Retrieval of gases and aerosols vertical profiles considering multiple scattering from OMEGA/MEx limb observations

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"From Mars Express to ExoMars", 27–28 February 2018, ESAC, Spain

Introduction

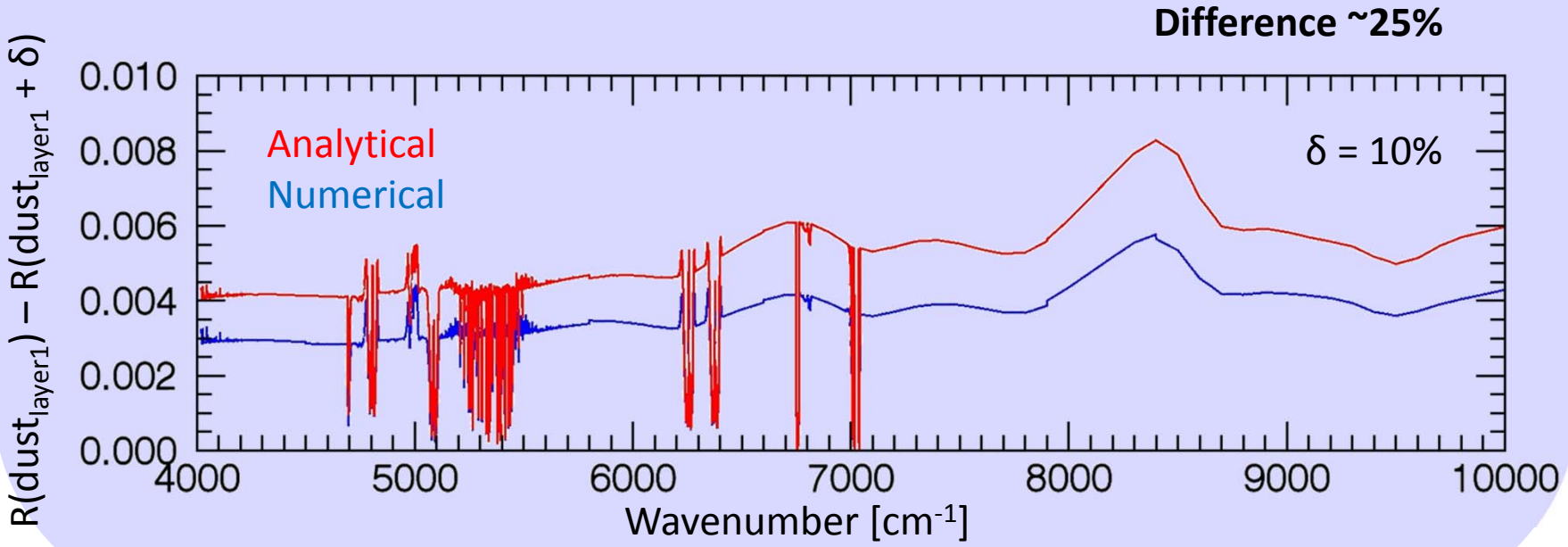
- Retrieval of the atmospheric content from limb observations
  - CO_2, (CO), H_2O, dust particles, water ice particles
- Application to the OMEGA/MEx spectra
  - Wavenumber range (IR): 3711 - 10,795 cm^{-1} (0.92 to 2.69 µm)
  - Spectral sampling: 17.6 to 164 cm^{-1}
  - Resolution (FWHM): 120 cm^{-1}
  - Altitude range: 0 – 60 km
  - FOV: 1.2 mrad
  - Data downloaded from the online PSA
- Orbit 941
  - Lat.: 40.6° N, Lon.: 50.5°W, LST: 17h30, Ls: 100°, FOV: 5 km
  - Spectra from contiguous lines averaged to increase SNR (~100)
  - Vertical sampling: 5 km
  - Number of spectra: 10

The multiple scattering radiative transfer scheme: JACOSPAR

- JACOSPAR is a full radiative transfer code, accounting for multiple scattering (Iwabuchi, 2006; 2009)
  - Spherical-shell atmosphere taking into account atmospheric refraction
  - Single-scattering components of radiance calculated analytically
  - Multiple scattering calculated by the Backward-propagating Monte Carlo
  - Photons trajectory represented by probability distribution functions
  - Dependent sampling approach (Marchuk et al., 1980):
    - Simultaneous simulation of a radiance spectrum at thousands of wavenumbers
    - Radiance not calculated for every wavenumber, only for a single wavelength, and used for estimation of spectral deviations for the remaining ones
  - Calculates high precision spectra and partially analytical Jacobians in a fast process
    - Precision on radiance and Jacobians: 0.5%
    - Computation time <1h for one spectrum with spectral sampling of 1 cm^{-1}
- JACOSPAR could be corrected and improved thanks to our study

JACOSPAR: Verification of the Jacobians

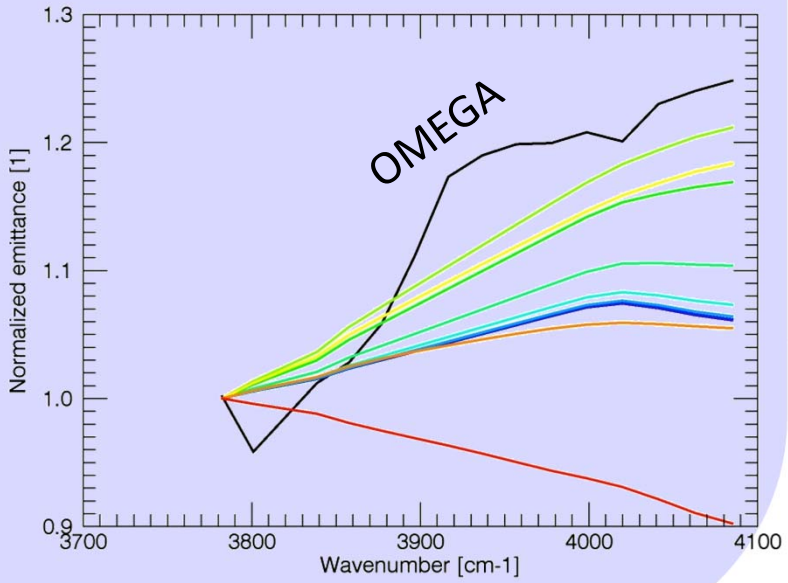
- Lots of efforts put on verifying the precision of the Jacobians
  - Critical information for precise retrieval
  - Analytical Jacobians precision >>> Numerical Jacobians precision
- Work done in collaboration with M. Toyooka (Tohoku University), see Poster *"Modification of the retrieval tool JACOSPAR for the Martian limb and solar occultation observations"*



The Bayesian inversion and inversion implementation

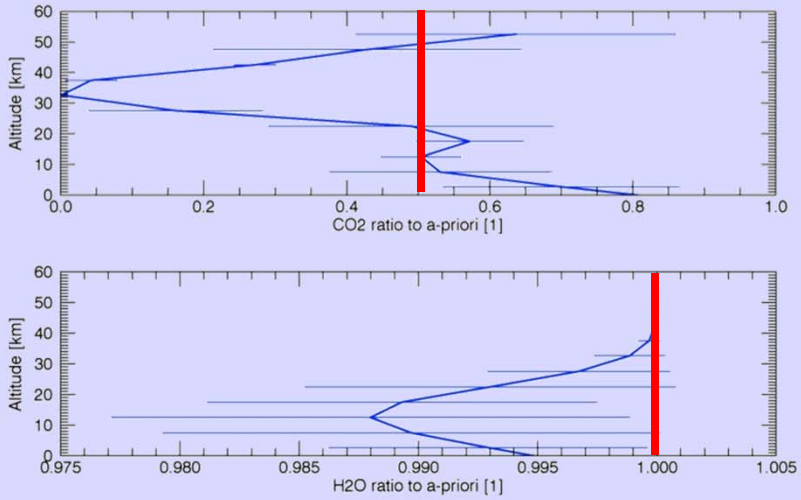
- JACOSPAR used in a Bayesian inversion scheme (Rodgers, 2000)
- A-priori obtained from GEM-Mars (Neary et al., 2017)
  - Total number density, temperature & pressure profiles not adjusted
- Lognormal distribution of the aerosol species
  - Variance is kept constant (0.5)
  - Mean radius is retrieved
- Factors to the mixing ratio and radius of each species are considered
- Covariances
  - 50% for the gas mixing ratios
  - 25% for the aerosol mixing ratios
  - 50% for the aerosols radii
- Prefit of the aerosols radii

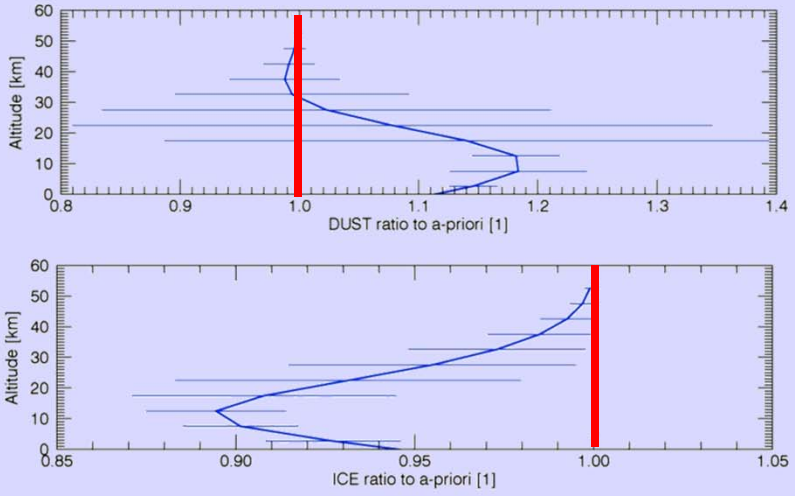
Radius: 0.1, 0.13, 0.16, 0.2, 0.25, 0.32, 0.4, 0.5, 0.63, 0.8, 1.0 µm



Sensitivity study (1)

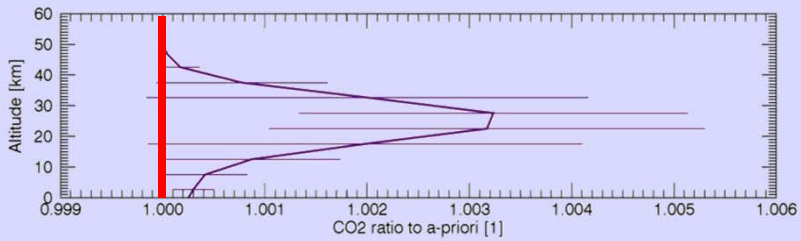
- To check the sensitivity of the code to the different species, we calculated synthetic spectra based on geometry of orbit 941 and GEM-Mars profiles and added noise with SNR 100
- We varied the a-priori value in the Bayesian scheme, and tried to retrieve the initial parameters
- Example:
  - CO_2

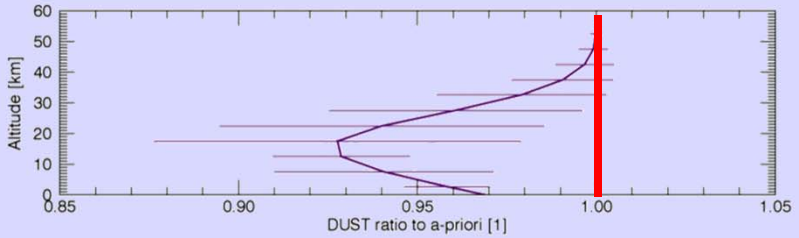


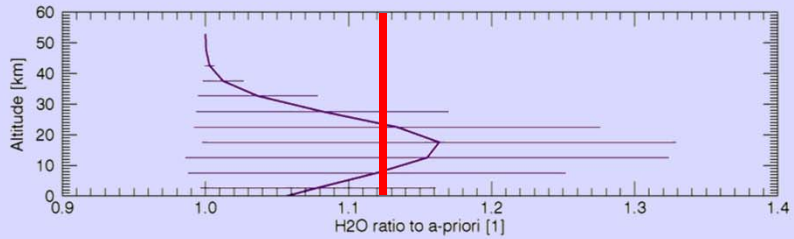


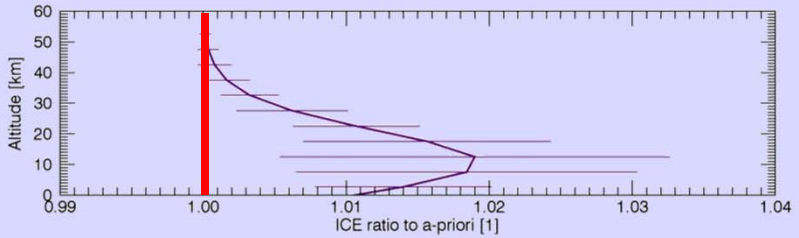
Sensitivity study (2)

- H_2O









- Conclusions of the sensitivity study:
  - Good sensitivity to dust mixing ratio
  - Medium sensitivity to CO_2 mixing ratios and dust mean radius
  - Weak sensitivity to H_2O and water ice mixing ratio and mean radius
  - No sensitivity to CO mixing ratio

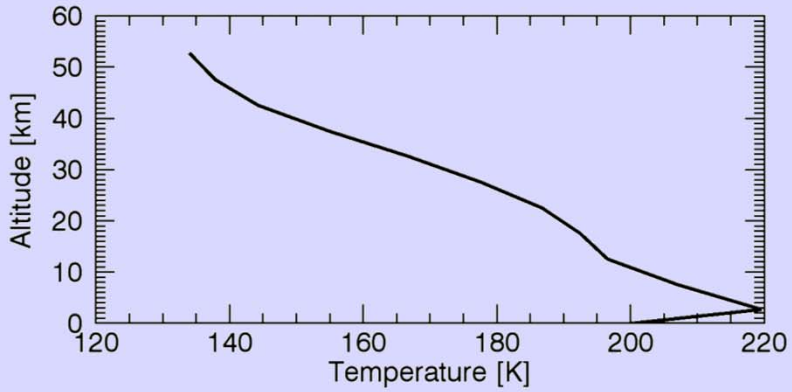
Application: Inversion of orbit 941 (1)

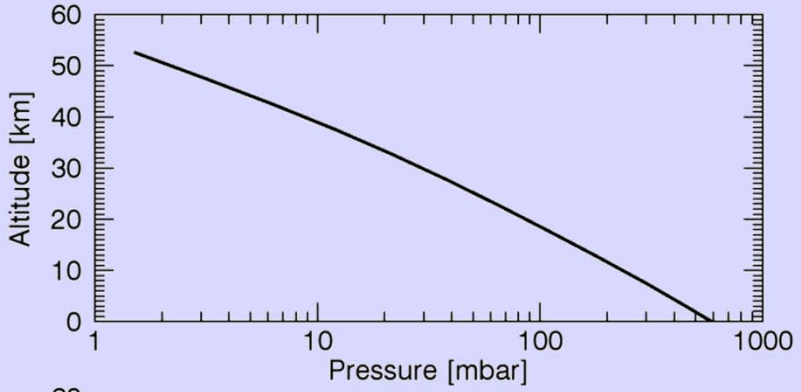
- Dust mixing ratio and radius vertical profiles retrieved in 8500 to 10,000 cm^{-1} region
- CO_2 retrieved in 4500 to 5180 cm^{-1}
- H_2O retrieved in 3780 to 4020 cm^{-1}
- 10 spectra are considered between 0 and 60 km

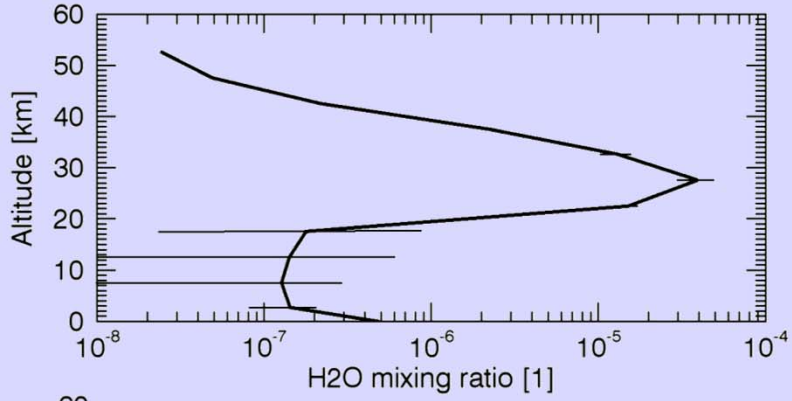
- No sensitivity to CO and water ice, as expected

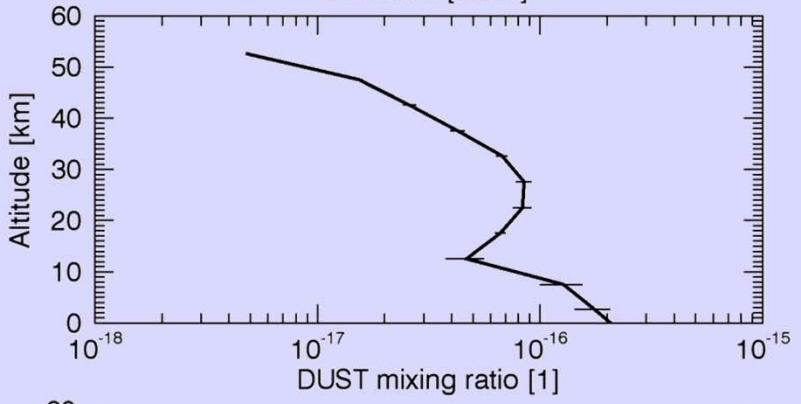
- Degree of freedom at each altitude level for
  - H_2O: ~5%
  - CO_2: ~10%
  - Dust mixing ratio and radius: ~75%

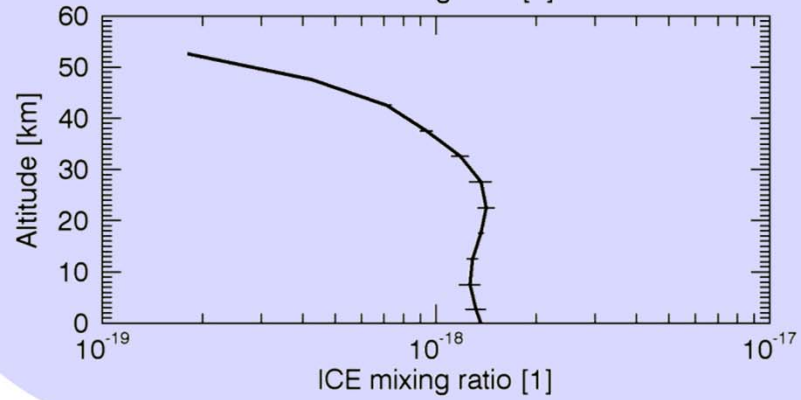
Application: Inversion of orbit 941 (2)

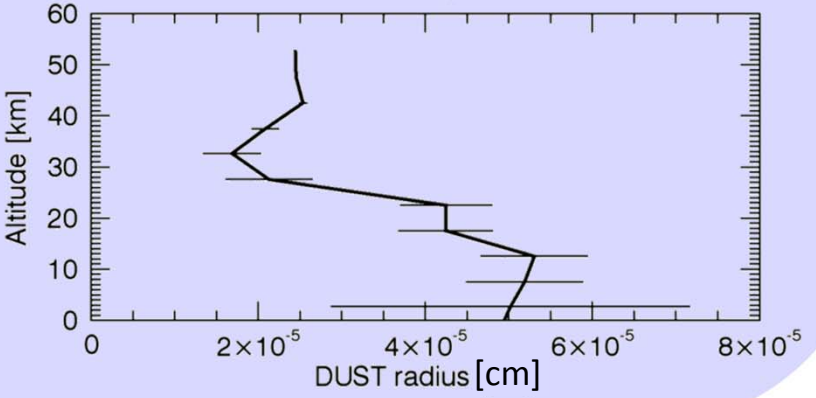












Conclusion and future prospects

- We showed that we have the capacity of retrieving CO_2, H_2O and dust mixing ratios, and dust mean particle size
- Error bars are large due to small SNR and poor spectral sampling
- We want to check the validity of the water profile
- We are still working on improving the retrieval procedure:
  - Choosing the right covariances
  - Fit simultaneous wavenumber intervals to increase our sensitivity
- Paper in preparation
- Future applications: OMEGA/MEx (Mars: S. Aoki), NOMAD/EMTGO (Mars: S. Aoki, A. Mahieux, A.C. Vandaele), CRISM/MRO (Mars: M. Toyooka), VIRTIS-H/VEx (Venus: A. Mahieux), CASSINI instruments (Enceladus: A. Mahieux)

Inversion of Mars atmosphere limb observations considering multiple scattering: Application to OMEGA/MEx observations, *A. Mahieux, S. Aoki, H. Iwabuchi, M. Toyooka, Y. Kasaba, G. Bellucci, F. Oliva, G. Sindoni, F. Altieri, A. Geminale, E. D'Aversa, H. Iwabuchi, H. Nakagawa, P. Wolkenberg,* (in preparation)