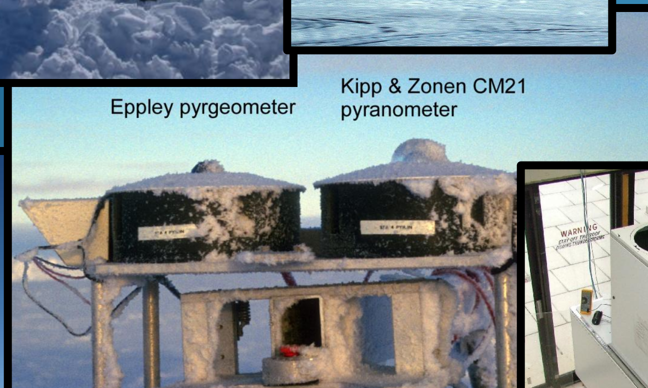
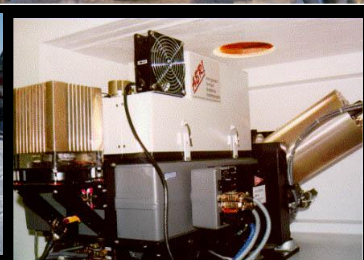
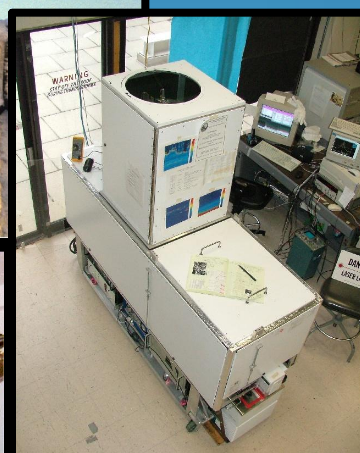
Meteorology Observations and Challenges



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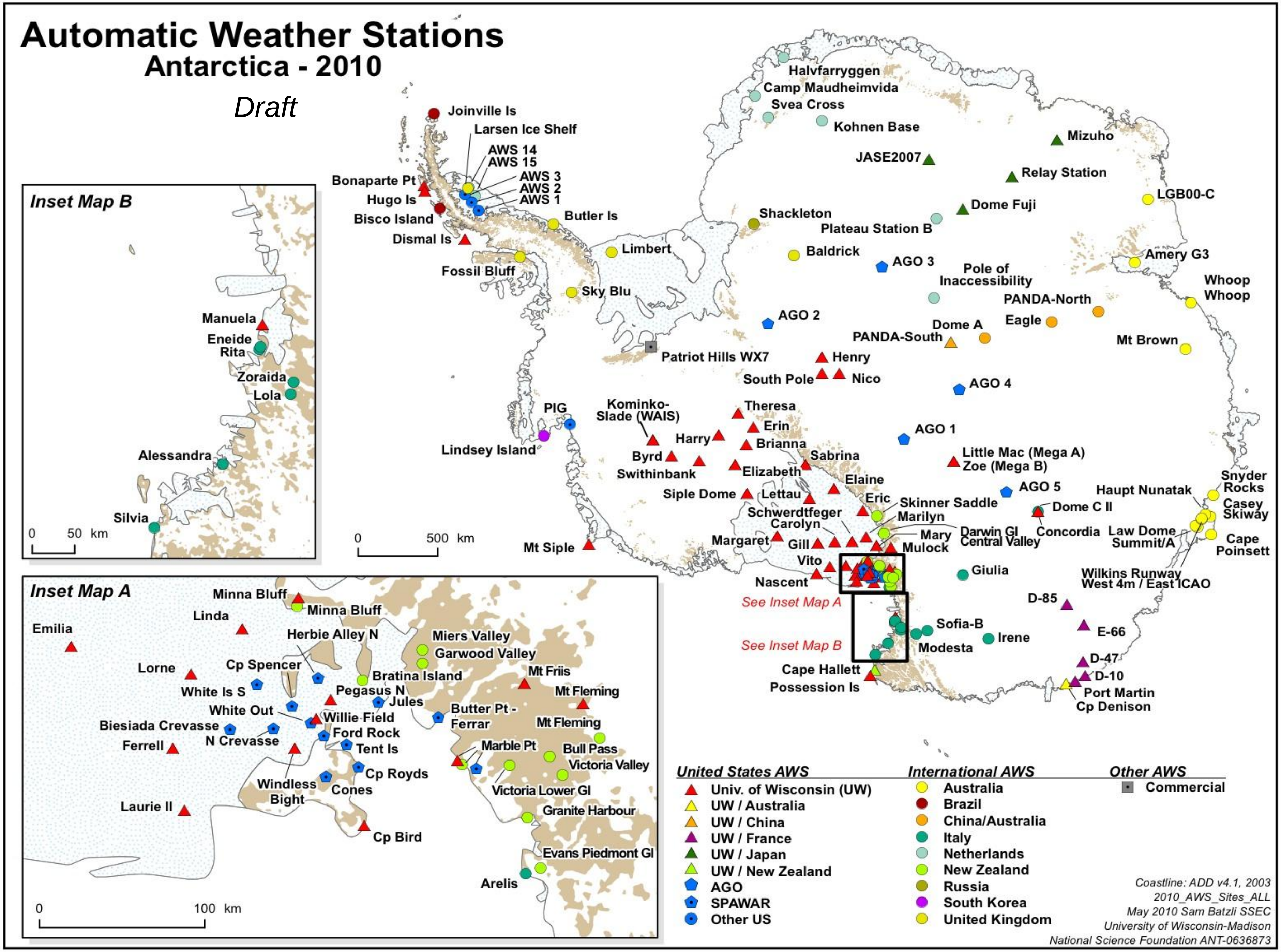
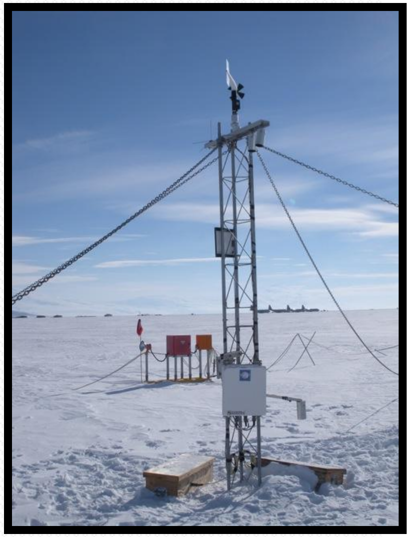
Outline: Meteorology Observations & Challenges

- Observing the near surface:
  - Wisconsin Antarctic AWS Network
    - A Tribute…
  - Antarctic Operations AWS and Surface Network
- Observing atmospheric state:
  - UAVs - Aerosondes
  - GPS/Met
  - (Radiosondes)
- Observing remotely sensed clouds & atmospheric profiles and precipitation - from the surface:
  - Arctic Super Sites
    - HRSL
    - Short Term Super Sites



Automatic Weather Stations
Antarctica - 2010
Draft
Inset Map B
Manuela
Eneide
Rita
Zoraida
Lola
Alessandra
Silvia
0 50 km
Inset Map A
Minna Bluff
Minna Bluff
Linda
Emilia
Herbie Alley N
Miers Valley
Garwood Valley
Cp Spencer
Lorne
White Is S
Bratina Island
Mt Friis
Pegasus N
Jules
Mt Fleming
White Out
Willie Field
Butter Pt - Ferrar
Biesiada Crevasse
N Crevasse
Ford Rock
Mt Fleming
Ferrell
Tent Is
Marble Pt
Bull Pass
Victoria Valley
Cp Royds
Windless Bight
Cones
Victoria Lower Gl
Laurie II
Granite Harbour
Cp Bird
Evans Piedmont Gl
Arelis
0 100 km
Joinville Is
Larsen Ice Shelf
AWS 14
AWS 15
AWS 3
AWS 2
AWS 1
Bonaparte Pt
Hugo Is
Bisco Island
Dismal Is
Butler Is
Fossil Bluff
Limbert
Sky Blu
0 500 km
Halvfarryggen
Camp Maudheimvida
Svea Cross
Kohnen Base
Mizuho
JASE2007
Relay Station
LGB00-C
Dome Fuji
Shackleton
Plateau Station B
Baldrick
AGO 3
Amery G3
Pole of Inaccessibility
Whoop Whoop
PANDA-North
AGO 2
Dome A
Eagle
PANDA-South
Mt Brown
Patriot Hills WX7
Henry
South Pole
Nico
AGO 4
PIG
Kominko-Slade (WAIS)
Theresa
Erin
Lindsey Island
Harry
Brianna
AGO 1
Byrd
Sabrina
Little Mac (Mega A)
Zoe (Mega B)
Swithinbank
Elizabeth
Elaine
AGO 5
Haupt Nunatak
Snyder Rocks
Siple Dome
Lettau
Eric
Skinner Saddle
Dome C II
Casey Skiway
Schwerdtfeger
Marilyn
Carolyn
Mary
Darwin Gl
Central Valley
Concordia
Law Dome Summit/A
Cape Poinsett
Margaret
Gill
Mulock
Mt Siple
Vito
Giulia
Wilkins Runway
West 4m / East ICAO
Nascent
See Inset Map A
D-85
Sofia-B
E-66
See Inset Map B
Irene
Modesta
D-47
Cape Hallett
D-10
Possession Is
Port Martin
Cp Denison
United States AWS
Univ. of Wisconsin (UW)
UW / Australia
UW / China
UW / France
UW / Japan
UW / New Zealand
AGO
SPAWAR
Other US
International AWS
Australia
Brazil
China/Australia
Italy
Netherlands
New Zealand
Russia
South Korea
United Kingdom
Other AWS
Commercial
Coastline: ADD v4.1, 2003
2010_AWS_Sites_ALL
May 2010 Sam Batzli SSEC
University of Wisconsin-Madison
National Science Foundation ANT-0636873

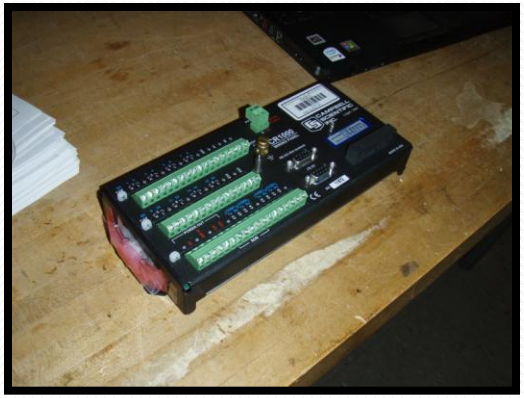
AWS Sensor Specifications



Variable	Sensor	Specifications AWS2 (CSI based)
Air Pressure	Paroscientific Model 215 A	Range: 0 to 1100 hPa Resolution: 0.050 hPa (0.0001 hPa) Accuracy: +/- 0.2 hPa (0.1 hPa) (0.01 hPa/year drift S/N > ~20000)
Air Temperature	Weed PRT Two-wire bridge	Range: to -100 C minimum Resolution: 0.125 C (0.01 C for CSI) Accuracy: +/- 0.5 C
Humidity	Vaisala HMP-35 Vaisala HMP-45 Vaisala HMP-155	Range: 0 to 100% Resolution: 1.0 % (Recorded to 1.0 %) Accuracy: +/- 5.0 % down to -55 C Corrections possible for lower temperatures
Wind Direction	10 K Ohm pot. 2-3 degree dead zone	Range: 0 to 355 Degrees Resolution: 1.5 Deg (read to 1.0 Deg) Accuracy: +/- 3.0 Degrees
Wind Speed	Bendix/Belfort RM Young Hydro-Tech	Resolution/Accuracy: 0.25 +/- 0.5 m/s Resolution/Accuracy: 0.20 +/- 0.5 m/s Resolution/Accuracy: 0.33 +/- 2% *Max speed along Adelie Coast ~50 m/s
Acoustic Depth Gauge	Campbell Sci. SR-50	Resolution: 0.25 mm Accuracy: 1 cm
Solar Radiation	LiCor 200x	Accuracy: +/- 5%
Temperature String	Thermocouple Two junction Copper-Cons.	Resolution: 0.06 C (0.01 C for CSI) Accuracy: +/- 0.125 C (+/- 0.02 for CSI)

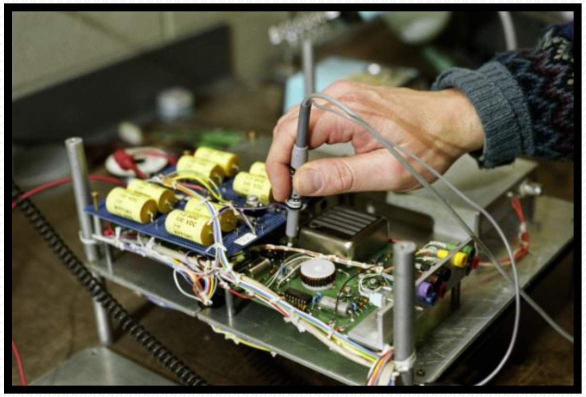
An AWS Power Story…

- AWS Wiscoinsin-2B:
  - 10 to 14 milliAmps
- AWS-CR10X:
  - 5 to 6 milliAmps
- AWS-CR1000:
  - 20 to 24 milliAmps!!
- With the Ethernet port on…
  - 4 to 5 milliAmps with the port off!!!

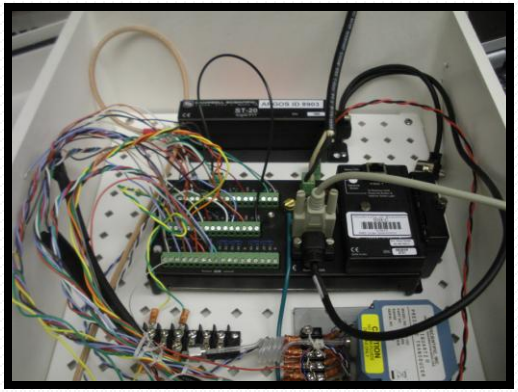


Homegrown vs. COTS

- Homegrown:
  - You know what you got
  - Can't buy out-dated components
  - New development cost prohibitive
    - Components & Effort
  - Comms issues?



- Commercial Off The Shelf:
  - Affordable
  - Quirks…(black box issues)
  - Too "Swiss Army Knife"?
  - Power and Comms issues?

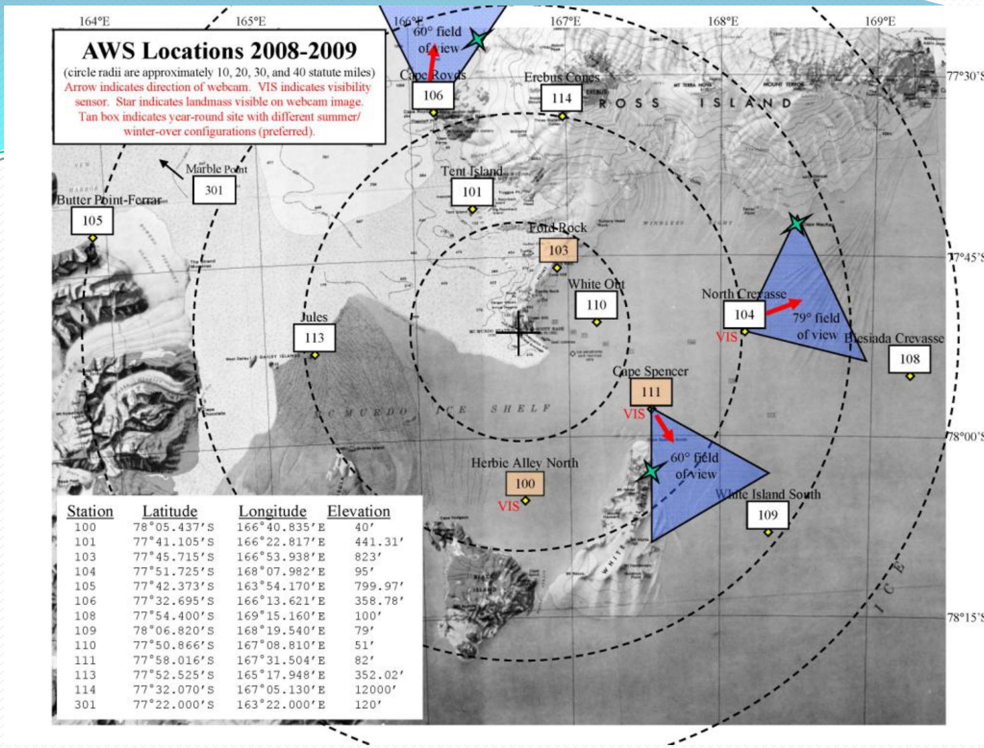


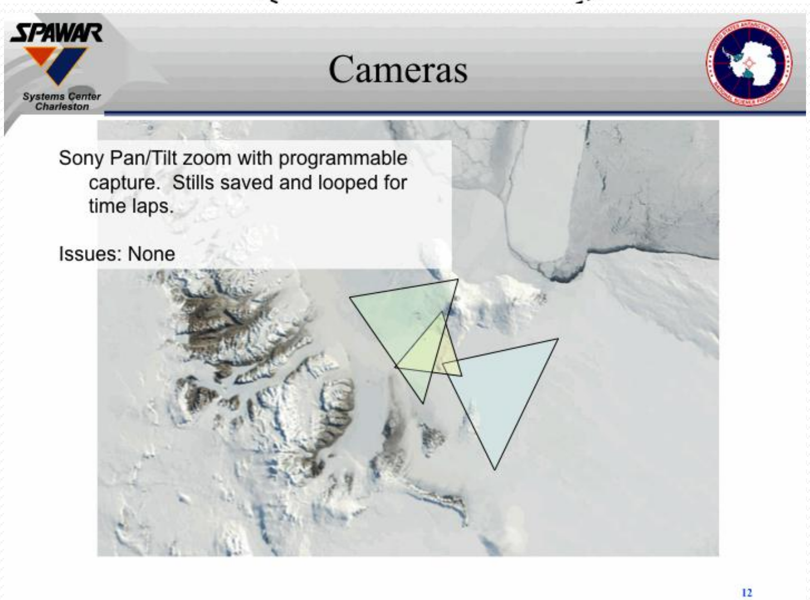
Prof. Charles R. Stearns 1925-2010

Operational AWS

SPAWAR
Systems Center
ATLANTIC

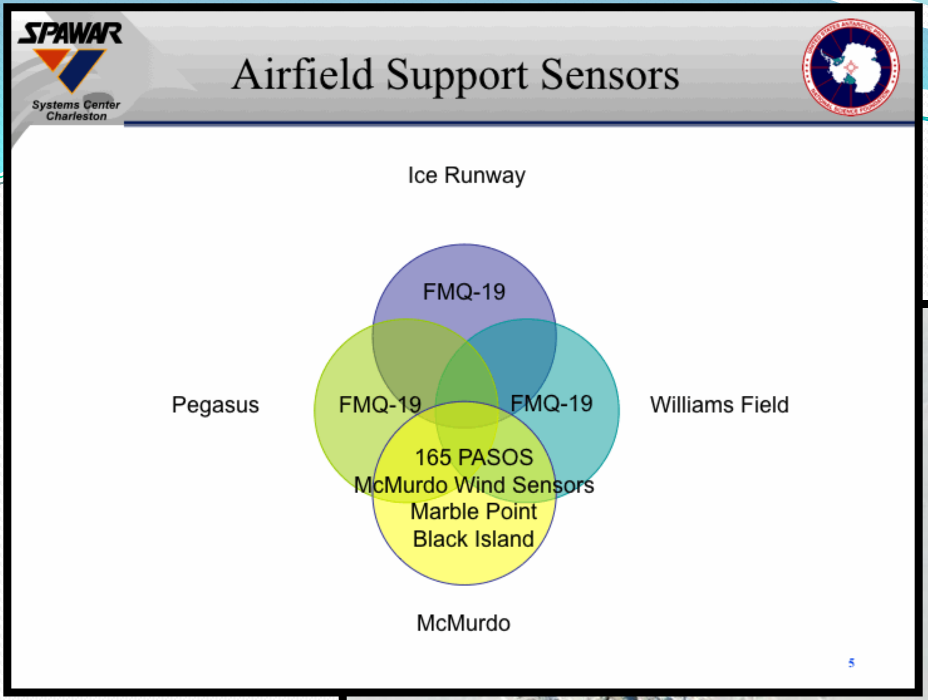
SOPP AWS LOCATIONS & Plans

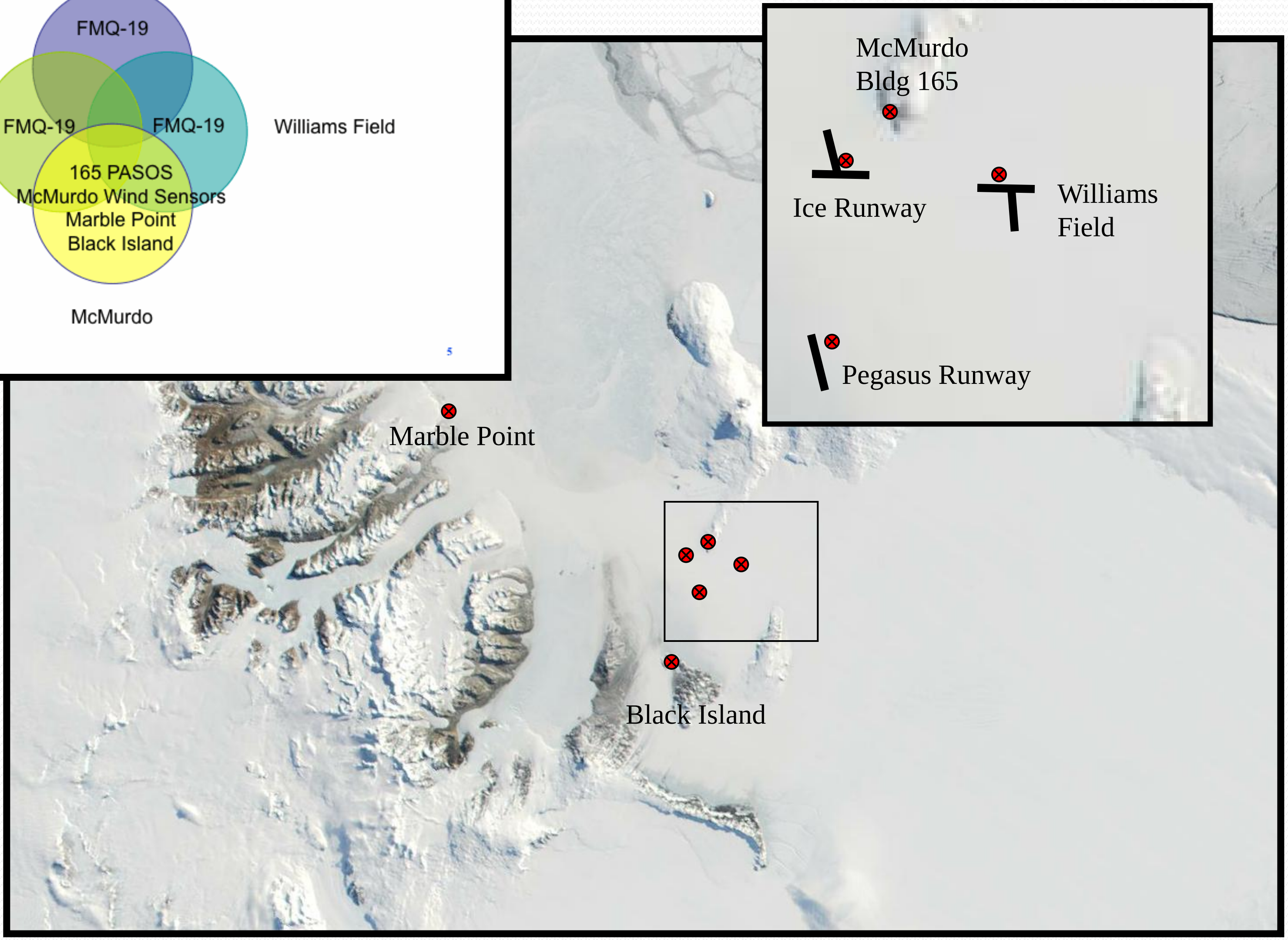




- **OPSEA 10/11 – 11/12**
- **Replacement of Coastal Environmental AWS**
- **Campbell Scientific AWS**
  - CR1000 Datalogger
  - Pressure (Vaisala)
  - Winds (RM Young)
  - Temperature/Humidity (Vaisala)
  - Camera (N. Crevasse, Cape Royds, Cape Spencer)
    - Hourly
    - On-demand
  - 900MHz RF
  - Year-round Operation

SOPP Locations





Airfield AWOS

- Coastal Environmental Systems – FMQ-19
  - Pressure
  - Winds (RM Young)
  - Temp
  - Humidity
  - Visibility
  - Clouds
  - Transportable (Trailer Mounted)

- Airport Weather Advisor Software
- Mesotech International

McMurdo 165 PASOS

- SMI/AWI Fixed based system
- Mounted on Tower (portability/power/heat)

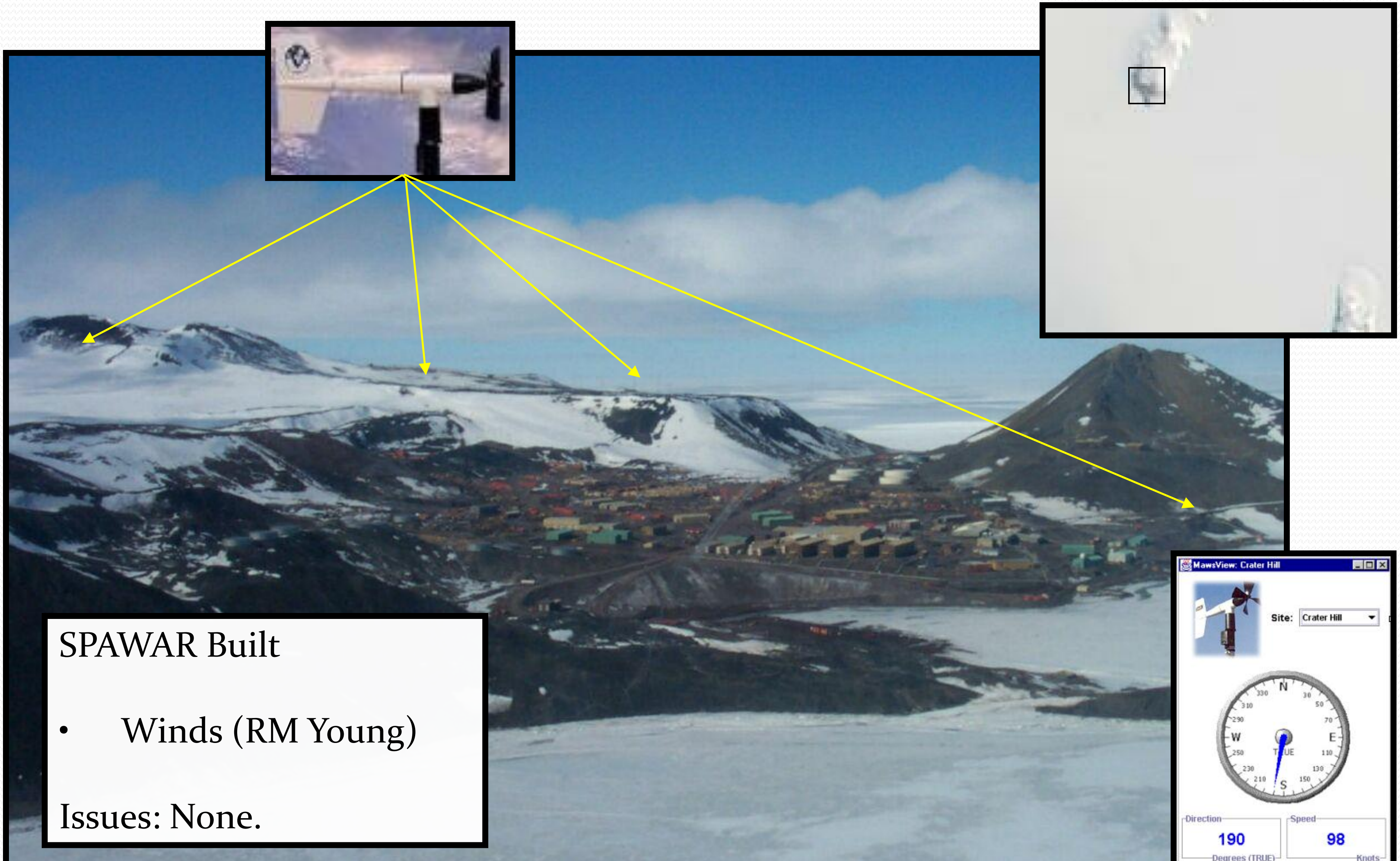
- Pressure
- Winds (RM Young)
- Temp
- Humidity

- Augmented with standard 8"rain gague with nepher shield.

- Issues: Location, age, non-operational/non-science support.

- Future: Replace during OPSEA 11/12

McMurdo Area Wind Sensors (MAWS) / Helo Pad Support



SPAWAR Built

- Winds (RM Young)

Issues: None.

Marble Point

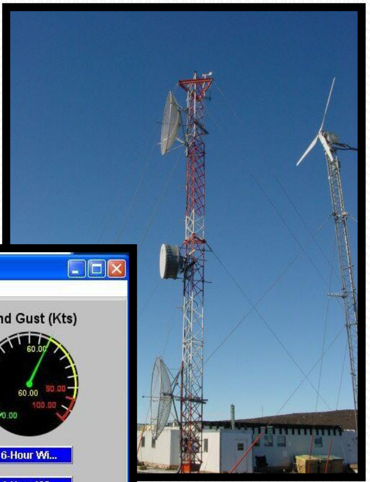
SPAWAR Designed Coastal system
- Pressure
- Winds (RM Young)
- Temp
- Humidity
- Visibility
- Clouds

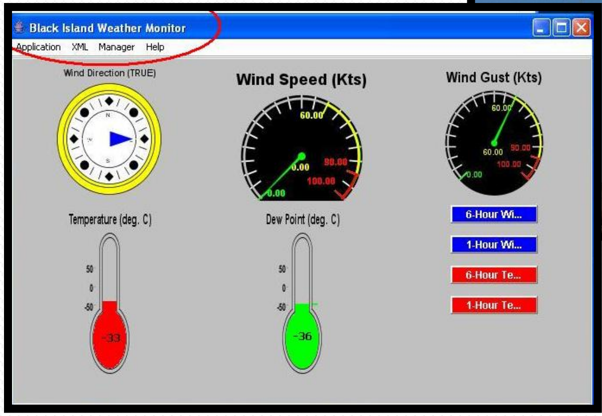
Issues: None

Black Island

SPAWAR Built system
- Winds (RM Young)
- Temp
- Humidity

Issues: None





Remote Camps

SPAWAR Designed Coastal Environmental System
- Pressure
- Winds (RM Young)
- Temp
- Humidity
- Optional – Visibility and clouds

Riming Example – SHEBA Radiometers

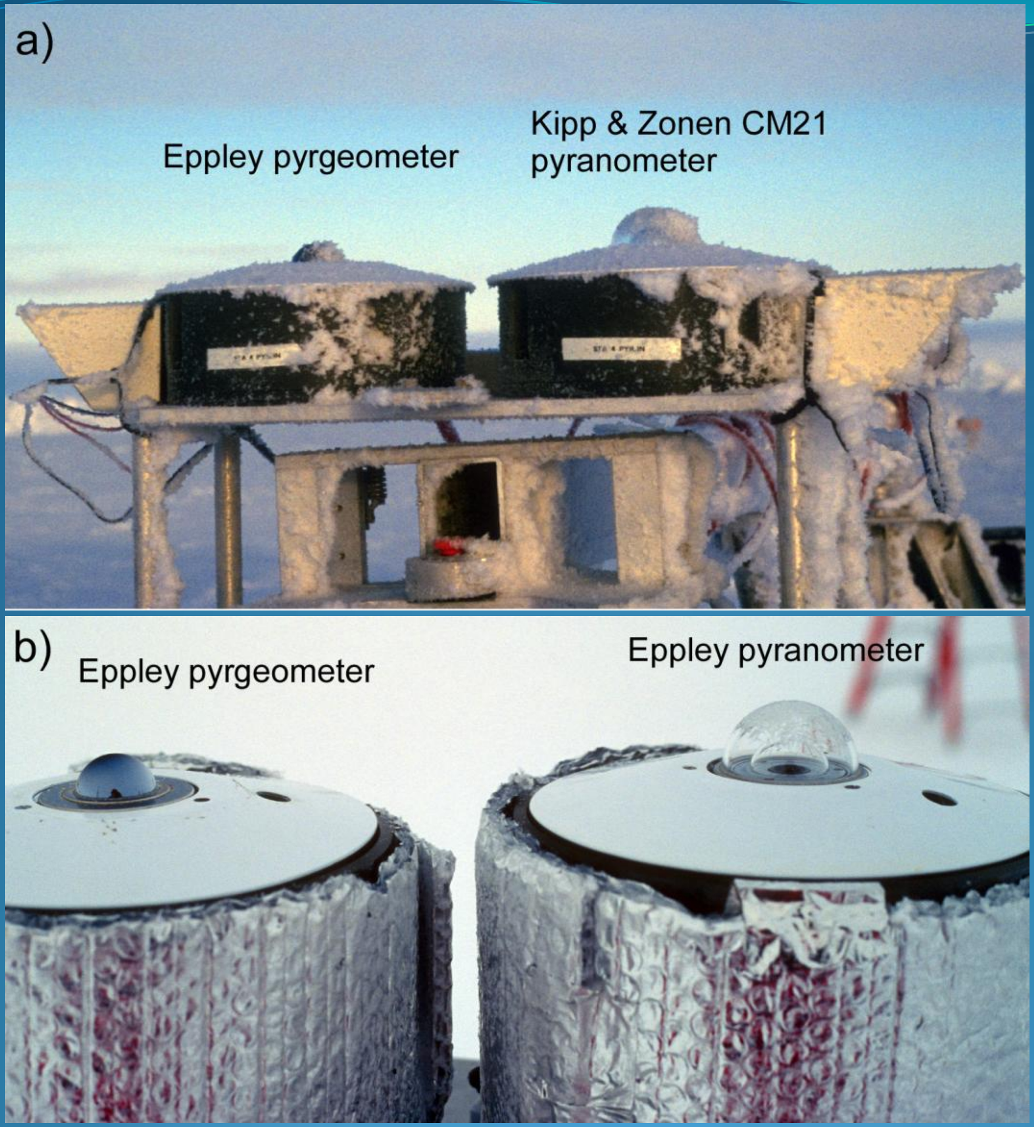


Fig. 2: a) Rimed pyrgeometer and pyranometer on Cleveland PAM station at SHEBA on 980404 at 1805 UTC (~0805 solar time). The radiometers are ventilated with DC power. b) Rimed pyranometer and unrimed pyrgeometer on ASFG mast at 1750 UTC 980408. These radiometers are ventilated (and heated) by AC fans. Logbook indicates this riming on ASFG domes is similar to or slightly less than that on the ASFG domes at time of photo in a). (photos: O. Persson)

UAV Observations

- Use Aerosonde unmanned aerial vehicles (UAVs) to make meteorological measurements in the vicinity of Terra Nova Bay
  - Make observations of horizontal and vertical variability of atmospheric state
  - Focused primarily on air-sea coupling and atmospheric boundary layer
  - AWS can only provide surface observations and at limited locations
- Prior to this project there were no in-situ atmospheric measurements of the wintertime atmosphere over the Terra Nova Bay polynya

Aerosonde UAV

Wingspan	3 meters
Weight	15 kg
Payload Capacity	2-5 kg
Endurance	12-17+ hrs
Range	1000+ km
Altitude	100-6000 m

Communications via 900 MHz radio and Iridium

Flies in fully autonomous mode with user-controlled capability

Aerosonde Measurements

Wind Speed/Direction	Pitot with GPS
RH/Temp/Pressure	Standard Radiosonde Met Sensors
Ocean /Ice Skin Temperature	Infrared Thermometer
Ocean/Ice Visible Imagery	Still Digital Camera
Net Shortwave Radiation	Pyranometer
Net Longwave Radiation	Pyrgeometer
RH/T/P/wind profiles	Dropsondes
Altitude and Surface Waves	Laser Altimeter

The Challenges: Cold Temperatures

- Aerosonde UAVs rated to -30 C but we flew at temperatures colder than -40 C
- The cold impacted:
  - Engine
    - Need to keep engine warm (> 0 deg C) prior to startup
  - Parts failure
    - Breakage of parts due to cold temperatures
    - Ex. Generator belt broke during flight (T was -42 C at launch)
  - Solution: Heated hangar and limited flight ops at very cold temperatures

The Challenges: Communications

- Communication failures
  - Use Iridium modem for communication with UAV
  - Experienced regular failures of this communication link
    - Source of the problem was unclear
    - Cold may have been a factor
  - Solution: Programmed UAV to reboot communication system if contact was lost

The Challenges: Wind

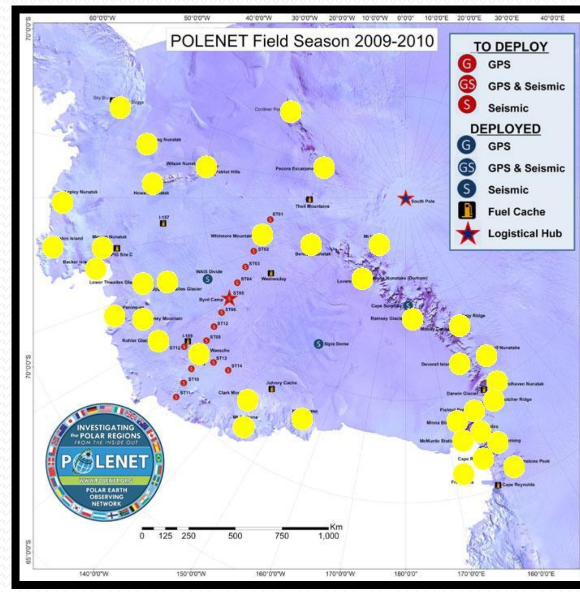
- Take-off / landing
  - Required crosswind less than 15 kts for take-off and landing
  - Solution: Careful forecasting / nowcasting of runway winds
- In flight winds
  - Max UAV airspeed is 25 m/s
  - Difficult to make forward progress (without excessive fuel burn) for headwinds greater than 15 m/s
  - Solution: Careful flight planning based on available forecasts
- AMPS forecasts proved surprisingly useful for detailed local forecasts at runway and for flight path

The Challenges: Aircraft Icing

- UAV can only tolerate small increase in weight due to icing before crashing
- Solutions
  - Use of AMPS forecasts to identify potential trouble spots
  - Real-time monitoring of atmospheric conditions at UAV (Focus on RH)
  - Surprisingly we did not encounter any icing while flying over the open water of the polynya

Meteorological application of the Antarctic GPS network

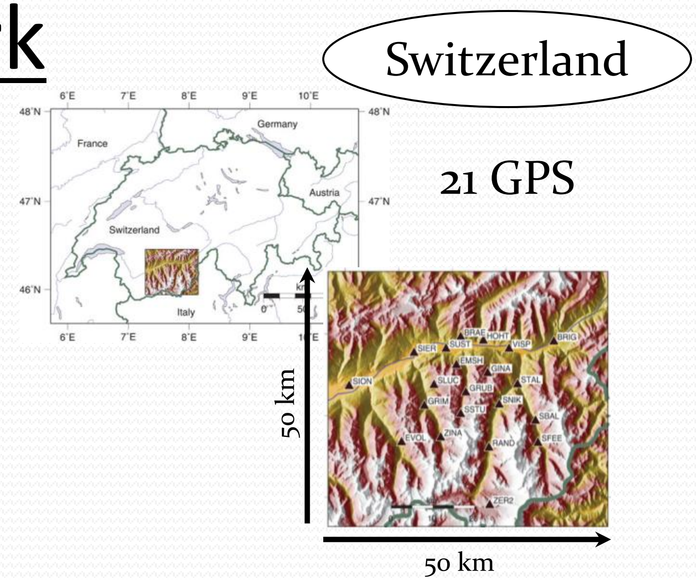
- Observations from ground-based GPS (tropospheric wet delay) can be used to estimate the integrated atmospheric moisture content [Bevis et al., 1992, 1994]
- The Antarctic GPS network has been considerably extended during the IPY
- Sensitivity studies of the assimilation of GPS data into regional climate models are expected to be carried out in the coming months
- The impact of these data will be first tested in retrospective analysis experiments prior to their possible use for operational NWP
- These studies will help determine whether/where the network could be optimized for atmospheric applications

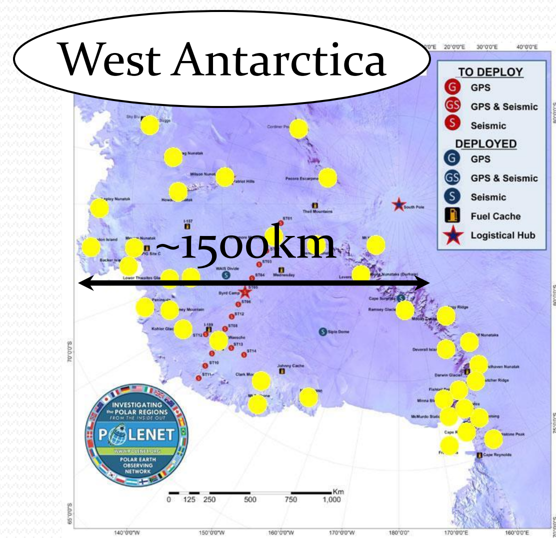


Site already (or to be) equipped with GPS

Meteorological application of the Antarctic GPS network

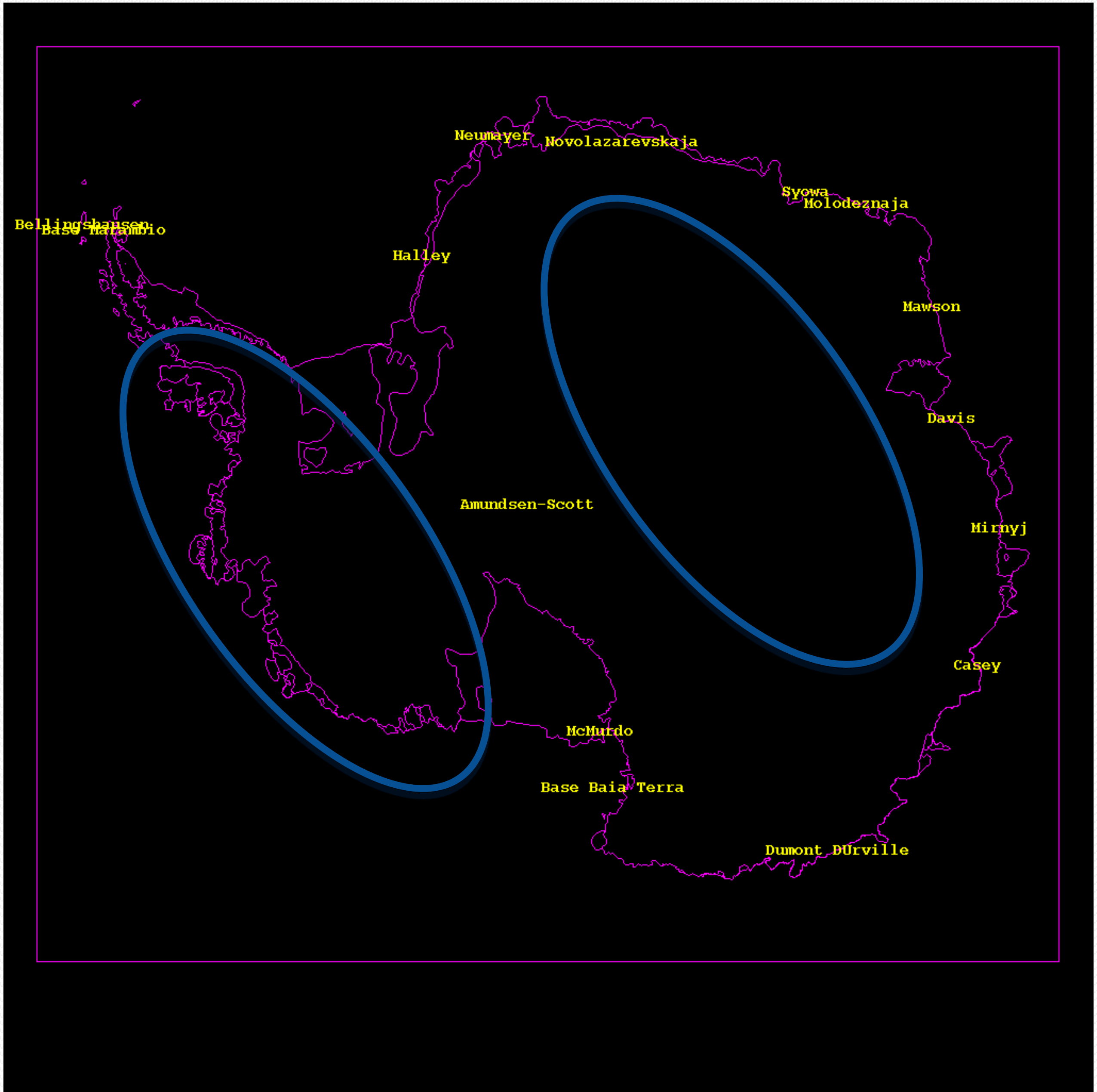
- Vertical moisture profiles can be derived from observations from multiple GPS receivers (water vapor tomography)
- Lutz et al. evaluated this method in Switzerland with GPS receivers distributed over a limited domain and demonstrated the benefits for operational NWP
- Applicability in West Antarctica? GPS network considerably less dense, but some "pockets" of denser network might be envisaged (e.g. coastal Marie Byrd Land, Transantarctic Mts)



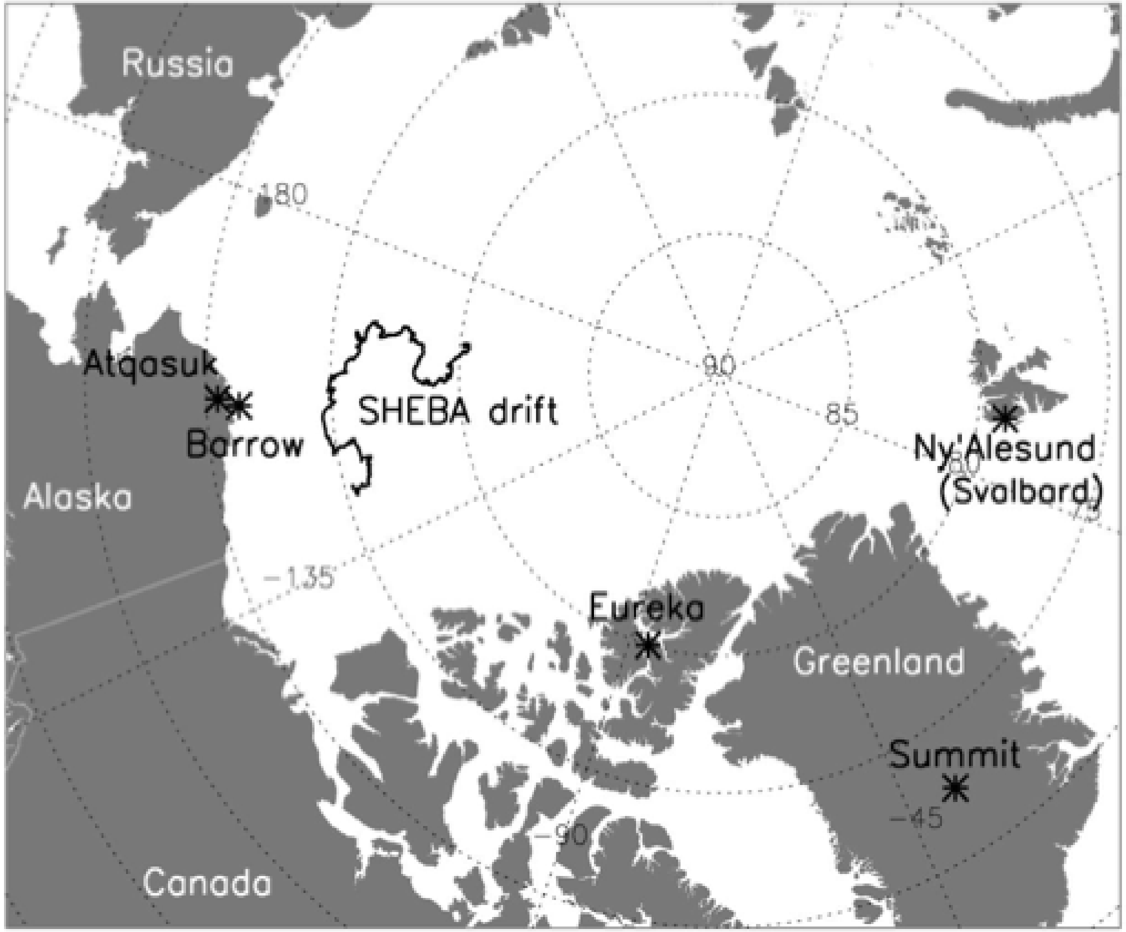


Reference: S. Lutz, M. Troller, D. Perler, A. Geiger, and H.-G. Kahle, 2010: Better weather prediction using GPS. *GPS World*, July 2010, 40-47.

Antarctic Radiosondes…



Arctic Atmospheric "Super Sites"



Instrumentation at "Super Sites" Barrow, Eureka, and Summit

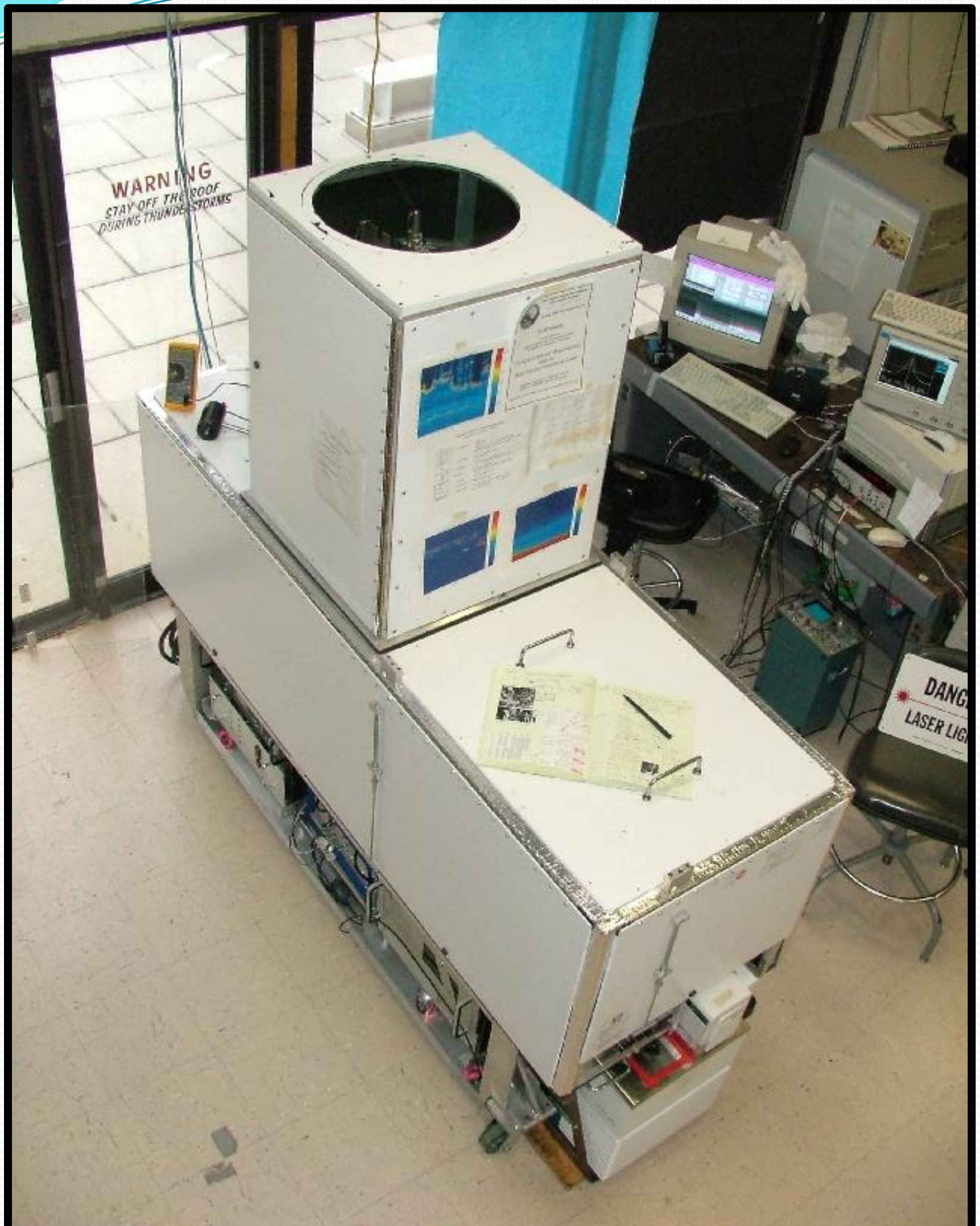
- **Millimeter Cloud Radar (MMCR)**
  - NOAA CIRES
- **Cloud Lidars**
  - HSRL (Eloranta), CAPABL (Neely), MPL and ceilometer (DOE)
- **Polar Atmospheric Emitted Radiance Interferometer**
  - PAERI measures spectral infrared radiance from 3 to 20 ⌠m (1 cm^{-1})
- **Microwave Radiometer (MWR)** - total column water vapor
  - NOAA, SSEC
- **Radiosondes** (from Barrow, Eureka Weather Office, now from Summit)
- **Precipitation Occurrence Sensor System**
- Others
  - NOAA (gases, ozonesondes), NOAA Sodar, 50-m Swiss tower (Sonic anemometers),

Variables being measured at "Super Sites"

Table 1. Details of the instrumentation described in this proposal, as well as the variables that are directly measured and retrieved from the observations. References: [1]Shupe et al. (2005); [2]Shupe (2007); [3]Shupe et al. (2008a); [4,5]Knuteson et al. (2004a,b); [5,6]Mahesh et al. (2001a,b); [7]Turner et al. (2003); [8]Turner (2005, 2007); [9]Crewell and Löhnert (2007); [10]Rose et al. (2005); [11]Löhnert et al. (2008); [12]Sheppard (1990); [13]Cady-Periera et al. (2008); [14]Rowe et al. (2008).

Inst.	Specifications	Variables	Refs.
MMCR	λ=8.4 mm *resolution*: 4 sec, 45-90 m	*Direct*: Doppler spectrum, reflectivity, mean Doppler velocity, spectrum width *Retrieved*: $C_F(z)$, LWC, IWC, r_{eff}, phase, in-cloud vertical velocities	*1-3*
P-AERI	λ=480-3300 cm^{-1} (22-3 μm) *resolution*: λ=0.5 cm^{-1}, 1-10 min	*Direct*: Spectral IR radiances. *Retrieved*: C_F, τ, ε_λ, r_{eff}, phase, T_C-brightness, CRF_λ , $T_{atm}(z)$, $RH_{atm}(z)$	*4-8*
HATPRO	λ = 22.2-30.0 and 51-58 GHz *resolution*: 14 freq. channels (1 s for observed T_b) (10 min, 100–4000 m for retrieved profiles)	*Direct*: Spectral microwave radiances *Retrieved*: LWP, PWV $T_{atm}(z)$, $RH_{atm}(z)$	*9-11*
MWRHF	λ = 90 and 150 GHz *resolution*: 2 freq. channels 1-s for observed T_b	*Direct*: Spectral microwave radiances *Retrieved*: LWP	
Ceilometer	λ = 905 nm *resolution:* 15 m, 30 s	*Direct:* Backscatter *Retrieved:* cloud base height	
POSS	λ=2.85 cm *resolution*: 1 min	*Direct:* Doppler spectrum, reflectivity *Retrieved:* Snowfall rate	12
Vaisala RS92 sondes	*resolution*: T = $\pm$0.5°C RH = $\pm$5%	*Direct*: $T_{atm}(z)$, $RH_{atm}(z)$, wind speed and direction profiles.	13-14

University of Wisconsin Arctic High Spectral Resolution Lidar (HSRL)



- Requires 110 VAC and Internet

- Data transfer and control via Internet

- Has operated since Sept 2004 at
- Eureka, Nunavut.

- Provides calibrated measurements of
- cloud and aerosol backscatter cross
- sections, optical depth and
- Depolarization.

- Vertical resolution 7.5 m
- Temporal resolution 2.5 s
- Altitudes 100m → 30 km

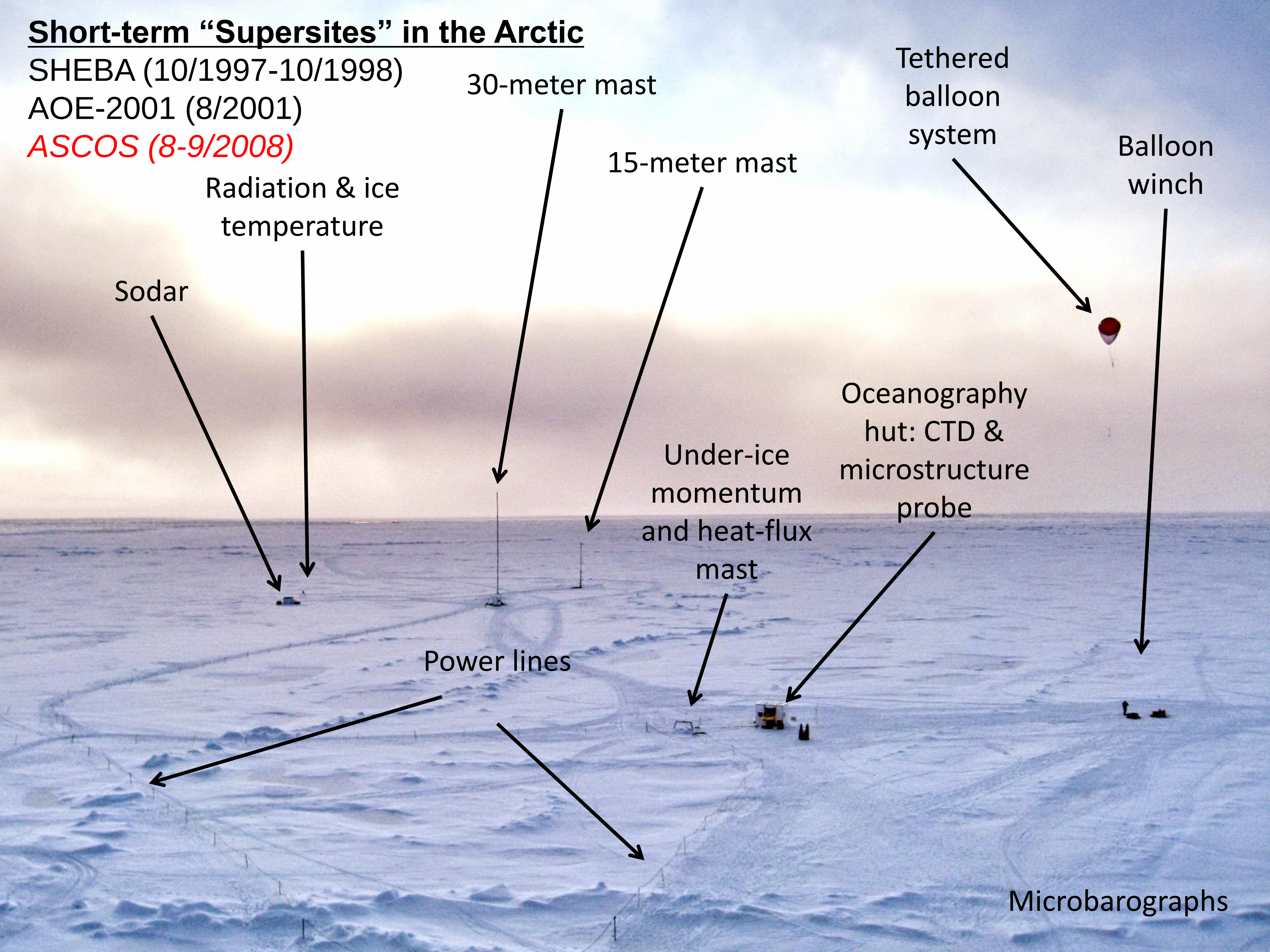
- Care: Keep the window clear of snow/frost!

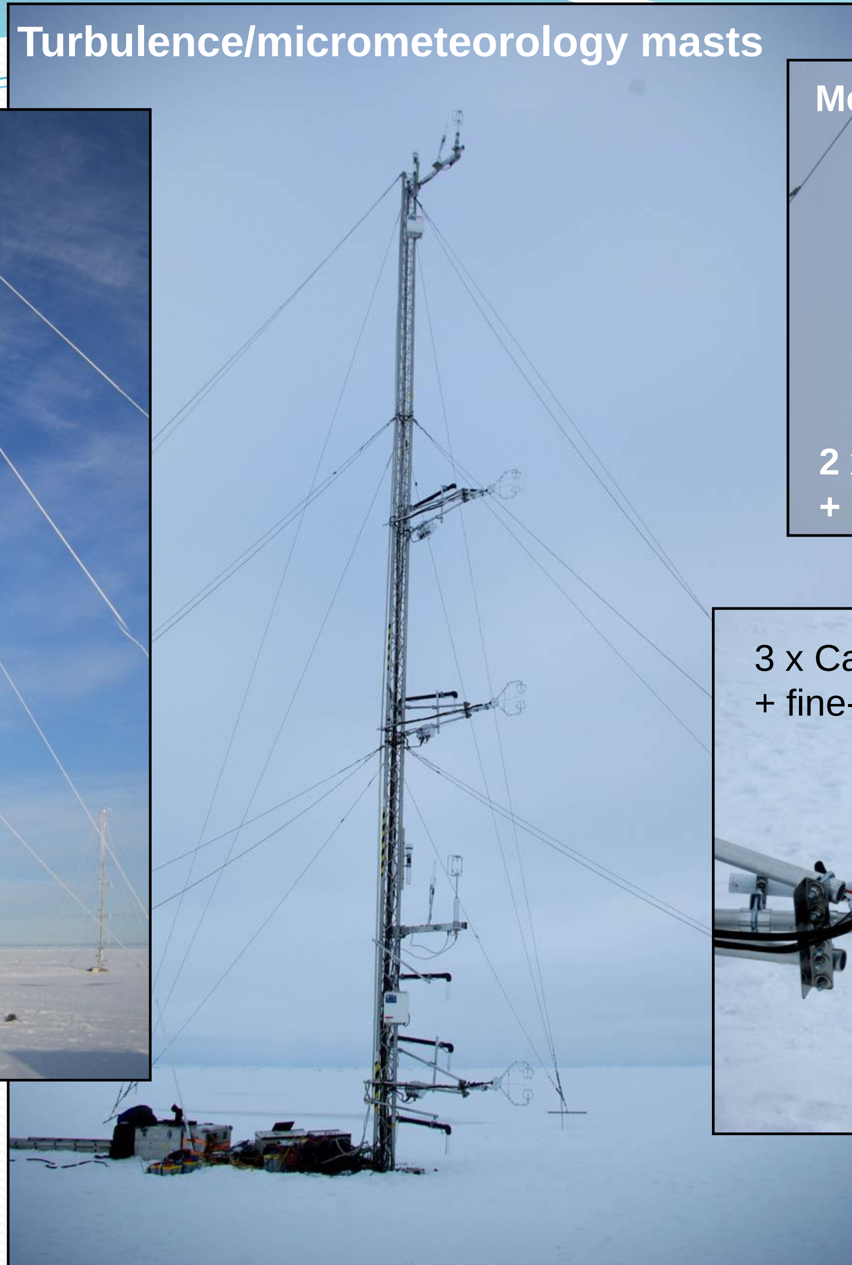
Short-term "Supersites" in the Arctic

SHEBA (10/1997-10/1998)

AOE-2001 (8/2001)

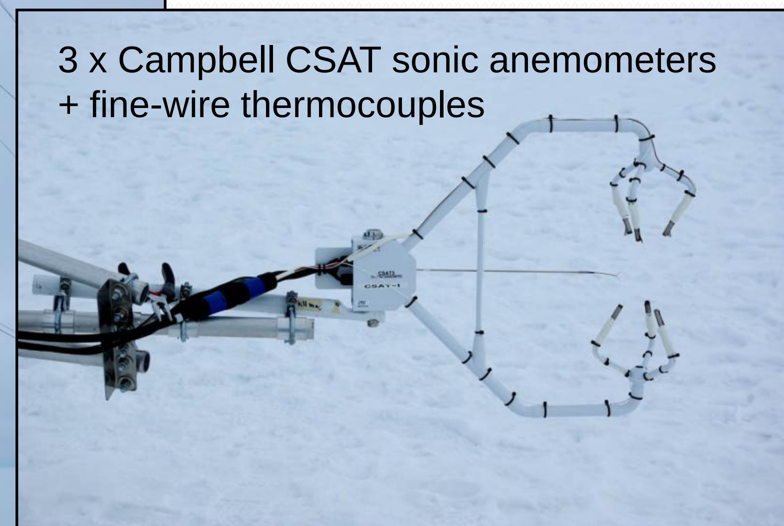
ASCOS (8-9/2008)




Turbulence/micrometeorology masts


1 Metek Sonic
anemometer
@30m


Mean T & RH
2 x Gill R3 sonic anemometers
+ LiCOR LI-7500 H_2O/CO_2 sensor


3 x Campbell CSAT sonic anemometers
+ fine-wire thermocouples

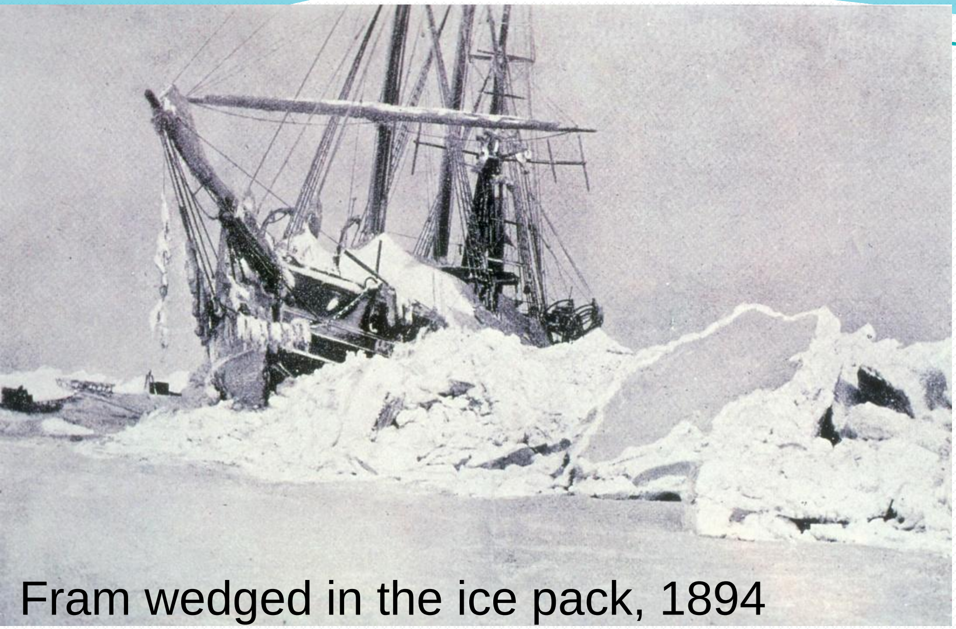
Logistical and Environmental Limitations
- ice movement, bears, etc.

- damage equipment, produce logistical problems & safety concerns

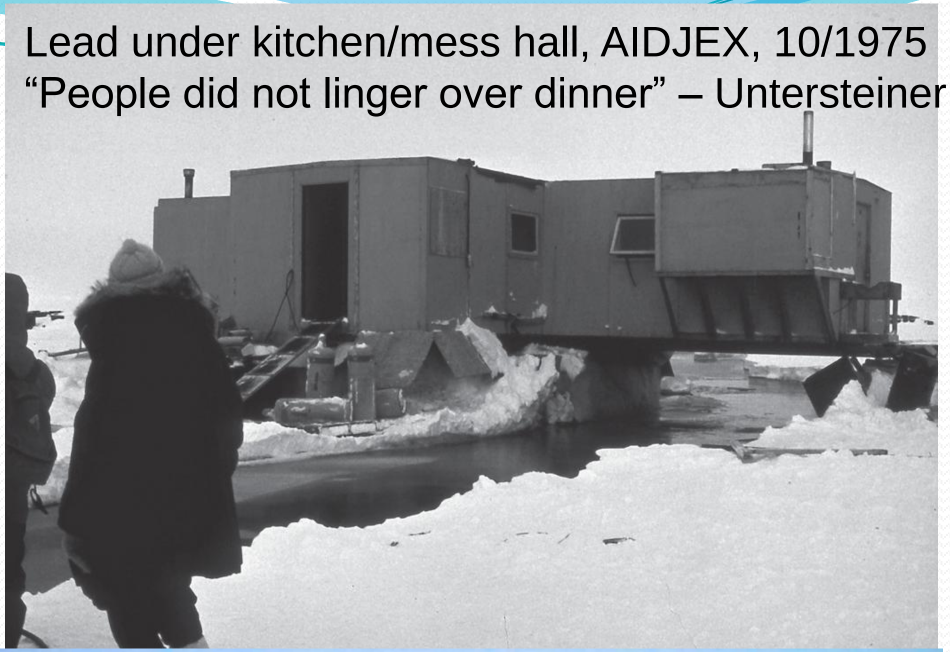
- increases cost & reduces access

Lead crushes automated station – SHEBA, 11/1997

Logistical and Environmental Limitations – Ice movements

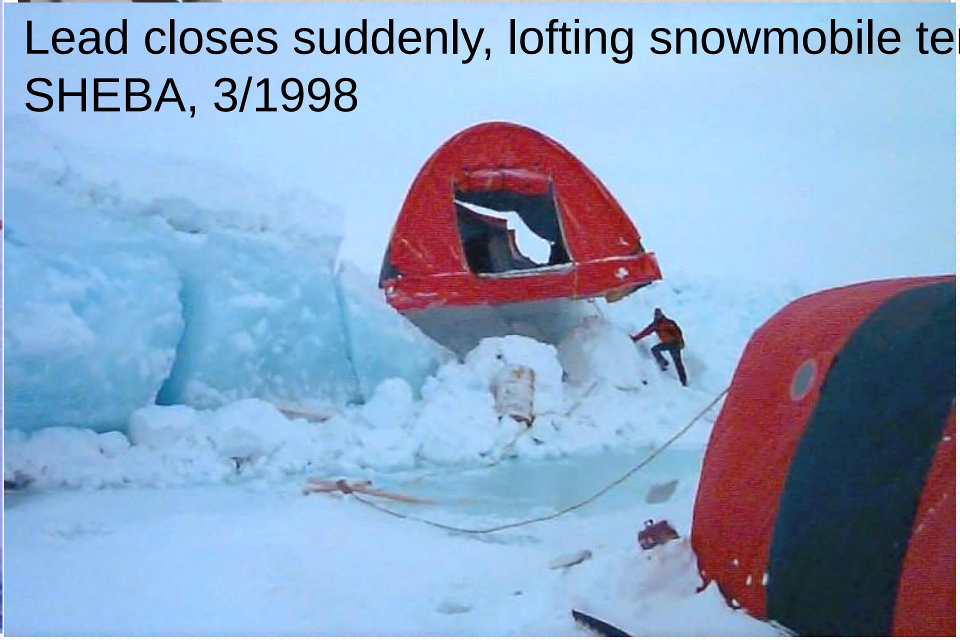


Fram wedged in the ice pack, 1894



Lead under kitchen/mess hall, AIDJEX, 10/1975
“People did not linger over dinner” – Untersteiner

Lead opens up between instrumentation tents
SHEBA, 2/1998



Lead closes suddenly, lofting snowmobile ten
SHEBA, 3/1998

Acknowledgements

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