

## Assignment: Global environmental change - phenology change

### Mode

Partner work allowed: yes, maximum groups of four.

Create a text document of 3-5 pages (A4, 11 pt) that answers the content points listed below. You may structure the document along the given questions or as you like. Make sure that references in your text are correctly cited and that each statement is referenced.

Ideally, your responses are complemented by a figure from original sources for each point. The document may be handed in as a Word, [RMarkdown](#), or [Quarto](#) document that can be added to the repository of the LES textbook (<https://geco-bern.github.io/les/>).

Present this work in a presentation of 30 min.

Supervised by Laura Marqués

### Content points

1. How are phenology observations commonly measured?
  - (Piao et al., 2019; Templ et al., 2018)
2. What are the trends in spring leaf unfolding and autumn leaf senescence?
  - (Piao et al., 2019)
  - Section 6.2 from LES book
3. Are the changes in start-of-season (SOS) and end-of-season (EOS) consistent across the globe?
  - (Liu et al., 2016; Piao et al., 2019)
4. What are the main drivers of spring and autumn phenology?
  - (Flynn and Wolkovich, 2018; Keenan and Richardson, 2015; Körner and Basler, 2010)
5. How does global climate change affect plant phenology?
  - (Richardson et al., 2013)
6. How do changes in plant phenology affect frost events?
  - (Bigler and Bugmann, 2018; Liu et al., 2018)
7. How do changes in phenology affect plant-pollinator interactions?
  - (Freimuth et al., 2022)

### References

Bigler, C. and Bugmann, H.: Climate-induced shifts in leaf unfolding and frost risk of European trees and shrubs, Sci Rep, 8, 9865, <https://doi.org/10.1038/s41598-018-27893-1>, 2018.

Flynn, D. F. B. and Wolkovich, E. M.: Temperature and photoperiod drive spring phenology across all species in a temperate forest community, *New Phytologist*, 219, 1353–1362, <https://doi.org/10.1111/nph.15232>, 2018.

Freimuth, J., Bossdorf, O., Scheepens, J. F., and Willems, F. M.: Climate warming changes synchrony of plants and pollinators, *Proceedings of the Royal Society B: Biological Sciences*, 289, 20212142, <https://doi.org/10.1098/rspb.2021.2142>, 2022.

Keenan, T. F. and Richardson, A. D.: The timing of autumn senescence is affected by the timing of spring phenology: implications for predictive models, *Glob Change Biol*, 21, 2634–2641, <https://doi.org/10.1111/gcb.12890>, 2015.

Körner, C. and Basler, D.: Phenology Under Global Warming, *Science*, 327, 1461–1462, <https://doi.org/10.1126/science.1186473>, 2010.

Liu, Q., Fu, Y. H., Zhu, Z., Liu, Y., Liu, Z., Huang, M., Janssens, I. A., and Piao, S.: Delayed autumn phenology in the Northern Hemisphere is related to change in both climate and spring phenology, *Global Change Biology*, 22, 3702–3711, <https://doi.org/10.1111/gcb.13311>, 2016.

Liu, Q., Piao, S., Janssens, I. A., Fu, Y., Peng, S., Lian, X., Ciais, P., Myneni, R. B., Peñuelas, J., and Wang, T.: Extension of the growing season increases vegetation exposure to frost, *Nat Commun*, 9, 426, <https://doi.org/10.1038/s41467-017-02690-y>, 2018.

Piao, S., Liu, Q., Chen, A., Janssens, I. A., Fu, Y., Dai, J., Liu, L., Lian, X., Shen, M., and Zhu, X.: Plant phenology and global climate change: Current progresses and challenges, *Glob Change Biol*, 25, 1922–1940, <https://doi.org/10.1111/gcb.14619>, 2019.

Richardson, A. D., Keenan, T. F., Migliavacca, M., Ryu, Y., Sonnentag, O., and Toomey, M.: Climate change, phenology, and phenological control of vegetation feedbacks to the climate system, *Agricultural and Forest Meteorology*, 169, 156–173, <https://doi.org/10.1016/j.agrformet.2012.09.012>, 2013.

Templ, B., Koch, E., Bolmgren, K., Ungersböck, M., Paul, A., Scheifinger, H., Rutishauser, T., Busto, M., Chmielewski, F.-M., Hájková, L., Hodzić, S., Kaspar, F., Pietragalla, B., Romero-Fresneda, R., Tolvanen, A., Vučetić, V., Zimmermann, K., and Züst, A.: Pan European Phenological database (PEP725): a single point of access for European data, *Int J Biometeorol*, 62, 1109–1113, <https://doi.org/10.1007/s00484-018-1512-8>, 2018.