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Visualization of A-Train vertical profiles using Google Earth

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ABSTRACT

Online tools, such as those pioneered by Google Earth (GE), are changing the way in which scientists and the general public interact with three-dimensional geospatial data in a virtual environment. However, while GE provides a number of features to facilitate geospatial data visualization, there is currently no readily available method for rendering vertical geospatial data derived from Earth—viewing remote sensing satellites as an orbit curtain seen from above. Here, a solution (one of many possible) is demonstrated to render vertical profiles of atmospheric data from the A-Train satellite formation in GE, using as a proof-of-concept data from one of the instruments—the NASA CloudSat satellite. CloudSat carries a nadir-viewing Cloud Profiling Radar that produces data revealing the vertical distribution of cloud characteristics along the satellite track. These data are first rendered into a long vertical image for a user-selected spatial range through the NASA Goddard Interactive Online Visualization ANd aNalysis Infrastructure (Giovanni) system (http://giovanni.gsfc.nasa.gov/). The vertical image is then chopped into small slices representing 15 s of satellite time (~103 km long ground distance). Each small piece, as a texture, is fed into a generalized COLLAborative Design Activity (COLLADA) three-dimensional (3-D) model. Using the satellite orbit coordinates, the repeated 15 s "3-D model slices" are spliced together to form a vertical "curtain" image in Keyhole Markup Language (KML) format. Each model slice is geolocated along the CloudSat orbit path based on its size, scale and angle with the longitude line that are precisely calculated on the fly. The resulting vertical cloud data can be viewed in GE, either transparently or opaquely, superimposed above the Earth's surface with an exaggerated vertical scale. Since CloudSat is just a part of the A-Train formation, the full utility of this tool can be explored within the context of the A-Train Data Depot (ATDD, http://disc.gsfc.nasa.gov/atdd/) and the corresponding Giovanni instance (http://disc1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=atrain). The latter portal allows scientists and the general public to access and visualize complex A-Train datasets without having to delve into data formats specific to a given mission.

1. Introduction

Google Earth (GE) combines satellite imagery, aerial photography, and map data to make a three-dimensional (3-D) interactive image of the world. People can then discover, add and share information about any subject

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that is geolocated. The virtual globe represented by GE allows the user to "fly" from space down through layers of progressively higher resolution data sets and hover above any point on the Earth's surface. GE then displays information relevant to that location from a vast number of sources. Its original purpose was to use the Earth itself as an organizing metaphor for digital information. Now, the GE virtual globe is changing the way scientists interact with geospatial data. A wide variety of information on the state of the planet, from toxic chemicals to the disease incidence rates, are becoming available to the public with just a few clicks of the mouse (Declan, 2006). With many applications moving from local machine-based environments to online web-based platforms with the emergence of new internet technologies, the virtual globe promises to play an increasingly important role in research, applications and the public's daily life in the near future.

In the few years since its 2005 introduction, GE has found numerous applications, including climate change, weather forecasting,[3] natural disasters (e.g., tsunamis, hurricanes), the environment,[4] travel, history, presidential elections, mapping avian flu,[5] online games and cross-platform view sharing. These applications primarily use two-dimensional (2-D) geospatial and socio-economic data to generate visualizations on virtual globe. For example, the NASA Goddard Space Flight Center (GSFC) Hurricane Portal is designed for viewing hurricanes by utilizing measurements from a variety of NASA satellite-based remote sensing instruments, including the Tropical Rainfall Measuring Mission (TRMM), the MODerate Resolution Imaging Spectroradiometer (MODIS), and the Atmospheric Infrared Sounder (AIRS). The Hurricane Portal (http://disc.gsfc.nasa.gov/hurricane/) provides visualizations of recent hurricanes (1998–present) in GE, as well as downloads of hurricane datasets to assist the science community in their research into tropical meteorology. For instance, atmospheric scientists may use real-time weather observations as visualized with GE's fly-by feature to understand local weather systems and refine weather predictions (Declan, 2006). NOAA researchers display real-time weather information in GE alongside the landmarks and routes familiar to the general public.[6] GE makes meteorological radar data and satellite images from NOAA, NASA and USGS more user friendly.

Apart from the CloudSat radar (Fig. 1) that in essence provides the vertical description of clouds, the A-Train formation includes several other instruments producing vertical profiles of various atmospheric parameters.

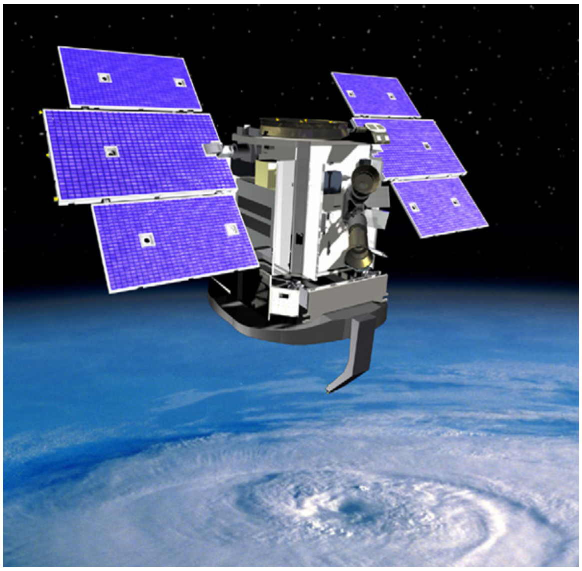

Fig. 1. Artist's rendering of CloudSat satellite. (Photo courtesy of NASA).

However, GE does not provide a simple solution for displaying this kind of vertical data. Using the method described in this paper, and CloudSat as a case study, we are able to transparently or opaquely display a "curtain" of high-resolution cloud parameters derived from CloudSat data and enable its visualization from all directions, including flying along the curtain. When viewed in the context of other related data sets (e.g., precipitation data), valuable insights into the nature of cloud processes can be gleaned by researchers and students.

There are indeed other methods for rendering orbit curtains. One is to process the geospatial data to produce a Keyhole Markup Language (KML) file that can render a 2-D curtain in GE directly. At the highest resolution, the curtain consists of many small rectangles, each of which represents the distance CloudSat satellite travels in 5 s. The problem with this method is that if the resolution is as high as the method discussed in this paper, the rendering and displaying speed in GE is unacceptably slow. To improve the rendering speed, the resolution has to be degraded to the point that the visualization is insufficient for use by scientists.

Geens (2006)[7] first suggested displaying vertical images in GE with a very rough, inaccurate solution. No systematic scientific procedures are used to calculate the position, scale and rotation of the data along the satellite orbit in GE. Yamagishi et al. (2006) provided a tool to convert a seismic tomography model into KML files. The KML file used the method discussed above. Latitude, longitude and altitude data are provided using a seismic model for rendering the flat rectangle in GE (Chen et al., 2008). We also tried visualizing the vertical data via

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