

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

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Observations from this morning's session

- “All models are wrong”

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- “I put my data on the web, therefore mission accomplished”
 - Three models: Atmosphere models, wave models, 3D circulation models
 - Each model has multiple ensembles
 - Someone will give us data in a memory stick
 - More data web sites

Observations from this morning's session

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 - “No model is perfect”
- “Modelers put their data on the web”, therefore mission accomplished
 - Three models: Atmosphere models, wave models, 3D circulation models
 - Each model has multiple ensembles
 - Someone will give us data in a memory stick
 - 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)

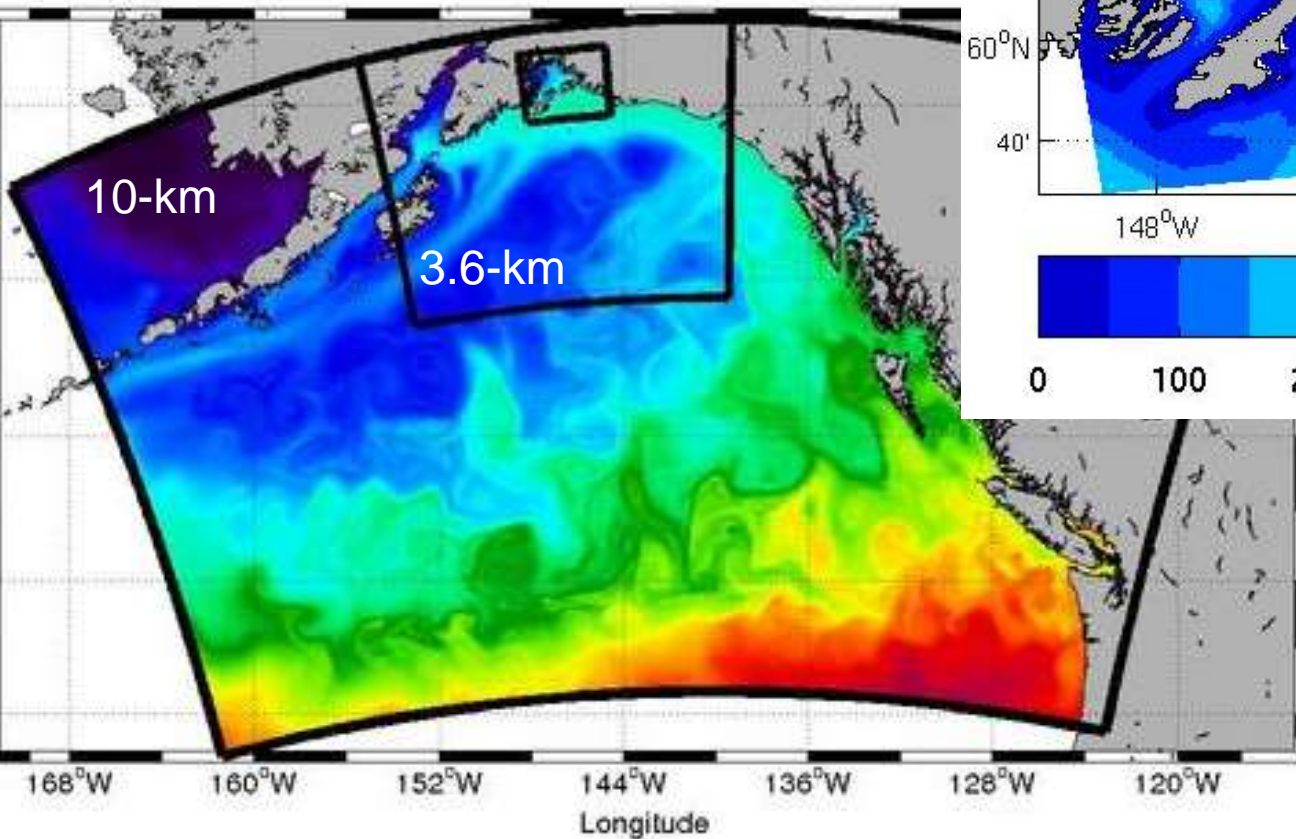
Brief Overview of a ROMS-Based Ocean Forecast System for Application Users

- 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

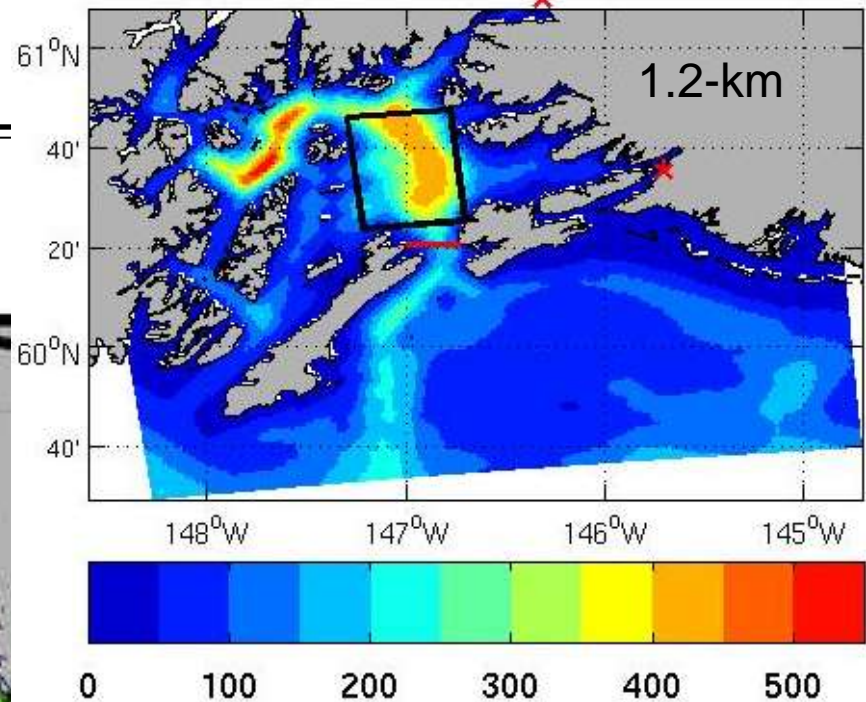
<http://ourocean.jpl.nasa.gov/>
MB06, PWS09, CI, SCB

Regional Ocean Modeling System (ROMS)

1.2-km



Topography for L2 ROMS



Horizontal Resolution

L0: 10-km

L1: 3.6-km

L2: 1.2-km

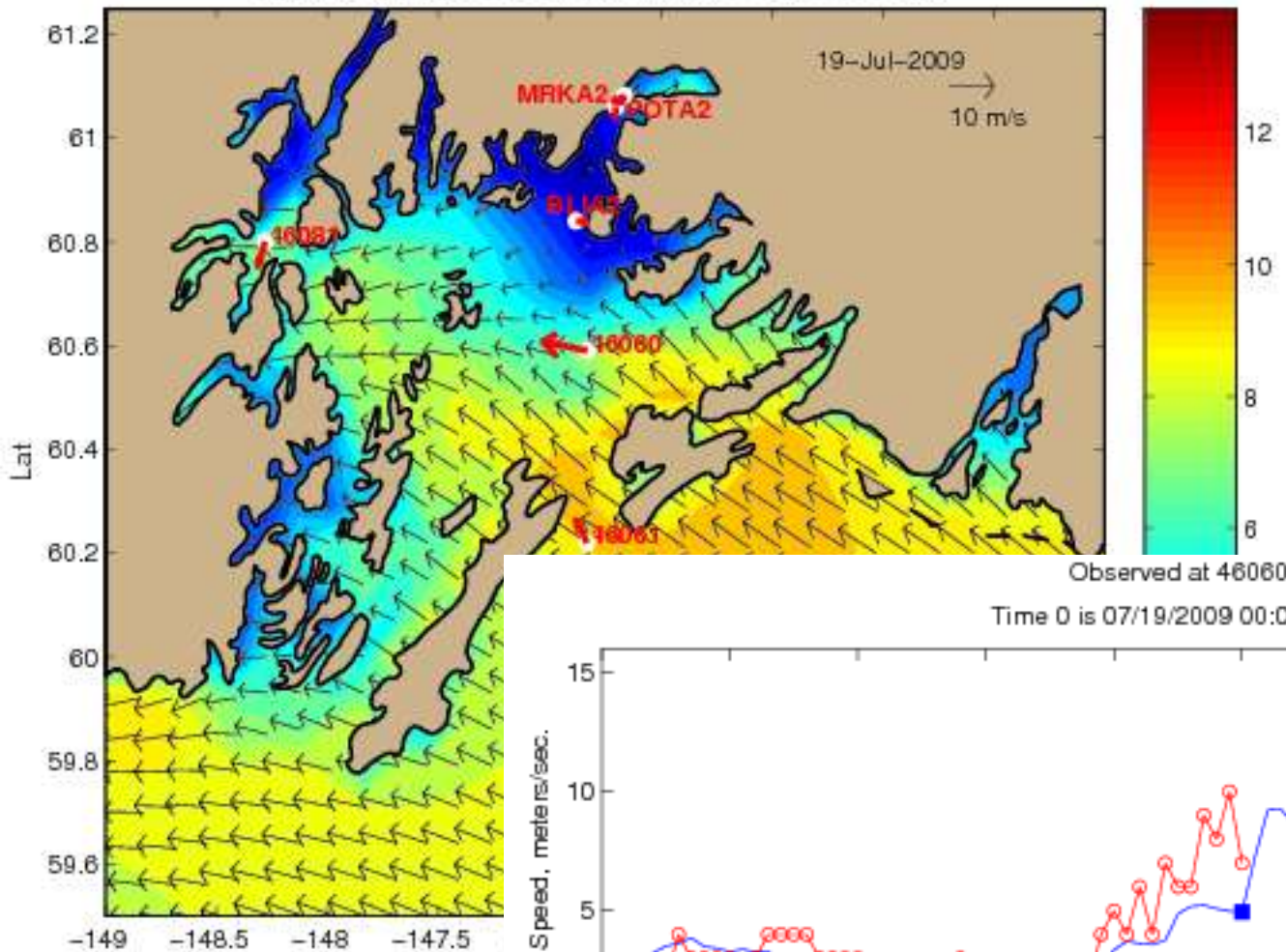
Vertical Resolution

40 layers

WRF Weather Forecast

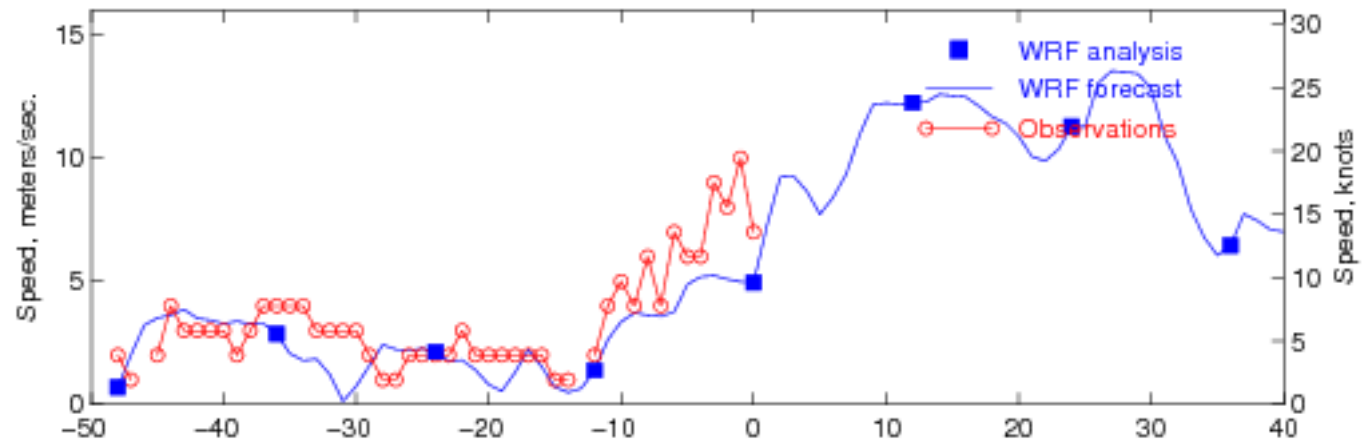
<http://ouroecean.jpl.nasa.gov/PWS09>

WRF 10m Wind Speed (m/s) for 19-Jul-2009GMT



(WRF by Peter Olsson)

Time 0 is 07/19/2009 00:00 GMT

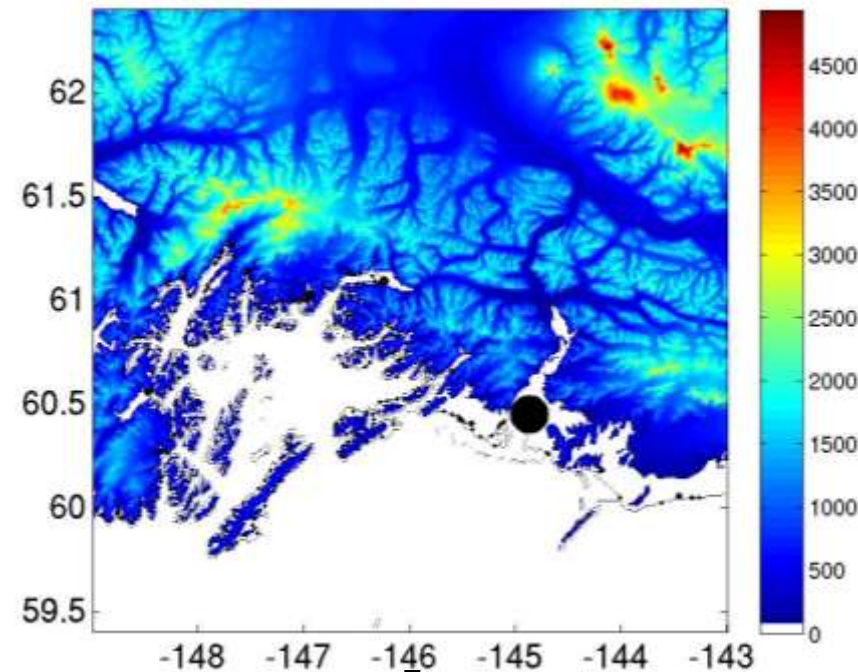


Freshwater discharge by a hydrological model vs. Copper River observations

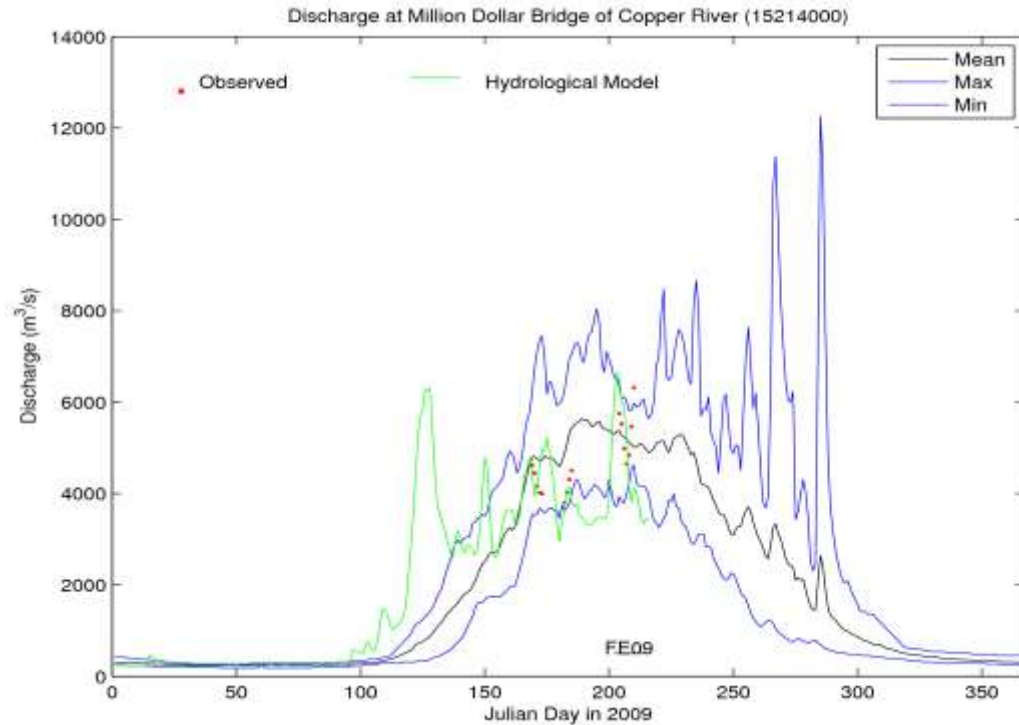
WRF Precipitation



DEM



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

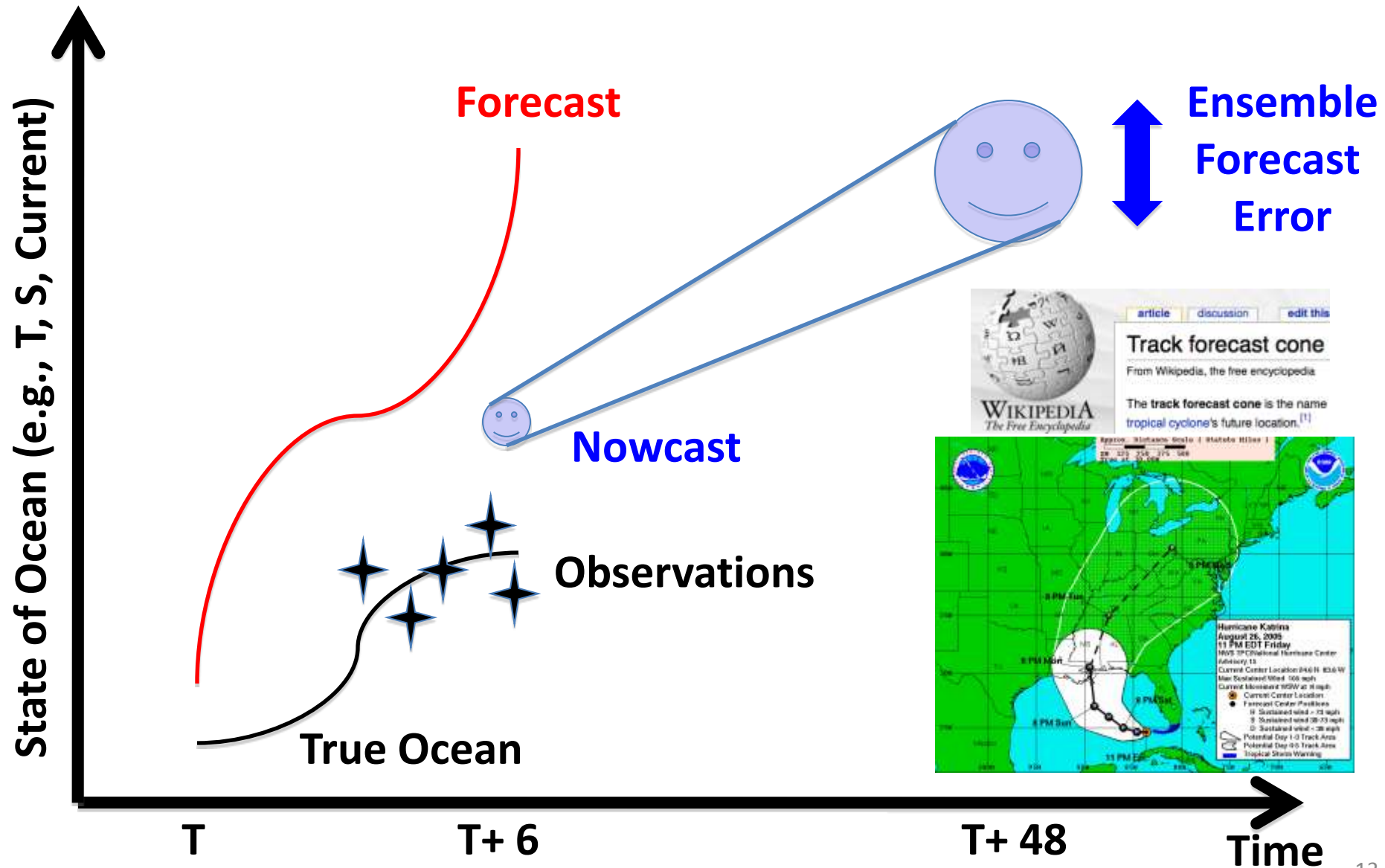


12.5-km

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

$$x = \begin{pmatrix} S \\ u \\ v \\ T \\ S \end{pmatrix} = \begin{pmatrix} x_\xi \\ x_{uv} \\ x_{TS} \end{pmatrix} = \begin{pmatrix} x_\xi^f + \Gamma \delta_{TS} + \delta_{\alpha\xi} \\ x_{uv}^f + \Gamma \delta_{TS} + \Phi \delta_{a\psi} \\ x_{TS}^f + \delta_{TS} \end{pmatrix}$$

$$\delta_{uv} = \Gamma \delta_{TS}$$

Geostrophic balance

$$\delta_{TS} = \Gamma \delta_{TS}$$

Hydrostatic equation

Five Control Variables:

Temperature: δT

Salinity: δS

Non-steric SSH: $\delta X_{a\zeta}$

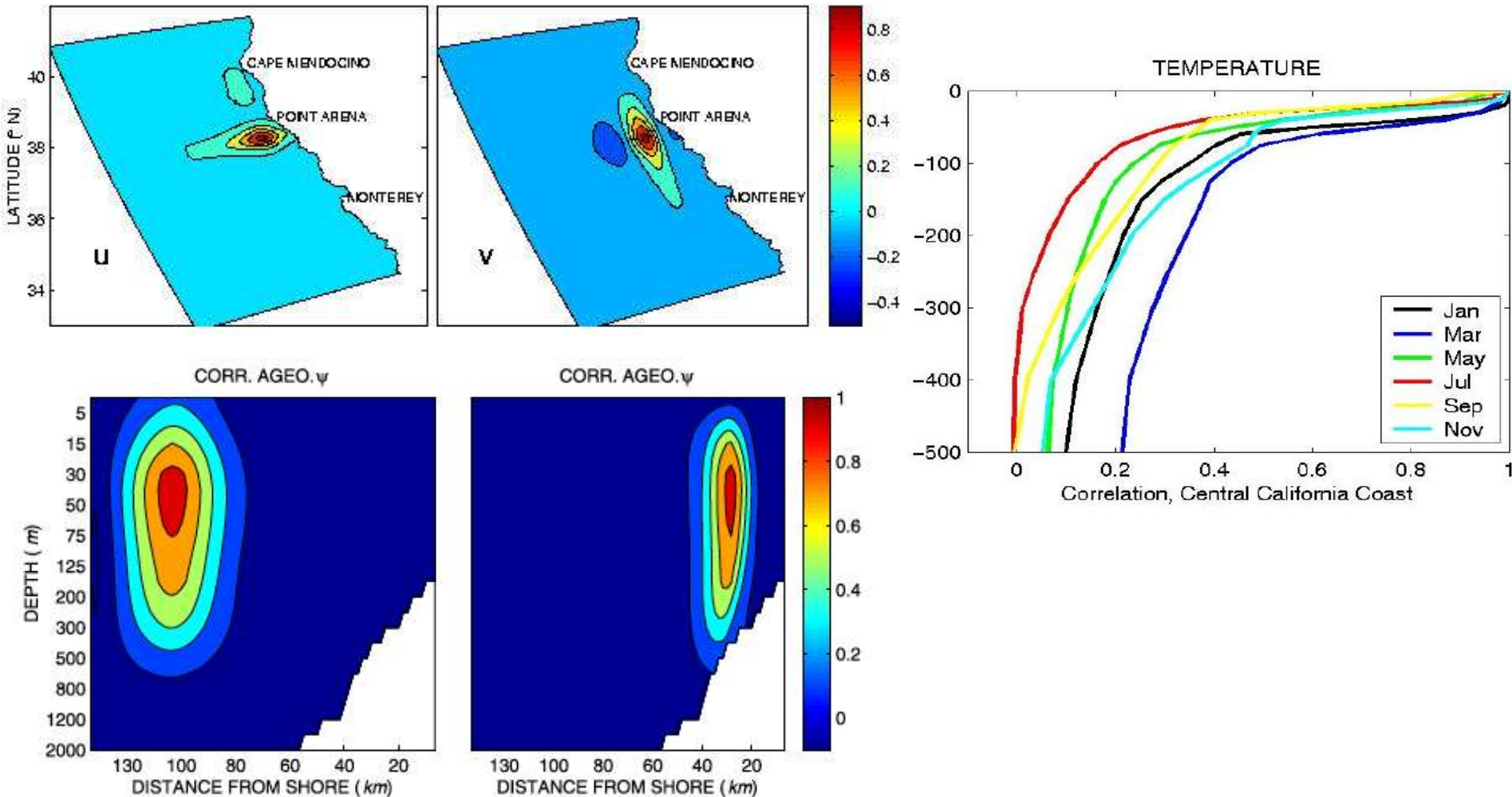
Ageostrophic streamfunction: $\delta X_{a\psi}$

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



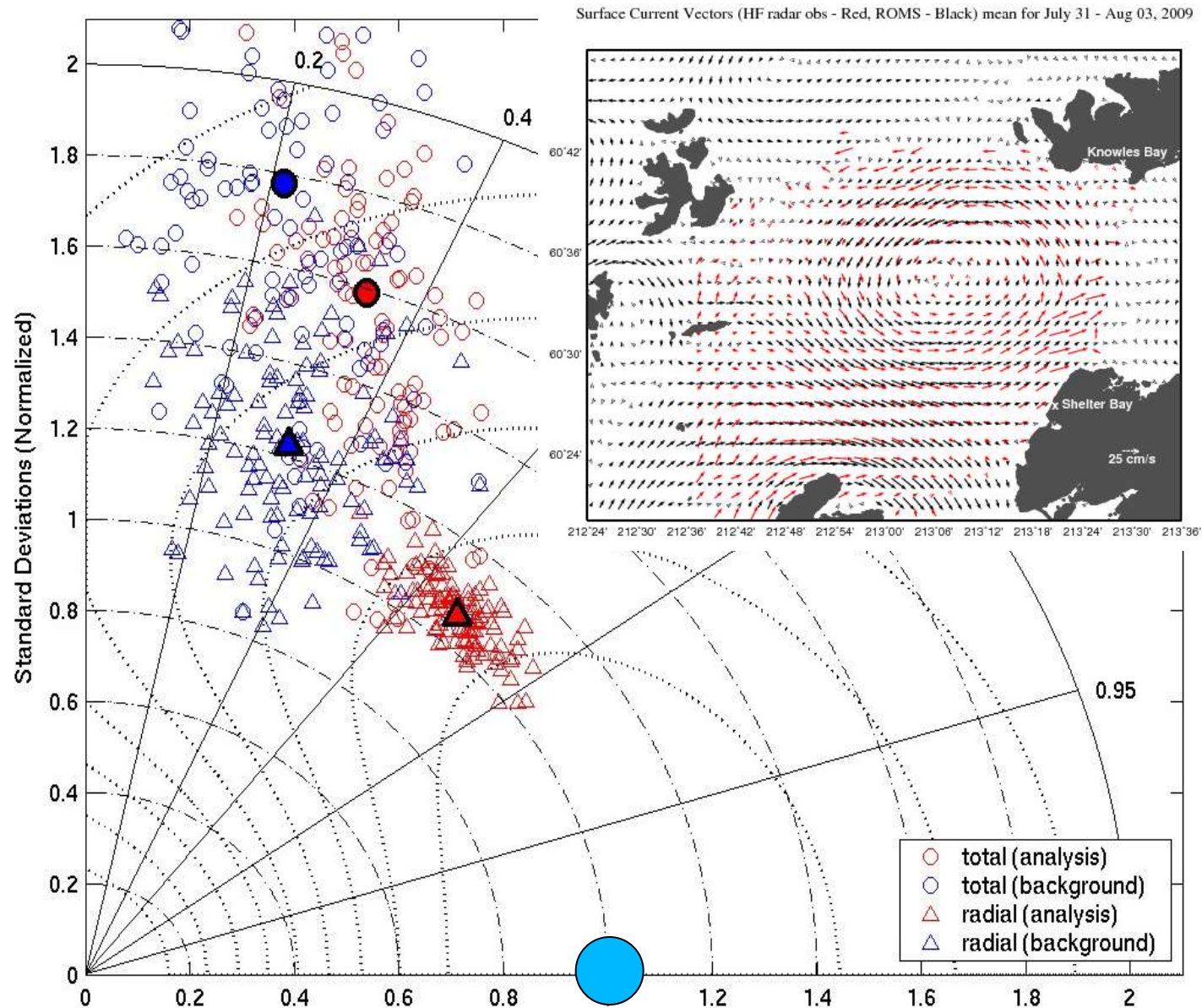
Validation of HF Radar Data Assimilation: Radial vs Total Current

Total currents data
assimilation (circle)

1st Guess before data
assimilation
(blue)

Nowcast after data
assimilation
(red)

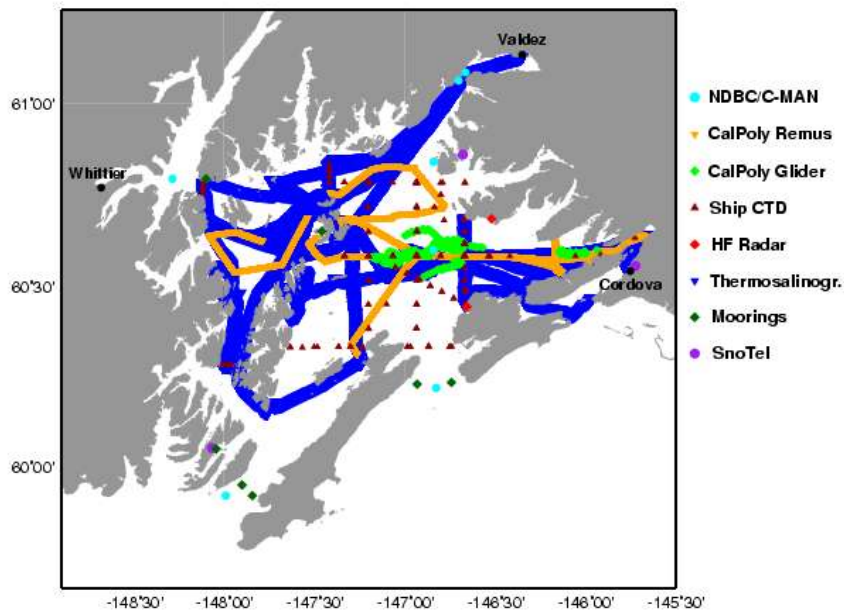
Radial current data
assimilation (triangle)



Validation of T/S: ROMS vs OBS

Temp Bias: -0.28 C

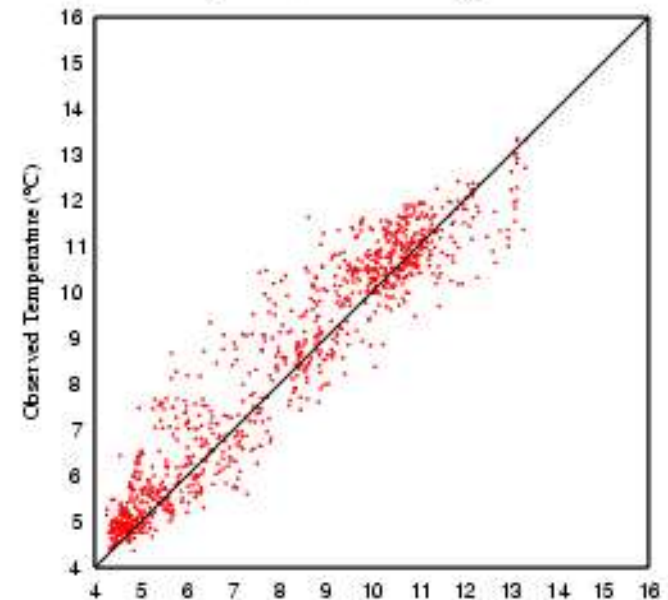
Temp RMS: 0.82 C



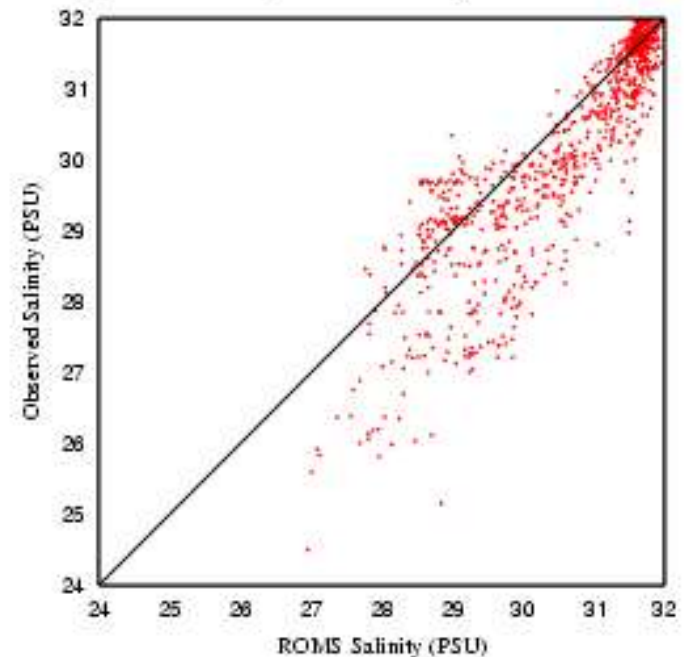
Salinity Bias: +0.35 PSU

Salinity RMS: 0.77 PSU

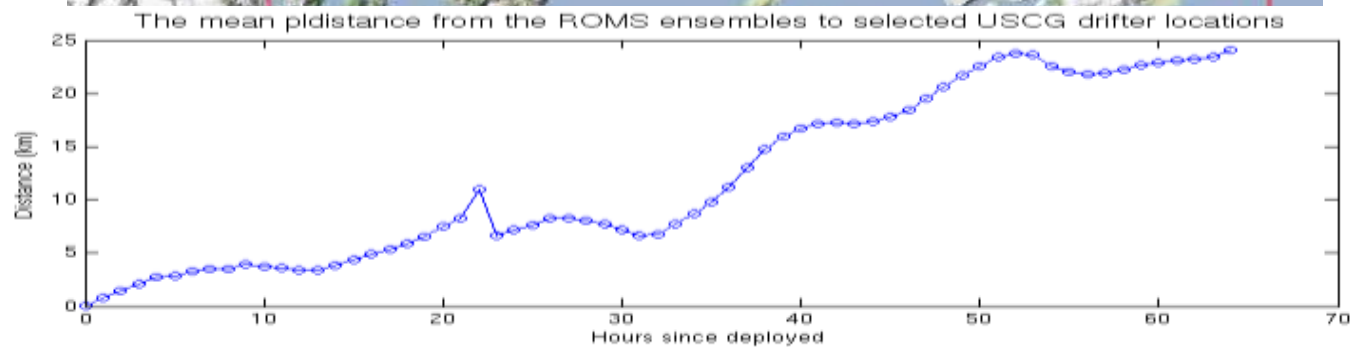
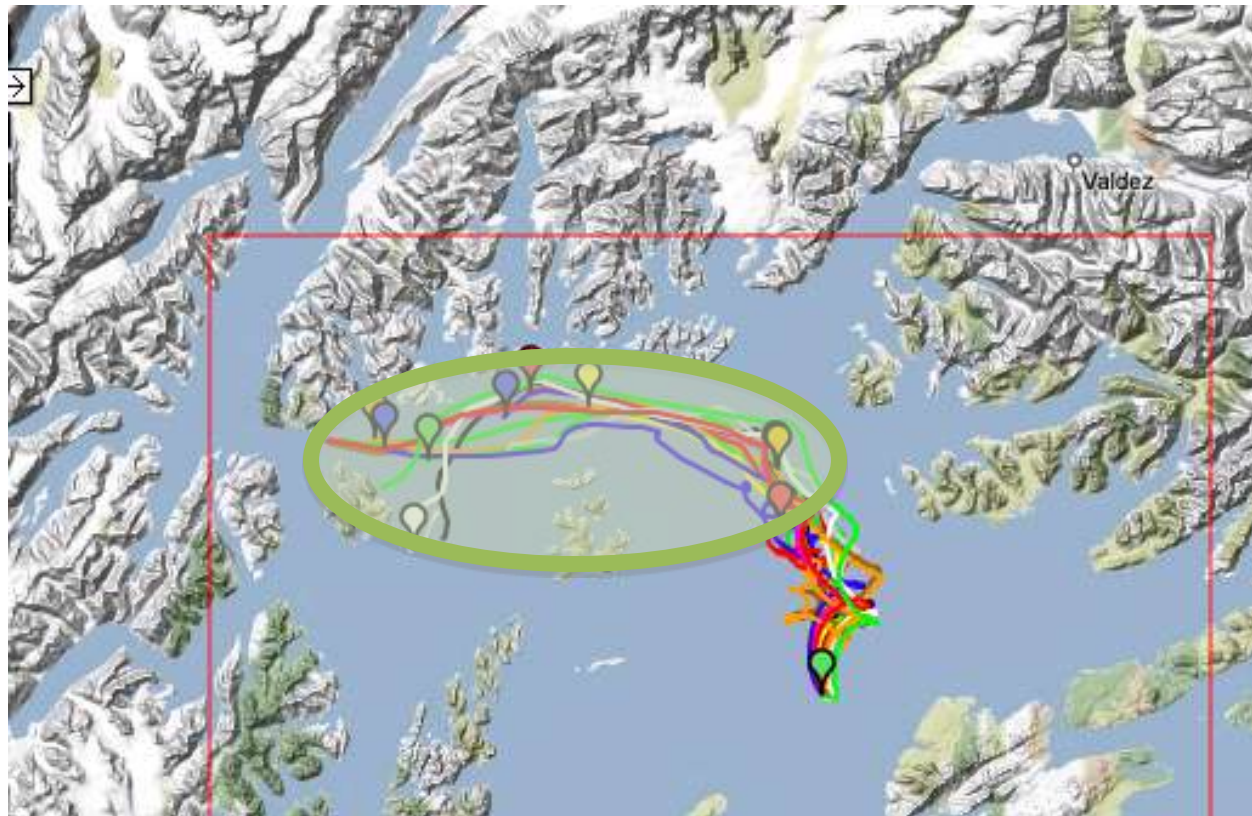
08 Field Experiment Temperature, ROMS vs. Sample of Observed Glide



09 Field Experiment Salinity, ROMS vs. Sample of Observed Glider, Ship (



ROMS Ensemble Forecast for Error Estimation



PWS ROMS Forecasting System Portal

<http://ocean.jpl.nasa.gov/PWS09>

View Nowcast and Forecast

July 2009

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	31	

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- ☒ ROMS Nowcast
 - ☐ Temperature
 - ☐ Salinity
 - ☐ Current
 - ☐ Sea Surface Height
- ☒ ROMS Forecast
 - ☐ 3D Output
- ☒ WRF
 - ☐ Wind
- ☒ ROMS vs. Data
 - ☐ Tide Gauge
 - ☐ Glider Profile
 - ☐ Ship CTD
 - ☐ REMUS
 - ☐ HF Radar
 - ☐ Sea Surface Temperature
- ☒ Drifter Trajectory
 - ☐ Observation
 - ☐ Prediction
 - ☐ Ensemble Prediction

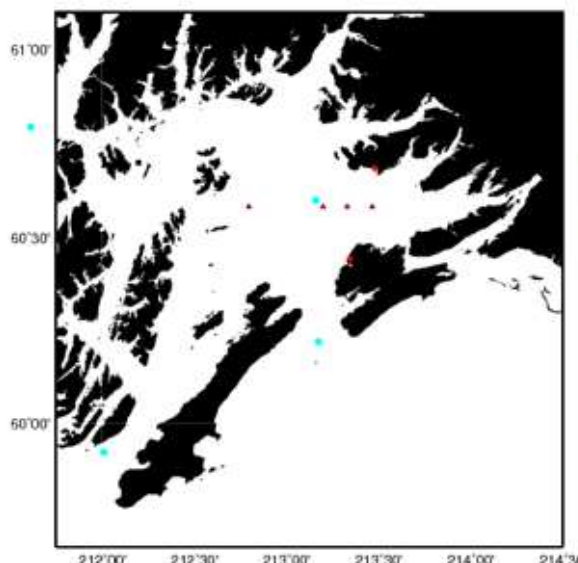
Prince William Sound Field Experiment

[The JPL Ocean portal user guide](#)

07/20/2009 - The south-central coast of Alaska has been under the influence of a slow moving low-pressure system south of the Kenai peninsula. A frequent consequence of such lows is a southeasterly coastal jet extending north from SE Alaska and terminating near the PWS. As a result, strong east to southeast winds up to 15 knots continue today across most of the PWS. These winds are forecast to persist in direction with only modest weakening over the next 24 hours or so. As is typical in these jet and decaying-jet situations, PWS-WRF is slightly overestimating the low level wind speeds. We will again defer commentary on the circulation and predicted drifter trajectories until tomorrow as the ROMS circulation is adjusting to newly-corrected atmospheric forcing. We note that the ship CTD profiles gathered yesterday are being assimilated. The tidal range will continue to increase during the coming 48 hours. At Valdez, this range will be close to 19 feet. The high water (8 feet) will be reached around 1AKDT and low water (-9.5 feet) around 8AKDT. At Whittier, the tidal range will be around 19 feet. At Cordova, it will be around 16 feet. Operationally, the major issue today was a significant delay in completing the ROMS nowcast and forecast due to issues related to the correction of the atmospheric forcing.

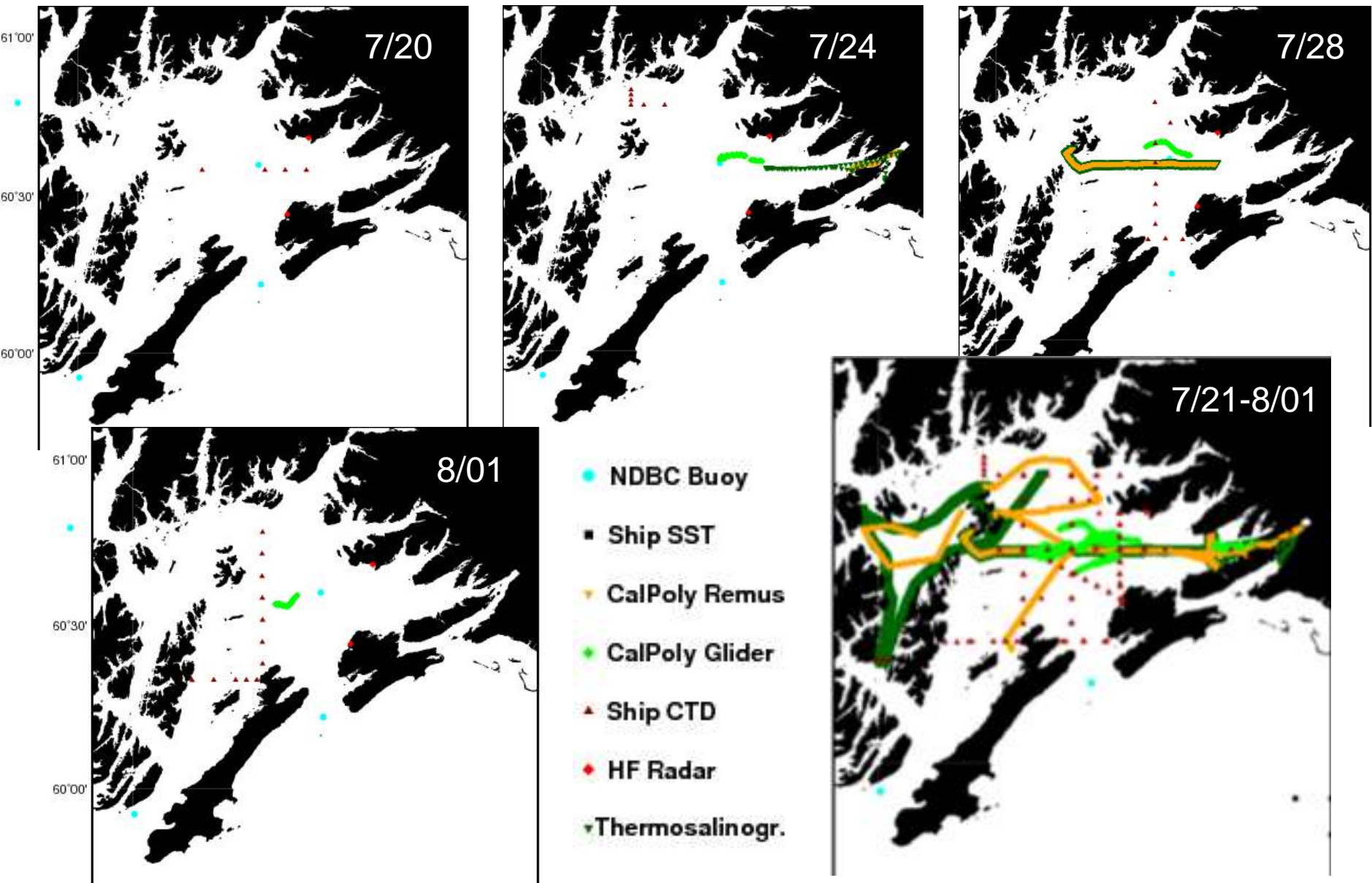
Click [here](#) to view a more detailed PWS daily summary.

Location of Assets 20090720



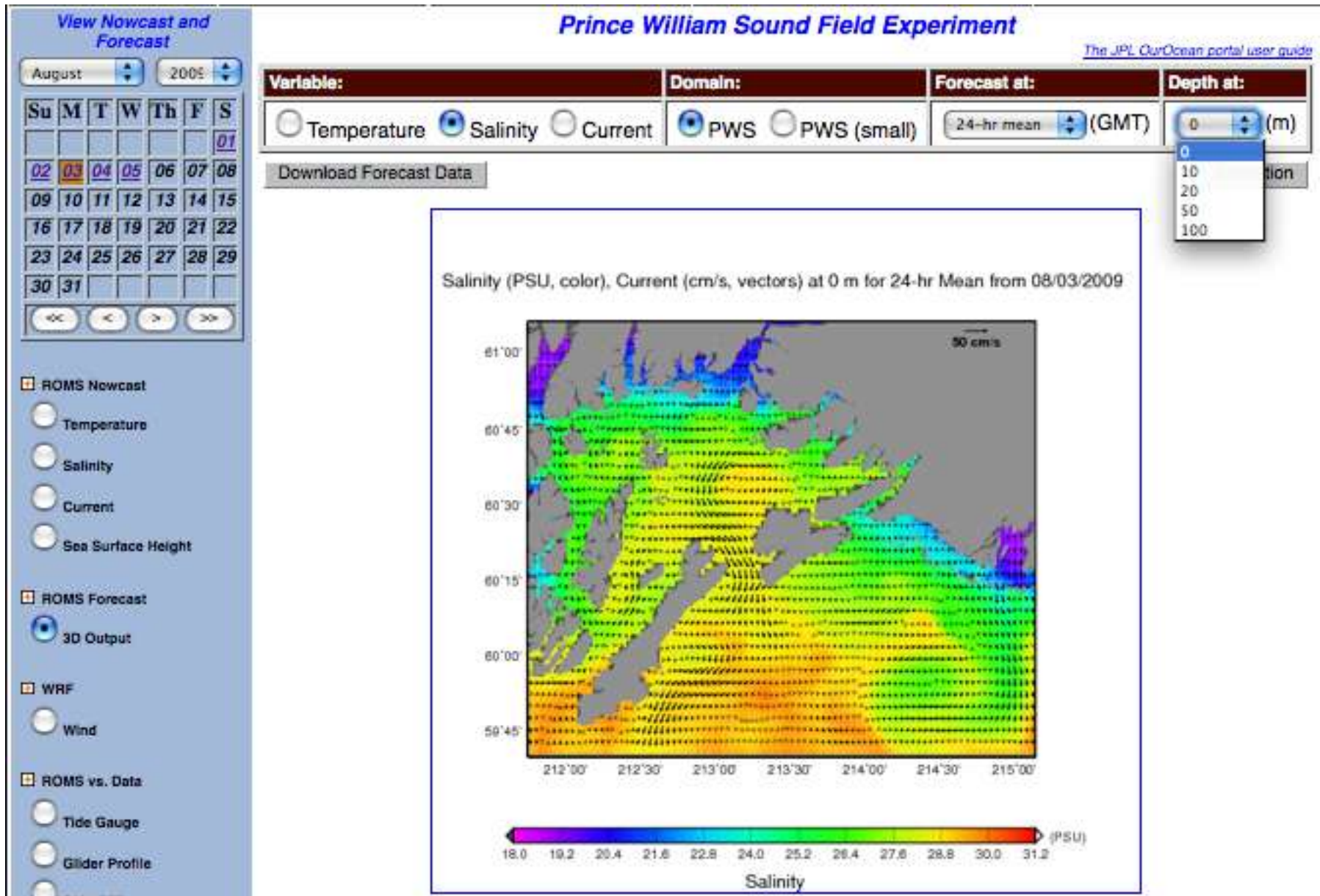
Observational Assets: Updated Daily

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

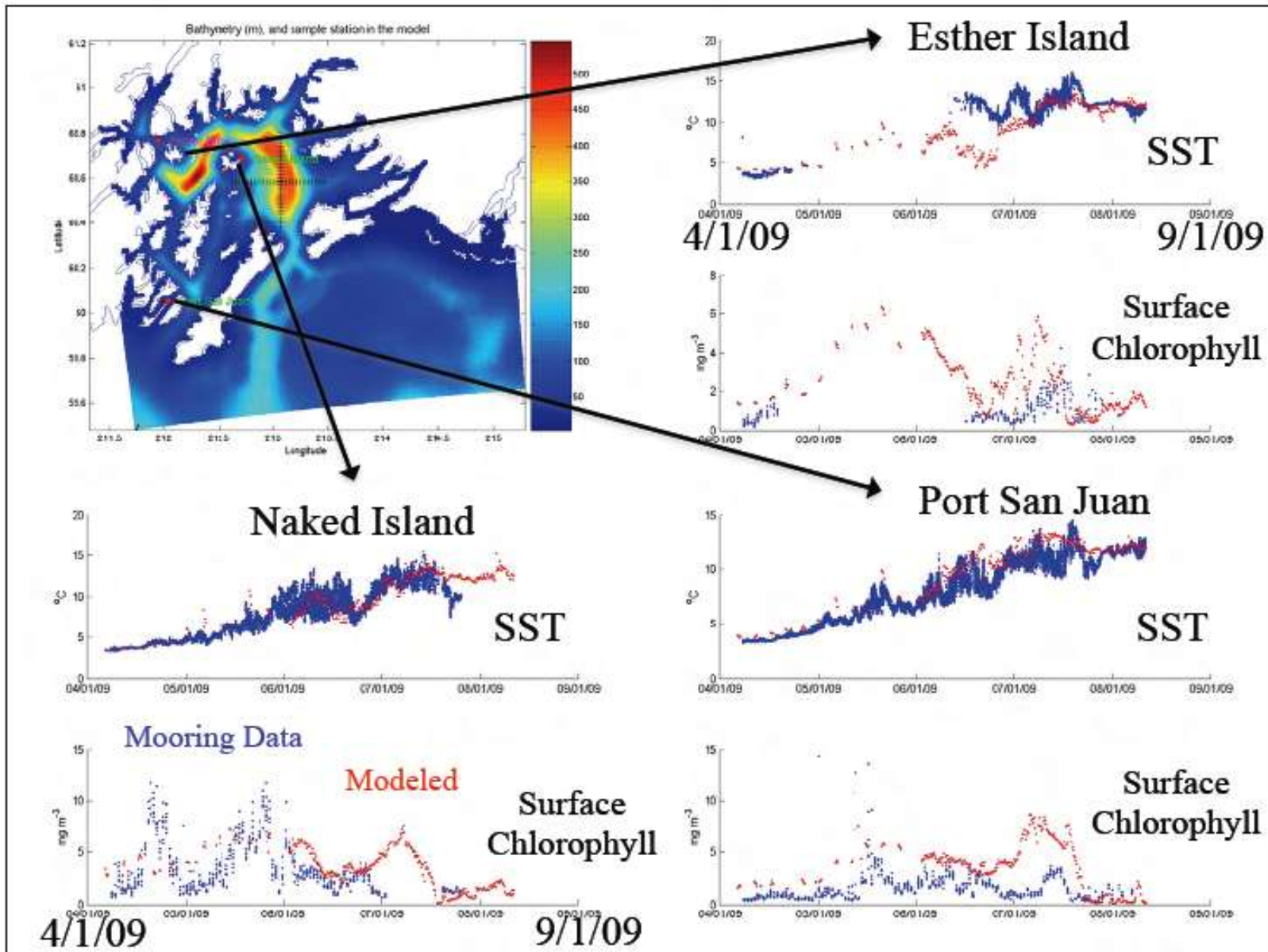


PWS ROMS Forecast: Access 3D output

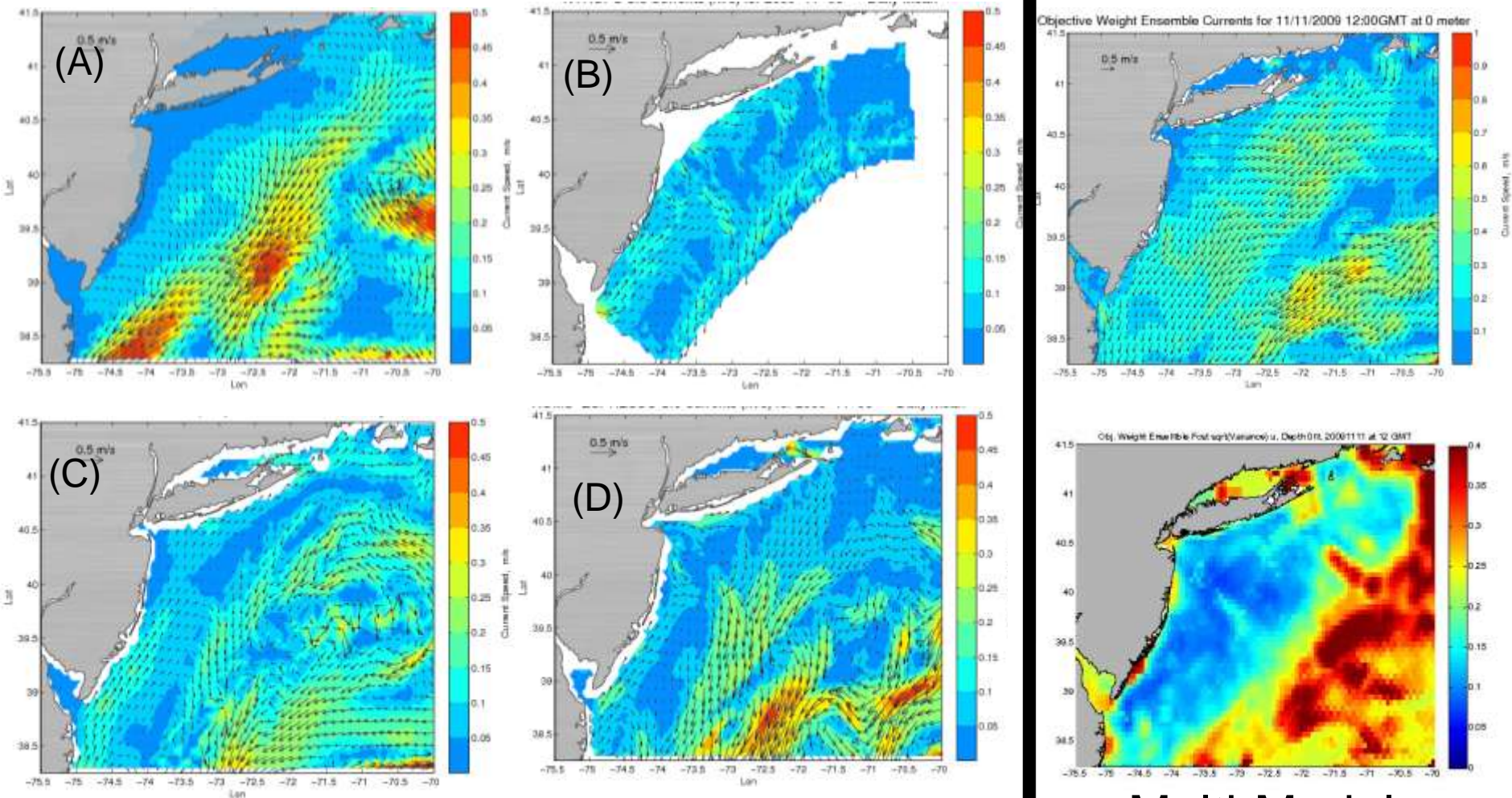
<http://ouerocean.jpl.nasa.gov/PWSS09>



Linking PWS ROMS with Biogeochemical Model



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

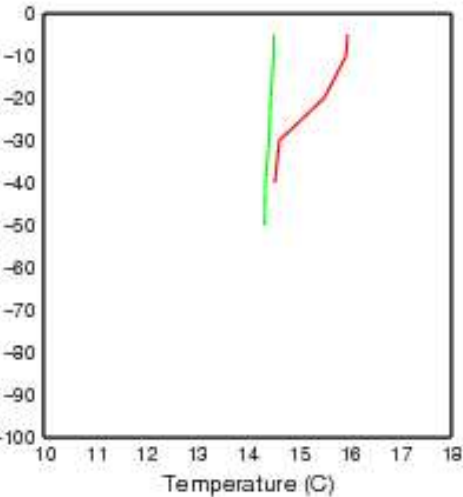


HOPS-UMass, NYHOPS/POM-SIT,
ROMS/USGS, ROMS/4DVAR-Rutgers

Multi-Model
Ensemble &
Error

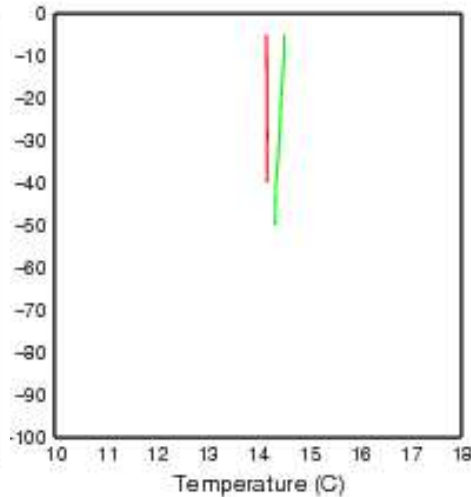
Glider Data (ru05) vs. Four Models (11/10)

Temperature Profiles



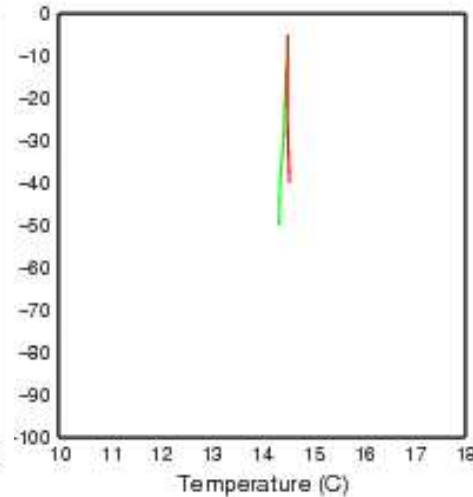
Model A

Temperature Profiles



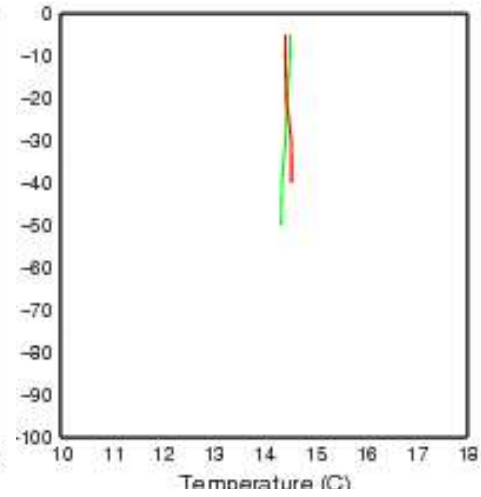
Model B

Temperature Profiles



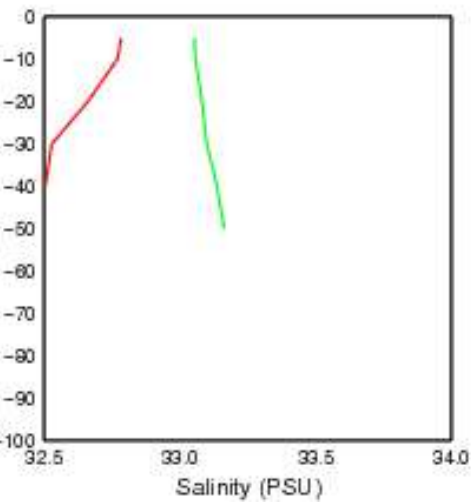
Model C

Temperature Profiles

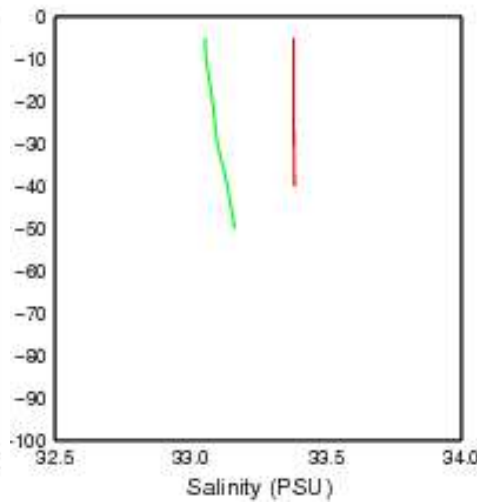


Model D

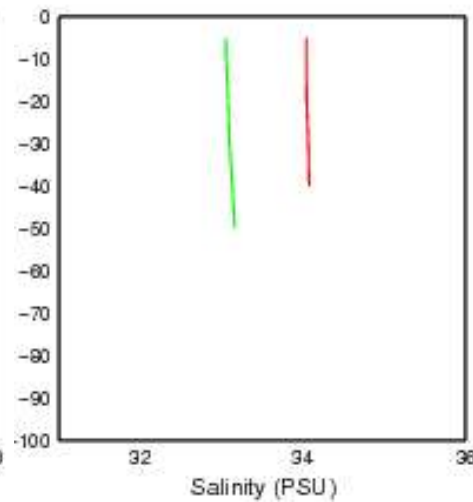
Salinity Profiles



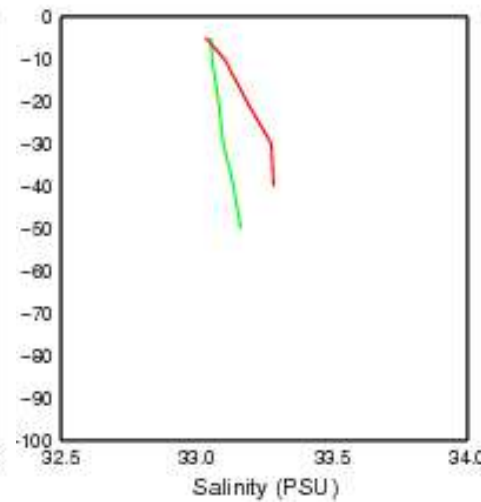
Salinity Profiles



Salinity Profiles



Salinity Profiles



Web-Based Virtual Drifter Tracker

<http://ocean.jpl.nasa.gov/PWS09>

View Nowcast and Forecast

July 2009

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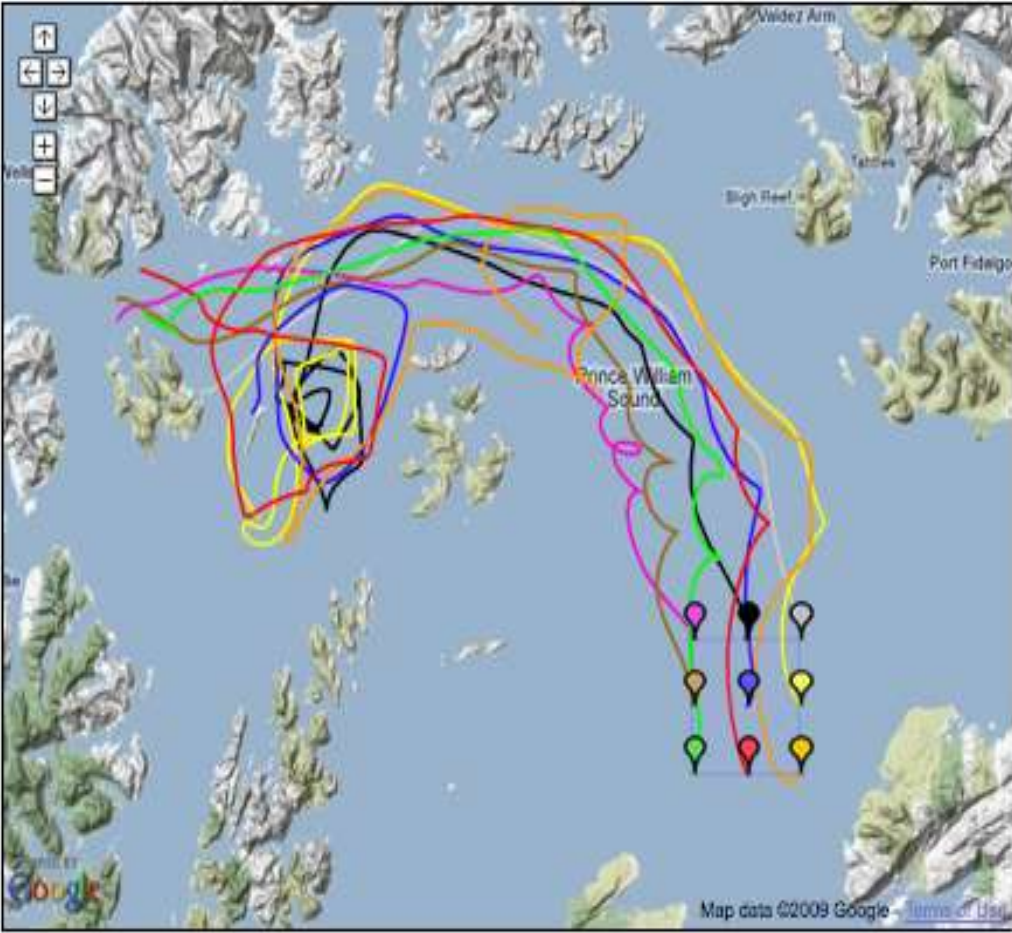
☐ Sea Surface Temperature

☒ Drifter Trajectory

☐ Observation

☐ Prediction

☐ Ensemble Prediction



Map data ©2009 Google - Terms of Use

Compute & Plot Clear Download Trajectory File

☐ Single Drop Mode ☒ Multiple Drop Mode
(Click & then move the mouse to draw a region for drifters)

Number Of Drifters:

X dimension: Y dimension:

Location

Lon: Lat:

(Enter longitude and latitude values that fall within the red box.
Long: between -148.25 & -146 W and lat: between 60.15 & 61.0 N)

Data Source

Start Time (GMT)

2009-07-21 06:00:00

End Time (GMT)

2009-08-01 06:00:00

- 2009-07-21
- 2009-07-22
- 2009-07-23
- 2009-07-24
- 2009-07-25
- 2009-07-26
- 2009-07-27
- 2009-07-28
- 2009-07-29
- 2009-07-30
- 2009-07-31
- 2009-08-01**
- 2009-08-02
- 2009-08-03
- 2009-08-04
- 2009-08-05



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	Regional Ocean Current Models
Navy Coastal Ocean Model (NCOM) Naval Research Laboratory 1/8 degree operational model	West Coast: Southern California Bight ROMS forecasting system run at Jet Propulsion Laboratory
Navy Layered Ocean Model (NLOM) Naval Research Laboratory 1/32 degree operational model	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
Measured currents	
Coastal HF radar Served by the National Data Buoy Center	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
Geostrophic currents Sea Surface Height derived currents	
Winds	
National Weather Service Forecast Winds Wind forecast from the NWS National Digital Forecast Database.	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
National Data Buoy Center Winds Wind data from the National Data Buoy Center.	

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

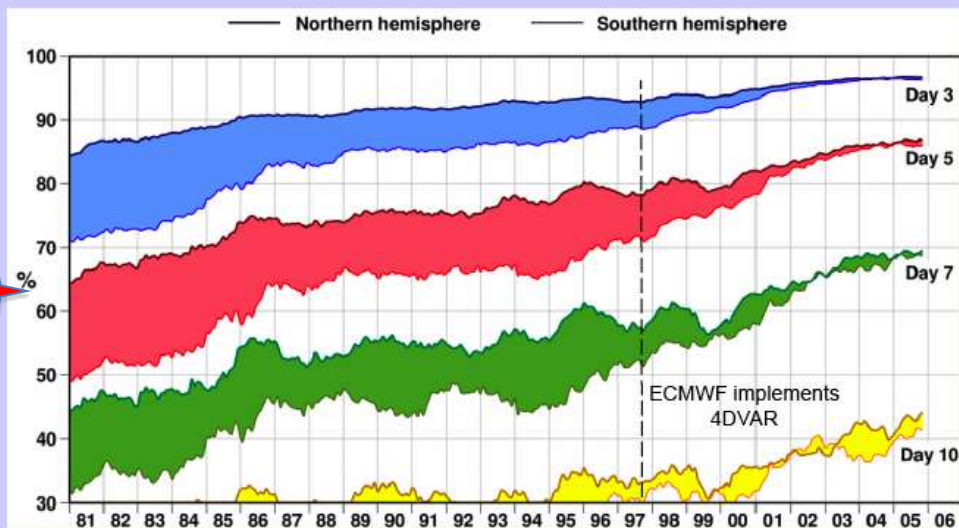


Private
service
(112+):
\$200M/yr
+5%/yr

weather.com

Increasing Skill of Numerical Weather Forecasts

ECMWF Anomaly Correlation of 500mb Height Forecasts



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

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

