HELLAS PLANITIA : WEATHER AND GEOLOGY

Short Introduction on Hellas

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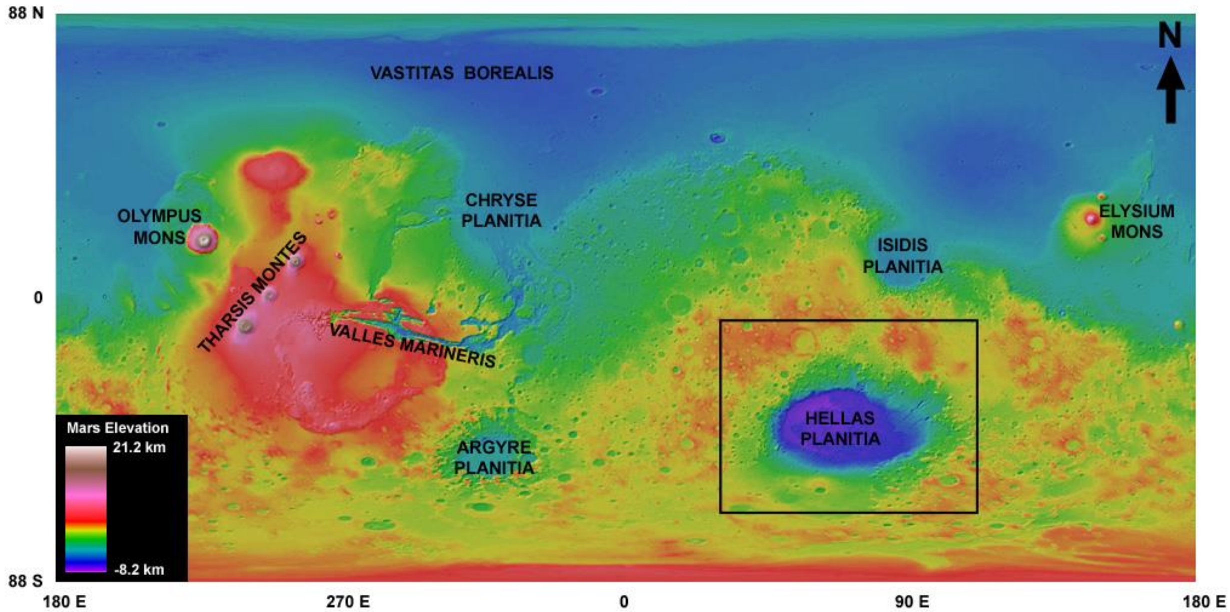

Figure 1. Colorized shaded relief portrayal of the Martian surface with the Hellas region outlined in black

Image: Color-coded elevation ranges draped over shaded-relief imagery from the Mars Orbiter Laser Altimeter

Location: Center of Hellas near 67° E, 42° S

Scale: Diameter of Hellas is greater than 2000 kilometers across

Hellas is the largest well-preserved impact structure on Mars and spans more than 2000 kilometers across in the southern hemisphere, a region that is much more heavily cratered and higher in average elevation than the northern hemisphere (Fig. 1). This region is often referred to as the "southern cratered highlands". The depth of Hellas from its bottom to its inner rim is more than 4 kilometers. To put this in perspective, the depth of the Grand Canyon in the United States is roughly 1 mile (1.6 kilometers), which means the depth of Hellas is about 2.5 times greater than the Grand Canyon. The western part of the Hellas basin contains the lowest point on Mars, about 8.2 kilometers below the Mars datum or Martian "sea level". The formation of the impact structure is believed to have taken place in the early Noachian epoch (click here for description of the Martian time scale), anywhere from 3.9 to 4.6 billion years ago. In the time since its formation, Hellas has been subject to infilling by eolian, fluvial, glacial, and volcanic materials.

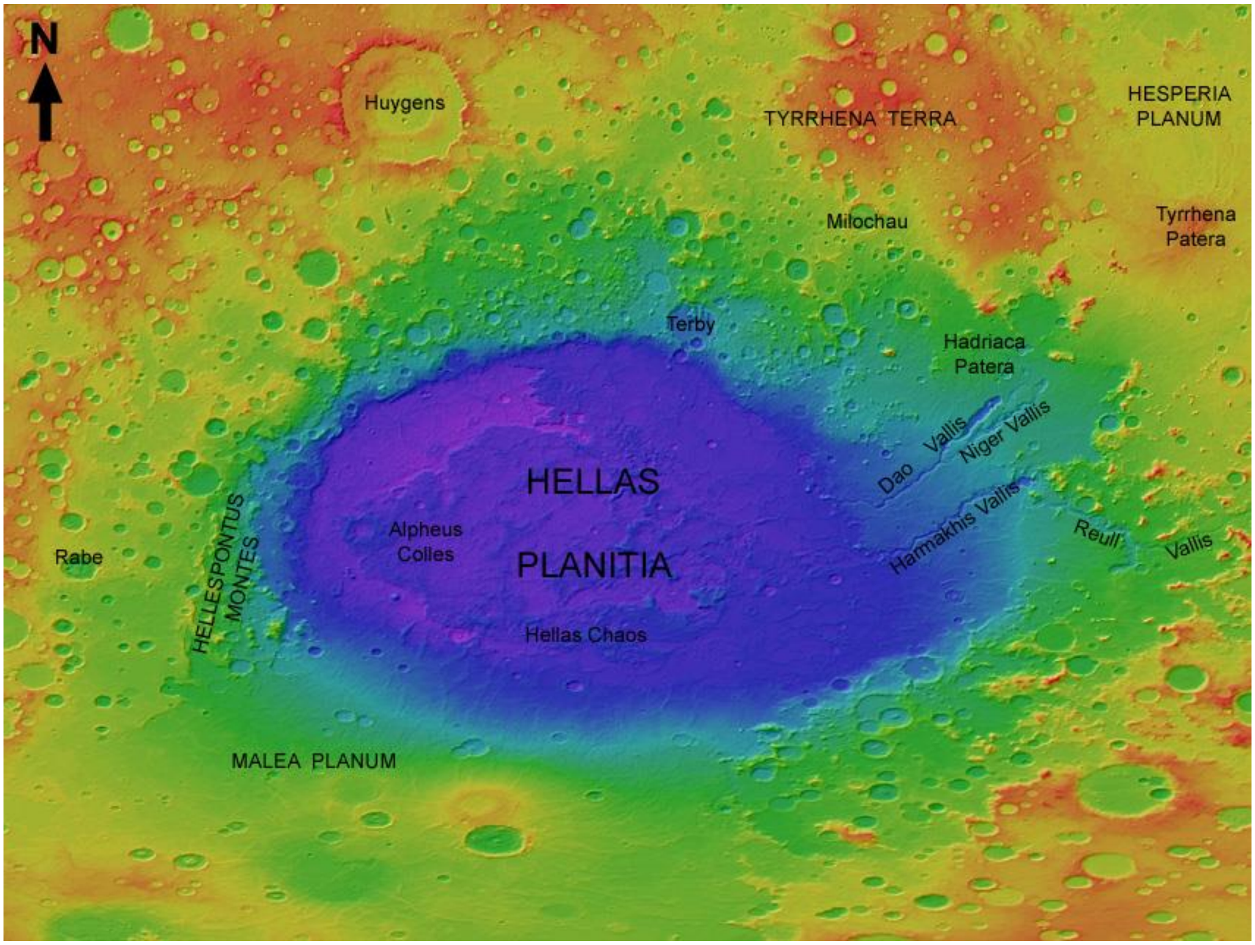

Figure 2. Colorized shaded relief portrayal of the Hellas region

Image: Color-coded elevation ranges draped over shaded-relief imagery from the Mars Orbiter Laser Altimeter

Location: Center of Hellas near 67° E, 42° S

Scale: Diameter of Hellas is greater than 2000 kilometers across

Scientists who have studied surface features all around the Hellas region have shown that a variety of geologic processes have acted to modify the original surface of Hellas over time (Fig. 2). These include impact craters that show exposed layered deposits (Milochau and Terby), volcanic flows and constructs along the inner and outer rim (Tyrrhena and Hadriaca Patera), large canyon systems (Dao, Niger, and Harmakhis Vallis), and kilometer-scale lobes of material that surround isolated hills and mountains (near Reull Vallis). So there's been a lot going on since Hellas was formed.

Weather analysis of Hellas Planitia

The Hellas Basin is the over 2000 km wide basin, created by an ancient meteor impact, is in places more than 7000 meters below the mean planetary horizon. It is believed to be the lowest place on the planet.

It is located at about 40 degrees south latitude, similar to that of central Argentina, and Melbourne, Australia. The Basin is one of the areas in which dust storms frequently erupt. It is also unusual because there are very few craters there.

Because of its latitude and great depth, it seems likely that there is an abundance of water ice under the surface in the Hellas Basin. Mossbaur spectra, which can detect the presence of hydrogen, suggest that, except for the poles, this may be one of the "wettest" places on the planet. It may possibly be the last place where liquid water ever existed on the surface of Mars. In mid summer, it is one of the "garden spots" of the whole planet, with atmospheric pressure of over 10 millibars, more than twice what it is at the mean planetary horizon. Since the vapor pressure of water is lower than 10 millibars if the temperature is less than 60 deg. F (16 deg. C), this may be one of the few places on the planet where any water on the surface will not immediately boil away. The days are long and relatively warm, and the nights are fairly mild, considering how far north the Hellas Basin is located.

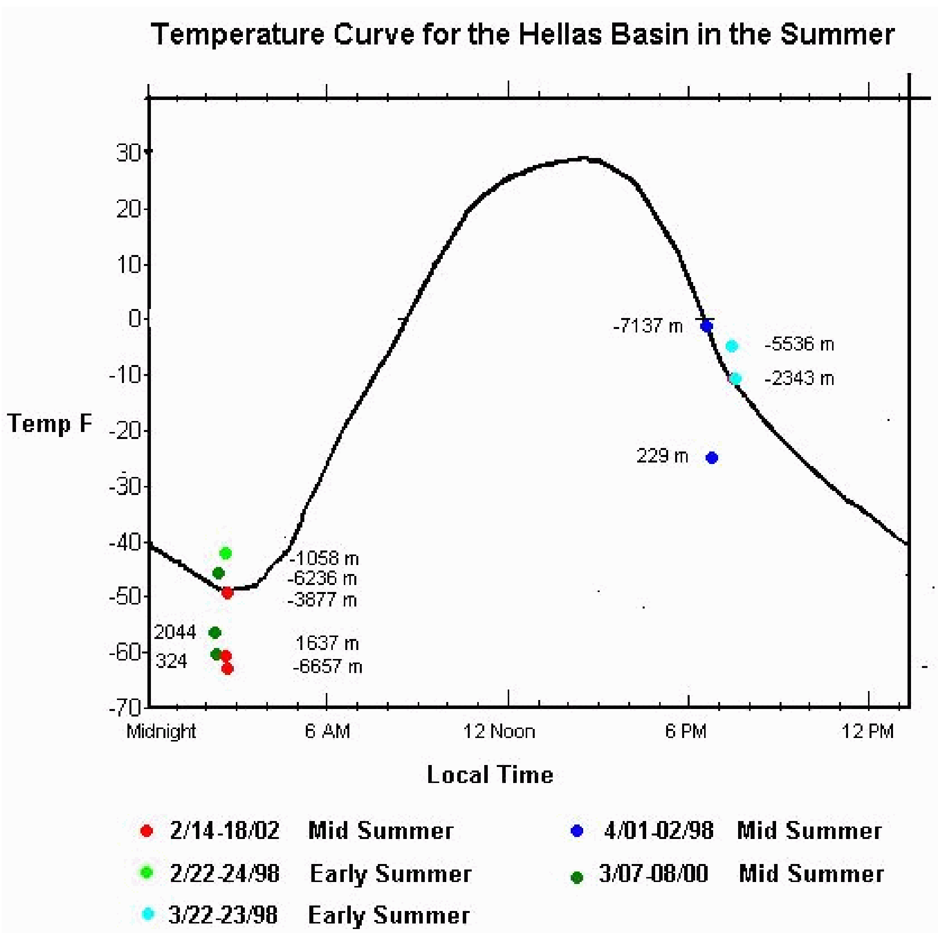

Figure 3. Temperature curve adjusted for summertime temperatures in Hellas Planitia

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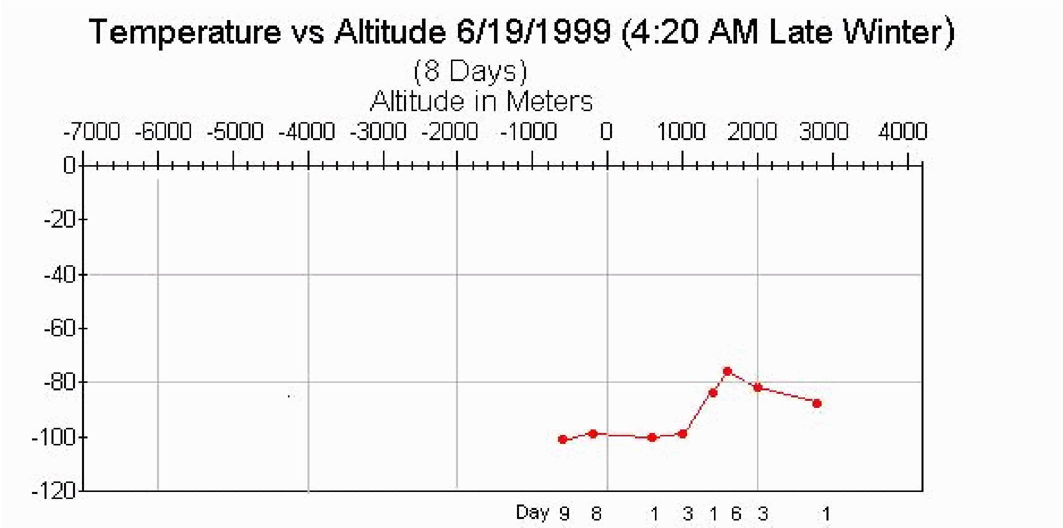
Late afternoon temperatures in the Hellas Basin are generally near or slightly above 0 deg. F (-18 deg. C), and nighttime temperatures at 2:00 AM are about 50 deg.F (-46 deg. C). Sometimes early morning temperatures at the lower altitudes can be unusually cold, possibly because of cold air pooling when there is little or no wind. Temperatures for different times during a Martian day can be estimated, using data obtained from the Viking spacecraft, which landed on Mars in 1979. The curve shown in Figure 3 was adjusted from the temperature curves of Viking 2 data to fit the temperature data from the Hellas Basin. It should be a fairly good match, as Viking 2 is about as far north of the equator, as Hellas is south of it.

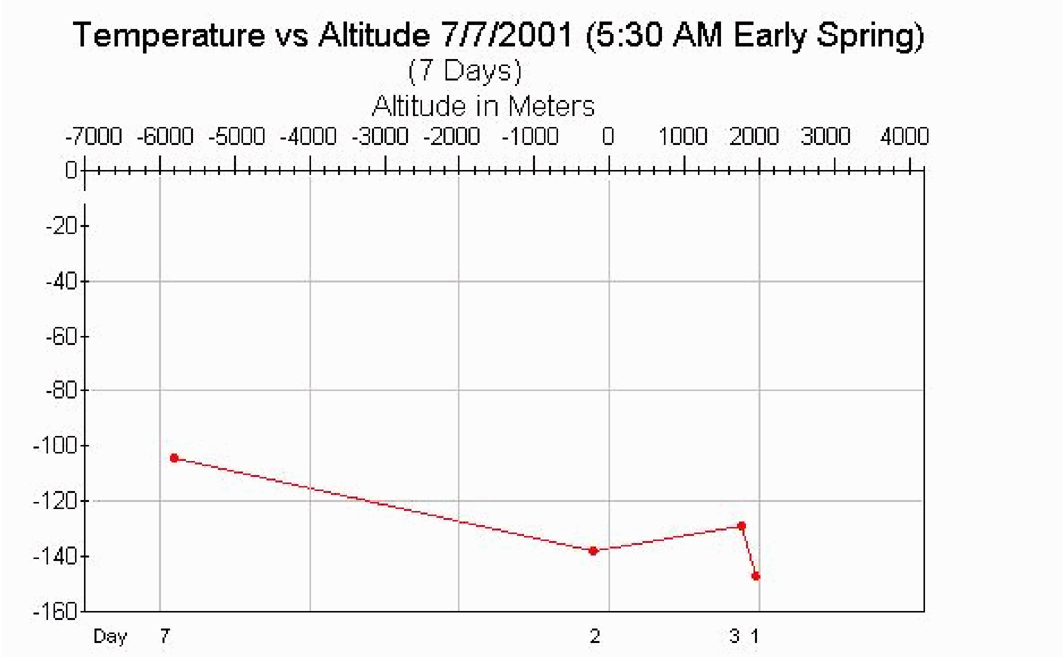
For a midsummer day in which the 6:00 PM temperature was 0 deg. F and the 2:00 AM temperature was of -50 deg. F (-46 deg. C), it is estimated from the temperature curve that the high temperature would probably be near freezing. The daily maximum soil temperature is about 45 deg. F (25 deg. C) warmer than the air temperature, or about 75 deg. F (24 deg. C) on the warmest days (1). Because the low point on the curve is at about 3:00 AM, the low temperature would be about -50 deg. F (-46 deg. C). The least cold morning temperature reported was -42 deg. F (-41 deg. C) in early summer. Early morning soil temperatures are about the same as the air temperatures.

Winter, of course, is a different story. With the short days and long nights, temperatures are much colder, dropping at night down to -140 F (-96 deg. C). The less cold winter nighttime temperatures may have resulted from dust in the air following a major dust storm in the northern hemisphere or equatorial regions.

Dependence of Temperature on Altitude

The data (Fig. 4) indicates that the nighttime temperatures are generally warmer at the lowest altitudes. This is probably because the higher density of the atmosphere and protection from prevailing winds allows heat to be better retained than on the surrounding high plains. In contrast, most of the few daytime temperatures that were reported indicate only a very slight dependence on altitude. However, on one day in mid summer, the nearby highlands were 20 deg. F (11 deg. C) cooler than the bottom of Hellas Basin. Note that the late winter early morning temperatues are much warmer than the early spring temperatures recorded two years earlier. The warmer temperatures may have resulted from atmospheric dust from a recent dust storm.


Temperature vs Altitude 6/19/1999 (4:20 AM Late Winter)
(8 Days)
Altitude in Meters
-7000 -6000 -5000 -4000 -3000 -2000 -1000 0 1000 2000 3000 4000
0
-20
-40
-60
-80
-100
-120
Day 9 8 1 3 1 6 3 1


Temperature vs Altitude 7/7/2001 (5:30 AM Early Spring)
(7 Days)
Altitude in Meters
-7000 -6000 -5000 -4000 -3000 -2000 -1000 0 1000 2000 3000 4000
0
-20
-40
-60
-80
-100
-120
-140
-160
Day 7 2 3 1

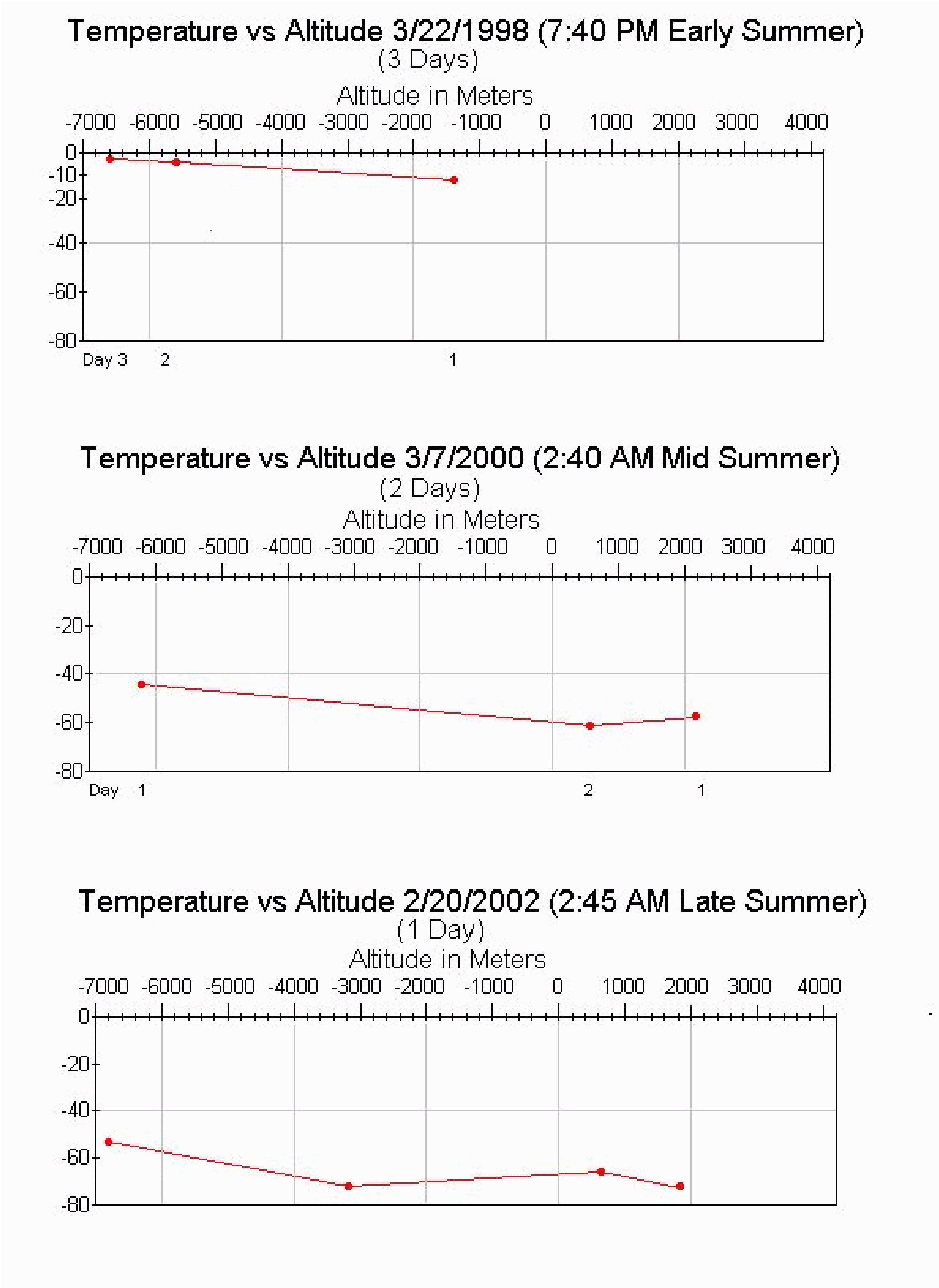


Figure 4. Plots of Temperature (Deg. F) vs Altitude.

Summertime Weather in the Hellas Basin

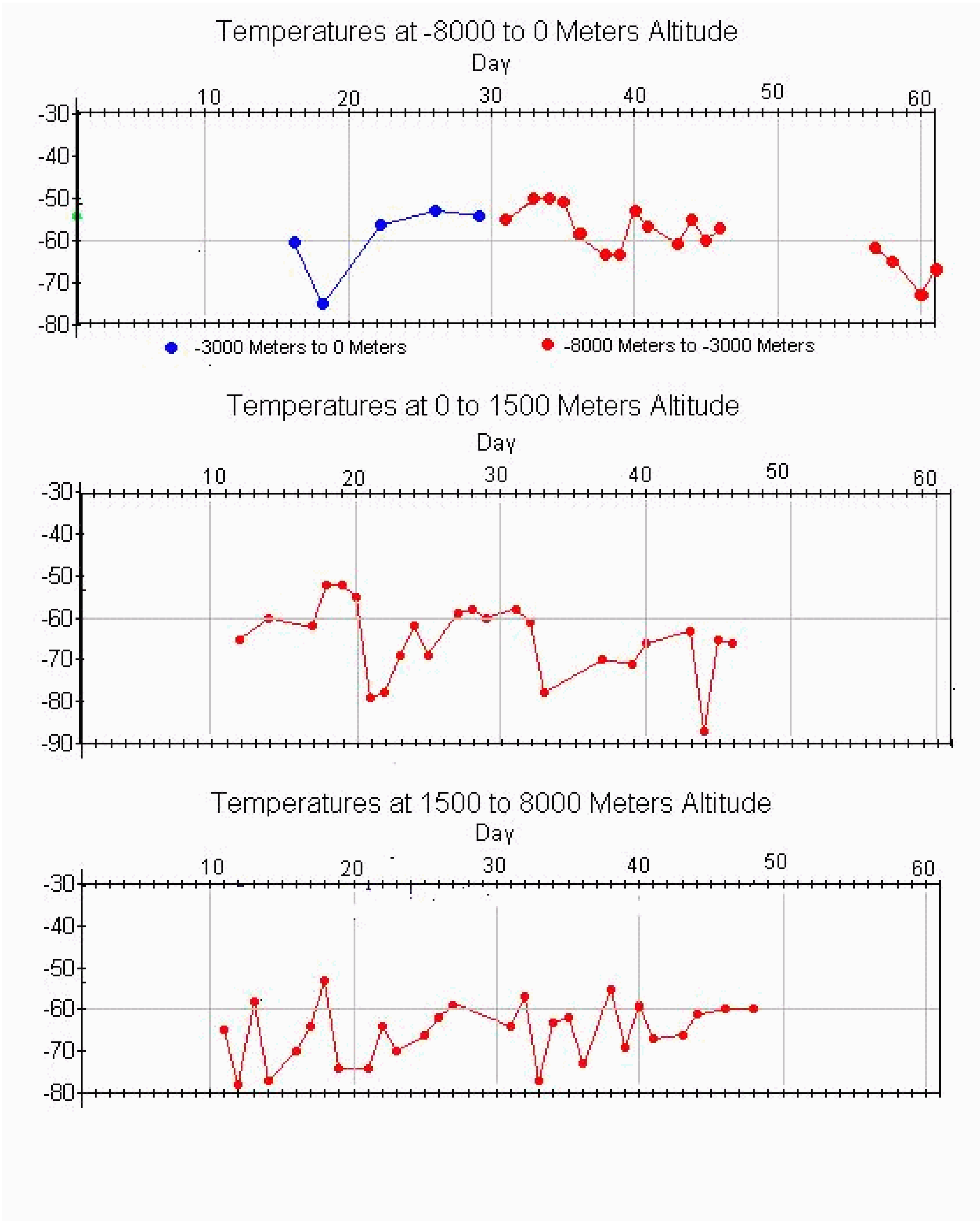


Figure 5. Summertime temperatures at different altitudes at 2:40 AM.

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The three plots in Fig. 5 suggest that a cold air mass moved across the Hellas region around day 20, a less intense one between days 30 and 40, and a moderate drop in temperature in the vicinity of day 44. Some of the variations in the low points in the curves may stem from the very wide area (4800 km east to west and 1600 km north to south) over which the measurements were taken. The temperatures at days 50 and beyond show a significant cooling as the season moves into late summer.

Weather on a Spring Night at a Northern Latitude

The following is a discussion of temperature and pressure data that were all recorded at different longitudes at 68 degrees north latitude during the Martian spring. The local mean time for each reading is within a few minutes of 2:47 AM mean time on the same day. The data was collected in December of 2002.

Fig. 6 shows an overview of the weather that was occurring all around Mars within a few minutes of 2:47 AM local mean time. It shows plots of temperature, height in meters above the mean altitude, and what the atmospheric pressure would be if the site measured was at zero meters altitude. The zero altitude atmospheric pressure was estimated from a plot of altitude vs. pressure readings obtained at about 2:20 AM at different altitudes in the Hellas Basin region during the late summer.

When comparing the temperatures here with the few available for spring in the vicinity of the Hellas Basin, it is noticed that the temperatures here are much warmer. Three reasons for this disparity could be suggested.

Firstly, the surface over most of this latitude is much lower than the highlands that surround the Hellas Basin. The heavier blanket of atmosphere over this wide area reduces the heat loss during the night. You do not get the phenomenon of heavier cold air descending from the highlands that you would expect to happen in the Hellas Basin.

Secondly, because of eccentricity of Mars' orbit, the winters in the northern hemisphere are not as cold as they are in the south. It is reasonable to expect that the evaporation of frozen carbon dioxide covering the southern ice cap would slow the warming that occurs with the coming of spring. The northern ice cap does not get cold enough to accumulate nearly as much solid carbon dioxide, allowing for a more rapid warming in the spring.

The third possibility, mentioned before, is that the presence of a lot of dust in the air could have moderated the temperatures during the time that temperatures were recorded. But, if this is the case, the similarities of most of the temperature readings would indicate that the dust would have to be uniformly distributed all around the planet

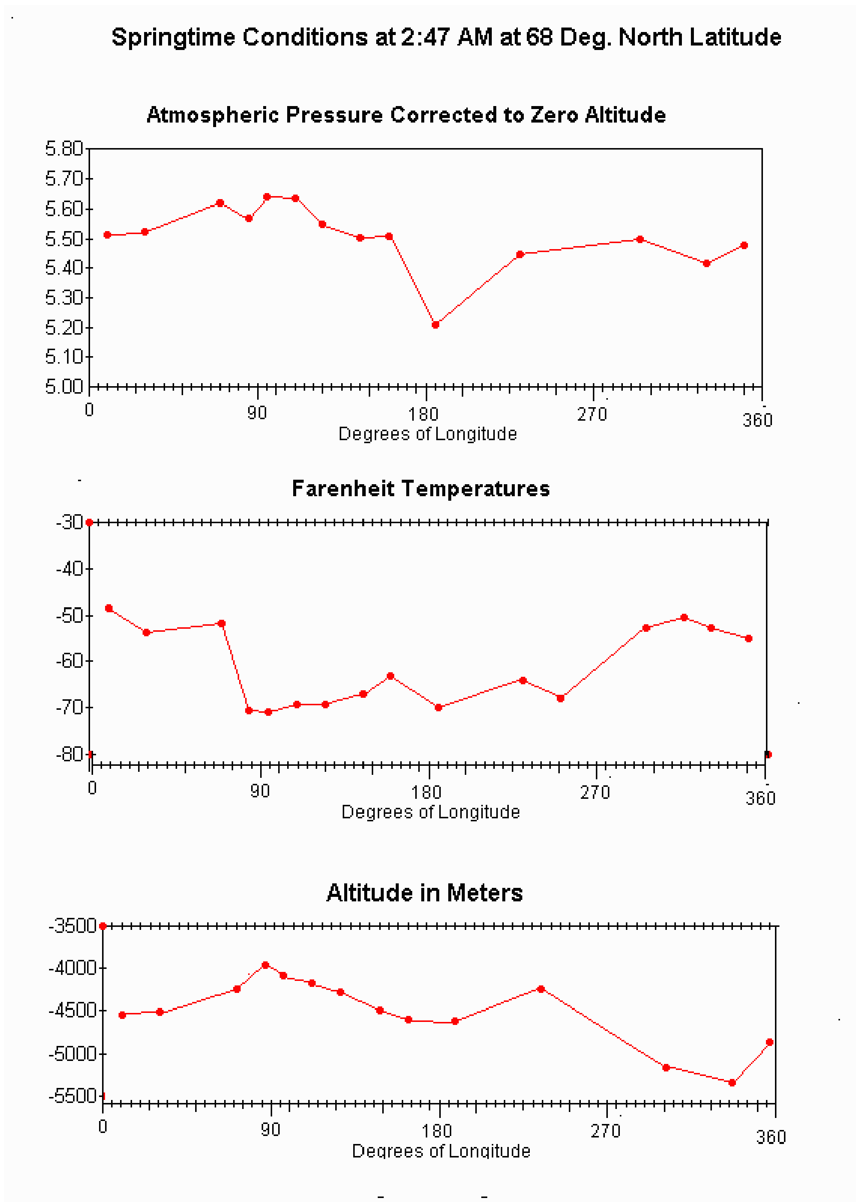

Figure 6. Pressure, temperature and altitude readings taken at Latitude 68

Weather Patterns Indicated

The plots of atmospheric temperature and altitude (Fig. 4) seem to indicate, as one would expect, that the nighttime temperatures are colder at the higher altitudes. But the altitudes are all between, -4000 meters and -5500 meters, an altitude range of less than 1500 meters. The Hellas Basin area showed much less temperature-altitude dependence over this altitude range. Therefore, it is likely that much of the temperature variation can be attributable to weather systems, rather than nightime heat loss due to radiation and convection.

At 90 degrees longitude, the estimated atmospheric pressure is above 5.5 millibars, suggesting the presence of a high-pressure area. The temperature on the east side of this air mass is about -70 degrees F, while it is 20 degrees warmer on the west side. This would suggest the clockwise motion of a cold air mass dropping down from the polar regions.

To the east, at about 180 degrees longitude there appears to be a low-pressure area that cold air from the high-pressure area is feeding into. But there is little evidence of any warm air being pulled up by the counterclockwise motion of the low-pressure area. At the postion where one would expect the warmest temperature would be, there is a seven degree temperature dip. I have read that the air temperature in still air on Mars is much warmer close to the ground. It follows from this that a wind strong enough to disrupt this layer of warm air would be expected to cause a temperature drop, even if it is pulling air in from the south. Note that the temperatures recorded immediately to the east and west (where the wind would be expected to be less) are slightly warmer than points east and west of them, respectively.

There appears to be another large air mass at about 300 (or -60) degrees latitude. This could be attributable to a weaker and less active high-pressure area. Unlike the other high pressure area, it is not a cold air mass. It is also different in that it does not appear to have a nearby low pressure area associated with it.

Geology of Hellas Planitia

Hellas basin on Mars has been the site of volcanism, tectonism, and modification by fluvial, mass-wasting, and eolian processes over its more than 4-b.y. existence. The detailed geologic mapping and related studies have resulted in the following new interpretations. The asymmetric distribution of highland massifs and other structures that define the uplifted basin rim suggest aformation of the basin by the impact of a low-angle bolide having a trajectory heading S60øE. During the Late Noachian, the basin was infilled, perhaps by lava flows, that were sufficiently thick (> 1 km) to produce wrinkle ridges on the fill material and extensional faulting along the west rim of the basin. At about the same time, deposits buffed northern Malea Planum, which are interpreted to be pyroclastic flows from Amphitrites and Peneus Paterae on the basis of their degraded morphology, topography, and the application of a previous model for pyroclastic volcanism on Mars. Peneus forms a distinctive caldera structure that indicates eruption of massive volumes of magma, whereas Amphitrites is a less distinct circular feature surrounded by a broad, low, dissected shield that suggests generally smaller volume eruptions. During the Early Hesperian, a-1- to 2-km-thick sequence of primarily fined-grained, eolian material was deposited on the floor of Hellas basin. Subsequently, the deposit was deeply eroded, except where armored by crater ejecta, and it retreated as much as 200-300 km along its western margin, leaving behind pedestal craters and knobby outliers of the deposit. Local debris flows within the deposit attesto concentrations ofgroundwater, perhaps in part brought in by outflow floods along the east rim of the basin. These floods may have deposited -100-200 m of sediment, subduing wrinkle ridges in the eastern part of the basin floor. During the Late Hesperian and Amazonian, eolian mantles were emplaced on the

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basin rim and floor and surrounding highlands. Their subsequent erosion resulted in pitted and etched plains and crater fill, irregular mesas, and pedestal craters. Local evidence occurs for the possible former presence of ground ice or ice sheets -100 km across; however, we disagree with a hypothesis that suggests that the entire south rim and much of the floor of Hellas have been glaciated. Orientations of dune fields and yardangs in lower parts of Hellas basin follow directions of the strongest winds predicted by a recently published general circulation model (GCM). Transient frost and dust splotches in the region are, by contrast, related to the GCM prediction for the season in which the images they appear in were taken.

The Hellas region of Mars consists of diverse topography, geology, and surface characteristics, yet it is dominated by one particular feature, the Hellas impact basin. Although the basin was formed during early bombardment, it is relatively well preserved and makes up the deepest and broadest (-9 km relief, -2000 km across). depression on Mars (Figures 1 and 2). Volcanism and channel dissection have modified large expanses of the northeastern and southern parts of the basin rim. Both of these modified areas and the floor of the basin are marked by wrinkle ridges. Also, a large deposit of proposed eolian origin covers the basin floor; this area is presently the site of origin of major dust storms [Martin and Zurek, 1993] and of the highest wind stresses on Mars predicted by general circulation models (GCM's) [Greeley et al., 1993].

Geologic history and evolution of Hellas Basin

Heavy bombardment of the early crust in the Hellas region resulted in densely cratered terrain during the Early Noachian. A southeast-trending low-angle impact probably formed the Hellas basin cavity and surrounding uplifted rim material. Much of the rim comprises disrupted, large massif blocks of relatively resistant crustal material. Concentric graben (outside the study area) associated with the impact formed soon thereafter. In the Middle Noachian, continued bombardment formed impact craters throughouthe study area. Ejecta, fluvial sediment from dissection of basin massifs, and possibly eolian mantles and volcanic deposits began infilling topographic lows, including the Hellas basin, highland areas outside the basin rim, and intermassif and intercrater areas of the basin rim. Such highland modification by local eolian, fluvial, and volcanic activity continued into the Late Noachian. Hellas basin became infilled, probably by lava flows that were apparently sufficiently thick to cause lithospheric sagging leading to wrinkle-ridge formation, normal faulting at Hellespontus Montes, and lava effusion along the edge of the basin interior. Pyroclastic volcanism formed low-relief highland volcanoes on the outer parts of the northeast and south basin rim; large areas of the inner rim slopes were buried by the deposits. A thick sequence of lava flows was emplaced south and west of Amphitrites and Peneus Paterae on Malea Planum. Subsidence under the weight of the volcanic rocks formed wrinkle ridges on the volcanoes and southern lava-flow fields. Highland-paterae pyroclastic volcanism continued into and culminated during the Early Hesperian, and summit collapse produced circular caldera structures on each volcano. Eruption of massive volumes of magma formed Peneus, a distinctive caldera structure, whereas generally smaller volume eruptions created Amphitrites, a less distinct circular feature surrounded by a broad, low, dissected shield. Runoff and (or) groundwater sapping, accompanied by mass wasting and eolian erosion, produced valleys and troughs on the paterae flanks and neighboring areas of the basin rim; a few large channels also formed (such as Reull Vallis). Lava flows were emplaced in Hesperia Planum and deformed by wrinkle ridges. Most of the Hellas basin floor was covered by a thick sequence of deposits; morphologic and stratigraphic relations and volume estimates indicate the deposits are predominantly eolian in origin, with some contributions of fluvial and volcanic material. The source of the eolian material likely was sand, silt, and dust eroded from highland terrains (particularly along the highland/lowland boundary, which was deeply eroded at this time). Local highland erosion and subsequent mantling probably occurred. During the Late Hesperian, the basin interior deposit was deeply eroded into hummocky and knobby terrain (except where armored by the ejecta of large craters), and its western margin retreated as much as 200-300 km, leaving behind pedestal craters, infilled craters, and knobby outliers. Late-stage effusive volcanism at Tyrrhena Patera produced a large rille structure and a field of lobate lava flows that apparently triggered collapse and outflow erosion, which produced Dao, Niger, and Harmakhis Valles. These channels debouched into Hellas Planitia, and their sediments likely buried much of the interridge plains of the basin ridged unit. Mantling and subsequent partial erosion of the basin rim and adjoining highlands resulted in (1) intracrater and intercrater etched plains material; (2) irregular mesas, pedestal craters, and channel fill on dissected and ridged plains material on the upper part of the basin rim; and (3) pitted plains and pedestal craters superposed on degraded and subdued valleys on northern Malea Planum. Mantling and mantle erosion continued through the Early and Middle Amazonian on the basin rim and interior. Interior mantles formed along the south edge of the retreated interior deposit and in more deeply eroded, central areas of the interior deposit. Mass-wasting of the interior deposit resulted in debris aprons and flows. On the basin rim, debris aprons formed along the bases of massifs and channel flanks. Late Amazonian activity included local mantling, mass-wasting, and erosion at low intensity throughout the Hellas region. In lower parts of the Hellas basin interior deposit and basin ridged unit, oriented ridges are interpreted as dunes and yardangs formed by strong, seasonal winds (among the strongest presently occurring on Mars). Presently, transient, seasonal frost and dust splotches form throughout the Hellas region and are commonly oriented along co-seasonal trends of GCM predictions

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