**Introduction:** Mars has lost and continues to lose its atmosphere into space. Strong evidence of this active process include observations of O+, O2+ and CO2+ ions that escape the red planet’s atmosphere with kinetic energies ranging from a few eV to several tens of keV. The small moon Phobos orbits only 6,000 kilometers above the surface of Mars and is therefore bombarded by these Martian ions.

The characterization of ions seen by Phobos along its orbit is now better than ever possible thanks to the NASA Mars Atmospheric Volatile and EvolutioN mission (MAVEN) which had its apoapsis right at Phobos’ altitude from September 2014 to February 2019. Onboard MAVEN, the SupraThermal and Thermal Ion Composition instrument (STATIC) is able to identify the mass per charge of ions and to therefore separate the contribution of solar wind H+ and He++ ions from heavy Martian ions. A previous work computed the omnidirectional long-term averaged flux of H+, He++, O+ and O2+ ions at Phobos [Nénon et al., *JGR: Planets* 2019]. From this, O+ and O2+ ions that escape the Martian atmosphere have been shown to significantly sputter the surface of Phobos, establishing the unique link between Phobos’ surface processing and its host planet atmosphere.

Here, this link is further explored by computing the directionally resolved (as opposed to previous studies using only omnidirectional data), long-term averaged flux of ions at Phobos, which in turns enables us to create the very first surface maps of precipitating ion fluxes. Using these fluxes, we quantify the implantation rate of Martian atmospheric material within Phobos’ regolith and reveal induced surface weathering inhomogeneities.

**Ion bombardment surface maps:** The orientation of Phobos in space is known as it is tidally locked and therefore always points its near side towards Mars. We assume that each location on Phobos’ surface is impacted by the 2n flux of ions seen by a local plane. This enables a conversion of the long-term average ion flux anisotropy observed by MAVEN STATIC into maps of the flux bombarding each location on Phobos’ surface. Figure 1 gives surface maps of precipitating solar wind 600 eV H+ ions and Martian 200 eV O2+ ions. Solar wind ions impact Phobos primarily on its far side, but we note that the flux near-side/far-side ratio is moderate as it is lower than a factor of 3. Martian ions bombard Phobos mainly on its near side, with a strong flux near-side/far-side asymmetry of a factor of 15 to 100, depending on the ion energy.

![Figure 1 Flux of ions impacting each location on Phobos. The West longitude of 0° points towards Mars (near side).](image)

**Ion implantation rates:** The SRIM software [Ziegler, 2013] has been used to quantify for the first time the rate at which atoms and molecules coming from Mars’ atmosphere have been implanted for millions of years inside the top tens of nanometers of exposed regolith grains located on Phobos’ near side. This has important implications for future sample returns as we find that near-side regolith grains (1) are contaminated by Martian atmospheric material and (2) contain unique archives of the past and current atmosphere of the red planet.

**Asymmetric surface weathering:** The SRIM tool has also been used to compute the production rate of vacancies that lead to the amorphization of an initially crystalline material [Carrez et al., *Meteoritics & Planetary Science* 2002]. On the near side of Phobos, Martian ions are found to accelerate the creation of vacancies by a factor of 2 in the top nanometers of the target material, whereas they have a negligible effect compared to solar wind ions on the far side. In addition, O+ and O2+ ions are found to accelerate the sputtering of the near side by a factor of 2. We therefore reveal that the near side and far side of Phobos have different ion weathering histories as a result of the Martian atmospheric escape.