Integrated modelling of regional water resources and their interactions with a changing environment

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Water resources can be defined as the volumes of water that are available for human use (withdrawals for drinking water or irrigation, cooling, hydraulic power, navigation, dilution of pollutions, etc.). They are classically defined quantitatively, but the quality of water is also critical for some uses. As such, water resources are a key element of the global water cycle and climate system, in interaction with the biogeochemical cycles, and both submitted to and controlling human activities, so that they are at the crux of many global and regional environmental problems, including climate and land-use change.

The Seine river basin is a very interesting case study to address these issues. Firstly, it is strongly human impacted (by both agriculture and urbanization); secondly, groundwater, which can induce long-term feed-backs but is still often neglected in global change impact studies, is an important part of the resource there; and thirdly, it has been studied for more than 15 years by the PIREN-Seine programme and other related projects, leading to a wealth of data and models to draw on.

We will first highlight results from recent studies performed in the Seine river basin with the hydrogeological model MODCOU coupled to the crop model STICS. They allowed us to show that climate change will decrease water availability in summer, for both plant uptake (in soils) and as a resource for human use (groundwater and rivers); that increased irrigation results in lower groundwater levels and river flows in summer; that nitrate pollution will continue to increase during the 21st century unless preventive measures, as catch crops, are implemented over the entire watershed and that climate change will enhance this trend. Another important result from the PIREN-Seine programme, based on extensive data analysis, is the quantification of the reduction of nitrate pollution through riparian wetlands (up to 50%), by means of the denitrification permitted by the anoxic conditions prevailing in these humid environments.

In perspective, we are trying to address more complex questions, such as the following ones. How can climate change increase irrigation, and will the resources be enough to permit it? If not, will this induce a land-use change? How would increased groundwater withdrawals (for irrigation or drinking water or other purposes) change the dynamic of nitrate contamination? How will climate change affect the frequency of critical low flows, floods and inundations? Can these changes cause riparian wetlands to shrink, and reduce the nitrate retention they favour?

The structure of the coupled models used up to now, however, is not amenable to address the above questions. In particular, the different compartments simulated to describe the water and nitrate fluxes within the river basin (surface, whether cultivated or not; unsaturated zone; saturated zone; river) are involved sequentially, the output of one compartment serving as the input to the next one, without any feedback. To overcome this limit, we initiated the development of fully integrated model, named EAU-Dyssée, characterized by improved coupling and modularity, to simulate synchronous retroactions and interface additional models (e.g. wetland functioning, macro-economics of the farming system or drinking water production).