Venus Express: Atmospheric Loss and Electrodynamics. C.T. Russell[1], J.G. Luhmann[2], H.Y. Wei[1], Y.J. Ma[1], J.T.M. Daniels[1], S. Barabash[3], T.L. Zhang[4], [1] University of California, Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, CA 90095-1567 USA, [2] University of California, Berkeley, Space Science Laboratory, Berkeley, CA 94720 USA, [3] Swedish Institute of Space Physics, SE-981 28 Kiruna, Sweden, [4] Austrian Academy of Sciences, Space Research Institute, Vienna, Austria

Introduction: In April 2006, ESA's Venus Express mission was successfully inserted into orbit about Venus in a highly elliptical 24-hour orbit, near polar in inclination with periapsis near the north pole. The payload of Venus Express includes ASPERA, a comprehensive detector of energetic charged and neutral particles, and a magnetometer capable of sampling up to 128 Hz to detect signals possibly associated with lightning. Since any intrinsic magnetic field of Venus is too small to dynamically affect the solar wind interaction, the solar wind interacts directly with the ionosphere and upper atmosphere of Venus. The magnetic field of the solar wind can both act as a shield and as a facilitator for removal of the atmosphere. The magnetic field piles up on the forward side of Venus and creates an obstacle to the flow. The solar wind flow is then deflected around the obstacle. While this magnetic barrier shields the planet on the dayside the magnetic field can diffuse into the ionosphere, and on the nightside, the field can pull ionospheric plasma out of Venus' gravitational potential well. Thus, the magnetic field contributes to plasma loss on the nightside. Further, the solar wind can directly lead to atmospheric loss by charge-exchange with the tenuous exosphere of the planet or by picking up ions when exospheric neutral particles become ionized through photo or impact ionization.

Deeper in the atmosphere near 50 km altitude, Venus is cloud covered. The particles in this cloud are not water but sulfuric acid, and like ice particles in terrestrial clouds, sulfuric acid particles can become electrically charged upon collision. Like on Earth, the potential difference between different portions of the cloud can become sufficient for electrical breakdown of the gas and an electrical discharge to occur, i.e. lightning. Venus Express is ideally suited to detect these discharges which create electromagnetic waves that first propagate through the atmosphere and then couple to the ionosphere and are guided by the magnetic field to the spacecraft.

Interaction of the Solar Wind with the Atmosphere: Venus Express has added significantly to our understanding of the interaction of the solar wind with the atmosphere, especially regarding the behavior at solar minimum. Most measurements before had been obtained near solar maximum. The magnetic field diffuses deeply into the solar minimum ionosphere and the ionosphere becomes largely magnetized. This is expected to reduce the loss rate of plasma and protect the ionosphere from loss. The ASPERA plasma detector sees two forms of atmospheric loss: ions carried downstream from the night ionosphere and fast neutrals caused by solar-wind charge exchange with the exosphere.

The magnetometer also detects another aspect of the solar wind-exosphere interaction, the pick-up of newly formed ions created from the exosphere. These ions receive gyrational energy in the process that can decay into the production of ion-cyclotron, electromagnetic waves. The identification of these waves has become controversial. If the rate of detection of the waves is as reported, then the density of the exosphere now is about 10 times its density at solar maximum during Pioneer Venus' visit. Other characteristics of the Venus waves are different than expected from observations at the other planets as well.

Lightning: Shortly after arrival, the Venus Express magnetometer began observing electromagnetic bursts indicative of lightning. These waves were circularly polarized, strong, up to 1 nT peak to peak, and propagating along the field. Their access to the spacecraft appeared to be controlled by the local direction of the magnetic field in the manner expected. Horizontal fields blocked access and radial fields allowed access. The propagation of signals to the spacecraft from the atmosphere requires both a direction of the magnetic field that allows coupling to the atmosphere and a sufficiently strong magnetic field to support propagation at the wave frequency of the lightning signals. It appears that at times, the magnetic field magnitude in the ionosphere is too weak to allow these signals to reach the spacecraft.

Summary: The solar wind interaction with Venus is eroding the Venus atmosphere in several different ways so that Venus is losing about 10^{25} ions per second. This number and the strength of the various loss mechanisms are still under active investigation. The Venus atmosphere is a strong generator of electromagnetic signals that have the properties expected from a lightning source in the clouds. The rate of these discharges is also still under active investigation.