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

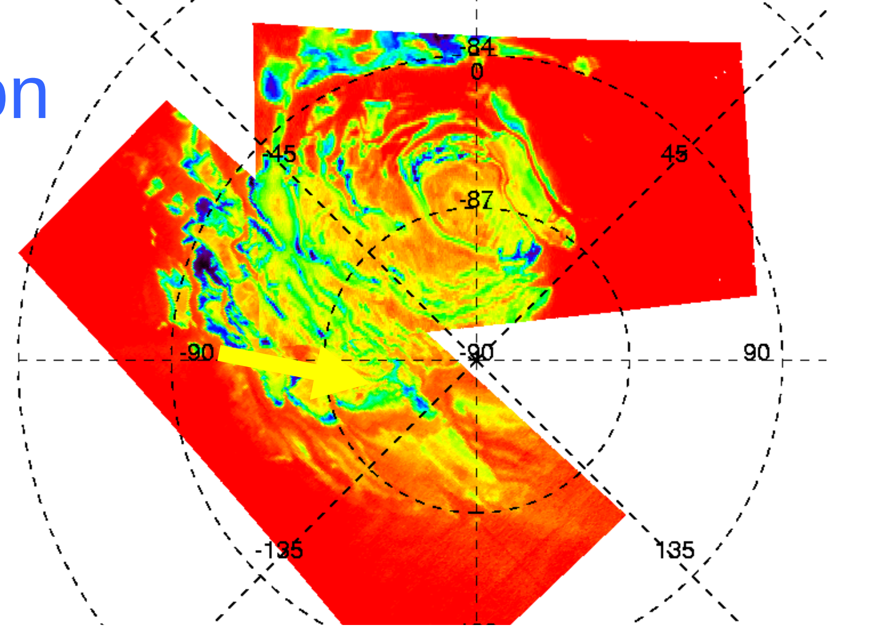
Montmessin, Forget, Haberle

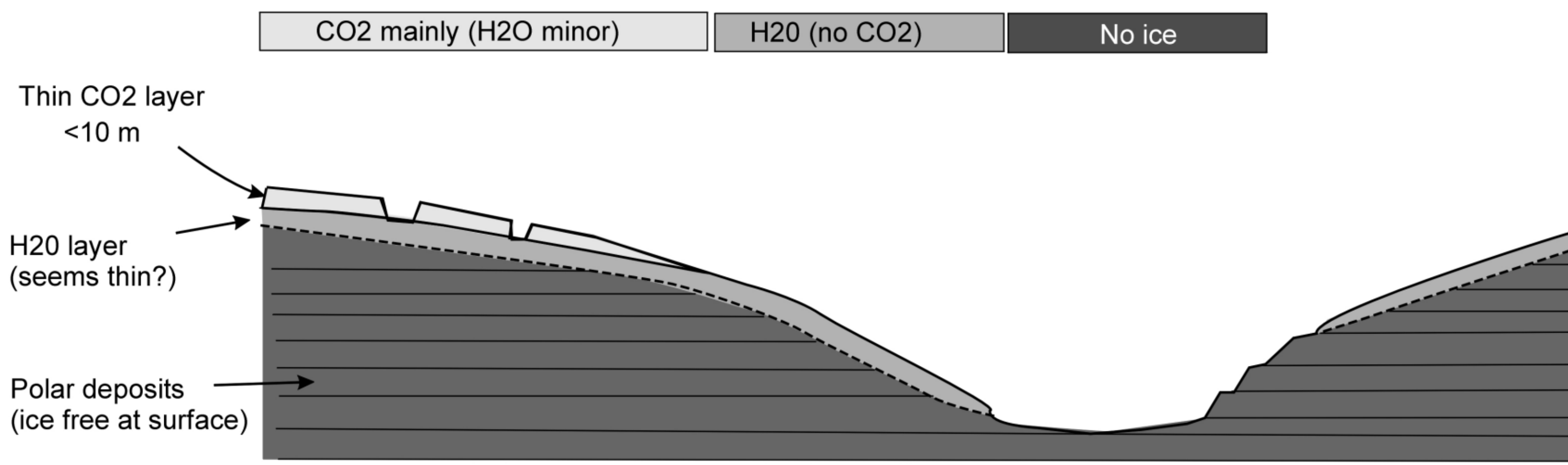
Climate simulation at high obliquity: interpretation of HRSC observations Martian glaciers

Forget, Levrard, Montmessin and Haberle

CO_2 and H_2O ice distribution on South Polar Cap

(Bibring et al. Nature 2004)





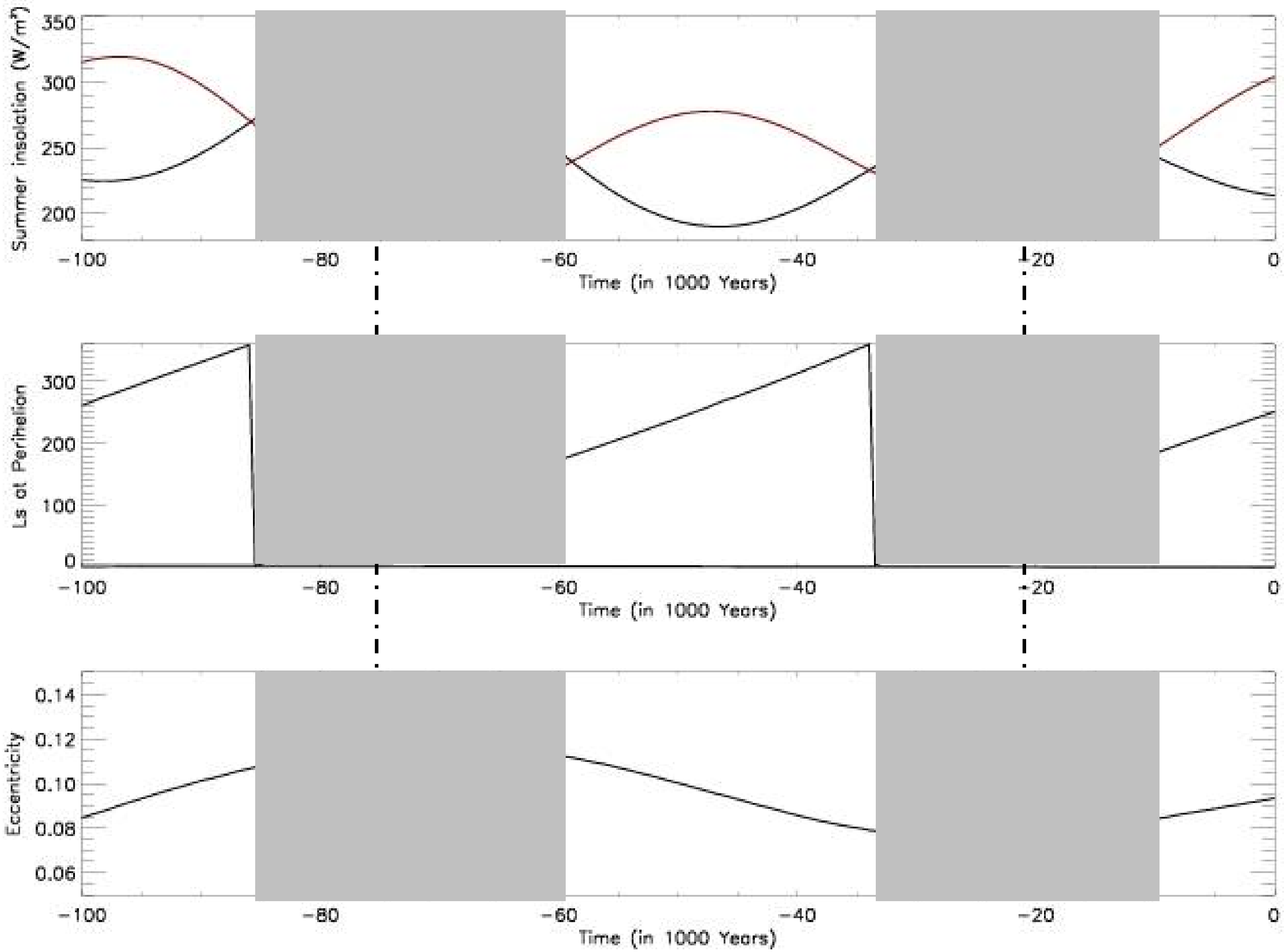
CO_2 ice

H_2O ice

- 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



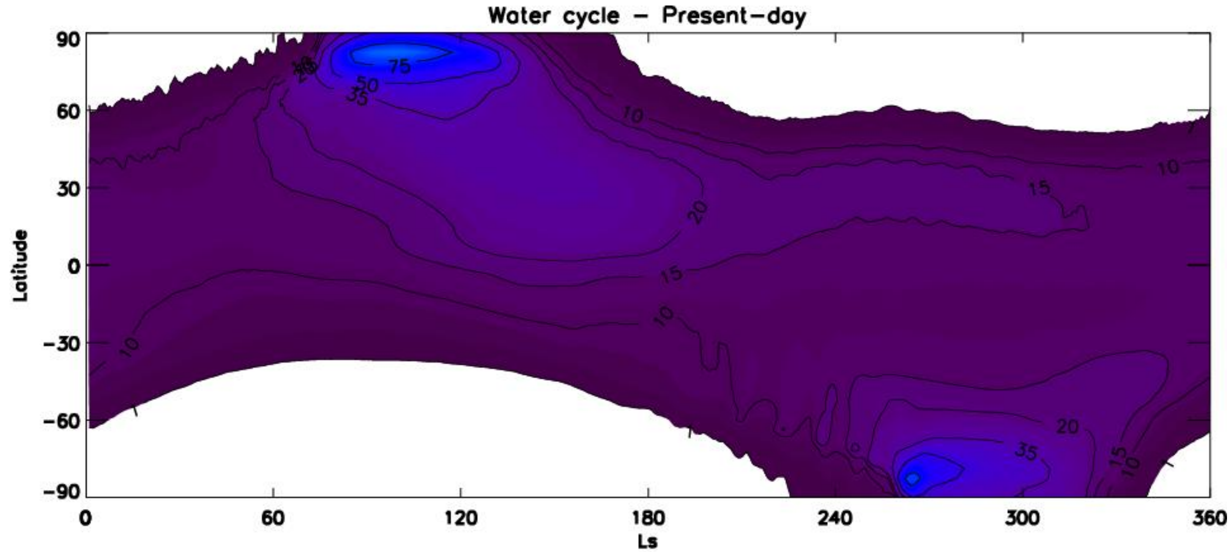
Data source: J. Laskar (IMC/Paris)

MGCM experiments: “reversing” Perihelion date…

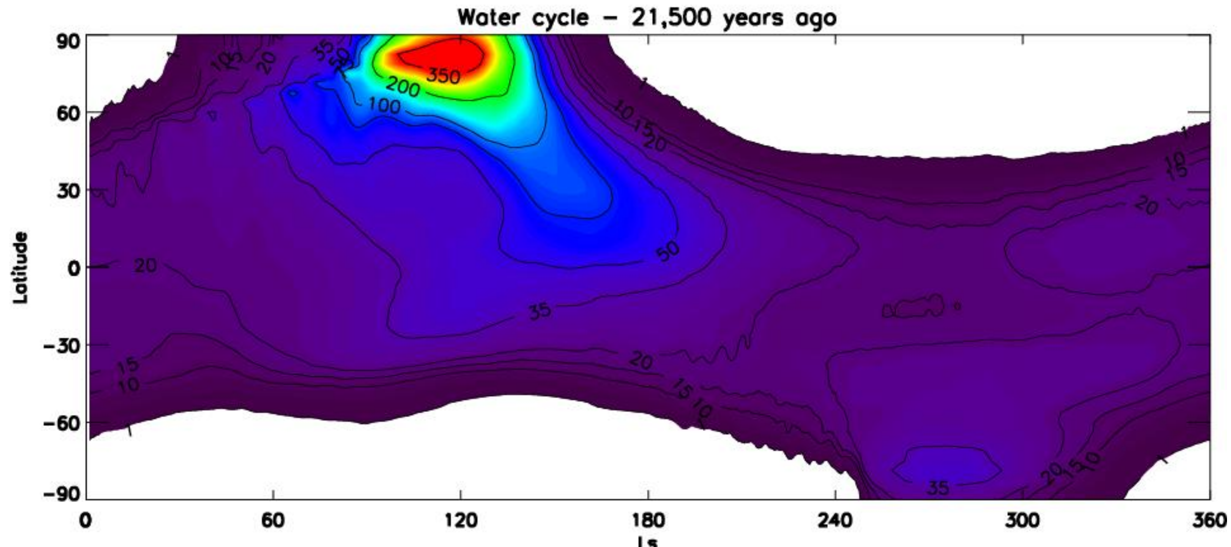
- **MGCM (LMD-Paris):**
  - Resolution 5,6° x 3.75°
  - Validated water cycle (Montmessin et al., 2004)
    - Cloud (predicted particle size)
    - **No CO_2 residual cap**
  - Perihelion phased with northern summer
  - Experiments with various dust scenarios

Mean water cycle

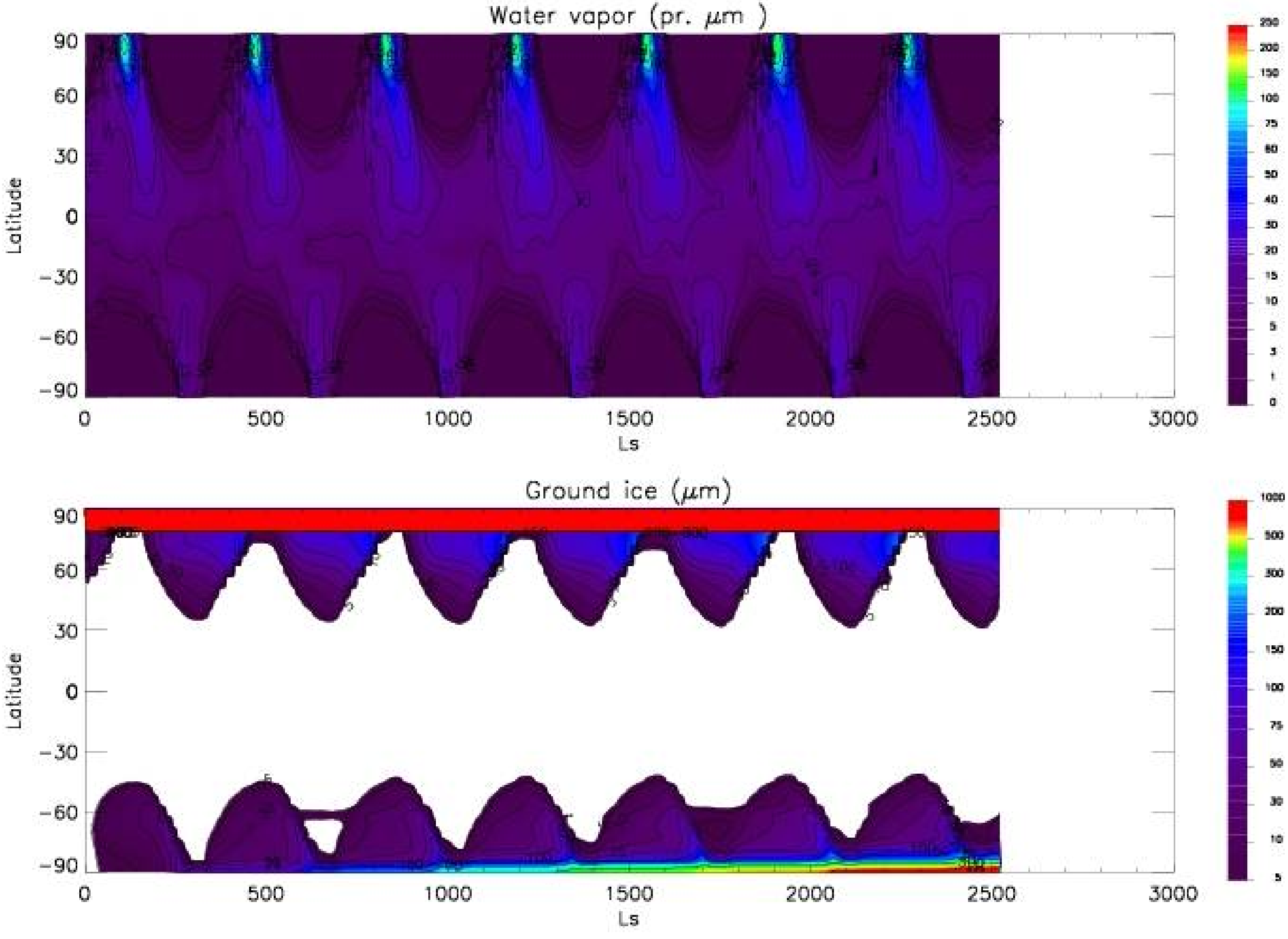
PRESENT



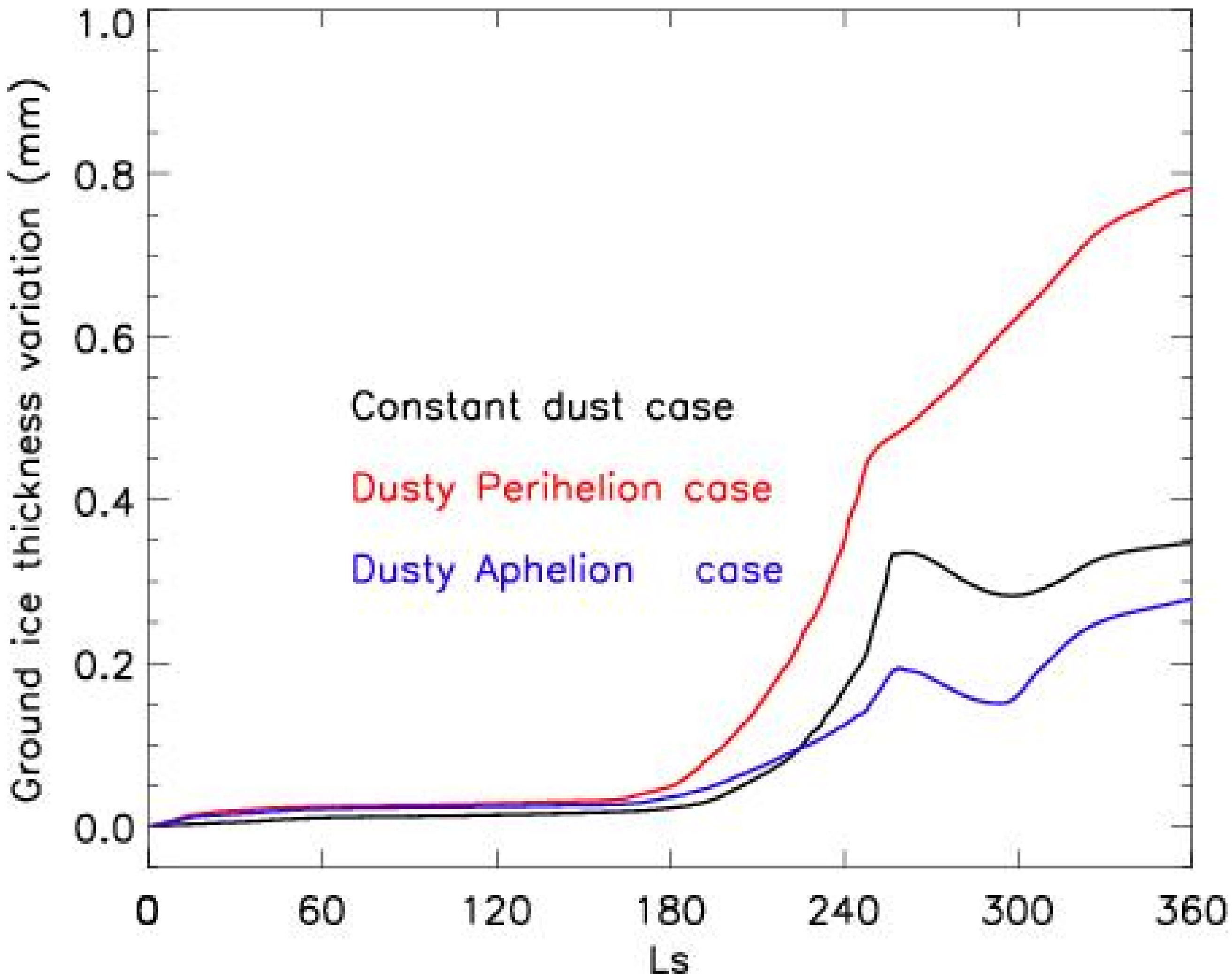
21,500 yr ago



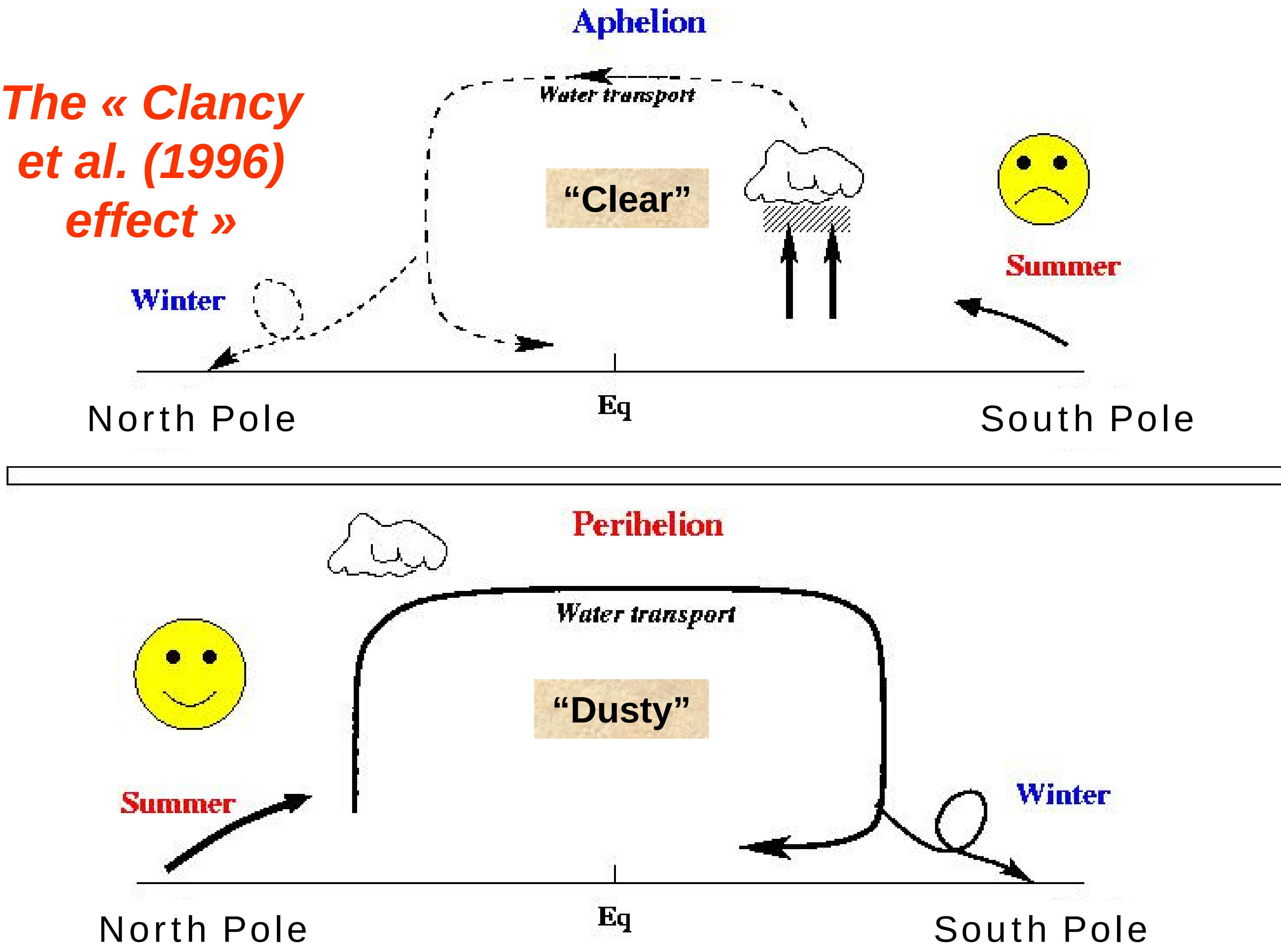
Water cycle -21K years ago

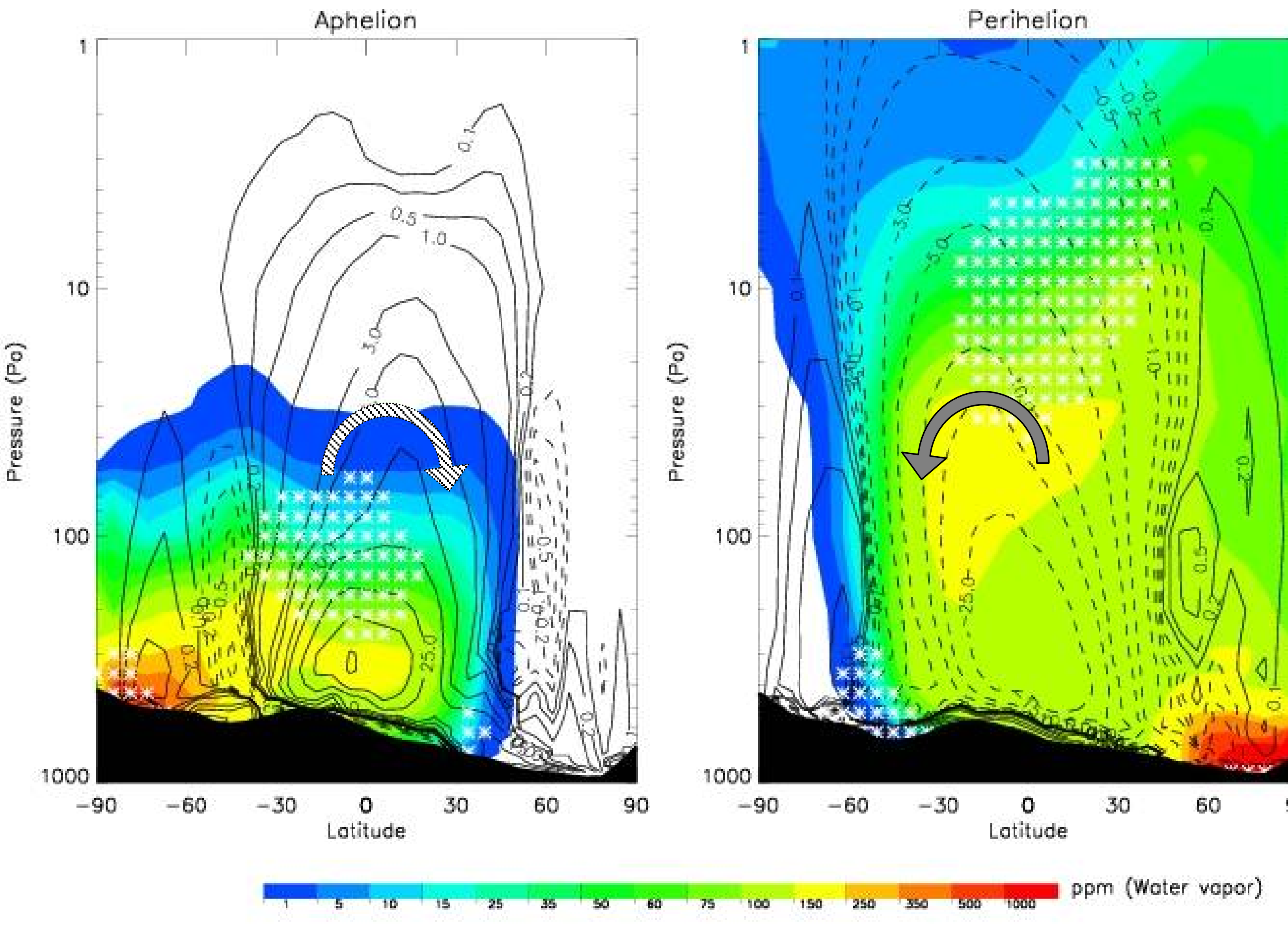


South pole accumulation rate

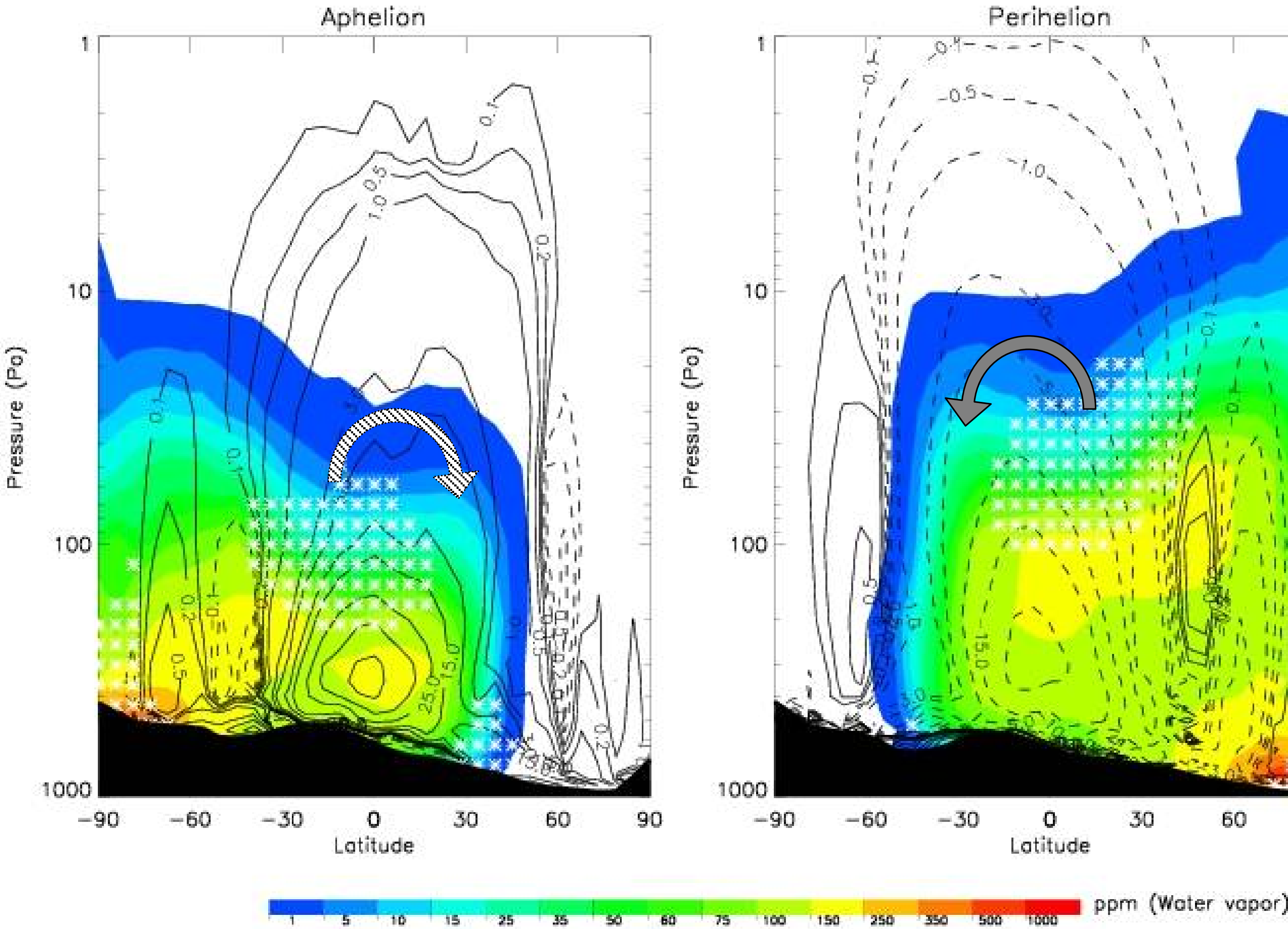


The « Clancy et al. (1996) effect »





Reversed Perihelion – « Dusty Perihelion »



Mars -21K years – constant dust opacity ➲ Favors South Pole

Summary (1)

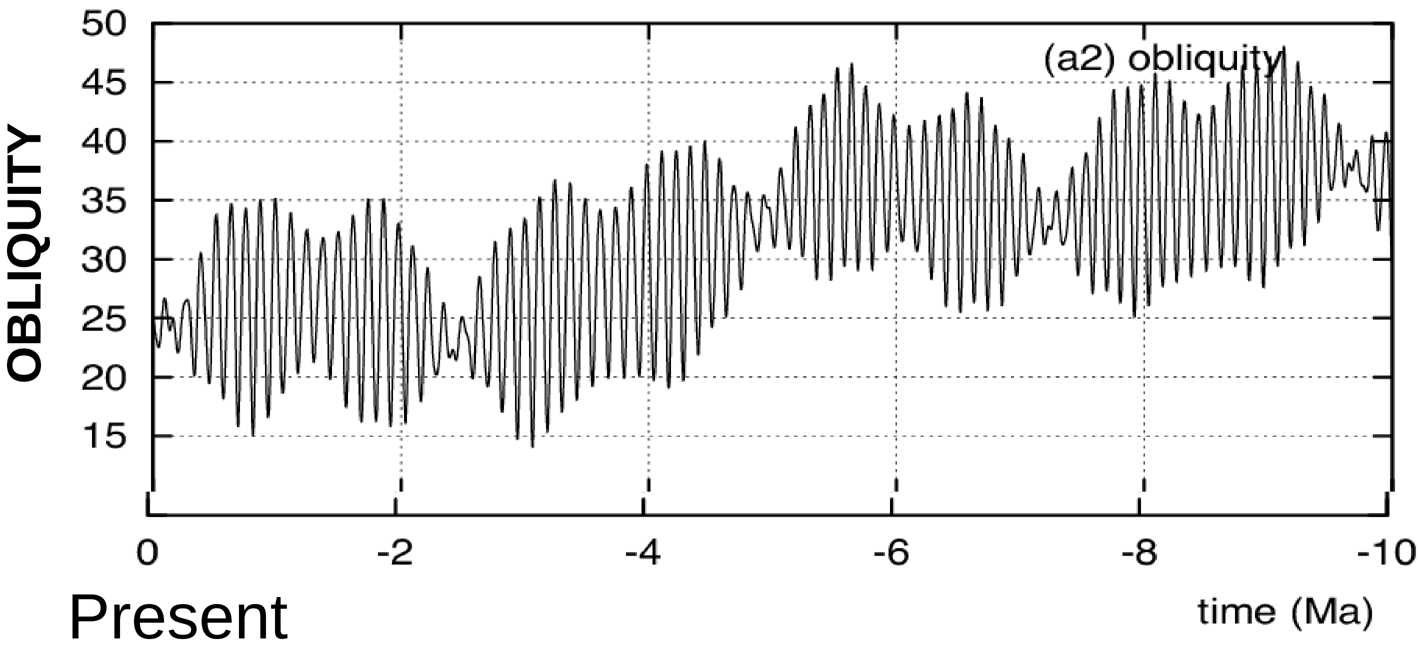
- **Recent past (10,000s of years) should have seen episods of significant water transfer from the North pole to the South,** **even in the absence of a CO_2 residual cap, and despite atmospheric circulation which favors volatile transport to the north pole (Richardson & Wilson, 2002)**

☞ ***Mechanism coupling:***

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

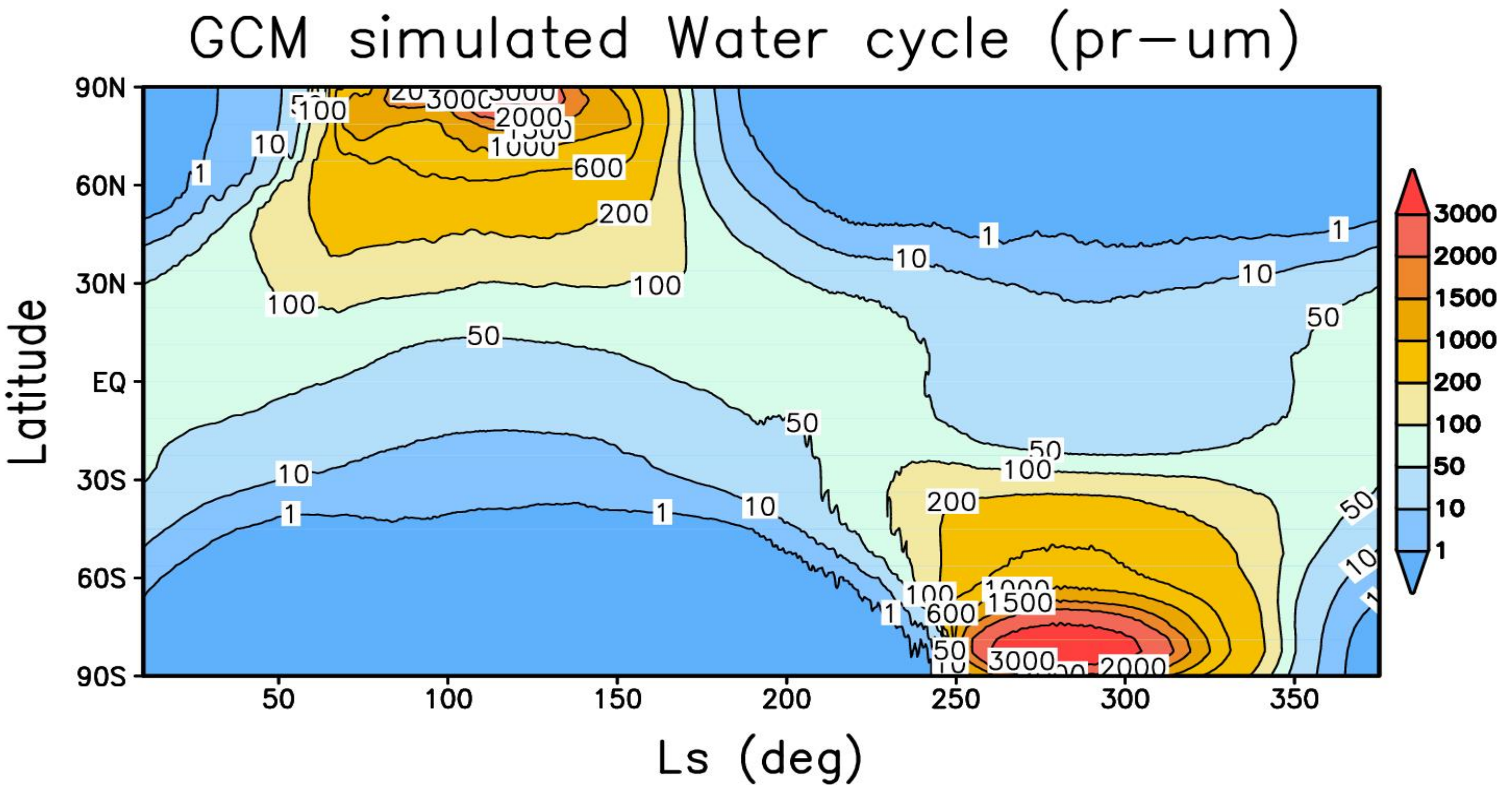
- **On the average however, a topographic bias (global circulation, dust lifting) should favor the accumulation of water ice in the North Polar Region.**

Climate simulation at high obliquity (poster tonight)



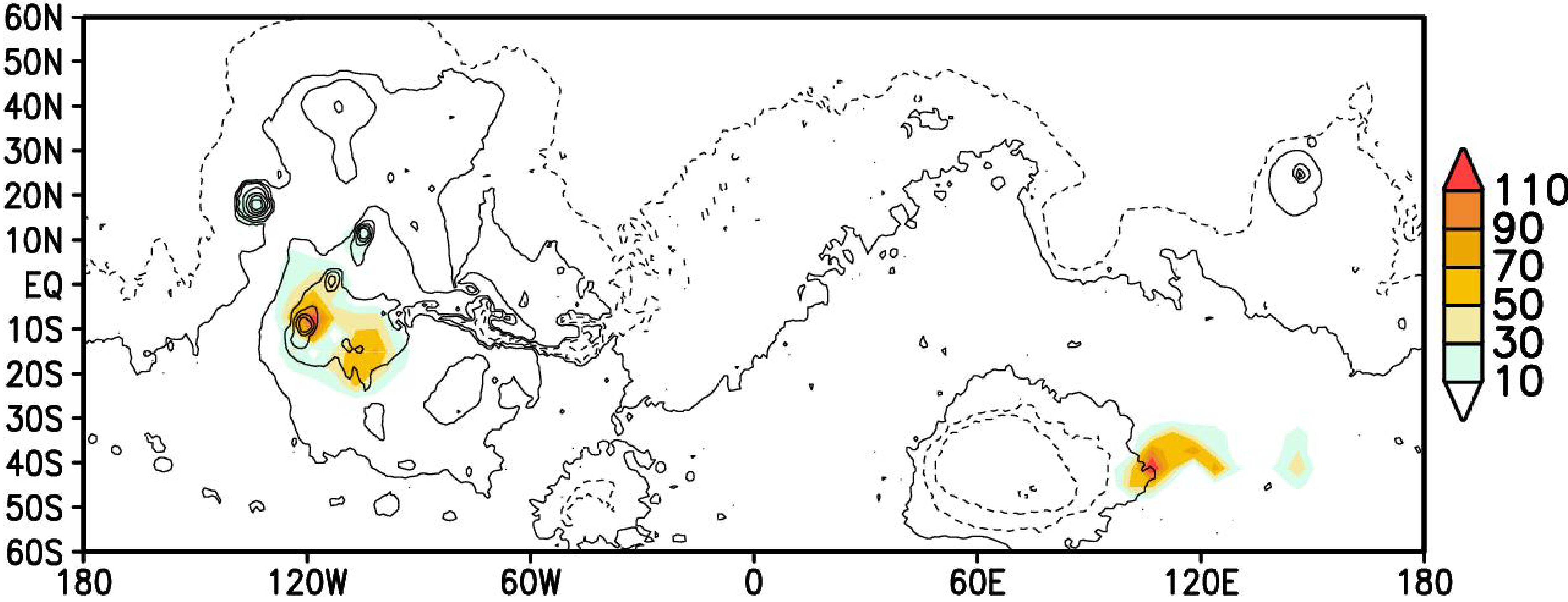
During Mars History, most likely obliquity: 41.8° (Laskar et al. 2004)

Our reference simulation :
Obliquity = 45° , Excentricity = 0, Dust Opacity =0.2
Only initial source of water : northern permanent cap



Yearly accumulation rate (mm/year)

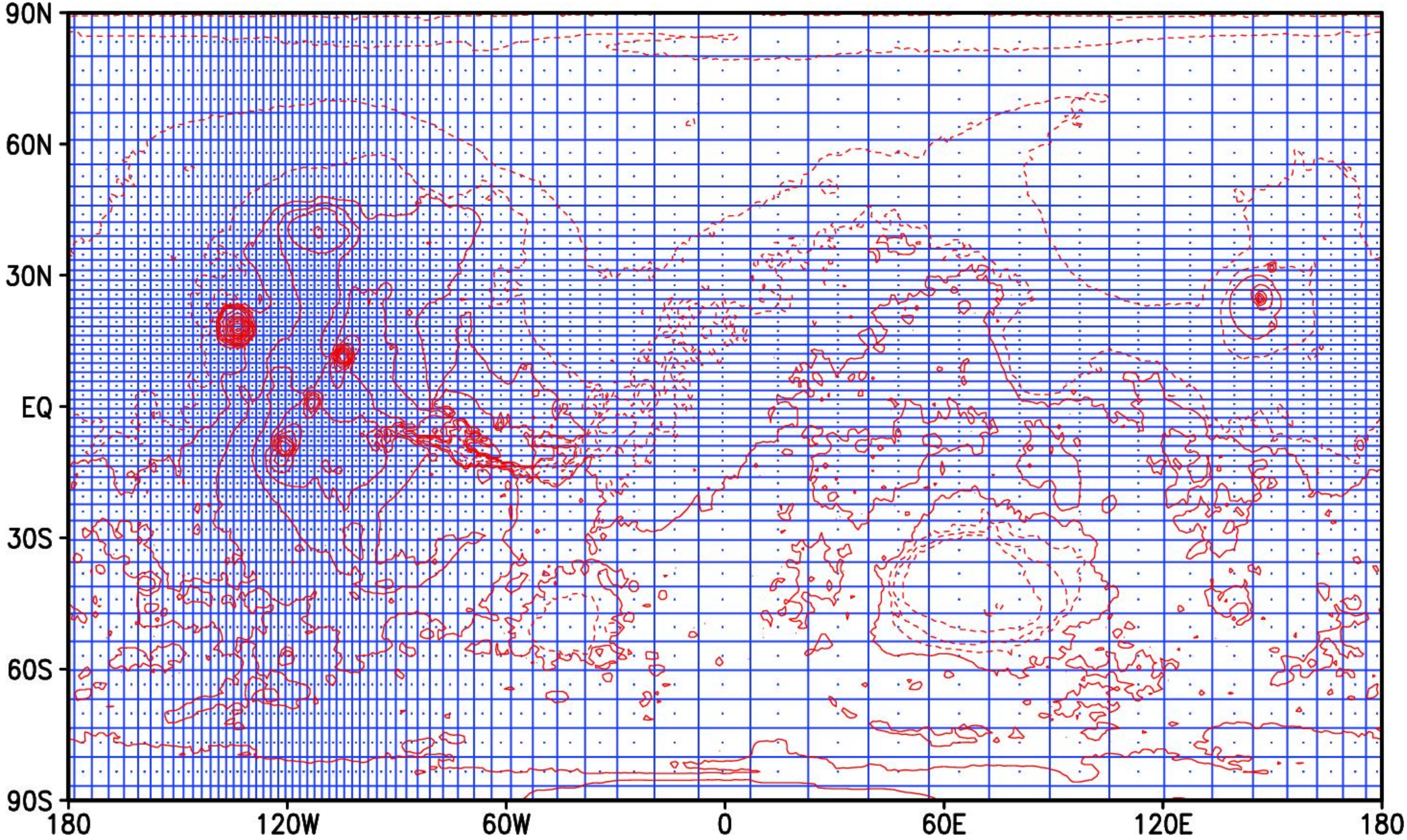
(1Oth year simulation)



⇨**Formation of glacier**

(Haberle et al. 2000, Mischna et al. 2003, Levrard et al. 2004)

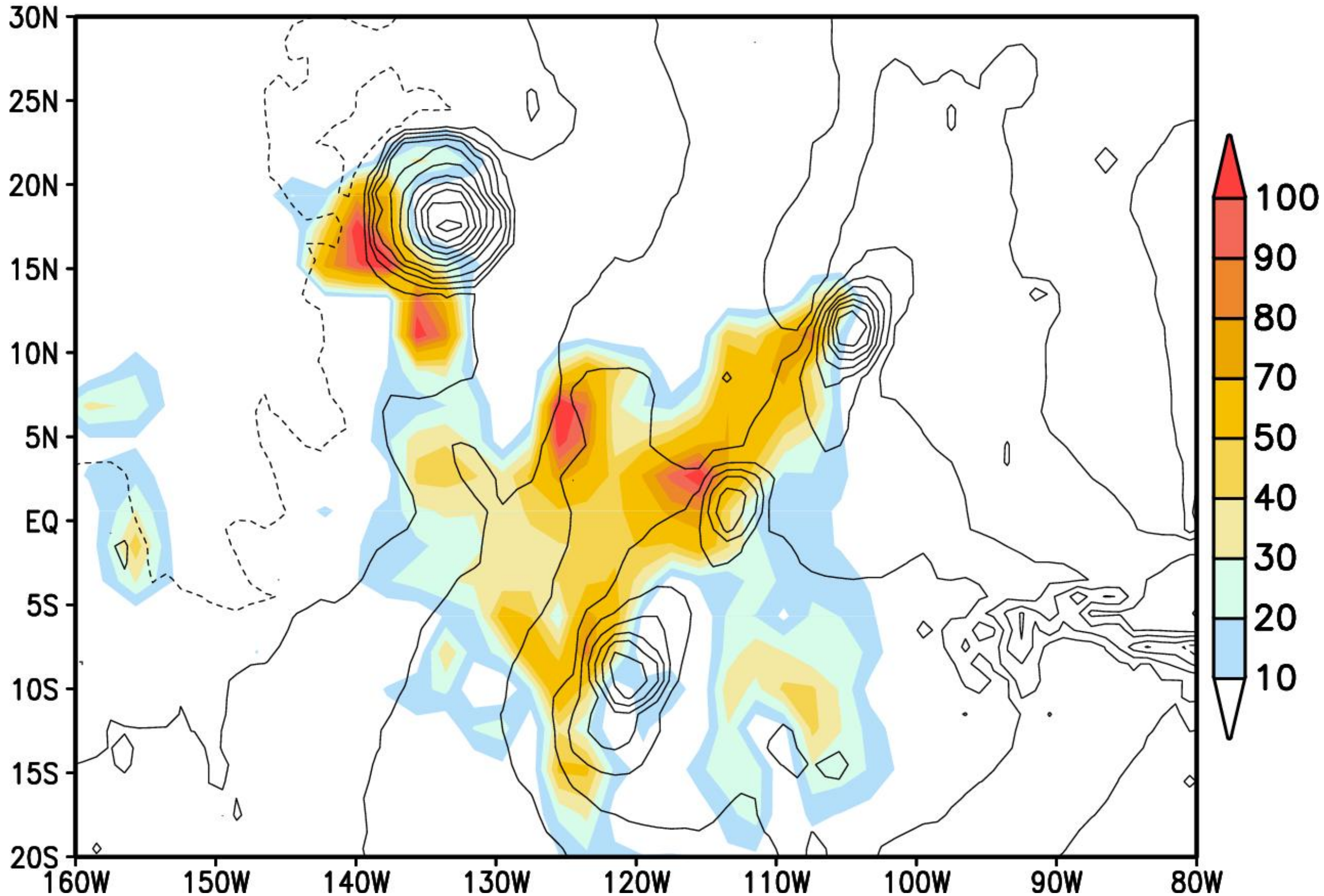
Zoom with The LMD Global Climate model



The formation of glacier : Ice accumulation rate (mm/yr)

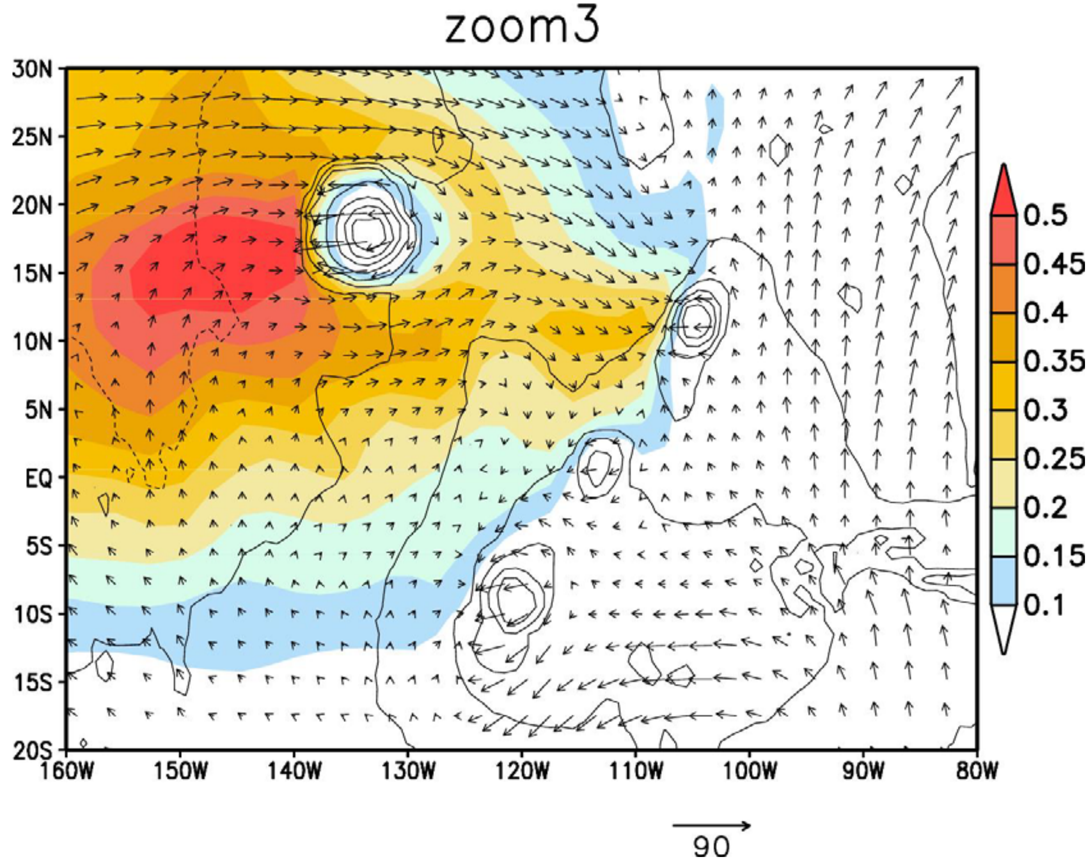
Our reference simulation : Obliquity = 45° , Excentricity = 0, Dust Opacity =0.2

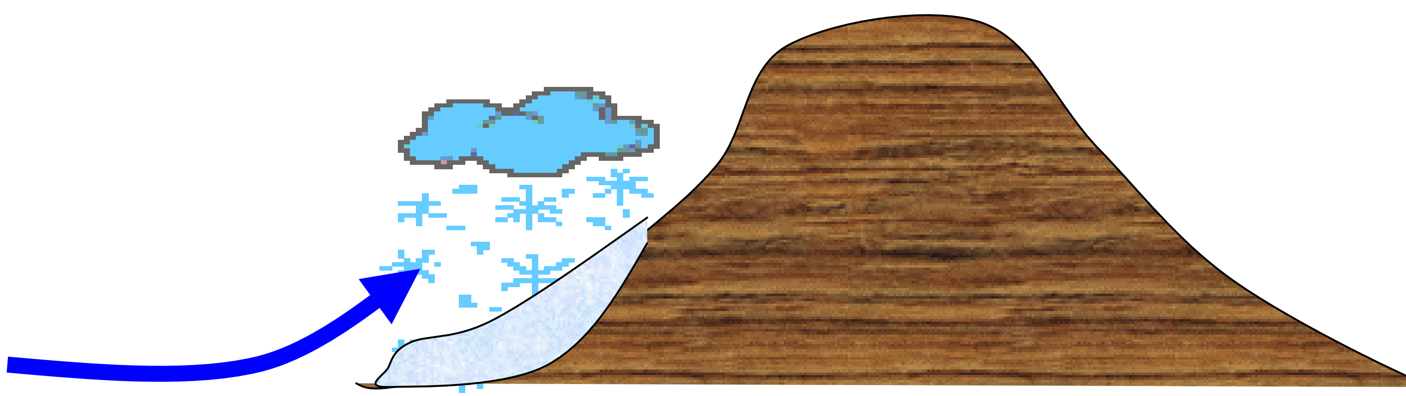
Only initial source of water : northern permanent cap



Why glaciers forms: precipitation on windward slope

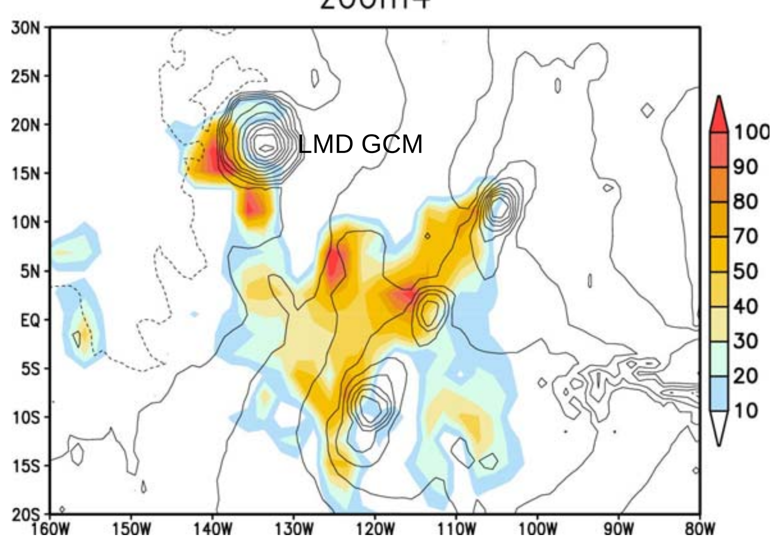
LEFT : *Cloud thickness (kg/m2) and mean winds at 1km above the surface during Northern summer*



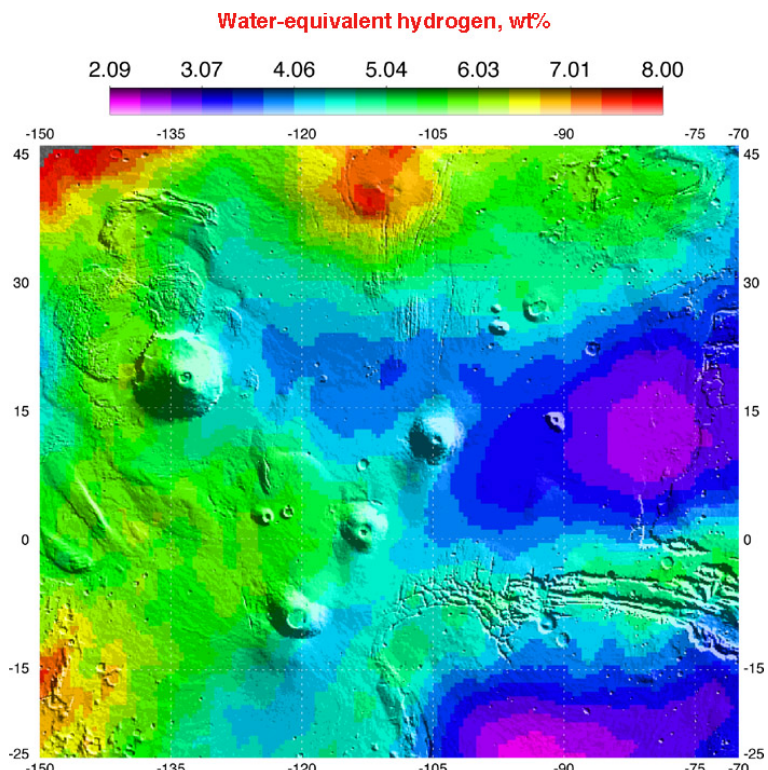


Comparison with observations ?

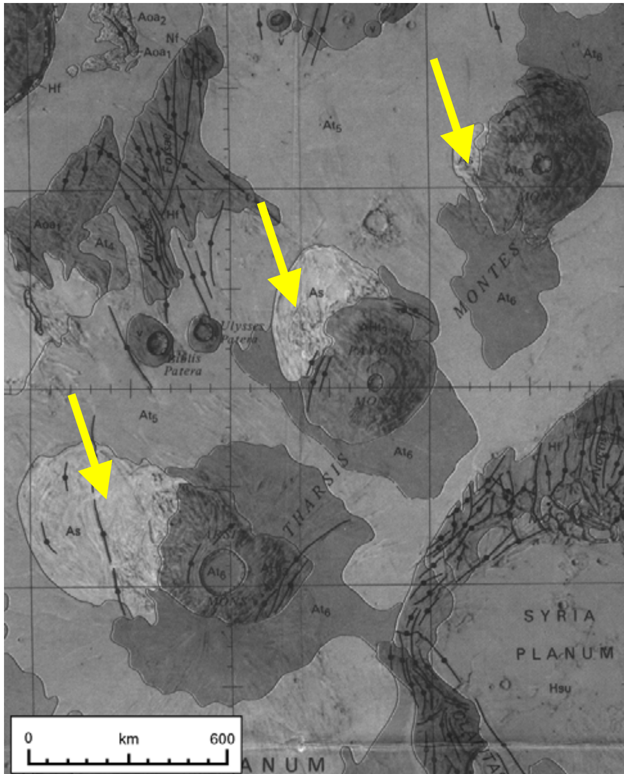
Check it out !



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



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



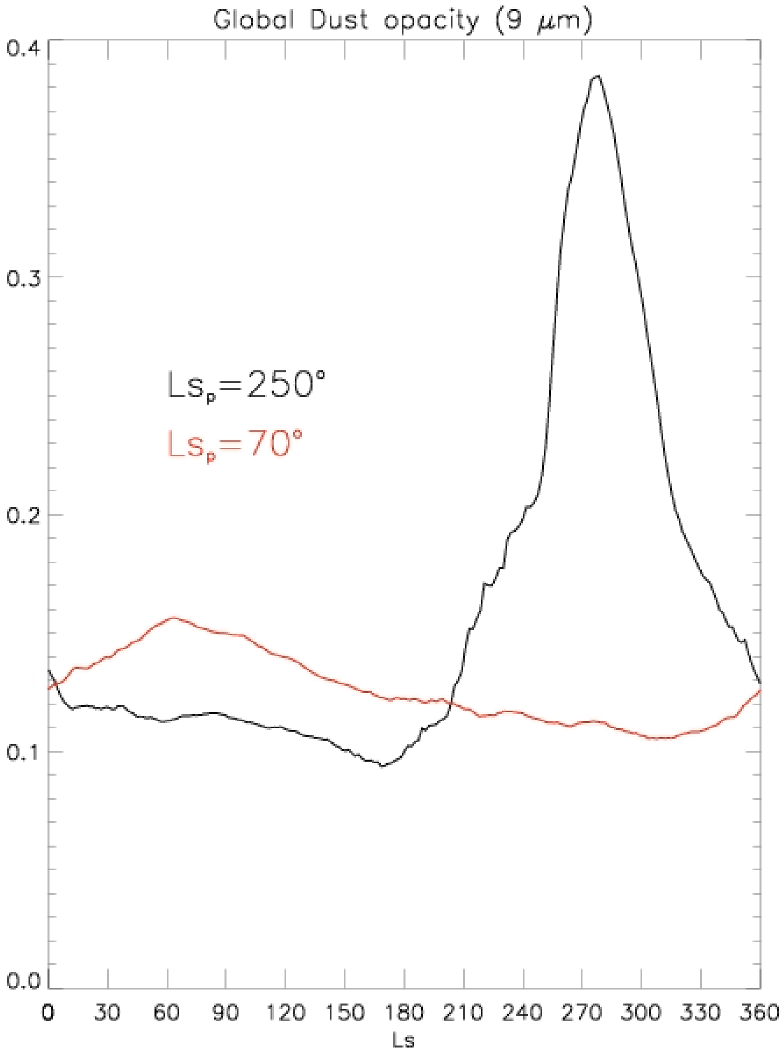
Summary (2)

- **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 cvcle sensitivity to Ls_p



- Ames GCM experiments:
  - Mars today: Ls_p = 250°
  - Rev. Peri: Ls_p = 70°
- Radiatively active dust cycle with lifting processes (no clouds/water cycle)
- "Dusty perihelion" = not achieved if Ls_p sync. with northern summer
  - ➢ *Topographic effect = robust forcing*