Geophysical Research Abstracts, Vol. 7, 05259, 2005
SRef-ID: 1607-7962/gra/EGU05-A-05259


# Free and open source GIS embedded hydrological modelling

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Hydrological models have made extensive use of Geographical Information System (GIS) functionality in the last decades but the integration between these two technologies has been mainly remained at an "independent" or "loosely coupled" level: a simple exchange of data. In recent years, given the necessity to evaluate the consequences of environmental changes exacerbated by the effects of human activities, researchers have turned their attention to an integrated approach among all physical processes. Hydrological modelling is also moving in this direction, developing physically based and spatially distributed models capable of interacting and/or integrating with other interconnected processes.

This kind of modelling has to handle with a large amount of data and parameters, often derived from different sources and measurement methodologies, corresponding to different spatial and temporal scales. Because of its advantages of data storage, analysis, visualization and maintenance GIS is a very powerful and promising tool to model the hydrological cycle and therefore a fully integrated approach ("embedded") is desirable. GRASS is the most idely used free and open source GIS and offers an attractive developing environment (C/C++/Fortran/shell script/pyton), a fully integrated database interface, a large amount of geospatial functions and some hydrological functions.

Therefore we decided to add into GRASS new hydrological modules, which can be easily combined to generate target-oriented hydrological models, in order to cope with different hydrological questions, such as flood forecast, water balance issues, water availability assessment, etc.

As a first application, a distributed and physically based hydrological model has been developed taking advantage of the already available GRASS functionalities (e.g.: slope, direction, accumulation and solar irradiation calculation) and the newly developed commands for:

- evapotranspiration, according to the Penman-Monteith approach (Allen et al., 1998);
- canopy interception, based on the Rutter approach (Zeng et al., 2000);
- snowmelt, based on the SHE approach (Abbott et al., 1986);
- runoff, based on the TOPKAPI approach (Ciarapica and Todini, 2002).