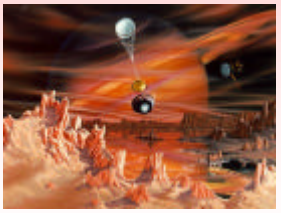
Titan atmospheric electricity investigation with the PWA-HASI instrument on the HUYGENS probe. Trial balloon flights in the terrestrial atmosphere

•S. Abaajan[1], M. Hamelin[1], V. Brown[2], P. Falkner[3], R. Grard[3],I. Jernej[4], J.J. Lopez-Moreno[2], G. Molina-Cuberos[5], K. Schwingenschuh[4]1CETP-CNRS, Saint Maur, France [2] IAA, Granada, Spain [3]RSSD/ESTEC, Noordwijk, NL [4]IWF, Graz, Austria [5]Univ. Granada, Spain and HASI team

PWA_HASI experiment

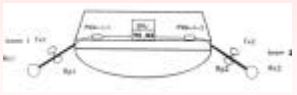
The HASI-PWA instrument has been designed to investigate the Titan atmospheric electricity and possible lightning activity. Theoretical models conclude to a stronger ionisation than in the Earth atmosphere. Then a DC global electric circuit and some lightning activity could exist. This consolidates the interest in the atmospheric electricity, that is one of the possible mechanisms able to produce complex organic prebiotic molecules. We show the two techniques used to measure the conductivity of the atmosphere through its main charge carriers: electron conductivity with the Mutual Impedance (MI) technique and polar ion conductivities with the Relaxation Probe (RP) technique. We discuss the results of two trial balloon experiments in the terrestrial atmosphere –including the most recent one in 2003- which fully validated the RP technique and provided in flight calibrations of the MI instrument.



The Experiment PWA :

The PWA experiment is part of the HASI experiment aboard the CASSINI/HUYGENS spacecraft . The principal objective of the experiment is to determine the electric properties of the atmosphere and Titan's ground. The main parameters investigated are :

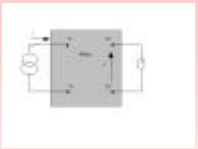
- **Polar ion conductivity**
- **Electron conductivity**
- AC electric fields (Schumann resonances).
- DC electric field
- Ground conductivity .
- Sounds
- Altimetry



The PWA conductivity measurements with the MI and RP instruments were tested in the terrestrial atmosphere during balloon flight with mock-up of the Huygens probe. We report here the main results of these tests.

Measurement of the electrons conductivity : Mutual Impedance Probe (MI)

The MI measurement performed by the HASI/PWA instrument aboard the Huygens probe is based on electric current injection into surrounding medium. This current injection is implemented by using an AC voltage source through small coupling capacitors.



The injected current flows along lines of the resulting electric field from the T1 to the T2 electrode. The R electrodes tap the potential difference between two regions in the medium; the difference in voltage is measured.

This voltage is measured for two conditions :

- Vacuum ($\varepsilon_r=1$, $\sigma=0$) yields a voltage A_0 and phase φ_0
- Any unknown medium yields a voltage A and phase φ

The conductivity of the atmosphere ($\varepsilon_r = 1$) can be calculated using: $\sigma = \left|\frac{A_0}{A}\right| \omega \varepsilon_0 \sin(\varphi - \varphi_0)$

Measurement of the polar ion conductivity : Relaxation Probe (RP)

Relaxation probe :

The two RP electrodes are set to ±5 Volt or 0 V. Then they are disconnected from the DC voltage source and connected to the PWA electrometer. We deduce the ion conductivity of the surrounding medium from the relaxation time constant τ of the theoretical potential time variation:

$$V=(V_0-V)\exp(-t/\tau)+V_f$$

Where V_f is the floating potential and V_0 the potential at time t=0 when the electrodes were connected to the DC source.

Then the conductivity is: $\sigma_{\pm}=\varepsilon_0/\tau_{\pm}$

Example of Potential decay in the Comas Sola flight

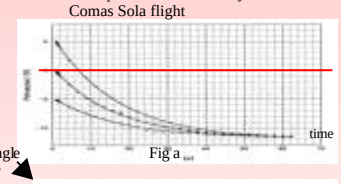


Fig a

RP1 Potential, Yaw angle and vertical velocity

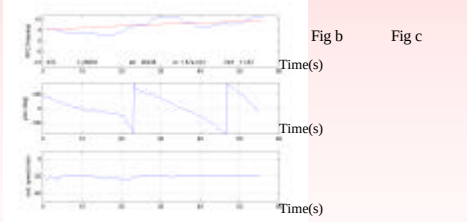


Fig b

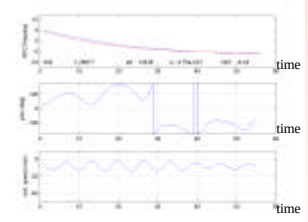


Fig c

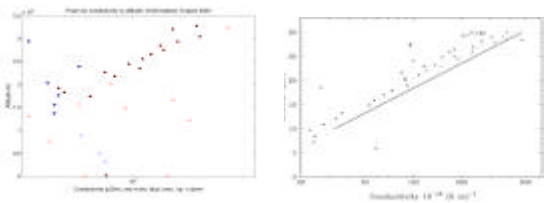
The balloon tests are performed in quiet atmospheric condition. However, the electrical parameters of the atmosphere are not the same for each flight and they are variable during the flights. In the most of the cases at altitudes greater than ~10 km the RP potential follows very well the theoretical equation, (Fig a).

In (Fig b) the potential is perturbed, and a very poor estimation of σ can be derived. The perturbation seems to be related to the rotation of the probe. It could be the effect of a horizontal component of the DC electric field.

In the last example (Fig c) on the contrary the potential follow very well the theoretical behaviour despite the very chaotic motion of the probe.

Conductivity measurements

Trapani 2003 León 1995

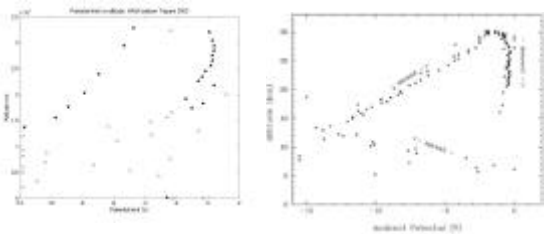


In the Trapani flight (2003) case, the altitude ionic conductivity profile is similar to the León (1995) one and close to current models in the Earth atmosphere.

Both polarities of ionic conductivity are shown.. The solid line represents the average profile for polar positive conductivity obtained in an other experiment by Holzworth(1991).

RP floating (limit) potential results

Trapani 2003 León 1995



In the Leon flight we see large negative V_f values during the ascent whereas the large negative V_f are observed during the descent in the Trapani flight. This is not still understood.

▲ : Potential limit during the ascent.

▼ : Potential limit during the descent.

Red: + ions; Blue: - ions

Discussion

As there are no electrons in the range of altitudes of the balloon flights, the MI measurements provided only the vacuum calibration reference for the electron conductivity measurement, but in better conditions than in the laboratory.

The results obtained during this balloon flight validate the RP performance. The conductivities measured during the flight correspond with the one expected in the Earth's atmosphere with some dispersion at altitude <15km where the measurements are not reliable. Both components of polar conductivity follow coherent and continuous altitude profiles at higher altitudes.

Perturbations: the influence of attitude and vertical motions are ambiguous. This will be investigated deeper during another balloon flight planned in 2004 (PEASMA).