Automated Atmosphere-Ice-Ocean Observations of the Nansen Ice Shelf

and a brief history of AMIGOS

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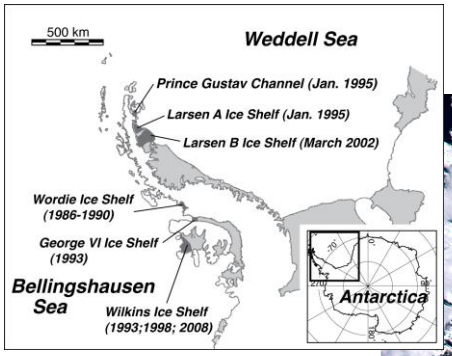
Ronald Ross, Martin Truffer, Dale Pomraning
Polar 66 Geophysical Institute, UAF

Thanks To KOPRI, Won Sang Lee, Choon-Kee Lee

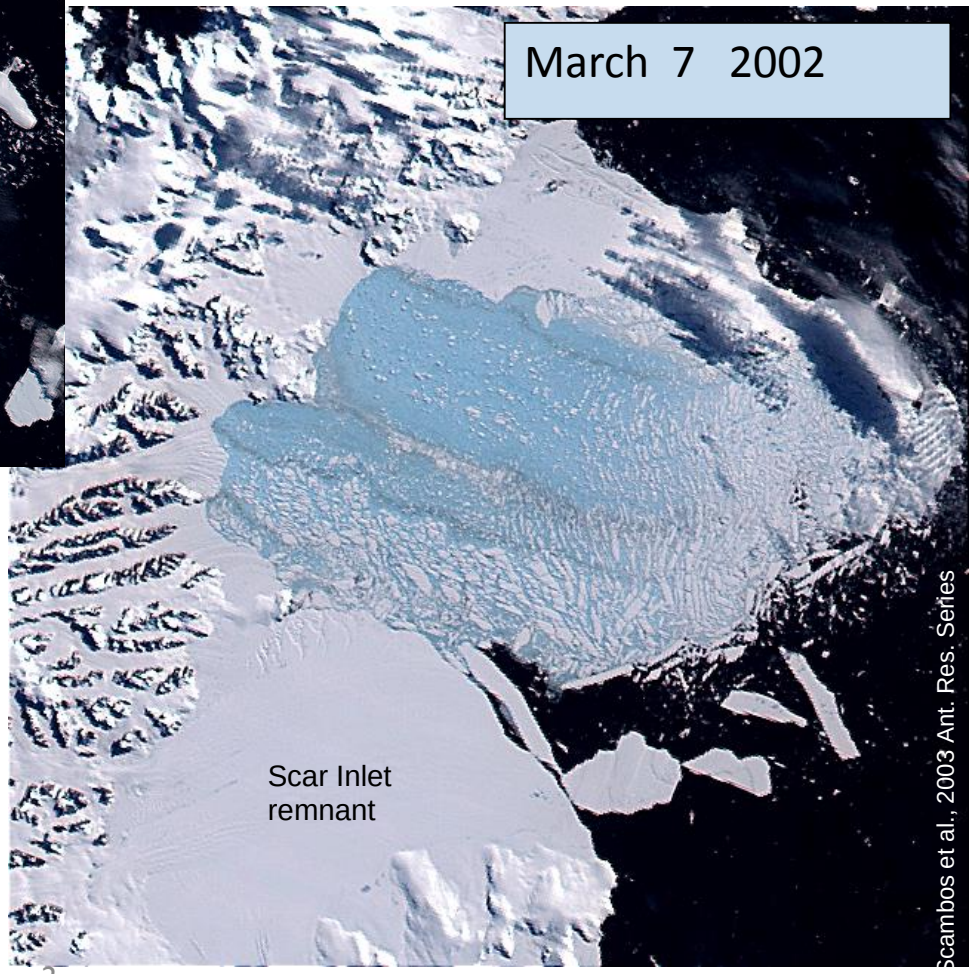
AMIGOS: ***A****utomated* ***M****eteorology-****I****ce-****G****eophysics* ***O****bserving* ***S****tations*

Photo by Martin Truffer, November 2010

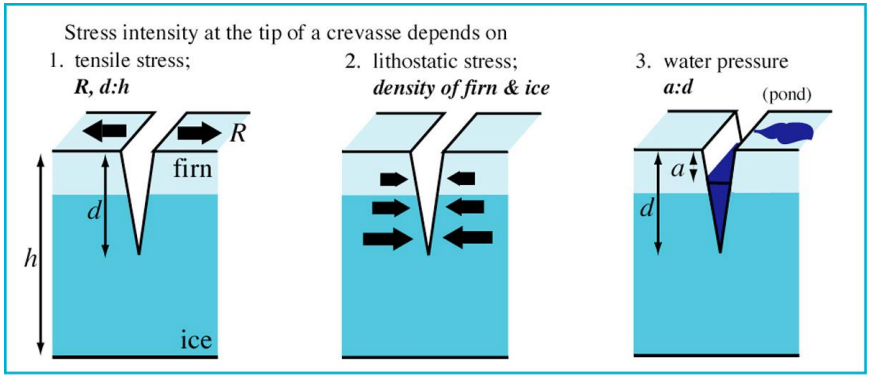
Antarctic Peninsula ice shelf disintegrations



Increased surface melting leads to ponding of meltwater and fracturing;

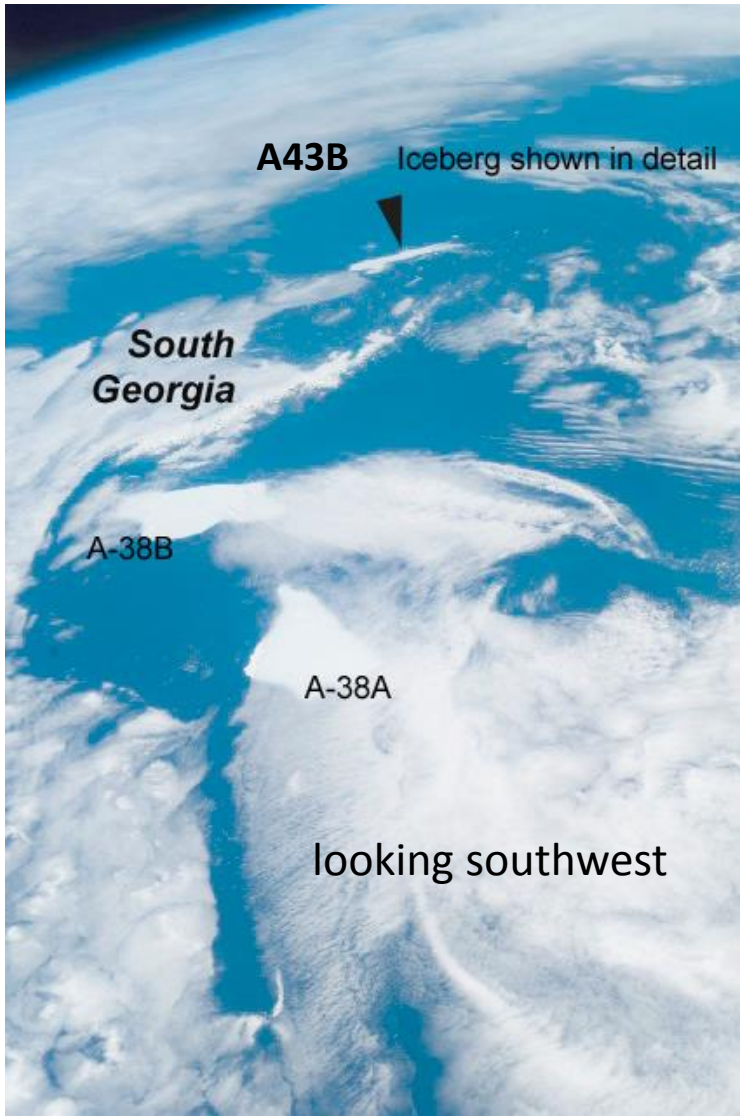


Hydro-fracture model: (other factors as well…)

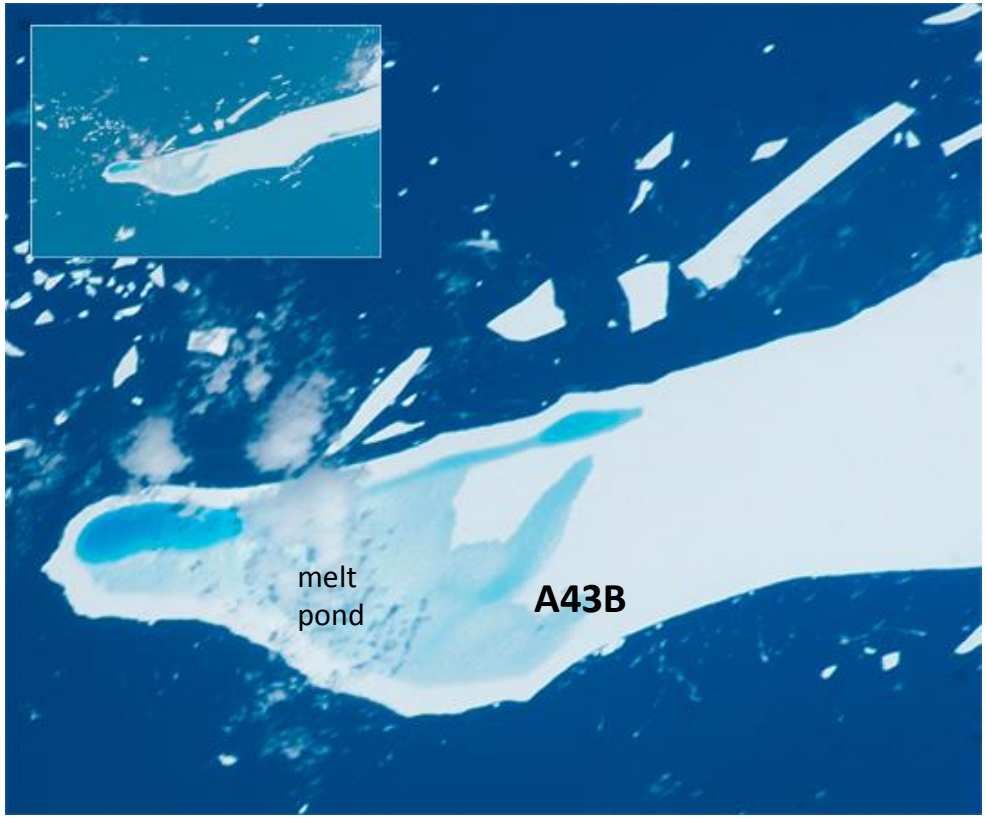


Scambos, Hulbe, Fahnestock, 2003 Ant. Res. Series

Icebergs - a way to learn more about ice shelf disintegrations



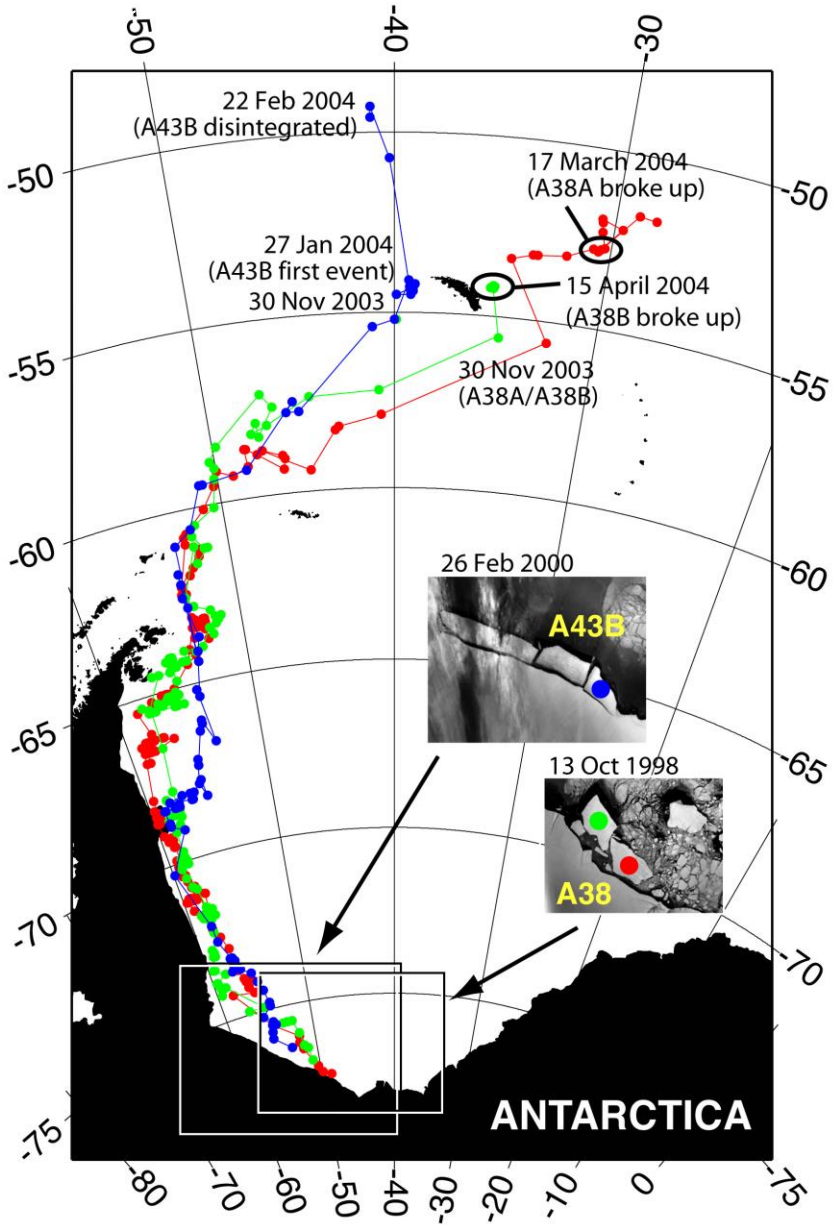
Images from **Intl. Space Station** hand-held camera

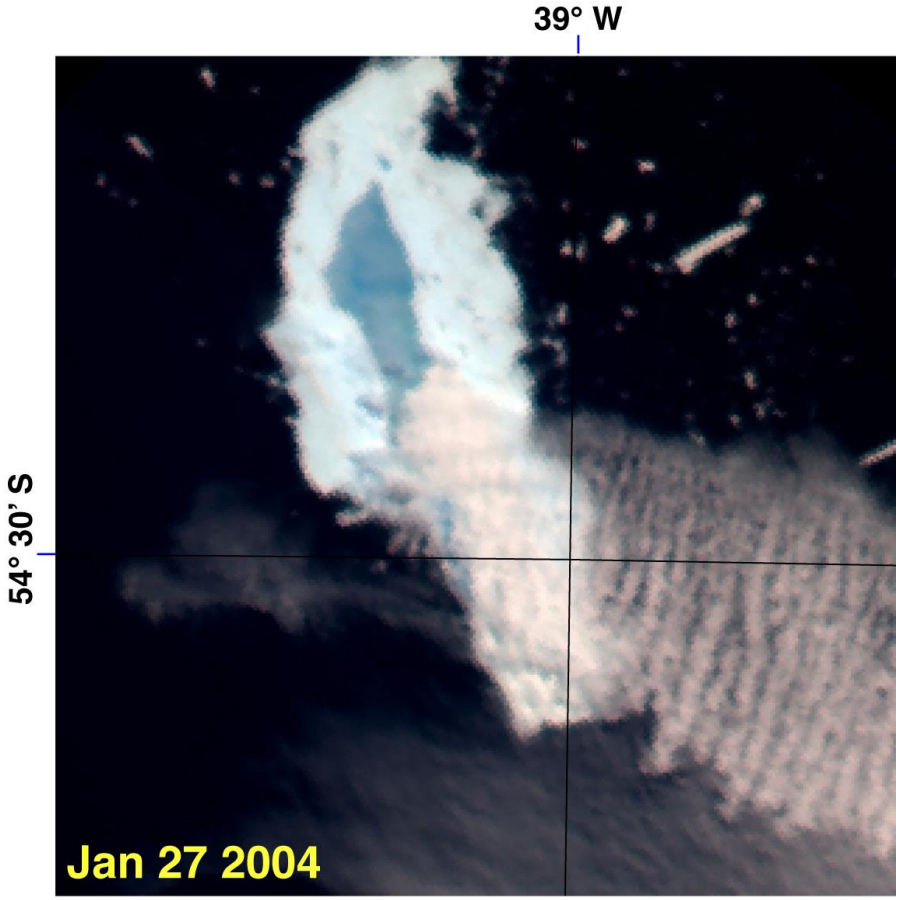


22 Jan 2004

looking ~nadir

Icebergs - a way to learn more about ice shelf disintegrations



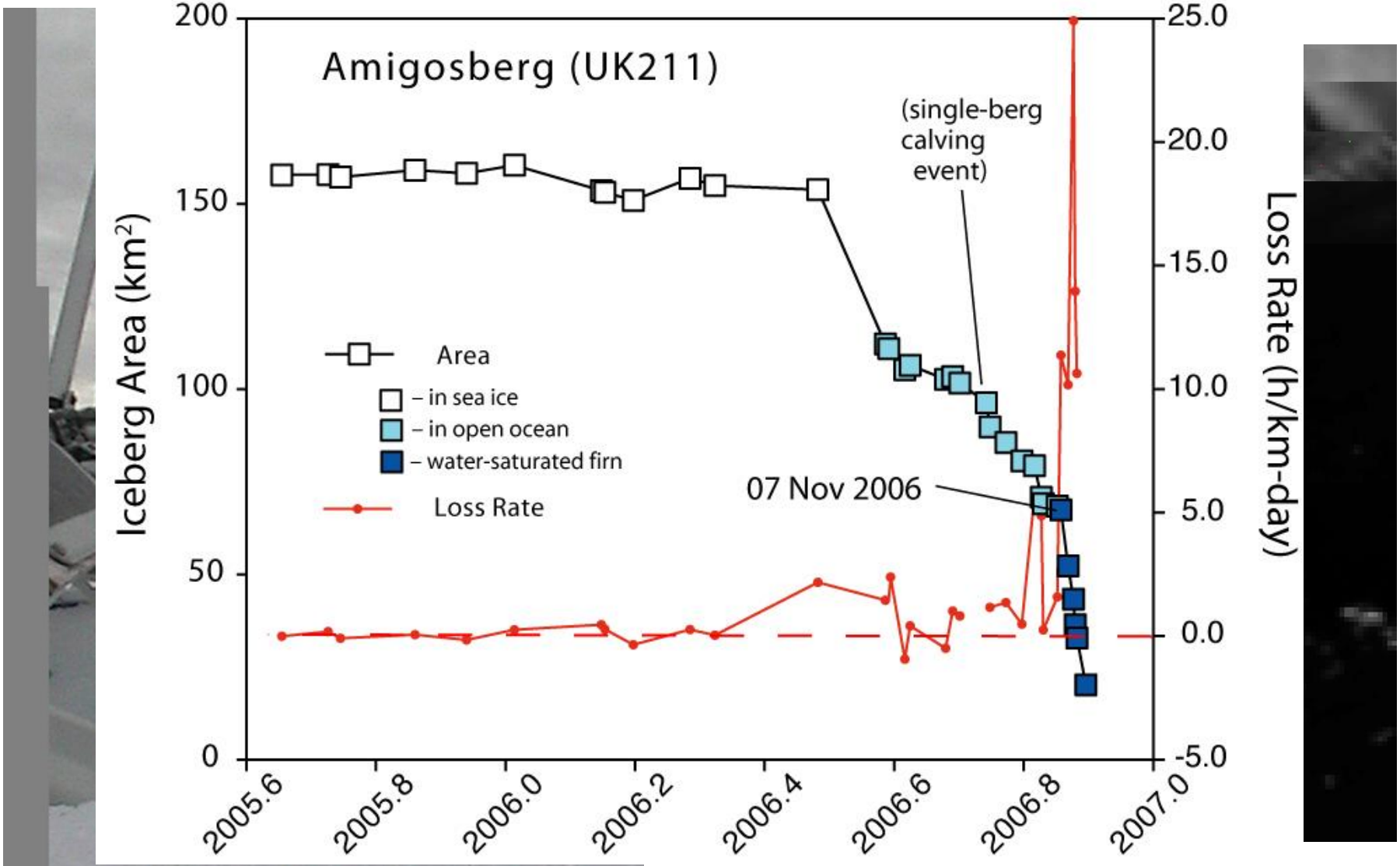


Scambos et al., 2005 GRL; 2008, J. Glaciol.

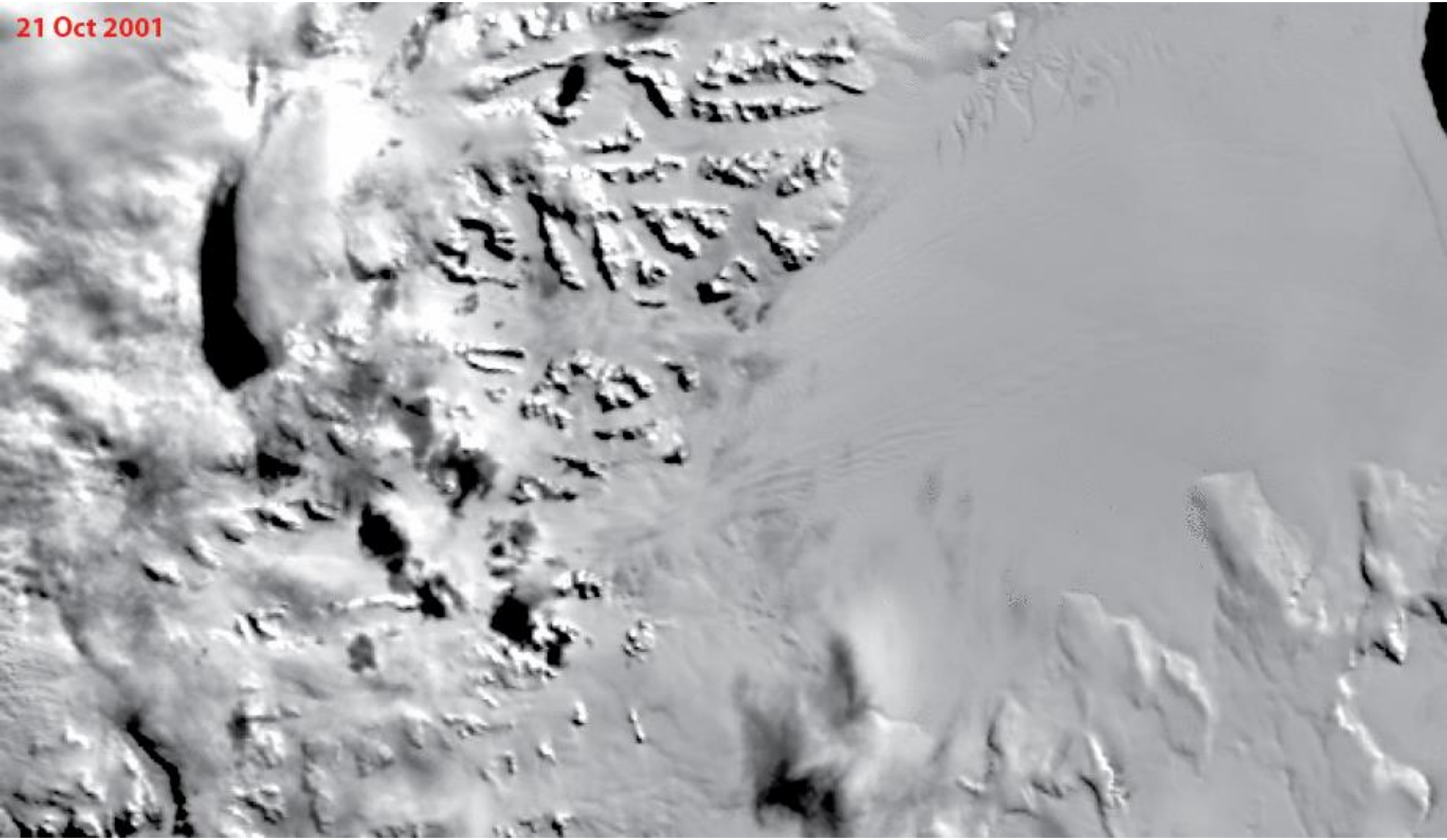
AMIGOS:
Automated
Met-Ice-Geophysics
Observing Stations

- GPS
- Camera
  - flag lines
  - accum/ablate
  - surface events
- Weather data
- Ice melt and thickness

Icebergs - a way to learn more about ice shelf disintegrations



Antarctic Peninsula ice shelf remnant at Scar Inlet --- destabilizing



'Glacier' AMIGOS System, for placement on moving ice

AMIGOS:
Automated **M**et-**I**ce-**G**eophysics
Observing **S**tations

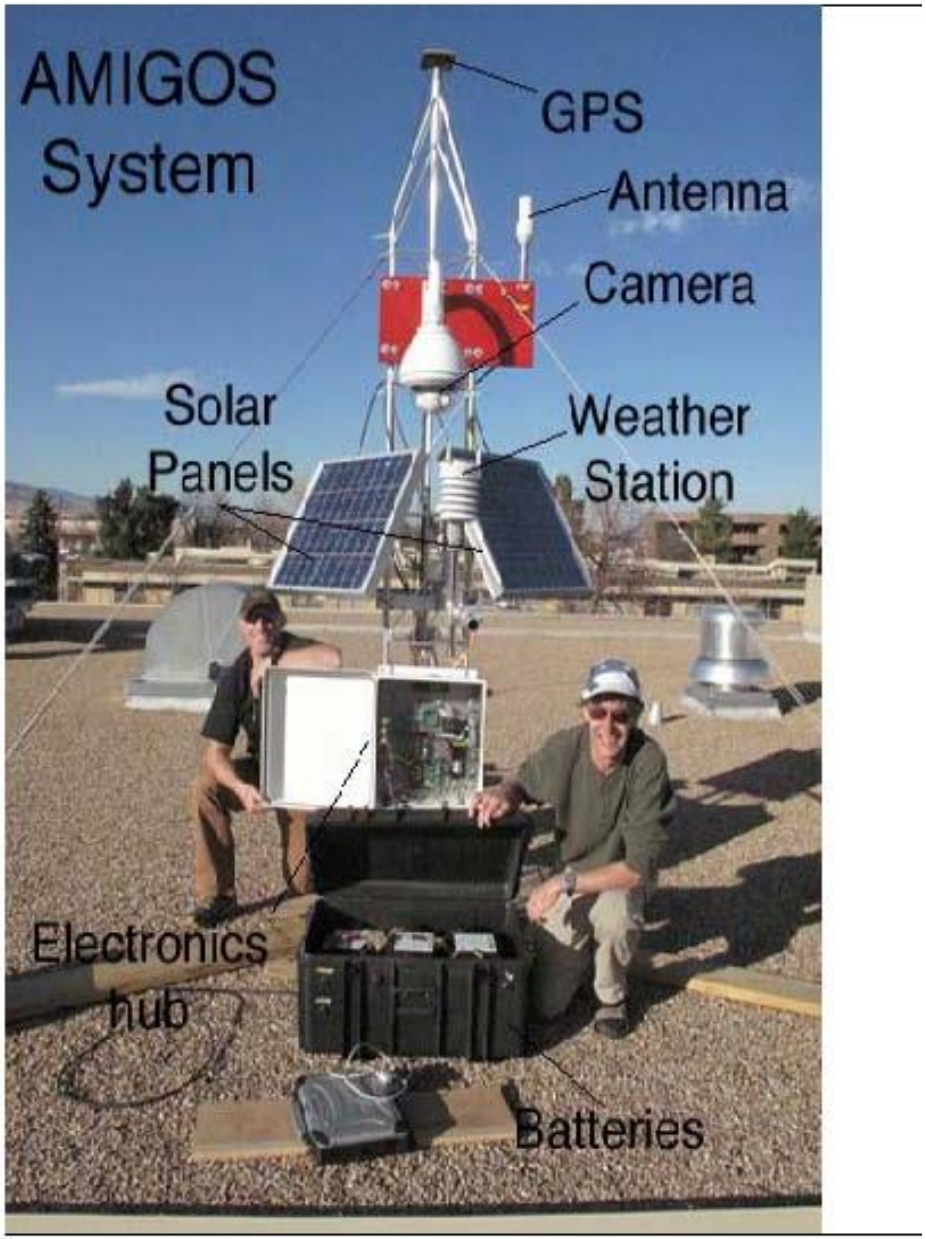
- Weather data
  Vaisala system: wind, temp, press, humid

- compact precision GPS system
  (Topcon GRS-1000)
  operating 20 min, 4x to 8x /day

- Camera
  six images, 2x /day
  accum/ablate, surface processes, flag line

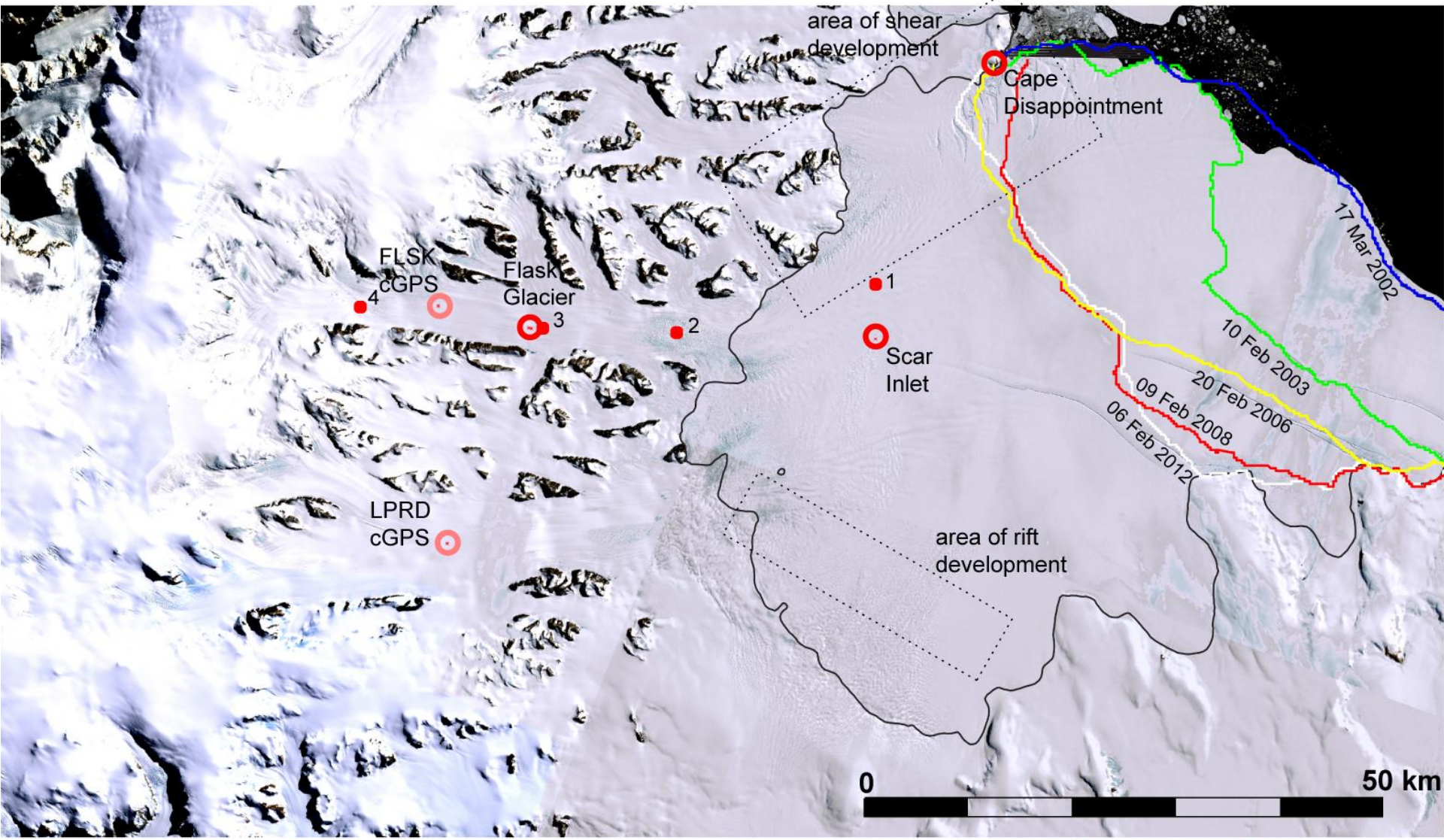
- Thermistor string (12 m)
  mean annual temperature
  melt penetration into firn

- Albedometer
  solar power, surface melt onset



Scambos, Ross, et al., 2013 Annals of Glaciology

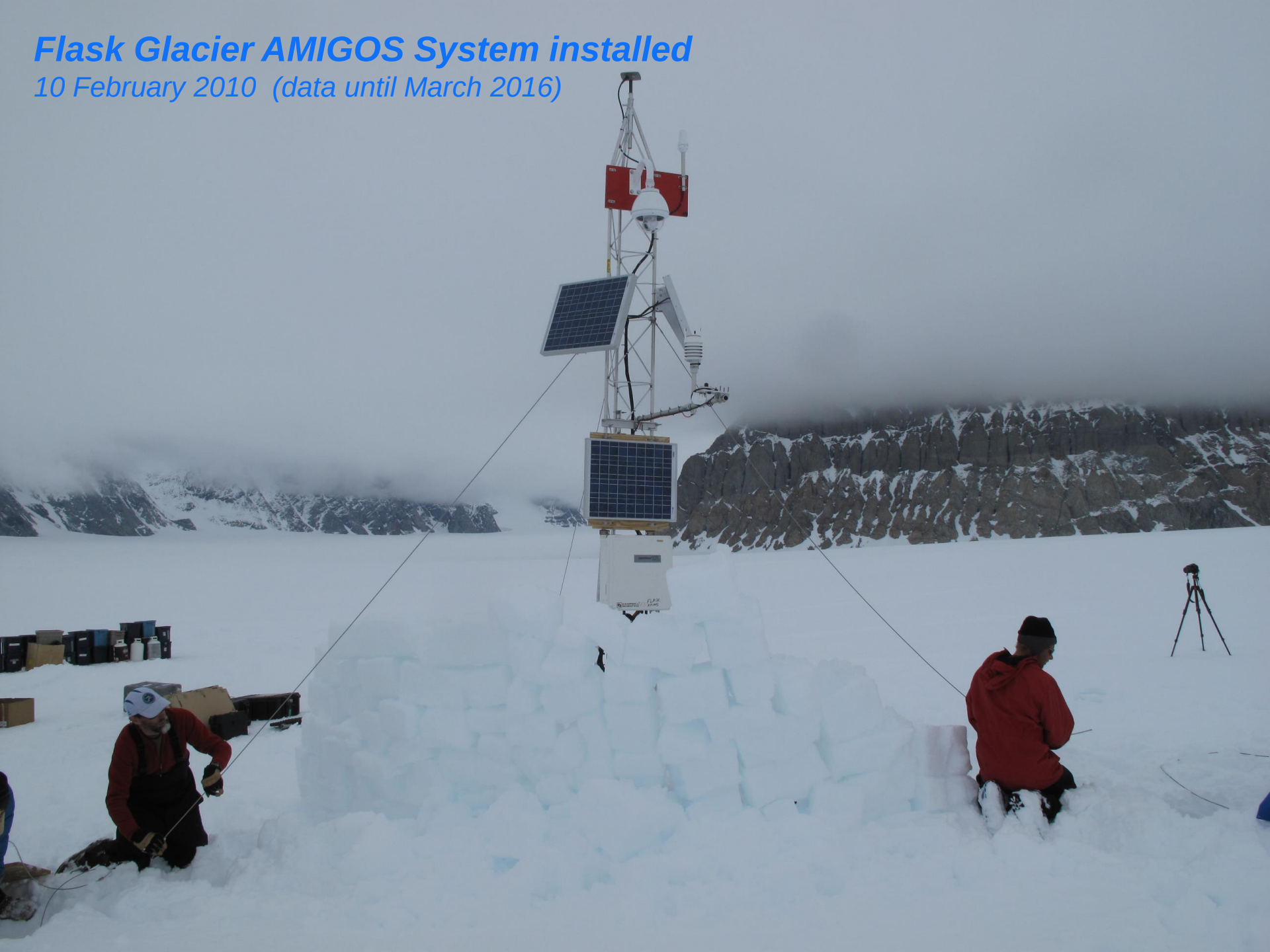
AMIGOS and iceGPS sites in the Scar Inlet Area



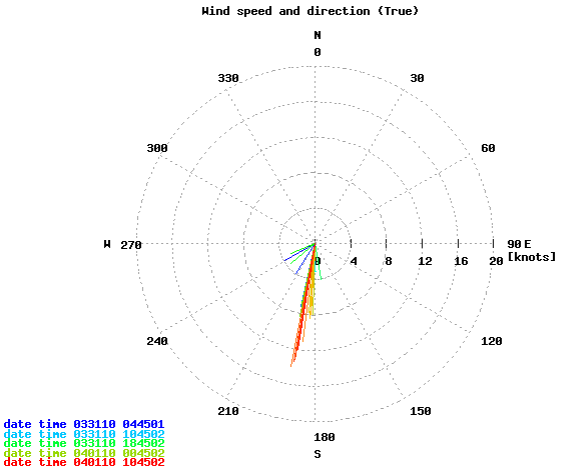
Landsat-7 LIMA Mosaic (see Bindschadler et al., 2008; images acquired 2002-2003) --AMIGOS --cGPS

Flask Glacier AMIGOS System installed

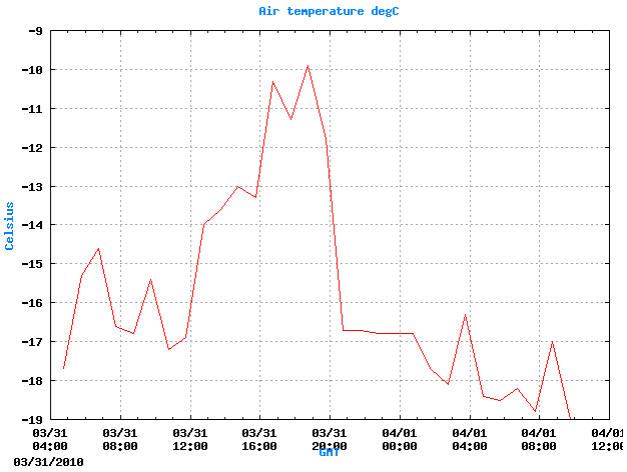
10 February 2010 (data until March 2016)



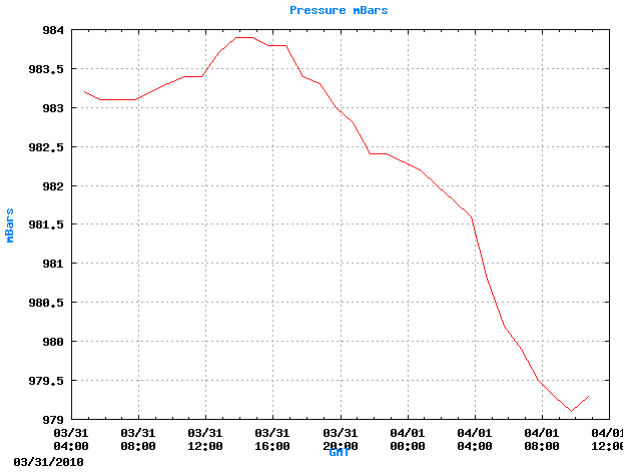
Weather and albedo data from Flask AMIGOS, single day



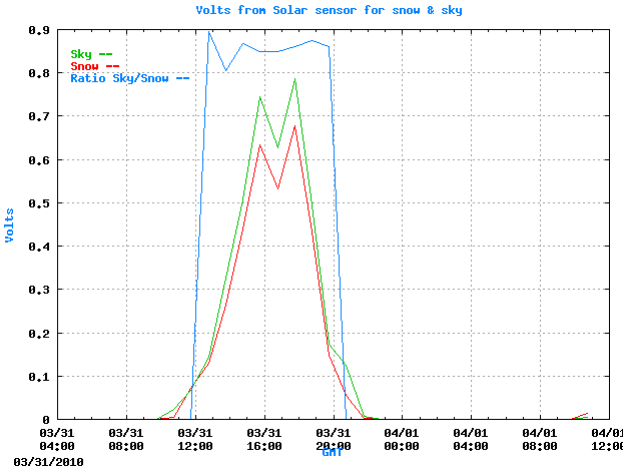
~2m wind



~2m Air Temp



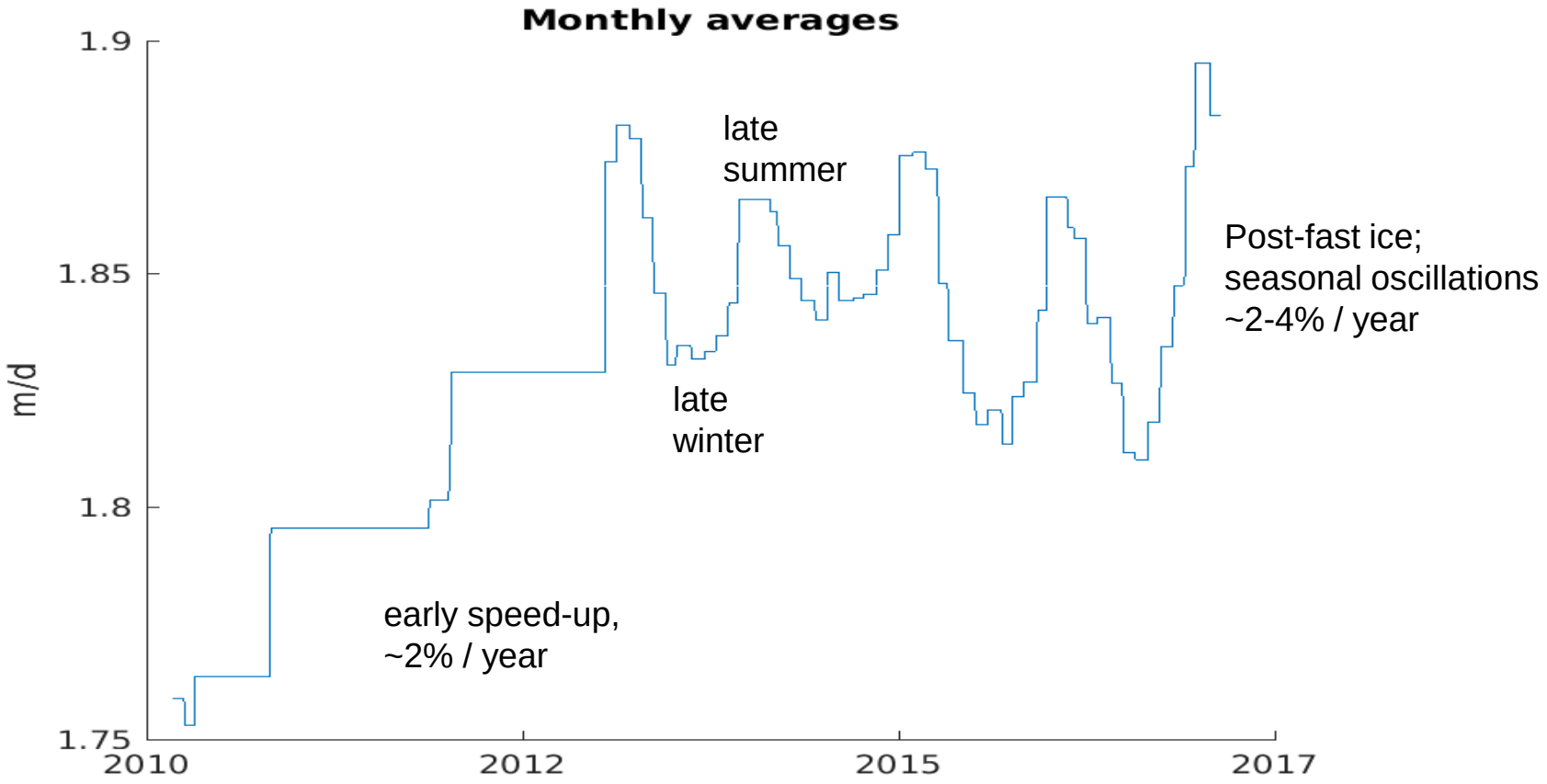
Pressure



Sky, Snow, Albedo

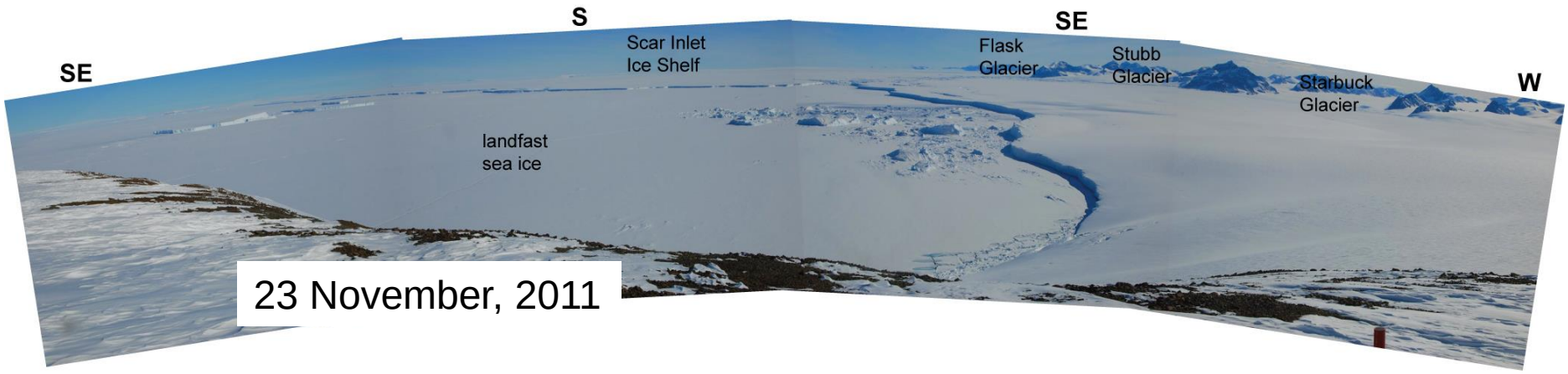
Scambos, Ross, et al., 2013 Annals of Glaciology

Monthly mean GPS ice speed data from Scar Inlet AMIGOS, 2010-2017



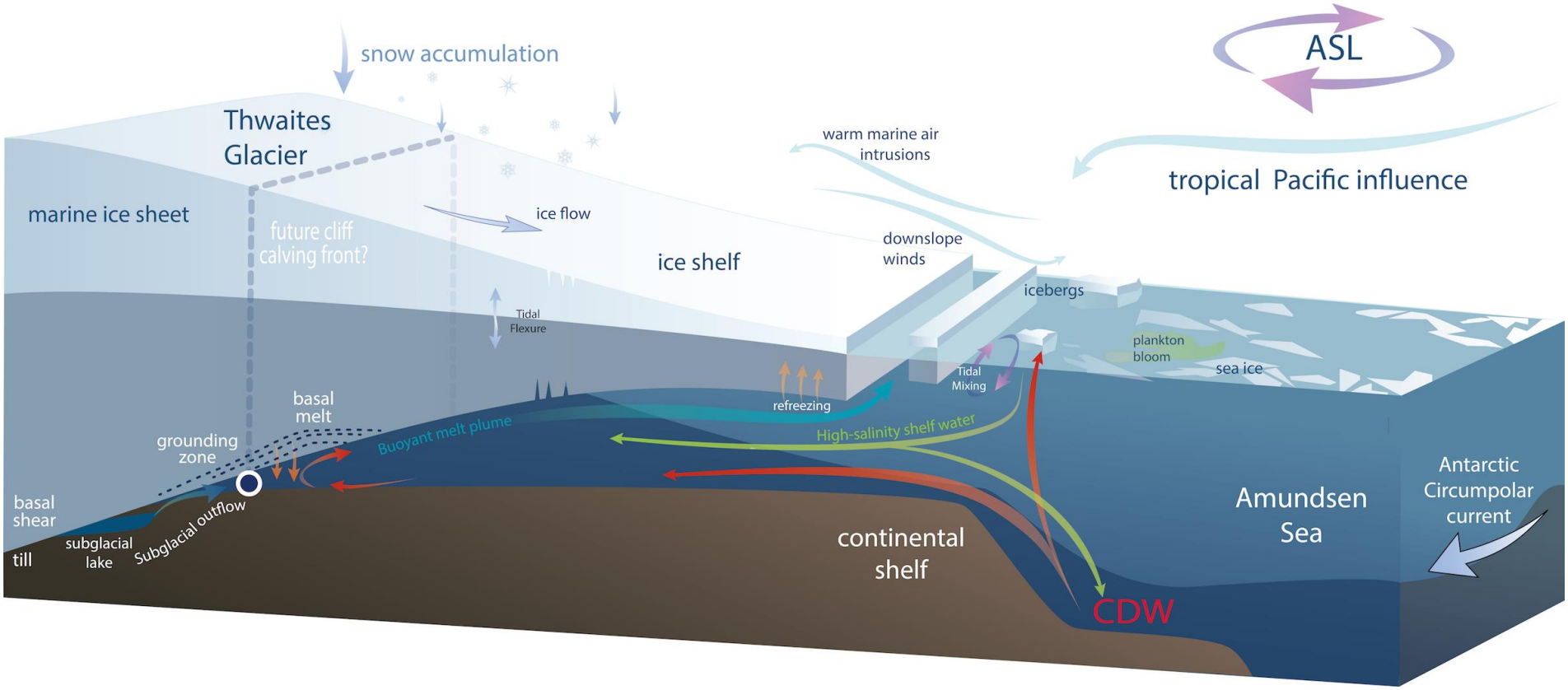
Formation of multi-year fast ice in Larsen B embayment (March 2012) has stalled ice shelf speed-up; seasonal modulation associated with fast ice strength; *Pettit et al., 2017 in prep*

AMIGOS high-resolution camera overlooking the Scar Inlet Area



Scambos, Ross, et al., 2013 Annals of Glaciology

The new concern: Ice-Ocean interaction



Scambos, Bell, et al., 2017 Global Planet. Change

AMIGOS-II: designed to study weather, ice, and the sub-ice-shelf environment

Table 1: AMIGOS-II Proposed Design Components

Structure, Power, and CPU

- •CPU: Triton-3 single-board computer, internal ethernet, serial, and USB ports; Linux OS, watchdog function;
- •Iridium modem and antenna;
- •10 cm tubular design, 2 m sections, total 6 m installed (1 m sub-surface, 5 m exposed);
- •Li batteries for winter; 4x100 amp-hr Pb gel-cells; 2 x 80 W solar panels

Imaging: Surface /Sky condition

- •Camera system, station view mirror, flag line (not shown)

Weather / Climate

- •Vaisala WXT520 weather station, 2 m;
- •R. M. Young propeller wind-vector system at top of mast

Ice Motion and Strain Sensors

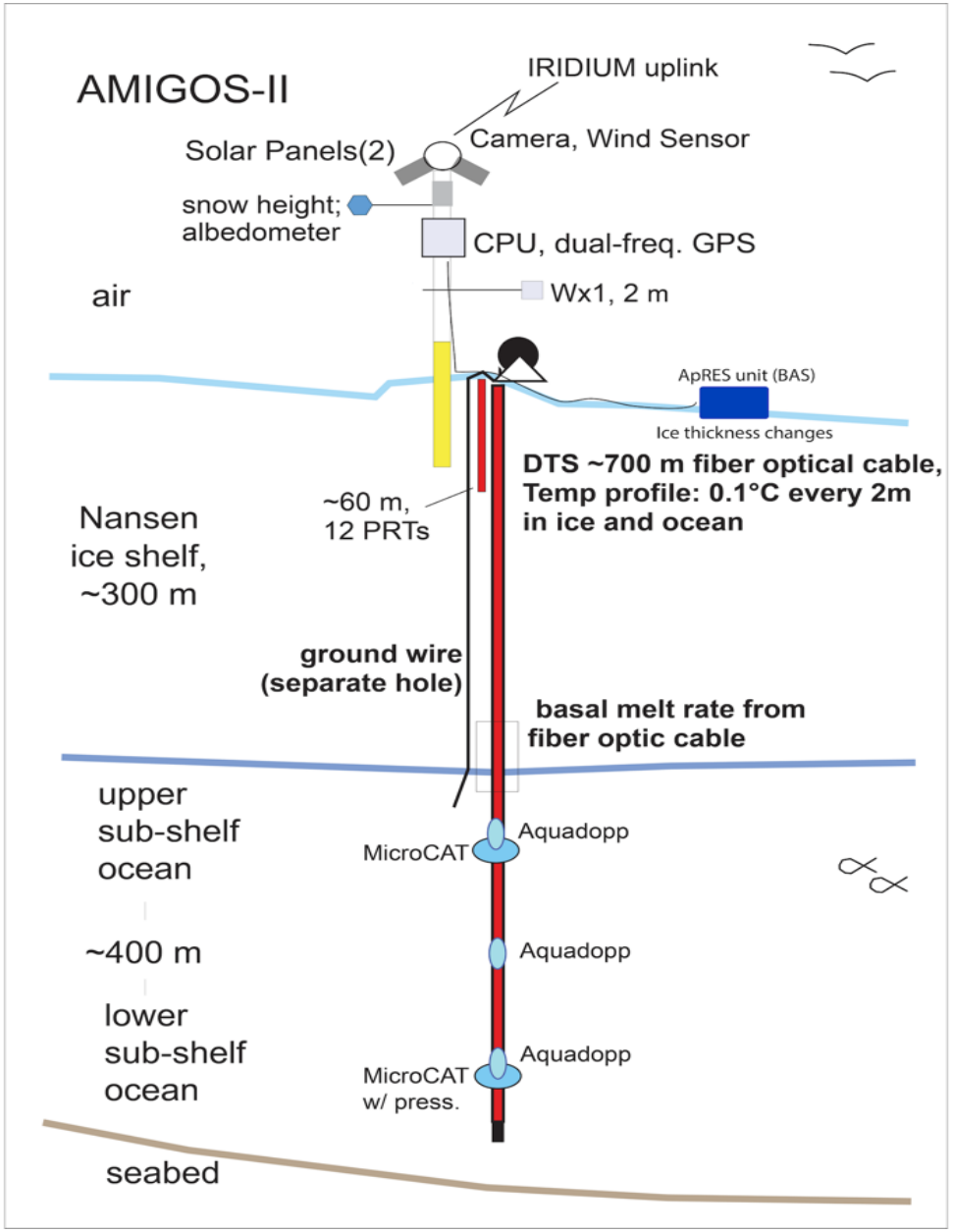
- •Dual-Frequency GPS – Topcon GRS-1 rcvr, PGA-1 ant.;

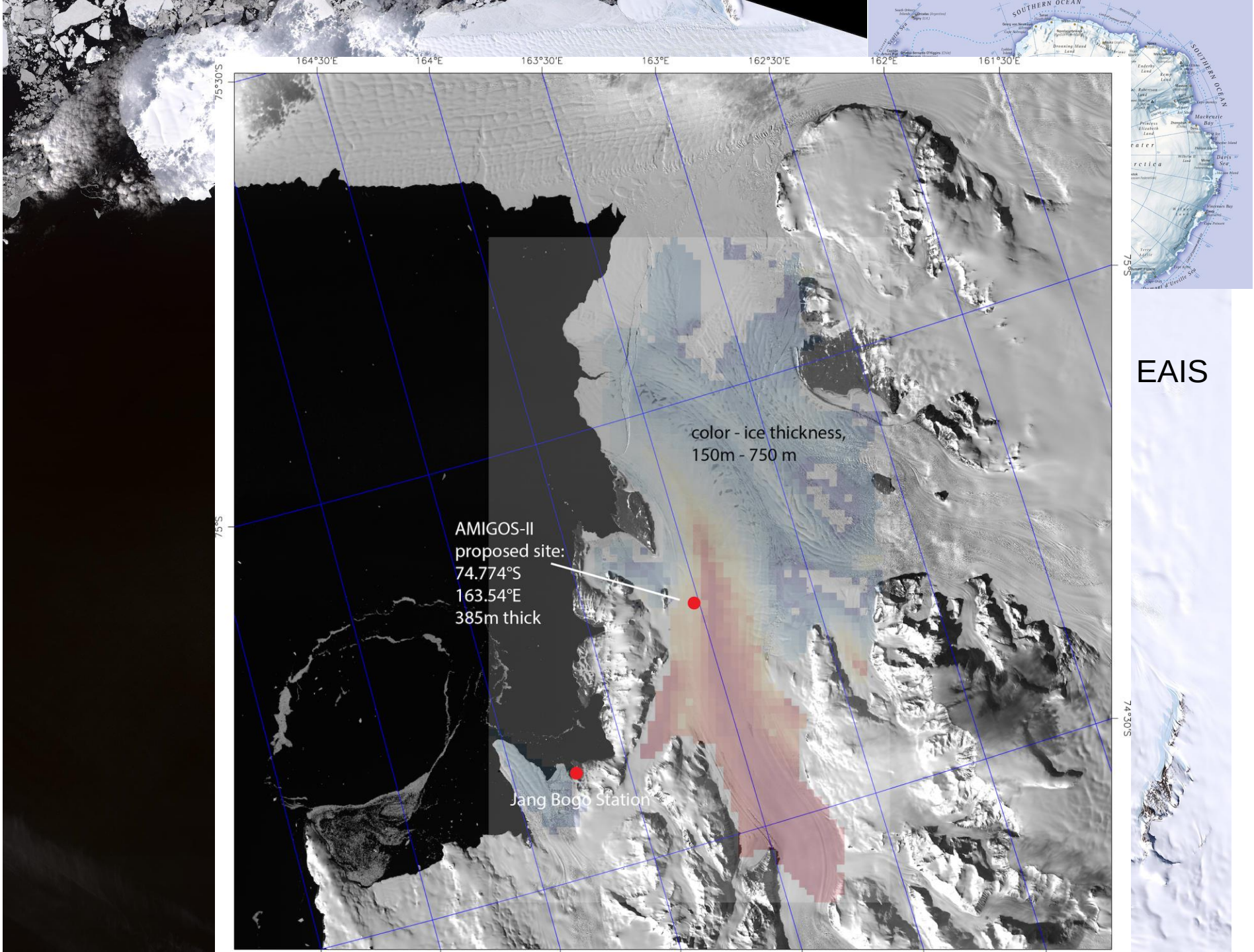
Snow-Firn Energy Balance Sensors

- •Albedometer (dual Apogee SP-212 all-sky lightmeters);
- • Campbell Scientific sonic snow-height sensor or similar
- •60-meter string, 12 PRT sensors m.

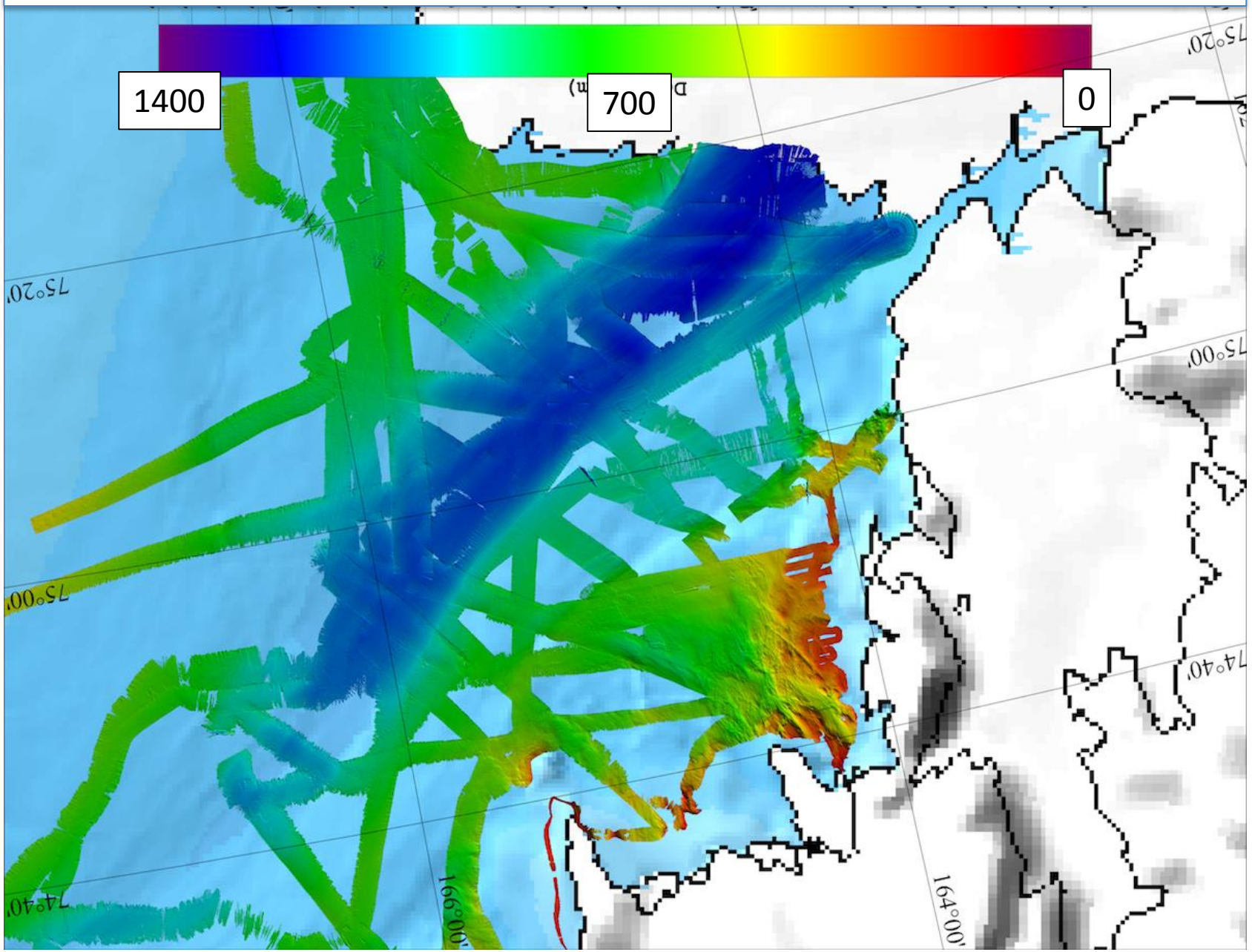
Ice and Sub-Ice Ocean Sensors

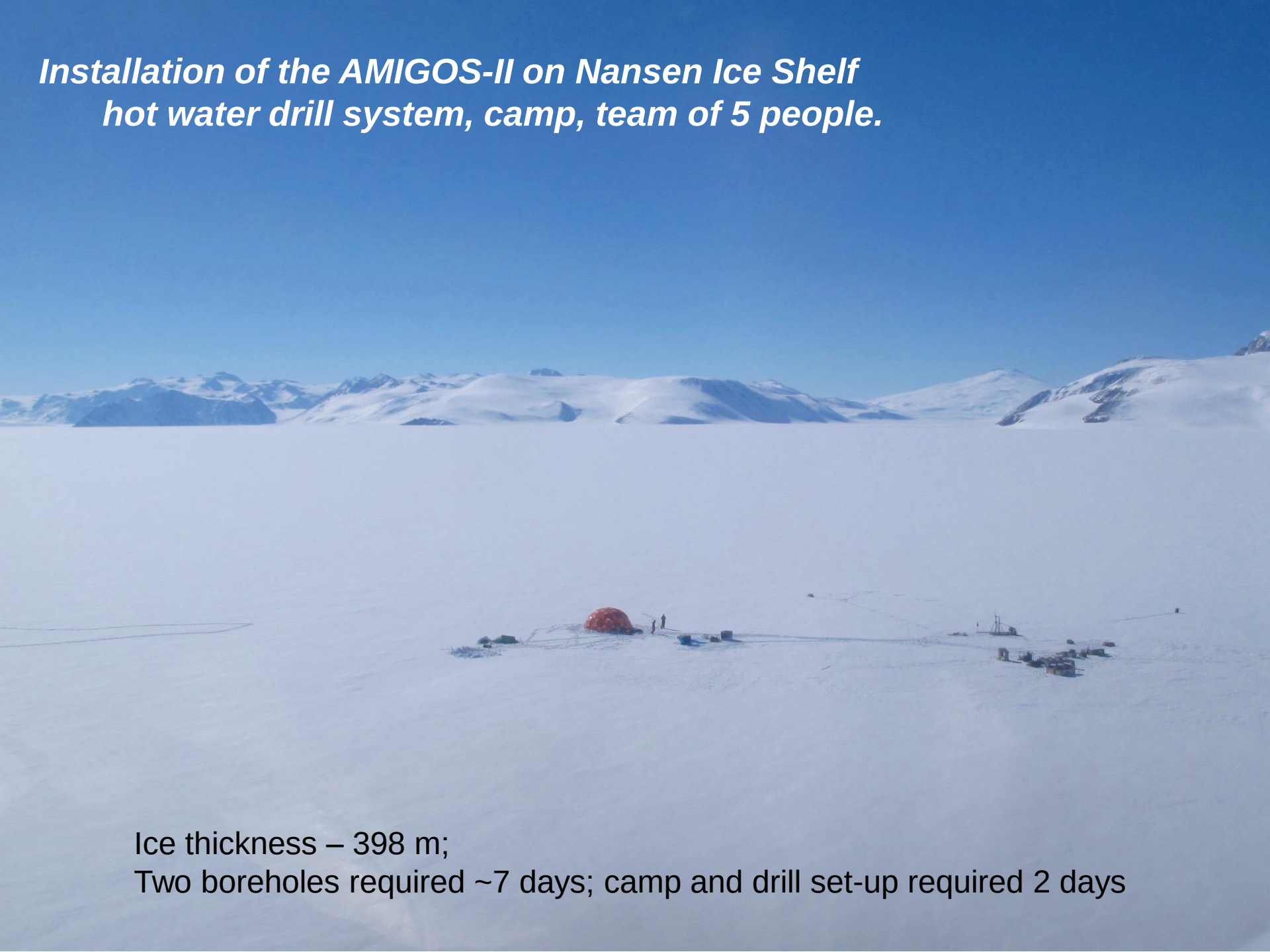
- •DTS laser fiber optic cable thermal profiling system;
- •2 SeaBird MicroCAT SBE-37IMP CT sensors, 1 w/ press;
- •3 Nortek Aqua-Dopp Doppler current meters;




164°30'E
164°E
163°30'E
163°E
162°30'E
162°E
161°30'E
75°30'S
75°S
74°30'S
color - ice thickness,
150m - 750 m
AMIGOS-II
proposed site:
74.774°S
163.54°E
385m thick
Jang Bogo Station
SOUTHERN OCEAN
EAIS

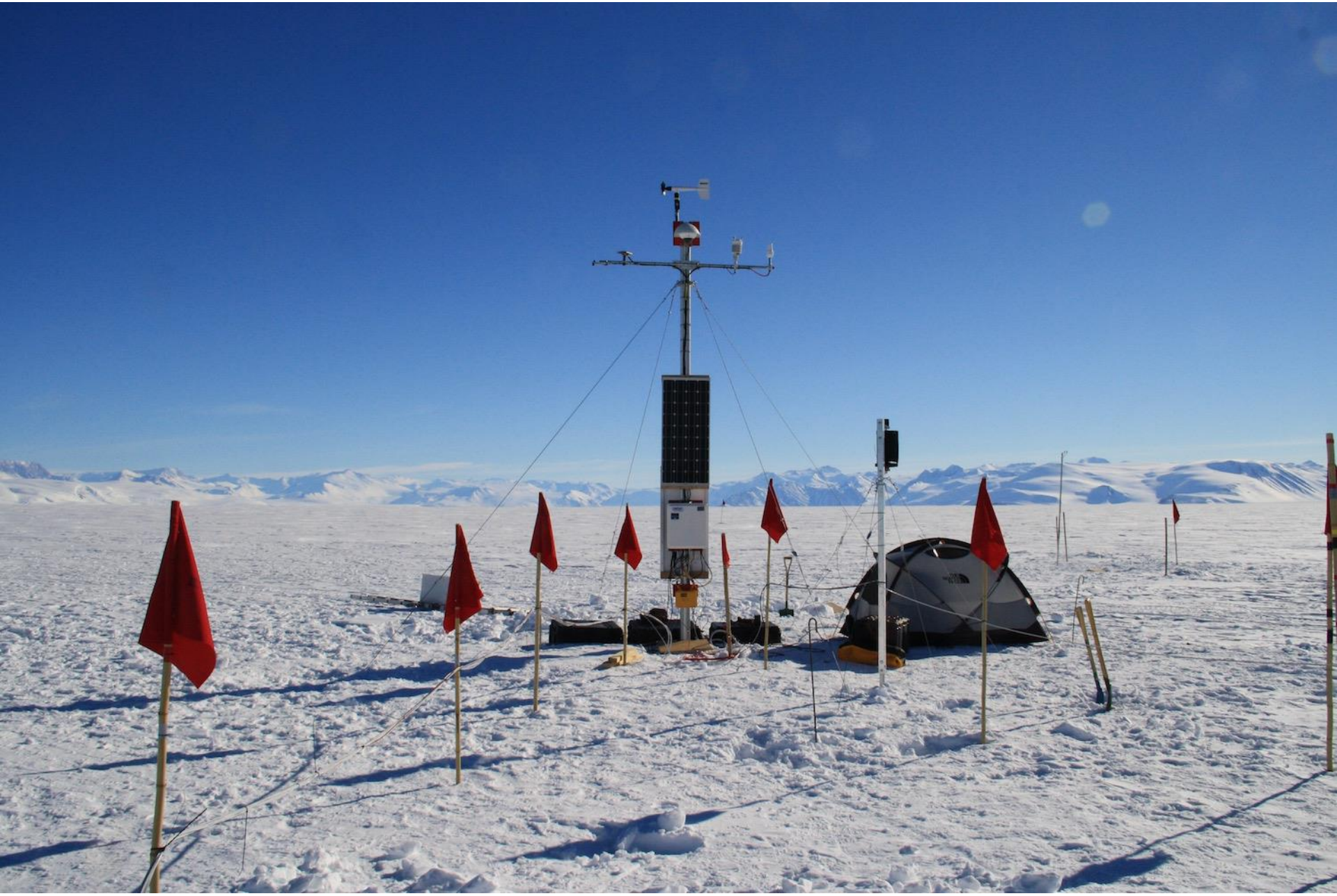
Bathymetry





Installation of the AMIGOS-II on Nansen Ice Shelf
hot water drill system, camp, team of 5 people.

Ice thickness – 398 m;
Two boreholes required ~7 days; camp and drill set-up required 2 days



AMIGOS-II on Nansen Ice Shelf --- as installed

Table 1: AMIGOS-II at Nansen Ice Shelf Components

Structure, Power, and CPU

- CPU: Triton-3 single-board computer, internal ethernet, serial, and USB ports; Linux OS, watchdog function;
- Iridium modem and antenna;
- 10 cm tubular design, 3 m sections, total 6 m installed (0.5 m sub-surface, 5.5 m exposed);
- 8 x 100 amp-hr Pb gel-cell batteries

Imaging: Surface /Sky condition

- Camera system, Mobotix

Weather / Climate

- Vaisala WXT520 weather station;
- R. M. Young propeller wind-vector system at top of mast

Ice Motion and Basal Melting

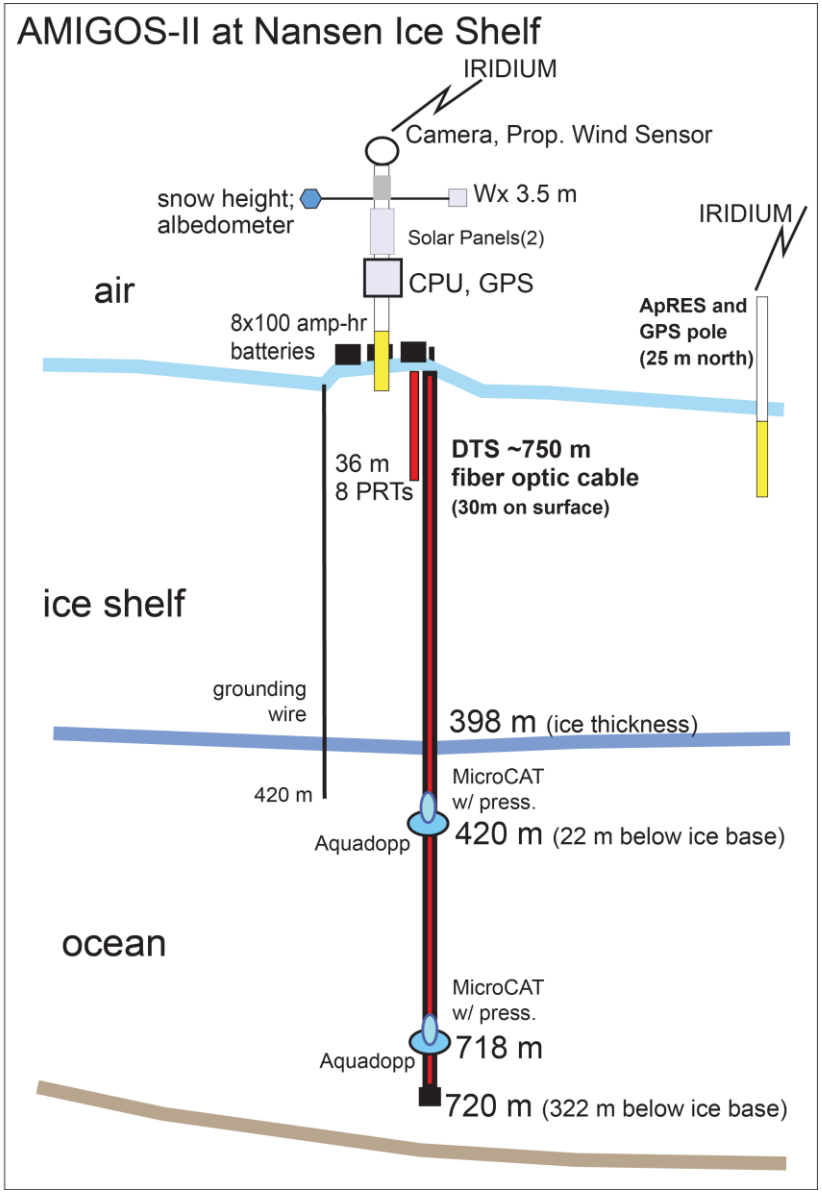
- Dual-Frequency GPS – Topcon GRS-1
- BAS ApRES and GPS *(provided by KOPRI / C-K Lee)*

Snow-Firn Energy Balance Sensors

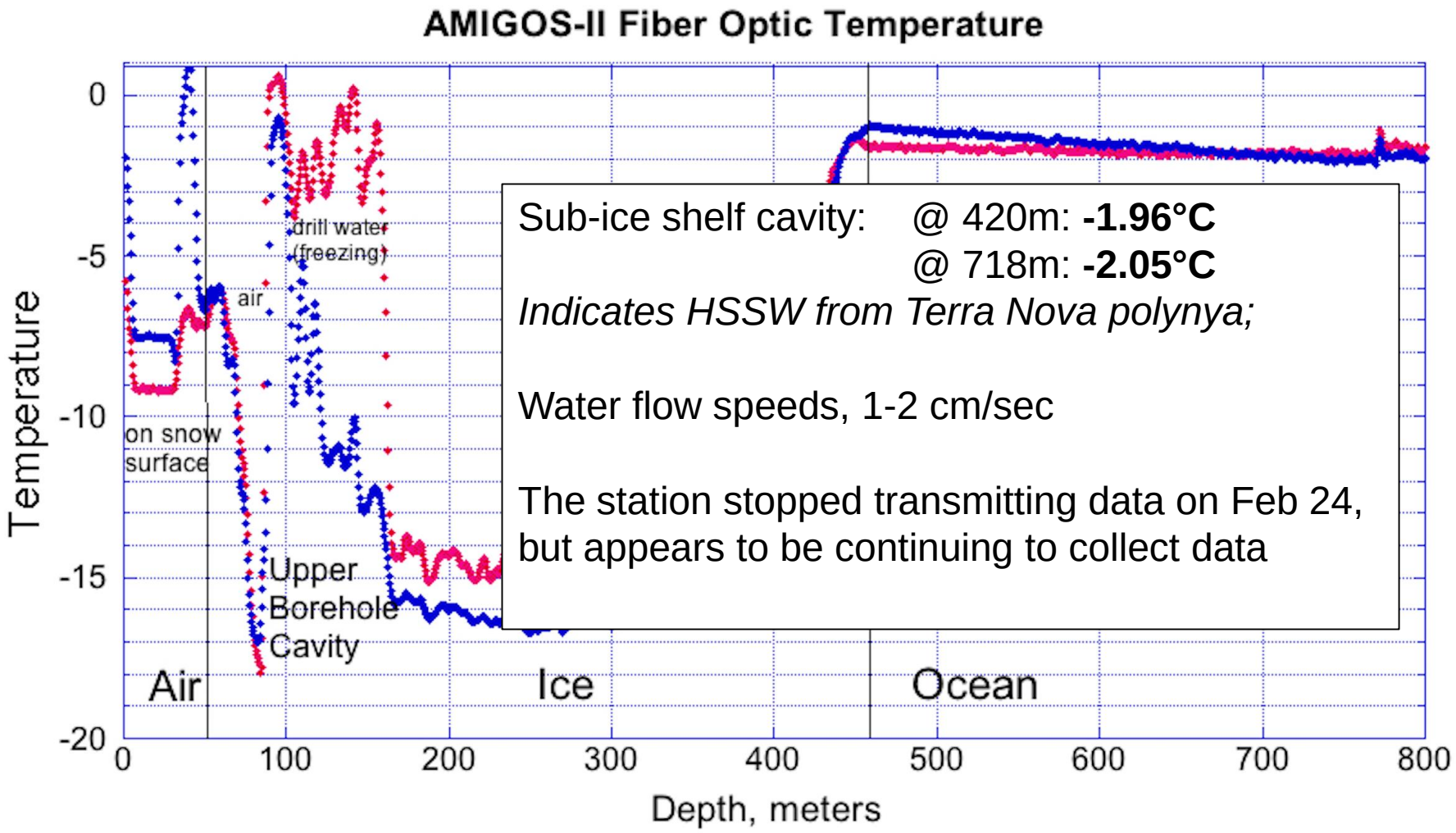
- Albedometer (dual Apogee SP-212 all-sky lightmeters);
- 36-meter PRT string; sensors at 1, 2, 4, 8, 12, 16, 24, 36m.

Sub-Ice Ocean Sensors

- DTS laser fiber optic cable thermal profiling system;
- 2 SeaBird MicroCAT SBE-37IMP CT sensors, w/ press. port;
- 2 SeaBird Aqua-Dopp Doppler current meters;



AMIGOS-II preliminary fiber-optic data



Sub-ice shelf cavity: @ 420m: **-1.96°C**
@ 718m: **-2.05°C**

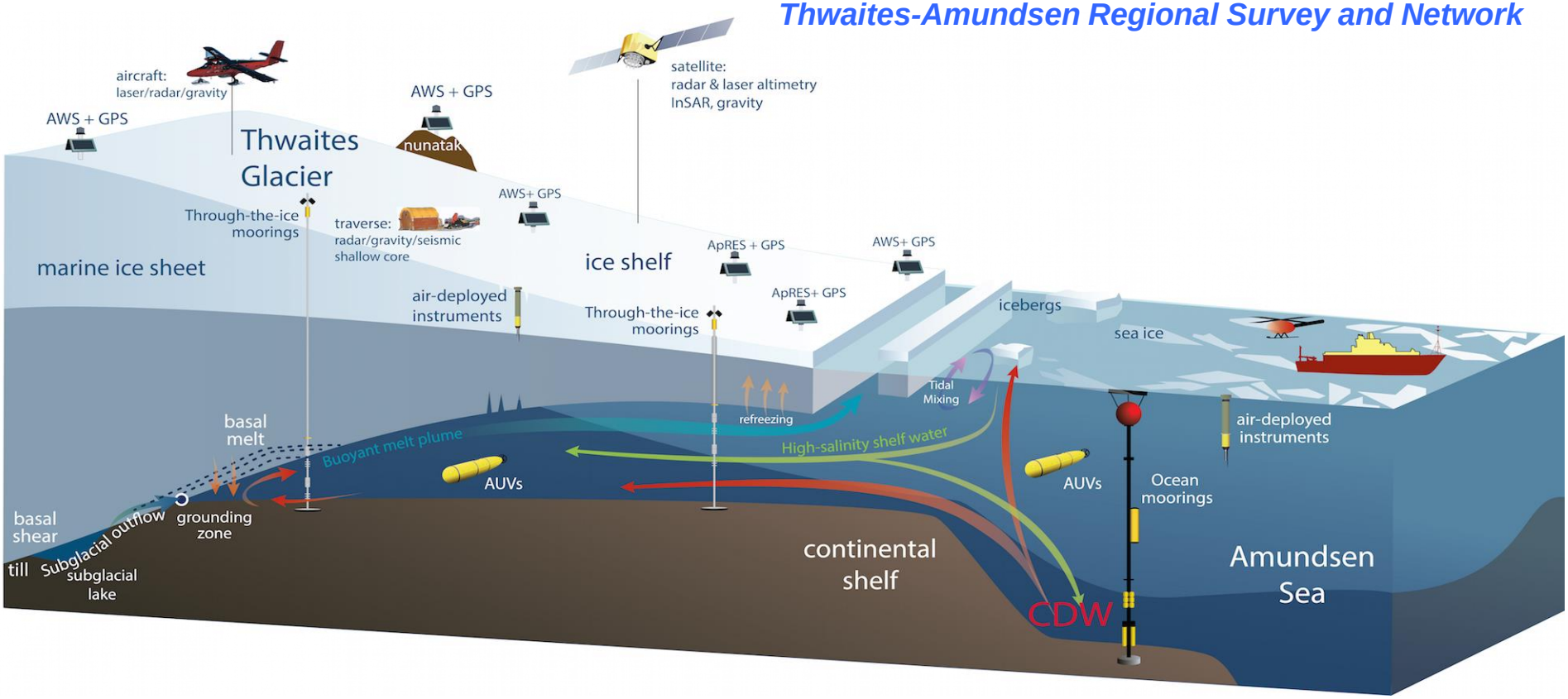
Indicates HSSW from Terra Nova polynya;

Water flow speeds, 1-2 cm/sec

The station stopped transmitting data on Feb 24, but appears to be continuing to collect data

NERC-NSF Thwaites Program – ~25 proposals submitted (funding ~8)

One of them is:
TARSAN –
Thwaites-Amundsen Regional Survey and Network



Scambos, Bell, et al., 2017 Global Planet. Change

Key ice-ocean interaction region: Thwaites – Amundsen

TARSAN –
Thwaites-Amundsen Regional Survey and Network

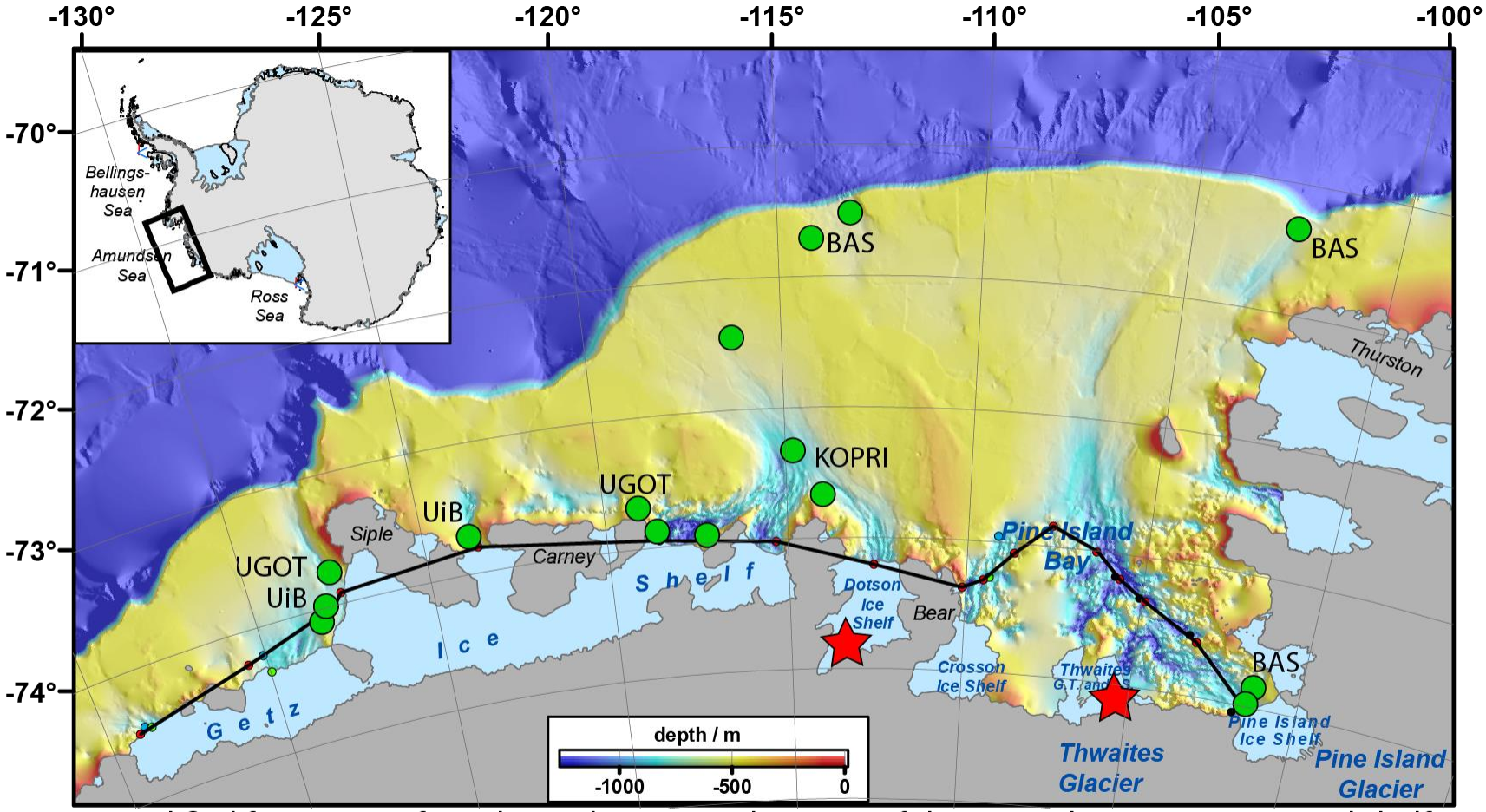


Figure 1: Modified from Fig 1 of Jacobs et al., 2012. Bathymetry of the Amundsen Sea continental shelf, with moorings (green dots) from BAS, KOPRI, and Universities of Gothenburg (UGOT) and Bergen (UiB). Red stars indicate the selected sites for AMIGOS-III (Fig 7). Black line is section shown in Figure 3.

AMIGOS-III: student-led redesign, instr. upgrades

TARSAN proposal

Table 1: AMIGOS-III Proposed Design Components

Structure, Power, and CPU

- •CPU: Student-designed single-board computer, ethernet, serial, and USB ports;
- •Iridium-NEXT modem and antenna;
- •10 cm tubular design, 2 m sections, total 6 m installed (1 m sub-surface, 5 m exposed);
- •Li batteries for winter; 4x100 amp-hr Pb gel-cells; 2 x 80 W solar panels.

Imaging: Surface /Sky condition

- •Camera system, station view mirror, flag line (not shown)

Weather / Climate

- •Vaisala WXT520 weather station, 2 m;
- •R. M. Young propeller wind-vector system at top of mast

Ice Motion and Strain Sensors

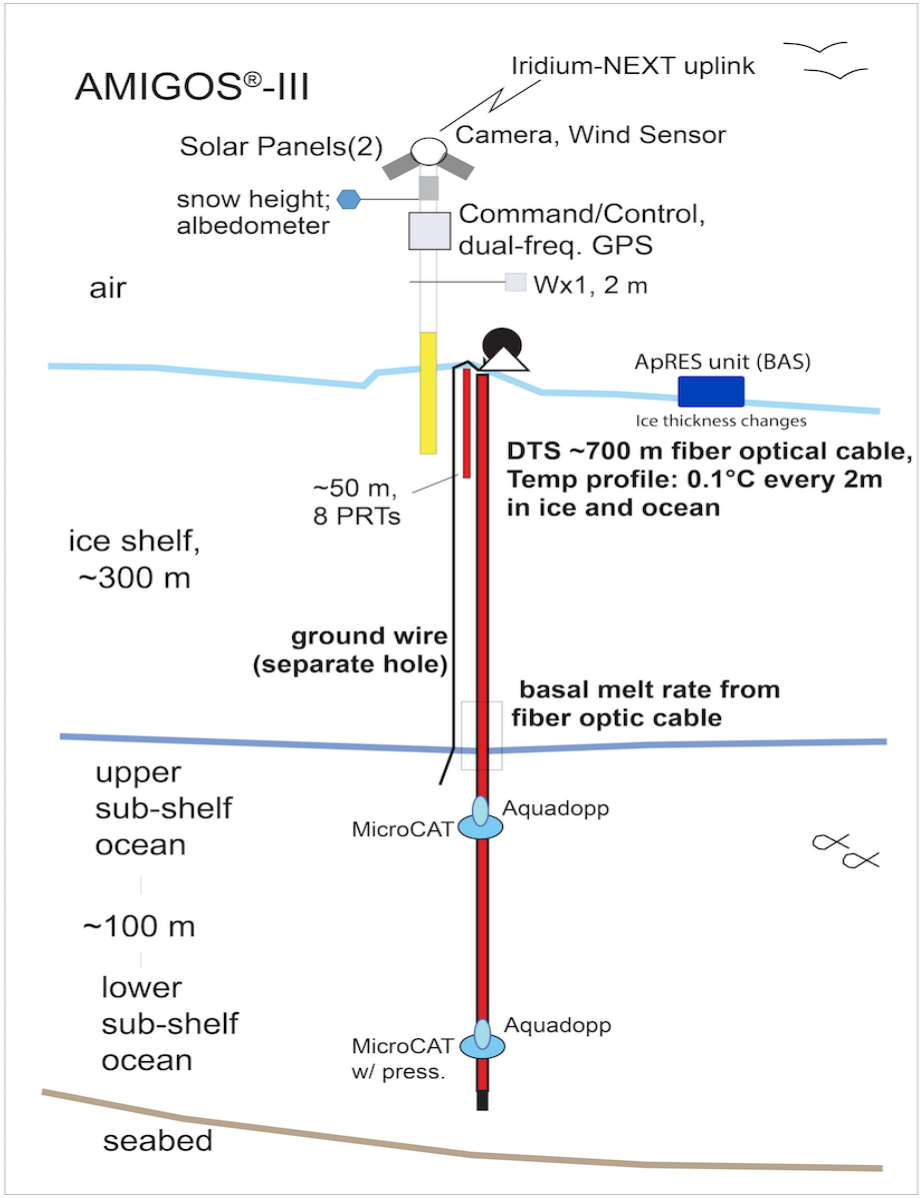
- •Dual-Frequency GPS – Topcon GRS-1 rcvr, PGA-1 ant.;

Snow-Firn Energy Balance Sensors

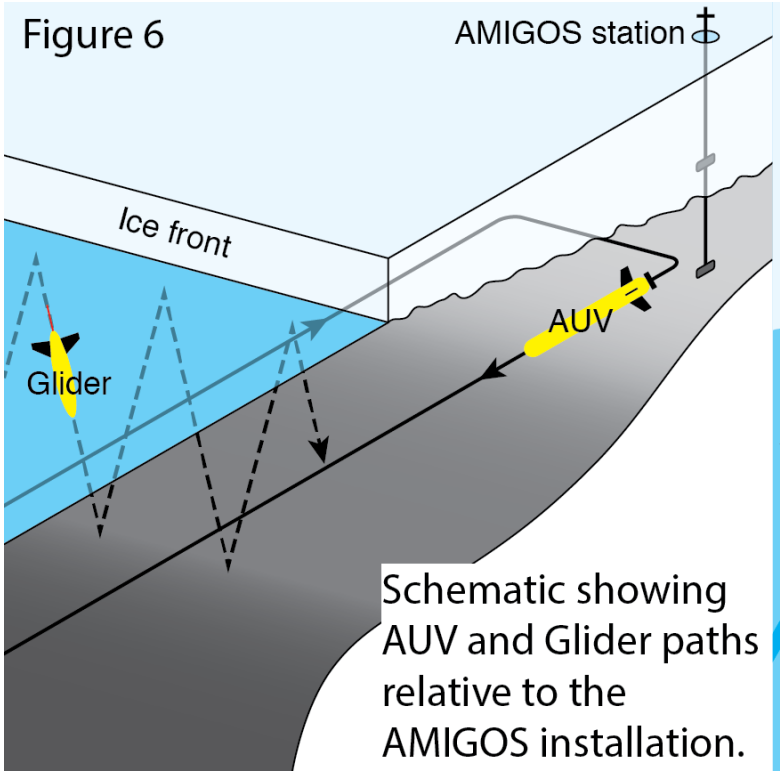
- •Albedometer (dual Apogee SP-212 all-sky lightmeters);
- • Campbell Scientific sonic snow-height sensor or similar
- •50-meter string, 8 PRT sensors.

Ice and Sub-Ice Ocean Sensors

- •DTS laser fiber optic cable thermal profiling system;
- •2 SeaBird MicroCAT SBE-37IMP CT sensors, 1 w/ press;
- •2 Nortek Aqua-Dopp Doppler current meters;



Integrating AMIGOS mooring with AUV and gliders *TARSAN proposal*



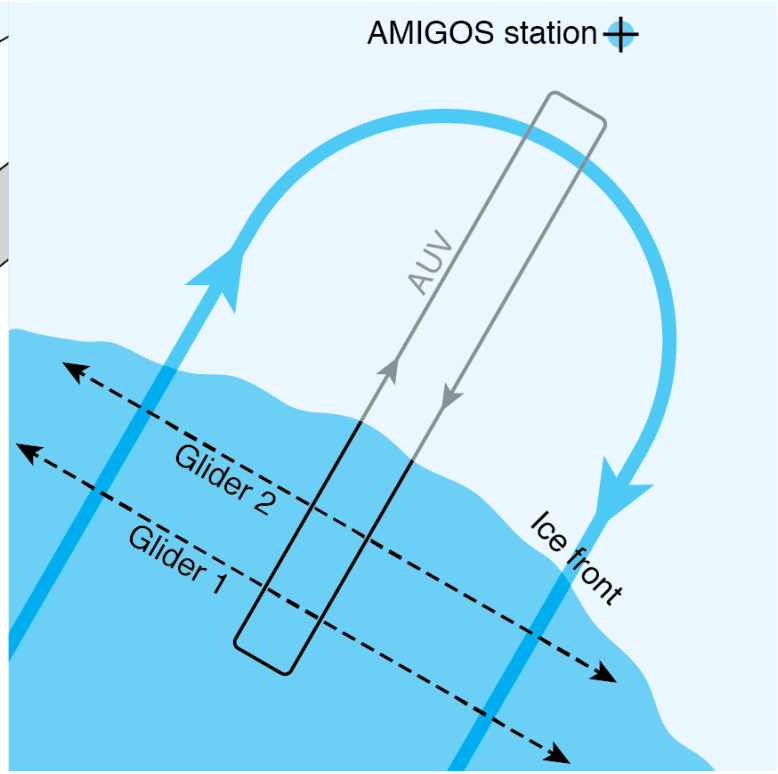
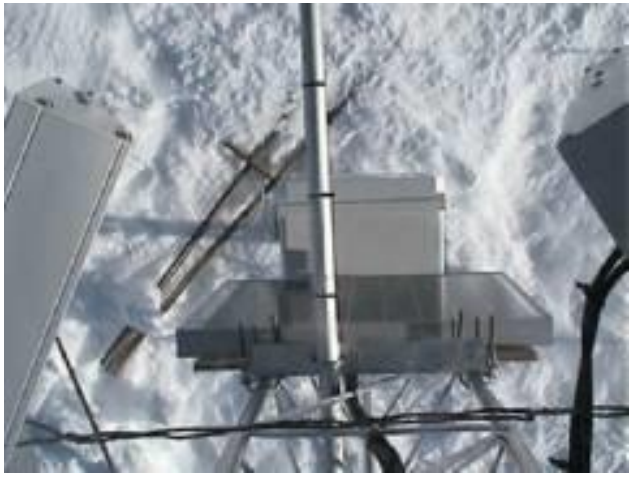


Photo by Martin Truffer, November 2010

Flask Glacier AMIGOS-3 image set





Scambos, Ross, et al., 2013 Annals of Glaciology

Integrating AMIGOS mooring with AUV and gliders *TARSAN proposal*

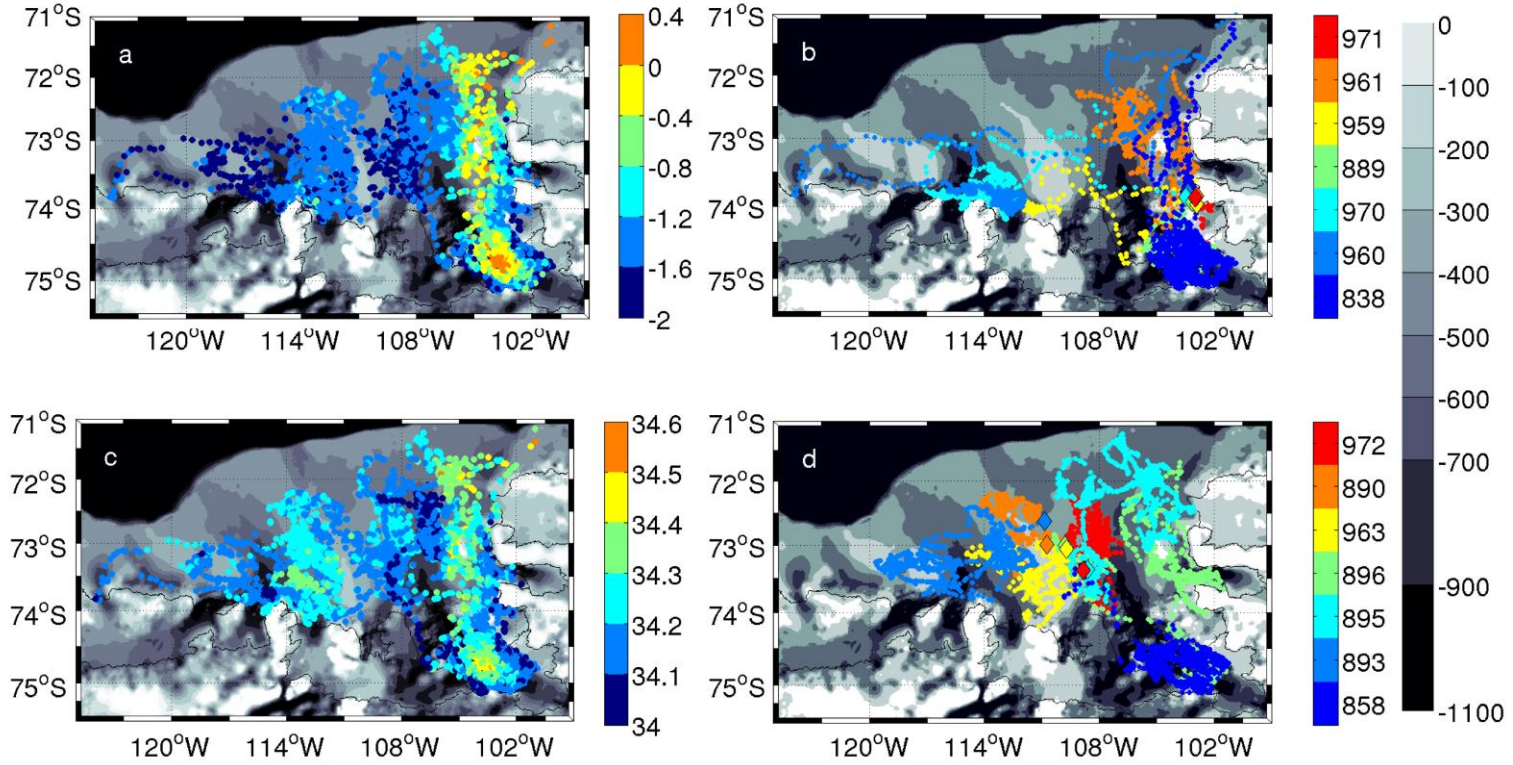


Figure 5. Seal tag data from 2014. (a) Potential temperature; (c) salinity at 300 m (Heywood et al., 2016); Tracks of (b) Elephant and (d) Weddell seals, diamonds are tagging location, colored dots are tag number.

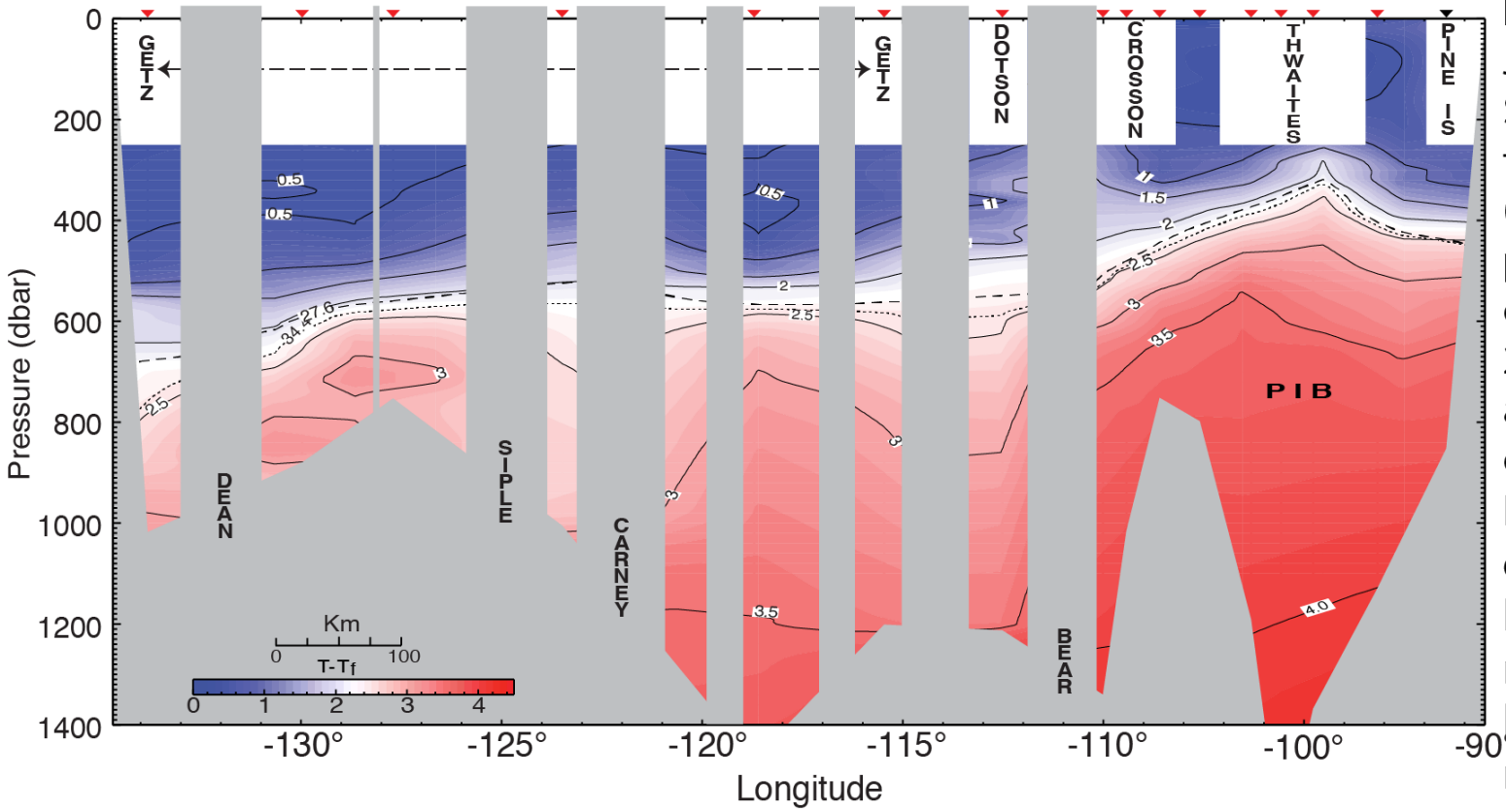
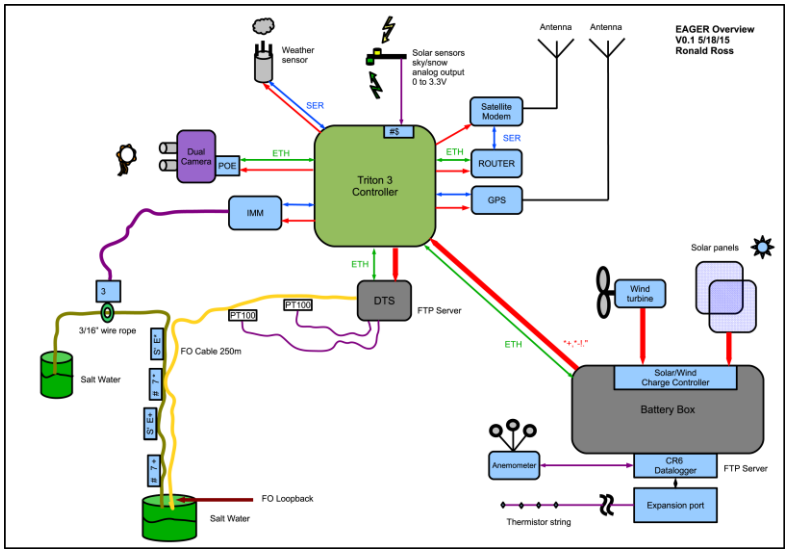


Figure 3: Fig 2 of Jacobs et al. 2012. Summary of temperature data (T above freezing point) for a series of 2007 and one 2009 CTD castings along the ice shelf edges (black line in Fig 1). Warmer ocean water with higher density marks the CDW layer in the region.


Eskimo


EAGER Overview
V0.1 5/18/15
Ronald Ross
Weather sensor
Solar sensors sky/snow analog output 0 to 3.3V
Antenna
Antenna
SER
Satellite Modem
#5
Dual Camera
POE
ETH
Triton 3 Controller
ROUTER
GPS
IMM
Solar panels
Wind turbine
DTS
FTP Server
PT100
PT100
3
3/16" wire rope
FO Cable 250m
Salt Water
Solar/Wind Charge Controller
Battery Box
Anemometer
CR6 Datalogger
FTP Server
Expansion port
Thermistor string
FO Loopback
Salt Water

AMIGOS System camera on Scar Inlet and Flask Glacier: accumulation pole movies

SCAR Inlet:

Near-zero net accumulation in 6 months;

Recent minor accumulation (10-20 cm)

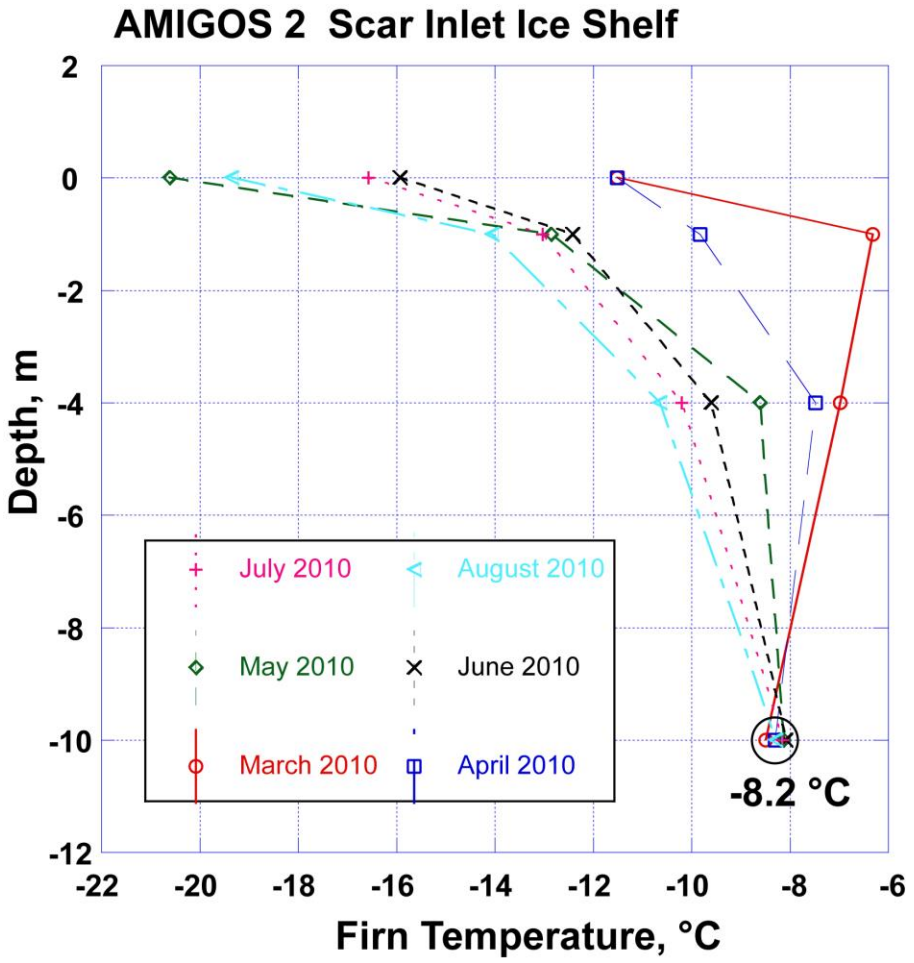
Flask Glacier:

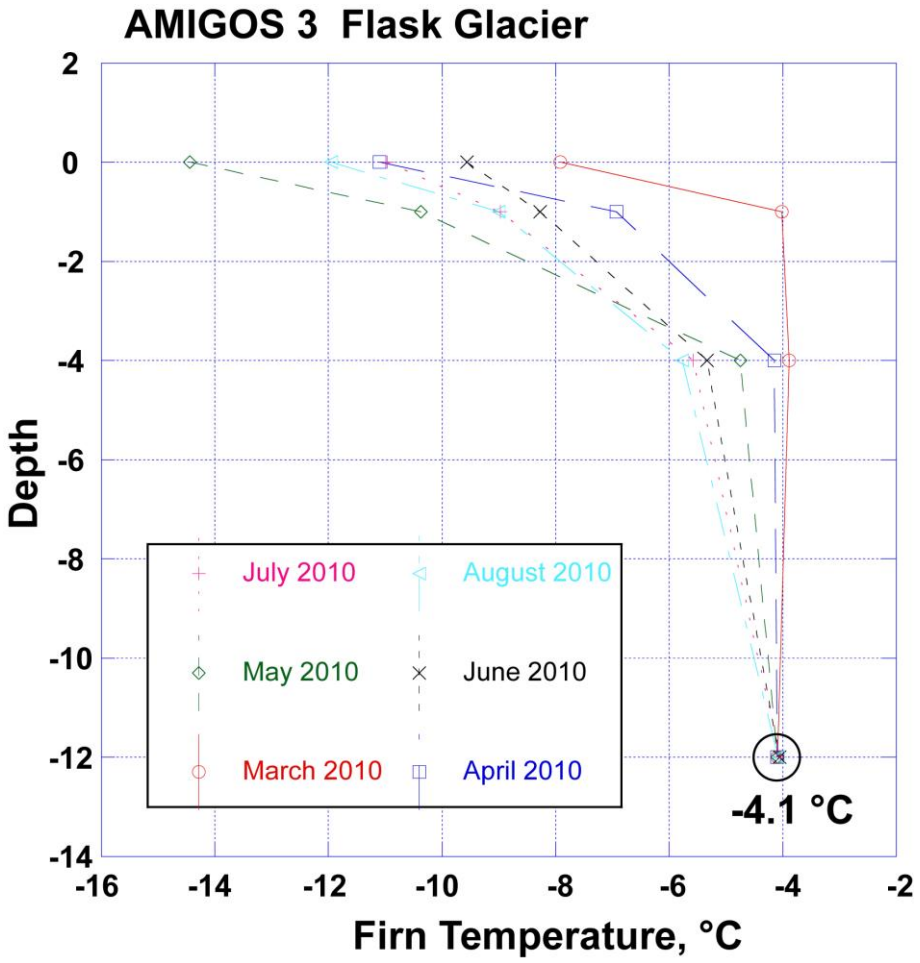
~0.7 m net accumulation in first 6 months;

Recent rapid accumulation of 1m (total 1.7 m)

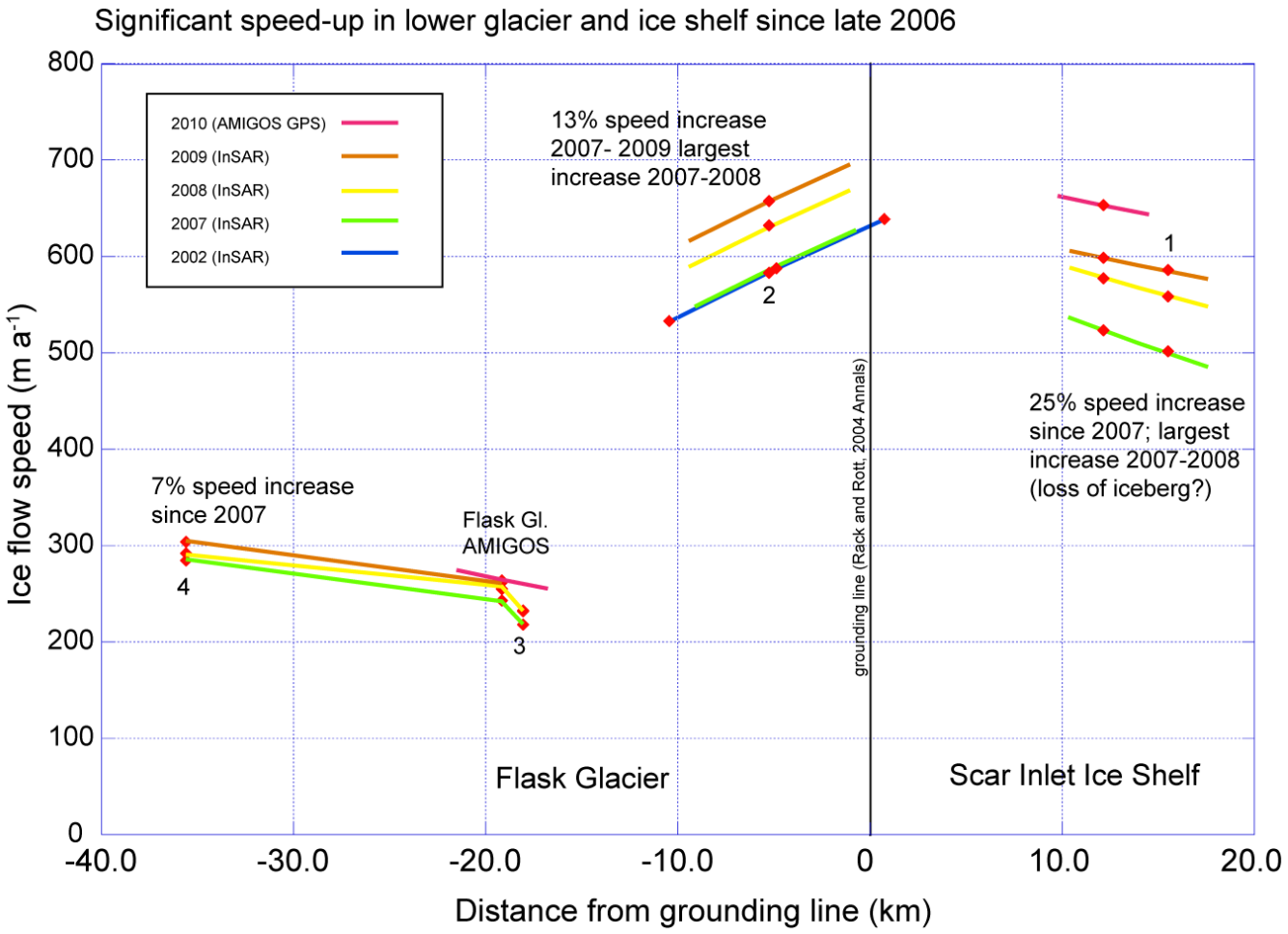
AMIGOS 2 and 3 Firn Temperature profiles:

Scar Inlet near the shelf stability limit; Flask is even warmer





AMIGOS and iceGPS sites in the Scar Inlet Area




SOUTHERN OCEAN
South Orkney Islands
Orcadas (Argentina)
Signy (U.K.)
Scotia Sea
Drake Passage
Capitán Arturo Prat (Chile)
General Bernardo O'Higgins (Chile)
Esperanza (Argentina)
Marambio (Argentina)
South Shetland Islands
Palmer (U.S.)
Faraday (U.K.)
Rothera (U.K.)
San Martin (Argentina)
Larsen Ice Shelf
Jason Peninsula
Alexander Island
Wilkins Ice Shelf
Antarctic Peninsula
Weddell Sea
Mount Jackson
Ronne Ice Shelf
Berkner Island
Filchner Ice Shelf
Recovery Glacier
Belgrano II (Argentina)
Coats Land
Halley (U.K.)
Brunt Ice Shelf
Lyddan Island
Stancomb-Wills Glacier
Cape Norvegia
Georg von Neumayer (Germany)
Sanae (South Africa)
Novolazarevskaya (Russian Federation)
Dronning Maud Land
Asuka (Japan)
Thorshavnheiane
Thyer Glacier
Mount Victor 2,588 m (8,491 ft)
Enderby Land
Syowa (Japan)
Molodezhnaya (Russian Federation)
Mount Elkins
Kemp Land
Mawson (Australia)
Mac. Robertson Land
Mount Menzies 3,355 m (11,007 ft)
Lambert Glacier
Lars Christensen Coast
Amery Ice Shelf
Cape Darnley
Mackenzie Bay
Zhongshan (China)
Davis (Australia)
West Ice Shelf
Drygalski Island
Philippi Glacier
Wilhelm II Land
Mirny (Russian Federation)
Davis Sea
Masson Island
Shackleton Ice Shelf
ANTARCTICA
Princess Elizabeth Land
Greater Antarctica
Amundsen-Scott (U.S.)
South Pole
Vostok (Russian Federation)
South Geomagnetic Pole
Support Force Glacier
Pensacola Mountains
Transantarctic Mountains
Vinson Massif 4,897 m (16,066 ft)
Ellsworth Land
Mount Seelig 3,022 m (9,915 ft)
Whitmore Mountains
Lesser Antarctica
Bellingshausen Sea
Peter I Island (Norway)
Thurston Island
Pine Island Glacier
Bear Peninsula
Marie Byrd Land
Amundsen Sea
Carney Island
Mount Sidley 4,181 m (13,717 ft)
Mount Siple 3,100 m (10,220 ft)
Russkaya (Russian Federation)
Beardmore Glacier
Mount Kirkpatrick 4,528 m (14,855 ft)
Nimrod Glacier
Mount Markham 4,351 m (14,275 ft)
Siple Coast
Ross Ice Shelf
Roosevelt Island
Mount Lister 4,026 m (13,208 ft)
Scott Base (New Zealand)
Mount Erebus 3,794 m (12,447 ft)
McMurdo Base (U.S.)
Edward VII Peninsula
Ross Sea
Coulman Island
Borchgrevink Coast
Victoria Land
Mount Minto 4,163 m (13,658 ft)
Cape Adare
Leningradskaya (Russian Federation)
George V Land
Terre Adélie
Dumont d'Urville (France)
Cape Gray
Cape Kellie
Dumont d'Urville Sea
Banzare Coast
Sabrina Coast
Wilkes Land
Casey (Australia)
Vincennes Bay
Cape Poinsett
Limit of summer pack ice
Limit of winter pack ice
Antarctic Circle