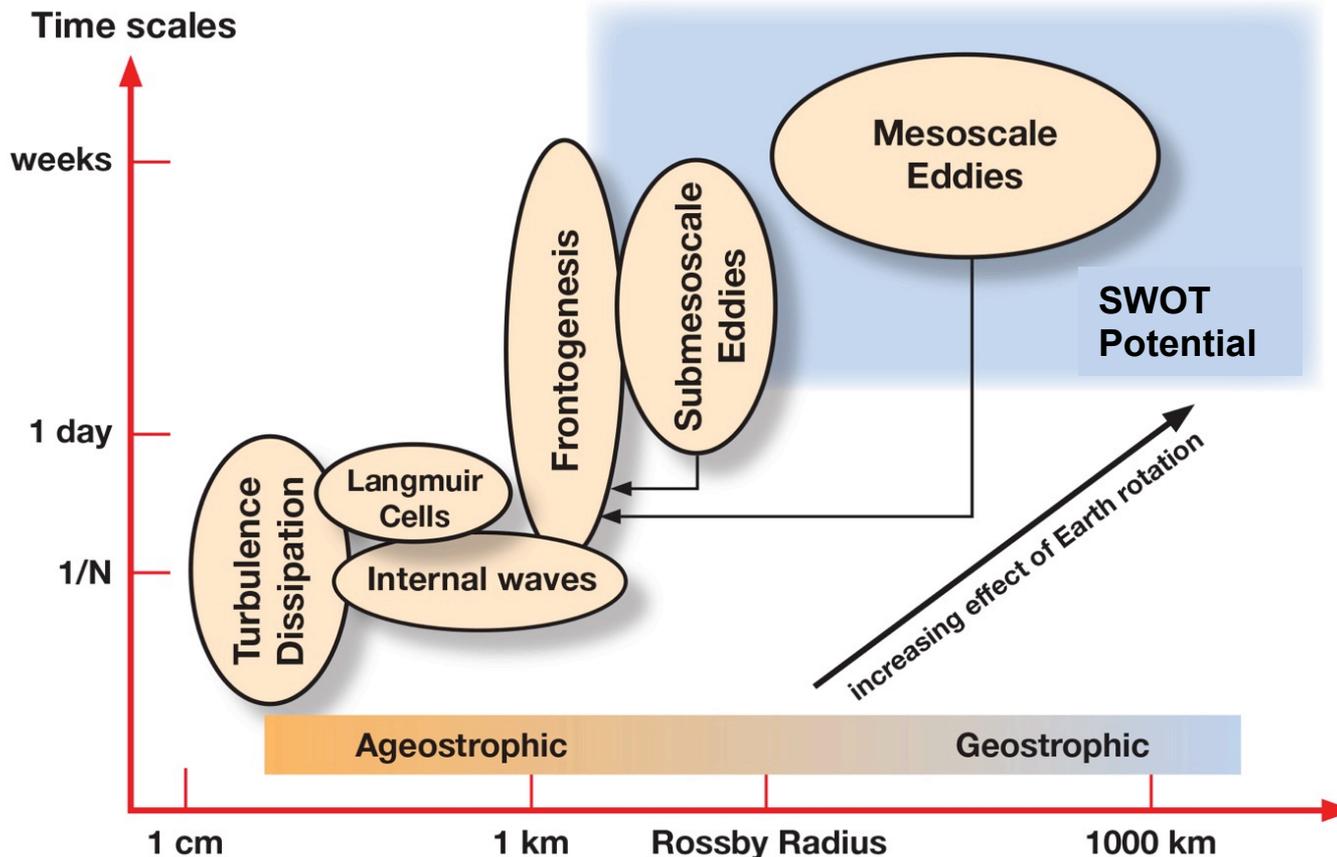
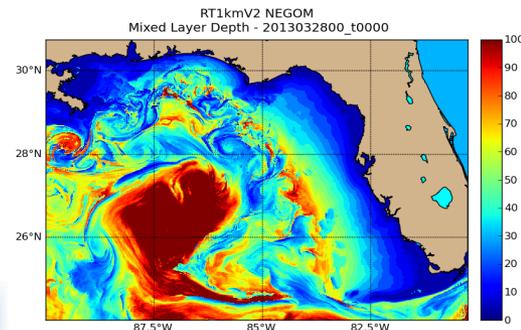
# SWOT Hydrology Applications





# SWOT Ocean Applications

Model forecasted mixed layer depth



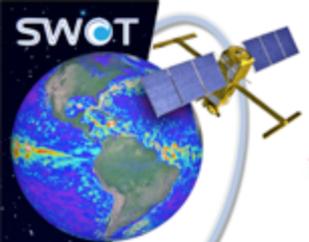
- Present altimeter capability allows limited mesoscale eddie forecast
- SWOT will enable forecast of submesoscale eddies
- These two forecasts will enable forecast of frontal effects



# Applications: Phase C/D Focus

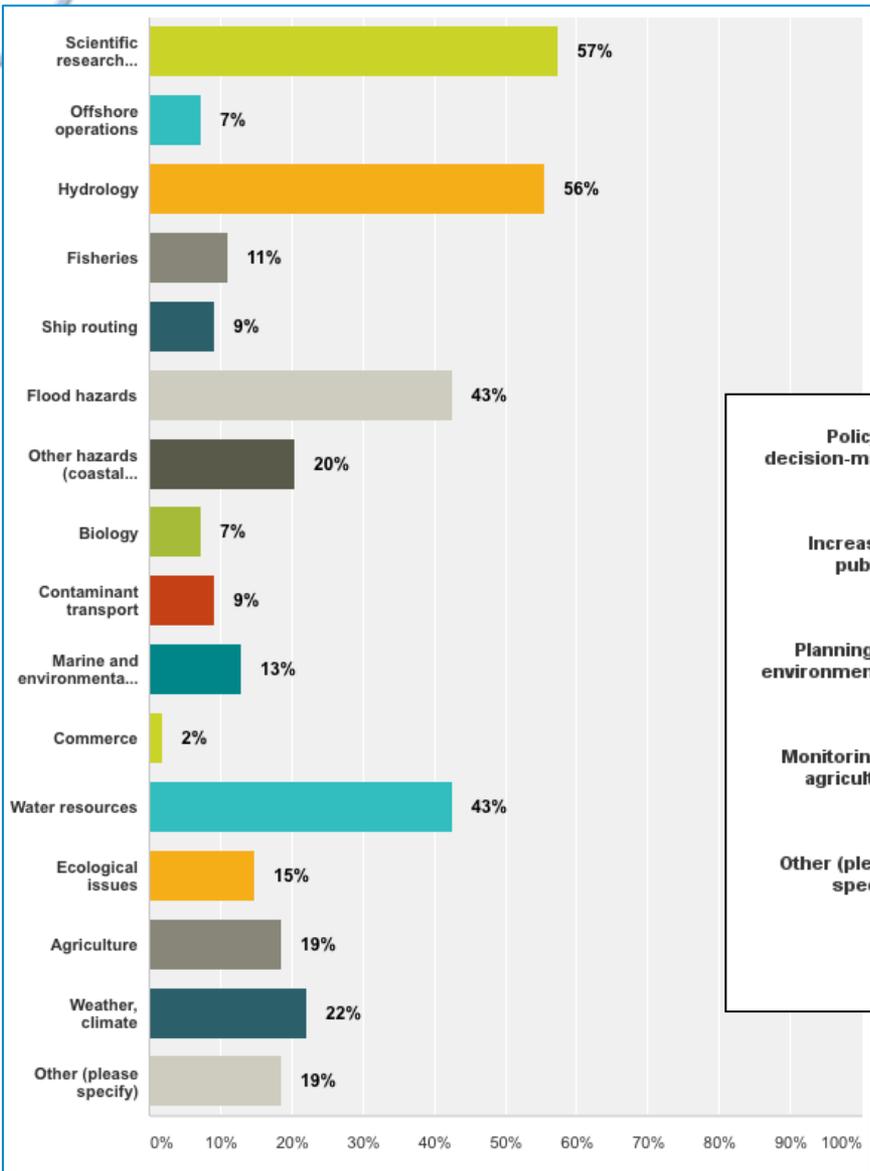
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- Early Adopters; Promote use of SWOT (proxy) data and products to key end-users and decision makers
  - Assess needs & capabilities
  - Facilitate data access including PO.DAAC tools & training
  - SWOT Application focused user workshops – topical
  - Target/seek research efforts with existing proxy data sets; AirSWOT, radar altimetry, simulator data
- User needs; High resolution and shorter latency is what many application users want (but not all users)
- Continue to work with Project, PO.DAAC, AVISO to identify users, understand their needs, & enhance/improve access to data and literacy
- SWOT Applications User Survey – summary at SWOT ST meeting
- Continue collaboration with PO.DAAC
- Continue international collaborations
- Build synergies for societal relevance

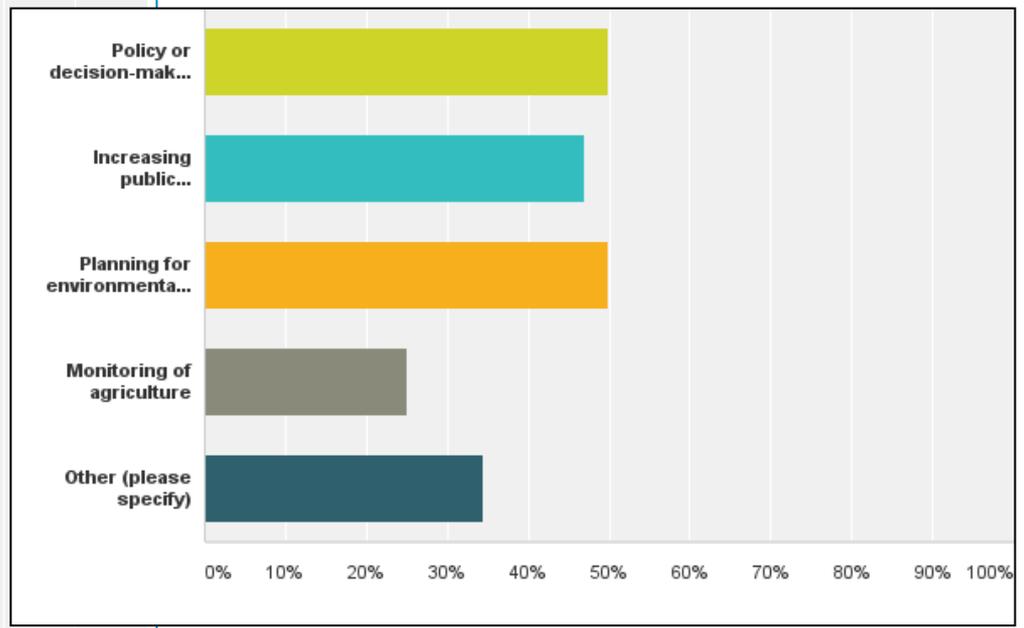


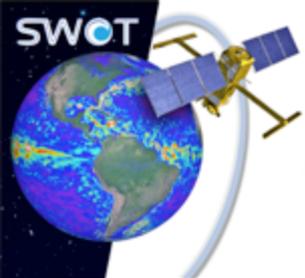
# SWOT User Survey

## Domain of interest:



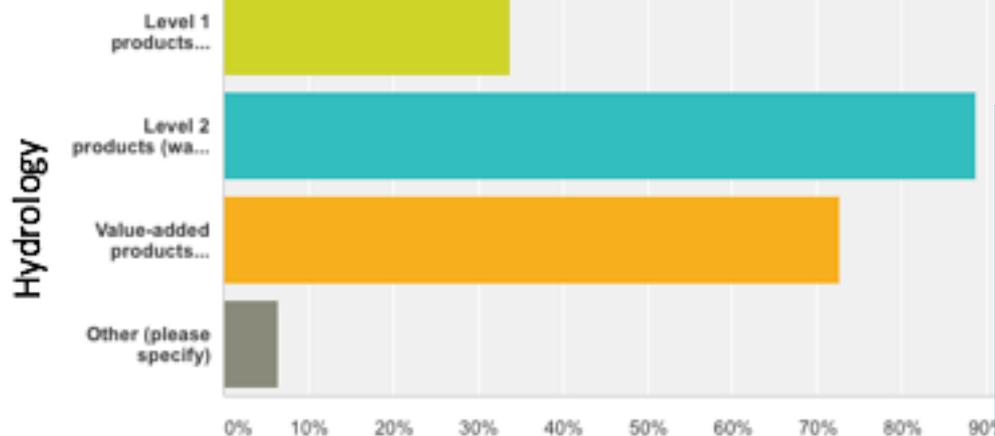
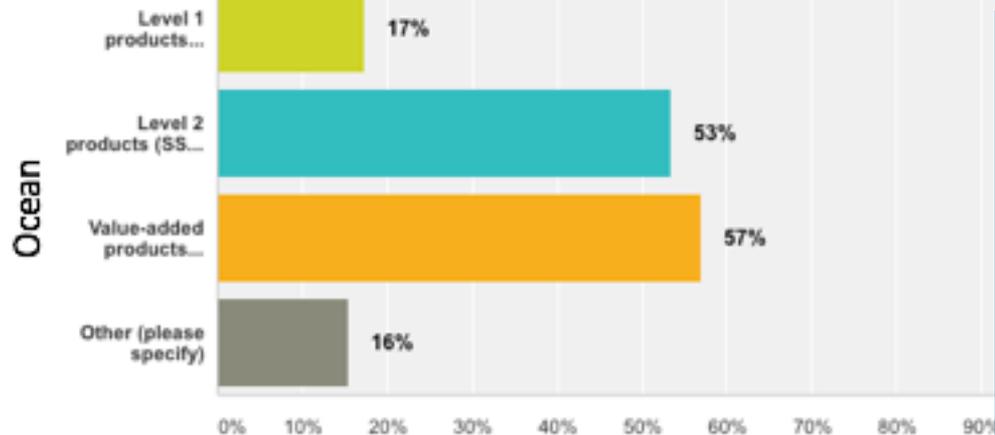
## Activities:



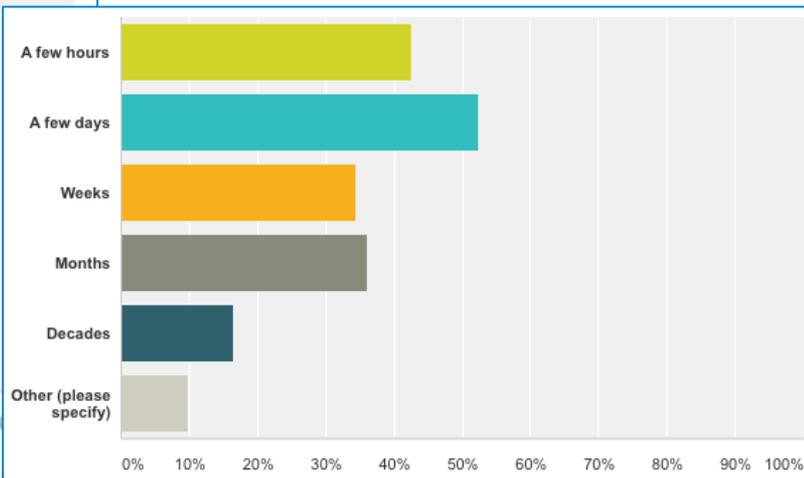


# SWOT User Survey

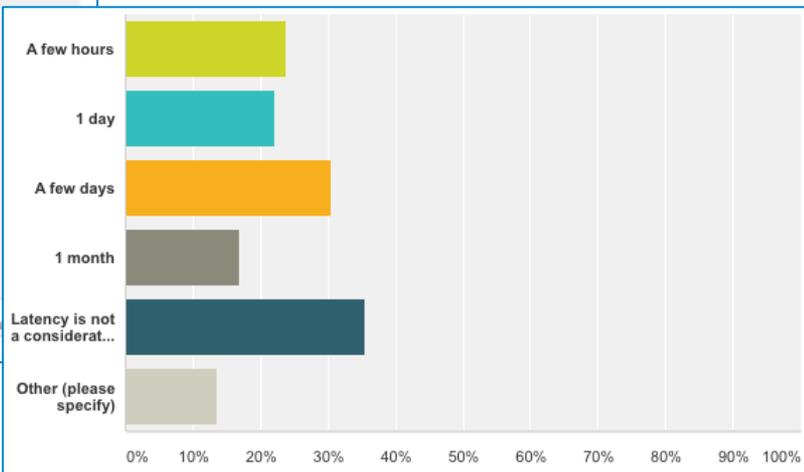
## Data Products:

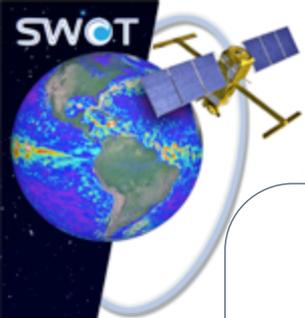


## Temporal Scale:

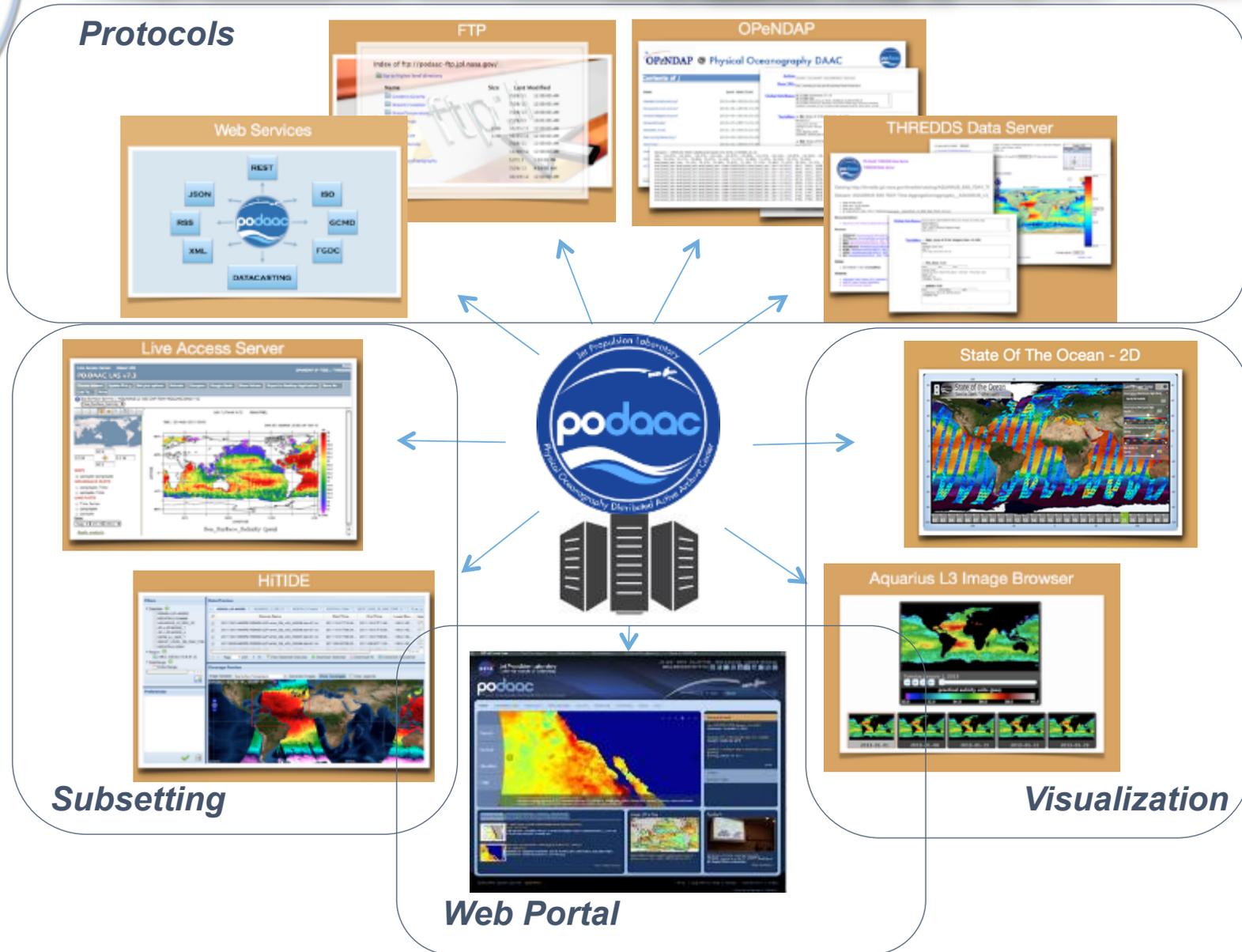


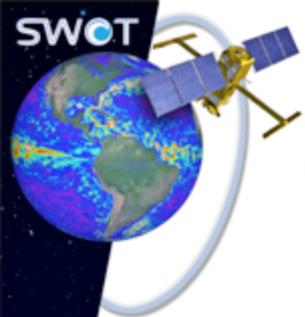
## Latency:





# PODAAC - Connecting Users to Data





# SWOT Survey Poster



## Pre-Launch Assessment of User Needs for SWOT Mission Data Products

SWOT Applications Working Group

Corresponding author: M. Srinivasan (m.srinivasan@jpl.nasa.gov)

NASA Administration and Space Administration



### 1. Abstract

In order to effectively address the applications requirements of future Surface Water and Ocean Topography (SWOT) mission data users, we must understand their needs with respect to latency, spatial scales, technical capabilities, and other practical considerations. We have developed the 1<sup>st</sup> SWOT User Survey for broad distribution to the SWOT applications community to provide the SWOT Project with an understanding of and improved ability to support users needs.

Actionable knowledge for specific applications may be realized when we can determine the margins of user requirements for data products and access. The SWOT Applications team will be launching a SWOT Early Adopters program and are interested in identifying a broad community of

### 3. Methodology

**Target:** Professionals in hydrology or oceanography, potential users with insight into how SWOT data may be used after launch, industry/academic, civic leaders, water managers and anyone who may find SWOT advantageous for their system or process.

**Development:** Developed jointly with SWOT Project, International partners, and SWOT Applications Working Group and deployed in September 2015.

**Distribution:** To SWOT Applications potential user database, Global Flood Working Group, and PODAAC email lists.

**Responses:** 69 responses as of 9 June 2016.

Visit: <http://www.surveymonkey.com/r/SWOTusersurvey2015>

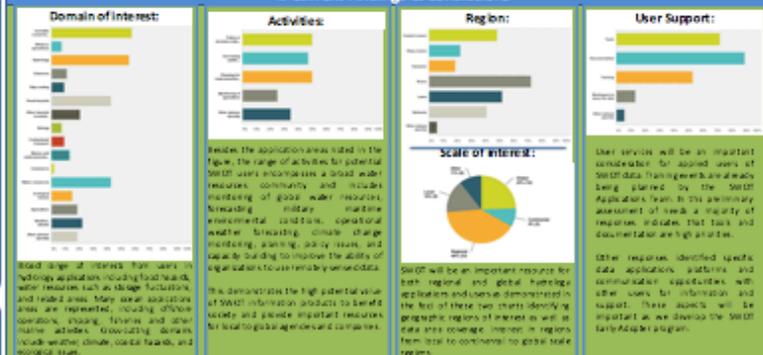
### 2. Objectives

**Purpose:** To identify the ways in which SWOT may be used by operational, private, institutional, and other individuals and organizations. The SWOT Applications team will be launching a SWOT Early Adopters program in 2016 and are interested in identifying a broad community of users who will participate in pre-launch applications activities including meetings, briefings, and workshops. The information provided can help NASA, CNES and mission partners (CSA, UKSA) to better support applications activities in the future.

**Survey:** To clearly measure effective means of communicating with our future user community, and optimal ways to disseminate information, this survey will help us understand how the future SWOT data will support decisions and processes and will be used as an important benchmarking component of SWOT's Applications program.

**Data Products:** SWOT is scheduled to launch in late 2020, so the data products identified are notional and anticipated, but not final. The final data products, as well as the attributes of those products, will be determined by the SWOT Project Team prior to launch.

### 4. Current Findings & Conclusions



Results indicate that for both ocean and hydrology applications, the main interest is in Level 2 and value-added products. However, a majority of respondents were interested in hydrology, reflecting the high value of SWOT for water resource-related applications. Accessible data formats (web-based and mobile) and products may provide a higher level of utility with data management by the water managers. Virtually all of the 69 respondents who answered a question on desired spatial scale (Fig. 3) indicated a preference for a broad range of temporal scales, leaning towards 1-hour to 1-day, was indicated, as a majority were distributed at latitudes suitable with a high fraction number of responses, including that latency is not an issue for their application.

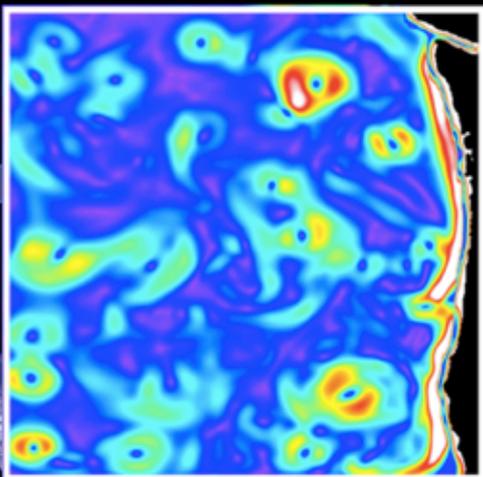
If you think SWOT data products may be able to help you...



Take the SWOT Applications User Survey

<http://swot.jpl.nasa.gov/applications>

High resolution products



Advanced wide  
swath technology

Ocean and surface water  
topography measurements

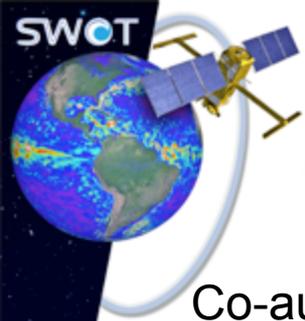


Supporting societal need

**SWOT**  
SURFACE WATER & OCEAN TOPOGRAPHY



# Backup

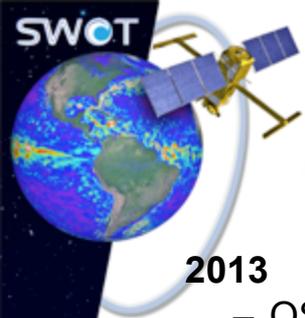


# Applications: Key Publications

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Co-authored papers, articles, conference talks/posters to disseminate info about

- 1. Paper submitted** to *Remote Sensing Applications: Society & Environment* journal, under review
- 2. Springer Book** "Earth Science Satellite Applications: Current and Future Prospects", F. Hossain, ed.; SWOT in EA chapter, April 2016.
- 3. BAMS article** in support of Decadal Survey, Societal benefits of RS, accepted.



# Applications: Phase B presentations

## 18 Joint NASA, Stennis, CNES, SDT, SAWG presentations

### 2013

- OSTST; SWOT Applications poster, Srinivasan, Peterson
- 3<sup>rd</sup> Texas Water Forum: Austin, Oct.; “*Hydrology from Space: NASA's Satellites Supporting Water Resources Applications*”
- GODAE Ocean 2013; Jacobs et al.
- AGU Fall; Dec., SF; Poster, SWOT Applications

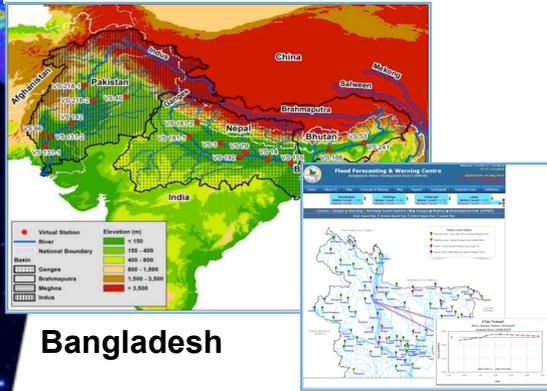
### 2014

- AGU Oceans: Feb., Hawaii; SWOT poster, Applications session
- SDT; June, Toulouse; Plenary, SAWG meeting, Poster
- SRR-MDR; May, Pasadena; SWOT presentation
- OSTST; Oct., Germany, SWOT Applications poster, GLOBE activities at OSTST Outreach/ Education splinter
- AGU; Dec., SF, SWOT coastal application poster, SWOT-GLOBE poster

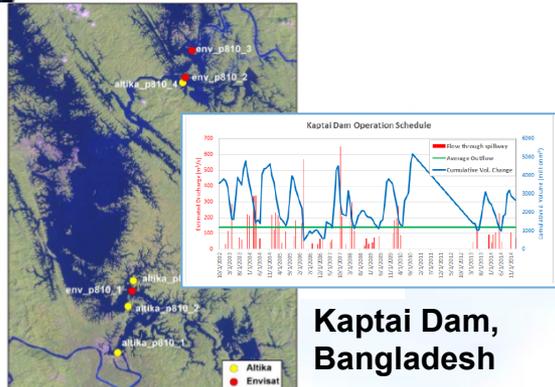
### 2015

- 1<sup>st</sup> Applications Working Group meeting, LA Jolla, Jan.
- 5<sup>th</sup> SWOT Science Definition Team Meeting, January, La Jolla, CA
- Climate Predictions Applications Science Workshop (CPASW), Las Cruces, Mar., “Water Resource Applications Of The SWOT And GRACE Missions”,
- ISRSE, May, Berlin; “Engaging the Applications Community of the SWOT Mission”,
- 6<sup>th</sup> SWOT SDT, Jul., Toulouse; SAWG meeting, Applications plenary,
- Marine Technology Society (MTS) Oceans In Action; Aug., Stennis; SWOT Early Adopter Program,
- OSTST, Oct., Reston, SWOT Applications poster, SWOT-GLOBE presentation,
- AWRA; Oct., Denver, CO; SWOT & GRACE Applications & Early Adopter plans
- Fall AGU; Dec., SF; “*Pre-Launch Assessment of User Needs for SWOT Mission Data Products*”

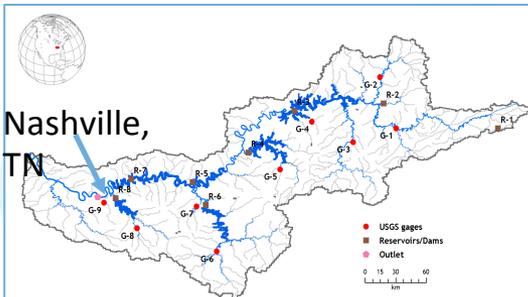
# Hydrology: From Nadir to Wide Swath Altimetry



Bangladesh



Kaptai Dam, Bangladesh



Cumberland River Basin reservoir network.

## Bangladesh Flood Forecast & Warning System – will be SWOT Early Adopter & trainer for Asian nations

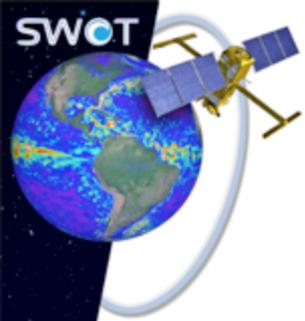
- SWOT+ altimetry are now a natural extension for flood model calibration and operations
- Satellite Altimetry now operational for flood forecasting
- Societal benefit - extending flood forecasting lead time from 5 to 8 days

## Asian Hydropower and Water Management Agencies will be Early Adopters of SWOT-based reservoir outflow estimation for regulated river basins

- Synthesis of multi-mission data – GPM, MODIS, LandSat
- SWOT+ Altimetry+ GPM – multi-mission constellation for outflow estimation for reservoir operations management
- SWOT will play a lead role with other water missions in addressing water management applications for regulated river basins & dam projects (i.e., Mekong)

## Flood Insurance Industry early adopters will be interested in simulating future/synthetic events to estimate flood hazards

- Satellite altimetry and reflectance now available for characterizing reservoir storage dynamics
- SWOT-derived, higher sampling frequency, characteristic reservoir storage patterns
- SWOT-derived gages reservoir model performance stable after only 1-year of synthetic SWOT measurements
- SWOT-derived storage patterns used to simulate reservoir operations during flood events without new measurements

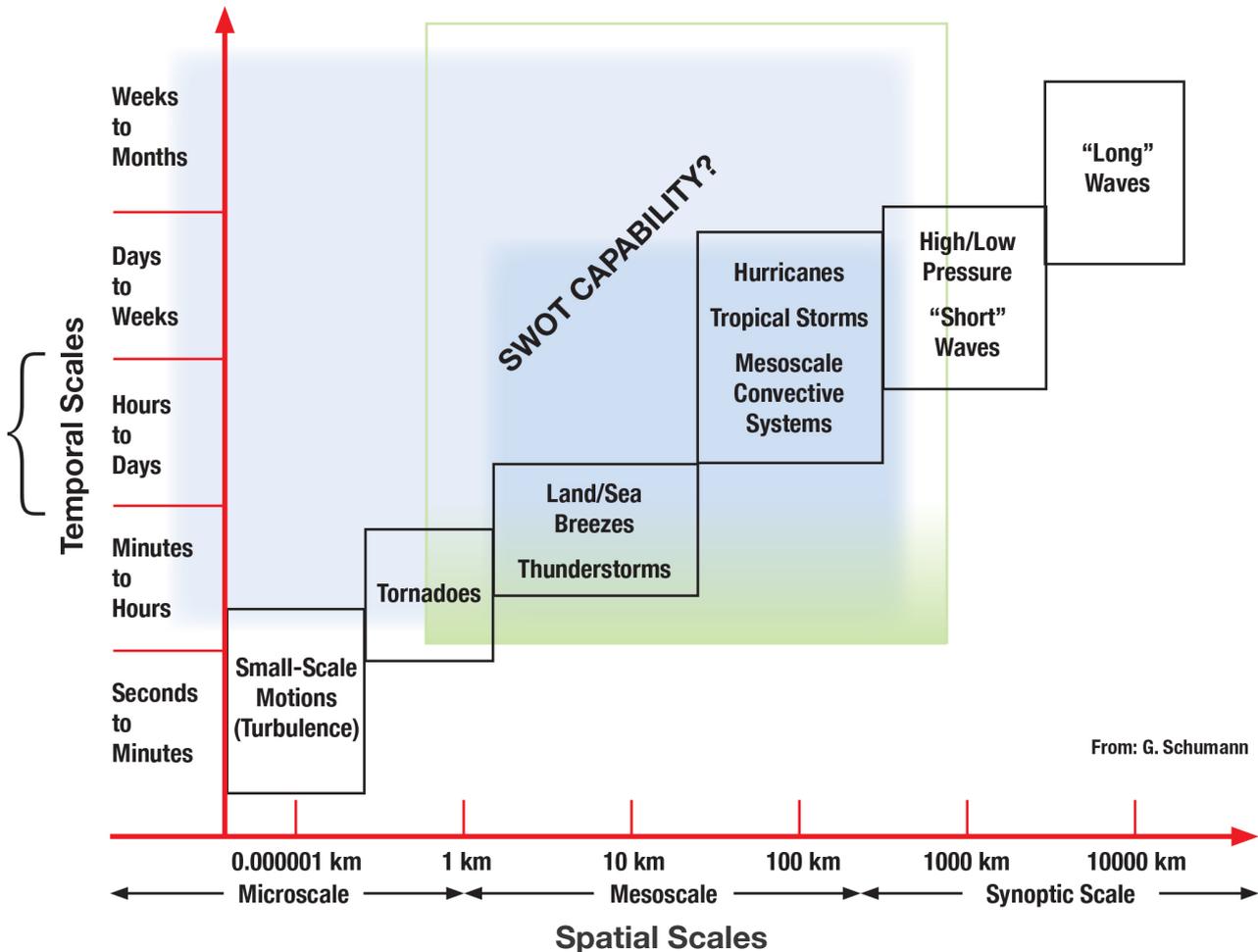


# Spatial vs Temporal Scales of Floods

Figure 1.9  
The spatial and temporal scales of various weather phenomena

Can SWOT meet these latency requirements (several hours to a few days) in order to maximize SWOT applications?

**NB: 2 day difference (e.g. 3 day vs 5 day latency) is significant, esp. for floods in medium-sized catchments such as many rivers in Europe!**





# Broad Issues

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- Where does Applications fit within overall SWOT mission?
- What tools do we have to provide for an effective and relevant SWOT applied science program pre- and post-launch?
- What are some effective (optimal) ways to involve applications and operational agencies?
- How do we promote private industry participation?
- Who is funding this effort? And who is not funding it?
- What are the available and future funding opportunities and programs?
- What synergies and collaborations with other missions (GRACE, Jason-class, GPM, SMAP, etc) will benefit SWOT mission & applications development?



# Open Questions & Issues

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- What applications do users and operational agencies want from SWOT?
- We don't want to oversell SWOT
- What applications are viable (temporally, spatially, economically)?
  - Solutions must be tailored to local and regional needs and circumstances
  - Real-time data will not be available, but does one- or three-month old data have value?
  - Does the entire time series of the mission data have value for some applications?
- Does global data have applied uses? What are they?



# Open Questions & Issues

- What is the role of observations in adaptation/mitigation studies and/or preparations (climate, global change)?
- Will SWOT be useful for observing rapid changes & feedbacks?
- What about sea level trends from SWOT?
- Are there SWOT applications for human health studies (i.e., SREX, 2012)?
- Can we use existing architecture (inputs and data distribution), i.e., IOOS?
- Is there a SWOT role in
  - Comprehensive, coordinated observing systems (i.e., IOOS)?
  - Long term risk reduction studies?
  - Observations coupled with adaptation?

\*SREX, 2012 – Special Report on Extremes; [http://ipcc-wg2.gov/SREX/images/uploads/IPCC\\_SREX\\_slide\\_deck.pdf](http://ipcc-wg2.gov/SREX/images/uploads/IPCC_SREX_slide_deck.pdf)