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VALIDATION OF COSMIC RADIO OCCULTATION ELECTRON DENSITY PROFILES BY INCOHERENT SCATTER RADAR DATA

Iurii Cherniak[*] and Irina Zakharenkova[†]

[*] Institute of Ionosphere NAE&MES of Ukraine
Kharkiv, Ukraine
e-mail: tcherniak@ukr.net
[†] West Department of IZMIRAN Kaliningrad, Russia
e-mail: zakharenkova@mail.ru

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Summary: For comparison we used the measurements provided by incoherent scatter radar located near Kharkiv, Ukraine. The comparison indicates that usually COSMIC RO profiles are in a good agreement with IS radar's profiles both in the F2 layer peak electron density and the form of profiles.

1 INTRODUCTION

The Constellation Observing System for Meteorology, Ionosphere and Climate / Formosa Satellite 3 (COSMIC/FORMOSAT-3) is a joint US/Taiwan radio occultation mission consisting of six identical micro-satellites. Each microsatellite has a GPS Occultation Experiment (GOX) payload to operate the ionospheric RO measurements. GOX receivers provide about 2500 vertical electron density distributions daily up to the satellite altitude, which enable a detailed analysis of the electron density profiles. The previous LEO missions were able to produce only 4000-6000 RO profiles per month (only several hundred per day). So, FS3/COSMIC data can make a positive impact on global ionosphere study providing essential information about height electron density distribution and particularly over regions that are not accessible with ground-based measuring instruments such as ionosondes and GPS dual frequency. Therefore, it is important to verify occultation profiles with other techniques and to obtain experience in the reliability of their derivation. In the given study we present results of comparison of electron density profiles derived from radio occultation measurements on-board COSMIC and from Kharkiv Incoherent Scatter Radar.

2 DATA BASE

Since May 2006 the retrieved Ne profiles are available from the Taiwan Analysis Center for COSMIC (TACC, http://tacc.cwb.gov.tw/en/) and the COSMIC Data Analysis and Archive Center (CDACC, http://www.cosmic.ucar.edu/cdacc/). At the CDAAC electron density profiles are retrieved by the Abel inversion from TEC along the LEO-GPS ray. We used the second level data provided by CDACC – ionprf files containing information about ionospheric electron density profiles. COSMIC soundings points during day have rather good global distribution. For this study we have preferentially selected such occultations whose tangential points of the signal ray path were in the vicinity of Kharkiv ISR. The path of this point during one occultation is named the occultation trace. For the given study it was analyzed COSMIC RO data of different seasons of 2008 year.

To validate the reliability of COSMIC data we have used the ionospheric electron density profiles derived from IS radar located near Kharkiv, Ukraine (geographic coordinates: 49.6°N, 36.3°E, geomagnetic coordinates: 45.7°N, 117.8°E). The Kharkiv radar is a sole incoherent scatter facility on the middle latitudes of European region. The radar operates with 100-m zenith parabolic antenna at 158 MHz with peak transmitted power ~ 2.0 MW. The Kharkiv IS radar is able to determine the heights-temporal distribution of ionosphere parameters in height range of 70-1500 km. At the ionosphere investigation by incoherent scatter method there are directly measured the power spectrum (or autocorrelation function) of scattered signal. With using of rather complex procedure of the received signal processing it is possible to estimate the majority of the ionospheric parameters – density and kinetic temperature of electron and main ions, the plasma drift velocity and others.

For measurements of electron density the sounding mode by compound two-element dual-frequency signal is applied. The double-frequency measuring channel provided ~ 20- km resolution in range ~100–400 km and ~100-km in range ~200–1100 km. The signal integration over 10–15-min intervals when the input signal-noise ratios are of 10–0.2 permits the ionosphere parameters to be determined with accuracy of about 3–10%. The temperatures and ion densities were estimated by comparing experimental and theoretical auto-correlation functions. For comparative analysis we selected IS radar data corresponded to the quiet geomagnetic conditions for 3 seasons of 2008 year.

3 RESULTS AND DISCUSSION

For correct using of the RO electron density profiles for geophysical analysis, modeling and other applications it is necessary to make validation of these data with electron density distributions obtained by another measurement techniques such as proven ground based facilities - ionosondes and IS radars. In fact as the ionosondes provide no direct information on the profile above the maximum electron density and the topside ionosonde profile is obtained by fitting a model to the peak electron density value, the COSMIC RO measurements can make an important contribution to the investigation of the topside part of the ionosphere. IS radars provide information about the whole electron density profile, so we can estimate the agreement of topside parts between two independent measurements.

The comparison of RO reveals that usually COSMIC RO profiles are in a rather good agreement with ISR profiles both in the F2 layer peak electron density (NmF2) and the form of profiles. The coincidence of profiles is better in the cases when projection of the ray path of tangent points is closer to the ISR location. It is necessary to note that retrieved electron density profiles should not be interpreted as actual vertical profiles. The geographical location of the ray path tangent points at the top and at the bottom of a profile may differ by several hundred kilometers. So the spatial smearing of data takes place and RO technique represents an image of vertical and horizontal ionospheric structure. That is why the comparison with ground-based data has rather relative character.

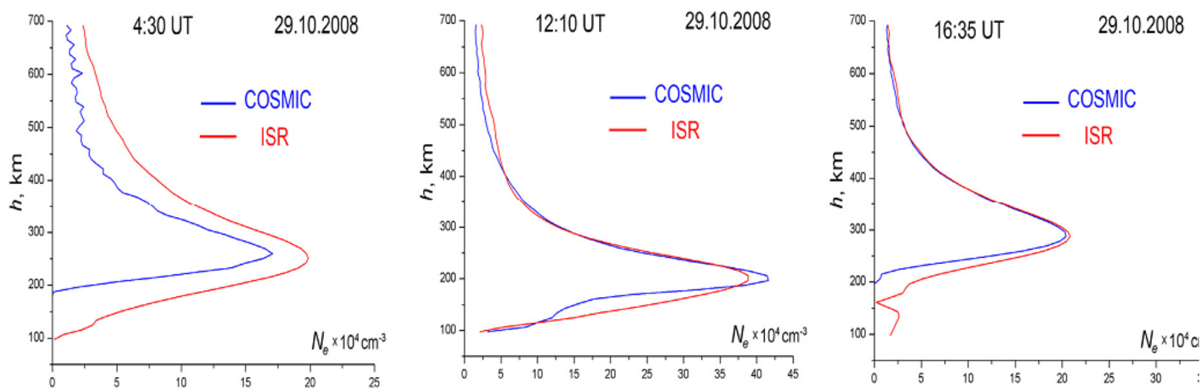

Figure 1: Superimposed electron density profiles for October 29, 2008.

	COSMIC		ISR			
Time	NmF2	hmF2	NmF2	hmF2	ΔNmF2 (%)	ΔhmF2 (km)
4:30	16,57	265	15,2	253	-9,01	12
12:10	41,82	202	38,89	207	7,53	-5
16:35	20,42	288	20,84	289	-2,01	-1

Table 1: Divergences in values and heights of the F2 layer peak for October 29, 2008.

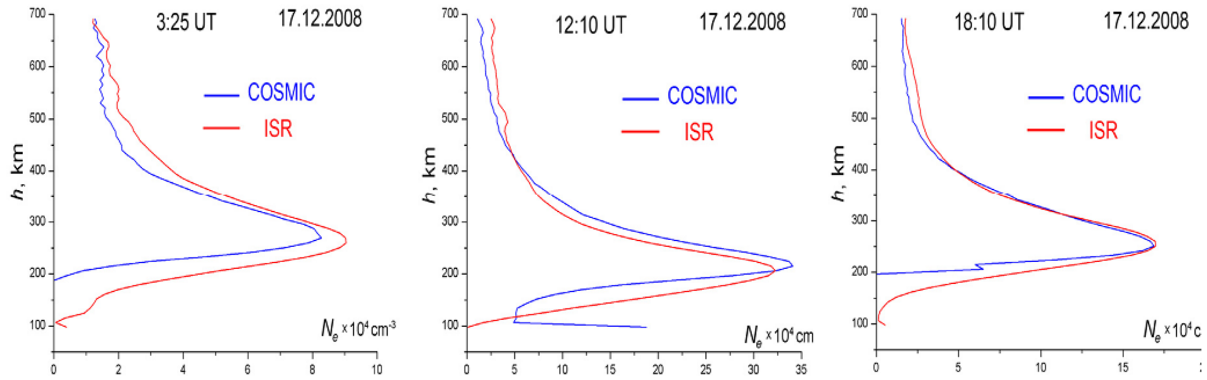

Figure 2: Superimposed electron density profiles for December 17, 2008.

	COSMIC		ISR			
Time	NmF2	hmF2	NmF2	hmF2	ΔNmF2 (%)	ΔhmF2 (km)
3:25	8,23	272	9,03	271	-8,86	1
12:10	34,14	219	33,7	210	1,31	9
18:10	16,87	246	16,97	244	-0,59	2

Table 2: Divergences in values and heights of the F2 layer peak for December 17, 2008.

Figures 1 and 2 demonstrate example of comparison between COSMIC and ISR electron density profiles for the cases of October 29 and December 17, 2008. One can see that for different moments of time there is rather good agreement between these profiles both in the peak electron density and in the profile form. Comparison with ionosondes revealed that practically for all analyzed cases there were observed the understated values of electron density in the topside part of the ionosonde profiles in compare with RO profiles, i.e. significant differences in the form of profile topside part between COSMIC RO measurements and model part of ionosonde profile. Tables 1 and 2 contain information about F2 layer peak characteristics derived from COSMIC and ISR profiles and differences between these values. We derived quantitative parameters to characterize the differences of the compared profiles: the peak height difference, the relative peak density difference. Most of the compared profiles agree within error limits, depending on the accuracy of the occultation- and the radar-derived profiles.

CONCLUSIONS

In general COSMIC RO profiles are in a good agreement with incoherent radar profiles both in the F2 layer peak electron density (NmF2) and the form of the profiles. The coincidence of COSMIC and incoherent radar profiles is better in the cases when projection of the ray path tangent points is closer to the radar location. COSMIC measurements can be efficiently used to study the topside part of the ionospheric electron density. To validate the reliability of the COSMIC ionospheric observations it must be done the big work on the analysis and statistical generalization of the huge data array (today the total number of ionospheric occultation is more than 2.300.000), but this technique is a very promising one to retrieve accurate profiles of the ionospheric electron density with ground-based measurements on a global scale.

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