DETECTION AND QUANTIFICATION OF VOLATILES AT MARS USING A MULTISPECTRAL LIDAR.

Introduction: We present a concept for using a polarizing sensitive multispectral lidar such as the ASPEN instrument proposed in [1] to map the seasonal distribution and exchange of volatiles among the reservoirs of the Martian surface and atmosphere.

Concept: The ASPEN instrument will be a multi-wavelength, altitude-resolved, active near-infrared (NIR, with 10 bands around 1.6 microns) instrument to measure the reflected intensity and polarization of backscattered radiation from planetary surfaces and atmospheres. The proposed instrument would be ideally suited for a mission to Mars to comprehensively investigate the nature and seasonal distributions of volatiles and aerosols. The investigation would include the abundance of atmospheric dust and condensed volatiles, surface and cloud/aerosol grain sizes and shapes, ice and dust particle microphysics and also variations in atmospheric chemistry during multiple overflight local times throughout polar night and day.

Figure 1 – Multispectral lidar concept in orbit around Mars, with science themes of Surface, Clouds and Dust

CubeSat opportunity: Although the full scale multispectral lidar requires a 1m receiver mirror that dictates space and weight of the instrument by today’s technological standards, an opportunity exists to carry out a pathfinder mission with a cubesat footprint similar to that used on the Lunar Flashlight mission [2]. Lunar Flashlight utilizes a multi-band laser reflectometer to measure the surface reflectance, thereby demonstrating this multiband lidar concept on a small spacecraft in lunar orbit. If payload space becomes available in the coming decade for Martian cubesat class missions, for example as part of a SpaceX ridesalong mission, we would like to exploit this for a trispectral lidar (at least 3 bands) and perform a proof of the concept of the ASPEN mission that provides some of the science discussed here (e.g. high altitude H$_2$O clouds and lower spatial resolution surface H$_2$O ice) for a reduced cost.

Previous work with passive hyperspectral instrument: As reported in [3], we have used observations from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) of the north polar cap during late summer for four Martian years, to monitor the summertime water cycle in order to place quantitative limits on the amount of water ice deposited and sublimed in summer. The most compelling result of this map is that we have identified regions and periods of 'net deposition' and 'net sublimation' on the summer north polar cap. Regions of the cap undergo a 'mode flip' from sublimation to deposition mode and the timing of mode flips is latitude dependent. This allows us to place firmer estimates on the dynamics by using the concept of depositional mode flips, a previously unknown observable that is also applicable to testing and verifying Martian Global Climate Models (GCMs).

H$_2$O index volatile tracking: Previous work has tracked the variations in the so called H$_2$O index [4-6] over the parts of the cap that received CRISM coverage throughout the summer period over four Mars Years. The index is based on the depth of the water ice 1.5μm absorption band. It is high when water ice is present, and grows with the water ice grain size. When deposition of fine grained ice occurs, the H$_2$O index decreases, because finer grained ice scatters light back to the observer more readily and in turn decreases the depth of the 1.5μm H$_2$O absorption band [7].

Applicability of a multispectral lidar: As described in detail in [1], a 10 band NIR multispectral lidar system can carry out the same measurements of atmospheric volatiles as CRISM in the polar regions, and is in fact more sensitive when the multispectral bands are chosen effectively. Not only will the lidar produce finer maps of the H$_2$O index (and a CO$_2$ index), but those indexes can be extended into the polar nighttime, thus extending our knowledge of the distribution of polar volatiles throughout the year. Finally, the lidar will provide time resolved measurements, allowing discrimination of clouds and fog, a task which is very difficult for CRISM and other passive instruments. As with the MOLA instrument, surface elevation can be measured to determine seasonal cap thicknesses and mass wasting processes on longer timescales.

Previous work on brightening of north polar cap: A long-standing problem of the Martian climate is the summer brightening of the north polar cap. This was first reported by Kieffer [8] using IRTM data, and subsequently observed with TES by Titus and Kieffer [9]. Bass and Paige [10] used IRTM and MAWD measurements to determine the peak of water vapor over the north polar cap. They found that the lowest visible albedo occurred during L$_s$=93-103$^\circ$ and water vapor was also released after L$_s$=103$^\circ$; however they could not determine whether this was caused by changes in water ice grain size or dust deposition.

Take home message: 1. Previous studies have identified regions and periods of net deposition and net sublimation on the Martian polar caps [3].

2. Studies such as [1, 4-6] have revealed the path forward for investigations into the transport of water in the Martian climate cycle. Using CRISM observations, we have now quantified the spring and summer water ice deposition for both poles. These measurements are crucial to our understanding of the construction and ongoing stability of the caps under today’s climate. However, there is a clear and pressing need to understand the fall and winter ‘dark side’ of the Martian polar region that is impenetrable to passive instruments like CRISM and MARCI and instead requires multi-wavelength lidar instruments such as the ASPEN concept discussed here.

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References: