ABSTRACT

This contribution deals with the long-term measurement of the floating potential (FP) and the electron temperature (Te) provided by the Thermal Plasma Measurement Unit (TPMU) scientific instrument on-board the PROBA II microsatellite. The device is working with limitations of scientific measurements caused by bug in on-board software. We present comparisons of the TPMU long-term measurement of the FP and the Te with the Te and the FP SWARM Langmuir Probes measured data. We implement the method of stochastic comparison of the probability distribution between measurements of FP and Te of both instruments to recognize seasonal and solar activity similarities. The analysis is performed for all seasons of the period from the years 2013 – 2014 for the Equatorial region, North and South hemisphere. This comparison confirms that the TPMU PROBAII Te and FP measurement statistically corresponds to the SWARM Te and FP measurement.

The annual seasonal changes in the floating potential are observed in this analysis. Changes in the beginning, the end and duration of seasons over a period of years reflect also changes over the solar cycle.

A measurement of the TPMU - PROBA II Microsatellite Instrument and its comparison with the SWARM Langmuir Probes results

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THERMAL PLASMA MEASUREMENT UNIT

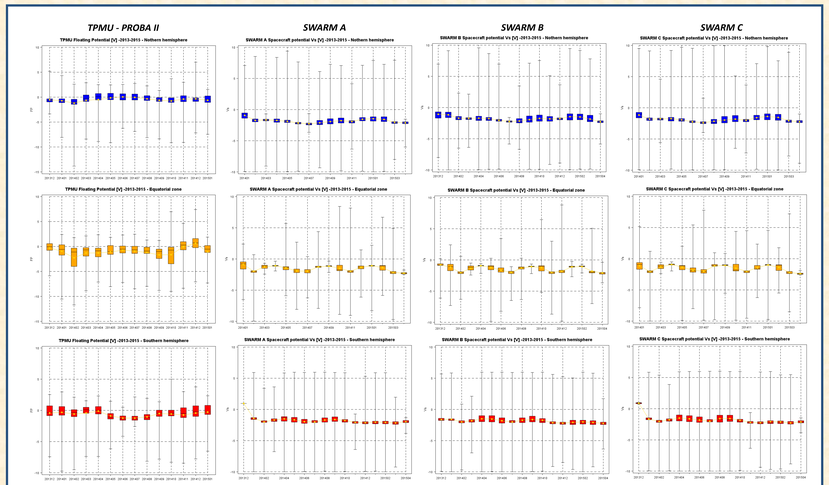
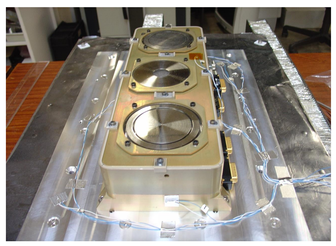


Fig.1: Box plots of FP[V] measured by TPMU PROBA II instrument and Vs[V] measured by SWARM Langmuir Probes.
Plots are organized in groups by year-month. A box-and-whiskers plots display the mean (yellow dots), quartiles (color boxes), and minimum and maximum observations (whiskers) for a data groups. The data are divided to three groups by geographical latitudes to the Nothern hemisphere (lat>15°), the Southern hemisphere (lat<-15°) and Equatorial zone (lat 15°– -15°). The analysis is performed for all seasons and Equatorial region, North and South hemisphere. The annual seasonal changes in the floating potential are reflected in changes of the variance in this analysis. Wider variability of the SWARM Vs data than the FP measured by TPMU PROBA II migth be caused by higher SWARM Vs measurement frequency.



The Thermal Plasma Measurement Unit *(TPMU) was designed and manufactured as a part of scientific payload of the PROBA II satellite.*
It is intended for research of the cold plasma parameters like electron temperature, ion density, ion temperature and floating potential of the satellite. The main TPMU goal is the validation and testing of new design of the instrument which is necessary for possible applications of TPMU design for future scientific missions. The device was designed and developed at the Institute of Atmospheric Physics ASCR.
The TPMU is placed in a box made of aluminium alloy containing the electronics block and block of measuring sensors with the retarding potential analyzer (RPA) and two RF sensors.
TPMU measurement range of densities and temperatures: *10 - 1 million ions per cubic centimetre, resp. 800 -10 000 K.* ***The floating potential measured range:*** *± 12 volts.*
PROBA II satellite
Orbit *Sun-sychronous.*
Altitude *720 km.*
Inclination *98.298 degrees.*
Attitude control:
Sun-pointing with automatic manoeuvring.
Size *0.65 x 0.7 x 0.85 m,* ***Mass*** *130 kg.*
Current status: *Active.*

Fig.4: TPMU - PROBA II Microsatellite Instrument.
PROBA II satellite *with the TPMU on board was launched on 2 November 2009. Source: IAP ASCR, http://www.esa.int/Our_Activities/Technology/Proba_Missions/About_Proba-2*

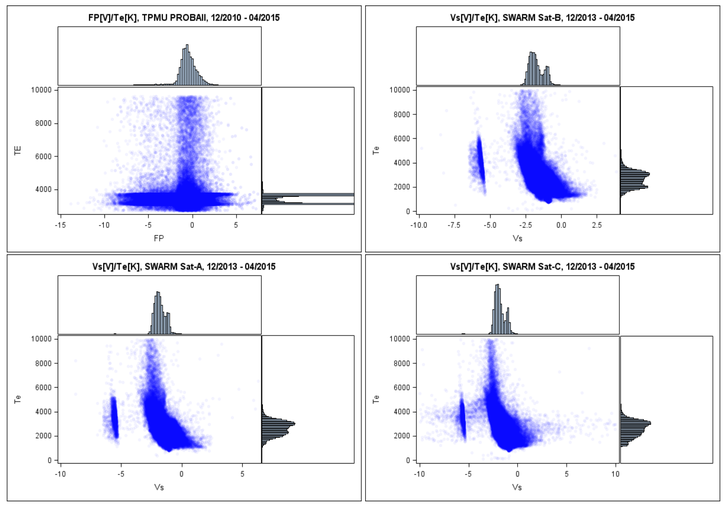


Fig.2: Comparison of FP(Vs)[V] and Te[K] measurement by TPMU PROBA II and SWARM Langmuir Probes measured data.
Plots are organized in panels by satellite (PROBAII, SWARM A, B, C) in central panels are the scatter plots of FP/Vs versus Te. Two separate panels in top and right depict the marginal density histograms of FP/Vs and Te measurement . SWARM Langmuir Probes data are standardized to TPMU PROBA II measurement frequency. The analysis was perform for 50 516 585 records of SWARM A measurement, 55 850 642 of SWARM B measurement and 52 399 715 of SWARM C measurement . Number of TPMU PROBA II measurement was 3 173 502.

SWARM *is an European Space Agency (ESA) mission to study the Earth's magnetic field. High-precision and high-resolution measurements of the strength, direction and variations of the Earth's magnetic field, complemented by precise navigation, accelerometer and electric field measurements.*
Two satellites orbit side-by-side decaying naturally from an initial altitude of 460 km to 300 km, while the third orbits at about 530 km

SWARM Langmuir Probes
Instruments: *Vector field magnetometer, absolute scalar magnetometer, electric field instrument, accelerometer, GPS receiver, startrackers and laser retroreflector*

SWARM satellite
Orbit: *Polar.*
Apogee
SWARM A: ≤460 km, SWARM C: ≤460 km, SWARM B: ≤530 km
Inclination
SWARM A: 87.4°, SWARM C: 87.4°, SWARM B: 88°
Attitude control:
Sun-pointing with automatic manoeuvring.
Size *9.1 m × 1.5 m × 0.85 m,* ***Mass*** *369 kg.*
Current status: *Active.*

Fig.5: SWARM satellite.
SWARM satellite constellation *consists of three satellites (Alpha, Bravo & Charlie) was launched on November 2013. http://swarm-wiki.spacecenter.dk/mediawiki-1.21.1/index.php/File:Swarm3.png*

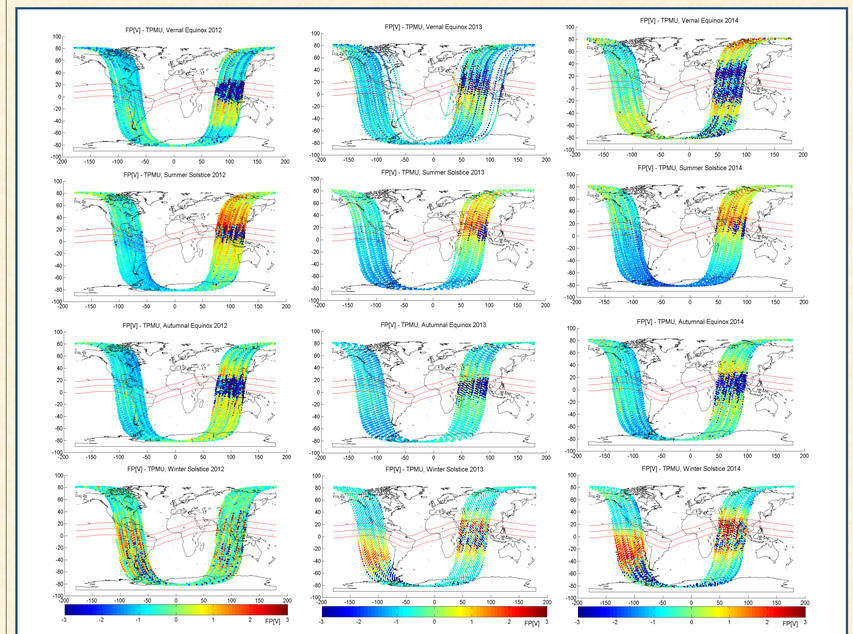


Fig.3: Geographical visualisation of FP measured by TPMU PROBA II instrument.
These plots visualise the floating potential FP data in geographical coordinates. Summer seasonal decrease of the floating potential FP plot is in evidence.
Since 2013, the unit is turned on for a short period at the same time. The satellite is synchronized to the Sun, so measuring is in the same geographical coordinates, ie there is no global coverage. Geomagnetic equator and the 10th parallels North and South are drawn with red line.

CONCLUSIONS

We present results for period of years 2013 – 2015. The similarities in time series of floating potential, electron temperatures were identified. This proves that the measurement of electron temperatures react physically and is only systematically biased. Changes in the beginning, the end and duration of seasons over a period of years reflect also changes of Kp index. The important TPMU goal is the validation and testing of design of the instrument which is necessary for possible applications of TPMU design on future scientific missions. We will continue to assemble and analyse data in the next period.

DATA SOURCES

The satellite Proba2 telemetry data, the TPMU unit onboard measurement.
The geographical coordinates computed from Tle parametres by ORBL algorithm.
World Data Center for Geomagnetism, Kyoto University, Japan, Space Physics Interactive Data Resource (SPIDR), National Geophysical Data Center, Boulder, USA.
SWARM Langmuir Probes *data provided by the European Space Agency.*

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Sokal, R. R., and Michener, C. D., *A statistical method for evaluating systematic relationships*, Univ. Kansas Sci. Bull, 1958, 38, 1409-1438. [1.2.4, 1.2.5, 5.1, 5.4.1, 5.5.1].
Berghmans, D. et al, The PROBA2 Mission: The First Two Years of Solar Observation, Solar Physics, Volume 286, Issue 1, 2013.

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