GEON: ArcIMS online mapping to facilitate integration of geoscience data

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Abstract

The Colorado Plateau-Basin and Range Transition Zone of Arizona and New Mexico comprises an important geologic setting in which the study of continental crustal evolution and deformation is particularly intensive. In addition, it is a region of rapid population growth where balancing resource use, resource preservation, and sustainable land use is increasingly important. To inform such efforts, we have gathered geological data (e.g., geologic maps at various scales, active fault maps), digital topography (USGS NED and SRTM 30 m), ASTER satellite imagery, and geophysical data (e.g., gravity, heat flow, seismicity, seismic anisotropy, magnetics, receiver functions, seismic tomography), and integrated them using ArcIMS. We have also developed a Java Servlet-driven IDL-cored image processing system to produce user-specified (from imagery footprints in ArcIMS) ASTER band combinations in GeoTiff format. This data system is an initial step in the development of a seamless data and scientific analysis portal as part of the GEON project.

Introduction

As part of the Geoinformatics initiative (`http://www.geoinformaticsnetwork.org`) and the GEON project (`http://www.geongrid.org`), we have constructed a data system for the Southwestern U. S., a region of great current interest to the Earth Science community and a number of state and federal agencies. The system consists of a data repository and specific software tools to exploit and model the contained data. Our team represents a variety of research centers at Arizona State University (ASU) and the University of Texas at El Paso (UTEP)with important collaboration from the US Geological Survey and the Arizona Geological Survey.

The earth science community-based Geoinformatics/GEON initiative is motivated by the recognition that the Earth functions as a collection of complex, interacting systems and that the information and tools being used to study this collection of systems are inadequate. Currently, the chaotic distribution of available data sets, lack of documentation about them, lack of easy-to-use tools to access them, and lack of access to computer codes for modeling Earth structure and processes are major obstacles for all users of Earth Science data-scientists, educators, engineers, planners, and regulators. These obstacles have hindered scientists and educators in the access and full use of available data and information, and hence have limited scientific productivity and the quality of education. Advances in computer design, software, disk storage systems as well as the growth of the World Wide Web (WWW) now permit the management of gigabytes to terabytes of data and the on-demand distribution of information to scientists, educators, students, and the general public. These technological advances provide the means to overcome inadequacies in the tools available for data archiving, distribution, and analysis.

We are constructing an ArcGIS database to constrain the geodynamics and tectonic evolution of the southern regions of the Colorado Plateau (CP)/Arizona Transition Zone (ATZ)/Basin and Range (BR) in Arizona and New Mexico. The CP and BR have responded differently to a broad range of tectonics over the past 100 Ma. Integrated analysis of these data provides important insights into the geologic history, geodynamics, surface processes, and human-earth system interactions in the region. The datasets and tools that we have assembled are highlighted and accessible through an ARCIMS interface: `http://aspen.asu.edu/website/Geoinformatics/viewer.htm`. In addition, most of the data are downloadable and further explained at the SWGEONET website: `http://www.geoinformaticsnetwork.org/swgeonet`. In this paper, we will introduce the database via the ARCIMS interface and emphasize the integrated "on-the-fly" image processing system.

A Geospatial Data System for the Transition between the Colorado Plateau and Basin and Range Provinces (SWGEONET) served up with ARCIMS

Although many geophysicists in particular use other cartographic tools (such as the Generic Mapping Tools–http://gmt.soest.hawaii.edu/), we have chosen the ArcGIS tool suite for our cartographic and geospatial needs. In order to allow those colleagues who do not have these tools or the expertise to use them, we have employed the ARCIMS component to deliver our maps and some GIS data via the Web. Initially, we tried to run it on the Sun-based Solaris platform, but the results were disappointing (poor support for GRIDS), so we now run it on a Windows 2000-based Pentium Xeon server.

Our data sets are divided thematically into remote sensing (NASA ASTER system–see below), political (cities and counties), geophysics point data, geophysics grids, geology and tectonics (mostly shape files), and digital elevation models (see Table 1). Figure 1 shows the topography, active faults (http://qfaults.cr.usgs.gov/), and seismicity for Arizona, New Mexico, and Utah displayed with ARCIMS and illustrating the localization of faulting, earthquakes and higher topographic gradients along the margins of the Colorado Plateau. We have also put considerable effort into the geophysics and geodynamics datasets and have developed a number of case studies such as comparing the gravity versus elevation to evaluate both data processing issues as well as the degree of isostatic compensation of the regional lithosphere, crustal thickness variation as manifest by several seismological techniques, crustal stress versus inferred upper mantle flow patterns (shear wave splitting), and stress orientation versus topographic gradient (Yoburn, et al., 2003 and Yoburn, et al., in preparation).

"On-the-fly" image processing using a Java Servlet Engine to link ARCIMS with image processing software

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER; http://asterweb.jpl.nasa.gov/) is a NASA satellite imaging system that provides synoptic remotely sensed coverage of the earth's surface. Standard ASTER data products from NASA are difficult to process for potential users who are not well versed in image processing or do not have access to the appropriate software. We designed a web-based system that allows a user to identify ASTER scenes of interest and then process them to produce images of broad potential use. These output files are useful at a number of levels of sophistication varying from low level presentation (.jpg) to incorporation into higher level Geographic Information Systems (GIS; full resolution and rectified GEOTIFF).

Our ASTER scene processing and delivery method uses a Java Servlet Engine with a Java server to link ARCIMS to our image processing scripts which are written in the Interactive Data Language (IDL). The IDL scripts take the original ASTER image data as delivered from NASA, uncompresses, reformats, performs the reqested band extraction and combinations, projects, and then converts to GeoTIFF and JPEG. The band combination choices include Visible to Near-Infrared (CIR), Normalized Difference Vegetation Index (NDVI), Shortwave Infrared (SWIR), Mid-infrared (Thermal) (TIR).

The CIR data product is comprised of bands 3, 2, 1 as Red-Green-Blue (RGB) at 15 m/pixel spatial resolution. This band combination highlights actively photosynthesizing vegetation in red (near-infrared band), with undisturbed bedrock and soils primarily expressed as browns, greens, and greys. Built materials and regions typically exhibit blue-green, reddish - purple, and white colors. The NDVI is the result of ((band 3 - band 2)/(band 3 + band 2)) calculated for each image pixel in a given scene. The resulting greyscale image provides a relative abundance map of actively photosynthesizing vegetation at 15 m/pixel. Bright pixels correspond to higher relative vegetation abundance, while dark pixels correspond to lower vegetation abundance. The SWIR images comprise bands 8, 6, and 4 as RGB at 30 m/pixel. As multiband data in this wavelength range tend to be highly correlated, a decorrelation stretch has been applied to obtain maximum separation in data values between bands. These bands have been selected primarily to highlight spectral features diagnostic for iron oxides, illite, and kaolinite (bands 8 and 6); and carbonates (band 4). This data product is designed for rapid reconnaissance based on these general mineral types; multispectral analysis using

Data set	**Description**	**Type (Grid, GeoTIFF, or shapefile)**	**Source**
Geology			
Arizona Geology	Geologic map of the state at 1:1,000,000 scale	Shapefile	Arizona Geological Survey
New Mexico Geology	Geologic map of the state at 1:1,000,000 scale	Shapefile	New Mexico Bureau of Geology and Mineral Resources
Phoenix area Geology	Geologic map of the Phoenix area at 1:250,000	Shapefile	Arizona Geological Survey
Cave Creek area Geology	Geologic map of the area north of Phoenix around Cave Creek at 1:24,000	Shapefile	Arizona Geological Survey
Quaternary Active Faults	Faults with activity attributes	Shapefile	Michael Machette, USGS and `http://qfaults.cr.usgs.gov`
Digital Topography			
US topography	1 km elevation data	Grid	US Geological Survey (USGS)
Arizona topography	100 m elevation data	Grid	Resampled from USGS 30 m data
Satellite Imagery			
NASA ASTER data	Several hundred scenes (see below)	GeoTIFF	NASA
Geophysical Data			
Complete Bouguer Anomaly	>100,000 measurements and gridded equivalent	Shapefile and grid	GeoNet - United States Gravity Data Repository System at University of Texas El Paso (`http://paces.geo.utep.edu`)
Heat Flow, Thermal Conductivity, and Heat Production	Points and gridded equivalents	Shapefile and grid	Pollack, et al., 1991.
Arizona seismicity	Arizona earthquakes 1830–1998	Shapefile	Arizona Earthquake Information Center
New Mexico seismicity	New Mexico and bordering areas earthquakes 1869–1998	Shapefile	New Mexico Institute of Mining and Technology
Utah seismicity	Utah earthquake listing 1962–1998	Shapefile	University of Utah Seismographic Stations
Shear wave splitting data	Measure of seismic anisotropy	Shapefile	Compilation of Derek Schutt
Receiver functions	Measure of depth to Moho, 410, and 660 km discontinuties	Shapefile and grid	All data courtesy of Hersh Gilbert, University of Arizona
Stress data for the region	Maximum horizontal compression direction as indicated from various geological and geophysical methods	Shapefile	(`www.world-stress-map.org`)
S-wave tomography	gridded shear wave speeds at various mantle depths	Grid	van der Lee and Nolet, 1997

Table 1: Principal earth science data sets gathered for SWGEONET.

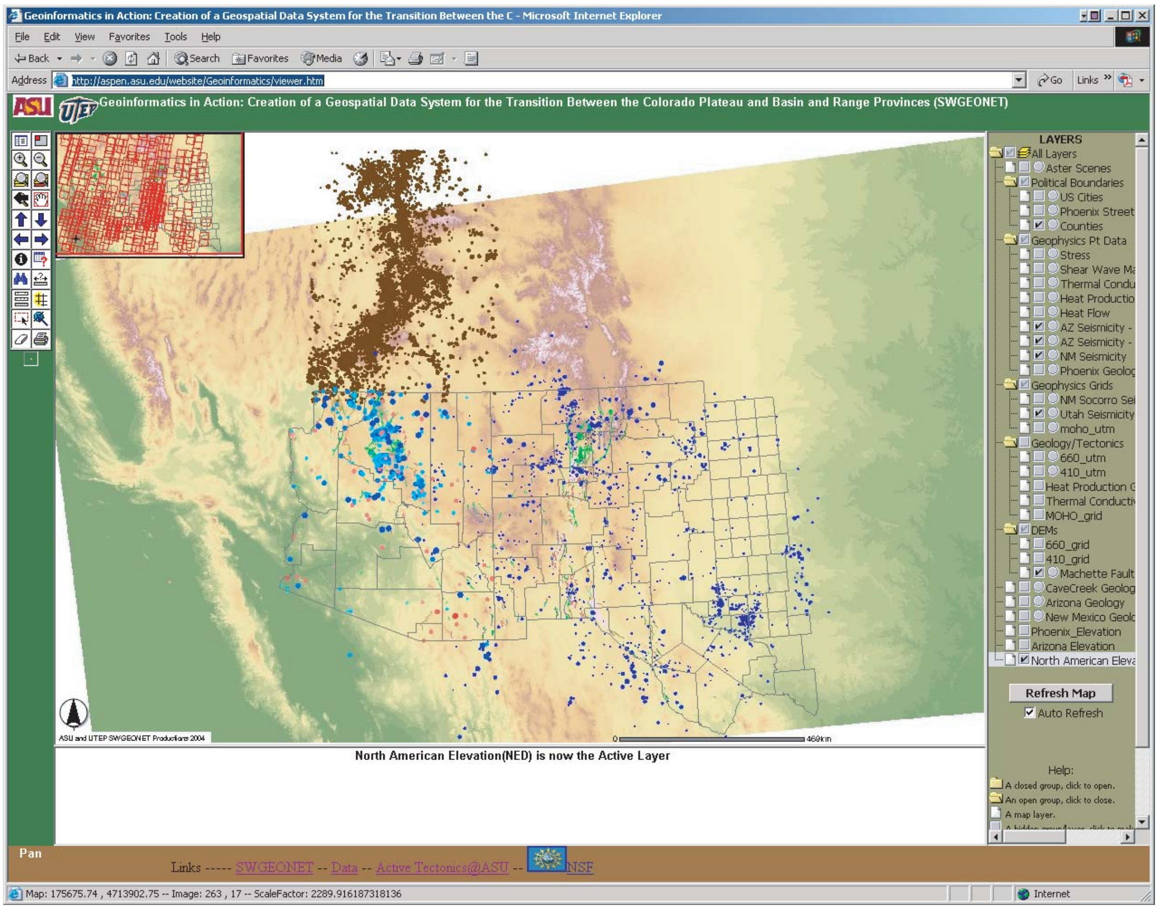

Figure 1: Topography, active faults (`http://qfaults.cr.usgs.gov/`), and seismicity for Arizona, New Mexico, and Utah displayed with ARCIMS and illustrating the localization of faulting, earthquakes and higher topographic gradients along the margins of the Colorado Plateau.

all six calibrated shortwave bands is recommended for detailed mineralogical investigations. Bands 13, 12, 10 as RGB at 90 m/pixel comprise the TIR product. As multiband data in this wavelength range tends to be highly correlated, a decorrelation stretch has been applied to obtain maximum separation in data values between bands. These bands have been selected primarily to highlight spectral features diagnostic for silicates (band 13), iron- and magnesium-bearing minerals and lithologic types (band 10), and carbonates (all three bands). Using these band combinations, quartzites are bright red; basaltic rocks are blue; granitoids are purple-violet; and carbonates tend to be green to yellow-green.

In order to make this process more efficient and utilize the GEON computing and data nodes, we also developed a Manager program to schedule IDL processing jobs on one of four compute nodes. See below for a detailed workflow and Figure 2:

1. ArcIMS–ArcIMS acts as a graphical interface to the ASTER system allowing the user to select which ASTER scene they wish to process. Each scene footprint (shapefile format) includes an attribute of a URL that redirects and passes information relative to the selected ASTER image to the Java Servlet (Figure 3).

2. Java Servlet - Welcome Screen–Upon receiving a request, the Servlet extracts information relative to the ASTER scene from the parameter data and builds a welcome screen: the ASTER metadata, links to other projects and information about this project, and a list of checkbox options specifying which image processing routines will be performed on the ASTER scene (Figure 4). Next to each checkbox item there

is a hyperlink to a page containing a brief description of each image processing routine. When the submit button is pressed the ASTER attributes as well as the user choices are passed to the manager program.

3. Manager Program–The manager program takes the ASTER attributes and the user selections from the Servlet and redirects them to the next available compute node for processing. If there are currently no available compute nodes then the request is placed into a queue until a compute node becomes available.

4. Java Implemented Server–Upon receiving a request from the manager node the compute node first extracts the ASTER information from the socket stream. It then builds an IDL executable command into a file with the desired user selected options as arguments. IDL then execute the files, the results of which are packaged up and placed on the data server. The server then notifies the manager that it has completed processing.

5. Java Servlet - Results Screen–Upon receiving notification from the server that it has completed processing, the manager in turn notifies the Servlet that processing is complete for that specific ASTER image processing request (Figure 5). The Servlet then builds the results page using the processed data. The results screen contains the ASTER information, links to other projects and information about this project, a thumbnail image of each requested image, and a series of downloadable files archived and compressed (*.tgz) that contain the processed image as GEOTIFF and .jpg formats in full resolution and 8x degraded resolution. The user can download the file, uncompress it, and then place the image into numerous applications (common user scenarios include: any basic image viewer, Microsoft Powerpoint or Word, Adobe Photoshop or Illustrator, and ArcGIS.

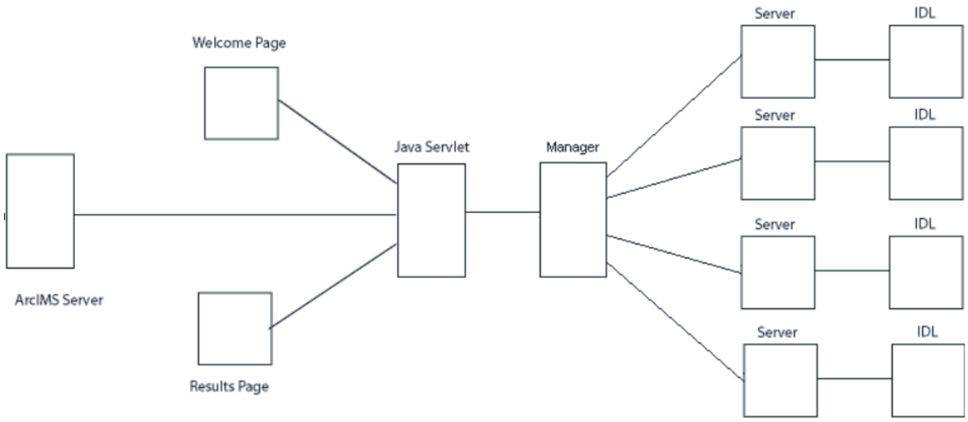

Figure 2: Illustration of connection method between ArcIMS, and the IDL image processing scripts via the Java Servlet and manager programs.

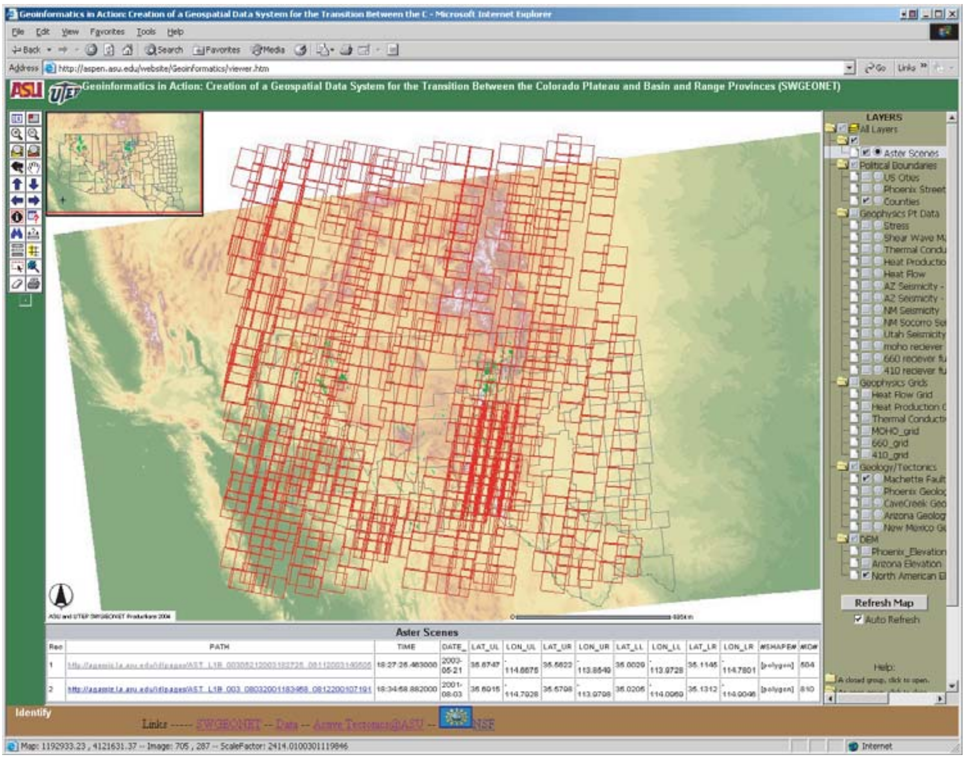

Figure 3: ArcIMS with ASTER footprints in red. User queries footprint of interest and information including URL to Welcome Screen appears in the bottom frame.

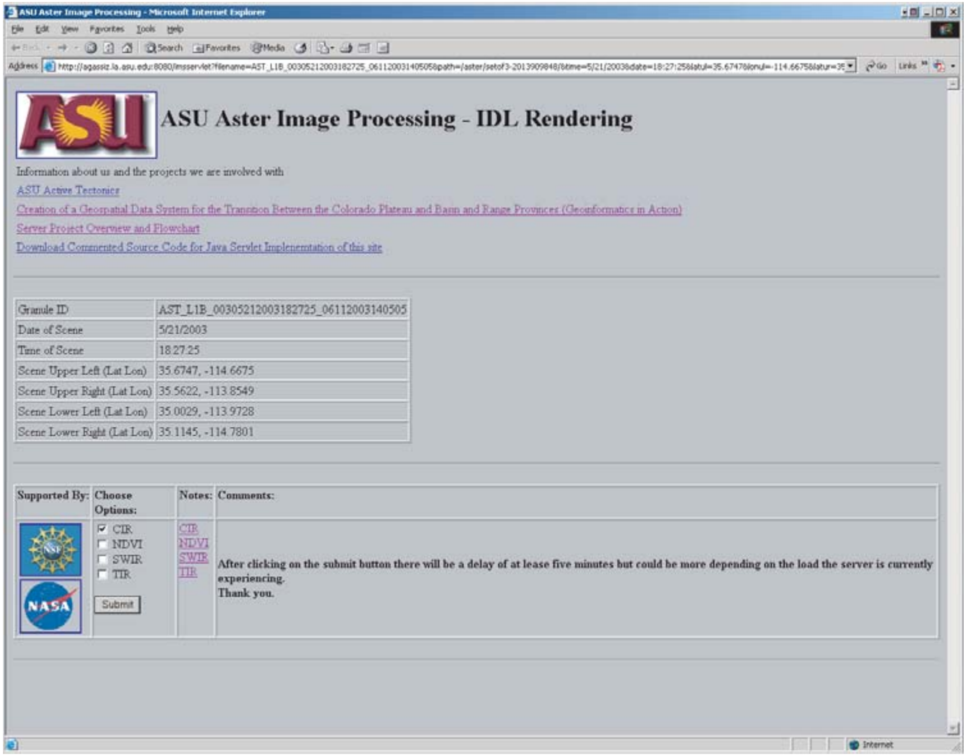

Figure 4: Java Servlet Welcome Screen with image metadata, processing options, and project links.

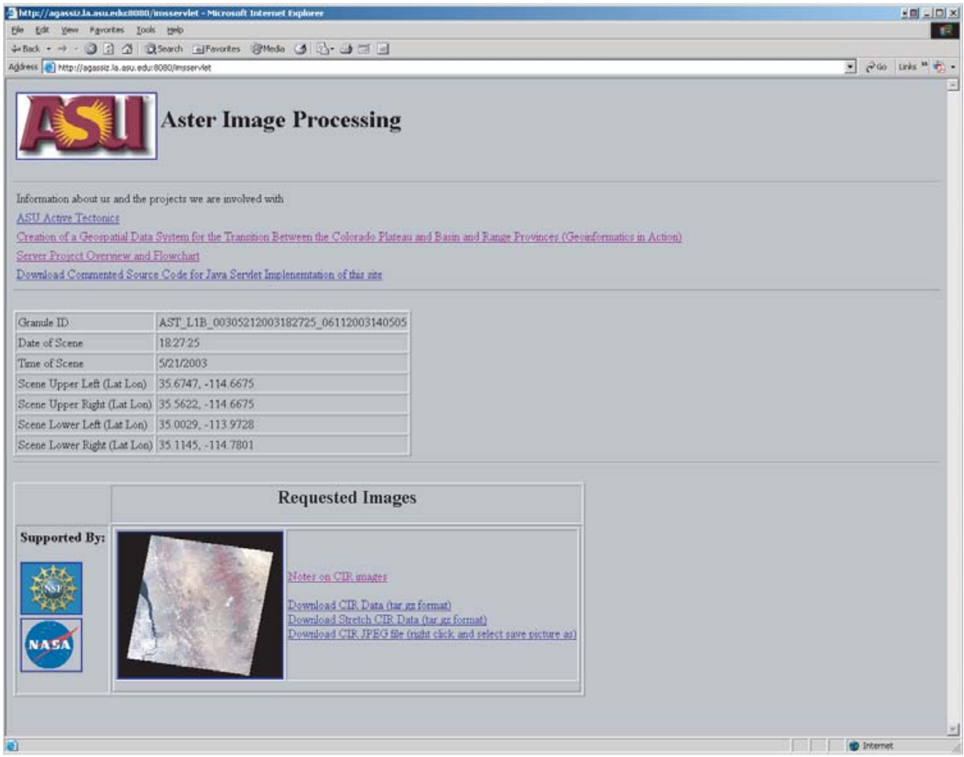

Figure 5: Java Servlet results Screen with resulting processed image, download options, and project links.

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References

Henry N. Pollack, Suzanne J. Hurter, and Jeffrey R. Johnson, assemblers; A New Global Heat Flow Compilation; Department of Geological Sciences, The University of Michigan. Ann Arbor, Michigan 48109-1063, U.S.A. March, 1991.

van der Lee, S., and Nolet, G., Upper mantle S velocity structure of North America: Journal of Geophysical Research, v. 102, no. B10, p. 22,815-22,838, 1997.

Yoburn, J., Arrowsmith, J R., Fouch, M. J., Ivanich, P. A., and Keller, G. R., Geophysical framework of the Colorado Plateau/Basin and Range Transition: Geoinformatics in action, *Geological Society of America Annual meeting*, Paper No. 183-14, 2003.

Yoburn, J., Fouch, M. J., Arrowsmith, J R., and Keller, G. R., A New GIS-Driven Geophysical Database for the Southwestern United States, in preparation.