Explanation of NECN revised for species cohort transpiration

GitHub Repo: https://github.com/kmcquil/Extension-NECN-Succession

PnET Transpiration Explanation:
ImprovedMethodsForCalculatingWUEAndTranspirationInPnET.pdf

Scripts with changes (See github repo. I added comments so everything should be clear)

- AvailableSoilWater.cs
  - I added this script. It is based on the logic in AvailableN.cs
  - This script allocates water between cohorts based on biomass
- CohortBiomass.cs
  - Added function to calculate VPD and cohort transpiration based on NPP. Located at the bottom of the script.
  - Since transpiration is coupled to NPP, I call the transpiration function within the CalculateNPPcarbon function
- Main.cs
  - No important changes. This script launches the other scripts so I just updated the commands to run the soil water in two parts, divy up the available water between cohorts, and run the new transpiration model.
- SoilWater.cs
  - I used the Henne model and modified it slightly by splitting it in two parts, before and after transpiration is calculated.
  - I updated how stormflow and baseflow are subtracted to minimize the water stress.

Explanation of overall changes

- I updated NECN to calculate transpiration for each cohort. The transpiration calculations were based on those in PnET, which are rooted in physics governing CO2 and H2O vapor diffusion between plant and atmosphere, and ultimately the physics translating H2O vapor lost to volume of groundwater extracted.
- Add monthly atmospheric CO2 and min/max rH as new inputs. These were both already part of the climate library, so that was easy.
- Calculating Transpiration
  - Gross photosynthesis is estimated as NPP x 2 based on the assumption that respiration makes up half of GPP (Chambers et al., 2004; Marthews et al., 2012; Zhang, Y., Xu, Chen, & Adams, 2009). NPP was estimated using available water calculated for each cohort based on biomass.
  - VPD is calculated using temperature and rH. .
  - Moisture limitation scalar is calculated using available water allocated to each cohort based on biomass.
  - Foliar nitrogen is calculated using species specific leaf CN ratios and assuming C is 47% of leaf biomass.
  - WUE (gC m2 month / kg H2O m2 month) is calculated based on VPD,

atmospheric co2, moisture limitation, and foliar nitrogen.
    - Gross photosynthesis is multiplied by WUE to get transpiration (mm m2 month) for each species age cohort.
- I used the Henne version of the soil water model because it was less water-limiting. I split the soil water model into two parts directly before and after transpiration is calculated. This was necessary because the transpiration was originally calculated in the middle of the soil water model but the new transpiration is based on NPP which is based on available water. Available water is calculated as the average of the min and max soil water in the cell each month, but the min isn't calculated until after transpiration is taken out in the original version of the code. To overcome this, we use the min soil water from the prior month.
    - Part 1
        - Precipitation, snow melt, evaporation, interception
        - Available water calculation necessary for NPP (and therefore transpiration) uses the minimum available water from the previous time step since the min available water comes after transpiration in order of calculations.
        - We separately calculate an upper limit on transpiration
            - Upper Limit = soil water content - soil water content at wilting point
            - This limit is used in the original NECN. Using the regular available water limit (avg of min and max available water) results in sharp declines in transpiration during drought that are not realistic.
    - Part 2
        - Subtract total transpiration, stormflow, and baseflow
        - I updated the calculations to take out stormflow and baseflow. If the soil water content is above the holding capacity of the soil, stormflow is subtracted directly, followed by baseflow. If it is not, then just baseflow is subtracted.
- The AvailableSoilWater.cs allocates soil water between cohorts
    - The upper limit on transpiration (soil water - wilting point) is allocated between cohorts based on biomass. This is used in the Calculate_Transpiration function in the cohortBiomass.cs to stop total transpiration in the cell from exceeding plant accessible water.

Reflections

- Allocating water between cohorts made the landscape more water limited. The model is sensitive to the exponent used to allocate water between cohorts.
- Calculation of 'available water' that is used in the calculate_waterLimit function is based on previous months minimum. This is not ideal but I couldn't find a way around it and it doesn't really matter over the course of decades.
- The updated version uses CO2 and min/max rH. The rH data is only used in the VPD calculation but you can calculate VPD using just temperature data, so addition of rH isn't actually necessary. The CO2 data was used in the transpiration calculations but we

talked in our meeting about just assigning a generic value if you didn’t want to add extra climate input requirements.