Annual and Long-Term Mars Northern Seasonal Cap Recession Observed with MARCI. V. L. Auerbach[1], W. M. Calvin[1], P. B. James[2] , and B. A. Cantor[3] , [1]Geological Sciences and Engineering, LME 427, University of Nevada, Reno, NV 89557 (vauerbach4@nevada.unr.edu), [2]Space Science Institute, 4750 Walnut Street, #205, Boulder, CO 80301, [3] Malin Space Science Systems, P.O. Box 910148, San Diego, CA 92191.

Introduction: Mars' seasonal caps undergo a constant cycling between the north and south, causing retreat and condensation throughout a Martian year. By utilizing spacecraft images from Mars Color Imager (MARCI) aboard the Mars Reconnaissance Orbiter (MRO), the retreat of the northern seasonal cap can be measured and plotted to observe the changes in recession over a range of Mars Year (MY). We made new measurements to compare both the changes in recession over time, as well as detect and understand diversity in the cap boundary between years.

Background: By collecting and analyzing photographs taken of the surface of Mars from MARCI, the rate of recession of the seasonal cap can be observed between Mars years. Here, we focus on the retreat of the northern seasonal cap by examining images of varying solar longitude (L_s) values. By utilizing data recorded and analyzed previously, coupled with new measurements, we are able to compare recession rates over many Mars years. Piqueux et al. [1], provided analysis for MY 24 through 31 through collated data from the Thermal Emission Spectrometer (TES) aboard Mars Global Surveyor (MGS) and Mars Climate Sounder (MCS) on the MRO, James and Cantor [2], looked at the northern seasonal recession for MY 25 through images obtained by the Mars Orbiter Camera (MOC), and Appéré et al. [3], gives recession data for MY 28 from OMEGA. Here, we specifically compare the results we found to the retreat observed by Piqueux et al. [1] using temperature, as this paper recorded a larger number of Mars years analyzed, and provided a climatology average. By evaluating more recent observations, as well as looking at the different methods used for each, we are able to work towards establishing a climatological model for the optical retreat of the northern cap.

Methods: Previous efforts to monitor seasonal cap retreat used varying methods, including best fit circles, as well as hand drawing the boundary using connecting points [2,4]. Here, we use the latter method to distinguish the boundary. MARCI acquires ~ 13 image strips per day, with significant overlap at the poles. The raw images are calibrated and mosaicked together into daily color polar stereographic projections.

We look at "regions of interest" (ROIs) in order to capture the cap boundary for a particular L_s value. These ROIs were defined by detecting locations of vastly different albedo in ENVI software. These areas of high albedo were defined to be within the seasonal cap. Seasonal cap boundaries were distinguished from clouds by contrasting images over several days. Figure 1 illustrates one example near the end of the northern retreat season. By analyzing approximately every five L_s values for the period of cap recession (L_s 350 to L_s 80), enough data was collected to measure and plot the retreat of the northern seasonal cap for each MY. Once the ROI was drawn, data was converted into an average latitude (as well as standard deviation) for each L_s measurement through custom routines developed in MATLAB. The average latitude value was calculated for every five degrees L_s for four separate MY (31 - 34) and plotted against previous data for MY 25 and 29 [2,4].

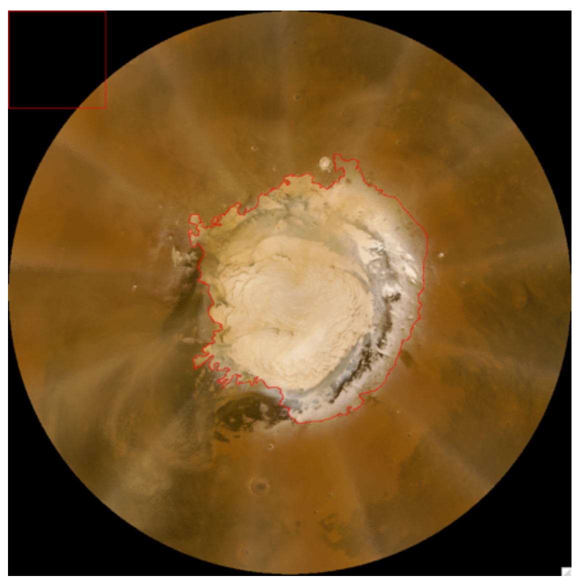

Figure 1: ROI depiction of L_s 80.1 from MY 34 on MARCI mosaic. This polar stereographic projection goes out to 55 degrees latitude at the edges of the image, with the center at 90 degrees latitude.

Data and Results: Similar to past work, we chose a linear fit model to represent the rate of recession of the seasonal cap boundary. This model worked reason-

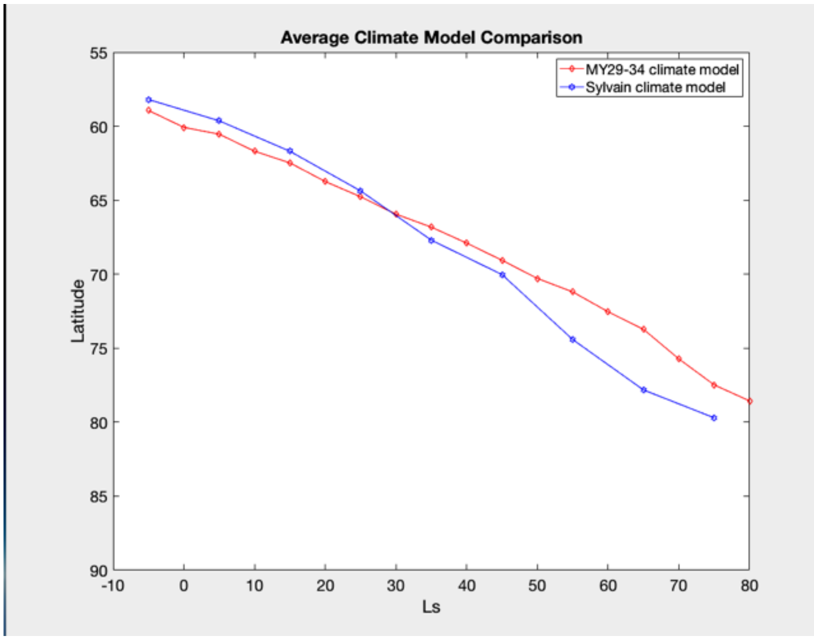

Figure 2: Average north cap recession for MY 29 through 34 from MARCI (red) compared to Piqueux et al.'s [1] climatological model for MY 24 through 31 of the same L_s values (blue). Negative 10 degrees L_s refers to L_s 350 of the previous MY.

ably well for the majority of years, showing initial average latitude values of approximately 57° at L_s 350, and final values nearing 80° latitude at L_s 80 for each year. We found that the uncertainty in average latitude is of order 1°, so that linear fits are nearly identical within the average latitude uncertainty. The cap edge retreat rate (slope of the fit) is fairly consistent for most Mars years. For the thermal data, Piqueux et al. [1] bin the data into a 1° x 1° grid, for map projections and assume an "equivalent" latitude if the cap were perfectly circular and centered on the pole. This equivalent latitude is used to fit an average, climatology model of retreat. We created a single climatological model as an average of all recession values for MY 29 through 34, each of which was created through this ROI methodology; this model is compared to Piqueux's climate model for the same L_s values, and is shown in Figure 2. Piqueux's model appeared to recede faster than the model we developed, as it began at a lower latitude boundary, yet the final boundary at L_s 80 was at a higher latitude, with the models crossing near L_s 30.

Differences between the thermal and optical average retreats may be due to several factors. First, the optical data use an average, rather than "equivalent" latitude. This may explain the small differences from L_s 350 to ~35. Second, the thermal data use temperature as a proxy for seasonal frost, where the optical data cannot distinguish between water and CO_2 ices, as both are high albedo. It is likely that the MARCI cap includes late water ice, and that this frost remains after the seasonal CO_2 has ablated, hence the appearance of a slower late retreat using MARCI. Finally, we note that north cap recession becomes asymmetric in both optical and thermal data near L_s 60, which may contribute to the larger differences at later L_s. In MARCI images, the cap boundary was found to be fairly circular in the early recession season, but became more and more asymmetric as time progressed. As shown in Figure 1, by L_s 80, frost persists longer over Olympia Planitia and the hemisphere adjacent to Gemini Scopuli. This asymmetry may be due to topographic features, such as elevation, or other variations in climate, and will also cause a stronger difference between our average latitude and the circular equivalent used by Piqueux et al. [1].

Further Research: The recession of the northern seasonal cap boundary using the average latitude linear fit model works fairly well; however, the asymmetry in the cap retreat goes unaccounted for with this technique. Future work will explore whether the asymmetry is similar in all MY and if so, in which locations. We hope to link late frost to underlying geologic units or surface materials. This will allow for a more complete view of the atmospheric interaction with the surface during northern seasonal cap recession. We expect to explore cap recession by quadrant as well as by local elevation in order to understand this phenomenon.

References: [1] Piqueux et al. (2015) *Icarus, 251*, 164-180. [2] James P. B. and Cantor B. A. (2001) *Icarus, 154,* 131-144. [3] Appéré et al. (2011) *JGR, 116,* doi: 10.1029/2010JE003762, 2011 [4] Calvin et al. (2015) *Icarus, 251,* 181-190.