A widespread low-latitude diurnal CO$_2$ frost cycle revealed by Mars Climate Sounder

Polar and Equatorial CO$_2$ ice

CO$_2$ ice Emissivity

Frequency of CO$_2$ ice Presence

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Surface CO$_2$ Cycle: Polar Seasonal Ice

000<\text{Ls}<010

Piqueux et al. 2015
Low Latitude Surface Temperatures

MCS 3AM Global Temperature Maps (32μm)

No Correction
020<\text{Ls}<030

Atmospherically-Corrected
020<\text{Ls}<030

No Correction
330<\text{Ls}<340

Atmospherically-Corrected
330<\text{Ls}<340

140 \text{ Temperature (K)} \ 240
CO₂ Frost Detection

CO₂ Frost Detection Methodology

TOPO + Viking + \( \ln(P) = a - b/T \)

- Predicted Frost Point
- MCS Observations

North CO₂ Ice Seasonal Cap
Arabia
Elysium
Olympus M.
Hellas
V. Marineris

South CO₂ Ice Seasonal Cap

Temperature Deviation (K)

Frost
No Frost
-10
0
10
Seasonal Trends of CO$_2$ Ice on Mars

3AM CO$_2$ Ice presence

Mid/Low latitude CO$_2$ Ice observed seasonally

South seasonal CO$_2$ cap

Elysium

000<Ls<010

North seasonal CO$_2$ cap

No CO$_2$ Ice

Arabia

Tharsis

Temperature Deviation (K)

Frost | No Frost

-10 | 0 | 10
Controlling Factors

- Albedo
- Thermal Inertia
- Elevation
- Insolation
- H₂O Clouds
- Pressure Cycle
- Dust Loading
- Eccentricity
MCS data is used to derive the emissivity of CO$_2$ ice and constrain the properties of the ice and its relationship with the regolith.

In the polar night, CO$_2$ snowfalls result in low emissivity ice ("cold spots") indicative of small crystals.

Low latitude CO$_2$ ice has a high emissivity similar to polar seasonal ice at the edges of the caps.

Low Latitude CO$_2$ ice has a high emissivity indicative of either 1) subpixel mixing with warmer regolith, 2) contamination by aerosols, 3) large slab-like crystals, or 4) optically thin ice layers.
CO₂ Ice Spectroscopy

1) Large slab-like crystals
2) Subpixel mixing with warmer regolith
3) Contamination by aerosols
4) Optically thin ice layers (Testable with optical modeling)
5) Growth within top Regolith

\[ \frac{dM}{dt} = L \epsilon \sigma T_{CO₂}^4 - Q_{IR} \]

- \( L \): CO₂ Latent Heat of Condensation J kg⁻¹
- \( \epsilon \): Frost Emissivity
- \( M \): Frost Mass kg m⁻²
- \( t \): time (s)
- \( Q_{IR} \): Atmospheric downwelling flux W m⁻²
- Length of streaks and shallow slopes require fluidization [Miyamoto et al. 2004]
- Subliming CO$_2$ frost mixed with dust behavior

Pilorget and Forget [2015]

Shorghofer et al. [2007]
Atmosphere/Regolith Relationship

- Rovers/Landers/Orbiters: Global process of soil cementation/induration

- In the dusty regions, this process is not effective and surface material remains at very low TI values (high porosity, no cementation)

- Does CO$_2$ ice cycle *fluffs up* upper regolith (porosity, cementation)?

- Self perpetuating process
  - high porosity, no cementation
  - low regolith Thermal Inertia
  - low nighttime temperatures
  - CO$_2$ ice
Mid/Low Latitude CO2 Ice: Conclusions

- ~ 60% of the surface experiences surface frost
- ~ 95% of terrains $T/l < 100 \text{ Jm}^{-2}\text{K}^{-1}\text{s}^{-1/2}$
- Nearly all latitudes
- Main controls: Albedo and Thermal Inertia
- Other controls: Elevation, Latitude, $\text{H}_2\text{O}$ Clouds
- Unclear Effect: Pressure Cycle, Dust Loading, Eccentricity
- Pre-dawn CO$_2$ Thickness 0-200 μm, most often much less, not measurable ($\Delta P << 0.1\%$)
- $\epsilon \sim 1$
- Relationship with regolith to clarify, potentially important
- Dedicated observations for MRO EM4