

Visualizing Airborne and Satellite Imagery

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Abstract

Remote sensing is a process able to provide information about Earth to better understand Earth's processes and assist in monitoring Earth's resources. The Cloud Absorption Radiometer (CAR) is one remote sensing instrument dedicated to the cause of collecting data on anthropogenic influences on Earth as well as assisting scientists in understanding land-surface and atmospheric interactions. Landsat is a satellite program dedicated to collecting repetitive coverage of the continental Earth surfaces in seven regions of the electromagnetic spectrum. Combining these two aircraft and satellite remote sensing instruments will provide a detailed and comprehensive data collection able to provide influential information and improve predictions of changes in the future. This project acquired, interpreted, and created composite images from satellite data acquired from Landsat 4-5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper plus (ETM+). Landsat images were processed for areas covered by CAR during the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS), Cloud and Land Surface Interaction Campaign (CLASIC), Intercontinental Chemical Transport Experiment-Phase B (INTEX-B), and Southern African Regional Science Initiative (SAFARI) 2000 missions. The acquisition of Landsat data will provide supplemental information to assist in visualizing and interpreting airborne and satellite imagery.

I. Introduction

Remote sensing is the science and art of collecting data about an object or area through a device that is not in contact with the object or area under examination.¹ The sensors used in this project CAR and Landsat 4-5, 7 are electromagnetic energy sensors which are operated from airborne and satellite platforms, respectively. These sensors are also passive sensors, which detect radiation either emitted or reflected by an object or area under investigation. Remote sensing makes it possible to collect data over large areas of interest and also assists in viewing inaccessible or dangerous regions. From these remote platforms, data are acquired to analyze and monitor Earth's resources and processes such as vegetation rates, pollution, weather, and land use.

Remote sensing consists of two processes; data acquisition and data analysis.¹ Data acquisition is a tedious process, which in itself requires steps in order to collect useful data. Data analysis is a procedure that involves data examination and manipulation in order to present understandable information. The particular steps to data acquisition are as follows:

- Energy is emitted from a source, for example the sun.
- Energy passes through and interacts with the atmosphere.
- Energy interacts with the Earth's surface.
- Energy is retransmitted through the atmosphere.
- Energy signal is sensed by the airborne or satellite sensors.
- Sensor data are generated into pictorial or digital format.

Data analysis encompasses the analysis of the sensor data, the analysis and extraction of more information about the area of interest, the compilation of information, and the application of information to users' work.

This project encompasses two types of remote sensing instruments; an airborne instrument, CAR, and satellite instruments, Landsat 4-5 and Landsat 7. This project acquired, interpreted, and created composite images from satellite data acquired from these two satellites. By referencing CAR flight paths and significant features in the CAR quicklook images, it is possible to create a composite Landsat image for areas covered by the CAR during the

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ARCTAS, CLASIC, INTEX-B, and SAFARI missions. The acquisition of Landsat data will provide supplemental information to assist in visualizing and interpreting airborne and satellite imagery.

II. Background

A. Cloud Absorption Radiometer (CAR)

The CAR is a fourteen spectral band airborne multi-wavelength scanning radiometer. The CAR is a National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) in-house instrument developed by Dr. Michael King with the current Principal Investigator being Dr. Charles K. Gatebe. The CAR is designed to:

- Determine the single scattering albedo of clouds
- Measure angular distribution of scattered radiation
- Acquire bidirectional reflectance measurements of various surfaces
- Obtain images of cloud and Earth features

This instrument scans 360° and collects data through a 190° aperture (five degrees before zenith and five degrees after nadir). The remaining 170° is used for temperature collection of detectors, door status, and other housekeeping items, darken detectors, and calibration of internal input ports. The cycle continues in collecting data and maintaining the equipment to ensure in accurate data collection.*

This instrument is able to operate from various aircraft and collect data in four different viewing positions. These positions; starboard viewing mode, downward-looking imaging mode, upward-looking imaging mode, and bidirectional reflectance distribution function (BRDF) viewing mode, allow the CAR to collect various types of data. BRDF measurements are needed in remote sensing for the correction of view and illumination angle effects. The aircraft housing the CAR must make circular flight patterns over the area of interest in order to collect the BRDF measurements as shown in Figure 1.

The CAR has been launched on many missions around the world including Alaska, the continental United States, Africa, Central America, and various other countries. The CAR has been flown in missions such as ARCTAS (2008), CLASIC (2007), INTEX-B (2006), SAFARI (2000), and many others.

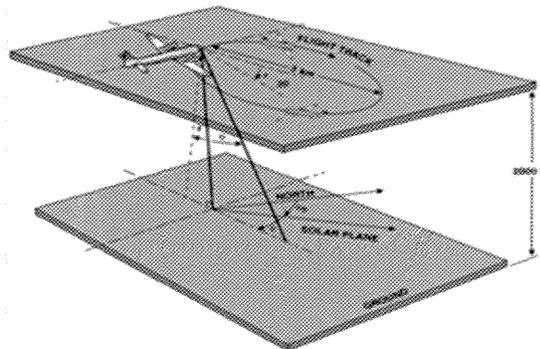


Figure 1: BRDF Flight Pattern. Multiple circular flight paths must be made in order to collect the BRDF data.

1. Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS)

Due to sensitivity in surface air temperatures, Polar Regions could provide evidence of anthropogenic influences on temperature changes across the globe. The melting of ice sheets has the potential to cause disastrous effects on humans because of the sea level rise and the possible effect of ocean and atmospheric circulation.

The ARCTAS mission provided opportunities to study the Arctic atmosphere and surface properties and processes from ground-, airborne-, and satellite-based measurements in an integrated manner. ARCTAS focuses on advancing understanding of the factors driving current changes in the Arctic region including transport of mid-latitude pollution, boreal forest fires, aerosol radiative forcing, and chemical processes.*

Many impacts can disrupt the natural cycle of the Arctic atmosphere such as pollutants, biomass burning, industrial, urban, and shipping activities, and natural emissions. These impacts alter the chemistry of the Arctic atmosphere and also affect the interactions between the atmosphere and surface.

Many factors on Earth play a role in acquiring optimal satellite images of the Arctic. These factors being; widespread cloud cover, seasonal darkness, and low sun angles. Imagery and data collected by the CAR in conjunction with satellite data can provide the validation, retrieval constraints, correlative data, and process information needed to provide a detailed and comprehensive data collection for the Arctic region.* The satellite and aircraft combination will provide influential information and improve predictions of changes in the future of the Arctic region.

The CAR was deployed from April 1, 2008 to April 21, 2008 to sample pollution plumes, fire plumes and halogen radical events. Flights from June 22, 2008 to June 24, 2008 and June 16, 2008 to July 12, 2008 were

* <http://car.gsfc.nasa.gov/index.php>

focused on boreal forest fire influences and California air quality and climate forcing. The CAR obtained imagery of clouds and Earth surfaces in the Arctic and measured spectral and angular distribution of scattered light by aerosols, clouds, snow, sea ice, and melt ponds in various of conditions in order to determine BRDF, and hence albedo, of sea ice, water ponds, and clouds, and to determine aerosol optical properties over various surfaces for satellite validation.*

2. *Cloud and Land Surface Interaction Campaign (CLASIC)*

During the summer growing season, the transportation of heat, moisture, and energy from the surface to the atmosphere, cumulus convection, is a significant component in the atmospheric radiation budget and hydrologic cycle of the United States Southern Grain Plain. Anthropogenic changes in the land related to plowing, crop rotation, and additional farming techniques can influence cumulus convection.

CLASIC worked closely with the CHAPS (Cumulus Humilis, Aerosol Processing Study) campaign. The collaboration of CLASIC and CHAPS will be used to compare aerosols above, below, and within areas of cumulus humilis. This information is vital in comparing cumulus humilis in areas downwind of cities to similar cumulus humilis in less polluted areas. The observations between these two environments will assist in the assessment of the transportation of aerosols by cumulus humilis at a local and global scale.

The CAR was deployed from June 9, 2007 to June 30, 2007 collecting images of clouds and Earth surfaces over Oklahoma. Spectral and angular distribution of scattered light was collected for clouds and aerosols as well as the bidirectional reflectance of various surfaces. The collection of various data is able to promote understanding between participants within the campaign and outside users.

3. *Intercontinental Chemical Transport Experiment-Phase B (INTEX-B)*

The transportation of pollutants causes great risk to health, agriculture, natural ecosystems, and man-made structures. In order to manage air quality effectively, local air quality risks are evaluated as well as emissions transported from other regions and continents.²

INTEX-B was one of four campaigns associated with MILAGRO (Megacity Initiative: Local and Global Research Observations), an initiative to measure pollutants and study the atmospheric processes leading to the development of secondary aerosols. The transportation and transformation of these gases will also supply new understanding on the chemistry of the atmosphere around megacities and the potential impact on a global scale. INTEX-B focused primarily on the long-range transportation of pollution, global atmospheric photochemistry, and the effects of aerosols and clouds on radiation and climate.³

The CAR was deployed from March 1, 2006 to March 20, 2006 collecting images of clouds and Earth surfaces over Mexico City, Veracruz, and additional areas of Mexico along the east coast. Spectral and angular distribution of scattered light was collected for clouds and aerosols as well as the bidirectional reflectance of various surfaces.

4. *Southern African Regional Science Initiative (SAFARI)*

Land-surface atmosphere interactions influence the energy and water cycle of the planetary boundary layer. The effect of humans and their emissions can cause disruption to this cycle. Understanding the interaction between land-surface and atmospheric cycles will provide the information needed to identify the effects of anthropogenic emissions on a diverse ecosystem.⁴

SAFARI provided the opportunity to understand and identify the association between the biological, geological, physical, and chemical systems of southern Africa. This mission concentrated on the anthropogenic emissions within the African ecosystem. Emphasis was centered on the transportation and transformations of emissions in the atmosphere, the influence on the local climate, the deposition of the emissions, and the effects of deposition on ecosystems.

The CAR was flown on twenty-one trips from August 15, 2000 to September 16, 2000 over Southern Africa to obtain measurements of BRDF for a variety of surfaces and ecosystems. In order to complete the mission, various techniques such as remote sensing, computational modeling, airborne sampling, and ground-based studying are all needed to gain valuable information on an ecosystem.

B. Landsat

The Landsat Program has provided over thirty-nine years of high-resolution data managed jointly by NASA and the United States Geological Survey (USGS). The Landsat satellites have enabled users to study Earth and evaluate the changes brought by natural and human processes. Landsat 7 ETM+ and Landsat 4-5 TM were the satellites specifically used in this project.

Landsat 4-5 is a polar-orbiting satellite with a sixteen day repeat cycle capable of providing a repetitive acquisition of multispectral data of Earth’s surfaces. Landsat 4-5 differed from the previous three Landsats in that Landsat 4-5 had a new instrument known as the Thematic Mapper (TM) which improved the spectral and spatial resolution. Data on Landsat 4-5 was also collected from seven spectral bands compared to the previous four spectral bands.

Landsat 7 replicated the capabilities of Landsat 4-5 while also enhancing features to make Landsat 7 more efficient in climate change studies and land cover monitoring. These additions were a panchromatic band with fifteen meter spatial resolution, a thermal infrared channel with sixty meter spatial resolution, a five percent radiometric calibration, and on board data recorder. A little over four years after the launch, the Scan Line Corrector (SLC) failed on May 31, 2003. Without an operating SLC, the line of sight makes a zigzag pattern which acquires approximately seventy-five percent of the data for any scene.[†]

III. Methodology

A. Study Areas

The areas of interest were the regions captured by the CAR and the path the aircraft flew on the missions ARCTAS, CLASIC, INTEX-B, and SAFARI 2000. These areas included but are not limited to regions in the Arctic, areas of Canada, the United States, Mexico, and southern Africa. Figure 2 depicts the areas covered by the CAR during the four missions for which Landsat images were processed.

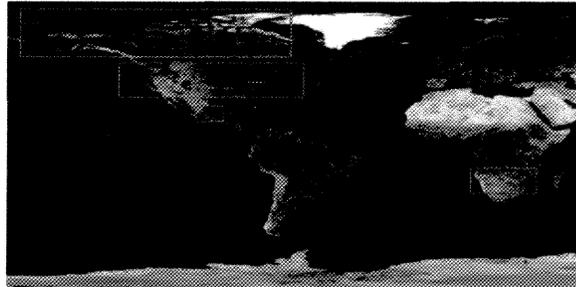


Figure 2. Study Areas. Areas included in the red rectangles are the areas of interest for missions ARCTAS, CLASIC, INTEX-B and SAFARI.

B. Data Acquisition

The USGS Global Visualization Viewer Landsat Archive was used to obtain the Landsat data. Scenes were collected from Landsat 7 ETM+ and Landsat 4-5 TM. The Landsat images were collected close to the CAR flight date and if no data were available, the images were chosen based on low cloud cover and continuity between images. The satellite images were acquired based on latitude and longitude coordinates on the CAR flight paths. Once the satellite images are collected, the images are then verified by the features within the CAR quicklook image as shown in Figure 3. While on the USGS website (<http://glovis.usgs.gov/>), the images were checked for cohesiveness from scene to scene over the area of interest.

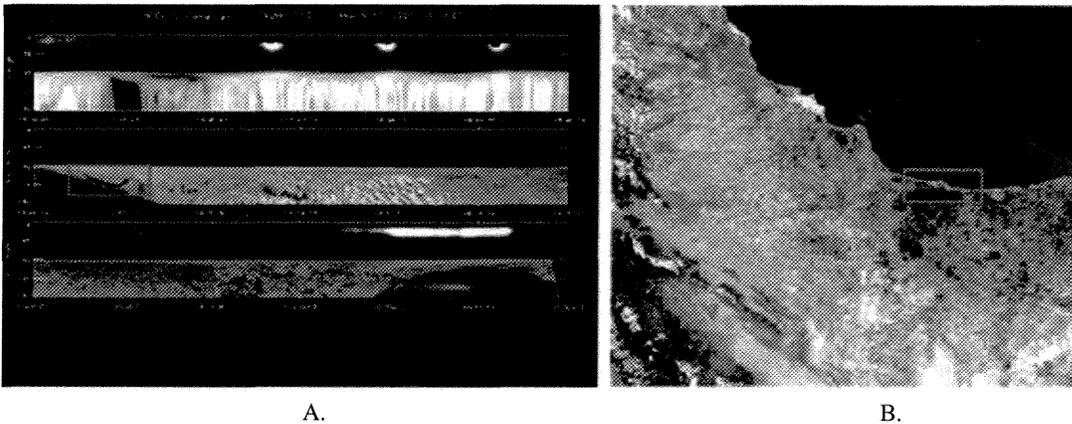


Figure 3. Verify images. To ensure features are in the final Landsat images, features are found in the CAR quicklook image (a) and then found in the Landsat scene (b).

[†] http://landsat.usgs.gov/products_slcoffbackground.php

C. Data Analysis

In order to process and analyze the images, an image processing and analysis software, ENVI 4.8 was used. Bands 3, 2, 1 (Red, green, blue) were opened in ENVI and were stacked to make a “true color image.” Layer stacking is used to build a new multiband file from georeferenced images of various pixel sizes, extents, and projections.[‡] The projection is automatically selected as UTM (Universal Transverse Mercator) coordinate system. The UTM is a grid based method of specifying location on Earth. This method is a horizontal position representation which allows users to identify locations on Earth independent from vertical position.

A Region of Interest (ROI) is then created to trim the visible displacement of the bands on the image using the polygon instrument. The displacement can be seen in Figure 4 to the right. Once the ROI is saved, a mask of the image can be created. Masking the image instructs the computer to keep the ROI and dispose of the material not included in the ROI (in this case, the displacement of bands in the image.)

Once all of the scenes are masked, a georeferenced mosaic is generated. Mosaicking is the process of combining multiple scenes into a single composite image. The georeference option establishes the position each scene is to be displayed within the area of interest. Upon inputting images into the mosaic, data values to ignore must be set to zero; not doing so will result in a mosaic image with missing areas and inaccurate data.

A clean, crisp image is ideal for the final image and to avoid losing data while masking, the image is rotated 350 degrees clockwise. Once again, a mask is created from the image using a selecting tool in ENVI, to obtain a well-defined image. To provide a sense of location, a latitude and longitude overlay is applied to the image. The file is exported and saved as a Portable Network Graphics (PNG) file.

In many ocean scenes, data are not collected continuously resulting in no continuity between these ocean scenes. So these images were imported into paint. While in paint, a color was selected from the Landsat ocean image and the ocean was made one cohesive color.

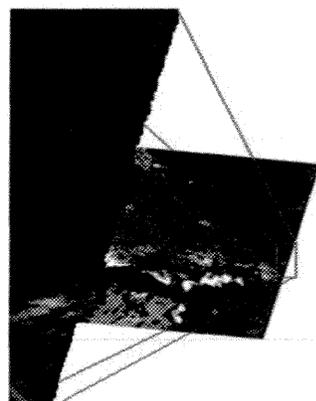


Figure 4. Visual displacement of bands. *The image enlarged depicts the band displacement of the “true color” INTEX-B Flight 1913 scene.*

IV. Results

The result is a 300 x 300 meter pixel Landsat image (Figure 5b) over the specified area of interest. A final comparison to the flight track map is performed to assure the flight path and features are present in the Landsat image created. The Landsat imagery processed will be available on the CAR website (<http://car.gsfc.nasa.gov/data>).

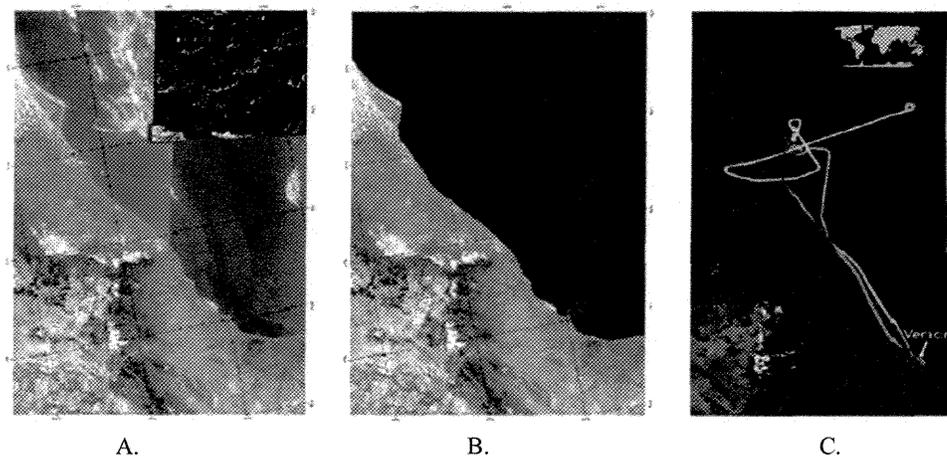


Figure 5. Images of INTEX-B for Flight 1913. *A before (a) and final (b) image of Flight 1913. The final image (b) is compared to flight track map (c) to ensure all features are included in the final Landsat image.*

[‡] http://www.gps.caltech.edu/gislab/howto/docs/Processing_ASTER_DATA_using_ENVI_4.pdf

V. Conclusion

This project enhanced my skills in image processing as well as developed my ability to correlate features in aerial and satellite images and gained a basic understanding of remote sensing. As this process made me proficient at processing satellite images, I also gained an appreciation of how remote sensing data are used to conduct scientific investigations and its application in areas such as environmental monitoring. In conjunction with this project, my project was displayed in a poster session where I was able to enhance my communication skills as well as display my work in a creative and intriguing way.

During the process of creating the Landsat images, many scenes did not coincide with one another due to cloud cover and other atmospheric effects. An atmospheric correction could have been performed to retrieve the surface reflectance and omit the atmospheric effects. This process would have saved time in searching through many different scenes to make the final image cohesive. This correction may have also produced images closer to the flight date of the CAR.

Future work in providing additional high-resolution data would be acquiring data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). ASTER provides a fifteen meter resolution but only collects eight minutes of data upon a complete orbit, thus scenes over a specific area do not have continuous data. This data could be collected over specific areas where definite BRDF data were collected. Acquisition of this data will further assist in the visualizing of airborne and satellite imagery.

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