Part I:
Scientific Motivation for Replicate Coring at Hercules Dome:

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1. Ability to replicate / confirm measurements and findings

• Why do measurements need to be replicated in general?
  • Verify measurement integrity
  • Mitigate analytical issues during main core measurements
  • Confirm novel findings / measurements made with new techniques

• Example of specific scientific application:
  • Is the decadal/centennial variability in water isotopes spatially coherent even on very short distance scales? (Markle)

• With a 98 mm diameter core, we will be very limited on available Herc Dome ice
  • Unlikely that ice for replication of any type of measurement would be immediately available from the main core
2. Provide larger ice amounts needed for some studies

- Last Interglacial (Eemian) ice annual layer thickness could be as low as $\approx 1$ mm. The entire Eemian could be contained in as little as $\approx 10$ m.

- Examples of studies/questions for Eemian that can probably only be answered if replicate cores were available (require $\approx 300 – 2000$ g ice):
  - Impact of regional and global volcanism on Eemian climate (tephra studies, Kurbatov, Dunbar and Iverson)
  - Investigating Eemian dust sources and atmospheric transport – geochemical composition and physical properties, including new techniques (Aarons; Kreutz and colleagues)
  - Investigating wildfire activity and emissions in a warmer world using $\text{C}_2\text{H}_6$, $\text{C}_2\text{H}_2$, CO isotopes, $\delta^{13}\text{CH}_4$ (Aydin, Saltzmann, Petrenko, Brook)
  - Climate sensitivity of terrestrial Gross Primary Productivity (GPP) using COS and possibly $\delta^{13}\text{CO}_2$ (Aydin, Saltzmann, maybe also Brook)
  - Investigating greenhouse gas cycling ($\text{CO}_2$, $\text{CH}_4$, $\text{N}_2\text{O}$) during Termination II and last glacial onset using isotopes (Brook)

- Studies in other time intervals that also require larger sample amounts -- see above; also $^{14}\text{CO}_2$ for improving radiocarbon calibration curve (Petrenko)
3. Improve chances of success with answering the key driving questions for Hercules Dome project

- “How much, how fast?” with respect to the possible WAIS collapse during Eemian
- What if the water isotope approach yields inconclusive results?
- $^{86}$Kr excess can record the intensity of firn barometric pumping (or storminess)
- If WAIS collapsed during the Eemian, Hercules Dome would be closer to coast, lower altitude and stormier $\rightarrow$ more pronounced $^{86}$Kr excess
- Can also get timing of collapse
- Large $\approx$800 g samples needed
Part II:
Shallow Coring at Dome C to Understand Galactic Cosmic Ray Flux Variability

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How constant is the galactic cosmic ray flux?

Useful for:

• Improving estimates of past solar activity and irradiance (based on atmospheric $^{10}$Be and $^{14}$C)

• Understanding glacial exposure histories, erosion rates, ice dynamics (based on in situ $^{14}$C, $^{10}$Be, $^{36}$Cl, $^{26}$Al)

• Discerning past changes in supernovae activity

Measurements of cosmogenic nuclides in meteorites suggest that cosmic ray flux is stable on long time scales, but uncertainties are 30% or larger.

Image: CERN
How can $^{14}$CO in ice cores record the past cosmic ray flux?

- In situ cosmogenic $^{14}$C: neutrons, muons
- Leaks out of firn grains, but fully retained below firn layer
- In situ cosmogenic $^{14}$C dominates the CO phase at most ice core sites
  - Muon-produced $^{14}$C signal below firn layer
  - Higher-energy cosmic rays
  - Insensitive to solar or geomagnetic modulation – pure signal of galactic cosmic ray intensity
- Dome C: low accumulation rate helps to maximize $^{14}$C signal
- Should be able to constrain long-term (kyr-scale) cosmic ray flux variability over past $\approx 7$ kyr to $\approx 15\%$
Logistics

- Partnership with French program
  - Joel Savarino
  - Melanie Baroni
- Target drilling season: 2022-23
- 2 dry-drilled cores to 300m with IDP 4” or Foro 400 drill

Image: European Space Agency