Oh, Stormy Weather

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Overview

A highly anticipated and exciting capability of JWST is the ability to directly image exoplanet and brown dwarf companions with high accuracy. A main goal of these efforts is to measure the spectral variability of these objects in time and understand the dynamical processes in their atmospheres. To meet this demand, we use the Exo-FMS GCM to simulate a 10x Solar metal enhanced, directly imaged Jupiter containing a fully coupled cloud tracer scheme (à la Tan et al.), miniature kinetic chemistry scheme (mini-chem) and spectral correlated-k radiative transfer.

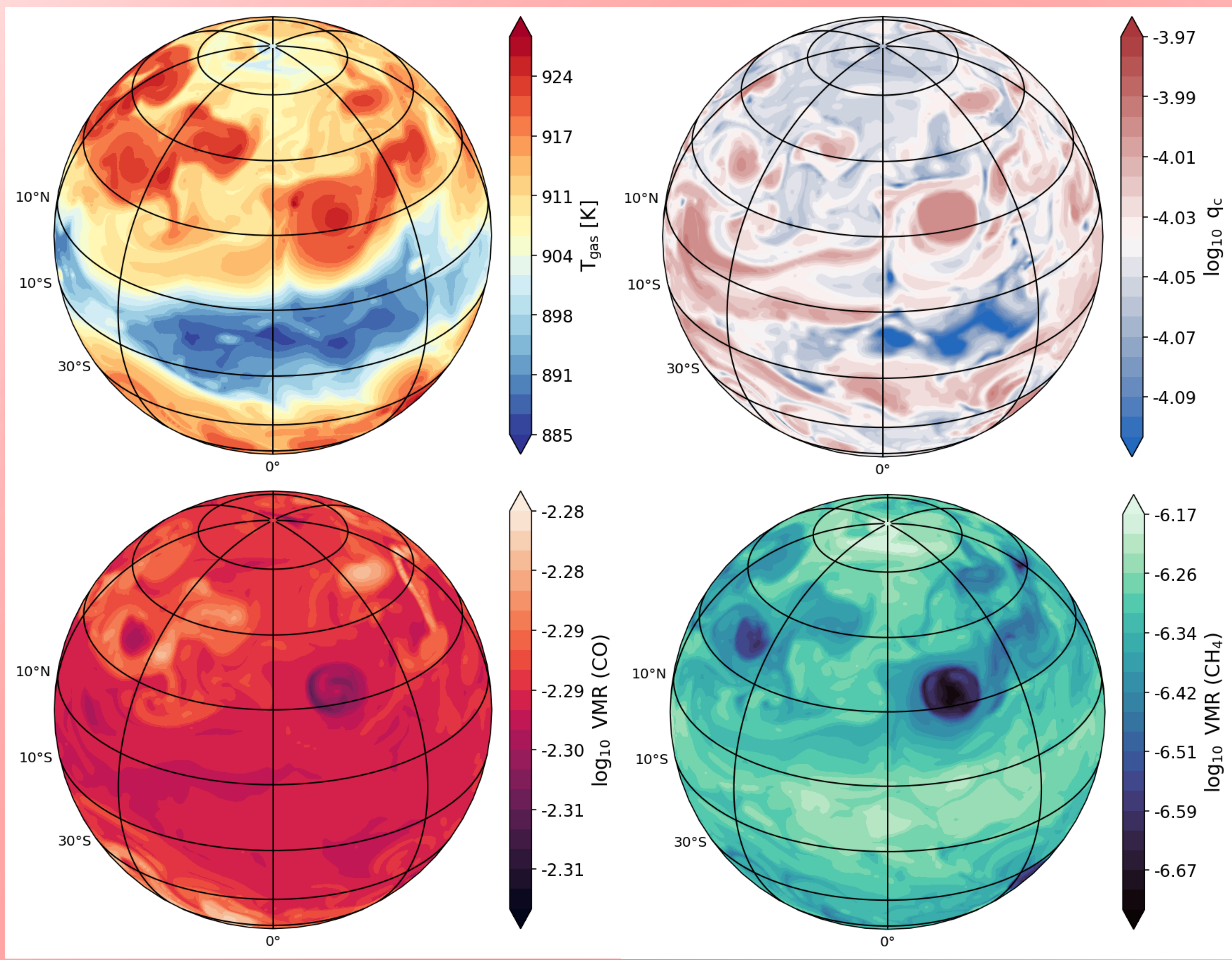

Figure 1. Output from the GCM at the end of the simulation at the 0.1 bar pressure level, showing the temperature (top left), condensed cloud mixing ratio (top right), CO volume mixing ratio (bottom left) and CH4 volume mixing ratio (bottom right).

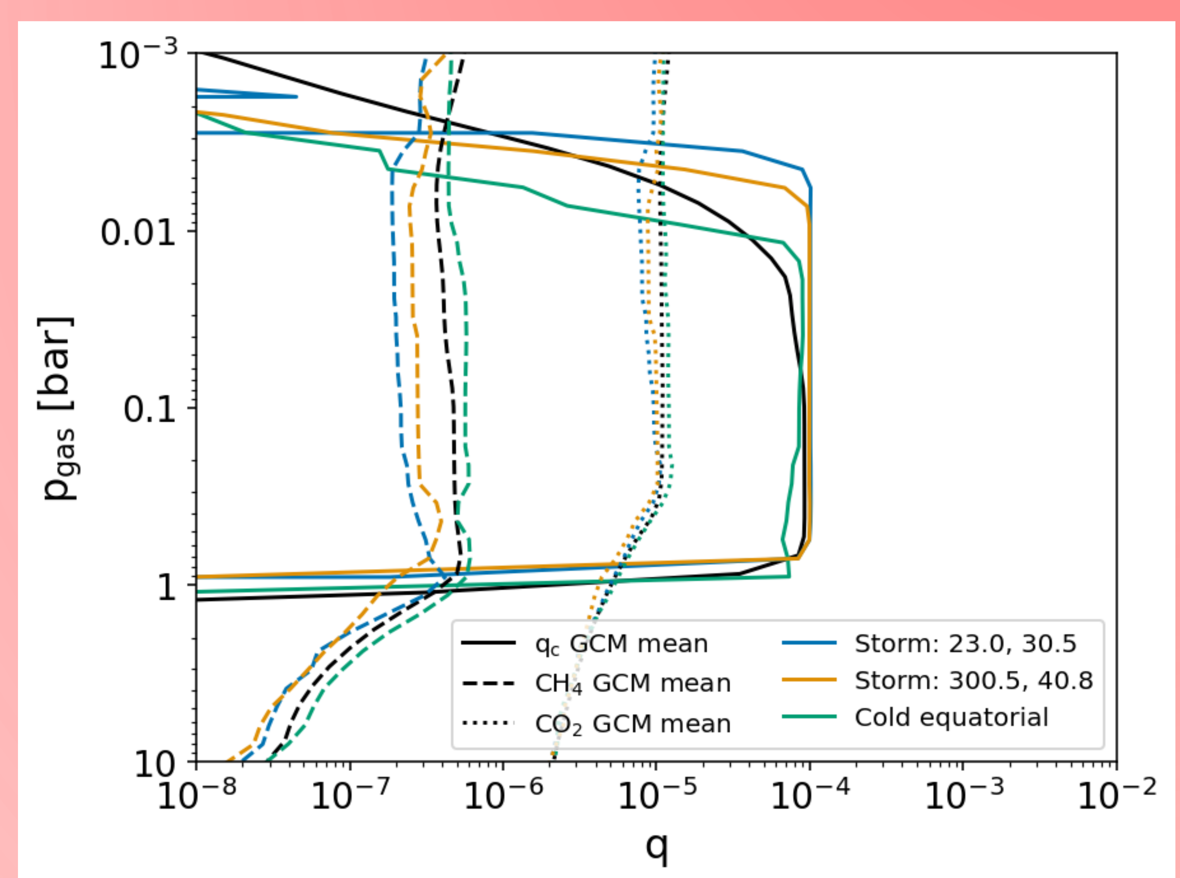

Figure 2. Vertical profiles of the condensed cloud fraction, CO volume mixing ratio and CH4 volume mixing ratio, comparing the global mean, storm regions and equatorial profiles. This shows a feedback between the clouds and chemistry, attributed to differences in the temperature and mixing profiles of atmospheric features.

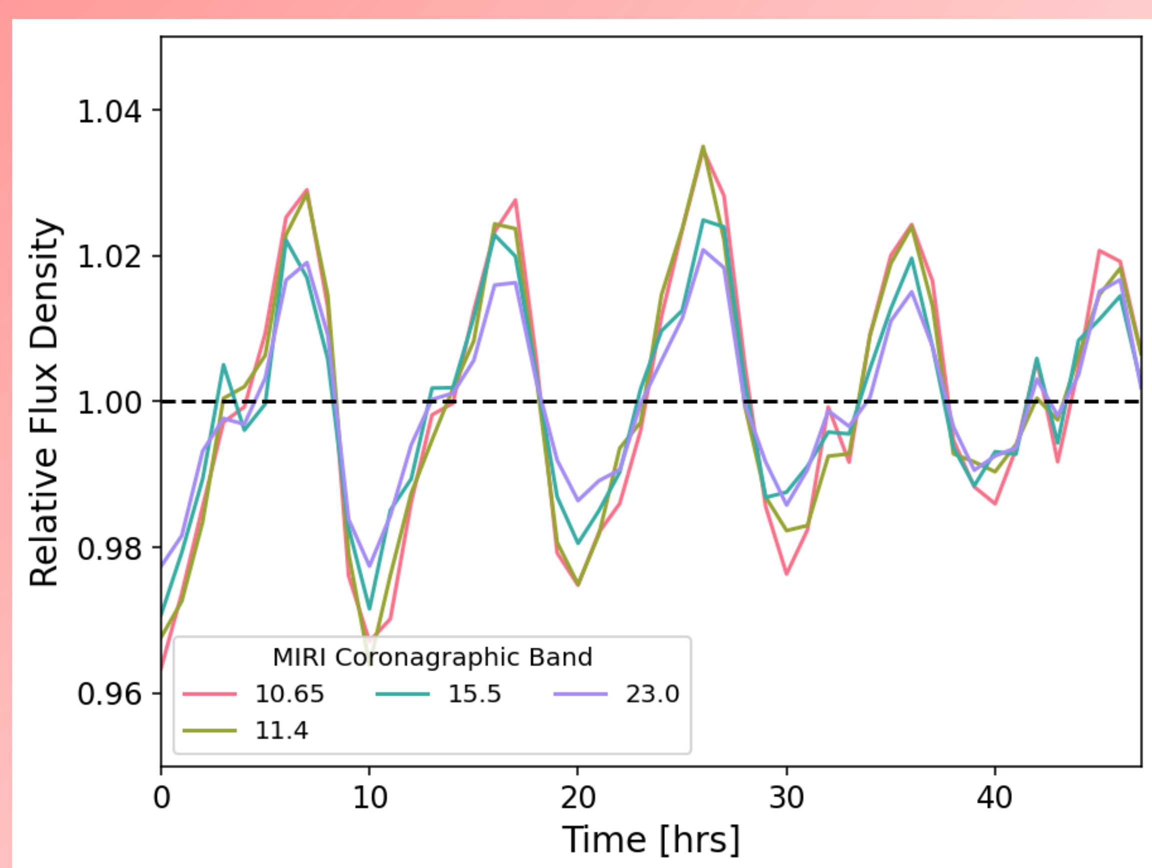

Figure 3. Normalised light curves of the simulation for 48 hours after simulation end for the MIRI coronagraphic bandpasses. This shows a long term variability over many rotation periods (10 hours), mixed in with smaller timescale weather effects.

Summary

Overall, our simulation shows a complex coupling of the clouds, chemistry and dynamics of the atmosphere, with the radiative feedback from the cloud in stormy regions producing local changes in the convective efficiency in the atmosphere, leading to chemical changes and inhomogeneity.
This mechanism leads to atmospheric variability, easily seen in the light curves of the object.
Our model represents some of the most self-consistent global simulations of an exoplanet atmosphere to date, showing the importance of considering complex feedback between different atmospheric processes.

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