Simple Mapping Project (SMP) Interim Report

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SUMMARY

This report provides an update of the accomplishments, current activities, and future plans for the Simple Mapping Project (SMP).

The radio sky at 1420.406 MHz has been mapped (in total intensity) from 00 to 24 h Right Ascension (RA) and +30 to +50° Declination with an angular resolution of ~1° using the Upper Dish at the Table Mountain Field Site (TMFS). Frequency-disperse data over 0.8 MHz with ~15 kHz resolution have been collected. These data have all been collected over the period January through June 2006.

The raw and processed data are stored in both plain-text format and as viewable images on a web-accessible host facilitating their retrieval and processing with user-defined methods.

No adverse events occurred with the operation of the Upper Dish at Table Mountain during this data collection period using the "unattended stationary" operating mode. The highest wind speed observed during this period was ~60 MPH using a purpose-built, on-line anemometer installed on-site. The greatest deviation from zenith was 10° during this period.

This work was accomplished with the radio reception equipment provided by Rodney Howe, the technical assistance of Jamie Riggs, and the long-term efforts of the many members of the Deep Space Exploration Society (DSES).

BACKGROUND

The Simple Mapping Project (SMP) was initiated by the DSES to accomplish several specific goals. The first was to exercise and validate DSES-built and installed hardware and software attached to the Upper Dish including an integrated, purpose-built feed structure, multi-purpose RF down converter, computer-controlled radio receiver, on-line data server, data processing software, and separate site co-located, on-line anemometer. Second, was to develop practical observational experience using those systems in making extended-time and precision scientific measurements. This included dependable project management tools, efficient search algorithm development, and data reduction and validation schema. The third goal was to create a sky survey in the Hydrogen I (HI) spectral line (Rest Frequency: 1420.406 MHz), continuum and frequency-disperse, to determine the experimental limitations of the created systems and prepare for other scientific projects. These measurements have been performed and published previously and comparison can be made with the current work for its validation. It is also useful to carry out extended, systematic observations for the purposes of establishing instrumental baselines, such as minimum detectable signal level, measurement stability, reproducibility, and accuracy to identify strengths and weakness of the systems in place.

The overall strategy is to perform meridian drift scans with the dish elevation (and azimuth as necessary) varied systematically to point it at various declinations. This is consistent with the state of readiness of component systems including the radio systems, dish position control system, and dish-safety-oriented anemometric measurement system. This type of observing scheme could be run continuously with time taken out for shorter length, more immediate observations and thereby make good use of "dish time". Beginning the observations with the dish pointed close to zenith provides the inherently safest situation with regard to the local winds. With time and experience it would be reasonable to advance further from zenith with the expectation that additional control systems would be brought on-line that could stow the dish remotely or automatically dependent on local weather conditions.

EXPERIMENTAL METHODS

A prime focus feed was developed specifically for this work consisting of a TE_{10} waveguide (single polarization), connected to a conical flared section, and terminated with a circular aperture designed for a –10dB tapered illumination of the main dish. A low noise amplifier (rated 0.4dB NF and ~30dB gain at 1420 MHz) was also located at the feed. Low-loss 1.25" helical-coax conveyed the signals into T-22 where two-stage down converter (severely modified Radio Astronomy Systems) translated 1420.406 to a 70.010 MHz IF. The IF was distributed with a multi-port splitter to various instruments including a sweep-tuned, diode-detected receiver (Radio Astronomy Systems) with internal microprocessor and serial communication port.

The serial output from the receiver was fed into a Pentium II-class desktop computer, internally named "itchy" for convenience, running the Linux operating system (Red Hat v8.0). A pair of purpose-built programs, written in Perl, controlled the receiver, sucked in the acquired data, created and organized hourly text data files, and purged those files after a specified expiration date. The Apache web server delivered those files to the outside world. The computer was assigned a fixed IP address inside the Institute for Telecommunications Sciences (ITS) domain and firewall. A separate computer ("rex") of similar composition located outside the ITS firewall mirrored the data for general use. This scheme served to minimize the trans-firewall traffic without limiting access to the data.

The mirrored text data was processed automatically each hour to create a preliminary frequency vs. Right Ascension map for each hour. At the end of each day (UTC) the hourly data were aggregated into a single daily text file and corresponding map as a PNG file using a pair of purpose-built programs on rex written in Perl. These daily maps were manually inspected for obvious flaws and either discarded or passed on for further processing. Periodically, the daily text files were combined into a single text file and turned into a master map using a manually executed Perl program.

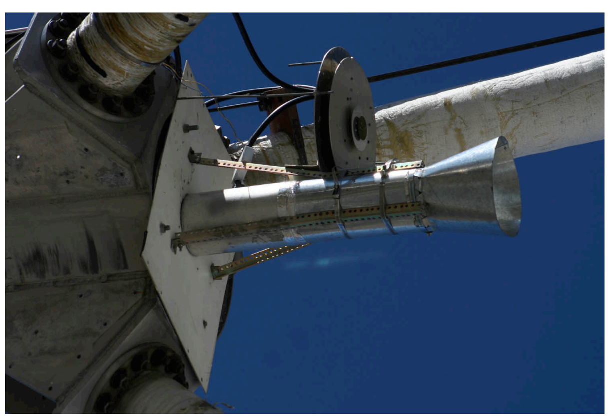

Figure 1. 1420 MHz feed and low noise preamplifier mounted at focal point of Upper Dish. The $\lambda/2$ waveguide, running left to right, is terminated in a flared cone designed to provide a 10dB tapered illumination of the main dish.

Dish pointing was performed manually by direct control of the direction motors. A three-cup anemometer was installed on-site and interfaced to a second computer ("morgie") configured as described above. The wind speed data was continuously available on-line as described above and periodically monitored through a web browser interface.

EXPERIMENTAL RESULTS

The integrated intensity map from the collected data can be seen in Figure 1. The bright orange and yellow regions of high signal intensity correspond to two "arms" of the Milky Way. The corresponding visible map with the imaged region identified can be seen in Figure 2. The more intense region around +42° Declination and 20 h RA corresponds to the well-known active region in the constellation Casseopia; the less intense region from 3 to 6 h RA corresponds to the constellation Auriga. The insets to this figure show the frequency-disperse spectra of bright areas in these regions. The frequencies observed correspond to Doppler-shifts of the basic spectral line at its so-called Rest Frequency.

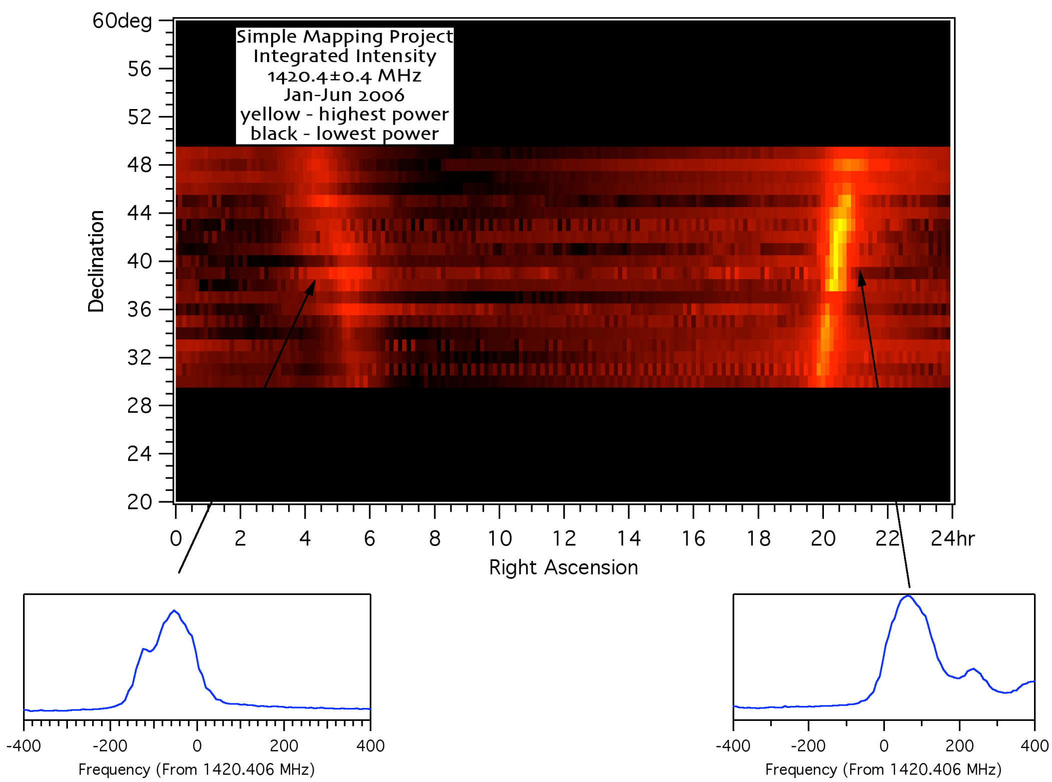

Figure 2. Continuum map of region from +30 to +50° declination presented using false color scale (black, red, orange, yellow signifies increasing intensity). Insets show frequency spectra at indicated locations.

These Doppler-shifts are interpreted as direct measures of the approach and recession speeds of the emitting clouds relative to the receiving antenna. The overall observed frequency is a complicated function of the compound mechanics of the antenna's orbit around the earth's polar axis, the earth's orbit around the sun, and the sun's motion relative to the observed emitter. These various classical motions can be isolated by

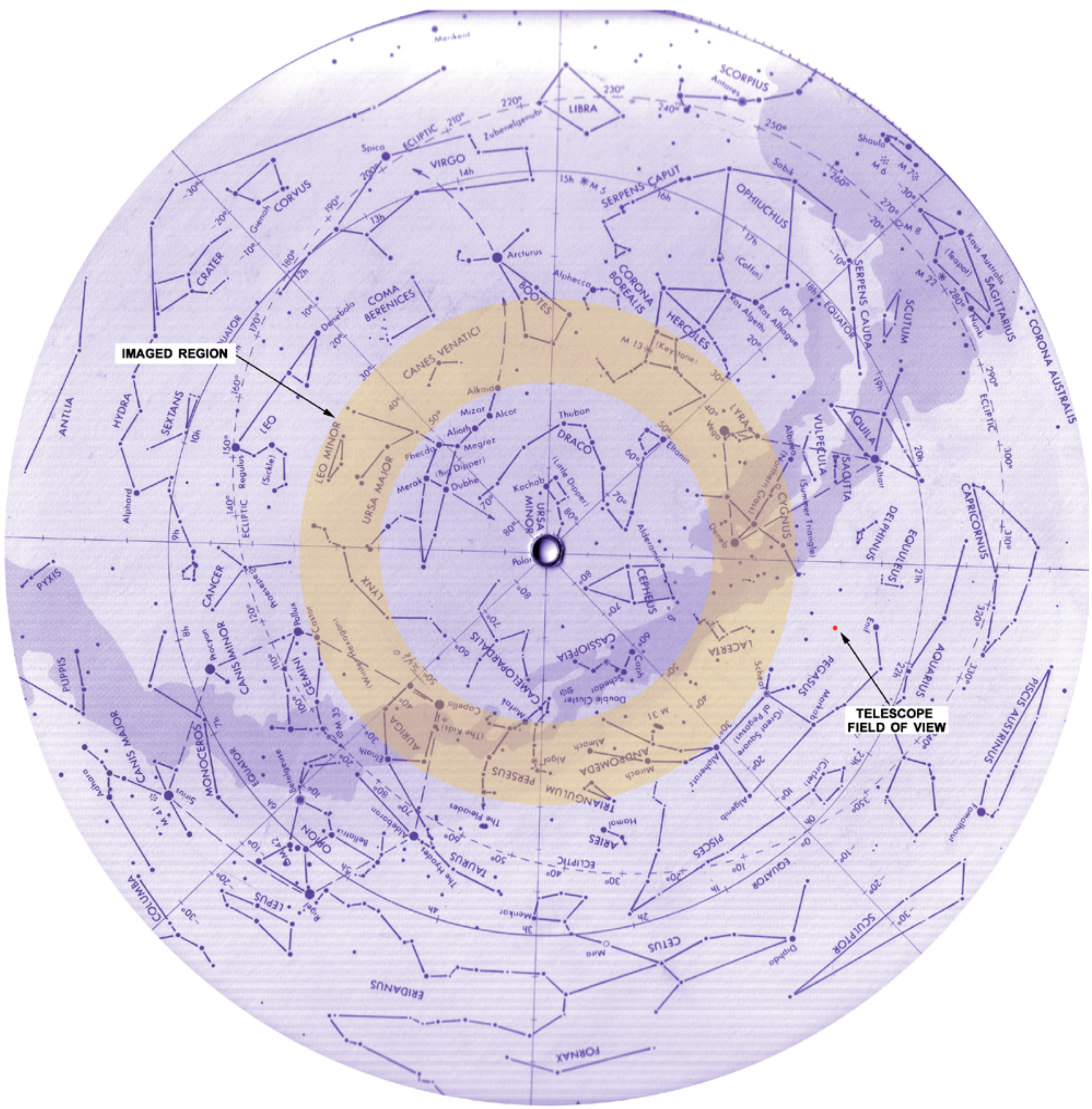

Figure 3. Celestial planisphere showing star fields and Milky Way locations superimposed with imaged region. The small red dot in the lower right quadrant shows the antenna's beam width at the frequency used.

multiple observations at strategic times in the component cycles and subsequent deconvolution. Such measurements are outside the scope of this document but have been successfully used by others together with model building to accomplish the difficult task of determining the structure of the Milky Way (our galaxy) from the inside out.

The entire data collection can be seen in a different format in Figure 3 where the three panels correspond, from top to bottom, of the Declination, Right Ascension, and the measured intensity. The Declination trajectory was selected to inoculate the data from certain common types of systematic pointing error. The Right Ascension trajectory is

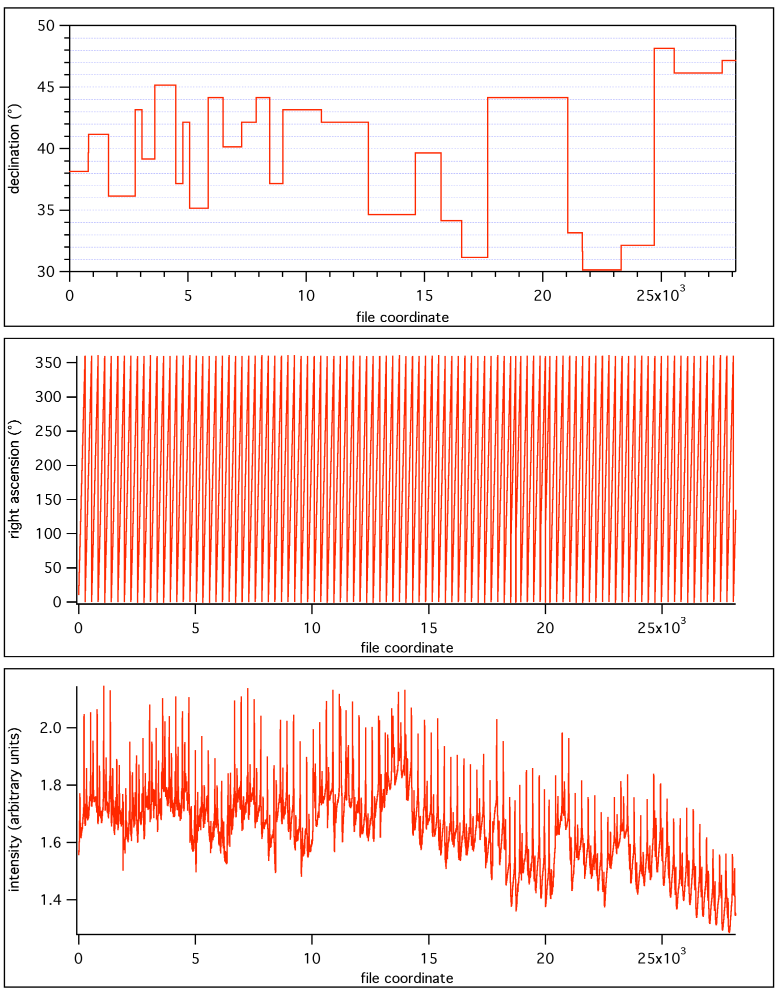

Figure 4. Display of entire continuum data record (at bottom) together with corresponding Declination (at top) and Right Ascension (in middle). The abscissa, labeled "file coordinate" corresponds to the point number in the data record.

characteristic of a meridian drift scan where the RA linearly increases with time and wraps around at local Sidereal midnight. The intensity data shows the overall periodicity of the data and the trend in the daily minimum and maximum.

Two individual data records are presented in Figure 4. Each record spans several sidereal days. The upper record suffers from high frequency (many per sidereal day) periodic variations of unknown origin while the lower panel is lacking this artifact and the diurnal periodicity is apparent.

Figure 5 shows a complete sidereal day's worth of data as an image with a false-color, hot metal (deep blue, medium blue, red, orange, yellow, and white representing increasing intensity, respectively) with observed frequency along the abscissa and Right

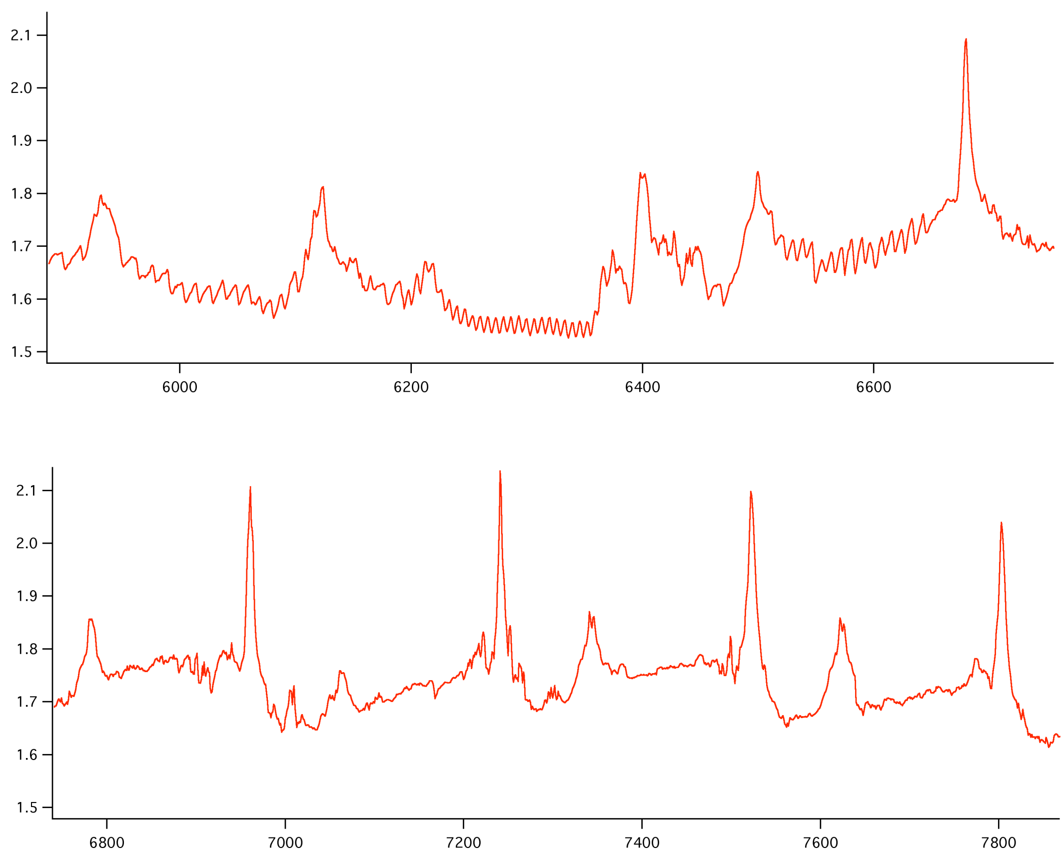

Figure 5. Individual, multi-day (sidereal) intensity data records. The upper panel shows data suffering from a short period periodic variation of unknown origin while the lower panel shows a record free from this artifact and clearly displaying the diurnal periodicity.

Ascension along the ordinate, both in arbitrary units. The two different arms of the Milky Way can be seen as the separate high intensity islands that have distinctly different frequency spectra. A thin line of deep blue intensity connects the two islands indicating that this particular scan skirts the edge of the Milky Way (see Figure 2).

A systematic drift in the receiver gain and/or noise floor has been observed in the five months of data collection (see Figure 3). This can be seen in the stacked plot of individual slices. Beginning with file coordinate of ~15,000 the minimum and maximum daily continuum intensity have decreased steadily. Without additional instrumentation it is not possible to assign this drift to any particular or more than one component. Systematic declination patterns are being included in current and future data collection to capture replicate values and attempt post-acquisition correction. Alternate data processing schemes are currently being evaluated. The inclusion of additional calibration hardware into the early stages of the receiver path is also being examined.

The region between ~13,000 to ~14,000 file coordinate shows a significant increase in overall level. This is attributed to the presence of several inches of snow on the surface of the dish that represents a relatively warm (in terms of radio emission) source when compared to the clean, reflecting, metal surface.

Figure 6 shows some early attempts at post-processing continuum data to remove the

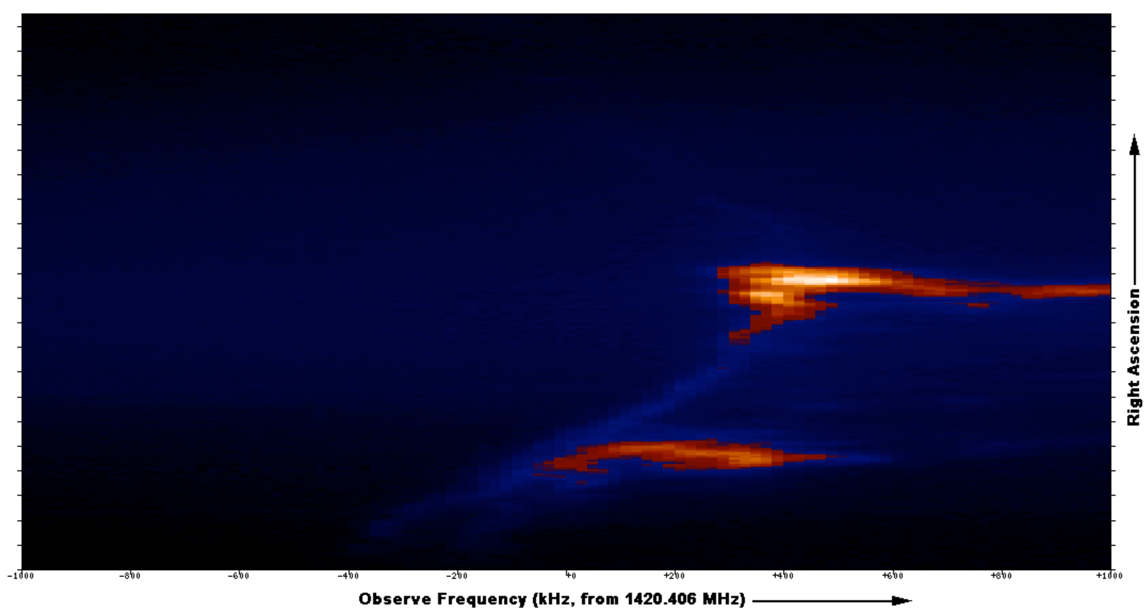

Figure 6. One sidereal day's worth of data presented as a false-color hot metal intensity image with observed frequency along the abscissa and Right Ascension along the ordinate.

systematic drift in intensity minima and maxima. Each (sidereal) day's data was examined and the minimum and maximum were extracted. A comparison is shown where either the daily minima and/or the maxima were forced to the same value. There is no theoretical justification for this approach but it was performed to evaluate its effects on the data. It is expected that the systematic and periodic inclusion of reference scans, for example, +40° Declination, will serve as a common reference to identify systematic, long-term drift in the intensity data and provide standard values with which to correct the intervening data. This will occur at the expense of additional observing time.

CONCLUSIONS

SMP has begun and been in operation for five months. Data has been collected which permits evaluation of many experimental parameters including radiometry and positioning accuracy, antenna feed performance, data collection, processing, and display systems, dish safety, and operational readiness. A preliminary map of the radio sky at the Hydrogen I spectral line and spanning +30 to +50° Declination has been made. Deficiencies in the observed data have been identified and work begun to address them.

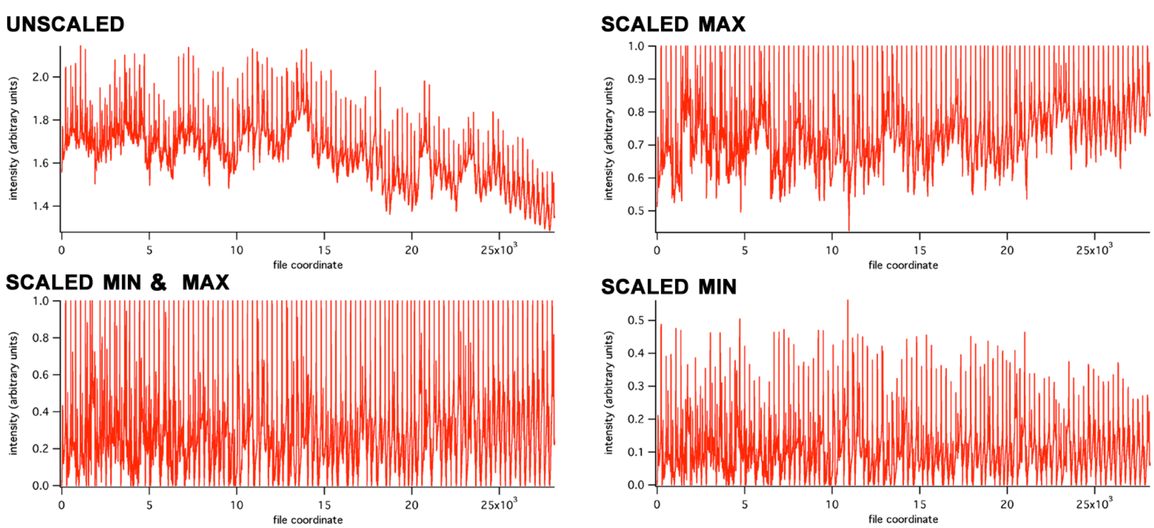

Figure 7. Results of several schemes targeted at removal of systematic drift using post-acquisition processing. Each (sidereal) day's wroth of data was examined and the minimum and maximum were extracted. The panels show the effect in the raw data of forcing all the minima and/or maxima to be the same values.

ACKNOWLEDGEMENTS

The work described here was performed using the Upper Dish at the Table Mountain Field Site made available to the DSES through a Cooperative Research and Development Agreement with the Institute of Telecommunications Sciences (ITS), the research and engineering branch of the National Telecommunications and Information Administration (NTIA), a part of the U.S. Department of Commerce (DOC). Some radio reception equipment was kindly provided by Rodney Howe. Some radio and data acquisition equipment was built by DSES members. The work of Jamie Riggs in organizing and executing the declination and observing schedules and the long-term efforts of many members of the DSES in bringing the facility into its current operational state are gratefully acknowledged.