# First results from new automated instruments measuring SWE, position and more on the Greenland Ice Sheet

PROMICE
Programme for Monitoring of the Greenland Ice Sheet

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INTAROS

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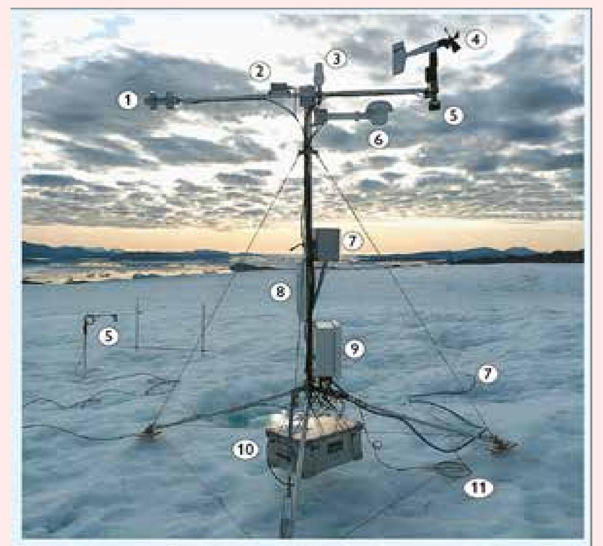
## Presenting a suite of instrument developments:

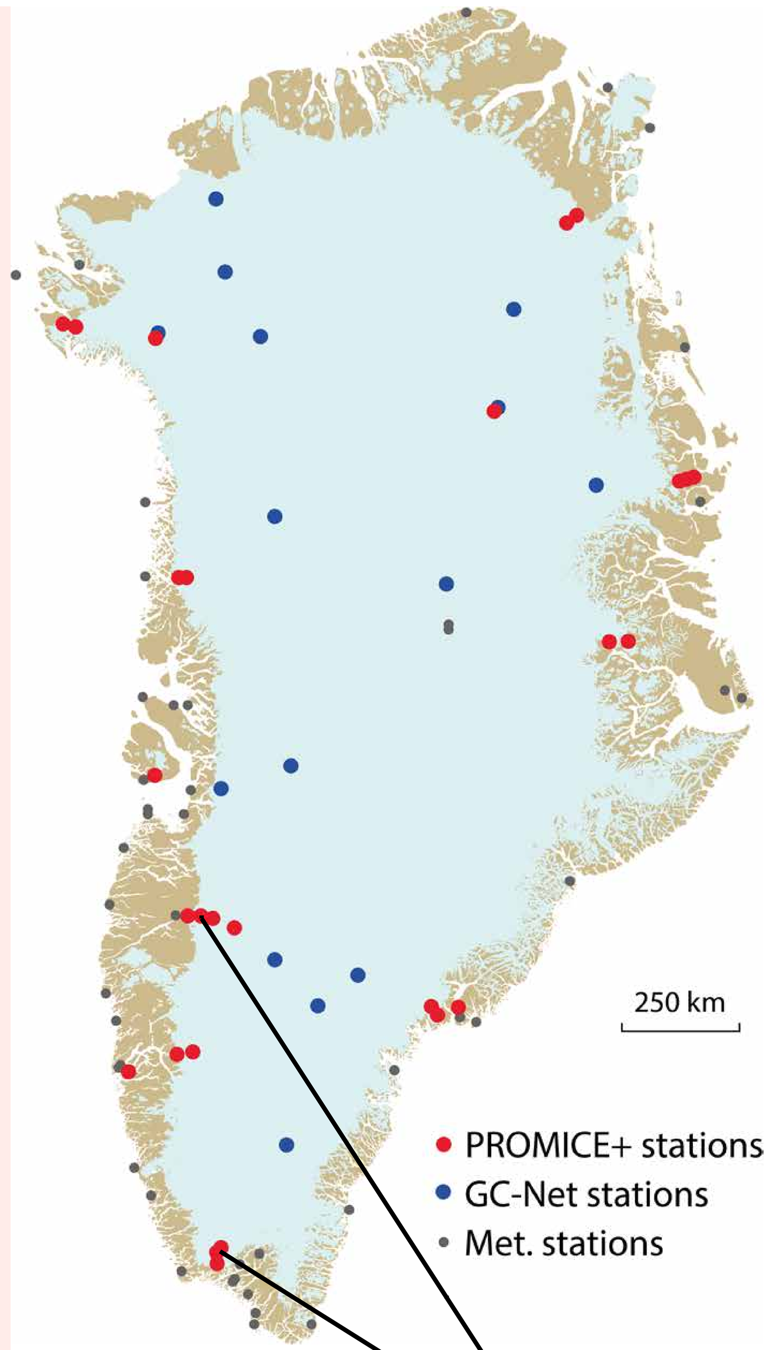
- Measurements of SWE from the Greenland Ice Sheet from an experimental SnowFox instrument deployment
- A new GNSS instrument improving the precision of 'floating' weather station position and elevation
- New instrument characterization facilities to improve the quality of in situ radiation observations




1: solar and infrared radiation, 2: tilt sensor, 3: satellite antenna, 4: wind speed & direction, 5: snow/ice surface height, 6: air temperature & humidity, 7: ice ablation 'hose', 8: solar panel, 9: data logger, barometer and GPS, 10: battery, 11: ice temperature profile (8 levels)

The SnowFox measures snow water equivalent (SWE) through the attenuation of cosmic-ray neutrons. The sensor records neutron events over a regular interval. To derive SWE, the raw neutron counting rate of the sensor must be corrected for variations in barometric pressure and solar activity. The corrected neutron counting rate is then normalized to a no-snow reference counting rate. Any subsequent counting rate will decrease exponentially as a function of the amount of SWE overlying the detector.

snow mass sensors




## Position & elevation

Two different types of data are produced by the INTAROS high accuracy GNSS positioning instrument: standalone positions available directly from the instrument in the field, and raw code and carrier phase observables meant for postprocessing of positions with cm-scale accuracy to GEUS AWS and Iridium SBD satellite service

### Requirements

- Data rate: record for 2 hours and deliver at least one accurate position per day in winter, record 24/7 and deliver up to one accurate position per hour in summer
- Accuracy: 0.5 m 1σ within 24 hours from observation, cm-scale (postproc.)
- Data storage: 2 years of data
- Power: run on less than 500 Wh of battery power through the polar night, on solar power during summer
- Communication: serial communication to GEUS AWS and Iridium SBD satellite service
- System configuration: standalone or connected to a PROMICE AWS

Table 2.1.2, power consumption (2.5 V < supply voltage < 18 V unless otherwise stated)

| **INTAROS GNSS receiver, dual frequency** | Measurement condition | Average power consumption |
|---|---|---|
| L1, L2 logging (GPS, GLONASS) | 5 sec., see Table 2.1.3 for details | 0.7 W |
| standby | | 2 mW |
| time-keeping only | no supply voltage (needs backup battery) | 0.1 mW |
| **INTAROS GNSS receiver, triple frequency** | | average power consumption |
| L1, L2, L5 logging (GPS, GLONASS, Galileo) | 5 sec., see Table 2.1.3 for details | 1.1 W |
| L1, L2 logging (GPS, GLONASS) | 5 sec., L5 and Galileo disabled | 0.9 W |
| standby | | 2 mW |
| time-keeping only | no supply voltage (needs backup battery) | 0.1 mW |

Table 2.1.4, power consumption (5.3 V < supply voltage < 30 V unless otherwise stated)

| **INTAROS tilt and azimuth** | Measurement condition | Average power consumption |
|---|---|---|
| actively measuring, all outputs active | first 5 sec. from power-up, 0 output current | 40 mA |
| measurement paused, all outputs active | 0 output current | 5 mA |

## Snow water equiv. & rain

The SnowFox measures snow water equivalent (SWE) through the attenuation (L) of cosmic-ray neutrons. The sensor records neutron events (N) over a regular interval.

$$SWE = -L \cdot \ln\left(\frac{N}{N_0}\right)$$

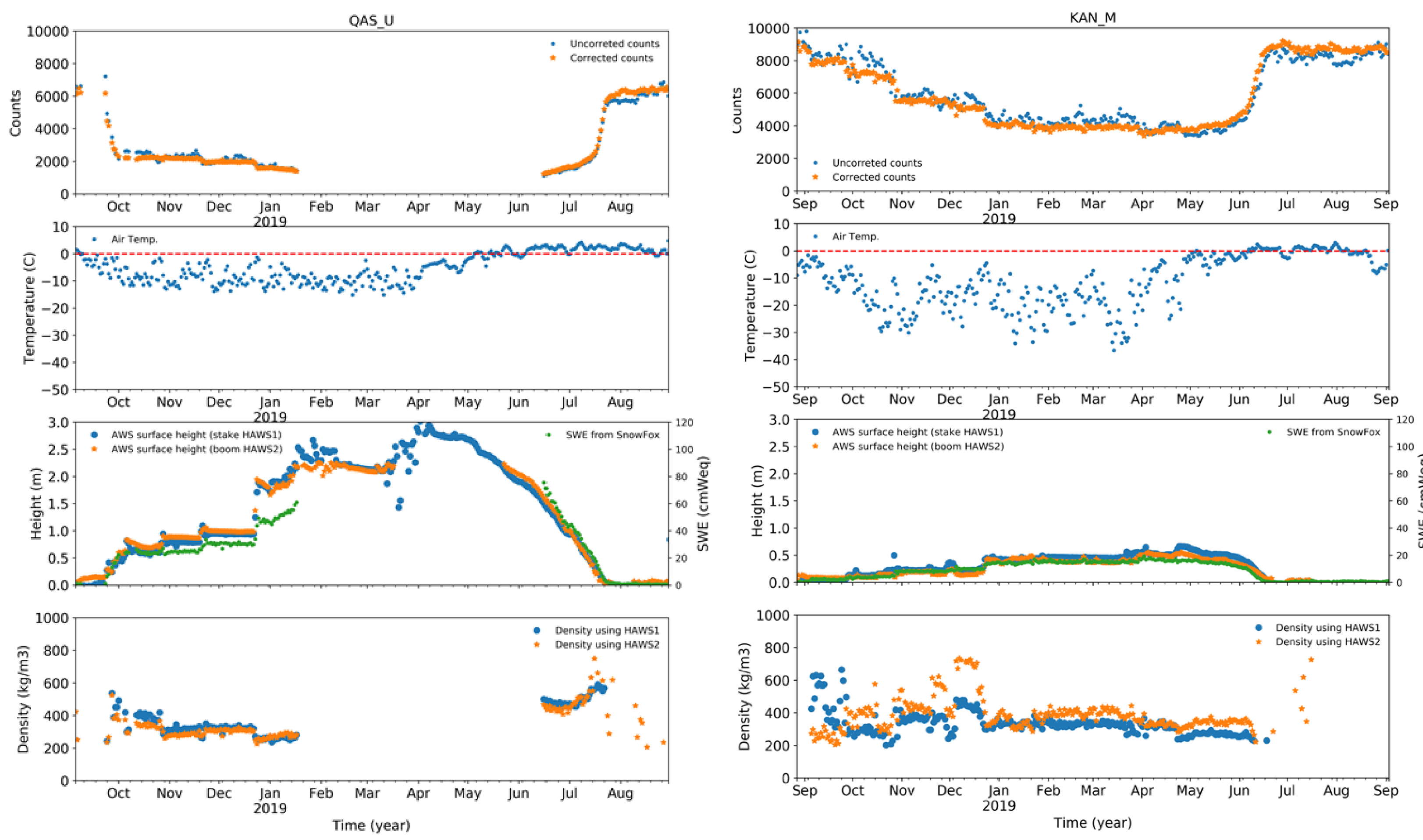
$$\frac{1}{L} = \frac{1}{L_{max}} + \left(\frac{1}{L_{min}} - \frac{1}{L_{max}}\right) \cdot \left(1 + \exp\left[-\frac{\frac{N}{N_0} - a_1}{a_2}\right]\right)^{-a_3}$$

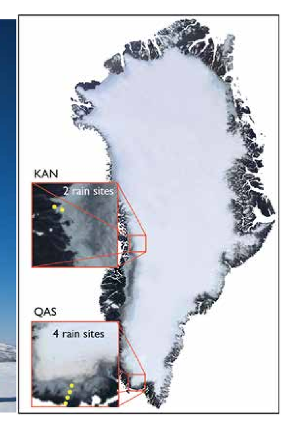
$$N = F(t) \cdot N_{raw}$$

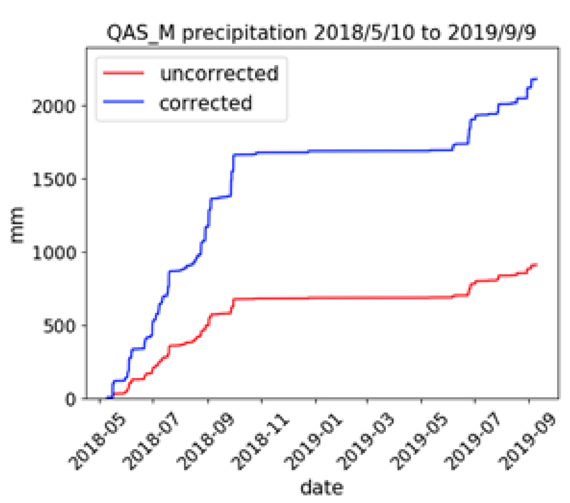
To derive SWE, the raw neutron counting rate of the sensor must be corrected for variations in barometric pressure and solar activity. The corrected neutron counting rate is then normalized to a no-snow reference counting rate.

Any subsequent counting rate will decrease exponentially as a function of the amount of SWE overlying the detector.

$$F(t) = f_{bar} \cdot f_{sol} \qquad f_{bar} = exp[\beta \cdot (P(t) - P_0)] \qquad f_{sol} = \frac{M_0}{M(t)}$$



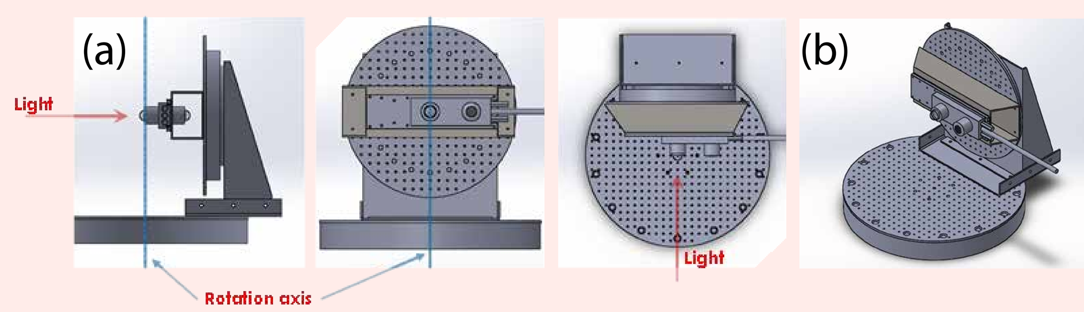




## Radiometer characterization

The schematic representation of the rotatory stage used for the angular characterization of the radiometers, including the mechanical jiigs required to attached the instruments, is illustrated below.

The angular and thermal characterization is performed using a 250 W calibrated lamp. In addition to the mechanical components, we also developed the software to controls the characterization experiments in the temperature controlled chamber and on the two-axis rotatory stage.




Above: schematic representation of a Kipp and Zonen net radiometer attached to the two-axis rotatory stage:
(a) 2D views of the light path and of the rotation axis
(b) 3D view of the system

## Our action list...

| | |
|---|---|
| SWE on ice sheet | Based on the results of the first deployment, we plan to fine-tune the instrument parameters and develop a solution to the power consumption/supply which is currently inadequate for wintertime operation |
| Precise positioning on ice sheet | Remaining GNSS units will be produced and the communication issues with the Campbell logger addressed. Subsequently, the new GNSS units will be implemented at the selected PROMICE and GEM sites visited in 2020 as part of routine maintenance |
| Tilt & azimuth of radiometers | Remaining tilt/azimuth units will be produced and the communication issues with the Campbell logger addressed. Subsequently, the new tilt/azimuth units will be implemented at the PROMICE and GEM sites visited in 2020 as part of routine maintenance |
| Rain gauges on ice sheet | Experimental deployment of rain gauges is continued through 2020, with implementation of a new AWS system including a rain gauge at all >20 PROMICE locations starting in 2021. The implementation phase of this new AWS system is expected to be on the order of 4 years |
| Radiometer characterization | The net radiometers recovered from the PROMICE network during summer 2019 will be characterized in winter 2020-2021 |