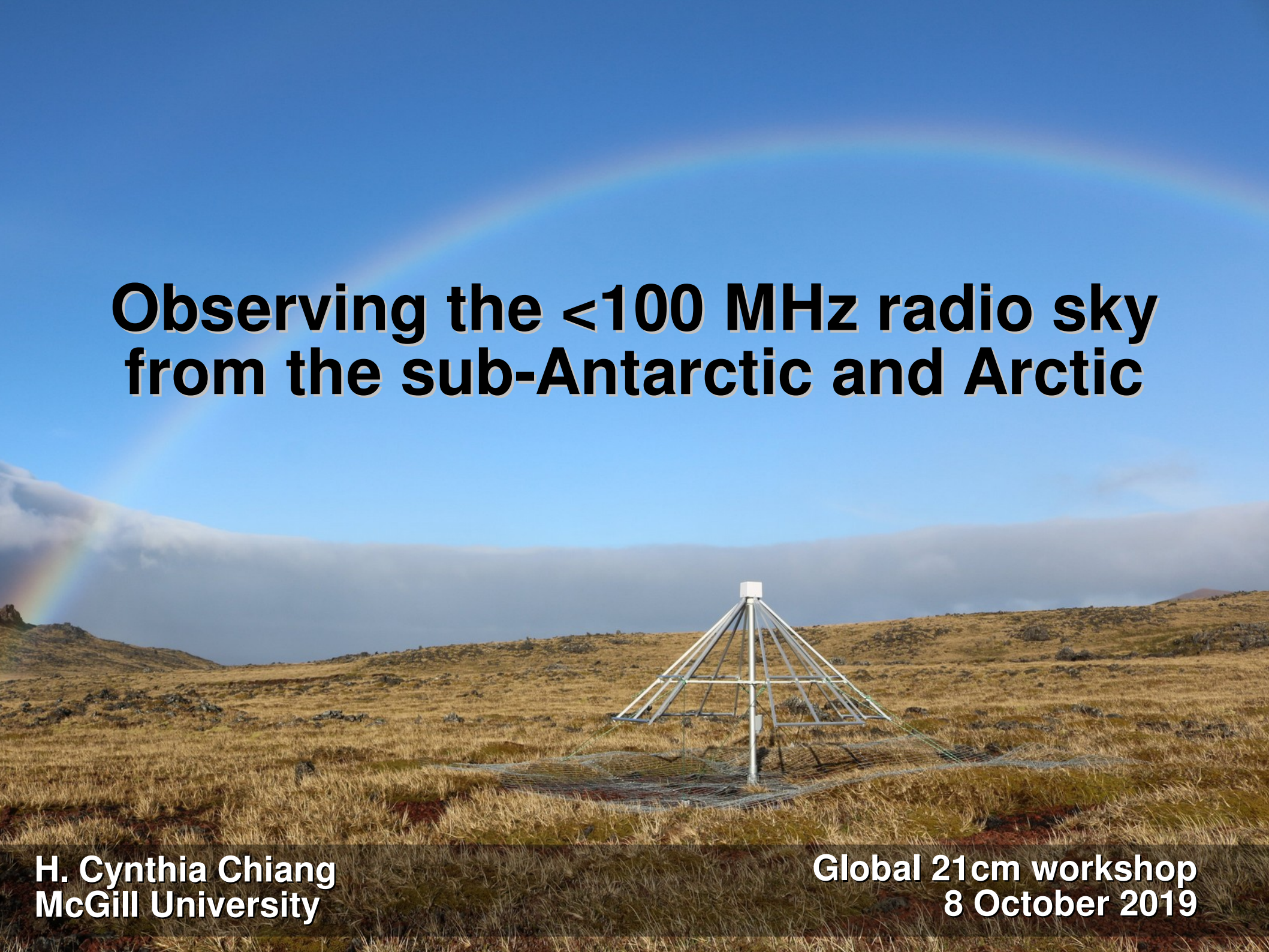
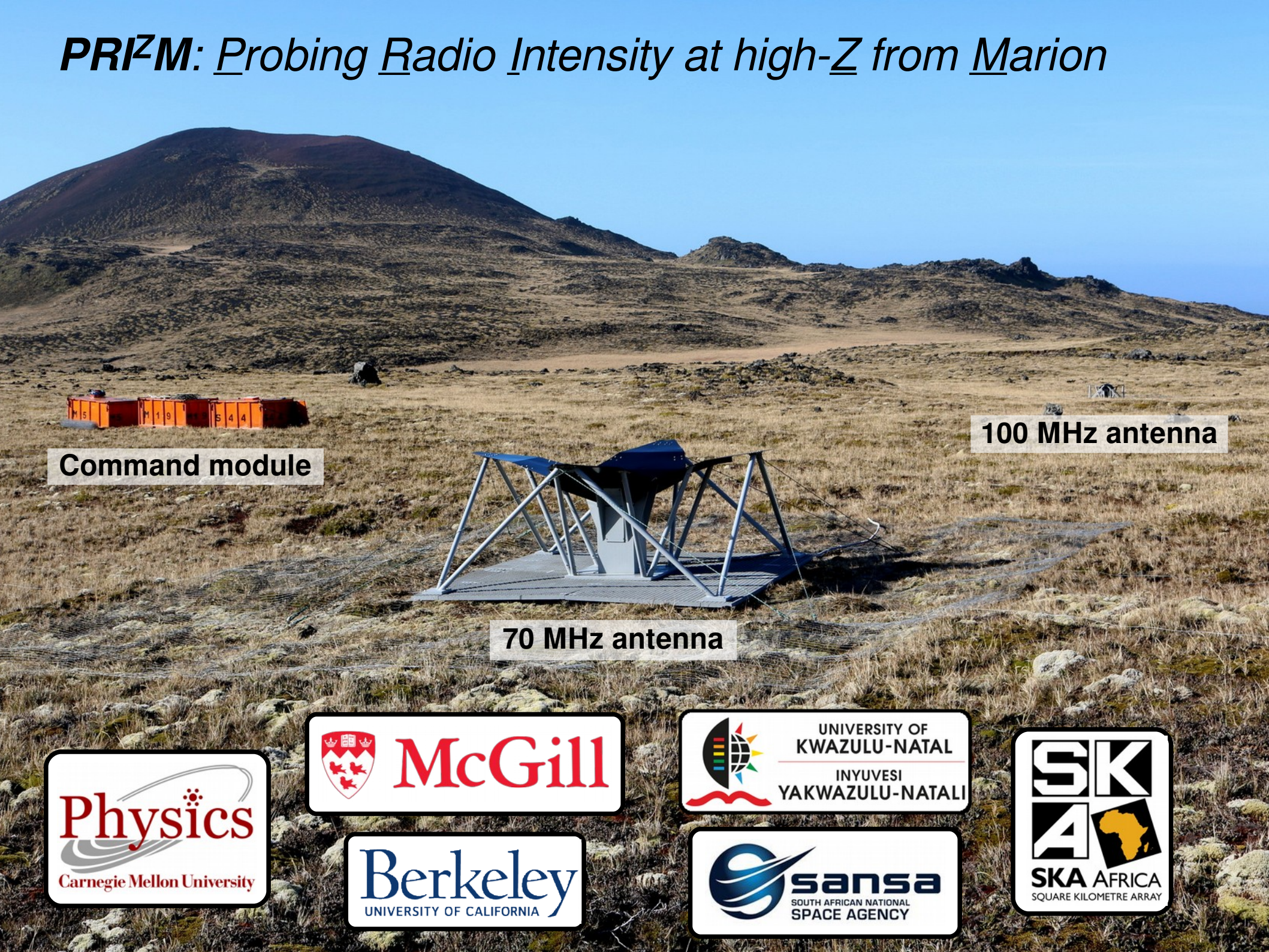
Observing the <100 MHz radio sky from the sub-Antarctic and Arctic



H. Cynthia Chiang
McGill University

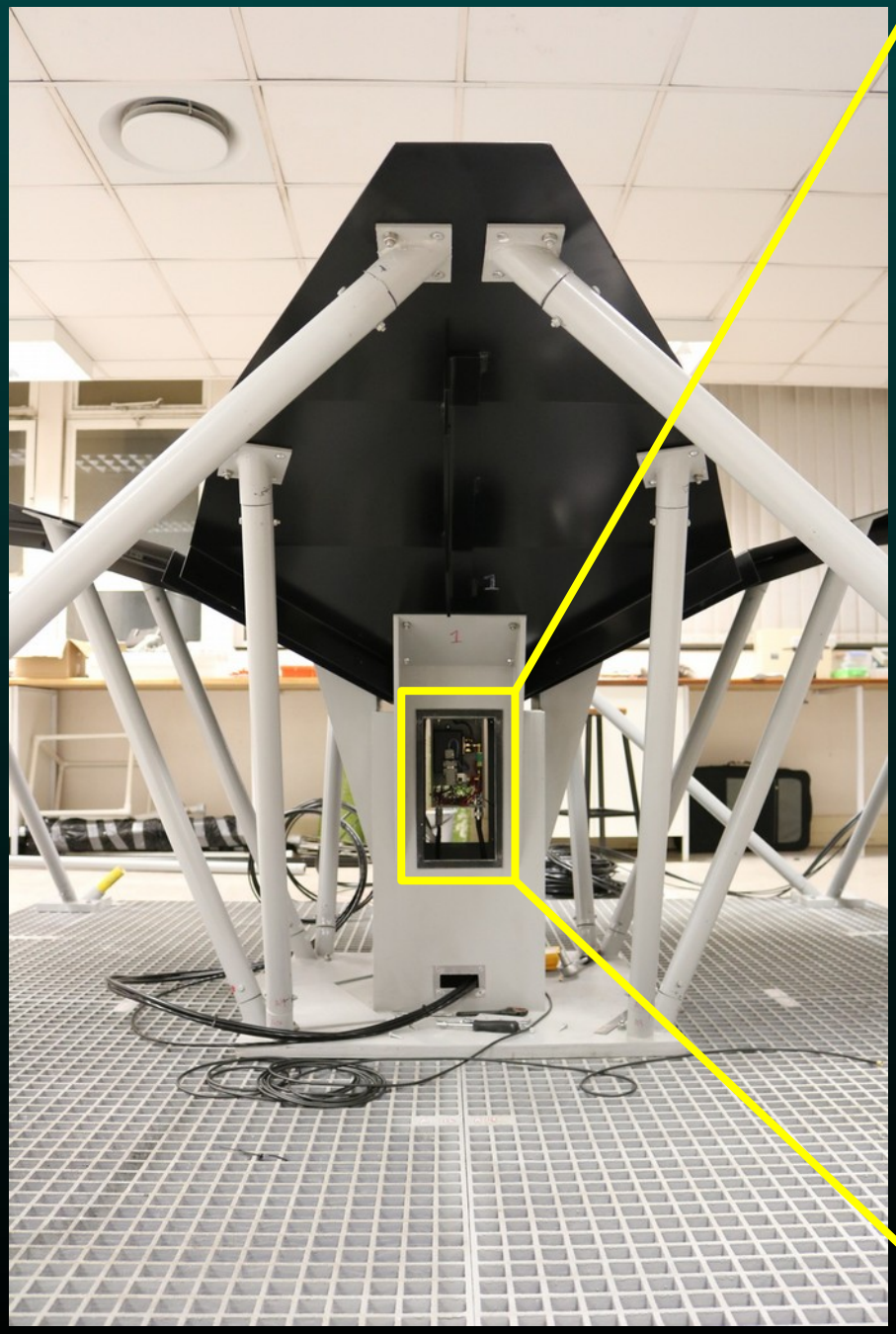
Global 21cm workshop
8 October 2019

PRI^{Z}M: Probing Radio Intensity at high-Z from Marion



PRIZM antennas

Front end RF electronics

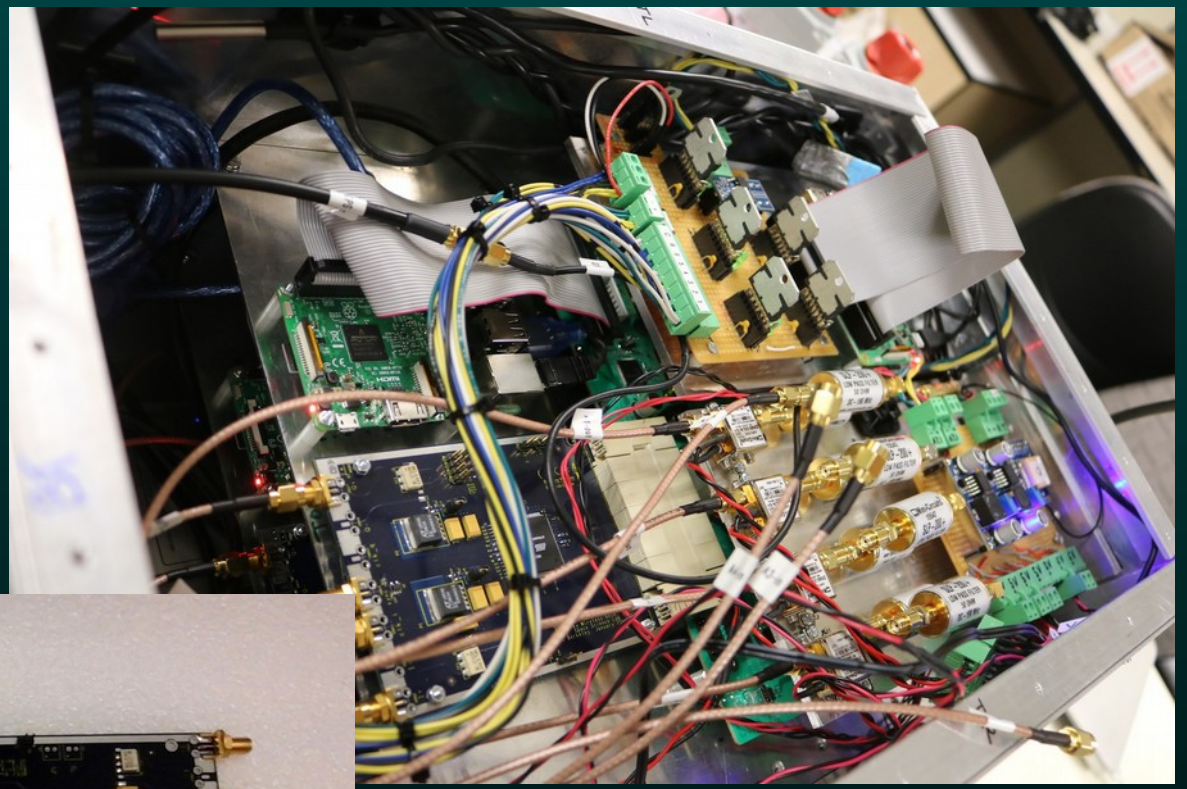


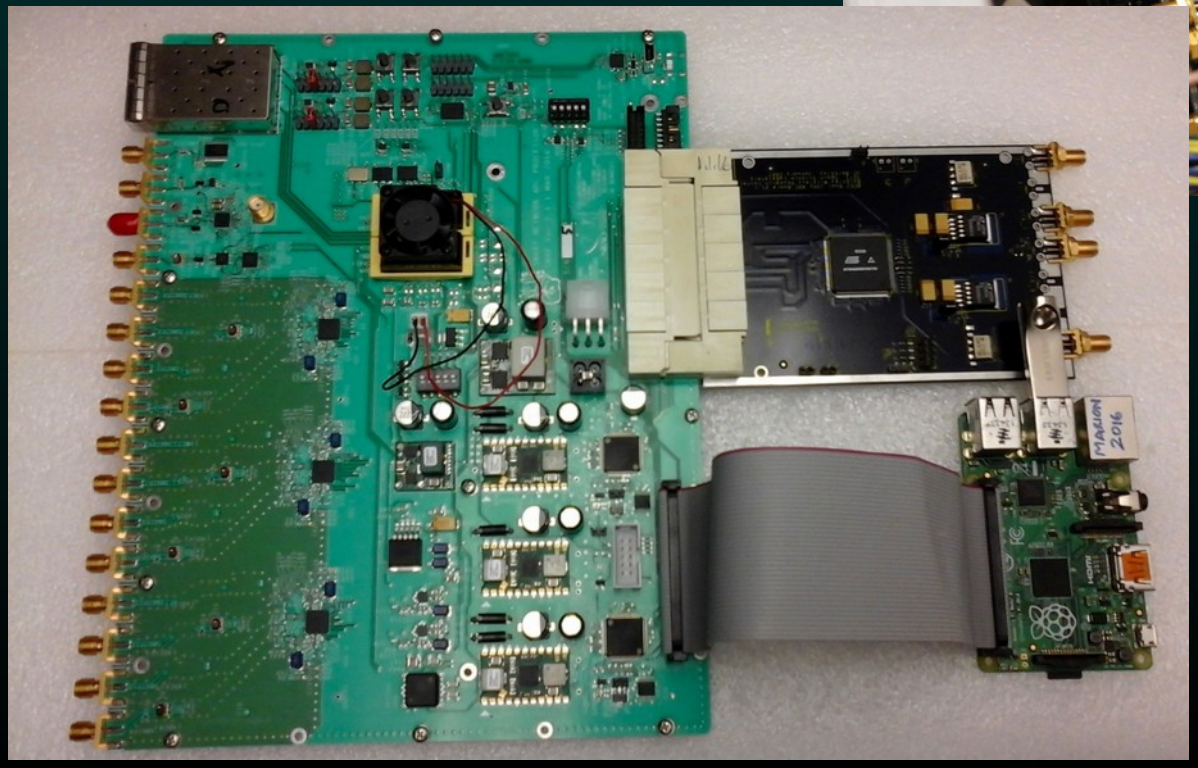
Back-end and readout electronics

30 – 200 MHz filters + 2nd stage amps

2 x SNAP boards with external ADCs sampling at 500 Msamp/s

Spectrometer firmware: 0 – 250 MHz, 4096 channels (61 kHz)





Total system power draw ~65 W, run time ~1 week on 8x AGM 200-Ah batteries

Whole assembly is placed ~50 m from the antenna to reduce self-generated RFI

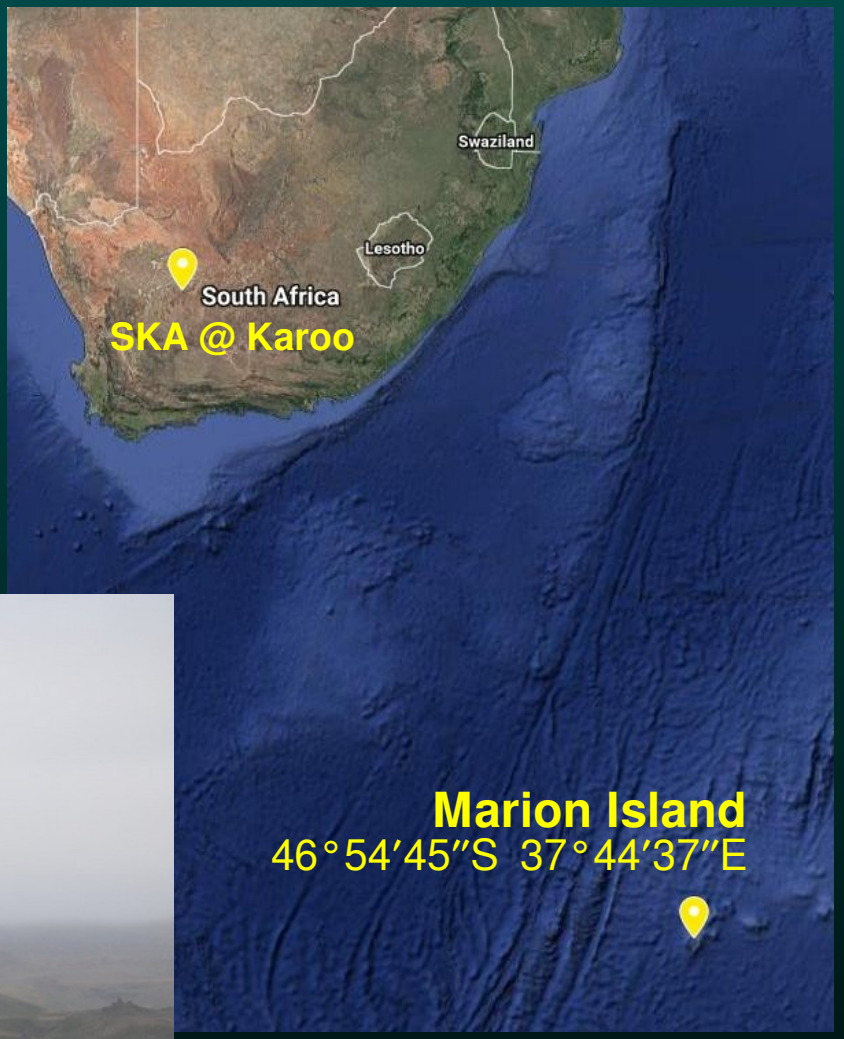
On-site operations

Marion Island

Marion Island base is operated by the South African National Antarctic Programme

2000 km from nearest continental landmass (also ~max distance for meteor scattering)

PRI^{Z}M = first astro experiment on Marion 2016 engineering run, science ops since 2017



Challenges:

Access once per year

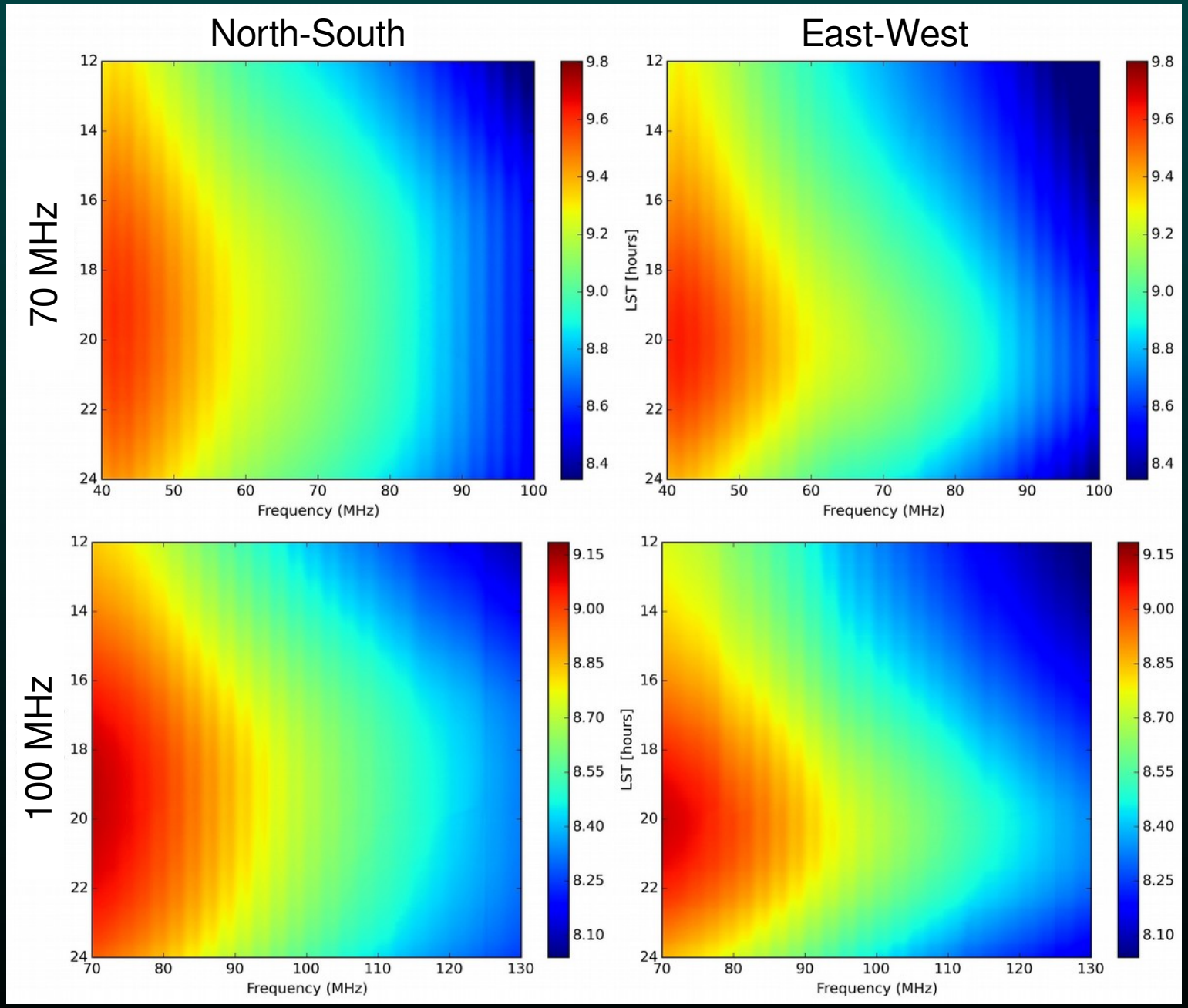
3 week deployment window

Roaring Forties weather

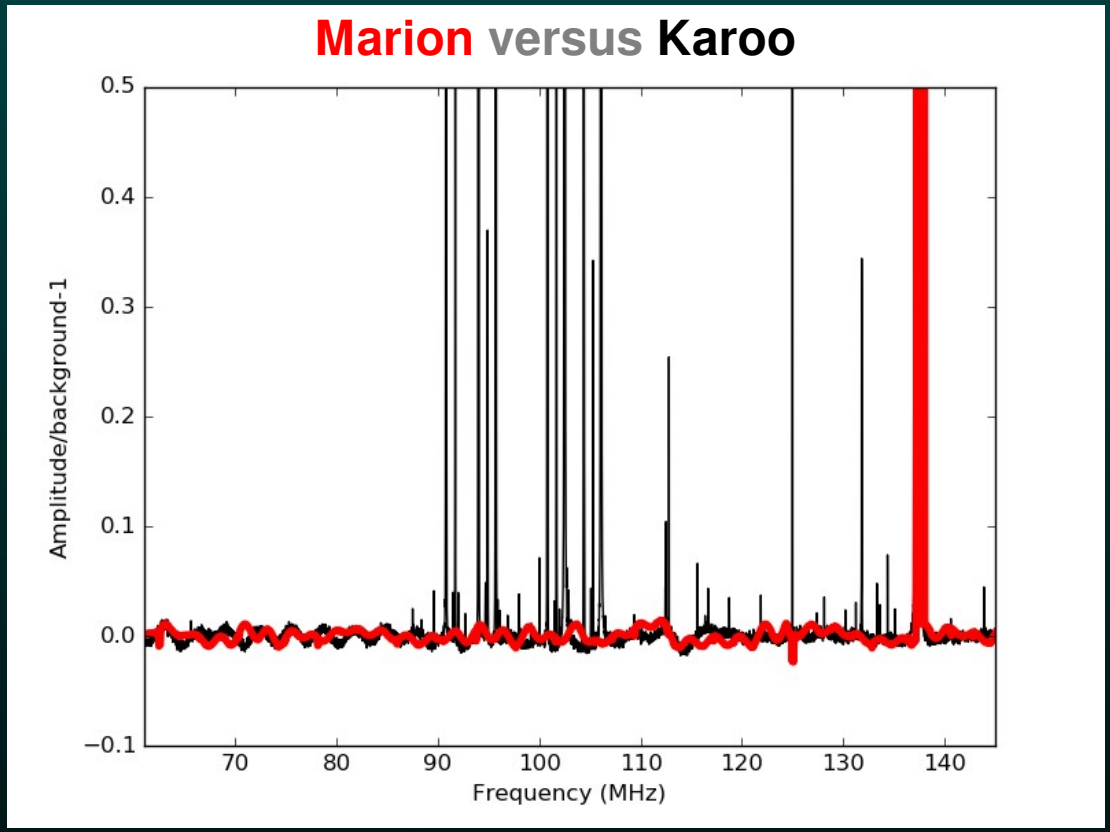
Mires and lava rocks

@#$% mice

Preliminary PRI^{Z}M raw data



Details in PRIZM instrument paper



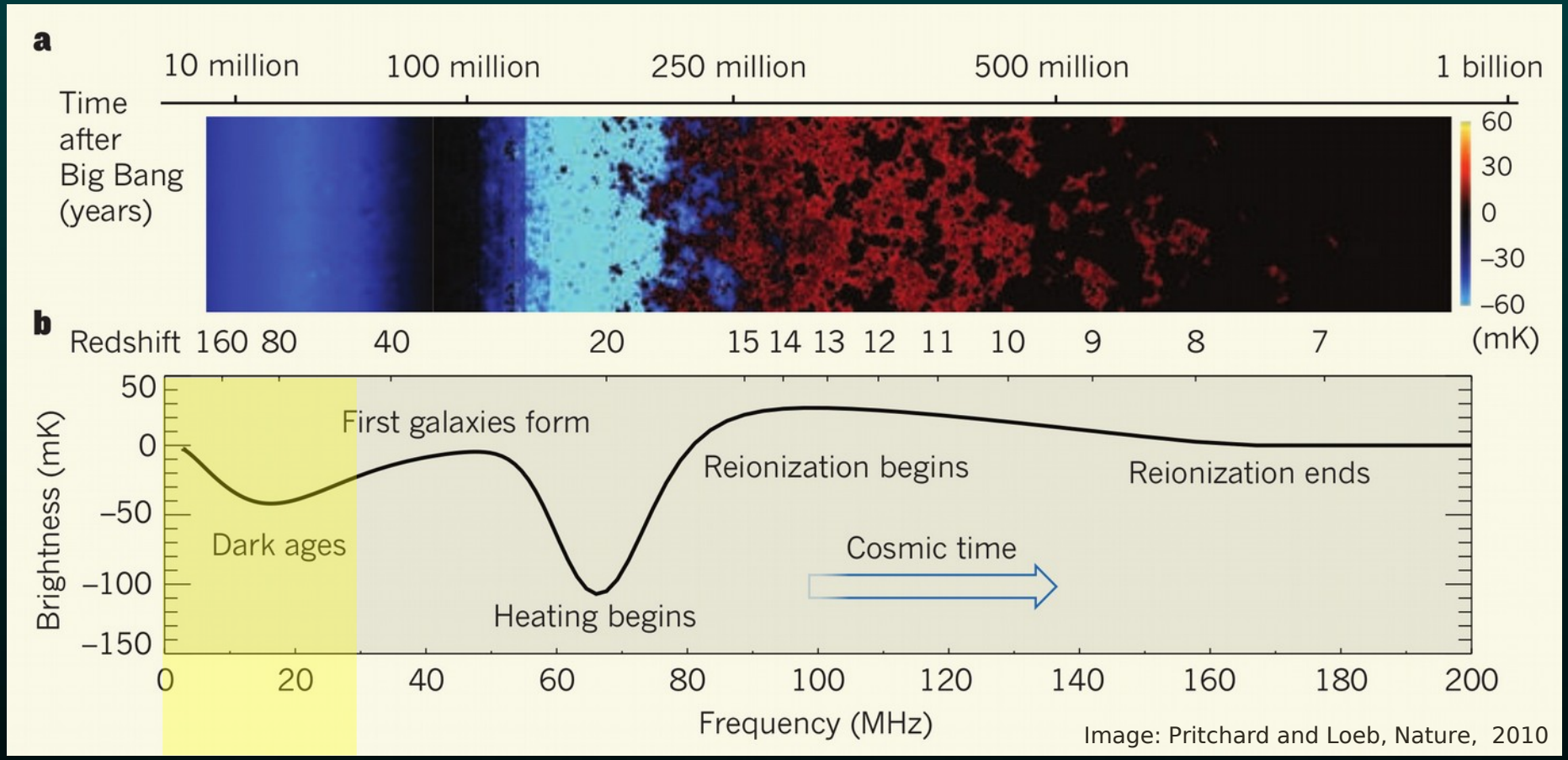
Marion is extremely radio quiet:
no visible contamination in the FM band!

L. Philip et al., “Probing Radio Intensity at High-Z from Marion: 2017 instrument,” JAI, 2019

2018 data in hand as of May, analysis is in progress

Exploring lower frequencies

$$\delta T_b \propto x_{HI}\,(1+z)^{1/2}\,(T_s - T_{CMB})\,/\,T_s$$



What lurks down here...?

Most experiments operate here.

The dream: lay groundwork for exploring dark ages

Ultimate dream: image the fluctuations

The state of the art at low frequencies

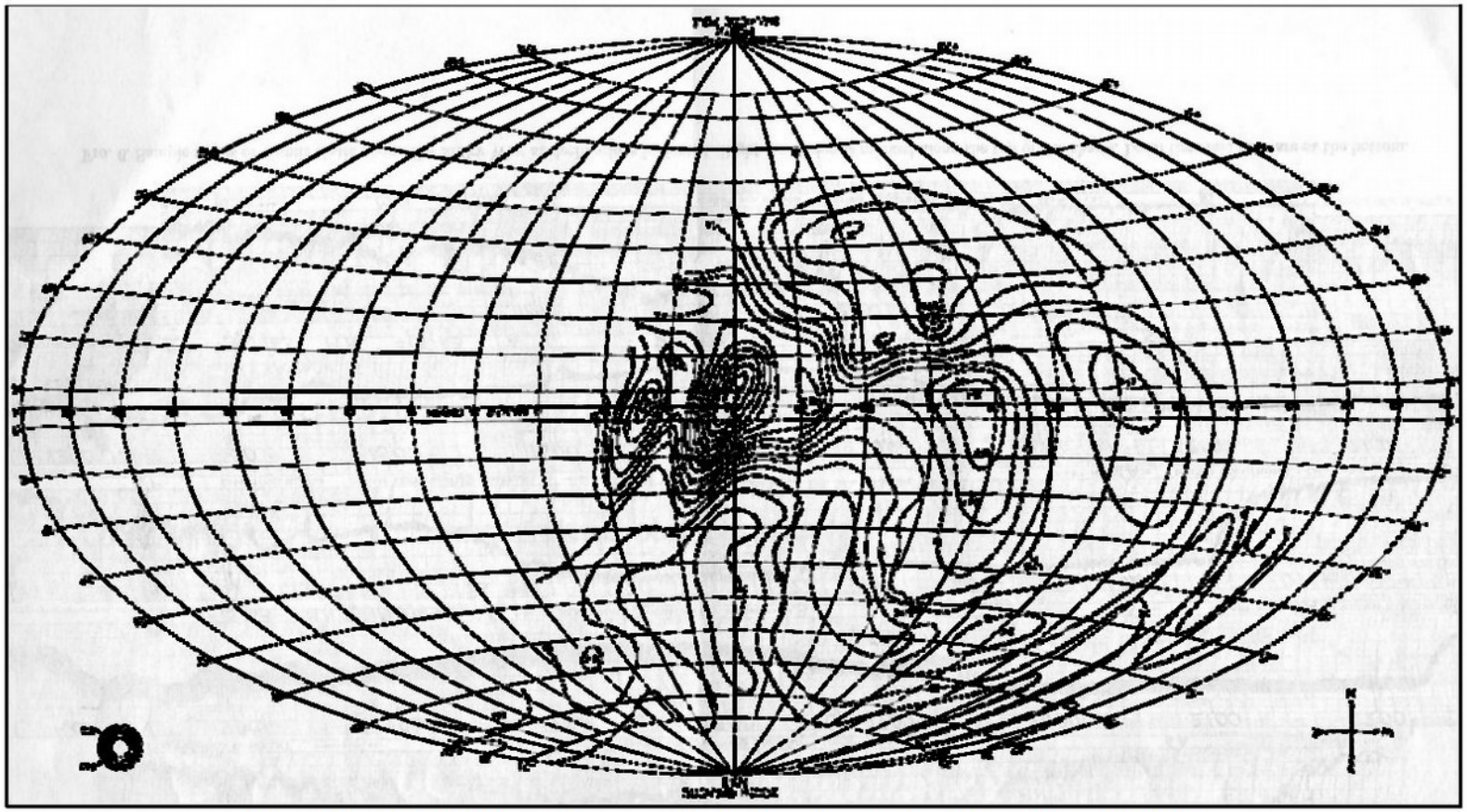
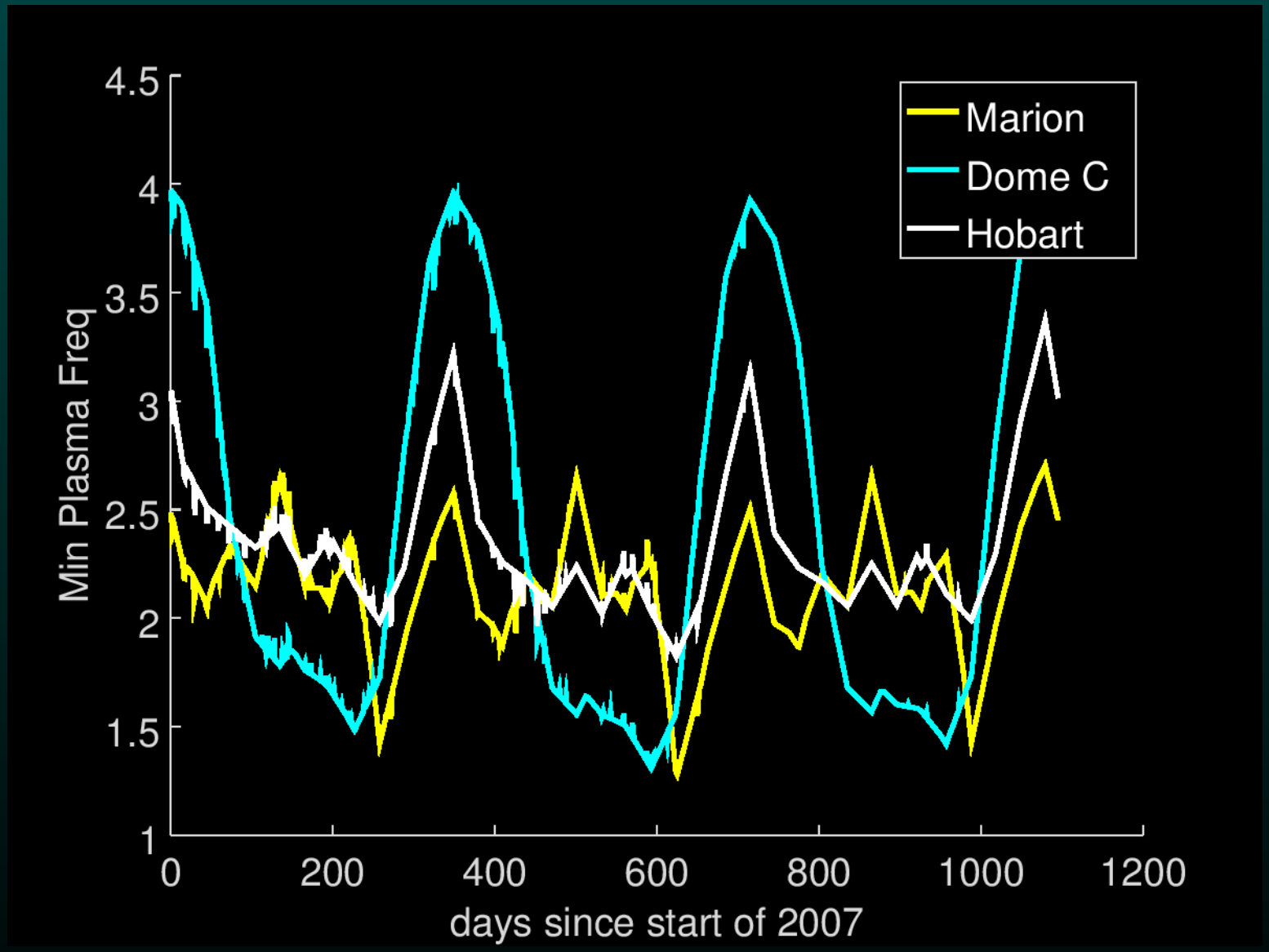


Figure 11: A 2.085 MHz contour map of galactic radio emission (after Reber, 1968: 10).

Experiment	Frequency	Resolution	Year
Grote Reber	2.1 MHz	~5 deg	1968
RAE-B satellite	4.7 MHz	~10 (??) deg	1978
DRAO	22 MHz	1.1–1.7 deg	1999
LWA	36.5 MHz	15 arcmin	2017

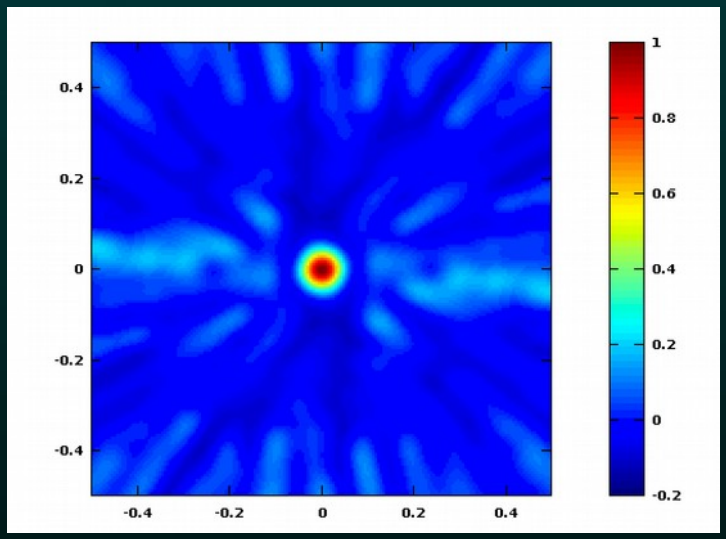
How low can we go from Marion?



IRI model prediction: plasma frequency down to ~1.5 MHz during last solar minimum, next one is coming up...

Exploratory low frequency measurements

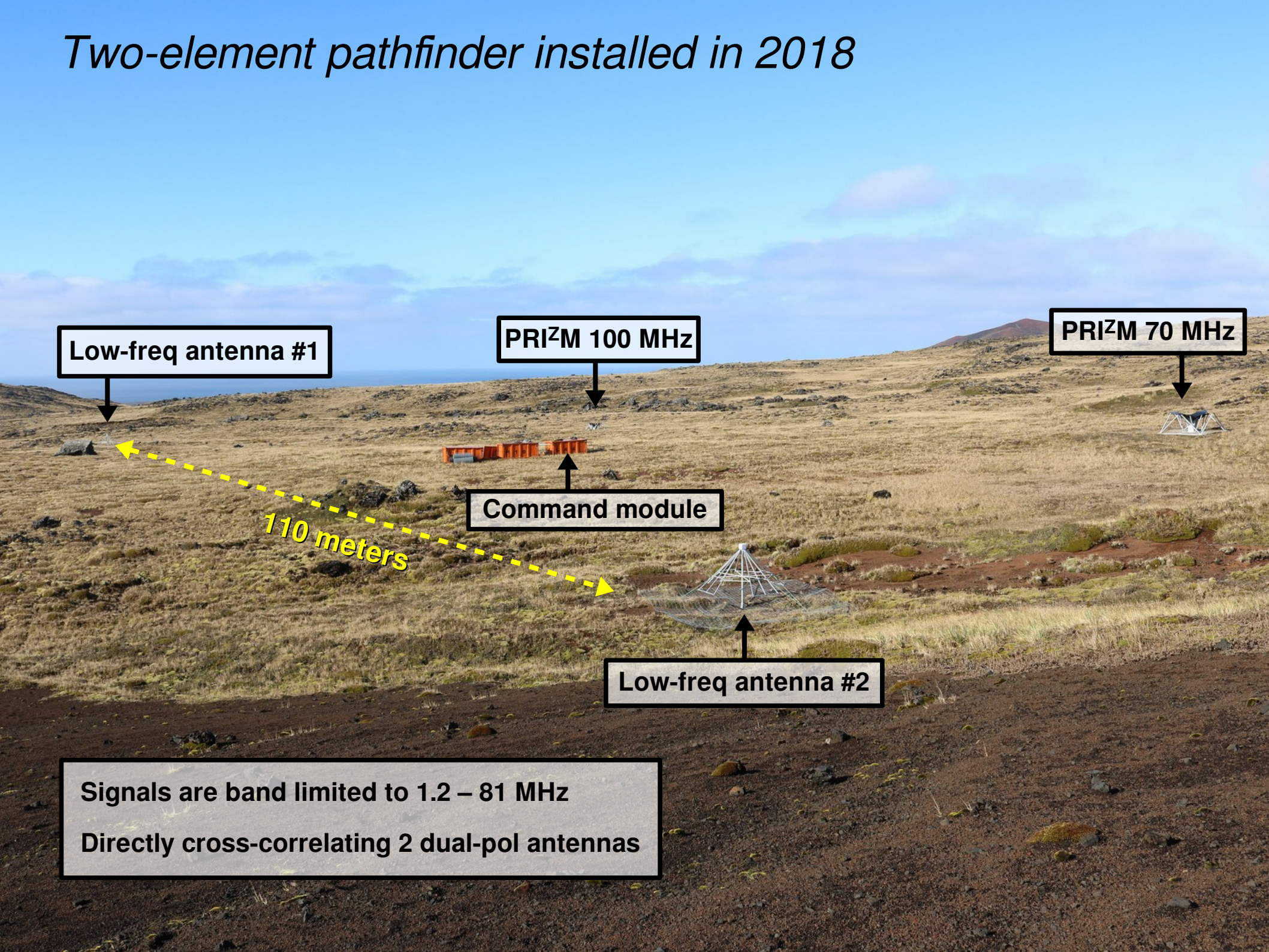
- Infrastructure: 9 huts around island perimeter, convenient ring-like layout for imaging
- The plan: deploy antennas at huts, save lowest 10–20 MHz baseband, correlate offline



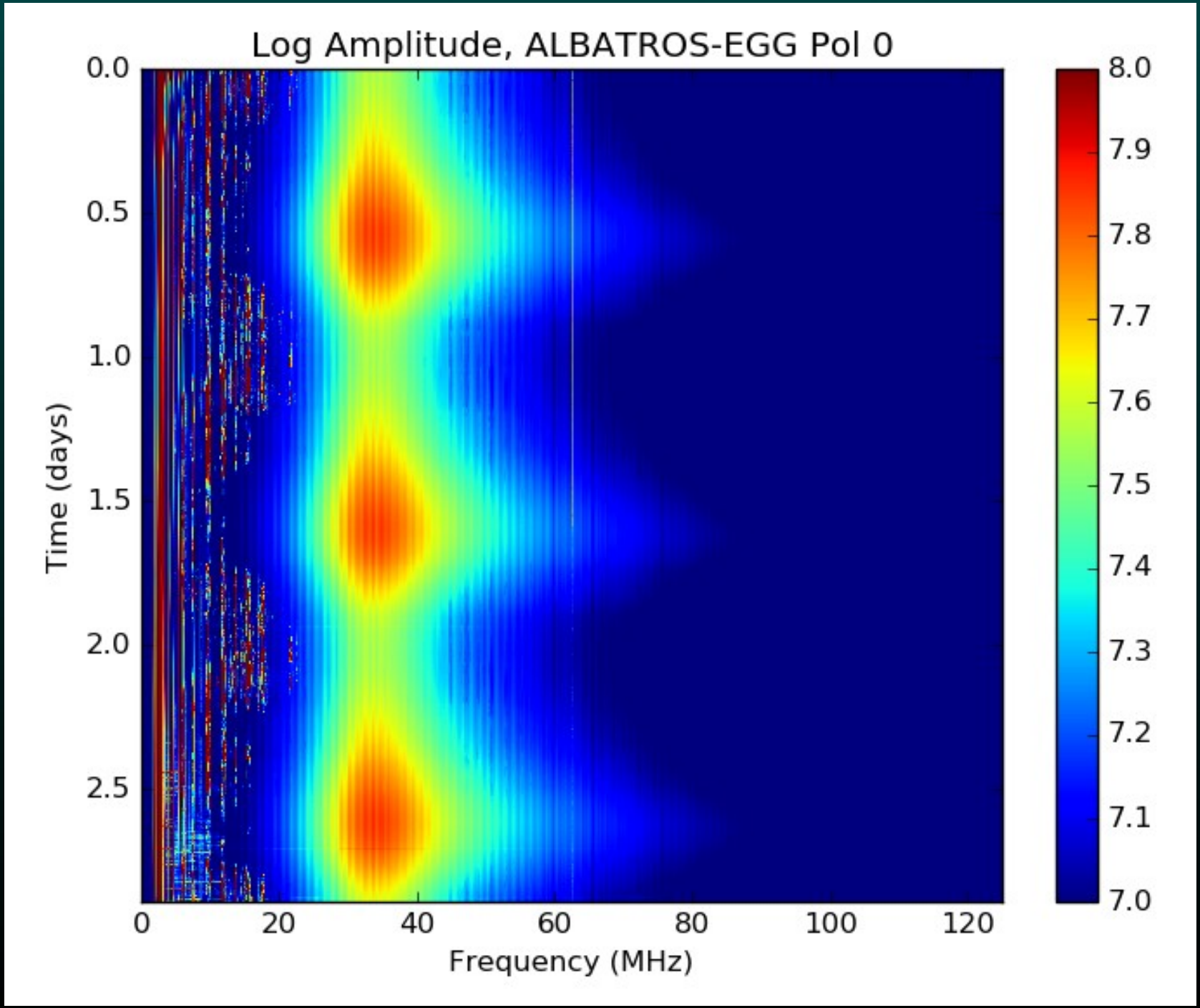
8' FWHM synthesized beam @ 5 MHz

ALBATROS = Array of Long Baseline Antennas for Taking Radio Observations from the Sub-antarctic / Seventy-ninth parallel

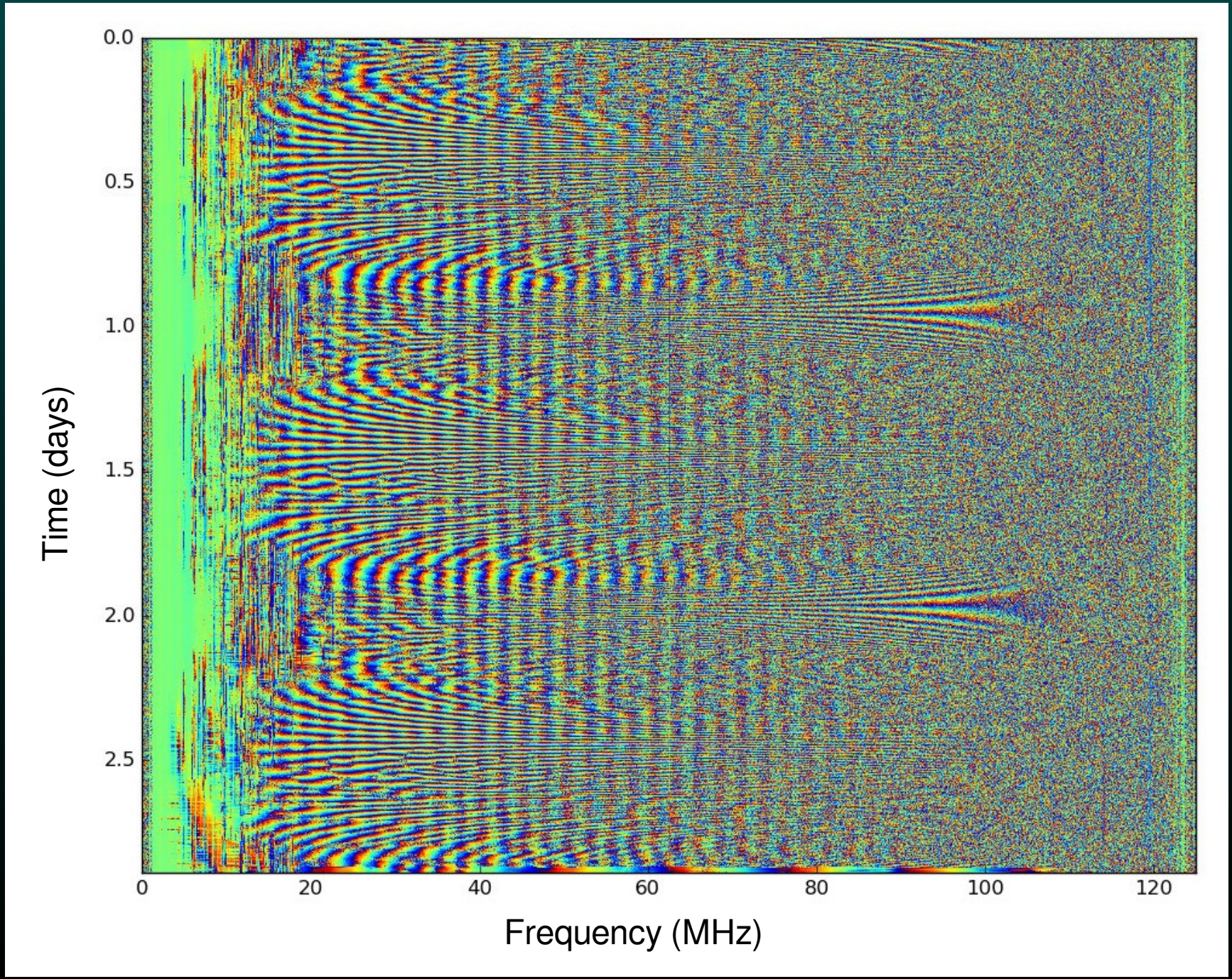
Two-element pathfinder installed in 2018



Raw autospectra from low-freq antenna



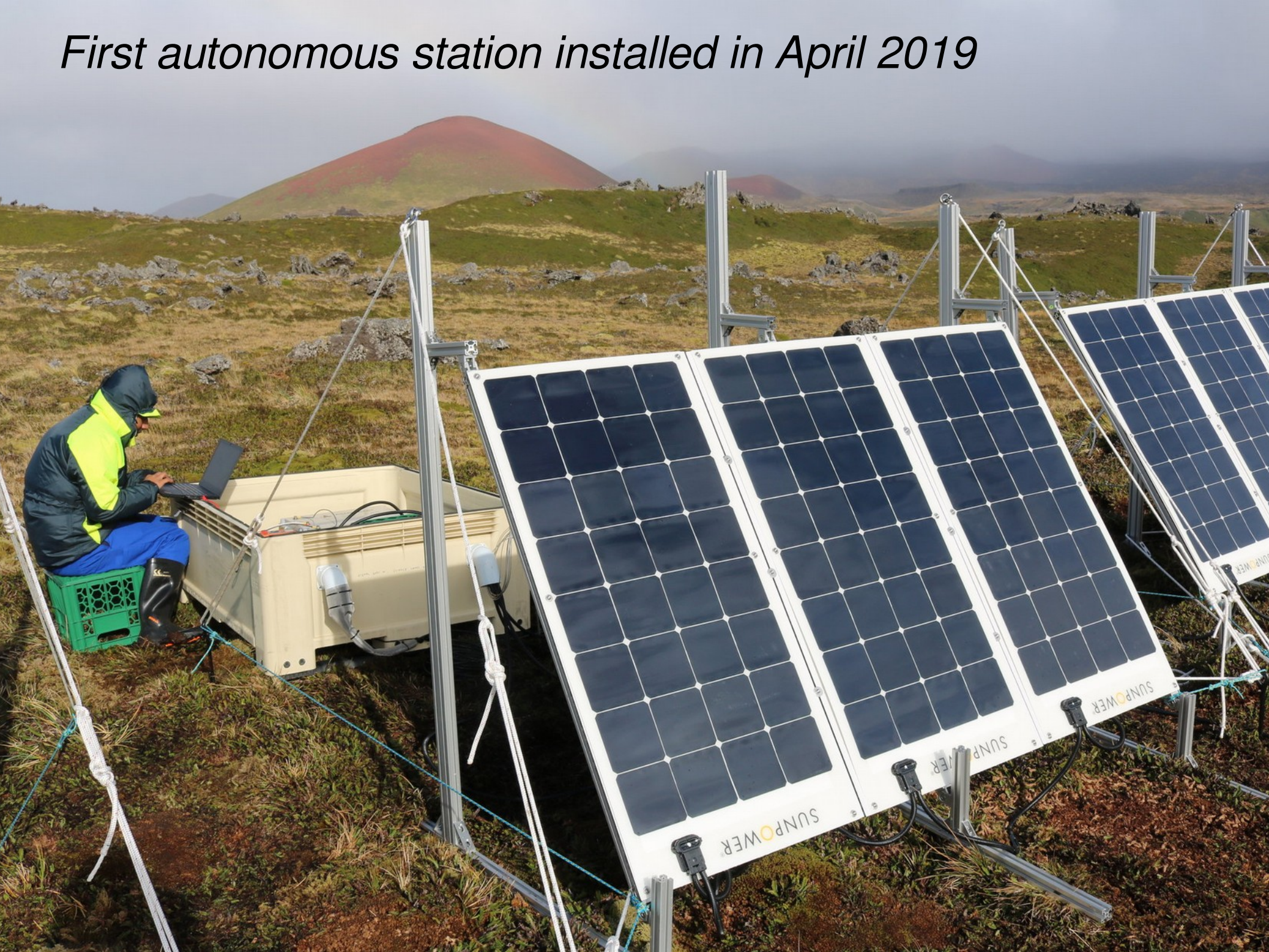
First fringes from low freq antennas



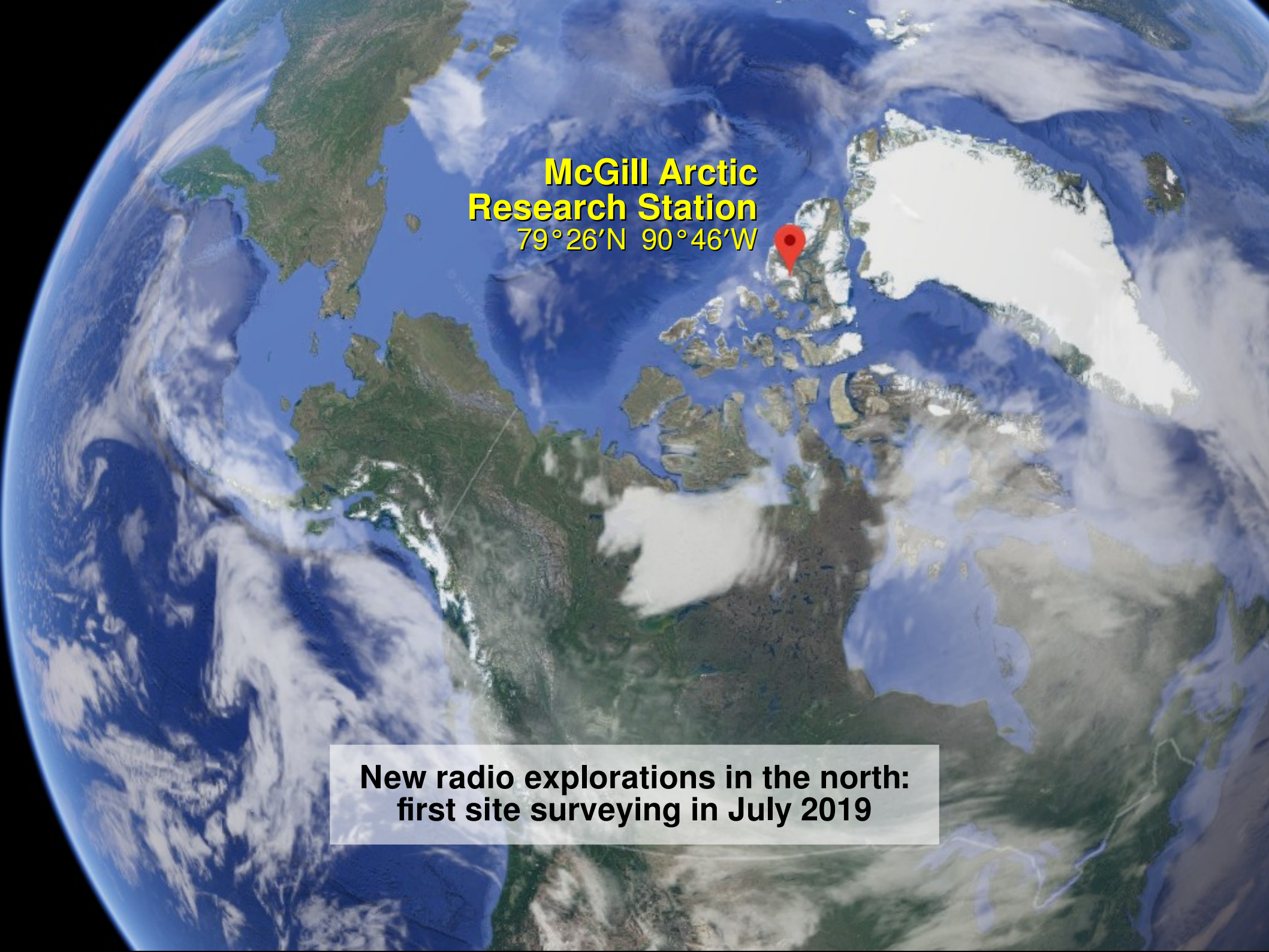
First autonomous station installed in April 2019

- Solar powered operation
- New dual-input SNAP enclosure
- Recording baseband + auto/cross-spectra
- GPS disciplined clock

First autonomous station installed in April 2019




All your baseband are belong to us

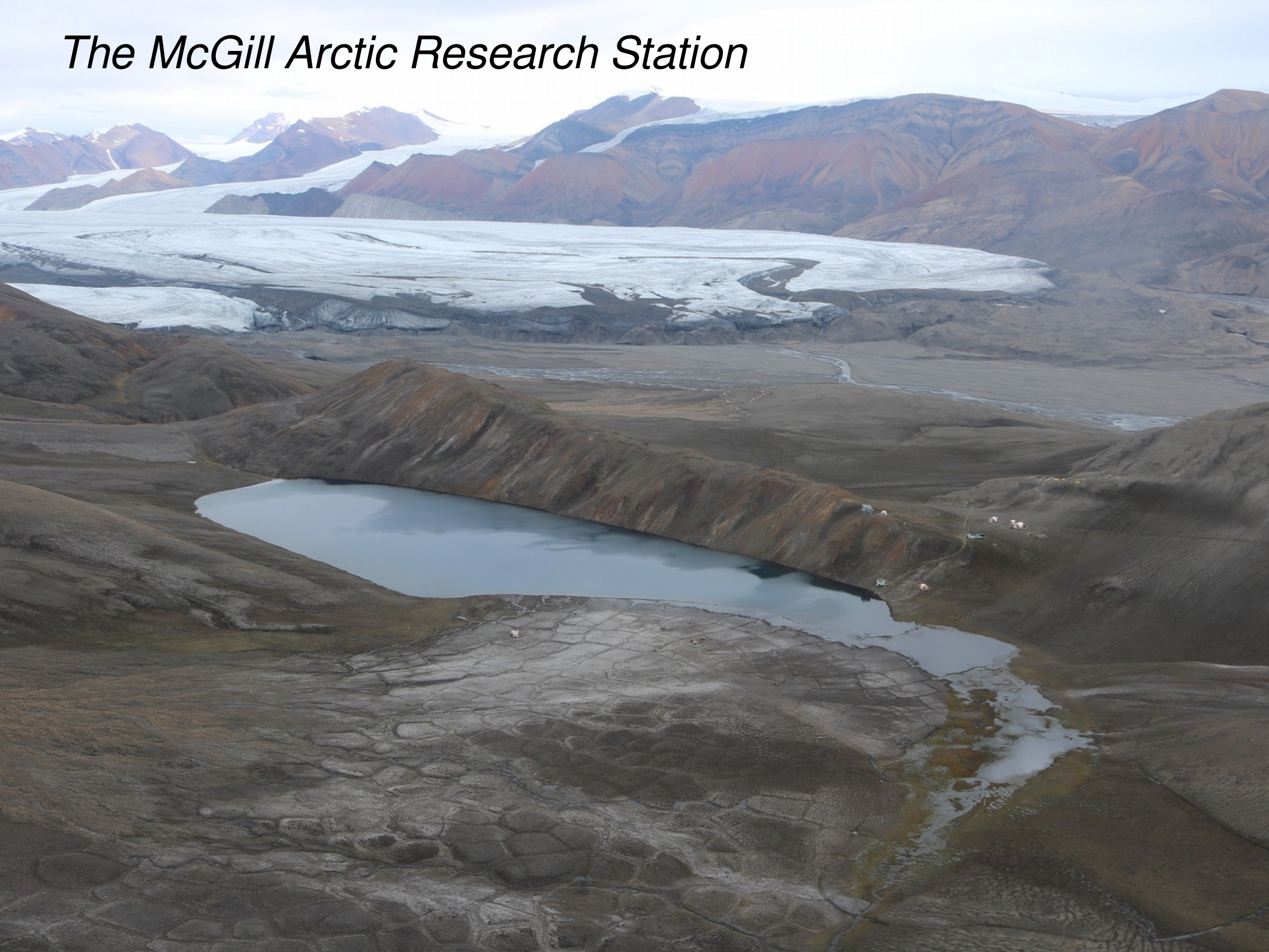


New radio explorations in the north: first site surveying in July 2019


Site surveying in Resolute

Not particularly quiet...

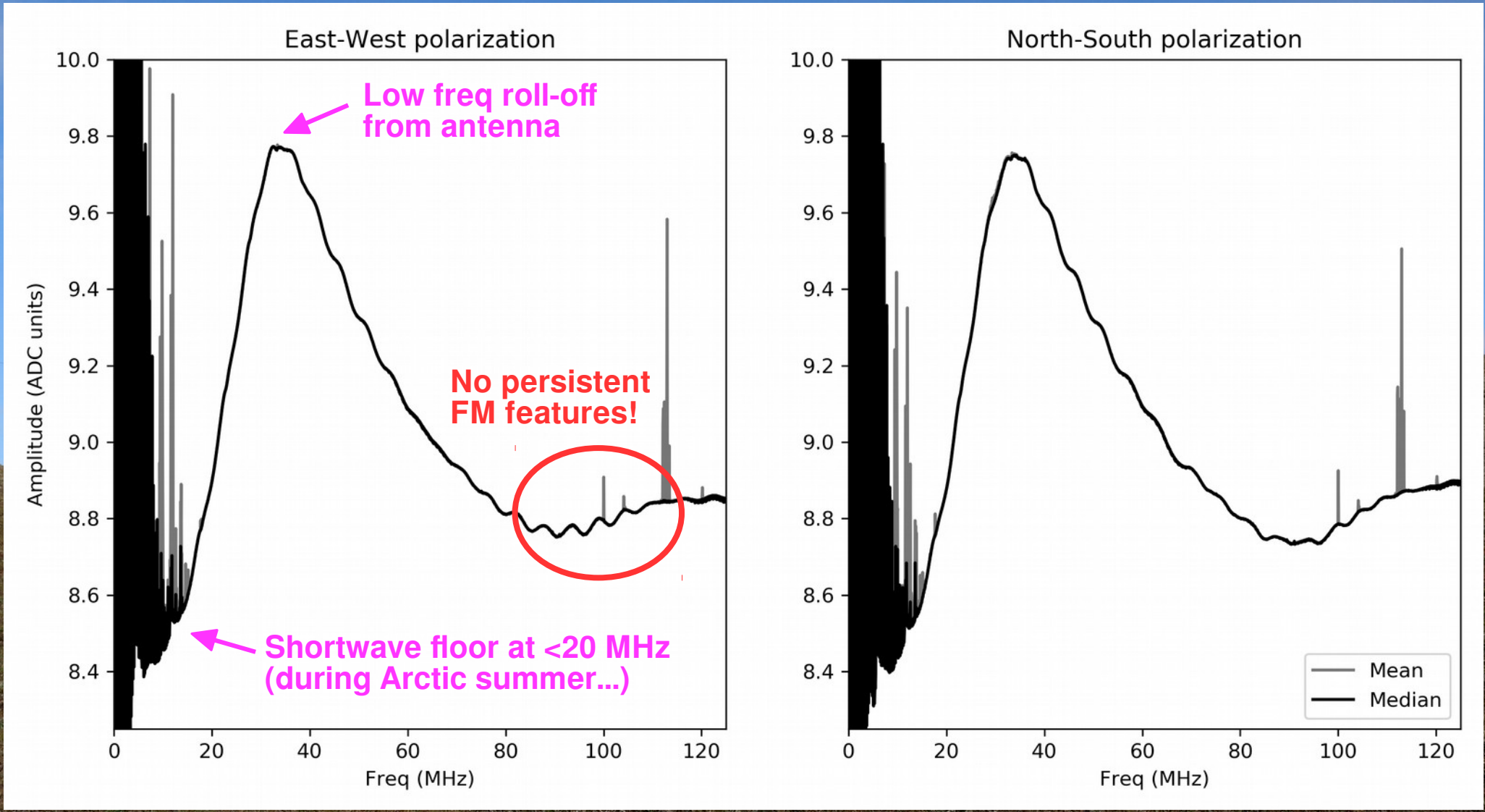
The McGill Arctic Research Station



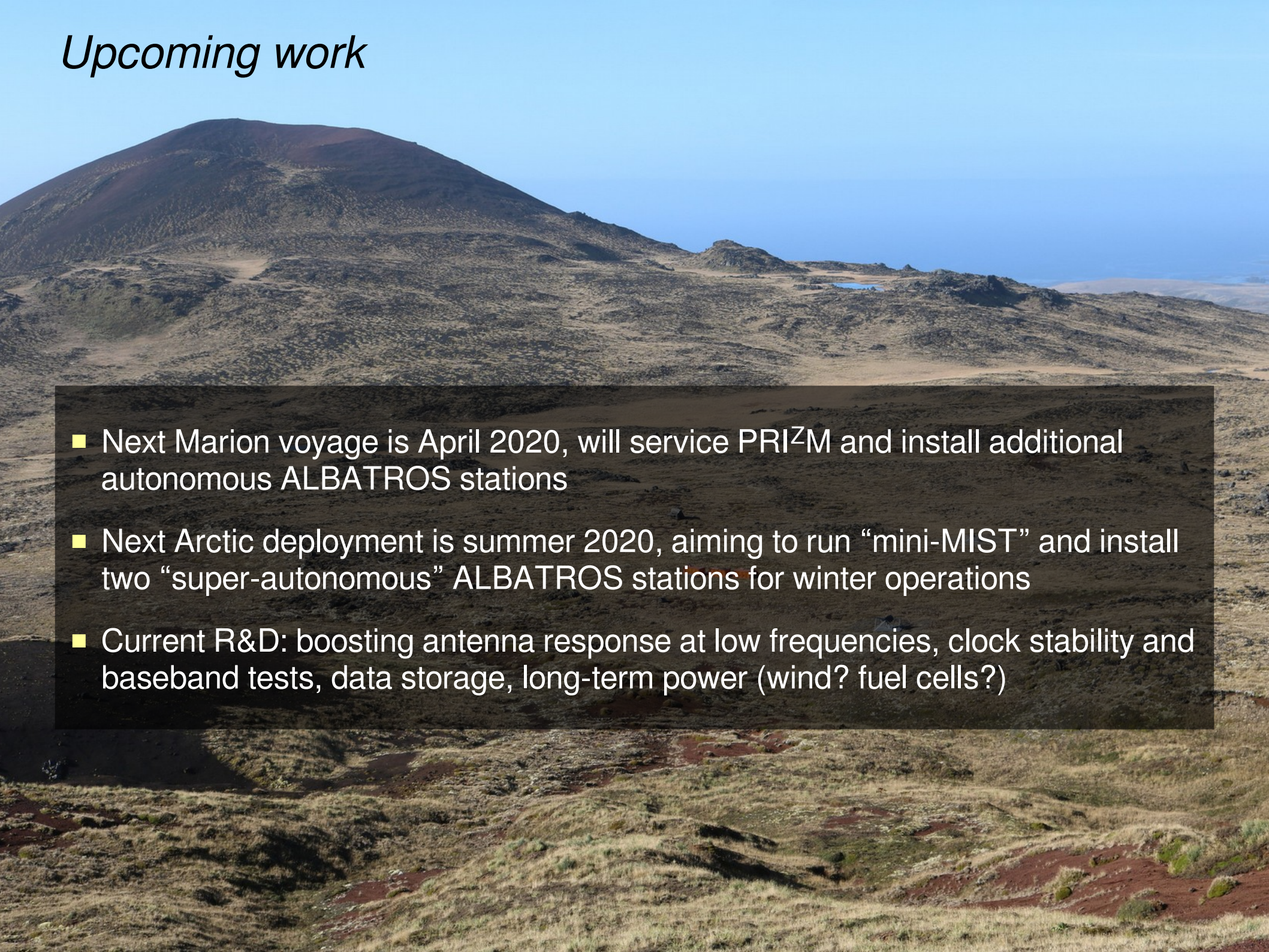
On-site installation

Completed antenna at MARS

Preliminary spectra



Upcoming work



- Next Marion voyage is April 2020, will service PRI^{Z}M and install additional autonomous ALBATROS stations
- Next Arctic deployment is summer 2020, aiming to run “mini-MIST” and install two “super-autonomous” ALBATROS stations for winter operations
- Current R&D: boosting antenna response at low frequencies, clock stability and baseband tests, data storage, long-term power (wind? fuel cells?)