INVESTIGATING THE RELATIONSHIP BETWEEN OZONE AND WATER-ICE CLOUDS IN THE MARTIAN ATMOSPHERE

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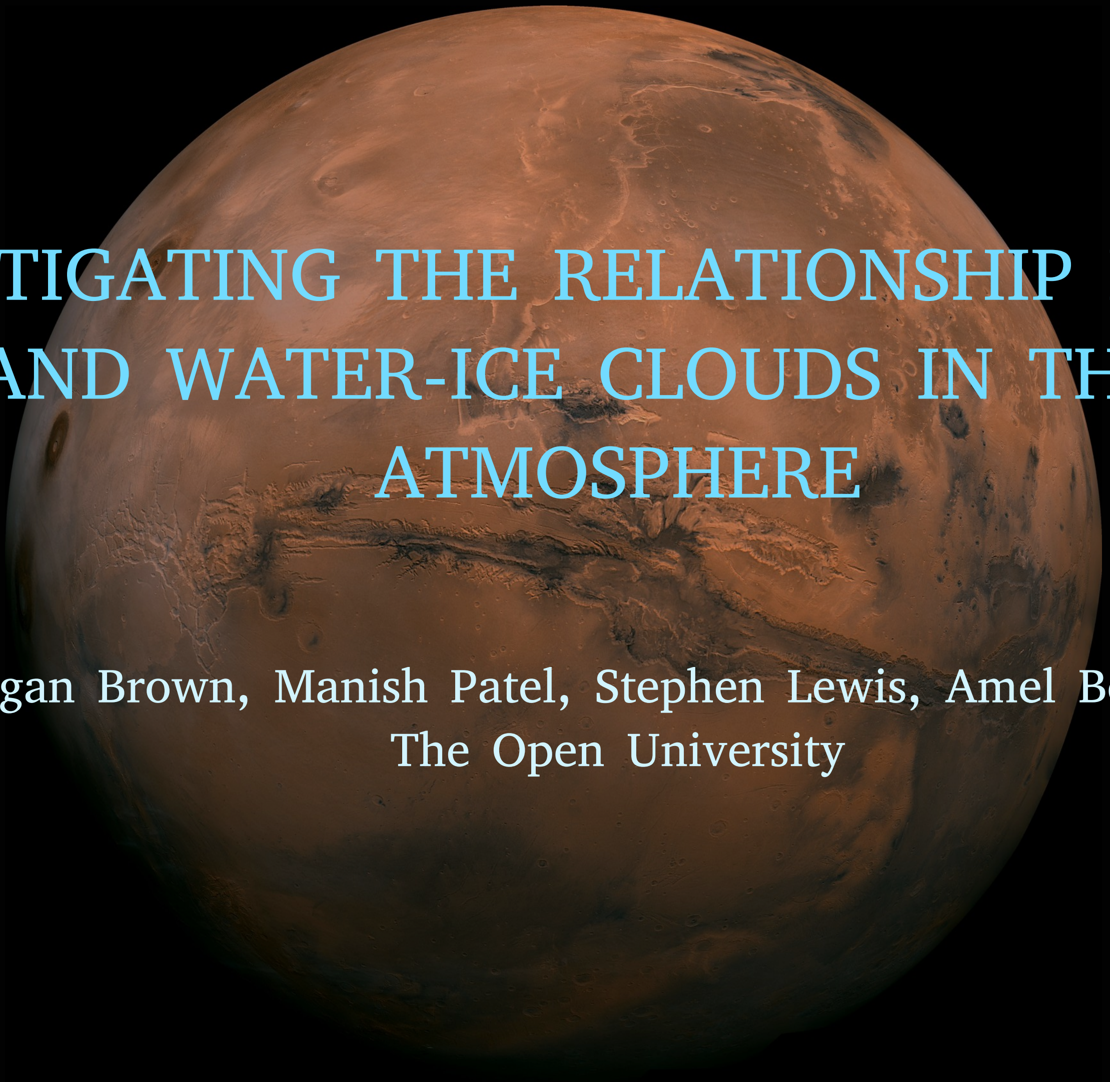


Image: NASA

Ozone on Mars

- Trace gas in the martian atmosphere <0.01%[1]
- Breaks down in ultraviolet (UV) light; 220-280nm[1,2]
- Used to track general circulation of the atmosphere and other trace gases[2]
- Is anticorrelated with water vapour (can be used as a proxy)[2,3,4]
- Varies diurnally and seasonally[4]

Composition of martian atmosphere

Gas	Volume / %
Carbon dioxide	95.32
Nitrogen	2.7
Argon	1.6
Oxygen	0.13
Carbon monoxide	0.08
Water	Trace
Ozone	**Trace**

NASA

[1]Barth et al. (1973); [2]Clancy and Nadir (1996); [3]Lefèvre and Montmessin (2013); [4]Perrier et al. (2006)

Aim: Improve the current understanding of the chemical processes in the martian atmosphere by investigating the interaction between ozone and water-ice and heterogeneous chemistry

Method: Use the 1-dimensional Laboratoire de Météorologie Dynamique (1-D LMD)[1,2] model to simulate a column of the atmosphere

Test 1-D model:

- Current hetero/homogeneous chemistry
- Equatorial and polar latitudes

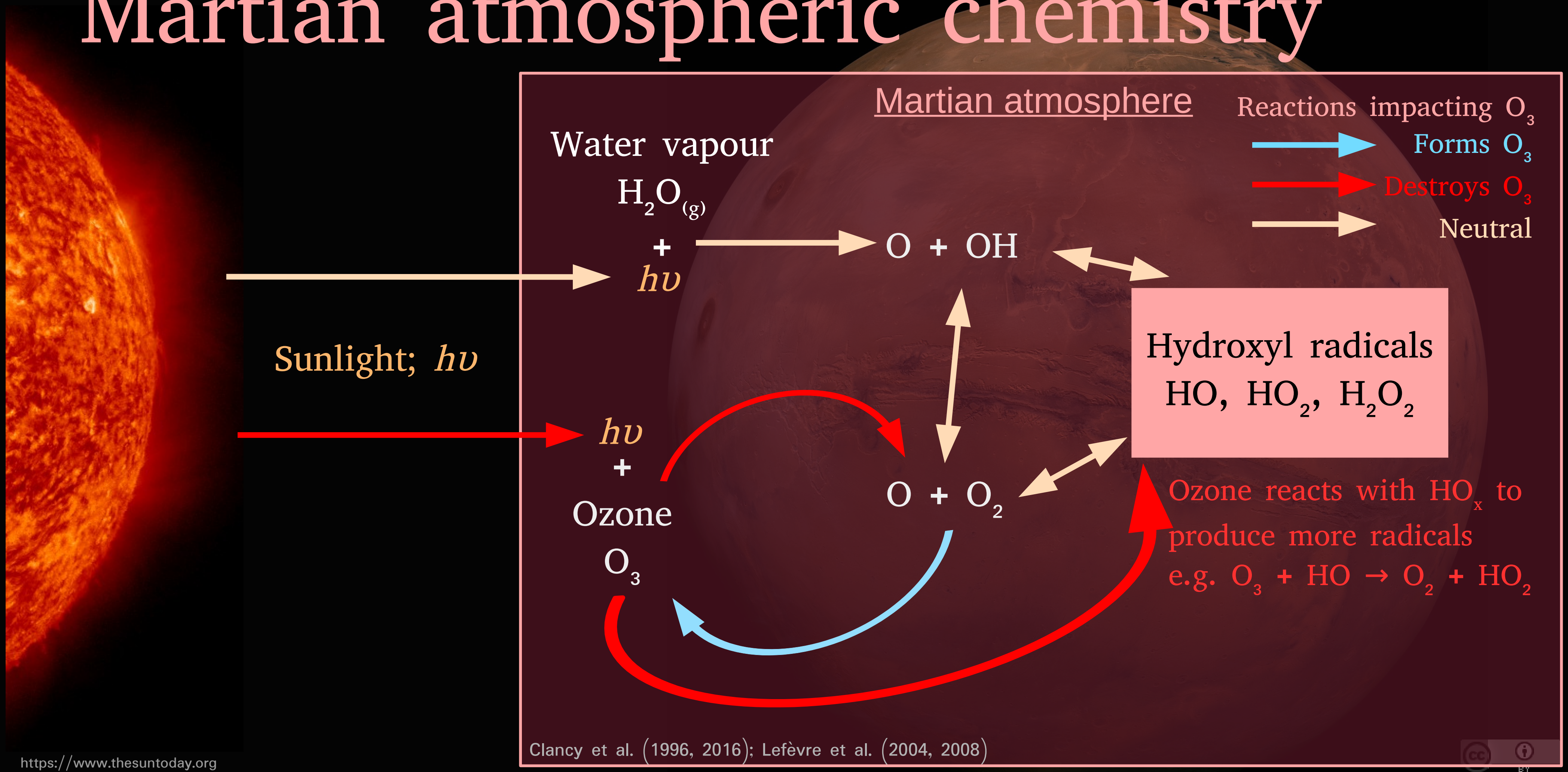
→ Develop heterogeneous chemistry —validate→ Compare with observations

Compare with observations —redevelop if needed→ Develop heterogeneous chemistry

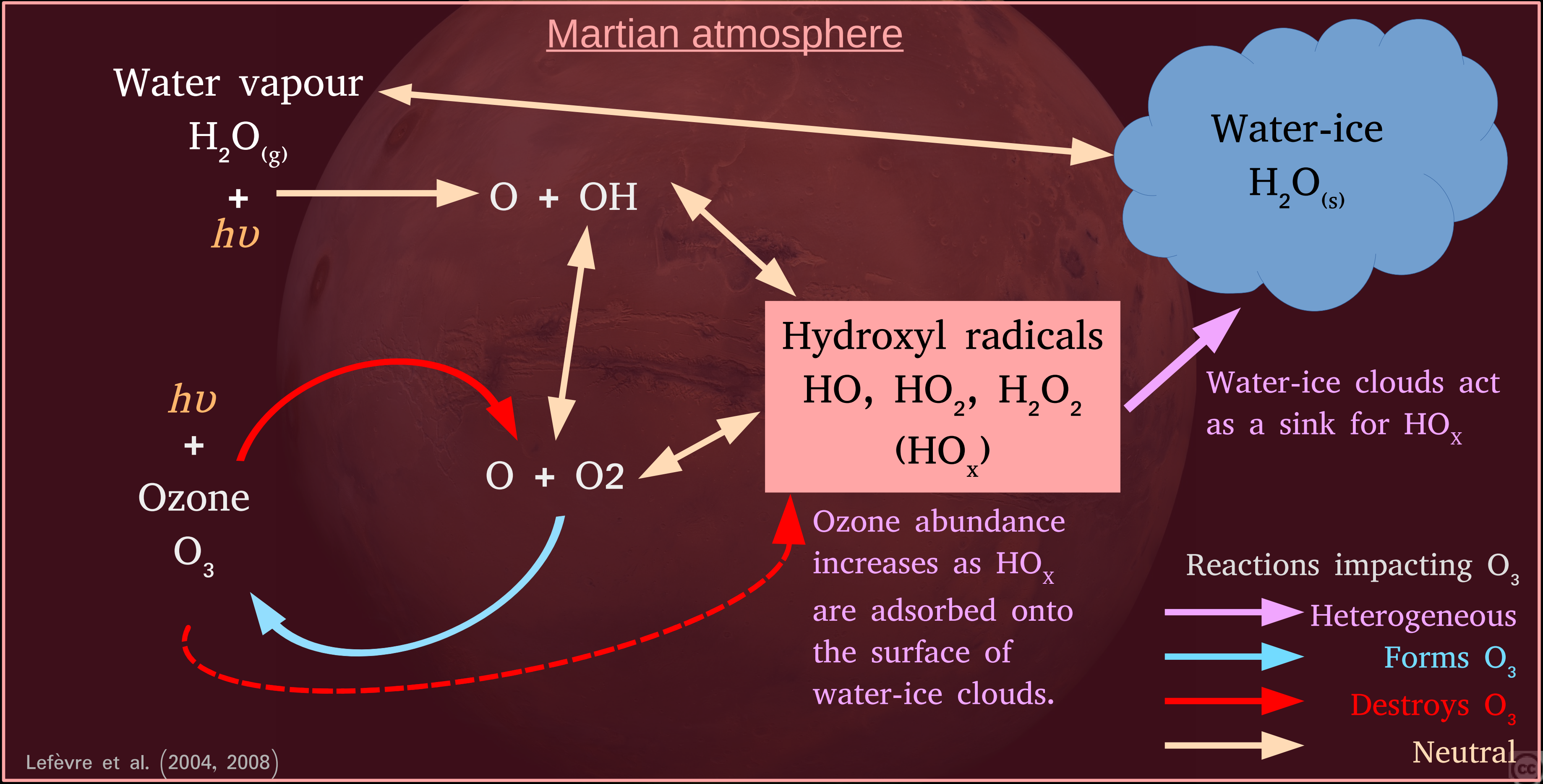
Model: The 1-D model is a physical submodel from the LMD global climate model (GCM) suited for testing chemical processes as it is not as computationally expensive as a full GCM.

[1]Forget et al. (1999); [2]Lefèvre et al. (2008)

Martian atmospheric chemistry



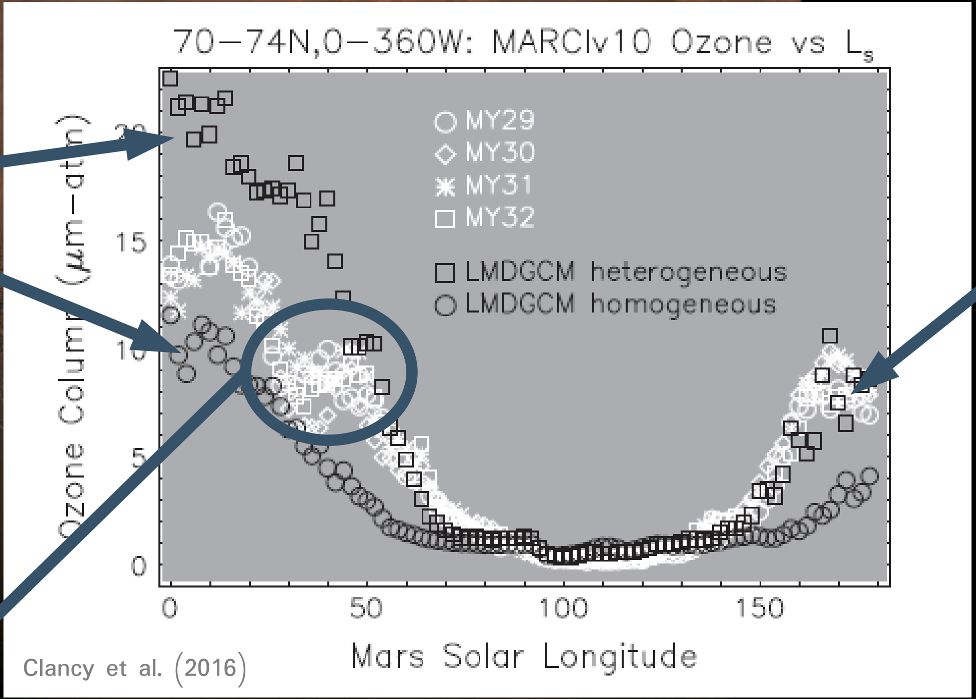
Heterogeneous chemistry



Current models

Fig. 11. The spring to fall (L_S = 0–180°) evolution of northern high latitude O_3 (70–74N) is presented for zonally averaged, L_s = 2° binned MARCI measurements (MY29-32, white symbols) and LMD GCM simulations for homogeneous (black circles) and heterogeneous (black squares) O_3 photochemistry. Neither model captures the observed spring behavior well, including an L_s = 40–50° secondary maximum (which exhibits the largest interannual variations among the observed MY). The heterogeneous model provides significantly improved comparison over the homogeneous model to the observed early fall (L_S = 150–180°) O_3 increases.

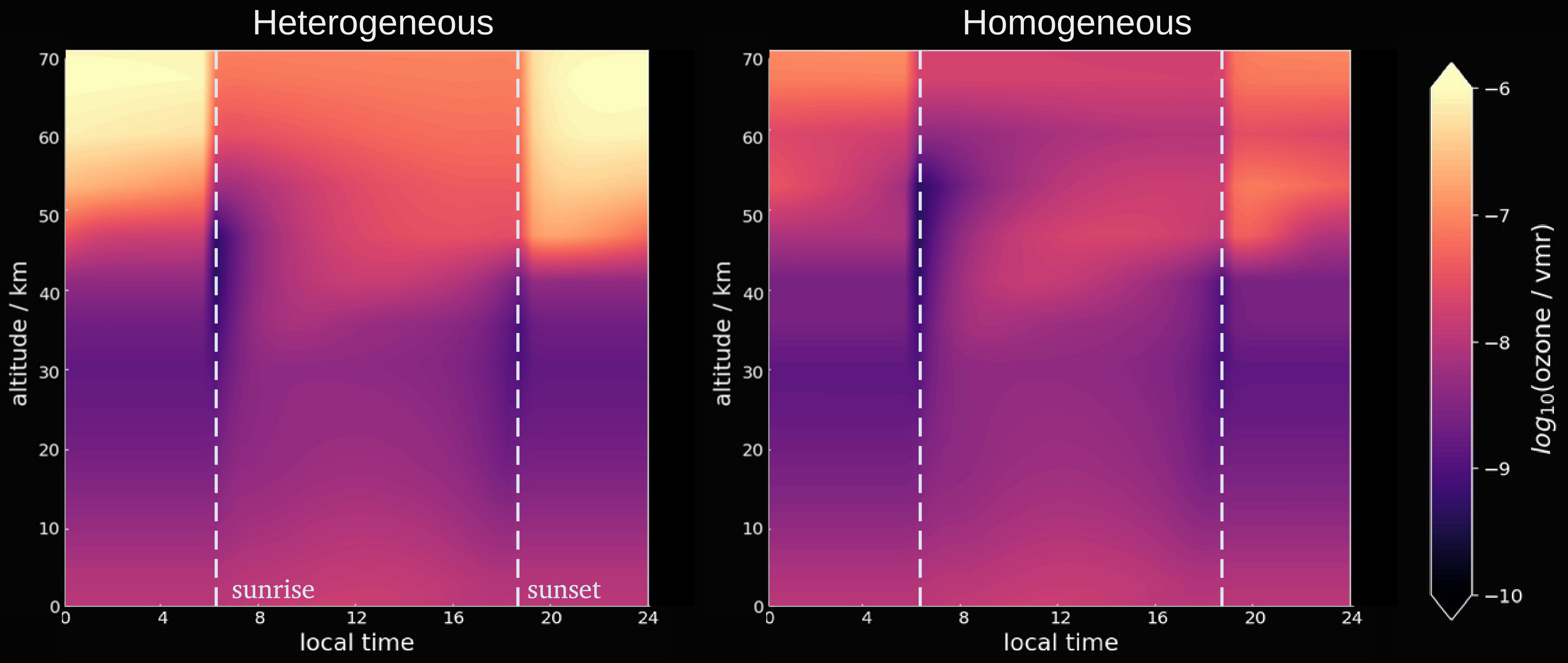
The heterogeneous GCM run over-predicts ozone abundance during aphelion, while the homogeneous run under-predicts during the start of aphelion



The heterogeneous model captures the increase in ozone from L_S 150° onwards

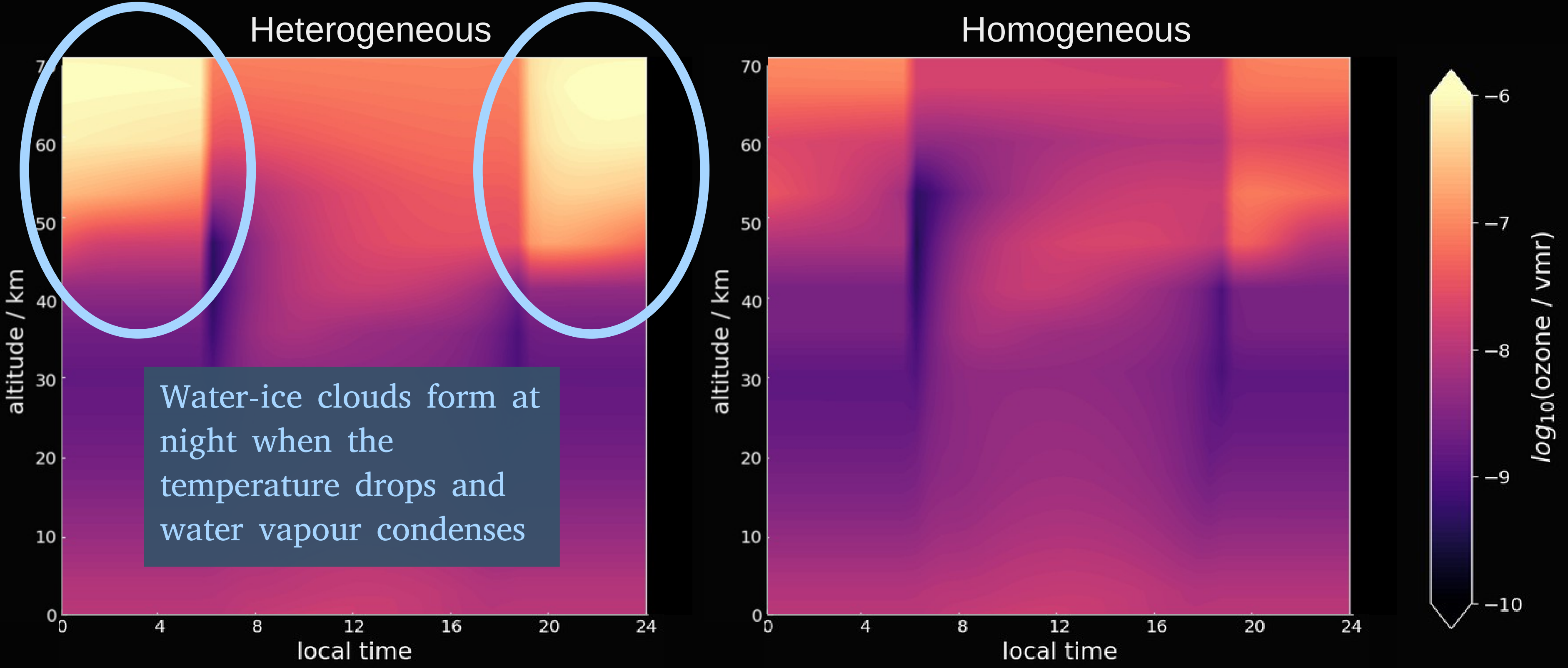
Neither model captures the increase in ozone just before L_S 50° well

1-Dimensional modelling (diurnal)



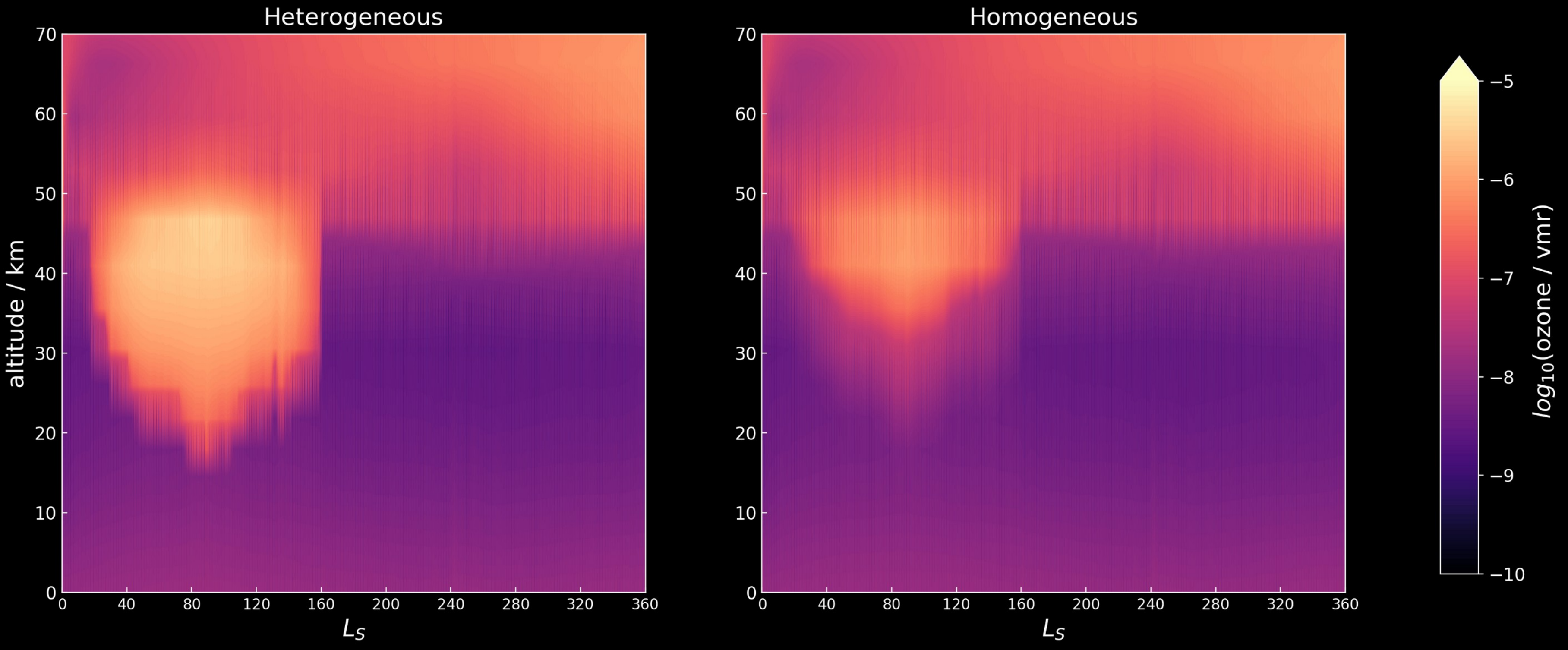
Simulated diurnal vertical profile of ozone with heterogeneous chemistry (left), and homogeneous chemistry (right) over one sol, at latitude 0° and L_s 0°.

1-Dimensional modelling (diurnal)



Simulated diurnal vertical profile of ozone with heterogeneous chemistry (left), and homogeneous chemistry (right) over one sol, at latitude 0° and L_s 0°.

1-Dimensional modelling (annual)

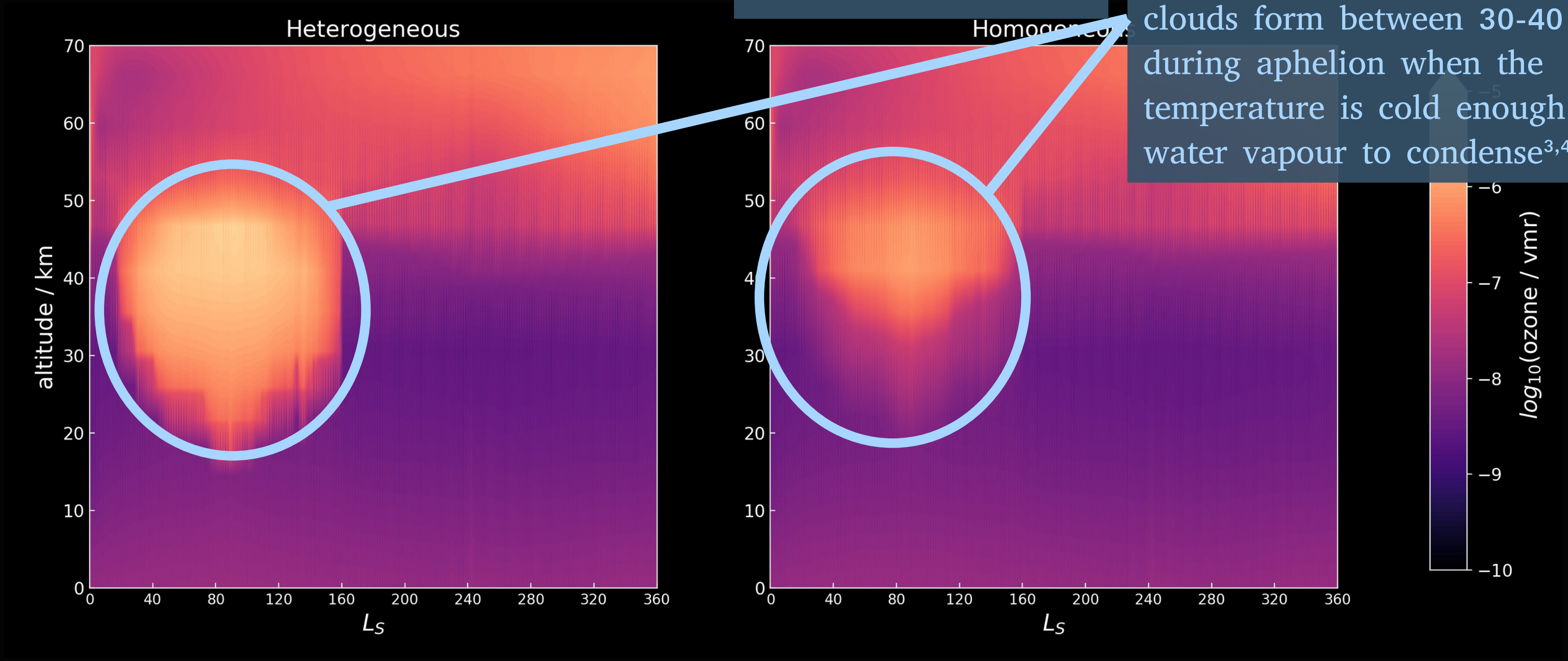


Full martian year of simulated ozone with heterogeneous chemistry (left) and homogeneous chemistry (right) at latitude 0° with 48 timesteps per sol. Time is given in solar longitude, L_s.

1-Dimensional modelling

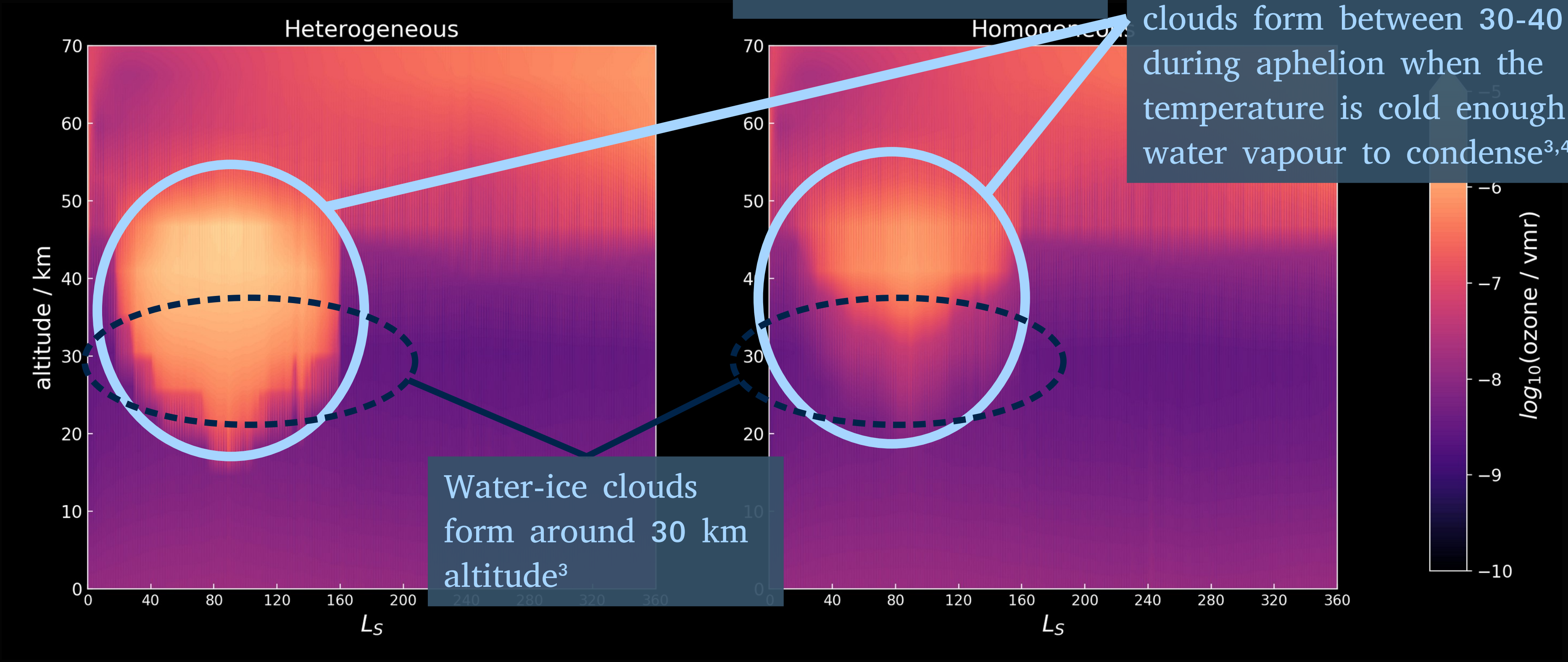
Water-ice clouds also form at high latitudes during the winter[1,2]

The ozone abundance is a result of a feature called the Aphelion Cloud Belt; water-ice clouds form between 30-40 km during aphelion when the temperature is cold enough for water vapour to condense[3,4]



[1]Benson et al. (2010); [2]Benson et al. (2011); [3]Mateshvili et al. (2007); [4]Wolff et al. (2019)

1-Dimensional modelling



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Water-ice clouds form around 30 km altitude[3]

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1-Dimensional modelling

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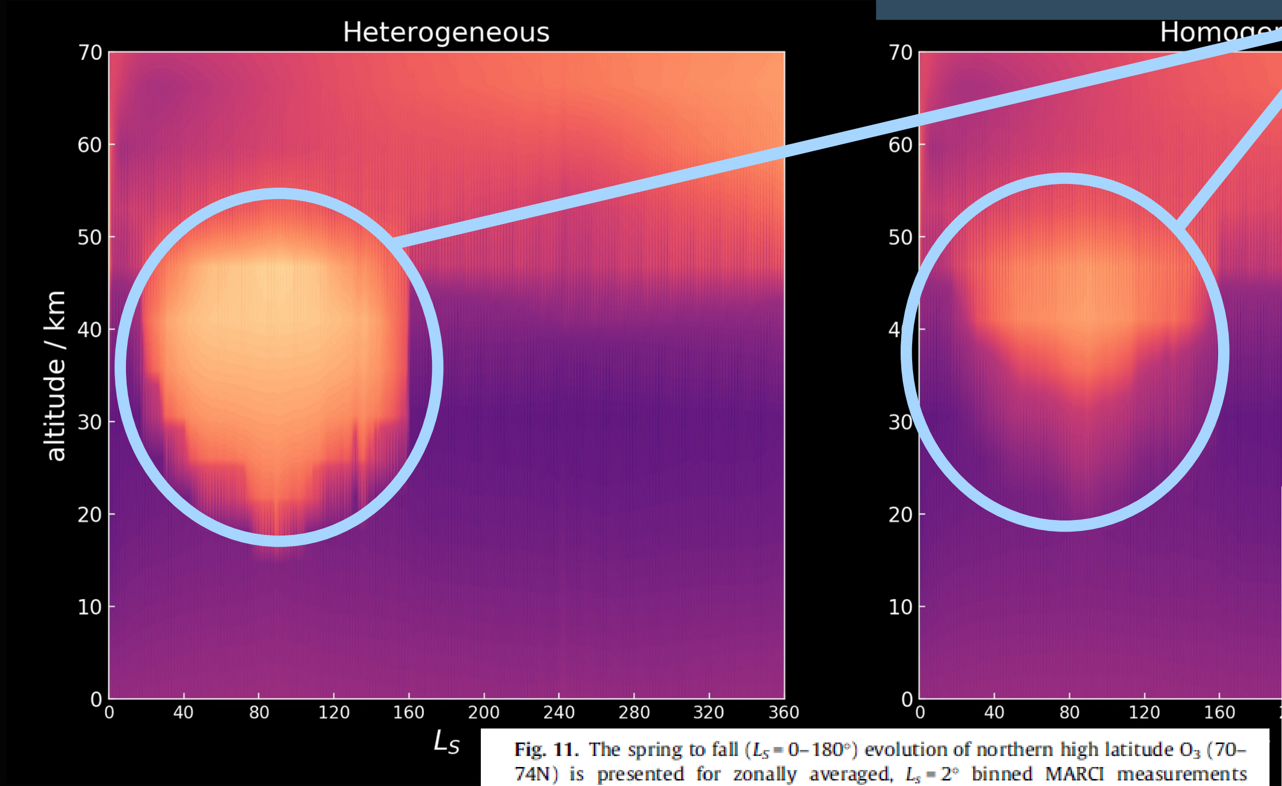
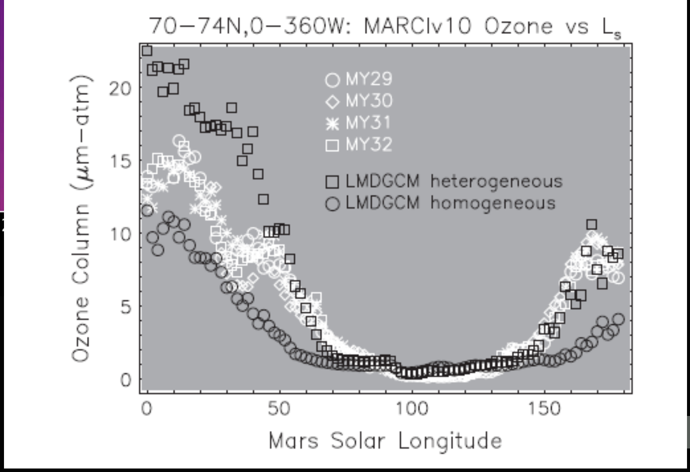
The current heterogeneous scheme over-predicts ozone abundance (Clancy et al. 2016)





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[1]Benson et al. (2010); [2]Benson et al. (2011); [3]Ma

Next steps

- Test 1-D model at high latitudes where clouds are expected to form
- Use observed vertical profiles of water vapour to simulate a more accurate water cycle
- Develop heterogeneous reactions between hydroxyl radicals and water-ice clouds
- Validate/compare results with ozone and water-ice observations from ExoMars Trace Gas Orbiter

Summary

- Ozone is photosensitive and anti-correlated with water vapour
- Current global climate models either over- or under- predict ozone abundance depending if the model is run with heterogeneous chemistry
- This project uses a 1-D model to test and develop the heterogeneous chemistry, using ozone abundance to highlight these effects