Dark Edge Expedition:

Robotics at the service of oceanography, an insight in the Arctic

Hugo SELLET
LOPS – IFREMER
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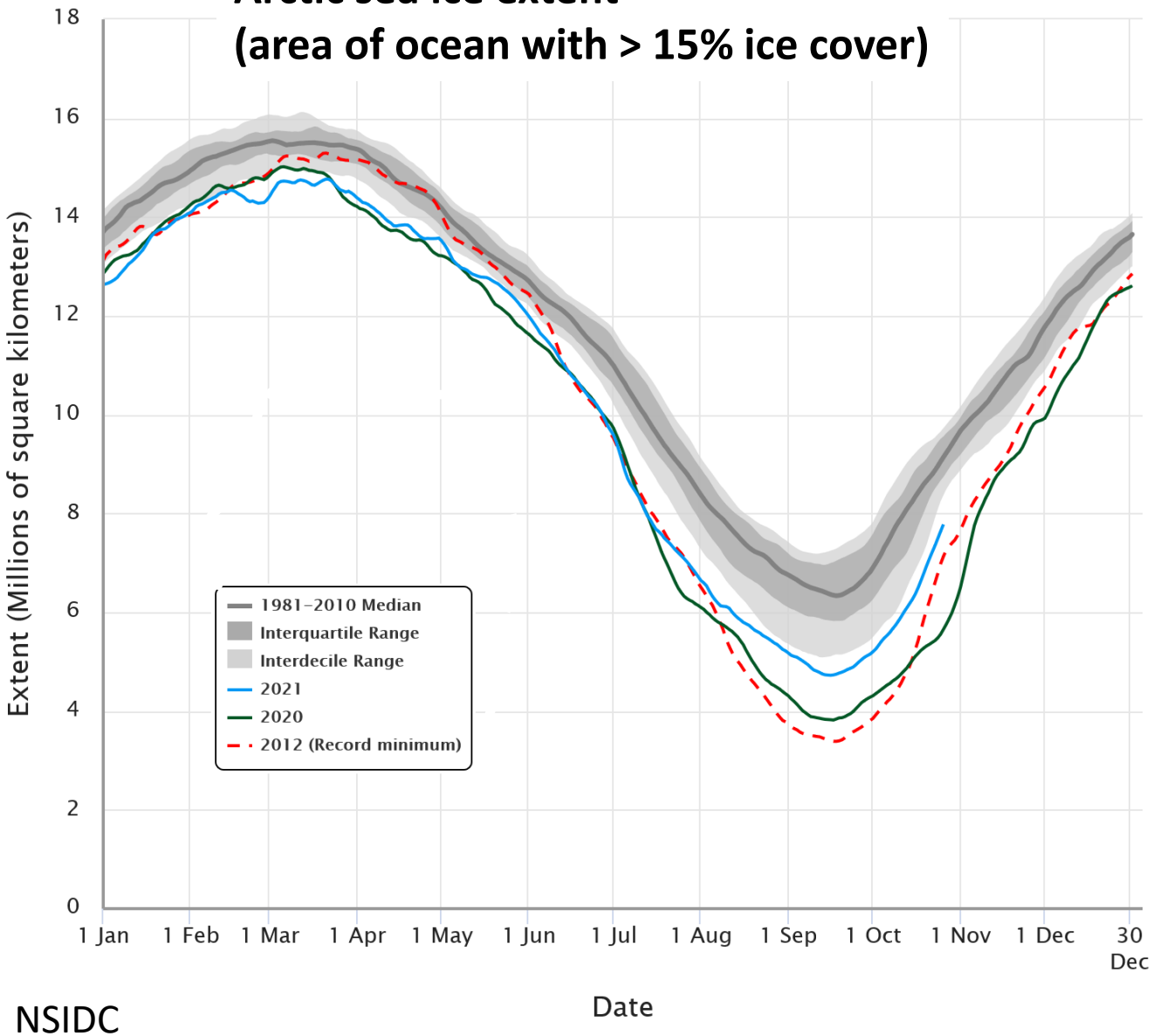
Where we were

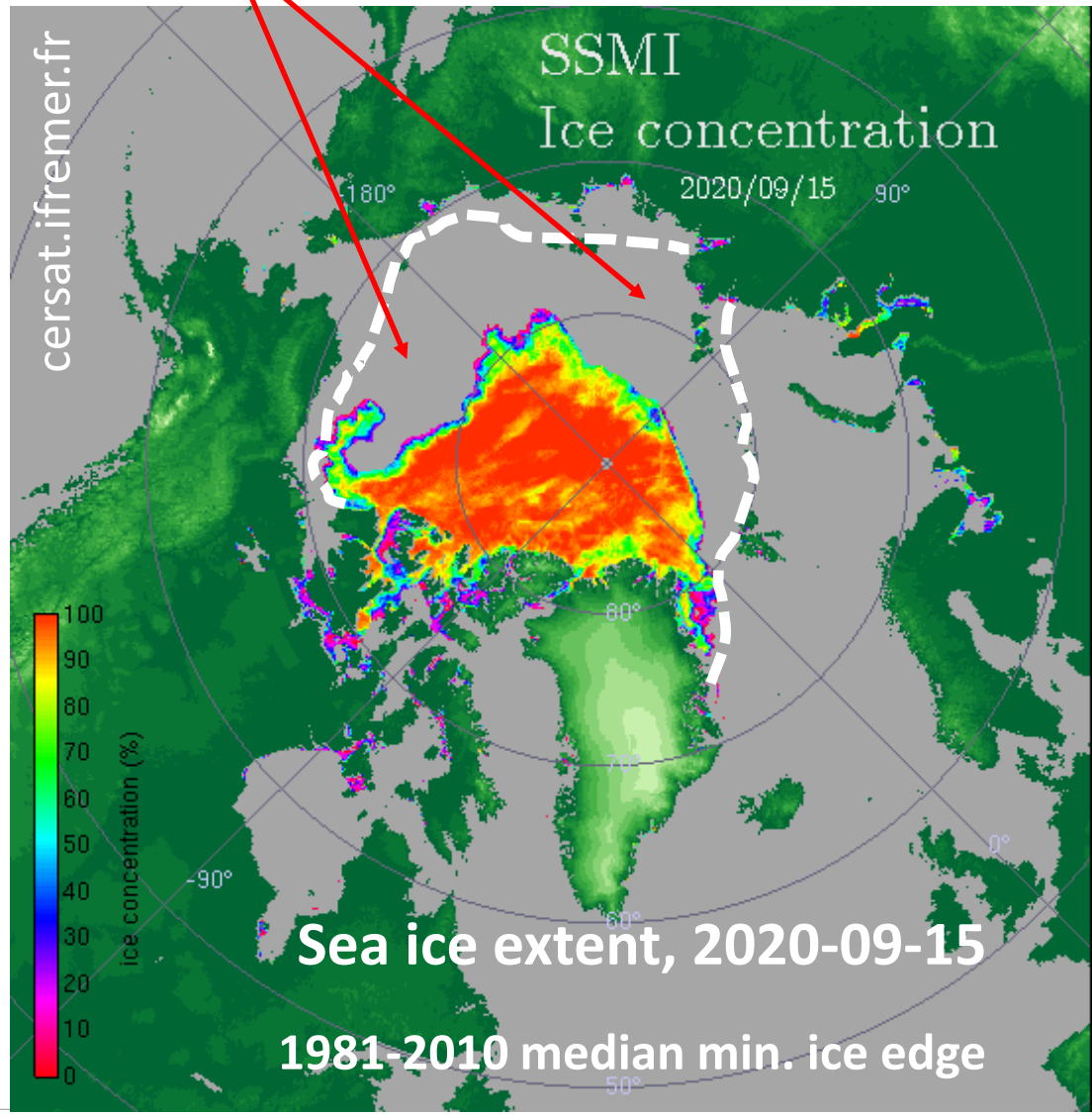
2020-2021 → The Arctic is changing

Arctic sea ice extent
(area of ocean with > 15% ice cover)



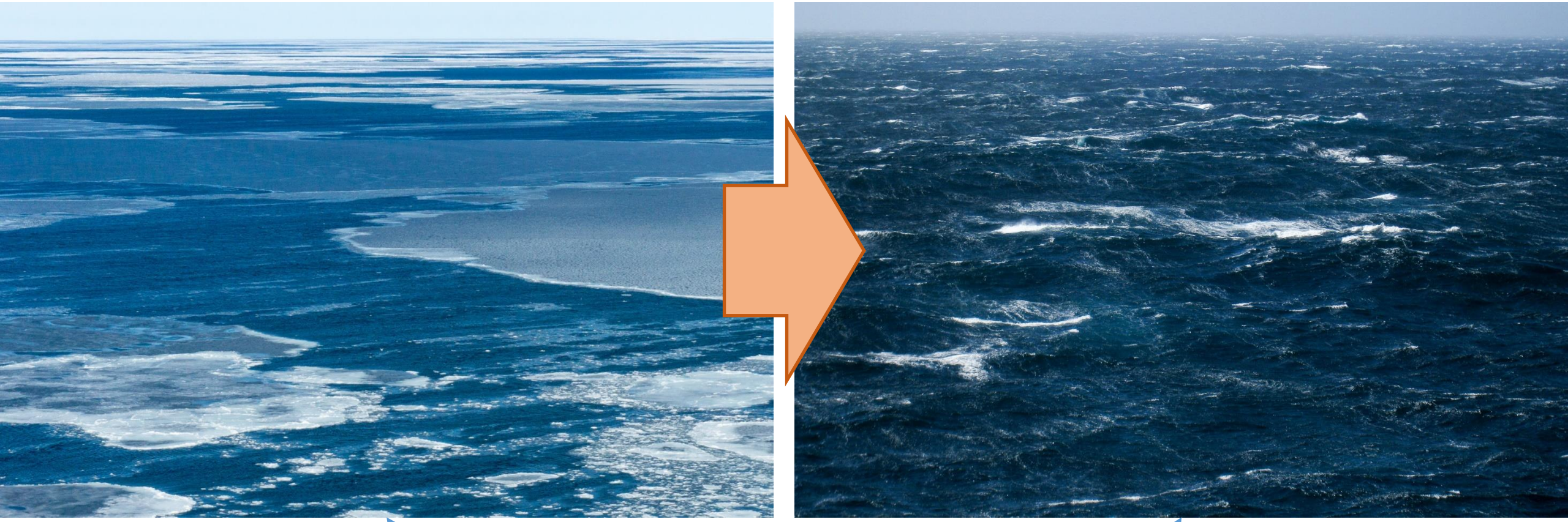
NSIDC

New “seasonal seas”



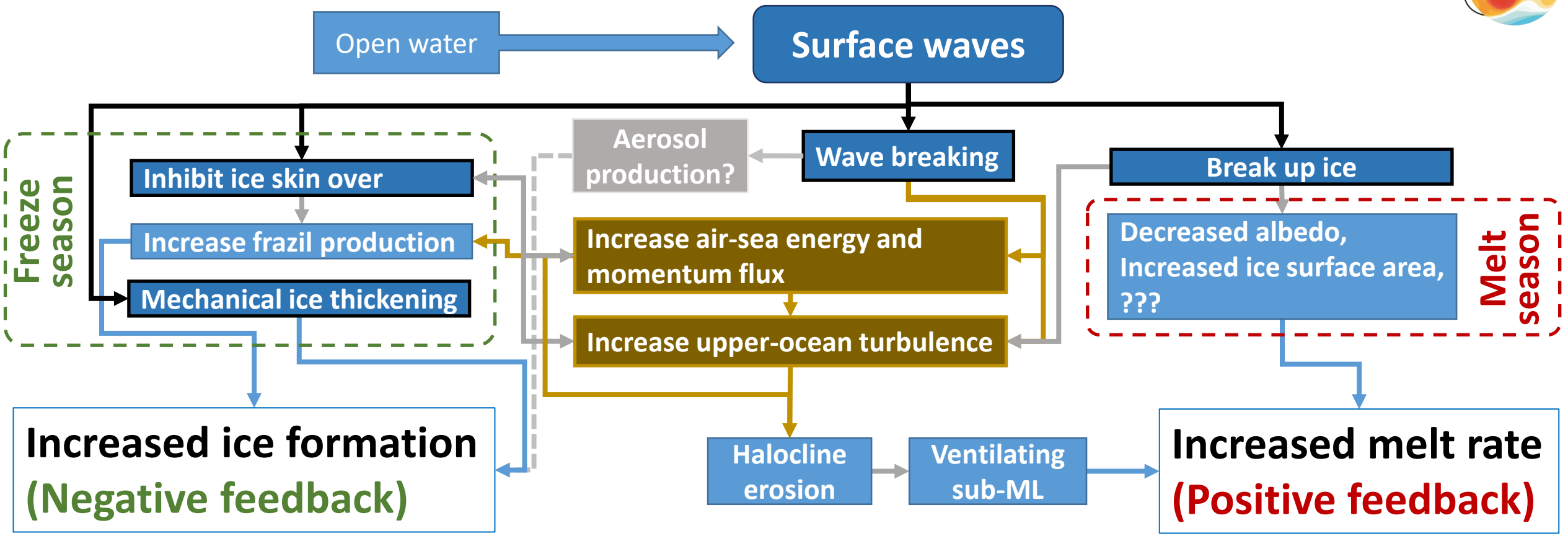
Transition to a seasonally wave-driven upper-ocean

- Less ice → more open water → larger fetch for wave development
  → More energetic wave climate → More vertical mixing



Same wind speed (17 m/s)… very different boundary layers

Emerging feedback mechanisms (first-order uncertainties)



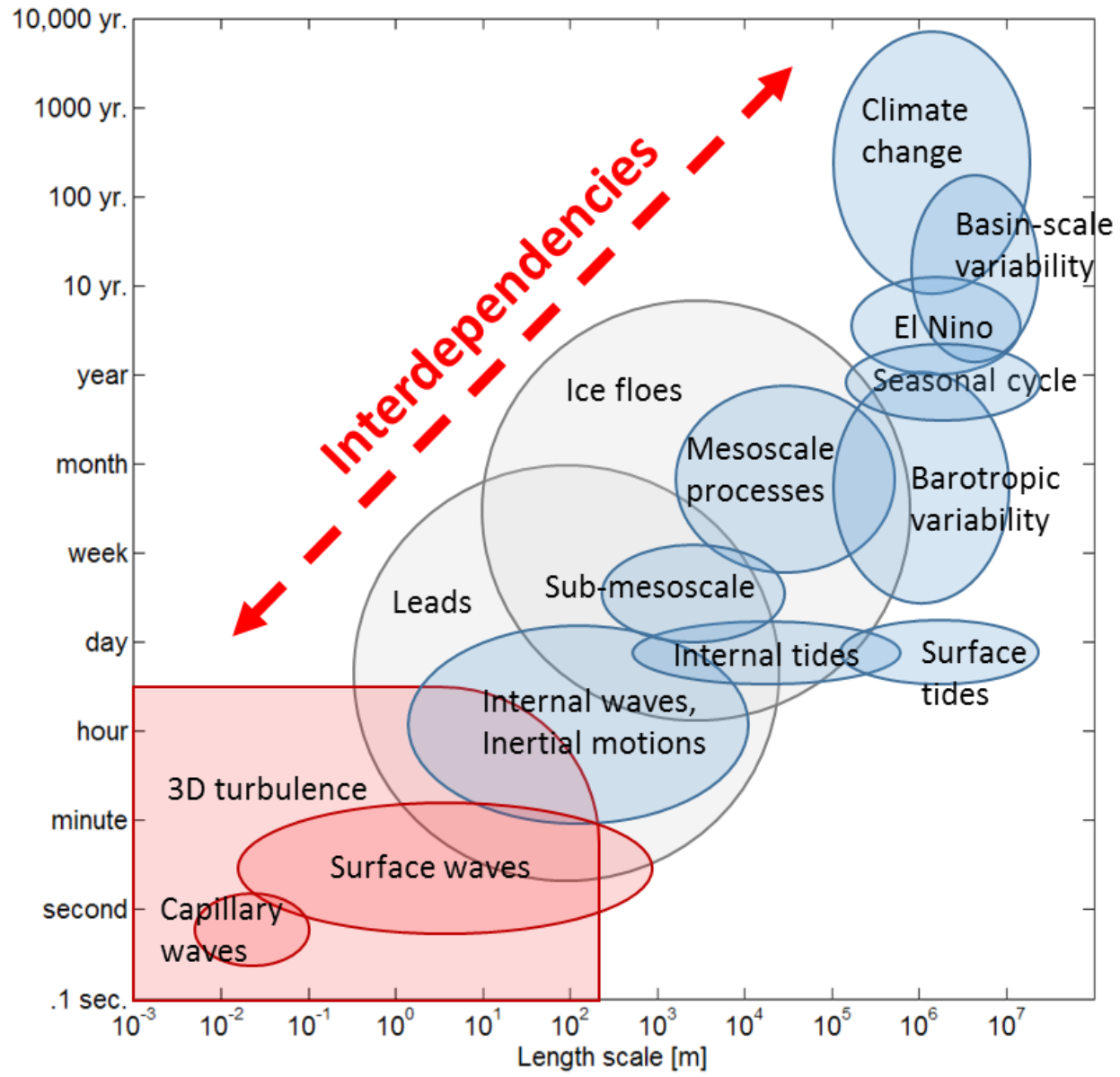
Need to **quantify these feedbacks** in order **to make accurate Arctic (and global) predictions.**

Why we are in the Arctic

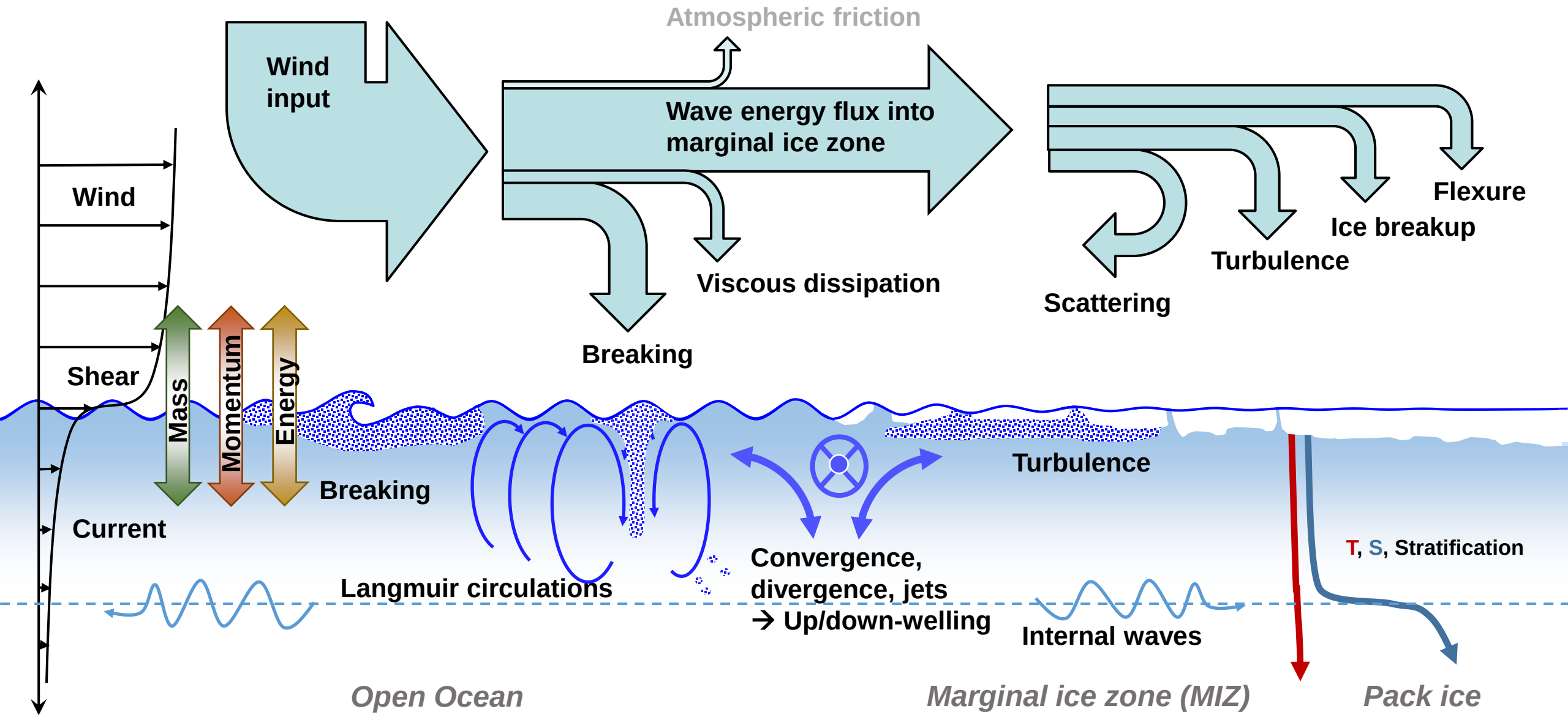
Large-scale processes are modulated by waves and turbulence at the smallest scales.

- Effects of waves and 3D turbulence must be properly parameterized in models.

- That requires **measurement schemes carefully designed to capture relevant scales**.



What we are measuring



Instruments used: Wave buoy

- Measures **wave spectra** and **wave height** with an inboard GNSS
- **20** were brought (**lost 4**)

Instruments used: Flamelite

- Gill anemometer
- SBG IMU with GNSS
- **2** were brought (**broke 1**)


SWL 10.0 TONNES MÉTRIQUES
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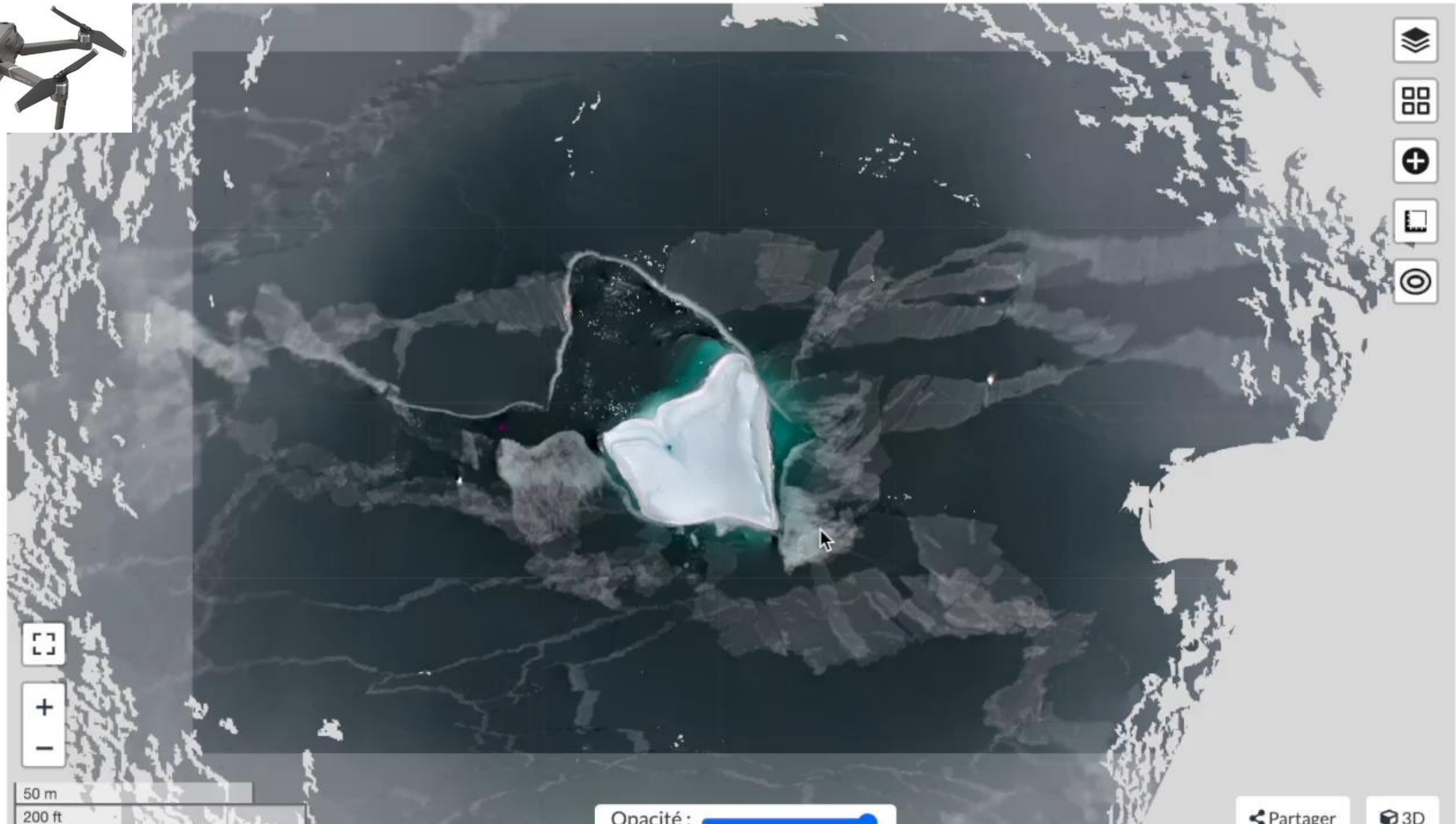
Instruments used: UAVs



Instruments used: Ice canoe

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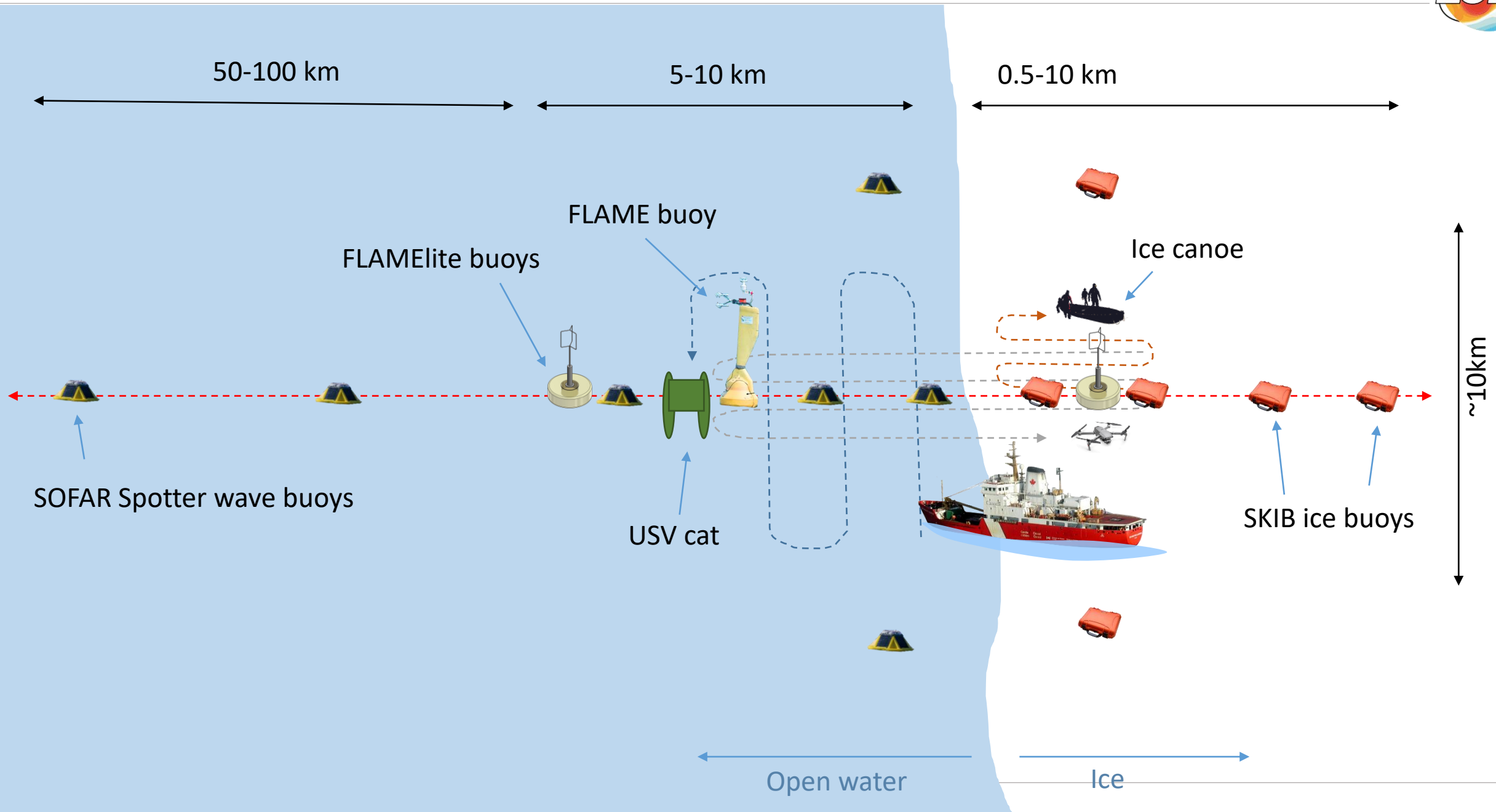
- Has an EM38 conductivimeter
- Several Ice buoys (SBG IMU with GNSS)

Recovering ice samples for biologists onboard

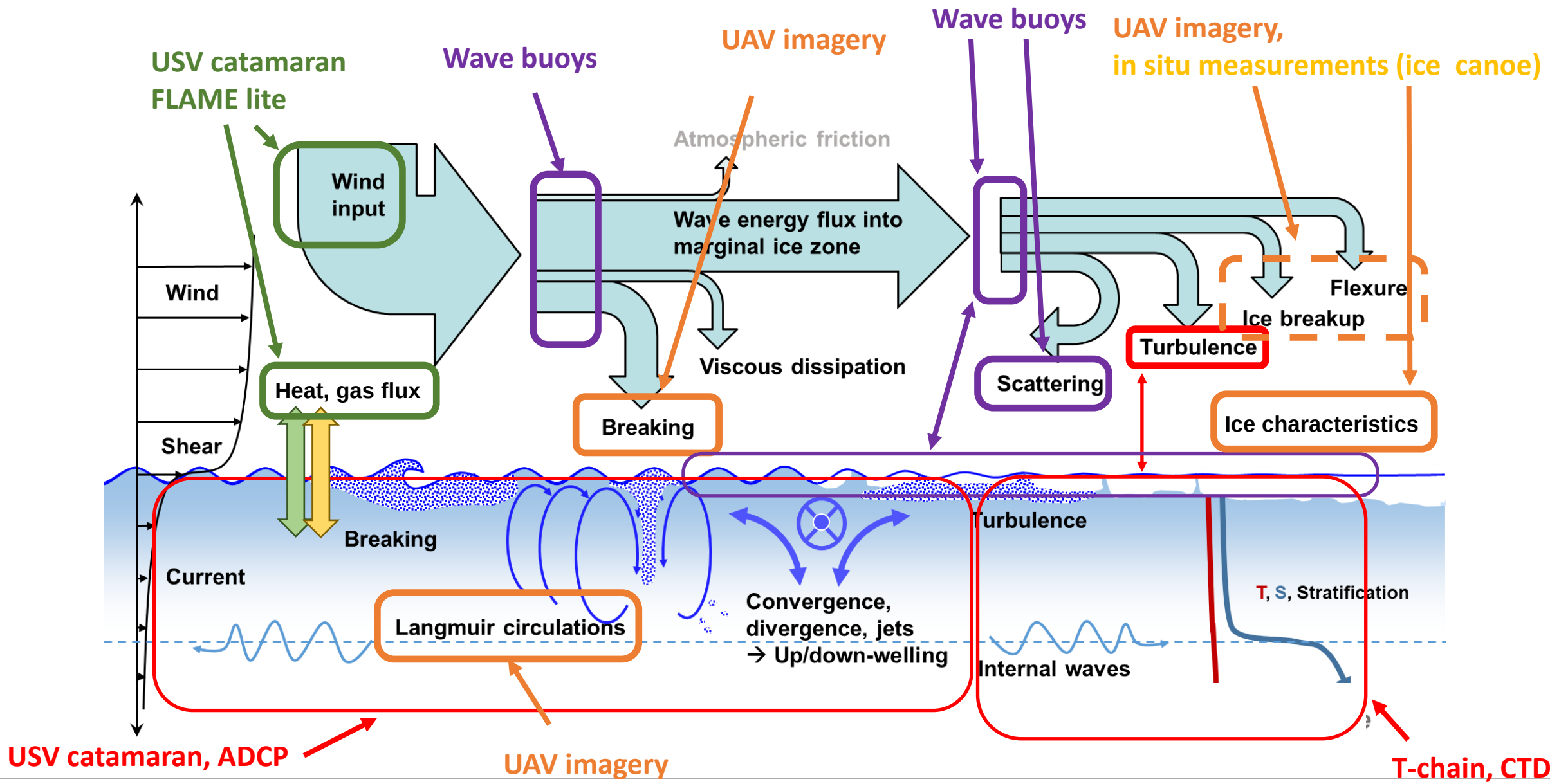
Future:
micro-AUV deployment

Instruments used: Catamaran

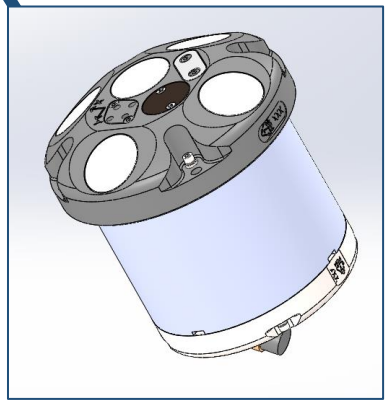
How we are measuring



What measures what



Why the catamaran ?



Specifications :

- **Autonomous**
- A very short build window
  → **2 months** to build
- No access to common machining technology
  → **TIG** welder, **3D printer**, power tools
- **6h** autonomy in the Arctic
- Holds **15kts** of wind and **2-3m** waves
- Does **NOT** need to be fast (**0,3 m/s** sampling speed)
- Obvious (reliable, low service, easy to use, cheap …)

Catamaran: Setup

Science:

- Irgason sonic anemometer / gas analyser
- Gill weather station
- 2x Nortek Signature 1000 ADCPs
- SBG Ellipse-D (Dual antenna RTK)
- Underwater and atmospheric thermometers

Dedicated for **lower atmosphere** and **upper ocean** measurements

Power:

- 2x Lifos 12V 105Ah Li-ion battery

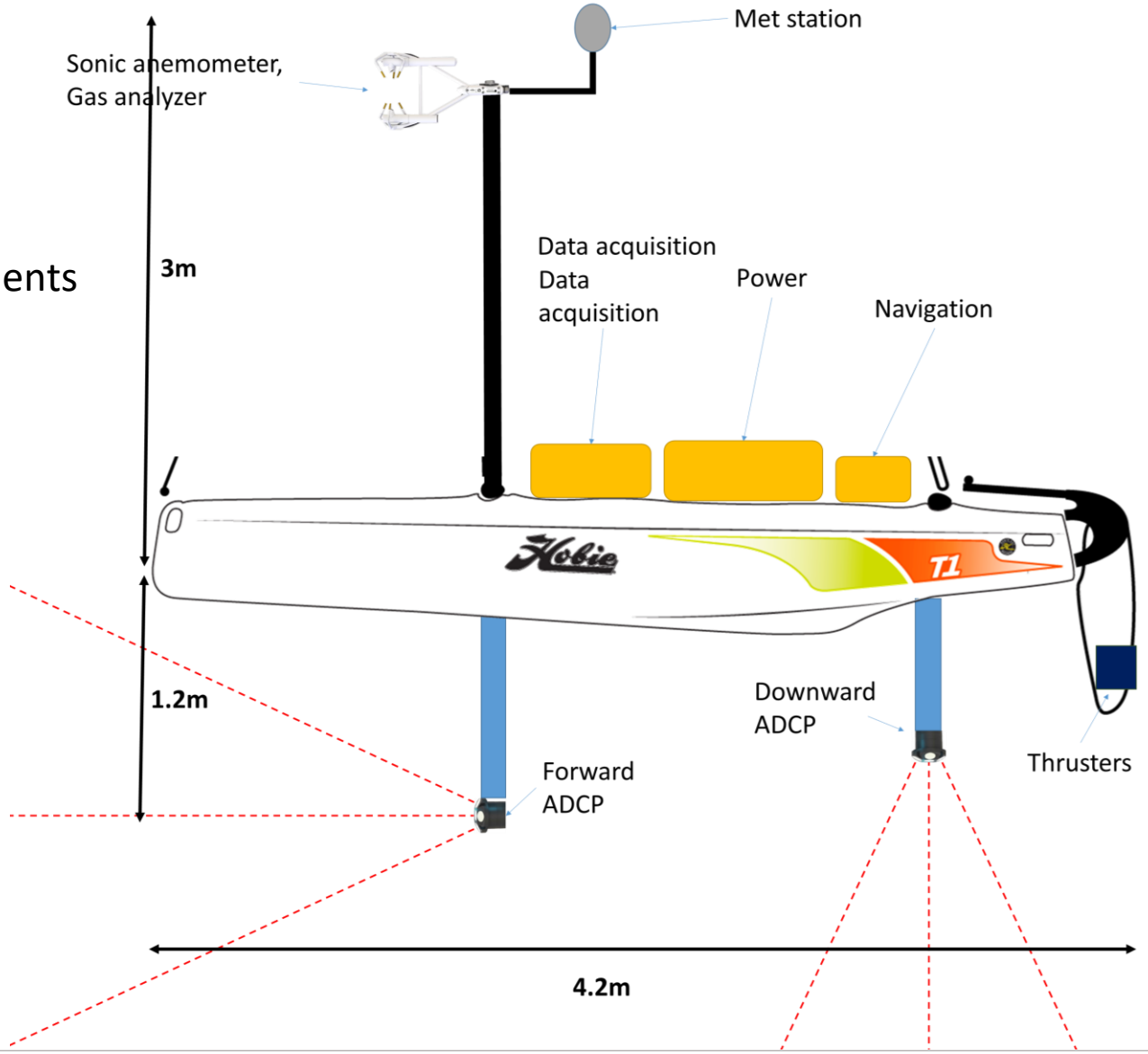
Mechanical:

- Heavy steel keels (to not capsize)
- **Differential propulsion only** (fixed rudders)

Navigation:

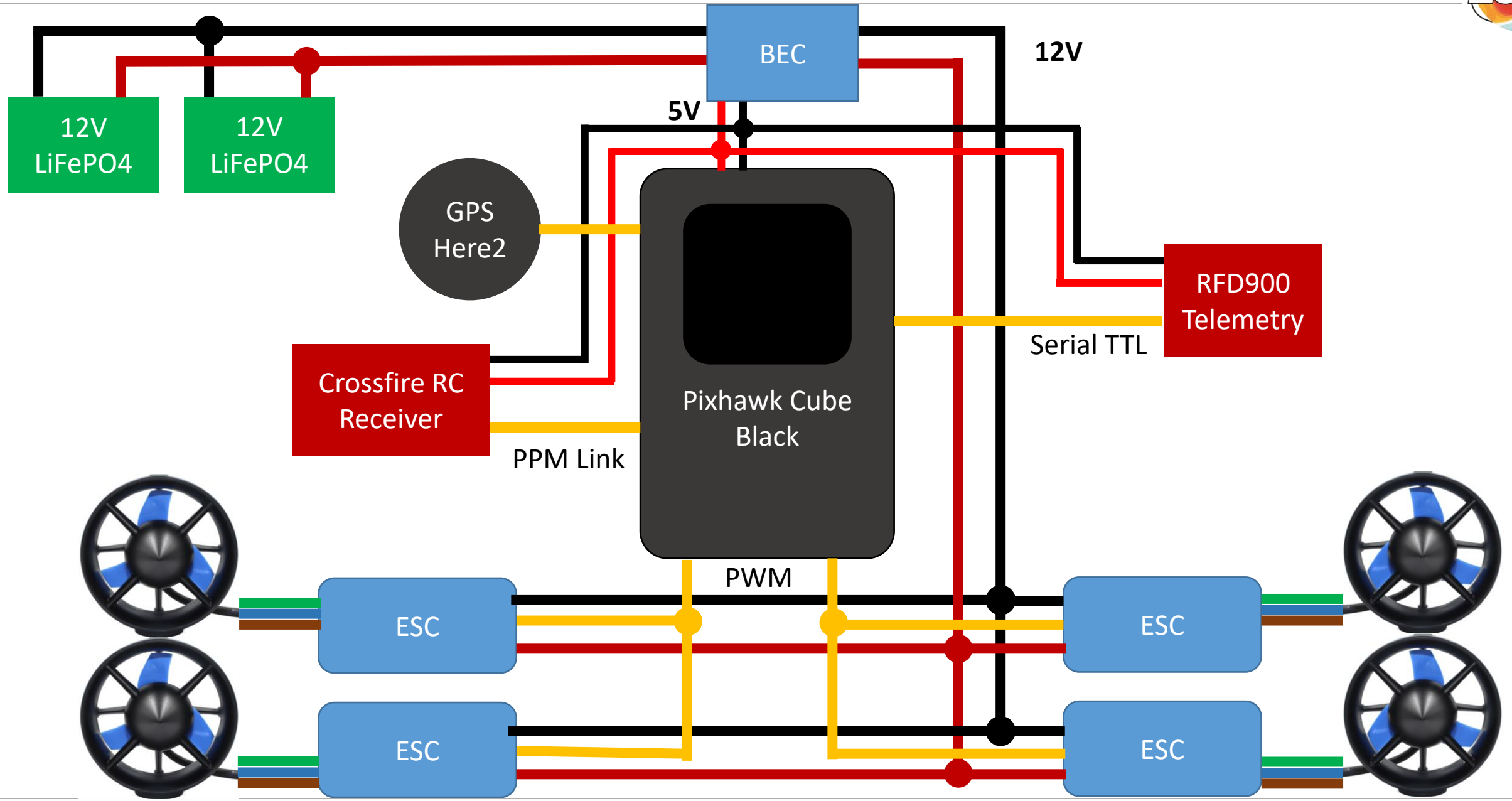
- 4x Blue Robotics T200 thrusters
- Pixhawk Cube black
- RFD900 telemetry
- TBS crossfire RC receiver

Off the shelf, available, **plug & play** components:



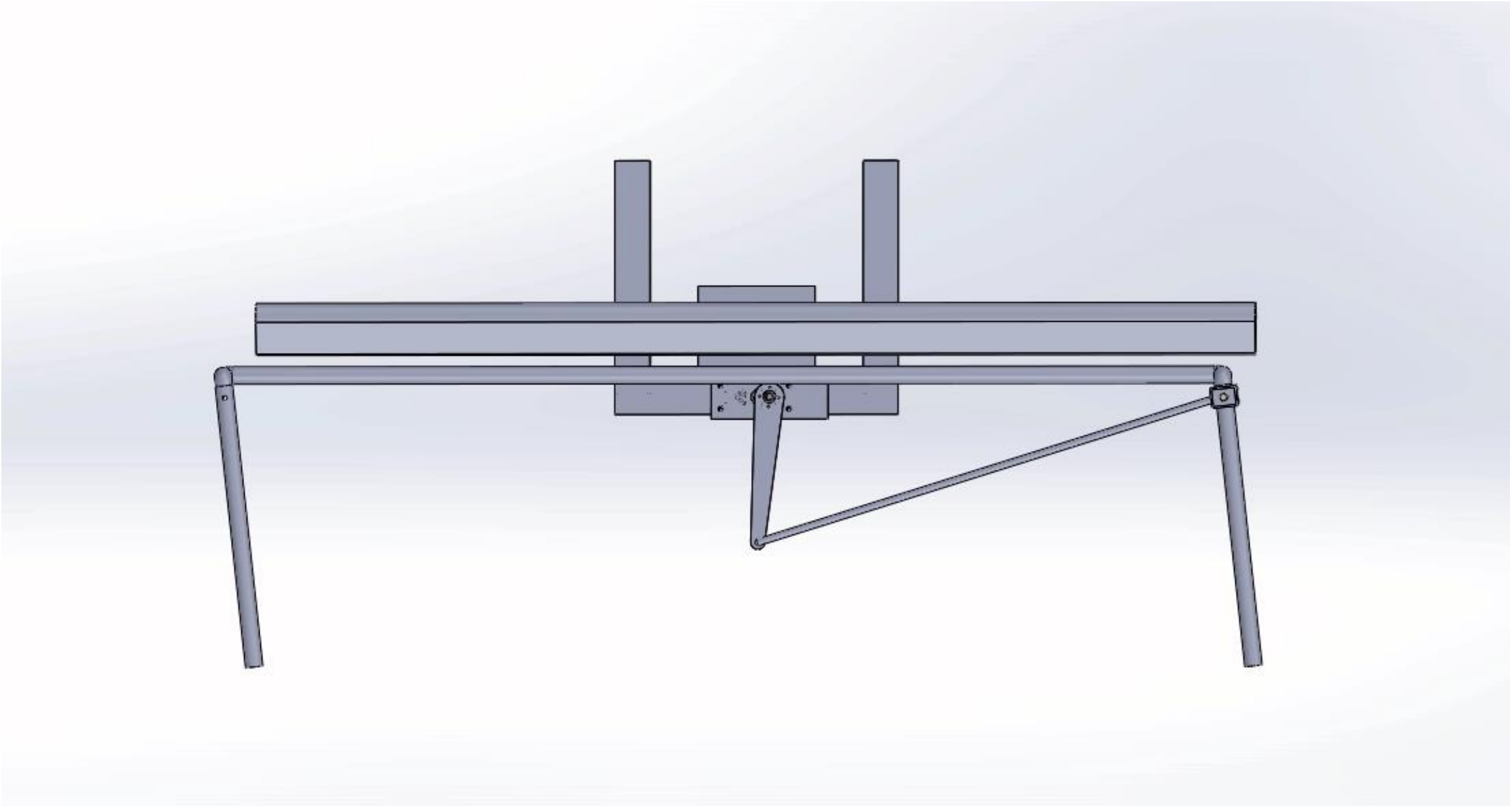
Shipped container

Catamaran: Navigation




PWM input:
1900
1100

Catamaran: Controlling the rudders with a servo

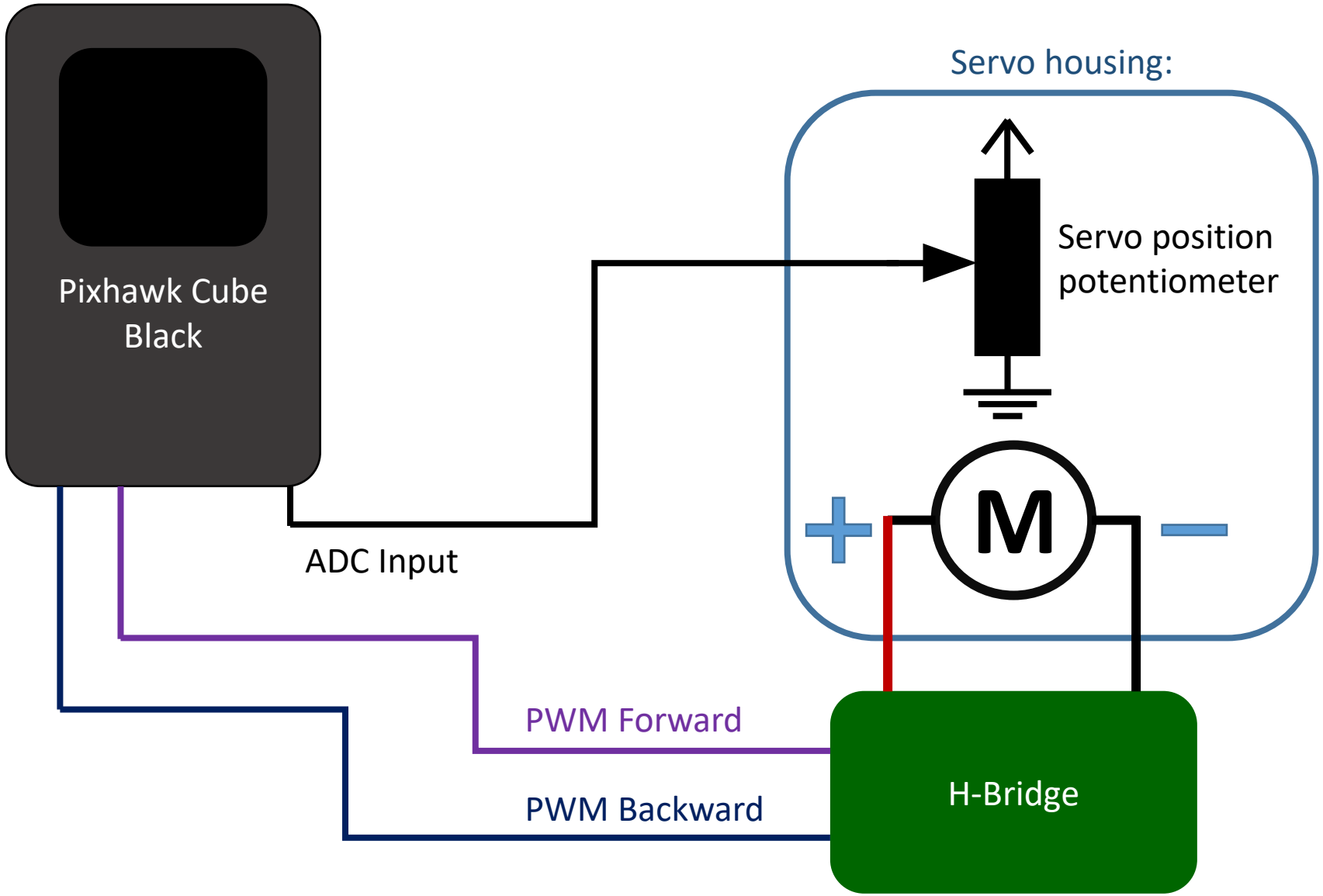


Servomotor: SSPS-105

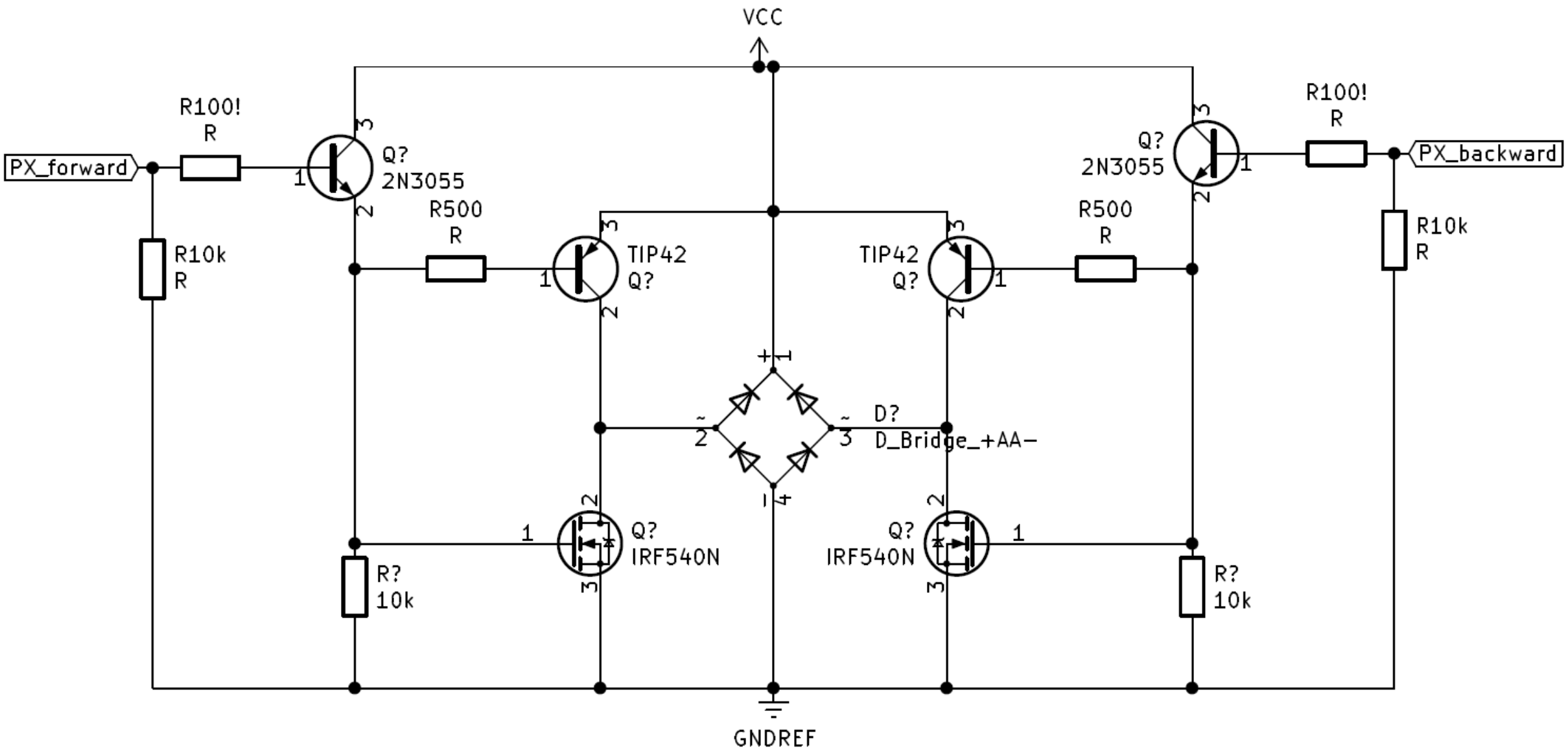
- Torque: **380 kg×cm**
- PWM input (**plug & play**)
- **12V**
- **Watertight**

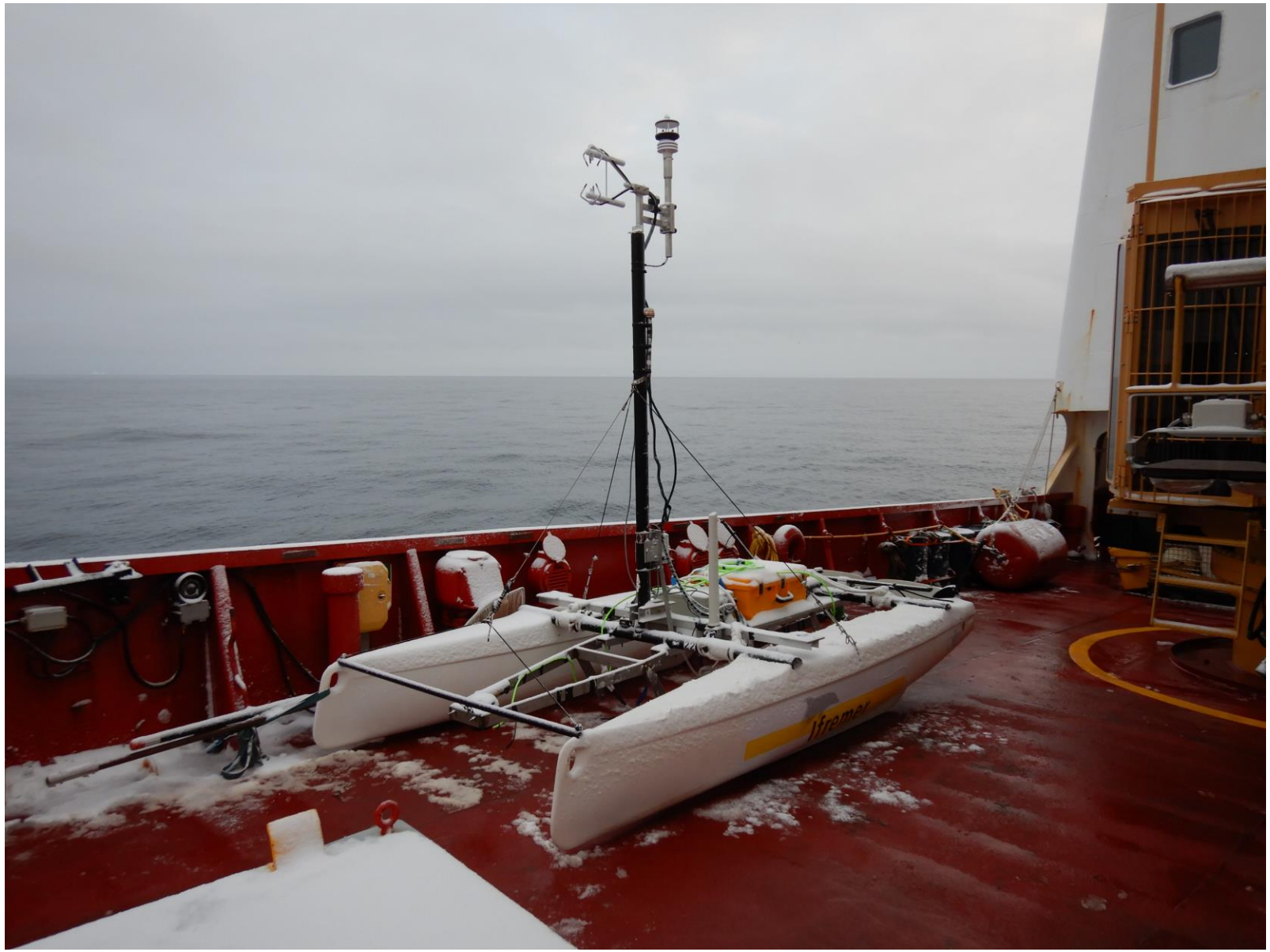
Shipped with the container and was **NOT tested**

Servomotor: A possible onboard fix



Servomotor: H-bridge

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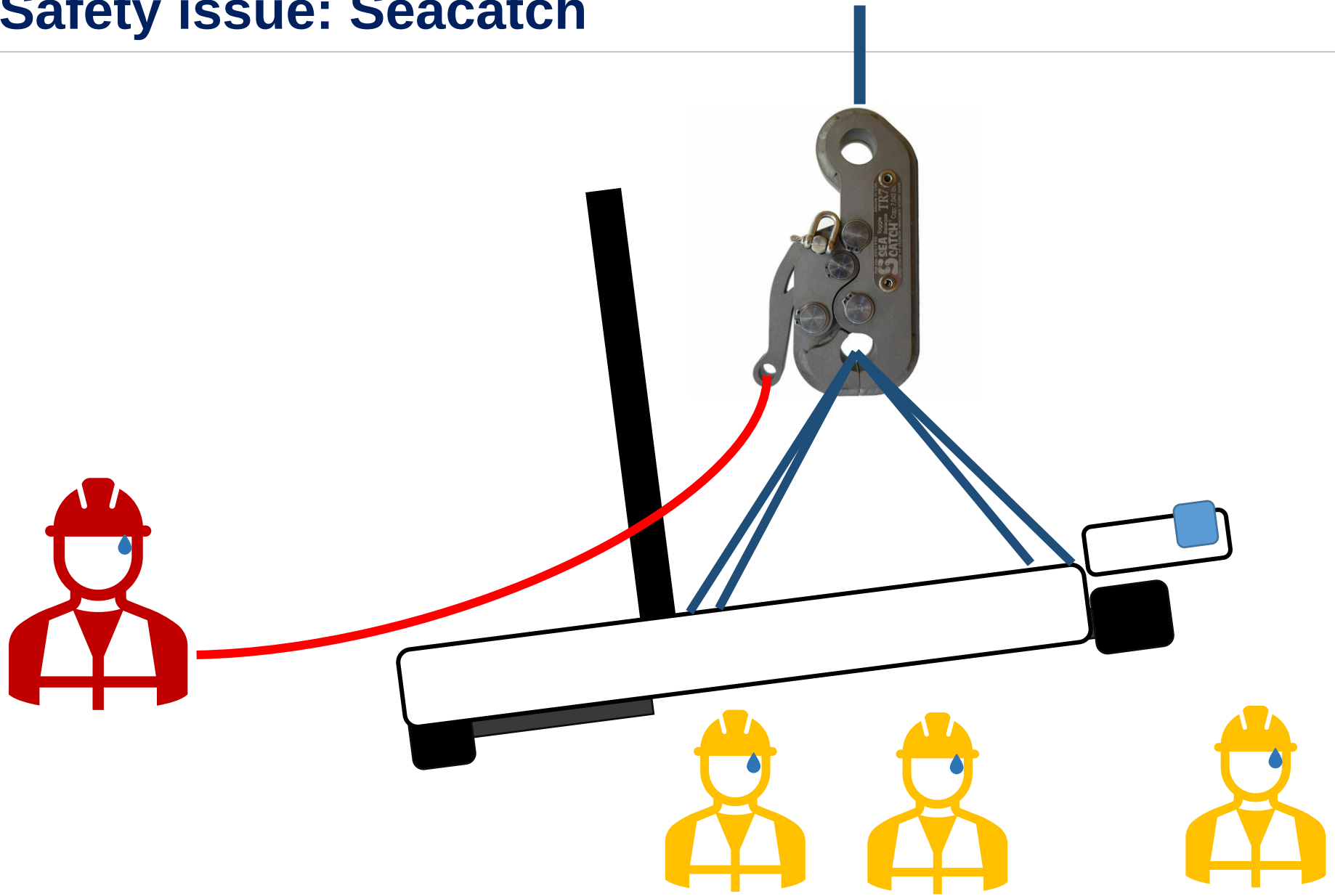
Safety issue: Seacatch



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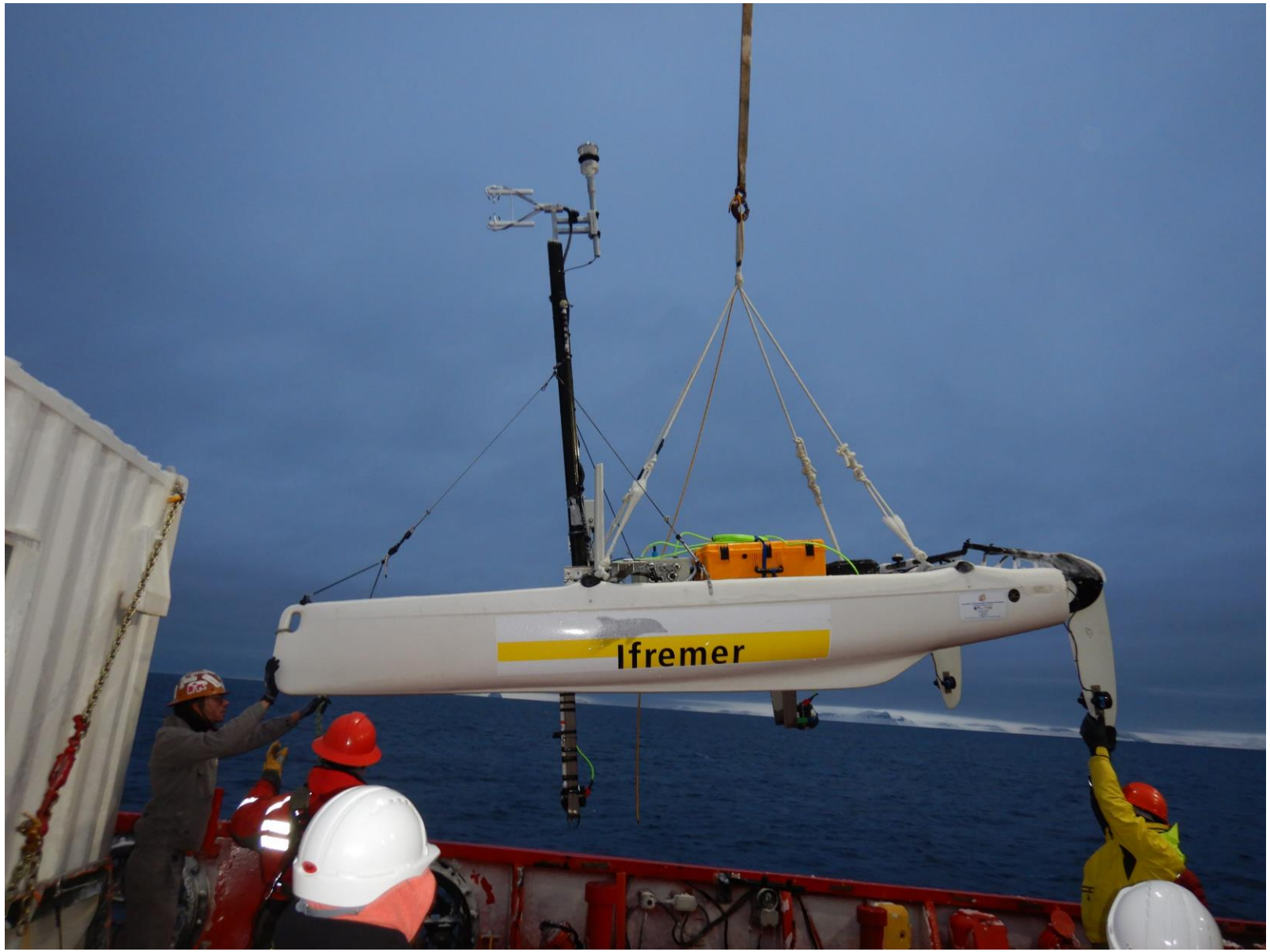


Catamaran: Controlability upgrade

- **Change weight distribution**

→ Add mass at the front

- 2x 1000W electric motor
- **More efficient** than previous T200
- DC brushless motor

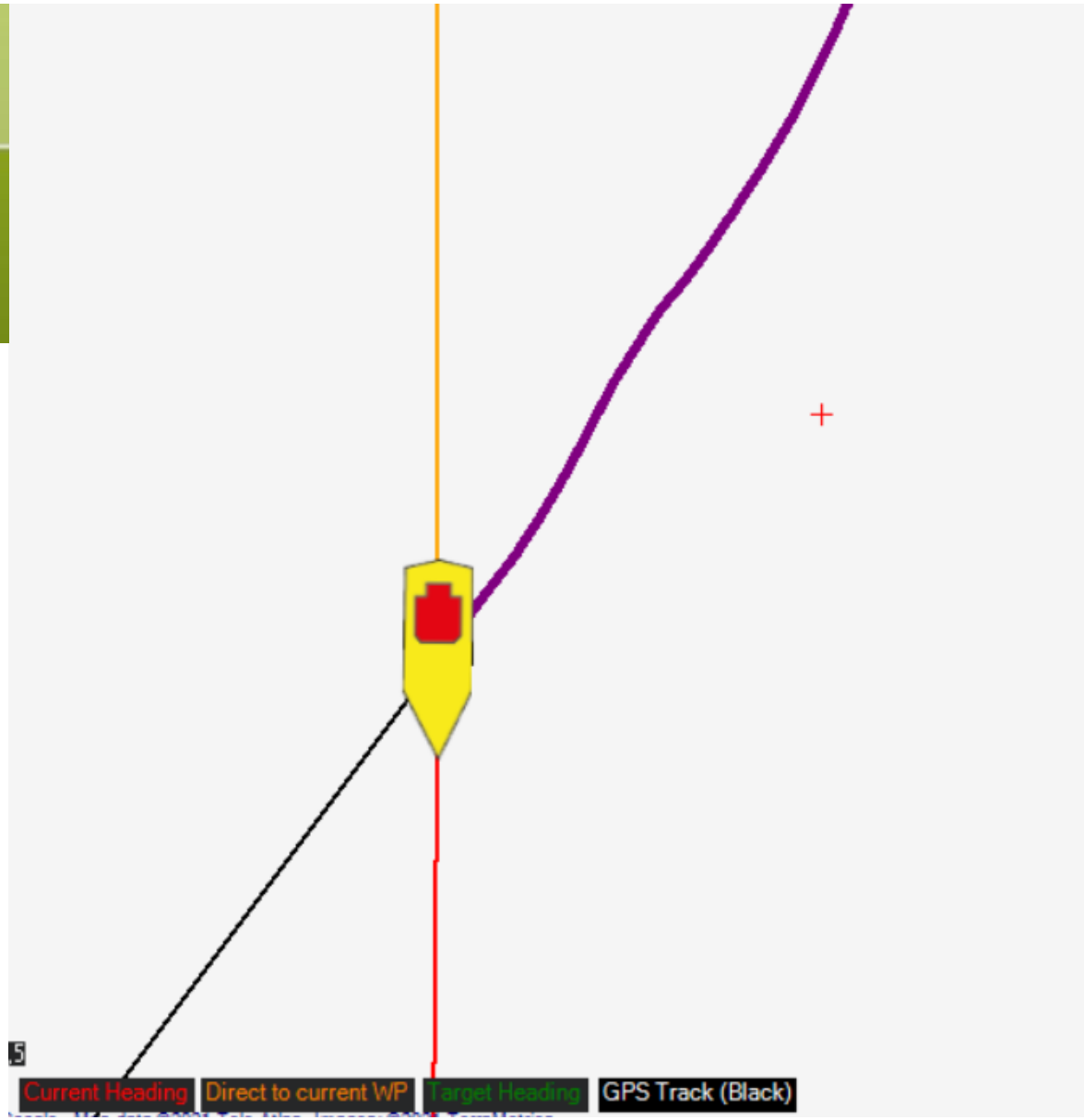
  → Can be controlled with **regular ESCs**

Autonomous navigation issue: Magnetometer

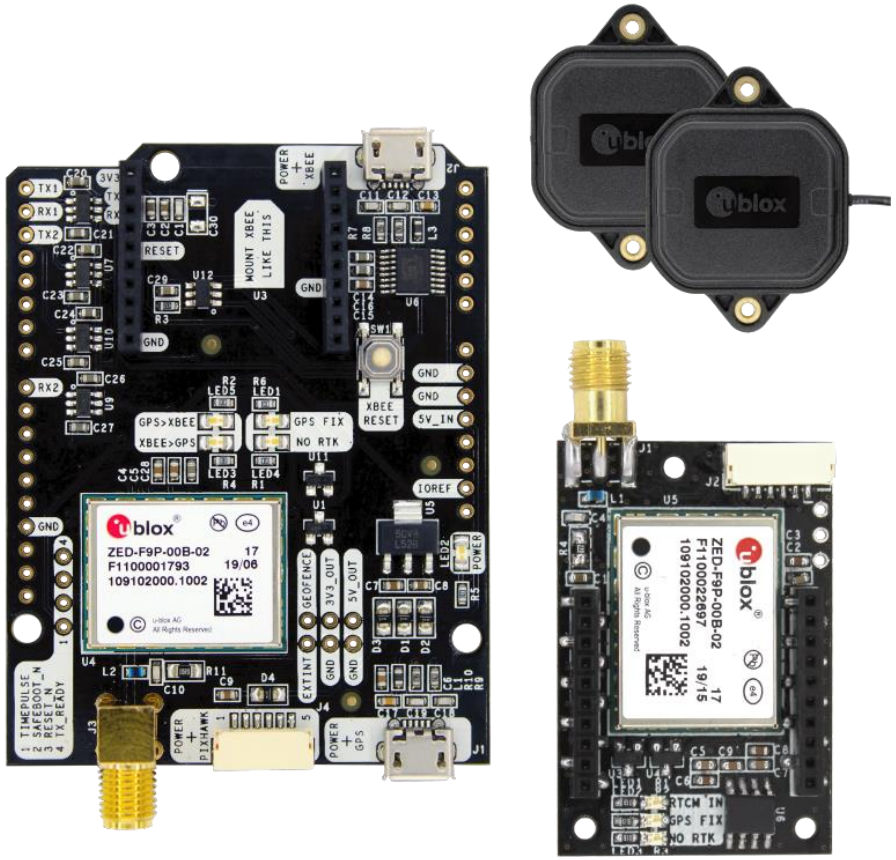
Pixhawk have a **world map** to take into account of magnetic declination that is apparently **not sufficient**

We chose **not to take the risk to re-calibrate it** in the water
→ Catamaran will **only be RC** controlled

Magnetometers are hard to re-calibrate
on a **steel ship** in the Arctic
→ Replace them with **RTK heading**



Fixing magnetometer issue



Pixhawk not really suited for using external sensors → Use of an onboard computer (eg. **raspberry pi**)

Tedious recovery

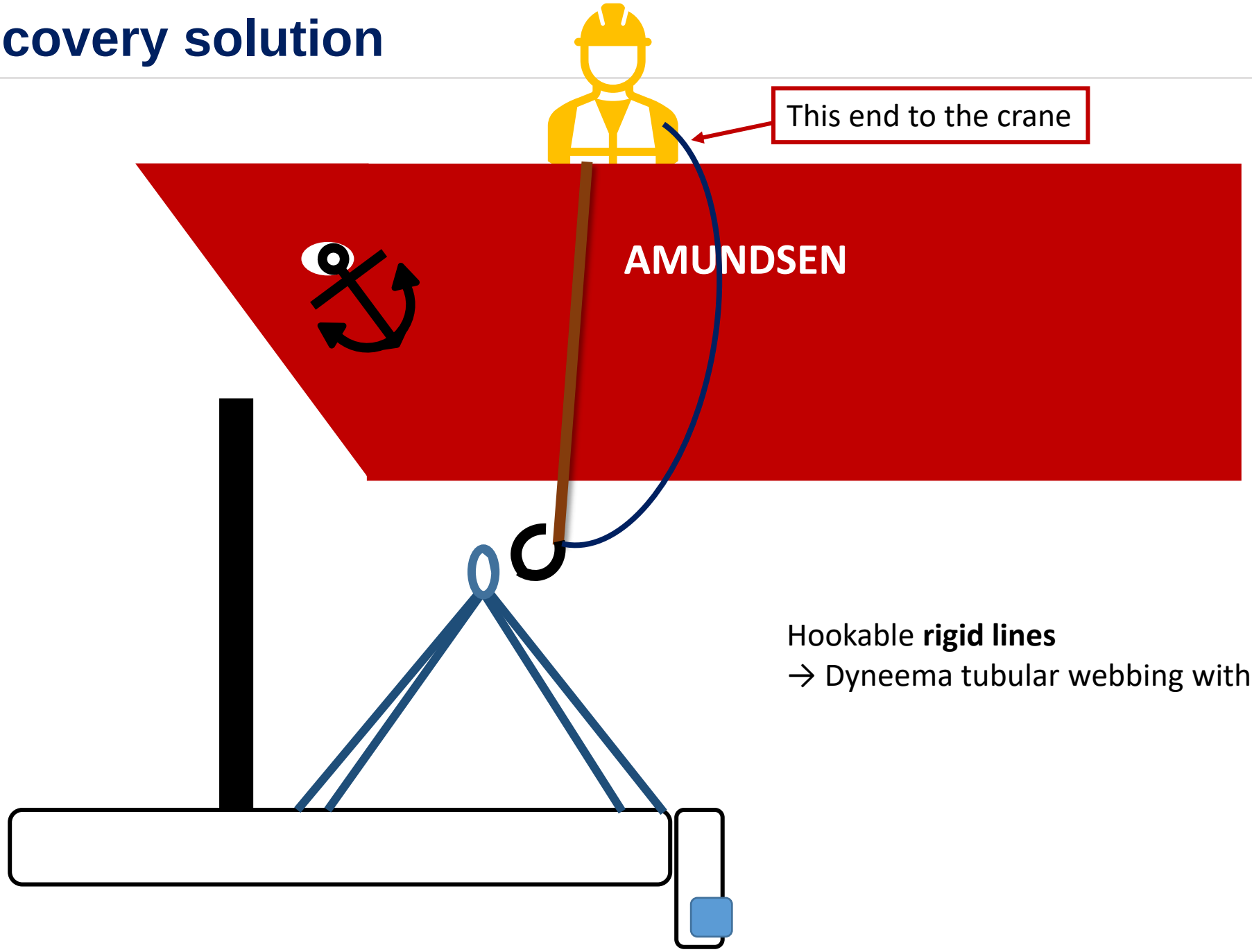
A zodiac has to be put in the water for recovery →
Key limiting factor in the number of deployments

Flexible lines

The cat is significantly heavier due to **ice coverage** and thus lower on the water.

Tedious recovery

Easier recovery solution



Hookable **rigid lines**
→ Dyneema tubular webbing with fiberglass strips

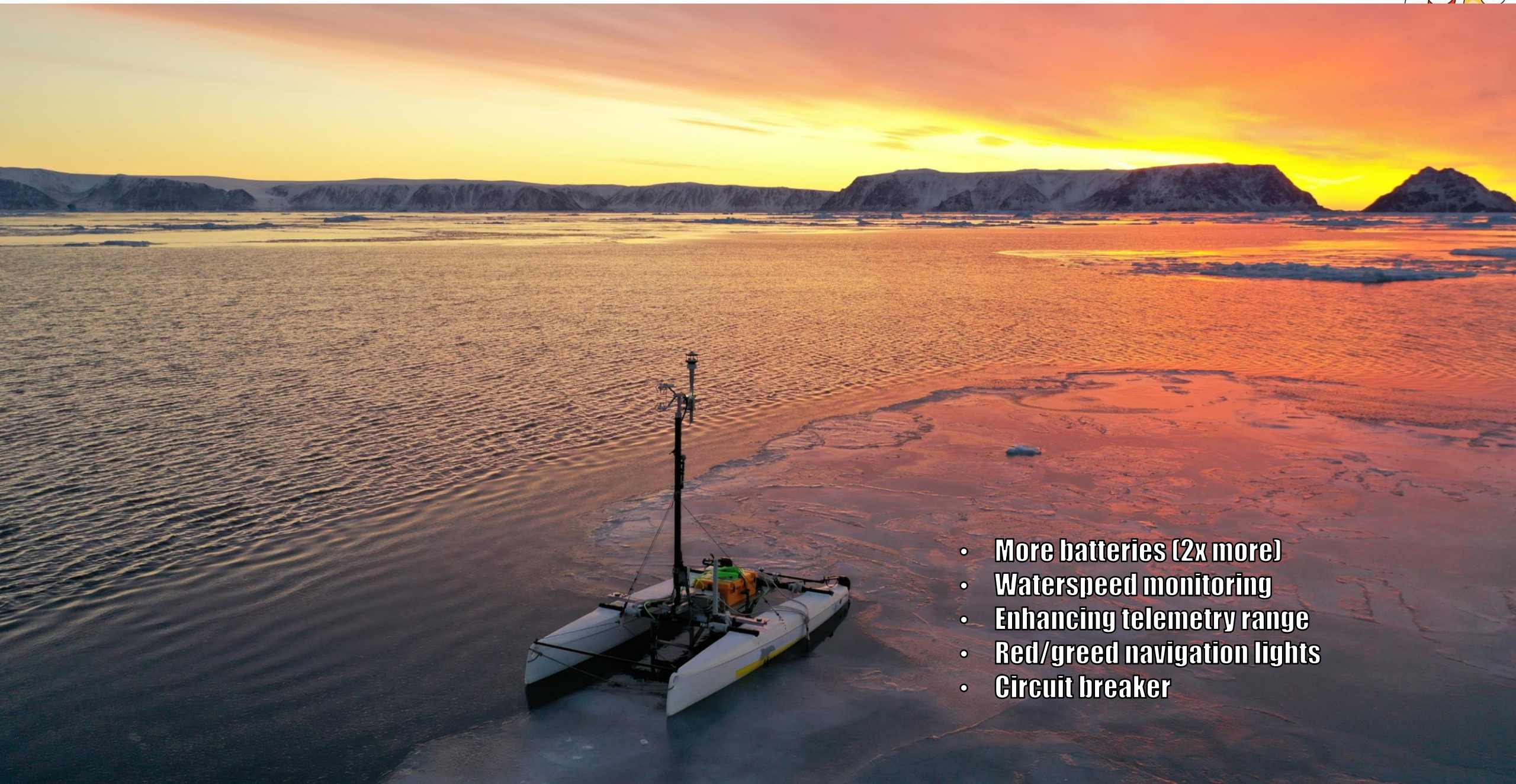
Jones sound 2021-10-20 1430Z

Jones sound 2021-10-20 1458Z – Langmuir turbulence?

Jones Sound 2021-10-20 1521Z – Langmuir turbulence


Jones Sound 2021-10-20 2056Z – No ice

Catamaran: miscellaneous improvements



- More batteries (2x more)
- Waterspeed monitoring
- Enhancing telemetry range
- Red/greed navigation lights
- Circuit breaker

Catamaran: Conclusion

- The mechanical base is **sane**.
- The autonomous part needs to be **reworked**, but **no big challenge** ahead.
- The catamaran did trigger the curiosity and interest of other scientific teams.

A very promising platform, that delivered 80% of the wanted data.

- Adding a **camera** for **ice edge following**, with ice floe **collision avoidance** algorithm

Future Arctic expedition: REFUGE-ARCTIC

- **Two months** in **2023** onboard of the icebreaker CCGS **Amundsen** in the **Lincoln Sea**
- Possible ice camp in **Alert**

Future: Micro-AUVs

Future: UAVs

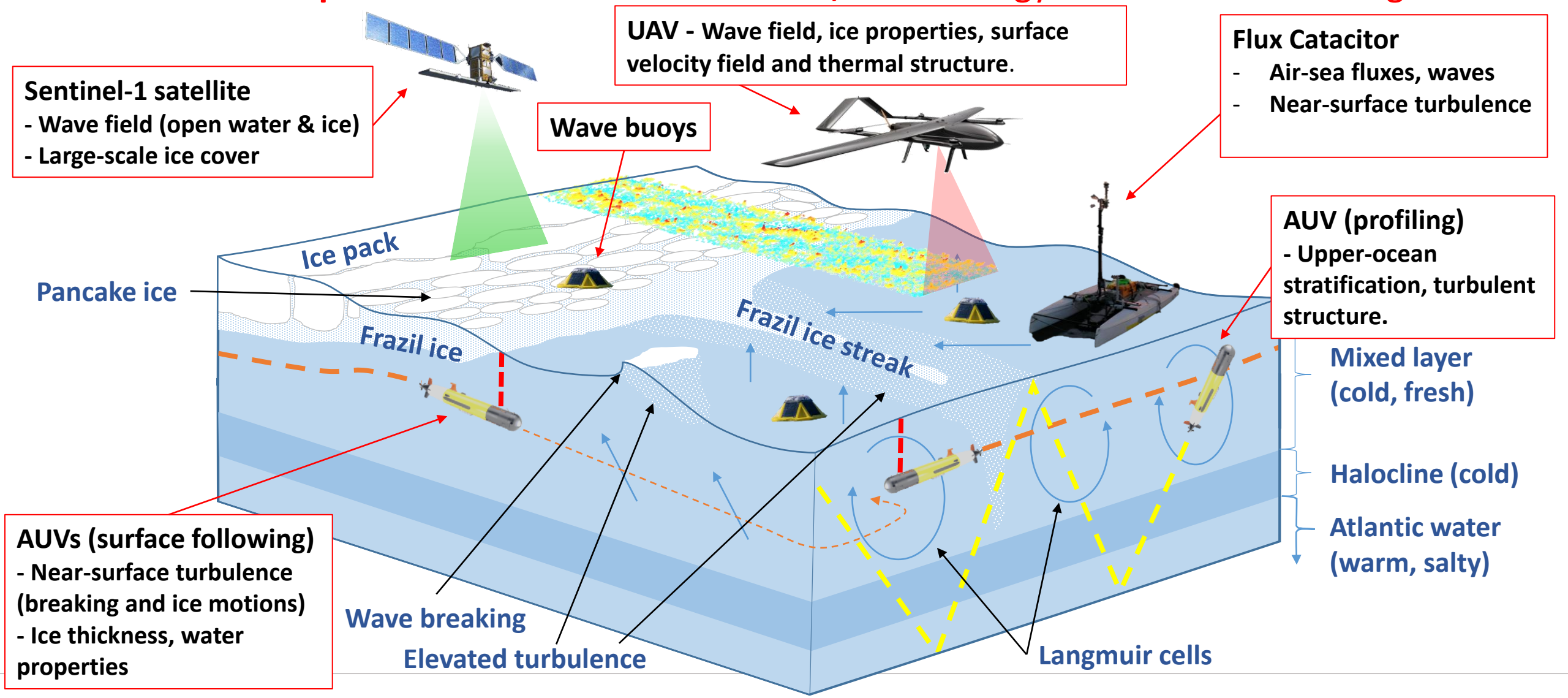
Hyperspectral cameras:

One will probably be equipped with a **LiDAR**

WAAXT measurement approach

→ **Capture spatial and temporal intermittency**

→ **Measure small processes and their bulk effects;** close energy and momentum budgets.

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NICOT Paul
PEDEN Olivier
PELLETIER Eloise
SUTHERLAND Peter

Thank you, for your attention

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