9B.7   **VISUALIZATION OF METEOROLOGICAL SATELLITE DAT IN GOOGLE EARTH**

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1. INTRODUCTION

Google Earth is an innovative free browser that permits an explorer or scientist to view a vast collection of aircraft and satellite imagery of the Earth. Like any browser, Google Earth can be programmed by a using markup language, in this case the Keyhole Markup Language (KML). KML permits a user to specify place marks and identifying points on the earth, script tours of selected sites on the earth, and to place image overlays on the earth and the screen. A very powerful feature is the ability to create polygons at altitude which can be extruded to the surface, and even three dimensional structures. All of these can be published to the web as long as the user has the Google Earth server software. This paper explores several environmental satellite applications of Google Earth which include: verification of the Amazon rainforest as a microwave vicarious calibration source, visualization of AMSU inhomogeneous footprints over land and coastlines and visualization of three dimensional atmospheric structure by vertically stacked AMSU fields of view.

2. METHODOLOGY

The visualizations presented in this paper use software written by the author which creates realistic instantaneous fields-of-view (fov) for an instrument with circular aperture on an arbitrary earth projection (Kleespies, 2005). The locations of actual AMSU observations are taken from standard level 1B data files obtained from the NOAA Comprehensive

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Large Array-data Stewardship System. Each field of view is color-coded based upon the antenna temperature of the observation. The color-coding is accomplished by entering blue-green-red-opacity 32 bit hexadecimal number into the KML description. An example of a single color specification is given in Figure 1.

Given a particular instrument, fov location and satellite height, the aforementioned code will compute the earth locations of a polygon which describes the fov. The author inserted write statements into this code which puts the KML tags around these locations in the output file. The filename is appended with ".kml" . Then all the user needs to do is open the file in Google Earth.

3. RESULTS

3.1 Amazon Rainforest Vicarious Calibration Site

Figure 3 displays a vicarious calibration site in the Amazon region which is used within NOAA for calibrating the AMSU-A. This site was chosen because it was believed to have a homogeneous forest canopy. Figure 4 is a zoomed image of the center of this area. A large deforested area is visible which in this example impinges on several AMSU-A footprints. Presumably, the deforested area has different emissivity than the forested area. It is not know how old the surface images are in Google Earth. However, it is possible to put recent clear sky MODIS data over the same region in Google Earth in order to evaluate the surface cover.

3.2 Partially Filled Fields-of-View along Coastlines

Figure 5 presents an image of AMSU-A channel 1 antenna temperatures over Australia. The opacity is set to 100% in this image, which does not allow imaging the underlying surface. The partially filled

fov along the coastline are clearly visible, as well as the coastline itself. Figure 6 is the same as Fig. 5, but at 50% opacity. This permits some of the surface features to be visible, verifying the coastline alignment.

3.3 Three Dimensional Atmospheric Structure Demonstrated by Stacked AMSU Fields-of-View

Figure 7 displays a three-dimensional representation of atmospheric structure over Brazil. This is produced by stacking all fifteen AMSU-A channels vertically. No attempt has been made to place the individual channel ellipses at the peaks of their respective weighting functions: some channels would be too close to resolve. Rather, they are separated by 10 km. The result clearly shows the atmosphere cooling through the troposphere, and then warming through the stratosphere. Note however that the top ellipse represents channel 15, which is the 89 GHz window channel, and thus is modulated by surface, not atmospheric properties.

The power of Google Earth cannot be demonstrated in a static presentation such as this paper. By manipulating the navigation controls of the browser, the user can fly through a presentation such as Fig. 7, and explore the 3-D structure of the atmosphere. The conference presentation is available at ftp://ftp.orbit.nesdis.noaa.gov/pub/smcd/spb/tkleespies/Kleespies_Presentation.zip

4. SUMMARY

Google Earth is a powerful visualization tool that was originally intended for exploring the earth's surface. This paper presents a few ideas of how to exploit this tool for atmospheric studies as well.

5. ACKNOWLEDGEMENTS

Google Earth is available at
http://earth.google.com
CLASS can be accessed at
http://www.class.noaa.gov .

The views expressed in this publication are those of the authors and do not necessarily represent an official position or policy of NOAA, the Department of Commerce, or the United States Government.

6. REFERENCES

Kleespies, T. J., 2005: "Plotting Realistic Instantaneous Field of View Ellipsoids on an Arbitrary Earth Projection", Proc. 14th International TOVS Study Conf., 25-31 May 2005, Bejing, China.

```
<Style id="color016">
 <LineStyle>
  <color>7F4D0000</color>
 </LineStyle>
```

Figure 1. Example of color specification in KML. This code defines color016 to be hex values of 7F for transparency (50%), 4D for blue, 00 for green and 00 for red. This will yield a moderately blue polygon through which the surface will be visible.

```
<Placemark>
<styleUrl>#color016</styleUrl>
 <Polygon>
 <altitudeMode>relative</altitudeMode>
  <outerBoundaryIs>
   <LinearRing>
    <coordinates>
-61.01801,50.22269,000000
-61.15082,50.31430,000000
-61.34150,50.35971,000000
-61.53358,50.37026,000000
-61.70233,50.36188,000000
-61.84543,50.34454,000000
-61.96798,50.32297,000000
-62.07594,50.29898,000000
-62.17448,50.27294,000000
-62.26785,50.24448,000000
-62.35963,50.21264,000000
-62.45302,50.17587,000000
-62.55092,50.13185,000000
-62.65553,50.07714,000000
-62.76669,50.00690,000000
-62.87741,49.91550,000000
-62.96473,49.80048,000000
-62.98426,49.67284,000000
-62.89867,49.56288,000000
-62.72909,49.49703,000000
-62.53537,49.47338,000000
-62.35707,49.47538,000000
-62.20454,49.48987,000000
-62.07489,49.51001,000000
-61.96226,49.53296,000000
-61.86110,49.55782,000000
-61.76680,49.58469,000000
-61.67554,49.61426,000000
-61.58393,49.64775,000000
-61.48886,49.68705,000000
-61.38757,49.73493,000000
-61.27842,49.79548,000000
-61.16372,49.87413,000000
-61.05663,49.97596,000000
-60.99154,50.09895,000000
-61.01801,50.22269,000000
    </coordinates>
   </LinearRing>
  </outerBoundaryIs>
 </Polygon>
</Placemark>
```

Figure 2. Example of an ellipse definition in KML using the color definition in Fig. 1. Note that each tag has an accompanying closing tag. The coordinates given on each line are latitude, longitude and elevation in meters.
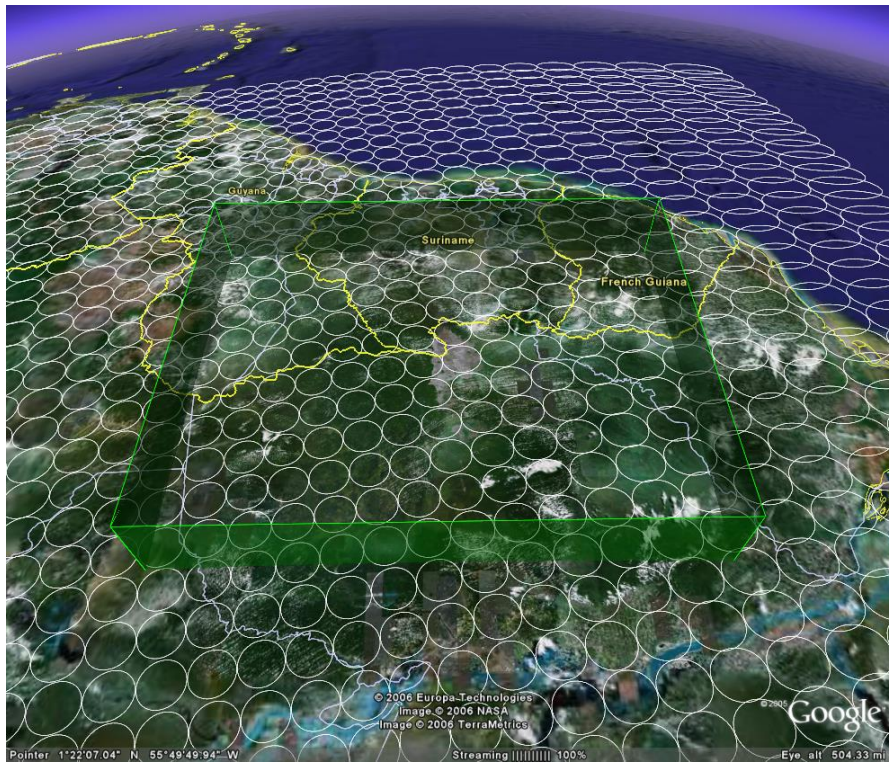
Figure 3. Vicarious Calibration area over Amazon rainforest outlined by green wall. AMSUA fields of view outlined in white to emphasize the underlying surface features.
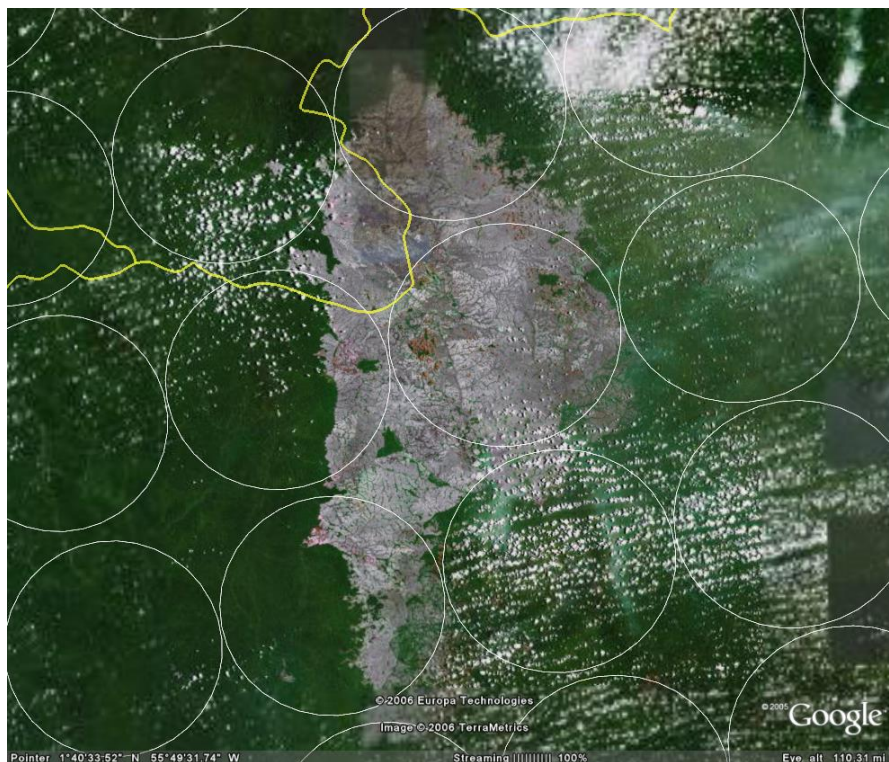

Figure 4. Zoom in of Amazon vicarious calibration site showing deforested area, which presumably will have different emissivity from surrounding forest.
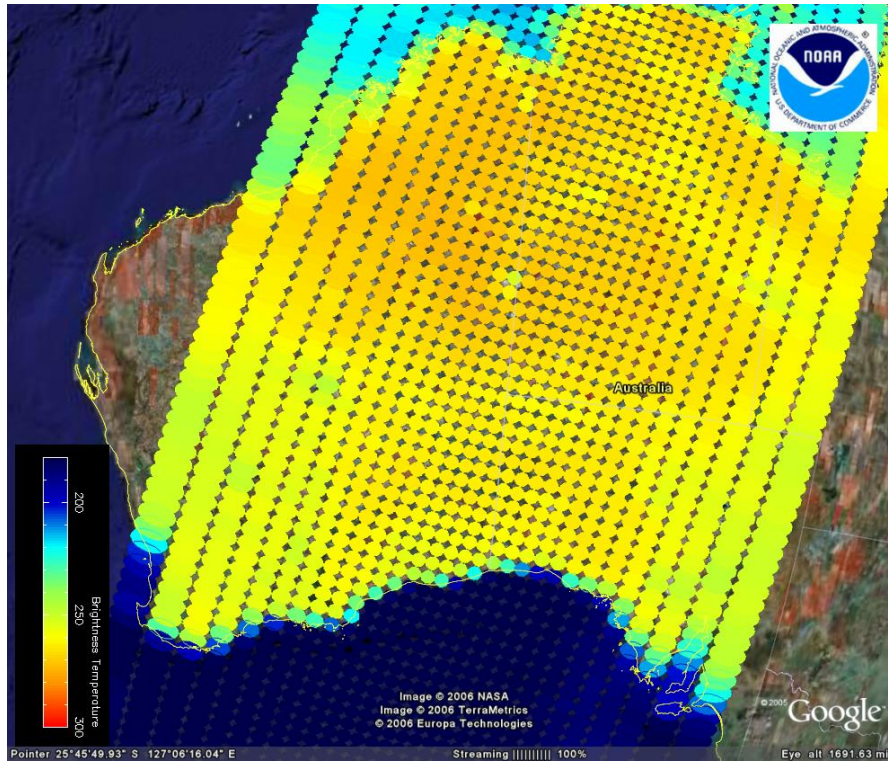
Figure 5. AMSU Channel 1 antenna temperatures over Australia at
100% Opacity. This image clearly shows the partially filled fields
of view at coastlines. It is coincidental that the color representing the
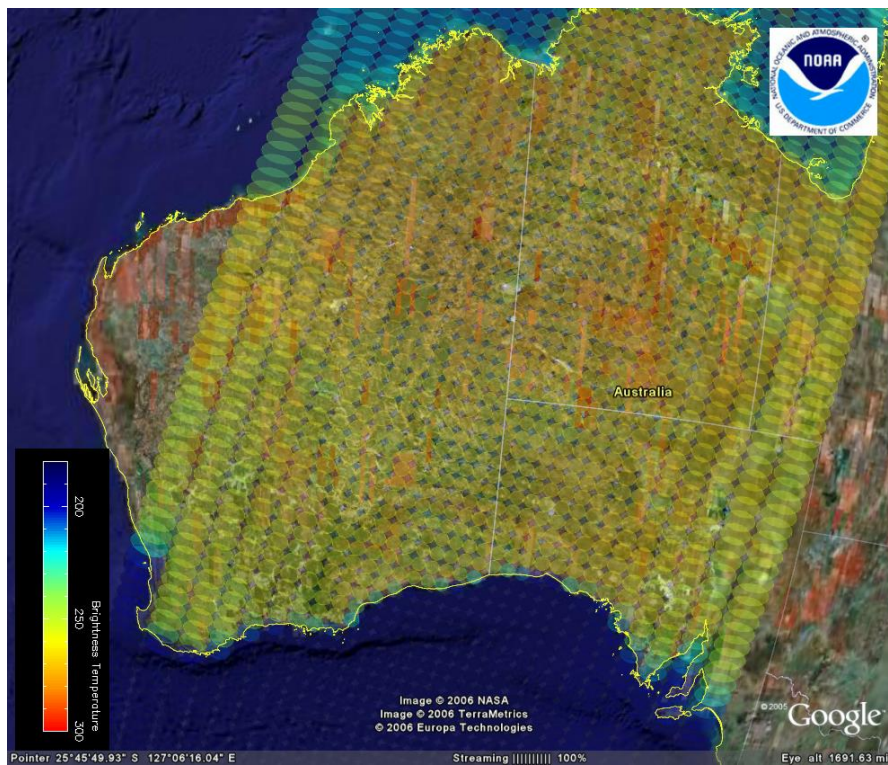coded antenna temperatures is the same color as the
Google Earth ocean color.

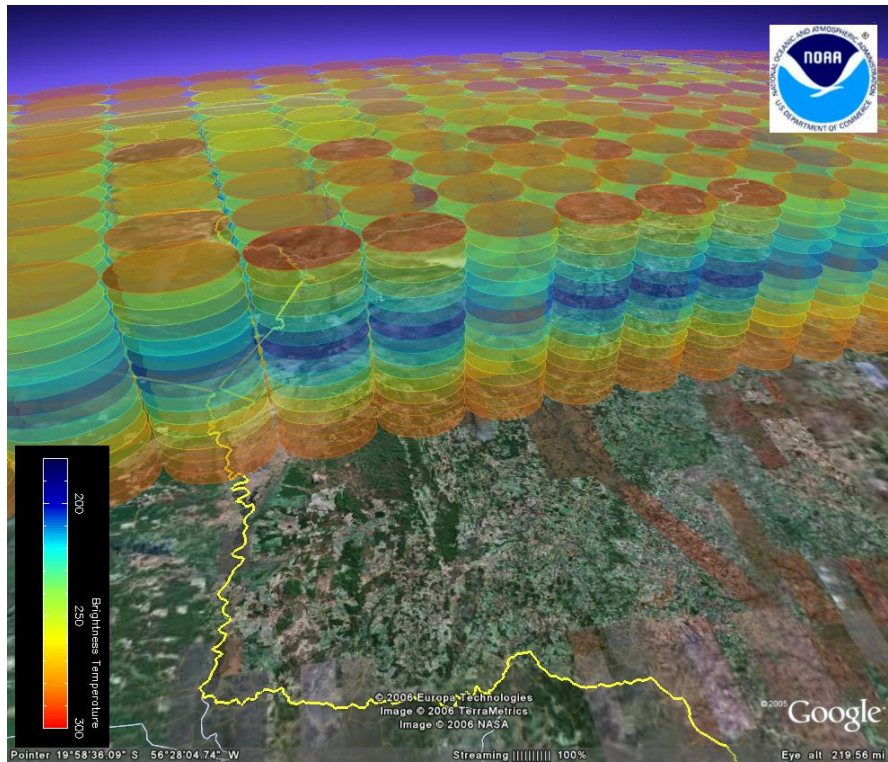**Figure 6.** Same as Fig. 5 but with 50% opacity.

Figure 7. All fifteen AMSU-A channels stacked at 10km intervals.
from the surface to the top, the channels can be seen
to cool through the troposphere, and warm through the
stratosphere. Channel 15 at the top is actually a surface
channel and thus responds to surface properties.