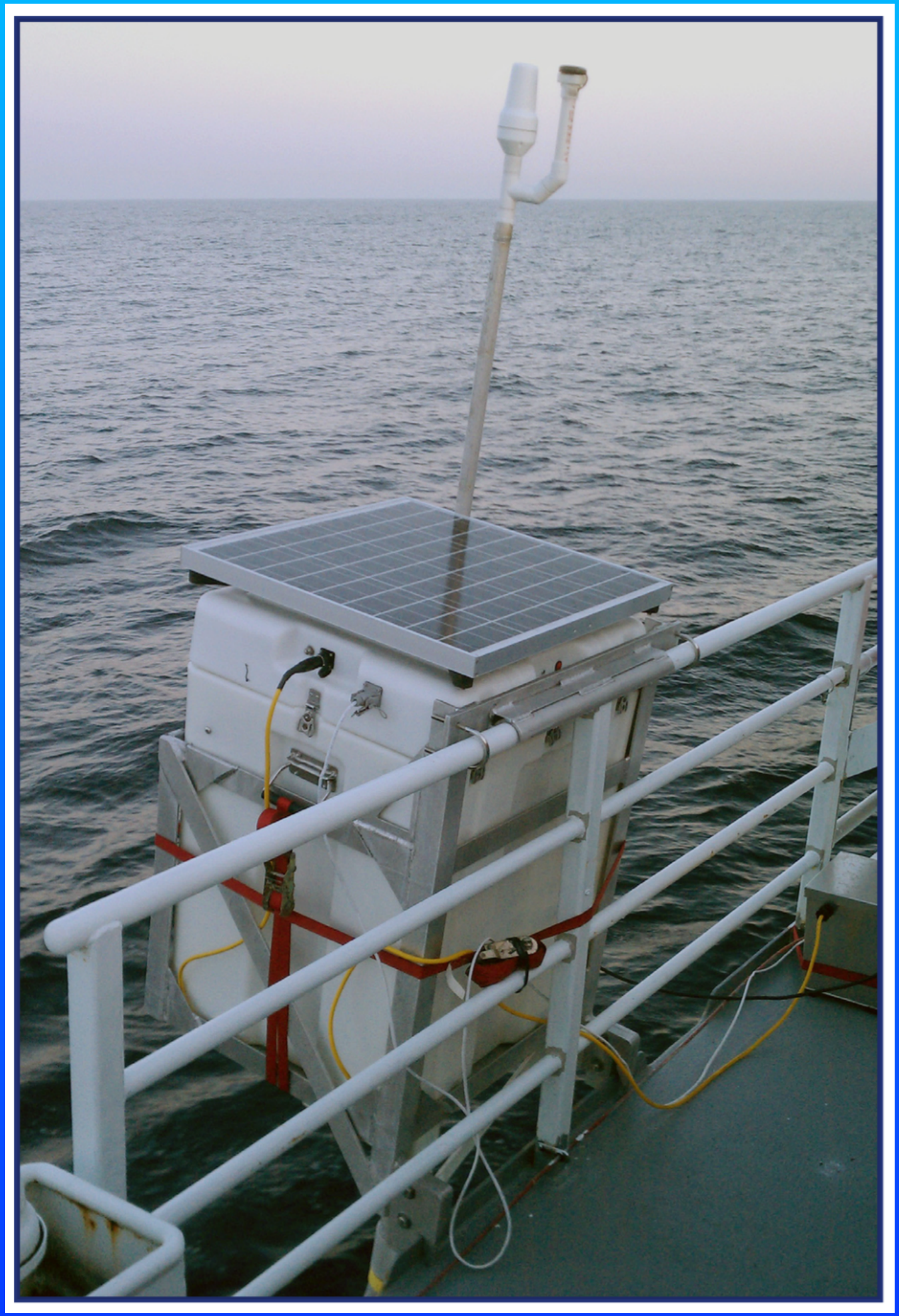
AXIS
Autonomous eXpendable Instrument System



AXIS has been developed to provide the capability to deploy probes on a predefined schedule, or adaptively in response to specific events without the presence of an observer onboard.

This will be a brief overview of its operation, capabilities, and some examples of how it is improving our coverage along two lines in the Atlantic.

Pictured here is the prototype solar-powered AXIS on the R/V Sharp. It has been in operation since Nov 2011.

Dr. David Fratantoni took the initiative to this development. Funded by NSF, he, Jeff O'Brien and Terry Hammar, all at WHOI, did the engineering and software development. Charlie Flagg has been the crucial partner in realizing and maintaining this capability.

The system in completely self-contained and controlled from shore via Iridium. Ship's personnel reload AXIS as needed.

Oleander

1990/6300 gt/118 m/4.5 m/15 k

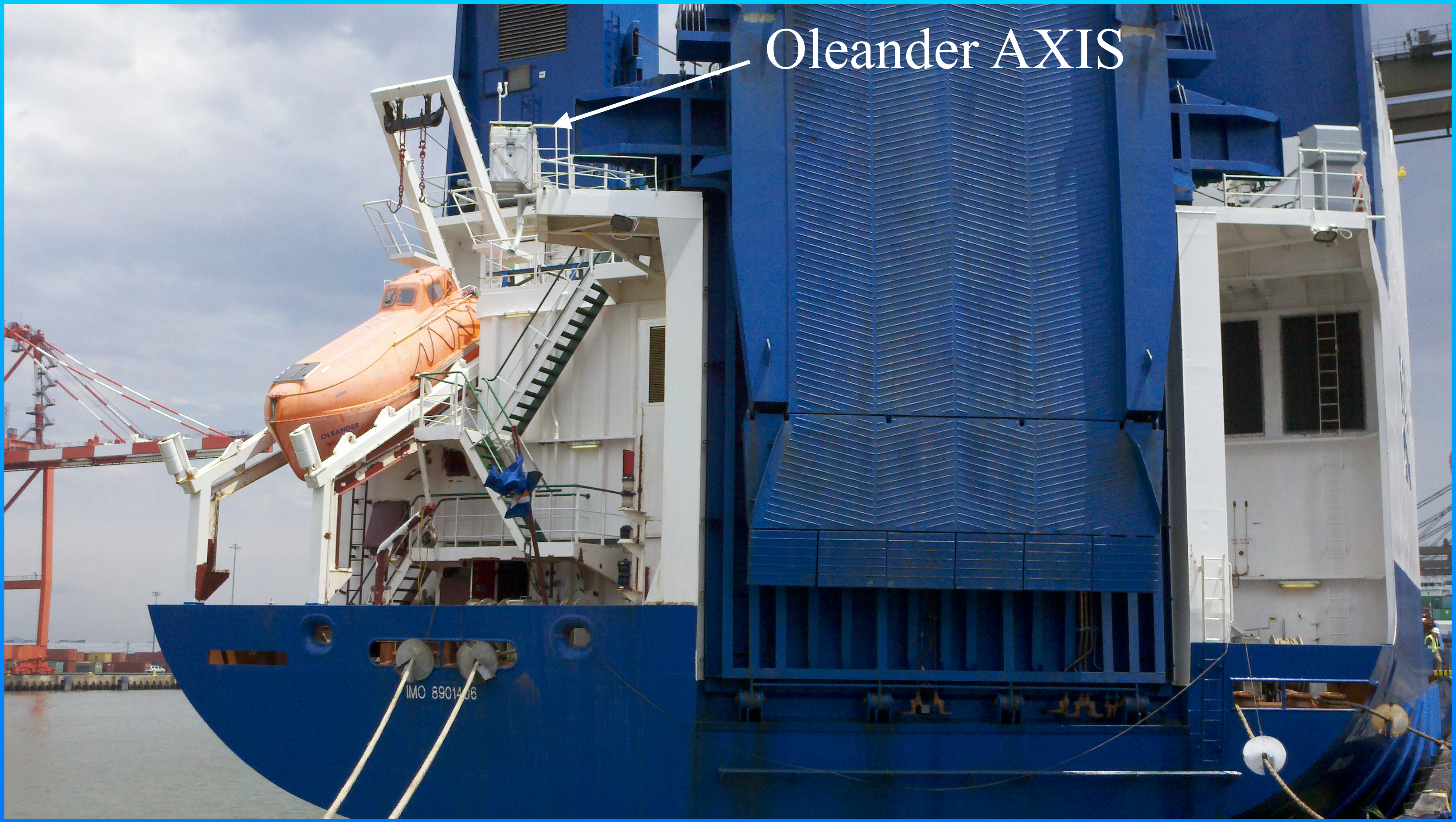
dead weight: 6533 t

Norröna

2003/36000 gt/165 m/6.5 m/21 k

dead weight: 6113 t

Two systems are in operation today, one on the container vessel Oleander that operates between Bermuda and New Jersey, and one on the high-seas ferry Norröna that operates out of the Faroes to Denmark and Iceland.



This prototype system started service in late 2011 and went through a major mechanical rebuild in 2012. Since then it has been in nearly continuous monthly service. See http://po.msrc.sunysb.edu/Oleander/XBT/NOAA_XBT.html

This system has been in operation since September 2013 through April this year. Operation should resume shortly. See http://po.msrc.sunysb.edu/Norrona/xbt.html

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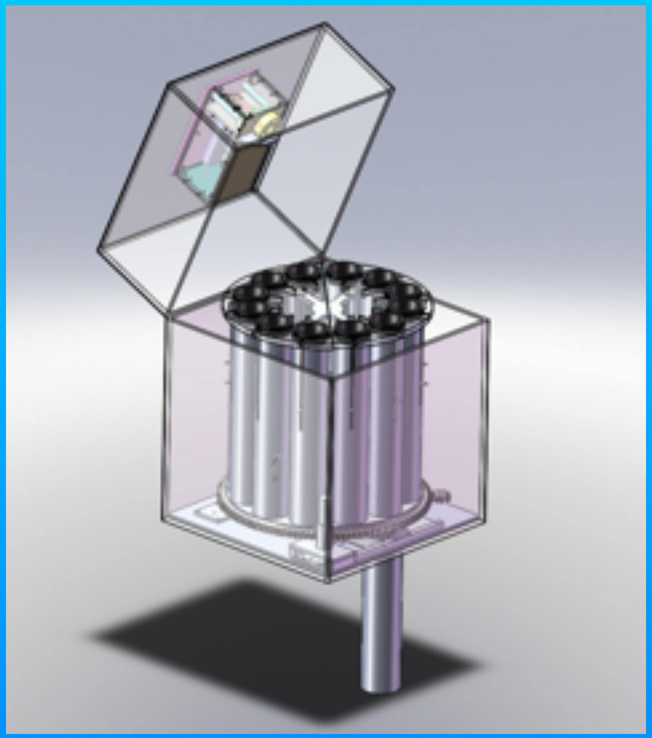
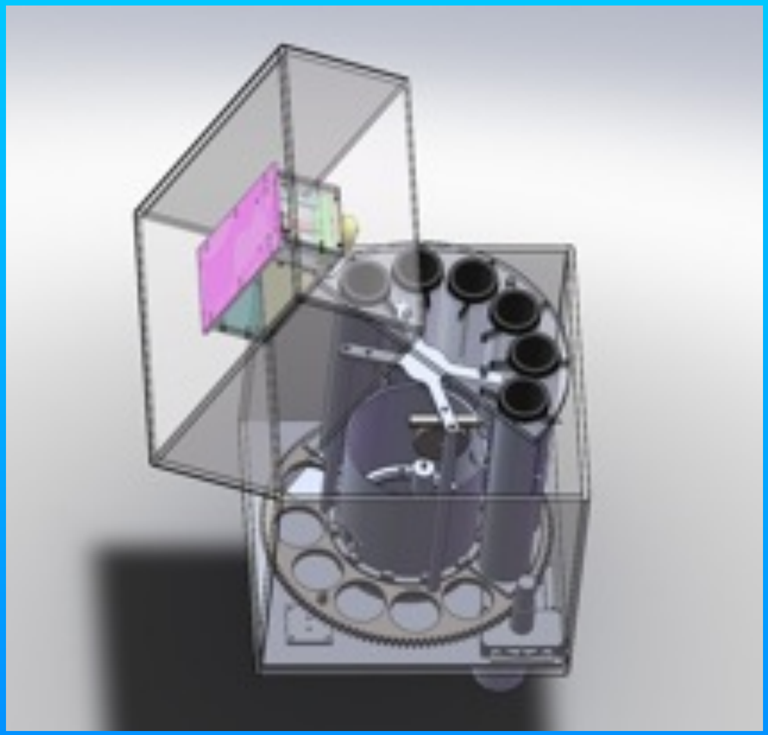
Close-up of the Norröna AXIS



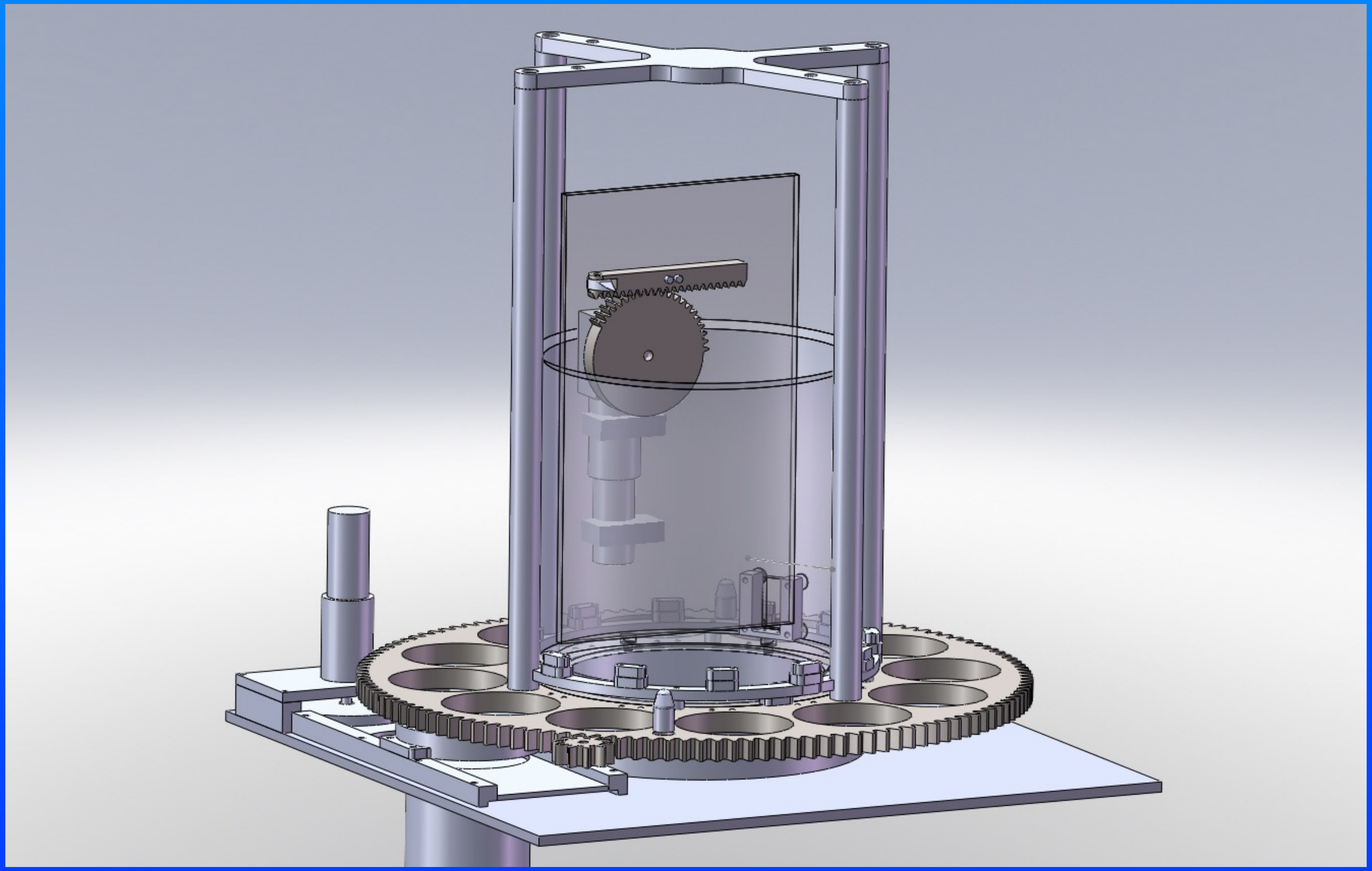
AXIS controller
in cover

12 XBT carousel

XBT chute



pin puller mechanism



Functional layout:

GPS/Wake Supervisor(GWS)

real-time clock; gets GPS fixes
powers up ASC if AXIS has reached StartDateTime, PositionStart, user-defined wake-up

AXIS System Controller(ASC)

'brain' of system; controls LCM, MK21 DAQ, shore-side communication through Iridium. Checks status of MK21 before initiating XBT launch.

Launcher Control Module(LCM)

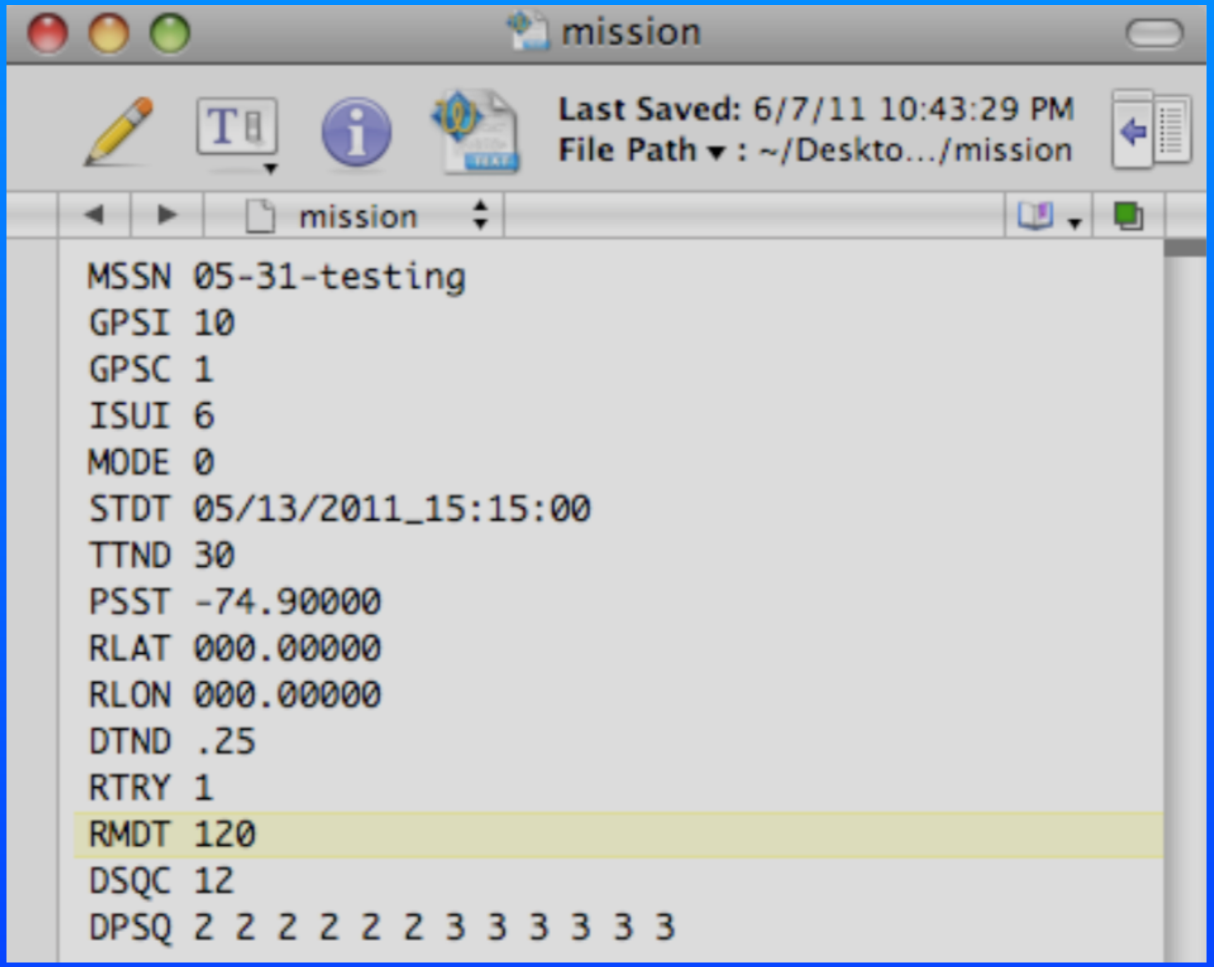
upon command plunges breech pins into top of new canister. After circuit and continuity tests, it initiates pull pin, probe falls out and circuit is completed when probe hits water.

Lockheed Martin MK21 Ethernet DAQ(MK21)

standard L-M DAQ with a few modifications so it can be controlled from ASC.

Mission file parameter definitions

MSSN: name of file
GPSI: wake-up interval to get GPS fix
ISUI: wake-up ASC if # of wake-ups > this
MODE: defines action (take probe, sleep, end activities, etc.
STDT: start date
TTND: time to next drop
PSST: Position start, lat or long which when exceeded triggers probe drop
RLAT: reference latitude
RLON: reference longitude
DTND: distance to next drop
RTRY: # of retries before deleting probe from list
RMDT: if disk space gets tight remove older data files
DSQC: drop sequence count
DPSQ: list of probes in drop sequence



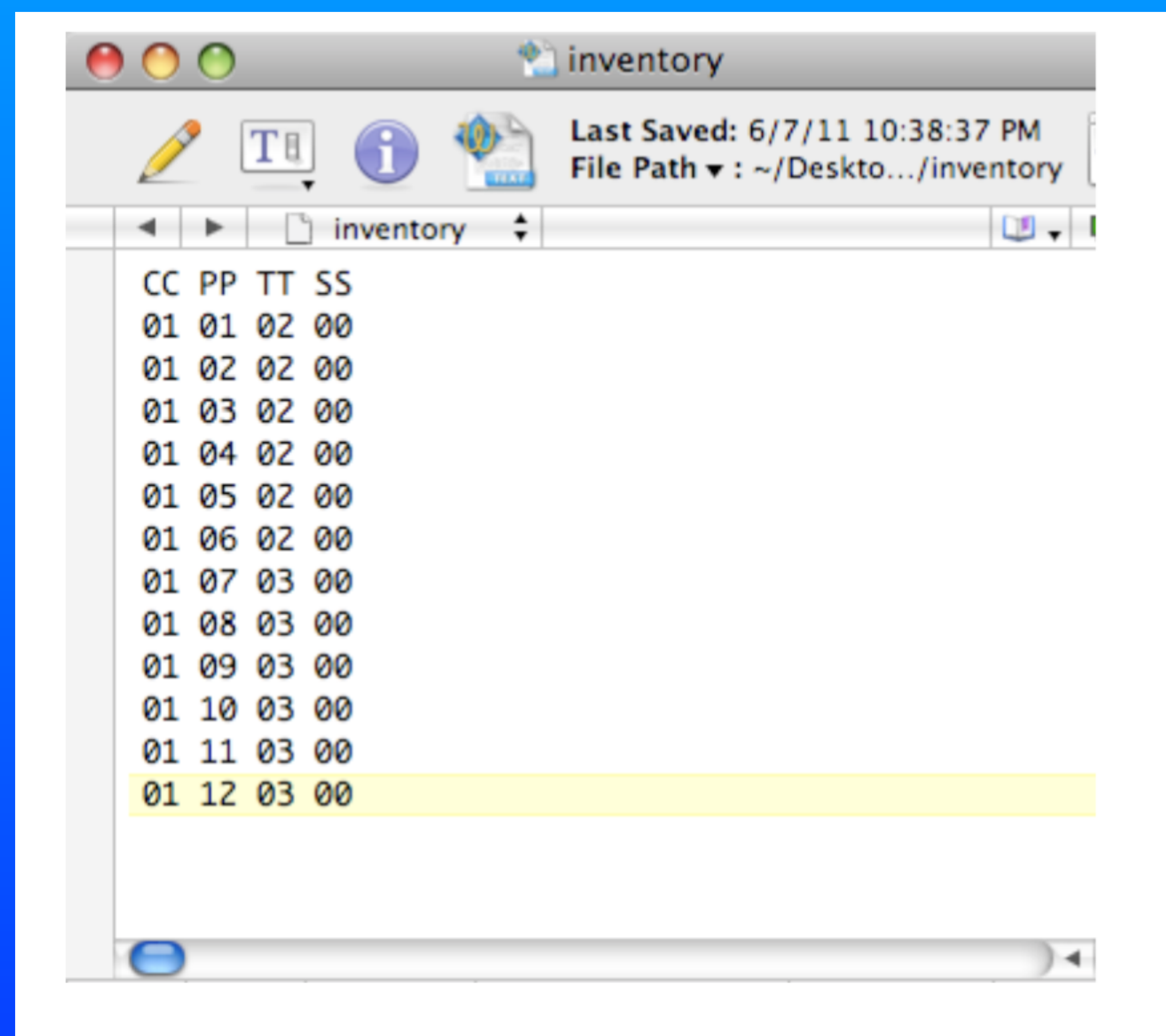
Inventory file parameter definitions

file is named ‘inventory’ and resides in SYS folder

CC: carousel (in case of multiple launchers)
PP: position (1-12)
TT: type of probe (can handle all MK21 compatible probes)
SS: status (0-3: available, drop_OK, drop-failed, get inventory)

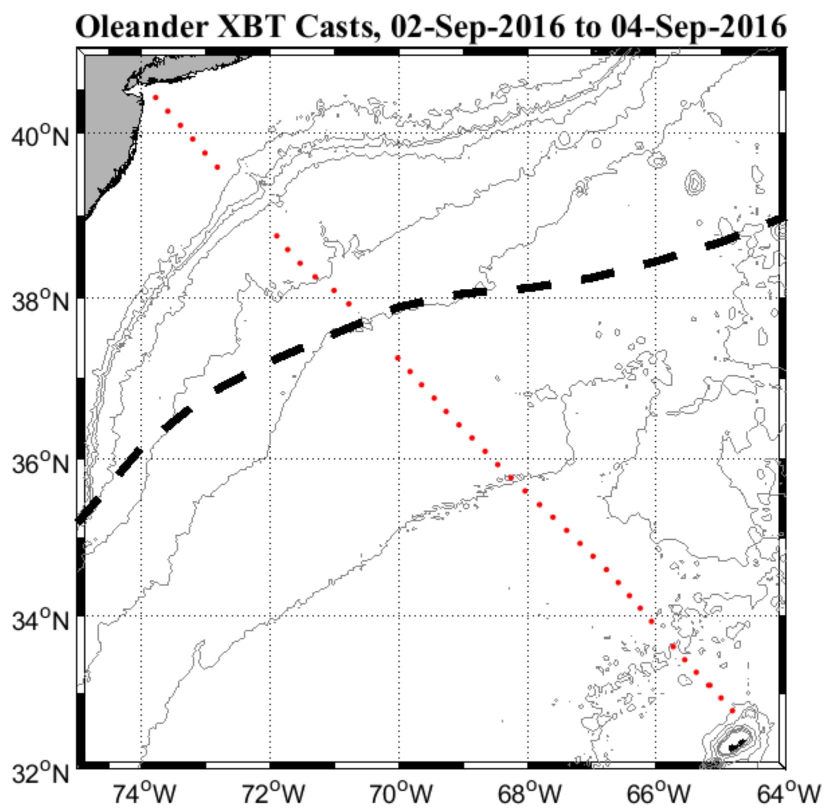
probe types 0-11:

T4
T5
T6
T7
T10
T11FS
DeepBlue
FastDeep
XSV1
XSV2
XSV3
XCTD1

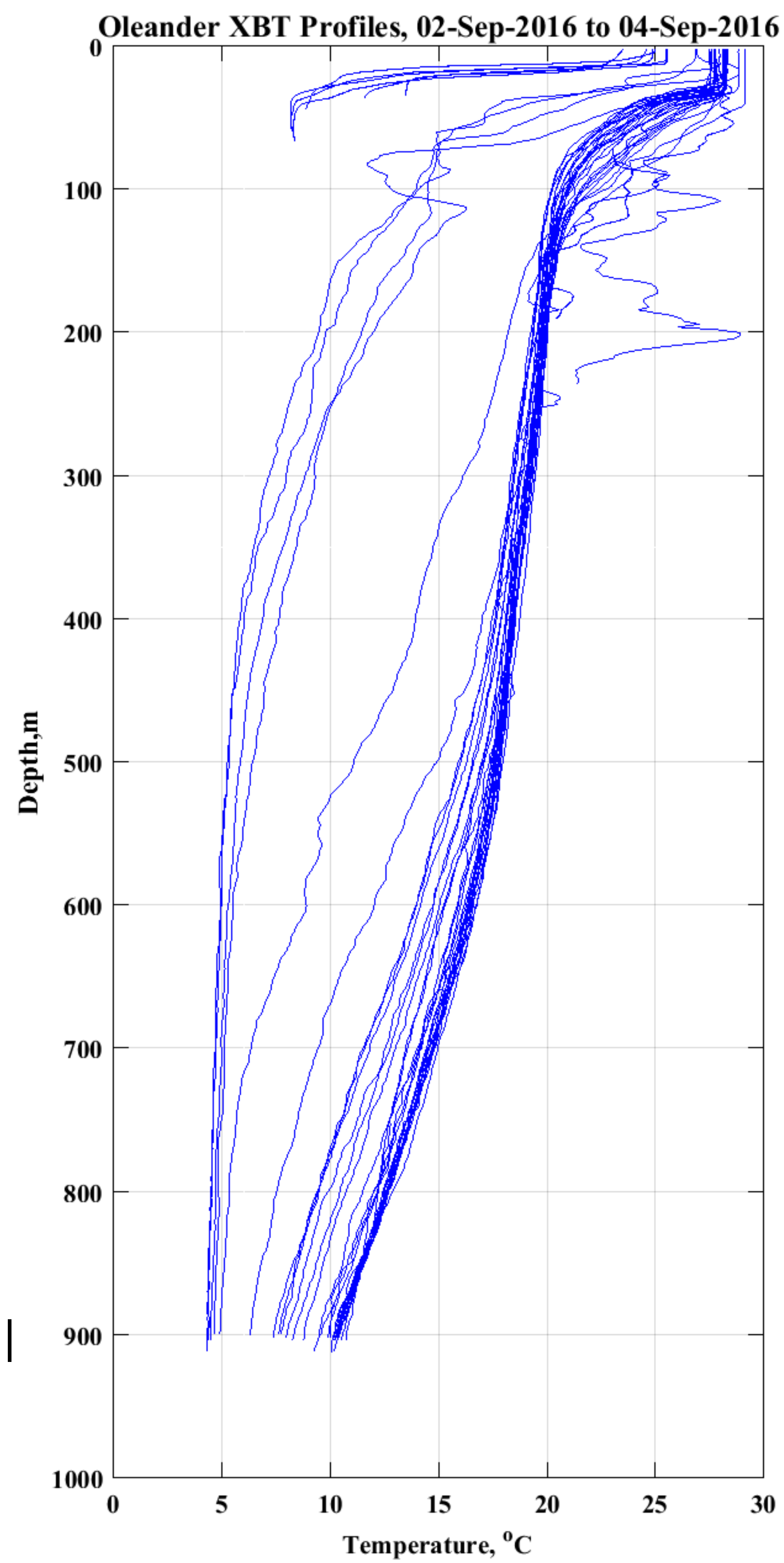


CC	PP	TT	SS
01	01	02	00
01	02	02	00
01	03	02	00
01	04	02	00
01	05	02	00
01	06	02	00
01	07	03	00
01	08	03	00
01	09	03	00
01	10	03	00
01	11	03	00
01	12	03	00

Oleander: The most recent section



http://po.msrc.sunysb.edu/Oleander/XBT/NOAA_XBT.html



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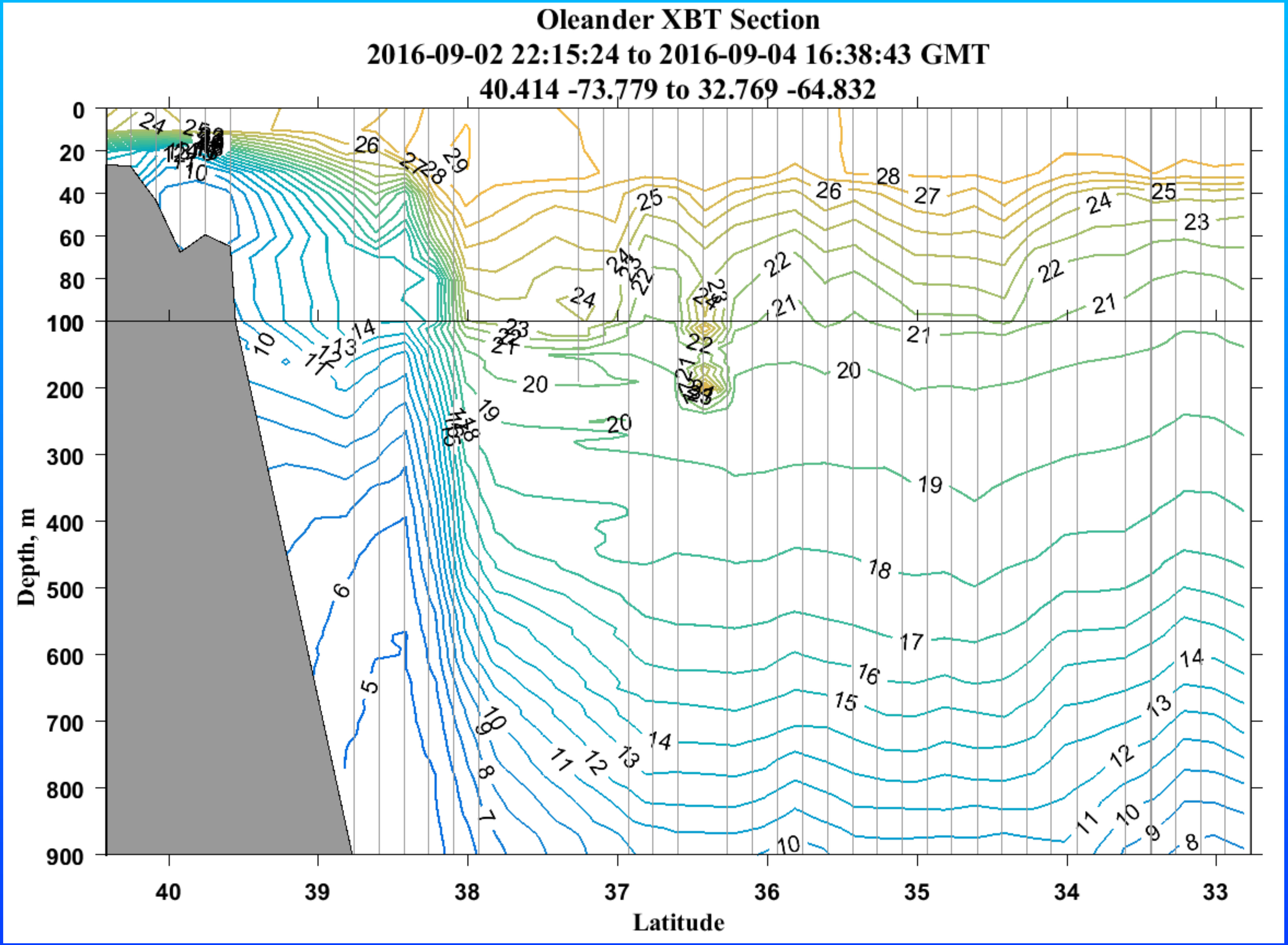
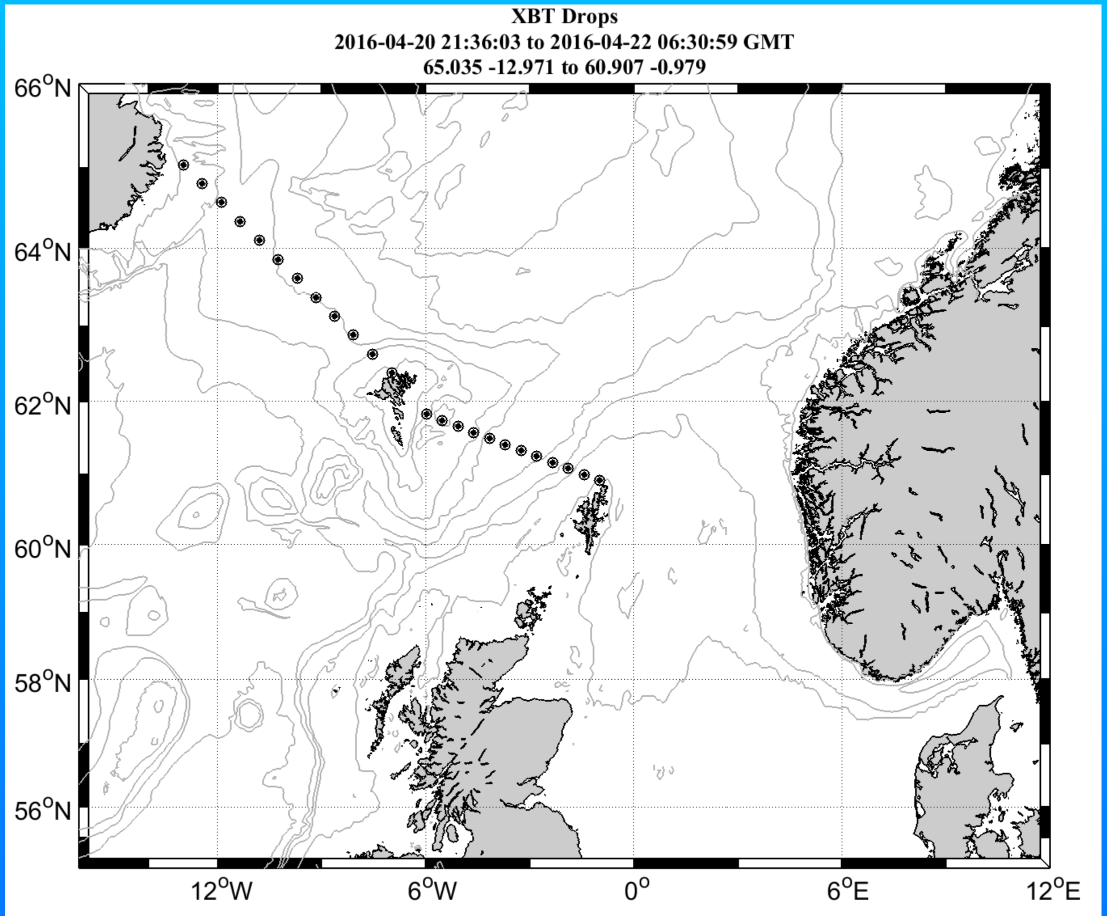
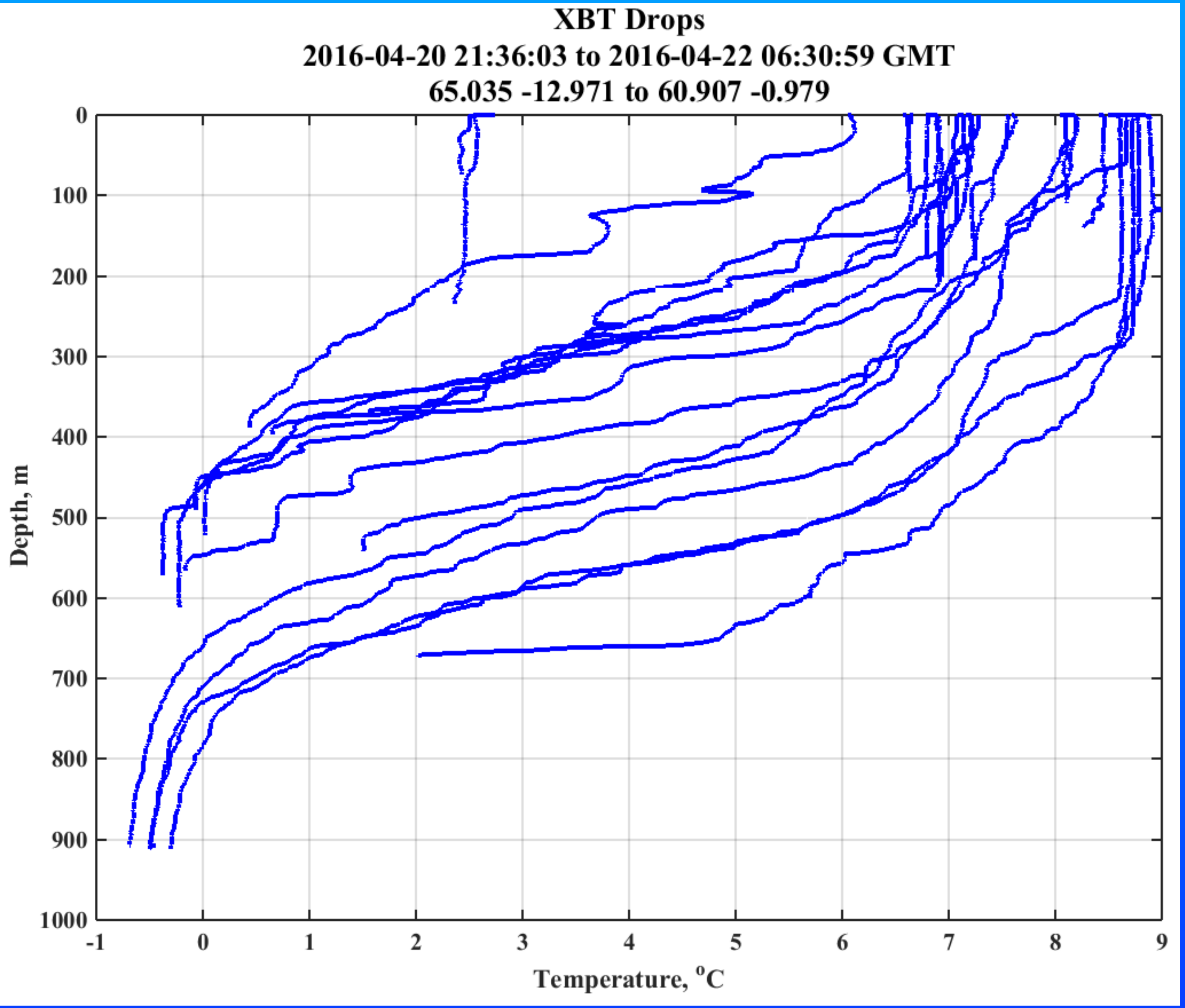


A long-range goal is to use combine the Oleander XBT and velocity data to estimate the MOC and its low-frequency variability at this latitude. The Oleander has recently been funded by NSF to expand operation with a 38 kHz ADCP to ~1100-1200 m.

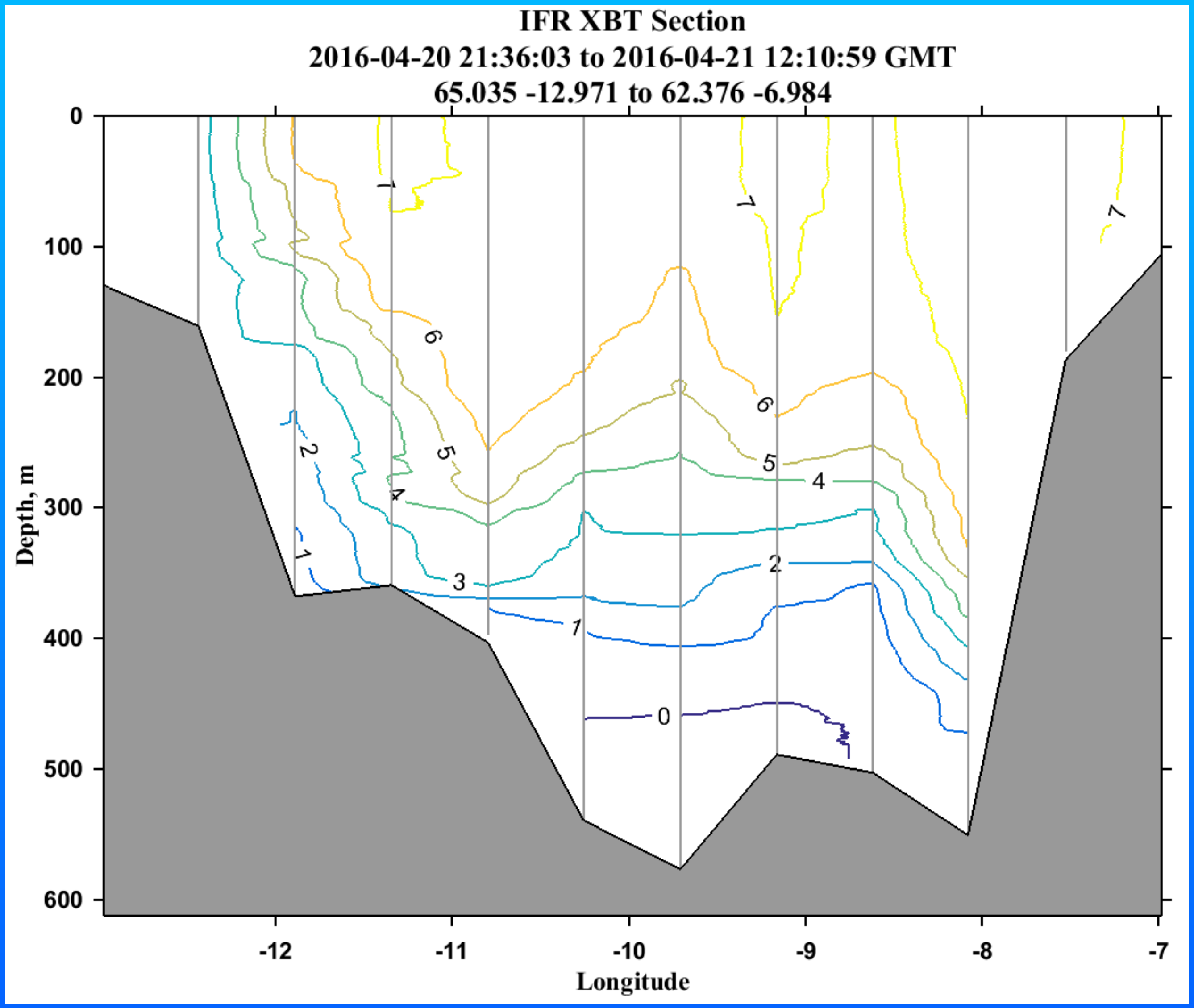
Norröna: The most recent section

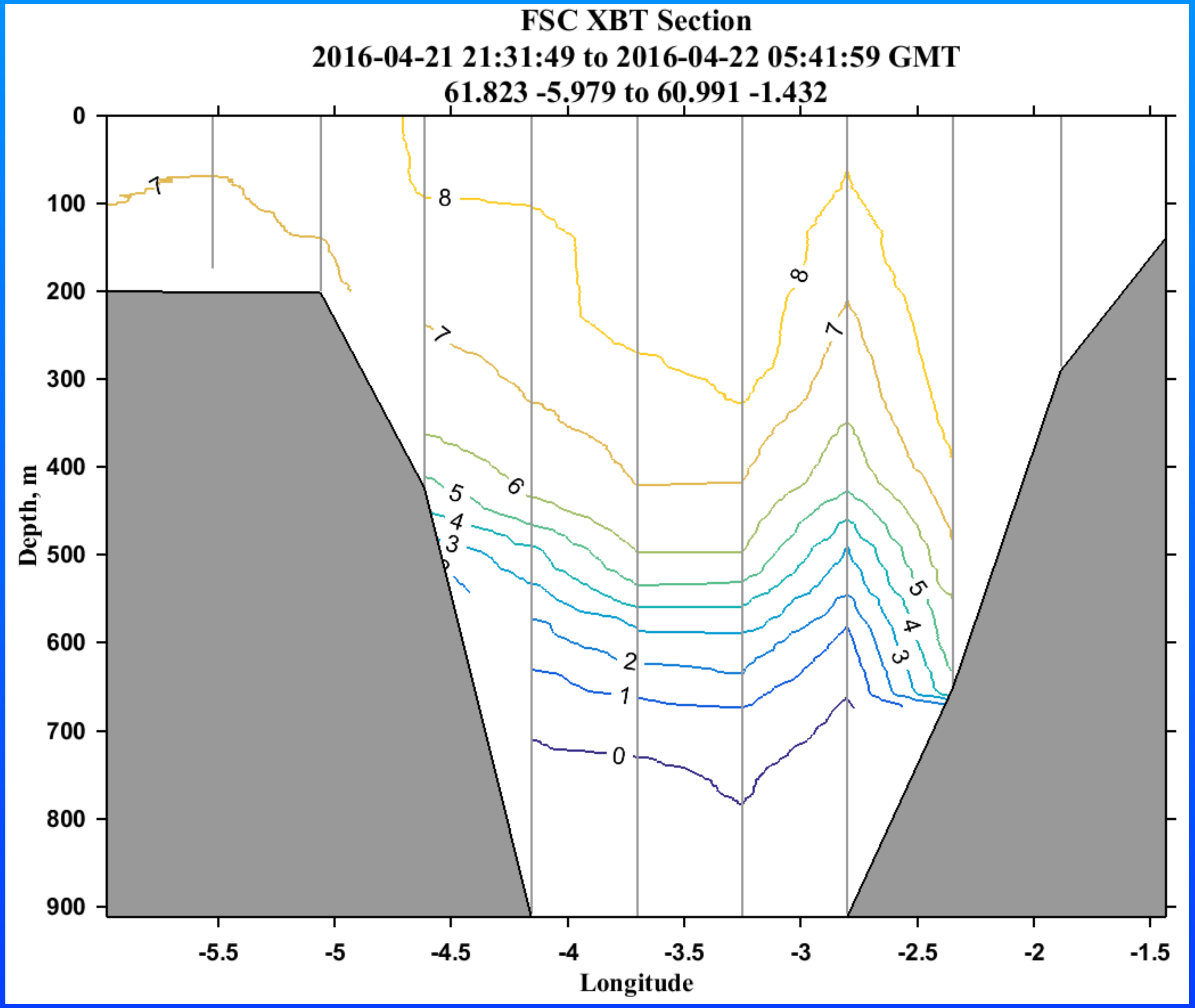


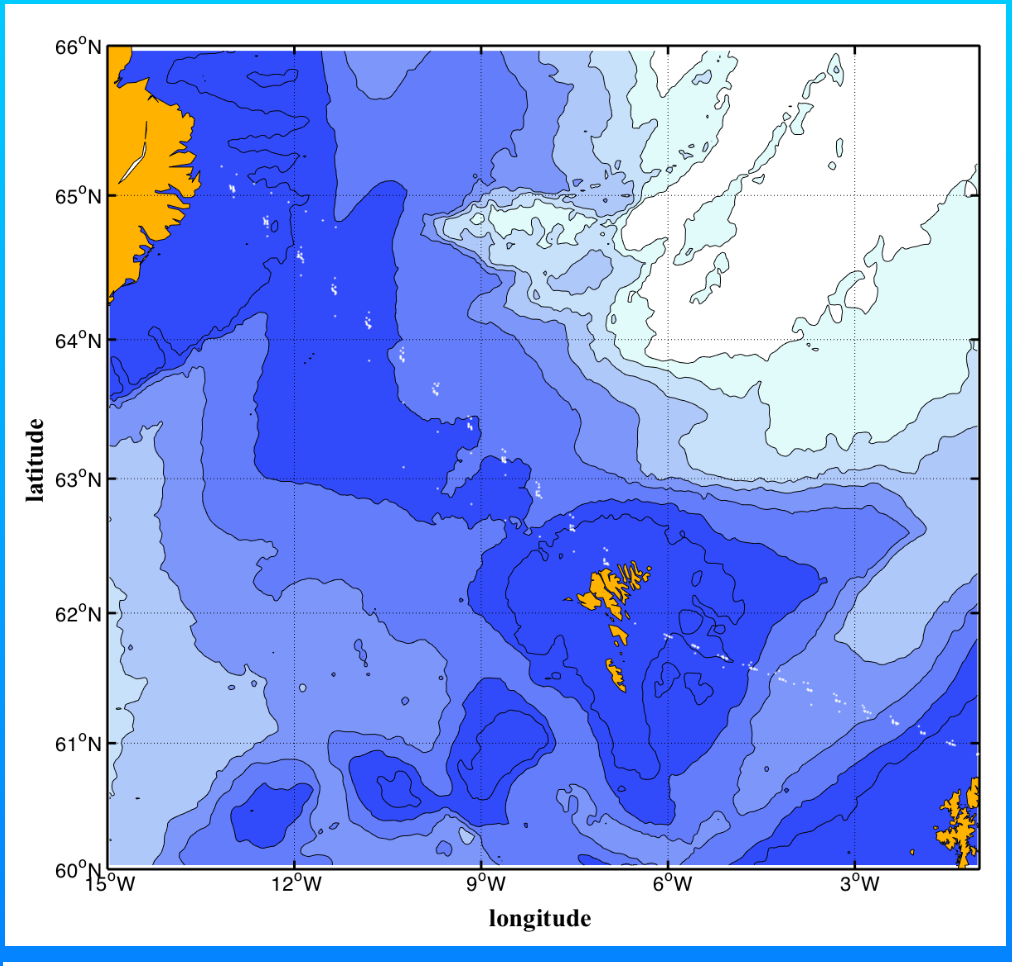


http://po.msrc.sunysb.edu/Norrona/xbt.html

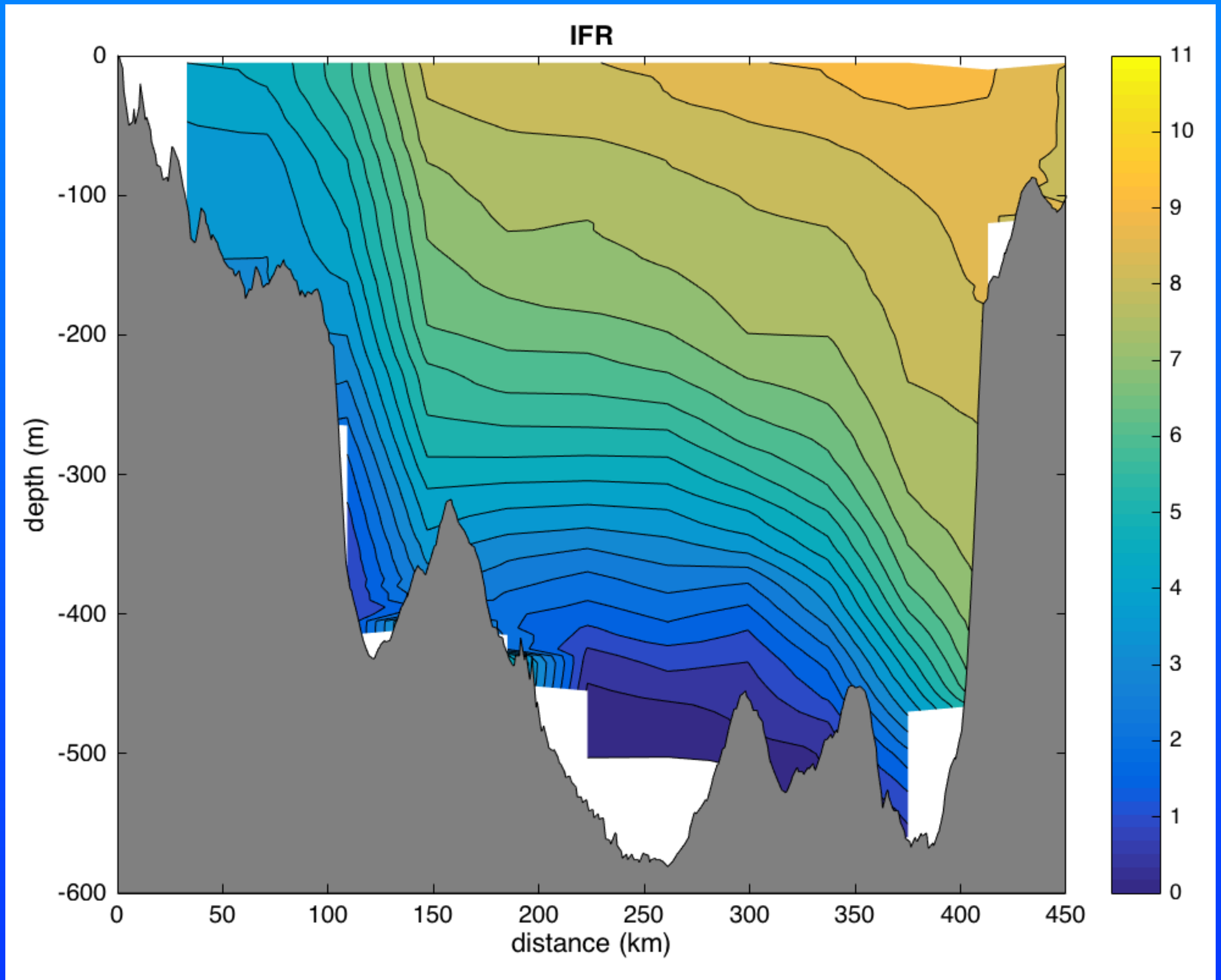
Norröna: The most recent section

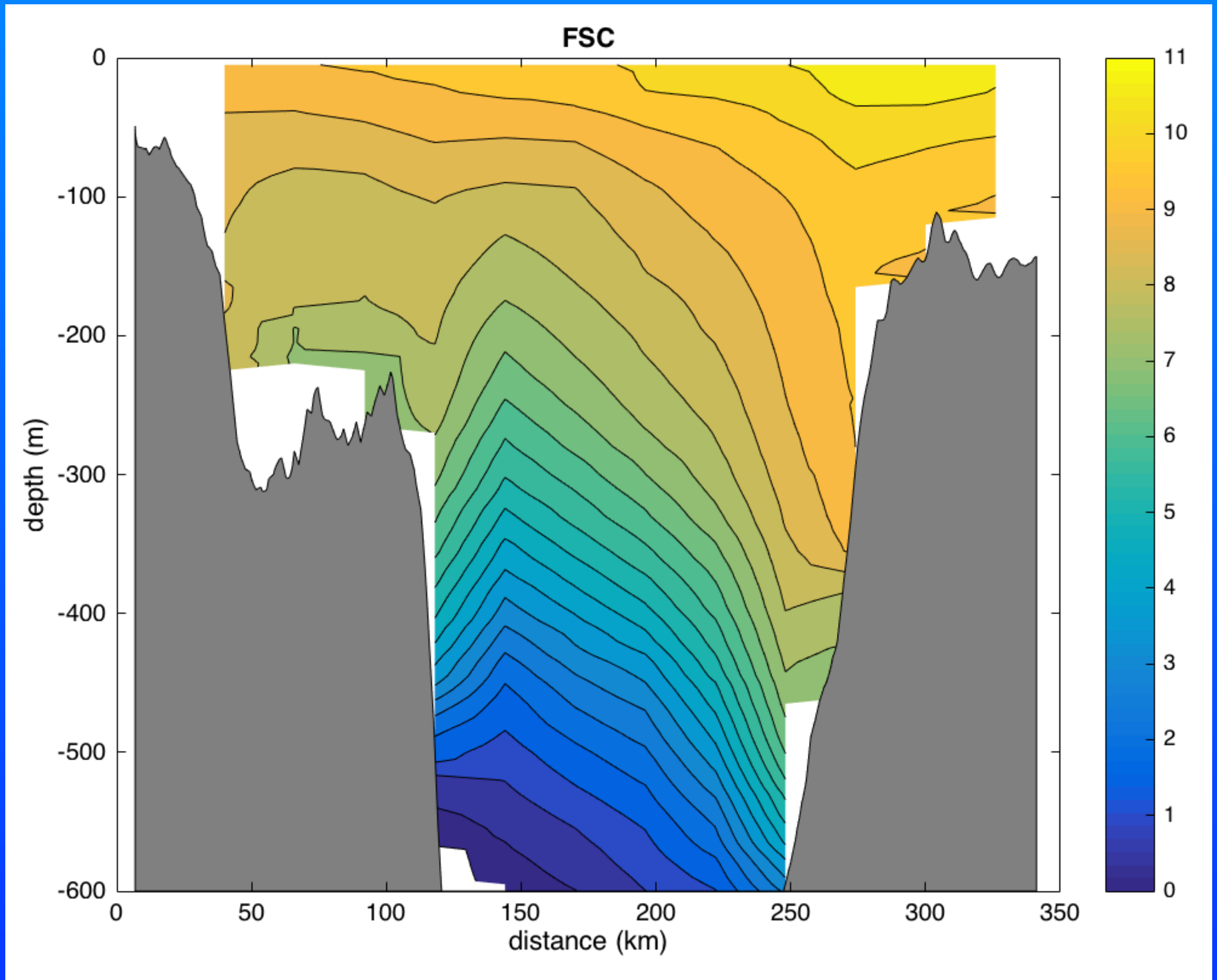


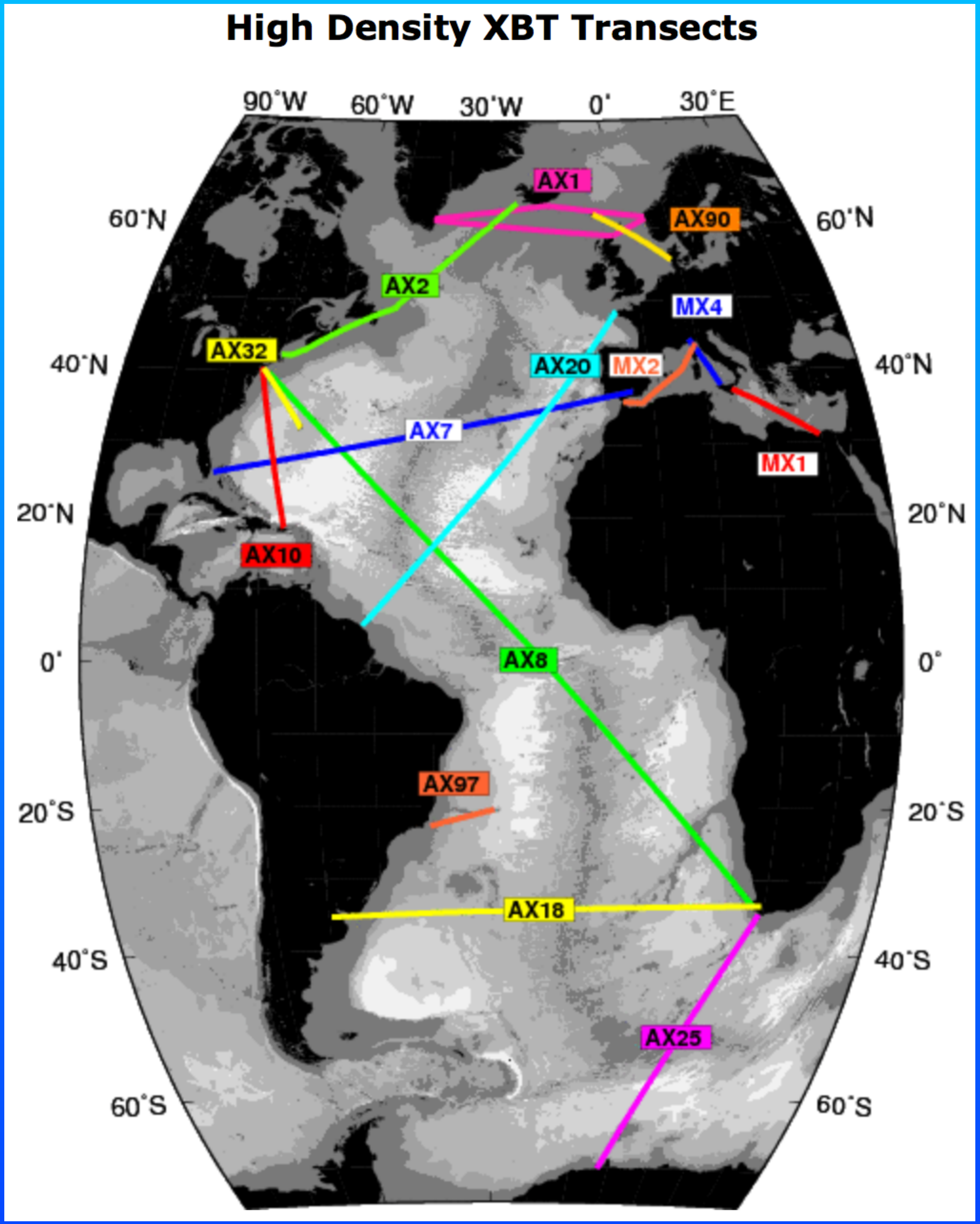




Mean temperature for the Iceland-Faroe Ridge and Faroe-Shetland Channel based on 2+ years of monthly AXIS sampling (white dots). Tomorrow I will discuss how these data are being used to determine heat flux into the Nordic Seas.







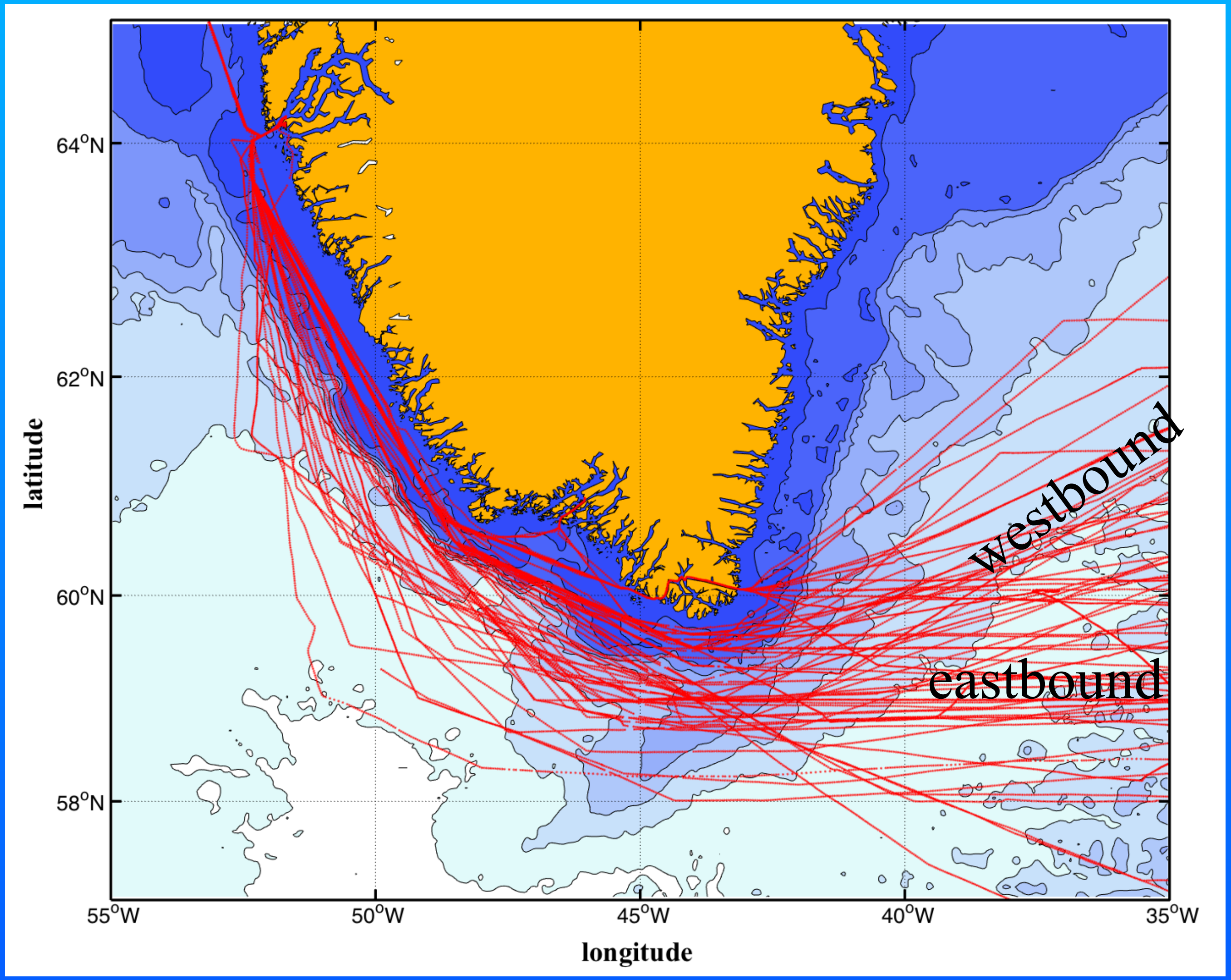
What's next?

We have sought funding to operate two sections with AXIS:

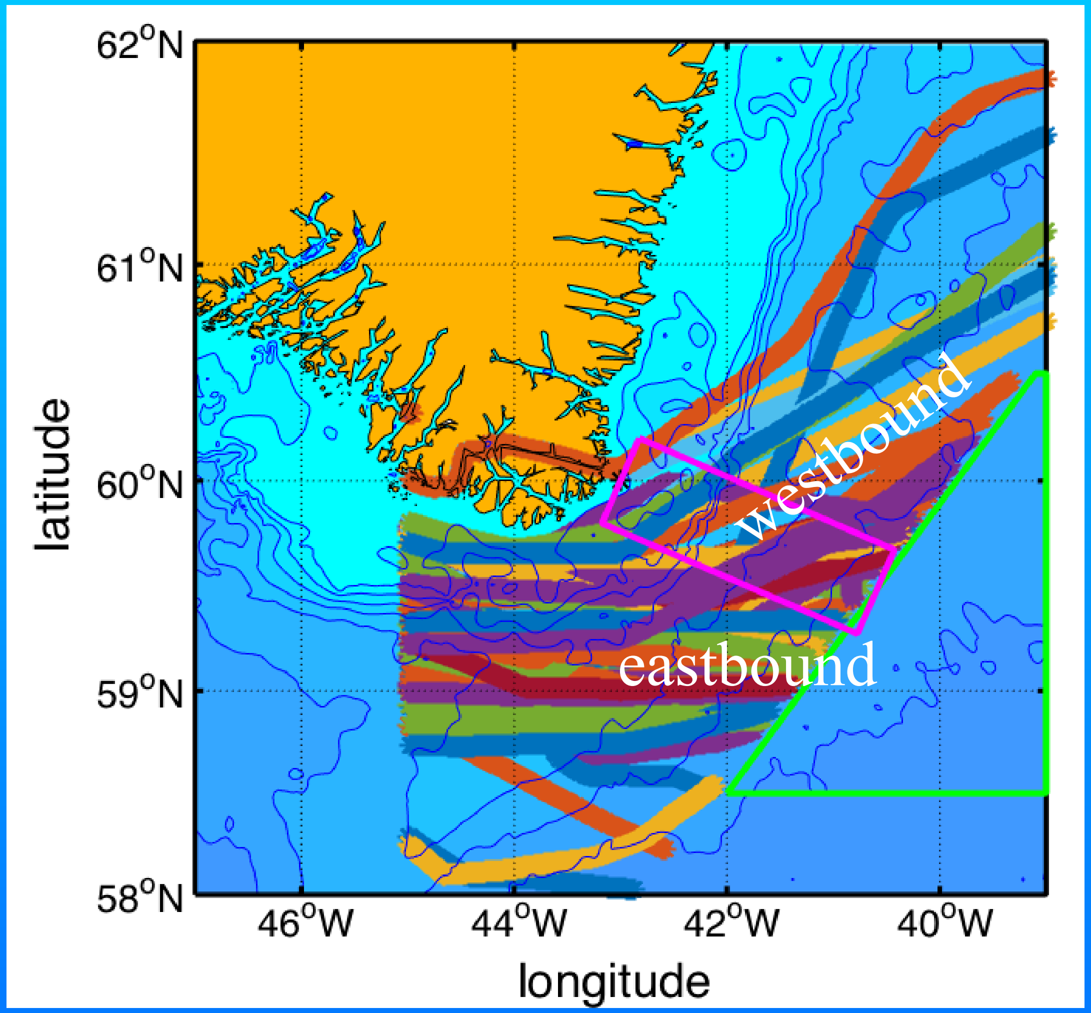
AX1 (Greenland-Scotland)
AX2 (Iceland-Newfoundland)

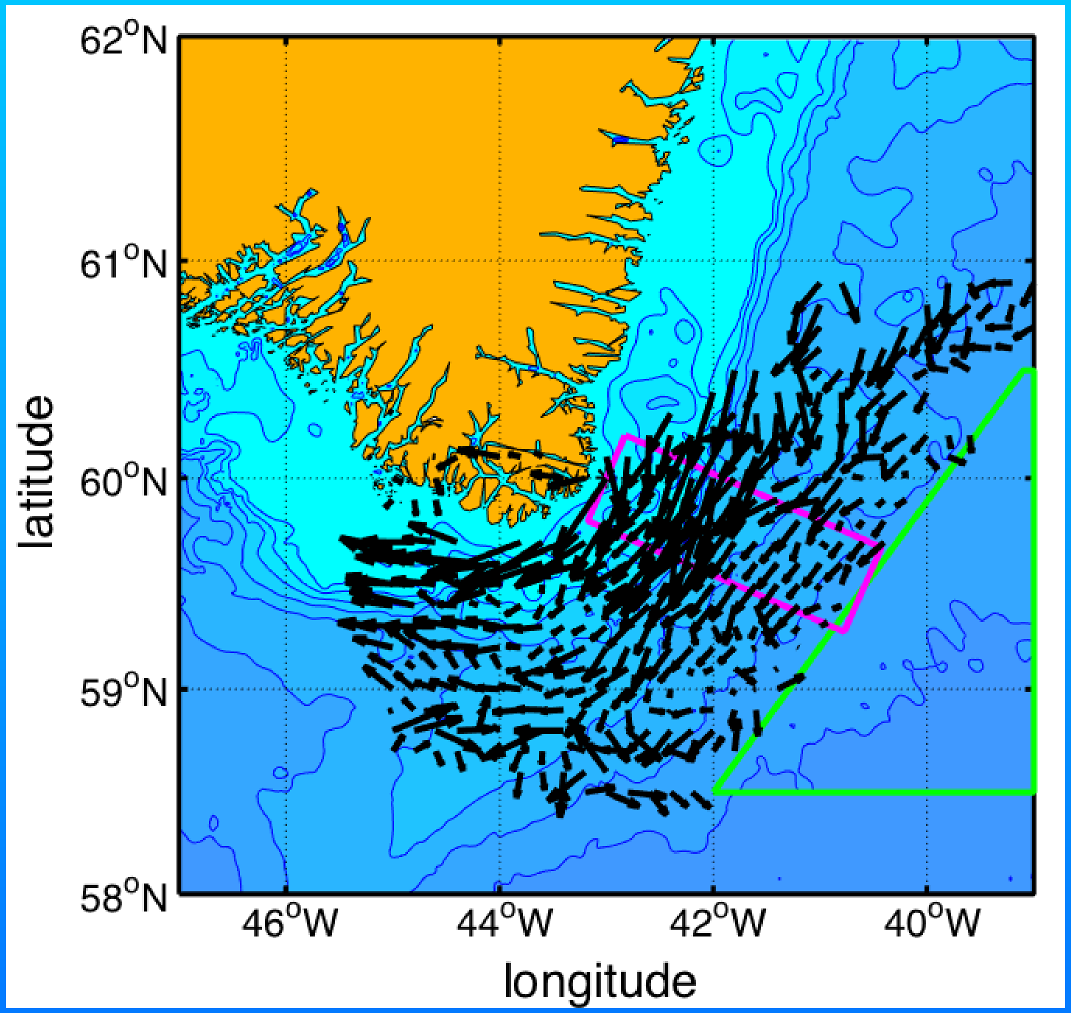
Both sections are severely impacted by weather. AXIS enables conditional sampling in response to weather, when on track, near fronts, and/or in regions otherwise inaccessible. For example:

Nuka Arctica tracks near Cape Farewell:



Crew takes XBTs only on eastbound transits, a problem re the East Greenland Current.





From a compilation of ADCP data on westbound transits we now know much about the east Greenland Current, but not of T or S.

With AXIS we could schedule XBTs in just the area of the red box or better yet XCTDs (which reach deeper) given that this is an area of strong salinity variability. By tracking the ship from shore release probes only if feasible - no waste.

The main point is that AXIS frees up the need for an observer onboard; this can allow for increased frequency of sampling at reduced cost. We are already doing this with the Oleander. An AXIS on Nuka Arctica would reduce and simplify the support from ship's personnel.

AXIS gives the program freedom to not run a section when the weather outlook is poor or far off track (less waste).

AXIS sampling can be scheduled ahead of time or it can work interactively such as for conditional or accelerated sampling in response to real-time events (f. ex. we have already profiled T in the immediate wake of a hurricane).