A multidisciplinary investigation of Martian atmospheric chemistry

Other

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The Open University

Introduction

Two of the major questions driving current research on Mars are:

"***Is there, or has there ever been, life on Mars?***" and "***Was Mars more habitable in the past than it is now?***"

Answers to these questions may be found by studying the Martian atmosphere. The Martian atmosphere is composed of 95% CO_2, 2.7% N_2 , 1.6% Ar, 0.13% O_2 and 0.08% CO. In addition, there are many variable trace components that may provide clues as to the habitability of Mars such as water (~2ppm), ozone (~30ppb) or even provide biomarkers such as methane. Investigating the sources and sinks of these trace molecules and the methods by which they are cycled in the atmosphere may give us an insight into the interactions taking place between the atmosphere, lithosphere and any potential biosphere.

My project combines laboratory and computer simulations to investigate the formation and transport of the most interesting trace species and explores how the global system behaves in order to constrain some of the chemistry that could be taking place.

Laboratory Simulations

Currently we are running a series of coronal discharge experiments using different mixtures of Martian gases. This is to recreate the present-day atmospheric chemistry occurring on Mars and explore abiotic sources of some of the trace species. Coronal discharge experiments have been used previously to investigate formation pathways of oxygen in Martian gas mixtures (Országh et al, 2008).

These experiments will be scaled up to run in the Open University's Mars Simulation Chamber. The chamber is kept at Mars atmospheric temperature and pressure. We will add a UV solar simulator and Mars analogue regolith to observe any changes that these may make to the chemistry and identify sources and sinks of trace gases.

Reaction rates

Reaction pathways

Yields

Lifetimes

Spatial distribution

Temporal distribution

Computer Simulations

Simulations are being run using the UK (spectral) version of the European Mars Global Circulation Model (MGCM) developed in collaboration between the Laboratoire de Météorologie Dynamique in Paris, Oxford University and The Open University (Forget et al. 1999). The model consists of a spectral dynamical core and a Lagrangian tracer advection scheme, coupled with a range of physical, radiative transfer, regolith and chemical schemes.

Experiments will begin by following the temporal evolution of the distribution of trace species released from various points on the surface of Mars. Then more complex chemical reactions and multiple species will gradually be introduced, testing the seasonal and spatial variation against recent spacecraft observations.

Trace species of particular interest on Mars

Ozone

The ozone layer in Earth's stratosphere protects life from harmful UV light. Ozone has been detected on Mars and shows a strong anti-correlation with water. This property can be used as a tracer for water in the atmosphere.

Could there have been a Martian ozone layer in the past?

Perchlorate

The Phoenix lander detected small amounts of ClO_4^- in the soil near the North Pole. This indicates the area has been dry for ~100,000 years. On Earth ClO_4^- is found in deserts and while an atmospheric origin is widely accepted no one yet knows the mechanism involved.

Could perchlorate originate from ancient volcanic outgassings?

Methane

A strong plume of CH_4 was detected in the Northern Hemisphere's Summer (Mumma et al, 2009) in 2003. Currently there is no photochemical reaction that can explain its concentration and temporal variability.

Is it a bacterial signature?

Or else what geochemical processes could be occurring?

Summary

It is hoped that these simulations will constrain some of the reactions occurring between trace species in the atmosphere, identify their sources and sinks and begin to address the question of atmosphere-lithosphere coupling. An understanding of the reactions involved is necessary to gain knowledge not just of Mars but other planets in our own solar system and beyond.
Mars is a dynamic world and it is only by studying its atmospheric chemistry in detail that we will gain an understanding of its climate and habitability in the present and throughout its history.

References

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Background picture of Mars Atmosphere showing Galle crater taken by Viking courtesy of NASA