56. SPHERE-GIS: IMPLEMENTATION OF AN HISTORICAL AND PALAEOFLOOD GEOGRAPHICAL INFORMATION SYSTEM

A. Casas Planes[1], G. Benito[1], A. Díez-Herrero[2] & M. Barriendos[3]

(1) Centro de Ciencias Medioambientales – CSIC, Serrano 115 bis, 28006 Madrid
(2) Dpto de Ingeniería Geológica y Minera, Universidad de Castilla la Mancha, 45071 Toledo
(3) GAMA Group, Department of Astronomy and Meteorology, Faculty of Physics, University of Barcelona, Av. Diagonal 647, E-08028 Barcelona, Spain

ABSTRACT

Palaeoflood and documentary flood data generated within the EU funded SPHERE project has been organized into relational database systems for its access and management and a geographical information system has been implemented for its storage and analysis. This paper describes the SPHERE-GIS, the structure of the conceptual data model for decision support, the design of an effective interface (GUI) to operate the computational model from a custom toolbar and menus, and the development of some GIS tools, which operate on ArcGIS in order to perform the required analysis and searches and for its explotation in the study and prevention of flood risks.

6 INTRODUCTION

Compilation of data related to past hydrological events has been the subject of different databases worldwide (see Oguchi et al., 2003). Specifically, past flood databases are focused either on documentary information and/or palaeoflood records. Pre-existing historical flood databases include the CLIMHIST database for Continental Europe in (Pfister et al., 1999), British Hydrological Events database for the UK (http:www.dundee.ac.uk/geography/cbhe), the National network of historical flood water level marks for China (Chen Chia-Chi, et al., 1975; Hua Shi-Qian, 1985), and PaleoTagus for Central Spain (Diez-Herrero et al, 1998; Fernández de Villata et al, 2001 and Benito et al., 2003). Geological-inferred flood information has been compiled either on general palaeohydrological databases (e.g. GLOCOPH and PHEIMS described in Oguchi, 2003) or in specific palaeoflood databases at the global scale (Ely and Hirschboeck, 2002) and on the regional scale (Diez-Herrero et al, 1998). Most of these databases are focused on simple data query displays but few of them have real capabilities for GIS spatial analysis.

SPHERE-GIS is a Geographical Information System which was developed to manage the palaeoflood and documentary flood information generated within the EU funded SPHERE project (Contract no. EVG1-CT-1999-00010). The GIS implementation provides an effective way of displaying past flood alphanumerical information within a geographical scenario as well as simple analysis resulting from any particular query (e.g. magnitude and frequency of flood events during a particular time period). Following the latest concepts of software components, SPHERE-GIS is ready to incorporate other software applications on

---

V.R.Thorndycraft, G. Benito, M. Barriendos and M.C. Llasat (2003). Palaeofloods, Historical Floods and Climatic Variability: Applications in Flood Risk Assessment (Proceedings of the PHEFRA Workshop, Barcelona, 16-19th October, 2002).

flood frequency analysis (e.g. FRESH Software, Ouarda et al., this volume) or hydraulic computation software such as HECRAS (Hydrologic Engineering Center, 2002).

The main objectives are to effectively collect and store palaeohydrologic and historical (documentary) data, to develop tools for spatial and temporal analysis of quantitative parameters (e.g. date, estimated discharge, duration, etc.) and its interpretation both within the context of flood risk analysis and for the study of long-term regional relationships of floods and climatic variability. In this context, SPHERE-GIS provides tools for the application of the query results in Civil Protection risk assessement and management , hazard delineation and civil engineering.

7 METHODOLOGY

7.1 SPHERE-GIS Data Model

7.1.1 Non-spatial data model

The system includes two Relational Database Management Systems (RDBMS): Histo and Paleo, the tables of which were normalized until the third normal form. Both consist of a Basic Data Table which includes the main information of a flood event and complementary data tables containing detailed information related to the main data fields. The Histo Database comprises documentary flood information obtained from official and ecclesiastic historical archives, whereas Paleo database contains palaeoflood records obtained from geological-geomorphological techniques. Paleo also includes two main tables, one with basic data and the other one with the on-board data, which contains information referring to the physical characteristics of the river section (type of river boundary, type of channel bed, drainage area, stream length and channel gradient), the methodology of flood identification (palaeostage-indicator techniques, competency-based techniques, regime-based techniques, historical observations of flows and botanical-based techniques); the methodology used for discharge estimation (type of hydraulic model, hydraulic regimen), numerical dating information (C-14, TL, OSL, etc.) and flow-hydraulic characteristics (flow velocity, stream power, and specific discharge). In addition, the Paleo database includes a group of annexed tables containing source information, sedimentary materials, boulder diameter, and dating methods. Histo comprises a main table including information on the flood date and duration (year, month, day, duration, time of overflowing, time of maximum flood height), flood cause (rain, snowmelt, etc.) and category of the event (ordinary, extraordinary, catastrophic). In addition, several secondary tables describe the flood in terms of damages, hydroclimatology, and bibliographic sources (Affected Areas, Agriculture & Livestock losses, Hydrologic Data, Geomorphology, Housing Damages, Industrial Damages, Infrastructure & Service Damages, Casualties & Evacues, Chronology, Meteorological Situation, Bibliographic Source of Information y Documentary Source of Information). Both of the RDBMS (Paleo and Histo) share, as much as possible, their design and structure.

7.1.2 Spatial data model.

Spatial data structure have been deployed under two models: vectorial data model and raster data model. Vectorial GIS application requires a data model based on topological models, whereas the raster data requires a GRID approach. The vectorial cover (*IntRioMuniMas*) results from the graphical intersection between the rivers (*River*) identified by a unique code (*RiverID*) and the municipality (*Municipality*) with its unique code (MunicipalityID). This cover is linked by a unique code (*HydroCode = RiverID & MunicipalityID*) with the related-table (*Hydro*) which relates the spatial intersectioned cover with the basic table of each RDBMS, Histo and Paleo. Hydrologic data (basin, sub-basins, rivers, reservoirs, gauging stations), geographical data (administrative limits, topography, rail ways, roads, urban centres, parks), digital elevation models of different resolutions, and some orthophotos are also integrated.

8 GIS IMPLEMENTATION

8.1 GIS Data inputs

Digital spatial data is coded in a cartesian coordinate system and must be in the same projection and scale. All spatial data have been transformed into the same coordinate system and into an ArcGIS format. Both of the RDBMS (Paleo and Histo) have been fed using Microsoft Access through a Microsoft Visual Basic application (Jennings, 1999), so they can be directly connected to the GIS, providing an integrated data management policy for all data. Figure 1.a shows the Visual Basic form used to enter the basic data table of the Histo RDBMS, with direct access to the related tables, depending on the information available for each particular event.

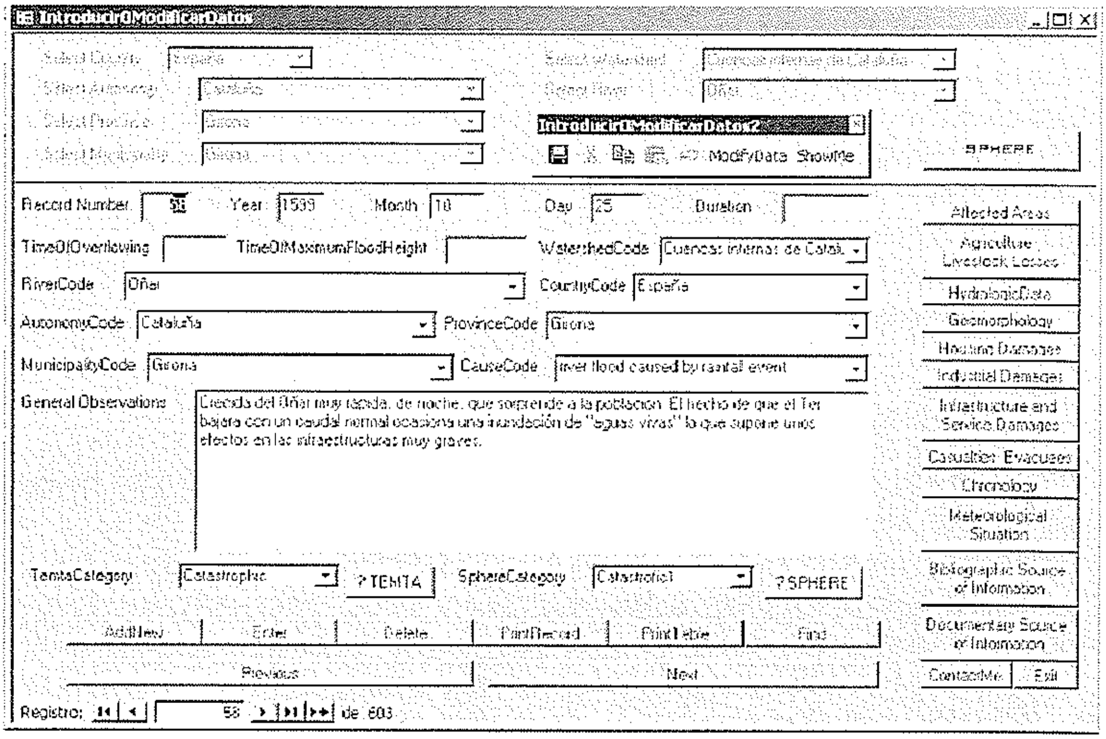
8.2 GIS Tools

The SPHERE-GIS has been implemented with the package *GIS ArcView 8.1,* GIS tools were built using Arc Objects (Environmental Systems Research Institute., 2001; Razavi, 2002) and Visual Basic (Microsoft Press, 1998) and the data format used for these components is the shapefile format. Custom tools extend the functionality of ArcMap to perform tasks specific to a user's need. The GIS functions programmed include: select, buffer, counting, statistics functions , map and data display. A friendly and easy-to-use user interface has been developed using Visual Basic for Applications (VBA), allowing the final user (scientist or technician) to obtain all the information required. The point is focused on detecting which is the functionality that is considered useful for the final user and to implement it on the system. The system is designed to present menus through a toolbar in which to manage the graphical and alphanumerical information and easily obtain the required information and its geographical location though queries, operations and analysis. All through the application, the menus will allow the user to add some graphical information to the map, to access the alphanumerical information, to perform some queries to the databases or to perform some analyses. Thematic selections through different means can be made with diferent criteria: causes, damages in agriculture, bibliography, etc.

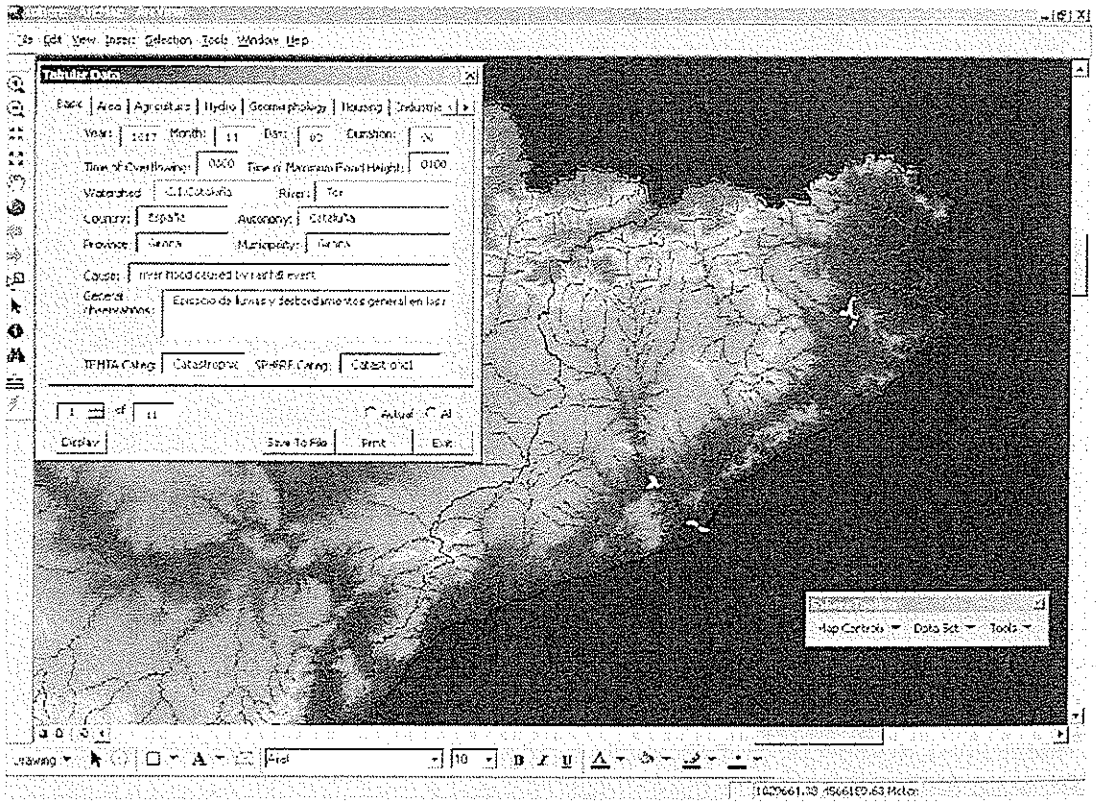
8.3 GIS Analysis

Figure 1c shows the menu to make a selection by an exact date in Histo. The result of the query is shown spatially in the basic map and through a form where the selected data is displayed (see Figure 1b). Some spatial data can be added at any time to the basic map like reservoirs, gauging stations, altimetry, urban centres, geographic names etc (see Figure 1d) or the table with the selected records can be displayed.

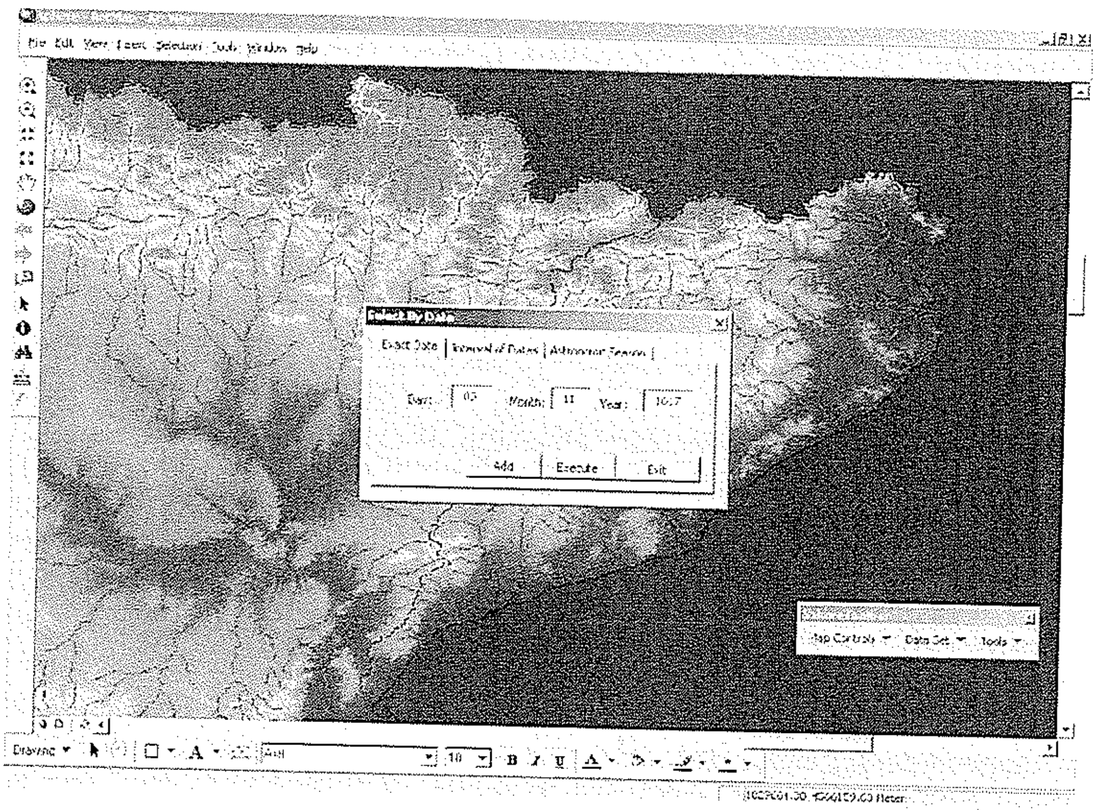
1a


IntroducirOModificarDatos
IntroducirOModificarDatos2
ModifyData ShowMe
SPHERE
Record Number
Year 1539
Month 10
Day 25
Duration
TimeOfOverflowing
TimeOfMaximumFloodHeight
WatershedCode
RiverCode
CountryCode
AutonomyCode
ProvinceCode
MunicipalityCode
CauseCode
General Observations
TemtaCategory
?TEMTA
SphereCategory
?SPHERE
AddNew
Enter
Delete
Previous
Next
Registro: 58 de 603
Affected Areas
Agriculture Livestock Losses
Geomorphology
Industrial Damages
Infrastructure and Service Damages
Casualties Evacuees
Chronology
Meteorological Situation
Bibliographic Source of Information
Documentary Source of Information
Exit

1b


Tabular Data
Map Controls
Data Set
Tools

1c



1d

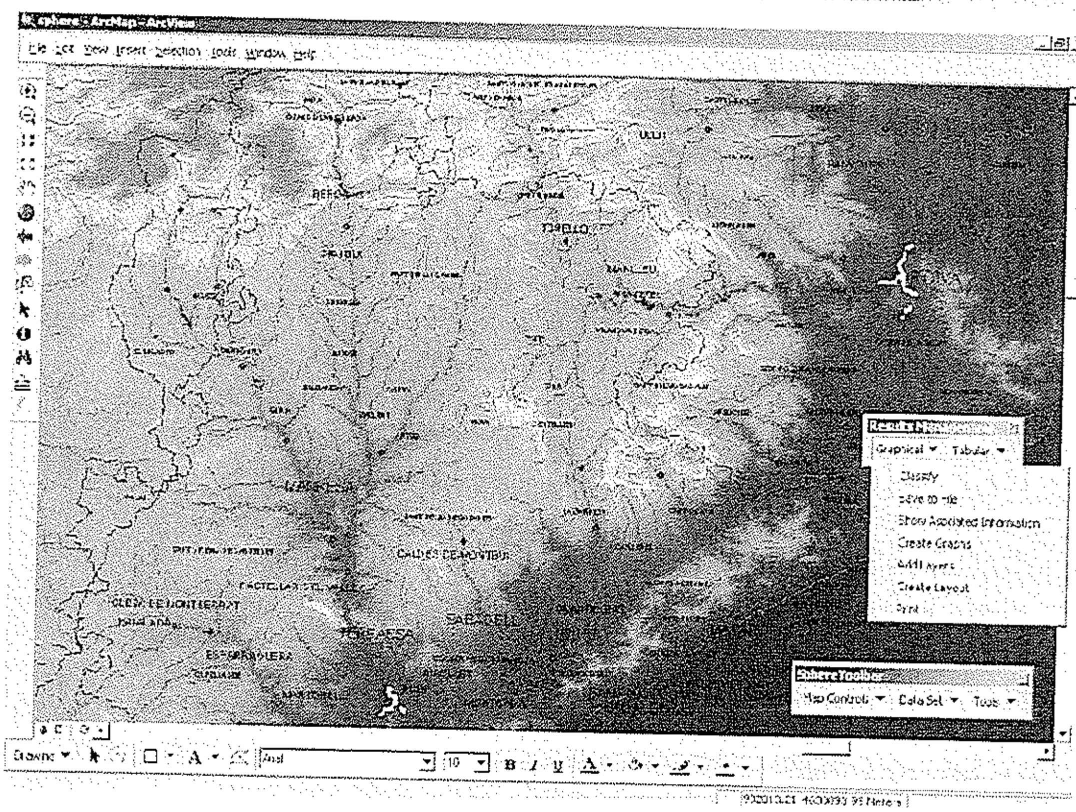


Figure 1. Views of the SPHERE-GIS. **Figure 1a. (previous page)** Data input form for the Historical basic data table with access to the rest of the related tables, **Figure 1b. (previous page)**. Menu to make a selection by the exact date, **Figure 1c**. Map with the selected spatial and tabular data displayed,, **Figure 1d**. Menu options to add graphical information to the results.

Acknowledgements. This research was supported by the Spanish Committee for Science and Technology (CICYT) grant REN2001-1633 (PALEOCAP Project), and by de European Commission (DG XII), through research contract number EVG1-CT-1999-00010 (Systematic, Palaeoflood and Historical data for the improvEment of flood Risk Estimation, "SPHERE" Project).

REFERENCES

Benito, G., Díez Herrero, A., Fernández de Villalta, M., Magnitude and frequency of flooding in the Tagus Basin (central Spain) over the last millenium, *Climatic Change*, 2003, 58, 171-192.

Chen Jia-Qi, Ye Young-Yi, and Tan Wei-Yan. The important role of historical fllod data in the estimation of spillway design floods. *Sciencia Sinica*, 1975, 18 (5), 669-680.

Diez-Herrero, A., Benito, G. and Lain Huerta, L. Regional palaeoflood databases applied to flood hazards and palaeoclimate analysis, ed. Benir, G., Baker, V.R. and Gregory, K.J., *Palaeohydrology and Environmental Change*. Wiley, Chichester, 1998, pp. 335-347.

Ely, L. and Hirschboeck, K. Palaeoflood database, Compiled at the Laboratory of Tree Ring Research, University of Arizona, Tucson, AZ, 2002.

Microsoft Press. Microsoft Visual Basic 6.0. Manual del Programador, McGrawHill, Madrid, 1998.

Environmental Systems Research Institute. Exploring ArcObjects, ed. Zeiler, M, California, USA, 2001.

Environmental Systems Research Institute ArcObjects Online: http://arconline.esri.com/arcobjectsonline/, 2001.

Fernández de Villalta, M.,Benito, G., and Diez-Herrero, A., Historical Flood Data Analysis using a GIS: The Paleotagus Database, *The Use of Historical Data in Natural Hazard Assesments*, ed. Glade, T. Albini P., and Francés, F., Kluwer Book Series, Advances in Natural and Technological Hazards Research, Dordrecht, 2001, pp. 101-112.

Goodchild, M. F., and Kemp, K. K., ed. NCGIA core Curriculum in GIS. National Center for Geographic Information and Analysis, University of California, CA., 1990, <http://www.geog.ubc.ca/courses/klink/gis.notes/ncgia/u23.html#UNIT22>.

Hua Shi-Qian. A general survey of flood frequency analysis in China, *U.S.- China Bilateral Symposium on the Analysis of Extraodinary Flood Events*, ed. Anonymous, Nanjing, China, 1985.

Hydrologic Engineering Center, HEC-RAS, River Analysis System, Hydraulics Reference Manual, CPD-69, U.S. Army Corps of Engineers, Davis, 2002.

Jennings, R. Using Microsoft Access 2000., Que, Indiana, USA, 1999.

Oguchi, T., Branson, J., Clark, M.J. Data sharing in palaeohydrology: Changing perspectives, *Palaeohydrology, Understanding Global Change*, ed. Gregory, K.J., Benito, G., Wiley, Chichester, 2003, pp 261-271.

Pfister,C. Brázdil, R. Glaser, R., Barriendos, M, Camuffo,D., Deutsch, M., Dobrovolný,P., Enzi, S., Guidoboni,E., Cotiza, O., Militzer, S., Rácz, L., Rodrigo, F. Documentary Evidence on Climate in Sixteenth-Century Europe, *Climatic Variability in Sixteenth-Century Europe and Its Social Dimension*, ed. Pfister, C., Brázdil, R., Glaser, R., Kluwer academic publishers, 1999.

Razavi, A. H. ArcGIS Developer's Guide for Visual Basic Applications (VBA), Delmar Learning, 2002.