EVALUATION OF THE UTILITY OF THE DISASTER MONITORING CONSTELLATION IN SUPPORT OF EARTH OBSERVATION APPLICATIONS

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ABSTRACT

The Disaster Monitoring Constellation (DMC) is an international micro-satellite constellation, currently capable of providing 32m spatial-resolution, tri-band, multi-spectral imagery over a 600km swath of any location in the world, within a 24-hour period. These satellites are soon to be augmented by further spacecraft, each carrying an additional 4m resolution panchromatic imager.

The spectral band selection for the DMC spacecraft has been deliberately chosen to be equivalent to that of the SPOT HRV multi-spectral imagers and bands 2, 3 and 4 of the LANDSAT Thematic Mapper. Previous satellites have used these bands in a multitude of application areas from land-use classification, crop yield assessments and vegetation stress monitoring, to burn scar mapping, urban growth modeling and insect threat assessment. However, the unique combination of high-swath, medium-spatial resolution and high-temporal resolution of the DMC opens up a new range of application areas: The system is found to be ideal for monitoring the development of fire risk over very short temporal scales using a combination of scene-derived vegetation indices, classification maps and external thermal data. Additionally, the DMC data provides a unique resource for higher resolution mapping of the fire effects (burn scars), without the need of extensive “stitching” of images. Similarly, timely data on flooding can be obtained, and changes monitored on a daily basis. Already the DMC satellites have provided image data for humanitarian relief efforts in Darfur and following the recent Asian tsunami.

INTRODUCTION

The Surrey (UK) conceived Disaster Monitoring Constellation (DMC) brings together an international partnership of micro-satellite-based missions to serve both national Earth Observation (EO) needs, and to achieve a unique system for global disaster monitoring. The constellation was initiated with the launch of ALSAT-1 (Algeria) in November 2002, followed by the launch of BILSAT (Turkey), NigeriaSat-1 (Nigeria)
and UK-DMC (UK) in September 2003. By 2004, the constellation had been fully established with the satellites in their correct orbital positions in their shared 686 km altitude, 10.30 am local-time at ascending node (LTAN) Sun-synchronous orbit.

All four spacecraft carry tri-band (near-infra-red, red, green) imagers that match LANDSAT bands 2, 3 and 4. BILSAT has an additional blue channel, and uses area-array CCDs, whereas ALSAT-1, NigeriaSat-1 and UK-DMC each carry a common 6-lens push-broom linear CCD-array-based imager, capable of imaging a line of 20,000 pixels over a 660 km swath. Images may be acquired in flexible formats using basic 2500 x 2500 pixel “tiles” (approximately equivalent to 80 km x 80 km). Up to 24 such tiles (in each of the spectral bands) can be supported in a single image-take every orbit. The image data are stored on-board the satellites in solid-state data recorders, and can be downloaded via an 8 Mbps S-band link to any of the DMC ground-stations worldwide. Up to 48 image tiles per band can be stored on-board each spacecraft at any time [1].

Each DMC-partner operates its own spacecraft through its own ground station. However, the scheduling of images is coordinated across the constellation via the Mission Planning System (MPS) software. This manages the demands for images within such constraints as power limits, data storage, downlink opportunities, etc. Various levels of processing can be requested ranging from “raw” (image data only band registered), “L1R” (radiometrically corrected) to “L1G” (radiometrically and geometrically corrected) [2]. Image requests are now handled through a central coordinating organization – DMC International Imaging (DMCII).

DMC CALIBRATION

At the outset, it was recognized that radiometric calibration would be key to providing a long-term reliable data source for a range of applications. To this end, the DMC imagers were each radiometrically calibrated prior to launch at the Surrey Space Centre using a 20” (50.8 cm) diameter integrating sphere, illuminated by a 150 W quartz-halogen lamp. The radiant flux was measured by a calibrated photometer.

Plans were also made for the regular re-calibration of the instruments in-orbit, recognizing that instruments do change their characteristics in the space environment. The method chosen was similar to that used for the AVHRR instrument on the NOAA satellites – that is to use a mixture of absolute calibrations using ground targets measured by ground instruments simultaneously with imaging during an overpass, and by imaging flat-field targets, such as the Antarctic ice sheets, for relative inter-calibration.

The first absolute calibration was carried out in July 2004 in conjunction with the Remote Sensing Group (RSG) at the University of Arizona, using a test site in Railroad Valley, Nevada, USA. Atmospheric characterization data were collected at the same time as the surface reflectance measurements. This site has also been used for calibration of SPOT, LANDSAT, MODIS and other spacecraft. Relative inter-calibration between the DMC spacecraft instruments is carried out by a regular campaign of imaging the East Antarctic ice sheet, or the Greenland ice sheets, depending upon the season. Dark images of deep space and the mid-Pacific ocean at night are also taken to establish black-level offsets.
The advantage of this method is that the absolute calibration provides a tie point that allows us to go back in time using the relative calibrations to update the calibration coefficients for each spacecraft. We can use the tie point as a start point for future observations and note relative changes from that point on, providing a baseline for future calibrations. Thus, all the DMC image data will be radiometrically “identical” and therefore interchangeable for applications that require precise radiometry and daily revisit.

Radiometric calibration has proven to be effective at “de-striping” the images (Fig.1) and to allow ratiometric parameters, such as normalized difference vegetation indices (NDVIs) to be derived. Such data has been used to direct food-relief efforts in Darfur.

DMCII employs an automated software system for generation of “L1G” (Georectified) image products from the DMC satellites. This system was developed by Spacmetric AB (Germany) specifically for the DMC.

“L1R” (radiometrically corrected) images are input in TIFF format, and the output “L1G” images are rectified to the UTM projection (north- or swath-oriented) in GeoTIFF format. The system uses an explicit geometric model with the following components: image model (sub-sectioning and mosaic parameters); sensor model (alignment angles between banks, CCD array linearity, and inter-band registration); body model (misalignment between the sensor coordinate frame and the attitude frame); attitude model (attitude variation model parameters); flight model (ephemeris accuracy); astronomic model (earth rotation) and geodetic model (earth shape).

Geometrically and radiometrically corrected imagery has allowed direct comparison between DMC images and those from other spacecraft, such as SPOT and LANDSAT (Fig.2).
DMC APPLICATION AND EVALUATION

The daily revisit and flexible image format of the DMC proved invaluable in obtaining timely image data following the October 2003 floods in Vietnam (Fig. 3). Erosion due to flooding/hydrology was also monitored in Nigeria and Morocco. Following the 2004 Asian tsunami, the DMC was able to quickly image the coastlines of the affected countries and map out the damage caused.

![Fig. 3: Overlay of DMC Flood Water Images for the Tra Khuc River Basin](image)

Fire monitoring and automatic fire scar evaluation has also proven to be viable, with particularly impressive results following forest fires in Alaska, Algeria and Nigeria. For the Alaskan fire, we estimated a burn-scar area of 5,007 acres based on DMC imagery. This was in good agreement with the US Geological Survey estimate of 5,600 acres based on ground samples.

DMC image data was compared to that from SPOT 5 and LANDSAT to determine the feasibility of automatic land-use classification for agriculture and urbanisation studies. It was found that the DMC images gave the same results as LANDSAT, but, as might be expected, the SPOT 5 data could more easily detect smaller vegetated areas and could distinguish more subtle variations in vegetation due to its higher spatial resolution and additional short-wave-infra-red channels. None-the-less DMC data has already found application in agricultural monitoring, urban development mapping, geological and hydrological mapping.

CONCLUSIONS

The DMC satellites have already proven their utility in providing imagery for disaster relief. However, by calibrating the imagers, the unique combination of wide swath, medium resolution and daily re-visit has found many other useful applications. DMC image data quality has been found to compare favourably with that of LANDSAT, enabling the DMC data to be used in many pre-existing applications, as well as in new areas.

REFERENCES