Climate simulation with a “Reversed Perihelion”. interpretation of Omega observation of water on the South polar cap

Montmessin, Forget, Haberle

Climate simulation at high obliquity: interpretation of HRSC observations Martian glaciers

Forget, Levrard, Montmessin and Haberle
CO₂ and H₂O ice distribution on South Polar Cap

(Bibring et al. Nature 2004)
• Water was not expected to be stable at the south pole

• It has been argued that transport to the North pole (and thus water ice accumulation) is favored because of the topography asymmetry

⇒ Need for a recent accumulation of water ice.
Recent variations of the summer insolation at the Poles

Data source: J. Laskar (IMC/Paris)
MGCM experiments: “reversing” Perihelion date…

• **MGCM (LMD-Paris):**
  – Resolution 5.6° x 3.75°
  – Validated water cycle (Montmessin et al., 2004)
    - Cloud (predicted particle size)
    - **No CO₂ residual cap**
  – Perihelion phased with northern summer
  – Experiments with various dust scenarios
Mean water cycle

PRESENT

21,500 yr ago
Water cycle -21K years ago

Water vapor (pr. μm)

Ground ice (μm)
South pole accumulation rate
Reversed Perihelion – « Dusty Perihelion »
Mars -21K years – constant dust opacity ✨ Favors South Pole
Summary (1)

• Recent past (10,000s of years) should have seen episods of significant water transfer from the North pole to the South, even in the absence of a CO$_2$ residual cap, and despite atmospheric circulation which favors volatile transport to the north pole (Richardson & Wilson, 2002)

– **Mechanism coupling:**
  – Differences of insolation between the poles
  – Seasonal variation of *cloud elevation in the tropics* ("Clancy Effect")

• On the average however, a topographic bias (global circulation, dust lifting) should favor the accumulation of water ice in the North Polar Region.
Climate simulation at high obliquity (poster tonight)

During Mars History, most likely obliquity: 41.8° (Laskar et al. 2004)
Our reference simulation:
Obliquity = 45°, Excentricity = 0, Dust Opacity = 0.2
Only initial source of water: northern permanent cap
Yearly accumulation rate
(mm/year)
(10th year simulation)

Formation of glacier
Zoom with The LMD Global Climate model
The formation of glacier: Ice accumulation rate (mm/yr)

Our reference simulation: Obliquity = 45°, Excentricity = 0, Dust Opacity = 0.2
Only initial source of water: northern permanent cap
Why glaciers form: precipitation on windward slope

LEFT: *Cloud thickness (kg/m²) and mean winds at 1km above the surface during Northern summer*
Comparison with observations?

Check it out!

Subsurface « water » mapped by GRS aboard Mars Odyssey (Feldman et al. 2004)

Mapping of remnant traces of cold-based glacier (Head et al., 2003)
Summary (2)

- Throughout Amazonian, and up to 5 million years ago, high obliquity climate enhance the water cycle

  ➞ Precipitation and accumulation of ice possible on the windward side of topography feature (due to adiabatic cooling in updraft)

  ➞ The predicted locations for ice accumulation match the HRSC and previous observations of glacier and ice related formations.
Dust cycle sensitivity to $L_{sp}$

- Ames GCM experiments:
  - Mars today: $L_{sp} = 250^\circ$
  - Rev. Peri: $L_{sp} = 70^\circ$
- Radiatively active dust cycle with lifting processes (no clouds/water cycle)
- “Dusty perihelion” = not achieved if $L_{sp}$ sync. with northern summer

\[\text{Topographic effect} = \text{robust forcing}\]