Improving the Australian Tropical Cyclone Database: Extension of the GMS Satellite Digital Image Archive

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Introduction

Japan's GMS series of satellites were, and MTSAT-1R currently is, located at a nominal sub-satellite of 0°S, 140°E in geostationary orbit to retrieve imagery for meteorological purposes. This suite of satellites has been active since 14 July 1977 when the first of five GMS satellites was launched. The Bureau did not start receiving imagery from GMS until late 1977 and it was not until early in 1978 that imagery was received regularly. The Bureau now has an archive of meteorological satellite data extending over 30 years. The best use of this data can be achieved by converting it all to a single format, which can be utilised within computer-based analysis systems. As the Bureau uses McIDAS as its primary visualisation and image-processing tool it was decided that all historical data should be converted to a format that would allow it to be utilised within McIDAS. The image data format within McIDAS is called AREA format, so all of the historical imagery needed to be converted to AREA file format. A search of relevant literature was undertaken to ascertain if others had attempted to resurrect scanned imagery in this manner. While no evidence of this was apparent it did reveal that the Japanese Meteorological Agency's (JMA) Meteorological Satellite Centre (MSC) had a significant part of their archive in a digital format (JMA,1980). This format is known as archived Visible Infrared Spin Scan Radiometer (VISSR) and will be referred to herein as VISSR format. These archive data comprise much of the IR imagery that the Bureau only has as scanned tiff files. Converting the VISSR data to AREA format is far more desirable as the quality of

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digital data does not degrade over time. This chapter concentrates on the processes involved in converting scanned imagery to AREA format as it will be needed to fill in the data gap and the conversion of VISSR to AREA in comparison is a trivial matter.

The GMS Satellite

The GMS series of satellites were spin stabilised and deployed into geostationary orbit with a nominal sub-satellite point (SSP) on the equator at 140° East longitude. The imaging system comprised both an IR and visible scanning array which imaged the Earth as its optical system spun past on each revolution, with a scanning mirror stepping the field of view each revolution. The visible imaging system of GMS1 had four detectors imaging each scan line therefore having four times the resolution of IR imagery. The visible imagery had a resolution of 1.25 km with a spectral bandpass of 0.55–0.75 micrometres and the IR imagery had 5 km resolution with a spectral bandpass of 10.5–12.5 micrometres. The appearance of GMS1 and an illustration of the scanning method are shown in Fig. 1 (BOM 1979).

The Reception, Distribution, and Display Method

GMS used the Data Utilisation system, which consisted of the following segments:

- A master control station in Japan that received the data from the satellite, reprocessed it to VISSR format, which was in turn archived to tape, reprocessed it to

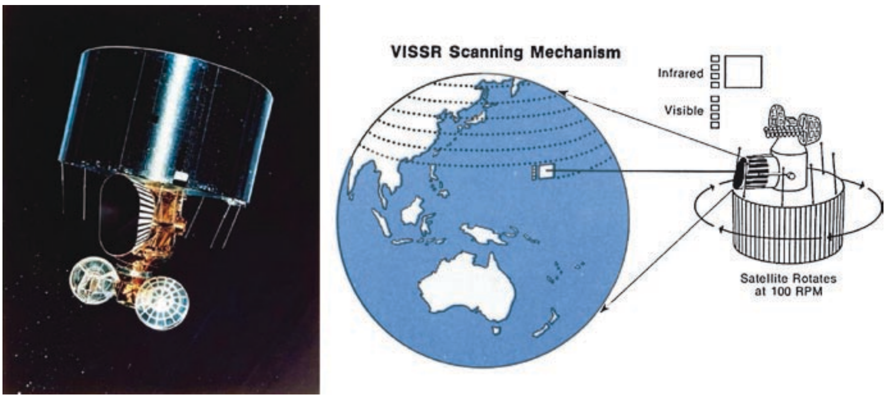


Fig. 1 Artists impression of GMS1 and an illustration of the spin scan method used to image the Earth

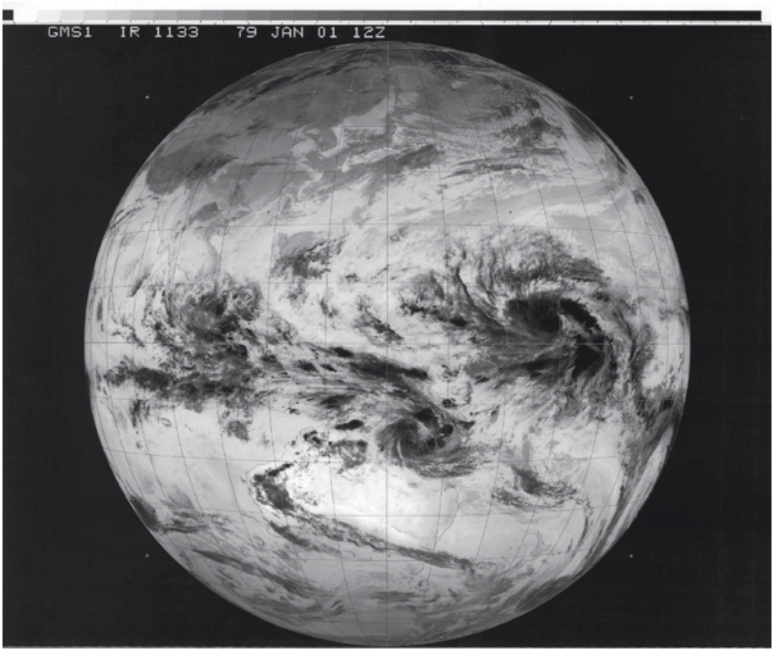


Fig. 2 HR-FAX image displayed here at low quality. This is the GMS 1 IR image for 1133 UTC on January 1, 1979

High Resolution facsimile format (HR-FAX) and transmitted it back to the satellite.

- The Satellite itself transmitted the analogue HR-FAX signal to the Western Pacific region.
- A receiving station complete with laser facsimile printing equipment.

The HR-FAX image produced by this process was printed to a 2’ × 2’ photo-negative from which contact prints were made and disseminated to forecasters. An example of an HR-FAX image can be seen in Fig. 2.

This image had coastlines and navigation lines spaced 10° apart imbedded in the image when it was reprocessed. The image also contains, a calibration bar at the very top, image type and date stamped into picture. These images were the Bureaus GMS archive.

From Photo-Negative to AREA Format

Converting the photo-negatives to AREA format involved removing the actual image of the globe from the photo-negative scan, retrieving calibration information by utilising the scale bar and navigating the image. The following will explain the calibration and navigation procedures.

Retrieving Calibration Information

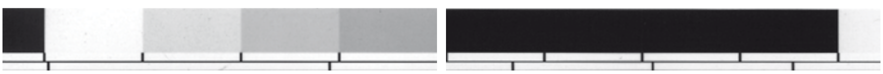
The scale bar consists of 32 rectangular boxes, each of which represents a single 6-bit greyscale level and a specific temperature range.

Figure 3 shows sections of the scale bar with the left-hand end representing warmer temperatures, starting at approximately 300 K with each successive box representing a temperature, which is 1.75 K cooler. It is obvious here that the right-hand side of the bar contains boxes which are indistinguishable from one another.

As the final McIDAS AREA format requires a temperature scale with 8-bit values some interpolation is required. The photo-negatives were scanned as 8-bit tiff files so that the entire image, including the scale bar had already been converted to 8-bit values. Each of the 32 boxes now had an 8-bit greyscale representing the same temperature scale. The new greyscale to temperature curve was constructed by interpolating between 32 known values to give 256 temperatures for corresponding greyscale values. This gave a scale that had four times the resolution of the original scale. This temperature scale was then written into the new AREA file header.

Navigating the Images

In order to successfully track any feature within a series of satellite images, the images must be consistently navigated or georeferenced. The navigation on the scanned images would have originally been done by visual interpolation of the position of a feature between the navigation lines imprinted into the image. McIDAS uses a navigation header, which contains parameters for orbital and attitudinal parameters



(a) Left hand end of the scale bar (b) Right hand end of the scale bar

Fig. 3 Two sections of the scale bar from Fig. 1. The LHS represents the warm end of the scale, the RHS the cold end of the scale. (**a**) Left hand end of the scale bar. (**b**) Right hand end of the scale bar to navigate each GMS image through computation. Each pixel should correspond to a unique position on the Earth and have a unique latitude and longitude position. If the scanned images are to be converted to McIDAS AREA format then there must be a navigation header created for each image. The first issue is then to establish known points within the scanned imagery that have a defined latitude and longitude. The most obvious approach is to use the intersections of the navigation lines. These are drawn at 10° intervals for both latitude and longitude with the primary lines at the equator (0°S) and 140°E. Identifying the intersections is simple with the naked eye but can be problematic with an automated process.

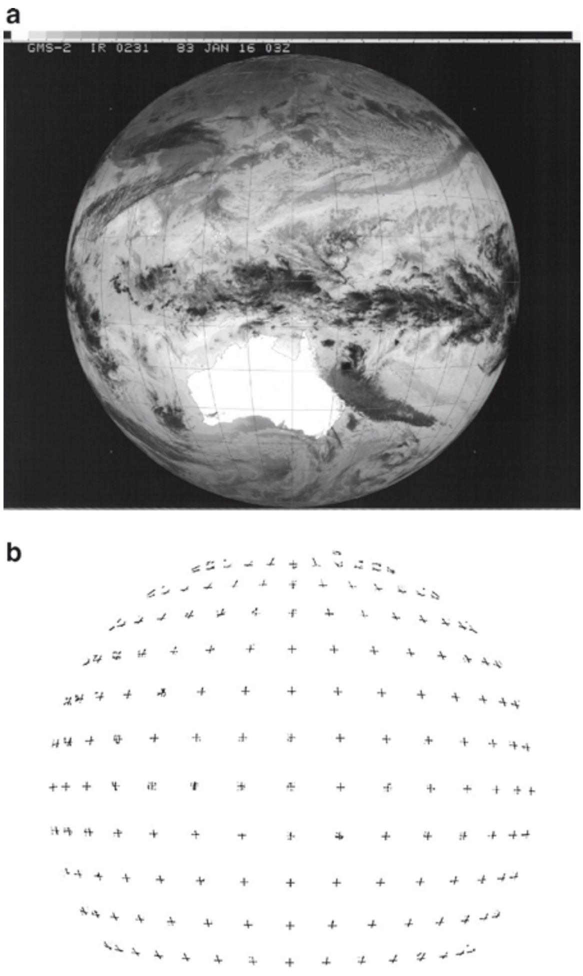


Fig. 4 The contrast enhancement technique is applied only where an intersection is likely. The exact centre pixel of each intersection is then easy to identify with an automated process. This method almost completely removes the background image

The first step is to extract the required part of image from the scanned photo-negative (a process which will not be discussed herein). Step 2 requires highlighting the navigation lines so that the intersection can be more readily found with automated processes. A contrast enhancement technique from Pham and Maeder (1989) is utilised. This highlights pixels that have a high level of contrast from the surrounding pixels. The process, however, is very slow and hence a method to target the areas where the intersection should be and adjust for orientation of the navigation lines was developed. The contrast enhancement process was only run in these locations. The result of this process is shown in Fig. 4.

When complete, the contrast enhancement allows a known latitude and longitude to be assigned to pixel positions within the image as the intersections are now easy to identify. These registered positions can then be used to apply navigation to each pixel in the image. As the ultimate goal is to convert the scanned image data into McIDAS AREA files, a method was found that used McIDAS in the navigation process, which effectively removed a final conversion step. The process also made use of an implementation of the Levenberg-Marquardt algorithm (LMA) for curve fitting called MPFIT (Markwardt 2008) as part of an optimisation process. This process started with a donor McIDAS AREA file with its own calibration and navigation header sections. The navigation header was altered so that it was reasonably close to fitting the scanned image. The alteration was done based on knowledge gained while converting archived VISSR files to McIDAS AREA format and experimentation. Using the donor AREA file, a set of pixel positions for known latitude and longitudes was produced utilising commands within McIDAS. This

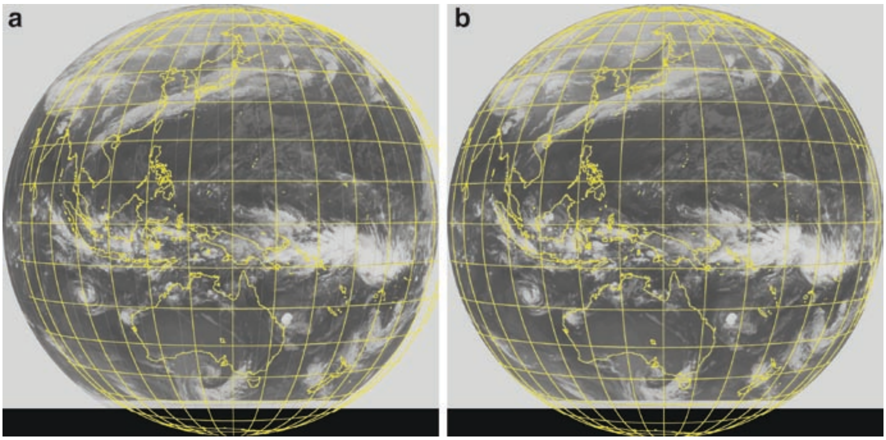


Fig. 5 Screen output from McIDAS of a poor guess (**a**) and the result of this after the optimisation process (**b**)

gave two sets of registered pixel positions that were compared. The comparison was done by calculating the absolute distance between the two sets of pixel values at the same latitude/longitude positions. The optimisation process utilised a Levenberg-Markwardt algorithm (LMA) to alter parameters within the navigation header until the absolute distance comparison was minimised.

An example of this output is shown in Fig. 5. Image (a) shows an exaggerated bad guess where the initial parameters are chosen to be far from the best estimate. Image (b) shows the final result after the optimisation process was run through and altered the navigation parameters to achieve the best fit.

Known Issues and Problems

This project is not complete but a method has been developed to calibrate, navigate, and convert the Bureau scanned GMS archive to McIDAS AREA format. There are still issues to resolve and improvements to be made. The major calibration issue is the lack of contrast at the cold end of the scale bar. In some cases the last 4–6 scale bar boxes cannot be separated by their greyscale value. This makes it very difficult to produce a sensible calibration curve. This lack of resolution at the cold end of the temperature scale may hinder some TC reanalysis techniques such as the Dvorak technique. The biggest issue with the navigation of the images is the manner in which they were scanned. If an image was not placed correctly within the scanning apparatus then it is possible that the image has an artificial tilt introduced. Presently, no method has been considered to identify and then to correct for any induced tilt.

Conclusion

While this remains a work in progress it appears that a viable technique to convert scanned HR-FAX imagery for quantitative computer-based analysis to digital McIDAS AREA has been developed. Utilising data derived from the imagery, knowledge provided by various user manuals and McIDAS algorithms, conversion of the Bureau of Meteorology GMS-scanned imagery to AREA files is now possible. A significant part of the GMS IR archive in VISSR format has been obtained from JMA extending over the period from December 1978 to January 1989 with a sizable gap of missing data. The 14 months of missing data (from November 1979 to March 1981) will have to be filled using the conversion processes outlined above. When this project is complete, the Bureau will have 30 years of continuous satellite data covering the Western Pacific including the Australian region. When available, this 30-year satellite meteorological record will allow analysis of longer-term trends and provide the ability to utilise modern techniques to re-analyse, in particular, hazardous weather phenomena such as tropical cyclones.

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