Group projects – General information and guidelines

- The project should be carried out in **groups**. Single person projects are only allowed for PhD students.
- Please **form groups on Moodle by the assigned deadline (see Moodle)**. Students that do not enroll by the deadline will be automatically allocated to a group not yet at full capacity. Similarly, groups of less than the pre-defined number of students will be merged by the instructor (this is not the case for PhD students).
- Each group can either choose a project from the list below, or come up with their own project idea (in the latter case, this should be discussed with the instructor).
- The use of different models from those presented in class is permitted. However, this should be agreed upon with the professor beforehand. All projects should include a major modeling component (be it analytical or numerical), they should not be purely based on data analysis.
- Projects can be new analyses or reproductions of existing papers (in the second case, students should use different datasets or parameters to demonstrate that they have effectively run their own simulations).
- A **3-min presentation** of the project topic and methods by each group is scheduled in **week 10** (see guidelines below).
- Students should submit a **project report by the given deadline** (**see Moodle** and guidelines below).
- **8-min oral presentations** from each group will be scheduled during the last lecture(s) of the course. This will be followed by a 5-min discussion during which the audience, instructor, and teaching assistants will have the opportunity to ask questions. While a detailed schedule for the presentations will be organized, all students are expected to attend each other's presentations (and possibly ask questions to enrich the discussion).
- Students will be evaluated based on the research performed and its critical appraisal, the quality of the report, and the quality of the oral presentation (equal weight to these three components).

3-minute presentations (week 10)

Please prepare **3 slides** with the following information:

1. (Provisional) **Title of project** + **Research question** that the project intends to answer.
2. **Methodology**: what model will you use? What simulations or analysis do you plan to perform?
3. **Risk management**: what major difficulties do you expect in carrying out the project? How do you plan to overcome them?

Project report

The report should be **maximum 10 pages** (at least font size 10 and line spacing 1, excluding title page, possible table of contents, bibliography) and should include the following sections:

- **Abstract**. The abstract should be a single-paragraph of fewer than 250 words. A good abstract sets the general question or topic that you are studying for the general reader, provides background on the specific question or problem, briefly describes key data or analyses, and describes the key results and uncertainties. Please avoid acronyms or, if used, define them.
- **Introduction.** The Introduction should provide readers with the background information needed to understand your study, and the reasons why you conducted your experiments. The final thing to include at the end of your Introduction is a clear and exact statement of your study aims. You might also explain in a sentence or two how you conducted the study.
- **Materials and Methods.** Describe your study design, model used, and analyses conducted.
- **Results and discussion.** Present your finding, explain what your results mean, possibly connect them to prior research studies, and mention the limitation of your study.
- **Conclusions.** Restate your main points and the relevance of your work. You may also offer suggestions on how your research can be expanded or improved.

In addition:

- All figures and tables should be cited in order in the text.
- Write appropriate captions for your figures.

- Make sure to include appropriate references for your statements and for the models used. These should be duly listed in the final Bibliography.
- Produce clear figures. The clarity of your report is very important and it is evaluated along with your results. Here are some tips on how to make figures clear:
  - All figures must include appropriate axes titles, units and legends. If these are missing, poorly readable or wrong, this is considered as an error.
  - Avoid taking screenshots and pasting them in your report because it is unprofessional and most importantly because the quality of the figures is typically poor.
  - Make sure that the font is not too small, lines are not too thin and that you can distinguish their colors.
  - Figure text has to be readable, even when printed on paper. It should be approximately the same size as the report text.
  - Make sure you use efficiently the figure space. If there is plenty of white space and all the information is compressed in a small region of your plot, you may want to modify the limits of the figure axes.
  - Legends should not hide the data.

List of possible project topics*

* The topics listed below should be intended as a limited set of examples of possible projects. Students can either choose a topic within this list or feel free to formulate their own research questions and design their project.

Topic 01 – Effect of soil hydraulic parameterization on water and carbon fluxes.

Terrestrial biosphere and ecohydrological models require spatially distributed soil hydraulic properties (SHPs) to represent surface energy, water, and carbon fluxes. SHPs are generally derived from soil pedotransfer functions (PTFs) that correlate readily-available soil information (e.g., texture, bulk density, organic matter) with difficult-to-measure soil hydraulic parameters (*Weber et al., 2024; Van Looy et al., 2017*). Several PTFs have been proposed in the literature, providing divergent estimates of SHPs for the same soil types. This project aims at evaluating how uncertainties in SHP estimation propagates into the estimation of ecosystem water and carbon fluxes (see e.g., *Paschalis et al., 2022; Weihermüller et al., 2021*).

This project can potentially be carried out using T&C, T&C-2D, SPAC model.

References:

- Paschalis, A., Bonetti, S., Guo, Y. and Fatichi, S., 2022. On the uncertainty induced by pedotransfer functions in terrestrial biosphere modeling. *Water Resources Research*, 58(9), p.e2021WR031871.
- Van Looy, K., Bouma, J., Herbst, M., Koestel, J., Minasny, B., Mishra, U., Montzka, C., Nemes, A., Pachepsky, Y.A., Padarian, J. and Schaap, M.G., 2017. Pedotransfer functions in Earth system science: Challenges and perspectives. Reviews of Geophysics, 55(4), pp.1199-1256.
- Weihermüller, L., Lehmann, P., Herbst, M., Rahmati, M., Verhoef, A., Or, D., Jacques, D. and Vereecken, H., 2021. Choice of pedotransfer functions matters when simulating soil water balance fluxes. *Journal of Advances in Modeling Earth Systems*, 13(3), p.e2020MS002404.
- Weber, T.K.D., Weihermüller, L., Nemes, A., Bechtold, M., Degré, A., Diamantopoulos, E., Fatichi, S., Filipović, V., Gupta, S., Hohenbrink, T.L. Hirmas, D.R. et al., 2024. Hydro-pedotransfer functions: a roadmap for future development. *Hydrology and Earth System Sciences*, 28(14), pp.3391-3433.

Topic 02: Effect of soil structure on water and carbon dynamics.

Biologically induced soil structure (defined as soil aggregation and formation of macropores due to growth and decay of plant roots and the activity of earthworms and other burrowing organisms) may strongly alter ecohydrological fluxes (e.g., infiltration and runoff partitioning, carbon fluxes, evapotranspiration). Despite its critical role, soil structure is generally omitted in traditional soil hydraulic parameterizations based on pedotransfer functions (*Weber et al., 2024*). Recent studies have emphasized the importance of incorporating soil structure information in soil parameterizations and proposed a framework to systematically include soil structure effects in soil hydraulic properties (e.g., *Bonetti et al., 2021; Fatichi et al., 2020; Jha et al., 2023, Fan et al., 2022*). This project aims at investigating the role of soil structure on water and carbon dynamics across a range of climatological regimes, biomes, and soil types by accounting for soil structure corrections.

This project can potentially be carried out using T&C, T&C-2D, SPAC model.

References:

- Bonetti, S., Wei, Z. and Or, D., 2021. A framework for quantifying hydrologic effects of soil structure across scales. *Communications Earth & Environment*, 2(1), p.107.
- Fan, L., Lehmann, P., Zheng, C. and Or, D., 2022. Vegetation-Promoted Soil Structure Inhibits Hydrologic Landslide Triggering and Alters Carbon Fluxes. Geophysical Research Letters, 49(18), p.e2022GL100389.
- Fatichi, S., Or, D., Walko, R., Vereecken, H., Young, M.H., Ghezzehei, T.A., Hengl, T., Kollet, S., Agam, N. and Avissar, R., 2020. Soil structure is an important omission in Earth System Models. *Nature communications*, 11(1), p.522.
- Jha, A., Bonetti, S., Smith, A.P., Souza, R. and Calabrese, S., 2023. Linking soil structure, hydraulic properties, and organic carbon dynamics: A holistic framework to study the impact of climate change and land management. *Journal of Geophysical Research: Biogeosciences*, 128(7), p.e2023JG007389.
- Weber, T.K.D., Weihermüller, L., Nemes, A., Bechtold, M., Degré, A., Diamantopoulos, E., Fatichi, S., Filipović, V., Gupta, S., Hohenbrink, T.L. Hirmas, D.R. et al., 2024. Hydro-pedotransfer functions: a roadmap for future development. *Hydrology and Earth System Sciences*, 28(14), pp.3391-3433.

Topic 03: Relative effects of soil moisture and atmospheric conditions on ecosystem functioning.

Water deficit in the atmosphere and soil are two key interactive factors that constrain transpiration, photosynthesis, and vegetation productivity, but the relative importance of these two factors for water and carbon flux responses to drought stress in ecosystems is still debated (Novick et al., 2016; Liu et al., 2020; Fang et al., 2021; Wankmüller et al., 2024). Recent work has shown the key role of soil texture in modulating the onset of ecosystem water limitation through the soil hydraulic conductivity curve, whose steepness increases with sand fraction (Wankmüller et al., 2024). This project aims at investigating the sensitivity of ecosystem water and carbon fluxes to VPD and soil moisture across a range of soil types, plant traits, and other biophysical conditions.

This project can potentially be carried out using T&C, T&C-2D, SPAC model.

References:

- Fang, Y., Leung, L.R., Wolfe, B.T., Detto, M., Knox, R.G., McDowell, N.G., Grossiord, C., Xu, C., Christoffersen, B.O., Gentine, P. and Koven, C.D., 2021. Disentangling the effects of vapor pressure deficit and soil water availability on canopy conductance in a seasonal tropical forest during the 2015 El Niño drought. *Journal of Geophysical Research: Atmospheres*, 126(10), p.e2021JD035004.
- Liu, L., Gudmundsson, L., Hauser, M., Qin, D., Li, S. and Seneviratne, S.I., 2020. Soil moisture dominates dryness stress on ecosystem production globally. *Nature communications*, 11(1), p.4892.
- Novick, K.A., Ficklin, D.L., Stoy, P.C., Williams, C.A., Bohrer, G., Oishi, A.C., Papuga, S.A., Blanken, P.D., Noormets, A., Sulman, B.N. and Scott, R.L., 2016. The increasing importance of atmospheric demand for ecosystem water and carbon fluxes. *Nature climate change*, 6(11), pp.1023-1027.
- Wankmüller, F.J.P., Delval, L., Lehmann, P., Baur, M.J., Cecere, A., Wolf, S., Or, D., Javaux, M. and Carminati, A., 2024. Global influence of soil texture on ecosystem water limitation. *Nature*, pp.1-8.

Topic 04: Impacts of topography on catchment water and carbon fluxes.

The topography of a landscape is a key feature of the Earth's surface, as it regulates the spatial distribution of water and energy states which are the main drivers of vegetation and nutrient dynamics (*Amatulli et al., 2018*). For example, the amount of solar radiation intercepted by a surface is affected by local slope and aspect, while surface and subsurface water redistribution is strongly influenced by micro-topographic attributes such as landscape connectivity, curvature, slope, and drainage area, thus regulating the local soil moisture available to plants (*Mastrotheodoros et al., 2019; Hoylman et al., 2018, 2019; Guo et al., 2022*). This project aims at quantifying the role of local (e.g., slope, aspect, curvature) and non-local (e.g., drainage area, shadowing) topographic properties on ecohydrological fluxes across a broad range of catchment types and climatic conditions.

This project can potentially be carried out using T&C-2D.

References:

- Amatulli, G., Domisch, S., Tuanmu, M.N., Parmentier, B., Ranipeta, A., Malczyk, J. and Jetz, W., 2018. A suite of global, cross-scale topographic variables for environmental and biodiversity modeling. *Scientific data*, 5(1), pp.1-15.
- Guo, J., Beverly, D.P., Mercer, J.J., Cook, C.S., Ewers, B.E. and Williams, D.G., 2022. Topographic controls on stomatal and mesophyll limitations to photosynthesis in two subalpine conifers. *International Journal of Plant Sciences*, 183(3), pp.205-219.
- Hoylman, Z.H., Jencso, K.G., Hu, J., Martin, J.T., Holden, Z.A., Seielstad, C.A. and Rowell, E.M., 2018. Hillslope topography mediates spatial patterns of ecosystem sensitivity to climate. *Journal of Geophysical Research: Biogeosciences*, 123(2), pp.353-371.
- Hoylman, Z.H., Jencso, K.G., Hu, J., Holden, Z.A., Martin, J.T. and Gardner, W.P., 2019. The climatic water balance and topography control spatial patterns of atmospheric demand, soil moisture, and shallow subsurface flow. *Water Resources Research*, 55(3), pp.2370-2389.
- Mastrotheodoros, T., Pappas, C., Molnar, P., Burlando, P., Hadjidoukas, P. and Fatichi, S., 2019. Ecohydrological dynamics in the Alps: Insights from a modelling analysis of the spatial variability. *Ecohydrology*, 12(1), p.e2054.

Topic 05: Effect of rainfall temporal variability on soil-plant processes

Climate varies across a wide range of temporal and spatial scales and projected changes in rainfall temporal structure (from variations in seasonality to changes in frequency and intensity of rainfall events and to interannual variability) are expected to have severe impacts on vegetation functioning (*Daly and Porporato, 2006; Mimeau et al., 2021, Paschalis et al., 2015*). This project aims at investigating the effect of changes in hydroclimatic fluctuations on water and carbon dynamics within the soil-plant system.

This project can potentially be carried out using T&C, T&C-2D, SPAC model.

References:

- Daly, E. and Porporato, A., 2006. Impact of hydroclimatic fluctuations on the soil water balance. *Water resources research*, 42(6).
- Mimeau, L., Tramblay, Y., Brocca, L., Massari, C., Camici, S. and Finaud-Guyot, P., 2020. Modeling the response of soil moisture to climate variability in the Mediterranean region. *Hydrology and Earth System Sciences Discussions*, 2020, pp.1-29.
- Paschalis, A., Fatichi, S., Katul, G.G. and Ivanov, V.Y., 2015. Cross-scale impact of climate temporal variability on ecosystem water and carbon fluxes. *Journal of Geophysical Research: Biogeosciences*, 120(9), pp.1716-1740.