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# DVMDOSTEM v0.8.3: a terrestrial ecosystem model designed to represent arctic, boreal and permafrost ecosystem dynamics

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**Software**

- Review
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## Summary

The impacts of climate change on natural ecosystems are the result of complex physical and ecological processes operating and interacting at a variety of spatio-temporal scales, that can be represented in process-based ecosystem models.

`DVMDOSTEM` is an advanced process-based terrestrial ecosystem model (TEM) designed to study ecosystem responses to climate changes and disturbances. It has a particular focus on permafrost regions (i.e. regions characterized by soils that stay partially frozen all year round for at least two consecutive years), encompassing boreal, arctic, and alpine landscapes. The model couples two previous versions of the Terrestrial Ecosystem Model (TEM) (McGuire et al., 1992): DVMTEM that includes a dynamic vegetation module (DVM) (E. S. Euskirchen et al., 2009), and DOSTEM that includes a dynamic organic soil module (DOS) (H. Genet et al., 2013; Yi et al., 2010). `DVMDOSTEM` simulates processes at yearly and monthly scales, with some physical processes operating at an even finer temporal resolution. Its versatility allows for site-specific to regional simulations, making it valuable for predicting shifts in permafrost, vegetation, and carbon (C) and nitrogen (N) dynamics. While `DVMDOSTEM` has been described in the methods sections of many manuscripts, this paper is the first stand alone description of `DVMDOSTEM`, independent of a particular scientific investigation.

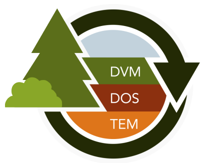


**Figure 1:** Logo for `DVMDOSTEM`

## Statement of need

Arctic and boreal regions underlain by permafrost store nearly half of the world's soil organic C - approximately 1,440-1,600 Pg (Hugelius et al., 2014; Edward A. G. Schuur et al., 2022). These regions are warming four times faster than the rest of the globe, driving widespread and rapid permafrost thaw (Rantanen et al., 2022; Smith et al., 2022). As permafrost thaws, soil organic C becomes available for decomposition and release as greenhouse gasses (GHGs) to the atmosphere. Climate-driven permafrost thaw and the associated release of GHGs can influence the global climate system, a phenomenon called the permafrost carbon-climate feedback or PCCF (Koven et al., 2011; E. A. G. Schuur et al., 2015). The PCCF has been identified as one of the largest sources of uncertainty in future climate projections and therefore needs to be accurately represented in global earth system models (Schädel et al., 2024). `DVMDOSTEM` has been developed with special emphasis on physical and biological processes driving permafrost and carbon cycling in high latitude ecosystems. `DVMDOSTEM` is therefore well suited to assessing and informing our understanding of the PCCF.

## Model Design

`DVMDOSTEM` is designed to simulate the key biophysical and biogeochemical processes between the soil, the vegetation and the atmosphere. The evolution and refinement of `DVMDOSTEM` have been shaped by extensive research programs and applications both in permafrost and non-permafrost regions (Briones et al., 2024; Eugénie S. Euskirchen et al., 2022; H. Genet et al., 2013; Hélène Genet et al., 2018; Jafarov et al., 2013, 2025; Yi et al., 2009, 2010). The model is spatially explicit and represents ecosystem response to climate and disturbances at seasonal (i.e. monthly) to centennial scales.

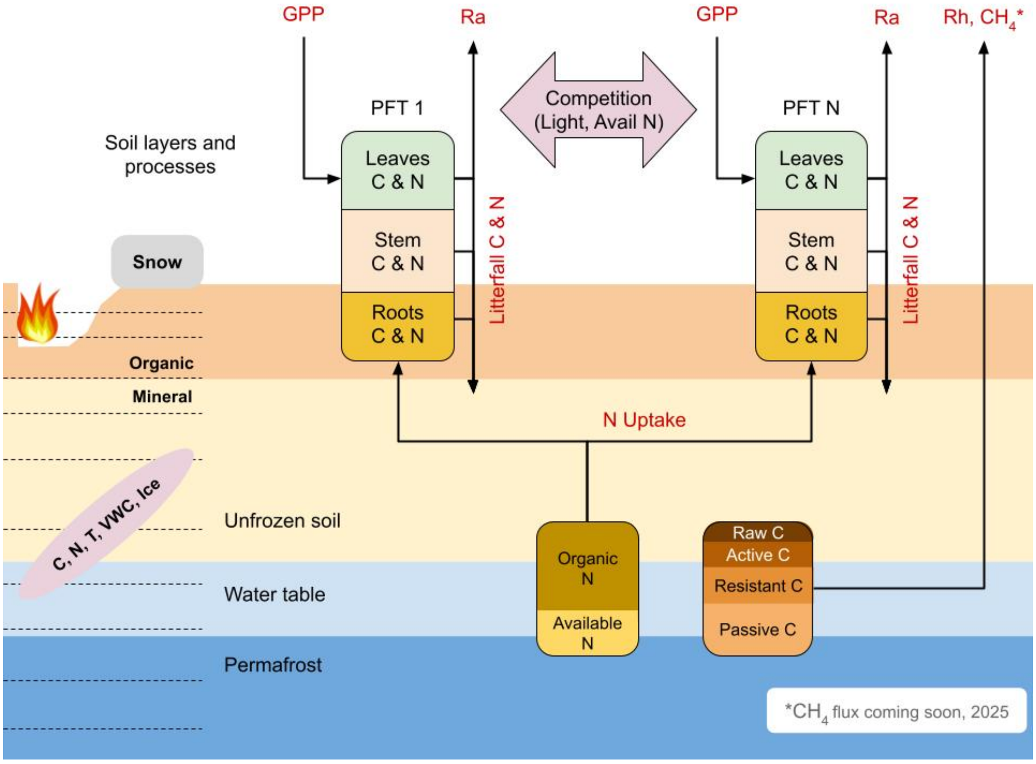


**Figure 2:** Overview of DVMDOSTEM soil and vegetation structure. On the left is the soil structure showing the layers and different properties that are tracked (purple bubble: carbon (C), nitrogen (N), temperature (T), volumetric water content (VWC), ice). Each of the layers with properties described above is also categorized as organic (fibric or humic) or mineral. Additionally, the model simulates snow layers and the removal of soil organic layers due to fire. On the right is the vegetation structure showing plant functional types (PFTs) within a community type (CMT) and the associated pools and fluxes of C and N. Each PFT is split into compartments (leaf, stem and root) which track their own C and N content and associated fluxes. The fluxes are represented with red text while the pools are black. In addition, there is competition among the PFTs for light, water, and available N, shown with the purple arrow in the top center.

The snow and soil columns are split into a dynamic number of layers to represent their impact on thermal and hydrological dynamics and the consequences for soil C and N dynamics. Vegetation composition is modeled using community types (CMTs), each of which consists of multiple plant functional types (PFTs - groups of species sharing similar ecological traits). This structure allows the model to represent the effect of competition for light, water and nutrients on vegetation composition (E. S. Euskirchen et al., 2009), as well as the role of nutrient limitation on permafrost ecosystem dynamics, with coupling between C and N cycles (E. S. Euskirchen et al., 2009; McGuire et al., 1992). Finally, the model represents the effects of wildfire in order to evaluate the role of climate-driven fire intensification on ecosystem structure and function (H. Genet et al., 2013; Yi et al., 2010). The structure of DVMDOSTEM is represented visually in Figure 2.

## State of the Field

In the field of ecosystem models, several prominent models such as CLM5 (Lawrence et al., 2019), ELM-FATES (Fisher et al., 2015), LANDIS (Scheller et al., 2007), and iLand (Seidl et al., 2012) have been developed to simulate ecological processes at various scales, resolutions and ecotypes. Like DVMDOSTEM, ELM-FATES, and early versions of CLM, are “offline” land models that do not include feedback with atmospheric or oceanic models, focusing instead on land surface processes. LANDIS and iLand emphasize forest dynamics with some interaction between grid cells, while `DVMDOSTEM` does not model interaction between grid cells. While `DVMDOSTEM` contains detailed representations of vegetation - multiple Plant Functional Types (PFTs) and individual compartments within PFTs - it also has the concept of community types (collections of PFTs and soil properties) and is designed to run at the landscape scale by representing more than a single stand of trees or a single forest type. `DVMDOSTEM` is unique in its detailed representation of high latitude processes, particularly the dynamic organic soils in regions with frozen ground coupled with dynamic vegetation and high latitude specific parameterizations. This focus allows `DVMDOSTEM` to simulate the complex interactions between soil, vegetation, and climate in permafrost ecosystems, providing valuable insights into the PCCF. For a more detailed assessment and comparison of high latitude vegetation modeling, see (Heffernan et al., 2024).


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