Strategy to Develop a 3D Ocean Circulation Forecasting System for Cook Inlet

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  - Three models: Atmosphere models, wave models, 3D circulation models
  - Each model has multiple ensembles
  - Someone will give us data in a memory stick
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  - Three models: Atmosphere models, wave models, 3D circulation models
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  - More data web sites
  - Imagine a day with a single CI portal where you can get all these data sets and model output in a common format

A 3D Ocean Circulation Forecasting System Should consist of

- A 3D ocean circulation model (tides, wet/dry, ice)
- Atmospheric forcing (wind, heat, rain) from a high-resolution model
- Fresh-water forcing (rivers, runoff) from a hydrological model
- Lateral boundary conditions from a large-scale 3D ocean circulation model (with tides)
- Observational data sets (surface & subsurface, T/S & current)
- Advanced and computational efficient data assimilation scheme

A 3D Ocean Circulation Forecasting System for Stakeholder/User Should also Include

- Systematic validation with quantifiable uncertainties
- Ability and standard/easy interface to link biogeochemical, ecosystem and fishery modeling modules
- Stakeholder/user driven products based on model variables (e.g., transport, energy density)
- Access to model output with common interface (web, apps), standard formats (OpenDAP, Excel), and tools for analysis (times series over 1- or 2-year)

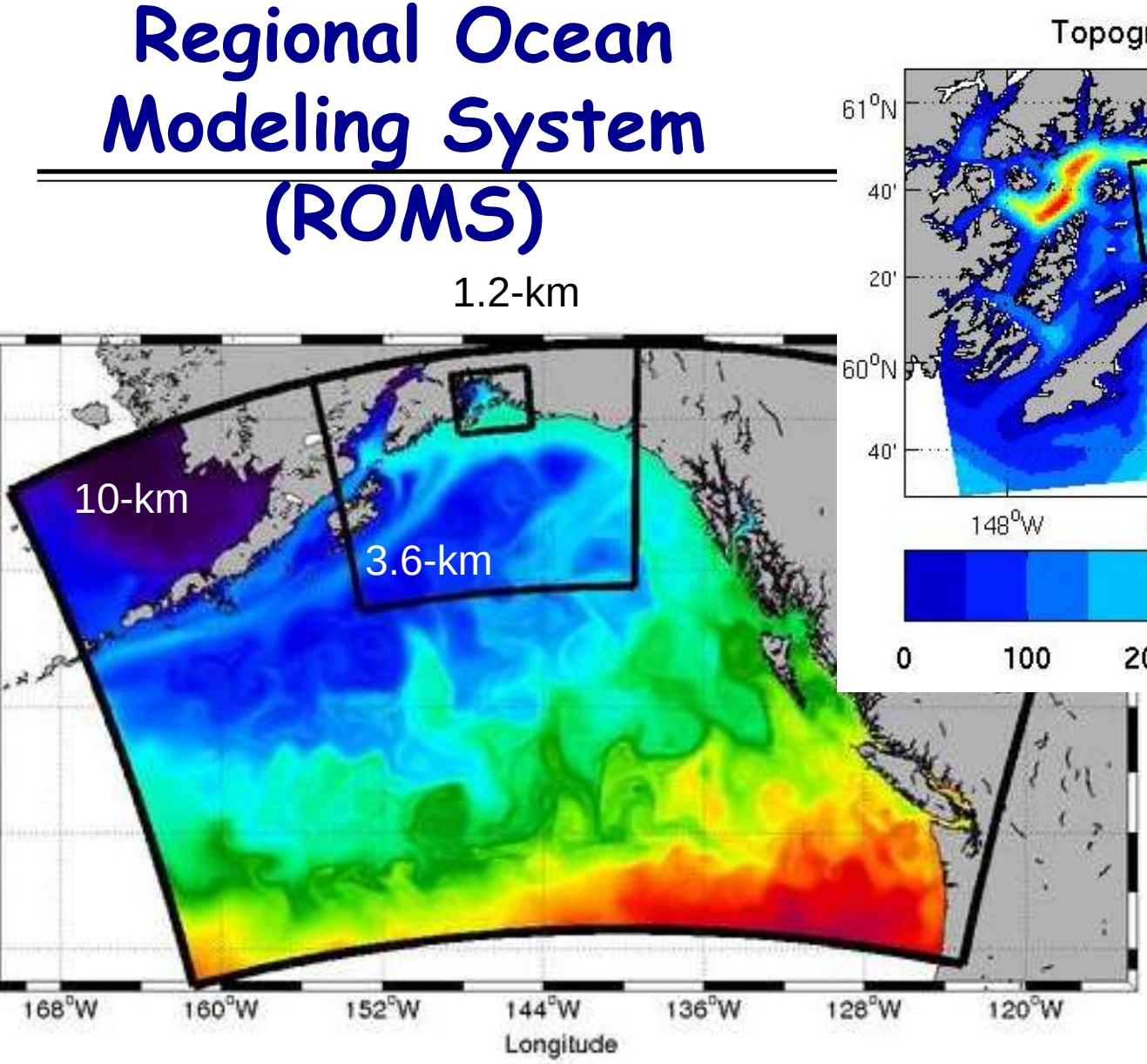
Brief Overview of a ROMS-Based Ocean Forecast System for Application Users

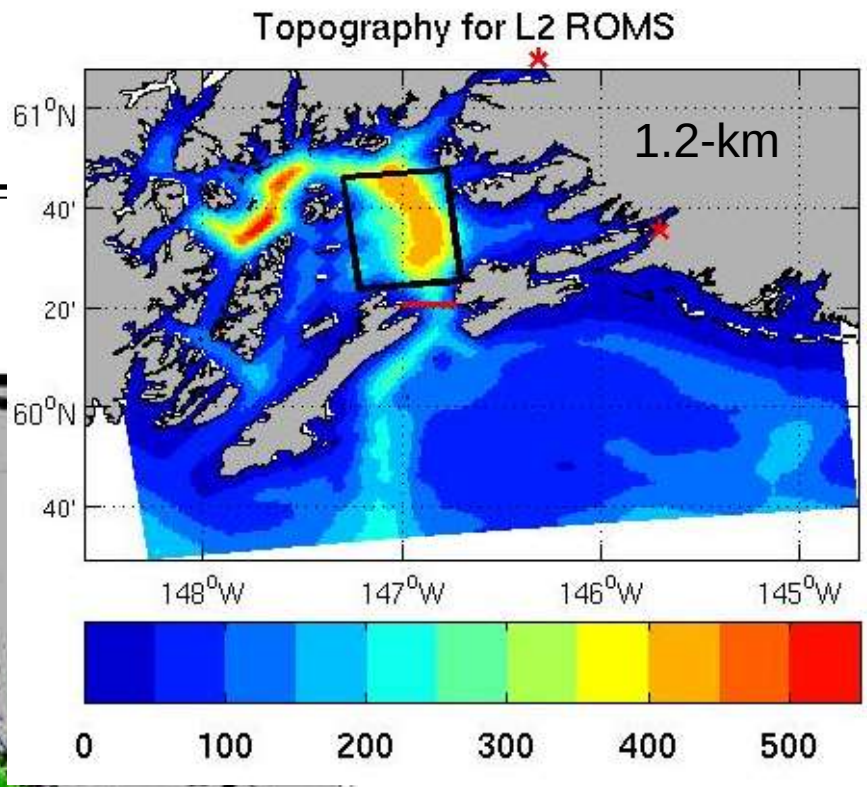
- Core support from NASA Physical Oceanography program and Advanced Supercomputing System
- Monterey Bay field experiments in 2003 and 2006, 2002-2010, Office of Naval Research
- Coastal Ocean Current Mapping Program (COCMP), 2006-2010, California State Coastal Conservancy
- Southern California Coastal Ocean Observing System (SCCOOS) 24/7 forecasting, 2006-present, NOAA/IOOS
- Central and Northern California Ocean Observing System (CeNCOOS), 2009-present, NOAA/IOOS
- Alaska Ocean Observing System (AOOS) Prince William Sound field experiment in 2009, 2006-present, NOAA/IOOS
- Mid-Atlantic Coastal Ocean Observing System (MARCOOS) field experiment in 2009, NOAA/IOOS-NSF

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

MB06, PWS09, CI, SCB

Regional Ocean Modeling System (ROMS)





Horizontal Resolution

L0: 10-km

L1: 3.6-km

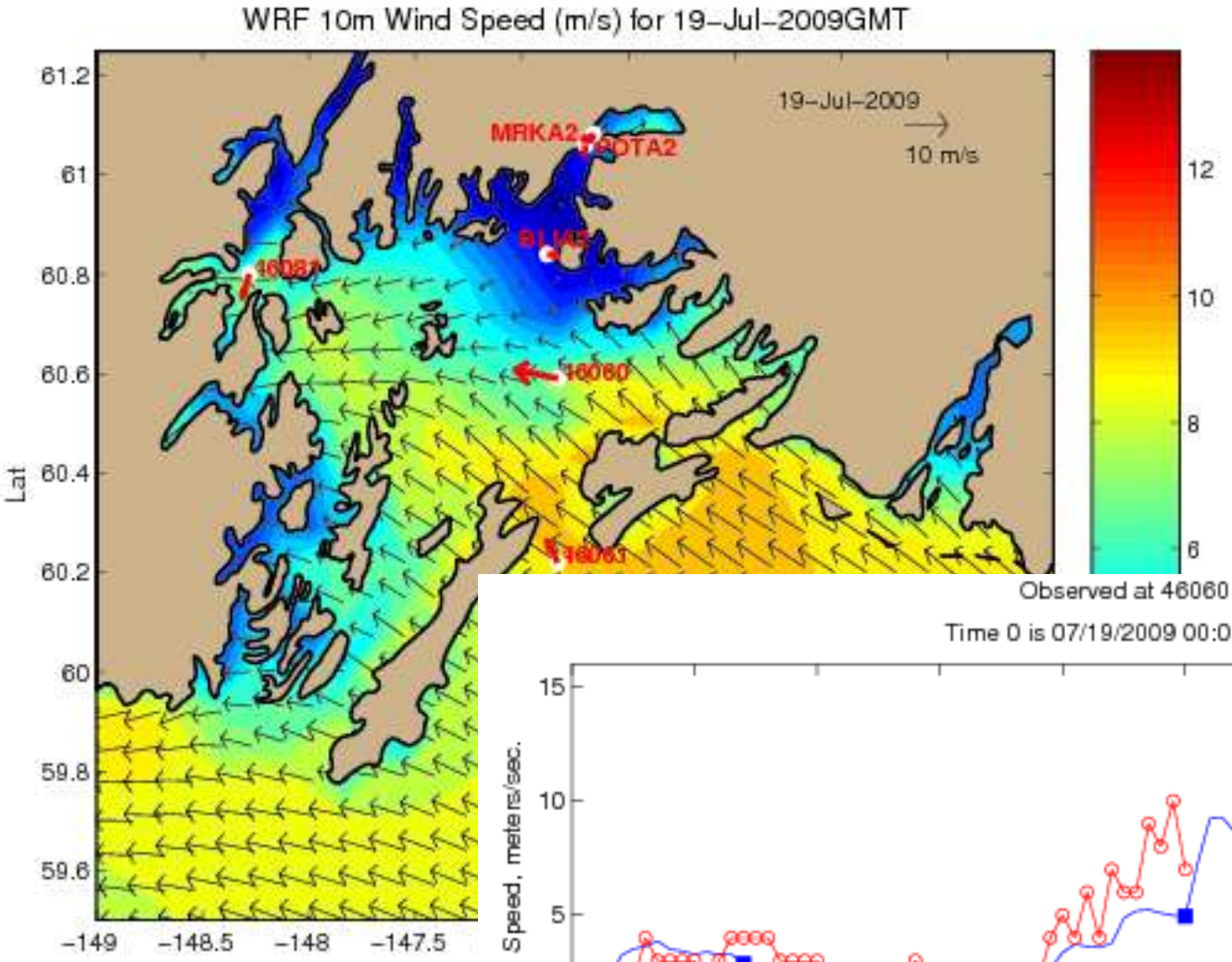
L2: 1.2-km

Vertical Resolution

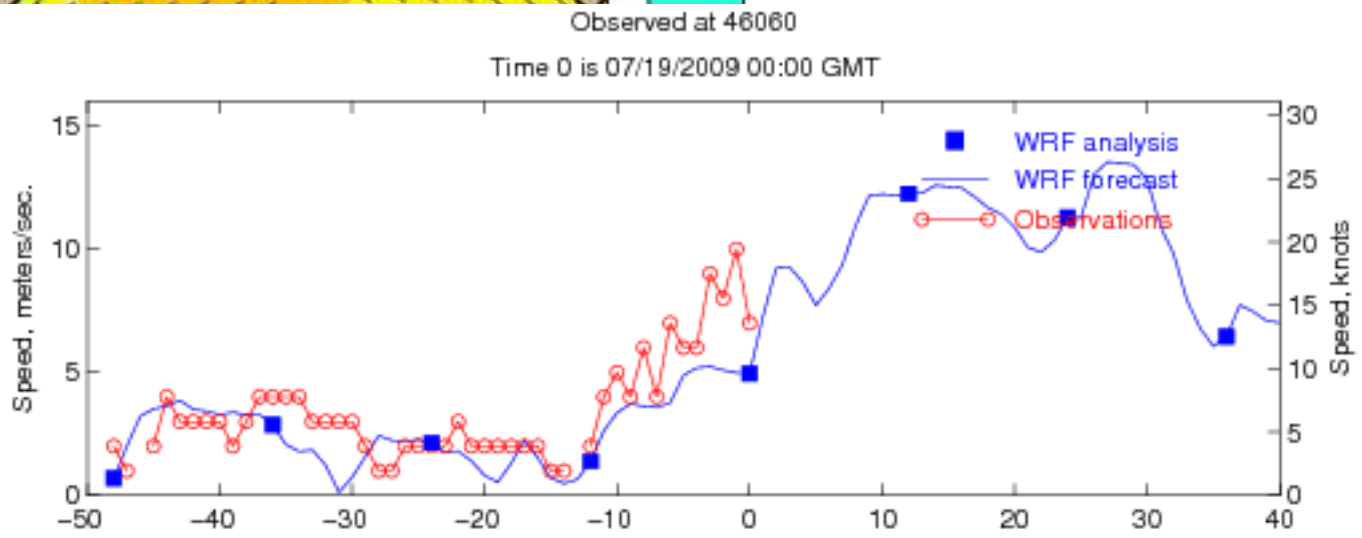
40 layers

WRF Weather Forecast

http://ourocean.jpl.nasa.gov/PWS09



(WRF by Peter Olsson)

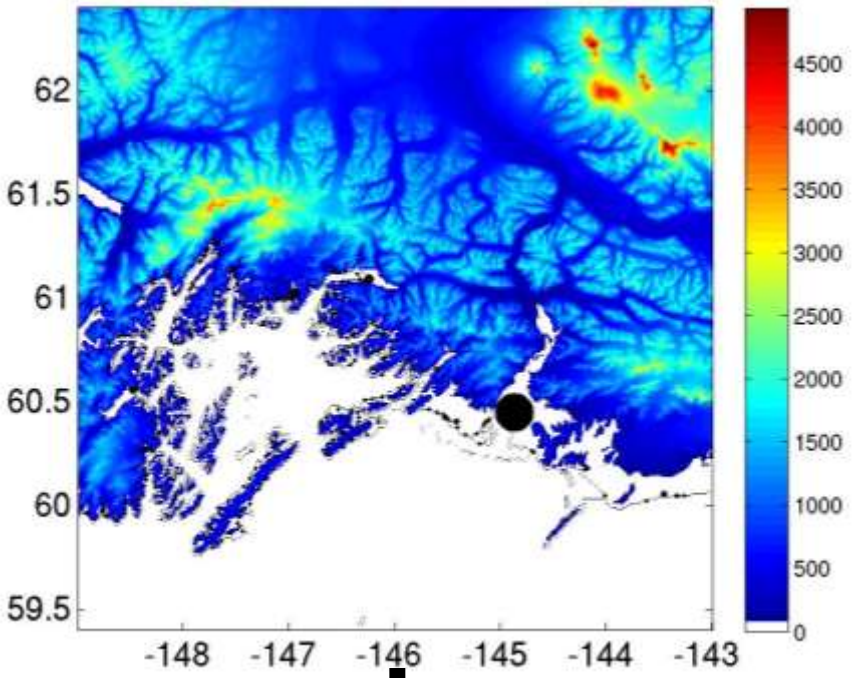


Freshwater discharge by a hydrological model vs. Copper River observations

WRF Precipitation

↓

DEM



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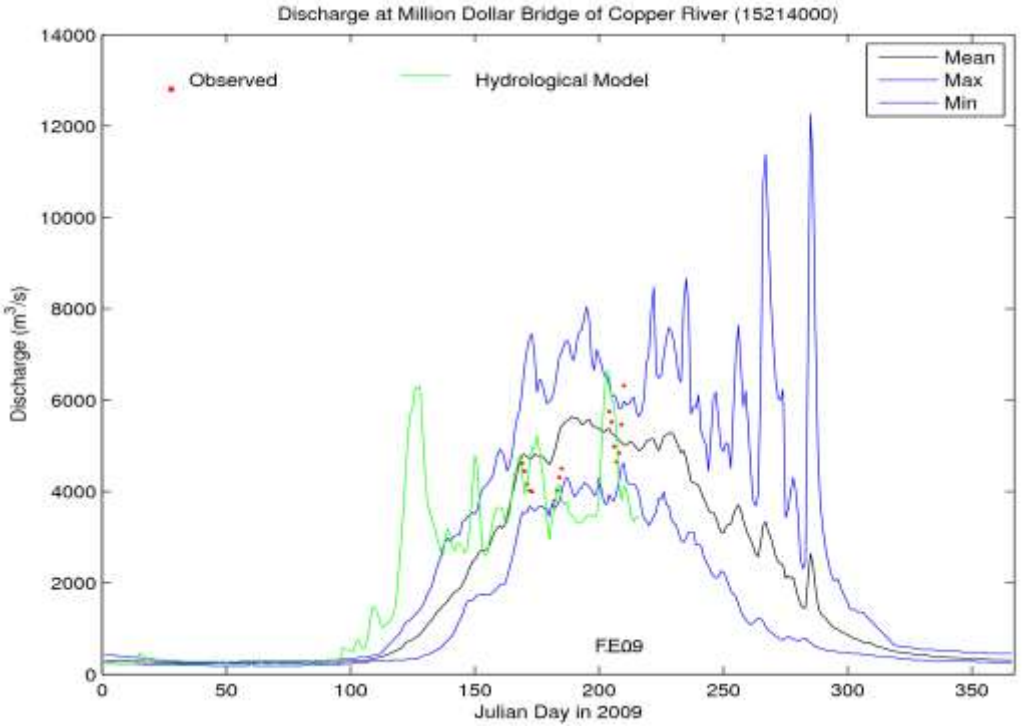
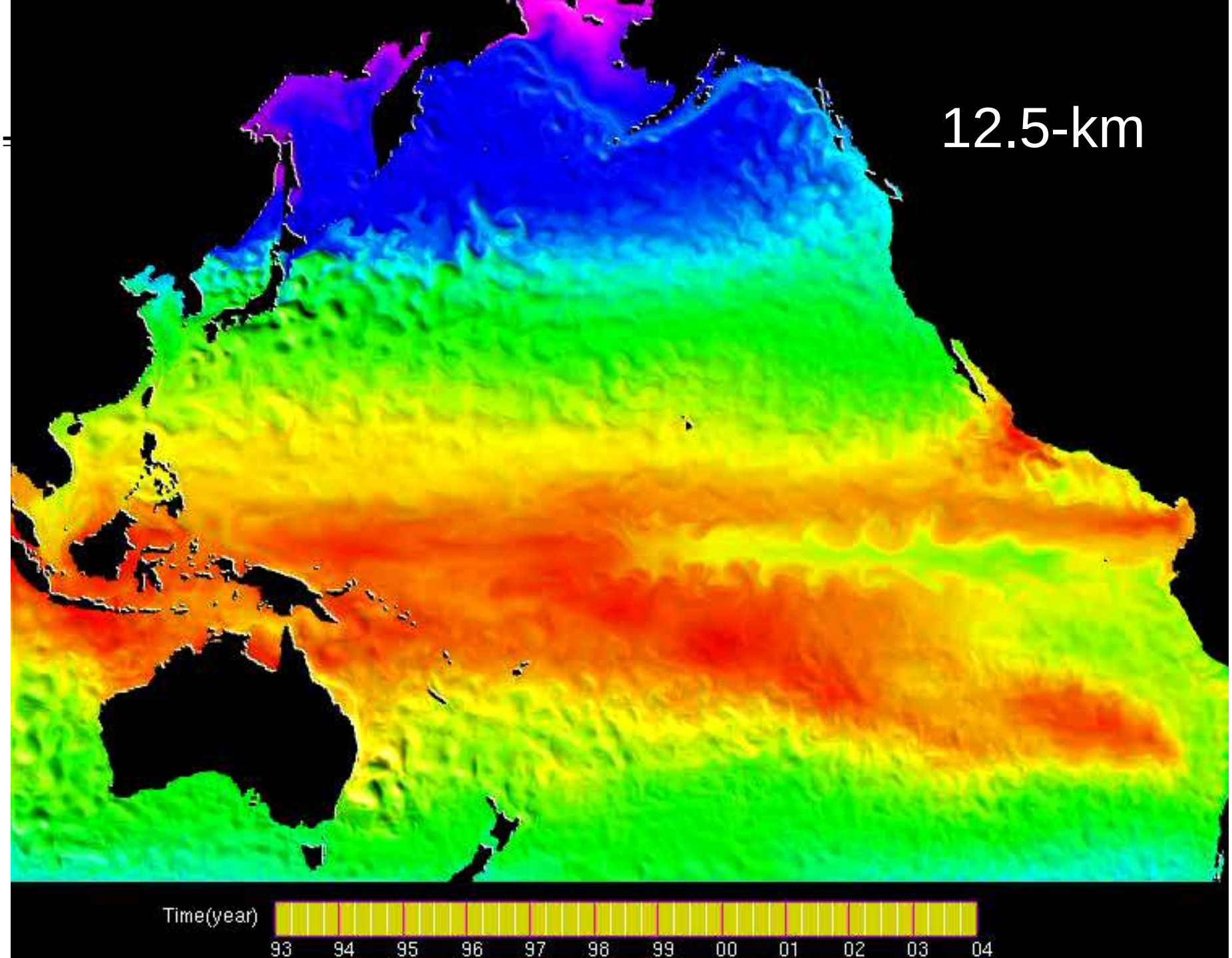
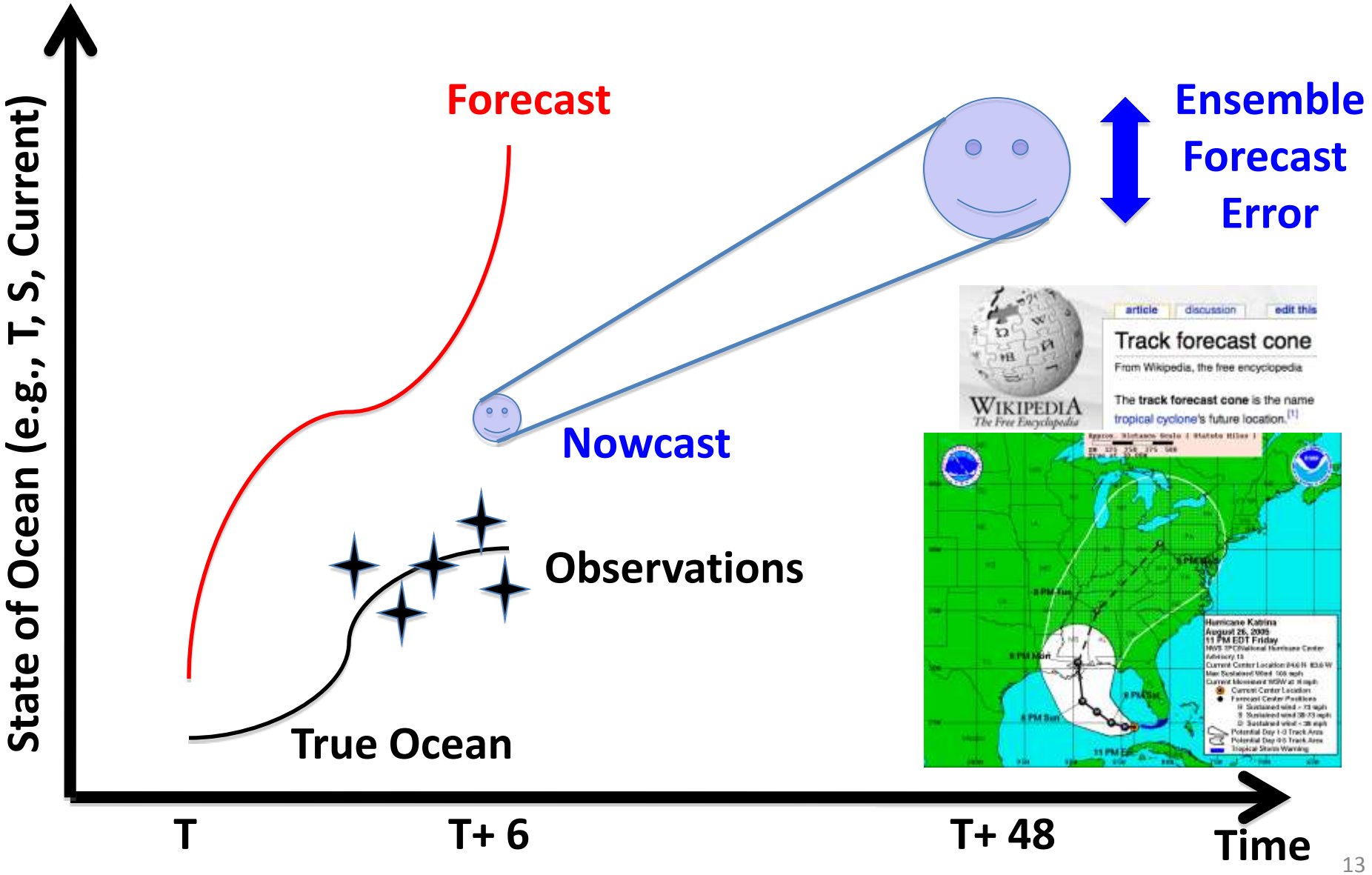
Freshwater input to ROMS from point sources (rivers) and line sources (runoff)

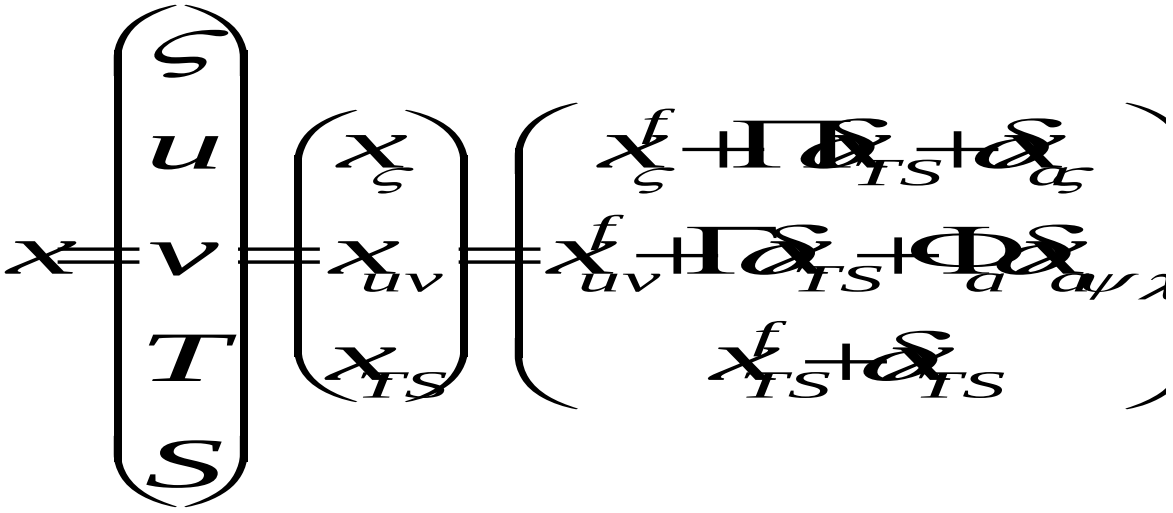



12.5-km
Time(year)
93
94
95
96
97
98
99
00
01
02
03
04

ROMS Data Assimilation to enable forecasting



3DVAR Data Assimilation to assimilate both in situ and remote sensed data



Geostrophic balance

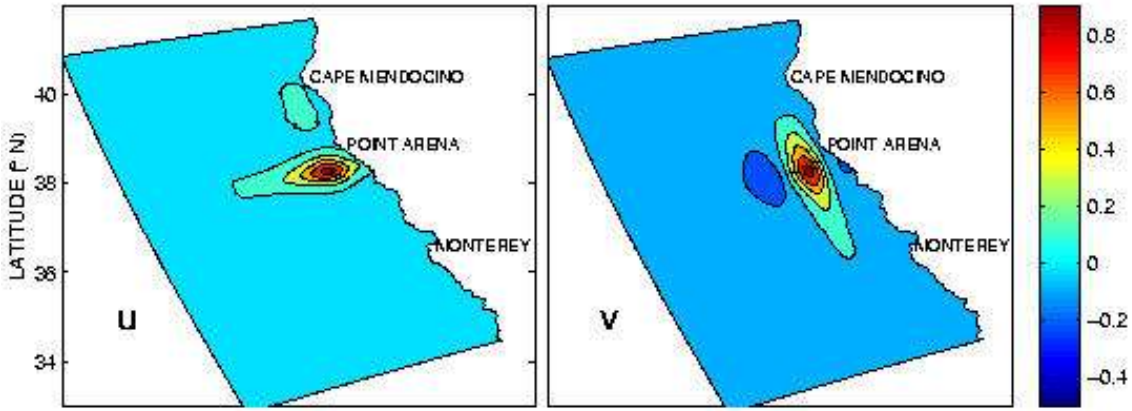
Hydrostatic equation

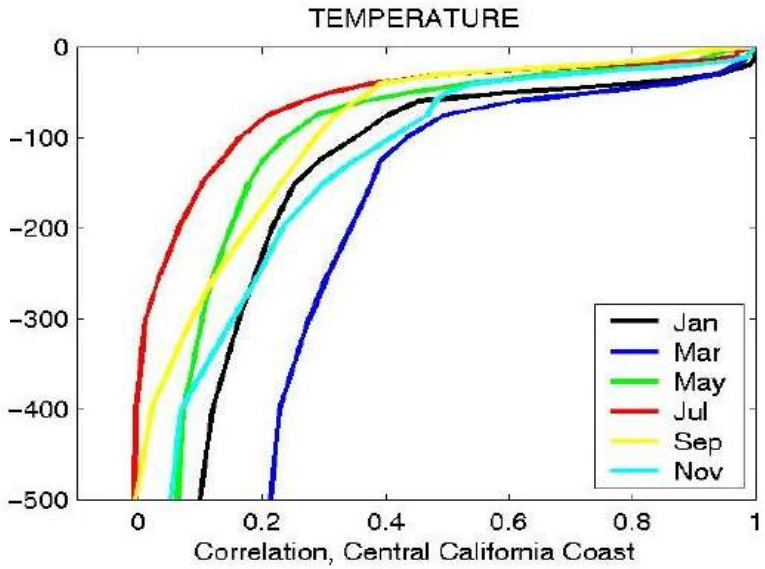
Five Control Variables:
Temperature: δT
Salinity: δS
Non-steric SSH: $\delta X_{a\zeta}$
Ageostrophic streamfunction: $\delta X_{a\psi}$
Ageostrophic velocity potential: $\delta X_{a\chi}$

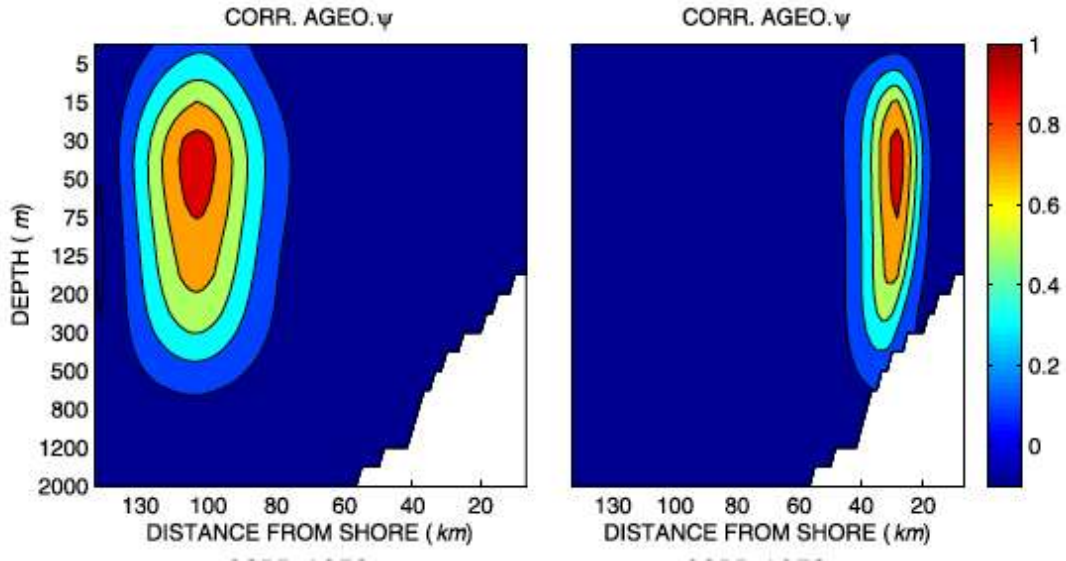
(Li and Chao et al., MWR, 2006; JGR-Ocean, 2008; JAOT, 2009)

Cross-Correlation between Variables & Spatial Varying Correlations (Monthly)

- Temperature and salinity data (e.g., CTDs) will influence current
- Surface data (e.g., aircraft or satellite SST) will influence subsurface structure







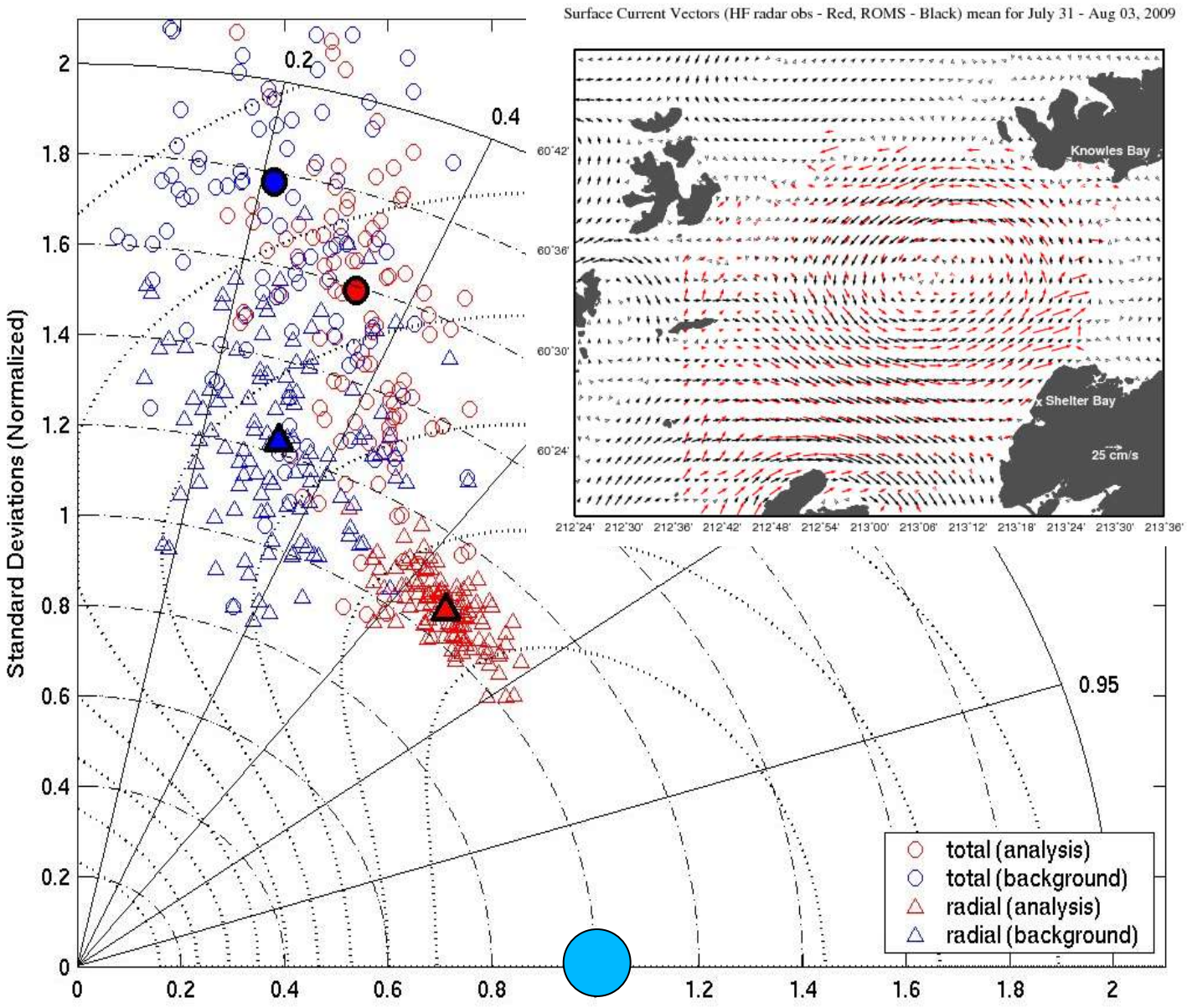
Validation of HF Radar Data Assimilation: Radial vs Total Current

Total currents data assimilation (circle)

1st Guess before data assimilation (blue)

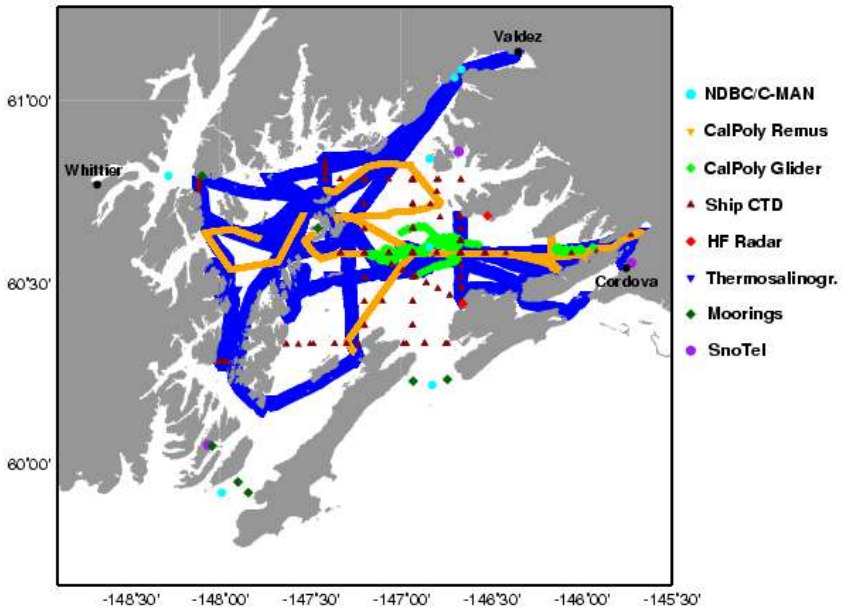
Nowcast after data assimilation (red)

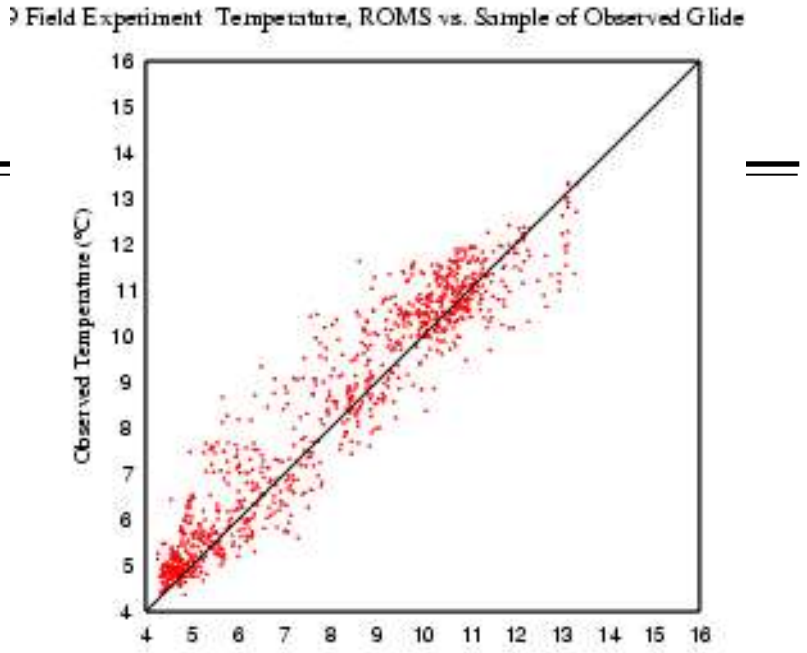
Radial current data assimilation (triangle)

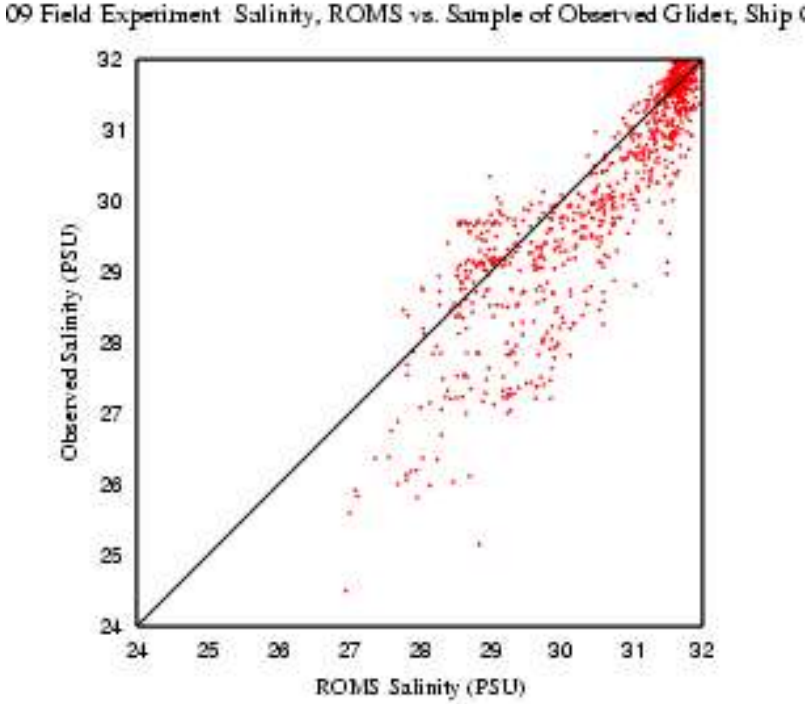


Validation of T/S: ROMS vs OBS

Temp Bias: -0.28 C
Temp RMS: 0.82 C

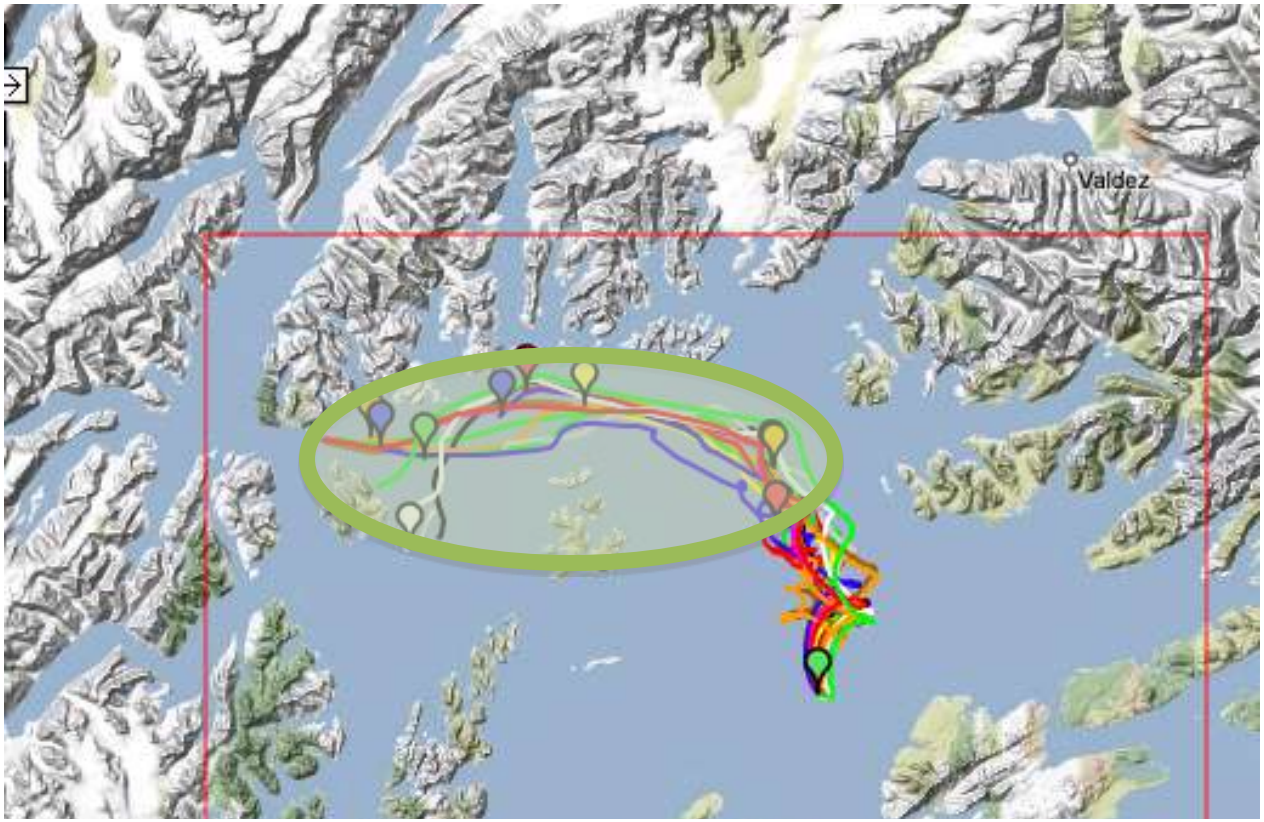






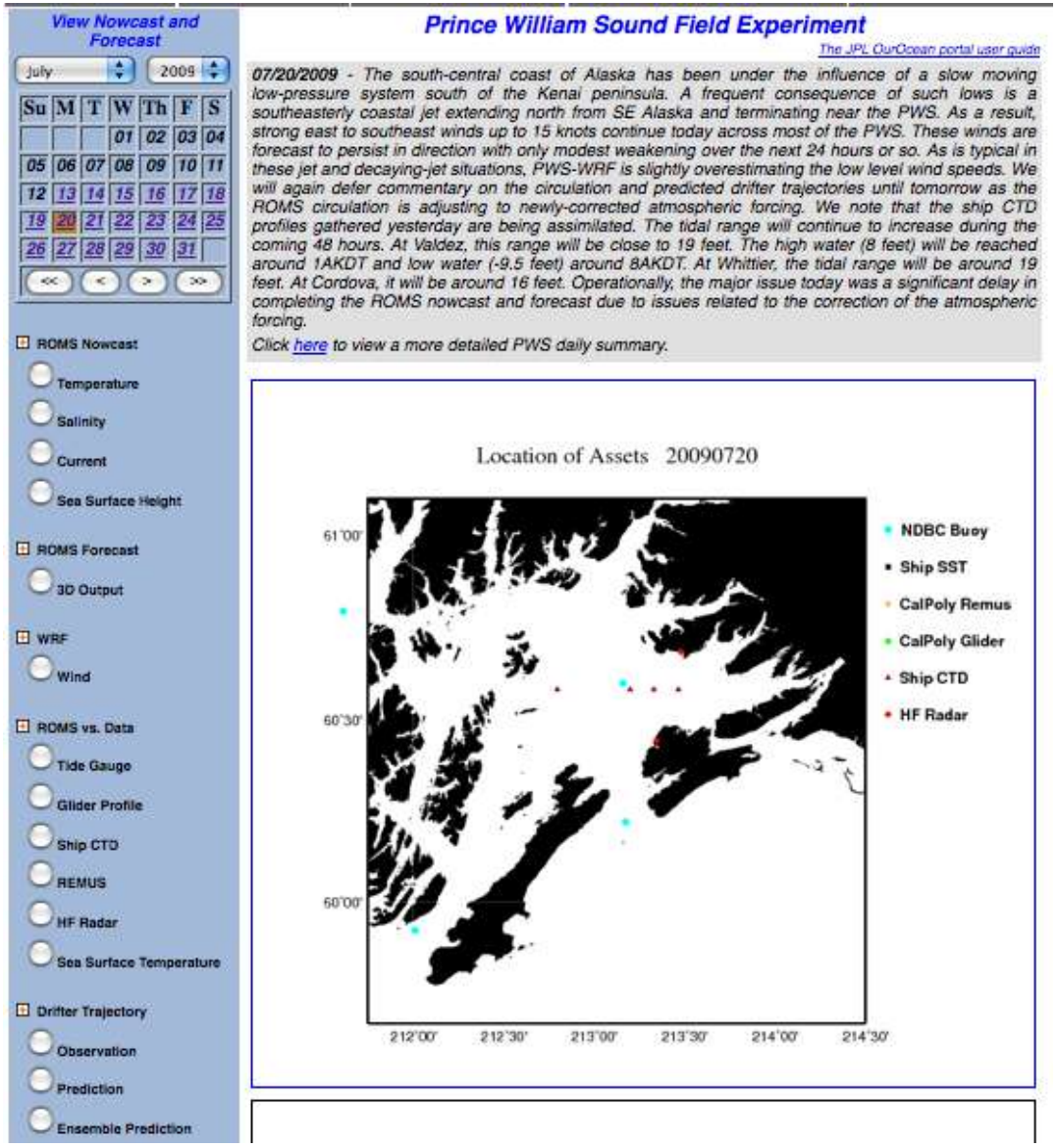
Salinity Bias: +0.35 PSU
Salinity RMS: 0.77 PSU

ROMS Ensemble Forecast for Error Estimation



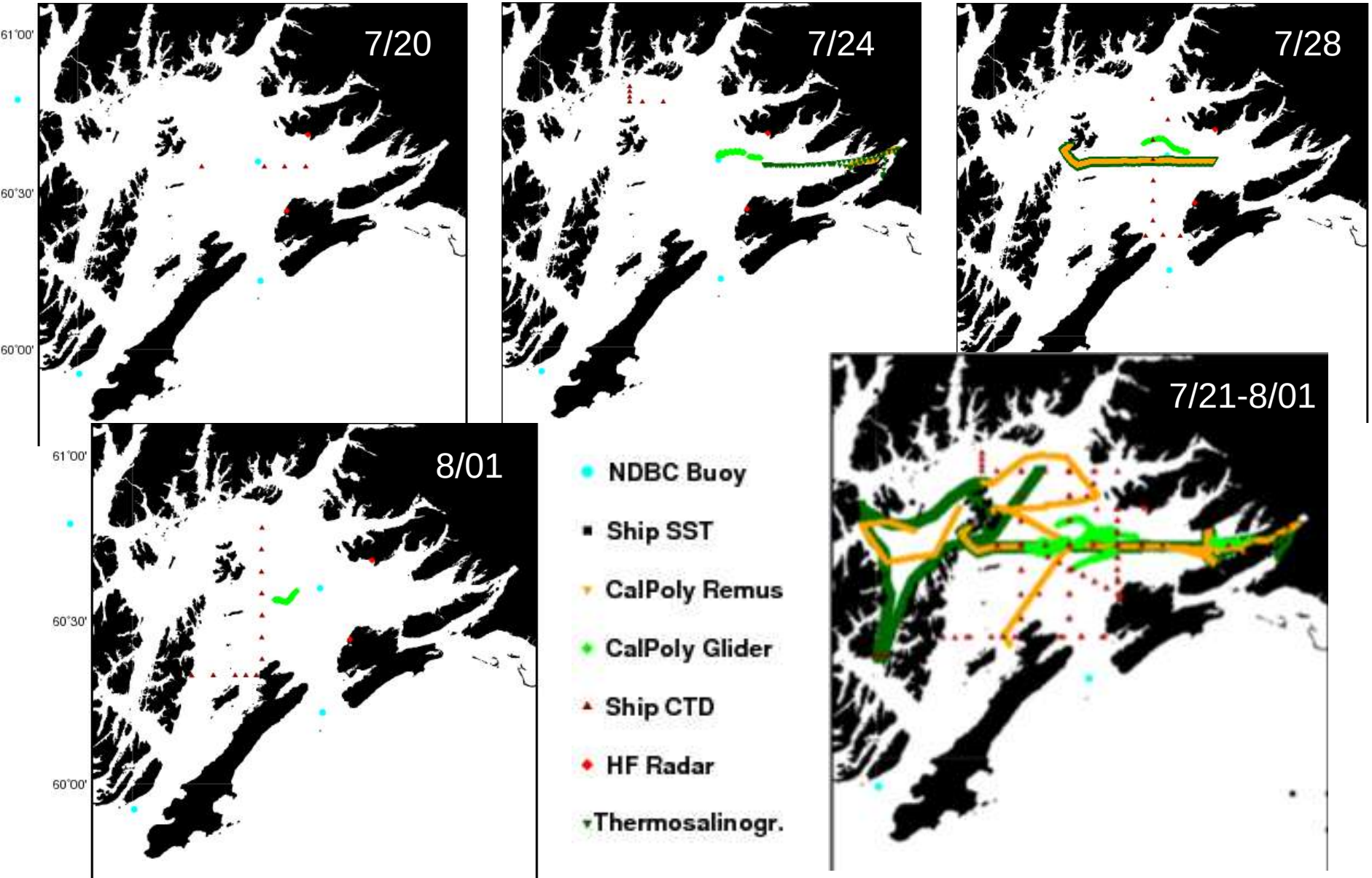
The mean pldistance from the ROMS ensembles to selected USCG drifter locations

PWS ROMS Forecasting System Portal
http://ourocean.jpl.nasa.gov/PWS09



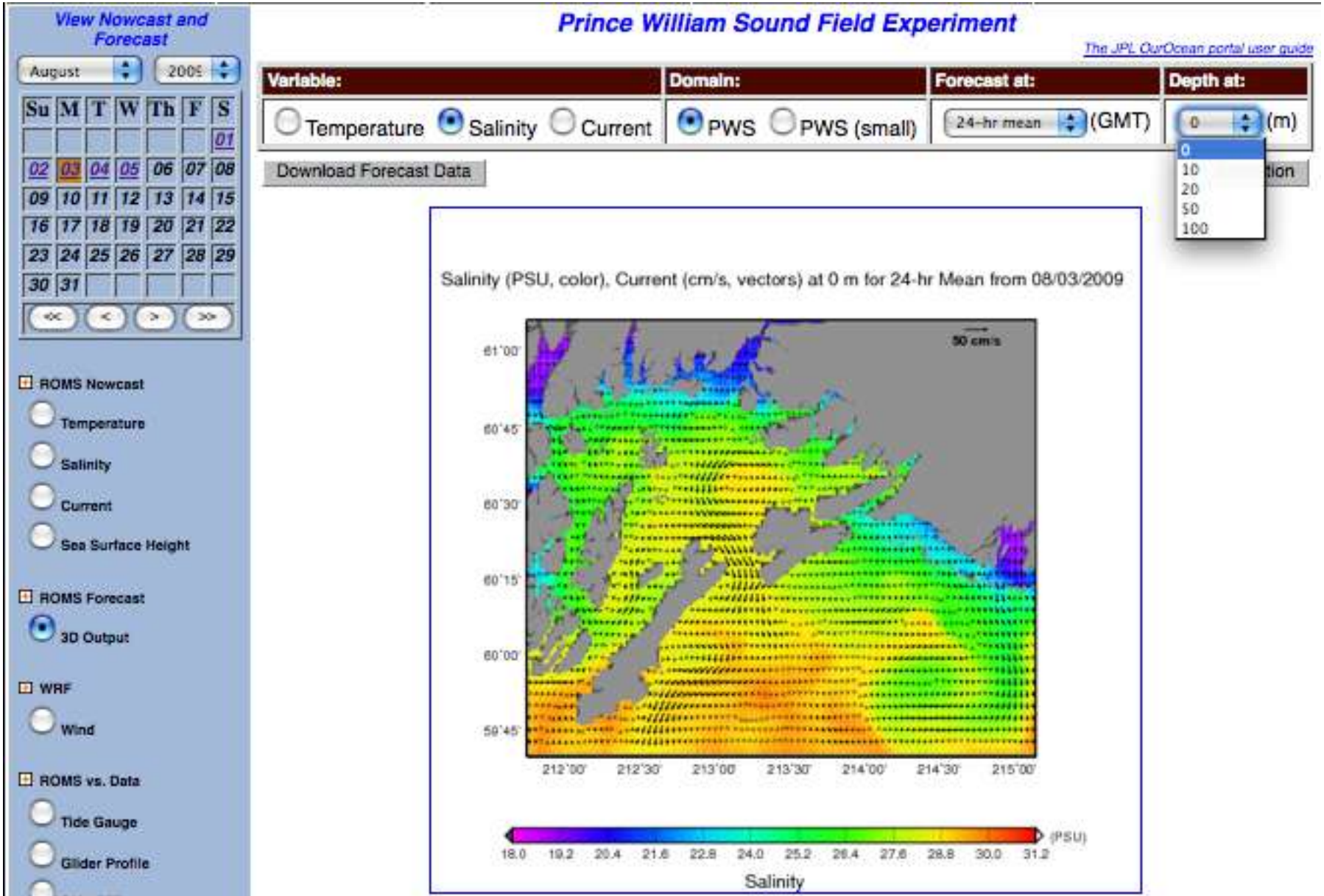
Observational Assets: Updated Daily

http://ourocean.jpl.nasa.gov/PWS09

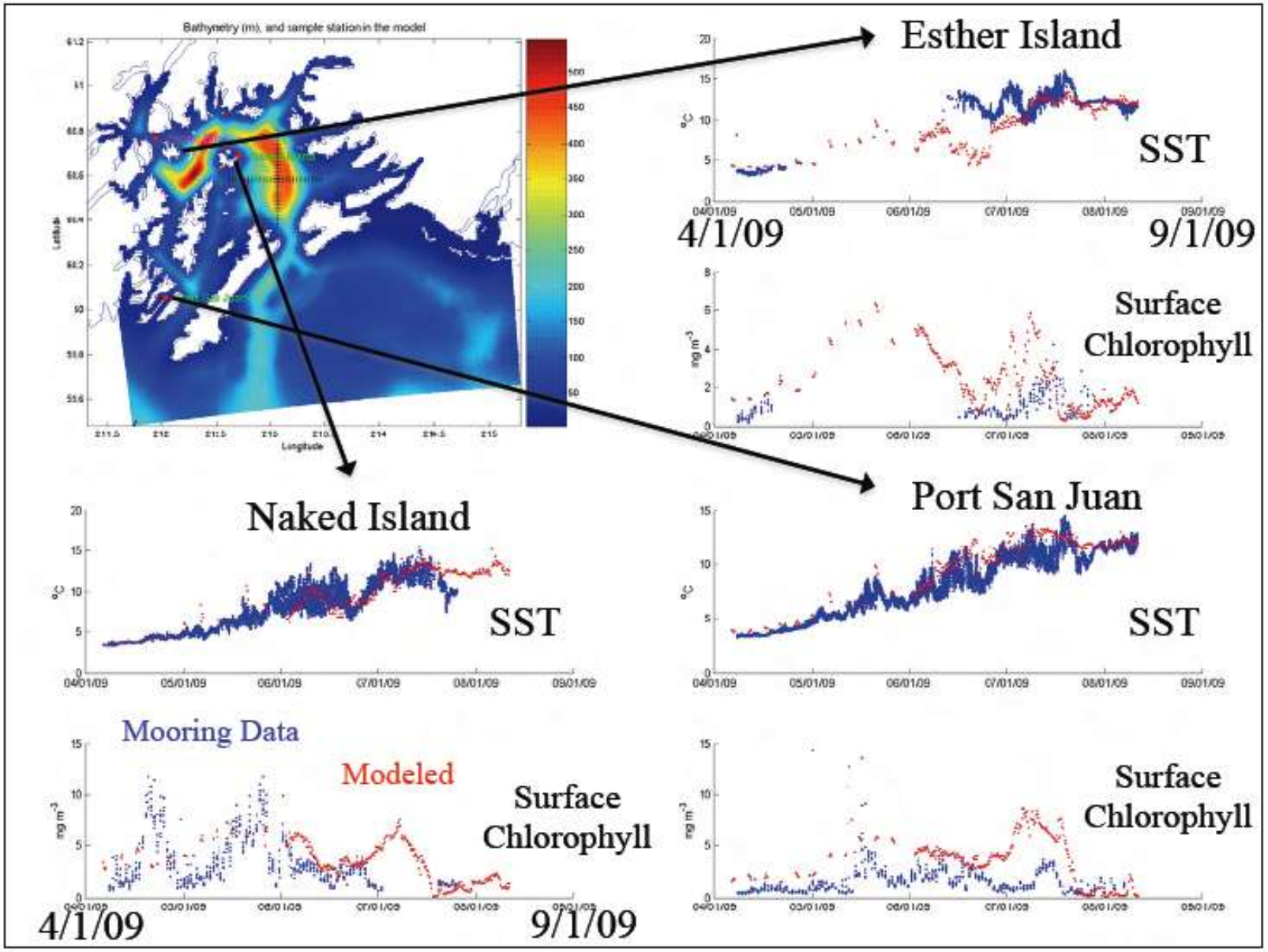


PWS ROMS Forecast: Access 3D output

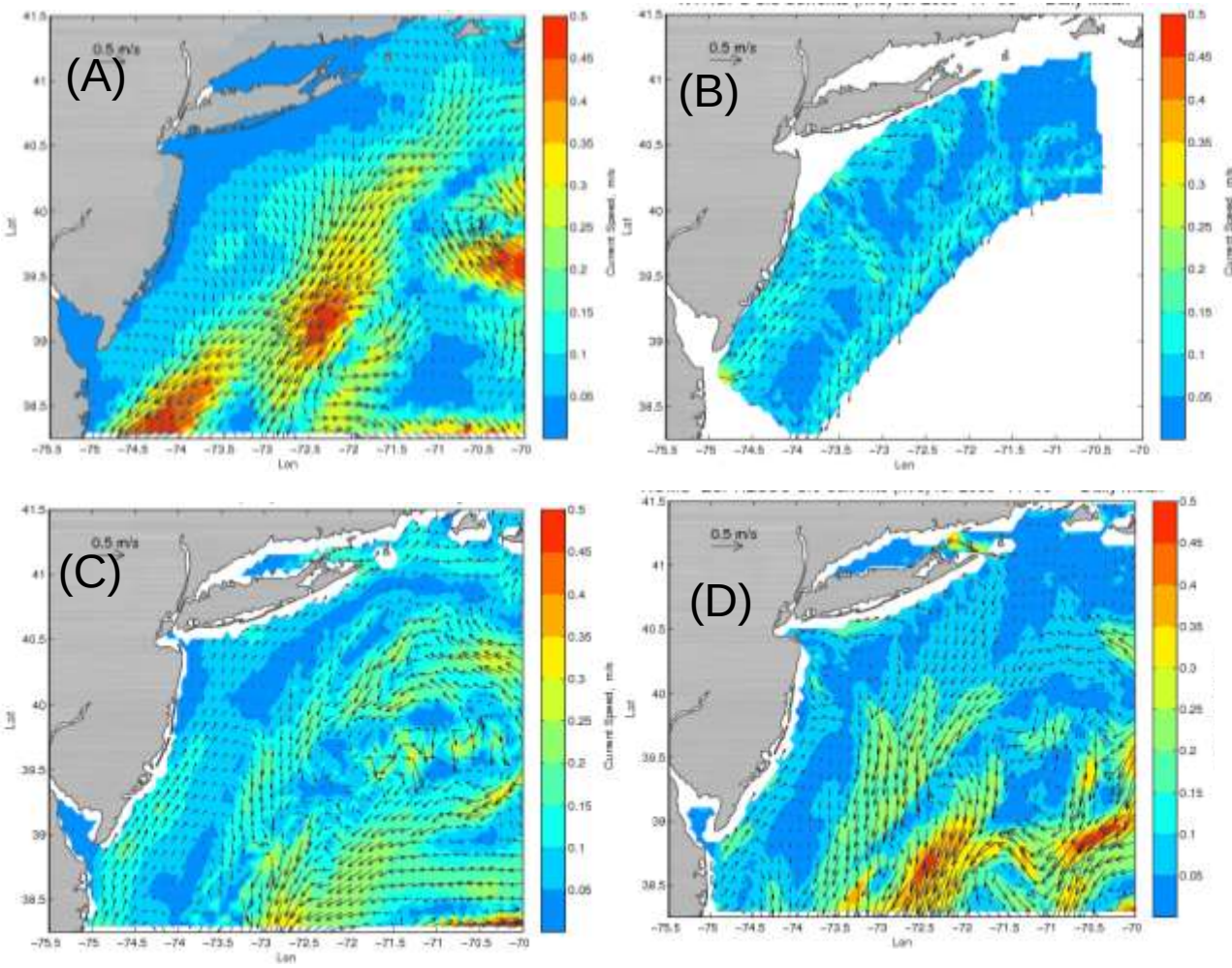
http://ourocean.jpl.nasa.gov/PWSS09



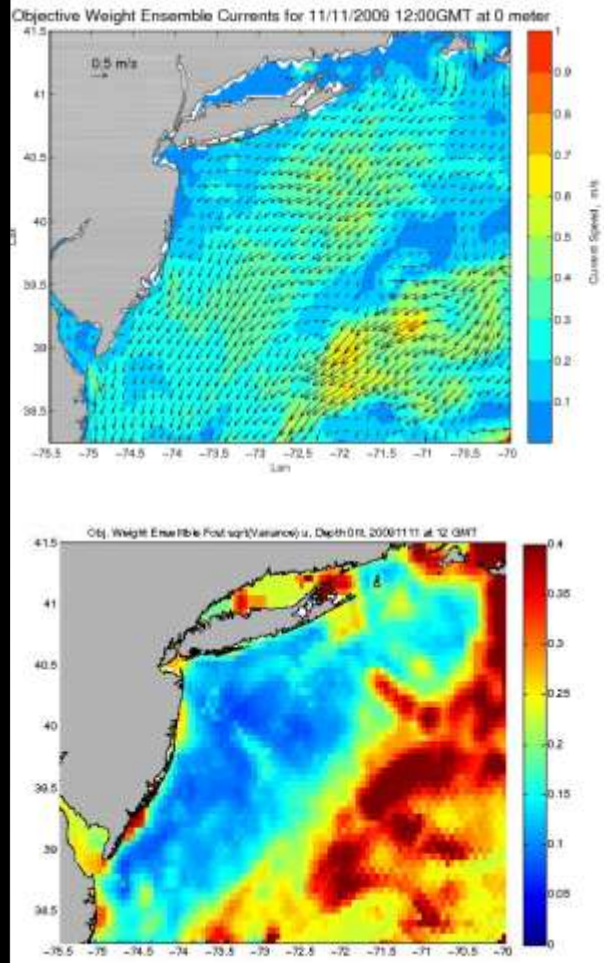
Linking PWS ROMS with Biogeochemical Model



Mid-Atlantic Coastal Ocean Observing System (MARCOOS) Field Experiment (Nov 2-13 2009)

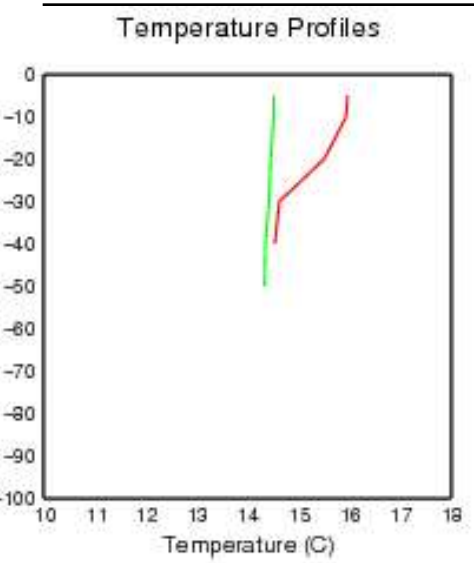


HOPS-UMass, NYHOPS/POM-SIT, ROMS/USGS, ROMS/4DVAR-Rutgers

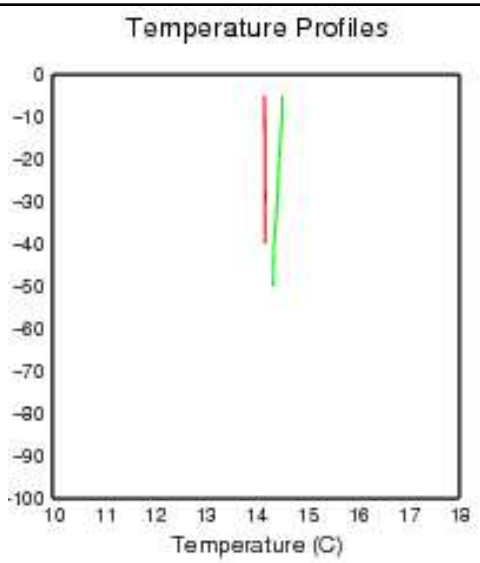


Multi-Model Ensemble & Error

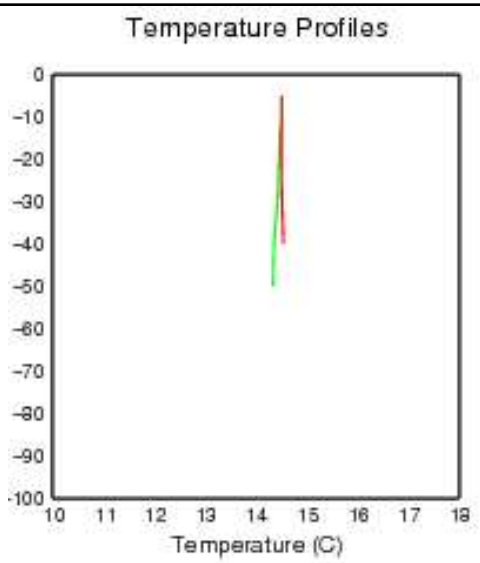
Glider Data (ru05) vs. Four Models (11/10)



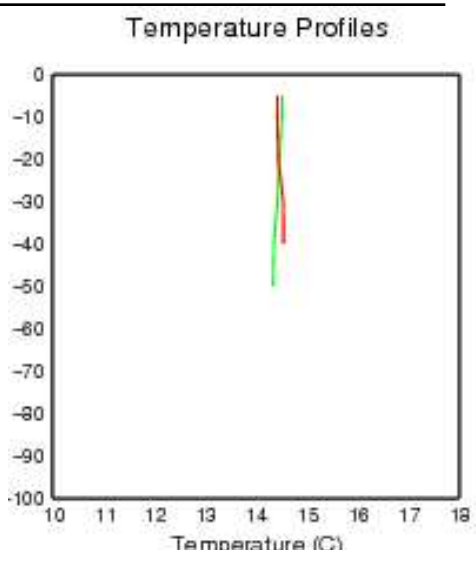
Model A



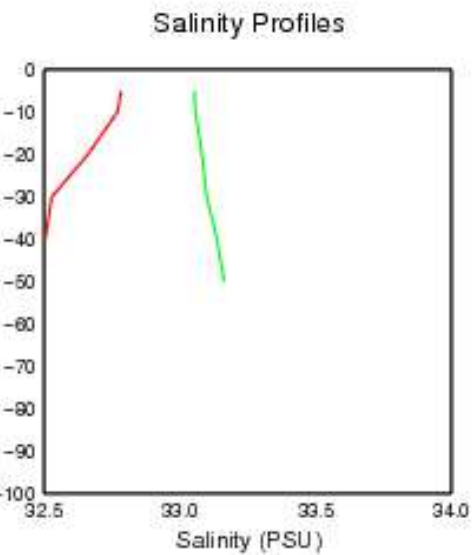
Model B

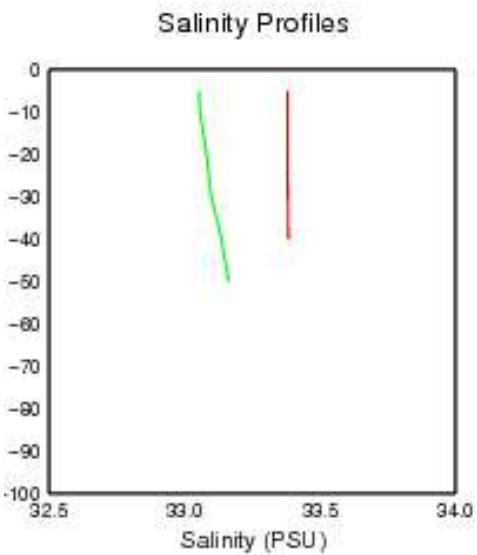


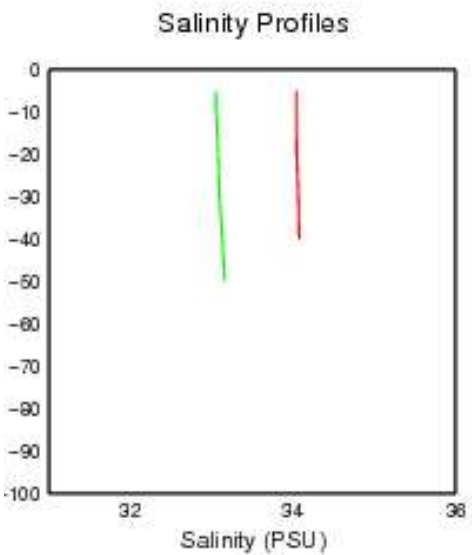
Model C

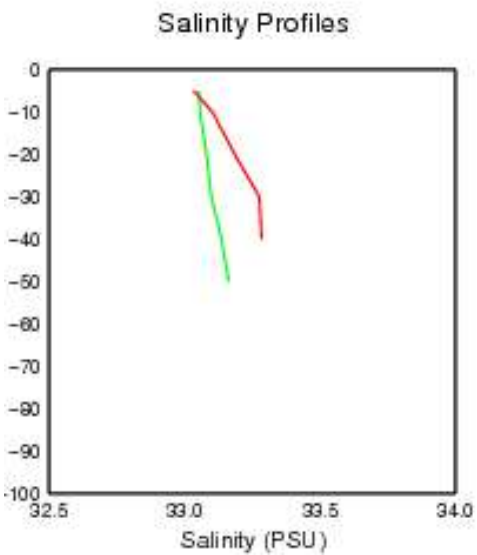


Model D



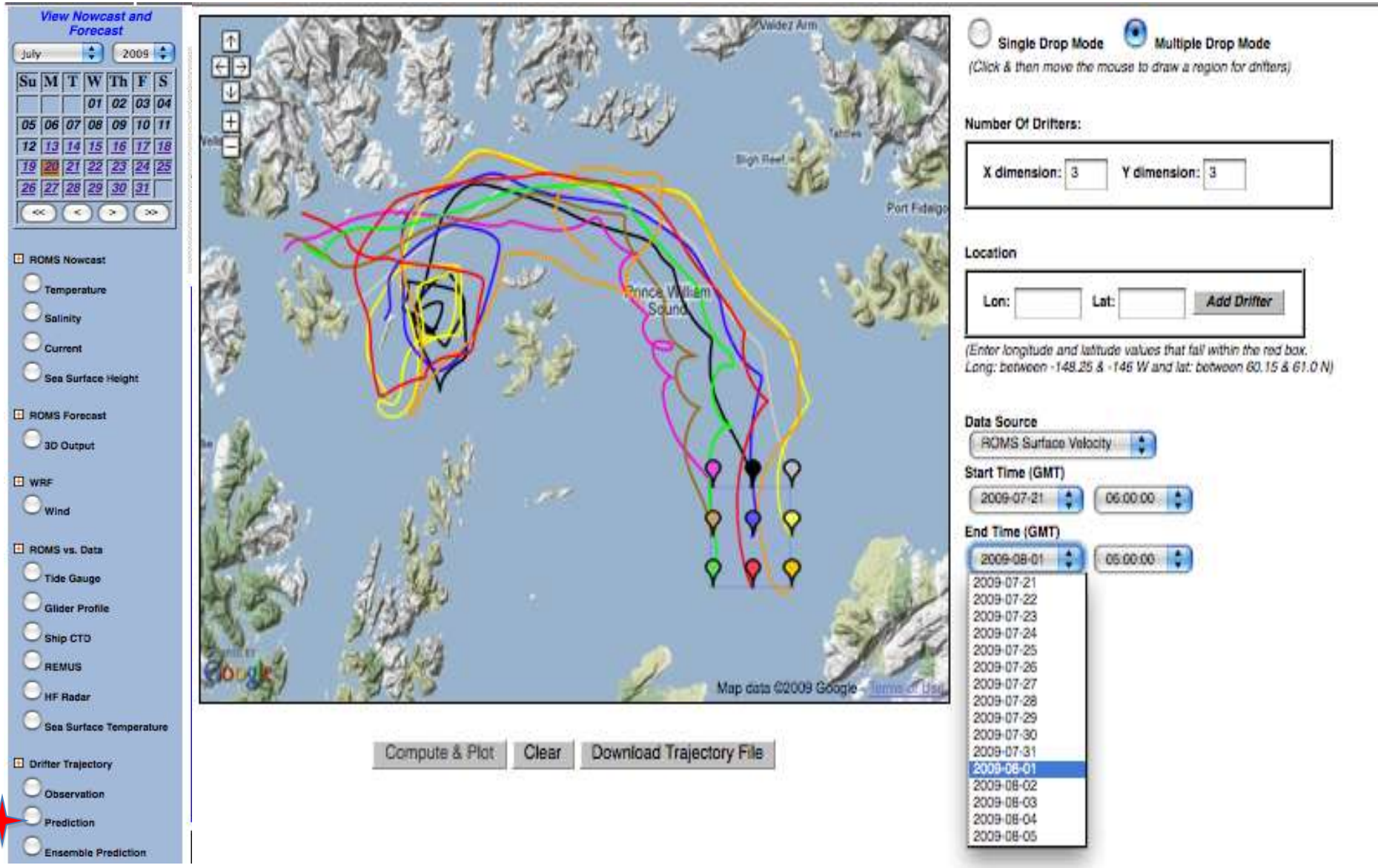






Web-Based Virtual Drifter Tracker

http://ourocean.jpl.nasa.gov/PWS09



GNOME Online Oceanographic Data Server (GOODS)

Use GOODS to access currents or winds from various models and data sources and convert to GNOME compatible NetCDF.

Global Ocean Current Models

Navy Coastal Ocean Model (NCOM)
Naval Research Laboratory 1/8 degree operational model

Navy Layered Ocean Model (NLOM)
Naval Research Laboratory 1/32 degree operational model

Hybrid Coordinate Ocean Model (HYCOM)
Naval Research Laboratory 1/12 degree model

Measured currents

Coastal HF radar
Served by the National Data Buoy Center

Geostrophic currents
Sea Surface Height derived currents

Winds

National Weather Service Forecast Winds
Wind forecast from the NWS National Digital Forecast Database.

National Data Buoy Center Winds
Wind data from the National Data Buoy Center.

Regional Ocean Current Models

West Coast:
Southern California Bight
ROMS forecasting system run at Jet Propulsion Laboratory

Gulf of Mexico:
TGLO/TAMU Gulf of Mexico
ROMS operational model developed at Texas A&M University and run operationally by the Texas General Land Office
NOAA Gulf of Mexico (NGOM)
Operational forecast model run at CSDL
Intra-Americas Sea Nowcast/Forecast System (IASNFS)
Naval Research Lab experimental real-time forecasting system

East Coast:
MARCOOS/HOPS
Mid-Atlantic Regional Observation System - Harvard Ocean Prediction System
New York Harbor Observing and Prediction System (NYHOPS)
Operational forecast system for New York and New Jersey including Hudson River Estuary run at Stevens Institute of Technology

Other:
Hawaiian Islands
ROMS forecast model under development at University of Hawaii
Center for Operational Oceanographic Products and Services
Various operational nowcast/forecast models for U.S. inland and coastal waters

GOODS toolbar: Extract Coastline

Final Remarks

- Transition from research to 24/7/365 operations
- Continue to reach out to the application users (beyond scientists)
  - Identify users
  - Develop data/model products
  - Deliver forecast
  - Collect feedback
- Continue to improve the model, data assimilation and the end-to-end system

What can we learn from weather forecast?

First operational NWP in 1955 sponsored by U.S. Air Force, Navy, and Weather Bureau

Observing

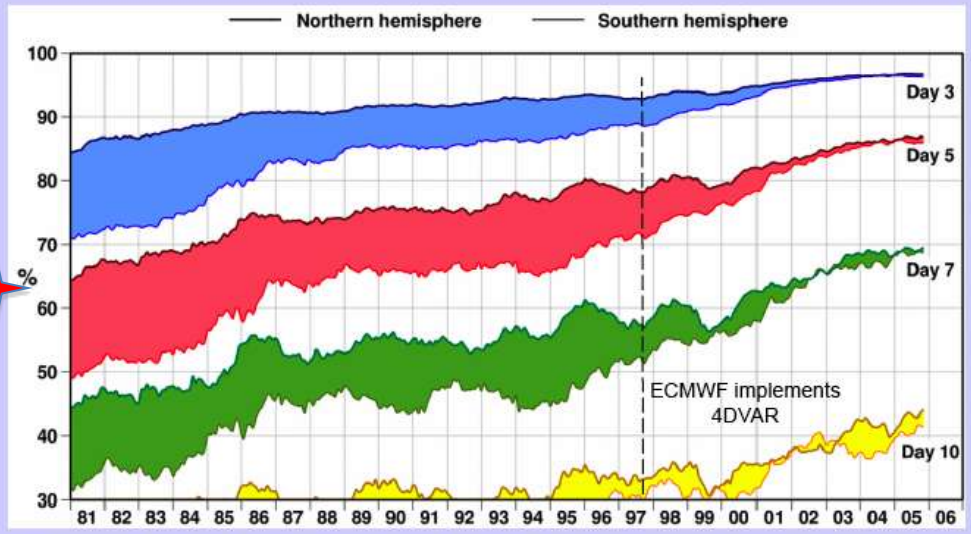
NOAA National Weather Service: $>1B/year

Forecast

Private service (112+): $200M/yr +5%/yr

weather.com

Increasing Skill of Numerical Weather Forecasts



Forecast skill has improved steadily due to increased computing, better models and assimilation ⇒ *increased satellite data usage!*

Establish an ongoing forecast system with enough users to justify its operation and further development