RoadMap to Understanding Atmospheric Dust on Mars

Ann Carine Vandaele describes how open scientific questions about dust and clouds in the atmosphere of Mars present major challenges to our current understanding of the Red Planet.

Dust in the atmosphere of Mars has a seasonal cycle and can vary substantially from year-to-year. Some years, dust storms are relatively small and regionally confined; in other years – like 2018 – a global, planet-encircling dust storm develops. Dust affects the thermal structure of the martian atmosphere, the water cycle and, potentially, the rate at which hydrogen is lost into space. However, we still have much to learn about the nature of its variability and the mechanisms involved in getting dust from the surface into the atmosphere.

Our knowledge of the physical processes governing the generation and transport of atmospheric mineral aerosols is based largely on observations and, in many cases, there is extremely limited experimental data. This is true for our understanding of aerosols in Earth's atmosphere, but it is an even greater problem for our understanding of dust particles in the martian atmosphere. To develop more reliable and predictive models to describe martian aerosols, we need to test conventional models through controlled, high-precision laboratory experiments.

RoadMap (ROle and impAct of Dust and clouds in the Martian AtmosPhere) is a new project, funded by the European Commission under Horizon 2020, that aims to create laboratory datasets and models to better describe martian dust and clouds. The project uses a simulant (analogue) for martian dust to investigate key dynamic processes, such as lifting, sedimentation, nucleation and scattering. The resulting data will be used to improve Global Circulation Models (GCMs) to provide more realistic atmospheric dynamics and climatology.

The team behind RoadMap brings together the laboratory community, scientists involved in space missions, and numerical modellers to promote synergies through their different perspectives and experiences. Laboratory scientists understand the reference data and know how to extract the most value from their experiments; mission scientists know the intricacies and potential of the instruments and the details of their calibration; and numerical modellers know what data, information and parameters are most pertinent to their simulations and how best to interpret the results.

RoadMap is led by the Planetary Atmospheres Research Group of the Royal Belgian Institute for Space Aeronomy (BIRA-IASB), which has been involved in multiple planetary missions, including SPICAM on Mars Express, SPICAV-SOIR on Venus Express, NASA's Phoenix Mars lander, and NOMAD on ESA's ExoMars Trace Gas Orbiter. As well as interpreting observed data, the group also provides state-of-the-art modelling of the martian atmosphere using clouds microphysics simulations and GCMs (Neary et al, 2020; Vandaele et al, 2019; Willame et al. 2017).

The first step of the RoadMap project is to synthesise

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a representative analogue for martian dust from powdered basaltic materials, and characterise the particles' size, shape and microphysical properties. The powder produced by the Funceramics team at CSIC-ICV can then be used in a diverse set of laboratory experiments at some of Europe's leading planetary simulation facilities.

The cryogenic low-pressure environmental chamber (Holstein-Rathlou et al, 2014; Merrison, 2011; Merrison et al, 2008) at Aarhus University is a unique facility that can generate wind flow to study the mobilisation and transport of particulates under martian conditions at temperatures down to -50 degrees Celsius. Mixtures of gas and dust analogue can be injected into the simulation chamber and dispersed via a jet. The velocity of individually suspended dust grains and the concentration and flow of the aerosol can be monitored by a Laser Doppler Velocimeter and a high-speed imaging system installed in the chamber in 2016 as part of the Europlanet 2020 Research Infrastructure project.

Complementary experiments at Duisburg-Essen University (UDE) track how dust particles can be liberated through the impacts of grains bouncing off the surface and study particle-lifting mechanisms at a microscopic level (Bila et al, 2020). Experiments at UDE also study particle-lift under reduced gravity (Musiolik et al, 2018) and under the influence of temperature gradients (de Beule et al, 2015), which is especially important for understanding the physics of gas-flow in granular material under the low-pressure conditions of Mars.

Credit: Aarhus University

The Aarhus Mars Simulation Wind TunneL

Finally, a unique database of the scattering properties of the martian dust analogues is being created through measurements at the Cosmic Dust Laboratory (CODULAB) at the Instituto de Astrofísica de Andalucía (CSIC-IAA), a worldwide reference for dust scattering studies (Muñoz et al, 2020; Muñoz et al, 2011). Scattering and absorption by the irregular particles of martian airborne dust and clouds is difficult to model accurately, but understanding these properties is vital for understanding how solar radiation heats the atmosphere and for interpreting space observations. Improved parameters for production, lifting and dynamics of dust resulting from the RoadMap lab experiments will be implemented and tested in the BIRA-IASB GCM. The scattering properties of the Mars dust analogue will be used to refine the radiative modules of Mars GCMs but also to improve the analysis of trace gases abundances in data from NOMAD and other mission instruments.

Overall, RoadMap aims to improve our vision of the martian atmosphere by providing a new generation of high-level data, increasing the science return of the past and current missions to Mars, and shaping future planetary missions.

More information can be found on the RoadMap project website. https://roadmap.aeronomie.be/

References

Bila et al. 2020. Icarus. DOI: 10.1016/j.icarus.2019.113569
de Beule et al. 2015. Icarus. DOI: 10.1016/j.icarus.2015.06.002
Holstein-Rathlou et al. 2014. DOI: 10.1175/JTECH-D-13-00141.1
Merrison. 2011. DOI: 10.5772/15019
Merrison et al. 2008. DOI: 0.1016/j.pss.2007.11.007
Muñoz et al. 2020. DOI: 10.3847/1538-4365/ab6851
Muñoz et al. 2011. DOI: 10.1016/j.icarus.2010.10.027
Musiolik et al. 2018. DOI: 10.1016/j.icarus.2018.01.007
Neary et al. 2020. DOI: 10.1029/2019GL084354
Vandaele et al. 2019. DOI: 10.1038/s41586-019-1097-3
Willame et al. 2017. DOI: 10.1016/j.pss.2017.04.011