*SubTask 4.2: Vegetation succession models for improved ET estimates*

# Objective:

To develop a vegetation-mediated evapotranspiration model (or set of models) that can be parameterized and applied to regions ranging from permafrost to tropical biomes.

# Summary:

Evapotranspiration, the process by which water is transferred from the soil to the atmosphere by plant processes, is a critical component in the estimation of local water balance and soil moisture. In terrestrial environments, evapotranspiration comprises greater than half of the water budget. The most commonly used evapotranspiration models either do not include vegetation parameters or use static descriptions of vegetation to select a single parameter for a given location.

The change of evapotranspiration over time is largely driven by vegetation succession dynamics, which are in turn controlled by disturbances. The ability to relate vegetation patterns to different climate and hydrologic states would significantly improve the estimation of evapotranspiration and therefore the overall water balance for a given set of conditions. Budyko (1974) derived a simple and accurate methodology for estimating the relationship between annual evapotranspiration and the long-term average water and energy balance at catchment scales. Plotting the evaporative index (potential evapotranspiration divided by precipitation) versus the dryness index (potential evapotranspiration divided by precipitation), hydrologic regimes can be identified that distinguish energy-limited and water-limited systems. Numerous studies have found that biomes tend to plot along the Budyko curve. This provides a simple methodology for predicting stable biome states from hydrometeorological measurements and estimations. It can also be applied in reverse to estimate evapotranspiration for a given set of vegetation patterns and hydrometeorological conditions.

Combining the Budyko methodology with a hydrology-vegetation model will enable simulation and prediction of evapotranspiration rates for a wide range of environments and climatic conditions. The objective of this task is to improve modeling capabilities for the evapotranspiration component of the water balance equation by developing parameters that take into account vegetation growth and succession patterns. Through field and lab experiments the approach will also be extended to examine the role of vegetation in the hydrologic evolution of thawing permafrost locations.

# Components:

* 4.2.1 Review of models and model parameters used to estimate water balance components to estimate/simulate infiltration and runoff
* 4.2.2 Estimation of evapotranspiration from remote sensing measurements and modeled vegetation parameters such as leaf area index, root depth, and root mass
  + 4.2.2.1 Correlate ET term with remote sensing measurements and modeled vegetation parameters
  + 4.2.2.2 Estimate root depth from remotely sensed measurements and modeled vegetation parameters
* 4.2.3 Estimation of evapotranspiration at high latitudes using vegetation indicators
  + 4.2.3.1 Literature review on permafrost active layer hydrologic succession
  + 4.2.3.2 Permafrost active layer vegetation root depth succession-ET lab experiments
  + 4.2.3.3 Permafrost active layer vegetation root depth succession-ET field measurements
* 4.2.4 Develop a process-informed stochastic hydrologic-vegetation model
  + 4.2.4.1 Develop a machine learning (ML) methodology to derive the parameters for a stochastically based hydrologic model using a high-resolution hydrologic model (GSSHA) and remotely sensed data
  + 4.2.4.2 Develop ML methodology to use Budyko relationships to derive vegetation parameters, and relate these to measurements to local climate conditions and trends
  + 4.2.4.3 Develop and test the hydrologic-vegetation model using a case study
* 4.2.5 Data and model analysis
* 4.2.6 Journal papers/final technical report

## Task 4.2 Details:

* Sub-task 1:
  + Review models and model parameters used to estimate water balance components to estimate/simulate infiltration and runoff
* Sub-task 2:
  + Design methodology to estimate evapotranspiration using remote sensing measurements and modeled vegetation parameters such as leaf area index, root depth, and root mass
  + Correlate ET term with remote sensing measurements and modeled vegetation parameters
  + Develop algorithms to estimate root depth from remotely sensed measurements and modeled vegetation parameters
* Sub-task 3:
  + Develop methodology to estimate evapotranspiration at high latitudes using vegetation indicators
    - Literature review on permafrost active layer hydrologic succession
    - Permafrost active layer vegetation root depth succession-ET lab experiments
    - Permafrost active layer vegetation root depth succession-ET field measurements
* Sub-task 4:
  + Develop a process-informed stochastic hydrologic-vegetation model
    - Develop a machine learning (ML) methodology to derive the parameters for a stochastically based hydrologic model using a high-resolution hydrologic model (GSSHA) and remotely sensed data
    - Develop ML methodology to use Budyko (1974) relationships to derive vegetation parameters, and relate these to measurements to local climate conditions and trends
    - Develop and test the hydrologic-vegetation model using a case study
* Sub-task 5
  + Data and model analysis
* Sub-task 6
  + Journal papers/technical report

# Deliverables:

The authors will deliver source code for a process-informed hydrology-vegetation model to estimate evapotranspiration from remotely sensed and meteorological data. Technical publications (journal papers/technical report) will be developed that describe the methodology, algorithms, literature review, and findings for sharing with military installation managers and the scientific community. Online repositories will be established to share code with the broader scientific community.

# Timeline:



# Budget:



# Research Team:

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* Todd Swannack
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