A new format for ionospheric characteristics: SAOXML

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Increasing demand for real time ionospheric data from ionosondes to support ionospheric assimilation projects has been accompanied by requests for additional information to be included in the data files. Starting in 1987, the Ionospheric Informatics Working Group (IIWG) of Commission G of URSI had developed recommendations for the data formats to be used for dissemination and archiving of scaled ionogram data. The Standard Archiving Output (SAO) format, published in the INAG Bulletin #62 in 1998, was accepted and is now widely used. Each SAO (text) file contains the scaled data for one ionogram including the echo traces h'(f), echo amplitudes, frequency and range spread, and most of the important ionospheric characteristics, as well as the vertical electron density profile (where available). The currently used version SAO_4.3 is described in http://ulcar.uml.edu/%7Eiag/SAO-4.3.htm.

Evolving requests for new characteristics to be added to the SAO files necessitate the transition to a more flexible format structure. Following an invitation by the INAG chair, Terry Bullett, and the Bulletin editor, Phil Wilkinson, we submit below the proposed new format structure SAOXML for review by the ionosonde community. Since the Ionospheric Informatics Working Group no longer exists, URSI's Ionosonde Network Advisory Group, INAG, clearly is the right group to review the new format. We recommend that a resolution be reached at the URSI General Assembly in New Delhi during the INAG Business Meeting.

The proposed format has been developed during the last two years. We appreciate the inputs/comments we have received so far from ionosonde groups in Europe, North America, Australia, and South Africa. We welcome further comments and requests and will strive to implement them before the New Delhi meeting.

SAOXML 5.0 Format

Introduction

Ionospheric characteristics derived from nominally vertical incidence HF sounding serves as an important source of information for many research projects and operational applications. In addition to the numerous case studies of the ionosphere, the ionogram-derived data contribute to a number of global ionospheric empirical and assimilative models (PRISM, GAIM, IRI), and also serve as the "ground truth" for validation of other instruments such as the spacebourne UV sensors on TIMED and DMSP (SSUSI, SSULI).

Growing requirements have forced a few revisions of the standard archival format for ionogram -derived ionospheric characteristics, each time causing problems for data users and providers because of the substantial software redesign effort associated with such changes. The current Standard Archival Output (SAO) format for scaled characteristics has practically reached the limit of its flexibility for accommodating new requirements. The time has come to revise the format vehicle of SAO.

All previous revisions of the SAO format followed the same "index of available data groups" principle [Gamache et al., 1996], where each SAO record starts with an 80-element index header showing how many data items are present in the remainder of the record. Such SAO files did not store metadata explaining the content of the files. This explanation existed only as a master description document at the UMLCAR home page, http://umlcar.uml.edu:

- SAO 4.2 format at http://ulcar.uml.edu/~iag/SAO-4.htm
- SAO 4.3 format at http://ulcar.uml.edu/~iag/SAO-4.3.htm.

Thus, changes to the SAO content had to be made in a coordinated effort of all users and providers. New format revisions were not forward-compatible (old software could not read new files).

A new format for ionospheric data should satisfy a number of important requirements:

1. It shall be able to store derived ionospheric information not only for digisondes, but also for other ionospheric sounders, other instruments such as incoherent scatter radars (ISR), ionospheric models such as IRI, and average representative profiles calculated over various periods of time.
2. It shall be easily expandable to accommodate specific information needs of particular instruments or researchers.
3. It has to be upward and downward compatible; new revisions or additions should not prevent older software from reading old contents in the new files.
4. It has to be intuitive and self-explanatory for a new user to easily find major data elements such as

- the time stamp,
- location,
- description of the data source (such as instrument type, ionospheric model name and version, station and equipment information, scaling expert or algorithm, etc.),
- ionospheric characteristics,
- ionogram traces,
- regular, auroral, and average profiles, and
- uncertainties of the scaling and uncertainties of the true height profiles.

1. XML

Many data exchange problems have been solved recently using a new Extensible Markup Language (XML). The XML standard is a subset of SGML (Standard Generalized Markup Language, ISO 8879:1986(E)). It is developed and supported by the World Wide Web Consortium (W3C, http://www.w3.org/). The latest W3C recommendation about XML 1.0 can be found at http://www.w3.org/TR/2004/REC-xml-20040204/.

Table 1 provides a brief comparison of the features of the existing SAO and suggested SAOXML format vehicles for ionospheric data.

Table 1. Comparison of SAO-4 and SAOXML-5 concepts

Feature	SAO 4	SAOXML 5
Underlying format Contents of one record	Plain ASCII Index and data groups	Plain ASCII XML data elements
Data length	Variable: group lengths are given in the index	Variable: start and end of each element are labeled by tags
Record structure	Linear (list of groups)	Tree
Number of elements in a record	79 groups+1 index	Unlimited
Data element identifier	Number from 1 to 79	Alphanumeric name
Data element structure	Array of numbers in a pre-determined fixed format	Free form text data, attributes, other elements
Metadata	Limited to a system description and software versions	Configurable, can also be comprehensive
Standard	Proprietary, adopted by the IIWG URSI	ISO
Support software	UMLCAR source code for reading and writing (Fortran, C++, Java)	Many standard libraries. Files are readable by most web browsers.

The differences and similarities of these two format vehicles for ionospheric data can be summarized as follows:

1. Both SAO and SAOXML formats make plain ASCII text files that can be read by a simple text editor.

2. One SAO record is a list of data groups prefixed by an index. One SAOXML record is a tree of data elements.
3. Each SAO data group length is specified in the index. SAOXML elements have start and end tags to separate them from other elements.
4. Number of SAO data groups is limited to 79. There is no limit on the number of XML elements.
5. SAO data groups are enumerated. Each SAOXML data element is given a name.
6. SAO data group contains a homogeneous set of numbers in a pre-specified FORTRAN-like format. SAOXML element may contain text data, attributes, and other elements.
7. No metadata are available in SAO except for system description line and software version numbers. SAOXML format allows configurable amount of metadata to be included with the data.
8. SAO is a proprietary format adopted for ionogram -derived data by IIWG URSI. XML is an international standard accepted for numerous applications.
9. Read/write software code by UMLCAR is available for SAO format. XML libraries are available from many sources.

Because all XML elements are named and separated from other elements by tags, XMLSAO format is upward compatible and expandable. Old software will easily skip new elements and element attributes whose names it cannot recognize. Addition of new elements (e.g., ionospheric characteristics) and their descriptions do not disrupt the work of existing SAOXML reading software.

2. SAOXML 5.0

This document gives a detailed description and structure of the new generation of Standard Archiving Output based on XML format (SAOXML 5.0). Suggested format uses only simple XML features and, essentially, specifies a standard vocabulary of names for the tags and attributes.

Each SAOXML (text) file contains one or more records. A single record represents one measurement (scaled ionogram, an ISR profile) or one calculated profile (using a model or an averaging algorithm, for example).

2.1. Top level structure

A SAOXML file is an ASCII text that is well-formed XML document. The nomenclature is as follows:

SAOXML file	A collection of many SAOXML r*ecords*
SAOXML record	All data for a single observation (e.g., one scaled ionogram)
Tag	Case sensitive separator of elements
Attributes	A sequence of properties for the element
Character data	A data for the element

The first line of SAOXML file contains XML tag

- **<?xml version="1.0"?>**

The second line of SAOXML file contains the opening root tag

- **<SAOList>**

The last line of SAOXML file contains the closing root tag

- **</SAOList>**

The third line of SAOXML file is the first line of the SAOXML record. It is the same for each SAOXML record in the file.

- **<SAORecord** *list of attributes* **>**

The last line of the SAOXML record is

- **</SAORecord>**

2.2. SAORecord Attributes

The **SAORecord** has a list of attributes that provides the basic information about the record. Each attribute has a format attributeName="atributeValue". Table 2-a describes the minimum required set of **SAORecord** attributes, Tables 2-b, 2-c, and 2-d provide explanations for other standard attributes of the **SAORecord** that can appear in the record.

Table 2-a. SAORecord *required* attributes

Attribute name	Description	Example
version	SAO version for this record.	version="5.0"
timeUT	UT Measurement time in ISO 8601 standard format: year, month, day, day of year, hour, minute, second, millisecond.	timeUT= "2000-02-01 –032 13:45:05.000"
latitude	Geographic latitude of the station. Required.	latitude="66.98"
longitude	Geographic longitude of the station. Required.	longitude="309.06"
source	Source of the data ("Ionosonde", "ISR", "Model", "UV-sensor", "Topside ionosonde")	source="Ionosonde"

sourceType	Type of source (version, name)	sourceType="DGS-256" for source="Ionosonde"
scalerType	Type of scaler ("auto", "manual"), required attribute for ionosonde data	scalerType="auto"

Table 2-b. Possible attributes of SAORecord

Attribute name	Description	Example
timeLT	LT Measurement time in ISO 8601 standard format: year, month, day, day of year, hour, minute, second, millisecond, time zone.	timeLT= "2000-02-01 –032 08:45:05.000 –5:00"
URSICode	URSI station code assigned by the World Data Center A for Solar-Terrestrial Physics	URSICode="SMJ67"
stationName	Station name	stationName="Sondrestrom"
gyrofrequency	Electron gyrofrequency in MHz	gyrofrequency="1.4"
dipAngle	Magnetic dip angle in degrees	dipAngle="-15"
sunspotNumber	Sunspot number used by the autoscaling algorithm	sunspotNumber="100"

If **scalerType** is "auto", additional attributes can be provided to describe the ionogram autoscaling algorithm and its version (see Table 2-c).

Table 2-c. Attributes of SAORecord for autoscaled data

Attribute name	Description	Example
algorithm	Name of algorithm	Algorithm="ARTIST4"
algorithmVersion		algorithmVersion="199905"

For manually scaled data, it is possible to provide additional attributes of the **SAORecord** shown in Table 2-d.

Table 2-d. Attributes of SAORecord for manually scaled data		
Attribute name	**Description**	**Example**
name	Only for attribute scalerType=”manual”	name="John SMITH" name=”HUANG Xueqin” name="unknown scaler"

An example of the opening **SAORecord** element:

```
<SAORecord
version="5.0"
time="2000.02.01 (032) 03:45:05"
stationID="067"
URSICode="SMJ67"
stationName="Sondrestrom"
latitude="66.98"
longitude="309.06"
source="Ionosonde"
sourceType="DGS-256"
scalerType="manual"
name="John SMITH"
>
```

2.3. Body of SAORecord

Body of the SAORecord element can contain other data elements:

- **<systemDescription>**
- **<comments>**
- **<ionosphericCharacteristics>**
- **<traces>**
- **<profiles>**

2.3.1. <systemDescription>

systemDescription is an optional element inside SAORecord element that provides basic information about operating settings of the equipment. Although many of the instrument settings are specific to its design (and therefore shall not be restricted to a standard description), some of the operating parameters are common and their format can be standardized for storage in the SAOXML.

Table 3 and 4 show recommended standard **systemDescription** contents for an ionosonde.

Table 3. systemDescription attributes		
Attribute name	**Description**	**Example**

startFrequency	Starting frequency, MHz	startFrequency="0.5"
endFrequency	End frequency, MHz	endFrequency="15.5"
frequencyStepping	Type of frequency stepping (“linear”, “logarithmic”, or “tabulated”)	frequencyStepping="linear"
frequencyStep	Frequency step, MHz (or %)	frequencyStep="0.1" (for % stepping “1”)
startHeight	Starting height, km	startHeight="80"
endHeight	End height, km	endHeight="1300"
heightStepping	Type of height stepping (“linear”, “logarithmic”)	feightStepping="linear"
heightStep	Height step, km (or %)	heightStep="2.5"

Table 4. systemDescription sub-elements

Attribute name	**Description**	**Example**
frequencies	List of operating frequencies, if frequencyStepping is set to “tabulated”.	<frequencies units=”MHz”> 1.0 1.2 1.6 2.0 2.5 2.75 3.0 4.5 5.0 </frequencies>
restrictedFrequencies	List of operating frequencies of the ionogram that were restricted for transmission	<restrictedFrequencies units=”MHz”> 1.1 1.3 1.4 1.5 1.7 1.8 1.9/>

A few examples of the **<systemDescription>** element can be given:

```
<systemDescription
startFrequency="0.5"
endFrequency="15.5"
frequencyStepping="linear"
frequencyStep="0.1"
startHeight="80"
endHeight="1300"
heightStepping="linear"
heightStep="2.5"
/>

< systemDescription
startFrequency="1.0"
endFrequency="12.0"
frequencyStepping="linear"
frequencyStep="0.1"
startHeight="80"
endHeight="1300"
```

```
heightStepping="linear"
heightStep="5"
>
<restrictedFrequencies units="MHz">
2.5 2.9 3.0 3.1 3.4 3.5 4.0 4.7 5.0 5.5 5.6 5.7 6.6 6.7 8.9 9.0 10.0 11.2 11.3 11.4
</restrictedFrequencies >
</systemDescription >

<systemDescription
frequencyStepping="tabulated"
startHeight="80"
endHeight="1300"
heightStepping="linear"
heightStep="2.5"
>
<frequencies units="MHz">1.0 1.2 1.6 2.0 2.5 2.75 3.0 4.5 5.0</frequencies>
</systemDescription >
```

2.3.2. <comments> - Operator's Message

This <comments> element contains text comments. The comments allow the scaler to give description of the scaling or the system that recorded the data and to store a free format text message.

2.3.3. <ionosphericCharacteristics>

The <ionosphericCharacteristics> element holds a number of **<item>** sub-elements, each containing one ionospheric characteristic. There are two categories of the **<item>** sub-element, *URSI-standard* and *user-specified*. Standard URSI characteristics (such as foF2) can be reported with less required attributes of the **<item>** element. Current list of standard URSI characteristics is given in Appendix A.

2.3.3.1. Standard URSI characteristics

For standard URSI characteristics, **<item>** element has two required attributes, **id** and **val** (Table 5-a).

Table 5-a. Required attributes of URSI-standard ionospheric characteristic		
Attribute name	**Description**	**Example**
id	URSI code of the characteristic, see Appendix A	id="00"
val	Value of the characteristic	val="3.4"

Other attributes can be provided for the **<item>** element holding a standard URSI characteristic (Table 5-b):

Table 5-b. Possible attributes of URSI-standard ionospheric characteristic		
Attribute name	**Description**	**Example**
name	Short name	name="foF2"
QL	Qualifying letter [see UAG-23 regulations]	QL="U"
DL	Descriptive letter [see UAG-23 regulations]	DL="F"
flag	Data description flag. For standard URSI characteristics can be set to "edited"	flag="edited"
units	Units [MHz, km, TECU]	units="MHz"
lowerUncertainty	lower uncertainty boundary	lowerUncertainty="-0.1"
upperUncertainty	upper uncertainty boundary	upperUncertainty="+0.1"
description	Description	description="F2 layer critical frequency"

It is recommended to provide **name** attribute for better readability of SAO 5.0 file.

The **flag** attribute can be set to "edited" only for manually scaled records (i.e., those with **SAORecord** attribute **scalerType** set to "manual") to indicate that human scaler entered new value of characteristic manually. If an autoscaled characteristic is left unchanged by the human operator, its value is assumed to be correct (verified), and its **flag** attribute is not provided. For autoscaled data records (i.e., those with **SAORecord** attribute **scalerType** set to "auto"), all reported characteristics are assumed autoscaled, and their **flag** attributes are not provided.

UAG-23 compliant **QL** and **DL** values do not have to be evaluated and reported. If it is customary not to evaluate **QL** and **DL** for characteristics, it is suggested to set **QL**="/" and **DL**=" " per URSI IIWG recommendations.

2.3.3.1. User-defined ionospheric characteristics

For non-standard URSI characteristics, **<item>** element has three required attributes, **name**, **val**, and **units** (Table 6-a).

Table 6-a. Required attributes of user-defined ionospheric characteristic		
Attribute name	**Description**	**Example**
name	Short name	name="foF2p"
val	Value of the characteristic	val="3.4"

It is important to use unique short names for user-defined characteristics to avoid confusion. A list of accepted user-defined characteristic names for use in SAOXML 5.0 files shall be maintained. Appendix B provides a table of suggested reserved names for ionospheric characteristics not in the URSI standard list.

Other attributes can be provided for the **<item>** element holding user-defined characteristics (Table 6-b).

Table 6-b. Possible attributes of user-defined ionospheric characteristic

Attribute name	Description	Example
QL	Qualifying letter [see UAG-23 regulations]	QL="U"
DL	Descriptive letter [see UAG-23 regulations]	DL="F"
flag	Data description flag. For user-defined characteristics can be set to “edited” or “predicted”	flag="predicted"
model	For predicted values, name and version of model	model=”URSI-88” or mode=”CCIR-82”
modelOptions	For predicted values, options of the model	modelOptions=”noStorm”
units	Units [MHz, km, TECU]	units="MHz"
lowerUncertainty	lower uncertainty boundary	lowerUncertainty=”-0.1”
upperUncertainty	upper uncertainty boundary	upperUncertainty=”+0.1”
description	Description	description=”F2 layer critical frequency”

Similar to the URSI-standard characteristics, **flag** attribute can be set to “edited” only for manually scaled records (i.e., those with **SAORecord** attribute **scalerType** set to ”manual”) to indicate that human scaler entered new value of characteristic manually. **flag** attribute is not provided for autoscaled characteristics and autoscaled characteristics left unchanged by the human scaler.

In addition to measurement data, SAO-XML can hold predicted characteristic values obtained using an ionospheric model. For such values, it is important to set **flag** attribute of the **<item>** element to “predicted”. Two additional attributes, **model** and **modelOptions**, can be used to describe used ionospheric model and its operating settings.

Example of <**ionosphericCharacteristics> element**:

```
<ionosphericCharacteristics>
<item name="foF2" id="00" val="3.5" QL="/" DL=" " flag=”edited” />
```

```
<item name="M(D)" id="03" val="2.7120712" QL="/" DL=" " flag="edited" />
<item name="MUF(D)" id="07" val="9.221042" QL="/" DL=" " flag="edited" />
<item name="fmin" id="42" val="0.9" flag="auto" units="MHz" />
<item name="foEs" id="30" val="2.8" flag="auto" />
<item name="foF2p" val="5.5" flag="predicted" model = "URSI-88"/>
</ionosphericCharacteristics>
```

2.2.4. <traces> – Ionogram Traces

The **traces** element has a list of **trace** elements inside, and one **dopplerTable** element.

<trace> – Ionogram Trace

The **trace** represents all data for one ionospheric layer scaled from an ionogram. The **trace** has a number of elements inside: **frequencies**, **heights**, **amplitudes**, and **dopplers**.

The **trace** element has two required attributes:

Table 7. Trace attributes

Attribute name	Description	Example
layer	Layer. Required.	layer="F2"
polarization	Polarization. If not reported, assumed “O” (ordinary)	polarization=”O”
numberOfPoints	Number of points for frequencies, heights, ... Required.	numberOfPoints="22"

<frequencies>

This element stores frequency values for each point of the trace. It has one attribute:

Table 8. Frequencies attributes

Attribute name	Description	Example
units	Units	units="MHz"

The character data for this element contain space-separated list of frequencies.

<heights>

This element represents all height data for one trace. It has one attribute:

Table 9. Heights attributes

Attribute name	Description	Example

units	Units	Units="km"

The character data for this element contain space-separated list of heights.

<amplitudes>

This element represents all amplitude data for one trace. It has one attribute:

Table 10. Amplitudes attributes		
Attribute name	**Description**	**Example**
units	Units	units="dB"

The character data for this element contain space-separated list of amplitudes.

<dopplers>

This element represents all Doppler data for one trace. There are two possibilities of representing Doppler frequency, “direct” and “translated”. In “direct” representation, the Doppler frequencies for each trace point are given in physical units, typically [Hz]. In “translated” representation values are given as Doppler Numbers that can be converted to [Hz] units using the **dopplerTable** element..

The <dopplers> element has one attribute:

Table 11. Dopplers attributes		
Attribute name	**Description**	**Example**
units	Units (“Hz” or “DopplerTable”)	units="Hz”
noValue	Value used to represent a missing value	

The character data for this element contain space-separated list of Dopplers.

<dopplerTable> - for *units=”DopplerTable”* only

This element establishes correspondence of Doppler Numbers given in the <dopplers> elements of the traces with the Doppler frequency shift in [Hz]. It has two elements inside:

- **<numbers>** to enlist possible Doppler Number values, except noValue specified as an attribute of the <dopplers> element, and
- **<frequencies>** to specify a sequence of floating point numbers that convert the Doppler Number into a Doppler frequency in Hertz. The <frequencies> element contains one attribute, **units**, to specify units of Doppler frequency.

Here’s an example of <traces> element in the SAOXML 5.0 format:

```
<traces>
<trace layer="F2" polarization=”O” numberOfPoints="9">
<frequencies units="MHz">3.3 3.4 3.5 3.6 3.7 3.8 3.9 4.0 4.1</frequencies>
```

```
<heights units="km">232.5 233.75 235.0 225.0 230.0 230.0 230.0 260.0
485.0</heights>
<amplitudes units="dB">106 0 106 106 102 102 102 102 106</amplitudes>
<dopplers noValue="99" units="Hz"> -.391 99 .391 -.391 .391 -.391 .391 .391 -
.391</dopplers>
</trace>
</traces>
```

2.2.5. <profiles> – True Height Profiles

This tag has a list of **profile** tags inside.

<profile> – true height profile

The <**profile>** represents all data for one true height ionospheric profile. It has a list of the attributes:

Table 13. Profile attributes		
Attribute name	**Description**	**Example**
type	Type	type="regular" ("auroral")
algorithm	Program name or "average" for averaging of profiles	algorithm="NH" ("average")
version	Version of program	version="4.21" if the algorithm attribute is a program
algorithmOptions	Free-form specification of the processing algorithm options	algorithmOptions="average over 30 sec"

The **type** attribute is used if more than one profile can be obtained using one set of measurements. For example, one ionogram can be used to calculate regular (vertical) profile and auroral E layer profile.

The <profile> element can store true height profile(s) in the tabulated form or as sets of coefficients. Correspondingly, it can have the following elements inside:

- **<tabulated> -** as table of values for a given range of true heights,
- <**coefficients> -** as coefficients of a compressed representation,

<tabulated > – tabulated presentation of Ne profile

This element can have a number of other elements inside, depending on the capability of algorithm:

- **plasmaFrequencies**,
- **heights**,
- **electronDensities**

Each of these elements of **<profile>** can have sub-elements inside to hold uncertainty of the provided values:

- **uncertainties** – for symmetric uncertainty intervals
- **lowerUncertainties**
- **upperUncertainties**

The **<tabulated>** element itself has the following list of the attributes:

Table 14. Frequencies attributes

Attribute name	Description	Example
numberOfPoints	Number of points for heights, frequencies, ...	numberOfPoints="86"

<plasmaFrequencies>

This element represents all data for one tabulated profile. It has a list of the attributes:

Table 15. Frequencies attributes

Attribute name	Description	Example
units	Units	units="MHz"

The character data for the tag contain space-separated list of plasma frequencies.

<heights>

This element represents all data for one tabulated profile. It has a list of the attributes:

Table 16. Heights attributes

Attribute name	Description	Example
units	Units	units="km"

The character data for the tag contain space-separated list of heights.

<electronDensities>

This element tag represents all data for one tabulated profile. It has a list of the attributes:

Table 17. Electron densities attributes

Attribute name	Description	Example
units	Units	units="cm -3"

The character data for the tag contain space-separated list of electron densities.

Reporting uncertainties of profile data

Each of the elements (<plasmaFrequencies>, <electronDensities>, and <heights>) can include sub-elements describing uncertainty of the reported values. This tag represents all data for maximum frequency uncertainty of profile. Two possible report forms of uncertainty can be used:

- **<uncertainties>** - for symmetric uncertainty intervals
- **<upperUncertainties>** and **<lowerUncertainties>** - for arbitrary uncertainty intervals

The uncertainty elements shall have one attribute, units:

Table 18. Attributes of uncertainty elements

Attribute name	Description	Example
units	Units	units="MHz"

The character data for the elements contain space-separated list of uncertainty values.

<coefficients> – representation of the profile as coefficients

<coefficients> element can contain three elements:

- **<chebyshev>** - as set of Chebyshev polynomial coefficients
- **<valley>** - as set of valley model parameters
- **<QPSegments>** - as set of quasiparabolic segments

<chebyshev> element represents true height coefficients for one of the layers: E, F1, or F2. If more than one ionospheric layer is present, more than one **<chebyshev>** element is stored. The coefficients for layer are calculated using the UMLCAR method. The **<chebyshev>** element has a list of attributes.

Table 19. <chebyshev> attributes

Attribute name	Description	Example
type	Type	Type="F2"
numberOfPoints	Number of true height coefficients	numberOfPoints="5"
startFreq	Start frequency	startFreq="0.545"
endFreq	End frequency	endFreq="3.5"
peakHeight	Peak height	peakHeight="294.8"
error	The fitting error in km/point.	error="0.0"

zhalfNm	Height at half peak electron density	zHalfNm="255.382"

The character data for the tag contain space-separated list of true height coefficients.

The **<valley>** element represents two parameters describing the width and depth of the valley region in the UMLCAR model. The tag has a list of attributes.

Table 20. Valley attributes

Attribute name	Description	Example
model	Valley model	model="ULCAR"
width	Width	width="102.1"
depth	Depth	depth="0.345"

<QPSegments>

An arbitrary number of parabolic segments may be fitted to the profile to approximate its shape.

This element has a list of **item** tags inside and some attributes:

Table 21. QPSegments attributes

attribute name	Description	Example
numberOfPoints	Number of quasi-parabolic segments	numberOfPoints="14"
earthRadius	Radius of Earth	earthRadius="6370.0"

The **item** tag represents the data for one quasi-parabolic segment.

Each segment can be expressed as: $f_N^2 = A/R^2 + B/R + C$, where

f_N - the plasma frequency in MHz,
A, B, and C - the parabolic coefficients
R – distance from the center of the Earth

Each **item** elementstores those values in the list of attributes:

Table 22. Item element for qpSegments

Attribute name	Description	Example
id	Ordered number of segment (0 to n)	id="0"
startHeight	Start height (R1)	startHeight="6460.011"
endHeight	End height (R2)	startHeight="6460.011"

A	A coefficient	A="-1.3025976E12"
B	B coefficient	B="4.02036288E8"
C	C coefficient	C="-31021.021"
error	The fitting error	error="0.00474"

Example:


```
<profiles>
<profile type="regular" algorithm="NH" version="4.21">
<tabulated numberOfPoints="48">
<plasmaFrequencies units="MHz">0.2 0.472 0.545 0.514 0.408 0.248 0.248 0.248
0.248 0.248 0.318 0.429 0.539 0.545 2.181 2.972 3.555 3.931 4.094 4.1 4.065 3.932
3.726 3.476 3.204 2.924 2.65 2.387 2.14 1.913 1.705 1.516 1.346 1.193 1.057 0.935
0.827 0.731 0.646 0.571 0.504 0.446 0.393 0.347 0.307 0.271 0.239
0.211</plasmaFrequencies>
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163.667 170.0 180.0 190.0 190.5 200.0 210.0 220.0 230.0 240.0 242.4 250.0 260.0
270.0 280.0 290.0 300.0 310.0 320.0 330.0 340.0 350.0 360.0 370.0 380.0 390.0
400.0 410.0 420.0 430.0 440.0 450.0 460.0 470.0 480.0 490.0 500.0 510.0
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191000.0 207000.0 208000.0 205000.0 191000.0 172000.0 150000.0 127000.0
106000.0 86900.0 70500.0 56700.0 45300.0 36000.0 28400.0 22400.0 17600.0
13800.0 10800.0 8470.0 6620.0 5170.0 4040.0 3150.0 2460.0 1920.0 1490.0 1160.0
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</tabulated>
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</profile>
</profiles>
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Reinisch, B.W., and X. Huang, Deducing Topside Profiles and Total Electron Content from Bottomside Ionograms, *Adv. Space Res.*, 27, 1, 23-30, 2001.

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Last Modified: June 12, 2005

APPENDIX A.

Standard URSI Codes for commonly reported ionospheric characteristics

GROUP	URSI name	URSI code	UAG23 ref.#	DEFINITION
F2	foF2	**00**	1.11	The ordinary wave critical frequency of the highest stratification in the F region
	fxF2	**01**	1.11	The extraordinary wave critical frequency
	fzF2	**02**	1.11	The z-mode wave critical frequency
	M3000F2	**03**	1.50	The maximum usable frequency at a defined distance divided by the critical frequency of that layer
	h'F2	**04**	1.33	The minimum virtual height of the ordinary wave trace for the highest stable stratification in the F region
	hpF2	**05**	1.41	The virtual height of the ordinary wave mode at the frequency given by 0.834 of foF2 (or other 7.34)
	h'Ox	**06**	1.39	The virtual height of the x trace at foF2
	MUF3000F2	**07**	1.5C	The standard transmission curve for 3000 km
	hc	**08**	1.42	The height of the maximum obtained by fitting a theoretical h'F curve for the parabola of best fit to the observed ordinary wave trace near foF2 and correcting for underlying ionization
	qc	**09**	7.34	Scale height
F1	foF1	**10**	1.13	The ordinary wave F1 critical frequency
	fxF1	**11**	1.13	The extraordinary wave F1 critical frequency
		12		
	M3000F1	**13**	1.50	See Code 03
	h'F1	**14**	1.30	The minimum virtual height of reflection at a point where the trace is horizontal
		15		
	h'F	**16**	1.32	The minimum virtual height of the ordinary wave trace taken as a whole
	MUF3000F1	**17**	1.5C	See Code 07
		18		
		19		
E	foE	**20**	1.14	The ordinary wave critical frequency of the lowest thick layer which causes a discontinuity
		21		

	foE2	**22**	1.16	The critical frequency of an occulting thick layer which sometimes appears between the normal E and F1 layers
	foEa	**23**		The critical frequency of night time auroral E layer
	h'E	**24**	1.34	The minimum virtual height of the normal E layer trace
		25		
	h'E2	**26**	1.36	The minimum virtual height of the E2 layer trace
	h'Ea	**27**		The minimum virtual height of the night time auroral E layer trace
		28		
		29		
Es	foEs	**30**	1.17	The highest ordinary wave frequency at which a mainly continuous Es trace is observed
	fxEs	**31**	1.17	The highest extraordinary wave frequency at which a mainly continuous Es trace is observed
	fbEs	**32**	1.18	The blanketing frequency of the Es layer
	ftEs	**33**		Top frequency Es any mode.
	h'Es	**34**	1.35	The minimum height of the trace used to give foEs
		35		
	Type Es	**36**	7.26	A characterization of the shape of the Es trace
		37		
		38		
		39		
Other 1	foF1.5	**40**	1.12	The ordinary wave critical frequency of the intermediate stratification between F1 and F2
		41		
	fmin	**42**	1.19	The lowest frequency at which echo traces are observed on the ionogram
	M3000F1.5	**43**	1.50	See Code O3
	h'F1.5	**44**	1.38	The minimum virtual height of the ordinary wave trace between foF1 and foF1.5 (equals h'F2 7.34)
		45		
		46		
	fm2	**47**	1.14	The minimum frequency of the second order trace
	hm	**48**	7.34	The height of the maximum density of the F2 layer calculated by the Titheridge method
	fm2	**47**	1.25	The minimum frequency of the third order trace
Spread F, Oblique	foI	**50**	1.26	The top ordinary wave frequency of spread F traces
	fxI	**51**	1.21	The top frequency of spread F traces

	fmI	**52**	1.23	The lowest frequency of spread F traces
	M3000I	**53**	1.50	See Code 03
	h'I	**54**	1.37	The minimum slant range of the spread F traces
	foP	**55**		Highest ordinary wave critical frequency of F region patch trace
	h'P	**56**		Minimum virtual height of the trace used to determine foP
	dfs	**57**	1.22	The frequency spread of the scatter pattern
		58	7.34	Frequency range of spread fxI-foF2
		59		
N(h) Titheridge	fh'F2	**60**	7.34	The frequency at which h'F2 is measured
	fh'F	**61**	7.34	The frequency at which h'F is measured
		62		
	h'mF1	**63**	7.34	The maximum virtual height in the o-mode F1 cusp
	h1	**64**	7.34	True height at f1 Titheridge method
	h2	**65**	7.34	True height at f2 Titheridge method
	h3	**66**	7.34	True height at f3 Titheridge method
	h4	**67**	7.34	True height at f4 Titheridge method
	h5	**68**	7.34	True height at f5 Titheridge method
	H	**69**	7.34	Effective scale height at hmF2 Titheridge method
T.E.C.	I2000	**70**	7.34	Ionospheric electron content Faraday technique
	I	**71**	7.34	Total electron content to geostationary satellite
	I1000	**72**	7.34	Ionospheric electron content to height 1000 km using Reinisch-Huang [2001] technique
		73		
		74		
		75		
		76		
		77		
		78		
	T	**79**	7.34	Total sub-peak content Titheridge method
Other 2	FMINF	**80**		Minimum frequency of F trace (50 kHz increments) Equals fbEs when E present
	FMINE	**81**		Minimum frequency of E trace (50 kHz increments).
	HOM	**82**		Parabolic E layer peak height
	yE	**83**		Parabolic E layer semi-thickness
	QF	**84**		Average range spread of F trace

	QE	**85**		Average range spread of E trace
	FF	**86**		Frequency spread between fxF2 and fxI
	FE	**87**		As FF but considered beyond foE
	fMUF3000	**88**		MUF(D)/obliquity factor
	h'MUF3000	**89**		Virtual height at fMUF
N(h)	zmE	**90**		Peak height E layer
	zmF1	**91**		Peak height F1 layer
	zmF2	**92**		Peak height F2 layer
	zhalfNm	**93**		True height at half peak electron density
	yF2	**94**		Parabolic F2 layer semi-thickness
	yF1	**95**		Parabolic F1 layer semi-thickness
		96		
		97		
		98		
		99		
IRI	B0	**D0**		IRI Thickness parameter
	B1	**D1**		IRI Profile Shape parameter
	D1	**D2**		IRI Profile Shape parameter, F1 layer
		D3		
		D4		
		D5		
		D6		
		D7		
		D8		
		D9		

APPENDIX B.

User-defined names for ionospheric characteristics not in the URSI standard repository

Table B-1. User-defined ionospheric characteristics for SAO XML 5.0

Name	Description	Units
foF2p	F2 layer ordinary wave critical frequency, predicted	MHz
foF1p	F1 layer ordinary wave critical frequency, predicted	MHz
foEp	F1 layer ordinary wave critical frequency, predicted	MHz
fminEs	Minimum frequency of Es layer	MHz
scaleHpeak	Scale height at hmF2, Chapman model	km
foF0.5	The ordinary wave critical frequency of F0.5 stratification between E and F layers	MHz
h'F0.5	The minimum virtual height of F0.5 layer trace	km
foF3	The ordinary wave critical frequency of F3 layer above foF2	MHz
h'F3	The minimum virtual height of F3 layer trace	km