Postdoctoral position offer:

Trajectories of regional hydrosystems in the Sahel

AFD-IRD offers a 24-months post-doctoral position at the Institute of Geoscience and Environment (IGE) in Grenoble to analyze past and future trajectories of sahelian hydrosystems, including aquifers and large basins of the region, running the model Parflow-CLM at hyper-resolution to give up-to-date scientific inputs to water managers and decision makers.

Context:

In the past, the Sahel has been submitted to one of the most intense climate signal ever recorded. The consequences of the severe and long-lasting drought in the eighties have deeply affected the hydrological cycle, which is, after 40 years, still moving to a new equilibrium (Wendling et al. 2018). While climate and land cover changes are expected to intensify in the coming decades, scientists are challenged to envision regional and integrative approaches rooting the development of evidence-based Integrated Water Resources Management (IWRM) in one of the most sensitive regions of the world to global changes.

The Sahelian paradox is the best known example in the past of cascading shifts impacting the water cycle : the drought of the 1980s saw an increase in surface runoff due to the concomitant decrease in woody cover and groundwater recharge increased over large areas (Favreau et al., 2009, 2011, Rodell et al. 2018). Today, the intensification of extreme rainfall events (Panthou et al., 2018) in links with global warming (Taylor et al., 2017) reinforces the phenomenon while the aquifers are reaching the surface in many places (Southwest Niger), causing new risks of salinization and increased flooding. The extension of the flooding of the Niger inner delta by a factor of 5 (Mahé et al., 2009) has had strong consequences on groundwater recharge. Furthermore, the major hydroelectric dam projects (Fomi/Moussako, 100MW, Guinea, Kandadji, 125MW, Niger, Maiga 2019), land management (growing of crops, great green wall, ...) and agricultural practices (underpinning, land restoration, benches) are expected to have strong direct and indirect impacts on the hydrological cycle. The massive development of irrigation is another essential factor to be taken into account, whether through the mobilization of surface water, groundwater (Altchenko and Villolth, 2015), small-scale (Nazoumou et al., 2016) or large-scale (CEA, AU, ADB, UNDP, 2017), with unprecedented impacts on water flows and stocks. The common denominator of all these examples, past and future, is the lack of tools to assess the effects of these global changes on the entire cycle and to derive sufficiently informed water resource trajectories and associated management strategies.

The decadal prediction of water cycle trajectories require integrated approaches to take into account interactions between all aforementioned factors in all their complexity. This requires in particular the availability of modelling tools able to explicitly address all the compartments of the water cycle and their interdependencies at different time scales, with a particular emphasis on the issue of groundwater. Today, the numerical limitation of such an approach has been lifted, and makes it possible to run continental scales models of the entire water cycle, based on physical data, allowing the best possible environment knowledge aggregation (Maxwell and Condon,

2016, Keune et al., 2016). These models, which are not calibrated, benefit from both remote sensing and databases (boreholes, soils, vegetation, water bodies) compiled at the national level to provide information on their parameters. Moreover, the main processes simulated are not explicitly specified, but are defined by the model parameters and forcings (the degree of knowledge one has of the system), and therefore likely to evolve over time. These properties become fundamental as we begin to realize that some hydrosystems have already switched from one state to another (Wendling et al., 2019).

In the context of the CECC (Cycle de l'Eau et Changements Climatiques) project between AFD (Agence Française du Développement) and IRD (Institut de Recherche pour le Développement), a regional scale integrated model will be set up to simulate integrated trajectories of the water cycle under changes over the Sahelian region.

Description of work:

The Parflow-CLM model is a physically based fully coupled hydro-geological to land surface model including water transfers in the saturated and unsaturated zone solving the Richard's equation, water transfers on the surface solving a kinematic wave equation and water and energy fluxes to the atmosphere solving the energy budget of the surface. It is parallelized and compiled on many platform including super-computers at University Grenoble Alpes (France), at Institute of Mathématique and Sciences Physiques (Porto-Novo Benin) and at the French national super computer center (IDRIS), among other. The PF/CLM model has been implemented over West-Africa (4M. km²) at km² resolution and already provided the first full year hyper-resolution simulation for this region. This will be the starting point for a long-term trajectory study for the Sahelian water cycle at ~km² resolution, specifically the Niger and the Senegal rivers and aquifers. The candidate will first analyze simulation outputs for this early run and contribute to the ongoing publishing work. This will serve as a basis for model setup corrections aiming at longer-term runs dedicated to the sahelian region. These corrections of the model setup will be tested on smaller domains or 1D configurations where in-situ data are available like the AMMA-CATCH observatory 1x1° box around Niamey (Niger).

The second task will consist in gathering the necessary data to run a 40-year simulation in the past. Several meteorological re-analyses are available (ERA5, MERRA2, ...). Those will have to be selected according to relevant metrics and prepare for the first long term regional run. A specific attention should be brought to vegetation maps to represent the evolution of land cover over this period.

The third task will consist in running the 40-year simulation with the gathered data set and analyze this simulation. In particular, the candidate will pay attention on the ability of the model to reproduce observed trends for ground water resources when compared to GRACE products and for rivers streamflow when compared to available long-term data. A focus will be made on the representation of the observed changes in Niger streamflow regime since the 1970s.

In interaction with the development of future climate and land use scenarios within the CECC project, the model will be run in future conditions to forecast potential trajectories for water resources for 2050.

Finally, model outputs will be shaped to fulfill stakeholder's expectations in term of useful hydrological products (recharge, streamflow, evapotranspiration maps). For such a task we will build on the Hydroframe tools (www.hydroframe.org). The purpose of this task will be to bring to end-users scientific results from up to date research. Those developments will benefit from a collaboration with Princeton University where Hydroframe is developed.

Expected skills:

• PhD in hydrological modeling including surface hydrology, hydrogeology and/or land surface

• Programing & Unix environment (shell, python, R...)

• Background in statistics, data processing (netcdf, geographic information systems)

• Strong teamwork skills (communication & collaborative work)

• Fluency in English (oral and written), French appreciated

• Scientific writing skills for reports and scientific papers

Supervision team:

The Position will be located at IGE (Institute of Geoscience of the Environment) in Grenoble (France) where the PHyREV team (Processus Hydrological Processes and vulnerable Water Resources) develops a long expertise on West African Hydrology in collaboration with scholars from West-African countries. They participate intensively to the AMMA-CATCH observatory gathering hydrological data for 30 years including rain, streamflow, evapotranspiration... The candidate will be supervised by Basile Hector and Jean-Martial Cohard who run the model in the West African context. The candidate will also benefit from expertise of the PHyREV team, from the CECC consortium and from international collaborations of the team.

Duration, location, and salary:

The post-doctorate will be recruited for 24 months at IGE (Grenoble, France), with a net monthly salary around 2100 euros for early doctors, commensurate with experience. This includes social services and health insurance.

Contact and deadline for application:

Applications will be considered until May 28th, 2023, and should include a resume, a statement of research interests, and the names of references including e-mail addresses. Applications should be submitted by e-mail to Jean-Martial Cohard (jean-martial.cohard@univ-grenoble-alpes.fr)

Cited references:

Altchenko, Y. and Villholth, K. G.: Mapping irrigation potential from renewable groundwater in Africa – a quantitative hydrological approach, Hydrol. Earth Syst. Sci., 19, 1055–1067, https://doi.org/10.5194/hess-19-1055-2015, 2015.

CEA, UA, BAD, PNUD: 2017 Africa sustainable development report :, African Union :, 2017.

Favreau, G., Nazoumou, Y., Leblanc, M., Guéro, A., Goni, I. B., Treidel, H., Martin-Bordes, J. L., and Gurdak, J. J.: Groundwater resources increase in the Iullemmeden Basin, west Africa, in: Climate change effects on groundwater resources: A global synthesis of findings and recommendations, Wallingford, UK, 2011.

Favreau, G., Cappelaere, B., Massuel, S., Leblanc, M., Boucher, M., Boulain, N., and Leduc, C.: Land clearing, climate variability, and water resources increase in semiarid southwest Niger: A review, 45, https://doi.org/10.1029/2007WR006785, 2009.

Keune, J., Gasper, F., Goergen, K., Hense, A., Shrestha, P., Sulis, M., and Kollet, S.: Studying the influence of groundwater representations on land surface-atmosphere feedbacks during the European heat wave in 2003, Journal of Geophysical Research: Atmospheres, 121, 13,301-13,325, https://doi.org/10.1002/2016JD025426, 2016.

Mahé, G., Bamba, F., Soumaguel, A., Orange, D., and Olivry, J.-C.: Water losses in the inner delta of the River Niger : water balance and flooded area, 23, 3157–3160, https://doi.org/10.1002/hyp.7389, 2009.

Maiga, F.: Hydrological Impacts of Irrigation Schemes and Dams Operation in the Upper Niger Basin and Inner Niger Delta., Thesis, Université d'Ottawa / University of Ottawa, http://dx.doi.org/10.20381/ruor-23300, 2019.

Maxwell, R. M. and Condon, L. E.: Connections between groundwater flow and transpiration partitioning, 353, 377–380, https://doi.org/10.1126/science.aaf7891, 2016.

Nazoumou, Y., Favreau, G., Adamou, M. M., and Maïnassara, I.: La petite irrigation par les eaux souterraines, une solution durable contre la pauvreté et les crises alimentaires au Niger ?, 25, 15003, https://doi.org/10.1051/cagri/2016005, 2016.

Panthou, G., Lebel, T., Vischel, T., Quantin, G., Sane, Y., Ba, A., Ndiaye, O., Diongue-Niang, A., and Diopkane, M.: Rainfall intensification in tropical semi-arid regions: the Sahelian case, 13, 064013, 2018.

Rodell, M., Famiglietti, J. S., Wiese, D. N., Reager, J. T., Beaudoing, H. K., Landerer, F. W., and Lo, M.-H.: Emerging trends in global freshwater availability, 557, 651–659, https://doi.org/10.1038/s41586-018-0123-1, 2018.

Taylor, C. M., Belušić, D., Guichard, F., Parker, D. J., Vischel, T., Bock, O., Harris, P. P., Janicot, S., Klein, C., and Panthou, G.: Frequency of extreme Sahelian storms tripled since 1982 in satellite observations, Nature, 544, 475–478, https://doi.org/10.1038/nature22069, 2017.

Wendling, V., Peugeot, C., Mayor, A. G., Hiernaux, P., Mougin, E., Grippa, M., Kergoat, L., Walcker, R., Galle, S., and Lebel, T.: Drought-induced regime shift and resilience of a Sahelian ecohydrosystem, Environ. Res. Lett., 14, 105005, https://doi.org/10.1088/1748-9326/ab3dde, 2019.