Characterizing Martian Crater Circulations with the NASA Ames Mars GCM

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Abstract

Observations made in Gale Crater by instruments on the MSL Curiosity Rover show that the diurnal amplitude of the surface pressure is increased and the depth of the Convective Boundary Layer (CBL) is decreased relative to other lander locations on flatter regions of Mars (Haberle et al., 2014; Moores et al., 2015). Mesoscale modeling studies of Gale Crater suggest that crater circulations produce these effects. Tyler & Barnes (2013) show that local upslope/downslope flows along the crater rim and Mt. Sharp amplify the diurnal pressure cycle. These same flows are thought to be at least partly responsible for the suppression of the CBL because upward air flow at the rim and in the center (due to Mt. Sharp) forces subsidence over the lowest regions of the crater during the day. Regional flows, largely due to the location of Gale near the dichotomy boundary, may also play a role in shaping the circulation internal to the crater. Whether the behavior of the CBL and the amplified diurnal pressure cycle are phenomena observed in craters morphologically different from Gale (i.e. bowl-shaped, irregular, degraded) is not yet understood. We will explore these questions by characterizing the behavior of these processes as they are shaped by the morphology of craters greater than 100 km in diameter. We use the NASA Ames Mars Global Circulation Model (GCM) that now utilizes the NOAA/GFDL cubed-sphere finite-volume dynamical core to examine ˜100 craters of varying size and shape from a database of known Martian craters (Robbins & Hynek, 2014). Run at 7.5 km resolution, the GCM is capable of resolving surface winds, temperature, and pressure inside craters of this size allowing for the analysis of dozens of craters simulated at various seasons and within the context of synoptic and global-scale phenomena.

Characterizing Martian Crater Circulations with the NASA Ames MGCM

National Aeronautics and Space Administration

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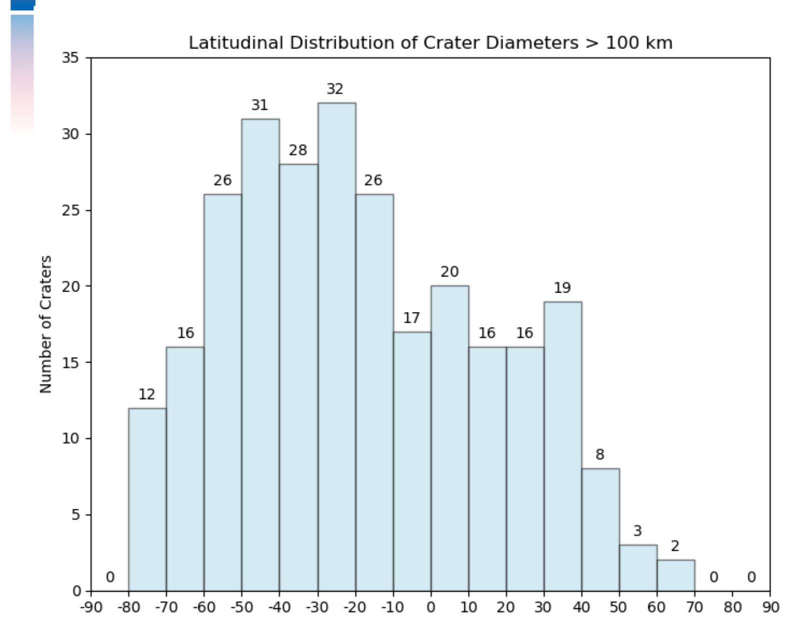
Introduction

Observations from the MSL Curiosity Rover show the amplitude of surface pressure in Gale Crater is increased and the depth of the Convective Boundary Layer (CBL) is decreased relative to observations in flatter regions of Mars (Haberle et al. 2014; Moores et al., 2015).

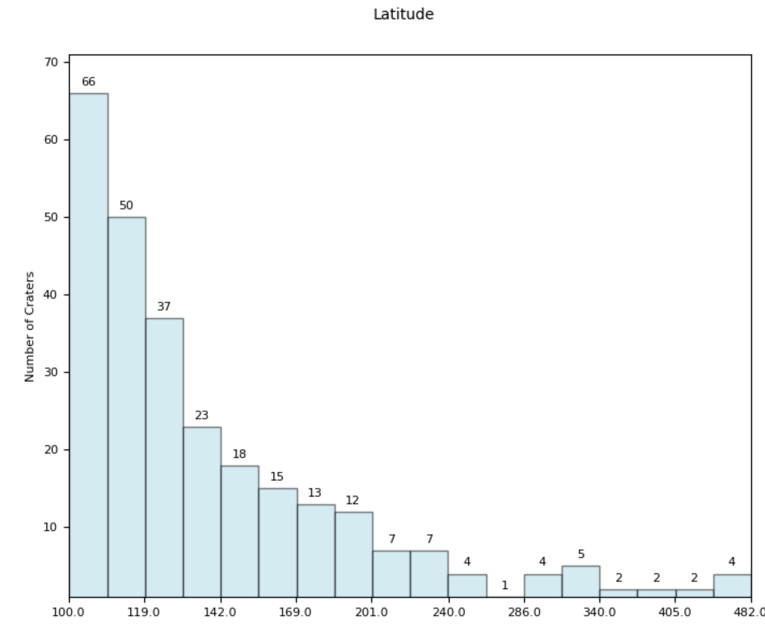
Mesoscale modeling suggests that crater circulations produce these effects (Tyler & Barnes, 2013). The local upslope/downslope flows along the crater rim and Mt. Sharp are at least partly responsible for the suppressed CBL as these flows amplify the diurnal pressure cycle and force subsidence over the lowest regions of the crater during the day. Regional flows due to Gale being near the dichotomy boundary might contribute to the suppressed CBL as well.

Whether craters that are morphologically different from Gale (i.e. bowl-shaped, degraded, irregular) and/or located in higher latitudes produce similar phenomena is unknown. We explore these questions using the NASA Ames Mars Global Circulation Model (NASA Ames GCM) to simulate atmospheric flows in craters greater than 100 km in diameter with varying topographical and locational characteristics.

Crater Characteristics



Most of the documented craters are located in the southern hemisphere tropics, just south of the dichotomy boundary.



The size distribution of the craters used in this project. Craters with diameters near the 100 km cutoff are more abundant than wider craters.

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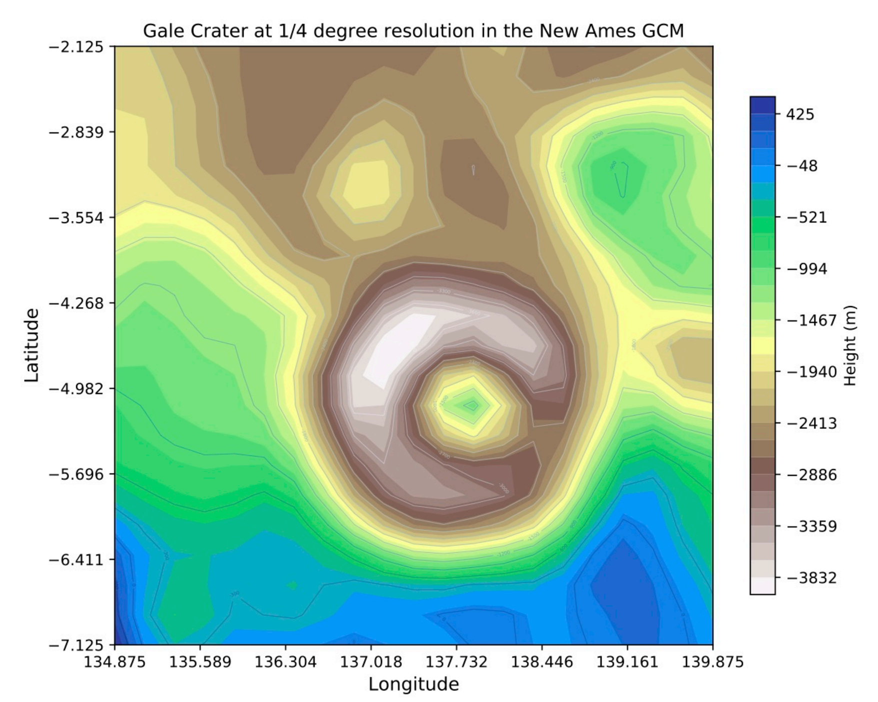
Project Plan

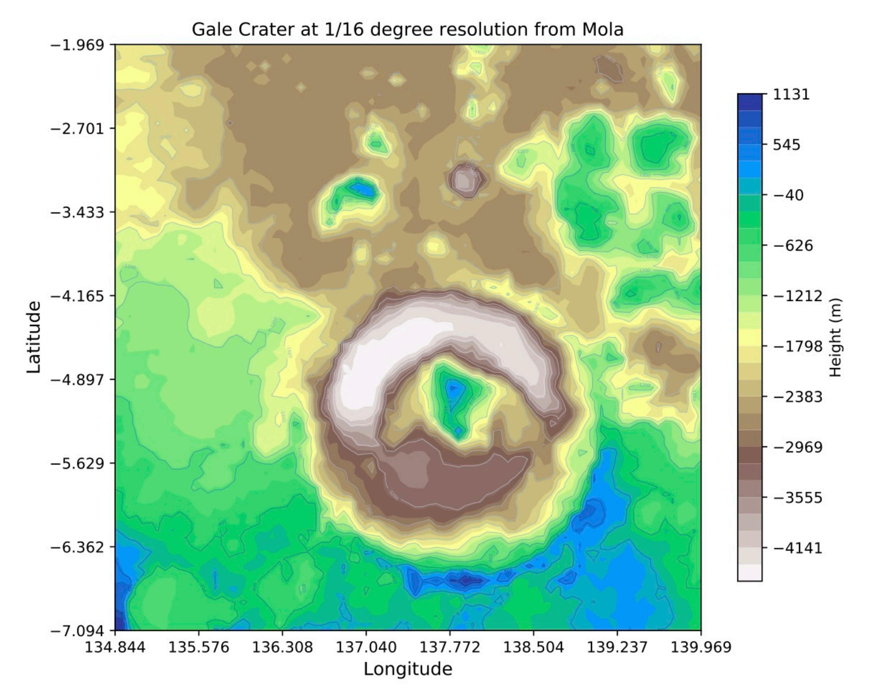
1. Choose a subset of craters of reasonable size and number from a list of known craters[1]
2. Tune the NASA Ames GCM
   - Tune the CO2 cycle
   - Find and identify known craters within the model
3. Sort craters by topographic similarities
   - Central peak
   - U - Shaped
   - Degraded
4. Simulate physical parameters that might influence local climate
   - Surrounding topography
   - Surface temperature
   - Surface pressure
   - Location (latitude)
   - Local season at aphelion/perihelion
   - Net solar radiation
5. Characterize crater circulation patterns

Project Goals

- Reproduce suppression of the CBL & enhanced pressure cycle in model simulations
- Identify the main force suppressing the CBL & enhancing the pressure cycle in Gale Crater
- Determine whether these effects are unique to craters with central peaks (like Gale)

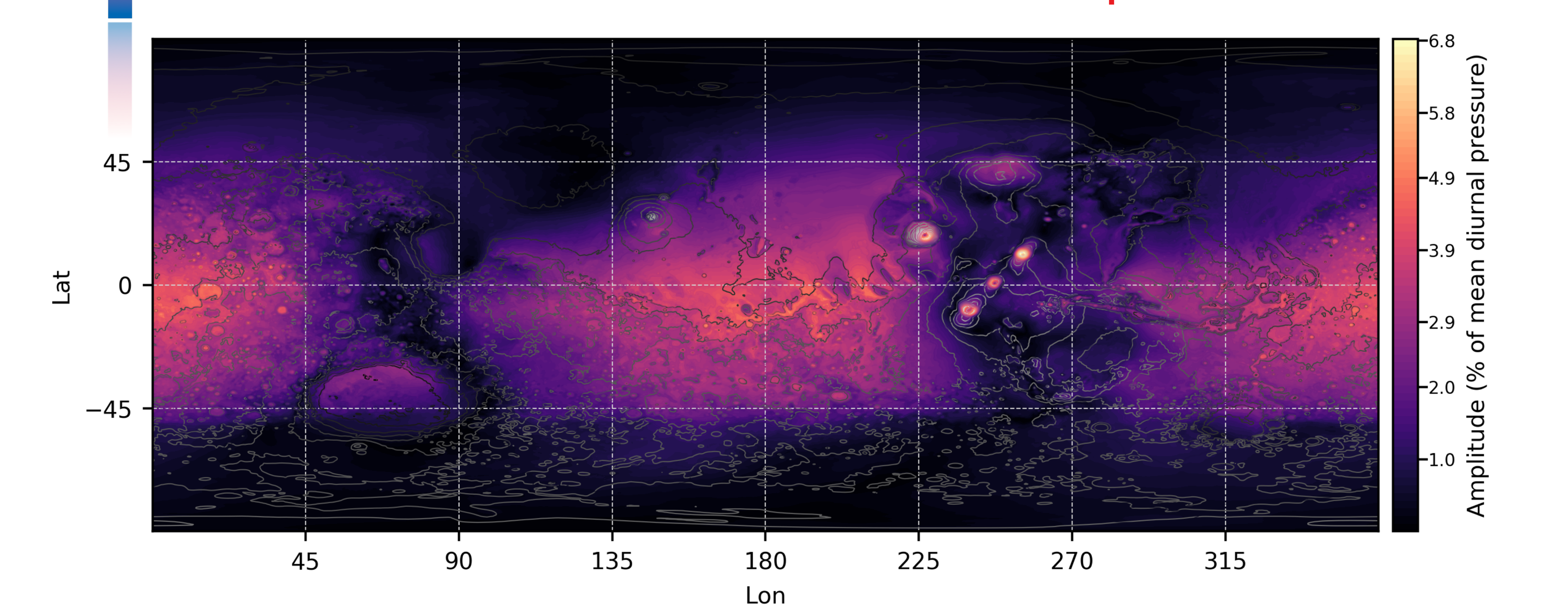
The NASA Ames MGCM





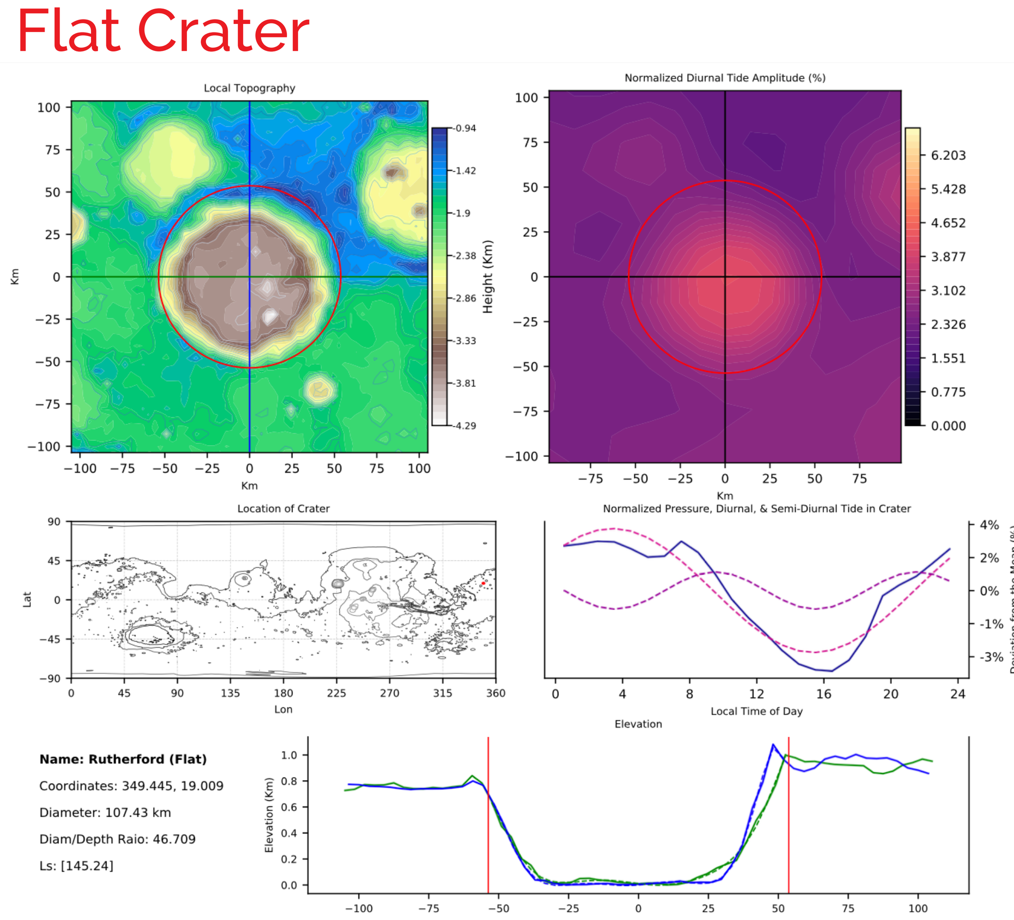
NASA Ames MGCM simulation of Gale Crater topography (¼° resolution). This new GCM uses the NOAA/GFDL cubed-sphere, finite-volume dynamical core and is capable of resolving surface winds, temperatures, and pressures at 7.5 km spatial resolution.

Global Normalized Diurnal Tide Amplitude

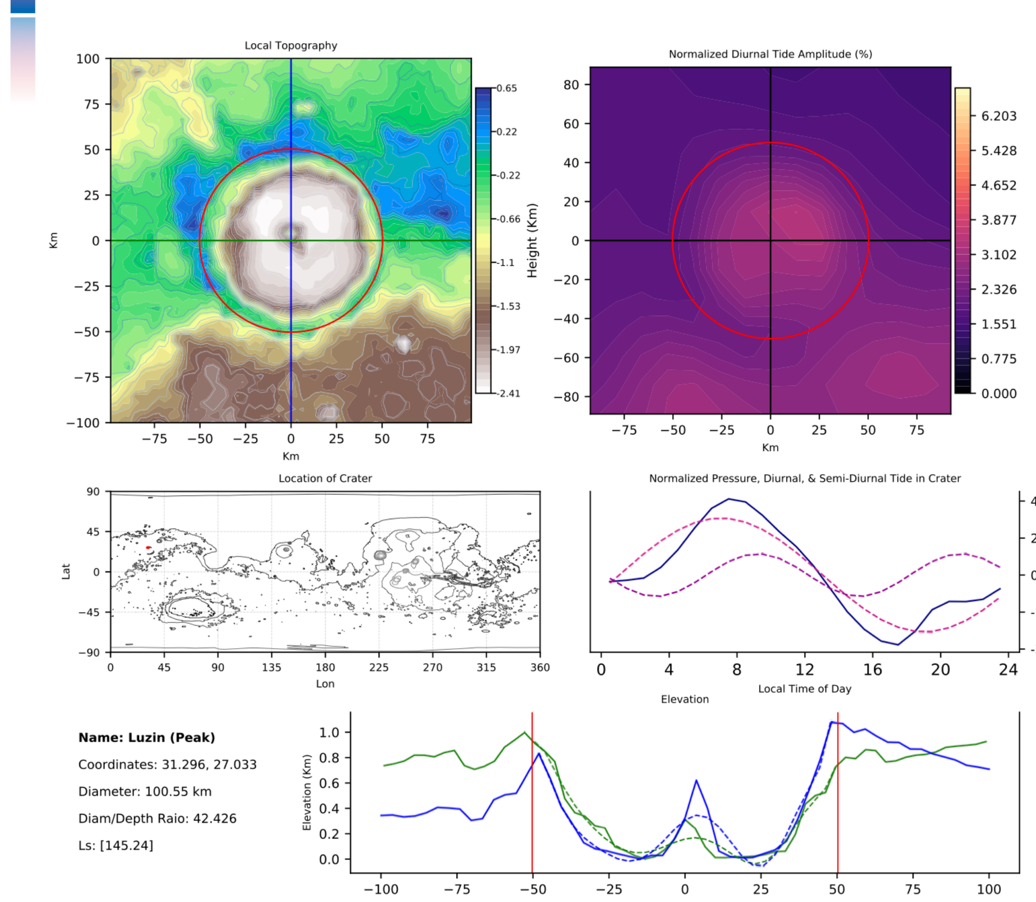


A simulated, normalized diurnal tide amplitude for Ls ~145 over the entire planet.

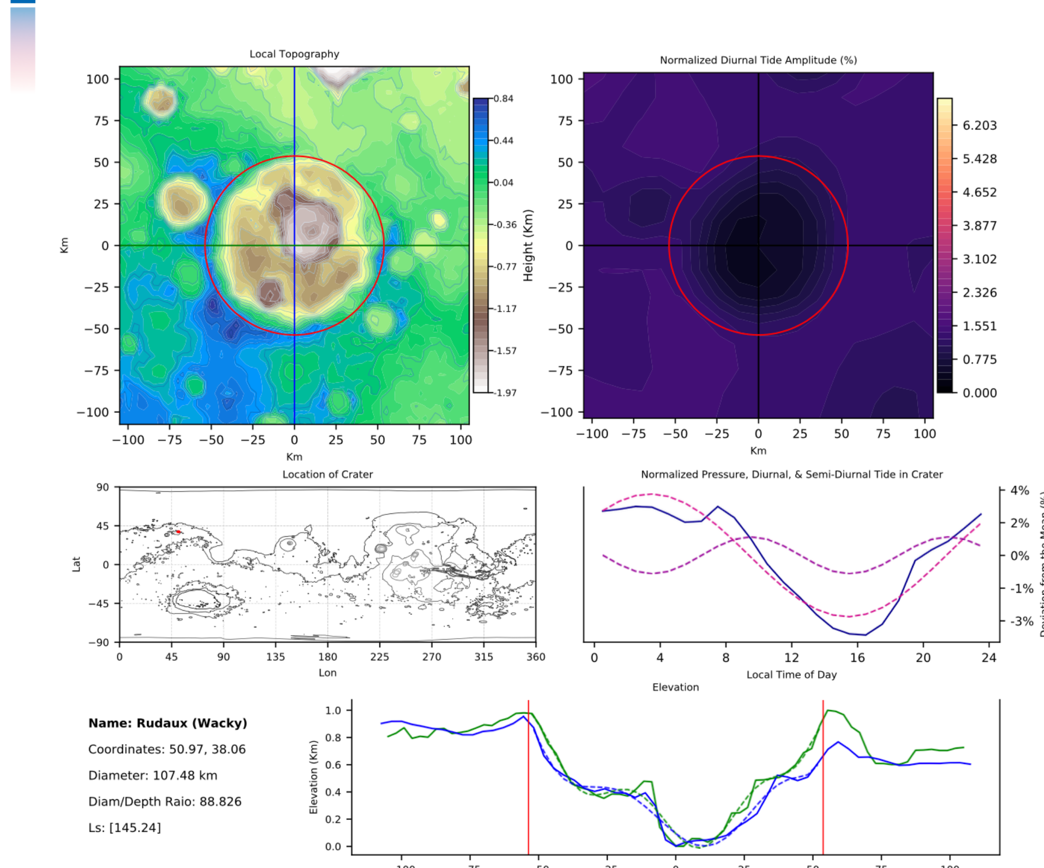
Flat Crater



Peaked Crater



Degraded Crater



Examples of the categorization of craters by morphology. A representative crater from each category (flat, peaked, degraded) is shown. Features include local topography, diurnal surface pressure, normalized diurnal tide amplitude in and around the crater, a cross-section of topography through the crater, and location of the crater on Mars.

(1) Robbins, S.J. & Hynek, B.M. (2012). A new global database of Mars impact craters ≥1 km: 1. Database creation, properties, and parameters. JGR Planets, 117(E05004). doi: 10.1029/2011JE003966

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