



Optical and Infrared Remote Sensing – from orbit and in situ

Wendy Calvin, Keck Workshop

Unlocking the Climate Record in Mars' Polar Layered Deposits

August 9, 2017

- Color and/or BW Imagery
 - Mariner 9, Viking
 - MGS- MOC (WA, NA)
 - Odyssey - THEMIS
 - MRO- HiRISE, MARCI, CTX
- Spectroscopy
 - MGS- TES, MRO-MCS
 - MRO-CRISM & Mars Express- OMEGA

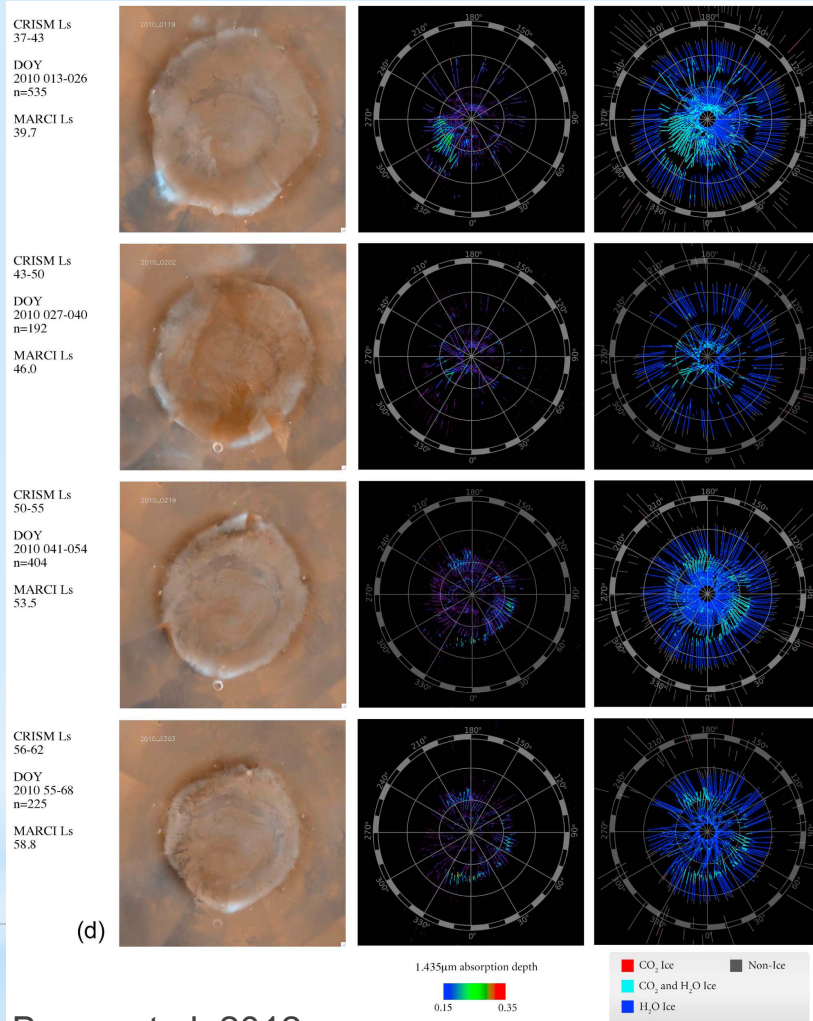
Types of observations

- Annual Processes
 - Seasonal cap advance and retreat
- Interannual Variability
 - Mass wasting, accumulation changes in RSPC
 - Mobility of high and low albedo deposits
- Composition and Physical state
 - Grain size or optical path length, grain coherence
 - H₂O vs CO₂ vs non-ice materials
- Stratigraphy (see Shane & Patricio's Short Course Talks)

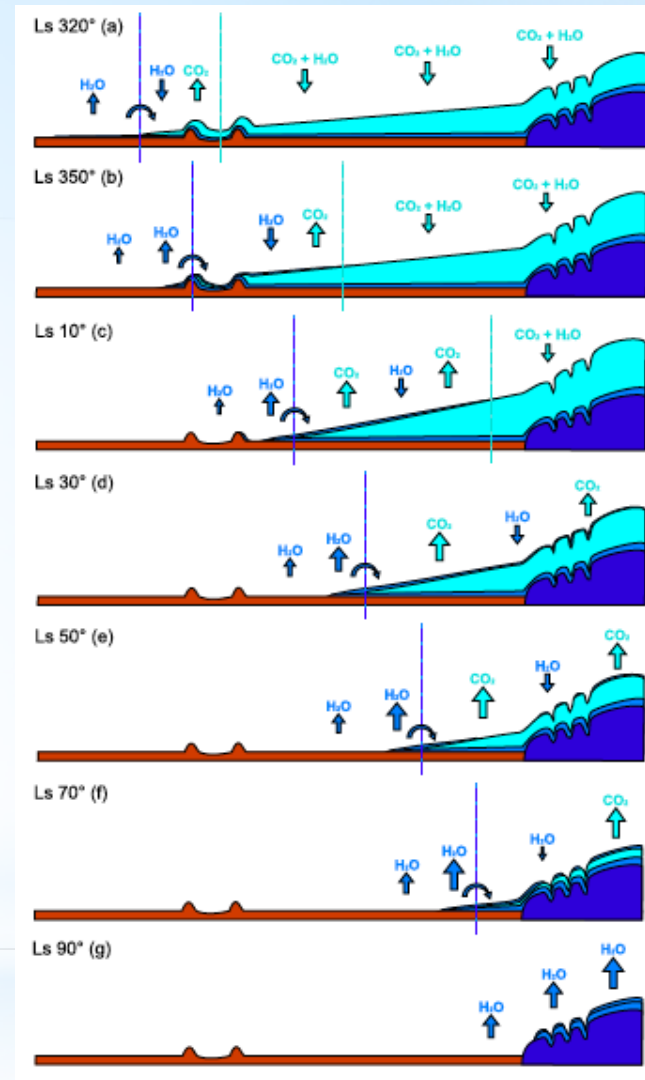
Primary Variables Observed

North Cap Recession

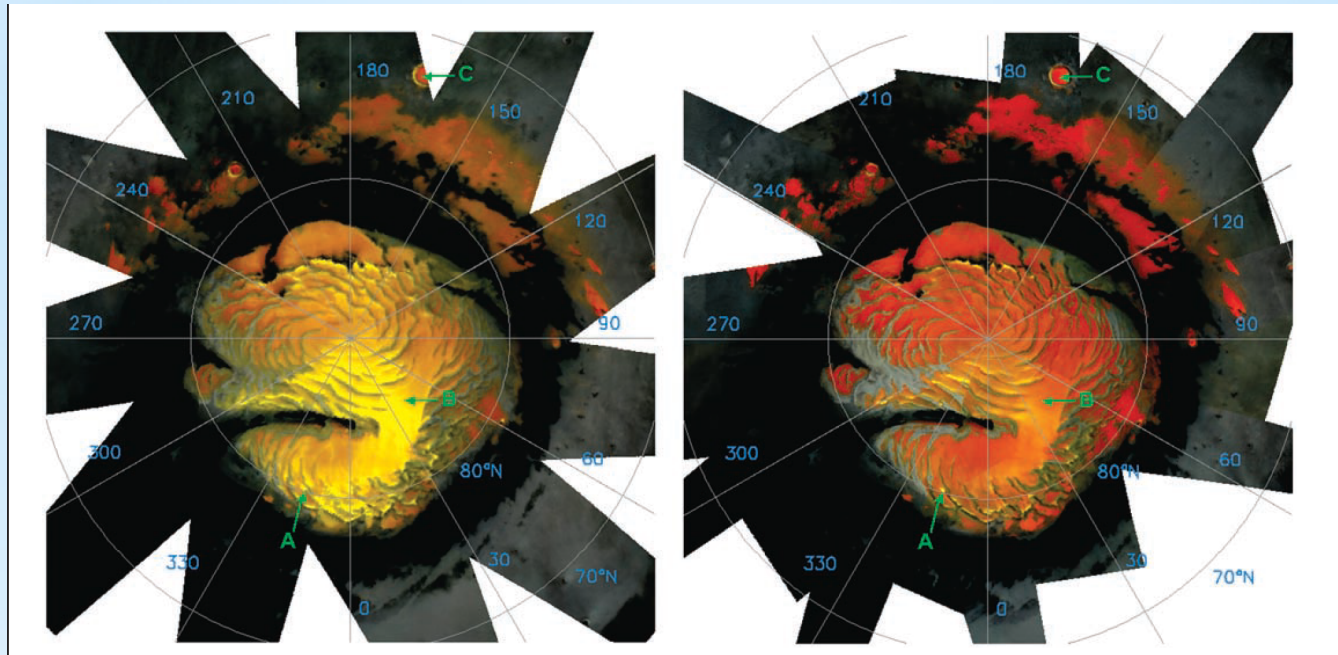
Appéré et al., 2011



Brown et al. 2012



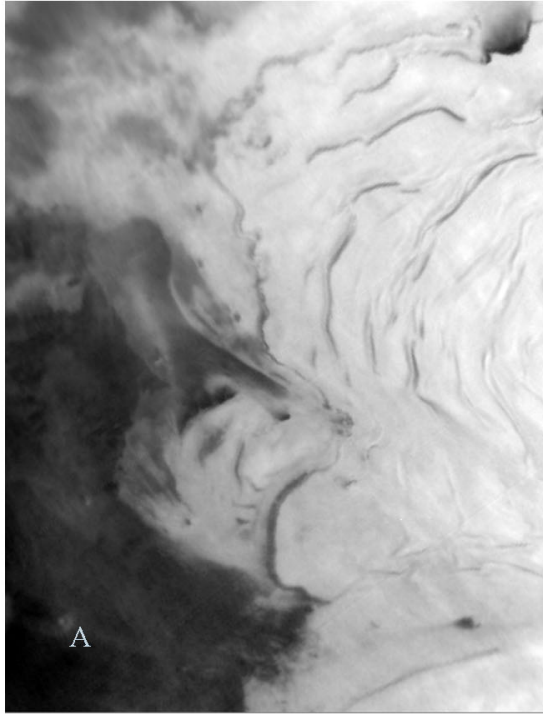
In contrast to retreating south cap, water ice signature appears throughout seasonal cap retreat in the north.



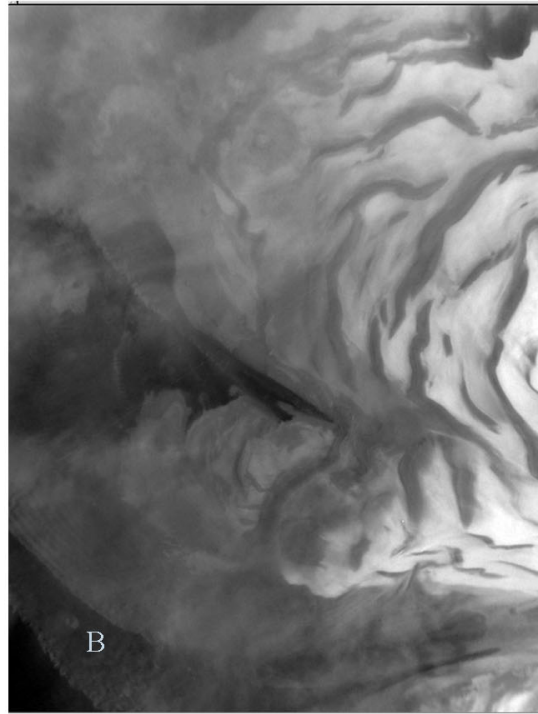
◆ Seasonal Change in Grain Size

Composite is 3 wavelengths in the water bands 1, 1.2 1.5 μm
Shift from yellow to red $\sim 100 \mu\text{m}$ to 1 mm

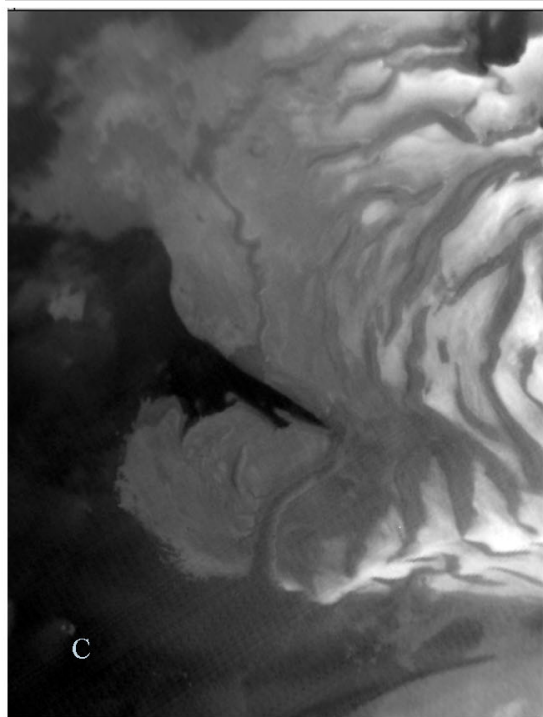
Langevin et al. 2005, Ls 96 vs 108



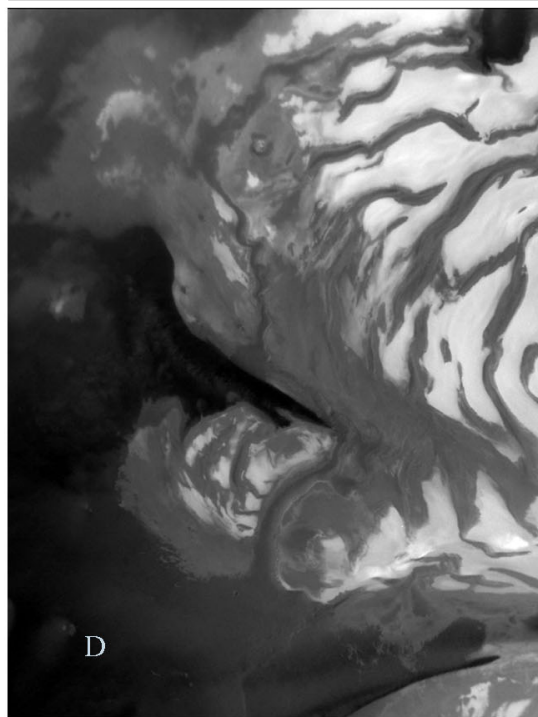
A



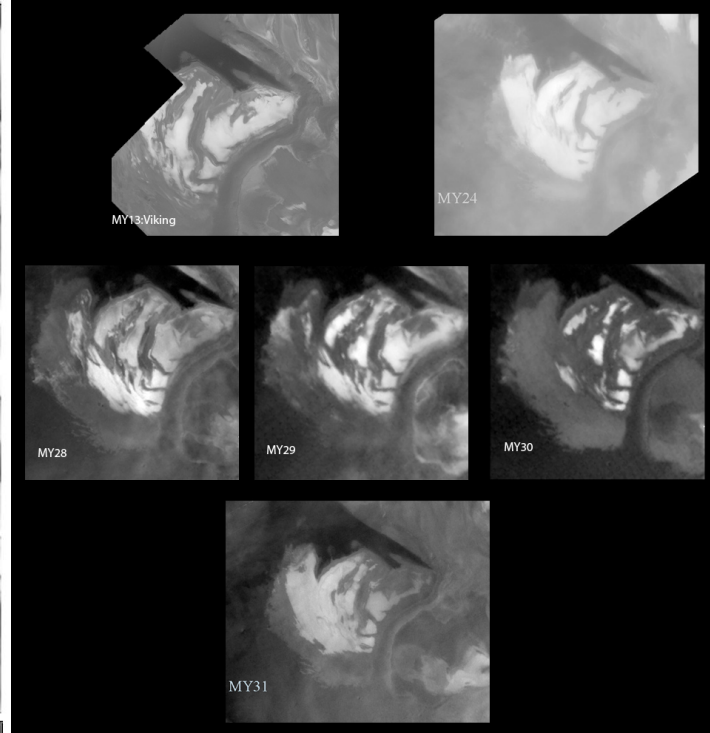
B



C



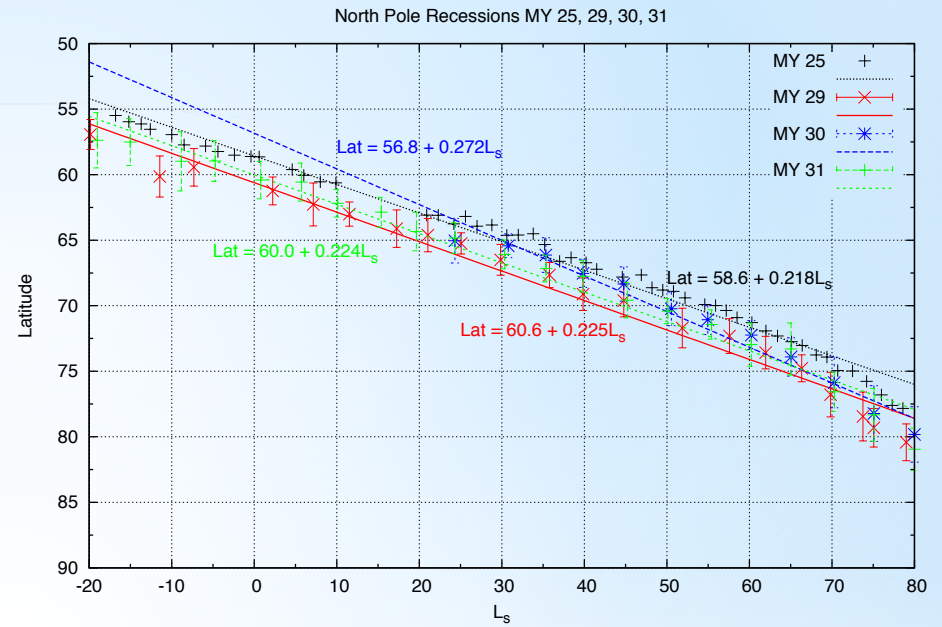
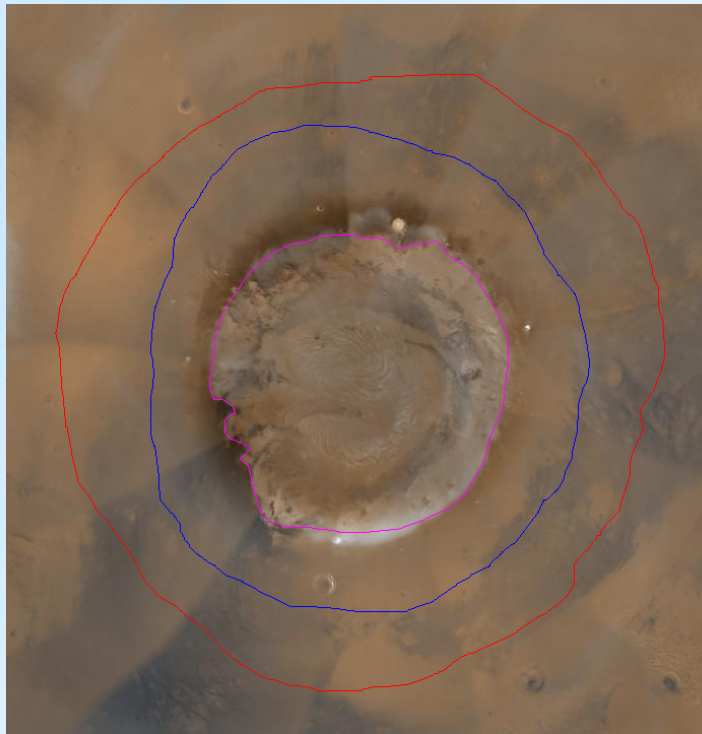
D



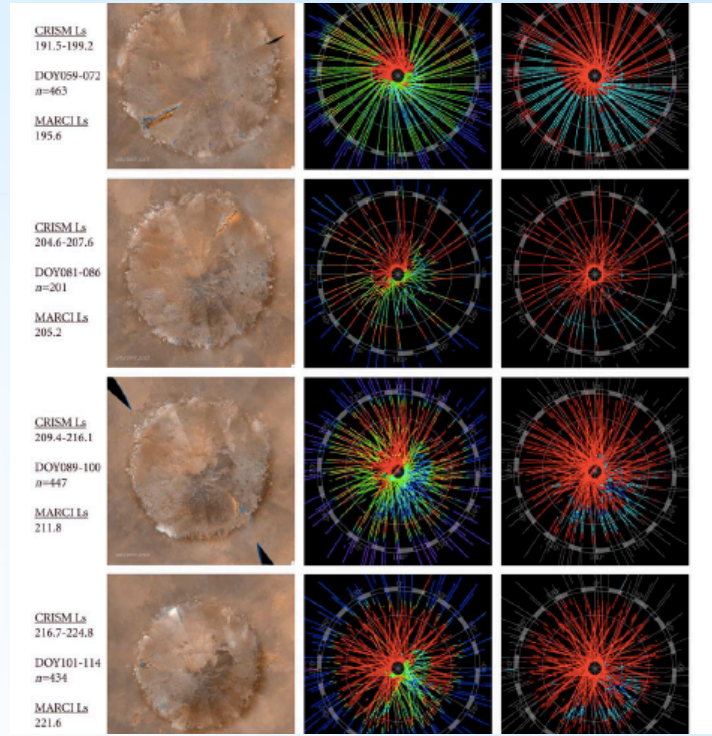
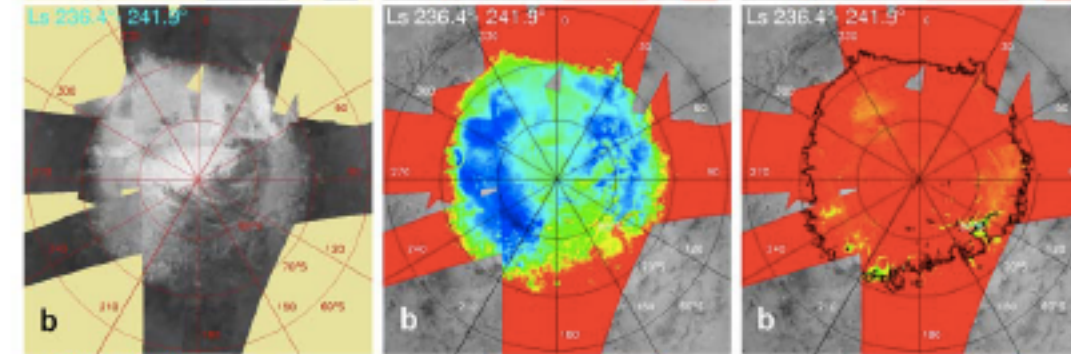
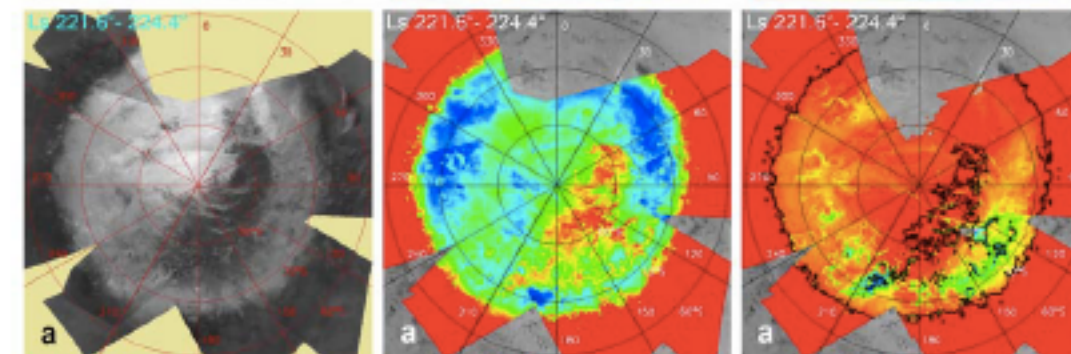
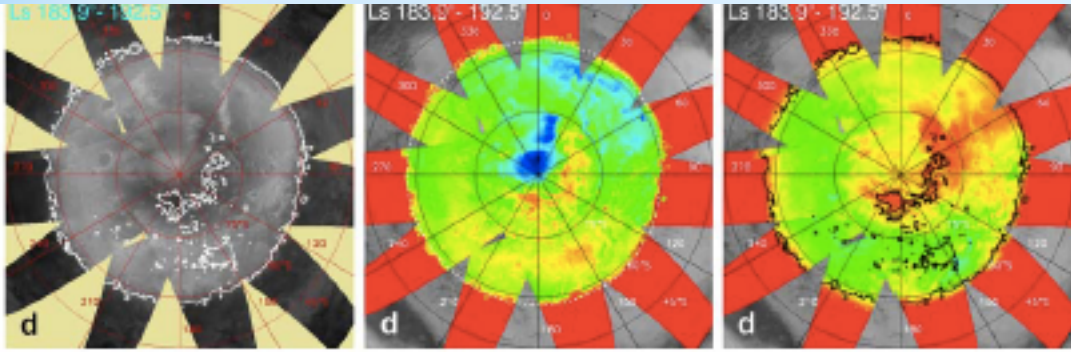
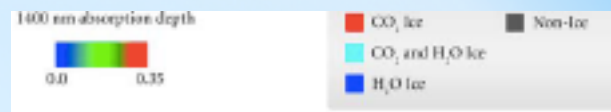
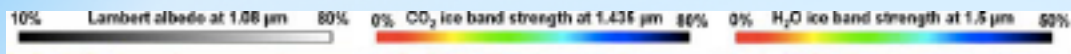
North retreat: Last of the CO_2 (Ls 73), last of the H_2O (87), minimum of high albedo (95), return of high albedo (118).

Abalos Mensae over many MY at Ls 137.

Dust and frost mobility.
Ice annealing?



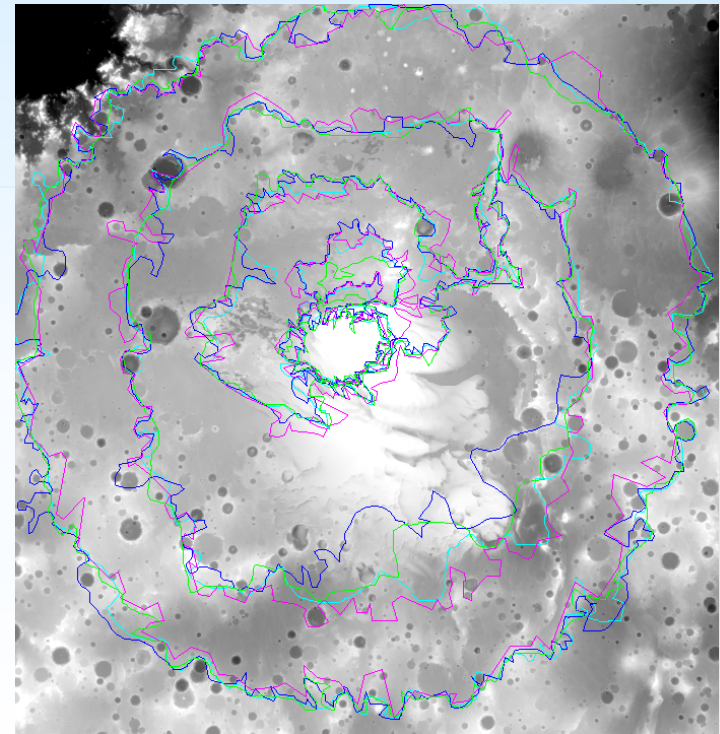
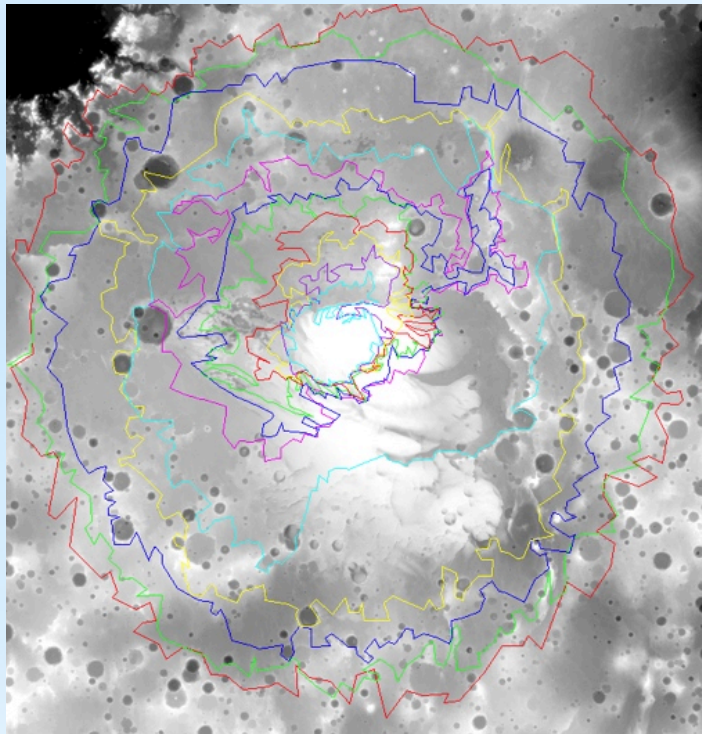
◆ North Recession Curves



Brown et al. 2010

Langevin et al. 2007

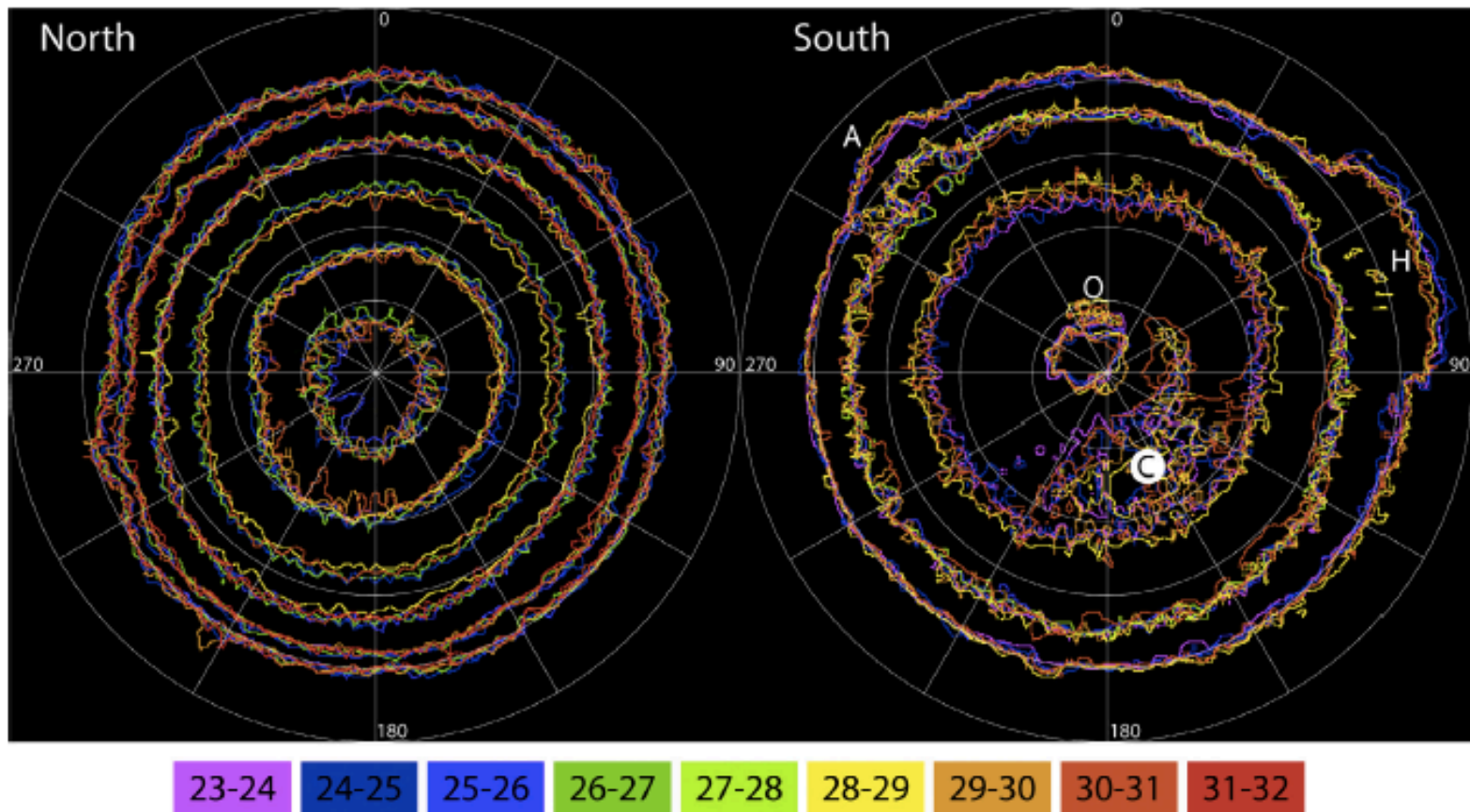
South Cap Retreat



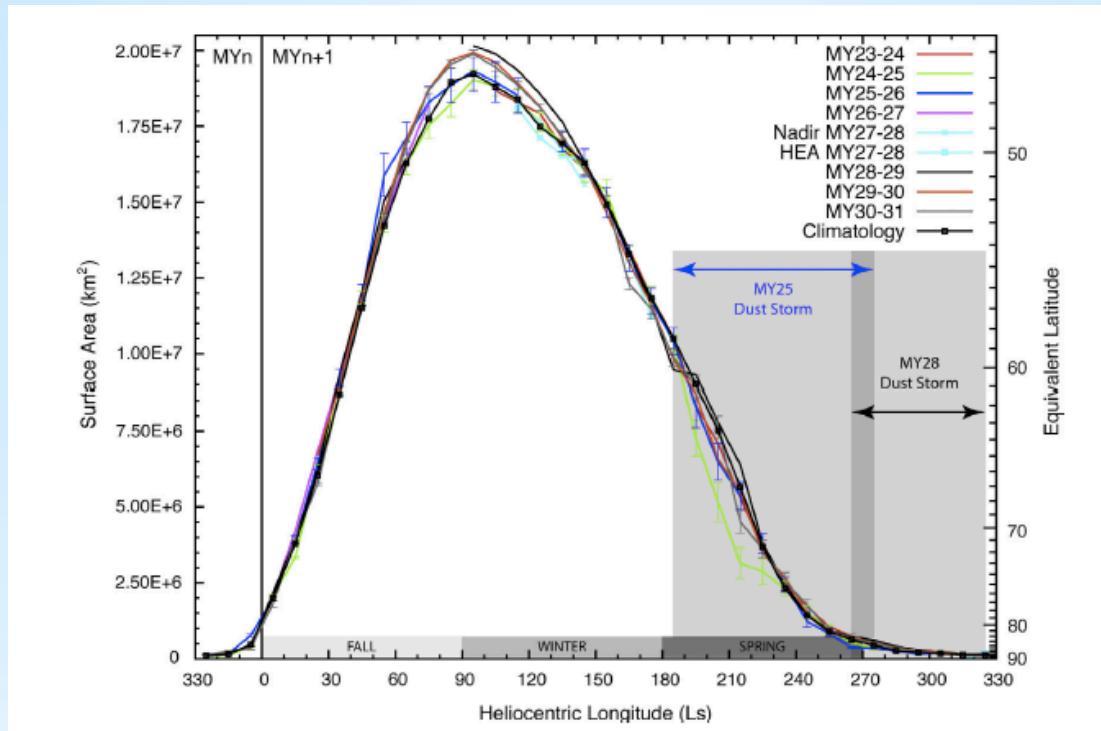
◆ MARCI Retreat Contours

MY 29
Ls 205 to 315, every 10

MY 28,29, 30, 31,
Ls 205, 235, 265, 295, and 315

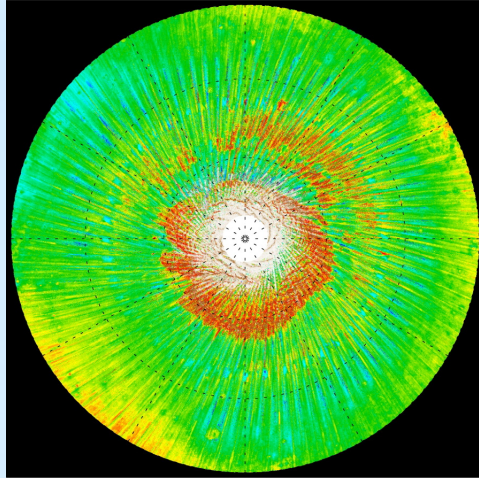


Piqueux et al 2015. Synthesized 8 years of thermal data from TES & MCS.

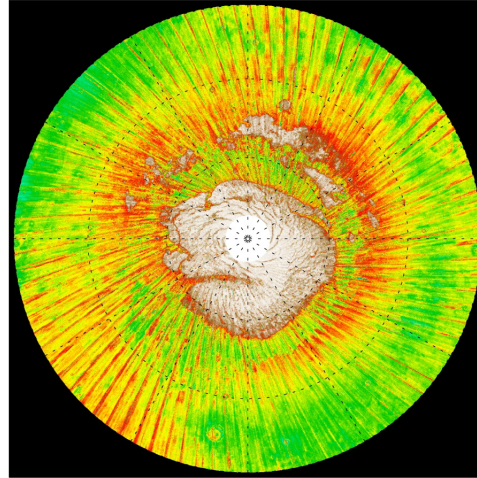


Multiple years – Climatological Model

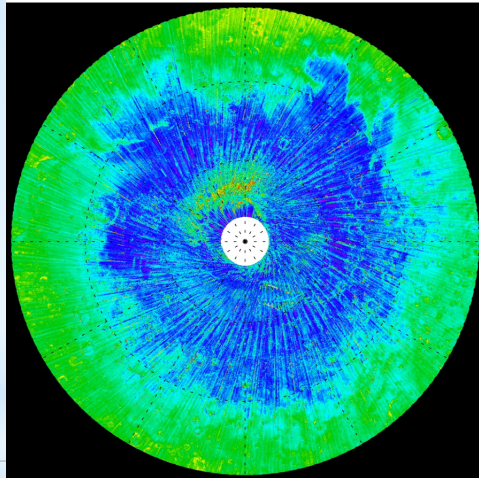
Nightside - North



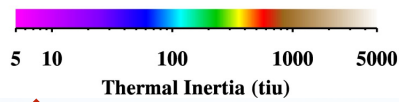
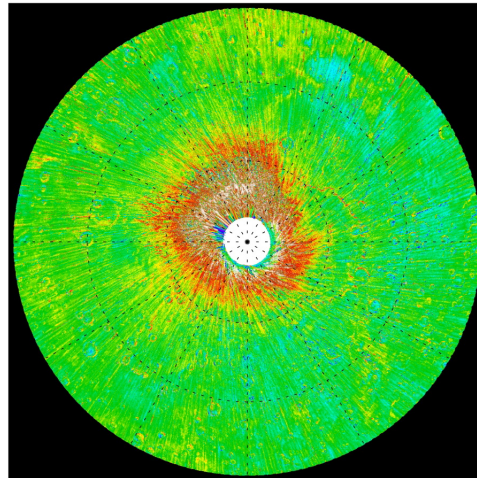
Dayside - North



Nightside - South



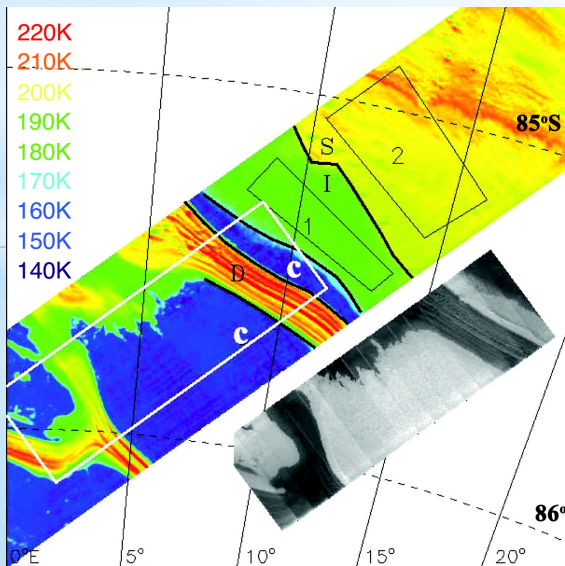
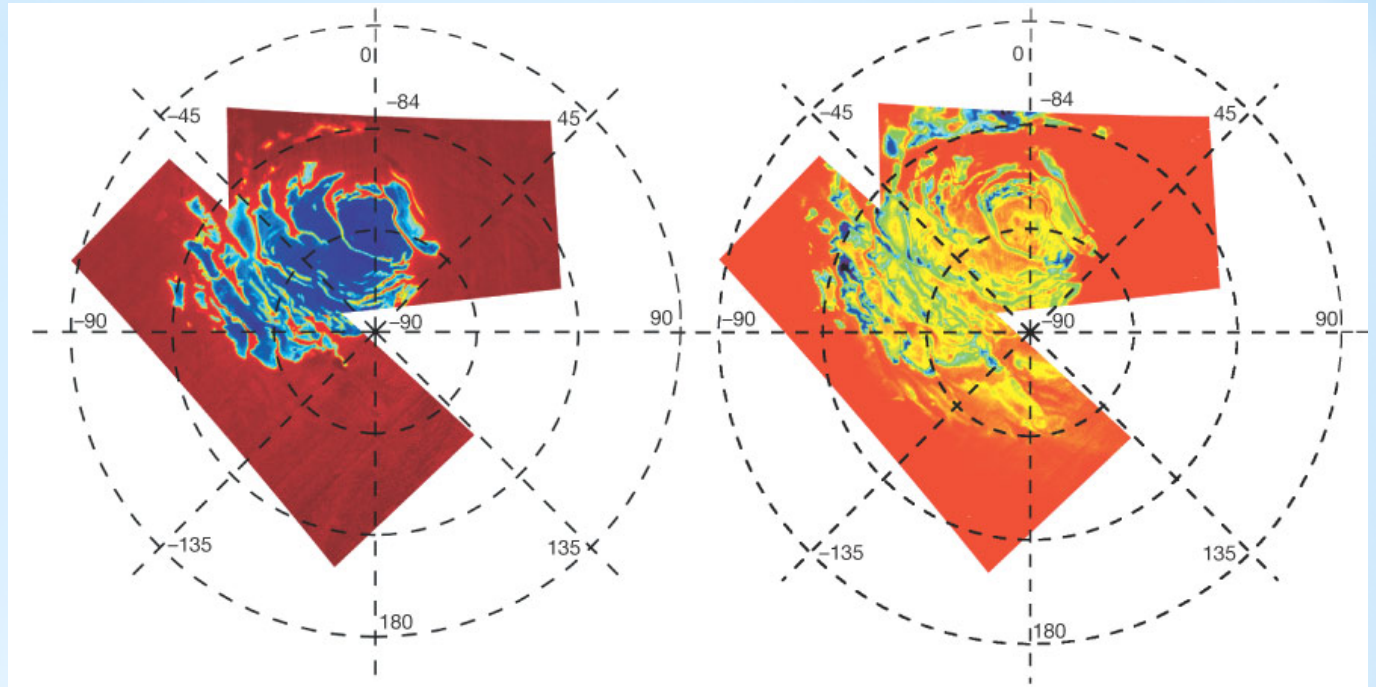
Dayside - South



Putzig and Mellon 2007.



Thermal Inertia



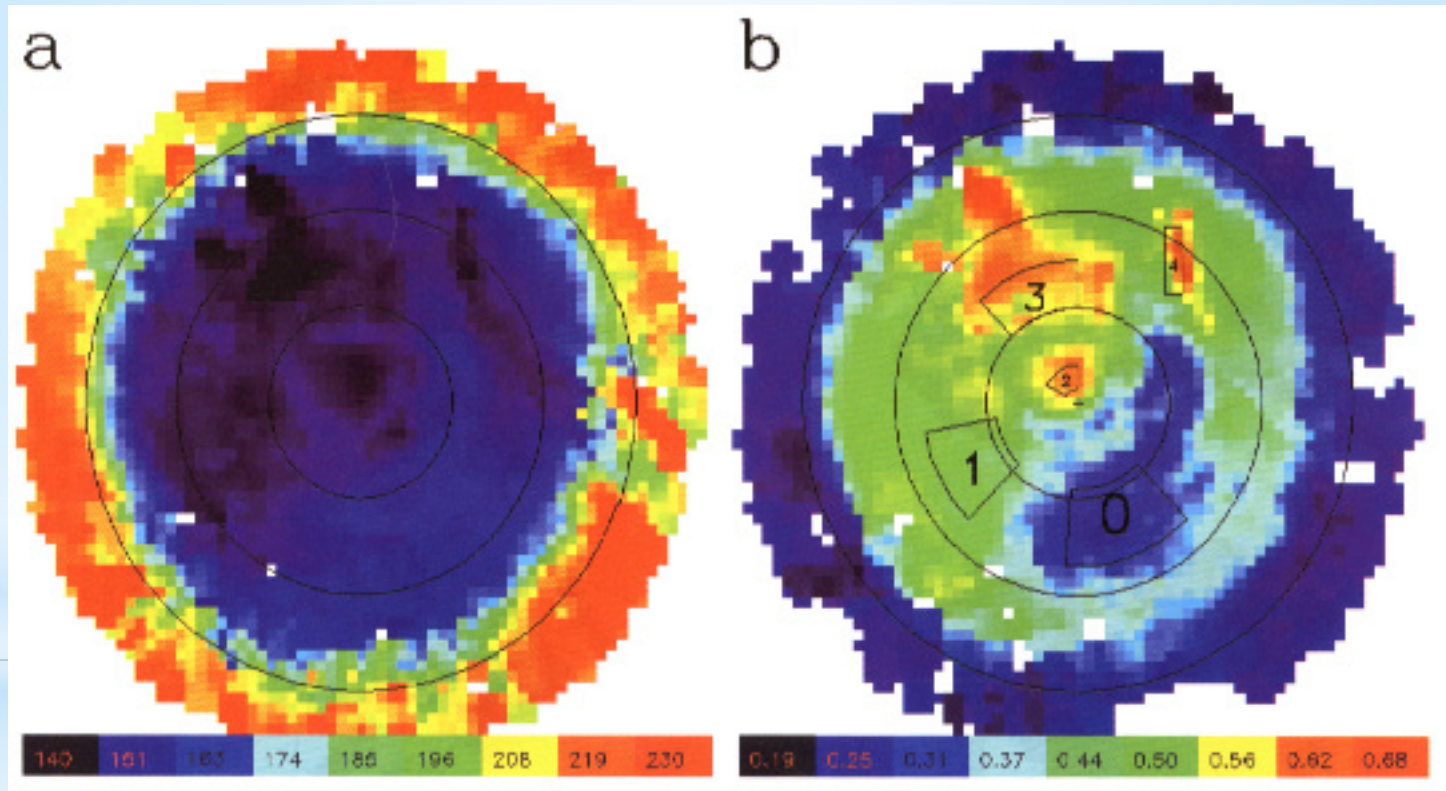
Water Ice Outlier

Titus et al. Science 2003
 Bibring et al. Nature 2004

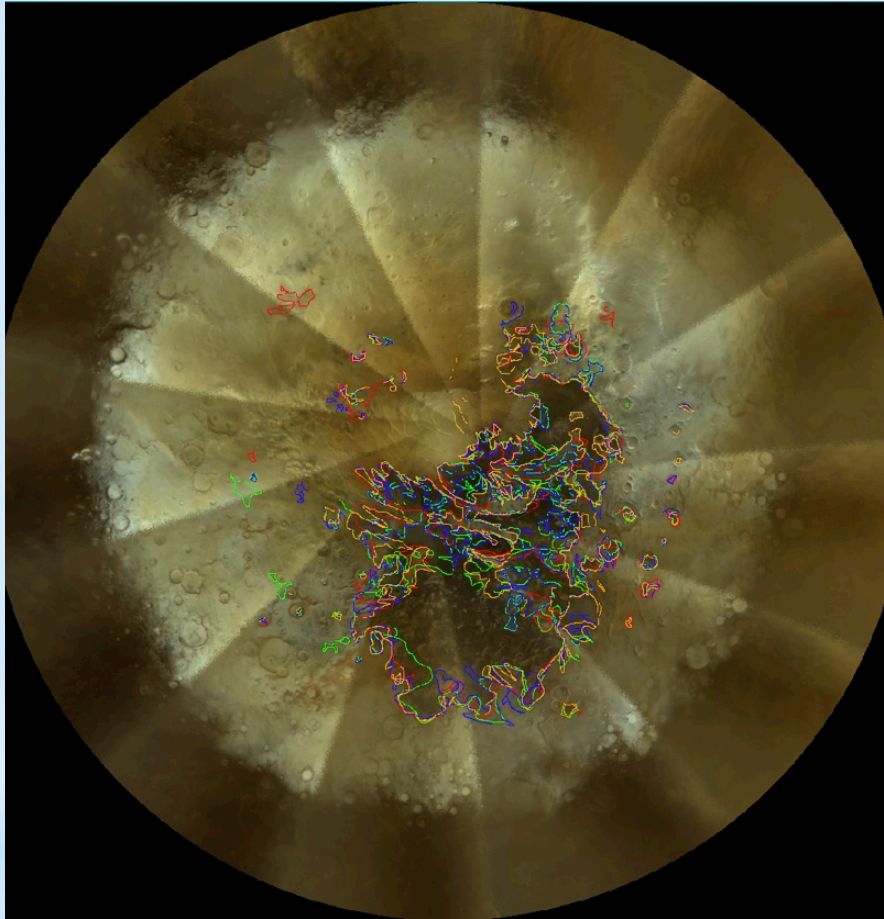
Cryptic Terrain

Temperature

Albedo



Kieffer et al. 2000. Cryptic region transparent slab ice.



- Cryptic terrain occurs in same general location but is not linked to elevation.
 - Anti-Argyre hemisphere
 - Lack of ground ice or other substrate properties of the PLD, including small scale local topography additional influences.
 - Once initiated, surface dust, strong albedo-temperature influence.
 - MARCI finds several smaller patches of “cryptic” terrain outside the classic boundaries.
 - Cryptic terrain develops and leads to isolation of the Mtns of Mitchel.

- Examples from the NEX-SAG Report
 - HiRISE follow on
 - MARCI follow on with SWIR for ices
 - SWIR mapper (6m/pixel)
 - TIR imaging (30m/pixel)
 - Lidar w/ Compositional ability

 **Potential Future Orbital
Instruments**

- Examples from 2020 rovers
 - Mast mounted imaging + spectroscopy (Supercam, with IR for distinguishing ices)
 - Drill imager (MA_MISS) or Spectrometer (μ -Omega, Lucina, Raman, Tunable Laser Spectroscopy)
- Of interest- CO₂ in clathrates or complexes with water, trace other ices, organics

	Spacecraft	Instrument	Best Spatial Footprint	Spectral Resolution	Wavelength range in μm
Orbit	Mariner 6, 7	IRS	200 km	1-2%	1.9 to 14.4
	Mariner 9	IRIS (atmosphere)	126 km	2.4 cm ⁻¹	5 to 50
	Phobos-2	ISM	22 km	40 nm	0.76 - 3.1
	MGS	TES	3 km	10 cm ⁻¹	6 to 50
	Mars Express	OMEGA	300 m	14 nm	0.35 to 5.1
		PFS (atmosphere)	12km	1.3 cm ⁻¹	1.2 to 45
MRO	CRISM	18 m	6.55 nm	0.36 - 3.9	
MER	Mini-TES	~15 cm	10 cm ⁻¹	5 to 29	
In Situ	MSL	LIBS (elemental chemistry)	0.3 mm	< 0.3nm	0.24 - 0.8
	Exo Mars (planned)	MicrOmega	5mm @20 μm	20 cm ⁻¹	0.9 - 3.1
		RLS	50 μm	7 cm ⁻¹	2.6 to 67
	Mars 2020	Lucina	1cm @100 μm	4 cm ⁻¹	1.8 to 12


**Potential Landed /
In-situ Instruments**