

Long term prospective of the Seine River system: Confronting climatic and direct anthropogenic changes

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Abstract

To explore the evolution of a human impacted river, the Seine (France), over the 21st century, three driving factors were examined: climate, agriculture, and point source inputs of domestic and industrial origin. Three future scenarios were constructed, by modification of a baseline representative of recent conditions. A climate change scenario, based on simulations by a general circulation model driven by the SRES-A2 scenario of radiative forcing, accounts for an average warming of +3.3 °C over the watershed and marked winter increase and summer decrease in precipitation. To illustrate a possible reduction in nitrate pollution from agricultural origin, a scenario of good agricultural practices was considered, introducing catch crops and a 20% decrease in nitrogen fertilisation. Future point source pollution was estimated following the assumptions embedded in scenario SRES-A2 regarding demographic, economic and technologic changes, leading to reductions of 30 to 75% compared to 2000, depending on the pollutants. Four models, addressing separate components of the river system (agronomical model, hydrogeological model, land surface model and water quality model), were used to analyse the relative impact of these scenarios on water quality, in light of their impact on hydrology and crop production.

The first-order driving factor of water quality over the 21st century is the projected reduction of point source pollution, inducing a noticeable decrease in eutrophication and oxygen deficits downstream from Paris. The impact of climate change on these terms is driven by the warming of the water column. It enhances algal growth in spring and the loss factors responsible for phytoplankton mortality in late summer (grazers and viruses). In contrast, increased seasonal contrasts in river discharge have a negligible impact on river water quality, as do the changes in riverine nitrate concentration, which never gets limiting. The latter changes have a similar magnitude under the three scenarios. Under climate change, riverine and groundwater nitrate concentrations increase and crop production is advantaged with reduced growing cycles and increased yields. In contrast, nitrate concentrations decrease under the good agricultural practices scenario, with a limited decrease in crop production. When these two scenarios are combined, the changes in nitrate concentrations balance each other and crop yields increase. The results

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of this numerical exercise indicate that the potential changes to the Seine River system during the 21st century will not lead to severely degraded water quality.

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1. Introduction

Major climate change as a result of anthropogenic emission of green-house gases (GHGs) is now widely accepted. Recent projections using general circulation models (GCMs) indicate that global mean surface temperature will increase by 1.5 to 6 °C by the end of the 21st century, with increased uncertainties at the regional scale, especially regarding the water cycle (Third Assessment Report of the International Panel for Climate Change IPCC; Houghton et al., 2001). The subsequent impacts of such changes on river systems are the subject of active research (Arnell et al., 2001), because of the importance of water for human settlements, in terms of resource and risk factors. Impacts on hydrology include changes in river flow (regimes, extreme events as flooding, more rarely interannual variability, Arnell, 2003) or groundwater storage (Bour-aoui et al., 1999). As for water quality, most climate change impacts are related to changes in either discharge, which controls dilution and residence times, or water temperature. When the latter increases, oxygen diffusion to the water column decreases, and biological activity is enhanced, with consequences on nutrients and biomass.

Direct anthropogenic pressures also affect water quality. In the Seine River basin (France, Fig. 1), one can presently identify two major anthropogenic alterations of the biogeochemical quality of the water bodies: 1) diffuse pollution by nitrates from agriculture, in the rivers and the large aquifers that sustain them in this sedimentary basin; 2) point source pollution to rivers, because of the heavy urbanisation and related industrial activity (Meybeck et al., 1998). This basin of 78,600 km² at Le Havre (14% of the area of metropolitan France) contains 17 million inhabitants (25% of the national population), with 10 million in the single agglomeration of Paris, and 40% of the national industrial activities.

In order to assess the impact of climate change on such a human impacted river system, one has to deal with two issues: 1) identify the relative magnitude of climate change impact compared to the one of direct anthropogenic pressures and their likely changes; 2) identify the uncertainties around the evolution of

climate and direct anthropogenic factors, which are both subjected to human decision, thus mostly unpredictable. To address these two questions, numerical modelling is used to analyse several scenarios accounting for the evolution of presumably important driving factors during the 21st century. Focus is put on the relative impacts of climate change, agriculture and point source pollution changes on the water quality of the Seine, France, where there is a wealth of research and background information to draw on.

2. Scenarios

Three future scenarios, for climate, agriculture and point source pollution, were considered, each accompanied by a baseline scenario, representative of recent conditions. The future scenarios were constructed by modification of their respective baseline to account for the selected changes.

2.1. Climate

2.1.1. GCM simulation of climate change

Climate change was described using two 30-year simulations performed with the variable resolution GCM ARPEGE-IFS cycle 18 (Gibelin and Déqué, 2003). The global resolution (T106) was refined around the centre of the Mediterranean Sea (40°N; 12°E) with a stretching factor of 3, leading to a resolution of about 50 km in the Seine watershed. Because of weak topographic gradients and strong oceanic influence, the climate of this watershed does not exhibit abrupt spatial contrasts, and there was no attempt to further regionalise these GCM simulations. The time-slice simulations correspond to 1960–1989 and 2070–2099 and were driven by the SRES-A2 scenario of radiative forcing for the two periods, including aerosols, and leading to a GHG concentration equivalent to 850 ppm of CO₂ at the end of 21st century. Sea surface temperatures (SSTs) were prescribed from monthly observations for the recent climate simulation. For the climate change simulation, these observations were blended with SSTs from ocean-atmosphere coupled simulations, following Douville et al. (2002).

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