PhD position on:

"Estimating methane wetland emissions at the global scale based on remote sensing: long term and inter-annual variabilities"

Location: LERMA, Observatoire de Paris, 77 avenue Denfert-Rochereau, 75014 Paris
Supervision: C. Prigent (LERMA), M. Saunois (LSCE), S. Peng (PKU)
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Atmospheric CH_4 concentrations have nearly tripled over the past 200 years, causing 20% of global warming. This increase is due to human emissions from the fossil fuel sector and agriculture, but natural emissions also respond to climate change. The causes of atmospheric CH_4 variations over the last three decades are still highly debated, in particular the recent increase after 2006 and its acceleration in the recent years. A synthesis of the global CH_4 budget including all sources and sinks is being regularly updated by the Global Carbon Project (Saunois et al., 2020) and shows large uncertainties at global and regional scales.

About 30% of CH_4 total emissions are produced by methanogenic bacteria in water saturated or inundated areas (wetlands, peatlands, lakes, rivers). The global extent, the dynamics, and characteristics of these water areas remain inaccurate. Moreover, the methane production processes and its transport to the atmosphere are complex and lead to large uncertainties on CH_4 emissions. The CH_4 production process, the water saturation level, and the horizontal area of a wetland area depend on meteorological parameters such as precipitation, radiation and temperature, and are thus climate-sensitive.

The PhD thesis aims at making a significant step forward to reduce uncertainties in CH_4 emissions from wetlands including peatlands at the global scale, and in their trend and inter-annual variabilities. This will be done using a state-of-the-art mapping of saturated and inundated area from remote-sensing observations, for which careful inter-calibration over time has been conducted. The production, transport, and oxidation processes leading to methane emissions will be calibrated against in-situ flux and chamber measurements, in the field and from manipulative experiments.

The thesis work will rely on the inundated area data set GIEMS-2 (Prigent et al., 2020) available from 1995 onward at a 0.25° resolution, with a downscaling available at 90 meters resolution for a fixed year. The first part of the thesis will analyze inundated areas to separate wetlands from other water bodies such as lakes, rivers, ponds. To this aim, we will use available datasets such as GLWD (Lehner and Döll, 2004) or Pekel et al. (2016).

The second part will improve the diagnostic of the extent and water dynamics in peatlands which are not always inundated, although they keep water levels close to water-saturation. Given that GIEMS-2 and its downscaled version only monitor the sporadic inundation of peatlands, the challenge will be to model changes of the water table when it drops below the surface, for instance during dry periods, and becomes invisible to GIEMS-2. Here, a sub-grid hydrological model inspired from the TOPMODEL scheme will be used to derive the time varying distribution of water-table depths within each grid, by using soil types, new flood-ability indexes, and permafrost indicators. This model will be forced by ERA-5 reanalysis soil moisture (other data set may be tested, such as GLEAM(Martens et al., 2017)) and calibrated against GIEMS-2 and its downscaling version for assessing the fraction of peatland in each grid that are intermittently inundated.

The third part will consist in building a data driven or hybrid model of CH_4 emissions either based on Walter and Heiman (2000) or on machine-learning models trained against in-situ flux measurements. The PhD candidate will select the necessary information forcing the model to characterize the different wetland areas (temperature, vegetation type, soil carbon content, water-table depths, permafrost presence, lateral transport from rivers and floodplains...). Simulations of wetland emission will be performed over the entire period of availability of GIEMS-2 at the global scale. The CH_4 emission maps will be evaluated against in-situ flux measurements, e.g. from FluxNetCH4 (Delwiche et al., 2021). Model parameters will be calibrated to obtain good agreement with the observations. Specific care will be dedicated to characterize uncertainties.

The fourth step will consist in assessing the final product against available published estimates based on land surface modeling using for instance the data base of the Global Methane Bugdet (Saunois et al., 2020). The product will be used to force a chemistry-transport model LMDz-SACs (Pison et al., 2009), in order to compare the simulated concentrations with in-situ CH_4 concentrations and atmospheric columns from satellites.

This work is part of the research activity of the **French-Chinese institute SOFIE** with strong collaborations between Beijing university (PKU), LSCE and LERMA (IPSL laboratories).
LERMA with the support of the Estellus company has developed the GIEMS-2 data set. LSCE has a great expertise on wetland modeling, especially through the development of the land surface model ORCHIDEE, in collaboration with PKU.

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