Mars: A Planet with a Dynamic Climate System

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Mars is a well-observed planet. Since the 1960s orbiters, landers, rovers, and earth-based telescopic observations show that its climate system is dynamic. Its dynamic nature, largely the result of atmosphere-surface interactions, is most obvious in the seasonal cycles of dust, water, and carbon dioxide that define the planet's climate system. These cycles are linked through the global circulation and MGS, Odyssey, Phoenix, MER, Mars Express, MRO, and now MSL have continuously observed them at Mars for the past 16 years. Their observations show that while the seasonal cycles are largely annually repeatable, there are interannual variations. Planet-encircling dust storms, for example, are quasi-triennial and originate over a broader range of seasons and locations than previously thought. Water moves from pole-to-pole each year in a largely, but not precisely, repeatable pattern that suggests but does not demand non-polar surface reservoirs. And the seasonal CO_2 polar caps grow and retreat in a very predictable way with only minor deviations from year-to-year in spite of significant differences in atmospheric dust content. These behaviors suggest a complicated but robust coupled system in which these cycles interact to produce the greatest interannual variability in the dust cycle and least variability in the CO2 cycle. The nature of these interactions is the subject of ongoing research, but clouds, both water ice and CO_2 ice, now appear to play a bigger role than believed at the end of the 20th century. There may also be some long-term trends in these cycles as there is evidence from imaging data, for example, that the south polar residual cap may not be stable on decadal to centennial time scales. On even longer time scales, the discovery of as much as 5 mb global equivalent of buried CO_2 ice near the south pole, the detection of vast quantities of subsurface water ice at very shallow depths in midlatitudes of both hemispheres, and the presence of remnant glacial features at almost all latitudes, strongly suggests the possibility of significant climate change associated with orbital variations. Some of the major questions these data raise concern how closed the seasonal cycles are and which reservoirs are gaining or loosing, the cause of the large interannual variability of the dust cycle and how it couples to the water and CO_2 cycles, and the mechanisms for the origin of past glacial activity and the emplacement and removal of subsurface ice. While many of these questions can be addressed with continued research based on existing data, new observations focused on atmosphere surface-interactions would provide valuable constraints on how dust, water, and CO_2 move between the surface and atmosphere.