PLANETARY REMOTE SENSING AND GIS: THE CONVERGENCE OF SOFTWARE, TECHNIQUES AND DATA. M. J. Smith[1], N. Petford[1] and L. Xiao[2], [1] School of Earth Sciences and Geography, Kingston University, Kingston-upon-Thames, Surrey, KT1 2EE, UK (michael.smith@kingston.ac.uk). [2] Research Center for Space Science and Technology, China University of Geosciences, Wuhan, Hubei, 430074, China.

Introduction: Geographic information systems (GIS), and more specifically remote sensing, have been used within the geosciences for well over two decades. In that time, the ability to handle a variety of increasingly voluminous data (both vector and raster) has allowed continued data analysis and exploitation within mainstream GIS. The uptake and use of GIS has not been mirrored within the planetary sciences, partly because of: 1. the origin of much research within astronomy; 2. lack of digital data; 3. the geo-centric nature of many GIS. The rapid advancement in the quantitative facilities of GIS has seen extensive application on Earth, with more limited use within planetary remote sensing. This abstract briefly explores how we are now seeing a convergence between the use of GIS, application of new techniques and availability of data.

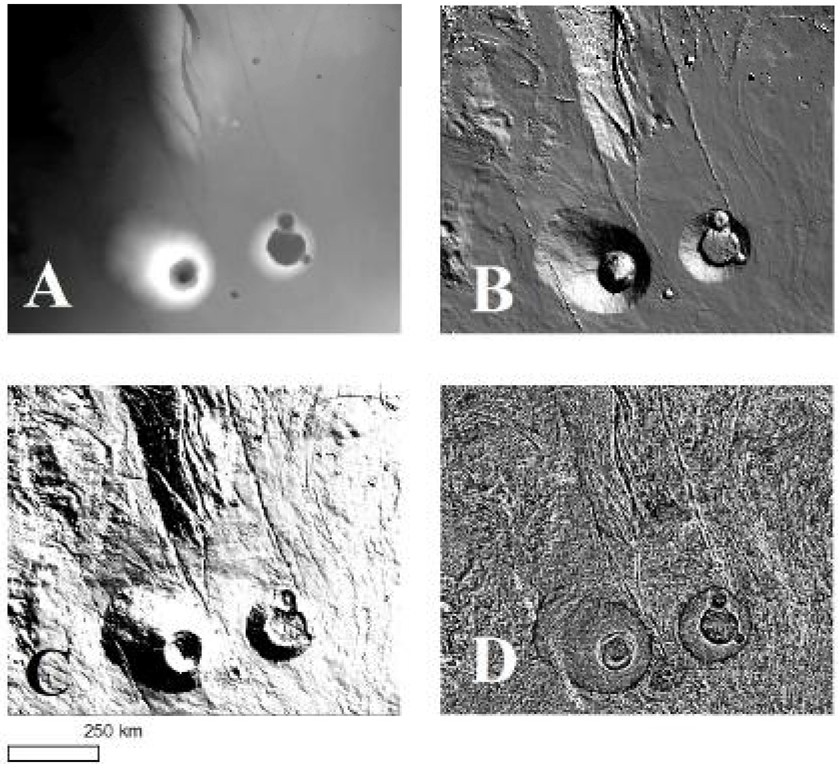
Software: GIS software products were historically based around their application domain (e.g. remote sensing). Generically, this meant software oriented around raster (e.g. Clark Labs IDRISI) or vector (e.g. ESRI ARC/INFO) processing. Developments over the last decade has seen the integration of vector and raster data models in to single, unified, products, that can handle large data sets, in different coordinate systems and consistently apply quantitative processing. It is particularly notable that ESRI's ArcMap integrates raster and vector visualisation *and* processing within one graphical user interface. With the release of version 9.0 ArcMap natively supports coordinate systems of planetry bodies. However commercial GIS are proprietary systems and support of planetry bodies is limited. For example, within ERDAS Imagine there is currently no way that a Martian coordinate system can be added by the user. It is hopeful that work by the Open Geospatial Consortium (OGC) [1] will make the inclusion of coordinate reference systems easier.

Quantitative Techniques: One of the benefits brought through the use of mainstream GIS applications is the simplified working environment and implementation of a variety of quantitative techniques. This can involve simple procesing such as contrast enhancements or convolution filtering [2], through to more complex techniques like principal components analysis or fourier transforms [3]. In understanding the evolution of planetary bodies, it is necessary to map the geographic distribution of surface features. A 1:200,000 scale series of topographic maps was planned for the Mars96 mission [4]. The loss of the mission meant that this project was delayed until the successful deployment of the High Resolution Stereo Camera (HRSC) on board Mars Express [5]. This project will provide a base line from which further topographic analyses can proceed and will use satellite based photogrammetry. The deployment of technologies that have been successfully applied on Earth (e.g. use of stereo ASTER data [6]) will mean the acquisition of stereo imagery and generation of high resolution digital elevation models (DEM). This will allow detailed visualisation [7] and analysis that has already been successfully used with Mars Oribter Laser Altimeter (MOLA) data (e.g. slope asymmetry [8]). DEMs have been used extensively within geomorphology from measurements of surface roughness [9], to hydrological modelling [10] and hypsometric studies [11]. Many of the quantitative advances that are being made using geographic data are implemented within GIS and are therefore easily transferrable to other planetary bodies.

Remote Sensed Data: Perhaps one of the biggest advances in the use of GIS within planetry remote sensing has been the increasing ease of access to projected digital datasets [12]. This is in part due to success of many recent (e.g. Mars Express, Mars Odyssey, Mars Global Surveyor) and on-going (e.g. Mars Reconnaissance Orbiter, Venus Express) missions. In particular, HiRISE (aboard MRO) will offer very high resolution imagery [13] that is better than the best Earth orbiting commercial systems. This will provide unprecented detail of the effects decimetre scale surface processes. In addition to the panchromatic and multi-spectral imagery that is currently available, surface elevation in the form of DEMs has been made available by the MOLA and the on-going HRSC mission. The MOLA data sets are significant in that a near-global DEM of Mars, at resolutions up to ~468 m per pixel, are available offering a detailed description of the Martian topography. Such data sets form important inputs to GIS for subsequent analysis and modelling.

Example Application: Figure 1 shows an example of the visualisation of MOLA data for the region between Olympus Mons and Pavonis Mons. Whilst a standard grey-scale image (A) shows little topographic detail, a relief shaded image (B) offers insight in to variations in morphology. However this image is biased as a result of the azimuth of illumination [14]. Non-azimuth biased visualisations are presented in C (slope) and D (local contrast stretch). The additional information presented allows the evaluation of considerably more morphological detail.

For example, the volcanic cones shown in Figure 1 show evidence of both impact deformation (cratering) and also eruption, the latter represented by a small flow that produces a distinct asymmetry in cone geometry seen in slope image (Figure 1c). The structure of the surface around the cones is also clearly highlighted. Linear features running approximately N-S may be collapsed dykes that both terminate and emanate from the volcanic centres. Closer examination may reveal cross cutting relationships and also information on dyke widths, a critical parameter governing magma flow rate. The high resolution images shown here can also be used as the basis for finite element numerical models aimed at quantifying cone collapse and lithospheric stress fields. Integrating structural, volcanic morphology and numerical data into a GIS should allow more complex models of Martian magma systems to be made in future.



Conclusions: This abstract has briefly presented how the use of GIS has been adopted in the study of surface features on Earth. When combined with appropriate remotely sensed data and techniques for the analysis and modelling of terrain, geoscience can take full advantage of the research methodologies available. Planetry science has been slower at adopting this technology, partly a result of the geo-centric focus of GIS and partly due to the availability of digital data. Planetry coordinate systems are slowly being adopted by commercial GIS vendors and, with readily available projected digital data, the full application of GIS techniques will be available to all planetry researchers.

References: [1] Hare, T. et al (2005) *LPS XXXVI,* Abstract #2213. [2] Lillesand, T.M., Kiefer, R.W. and Chipman, T. (1999) Remote sensing and image processing, Wiley. [3] Mather, P. (2004) Computer Processing of Remotely-Sensed Images, Wiley. [4] Lehmann, H. et al (1996) Mapping a Whole Planet – The New Topographic Image Map Series 1:200,000 for Planet Mars. ISPRS, Vol. XXXI, B4. [5] Albertz, J. et al (2005) HRSC on Mars Express – A new Era in Planetry Cartography, AOGS 2005. [6] Toutin, T. (2002) IEEE Trans. Geosci. Rem. Sens., 40, 2241-2247. [7] Smith. M.J. et al Earth Surface Processe and Landforms, 30, 885-900. [8] Kreslavsky, M.A., Head, J.W. (2003) Geophys. Res. Letters, 30, PLA1-1 – 1-4. [9] McKean, J., Roering, J.J. (2004) Geomorph., 57, 331-351. [10] Moore, I.D. (1991) Hyd. Proc., 5, 3-30. [11] Bishop, M. et al (2004) Geographic Information Science and Mountain Geomorphology, Springer-Praxis. [12] Hare T., Tanaka K., Skinner J., GIS 101 for Planetary Research, ISPRS WG IV/9: Extraterrestrial Mapping Workshop, Advances in Planetary Technology, LPI, Houston, 2003. [13] Okubo, C.H., McEwen, A.S. (2005) A new scale of science observations from the High Resolution Imaging Science Experiment for the Mars Reconnaissance Orbiter. AGU, 2005 Fall Conf. [14] Smith, M.J. et al (2001) Slovak Geological Magazine, 7, 262-274.