Standard Archiving Output (SAO) Format

Introduction

Automatic scaling of ionogram data has come a long way and the quality of the autoscaled data has reached a remarkable level. Consequently the time has arrived to directly transfer ionosonde data to the World Data Centers using the Internet. We have begun to equip the Digisondes with Internet connections. The first Internet links were established between the Okinawa Digisonde (CRL, Japan) and the WDC-C2 in Tokyo, the Millstone Hill Digisonde (UML, USA) and the WDC-A in Boulder, Colorado, and Chilton Digisonde (RAL, GB) and the WDC-C1 in Chilton. All data generated in the Digisonde are made available for electronic transfer: ionogram data, scaled data, and drift data.

Starting in 1987, the Ionospheric Informatics Working Group (IIWG) of Commission G of URSI has developed recommendations for the data formats to be used for dissemination and archiving of scaled ionogram data and for the monthly ionospheric characteristics. The IIWG abstained (wisely) from trying to develop a common data format for the system-dependent ionogram and drift data.

The attached report gives a detailed description of the Standard Archiving Output (SAO) format. Each SAO (text) file contains the scaled data for one ionogram including the echo traces h'(f), echo amplitudes, frequency and range spread, etc. and the electron density profile.

The upgraded or new Digisondes produce the SAO files in real time for local recording and/or electronic transfer. The older Digisondes generate only binary files, but offline editing results are usually stored in the SAO format. Since these Digisonde ionograms SAO files are now becoming available to any user either through the WDC sites or via the web pages of the connected Digisonde stations it seems important to publish a description of the SAO format.

The SAO format was originally designed for storing Digisonde ionograms scaled by autoscaling software ARTIST and edited using ADEP utility. However, in subsequent releases a special effort was made to generalize SAO design so that it can hold scaled data produced by other sounder systems. With release of version 4.1, the degree of format universality became high enough to promote SAO as a standard format for exchange of scaled ionogram data.

SAO Format version 4.3

The SAO file structure has remained the same since it was developed by the IIWG in 1989, but the content has been expanded in subsequent releases. The following is a description of the SAO format version 4.3 *[Gamache et al.,* 1996*]*.

A SAO file is an ASCII text file with a maximum line length of 120 characters. In order to concisely describe the database some definitions are necessary. The nomenclature is as follows:

File	a collection of many *Records*
Record	all data for a single observation (ionogram)
Group	all *Lines* of a datum type
Line	a sequence of *Elements* of a datum type, CR/LF terminated
Element	a single datum in the specified format

The *Record* structure is composed of two basic components: a **Data Index** and **Data.** The format and size of the **Data Index** is fixed. It describes the contents of the **Data** in the *Record*. The **Data** component of each *Record* contains a varying number of *Groups* as indicated by the **Data Index***.* The format and length of data varies from one *Group* to the next; however, all data *Elements* within a single *Group* are of the same type and length. The number of characters in a given *Group* can easily exceed the 120 characters per line limit. In this case, the output overflows to succeeding lines, thus a data *Group* may extend over several *Lines*.

This format design allows storing variable amount of information per ionogram, depending not only on ionospheric conditions, but also on sounder system specifics. There is only a subset of *Groups* that have to be present in a *Record.* As explained below, all others may be omitted and their corresponding index in the **Data Index** section set to zero. Data systems engineers have to decide which *Groups* to use to report data available from their sounders, if different from Digisonde. There are three situations, described in detail below, where system-specific data can be readily ingested using existing SAO-4 format:

- System Description line (using *tokens* of an arbitrary format)
- Operator's Message (using any text format)
- Sounder Settings (by requesting a version indicator and submitting format specification to their local WDC)

Groups 63 to 79 are currently vacant for specification formats of other data items currently missing from SAO-4. Each addition of a Group has to be accompanied with a new release of SAO 4 format (versions 4.2, 4.3,...) which contains format specification for the new Group. If necessary. the number of vacant *Groups* may be expanded by addition of new line(s) in the **Data Index**.

Data Index

The Data Index contains 80 three digit integers. The position in the list corresponds to the data for the data *Group* number. These are shown in Table 1. The first integer is the **number of *Elements*** in the data *Group* 1, Geophysical Constants, in the current *Record*. The second integer represents the **number of *Elements*** in the second data *Group*, System Description, etc. A value of zero indicates that there is no data for the *Group* in the *Record*. Position 80 of the Data Index array is not used to specify the format of the data to follow. It is reserved for the SAO version indicator:

0	SAO-3
1	SAO-3.1
2	SAO-4.0
3	SAO-4.1
4	SAO-4.2
5	SAO-4.3

If the demand for vacant *Groups* grows beyond the existing limit, the Data Index will have to expand and include more lines. The 80th element of the Data Index will still be used as the Version Indicator so that the reading logic will be aware of extra index lines.

Column **Req.** of Table 1 indicates which Groups are required to specify in a minimum content SAO-4 file. Red "x" marks indicate mandatory groups. If trace points are availble for output in the file, each trace has to be specified with at least two groups (virtual heights and frequencies) as indicated by a "xx" cyan marks.

Table 1. SAO Record Format

Group	Req.	FORTRAN Format	Description	Reference
	x	2(40I3)	DATA FILE INDEX	
1	x	16F7.3	GEOPHYSICAL CONSTANTS	Table 2
2		A120	SYSTEM DESCRIPTION AND OPERATOR'S MESSAGE	
3	x	120A1	TIME STAMP AND SOUNDER SETTINGS	Table 3,4,5
4	x	15F8.3	SCALED IONOSPHERIC CHARACTERISTICS	Table 6,7
5		60I2	ANALYSIS FLAGS	Table 8
6		16F7.3	DOPPLER TRANSLATION TABLE	
			O-TRACE POINTS - F2 LAYER	
7	xx	15F8.3	VIRTUAL HEIGHTS	
8		15F8.3	TRUE HEIGHTS	

9		40I3	AMPLITUDES	
10		120I1	DOPPLER NUMBERS	
11	xx	15F8.3	FREQUENCIES	
			O-TRACE POINTS - F1 LAYER	
12	xx	15F8.3	VIRTUAL HEIGHTS	
13		15F8.3	TRUE HEIGHTS	
14		40I3	AMPLITUDES	
15		120I1	DOPPLER NUMBERS	
16	xx	15F8.3	FREQUENCIES	
			O-TRACE POINTS - E LAYER	
17	xx	15F8.3	VIRTUAL HEIGHTS	
18		15F8.3	TRUE HEIGHTS	
19		40I3	AMPLITUDES	
20		120I1	DOPPLER NUMBERS	
21	xx	15F8.3	FREQUENCIES	
			X-TRACE POINTS - F2 LAYER	
22		15F8.3	VIRTUAL HEIGHTS	
23		40I3	AMPLITUDES	
24		120I1	DOPPLER NUMBERS	
25		15F8.3	FREQUENCIES	
			X-TRACE POINTS - F1 LAYER	
26		15F8.3	VIRTUAL HEIGHTS	
27		40I3	AMPLITUDES	
28		120I1	DOPPLER NUMBERS	
29		15F8.3	FREQUENCIES	
			X-TRACE POINTS - E LAYER	
30		15F8.3	VIRTUAL HEIGHTS	
31		40I3	AMPLITUDES	
32		120I1	DOPPLER NUMBERS	
33		15F8.3	FREQUENCIES	
34		40I3	MEDIAN AMPLITUDES OF F ECHOES	
35		40I3	MEDIAN AMPLITUDES OF E ECHOES	
36		40I3	MEDIAN AMPLITUDES OF ES ECHOES	
37		10E11.6E1	TRUE HEIGHTS COEFFICIENTS F2 LAYER UMLCAR METHOD	Table 9
38		10E11.6E1	TRUE HEIGHTS COEFFICIENTS F1 LAYER UMLCAR METHOD	Table 9
39		10E11.6E1	TRUE HEIGHTS COEFFICIENTS E LAYER UMLCAR METHOD	Table 9

40		6E20.12E2	QUAZI-PARABOLIC SEGMENTS FITTED TO THE PROFILE	Table 10
41		120I1	EDIT FLAGS - CHARACTERISTICS	Table 12
42		10E11.6E1	VALLEY DESCRIPTION - W,D UMLCAR MODEL	
			O-TRACE POINTS - Es LAYER	
43		15F8.3	VIRTUAL HEIGHTS	
44		40I3	AMPLITUDES	
45		120I1	DOPPLER NUMBERS	
46		15F8.3	FREQUENCIES	
			O-TRACE POINTS - E AURORAL LAYER	
47		15F8.3	VIRTUAL HEIGHTS	
48		40I3	AMPLITUDES	
49		120I1	DOPPLER NUMBERS	
50		15F8.3	FREQUENCIES	
			TRUE HEIGHT PROFILE	
51		15F8.3	TRUE HEIGHTS	
52		15F8.3	PLASMA FREQUENCIES	
53		15E8.3E1	ELECTRON DENSITIES [e/cm^3]	
			URSI QUALIFYING AND DESCRIPTIVE LETTERS	
54		120A1	QUALIFYING LETTERS	
55		120A1	DESCRIPTIVE LETTERS	
56		120I1	EDIT FLAGS - TRACES AND PROFILE	Table 13
			AURORAL E_LAYER PROFILE DATA	
57		10E11.6E1	TRUE HEIGHTS COEFFICIENTS Ea LAYER UMLCAR METHOD	Table 9
58		15F8.3	TRUE HEIGHTS	
59		15F8.3	PLASMA FREQUENCIES	
60		15E8.3E1	ELECTRON DENSITIES [e/cm^3]	
80		--	(Reserved)	

Group 1: Geophysical Constants

The values of the Geophysical Constants shown in Table 2 are specified for the station producing the data in the file. Frequencies are in MHz, angles are in degrees.

Table 2. Geophysical Constants

Position	Req	Description
1	x	Gyrofrequency (MHz)
2	x	Dip angle (-90.0 to 90.0 degrees)
3	x	Geographic Latitude (-90.0 to +90.0 degrees)
4	x	Geographic Longitude East(0.0 to 359.9 degrees)

5		Sunspot Number for the current year

Group 2: System Description and Operator's Message

This Group allows the user to give a description of the system which recorded the data and to store a free format text message. The Group 2 is given in A120 format, so the Data Index entry for the Group 2 counts total number of 120-character *Lines* of text. One text line is used to store system description; if an operator's message is given, it takes another text line. Thus, the Data Index can be 0 (no information), 1 (system description) or 2 (system description and operator's message).

The minimum contents of the System Description line should include sounder model and station IDs. To accomodate all possible station-specific information in an organized and flexible fashion, the concept of a *token* is introduced. System Description line is arranged in comma-separated tokens, where each token consists of a registered keyword and a data field. The first token is always the sounder model, local station ID and URSI station code number. One space character separates sounder model and IDs. Station IDs are separated by a forward slash. Local station ID is determined by host institution or sounder manufacturer. URSI station code number is assigned through World Data Center A for Solar-Terrestrial Physics, contact person Raymond O. Conkright.

For example, the System Description Line for a UMLCAR Digisonde Portable Sounder may look like this:

DPS-4 042/MHJ45, ARTIST 1297, NH 1.3, ADEP 2.19

It contains four tokens:

- **DPS-4 042/MHJ45** -- keyword **DPS-4** indicates the Digisonde model "DPS-4", and data filed **042/MHJ45** contains UMASS Lowell Station ID *(042)* and URSI station code number *(MHJ45)*
- **ARTIST 1297** -- keyword **ARTIST** indicates ARTIST software, and **1297** is the ARTIST version number,
- **NH 1.3** -- keyword **NH** indicates true height profile inversion algorithm, and **1.3** is the algorithm version number,
- **ADEP 2.19** -- keyword **ADEP** indicates ADEP software, and **2.19** is the ADEP version number.

Thus, each item that the data support engineer needs in include into the SAO-4 System Description line has to form a token where the item is preceeded by a keyword. Another example can be given for a DISS sounder:

DISS 038/, NAME Wallops Island, WMOID HIGL BTGS 04231, ARTIST 0790, NH 1.3, ADEP 2.19

The SAO reading routine works as a simple string parser. It has to get the first word in the System Description line to identify the sounder system. Then, depending on the sounder model, it can scan the rest of the line for keywords and fill appropriate structures with corresponding data field contents. If the sounder model could not be identified, then the system Description line is used only as single text line, without analysis of individual tokens.

Group 3: Timestamp and Sounder Settings

Group 3 contains three fileds: **Version Indicator**, **Timestamp** of the measurement and a **Sounder Settings.** Only the first two fields are required in the minimum contents of the Group. In the minimum case, the Version Indicator should be set to AA as shown in the Table 3.

Table 3. Minimum Contents of Group 3

Number	Req.	Description	Possible Values
1-2.	x	Version Indicator	AA
3-6.	x	4 digit Year.	(1976-...)
7-9.	x	Day of Year	(1-366)
10-11.	x	Month	(1-12)
12-13.	x	Day of Month	(1-31)
14-15.	x	Hour [All times and dates correspond to UT.]	(0-23)

16-17.	x	Minutes	(0-59)
18-19.	x	Seconds	(0-59)

The Sounder Settings field is intended to allow users to assign codes that identify how the measurement is made with reference to particular sounders. For each particular sounder system, the format of System Preface Parameters Group must be personalized and a unique two-letter Version Indicator should be chosen to distinguish it from other sounder systems. The Version Indicator is then stored in the first two positions of the Group 3.

DPS data is represented by "FF" Version Indicator, and "FE" is allocated for Digisonde 256 data. Example formats of this Group for Digisonde Portable Sounder (DPS) and Digisonde 256 are shown in Table 4 and Table 5, respectively.

Table 4. DPS System Preface Parameters

Number	Description	Possible Values
1-2.	Version Indicator	FF
3-6.	4 digit Year.	(1976-...)
7-9.	Day of Year	(1-366)
10-11.	Month	(1-12)
12-13.	Day of Month	(1-31)
14-15.	Hour [All times and dates correspond to UT.]	(0-23)
16-17.	Minutes	(0-59)
18-19.	Seconds	(0-59)
20-22.	Receiver Station ID (three digits)	(000-999)
23-25.	Transmitter Station ID.	(000-999)
26.	DPS Schedule	(1-6)
27.	DPS Program	(1-7)
28-32.	Start Frequency, 1 kHz resolution	(01000 - 45000)
33-36.	Coarse Frequency Step, 1 kHz resolution	(1-2000)
37-41.	Stop Frequency, 1 kHz resolution	(01000 - 45000)
42-45.	DPS Fine Frequency Step, 1 kHz resolution	(0000 - 9999)
46.	Multiplexing disabled [0 - multiplexing enabled, 1 - disabled].	(0,1)
47.	Number of DPS Small Steps in a scan	(1 to F)
48.	DPS Phase Code	(1-4, 9-C)
49.	Alternative antenna setup [0 - standard, 1 - alternative].	(0,1)
50.	DPS Antenna Options	(0 to F)
51.	Total FFT samples [power of 2]	(3-7)
52.	DPS Radio Silent Mode [1 - no transmission]	(0,1)
53-55.	Pulse Repetition Rate (pps)	(0-999)
56-59.	Range Start, 1 km resolution	(0-9999)
60.	DPS Range Increment [2 - 2.5 km, 5 - 5 km, A - 10 km]	(2,5,A)
61-64.	Number of ranges	(1-9999)
65-68.	Scan Delay, 15 km units	(0-1500)
69.	DPS Base Gain	(0-F, encoded)
70.	DPS Frequency Search Enabled	(0,1)
71.	DPS Operating Mode [0 - Vertical beam, 5 - multi-beam ionogram]	(0-7)
72.	ARTIST Enabled	(0,1)
73.	DPS Data Format [1 - MMM, 4 - RSF, 5 - SBF]	(0-6)

74.	On-line printer selection [0 - no printer,1 - b/w, 2 - color]	(0,1,2)
75-76.	Ionogram thresholded for FTP transfer [0-no thresholding]	(0-20, encoded)
77.	High interference condition [1 - extra 12 dB attenuation]	(0,1)

Table 5. Digisonde 256 System Preface Parameters

Number	Code	Description	Possible Values
1-2.	-	Version Indicator	FE
3-6.	-	4 digit Year.	(1976-...)
7-9.	-	Day of Year	(1-366)
10-11.	-	Month	(1-12)
12-13.	-	Day of Month	(1-31)
14-15.	-	Hour [All times and dates correspond to UT.]	(0-23)
16-17.	-	Minutes	(0-59)
18-19.	-	Seconds	(0-59)
20-30.	-	Digisonde Preface Timestamp	YYDDDHHMMSS
31.	S	Program Set	(1-3)
32.	P	Program Type	(A,B,C,F,G)
33-38.	J	Journal	encoded
39-44.	F	Nominal Frequency, 100 Hz resolution	(001000 - 045000)
45-51.	P#	Output Controls	encoded
52-53.	SS	Start Frequency, 1 MHz resolution	(00-10)
54.	Q	Frequency Increment	(0-9,A-C,encoded)
55-56.	UU	Stop frequency, 1 MHz resolution	(01-30)
57-59.	CAB	Test Output	encoded
60-62.	V	Station ID	(000-999)
63.	X	Phase Code	(0-F, encoded)
64.	L	Antenna Azimuth	(0-F, encoded)
65.	Z	Antenna Scan	(0-7, encoded)
66.	T	Antenna Option and Doppler Spacing	(0-F, encoded)
67.	N	Number of Samples	(1-8)
68.	R	Repetition Rate	(0,2-8,A,B, encoded)
69.	W	Pulse width and code	(0-7, encoded)
70.	K	Time control	encoded
71.	I*	Frequency correction	(0-4, encoded)
72.	G*	Gain correction	(0-7, encoded)
73.	H	Range increment	(0-3,8-C, encoded)
74.	E	Range start	(0-7, encoded)
75.	I	Frequency Search	(0-7, encoded)
76.	G	Nominal Gain	(0-F, encoded)
77.	-	Spare	0

Group 4: Scaled Ionospheric Characteristics

The Scaled Ionospheric Characteristics may be obtained by ARTIST, ADEP, some other autoscaling or editing/validating software, or typed in manually. All numbers represent either frequency in Megahertz or altitude in kilometers except as indicated in Table 6. The format *F8.3* (DDDD.DDD) is used to report the characteristics which is equivalent to 1 kHz precision in frequencies and 1 m precision in heights. The accuracy of the stored values is usually 1 ionogram pixel (frequency step or height increment) except as indicated in Table 6.

There are currently 49 Scaled Ionospheric Characteristics defined. It is possible to report less than 48 characteristics and indicate that in the Data Index section of the record. Otherwise, all characteristics which are not scaled for a particular ionogram must be set to a default "No reading" value. which is 999.900 MHz for frequencies and 9999.000 km for heights.

Table 6. Scaled Ionospheric Characteristics

#	Description	Units	Accuracy	No reading
1	foF2 : F2 layer critical frequency, including the adjustment by the true height profile algorithm	MHz	at least quarter of frequency increment	9999.000
2	foF1 : F1 layer critical frequency	MHz	1 frequency increment	9999.000
3	M(D) = MUF(D)/foF2	-	-	9999.000
4	MUF(D) : Maximum usable frequency for ground distance D	MHz	1 frequency increment	9999.000
5	fmin: minimum frequency of ionogram echoes	MHz	1 frequency increment	9999.000
6	foEs : Es layer critical frequency	MHz	1 frequency increment	9999.000
7	fminF : Minimum frequency of F-layer echoes	MHz	1 frequency increment	9999.000
8	fminE : Minimum frequency of E-layer echoes	MHz	1 frequency increment	9999.000
9	foE : E layer critical frequency	MHz	1 frequency increment	9999.000
10	fxI : Maximum frequency of F-trace	MHz	1 frequency increment	9999.000
11	h'F : Minimum virtual height of F trace	km	1 height increment	9999.000
12	h'F2 : Minimum virtual height of F2 trace	km	1 height increment	9999.000
13	h'E : Minimum virtual height of E trace	km	1 height increment	9999.000
14	h'Es : Minimum virtual height of Es trace	km	1 height increment	9999.000
15	zmE : Peak height of E-layer	km	1 height increment	9999.000
16	yE : Half thickness of E layer	km	1 height increment	9999.000
17	QF : Average range spread of F layer	km	1 height increment	9999.000
18	QE : Average range spread of E layer	km	1 height increment	9999.000
19	DownF : Lowering of F trace to the leading edge	km	1 height increment	9999.000
20	DownE : Lowering of E trace to the leading edge	km	1 height increment	9999.000
21	DownEs : Lowering of Es trace to the leading edge	km	1 height increment	9999.000
22	FF : Frequency spread between fxF2 and fxI	MHz	1 frequency increment	9999.000
23	FE : Frequency spread beyond foE	MHz	1 frequency increment	9999.000
24	D : Distance for MUF calculation	km	1 km	9999.000
25	fMUF : MUF/OblFactor	MHz	1 frequency increment	9999.000
26	h'(fMUF) : Virtual height at MUF/OblFactor frequency	MHz	1 height increment	9999.000
27	delta_foF2 : Adjustment to the scaled foF2 during profile inversion	MHz	1 kHz	9999.000
28	foEp : predicted value of foE	MHz	±0.3 MHz	9999.000
29	f(h'F) : frequency at which h'F occurs	MHz	1 frequency increment	9999.000
30	f(h'F2) : frequency at which h'F2 occurs	MHz	1 frequency increment	9999.000
31	foF1p : predicted value of foF1	MHz	± 0.5 MHz	9999.000
32	peak height of F2 layer	km		9999.000
33	peak height of F1 layer	km		9999.000
34	zhalfNm : the true height at half the maximum density in the F2 layer	km	1 km	9999.000
35	foF2p : predicted value of foF2	MHz	± 2.0 MHz	9999.000
36	fminEs : minimum frequency of Es layer	MHz	1 frequency increment	9999.000

37	yF2 : half thickness of the F2 layer, parabolic model	km	100 m	9999.000
38	yF1 : half thickness of the F1 layer, parabolic model	km	100 m	9999.000
39	TEC : total electron content	10^{16} m^{-2}	-	9999.000
40	Scale height at the F2 peak	km	1km	9999.000
41	B0, IRI thickness parameter	km	-	9999.000
42	B1, IRI profile shape parameter	-	-	9999.000
43	D1, IRI profile shape parameter, F1 layer	-	-	9999.000
44	foEa, critical frequency of auroral E layer	MHz	1 frequency increment	9999.000
45	h'Ea, minimum virtual height of auroral E layer trace	km	1 height increment	9999.000
46	foP, highest ordinary wave critical frequency of F region patch trace	MHz	1 frequency increment	9999.000
47	h'P, minimum virtual height of the trace used to determine foP	km	1 height increment	9999.000
48	fbEs, blanketing frequency of Es layer	MHz	1 frequency increment	9999.000
49	Type Es	-	See Table 7	9999.000

Type Es is a letter characteristic which has to be reported in the Table 6 as a number using Lookup Table 7.

Table 7. Lookup Table for Type Es Characteristic

Type Es	Value reported in Group 4	Description
A	1.0	Auroral
C	2.0	Cusp
D	3.0	below 95 km
F	4.0	Flat
H	5.0	Height discontinuity with normal E
K	6.0	in the presence of night E
L	7.0	Flat Es below E
N	8.0	Non-standard
Q	9.0	Diffuse and non-blanketing
R	10.0	Retardation

Group 5: ARTIST Analysis Flags

The ARTIST Analysis Flags are a sequence of two digit integers (60I2 format) which indicate and qualify some of the ARTIST scaled results. Table 8 is a description of the flags and the meaning of their possible values.

Table 8. ARTIST Flags

Position	Content	Description
1	1	foE scaled using E-region trace data
	2	No E-region trace obtained, only predicted foE available
	3	No E-region trace obtained, but foE scaled using F trace
2	0	No F trace scaled

	1	E layer profile only
	2	Separate soliutions for E and F layers
	4	Frequency range error in E trace
	5	Frequency range error in F2 trace
	6	Frequency range error in F1 trace
	7	Physically unreasonable E trace
	8	Physically unreasonable F2 trace
	9	Physically unreasonable F1 trace
	10	F1 layer solution too thick
	11	Oscillating solution in F1 layer
	12	F2 trace too short
	13	F1 trace too short
	18	Oscillating solution in F1 layer
	25	Root in F1 layer too severe to correct
	26	Root in F2 layer too severe to correct
3		Not used
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
6-9		Not used
10	11-55	Confidence level: two digits, each ranging from 1 (highest confidence) to 5 (lowest confidence)
11-19		Not used
20		Internal ARTIST use

Group 6: Doppler Translation Table

The Doppler Translation Table is a sequence of floating point numbers in the 16F7.3 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. The first element of the Doppler translation table corresponds to the Doppler number 0.

Trace Points

The following Groups include ionogram trace information obtained in some automated or interactive manner. The data format and content is identical for any of the F2, F1, E, or Es traces with either ordinary (O) or extraordinary (X) polarization although not all traces may be present in any one ionogram. For example, the ARTIST program currently does not scale the complete X-traces, however space has been provided for implementation of this feature at a later date.

The data for each trace are contained in five *Groups*. For the F2 O-trace they are in *Groups* 7, 8, 9, 10, and 11; for the F1 O-trace they are in *Groups* 12, 13, 14, 15, and 16; etc. (see Table 1). The groups for sporadic E, auroral night E leayrs and all extraordinary data groups do not contain the true height group. Also, Groups 51, 52, and 53 are reserved for an accurate representation of the electron density profile, including the valley. There is a one-to-one positional correspondence between *elements* in these five *Groups*, in that the first Virtual Height, True 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.

Autoscaling or editing software may interpolate or extrapolate missing trace points to maintain consistent frequency stepping within the trace or provide better accuracy of the scaled characteristics. Because of explicit specification of all trace point frequencies in the SAO format, the interpolated or extrapolated points may be omitted. However, in this case the value of true hieght obtained for that frequency will be missing as well. If included, the interpolated/extrapolated points shall be reported with amplitude set to 0 and Doppler number set to 9.

Groups 7, 12, 17, 22, 26, 30, 43, 47: Trace Virtual Heights

This *group* consists of a number of Virtual Heights in 15F8.3 format 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.

Groups 8, 13, 18: True Heights

This *group* consists of a number of True Heights in 15F8.3 format for the layer indicated. The number of these heights depends upon the length of the trace on the corresponding ionogram (compare to complete profiles specification in *Groups* 51-53). True Heights are reported in kilometers of altitude. Virtual heights of 0 km can be present in this group as "no-value" filler of missing trace points added to preserve continuous frequency stepping.

Groups 9, 14, 19, 23, 27, 31, 44, 48: Trace Amplitudes

The amplitude in dB of each trace point is recorded in 40I3 format.

Groups 10, 15, 20, 24, 28, 32, 45, 49: Trace Doppler Numbers

The Doppler Number, as measured by the Digisonde, for each trace point is recorded here in 120I1 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 *Group* 6. Index for 8 element Doppler Translation Table runs from 0 to 7. Value 9 is reported for interpolated or extrapolated points where information about Doppler frequency shift is unavailable.

Groups 11, 16, 21, 25, 29, 33, 46, 50: Trace Frequencies

The frequency (in MHz) of the trace point is given in this *Group* in the 15F8.3 format. Originally, this *Group* was provided for the possibility of uneven frequency stepping and would normally be left empty for Digisonde ionograms with a constant frequency step. This is no longer acceptable. The sounder settings which are required to restore linear step frequencies can be obtained only from a valid Sounder Settings *Group* 3 and Scaled Characteristics *Group* 4 and may appear to be missing for some sounder systems.

Group 34: Median Amplitude of F Echo

These values are an amplitude in dB for the F trace. It is calculated every integer MHz between fminF and foF2. See Code 4 for fmin and foF2. The Median Amplitude is calculated by taking the median of the trace amplitudes over a 0.5 MHz in frequency by five height range rectangle and then scaling this median value to appear as if it were at 100 km altitude.

Group 35: Median Amplitude of E Echo

Same as per Code 34, but for the E echo between fminE and foE.

Group 36: Median Amplitude of Es Echo

Same as per Code 34, but for the Es echo between fminE and foEs.

Group 37: True Height Coefficients for the F2 Layer

The True Height Data for F2 layer from the UMLCAR method are stored in the E11.6E1 format. There are up to 10 *elements*. The meaning of each *element* is given in Table 9.

Table 9. True Height Coefficients

Position	Parameter	Description
1	fstart	Start frequency (MHz) of the F2 layer
2	fend	The end frequency of the F2 layer
3	zpeak	The height of the peak of the F2 layer
4	dev	The fitting error in km/point.
5-9	A0-A4	Shifted Chebyshev polynomial coefficients
10	zhalfNm	Height at half peak electron density

Group 38: True Height Coefficients for the F1 Layer

The True Height Data for the F1 layer from the UMLCAR method have the same format as those for the F2 layer (*Group* 37) above with the exception of zhalfNm (see Table 9).

Group 39: True Height Coefficients for the E Layer

The True Height Data for the E layer from the UMLCAR method have a format very similar to that for the F2 and F1 layers (*Codes* 37 and 38) above. The difference lies in that there are only seven *elements* stored in this *Group*. The first four parameters are fstart, fend, zpeak 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.

Group 40: Quazi-Parabolic Segments Fitted to the Profile

An arbitrary number of parabolic segments may be fitted to the profile to approximate its shape. Each segment can be expressed as:

$$f_N^2 = A/R^2 + B/R + C$$

where

f_N is the plasma frequency in MHz,
A, B, and C are the parabolic coefficients
R is the distance from the center of the Earth in km, which varies from R1 to R2 for the segment.

If *n* segments are fitted to the profile, the Group 40 will contain *n*+1 entries. The first *n* entries store 6 values per segment (R1, R2, A, B, C, and fitting error E) in the E20.12E2 format, and the last lines contains the Earth radius, as is shown in Table 10.

Table 10. QP Segments reported in Group 40

#	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6
1	R11	R12	A1	B1	C1	E1
2	R21	R22	A2	B2	C2	E2
...						
n	R*n*1	R*n*2	A*n*	B*n*	C*n*	E*n*
n+1	R_e	-	-	-	-	-

The Earth radius, R_e, is the actual value used in the fitting process and is given in SAO file to ensure proper restoring of the profile shape.

Group 41: Edit Flags: Characteristics

The edit flags are written in 120I1 format and are used to indicate whether the reported ionospheric characteristics are result of autoscaling, manual input, or long-term prediction. One edit flag is a sum of three indicators, EDITED(1), PREDICTED(2) and VALIDATED(4). Table 11 shows possible combinations of the indicators.

Table 11. Edit Flag (characteristics) and its possible meanings

EDITED	PREDICTED	VALIDATED	EDIT FLAG VALUE	Description
0	0	0	0+0+0 = 0	autoscaled value
0	0	4	0+0+4 = 4	autoscaled value, validated by an operator
1	0	4	1+0+4 = 5	manually specified value; the autoscaled value was incorrect or unavailable
0	2	0	0+2+0 = 2	long-term prediction

The position in the edit flag list corresponds to the order of the characteristics listed in Table 6. A complete list is given in Table 12. The edit flags may be used to set the slash (/) indicators in the URSI-IIWG characteristics database, if the indicators are not given in the *Groups* 54-55.

Table 12. Edit Flags: Characteristics

#	Scaled Characteristic	Description
1	foF2	F2 layer critical frequency
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	Peak of E layer using parabolic model
16	Ym	Corresponding 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	foF1p	Predicted foF1
32	Zpeak	Peak height F2 layer
33	ZpeakF1	Peak height F2 layer
34	zhalfnm	Height at half peak electron density
35	foF2p	Predicted foF2
36	fminEs	Minimum frequency of Es layer
37	YF2	Half-thickness of F2 layer in parabolic model
38	YF1	Half-thickness of F1 layer in parabolic model
39	TEC	Total electron content
40	HscaleF2	Scale height at F2 peak
41	B0	IRI thickness parameter
42	B1	IRI profile shape parameter
43	D1	IRI F1 profile shape parameter
44	foEa	Critical frequency of auroral E layer
45	h'Ea	Minimum virtual height of auroral E layer trace
46	foP	Highest ordinary wave critical frequency of F region patch trace
47	h'P	Minimum virtual height of the trace used to determine foP
48	fbEs	Blanketing frequency of Es layer
49	Type Es	Type of Es layer

Group 42: Valley Characteristics UMLCAR model

The current content for this Group is two parameters describing the width and depth of the valley region in the UMLCAR model.

Group 51-53: Regular True Height Profile

The complete true height profile of electron density up to 1000 km is given here, including all layers and the valley. The profile is reported with the true height as the argument of the N(h) function, i.e. all heights within the valid range are scanned with a fixed increment, say, 1 km, and put in Group 51. Corresponding frequencies and electron densities are given in Group 52 and Group 53. Also, a few additional height points are reported in the groups: all peak heights of the layers and the starting height of the profile. The additional points might not be multiples of the height increment. One-to-one positional correspondence of individual elements in Groups 51-53 is preserved, so that, for example, the first element of Groups 51-53 refers to the starting height of the profile.

The height increment and coverage for the profile specification is determined by the program which created the SAO file.

Group 54-55: Qualifying and Descriptive Letters

These two groups store URSI Qualifying (Group 54) and Descriptive (Group 55) letters *[URSI Handbook of Ionogram Interpretation and Reduction, 1972]* using 120A1 format. The letters are used by manual scaling operators to reflect reliability of measurement and indicate the presence of certain ionospheric phenomena. The layout of the Groups 54-55 corresponds to Table 6 (Scaled Ionospheric Characteristics). The number of items stored in the Groups 54 and 55 must be the same as in Group 6.

When no qualifying or descriptive letter is applied to a characteristic but its value has been verified or edited, the correspoding entry in the Group 54 should read "/" (forward slash) and Group 55 should read " " (space) [see IIWG regulations, Table 3, here]. For autoscaled data, the IIWG regulations suggest storing "/" in both groups, but SAO-4 file created by the autoscaling software may simply omit Groups 54 and 55 and report only Group 41 (Edit Flags).

Group 56: Edit Flags: Traces and Profile

The edit flags are written in 120I1 format and correspond to whether ionogram traces and profile were modified as a result of manual scaling of the data. Autoscaling software must not report this group to distinguish it from the manual editing/validating. If no trace points were adjusted and profile was not recalculated in the process of manual editing/validation, the Group 56 must still be reported with all zero settings to distinguish it from autoscaled data.

Table 13. Edit Flags: Traces and Profile

#	Name	Description
1	F2 trace	F2 trace points were edited
2	F1 trace	F1 trace points were edited
3	E trace	E trace points were edited
4	z(h)	true height was recalculated with edited traces
5	Es trace	Es trace points were edited

Group 57: True Height Coefficients for the Ea Layer

The True Height Data for the E auroral layer from the UMLCAR method have a format identical to Group 39 for E layer above.

Group 58-60: Auroral True Height Profile

The complete true height profile of electron density up to 1000 km is given here, including all layers and the valley. The profile is reported with the true height as the argument of the N(h) function, i.e. all heights within the valid range are scanned with a fixed increment, say, 1 km, and put in Group 58. Corresponding frequencies and electron densities are given in Group 59 and Group 60. Also, a few additional height points are reported in the groups: all peak heights of the layers and the starting height of the profile. The additional points might not be multiples of the height increment. One-to-one positional correspondence of individual elements in Groups 58-60 is preserved, so that, for example, the first element of Groups 58-60 refers to the starting height of the profile.

References

Gamache R. R., I.A. Galkin, and B. W. Reinisch, "A Database Record Structure for Ionogram Data", University of Lowell Center for Atmospheric Research, UMLCAR 96-01, 1996.

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