Use of Profiling Floats for Real-time *in-situ* Observations in the Arctic

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Development and Operational Support from NOAA and ONR

Website: alamo.whoi.edu

All Argo Floats are Profiling Floats
Not All Profiling Floats are Argo Floats

- Argo is an international program to survey blue-water global ocean. Initial design did not include coverage of:
  - marginal seas
  - continental shelves
  - high-latitude oceans
- Primary characteristics of an Argo float mission
  - Profile depth to 2000 dbar
  - Park (passive drift) at 1000 dbar
  - 10-day repeat cycle
- Key strength of Argo program: nearly all floats are programmed with common mission and use a common sensor (Seabird SBE41cp)

Essential components of a Profiling Float:

• **Buoyancy Engine** – Ability to change volume displacement of the instrument - typically achieved by pumping fluid from internal reservoir into external bladder. Must be energy efficient and capable of pumping against maximum pressure at profile depth (2000 dbar)

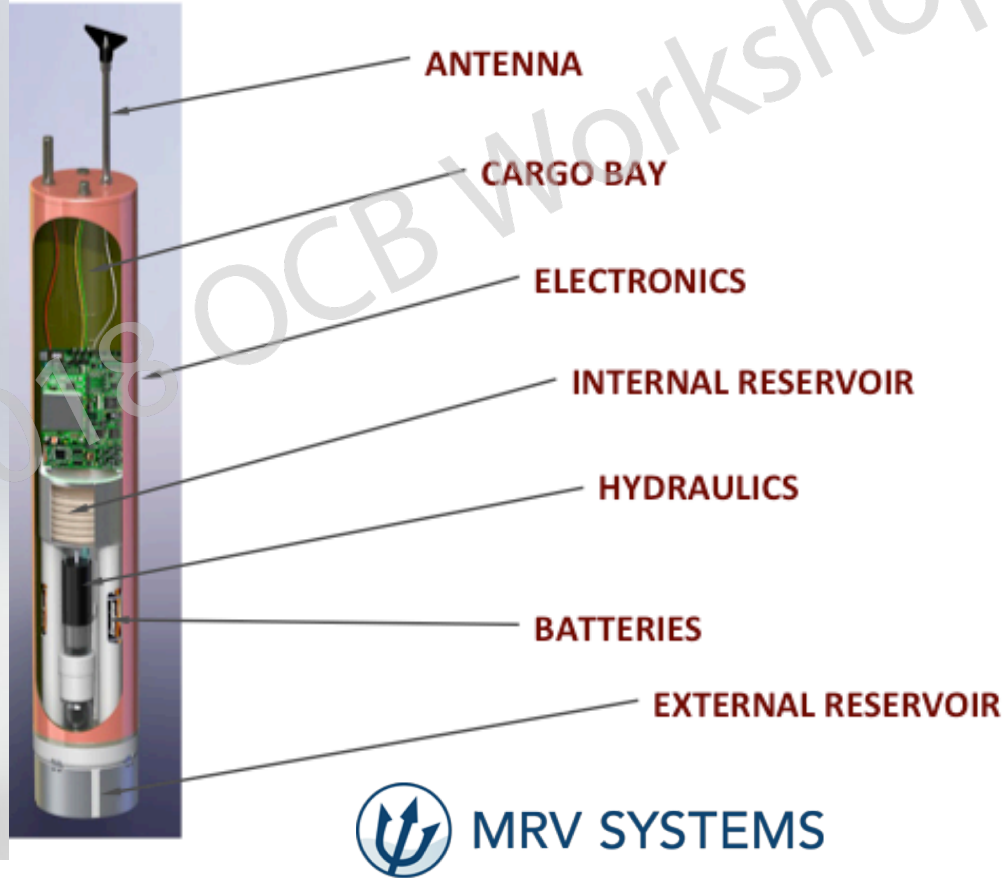
• Sensor package
• Satellite communications system (ARGOS, Iridium)
• Geo-location system (i.e. GPS)
• **Central controller (CPU) and firmware**

-Bruce Warren's blackboard

ALAMO Air-Launched Autonomous Micro-Observer

A-sized profiling floats were originally developed under funding from ONR, and redeveloped under NOAA Sandy Supplemental funding. Initial use was collecting *in-situ* observations for improving hurricane forecasts and rapid-sampling of ocean response to hurricane-force winds

S2A ALAMO



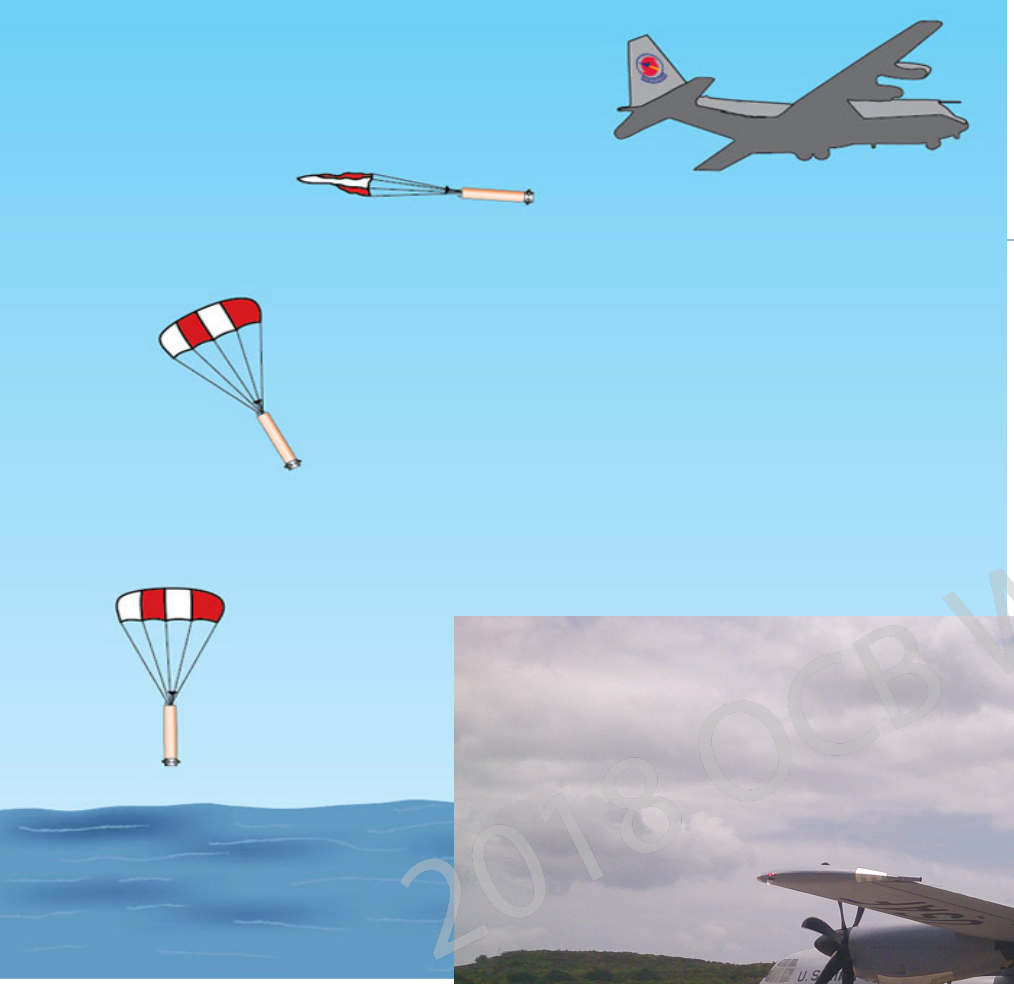
A-sized case

Weight <9 kg

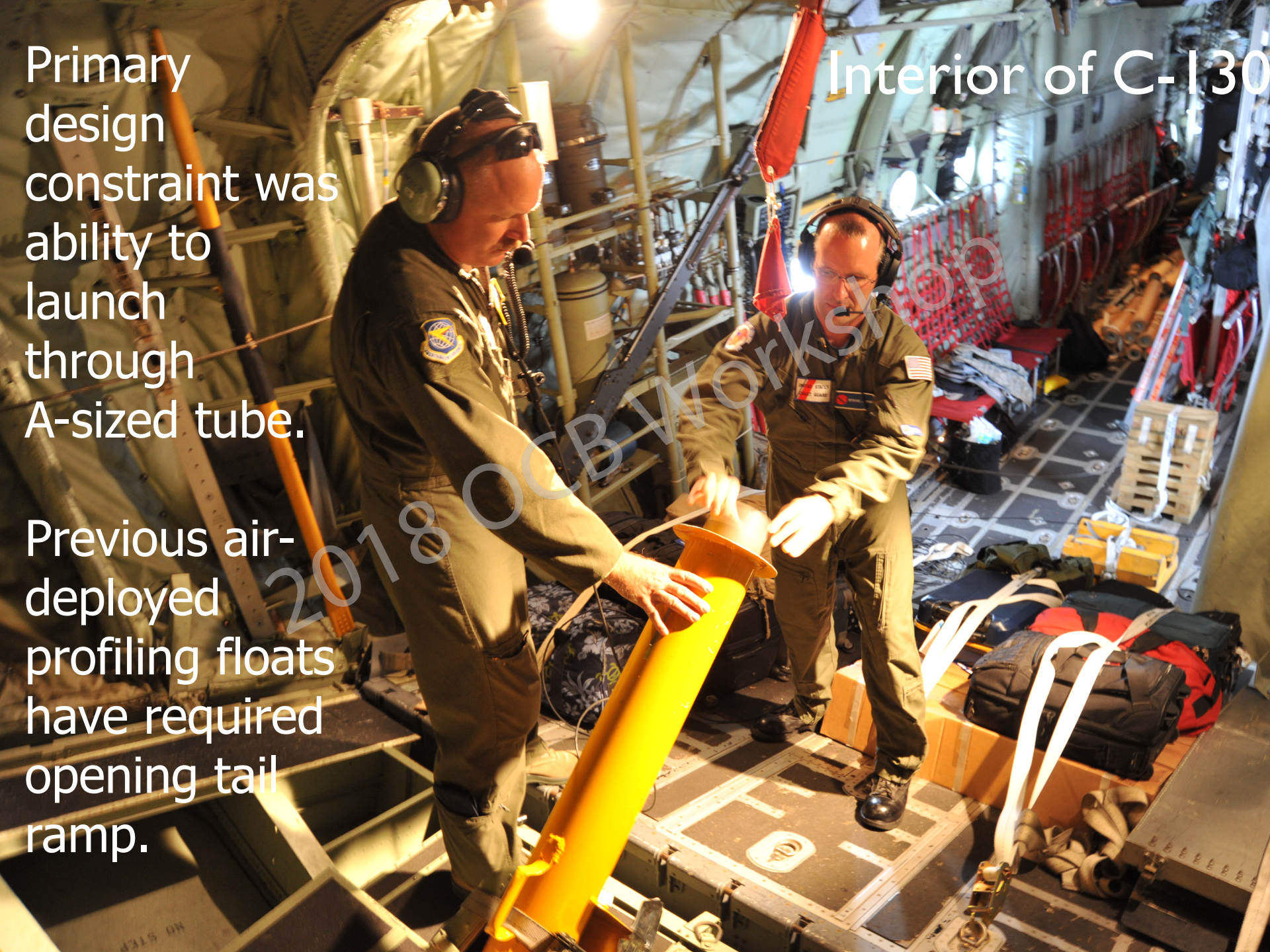
1000-meter depth rating

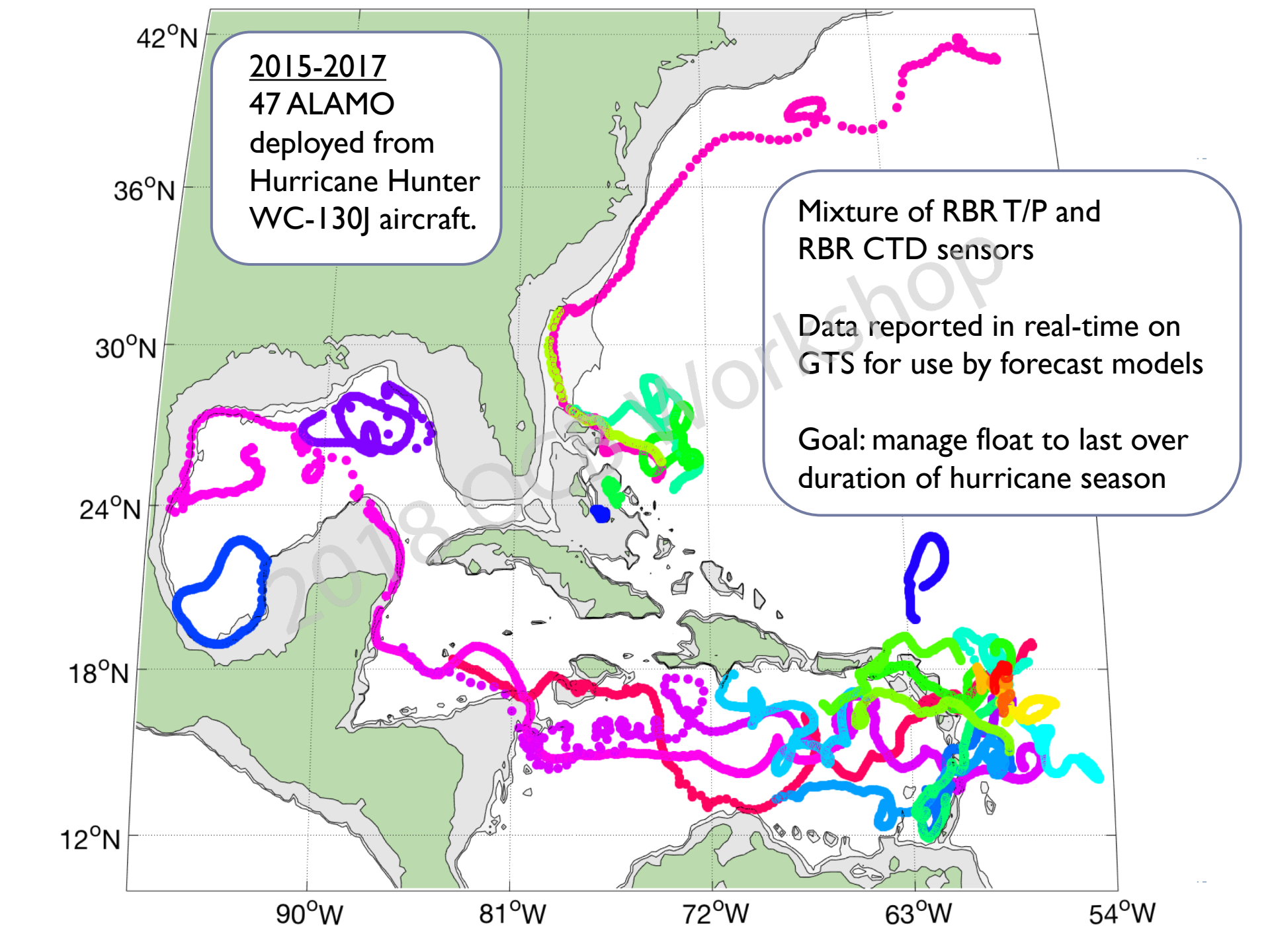
1 meter bin-averaged data

Iridium Short-Burst Data communication



The ALAMO floats have been tested and deployed in cooperation with US Air Force 53rd Weather Reconnaissance Squadron

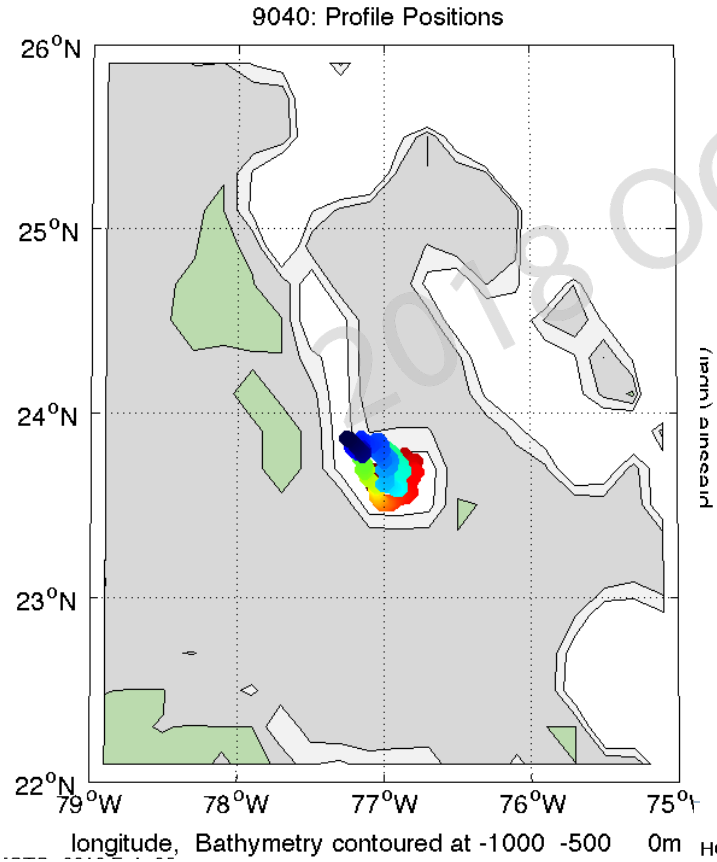

Primary design constraint was ability to launch through A-sized tube.
Previous air-deployed profiling floats have required opening tail ramp.
Interior of C-130
2018 OCB Workshop

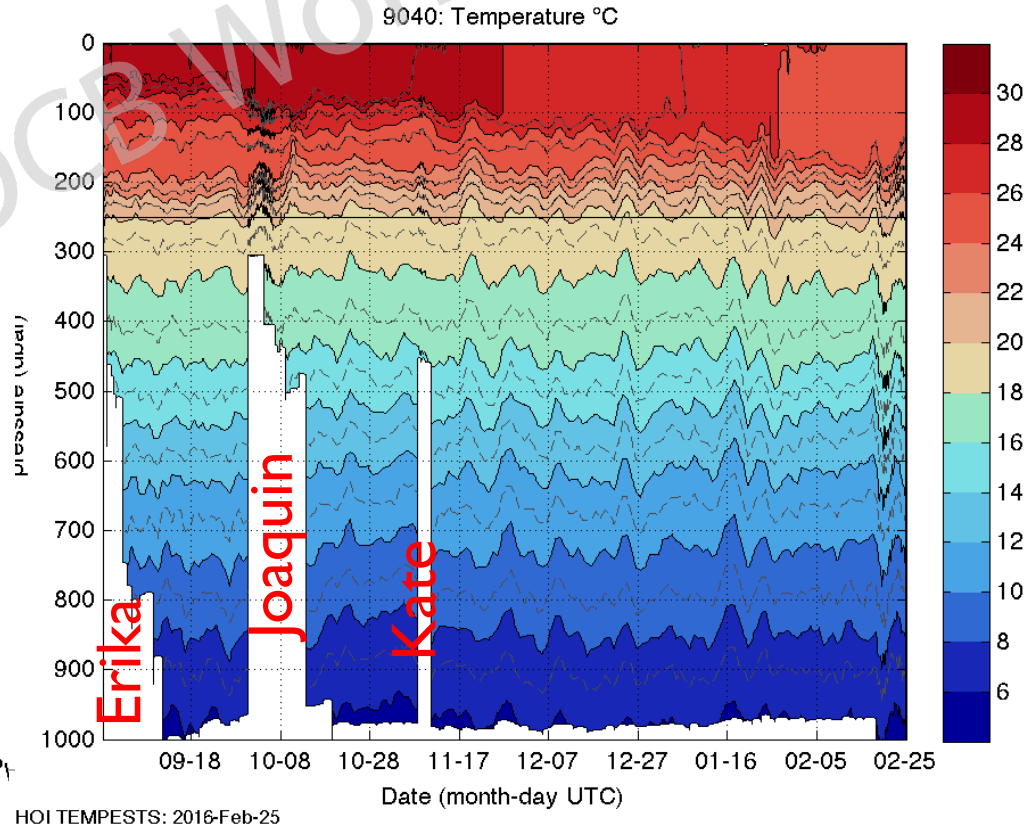

2015-2017
47 ALAMO deployed from Hurricane Hunter WC-130J aircraft.
Mixture of RBR T/P and RBR CTD sensors
Data reported in real-time on GTS for use by forecast models
Goal: manage float to last over duration of hurricane season
42°N
36°N
30°N
24°N
18°N
12°N
90°W
81°W
72°W
63°W
54°W

Atlantic Ocean: 2015 Hurricane Season

-#9040 Deployed in the Tongue Of The Ocean (TOTO) in Bahamas Bank, trapped as a virtual mooring.

-Daily cycle to 1000m but when hurricanes passed over, float switched to burst sampling of rapid, shallow cycles





HOI TEMPESTS: 2016-Feb-25

ALAMO sensor package variants:

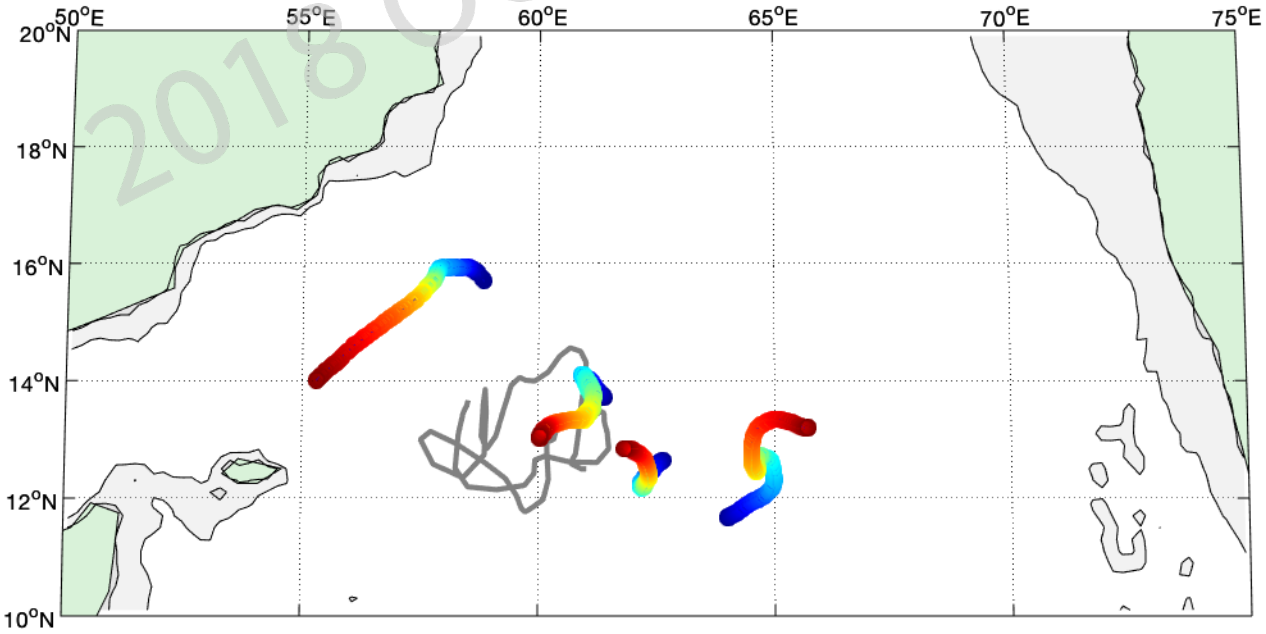
- RBR Temperature/Pressure
- RBR CTD - compact, low-power inductive conductivity cell
- RBR CTD w/ PAR (Photosynthetically active radiation)
- (RBR CTD w/ 0_2-Optode)

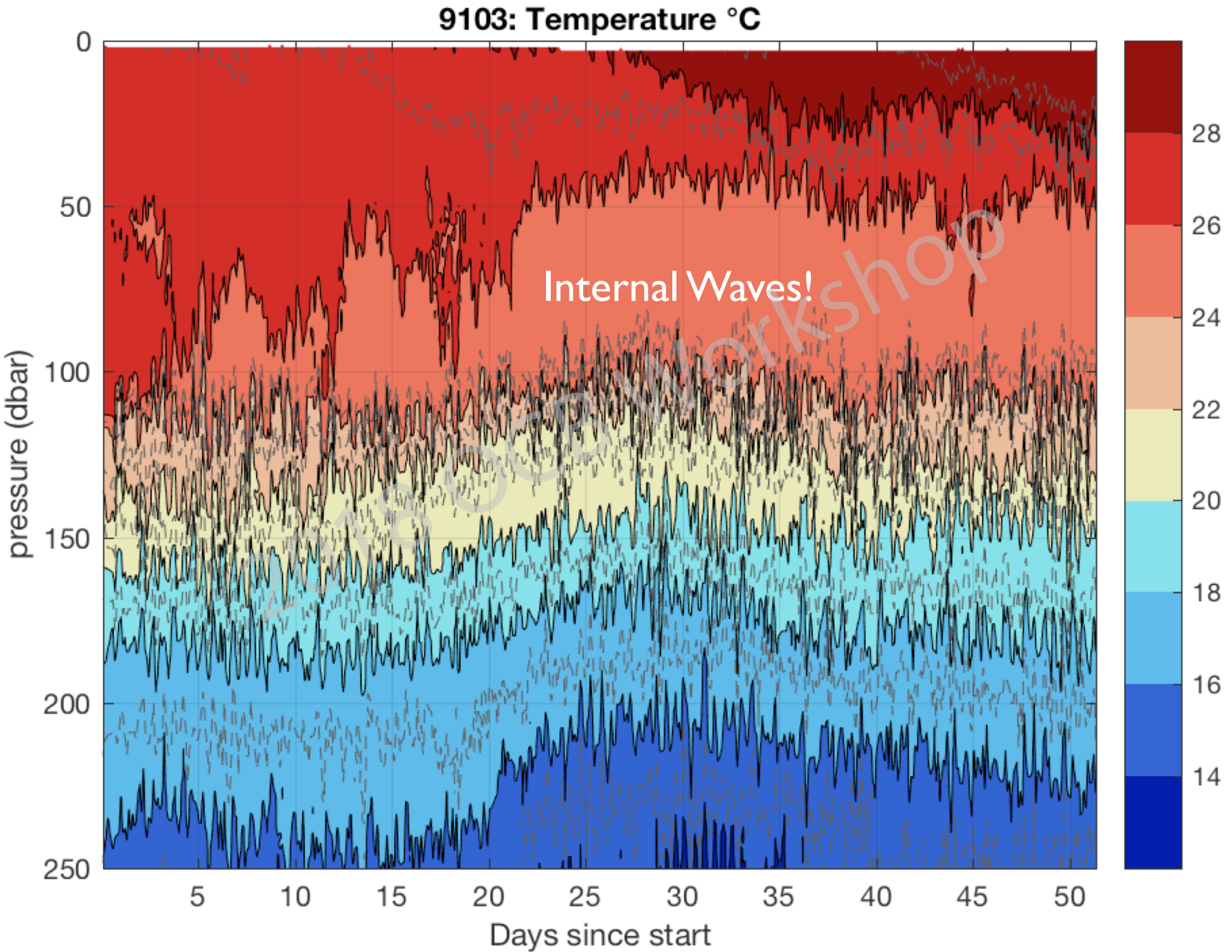
- Seabird SBE 41cp CTD (extended case)

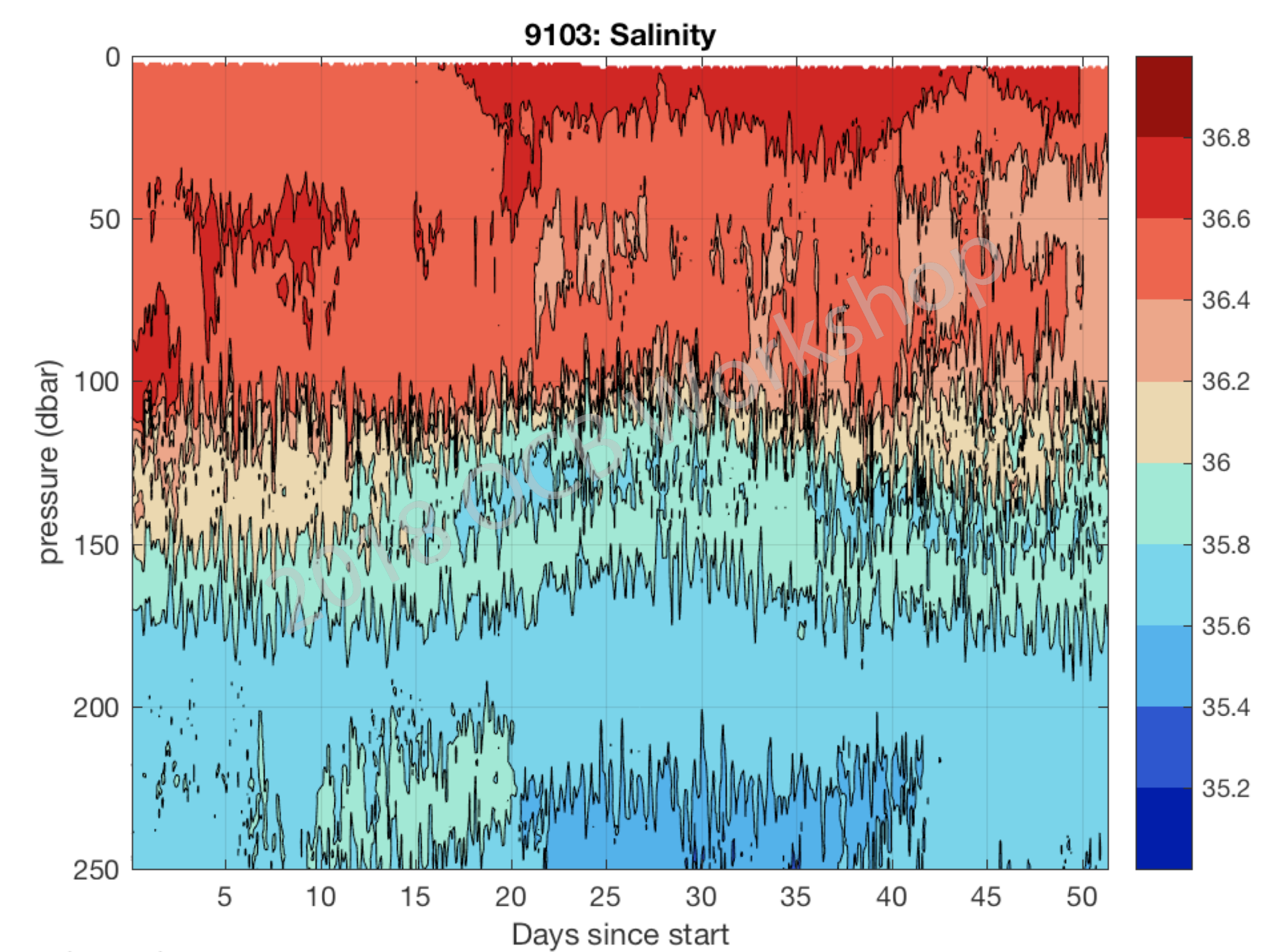
ONR NASCar: 6 ALAMO with SBE 41cp CTDs ship-deployed in Arabian Sea on March 3rd and 4th, 2017.

Programmed to repeatedly profile from 0-300 dbar (10 profiles per day)
Each cycle: 2 hrs submerged, 20 minutes on surface.
Vertical Speed ~10 cm/s (ascent speed controlled by CPU)

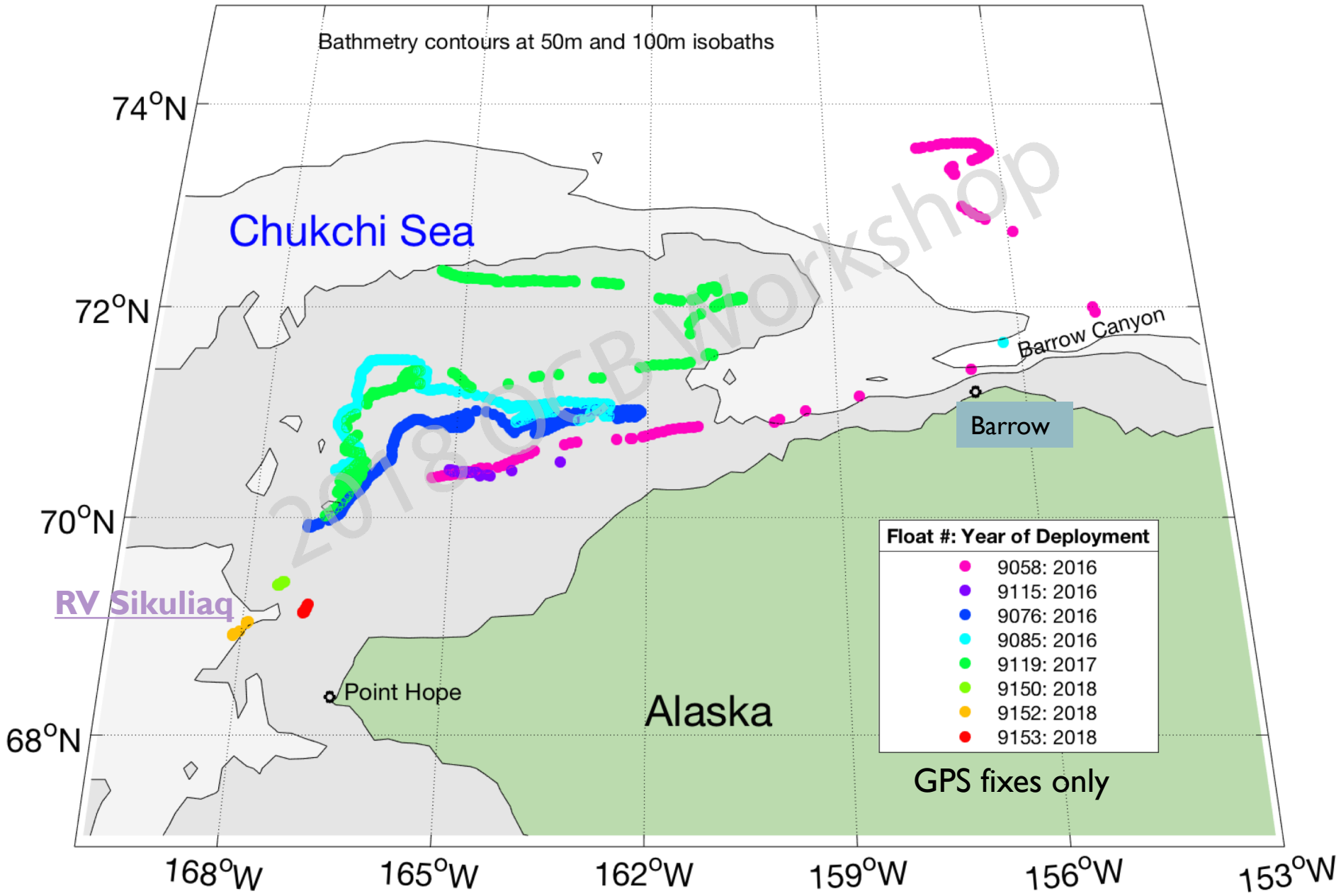
Average Duration:	50 days	(37-58 days)
Average # of Profiles:	496	(368-573)
Average distance profiled:	158 km	(127-179 km)




9103: Temperature °C
pressure (dbar)
0
50
100
150
200
250
5
10
15
20
25
30
35
40
45
50
Days since start
28
26
24
22
20
18
16
14
Internal Waves!


9103: Salinity
pressure (dbar)
0
50
100
150
200
250
5
10
15
20
25
30
35
40
45
50
Days since start
36.8
36.6
36.4
36.2
36
35.8
35.6
35.4
35.2

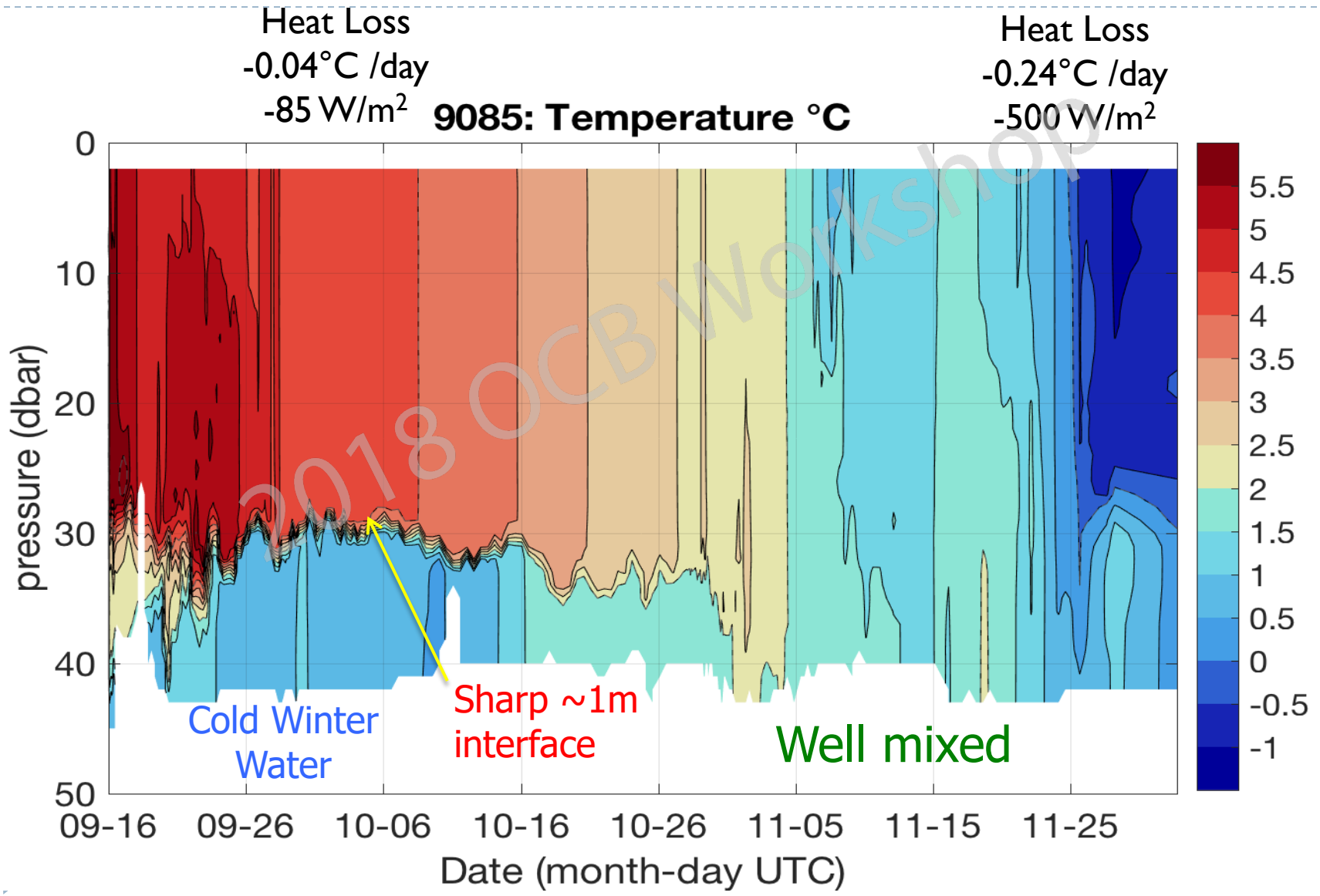
Reported Positions of ALAMO floats deployed in Chukchi Sea: 2016-2018



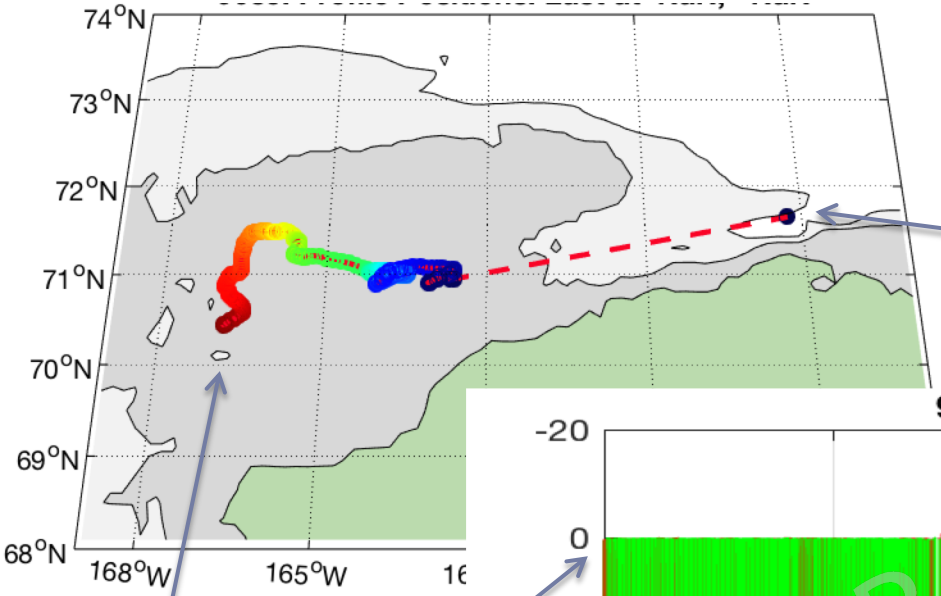
Air-launched deployments from NOAA DeHavilland Twin Otter

Deployment videos at alamo.whoi.edu

#9085-PT: 245 profiles over 77 days, Fall 2016

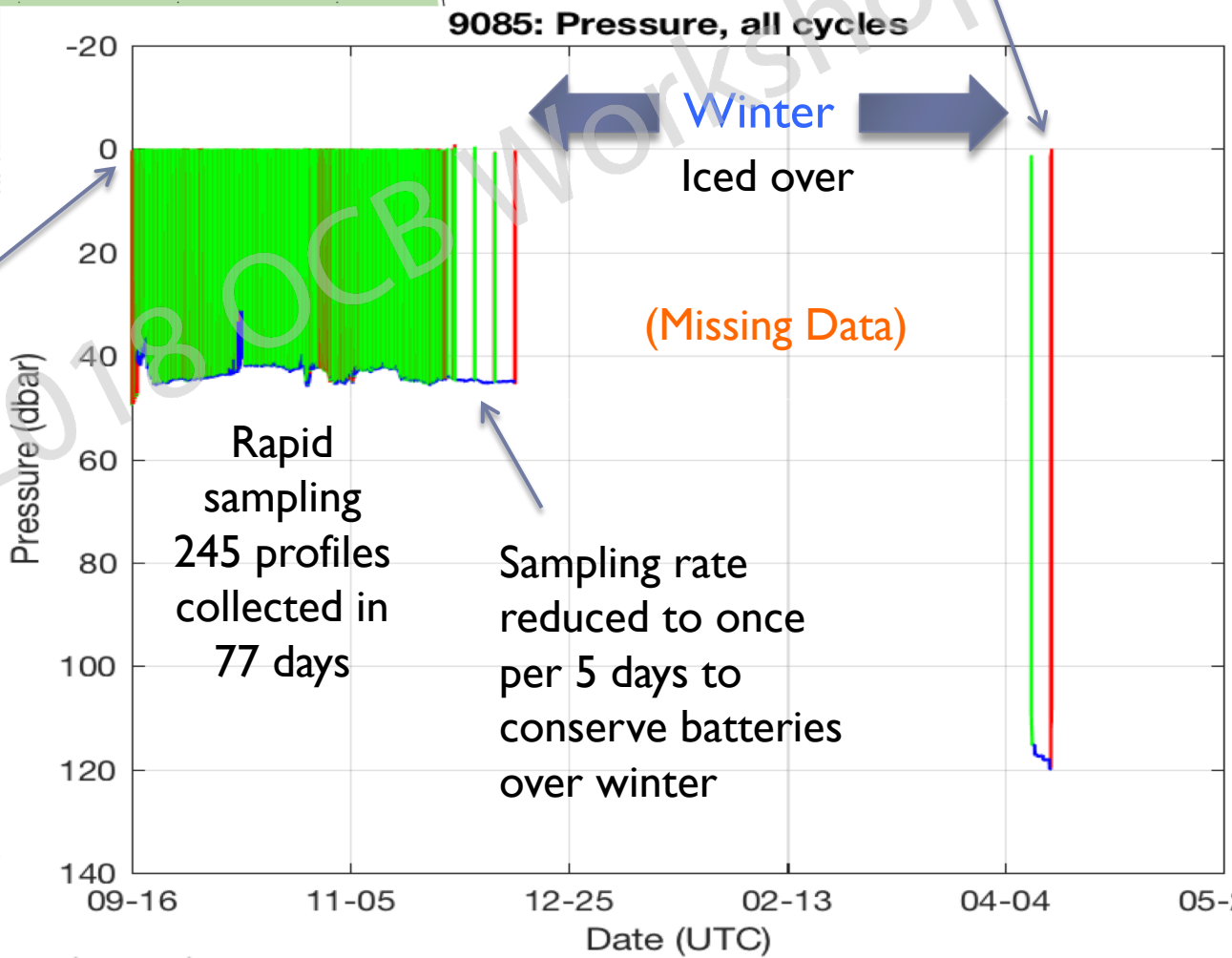


#9085 overwinter



Surfaced April 24 2017 but was only able to offload a few SBD messages

Deployed Sept 16 2016



Challenges for profiling floats in the Arctic

1. Sea Ice - float needs to be able to surface in order to:

• Communicate with satellite – Offload data, receive commands to change mission

• Determine Location via GPS. (*Location can be determined while submerged by acoustic methods if an appropriate network of sound sources is available)

Ice Avoidance Algorithms:

• Measure near-surface water temperature to determine likelihood of the presence of sea ice (supplement with calendar date). If water at freezing point then high likelihood of sea-ice => bail out of ascent before striking ice. Decision-making loop has to happen quick in Arctic

• If possibility of broken ice or open leads, have option to make repeated surfacing attempts in effort to find open water. (Choices: How many attempts?, how long to wait between?, how long to remain at surface?)

Challenges for profiling floats in the Arctic

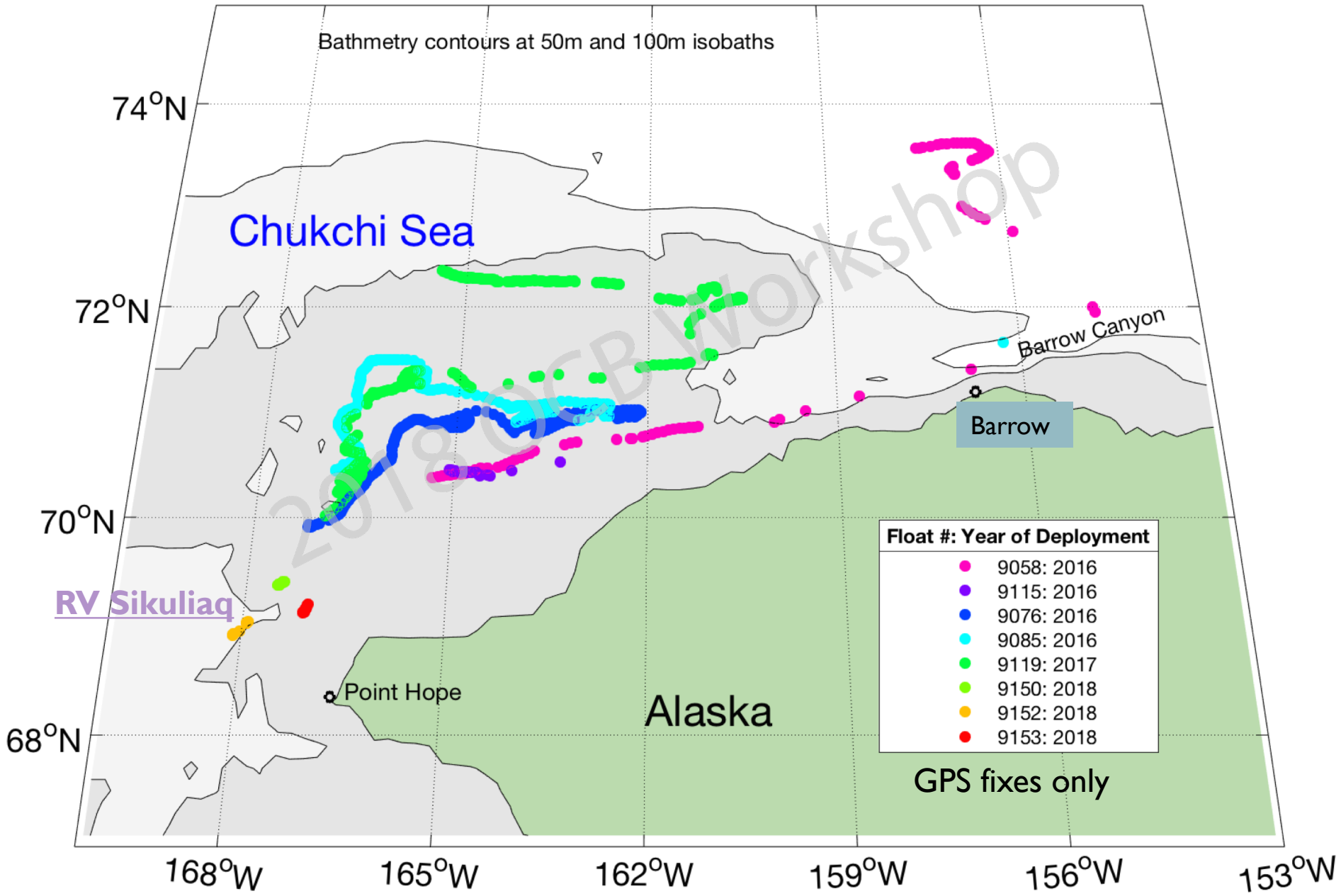
2. High density stratification due to surface freshwater layers.

Measure of a float's ability to overcome density stratification: **ΔV / V**
(fractional change in volume divided by total volume)

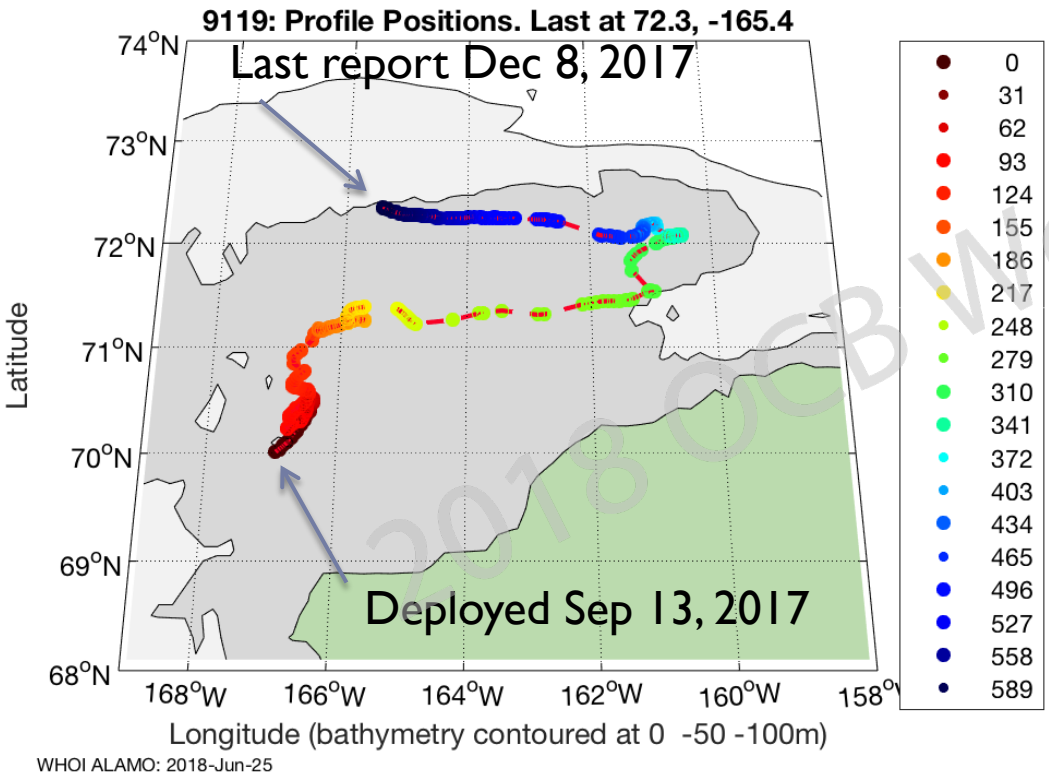
	VOLUME (LITERS)	ΔV* (ml)	ΔV / V
APEX / SOLO-I	~24	260-280	1.2%
SOLO-2 / S2A	~19	650	3.4%
ALAMO	9 to 10.5	400	3.8%

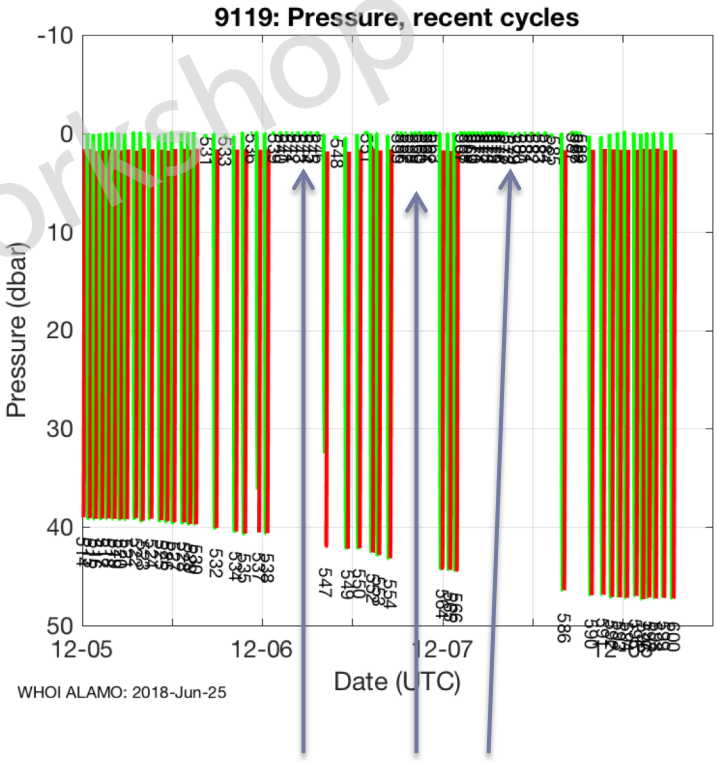
*Fluid moved by hydraulic system. Additional factors determine the overall ability to overcome stratification: hull compressibility, thermal expansion, and inclusion of 'compressee' compensator.

Reported Positions of ALAMO floats deployed in Chukchi Sea: 2016-2018

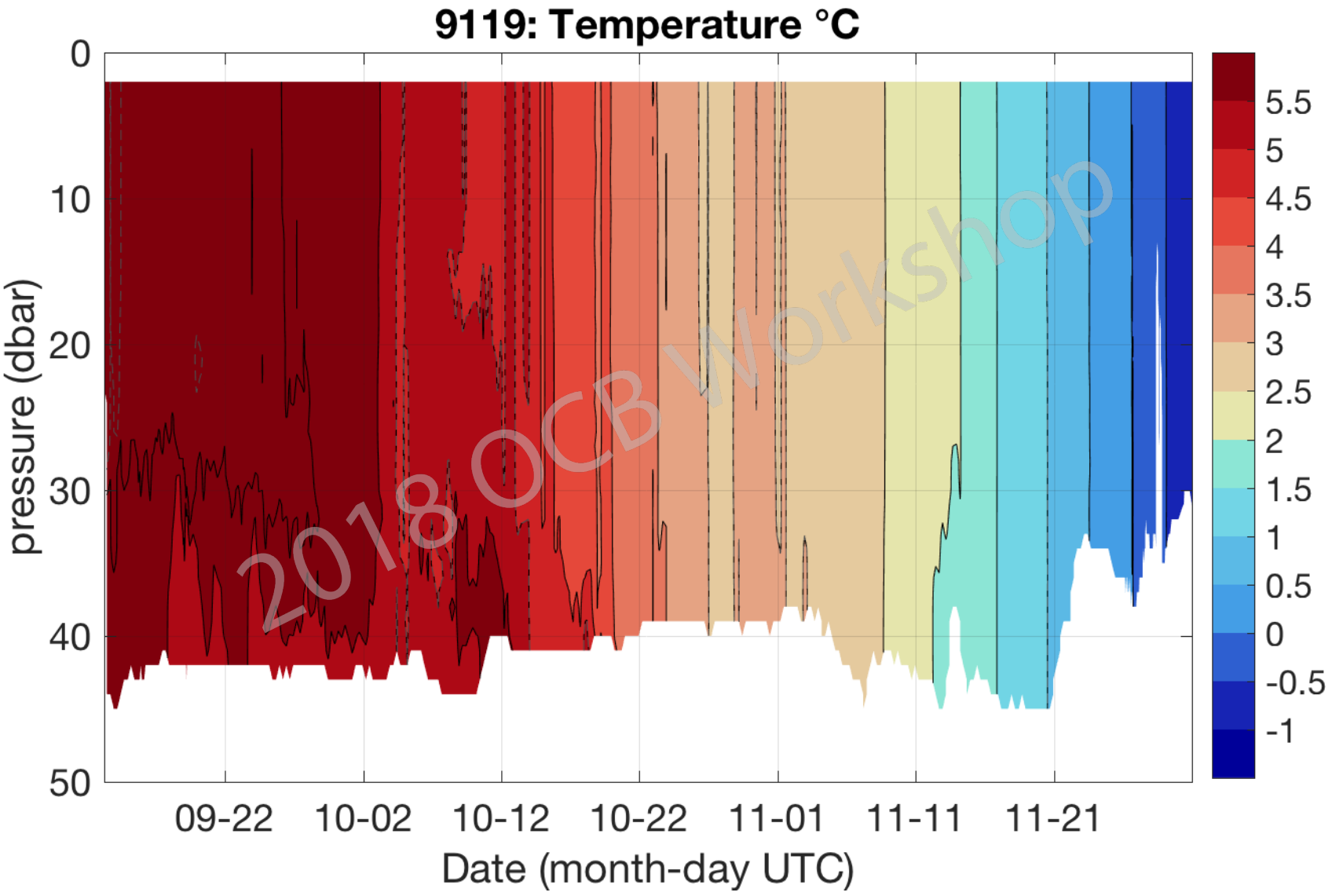


Float #9119 equipped with RBR CTD w/ PAR





Based on satellite imagery and observed water temperature, it appears float became lodged in sea-ice and was unable to descend.


9119: Temperature °C
pressure (dbar)
0
10
20
30
40
50
09-22
10-02
10-12
10-22
11-01
11-11
11-21
Date (month-day UTC)
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
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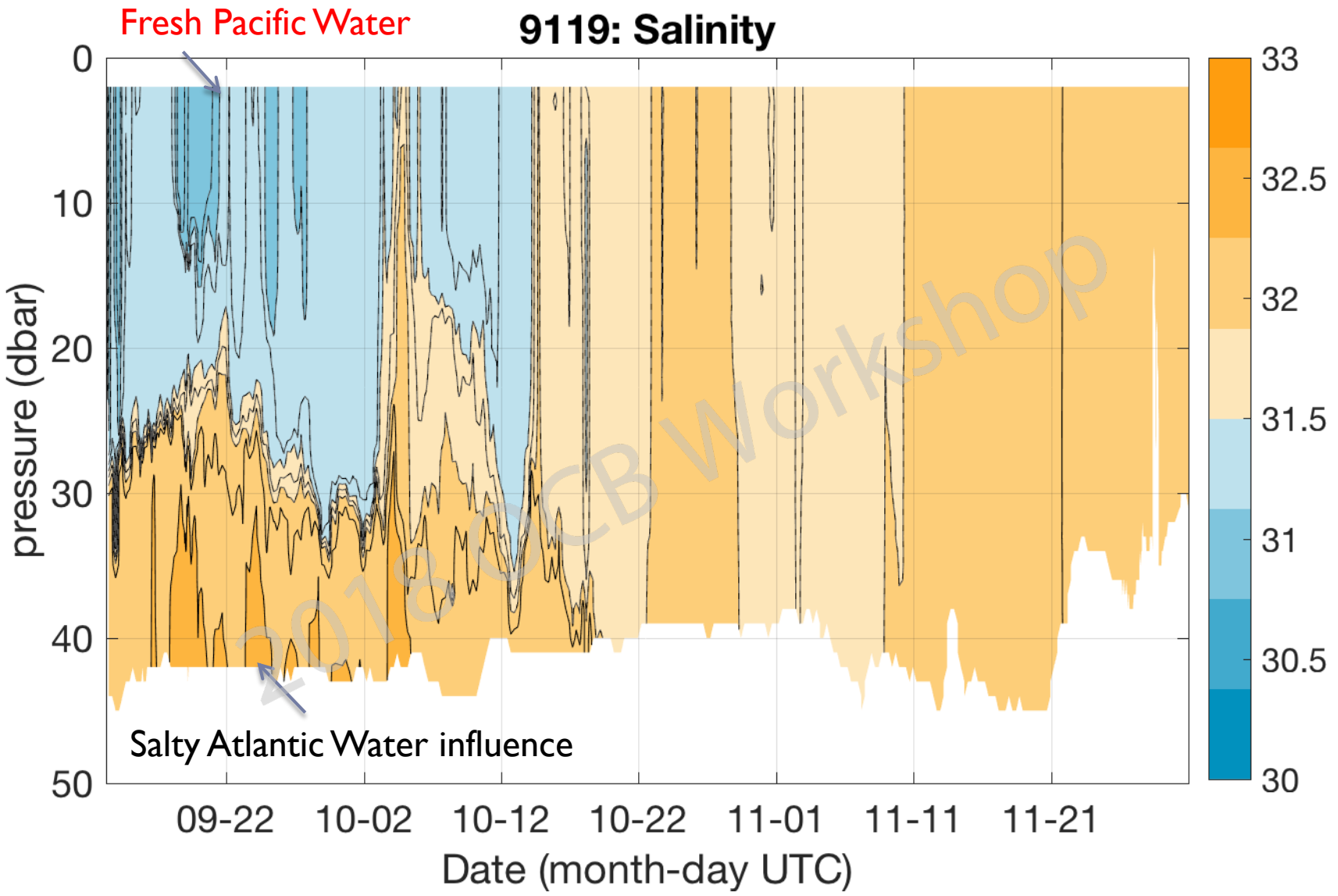
Fresh Pacific Water
9119: Salinity
Salty Atlantic Water influence
pressure (dbar)
0
10
20
30
40
50
09-22
10-02
10-12
10-22
11-01
11-11
11-21
Date (month-day UTC)
33
32.5
32
31.5
31
30.5
30
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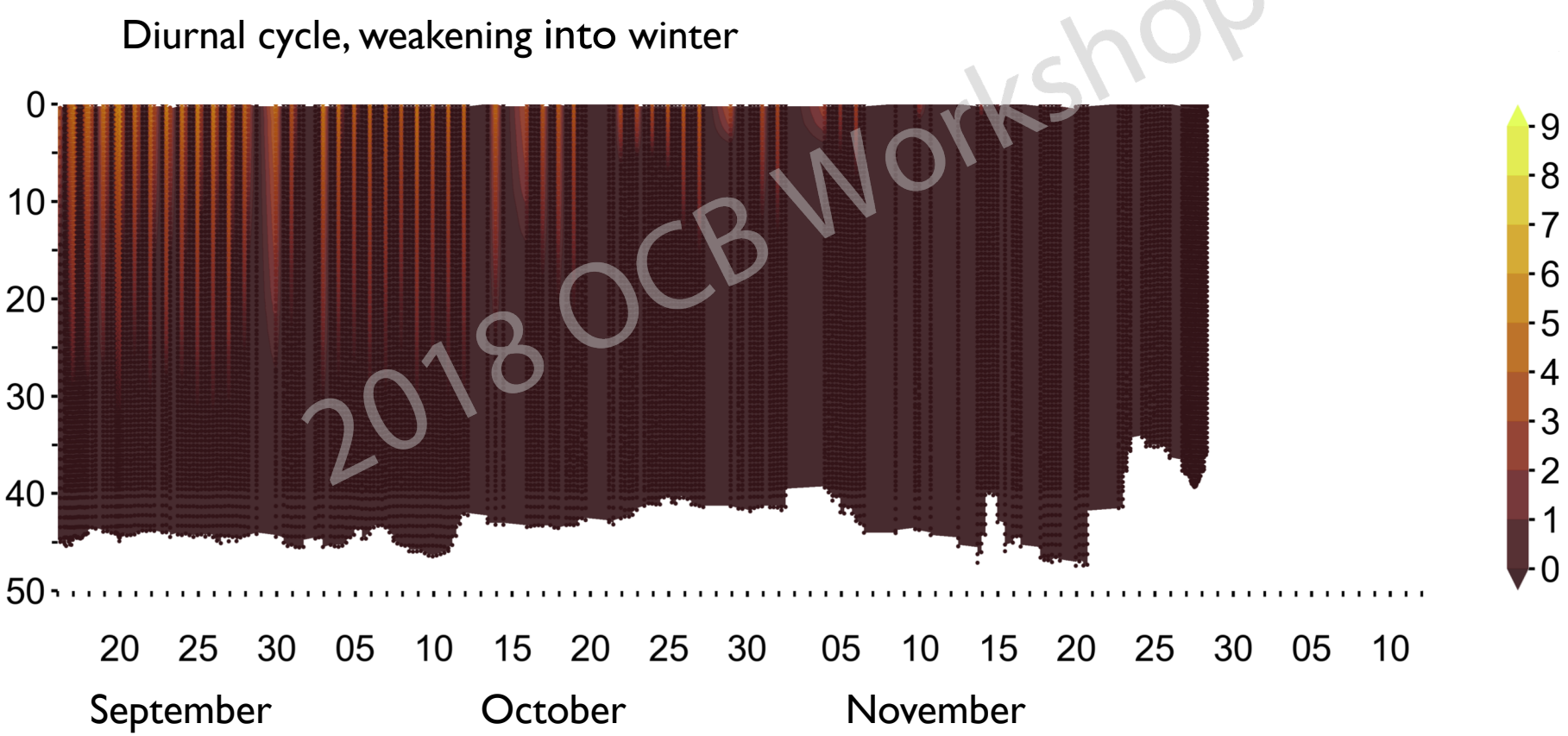
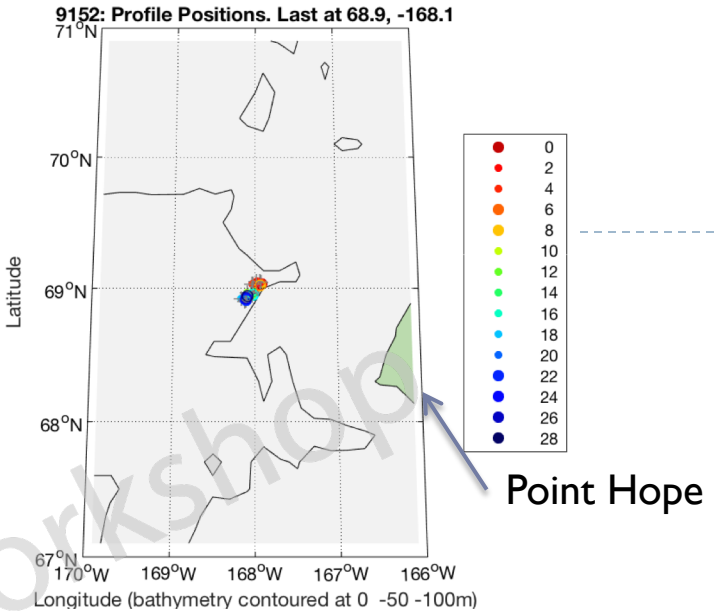
#9119: RBR CTD with PAR sensor

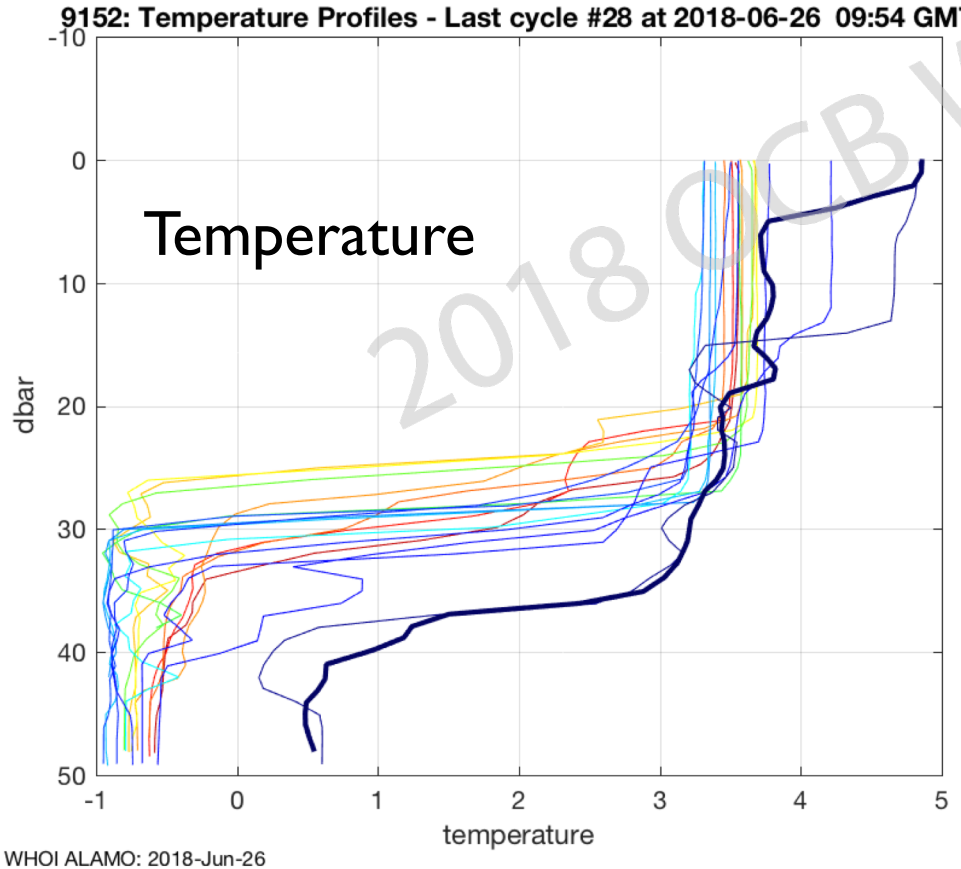
Photosynthetically Active Radiation



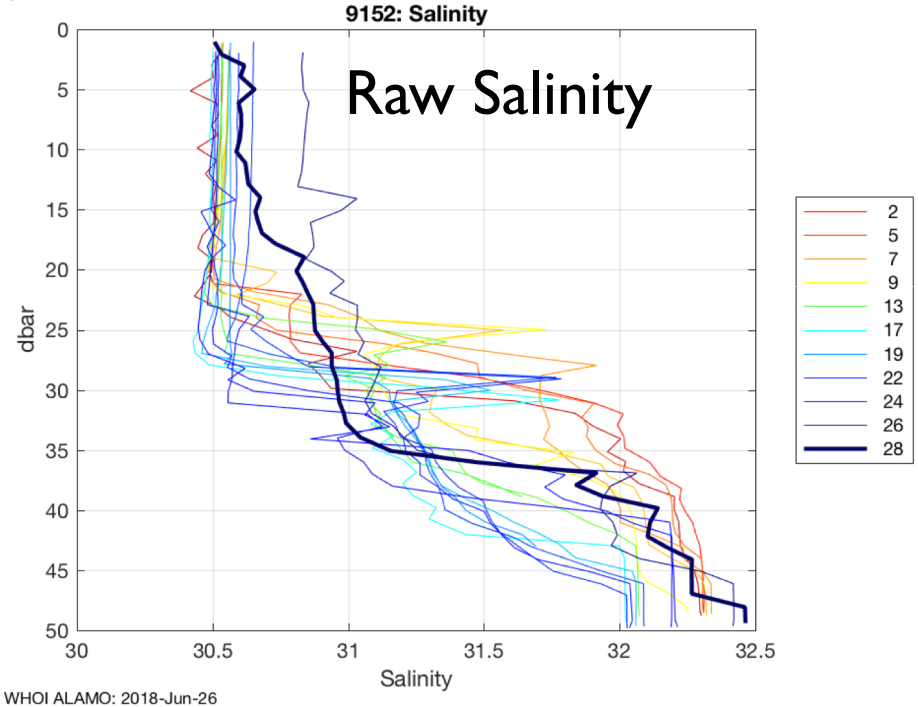
Float #9152-SBE CTD

Deployed June 17, 2018
from RV Sikuliaq





WHOI ALAMO: 2018-Jun-26



WHOI ALAMO: 2018-Jun-26

Summary

• ALAMO: compact, air-deployable instruments offer increased opportunity for deployment from multiple types of platforms. Small size also advantageous when stowage space is limited.

• Rapid profiling frequency provides capability to resolve internal waves and diurnal processes.

• Two-way Iridium satellite communications supports real-time transmission of data and ability to reprogram float mission.

• Jayne, S.R. and N.M. Bogue, 2017. Air-deployable profiling floats, *Oceanography*, **30**. pp 29-31.

• Wood, K.R., *et. al.*, 2018. Results of the First Arctic Heat Open Science Experiment, *Bulletin of the American Meteorological Society*, pp 513-520.

• Future work: SODA (**Stratified Ocean Dynamics of the Arctic**) plans to deploy a "float garden" in Barrow Canyon. A cluster of ALAMO will be anchored to sea floor, every two weeks one will release and start mission. Goal: monitor pathways of Pacific Summer Water flowing into Arctic interior.