Reference papers

Look for:

Photolysis in the martian atmosphere

(CO2, O3, O2)

Effects of temperature on O3 photolysis rates in the martian atmosphere

Attenuation of light in the martian atmosphere:

* Papers for this
* MCD/ model values
* Find distances of mars at solar longitudes I have (all 8)
* Calculate real values

CO2 cross sections

CO2 photolysis rates

**[1]ExoMars TGO/NOMAD-UVIS Vertical Profiles of Ozone: 1. Seasonal Variation and Comparison to Water**

[**https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JE006837#jgre21778-bib-0077**](https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JE006837#jgre21778-bib-0077)

**-nomad paper**

[2] **ExoMars TGO/NOMAD-UVIS Vertical Profiles of Ozone: 2. The High-Altitude Layers of Atmospheric Ozone**

<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021JE006834>

-companion paper

[3] **Climatology and Diurnal Variation of Ozone Column Abundances for 2.5 Mars Years as Measured by the NOMAD-UVIS Spectrometer**

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023JE008270>

* Diurnal variation of ozone
* Dayside diurnal variation
* follows established seasonal trends through prev. O3 measurement
* aphelion: equatorial o3 distr. Strongly correlated with water ice distr.
* Strong latitudinal and longitudinal variation in diurnal behaviour of O3 around northern summer solst.
* Areas with weak o3 upper layer, o3 column abund. Peaks in mid-morning: driven by changes in near surf. O3 layer.
* Regions with greater o3 abund. O3 observed to gradually increases throughout the day
* Consistent with expected diurnal trend of O3 above hygropause: suggested these areas an upper o3 layer persists throughout martian day.

[4] **Global distribution of total ozone on Mars from SPICAM/MEX UV measurements**

<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2006JE002681>

significant findings:

* Large increases in ozone column density at high latitudes during late winter-early spring of each hemisphere that completely disappears in summer
* Large variability of northern spring content related to polar vortex osciallations
* Low ozone columns in equatorial regions all year long
* Local variations of ozone column related to topography, mainly above Hellas Planitia.
* Good overall agreement with SPICAM and predictions of Chemical General Circulation Model
* Significant discrepancies in total abundances found near northern spring when ozone reaches its annual peak.

[5] **Heterogeneous Processes in the Atmosphere of Mars and Impact on H2O2 and O3 Abundances**

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023JE008014>

- explores uptake of odd hydrogen species on water ice clouds

- hydrogen peroxides photolytic destruction in ices with model simulations with model simulations and compact reconnaissance imagin spectrometer for mars observations

- find only uptake of HO2 and H2O2 on dust are efficient on mars

- attenuation of sunlight by water ice clouds in the calculation of photolysis rates leads to increased O3 and H2O2 abundances below ice clouds

-physical states of h2o2 on mars, its photolytic destruction in ice, uptake of h2o2 and ho2 by mineral dust

-these processes lead to O3 increases without the need for strong uptake of HO2 on ice

-remains difficult to find good agreement with o3 and h2o2 observations on the global scale

[6] **Seasonal, Latitudinal, and Longitudinal Trends in Nighttime Ozone Vertical Structure on Mars From MAVEN/IUVS Stellar Occultations**

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022JE007697>

Includes some photochemistry. Check citations.

* Mars Atmosphere and Volatile and EvolutioN/Imaging UltraViolet Spectrograph instrument
* vertically resolved measurements of ozone density in the middle martian atmosphere that offered good coverage wrt. Latitude longitude and local time
* used to identify systematic variations in vertical structure of ozone with longitude, could be distinguished from general trends in evolution of ozone w.r.t season and latitude
* total 583 individual nightside occultations between MY 32 and MY36 analyzed, 224 confirmed to have ozone
* all found between Ls 15-165.
* Close to aphelion (Ls = 60 to 90) peakozone densities between 30-40km altitude observed to be within error of model predictions at all measured latitudes, diverged from model predictions before and after this time.
* Low latitudes, seasonal changes seen to have greatest effect on observed vertical structure of ozone, with detached ozone layer densities at altitudes above 30km, usually varying within approximated a factor of 2 along a given latitudinal band at a given time of year.
* Persistent regional enhancement of ozone abundance observed over equatorial latitudes during aphelion season, spanning longitude range of approx.. 50-130 longitude.
* Planetary waves clearly observed at higher southern latitudes during southern winter, often resulting in order of magnitude variations in ozone density with longitude
* FIRST STUDY PRESENTED DISTINGUISHING ZONAL VARIATIONS IN VERTICAL OZONE STRUCTURE FROM SEASONAL AND MERIDIONAL (points of equal longitude) TRENDS
* Ozone variability mostly driven by seasonal changes in the tropics but zonal circulation patterns at higher latitudes
* Persistent regional enhancements in mesospheric ozone are observed at equatorial latitudes during aphelion season
* close to equator, ozone tended to vary more with season than with longitude
* However, a region of increased ozone density was observed in the Eastern hemisphere of Mars, centered over the equator. Region was consistently seen during the same season each martian year.
* At higher latitudes, variations with longitude tended to be much larger and more important than seasonal variations.
* Variations in ozone also exhibited wave structures at southern subpolar latitudes

[7] **Atmospheric Photochemistry**

<https://www.cambridge.org/core/books/abs/atmosphere-and-climate-of-mars/atmospheric-photochemistry/E86CADD27001D365DDAD1B607E5B063F>

* mars atmosphere almost entirely CO2
* as a result, only processes initiating mars photochemistry are photolysis of CO2 and H2O by UV
* therefore photochemistry can be summarized by interactions between oxygenated products of CO2 and hydrogen products of H2O
* Mars can maintain an almost pure atmosphere of CO2 (95.5%), with only trace amounts of photodissociation products CO (volume mixing ratio ~9x10^-4), O (~10^-3 at 100km) and O2 (1.4x10^-3) Kliore et al., 1965; Belton and Hunten, 1966; Kaplan etal. 1969)
* UV reaches all the way to surface and photodissociated CO2 into CO and atomic oxygen at its ground state or excited state.
* Composition of mars atmosphere can be precisely controlled by odd-hydrogen species
* Odd hydrogen species only present in parts per billion
* Section 13.2 shows the short lived species can catalytically convert CO into CO2 at a rate orders of magnitude higher than the direct reaction shown in section 13.3.

[8] **Seasonal Changes in the Vertical Structure of Ozone in the Martian Lower Atmosphere and Its Relationship to Water Vapor**

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022JE007213>

-explanation of why perihelion has little to no data.

-around exquinoxes in both hemispheres and over the southern winters, we regularly observe around 200-500 ppbv of O3 below 30km.

-warm southern winters: near perihelion, produce enough atmospheric moisture that o3 is not detectable at all. Observations rare even at high northern latitudes

-during northern summers, water vapor restricted below 10km: an o3 layer (100-300 ppbv) visible between 20-30km: same time, aphelion cloud belt form; condenses water vapor; allows O3 to build up between 30-40km

-comparison to vetical profiles of water vapour and temperature in each season reveals that water vapor abundance is controlled by atmospheric temperature, and h2o and o3 are anti-correlated.

-when the atmosphere cools, over time or over altitude, water vapor condenses (reduces in mixing ratio): production of odd hydrogen species is reduced, allows o3 to build up.

-warmer temperatures lead to water vapor enhancements and oxone loss.

-refers to MCD: able to reproduce vertical structure and seasonal changes in temperature, h2o and o3 we observe: however, observed O3 abundance is larger by factors between 2 and 6, indicating important differences in the rate of odd-hydrogen photochemistry

^Ozone observed in higher abundances than photochemical models predict.

-differences between expected O3 abund. And observed suggest destruction of odd-oxygen by odd-hydrogen is less active on Mars than in current GCM simulations.Possibly due to differences in odd-hydrogen production rates, or the reaction rates involving odd-hydrogen species.

[9] **Annual (perihelion-aphelion) cycles in the photochemical behavior of the global Mars atmosphere, 1996**

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/96JE00836>

* Hydrgopause altitude 10-30km
* 1D diffusive transport photochemical model Nair et al [1994] run in a diurnally averaged mode for time-dependent calulations of the annueal behaviour of Mars photochem. At low to mid altitudes.
* Due to long photochemical lifetimes, CO and O2 expected in significant non-equilibrium with annually varying water vapor (and hence HO\_x) densities, and nearly constant abundances at the time of the paper [1996]
* Contrast: o3 has photochemical lifetime of hours; exhibits very large annual variations in response to the annual variation in hygropause altitude.
* Global scale abundance of O3 at altitudes of 20-40km predicted to vary from >10^9cm^-3 around Mars aphelion (norther spring/ summer, Ls =71)
* Abundance ~10^8cm^-3 around Mars perihelion (southern spring/summer, Ls 251)

[10] Line parameters for CO2- and self-broadening in the ν3 band of HD16O

<https://www.sciencedirect.com/science/article/pii/S0022407316308998?via%3Dihub>

* Temp dependencies of Co2 line width shifts

[11] **Planet-Wide Ozone Destruction in the Middle Atmosphere on Mars During Global Dust Storm**

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022GL098821>

-some photochemistry

[12] **Absolute absorption cross section measurements of CO2 in the wavelength region 163-200 nm and the temperature dependence**

<https://www.webofscience.com/wos/woscc/full-record/WOS:000182950800012>

-lab measurements of CO2 absorption cross section CO2

-temperatures 195K to 295K

-wavelength region 163-200nm, using high resolution grating spectroscopy

-Cross sections at 195K smaller than those at 295K: band structures more emphasised

-cross sections available between 117.8-200nm at 295K and 117.8-192.5nm at 195K

[13] **Room temperature photoabsorption cross section measurements of CO2 between 91,000 and 115,000 cm-1**

[**https://www.webofscience.com/wos/woscc/full-record/WOS:000315362400009**](https://www.webofscience.com/wos/woscc/full-record/WOS:000315362400009)

* High res. Vacuum UV photoabsorption cross sections
* Measurements between 87-110nm at spectral resolutions 1.15cm^-1 (91,000-102,000cm^-1) and 0.58cm^-1 (102,000-115,000cm^-1)
* Higher resolution gives deviations from previous, lower resolution data
* Especially in regions with sharp spectral structure

[14] **Photodissociation dynamics of CO2 + *hv* → CO(X1σ+) + O(1D2) via the 3P1πu state**

<https://www.webofscience.com/wos/woscc/full-record/WOS:000752578200007>

--photodisociation of CO2 at 108.22, 107.5, 106.10 and 104.74nm gives a Beta value great than 1 (less anisotropic and inverted distributed CO photoproducts

-observations show clear influence of the initally vibrational excitations

[15] **Determination of Rayleigh scattering cross sections and indices of refraction for Ar, CO2, SF6, and CH4 using BBCES in the ultraviolet**

<https://www.webofscience.com/wos/woscc/full-record/WOS:000581971300022>

* Scattering cross section for CO2 at UV wavelengths
* Between 264 and 297
* For CO2 experimentally dervived values are in excellent agreement with refractive index calculations: within 08-1% average.
* Graphs to read off
* For higher energy UV rays: UV-B and UV-C

[16] **PHOTODISSOCIATION IN THE ATMOSPHERE OF MARS - IMPACT OF HIGH-RESOLUTION, TEMPERATURE-DEPENDENT CO2 CROSS-SECTION MEASUREMENTS**

<https://www.webofscience.com/wos/woscc/full-record/WOS:A1993LK09600010>

* High res temp-dependent CO2 cross sections
* Calculations on the photodissociation rate coefficients in martian atmosphere
* Cross sec. measurements large variations 10-20 angstrom scale: wavelength dependent
* Errors less than 10% most cases, some 20%
* CO2 cross section large temp dependence
* Decrease In the diurnally averaged rate of CO2 photodissociation as large as 33% at some altitudes
* Increases of between 950% and 80% in photodissociation rate coefficients of H2O and O2

[17] **A ground-to-exosphere Martian general circulation model: 1. Seasonal, diurnal, and solar cycle variation of thermospheric temperatures**

<https://www.webofscience.com/wos/woscc/full-record/WOS:000264865000002>

* Martian GCM from ground to thermsosphere
* Physical processes important for thermospheric altitudes
* 1 full martian year
* Seasonal, diurnal and ay to day variability of temps in exobase region
* Variation in solar force leads to seasonal variation of zonal mean temperatures of around 100K
* Temperature of mesopause ranges between 115-130K: little seasonal day-night changes
* Pressure level has significant seasonal day-night variation (mesopause)
* Homopause located higher in the atmosphere during the solstices
* Day-night temperature differences found in thermosphere, around 60K at aphelion and 110K at perihelion
* Seasonal variation of temperatures overestimated by the model