Review of Circulation Studies and Modeling in Casco Bay

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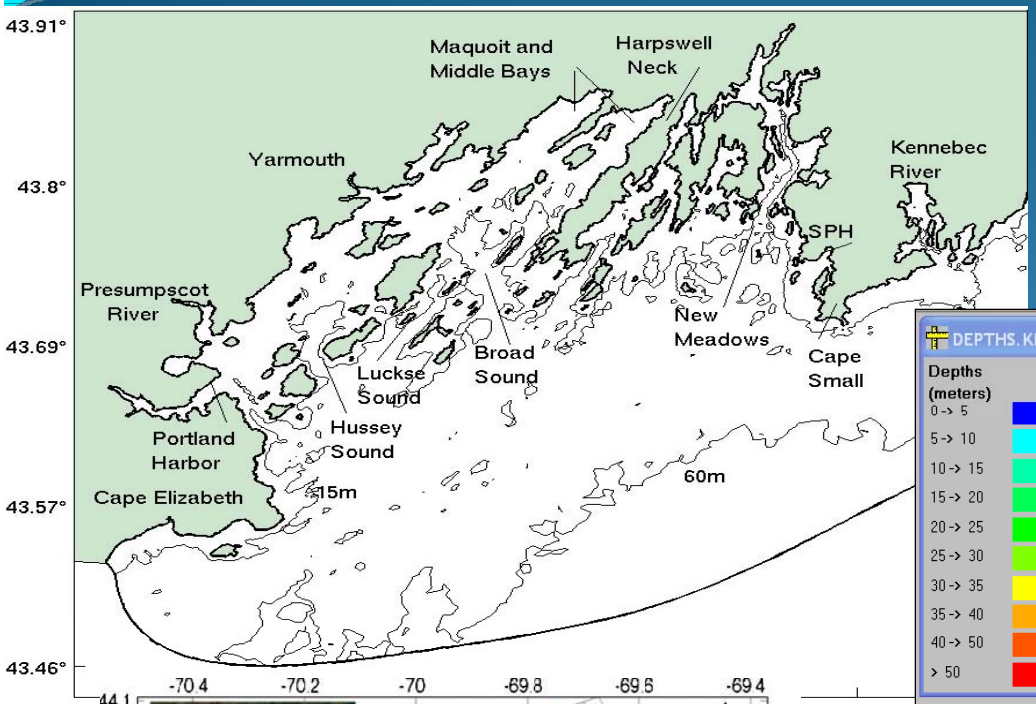
- ASA is a global science and technology solutions company. Consulting, environmental modeling, and application development.
- Offices: South Kingstown, RI; Queensland and Perth, Australia; San Palo, Brazil; Dubai; and Shanghai, China (90 employees)
- Suite of integrated model systems: WQMAP (BFHYDRO), HYDROMAP, OILMAP, SIMAP, SARMAP, CHEMMAP, AIRMAP, COASTMAP et al.

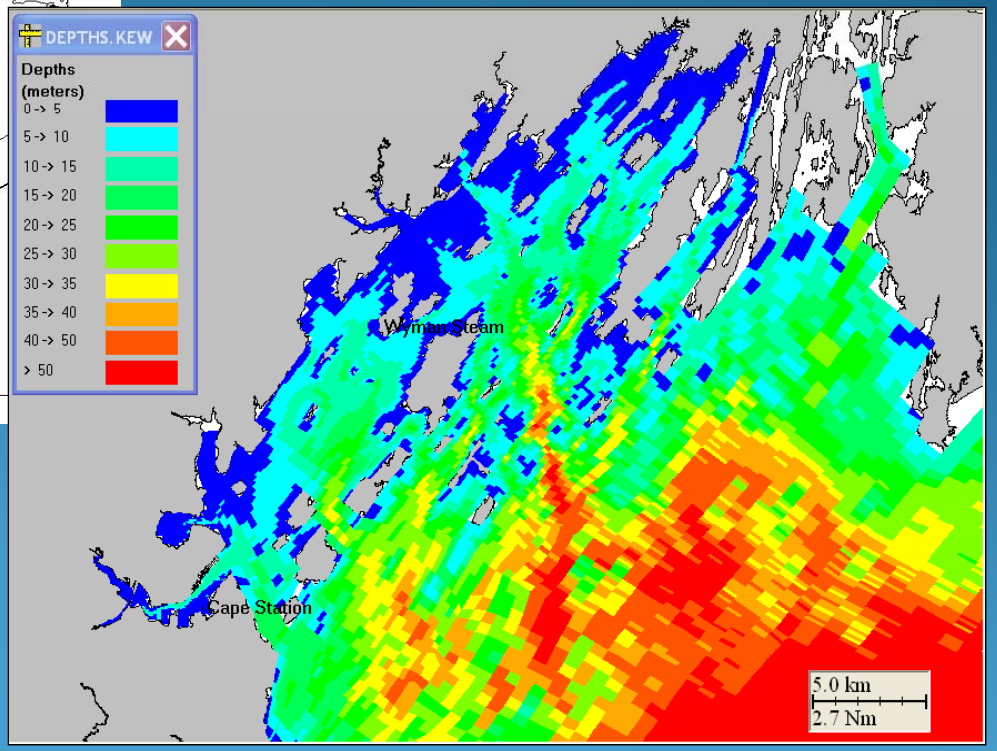
Study Objectives

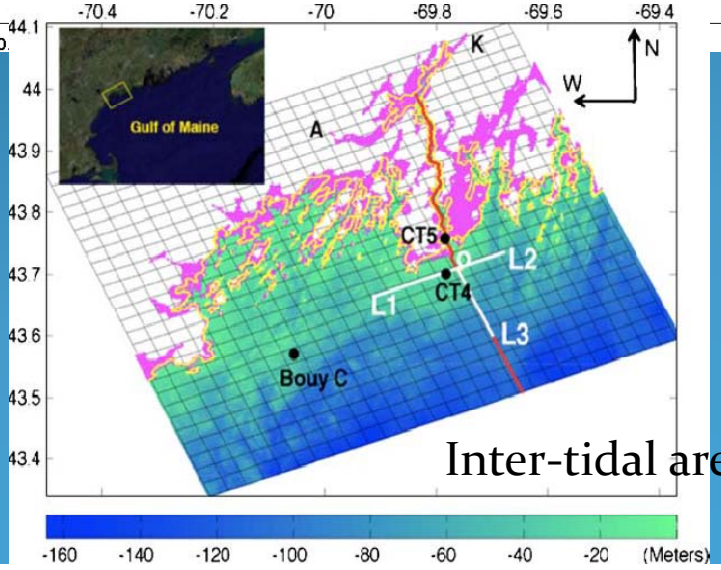
- To develop a report reviewing the state of knowledge of circulation in Casco Bay, discussing relevant hydrodynamic and other modeling approaches, and identifying available data sets relevant to circulation.
- To present the results at a Circulation Modeling Workshop)(May 2010) and summarize the key recommendations of the workshop in a succinct summary (2-3 pg).

Casco Bay Study Area



Bathymetry





Inter-tidal areas

Selected Management Drivers for Models and Circulation Studies

- Harmful algal blooms - *Alexandrium fundyense*
- Oil spill transport and fate - emergency response and impacts
- Larval transport and settling- lobster and clam
- Nutrient and water quality – treatment plant discharges, storm water discharges
- Sea level rise and climate change

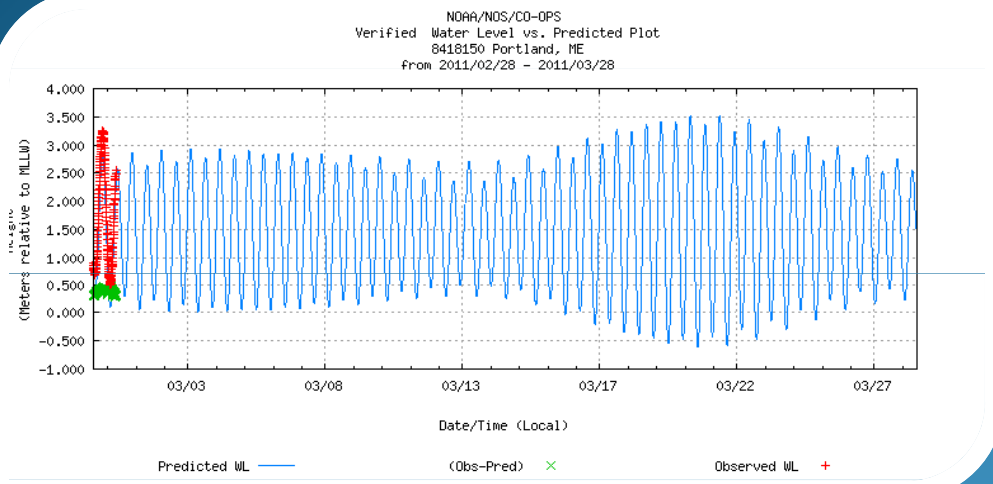
Understanding circulation in Casco Bay is critical to managing the system.

Process to Gather Information

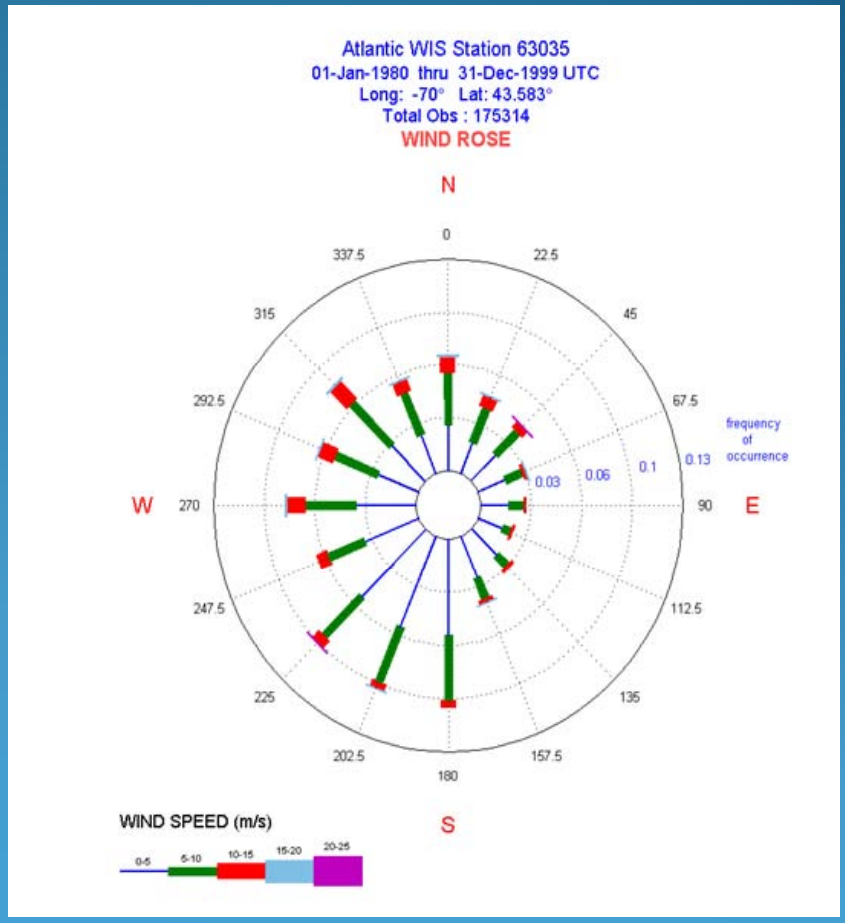
- Review existing CBEP holdings
- Professional contacts (University of Maine, WHOI, Dartmouth College, Univ. Mass -Dartmouth, Texas A&M, Norwich University, Bowdoin College, NOAA ORR, US Geological Survey, EPA Region 1, NERACOOS, GMRI, National Fisheries Science Center, Canadian Department of Fisheries and Oceans).
- Web searches: models and data bases (NOAA NDBC and NOS COOPS, and USGS)

Forcing (tides, wind, and river discharge)

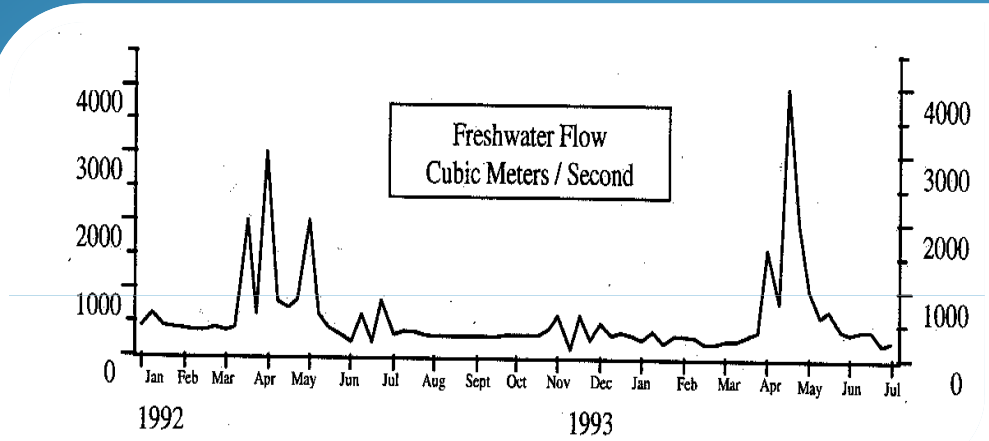
Tidal forcing



Winds



Kennebec River discharge (Pearce et al, 1996)

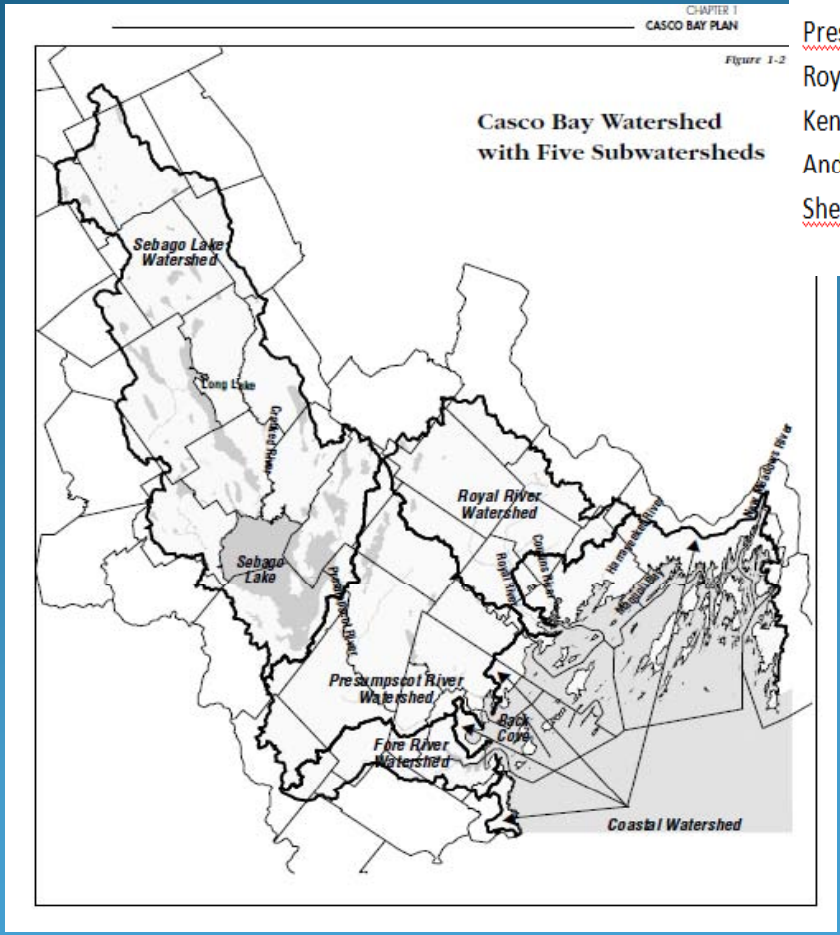


Casco Bay Watershed

Table 1 Estimate peak flows for rivers discharging into Casco Bay, 2, 10, 50 and 100 yr recurrence intervals

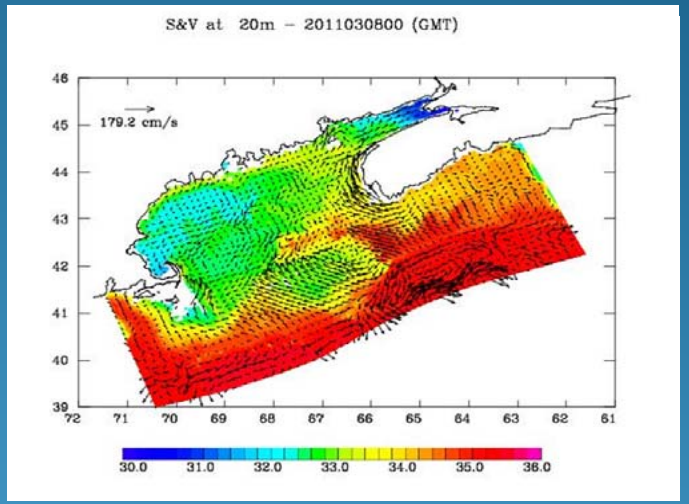
Source: Hodgkins (1999)

River	Station Number	Flow rates (m^3/sec) 2 year recurrence interval	10	50	100
Presumpscot	1064118	150	280	446	534
Royal	1060000	107	194	280	318
Kennebec	1049205	1700	3200	4370	4820
Androscoggin	1059000	1090	1650	2100	2280
Sheepscot	1038000	57	108	165	192

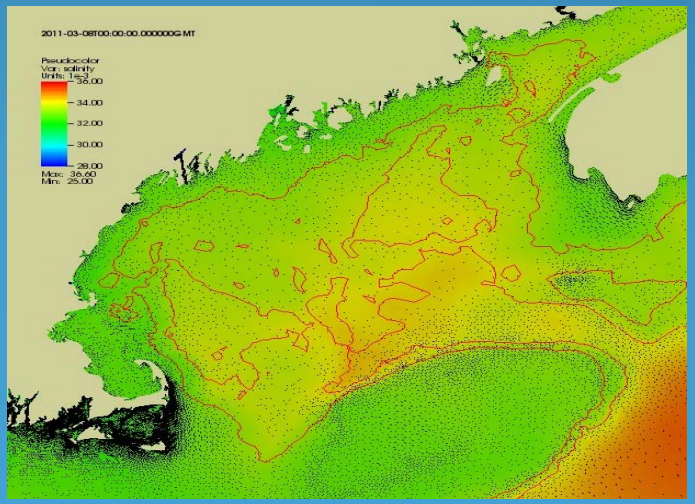


Basin Wide Circulation Modeling Efforts: Operational Systems

Gulf of Maine Ocean Obs Forecasting System (Xue et al, Univ. of Maine, Marine Sciences)



NECOFS (Chen et al, Univ. Mass – Dartmouth, SMAST)



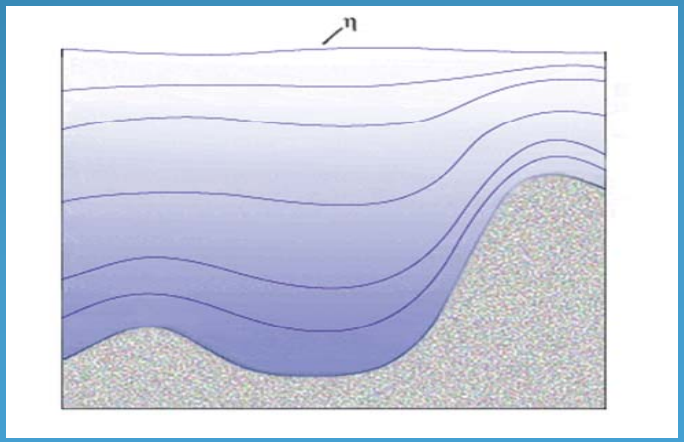
Circulation Models Applied to Casco Bay

- Pearce et al (1996), University of Maine, CBEP
- True and Manning (undated), Norwich and NOAA NFSC
- McCay et al (2008), ASA
- Xue and Du(2010), University of Marine, School of Marine Sciences

- Watabayashi, NOAA ORR Spill Response Model

Terminology

- *Domain*: area included in the model application
- *Wetting (flooding) and drying*: overflow of land that is normally dry by water (on high tide) and removal of water from land (on ebb tide).
- *Sigma coordinate (vertical)*: terrain following coordinate system, equal number of vertical grid cells at all locations

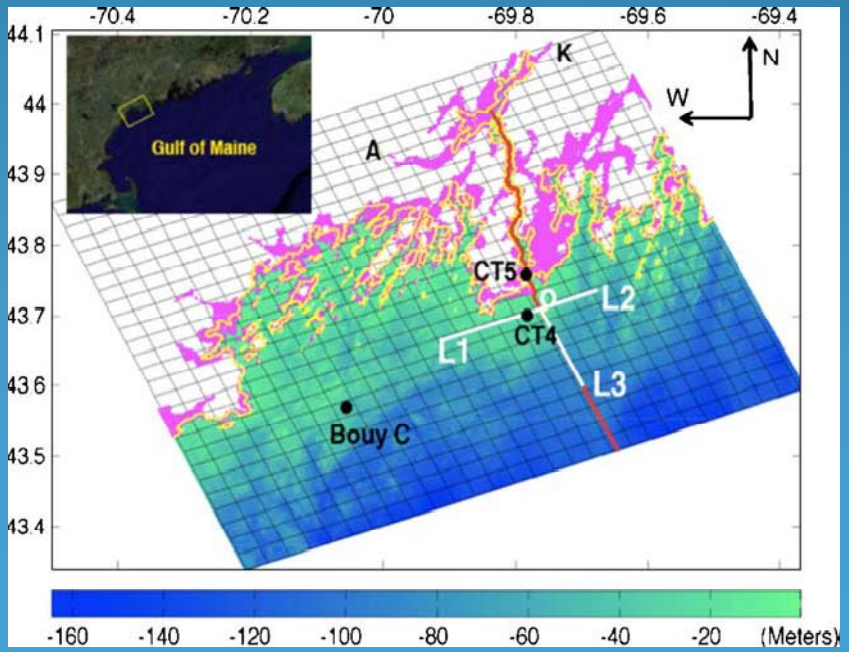


$$\sigma = z/D$$

where z - vertical distance and D - total water depth

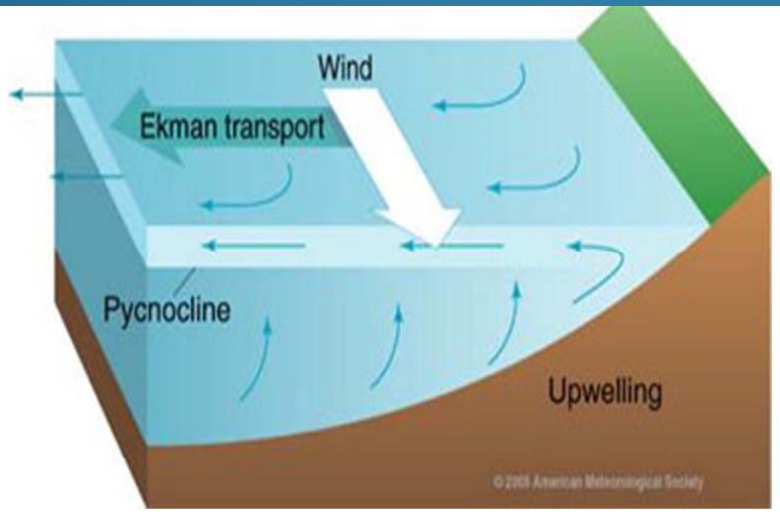
Terminology (cont'd)

- *Boundary conditions*: specification of forcing from areas outside model domain. At the surface due from the atmosphere (wind and heat transfer), laterally by freshwater input, and at the interface with waters outside the domain (laterally)



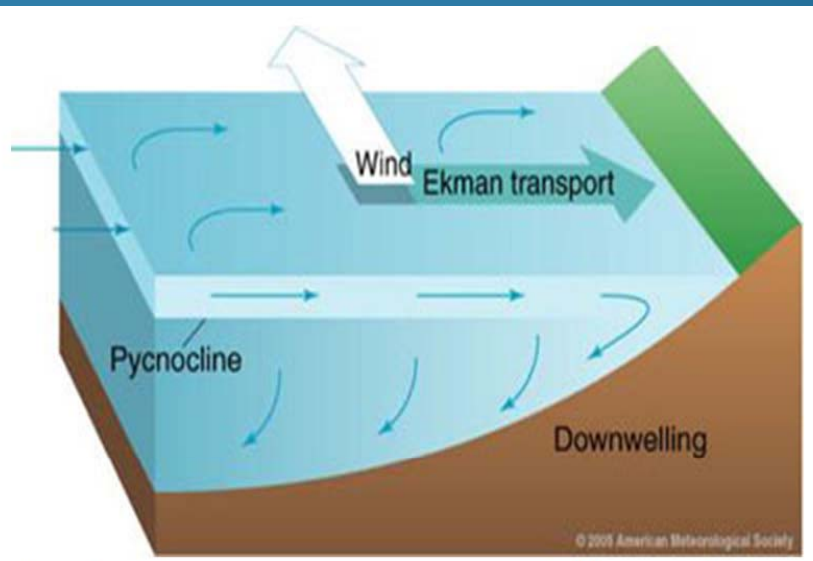
Terminology (cont'd)

Up-welling



Where Ekman transport moves surface waters away from the coast, surface waters are replaced by water that wells up from below in the process known as upwelling. This example is from the Northern Hemisphere.

Down-welling

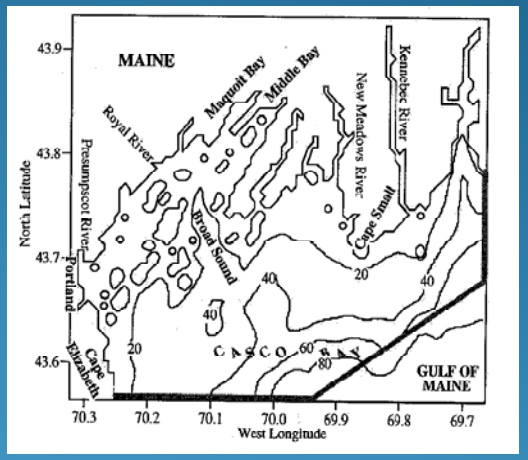


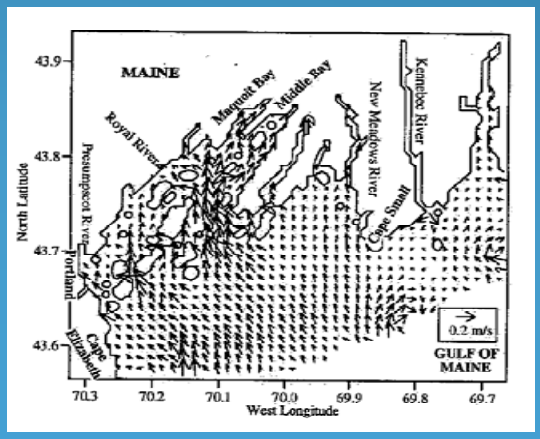
Where Ekman transport moves surface waters toward the coast, the water piles up and sinks in the process known as downwelling. This example is from the Northern Hemisphere.

(http://oceanmotion.org/html/background/upwelling-and-downwelling.htm)

Pearce et al (1996), Univ. Maine

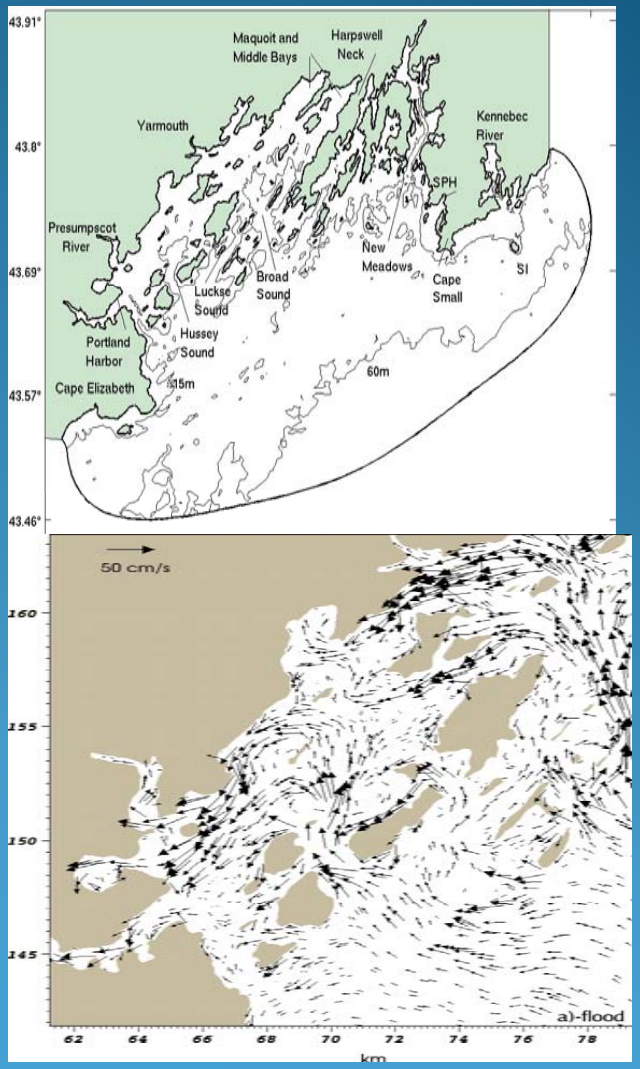
- Funding: Casco Bay Estuary Partnership (CBEP)
- Model: NOAA MECCA, 2-3 D
- Wetting and Drying: Yes
- Domain: Casco Bay and adjacent shelf, 250 to 600 m grid size, 10 sigma levels
- Boundary condition: tides from GOM model
- Verification: tides, water level and currents
  Additional simulations: wind and density forcing





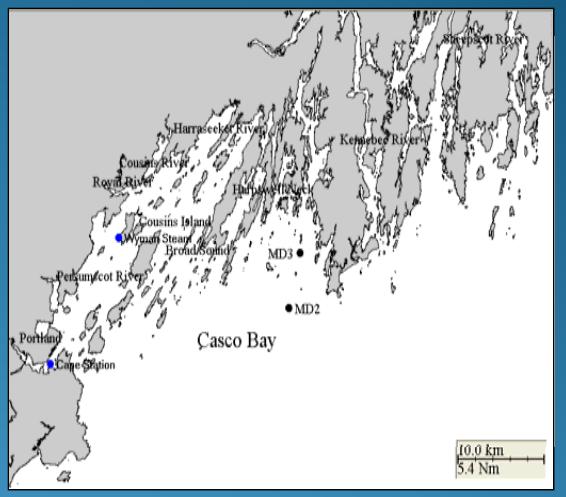
True and Manning (undated), Norwich Univ.

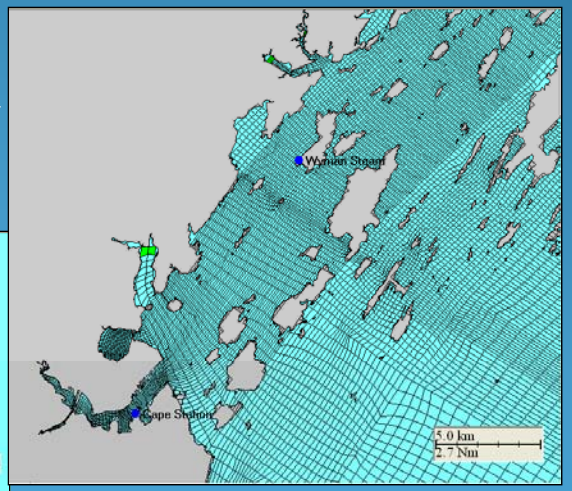
- Funding: Internal/self
- Model: FVCOM (Chen et al) 2-3 D
- Wetting and Drying: No
- Domain: Casco Bay and adjacent shelf, 125 to 500 m grid size, 9 sigma levels
- Boundary condition: Naime et al(1994) GOM model
- Verification: tides, water level and currents
- Additional simulations: wind forced

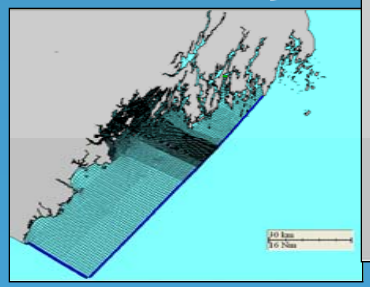


McCay et al (2008), ASA

- Funding: Florida Light and Power
- Model: BFHYDRO (Muin et al, 1997)
- Wetting and Drying: No
- Domain: Casco Bay and adjacent shelf, 125 to 1 km grid size, 2 D
- Boundary condition: TOPEX tidal data
- Verification: Tides and Janzen (2005), MD2 and MD3.

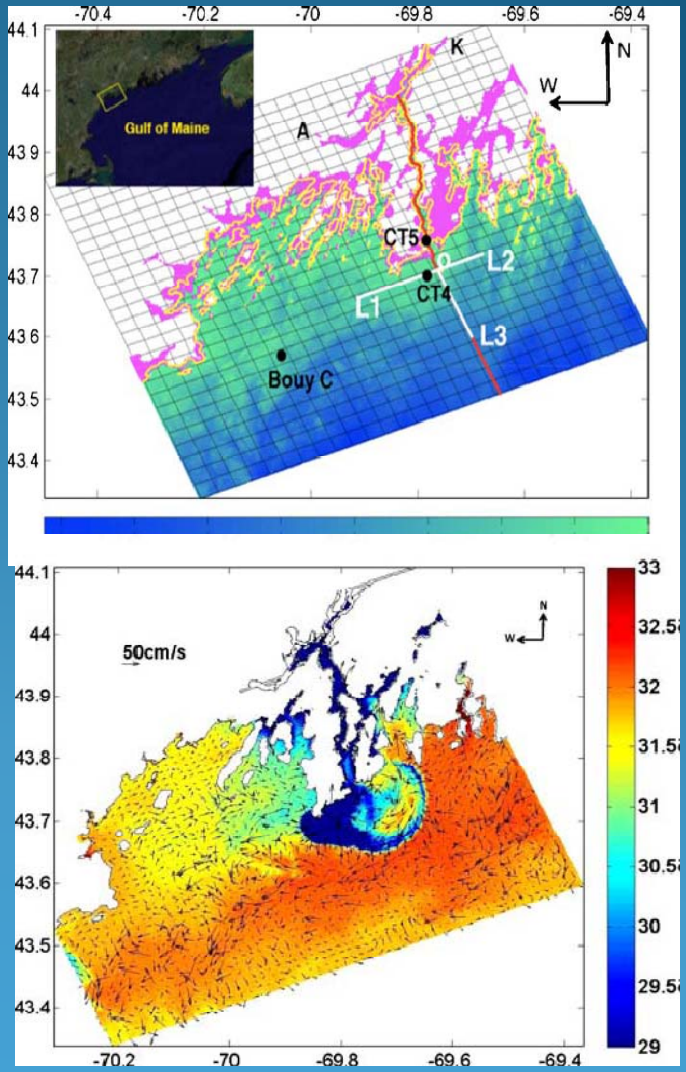






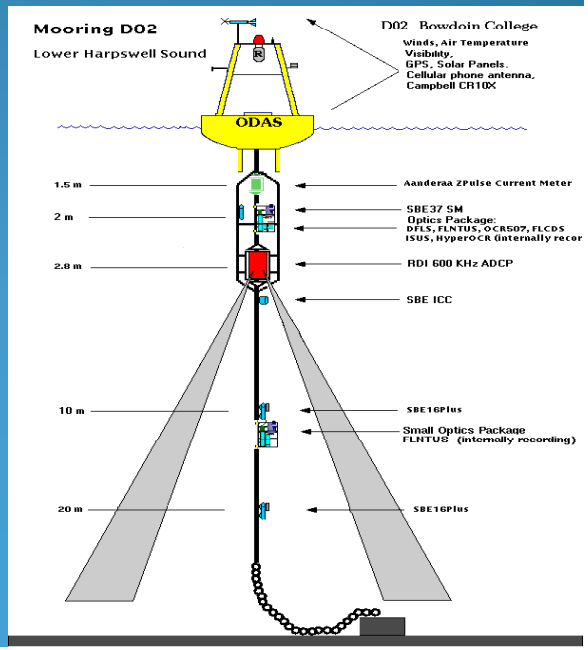
Xue and Du (2010), University of Maine

- Funding: NOAA and NASA
- Model: POM (Mellor, 2003), 3 D
- Wetting and Drying: Yes
- Domain: Casco Bay and adjacent shelf, 125 to 500 m grid size, 22 sigma levels
- Boundary condition: GOM model
- Verification: Janzen et al (2005), river plume dynamics



Data Sets Available

- NOAA Bathymetry
- USGS Stream Gauging (Kennebec, Androscoggin, Sheepscot, and Presumpscot Rivers)
- NOAA NOS COOPS, 8418150 Portland, ME water level
- NOAA, NDBC, Buoy 44007
- US Army Corp, Wave Information Study (WIS) , wind and wave hindcast
- NOAA, NEFSC Drifters and temperature
- Gulf of Maine, Observing System
  - Buoy C, 2002-2009
  - Buoy D (Bowdoin), 2008 to present



Data Sets from Programs

- ECOHAB (Janzen et al, 2005)

Table 1
Details of data collected during 1998 ECOHAB-GOM

Data type	Station/transect ID	Location (lat/lon) survey names	Water depth	Deployment dates 1998	Instrument/sensor (depth m)
Mooring	MD1 (Inner shelf)	43.6083N, −69.8697W	85.1 m	04/02 08/09	VACM (3,5,27) Temp (1,5,27) Salinity (1,27)
Mooring	MD2 (Bay entrance)	43.6870N, −69.9072W	39.1 m	04/02 08/09	ADCP (32.1) VACM (3,5,31) Temp (1,31) Salinity (3,31)
Mooring	MD3 (Inner Casco Bay)	43.7312N, −69.8945W	17.2 m	04/02 08/09	ADCP (16) Temp (1) Sal (1)
Hydrography	A,B,D,E,F B,D,E,F B,D B,D,E,F D B,D,E,F B,D B,D,E,F B,D B,D,E,F B,D	CB01 CB02 CB03 CB04 CB05 CB06 CB07 CB08 CB09 CB10 CB11		04/06–04/09 04/21–04/23 04/29–04/30 05/04–05/07 05/14 05/18–05/20 05/27–05/28 06/02–06/04 06/10–06/11 06/17–06/19 06/29–06/30	
Drifters	MD2 deployment	43.6870N, −69.9072W	39.1 m	04/21–04/23 05/04–05/07 05/14–05/21 05/18–05/20 05/27–05/31 06/02–06/05 06/19–06/20	
Sea level	Portland, ME Station 8418150	43.657N, −70.247W	NA	1983–2001	
Meteorology	SE of Portland, ME Station EB44007	43.54N, −70.14W	Anemometer height 5 m		Water depth 18.6 m

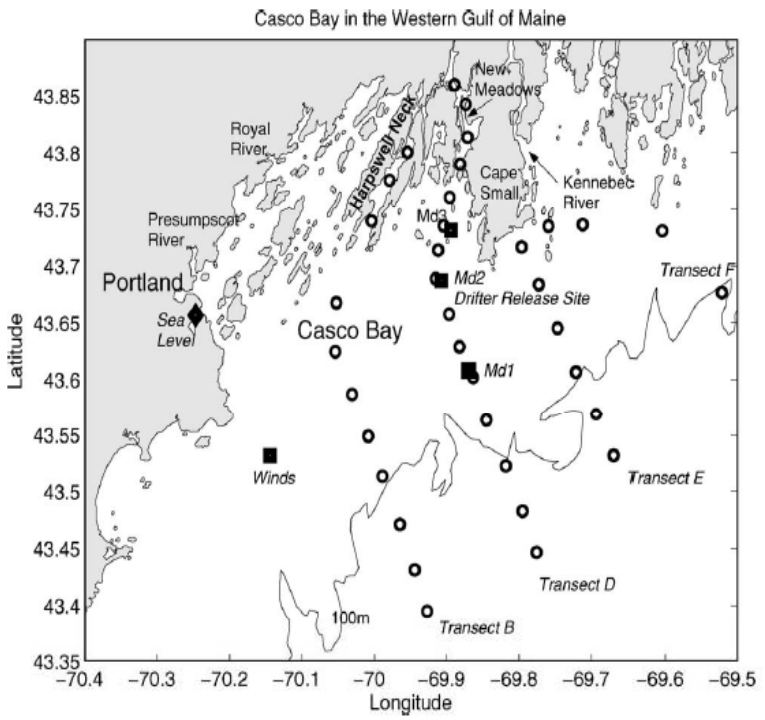
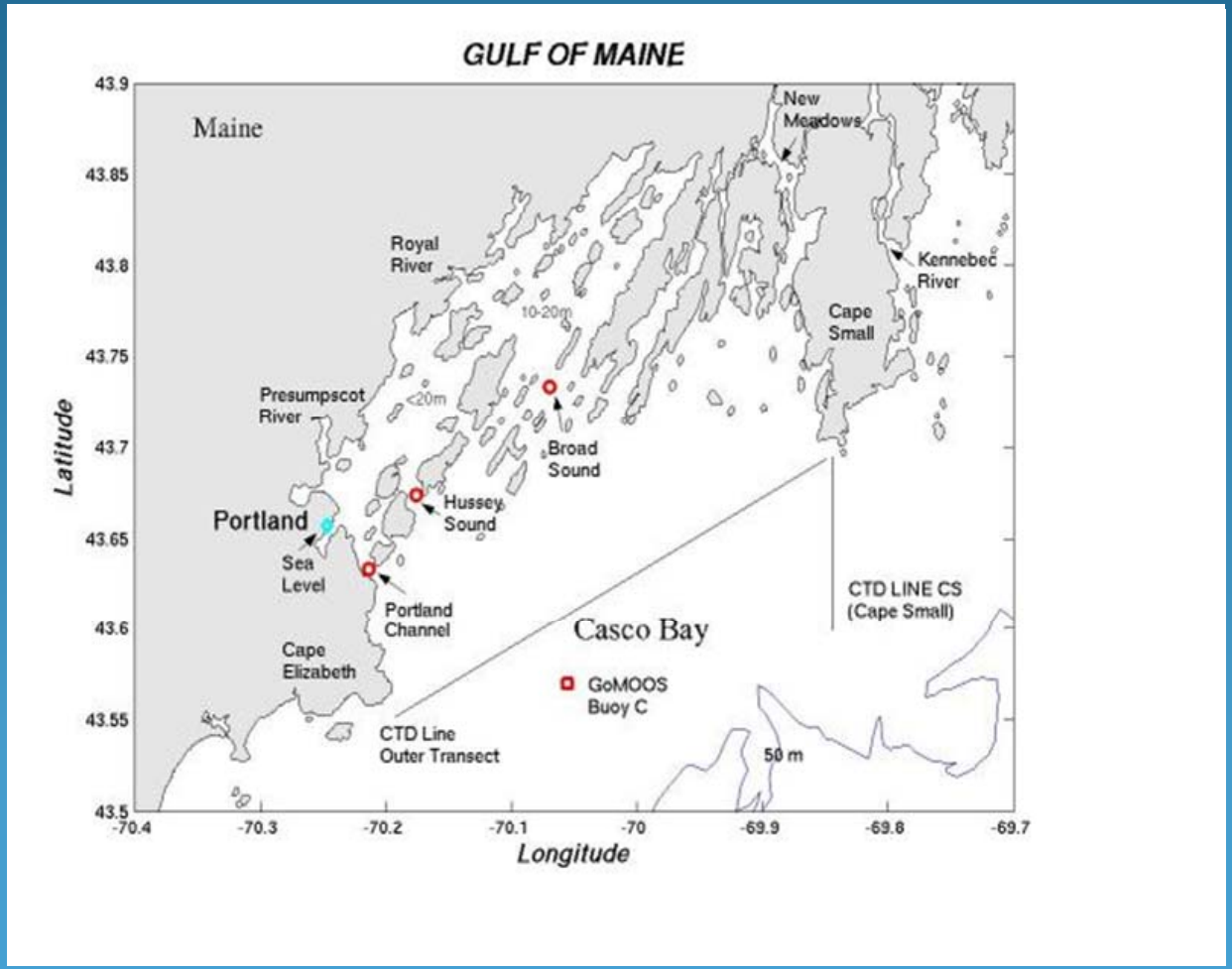
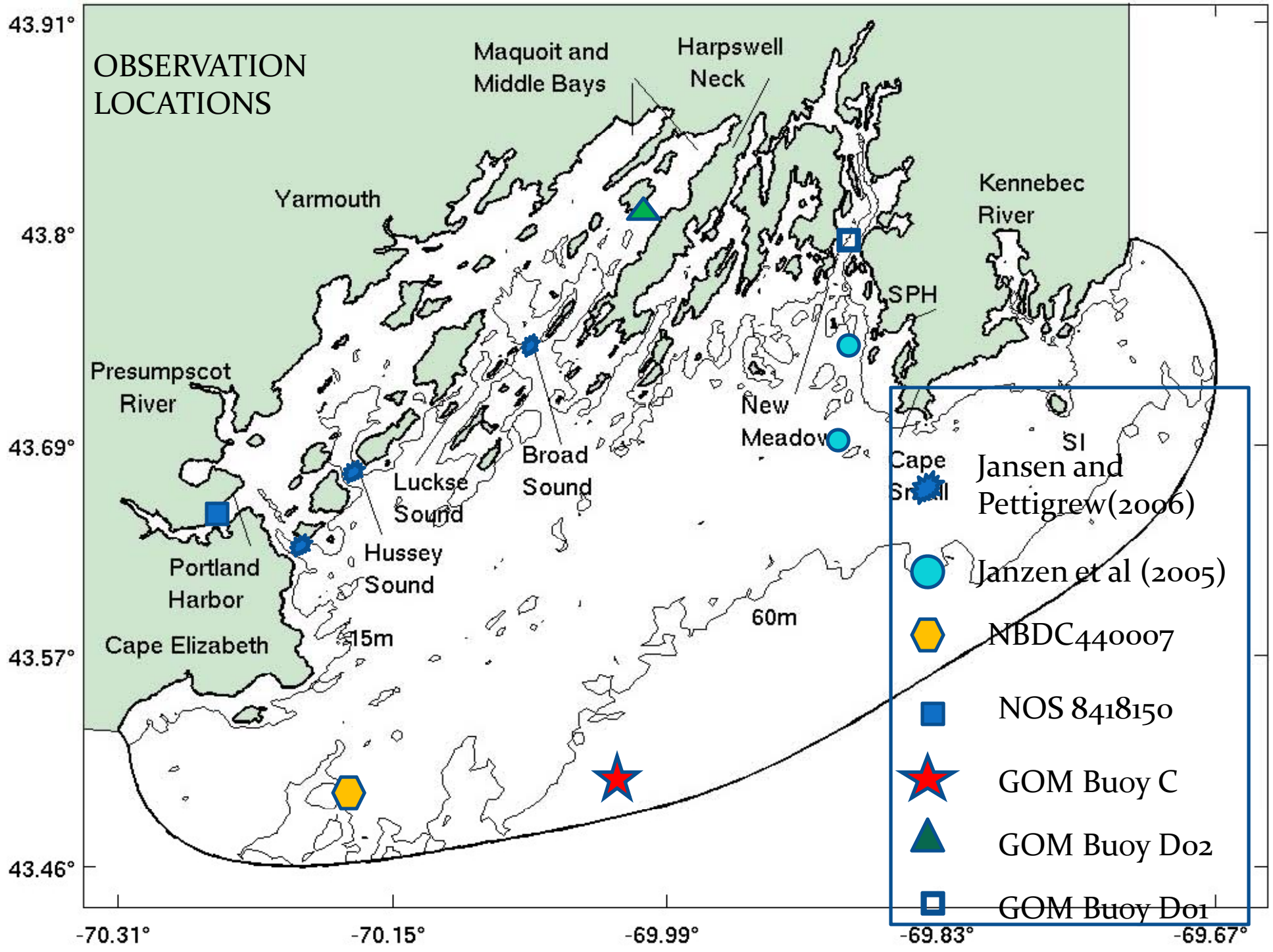


Fig. 1. Map of Casco Bay, showing CTD survey stations and mooring locations.

MOSAC/DEP Janzen and Pettigrew(2006) (in progress)




OBSERVATION LOCATIONS
Maquoit and Middle Bays
Harpswell Neck
Yarmouth
Kennebec River
SPH
Presumpscot River
New Meadow
Broad Sound
Luckse Sound
Hussey Sound
Portland Harbor
Cape Elizabeth
15m
60m
43.91°
43.8°
43.69°
43.57°
43.46°
-70.31°
-70.15°
-69.99°
-69.83°
-69.67°
Jansen and Pettigrew(2006)
Janzen et al (2005)
NBDC440007
NOS 8418150
GOM Buoy C
GOM Buoy D02
GOM Buoy D01

Recommended Model and Application Attributes

- 3 (or 2 D), structured or unstructured grid, solve 3-D primitive equations, include wetting and drying boundary.
- Domain: Casco Bay, adjacent shelf (80 m) and river discharge from Androscoggin and Kennebec Rivers.
- Resolution: 150 m inner bay, 500 m to 3 km offshore; 10 to 20 levels depending on application.
- Boundary conditions: USGS stream forcing, NOAA atmospheric forcing, large domain model for Gulf of Maine or data based estimates, depending on application. Concern about two way coupling, locally forced or driven.

Observations of historical modeling efforts

- Rich history of modeling in Casco Bay and the Gulf of Maine. Many models and options available.
- Field observations have been quite limited and represent primary impediment to future modeling investigations.
- Assessment based on forcing

  Tides- good understanding of surface elevation response, more limited for basin wide currents, particularly in the transition to inner bay regions and role of wetting and drying.

  Winds- some insight from models but no comparisons to data, no analysis of role of wind on exchange between inner and outer bay.

Observations of historical modeling efforts (cont'd)

Density (river discharge)- Initial understanding of role of Androscoggin Kennebec River plume and impact on near shore circulation, insight into role of wetting and drying on plume dynamics, limited insight into impact on circulation in Casco Bay or offshore.

Interaction between Casco Bay and adjacent offshore waters is critical to key management issues and modeling studies and will need careful consideration of the linkage and interaction between basin wide or coastal Maine circulation model and that for the bay.

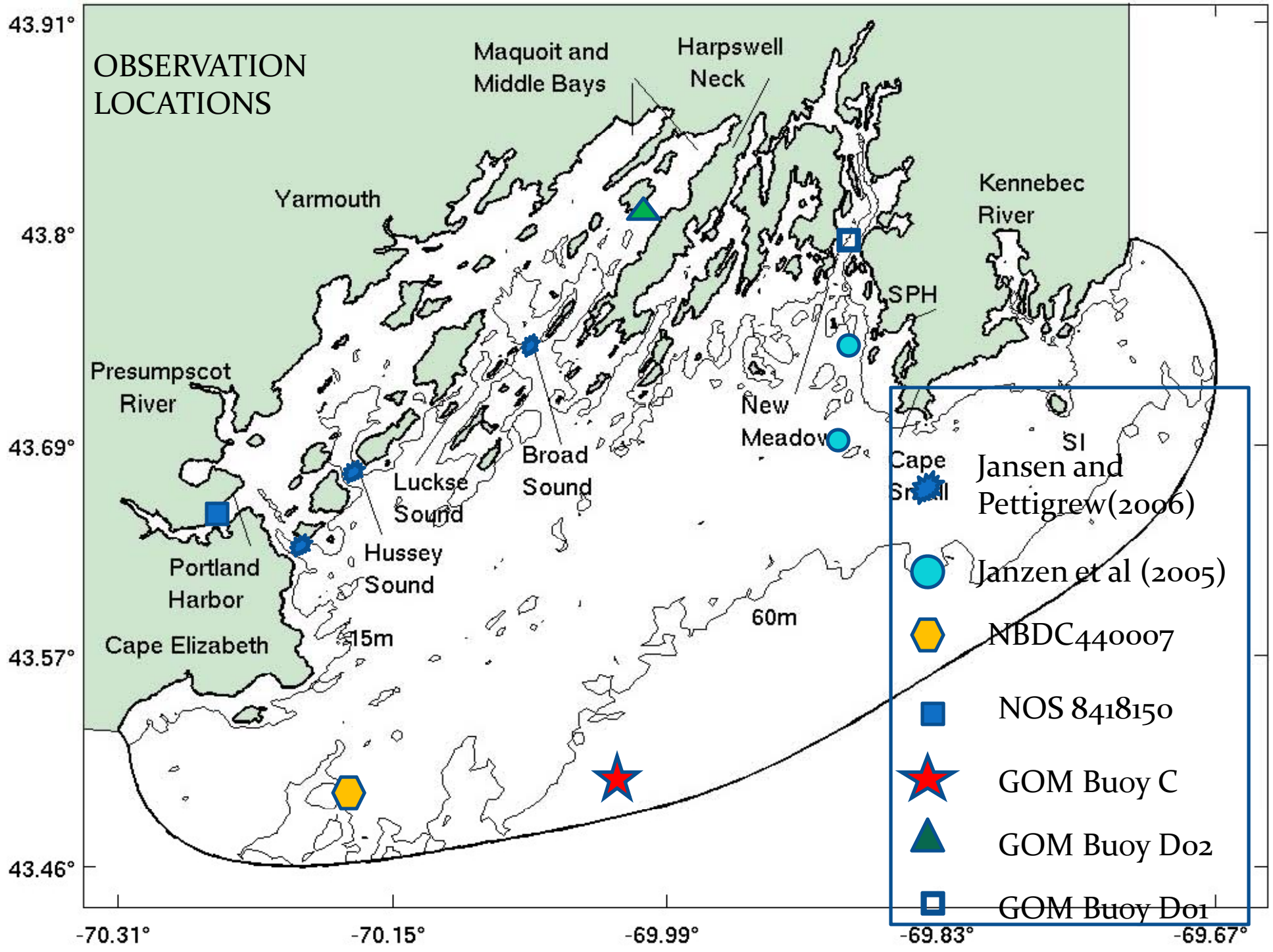
Overarching recommendations

- Program of modeling and data collection should be carefully integrated to answer key management questions.
- Modeling program should be designed so confidence builds with time in model's performance.
- For most key management drivers, circulation is intermediate step to reach management goal, need to consider transport modeling system as well (particle based for many applications)

Some thoughts on future observation programs

Insight gained from Janzen and Pettigrew (1996) MOSAC/DEP study.

- River flow data for Kennebec and Androscoggin.
- Meteorological data from NOAA 44007 buoy.
- Water level data from NOAA Portland station.
- Moored ADCP and CTD data for major passages between inner and outer bay, cross and along shelf offshore.
- CTD survey of shelf area, concentration of sampling in vicinity of Kennebec and Androscoggin River discharge and eastern Casco Bay. During peak river discharge.
- Towed ADCP and CTD measurements along selected transect lines: major passages, inner harbor and adjacent shelf, tidal cycle time scales.
- Sampling period must capture pre, during, and post major spring runoff event, ice free period.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