Landed Science and Mission Concepts in the Polar Regions

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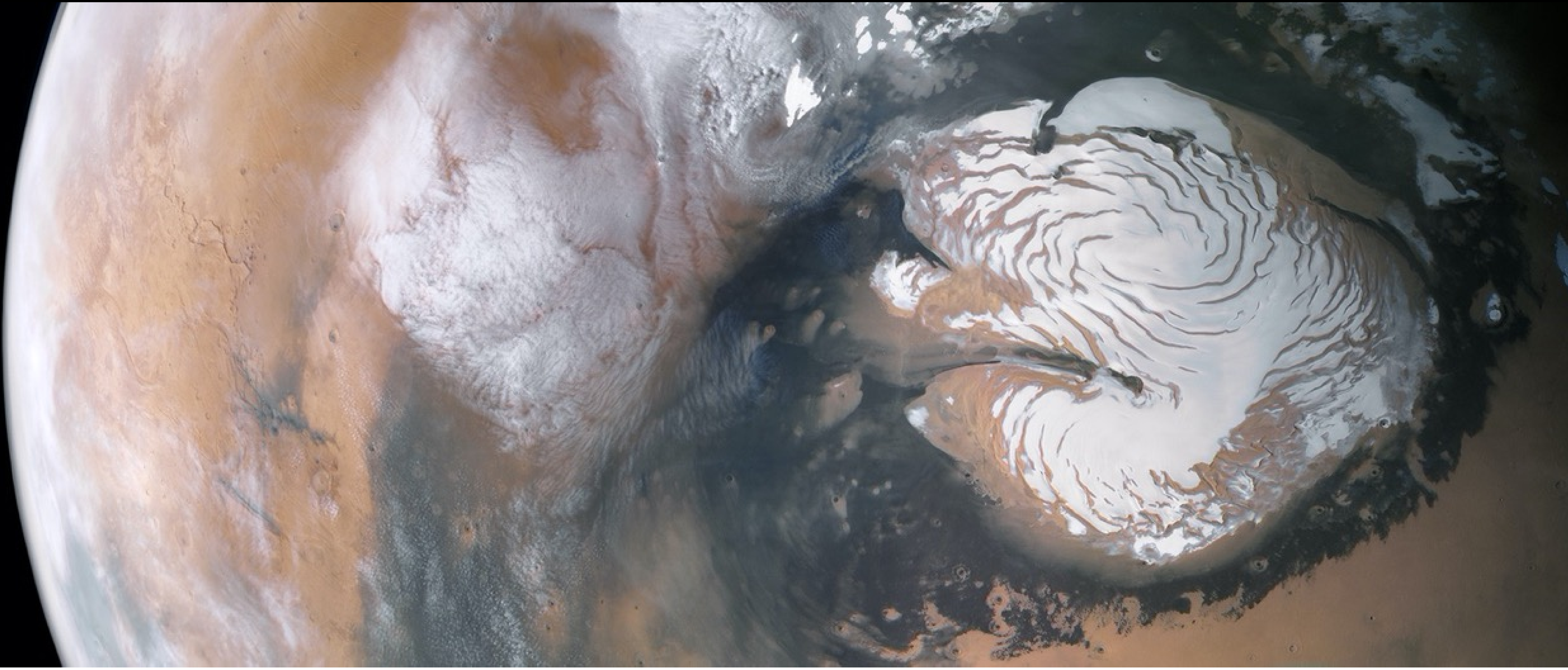
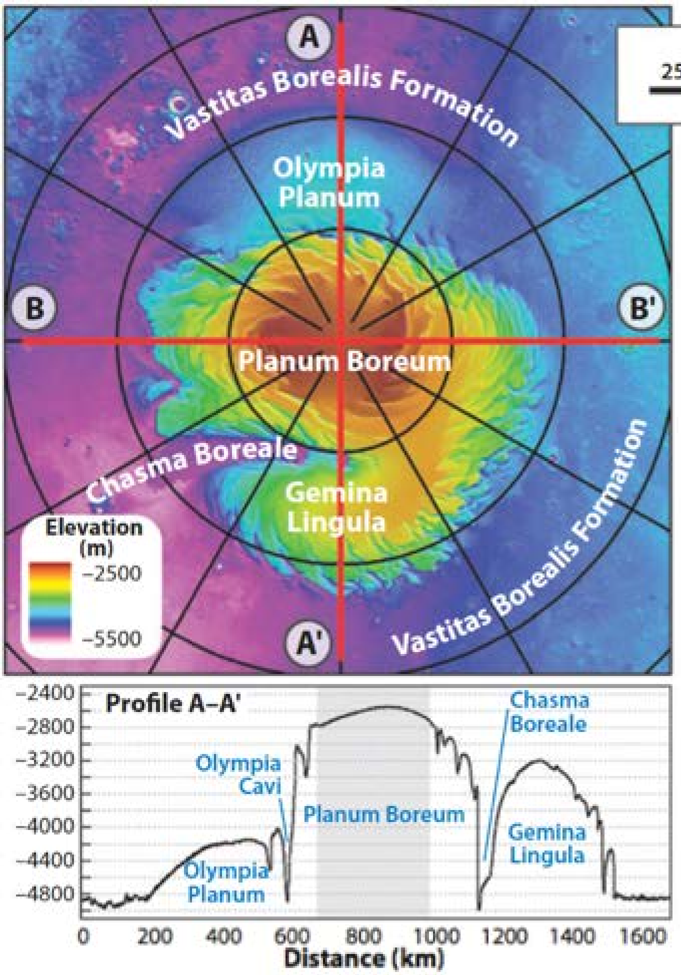
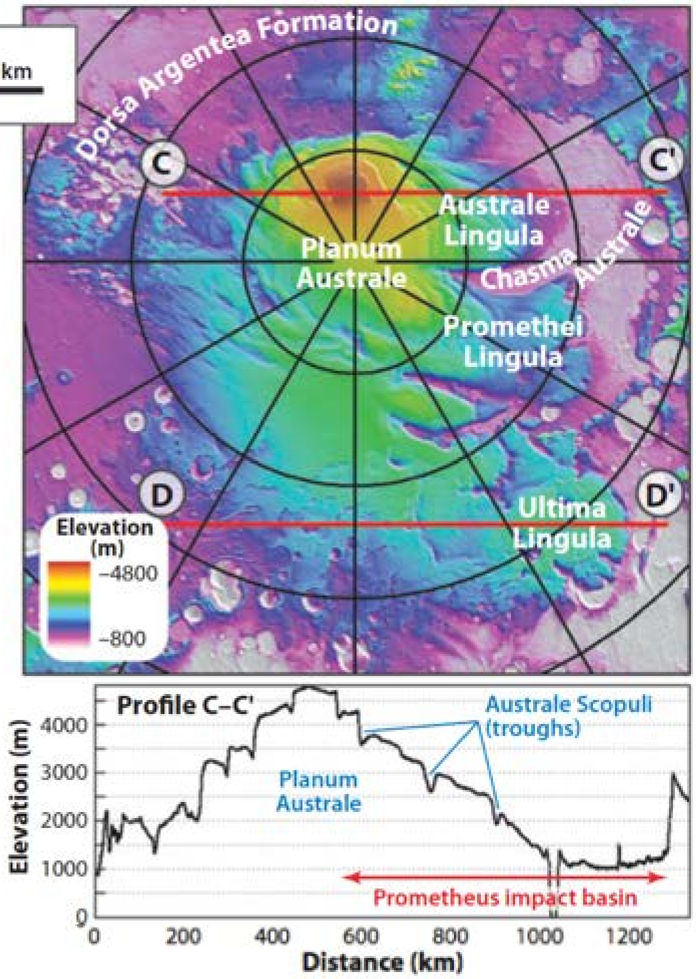


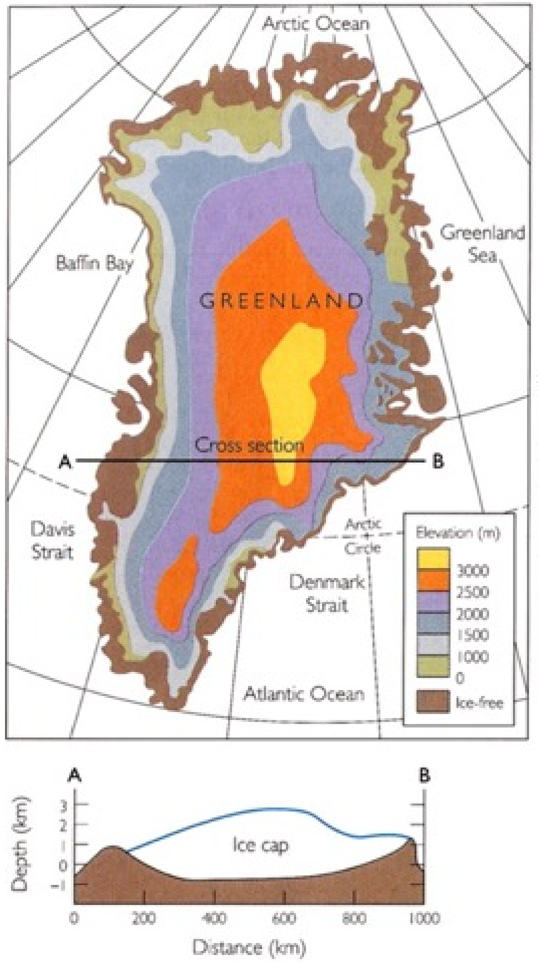
Layered ice at the martian poles holds a record of terrestrial-planet climate change



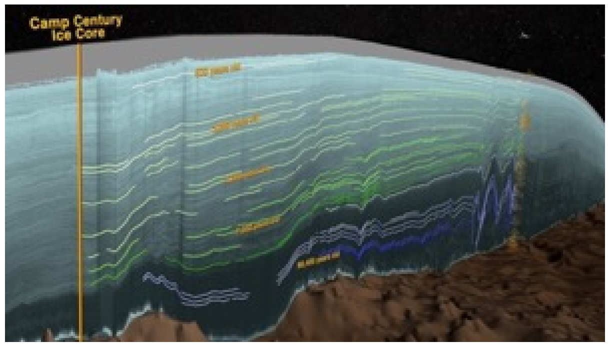
NPLD: 1.1 million km^3

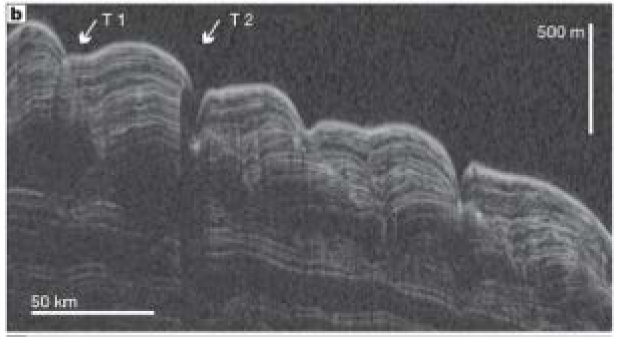


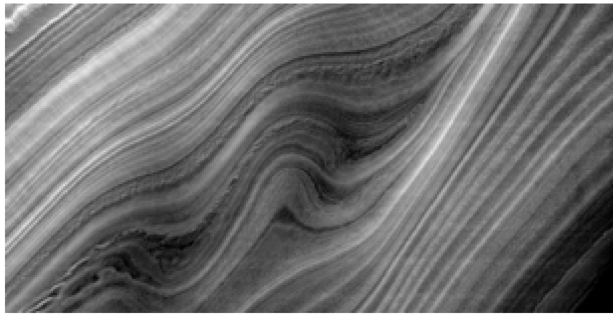
SPLD: 1.2 million km^3



Greenland: 6 million km^3

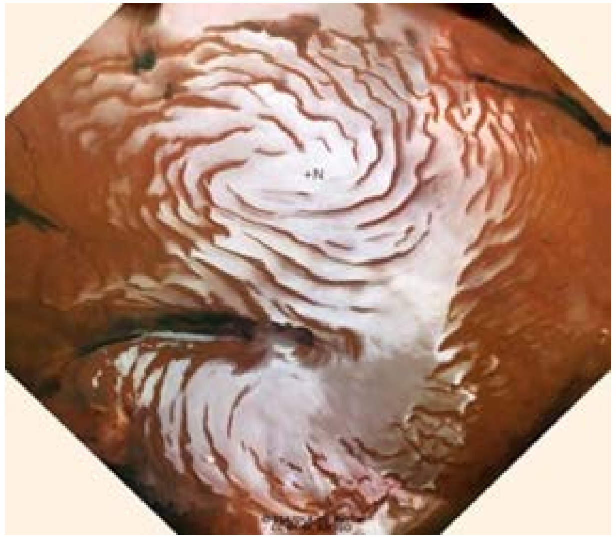


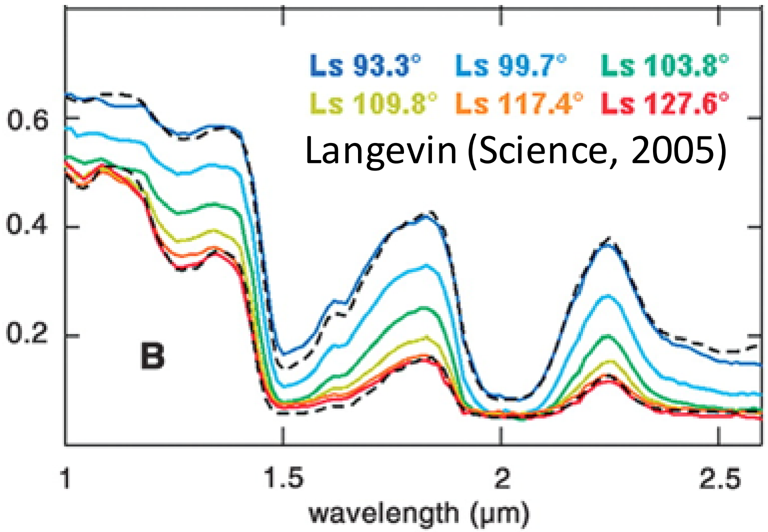


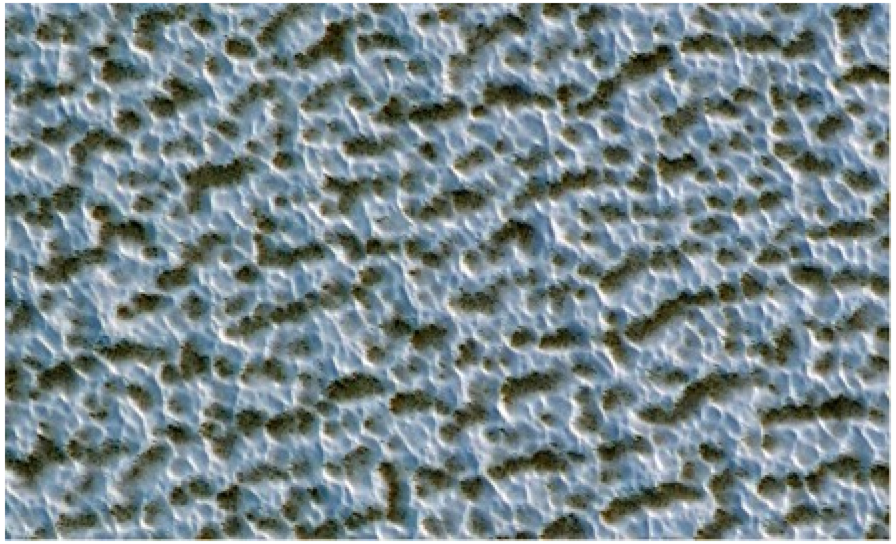


Significant differences also exist between the two Polar Layered Deposits in age, dustiness, and surface materials.

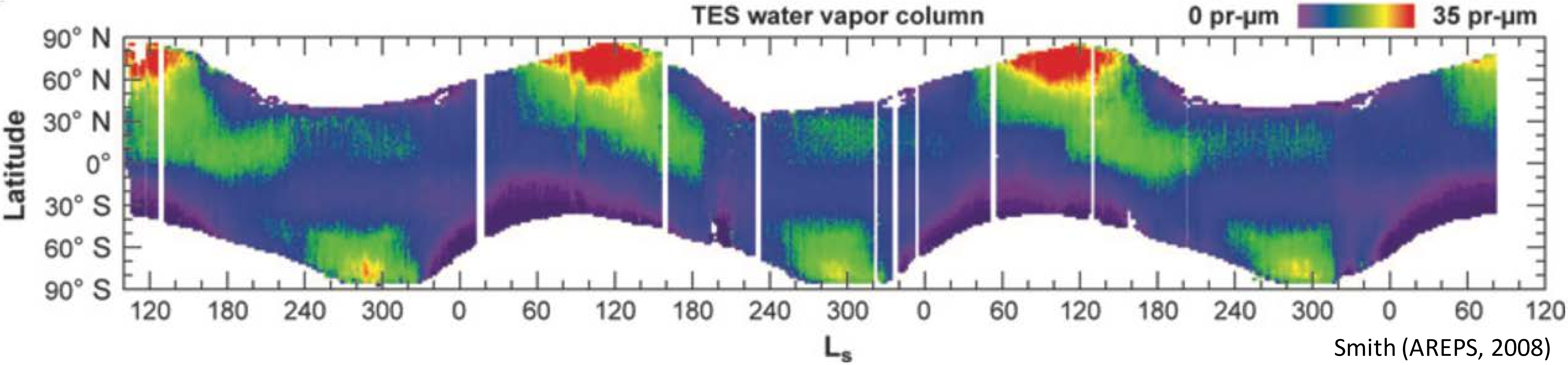
The North Pole is capped with large-grained dust-free water ice – a layer in the making





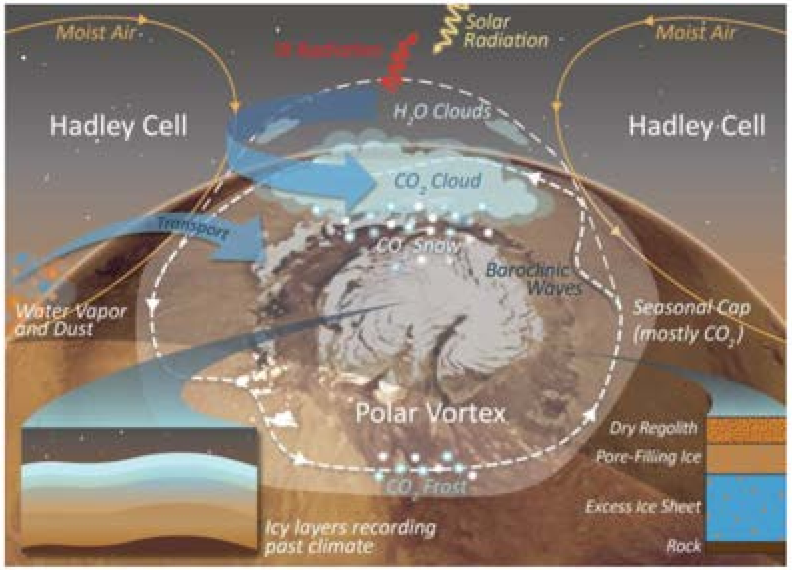


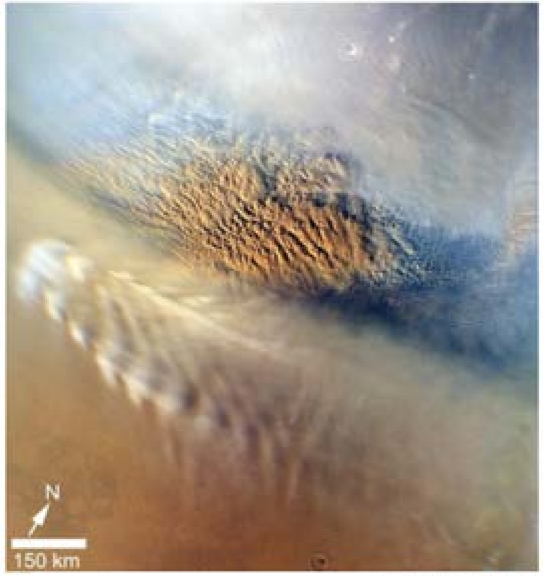
The North polar cap dominates the martian water cycle and, by extension, all water ice stability



Smith (AREPS, 2008)

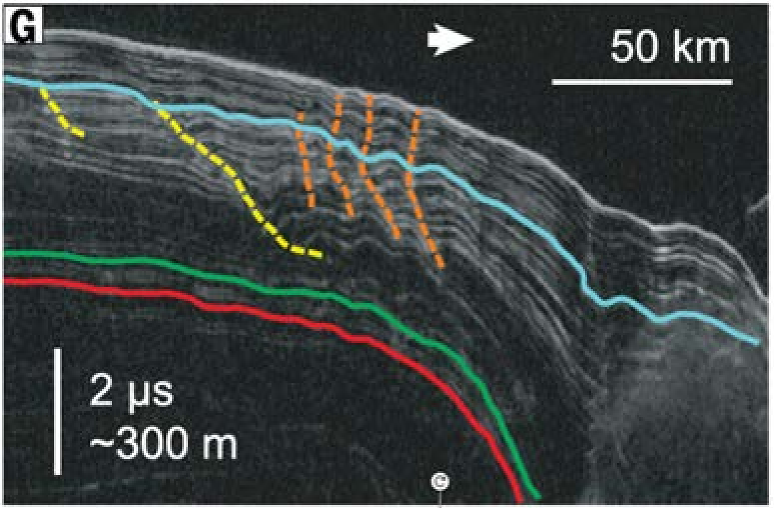
Ancient layers and present climate are better characterized than ever



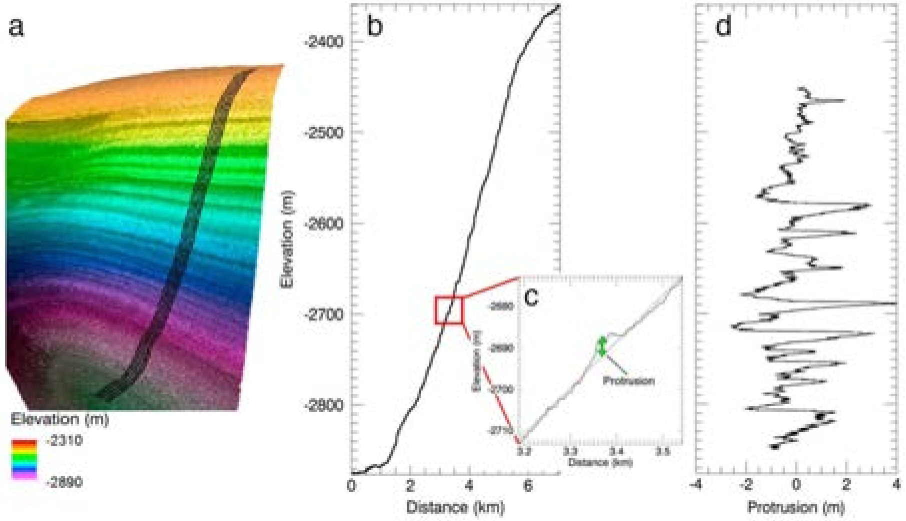


Transport of dust and water can be measured

Vertical water distribution and wind speeds unknown though…



Smith et al. (2016)



Becerra et al. (2016; 2017; 2019)

Stratigraphy can be mapped
All at low resolution though…

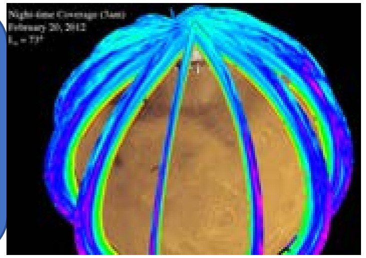
Astronomical signals can be detected
Without dating layers though…

Overarching problem… we can't connect layer properties with climate properties

There are several steps to connect the snapshot of current climate to the polar record.

Non-Polar Boundary-Layer & meteorology

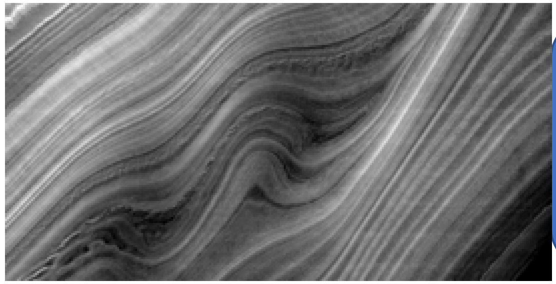
Global Transport, fractionation & Loss



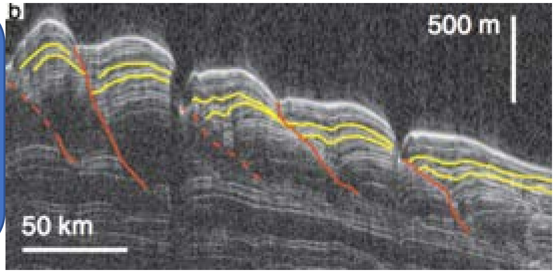
Polar Boundary-Layer & meteorology

Layer Formation Processes

Connect Surface Layers to the Deeper record



Survey Deeper Layers

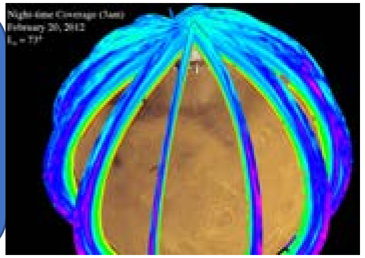


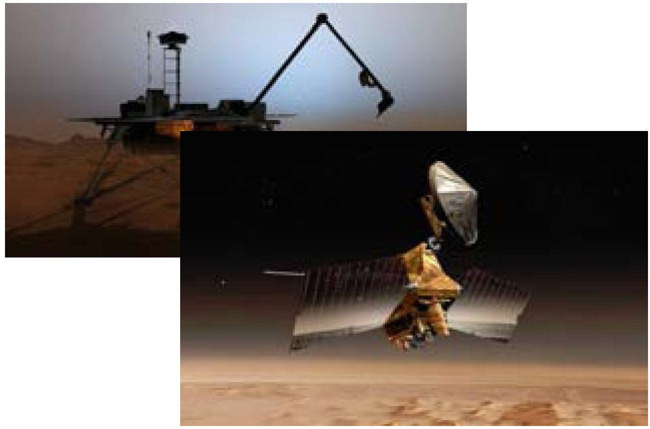
There are several steps to connect the snapshot of current climate to the polar record.

Some Data

Non-Polar Boundary-Layer & meteorology

Global Transport, fractionation & Loss





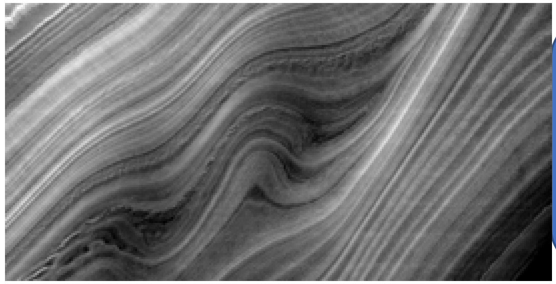
No Data

Polar Boundary-Layer & meteorology

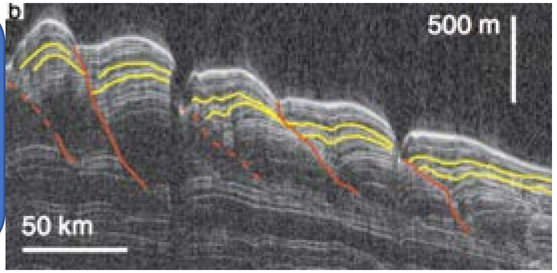
Layer Formation Processes

Connect Surface Layers to the Deeper record

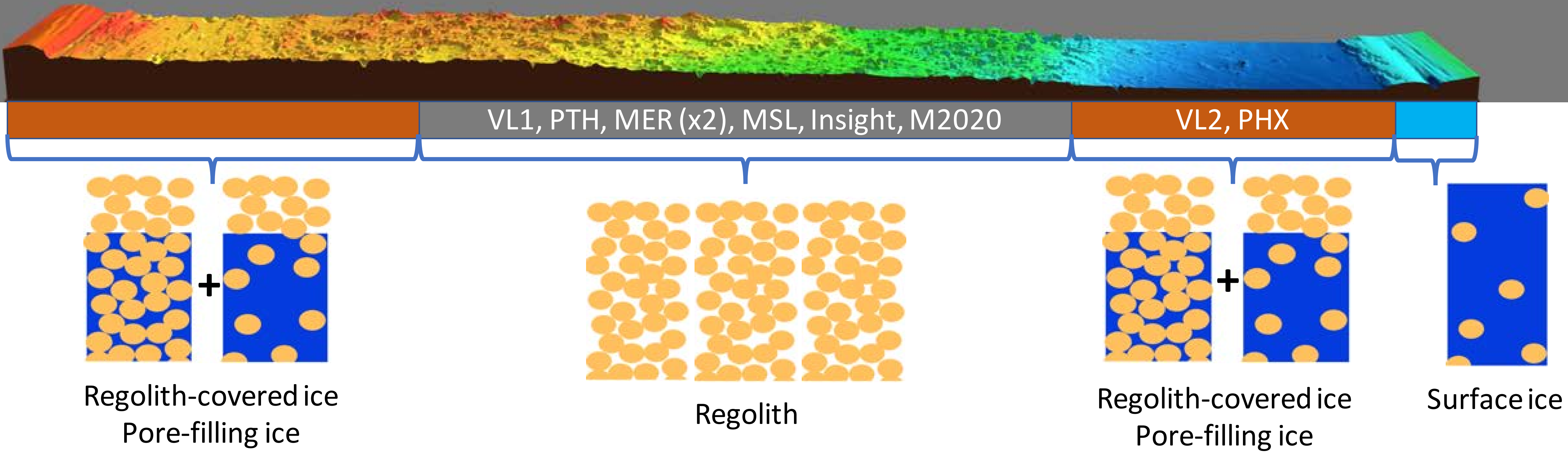
Some Data



Survey Deeper Layers



Mars Landers have investigated 2/3 of relevant terrain types



Viking Lander 2 – 48N

Phoenix – 69N

Essentially the same kind of site from an ice/climate perspective

***i.e.* not polar missions**

Measurements needed on the surface of the NPLD

(a Keck Workshop, ICE-SAG mash up with some extra proposal studies, and MASWG example mission arc #3 included)

Polar Boundary-Layer & meteorology

Meteorological package plus other surface/atmospheric characterization:

- Pressure, Temperature, Humidity
- Stable Isotopes
- Surface windspeeds
- Radiative forcing
- Deposition rates of dust, CO_2 and water.

Survival through the polar night

Layer Formation Processes

Drill 1-2m to characterize material as a function of depth:

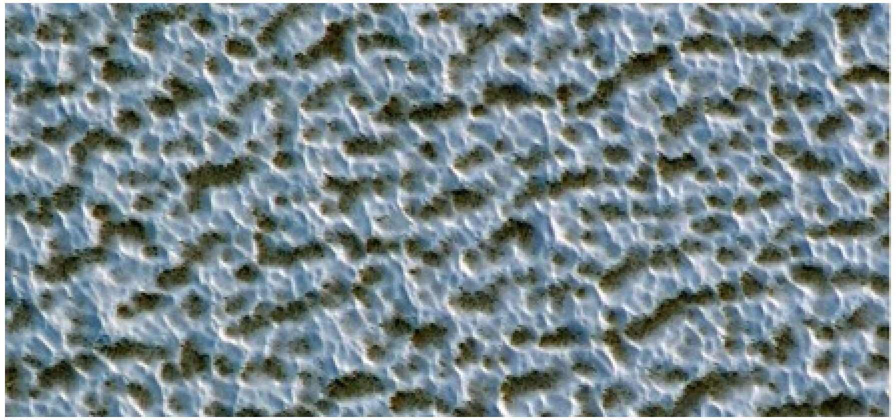
- Porosity, dust fractions
- Water ice grain sizes
- Stable isotopes
- Cosmogenic isotopes
- Vertical structure

Connect Surface Layers to the Deeper record

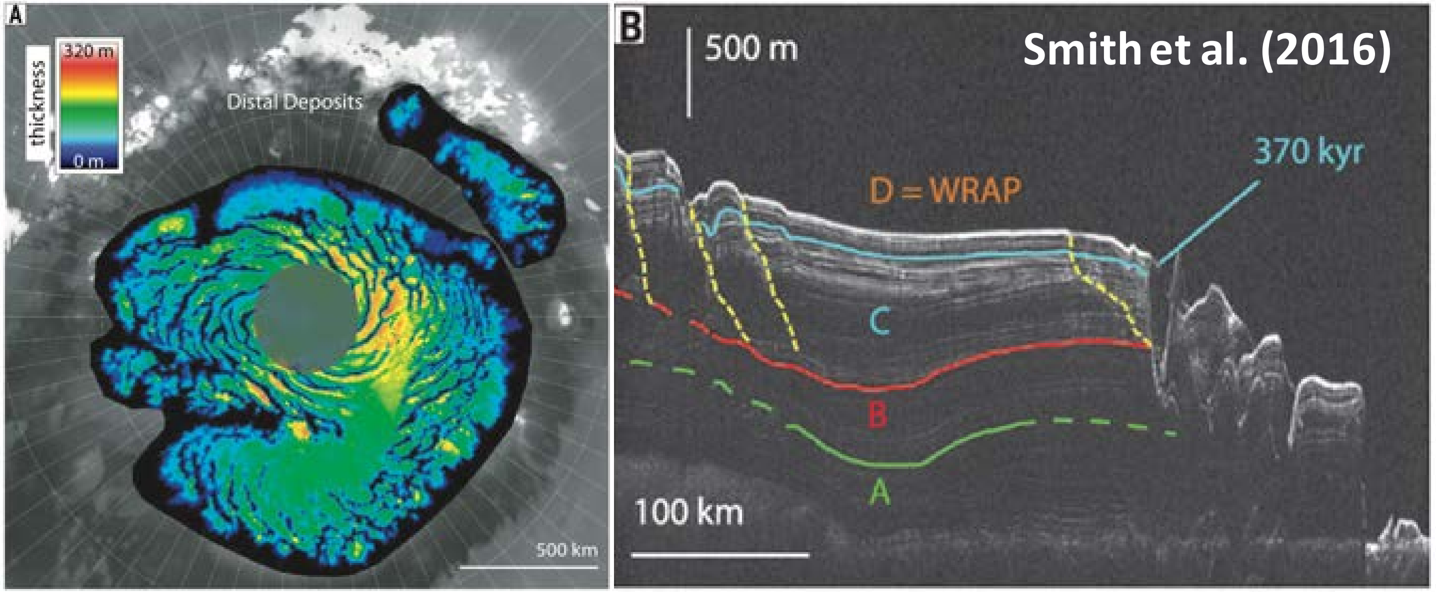
Drill or use GPR to connect these surface results to orbital radar

- 10s of meters
- If using GPR then frequency must resolve structure in the first 1-2 m as well

Easy to land on, but hard not to contaminate the surface



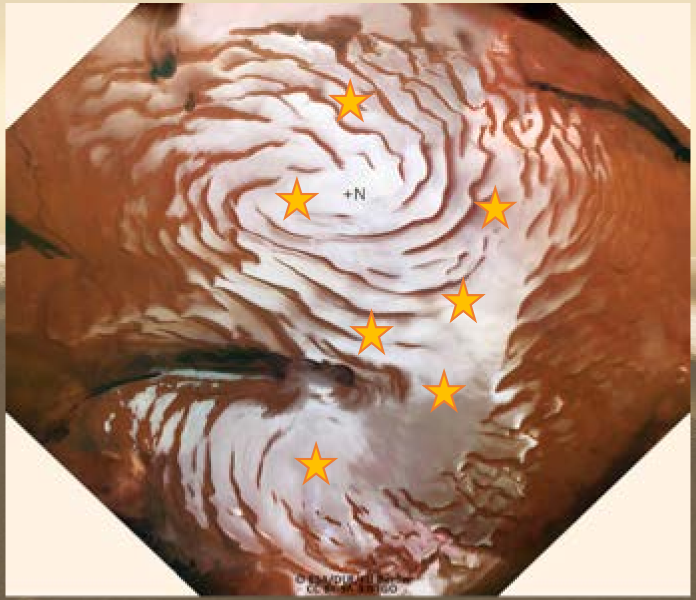
- Low Surface roughness
- No boulders
- Low elevation
- Precision landing irrelevant
- 24.5 hr sunlight in summer
- Extremely stable temperatures



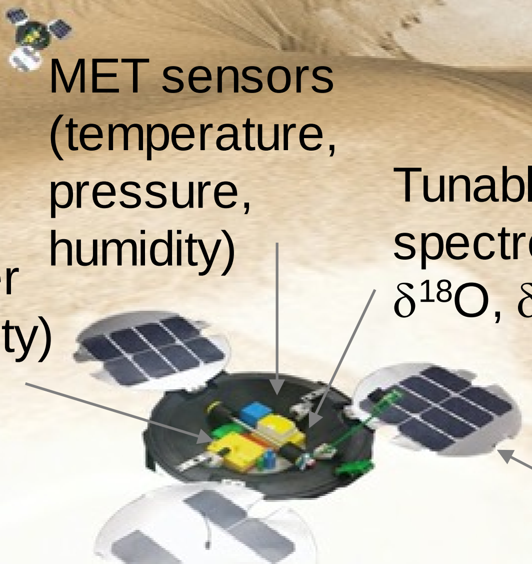
Avoiding spraying the surface with hydrazine is preferred – limits delivery system options

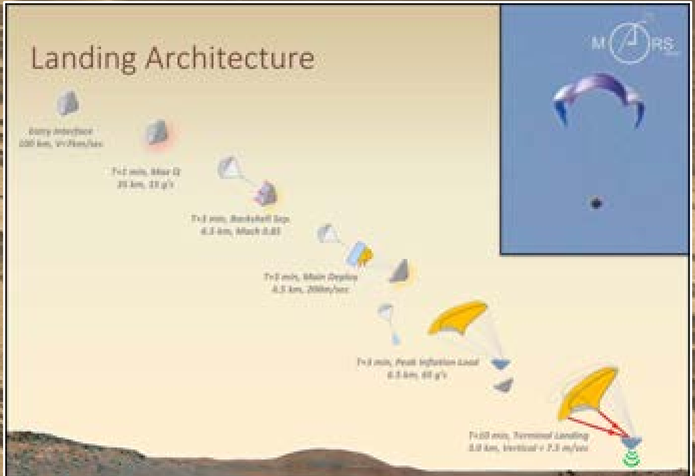
Mars Polar$_{\text{DROP}}$: Distributed Micro-landers to Investigate the Polar Ice Caps and Climate of Mars

P.O. Hayne[1], S. Byrne[2], I.B. Smith[3], D. Banfiled[4], R. L. Staehle[5]
[1]University of Colorado, Boulder, CO. Paul.Hayne@Colorado.edu [2]University of Arizona, Tucson, AZ. [3]Planetary Science Institute, Denver, CO. [4]Cornell University, Ithaca, NY. [5]NASA – Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.



- One or more "micro-landers" deliver ~1 kg payload to surface of PLD
- Determine isotopic composition of ice layers, atmospheric fluxes





Mars$_{\text{DROP}}$: *Staehle et al.* (2015)

M-PRESS: Mars-Polar Reconnaissance of Environment and Subsurface Stratigraphy

Land and drill to unlock the climate history of the Mars Polar Layered Deposits (PLD)

Science Objectives:

- Determine present and recent accumulation rates of the polar deposits
- Characterize surface & subsurface environment, materials & stratigraphy
- Relate measurable quantities to recent climate change on Mars.

Unique Capabilities: Year-round meteorology. Drill 0.5-1m and deliver samples from multiple depths. GPR to link *in situ* results to orbital data from SHARAD radar

Instruments and Accommodation

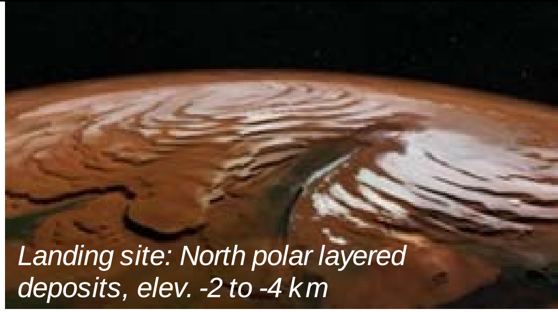
- Surface/subsurface: High-frequency GPR, near-IR/Raman spectrometer, TLS, Wet Chemistry, APXS, Microscopic Imager, surface and borehole cameras, TECP.
- Meteorology: DiAL, Sonic Anemometer, Bolometer(s), Thermogravimeter

Resources:

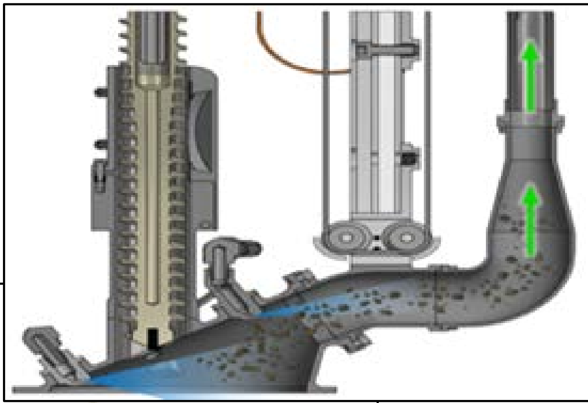
- **Mass:** 50 kg for Instruments & Sample handling (drill)
150 kg for other lander systems

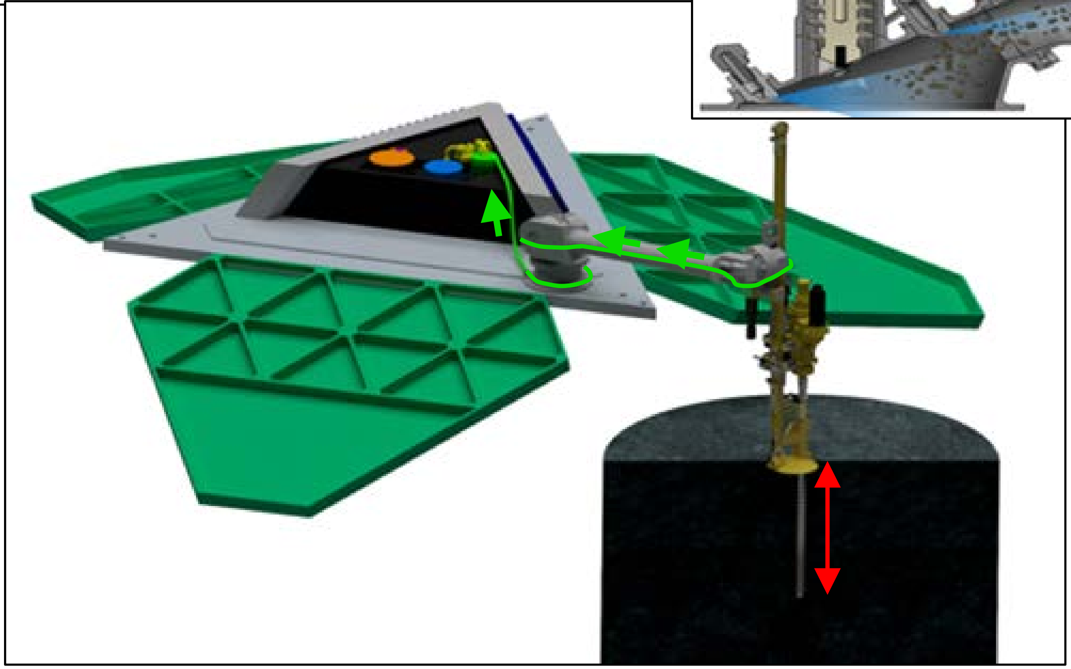
Mission Architecture

- Re-use Pathfinder landing system to deliver 200 kg w/ no precision landing requirements
- 0.5 m drill delivers samples to instruments
- Energy-intensive summer activities benefit from constant solar power
- Winter meteorology enabled by RHUs and tech-demo: wind turbines



Landing site: North polar layered deposits, elev. -2 to -4 km





M-PRESS: Mars-Polar Reconnaissance of Environment and Subsurface Stratigraphy

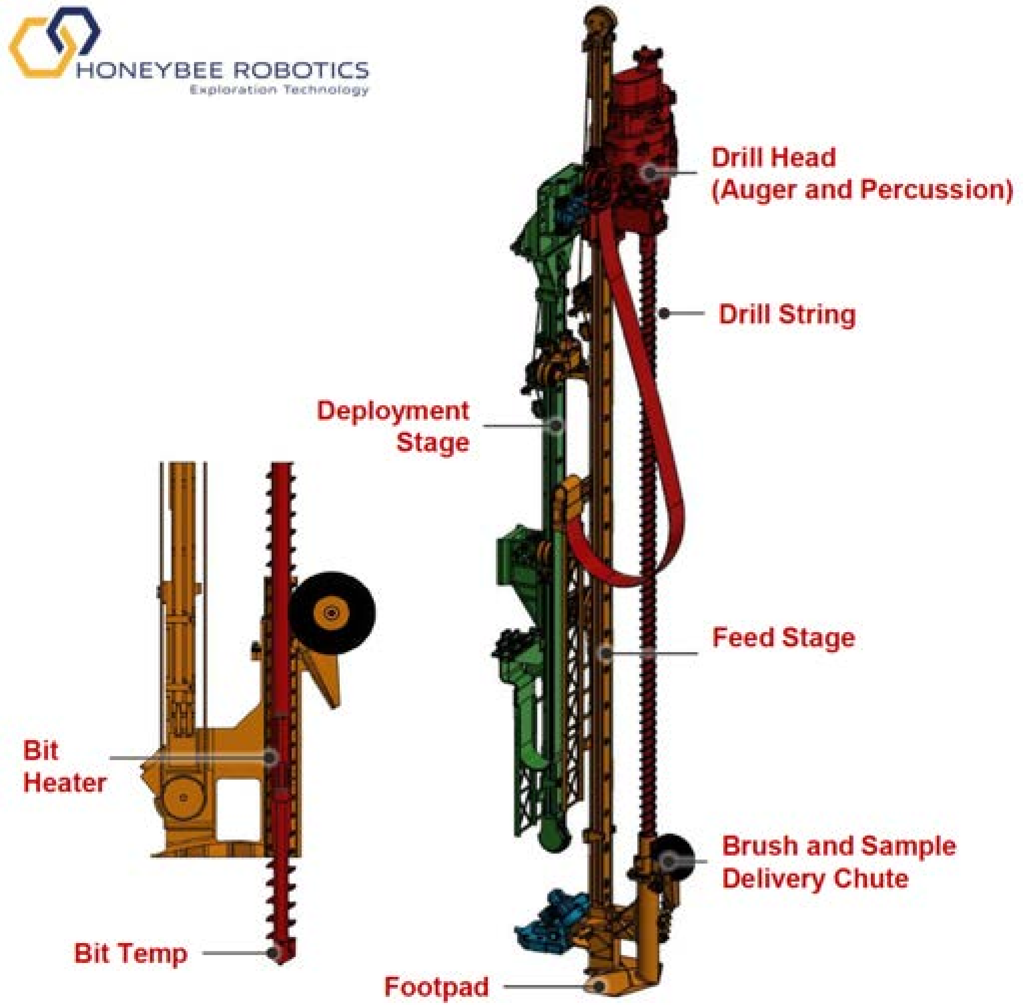
*Threshold Payload

	*	Baseline Payload Element	Heritage	Purpose
Current Climate	T	DiAL	**Mature designs (MARBLL) and simpler flight models (Phoenix lidar) - TRL high**	Water vapor with height
	T	Sonic Anemometer	**TRL 5 (clear path to TRL 6)**	Surface Winds in 3D and eddy fluxes
		Bolometer(s)	Flight on orbiters: TES	Downwelling VIS & IR flux
		Thermogravimeter	**Common & robust terrestrial instrument**	Mass of seasonal frost and deposited dust
	T	MET package	Flight on Phoenix, Curiosity etc...	Pressure, Temperature, Humidity
Climate Record	T	Drill - 10s of cm	Components @ TRL 5 or 6 - Honeybee Robotics	Sample acquisition and delivery
	T	High-frequency GPR	M2020 - RIMFAX	Connect orbital and in-situ stratigraphy
	T	near-IR/Raman spectrometer	M2020 – SHERLOC (UV)	Salts, silicates, oxides (soluble and insoluble)
	T	TLS	Flight on Curiosity - SAM	O, C & H (water+CO2) Isotopes, humidity
		Wet Chemistry	Flight on Phoenix - MECA	Soluble species
	T	APXS	Flight on MER, Curiosity	Elemental composition of non-ice material
	T	Microscopic Imager	Flight on MER, Curiosity	Particle-size distribution, porosity
	T	Color Surface stereo cameras	Flight on Phoenix (and many others)	Landing site geology - winter frost depths
		TECP	Flight on Phoenix (improvements needed)	Thermal properties - modeling mass balance

More expensive, but better, drilling options

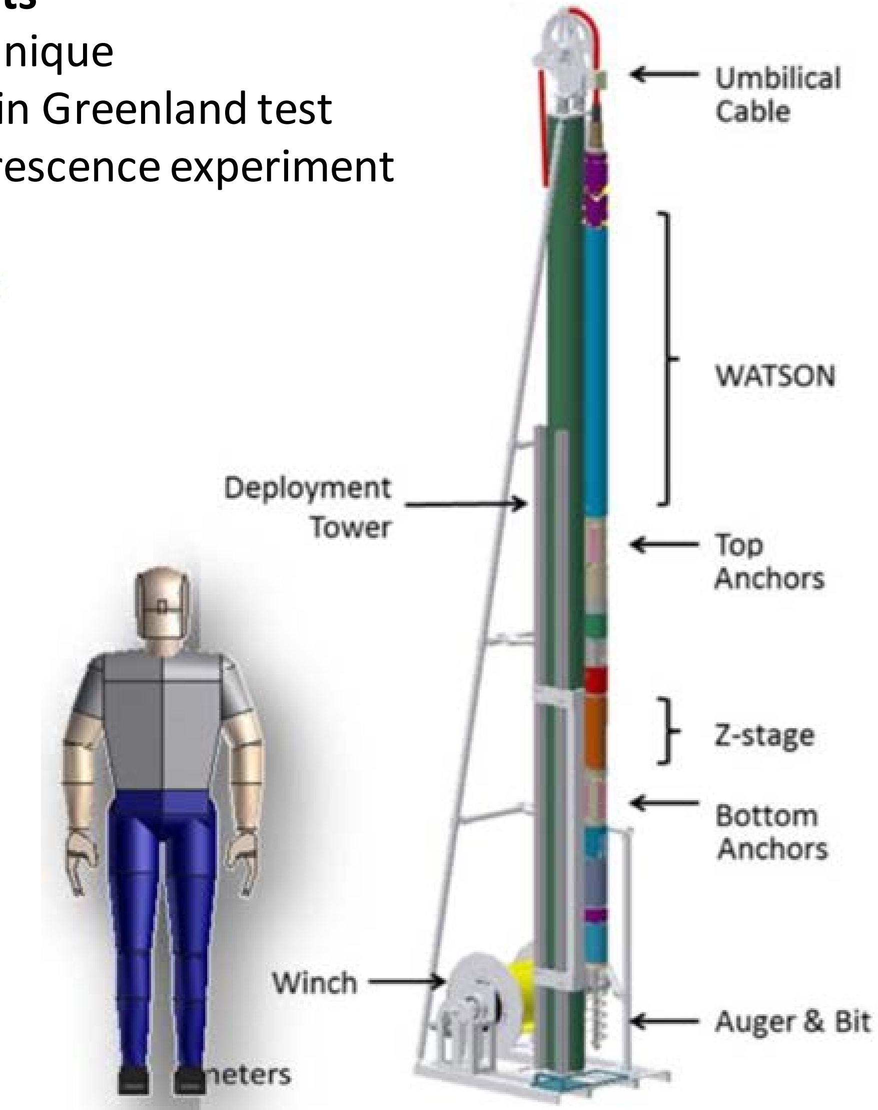
(Thanks to Kris Zacny at Honeybee Robotics)

Trident – 1-2m class drill
- 1 inch borehole
- Fiber optic or separate logging tool also possible



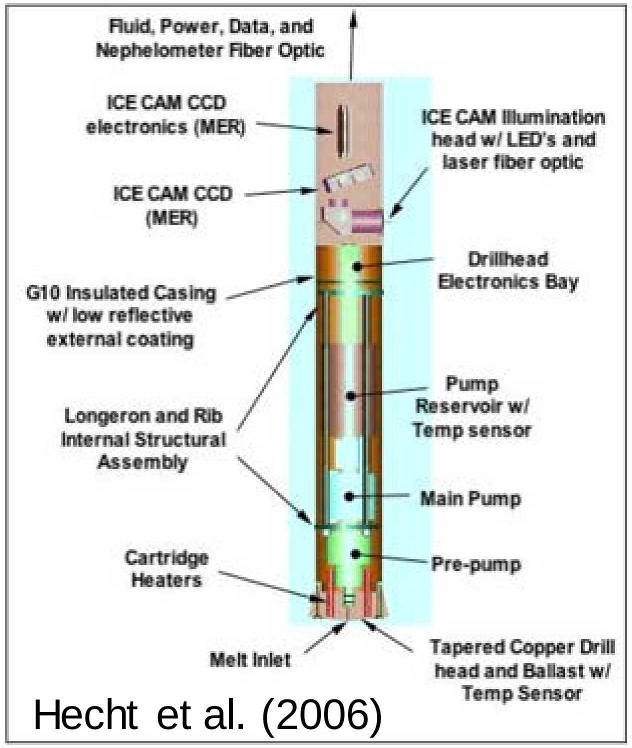
WATSON: Wireline Analysis Tool for Subsurface Observation of Northern-ice-sheets
- Inch-worm technique
- Reached 110m in Greenland test
- Carries UV fluorescence experiment

HONEYBEE ROBOTICS
Exploration Technology

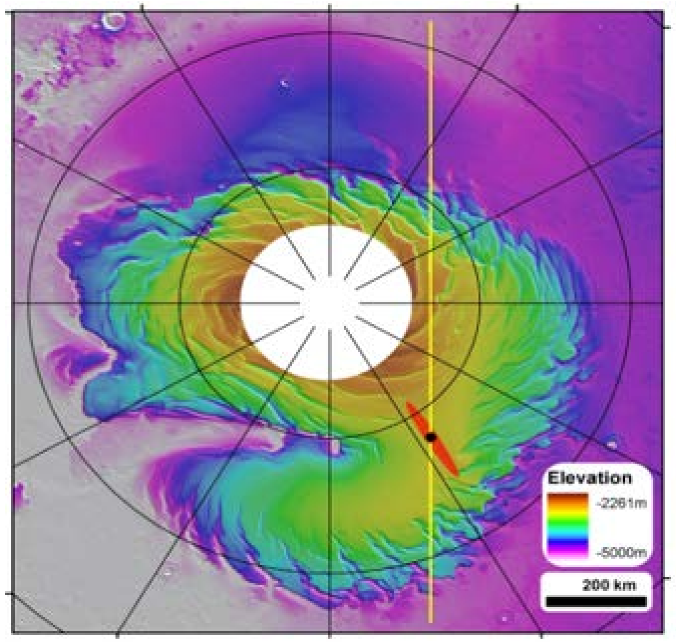


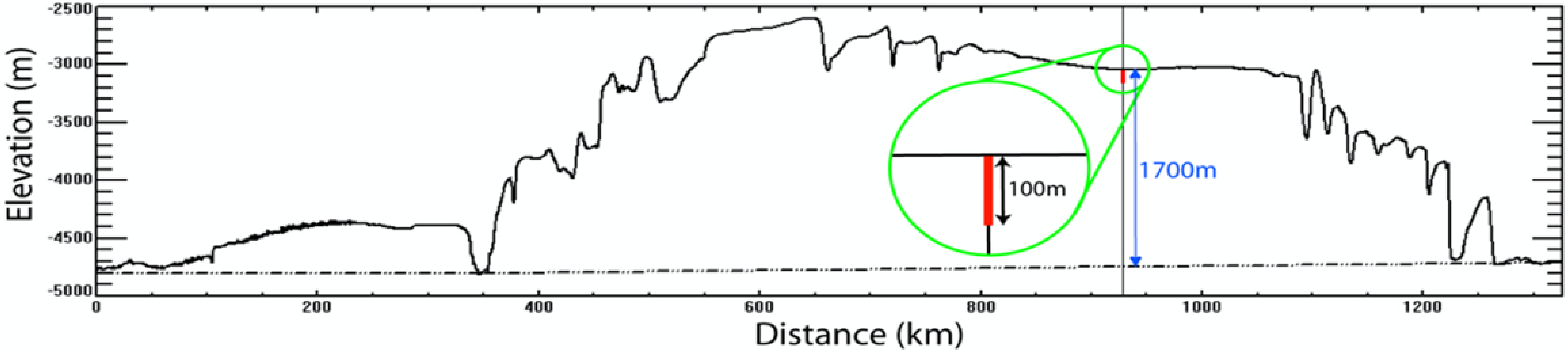
Chronos – Scout proposal from the mid-2000s

- Thermal drill with meltwater pumped up to surface analysis station
  - Tested in Greenland to 10s of meters
- Sublimation based process may be more efficient



Hecht et al. (2006)





Summary

- Terrestrial-Planet climate change is a pressing scientific issue
- Although large gaps in understanding remain, much progress has been made in measuring martian polar layers and present-day climate
- A way to link the climate and the layers remains elusive and requires a lander on the North Polar Layered Deposits
- Three required elements:
    1. Near surface meteorology including during polar night
    2. Drilling to 1-2m, with detailed compositional analysis as a function of depth
    3. A way to link the upper 1-2m to orbital radar datasets or a deep drill core
- Possibilities for progress exist from Small-spacecraft up to Flagship level.
- A small surface mission should come before flagship-level deep drilling

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