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INSPIRESat-1 sampling and observation using the coupled whole atmosphere model and ionosphere model

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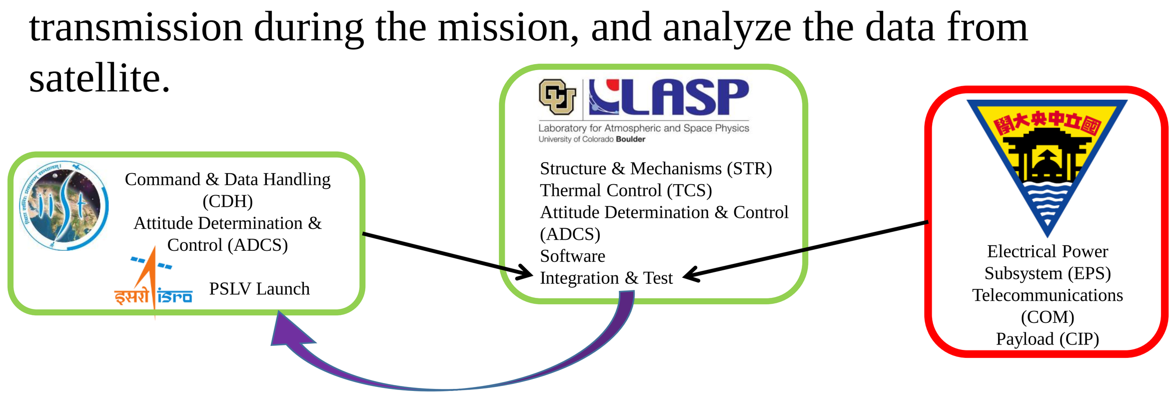
Abstract

The International Satellite Program in Research and Education (INSPIRE) is an international collaboration for CubeSat development and for Earth and space science research, which consists of National Central University (NCU) in Taiwan, University of Colorado at Boulder (CU) in U.S., and the Indian Institute of Space Science and Technology (IIST) in India. INSPIRESat-1 is the first CubeSat mission of this program, which will use the Compact Ionosphere Probe (CIP) as its payload, and is expected to be launched in 2019. CIP has the ability to measure ionospheric parameters in situ, including ion and electron temperature, ion velocity, electron density, and ion composition.

The objective of this research is to sample the model result along possible orbits for INSPIRESat-1. To achieve the science objectives of INSPIRESat-1 and to complement the upcoming two low-latitude missions, FORMOSat-7/COSMIC-2 and the NASA Ionospheric Connection Explorer (ICON), the higher inclination orbits are considered for INSPIRESat-1. In this poster, we sample the electron density and ion temperature within one month from simulations of the coupled Whole Atmosphere Model (WAM) and Global Ionosphere and Plasmasphere Model (GIP) to demonstrate the variations of these parameters with some different orbits. We exam whether certain features of some ionospheric phenomena such as the Midnight Temperature Maximum (MTM), Equatorial Ionization Anomaly (EIAs), Mid-latitude Summer Nighttime Anomaly (MSNA) and Weddell Sea Anomaly (WSA) exist in the model and show up when sampled along the satellite trajectory, as well as the relation to current and upcoming missions carrying similar in-situ plasma sensors. Although the N_e & T_i data within one month from WAM-GIP model in this research seems without the good features of MTM, MSNA and WSA. It just see the feature that during the daytime, the electron density at the latitude of -20° and 20° will enhance and maybe contribute from EIAs. But we can see distribution of the satellite access counts as the function of latitude and longitude, and realize some regulation with different orbital inclination and sampling density at different latitudes and longitudes. In the future, we will continue to do more sampling analysis of the satellite trajectory, this exercise helps to identify the most suitable orbit for INSPIRESat-1. We expect the comprehensive ionospheric measurements taken by INSPIRESat-1 will provide better insights into the ionospheric physics.

INSPIRE

The International Satellite Program in Research and Education (INSPIRE) is the international cooperation CubeSat program began in 2015. It's expected that independent design, development for CubeSat. Controlling the satellite as well as data transmission during the mission, and analyze the data from satellite.



CIP

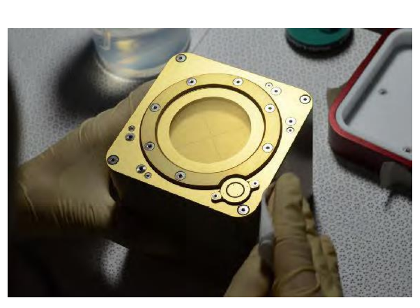


Figure 1. Compact Ionosphere Probe (CIP), is researched and developed by National Central University. It will be the payload on INSPIRESat-1. CIP can collect the ionospheric parameters including:

① electron density
② ion and electron temperature
③ ion velocity
④ ion composition

Model Introduction

Whole Atmosphere Model (WAM)

- General circulation model of the neutral atmosphere
- The earth surface to the exobase at the average height of about 600 km
- Spatial resolution of 1.8° × 1.8° in latitude-longitude
- Used to produce realistic day-to-day thermospheric conditions

Global Ionosphere and Plasmasphere Model (GIP)

- Upgraded ionosphere-plasmasphere-electrodynamics model from CTIPe
- Magnetic Apex coordinate system is applied
- Horizontal resolution is about 1° × 4.5° in latitude-longitude
- Mid-latitude and low-latitude: Closed flux tubes with magnetic latitude up to 60°
- High-latitude: Open flux tubes extend to ~10000 km
- The altitude covers from 100 km to higher than 20000 km

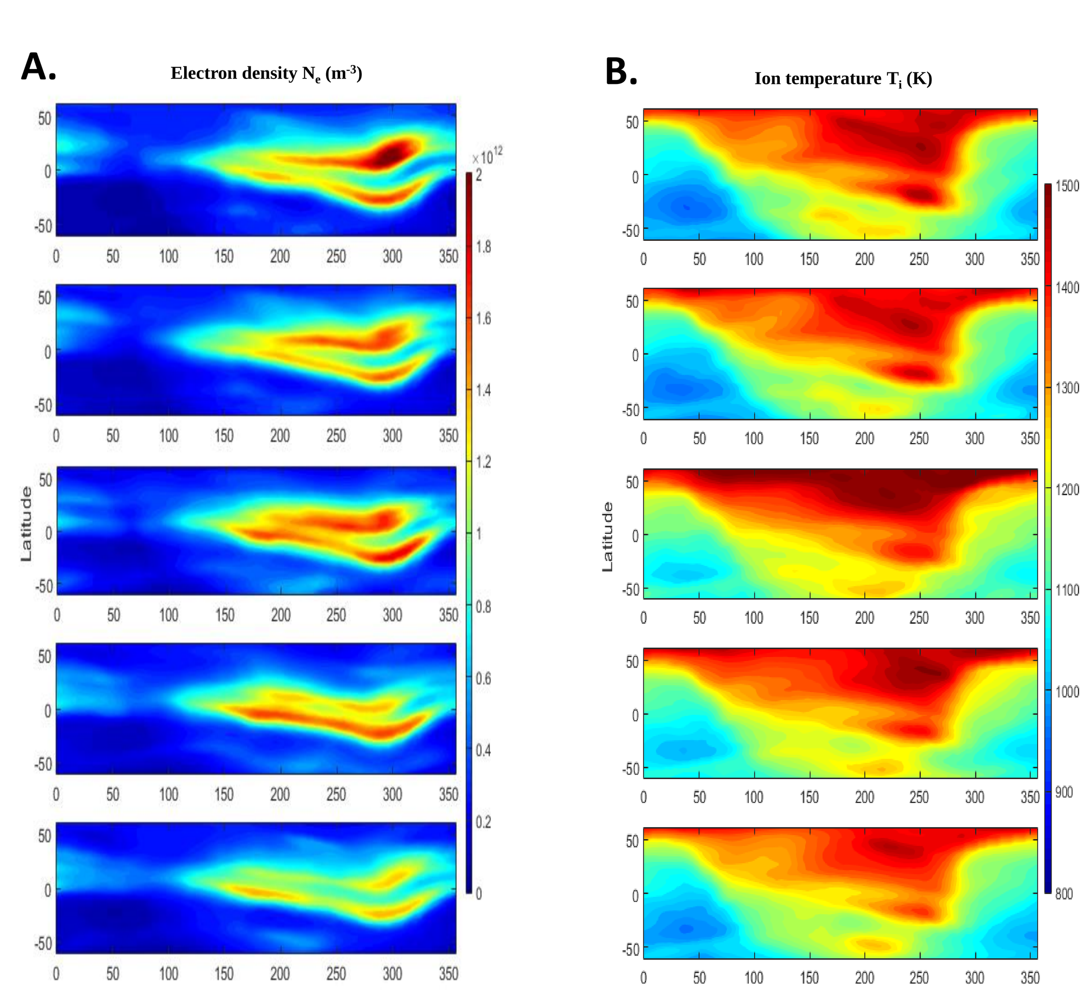
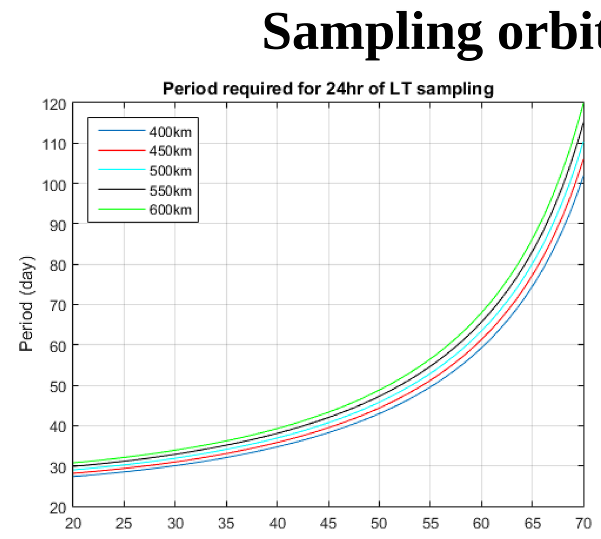


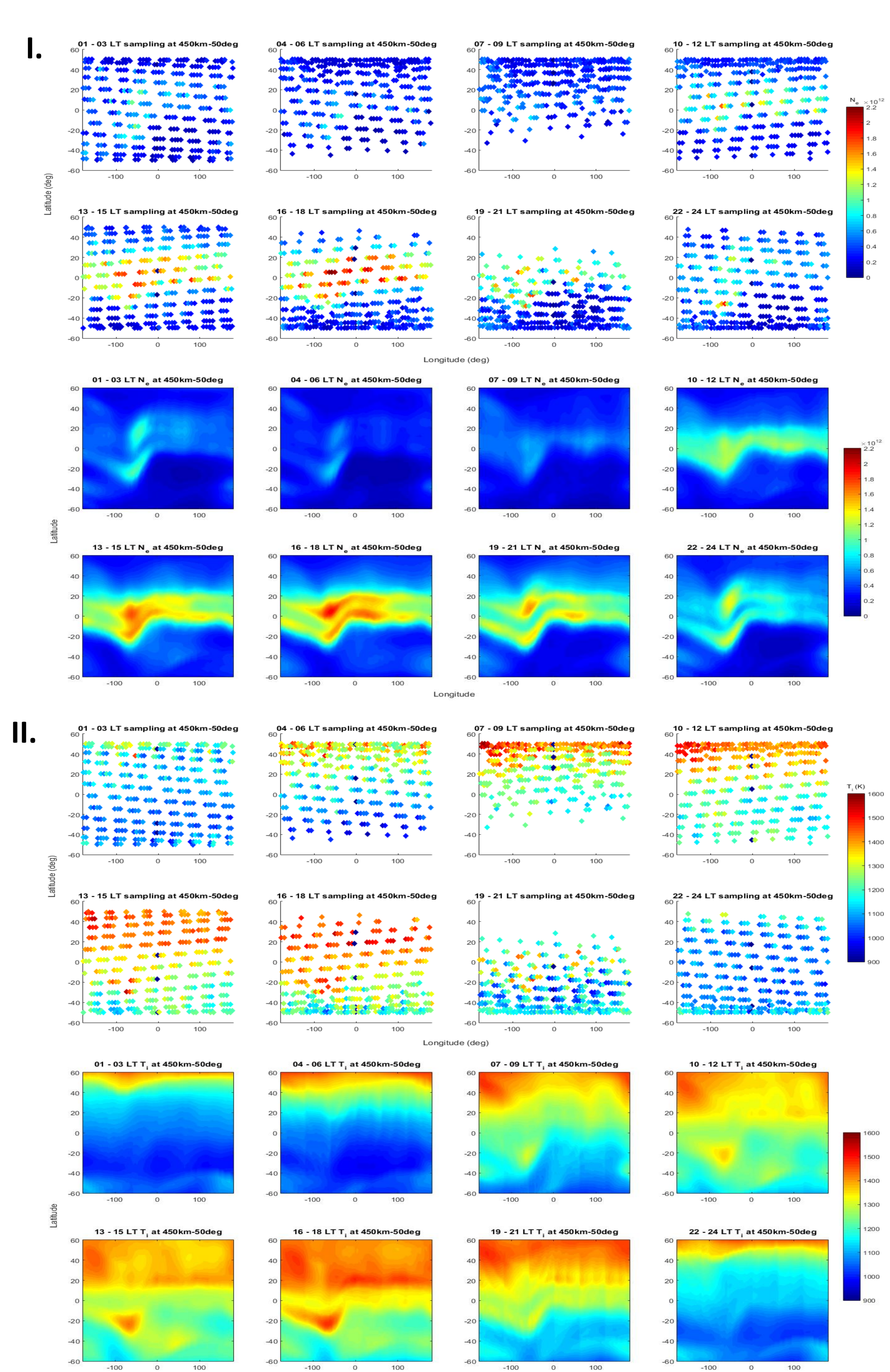
Figure 2. The distribution of N_e and T_i output in continuous five days from the WAM-GIP model that shows significant changes of day-to-day variation.
(A) Electron density N_e (m^{-3}) at 450 km altitude at 01:00 UT between 16 to 20 June, 2016.
(B) Ion temperature T_i (K) at 450 km altitude at 01:00 UT between 16 to 20 June, 2016.

Sampling orbits and Result



Inc.	400 (km)	450 (km)	500 (km)	550 (km)	600 (km)
20°	27.36 (day)	28.18	29.03	29.89	30.78
25°	28.51	29.37	30.26	31.17	32.1
30°	30.05	30.97	31.91	32.88	33.87
35°	32.08	33.06	34.08	35.12	36.19
40°	34.72	35.8	36.92	38.06	39.24
45°	38.22	39.43	40.68	41.97	43.29
50°	42.86	44.34	45.77	47.25	48.78
55°	49.54	51.19	52.9	54.67	56.49
60°	59.2	61.26	63.4	65.61	67.9
65°	74.47	77.23	80.11	83.1	86.22
70°	101.84	106.04	110.44	115.07	119.93

Figure 3. Because of the earth oblateness and procession rate of the satellite. The period required for sampling of 24 hours local time directly related to the altitude and inclination of the satellite. The diagrams display the period as a function of altitude and inclination. To meet some requirements of INSPIRESat-1 mission design, we prior to consider the orbits of 450 km - 50 degree. Using two orbits as the comparison. One utilizing the orbit at 450 km - 25 degree which can finish the data sampling of 24 hours local time within one month, and it will have more data point within the latitude between -25° to 25°. Another is the higher inclination orbit at 450 km - 65 degree which can finish the data sampling of 24 hours local time within two month, and it can sample the plasma data at higher latitude.



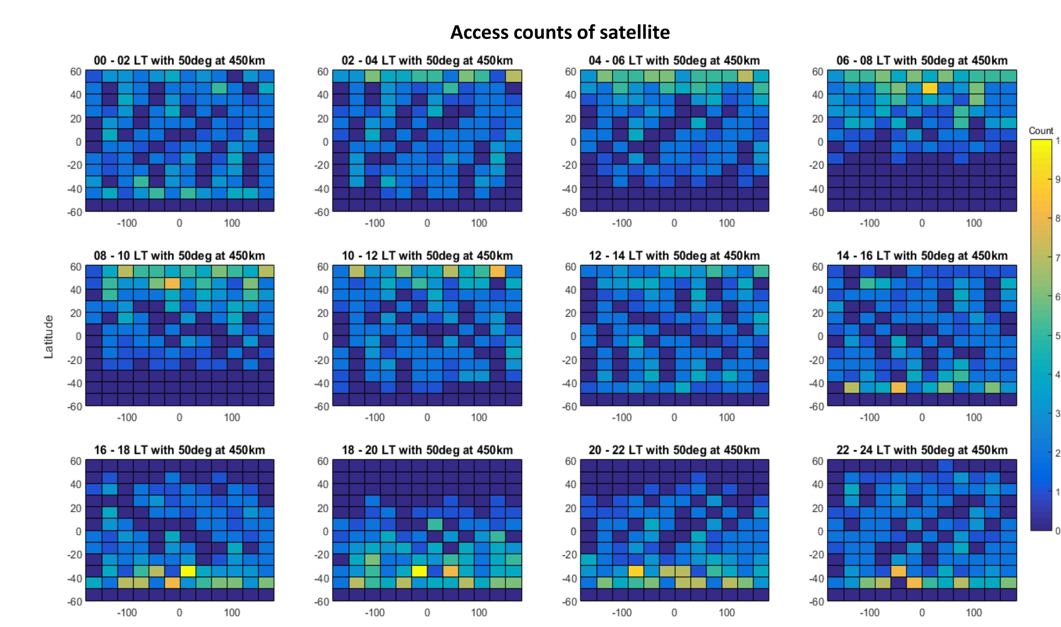


Figure 5. This diagram is the access counts of the satellite orbit at 450 km and the inclination of 50 degree in different local time intervals within one month. It can see it generally gather at the latitude at about 50° (02:00 - 12:00) or -50° (14:00 - 24:00). At 06:00 - 08:00 LT, however, it has less access counts within about -20° to -50°. And it has less access counts at about 20° to 50° within 18:00 - 20:00 LT. The access counts has more at the longitude within -90° to 30°.

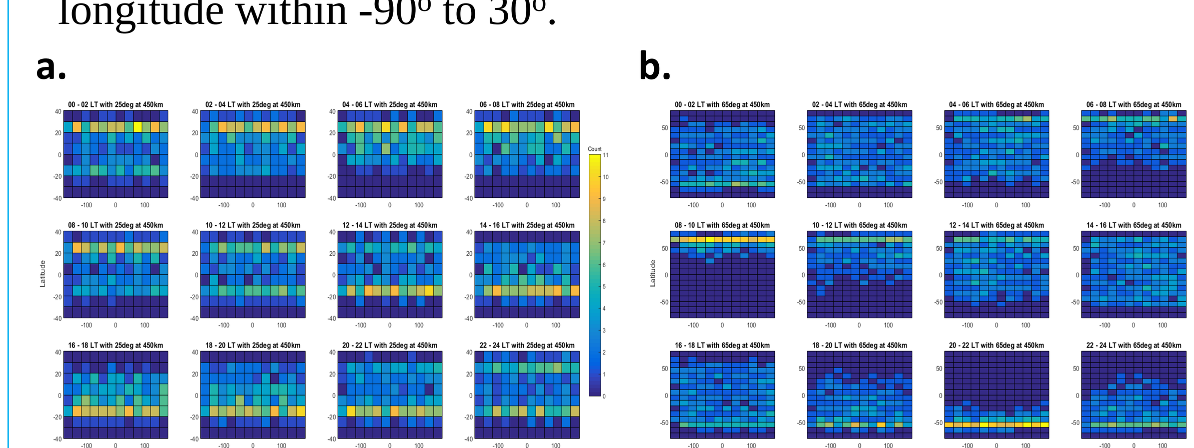


Figure 6.
(a) The access counts from the orbit of 450 km - 25 degree. It can see at 00:00 - 10:00 LT will has more access counts at about 20° to 30°. And it has more access counts at about -10° to -20° within 12:00 - 24:00 LT. And in general the larger latitude has the more access counts. The access counts variation as longitude not very obvious.
(b) The access counts from the orbit of 450 km - 65 degree. It shows at 06:00 - 12:00 LT have the least access counts in southern hemisphere, even 08:00 - 10:00 LT only concentrate at within 20° to 70°. And at 18:00 - 24:00 LT are reverse, it's less in northern hemisphere, 20:00 - 22:00 LT only gather at -20° to -70°. Comparing to the result in (**Figure 5**), if the satellite has larger orbital inclination, it will has more extreme sampling result at 06:00 - 12:00 LT and 18:00 - 24:00 LT.

Figure 4. The N_e and T_i sampling of the satellite orbit with the inclination of 50 degree at 450 km within different LT intervals between one month compare with the N_e and T_i distribution at the altitude of 450 km in June from WAM-GIP model. It seems has the feature of EIAs from N_e diagram, the N_e enhance at the latitude of -20° and 20° during daytime.
(I) The top is N_e sampling of the satellite trajectory from the model, its sampling period is 15 minutes and has a total of 2880 sampling points scatter in 8 subgraphs. The bottom is location distribution of N_e value from the model, the latitude-longitude resolution is 2° × 4°.
(II) The top is T_i sampling of the satellite trajectory from the model, its sampling period is 15 minutes and has a total of 2880 sampling points scatter in 8 subgraphs. The bottom is location distribution of T_i value from the model, the latitude-longitude resolution is 2° × 4°.

Future Works

- ☐ Analyzing the other months data to more complete the sampling research.
- ☐ Using more systematic method to evaluate whether some ionospheric phenomena can be resolved or not.