
GPS / SEISMIC REMOTE STATIONS MRI PROJECT

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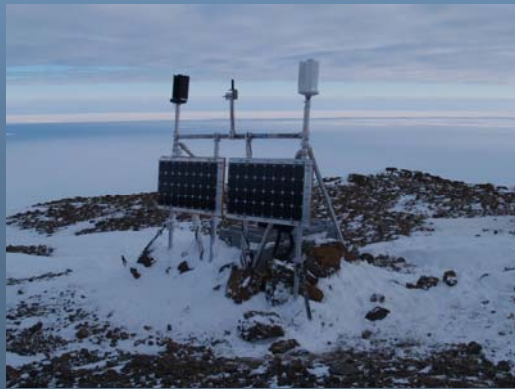
Project Goals

- NSF Major Research Infrastructure (MRI) project
 - “Collaborative Research: Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica”
 - IRIS/PASSCAL seismic consortium & UNAVCO GPS consortium
 - Unique challenges for GPS versus seismic, but much overlap
 - Broader goal: provide a polar power/comms platform for other disciplines, instruments.
- Ultimate goal is a long-lifetime, lightweight, easily deployable system
 - Year-round power at high latitudes, modular for 2.5 - 10 watt loads
 - Year-round comms for data retrieval and limited system control
 - Deployable by 3 person team, two flights with 212 helo or Twin Otter (including recon)
 - Similar goals to ARRO MRI project but different in scale
 - Many more stations, each station less logistically intensive
 - Much lower power and smaller data rates
- Design for operation in two different regimes
 - Continental Margin: moderate cold, extreme winds
 - Polar Plateau: extreme cold, moderate winds

Margin GPS System: Development

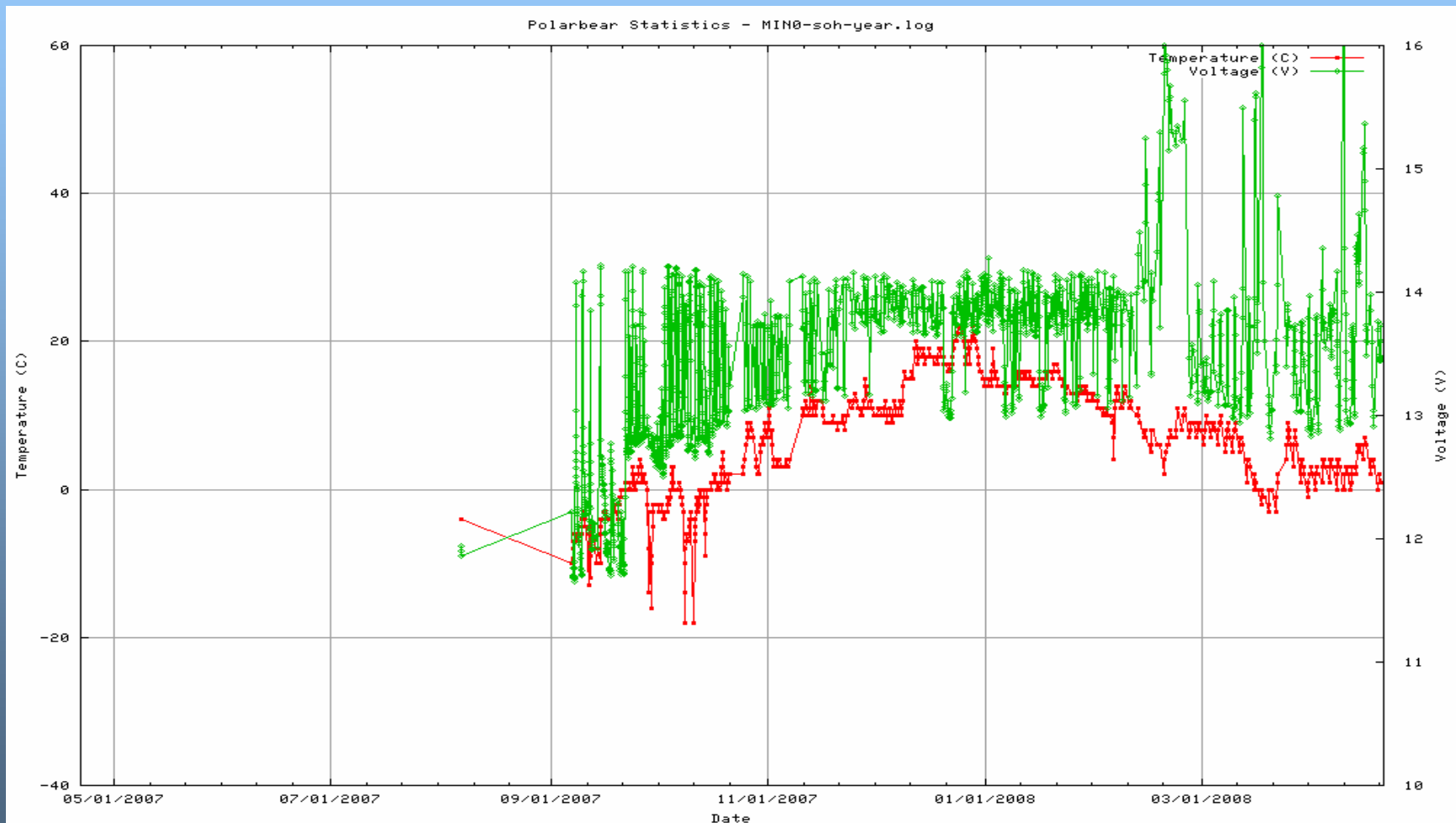
Margin Prototype: Minna Bluff

- Installed Feb 2007, re-visited Feb 2008
 - Added second wind turbine, raised Iridium antenna.
 - New Iridium timer, 24 hrs on/24 off: system now ~4.5W instead of ~5.2W
 - Station now a POLENET site
- Key results
 - Station ran near-year-round with comms
 - Power cycling due to solar regulator LVD malfunction (~1.5 months downtime), solved by wiring GPS direct to batteries
 - System in great condition except turbine
 - Forgen 500 performance
 - Wired direct to battery bank (unregulated)
=> Powers electronics first, then batteries
=> Slows down battery bank drain rate
 - Powered system thru winter; shutdown in June otherwise
 - Damage from wind-blown sand and rocks



Margin GPS System: Development

MIN0 (78.7S): Temp/Voltage. Charging from new turbines after site visit Feb 2008



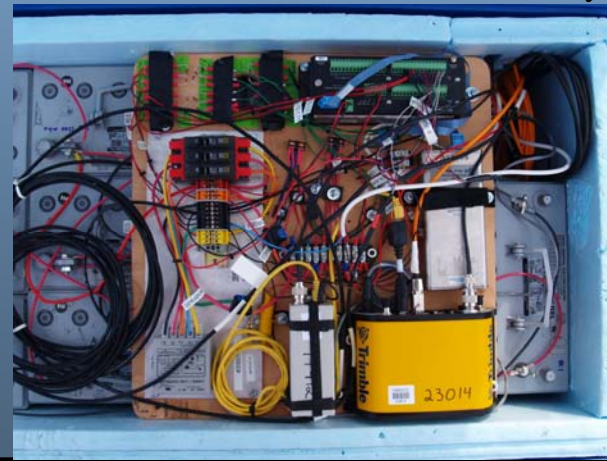
Margin GPS System: Development

Margin Testbed: McMurdo

- 2007: System characterization
 - Temperatures, voltages, power inputs/outputs recorded
 - Clean shutdown and startup behavior
 - Integrated Vaisala weather station
 - Forgen 500 and Ampair Dolphin tested side-by-side

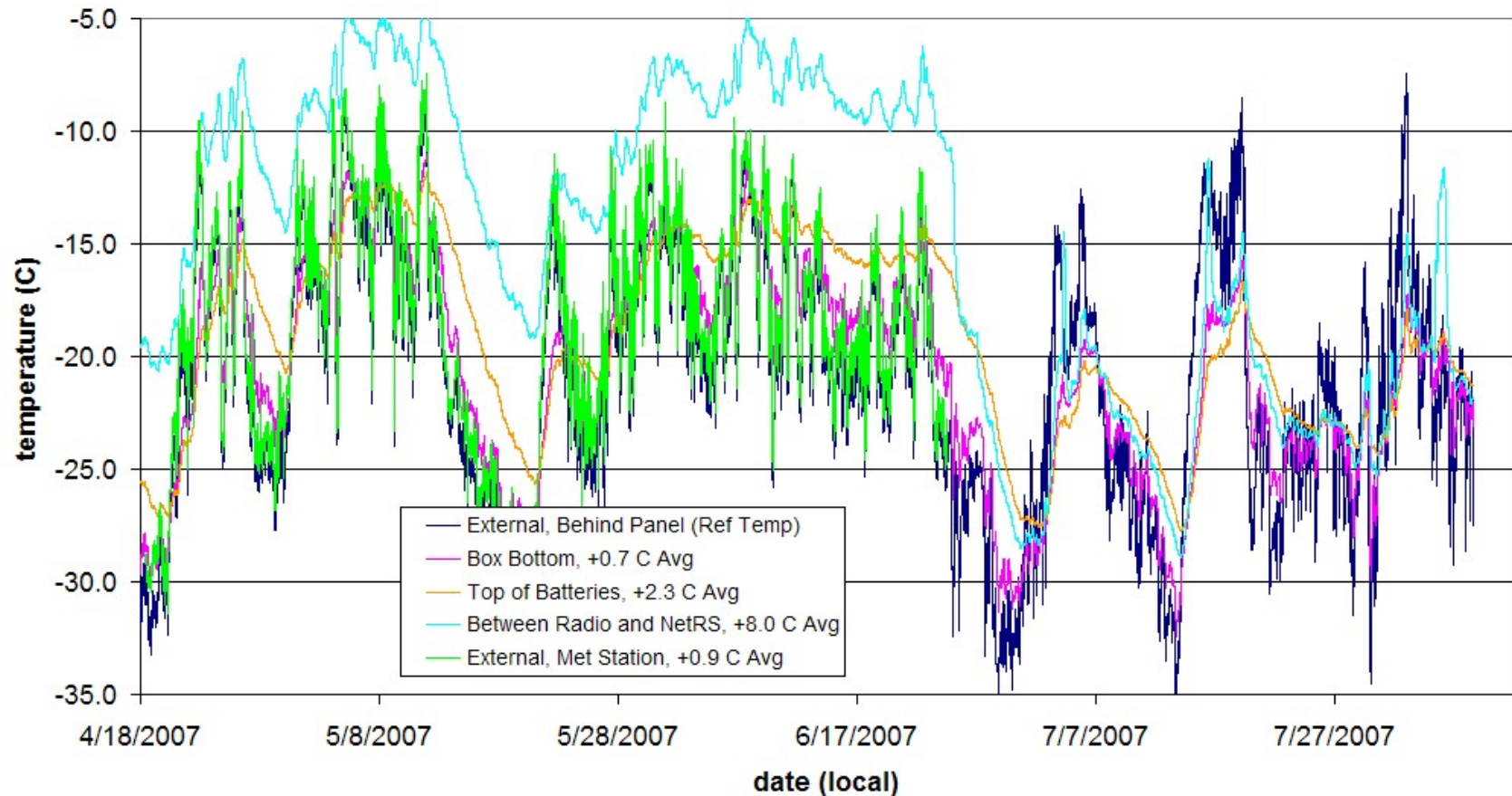


- Key results
 - GPS margin sites: foam insulation is enough
 - Low winds but abrasion on back of panels
 - recommend backing on all solar panels
 - Ampair Dolphin (discontinued by mfg.)
 - 40% more power than Forgen 500
 - Stronger mechanical design
 - Forgen 500
 - Output power versus windspeed quantified
 - Electrical failure 11/07, no system damage



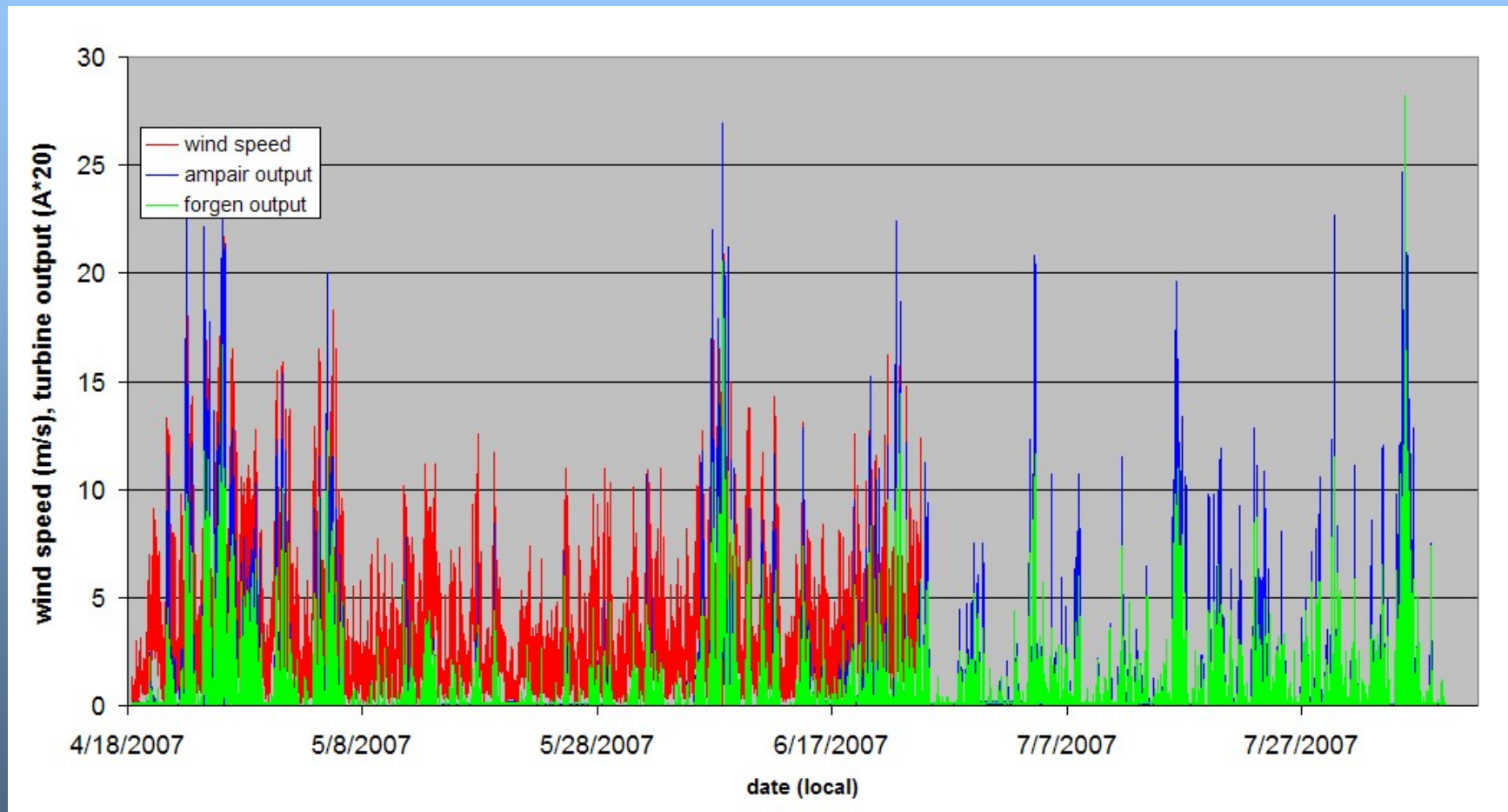
Margin GPS System: Development

McMurdo Temperatures, Winter 2007



Margin GPS System: Development

McMurdo Wind Turbine Data, Winter 2007



Margin GPS System: Development

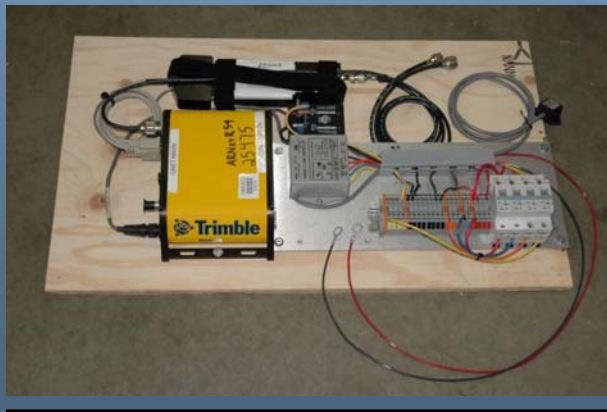
Iridium data retrieval: 1 MB/day

- Development

- Iridium hardware fully integrated into remote NetRS GPS system
- Still modem-to-modem (not optimal)
- This was a significant development effort (whack-a-mole!)

- Key results

- Robust download scripts cleanly handle call drops, comms errors, file catchup
- Scalable download hub
 - 6-7 sites per channel, up to 24 channels
 - All data into UNAVCO archive
- Full data retrieval with remote modem powered off 50% of time (save ~0.4W)
- Automated state-of-health info online

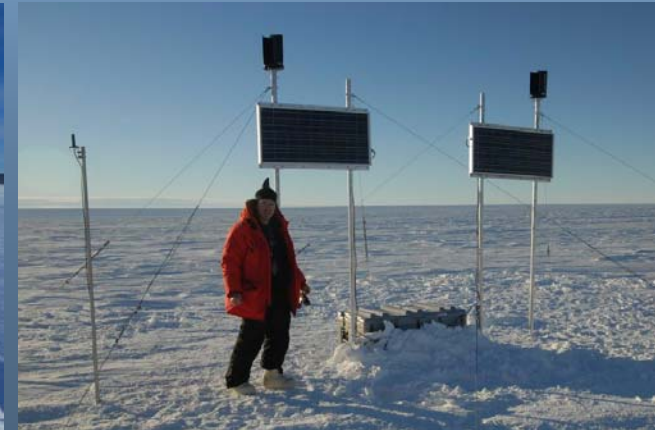
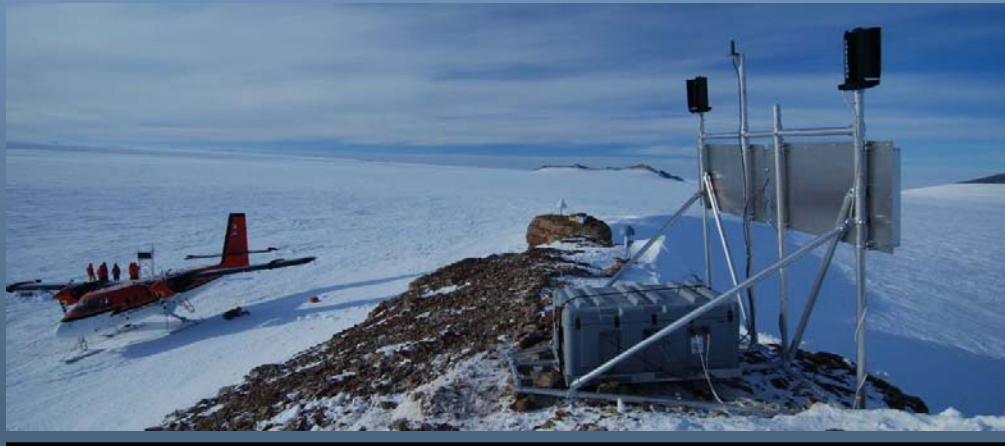


Margin GPS System: Summary

- Design foundation from TAMDEF project (OSU, USGS, LINZ)
 - Elements from former TAMDEF and current POLENET sites ROB4, FLM5, FTP4
- Mechanical improvements
 - Structural frame redesign. Enclosure and batteries placed on frame.
 - Wind-hardening (solar panels, frame, anchoring)
 - Optimization of field installation: 3 person team, 5 hours ground time, 1 or 2 flights
- Electrical improvements
 - Trimble NetRS receiver fully field-qualified. System power draw reduced to ~4.5W.
 - Clean and simple wiring scheme. Rugged cables and connectors.
 - Use of wind power at high-wind locations w/somewhat novel electrical approach
- Communications solutions
 - Point-to-point to research bases: Intuicom ethernet and FreeWave serial radios
 - Deep field: Iridium satellite system
 - Scalable Iridium download hub at UNAVCO office
 - Robust download scripts, state-of-health plots automated

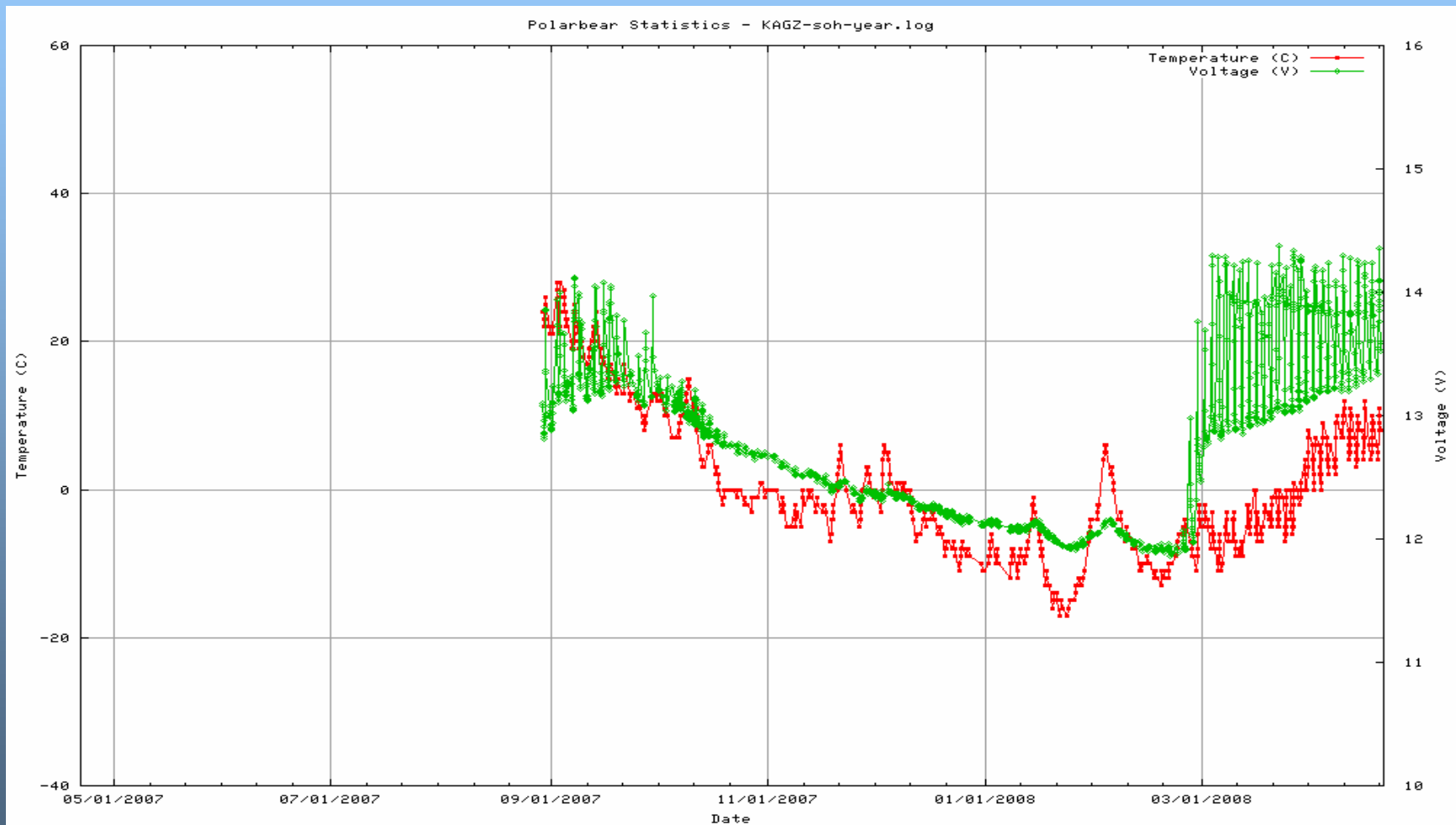
Margin GPS System: Summary

- So what?
 - IPY-POLENET project: Year 1 is finished
 - 18 of 30 remote Antarctic GPS stations installed
 - 20 of 37 remote Greenland GPS stations installed
 - PI projects: ongoing demand for year-round polar GPS data
 - Currently 15 UNAVCO-supported sites in Antarctica, 5 with comms.
 - System is modular and adaptable, suitable for powering other polar instrumentation
 - David Holland (NYU): weather stations with met sensors, cameras, state of health. One installed at Pine Island Glacier Antarctica, one proposed for Helheim Greenland.
 - Magnetometers w/LDEO on Polar Plateau summer 2008-09 (?)



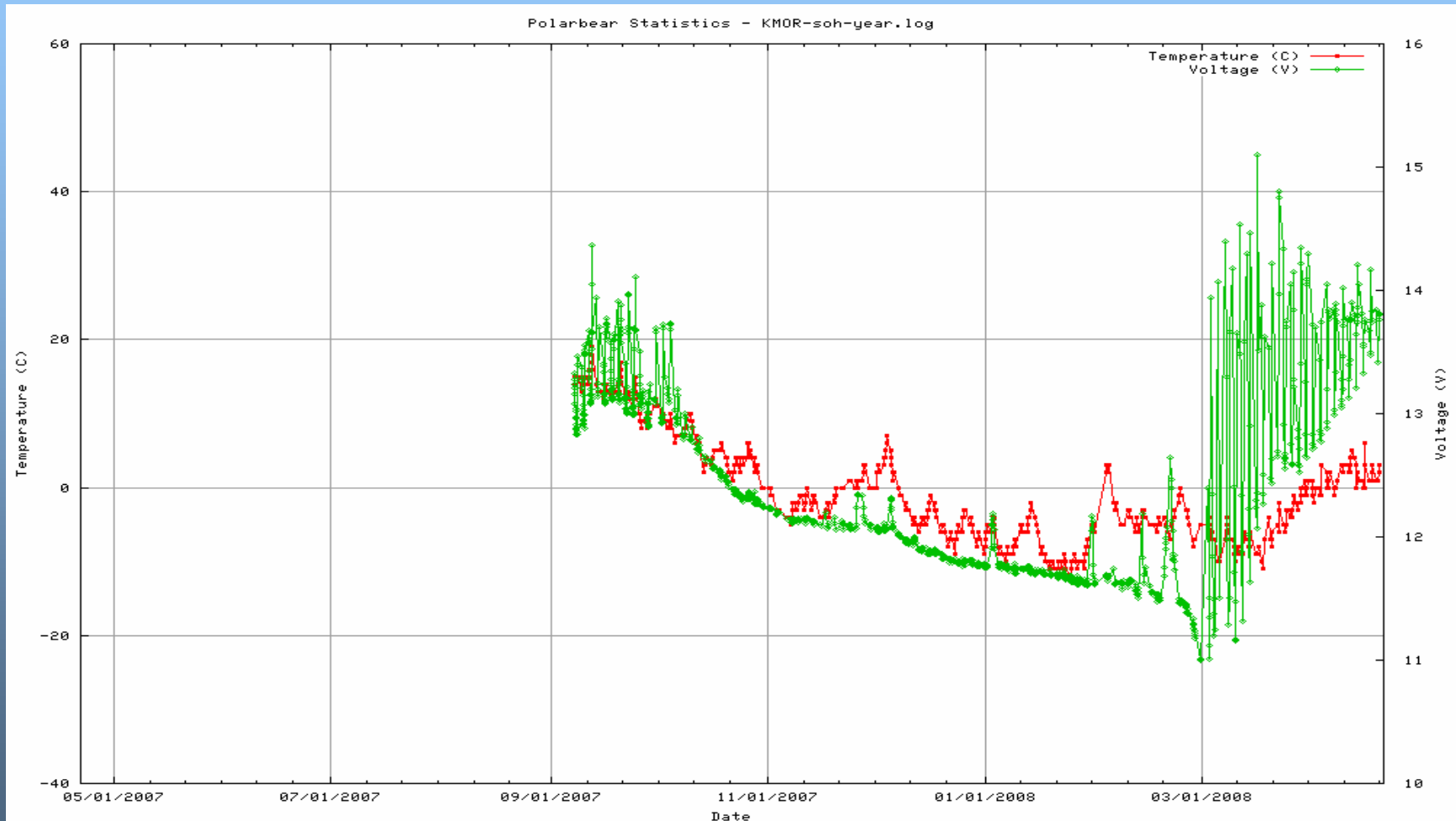
Margin GPS System: Summary

GNET site KAGZ (79.1N): Winter Temp/Voltage. Operational all Winter



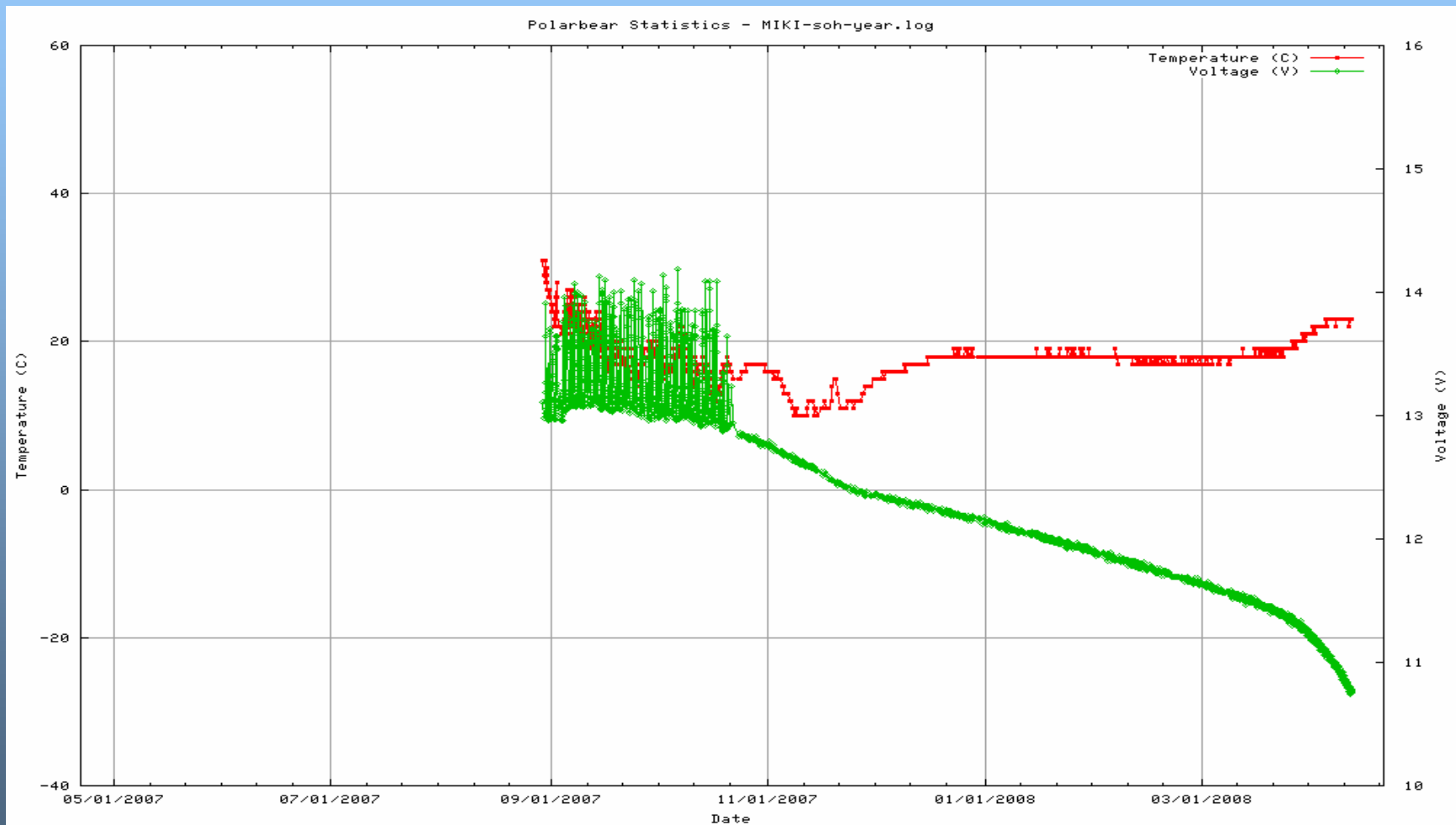
Margin GPS System: Summary

GNET site KMOR (81.5N): Winter Temp/Voltage. Two-day power loss, then recovery from solar



Margin GPS System: Summary

GNET site MIKI (68.1N): Winter Temp/Voltage. Ran all winter 2007-08 but buried in snow



Margin GPS System: Future Work

- Forgen 500 is very good but not ideal for Antarctica
 - Two unregulated turbines can operate w/o overcharging 1000 amp-hour bank
 - Electrical redesign of Forgen 500 to yield ~2x more power (available summer 2008)
 - Small, vertical axis turbine is ideal for high-wind polar sites, but key mechanical weaknesses exist.
 - Not suitable for most extreme Antarctic locations (Minna Bluff is not atypical)
 - Goodridge Engineering has expressed interest in possible modifications to Forgen design
- Solar chargers
 - Flexcharge: several field failures, no MPPT, and noisy ON/OFF charging operation
 - Ideal regulator has not yet been found
 - ALL regulators tested so far will fail at low temperatures. Very difficult to cold-cull units.
 - PASSCAL and UNAVCO are pursuing custom solar charger design
- Improved thermal management: even when not strictly necessary, extra heat helps
 - Better foam insulation and more of it
 - Self-regulating heat pads w/solar panel: heat batteries to improve charging in fall/spring
 - Prototype fielded at Miller Range Antarctica Jan. 2008. Lost comms during major storm. Why? a) Iridium antenna snapped, b) regulator LVD failed, or c) it became airborne. Either way this sucks.

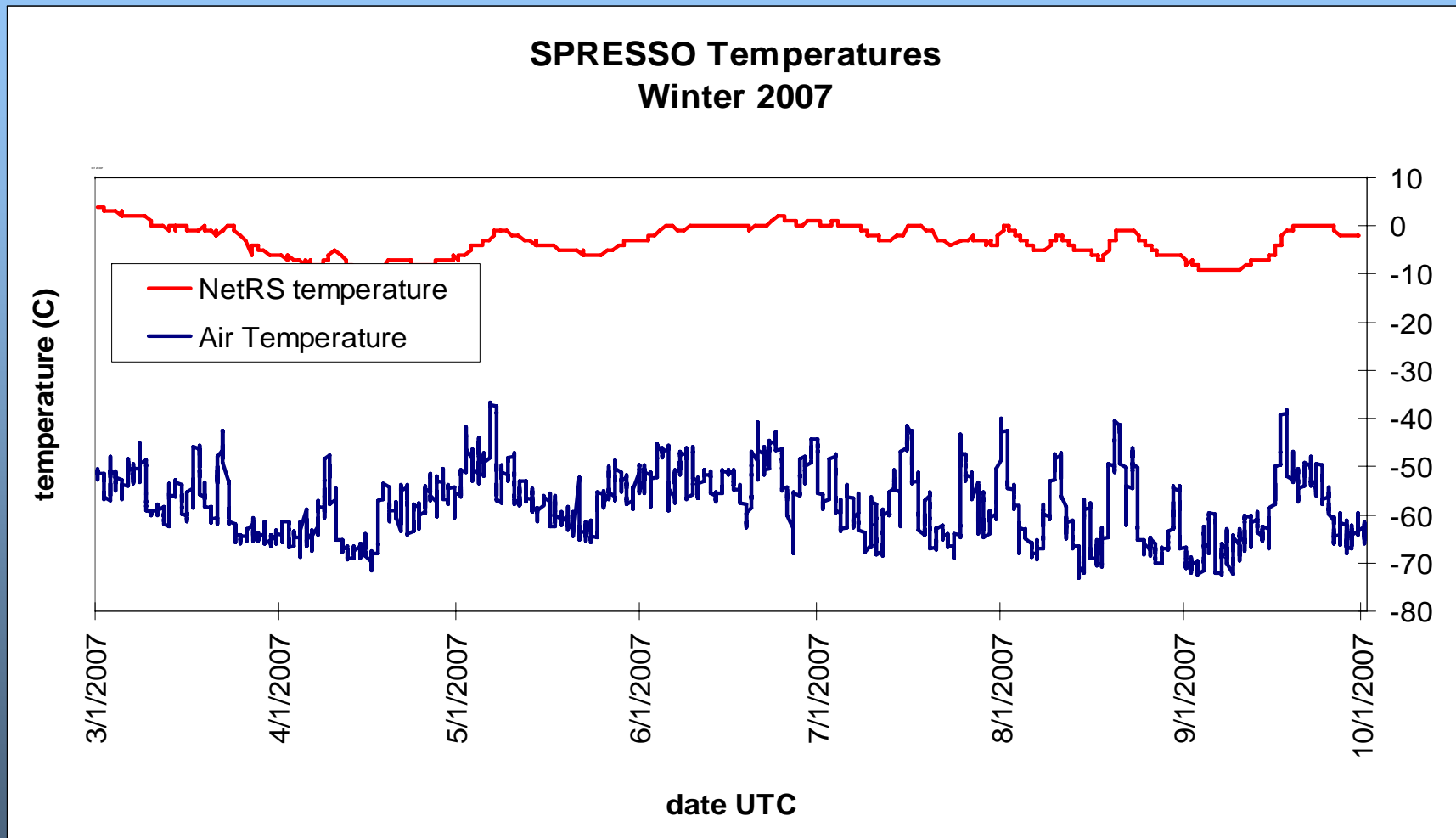
Plateau GPS System: Development

Plateau Testbed: South Pole

- PASSCAL has demonstrated year-round plateau seismic operation
 - Super-insulated precision vacuum panel enclosures
 - Solar and rechargeable SLA, plus non-rechargeable lithium-ion batteries
 - Relatively small, lightweight, deployable in one flight
- With ~2.5x more heat available, can GPS operate with less precise enclosures and less expensive, rechargeable SLA batteries?
 - GPS uses enough power to self-heat electronics with foam insulation only (verified at SPRESSO, winter 2007, running off station power)
 - Must also keep SLA batteries warm to deliver and accept charge
 - Low-speed wind turbine needed to utilize plateau winds

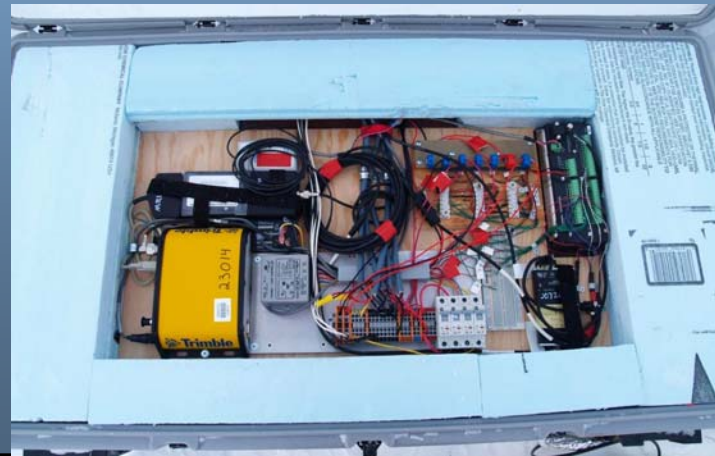
Plateau GPS System: Development

SPRESSO Temperatures, Winter 2007



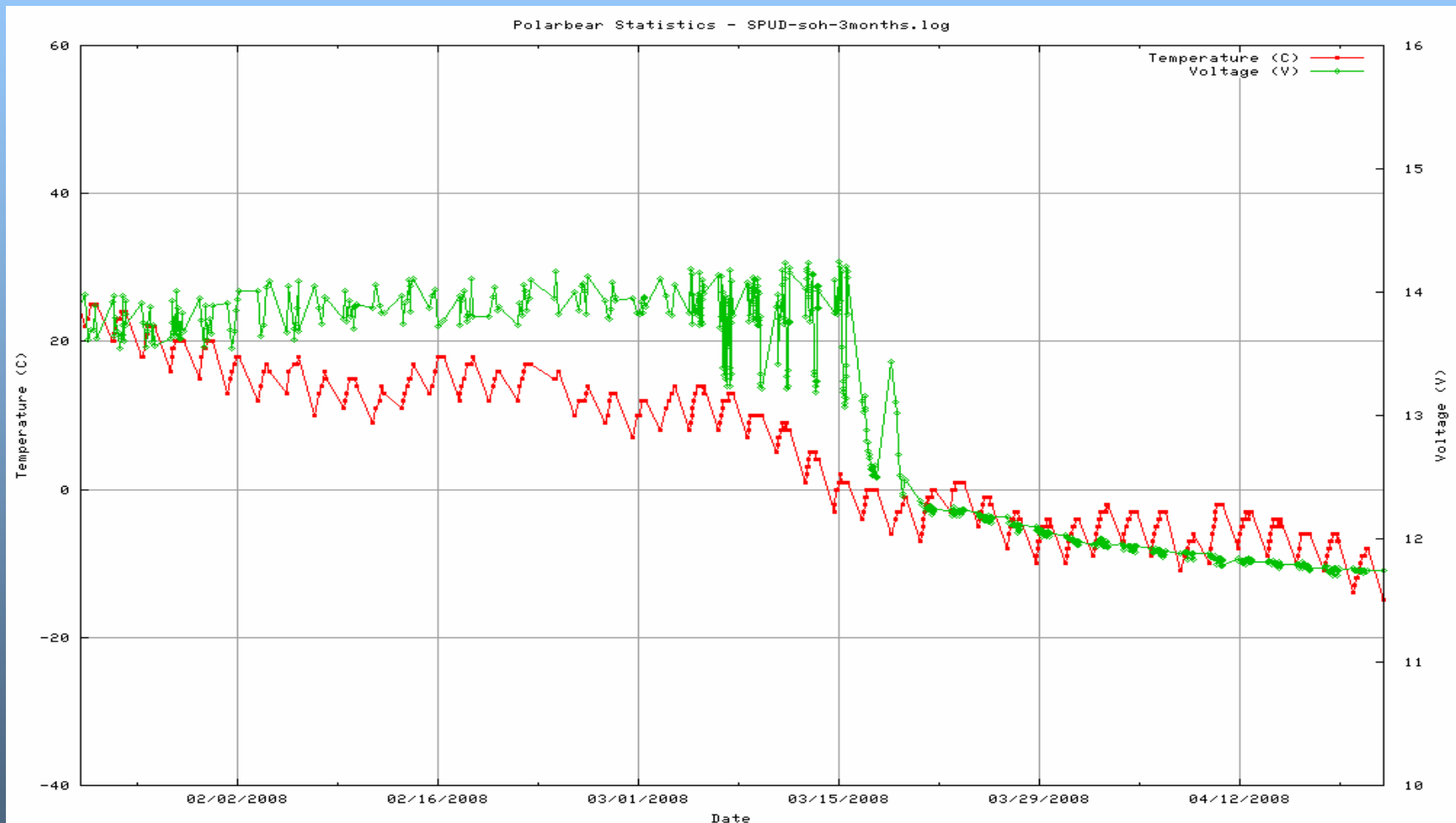
Plateau GPS System: Development

- First design: evaluate minimalist approach
 - Two Forgen 1000: one for electronics, one for heat
 - Good size, weight, cost, but cut-in speed (~10 knots) is average S. Pole wind
 - Vacuum panel insulation: ~8x better than foam
 - Used Acutemp panels – cheaper and more available than Glacier Bay (Nanopore)
 - Bought panels with tough backing => more rugged but very poor precision and fit
 - Self-regulating heat pads – one on wind turbine, two on solar panel
 - So far, not promising
 - Electronics fine, but need to keep batteries warmer and better charged with wind
 - Datalogger recording voltages, temperatures, power inputs/outputs



Plateau GPS System: Development

Recent Temp/Voltage: Will probably die by early June



Plateau GPS System: Development

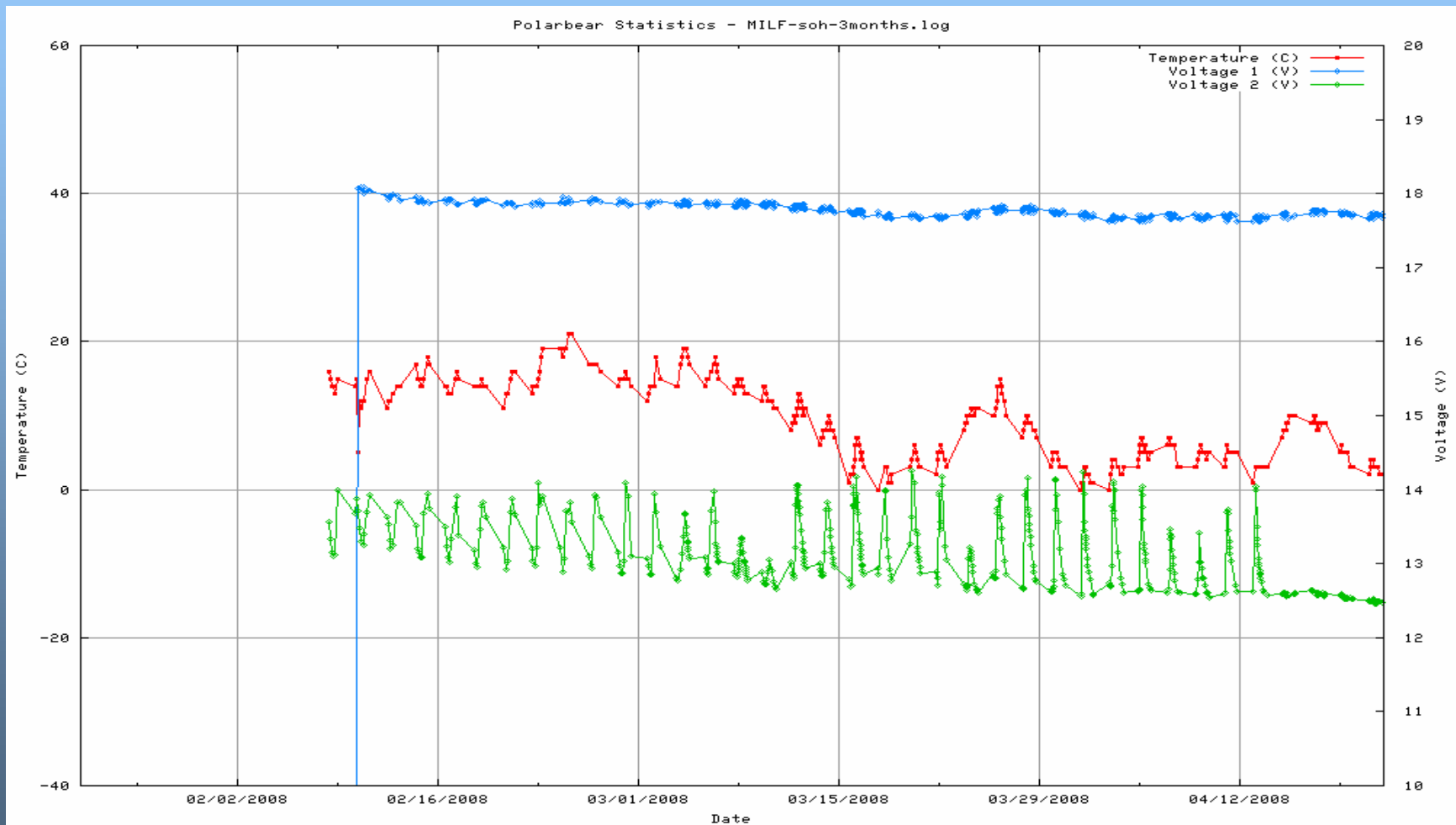
Lithium Testbed: McMurdo

- Lithium-ion / SLA battery systems proven for seismic systems (PASSCAL winter 2007)
 - High power density and good yield in extreme cold
 - Expensive and non-rechargeable, but lightweight
- Demonstration with GPS/Iridium system
 - Rechargeable gel cell batteries used first
 - Power switching
 - 3.5W GPS receiver automatically switches to lithium-ion once SLA below 11.5V
 - 1.0W Iridium remains on SLA batteries
 - Using lithium packs designed for seismic systems: not optimal but will prove feasibility. Re-engineer for GPS.



Plateau GPS System: Development

Lithium Testbed battery packs on standby at 18V



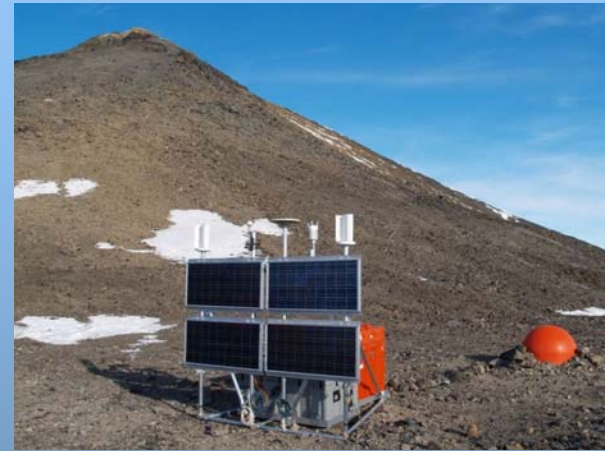
Plateau GPS System: Future Work

- Low-speed wind turbine
 - Need loose bearings! Rotating machinery generally has higher friction at low temps...
 - Low startup speed (~5 knots) even at cold temps
 - Size/weight: must be mountable on one pipe w/guy wires
 - Turbines considered so far:
 - Rutland 910-3: Horizontal axis, ~40 lbs, rugged
 - Windside 0.30: Vertical axis, ~80 lbs, solidly built, EXPENSIVE
 - African Wind Power 3.6: Horiz axis, excellent for AGO systems but too powerful for our use
 - Forgen 1000: Vertical axis, ~30 lbs, solid enough for plateau, cut-in wind speed too high
- Better vacuum panel insulation
 - Nanopore now selling “bare” panels direct – better alternative to Acutemp
 - Need to protect fragile panels yet ensure tight fit all around
- Heating scheme:
 - STEP self-regulating heat pads: resistance up with temp. Different sizes, power ratings.
 - Run output of wind turbine through heat pads before connection to batteries?
 - This approach could yield failsafe dissipation of excess heat (passive, no switching or controls)
 - Size heat pads to optimize amount of heat generated per amp delivered to battery bank

Integrated Seismic/GPS System: Development

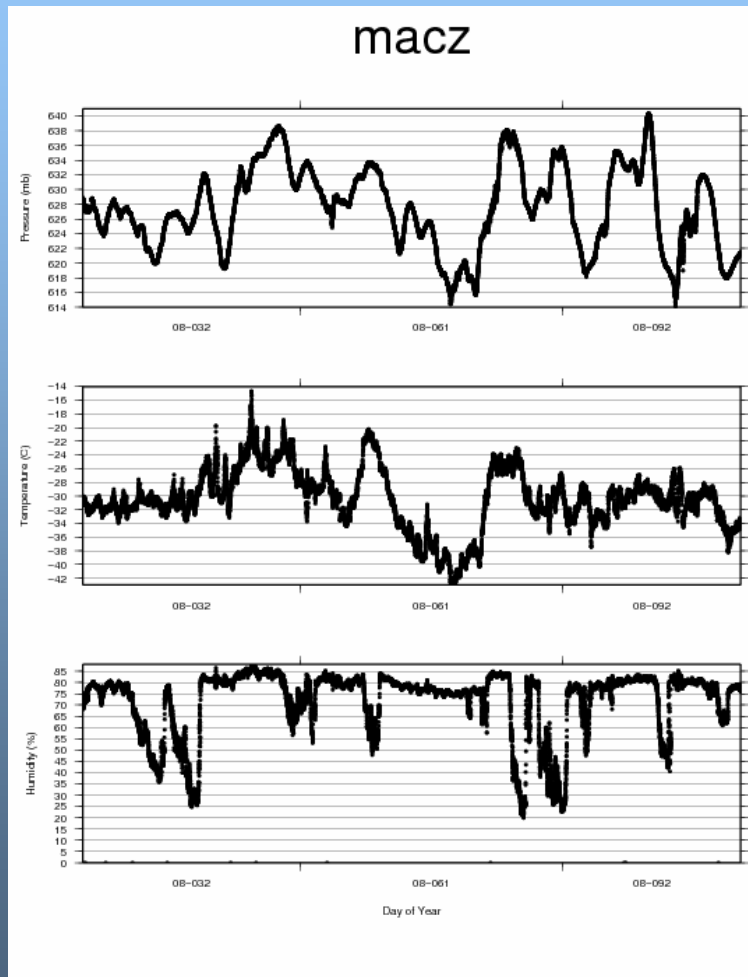
Integrated Testbed: McMurdo

- Single GPS/seismic station demonstration
 - One frame with two enclosures; power and ethernet cables between boxes
 - 4 panels, 2 turbines, weather station, 2000 AH SLA
- 900 MHz point to point comms (to Crary lab)
 - Single radio; comms shared via ethernet switch
 - Radio powered 1 hour/day
- Install shared Iridium link next season?



Vaisala WXT-510 weather data

Station MACZ (Mt. Erebus)



- Data extracted from GPS datafiles (plots from Mike Willis, OSU)
- Sensor heating disabled, so rime ice can stop ultrasonic wind measurements

