# Developing and OSSE for Mars: The case for wind and water vapor profile sounding

**Principal Investigator: Leslie K. Tamppari (322)**
**Co-Is: Don Banfield (Cornell), Nathaniel Livesey (329), Bill Read (329)**
**Program: SURP**

## Project Objective:

The objective of this proposal was to construct the key components of an end-to-end *Observing System Simulation Experiment* (OSSE) suitable for quantifying the potential scientific value of new (proposed) vertically resolved observations of the Martian atmosphere from an orbital vantage point. Specifically, we quantified the utility of atmospheric wind and temperature profile observations made of a known, simulated atmosphere using a potential sub-mm wave sounder to determine wave structure in the atmosphere. Profile observations of winds and water vapor in the Martian atmosphere have not been achieved to date, and both have long been recognized as a key outstanding needs for advancing our understanding of the Martian atmosphere, as described in the Mars Exploration Program Analysis Group "Goals" document [1], and more recently in the Next Orbiter Science Advisory Group report [2]. This OSSE methodology allows demonstration that proposed instruments can (or cannot) meet the needed science objectives and allows for selection of the best observing strategies to meet those objectives.

## FY18/19 Results:

We produced both the "truth" dataset set sampled from the *Laboratoire de Météorologie Dynamique,* LMD, global circulation model output and a "Level 2" measurement data (also called "synthetic observations") set that applied averaging kernals and instrument noise estimates to the truth dataset to simulate actual instrument retrieved values (**Figure 1**). For the test case shown, we assumed the instrument had 2 antennas, each with 180 azimuthal articulation, covering ~360 in azimuth (T**able 1, Dataset** 1).

**Figure 1** shows a comparison of the "truth" and "synthetic obs" for the zonal means (left two columns) and the wavenumber 2 stationary wave (right two columns) of temperature (top), zonal wind (middle), and meridional wind (bottom). The "truth" dataset covered a little over a Mars month of data in late northern winter. The overall temperature structure (left 2 panels, top) agrees quite well, but there are locations where the synthetic observations are off by about 5K. The zonal mean zonal wind structure (left 2 panels, middle) also agrees quite will with the "truth" data, except that the chosen cadence of observations (148-sec scan that allows 5 deg latitudinal sampling) causes a "hole" in the polar vortex. The position of this jet stream is well-estimated, but the winds are not. This insight is valuable and argues in favor of choosing a more rapid scan to achieve denser latitudinal coverage. The zonal mean meridional wind (left 2 panels, bottom) shows a relatively poor match with the "truth" data, not only in magnitudes, but also in overall meridional structure. The cause of this discrepancy is not immediately clear and will require further investigation. The wavenumber 2 stationary wave results exhibit the same troubling latitudinal gaps as the zonal mean results, but in general have an overall better accord with the "truth". In all cases, a notable (but not unexpected) gap was apparent in the results for Z<1H (i.e., the bottom scale height of the atmosphere. This was a known and unavoidable weakness of the sub-mm sounding technique, but this OSSE analysis highlights its scientific impact.

**Table 2** and **Figures 2-4** show the sensitivity of the precisions on the retrieved water vapor, wind, and $^{13}CO$ as a function of varying atmospheric water vapor amount. The "Level 2" (or "synthetic obs") data used noise estimates based on moderate water vapor profiles, Case 1. For all cases, except Case 6, the water vapor signal to noise is about 10 for a single profile and only varies by a factor of ~5 even though the vapor amount varies by a factor of 40 (**Fig. 2**). **Figure 3** indicates that for all but the driest case, the single-profile wind precisions are all 10-20 m/s. **Figure 4** shows the precision on $^{13}CO$; the driest case (Case 6) yields about half of the signal to noise ratio as the other cases, below 20 km.

**Figure 1.** Comparison of "truth" to "synthetic obs."

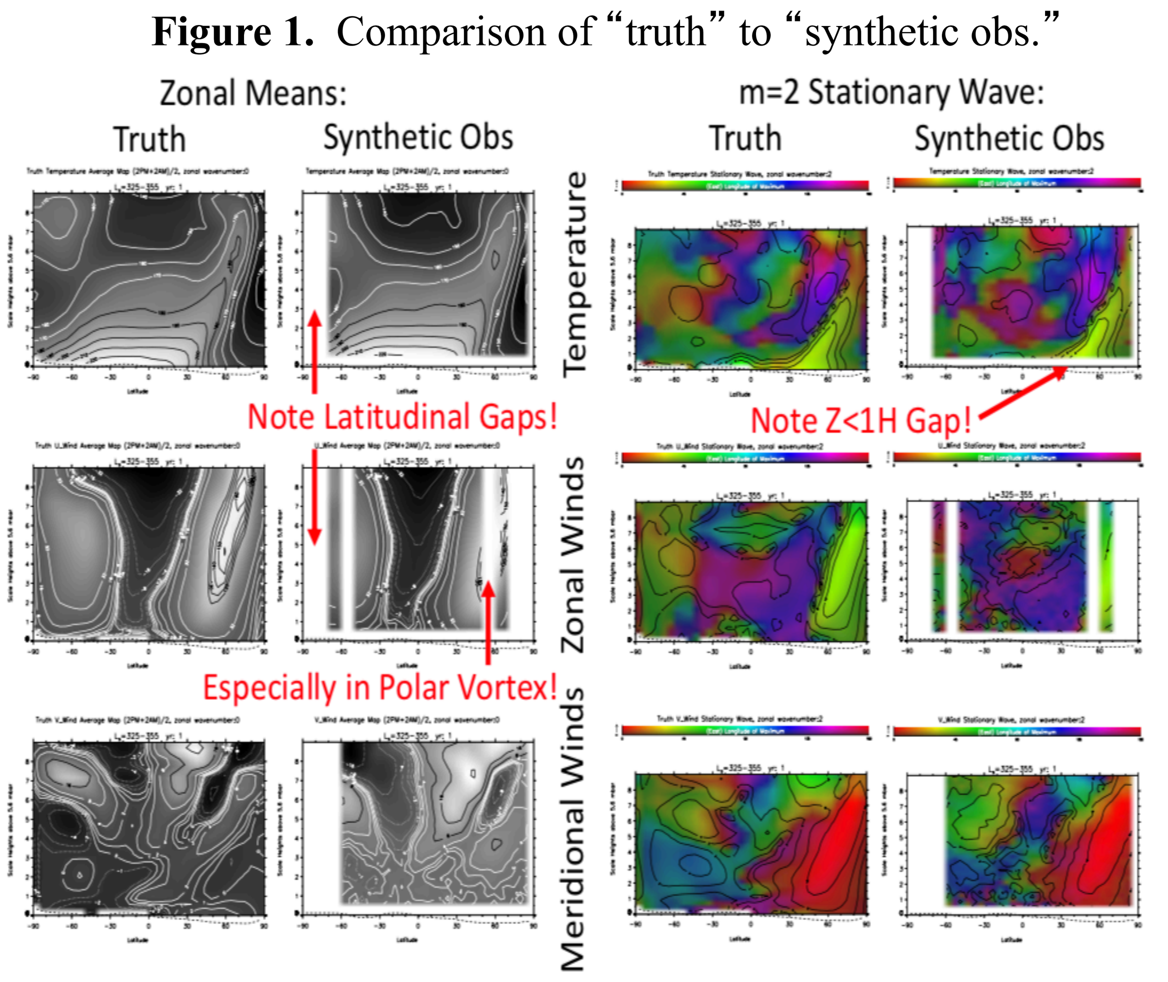


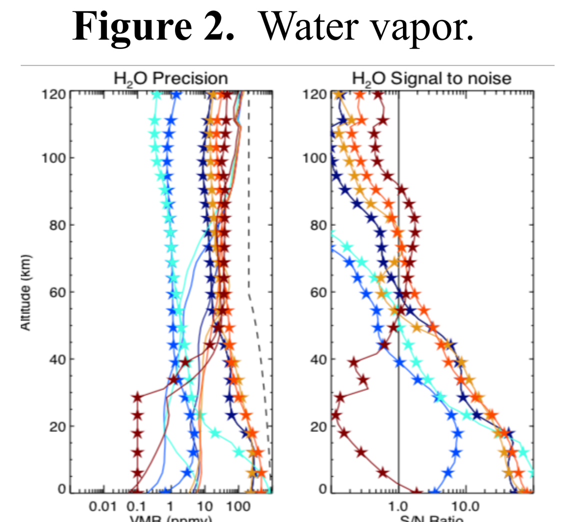

**Table 1.** Scenarios used in creating "synthetic obs."

| Dataset # | Antenna 1 orientation | Antenna 2 orientation | Orbit Characteristics |
|---|---|---|---|
| 1 | Azimuthal scanning such that zonal winds are measured at all latitudes, 5º spacing | Azimuthal scanning such that meridional winds are measured at all latitudes, 5º spacing | 300 km altitude, 92° inclination |
| 2 | 0° (ahead of spacecraft) | 90° (to the right of the flight direction) | 300 km altitude, 92° inclination |
| 3 | 45° | 135° | 300 km altitude, 92° inclination |
| 4 | 45° | 135° | 300 km altitude, 75° inclination |

**Table 2.** Six water vapor abundance cases used to examine precisions (signal to noise) on retrieved values.

| Case # | Latitude | Season | Reason | Figure 2 color |
|---|---|---|---|---|
| 1 | 0° | $L_s$ = 154° | Original case | Dark blue |
| 2 | 45° S | $L_s$ = 45° | Minimum water, column | Light blue |
| 3 | 72° N | $L_s$ = 110° | Maximum water, north | Cyan |
| 4 | 0° | $L_s$ = 180° | Medium water | Gold |
| 5 | 65° S | $L_s$ = 280° | Maximum water, south | Orange |
| 6 | 90° N | $L_s$ = 270° | Low altitude minimum water | Dark Red |

**Figure 2.** Water vapor.



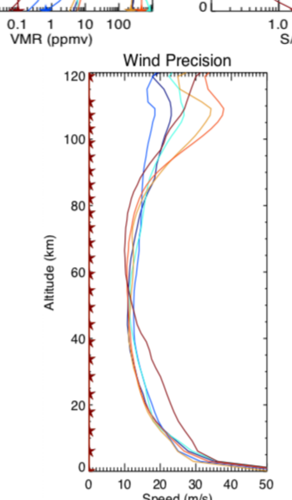
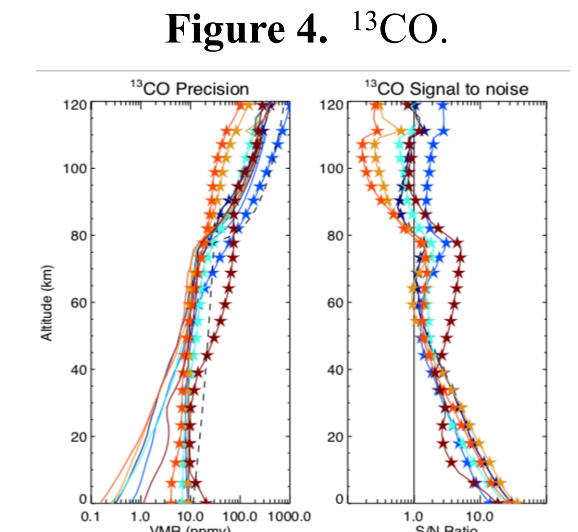




**Figure 3.** Wind.

**Figure 4.** $^{13}CO$.




## Benefits to NASA and JPL (or significance of results):

Never before has an OSSE been developed for Mars, nor has an atmospheric instrument for Mars been designed and optimized with an OSSE to ensure that the proposed instrument can achieve the specific scientific goals established for it. This approach, as demonstrated by our work, sets the standard for justifying an instrument in a mission proposal and for justifying instrument selection. We envision that developing this OSSE capability will be a competitive advantage for JPL instruments in near-term mission proposals (from cubesat to Discovery-class to any possible directed-mission instrument calls). In fact, our sub-mm instrument has been proposed as part of the COMPASS mission which was submitted to the Discovery program, and is currently being evaluated in the Step-1 down-selection process. Should the COMPASS mission be selected for the Step-2 competition, this work has the potential to ensure that the instrument is technically well-rated by demonstrating that it will be able to achieve the stated science measurements.

### References:

•[1] MEPAG, Mars Scientific Goals, Objectives, Investigations, and Priorities: 2015. http://mepag.nasa.gov/reports.cfm.

•[2] MEPAG Report from the Next Orbiter Science Analysis Group (NEX-SAG). http://mepag.nasa.gov/reports.cfm.

## Publications:

EPSC-DPS2019-1001, "Assessing Observability of Mars Wind using Various Options in Sub-mm Limb Sounding", Banfield, Tamppari and Livesey, 2019.

Acknowledgements: Mars Global Circulation Model output was generously provided by Dr. Francois Forget (*Laboratoire de Météorologie Dynamique*).

## PI/Task Mgr. Contact Information:

**Leslie Tamppari**
leslie.tamppari@jpl.nasa.gov
818-393-1226

**National Aeronautics and Space Administration**
**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California

**www.nasa.gov**



**Poster No. RPC-096**
**CL#-URS287287**