INTEGRATING GLOBE MEASUREMENTS WITH BASIC GAPS TO UNDERSTAND EARTH SYSTEM SCIENCE

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ABSTRACT

Simulation modeling is an excellent tool for understanding processes and predicting outcomes within the Earth system. GLOBE student data can be used with Soil-Vegetation-Atmosphere (SVAT) models such as GAPS for a variety of purposes including model validation, understanding feedbacks within water and energy cycles, testing scenarios, and interpreting satellite imagery. Basic GAPS is a version of the GAPS model that provides accessible modeling capabilities to students. It allows students to make predictions about energy and water dynamics and create inquiry based scenarios that can help demonstrate the importance of using all of the GLOBE protocol measurements to explain how Earth System Science operates in an integrated way. Results from a scientist driven and 2 student driven research projects using GLOBE data with GAPS and Basic GAPS are presented.

INTRODUCTION

The goal of Earth system science is to understand the feedbacks and interactions between all parts of the Earth system, and to predict the effect of changes in one part of the system on the others. Simulation models at varying scales of spatial and temporal resolution are commonly used as a framework for quantifying the processes functioning within the Earth system. In this way, cycles of energy and water, carbon, nutrient cycling, and other processes can be tracked and monitored over time. In order to successfully drive and validate these models, data representing each component being modeled must be available. GLOBE student data provides the input required for modeling at the process level. Ultimately, the combination of simulation modeling and GLOBE student data at the process level allows scaling to regional and global levels.

In addition to providing information about the functioning of processes through the Earth system and making predictions about possible scenarios, simulation models can also function as an important tool for inquiry based student learning and research. One such model, GAPS (General Purpose Simulation Model of the Atmosphere-Plant-Soil System), is a menu-driven soil-vegetation-atmosphere transfer (SVAT) model developed by Riha et al. (1994). A student version, Basic GAPS has also been developed. Like GAPS, Basic GAPS can simulate the cycles of water and energy between the atmosphere, soil, and vegetation. Students can easily obtain the required soil, vegetation, phenology, and climate data from sources such as the GLOBE data archive and input the information through guided menus. Once the model simulation runs, the change in soil water content, evaporation, transpiration and other environmental parameters can be displayed so that students can observe how different parts of the system change and are affected by each other.

While GAPS has been used primarily for scientific research, a major goal of the Basic GAPS model is to teach students that the Earth's ecosystems are the result of closely linked, dynamic interactions among many processes and many components. Basic GAPS enables students to study the interplay among these processes in a quantitative way. They can examine linkages within a particular biome, such as the sensitivity of soil moisture to seasonal changes in the overlying vegetation or the amount of evaporation and transpiration under certain types of soil or land use. Using Basic GAPS, students can also make up different scenarios (such as increasing the temperature, changing the pattern of precipitation, or modifying the soil properties or vegetation type) to make predictions about how the ecosystem may respond. They can also test the accuracy of their GLOBE measurements against model output to determine whether more accurate methods or measurements should be used. In this way, students, like scientists, can pose and address questions regarding the impact of climate, land cover, land use, and other inputs on the environment as well as understand issues related to data processing.

RESEARCH STUDIES USING GAPS AND BASIC GAPS WITH GLOBE DATA

The following are examples of studies in which GAPS and Basic GAPS have been used with GLOBE data by scientists and students to understand climate, soil hydrology, satellite imagery, and other ecological parameters.

Validation of GAPS with GLOBE and Remotely Sensed Data

In a recent study, scientists from NASA/GSFC and Cornell University used the GAPS model to simulate soil water dynamics from 1998 through 2001 for Greenville, PA, USA (41.3393º N, 80.3955º W, 350 m) (Robin et al., 2004). GLOBE student data, coupled with normalized difference vegetation index (NDVI) data derived from SPOT4 Vegetation imagery, were used to parameterize and validate the model. Data collected by GLOBE students from Reynolds Junior and Senior High School showed a strong positive correlation to the NDVI data for the study site. The correlations (r^2) between NDVI and the students' mean air temperature, maximum air temperature, 5 cm soil temperature, and 10 cm soil temperature for 1998-2001 were .79, .77, .68, and .68, respectively. The students' snow data also corresponded with the NDVI values for the site. Large (>30mm) snow events precipitated sharp declines in NDVI throughout that period. The close correspondence between the Reynolds and NDVI data sets increased confidence in using the student measurements to parameterize the model. Simulated daily soil water within the root zone showed a reasonable fit with students' field soil water measurements. In addition, the simulations showed that NDVI could be utilized to predict transpiration periods (QI, QII, and QIII) for northern latitudes > 35º with a distinct winter period (Figure 1). In phenological terms, QI reflects the onset of the growing season when vegetation is greening up (NDVI < 0.60) and transpiration is beginning (< 2mm/day) and QII reflects the end of the growing seasons when vegetation is greening down and transpiration is decreasing. QIII reflects the height of the growing season when transpiration rates average between 2 and 5 mm per day and NDVI is at its maximum (>0.60). Results of this study demonstrate that GLOBE student data, coupled with remotely sensed data, can provide an important source of input and validation information for capacitance SVAT models such as GAPS.

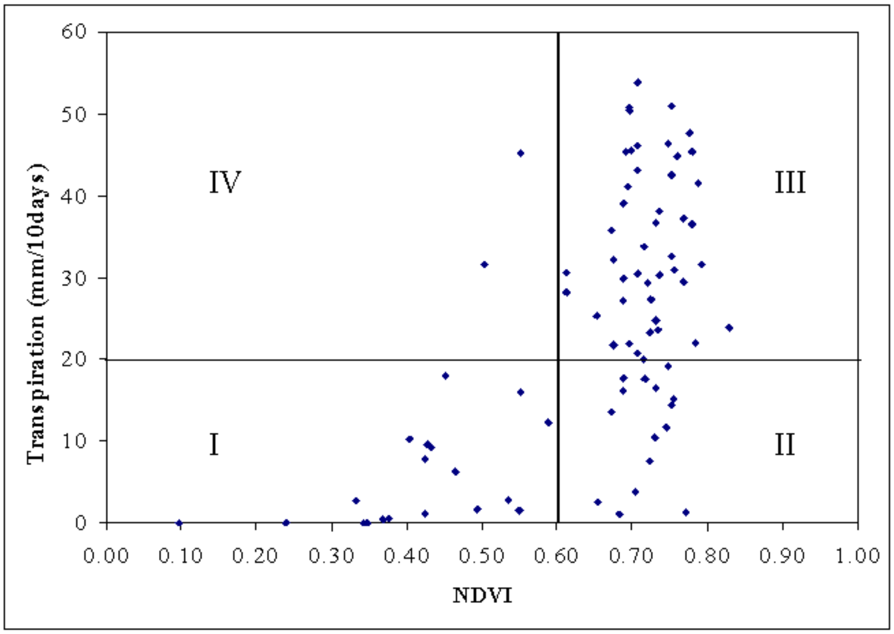

Figure 1: NDVI to simulated transpiration (1998-2001)

<u>Using Basic GAPS to Predict Hydrologic and Climate Changes Due to Climate Warming</u>

In another study, Basic GAPS was used by Katherine Lerner, a High school senior from Eleanor Roosevelt School in Greenbelt, Maryland, as part of her Senior Research Practicum project. In this study, the Basic GAPS model was used to examine the effects of increasing air temperature on the hydrologic cycle in a northern temperate deciduous forest with a sandy loam soil. GLOBE data from Northville Central School in Northville, NY (Lat 43.2245N, 74.1755 W elevation 282 m), Moreau Elementary School in South Glens Falls, NY (Lat 43.2992 N, 73.6356 W elevation: 84 m) and Jansen Avenue Elementary School in Johnstown, NY (Lat. 43.0115 N, 74.3630 W elevation: 152 m) were used to initialize the model. Actual 1999 climate data were used as the control simulation. Five additional sets of simulations were run, each time increasing the daily maximum temperature by two-degree intervals (+2°C, +4°C, +6°C, +8°C, and +10°C). There were no differences in hydrologic properties observed between the control and the +2°C scenario. However, the other simulations showed that an increase in temperature resulted in increased drainage, decreased run-off and increased transpiration and evaporation, especially during the summer months. The +10°C simulation demonstrated the largest climate and hydrologic changes. Table 1 shows the annual amounts for each simulation.

Table 1. Predicted changes in hydrologic and climate conditions with increasing temperature

	1999 Control Temperature	**Control +2°**	**Control +4°**	**Control +6°**	**Control +8°**	**Control +10°**
Precipitation (mm)	1066	1066	1135	1135	1153	1177
Drainage (mm)	422	422	478	469	479	493
Runoff (mm)	115	115	113	109	106	100
Transpiration (mm)	369	369	387	396	401	406
Evaporation (mm)	162	162	159	163	168	179

Validation of Soil Moisture Simulation with Basic GAPS and GLOBE Data

In a research project from GLOBE Estonia, students Sven-Erik Enno and Kaupo Mandla investigated how soil properties, land cover, air temperature, and precipitation affect soil moisture and in turn, how varying atmospheric conditions affect plant available water. GLOBE soil characterization, land cover, air temperature, precipitation , and soil moisture data were collected during the summer of 2003 at three study sites: a potato field (58°48’31”N, 25°24’38”E), a natural hayfield (58°48’31”N, 25°24’38”E), and a forest (58°48’04”N, 25°24’35”E). Soil properties in the potato field and natural hayfield were similar, and. both were different from the forested soil. Using these data, the students attempted to validate how well Basic GAPS could simulate soil moisture content for the three sites. They initialized the model with the GLOBE atmosphere, land cover, and soil characterization data and validated the model outputs with GLOBE soil moisture data collected at 10, 30, 60 and 90 cm depths. Their results showed that Basic GAPS was able to predict the durations and directions of most changes in water content in the surface soil for all three sites. However, the model was not as accurate in estimating the actual soil water contents. In general, Basic GAPS tended to overestimate the moisture content in the hayfield site and underestimate it in the forest site. The students concluded that possible errors in the soil texture, determined by the “texture by feel” method that was used in the input data, may have contributed to the model’s inability to accurately predict actual soil moisture content. The texture by feel method is a qualitative method and not as accurate as the particle size distribution laboratory method for determining soil texture. Thus, having more accurate field data may help improve the accuracy of the computer model.

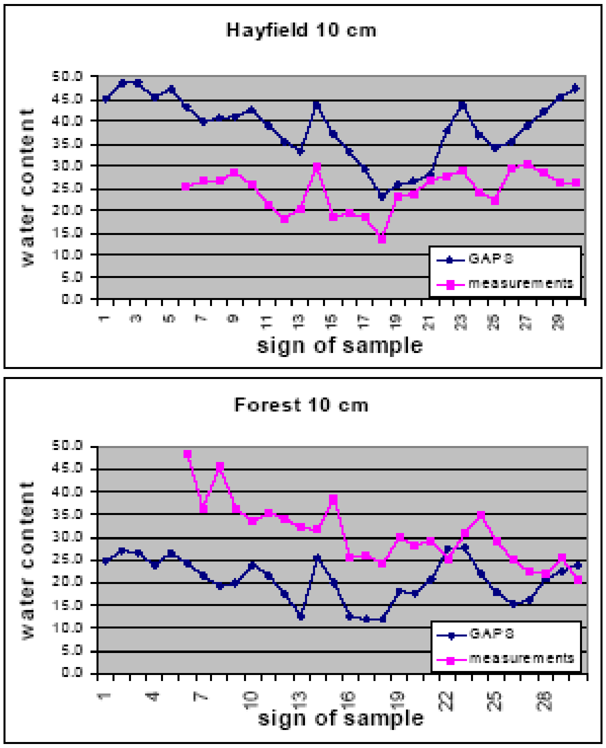

Figure 2. Comparison of GLOBE student measurements of soil moisture with prediction of soil moisture from Basic GAPS

CONCLUSION

The three studies presented here demonstrate the potential application of GLOBE data with models such as GAPS and Basic GAPS to understand and predict the fundamental feedbacks and potential changes in the Earth system. In addition, the importance of accurate and regular data collection is emphasized as an important component as shown by the sensitivity of the results of the models to their inputs. None of these three studies could have been accomplished without the availability of a complete set of data from each of the GLOBE protocols, and results may have been improved if data quality was improved. Thus, the need for accurate scientific predictions justifies the need for proper training, collection, and understanding of the importance of GLOBE data. The combination of simulation modeling with GLOBE student data can provide answers to important questions related to global change that today's students can begin answering as they become the scientists in the future.

REFERENCES

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