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Using NASA's World Wind virtual globe for interactive internet visualization of the global MODIS burned area product

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Three-dimensional virtual globes are radically changing the way geographic information is perceived by the public. This article describes how NASA World Wind, an open source virtual globe, is currently being used for visualization of the MODIS burned area product. The procedures adopted for converting the product into a format compatible with World Wind, as well as the spatial generalization of these data at different scales, are described. Directions to instructions on how to obtain the MODIS burned area product visualization imagery and use it in World Wind are included. This article highlights the potential benefits of integrating the visualization capability of virtual globes into the next generation of remotely sensed product internet analysis and distribution systems.

1. Introduction

There has been an information revolution in remote sensing, in the capacity to generate products and to disseminate products to users. Before the 1990s, satellite sensor data were obtained primarily by installation of a satellite receiving station, or by data requests to such stations or the associated data distributors. Data were usually mailed to users on analogue tape media or as printed photographs or diapositives. Today, digital satellite data products can be obtained from dedicated centres that may be separated physically and institutionally from the place of product generation. Users can submit requests via the internet using personal computers, and can request that products be sent on media or over the internet using file transfer protocols. For example, National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS) land products are generated systematically on a global basis and distributed to the global user community via the internet from dedicated data active archive centres (Justice *et al.* 2002). Visualization of satellite products greatly aids the product browse and ordering process and is also required to ensure the quality of products as part of the production process (Roy *et al.* 2002).

Commercial internet search engines and services have raised expectations and awareness for the delivery of geographic information and services over the internet (Jones and Ware, 2005, Butler 2006). Virtual globes provide visualization of

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spatially explicit data from different views projected onto the Earth's surface in three dimensions. Users may interactively pan, zoom and rotate the data, usually superimposed on a selected background that provides geographic context. Virtual globes are changing the way in which geographic information is distributed and how the public perceive such information (Butler 2006). NASA and a number of commercial companies have developed virtual globe software. The software architecture uses a thick client approach, whereby software runs on the user's computer to render image data that are downloaded *a priori* via the internet from a centralized server. This usually enables faster visualization and requires less internet network bandwidth compared to thin client approaches, where image rendering is performed at the server and the rendered image data are sent to the user.

2. World Wind

World Wind is a three-dimensional geographic information system developed by NASA Ames Research Centre that is installed on a user's personal computer (Hogan and Coughlan 2006; http://worldwind.arc.nasa.gov/). Unlike similar virtual globe software, such as Google Earth or Microsoft Virtual Earth, World Wind was developed and distributed from the beginning under an Open Source Agreement (http://www.worldwindcentral.com) to enable users to study, change, improve and redistribute the code and to develop add-on components and customized data layers. World Wind was initially developed as a .NET application for Windows platforms; recently a Java-based World Wind Software Development Kit was released to allow platform-independent World Wind applications (http://worldwind.arc.nasa.gov/java/).

The initial World Wind view displays global MODIS surface reflectance data (Stöckli *et al.* 2006) projected onto a three-dimensional Earth; zooming in to larger scale, these data are replaced by Landsat Enhanced Thematic Mapper Plus (ETM+) data draped over a digital terrain model derived from the Shuttle Radar Topography Mission. The graphical rendering is undertaken efficiently in DirectX. Available spatially explicit data sets may be overlaid as different layers according to user selections. The data to be visualized must be defined at different spatial resolutions and/or levels of generalization. This is facilitated by a pyramid data structure defined in the Plate Carrée projection. At the coarsest level, the Earth's surface is described by $36^\circ \times 36^\circ$ square tiles of 512×512 pixels (0.07° pixels). At progressively larger scales, the pixel size decreases by a factor of two and the number of pixels per tile remains constant; the second coarsest level is composed of $18^\circ \times 18^\circ$ tiles (0.035° pixels), the third of $9^\circ \times 9^\circ$ tiles (0.0175° pixels) and so on, until the native data resolution is reached. World Wind software is capable of reading files in a variety of image formats, but each dataset must be complemented by an Extensible Markup Language (XML) file containing descriptive geographic metadata.

3. MODIS burned area product

The MODIS burned area product has been recently implemented in the MODIS land production system to systematically map burned areas globally for the 6+ year MODIS observation record. The algorithm uses a bidirectional reflectance model-based expectation change detection approach to map at 500 m the location and approximate day of burning (Roy *et al.* 2005). The product is distributed as a monthly gridded 500 m product in Hierarchical Data Format (HDF) and is currently available from the MODIS Fire website (http://modis-fire.umd.edu/MCD45A1.asp). It is defined, like the other Collection 5 geolocated MODIS land products, in the Sinusoidal projection in fixed earth-location tiles, each covering approximately 1200×1200 km ($10^\circ \times 10^\circ$ at the equator) (Wolfe *et al.* 1998).

Figure 1 illustrates a preliminary version of the MODIS burned area product mosaicked in the MODIS Sinusoidal projection. This visualization is based on the MODIS global browse approach (Roy *et al.* 2002), where reduced spatial resolution data products are projected into a global coordinate system and displayed on the MODLAND Quality Assessment website (http://modland.nascom.nasa.gov/QA_WWW/).

4. World Wind MODIS burned area layer generation

The MODIS product cannot be simply loaded into World Wind. To provide World Wind compatible imagery, the monthly burned area product tiles are generalized and converted into JPG browse images:

(1) The monthly burned area product tiles are reprojected from the Sinusoidal projection to the Plate Carreé projection, maintaining the original 500 m spatial resolution and mosaicking the different tiles together to produce a single global mosaic HDF file. This task is performed using the MODIS Reprojection Tool (http://edcdaac.usgs.gov/landdaac/tools/modis/index.asp).

(2) The monthly global mosaic file is generalized at different spatial resolutions. Custom C code to compute the median day of burning and the mode of the non-burning values (fill, water, snow, no-burning) in an arbitrary sized window is used. Each window is assigned the median day of burning, and if no burning occurs then it is assigned the mode non-burning value. In this way the burned areas remain visible even at the smallest scales (zoomed out far from Earth), and at larger scales (zoomed in close to Earth) their correct areal proportions are evident. Five levels of generalization are sufficient to

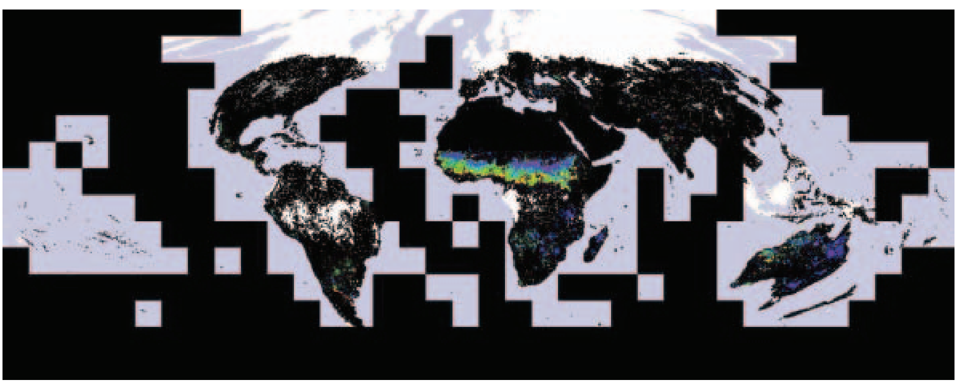

Figure 1. Global mosaic of MODIS burned area product tiles for the month of November 2000, generalized to 40 km pixel size using the method described in the text. The rainbow colours (blue to red) indicate the approximate day of burning in November 2000, black indicates no burning, white indicates no decision because of persistent cloud cover or missing data, grey indicates no burning but snow detected, lilac indicates water.

support visually smooth World Wind zooming from the coarsest World Wind resolution to the original 500 m MODIS resolution: 0.07°, 0.035°, 0.0175°, 0.008775° and 0.0043875°.

(3) The five generalized global mosaic HDF files are converted to JPG images with fixed contrast stretching and colour look-up tables using specific tools developed to support MODIS land quality assessment. A rainbow colour scale describing the approximate day of burning and non-rainbow colours for non-burning days is used (see figure 1).

(4) The JPG files are converted to World Wind format by dividing each into 512×512 pixel tiles using ImageMagick (http://www.imagemagick.org). An accompanying XML file describing the geographic corner coordinates, the number of levels of generalization and the tile dimensions at the coarsest spatial resolution is generated by a shell script.

The World Wind compatible JPG browse images, together with instructions for downloading and integration into World Wind, are available at the MODIS Fire website (http://modis-fire.umd.edu/MCD45A1.asp). These imagery are made available on a systematic basis as the monthly burned area product is generated.

Figures 2 and 3 show the figure 1 data displayed in World Wind, illustrating how a user can identify and explore areas of interest at different scales and perspectives. The areas that are not detected as burned, and that were not snow covered or persistently cloudy, are transparent and so allow the MODIS background image to be viewed, making it possible to assess qualitatively in what type of environment the burning activity is occurring.

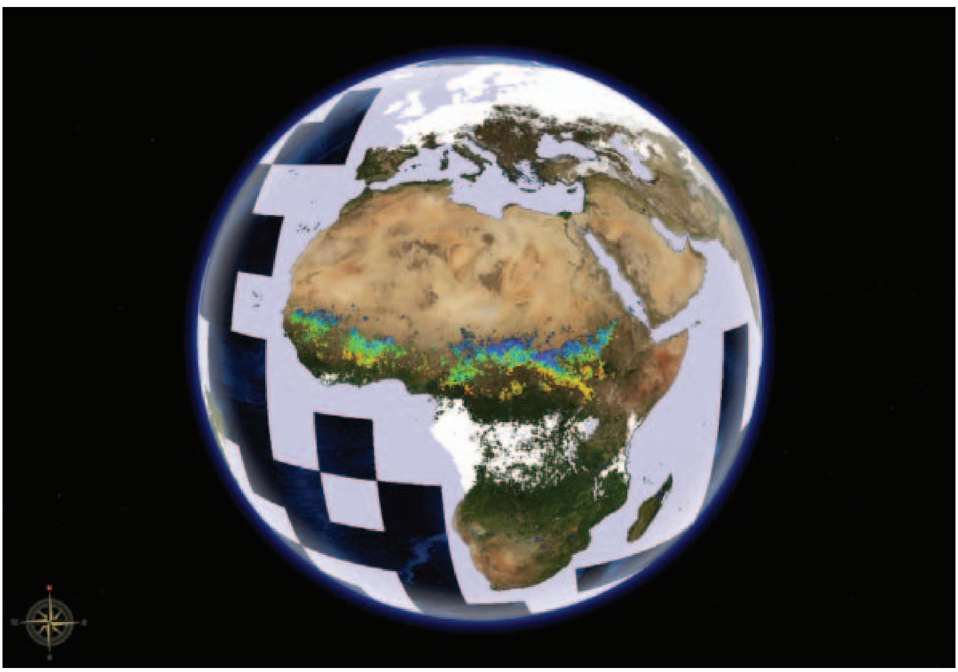

Figure 2. World Wind display of the November 2000 burned area product data shown in figure 1. The non-burned, non-fill pixels (black in figure 1) are set as transparent in order to visualize the MODIS surface reflectance background. Users can interactively pan and zoom by mouse clicks, allowing for large-scale and synoptic small-scale inspection.

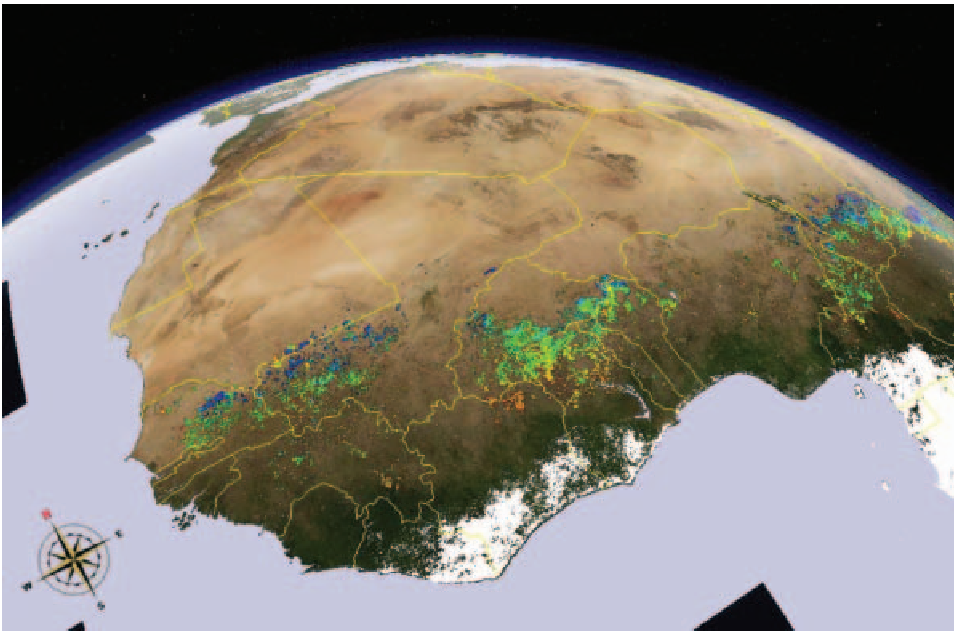

Figure 3. World Wind display of the November 2000 burned area product, as figure 2 but with a different zoom level and from a non-nadir viewpoint.

5. Conclusions

Although virtual globes have received considerable attention, they have yet to be used broadly by the scientific community. This article highlights the potential benefits of integrating the visualization capability of virtual globes with the next generation of remotely sensed product internet distribution and analysis systems. This is in keeping with NASA's goal to move towards a more distributed, heterogeneous data and information environment, with an interoperable architecture and increased data access and usability for the science research, application and modelling communities. With increasing attention to making Earth observation information readily available to decision makers, it is important that web-based graphic interfaces be easy to use, familiar and intuitive.

Studies based in the USA and Europe have posited that fast internet connectivity is essential to transfer products efficiently from data providers to users (e.g. Kalluri *et al.* 2003). However, we recognize that slow internet connectivity remains the norm for scientists in many parts of the world. Narrowing this digital divide to make the open-source tool described here available in such regions requires focused efforts to increase global connectivity and places the onus on product providers to facilitate uptake by minimizing product file size and providing low bandwidth interfaces (Trigg and Roy 2007).

This tool is currently being used as an integral component of the science quality assessment of the MODIS burned area product. However, World Wind is a visualization rather than a data distribution tool, so it is not possible for users to download or order the data beyond accessing the displayed images. As the majority of science data users need the original product and the associated quality assessment data for use in their applications, the next step will be to develop procedures to access the data directly through this visualization tool. In the meantime, this study contributes to recent developments in internet technology to enhance the usability and facilitate the analysis of NASA data.

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