UPWARDS

UNDERSTANDING PLANET MARS

www.upwards-mars.eu

Technical Summary March 2018

CONTEXT AND OVERALL OBJECTIVES

The goal of UPWARDS is to analyze unexploited data, mostly from the European Mars Express (MEx) mission, using a novel combination of state of the art retrieval tools and models, in preparation for the European ExoMars mission. The synergistic UPWARDS teams addressed a set of open, key scientific problems in Mars sciences : the subsurface atmosphere exchanges of trace species, the global cycle of water, the variability of atmospheric dust and storms, the links between lower and upper atmosphere, and the dramatic day-night transitions in atmospheric composition.

MAIN RESULTS ACHIEVED

1. Development of innovative state of the art tools for data analysis

Development of new tools for ExoMars, tested on MEx datasets: 1) two synergistic retrieval methods to combine nadir data from diverse spectral ranges 2) Two innovative retrieval techniques for observation of the limb to analyze dusty lower atmospheres and treating non thermal emissions (NLTE) from the upper atmosphere and 3) trajectory reconstruction model for Martian entry probes.

Major results:

- First synergistic retrieval of H2O vapor combining NIR and thermal data from MEx nadir data shows near surface confinement.
- Successful retrieval of H2O vapor profiles from limb observations in dusty conditions
- First derivation of CO2 densities at high altitudes from NLTE emission.
- New method for reconstructing density and temperature from heat shield pressure data validated with Curiosity and applied to Exomars Schiaparelli.

2. Subsurface reservoirs and transport of trace gas species

Development of models of the subsurface of Mars to link the heat flow and the destabilization of ice/clathrate deposits with their transport to the surface and their atmospheric distribution.

Major results:

◆ Global maps of Mars crustal heat flow from available observations. Application to Insight and ExoMars landing sites.

◆ Evolution of subsurface water vapor and impact on high latitude ice deposits, applied to the Phoenix landing site

◆ First global maps of the methane hydrate stability zone.

3. Intrinsic (aerosol-free) surface reflectance

Correction of atmospheric scattering and photometric effects in OMEGA visible and near-IR spectra to derive true surface reflectance. Application to mineralogy, albedo mapping.and study of seasonal and interannual changes

4. Water cycle and water-ice clouds

The objective was to combine unprecedented observation of Mars clouds with atmospheric models to better understand this key aspect of Mars Climate.

Major results:

◆ Two complete climatologies of clouds from MEx NIR imaging spectrometer OMEGA and UV spectrometer SPICAM, revealing diurnal and seasonal processes.

◆ Derivation of cloud physical properties like opacity, mass, particles size.

◆ Improvements in the global climate model (LMD-GCM).

◆ Discovery of a cloud-induced night-time convection using high-resolution atmospheric models.

5. Atmospheric aerosols

Development of a code for the simultaneous retrieval of temperature profiles, surface temperature and dust and water-ice optical depths. Production of climatologies for 6 Martian years with PFS/MEx measurements.

Major results:

◆ Development of routines to retrieve dust properties from limb and grazing observations.

◆ Derivation of H2O and CO abundances during a global dust storm, revealing interesting correlations..

◆ Dust opacities and particle sizes from MEx limb observations using a spherical radiative transfer model accounting for multiple scattering and surface shine.

6. Day-night transitions around the Mars terminator

Modeling the atmosphere and trace species like ozone at the day-night terminator. Implementation of concentration gradients in solar occultation analysis and application to selected SPICAM data.

Major results:

◆ Fast variations with local time at the terminator of species with strong daily cycles, and
sensitivities to altitude and dawn/dusk

◆ Impact of the line-of-sight variations on the retrieval of ozone from SPICAM solar occultations

7. Atmospheric structure and escape at high altitudes

Analysis, including clustering techniques, of MEx IR daylight limb emissions, derivation of CO2 and temperature vertical profiles above 120 km, and interpretation with a 3-D global model. Analysis of SPICAM UV dayglow data and 3D model simulations. Study of H escape combining SPICAM observations and model simulations.

Major results:

◆ 1st time retrieval of CO2 density and temperature profiles (120-170 km) from OMEGA data. Comparison with GCM predictions show systematic differences, either due to an unidentified observation bias or to an underestimation of the modeled mesopause height.

◆ First 3D simulation of UV dayglow for a full Mars year. Good agreement with SPICAM data validates the predicted thermal structure at high altitudes

◆ Simulation and SPICAM observations of Lyman-alpha profiles show overall agreement, except during southern summer solstice, possibly due to water vapor injection to the upper atmosphere

8. Data assimilation and interpretation

Thermal, dust, water and ozone data from two NASA missions (TES and MCS), as well as ESA Mex were assimilated using with a previously validated “Analysis Correction” assimilation scheme (ACS). A new data assimilation method based on a Local Ensemble Transform Kalman Filter (LETKF) was developed and tested against the ACS.

Major results:

◆ Comparisons of control simulations and data assimilation of total ozone from SPICAM show that the standalone GCM can be up to 40% biased in several regions and seasons.

◆ Comparisons of SPICAM ozone reanalysis and TES water vapor reanalysis reveals interesting systematic biases of the standalone GCM.

◆ First successful assimilation with the LETKF method, and confirmation of the importance of assimilating Martian aerosols (dust and water ice) together with temperatures.

EXPLOITATION AND DISSEMINATION

UPWARDS results were disseminated through 50 scientific publications and nearly 100 presentations in conferences. Datasets were delivered to the ESA Archive with 75 GB in 24 sets from all teams. Two international workshops were organized by UPWARDS members in 2017 (“Mars Atmosphere Modeling and Observations”) and 2018 (“From MEx to ExoMars”).

FUTHER IMPACTS

Beyond scientific communications, UPWARDS' impacts include analysis tools developed for the science community, quality employment in Europe, with 18 contracts of early-career technicians and scientists, and various outreach activities across Europe, like:

- Press releases to general and specialized media
- 3 videos on UPWARDS results including interviews from all teams.
- “Understanding Planet Mars”, a 50 min long documentary, broadcasted twice by the Spanish TV (international channel)
- “Lets go to Mars”, an app for all OS and platforms, with over 200,000 downloads
- Live events like meetings with high-school students, participation in science fairs, live streaming and commentaries during ExoMars launch, and many seminars to the general public
- “The Martian Puzzle”, an exhibition shown in two major science museums in Spain and France

UPWARDS - Understanding Mars With Advanced Remote-sensing Datasets & Synergistic Studes

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