

XML Integration of Data from CloudSat Satellite and GMS-6 Water Vapor Satellite

W. Srisang, K. Jaroensutasinee, and M. Jaroensutasinee

Abstract—This study aimed at developing visualization tools for integrating CloudSat images and Water Vapor Satellite images. KML was used for integrating data from CloudSat Satellite and GMS-6 Water Vapor Satellite. CloudSat 2D images were transformed into 3D polygons in order to achieve 3D images. Before overlaying the images on Google Earth, GMS-6 water vapor satellite images had to be rescaled into linear images. Web service was developed using *webMathematica*. Shoreline from GMS-6 images was compared with shoreline from LandSat images on Google Earth for evaluation. The results showed that shoreline from GMS-6 images was highly matched with the shoreline in LandSat images from Google Earth. For CloudSat images, the visualizations were compared with GMS-6 images on Google Earth. The results showed that CloudSat and GMS-6 images were highly correlated.

Keywords—CloudSat, Water vapor, Satellite images, Google Earth™.

I. INTRODUCTION

GOOGLE Earth combines satellite image, aerial photograph, and map to make a 3D interactive template of the world. People can discover, add, and share geographical information from around the world [1]. The virtual globe represented by Google Earth is a digitalized earth that allows ‘flying’ from space (virtually) down through progressively higher resolution data sets to hover above any point on the Earth’s surface, and then displays information relevant to that location from an infinite number of sources [2]. The appeal of Google Earth is the ease with which the user can zoom from space right down to the street level [2]. In the last few years, Google Earth has been used in many scientific studies such as climate change, weather forecasting, natural disasters (e.g. tsunami, hurricane), geography, coral bleaching, and avian flu [1, 3]. All applications are involved with flat geospatial data and socioeconomic data and displaying them on the virtual

globe using geographic elements. US NASA’s GSFC (Goddard Space Flight Center) Hurricane Portal [4] is designed for viewing and studying hurricanes. This hurricane portal utilizes measurements from the NASA remote-sensing instruments, e.g. TRMM (Tropical Rainfall Measuring Mission), MODIS (MODerate Resolution Imaging Spectroradiometer), and AIRS (Atmospheric InfraRed Sounder). The portal displays most of the past hurricanes on Google Earth and provides downloadable hurricane data to assist the scientists’ community in future research and investigations of hurricanes. In addition, NASA’s GSFC uses Google Earth’s fly-by feature to understand local weather systems and try to use real-time observations to refine the weather prediction. Google Earth makes meteorological radar data and satellite images, e.g. from NOAA, NASA and USGS, more useful and user friendly [2].

The CloudSat satellite was launched on April 28th 2006. The new vertical geospatial data, which reflects the characteristics of the cloud used for weather forecast, have not been visualized as they are in real world on the virtual globe. GMS-6 images are satellite images of water vapor in the atmosphere and can be used to predict flash flooding [5].

Little has been done on visualizing CloudSat images and Water Vapor images. This study is the first to develop visualization tools for integrating CloudSat images and Water Vapor Satellite images. KML, which uses a tag-based structure with nested elements and attributes and is based on the XML standard, was used to integrate these data for visualization on Google Earth. The tool allows users to visualize vertical clouds and their interactions with water vapor data on Google Earth.

II. CLOUDSAT IMAGE PROCESSING AND VISUALIZATION

A. CloudSat Image

Original CloudSat images were downloaded from a CloudSat official website (Fig. 1) [6]. These images were composed of three components: bottom part, middle part and upper part of the image. First, the bottom part of the image showed the image description including when and where the image was taken. Second, the middle part of the image showed the terrain where CloudSat passed (the blue and brown colors represent ocean and land, respectively). Third, the upper part of the image represented clouds within 30 km above mean sea level.

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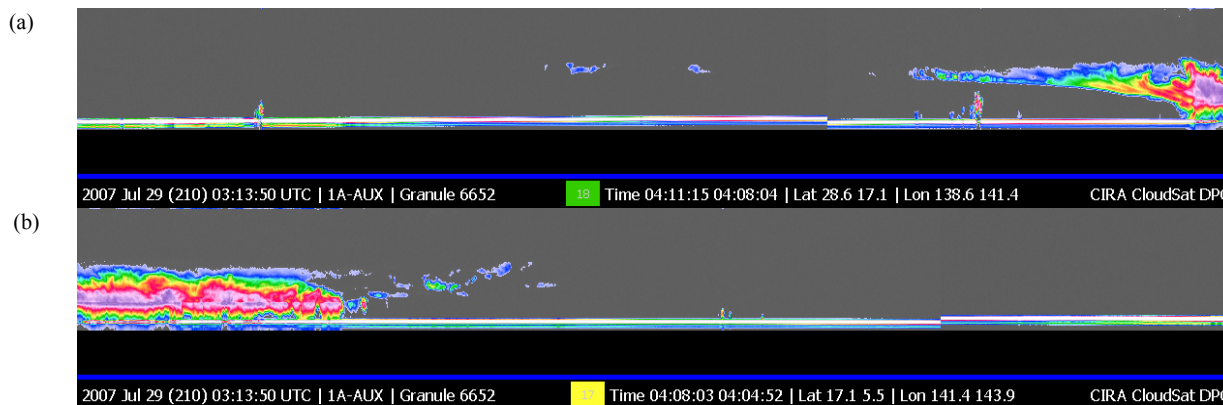


Fig. 1 CloudSat images on 29 July 2007. (a) Latitude 28.6-17.1 °N and Longitude 138.6-141.4 °E and (b) Latitude 17.1-5.5 °N and Longitude 141.4-143.9 °E

B. Preprocessing CloudSat Image

The upper part of CloudSat images (cloud) where cloud was present was being preprocessed. We deleted no cloud pixels from CloudSat image. Where there was no cloud, the background pixels were composed of the same amount of red, green and blue values in the pixels. This was showed in grey color in Fig. 1a,b. Where the cloud was present, we measured their pixel values and positions on images.

C. Google Earth Visualization

The preprocessed images were visualized on Google Earth. We transformed 2D images into 3D polygons in order to achieve 3D images. General 3D polygons were composed of points with three components (i.e. x, y, and z). In this case, x, y, and z were the latitude, the longitude and the elevation of pixels. The latitude and the longitude of pixels were calculated from the latitude and the longitude showed at the bottom of the images. The interpolation function was created for the calculation of the latitude and the longitude of each pixel. The same process was applied for the calculation of the elevation of pixels. The Latitude, the longitude and the elevation of pixels were used to generate KML file for visualization on Google Earth (Table I).

TABLE I
KML CODE FOR CLOUDSAT VISUALIZATION

```

<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.1">
<Document>
<open>1</open>
<Placemark>
<Style>
<LineStyle><color>00000000</color></LineStyle>
<PolyStyle><color>ffffc1be</color></PolyStyle>
</Style>
<Polygon>
<extrude>0</extrude>
<altitudeMode>absolute</altitudeMode>
<outerBoundaryIs>
<LinearRing>
<coordinates>
141.425,16.9835,0.
141.425,16.9835,240.
141.427,16.9738,240.
141.427,16.9738,0.
141.425,16.9835,0.
</coordinates>
</LinearRing>
</outerBoundaryIs>
</Polygon>
</Placemark>
</Document>
</kml>
    
```

III. WATER VAPOR IMAGE PROCESSING AND VISUALIZATION

A. Water Vapor Satellite Image

GMS-6 satellite images, (taken at Latitude 5 °S to 45 °N and Longitude 90 °E to 190 °E (Fig. 2a)) were used in this study. These water vapor images showed the amount of water vapor in the atmosphere. Thicker clouds and larger droplets were shown in yellow/red tones, while thinner clouds were shown in blue.

B. Preprocessing Water Vapor Satellite Image

The GMS-6 satellite turns 3D surface into 2D pictures. This process made the images became nonlinear (i.e. the distance between 0 °N and 15 °N was less than that between 15 °N and 30 °N, Fig. 2a). Before we overlaid the images on Google Earth, we rescaled those images into linear images. Interpolation functions were created from a pixel position, latitude and longitude of the reference line in the images. After we applied the interpolation functions on the images, rescaled linear images were created (Fig. 2b).

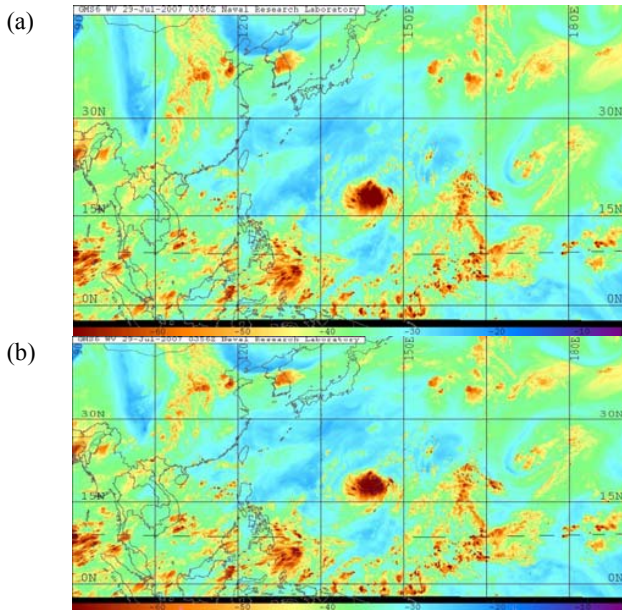


Fig. 2 GMS-6 satellite image on 29 July 2007. (a) original water vapor image and (b) rescaled water vapor image

C. Google Earth visualization

GMS-6 satellite images were overlaid on Google Earth. We created KML files. These images were visualized as ground overlay (see Table II).

TABLE II
KML CODE FOR GMS-6 VISUALIZATION

```

<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.1">
<GroundOverlay>
<Icon>
<href>GMS6.jpg</href>
<viewBoundScale>0.75</viewBoundScale>
</Icon>
<LatLonBox>
<north>45</north>
<south>-5</south>
<east>190</east>
<west>90</west>
</LatLonBox>
</GroundOverlay>
</kml>
    
```

IV. WEB SERVICE

A web service for GMS-6 satellite image and CloudSat images visualization was created using webMathematica. User uploaded a selected satellite image and its data into a website. We computed satellite images and data using Mathematica version 5.2 [7] by using web service. KML files and rescaled images were generated for users to download.

V. RESULTS AND DISCUSSION

We evaluated the visualization of GMS-6 satellite images by comparing the shoreline in GMS-6 images with the

shoreline in LandSat images from Google Earth. The results showed that the shoreline in GMS-6 images was highly matched with the shoreline in LandSat images from Google Earth.

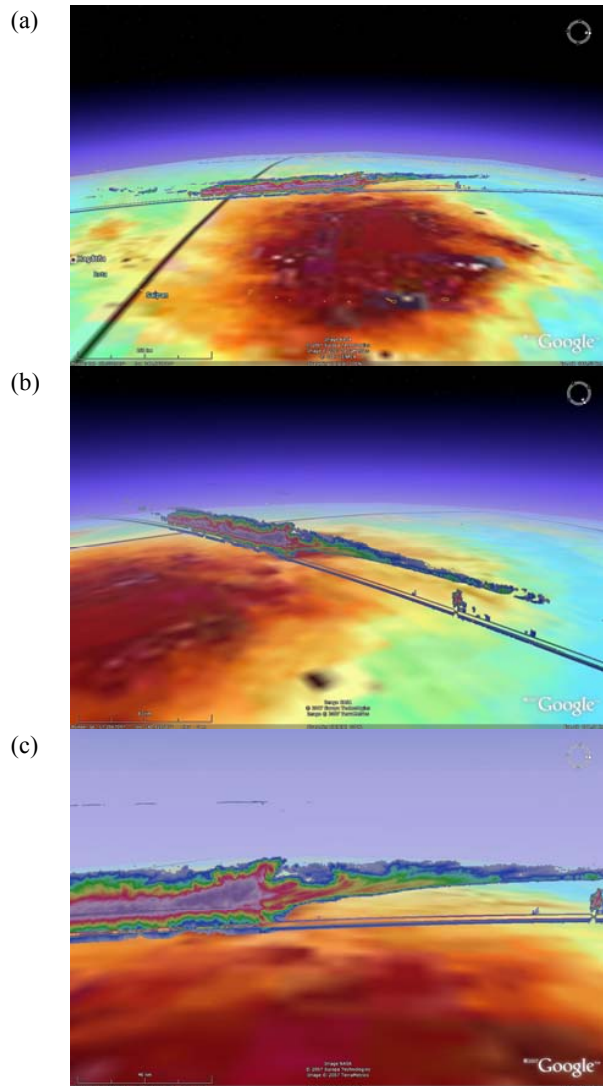


Fig. 3 CloudSat and GMS-6 satellite image visualization using Google Earth. (a) zoom out image, (b) different orientation, and (c) zoom in image

For CloudSat images, the visualizations were compared with GMS-6 images on Google Earth. The results showed that there was some correlation between CloudSat and GMS-6 images. In the depression zone where high water vapor occurred, CloudSat images showed thick clouds and high cloud types (Fig. 3a). This implies that there might be cumulonimbus clouds. There are several advantages of using this visualization. First, users can compare CloudSat data with water vapor images, LandSat images, and images from 3D Digital elevation model. Second, users can locate their CloudSat study sites from GPS reading and marking

coordinates on Google Earth. Third, users can find directions of CloudSat path. Fourth, users can visualize CloudSat images with the 3D interactive function on Google Earth.

Google Earth is becoming a new platform for information and knowledge sharing, collaborative scientific research, visualized education in Earth-related disciplines, and any digital-data related activities. This research provides a method for using Google Earth to vividly visualize and integrate geospatial satellite data, provides more user friendly interfaces, easily to understand and facilitates scientific research of our planet-related phenomena. It is also a pioneering for sharing and spreading information, knowledge, and the newest scientific research results through a well known unified framework – the virtual globe. CloudSat visualization is extremely helpful as a teaching material for grade 10-12 students. This tool helps students to gain a better understanding about CloudSat images, cloud formation, and cloud types [8]. Using web $Mathematica$ allows us to perform an advanced computation (e.g. image processing, interpolation function, functional programming) via web service.

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REFERENCES

- [1] Nature. (2007, May 3) Avian Flu. [Online]. Available: <http://www.nature.com/nature/multimedia/googleearth/index.html>.
- [2] D. Butler. "Virtual Globes: The web-wide world," *Nature*, vol. 439, pp. 776-778, 2006.
- [3] NIEES. (2007, May 1). Google Earth and other geo browsing tools in the environmental sciences. [Online]. Available: <http://www.niees.ac.uk/events/GoogleEarth/index.shtml>.
- [4] D. Leptoukh, D. Ostrenga, Z. Liu, J. Li, and D. Nadeau. "Exploring hurricanes from space: utilizing multi-sensor NASA remote sensing data via Giovanni," presented at AGU Fall Meeting, San Francisco, CA, USA. December 11-15, 2006.
- [5] W. Ruairuen and K. Jaroensutasinee, "Flash Flooding Prediction by GOES-9 Satellite Data," *The Eighth Annual National Symposium on Computational Science and Engineering Reference Proceeding*, Suranaree University of Technology, Nakhon Ratchasima, Thailand, 2004.
- [6] <http://cloudsat.atmos.colostate.edu>
- [7] S. Wolfram, *The Mathematica Book*, 5th ed., Wolfram Media, 2003.
- [8] C. Choksrichan, R. Ditsathan, S. Chaikasertsin, P. Pongmanawut and T. Tawornmat. "Relationship between cloud observation data at ground, CloudSat and water vapor satellite images". *The first Thai Annual GLOBE and CloudSat Student Conference*, IPST, Bangkok, Thailand, August, 11, 2007 (in press).