Converting from Film to Digital Ionograms - not as easy as it looks

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During May 2-3-2002, Ray Conkright, Terry Bullett and Phil Wilkinson met in Boulder and discussed a number of topics related to INAG. Below are a few comments from a discussion we had on the conversion from film based ionosondes to digital ionosondes. When digital ionograms first came available we all thought data handling would become much easier and that has not really been the case. We felt this needed to be acknowledged more widely.

During the gradual transition from film records several stages were passed, almost unnoticed. Probably, most networks did the same thing.

In the case of ionosonde station networks we were familiar with, initially, a person who may or may not have been responsible for scaling and releasing the data prepared from film-based ionosondes operated the ionospheric station. This person was responsible for a wide range of duties, including being the unofficial historian. Manual scaling methods usually developed alongside the many eccentricities of both the ionosonde equipment and the person operating it. The ultimate authority in all matters ionospheric became UAG-23A by the early 1970s. Globally, manual scalers sought to produce similar, if not identical results that could be easily shared and recognised by others. This was not at all easy to establish and maintain and different methods for achieving these ends are reported on in the INAG Bulletins that can be found on this Website.

Gradually, manual methods were replaced by semi-automatic methods, but still there was a high degree of participation in producing data. Error checking and a firm belief in a *correct* interpretation of ionograms lead, we believe, to reliable data being produced from ionospheric stations. The early digital methods sometimes introduced their own special errors, but generally they streamlined ionogram processing, carrying out the tedious work of registering an ionogram, while leaving the interpretation to the manual scaler, or data processor. The main aim of semi-automatic scaling was to speed up the rate at which a manual scaler could make decisions about ionograms. However, the film-based ionograms limited how far these methods could be extended. By the time the IPS-42 ionosonde was commonly used around the world, in the late 1970s and early 1980s, the main source of missing data at many ionosonde stations was failure to process the film correctly. Typical errors, surprisingly, were: film jamming; wrong focus and brilliance setting; and mistakes in film developing. The ionosondes were by then, and now, very reliable hardware compared with their ancestors.

The next step, to record digital ionograms, was taken between, roughly, 1985 and 1995 at many ionosonde networks around the world. At IPS, John Titheridge's digion hardware and software assisted us make the very convenient transition to preparing digital ionograms from a film-based ionosonde. The semi-manual scaling software was converted to work with digital images and it appeared we had made a great leap forwards in managing our stations. At the Air Force Research Laboratory (AFRL), the recording of ionogram data electronically was the standard for the early Digisondes, and the various recording methods were also the main source of data loss. Large, expensive and fragile 7 and 9 track tape drives were about the only option, and now these media face obsolesce. Much effort has gone into updating the data recording hardware at the ionosonde, recognizing that most solutions are significantly better than their predecessor, but also possess dramatic limitations. Following this moving target of data storage technology has also produced an historical database that is fragmented onto a variety of physical formats. Either option of keeping antique recording equipment or converting all older media to the latest format is a significant effort. At IPS, although we had different media, and different problems, we shared the common experience that these were the main cause of the loss of data.

As automation increased, the number of people associated with each ionospheric station reduced. Inevitably, local knowledge was lost. The big jump came when digital records replaced film records, but this was largely unnoticed. Taking IPS, in Australia, as an example, as the conversion to digital records was made, we also moved towards managing our stations from a central site, transferring digital records by telephone and more recently by the internet. Many sites globally were automated about the same time and we believe it would be most unusual now for a single person to spend more than a small fraction of their working life looking after an ionospheric station.

Associated with this change, automatic scaling software replaced the majority of aging ionogram scalers. Computer scaling can gracefully produce poor quality data. The manual scaler is the standard against which automatic scaling methods are judged. In fact, few ionosonde network managers would be happy to pay a scaler who consistently produced the errors found in automatic scaling. Irrespective of the apparent contradiction, people never scale as arbitrarily as a computer program, but nor do they scale anywhere near as fast, or work 24-hours a day. There are many traps created by these computer-generated data sets and it seems that data users have little regard for or knowledge of the risks. In fact, their acceptance of substandard outputs has made it difficult to be either be critical of computer scaling or raise funds to improve what is now available. This is ironic, because the same people would be far more circumspect about the output of a physical model, yet a computer-scaling program is the same type of software solution. More correctly, the output of a computer ionogram scaling program should be called *output* not *data*. On the credit side, for some locations there is now a ready supply of real-time ionospheric data and, while we are rightly critical of automatic scaling methods, there is a high degree of utility to be found in these outputs. Perhaps some of these contradictions can be explained by the fact that properly scaled ionosonde data are very accurate compared to other ionosphere sensing techniques such as GPS, occultation or optics. The accuracy of even poorly autoscaled ionosonde data is commensurate with what is routinely obtained from these other techniques. Users of data are often unaware of the relative accuracy differences.

Data errors due to mismanagement of film records were more obvious and therefore easier to diagnose. Modern digital records can hide a variety of errors that are all but invisible. For instance, decisions made to replace recognised faulty outputs with climatology estimates may make the results more useful to some groups, but there is a long term penalty if this is not clearly flagged and, even more important, these flags are easily recognised by later researchers *who use them*. Since many researchers can already ignore the qualifying letters E and D, and perhaps all qualifiers, we feel sure they will easily ignore the less obvious climatology intrusions.

It now appears that local knowledge of ionogram content has been seriously eroded and is replaced by a fair degree of confidence in the operating software together with a belief that the raw ionograms can always be re-scaled if there are severe software errors. While manual re-scaling is possible, in reality it is often performed sporadically to support specific studies, leading to inconsistencies in the long-term record. Re-application of automatic scaling software to archived ionograms can produce more consistent output, but this is rarely accomplished.

However, probably the most significant outcome of the move to digital ionograms has been that fewer data are available and we now have a more fragmented global network of ionosondes. While different film-based ionosondes all produced roughly the same type of ionograms that could all be readily reviewed on film, each different digital ionosonde produces a different ionogram. It is no small task to build up and support a comprehensive library of different ionogram interrogation programs. Consequently, data that are available cannot be shared easily. Added to this fragmentation factor, there are less routine ionosondes reporting data. It is unclear why this is the case, but the data from different ionosonde stations available in World Data Centres is reducing markedly.

We felt it would be useful to share these observations more widely in the hope that as we all come to realise the changes we have lived through, we may start to realise that not all of these changes have been beneficial. That said, it is still clear that a well-run digital ionosonde network can be a great deal more valuable and responsive than the older film-based networks. We don't dispute that. However, we feel there are aspects of the earlier networks that have been lost: local knowledge; facility in scaling ionogram records; and a more direct interest in and oversight of the data produced rather than complete reliance on computer methods. Somehow, as we reap the benefits of the digital ionosonde network, we must also replace, or recover, some of the old values.