Instrumenting the Fumarolic Ice Caves of Erebus Volcano

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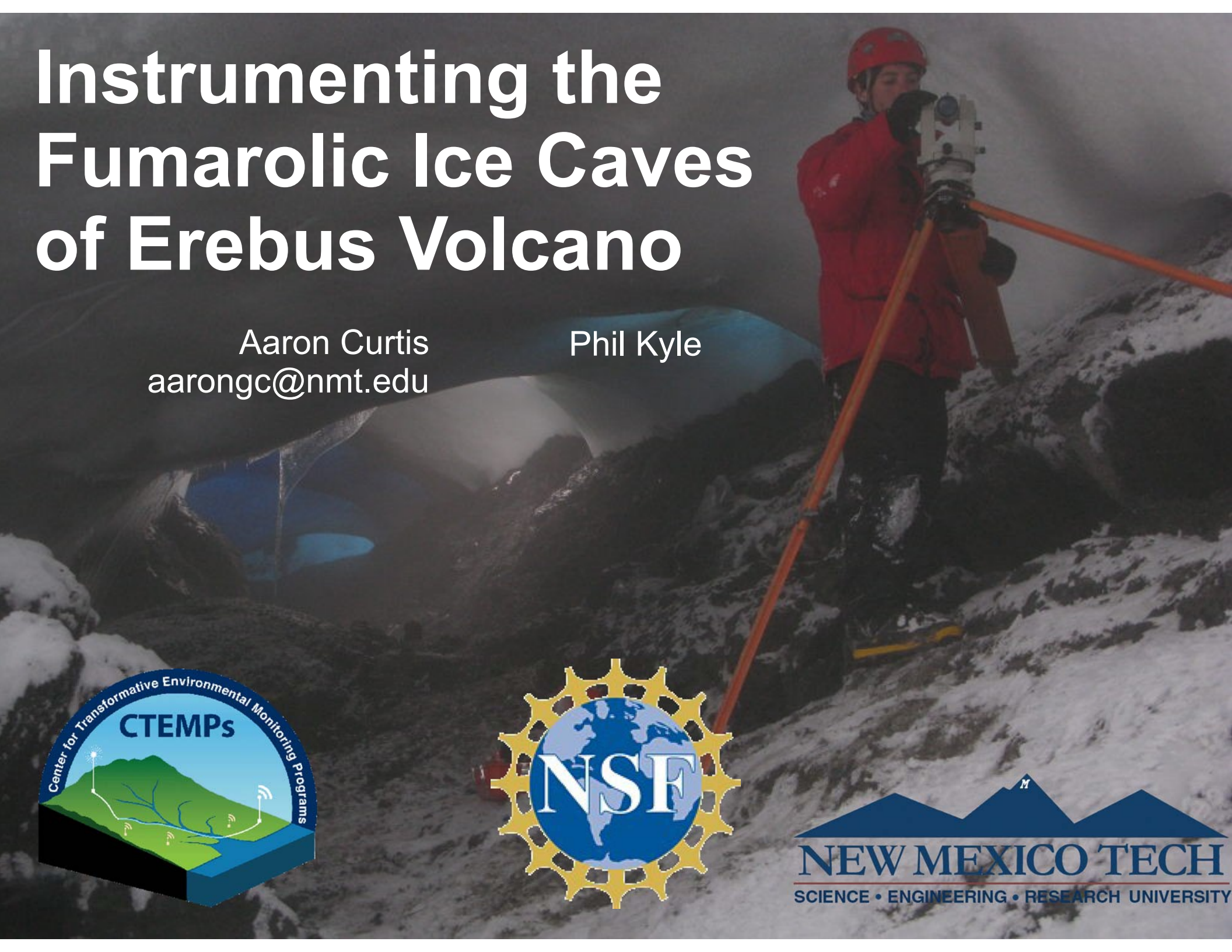
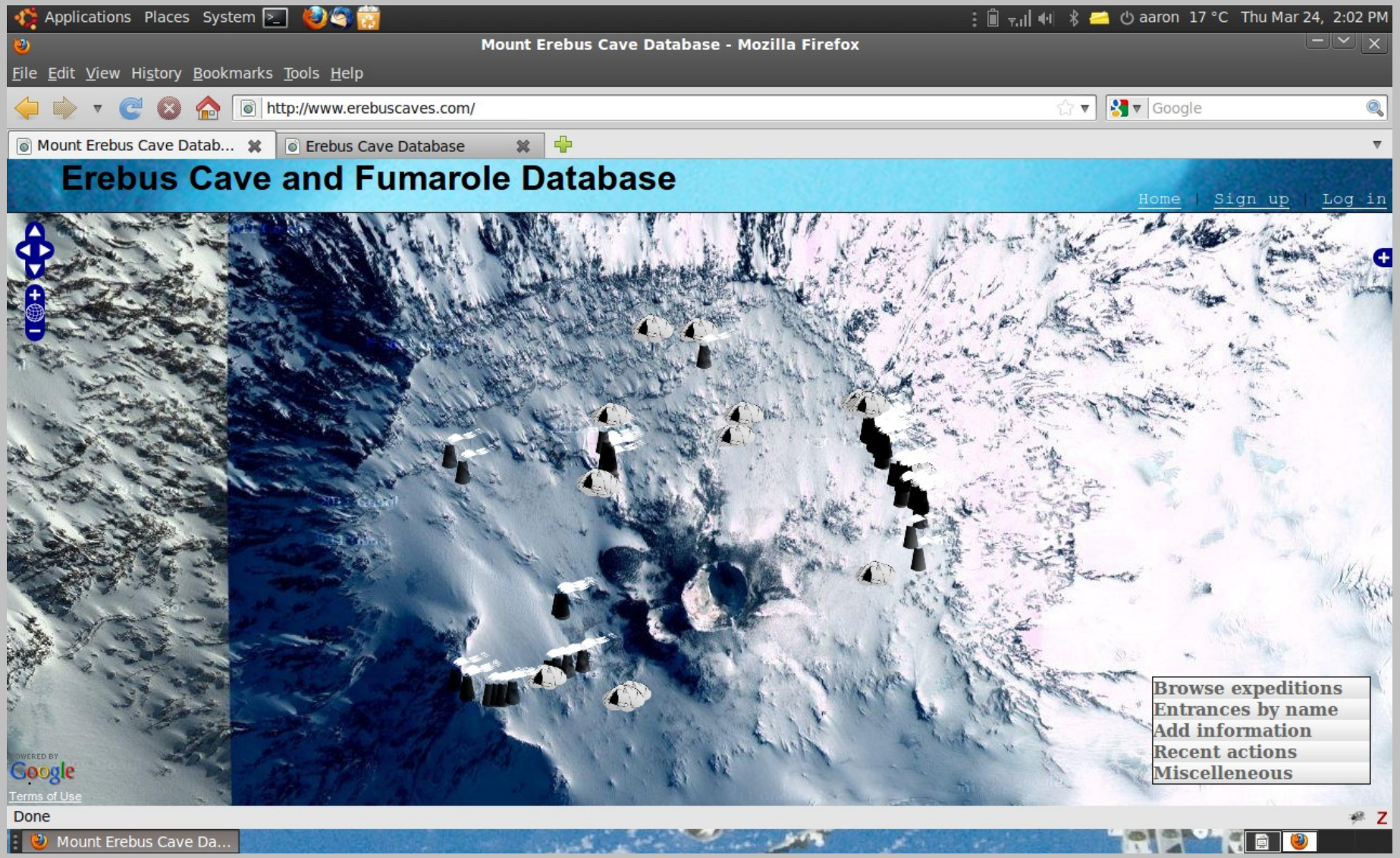


The Erebus Caves



soon to be http://erebus.nmt.edu/caves

The Erebus Caves Project

I) Characterize volcanic processes	Objectives						
II) Characterize FIT/FIC-scale processes							
III) Determine biological potential							
	Questions	A) What is the importance of diffuse heating versus RFs for the formation of FIT/FICs?	B) What is the source of the water from which FITs are formed?	C) What is the range and variability of FIT/FIC micrometerology?	D) What is the range and variability of RF emissions?	E) What is the distribution of FITs and FICs on Erebus?	F) What are the controls on FIT/FIC morphology?
	Hypotheses	A1) Every FIT and every chamber in FICs is caused by an individual RF A2) A combination of diffuse heating and RFs is responsible	B1) Hydrothermal fluid B2) Degassed magmatic water B3) Meteoric water	C1) FIT/FIC micrometerology reflects RF emissions C2) FIT/FIC micrometerology reflects atmospheric conditions.	D1) RF emissions reflect volcanic activity, and correlate with measurements at Erebus' lava lake.	E1) There is increased FIC activity on the NE flank due to a tilted magma conduit E2) FICs and FITs are controlled by zones of weakness in underlying lava E3) Some FICs and FITs are related to lava tubes	F1) Scallops on cave walls reflect airflow F2) Cave passages are the path of least resistance between RFs and the surface
FIT/FIC microclimate monitoring	Data collection						
RF emissions monitoring							
d18O of FIT ice cores and RF gas sample water							
Chromatography of RF gas samples							
d13C of RF gas samples							
Cave surveys							
FIT/FIC entrance inventory							

Technologies we used / abused

Dataloggers

- 3 Onset Computing HOBO U12-008
- 15 Gemini Tinytag TGP-4017
- 3 Campbell CR-1000

Telemetry

- Iridium
- Freewave

Cameras

- Birdcam (timelapse)
- FLIR i7 (infrared)

Distributed Temperature Sensing

- Sensornet Oryx DTS

Gas sensors

- Vaisala carbocap (CO2)
- Draeger Multiwarn II
- Draeger X-am 7000
- Telaire

Anemometers

- RMY81000
- RMY9101

Survey equipment

- DistoX
- Transit
- Prototype pocket transit

Condensate collection

Gas Collection

- Teflon bags
- Plastic tubes

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Challenging conditions

Cameras: Timelapse (Birdcam)

Chosen to

- Watch slowly changing cave structures

Pitfalls

- Poor circuit design – fixed in newer model

Results

- None in caves – only worked without flash

Dataloggers: Tinytag

Chosen because: easy deployment

Pitfalls

- Hard to re-find, not detectable by metal detector!
- Batteries are haz cargo
- Non-standard USB connection
- Slow equilibration time
- Cable ties not robust!

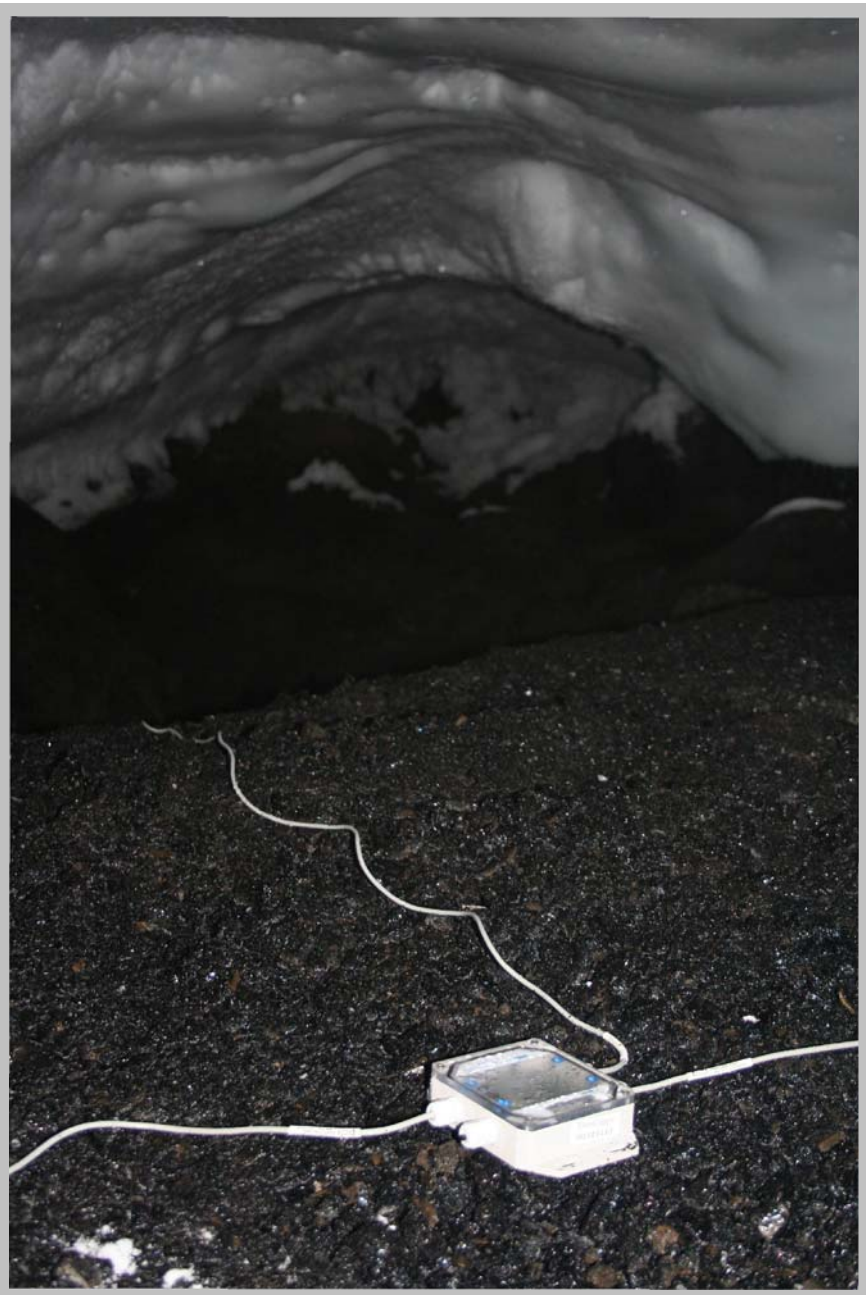
Dataloggers: HOBO

Chosen for: multiple inputs, small, USB connection

Sucess: 2 years worth of temperature data from 4 loggers except for CO2

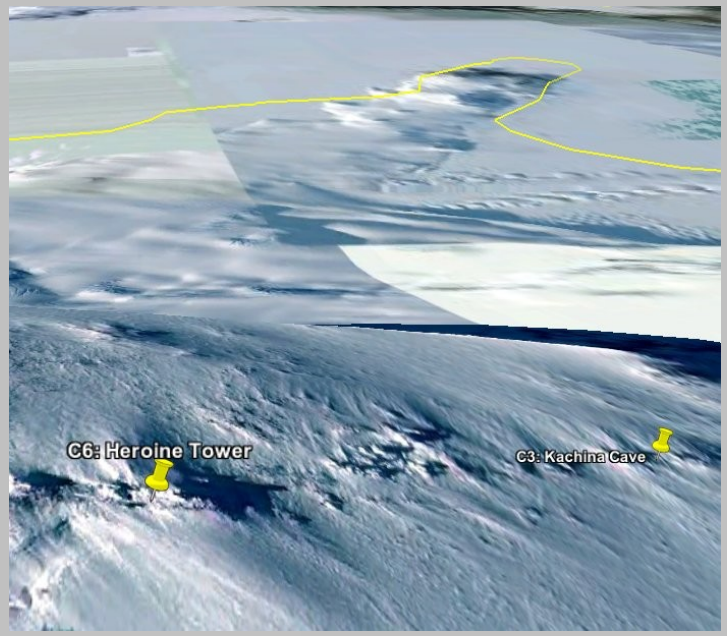
Pitfalls

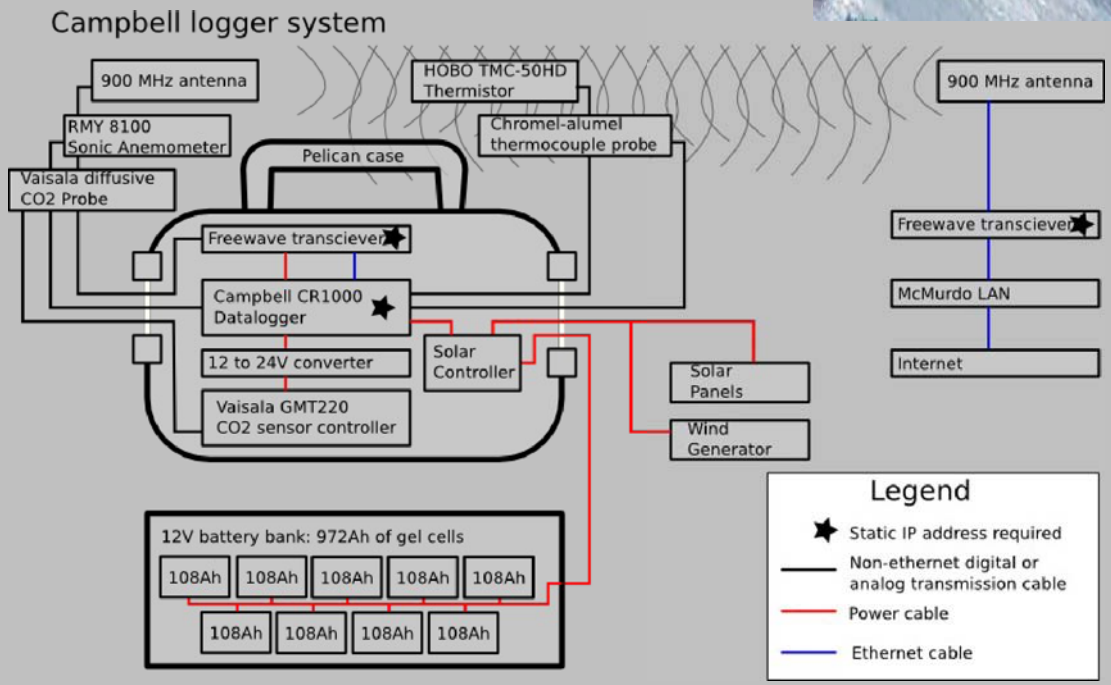
- Poorly designed USB port
- Cables difficult to attach in field
- Requires 0 to 2.5V input; unusual on sensors



Dataloggers: Campbell

Chosen for complex installations with multiple sensor types and / or telemetry

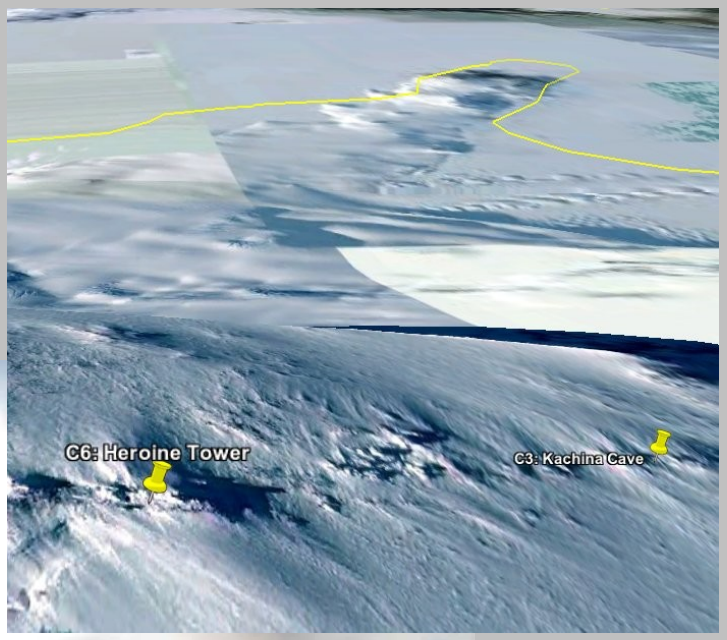




Dataloggers: Campbell

Pitfalls

- Sleep mode requires careful programming
- Antenna needed some altitude
- E-commerce security vulnerability!
- Problematic password system



Iridium datalogger

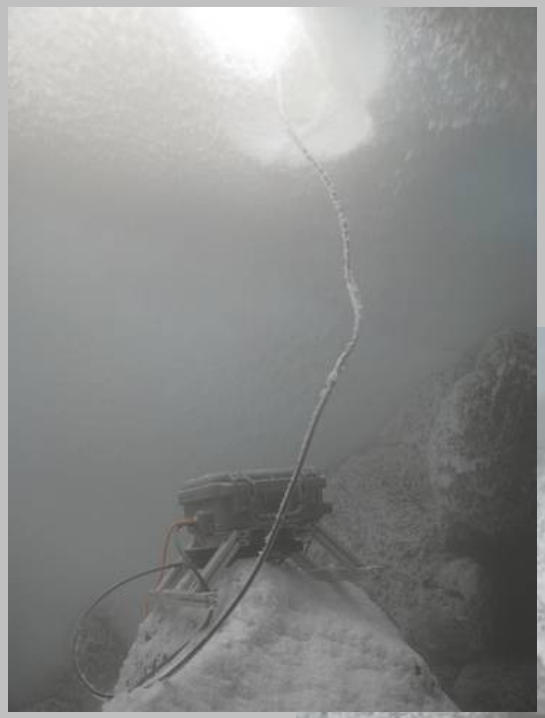
Chosen to get live data from NE Erebus

Results

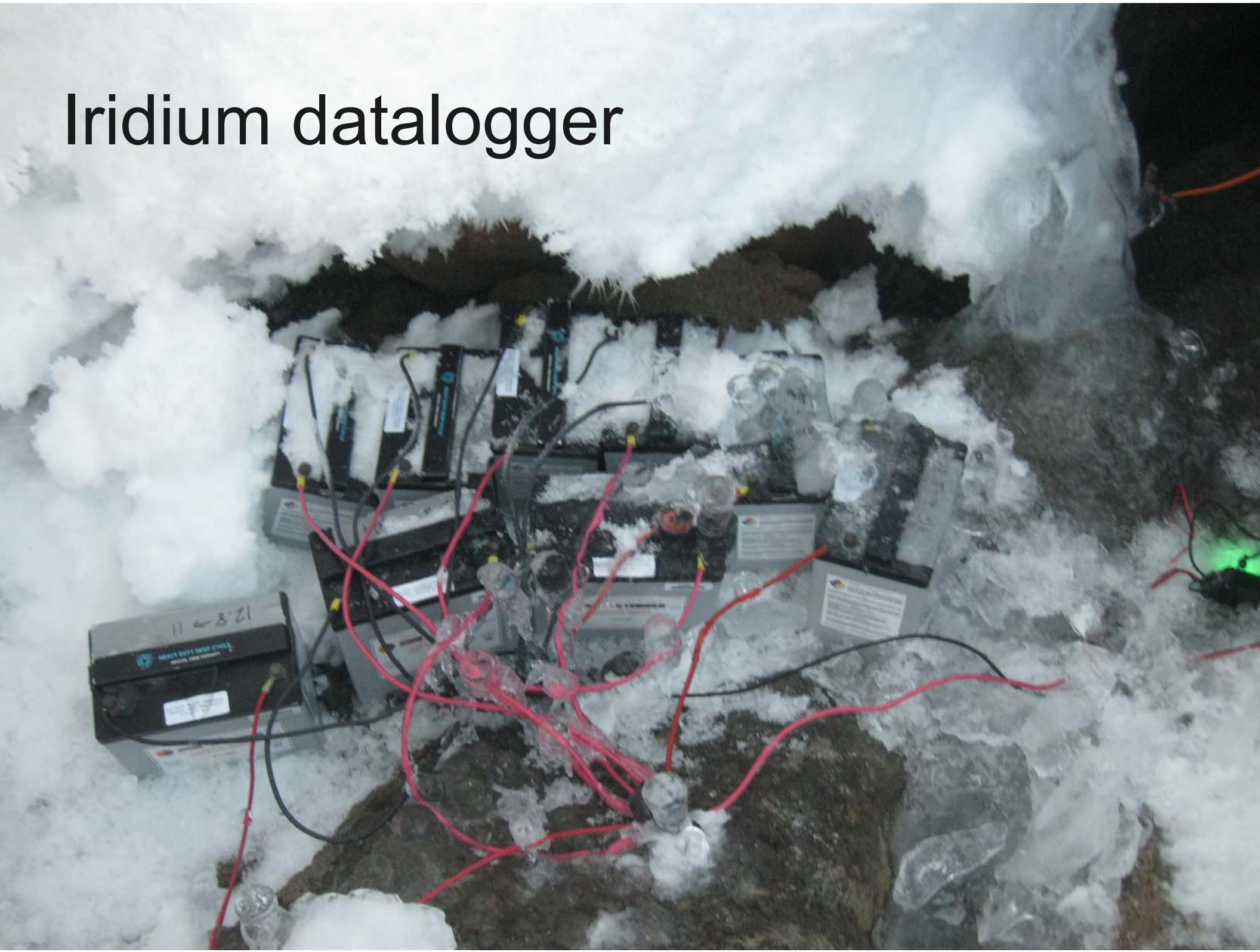
- Over 1 year of data

Pitfalls

- Antenna cable length limiting
- BASIC stamp uP with 9601 Short burst data
- Faulty Iridium modem swapped at last minute
- Freezing-in

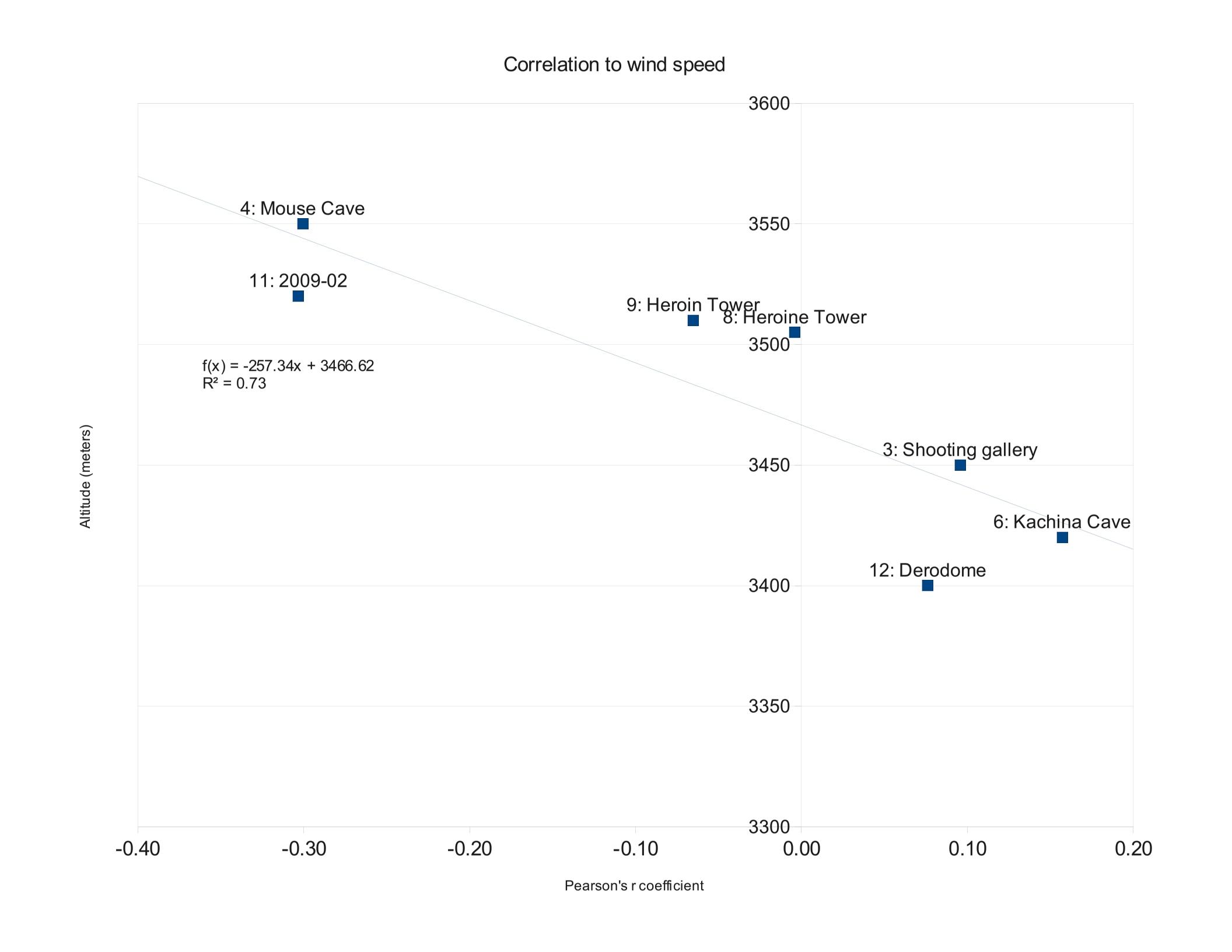


Iridium datalogger



Iridium datalogger

Dataloggers: some results


Correlation to wind speed
4: Mouse Cave
11: 2009-02
9: Heroin Tower
8: Heroine Tower
f(x) = -257.34x + 3466.62
R² = 0.73
3: Shooting gallery
6: Kachina Cave
12: Derodome
Altitude (meters)
3600
3550
3500
3450
3400
3350
3300
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
Pearson's r coefficient

Cameras: Thermal (FLIR i7)

Chosen to

- observe diffuse cave floor heating
- provide context for other instrumentation

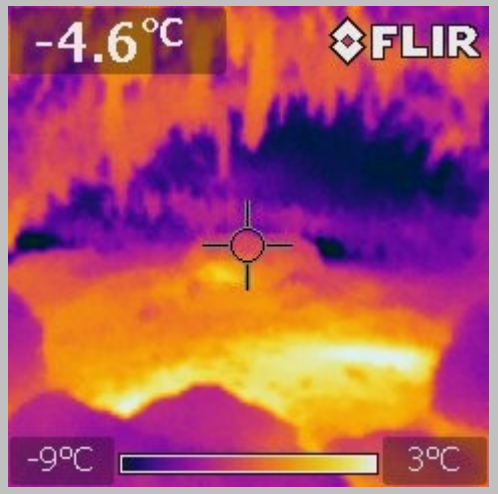
Observed

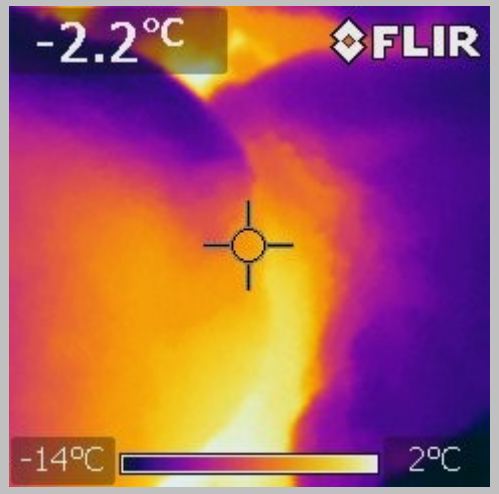
- diffuse heating patterns change
- hoarfrost temperature gradient

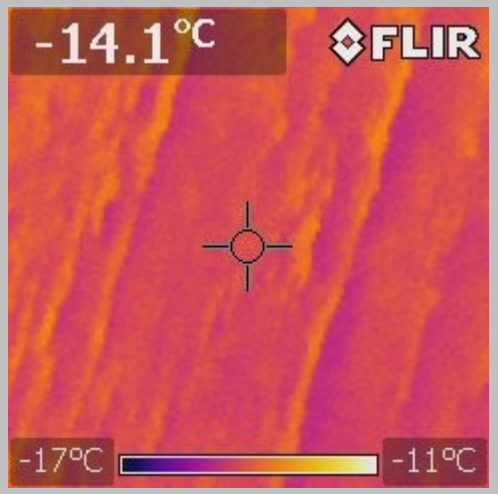
Cameras: Thermal (FLIR i7)

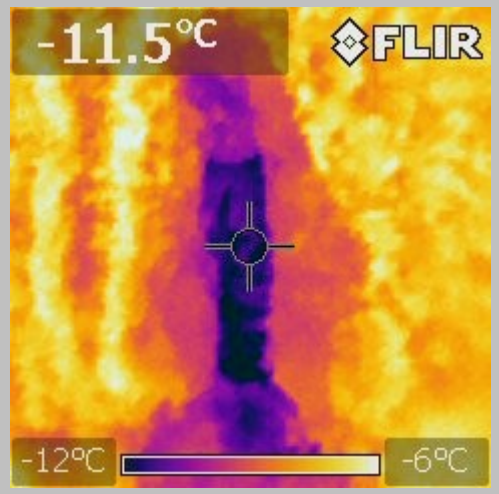
Pitfalls

- quantitative image processing requires extra software
- difficult to constrain emissivity

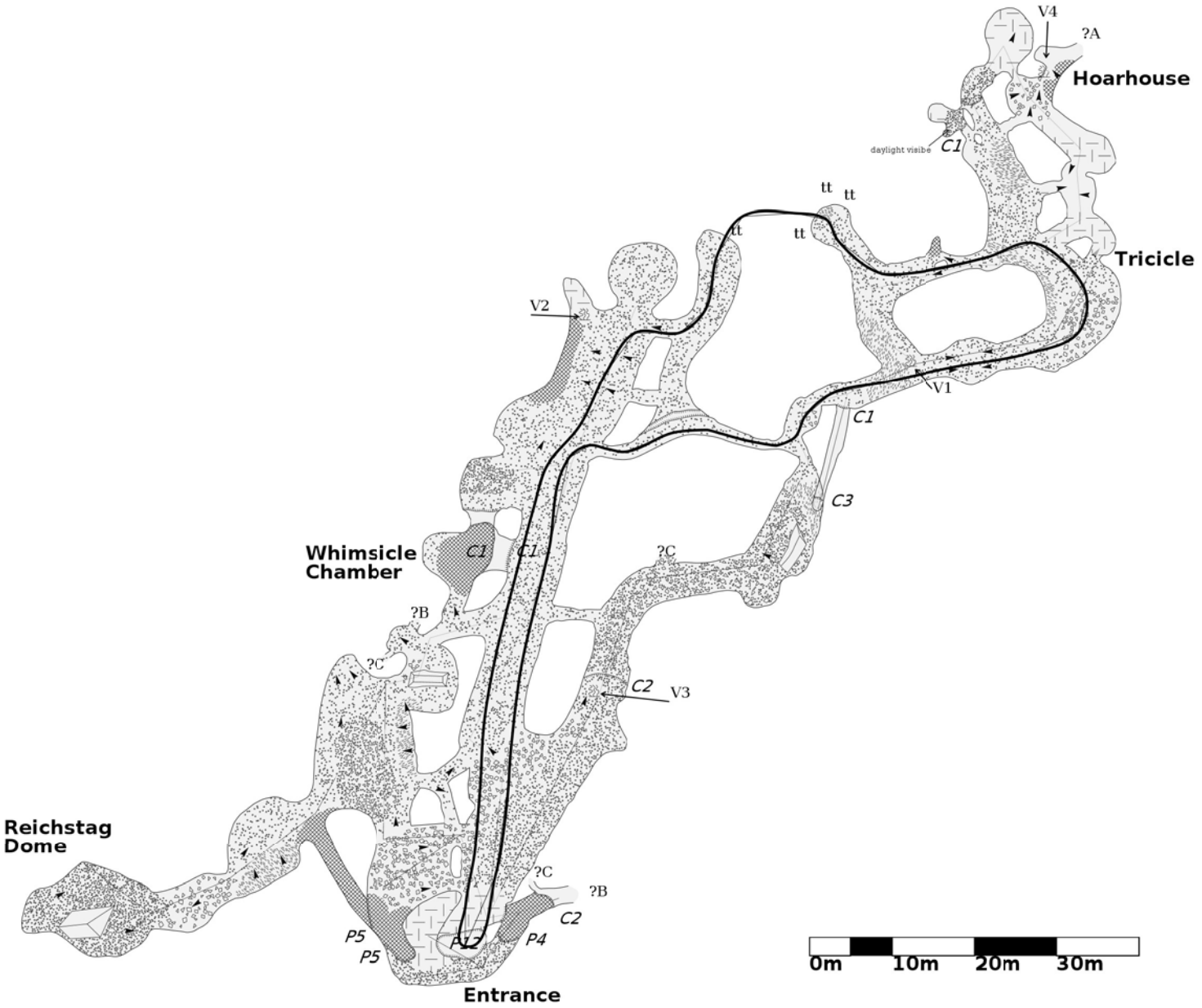








Distributed temperature sensing



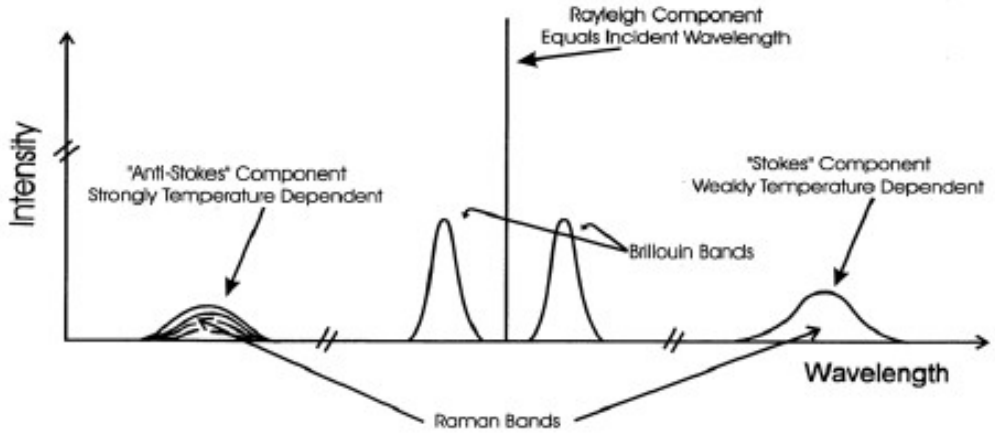
Distributed temperature sensing

Sensornet Oryx Chosen to:

- Determine relative importance of vents
- Find cryptic heat sources

Our configuration:

- 470m
- Double stranded
- 1m resolution
- < 0.1 C accuracy and precision
- 20mA standby, 100mA energized

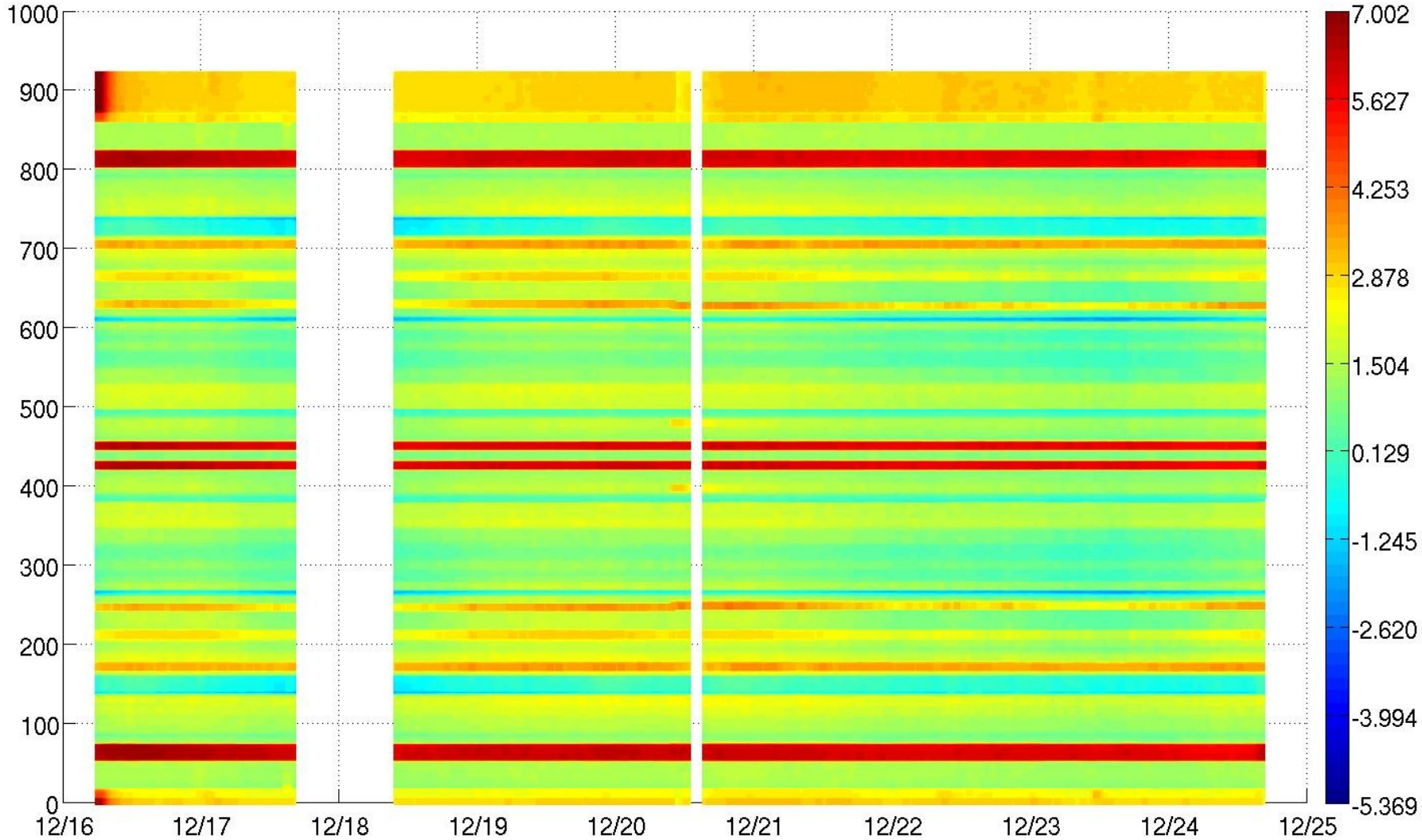


Pitfalls

- Calibration baths
- Use two 12V batteries in series, not parallel
- Good notes on cable position essential
- Slow download communications

Smolen, J and van der Spek, A (2003). Distributed Temperature Sensing

Distributed temperature sensing



Conclusions

Fumarolic ice cave dynamics

- Ice tower ridge has an underground airflow channel and responds to wind
- Gas and heat fluxes into the caves are decoupled due to magma plumbing

Technology

- Thermal camera and DTS excellent for spatial temperature data collection in the FICs
- Even within this study, multiple types of logger systems were required due to cave variety

Thanks to:

Phillip Kyle

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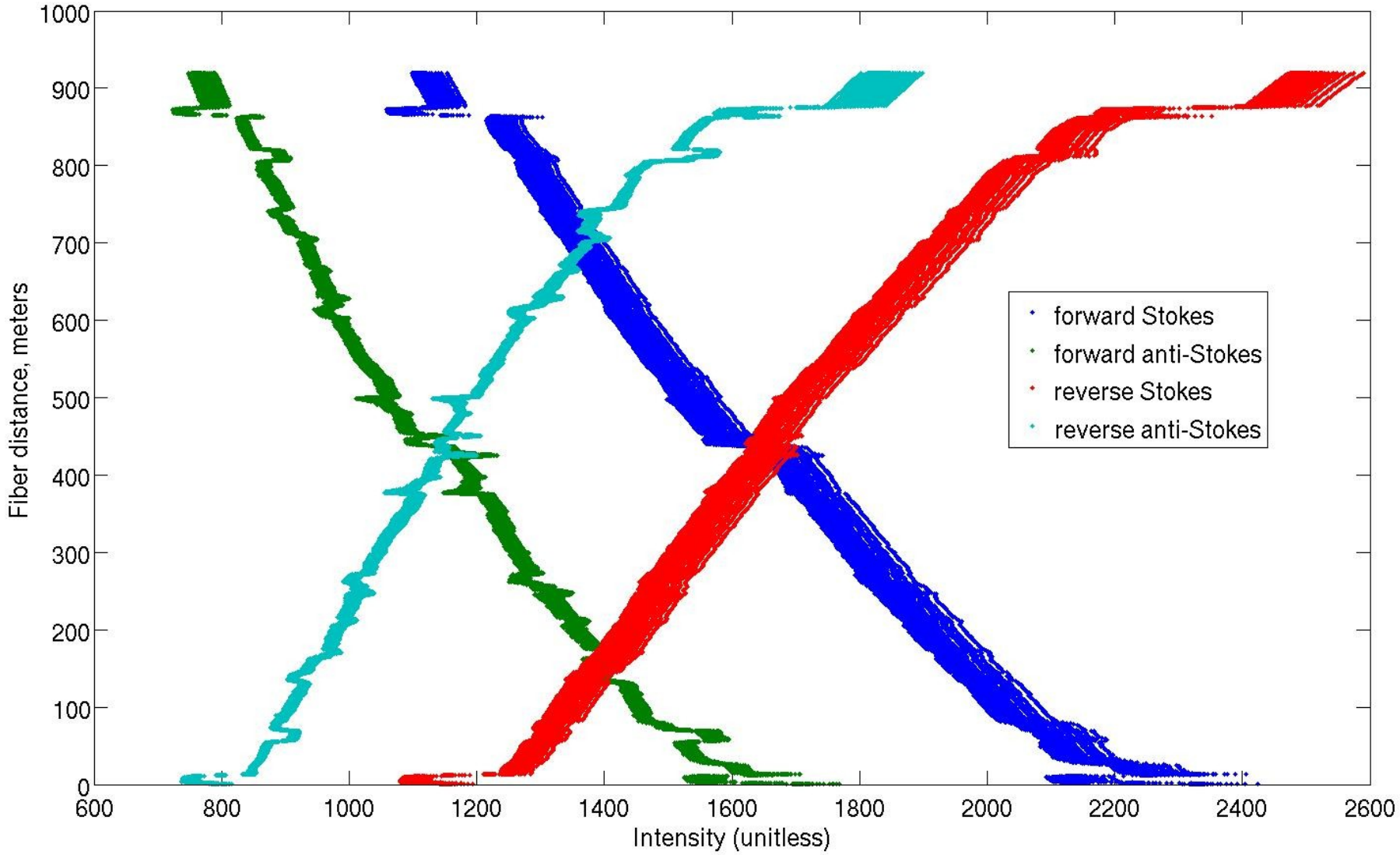
Scott Taylor

NSF

Distributed temperature sensing



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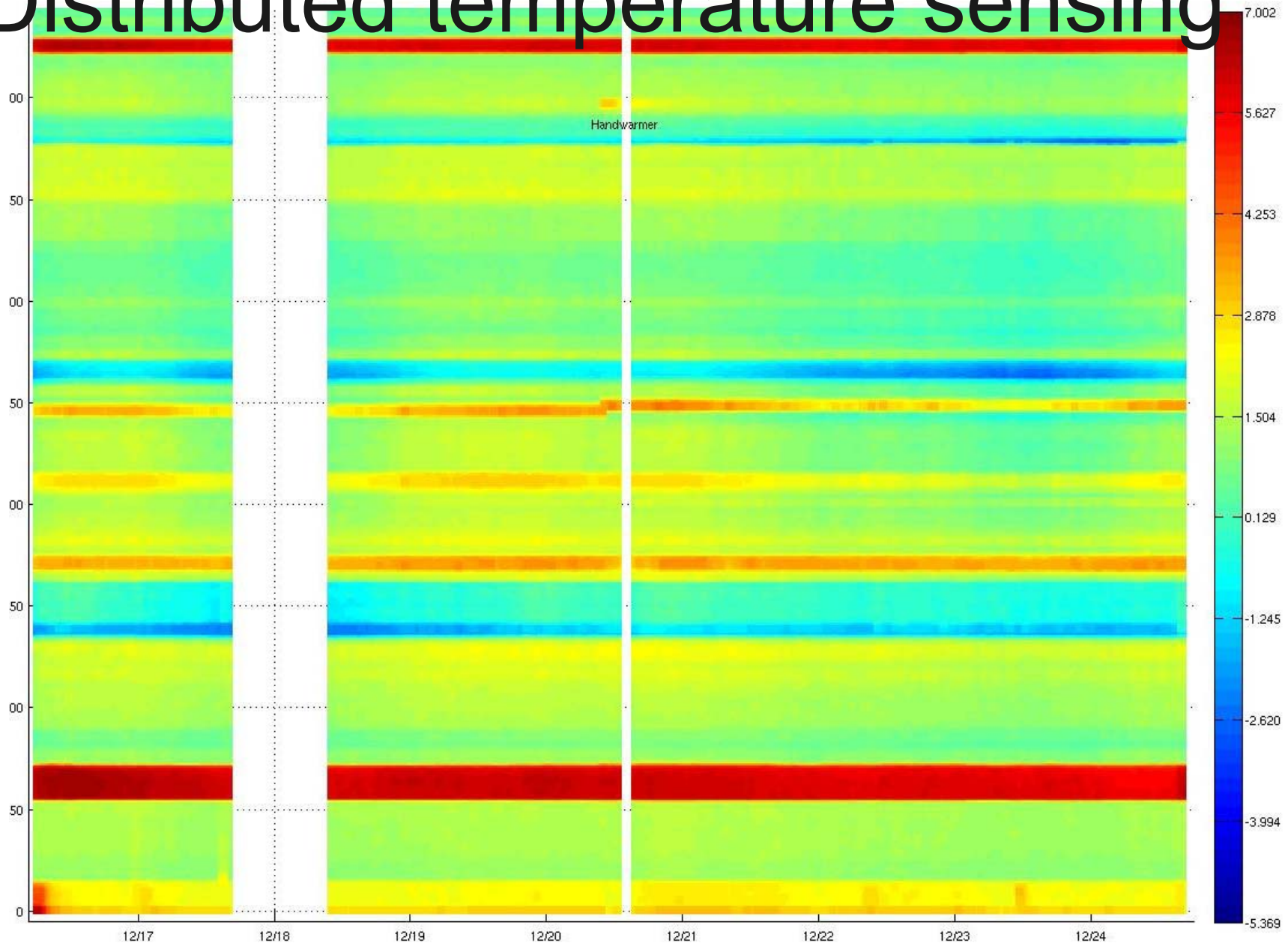
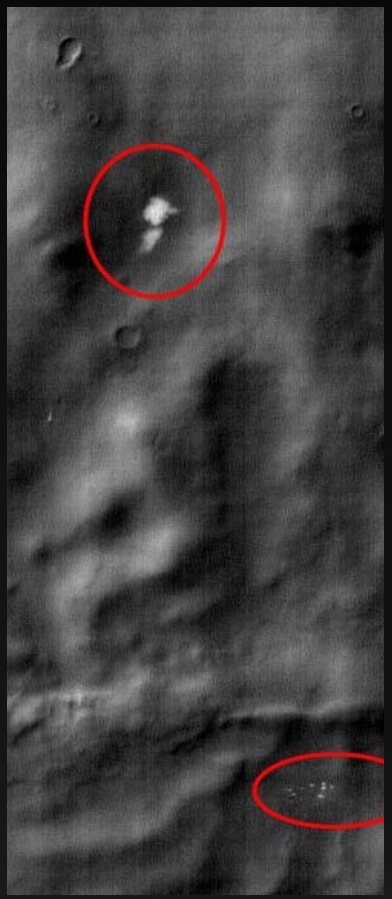


The Erebus Caves Project

- Enceladus “geysers”
- Past Martian hydrothermal systems
- Biological potential



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