



Л.В.Пустовалова, С.А.Пулинец

Интернет-ресурс

“База данных внешнего зондирования ионосферы со спутника Интеркосмос-19”

Семинар-конференция “30 лет спутника Интеркосмос-19”

г.Троицк, 28 октября 2009 г.

История

База данных создана в рамках проекта
NASA NRA 98-OSS-03(5.2)

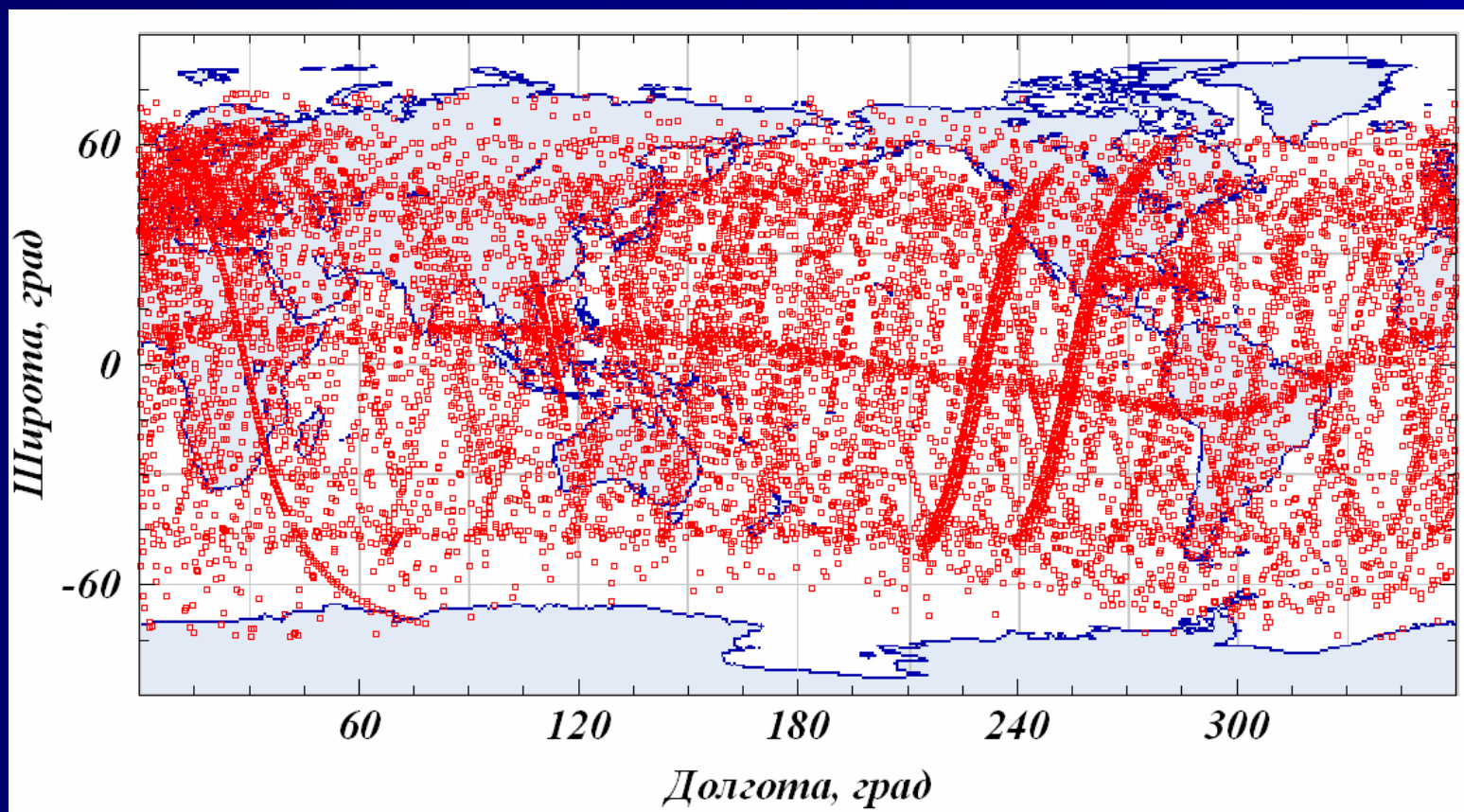
“Intercosmos-19 satellite topside sounder
data rescue project ”

On-line база данных внешнего зондирования ионосферы

А. Файловый архив оцифрованных ионограмм

~8000 ИСЗ Интеркосмос-19 и

~1000 ИСЗ Космос 1809



On-line база данных внешнего зондирования ионосферы

В. Программная оболочка и пользовательский интерфейс для работы с данными:

- позволяет сделать выборку профилей по времени (дата, UT, LT) и пространству (долгота, широта, наклонение);
- рассчитать и построить профиль электронной концентрации $N_e(h)$;
- посмотреть оцифрованную ионограмму;
- получить профиль $N_e(h)$ в табличном виде.

ИЗМИРАН

Учреждение Российской академии наук
Институт земного магнетизма, ионосферы и распространения радиоволн им. Н.В. Пушкова РАН

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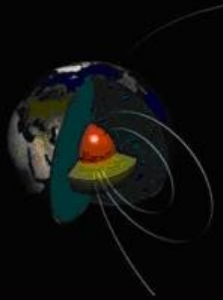
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Магнетизм



Ионосфера



Солнечно-земная физика



События

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[Симпозиум INU2007-NISTP](#)
[Международный семинар VLF-2007](#)

Прогноз солнечной активности



Прогноз геомагнитной
активности



ЦКИТ



ИВЦ

0C4F3E82
20EFB68E
75ACD083
E8CD5E6A
8DE4A38F

[webmail](#)

Новости

10.03.2009 10:00 Премия 2008
[Премия правительства РФ в области науки и техники за 2008 год](#) присуждена за достигнутые успехи при осуществлении проекта [КОРОНАС-Ф](#)

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[Бюллетень по Солнечно-земной физике](#)
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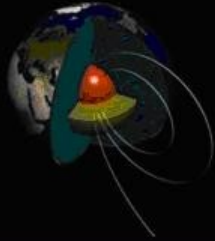
Учреждение Российской академии наук
Институт земного магнетизма, ионосферы и распространения радиоволн им. Н.В. Пушкова РАН

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Магнетизм



Ионосфера



Солнечно-земная физика



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Прогноз солнечной активности



Прогноз геомагнитной активности



ЦКИТ



ИВЦ

0C4F3E82
20EFB68E
75ACD083
E8CD5E6A
8DE4A38F

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Аэростатные эксперименты

Солнечные затмения



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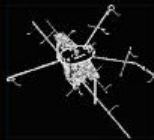
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Завершенные космические проекты



[КОМПАС-2](#)

Complex Orbital Magneto-plasma Autonomous Small Satellite (2006-2007)



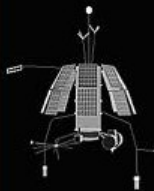
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[ИНТЕРКОСМОС-25 \(АПЭКС\)](#)

Активные Плазменные Эксперименты (1991-1999)

ИНТЕРБОЛ (1995/1996-2000)

Интеркосмос-25 (АПЭКС) (1991-1999)

Интеркосмос-24 (Активный) (1989-1991)

Фобос-2 (12.07.1988)

Космос-1809 (1986-1993)

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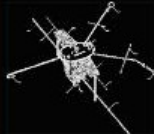
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Завершенные космические проекты



[КОМПАС-2](#)

Complex Orbital Magneto-plasma Autonomous Small Satellite (2006-2007)



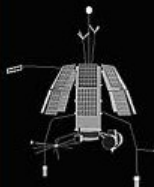
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[Космос-1809 \(1986-1993\)](#)

[Вега-2 \(21.12.1984 - май 1986\)](#)

[Вега-1 \(15.12.1984 - май 1986\)](#)

[Прогноз-9 \(03.07.1983-07.02.1984\)](#)

[Болгария-1300 \(1981-1983\)](#)

[Орел-3 \(1981\)](#)

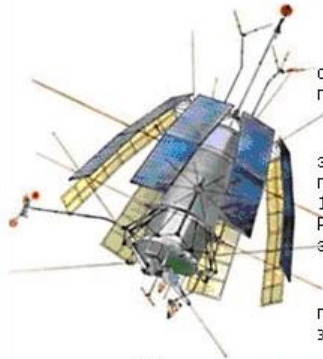
[Интеркосмос-19 \(1979-1982\)](#)

[Интеркосмос-18 \(1979\)](#)

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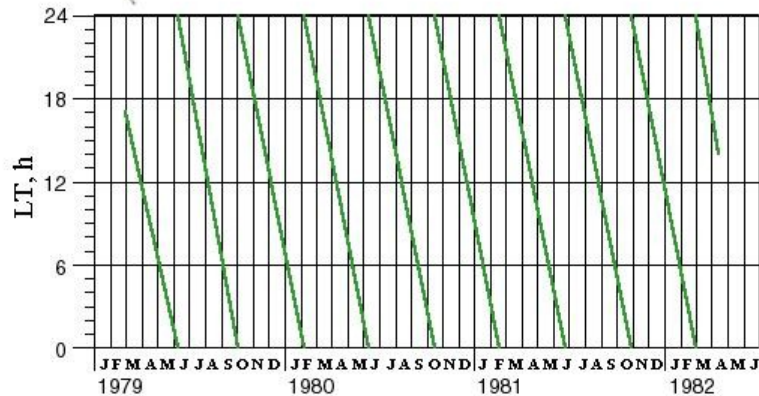
ИНТЕРКОСМОС 19



ИСЗ Интеркосмос-19 разрабатывался для исследований структуры внешней ионосферы Земли и электромагнитных процессов, происходящих в ней.

Спутник был запущен 27 февраля 1979 года на эллиптическую орбиту с параметрами: апогей - 995 км, перигей - 502 км, наклонение - 74, период обращения - около 100 мин и активно работал более 3 лет (до апреля 1982 г.). Расстояние между последовательными пролетами над экватором составляло около 25 градусов долготы.

Местное время пересечения ИСЗ Интеркосмос-19 плоскости экватора, изменявшееся приблизительно на 1 час за 5 дней, приведено на рисунке:



Комплекс научного оборудования, установленный на борту Интеркосмос-19, был разработан и изготовлен специалистами Болгарии, Венгрии, Польши, Чехословакии и СССР и включал: ионозонд внешнего зондирования ионосферы ИС-338 (СССР), зонд Ленгьюра П-4 (Болгария, СССР), ВЧ зонды КМ-3 для измерения электронной температуры и скоростей тепловых электронов (СССР, Чехословакия), фотометр ЭМО-1 (Болгария), спектрометр электронов СФ-3 (СССР), дифференциальный регистратор космической радиации Перо-3 (СССР), ОНЧ анализатор АНЧ-2МЕ (СССР, Чехословакия), широкополосный ВЧ анализатор АВЧ-2, трехчастотный когерентный передатчик МЧК-3 (Чехословакия).

Цифровой ионозонд ИС-338 работал с 5 марта 1979 г. по 8 апреля 1982 г. Диапазон частот зондирования 0.3-15.95 МГц. Данные зондирования передавались на приемные станции в зоне прямой радиовидимости (режим Непосредственная Передача) или записывались в бортовом запоминающем устройстве на протяжении нескольких витков и затем передавались на Землю (режим Запоминание). Использовались три режима Запоминания. В режиме ЗАП-2 зондирование проводилось каждые 8 с в течение 30 мин, в



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Вход для зарегистрированных пользователей:

E-mail:

Регистрация on-line

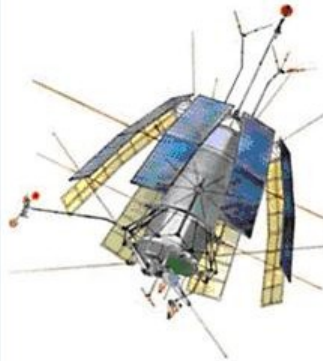
Если Вы впервые зашли на наш сайт, зарегистрируйтесь, пожалуйста! Это позволит получить свободный доступ к данным внешнего зондирования ионосферы.

Имя:

Фамилия:

E-mail:

Организация:



Ваш адрес abc@gmail.com

Добро пожаловать!

Надеемся, что наши данные будут полезны в Ваших исследованиях, и в своих публикациях Вы не забудете сослаться на этот ресурс. Мы также будем весьма признательны, если Вы [пришлете](#) копии этих публикаций.

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Месяц:

День: from to

UT(hh):

from

to

LT:

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Latitude:

from

to

Longitude:

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Inclination:

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to

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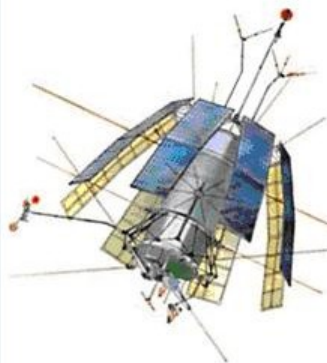
ИЗМИРАН

Учреждение Российской академии наук
Институт земного магнетизма, ионосферы и распространения радиоволн им. Н.В. Пушкова РАН

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Год:

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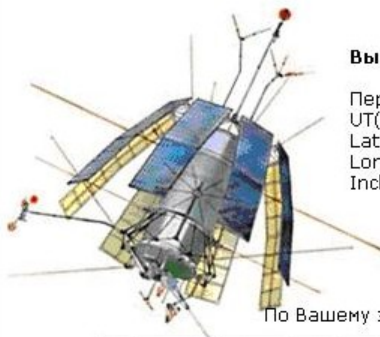
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Вы выбрали параметры:

Период: **1-31.03.1979**
UT(hh): **0-24**, LT: **0-24**,
Latitude: от **-90** до **90**,
Longitude: от **0** до **360**,
Inclination: от **-90** до **90**.

По Вашему запросу найдено ионограмм: 11

| NN | Date | UT | LT | Lat | Long | Alt | Incl | foF2 | File | NS | NI |
|----|--------|--------|------|-------|-------|-------|-------|-------|------------------------------|-----|-----|
| 1 | 250379 | 160231 | 12.2 | -18.1 | 303 | 898.8 | -10.9 | 14.15 | 0385-003.dat | 385 | 3 |
| 2 | 250379 | 173000 | 10.8 | -57 | 260.2 | 999.9 | -61.1 | 9.65 | 0385-085.dat | 385 | 85 |
| 3 | 250379 | 173207 | 11.2 | -50.7 | 265.4 | 996.3 | -55.4 | 13.1 | 0385-087.dat | 385 | 87 |
| 4 | 250379 | 173831 | 11.9 | -30.4 | 274.5 | 943 | -32.6 | 15.45 | 0385-093.dat | 385 | 93 |
| 5 | 250379 | 174040 | 12.1 | -23.4 | 276.5 | 918.4 | -21.6 | 16 | 0385-096.dat | 385 | 96 |
| 6 | 250379 | 174703 | 12.5 | -2 | 281.4 | 831 | 19.5 | 15.1 | 0385-101.dat | 385 | 101 |
| 7 | 250379 | 175120 | 12.8 | 12.7 | 284.6 | 766.6 | 43 | 14.45 | 0385-105.dat | 385 | 105 |
| 8 | 250379 | 175951 | 13.6 | 42.4 | 293.9 | 642.4 | 70.6 | 7.85 | 0385-113.dat | 385 | 113 |
| 9 | 250379 | 193135 | 12.9 | 14.6 | 259.9 | 757.8 | 40.7 | 15.25 | 0385-199.dat | 385 | 199 |
| 10 | 250379 | 193655 | 13.3 | 33.1 | 265 | 678.5 | 63.3 | 14.05 | 0385-204.dat | 385 | 204 |
| 11 | 250379 | 193903 | 13.5 | 40.6 | 267.9 | 648.9 | 70.2 | 12.65 | 0385-206.dat | 385 | 206 |



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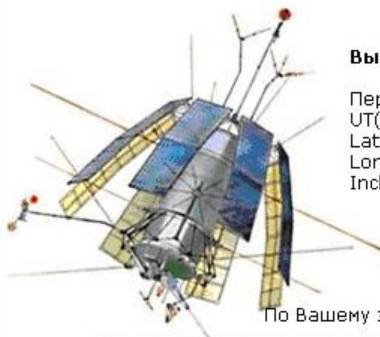
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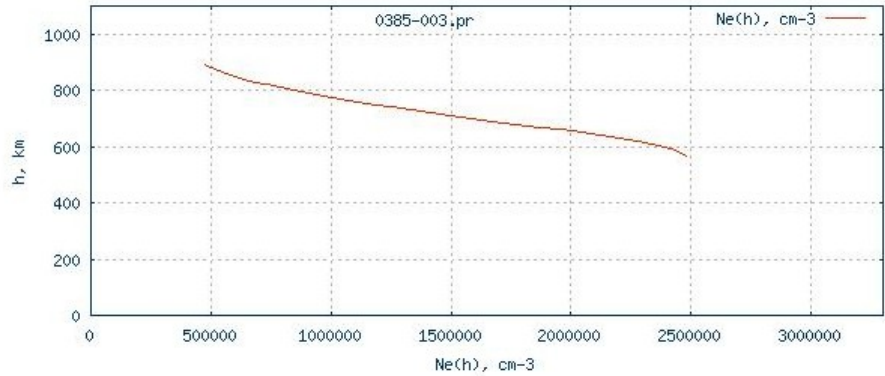
Период: 1-31.03.1979
UT(hh): 0-24, LT: 0-24,
Latitude: от -90 до 90,
Longitude: от 0 до 360,
Inclination: от -90 до 90.

По Вашему запросу найдено ионограмм: 11

| NN | Date | UT | LT | Lat | Long | Alt | Incl | foF2 | File | NS | NI |
|----|--------|--------|------|-------|-------|-------|-------|-------|------------------------------|-----|-----|
| 1 | 250379 | 160231 | 12.2 | -18.1 | 303 | 898.8 | -10.9 | 14.15 | 0385-003.dat | 385 | 3 |
| 2 | 250379 | 173000 | 10.8 | -57 | 260.2 | 999.9 | -61.1 | 9.65 | 0385-085.dat | 385 | 85 |
| 3 | 250379 | 173207 | 11.2 | -50.7 | 265.4 | 996.3 | -55.4 | 13.1 | 0385-087.dat | 385 | 87 |
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| 5 | 250379 | 174040 | 12.1 | -23.4 | 276.5 | 918.4 | -21.6 | 16 | 0385-096.dat | 385 | 96 |
| 6 | 250379 | 174703 | 12.5 | -2 | 281.4 | 831 | 19.5 | 15.1 | 0385-101.dat | 385 | 101 |
| 7 | 250379 | 175120 | 12.8 | 12.7 | 284.6 | 766.6 | 43 | 14.45 | 0385-105.dat | 385 | 105 |
| 8 | 250379 | 175951 | 13.6 | 42.4 | 293.9 | 642.4 | 70.6 | 7.85 | 0385-113.dat | 385 | 113 |
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| 10 | 250379 | 193655 | 13.3 | 33.1 | 265 | 678.5 | 63.3 | 14.05 | 0385-204.dat | 385 | 204 |
| 11 | 250379 | 193903 | 13.5 | 40.6 | 267.9 | 648.9 | 70.2 | 12.65 | 0385-206.dat | 385 | 206 |



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ИЗМИРАН

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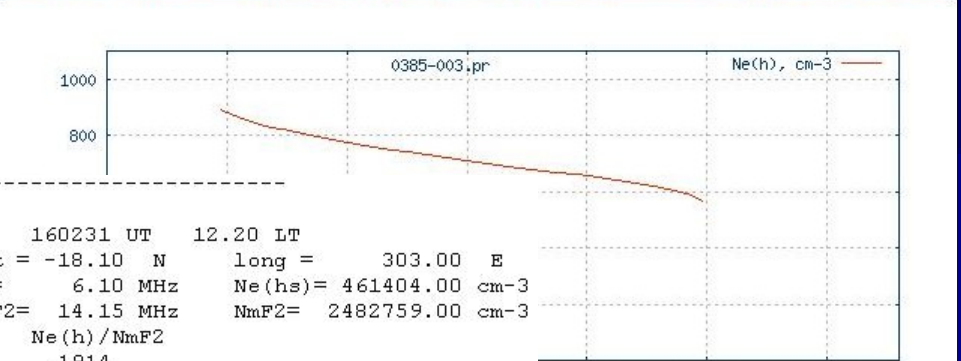
0385-003

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--- 0385-003.dat ---

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0385    orbit
003     frame
250379  date
160231  UT
12.2    IT
898.8   altitude
-18.1   latitude
303.0   longitude
-10.9   inclination
.48     fhs
6.10    cut-off frequency
1       mode
6.15    80.0
6.20    100.0
6.40    125.0
6.80    170.0
7.20    200.0
8.00    240.0
9.30    300.0
10.00   340.0
11.20   400.0
12.00   430.0
12.90   500.0
13.40   550.0
13.80   630.0
14.00   700.0
14.10   760.0
14.15   critical frequency
```

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- [Библиография](#)
- [Каталог](#)
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- [Данные](#)



```

0385.003
      250379      160231 UT      12.20 LT
incl =-10.90 deg  lat = -18.10 N      long =      303.00 E
hs=   898.80 km   fh=    6.10 MHz     Ne(hs)= 461404.00 cm-3
hmF2= 566.09 km  foF2= 14.15 MHz     NmF2= 2482759.00 cm-3
  h, km   Ne(h), cm-3   Ne(h)/NmF2
  890.0   475085.30     .1914
  880.0   498460.50     .2008
  870.0   531322.50     .2140
  860.0   564895.70     .2275
  850.0   599628.90     .2415
  840.0   639133.70     .2574
  830.0   683734.20     .2754
  820.0   732704.60     .2951
  810.0   786626.60     .3168
  800.0   845168.30     .3404
  790.0   907105.80     .3654
  780.0   972574.90     .3917
  770.0  1041737.00     .4196
  760.0  1114033.00     .4487
  750.0  1186423.00     .4779
  740.0  1258922.00     .5071
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  720.0  1412572.00     .5690
  710.0  1494883.00     .6021
  700.0  1581121.00     .6368
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  680.0  1771263.00     .7134
  670.0  1869925.00     .7532
  660.0  1960275.00     .7896
  650.0  2044956.00     .8237
  640.0  2125747.00     .8562
  630.0  2203964.00     .8877
  620.0  2276517.00     .9169
  610.0  2337523.00     .9415
  600.0  2390384.00     .9628
  590.0  2434564.00     .9806
  566.1  2482759.00     1.0000
  
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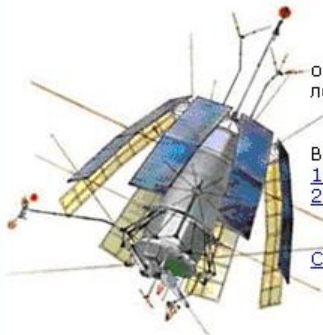
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webmaster@izmiran.ru

Статистика

| Интеркосмос-19 | | Космос 1809 | |
|-----------------------------|------------------------------|------------------------------|--|
| 1979 | 1980 | 1987 | |
| | Январь 0 | Январь 0 | |
| | Февраль 288 | Февраль 0 | |
| Март 11 | Март 0 | Март 139 | |
| Апрель 0 | Апрель 0 | Апрель 0 | |
| Май 108 | Май 1099 | Май 0 | |
| Июнь 178 | Июнь 874 | Июнь 282 | |
| Июль 1614 | Июль 437 | Июль 0 | |
| Август 296 | Август 611 | Август 0 | |
| Сентябрь 0 | Сентябрь 44 | Сентябрь 370 | |
| Октябрь 0 | Октябрь 46 | Октябрь 0 | |
| Ноябрь 582 | Ноябрь 65 | Ноябрь 45 | |
| Декабрь 262 | Декабрь 1465 | Декабрь 0 | |
| Всего: 3051 | Всего: 4929 | Всего: 836 | |

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Библиография



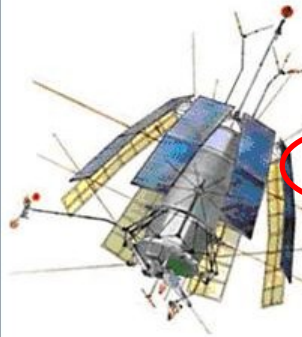
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Библиография



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1980

- ♦ Аппаратура для исследования внешней ионосферы М.: ИЗМИРАН. 1980.

1981

- ♦ Васильев Г.В., Гончаров Л.П., Кушнеревский Ю.В., Мигулин В.В., Флигель М.Д., Шаулин Ю.Н. Предварительные результаты зондирования внешней ионосферы с борта ИСЗ ИК-19 // Геомагнетизм и аэрномия. - 1981. - Т.21. - N.3. - С.451-456.
- ♦ Гальперин Ю.И., Сагдеев Р.З., Шуйская Ф.К., Лисаков Ю.В., Мигулин В.В., Кушнеревский Ю.В., Флигель М.Д., Васильев Г.В. Обнаружение явления ускорения электронов в ионосферной плазме под действием излучения мощного радиопередатчика вблизи локальной плазменной частоты со спутника "Интеркосмос-19" // Космические исследования. - 1981. - Т.19. - N.1. - С.34-44.
- ♦ Васильев Г.В., Гончаров Л.П., Данилкин Н.П., Иванов И.И., Кушнеревский Ю.В., Денисенко П.Ф., Киселев Г.Н., Ковалев В.А., Мигулин В.В., Соцкий В.В., Флигель М.Д. Предварительные результаты исследования трансionoсферного зондирования с ИСЗ ИК-19 // Геомагнетизм и аэрномия. - 1981. - Т.21. - N.6. - С.1117-1120.



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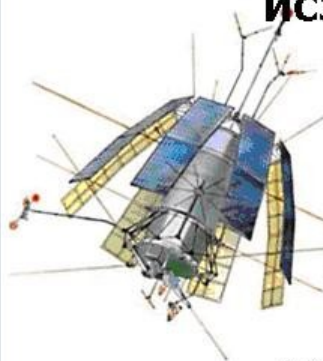
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Временные интервалы работы ионозонда ИСЗ Интеркосмос-19



Pages: [1](#) | [2](#) | [3](#) | [4](#) | [5](#)

В каталоге приведены:

Столбцы таблицы:

- код сброса (номер орбиты, на которой осуществлялась передача информации с борта спутника);

- режим работы ионозонда:

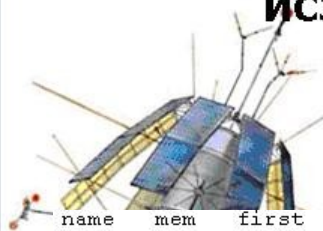
- d - режим непосредственной передачи данных;
- ri - режим запоминания;
- i=2 - i = 2 - зондирование каждые 8 с в течение ~ 33 мин;
- i=3 - зондирование каждые 16 с в течение ~ 120 мин;
- i=4 - зондирование каждые 64 с в течение ~ 1030 мин.

- номер орбиты, дата (ГГММДД), время (ЧЧММ, UT) начала сеанса зондирования;

- номер орбиты, дата (ГГММДД), время (ЧЧММ, UT) окончания сеанса зондирования.



Временные интервалы работы ионозонда ИСЗ Интеркосмос-19



Pages: [1](#) | [2](#) | [3](#) | [4](#) | [5](#)

В каталоге приведены:

| name | mem | first | date_f | UT_f | last | date_l | UT_l | comment |
|------|-----|-------|--------|------|------|--------|------|---------|
| 0092 | d2 | 0092 | 790306 | 0332 | 0092 | 790306 | 0338 | |
| 0115 | r3 | 0113 | 790307 | 1117 | 0114 | 790307 | 1317 | i |
| 0170 | r4 | 0159 | 790310 | 1700 | 0169 | 790311 | 1000 | |
| 0192 | d2 | 0192 | 790313 | 0145 | 0192 | 790313 | 0153 | |
| 0199 | r3 | 0198 | 790313 | 0833 | 0199 | 790313 | 1005 | |
| 0213 | r3 | 0212 | 790314 | 0748 | 0213 | 790314 | 0920 | |
| 0214 | r3 | 0213 | 790314 | 0930 | 0214 | 790314 | 1100 | i |
| 0216 | r2 | 0214 | 790314 | 1112 | 0214 | 790314 | 1142 | |
| 0226 | r4 | 0216 | 790314 | 1425 | 0226 | 790315 | 0655 | |
| 0227 | r3 | 0226 | 790315 | 0704 | 0227 | 790315 | 0830 | |
| 0230 | r4 | 0227 | 790315 | 0846 | 0230 | 790315 | 1336 | |
| 0231 | d2 | 0231 | 790315 | 1819 | 0231 | 790315 | 1826 | |
| 0235 | d2 | 0235 | 790316 | 0112 | 0235 | 790316 | 0121 | |
| 0244 | d2 | 0244 | 790316 | 1555 | 0244 | 790316 | 1559 | |
| 0287 | r3 | 0286 | 790319 | 1054 | 0287 | 790319 | 1219 | |
| 0288 | r3 | 0287 | 790319 | 1228 | 0288 | 790319 | 1421 | |
| 0299 | r4 | 0288 | 790319 | 1428 | 0298 | 790320 | 0728 | |
| 0300 | r3 | 0299 | 790320 | 0828 | 0300 | 790320 | 0956 | |
| 0301 | r3 | 0300 | 790320 | 1006 | 0301 | 790320 | 1135 | |
| 0312 | r4 | 0301 | 790320 | 1144 | 0311 | 790321 | 0444 | i |
| 0316 | d2 | 0316 | 790321 | 1535 | 0316 | 790321 | 1543 | |
| 0331 | d2 | 0331 | 790322 | 1632 | 0331 | 790322 | 1640 | |
| 0344 | r3 | 0343 | 790323 | 0935 | 0344 | 790323 | 1104 | |
| 0345 | r3 | 0344 | 790323 | 1113 | 0345 | 790323 | 1249 | |
| 0385 | r4 | 0375 | 790325 | 1600 | 0385 | 790326 | 0718 | i |
| 0388 | d2 | 0388 | 790326 | 1516 | 0388 | 790326 | 1525 | |
| 0415 | r3 | 0414 | 790328 | 0739 | 0415 | 790328 | 0908 | i |
| 0420 | r4 | 0415 | 790328 | 0916 | 0420 | 790328 | 1747 | i |
| 0429 | r4 | 0420 | 790328 | 1755 | 0429 | 790329 | 0823 | i |
| 0430 | r3 | 0429 | 790329 | 0832 | 0430 | 790329 | 1002 | |
| 0434 | r4 | 0430 | 790329 | 1010 | 0434 | 790329 | 1703 | |
| 0444 | r4 | 0434 | 790329 | 1711 | 0444 | 790330 | 0925 | i |
| 0450 | d2 | 0450 | 790330 | 2235 | 0450 | 790330 | 2244 | |
| 0459 | d2 | 0459 | 790331 | 1317 | 0459 | 790331 | 1324 | |
| 0460 | d2 | 0460 | 790331 | 1457 | 0460 | 790331 | 1507 | |



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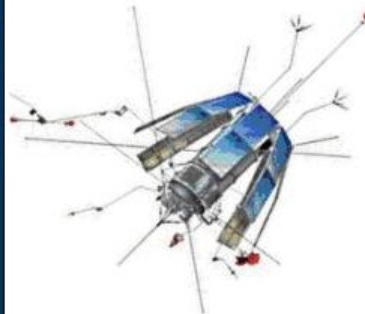
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21/10/2009 16:58 MSD
webmaster@izmiran.ru

Персоналии



Ионосферная станция ИОН-1 и ионозонд ИС-338, установленные на борту ИСЗ Итеркосмос-19, были разработаны и изготовлены талантливыми учеными и инженерами старшего поколения сотрудников ИЗМИРАН: М.Д.Флигелем, Л.П.Гончаровым, Ю.В.Кушнеревским, Г.В.Васильевым под руководством академика В.В.Мигулина. В изготовлении оборудования принимала участие группа инженеров Специального конструкторского бюро ИЗМИРАН: Е.В.Погода, В.П.Полянский, В.И.Розин и др. В работе участвовали также С.П.Гайдаш, А.Т.Карпачев, С.А.Пулинец, в то время – молодые специалисты ИЗМИРАН. Все время активной работы спутника этот коллектив контролировал работу аппаратуры и осуществлял приём и первичную обработку данных внешнего зондирования.

В течение ряда лет Н.П.Бенькова, Н.А.Коченова, А.Х.Депуева, А.Д.Легенька, А.Е.Индюков, П.Ф.Денисенко и многие др. осуществляли обработку и научный анализ наблюдений. Результаты этих работ приведены в Библиографии.

База данных создана в рамках проекта NRA 98-OSS-03(5.2) "Intercosmos-19 satellite topside sounder data rescue project". Руководители проекта – С.А.Пулинец (ИЗМИРАН) и Р.Бенсон (GSFC, NASA), исполнители - [Л.В.Пустовалова](#) (программное обеспечение, web-дизайн), Г.Ф.Деминова, [В.Х.Депуев](#), А.Т.Карпачев, А.Д.Легенька и др.

С.А.Пулинец, ИЗМИРАН



Р.Ф.Бенсон, НАСА



Программное обеспечение:

- СУБД MySQL version 4.1
- PHP version 4.4.0
- GNUPLOT version 4.0



Hermanus Magnetic Observatory

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Modelling of the topside ionosphere

Dr Pierre Cilliers
Space Physics Group

1. Introduction

The topside ionosphere is not well modelled due to sparsity of data. The Bent model for the topside ionosphere used in the International Reference Ionosphere (IRI) [Bilitza 2001] is not adequate, especially for periods of high solar activity. Satellite borne topside sounders, such as that on board the Intercosmos-19 mission is a useful source of data on the topside ionosphere, but topside sounder missions are infrequent. Terrestrial ionosonde data are inadequate to model the topside ionosphere. Various models exist for the topside ionosphere. There is a need for a qualification of the accuracy of the topside models using measured data during various stages of the solar cycle and over a variation of latitudes.

2. Objectives

- 2.1. To map the availability of topside ionosonde measurements available from the ~~the~~ intercosmos-19 mission.
- 2.2. To compare the measured topside data with the International Reference Ionosphere model.
- 2.3. To derive the parameters of various topside models from topside sounder data.

3. Electron density models to consider.

In each of the following models, the electron density is that which applies at a solar zenith angle of 0° , $N(z)$ is the normalised vertical electron density distribution

$$N(z) = \frac{N(z)}{N_{F2}} \quad (1)$$

where N_{F2} is the peak electron density of the F2 layer and z is the normalised height

$$z = \frac{h}{H} \quad (2)$$

where h is the distance above the F2-peak and H is the scale height

$$H = \frac{kT}{mg} \quad (3)$$

where k = Boltzmann's constant

T = Kelvin temperature

M = molecular mass of gas

g = gravitational acceleration



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A correction for the IRI topside electron density model based on Alouette/ISIS topside sounder data

D. Bilitza *

Raytheon ITSS/ISS/IC, GSFC, Code 65, Greenbelt, MD 20771, USA
 Received 17 June 2003; received in revised form 25 July 2003; accepted 23 July 2003

Abstract

The topside segment of the International Reference Ionosphere (IRI) electron density model (and also of the Bent model) is based on the limited amount of topside data available at the time (~40,000 Alouette 1 profiles). Being established from such a small database it is therefore not surprising that these models have well-known shortcomings, for example, at high solar activity. Meanwhile a large data base of close to 200,000 topside profiles from Alouette 1, 2, and ISIS 1, 2 has become available online. A program of automated scaling and inversion of a large volume of digital ionograms adds continuously to this data pool. We have used the currently available ISS/Alouette topside profiles to evaluate the IRI topside model and to investigate ways of improving the model. The IRI model performs generally well at middle latitudes and shows discrepancies at low and high latitudes and those discrepancies are largest during high solar activity. In the upper topside IRI consistently overestimates the measurements. Based on averages of the data-model ratios we have established correction factors for the IRI model. These factors vary with altitude and modified dip latitude, and local time.

Keywords: Electron density model; Ionosphere; Topside data; Alouette/ISIS

1. Introduction

A number of studies have found discrepancies between the IRI topside model and measurements in the altitude region, e.g. Erker et al. (1998), Bilitza and Williams (2000), Iwamoto et al. (2002), and Triakova et al. (2002). Most importantly it was found that the IRI topside model overestimates the electron density in the upper topside and underestimates the electron density in the lower topside. Additionally, comparisons with electron content (EC) measurements have found IRI/EC predictions consistently lower than the observation at low latitudes especially during high solar activities. This points to an underestimation of the electron density in the lower topside since the high densities in the lower topside primarily determine EC.

We have used a large amount of topside sounder electron density profiles from Alouette 1, 2, and ISIS 1, 2 to deduce correction terms for the IRI model. We will first discuss the background and build-up of the current IRI topside model and possible causes for the discrepancies and then present the correction factors that we propose to improve the IRI topside model.

2. Current IRI topside model

The topside electron density model in the International Reference Ionosphere is based on work by Rawer and Ramkrishnan as reported in Rawer et al. (1978) and in Rawer (1984) especially on pages 351–353. The model is an analytical description of the Bent et al. (1973) model, which in its original form was provided as a set of graphs providing the exponential scale heights in three altitude regions in terms of critical frequency f_oF_2 , geomagnetic latitude, and monthly solar F10.7

*IRI: +1-301-286-0190; fax: +1-301-286-1771.
 E-mail address: bilitza@mail66.jsgfc.nasa.gov (D. Bilitza).



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Regional mapping of F2 peak plasma frequency by spherical harmonic expansion

B. Lazo *, A. Calzadilla, K. Alazo, M. Rodríguez, J.S. González

Institute of Geophysics and Aeronomy, 212 Street, La Lisa, Havana City 2906, Cuba

Received 12 September 2002; received in revised form 10 February 2003; accepted 12 March 2003

Abstract

We use spherical harmonic analysis to obtain a 2-D map for the critical frequency of the F2 layer in two selected sectors: America and Europe/Africa within the area (15°S to 70°N latitude and 120°W to 55°E longitude). Basic data are monthly median f_oF_2 values obtained in the global network of ionospheric stations. Additionally, we compare our results for a few locations with those observed by INTERCOSMOS-19 topside sounder satellite and with the CCIR numerical maps, for different solar activity levels and seasons. It is shown that our monthly median regional maps are preferable to use of the world-wide CCIR numerical maps.

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Keywords: Ionosphere; Spherical harmonic analysis; Solar activity; Topside sounder

1. Introduction

Spherical harmonic analysis (SHA) is an appropriate technique for modeling spherically distributed data, using an expansion in orthogonal functions that are also solutions of Laplace's equation as yet demonstrated by Gauss (1838). SHA is a widely used technique in geophysics as shown more recently for the ionosphere by Bradley (1967) and Zelená and Gao (1991). Like other geophysical techniques, SHA has certain mathematical limitations when applied to regional mapping. Therefore, the spherical cap harmonic analysis (SCHA) as a new technique was introduced by Haines (1985) to avoid some of the difficulties arising when SHA are used to model a limited region of the Earth. To avoid some of the intrinsic mathematical limitations in the applicability of this analytical method was created the adjusted spherical harmonic analysis (ASHA). This novel technique was proposed by De Santis (1992) in view of mapping the geomagnetic field, using conventional Legendre functions after an artificial enlargement of the spherical cap into a hemisphere.

Thanks to the high density of ionospheric stations in Europe, De Santis et al. (1992) and De Franceschi et al. (1994) were able to determine a new regional model based only on the available data within this region giving a better fit than obtained with global mapping methods. Contrary to Europe, in the Caribbean Region there are a very low density of ionospheric stations and that is why we cannot apply the program (BMASHA) developed by De Santis et al. (1994) to model f_oF_2 over this region.

For avoiding this limitation (low density of ionospheric stations in the Caribbean area) the traditional spherical harmonic analysis is employed for 2-D regional mapping of the monthly median values of f_oF_2 , including data sets of ionospheric stations placed out of the region of interest, as boundary conditions at the infinity.

Mathematical expression (Eq. (1)) for the expansion of the f_oF_2 ionospheric parameter by Spherical Harmonic functions.

$$f_oF_2(\theta, \phi) = \left[\sum_{n=0}^N \sum_{m=0}^n P_n^m(\cos \theta) \{ h_n^m \cos(m\phi) + k_n^m \sin(m\phi) \} \right] \quad (1)$$

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Ionospheric topside models compared with experimental electron density profiles

Pierluide Colson and Sandro M. Rufficella
The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy

Abstract
Recently an increasing number of topside electron density profiles has been made available to the scientific community on the Internet. These data are important for ionospheric modeling purposes, since the experimental information on the electron density above the ionosphere maximum of ionization is very scarce. The present work compares NeQuick and IRI models with the topside electron density profiles available in the databases of the ISES2, IK-19 and Cosmos 1989 satellites. Experimental electron content from the F2 peak up to satellite height and electron densities at fixed heights above the peak have been compared under a wide range of different conditions. The analysis performed points out the behavior of the models and the improvements needed to be assessed to have a better reproduction of the experimental results. NeQuick topside is a modified Epstein layer with thickness parameter determined by an empirical relation of its formalization. IRI topside is strongly affected by this parameter, indicating the need for improvements of its formalization. IRI topside is based on Booker's approach to consider two parts with constant height gradients. It appears that this formalization leads to an overestimation of the electron density in the upper part of the profiles, and overestimation of TEC.

Key words: topside ionosphere - electron density models - topside soundings

1. Introduction

Information on the topside electron concentration distribution is not obtainable from ground-based measurements. In the past decades few satellites were equipped with ionosondes for ionosphere sounding above the F2 maximum recorded in the 60s and 70s were processed at that time due to the limited techniques available for automatic ionogram scaling. However, recently large amounts of newly scaled ionograms have been made available on-line (Bilitza et al., 2003). This kind of data is particularly important for ionospheric modeling purposes, since ionospheric electron density models have their topside formalization based on old databases or different kind of measurements. Experimental vertical profiles are very important for model comparison, because they provide the spatial distribution of the electron concentration and they contain the information on foF2, which is generally used by the NeQuick and IRI models, adopted by International Telecommunication Union, Radio-communication sector (ITU-R) Recommendation P.531-6 (now superseded by P.531-7) (ITU, 2001), with respect to the topside electron density profiles available in the databases of the ISES2, IK-19 and Cosmos 1989 satellites. This work is part of one author (Colson, 2002).

1.1. NeQuick model

NeQuick model is an ionospheric electron density model, based on the original IONOSPHERIC

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Global mapping of F2 peak plasma frequency by spherical harmonic expansion

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Geophysics and Aeronomy, 212 Street, La Lisa, Havana City 2906, Cuba
2002; received in revised form 10 February 2003; accepted 12 March 2003

In a 2-D map for the critical frequency of the F2 layer in two selected sectors; 5°S to 70°N latitude and 120°W to 55°E longitude. Basic data on monthly median spherical stations. Additionally, we compare our results for a few locations with under satellite and with the CCIR numerical maps, for different solar activity. Our regional maps are preferable to use of the world-wide CCIR numerical

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Thanks to the high density of ionospheric stations in Europe, De Santis et al. (1992) and De Franceschi et al. (1994) were able to determine a new regional model based only on the available data within this region giving a better fit than obtained with global mapping methods. Contrary to Europe, in the Caribbean Region there are a very low density of ionospheric stations and this is why we cannot apply the program (BMASHA) developed by De Santis et al. (1994) to model foF2 over this region.

avoiding this limitation (low density of ionospheric stations in the Caribbean area) the traditional harmonic analysis is employed for 2-D regional mapping of the monthly median values of foF2, including ionospheric stations placed out of the region, as boundary conditions at the infinity. The analytical expression (Eq. (1)) for the expansion of the ionospheric parameter by Spherical Har-

$$f_oF2(\theta, \phi) = \left[\sum_{n=0}^N \sum_{m=0}^n P_n^m(\cos \theta) (g_n^m \cos(m\phi) + h_n^m \sin(m\phi)) \right] \quad (1)$$

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2. Objective
 - 2.1. To determine the ionospheric parameters
 - 2.2. To compare the experimental data with the topside models
 - 2.3. To determine the accuracy of the models
3. Electron density profiles
In each of the following sections, $N_e(z)$ is the normalized electron density

where N_{eF2} is the peak electron density

where h' is the virtual height

where k = Boltzmann's constant
 T = Kelvin temperature
 M = molecular mass of gas
 g = gravitational acceleration

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Ionospheric topside models compared with experimental electron density profiles

Pierluigi Colucci
The Abdus Salam International Centre for Theoretical Physics

Available online at www.sciencedirect.com



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RADIO SCIENCE, VOL. 39, RS1S27, doi:10.1029/2002RS002840, 2004

Topside Ionogram Scaler With True Height Algorithm (TOPIST): Automated processing of ISIS topside ionograms

Dieter Bilitza,¹ Xueqin Huang,² Bodo W. Reinisch,² Robert F. Benson,³ H. Kent Hills,⁴ and William B. Schar^{5,6}

Received 21 November 2002; revised 24 March 2003; accepted 8 May 2003; published 16 January 2004.

[1] The United States/Canadian ISIS-1 and ISIS-2 satellites collected several million topside ionograms in the 1960s and 1970s with a multinational network of ground stations that provided good global coverage. However, processing of these ionograms into electron density profiles required time-consuming manual scaling of the traces from the analog ionograms, and as a result, only a few percent of the ionograms had been processed into electron density profiles. In recent years an effort began to digitize the analog recordings to prepare the ionograms for computerized analysis. As of November 2002, approximately 390,000 ISIS-1 and ISIS-2 digital topside-sounder ionograms have been produced. The Topside Ionogram Scaler With True Height Algorithm (TOPIST) program was developed for the automated scaling of the echo traces and for the inversion of these traces into topside electron density profiles. The program is based on the techniques that have been successfully applied in the analysis of ground-based Digisonde ionograms. The TOPIST software also includes an “editing option” for manual scaling of the more difficult ionograms, which could not be scaled during the automated TOPIST run. TOPIST is now successfully scaling ~60% of the ISIS ionograms, and the electron density profiles are available through the online archive of the National Space Science Data Center at [ftp://nssdcftp.gsfc.nasa.gov/spacecraft_data/isis/topside_sounder](http://nssdcftp.gsfc.nasa.gov/spacecraft_data/isis/topside_sounder). This data restoration effort is producing a unique global database of topside electron densities over more than one solar cycle, which will be of particular importance for improvements of topside ionosphere models, especially the International Reference Ionosphere. **INDEX TERMS:** 2481 Ionosphere; 2415 Ionosphere; Modeling and forecasting; 2415 Ionosphere; Equatorial ionosphere; **KEYWORDS:** topside sounder, TOPIST, ionogram inversion, topside ionogram, ISIS

Citation: Bilitza, D., X. Huang, B. W. Reinisch, R. F. Benson, H. K. Hills, and W. B. Schar (2004), Topside Ionogram Scaler With True Height Algorithm (TOPIST): Automated processing of ISIS topside ionograms, *Radio Sci.*, 39, RS1S27, doi:10.1029/2002RS002840.

1. Introduction

[2] Modeling of the topside ionosphere, i.e., the region from the F₂ peak to about 2000 km, suffers from a

scarcity of data because ground-based ionosondes only probe up to the F₂ peak. Satelliteborne sounders provided information about the topside ionosphere. However, only a small percentage of these data have been processed into electron density profiles, which is the parameter of greatest interest for topside modeling.

[3] A topside ionosonde transmits signals sweeping through a typical frequency range from 0.1 to 10 or 20 MHz and records the time delay of the ionospheric echoes. The ionogram established in this way usually includes an ordinary and an extraordinary reflection trace (O and X trace). Ionogram analysis requires finding these traces and then inverting them into an electron density profile. The problem of the topside sounder missions in the 1960s and 1970s and the reason for the low percentage of electron density profiles obtained is that the scaling had to be done manually. In the 1980s and 1990s,

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3. Electron den. In each of the foll. 0°, N(z) is the norm

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where k = Boltzmann's constant
T = Kelvin temperature
M = molecular mass of gas
g = gravitational acceleration

Abstract
Recently an increasing number of topside information on the electron density above computers, Netbook, and RFI models w ISIS-2, IK-19 and Cosmos 1909 satelli and electron densities at fixed height diffrons. The analysis performed w sed to have a better reproduc ed by this parameter, indicating approach to consider two post- estimation of the electron de

Key words: topside ionograms; topside sounder

1. Introduction

Information distribution based on satellite ionospheric records that is for y

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⁶Deceased 8 March 2003.

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