DATA ASSIMILATION CHANGES LOW-LEVEL JETS IN MARS GCMS

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Introduction: The most comprehensive source of information about the dynamical state of the Martian atmosphere is the increasingly vast collection of infrared spectra collected by orbiting spacecraft. Temperature retrievals made from these spectra can be assimilated to produce reanalyses, which cover more variables and are more spatiotemporally complete than the underlying retrievals. The simplest physical explanation of why this process produces apparently reasonable results is that the temperature and horizontal wind fields are linked by thermal wind balance in a large fraction of the atmosphere.

Thus the temperature data underlying current reanalyses are most obviously informative about the baroclinic component of the flow—surface pressure fields would be informative about the barotropic flow [1] but because pressure data are quite sparse, to our knowledge no assimilation of real Martian pressure measurements has yet been attempted.

It is thus unclear how accurately Mars data assimilation systems reconstruct the barotropic component of the flow. Although this question is at least indirectly addressed in a number of previous studies [2-4], their results cannot be readily compared because of methodological differences.

In this study we aim to take a first step towards assessing the quality of barotropic flows in Mars reanalyses by quantifying how data assimilation alters low-level winds and surface pressures relative to free-running Mars GCM (MGCM) simulations. Implications of the findings for future reanalysis development and observational work are also discussed.

Reanalyses and free-running simulations: To enable assessment of the robustness of our findings to various choices made in the course of MGCM and data assimilation algorithm development, we examine both the Mars Analysis Correction Data Assimilation (MACDA, [5]) and the Ensemble Mars Atmosphere Reanalysis System (EMARS, [6]). The reanalyses use essentially the same temperature retrievals from the Mars Global Surveyor Thermal Emission Spectrometer (TES), but differ in many

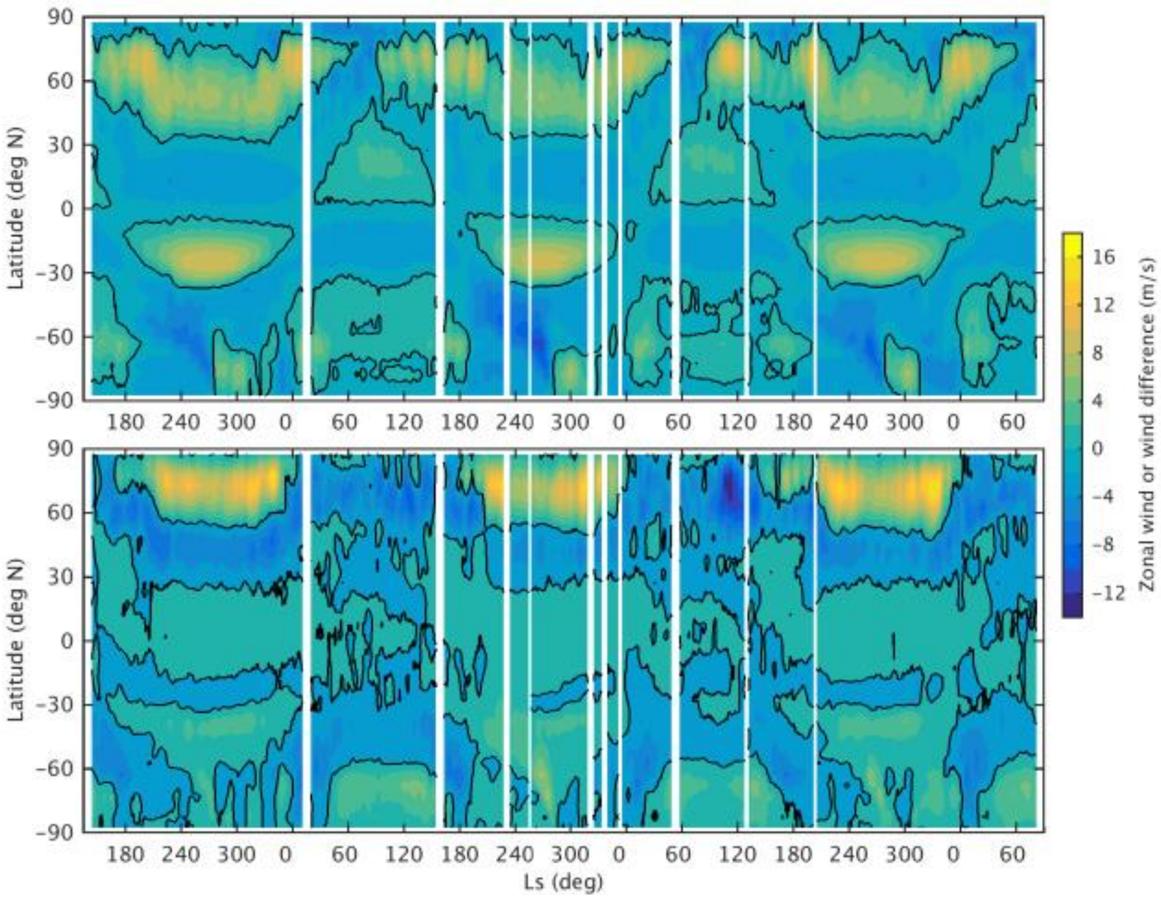

Figure 1: (top) MACDA zonal mean zonal wind on σ = 0.90, with a 10-sol running mean applied and the zero contour marked in black. MACDA begins at MY24 Ls 141° and ends at MY27 Ls 86°, notable periods of missing TES data are masked out. (bottom) Difference between MACDA control run and MACDA, plotting conventions otherwise similar to top panel.

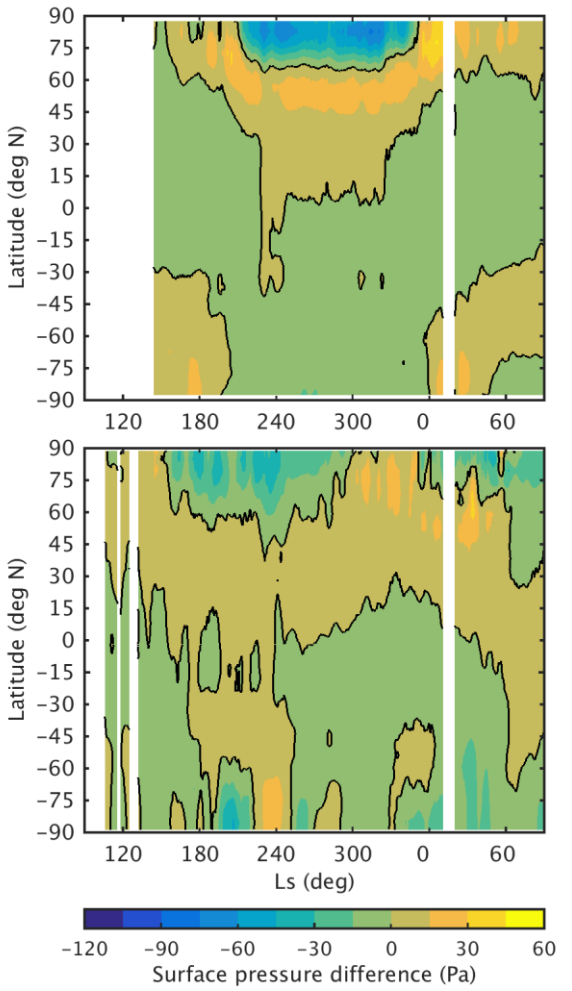

Figure 2: Zonal mean 10-sol running mean control minus reanalysis surface pressures for the UK MGCM/MACDA (top) and the GFDL MGCM/ EMARS (bottom). To emphasize the meridional structure of these surface pressure differences, the global mean difference at each timestep has been removed. Temporal extent of figure panels is one Mars year beginning at MY24 Ls 90°—the EMARS control run does not cover the full length of the associated reanalysis, unlike the MACDA control run.

other respects: for example, MACDA uses the analysis correction method with the UK spectral dynamical core MGCM, while EMARS uses an ensemble Kalman filter and the GFDL MGCM with a finite-volume latitude-longitude grid dynamical core.

Both products also have associated free-running control simulations, which differ from the reanalyses only in not assimilating temperature data. (Dust fields based on TES observations are used in both reanalyses and control runs.)

Results:

Low-level zonal winds: Zonal mean zonal wind information for MACDA on a model level ~90 m above ground is shown in Figure 1. The upper panel demonstrates that extratropical near-surface westerly jets are most prominent in northern winter. The lower panel shows that these jets are located farther poleward in the control simulation than in MACDA.

Inspection of a plot similar to the upper panel but for the control simulation (not shown) confirms that not only are its jets farther poleward, they have higher peak intensities. Assimilation of TES data into the UK MGCM thus weakens the northern winter near-surface jets and shifts them equatorward. Somewhat similar behavior is found in EMARS—data assimilation weakens the GFDL MGCM's jet on a model level ~120 m above ground, but a clear position shift is not evident (not shown).

Surface pressure: The circulation changes induced by data assimilation also manifest in the surface pressure field. Figure 2 shows the difference in surface pressures (control run minus reanalysis) for parts of MACDA and EMARS. These differences are qualitatively consistent with the jet differences and geostrophic balance. Data assimilation apparently has a smaller effect on the GFDL MGCM than on the UK MGCM, although it is unclear whether this is due to MGCM or assimilation method differences (or both). Interestingly, the seasonality of the data assimilation effect differs between the models.

Discussion: Assimilating temperature data into two MGCMs alters their low-level zonal wind and surface pressure fields. Changes are most prominent in northern extratropical winter and are interannually repeatable, at least for MACDA and its control run.

The jet differences between reanalyses and control runs imply differences in their zonal momentum budgets, which we are currently investigating for EMARS. As a byproduct of this analysis, we hope to estimate the degree of closure of the EMARS momentum budget. Because the Martian atmosphere obeys many conservation laws, calculations of budget closure should be usable as metrics of reanalysis quality [7].

Of course, the different MGCMs and reanalyses cannot all be correct. Further work is warranted on the implications of different possible near-surface wind fields for dust lifting and other climate and geologic processes. The ability of proposed missions such as Aeolus [8] to characterize low-level circulations should be evaluated. Furthermore, it may be possible to conduct a limited evaluation of reanalysis and MGCM surface pressure gradients using existing observations.

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