I am an ocean scientist, not an engineers like all of you. So we will talk about a lot of new technologies but will try to focus on what things they can teach about the ocean.

A brief view of big ocean questions facing us. What technology do we need?

A look to where the ocean is going

What are the backbone technologies to ocean observatories

Case example I: Southern Ocean processes and a future observatory

Case example II: Transport of urbanized rivers on broad continental shelves

What are some of the big initiatives in the United States?
My father was a scientist/engineer from Sweden
I grew up surfing, swimming, skin diving, fishing, and scuba diving. The ocean has always been central to my life.
First cruise at 18, once science became an active hands-on experience, I loved it.
To look to the future it is useful to how far we have come?
Where were we 30 years ago?

Apple II Introduced
4K of Memory

Viking 1 lands on Mars
Modest change in HOV capabilities. Alvin launched stern first in 1990.
Alvin launched bow first in 2010. Biggest changes are in support ship.
Much greater change in capabilities of remotely operated vehicles, but not more vehicles. 1 ROV in National Facility. Several in private facilities.
Main satellite sensors used today were operating in 1990’s. Data access and quality is better.

Satellite Altimetry (Walter Munk described TOPEX/Poseidon as "the most successful ocean experiment of all times") has gone from one platform in 1992 to an array today.
Coastal Zone Color Scanner operated 1978 to 1986 and then a hiatus until 1997. A large array of ocean color missions with different functions:

### Ocean Colour Radiometry Missions

<table>
<thead>
<tr>
<th>Year</th>
<th>Mission</th>
<th>Status</th>
</tr>
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<tbody>
<tr>
<td>01</td>
<td>KOMPSAT-1/OSMI (KARI)</td>
<td>Launched</td>
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<tr>
<td>02</td>
<td>Oceansat-1/OCM (ISRO)</td>
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<tr>
<td>03</td>
<td>Envisat/MERIS (ESA)</td>
<td>Planned/Pending Approval</td>
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<td>04</td>
<td>POLDER-3 (CNES)</td>
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<td>05</td>
<td>MODIS-Aqua (NASA)</td>
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<td>06</td>
<td>MODIS-Terra (NASA)</td>
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<td>07</td>
<td>SeaWiFS (NASA)</td>
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<tr>
<td>08</td>
<td>MOS (DLR)</td>
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<td>09</td>
<td>COMS-1/GOCI (KARI)</td>
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<td>10</td>
<td>Oceansat-2/OCM-2 (ISRO)</td>
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<td>SENTINEL-3A (ESA/EUMETSAT)</td>
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<td>SENTINEL-3B</td>
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<td>GCOM-C SGLI (JAXA)</td>
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<td>GOCEP (NASA)</td>
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<td>NPOESS-VIIRS C1</td>
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</tr>
<tr>
<td>16</td>
<td>NPOESS-C2</td>
<td>Approved</td>
</tr>
</tbody>
</table>
Sea Surface Temperature – “NOAA has been providing research quality SST data continuously since 1981”

Other ocean relevant missions include winds – (scatterometer – QuikScat), precipitation (TRMM)

OCO/Atmospheric CO₂ – coming

Aquarius/Sea Surface Salinity - coming
Moorings – TAO array of 70 moorings completed in 1994

Current NDBC buoy array. Mostly for meteorology.
From this morning at 6AM
Gliders Provide an Adaptive Global Presence in the Ocean


Over 85441 km (Earth’s circ. ~ 40,000 km)
3970 days at sea, 516461 profiles

Liverpool Bay Coastal Observatory

Mid-Atlantic Shelf
West Florida Shelf
Mediterranean Sea
Perth, Australia
Glider data from this morning
Sensors:

1990 Vector averaging current meters, temperature and salinity (Seacat introduced 1986), data still recorded to magnetic tape in many cases. ADCP’s just entering the market.

Some biooptics

Sensors – 25 years ago ADCP’s were just entering the market and moored CTD’s barely available. Now biogeochem. sensors more widely available, an ADCP and CTD in every pot

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 97, NO. C5, PP. 7399-7412, 1992
doi:10.1029/92JC00408
Estimation of Seasonal Primary Production From Moored Optical Sensors in the Sargasso Sea
Challenge 3) Gliders are just the platform, what can we measure?

Rutgers, Webb Research, and Instrument Companies

Spiral Development Cycle

- Inception
- Elaboration
- Construction
- Transition

Design → Develop → Iterate → Deploy

Validate → Test → Refine → Promote
Couple data assimilative models to glider data.

S4DVAR procedure

- Lagrange function $L = J(x) = \sum \left( \frac{\partial J}{\partial x} - \nabla x \right)^2$
- $F = F(u(x))$
- $x_i = 0$

At optimum $x$, we require: $\frac{\partial J}{\partial x} = 0$

4-D Forecasts

3-D Nowcasts

Remote Sensing

Giders

3-D Nowcasts

Nested Models

Data Assimilation

4-D Forecasts
1990 – end of box models to low resolution (3x3 degree) 3D models for biogeochem.

Fig. 1. Structure of the HILDA model. The biosphere box is included only for calculating isotopic perturbations due to the anthropogenic CO₂ emissions, i.e., the Suess effect.

Temperature (°C) at 5 meters (SST); 5 July 1993

New Production, log₁₀(mmol N/m²/day); 5 July 1993

Figure 7. Snapshots of temperature (top) and new production (bottom) in a 0.1° resolution simulation of the North Atlantic. The temperature field reveals active mesoscale processes throughout the basin; biological uptake of nutrients is replete with mesoscale structure in nearly all areas except for the subpolar region, where production is still light limited in early July. Eddies play an important role in determining the mean.

Data communications – 1980 – 300 baud

Circa 1990 - 2400 to 4800 baud

WiFi 802.11g – 50,000,000 baud
Ship to shore communications – 1990 we used the ATS satellite on Saturday mornings served by a shore-based operator in Malabar, FL or San Diego, CA, who made a collect telephone call. The whole fleet listened in on each conversation:

“Hello honey, how are the kids? And you have to say “over”, over.”
HiSeasNet Technology

- Uses marine-stabilized antennas
  - 2.4m dishes for larger vessels (C-band)
  - 1m-1.5m dishes for smaller vessels (Ku-band)
- Connectivity is all IP based
  - 64kbps to 96kbps ship-to-shore
  - Shared shore-to-ship links between 192kbps (3 ships) to 256kbps (5 ships)
  - Allows for flexibility of any type of traffic to be sent (e-mail, web, FTP, SSH, IM, VoIP, etc.)
Sustained Observatory Operations from Multiple Locations

McDonald’s WiFi

Scott’s Living Room – Glider Recovery in Hawaii
Gliders Provide
A Distributed Subsurface Mobile Sensor Networks:

In Navy talk:
Ideal for asymmetric needs
given the ability for sustained persistent and linger capacity

Take home: We are now capable of sustained observations

Challenges?
Batteries – more power

1990 rechargeable Lead acid energy density 0.14 MJ/kg

1990 primary alkaline 0.4-0.59 MJ/kg

2010 rechargeable Lithium ion 0.5 MJ/kg

2010 primary Lithium 1 MJ/kg
**Mission Complete:** Scarlet Knight is the first underwater robot to cross an ocean basin

- 221 Days
- 7,409 km
- 11,000 Dives
- 11,000 Climbs

*Energy Equivalent of 8 minutes power for lights on the Rockefeller Center Tree.*

Tuckerton, New Jersey, USA

Baiona, Galicia, Spain
Mission Complete: Scarlet Knight is the first underwater robot to cross an ocean basin

*A hero’s Welcome, December 9, 2009*
Imaging – a scientific CCD with much < 0.5 Mpixel and 10’s of $1k was the 1990 standard. Now, high def, stereo..... Red – 14 Mpixel...
Analytical capabilities allowing greater number of samples to be analyzed.

Late 1980’s state of the art for Fe – meridional section from Alaska to south of Equator and zonal section from California to Hawaii for iron. About 80 samples each, and each took 2 years in a shore based lab to analyze.
Mid-2000’s – 720 Fe samples analyzed at sea.

Figure 1. Property distributions between 62°N and 5°S, contoured using Ocean Data View of (top) dissolved Al, (nM) overlain with potential density contours in kg m$^{-3}$; (middle) Fe, (nM) overlain with oxygen contours in μM; (bottom) salinity, (PSS78) overlain with potential density contours in kg m$^{-3}$. 
Why is this important now?

Growing Human Population – Greatest in Less Developed Countries

Reduced Fish Population – Fishing Displaced to Less Developed Countries