The challenges of changing technologies for the USAP AWS program

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The Vision in the late 1970's

- AWS network –circa late 1970's
- "State-of-the-art" was

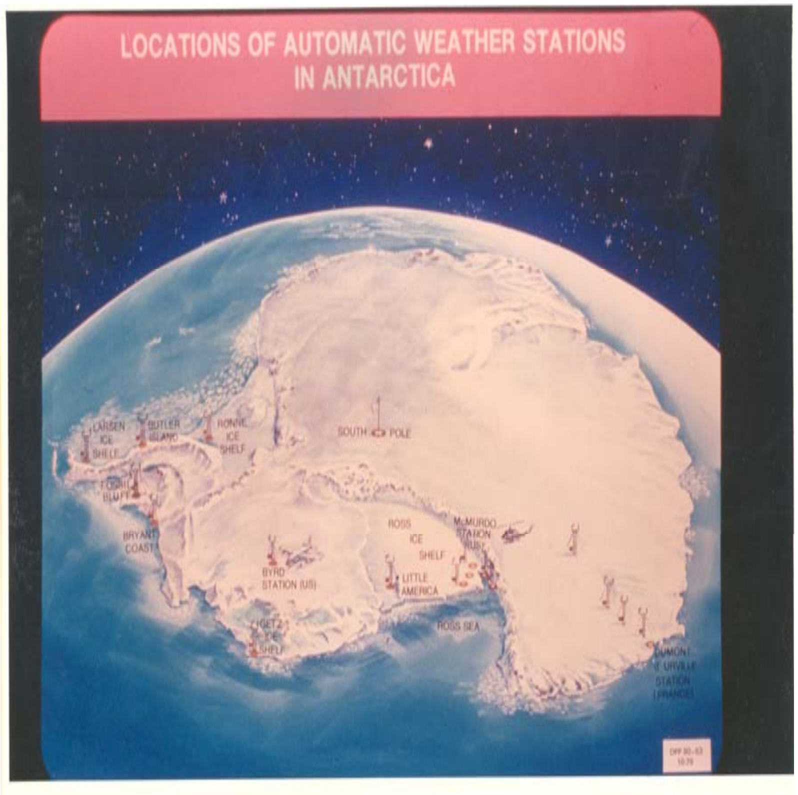
  Low power CMOS ICs

  Cold temperature operation

  Argos telemetry (satellites)

  Solar panels

  Batteries (gel cell)



AWS program transferred in 1980

- The first AWS were developed at the Center for Radar Astronomy, Stanford University
- Dr. Alan Petersen
- First version used the Nimbus satellites
- A later version was developed for the NOAA series of satellites making use of the Argos System.
- Dr. Charles Stearns became the PI for the AWS program here at the University of Wisconsin.

UNIVERSITY OF WISCONSIN–MADISON

Research Administration–Financial

Telephone 608-262-3822

750 University Avenue
Madison, Wisconsin 53706

June 9, 1980

Reply to Attn. of
Proposal #17402

Central Processing Section
National Science Foundation
Washington, D.C. 20550

SUBJECT: Revision of Proposal DPP 7925040

C O P Y

Gentlemen:

Submitted herewith, in behalf of the Board of Regents of the University of Wisconsin System, is an application requesting $147,178 for the period June 30, 1980 through June 20, 1981 in support of research entitled "The Collection and Analysis of Antarctic Automatic Weather Station Data" under the direction of Dr. Charles R. Stearns of the Department of Meteorology.

This proposal has been administratively approved and is submitted for your consideration. Will you please keep this office advised as developments occur with regard to this application.

Please use the above-referenced proposal number in any future correspondence.

Sincerely,

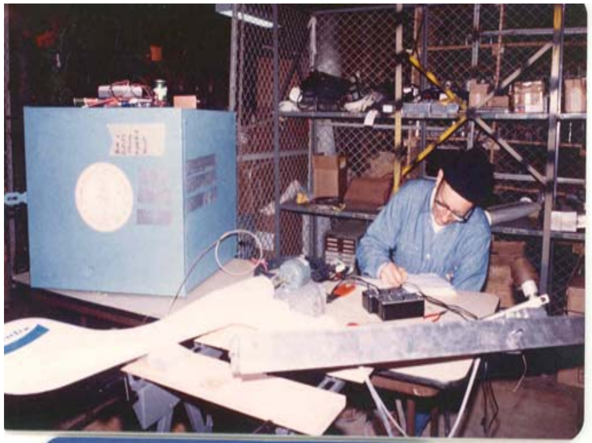
Robert W. Erickson
Director

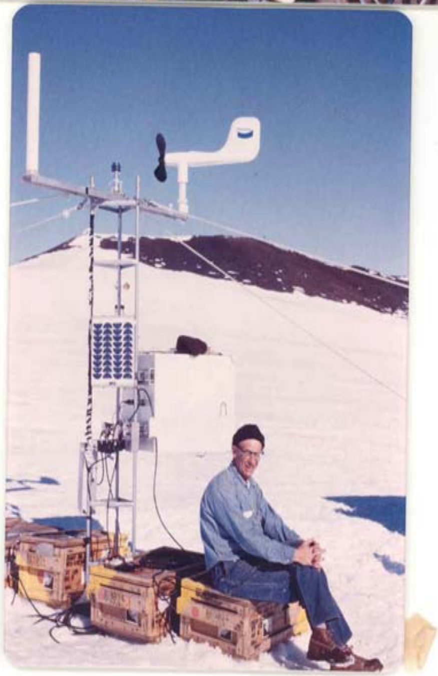
RWE:GLP:ts
Enclosure

cc: Dean R.B. Doremus
Dr. Charles R. Stearns
Ch., Dept. of Meteorology
Dir., Federal/State Relations

Prime lab space in the early 1980's

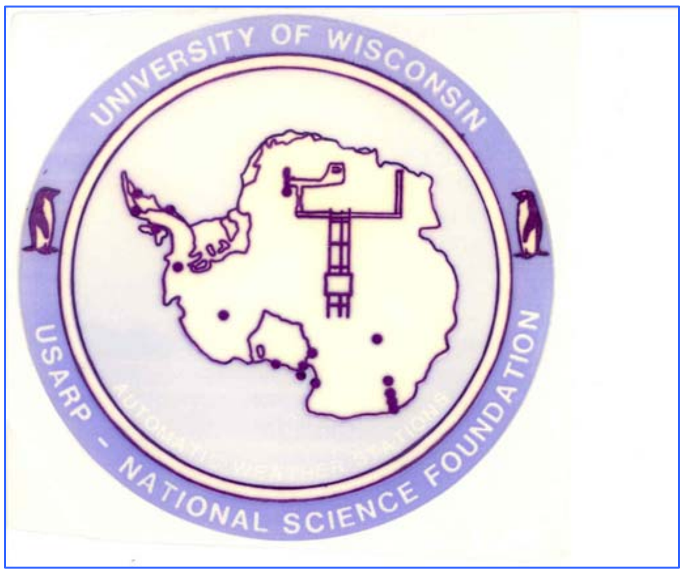
- Top photo shows Dr. Charles R. Stearns in our "lab" – a storage cage in "Annex"
- The lower photo show Dr. Stearns at our "test" AWS site about 1 mile from Mcmurdo Station.
- The AWS program was at this time under the same program manager as the USARP Astronomy , Dr. Ben Fogle.
- The Earth's atmosphere extended out to the "edge" of the universe.
- At this time we had to make do with whatever resources were given to us.

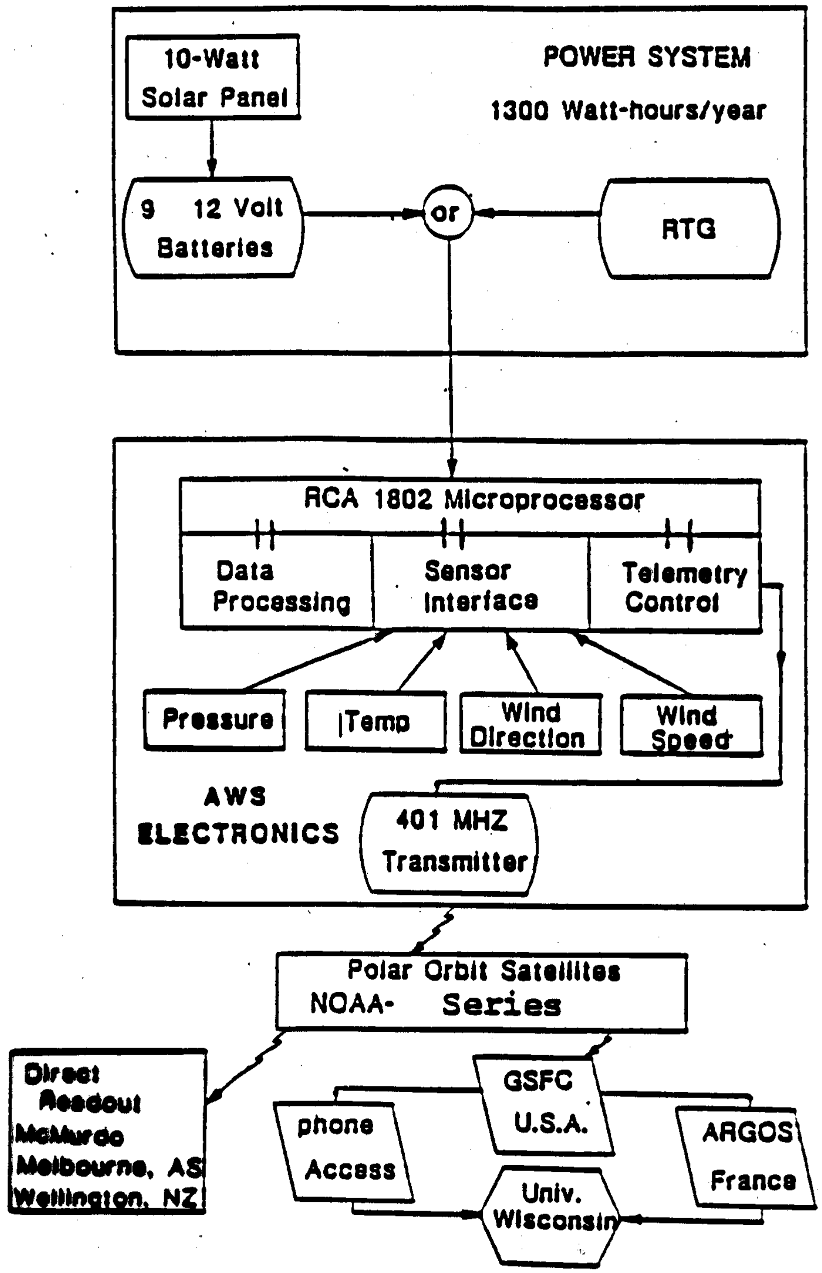




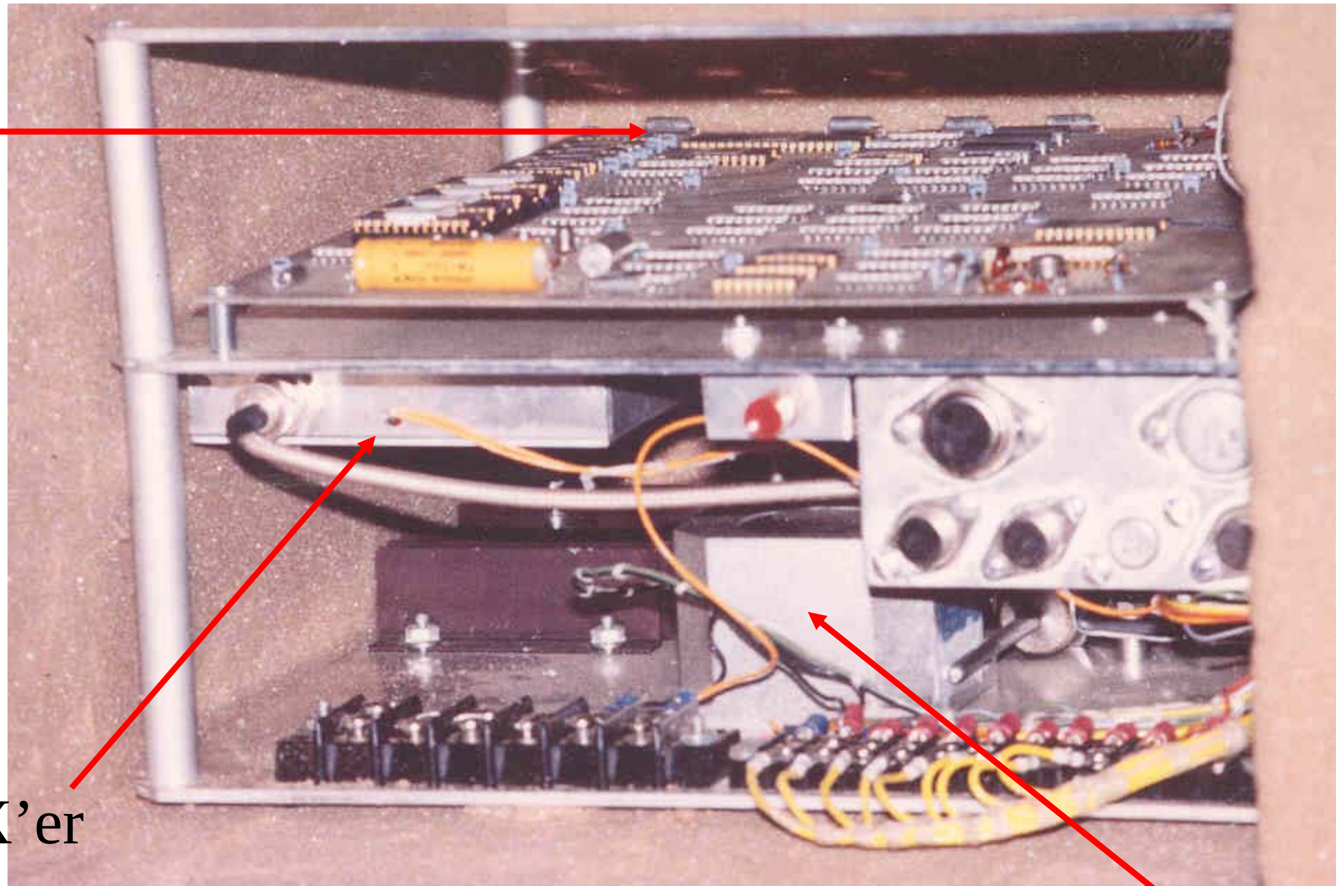
The AWS system

- The Argos system allowed for 256 bits (32 bytes) of data
- Some AWS were to be powered by Radioactive Thermo-electric generators (RTG) or batteries.
- The 1802 Microprocessor was also used on various NASA spacecraft.
- Used low power CMOS integrated circuits. Power consumption is a nominal 1300 watt-hours per year





State of the Art – 1978



AWS2A Model of the Stanford AWS

AWS in early 1980's

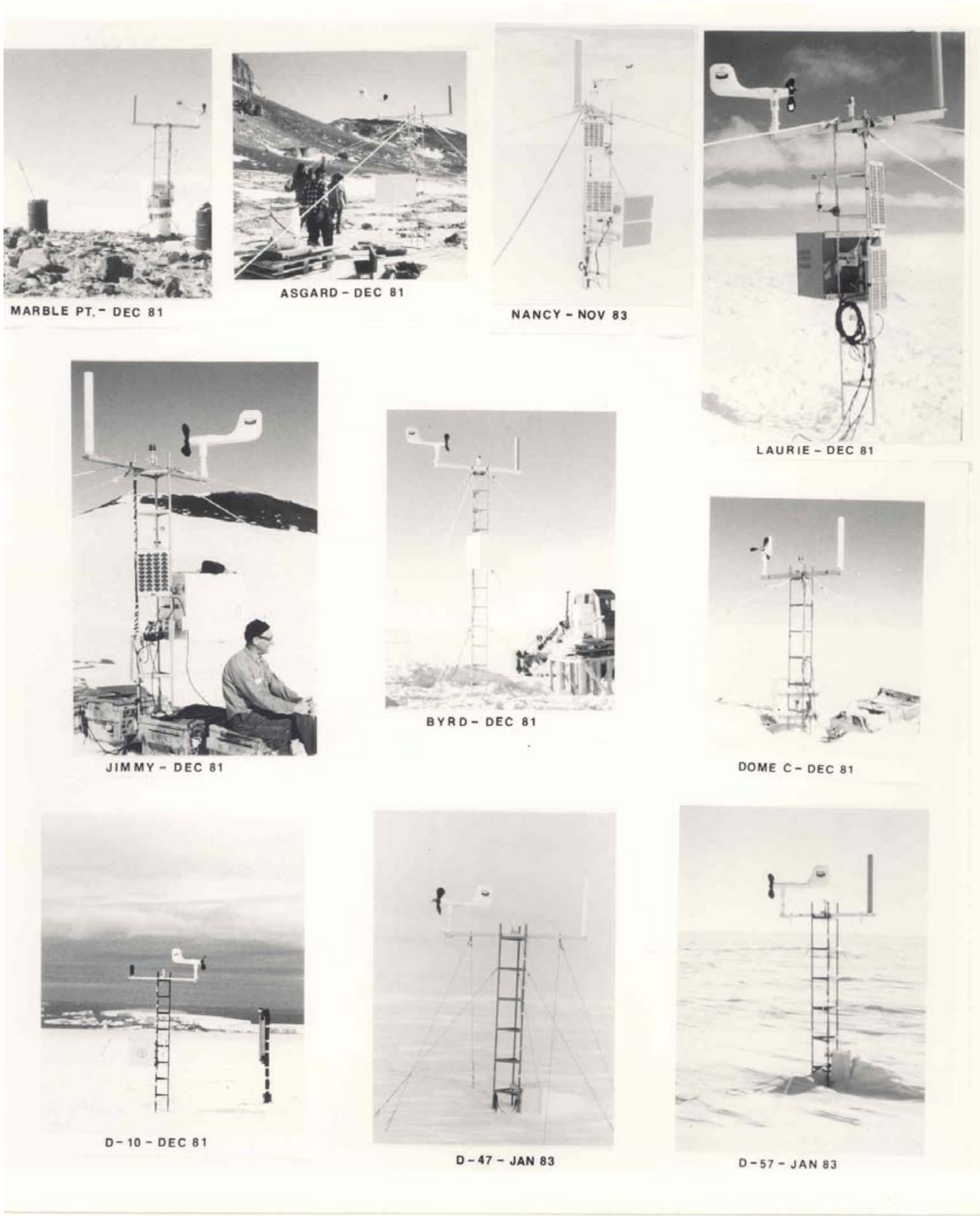
The high tech sensors –

Pressure – Paroscientific gauge

Temperature – PRT (ours)

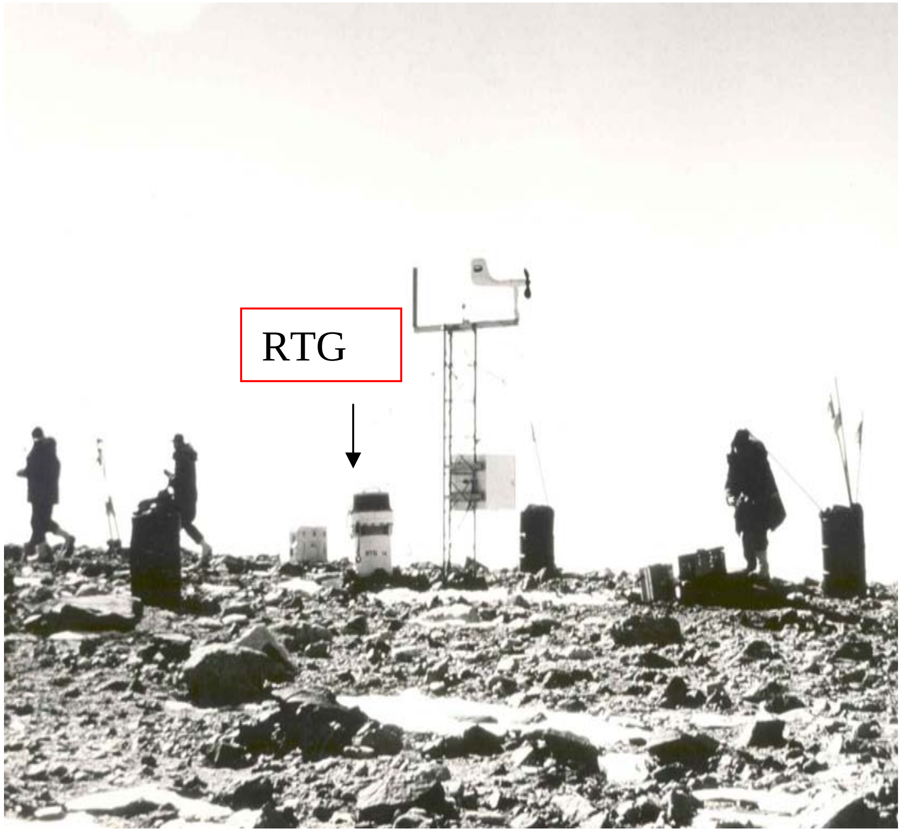
Wind – Belfort Aerovane

Humidity – Vaisala HMP14



An original RTG powered AWS

- The AWS at Marble Point
- The radioactive thermoelcetric generator (RTG) provided enough power to heat the large 8 cubic foot AWS enclosure.
- Unlike Marble Point, the AWS sites powered by RTG's on the Ross Ice Shelf had to be dug up every few years.
- Their weight (~one ton) was at about the limit for the UH-1N and it was an all day project to raise them above the snow surface.



AWS2A specs

- RCA 1802 microprocessor (Voyager etc)
  CMOS, Low temp (–55C), SOS , Static …
- On board ROM (EPROM) – 2KB
- On board RAM (SRAM) – 256 Bytes
- Operating system – RCA 1802 based Interpreter
- Operating program could be changed in field
- 8-bit two-cycle instructions – effectively 16 bit
- CMOS 4000 series IC s for other circuits

AWS2A Measurements

- Pressure – counts for 5.120 seconds (two counts)
- 1 MHz reference oscillator for 0.1 mb accuracy
- Temperature - Ratiometric with precision resistor
- Accuracy of +/- 0.5 C over temperature range
- Wind speed to 0.25 meters per second
- Wind direction to +/- 1.5 Degrees
- Humidity (HMP14) +/- 5% at best

AWS2 data forma

- Only 256 Bytes per transmission!
- AWS data format revised by George Weidner in 1983/1984.
- Only one checksum was used for the entire data transmission, thus freeing up ¼ of the data stream.
- Typical overpass of satelli allows for nominal 1-5 transmissions per pass.
- For snow temperature profile alternating data transmissions were devise in 1989.

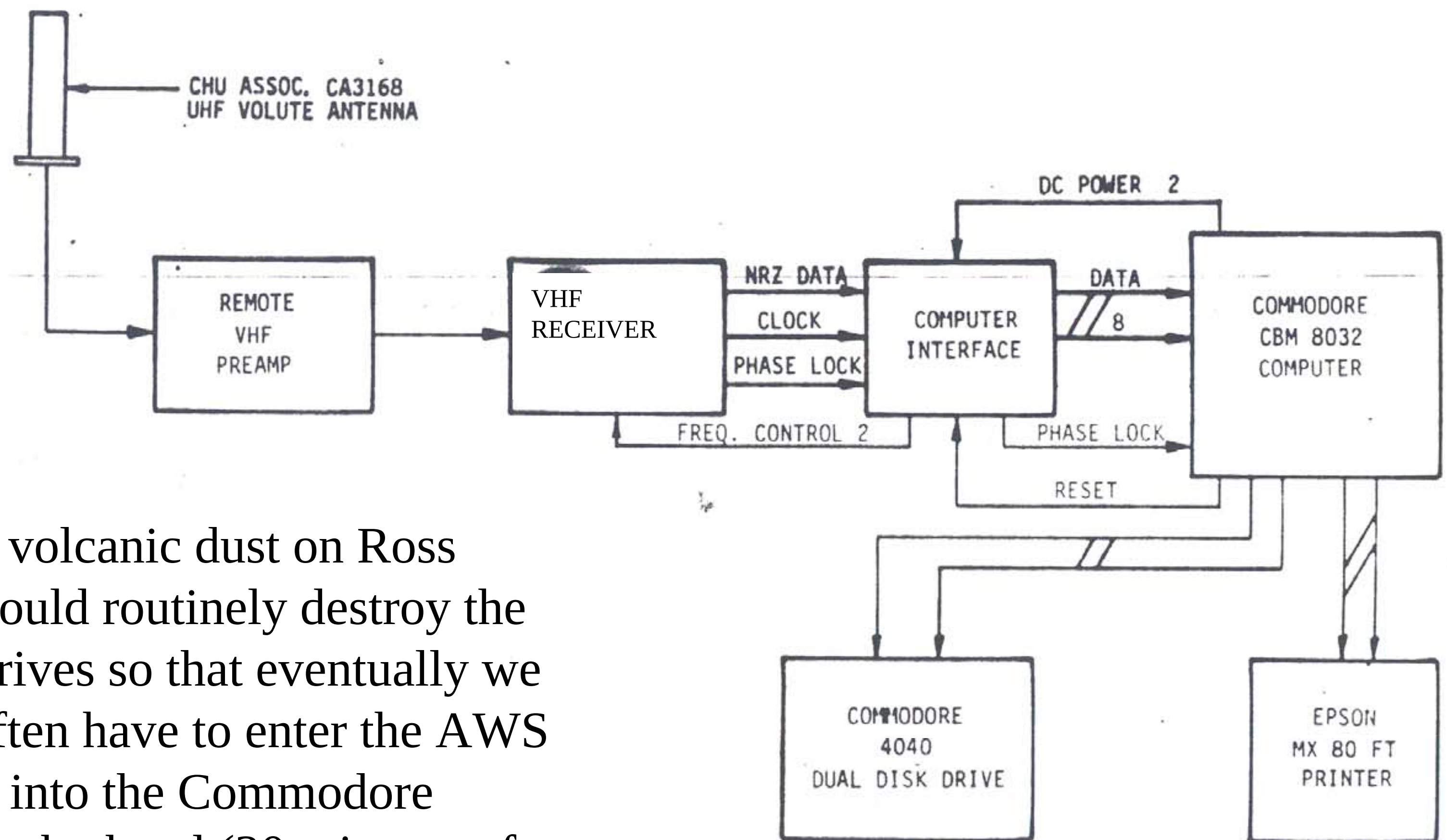
8	16	24	32
Air Temperature	Internal Temperature		CRC
Atmospheric Pressure		Air Pressure (0.-10)	CRC
Wind speed	Wind Direction	Humidity	CRC
Air Temp (0, -10)	Air Temp (-10,-20)	Air Temp (-20,-30)	Air Temp (-30,-40)	CRC
Internal Temp (0,-10)	Internal Temp (-10,-20)	Internal Temp (-20,-30)	Internal Temp (-30,-40)	CRC
Air Pressure (-10,-20)	Air Pressure (-20,-30)	Air Pressure (-30,-40)	CRC
Mean Wind Speed	Vector Wind Direction	Cycle Count	CRC
Voltage check	Battery Voltage	Voltage check	CRC

Table 4.2a. Bit map for the data transmission for the AWS2A version of the AWS.

8	16	24	32
Air Temperature (0)	Internal Temperature (0)		Delta – T (0)
Atmospheric Pressure (0)		Air Pressure change (0,-10)	Humidity (0)
Wind speed (0)	Wind Direction (0)	Wind Speed (0,-10)	Wind Direction (0-10)
Air Temp Change (0,-10)	Air Temp Change (-10,-20)	Air Temp Change (-20,-30)	Air Temp Change (-30,-40)
Wind speed (-10,-20)	Wind Direction (-10,-20)	Wind speed (-20,-30)	Wind Direction (-20,-30)
Air pressure change (-10,-20)	Air pressure change (-20,-30)	Air pressure change (-30,-40)	Humidity (-10,-20)
Wind speed (-30,-40)	Wind Direction (-30,-40)	Cycle Count	Humidity (-30,-40)
Delta-T change (-10,-20)	Delta-T Change (-30,-40)	Battery Voltage	CRC

Table 4.2b. Bit map for the data transmission of the AWS2B version of the AWS.

AWS data acquisition circa 1985

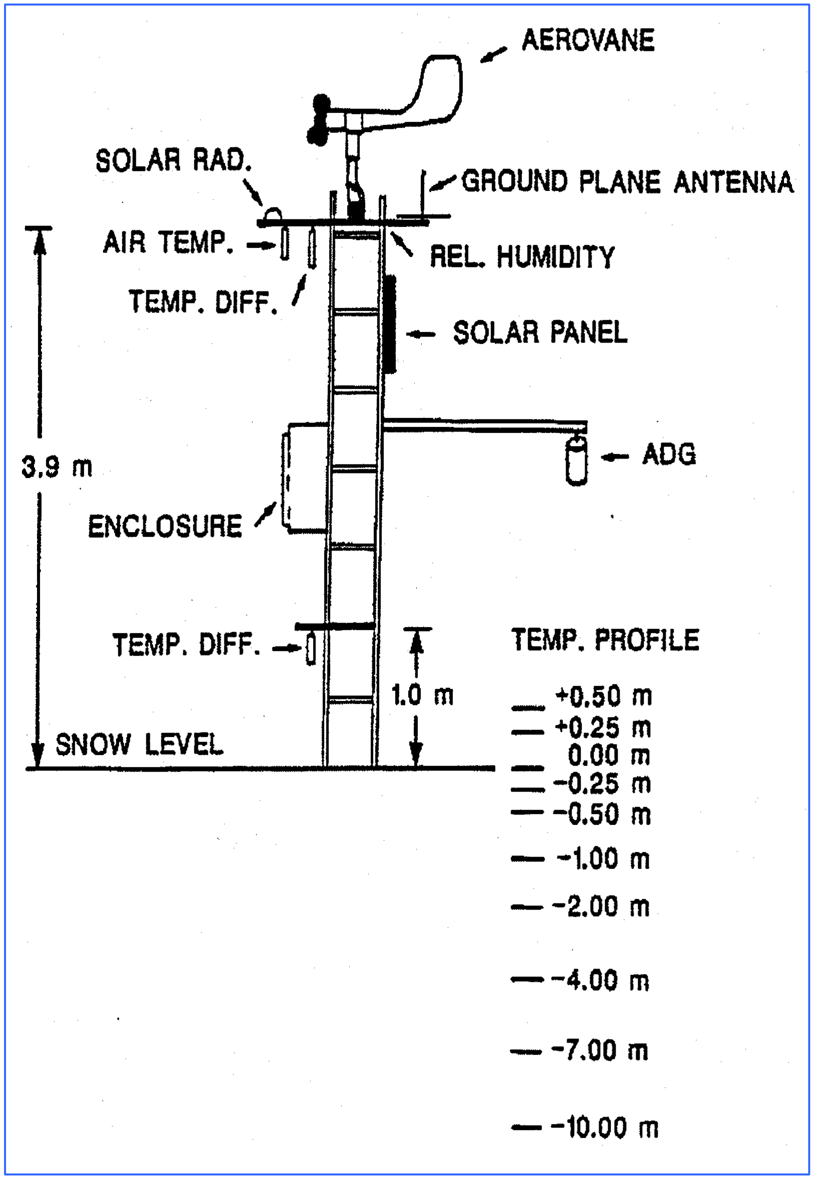


The fine volcanic dust on Ross Island would routinely destroy the floppy drives so that eventually we would often have to enter the AWS program into the Commodore Computer by hand (30 minutes of no typos).

FIG 1 ARGOS SYSTEM VHF LOCAL USER TERMINAL BLOCK DIAGRAM

The AWS2B version

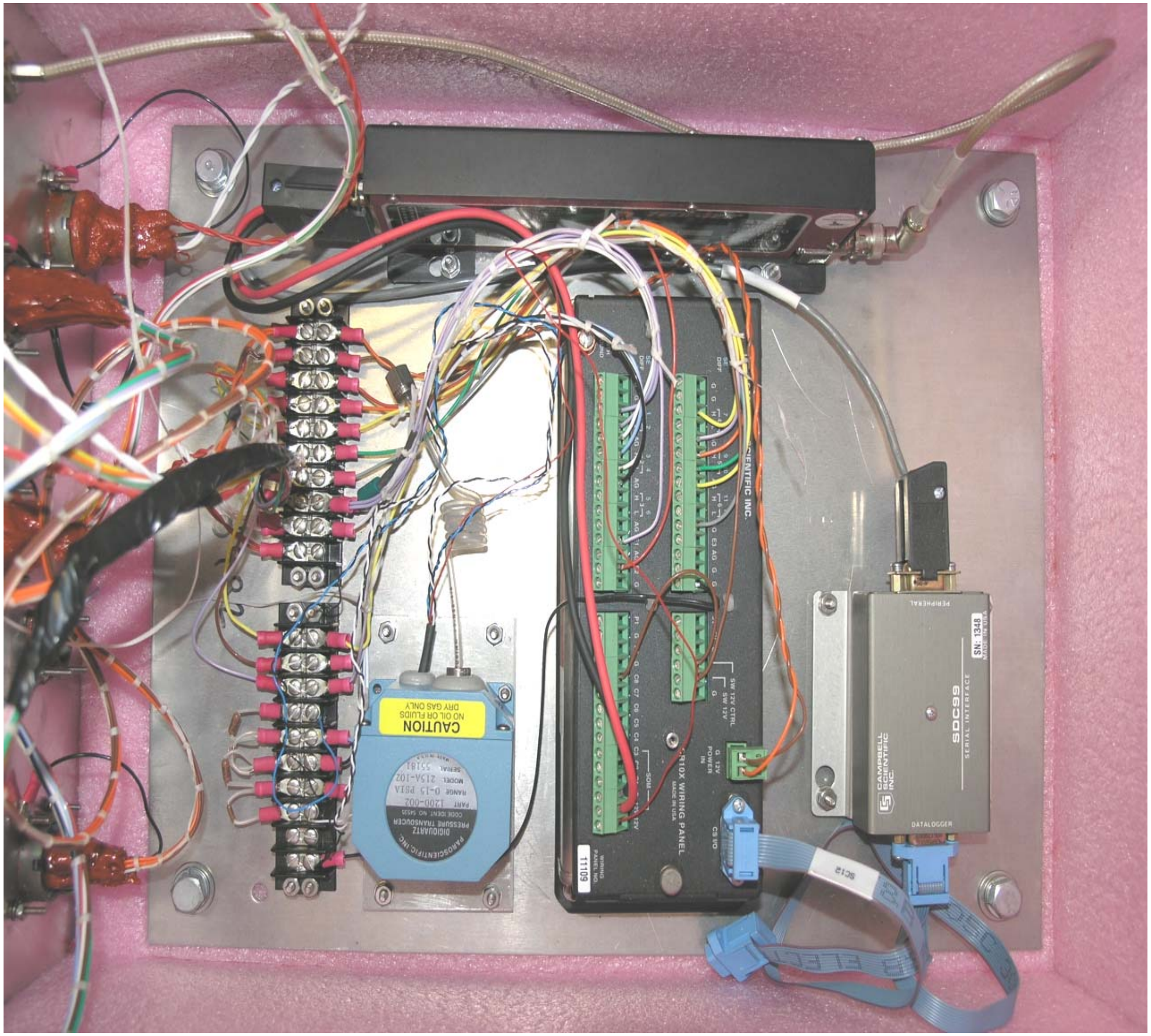
- The UW AWS2B as it was designed in the mid 1980's and is in use today.
- It also included an acoustic depth gauge (ADG) that measures the distance to the snow surface, thereby giving a measurement of net snow accumulation.
- An amplifier board was designed in 1980 to enable measurement snow temperature profiles from thermocouples.



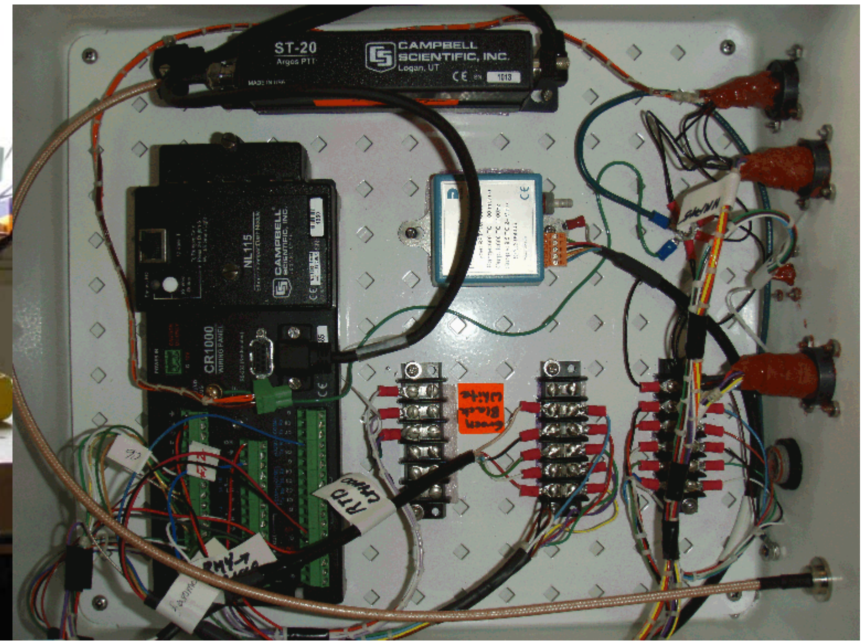
AWS based on CR10X used on Icebergs

- In 1999 we first the used Campbell Scientific, Inc. CR10X data logger as the controller for the AWS systems.
- This shows one of the CR10X based AWS on one of the large icebergs that calved off the Ross Ice Shelf in 2000.
- Allowed for storage on various mediums – several MB

The AWS – CR10X electronics



AWS CR1000 replaced CR10X in 2005



CR1000 increased on site data storage using a flash card to 2 GB

And can use a Telonics ST-20 (and soon to be ST 21) transmitter.

Sensors

- Wind sensors
- Bendix Aerovane 1978 – 1992*
- RM Young 05103 1992 – present
- High wind speed 1992 – present (no longer available)

* Bendix sold meteorological instruments to Belfort in the 1980’s. Quality became an issue. Price is now much more than RM Young model

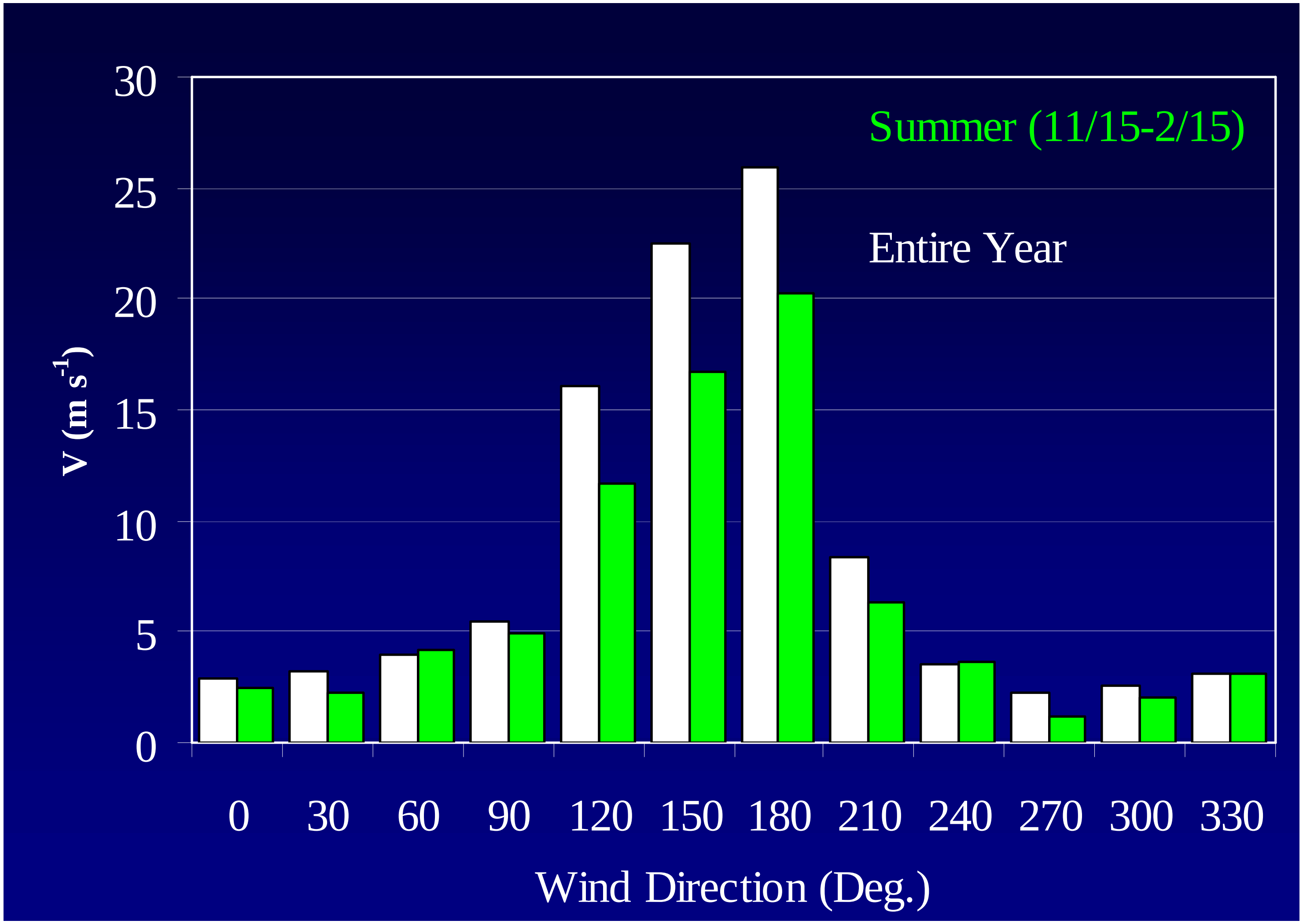
High wind speed version of AWS

- This AWS site had the high wind speed system developed by Phil Taylor (Taylor Scientific).
- Winds at the sites along the Adelie Coast would exceed 40 ms^{-1} for up to 48 hours.
- The Bendix aerovanes would last maybe on year at these sites.
- The high wind system has lasted up to 4 years.

Katabatic Winds

Parish,2005

Cape Denison 1995



Temperature measurements

- Air/snow temperature and internal temperature -

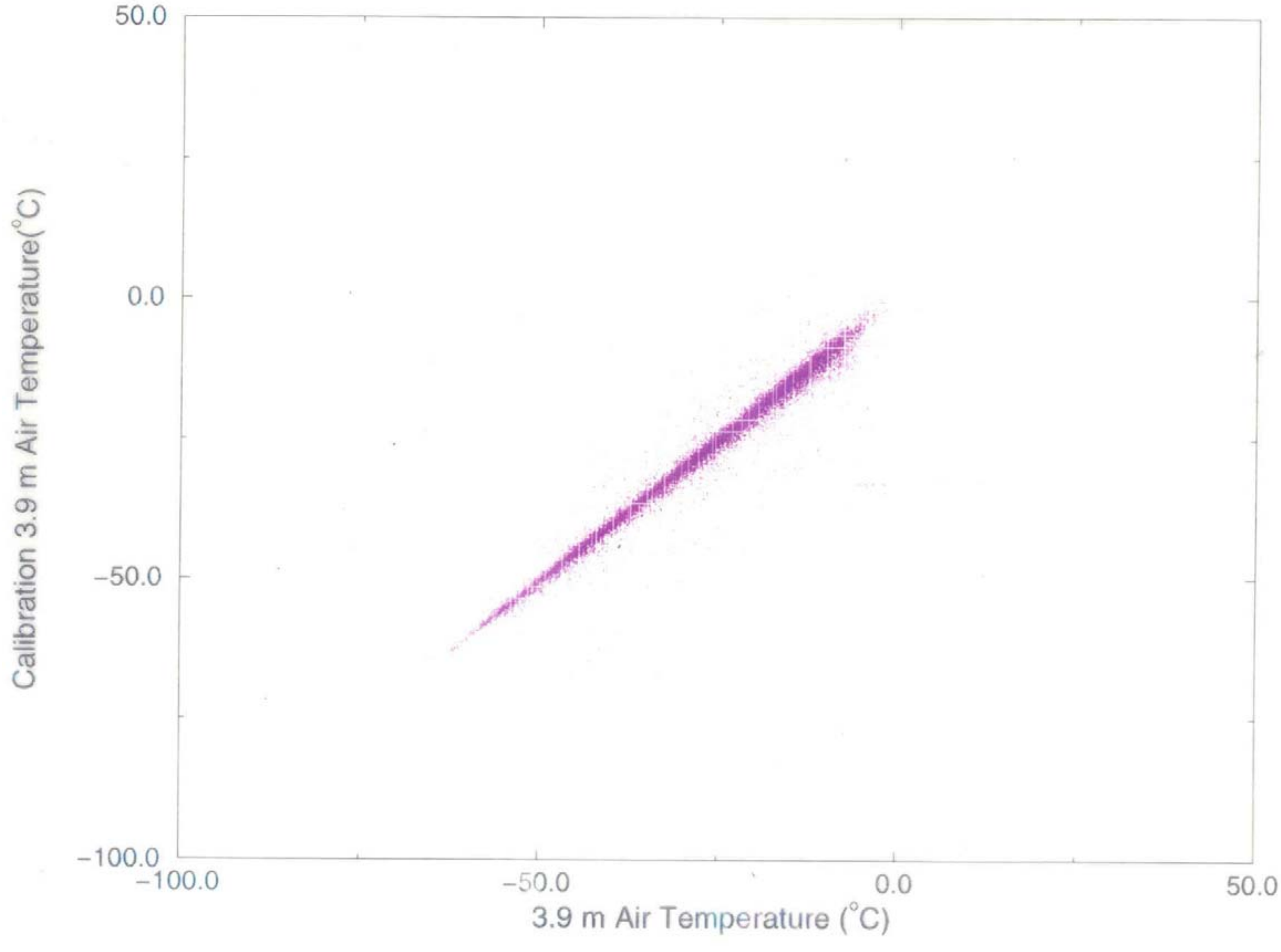
  Weed 1000 ohm platinum resistance Thermometers

  Two wire modified half-bridge circuit that is calibrated with two precision resistors.   A ratio-metric measurement is taken with accuracy of +/- 0.5 C over the –40 to 20 C range.
- Snow profile measurement -

  copper constantan thermocouple , two or four junctions measured by an in house amplifier circuit

  results were very good for profile measurements.

Temperature data validation



Pressure measurements

- **Paroscientific Gauge 1978 - present**
- 0.01% Accuracy
- 0.0001% Resolution
- Low Power Consumption
- High Stability and Reliability
- Fully Calibrated and Characterized Quartz Crystal Frequency Outputs
- NIST Traceable - ISO 9001:2000 Quality System

- Also using the Campbell Scientific Vaisala gauges at selected sites
- **Total Accuracy1:**
- ±0.3 mb @ +20°C
- ±0.6 mb @ 0° to 40°C
- ±1.0 mb @ -20° to +45°C
- ±1.5 mb @ -40° to +60°C

Humidity

- Vaisala series of humidity probes
- HMP 14 1979-1982
- HMP 31UT 1983-1989
- HMP 35A 1989-1999
- HMP 45A/D 1999-2009
- HMP155 2009 –

- Each model improved on performance. Recalibrated a HMP35A deployed on Ross Ice Shelf for three years … within 2% of original calibration.

HMP45

•RH Measuring range: 0.8 to 100% RH
•RH Output scale 0 to 100% RH equals 0 to 1 VDC
•RH Accuracy at +20 C against factory references: +/-1% RH
•Field calibration against references: +/-2% RH (0 to 90 %RH); +/-3 %RH (90 to 100% RH)
•RH Typical long-term stability:< 1% RH / year
•RH Temperature dependence: +/-0.05% RH/ C
•RH Response time (90% at +20 C): 10s with membrane filter

Acoustic Depth gauges

- Campbell Scientifics models since original
- Belfort ADG 1987-1989
- UDG 01 1989-1994
- SR50 1994 - present
- SR50A 2007 - present

•Power Requirements: 9-16 Vdc

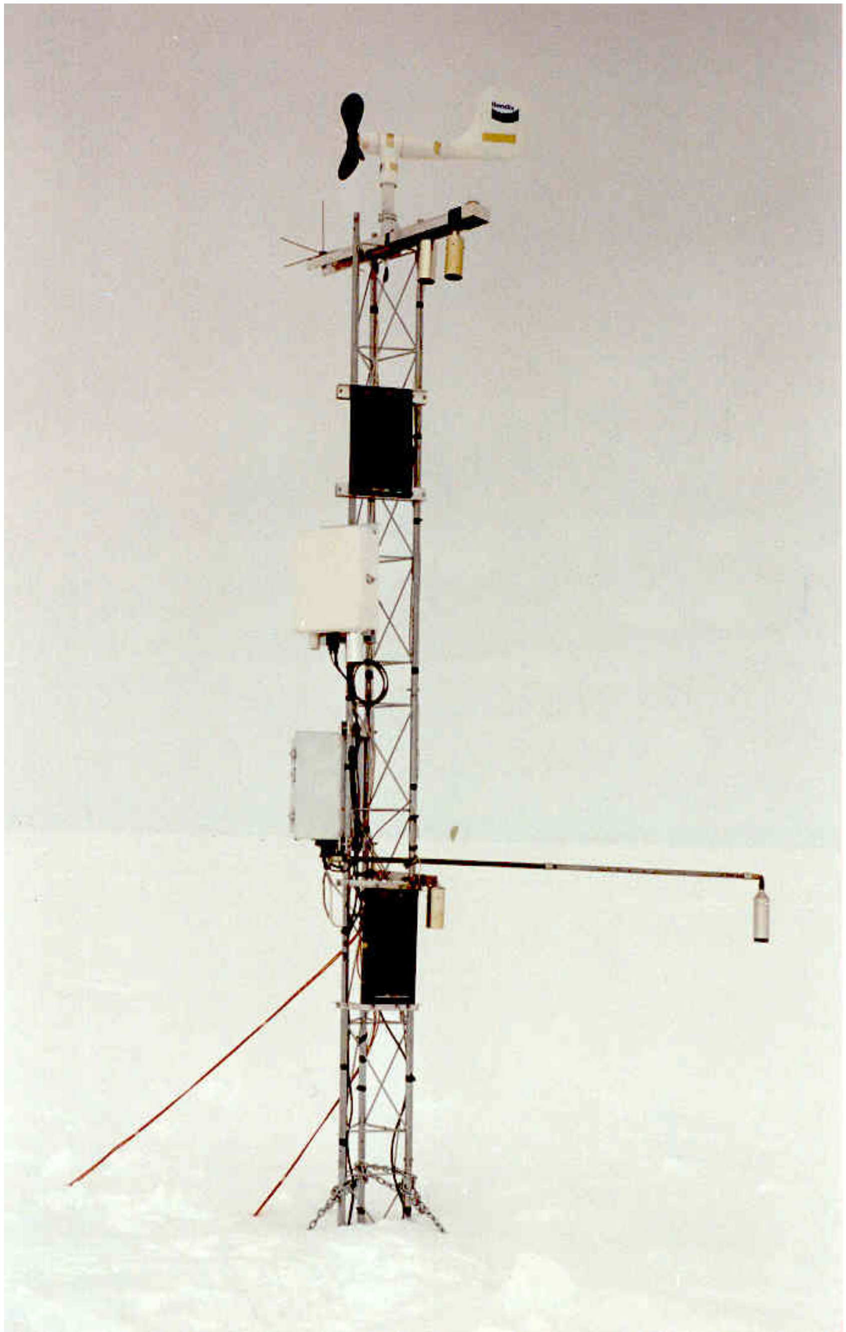
•Measurement Time: 0.6 seconds typical

•Measurement Range: 1.6 to 32.8 ft (0.5 to 10 m)

•Accuracy: ±0.4" (1 cm) or 0.4% of distance to target whichever is greatest

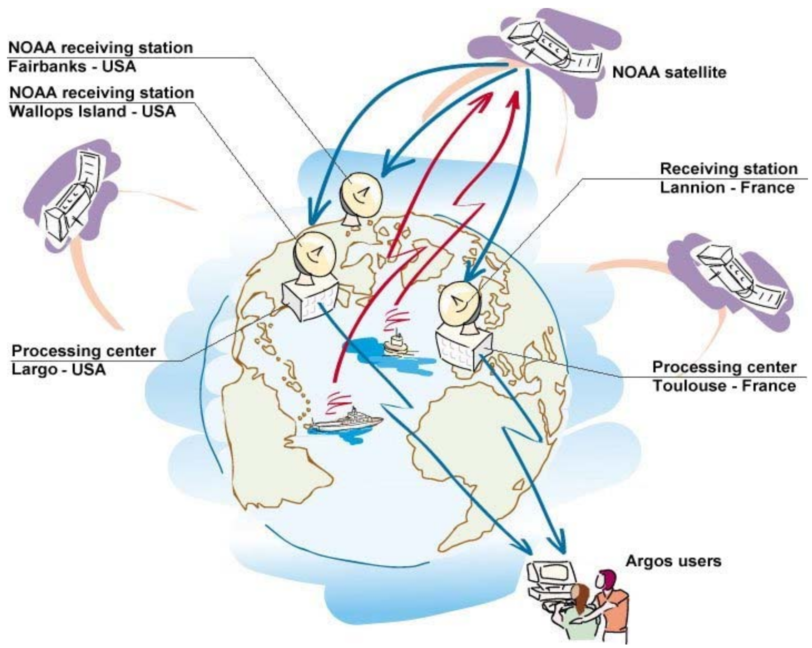
•Operating Temperature: -45° to +50°C

AWS with snow profile and ADG

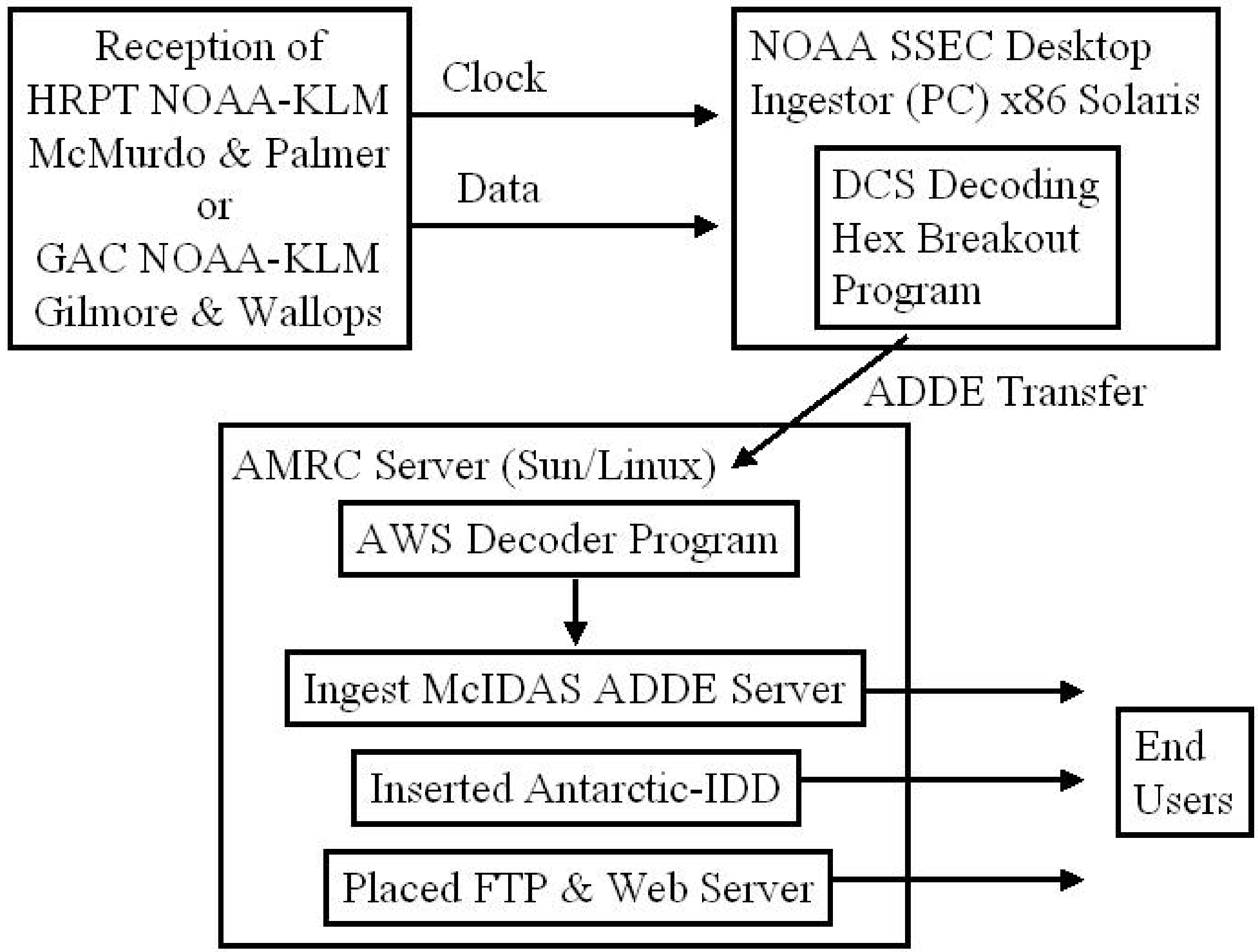


Telemetry

- We have always used the Argos System to transmit data.
- Data link is one way.
- Limited bandwidth of 256 bits of data.
- Has had a remarkable record.
- Argos is moving to a two-way higher bandwidth (2KB) Argos-3 system
- Other system are in available – e.g. Iridium

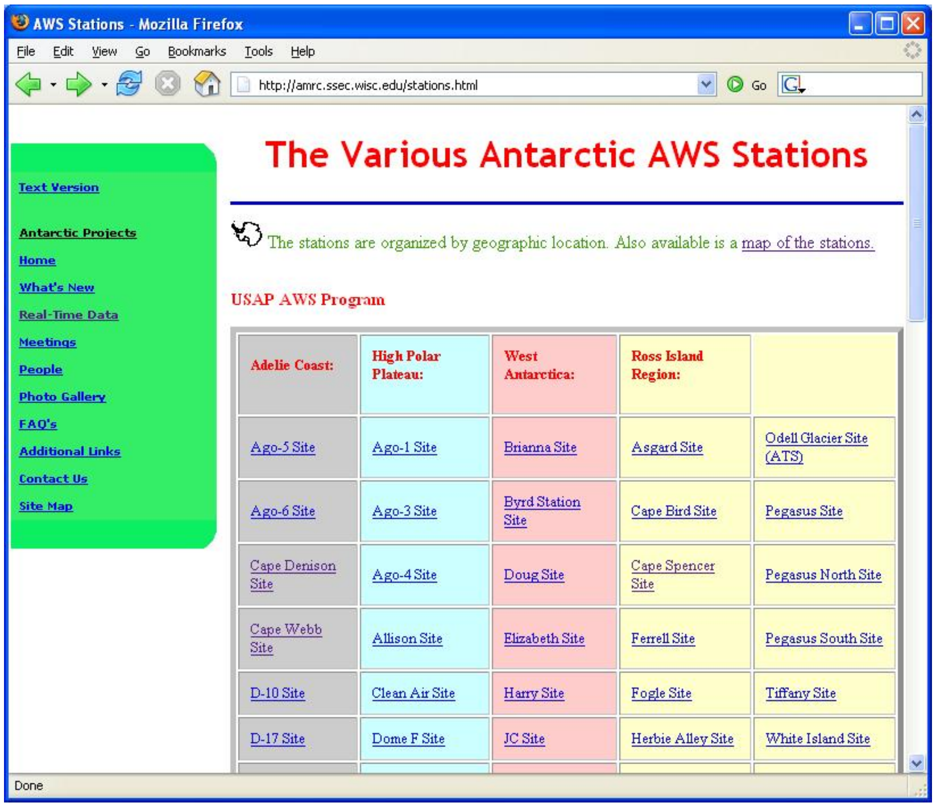


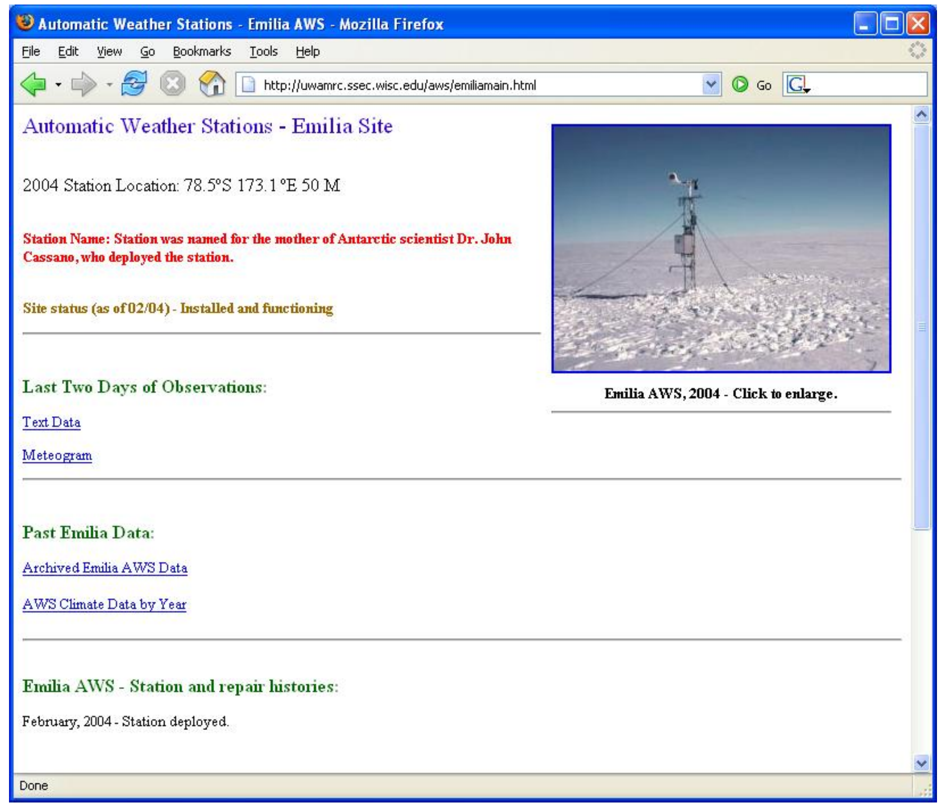
Current data acquisition scheme



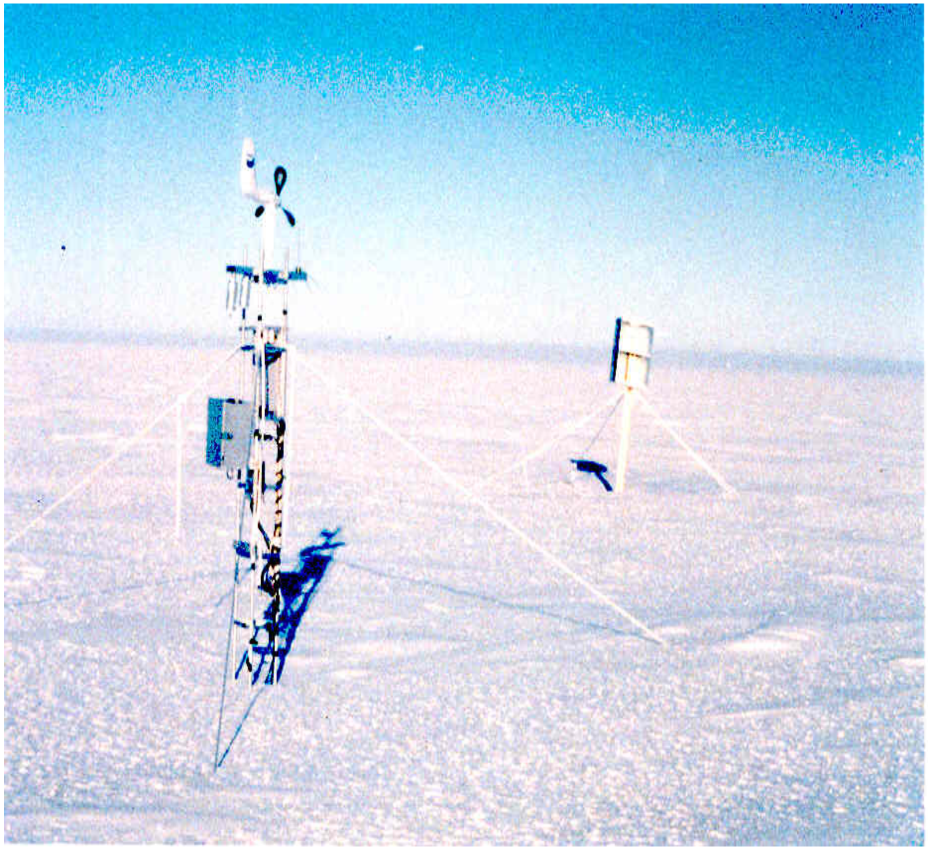
Web page for AWS

AWS data is available at
http://amrc.ssec.wisc.edu/aws.html

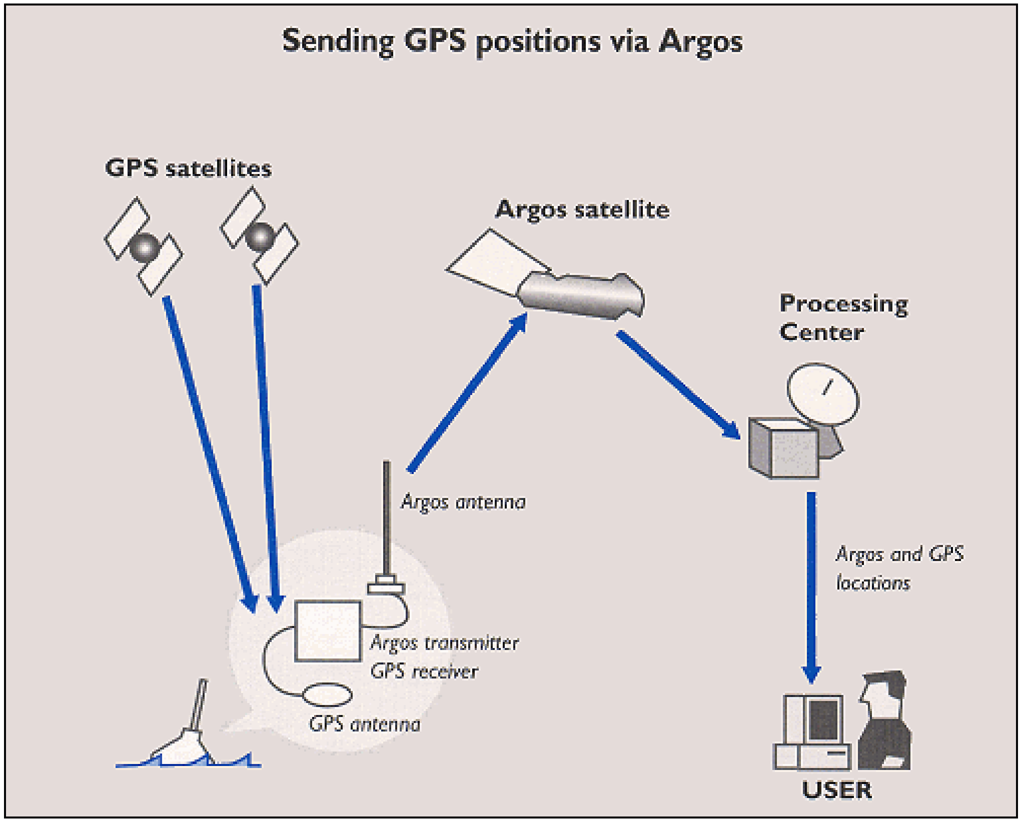




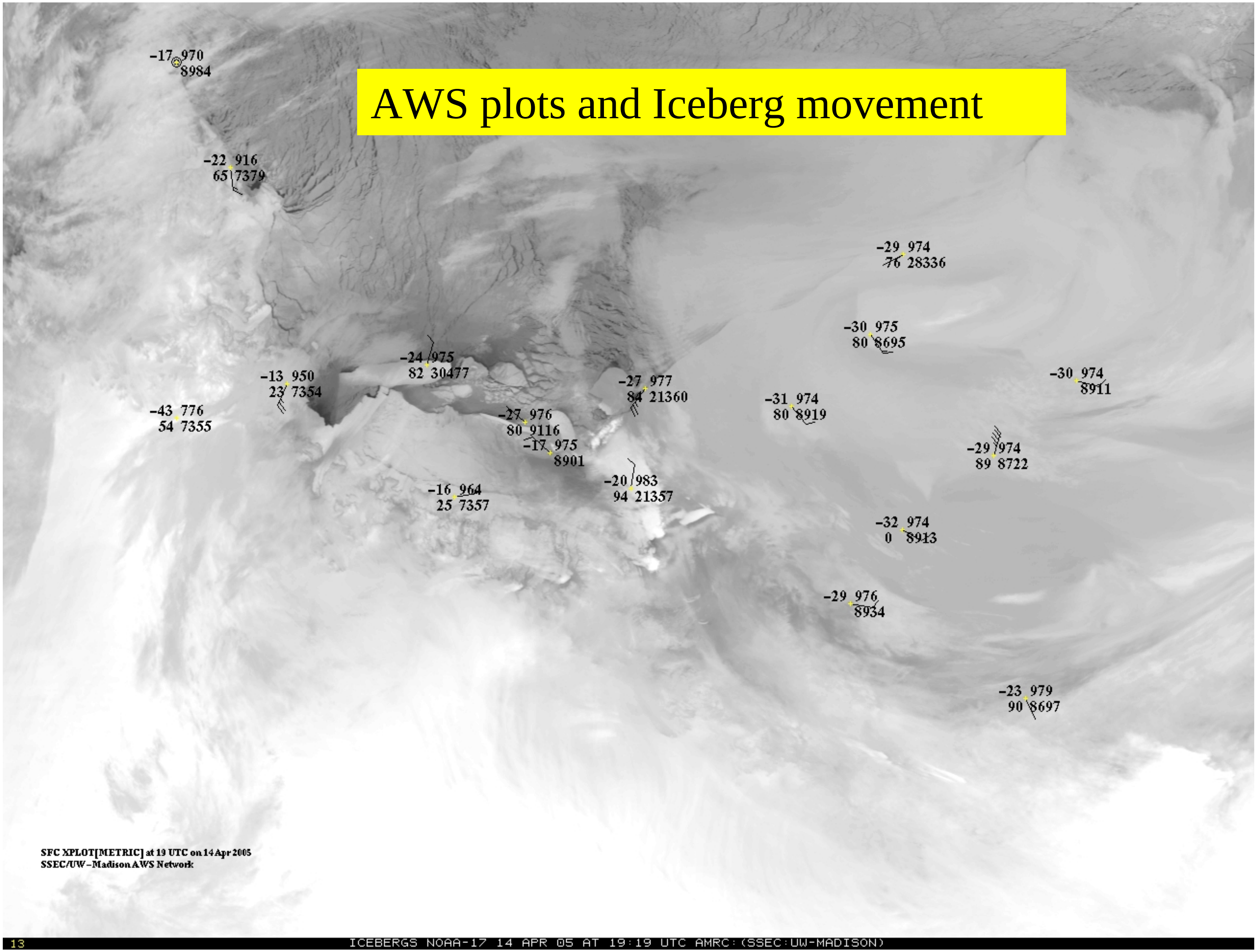
Locating the AWS in the great white expanse GPS via Argos



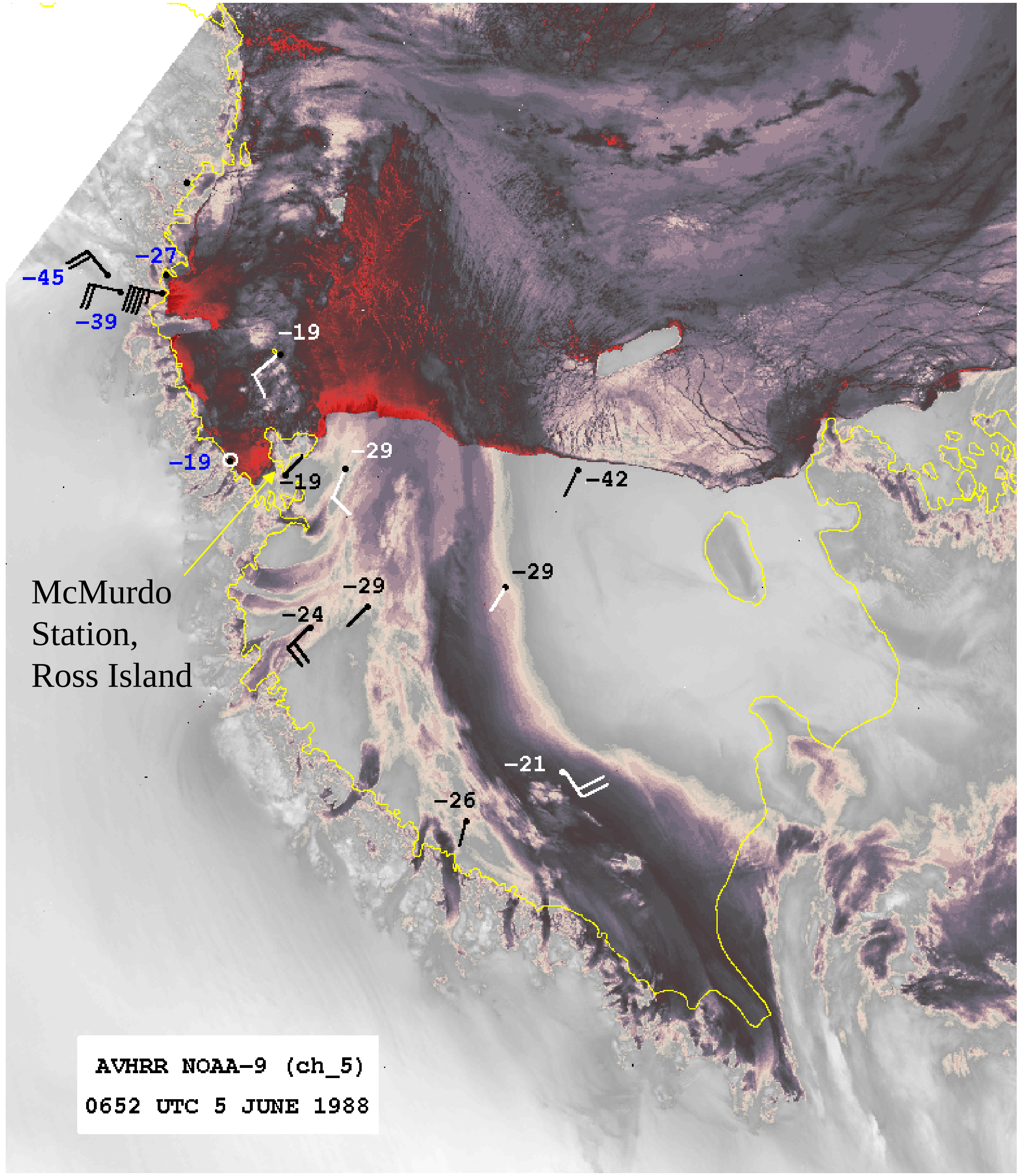
The AWS placed on icebergs have GPS receivers providing location data.



AWS plots and Iceberg movement



Ross Ice Shelf Air Stream

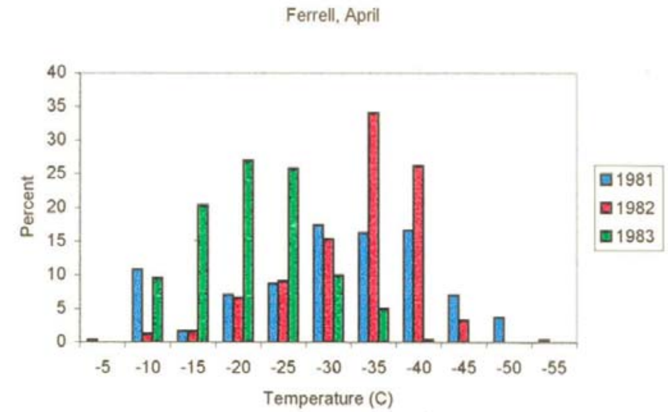


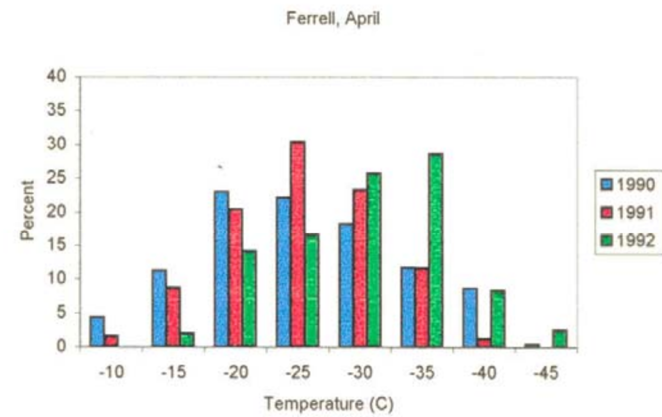
Research areas supported by AWS Program include:

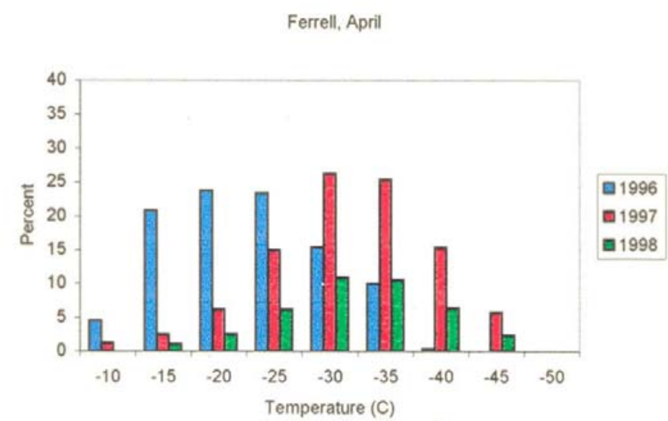
- Ross Ice Shelf Air Stream (RAS)
- Meteorological support for United States Antarctic Program Field and Flight Operations
- Ross Sea Iceberg Drift
- Barrier wind along the Antarctic Peninsula and the Transantarctic Mountains
- Katabatic wind down the Byrd and Beardmore Glaciers, the Siple and Adelie Coast
- Mesoscale circulation and sensible and latent heat fluxes on the Ross Ice Shelf
- Climatology of Byrd and Dome C sites
- Meteorological support for the West Antarctic Ice Sheet Initiative and the International Trans-Antarctic Scientific Expedition
- Long Term Ecological Research (LTER) along the Antarctic Peninsula
- Southern Ocean Global Ocean Ecosystems Dynamics
- Support for Initialization of Antarctic Mesoscale Prediction System

Ferrell AWS temperature data

- Temperature distribution shifts during ENSO transitions







Challenges have arisen

- Logistical support (cost and limited resources)
- Accelerating changes in technologies (e.g. CSI – Argos solution)
- Human costs are rising as well (% of funding that goes towards hardware has gone down every grant cycle, reflecting increasing people costs)

UH-1N Huey

The LC-130 Hercules

- In the mid 1980’s we used the ski-equipped LC-130’s to place AWS at locations to far from Mcmurdo for the Helos
- This was later deemed to risky for the limited number of 130’s in the Antarctic Program.

Twin Otter is now the primary aircraft used for servicing AWS outside of helo range

Logistics in the USAP

- First and foremost requirement is the logistical support.

Originally limited to Helos (UH1N) LC 130 and the Coast Guard's icebreaker based helos – 1980-1985.

In 1985 the Twin Otter was reintroduced into the USAP and provided a much more nimble and adaptable transportation option for the AWS program.

By 1990 the demands on the Twin Otter by other groups began to limit how much time we could expect for a field season.

With VXE-6 being replaced by the ANG in the late 1990's LC130's were limited to base to base movements. All deep field AWS work was via the Twin Otter. Demands on the Twin Otters continued to increase.

With the large icebergs breaking off in 2000 and the subsequent heavy ice in Mcmurdo Sound the Coast Guard no longer brought the helos on the two Polar Class icebreakers and finally even the US icebreakers no longer come south. As a result we no longer can service some AWS sites.

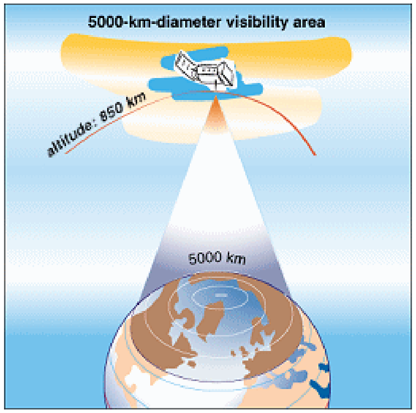
Changes in the USAP

- **AWS that transmit data in real time via the Argos system are important for forecasting operations – both locally and for global models.**
- **Recent changes in charging for Argos usage (now to be directly charged to grants) may lead to reductions in the number of AWS.**
- **The original UW AWS was limited in how it took measurements.**
- **The dramatic increase in data logger capabilities allow for a wide range of data acquisition choices. This can result in a wide variation sampling protocols available.**
- **There are calls for a adopting a standard measurement scheme (perhaps a WMO standard).**

Argos system still the best choice?

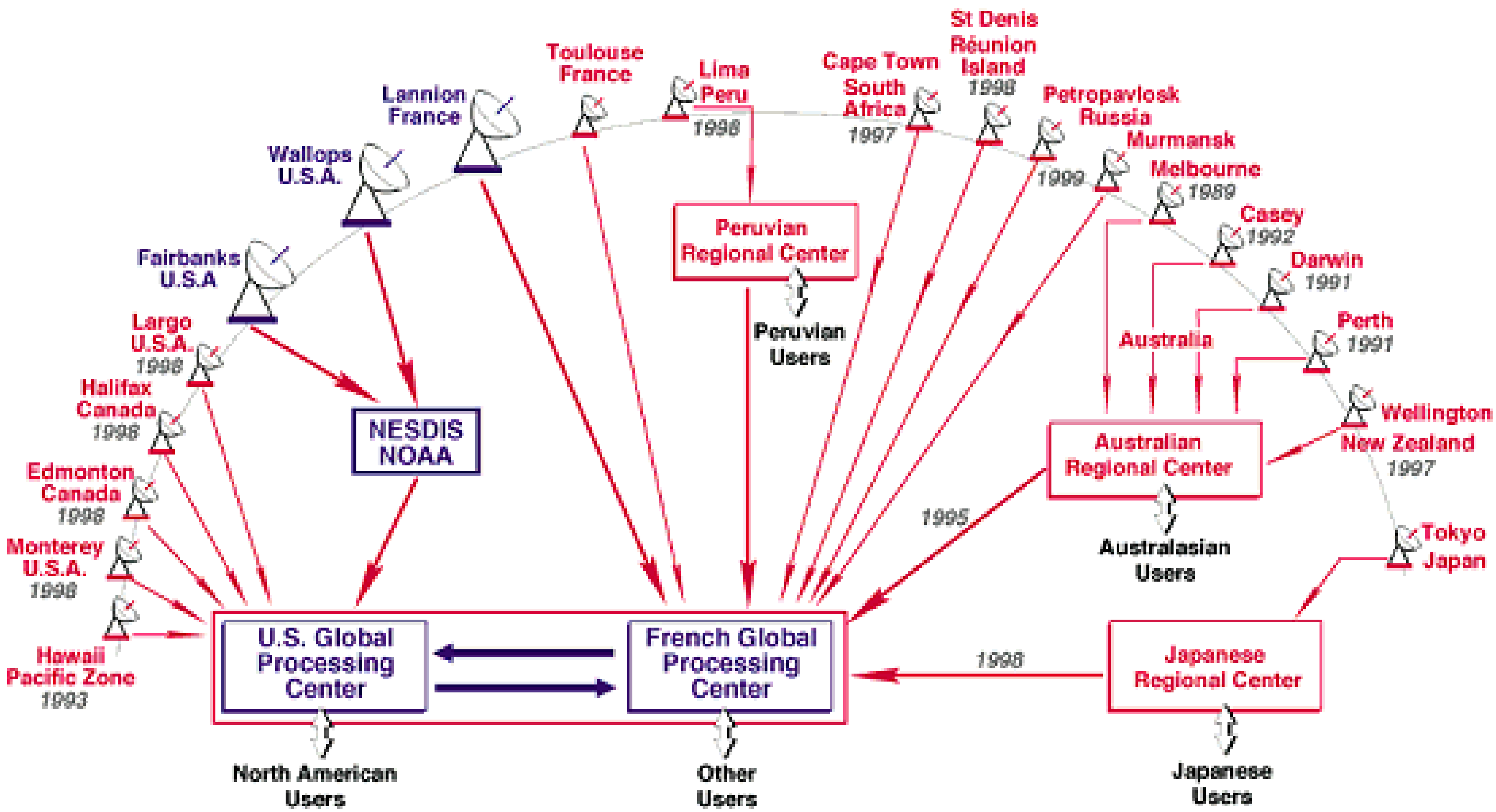
- The number of overhead passes by the satellite as a function of latitude
- Latitude Mean number of passes
- 55 16
- 65 22
- 75 28
- 90 28

- Typical transmitter power is now less than 1.0 watt down from 1.5 to 2.0 watts with early platforms



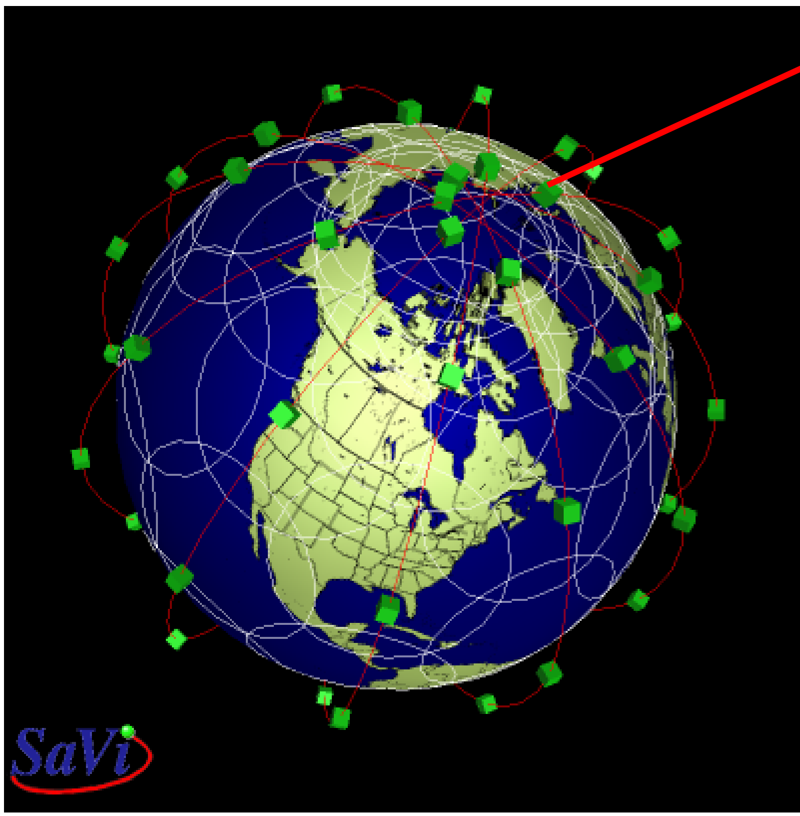
- Argos has expanded in the last 25 years

Current data distribution



Iridium – a better choice?

Collision zone



Iridium application in Antarctica

- Webcams were deployed on icebergs and near the Rift area near Ross Island

- BAS are using Iridium modems to bring data back from AWS (CSI CR1000 based)

Iridium based sites - AGAP

s#	Station	Project	Last Update (UTC)	cltncy	cldrf	m0	m1	m2	temp	volt	amp	gps	pll	lat	lon	elev	Last Message
107	P80	AGAP	2009-04-09, 22:18:28	0	-42767us	-1.3V	-0.1V	-0.4V	-49°C	11.25V	74mA	3D	T	82° 48' 32.54"S	077° 21' 82.94"E	3803.3M	5d 17h 1.2m
109	N140	AGAP	2009-04-14, 19:00:45	0	-38793us	-1.4V	-0.6V	0.7V	-49°C	10.95V	74mA	3D	T	82° 00' 51.37"S	096° 46' 15.05"E	3569.6M	20h 19.0m
110	GM02	AGAP	2009-04-13, 18:59:23	0	-13023us	1V	-0.9V	2.9V	-49°C	11.25V	72mA	3D	T	79° 25' 50.53"S	097° 34' 88.82"E	3722.1M	1d 20h 20.3m
111	N206	AGAP	2009-04-14, 18:58:13	0	-1us	0.3V	2.6V	-0.1V	-43°C	11.4V	72mA	3D	L	79° 23' 68.14"S	062° 51' 33.92"E	3658.1M	20h 21.5m
117	P061	AGAP	2009-04-15, 06:00:13	0	0us	-0.6V	-1.1V	-0.7V	-43°C	14.7V	46mA	3D	L	84° 29' 97.66"S	077° 13' 42.18"E	3511.3M	9h 19.5m
121	N124	AGAP	2009-04-14, 19:22:55	0	18us	-0.2V	-0.6V	-0.8V	-43°C	10.95V	76mA	3D	T	82° 04' 46.59"S	107° 38' 39.9"E	3384.3M	19h 56.8m
125	N182	AGAP	2009-04-08, 19:10:51	0	-38945us	-1.3V	1.1V	0.8V	-49°C	11.4V	64mA	3D	T	80° 44' 17.59"S	073° 11' 38.84"E	4037.3M	6d 20h 8.9m

Collaboration in the USAP

Directly related to logistics is the increasing cost of field support (fuel in particular). This should lead to more collaboration between programs.

We have several cooperative programs with other countries for placing our AWS at sites that USAP does not provide transportation (either because of cost or remoteness US bases). These were very important in the placement of AWS in remote areas of Antarctica.

Other countries (Italy, Australia , Belgium etc) began to install their own AWS networks.

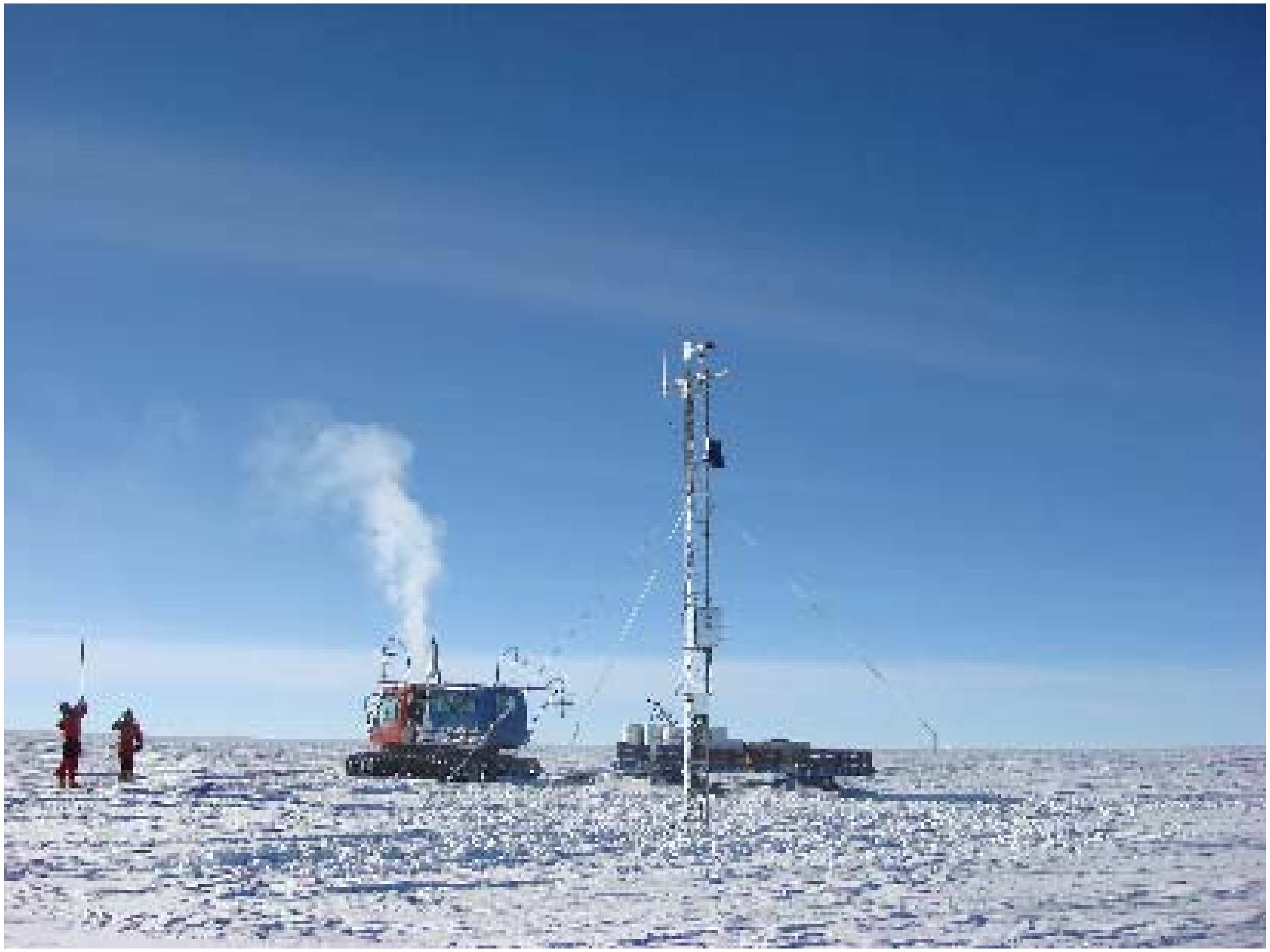
Recent advances in datalogger robustness and decreasing costs have allowed placement of AWS at many sites in Antarctica by many programs.

Through meetings and experiences in the field a more or less standard set of instruments has evolved – essentially the sensors with our AWS.

Collaboration with other countries

- The initial AWS program had cooperative agreements with both the French and British Antarctic Programs.
- Since then we have also worked with the Italian, German, Australian, and Japanese.
- This is a photo of an early two-aerovane AWS installed by the British in the Antarctic Peninsula – circa 1982.

International collaboration

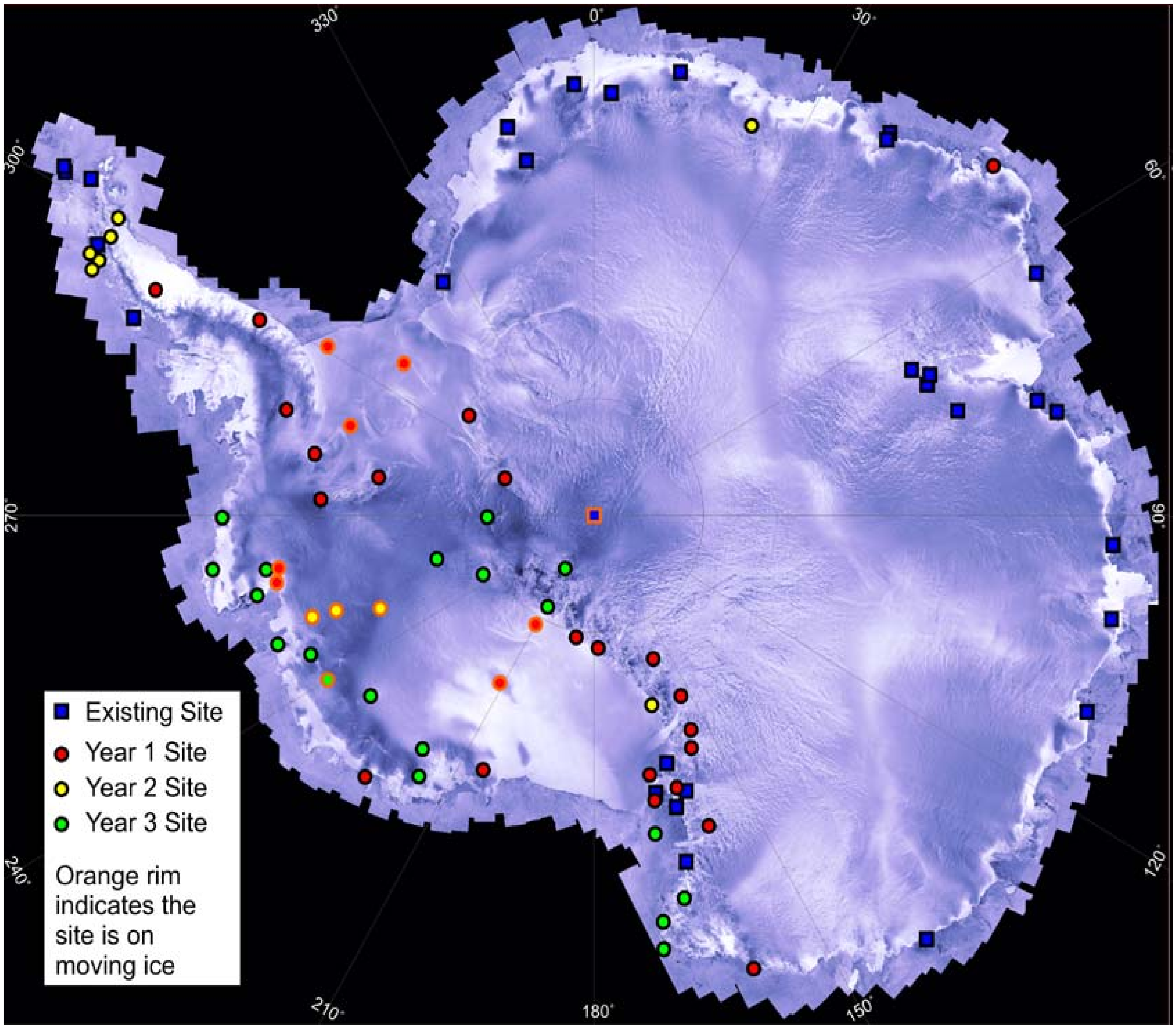


Chinese Antarctic Program installing
Panda South a UW AWS.

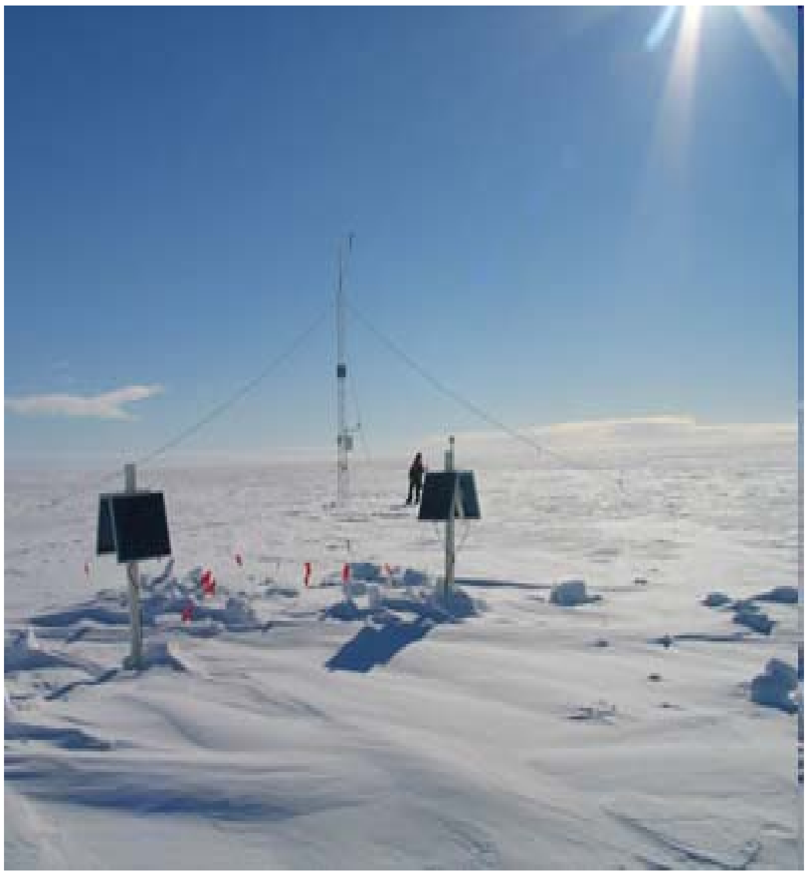
Forum for collaboration

- Host a collaborative web forum, wiki-type server running Plone
- Topics of discussion
  - Standardization
  - Sharing what has worked, setups to avoid
  - New AWS deployments
  - Ships of opportunity
  - Campbell Scientific programs that you are using for your stations
  - Other platforms that can be use to imbed met data
- Information will be on our website soon
- Examples of potential current projects follow:

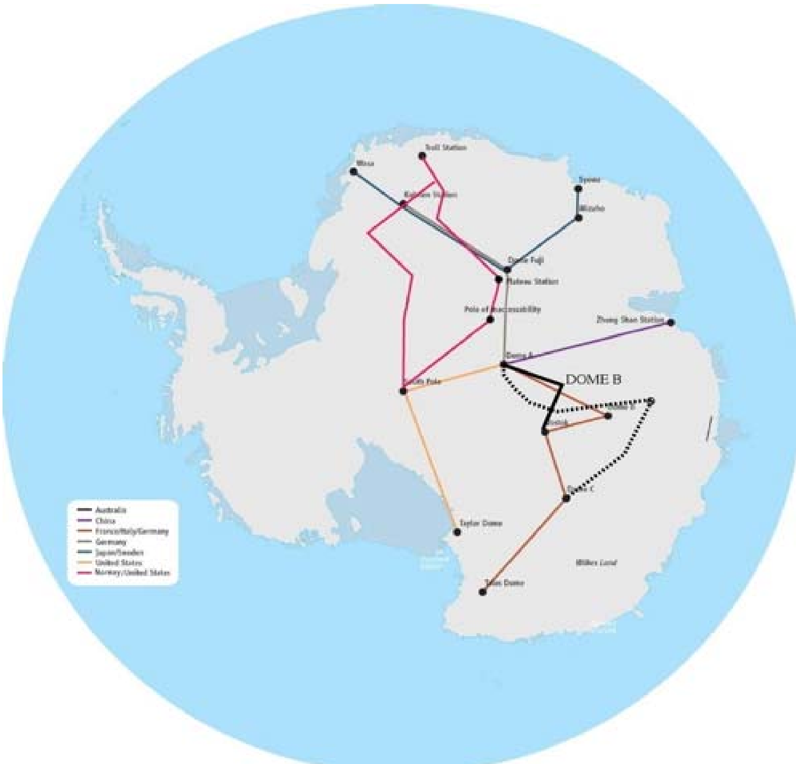
POLENET sites



IRIS PASSCAL and UNAVCO



Remote field sites and traverses



Traverse routes

An AGO site with wind power

The future of UW network

- The AWS network will likely decrease in numbers (but AWS may be easily incorporated into other platforms).
- Focus on long term climate monitoring
- Changes in data acquisition
  - Number of Argos transmitting stations will decrease, not all stations will have real-time data
  - All new stations will include on-station storage
  - Real-time data will likely be reduced
- Improvements in data access
  - Web based data request
  - netCDF data delivery

UNIVERSITY OF WISCONSIN

Space Science &
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AUTOMATIC WEATHER STATIONS

USAP - NATIONAL SCIENCE FOUNDATION