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Investigating the Relationship Between Ozone and Water-Ice Clouds Using Data From the ExoMars Trace Gas Orbiter

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Background: Ozone on Mars

Ozone is a trace gas in the martian atmosphere (<0.01%) and is:
- Formed by photodissociation of CO₂
- Absorbed, breaking down in the ultra violet (UV) region (220–260 nm)
- Photooxidised
- Anti-correlated with water vapour
- Seasonal with diurnal variation

Ozone–water anticorrelation

Photolysis of water vapour produces hydroxyl radicals (HO)²³
HO are highly reactive and destroy ozone:
\[ \text{H}_2\text{O} + h\nu \rightarrow \text{HO} + \text{H}_2 \]
\[ \text{HO} + \text{O} \rightarrow \text{HO}_2 \]
\[ \text{O}_3 + \text{HO}_2 \rightarrow \text{HO} + 2\text{O}_2 \]

Water vapour abundance reduces in colder seasons and ozone can form in its absence²⁴
Ozone detected at similar altitudes to water-ice clouds²⁵,²⁶
Ozone–water relationship is not universal to all states of water

Water

Clouds on Mars

Most water-ice clouds form at the water vapour saturation level. Three main types of clouds²⁷,²⁸
- Orographic
- Polar hood
- Higher opacity
- Larger particle size
- Aphelion Cloud Belt

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Next steps

- Examine the relationship between water-ice and ozone at different latitudes
- Use UVIS vertical profiles to compare altitudes of ozone and water-ice layers
- Heterogeneous chemistry is dependent on particle size: compare different cloud regions with ozone
- Investigate heterogeneous and homogenous chemistry throughout the martian year

Hypothesis: Water-ice chemistry

Known:
- Water-ice and ozone relationship are used as a proxy for HO₂
- Global climate models (GCMs) are in disagreement of HO₂ and water-ice chemistry
- Two types of chemistry GCMs were tried (figure below)
  - Heterogeneous – positive correlation between ozone and water-ice
  - Homogeneous – negative correlation between ozone and water-ice

Unknown:
- Ozone near water-ice cloud regions
  - Chemical processes preventing the destruction of ozone from HO₂
  - Positive correlation
  - Water-ice clouds act as a sink for hydroxyl radicals

Importance: why we care

Ozone is dependant on other atmospheric species and has a short lifetime:
- Tracking global wind patterns with little photochemical destruction which extends its average lifetime
- Proxy for water vapour and trace gases such as hydroxyl radicals which are necessary to keeping the CO₂ in the atmosphere stable
- Understanding photochemical processes

Observations: Trace Gas Orbiter

One of the Trace Gas Orbiter’s (TGO’s) main missions includes mapping trace gases in the martian atmosphere²⁹
NOMAD (Nadir and Occultation for Mars) is an instrument aboard TGO which contains a UV and visible spectrometer, UVIS³⁰
Both ozone and water-ice are detected in the UV region and so retrieved data from UVIS will be used to investigate the ozone and water-ice
Data will be temporally and spatially binned to visualise patterns
Correlation tests to compare ozone and water-ice in different cloud regions

Below shows the nadir latitudinal coverage of UVIS since it began scientific mapping back in April 2018
UVIS has two observational modes:
- Nadir – spatial coverage and total column abundance
- Occultation – vertical profiles

Credit (figures/images):
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