PHOENIX AND MRO COORDINATED ATMOSPHERIC SCIENCE. L. K. Tamppari[1], D. S. Bass[1], B. Cantor[2], I. Daubar[3], D. Fisher[4], K. Fujii[1], H. P. Gunnlaugsson[5], T. L. Hudson[1], D. Kass[1], A. Kleinboehl[1], M. Lemmon[6], M. Mellon[7], A. Pankine[1], M. Searls[7], F. Seelos[8], S. Smrekar[1], P. Taylor[9], C. von Holstein-Rathlou[5], J. Whiteway[9], M. Wolff[10], [1]Jet Propulsion Laboratory/California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA (leslie.tamppari@jpl.nasa.gov), [2]Malin Space Science Systems, Inc., San Diego, CA, [3]University of Arizona, Tucson, AZ, [4]Geological Survey of Canada, Ottawa, ON, [5]Aarhus University, Aarhus-C, Denmark, [6]Texas A&M University, College Station, TX, [7]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, [8]Johns Hopkins University/APL, Laurel, MD, [9]York University, Toronto, ON, [10]Space Science Institute, Brookfield, WI.

Introduction: The Phoenix Mars lander (PHX) spacecraft and the Mars Reconnaissance Orbiter (MRO) have collaborated during the course of the Phoenix mission to simultaneously observe the same atmospheric column with a variety of instruments. PHX carries pressure and near-surface air temperature sensors [1], an upward-looking LIDAR [2] that probes up to 20 km altitude, a wind telltale [3], a humidity sensor [4], and a multi-spectral camera that can be used to observe the atmosphere and obtains aerosol and water vapor amounts. The Mars Reconnaissance Orbiter carries four instruments that we employ in our coordinated campaign: the Mars Climate Sounder [5, MCS] which provides vertical profiles of atmospheric temperature, aerosols, and water vapor; the Compact Reconnaissance Imaging Spectrometer for Mars [6, CRISM] which provides column abundances of atmospheric aerosols and water vapor; the Mars Color Imager [7, MARCI] which provides very wide-angle, context views of the aerosols; the High Resolution Imaging Science Experiment [8, HiRISE] camera for examining frosts on the ground.

The coordinated campaign between the two spacecraft began shortly after PHX landed safely in the northern plains of Mars (68 N), in the Martian late springtime (Ls=76) and continued nearly 5 months (to Ls~150), through the PHX extended mission (and with MRO measurements continuing slightly longer). The campaigns were structured to provide both diurnal and seasonal observations focussed on water vapor, water-ice clouds, and dust to gain insight into some of the major outstanding questions such as (a) what are the relative roles of the different reservoirs of water, (b) is there net water transport out of this region, (c) what is responsible for the internnual variability in the atmospheric aerosols, and (d) what is the relationship between the dust, water and CO2 cycles? The use of two spacecraft to examine the same atmospheric column allows cross-calibration of experiments. Additionally, MRO supplements PHX by providing the context in the northern polar region. PHX supplements MRO by providing the detailed measurements near the surface and a full set of information at multiple times of day.

To accomplish these atmospheric objectives, we defined a series of campaigns: dust and ice vertical distribution, dust and ice diurnal variability, water vapor vertical distribution and diurnal variability, sky brightness (for particle properties), and frost. Figure 1 shows the seasonal coverage and when observations within each of the campaigns were taken.

Each campaign was defined to have a minimum set of participating instruments as well as a minimum number of observations over the course of a diurnal cycle. In the beginning of the PHX mission, PHX did not observe outside of the ~8 am – 6 pm timeframe, and so did not achieve diurnal coverage. However, after the first 1/3rd or so of the mission, PHX was able to start taking some nighttime measurements. Apart from a few MRO spacecraft issues, the MRO instruments were able to take all desired campaign measurements. While a minimum set of experiments were defined, we typically, when able to acquire data, got all the desired experiments, not just the minimum set.

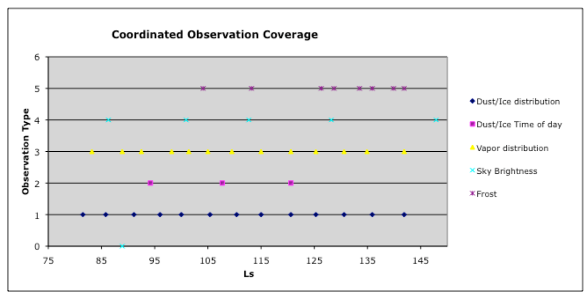

Figure 1. Coordinated atmospheric observations as a function of Ls.

Results: The campaigns were designed to take seasonal as well as diurnal observations. Preliminary results for each are provided below.

Seasonal observations. We observed water vapor, ice and dust over the course of the PHX mission. Past work has shown that water vapor column abundances increase in the north polar region in late spring, peak near Ls=110 and then decrease throughout the rest of the summer [e.g., 9, 10 11]. With PHX and MRO measurements, we will be able to derive water vapor column abundances, for comparison to historical quantities, with both the SSI camera and the MRO CRISM experiment. MCS will be able to provide vertical profiles of water vapor. In addition to these measurements, PHX carried a humidity sensor (TECP) that provided near-surface measurements. As of this writing, only CRISM and TECP measurements are retrieved. CRISM matches with the historic values (Fig. 2), showing a gradual rise in column abundance through Ls=110 and then a decrease. The TECP measurements, taken within 2 m of the surface, do not show such a trend. Their variability is much higher indicating a non-uniform mixing ratio profile.

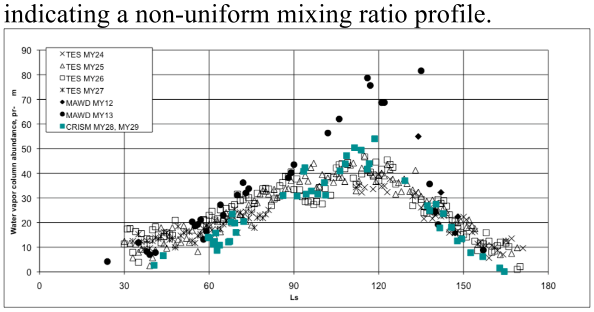

Figure 2. MAWD, TES, and CRISM column water vapor abundances for the PHX lat/lon location.

Past work has indicated that seasonal dust and water ice column amounts would decrease over the course of the PHX mission to about Ls=80 (ice) and Ls=110 (dust), remain low all summer, and then begin to increase again ~Ls=155-160 [e.g., 12, 13]. These coordinated measurements bear this out and Figure 3 shows that the CRISM and SSI measurements of optical depths compare well. The large dust events near Ls=140 are seen in MCS data as increased dust amount at higher altitudes as well.

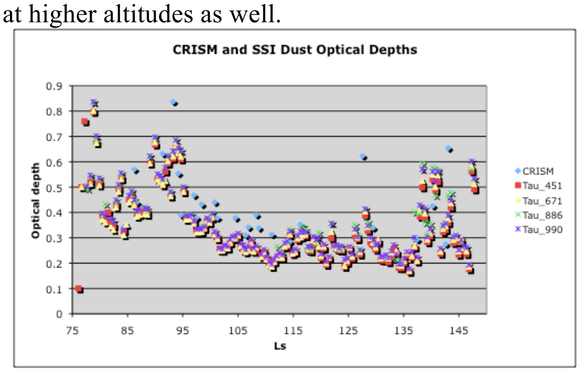

Figure 3. CRISM and SSI optical dust depths.

Diurnal observations. In addition to the seasonal coverage, we periodically obtained multiple measurements over a diurnal cycle. Since MRO is in orbit, it flies nearly over the PHX spacecraft twice per day (~3am LST and ~3pm LST). Marci, due to its wide FOV was able to observe the lander site at multiple times of day, but HiRISE and CRISM were only able to observe 2x/day. MCS employed the use of an azimuthal scanning mechanism within their instrument and as such, was able to observe at multiple times of day as well. Two such campaigns were on Sols 55 (~Ls=101) and 70 (~Ls=108) of the PHX mission.

Near Sol 70, a low-pressure cold-front crossed over PHX. The coordinated Marci images show dust being carried with this weather system, ice clouds, probably from nucleation onto dust particles, and cloud shadows enabling cloud heights to be measured. The PHX pressure measurements show the low-p system as well when the daily maximum pressures are compared to a seasonal pressure decrease rate. The MCS experiment can also provide some regional context by mapping each of their daytime or "3 pm" passes in the north polar region. A map done this way for this time period also shows enhanced dust to the N/NW of the lander site, as seen with Marci.

Dust optical depths for this storm were compared between the various instruments (MCS, CRISM, SSI). One issue was that the orbiter was not always able to roll to view directly over the PHX lander site. Given the non-uniformity of dust amounts within a dust storm, the exact pointing of the MRO experiments vs. where PHX looks can lead to different results making a direct comparison difficult. In many cases, the 3 am/3 pm MRO overflights were rolled a small amount to view the lander site as directly as possible. The 3 pm overflight on Sol 70 was such a case and the dust optical depths compare within errors at ~0.3.

Cloud heights can also be measured and compared between spacecraft. The PHX LIDAR detects cloud heights within the boundary layer, the MCS can see clouds at higher alititudes, and the Marci can measure cloud heights via cloud shadows.

Conclusions: We have an excellent data set of coordinated PHX/MRO measurements for studying the Martain polar atmosphere. Preliminary results show that, for the most part, the various instruments are providing comparable results. Throughout the duration of the observation campaign, we observed the peak of the water cycle, the minimum of the water-ice and dust cycle in this region, large dust events, and storm fronts.

References: [1] P. A. Taylor et al. (2008) *JGR-Planets* 113, E00A13 [2] J. Whiteway et al. (2008) *JGR-Planets* 113, E00A0, [3] H. P. Gunnlaugsson et al. (2008), *JGR-Planets* 113, E00A04, [4] A.P. Zent et al. (2009), *JGR-Planets*, *in press*, [5] D. J. McCleese et al. (2007), *JGR-Planets* 112, E05S06, [6] S Murchie et al. (2007), *JGR-Planets* 112, E05S03, [7] M. C. Malin et al. (2001), *JGR-Planets* 106, 17651-17672, [8] A. S. McEwen et al. (2007), *JGR-Planets* 112, E05S02, [9] B. M. Jakosky and R. M. Haberle, (1992), Mars, [10] M. D. Smith (2002), *JGR-Planets* 107, 5115, [11] A. Pankine et al. (2009), *JGR-Planets,* submitted, [12] L. K. Tamppari et al. (2008), *Plan. and Sp. Sci.* 56, 227-245, [13] M. D. Smith (2004), *Icarus* 167, 148-165.