Report on the

URSI Working Group G.4 Ionospheric Informatics
International Workshop
on

Digital Ionogram Data Formats for World Data Center Archiving

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University of Lowell
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USA

by

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1.0 INTRODUCTION

The International Workshop on Digital Ionogram Data Formats for World Data Center Archiving held at the University of Lowell from July 17 - 20, 1989 focused on three topics, the foremost of which was to reach a consensus on data formats for the archiving of scaled ionogram data. Recording media for the archiving and archiving of N(h) profiles were also discussed. The workshop was attended by members of the World Data Centers and by experts in ionospheric physics and databasing. A list of the participants is given in Appendix A, and the agenda of the workshop is presented in Appendix B. Reports of each session are given in Section 2.0, and Section 3.0 summarizes the results of the workshop.

The Workshop was successful in reaching unanimous agreement on a data format for the archiving of the monthly ionogram characteristics. To arrive at this goal it had been necessary to distinguish and define four levels of ionogram data: (1) raw ionograms, (2) scaled ionogram data, (3) edited scaled data, and (4) monthly tabulation of ionogram characteristics (see Section 3.). The monthly tabulations of the ionogram characteristics like foF2, foF1, h'F2, etc. are the most widely used outputs of ionosonde observations, and a new format had to be developed that can accommodate uneven data rates. Modern ionosondes with automatic scaling capability generate large data sets with varying data rates, e.g. 60 min, 15 min, 5 min, 3 min or 1 min. The Workshop proposed the format shown in Table 3.2 and discussed in Appendix D as the new standard URSI format for the monthly ionogram characteristics.

No standard data format was proposed for data levels 1 to 3 since these data are generally determined by the type of ionosonde and scaling system used. The Workshop did, however, make a recommendation for the format of level 3 data to use or to stay close to the ADEP output format used by the Digisonde 256 network. The ADEP format is shown in Table 3.3 and explained in Appendix C. All data for one ionogram are stored in one data file to 1 to 2 kbyte length. The data base format is designed for automatically scaled data, however, it is also suitable for manually digitized ionogram data. The slash (/) is introduced as a new scaling "letter" to indicate whether a data entry was or was not edited by a human analyst. The slash indicator allows to archive the growing database of unedited autoscalings and thus make this database quickly available.

2.0 IIWG WORKSHOP SESSION REPORTS

2.1 Session 1: Ionospheric Data at the World Data Centers

Chairperson: A. Ya. Feldshtein, WDC-B, USSR

Reporter: Ray Conkright, NOAA, USA

I. WDC-A (Boulder, USA)

a. Archived Data

We have 5028 station years of vertical sounding data from 321 different stations archived at WDC-A. About 600 Mbytes of hourly data are on magnetic tape.

Ionograms	=	20,859 sta. mo.
Monthly Tabs	=	47,855 sta. mo.
Digital Hr	=	17,665 sta. mo.
Digital Med	=	28,057 sta. mo.

plus DISS

In most cases, for the analog data, all 14 of the URSI recommended parameters and the qualification and descriptive letters are scaled. A large contribution to the digital hourly data (7838 sta. mo.) came from the Soviet Union recently and for those data only the numerical values for four parameters were scaled.

b. Incoming Data

1. Old Network Analog Sounders Network

   We currently have 63 stations sending data to us in the old standard analog media custom.

2. DISS Data (US Air Weather Service Digisonde 256 Network)

   Five stations in operation now (Wallops Is., Goose Bay, Argentia, Bermuda, College) and 11 more to be in operation by end of 1990 (Learmonth, Vandenburg, Dyess, Ramey, Amchitka, Petersburg, Kemble, Diyarbakir, Elgin, Osan, Manila).

3. KEL Digital Data - Six Stations

   Old URSI style and near old URSI format (Ottawa, Churchill, Resolute Bay, Taiwan, Rome, Gibilmanna).

Table 2.1 is a summary of ionogram data held at WDC A-STP.

II. WDC-B (Moscow, USSR)

Much the same problems as WDC-A.

Questions on their data holding.

The data at each WDC has overlap with other WDC's of the 17,000 digital hourly value data at WDC-A, 7800 was contributed by WDC-B. Each Data Center has shared their data to some extent. This sharing will increase in the future.

There is a program underway where each Data Center and the Ionospheric Prediction Service (IPS) in Sydney, Australia, have decided to pool their hourly values (and median) digital sets to create one international data set containing all the digital hourly value data in existence. The data set will be archived on high density media for distribution.

WDC-B reviewed the newly accepted format for digital hourly value data and suggested how it could be expanded for 30 and 15 min value data.

WDC-B has software on main frame now but have started to build PC system.

Cost of recovery is an issue at WDC-B now like it has been in other organizations.

Data Center have been and will continue exchanging data with each other, but in general do not exchange across disciplines. (Ionospheric data is not generally exchanged for geomagnetic data.)

III. WDC-D

WDC-D data supplying stations are cutting back on data sent to Data Center.

The current network of 15 stations are supplying RWD ionograms instead of all data. If WDC-D desires more, they must pay. It is expected that because of money problems, after next year the active stations will be down to ten stations.

Cost recovery is a big concern at most WDCs (and IPS) and other organizations. It is an issue we would like to play down.

IV. NSSDC (Goddard, USA)

NSSDC has a very extensive on-line service for data, information and models. Much work has been put into the

"Worldwide Ionospheric Data Base" publication. It is a wealth of information and should be a help to all of us.

V. WDC-C2 (Tokyo, Japan)

WDC-C2 has a network of "digital sounders".

Four Japanese units at remote sites and a Lowell Digisonde 256 at Kokubunji. All ionograms from remote sites are "cleaned" and sent over phone line to center location at Kokubunji for scaling. The ionograms from all five stations are autoscaled. In addition Kokubunji data are manually scaled for quality check. The cleaned ionograms are about 2 Kbytes; 4800 baud phone lines are used.

2.2 Session 2: Databasing for Ionospheric Characteristics

Chairperson: D. Bilitza, NASA/NSSDC, USA

Reporter: Phil Wilkinson, IPS Radio and Space Services, Australia

At the conclusion of this session a new data format for archiving ionospheric characteristics for variable sampling (more frequent than hourly) was proposed.

There were two main motivations for producing this format. First, there now exists a large body of data which has been sampled more frequently than once per hour and is likely to be lost to the scientific community if it is not archived soon. Second, some of the forthcoming STP programs (e.g. WAGS, WITS, GEM) need a general format to allow data with variable and uneven sampling to be easily exchanged.

In discussing the various types of data that should be archived, three data classifications were noted.

1) Raw ionograms. Here it is anticipated that the format of raw digital ionograms will be system dependent and it is inappropriate to attempt to suggest an archive format. Raw ionograms will have to be accompanied by a decoding program when exchanged or archived in a WDC.

2) Processed or scaled ionograms. These are ionograms that have been treated by an autoscaling program (e.g. ARTIST) but have not been checked manually (called editing) to ensure the processing is reasonable. (Later in the meeting this section was subdivided into scaled and edited data.) It is most unlikely that a standard format can be developed for this type of data at present.

3) Tabulated characteristics. This final group of data includes the recommended URSI characteristics and is a set of data generally regarded as useful for characterizing the ionogram for synoptic studies. A standard format has been proposed for this last data set.

The meeting considered two proposed formats, both of which were based on the recently circulated new WDC hourly format for exchanging hourly ionospheric data. The format finally accepted by the meeting as worth recommending for general discussion was, with minor modifications, the same as that proposed by Bob Gamache of ULCAR. It appears elsewhere in the report. The main innovation in this format is the introduction of a header block at the start of a month of data which controls reading of the data following it.

There was much discussion on how to discriminate between edited and unedited data. Problems arise when only partial editing of a month is carried out and when an autoscaling system supplies some scaling letters along with the scaled values. The following recommendations were made to cover these conditions.

- Unedited, tabulated characteristics coming from an autoscaling program will enter a slash (/) in both the qualifying and descriptive letter positions.

- If the autoscaling program also generates scaling letters, these will be entered in the appropriate positions, overwriting the slash.

- An autoscaling program will never enter a blank into either of the letter positions.

- When the tabulated data is edited, the slash is replaced by the appropriate scaling letter, which in most cases will be a blank. Thus the absence of slashes will confirm that the data has been edited.

  When only a few days out of a month have been edited, it will be up to the researcher to note the presence or absence of slashes. Some thought may have to be given to median calculations for this type of data, and experience should indicate the most appropriate course of action to take.

This leads to the recommendation that a new scaling letter, the slash, be introduced to indicate that no attempt has been made to determine scaling letters for the position occupied by the slash. Introducing this new letter appeared a better course to take than to use an entire new set of letters to indicate autoscaled unedited scaling letter assignment. A suggestion was also made to enter a slash in the letter position when edited data held in analogue form are digitized without the use of letters.

IONOSPHERIC DATA

Data Archived at WDC-A/STP

Vertical Sounding Data

Sounding Data from Analog Ionograms	
Analog Vertical Sounding Data	5,028 Station Years
Digital Vertical Sounding Data	600 Mbytes
Locations	321 Stations
Ionograms	20,859 Station Months
Monthly Tabulations	47,855 Station Months
Digital Hourly Values	17,665 Station Months
Digital Median Values	28,057 Station Months
N(h) Data	6 Mbytes
Sounding Data from Digital Ionograms	
DISS Data	16 Station Months 1,785 Mbytes

Table 2.1

2.3 Session 3: On-Line Digital Ionogram Data

Chairperson: J. C. Jodogne, Institut Royal Meteorologique, Belgium

Reporter: Robert R. Gamache, ULCAR, USA

This session was devoted to the networks that provide the digital ionogram data that is being archived. Some of the characteristics of the sounders from each network and the type and rate of the data recorded were described.

I. Terry Kelly of KEL Aerospace, Australia, described the worldwide network of KEL sounders. A map of the locations of the KEL sounders was shown. He explained that the KEL sounder was developed for routine sounding of the ionosphere and not for research purposes like the Lowell Digisonde 256s. This makes the KEL unit relatively inexpensive allowing institutions to buy several and set up their oun networks. The new semi-automatic scaling feature of the sounder was presented and a description of the recording of the data on quarter inch cartridges. KEL has used these tapes successfully for some time with minor problems. In the future KEL will consider Bernoulli box storage of the data and may go to this storage after tests.

II. Jurgen Buchau of the Geophysics Laboratory discussed the US Air Force's Air Weather Service (AWS) network of Digital Ionospheric Sounding System (DISS). A map of the DISS network was shown. The routine data recorded by the DISS stations and transfered to the Global Weather Central location was presented along with the remote communication capabilities to certain users. The AWS support for the deployment of the DISS systems (19 locations), the quality control of the data, scientific uses of the database, and use of the data for storm/disturbance forecasting was also presented.

III. Next Bodo Reinisch of ULCAR, USA, discussed the network of some 34 Lowell Digisonde 256s which are in or soon to be in operation worldwide. The Digisonde 256 system automatically scales the ionograms and extracts the ionogram characteristics in real time using the ARTIST routine. This allows for very fast and uneven sampling rates The versatility of the DGS 256 as a research quality sounder was presented and the capabilities of the instrument discussed. Examples of digital ionograms and the resulting scaling and characteristics were shown, the use of the DSG 256 for measuring ionospheric drift, ionospheric disturbances, and irregularities was also demonstrated. The storage of the data, raw and processed, on 9-track magnetic tape and the post processing of the recorded data by the ULCAR ADEP program was also mentioned.

IV. The last talk of this session was by Phil Wilkinson of the Ionospheric Prediction Service (IPS) of Australia. He discussed the functions of the IPS in regards to primarily ionogram data, although TEC, absorption, riometer, and solar data were also mentioned. The structure of the IPS was diagramed and the routine services offered by IPS presented. Phil described the data that the IPS maintains and what data they exchange with others. A diagram of the IPS data network was shown and the data format for scaled data and raw ionogram data exchange was shown as well as the exchange medium and data conventions used by the IPS.

2.4 Session 4: General Concepts of Databases

Applications to Extended Data Sets

Chairperson: P. Wilkinson, IPS Radio and Space Services, Australia

Reporter: Robert R. Gamache, ULCAR, USA

This session was devoted to database structures for application to extended data sets. The use of relational databases vs. more general databases was considered with emphasis on archiving of scaled ionogram data.

I. D. Bilitza presented a very general discussion of database management systems, database systems, and data and management systems used at NSSDC. The differences and similarities were stated and the advantages and disadvantages of each system were given.

The levels of archiving at the NSSDC are:

- deduced parameters
- scaled, analyzed
- raw

Outside users may access the data at several levels:

- on-line
- operator needed (tape-disk)
- off site storages.

The NSSDC on-line services were presented and several copies of the new NSSDC report "The National Space Science Data Center," Goddard Space Flight Center, Greenbelt, Maryland, NSSDC 88-26, January 1989 were distributed by D. Bilitza.

II. G. Rastogi presented a paper on ionospheric studies over India. These encompass equatorial to mid-latitude conditions. The Indian Institute of Geomagnetism's work on neutral and ion dynamics and interaction, coupling of the IMF and magnetic field, equatorial anomalies, and spread condition over India were reported. Graphs and figure relating spread conditions to the electrojet shifts and the anomaly were shown.

III. R. Gamache described the database developed by ULCAR for archiving the results from ADEP (ARTIST Data Editing and Printing). The features of the database structure that allow the versatility to consider greatly varying data sets was presented. Examples of database records were shown and the reconstruction of the scaled traces from the database described. During the discussion T. Kelly suggested adopting this structure as a standard. This generated more discussion of what other information should be "keyed" into the database. A tentative structure was developed and is shown below. This new structure is being considered and modifications may come about in future discussions.

2.5 Session 5: Recording Media

Chairperson: J. Buchau, Geophysics Laboratory, USA

Reporter: Terry Kelly, KEL Aerospace, Australia

Ray Conkright World Data Center (WDC), Boulder

1) Ray Conkright presented a Viewgraph (Overhead #1) summarizing the various recording techniques available today.

1. Floppy Disks - 360K, 720K, 1.2 Mb, 1.44 Mb

2. Magnetic Tape - 1600 BPI, 9 inch, ASCII (40 Mb)

3. Optical Disks - A. WORM (Write Once, Read Memory) 400-800 Mb.

   B. CD-ROM (Compact Disk-Read Only Memory) 600-700 Mb.

   C Re-Usable Optical Disk

4. VHS Helical Scan

5. Removable Hard Disk (Bernoulli Box) 40 Mb.

6. 1/4 inch magnetic tape cartridge (Q.I.C.)

Due to the proliferation of personal computers (PC's) the floppy disk has become the norm for transfer of small amounts of data. Many files are less than 120 Kbytes or so and it is very easy to transfer these small files. Archiving/Packing (e.g. PKARC) is possible but retrieval problems may occur.

1600 BPI 1/2 inch 9 track magnetic tapes are still the most-used and most universal format for data exchange. Almost everybody has access to these drives.

Ray Conkright had intended to use a "Write Once Read Many" (WORM) optical disk drive but then read about problems which may not be universal. WORM drives presently cost about $3000.00 and $140.00 for a 400 Mbyte Disk. It is still not clear which manufacturer's standards for WORM's will prevail. WDC has been using an Optitech WORM drive. Even with this well established manufacturer there have been problems with support (Optitech's apparent non-concern with their drivers working with the new DOS 4.1) and reliability as demonstrated by Read/Write problems.

2) CD ROM's are super-economical for wide distribution of large amounts of data, for example: 1000 copies of 550 Mbytes of "read-only" data. Readers are approximately $900.00 each. Recently WDC distributed Magnetic and Solar data on their first "test" disk, distributed free. (Subsequent disks are being charged for.) A surprising number of people did actually buy a Reader to be able to use these disks. A small number of copies (say 200) can be produced for about $1500.00. Ray Conkright has developed software for reading/plotting the WDC data.

3) Re-Useable Optical Disks can be both read and written many times. There is supposed to be a "standard" for these systems. Ray has only read the literature about (not physically tested) these systems. Re-Useable Optical Disks are more expensive and thus not suitable for large quantities.

4) Another interesting possibility is the VHS video tape cartridge, for example the Exebyte recorder. WDC has started tests on one of these units. A disadvantage is the sequential format as with all tapes. The storage capacity is gigantic at 2 Giga Bytes creating an extremely compact data storage. One problem is a large 4 Mbyte inter-record gap, making the writing of small files inefficient. Maximum access time is 20 minutes to get to the end of a full tape. A new digital indexing scheme should reduce the maximum access time to 4 minutes.

5) 1/4 inch tape cartridge. A typical 1/4 inch tape cartridge is the Everex 20 Mbyte system using DC-600 Tapes mainly used for backing up hard disks on a weekly routine.

6) 8 mm VHS. Now that hard disks are much larger, the advantages are decreasing. The tapes are identical to the "KEL" DBD-43 tapes. There is also a problem with access time.

7) Bernoulli Boxes. Originally considered expensive, a Bernoulli box provides 40 Mbytes on a sealed removeable hard disk. These devices have been on the market for 5 years. Dr. Bodo Reinisch commented at this time that 400 Mbytes would be more desireable.

Ray Conkright summarizes:

After originally being concerned about WORM "support," he now considers these problems may relate to only one of a number of suppliers.

Discussion:

T. D. Kelly commented that KEL was attracted to the "sealed" nature of Bernoulli Boxes.

Ray C. confirmed that his organization had been successfully mailing BB's for a number of years.

Jurgen B. commented on the problems of accessing data in the "middle" of tape systems.

David Kitrosser, University of Lowell Center for Atmospheric Research, Lowell, Massachusetts

Although 1/2 inch magnetic tape has been universal and served well for many years, there is presently interest in updating recording techniques to modern equipment with greater density and reliability as well as lower cost. Considering how rapidly recording technology is evolving there is concern that a technique or media chosen today might become obsolete in a few years. It is possible to consider that in the future no one technique is optimum for all recording applications in our field. We consider three recording applications:

1) The taking of data in the field

2) Long term archiving of data

3) Distribution of data

Refer to "Chart of Products/Manuf./Capacity/Standards, etc., Table 2.2 to see a summary of the recording techniques considered here.

We have reservations regarding the long term integrity of the new very high density magnetic recording even with error correction. To the best of our knowledge there are no examples of data stored for more than a few years at the very high densities. We are suggesting 150 Mbyte 1/4-inch tape cartridge (QIC) for the recording of data in the field. Samples of 150 Mbyte QIC's have demonstrated 5 year storage. Slow access time is a concern when playing back data on these tapes.

Due to the lack of stable standards no consideration has been given to floppy tape, digital audio tape (DAT), or video tape (VHS) techniques.

For archiving of data we should be thinking in terms of 20 years or so. Optical media would seem to be a good choice due to the long term stability and storage capacity. Write Once Read Many (WORM) disks still appear to have problems with standards among the several manufacturers and long term support as hinted at by R. Conkright earlier. An interesting possibility is CD-ROMS. The media itself is well standardized and playback units are inexpensive. The industry is making an effort to develop affordable recording units. Shortly one

DEVICE	MANUFACTURER	CAPACITY	STANDARDS	MEDIA	DRIVE COST	MEDIA COST	SOFTWARE REQUIRED
DAT DIGITAL AUDIO TAPE	Exabyte Sony Phillips	2 GB	interface level only	8x4 cm Cartridge	$2000	$15	DOS Drivers
QIC QUARTER INCH CARTRIDGE	Archive Wangtek Cipher Data Tallgrass	150 MB 300 MB soon	all	DC-600	$1000	$30	Dos Drivers
FLOPPY TAPE	Irwin Mag.	80 MB	none	DC-2000	$800	$30	none
	Wongtek Archive Mountain Comp.	100 MB	all				
DIGITAL CASSETTE	Teac JVC	150 MB	some	DC-60	$600	$15	none
CD-ROM *	Tandy LMS Sony Phillips	600 MB - 1 GB	all	CD	$1000 playback / $7000 record	$150	none
VHS DIGITAL TAPE	Digidata Honeywell	2.5 GB	none	VHS Tape	$5000	$10	none
WORM WRITE ONCE READ MANY	Maxtor Sony IBI Hitachi	800 MB - 1 GB	interface level only	Optical Disk	$3000	$200	none
OPTICAL DISK	Ricoh Sony Maxtor Phillips	1-2 GB	interface level only	Optical Disk	$3000	$200	none
BERNOULLI BOX	IOmega	20 MB	interface level only		$3000		none
REMOVABLE HARD DISK	I^2 Interface	40 MB					

Table 2.2

ULCAR JULY 89
M. Regan
D. Kitrosser

manufacturer (Yamaha, I believe) will introduce a $ 7000.00 CD-ROM format recording unit which will use special media which will cost about $ 150.00 per disk. Hopefully the prices of this CD-ROM recording technology will decrease in the next couple of years making it an excellent choice for the archiving of Ionosonde data.

Discussion:

1) Ray Conkright raised the question of the relevance of 300 Mbyte media to 40 Mbyte per month recording rates.

2) Terry Kelly cautioned with regard to 1/4 inch tapes about speed variations and dirt on the tapes but could not offer any experience with Bernoulli boxes.

3) Ray Conkright spoke in favour of WORMs subject to manufacturers' support.

4) Bodo Reinisch commented that it is a continuously changing technology.

2.6 Session 6: Archiving of N(h) Profiles

Chairman: R. G. Rastogi, Indian Institute of Geomagnetism, India

Reporter: Phil Wilkinson, IPS, Radio and Space Services, Australia

No strong conclusions were reached on archiving N(h) profiles although a possible format appears in the ADEP example for archiving autoscaled data.

The main problem arising in deciding how to archive N(h) profiles is that this is an area still open to much discussion about methods of analysis and interpretation of ionograms on which the analysis is based. Some analysts will want to record their profiles in different ways from others and because of the small number of workers in the field a consensus is unlikely. Probably the most likely method to be used in calculating profiles is POLAN, but its results can be expressed in different ways. A reasonable suggestion is to save real height estimates of the electron density expressed as a plasma frequency every 5 km starting with a zero frequency estimate, then from fmin upwards, possibly adding the various peak heights calculated. It may also be worth adding an extrapolation above the hmF2 peak to assist later researchers calculating median profiles.

Notwithstanding these issues, the meeting received two quite different deliveries on N(h) profiles stressing some of the problems encountered in the field and some uses the profiles can be put to.

The first talk, after mentioning the possibility of archiving df_p/dh, the gradient in the plasma frequency with real height, continued by using several examples to stress that researchers should not discard the old tabulated characteristics in favor of N(h) profiles as there were still many properties of the ionosphere that can be studied using combinations of these characteristics. This point was reinforced by reminding those present of the problems forced in obtaining an N(h) profile in the presence of ionization gradients.

The second talk emphasized the problems faced in modelling the ionosphere using the IRI. While the critical frequencies are well known, there is less information on layer heights and thicknesses. Some changes are being proposed for the IRI to overcome these difficulties but more may be achieved by refining our ionosonde data. In this respect, more comparisons of incoherent scatter radar data and ionosonde data should prove valuable.

3.0 SUMMARY OF IIWG WORKSHOP

The discussions of data formats for archiving of ionospheric data brought forth the new problems generated by the high data rates of advanced ionospheric sounders. It is clear that large amounts of data are now being processed at uneven time spacings. The existing formats are unable to manage this data. In the discussions of how to deal with this problem in the future several conclusions were reached. First, the Workshop agreed to define four levels of ionogram data as shown in Table 3.1.

Table 3.1. Data levels for ionogram data

Level of data	Format	Comment
Raw ionograms	No Standard	determined by ionosonde
Autoscaled Data	No Standard (1 file/ionogram)	defined by autoscaler
Edited Data	No Standard (1 file/ionogram)	use ADEP database as a guide
Tabulated Characteristics	IIWG (1 file/month)	for archiving and exchange of unevenly spaced data

The four levels of ionogram data are raw ionograms (digital or analog), autoscaled data, edited data, and monthly tabulated characteristics. For raw ionograms, the differences in the measurement and functional capabilities of the various ionosondes makes it difficult to define a standard that will accommodate all systems. Thus the format will be determined by the ionosonde. The same conclusion was reached for the autoscaled data. For the edited data, the presentation of the ADEP database showed the needed flexibility to be adapted to most edited data. It was recommended as a guide, and several improvements were suggested to make it versatile enough for edited data from systems other than the Digisonde 256. In appendix C, the presentation of the ADEP database is given.

A database was proposed for archiving and distributing monthly tabulated characteristics. Transportability and flexibility were some of the features built into the database. The database has the feature of being able to consider data recorded at uneven time spacing yet the database becomes very similar to the presently existing URSI monthly characteristics database when only hourly values are available for a month. It was unanimously decided that this database be adopted in the future for application to data for uneven time spacing. The presentation of this database is given in Appendix D.

The current state of the art in recording media was discussed in the workshop. A summary of the available recording media was presented in Table 2.2. Here, there was no decision formed for the "best" recording media. Each has its pros and cons. While it is clear that the storage capacity is increasing dramatically, there remains the problem of standardization and rapid changes in the state of the art make it difficult to choose one medium over all others.

Electron density profiles were also discussed. The discussions centered on archiving of the N(h) profiles rather than on problems encountered in the inversion process or on the relative merits of different inversion schemes. The final consensus was to store the true height vs. plasma frequency in the edited database presented in Appendix C. The final format was left to be discussed at future meetings of the working group.

To conclude, the participants of the IIWG workshop felt that the workshop was very successful. Members agreed on two databases: the IIWG database for monthly ionogram characteristics tabulated at uneven data rates and the ADEP database (with some extensions) for databasing edited ionogram data. These two database formats are given in Tables 3.2 and 3.3. A detailed explanation of these formats is given in Appendices C and D.

URSI IIWG Database Structure for Flexible Data Rates

Block #	Format	Description
1	A20	Station Name
1	A5	Station Code
1	I4	Longitude E of time base.used
1	I4	Latitude N
1	I4	Longitude E
1	A10	Scaling type; Manual/Auto
1	A10	Data editing; Edited/Not-edited/Mixed
1	A20	Ionosonde system name
1	I4	Year
1	I2	Month
1	I2	Number of Characteristics
1	40(A4)	List of characteristics Dimensions
1	40(I2)	List of corresponding URSI codes
1	I2	Number of days in the month, M
1	31(I4)	Numbers of measurements for each of the M days, N_M
2	ΣN_M(I6)	The N_M sample times Hh:Mm:Ss
•	• •	for each of the M days
J	N(I3, A2)	The N_1 values of characteristic 1 for day 1
•	• •	•••repeated for each of the M days
•	24(I3, A2)	HourlyMedians of characteristic
•	24(I2)	The counts for the hourly medians
•	24(I3, A2)	Upper quartile
•	24(I3, A2)	Lower quartile
•	24(I3, A2)	Upper decile
•	24(I3)	Range
•	24(I3, A2)	Lower decile
K	N(I3, A2)	The N_2 values of characteristic 2 for day 1
•	• •	etc.
		repeated for each characteristic
•	• •	• • •

Monthly Tabulated Ionogram Characteristics
Proposed by the IIWG Workshop in Lowell, MA, USA, July 1989
as the standard URSI format

Table 3.2

IIWG ADEP Structure

Code	Format	Description	
	80I3	DATA FILE INDEX	
1	10F7.3	GEOPHYSICAL CONSTANTS	
2	120Z1	IONOGRAM SOUNDING SETTINGS (PREFACE)	
3	50F8.3	SCALED IONOSPHERIC PARAMETERS	
4	20I2	ANALYSIS FLAGS	
5	16F7.3	DOPPLER TRANSLATION TABLE	
		O-TRACE POINTS - F2 LAYER	
6	400I3		VIRTUAL HEIGHTS
7	400I3		TRUE HEIGHTS
8	400I2		AMPLITUDES
9	400I1		DOPPLER NUMBER
10	400F6.3		FREQUENCIES
		O-TRACE POINTS - F1 LAYER	
11	150I3		VIRTUAL HEIGHTS
12	400I3		TRUE HEIGHTS
13	150I2		AMPLITUDES
14	150I1		DOPPLER NUMBER
15	150F6.3		FREQUENCIES
		O-TRACE POINTS - E LAYER	
16	150I3		VIRTUAL HEIGHTS
17	400I3		TRUE HEIGHTS
18	150I2		AMPLITUDES
19	150I1		DOPPLER NUMBER
20	150F6.3		FREQUENCIES
		X-TRACE POINTS - F2 LAYER	
21	400I3		VIRTUAL HEIGHTS
22	400I2		AMPLITUDES
23	400I1		DOPPLER NUMBER
24	400F6.3		FREQUENCIES
		X-TRACE POINTS - F1 LAYER	
25	150I3		VIRTUAL HEIGHTS
26	150I2		AMPLITUDES
27	150I1		DOPPLER NUMBER
28	150F6.3		FREQUENCIES
		X-TRACE POINTS - E LAYER	
29	150I3		VIRTUAL HEIGHTS
30	150I2		AMPLITUDES
31	150I1		DOPPLER NUMBER
32	150F6.3		FREQUENCIES
		O-TRACE POINTS - ES LAYER	
33	20I2	MEDIAN AMPLITUDE OF F ECHO	
34	20I2	MEDIAN AMPLITUDE OF E ECHO	
35	20I2	MEDIAN AMPLITUDE OF ES ECHO	
36	20E9.4E1	TRUE HEIGHT F2 LAYER COEFFICIENTS	
37	20E9.4E1	TRUE HEIGHT F1 LAYER COEFFICIENTS	
38	20E9.4E1	TRUE HEIGHT E LAYER COEFFICIENTS	
39	20E9.4E1	TRUE HEIGHT MONOTONIC SOLUTION	
40	20E9.4E1	VALLEY DESCRIPTION	

Format recommended by IIWG Workshop in Lowell, MA, July 1989

TABLE 3.3 EDITED AUTOSCALED IONOGRAM DATA BLOCK

APPENDIX A

Participants to the International Workshop on Digital Ionogram Data Formatting for World Data Center Archiving

University of Lowell
Lowell, MA, USA
July 1989

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APPENDIX B

Agenda for the International Workshop on Digital Ionogram Data Formatting for World Data Center Archiving

University of Lowell
Lowell, MA, USA
July 1989

Monday, 17 July 1989 Fox Hall, Room 501

Morning:

8:30 - 10:30	Registration, Lobby of Fox Hall
10:00 - 10:30	Coffee and pastries, Room 501 Fox
10:35	Welcoming Remarks Dr. Bodo W. Reinisch
10:45	Opening Remarks: Dr. Aldo M. Crugnola Dean, College of Engineering

Survey of World Data Centers

11:00 - 11:20	Ionospheric Data at WDC-A (R. Conkright)
11:30 - 11:50	Ionospheric Data at WDC-B (Yu. Tyupkin)
12:00 - 13:30	Lunch
1:30 - 1:50	Ionospheric Data at WDC-A-R&S (D. Bilitza)
1:55 - 2:15	Ionospheric Data at WDC-C2 (S. Igi)
2:20 - 2:45	Discussion
2:45 - 5:00	Tour: Millstone Hill Incoherent Scatter Radar and Digisonde 256

Tuesday, 18 July 1989 Fox Hall, Room 501

Morning Session:

Databasing for Ionospheric Characteristics
Characteristics, Formats, and Data Rates

Speakers:

8:30 - 8:50	R. Conkright
8:55 - 9:15	A. Feldstein
9:20 - 9:40	R. Gamache
9:45 - 10:05	P. Wilkinson
10:15 - 10:45	Coffee and pastries
10:45 - 12:00	Discussion
12:00 - 13:30	Lunch

Afternoon Session:

On-Line Digital Ionogram Data

KEL Sounder Network
Lowell Digisonde 256 Network

Speakers:

1:30 - 1:50	T. Kelly
1:55 - 2:15	J. Buchau
2:20 - 2:40	B. Reinisch
2:45 - 3:05	P. Wilkinson
3:10 - 3:30	Discussion
3:30 - 5:30	Tour: ULCAR, University of Lowell

Wednesday, 19 July 1989 | Fox Hall, Room 501

Morning Session:

General Concepts of Databases
Applications to Extended Data Sets

Speakers:

8:30 - 9:00	R. Gamache
9:10 - 9:40	R. Rastogi
9:50 - 10:20	D. Bilitza
10:20 - 10:45	Coffee and pastries
10:45 - 12:00	Discussion

Afternoon Session:

Recording Media

Speakers:

1:30 - 1:45	R. Conkright
1:50 - 2:05	D. Kitrosser
2:05 - 2:30	Discussion
2:50 - 6:00	Tour: City of Lowell
6:30	Evening Social

Thursday, 20 July 1989 Fox Hall, Room 501

Morning Session:

Archiving of N(h) Profiles

Speakers:

8:30 - 8:50	A. Paul
8:55 - 9:15	D. Bilitza
9:20 - 9:40	Discussion
9:45 - 10:15	Coffee and pastries

Summary of Workshop Results

10:00	General Discussion
12:00	Closing Remarks

APPENDIX C

Presentation of the ARTIST Data Editing and Printing (ADEP) Output Format

UNIVERSITY OF LOWELL
CENTER FOR ATMOSPHERIC RESEARCH
Lowell, Massachusetts

ARTIST DATA EDITING AND PRINTING OUTPUT FORMAT (ADEP)

R. R. Gamache, T. W. Bullett, Z.-M. Zhang,
B. W. Reinisch, and W. T. Kersey

July 14, 1989

LIST OF TABLES

The ARTIST Data Editing and Printing (ADEP) program was developed by the University of Lowell Center for Atmospheric Research (ULCAR) as a tool to manually edit automatically (ARTIST) scaled ionogram data. The output of the ADEP program was designed to be flexible in the storing of data as well as compact and easy to use. This document describes the format and usage of the standard ADEP output (SAO) files.

The basic construction of an ADEP file is shown in Table 1 as a series of Blocks of data in an ASCII sequential text file. Each Block of data represents a single ionogram and is preceeded by a line of integers called the Data File Index. These integers determine which of the Groups of data are present and how many elements are in each Group.

The ADEP output file is a standard IBM PC format ASCII text file with a maximum line length of 120 characters. It can easily be printed, edited with standard text editors, read in a programming environment such as FORTRAN, C, Pascal or BASIC, or read and processed by databases such as dBASE III.

Although the format of the data does vary from one Code Group to the next, all data within any one code group are of the same type and length. This simplifies the decoding and unpacking of the data. The number of characters in a given Code Group can easily exceed the 120 characters per line limit. In this case, the output overflows to succeeding lines, thus a Code Group may extend over several Lines of data.

Most data can be used without further scaling or manipulation. Dimensional uniformity exists in that all heights are reported in kilometers, all sounding frequencies are in megahertz, all Doppler frequencies are in Hertz, amplitudes are given in decibels and angles such as latitude, longitude and dip angle are in degrees. All Digisonde times are given in Universal Time (UT).

Code	Format	Description	
	40I3	DATA FILE INDEX	
1	60Z1	IONOGRAM SOUNDING SETTINGS (PREFACE)	
2	50F8.3	SCALED IONOSPHERIC PARAMETERS	
3	20I2	ARTIST ANALYSIS FLAGS	
4	10F7.3	GEOPHYSICAL CONSTANTS	
5	16F7.3	DOPPLER TRANSLATION TABLE	
6	400I3	ARTIST O-TRACE POINTS -	F2 LAYER VIRTUAL HEIGHTS
7	400I2		AMPLITUDES
8	400I1		DOPPLER NUMBER
9	400F6.3		FREQUENCY TABLE
10	150I3	ARTIST O-TRACE POINTS -	F1 LAYER VIRTUAL HEIGHTS
11	150I2		AMPLITUDES
12	150I1		DOPPLER NUMBER
13	150F6.3		FREQUENCY TABLE
14	150I3	ARTIST O-TRACE POINTS -	E LAYER VIRTUAL HEIGHTS
15	150I2		AMPLITUDES
16	150I1		DOPPLER NUMBER
17	150F6.3		FREQUENCY TABLE
18	400I3	ARTIST X-TRACE POINTS -	F2 LAYER VIRTUAL HEIGHTS
19	400I2		AMPLITUDES
20	400I1		DOPPLER NUMBER
21	400F6.3		FREQUENCY TABLE
22	150I3	ARTIST X-TRACE POINTS -	F1 LAYER VIRTUAL HEIGHTS
23	150I2		AMPLITUDES
24	150I1		DOPPLER NUMBER
25	150F6.3		FREQUENCY TABLE
26	150I3	ARTIST X-TRACE POINTS -	E LAYER VIRTUAL HEIGHTS
27	150I2		AMPLITUDES
28	150I1		DOPPLER NUMBER
29	150F6.3		FREQUENCY TABLE
30	20I2	MEDIAN AMPLITUDE OF F ECHO	
31	20I2	MEDIAN AMPLITUDE OF E ECHO	
32	20I2	MEDIAN AMPLITUDE OF ES ECHO	

Code	Format	Description
33	20E9.4E1	TRUE HEIGHT F2 LAYER COEFFICIENTS
34	20E9.4E1	TRUE HEIGHT F1 LAYER COEFFICIENTS
35	20E9.4E1	TRUE HEIGHT E LAYER COEFFICIENTS
36	20E9.4E1	TRUE HEIGHT MONOTONIC SOLUTION
37	20E9.4E1	VALLEY COEFFICIENTS

NOTES

Nomenclature:

Block	--	All data for one ionogram.
Group	--	All lines of data for a single Code.
Line	--	A sequence of Elements, CR/LF terminated.
Element	--	A single datum in the specified format.

Table 1. ARTIST Data Editing Program (ADEP) Block Format

This data file structure separates the E, F1 and F2 layers whenever possible. When there is no foF1, separation of F1 and F2 is not possible and all information for the F layer trace as a whole is contained in the F2 data Groups. When there is a Monotonic Solution to the True Height profile, there is no layer separation for the profiles and the E and F layers are described by one analytic expression.

A file may contain one or more Blocks of data, with each block corresponding to one ionogram. A Block must contain one or more Groups of data, the Data File Index Group being mandatory and all others optional. A Group may have its data spread across one or more Lines. Each Line has one or more Elements.

Edit Descriptor repeat factors represent a maximum possible number of fields in that code group. Most code groups will be of variable length and read by loops which require only a single, non-repeated Edit Descriptor.

Lines must be formatted such that there are no more than 120 characters per line and terminated with a carriage return and line feed combination.

Some of the above defined code Groups are yet unimplemented, but their definition and position in the ionogram Block are reserved for future use.

CODE DESCRIPTIONS

Data File Index

The Data File Index contains 40 three digit integers. The first integer is the number of elements in the Code 1 group in the current block. The second integer represents the number of elements in the Code 2 group, etc. A zero value here indicates that there is no Code Group corresponding to the position of that zero.

Code 1 -- Ionogram Sounding Settings

These single digit Hexadecimal numbers represent the Preface as recorded by the ARTIST at the time the ionogram was produced. Table 2 is a list of the information provided in the Preface. For further information, see "Digisonde 256 General Description of the Compact Digital Sounder." At present there are 57 values defined in the Preface.

Code 2 -- Scaled Ionospheric Parameters

The Scaled Ionospheric Parameters are the output of the ARTIST ionogram scaling program. They are written to the ADEP file as a sequence of floating point numbers in the F8.3 format. All numbers represent either frequency in Megahertz or altitude in kilometers except the dimentionless MUF factor. The content of each number is explained in Table 3. A frequency value of 999.9 MHz or a height value of 9999. Km indicates that no data is available for this parameter in this ionogram Block. There are currently 31 Scaled Ionospheric Parameters defined.

Code 3 -- ARTIST Analysis Flags

The ARTIST Analysis Flags are a sequence of two digit (I2) integers which indicate and qualify some of the ARTIST scaled results. Table 4 is a description of the flags and the meaning of their possible values.

Position	Symbol	Function
Date and Time		
1 - 2	Y=YY	Year
3 - 5	D=DDD	Day number
6 - 7	H=HH	Hour \
8 - 9	M=MM	Minute > Universal Time
10 - 11	S=SS	Second /
General Control		
12	S	Program Set
13	P	Program Type
14 - 19	J	Journal (Internal Controls)
Nominal Frequency		
20 - 25	F=FFFFFF	Frequency (100's of Hz)
Output Controls		
26	P1	Tape Write Control
27	P2	Printer Control
28	P3	Maximum Method Options
29	P4	Printer Cleaning Threshold
30	P5	Printer Gain Level
31	P6	Oblique Sounding Sequence
32	P7	Reserved for Future Use
Frequency Choice		
33 - 34	S=SS	Start Frequency (MHz)
35	Q	Frequency Increment
36 - 37	U=UU	End Frequency
Test Output		
38	C	Trigger
39	A	Channel A: Digital
40	B	Channel B: D/A
Station Identification		
41 - 43	V	Station Number (INCPU Personality)
Operating Parameters		
44	X	Phase Code
45	L	Antenna Azimuth
46	Z	Antenna Scan
47	T	Antenna Option/Doppler Spacing
48	N	Number of Samples
49	R	Pulse Repetition Rate

Position	Symbol	Function
50	W	Pulse Width and Coding
51	K	Time Control
52	I*	Frequency Correction (from CORE)
53	G*	Gain Correction (from CORE)
54	H	Range Increments
55	E	Range Start
56	I	Frequency Search
57	G	Nominal Gain

Table 2. Digisonde 256 Parameters

Position	Scaled Characteristics	Description
1	foF2	F2 layer critical frequency calculated by hyperbolic fit
2	foF1	F1 layer critical frequency
3	M(D)	M-factor, MUF(D)/foF2, for distance D
4	MUF(D)	Maximum usable frequency for distance D
5	fmin	Minimum frequency for E or F echoes
6	foEs	Es layer critical frequency
7	fminF	Minimum frequency of F-trace
8	fminE	Minimum frequency of E-trace
9	foE	E layer critical frequency
10	fxI	Maximum frequency of F-trace
11	h'F	Minimum virtual height of F trace
12	h'F2	Minimum virtual height of F2 trace
13	h'E	Minimum virtual height of E trace
14	h'Es	Minimum virtual height of Es layer
15	HOM	Maximum trace height of E layer using parabolic model
16	Ym	Half thickness of E layer
17	QF	Average range spread of F-trace
18	QE	Average range spread of E-trace
19	Down F2	Lowering of F-trace maximum to leading edge
20	Down E	Lowering of E-trace maximum to leading edge
21	Down Es	Lowering of Es-trace maximum to leading edge
22	FF	Frequency spread between fxF2 and fxI
23	FE	As FF but considered beyond foE
24	D	Distance used for MUF calculation†
25	fMUF(D)	MUF(D)/obliquity factor*
26	h'MUF(D)	Virtual height at fMUF
27	foF2c	correction to add to foF2 to get actual foF2
28	foEp	Predicted foE
29	f(h'F)	Frequency at which hminF occurs
30	f(h'F2)	Frequency at which hminF2 occurs
31	~~df~~ NO!	Frequency step for the ionogram (MHz)

† Normally 3000 km

* Obliquity factor(h', D) is the ratio of frequencies for vertical and oblique propagation to distance D with virtual height h'.

Table 3. ARTIST Scaled Characteristics Recorded on Magnetic Tape

Position	Content	Description
3	N	Number of roots, if any, found in the F profile
4	0	foF1 not scaled
	1	foF1 scaled
5	0	No AWS Qualifier applies
	1	Blanketing Sporadic E
	2	Non-Deviative Absorption
	3	Equipment Outage
	4	foF2 greater than equipment limits
	5	fmin lower than equipment limits
	6	Spread F
	7	foF2 less than foF1
	8	Interference
	9	Deviative absorption
6	N	Number of roots, if any, found in the E profile
7	N	Number of roots, if any, found in the F_l profile
8-19	-	Not used
20	-	Internal ARTIST use

Table 4. ARTIST Flags

Code 4 -- Geophysical Constants

The values shown in Table 5 are specified for the station producing the data in the file. The format is F7.3. Frequency is in MHz, angles are in degrees.

Position	Description
1	Gyrofrequency (MHz)
2	Dip angle (-90.0 to 90.0 degrees)
3	Geographic Latitude (-90.0 to +90.0 degrees)
4	Geographic Longitude East(0.0 to 359.9 degrees)
5	Sunspot Number for the current year
6	Station Number (ULCAR)

Table 5. Station Parameters

Code 5 -- Doppler Translation Table

The Doppler Translation Table is a sequence of floating point numbers in the F7.3 format which convert the trace Doppler Number into a Doppler frequency in Hertz. These numbers should be read into a floating point array. Using the Doppler Number as an index to that array will result in the Doppler shift for the scaled trace point in question.

ARTIST TRACE POINTS

The information pertaining to the ARTIST autoscaled traces is included in this section. The information format and content is identical for any of the F2, F1 or E traces with either Ordinary or eXtraordinary polarization although not all traces may be present in any one ionogram. Currently, the ARTIST program does not scale any of the X traces, but space has been provided for implementation of this feature at a later date.

The information for each trace is contained in four Code Groups. For the F2 trace it is in Codes 6, 7, 8, and 9; for the F1 trace it is in Codes 10, 11, 12, and 13; etc. There is a one-to-one positional correspondence between elements in these four Groups in that the first Virtual Height, Amplitude, Doppler Number and Frequency all correspond to the first Trace point on the ionogram. The same is true of the second point, and so on throughout the entire trace. When trace points are missing they are represented by a 9999. for the virtual height, 0 amplitude and Doppler number.

Codes 6, 10, 14, 18, 22, 26 -- ARTIST Trace Virtual Heights

This group consists of a number of I3 format Virtual Heights for the layer indicated. The number of these heights depends upon the length of the trace on the corresponding ionogram. Virtual Heights are reported in Kilometers of altitude.

Codes 7, 11, 15, 19, 23, 27 -- ARTIST Trace Amplitudes

The amplitude of each trace point is recorded here in I2 format and is measured in dB.

Codes 8, 12, 16, 20, 24, 28 -- ARTIST Trace Doppler Numbers

The Doppler Number, as measured by the Digisonde 256, for each trace point is recorded here in I1 format. To convert this number to an actual Doppler shift in Hertz, use this integer as the index to the Doppler Translation Table provided in the Code 5 Group.

Codes 9, 13, 17, 21, 25, 29 -- ARTIST Trace Frequencies

The frequency (in MHz) of the trace point is given in this Code Group in the F6.3 format. This Code Group is provided for the possibility of uneven frequency stepping and will normally be empty for ionograms with a constant frequency step. If this table is empty, the frequency of a trace point can be found by the following means. The frequency of the first trace point is fmin (Code Group 2 -- Scaled Ionospheric Parameters, datum #5) and each successive point is df (Code Group 2 -- Scaled Ionospheric Parameters, datum #31) higher in frequency. For the Nth point in the trace, the frequency is:

$$f = fmin + (N-1)*df.$$

Code 30 -- Median Amplitude of F Echo

This I2 value is an amplitude in dB for the F trace. It is calculated every integer Megahertz between fminF and foF2. See Code 2 for fmin and foF2. The Median Amplitude is calculated by taking the median of the trace amplitudes over 0.5 MHz in frequency and five height ranges and then scaling this median value to appear as if it were at 100 km altitude.

Code 31 -- Median Amplitude of E Echo

Same as per Code 30, but for the E echo between fminE and foE.

Code 32 -- Median Amplitude of Es Echo

Same as per Code 30, but for the Es echo between fminE and foEs.

Code 33 -- True Height Coefficients for the F2 Layer

The True Height Coefficients for F2 layer are stored in the E9.4E1 format. There are nine of them. For more information on the meaning and use of these coefficients, see "Electron Density Profiles from Automatically Scaled Digital Ionograms -- The ARTIST's Valley Solution," University of Lowell Center for Atmospheric Research, Scientific Report No. 1 by R. R. Gamache, W. T. Kersey and B. W. Reinisch.

Position	Parameter	Description
1	fstart	Start frequency (MHz) of the F2 layer
2	fend	The end frequency of the F2 layer
3	peakht	The height of the peak of the F2 layer
4	dev	The deviation in km/point.
5-9	A0-A4	Shifted Chebyshev polynomial coefficients

Table 6. True Height Coefficients

Code 34 -- True Height Coefficients for the F1 Layer

The True Height Coefficients for the F1 layer have the exact same format as those for the F2 layer (Code 33) above.

Code 35 -- True Height Coefficients for the E Layer

The True Height Coefficients for the E layer have a format very similar to that for the F2 and F1 layers (Codes 33 and 34) above. The difference lies in that there are only seven parameters stored in this Code Group. The first four parameters are fstart, fend, peakht and dev as defined for the F2 layer. There are, however, only three coefficients for the shifted Chebyshev polynomials (A0 - A2) for the E layer true height.

Code 36 -- True Height Monotonic Solution Coefficients

The True Height Coefficients for a Monotonic Solution include both the E and F layer information and are in a format similar to that for the F2 layer (Code 25) except that there are 11 parameters in total. The first four parameters are fstart, hstart, peakht and dev as defined for the F2 layer. There are, however, seven coefficients for the shifted Chebyshev polynomials (A0 - A6) for the monotonic solution true height.

Code 37 -- Valley Coefficients

The content for this Group has yet to be defined. It will include information concerning the height, depth and shape of the E region valley.

APPENDIX D

Presentation of the Database for Ionogram Characteristics at Uneven Data Rates

IONOGRAM CHARACTERISTICS AT UNEVEN DATA RATES

Robert R. Gamache and Bodo W. Reinisch

The University of Lowell Center for Atmospheric Research

ABSTRACT

The routine collection of ionospheric data at high measurement rates forces one to question the archiving of only hourly characteristics. The databasing of ionospheric characteristics recorded at uneven time sampling is explored. A database is proposed that is similar to the fixed block format database[1] currently in use when only hourly data are available. The database has the advantage of being flexible enough to consider uneven measurement times, thus no data are discarded, yet it is simple enough so it can be implemented by simple programs written in FORTRAN or C.

INTRODUCTION

The archiving of hourly ionospheric characteristics is a relatively straightforward task. The small amount of data (24 values per day times 31 days) yield block lengths well below maximum values. Data blocks of a fixed size can be constructed and blank or zero filled when data are missing. The format within each block can be standardized for many different characteristics so that the structure of the data base is the same for each characteristic for each month. This has been done and the results can be found in INAG

Ionospheric Station Information Bulletin No. 45,[1] Appendix A (included here as Appendix A). The drawback of such a structure is that null data are stored (≈ 5% waste in the best situations) and there is no flexibility allowed. For example, many modern ionosonde stations routinely run a 15 minute schedule, under the current scheme three quarters of the data are not saved. Allowing for changing data rates requires completely different data formats than the one described in Appendix A. A structure which allows variable data rates is desirable. In creating such a structure, the main considerations are ease of use, standardization, transportability, and flexibility. The aim is to create a database from this structure. Relational databases, ones where "fields" are defined and related by "keys", are not considered here due to transportability problems. The database described here is ASCII (or EBCDIC) files containing the characteristics and other information in a prescribed format.

STRUCTURES

Before attempting to define a structure for a database, the type, range, number of data and application must be considered. For example, many scientific databases have a reference field which relates to a particular measurement e.g. this may be a time or an experiment number, followed by the results of the measurements. These include such things as geophysical data, pollution levels at sites, or the daily price of gold. Another type of database requires that a number of data be collected for a particular item, e.g. a health record may include height, weight, sex, cholesterol level, etc. and the principal key is the patients name. Perhaps a better example is a database for absorption of radiation by molecules. Although much of the data comes from experiment, the data does not change with time so there is no need to relate the database to the experiment time or number. Figures 1 and 2 give simple examples of these types of databases respectively. The second type of database is more rigid in that a fixed format is determined and then used for all entries whether or not all fields are used. In practice however, there is often overlap between the two types as in the case of the database in Appendix A.

DATABASE FOR IONOSPHERIC CHARACTERISTICS

The concern is the databasing of ionospheric characteristics. Historically, hourly values were archived when available. The tedious task of manually scaling ionograms and entering the data into some type of computer readable storage form, originally punched cards, meant that times shorter than hourly values were not practical. With the advent of digital ionospheric sounders and robust autoscaling techniques, this is no longer true. Fifteen minute schedules are common and, during many occasions, five minute schedules are often employed. Computerized verification and correction programs, like ULCAR's automated editing program ADEP[2], which can edit autoscaled results at very high rates are becoming available. Thus, there is a large and growing amount of reliable characteristics data at unevenly spaced times. The aim here is to construct a database structure that is sufficiently flexible to apply to this data, is easy to use and understand. Figure 3 shows some of the many possibilities of the directions one can follow.

Sample Number __________ Sample Site _______ Date ___/___/_____

Street ____________ City ________________ State _____ Zip _____

% Cu ______ % Pb ______ % As ______ % Ca ______ % Mo ______

Specific Gravity ________________

Figure 1. Simple example of a time dependent database

Patient Name _________________ Date ___/___/_____

Street ___________ City ________________ State _____ Zip ____

Age _____ Sex _____ Height ________ Weight ________

Cholesterol Level _____ Blood Pressure _______

Insurance _________

Figure 2. Simple example of a health record database

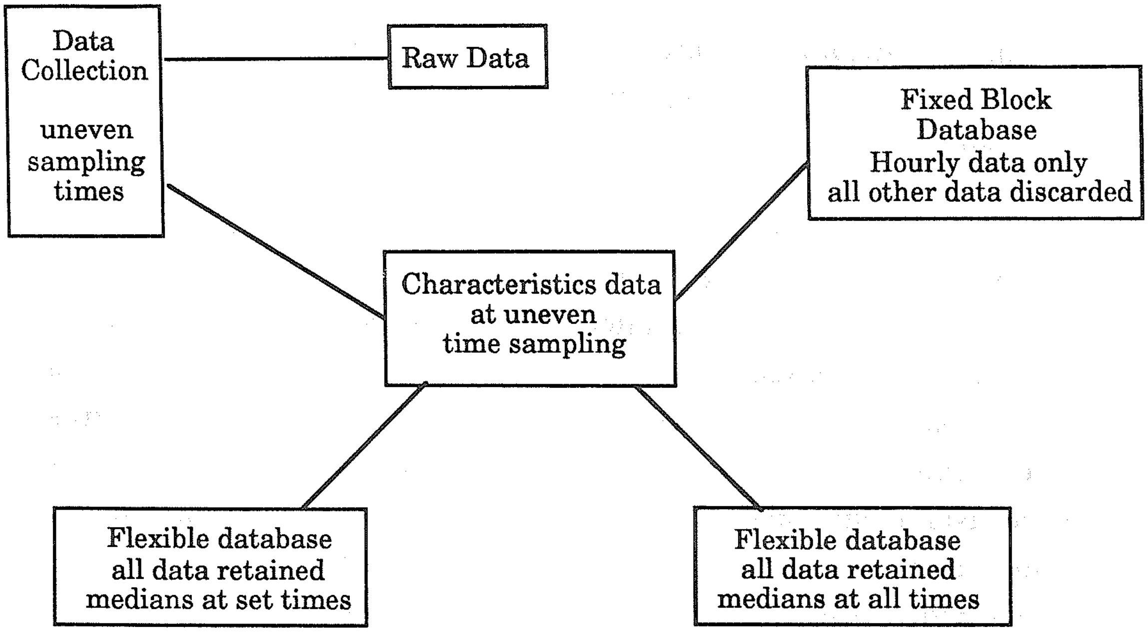

Figure 3. Possible directions for Characteristics database.

The end use of the data should also enter into the determining of the structure of the database. Those wishing to study diurnal variations of a particular characteristic want data from many observations per day, study of seasonal variations may only require hourly values, and correlation with solar activity may only require several measurements per day. One question to ask is should one or several databases be kept for the same data depending on the application. This becomes more important as the size of the database increases.

What is discussed below is the archiving of ionospheric characteristics unevenly spaced in time. To simplify the structure, only monthly data sets will be considered. The reason for a monthly period is its historically proven usefulness. Not knowing the number of data to be stored before hand introduces many problems. The most difficult case is irregularly changing data rate, e.g. on a given day the data are collected at 5 minute intervals for a few hours followed by hourly sampling after which they are taken every 15 minutes. Index indicators giving the number of data stored will have to precede the record containing the actual data and the times of the data points must be stored.

The definition of the monthly median of such data must be addressed. The enhanced time resolution raises questions on which medians should be calculated. It may make little sense to calculate monthly medians for five minute time intervals. The uneven time spacing of the data generates many problems. The time spacing to group the daily values into must be addressed. For example, measurements may occur at 9:05, 9:09 and 9:14 on several days of the month. These could be grouped together or 3 separate medians reported. The logistics of the latter are difficult, would lead to much larger files, and given the roughness of medians probably do not make sense. Even if groupings are defined the collection and grouping of the data are not straight forward. For these reasons, we suggest hourly medians only. This will result in a database similar to that described in Appendix A when only hourly data are available.

The proposed structure of the database, displayed in Table 1, is as follows. For a given month, the database is comprised of a number of blocks of data, the total number of blocks being determined by the number of days in the month, the number of measurements per day, and the number of characteristics reported. For storage on magnetic tape, the block size is set by considering a reasonable maximum amount of data and adjusting the block size to maximize the ratio of EOR gaps (0.6 in) to data stored. The maximum block size for writing to magnetic tape is governed by software that limits the counter to a four byte word yielding a maximum block size of 9999 bytes.

There are three types of blocks in the database; the first block contains station information, a list of characteristics, etc. and is a key for the following blocks. The other blocks are for measurement times or characteristics. The measurement times are

Table 1. Database Structure for Flexible Data Rates

Block #	Format	Description
1	A20	Station Name
1	A5	Station code
1	F5.1	Latitude N
1	F5.1	longitude E
1	I3	Longitude E of time base.
1	I4	Year
1	I2	Month
1	I2	Number of Characteristics
1	20(A4)	List of characteristics
1	20(I2)	List of corresponding URSI codes
1	I2	Number of days in the month, M
1	31(I4)	Numbers of measurements for each of the M days, N_M
2	ΣN_M(I6)	The N_M sample times Hh:Mm:Ss
•	• •	for each of the M days
•	NFx.y	The N_1 values of characteristic 1 for day 1
•	• •	•••repeated for each of the M days
•	• •	Medians
•	• •	The counts for the medians
•	• •	Upper quartile
•	• •	Lower quartile
•	• •	Upper decile
•	• •	Range
•	• •	Lower decile
•	NFx.y	The N_2 values of characteristic 2 for day 1
		repeated for each characteristic
•	• •	• • •

given in 6 byte integers (hours, minutes, seconds, hhmmss) and the maximum day count is 31 days. The characteristic blocks contain 6 byte characteristics (4 byte integer and 2 qualifying and descriptive letters) with a 31 day maximum followed by the monthly medians, median count, upper and lower quartiles, upper decile, range, and lower decile and requires 672 bytes (24 hourly values at 4 bytes each). Table 2 relates block size to the number of measurements per day and the average time schedule.

Table 2. Block sizes (bytes), measurements per day, and average sample spacing for measurement times or characteristics.

Block Size	6000	7000	8000	9000
Measurements/day	32	38	43	48
Sample Spacing [min.]	45	38	33	30
Characteristics				
Block Size	6000	7000	8000	9000
Measurements/day	31	37	42	47
Sample Spacing [min.]	46	38	34	30

The time block is the limiting factor. With a choice of a 9000 byte block a routine half hour schedule could occupy a single block. With this choice and an hourly schedule, two characteristics could be written to a single block thus conserving tape. A fifteen minute schedule would require two blocks per characteristic, etc. The block size could be reduced to any of the other values and the times and characteristics would require several block storage. This poses no significant problem since from the first block of data the procedure for writing and reading the database is automated.

The first block of information is the key block for reading the database. It contains the station name and code, the latitude north and longitude east, an indicator for time measured in UT or LT, the year and month, the number of characteristics, the list of characteristics followed by the corresponding URSI code, the number of days of the month, and finally the number of measurements made each day. For evenly spaced data this could be set to a negative number for the first value after which the starting time and time increment follow. With this option, the sample time blocks would have to be skipped. This block is 286 bytes long. From this block of information one is able to read the characteristics data for the month.

With uneven time spacing the sample times for the month must be recorded. This requires that hours, minutes, and seconds of each measurement be entered into the database. Because of the space requirement, this is written once per month and all measured characteristics are reported for the particular month to reduce storage space. The measurement times of each day are written for each day of the month. These are recorded in 3I2 format for the hours, minutes, and seconds, HHMMSS, of the measurements. The number of blocks needed for this is determined by the data sampling rate for the month. An described above, these blocks need not written when even spacing of measurements is done, e. g. hourly values.

The database then continues with each characteristic as given in the list in the first block. The number of blocks and their length are determined automatically from the data of the first block.

The reading and writing of the blocks to magnetic tape can be accomplished by FORTRAN (or other high level languages) programs distributed with the database. The uneven time spacing leads to record lengths that change with the data. We have shown that this is no problem given the structure of the database. This is an important factor for transportability.

Some of the advantages of such a structure are: the flexibility of the resulting database would allow data rates to change from month to month or from station to station. The database would be transportable and would be easily maintained and used by routines written in any high level language (FORTRAN, C, etc.). The proposed structure is very flexible and most importantly does not leas to data being discarded. Although it is slightly more difficult to use it is a necessary part of the evolution of the databasing of ionospheric characteristics. The drawback of the structure is the loss of the fixed block structure, however this is not very important, especially when one considers the present state of computers in physics.

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