FRAM-2014/15: 50 Weeks of Arctic Science from Drifting Sea Ice

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12th Annual GEBCO Science Day
Busan, Republic of Korea
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Aerial view of 1962-74 camp of Fletcher’s Ice Island (T-3)

Four periods of Occupation - 7,240 days total
U.S Air Force - 19 March 1952 to 14 May 1954 - 768 days
U.S Air Force - 25 April 1955 to 24 Sept 1955 - 153 days
U.S Air Force - 7 March 1957 to 24 Oct 1961 - 1,692 days IGY Station Bravo
U.S. Navy - 17 Feb 1962 to 1 October 1974 4,609 days ONR - NARL

USGS Hydrohut: Source of FL Cores
Lamont Hydrohut
This was the area of my 1970 PhD thesis at Lamont-Doherty Geological Observatory. The data was good, but all my interpretations were WRONG.

Between 14 May 1962 and 15 Sept 1974 (4507 days or 12.34 years) T-3 drifted 23,561 km. The average drift was 5.2 km/day. The cost of the station, run by the US Navy, was quoted as being one million dollars per year - i.e. $524/km in 1967 dollars.
T-3 Track and location of the four oldest (45–76 my) cores in the Arctic Ocean. The shaded Area is 20,000 km².
In 2004 my LDGO classmate Prof Yngve Kristoffersen invited me to bring the original 1966-1974 T-3 seismic profiles to Bergen.
The Result

Poster from 2006 Fall AGU Meeting, after examining old 1966-1974 seismic data
R/H SABVABAA Arrives in Longyearbyen, Svalbard at 79°-14'N in June 2008.
Since its arrival in Longyearbyen, Svalbard (78-14N) in June 2008, the craft has been to the ice over 20 times, and has traveled approximately a distance equal to halfway around the world. Its sexy form has already graced a number of serious publications. A search on SABVABAA on Google has given up to 80 pages.
Healy 1102 CHIRP Profile of 'Hyperbolic Echoes' on the Alpha/Mendelev Ridge
EM122 multibeam 8 km wide swath showing slopes of the Ejecta Zone, red color is up to 40°. These are not sediment waves.
CHIRP Subbottom Profiler record showing a uniform and conformal 25 m thick acoustically transparent layer over the 'ejecta zone'. I believe that this was the fallout of the muddy ocean following the impact.
During Healy Cruise in 2011, Yngve and I were invited to bring the hovercraft up to the Alpha Ridge in 2014 aboard the Alfred Wegener Institute (AWI) icebreaker Polarstern.
This then set in motion the plan for the next two years (2012-2013) to get the hovercraft ready for work on the Alpha Ridge in 2014. New equipment was to be built, support arranged, rescue plans made, and personnel found for what was expected to be a 500 day drift.
Preparation of specialized light-weight equipment for FRAM-2014/15 in Yngve Kristoffersen’s machine shop.
Our intrepid FRAM-2014/15 Arctic Heroes. Prof. Yngve Kristoffersen of NERSC and Emeritus Professor at the University of Bergen, and Audun Tholfsen of Spitzbergen, and various very high Arctic adventures. Tromsø, Norway, 4 August 2014.
The original plan of getting to the Alpha Ridge and the site of the 4 Mesozoic short cores.

Note how the Alpha Ridge is void of icebreaker tracks.
Therefore a site (green dot) was selected for offloading FRAM. The ice conditions were such that despite much backing and ramming the Polarstern was unable to get to the asteroid impact area on the Alpha Ridge.

A two-icebreaker Canadian effort (Terry Fox and Louis St. Laurent) to do seismic refraction was also stymied by the ice.

Therefore a site (green dot) was selected for offloading FRAM.
The obligatory group photo of the 44 member science party for Polarstern Cruise ARK-XXVIII/4 (Expedition PS87) at the North Pole on 26 August. This was the 4th time that Polarstern has been to the North Pole.

This will be the last time as the 34 year old ship will be replaced by a new icebreaker, the Polarstern II in 2017.
Early morning, Saturday, August 30th 2014.
the FRAM-2104/15 drift station is set up at 87° 20.7' N, 153° 58.8' E, 296 km from the North Pole.

Some of the 12 1000 liter rubber bladders with special Arctic diesel fuel.
The R/H SABVABAA is offloaded from the forepeak of the Polarstern. Note the 100 rubber 'fingers' below the skirt, which confine the air under the craft. The craft is 12 m long and weighs 5 tons. Its official payload is 2,200 kg but the usual load is closer to 3,000 kg.
Polarstern’s helicopter, crew and scientists worked 10 hours to offload 21 tons of supplies and fuel plus the hovercraft.

After waving goodbye as the icebreaker departed, (First Slide) they were faced with the job of setting up the ice camp and beginning the science program.
The plan for the FRAM-2014/15 rift was multi-disciplinary.

The cartoon shows the many sensors above and below the ice.

**Geophysics**: Seismic profiling with an airgun and single hydrophone. No gravity or magnetics was planned as aerial surveys have completely covered the Arctic. Echo-sounders from four element CHIRP to 12, 30, and 200kHz. Five autonomous 10kHz E/S buoys from WHOI.

**Geology**: Hydrostatically boosted sediment and gravity corers. GoPro bottom camera. Dredge.

**Oceanography**: CTD, ADCP, current meters at 800 and 1200 m, thermistor string.

**Meteorology**: Weather and incident and reflected radiation.

**Glaciology**: Ice thickness
SPOILER ALERT
Overall Summary of the FRAM-2014/15 Drift

Atmosphere
- Radiation: High (yellow)
- Weather: Moderate (blue)

Ocean
- Temp./salinity: Low (blue)
- Heat transfer: High (red)
- Currents: Moderate (blue)

Sea bed
- Bathymetry: Constant (yellow)
- Bottom camera: Active for 1,000 km
- Seismic & seabed sampl.: Active

Logistics
- Camp: Build-up, Destruction, Rebuilding

Delivery 30 Aug 2014
Audun leaves 5-6 Jul 2015
Pickup 18 Aug 2015
3-D Display of the track through 20 June 2015 on the 2012 IBCAO 3rd Version 500m grid.

The track is about 2,014 km long. Positions are generally reported daily by internet.
Installation of the Weather Station for the Geophysical Institute (GFI) of the University of Bergen.

Radiation flux Measurements are also recorded for Meteorology Norway.
Making holes through the ice:
Home-made battery-powered auger
Home-made compressed air powered chainsaw for cutting through 1 m of sea ice. The saw is anchored in a 3” augured hole, and is then pushed down to make the cut. This allowed many hydro-holes to be made comparatively easily.

Making hydro-holes: Specialized equipment
Emplacement of recording current meter. Note the rectangular hole made with a home-built ice auger powered by an auto starter motor and 12v battery.
Making a hydro-hole, within what was to become the ice hanger. The ice was about 1.1 m thick.
Lee Freitag at Woods Hole Oceanographic Institution (WHOI) built five Autonomous Echo-Sounding buoys for the FRAM-2014/15 expedition. The first such deployment ever. Set out at distances of up to 6 km from the main camp they buoys produce soundings from a single 10 kHz ping. As recovery seemed possible they were housed in Pelican cases. They send soundings and health messages to WHOI via Iridium, and generally ping once every 6 hours unless the topography is changing, in which case 2 hour intervals were generally used.
On Nov 4th, WHOI's Lee Freitag e-mailed: 'It appears as though there was an event on Oct 25th and that the floe or set of floes that the buoys are on broke up. Buoy 5 moved relative to the others, and Buoy 2 may have fallen in or been covered by ice.

These events coincided with the breakup of the camp area.

Overall, the deployment was very disappointing. By the end of the drift all the batteries were dead, three buoys had disappeared, and the depths reported were not consistent with the IBCAO grid of Arctic bathymetry.
FRAM brought 6500 m of 3/8” kevlar aramid fiber rope for coring, dredging, and bottom photography. This home-built rig with GoPro camera in a 4000 m pressure housing allowed movies of the seafloor, shrimp, and a half-meter long eel-like fish, as yet unidentified. This video was taken at 1,450m.

The camera sled was self-righting and could be pulled along the seafloor as the ice drifted. LED lights provided excellent illumination.
Layout of the hanger before a fabric cover was put over the whole structure
The short-lived ice hanger, whose 30 ton weight caused flooding from the hydro-hole, followed by ice cracks which scattered its various sections.
The heavy snowfall with high winds added additional weight to the floe and buried all the equipment and supplies.
The seawater around the hydro-hole rose up to 50 cm above the ice.
Food was taken for two persons for 500 days.

Note one of many GoPro cameras for making videos.
A very warm and cozy cabin for two.
SABVABAA has four Iridium satellite telephones for e-mail and data links.
Seismics: The airgun above was fired every 25 m over a distance of 1000 km (40,000 shots).

Left: Comparison of Polarstern profile over the Lomonosov Ridge with multichannel streamer vs the small airgun and a single hydrophone.

The digital data are now being harmonized in Norway at Bergen and Lundin.
The seismic data revealed another 5 km wide submarine channel feeding into the NP-28 Channel System.

In addition the crossing of the Morris Jessup Rise cast new light on the provenance of this feature.
Winch system for coring, CTDs, GoPro bottom camera etc.

3/8” kevlararamid rope, 2 ton breaking strength

Capstan with Meter
All Hydraulics

Hydro-Hole
Ice Chisel
The camp was in the polar winter for about 5 months. Moonlight allowed some visibility but generally everything was done with headlamps.
The pastoral camp was eventually thrown into disorder by the ice dynamics, occasioning a 300 m move to an undisturbed flow.
The red X marks the only woman in town.
This snow lady was a parting gift of the Polarstern’s science contingent.
Disruptions of the Camp fuel supply, stored in 1 cu meter bladders.

fuel bladders

fuel bladder fallen into a lead
The ice dynamics caught a number of the 1 m$^3$ (1000 liter) fuel bladders in the crushed ice. Fuel was moved by pumping between bladders.

Putting the 100 ft hose into the bladder. Note the bare hands!
On the evening of 16 October a light was seen. It was on for some 4 hours. The crew walked out some 3 km to see what it was.
It appeared to be a submarine, with its bow and sail protruding through the rubble ice. On approaching to within 100 m, the light went out, and the submarine submerged.
On the web there was a photo of the Russian submarine **Orenburg**, displacing over 13,000 tons. An early 1970s Delta III class ballistic missile submarine, it was converted into the mother ship of a nuclear powered submersible with great depth capability (6 km). In 2012 that **Losharik** submersible had been used to make three drillings on the Mendeleev Ridge in support of Russian UNCLOS Article 76 submissions.
Another visitor, an Arctic Fox (	extit{Vulpes lagopus}) known as Terianniag Qaqortaq in West Greenland. Stayed a week.
An iconic picture of FRAM-2014/15 versus the original.
CHRISTMAS Airdrop from the 333rd Squadron at 1040 GMT 23 December. A much-needed drop of a supposedly cold-proof tent, stoves, and supplies. A seven hour flight for a four engine aircraft. Temperature -34°C.
The New Year 2015 was celebrated at 87°-36.8’N, 65°-04’W, temperature -28°C, air pressure 1020 hPa, and wind 21 knots from ENE.
As fuel and electrical power became limited, a program of making CTDs every 5 nm was initiated. These lowerings were important additions to a recent paper on layer mixing north of Greenland.

After 1\textsuperscript{st} March there was again daylight for operations outside.
By April 10 the lack of generators and engine problems had reduced the power to one battery for GPS, Iridium, and UHF radio. The 333rd Squadron again made an air drop of generators, spares, and other supplies. This provided the first idea of the camp area.

One high-speed pass and the Orion P3C is on its way back to the island of Andøya the northernmost island in the Vesterålen archipelago, situated about 300 km inside the Arctic circle.
One of the FLIR color and infrared images taken by the aircraft during the air-drop. GPS navigation, satellite communications, and advanced reconnaissance imagery has removed much of the isolation experienced on the ice stations some 50 years ago.
Unlike this mother polar bear and her three cubs, observed from the Polarstern in 2014, there was little contact with bears during FRAM 2014/15. Footprints of a bear with one or two cubs were seen near the camp October 10. Then, 42 weeks later, a scruffy bear visited the camp June 15, and one or two bears investigated the food stores on June 23. The beginning of July (Week 44) saw visits for seven days running, with one young bear being quite aggressive.

During the previous 6 years the hovercraft had been somewhat of a bear magnet.
Week 29 saw a second cycle of ice dynamics. Hovercraft engine problems, stiff skirts, and a burnt out electrical winch required heroic efforts to remove the hovercraft from its trench before the parking place was subducted under neighboring ice. That was the craft’s brush with disaster.
First sight of land - NW Greenland

Leads opened up quite quickly

Ice dynamics at work

Everything moved to a relatively stable area
A planned visit by aircraft in the spring was abandoned when the April air-drop showed no suitable landing areas.
Audun departs 6 July after 11 months at sea, returning to Tromsø on 18 July with the Polarstern
The pickup - 7:20AM 18 August 2015
81°-11.7'N 10°-17.1'W in the Fram Strait
27 km off NE Greenland
Mission Almost Accomplished

M/V HAVSEL - the last operating sealer in the world
19 August - Navigating the ice fields on the way to Svalbard; SABVABAA’s most efficient speed is 25 kts versus HAVSEL’s 9.8 kt.

Shortly afterward, while waiting on an ice floe for the HAVSEL to catch up, a strut on the fiberglass propulsion fan shroud broke. This caused one of the propeller blades to break off, and damage to the shroud. The hovercraft then was towed while the lift fan raised it above the water. Luckily the sea was flat all across the Atlantic Ocean.
18:00 LMT 22 August 2015, Longyearbyen, Svalbard.

Home is the sailor, home from the sea
The welcome in the HAVSEEL wardroom, from NERSC and the Norwegian Academy of Sciences.
Weekly Reports

A Norwegian ice drift 118 years later

Welcome to the Geonova Diary of the Norwegian scientists Yngve Kristoffersen and Audun Thølen who lived and worked on their ice drift station including the hovercraft “Sabvabaa”. From August 2014, the team was drifting for 353 days over a distance of 2,200 km along the submarine Lomonosov Ridge.

FRAM-2014/15

a Norwegian ice drift 118 years later

Weekly Reports

SABVABAA has 4 Iridium satellite phones for almost instantaneous communication with all the world. Weekly reports were sent out via E-Mail to hundreds of followers. In all, the reports take up 780 pages, including 311 photos suitable for reproduction.

www.geonova.no (above) has the full archive and was followed by 800 people during the drift.

www.geonova.no/diaries/sabvabaa/
Thank you for your attention

Photo courtesy Dave Monahan, UNH-CCOM-GEBCO/Nippon