Argon: The mixing standard for methane in Mars’ atmosphere

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Presented by Francois Forget
“Hello to All, we are sorry we couldn’t attend”,

Ann Sprague
and
Bill Boynton
Noncondensables like Methane should all show similar behaviour

- Seasonal accumulation on polar regions during winter
- Dilution and transport to low latitudes
  - Late winter
  - Spring
- Depletion below average value during summer at some latitudes
- Static instability and vertical mixing
Observed Noncondensables’ in Mars atmosphere

- **N₂, Ar**
  - neutron spectrometer (N₂ + Ar)
  - gamma ray instruments (Ar 1294 keV γ-ray line)
- **CO**
  - ground based and spacecraft spectroscopy
    - OMEGA, PFS on Mars Express and CRISM on Mars Reconnaissance Orbiter
    - 1.6 and 2.35 μm band depth
- **O₂**
  - Viking landers (O₂ singlet Δ not really relevant here)
- **CH₄**
  - ground based and spacecraft spectroscopy
    - CSHELL /IRTF and NIRSPEC/Keck-2
    - PFS Mars Express
Seasonal Picture

• Enhanced mixing ratio at high latitudes during late autumn and early winter
  – Ar Sprague et al. (2004, 2007, in progress) shows enhancement of a factor of 6 for three southern winters (MY 26, 27 and 28)
    • 800 ppm in northern latitudes and 1200 ppm in southern latitudes during northern summer (Ls 112°)

• Dilution and transport to lower latitudes during late winter and spring

• Depletion below homogeneous (well mixed) mixing ratio for short periods during summer

• Northern winter enhancements chaotic and less pronounced than southern enhancements

Methane at Mars: 25 – 27 Nov 2009
Argon enhancement observed by Mars Odyssey GRS

Sprague et al. 2007
Seasonal Picture

- Enhanced mixing ratio at high latitudes during late autumn and early winter
  - $\text{Ar}$ Sprague et al. (2004, 2007, in progress) shows enhancement of a factor of 6 for three southern winters (MY 26, 27 and 28)
  - $\text{CO}$ Krasnopolsky (2002)
    - 800 ppm in northern latitudes and 1200 ppm in southern latitudes during northern summer ($L_s 112^\circ$)

- Dilution and transport to lower latitudes during late winter and spring
  - $\text{CO}$ : Smith et al (2008) (next slide)

- Depletion below homogeneous (well mixed) mixing ratio for short periods during summer

- Northern winter enhancements chaotic and less pronounced than southern enhancements

Methane at Mars: 25 – 27 Nov 2009
Observation of CO by CRISM (ppm)
(Smith et al. 2009)
Simulations in the LMD Global Climate Model

- Forget et al. 1999 GCM
- 64x48 grid, 25 layers
- *Hourdin and Armengaud (1997)* transport scheme
- Compute enhancement and dilution
- Account for 3D change in atmospheric composition to compute convection and turbulence
Simulated Argon column averaged mixing ratio (%)
Comparison with Argon measurements
Comparison with Argon measurements
Comparison with CO observations by CRISM (ppm) (Mike Smith 2008)

Observations

Model
Departures from the simple picture

- **Influence of topography**
  - CO Encrenaz et al. (2006) OMEGA data - enhancement of 2 over Hellas at $L_s = 130-150^\circ$ (*end of southern winter compared to southern summer*)
  - Ar Sprague et al. work in progress
    Helias longitude sector MY 26?

- **Sources**
  - CH$_4$ Geminale et al. (2008)
  - CH$_4$ Mumma et al. (2009)

- **Sinks**
  - photochemistry
  - photolysis
Figure from Mumma et al. 2009 Science paper shows absolute abundances as a function of latitude and L$_s$:

A. Total CH$_4$ column density in molecules/ m$^2$ in two way path  
B. Local mixing ratio in parts per billion  
C. Geographic and temporal variability
In the next slide

• Compare Ar data to CH₄ data
  – CH₄ data from Mumma et al. 2009
  – Ar data from GRS γ-ray measurements
    • Approximate the ground-based CH₄ longitudes and latitudes by using data from a 90° longitude sectors in 30° increments of latitude that encompass the ground based measurements
    • The two relevant longitude sectors are Elysium and Hellas
The opaque “blob” indicates approximate regions over which ground-based CH$_4$ observations were obtained.

GRS Ar data

Telescope CH$_4$ data
• Compare Ar data to CH$_4$ data
  – CH$_4$ data from Mumma et al. 2009
  – Ar data from GRS $\gamma$-ray measurements
  – Ar represents the “background noncondensable gas”

• Only the spring telescopic CH$_4$ data have a similar latitude distribution to the Ar data

• The CH$_4$ data depart significantly from the Ar data and show a definite unique enhancement at mid latitude
Summary

• Ar and CO are good tracers for the movement and concentration of noncondensable atmospheric species
  – In the absence of short time scale sources/and or sinks
• Comparison of other noncondensable atmospheric species to Ar concentrations and distributions give some insight
  – To the possibility of sources and/or sinks