Rise of the Machines

Themes
- Some of the new technologies your generation will have
- There are MANY UNKNOWN UNKNOWNS
- Automation is coming
Natural Variability: Where do you put a mooring? Where do you drive the ship? When should you be out there?

Color variability at multiple scales around Tasmania from CZCS (winds? currents? bottom topography?)

Simulations of required number of moorings to predict THE SIGN of cross shelf carbon transport
Rumsfeld “Unknown unknowns”

Prior to Deployment

After to Deployment
Rumsfeld “Unknown unknowns”
HOW WE ARE TRAINED TO GO TO SEA
Ocean is hard to sample
Technology will rescue us!!!!
Satellites
-Thousands of satellites
-After the ships one of the great technical revolutions for oceanography
AUVs: They can be big

Autosub
Southampton Oceanography Center UK

Hugin
Kongsberg Simrad, Norway

Martin-600
Maridan, Denmark

Explorer family,
ISE research, Canada

Odyssey,
Bluefin Robotics, USA

Thanks to Gwynn Griffiths
AUVs: They can be small

- Slocum gliders
- Seaglider
- Spray
- REMUS
- Mauve
- C-Scout
- Gavia

Thanks to Gwynn Griffiths
The Communication Revolution
Darwin’s Odyssey
The Communication Revolution
Darwin’s Odyssey
The Communication Revolution
Darwin’s Odyssey
The Communication Revolution
Darwin’s Odyssey
Remote Sensing

Robots

3-D Nowcasts

+ +

Nested Models

Data Assimilation

4-D Forecasts

54DVAR procedure

Lagrange function $L = (x - F(x))^2$ + $\sum_{i=1}^{m} (x_{i} - S_{i})^2$ + $k = 0$ (lagrangian multiplier) $k = 0$ (lagrangian multiplier) $k = 0$ (lagrangian multiplier) $k = 0$ (lagrangian multiplier)

x

\[ \frac{\partial}{\partial x} L = 0 \]

\[ \frac{\partial}{\partial k} L = 0 \]

54DVAR procedure

Nowcasts

4-D Forecasts

Robots

3-D Nowcasts

Nested Models
Lets say you are hunting “whales”

Knowledge of the environment will give you a tactical advantage
Knowledge of future environment will give you a bigger tactical advantage

No in situ data into the model

BSP in situ data into the model

Gliders (4) in situ data into the model
Science enabled by social networking
Network allows for construction of ad hoc networks when needed

**Contributed Assets:**
- HF Radar Networks
  - USF, USM
- Gliders
  - iRobot, Mote, Rutgers, SIO, USF, Navy
- Drifters & Profilers
  - Horizon Marine, Navy
- Satellite Imagery
  - CSTARS, UDel
- Ocean Forecasts
  - Navy, NCSU
- Data/Web Services
  - ASA, Rutgers, SIO

USM HFR validation of SABGOM Forecast in region with satellite detected oil slicks
Data and models for situations where the University does not allow me to send graduate students.

Hurricane Irene
August 2011
Challenges in Predicting the Intensity of Storms

Scientists say that it is much easier to accurately predict what path a hurricane will take.

By HENRY FOUNTAIN
Published: August 27, 2011
Challenges in Predicting the Intensity of Storms

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Two Gliders Deployed by MARACOOS in Hurricane Irene

RU16
- Deployed for EPA.
- Map bottom dissolved oxygen.
- Provided data on mixing during storm.

RU23
- Deployed for MARACOOS.
- Map subsurface T/S structure for fisheries.
- Damaged early - drifter
- Recovered by fisherman
- Provided data on inertial currents during storm.

Sunday, July 1, 12
Hurricane Irene

Temperature:

Salinity:

% Oxygen:

Last Surfacing: ru16

Current Waypoint: ru16

Sunday, July 1, 12
Winds assuming warm temperatures

Winds using glider temperatures
Optical data collected by gliders

Phytoplankton communities

CDOM

Backscatter

Depth (m)

Distance Offshore

% phytoplankton (440 nm)

% detritus (440 nm)

% CDOM (440 nm)
Diverse funding with an evolving suite of questions

1996-2001
Local scale observatories

Upwelling, hypoxia & coastal predictive skill

Schofield et al 2002
Glenn & Schofield 2003

2001-2006
Regional scale observatories

Shelf transport, land/ocean communication

Glenn & Schofield 2009

2006-2011
Large marine ecosystem observatories

Ecosystem dynamics, climate scale mediated change

Schofield et al. 2011

Schofield et al 2002
Glenn & Schofield 2003

Shelf transport, land/ocean communication

Glenn & Schofield 2009

Ecosystem dynamics, climate scale mediated change

Schofield et al. 2011
Phase development: The nearshore coastal system
Question driving science deployment: Are humans causing coastal hypoxia?
Phase development: The nearshore coastal system
Question driving science deployment: Are humans causing coastal hypoxia?
July 6, '98 - AVHRR

Temperature °C

| 19 | 20 | 21 | 22 | 24 |

Historical Hypoxia/Anoxia Field Station

July 11, '98 - SeaWiFS

Chlor-a (mg/m³)

| .1 | .3 | .5 | 1 | 2 | 4 |

Field Station

LEO
Figure 6

Song et al (JGR) 2002

North

B) Cape May delta

C) LEO delta

D) Barnegat delta

8/5/93 CTD Transect

Temp (°C)

10.8

12.2

13.6

15.0

16.4

17.8

19.2

20.6

22.0

23.4

24.8

E) Wind

F) CODAR & SST – 7/98
30 X 30 km LEO CPSE
An Integrated Observatory
Month Long Experimental Effort

2001 Real-time Ensemble Forecasts
Real-time validation of the ensemble forecasts

- In an observationally rich environment, ensemble forecasts can be compared to real-time data to assess which model is closer to reality and try to understand why.
Shipboard surveys

![MiniBat Temperature Section: Date: 980723, Leg 3](image1)

![Surface Towed-ADCP Velocity Section: Date: 980723, Leg 03](image2)

![REMUS ADCP Velocity Section: Date: 980723](image3)

![MiniBat Fluorometer Section: Date: 980723, Leg 3](image4)
Adaptive Sampling of Resolved Scales - Shipboard & AUV surveys

North Velocity

North Fluorometer

South, offshore flow
Optical profiler deployed on LEO-15 guest port

Nerd summer camp

Depth (m)

Time (hr)

Absorption at 440 nm (m$^{-1}$)

Tidal cycle

Upwelling
That Pristine Blue NJ Water
POC represents potentially 182 µmol oxygen/kg. Upwelling can account for spatially distribution of recurrent upwelling eddies.
What is happening in the northern zone?

Science focus Land-Ocean: How does the dynamics in the physical oceanography influence the transport and transformation of the particulate and dissolved matter in coastal buoyant plumes?

Downwelling

Upwelling

Southern flowing turbid plume

Eastern offshore flowing shallow turbid plume
Input of organic matter is pulsed to coastal system as floods and punctuated tidal squirts. Example, a tidal bore as it flows past the R/V Cape Hatteras.
HF RADAR tracking and dye labeling of plume

Wind data from NOAA NDBC station at Ambrose Light
HF RADAR tracking and dye labeling of plume
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The diagram illustrates the relationship between salinity and percent oxygen saturation for Hudson Bay and the ocean. The data points show a trend of decreasing oxygen saturation with increasing salinity, with a clear distinction between the Hudson Bay and ocean regions. The LATTE April 2005 data is plotted, indicating a specific time frame for the measurements.
>20 µm particulate trace metals and phosphorus - Ag, Al, Cr, Cu, Fe, P, Pb

50 ng L⁻¹ (Al, Fe, P µg L⁻¹; Ag x 10, Al x 5, P x 10)
Freshwater Plume Moves Out Across the Shelf: Hudson Shelf Valley
“The survey began on the 'Highway'. We were near the glider when it surfaced. We saw currents ripping southward in a 10 m thick layer of freshwater along the highway -- perhaps the most significant freshwater transport we saw all week.”

“Perhaps the most perplexing to me is 'the Highway' and why there has been a lack of a strong coastally trapped flow this week.”

--- Bob Chant aboard the Cape Hatteras, April 21, 2005
Temperature stratification dominates the hydrography of the shelf. Temperature stratification extreme, 25 to 8 degrees in a only three meters. Salinity gradients show inshore and offshore gradients.
Mode 1: Largest and most recurrent bloom. Occurs during the dimmest months of the year which is interesting.

Mode 2: The canonical spring bloom which occurs prior to strong shelf stratification.
Dynamics in phytoplankton variance is described by 2 modes. Mode 1 occurs in the winter on the inner shelf. Mode 2 occurs in spring on the outer shelf. Summer phytoplankton explain little of the shelf-wide variance however is extremely important to the nearshore coastal ecosystems.
Numerical experiment: Measured wind and no wind in Zone 1

No wind condition, later bloom, larger bloom during darkest winter months, but integrated productivity over the winter is smaller by ~20%

Yi et al submitted
WHERE DO WE GO FROM HERE?

Machines have improved

A technicians solution in integrating the observatory components
WHERE DO WE GO FROM HERE?

Machines have improved

A technicians solution in integrating the observatory components

People need to sleep and are fragile

Humans become the bottle neck for collecting data bytes

Sunday, July 1, 12
WHERE DO WE GO FROM HERE?

Machines have improved

A technicians solution in integrating the observatory components

People need to sleep and are fragile

Humans become the bottle neck for collecting data bytes

Scientists need time to think

Oscar tries to reintegrate into society after the field experiments
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Idea of Test (May 2009)
↓
Virtual Test (Sep 2009)
↓
Wet Test (Nov 2009)
Scientists were distributed throughout the country & interacted in real-time
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Weather Forecasts
The OOI Observing System Experiment (OSE)

5 different satellite sensors
The OOI Observing System Experiment (OSE)

5 ocean numerical models run in forecast mode:
- 2 versions of ROMS
- 2 versions of HOPs
- 1 version of POM
Scientists could compare observations (single platform or means) with models (individual or means).
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009
The same for *in situ* measurements
The OOI Observing System Experiment (OSE)  
Nov 2 to Nov 13 2009

- Known constraints (slow 0.5 knot, Battery, shipping lanes)
- Uncertain constraints (time-varying 3D currents)
- Operate autonomously & re-plan daily
- From A to B in the shortest time
- Follow a time-varying feature (shelf-slope salinity intrusion)
The OOI Observing System Experiment (OSE)

Scientific community

Two-phase planning

Marine operators
Distributed decision making using live web service tools
The OOI Observing System Experiment (OSE)

How well did we do?

- Increase model resolution
- Reduce forecast error

- ru05
- ru21
- ud134
- ru23

Position difference from plan (km)

Plan prediction accuracy

Day of operations

Resolution of forecast model grid
The OOI Observing System Experiment (OSE)

Science Event Manager
- Processes alerts and prioritizes response observations
- Schedules observations on EO-1
  - ASPEN
  - EO-1 Flight Dynamics
    - Tracks, orbit, overflights, momentum management

Scientists
- Priorities response observations

Science Agents
- Science Alerts
- Observation Requests

Hyperion on EO-1
- Updates to onboard plan

Science Community Workshop 1
Sunday, July 1, 12