Floats in the
(seasonal) ice zone

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With contributions from Marcel Babin, Olaf Boebel, Steve Jayne
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Status report for

- Floats in the Nordic Seas
- Floats in the Southern Ocean (incl. SOCCOM)
- Floats in the Arctic domain (incl. Baffin Bay and marginal ice zone in the Arctic and non-Argo programs)

- Technical issues with float manufacturers
- Issues for data management
The ERIC council has accepted the strategy paper which included amongst other issues sampling goals for the high latitudes: Nordic Seas, Southern Ocean and potential extension into the Arctic in combination with other technology.

Target numbers for deployment and numbers adopted by the ERIC
Nordic Seas: 39 active floats, including 10 floats in the boundary current
  -> 9-10 deployments in the deep basins
  -> 5 deployments in boundary current
Southern Ocean: concentration on Weddell Gyre
  -> 81 active floats in Weddell Gyre (vs. 360 floats in the entire latitude belt)
  -> 25 deployments per year
  SOCCOM covering the entire Southern Ocean
Arctic ocean: generally not feasible for Argo technology
  but larger seasonally ice-free areas in Chukchi, East Siberia, Laptev, Kara and Barents Seas
  Cooperation with NAOS for Baffin Bay
  IAOOS in the Central Arctic
  Beaufort Gyre will be targeted by WHOI within SODA
  Barents Sea could first target for trials within ERIC, but EEZ issues
Discussion during last year involved:

Marcel Babin (Baffin Bay)
Olaf Boebel (Southern Ocean)
Mat Donnely (BODC\SARC)
Ilona Goszczko (Nordic Seas+ north of Fram Strait)
Steve Jayne (SODA)
Katrin Latarius (Nordic Seas)
Edouard Leymarie (Baffin Bay)
Breck Owens (Ice Tethered floats)
Christine Provost (IAOOS, ice-tethered profilers)
Jean-Baptiste Sallée (Southern ocean)
Kevin Speer (Dimes project)
Esmee van Wijk (SOOS contact)
Lynne Talley (SOCCOM)
Float manufacturers (MetOcean, NKE, Seabird and Webb/Teledyne)
+.....
Goal within ERIC is 39 active floats in the Nordic Seas: 10 in the boundary currents and 29 in the 4 deep basins.

At the moment there are 45 active floats in the Nordic Seas:

1 Float 6900563 in Kara Sea
1 Float at Bering Strait 4902129

Deployments need to be realized from European national plans and EU contributions.

Source: AIC 01.03.2016
Why the Baffin Bay? : Ice edge blooms are systematically observed there. And, observations by Ocean Remote Sensing show that the spring blooms occur now 50 days earlier than in 1997.

Goal: To understand the ice-edge blooms

- Physical mechanisms responsible for nutrients inputs
- Sunlight propagation (ice floe and water column)
- Ice blooms dynamics
- Response of involved phytoplankton species

How? PRO-ICE
(CTD O2 +payload)
- SUNA (nitrates)
- OCR 504 (Ed 3 wavelengths: 380, 410, 490nm) + PAR (400-700nm)
- FLBBCD (fluo chla, fluo CDOM, backscattering)

Ice detection (up-looking altimeter and ISA)
Soon: optical ice-detector
**Deployment schedule:**


Fall 2015: 2 Pro-ice were deployed but one is unfortunately lost.

Summer 2016 + summer 2017: 17 Pro-ice

4 PRO-ICE floats will be deployed in early summer 2016 during the Greenedge cruise onboard the CCGS Amundsen.

Greenedge is a large multidisciplinary research project with Marcel Babin as a PI. [http://www.greenedgeproject.info/](http://www.greenedgeproject.info/)

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Ice Breaker Amundsen

Courtesy: Marcel Babin, Claudie Marec
**Environmental conditions/tactical pattern for deployment**

The strategy for float deployment in **Baffin Bay** will make provision for different environmental conditions (global circulation, climatology…).

**Global circulation** (mainly cyclonic): the choice of location for float launch and the tactical pattern for their deployment will be optimized using **Ariane (LPO)** as a computational tool. Work in collaboration with **CONCEPTS** : Canadian Operational Network of Coupled Environmental Prediction System / Fraser Davidson, DFO-St John's,NF).

**Sea ice cover in Baffin Bay**: Taking into account typical sea-ice cover maps, floats are programmed to park at a safe depth during the period of ice cover and start profiling again in spring.

**Example for a deployment location in Baffin Bay:**
- Release ~45 particles at a CGCS Amundsen station:
- 3 drift depths: 500 m, 750m, 1000m
- 3 profiling scenarios: Thanks to Jinshan Xu, DFO, St. John’s & Eric Rehm, TAKUVIK (here a typical biogeochemical pattern)

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green circle = release, black circle = end, black dot = profile

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Courtesy: Marcel Babin, Claudie Marec
Arctic Ocean: ice tethered profilers

IAOOS
Ice Atmosphere Arctic Ocean Observing System

EQUIPEX Project
ANR-10-EQPX-32-01

http://www.iaoos-equipex.upmc.fr/

Courtesy: Christine Provost
IAOOS (ice, atmosphere, ocean)


April 2014: complete platform deployed at the North Pole

• First array deployment summer **2015**
• Further array deployments in 2016, 2017, 2018…

Courtesy: Christine Provost
6 platforms deployed in summer 2015

2 from KOPRI icebreaker Araon

4 from AWI icebreaker Polarstern

More deployments in spring and summer 2016, 2017, 2018…

Courtesy: Christine Provost
Biogeochemical sensors

- within the **EU FP7 project ICE-ARC**, biogeochemical sensors are being added on the IAOOS platform and on the IAOOS profiler. On the profiler: bio-optics; nitrate, pH  On the platform: pH, pCO2

- During **N-ICE 2015**, a profiler with bio-optical sensors and a new pH sensor were successfully tested

- Summer 2016: tests profiler nitrate and platform with pCO2 and pH

Courtesy: Christine Provost
Marginal Ice Zone Experiment is an ONR funded program for 2012-2016, is finished

Technical objective:
Develop and demonstrate new robotic networks for collecting observations in, under, and around sea ice.

Steve Jayne (WHOI) is involved in the float development

SODA project:
• will begin next year
• WHOI plans to put ~20 floats in the Beaufort gyre.
• Improvements for a better Arctic float are underway (with an ice strengthened antenna, more robust ice detection algorithm).
• WHOI will test deployments of 4 floats this summer (joint with Kevin Woods at NOAA/PMEL).
Southern Ocean Antarctic array growth has stalled at 45% of goal (146/360)
Concentrated in some sectors, others are not sampled
• Extension of Argo beyond 60°S into the seasonal ice at the nominal Argo density requires **360 active floats**.

• Strong European research interest is focused on the Weddell Gyre, RAFOS array already installed:
• Requires **81 floats** to be active in the Weddell (likely increased failure rate of floats of 20% -> **25 deployments per year**)

• Other key groups deploying ice floats in the Southern Ocean are SIO, UW and CSIRO with good success over multiple winters – many floats returned recently!

- 146 floats active south of 60° S (45% of required density)
- 259 floats south of 55° S
- Only 16 active floats in Weddell
Retention of floats in the southern ocean

North of the ACC

If we can deploy floats south of 60°S they are likely to stay there

For floats deployed in the latitude band 60-65°S (grey region) retention south of 60° S is high for up to 7 years

Courtesy: Esmee van Wijk
Array of RAFOS sound sources will be maintained by AWI, they will provide for retrospective positioning of under-ice floats.
25 floats with RAFOS antenna will be deployed during Polarstern campaign 2016/2017
Southern Ocean: RAFOS tracked floats

RAFOS subsurface tracking

Courtesy: Olaf Boebel
How useful is the winter under-ice data without positions?

• East Antarctic coast: linearly interpolated positions differed from reported positions by 20 km (Wong and Riser, 2011)

• Do floats follow f/H contours?

• Need to quantify this elsewhere – now two efforts to do this:
  • Olaf Boebel will use the RAFOS floats in the Weddell to compare interpolated and post-processed positions (late 2016 once RAFOS data processed)
  • Paul Chamberlain (working with Lynne Talley & Kevin Speer) is using data from 18 of 28 of Steve Riser’s acoustically-tracked Weddell floats and is also using ice-free floats and withholding data to simulate missing winter data to compare uncertainties in position.
Range of RAFOS-signals in the Weddell Sea

Courtesy: Olaf Boebel
Extend the sound source network toward the continental shelf + ~ 10 floats

**Aims:** Slope current experiment + CDW inflow onto the continental shelf

http://wapiti-project.com/ project lead by JB Sallée; Paris

Courtesy: Jean-Baptiste Sallée
SOCCOM Status

- Funded by NSF
- 6 year initiative from Sep 2014
- 200 BGC floats in the Southern Ocean
- T,S,P,O₂,NO₃,pH,Chl and backscatter
- ~ 50% will end up under-ice
- 35 floats deployed per year for next 5 years
- 38 floats operational (~23 under ice most winters)
- 5 dead
- 15 deployed soon (4 under-ice)
  - Bio Argo and SOCCOM (BGC) are combining forces to a single global effort.
Technical issues with float manufacturers for RAFOS floats

Use of Rafos system requires manufacturer willing to integrate technology (Optimare has moved its business). Contacts have been made with manufacturers to inquire about interest in technical integration of Rafos antenna. SBE, NKE and WEBB/TELEDYNE have expressed interest. Olaf has specified sensor equipment for floats with RAFOS and requirements for the tracking

**Sensory equipment**

- Seabird SBE 41 / 41CP CTD (or alternatively “WOCE for life” CTD if feasible)
- Seascan RAFOS Sensor
- GPS receiver for position determination, IRIDIUM transceiver for bidirectional communication
- Top cage to protect CTD/antennas against ice contact (e.g. fiberglass loops).
RAFOS tracking: This function requires additional hardware payload. To enable reception and processing of RAFOS signal the following components need to be embedded:

- A RAFOS compatible hydrophone (e.g. Benthos-RAFOS2

- A RAFOS receiver board (e.g. a SEASCAN receiver). To retrospectively determine the float’s positions at drift depth, the float shall feature a RAFOS receiver and “listen” for RAFOS signals between user settable times (typically 12:30 to 14:30 GPS or UTC).

- An internal clock to track the start time of the RAFOS receiver to 1 second accuracy. This accuracy might be achieved by post-processing e.g. by tracking the internal clock drift via desktop comparison of time stamps of the internal clock with GPS or Iridium timestamps.
Future outlook

• Ice float capability is proven
• Lifetimes of 3-6 years – comparable to regular Argo
• Retention in deployment regions south of 60° S is high
• Cost is the same as a regular float – ISA algorithm is free (RAFOS more expensive + maintain sound source array)
• Biggest vulnerability is the lack of position information under-ice
• Need to prevent thinning of the array in future
• If we had a full strength Under-Ice Argo array – what could we expect to know after 10 years?
  – Circumpolar seasonal climatology
  – 1 dimensional budgets of heat content/flux, sea ice production
  – Better constraints on air-sea flux estimates
  – Observations of cross-slope/shelf exchange of warm water onto the continental shelves
  – Year round observations to constrain and validate models

Courtesy: Esmee van Wijik, Lynne Talley
Summary and challenges

- Under-ice observations in the Southern Ocean are critical to understanding global climate, circulation and variability, inventory of heat and freshwater, biogeochemical cycles etc.

- As part of the integrated GOOS, many enhancements and extensions to Argo are gaining momentum, e.g. Deep Argo, Bio-Argo, SOCCOM, Under-Ice Argo, EuroArgo...

- Several major contributors (U.S., Aust., Japan) will see significant declines in deployments due to flat (below inflation) or decreased funding. Growth by Europe and China will not likely compensate for this.

- Under-Ice Argo in the Southern Ocean currently at 45% of the required density.

- Real potential for the degradation of array densities over the next few years, with the Southern Ocean particularly at risk (despite SOCCCOM).
Parameter names for the RAFOS correlation heights (COR) and Time of Arrival (TOA) have been found.

These interim variables will be stored in b-traj files and only the final LATITUDE, LONGITUDE values will be stored in the d-traj and merged files.

AWI plans to work on the stored RAFOS data and submit RAFOS positions in the second half of 2016.