

# Combined autonomous surface vehicle & underwater vehicle operations – lessons from ‘MASSMO’



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**AUT 2017 Perth**

With thanks to the UK National Oceanography Centre [www.noc.ac.uk](http://www.noc.ac.uk)

# UK has been active in civilian Marine Autonomous Systems since the late 1980s

- I managed the 'Autosub Science Missions' programme 1997-2002
- This led to the follow-on 'Autosub Under Ice' programme.
- Since then AUVs have become an indispensable part of UK marine science hardware, acting as 'force multipliers', and going where expensive research ships can't.
- Next phase was 'do we still need the surface ships too?'
- Answer is 'yes, for now' – but the state of the art is changing fast.
- Here's how UK researchers are now combining the best of surface & sub-surface autonomy, in the MASSMO programme.

## Marine Autonomous Systems in Support of Marine Observations (MASSMO)



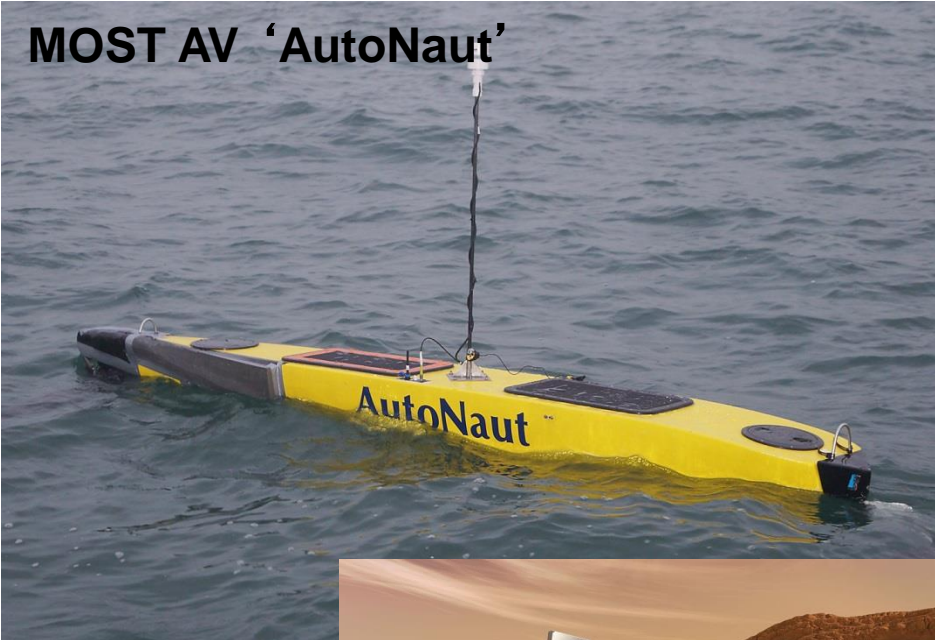
Roland Rogers (MASSMO Operations Manager)



# MARS Unmanned Surface Vehicles (USVs)

- New USVs developed as part of SBRI (co-funded by NERC/NOC and DSTL)
- Collect acoustic, metocean and biological data with a range of MAS sensors
- Clean, quiet, portable, low-cost technology (compared to survey vessels)
- Future potential to remotely collect water samples for e.g. pollutants, eDNA

**MOST AV 'AutoNaut'**



**ASV 'C-Enduro'**



*"50% of our country lies beneath the sea, and we have better maps of Mars than that 50%"*  
Bob Ballard

## Capital investment

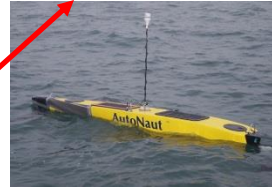


Eight Great Technologies

David Willetts



## Supporting business



LIQUID ROBOTICS



## Joint operations



National Oceanography Centre  
NATURAL ENVIRONMENT RESEARCH COUNCIL



MASSMO1  
Autumn 2014

## Public engagement



Research projects



Data management



End users

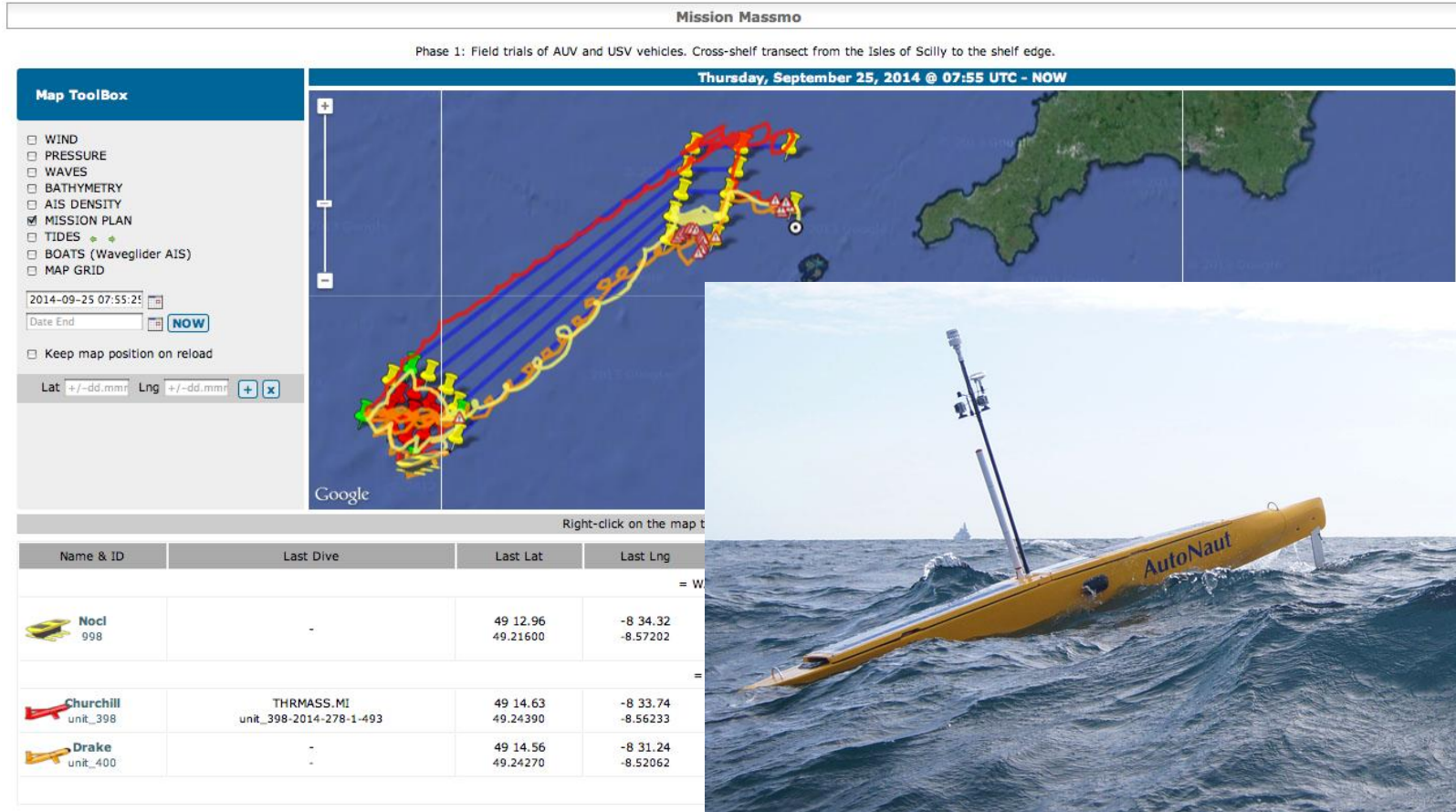


Operational products





# MASSMO – coupled surface and submarine environmental observation



- 3 USVs + 2 submarine gliders, satellite data, metocean data, fixed moorings
- 5 vehicles traveled up to 400 km in a 12-day period reaching >150 km from land
- Winds >70 mph and waves >7 m high affected vehicles, oceanography and biology!
- Valuable test of platforms and operations (piloting, C&C, data management etc)

**GoPro image from Autonaut showing Royal Navy vessel**

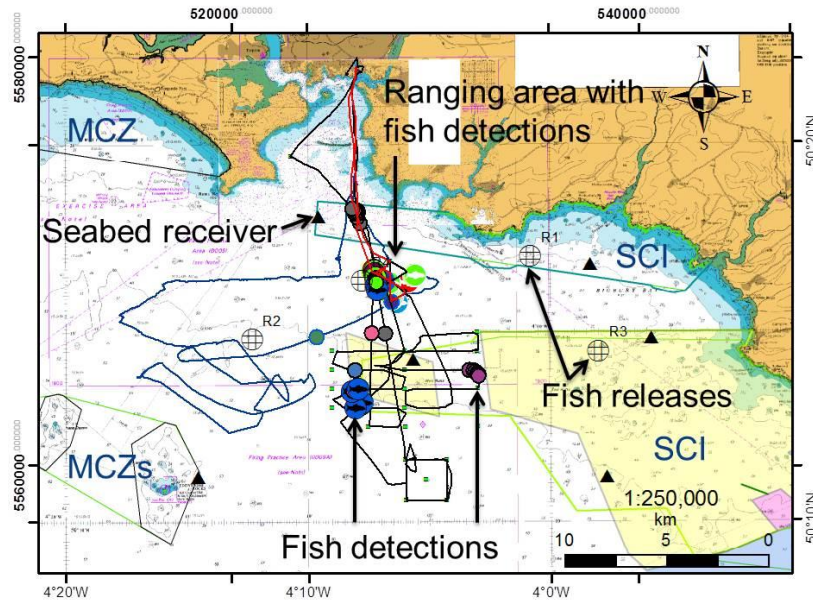


**GoPro image from Autonaut showing vehicle rolling in rough seas**





# Fish tracking using Unmanned Surface Vehicles (USVs) and seabed receivers



*USVs fitted with acoustic receivers*

*85 rays and flatfish tagged and released*



*Seabed receivers deployed*

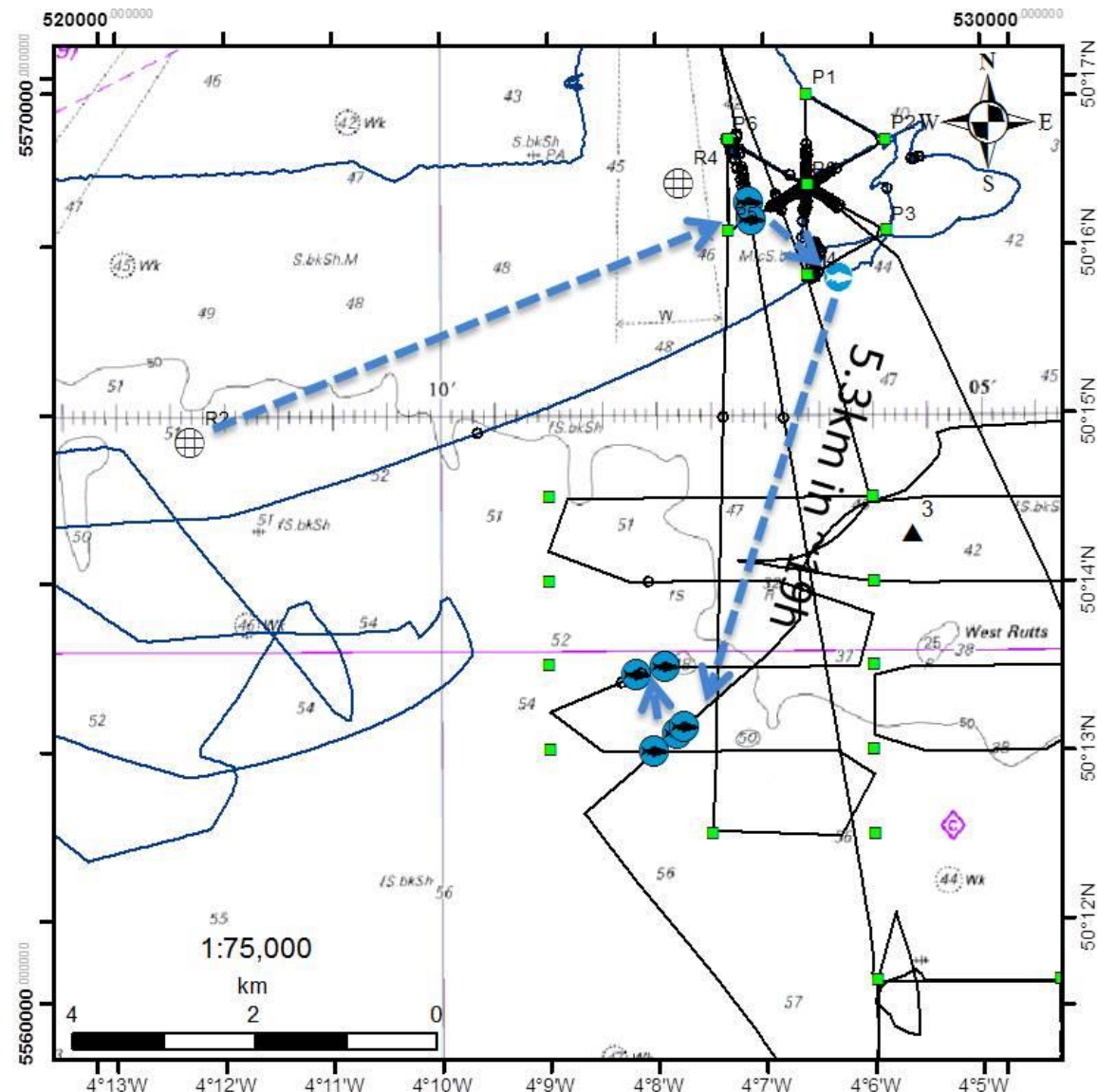
# Fish tracking using Unmanned Surface Vehicles (USVs) and seabed receivers

4 plaice detected by both Autonaut and SV3, e.g. PLE1466

- Released at R2 on 14/10
- Detected by SV3 at 1500 hrs on 04/11
- Detected by Autonaut at 1822 hrs same day (~1.1km)
- 5 further detections by SV3 on 05/11; moved 5.3km in 19h (~280m h<sup>-1</sup>), then 0.9km in 1h



Est. 1884  
Incorporated by  
Royal Charter 2013





## Capital investment



[dstl]



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## Supporting business



## Joint operations



National Oceanography Centre  
NATURAL ENVIRONMENT RESEARCH COUNCIL



Port of Milford Haven  
delivering port infrastructure and services



MASSMO2  
Autumn 2015

## Public engagement



UNIVERSITY OF  
Southampton

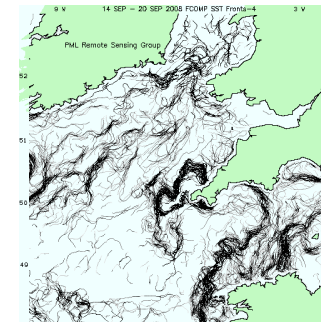


Research projects

Data management

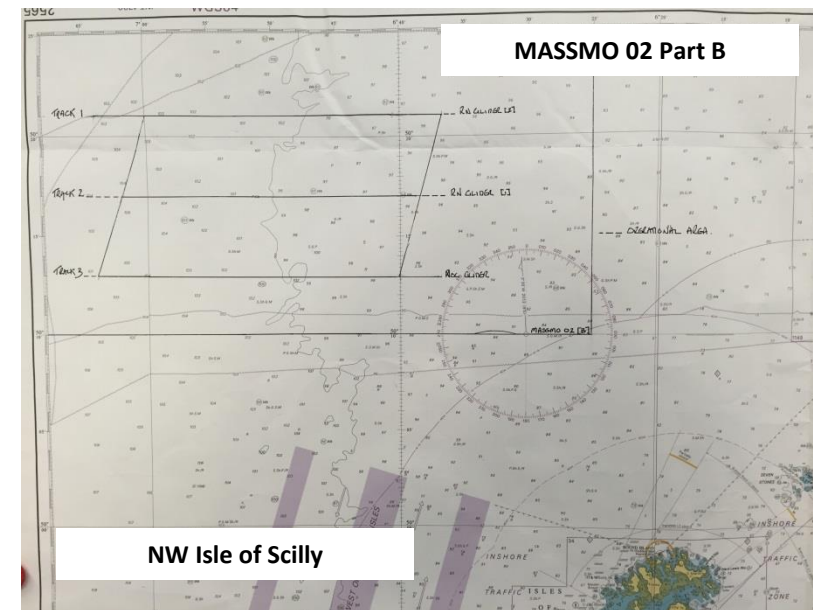
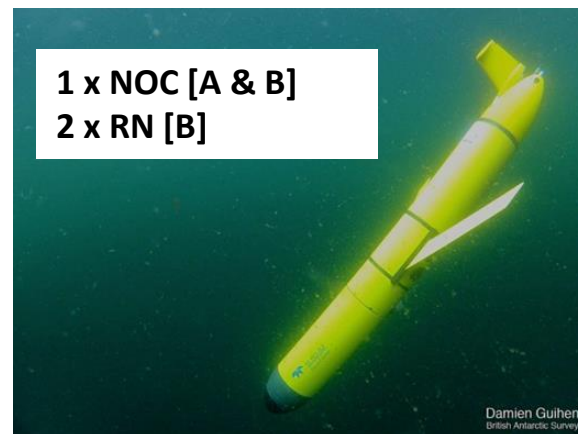
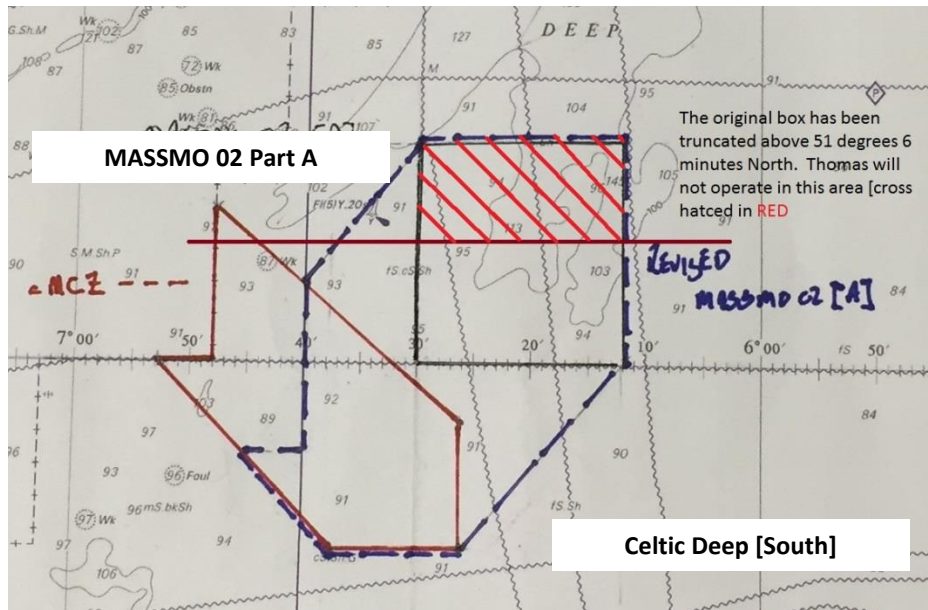


End users



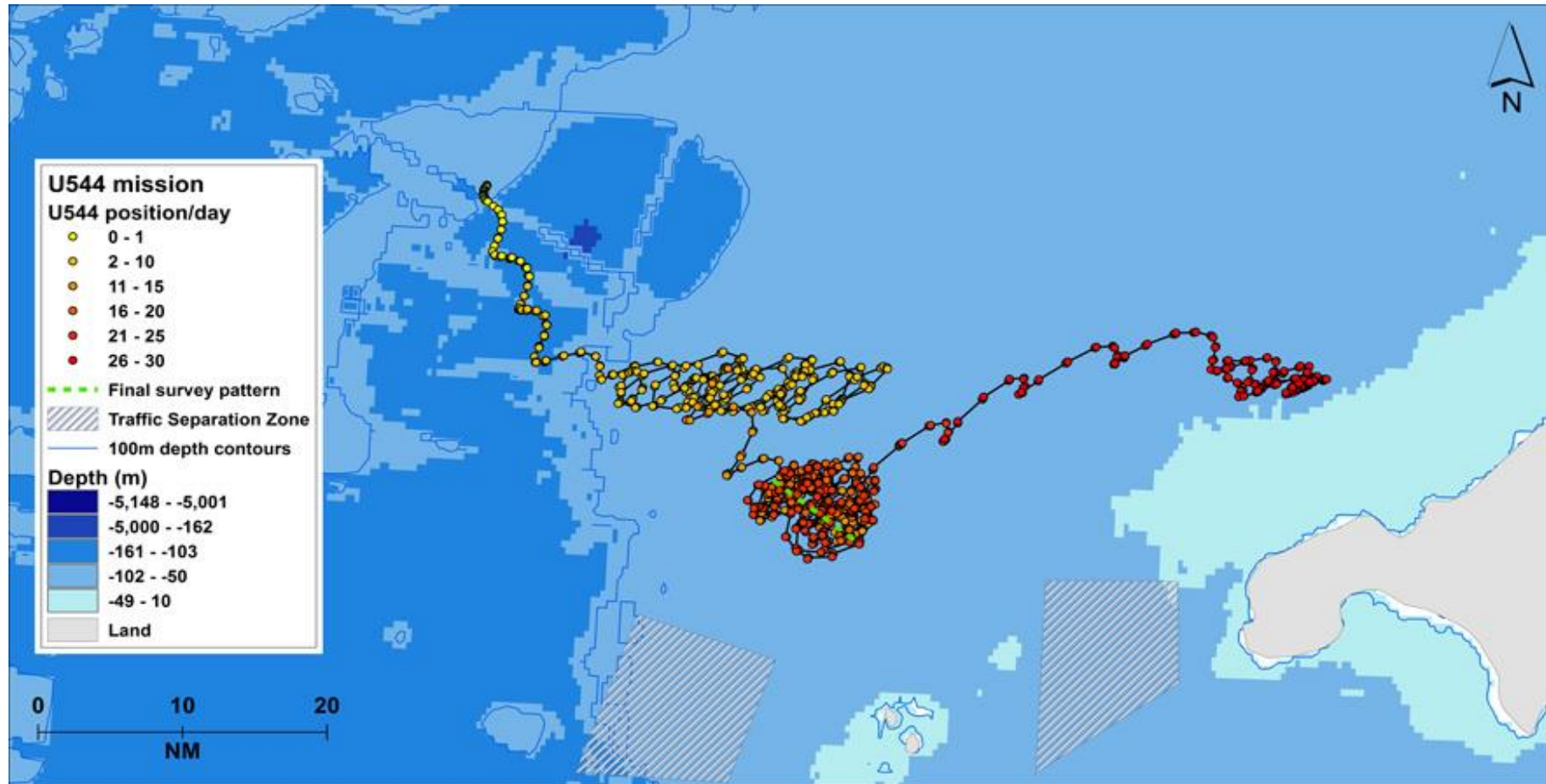
Operational products



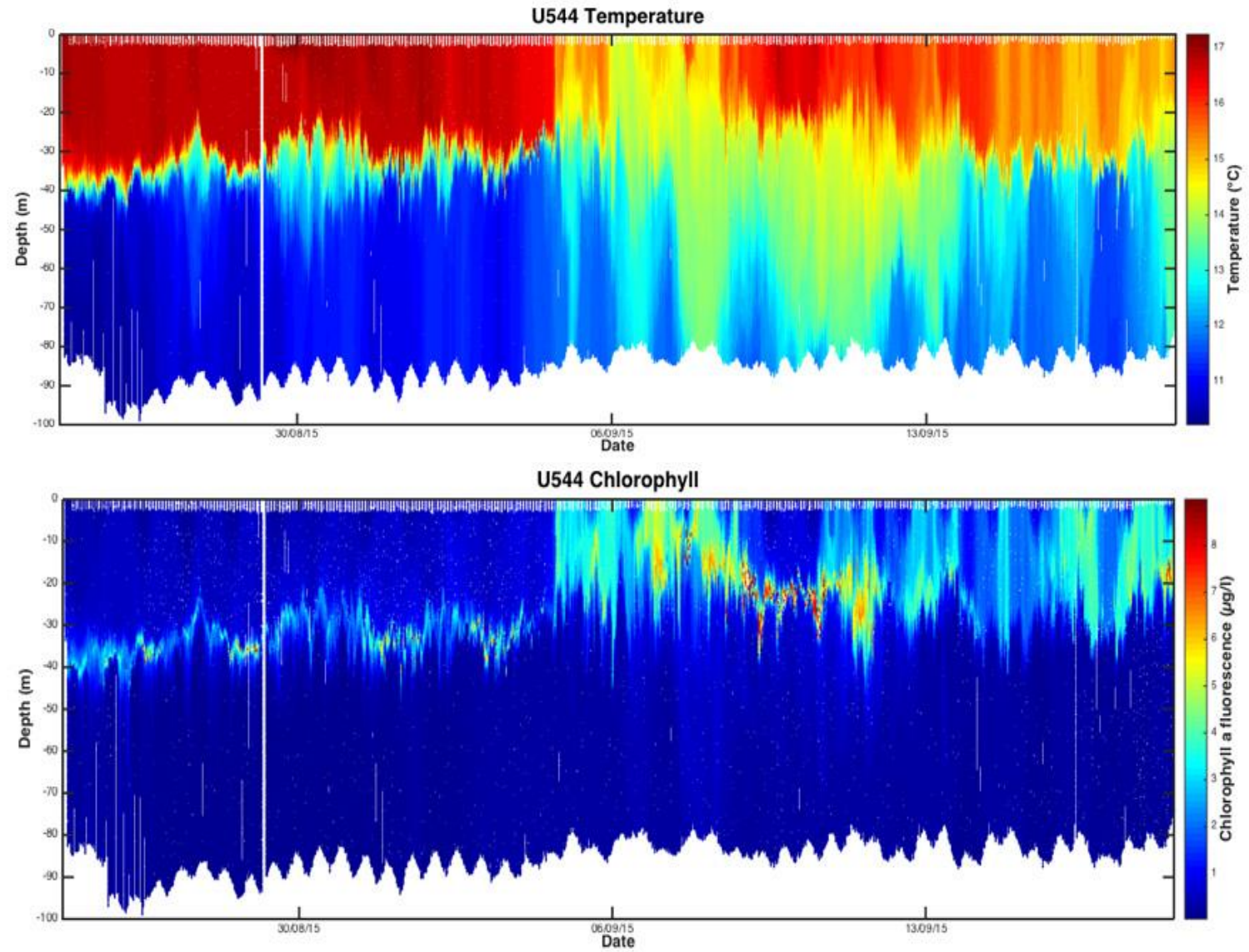


**MASSMO2  
Autumn 2015**

## U544 glider track during MASSMO2B



# U544 temperature and chlorophyll data during MASSMO2B





## Project funding



## Promoting innovation



KONGSBERG



LIQUID ROBOTICS



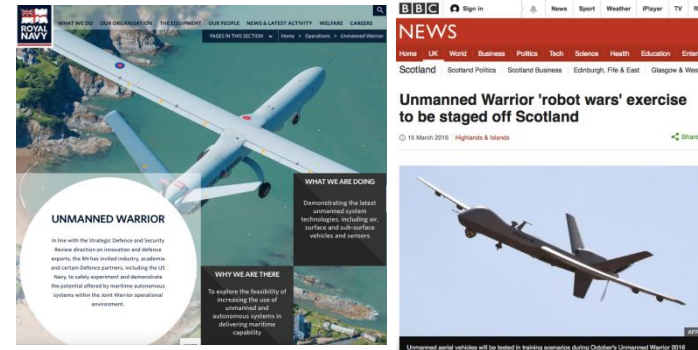
## Joint operations



QinetiQ

MASSMO3  
Autumn 2016

## Public engagement

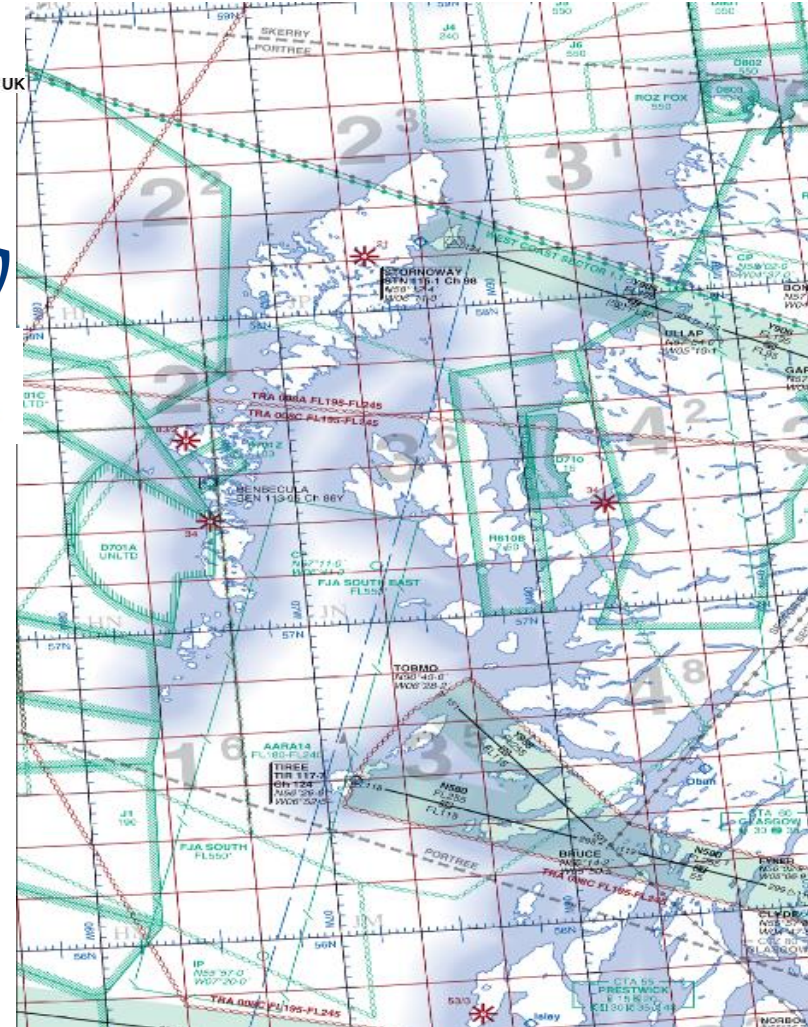


## Data management



## Operational products





**Commander Peter Pipkin**  
**Royal Navy**

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**#uw2016**

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**+44 (0)2392 625995**

## MASSMO 03 Autumn 2016

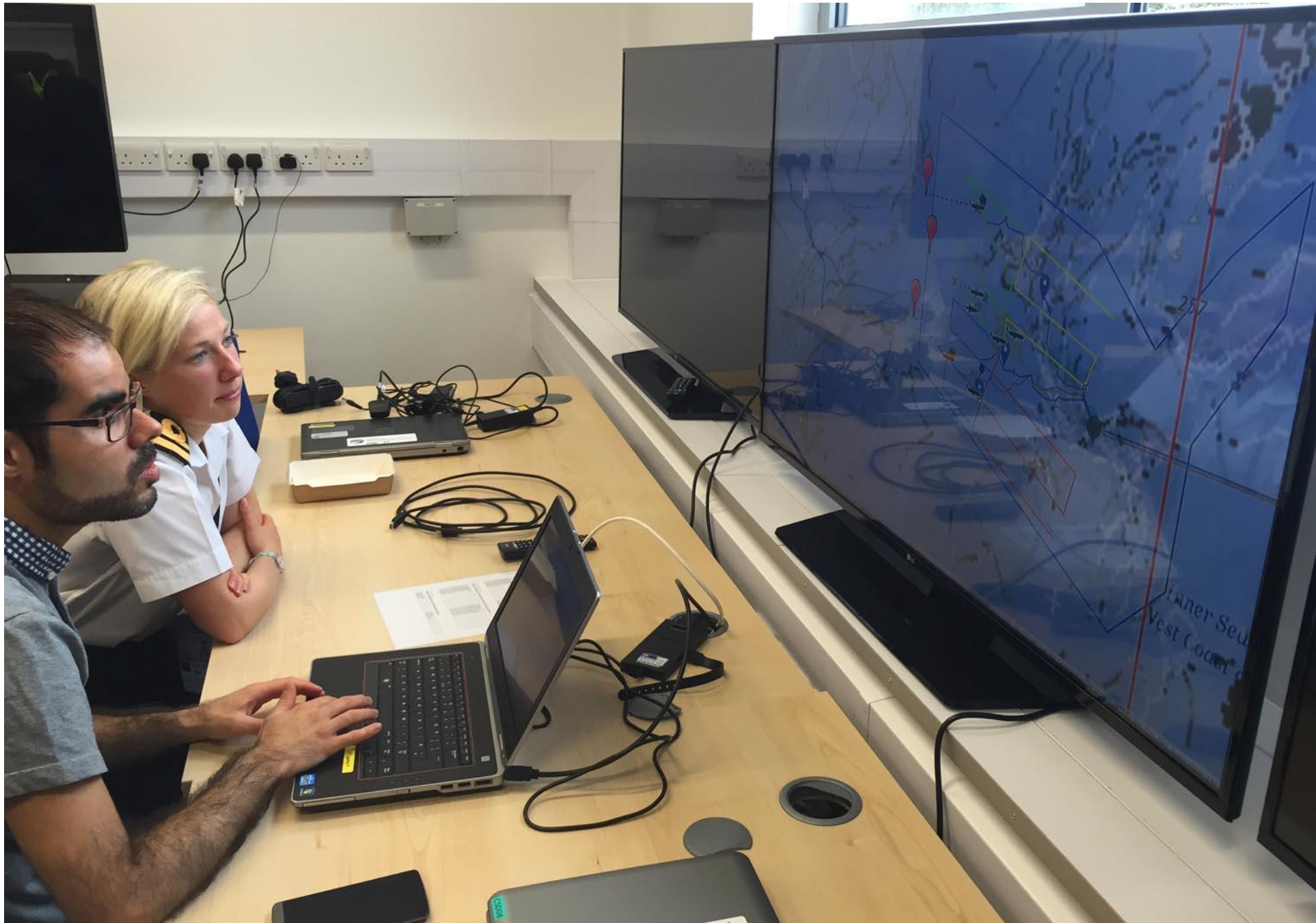


### MASSMO3 in autumn 2016

*DSTL objectives for the task to be issued to NOC will focus on **real-time delivery of geospatial intelligence data** collected with a fleet of **seven submarine gliders and one waveglider**, to inform operations during Exercise Unmanned Warrior and Exercise Joint Warrior 16/2; the focus will be on **generating products** such as sound speed profiles and cetacean presence/absence that can be used in support of ASW and other operations*

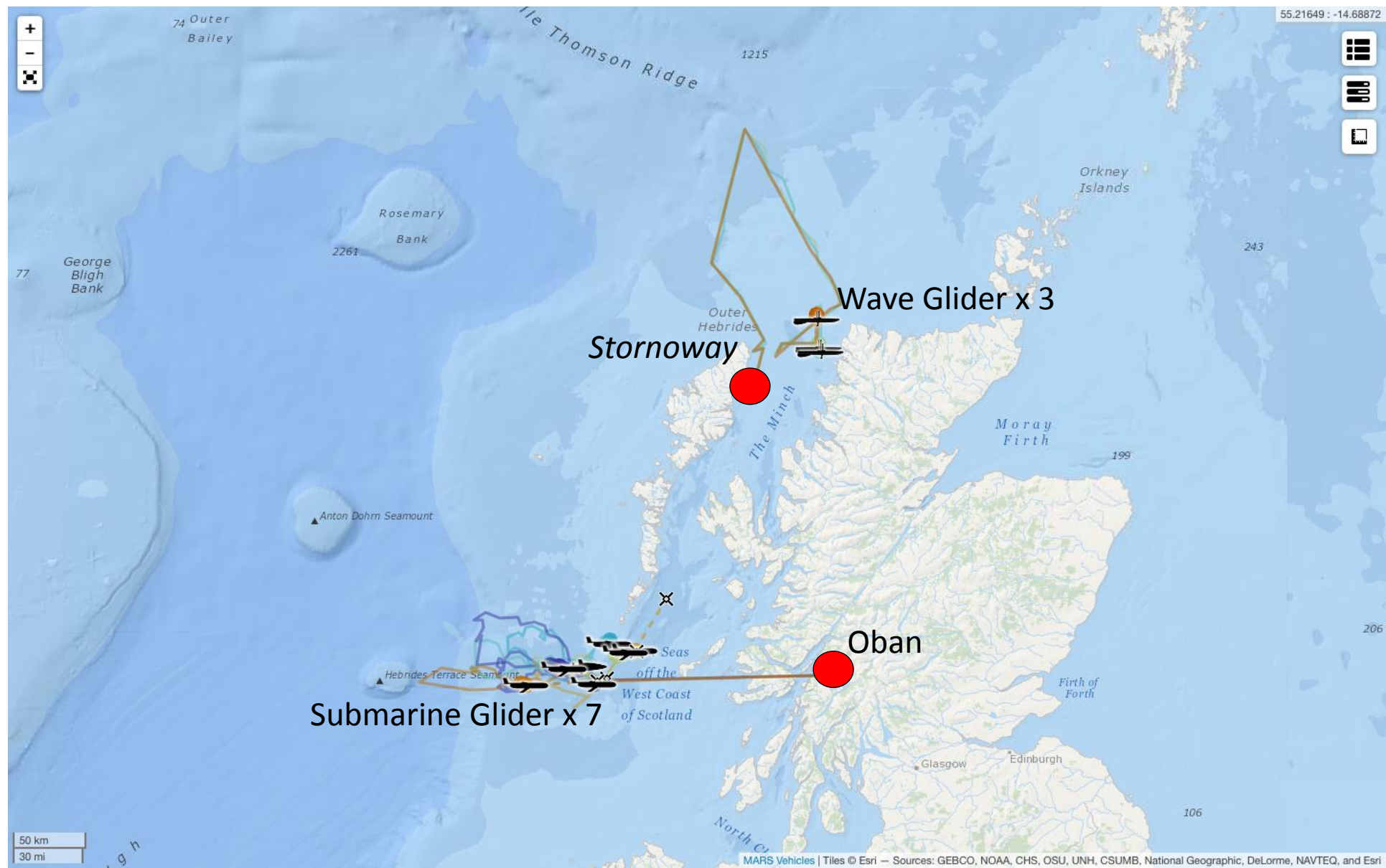


## Royal Navy and NOC pilots in the NOC Operations Room



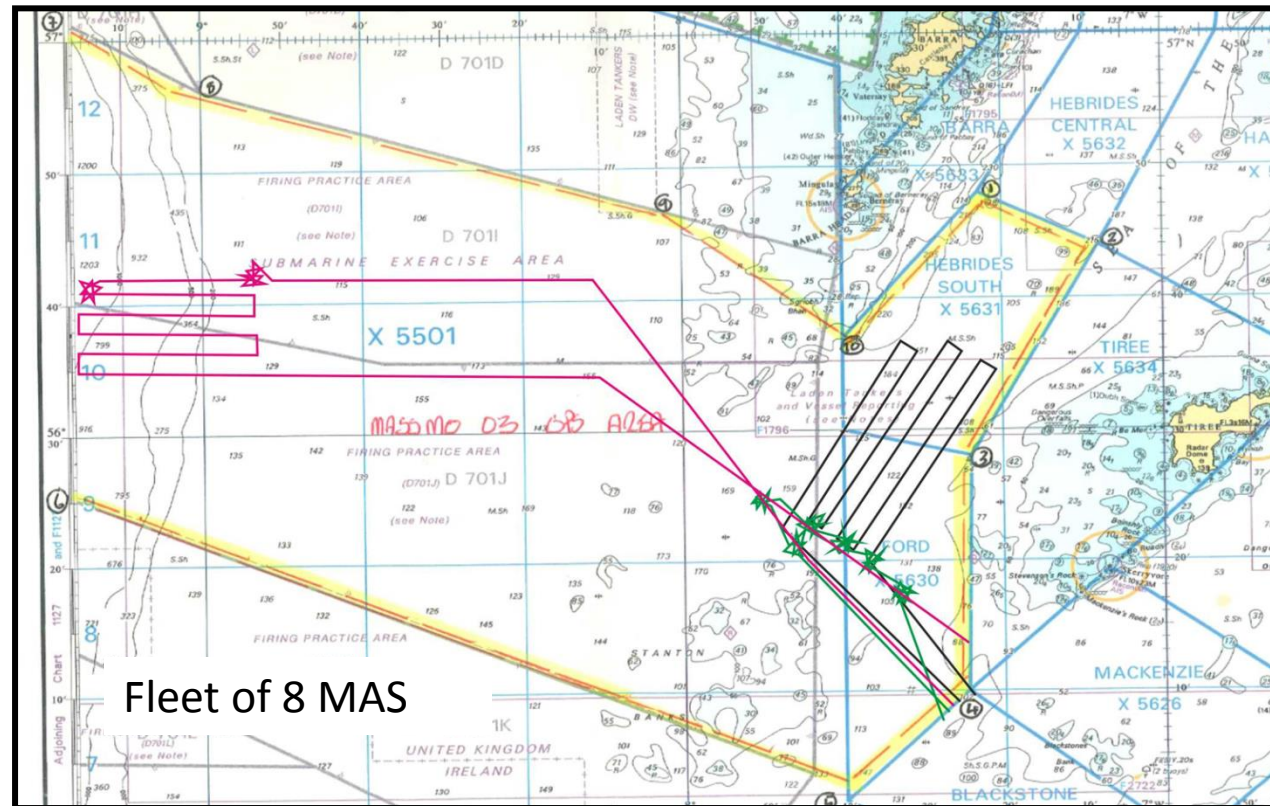
## The MASSMO3 fleet at 1220 hrs on 29 Sept 2016

The largest simultaneous deployment of operational MAS in UK waters to date





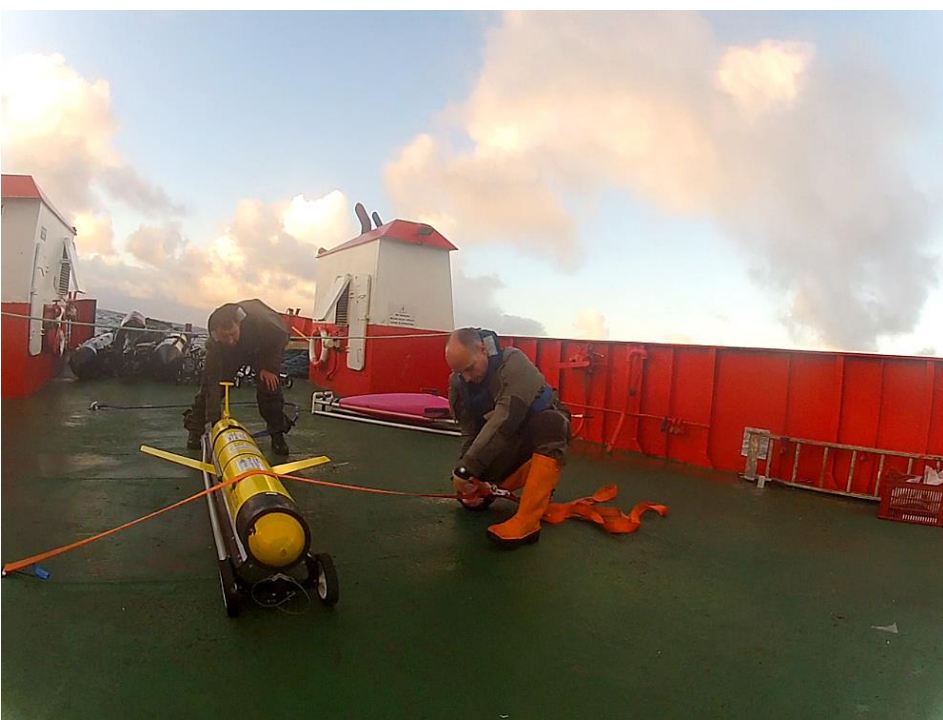
# MASSMO 03 Autumn 2016

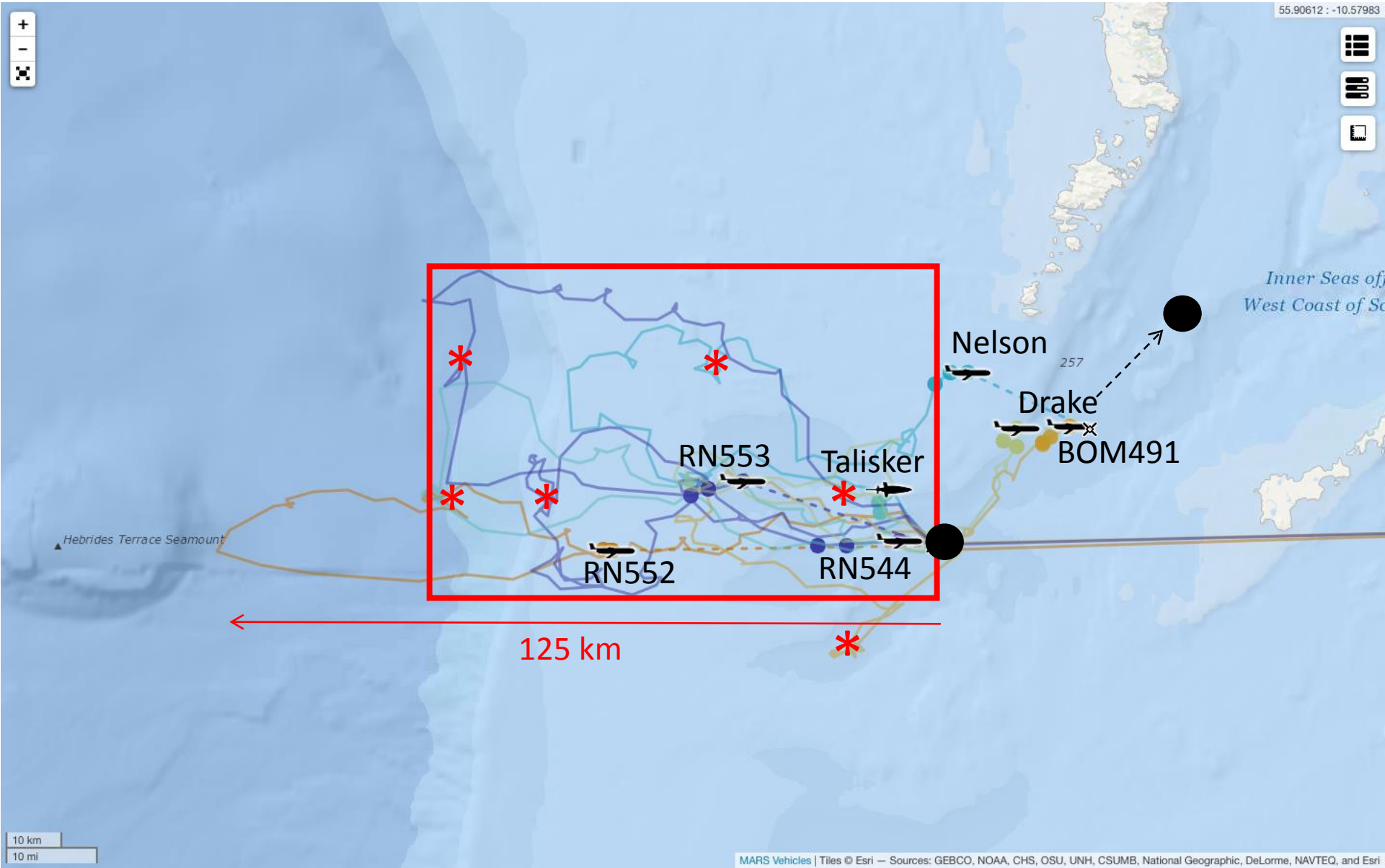










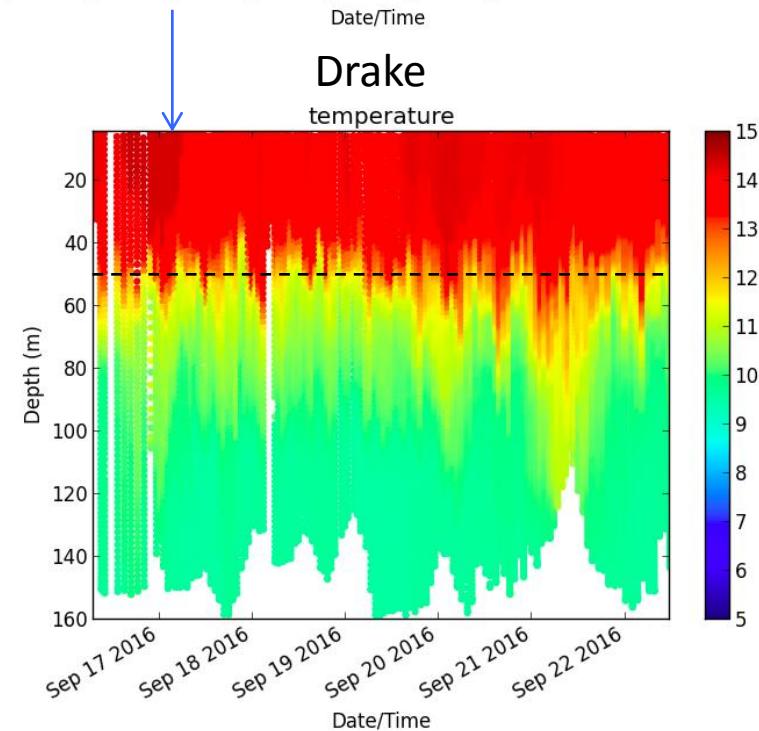
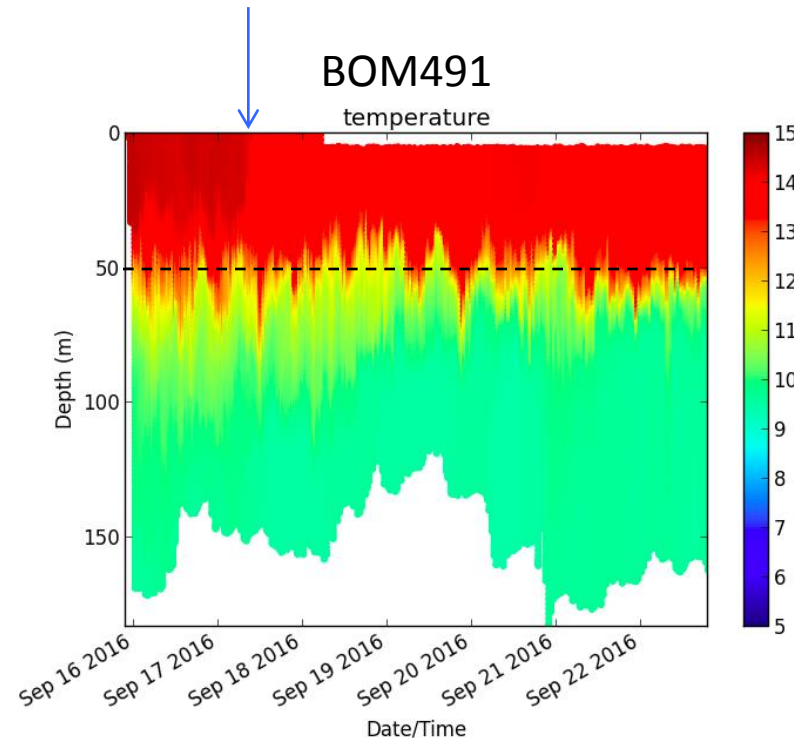
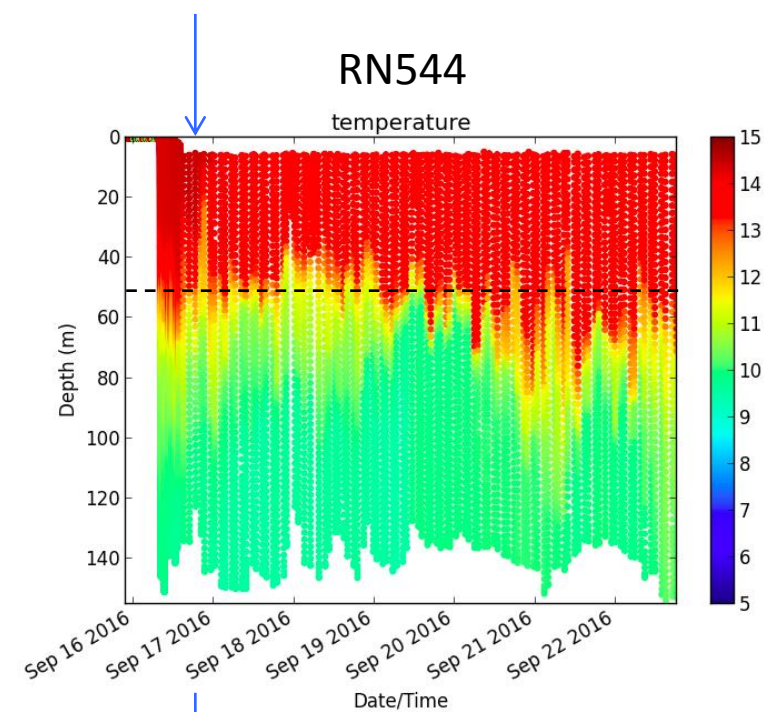




## Temperature data from three shallow gliders

### 16-22 Sept 2016

- Note surface temperature decrease on 17 Sept (blue arrows)
- Note consistent thermocline depth at ~50 m (black dashed line)



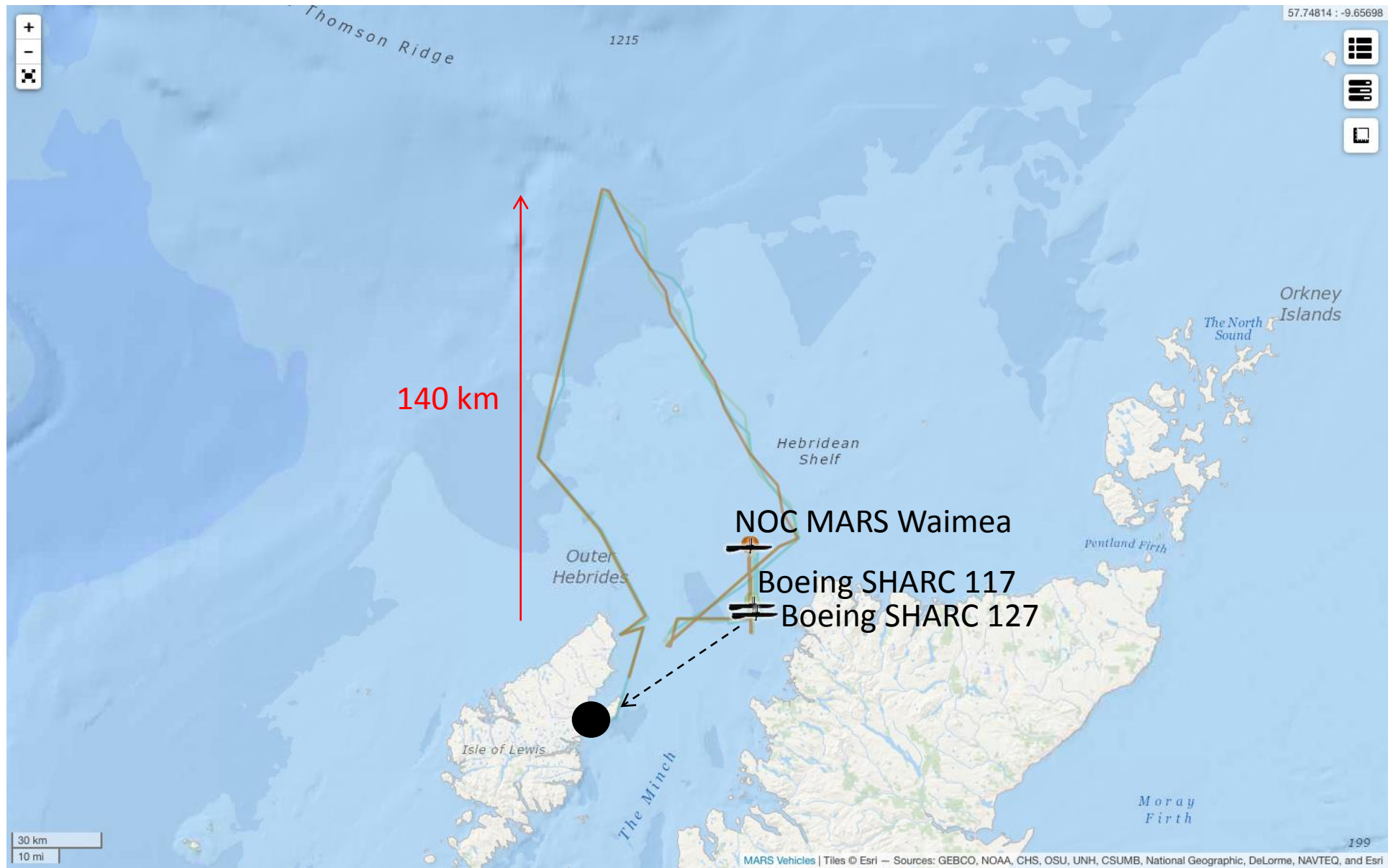






## Wave Glider locations at 1100 hrs on 29 Sept 2016

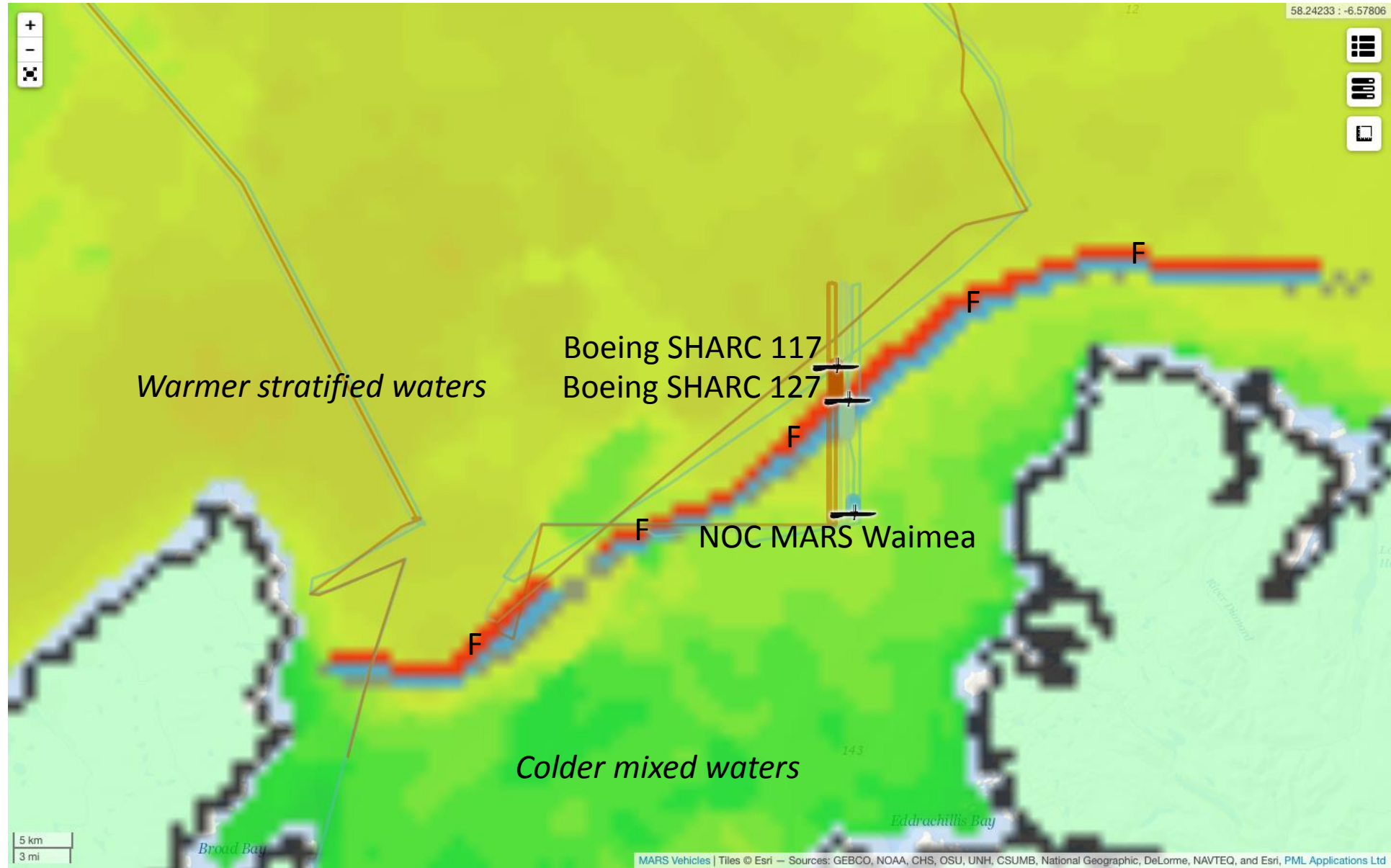
Wave Gliders have covered >1000 km and reached up to 140 km offshore





## Wave Glider locations at 0630 hrs on 28 Sept 2016

Wave Gliders are undertaking repeat crossings of the front marked F below  
Sea surface temperature map shows colder mixed surface waters south of this front



## Marine Autonomous Systems in Support of Marine Observations (MASSMO4)



- Mass deployment of 11 surface and submarine MAS (in partnership with CMRE and MSS)
  - Focus on passive acoustic monitoring of marine mammals and oceanographic features
  - Track submarine gliders carrying acoustic pingers with USVs carrying acoustic receivers
  - Demonstration of 'rapid' offshore transits and virtual moorings with submarine gliders
  - Interpretation of collected acoustic data in context of highly complex physical environment
  - Assess optimal deployment of MAS in heterogeneous ocean environment (with other data)
- 
- *2 x UEA Seaglidors (PAM and microstructure)*
  - *2 x RN Slocum gliders (deep, with thrusters); 1 x BOM Slocum glider; 1 x NMF-MARS Slocum glider*
  - *2 x CMRE Slocum gliders (PAM and oceanography)*
  - *1 x NMF-MARS C-Enduro (with Seiche towed array and Vemco acoustic receiver)*
  - *1 x NMF-MARS SV3 Wave Glider (with Vemco acoustic receiver)*
  - *1 x NMF-MARS Autonaut (with Seiche towed array)*
  - *NRV Alliance and MRV Scotia*



## Project funding



## Promoting innovation



LIQUID ROBOTICS



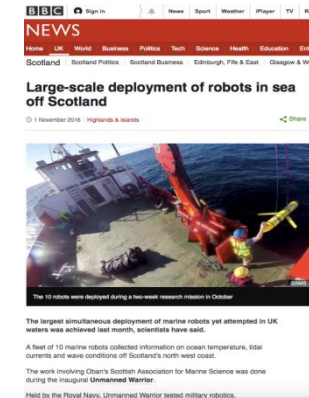
## Joint operations



MASSMO4  
May-June 2017



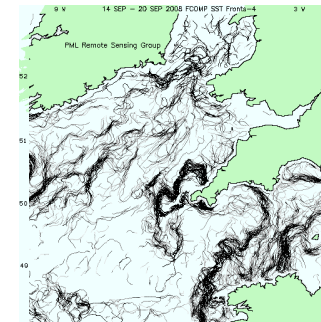
## Research and public engagement



Data  
management



Operational  
products

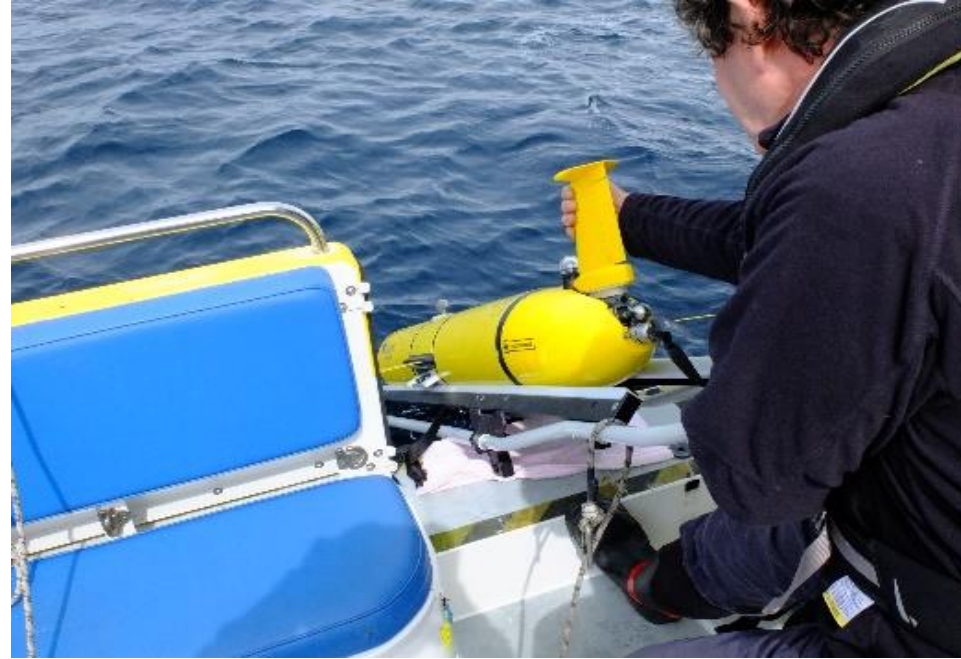


## Submarine gliders and Autonaut being prepared for deployment in Orkney





## NMF-MARS team deploying RN and BOM gliders off Orkney on 19 May 2017





## Daily briefing in the MASSMO4 Operations Room on 19 May 2017

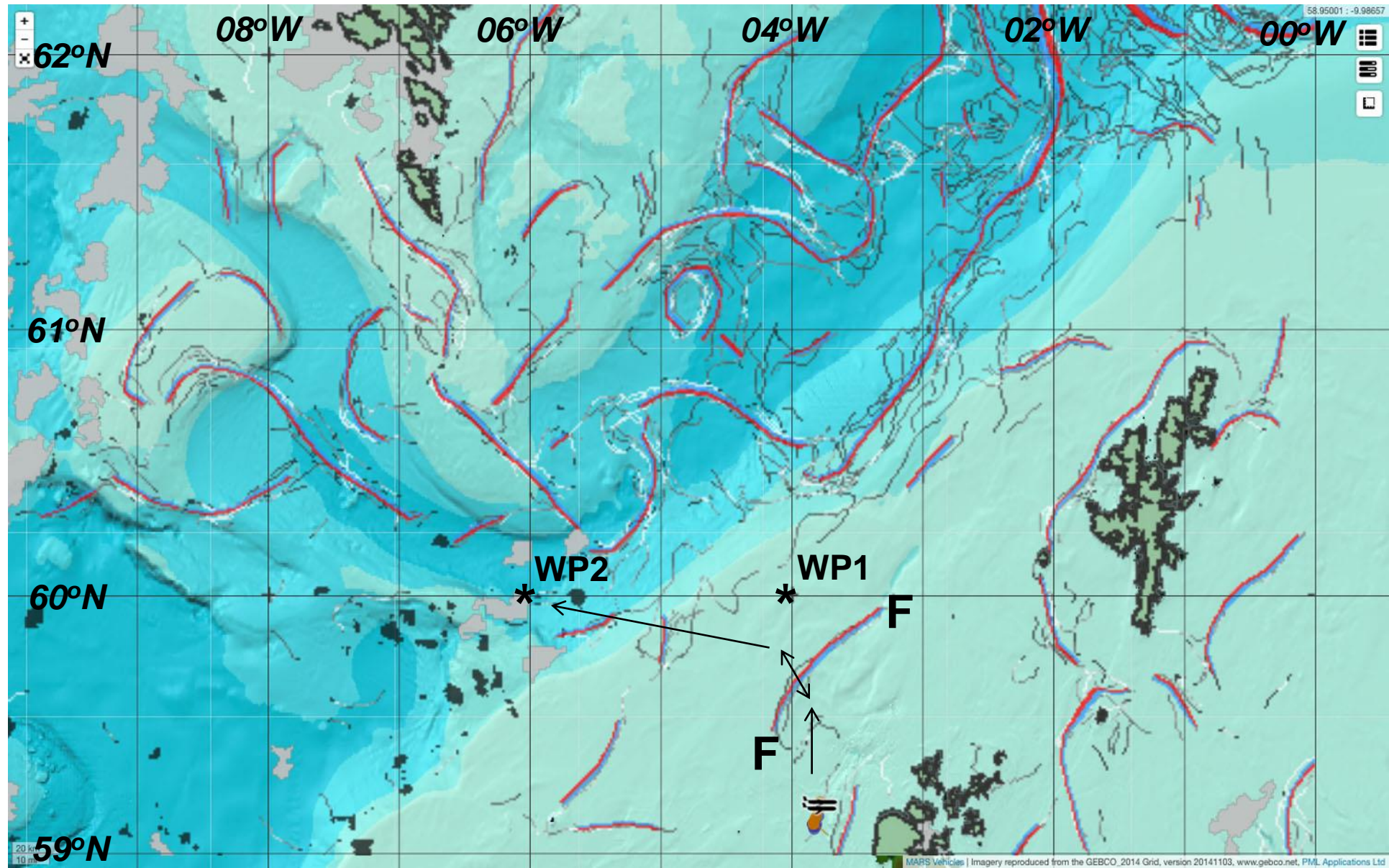




# GEBCO bathymetry of the MASSMO4 work area with simplified front map overlay

*Front map is seven-day composite image covering period 13-19 May 2017 (from PML)*

*Proposed glider transect shown with black arrows, targeting front NNW of Orkney*

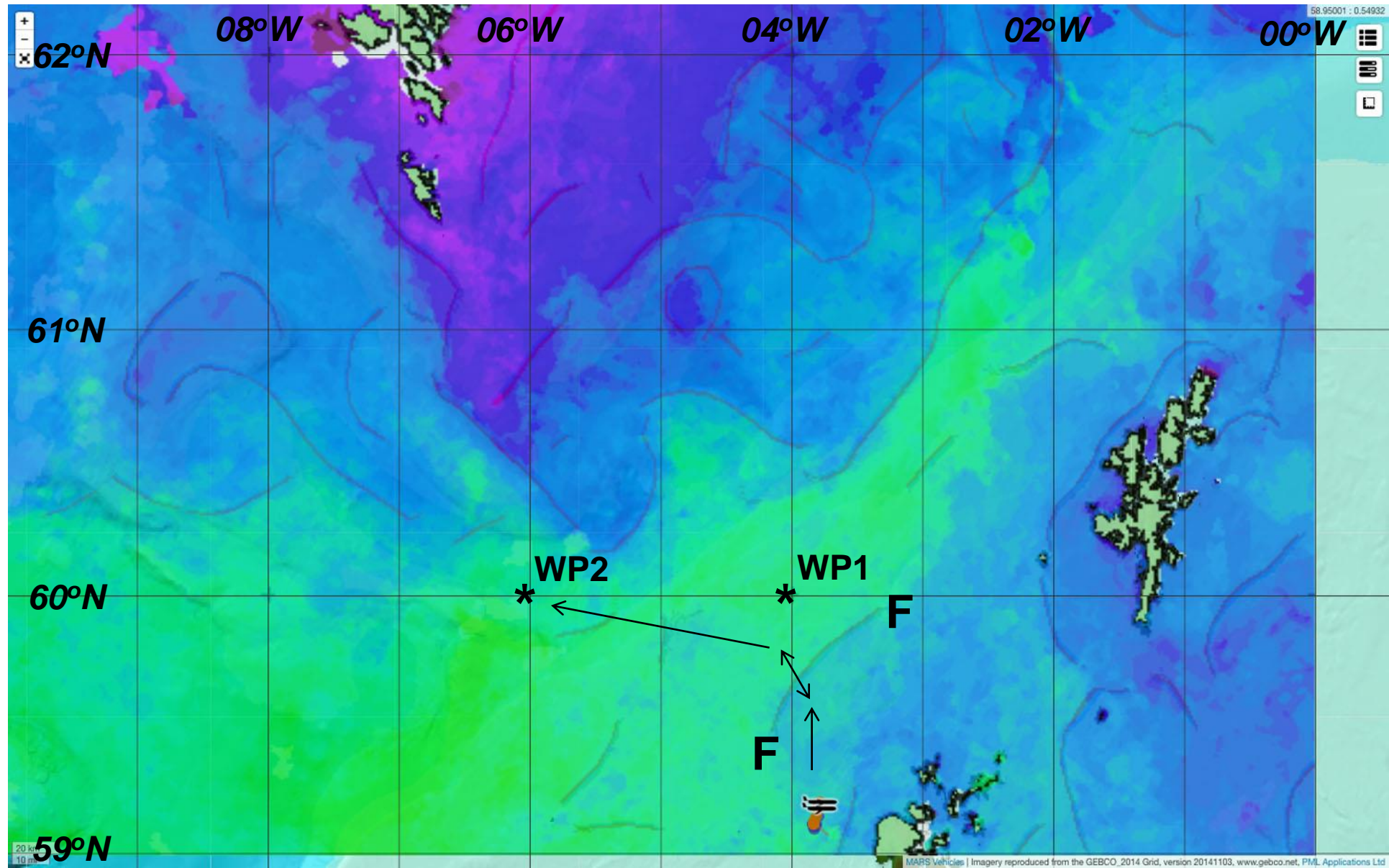




## Image of the MASSMO4 area showing SST data and simplified fronts

*Maps are seven-day composite images covering period 13-19 May 2017 (from PML)*

*Note the presence of cooler mixed waters on the SE side of targeted front*

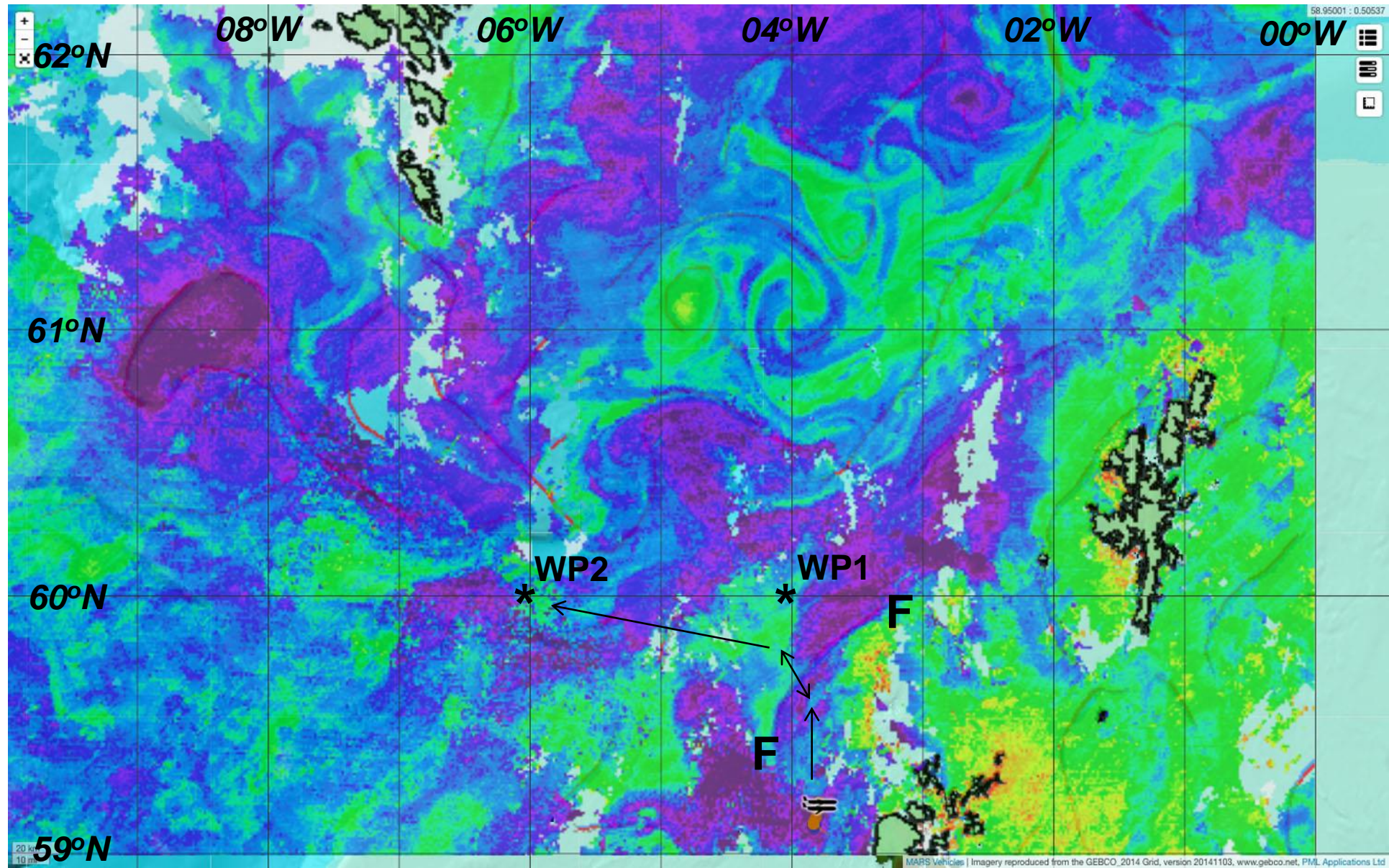




# Image of the MASSMO4 area showing chlorophyll-a data and simplified fronts

*Maps are seven-day composite images covering period 13-18 May 2017 (from PML)*

*Note the variable productivity either side of the targeted front, and the eddies to the N!*

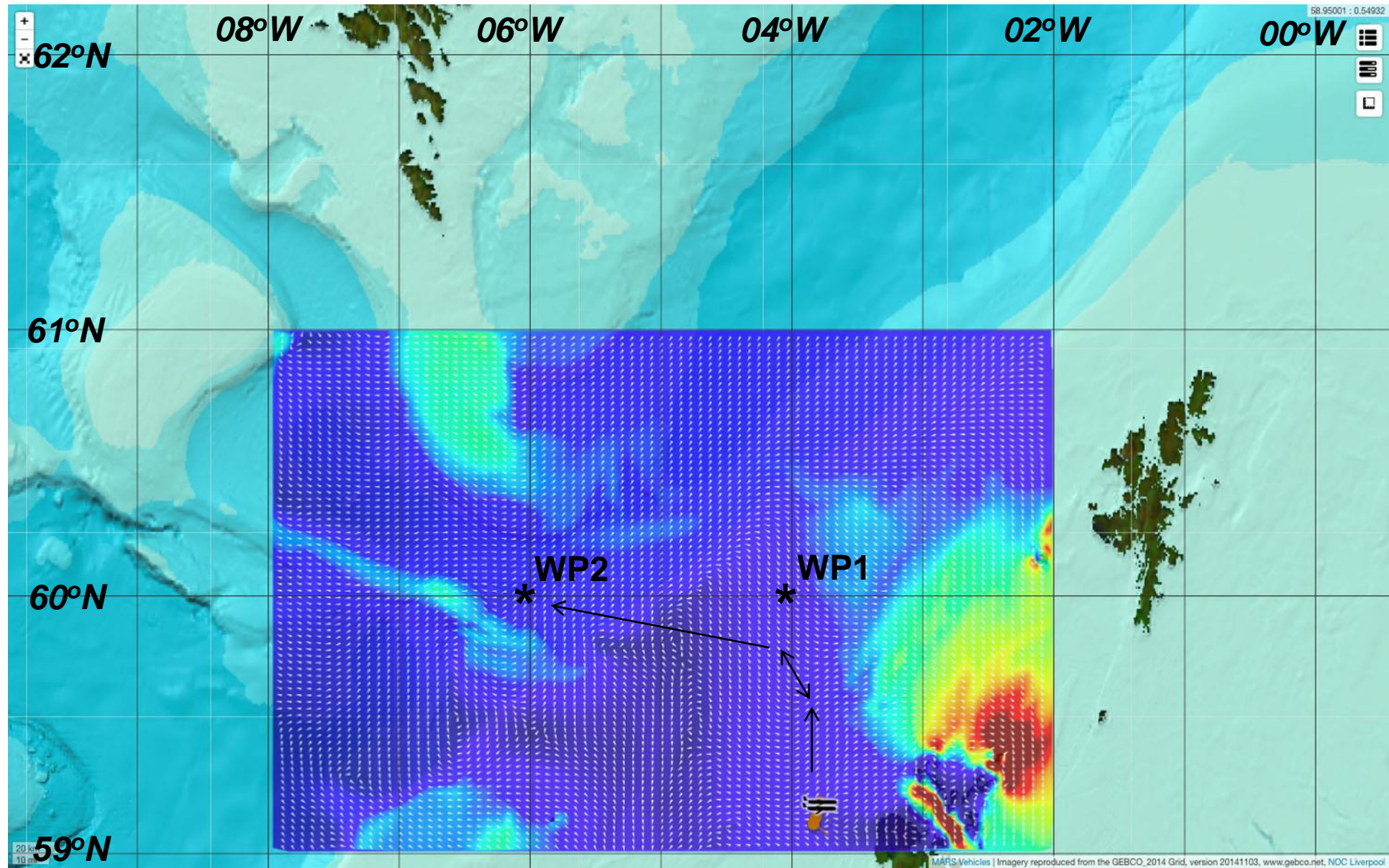




# Image of the MASSMO4 area showing tidal prediction model data

*Maps updated every 15 mins; hotter colours indicate stronger tidal flows (from NOC-L)*

*Note the strong tidal flows around the Orkney archipelago*

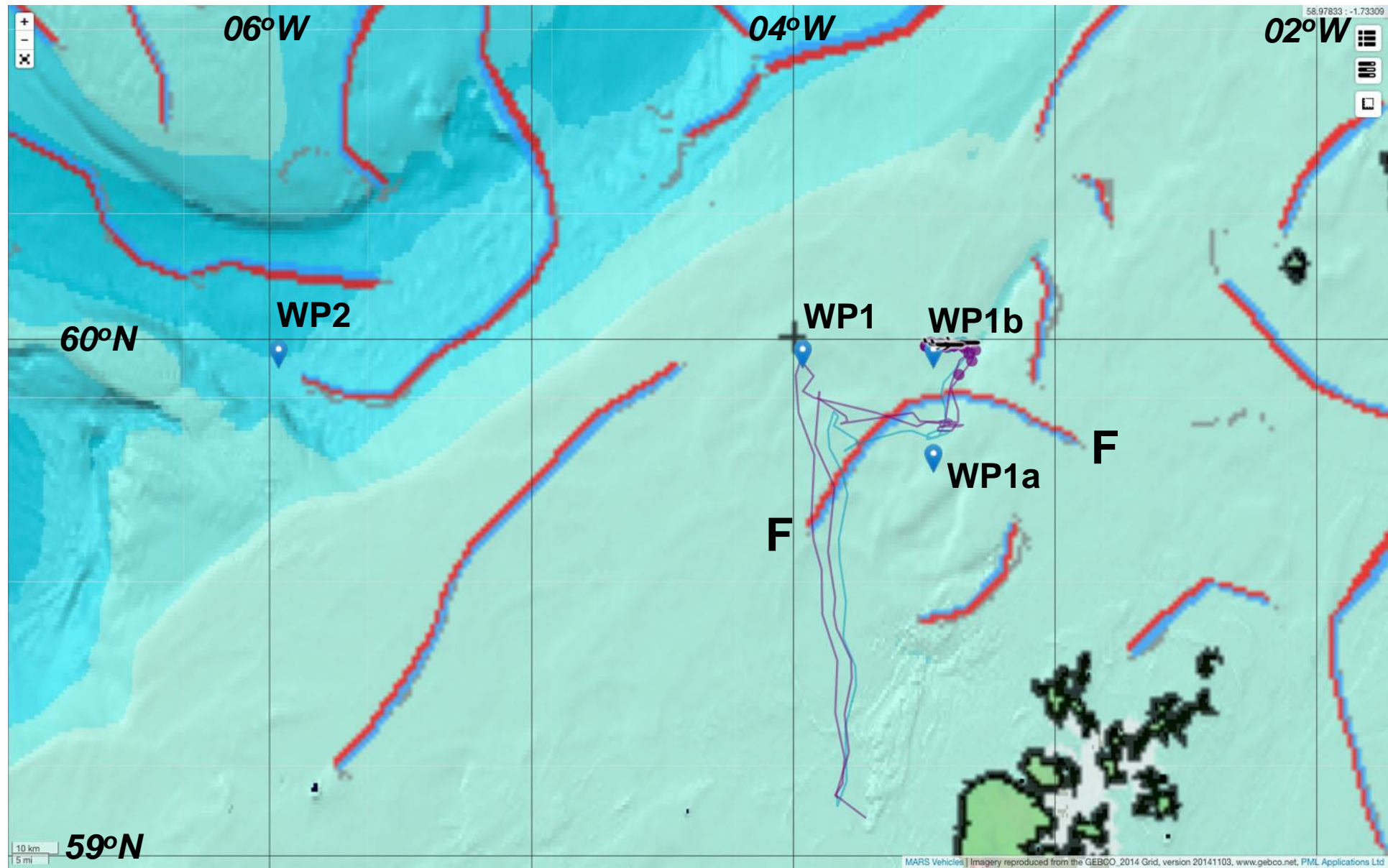




## Simplified front maps overlain on GEBCO bathymetry

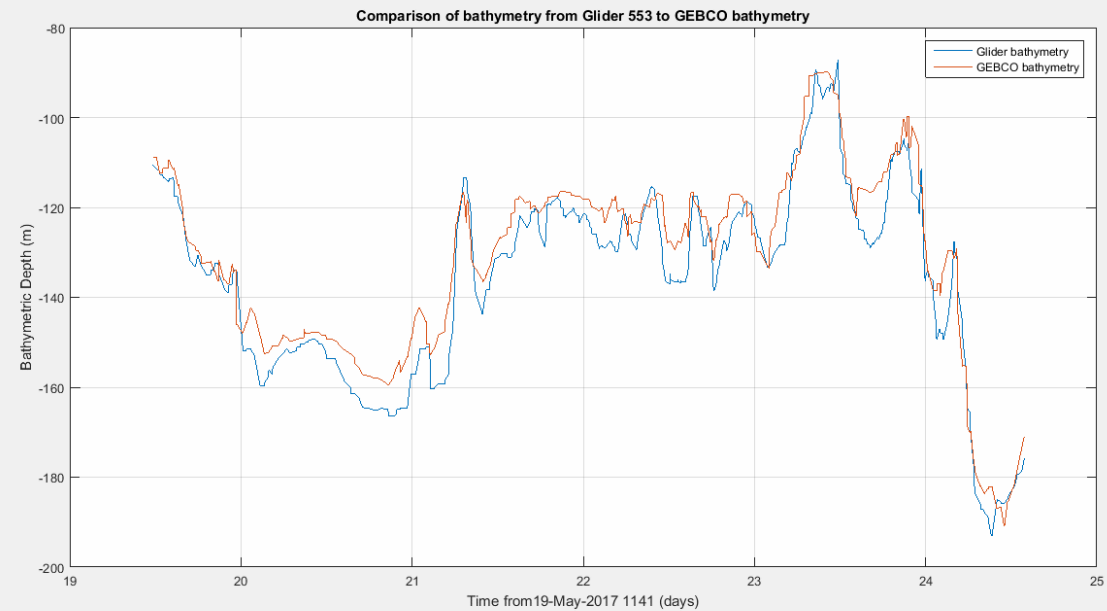
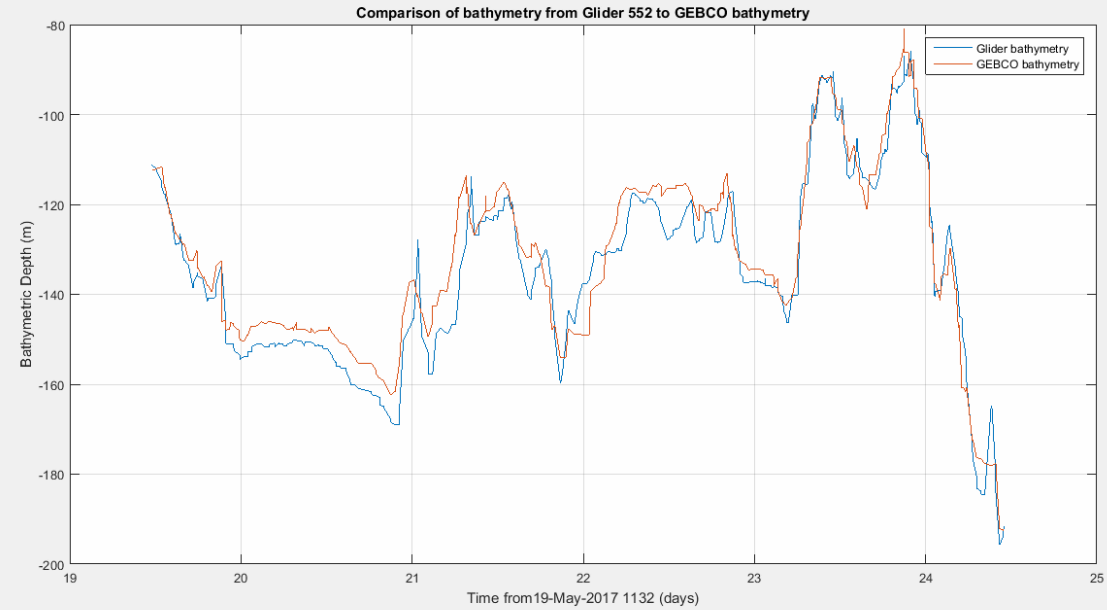
*Front map is seven-day composite image covering period 18-24 May 2017 (from PML)*

*The RN and BOM gliders are currently targeting the front (F-F) NNW of Orkney*

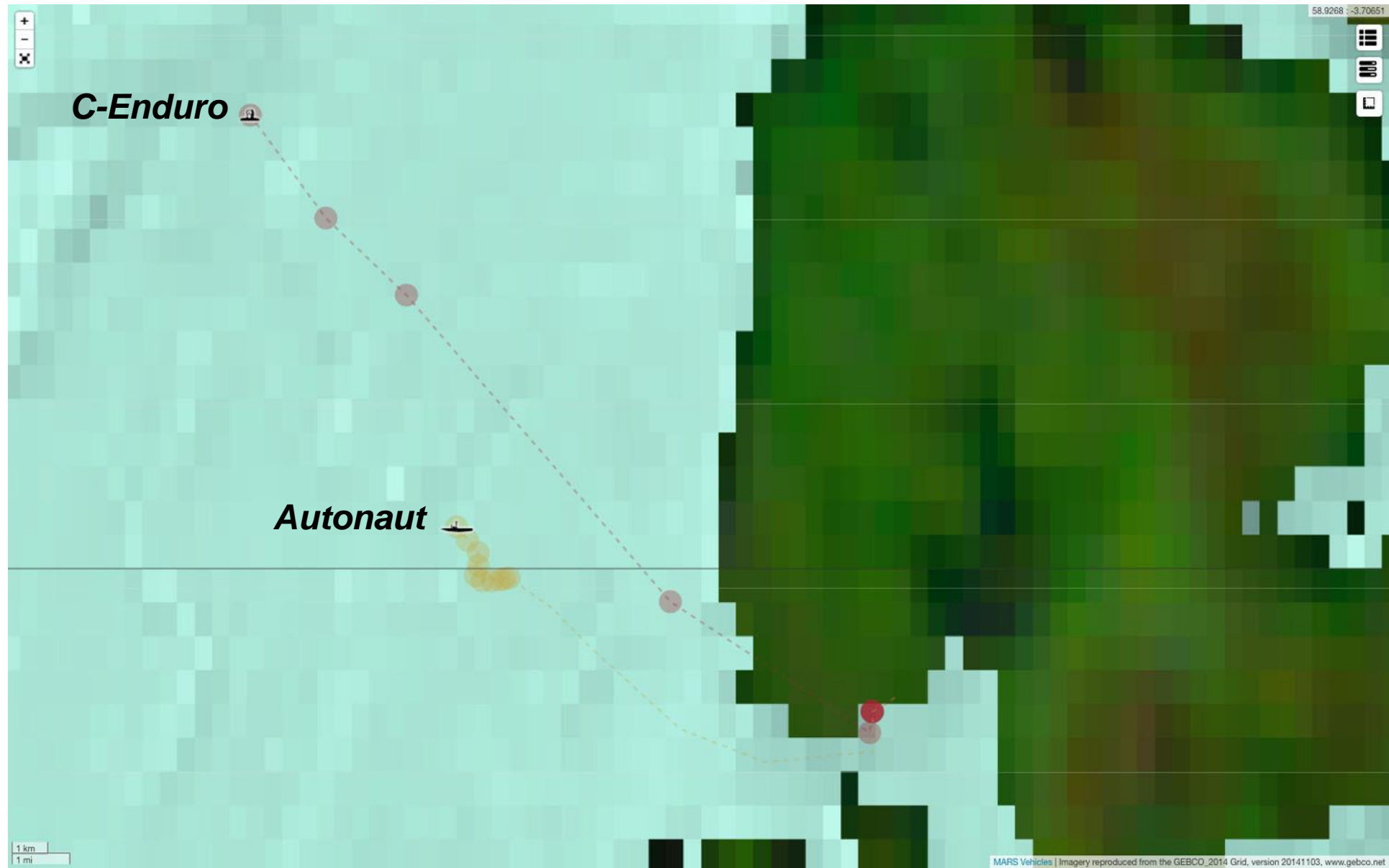




# Comparison of bathymetry from RN gliders with GEBCO data for 19-24 May 2017

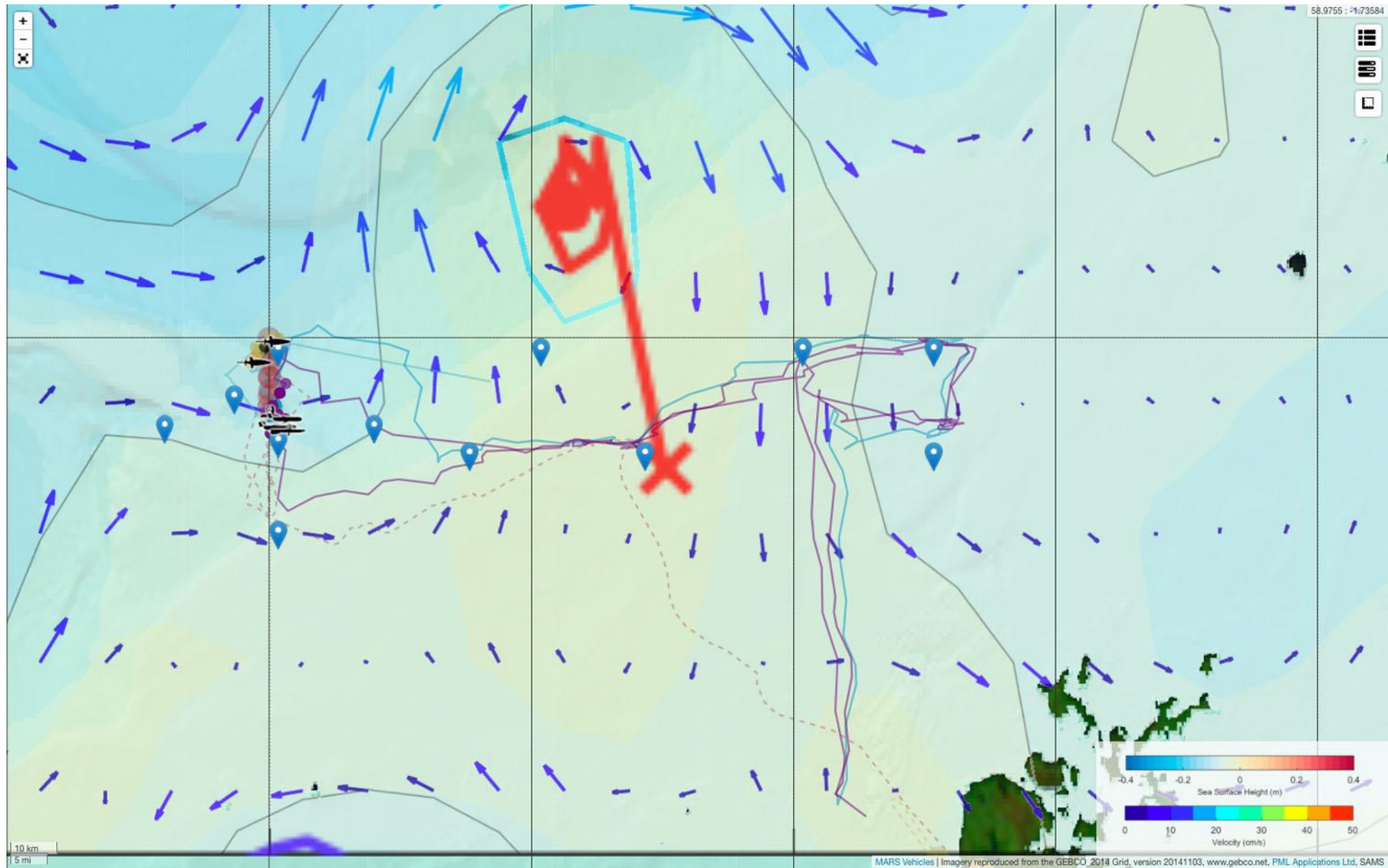


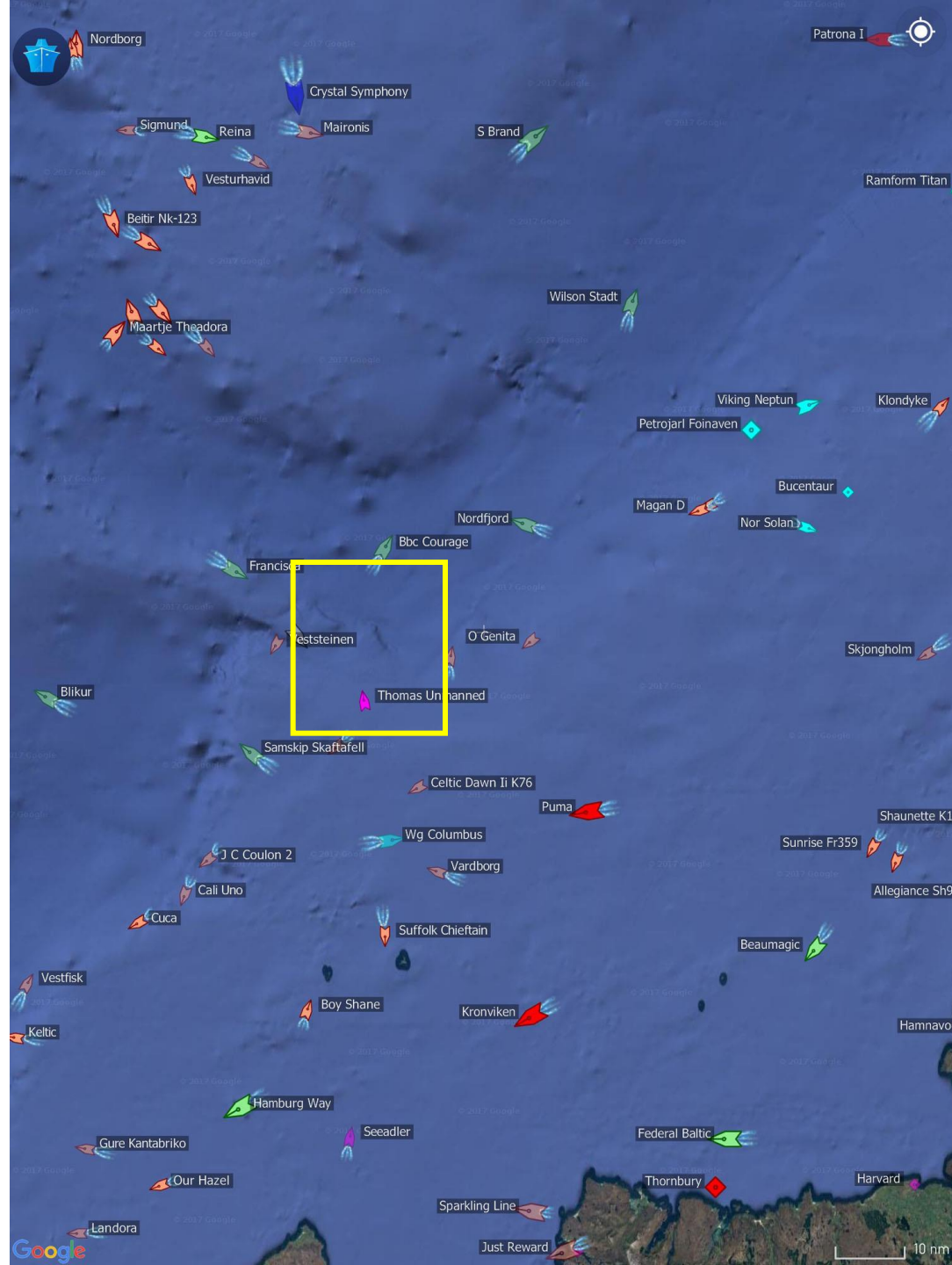
# C-Enduro and Autonaut USVs departing Orkney at 2200 hrs on 25 May 2017





**The MASSMO4 fleet at 0745 on 03 June 2017 with GEBCO bathymetry underlay**  
*Additional data layers include Aviso surface currents (SAMS) and eddies (PML)*





Screengrab from MarineTraffic showing AIS positions of vessels in the MASSMO4 work area at 2235 on 03 June 2017

MASSMO4 fleet is located within the yellow box

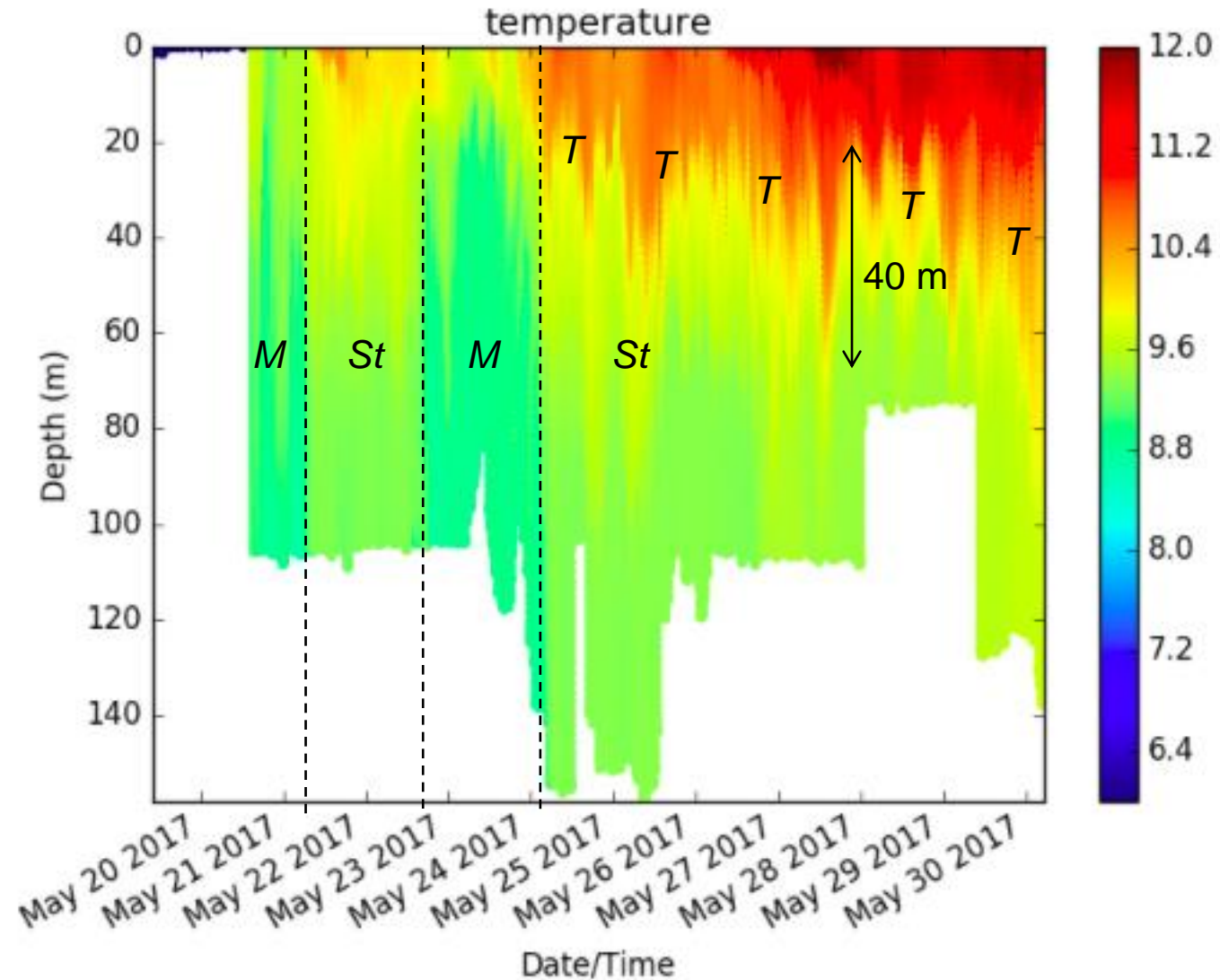


## Temperature plot for RN glider (unit 553) for 20-30 May 2017

*Note progressive development and deepening of thermocline (T)*

*Note progressive warming of surface stratified waters (St) from ~10-12°C*

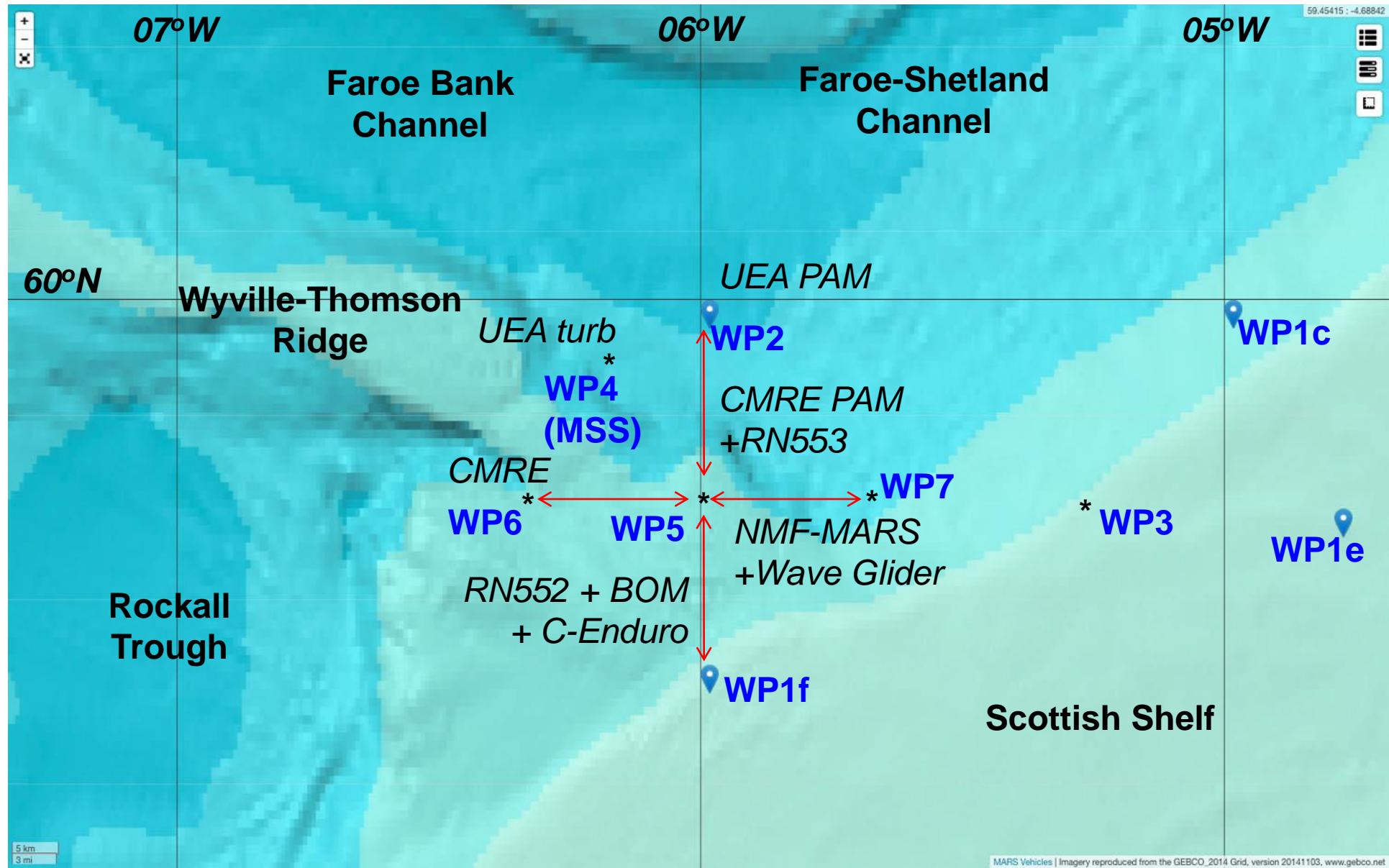
*Thermocline shows semi-diurnal vertical oscillation of up to 40 m due to internal tides*



# MASSMO4 Best Composite Picture (BCP) experiment on 03-05 June 2017

*Red arrows show planned transects for gliders during BCP experiment*

*Aim was to deploy fleet to cover an area of ~1500 km<sup>2</sup> in a 48-hour period*

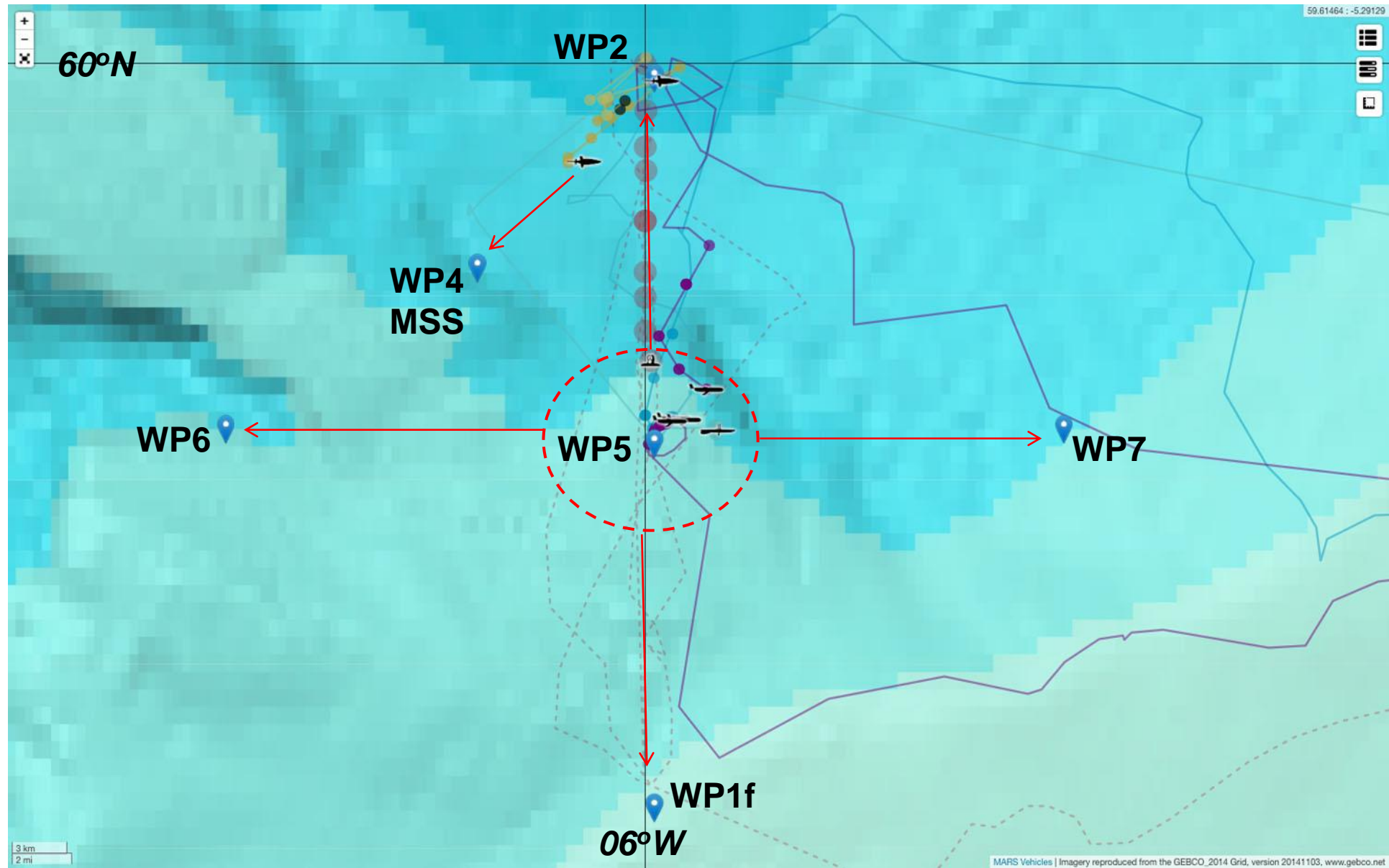




# The MASSMO4 fleet at 0730 on 03 June 2017 with GEBCO bathymetry

*Most vehicles and NRV Alliance at WP5 in advance of BCP experiment*

*UEA Seagliders undertaking virtual moorings around WP2 and WP4*



# Conclusions

- Well-planned combined AUV/ASV operations work very well.
- Still some technology limitations, especially bandwidth for submerged vehicles, and installed power supply for anything geophysical.
- Legal and safety considerations matter – must ensure ‘notices to mariners’ are in operation, take account of shipping & fisheries activity, and if required ensure plenty of time for diplomatic clearance because you can’t place a foreign observer on a robot vehicle.
- Common pilot interface very useful – shouldn’t have different systems for different vehicles if at all possible.
- Launch & recover from shore is possible, and cost effective.
- Technology is improving quickly – large cost saving possible over use of conventional surface and sub-surface vessels.



THANK YOU 😊



For more details please email Steve Hall, or Dr Russell Wynn at the UK National Oceanography Centre [rbw1@noc.ac.uk](mailto:rbw1@noc.ac.uk)  
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