



— *Leovy Symposium*

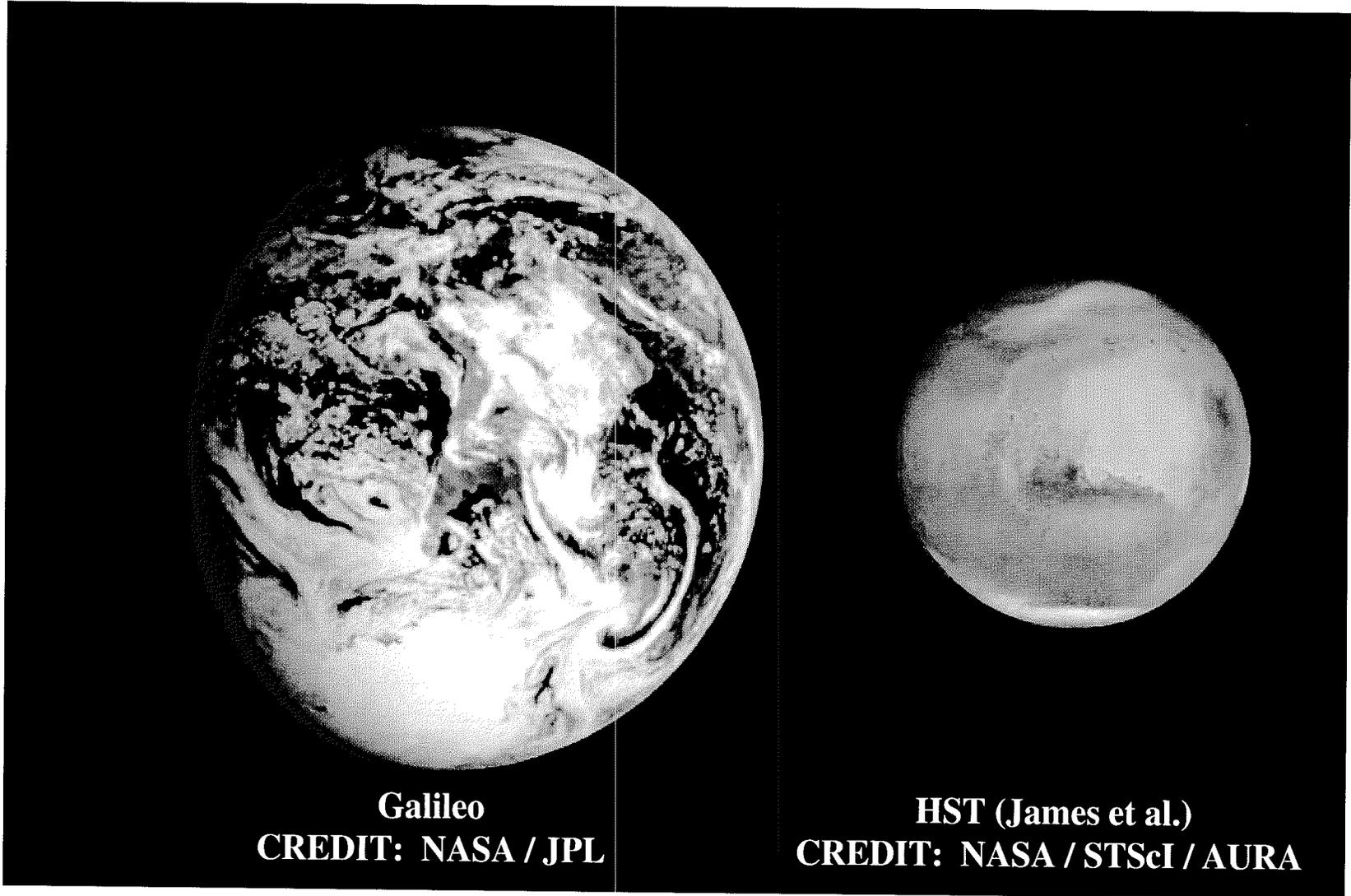
Mars: The Nature of its General Circulation

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Jet Propulsion Laboratory
California Institute of Technology

Earth & Mars



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Galileo
CREDIT: NASA / JPL

HST (James et al.)
CREDIT: NASA / STScI / AURA

Mars as an older Earth - P. Lowell



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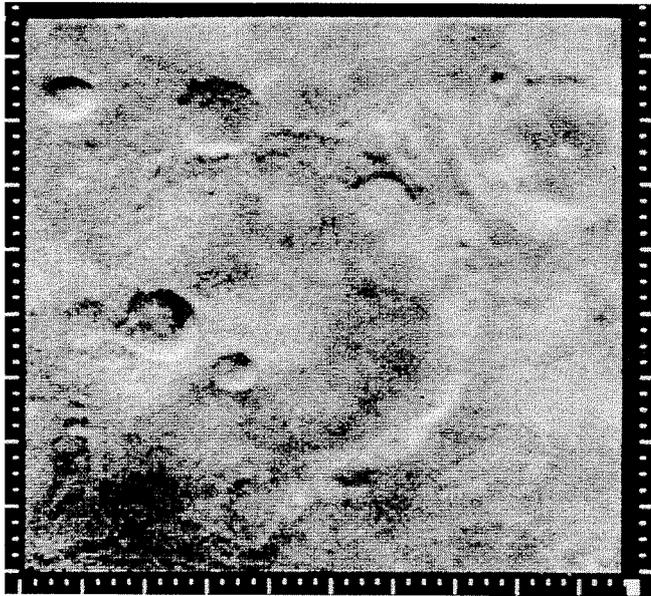
Both Earth and Mars had:

- **Seasons and Seasonal Change**
 - Polar Caps that come and go seasonally
 - Changes in color or albedo, also with season
- **Atmospheres**
 - Mars thinner than Earth, but enough (estimated to be ~100 hPa)
- **Active Water Cycles**
- **Similar length of day: Moderate diurnal variations**
- **Same evolutionary path--Mars was just older**
 - Losing atmospheric and surface water over time
- **Abodes of Life**

Early Views from Space



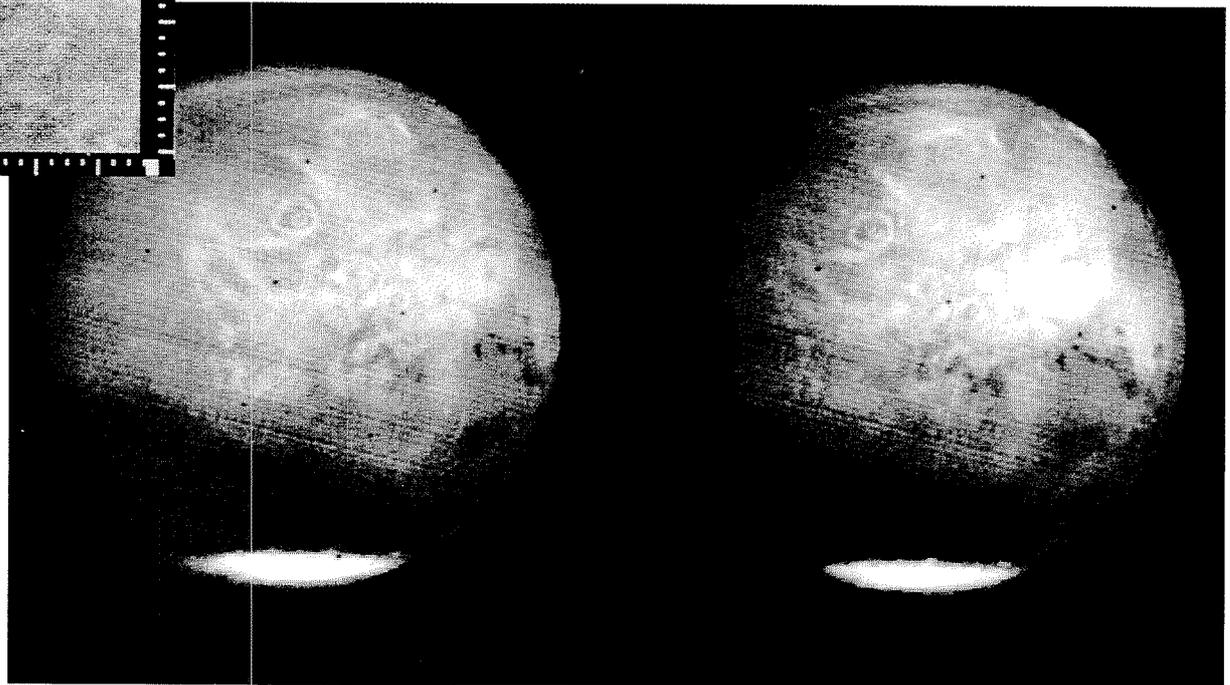
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1965: Mariner 4 photos reveal
a moonscape

1969: Mariner 6 & 7 photos
continue to puzzle

Mariners 4 & 7
CREDIT: NASA / JPL



Expected Mars Circulation Modes



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Based on Theory and Atmospheric Modeling, Mars should have:

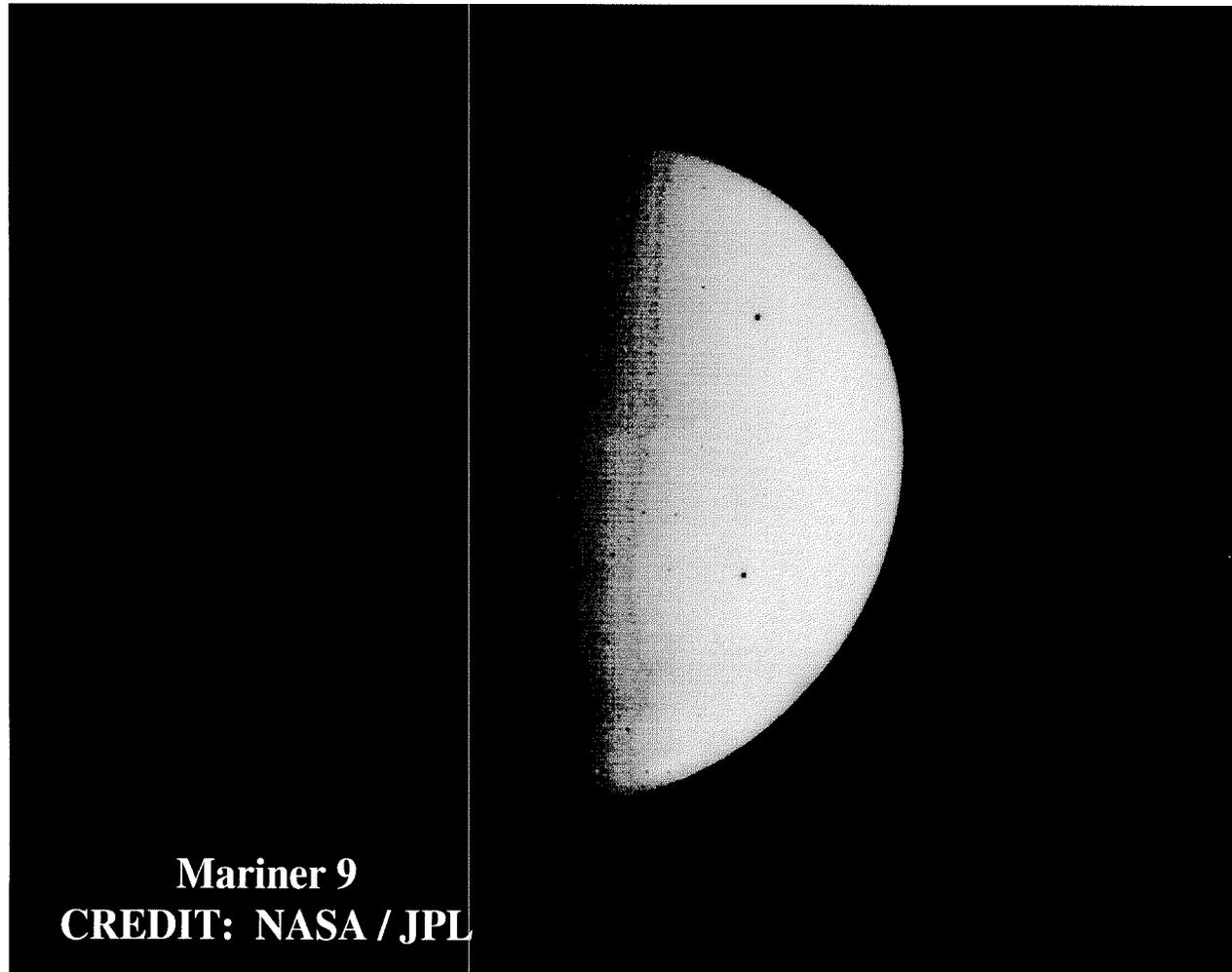
- **Stronger Seasonal Variation**
 - Even atmosphere mass will change globally by 20-30% over a (Mars) year
 - CO₂ cycle controlled by polar radiative balance, modulated by dynamics
- **Stronger (?) Hadley-type circulations**
 - Atmospheric mass changes should drive a stronger zonal circulation
 - Strongest at solstices; not symmetric because of Mars orbital eccentricity
 - Easterlies in summer hemisphere
- **Planetary Waves**
 - Winter Hemisphere should have Rossby regime
 - Comparable physical length scale
 - => baroclinic waves are planetary scale on Mars
- **Stronger Diurnal Cycles (atmospheric thermal tides)**
 - No heat reservoir for Mars: dry surface and thin atmosphere

Was there any Evidence? Did the atmosphere really matter?

Mariner 9 View in 1971



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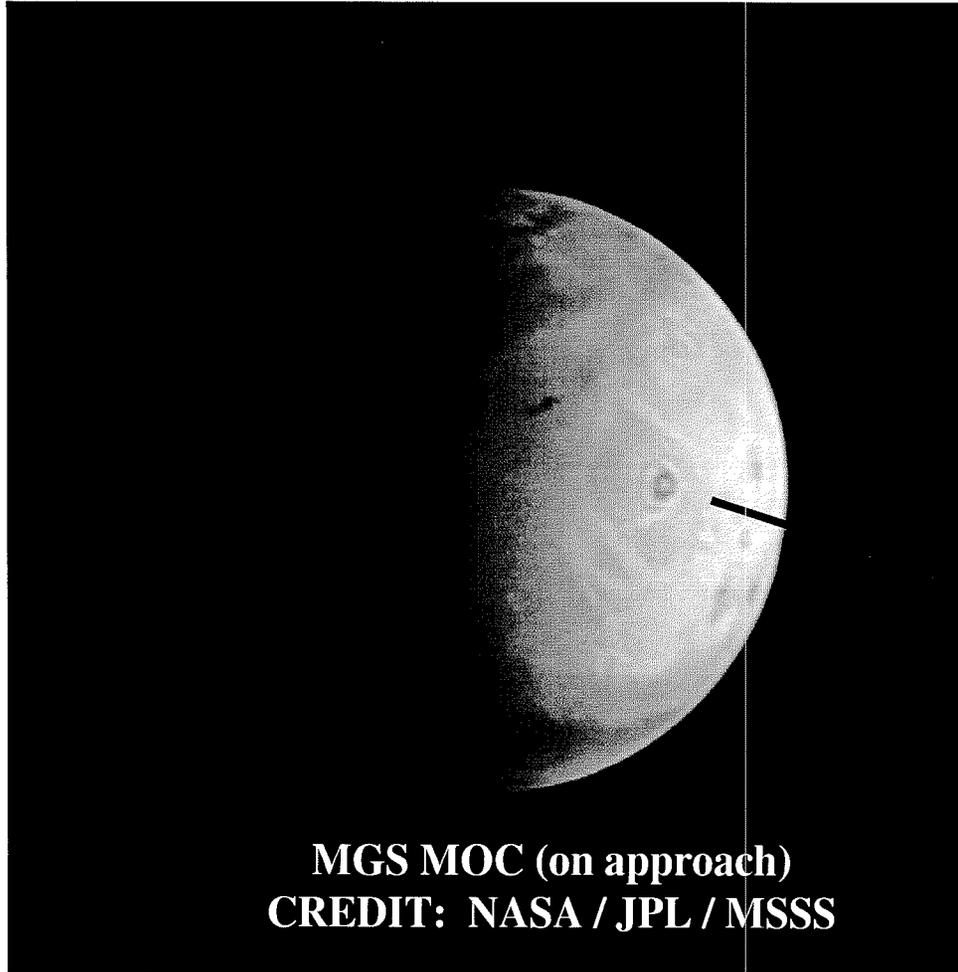


Mariner 9
CREDIT: NASA / JPL

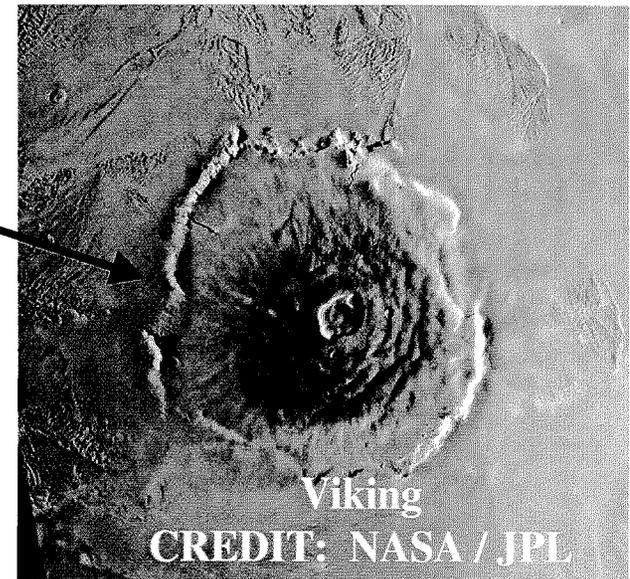
Now We Know!



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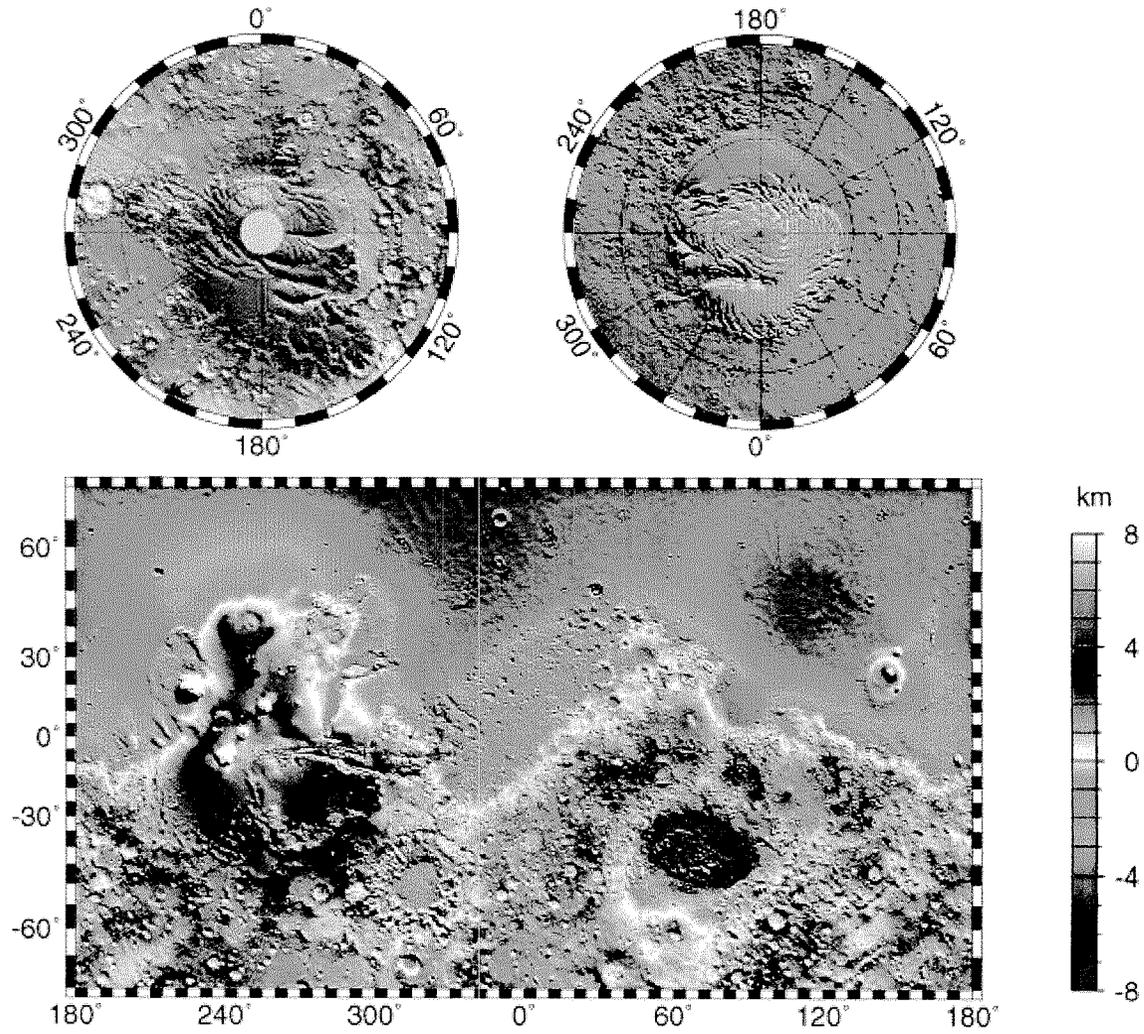
Olympus Mons



Mars Topography (MGS MOLA)



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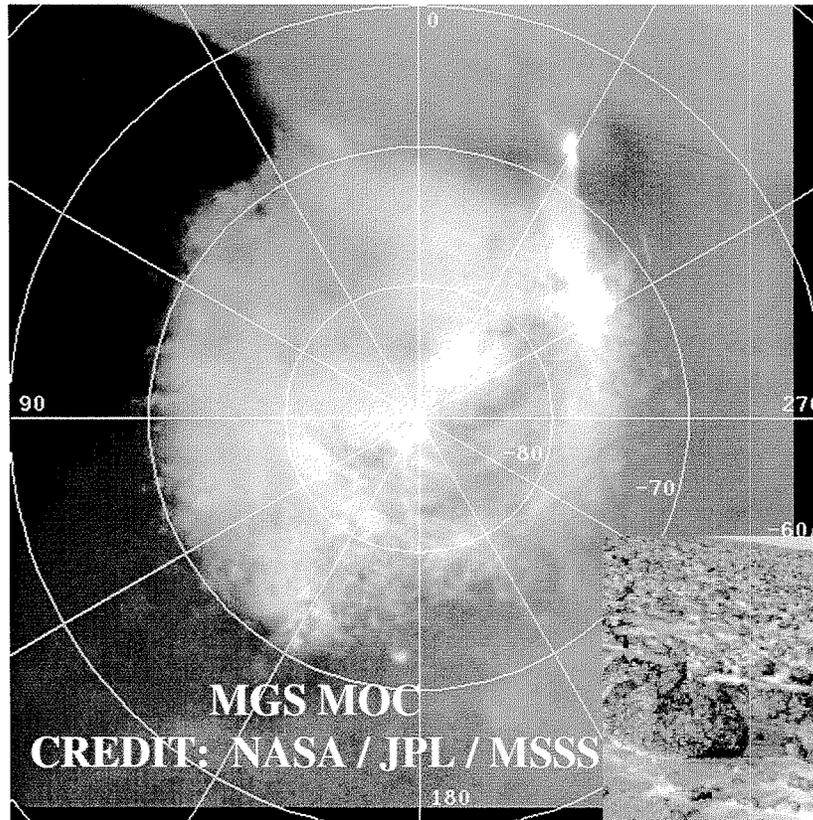


CREDIT: NASA / JPL / GSFC

CO₂ Cycle: Seasonal Frosts



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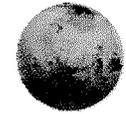


South Pole in
late summer

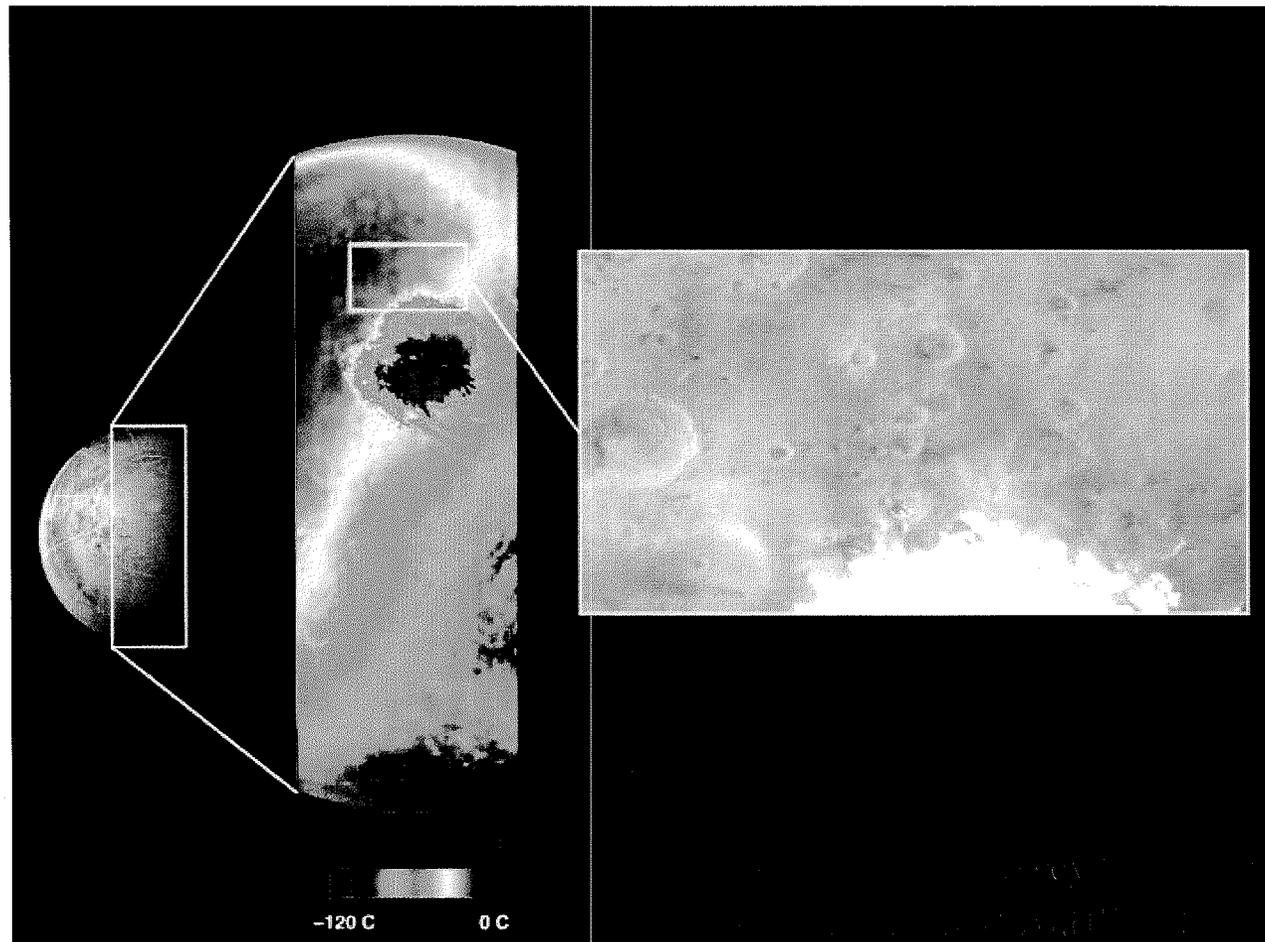
Northern mid-latitudes
(48N) in late winter



South Pole in Late Summer



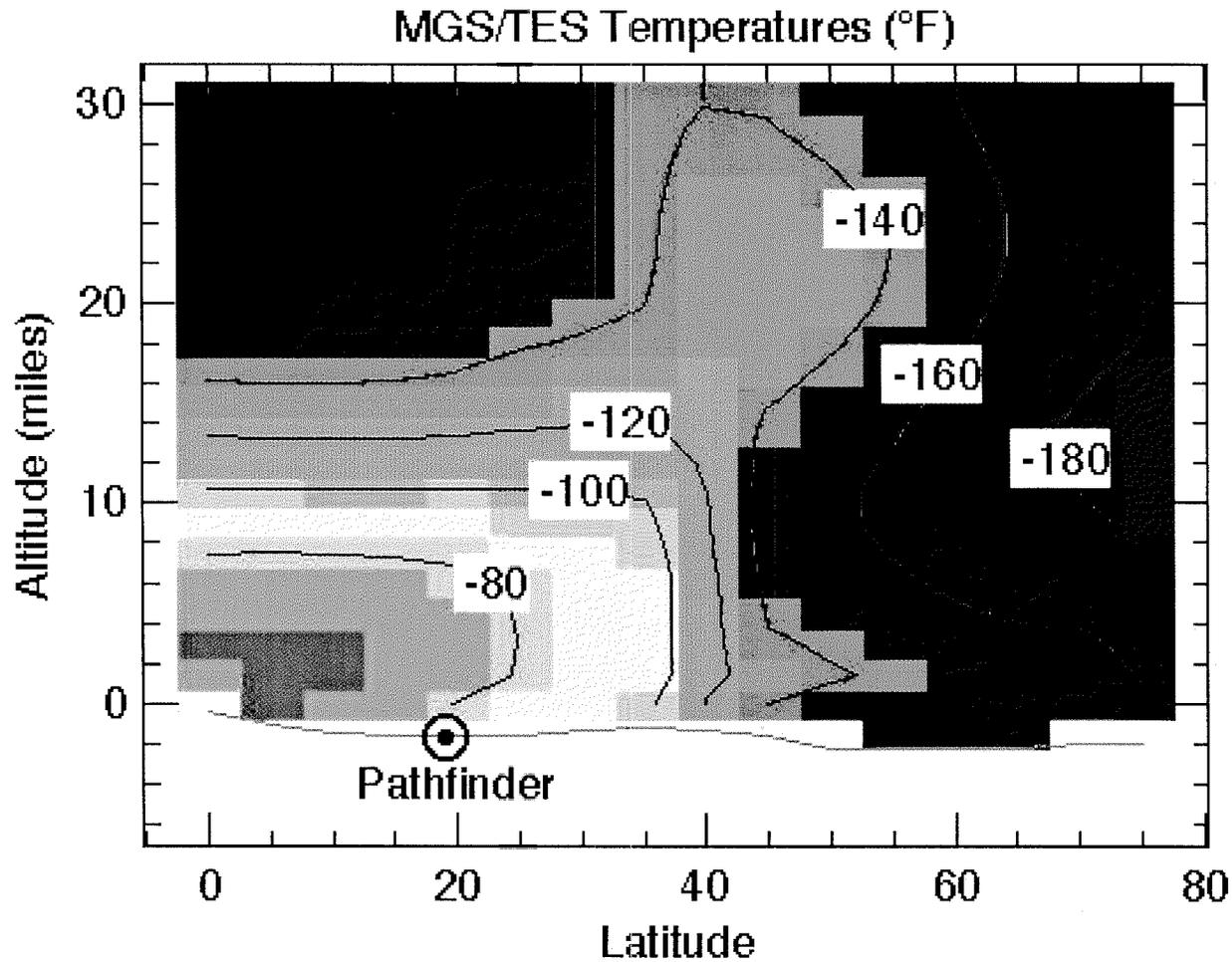
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Zonal Temperatures in N. Winter



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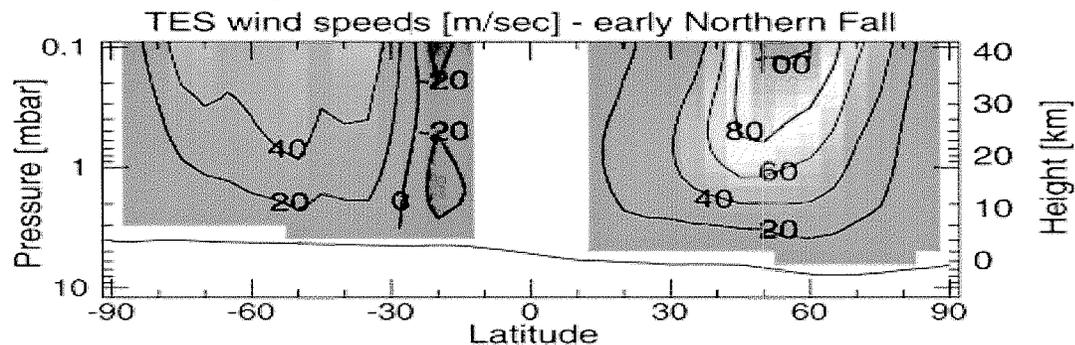


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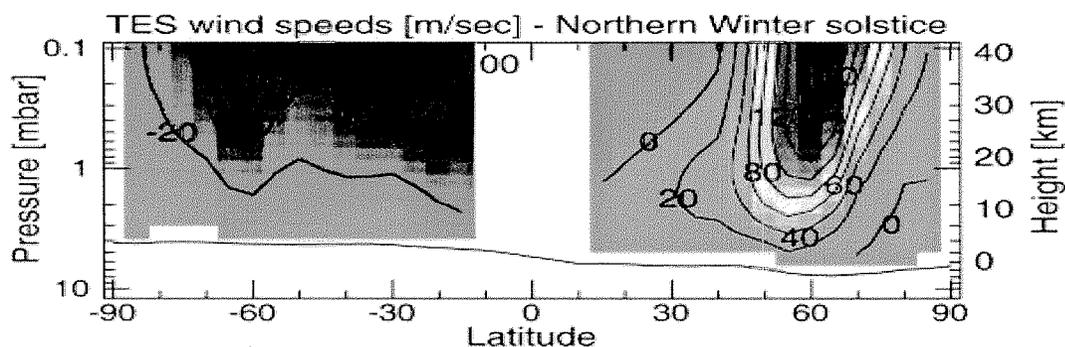
Geostrophic Winds



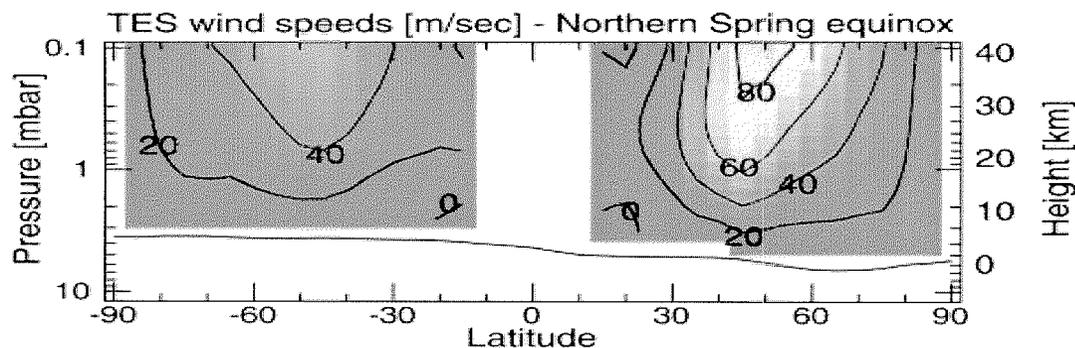
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*Early Southern Spring
Early Northern Fall*



*N. Winter Solstice S.
Summer Solstice
(near perihelion)*



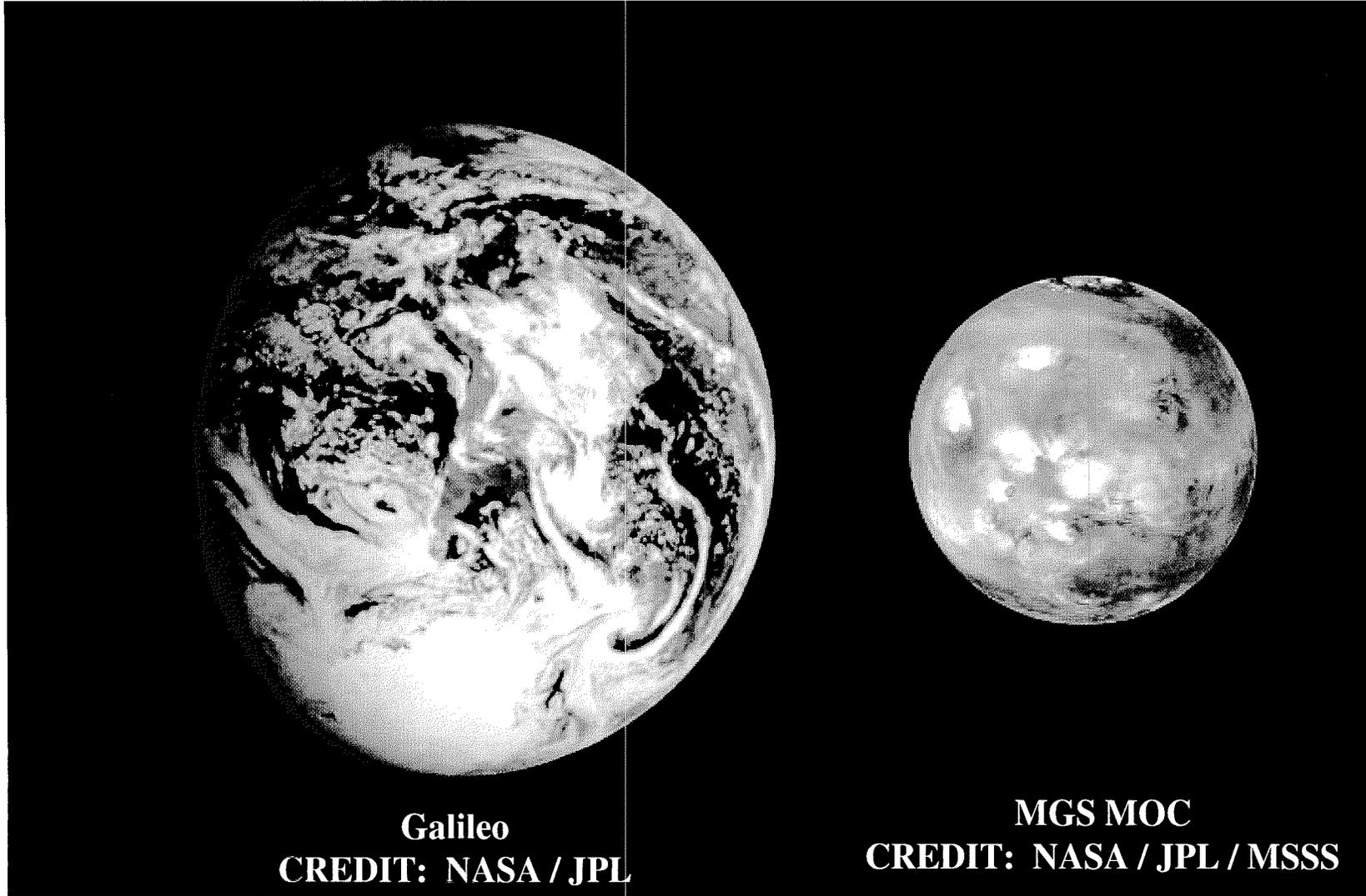
Vernal Equinox

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Earth & Mars



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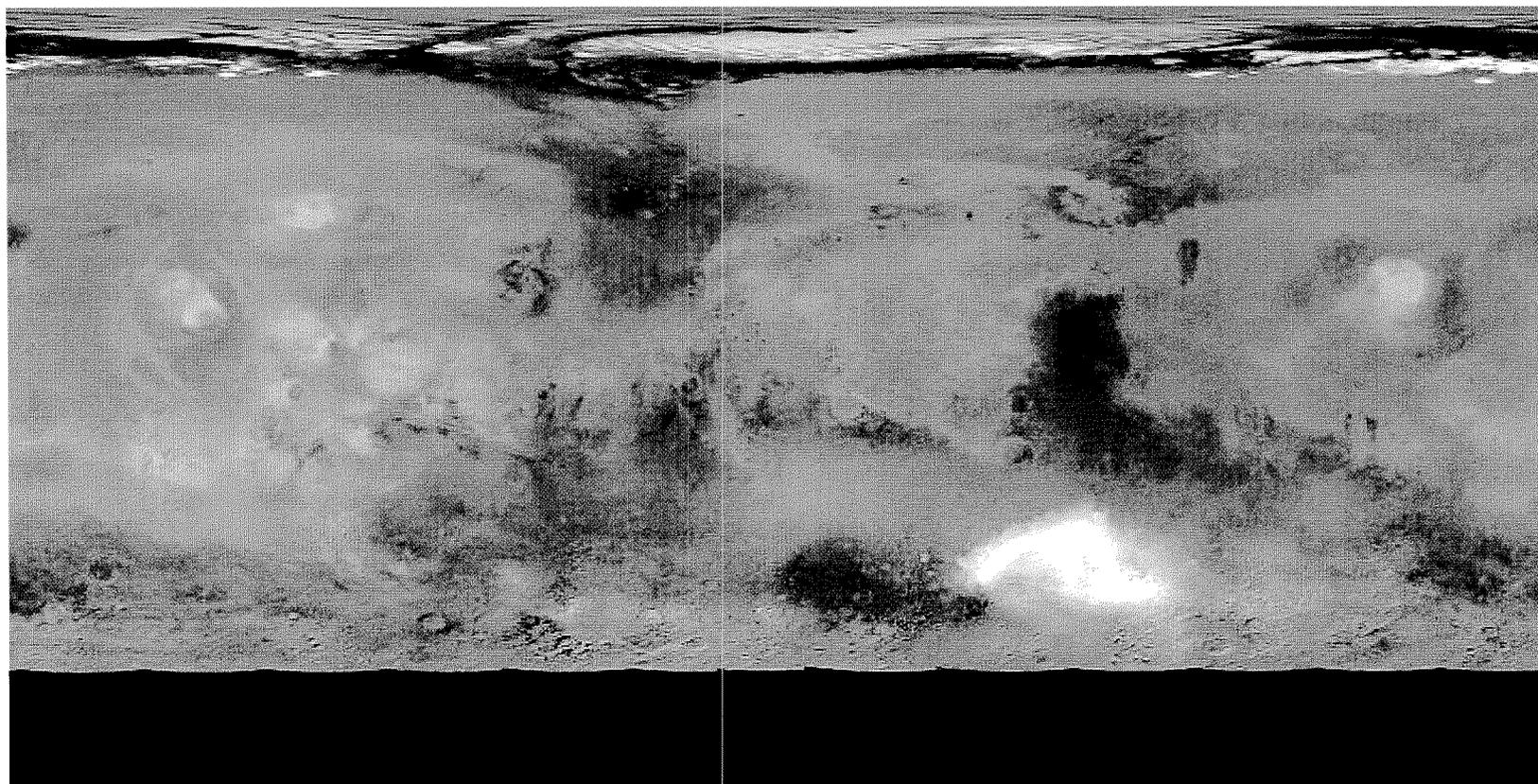
Galileo
CREDIT: NASA / JPL

MGS MOC
CREDIT: NASA / JPL / MSSS

Equatorial Cloud Belt (Mars ITCZ?)



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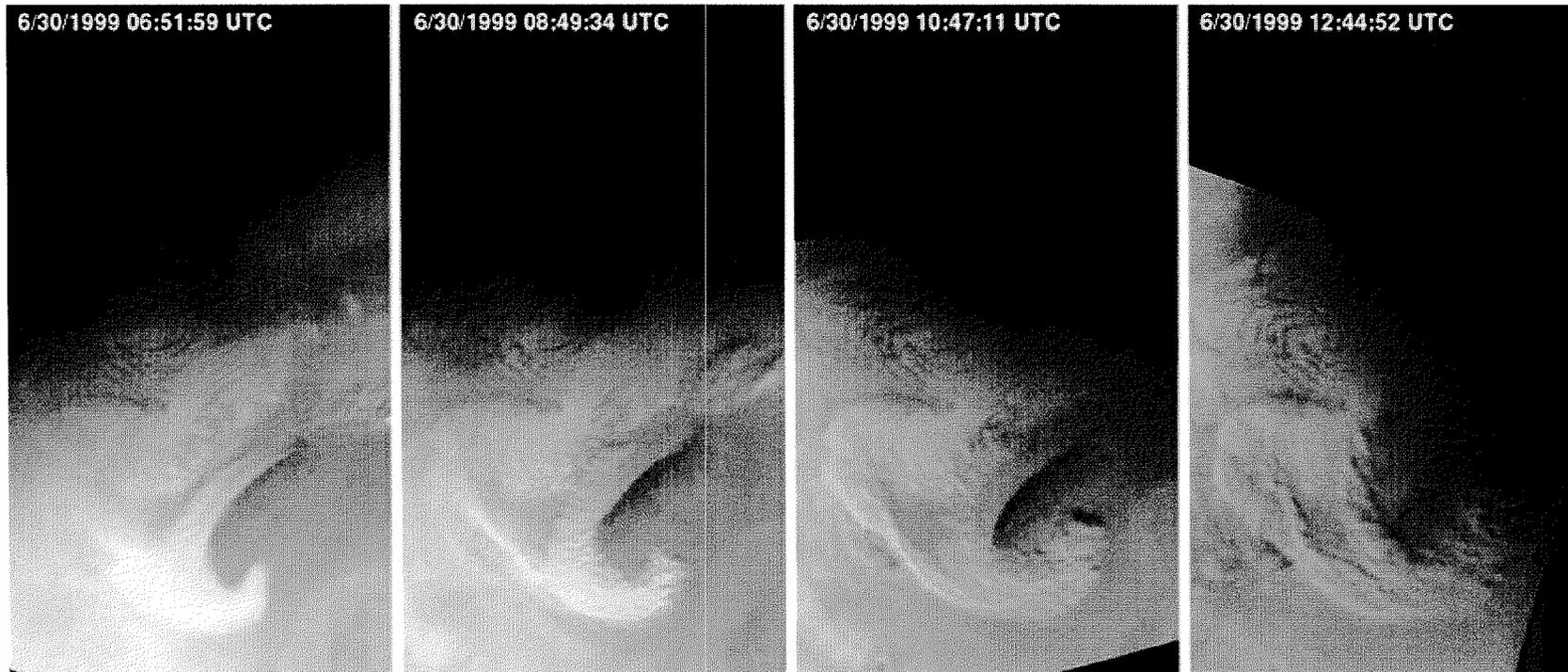
MGS MOC

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North Polar Dust Storm



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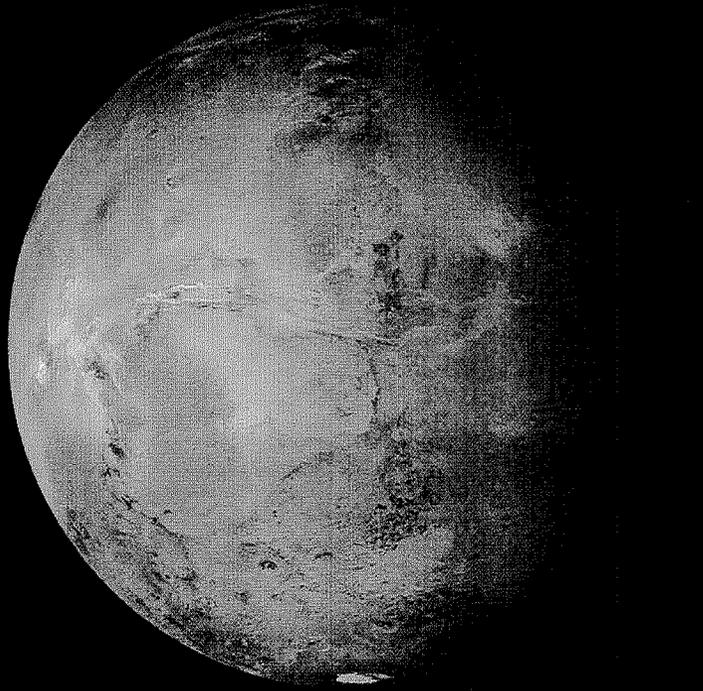
Viewed on Consecutive MGS Orbits (~ 2 hrs apart)

MGS MOC

CREDIT: NASA / JPL / MSSS

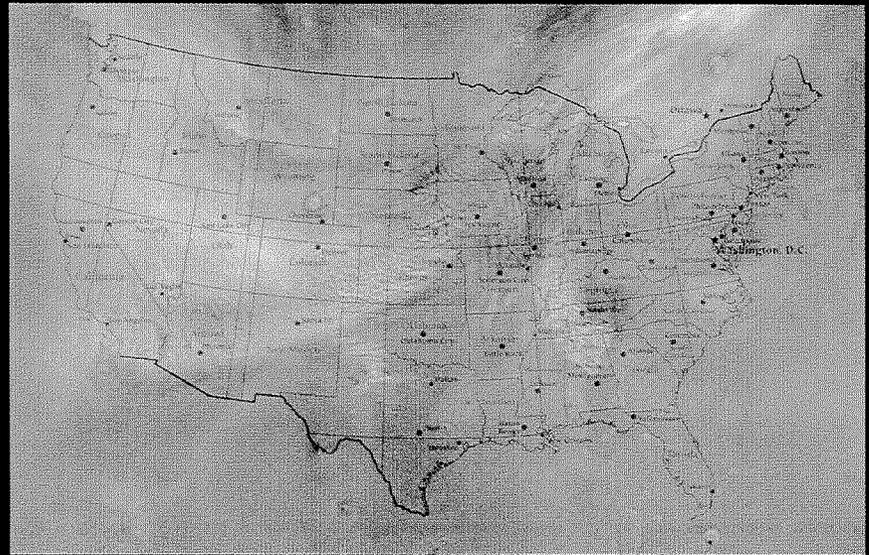
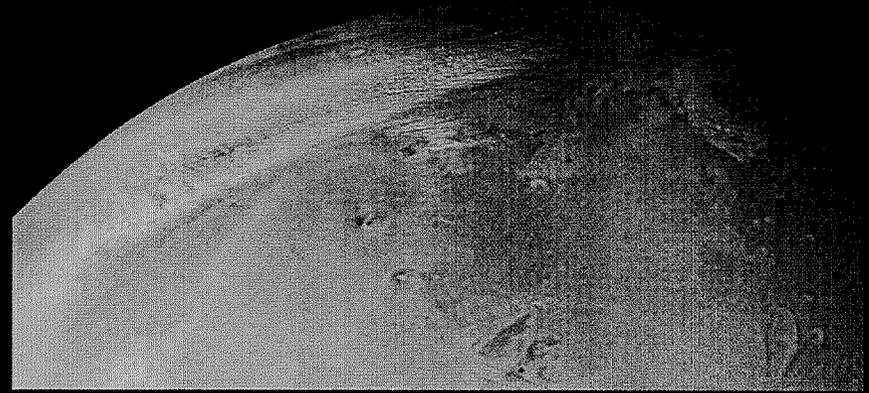
Mars Orbiter Camera Mars Weather Update

for the week of February 5 - 12, 2002



Two large, sub-regional dust storms, one in Acidalia/Chryse/Xanthe (left, global image, upper right) and the other in Utopia/Elysium (right top, oblique and bottom, Albers equal area projection), dominated the past week's weather. The Xanthe storm was first observed on February 9th over the Viking 1 landing site, having moved in less than 24 hrs from Acidalia south through Chryse. On the 10th, the leading edge of the storm had crossed the equator, traveling at an average speed of ~20 m/s, and leaving a large dust haze/cloud in its wake. By the 11th, the storm had entered eastern Valles Marineris. The Utopia/Elysium storm occurred at essentially the same time this year as a large storm in the same region last year, continuing its closely repetitious behavior. It stretches more than 3000 km, equivalent to the distance from the Great Lakes to southern California.

Small, local storms were seen throughout the northern mid-latitudes (in Arcadia, Amazonis and Tempe). Aside from cross-equatorial dust activity associated with the Acidalia/Chryse/Xanthe storm, no additional activity has been seen in the southern hemisphere. The south polar seasonal cap continues to wane towards its minimum extent. The North Polar Hood is beginning to break down. Where the hood cloud cover has thinned (between 180°W and 20°W), the seasonal polar cap edge can be seen around 51-53° N.

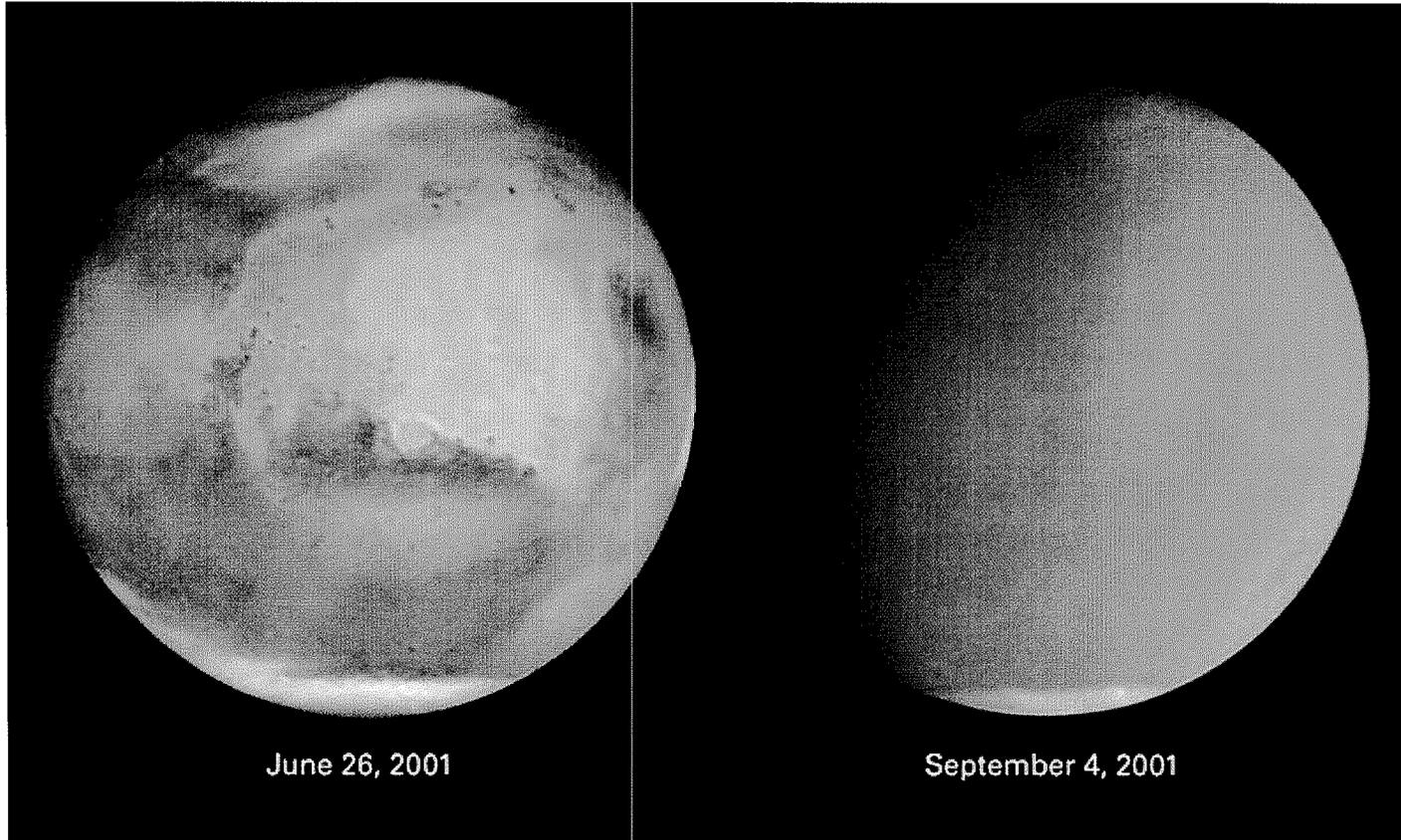


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HST View in 2001



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CREDIT: NASA / STScI / AURA / J. Bell & M. Wolff

GDS Onset - A Threshold View (1973)



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Dust Storms originate in southern spring and summer

- **Solar heating is critical; strongest at perihelion**

Dust Storms originate in southern subtropics

- **Tidal winds are strongest there**
- **Once dust is raised over extended areas, Hadley cell amplifies and raises more dust and over larger areas**

Dust Storms don't occur every year

- **Hadley cell + tides only strong enough if there is enough “background” dust in the atmosphere**

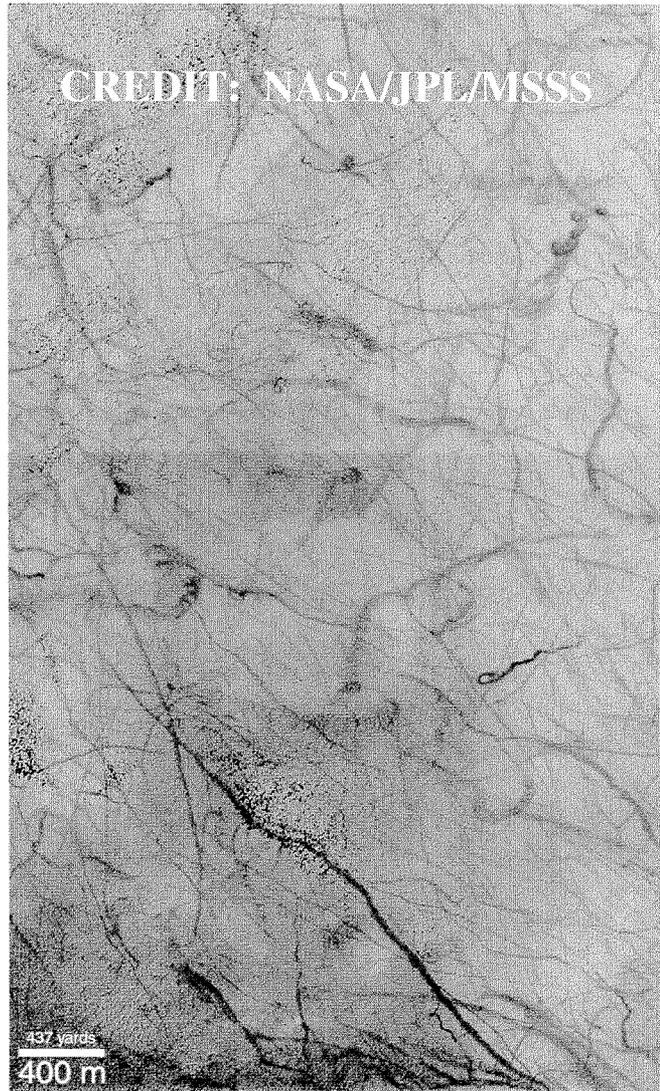
Cap Edge Storms and Dust Devils provide background dust

Is this the way it works? (Listen to Bob's talk!)

How to Raise Dust on Mars



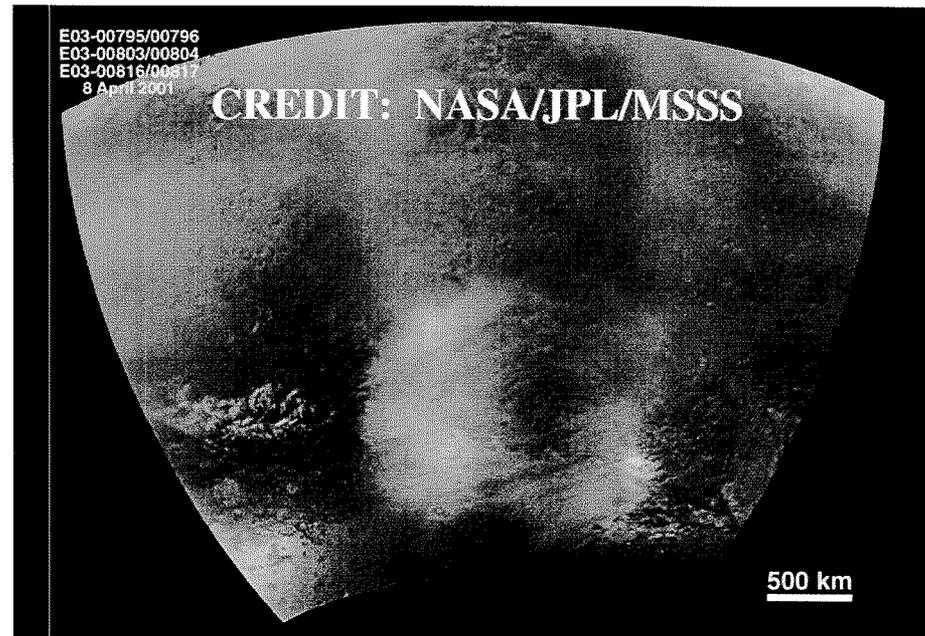
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MGS Mars Orbiter Camera (MOC)

← *Dust Devil Tracks*

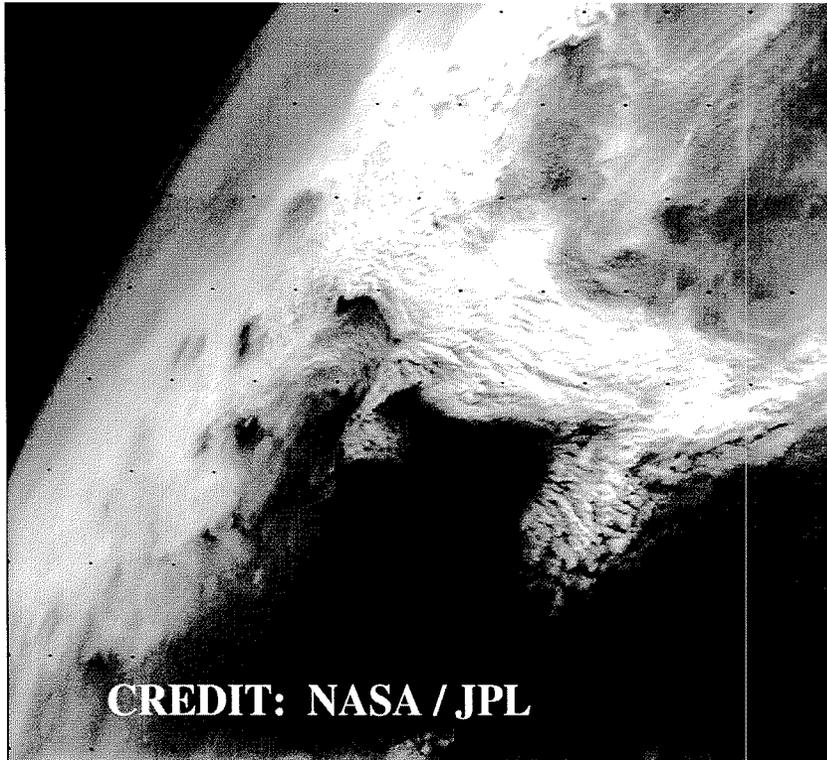
*Local Dust Storm at
South Pole Cap Edge*



Two Faces of Dust Storm Onset

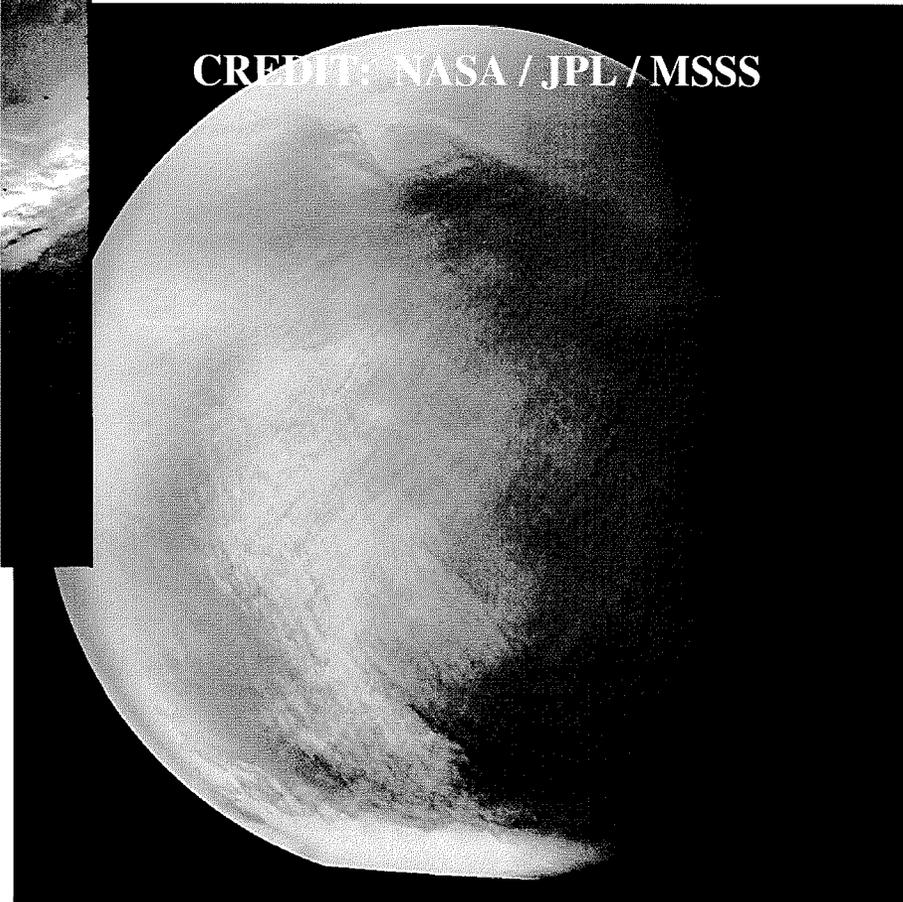


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CREDIT: NASA / JPL

← Viking views
the 1977a GDS



CREDIT: NASA / JPL / MSSS

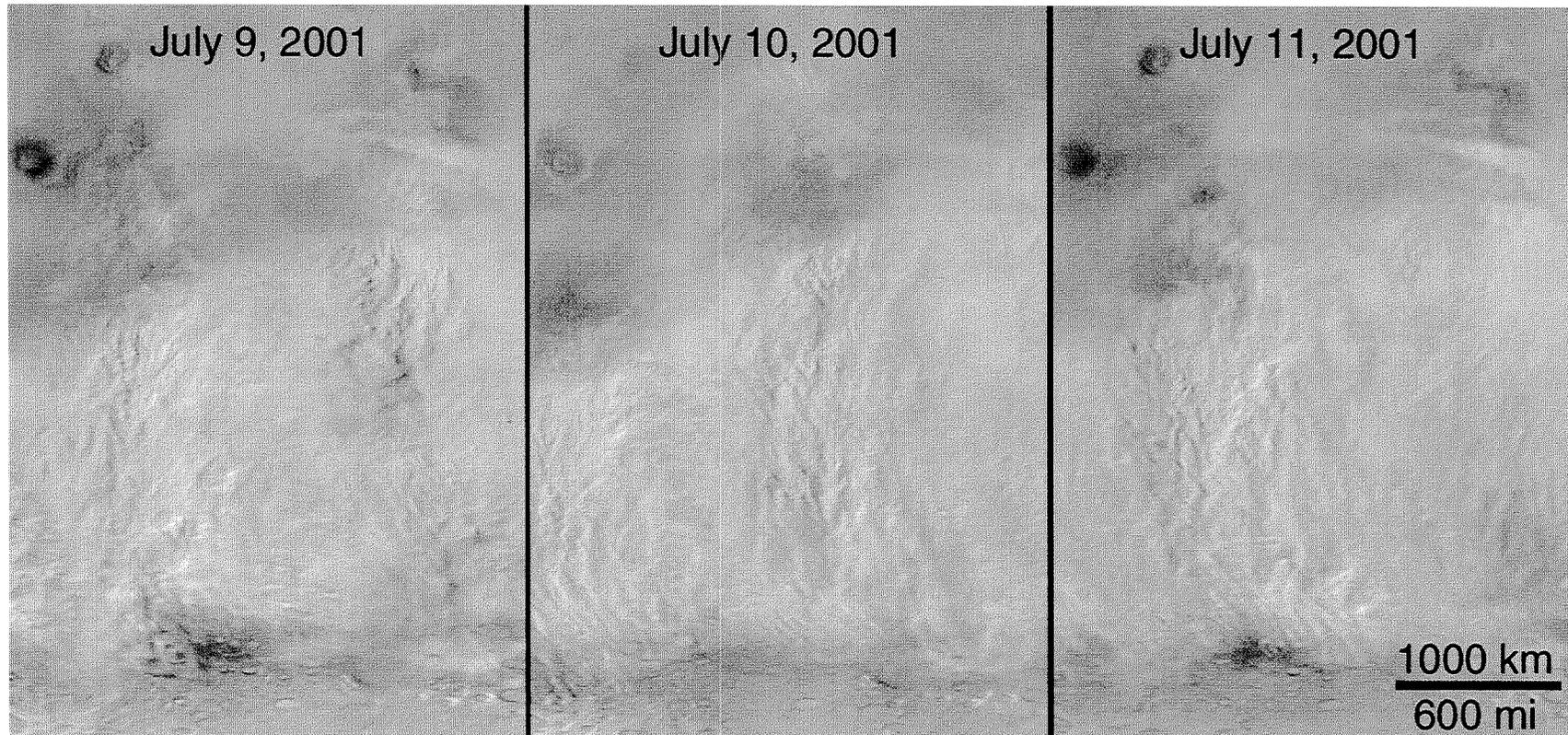
MGS views
the 2001 GDS



GDS Onset: Sustained Activity



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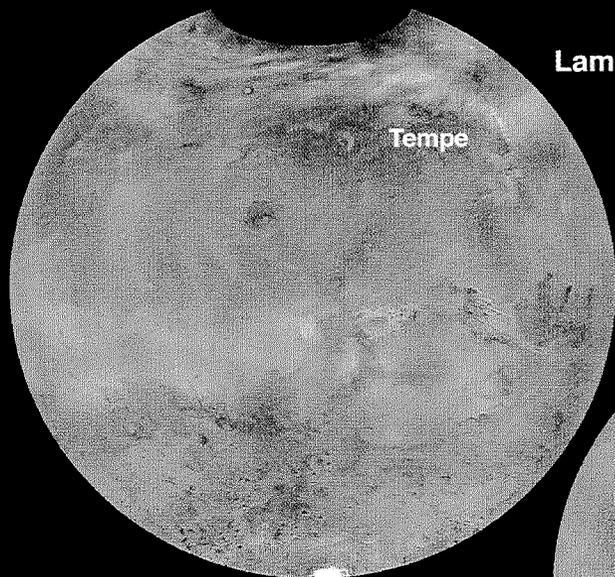
MGS MOC

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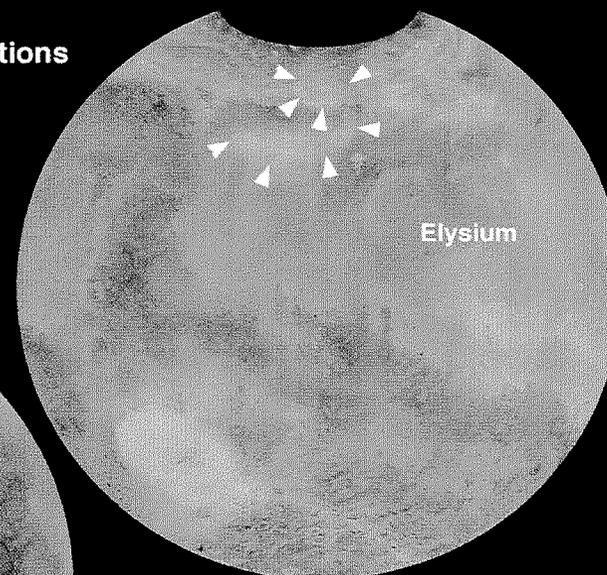
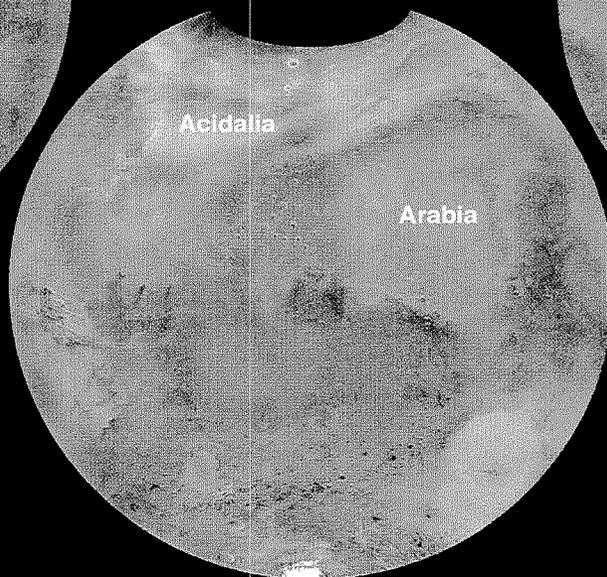
Mars Orbiter Camera Mars Weather Update

for the week of January 30 - February 5, 2002

Lambert-Azimuthal Equal Area Projections



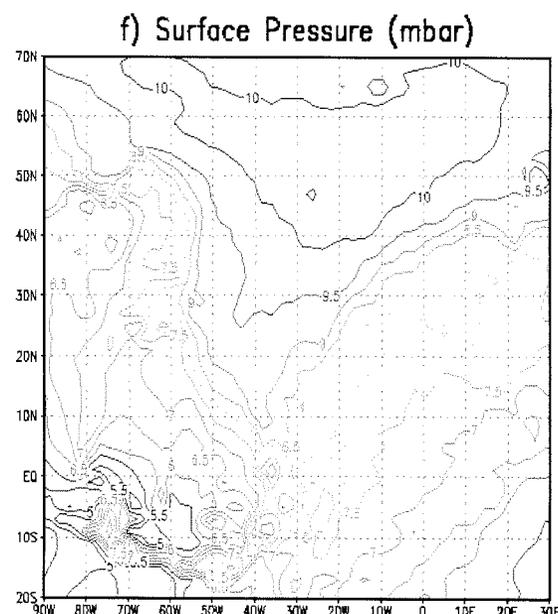
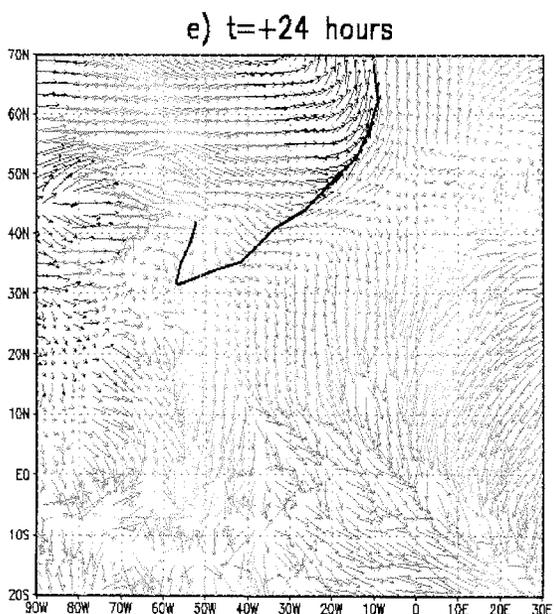
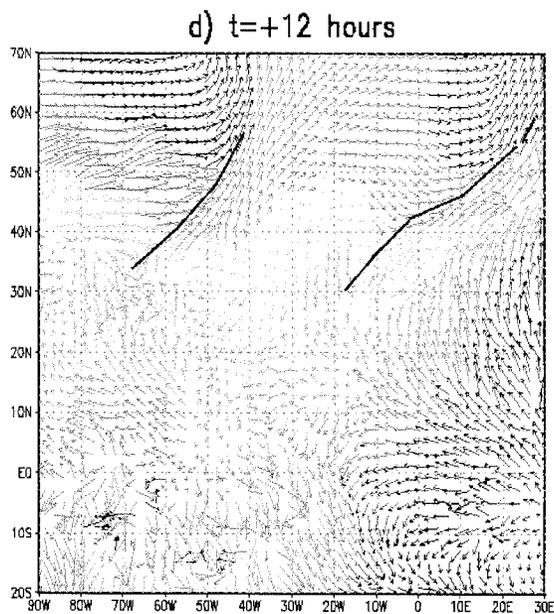
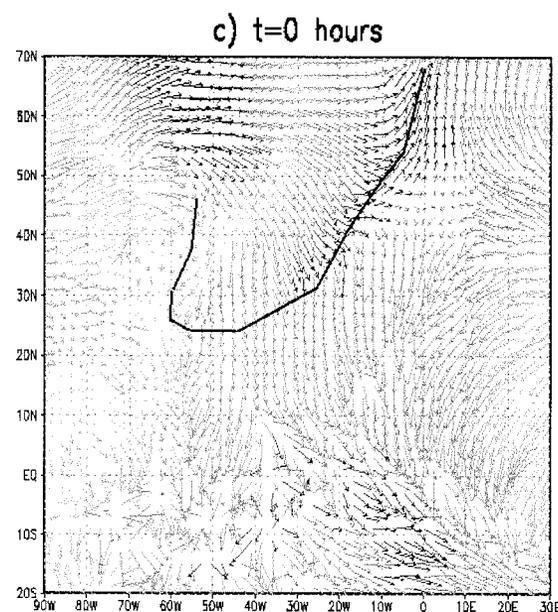
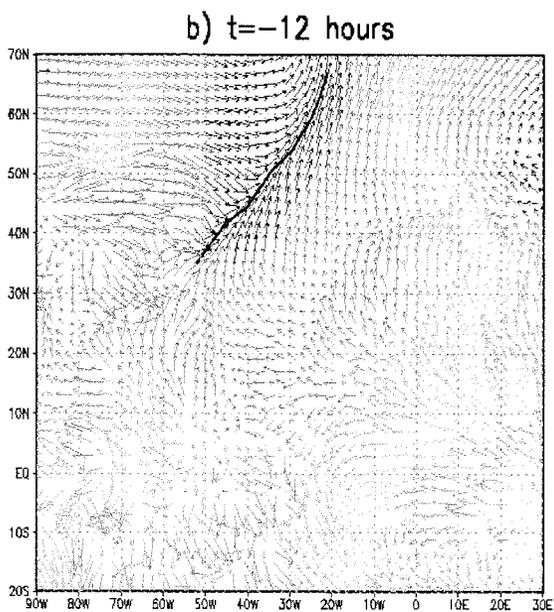
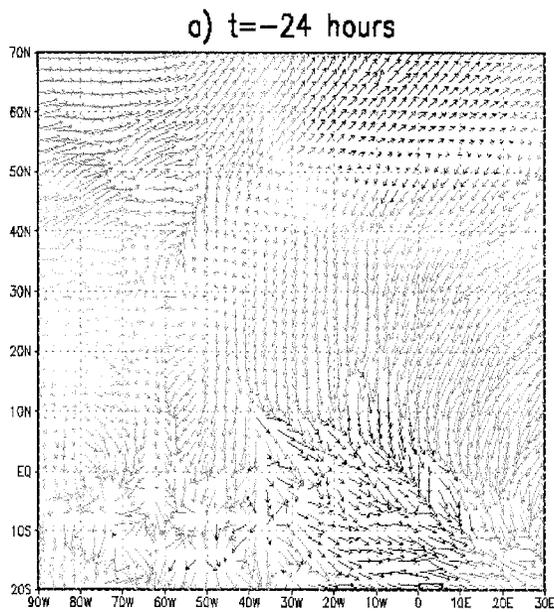
Central Meridians
240°W (left)
0°W (below)
120°W (right)



Meteorological activity this past week on Mars began at a low level following the period marked by several intense, short duration sub-regional storms that occurred the preceding week. However, by the middle of the week, storm activity along and near the cloudy North Polar Hood (NPH) edge was on the increase again. Water-ice clouds plunged southward along the eastern margin of Tempe Terra into Acidalia and Chryse following the path of the sub-regional dust storm reported last week. The resulting perturbation of the circumpolar jet stream could be seen propagated in an intense wave-2 pattern resulting in a similar southward excursion in Utopia. A large polar cyclonic storm showing both water-ice clouds and dust clouds formed east of Utopia and north-northeast of Elysium. Two spiral arms extending in a counter-clockwise direction from the vortex's central core are noted (arrows). This phenomena is similar to smaller polar vortices observed in the Earth's atmosphere. The periodicity of the sub-regional storms appears to be on the order of about a week or so for this season.



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H. Wang, et al., manuscript in preparation

To be Continued



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Maybe--just maybe--all the components of the general circulation are needed to trigger the biggest perturbations of the present Mars climate.

The circulation mechanisms are initiated like clockwork as the dust storm “season” approaches due to the radiative control; however, once initiated, their temporal evolution and interaction chaotically determine the season’s events.