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Motivation for Atmospheric Measurements of Water Ice using the Mars Science Laboratory Instrument Suite and beyond

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Abstract

The Mars Science Laboratory (MSL) Spacecraft has an excellent suite of instruments for near surface measurement of humidity, pressure, wind speed, down-welling radiation and the hydration state of the surface (REMS and DAN) [1]. We describe two sets of observations that can be conducted using the existing instrument compliment that would extend the science return to include observations of water ice. Each of our proposed experiments has been validated using existing data sets from spacecraft at Mars. We also motivate the use of onboard image processing for future landed spacecraft to enhance the value of atmospheric science return.

1. Introduction

While the MSL Spacecraft is not designed primarily as a vehicle from which to study the martian atmosphere, several of its instruments can be used to improve our knowledge [1]. For instance, the Mastcam (or Mahli) can be used to make observations of moving clouds to compliment the observation of wind speed close to the surface with the angular speed of features aloft. If these observations are captured in more than one filter, it becomes possible to make determinations about the ice-water content of the atmosphere [2]. As well, the LIBS laser system and MastCam can work in concert to perform active sounding of the lower atmosphere to investigate dust and search for water-ice fogs. Each of these measurements has been validated in flight using the Phoenix Lander [2,3].

2. Cloud Tracking Development

To improve upon the results from the Phoenix Mission, a cloud-tracking algorithm is being developed based upon the model of Choi [4] (Fig 1). This will allow cloud direction and angular speed to be more accurately determined and will allow cloud direction to be ascertained from non-vertically pointed images. Results from re-analyzing the Phoenix data set using this algorithm over the summer will be presented.

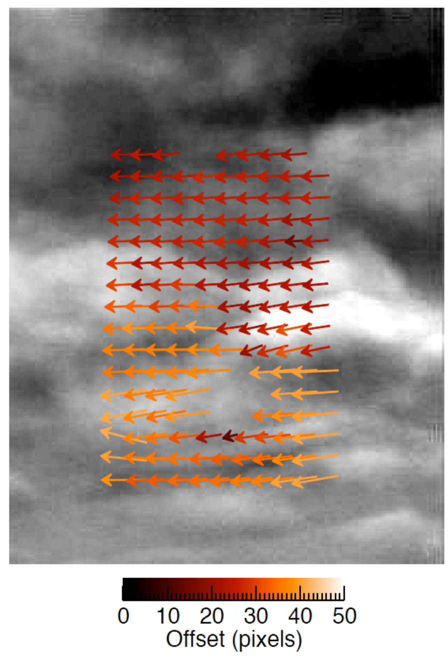

Figure 1: *Cloud Tracking Algorithm applied to a super-horizon movie on sol 128 of the Phoenix Mission. This is a relatively benign sol and we hope to extend our capabilities to the entire mission.*

For MSL this algorithm could be used on the ground. However, looking beyond, there would be significant advantages to using pre-processing onboard landed spacecraft. Atmospheric imaging is not power-intensive, but it can be data-intensive since the sky is a large and changeable target for observation. Realistically, only a few image sequences per day are returnable within data constraints [2]. Thus, Phoenix returned less than $1/10000^{th}$ coverage of the sky in time and space using the SSI. This meant that luck had to been relied on to find examples of unusual atmospheric phenomena such as precipitation (2 examples) and wind shear (1 example).

Despite this, many atmospheric measurements can be reduced to less data-intensive products. When clouds are not present, observations can be reduced to a single average pixel in each filter along with the statistical variation. When cloud streets or other simple cloud forms are present, the direction and angular velocity may be added. Failure of the algorithm would suggest interesting meteorological phenomena that could then be returned as full image sequences. Thus, it is possible to obtain vastly improved coverage of the atmosphere under the same data budget.

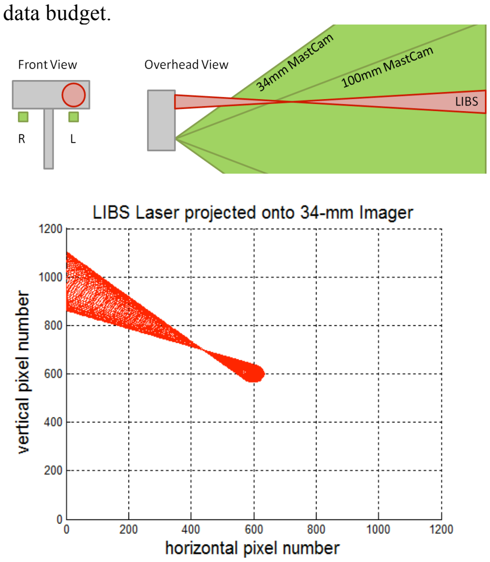

Figure 2: *Geometry of the active sounding technique (above) and the projected backscatter on the MastCam CCD for a 34-mm imager mounted opposite the LIBS window with the LIBS laser focused at 7-m (below). Note that angles are not to scale.*

3. Active Sounding using LIBS/MastCam

LIBS, when paired with MastCam, offers a powerful tool for sounding the atmosphere. The high energy pulses of LIBS and relatively fast capture frame rate of the MastCam can be paired using lucky frame imaging. While the LIBS fires at 1067nm where the MastCam Quantum Efficiency is low, the SNR is expected to be 28 or almost twice as high as the SSI observations of Fog (SNR=15). Additionally, range information is available from two sources. First, the spot size of the LIBS increases with distance past the focus point. Second, as with [3] there is a baseline distance between the MastCam and the LIBS laser, thus more distant laser illumination is displaced on the MastCam frame (Fig. 2).

4. Scientific Application of Techniques

Each observation answers fundamental scientific questions addressed by the MSL Mission. The observations of clouds help to constrain the local water cycle. Convective morphologies and vertical movement indicate local formation of clouds within the planetary boundary layer from near-surface water. Horizontal movement of clouds may indicate advection of water-rich air into the local environment. As well, the presence of fog overnight would suggest a direct and substantial interaction between atmospheric water and surface regolith. The potential presence of fogs and subsequent precipitation at MSL Candidate landing sites [5] has been suggested as a mechanism for forming Equatorial deposits of Water-Equivalent Hydrogen [6]. This mechanism is in dispute [7] and having in-situ measurements would help to settle the debate. Additionally, as similar measurements were performed using the Phoenix Lander, MSL gives an opportunity to expand this dataset to also consider equatorial latitudes.

References

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