# P5.12 A Proposed Multiangle Satellite Dataset Using GEO, LEO and Triana

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## 1. INTRODUCTION

Simultaneous multi-angle viewing of the Earth has recently been achieved with multi-angle satellite instruments such as POLDER (Polarization and Directionality of the Earth's Reflectance), MISR (Multi-angle Imaging Spectro-Radiometer) and the ATSR2 (Along Track Scanning Radiometer). These multi-viewing instruments on polar orbiting satellites are useful for estimating several parameters including cloud height, optical depth and phase. However, due to orbital constraints and matching difficulties, the applicability of data from multi-angle instruments on a single satellite and the dual views from paired satellites has been limited in angular coverage and temporal sampling.

The Triana satellite with the Earth Polychromatic Imaging Camera (EPIC) is designed for insertion into a Lissajous orbit around the L1 point (Valero et al. 1999). EPIC is an imager with a nominal resolution of 8 km at nadir and 10 channels that include several solar bands common to many operational and research meteorological satellites, such as 0.645-μm visible (VIS) channel. Images of the Earth will be taken with 3 or more EPIC channels every 15 minutes. Thus, every Earth-viewing low Earth orbit (LEO) or geostationary Earth orbit (GEO) satellite imager observing the sunlit Earth will have the potential for viewing the same location as Triana to within ± 7.5 minutes. Because of Triana's orbit, the EPIC will view 83 to 98% of the sunlit Earth at a scattering angle varying between 165° and 177°. However, most views from other satellites are at scattering angles between 60° and 170°. Since reflectances in the back-scattering direction are very sensitive to features such as cloud particle shape (e.g., Chepfer et al. 2001) or surface canopy structure, the EPIC will provide a unique contribution to Earth remote sensing.

Radiance measurements from the Triana EPIC will be continuously matched with operational and research satellite data to create a new source of data for multi-angle studies of the Earth and atmosphere. This paper describes the development of the proposed multi-angle dataset and applies it to currently available datasets. The Triana dataset is simulated using Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite. The simulated Triana EPIC data are then matched with several GEO satellites (GOES-East, GOES-West, and GMS-5) and LEO satellites, including MODIS and the AVHRR (Advanced Very High Resolution Radiometer) on NOAA-12, NOAA-14, 15, and 16. A technique is developed to collocate and nearly simultaneously match visible images from Triana with current available satellites to build new multi-angle, multi-satellite VIS imagery. The imager data from each satellite will be matched to the Triana's EPIC view within 5-15 minutes. This methodology will also be useful for combining currently available datasets.

## 2. METHODOLOGY

### *2.1 Image Matching and Extracting*

The first steps in creating the matched dataset are image selection and pixel extraction. Programs were developed for the Man-computer Interactive Data Analysis System (McIDAS; Lazzara et al. 1999) to search through all available satellite image files organized in the Abstract Data Distribution Environment (ADDE) to find matching

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images. The criteria for pairing images include common regions, time $t$, and tolerant time difference $\Delta t$. The matched simultaneous measurements of Triana, all GEOs and LEOs are defined as collocated measurements made within $\pm\Delta t$ = 5-15 minutes of specific time $t$. For VIS data, the solar zenith angle SZA is specified to be less than 90°. Each pixel's latitude and longitude are obtained from the navigation information of each satellite. If the pixel is located in a matching region, its SZA, view zenith angle VZA, relative azimuth angle RAZ and scattering angle SCA are calculated. The most current calibrations (e.g., Minnis et al. 2001) are used to convert the observed pixel's brightness count or radiance to reflectance. These values are stored into an intermediate file, designated the Multi-View Dataset (MVD) Level 0.

### *2.2 Image Gridding and Merging*

The SZA, VZA, RAZ, SCA and reflectance of matching pixels are averaged into a grid box, such as 0.2° latitude by 0.2° longitude. These grid-averaged variables from a given satellite are output into a Hierarchical Data Format (HDF) file, which organizes all values from one satellite as an independent group. The dataset is called the Multi-View Dataset Level 1 (MVD1).

### *2.3 Structure of MVD HDF File*

Figure 1 shows the structure of a multi-view angle dataset. The MVD1 is written in standard HDF using HDF-defined data models, such as the Scientific Data Set (SDS), the Vdata, and the Vgroup model. Each HDF Vgroup acts like a container that holds all information associated with one satellite.

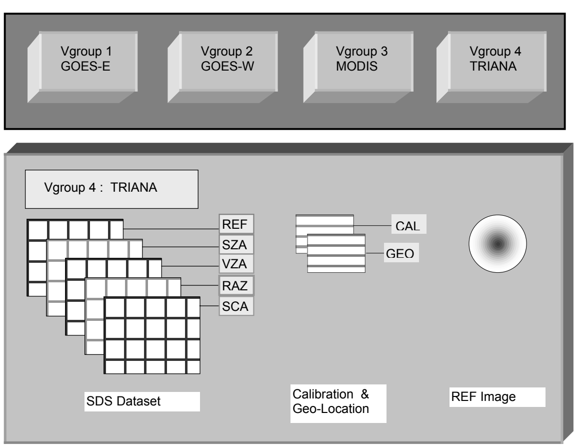


Figure. 1. Schematic structure of MVD1.

## 3. EXAMPLE DATA

An example data set is created here to simulate the process for Triana.

### *3.1 Simulated Triana EPIC Earth Views*

The 5 MODIS visible channels (0.466 μm, 0.554 μm, 0.647 μm, 0.857 μm and 0.904 μm) are used to simulate hourly Triana EPIC views on September 7, 2000. The MODIS images are analyzed with the CERES cloud retrieval algorithms to define each pixel according to surface type and state of cloudiness. Anisotropic correction factors are applied to each pixel according to the amount of cloudiness and underlying surface type to compute the spectral albedo. Thus, each pixel has a record of angles, scene type, and albedo. These pixels are then used to simulate the view from Triana.

Since Triana will orbit around the L1 point in an elliptical path that takes it from within 4° to as far as 15° from the L1 position, its orbital parameters can be specified for nearly any conditions that satisfy those constraints. The simulation here uses a satellite position of $10^o$ north and $10^o$ east of L1 in the simulation. The latitude and longitude of the Sun nadir point (same as the L1 sub-point) varies with time. For example, at 1800 UTC, the sun nadir point is at $5.84^o$N and $90.53^o$W. Thus the Triana's nadir point at 1800 UTC is at $15.84^o$N and $80.53^o$ west. The simulated Triana view has an 8-km resolution at its nadir point. To simulate the view to any location, the SZA, VZA, and RAZ are first computed for the Triana view and the reflectance for those angles is computed for each MODIS pixel by applying directional and bidirectional reflectance models to the albedo for each pixel. The models depend on the scene type. The size and latitude-longitude boundaries for each Triana pixel are then computed with spherical geometry to account for growth of the pixel with VZA. The reflectance for each Triana pixel is then computed by averaging the reflectance for each of the MODIS pixels as computed for the Triana angles. Although a nearly complete 24-h Triana dataset has been simulated (see http://www-pm.larc.nasa.gov/, click on Triana) the simulated Triana dataset for matching is initially computed only for the time of the actual MODIS data obviating the need for the directional reflectance models. With these simulated Triana chunks, it is now possible to perform the matching process with other satellites.

### *3.2 GEOs, LEOs and MODIS data*

GOES-8 (east), GOES-10 (west), NOAA-14 AVHRR and MODIS image data were collected for September 7, 2000. All four datasets, including the simulated Triana data were calibrated to each other using the results of Minnis et al. (2001) and the approach of Nguyen et al. (1999).

## 4. RESULTS

The ARM SGP (Southern Great Plains) region (105°W - 91°W, 30°N - 40°N) is used to demonstrate the multi-view angle, multi-satellite dataset. Figure 2 shows, from top to bottom, the VIS reflectances (left column) and scattering angles (right column) at 1800 UTC, September 7, 2000 for GOES-E, GOES-W, MODIS and the simulated Triana EPIC. The latter image for EPIC has an almost constant scattering angle between 166° and 167°. GOES-E also has a near retro-reflection scattering angle between 160° to 163° for the selected region. The scattering angles for GOES-W are between 128° to 131°. The MODIS scattering angles vary from 100° to 150°.

Typically, clouds are more reflective in the backscatter and forward scatter directions than in the cross-scatter (~90°) direction or near nadir. Clear land surfaces are most reflective in the retro direction, except at large SZAs. The results in Fig. 2 confirm these general characteristics. The clear and cloudy areas for both GOES-E and Triana are noticeably brighter than either MODIS or GOES-W. Because MODIS has more views near nadir, it is darker than GOES-W. The consistency between the GOES-E and simulated Triana images conforms the approach used to simulate the upcoming Triana imagery. Careful examination of the images reveals the presence of some geolocation differences between various cloud features. These are due primarily to time differences and to parallax effects due to cloud altitude.

## 5. FUTURE RESEARCH

The results shown here represent the beginning of this process. A useable hourly matched multi-angle satellite dataset will be produced prior to the Triana launch. Those datasets will be used for some initial scientific studies. Concurrently, we will develop methods to account for the spatial and temporal mismatch of cloud fields because of (1) movement between image times, (2) parallax due to cloud, and (3) navigation errors for each pixel. To solve those problems, we will correlate the pixels for the entire image chunk initially, and then progress to correlations of pixels having similar temperatures rather than a single set of pixel shifts for each image.

The dataset derived with this technique will be used to determine cloud phase, particle shape, and height. The dataset will also be made available to the scientific community for other studies. An application package with a GUI interface will be developed to let users browse and analyze the Multi-View Angle Dataset much easier.

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