# Ocean Modeling and Data Assimilation: Linking River Discharge with Coastal Processes

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(Discussions with Jim McWilliams, UCLA;
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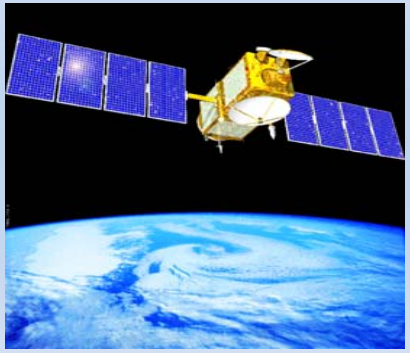
21 October 2010
Lisbon, Portugal

# 18-Year Satellite Altimetry Missions Enable New Discoveries and Breakthroughs in Oceanography

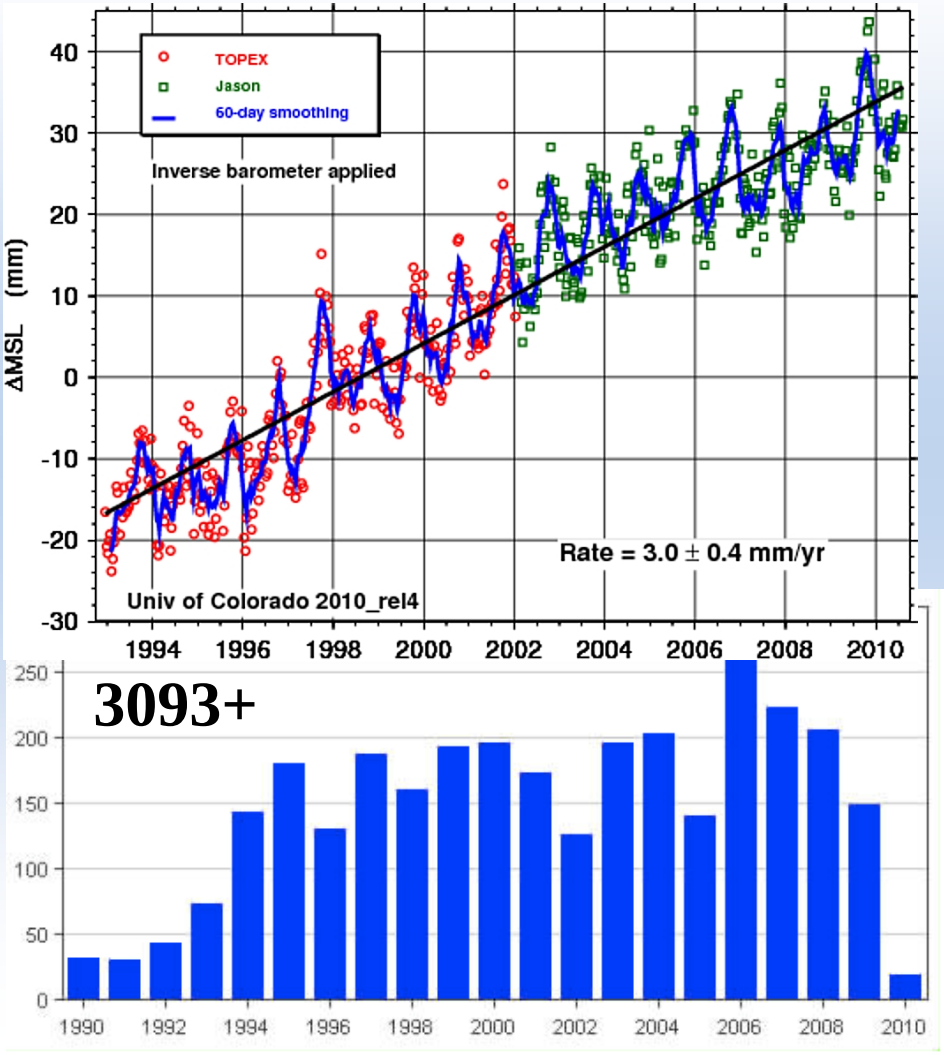
TOPEX/Poseidon

Jason-1



OSTM/Jason-2

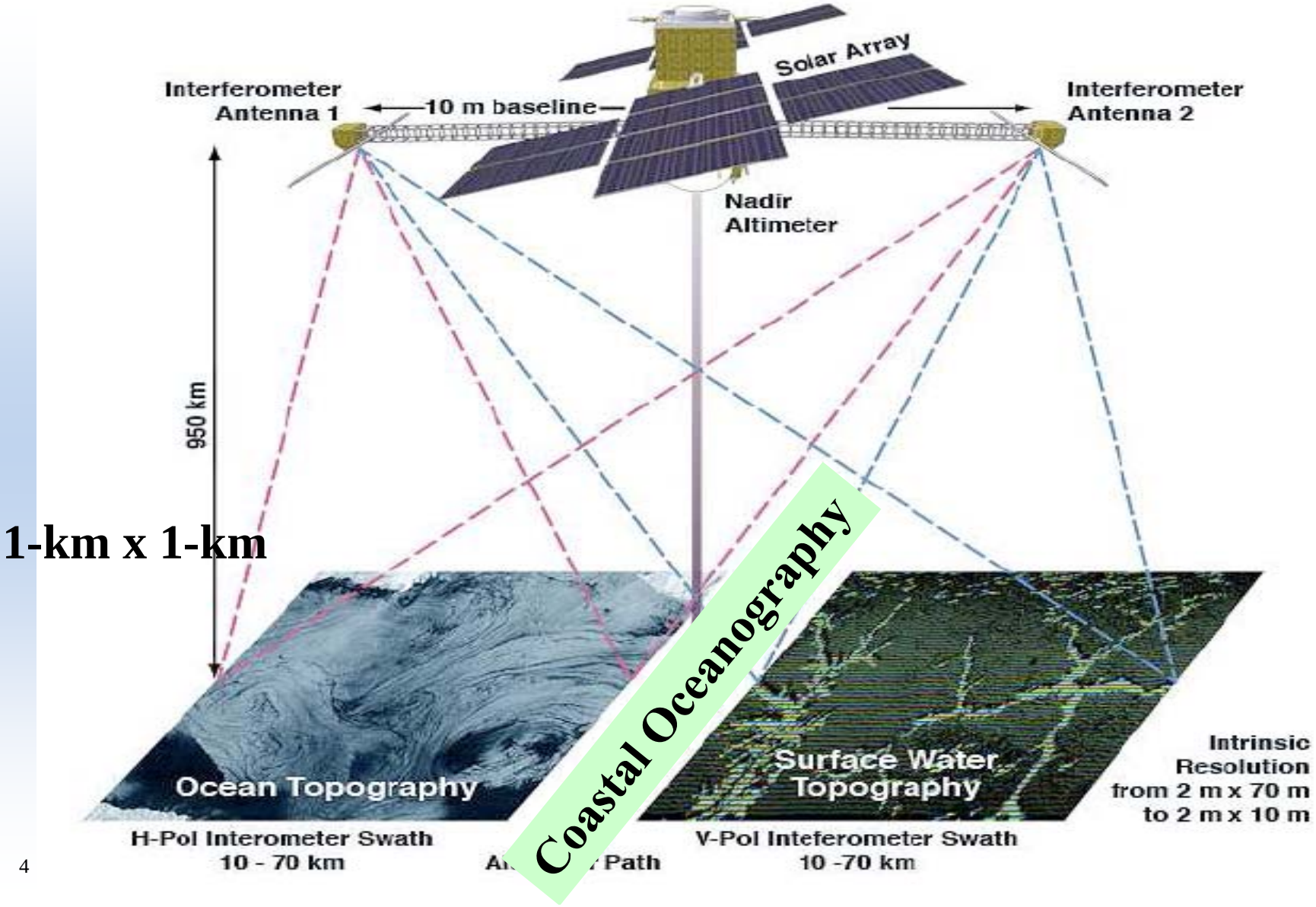
First global sea level rise estimate (e.g, Nerem et al., 2006)



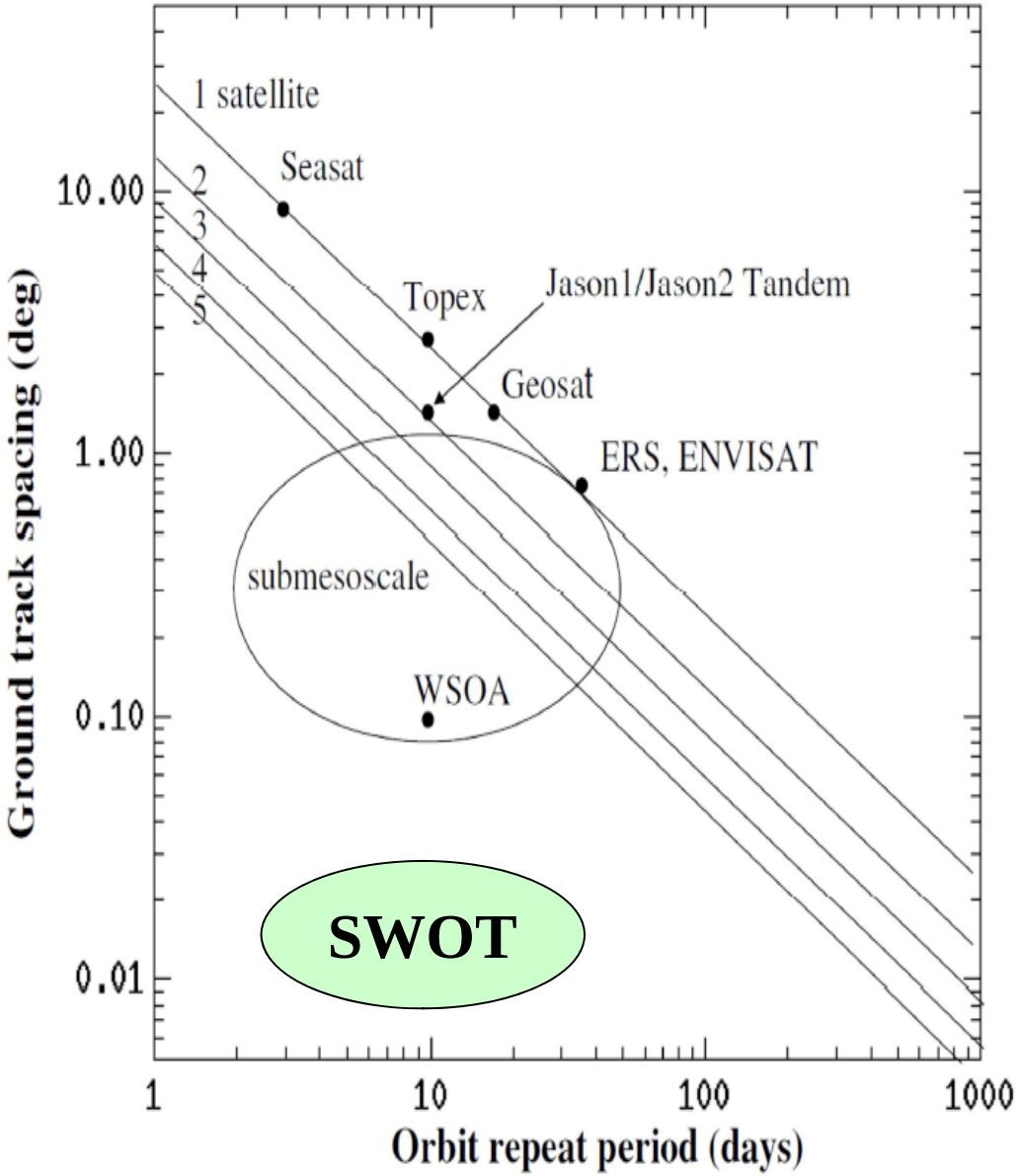
# SWOT Mission to Enable New Discoveries and Breakthroughs in the Field of Terrestrial Hydrology



# Unique among Decadal Survey Missions: Linking Physical Oceanography and Terrestrial Hydrology

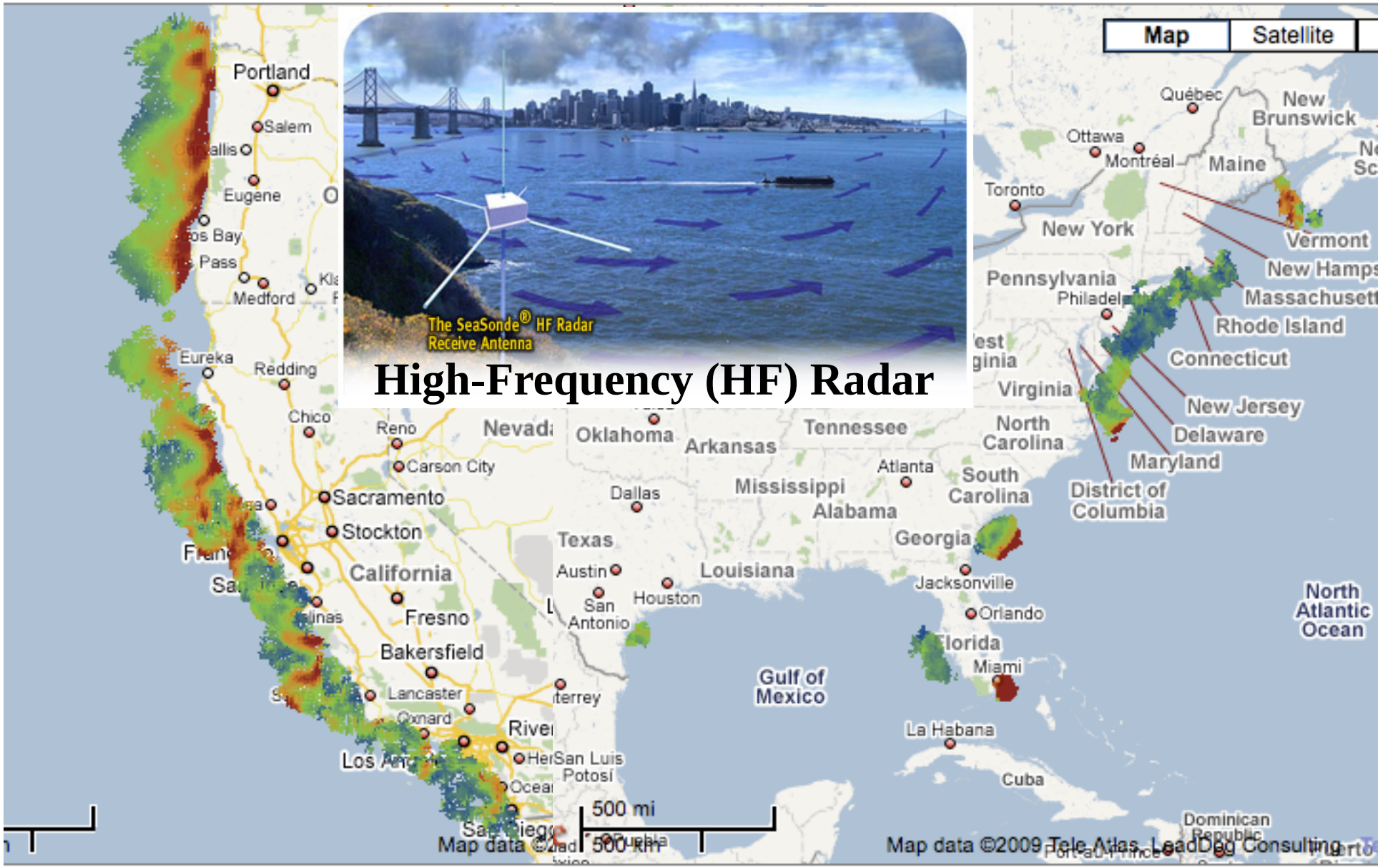


# Coastal Oceanography Enabled by SWOT: Challenges from Requirements to Implementation



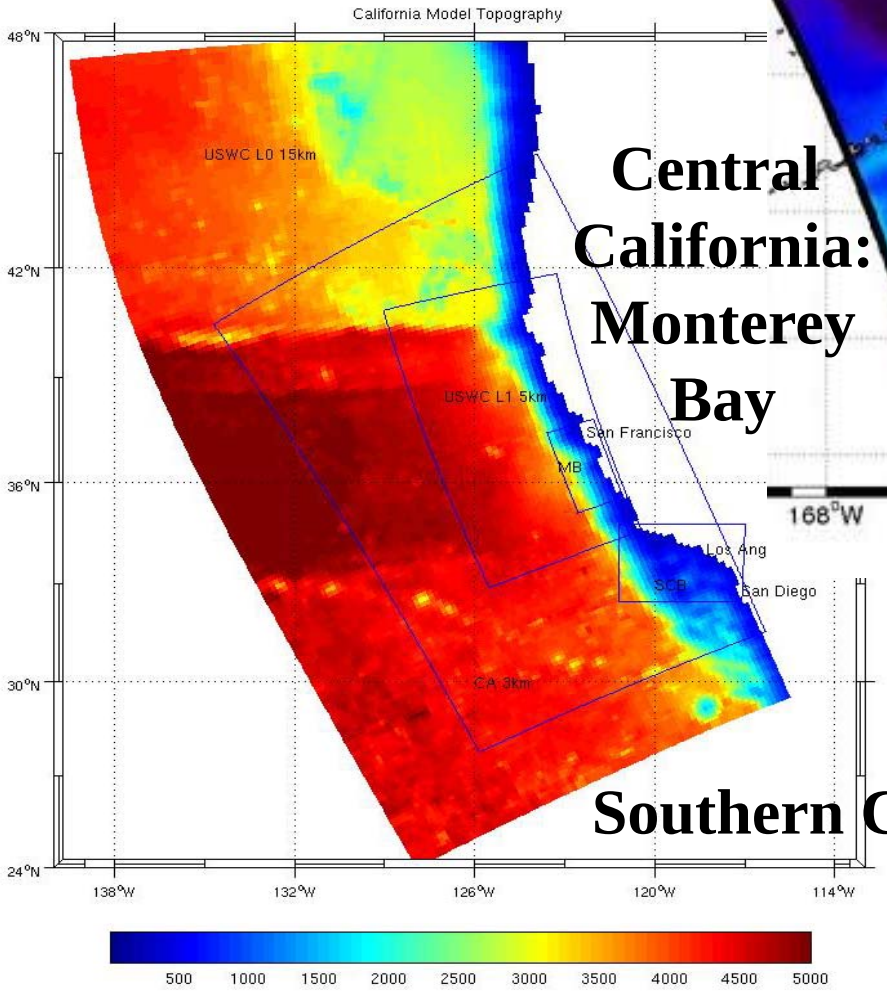

- Data processing & onboard averaging: Terabytes of data daily
- Model & data assimilation: synthetic data
- Synergy with other data (e.g., SST) and models (Level 4 data): High spatial resolution but infrequent
- Design & trade: 3-day fast-phase, Cal/Val targets
- Science, applications, decision/policy makers, societal impact (learn from weather prediction success)

# Synergy between SWOT and other coastal programs:
## SWOT provides an important piece of the coastal puzzle

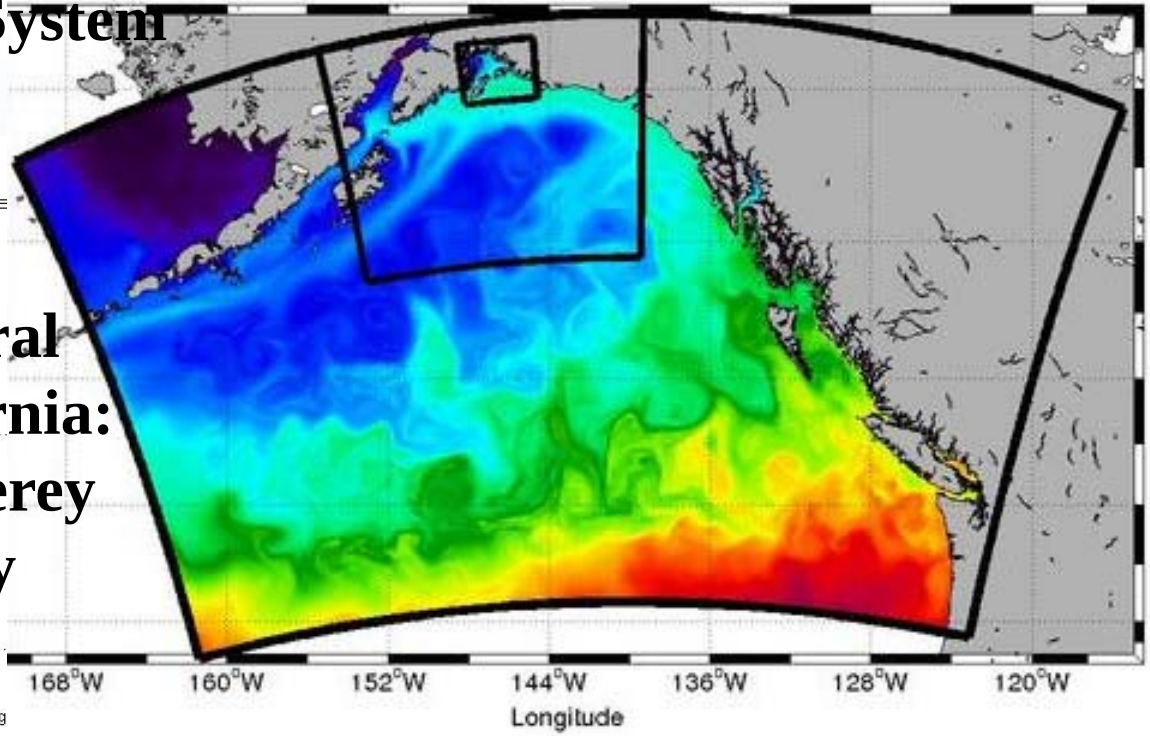


# US West Coast Example:
# Linking River Discharge with Coastal Processes

**Regional Ocean Modeling System (ROMS)**




**Central California: Monterey Bay**

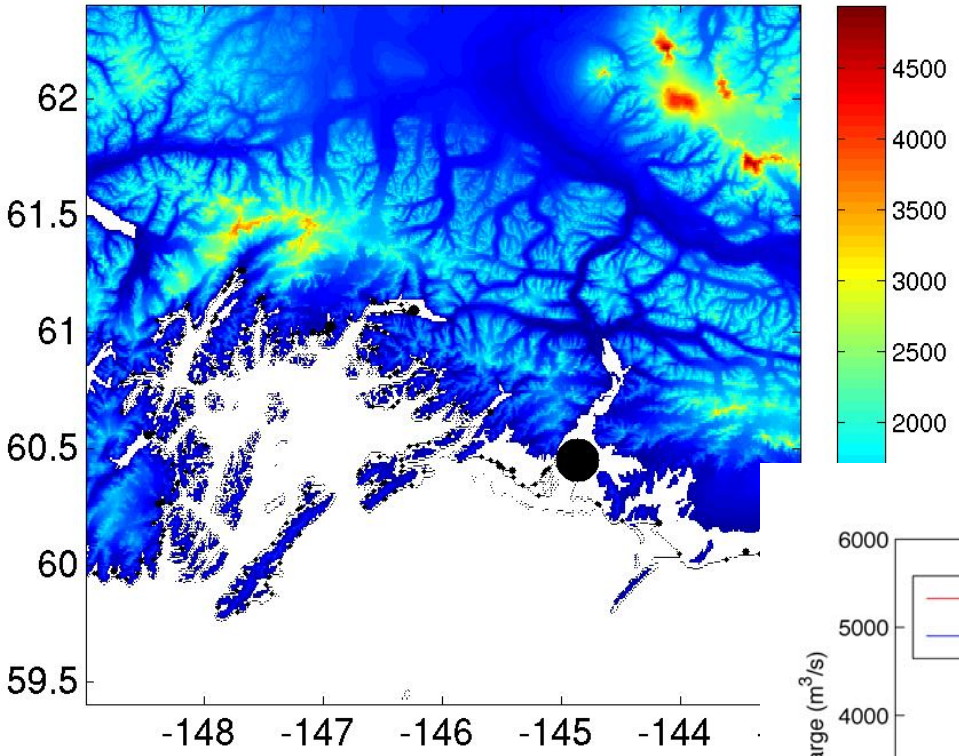


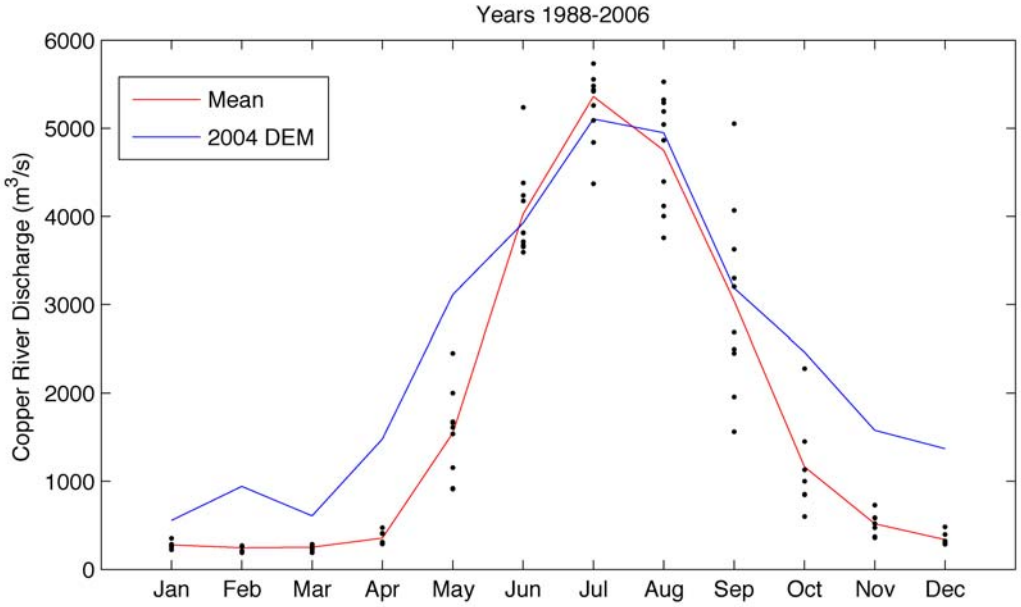

**Prince William Sound, Alaska**

**Southern California Bight**

**http://ourocean.jpl.nasa.gov**

# Atmospheric (WRF) Rainfall, River Discharge and Fresh-Water Forcing in Coastal Ocean



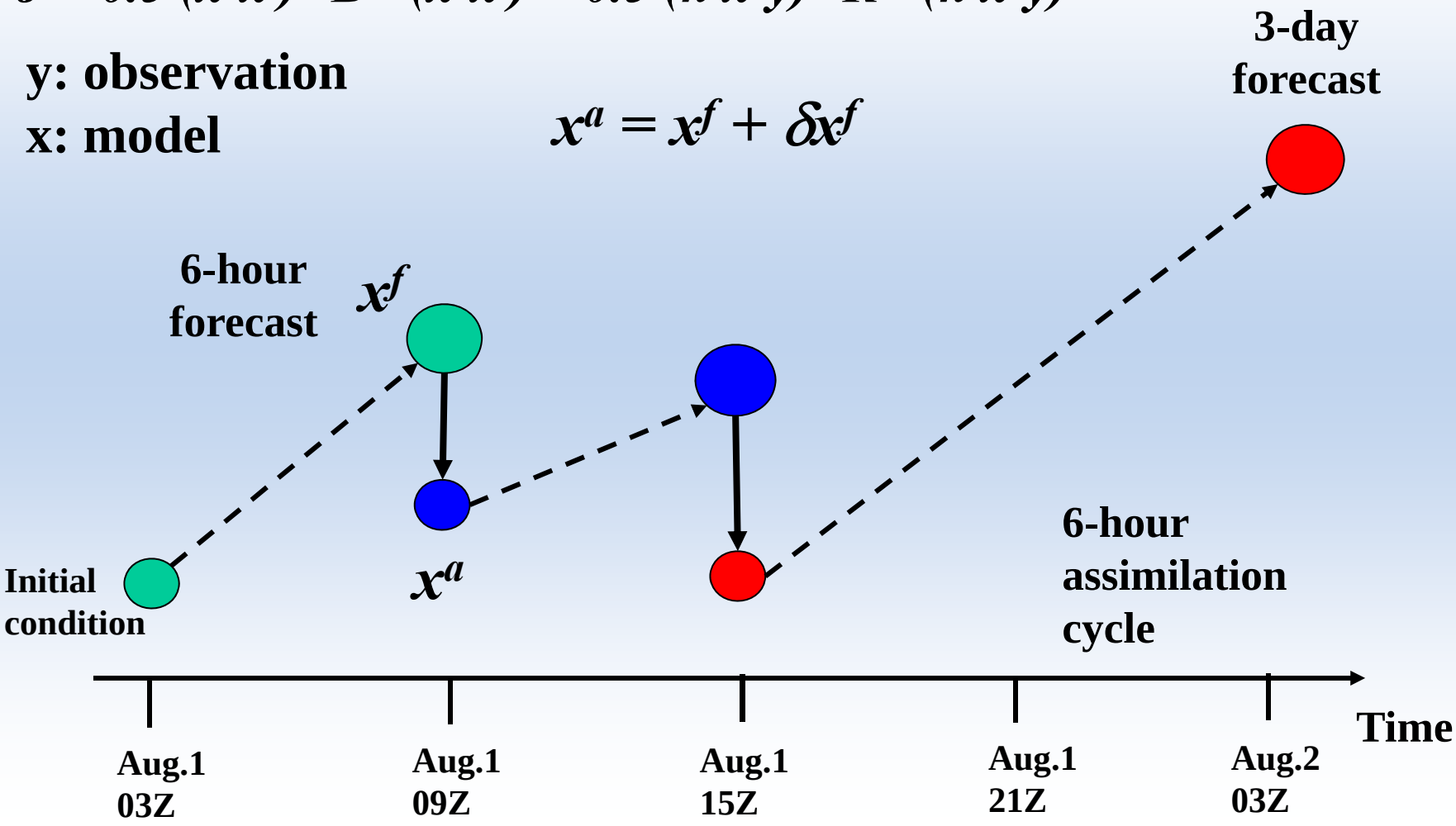
# Data Assimilation: Incremental 3DVAR (6-hour window)

**3-dimensional variational (3DVAR) method:**

$$J = 0.5\,(x-x^f)^T B^{-1} (x-x^f) + 0.5\,(h\,x-y)^T R^{-1} (h\,x-y)$$

**y: observation**
**x: model**

$$x^a = x^f + \delta x^f$$



# 3DVAR Unique Implementation: Geostrophic & Hydrostatic Balance U/V vs. Streamfunction/Velocity-Potential

$$x = \begin{pmatrix} \varsigma \\ u \\ v \\ T \\ S \end{pmatrix} = \begin{pmatrix} x_\varsigma \\ x_{uv} \\ x_{TS} \end{pmatrix} = \begin{pmatrix} x_\varsigma^f + \Pi \delta x_{TS} + \delta x_{a\varsigma} \\ x_{uv}^f + \Gamma \delta x_{TS} + \Phi_a \delta x_{a\psi\chi} \\ x_{TS}^f + \delta x_{TS} \end{pmatrix}$$

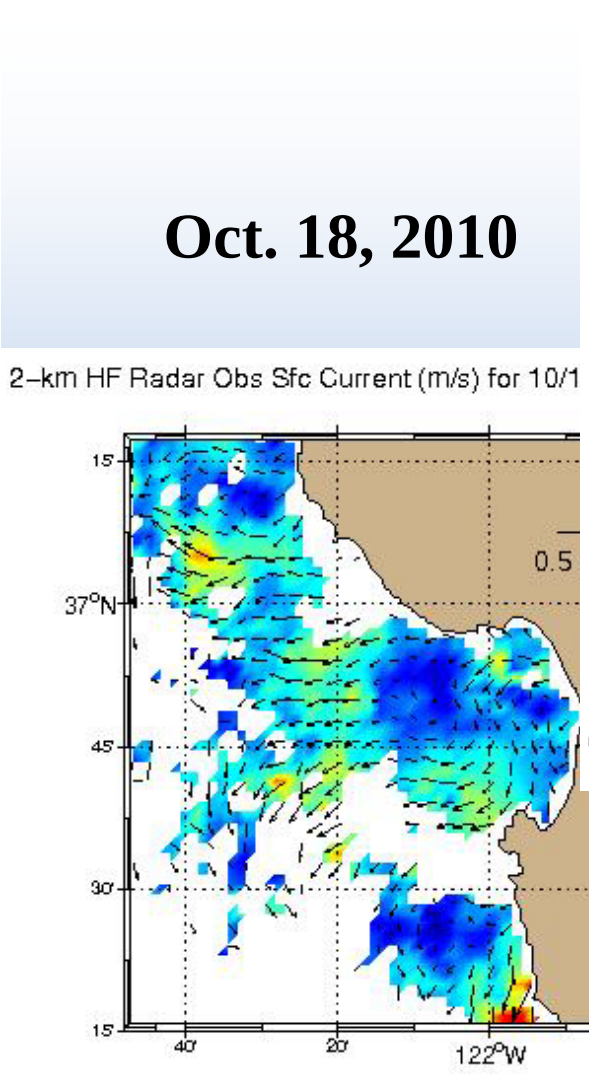
$\delta x_{uv}^G = \Gamma \delta x_{TS}$ Geostrophic balance

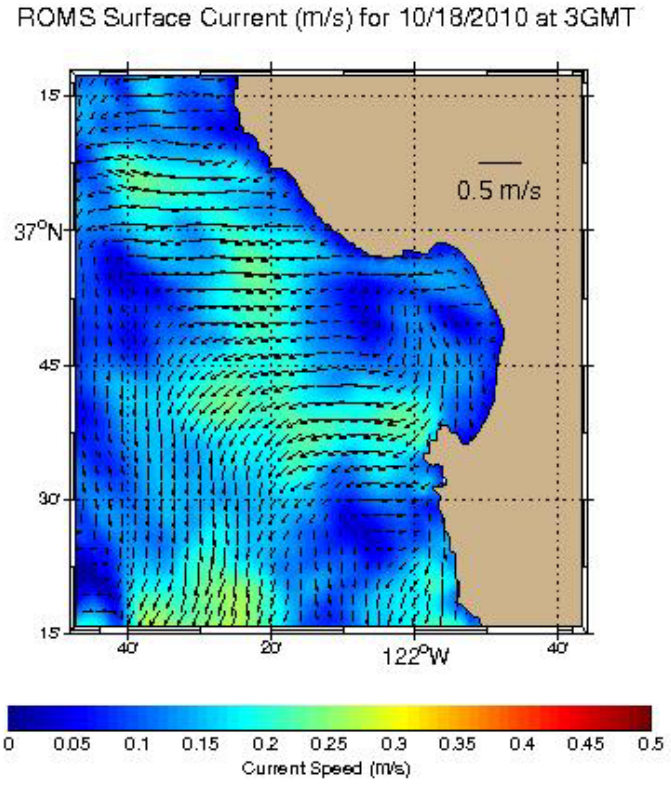
$\delta x_\zeta^S = \Pi \delta x_{TS}$ Hydrostatic equation

Five Control Variables:
Temperature: $\boldsymbol{\delta T}$
Salinity: $\boldsymbol{\delta S}$
Non-steric SSH: $\boldsymbol{\delta X_{a\zeta}}$
Ageostrophic streamfunction: $\boldsymbol{\delta X_{a\psi}}$
Ageostrophic velocity potential: $\boldsymbol{\delta X_{a\chi}}$

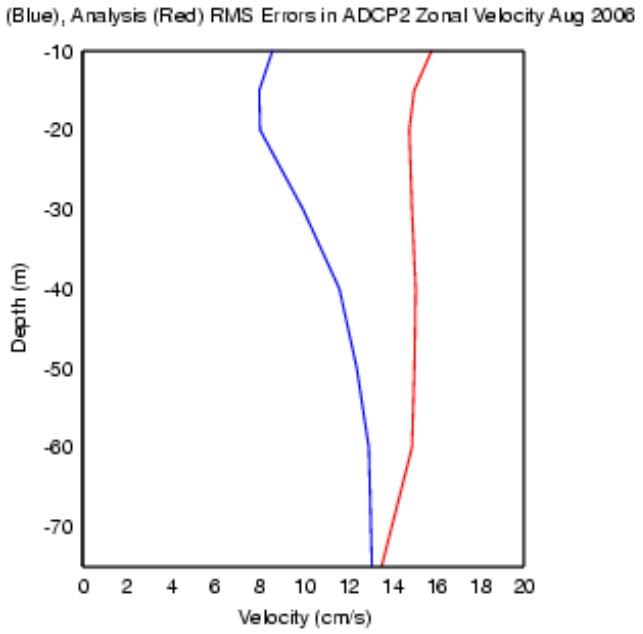
# Impact of HF Radar Surface Data Assimilation (1-km resolution, hourly)

**Oct. 18, 2010**




RMS




ROMS w/o data assimilation
ROMS with data assimilation

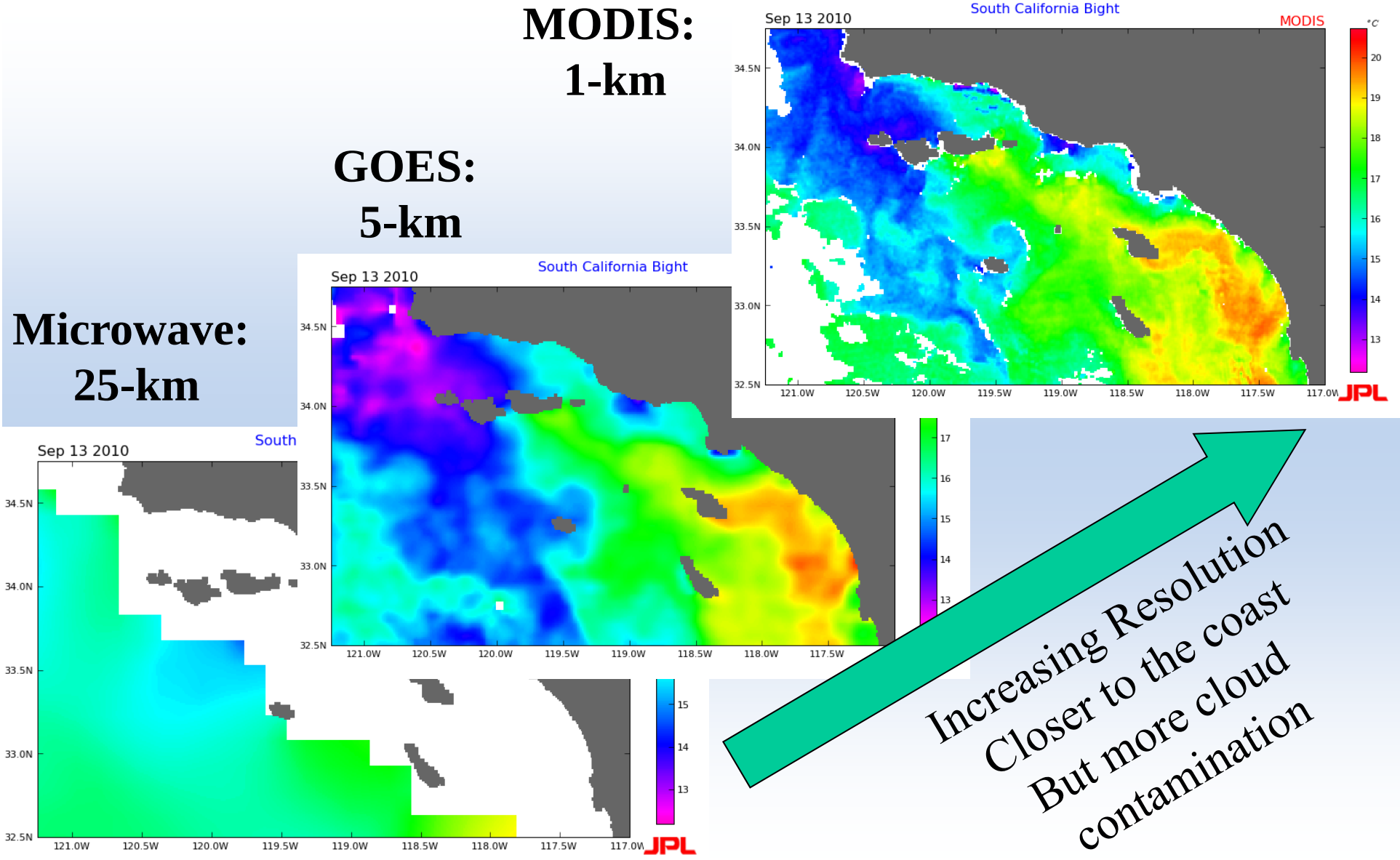
**http://ourocean.jpl.nasa.gov/MB**

# How to assimilate multi-scale satellite SST data? (25-km to 1-km, daily)

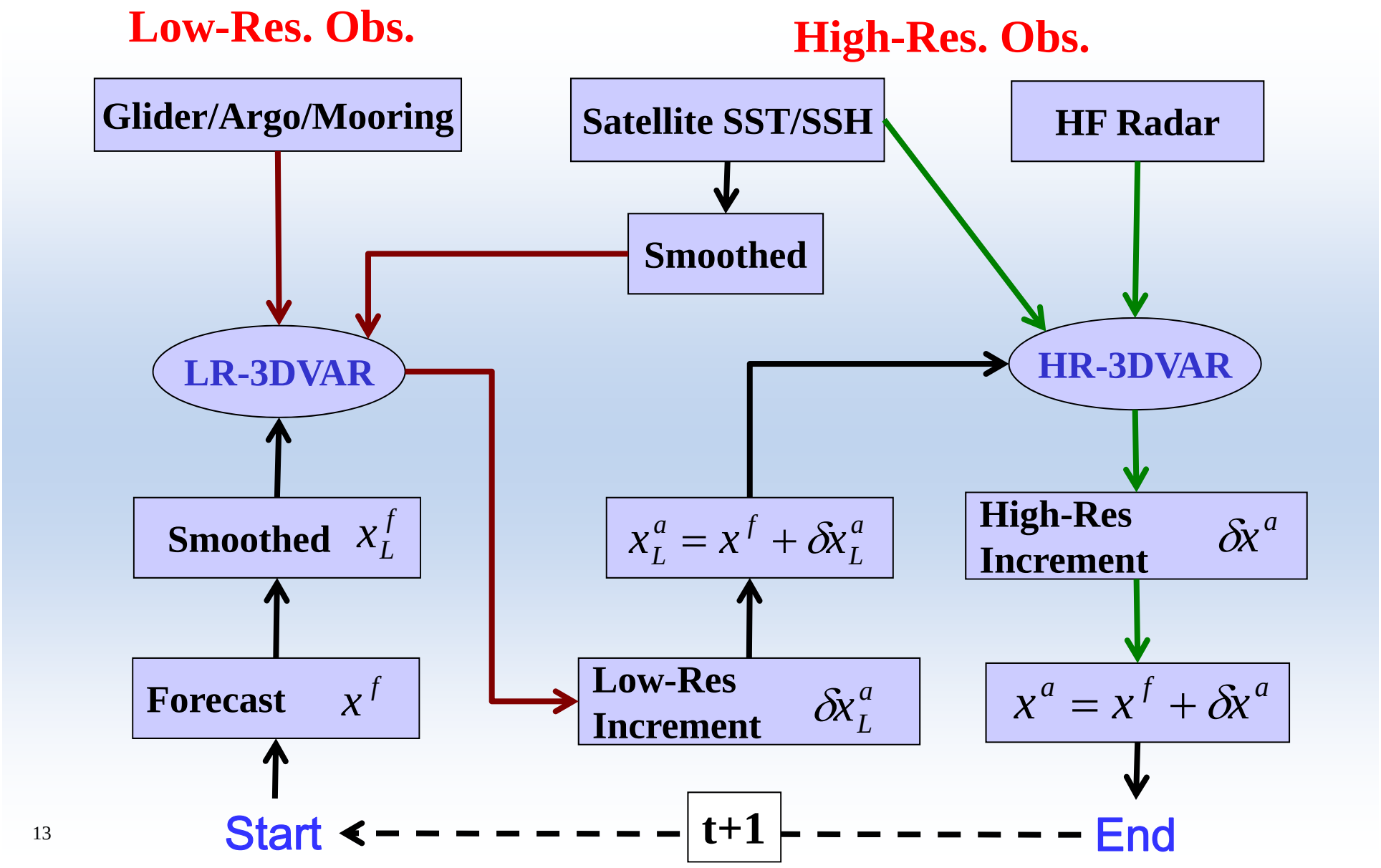
**MODIS: 1-km**

**GOES: 5-km**

**Microwave: 25-km**

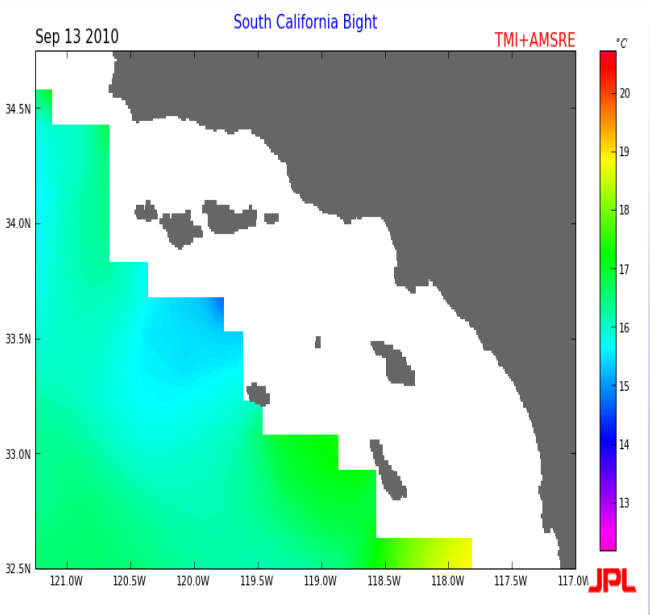


# Multi-Scale 3DVAR Data Assimilation
# Two-Scale: High vs Low Resolution



# Multi-Scale 3DVAR Data Assimilation
# Two-Scale: High vs Low Resolution

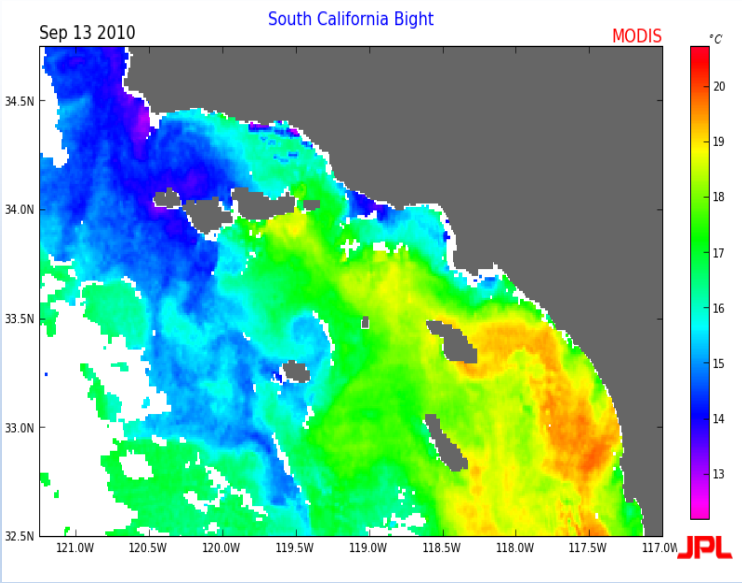
**Low-Res. Obs.**




$$x_L^a = x_L^f + \delta x_L^a$$

$$x^a = x^f + \delta x^a$$

**High-Res. Obs.**




$$\min_{x_L} J = \frac{1}{2}(x_L - x_L^f)^T B_L^{-1}(x_L - x_L^f) + \frac{1}{2}(H_L x_L - y_L)^T R_L^{-1}(H_L x_L - y_L)$$

$$\min_{x} J = \frac{1}{2}(x - x_L^a)^T B^{-1}(x - x_L^a) + \frac{1}{2}(Hx - y)^T R^{-1}(Hx - y)$$

# Operational Coastal Oceanography for Decision Making
# Southern California Bight Forecasting System
# Real-time 24/7 following the weather forecast example

## http://ourocean.jpl.nasa.gov/SCB

**View Nowcast and Forecast**

Septemb 2010

| Su | M | T | W | Th | F | S |
|---|---|---|---|---|---|---|
| | | | 01 | 02 | 03 | 04 |
| 05 | 06 | 07 | 08 | 09 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

<< < > >>

**ROMS Nowcast**
- (•) Temperature
- ( ) Salinity
- ( ) Current
- ( ) Sea Surface Height

**ROMS Forecast**
- ( ) 3D Output

**WRF**
- ( ) Wind

**ROMS vs. Data**
- ( ) Tide Gauge
- ( ) HF data and ROMS data
- ( ) SIO Glider Profile
- ( ) USC Glider Profile
- ( ) 1km SST

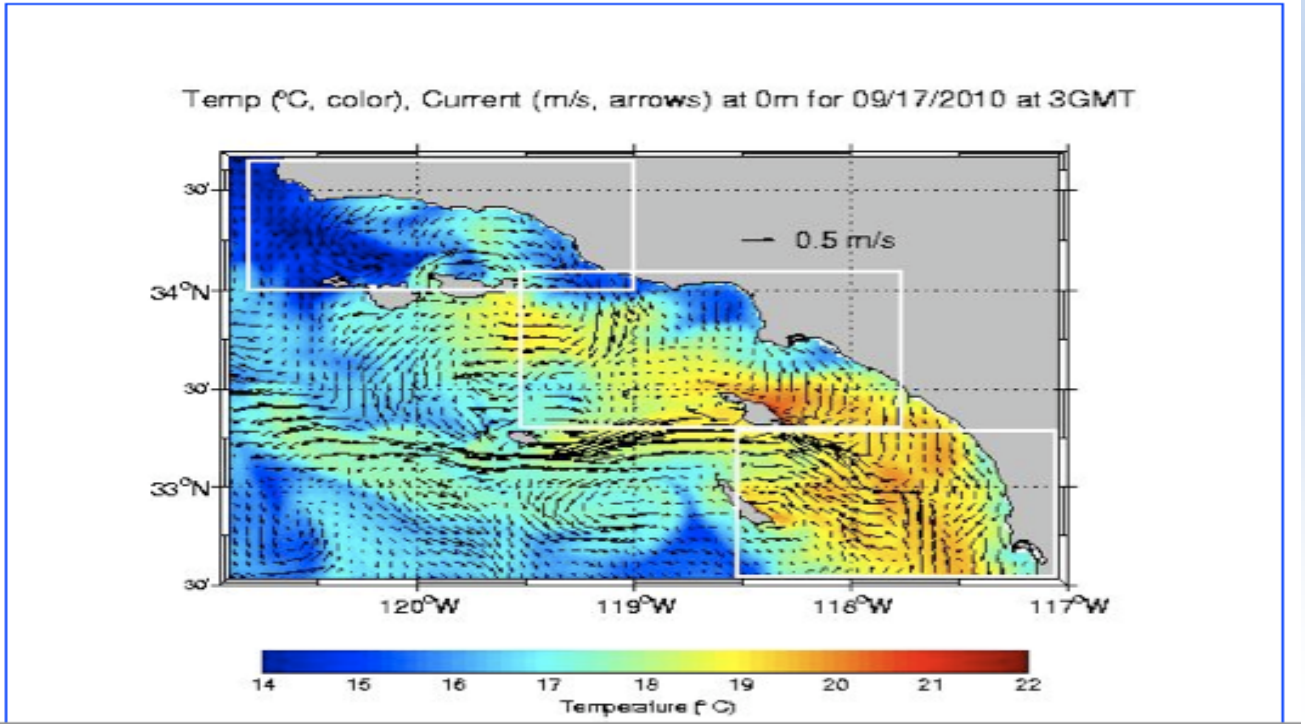
**Drifter**
- ( ) Trajectory

### Temperature Nowcast

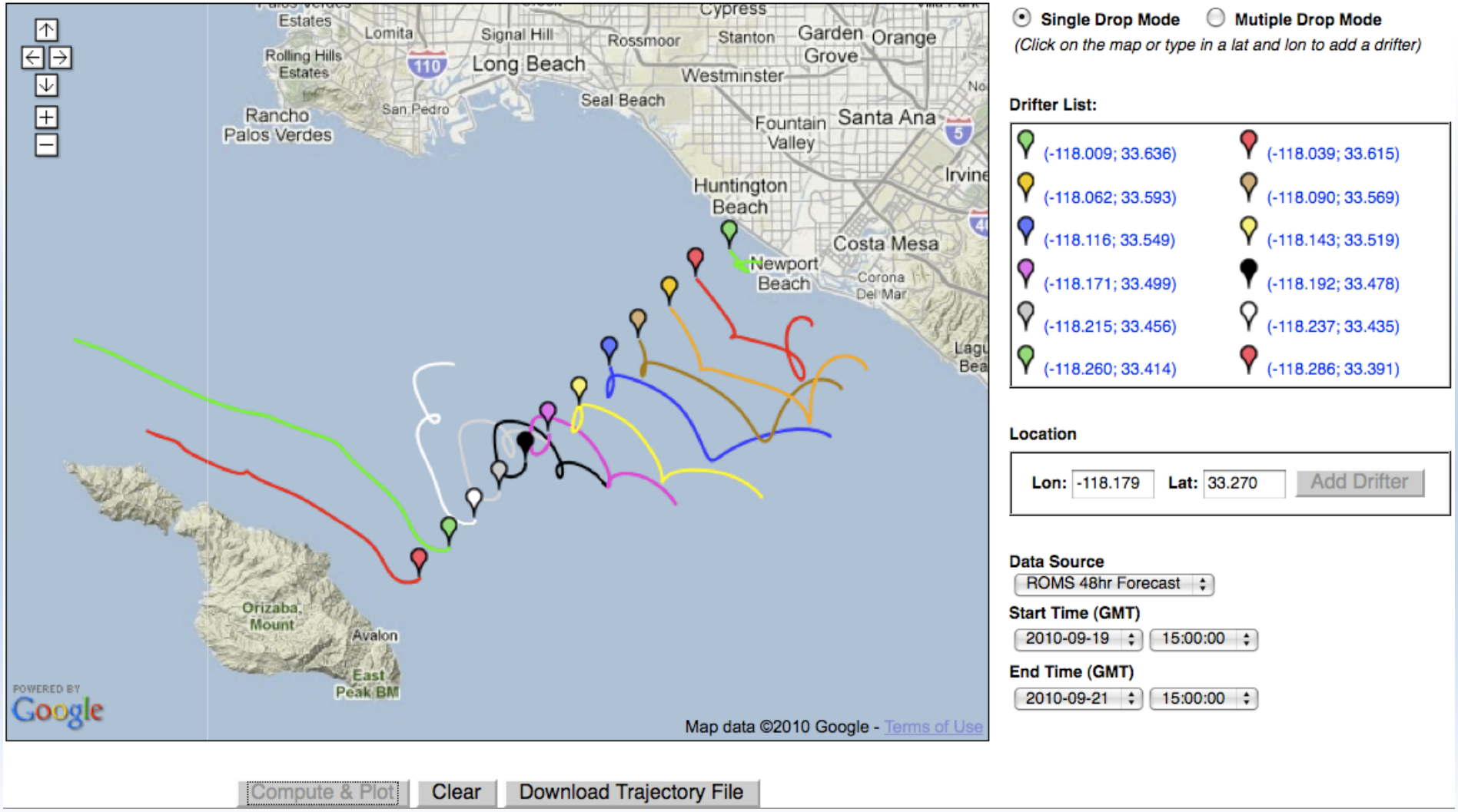
*The Southern California Bight (SCB) ocean forecasting system is based on the Regional Ocean Modeling System (ROMS). The ...* more

| File Name | File Size | Download | View |
|---|---|---|---|
| scb_das_2010091703.nc | 9090984 | http | Header Image |
| scb_das_2010091709.nc | 9090984 | http | Header Image |
| scb_das_2010091715.nc | 9090984 | http | Header Image |
| scb_das_2010091721.nc | 9090984 | http | Header Image |

*Click inside the white boxes in the images below to zoom in on sub-regions of the domain*



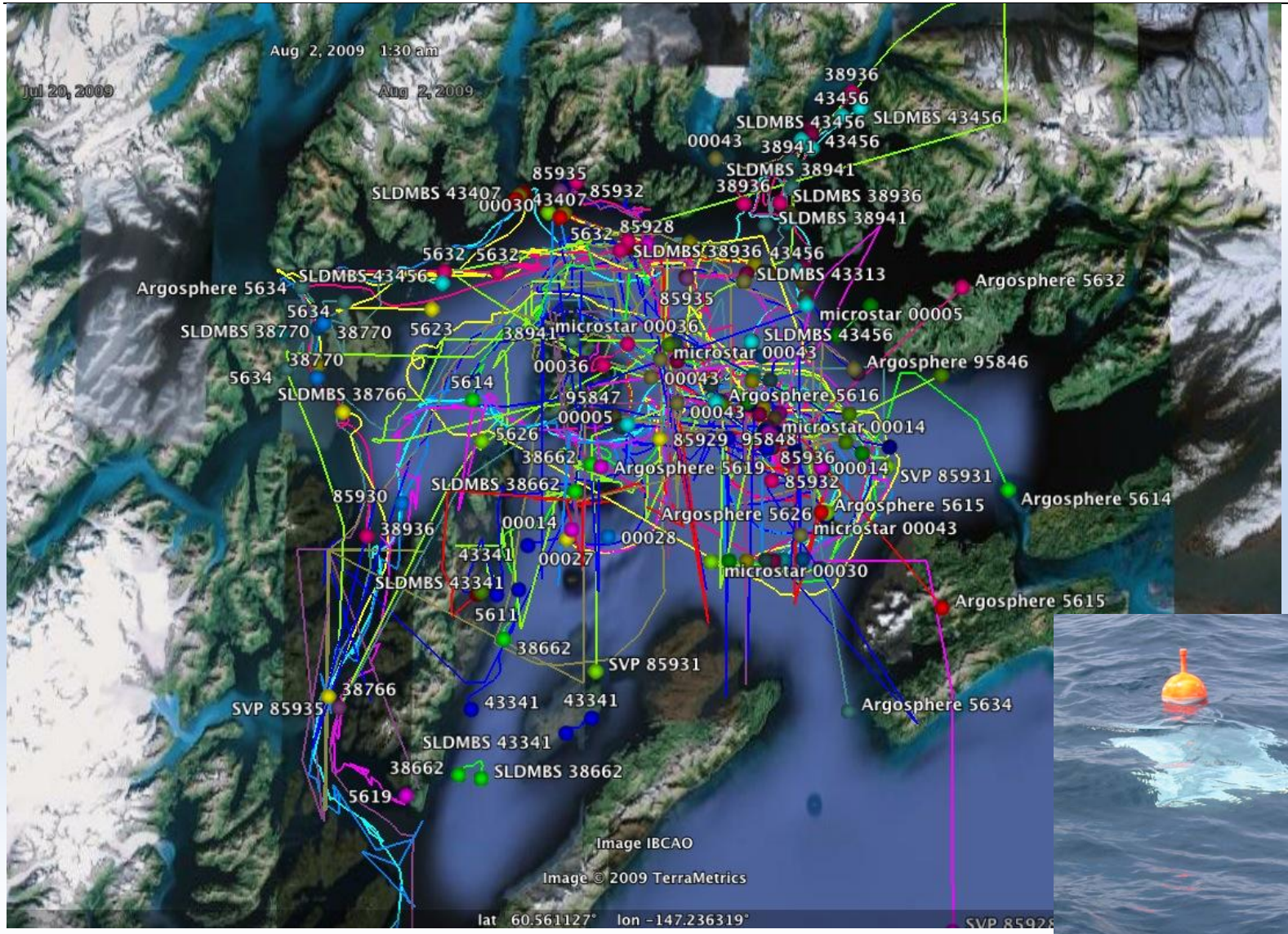
# Model-Data Integrated Product: Web-Based Interactive Trajectory Tool to enable decision making

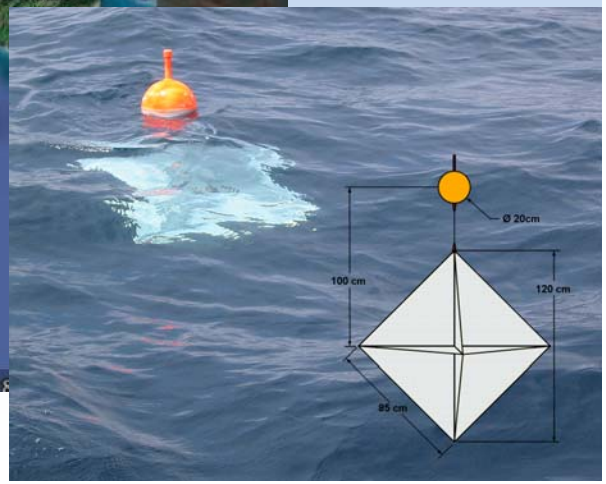



**Enable Real-Time Decision Making:**

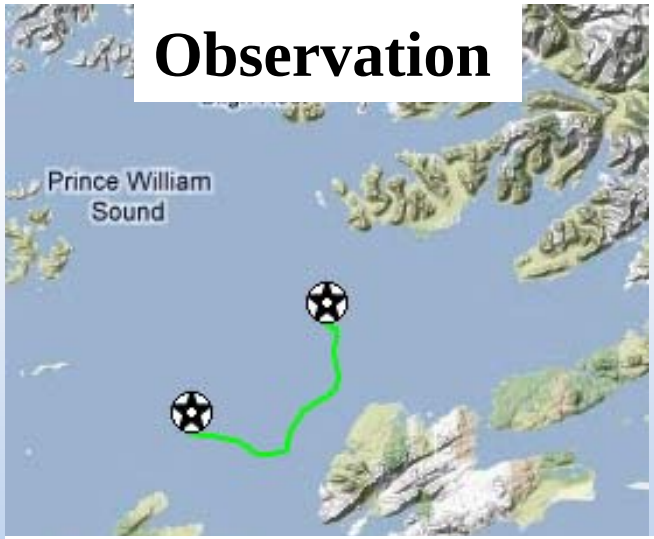
**Search & rescue, Oil spill response, Water quality, Ecosystem/fishery**

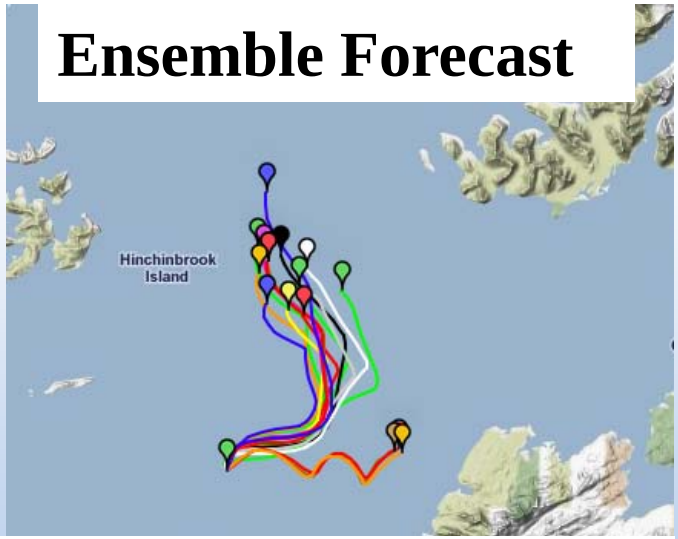
# Validation Experiment
# 2009 Prince William Sound Alaska

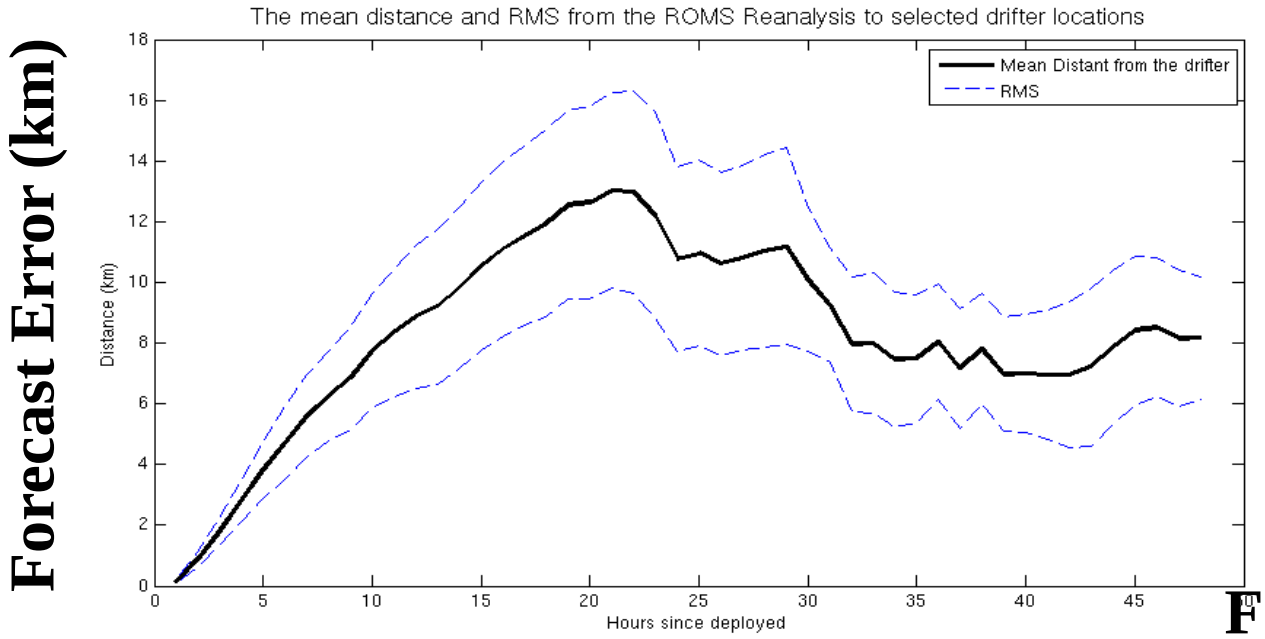


# Practical Application related to the USCG: Forecasting Drifting Trajectory and Uncertainty




Forecast Error (km)

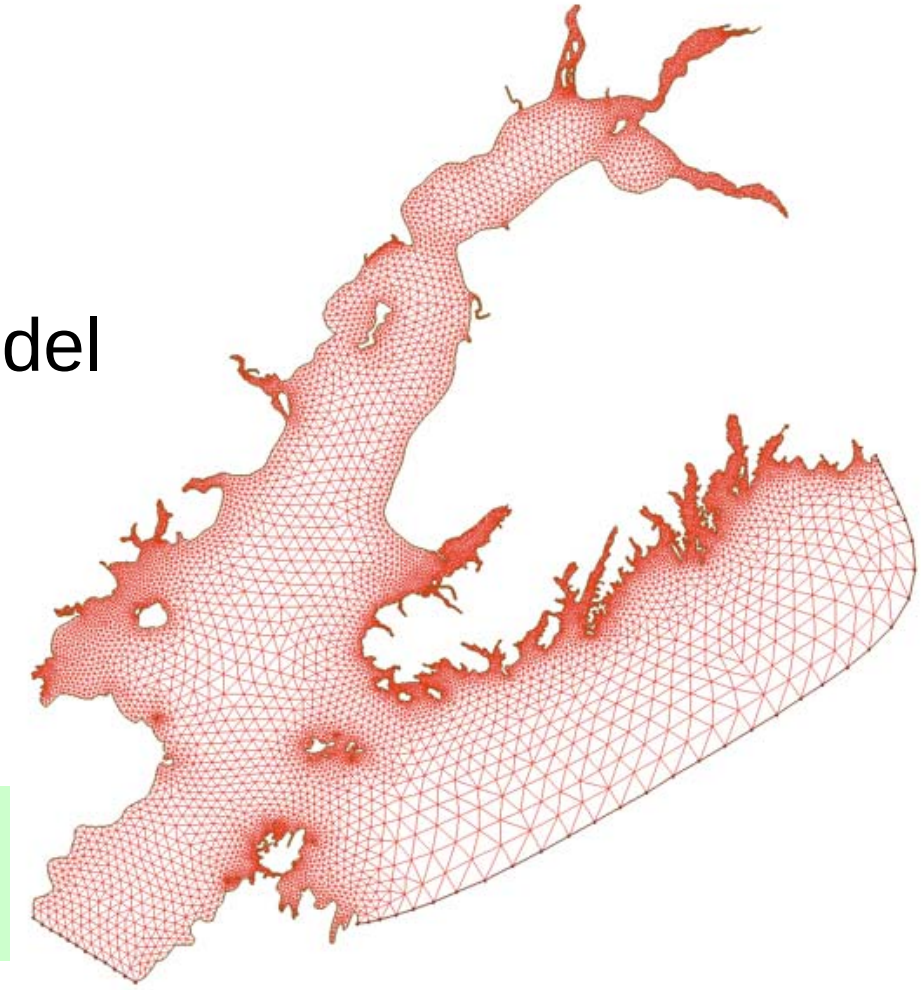
Forecast Time

# SWOT is beyond Coastal Physical Oceanography: Coastal Tides, Coastal Meteorology, Rivers/Estuary

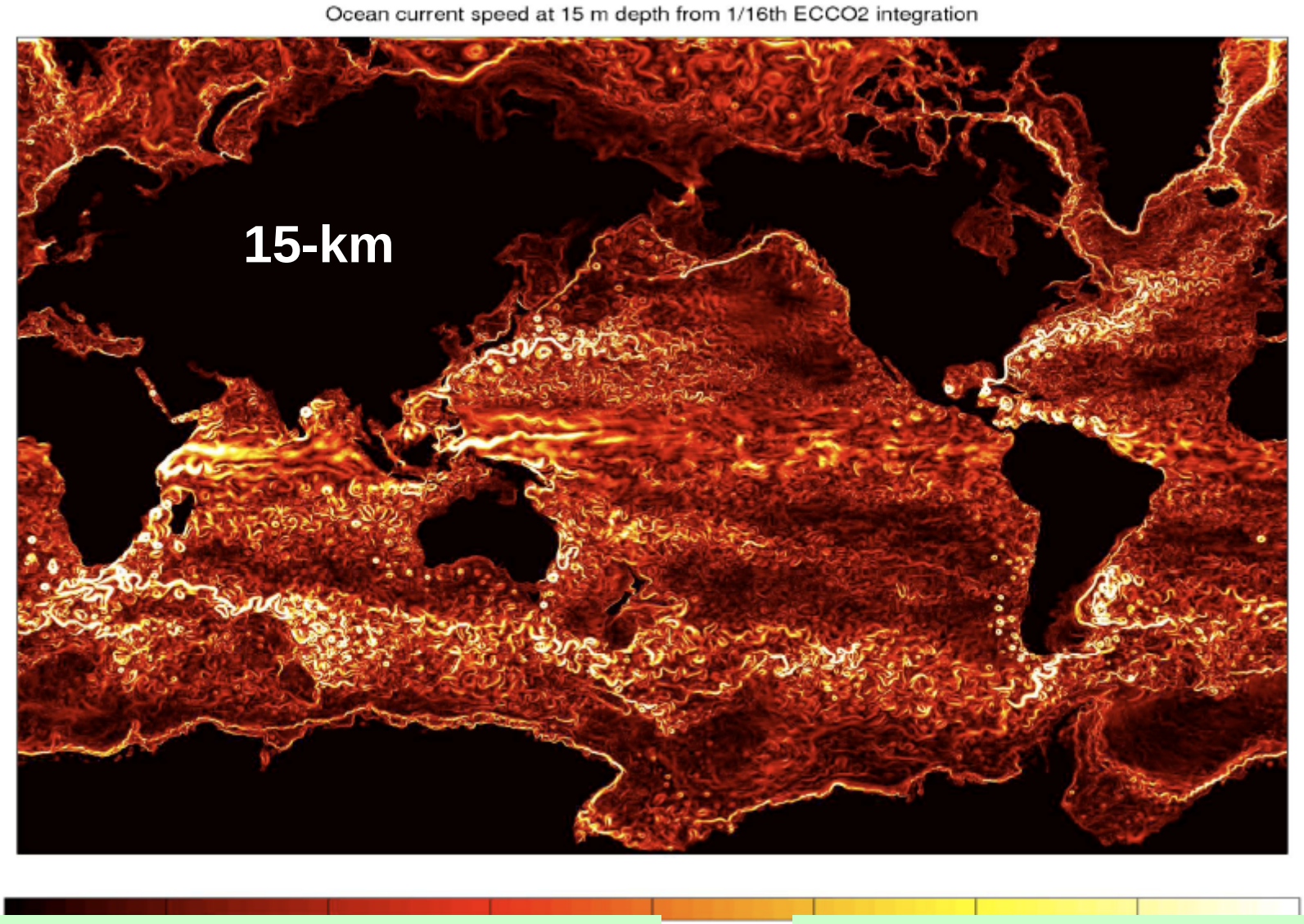
- ✓Coastal and internal tides: 3D tidal modeling with assimilation SWOT and coastal radar data
- ✓Water vapor corrections: regional atmospheric model with assimilation of radiometer data
- ✓River and Estuary: un-structured grid modeling

**A global framework of regional Processes**

**Example for Cook Inlet, Alaska**



# Modeling Current State-of-the-Art: ECCO-2

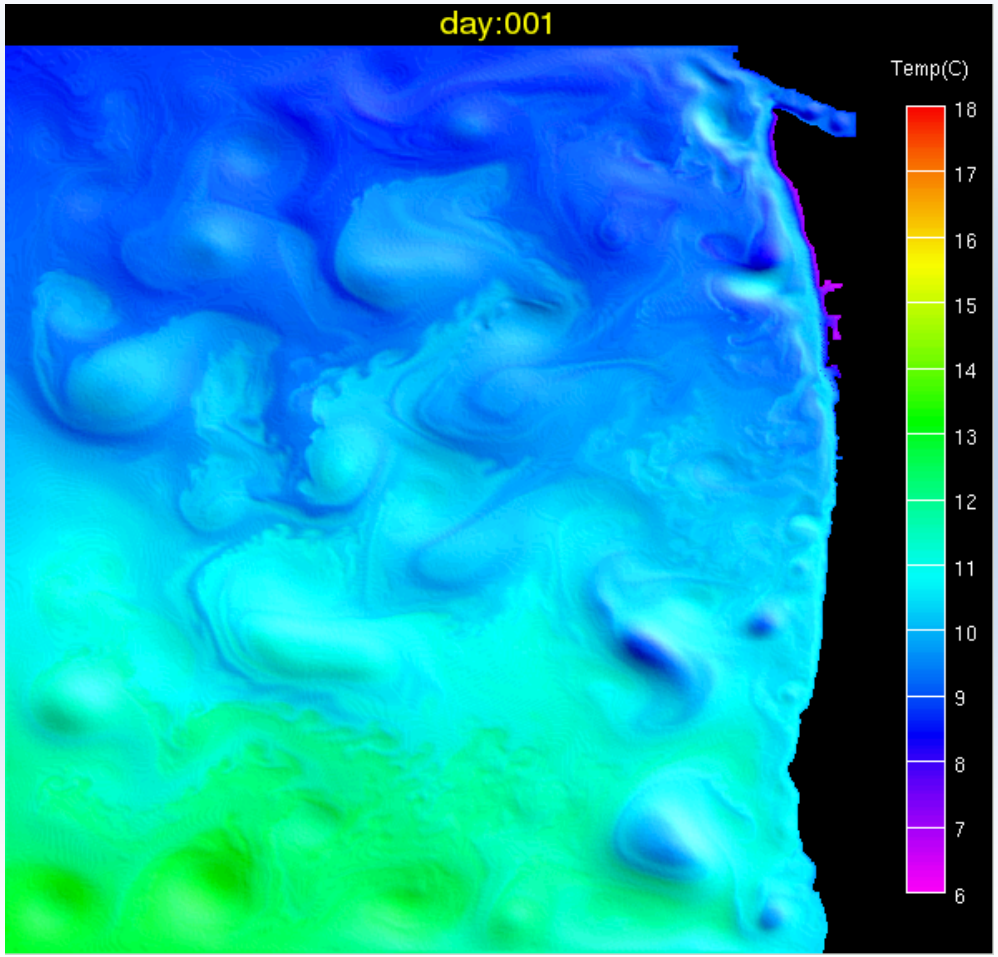


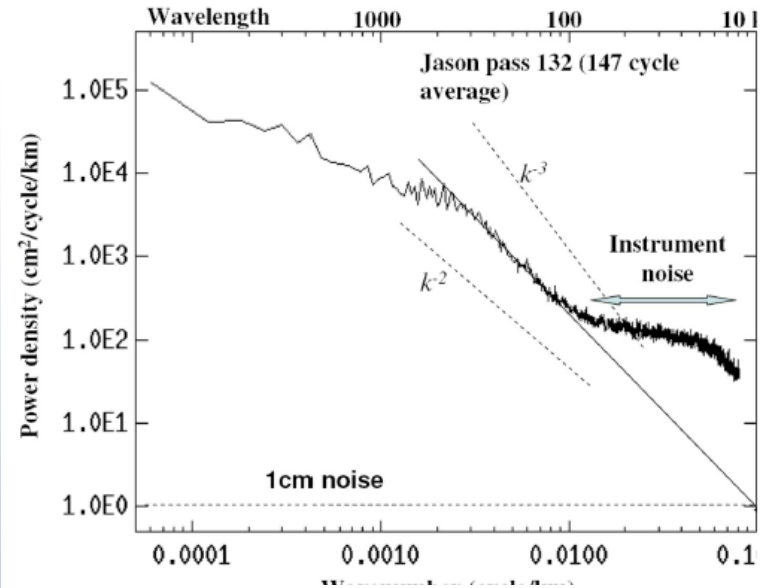

**(From Dimitris Menemenlis, JPL)**

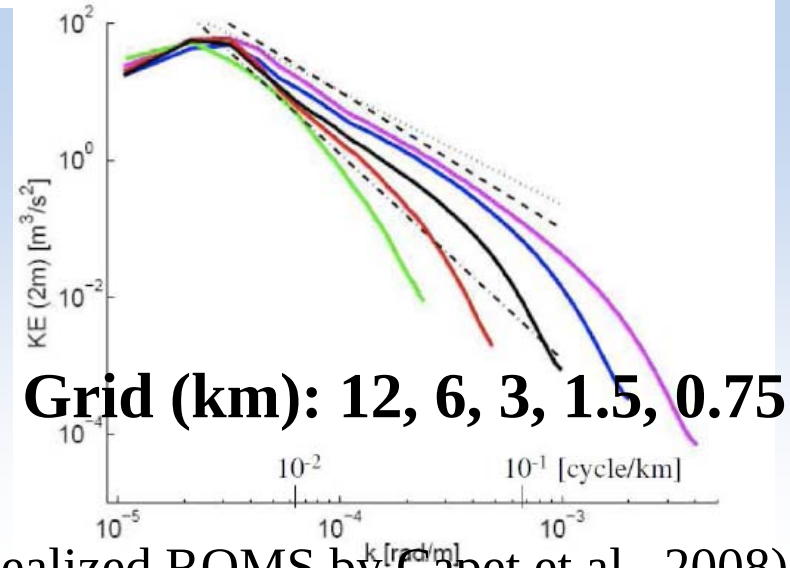
**(also B. Arbic talk Friday)**

# Coastal Modeling State-of-the-Art: ROMS

## Sea Surface Temperature
## 2-km ROMS



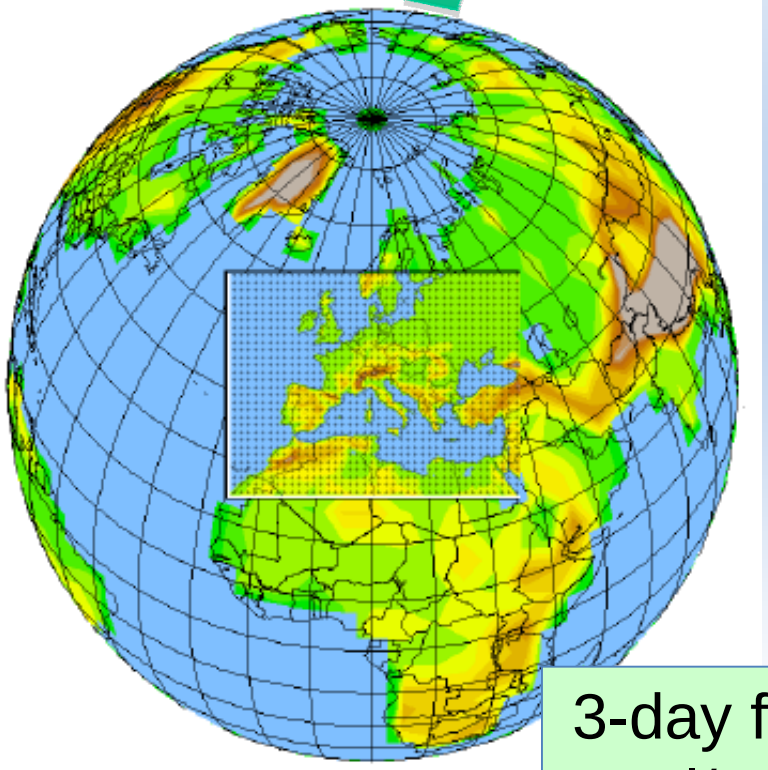




**Grid (km): 12, 6, 3, 1.5, 0.75**

(Idealized ROMS by Capet et al., 2008)

# New and Innovative Approach:
# SWOT Ocean Modeling Cloud

- Divide and Conquer for Tractable Computations on the Clouds

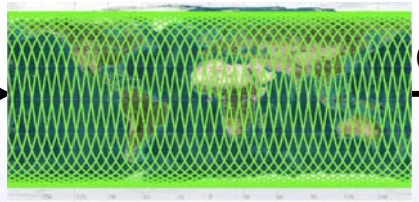


**Cloud Computing Providers**


3-day fast-phase Cal/Val targets

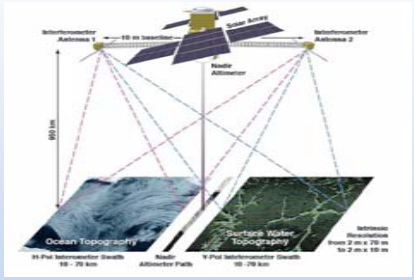
# Observing System Simulation Experiment (OSSE)

Design, Testing and Deploy



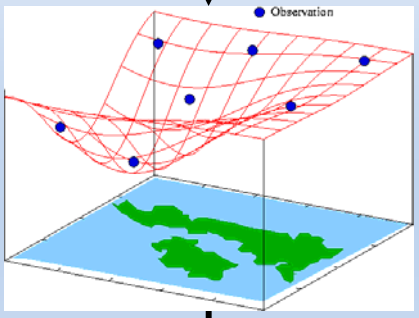
Observatory (simulated) data

Models




Sensor & Platform

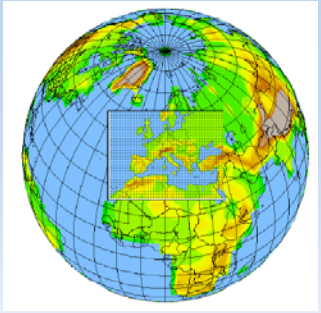
Data Assimilation

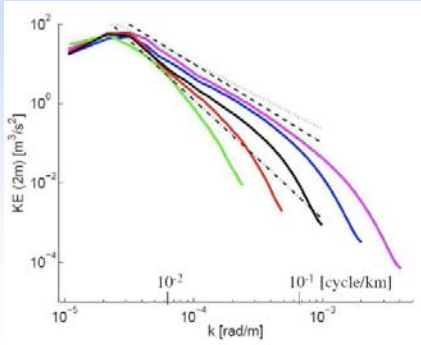



**Model + Data Assimilation:**

**Data and Model Integration**

Virtual Ocean






Data Analysis

Science Questions & Drivers

Data Synthesis:
Nowcast & Data Impact



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