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ONLINE DATA BASE OF SATELLITE SOUNDER AND INSITU MEASUREMENTS COVERING TWO SOLAR CYCLES

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ABSTRACT

Accurate descriptions of the solar cycle variations of ionospheric parameters are an important goal of ionospheric modeling. Reliable predictions of these variations are of essential importance for almost all applications of ionospheric models. Unfortunately there are very few global data sources that cover a solar cycle or more. In an effort to expand the solar cycle coverage of data readily available for ionospheric modeling, we have processed a large number of satellite data sets from the sixties, seventies, and early eighties and have made them online accessible as part of NSSDC's ftp archive (ftp://nssdcftp.gsfc.nasa.gov/spacecraft data/) and it's ATMOWeb retrieval and plotting system (http://nssdc.gsfc.nasa.gov/atmoweb/). We report about two data restoration efforts supported through NASA's Applied Information Systems Research Program (AISRP). The first project deals with insitu data from a large number of US, Canadian, Japanese and German satellites that measured ionospheric densities and temperatures from 1964 to 1983. The accumulated data base includes data from the BE-B, DME-A, AE-B, Alouette 2, ISIS 1, 2, OGO-6, AEROS A, AE-C, -D, -E, Hinotori, ISS-b and DE-2 satellite missions. The second project involves the production of digital topside sounder ionograms from the ISIS 1 and 2 satellites and their subsequent inversion to produce electron-density profiles. Approximately 340,000 ionograms are available from NSSDC as of July 2002. An automatic topside ionogram scaler with true height algorithm (TOPIST) was developed as part of this project and is now being used to obtain electron density profiles from these ionograms. Providing global coverage over more than two solar cycles the database established by this two projects is a valuable asset for improvements of the International Reference Ionosphere model and for ionospheric research.

INTRODUCTION

Ionospheric satellites have accumulated a large volume of data over the past decades. Usage of these data for ionospheric modeling is hindered since many of these data sets reside on old media in machine-specific and project-specific formats requiring a considerable decoding effort before the actual research study can begin. Documentation is in many cases quite limited and after 30 to 40 years it is often difficult to find people who can answer specific mission- and data-related questions. Recognizing the need for action the authors have

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undertaken a data restoration effort that has resulted in a large online data base in ASCII format that will be described in this article.

But media and decoding problems are not the only hindrance in accessing older data sets, in the case of ionograms from the Alouette and ISIS topside sounder experiments the data itself were in danger of being lost. Our article briefly describes the successful salvage of a portion of these irreplaceable data and the processing of the data first into digital ionograms and than into electron density profiles.

INSITU DATA

The data sets considered by our first data restoration project are listed in Table 1. Figure 1 provides a graphical representation of the altitude range and time periods covered by these missions. The original data exist in various machine-specific, highly compressed, binary encoding on 7-, or 9-track magnetic tapes. All data were converted to a common ASCII data format and solar and magnetic indices were added. The magnetic coordinates were checked with the predictions of the International Geomagnetic Reference Field (IGRF). If dip and/or L value were not included then IGRF-computed values were added. Fill values were introduced for out-of-range parameter values. The data are primarily electron and ion densities and temperatures measured by Langmuir Probes, Retarding Potential Analyzers, and Ion Mass Spectrometers flown on these satellites. The time resolution of the measurements is typically seconds to minutes. For Atmosphere Explorer C, D, and E, and Dynamics Explorer 2 the "Unified Abstract" (UA) data set was employed which includes 15 second data not only from the LP, RPA and IMS instruments aboard these satellites but also from most of the other experiments. For the Ariel 1, 3, and 4 LP data documentation available is insufficient for decoding the data. Any help from colleagues familiar with these data would be greatly appreciated.

The data are now available online on NSSDC's anonymous ftp archive site and on the ATMOWeb web interface (see URLs in ABSTRACT). The ATMOWeb is a WWW-based retrieval and browsing interface to online data. It was developed using C/C^{++} and PERL.

Table 1. Data Sets Considered by the Insitu Data Restoration Project

Satellite		*Instrument*	*Time Period/ ddmmyy*	*Height Range/ km*	*Inclin./ degree*	*Volume/ MByte*
BE-B	A	LP	10/10/64 - 26/08/67	900 - 1100	80	4.3
DME-A	A	LP, (IMS)	29/10/65 - 20/08/68	500 - 3000	80	6.4
Alouette-2	A	LP	21/02/66 - 12/05/67	500 - 3000	80	3.9
AE-B	A	IMS	09/06/66 - 17/01/67	280 - 2700	65	4.6
Ariel-3		LP, RPA	5/67 - 10/67	500 - 600	80	
ISIS-1	A	LP	30/01/69 - 01/06/71	550 - 3500	88	14
OGO-6	A	IMS	12/06/69 – 31/12/70	400 - 1000	82	260
ISIS-2	A	LP, IMS	4/71 - 3/73	1400	88	180
Ariel-4		LP	12/71 – 12/73	500 - 600	83	
AEROS-A	A	RPA	03/01/73 - 03/08/73	250 - 850	97	48
AE-C UA	A	LP, RPA, IMS, more	16/12/73 - 11/12/78	150 - 350	68	296
AEROS-B		RPA, IP	7/74 - 9/75	250 - 850	97	
AE-D UA	A	LP, RPA, IMS, more	06/10/75 - 29/01/76	150 - 3000	90	52
AE-E UA	A	LP, RPA, IMS, more	01/12/75 - 06/06/81	150 - 450	20	170
ISS-b	A	IMS	8/78 - 3/80	950 - 1200	69	
Hinotori	A	RPA	23/02/81 - 19/06/82	550 - 600	31	137
DE-2 UA	A	LP, RPA, more	06/08/81 - 15/02/83	300 - 1000	90	244

LP=Langmuir Probe, **RPA**=Retarding Potential Analyzer, **IMS**=Ion Mass Spectrometer, **IP**=Impedance Probe, **A**=available on ATMOWeb

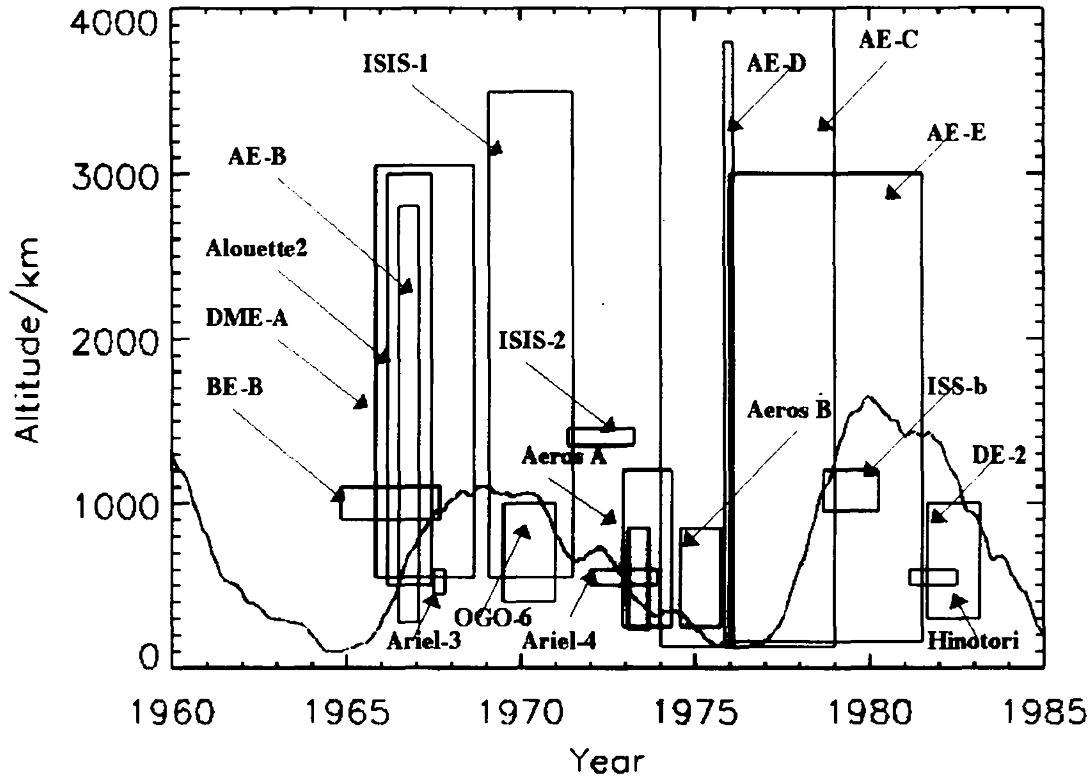

Fig. 1. Time-altitude coverage of the different data sets. Also include is the 12-month running mean of sunspot number indicating the almost two solar cycles covered by the combined data base.

The graphical capabilities are based on IDL running on the NSSDC web-server, and (for some spacecraft) on Java applets. ATMOWeb provides data listings and time series plots for the user-specified parameters and time periods. Two new capabilities were recently added: (1) The ability to generate scatter plots of any two data set parameters, and (2) the ability to constrain with minimum and maximum values any one of the data set parameters. This lets users generate

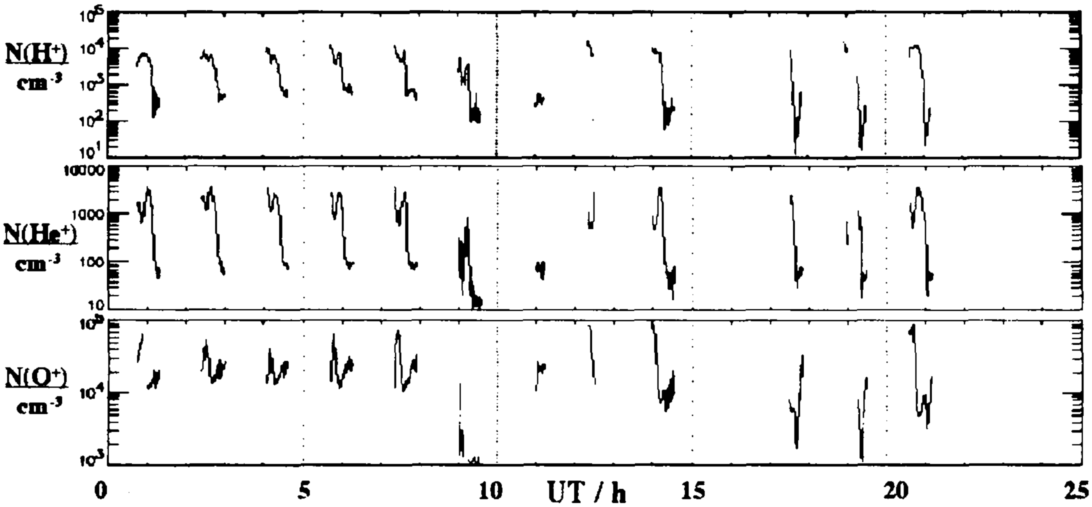

Fig. 2. OGO-6 panel plots of H^+, He^+, and O^+ densities (altitude filter=900-1100km) for March 5, 1970

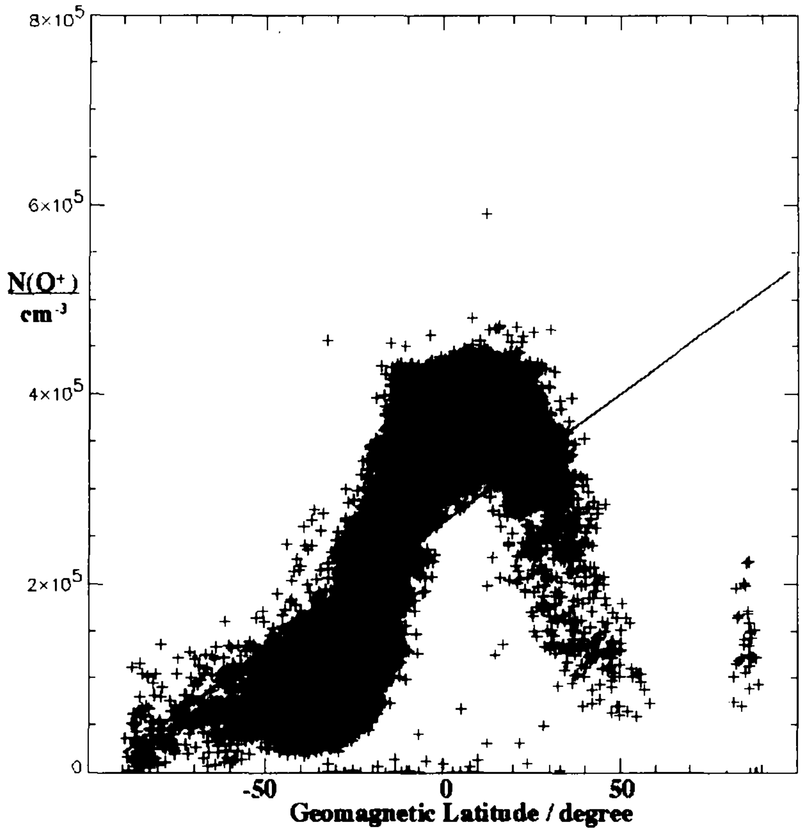

Fig. 3. ATMOWeb plot of the OGO-6 O^+ density vs. geomag. lat. for MLT=11-13 and h=300-500 km.

plots for their specific study objectives. The new capabilities are currently only implemented for the OGO-6 data. Figure 2 shows an example time series plot created with the standard ATMOWeb interface and Figure 3 shows a scatter plot created using the new capabilities.

TOPSIDE SOUNDER DATA

The US/Canadian Alouette 1, 2, and ISIS 1, 2 satellites collected a huge amount of topside ionograms (several millions) in the sixties and seventies. These early satellites had either limited onboard recording capabilities (ISIS) or none at all (Alouette). But a multi-national network of ground stations provided good global coverage (Table 2). Only a few percent of the ionograms, however, have been processed into electron density profiles, because this process requires a tedious manual scaling of the traces from the analog ionograms. NSSDC provides online access to about 170,000 profiles processed in this way by various groups. To unlock the full science potential of the entire data set the ionograms have to be processed in an automated fashion. The automatic TOPside Ionogram Scaler with True height algorithm (TOPIST) program was developed for this purpose (Huang et al., 2002, and Bilitza et al., 2002). In a first step , however, the analog ionograms have to be digitized to make them computer accessible.

The Alouette and ISIS telemetry data were stored on more than 100,000 7-track tapes in the Canadian Public Archives (CPA). In the early nineties the CPA indicated its intent to discard these tapes because of storage space and cost limitations and the dormant state of these data. With help from G. James (CRC, Ottawa) and with funding from NASA/OSS/AISRP, one of the authors (R.B) managed to save more than 10% of these tapes (specifically selected for time and location) and start the digitization process at GSFC. As of July 2002 about 340,000 ionograms are available online from NSSDC's archive in digital format (binary and CDF).

Table 2. Ground Stations from which Tapes were Selected.

Location	*Station ID*	*Lat*	*Lon*	*Al-1*	*Al-2*	*ISIS-1*	*ISIS-2*
Resolute Bay, Canada	RES	75	265			327 (76)	504 (73-79)
Tromso, Norway	TRO,TRM	70	19			320	141 (73-76)
Sodankyla, Finland	SOD	67	27				63 (77-79)
Fairbanks, Alaska	ULA	65	212	1(62)		244 (73-79)	439 (73-79)
Winkfield, U.K.	WNK	51	359		2(66)	319	405 (73-79)
Ottawa, Canada	OTT	45	284			1187(69-83)	991 (73-83)
Kashima, Japan	KSH	36	141			103 (78-81)	879 (73-79)
Canary Island, Spain	CAN	28	345				106 (74-75)
Ahmedabad, India	AME	23	73				265 (73-77)
Ouagadougou, Burkina Faso	ODG	14	359			745 (73-?)	214 (73-75)
Kwajalein, Marshall Is.	KWA	9	168				140
Kourou, French Guyana	KRU	5	307				212 (74-77)
Quito, Equador	QUI	-1	281	1(62)	700	483 (69-72)	366 (73-79)
Brazzaville, Congo	BRZ,BZV	-4	15				34 (73-74)
Ascension Island, U.K.	CAN	-8	346				174 (75-77)
Lima, Peru	LIM	-12	283		11		
Johannesburg, SA	BUR,JOB	-26	28				192 (73-75)
Santiago, Chile	SNT,AGO	-33	298		428	209 (69)	240 (73-76)
Orroral, Australia	ORR	-36	149			66 (72-?)	232 (72-78)
Lauder, New Zealand	LAU	-45	170				604 (73-80)
Kerguelen Is., France	KER	-49	70			98 (81-83)	464 (77-83)
Falkland Island, U.K.	SOL	-52	302		421		45 (72)
Terre Adelie, Antarctica	ADL	-67	140			54 (82-83)	738 (73-83)
Syowa Base, Antarctica	SYO	-69	40				241 (78-82)

Columns 5-7 list the number of tapes and in brackets the years covered.

The tapes were selected in order to obtain global coverage and to accommodate special requests that address subjects and time periods of particular interest. Typically, 80-100 tapes/year were specified centered on each of the equinoxes and solstices. About 8,000 tapes were selected with special emphasis on time periods coinciding with the DE satellites and from stations close to the magnetic equator, an area not so well covered by the existing datasets. Table 2 lists the number of tapes for a specific satellite and station and the years covered.

An example of a TOPIST-processed ionogram is shown in Figure 4. The digital ionograms and the TOPIST-generated electron density profiles are available from NSSDC's online archive (see URL in previous section). The ionograms are also being loaded onto the CDAWeb system for plotting and browsing (http://cdaweb.gsfc.nasa.gov/). Information about all phases of the ISIS effort can be found on the ISIS homepage (http://nssdc.gsfc.nasa.gov/space/isis/isis-status.html), which also provides access to a search page for locating ionograms for specific times, locations, and other search criteria and to software for an interactive IDL interface for plotting, scaling, and inverting the ionograms.

SUMMARY

The projects described in this article have put several decades' worth of ionospheric data at the fingertips of ionospheric researchers. The data base of electron and ion densities and temperatures covers solar cycles 20 and 21 over a wide latitudinal and altitudinal range. Use of these data should lead to major improvements of the International Reference Ionosphere (IRI). The insitu data should be helpful in modeling the solar cycle variations of plasma temperatures

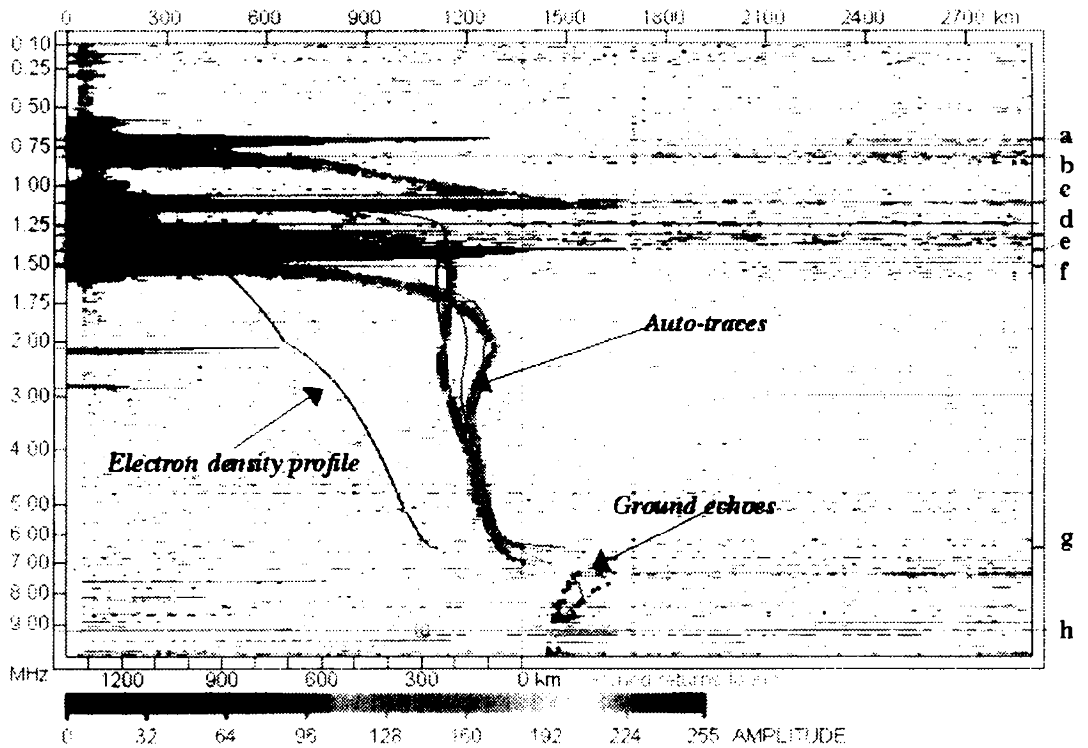

Fig. 4 Example of TOPIST-produced traces and electron density profile from an ISIS-2 ionogram. (a=fH1, b=fZs, c=fNs, d=fTs, e=fH2, f=fXs, g=scaled foF2 and hmF2, h=modeled foF2 and hmF2; the TOPIST display lists the actual values of the resonance and peak frequencies on the right side of the figure which we have replaced here with the letters a-h.

in the topside and should be an invaluable resource for studies trying to quantify ionospheric variability.

The topside part of IRI is based on about 40,000 Alouette 1 electron density profiles. As a result of the ISIS data-restoration effort there are more than 200,000 additional topside electron density profiles online that will lead to a more reliable topside ionospheric presentation, especially in terms of solar activity

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