Model experiments incorporating the solar cycle show the katabatic wind to be completely suppressed only during the midsummer daytime simulation. The adjustment time for the development of the katabatic wind is quite short; during the early morning hours of midsummer the drainage flows are able to develop. This implies that once the Sun sets, the development of the katabatic wind is very rapid and near-steady conditions prevail in just a few hours.

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ANTARCTIC LAKES (ABOVE AND BENEATH THE ICE SHEET): ANALOGUES FOR MARS.

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The perennial ice-covered lakes of the Antarctic are considered to be excellent analogues to lakes that once existed on Mars. Field investigations of ice-covered lakes, paleolakes, and polar beaches have been conducted in the Bunger Hills Oasis, Eastern Antarctica. These studies will also be extended to the Dry Valleys, Western Antarctica, and the Arctic.

Important distinctions have been made between ice-covered and non-ice-covered bodies of water in terms of the geomorphic signatures produced. Field investigations have revealed that the classical lacustrine landforms created by non-ice-covered lakes (spits, bars, berms, cusps, tombolos, and wave-cut platforms) are absent in an ice-covered lake regime. The features mentioned above are the result of the direct coupling of wind and the free water surface. The ice cover acts as a geomorphically protective agent. Therefore, the shores of ice-covered bodies of water are low-energy environments, i.e., poorly sorted, due to restricted or nonexistent wave action.

The most notable landforms produced by ice-covered lakes are ice-shoved ridges. These features form discrete segmented ramparts of boulders and sediments pushed up along the shores of lakes/seas. The shorelines are generally planated with the ramparts defining the inner edge of the shoreline. These ridges usually have a heterogeneous veneer of boulders, pebbles, sand, and gravel mantling an ice core. The ice core normally melts out and leaves behind its mantle of material in the form of irregular discontinuous ridges. The ice core can persist for years if it is sufficently insulated by its mantle of material.

The ice-shoved features observed in the Bunger Hills Oasis were up to 83 m long, 2 m high, and 4 m wide. Ice-shoved ridges up to 300 m long and 10 m high have been reported [1]. Other unique landforms associated with polar beaches are frost cracks and mounds, patterned ground, pingos, pitted beaches, coastal striated bedrock, and ventifacts. Investigations of ice-covered lakes in Antarctica has also disclosed information that may have important exobiological implications [2–4], namely the discovery of modern, cold-water, blue-green algal stromatolites that are adapted to extremely cold temperatures, fresh-to-saline water, and low light intensities, and the fact that an ice cover acts as both insulating blanket and protective seal for the liquid water located below. The ice cover's "sealing effect" allows the liquid water to retain biologically important gases that are dissolved in the water column.

Several paleolacustrine basins have been located and mapped on Mars [5,6]. The last vestiges of these martian lakes, which eventually froze throughout because the influx of meltwater ceased, are expected to be found at high latitudes. Provided that the ice cover was covered with the appropriate sediment thickness [7], these paleolake remnants would form a massive lens of buried ice. It is proposed that this lacustrine ice lens would be composed of interlayered fluvial/lacustrine sediment and ice. This layering would be created by the influx of sediment brought in by multiple flow episodes from channels located along the periphery of the basin [8–10]. Aeolian deposits would also contribute to the ice cover mantling. More investigative studies and field work will be conducted on these problems.

Sub-Ice-Sheet Lakes: Sub-ice lakes have been discovered [11] under the Antarctic ice sheet using radio echo sounding. These lakes occur in regions of low surface slope, low surface accumulations, and low ice velocity, and occupy bedrock hollows.

The development of Radio Echo Sounding (RES) in the late 1950s was driven by the necessity to measure ice thickness in a rapid, accurate, and continuous manner. RES provides information on electrical properties in ice, enables the study of ice-sheet surface form, thickness, internal structure, dynamics, thermodynamics, and basal conditions and processes [12].

Most of the lakes beneath the Antarctic ice sheet are located near Dome C in Eastern Antarctica [11]. Several very large lakes, up to 8000 km^2, have been discovered [12]. RES studies do not allow the depth of these lakes to be determined; however, the minimum thickness of a fresh-water layer can be estimated by the skin depth necessary for radio reflection [12]. Some of these lakes may have a minimum depth of 6.5 m.

The sub-ice lakes of Antarctica may have formed more than 5 m.y. ago [11]. This age is based upon deep-sea cores taken in the Ross Sea that indicate that the main Antarctic ice sheet has changed little in size since a retreat some 5 m.y.

ago [13]. The existence of these polar lakes may provide yet another oasis for life. Once basal melting of the ice sheet started, it would supply a slow but steady influx of microorganisms deposited in the past on the surface of the ice [11].

The presence of sub-ice lakes below the martian polar caps is possible. Calculations [14] suggest that basal melting is currently an active process in the polar regions. It has even been suggested [15] that the catastrophic drainage of basal lakes formed Chasma Boreal.

The discovery of the Antarctic sub-ice lakes raises intriguing possibilities concerning martian lakes and exobiology. The polar regions of Mars, like those on Earth, may preserve organic compounds [16]. Dark organic-rich carbonaceous chondrites would melt, sink, and be buried in the ice. The burial process would protect the meteorites from decomposition. It is conceivable that the sub-ice lakes may provide a refuge for any microorganisms, which either survived the downward passage through the ice or existed before the emplacement of the ice. I agree with Clifford [14] and propose that a RES be flown on a future mission to provide information on the martian ice bedrock interface: ice thickness, internal structure, basal conditions and processes, and thermodynamics. RES techniques used in the Antarctic are capable of measuring ice thicknesses greater than 4 km. This would be capable of penetrating martian polar ice thicknesses.

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MARS OBSERVER RADIO SCIENCE (MORS) OBSERVATIONS IN POLAR REGIONS.

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Mars Observer Radio Science observations will focus on two major areas of study: (1) the gravity field of Mars and its interpretation in terms of internal structure and history and (2) the structure of the atmosphere, with emphasis on both temperature-pressure profiles of the background atmosphere and small-scale inhomogeneities resulting from turbulence (Fig. 1) [1]. Scattering of centimeter-wavelength radio signals from Mars' surface at highly oblique angles will also be studied during the primary mission; nongrazing scattering experiments may be possible during an extended mission. Aspects of each of these investigations will have implications for polar studies, especially since the radio path preferentially probes polar regions.

During the Mars Observer primary mission, measurements of the spacecraft distance and velocity with respect to Earth-based tracking stations will be used to develop models of the global gravity field. Doppler measurement accuracy is expected to be better than 0.1 mm/s for 10-s observation times; the resulting uncertainties in model coefficients will be comparable to or less than the values of the coefficients for all degrees less than about 50 (Fig. 2). The corresponding lateral resolution at the surface for fields of degree and order 50 should be about 220 km, leading to an order of magnitude improvement in knowledge of Mars' gravity field.

The improvement in knowledge of the gravity field will be especially evident in polar regions. The near-circular, near-polar orbit provides much better measurements at high latitudes than previous spacecraft orbits, which were ellipical and had periapses near Mars' equator. Study of long tracking arcs and evolution of the orbit through the two-year nominal Mars Observer mission may allow derivation of solar tidal forces exerted on the planet; the main tidal component likely to be sensed results in orbit perturbations with a period of about half of one of Mars' years. Seasonal variations in model coefficients resulting from redistribution of CO_2 between polar caps and the atmosphere are near the detection limit. Secular variations in J_2 may also be detected if Mars is not in hydrostatic equilibrium and the planet's shape is continuing to evolve.

The spatial and temporal coverage of atmospheric radio occultation measurements are determined by the geometry of the spacecraft orbit and the direction to Earth. The low-

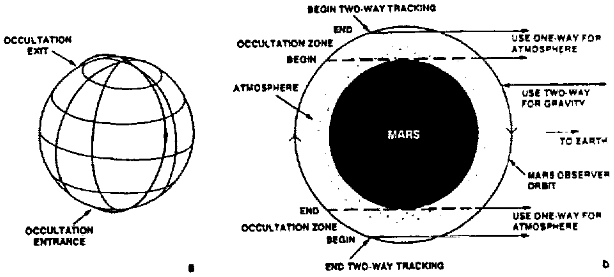

Fig. 1. Mars Observer geometry for Radio Science investigations. (a) Typical view from Earth when view angle is approximately 40° out of the orbit plane. (b) Sketch showing partition of orbit for gravity and atmospheric occultation observations.