Modeling leaf phenology variation by groupings of species within and across ecosystems in northern Alaska

E.S. Euskirchen[1] T.B. Carman[1] , A.D. McGuire[2]

[1]University of Alaska Fairbanks, Institute of Arctic Biology,

[2]U.S. Geological Survey, Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks, Fairbanks, Alaska

Background

The phenology of arctic ecosystems is driven primarily by abiotic forces, with temperature acting as the main determinant growing season onset and leaf budburst and in the spring. However, while the plant species in arctic ecosystems require differing amounts of accumulated heat for leaf-out, dynamic vegetation models simulated over a regional to global scale typically assume some average leaf-out for all of the species within an ecosystem. Here, we introduce a new phenology algorithm in the Dynamic Vegetation Module of the Terrestrial Ecosystem Model (TEM-DVM) that individually simulates the timing of each species within an ecosystem compared to the previous algorithm that simulated the onset of photosynthesis for all the species in an ecosystem when the soil at 5 cm depth thawed.

Model Parameterization Data and Model Simulations

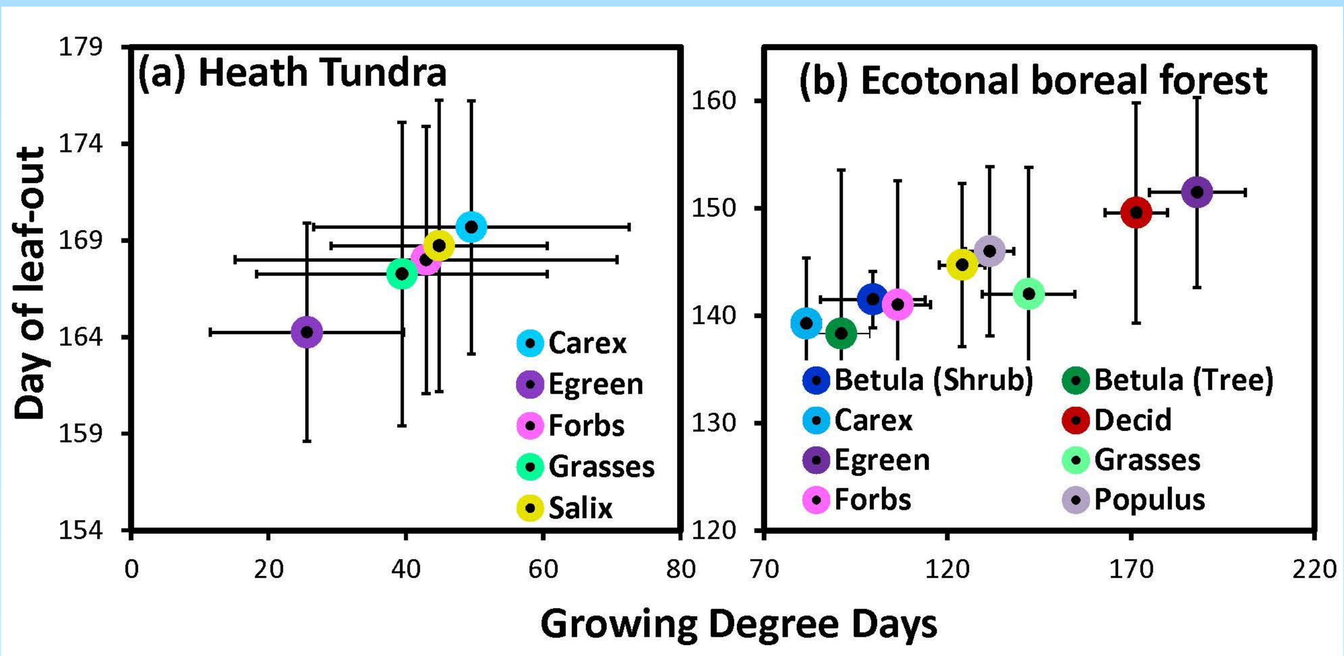

Figure 1. Day of leaf-out versus growing degree days for heath tundra and boreal forest. Note the different order of leaf-out by the plant functional types between the heath and forest ecosystems.

The model was parameterized for four tundra types: heath, wet sedge, shrub, and tussock, as well as ecotonal boreal forest. Each plant functional type (PFT) in an ecosystem was parameterized according to data synthesized by growing degree day versus leaf-out using data from various sources (Figure 1). Model simulations were conducted from the treeline ecotone in northern Alaska to the Arctic Ocean for the five vegetation types over the years 1900 – 2100.

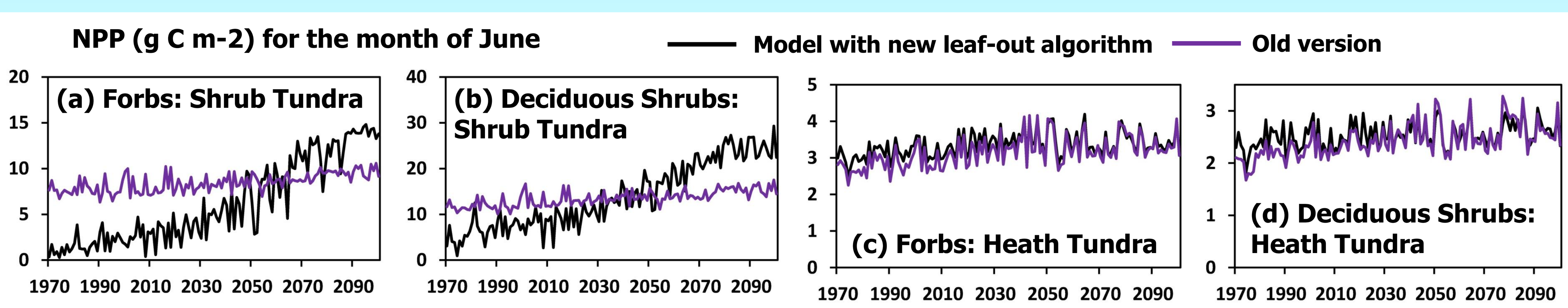

Figure 2. The implementation of the leaf phenology algorithm had an impact on the productivity of the species in some ecosystem types, but not in others. For example, in the shrub tundra, both the forbs (a) and deciduous shrubs (b; above shown without willow and dwarf birch) showed differences in NPP between the two model simulations. However, in the heath tundra, the forb (c) and deciduous shrubs (d) showed little difference in NPP between the simulations.

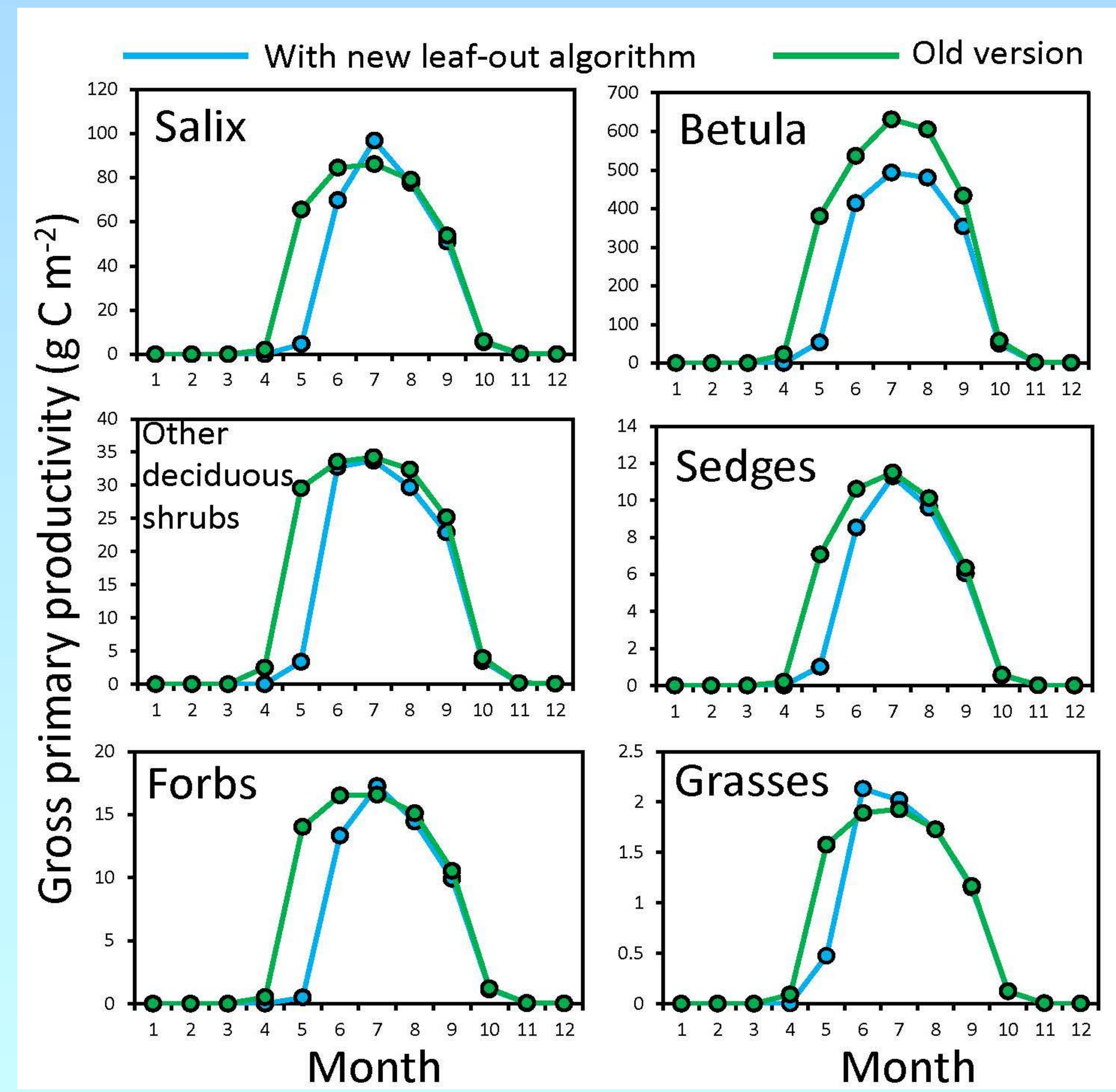

Figure 4. The addition of the phenology algorithm into TEM-DVM improved the timing of the onset of GPP in the spring. In the 'Old version' of the model timing of the onset of GPP was a month too early for our study region (May), while the version of the model with the new algorithm correctly simulated the more realistic onset of GPP (in June). Simulations are the mean across years 1990 – 2100 in shrub tundra in northern Alaska.

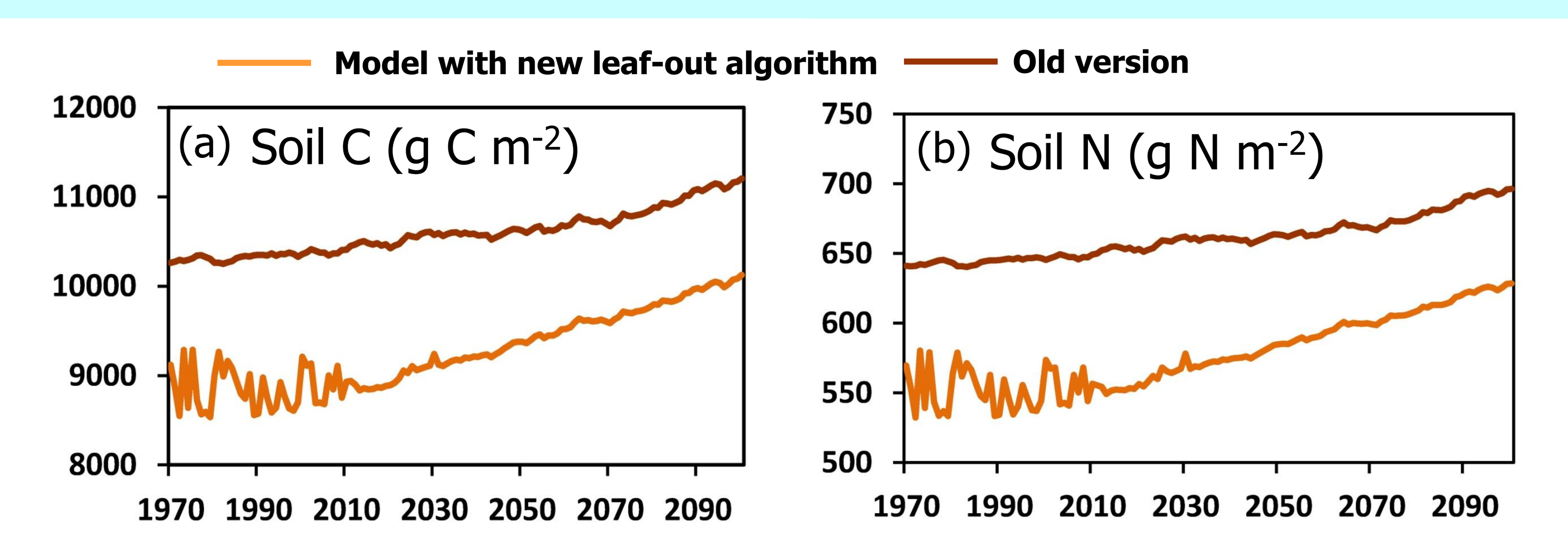

Figure 3. The implementation of the new phenology algorithm not only impacted the productivity of some species in some ecosystems, but also the carbon and nitrogen pools of the entire ecosystem. Shown above are the soil C and soil N pools between 1970 – 2100 for the shrub tundra, with greater amounts of both C and N in the older model version, but a faster accumulation in the newer version.

Implications for Using the Dynamic Vegetation as an Animal Habitat Model: Caribou diet vs. leaf-out

Plant Functional Type	Percent of diet early June	Percent of diet July
Eriophorum	55.89	5.77
Grasses	2.32	2.48
Horsetails	4.16	1.22
Mosses	4.06	1.37
Lichens	15.07	5.98
Evergreen shrubs	5.13	3.63
Salix	8.29	40.53
Betula	0.00	0.00
Forbs	5.08	39.02
Total	100	100

Table 1. Diet of the Porcupine Caribou Herd for early summer (early June) versus later in the summer (July) based on data collected over two years (1993 – 1994). Unpublished data (B. Griffith)

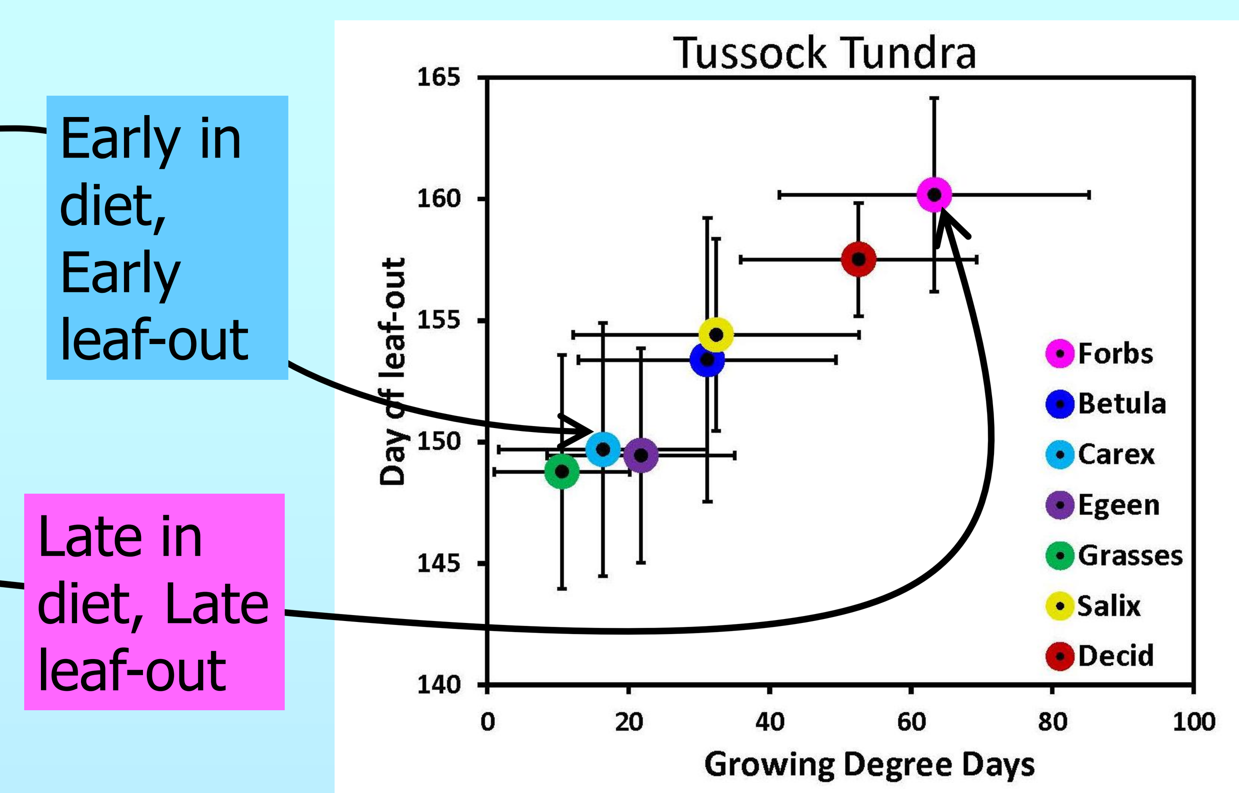

Figure 6. Day of leaf out versus growing degree days in the tussock tundra. Note that the day of leaf-out for a given plant functional type generally corresponds with the caribou percent of diet for that plant functional type. That is, the Carex species (including Eriophorum) has an early leaf-out in late May, corresponding to a over 55% of the caribou diet during early June.

Dynamic Vegetation Modeling

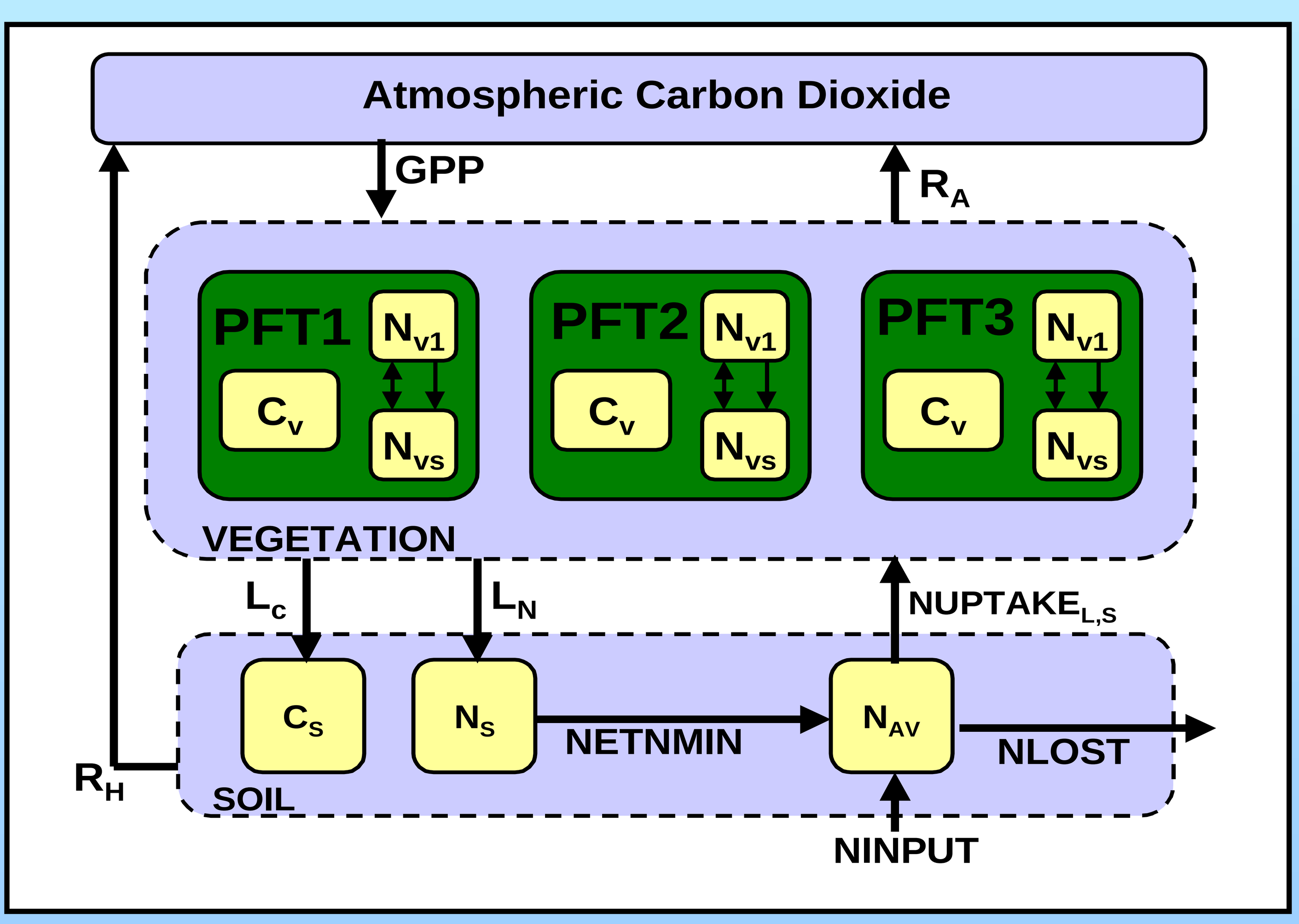

Figure 5. Simplified diagram of the Dynamic Vegetation Module in the Terrestrial Ecosystem Model. Each ecosystem is comprised of up to 9 plant functional types (PFTs). The model is specific to high latitudes, simulating permafrost, and arctic and boeral specific PFTs.

Conclusions

- **The inclusion of this new leaf phenology algorithm (based on growing degree days for a given grouping of species) in our model resulted in a more realistic estimate of the onset of photosynthesis in the spring.**
- **While some species showed differences in productivity in some ecosystems due to the new phenology algorithm (based on growing degree days for a given grouping of species), the same species may not have shown differences in productivity with the new algorithm in other ecosystems.**
- **The effects of this new algorithm included impacts not only on the vegetation productivity of some species, but also on the overall ecosystem carbon and nitrogen pools.**
- **Our ability to model the leaf-out for the plant functional types or species within an ecosystem has clear implications for interfacing with habitat modeling. In particular, the caribou diet is strongly influenced by the availability of forage over the course of a given year.**

Data sources for parameterization data: *National Phenology Network*: http://www.usanpn.org/results/data
Toolik Field Station Monitoring Program: Environmental Data Center Team. [2011]. *http://toolik.alaska.edu/edc/plants/index.php*
Archived data from the International Tundra Experiment: Data source: http://data.eol.ucar.edu/codiac/ds_proj/group?ITEX

Acknowledgements Funding was provided by the National Fish and Wildlife Foundation, the U.S. Geological Survey, the U.S. Fish and Wildlife Service, and the Department of Energy.