Multi-Scale Data Assimilation and Model Comparison for ABoVE to Identify Processes Controlling CO_2 and CH_4 Exchange and Influencing Seasonal Transitions in Arctic Tundra Ecosystems

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Project components

- **Empirical Modeling** – represents the mean state of the ecosystem and its response to environmental forcing that captures temporal and spatial patterns defined by meteorological and remote sensing fields.
- **Process Modeling** – simulate the physical state and biological processes within the ecosystem.
- **Data Assimilation** – Convolve spatially resolved carbon exchange estimates with meteorological transport model to predict CO_2 and CH_4 mixing ratios at receptor sites with observed mixing ratios as a top-down constraint. *Challenge models to capture integrated spatial signal rather than match a single point.*

Project Objectives

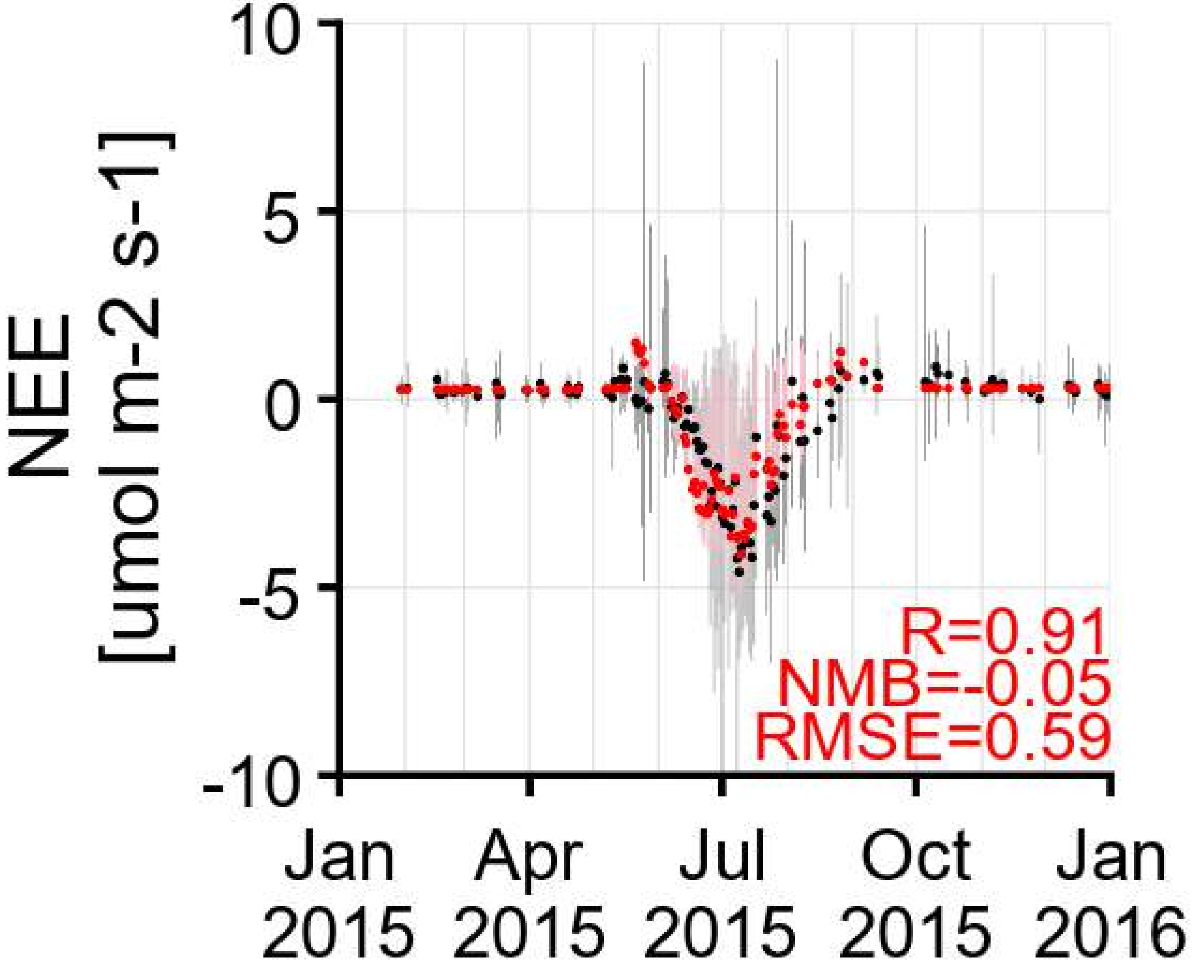
- Are observed patterns of transition-season carbon exchange occurring throughout the region, or are they confined to local “hotspots”?
- What environmental state variables best predict the timing of seasonal transitions in carbon exchange at the local level, and how can they be extended to larger regions?
- Are simulated carbon exchange rates consistent with the top-down constraint imposed by observed CO_2 and CH_4?
- If there are mismatches to the observations, what missing processes are suggested?

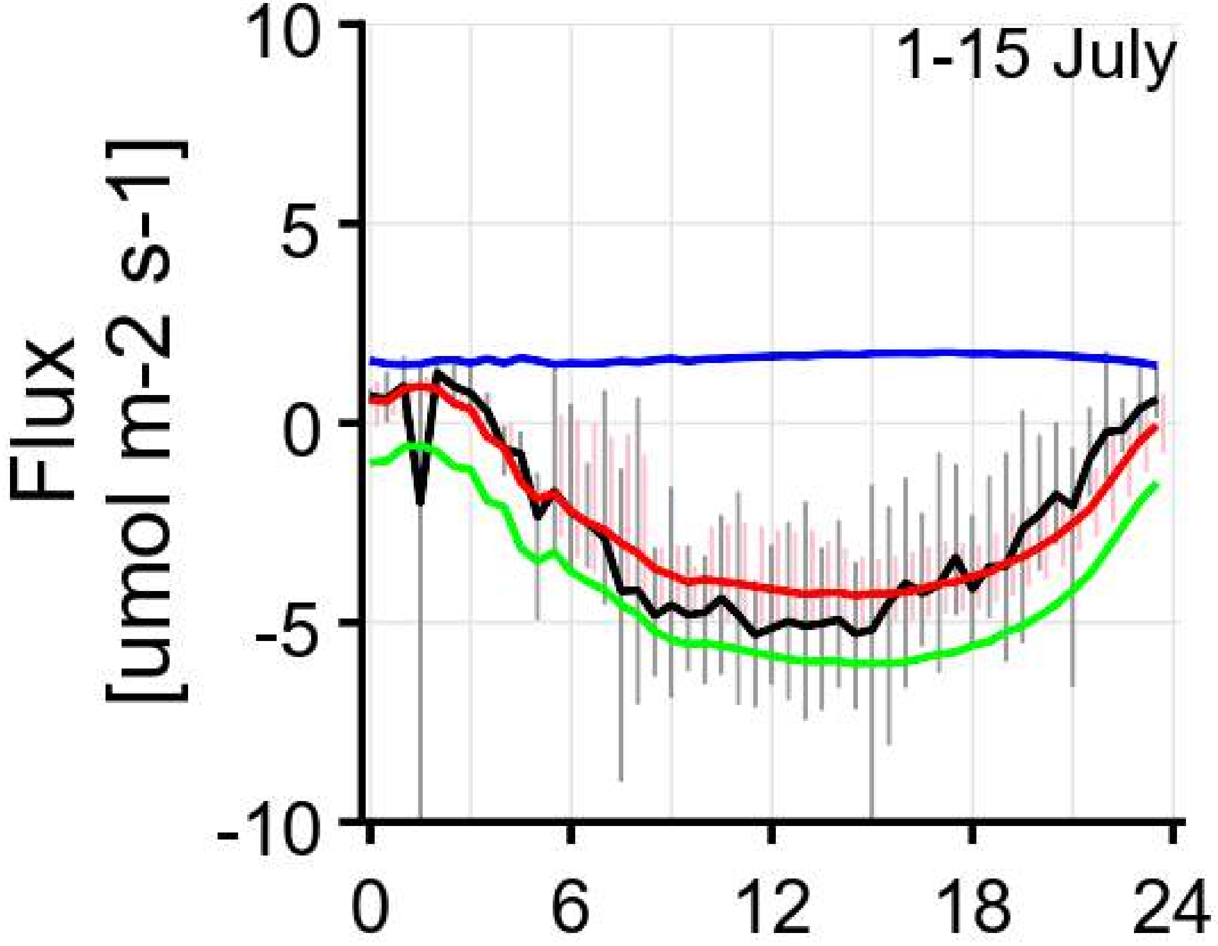
Status update – Empirical Modeling

- Reformulated Polar Vegetation Photosynthesis and Respiration model with **SIF** and **separated plant and soil respiration**
- Parameters tuned to flux and meteorology data from sites spanning tundra ecosystem and up to 10 years data
- Quantified uncertainties and sensitivity to variation in input data sources – land cover classification matters most

See Poster #21

Example PVPRM-SIF Tuning at ICH

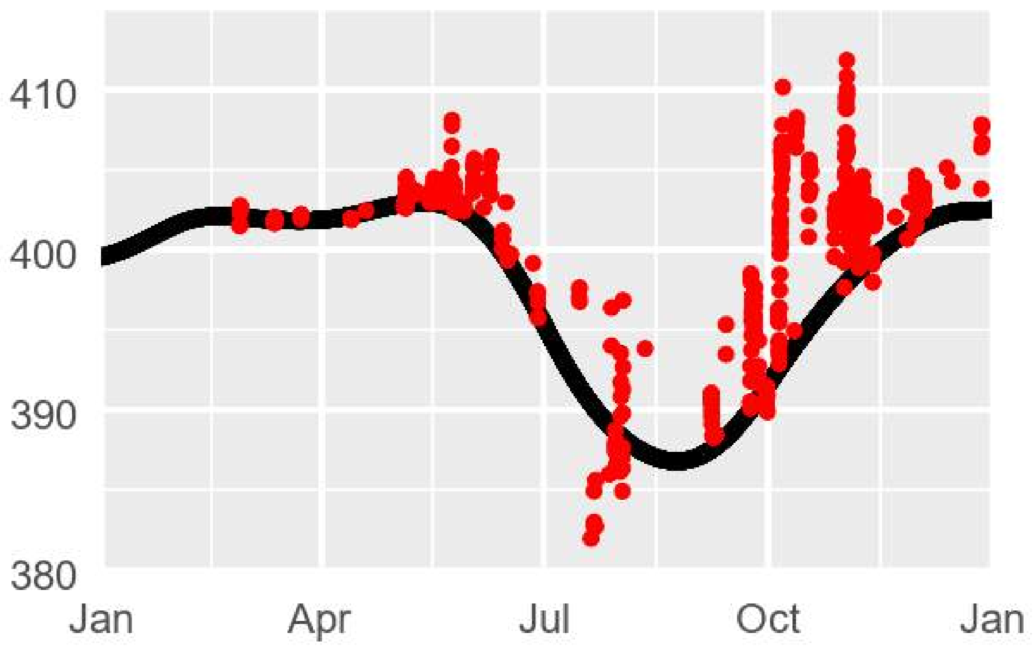




NOAA BRW tower

CO_2 concentration observations since 1973

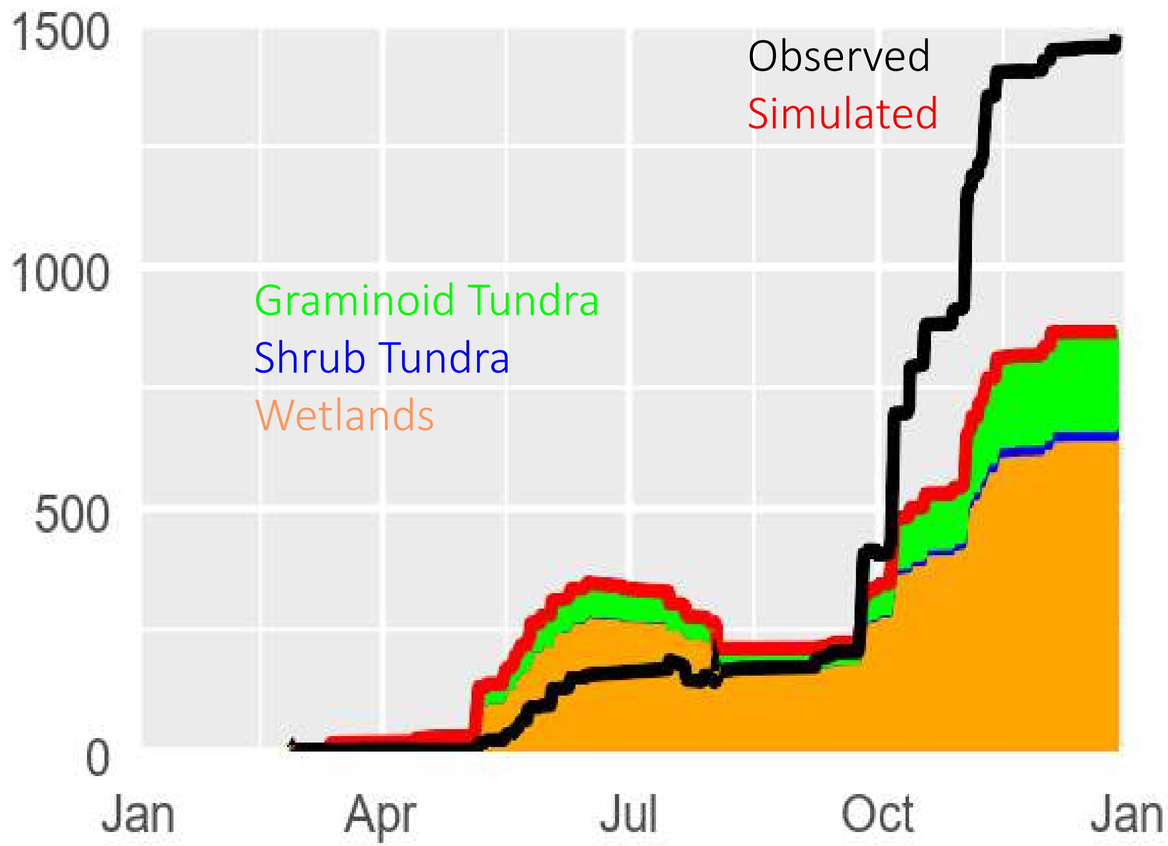
Isolate North Slope CO_2 enhancement



Static model driven by observed temperature and light only accounts for half of observed CO_2 enhancement

preliminary convolution example

Cumulative North Slope CO_2 Enhancement



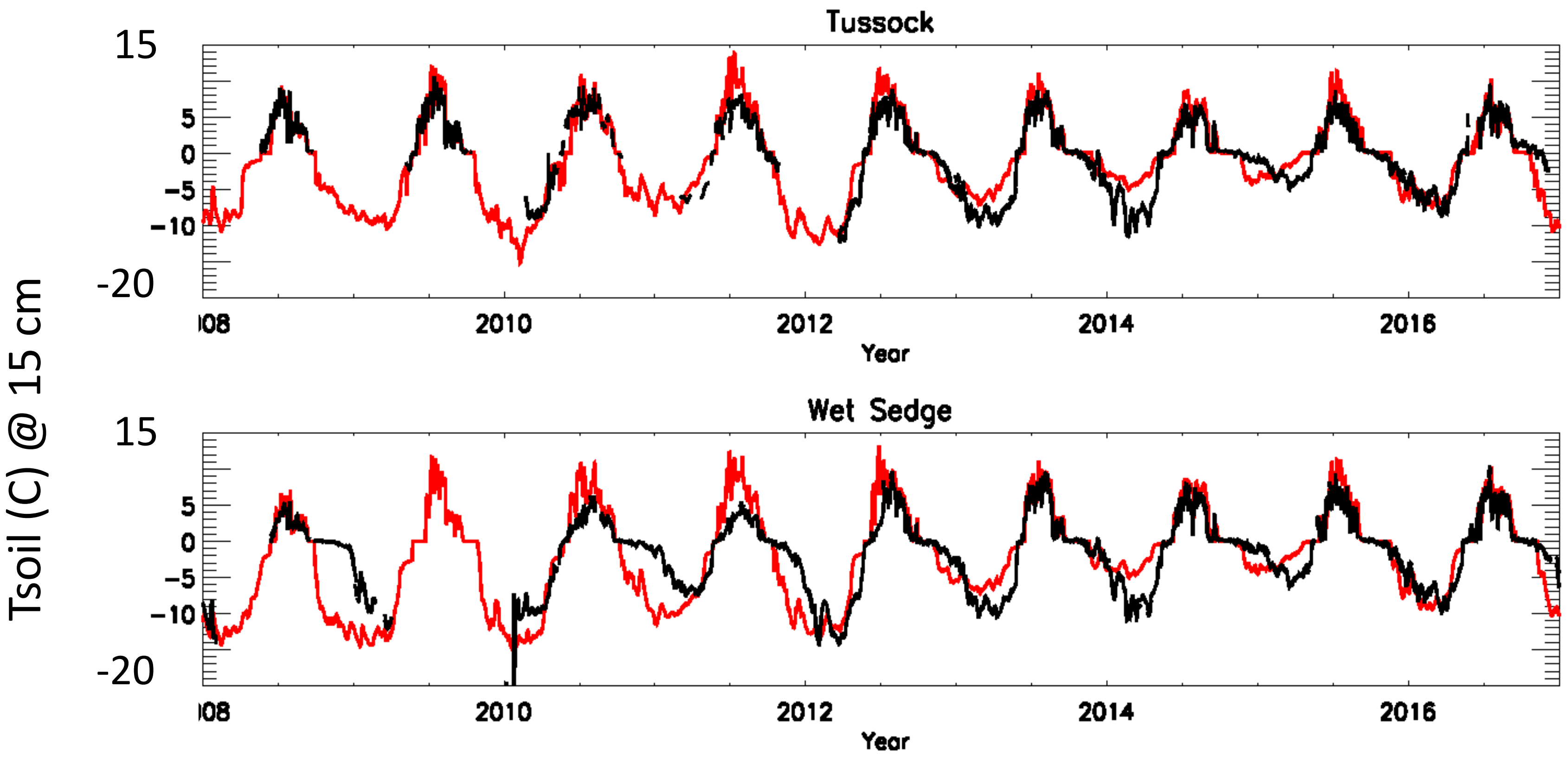
PVPRM provides the handle to attribute signal to ecosystem type

Status Update – Process modeling

- Adapted from previous implementations of Ecosystem Demography model v2.2: driven by observed meteorology
- Parameterized 3 tundra-specific plant functional types.
- Implemented vertically resolved Soil Organic Carbon and respiration that respond to temperature and moisture
- Tested against observations at Imnaviat Creek tower array, which include eddy flux measurements and ancillary meteorology, vegetation and soil properties.
    - Focus here on Tussock and Wet Sedge, Heath site vegetation distribution and soil organic mater initialization didn’t match site observations well

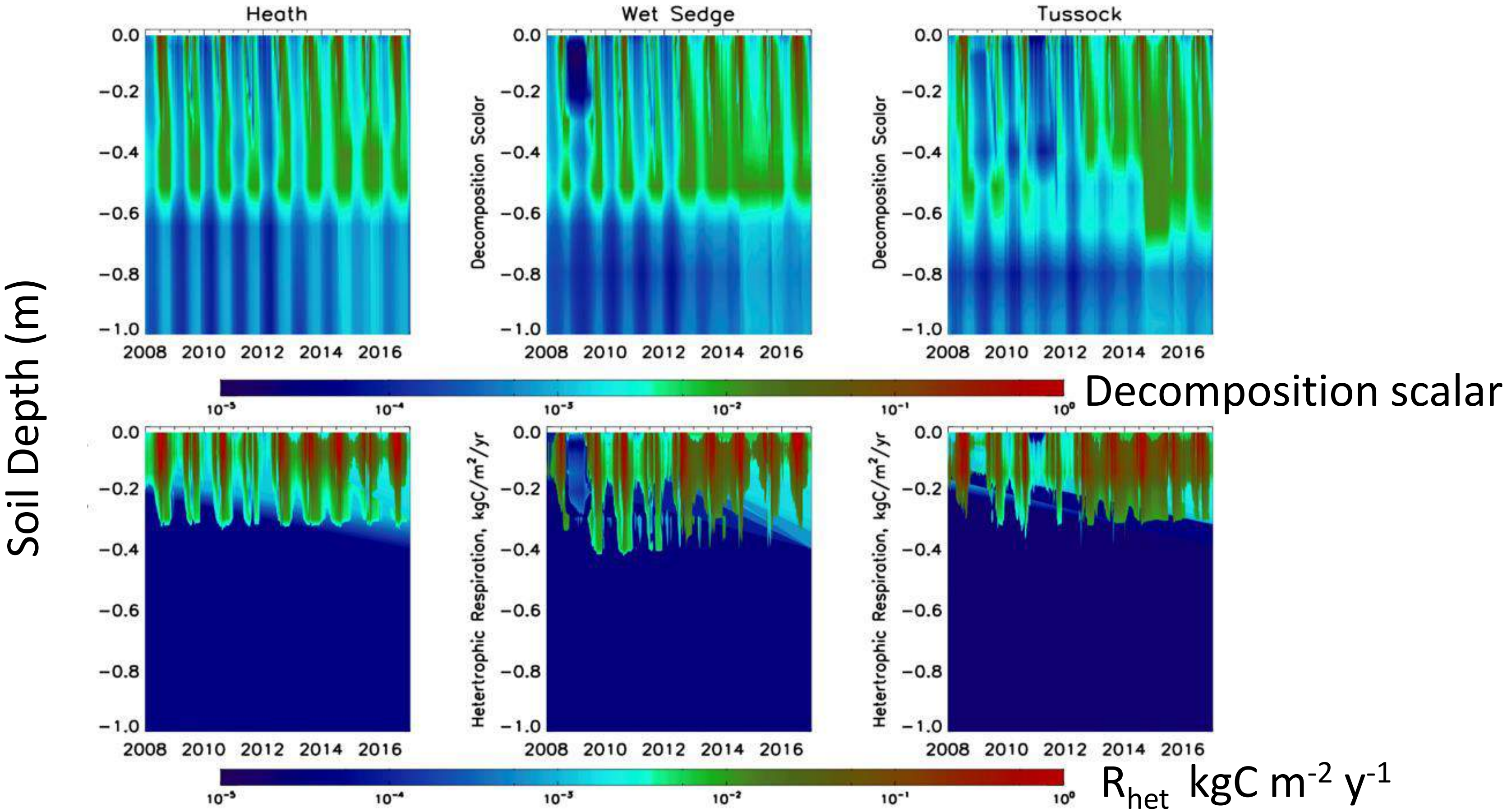
See poster #30

Soil physical processes

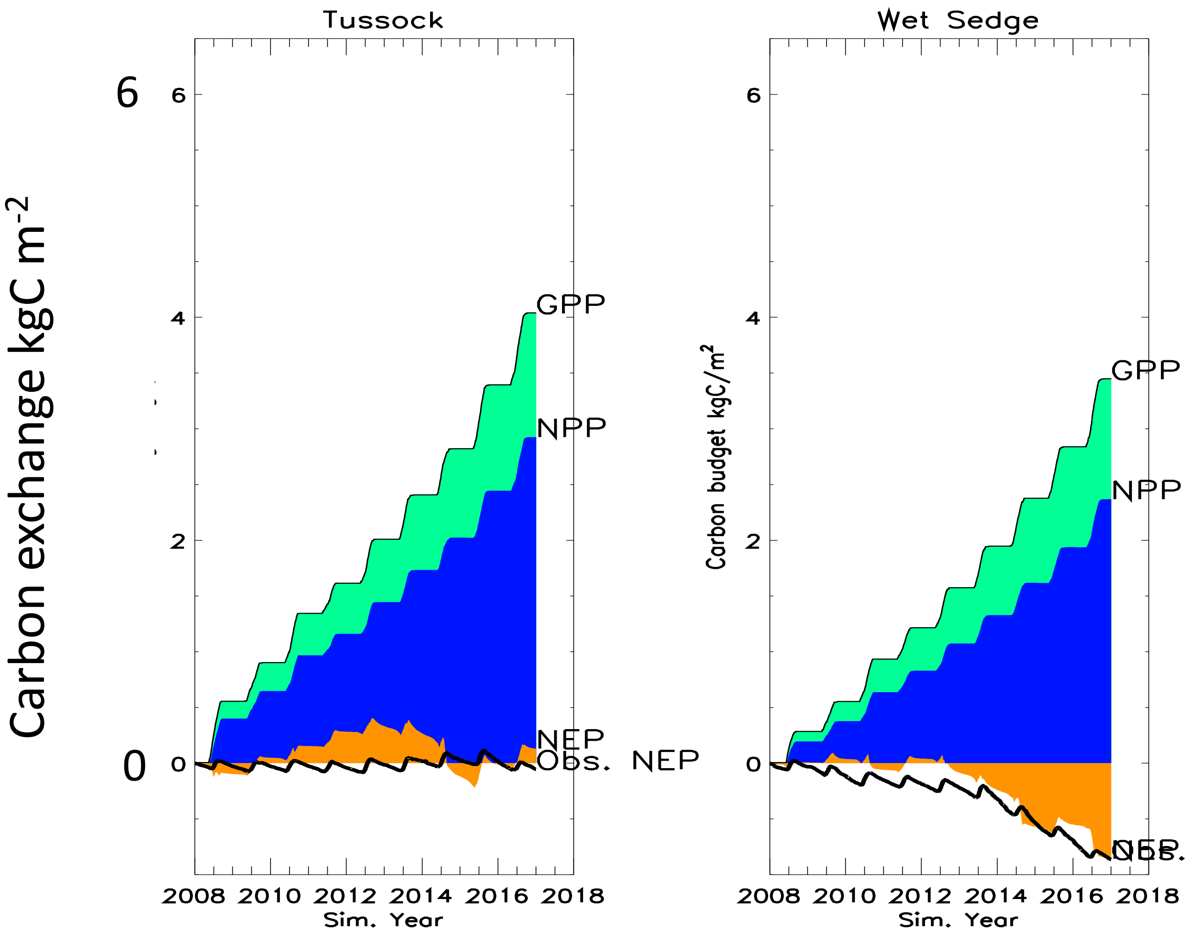


- Soil temperatures (driven by surface air temperature) track observations.
- Soil moisture (not shown) consistent with range of observations, but sparse sensor array for soil moisture observations had larger uncertainty.
- Good representation of soil conditions is key to simulating the SOC dynamics and respiration.

Soil Respiration



- Simulation shows increasing respiration over time and persistence of increased respiration at depth as noted in observations of ‘zero-curtain’ effect

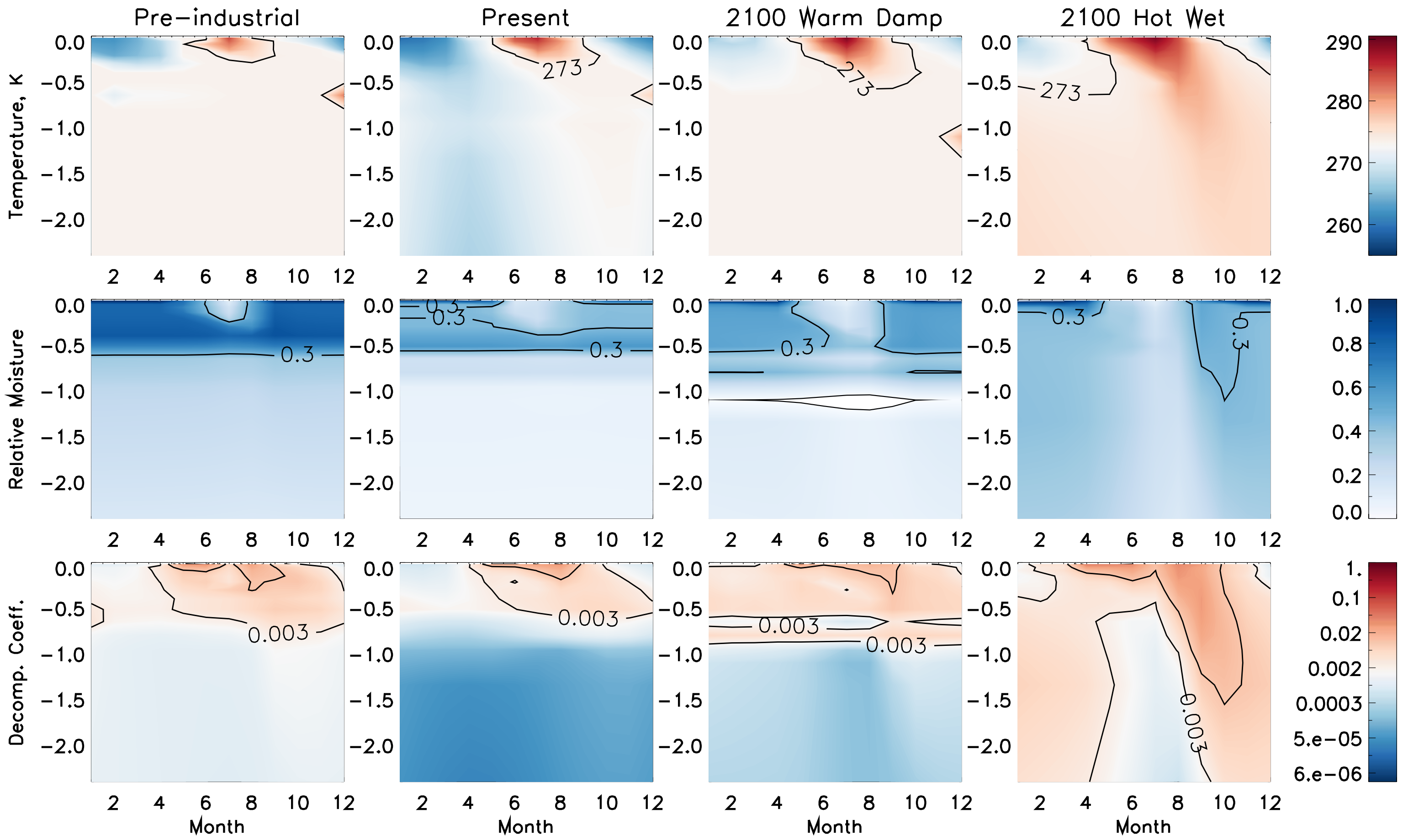


- In the simulation, warm and wet years of 2013-2015 induce a transition to a net carbon source due to **increased soil respiration**.
- Consistent with observed trends in NEP

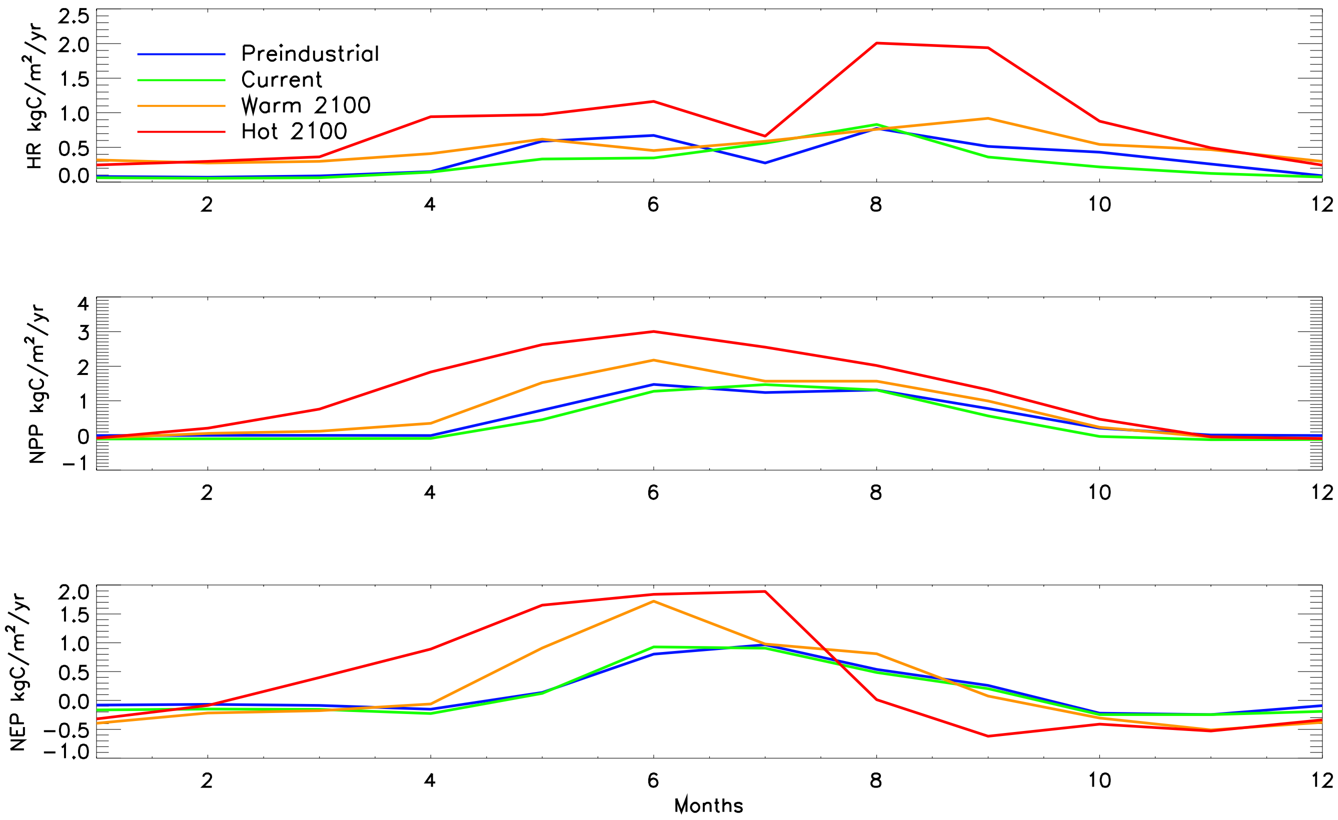
Future projections with ED2-arctic

- Run ED2-arctic under pre-industrial, current conditions and future scenarios (warm-damp, hot-wet)
- Examine soil condition
- Predict equilibrium carbon budgets for each

Thawing soils



Carbon Budget

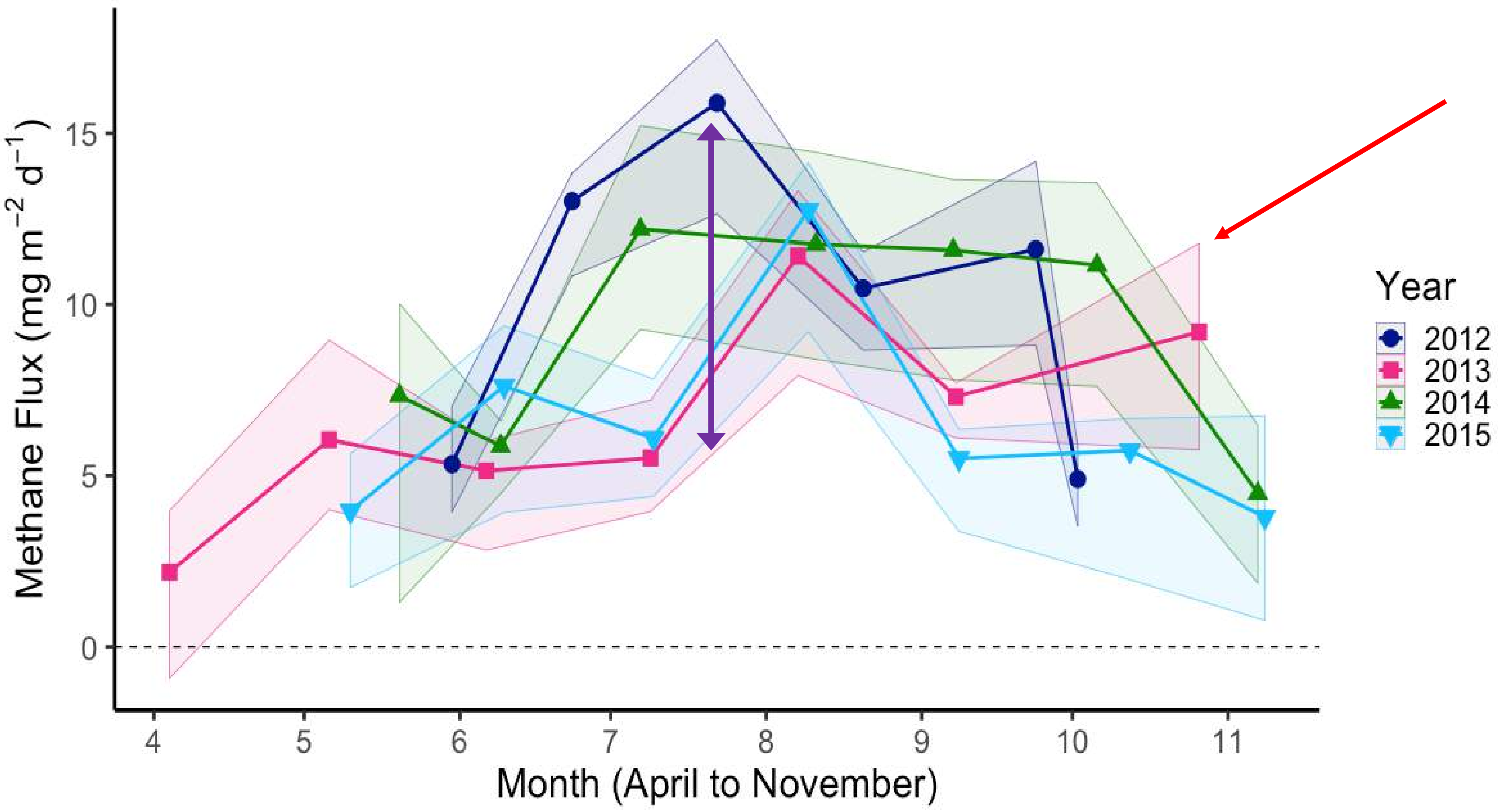


- All scenarios predict net annual carbon sink.
- Sink strength **increases** for warmer conditions on account of vegetation shifts
- Warming conditions shift seasonality in NEP due to decoupling of photosynthesis and respiration

Status Update - Assimilation

- Example from assimilation framework applied to CH_4 from CARVE campaign
- More to come in next quarter

Regional Monthly Methane Flux Estimates (120 to 170 °W and 50 to 75 °N)



Top down constraint from atmospheric mixing ratios indicates large interannual variability and existence of late season emission

Products

- ED-2 model update description – *Paper in progress*
- Assessment of Ecosystem Response to Climate Scenario – *Paper in progress*
- Revised Polar VPRM flux estimation and identification of excess CO_2 efflux in late fall –early winter that is only partly explained by warming temperatures
    - Implies shift in ecosystem function, change in active layer depth that is not accounted in soil temperature product, or influence from soil moisture that is not included.
- Increased CO_2 efflux during fall-winter transition is identified in flux and mixing-ratio observations and attributed by process and empirical modeling to respiration response to warmer soils