Institut Pierre-Simon Laplace (IPSL)

Sciences du climat et de l'environnement

Postdoctoral position offer: Optimization of the ORCHIDEE land surface model over Europe for hydrological applications

The Institut Pierre-Simon Laplace (IPSL) offers an 18-months post-doctoral position to optimize the IPSL land surface model ORCHIDEE over Europe, and better answer the needs of applied research projects and climate services focused on hydrology.

Context:
Water resources are crucial for many stakes (socio-economical activities like agriculture, hydropower generation, drinking water production, tourism; preservation of water-related ecosystems in rivers, wetlands, and even drylands), which are likely to enter in conflict if water becomes limiting. This is already the case in severely water stressed regions, and water related problems are anticipated to develop in many areas of the world including Southern Europe, because of increasing anthropogenic pressures [1,2,3]: direct withdrawals from human settlements (for agriculture, industry, drinking water) and climate change (following an overall "dry gets drier, wet gets wetter" pattern). The wet get wetter trend is also related to serious concerns about enhanced river flooding, in conjunction with sea level rise in coastal areas.

This worrisome context has motivated lots of research on the hydrological consequences of climate and land-use changes (impacts, sometimes including adaptation or mitigation pathways), with a strong support, in France, by the Ministry of Ecology: interdisciplinary research program "Gestion et impacts du changement climatique" (1999-2016), with many projects focused on major river basins, often in collaboration with public and private stakeholders [4,5,6]; nationally-coordinated program Explore2070 [7] focused on the water sector (2010-2012). This research work has been an important contribution to regional adaptation networks (like AcclimaTerra, headed by Hervé Le Treut of IPSL), and official plans for climate change adaptation in large river basins. In parallel, owing to more frequent water resource problems because of climate change and other human activities, there is more and more demand for precise hydrological projections from public or multi-national private companies (energy, water distribution, insurance, etc.), in the framework of "climate services", for which the European scale is particularly interesting.

Hydrological projections classically involve validated hydrological or land surface models, up-to-date climate projections, and bias-correction methods, often coupled with downscaling, in a way that is mostly top-down, with offline impact models and no feedback from the land surface to the simulated climate. Yet, there is a growing body of evidence showing that natural and human-induced land surface water fluxes can influence past and future climate and water resources [1,8,9,10], as previously demonstrated for the carbon flux processes [11,12]. These land surface water fluxes, usually overlooked by operational hydrological models, include: soil moisture (SM) increase by capillary rise from groundwater (GW) and river flooding, often in depressions and riparian wetlands, which are also the place of significant focused GW recharge, especially in dry environments; surface water and GW depletion, or sometimes exhaustion, by irrigation (38% of which is GW-fed globally); SM, GW, and irrigation response to but also impact on mean climate and extreme events (droughts, heatwaves, floods), via modifications of evapotranspiration, soil thermodynamics, and the properties of the atmospheric boundary layer.

The IPSL land-surface model ORCHIDEE has been the bed of many developments to describe these coupled hydrological processes, as well as other relevant processes related to the soil-vegetation-atmosphere continuum. The proposed research aims at gathering these developments in a unique version, to be calibrated over Europe using detailed input datasets over space and time, in order to describe efficiently the main signatures of climate and land-use changes (average patterns but also decadal trends) and support attribution and projection activities, for both research and climate services.

Description of work:
The ORCHIDEE land surface model describes a wide range of interlinked land surface processes, mostly natural but also human-induced, controlling the water, energy and carbon budgets of all terrestrial ecosystems (boreal, temperate and tropical forests, croplands (wheat, maize, soy, and rice, with specific irrigation rules), rangelands, wetlands and peatlands. It works at sub-hourly time steps, over grid-meshes of variable resolution depending on the objectives and availability of input data. It can be used either in stand-alone mode (using meteorological forcing datasets), or coupled with the IPSL climate model [13] used in all CMIP (Coupled Model Intercomparison Project) exercises, or with the regional higher-resolution atmospheric model WRF (Weather Research and Forecasting) used in the CORDEX regional simulations [14]. It has been labeled as a French community code by INSU in 2019.

The ORCHIDEE code (in FORTRAN) is managed by a versioning software (svn), keeping track of all modifications, and distinguishing a standard version (trunk) from thematic versions developed to describe specific processes (branches). Many branches address separate hydrological developments (improved soil properties [15], high-resolution routing scheme [16], flooding [17], wetlands and groundwater [10], irrigation and dams [18,19]), and the first task will be to gather them in a comprehensive version for hydrological applications.

The second task will be to run the corresponding simulation over Europe, and assess its hydrological performances against observations, either hydrologic (river discharge, evapotranspiration, total water storage from GRACE satellite, surface soil moisture, water table depth, irrigated volumes), or linked to water stress (LAI, terrestrial biomass, albedo). This will require to collect the validation data and build the detailed input data for high-resolution long-term stand-alone simulations over Europe. The spatial resolution is given by the meteorological forcing, which will be taken from high-resolution bias-corrected reanalyzes over Europe, and the SAFRAN reanalysis over France [20]. The hired researcher will also obtain and format up-to-date soil, hydrographic, land use and land management data to support the best informed simulations. If necessary, new PFTs (plan, or surface, functional types) will be parametrized, for instance for important French crops, or for urbanized areas (with reduced infiltration capacity).

The third task will address the calibration of the corresponding application, based on existing parameter sensitivity analyses, and using the ORCHIDAS data assimilation tool, developed at LSCE, for parameter optimization [21,22]. This work will target the evaluation variables that are worst-captured at second stage.

In terms of calendar, each task should be manageable in 6 months, if the hired researcher is experienced enough with ORCHIDEE or similar land surface models. Timely reports will be produced for the IPSL reporting.

Expected skills:
- PhD in hydrology or land surface modelling
- Programing & Unix environment (fortran, shell, svn, post-processing software like python or 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 work will lead to construct a version of ORCHIDEE tailored for hydrological applications. To combine several existing developments and datasets, it will involve collaborations with many developers of the ORCHIDEE group, at METIS (where the work will be mainly based), LSCE, and LMD, under the supervision of Agnès Ducharne (METIS, leader of ORCHIDEE's hydrological developments), Philippe Peylin (LSCE, leader of the ORCHIDEE group and coordinator of ORCHIDAS), and Jan Polcher (LMD, high-resolution modelling leader). The work progress will regularly be presented at the ORCHIDEE group meetings, and shared with the IPSL Climate Modelling Centre (supervised by Olivier Boucher, LMD).

Duration, location, and salary:
The post-doctorate will be recruited for 18 months at METIS (Sorbonne Université, Paris) with a net monthly salary around 2000 euros for early doctors, commensurate with experience. This includes social services and health insurance.

Contact and deadline for application:
Applications will be considered until December 18th, 2020, and should include a vita, a statement of research interests, and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to Agnès Ducharne (agnes.ducharne@upmc.fr).

Cited references:

1. Sterling S, Ducharne A, Polcher J (2013). The impact of global land-cover change on the terrestrial water cycle. Nature Climate Change, 3, 385-390, doi:10.1038/nclimate1690
2. Vicente-Serrano, S. M., Peña-Gallardo, et al. (2019). Climate, irrigation, and land cover change explain streamflow trends in countries bordering the Northeast Atlantic. Geophys. Res. Lett., 46, 10821– 10833.
3. Wu WY, Lo MH, Wada Y, Famiglietti JS, Reager JT, Yeh PJF, Ducharne A, Yang ZL (2020). Divergent effects of climate change on future groundwater availability in key mid-latitude aquifers. Nat Comm 11, 3710.
4. Habets F, Boé J, Déqué M, Ducharne A, Gascoin S, Hachour A, Martin E, Pagé C, Sauquet E, Terray L, Thiéry D, Oudin L, Viennot P (2013). Impact of climate change on surface water and ground water of two basins in Northern France: analysis of the uncertainties associated with climate and hydrological models, emission scenarios and downscaling methods. Climatic Change, 121, 771-785.
5. Sauquet and 27 co-authors (2016). Le partage de la ressource en eau sur la Durance en 2050 : vers une évolution du mode de gestion des grands ouvrages duranciens ? La Houille Blanche, N°5, Octobre 2016, pp 25-31, doi:10.1051/lhb/2016046. PDF
6. Arama, Y., Goulard, F., Lamblin, V., L'Huissier, L., Sauquet, E. (2015). Garonne 2050. Un exercice de prospective participative sur la gestion de l'eau du bassin de la Garonne, Futuribles, N° 407, 57-65.
7. Carroget, A., Perrin, C., Sauquet, E., Vidal, J., Chazot, S., Rouchy, N. & Chauveau, M. (2017). Explore 2070 : quelle utilisation d'un exercice prospectif sur les impacts des changements climatiques à l'échelle nationale pour définir des stratégies d'adaptation ? Sciences Eaux & Territoires, 22(1), 4-11.
8. Quesada B, Vautard R, Yiou P, Hirschi M, Seneviratne S (2012). Asymmetric European summer heat predictability from wet and dry southern winters and springs. Nature Climate Change, 2, 736-741.
9. Thiery, W., Visser, A.J., Fischer, E.M. *et al.* Warming of hot extremes alleviated by expanding irrigation. Nat Commun 11**,** 290 (2020).
10. Ducharne A, Cheruy F, Decharme B, Colin J, Jost A. (2020). Impact of Groundwater in Earth-System Models. Compte rendu final à l'ANR, 79 pp.
11. Piao, S., Friedlingstein, P., Ciais, P., de Noblet, N., Labat, D., Zaehle, S. (2007). Changes in climate and land use have a larger direct impact than rising CO2 on global river runoff trends, PNAS, 104, 15242, 2007.
12. Xi, Y., Peng, S., Ciais, P., Guimberteau, M., Li, Y., Piao, S., Wang, X., Polcher, J., Yu, J., Zhang, X., Zhou, F., Bo, Y., Ottle, C., and Yin, Z. (2018). Contributions of Climate Change, CO2, Land-Use Change, and Human Activities to Changes in River Flow across 10 Chinese Basins, J. Hydrometeorol., 19, 1899-1914.
13. Boucher O, Servonnat J, et al. (2020). Presentation and evaluation of the IPSL-CM6A-LR climate model. JAMES, accepted.
14. Jacob, D., Teichmann, C., et al. (2020). Regional climate downscaling over Europe : perspectives from the EURO-CORDEX community. Regional Environmental Change, 20 (2).
15. Tafasca, S., Ducharne, A., and Valentin, C. (2020). Weak sensitivity of the terrestrial water budget to global soil texture maps in the ORCHIDEE land surface model, Hydrol. Earth Syst. Sci., 24, 3753–3774.
16. Nguyen-Quang T, Polcher J, Ducharne A, Arsouze T, Zhou X, Schneider A, Fita L (2018). ORCHIDEE-ROUTING: revising the river routing scheme using a high resolution hydrological database. GMD, 11, 4965-4985.
17. Lauerwald R, Regnier P, Camino-Serrano M, Guenet B, Guimberteau M, Ducharne A, Polcher J, and Ciais P (2017). ORCHILEAK: A new model branch to simulate carbon transfers along the terrestrial-aquatic continuum of the Amazon basin. GMD, 10, 3821-3859.
18. Yin, Z., Wang, X. H., Ottlé, C., Zhou, F., Guimberteau, M., Polcher, J., et al. (2020). Improvement of the irrigation scheme in the ORCHIDEE land surface model and impacts of irrigation on regional water budgets over China. JAMES, 12, e2019MS001770.
19. Zhou, X, Polcher, J., Dumas, P. (2020). Representing human water management in a land surface model using a supply/demand approach, Water Resources Research, under review.
20. Vidal, J.-P., Martin, E., Franchistéguy, L., Baillon, M. and Soubeyroux, J.-M. (2010), A 50-year high-resolution atmospheric reanalysis over France with the Safran system. Int. J. Climatol., 30: 1627-1644.

21. MacBean, N., Maignan, F., Bacour, C., Lewis, P., Peylin, P., Guanter, L., Köhler, P., Gomez-Dans, J., and Disney, M. (2018). Strong constraint on modeled global carbon uptake using solar-induced chlorophyll fluorescence data, Scientific Reports, 8, 1973.
22. Wang, F., Polcher, J., Peylin, P., and Bastrikov, V. (2018). Assimilation of river discharge in a land surface model to improve estimates of the continental water cycles, Hydrol. Earth Syst. Sci., 22, 3863-3882.