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Climate Orbiter for Mars Polar Atmospheric and Subsurface Science (COMPASS): Deciphering the Martian Climate Record

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Abstract

We propose a Mars orbiter focused on deciphering the recent Martian climate record through the study of its ice deposits and their interaction with current climate.

1. Introduction

Mars' extensive ice deposits interact and record climate in a manner not yet fully understood. The stratified structure of Mars' Polar Layered Deposits (PLD) of water ice and dust (NPLD & SPLD) likely records climate over millions to tens of millions of years [1]. Surface water ice deposits that cover the NPLD interact with the current climate and may be the dominant source of water vapor in the annual global cycle [2]. Models suggest that depths to buried ice-sheets and pore-filling ice in the mid-latitudes should adjust with changing atmospheric conditions [3]. The geomorphology of a surficial CO_2 ice cap near the South Pole evolves by meters per year [4,5], and a buried CO_2 ice deposit at least equivalent in mass to the current atmosphere also resides here [6].

Despite decades of research, key knowledge gaps prevent a full understanding of the martian climate and how it is recorded in icy deposits. Interaction of the atmosphere with surface and subsurface ice depends on atmospheric humidity near the surface, yet water vapor has only been quantified in column-integrated measurements or at landing sites. Winds have never been systematically measured on Mars – introducing large uncertainties into the modeling of volatile transport. Buried ice sheets in the mid-latitudes have been detected by various means, but systematic measurements have not been made. PLD layers can only be viewed at heavily-mantled outcrops or in radar data that do not fully resolve them.

The Climate Orbiter for Mars Polar Atmospheric and Subsurface Science (COMPASS), is a NASA Discovery-class mission that will provide the key missing datasets to leverage and apply our understanding of terrestrial climate records and meteorology to Mars. COMPASS will study Mars from the subsurface through the atmosphere to definitively answer the question, "*How is the climate we observe today related to past climate variations recorded in Mars' ice deposits*?"

2. Science Objectives

Ice is the key to understanding past climate variations on Mars, because volatiles are sensitive tracers of atmospheric and surface temperatures through time [7]. Surface and subsurface ices interact with the atmosphere on different timescales, ranging from the seasonal CO_2 cycle to the multi-year advance and retreat of ground ice, to glacial/periglacial landforms and the polar layered deposits, which formed ~1 – 10 Myr ago [1,3,8]. The atmosphere acts as a conduit between these different ice reservoirs under changing conditions.

To fully understand past volatile exchange and the underlying climate forcings, COMPASS will observe present climate processes and volatile transport contemporaneously with measurements of icy reservoirs (Fig. 2) to achieve two science goals:

1. Understand interactions between the current climate and icy deposits
2. Map locations, quantify volumes and characterize layering of Amazonian-aged ice reservoirs globally

3. Proposed Mission Overview

The COMPASS mission accomplishes its science goals with four instruments (Figs. 2,3):

CROME (COMPASS Radar Observer for Mars Exploration), a dual-mode L-band radar (Fig. 2) to locate and resolve sub-meter scale layering within ice deposits on Mars. Buried ice will be detected by near-global Synthetic Aperture Radar (SAR) coverage. SAR data will also penetrate and characterize the dust that covers 30% of the martian surface, and overlies subsurface ice deposits. Layers of ice and dust within the PLD and buried mid-latitude ice-sheets will be examined in a radar sounder mode. At an order of magnitude higher vertical-resolution than MRO's SHARAD, these sounder data allow the detailed correlation of stratigraphic beds with oscillations of orbital elements.

AMCS (Advanced Mars Climate Sounder), a thermal IR limb sounder based on MRO's MCS [10] and LRO's Diviner will retrieve temperature and content of water vapor, dust, and condensates as a function of height. Nadir observations can monitor surface frosts and surficial thermal behavior to deduce the presence of the shallowest and lowest-latitude ground ice. AMCS will have twice the vertical resolution of MCS and new filters specifically designed to discriminate water vapor from the other atmospheric components.

WAVE (Wind And Vapor Experiment), a sub-mm limb sounder [11] allows the systematic measurement of winds for the first time. Two antennae observe the limb allowing for reconstruction of both horizontal velocity components as a function of height. Isotopic abundances will be tracked as tracers between sources and sinks of water vapor.

MAVRIC (Mars Atmosphere Volatile and Resource Investigation Camera), a wide-angle camera with a near-simultaneous stereo imaging capability, images limb-to-limb each dayside pass in visible and near-IR bands. Daily global coverage characterizes seasonal frost, clouds and dust storm evolution. Near-IR bands discriminate CO_2 and H_2O frosts, while visible bands discriminate dust and volatile clouds.

COMPASS will have a low-eccentricity sun-synchronous orbit at an altitude of 250–300 km and with 93º inclination during its one-Mars-year primary science mission. Such an orbit is naturally concentrated in the ice-rich higher latitudes and provides near-global coverage. An equator-crossing local time of 3 pm allows integration of the IR sounder and imaging data with the legacy datasets of MRO, Mars Odyssey and Mars Global Surveyor.

COMPASS brings together highly-experienced partners and high-heritage technology resulting in high science return at low risk and cost. The University of Arizona (UA) runs the PI office and Science Operations with experience from the Osiris-Rex mission and the Phoenix Lander. The Laboratory for Atmospheric and Space Physics (LASP) provides the Astrolabe spacecraft bus as well as mission management and operations. The Canadian Space Agency (CSA) contributes CROME based on Earth-orbiting heritage through industry partner MDA Corporation. The Jet Propulsion Laboratory (JPL) provides AMCS and WAVE based on heritage instruments in orbit around Mars and Earth. The Applied Physics Laboratory (APL) provides MAVRIC based on existing Mars systems. Our diverse science team is comprised of leaders in the field from throughout the US, Canada and Europe.

4. Figures

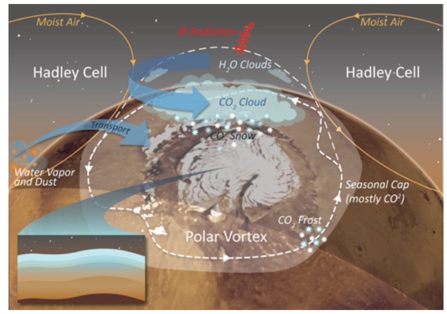

Fig. 1: COMPASS investigates interconnected processes in Mars' climate-ice system, including those illustrated here for the north polar winter. (Adapted from [9]).

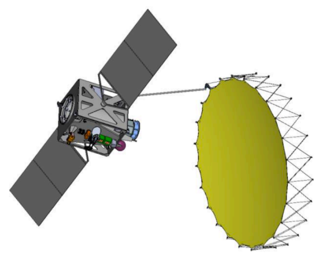

Fig. 2: COMPASS spacecraft with deployed six-meter mesh antenna. Orbital motion parallel to solar panels. CROME is located on the deck facing the antenna.

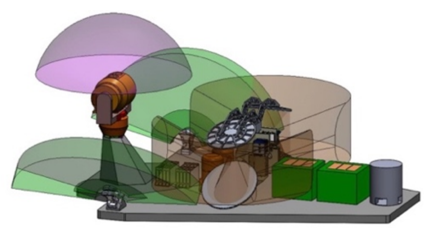

Fig. 3: COMPASS nadir instrument panel with FOVs indicated for AMCS (purple), WAVE (brown) and MAVRIC (green). Orbital motion into page.

References

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