6.14 GIS CALIBRATION AND VALIDATION OF SATELLITE MEASUREMENTS

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1. INTRODUCTION

This paper addresses the potential of Geographic Information System (GIS) technology to support the Calibration and Validation (CAL/VAL) of satellite remote sensors and measurements on a global basis. GIS utilities for the CAL/VAL of remote sensing instruments and products have been prototyped using NASA Earth Observing System (Eos) MODIS data and supplemental or "ancillary" information from ground based and airborne (in situ) platforms. GIS provides broad capabilities "out of the box" for remote sensor and ancillary data acquisition, data management, display and interactive editing, and data processing in multiple dimensions, including spatial/relational methods in time and space. GIS can also incorporate external user functions and programs with a user-configurable interface, and can be quickly adapted to changes in sensor operating characteristics and environments.

The results of this study demonstrate the broad capability of Commercial Off-The-Shelf (COTS) GIS to support the CAL/VAL of space-based sensors and their associated Sensor and Environmental Data Records (SDRs & EDRs). These simulations were performed using the ESRI ArcView GIS suite (version 3.2) on a Microsoft NT platform, including the Spatial Analyst and 3D Analyst extensions. Future plans include a transition to ESRI ArcGIS (ArcView version 8.x) currently underway with an SDE-driven distributed geodatabase.

2. SENSOR SPACE vs. MAP SPACE

Remotely sensed imagery can be displayed and manipulated by GIS in either a "sensor space" or "map space". Map space is a standard geographic projection where remotely sensed data is remapped with respect to projection coordinates (e.g. Fig. 1) Sensor space is a regular rectangular grid of data as observed by the sensor, and is typically mapped by cross-track angle (x) and scan line (y) for cross-track scanning sensor systems (e.g. Fig. 2). Each has computational and display advantages and disadvantages. In map space, satellite imagery is remapped to a standard map dataset. In sensor space, the map dataset is "warped" to match the unique satellite point of view.

MODIS data is distributed in "granules", typically comprised of contiguous and complete image lines but of variable size. The moderate resolution channels are 1-km pixels organized in about 204 scans of the 110 degree cross-track MODIS swath. This swath is sampled approximately 1354 times, and each scan samples 10 spatial elements in each data frame. Therefore, the MODIS granule contains about 1354 by 2048 pixels (Nishihama et al).

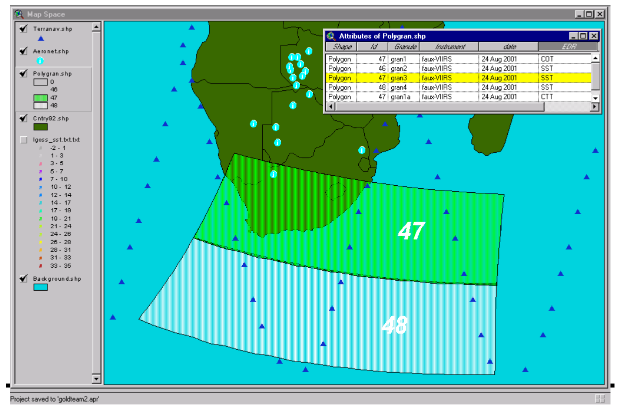

Figure 1 – Conventional "map space" view of MODIS data granules over Southern Africa. GIS provides an integrated relationship between the spatial data objects (granules #47 and #48) and an associated relational data table (inset with granule #47 selected).

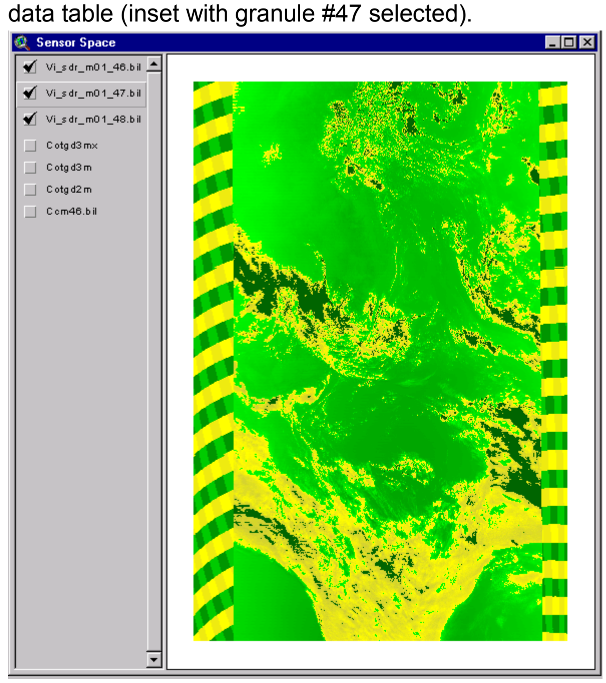

Figure 2 – MODIS data granules for August 24, 2000 corresponding to the spatial objects in Figure 1. Three contiguous granules are shown (#46 - #48) running from top to bottom with 2048 lines each. Padding has been inserted to the edges to simulate the wider domain of the proposed VIIRS sensor.

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3. APPLICATION TO FIELD EXPERIMENTS

SDR/EDR validation requires the collocation of several disparate data sets. Fig. 3 shows the map space finished product for cloud properties (every 16th point) with an overflight of the ER2 aircraft on 24 Aug 2000 from the SAFARI Field Experiment (Spinhirne & Hart, 2001), plus ground-based AERONET sites (http://aeronet.gsfc.nasa.gov:8080/). This approach allows the full use of GIS tools for comparison of MODIS data products with aircraft and ground-based instrumentation both spatially and temporally. GIS x-y coordinates can also be used to map cross sections (x-z), time series (f-t), and even spectral information.

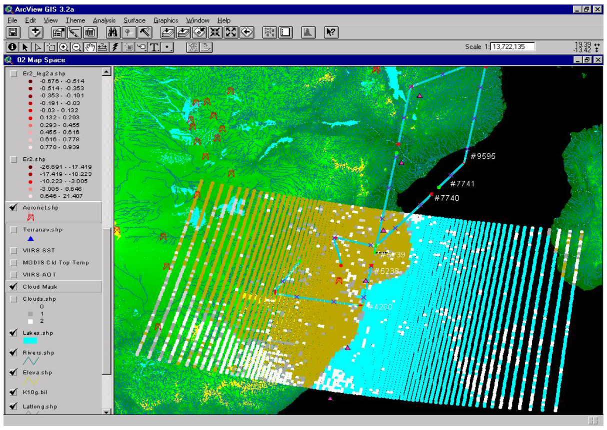

Figure 3 – Map space view of granule #46 on 24 August 2002 over Southeastern Africa (and Madagascar), with overlay of flight track of the ER2 cloud lidar (Spinhirne & Hart, 2001).

3.1 *Spatial Registration Example*

Fig. 4 shows a 5-minute swath of MODIS data taken from Eos Terra on March 1, 2000, during an overflight of the Kansas CART site as part of the U. Wisconsin WISC T2000 Experiment. Also shown on the 5-minute granule is the map overlay of state boundaries and one-minute ephemeris points transformed to sensor space, plus lakes and reservoir spatial databases at 1:50,000 scale. These features are visible in the MODIS imagery in cloud free regions and can be used to verify spatial registration. In this example, the preliminary Terra ephemeris was found to be displaced to the right of the ground track by 14 km. This error was corrected in the final ephemeris provided after image geolocation by the MODIS Team.

Fig. 5 shows the ER2 overflight of the CART site on 1 Mar 2002 with cloud lidar data in 3-dimensions. GIS provides the ability to view the registration of cross sections and surfaces in space and time (x,y,z,t). The cloud lidar cross section in Fig. 5 shows thin cirrus at 6 to 9 km over a 15-minute sampling period. Comparing Figs. 4 and 5, it is interesting to realize that the MODIS image is nearly instantaneous relative to the lidar cross section, and that they coincide in time and space only at one point. Spatial coherence limits the ability to validate SDR/EDR products after significant time delays.

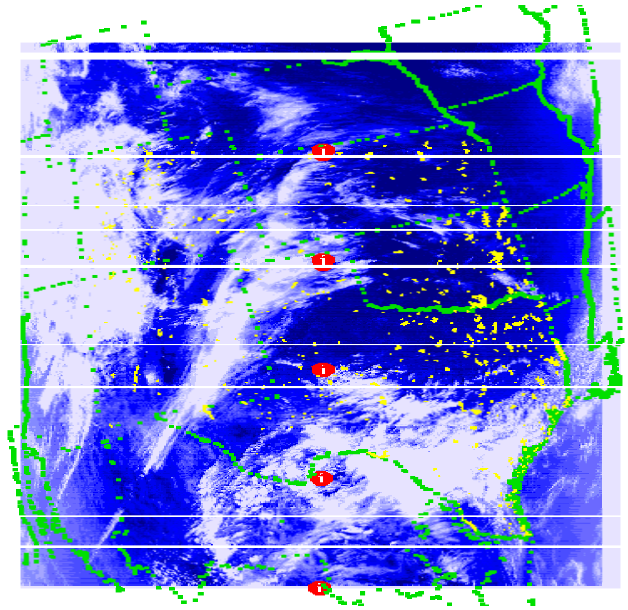

Figure 4 – Eos Terra, MODIS overflight of the Kansas CART site during the U. Wisconsin WISC T2000 Experiment in sensor space. (Huang, 2000)

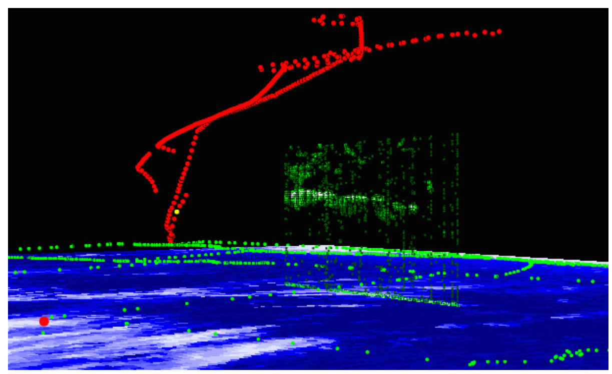

Figure 5 – ER2 flight track with cloud lidar data in 3 dimensions. A thin cirrus layer is shown at 6 to 9 km (Spinhirne & Hart, 2000).

4. REFERENCES AND ACKNOWLEDGMENTS

Spinhirne, J.S. and Hart (2000, 2001) ER2 Cloud Lidar data (personal communication).

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Nishihama, M., R. Wolfe, D. Solomon, F. Patt, J. Blanchette, A. Fleig, E. Masuoka (1997) MODIS Level 1A Earth Location: Algorithm Theoretical Basis Document Version 3.0.

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