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Validating Mars GCMs Using High Resolution Ground-Based Observations

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Abstract

Validation of Global Climate Models (GCMs) for other planets requires observational data, but in-situ measurements are expensive and constrained to their orbit or landing site. We used archival Atacama Large Millimeter/submillimeter Array (ALMA) data to observe spatial distribution of carbon monoxide around Mars and compared this data to a simulated map generated by the Laboratoire de Météorologie Dynamique (LMD) Mars GCM. By comparing predicted concentrations in the GCM to actual observations, we can help refine the GCM and improve its predicting power.

1. Introduction

As a non-condensable gas with a long lifetime, [2] carbon monoxide lets us track dynamic patterns in the Martian atmosphere. In-situ observations of CO distribution in the atmosphere have taken place since the Viking Landers arrived in 1976 [5]. Observations from the handful of successful Mars missions have helped us understand the seasonal and yearly cycles of Martian CO. However, the data from these missions is constrained by their specific orbits and landing sites.

On the other hand, we can use observations from Earth to take full-disk snapshots of Mars, providing simultaneous data for the visible hemisphere of the planet. Full disk images help us check our modeled predictions against observations by letting us see the state of a full half of the atmosphere at once, rather than only the portion directly observable by the orbiters currently in operation. This research aims to serve as a proof-of-concept demonstration of the capacity for Earth-based radio interferometers to provide novel verification and validation pathways for GCMs of Mars. ALMA is particularly valuable in this capacity as its archive contains publicly available datasets of Mars from prior observations.

2. Climate Reference Model

The Laboratoire de Météorologie Dynamique, in Paris, France, has developed a GCM for Mars. Simulated data from this GCM can be found on the Mars Climate Database (MCD), which is managed by LMD [4]. To demonstrate our ability to use ALMA archive data as a validating mechanism for GCMs, we acquired data from MCD corresponding to the same date and time as our observations. Adapting this data to simulate what ALMA would observe on a given date, with appropriate adjustments to account for emission angle to the receivers, will provide a simulated target to which we will compare our observations.

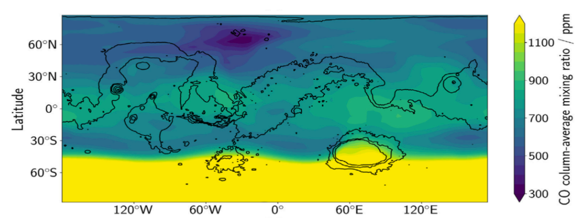

Figure 1: A Longitude/Latitude map of CO mixing ratio, as predicted by the UK version of the LMD Mars GCM. [3]

3. ALMA Observation

ALMA is representative of a new generation of Radio Telescopes. This generation of ground-based observations opens up the opportunity to provide spatial validation of GCM predictions that could previously only be provided by spacecraft at Mars. For our work, we are utilizing data already in the ALMA archive [1]. After generating an integrated flux (Moment-0) map of the 337GHz line for the $C^{17}O$ J = 3-2 transition, we can clearly see the spatial distribution of CO at the edge of the Martian disk, as shown in Figure 2.

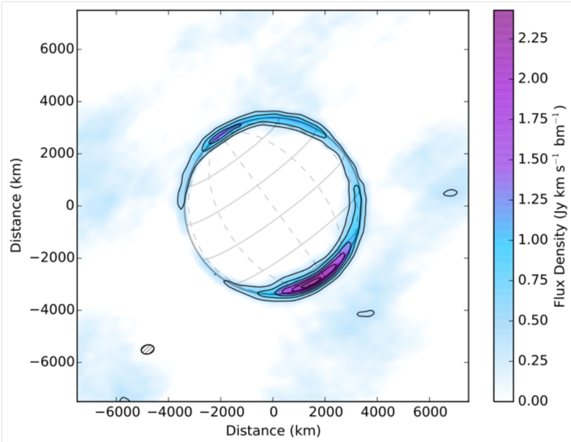

Figure 2: Mars $C^{17}O$ J = 3-2 Transition at 337 GHz. Observed on March 13th, 2016. L_s: 121.6

We will present a comparison of the distribution depicted in Figure 2 to the distribution predicted by LMD's Martian GCM, demonstrating the newly developed capacity of ground observations to help constrain and validate GCMs for Mars.

Additionally, the archival data we are working with have been set aside as unusable for their original science goals, as the observational parameters of these data prohibit the determination of an absolute flux scale - and thus a quantitative analysis of the CO abundance/temperature profile. However, the spatial resolution and relative distributions remain intact. The possibility of salvaging meaningful science out of data which were previously considered unusable is particularly exciting, as it further demonstrates the flexibility and utility of the publicly available datasets found in the archive.

4. Summary and Conclusions

Using ground-based radio telescopes to observe spatial distributions in Mars' atmosphere provides the Martian meteorological community a new tool with which to validate and refine our models. Ground based observations can provide global context to the spatially constrained measurements currently acquired by in-situ spacecraft.

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