Report from the 2nd NCAR Workshop on GIS in Weather, Climate and Impacts

by Olga Wilhelmi (NCAR/ISSE)

Introduction

Earth system science community is challenged not only with integration of complex physical processes into weather forecast and climate prediction models but also with understanding the interactions between climate, environment, and society, and integrating societal and environmental information with weather and climate. In addition, climate- and weather-related policy and decision-making largely depend on usability of earth system science output and accessibility of data.

Over the past two decades Geographic Information Systems (GIS) tools and methods have been widely used in many societal sectors and academic disciplines for data integration, analysis and decision-making. Geographic information science and technology have evolved from the requirements of a GIS community which until recently did not include atmospheric scientists. To introduce GIS to atmospheric science community, in 2001, NCAR created a GIS Strategic Initiative. The Initiative has been an interdisciplinary effort to foster collaborative science, spatial data interoperability, and knowledge sharing with GIS. With the goal to integrate data and knowledge across disciplines the GIS Initiative aims to bridge communities of atmospheric scientists, data managers and the GIS community at large.

As a step towards fuller integration of the Earth system sciences and bridging atmospheric and GIS communities, on July 6-8, 2005, NCAR GIS Initiative held its 2nd community workshop on *GIS in Weather, Climate and Impacts*. The workshop brought together sixty five representatives from academia, the private sector, the government, and several international organizations. The workshop program included plenary sessions, panel discussions, poster session, and break-out sessions of interdisciplinary working groups. The workshop proceedings are available on-line at http://www.gis.ucar.edu/05workshop/index.html. Summary of workshop discussions and recommendations are presented below.

Previous Workshops in the Series

This workshop is second in its series of workshops organized by the NCAR GIS Initiative. First community workshop on *GIS in Weather, Climate and Impacts* took place in August 2002 in Boulder, Colorado. The proceedings of the 1st workshop are available on-line at http://www.gis.ucar.edu/02workshop/index.html and summarized in 2003 *BAMS* article by Wilhelmi and Brunskill.

Goals

The purpose of the second community workshop was to evaluate the progress made in integration of GIS with atmospheric and related geo- and social sciences since the first NCAR workshop; define research needs and opportunities in geospatial research and education; and address issues of data management and discovery with a goal of increasing usability of the atmospheric and the Earth system sciences.

Workshop overview

GIS Workshop: Day 1

Welcome remarks were given by Olga Wilhelmi (NCAR, GIS Initiative PI) and Diana Josephson (NCAR, Associate Director of SERE).

In the first plenary session, Olga Wilhelmi and Jennifer Boehnert (NCAR, GIS Coordinator) presented progress to date on the work of the NCAR GIS Initiative and outlined goals and objectives for the workshop. Following the GIS Initiative presentation, the session focused on the topic of using atmospheric data in a GIS. David Maidment (University of Texas at Austin) talked about innovative ways to use GIS to connect atmospheric sciences and hydrology. Peter Thornton (NCAR, Climate and Global Dynamics) presented method for mapping and distributing gridded daily surface weather data and discussed challenges of using spatio-temporal data in GIS. James Rattling Leaf (Sinte Gelska University) talked about tribal college perspective on geospatial activities, and Susan Gallagher (The Globe Program) discussed challenges and successes in using GIS in K-12 education.

In the second plenary session the focus shifted towards using GIS as a research tool in atmospheric sciences. John Wilson (University of Southern California) discussed the role of interpolation in GIS-based climate studies. Izabela Dyras (Institute of Meteorology and Water Management, Krakow, Poland) presented GIS techniques for mapping satellite precipitation data. Scott Shipley (George Mason University) shared his classroom exercises for teaching GIS to meteorology students, and Johannes Feddema (University of Kansas) presented challenges and solutions on incorporating social and environmental data into a global circulation model with an example of the Community Climate System Model (CCSM).

Presentations of the plenary sessions included a diverse range of topics. Speakers covered many important issues associated with the use of GIS in atmospheric sciences and addressed questions of users of atmospheric information. Presentations are available on-line at http://www.gis.ucar.edu/05workshop/agenda.html.

First panel discussion focused on the two topics presented at earlier plenary sessions: use of GIS in atmospheric research and use of atmospheric data in GIS. The panelists, David Gochis (Research Application Laboratory/NCAR), May Yuan (Geography Department/ University of Oklahoma), Dennis Ward (Education and Outreach/UCAR), and Christine

Wiedinmyer (Atmospheric Chemistry Division / NCAR), discussed current challenges in using GIS in research or in using atmospheric science data outside of the atmospheric science domain, and suggested ways for improvement of the interactions between atmospheric scientists and the users. Role of GIS in fostering those interactions was also discussed.

Key points to take away from Day 1 presentations and panel discussion included:

- Lack of knowledge in GIS concepts still remains the largest impediment in adoption of GIS technology by the atmospheric science community. The learning curve can be overcome with training, although there is a question of relevance and immediate needs.
- Although GIS specialists have limited knowledge about atmospheric science, multidimensional data, and model outputs, in the past several years (since 2002 workshop), significant progress has been made by the GIS community in learning about atmospheric models and observational data structures. A major breakthrough in bridging two communities is the adoption of the NetCDF CF (climate and forecast) convention data format by ESRI GIS software products (ArcGIS 9.2).
- Development of an atmospheric science analysis tools in a GIS is important for meaningful analysis of atmospheric data, and for giving scientists analysis tools with familiar terms and concepts. Major improvements need to occur in the areas of spatio-temporal analysis (for time-varying, dynamic phenomena) and addressing issues of cross-scale integration. Significant work has been done in developing concepts and methods for temporal GIS however there has been limited technological implementation.
- Scientists involved in global modeling are faced with problems of file size limitation in addition to compatibility between atmospheric models, satellite observations, and GIS.
- Reaching out to K-12 user community requires real partnership between researchers and classroom teachers (GIS tools, science lessons – prepackaged, step-by-step materials).
- Building an atmospheric-GIS community is critical to ensure further development and progress.

Discussion among speakers, panelists and the workshop participants was carried out further into the evening reception and poster session. Poster presentations included a variety of topics from GIS applications providing access to real-time observations (Allard et al.) to GIS tools for interactive climate vulnerability mapping (West). List of posters is available in Table 1.

GIS Workshop: Day 2

Second day of the workshop started with the plenary session and panel discussion devoted to data management and discovery. David Froehlich (NOAA National Geophysical Data Center) presented NGDC's spatial portal for accessing data from

NOAA's observing systems. Gary Strand (Climate and Global Dynamics/NCAR) discussed data management challenges and lessons learned form contributing climate model output to the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 4. May Yuan (University of Oklahoma) gave a talk on a GIS representation and geographic dynamic data discovery. Greg Yetman (CIESIN, Columbia University) discussed CIESIN's work on integration of socioeconomic and biophysical data. Ben Domenico (Unidata) presented update on the Open Geospatial Consortium (OGC) interoperability experiment, GALEON.

The panel discussion continued the morning themes of data management and discovery. The panelists, John Cartwright (CIRES/University of Colorado), Lawrence Buja (NCAR CGD-CCSM), Steve Aulenbach (NCAR Data Management Working Group), Michael Burek (NCAR Community Data Portal), and Greg Yetman (CIESIN, Columbia University), shared their experience in data management and suggested ways for improving data management and discovery.

Key points to take away from Day 2 presentations and panel discussion included:

- Current trends show convergence between the Internet, spatial data bases and GIS. Many organizations and data providers are starting to move from information systems to knowledge systems, aimed at providing context for the data, including educational resources.
- Among the challenges that data managers face are: dealing with variety of data (e.g., types, formats, holdings at multiple locations); limited resources; limited recognition of data management and data services in many organizations; limited capabilities for effective data discovery, including search and browsing, and data interpretation by diverse users due to existing metadata practices.
- Addressing those challenges could be done using some of the current solutions (e.g, following standards and conventions; utilizing spatial databases and Internet-based maps as a gateway to data; using informal networks of data providers) and future implementations (e.g., building stronger community; bridging gap between science and GIS; improvements in metadata standards, practices and creation; promoting interactive data access for a variety of users)
- Data managers emphasized their interest in learning about GIS community's needs and requirements in metadata conventions.

Breakout Group Discussions

Advances in Earth Systems sciences require collaboration of scientists, researchers and engineers from various fields. This trend is driven by the need to address complex problems that cut across traditional disciplines, and the capacity of new technologies to both transform existing disciplines and generate new ones. In addition, these new cross-disciplinary projects generate large volumes of datasets from different disciplines and of different formats. Management, use and discovery of these datasets are essential for making the new science and education more usable and effective.

Earlier presentations and panel discussions set the stage for the in-depth discussions in working breakout groups. Similar to the structure of the plenary sessions the breakout groups focused on the two major topics: research directions in geospatial and earth systems sciences and data management in interdisciplinary scientific organizations. The working groups addressed a set of questions (Appendix A) and provided a list of specific recommendations. Two *research directions* breakout groups were chaired by Rebecca Morss (NCAR MMM/ISSE) and Christine Wiedinmyer (NCAR ACD). Steve Aulenbach (NCAR DMWG) and Lawrence Buja (NCAR CGD-CCSM) co-chaired the *data management* breakout group.

GIS Workshop: Day 3

The concluding day of the workshop started with presentations from the breakout groups. Summaries of breakout group discussions are presented below.

Research Directions: discussion summary

In group discussions, GIS was identified as an enabling technology for moving cross-cutting interdisciplinary science forward. Several major advantages of using GIS in earth system and related sciences were specified.

- Enabling integration of earth sciences with socio-economic information
- Enabling investigation of coupled systems / processes
- Enabling cross validation of observational data and model outputs
- Conveying uncertainty in spatial environment.

Working groups identified directions in research with specific themes/questions that would advance geographic information science. Those themes included:

- Development and testing of spatial interpolation techniques appropriate for earth system sciences
- Development of methods for working across scales (up-scaling and downscaling methods and tools)
- Development of methods for operating in n-dimensional data space
    - Temporal GIS is a priority area in both research and technological implementation

Those GIS science / technology questions can help solve important problems of the earth system sciences and its connection to the users. Examples include:

- Research on coupled systems: (i.e., the links between the atmosphere and land processes; the water cycle and fisheries, urban heat island, biosphere/ atmosphere interactions, etc.)
- Weather and climate impacts assessments
- Natural resource / risk management and policy development

Addressing these challenging questions will require cross-discipline collaborations, data integration and methodological innovation. Collaborative research between GIS and atmospheric researchers was identified as a critical step. Community building and education were specified as two essential components for building stronger collaborations.

Working groups also discussed how to make scientific data and results more usable to non-scientific audience; GIS community; policy makers; educators. Participants provided these recommendations on how to improve usability of science and the interactions between scientists and users:

- Data and science output need to be simplified (e.g., interfaces among a variety of file formats, reduction of data size, use of metadata and documentation, use 'game-like' interfaces to interest younger generation).
- Spatial data sets should come bundled with relevant tools (e.g., appropriate analysis, symbology, etc.).
- Determine standardized (OGC compliant) data formats.

Data Management and Discovery: discussion summary

The *data management and discovery* working group discussed successes and challenges in managing multidisciplinary datasets of different formats, including the role of a data manager in scientific organizations. Despite the growing number of successes in managing, integrating and distributing GIS and earth science datasets, a number of challenges still exist. The following were identified:

- Recognizing opportunities for change and overcoming organizational culture change with regards to data management and roles of data managers
- Evaluating changeover cost versus increased efficiency
- Need for real standards
- Need for better community coordination

Participants of *data management and discovery* breakout group proposed following mechanisms for increasing usability of atmospheric and earth system sciences in relation to data accessibility.

- Demonstration of economic rational and increased visibility of data
- Data management presentations at science meeting
- Providing replica location service and ensuring data safety / media refresh / offsite data storage capabilities

The group also identified procedures for effective data management and discovery. Those included:

- Early involvement of data mangers in scientific projects
- Increased attention to metadata (automated collection, templates, record of science notes, usages of controlled vocabulary)
- Establishing data quality control process (e.g., peer-review, documentation standards)

To facilitate data discovery by a wide range of users, participants proposed the following:

- Making data appropriate for users
- Conducting outreach at professional meetings, data marketing and press releases
- Metadata sharing among different portals (e.g., Geography Network and Geospatial One Stop)
- Geo-anchored searching

With the notion that in 3-4 years from now, the technology will evolve so that there will be supercomputer-scale laptops, huge databases, and distributed data/knowledge sources, the data management and discovery breakout group named the following priorities:

- Community building (e.g., atmospheric/geospatial consortium)
- Data management with increased emphasis on standards, metadata and user needs
- Integration with community data portals

Presentations from each breakout group are available on-line at http://www.gis.ucar.edu/05workshop/agenda.html.

In the concluding panel discussion, the panelists, John Wilson (UCGIS/University of Southern California), Dennis Ward (UCAR Education and Outreach), Linda Mearns (NCAR ISSE), and Scott Shipley (George Mason University), discussed integration of GIS and earth system science research, specific items for research agenda, and the role of the community.

Key points to take away from this concluding panel and workshop discussion.

In relation to questions about fostering integration of GIS and earth systems communities panelists identified the following strategies:

- Fostering integration of GIS and earth system science communities requires increased interaction among both communities through frequent meetings, brown bag lunches, conversations about data models. Links to outside organizations (e.g., UCGIS) can be beneficial.
- Partnerships and collaborations between producers and users of information are critical
- There is a need for improved linkages among different earth science disciplines (e.g., atmospheric and hydrological communities) and between geosciences and social sciences.

Among the research themes important for both GIS science and earth system science, the following were identified as high priority topics:

- Investigating the role of land use/land cover in relation to climate change.
- Working across scales: upscaling / downscaling methods
- Development of appropriate interpolation methods
- Generalizing GIS to *n* dimensions.
- Temporal dimension in GIS
- Representation of confidence levels and uncertainty in a GIS.
- Describing atmospheric science boundaries in a GIS data model

Panelists and the workshop attendees presented the following recommendations for the GIS / atmospheric science community, in general, and for NCAR, in particular:

- Need to think big but act incrementally. Need projects that demonstrate ability to build coupled systems and deploy these coupled systems to aid in decision making.
- Continue to advocate for GIS within organization.

- Develop atmospheric GIS toolbox: solutions on how to deal with the data should be packaged with the data.
- Continue building community. Establish communication among NCAR workshops participants and a larger community.
- Improve interfaces between climate models and impacts
- Building on the success of Climate Change Scenarios in GIS project, expand data access to a range of climate models.
- Make developments in n-dimensional GIS one of the missions of NCAR GIS work.

Major progress in a GIS community over the last several years indicated the growing interest and recognition that GIS can serve as an integrating tool in research. The workshop came to a compelling consensus that a number of collaborative GIS-based projects in earth systems science can be developed. These projects would address important questions of interactions among land surface, population and atmosphere in addition to developing and testing new geospatial methods and techniques.

In discussions about the role of NCAR in general and the GIS Initiative in particular, the workshop participants recommended that the GIS Initiative continues with demonstrating GIS capabilities and benefits to scientists; with training and education; development of analysis tools and of the atmospheric data model. Participants recommended that NCAR should play a role of a facilitator in building community of GIS practitioners and earth system science researchers. It was recommended that NCAR provides investigational help to sift through information for end users by reviewing and giving a "stamp of approval" on methods and datasets.

The workshop participants expressed interest in continuing communication through on-line collaborative SWIKI site. SWKI has been set up and can be accessed at https://swiki.ucar.edu/atmosgis. The third community workshop on GIS in Weather, Climate and Impacts is tentatively scheduled for August 2007.

Student Participation

Following **students** received **travel grants** though competitive application process:
Julie Earls (University of South Florida)
James Bothwell (University of Oklahoma)
Colin West (Arizona State University)
Christopher Uejio (Arizona State University)

Workshop Organizers

Olga Wilhelmi (NCAR ISSE, GIS Initiative PI)
Jennifer Boehnert (NCAR RAL/ISSE, GIS Coordinator)

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Table 1. Workshop Poster presentations

Michael Allard, Micah Wengren, and John G.W. Kelley	"NowCOAST: A GIS-Application Providing Access to Real-time Observations and NOAA Forecasts to the Coastal Community via the Internet"
Steve Ansari	"Applications of the NCDC Java NEXRAD Software"
Dan Berkowitz and Randy Steadham	"Introducing GIS Applications in the WSR-88D Program"
Gerry Creager	"Presenting OGC-compatible data through the Texas Mesonet"
Izabela Dyras	"Possibilities of the precipitation monitoring from meteorological satellites using GIS techniques"
Braxton Edwards	"A flood risk assessment of the Colorado Front Range region using GIS"
Melissa Higgins	"The National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln"
Arlene Laing	"The Influence of the El Nino-Southern Oscillation on Cloud-to-Ground Lightning Along the U.S. Gulf Coast"
Christopher Ueijo	"Ecological Niche Theory Applied to West Nile Virus"
Louis Wasson	"Meteorological Parameters in Watershed Modeling Derived Through Remote Sensing"
Colin West	"Climate Vulnerability Interactive Mapping Tool"

Appendix A.

Guiding questions for breakout groups:

Research Directions Breakout Group

1. Discuss the role of GIS, as an enabling technology, for moving cross-cutting interdisciplinary research forward.
2. What are the most significant research questions in the Earth Systems sciences that could be addressed with GIS? What types of data are needed to effectively conduct this research?
3. Identify key research questions in GIS Science that are also important for the Earth Systems science research (e.g., scale, temporal GIS, ontologies, etc.)?
4. Discuss new themes and directions for collaborative research between GIS and atmospheric researchers. Identify the next steps in developing stronger collaborations. Discuss funding opportunities.
5. Identify the users (especially those in GIS community) of scientific information. Discuss ways of making scientific data and results more usable to non-scientific audience; GIS community; policy makers; educators.
6. What needs to be done to improve the interactions between scientists and users? Prioritize specific recommendations.
7. Are there impediments / challenges in using GIS in Earth Systems science research? What needs to be done to reduce those impediments? Discuss the role of education in the process.
8. What needs to be done to develop a stronger community of GIS and atmospheric sciences? What role should NCAR GIS Initiative play in the research community (collaborative research, partnerships, education, etc.)?

Data Management and Discovery Breakout Group

1. Discuss mechanisms / challenges / successes in managing multidisciplinary datasets (atmospheric, GIS, social science, etc.) of different formats?
2. Discuss the role of data managers in scientific organizations.
3. What needs to be done in data management and discovery to increase usability of atmospheric and earth system sciences? How can we develop better interactions between scientists / researchers and data managers? What needs to be done to move scientific data from the desktops to the data portals?
4. Identify procedures for effective data management. What needs to be done to ensure metadata creation? Data legacy? Data quality?
5. Discuss effective mechanisms for data discovery for a wide range of users
6. What role should NCARGIS Initiative play in working with data managers and addressing the need for more effective discovery of spatial data?
7. Prioritize specific recommendations