

Ionospheric Sounding: An Archival Odyssey

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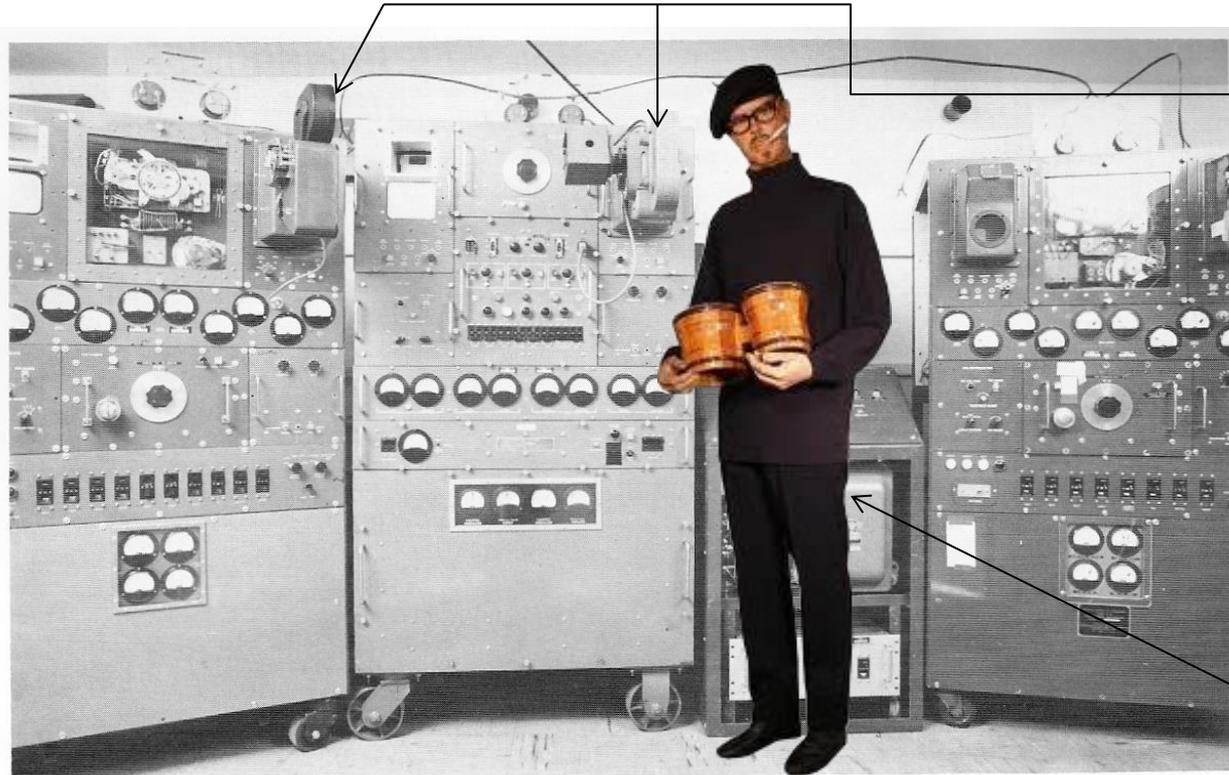
USU Space Weather Center
and
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Ionospheric Sounding: A Long History

- The first soundings in the 1920s established the existence of an “electrified” or E layer at around 100 km altitude
- Additional layers were named alphabetically when they were detected: D below, F above
- Soundings became strategically important in World War II but were tedious manual measurements
- Automated sounders were developed after WW II, recording data on photographic film
- Film archives going back to the late 1940s exist at the World Data Centers (WDCs)

NBS C-Series Ionosondes: 1950s and 1960s



35mm film
reel recorders



1950s grad
student

Probably for the first time ever, NBS Model C-2, C-3, and C-4 ionosondes appeared in one photograph. The occasion was in July 1977 at the Boulder Laboratories where the units had come in for refurbishing between deployment at field sites (see adjacent photo and caption on Boulder Ionosphere Station). These ionosondes have had long service by the Environmental Data Service operation of NOAA (National Oceanic and Atmospheric Administration).

From left to right are: Model C-3, Model C-4, and Model C-2 ionosondes. Voltage regulator for the C-2 is to its left, Model C-4 ionosondes were used worldwide at the many recording stations of the IGY program during 1957-1958.

Ionospheric Sounding Data and Metadata

Sounding data

- Echo strength and time delay (“virtual height”) at each frequency (typically 2-20 MHz)
- Modern sounders: polarization, angle of arrival, etc.

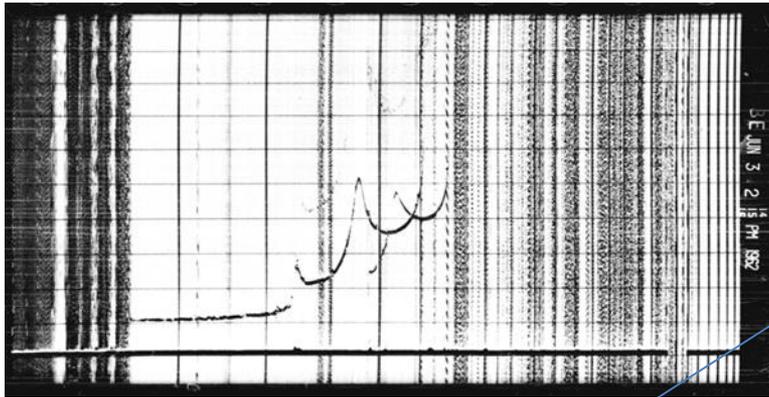
Metadata

- Time, date, site location; geophysical conditions
- Instrument settings, operator comments

Post-processed data

- Scaled values: critical frequencies, layer heights
- Electron density profile (EDP)

Ionospheric Sounding Data and Metadata



Data from the archives

Sounder data on 35mm film

Metadata included on 35mm film

Processed data (from Davies, 1969)

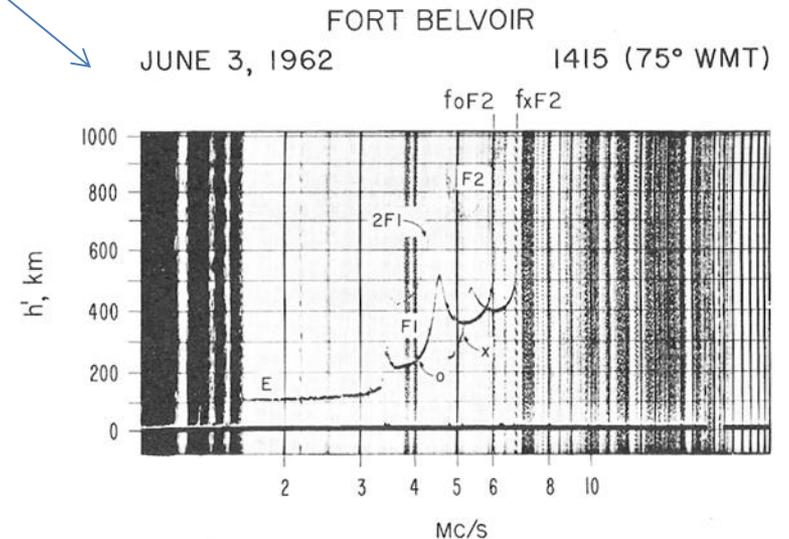


FIGURE 3.7. Ionogram on a quiet summer day in middle latitudes.

Why Old Ionograms Matter

- Film ionograms were typically taken at 15-minute intervals, though some periods had higher cadence
- Available hourly database values do not reveal the phenomena visible in the ionograms:
 - Sporadic E occurrence, descending layers
 - Tides, TIDs, other wave signatures
 - Ionospheric storm effects
- Modern analysis can provide an electron density profile for most of these ionograms
- Thus a 50-60 year ionospheric history is potentially available for many locations around the world

The Digital Dark Ages?

- Sounding data began to be recorded on magnetic tape in the 1970s
- For archiving purposes, that was not a good thing:
 - Magnetic tape has a limited shelf life compared to film
 - Not many functioning tape readers still exist
 - Data files were in proprietary formats
 - Resolution was reduced due to storage limitations
- WDC holdings are mostly scaled values for modern times with some proprietary binary data sets
- We can do a more thorough sounding analysis for the 1950s than for the 1980s (?!)

Standard Archiving Output (SAO)

- The SAO specification was developed in 1987
- Stores metadata, processed data (scaled parameters, EDP), and limited original trace data
- FORTRAN card-image format, not human-friendly
- Biased towards Digisonde/ARTIST sounder outputs
- Excerpt:

```
4 3 19 40 0 8372 0372372372 0 0 0 0 0 54 0 54 54 54 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 32 32 32 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 4
1.338 66.593 39.993254.631
```

```
DYNASONDE /BD840, CU Boulder CO, INFILE =
BD840_20130812005
MORE COMPLETE INFORMATION MAY BE FOUND AT http://www.ngdc.noaa.gov/stp/IONO/Dynasonde/AA20130810322200505
6.9639999.0009999.0009999.000 2.6359999.000 4.340 2.635 3.332
7.4009999.0009999.0009999.0009999.000 104.344
```

SAO XML

- SAO parameters are re-packaged with XML tags
- More flexible than SAO, but more difficult for traditional processing software to deal with
- Files are larger than SAO but still small (<20kB typ.)

```
<?xml version="1.0"?>
<SAORecordList>
<SAORecord FormatVersion="5.0" StartTimeUTC="2012-01-28 -028 20:00:00.000"
URSIcode="EG931" StationName="Eglin AFB" GeoLatitude="30.5" GeoLongitude="273.5"
Source="Ionosonde" SourceType="DPS-4D" ScalerType="auto">
<SystemInfo UMLStationID="084">
<FrequencyStepping StartFrequency="1.0" StopFrequency="15.0">
<LinearStepping Step="0.025" Units="MHz" />
</FrequencyStepping>
<RestrictedFrequencyList Num="12" Units="MHz" >
<LowerLimitList> 2.175 2.500 3.000 4.125 5.000 5.675 6.200 8.350 10.000 11.550 13.350
14.975 </LowerLimitList>
<UpperLimitList> 2.200 2.500 3.025 4.125 5.000 5.700 6.225 8.375 10.150 11.575 13.425
14.975 </UpperLimitList>
</RestrictedFrequencyList>
... and so on for another 200 lines or so
```

SAO XML

- XML could allow the entire ionogram to be packaged with the metadata and processed data
- This isn't being done because the files would be inconveniently large for operational use (e.g. GAIM)
- Additional information such as confidence limits are usually included in XML
- We have encountered some problems with vendor-supplied parsing software:
 - Long records were silently truncated
 - Missing value attributes were not handled consistently

NetCDF

- The VIPIR (new Dynasonde) packages ionograms in netCDF files
- NetCDF files include detailed metadata and may include processed data with the ionogram
- Easily read/written via standard libraries
- No roundoff/significant figure problems from conversion to text
- Not human-readable, but “ncdump” utility can produce listings of any or all stored quantities
- A little bulky for operational use

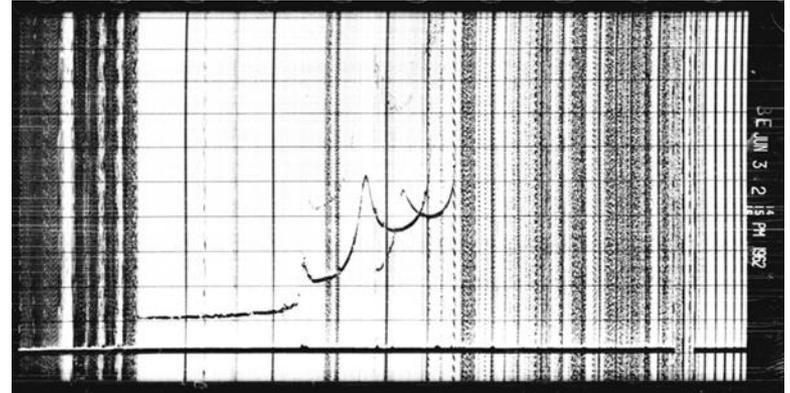
Image Metadata

- How about updating the historical archives?
- Modern image formats (GIF, PNG, JPEG) allow metadata to be embedded in the image
- Limited access to metadata via image editors such as GIMP
- More complete access via command line tools such as ImageMagick, e.g.:

```
$ mogrify -comment "WA938 1962/06/03 1915 UT" \  
    WA938_196206031915.png
```

Image Metadata

- ImageMagick can set and retrieve arbitrary metadata keyword/value pairs
- ImageMagick metadata display:



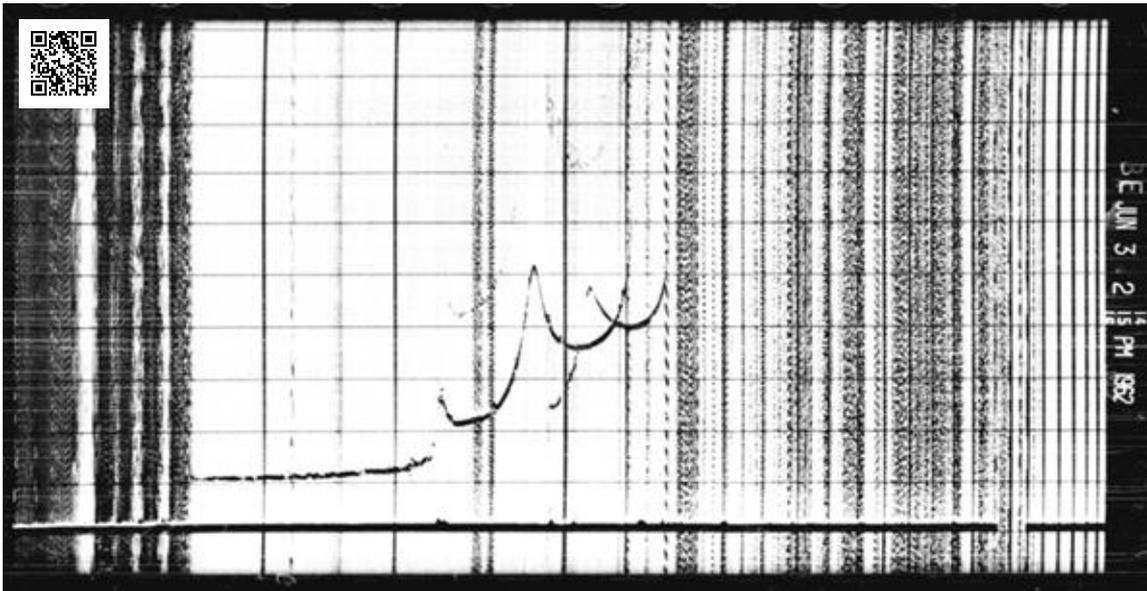
```
$ identify -format "%[*]" WA938_196206031915.png
comment=WA938 1962/06/03 1915 UT
date:create=2013-03-24T15:47:47-06:00
date:modify=2013-03-24T15:47:47-06:00
foE=3.4 MHz
foF1=4.6 MHz
foF2=6.1 MHz
hmE=104 km
hmF1=210 km
hmF2=360 km
```

Image Metadata: Links for Viewers

- Embedded metadata is invisible to casual viewers
- Quick Recognition (QR) or “zebra crossing” (zxing) codes may be used for linking smart phone/tablet viewers to resources
- Several formats are defined: see <http://zxing.appspot.com/generator>
- Three sizes available:
 - Small 120x120 pixels (basic information like URL)
 - Medium 230x230 pixels (more descriptive)
 - Large 350x350 pixels (full business card metadata)

Image Metadata: Links for Viewers

- QR codes are useful for taking viewers of publications or presentations back to the source
- Good idea for data plots on public web sites that may “migrate”



Summary

- Simple ionogram images on film have survived better than early digital attempts (magnetic tape)
- SAO and SAO XML are useful for operational users (e.g., GAIM) but not really archival
- NetCDF is a good archival format at present...will it survive 20 years? 50 years?
- Images (scanned or generated) are useful to humans and can have detailed metadata embedded
- No single solution satisfies all needs

Questions to Consider

- Will your data survive the Digital Dark Ages?
- Are we building data sets for future long-term studies or just throw-away data for the project duration?
- Do your data sets provide a suitable built-in provenance for future users? Do you point to web pages that may not exist a few years hence?
- What data formats will be useful in decades from now? Plain text? XML? NetCDF? Images with metadata?

References

- **Standard Archiving Output (SAO)**

<http://ulcar.uml.edu/~iag/SAO-4.3.htm>

<http://ulcar.uml.edu/SAOXML/>

- **NetCDF**

<http://www.unidata.ucar.edu/software/netcdf/>

<http://www.unidata.ucar.edu/software/netcdf/docs/BestPractices.html>

- **ImageMagick**

<http://www.imagemagick.org/script/index.php>

- **Quick Recognition Codes**

<http://zxing.appspot.com/generator>