Seaglider: Capabilities, achievements, development efforts

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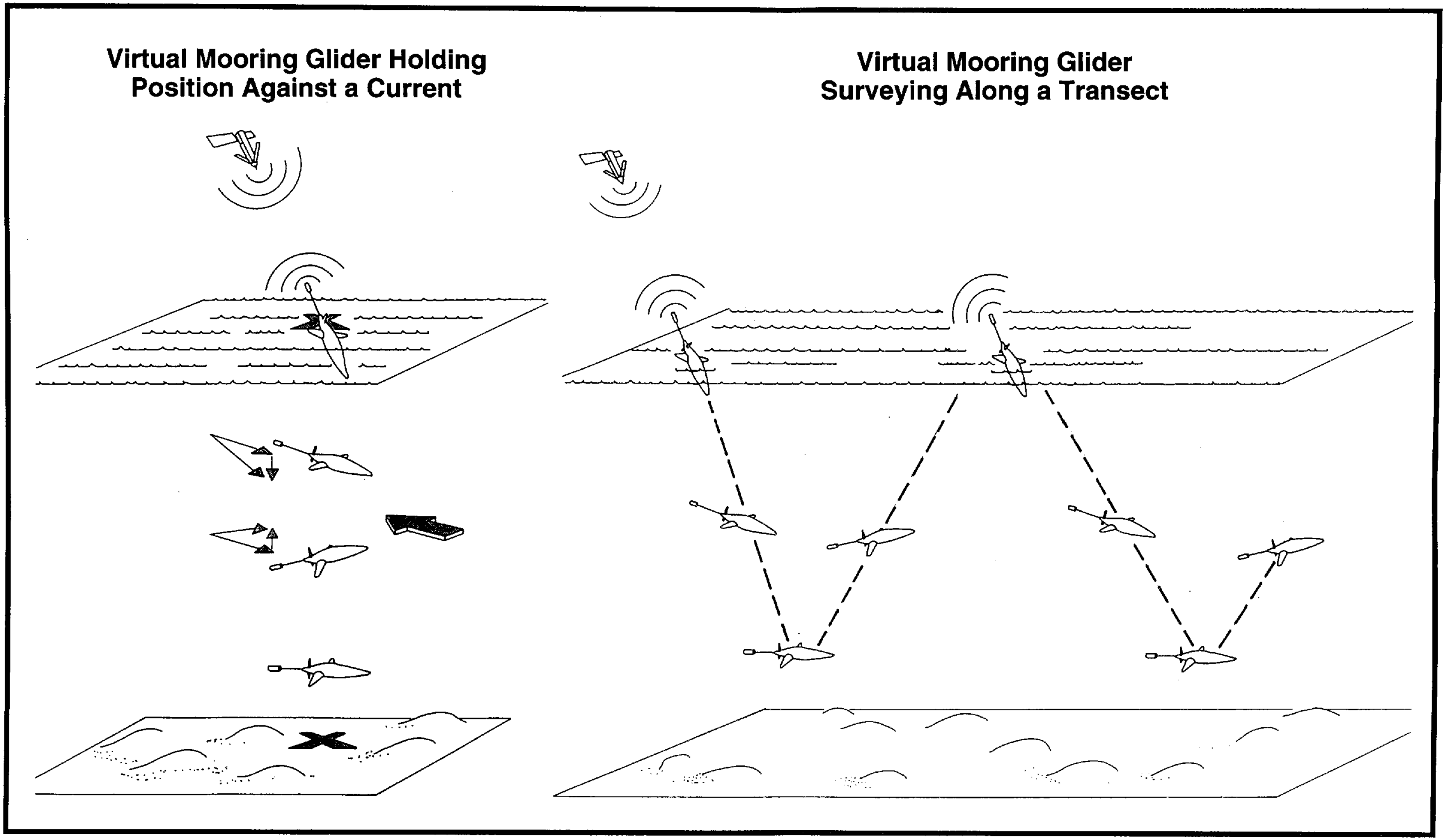
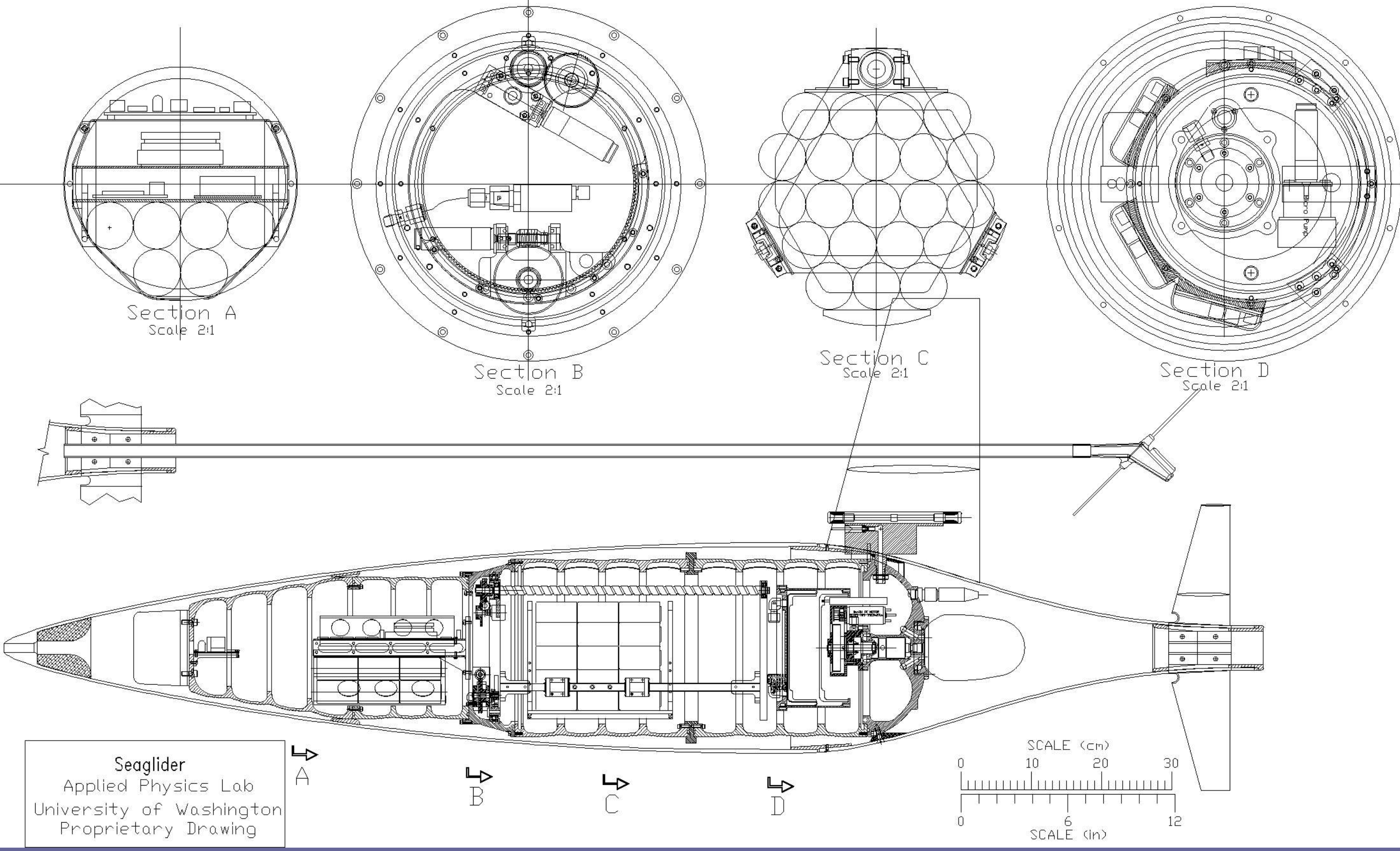

Virtual Mooring Glider Holding Position Against a Current
Virtual Mooring Glider Surveying Along a Transect

Autonomous, Telemetering Profiling Vehicle

- Hull length: 1.8 m
- Wing span: 1.0 m
- Mass: 52 kg
- Easy to deploy and recover- RIBs, fishing boats, research vessels, aircraft (?).

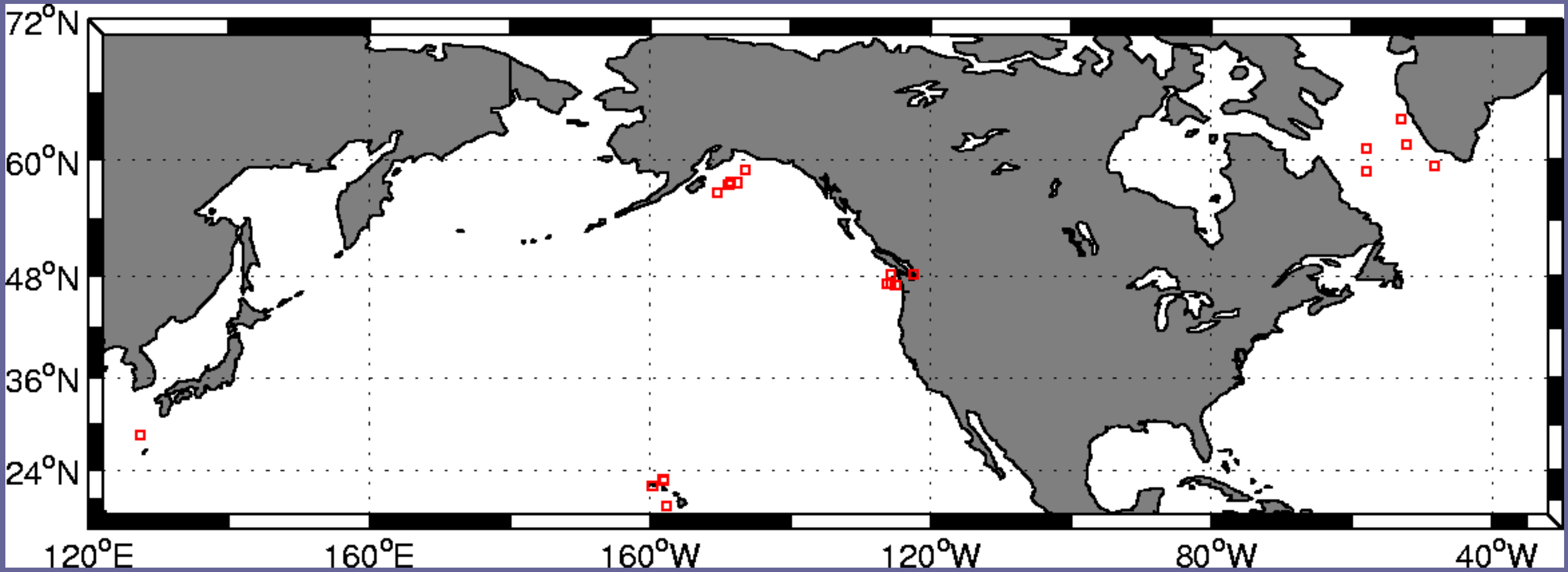
- Surface to 1000 m.
- Horizontal speed 0.25 m/s (22 km/day)
- Nominal vertical speed 0.1 m/s.
- Current endurance: 600 dives to 1000 m, 3600 km track (environment dependent).

- Strain gauge pressure (now 0.04%)
- Seabird temperature, conductivity and dissolved oxygen (free-flow).
- Omni-directional, low frequency altimetry.
- Depth-averaged flow (predicted-actual position).
- Vertical velocity (predicted-actual vertical speed).
- Vertical resolution 0.5–1.0 m.


Section A
Scale 2:1
Section B
Scale 2:1
Section C
Scale 2:1
Section D
Scale 2:1
Seaglider
Applied Physics Lab
University of Washington
Proprietary Drawing
A
B
C
D
SCALE (cm)
0
10
20
30
0
6
12
SCALE (in)

Glider Deployments

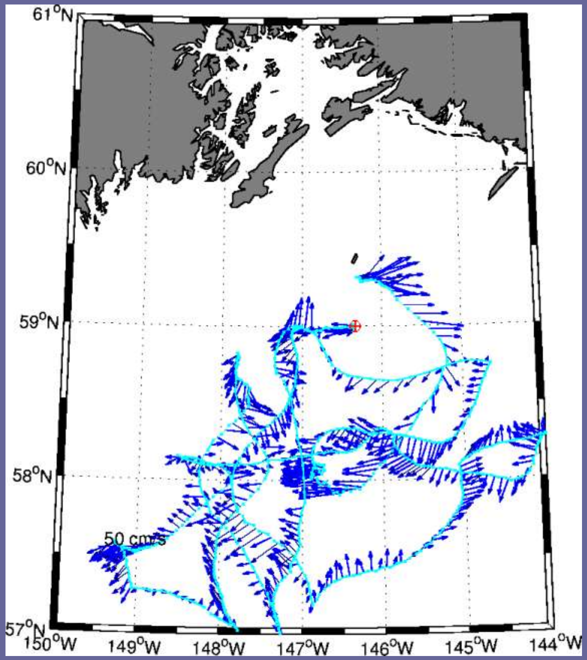
- Deployments exceeding 5 months off Washington Coast (Eriksen and Lee), Gulf of Alaska (Lee and Eriksen), Labrador Sea (Eriksen and Rhines), North Pacific (Howe and Mercer). Eight such missions to date.
- Currently: Washington coast, Hawaii, Labrador Sea.
- From September 2003 (start of first complete mission) to March 2005 (last time I counted), the program had accumulated 1650 glider-days and covered 25000 km of survey track.



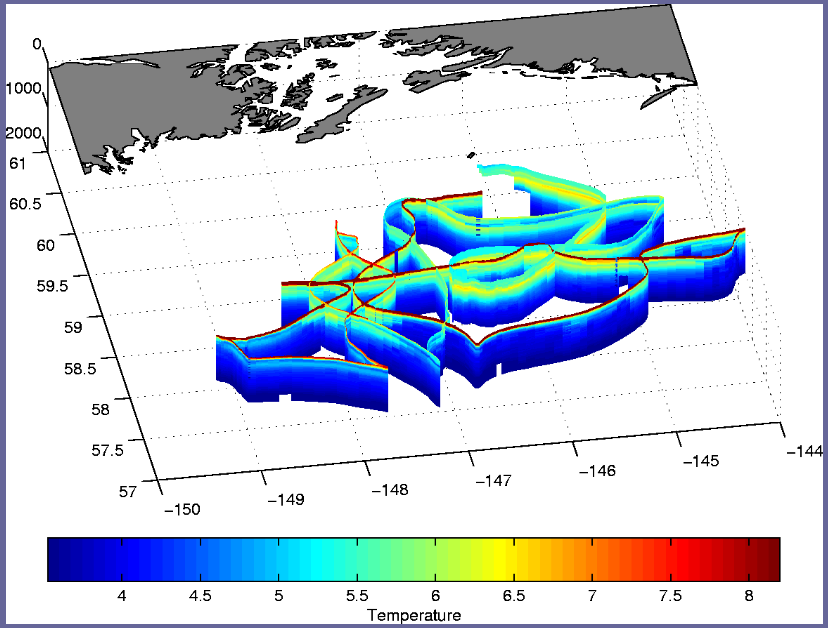
Glider Deployments (Continued)

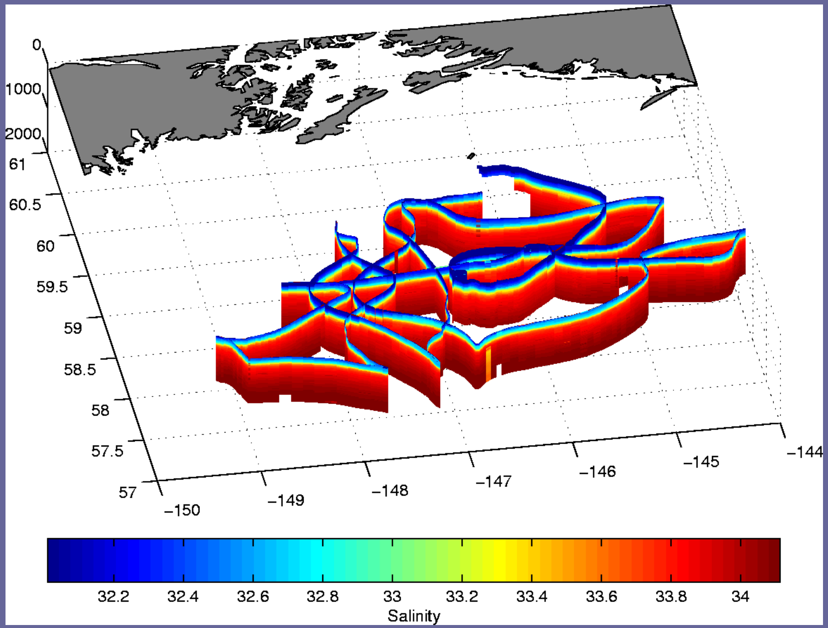
- From late August to early October 2004, two groups working together fielded 7 vehicles in 3 colors, spanning 180 degrees of longitude in two oceans. All deployments executed within 2-month time frame.
- Five vehicles completed 5+ month missions, four of them successively breaking endurance records. Another vehicle operated in Kuroshio as part of a short-term Navy exercise.
- Current record is 663 dives over 217 days and 3970 km over ground (SG014 in Labrador Sea).

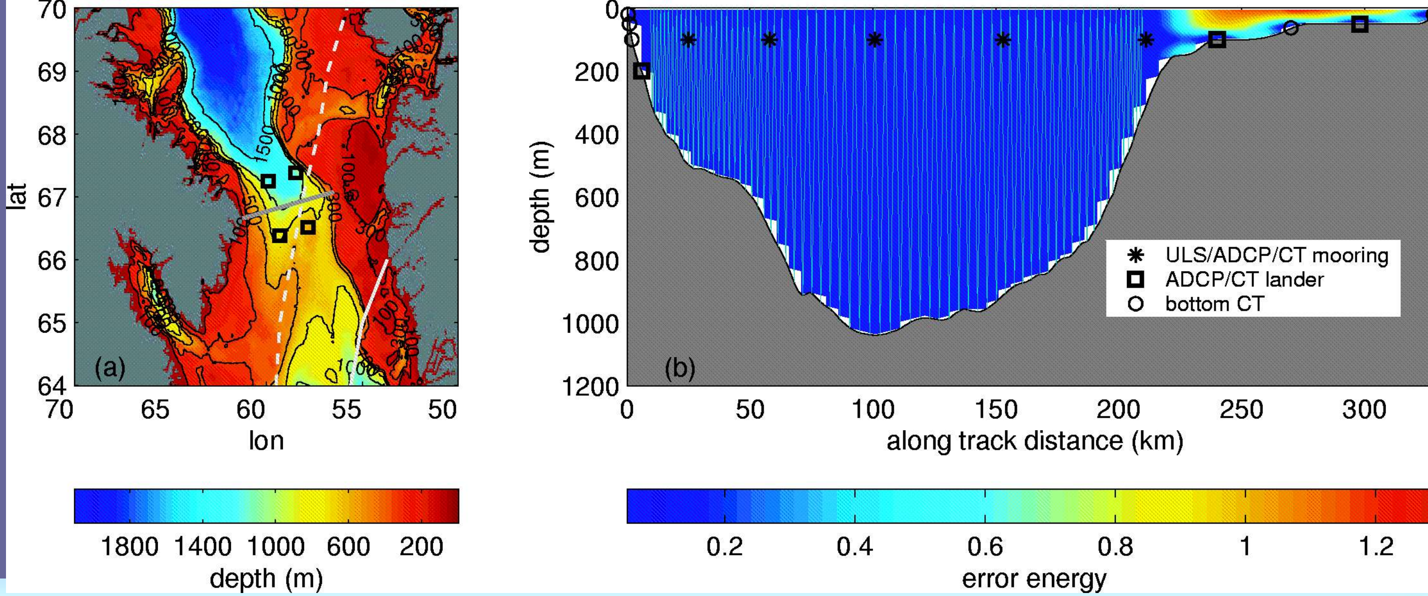
SG011 Gulf of Alaska
March – August 2004



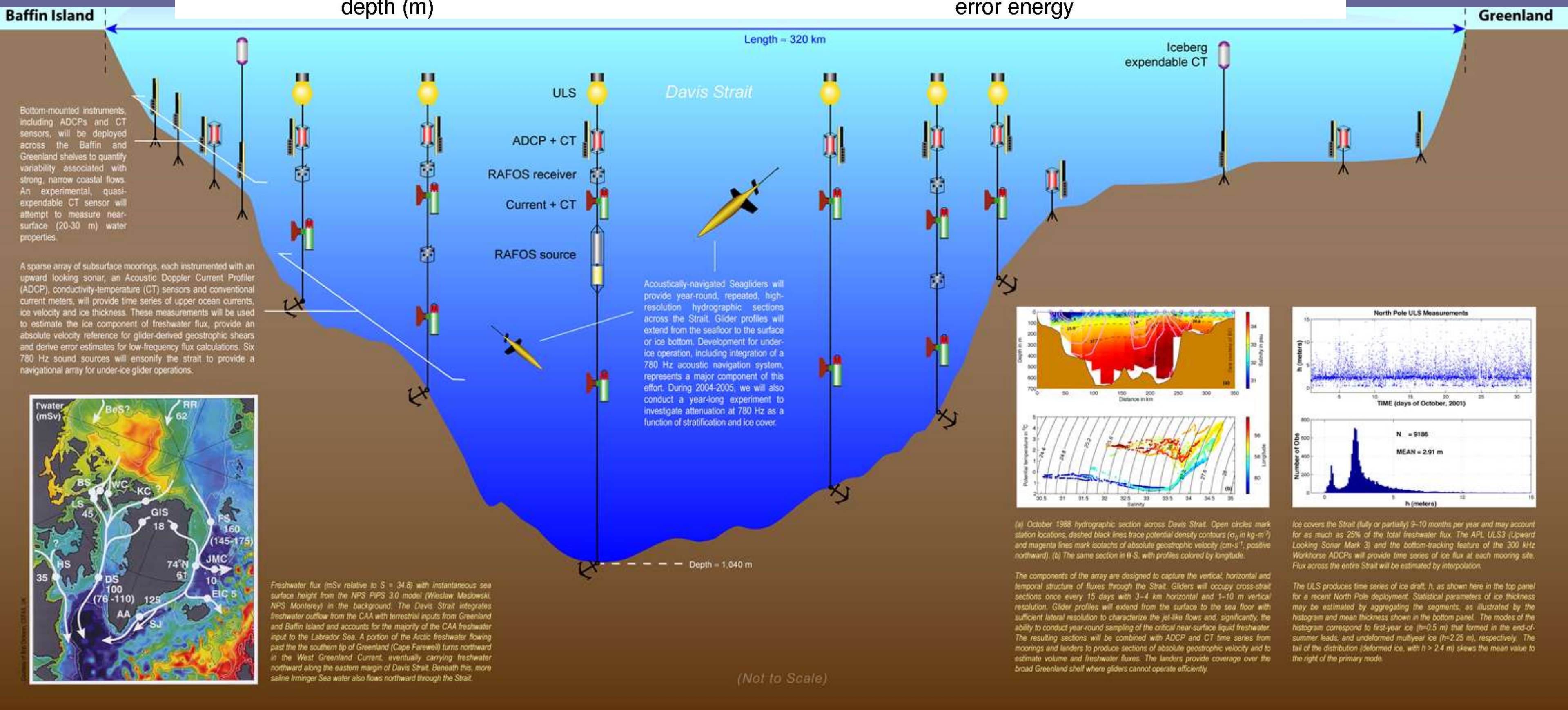
- First complete mission for Alaska GLOBEC project (Lee and Eriksen) after two lost gliders.
- First mission in which we tried to sample a translating eddy.
- Plots taken directly from real-time operations web site: http://iop.apl.washington.edu/seaglider/ops.html.







(a)
lat
lon
1500
1000
depth (m)
1800 1400 1000 600 200
(b)
depth (m)
along track distance (km)
ULS/ADCP/CT mooring
ADCP/CT lander
bottom CT
error energy
0.2 0.4 0.6 0.8 1 1.2

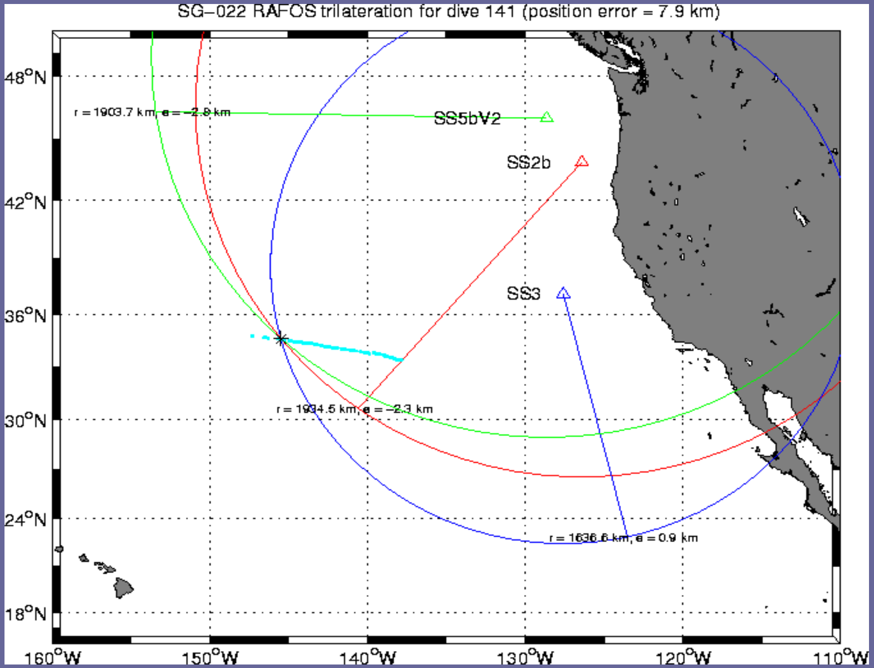


Baffin Island
Greenland
Length ≈ 320 km
Davis Strait
Iceberg expendable CT
ULS
ADCP + CT
RAFOS receiver
Current + CT
RAFOS source
Depth ≈ 1,040 m
(Not to Scale)
Bottom-mounted instruments, including ADCPs and CT sensors, will be deployed across the Baffin and Greenland shelves to quantify variability associated with strong, narrow coastal flows. An experimental, quasi-expendable CT sensor will attempt to measure near-surface (20-30 m) water properties.
A sparse array of subsurface moorings, each instrumented with an upward looking sonar, an Acoustic Doppler Current Profiler (ADCP), conductivity-temperature (CT) sensors and conventional current meters, will provide time series of upper ocean currents, ice velocity and ice thickness. These measurements will be used to estimate the ice component of freshwater flux, provide an absolute velocity reference for glider-derived geostrophic shears and derive error estimates for low-frequency flux calculations. Six 780 Hz sound sources will ensonify the strait to provide a navigational array for under-ice glider operations.
Acoustically-navigated Seagliders will provide year-round, repeated, high-resolution hydrographic sections across the Strait. Glider profiles will extend from the seafloor to the surface or ice bottom. Development for under-ice operation, including integration of a 780 Hz acoustic navigation system, represents a major component of this effort. During 2004-2005, we will also conduct a year-long experiment to investigate attenuation at 780 Hz as a function of stratification and ice cover.
f'water (mSv)
Freshwater flux (mSv relative to S = 34.8) with instantaneous sea surface height from the NPS PIPS 3.0 model (Wieslaw Maslowski, NPS Monterey) in the background. The Davis Strait integrates freshwater outflow from the CAA with terrestrial inputs from Greenland and Baffin Island and accounts for the majority of the CAA freshwater input to the Labrador Sea. A portion of the Arctic freshwater flowing past the the southern tip of Greenland (Cape Farewell) turns northward in the West Greenland Current, eventually carrying freshwater northward along the eastern margin of Davis Strait. Beneath this, more saline Irminger Sea water also flows northward through the Strait.
North Pole ULS Measurements
TIME (days of October, 2001)
h (meters)
N = 9186
MEAN = 2.91 m
(a) October 1988 hydrographic section across Davis Strait. Open circles mark station locations, dashed black lines trace potential density contours (σ_0 in kg·m⁻³) and magenta lines mark isotachs of absolute geostrophic velocity (cm·s⁻¹, positive northward). (b) The same section in θ-S, with profiles colored by longitude.
The components of the array are designed to capture the vertical, horizontal and temporal structure of fluxes through the Strait. Gliders will occupy cross-strait sections once every 15 days with 3–4 km horizontal and 1–10 m vertical resolution. Glider profiles will extend from the surface to the sea floor with sufficient lateral resolution to characterize the jet-like flows and, significantly, the ability to conduct year-round sampling of the critical near-surface liquid freshwater. The resulting sections will be combined with ADCP and CT time series from moorings and landers to produce sections of absolute geostrophic velocity and to estimate volume and freshwater fluxes. The landers provide coverage over the broad Greenland shelf where gliders cannot operate efficiently.
Ice covers the Strait (fully or partially) 9–10 months per year and may account for as much as 25% of the total freshwater flux. The APL ULS3 (Upward Looking Sonar Mark 3) and the bottom-tracking feature of the 300 kHz Workhorse ADCPs will provide time series of ice flux at each mooring site. Flux across the entire Strait will be estimated by interpolation.
The ULS produces time series of ice draft, h, as shown here in the top panel for a recent North Pole deployment. Statistical parameters of ice thickness may be estimated by aggregating the segments, as illustrated by the histogram and mean thickness shown in the bottom panel. The modes of the histogram correspond to first-year ice (h=0.5 m) that formed in the end-of-summer leads, and undeformed multiyear ice (h=2.25 m), respectively. The tail of the distribution (deformed ice, with h > 2.4 m) skews the mean value to the right of the primary mode.

Glider Acoustic Navigation

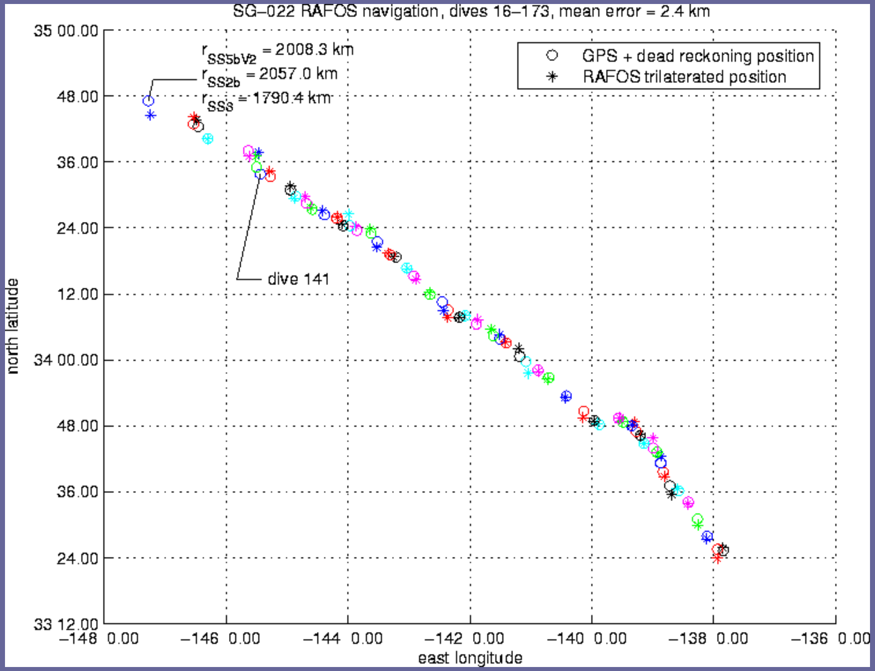
- Two gliders in North Pacific equipped with 260 Hz RAFOS receivers. Ranging on sources located off California coast (2000 km range). Tests of 780 Hz sources and (moored) receivers in Davis Strait. Ranging at ~100 km.
- Year-long 780 Hz acoustic propagation experiment underway in Davis Strait. Attenuation as a function of ice cover and stratification. Two sources, six receivers, two depths, ranges 0 – 200 km.
- Glider off Norwegian coast (collaboration with E. Hansen, NPI). Navigation in JC Gascard RAFOS field. To be launched June 18, 2005.

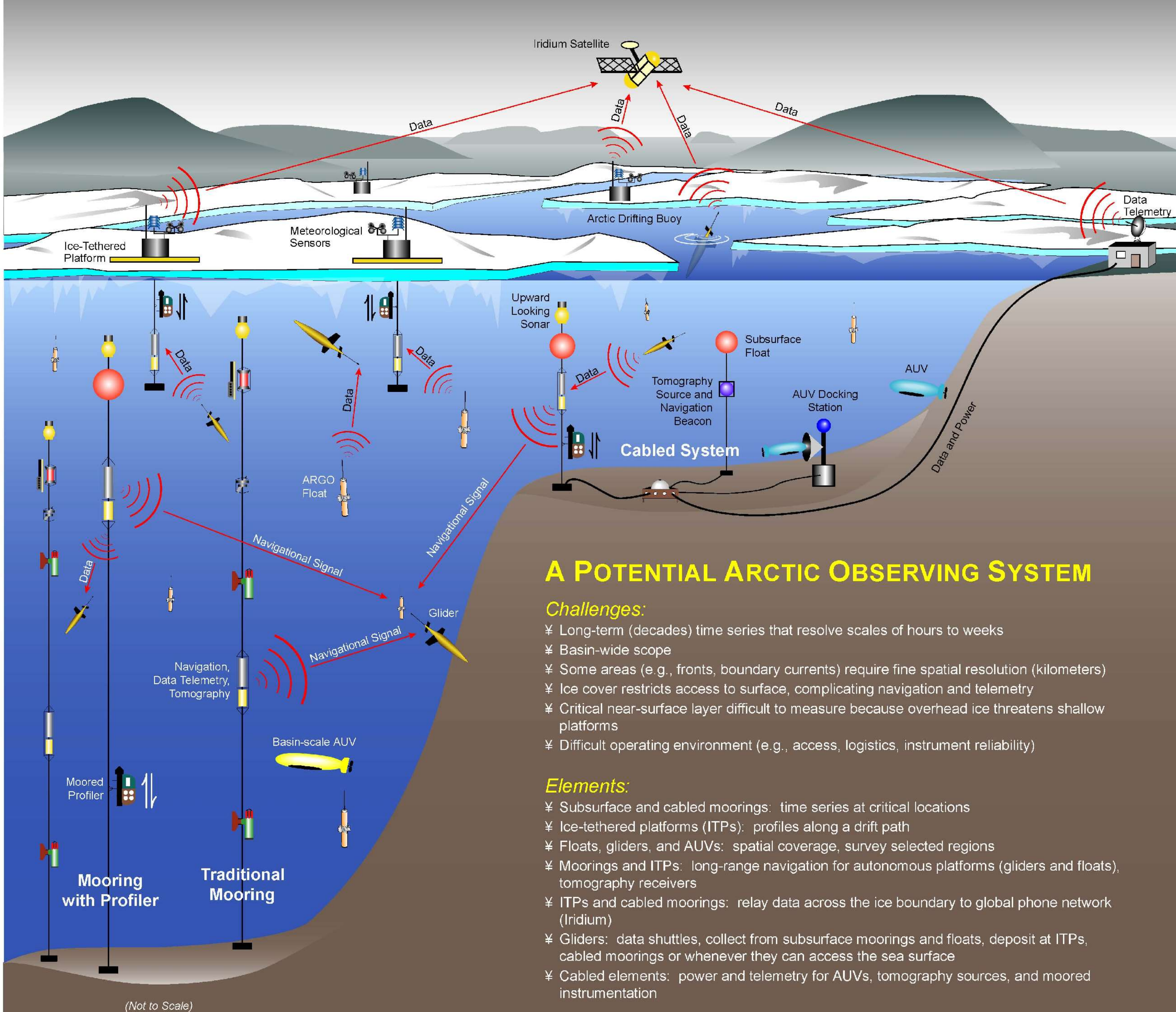
North Pacific RAFOS Results



- SG022 and SG023 deployed Sept. 2004 for NPAL LOAPEX experiment.
- Added 260 Hz RAFOS receivers and hydrophones to listen for broadcasts from the NPS sources (Curt Collins) deployed off California and Oregon.

- Good receptions to 2000 km.
- RMS position error after soundspeed and clock drift correction was 2.4 km.





A Potential Arctic Observing System

Challenges:

¥ Long-term (decades) time series that resolve scales of hours to weeks
¥ Basin-wide scope
¥ Some areas (e.g., fronts, boundary currents) require fine spatial resolution (kilometers)
¥ Ice cover restricts access to surface, complicating navigation and telemetry
¥ Critical near-surface layer difficult to measure because overhead ice threatens shallow platforms
¥ Difficult operating environment (e.g., access, logistics, instrument reliability)

Elements:

¥ Subsurface and cabled moorings: time series at critical locations
¥ Ice-tethered platforms (ITPs): profiles along a drift path
¥ Floats, gliders, and AUVs: spatial coverage, survey selected regions
¥ Moorings and ITPs: long-range navigation for autonomous platforms (gliders and floats), tomography receivers
¥ ITPs and cabled moorings: relay data across the ice boundary to global phone network (Iridium)
¥ Gliders: data shuttles, collect from subsurface moorings and floats, deposit at ITPs, cabled moorings or whenever they can access the sea surface
¥ Cabled elements: power and telemetry for AUVs, tomography sources, and moored instrumentation

Arctic Navigation and Telemetry

- Long-range Navigation (basin scales): Low-frequency (~20 Hz). Small numbers, large and costly.
- Medium-range Navigation (O(100 km)): 200-1000 Hz, encoded position. Moorings and ice tethered platforms, homing.
- High-bandwidth Communications: 15-30 kHz, ranges of a few kilometers. Data transfer, carried by all platforms.
- Upcoming NSF-sponsored workshop to develop system specifications,
- Target date for workshop is early 2006.