A Regional Ocean Modeling, Data Assimilation and Forecasting System: Anywhere and Anytime

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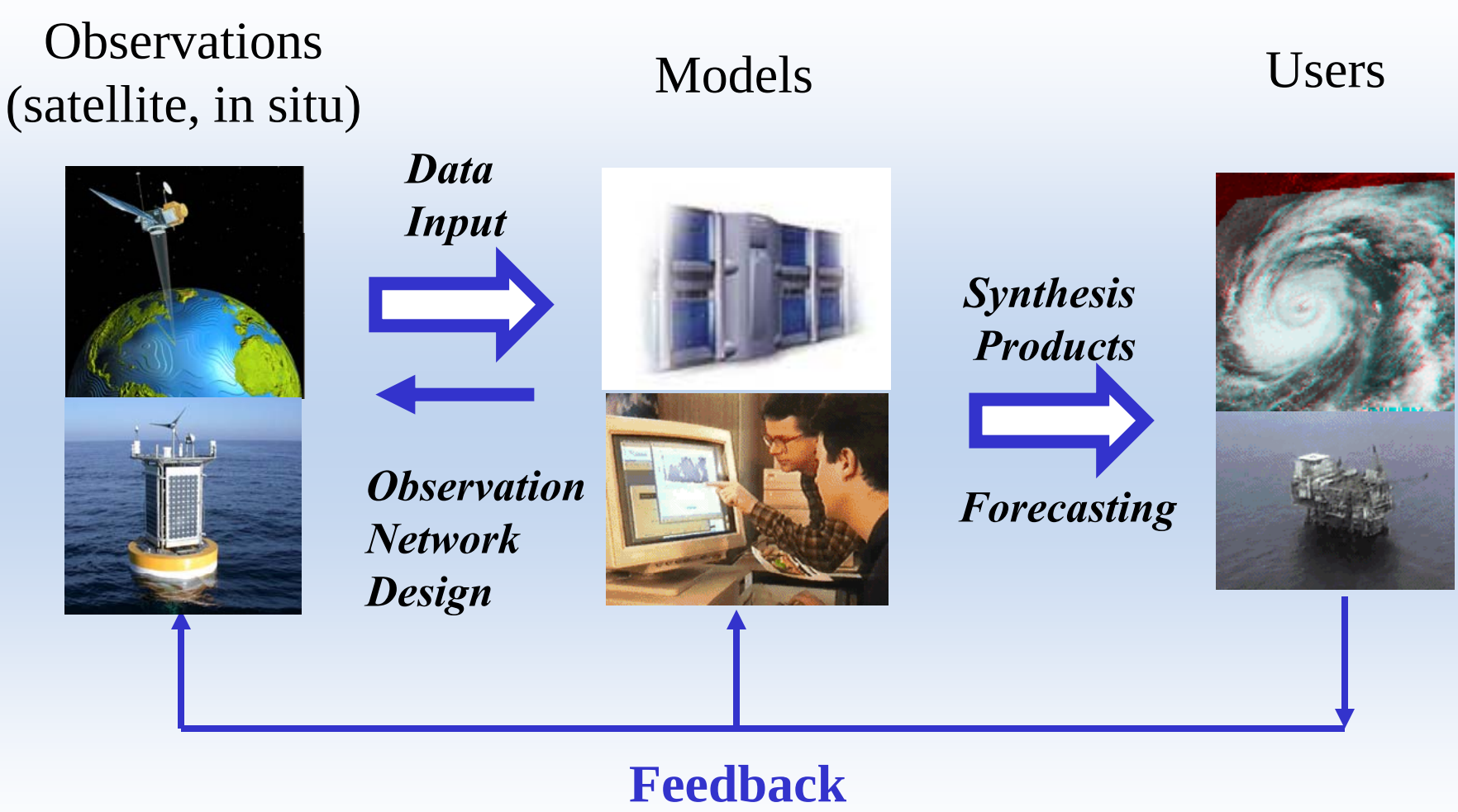
------ OUTLINE ------

- Objectives
- Regional Ocean Modeling System
- Multi-Scale 3-Dimensional Variational Data Assimilation
- Implementation, Testing, Validation: Adding Capabilities through Field Experiments
  - 2003 AOSN, 2006 ASAP, 2009 Alaska, 2009 OSSE, 2010 Biospace/BloomEx, 2011 Alaska, 2012 SPURS…
- Transition from Research to Operations
- Future Plan

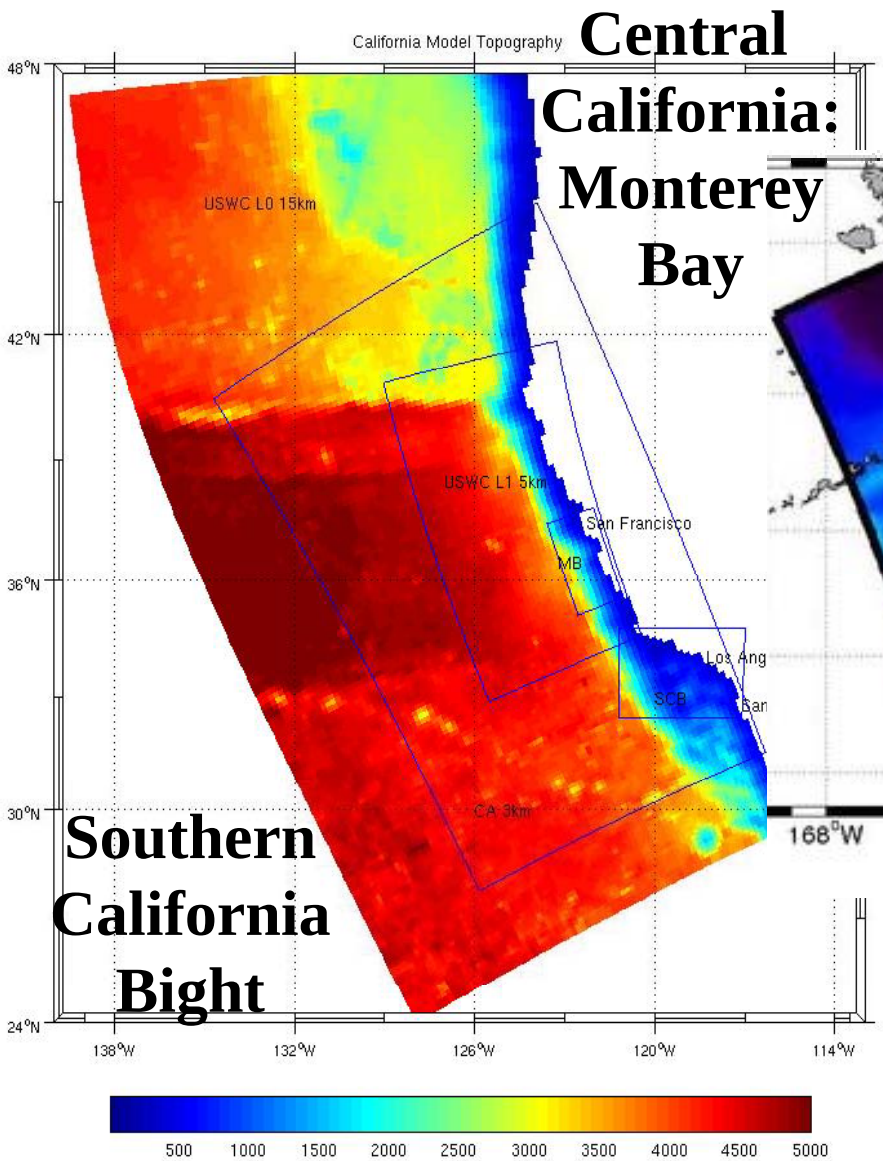
Objectives (Constraints & Challenges)

- 3-dimensional ocean circulation with tides
- 1-km resolution comparable to the highest resolution observations (e.g., satellite infrared SST, HF radar current)
- Desktop computer or clusters (<16 processors)
- Assimilate all data types, including both prognostic and indirect (diagnosed from prognostic) variable
- Product development for non-expert users (bridge gaps between researchers and decision makers)

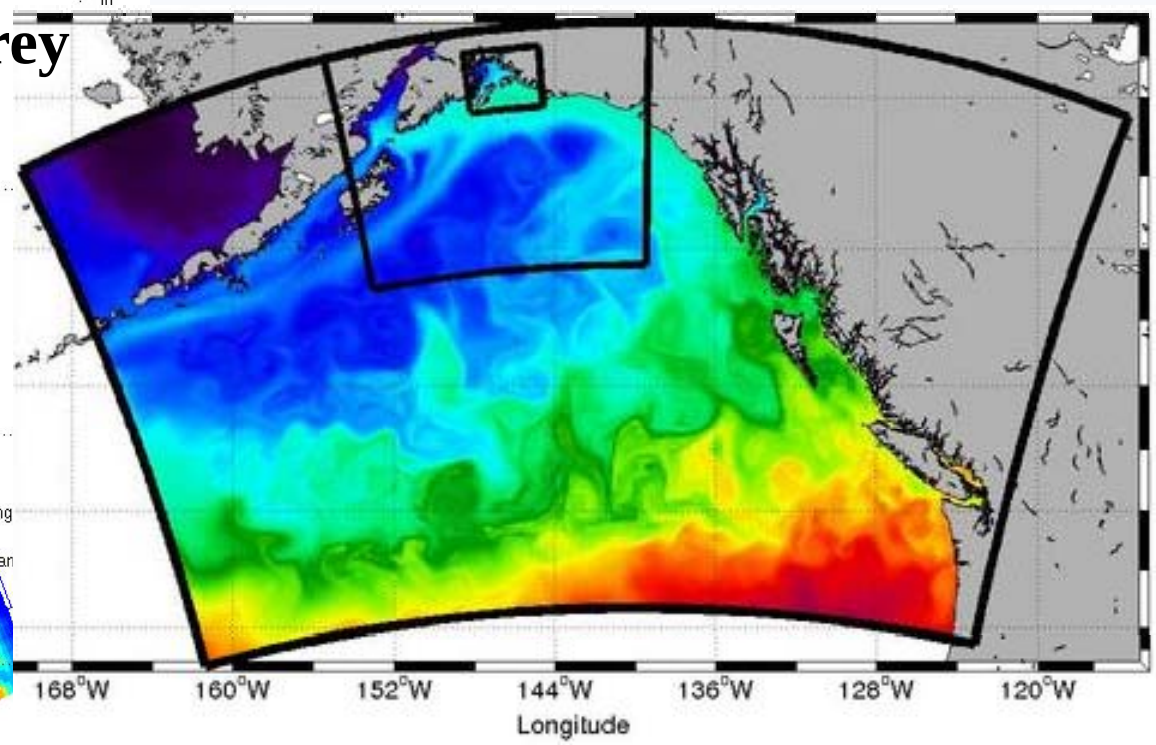
Architecture: Development, Implementation, Test, Validation, Operation Transition, Outreach/Feedback



Regional Ocean Modeling System (ROMS)



Online (one-way) nesting



Prince William Sound, Alaska

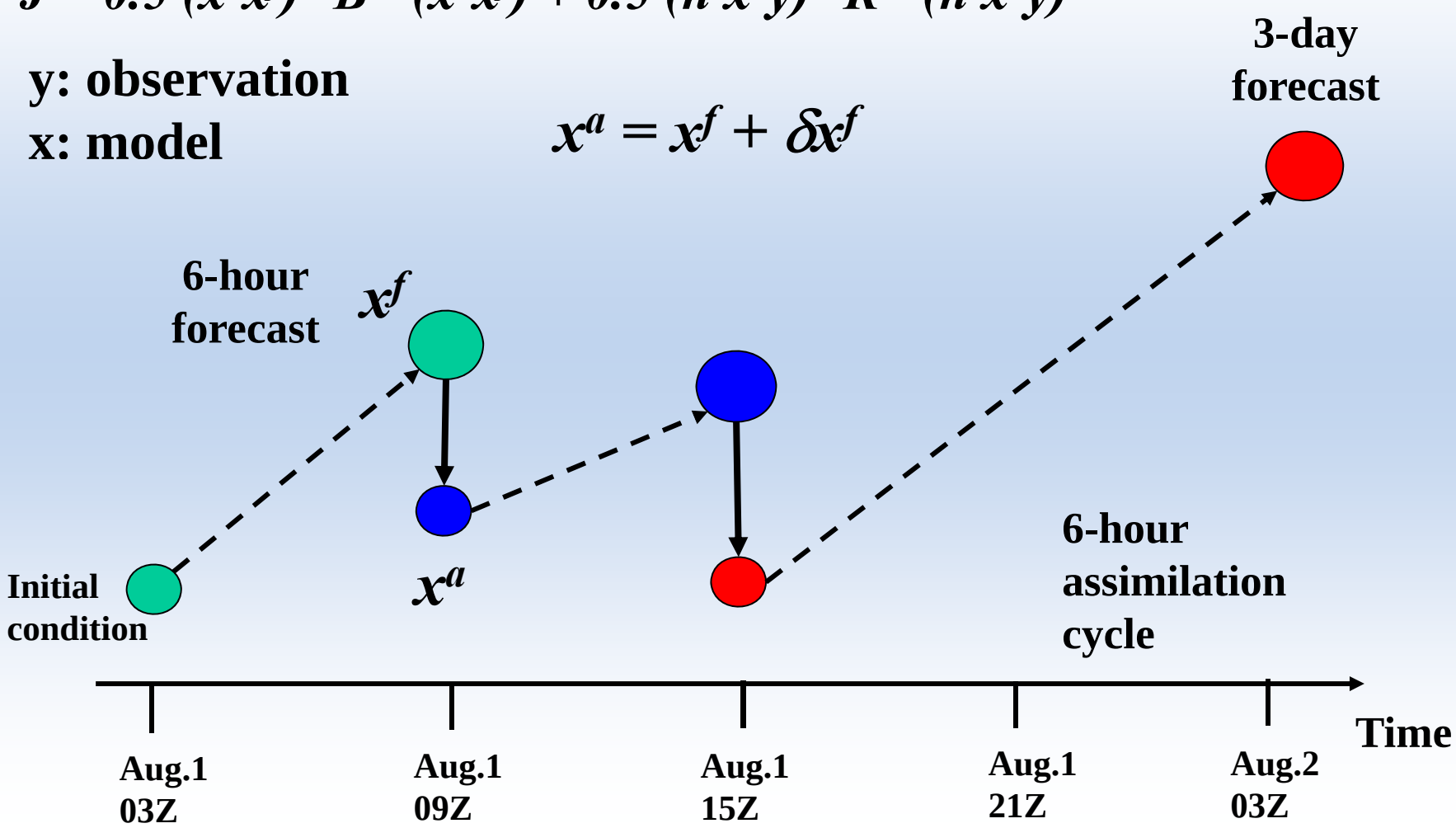
1st Generation Data Assimilation: Incremental 3D-Variational (3DVAR) Method

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

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



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

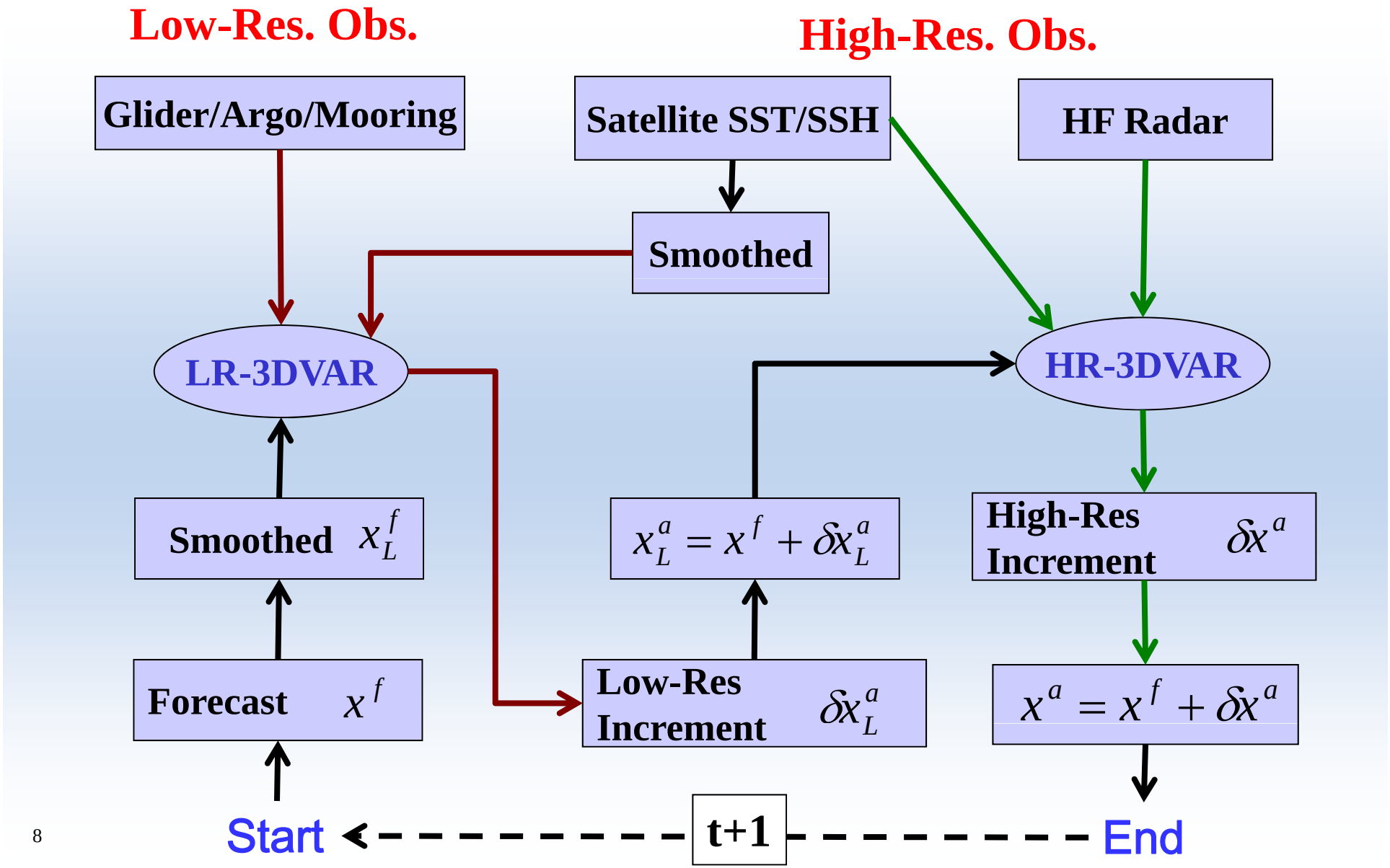
$$x = \begin{pmatrix} \varsigma \\ u \\ v \\ T \\ S \end{pmatrix} = \begin{pmatrix} x_{\varsigma} \\ x_{uv} \\ x_{TS} \end{pmatrix} = \begin{pmatrix} x_{\varsigma}^{f} + \Pi \delta x_{TS} + \delta x_{a\varsigma} \\ x_{uv}^{f} + \Gamma \delta x_{TS} + \Phi_{a} \delta x_{a\psi\chi} \\ x_{TS}^{f} + \delta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

$\delta x_{uv}^{G} = \Gamma \delta x_{TS}$ 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: $\boldsymbol{\delta X_{a\chi}}$

2nd Generation Data Assimilation: Multi-Scale 3DVAR



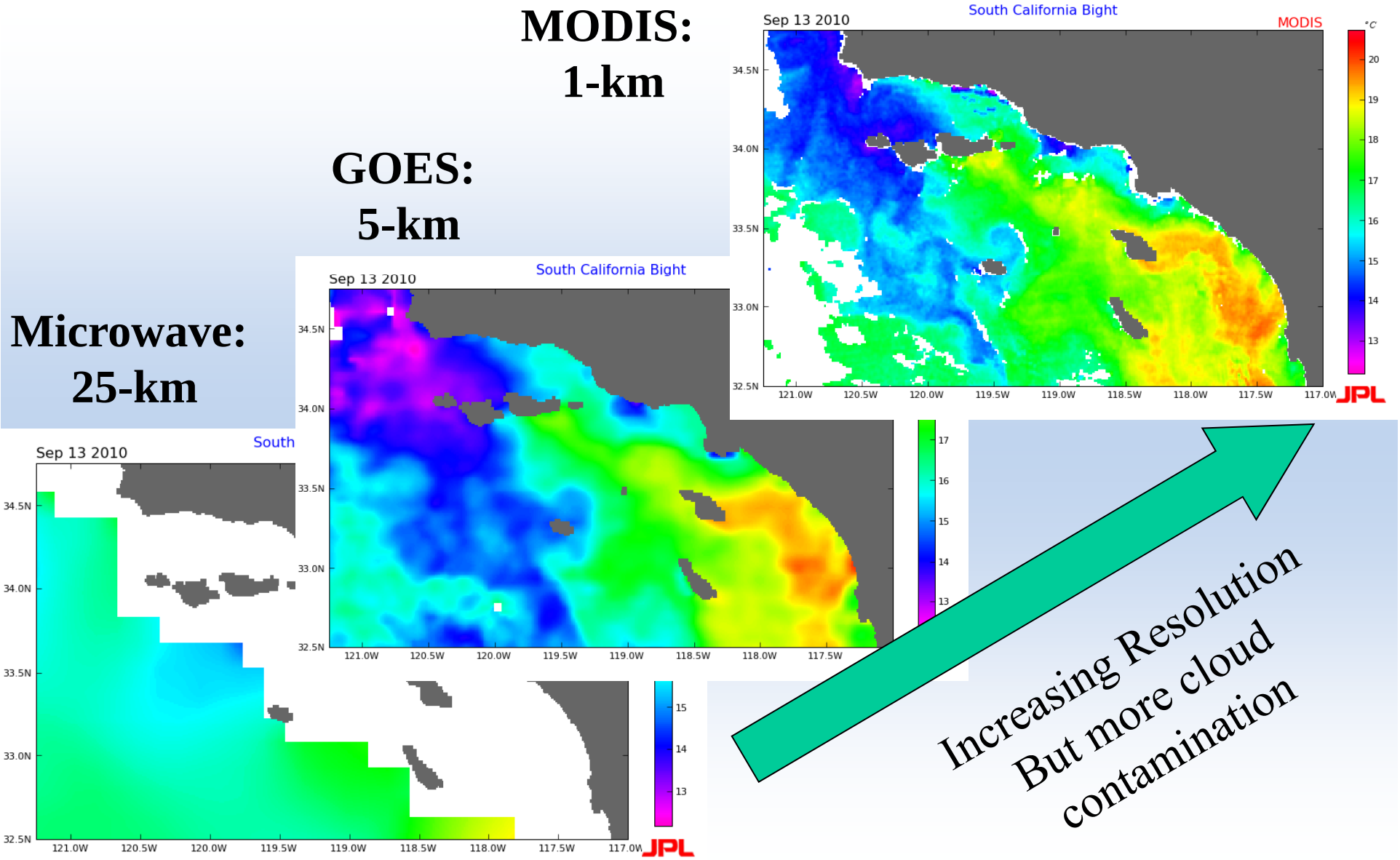
Multi-Scale Sea Surface Temperature (SST)

(Available global, daily from http://ourocean.jpl.nasa.gov/SST)

MODIS: 1-km

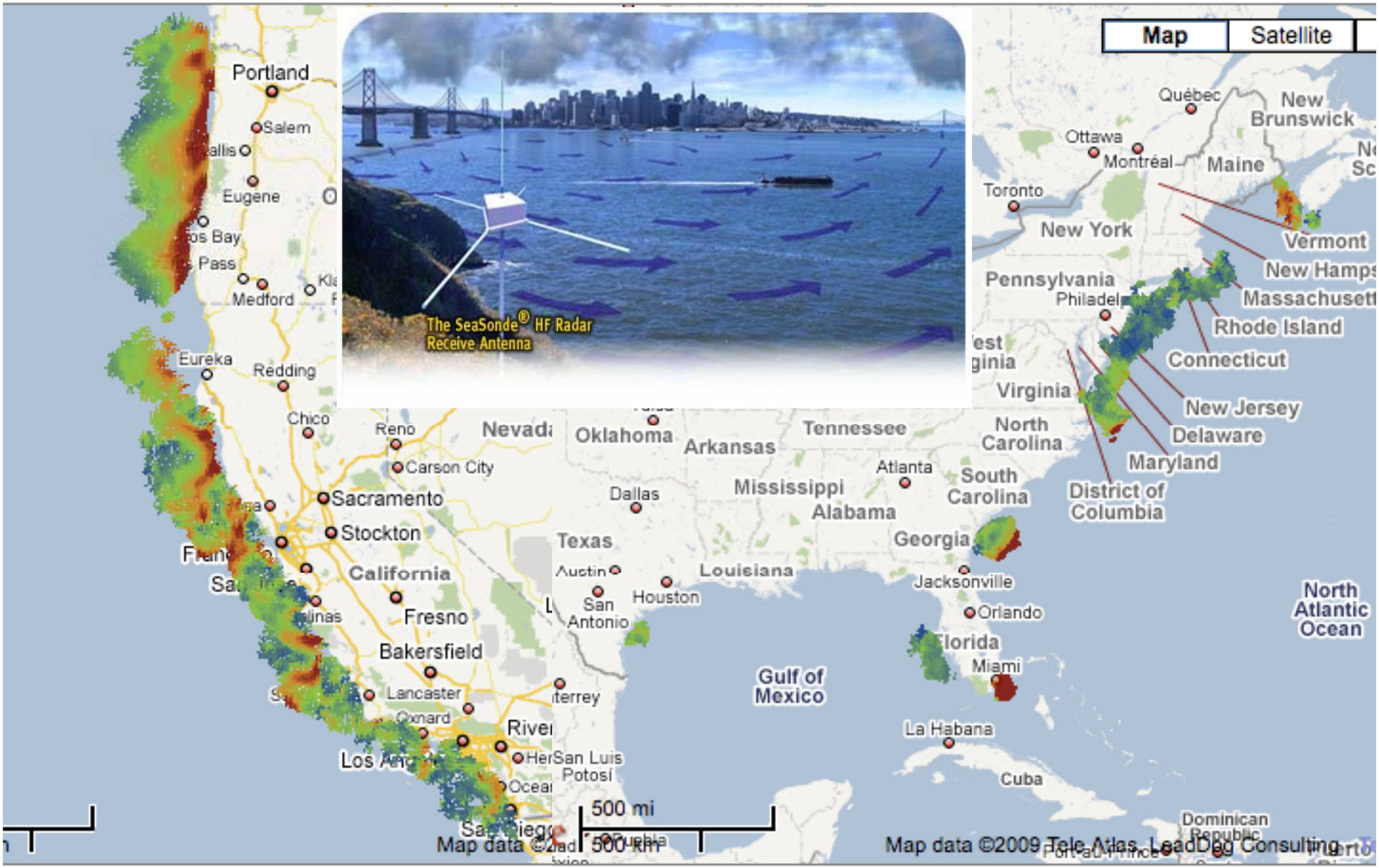
GOES: 5-km

Microwave: 25-km



Surface Current from High-Frequency (HF) Radar

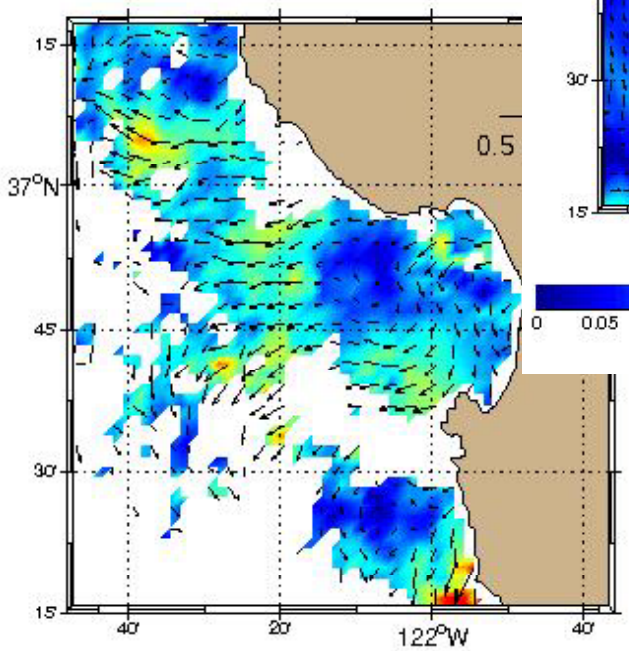
(Available hourly, 1-km, but only near the coast)



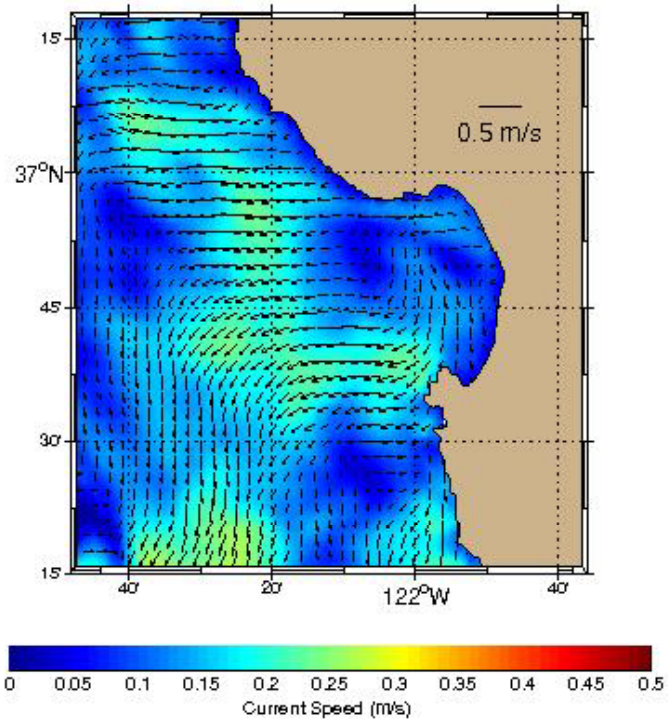
Impact of HF Radar Surface Data Assimilation

Oct. 18, 2010

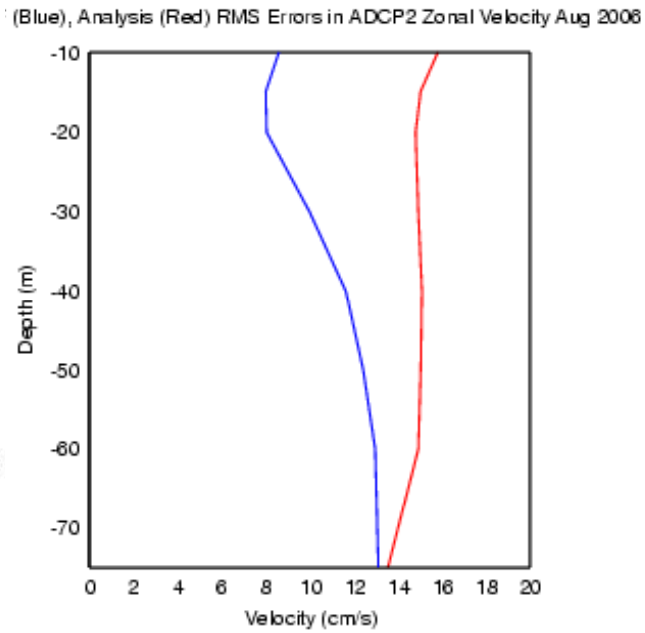
2–km HF Radar Obs Sfc Current (m/s) for 10/1



ROMS Surface Current (m/s) for 10/18/2010 at 3GMT



RMS



ROMS w/o data assimilation
ROMS with data assimilation

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

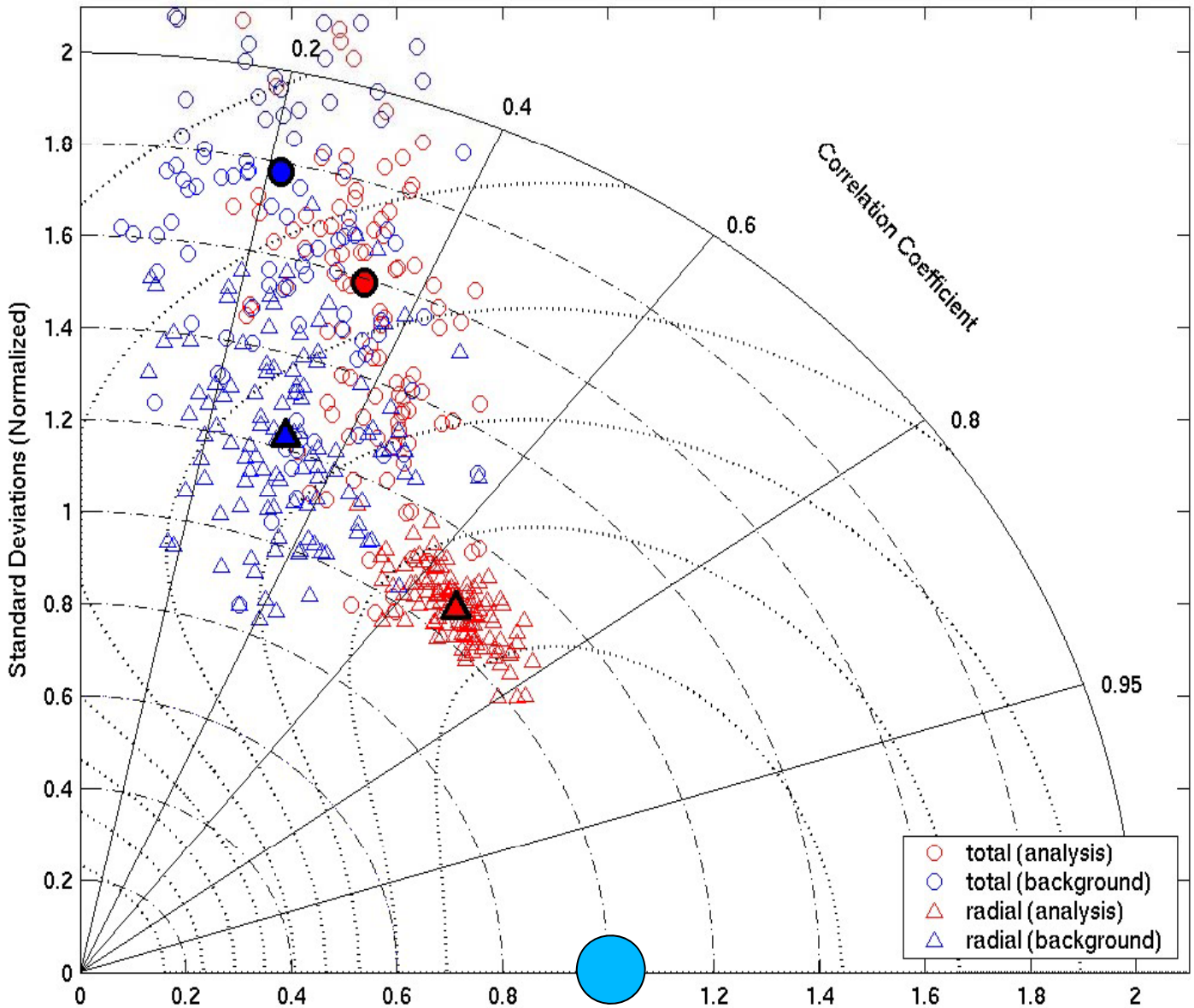
Assimilate original (radial) vs processed (total) data: Special care with pre-processing of data

Total currents data assimilation (circle)

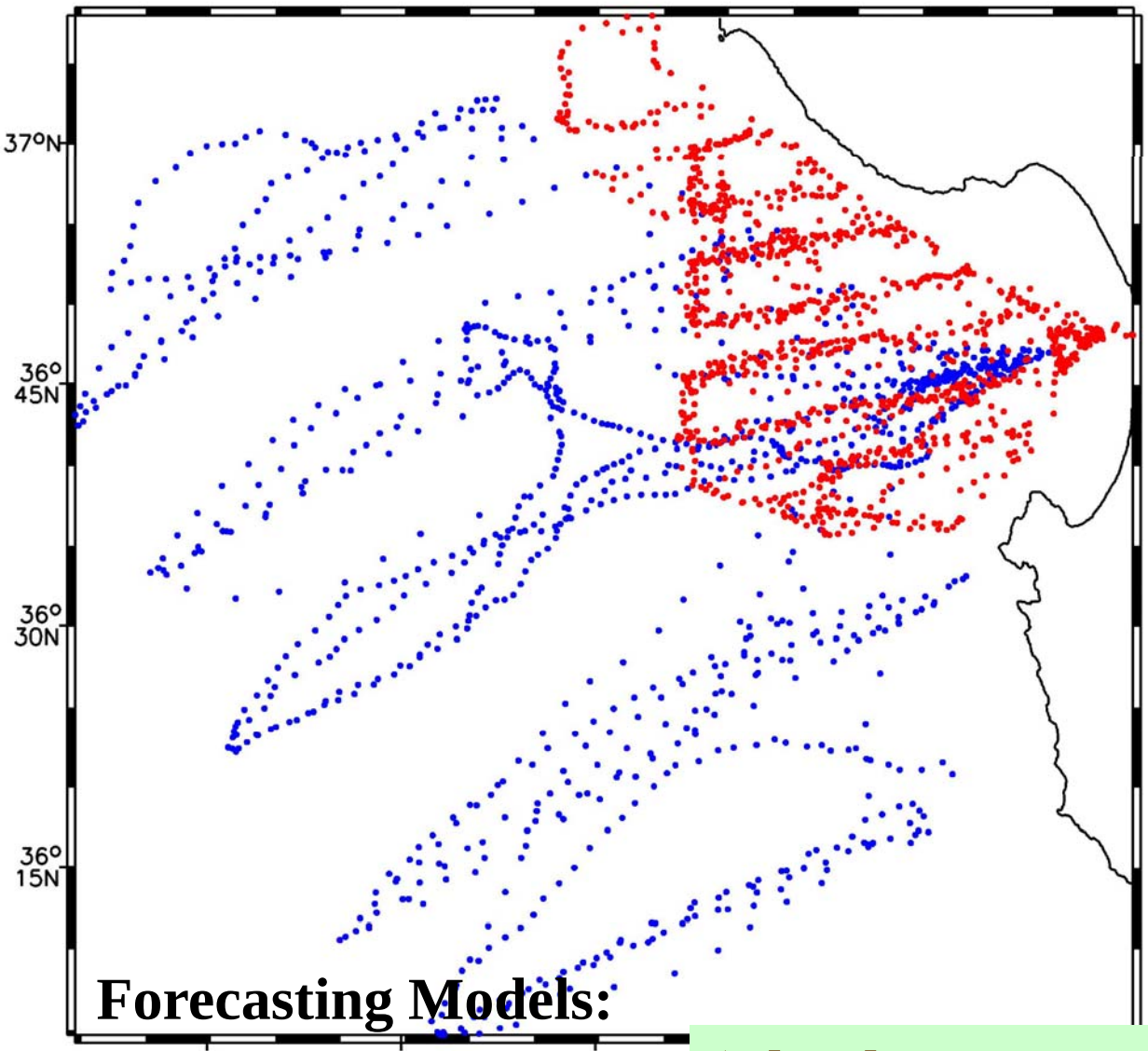
1st Guess (blue)

Reanalysis (red)

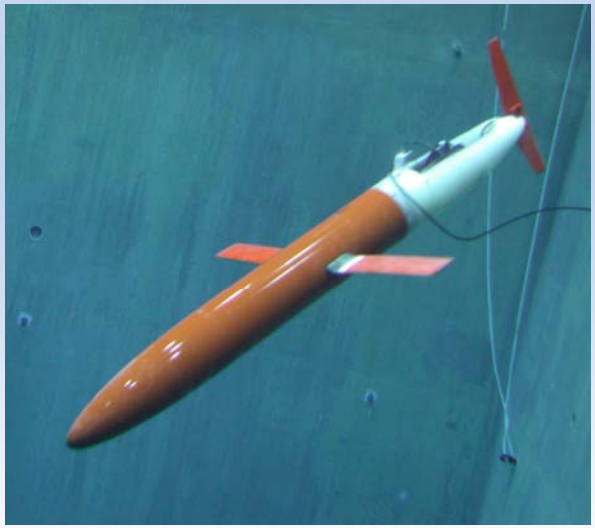
Radial current data assimilation (triangle)



Glider: Controlled Deployment
2003 AOSN-2 Field Experiment in Monterey Bay



0-200 m Slocums



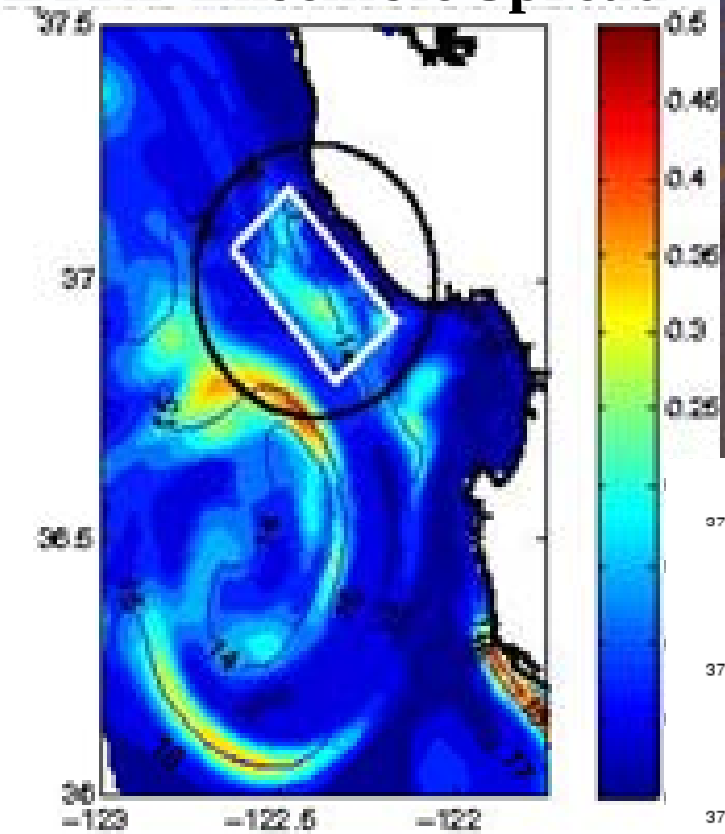
0-700 m Sprays

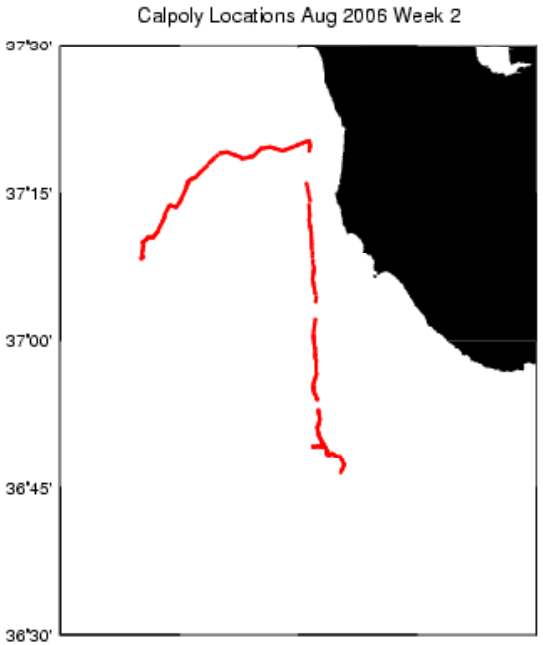
Forecasting Models:
HOPS, NCOM, ROMS

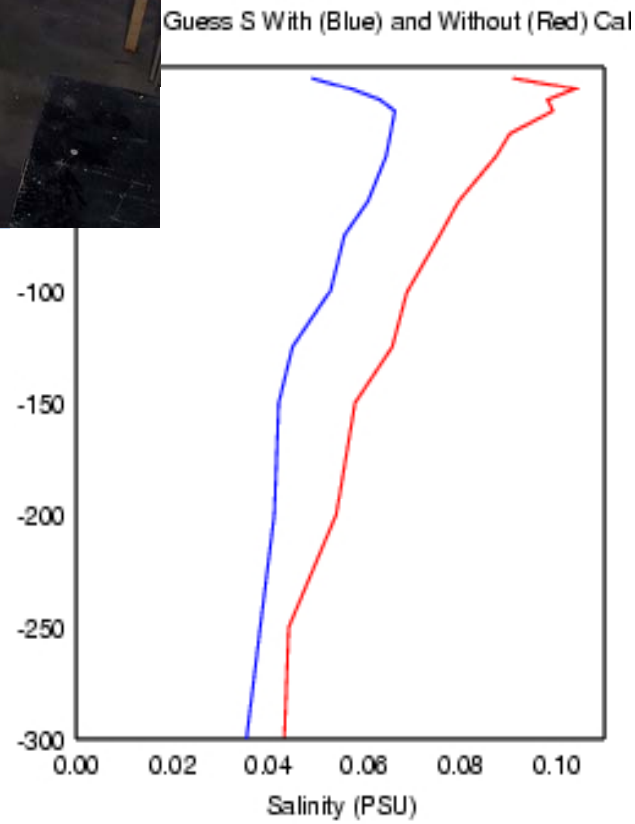
(Thanks to Tom Curtin)

Ensemble Forecasting & Adaptive Sampling During 2006 ASAP Field Experiment

ETKF Ensemble Spread



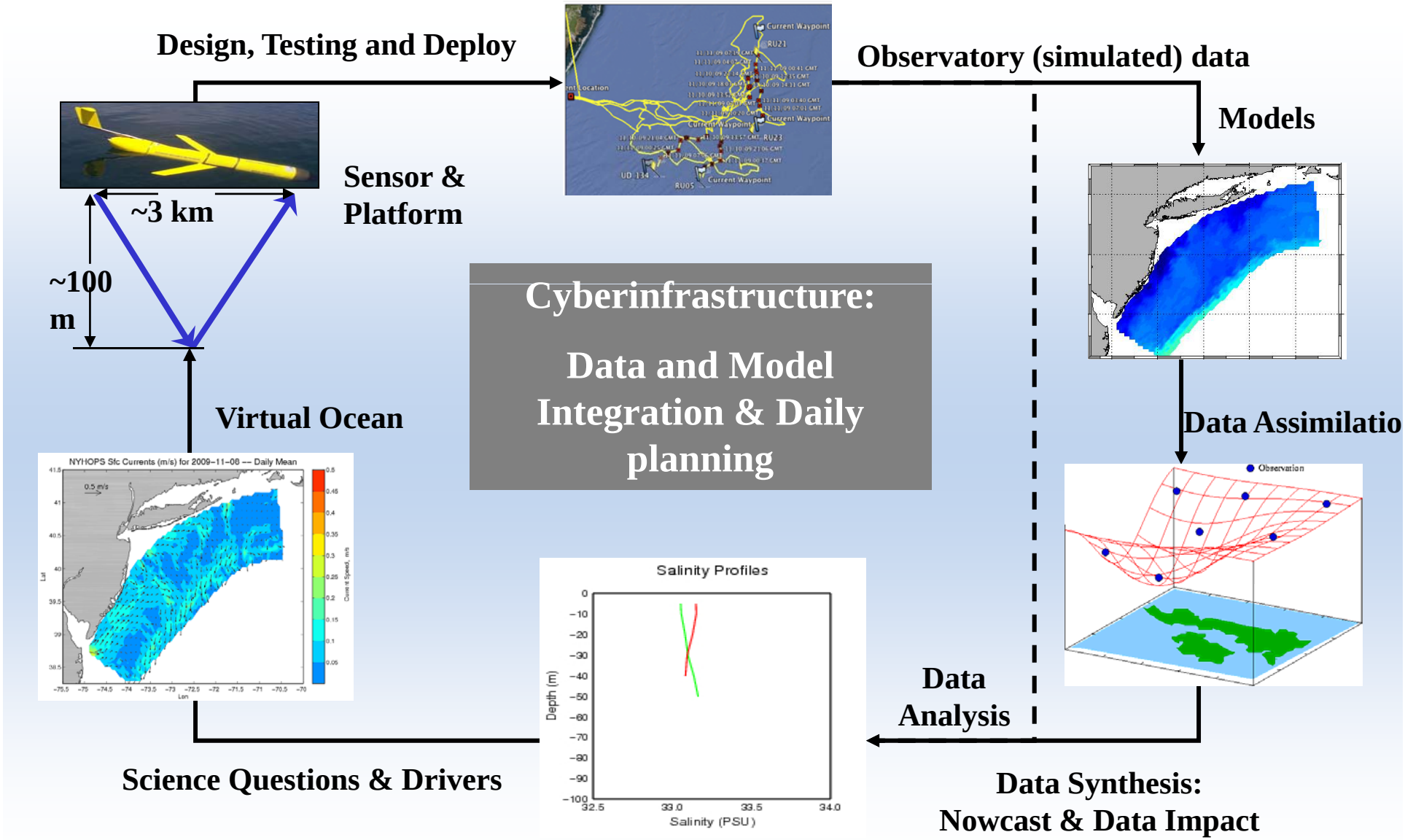




Error Reduction

In collaboration with Sharan Majumdar, Mark Moline

Observing System Simulation Experiment (OSSE) & Observing System Experiment (OSE) 2009



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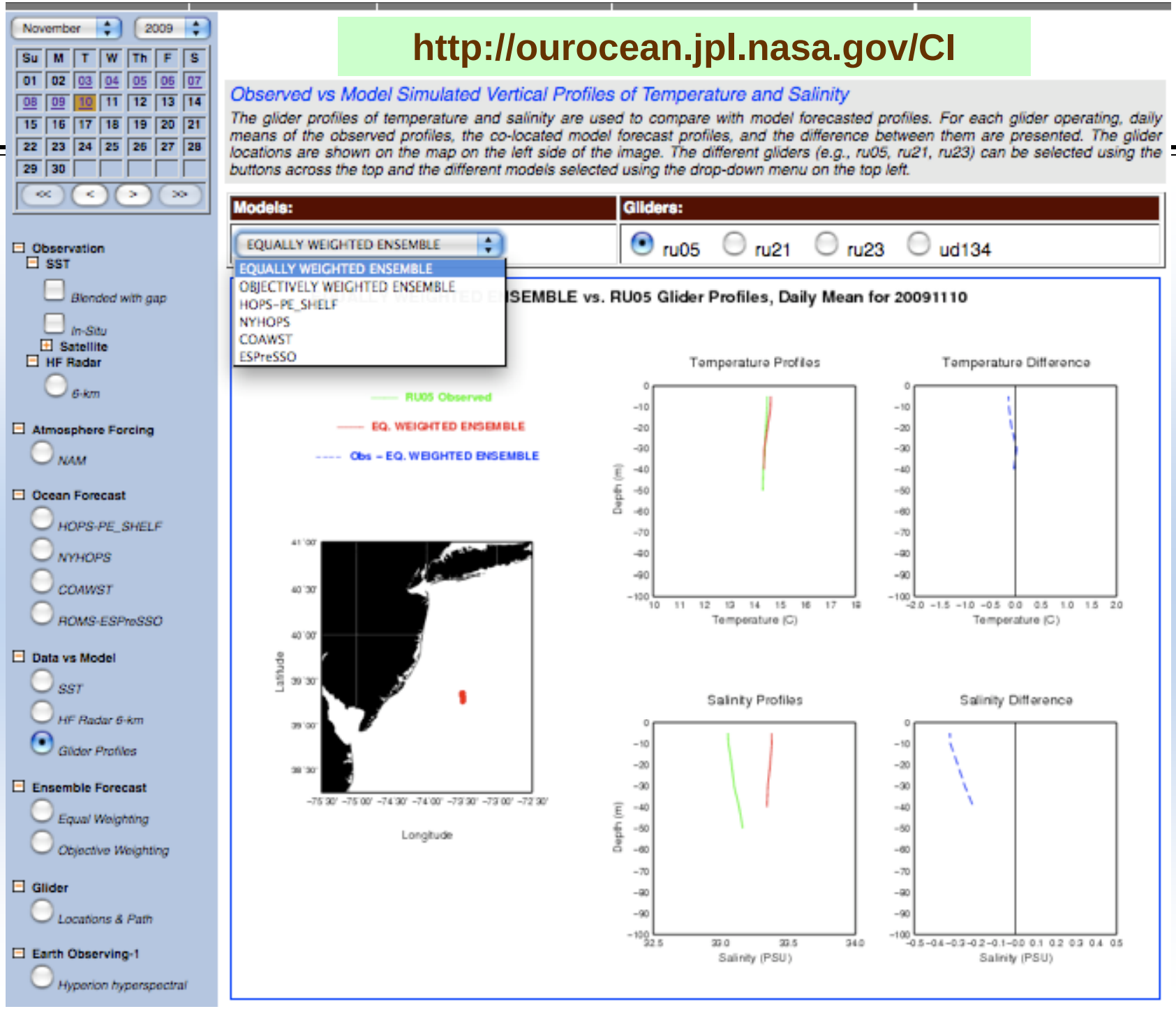
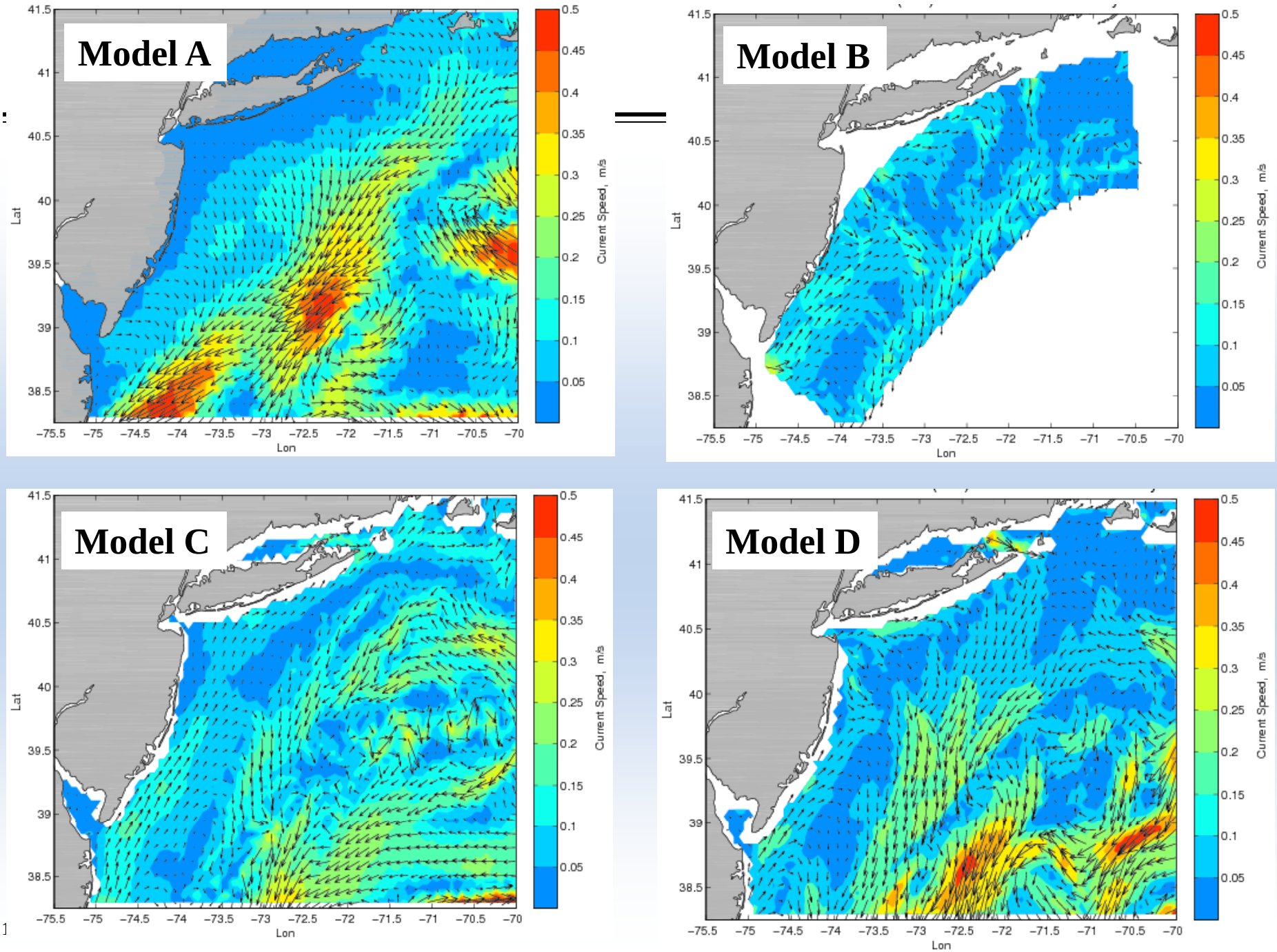
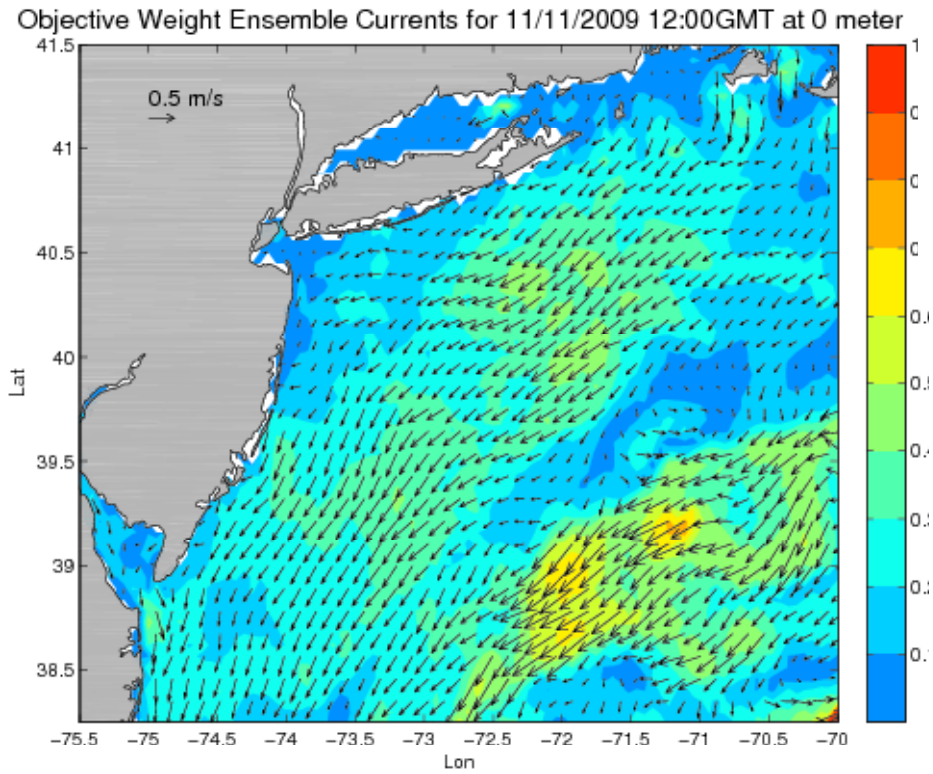
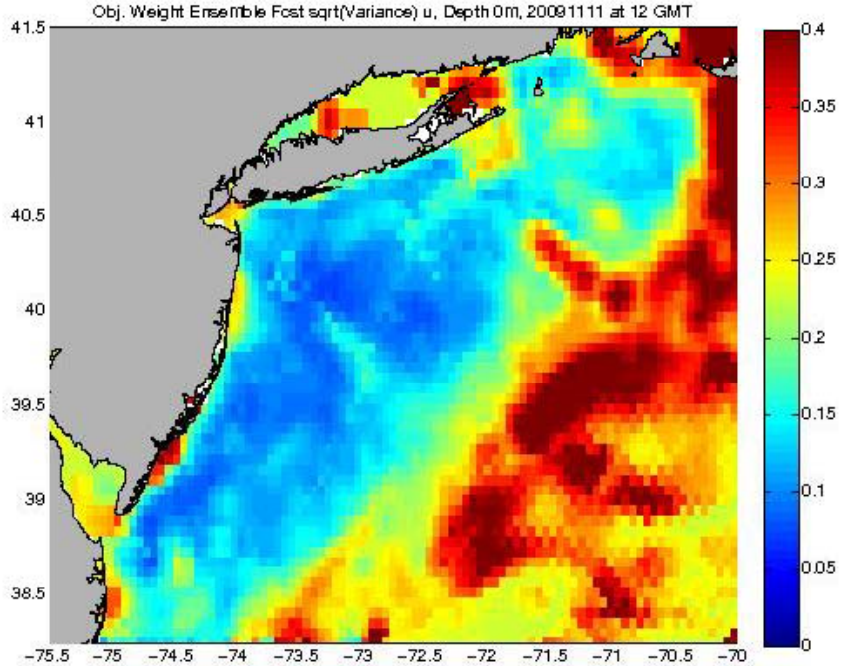
http://ourocean.jpl.nasa.gov/CI

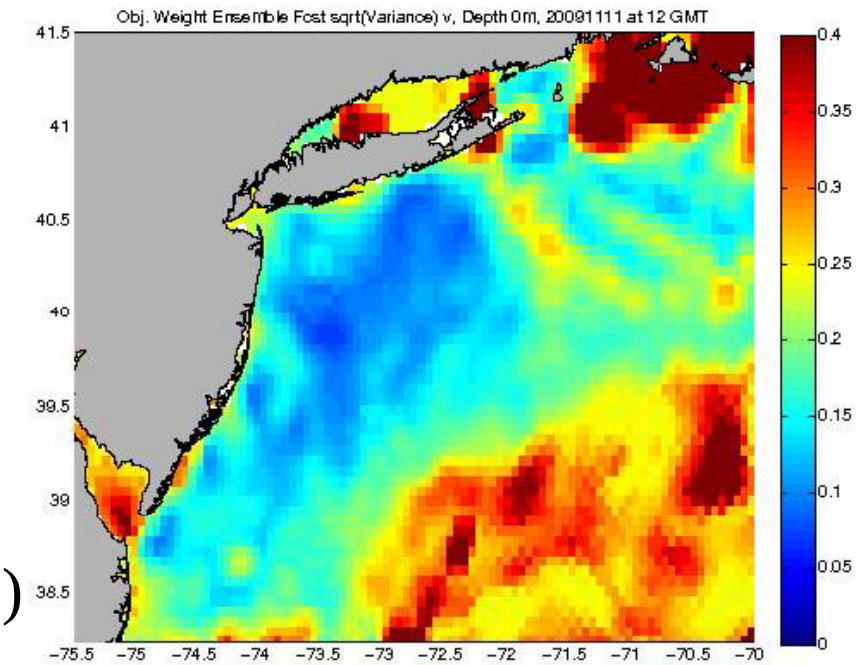



Model A
Model B
Model C
Model D
Lat
Lon
Current Speed, m/s
41.5
41
40.5
40
39.5
39
38.5
−75.5
−75
−74.5
−74
−73.5
−73
−72.5
−72
−71.5
−71
−70.5
−70
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05

Multi-Model Ensemble and its Uncertainty

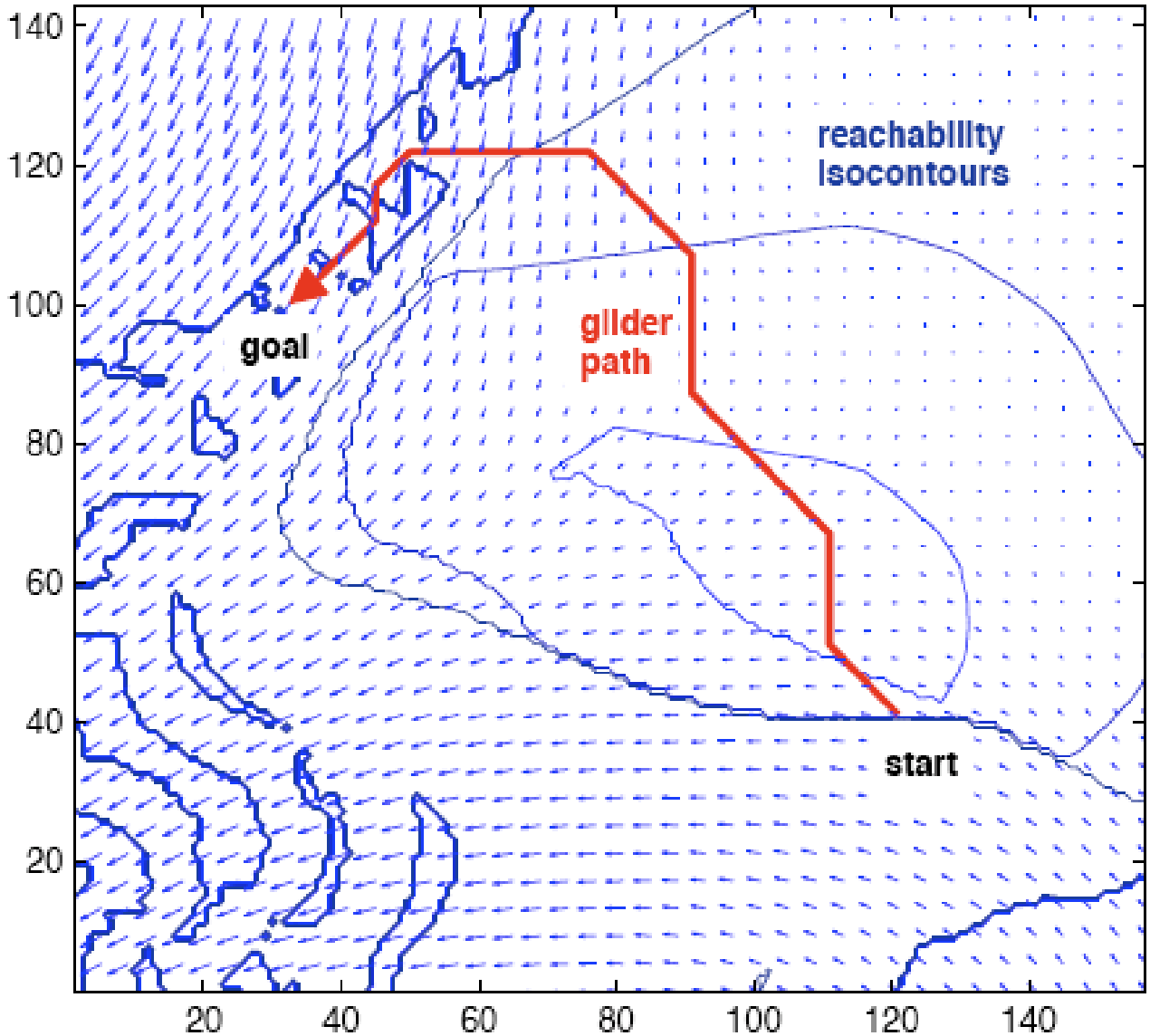






(Raftery, et al. 2005, Mon. Wea. Rev.)

Glider Path Planning: A to B



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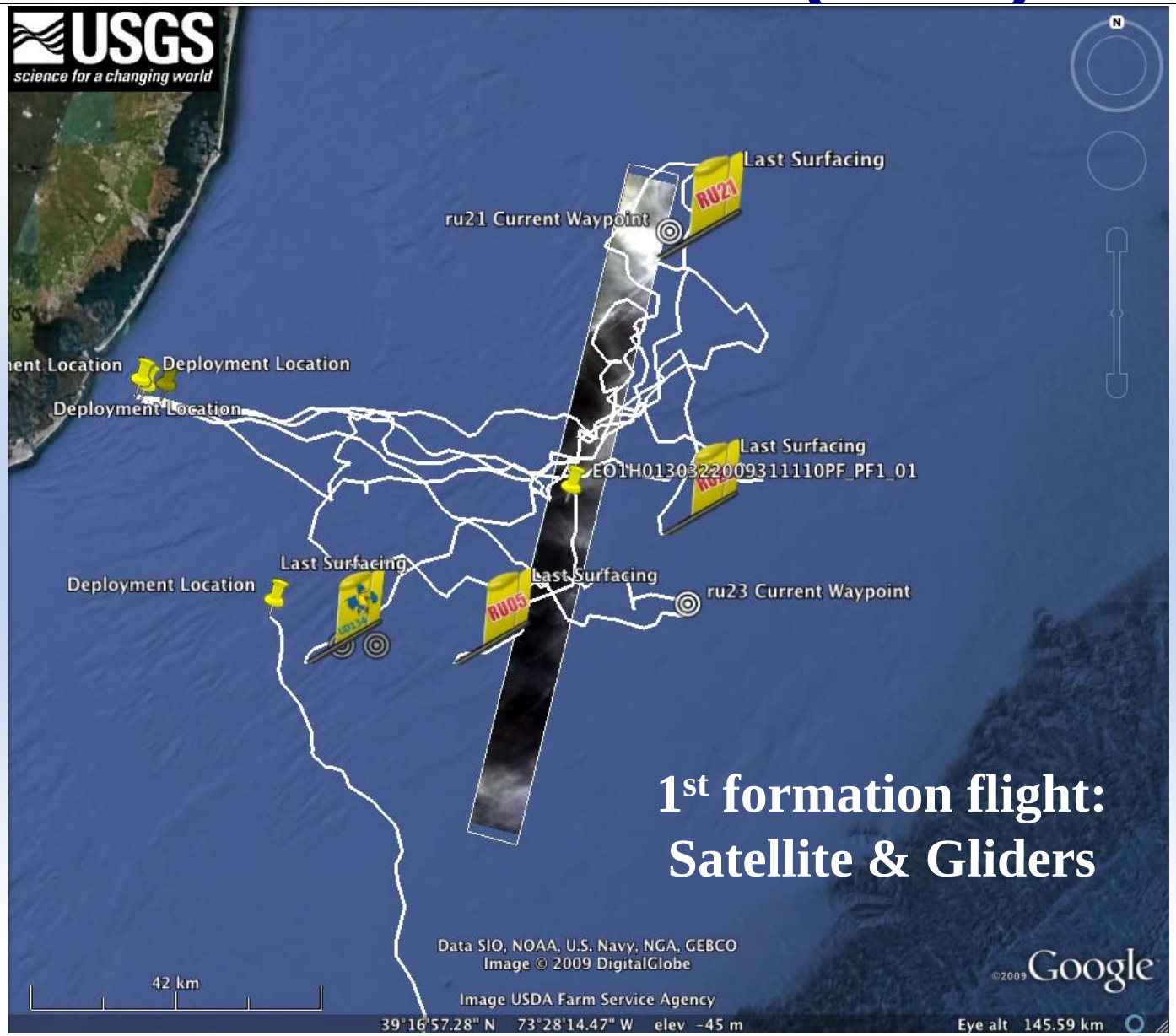
Hyperion Imager on EO-1 Satellite: 7.5km x 100km (30-m)



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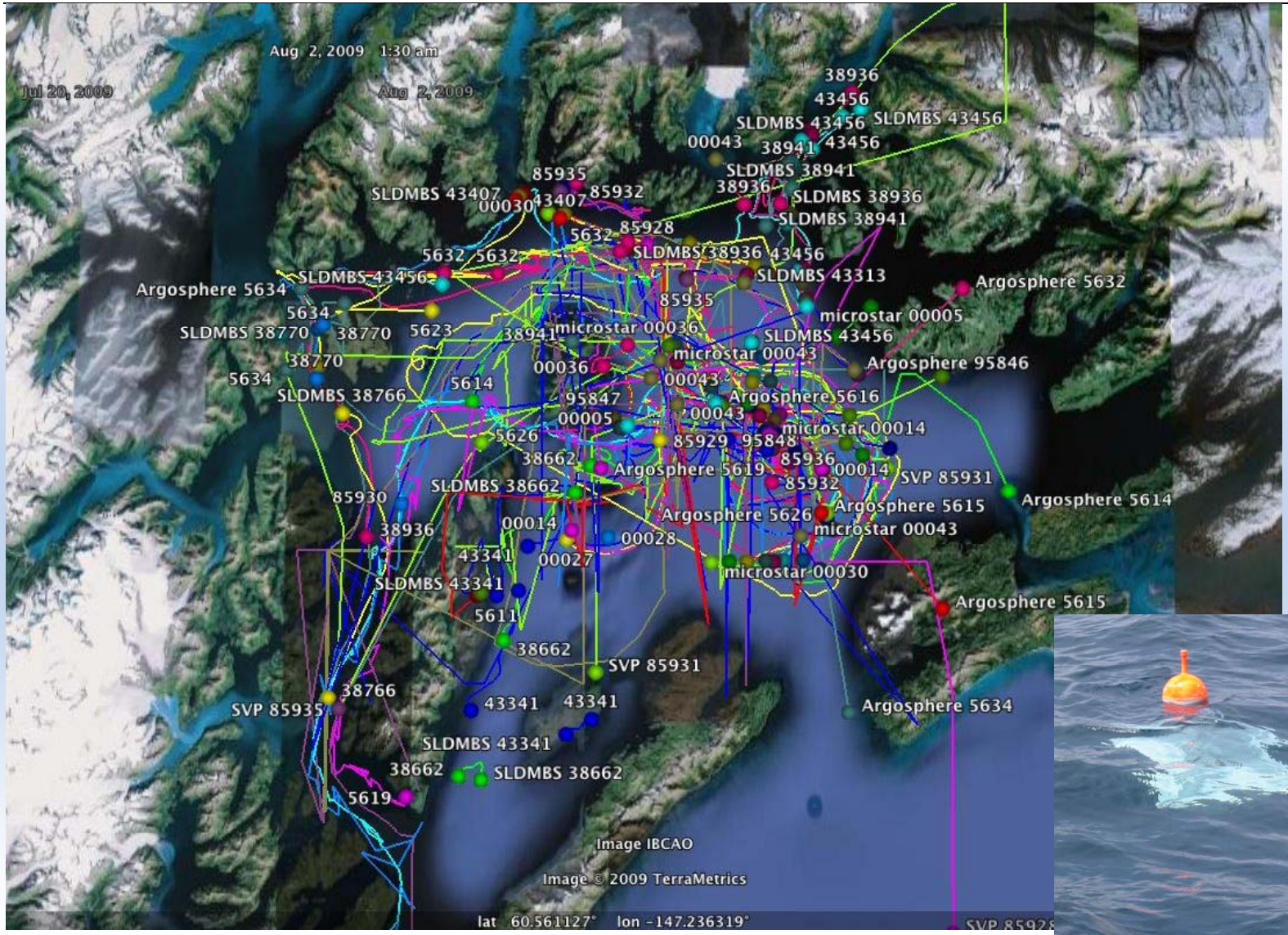
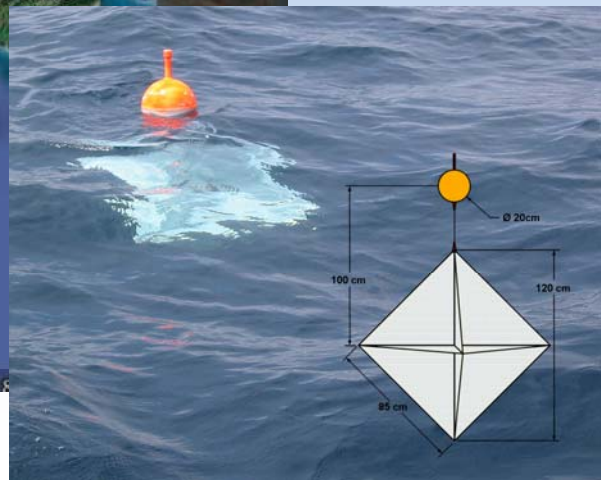
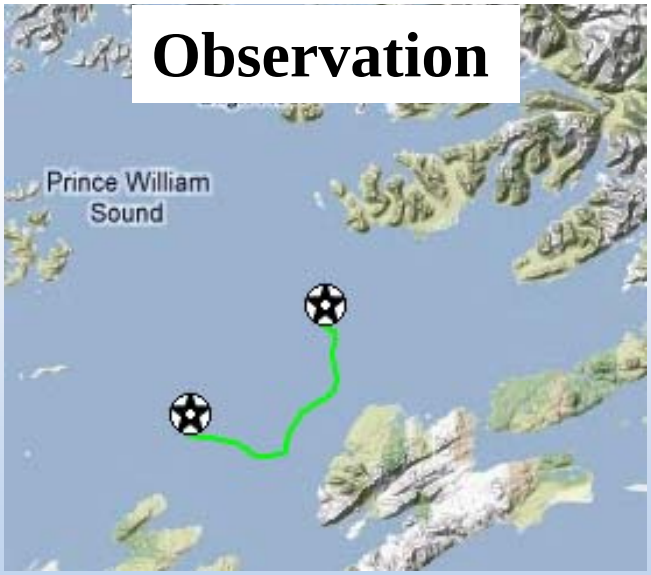
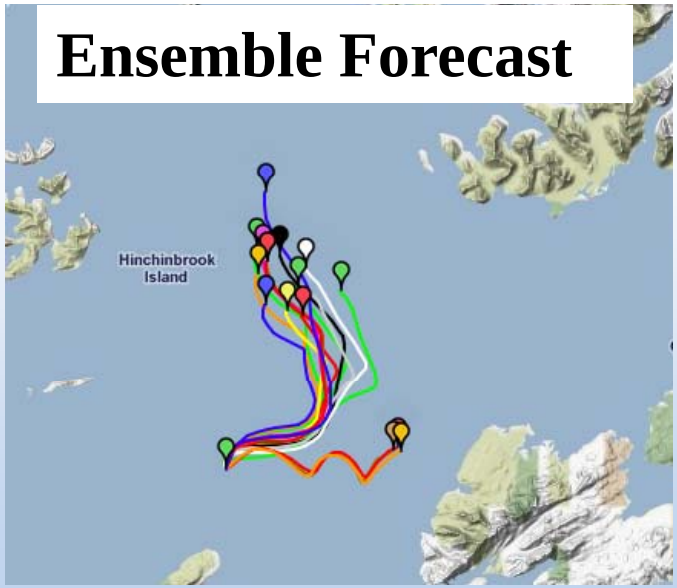
2009 Alaska Field Experiment
Prince William Sound

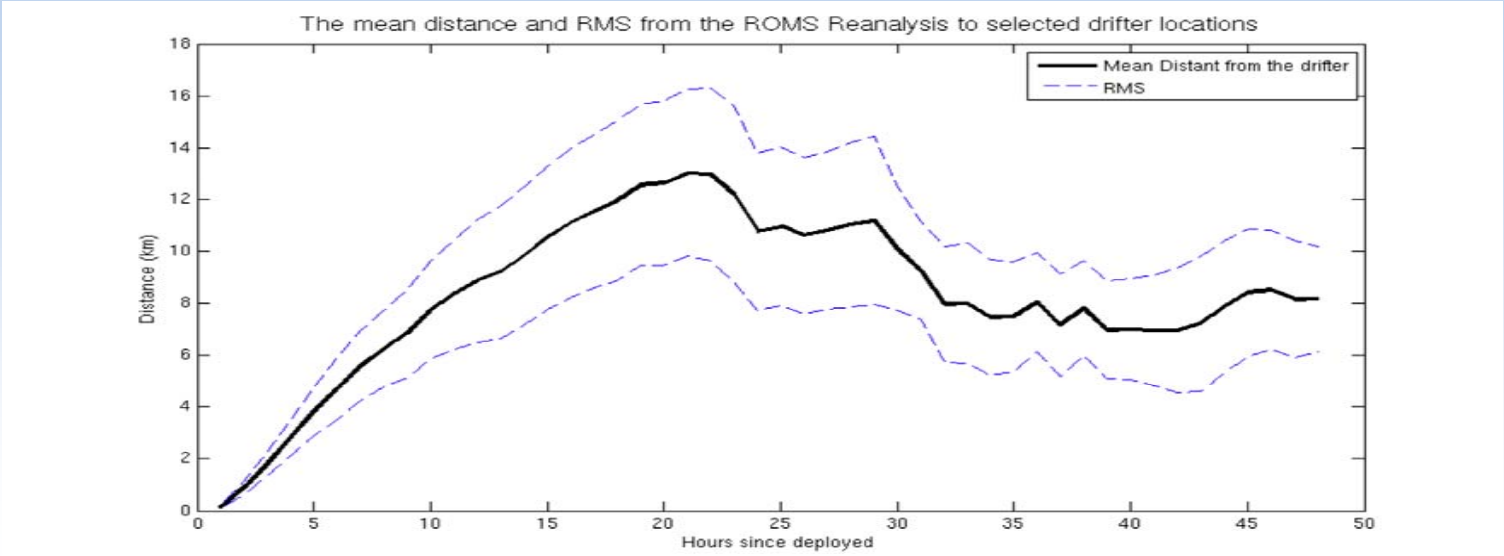




Drifting Trajectory and Uncertainty

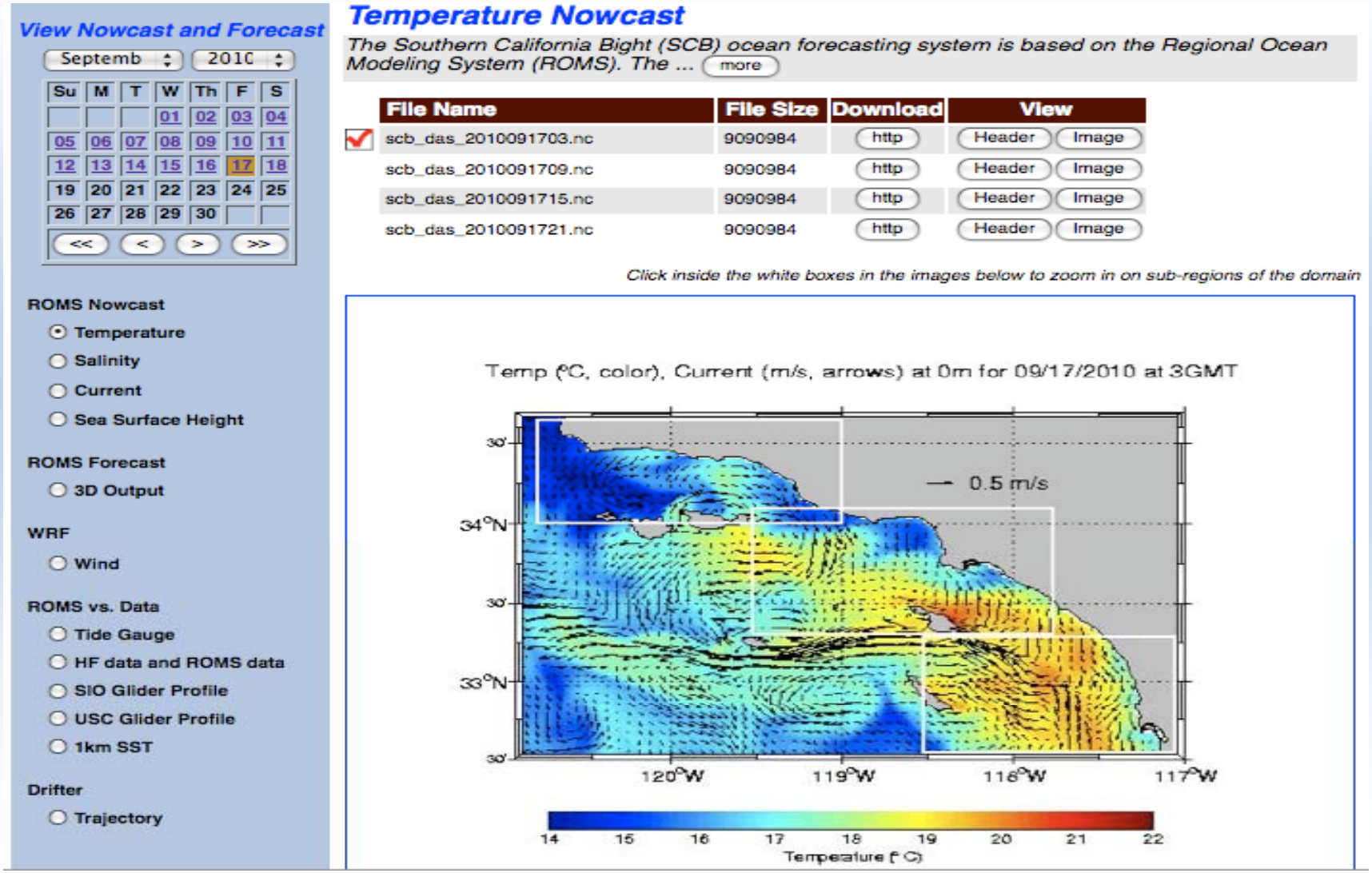






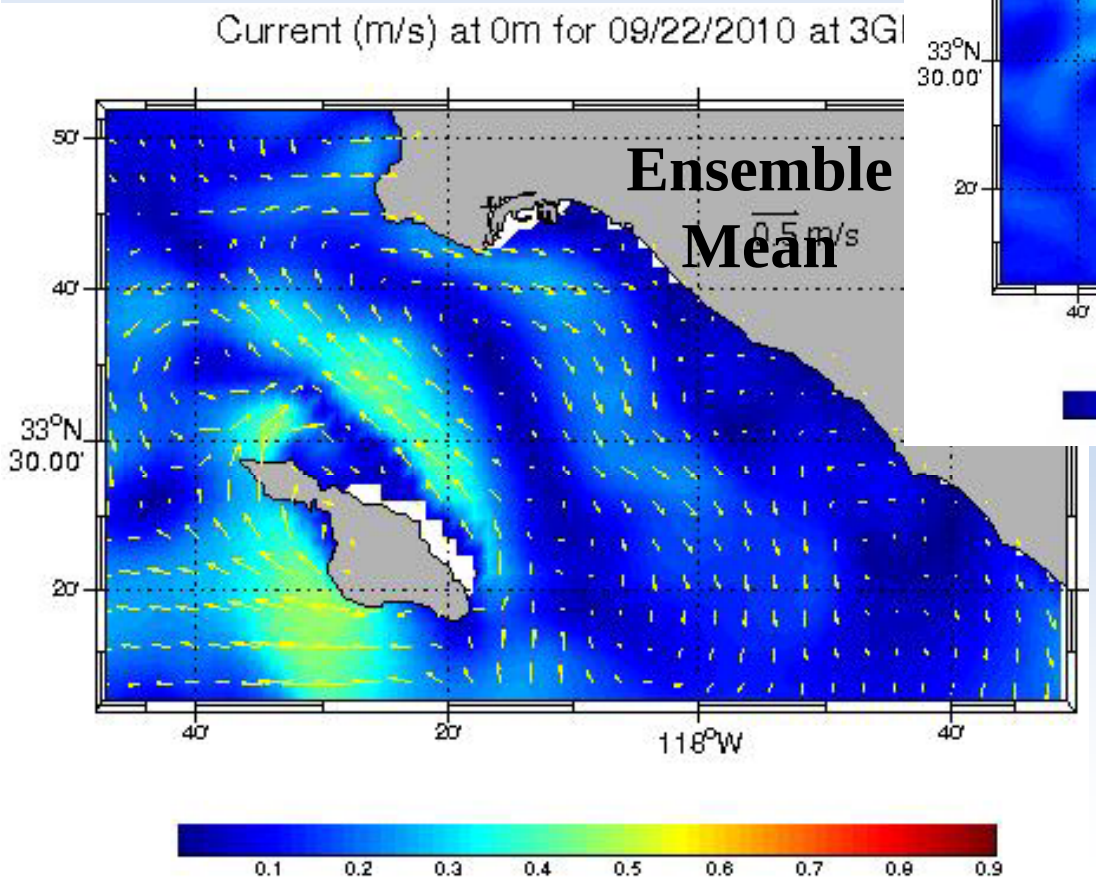
Operational Coastal Oceanography: Southern California Bight Forecasting System is operated in real-time 24/7 since April 2007

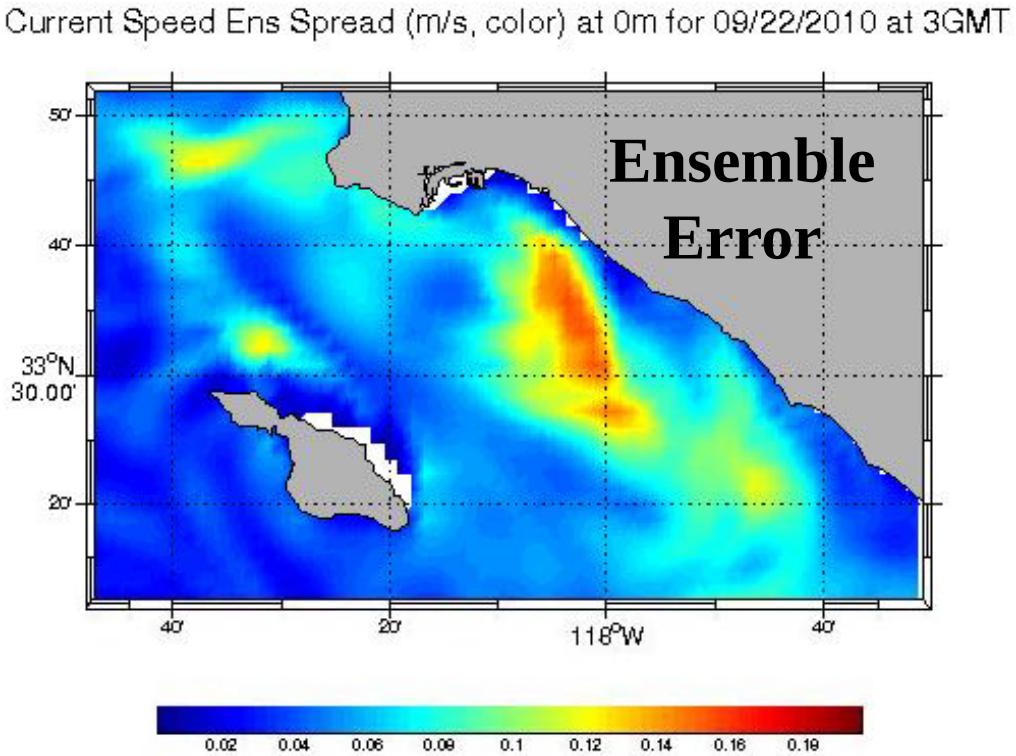
http://ourocean.jpl.nasa.gov/SCB



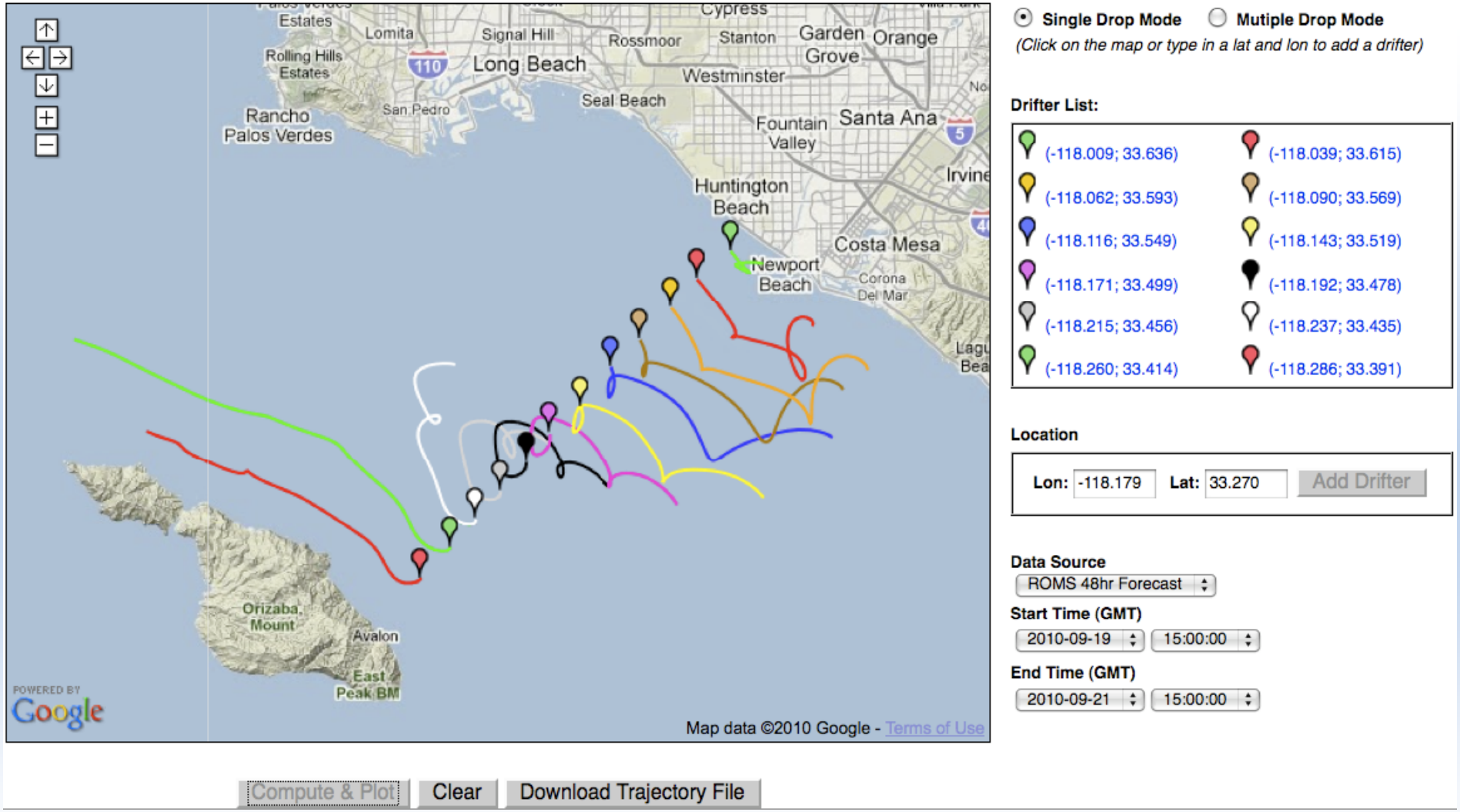
Ensemble Forecast To Quantify Uncertainty

72-hour forecast issued daily with 20-member ensembles





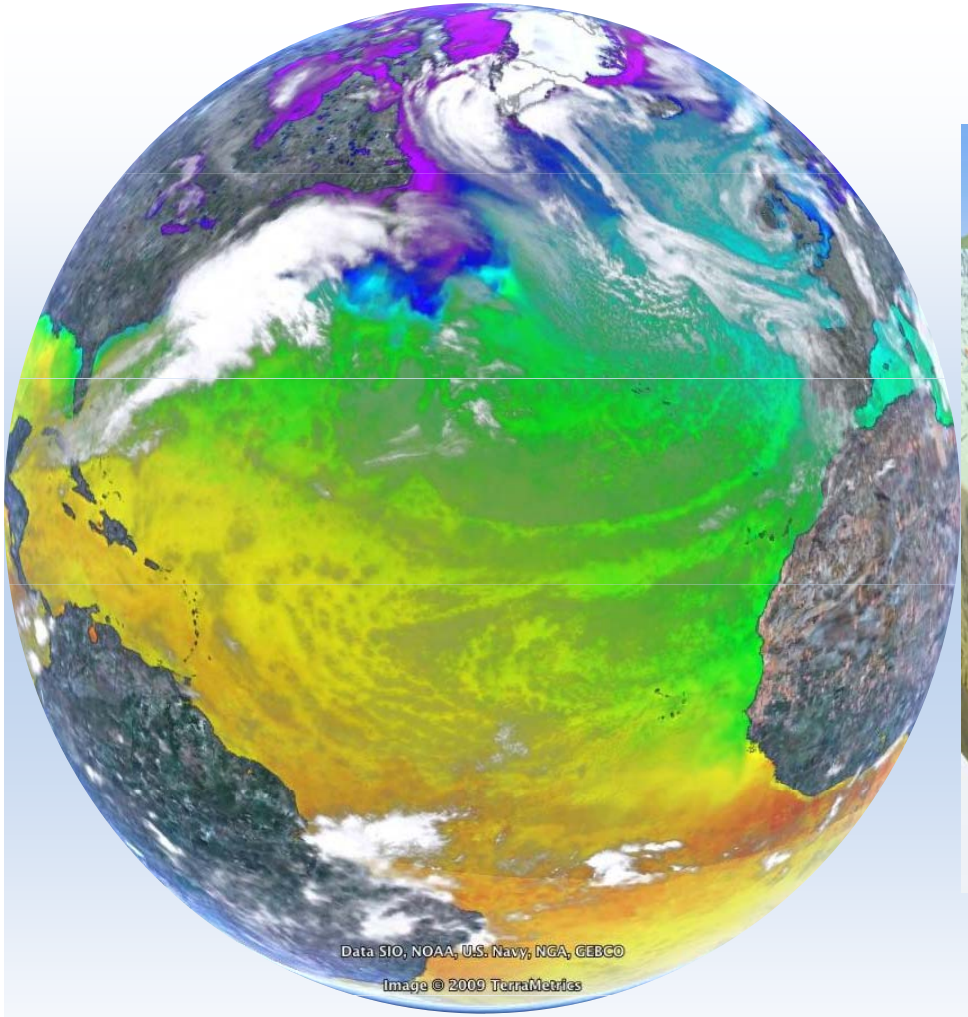
Web-Based Interactive Trajectory Tool to enable Decision Making

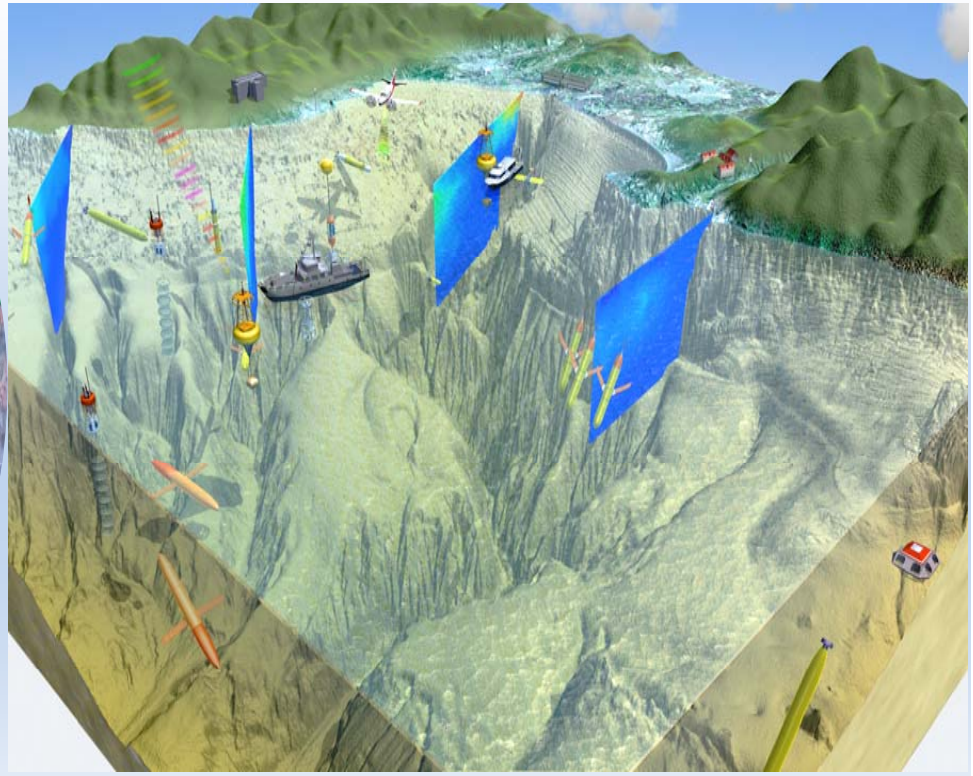


Enable Real-Time Decision Making:

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

A Changing 3D Ocean:
Anywhere & Anytime & On-Demand





Access 3D ocean anywhere/anytime at the observing resolution

(Tom Curtin's Challenge in 2003)

More Info: http://ourocean.jpl.nasa.gov
Contact: Yi.Chao@jpl.nasa.gov

JPL/UCLA OurOcean Team:

Gene Li, John Farrara, Xin Jin, Peggy Li, Benyang Tang, Quoc Vu, Adam Wang, Carrie Zhang

In collaboration with UCLA ROMS group led by Prof. Jim McWilliams