White paper brief

IdahoView Imagery Services: LISA[1] Technical Report no. 1 Processing and Evaluation

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Introduction

The use of satellite imagery is becoming increasingly common today. This may be because Landsat and other remote sensing data can be acquired free of charge, however a much broader reason suggests the proliferated use of satellite imagery is due to an increased need for the type of information satellite imagery can uniquely provide. No other technology offers a spatially continuous dataset with the frequent temporal periodicity and multi-decadal historical archive as does Landsat. This rich dataset represents a significant asset to the scientific community to aid research focusing on land cover change, energy balance, and global climate change.

Concurrent with the increased use and need for satellite imagery is the development of web services. Following the vision of Jack Dangermond (esri), numerous organizations and institutions have begun offering geospatial data as a web service and as a result the Geoweb was developed. To date, the great majority of data available via the Geoweb represents framework data commonly used by the GIS community (e.g., seamless roads layers, aerial imagery, state and political boundaries). These services, while widely used and broadly applicable, do not fully leverage the potential of web services. A tremendous advantage of web services are their ability to further improve access to high-quality, value-added satellite imagery that has been consistently processed (i.e., atmospherically corrected using the same techniques), co-registered, and prepared for scientific inquiry (e.g., NDVI). Developing services like these allows researchers to quickly and effectively analyze imagery by eliminating download, extraction, correction, and georectification tasks from the analysis workflow. These services, coupled with detailed pre-processing documentation, will also better allow comparison of results as input data was uniformly produced and documented.

This white paper describes the process of developing NDVI image services, summarizes the results of image service technical evaluations, and provides guidelines/considerations for implementation of similar image services in the future.

Processing

NDVI and cNDVI development

Seventy-eight Landsat 5 TM scenes (path 039 row 030) were acquired between 1984 and 2009 (Appendix A). To capture the phenology and ephemeral productivity periods of the various grasses, forbs, and shrubs in the semiarid rangelands of eastern Idaho, three scenes were used for each growing season (Weber et al. 2009). Capturing peak photosynthetic activity in this region was accomplished by acquiring one or two scenes in the spring (April or May) and one or two scenes in the early fall (September or October) (Pettorelli et al. 2005; Tedrow and Weber 2010). By satisfying these criteria, an increased probability of capturing maximum photosynthetic activity throughout the growing season was more likely achieved.

All acquired imagery were corrected for atmospheric effects using Chavez' Cos(t) model in Idrisi Taiga's ATMOSC module (Chavez 1996). NDVI was calculated using bands 3 and 4 (red and near-infrared, respectively) for each scene using Idrisi Taiga (VEGINDEX). Composite NDVI (cNDVI) layers were created for each year of the study (1984-2010) using the NDVICOMP utility of Idrisi Taiga. cNDVI uses

[1] The LISA project was funded by a grant from AmericaView (http://americaview.org/)

maximum NDVI values observed throughout a growing season and in most cases, three Landsat scenes were used per year to calculate the respective cNDVI layers (Table 1). cNDVI layers were tested for georegistration error using 2004 National Agricultural Imagery Program (NAIP) aerial orthophotography (1m x 1m pixels) and corrected as needed (i.e., where RMSE > 15.0). Image to image co-registration was tested and similarly corrected when needed (figure 1). The resulting cNDVI layers were then used to produce various web services for this study. A graphical overview of the processing steps used to develop the LISA dataset is given in figure 2.

Table 1. cNDVI layers were developed using three NDVI layers each year. To correctly characterize the phenology of each growing season, three distinct time periods were selected; early spring (April 15-May 30); late spring (May 15-June 30), and early fall (September 1-September 30). Input NDVI layers acquired within these time periods were coded with one (true) while input NDVI layers acquired outside this time periods were assigned a zero (false). A concatenation of each code was used to describe the temporal quality code.

	INPUT NDVI LAYERS			
YEAR	**APRIL 15-MAY 30**	**MAY 15-JUNE 30**	**SEP 1-SEP 30**	**TEMPORAL QUALITY CODE**
1984	1	0	1	101
1985	1	1	0	110
1986	1	1	0	110
1987	1	1	1	111
1988	0	0	1	001
1989	0	1	0	010
1990	0	0	1	001
1991	1	1	1	111
1992	1	0	1	101
1993	0	0	0	000
1994	1	1	1	111
1995	0	0	0	000
1996	1	1	0	110
1997	0	0	1	001
1998	1	0	1	101
1999	1	0	1	101
2000	1	1	1	111
2001	1	1	1	111
2002	1	0	1	101
2003	1	1	0	110
2004	1	1	1	111
2005	1	1	1	111
2006	1	1	1	111
2007	1	1	1	111
2008	1	0	1	101
2009	1	0	1	101
2010	0	0	1	001

Optimal cNDVI layers should capture early spring (April 15-May 30) biomass production of annual grasses and forbs, late spring (May 15-June 30) biomass production of perennial grasses and shrubs, and early fall (September 1-September 30) biomass production of grasses. The latter production period does not always occur however but is substantial when weather conditions permit such growth (adequate fall rains and delayed frost). cNDVI layers can be developed regardless of the date of acquisition and in some cases cNDVI layers were produced with imagery from sub-optimal time periods. To facilitate an understanding of the temporal quality of imagery used to produce annual cNDVI layers, a Boolean quality code rating was used (Table 1). Annual cNDVI layers should have a temporal quality code of 111 ($n = 9$) with 000 designating an unacceptable temporal quality code ($n = 2$).

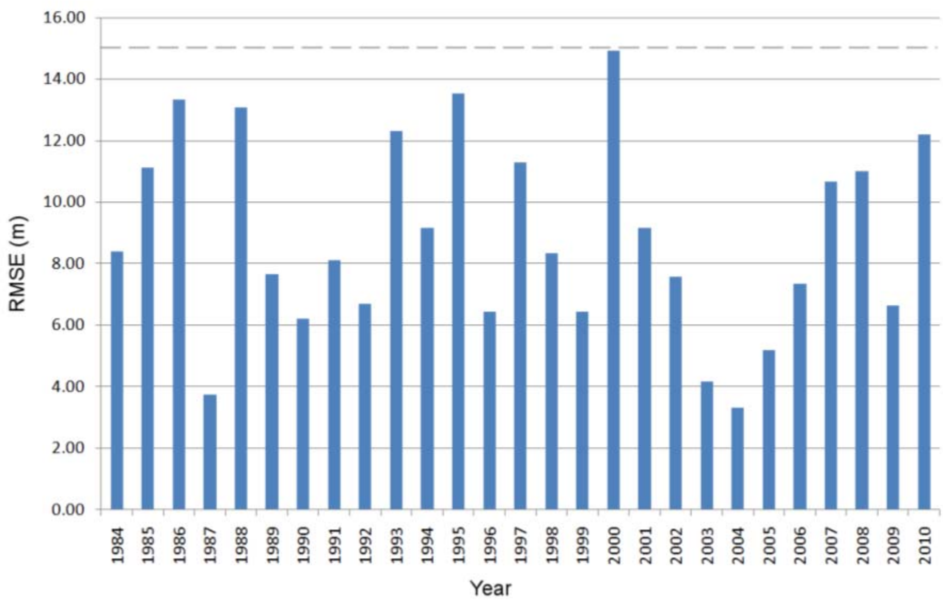

Figure 1. Image to image co-registration results for each cNDVI layer developed. The dashed line (RMSE = 15.0) indicates the maximum allowable RMSE ($\bar{x} = 8.81$; SE = 0.62)

Web service development
A file geodatabase (fGDB) was created using ArcGIS 10 and an empty raster mosaic dataset was created for each year ($n = 27$; 1984-2010). Corresponding cNDVI TIF imagery layers were added to each raster mosaic dataset with overviews, pyramids, and statistics calculated for each during the data loading process. An additional mosaic dataset was then created to act as a master and allow the enablement of temporal queries within ArcGIS 10.

The completed fGDB and associated TIF imagery were copied to a production server and image services were created from each raster mosaic dataset using ArcGIS Server image extension. To allow end-users to easily access the time-enabled features of the fGDB, an ArcMap document was created with necessary features and tools enabled. This map document was then served as a map service. All LISA map and image services are freely available by making an ArcGIS server connection to http://ags.giscenter.isu.edu/arcgis/services.

To further enable accessibilty, ArcGIS layer files were created for each image service and map service. These files were placed on the GIS TReC's spatial library at
http://giscenter-sl.isu.edu/AOC/AOC_Satellite/LISA/

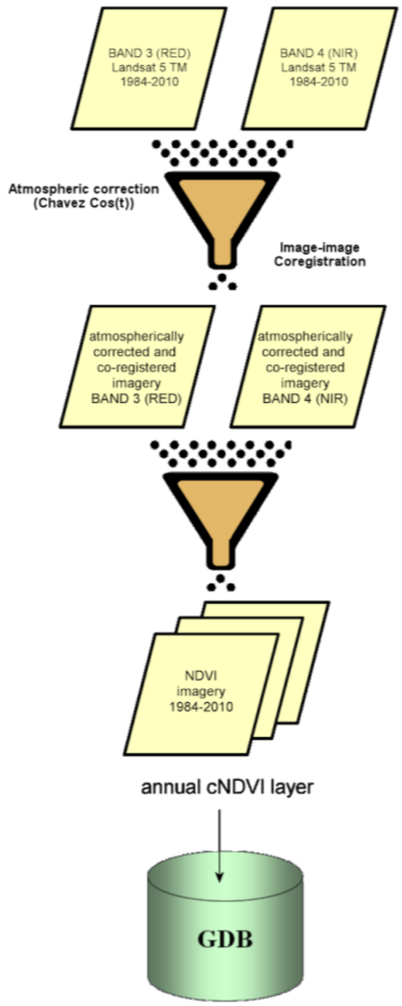

Figure 2. Cartographic model or flowchart of the general processing steps followed to develop the LISA dataset.

Technical evaluation
Following completion of fGDB and web service development a two-week internal test period was conducted. Next, using the Idaho geo-list and AmericaView list-serve, volunteer evaluators were sought to perform a technical evaluation of the LISA services. While only three volunteers and evaluations were received, their results verify the LISA project's functionality and like many other web services, its requirement for fast broadband connectivity (>10 Mbps) to be used effectively. Overall results and comments were very positive. The results of internal testing reveal low server side CPU loading with only a 10.5% processor time commitment and 5.8% processor privileged time (where the CPU was used primarily or wholly by the web services.

Conclusions
Just a few years ago the technologies to enable web services like those leveraged by the LISA project were in their infancy. At that time, standard procedures for using Landsat imagery were workstation-centric and involved each investigator locating, downloading, and processing imagery individually. The LISA project has demonstrated that research-quality imagery can be made available and effectively used as a web service. The implications of this study are numerous and suggest that geospatial scientists can realize improved productivity and a more streamlined research workflow by developing and leveraging similar image service archives.

Appendix A

Table 2.Dates of Landsat 5 TM imagery used to develop NDVI layers throughout each year of the archive.

YEAR	EARLY SPRING	LATE SPRING/EARLY SUMMER	EARLY FALL
1984	13-May	2-Jul	20-Sep
1985	18-May	19-Jun	6-Aug
1986	19-Apr	22-Jun	12-Oct
1987	8-May	25-Jun	29-Sep
1988	13-Jul	29-Jul	15-Sep
1989	30-Jun	17-Aug	n/a
1990	3-Jul	21-Sep	7-Oct
1991	19-May	20-Jun	24-Sep
1992	5-May	24-Jul	26-Sep
1993	11-Jul	12-Aug	28-Aug
1994	11-May	28-Jun	16-Sep
1995	17-Jul	2-Aug	18-Aug
1996	14-Apr	1-Jun	20-Aug
1997	22-Jul	23-Aug	8-Sep
1998	20-Apr	9-Jul	11-Sep
1999	25-May	29-Aug	5-Sep
2000	27-May	28-Jun	16-Sep
2001	14-May	30-May	3-Sep
2002	17-May	4-Jul	22-Sep
2003	20-May	5-Jun	24-Aug
2004	6-May	7-Jun	11-Sep
2005	25-May	26-Jun	14-Sep
2006	26-Apr	12-May	1-Sep
2007	15-May	31-May	20-Sep
2008	17-May	18-Jun	6-Sep
2009	18-Apr	20-May	9-Sep
2010	21-Apr	7-May	14-Oct