Development of a MODIS Data Reception System for Regional Environmental Monitoring in Southeast Asia

LIM Kim Hwa, KWOH Leong Keong, LIEW Soo Chin
Centre for Remote Imaging, Sensing & Processing (CRISP)
National University of Singaopore, SOC-1, Level 2, Lower Kent Ridge Road, Singapore 119260
Tel : (65) - 874 4411, Fax: (65) – 775 7717, Email : crslimkh@nus.edu.sg or crsklk@nus.edu.sg

Abstract:

CRISP has been preparing to receive MODIS data in Direct Broadcast (DB) mode since 1999. One of the purposes of receiving MODIS DB is to enable us to carry out near real-time environmental monitoring. Several equipment have been purchased and integrated into CRISP's existing antenna system. The MODIS DB is recorded on the direct ingest system (disk arrays). A reformatting program, with the option of performing Reed Solomon error correction, has been written to convert the recorded signal data into MODIS level-0 formatted data. This level-0 data is then fed into a level 1 processing program. The level 1 processing is done by IMAPP software by the University of Wisconsin. A georectification code, which is able to eliminate "bowtie" effect, has been developed to georectify the level1b products onto a map. Another development is the generation of browse images directly from the level-0 data. The generated browsed images together with its meta files are sent to a web-based Catalogue Browse System. The acquisition, archival, browse image generation and catalogue updating are performed automatically. Once a level1b data is produced, it is georectified and a hotspot image is generated from it. The entire process, from data acquiring to hotspot generation, is performed automatically and can be done in about one hour time. This has enabled CRISP to perform near real-time fire monitoring of the entire Southeast Asia.

I. INTRODUCTION

MODIS is one of the instruments on board the TERRA satellite. One of the unique features of the MODIS instrument is its ability to broadcast data from the satellite to anyone within line-of-sight. Any ground stations equipped with a 3m or larger X-band reception system and the necessary hardware and software can receive the data. The direct broadcasting mode is particularly useful for regional ground stations to perform near-real-time environmental monitoring.

CRISP has carried out daily forest fire monitoring using SPOT imagery since 1997. The high-resolution SPOT images were used to detect individual fires and to determine their nature in terms of the size of the smoke plumes, their locations and the landcover of the affected area. The shortcoming of using SPOT imagery for fire monitoring is that it cannot give an overview of the fires situations of the entire Southeast Asia. The conventional tool for monitoring the entire region is the NOAA-AVHRR system. However, due to its poor calibration and low saturation temperature, fires (or hotspots) detected by NOAA-AVHRR always have false alarms. MODIS has 16 thermal bands and some of these bands have a saturation level of 500K. Therefore, MODIS is well suited for hotspots detection.

CRISP has been preparing to receive MODIS direct broadcast data since the TERRA satellite was launched in December 1999. An ALCATEL OMNISAT demodulator multi-mission capability was purchased and integrated into our existing antenna system. With our direct ingest system, we are able to receive and process the MODIS direct broadcast data into higher level immediately.

II. LEVEL-0 PROCESSING

The direct broadcast MODIS data is acquired by our 6m X-band antenna, the signals are fed into the Alcatel OMNISAT demodulator. The Alcatel OMNISAT demodulator has a built-in vertebi decoder. The resulting output is recorded on our existing Datron direct ingest system. A reformatting software program, with the option of performing Reed Solomon error correction, was developed to convert the recorded signal into MODIS level-0 formatted data. The RS error correction option has enabled us to filter off almost all the corrupted packets by employing the strategy of discarding all the packets with unsuccessful RS corrections. This reformatted level-0 data is packaged in Production Data Sets (PDS), and is basically ready for subsequent level-1 processing.

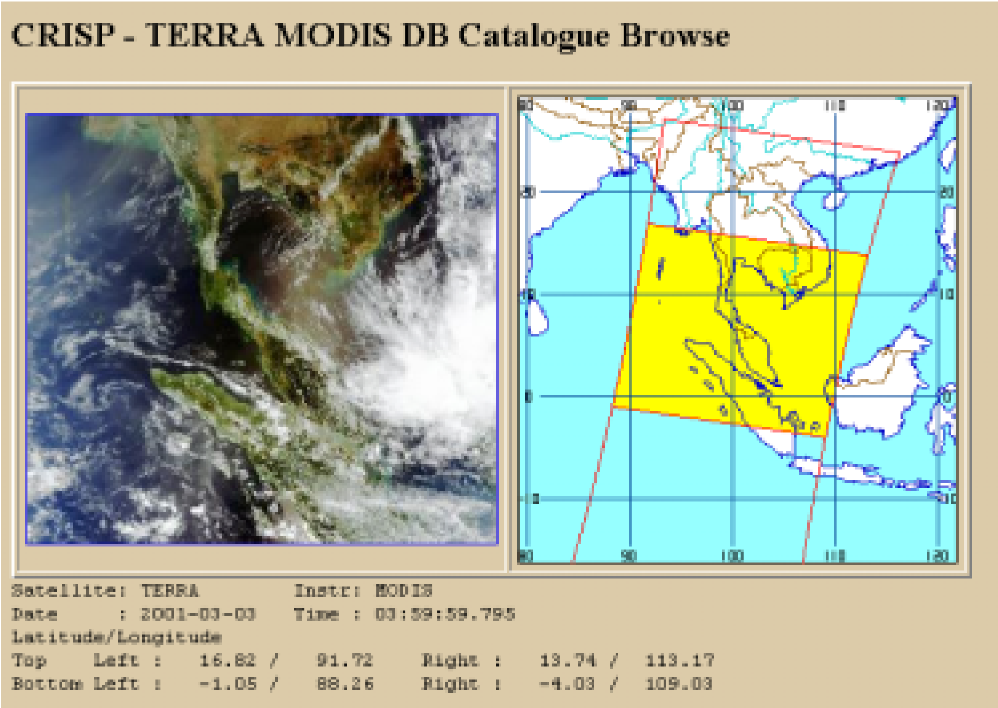

Fig. 1. A snapshot of MODIS Catalogue Browse search result.
The image on the left is the browse image and the map on the right depicting the location of the pass.

Another development that we have carried out is the generation of browse images directly from the level-0 files. The browse image can be generated quickly as the software does not care about the science and engineering components of the data. The software incorporates a simple geometry to 'flatten' the image and remove the 'bowtie' effect.

From the start time, end time and the NORAD two line-elements, the swath coverage of the pass is computed by the SGP4 orbit propagator. With the swath coverage and the browsed image, a web based catalogue system for MODIS is developed and integrated into CRISP's existing catalogue system. A snapshot of our web based catalogue search result is shown in Fig.1. The acquisition, archival, browsed image generation and catalogue updating are performed automatically.

III. LEVEL-1 PROCESSING

We have tested two versions of level-1 processing – University of Wisconsin International MODIS/AIRS Processing Package (IMAPP) and NASA GSFC MODIS Level 1 Processing Software. The NASA software has a limitation of processing a maximum of 5 minutes of data per granule and the longest MODIS direct broadcast pass is about 13 minutes, which is about three times the granule size. Hence, the NASA software will produce an average of three granules per pass. However, there are no limitations of data size for IMAPP. Furthermore, the IMAPP software runs faster than the NASA software. Therefore, IMAPP is preferable for near real-time environmental monitoring, which need to process the data as quickly as possible. Once the level-0 processing, browsed image generation and catalogue updating are done, level-1 processing are carried out automatically by a perl script.

IV. HOTSPOT GENERATION

To generate hotspot, we first georectify the MODIS level 1b data onto a map. The georectification code is able to taken away the "bowtie" effect completely. This is crucial since the locations of the hotspots will be misplaced if the "bowtie" effect has not been elimated. The code can generate different combination of bands, different resolutions and written in different formats such as tiff and 16bit generic binary format.

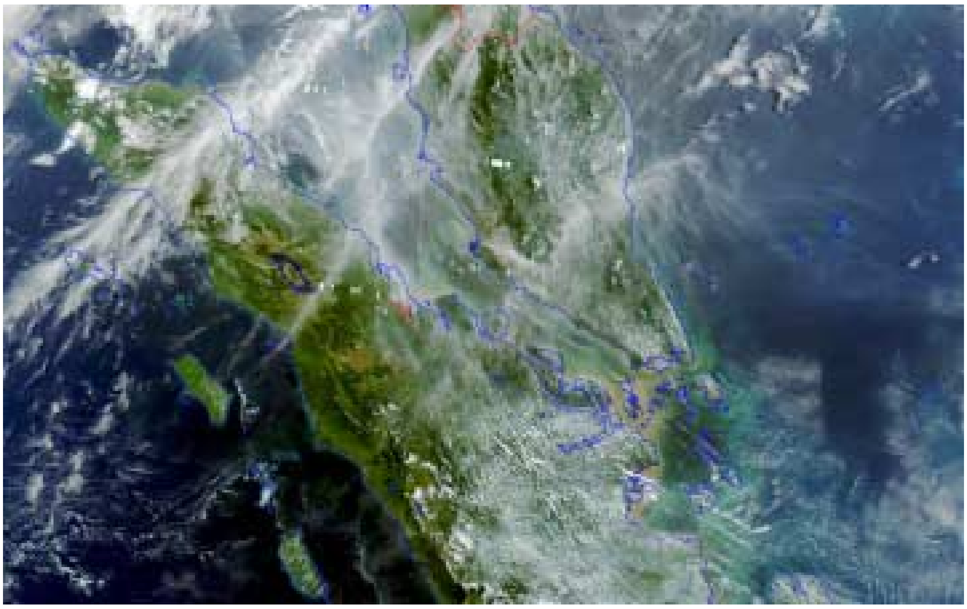

Fig. 2. MODIS Hotspot image generated on 7 Sep 2001. Smoke plumes coming out from hotspots can be seen clearly in Riau Province of Sumatra.

The 16 emissive bands of MODIS are very sensitive to temperature. Two of the emissive bands were used in determining hotspots band 21 and band 31, which have wavelengths 3.959μm and 11.03μm. The following criteria are used to determine the hotspot:

- BT_{21}>360K or
- BT_{31}>320K and BT_{21}- BT_{31}>20K.

Once a pixel is found to be hotspot, the georectified image will be marked by red colour. The final hotspot image is in 1km resolution. The entire process of hotspot generation is carried out immediately after the level-1 processing. From acquiring, level-0 processing, level-1 processing to hotspot generation, the total time taken is about one hour.

Fig. 2 is the hotspot image generated on 7 Sep 2001. Many hotspots are detected in Riau Province of Sumatra and some near Kuala Lumpur of Peninsular Malaysia. The smoke plumes coming out from the hotspots can been clearly in Riau Province of Sumatra.

In Fig. 3, the image on the left is the zoom-in of the hotspot image in Fig. 2. The hotspots area is generating a lot of smoke plumes blowing toward the north. The image on the right is the SPOT1 image captured on the same day. The source of the smoke plumes can now be seen clearly.

The hotspot image generated from MODIS is very accurate. The number of false alarms is far less than that of NOAA-AVHRR system. This is because MODIS is well calibrated and its emissive bands have a much higher saturation temperature. This has enabled MODIS to image the fires without saturating the sensor.

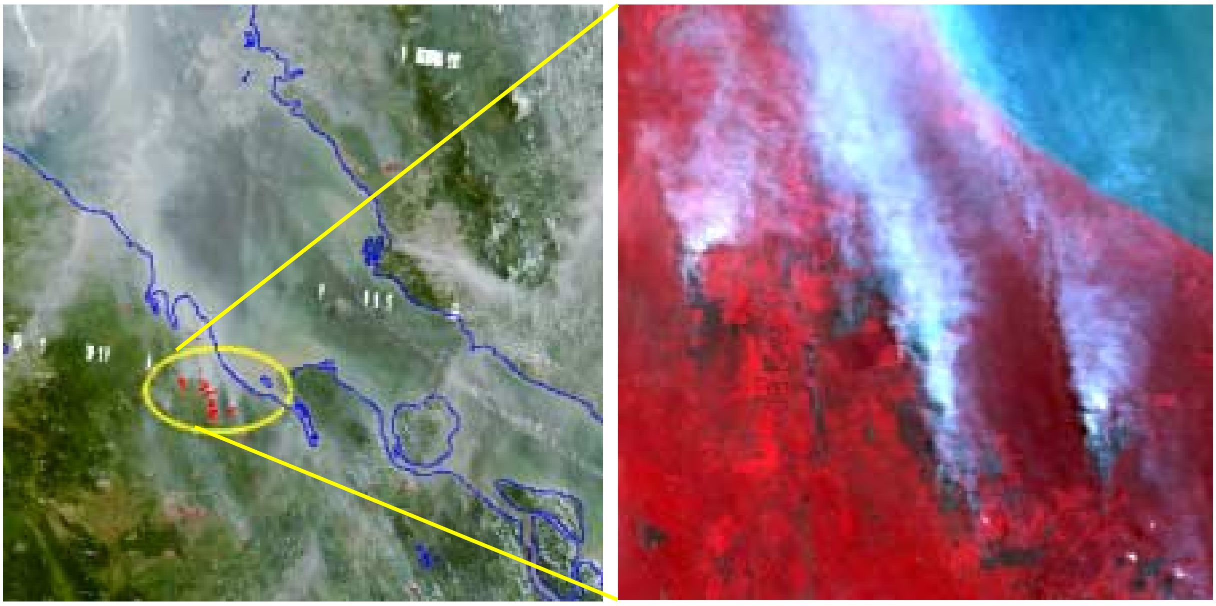

Fig. 3 Image on the left is the zoom-in of the hotspot image with 1km resolution and on the right is the SPOT image captured on the same day. The resolution for SPOT is 20m.

V. CONCLUSIONS

CRISP has successfully implemented an end-to-end MODIS direct broadcast reception, archival and processing system for near real-time environmental monitoring. The entire process, from data acquiring to hotspot generation, is performed automatically and can be done in about one hour time. The level 1 processing is done by IMAPP software, which has a full pass processing capability. The georectification software developed is able to eliminate the "bow-tie" effect completely. The hotspot image generated is proved to be more accurate than the conventional NOAA-AVHRR hotspot. In future, we can in corporate our cloud-free MODIS composite into the processing. Cloud-free MODIS composite can further enhance our environmental monitoring capabilities into area such as flood monitoring, burned scars mapping and so on.

VI. REFERENCE

[1] *Dundee Satellite Receiving Station MODIS downlink packet format*. Available at http://www.sat.dundee.ac.uk/modisformat.html.
[2] *EOS Direct Readout Documentation.* Available at http://sdcd.gsfc.nasa.gov/ISTO/dro/eos/doc.html.
[3] *EDOS-DAAC Interface Design Section 8.* Availble at http://esdis-it.gsfc.nasa.gov:8080/dbdocs/14/Sec_8_Rev2.pdf.
[4] *Level 1B Earth View and OBC File Format Specifications*. Available on-line at http://mcstweb.gsfc.nasa.gov/product.htm.
[5] *Prelaunch Algorithm and Data Format for the Level 1B Calibration Products for the EOS AM-1 Moderate Resolution Imaging Spectroradiometer (MODIS).* B. Guenther, G. D. Godden, X. Xiong, E.J. Knight, S. Y. Qiu, H. Montgomery, M. M. Hopkins, M. G.Khayat, and Z. Hao. IEEE Transactions on Geoscience and Remote Sensing, 36, 1142 (1998)
[6] *MODIS Level 1B Products Data Dictionary for Version 2.3.1*, *Release 1*. J. Rogers, Z. Gu and G. B. Berriman, January 6, 2000. Available on-line at http://mcstweb.gsfc.nasa.gov/product.html
[7] *HDF Users Guide v4.1r3.* Available on-line from ftp://ftp.ncsa.uiuc.edu/HDF/Documentation/HDF4.1r3/Users_guide
[8] HDF-EOS Library Users Guide for the ECS Project, Volume 1: Overview and Examples. 170-TP-100-02. Available on-line at http://hdfeos.gsfc.nasa.gov/hdfeos/hdf.html

[9] *MODIS Level 1A Earth Location Algorithm Theoretical Basis Document Version 3.0* M. Nishihama, R. Wolfe, D. Solomon, F. Patt, J. Blanchette, A. Fleig, E. Masuoka. SDST-092 August,1997
[10] *IMAPP docoments.* Available on-line at http://cimss.ssec.wisc.edu/~gumley/IMAPP/IMAPP.html.
[11] *MODIS FIRE PRODUCTS Algorithm Theoretical Basis Document Version 2 .2* Yoram Kaufman and Chris Justice