Cosmic dust fluxes in the atmospheres of Earth, Mars, and Venus

Juan Diego Carrillo-Sánchez, John M. C. Plane, Juan Carlos Gómez-Martín, David L. Bones, David Nesvorný, Petr Pokorný, Mehdi Benna, George J. Flynn

The ablation of cosmic dust injects a range of metals into planetary upper atmospheres. In addition, dust particles which survive atmospheric entry can be an important source of organic material at a planetary surface. In this study the contribution of metals and organics from three cosmic dust sources – Jupiter-Family comets (JFCs), the Asteroid belt (AST), and Halley-Type comets (HTCs) – to the atmospheres of Earth, Mars and Venus is estimated by combining a Chemical Ablation Model (CABMOD) with a Zodiacal Cloud Model (ZoDy). ZoDy provides the mass, velocity, and radiant distributions for JFC, AST, and HTC particles. JFCs are shown to be the main mass contributor in all three atmospheres (68% for Venus, 70% Earth, and 52% for Mars), providing a total input mass for Venus, Earth and Mars of 31 ± 15 t d^{-1}, 28 ± 8 t d^{-1} and 2 ± 1 t d^{-1}, respectively. The mass contribution of AST particles increases with heliocentric distance (6% for Venus, 9% for Earth, and 14% for Mars). A novel multiphase treatment in CABMOD, tested experimentally in a Meteoric Ablation Simulator, is implemented to quantify atmospheric ablation from both the silicate melt and Fe-Ni metal domains. The ratio of Fe:Ni ablation fluxes at Earth, Mars and Venus are predicted to be close to their CI chondritic ratio of 18, in agreement with mass spectrometric measurements of Fe^+:Ni^+ = 20.0 in the terrestrial ionosphere. In contrast, lidar measurements of the neutral atoms at Earth indicate Fe:Ni = 38 ± 11, and observations by the Neutral Gas and Ion Mass Spectrometer on the MAVEN spacecraft at Mars indicate Fe^+:Ni^+ = 43 . Given the slower average entry velocity of cosmic dust particles at Mars, the accretion rate of unmelted particles in Mars represents 60% of the total input mass, of which a significant fraction of the total unmelted mass (22%) do not reach an organic pyrolysis temperature (~900 K), leading to a flux of intact carbon of 14 kg d^{-1}. This is significantly smaller than previous estimates.