4pm Today in D142 Oudane is a joint LASS/Astrobiology Seminar by John Grant of the National Air & Space Museum entitled "Selecting Landing Sites for the 2003 Mars Exploration Rovers."

Right now: Anthesis defense of Jenny Richardson on measurements of the atmosphere of an extrasolar planet using spectroscopy.

Answer question about albedo variation on surface of Jupiter's Moon Io.

Seasons on Mars.

At the end of last class we had started to talk about Martian Seasons.

Recall: For a planet with a perfectly circular orbit, the seasons are of equal length (2π period).

\[ L_s = \text{Solar Longitude} = 0^\circ \text{ at N Spring Equinox} \]
Mars Eccentric Orbit - affects length & intensity of seasons

\[ e = 0.0934, \quad a = 1.52 \text{ AU} \]

Perihelion Distance = \( a(1-e) = 1.38 \text{ AU} \)

Aphelion Distance = \( a(1+e) = 1.67 \text{ AU} \)

"Exaggerated Drawing of Mars Orbit"

Argument: \( \theta = 0^\circ \) at perihelion, \( \theta = 180^\circ \) at aphelion

Solar Longitude: \( L_s = 0^\circ \) at North Spring Equinox, \( L_s = 180^\circ \) at N. Fall Equinox

For Mars, \( L_s = \theta + 25^\circ \)

The offset between \( L_s \) and \( \theta \) is different for different planets and can change with time.

North
Long, warm summer
Short, cool winter

South
Long, cold winter
Short, hot summer
Recall CO₂ atmospheric pressure variations:

Pressure

N. Spring  N. Summer  N. Fall  N. Winter
S. Fall  S. Winter  S. Spring  S. Summer

This is plotted vs L₅

In winter as much as 1/3 of atmosphere freezes out at pole!

Plot same thing vs Time & it makes more sense:

1841 1844 1861 1874

N. Spring  N. Summer  N. Fall  N. Winter
S. Fall  S. Winter  S. Spring  S. Summer

Long seasons far from Sun ⇒ lots of CO₂ frozen out @ S. pole,
very little released from N. pole

Short seasons close to Sun ⇒ lots of CO₂ released from S. pole, very little frozen out at N. pole.

Also recall Dust Storms tend to start in S. Summer (but with small ones in N. Summer near pole)
Martian Temp Profile:

- High, cool thermosphere
- Lesser heatings and coolings
- CO$_2$ ice clouds
- Water ice clouds
- Adiabatic near surface (~45 K)

Note: at surface pressures, CO$_2$ freezes out @ 160 K so atmosphere at poles can never get below this temp unless all atmosphere freezes out.

T (K)

Martian Circulation Patterns

During equinoxes get standard 2-Hadley cell configuration, plus a cell near the edge of the retreating spring polar cap (differential heating due to albene)

Note that CO$_2$ is coming off the spring pole, increasing atmosphere

During solstices two-cell system falls apart & really get a single cell (rising from summer hemisphere & falling in winter pole hemisphere)

Note CO$_2$ coming off summer pole
Fig. 9. Temperatures derived from data taken during descent of the Viking Landers to the surface of Mars (early northern summer). Dashed straight lines indicate approximate temperature variations corresponding to adiabatic lapse rates (A) and CO$_2$ condensation temperatures (C). Note the cold thermosphere and the often anti-correlated wave structure in the two profiles (figure from Seiff and Kirk 1977).
Fig. 12. Cartoon showing the main features of the atmospheric circulation at the equinox (top) and at the solstice (bottom). EJ and WJ represent the locations of the easterly and westerly jets, respectively. Slanting lines at the surface represent the seasonal polar caps. Arrows indicate zonally symmetric overturning, and spirals indicate mixing by atmospheric waves. For more discussion, see text or chapter 26.

Departures from the zonal-mean circulation include high-latitude eastward-propagating traveling waves, which are believed to be manifestations of baroclinic instability (Ryan et al. 1978; Barnes 1980, 1981; Sharman and Ryan 1980); low-latitude westward-propagating thermal tides, which are driven by the daily solar heating cycle (Zurek 1976; Leovy and Zurek 1979); and quasi-stationary planetary waves, which can be found at both high and low latitudes, and which arise from the mechanical and thermal effects of
The Water Cycle on Mars

Recall: N. pole in summer all CO₂ ice sublimates away, exposing a residual H₂O ice pole which then can heat up warmer than 150 K (can get up to ~300 K)

At ~ 6 mb, water can't exist as a liquid so get only H₂O ice or H₂O vapor

So Summer N. pole is source of H₂O vapor

Both poles are sinks of H₂O vapor in winter (winter poles get down to 150 K)

North Polar Cap is source of H₂O in Summer & sink in Winter

South Polar Cap is always a sink for H₂O
Fig. 1. Contours of column water-vapor abundance as a function of latitude and season, based on Viking MAWD observations, in units of precipitable microns (1 μm). Data span one Martian year covering the Earth years 1977-1978, and are spliced at L = 180° (vertical dashed line). Shaded regions indicate no observations, and the smooth curves are the latitude poleward of which the Sun will not rise above the horizon. Horizontal arrows mark the times of the two 1977 dust storms as observed by the Viking Landers and Orbiters. Earth years are shown along the top of the figure. This is a re-display of the data inversion of Jakosky and Farnet (1982).
North pole residual cap is shrinking because of loss of H₂O to S. cap & atmosphere & regolith (~1 mm or less per year)

Also H₂O in regolith (top layer of crust)

⇒ Perma-Frost = permanent frost (just like in Alaska or Canada)

Frost layer & perma-frost are reservoirs of H₂O

Lots of Evidence For Climate Change on Mars

1. Polar Layered Terrain
   - quasi-periodic climate change due to changing obliquity

   Mars obliquity range = 15° - 35° (currently 25.2°)
   Earth obliquity range = 22° - 25° (currently 23.5°)

   Change causes ice ages on Earth
The schematic summary of the seasonal water cycle. Boxes represent places where water can reside, and include both atmospheric and non-atmospheric reservoirs. Arrows represent the exchange of water between reservoirs at this season. See text for more detailed discussion.

Northern Spring/Summer

Northern Fall/Winter

Southern Fall/Winter

Southern Spring/Summer

(Residual Condensates)

The same issue, water is lost (at least in the years observed by Viking) from
Isotope Ratios

4 Enrichment of $^{15}$N relative to $^{14}$N.

$\frac{^{15}}{^{14}}$N ratio on Mars higher than Earth

$\Rightarrow$ indicates significant loss of nitrogen to space

Mars originally had $\sim$ 3-30 millibars $N_2$

5 Enrichment of O relative to H

$\frac{O}{H}$ Mars $\sim 6 \times$ Earth's

$\Rightarrow$ indicates loss of $H_2O$

Mars may have lost as much as 60-600 m deep ocean worth of water

6 Other isotope ratios also indicate significant atmospheric escape

Presence of Fluid-encoded valley networks

- indicate liquid flowed on surface in past (recent? and definitely long ago past)

Major result from MGS images indicating current liquid water flow!