

Planetary Interactive GIS-on-the-Web Analyzable Database (PIGWAD)

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Abstract --The United States Geological Survey (USGS) in Flagstaff, Arizona is producing a Web-based, user-friendly interface that integrates powerful Geographic Information Systems (GIS) statistical and spatial relational tools for analyses of planetary datasets. The interface, known as "Planetary Interactive GIS-on-the-Web Analyzable Database" (PIGWAD), provides database support for the research and academic planetary science communities, particularly for geologic mapping and other surface-related investigations.

I. Introduction

Application of GIS in the planetary sciences has grown dramatically over the past few years, as scientists have been able to prepare thematic maps and determine spatial relations among multiple datasets [1-4]. However, the creation of a GIS can be an expensive and daunting task for an organization that does not have the necessary hardware, software, and technical expertise. Such investment is not justifiable for most planetary projects. Thus, NASA's Planetary Geology and Geophysics Program supports a planetary, Web-based GIS that the entire science community may utilize. The USGS in Flagstaff provides this service, given our expertise in both terrestrial and planetary GIS. A NASA committee has approved datasets that are incorporated. In addition, we also have constructed specialized interfaces to support the distinct needs of particular spacecraft missions or science projects.

II. Data Conversion and Creation

Most GIS managers will agree that the most expensive and time-consuming part of any GIS product is data conversion or creation. Most planetary datasets have the benefit of being collected straight into a digital form. However, a lot of computer and user time must be spent to prepare these datasets for a GIS. Datasets available for planetary research vary as much as Earth-based datasets. For Mars, Mars Orbiter Camera image resolution ranges from less than one meter per pixel on up. Mars Global Surveyor (MGS) and its' Mars Orbiter Laser Altimetry (MOLA) instrument [5, 6] have gathered billions of elevation data points from which thematic datasets like digital elevation models (DEM), slope, and surface roughness maps can be generated. MGS is also returning thermal spectroscopy data, which can be used to generate a variety of mineral abundance maps. Based on these layers scientists have also been creating derivative datasets like geologic, structural, impact crater, and channels maps. Thus, a major task we face is to translate these extraterrestrial datasets, whether they are raster or vector based, into a GIS-ready format. For many of these tasks, we rely heavily on software produced by USGS.

A. Raster

For imagery, PIGWAD relies on the software package Integrated Software for Imagers and Spectrometers (ISIS) [7] written at the USGS in Flagstaff. At the lowest level ISIS gives the user capabilities for data ingestion, cosmetic processing, radiometric correction, geometric rectification, photometric correction, and image mosaicking. The most important GIS-related

task is the ability to geometrically rectify images. This involves the process of taking the imagery from the original raw space to a map projected space (fig 1). Until recently there was never enough topographic data available to actually orthorectify imagery on a global scale, thus most planetary imagery is rectified to a defined sphere [8]. For Mars, because of the immense amount of MOLA topographic data currently being collected, we will soon start to orthorectify imagery.

Like most image packages, ISIS has its own image and label formats, which is incompatible with GIS packages. ISIS also prefers to work on imagery as a thirty-two bit file. Whereas, packages like Arc/Info and ArcView by Environmental Systems Research Institute (ESRI)¹ can only read eight bit and unsigned sixteen bit image formats. Thirty-two bit files require a conversion into ESRI's proprietary image format Grid. Thus converting images from ISIS to a GIS-ready format is not always straightforward. To allow our GIS packages the ability to read ISIS images, we have generated several different methods for modifying or converting ISIS imagery to a GIS-ready format. The most straightforward method requires the user to convert the ISIS image file into a Tiff format with an ASCII world file or a GeoTiff file. The world file defines the pixel size and the upper left pixel's location on a Cartesian coordinate system in a projection. These values are easily calculated from the ISIS label information. Tiff or GeoTiff files are recognized by most software packages that read imagery. Another method requires generation of an ASCII header file and the world file. The header file defines the number of lines, samples and bands, bit type, machine type, and how many bytes to skip the imbedding ISIS label.

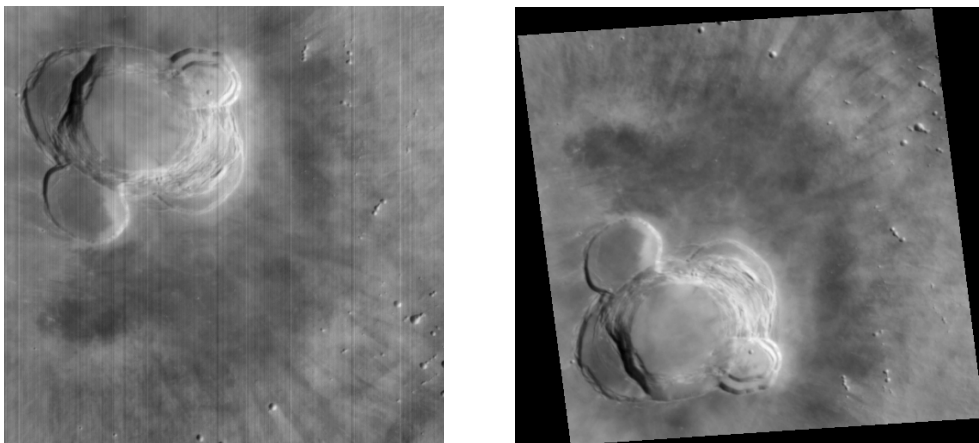


Figure 1. The image on the left shows a raw Mars Orbiter Camera (MOC) frame of the Ascreaus Mons caldera. The image on the right has been radiometrically and cosmetically corrected and projected to a sinusoidal projection.

B. Vector

For non-imagery datasets we have created our own translators to get from other vector formats like straight ASCII formatted files to file formats like postscript, Digital Exchange Format (DXF), and even our own digitizer formats. If the original data is not already in a digital form then we either scan or digitize them. As computers become more pervasive, we are also recommending to the science community that any person attempting to generate a new map either use a GIS or other computer-drafting program like Adobe Illustrator or Canvas. This will dramatically reduce the effort needed to convert maps to a GIS format and the potential for errors.

¹ Description of our use of this commercial software does not represent an endorsement of the product.

C. Longitude Systems

Unlike Earth, most other bodies in our solar system are defined with a positive west longitude system. Although this seems like a trivial problem, most GIS applications and remote sensing applications do not understand this longitude system. While a simple shift in longitude values fixes the problems, there is a lot of potential for confusion. For example, the images in figure 1 are located around 104° longitude and (11° latitude) increasing to the left. A vector map of this same area in a PIGWAD database would be centered at -104° longitude, with longitude increasing to the right (fig 2). While we use a positive east system for our digital files, on output we still use the positive-west system for referencing and labeling. The MOLA team has been adamantly using a positive-east coordinate system for all its Martian products. This has caused much concern in the planetary community since there are thousands of older maps and papers that reference the positive-west coordinate system. Even with this concern, the longitude systems for all planetary bodies may eventually become positive east. While the transition may be unpleasant, it will make using commercial programs and handling digital files much less confusing.

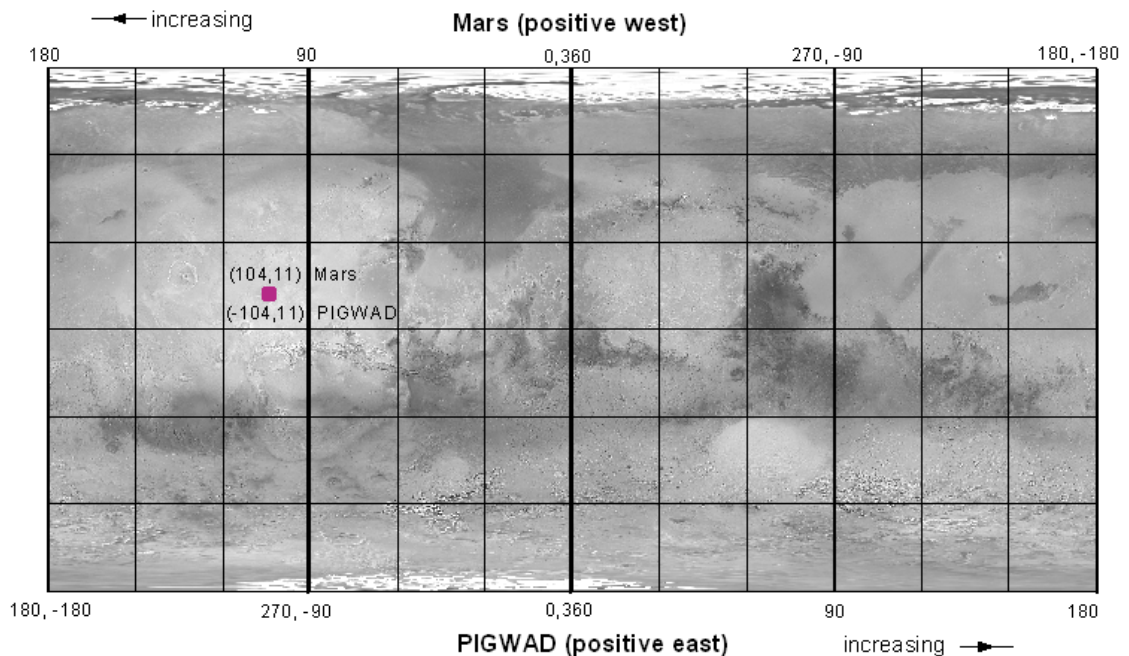


Figure 2. This image portrays the problem using a positive west longitude system in a GIS application. PIGWAD uses the same system as Earth, positive east, because the GIS packages we use only recognizes this system. Thus care must be taken when a user who is not familiar with the differences when using a PIGWAD layer.

III. Website

A. Web Technologies, ArcView IMS

Our initial solution in 1999, based on ESRI's ArcView Internet Map Server (IMS) (fig 3), permitted us to easily generate a GIS website. This interface allows one to view any combination of datasets, zoom, query, and then create a layout that automatically adds a key, scale bar, and title for printing. However, adding the scale bar turned out to be a little harder than we imagined. Since we wished to have the interface display the coordinates in decimal degrees (positive east), we were forced to not set a projection. By setting a geographic 'projection' ArcView's java software automatically sets an Earth radius to define the scale

bar. If we actually used a Martian projection, the scale bar would be correct but the user was offered meters for the X, Y readout. To solve this, we had to edit the java code such that it would show the appropriate scale. We can also add advanced levels of GIS customizations through its programming languages Avenue and Visual Basis. This allows us to generate sites with specific goals. For example, to assist with Mars Exploration Rover (MER) 2003 landing-site selection, we can offer planetary scientists a landing-site ellipse generator, which gathers statistical information about the site's rock abundance, elevation, slope, morphological descriptions and other data deemed necessary to choose an optimally safe and scientifically interesting landing site (fig 3). And while ArcViewIMS design is extremely powerful, some crucial elements that we desired were still missing [9]. Several software advances have been recently produced that allowed us to use pre-built tools, thus reducing the high costs of in-house customizations.

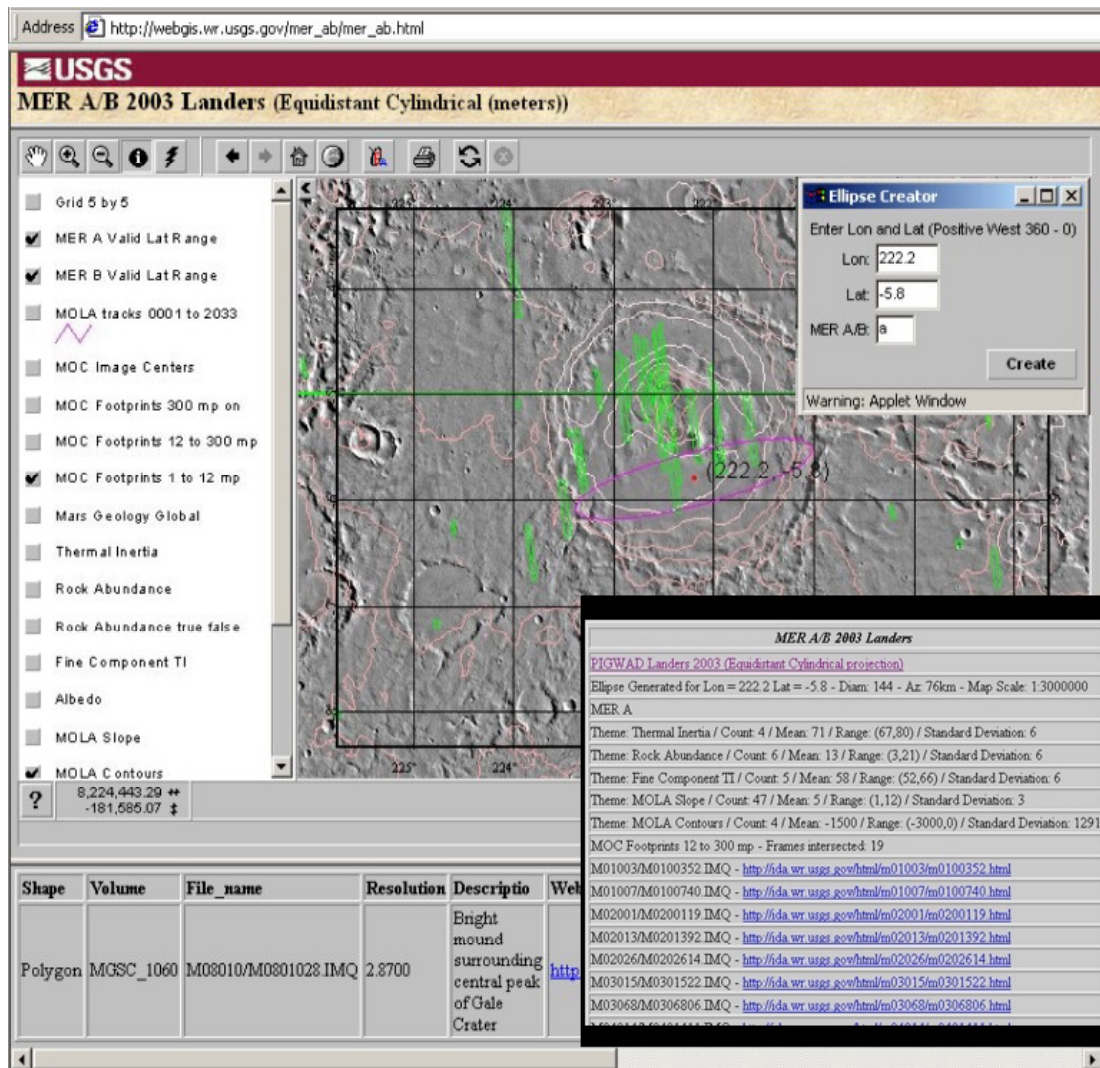


Figure 3. The customized ArcViewIMS MER 2003 interface is shown above. The layers visible are the Mars Digital Image Mosaic 2, elevation contours, and MOC footprints. The client using the applet window shown in the upper right generated the ellipse. The table on the bottom right is a separate web page that is generated from listing the layers intersected by the ellipse and their statistical information.

B. Web Technologies, ArcIMS

ESRI released their next generation GIS on the web application in 2000. This application, called ArcIMS (fig 4), was to supersede all of their previous web GIS technologies. Although

we will lose some of the customization abilities in ArcViewIMS, ArcIMS will offer many technology enhancements. Like ArcViewIMS, ArcIMS has the capability for image-streaming, which is the ability to stream small compressed 'snapshots' of the chosen map layers. But the ArcIMS image interface allows for an extremely flexible map extent and more complex queries. The on-the-fly map extent will greatly enhance the usability for those who use a simple Internet browser like Netscape Navigator or Microsoft Internet Explorer. The ArcView interface defaults to one map extent, which most will find too large or too small. The query engine has also been enhanced to allow one to build complex questions using multiple fields. The improvements made in the image-based solution were enough to justify upgrading, but they also added vector-streaming capabilities.

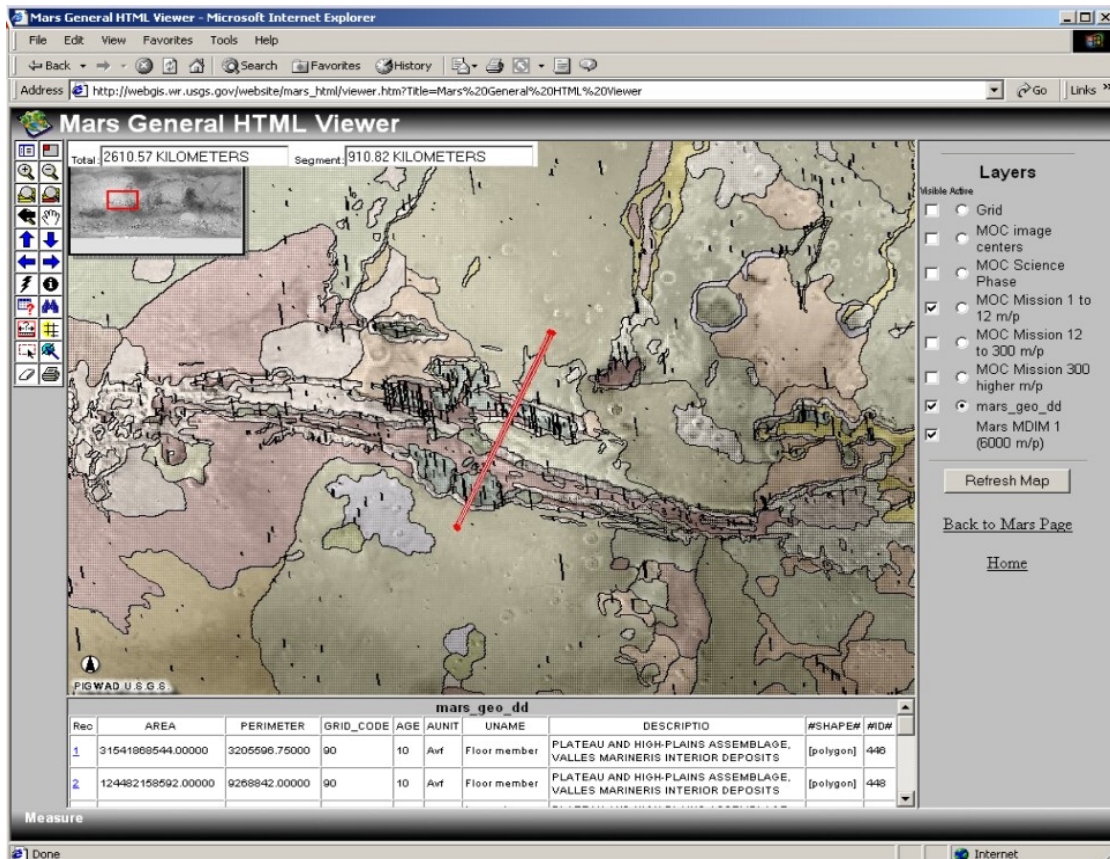


Figure 4. The ArcIMS Mars General interface is shown above. The layers visible are the Mars Digital Image Mosaic 1, global geologic map, and MOC narrow angle footprints. The red line, drawn by the user selected the intersected geologic units listed in the bottom frame.

As stated above, image-streaming sends small image 'snapshots' of the map. Vector-streaming actually sends the vector data as points, lines, or polygons. Once the data are downloaded in memory, the response rate is extremely fast because the interface does not need to ask the server for every map. This also allows one to change how a layer is drawn. For example, if the user does not like the default color ramp for a contour layer, it can be changed. One can also change the order in which the layers are drawn. Since the vector features are in memory the user can actually edit the features within his/her browser. The client can move, change the shape, or even change the data values of any feature. Once the changes are final, the user submits the changes to the webmaster for acceptance. We also hope to provide blank layers that can be used for creation of new layers. The user can buffer a layer or a feature, which can then be used to intersect features from a completely different layer. Users can save a project to their own machine, which can be called up for later use or sent to a colleague. The ArcIMS software also gives the webmaster the ability to allow the

client to downloading part of a vector dataset. This will allow the client to select a portion of the map, which will then be automatically packaged and downloaded.

One of the greatest improvements of ArcIMS over ArcViewIMS is the concept of map services. This allows a machine to run many mapping layers without having to design an entire website for each grouping of layers. The user is then free to choose which layers to incorporate in their GIS. Viewers that give you this power is the free program called ArcExplorer Java and all the new ESRI commercial products, ArcView, ArcEditor and Arc/Info version 8.1. Because ESRI has made this streaming capability non-proprietary, other viewers will also support this. Another benefit of using these viewers is that one can incorporate data local to their machine to any map view. This will allow the user the utmost control in creating maps and querying data from multiple locations without having to download anything.

As with ArcView, there were several java code modifications that were needed. ArcIMS, does not currently support setting a projection, thus the data either needs to be in geographic or hard-wired into a meters projection. Because we wanted the viewer to see a decimal degree coordinate system, even though it is positive east, the data must be in decimal degrees. So once again the java code was modified to read out the correct scale and changes were made to also to read correct measured distances. However, because users can bring these layers into a stand-alone viewer that we have no control over, there is potential for errors that the users would not know about. To solve this, we may have to send all the independent map services in an undesirable meters projection. We have yet to determine the best path for this. ArcIMS version 3.1, which will be released around May of 2001, may help rectify this problem.

C. Downloads

Besides the on-line interfaces, PIGWAD will also support non-imagery downloads. Currently, the Planetary Data System (PDS) exists as a clearinghouse for planetary datasets, but it does not support vector datasets. Conversion from vector to raster is an easy process but the dataset will lose its' precision and tabular data that are maintained in a vector layer. We are currently supporting the Shapefile format, designed by ESRI, because it is widely recognized and is non-proprietary. In the near future we will also support the Spatial Data Transfer Standard (SDTS) format. Users currently have access to geologic and structural maps for Mars, Mercury, the Moon, and the Jovian Satellites (Io, Ganymede, and Callisto) in their original meters projection or decimal degrees. As more maps get generated in a digital format this list will quickly expand. For every layer generated, we comply with the Federal Geographic Data Committee (FGDC) metadata guidelines [10]. Metadata attempt to provide a common set of terminology and definitions for the documentation of digital geospatial data.

D. Learning to use a GIS with Planetary Datasets

While PIGWAD's main focus is its online mapping pages, we have spent much time documenting and writing tutorials and tools that we rely on. We have added tools written in C, Perl, and Avenue to help the conversion from ISIS and other image formats to a GIS capable image, including specific tutorials on working with MOC imagery. We also support planetary GIS tools and tutorials in the ArcView 3.x program environment. These tools give access to planetary projections, GIS converters for MOLA point data, and MOC footprint generation. We have also added tutorials on DEM or surface creation in the Arcview Spatial Analyst or 3D Analyst environment from MOLA data, on importing tabular data, on how to create image catalogs, and more.

IV. Future

We will continue to improve and add more capabilities to our GIS interface according to the needs of the PGG community. In particular, we will focus on advanced tools that will assist geologic mappers. As more data become available, we will continue to update and

expand planetary GIS databases and to incorporate more GIS tutorials and user-friendly functions. We are also hoping to team up with other organizations, like PDS, to put all relevant planetary datasets into on-line ArcIMS systems or similar technologies. As the Internet and clients' Internet connections become faster, building a multi-layered GIS strictly from on-line data layers will become commonplace. Thus without downloading or converting any data, a user would be able to view and query an image base from a PDS server, multiple geologic maps from a PIGWAD server, mineral layers from a universities server, and include the user's own layers on top (fig 5). The use of this technology in this manner has already become popular for Earth-based products [11].

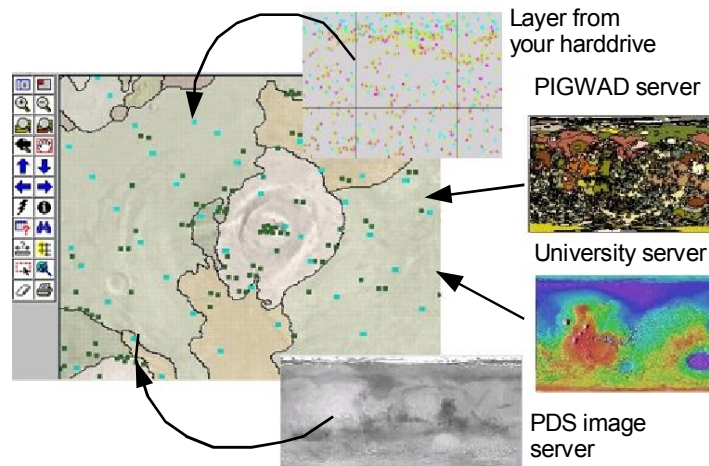


Figure 5. A diagram depicting how in the near future a researcher can build a multi-layered planetary database from multiple GIS Internet services residing at different locations. Currently only PIGWAD allows this type of layer building.

V. Summary

GIS gives one the tools to not only view several different types of data together, but also to perform various data analyses including advanced spatial intersections, unions, and robust conditionals. ESRI's ArcViewIMS and ArcIMS Internet Map Servers, permits us to easily generate a web site with predetermined datasets. By incorporating this functionality into a user-friendly web environment, a wide array of investigators and educators can easily implement the analytical power of a planetary GIS.

VI. References

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