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Cryoegg: development and field trials of a wireless subglacial probe for deep, fast-moving ice

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Cryoegg project history

We aim to develop a wireless subglacial probe to measure temperature, pressure and electrical conductivity of meltwater and transmit data via radio frequency to receivers on the ice surface

Why? To observe subglacial hydrological conditions, particularly beneath fast-moving ice

ETracer (50mm diameter)

Cryoegg (2012) – 150mm diameter

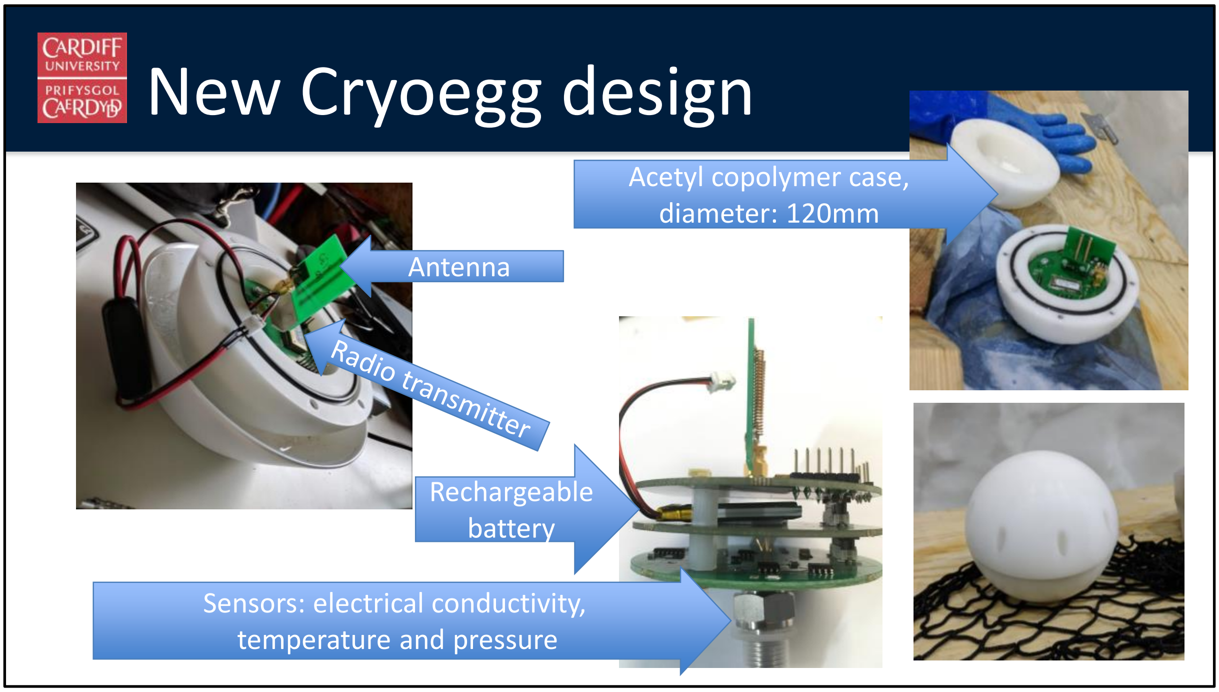
Cryoegg (2019) – 120mm diameter

The project originally began at the University of Bristol. Subsequently Liz moved to work for Cardiff University and brought the project with her.

2014: tests at margin in Greenland, data transfer through 200m temperate ice.
2016: tests of ‘ETracers’ at EastGRIP field camp (NE Greenland) to see if the electronics would withstand the cold.
2017: tests of prototype Cryoegg electronics in EastGRIP borehole to see if borehole fluid impacted signal transfer.
2018: received funding from EPSRC to pay for a two-year post-doc, manufacturing and fieldwork costs.
2019: new prototype tested at two sites in Greenland and one in Switzerland.

ETracers: 50mm diameter, originally intended to be deployed in moulins and recovered from the glacier outlet fjord. Later versions sent data by radio.
Cryoegg was originally 150mm diameter, intended for use in deep ice and with all data transmitted by radio.

Mike Prior-Jones joined the project as post-doc in 2019 and did a complete re-design of the electronics.

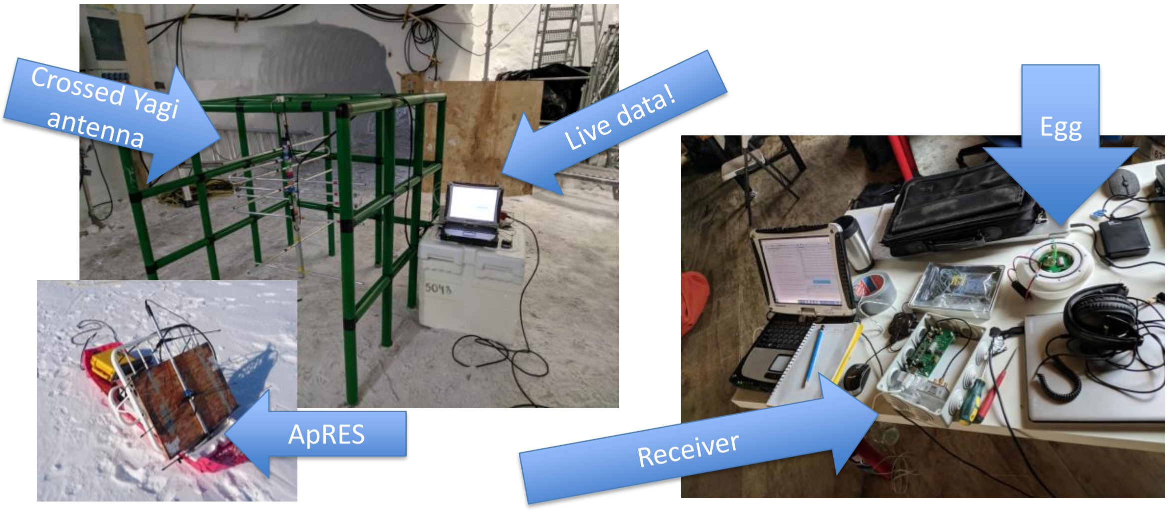


The 2019 redesign reduced the case size to 120mm.
The new electronics are very low power - the very compact lithium-polymer battery can potentially take an observation every two hours for a year, even at -30C.

The radio module is from Radiocrafts and operates using the Wireless M-Bus Mode N1 protocol on a frequency of 169MHz. The radio technology comes from utility metering – it's used to read water meters in Paris, France.

The antenna (Taoglas HA.10) is electrically much too small which makes it inefficient, but that's a necessary compromise to make the unit fit into a borehole.

Receivers



The crossed Yagi antenna was custom-made for us by Innovantennas and provides about 7dBi of forward gain. The crossed design means we don't need to worry about Cryoegg's orientation.
The green plastic frame supporting the antenna is needed because we needed to support the antenna without having any metalwork close to it – anything conductive affects the antenna performance. We used a product called Quadro, which is a construction kit / climbing frame intended for children, and it proved very convenient in the field. The Quadro company supplied it for free in return for some photos of it in use in Greenland.

Another Radiocrafts module is used to receive and decode the data in real time.

It is also possible to receive the signal using British Antarctic Survey's ApRES autonomous glaciological radar, though this cannot presently be decoded in real time.

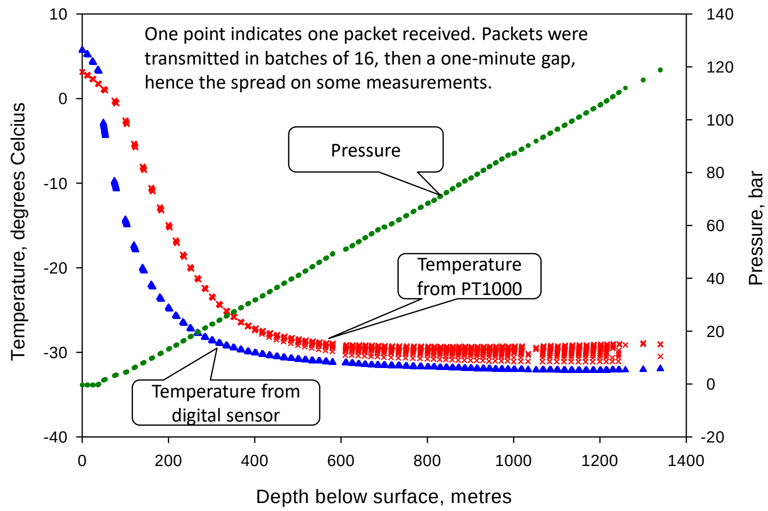
2019 field trials

- Deep borehole at EastGRIP (NE Greenland)
  - data received from 1340m down
  - mechanical failure (leaks) beyond 1340m
- Sermeq Kujalleq (Store Glacier) in W Greenland
  - Loss of unit in large moulin
- Rhône Glacier in Switzerland
  - data from 150m deep artificial moulin
  - demonstration of salt discharge gauging

Thanks to all our partners for access to their field sites and help with logistics.

Greenland fieldwork was in July; Swiss fieldwork in August.

Cryoegg in EastGRIP borehole

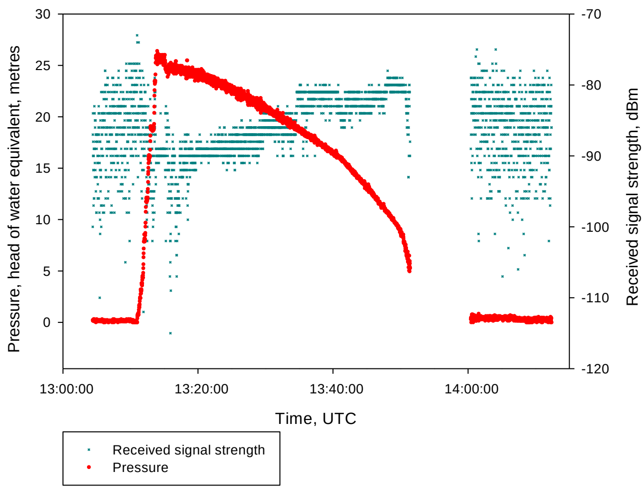


Here is the sensor data from EastGRIP. The difference between the two temperature traces reflects the location of the two different sensors: the PT1000 is inside the enclosure; the digital sensor is part of the pressure sensor which protrudes out into the surrounding liquid. Cryoegg was deployed "warm" so much of the temperature data shows it coming to equilibrium with the surrounding Estisol drill fluid.

Moulin drainage (Rhône)

15th August 2019

Moulin level dropped by 25m over ~50 minutes.
Cryoegg was about 150m below the surface.



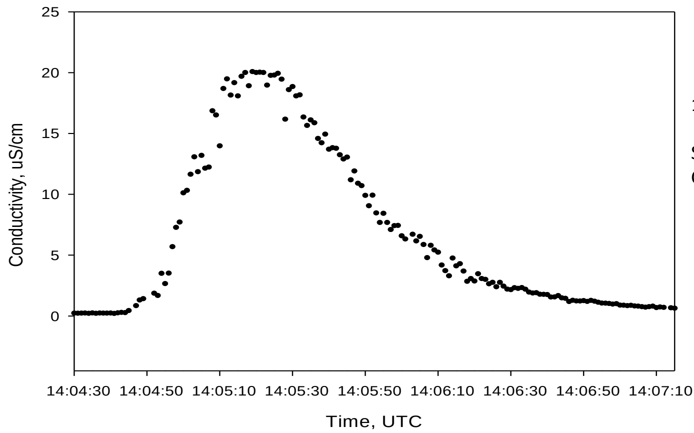
At the Rhône site we deployed Cryoegg on a rope into an artificial moulin, created the previous year by diverting a stream into a hot-water drill hole. The moulin had evolved plunge pools, and so we were not able to reach the glacier bed, which was ~200m below the surface at this site.

Over the course of around 40 minutes, we were able to observe a pressure reduction in the moulin, suggesting that backed-up water in the column of the moulin was draining away. The gap just before 1400 UTC was an interruption in data logging.

The dark green points show the variation in reported signal strength at the receiver. The variation in signal is much greater when Cryoegg is in the “atmospheric pressure” region of the moulin rather than when it is in >1 m of water. When Cryoegg is reporting pressure close to atmospheric pressure, it is being splashed by the water, or water is flowing smoothly past it. In this scenario the water flow will spin and agitate Cryoegg on the end of the rope, creating variation in signal level because of the antenna pattern. The turbulent flow of the water will also create ever-changing levels of attenuation . However, once Cryoegg is below the water surface, the viscosity of the water will reduce its spinning and agitation, and the attenuation due to the water will be largely constant.

One significant benefit of Cryoegg was being able to observe this in real time in the field – it makes for more efficient fieldwork if you get results immediately rather than having to process the data after your return.

Moulin salt tracing (Rhône)



15th August 2019

Salt trace recorded with Cryoegg 150m down a moulin.

Because Cryoegg carries an electrical conductivity sensor, it is possible to use it for salt dilution gauging (“salt tracing”). Here is one result from the Rhône glacier site, with Cryoegg in the same artificial moulin as the results on the previous page.

The very low conductivity of glacial meltwater means than even a small volume of table salt (sodium chloride) can be used as a tracer.

In this case, we were able to see the salt wave pass through the moulin, giving the capability for an in-situ discharge measurement within a moulin. This could be extended in future to study the coupling between surface and subglacial hydrology.

What next?

- Design enhancements:
  - Improve sealing against external pressure
  - Hook attachment point to be added
  - Improve transmitting antenna performance
  - Use Tadiran primary cells to give longer battery life

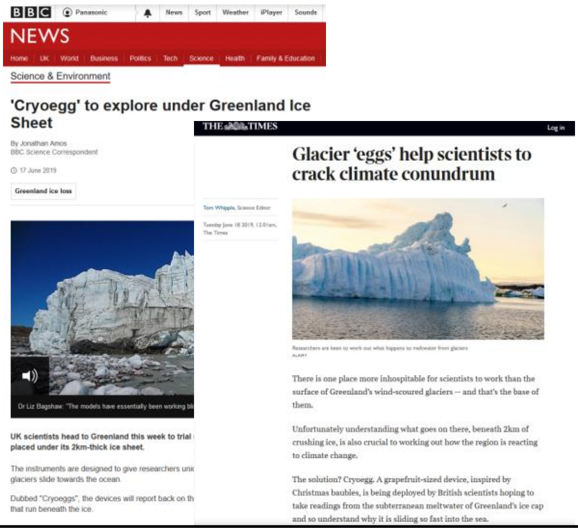
Summary and thanks

- **Cryoegg is a wireless sensor platform for both temperate and polar glaciers.**
- **The existing design is suitable for operation through up to 1.3km of ice.**
- **We will make design improvements in 2020 with the aim of operating through 2.5km of ice.**
- **A paper with the full results is in preparation.**

Thanks

- EastGRIP Steering Committee for generous support of all our tests
- EastGRIP drill team for good humour in the face of disaster
- Poul Christoffersen, Bryn Hubbard and all the RESPONDER team
- Mauro Werder and colleagues from ETH Zurich
- Support in kind from Quadro, Tadiran, Radiocrafts and Taoglas
- Funding from the UK EPSRC

Media coverage


BBC NEWS

Science & Environment

'Cryoegg' to explore under Greenland Ice Sheet

By Jonathan Amos
BBC Science Correspondent

17 June 2019

Greenland ice loss

Dr Liz Bagshaw: "The models have essentially been working bl

UK scientists head to Greenland this week to trial
placed under its 2km-thick ice sheet.

The instruments are designed to give researchers uni
glaciers slide towards the ocean.

Dubbed "Cryoeggs", the devices will report back on th
that run beneath the ice.

THE TIMES

Glacier 'eggs' help scientists to crack climate conundrum

Tom Whipple, Science Editor

Tuesday June 18 2019, 12.01am, The Times

Researchers are keen to work out what happens to meltwater from glaciers

There is one place more inhospitable for scientists to work than the surface of Greenland's wind-scoured glaciers — and that's the base of them.

Unfortunately understanding what goes on there, beneath 2km of crushing ice, is also crucial to working out how the region is reacting to climate change.

The solution? Cryoegg. A grapefruit-sized device, inspired by Christmas baubles, is being deployed by British scientists hoping to take readings from the subterranean meltwater of Greenland's ice cap and so understand why it is sliding so fast into the sea.

A video presentation on Cryoegg is available here: https://www.youtube.com/watch?v=PC96ZMofZLM

Press coverage:

- https://www.bbc.co.uk/news/science-environment-48638958
- https://www.thetimes.co.uk/article/glacier-eggs-help-scientists-to-crackclimate-conundrum-m3fdjhxqj