Gliders for sustained observations and research

experience from the Norwegian Sea

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with help from the glider team of
the The Norwegian Atlantic Current Observatory (NACO):
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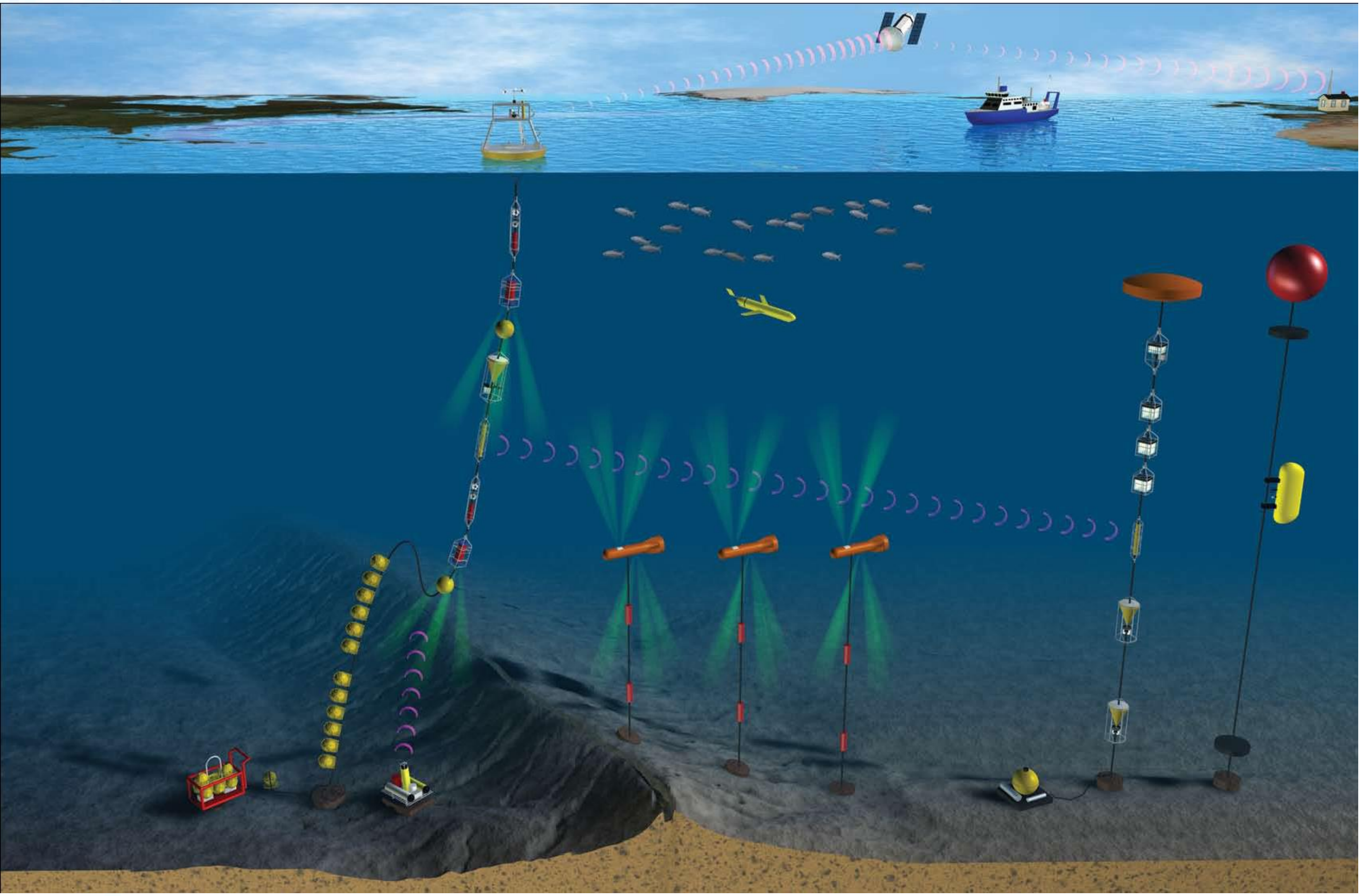
Karsten Kvalsund, Runde Environmental Centre

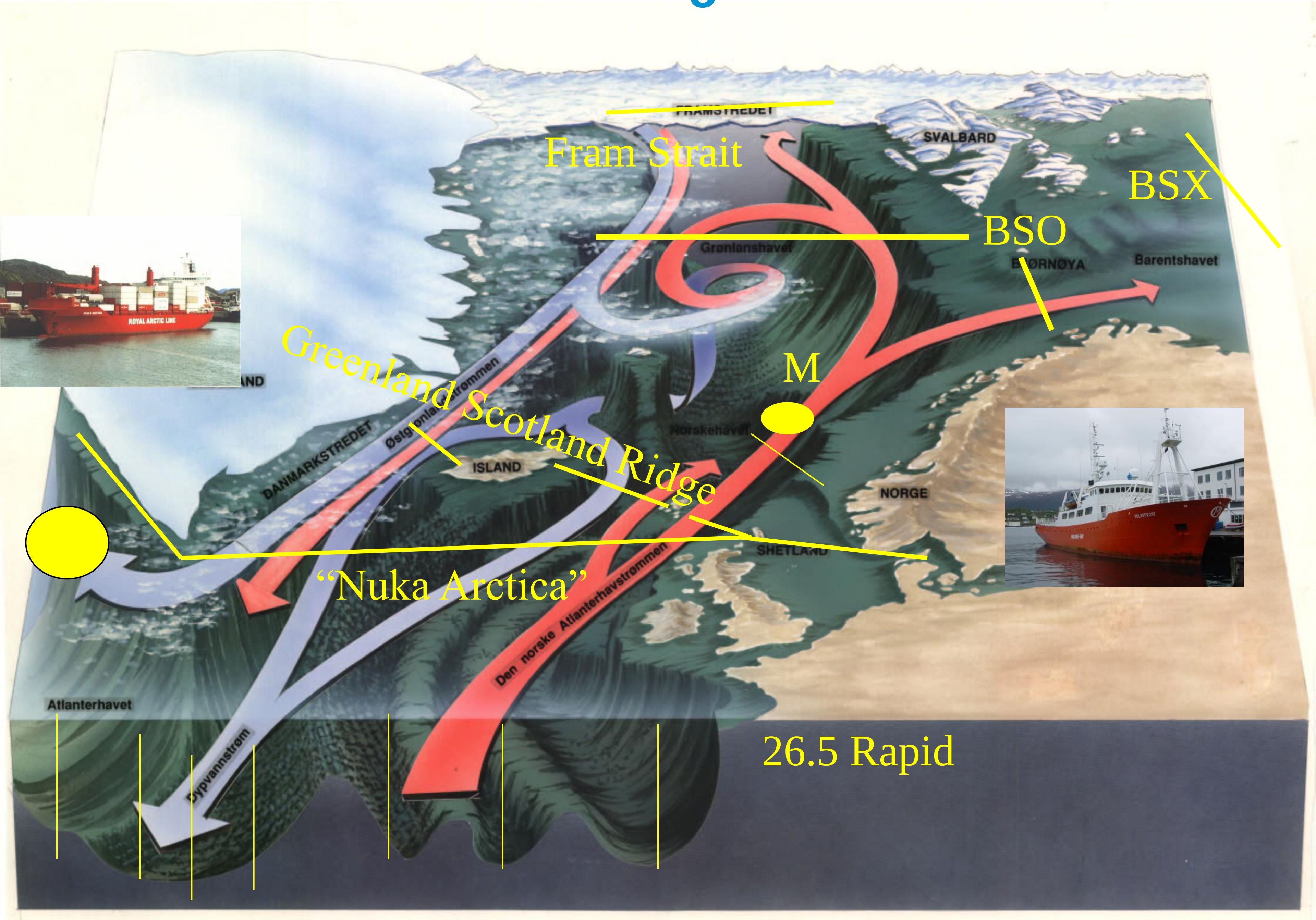
www.gfi.uib.no

How can we understand the ocean?



- Remote sensing
- Research cruises
- Ships of opportunity
- Lagrangian observatories (such as Argo)
- Eulerian observatories (such as EMSO and EuroSITES)
- **gliders and new technology**

Past North Atlantic/Norwegian Sea sites/sections



United Nations
Educational, Scientific and
Cultural Organization

Intergovernmental
Oceanographic
Commission

Why monitor the Arctic Ocean?

Services to society from a sustained ocean observing system

UNESCO/
IOC report

Long time series facilitate

1. **Effective policy making and sustainable management of the seas and oceans**
2. **Monitoring of the rate and scale of environmental change, including climate change and biodiversity loss**
3. **Detection of hazards and events**
4. **Understanding ocean, earth and climate system processes**

A network of marine observatories should integrate observations for research and observations for management purposes.

Marine Observatories (Marine Board definition)

Marine observatories are strategic in situ observing capacities which provide long-term time-series data.

- Continuous observations to capture episodic events
- Observation and capacity building
- Coastal laboratories
- Marine biosphere reserves
- Argo floats
- Ferrybox
- Gliders
- Seafloor based systems, ...

Marine observatories provide the backbone of the ocean observation system and the EMODNET

The vision: The 2nd Marine Board Forum culminated in a unanimous call from its participants for the prioritization at national and EU level of actions to deliver:

"A long-term, stable and integrated network of strategic marine observatories, installed and operated through multi-national cooperation and support, providing consistent in situ data from the seas and oceans in support of the EU Integrated Maritime Policy and as a driver for smart, sustainable and inclusive growth in Europe (Europe 2020).

Actions

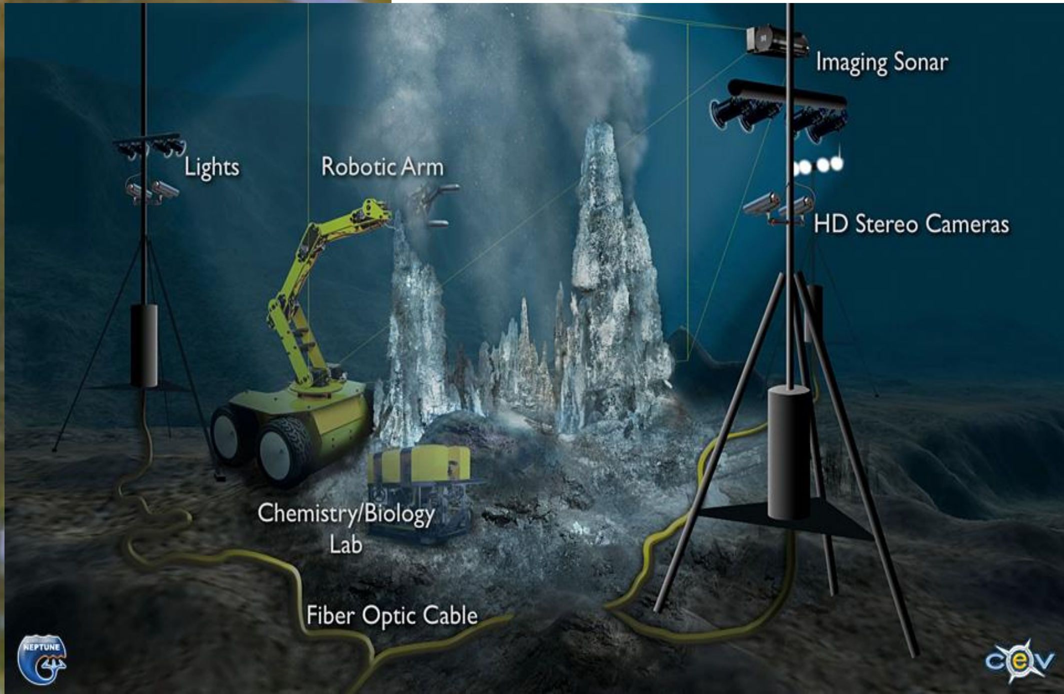
1. A Europe-wide mapping exercise and gap analysis on long-term marine data provision

2. A European strategy on the development of an integrated network of marine observatories.

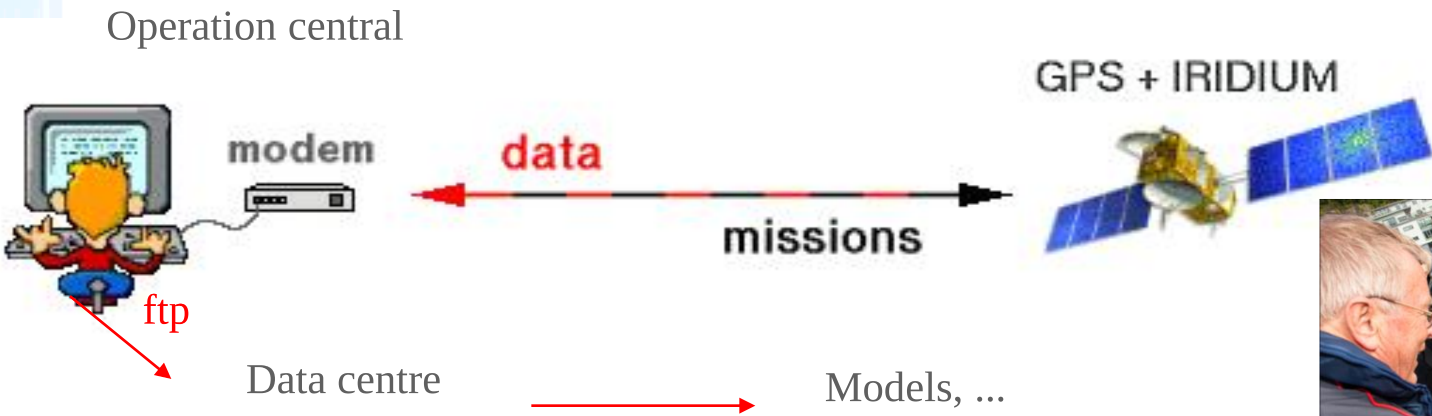
Future COSMOS?

Cabled ObservatorieS for Monitoring of the Ocean System (COSMOS) may obtain advanced process measurements in selected locations.

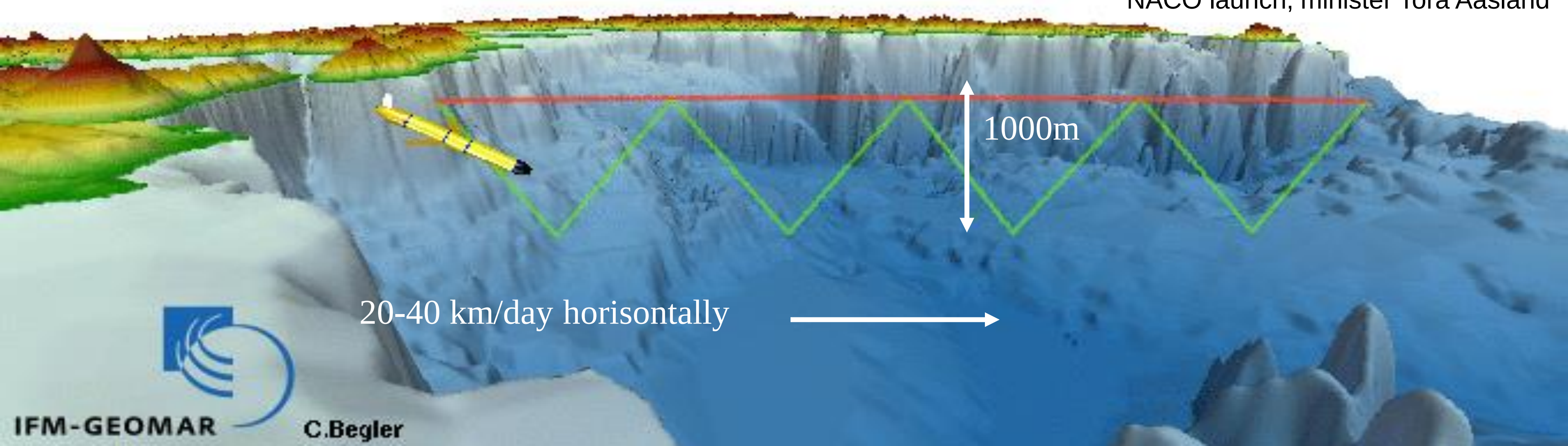
This would build upon MARS, VENUS and NEPTUNE and contribute to EMSO and FixO3.



Present: Norwegian Atlantic Current Observatory (NACO)
National glider observatory off the Norwegian shelf

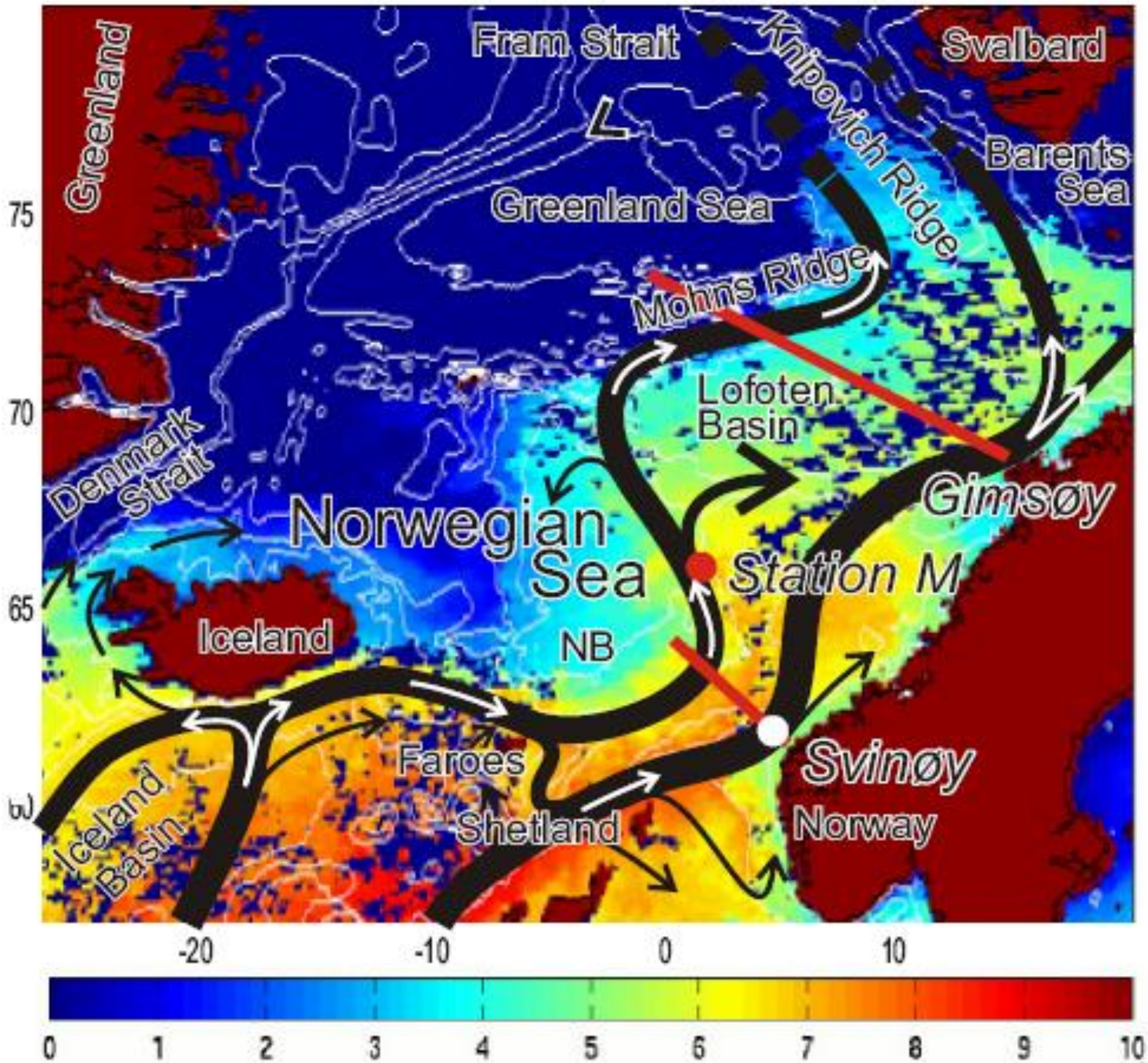


NACO launch, minister Tora Aasland



NACO =

National base funding for gliders, available also for national and international research projects contributing to running costs.



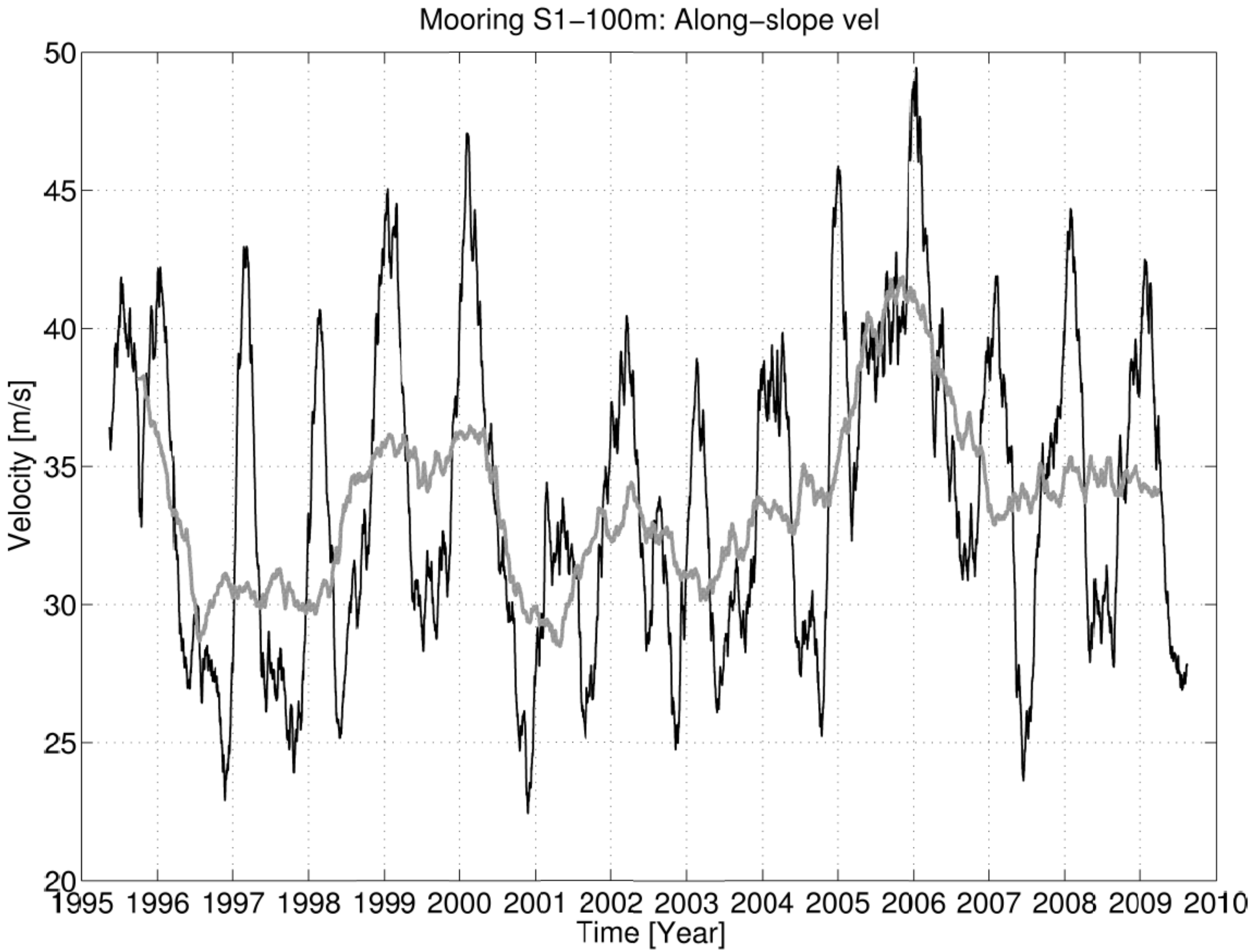
Run by GFI/UiB with IMR and Runde Environmental Centre as partners

The ocean near Runde

Nationally unique in terms of marine biodiversity and bioproduction – spawning areas, seabirds, flora/fauna, and wave energy resources. Start of Svinøy section.

Historical data from reference mooring at Svinøy

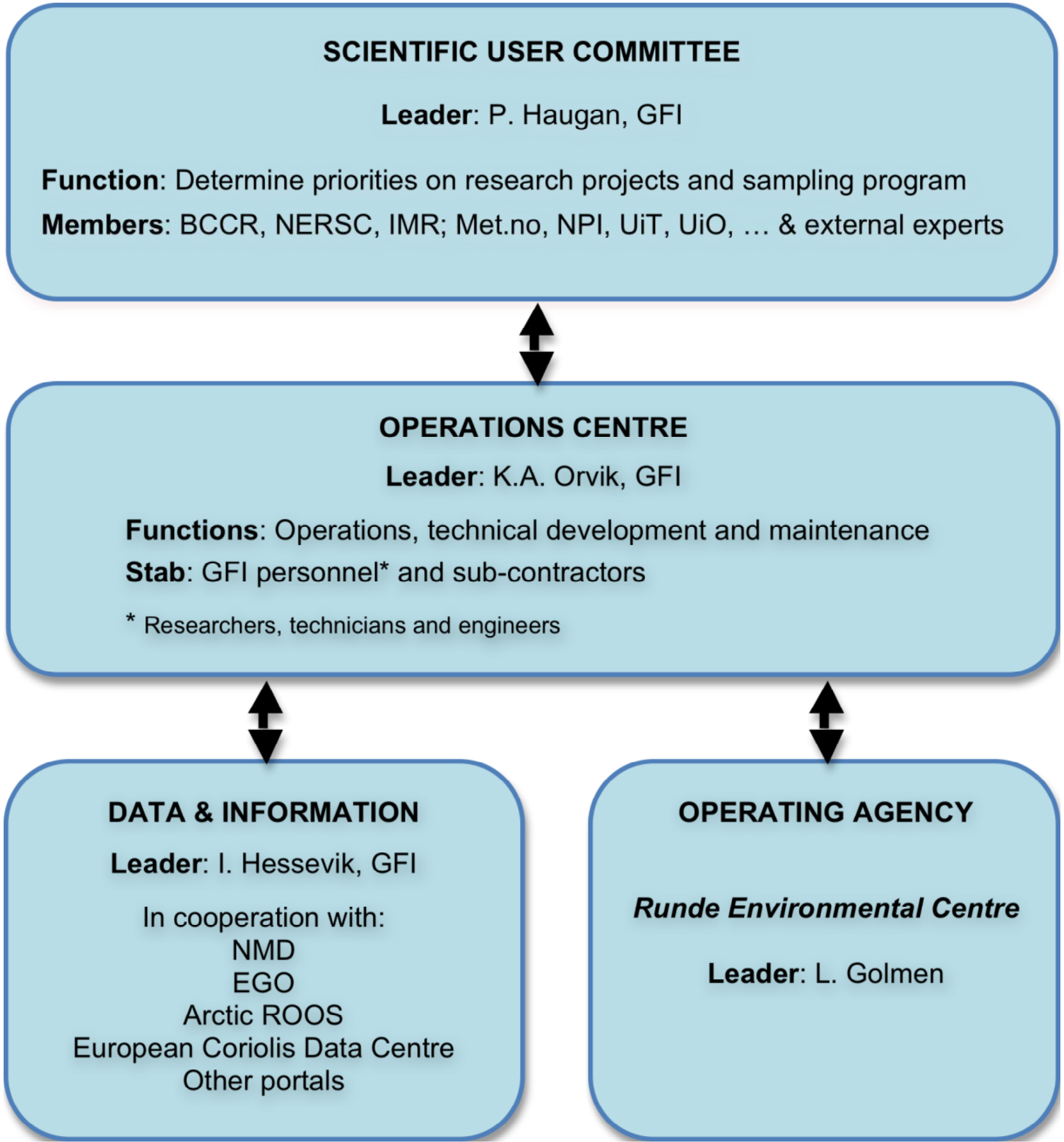
(many publications, Orvik et al.)



The Norwegian Atlantic Current Observatory

- National Norwegian research infrastructure application June 2009 - gliders as vehicles for AW monitoring
- Revised application January 2010 including mooring
- Project start 2011
- Reference mooring at Svinøy section tested fall 2011 and winter 2012
- Three Teledyne Webb Slocums owned by IMR refurbished and made available from spring 2012
- Six iRobot Seagliders purchased winter/spring 2012
- Training courses for our personnel at Webb and iRobot
- Acceptance tests in Sognefjord 13-14 March 2012 iRobot and Bjørnefjord 15-16 March 2012 Webb
- Start regular use of Seaglider April and Slocum May 2012

Structure of NACO project



Users who provided letters of support

National infrastructure
- Only one glider facility

The European projects
- EGO COST
- FP7 GROOM

provide possibilities for glider port coordination in Europe

Ramp-up demo period, but will need user fees for sustained operations

Local facilities in Bergen - Marineholmen

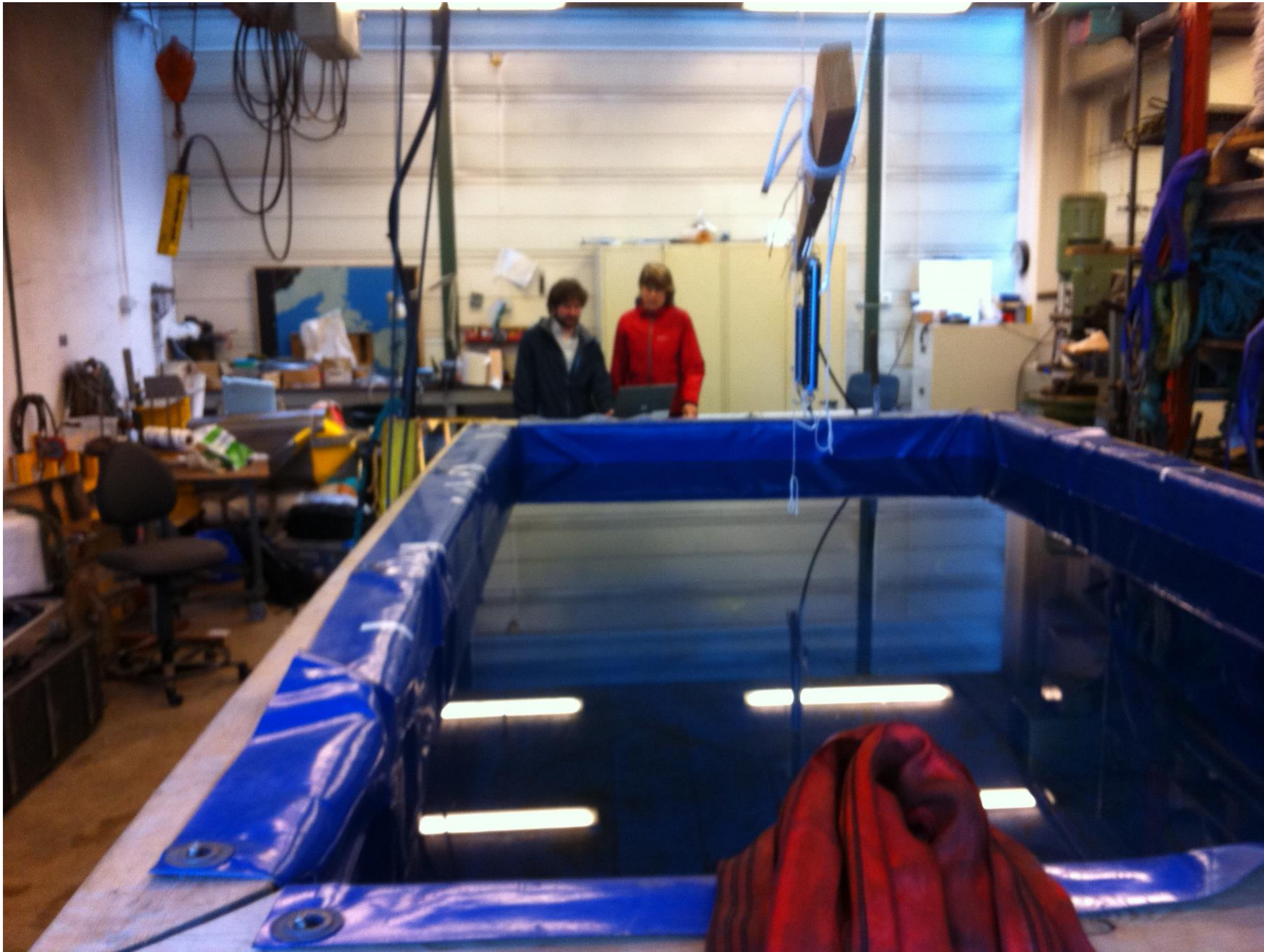
Geophysical Institute (GFI)

GFI workshop
Glider lab

Glider preparation and tests GFI 12-16 March 2012

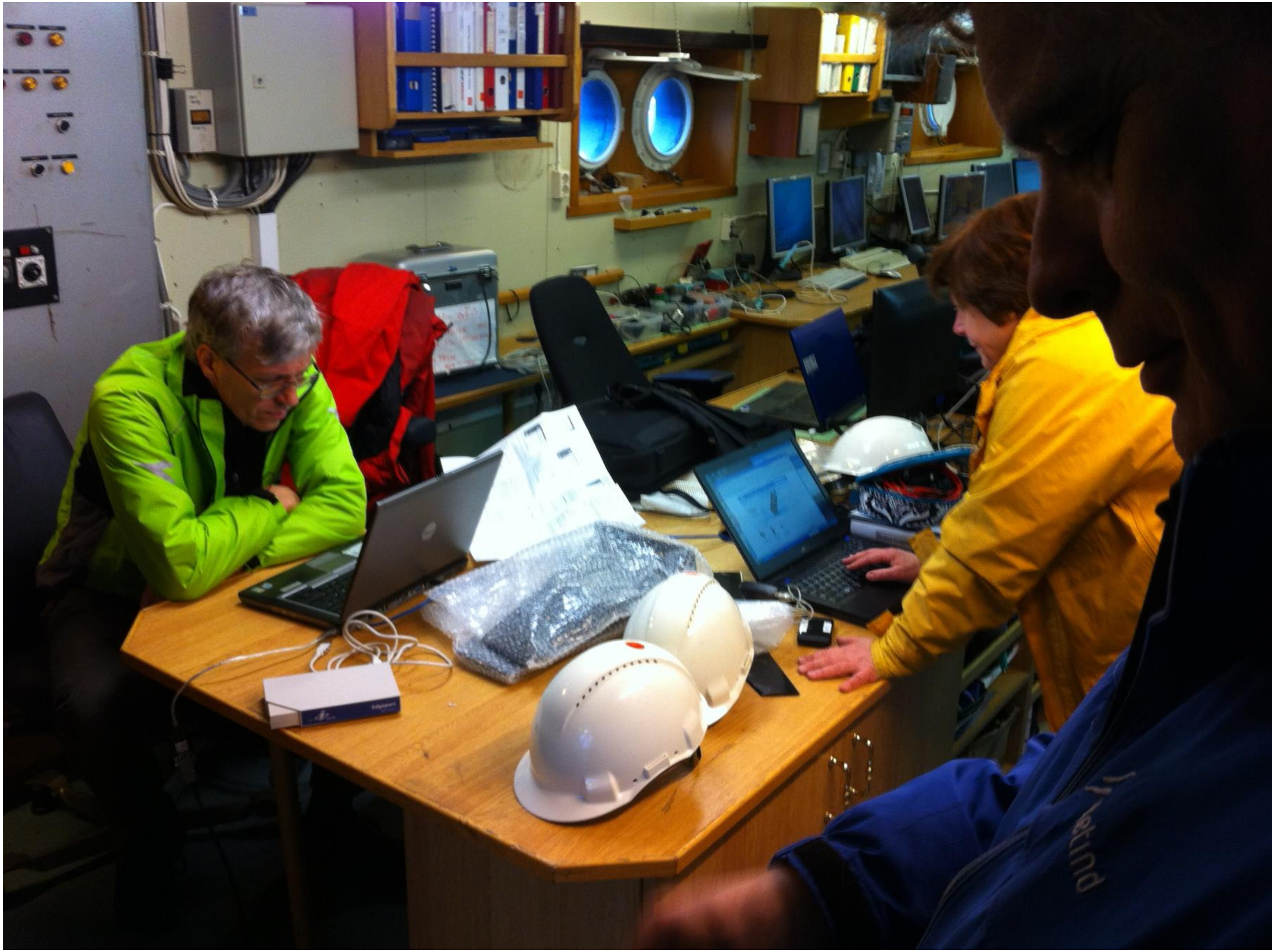
Slocums, one with turbulence sensors

Weight balancing required when changing payload or conditions



Seaglider onboard R/V Håkon Mosby before deployment

Communicating with the glider and piloting for the first time!



Glider use within NACO so far:

Short term research projects, e.g. two Slocums for process studies around the Faroes.

Sustained monitoring with two Seagliders in the primary NACO area (Svinøy section and Lofoten basin) from May and July 2012 respectively.

Recovery/redeployment after 6-7 months and again soon (now).

Demonstrating more sensors.

Which other missions 2014-2015?

Calls - Scientific user committee.

andøyposten

Tysker på dannelses-reise

Siste

Torsdag 5. juli 2012 · Nr 74 · 34. årgang · Løssalg kr 20,–

Gode sjanser for mer Norwegian i 2013

– Andenes og Reykjavik er de nye rutene som går aller best hos Norwegian, sier informasjonssjef Lasse Sandaker Nilsen i Norwegian. Han sier at det er gode sjanser for at direkteruten til Oslo videreføres i 2013, og da kan det bli rutetilbud fra april til og med oktober. – Vi er kjempefornøyd med responsen, men er avhengig av at folk benytter tilbudet, sier han. (Foto: Linda Nordstrand, Andøya flystasjon)

Side 6

Undervannsrobot slippes ut i Golfstrømmen

I dag er oseanograf Kjell Orvik fra Geofysisk institutt på besøk på Andøya i anledning et stort forskningsprosjekt kalt «Norsk atlantisk havstrøm». Med seg har han en «Seaglider iRobot» som skal ut med båten «Dina» for å måle data i Golfstrømmen.

Sunniva Bornøy
andoyposten@redaksjonen.no

Seaglider iRobot er en undervannsrobot som dukker ned til 1.000 meter, går 0,3 meter i sekundet og kommer opp til havoverflata med jevne mellom, etter en seks-sju timer. Den kan være ute på egen hånd i opptil åtte måneder i gangen og ta prøver kontinuerlig. Det er viktige miljødata som blir målt og som har innvirkning på værvarslinga, klimaforskninga, fiskeriforvaltninga og havforskninga generelt. Slike undervannsroboter kan også brukes i offshorevirksomhet.

Målingene går blant annet på salt, temperatur, oksygen, indirekte strøm i havet og å få kartlagt virvler i havet. Undervannsroboten slippes ut i Lofotbassenget og går gjennom Golfstrømmen til Jan Mayen og tilbake. Slik går den over lengre tid. Roboten styres og gir data via satellitt som sender informasjon til basestasjonen.

– Det er et veldig interessant område i forhold til varmeutveksling og mye av varmetapet via Golfstrømmen skjer i Lofotbassenget, avslutter Orvik.

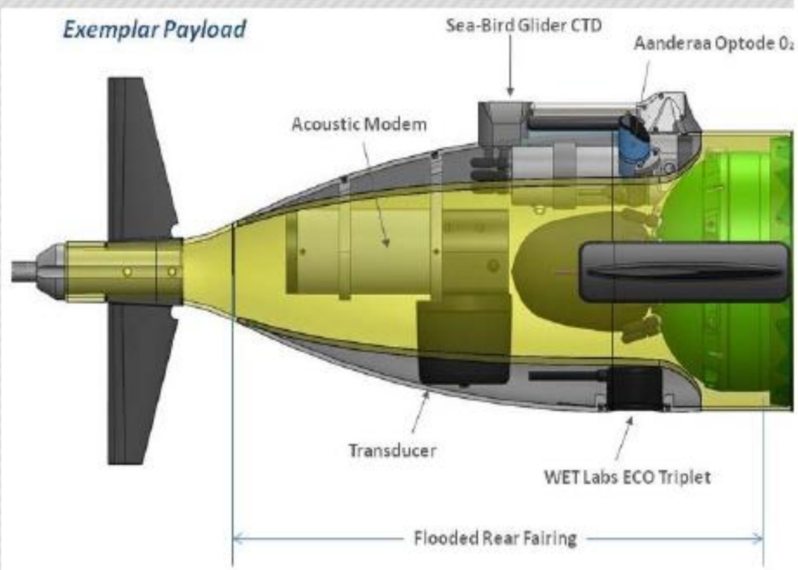
SKRUR: Kjell Orvik skrur på vingene til undervannsroboten for å få den klar til å slippes ut i havet. (Foto: Sunniva Bornøy)

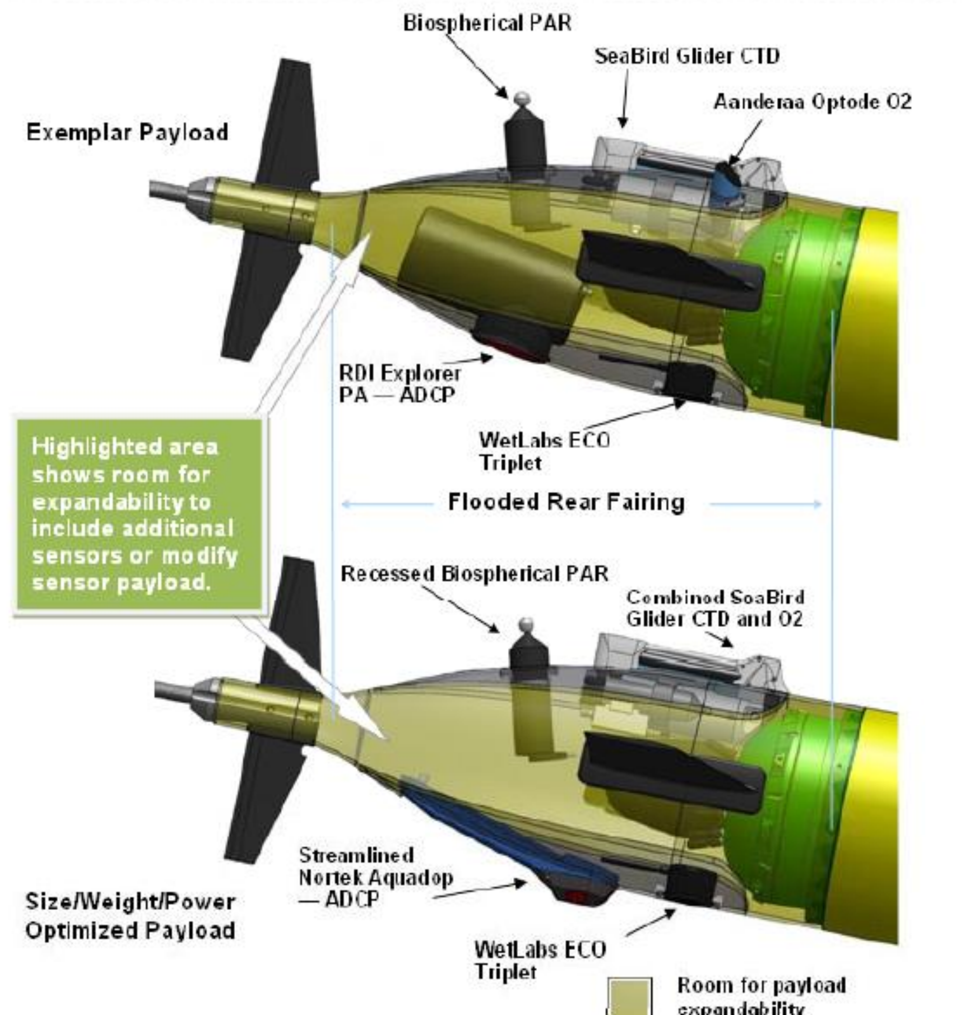
Ogive Fairings - Payload bay: 22 liter

Increased capacity for multi-sensor missions

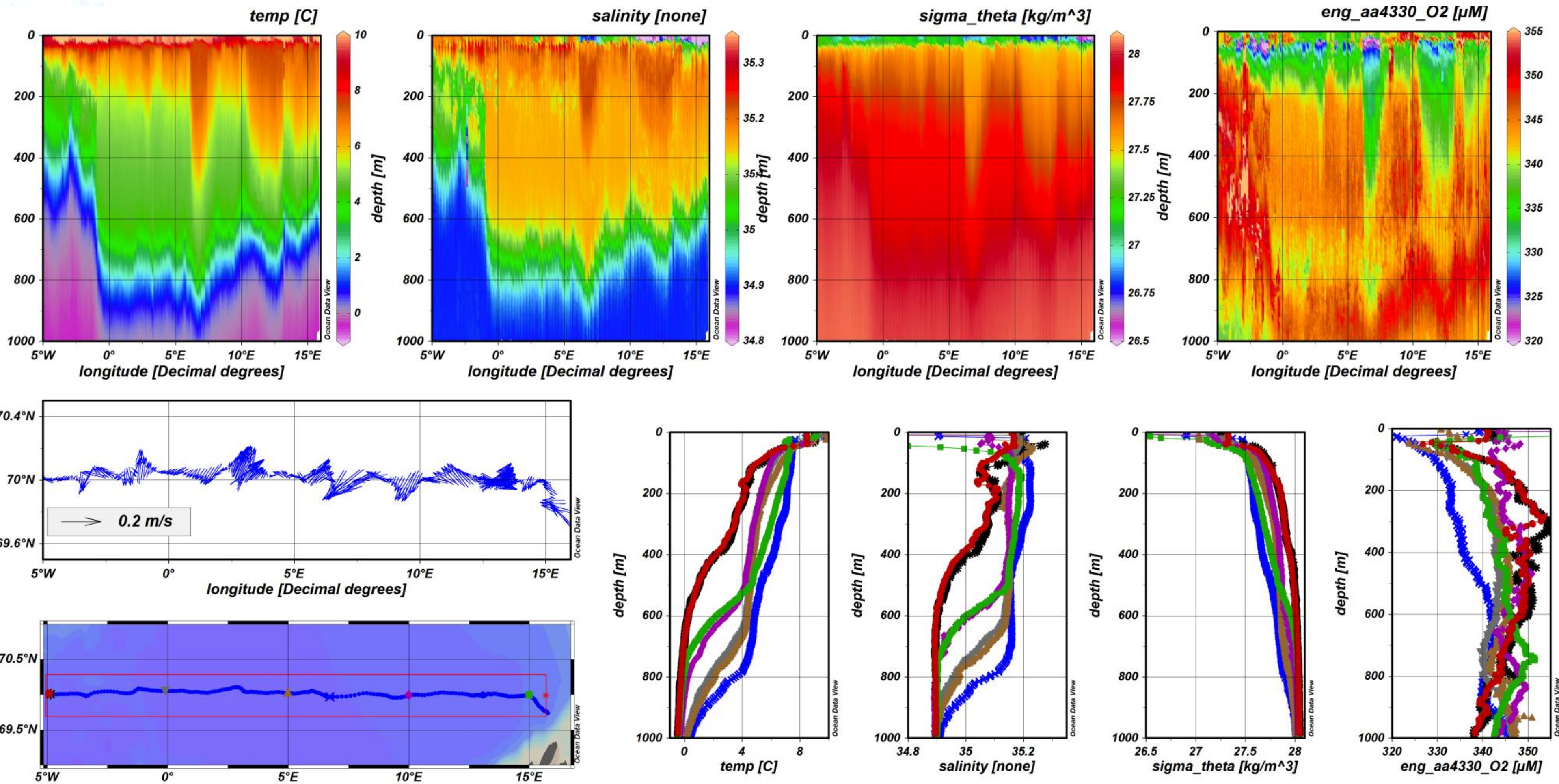
iRobot Seaglider

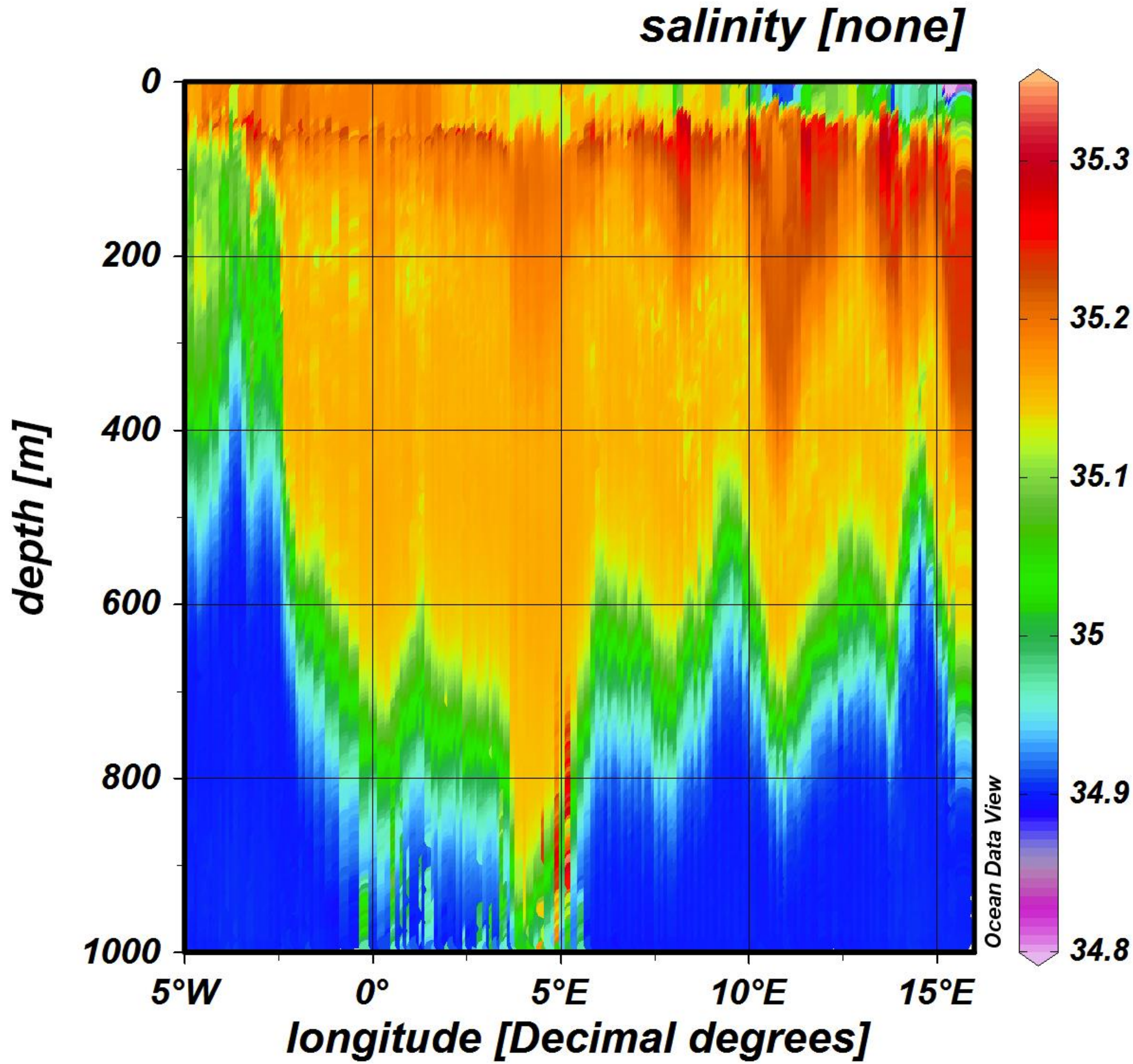
Seaglider now supports mutliple sensors in flooded payload bay that has 22 liter capacity





Typical standard section data

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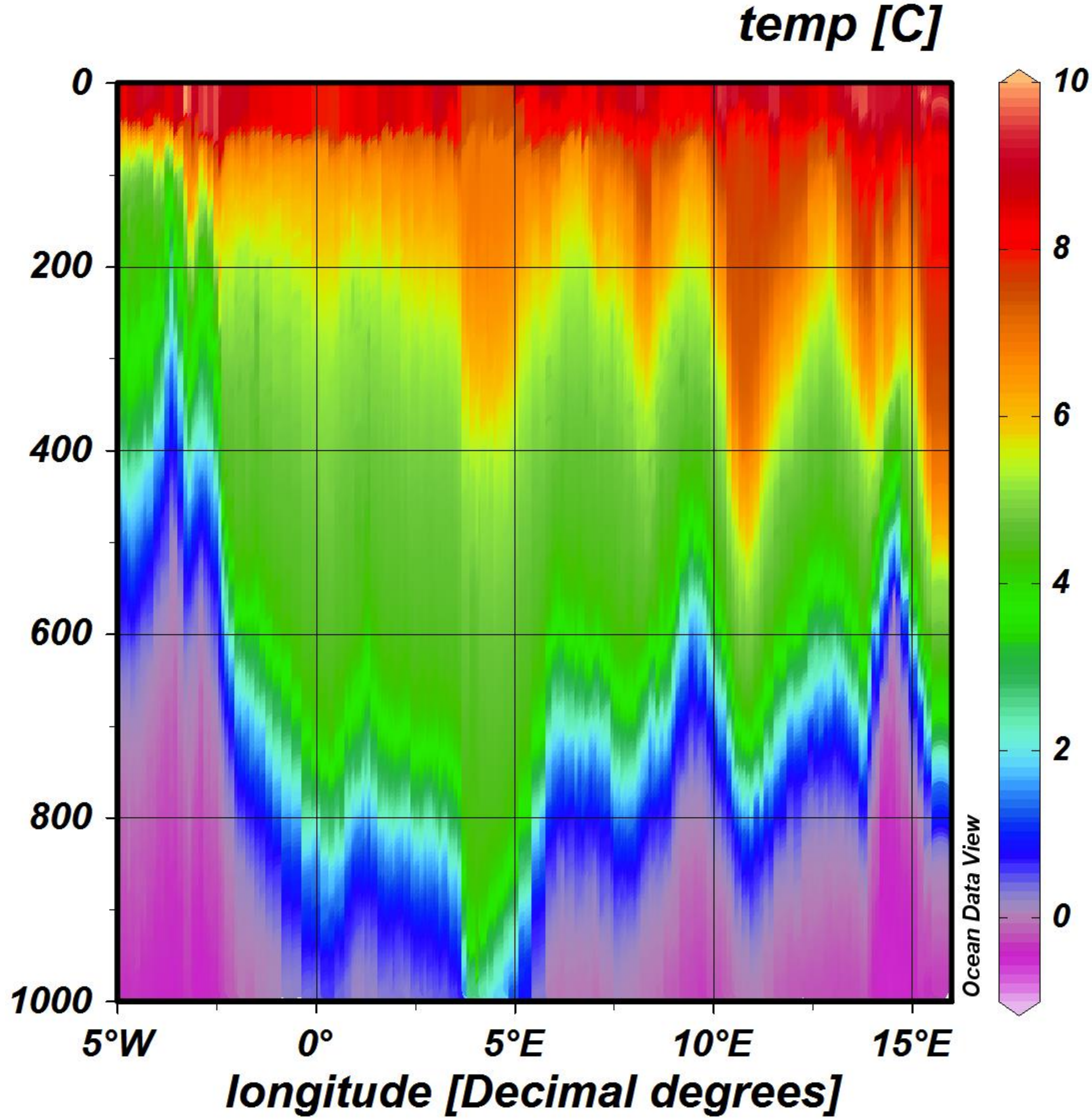
Ocean Data View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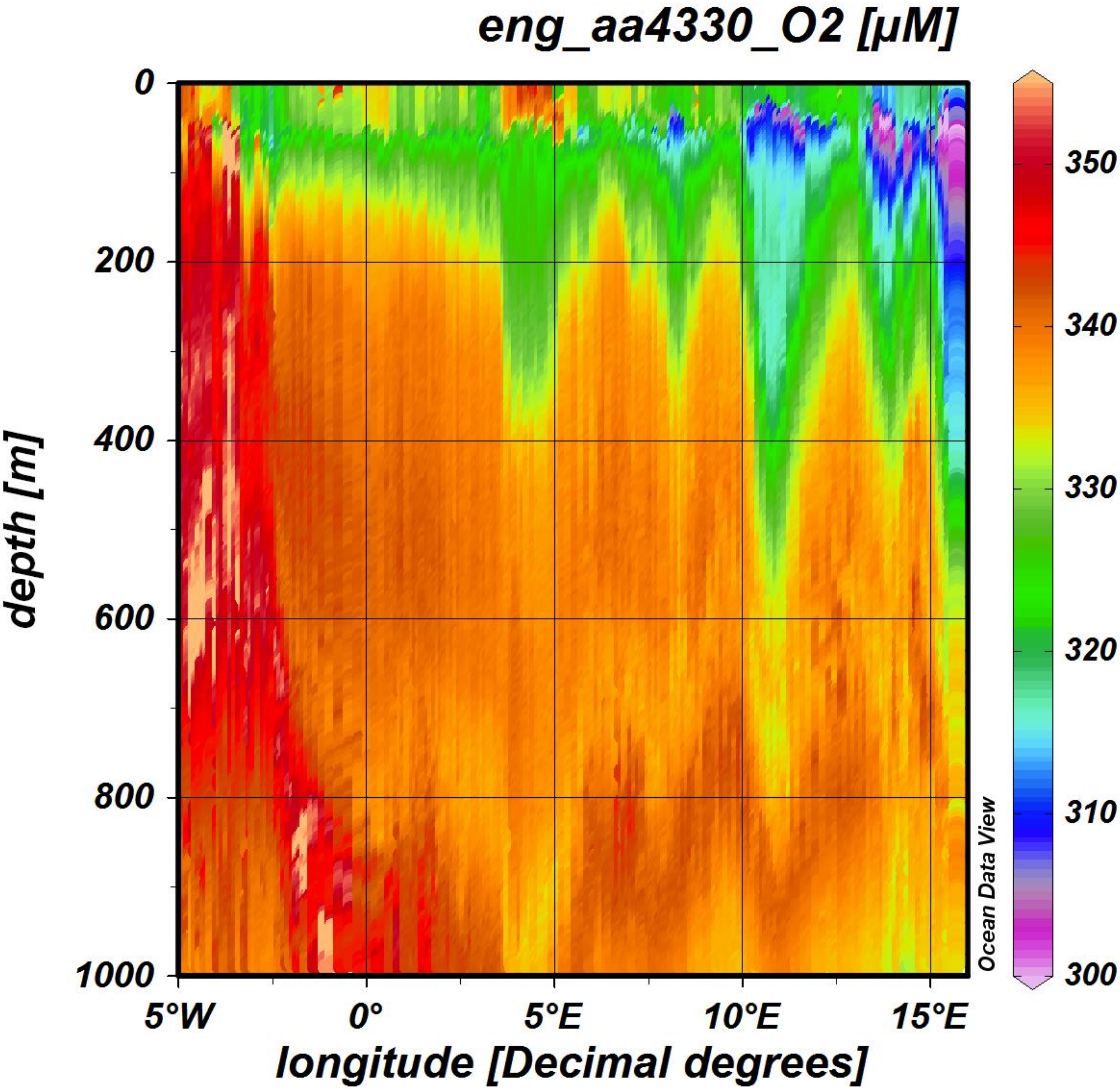
Ocean Data View



eng_aa4330_O2 [µM]
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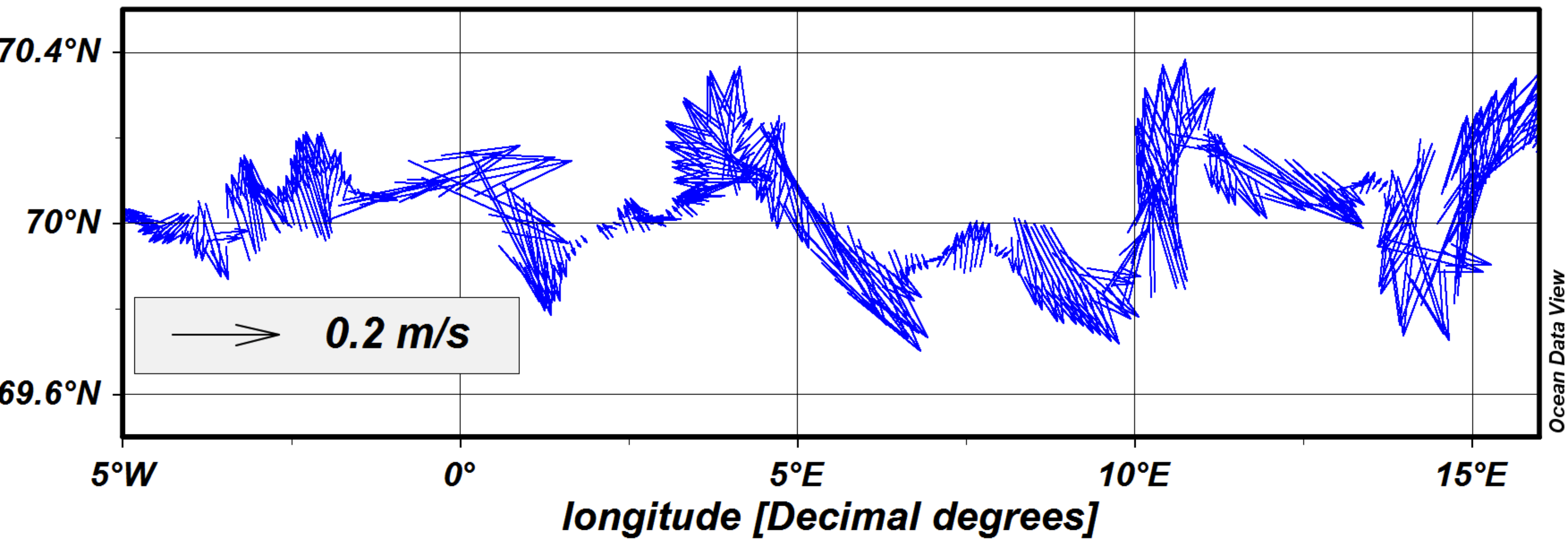
Ocean Data View


70.4°N
70°N
69.6°N
0.2 m/s
5°W
0°
5°E
10°E
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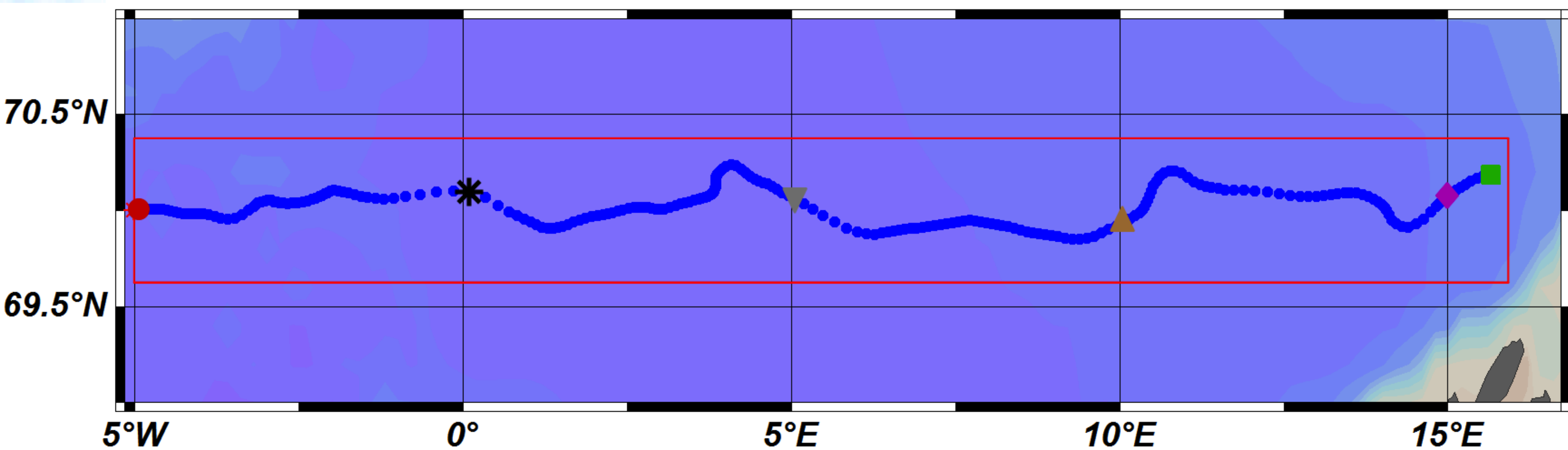
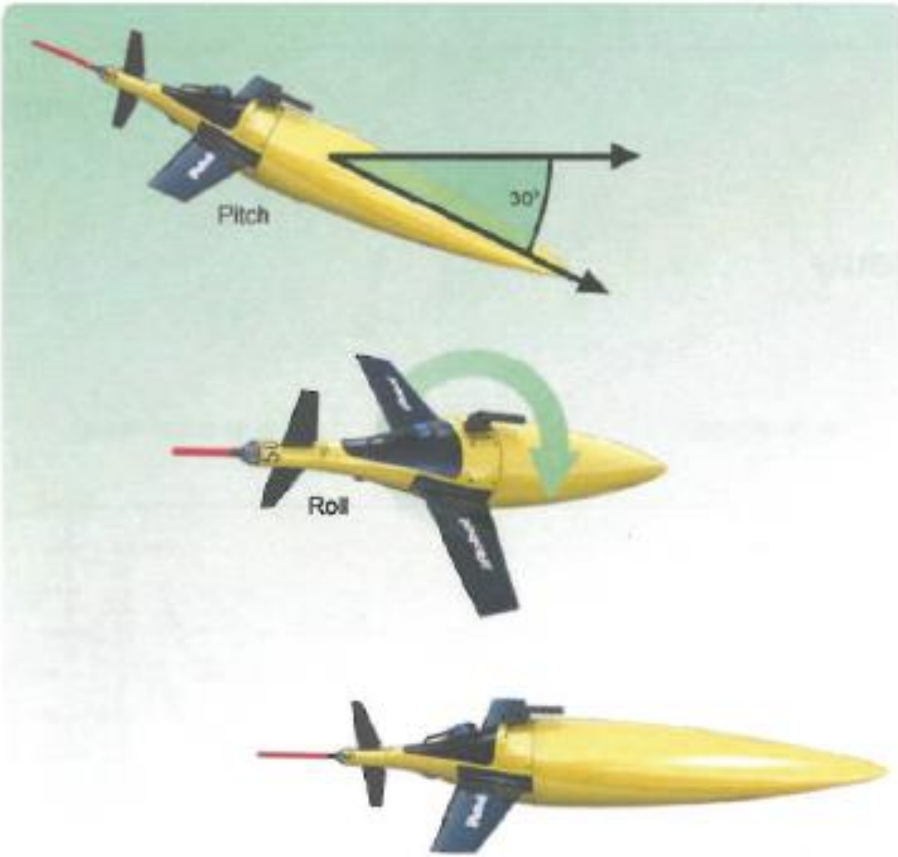
Ocean Data View


70.5°N
69.5°N
5°W
0°
5°E
10°E
15°E

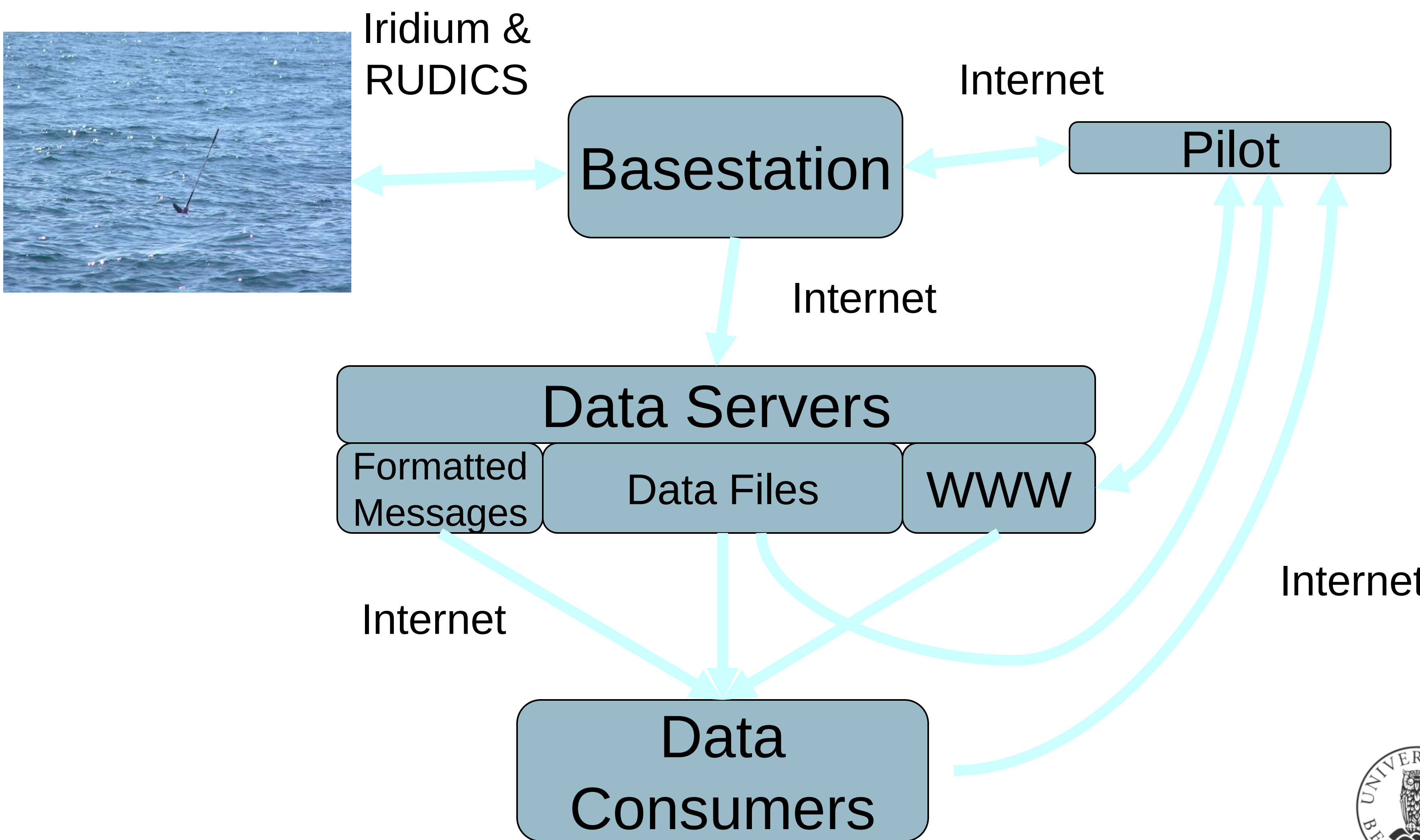
Seaglider – Key parameters for piloting



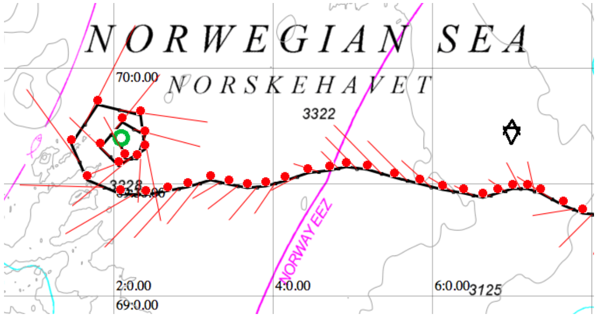
1. Pitch ($C_PITCH) first to make glider fly, not stall, through dive, apogee, and climb phases
2. Buoyancy ($C_VBD) to make vertical velocity cross zero where buoyancy does
3. Roll last to make fly straight (roll rate vs. control) - start by making approximately flat (roll deg. vs. control)

Monitoring the Seaglider

Seaglider Data flow



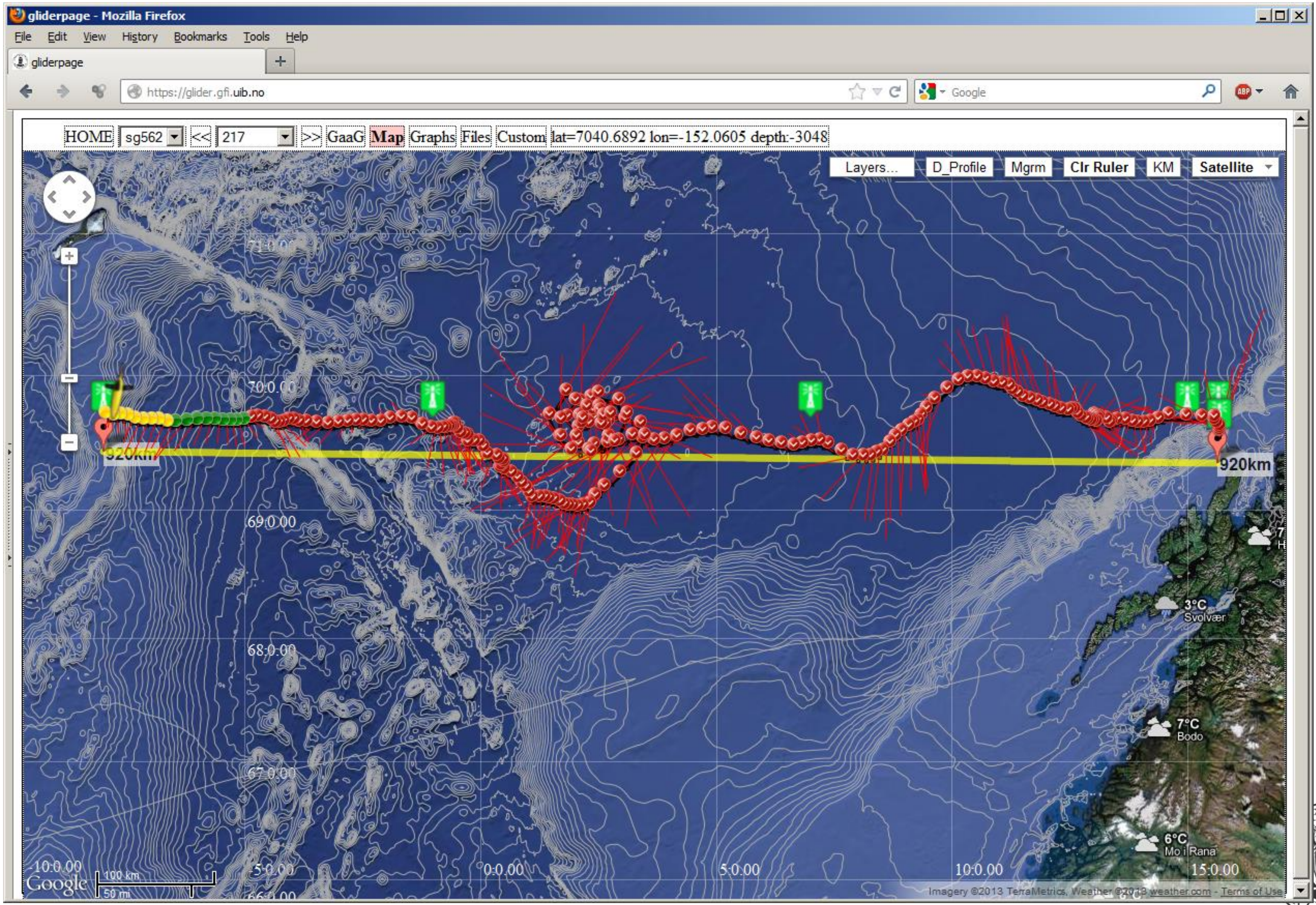
Piloting tool: Gliderpage – developed at GFI



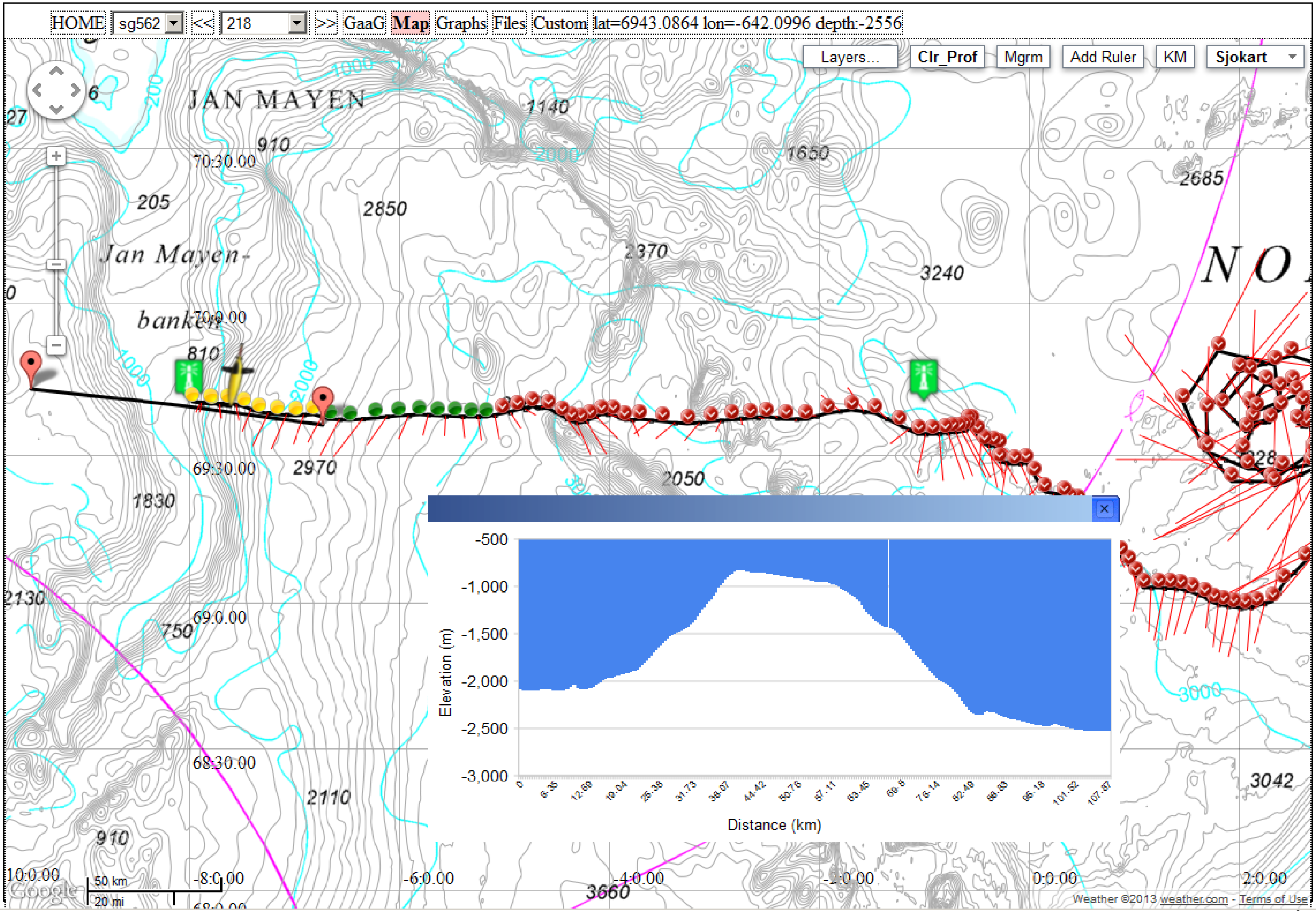
- Web client based on Google Maps API v.3
- Integration between Google Maps and open wms map data from statkart.no/geonorge.no
- Integration between Google Maps and weather data from met.no/yr.no
- Integration between map application and technical matlab plots, communication with base station for editing of cmdfile/science/target, copy of data- and logfiles, monitoring of technical condition of glider

- javascripts, html, python og matlab

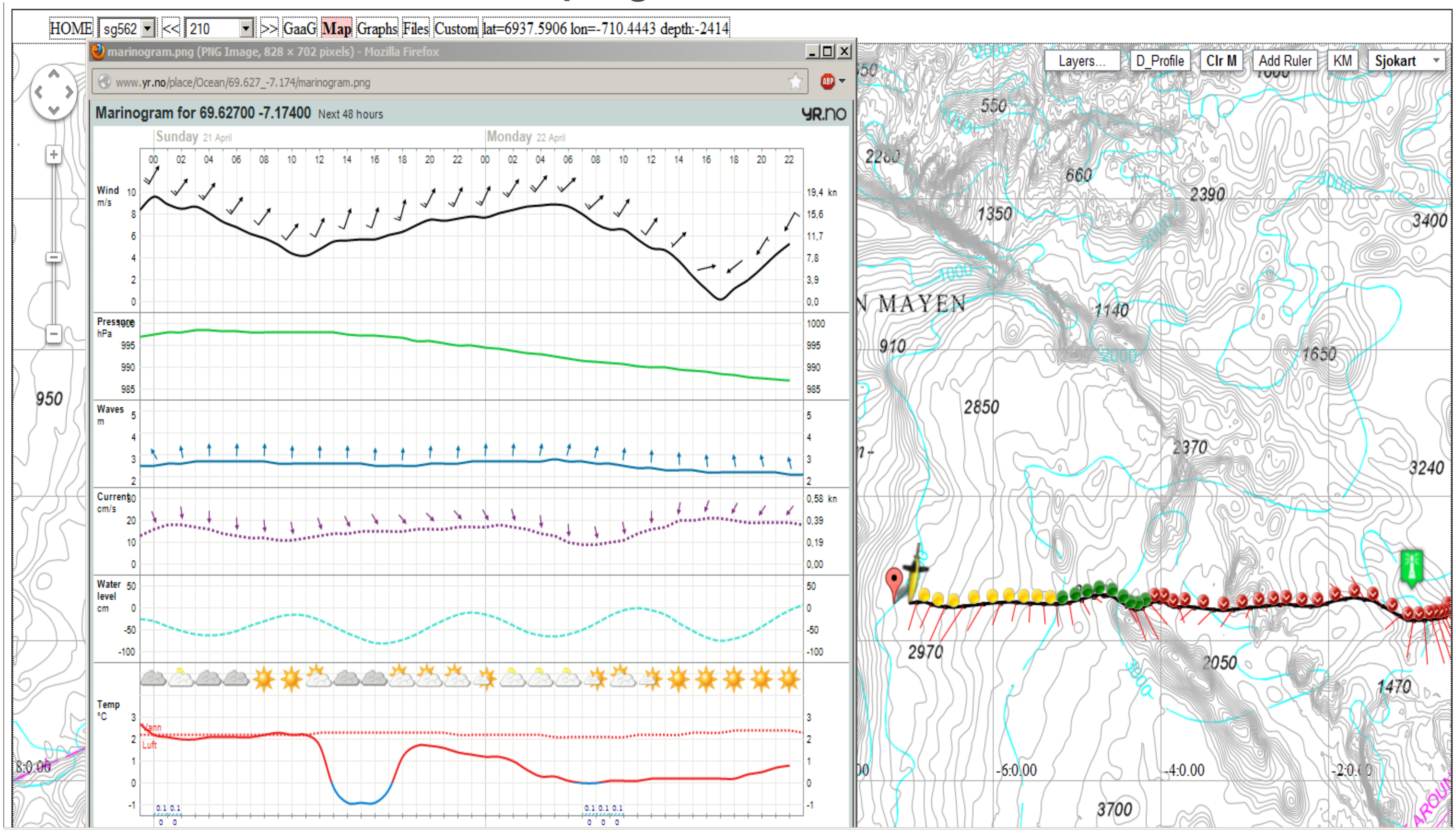
Gliderpage


gliderpage - Mozilla Firefox
File Edit View History Bookmarks Tools Help
gliderpage
https://glider.gfi.uib.no
HOME sg562 << 217 >> GaaG Map Graphs Files Custom lat=7040.6892 lon=-152.0605 depth:-3048
Layers... D_Profile Mgrm Clr Ruler KM Satellite
920km
3°C Svolvær
7°C Bodø
6°C Mo i Rana
Imagery ©2013 TerraMetrics, Weather ©2013 weather.com - Terms of Use

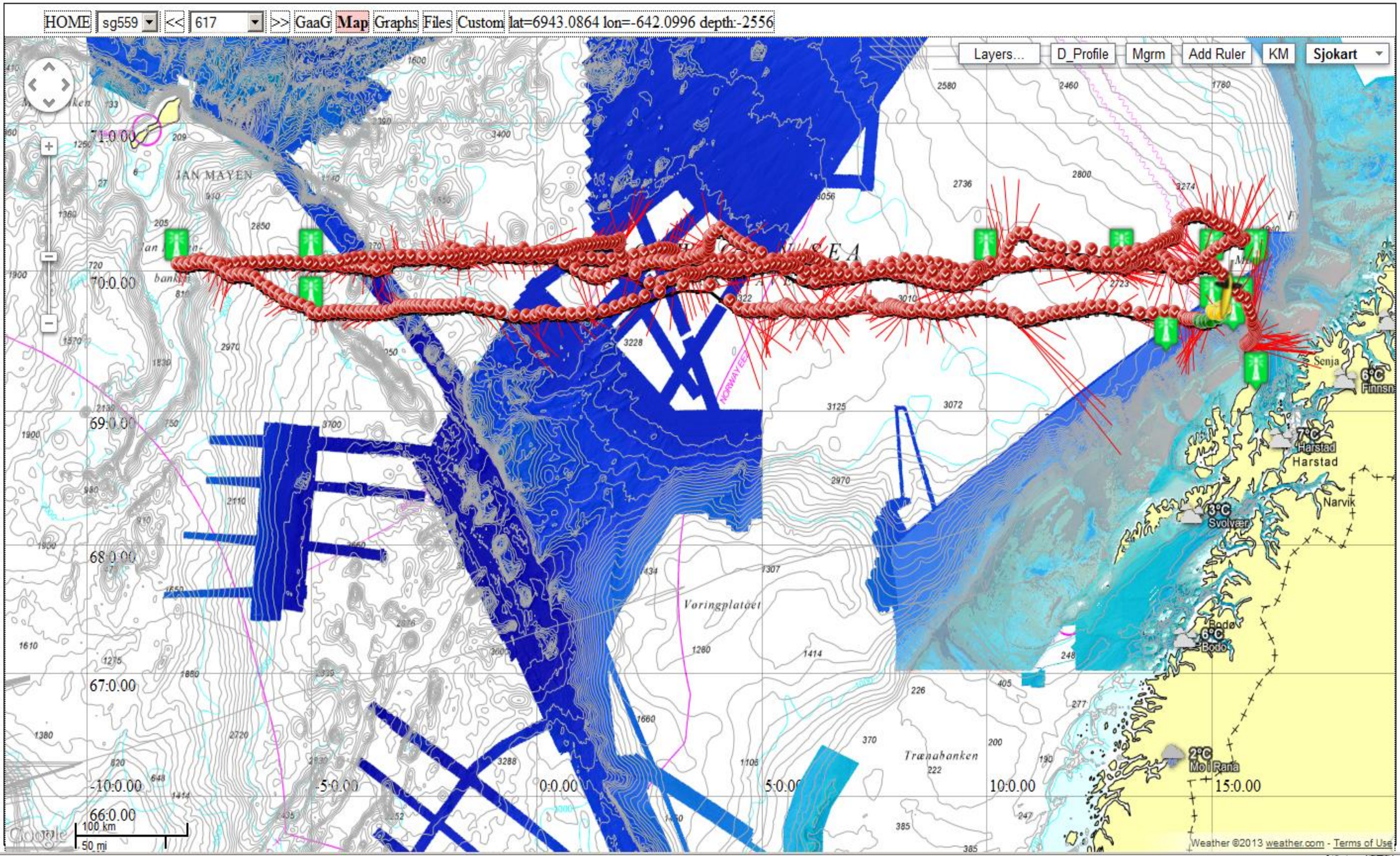
Gliderpage – depth profile



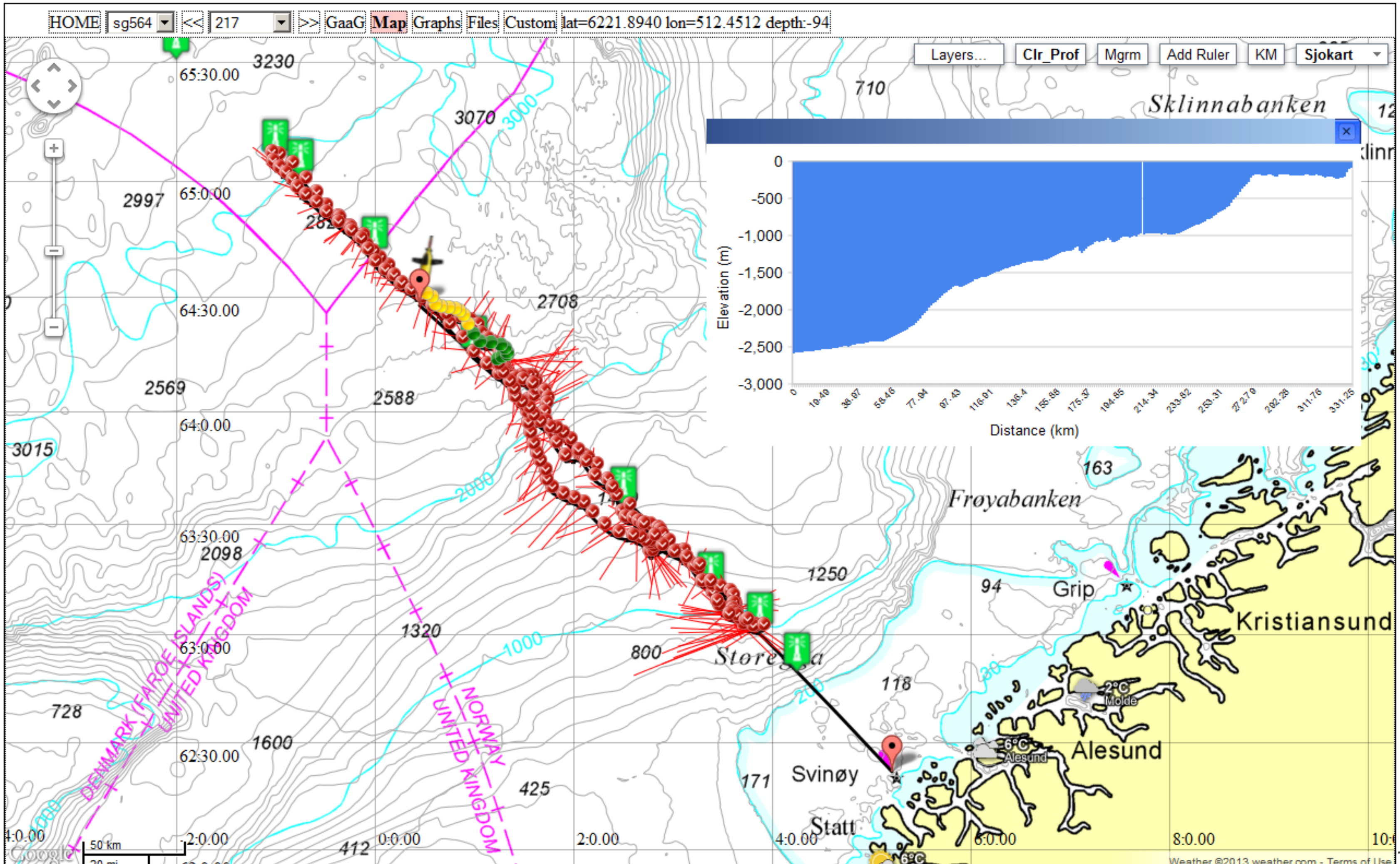
Gliderpage – weather data



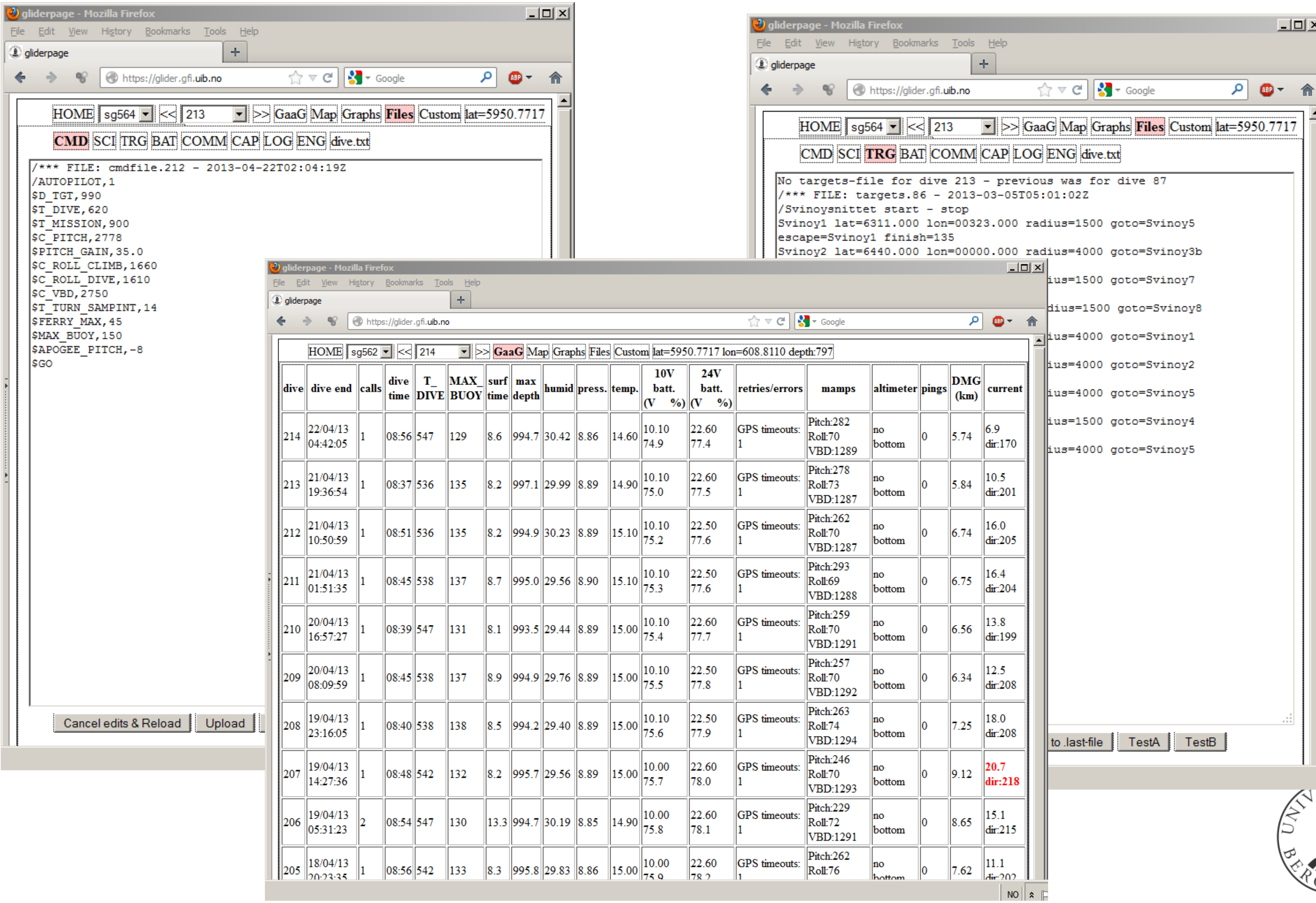
Gliderpage – wms map layer



Gliderpage – current vs depth profile

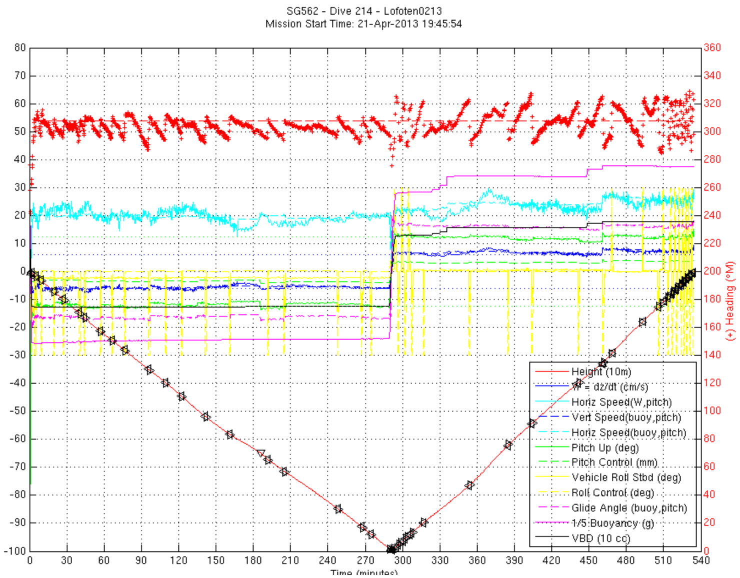


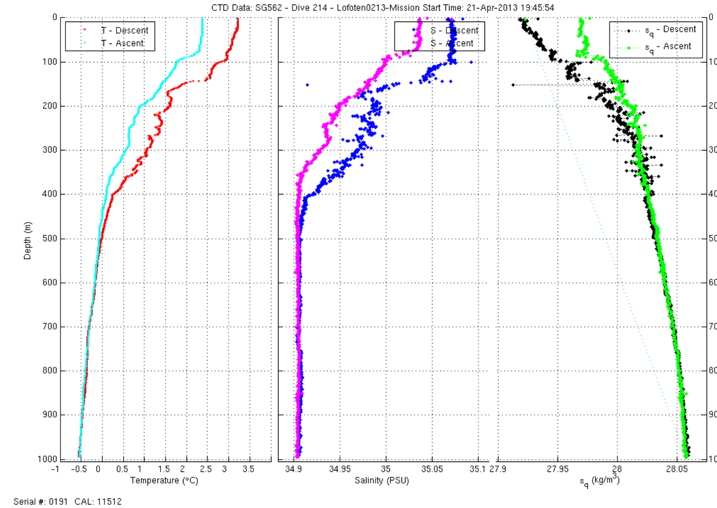
Gliderpage – editing of cmdfil/targets

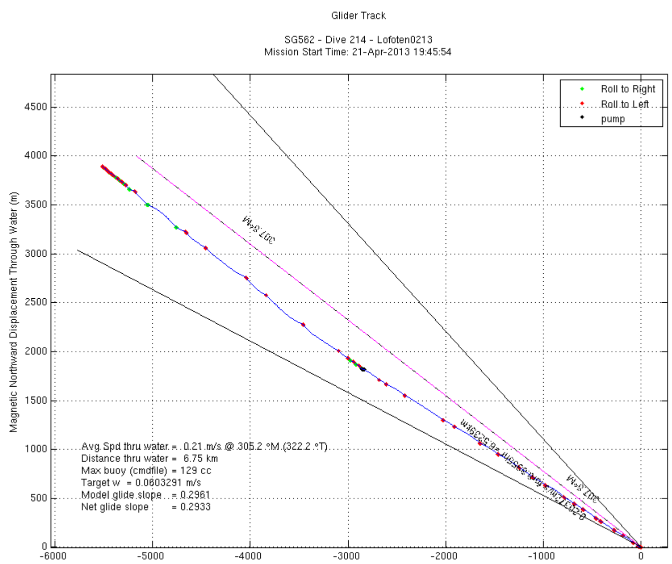


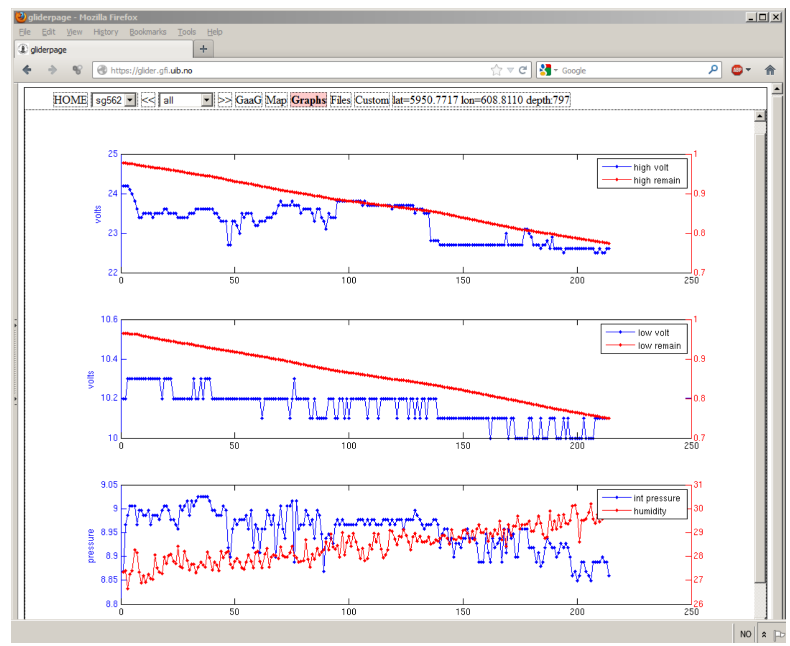
dive	dive end	calls	dive time	T_DIVE	MAX_BUOY	surf time	max depth	humid	press.	temp.	10V batt. (V %)	24V batt. (V %)	retries/errors	mamps	altimeter	pings	DMG (km)	current
214	22/04/13 04:42:05	1	08:56	547	129	8.6	994.7	30.42	8.86	14.60	10.10 74.9	22.60 77.4	GPS timeouts: 1	Pitch:282 Roll:70 VBD:1289	no bottom	0	5.74	6.9 dir:170
213	21/04/13 19:36:54	1	08:37	536	135	8.2	997.1	29.99	8.89	14.90	10.10 75.0	22.60 77.5	GPS timeouts: 1	Pitch:278 Roll:73 VBD:1287	no bottom	0	5.84	10.5 dir:201
212	21/04/13 10:50:59	1	08:51	536	135	8.2	994.9	30.23	8.89	15.10	10.10 75.2	22.50 77.6	GPS timeouts: 1	Pitch:262 Roll:70 VBD:1287	no bottom	0	6.74	16.0 dir:205
211	21/04/13 01:51:35	1	08:45	538	137	8.7	995.0	29.56	8.90	15.10	10.10 75.3	22.50 77.6	GPS timeouts: 1	Pitch:293 Roll:69 VBD:1288	no bottom	0	6.75	16.4 dir:204
210	20/04/13 16:57:27	1	08:39	547	131	8.1	993.5	29.44	8.89	15.00	10.10 75.4	22.60 77.7	GPS timeouts: 1	Pitch:259 Roll:70 VBD:1291	no bottom	0	6.56	13.8 dir:199
209	20/04/13 08:09:59	1	08:45	538	137	8.9	994.9	29.76	8.89	15.00	10.10 75.5	22.50 77.8	GPS timeouts: 1	Pitch:257 Roll:70 VBD:1292	no bottom	0	6.34	12.5 dir:208
208	19/04/13 23:16:05	1	08:40	538	138	8.5	994.2	29.40	8.89	15.00	10.10 75.6	22.50 77.9	GPS timeouts: 1	Pitch:263 Roll:74 VBD:1294	no bottom	0	7.25	18.0 dir:208
207	19/04/13 14:27:36	1	08:48	542	132	8.2	995.7	29.56	8.89	15.00	10.00 75.7	22.60 78.0	GPS timeouts: 1	Pitch:246 Roll:70 VBD:1293	no bottom	0	9.12	20.7 dir:218
206	19/04/13 05:31:23	2	08:54	547	130	13.3	994.7	30.19	8.85	14.90	10.00 75.8	22.60 78.1	GPS timeouts: 1	Pitch:229 Roll:72 VBD:1291	no bottom	0	8.65	15.1 dir:215
205	18/04/13 20:23:35	1	08:56	542	133	8.3	995.8	29.83	8.86	15.00	10.00 75.9	22.60 78.2	GPS timeouts: 1	Pitch:262 Roll:76	no bottom	0	7.62	11.1 dir:202

Gliderpage – technical plot for pilot control



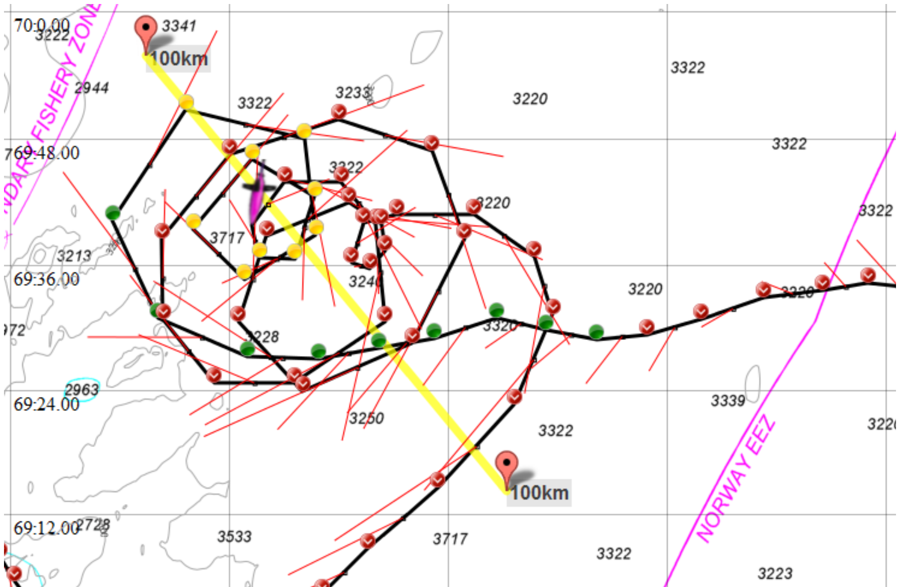


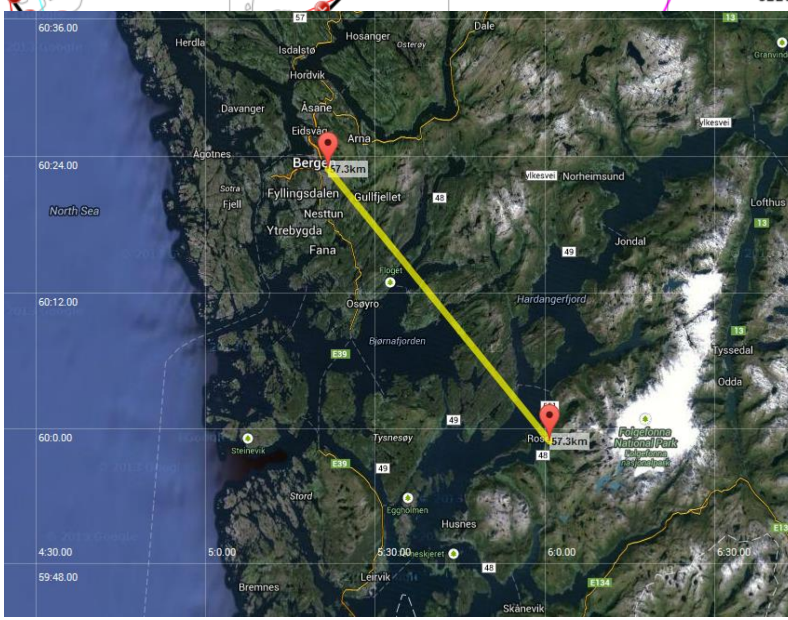


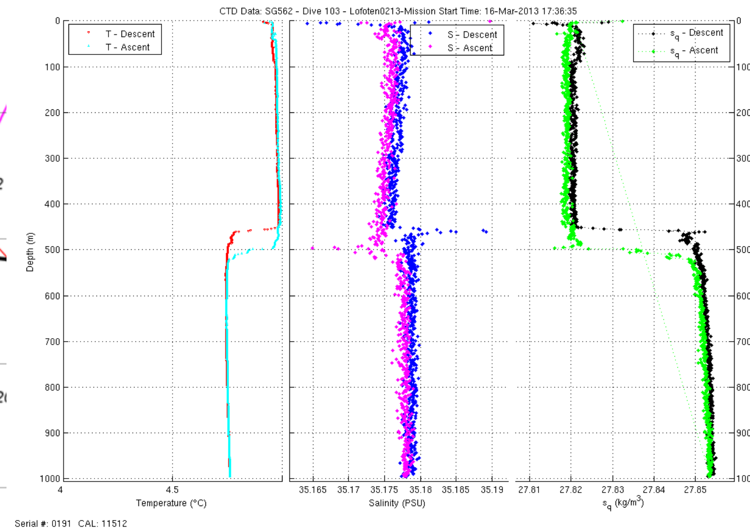


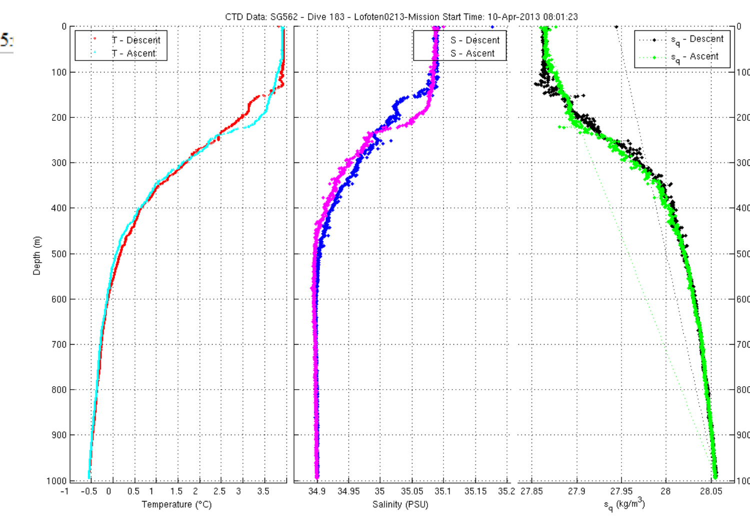
uib.no

Lofoten basin - Eddy









Exercises within the project 2013-2014

Test different “business models” for operational phase:

- NACO mission planning, ballasting, deployment, piloting, recovery, refurbishment
- Piloting:
  - Purchase 24/7 piloting services from third party (OPTIMARE; 2012- early 2013)
  - Inhouse capability - present, later separate unit in Norway?
  - EGO/GROOM network?
- Develop proper cost model for users including freight, deployment/recovery, maintenance, piloting services per month, depreciation (including risk of loss)
- Decide level of research user involvement in piloting, competence, responsibilities, decisions/risks
- Cost model for other (non-research) users

Status of infrastructure

The application stated that critical factors include:

1. technical demonstration of success in an early stage,
2. development of confidence in the technology from potential users, and
3. development of easy-to-use flight control and longer service intervals to bring down operational costs and ease user involvement.

OK with 1, working on 2, progress on 3.

Experience and recommendations

- Gliders are very suitable for long section monitoring in areas with not too strong currents.
- Sections can be combined with fixed point observations with good results; also worthwhile and relatively easy to make room for eddy and other process studies.
- Initial investment cost in gliders and training of personnel is considerable; cost of glider lab / glider port is less.
- Own work on tailoring and embedding of manufacturer software turned out to be well worth the effort; in less than one year we could pilot ourselves with a small team at less than commercial cost.
- Flexibility in sensor package is essential and increasing.
- Gliders provide useful supplement to Argo in regional seas; impact on assimilation and prediction being tested.

UNIVERSITETET I BERGEN

Geofysisk institutt

Future of ocean and atmosphere measurements