The meteorology of Gale Crater from an embedded mesoscale model into a global reanalysis and REMS observations. A. M. Valeanu[1] and P. L. Read[1], [1]University of Oxford, Atmospheric, Oceanic and Planetary Physics Clarendon Laboratory Parks Road, Oxford OX1 3PU, UK. email: valeanu@atm.ox.ac.uk.

Introduction: We study the circulation at Gale crater from the comparison between model and observations. The novelty of this work comes with the involvement of a global reanalysis to provide boundary conditions for a mesoscale model and the use of the Singular Spectrum Analysis (SSA) decomposition for accomplishing the comparison. The (correlative) eigenvectors extracted from the time series of observations and predictions show perfect agreement in the first two signals (diurnal and semidiurnal); an expected feature provided that a reanalysis is driving the mesoscale fields. The (noncorrelative) principal components show a larger amplitude for the REMS observations in comparison to model predictions. Hence the matching eigenvectors are simply amplified incorrectly by the model predictions. The rest of the SSA components (containing the remaining variance of the time series, i.e. terdiurnal correlations, quadiurnal correlations, etc) show an increased discrepancy between model and observations.

Motivation: As Gale Crater is close to the equator, its location motivate [1] to analyse atmospheric tides using a mesoscale model designed for Mars (namely the MarsWRF) in comparison to the atmospheric data from the Rover Environmental Monitoring Stations (REMS). The landing site of Curiosity, unlike the Viking landing sites, is ideal for studying atmospheric tides. This comes from the low latitudes of Curiosity which inhibits the REMS instrument from observing baroclinic waves (in contrast to the high latitude Viking landers). Instead, the meteorology of the region is actively locked to tides. This diurnal variability is altered by the rich and tight topography of Curiosity's landing site, making REMS valuable for studying the effects of topography on the regional atmospheric circulation, and for studying the smaller scale meteorological effects, such as orographic gravity waves, small scale convection, effects on the planetary boundary layer (PBL) and many others ([2][3][4] and more). Other studies focused on more direct effects of the crater, such as comparing the atmospheric tides in and outside the crater, and concluding that the topography simply amplifies the influence of the circulation outside the crater [5]. And many papers focused on the climatology that REMS observes, to try and simulate the environment that the rover encounters [3][6].

Methodology: The models. In order to accurately render Mars' general circulation and exotic planetary boundary layer (PBL) a realistic model was needed, with the best candidate being the UK version of the Laboratoire de Météorologie Dynamique (LMD) Mars GCM (which will be abbreviated MGCM) for its ability to assimilate satellite data. To deliver as much detail as computationally possible for comparison with REMS, we opted to embed the LMD Mars Mesoscale Model (abbreviated as MMM) into the output from the MGCM centred around Gale Crater, to spatially downscale the assimilated reanalysis. For such a feat, the MGCM was updated to assimilate satellite data at the spectral resolution T170L25 so that its output is feasible for driving the MMM by the provision of high resolution boundary conditions. The interface between the MGCM and MMM automates the use of both models, reducing the time spent on producing a full MGCM+MMM reanalysis to only computational (thus eliminating the time spent on cumbersome manual connections between the models). The embedded simulations from the MGCM+MMM configuration were carried out for 4 typical Martian seasons around Gale Crater, at a resolution of 80x80x60 grid-boxes of 5km side-lengths, covering a 400(km)x400(km) region surrounding the crater. Ulteriorly, the assimilated analysis was interpolated to the location of the Curiosity rover (situated in the crater floor) for comparison with in situ measurements.

The comparison. The REMS observations were rebinned to match the MGCM+MMM 2-hourly output and both time series were decomposed into eigenvectors and principal components, using the SSA method.

Results: The eigenvectors from the SSA method showed almost perfect correlations between the reanalysis and REMS observations in the diurnal and semidiurnal tidal components. The principal components were showed a larger amplitude for the REMS time series, proving that the differences in the first two tidal components between the reanalysis and REMS is almost completely noncorrelative. As the correlations are virtually identical between model and observations, we proved a previous result by [5], that the differences come from amplification effects from the crater topography. Taking previous studies into account [1][7], we connected the differences in the principal components to atmospheric dust and aerosol loading. An SSA analysis of REMS dust observations would be a practical addition to our analysis, however, the response of the first two tidal components to atmospheric dust and aerosol loading is so efficient that the amplitude of the semidiurnal tide was even used in estimating the global mean aerosol loading [7][8]. The other tidal components were influenced by local meteorological effects and their matching between model and observations was situational (in the spring season), but certainly not perfect.

Overall, the superposition of the diurnal, semidiurnal and terdiurnal tides offer an explanation to the evolution of the surface pressures and temperatures detected by REMS, and the local meteorology simulated by the reanalysis does seem to be periodic and correlated to the tides as well.

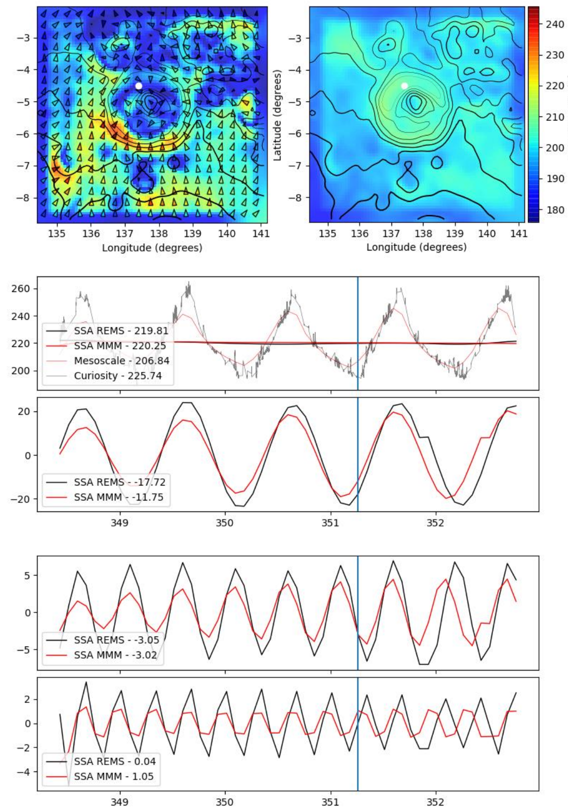

Figure 1: The SSA decomposition of temperatures from the MMM and Curiosity-REMS from the start of northern spring. The first two colour maps are MMM velocities (top left plot) and temperatures (top right) taken from a terrain-following interpolated layer, which is 5m above the local surface. The following 4 plots contain SSA reconstructions of REMS observations (black lines) and MMM values (red lines). The blue vertical line shows the frame from which the two color maps were extracted.

References: [1] Guzewich et al. (2016) *Icarus*, 268, 37-49. [2] Pla-Garcia et al. (2016) *Icarus*, 280, 114-138. [3] Rafkin et al. (2016) *Icarus*, 280, 114-138. [4] Kahanpaa et al. (2016) *JGR*, 121, 1514-1549. [5] Tyler D. and Barnes J. R. (2013) *MJ*, 8, 58-77 [6] Gomez-Elvira et al. (2014) *JGRP*, 119, 1680-1688. [7] Lewis S. R. and Barker P. R. (2005) *ASR*, 36(11), 2162-2168. [8] Zurek R. W. (1980) *JAS*, 37, 1132-1136.