BJERKNES CENTRE for Climate Research

Dynamic wetlands parameterization under permafrost thaw in the CLM

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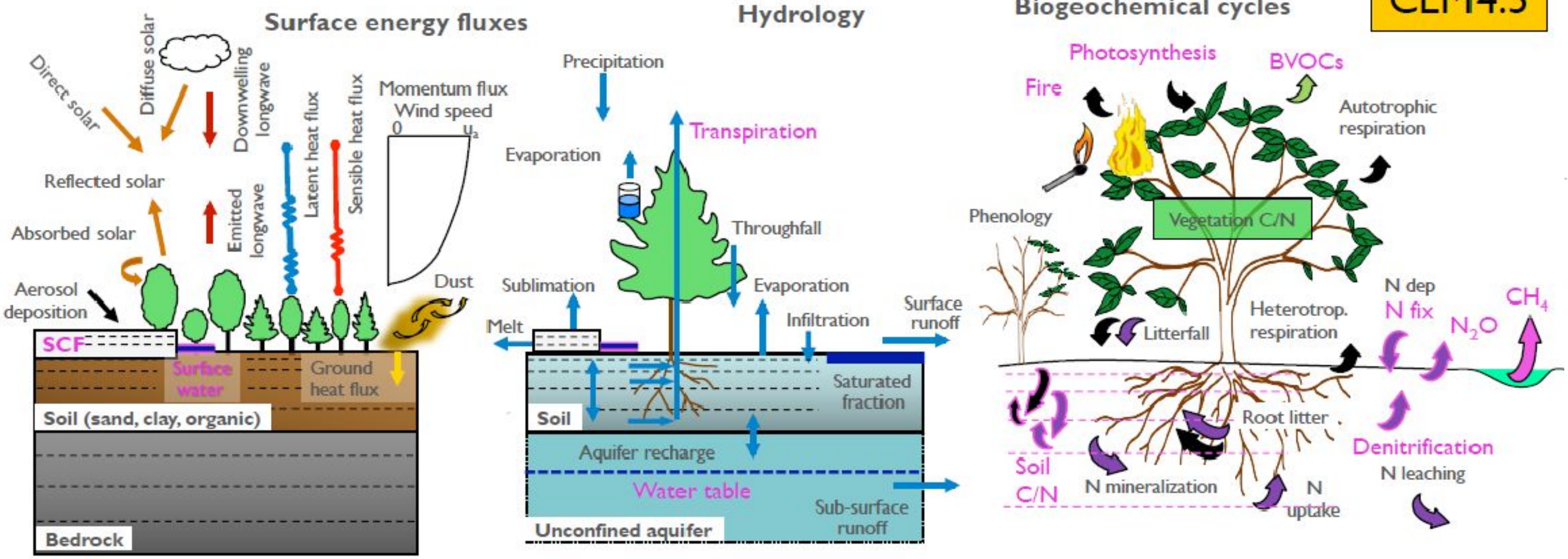
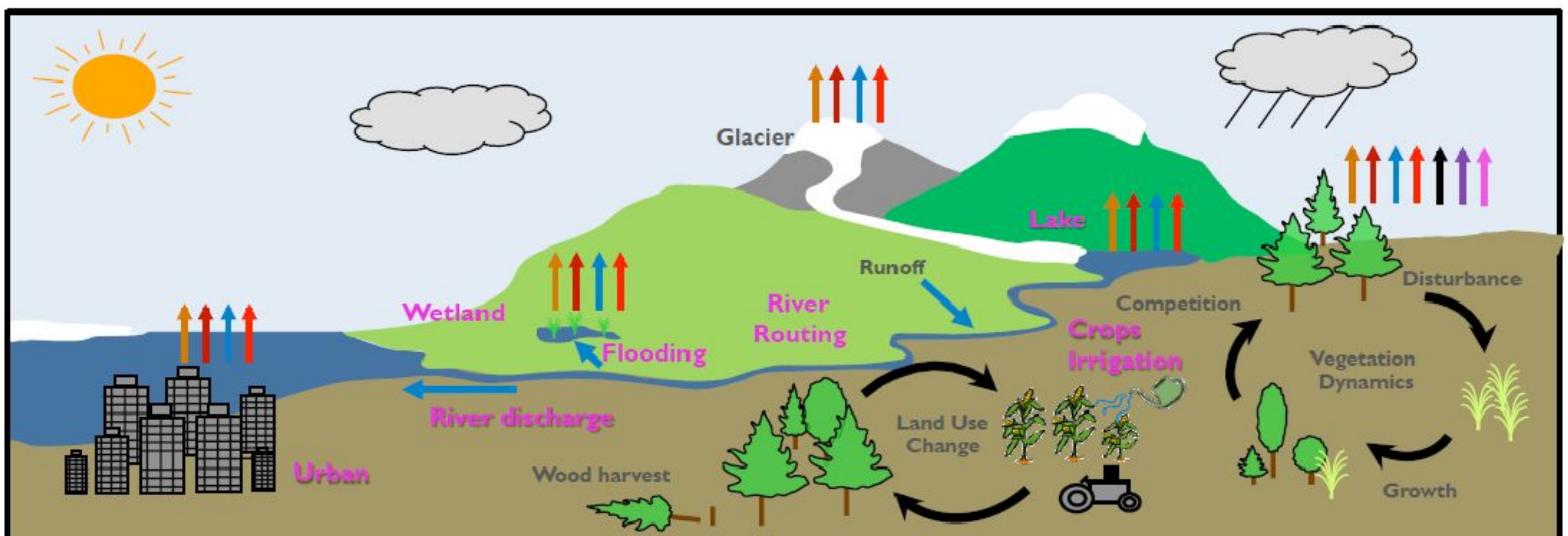
CLM4.5

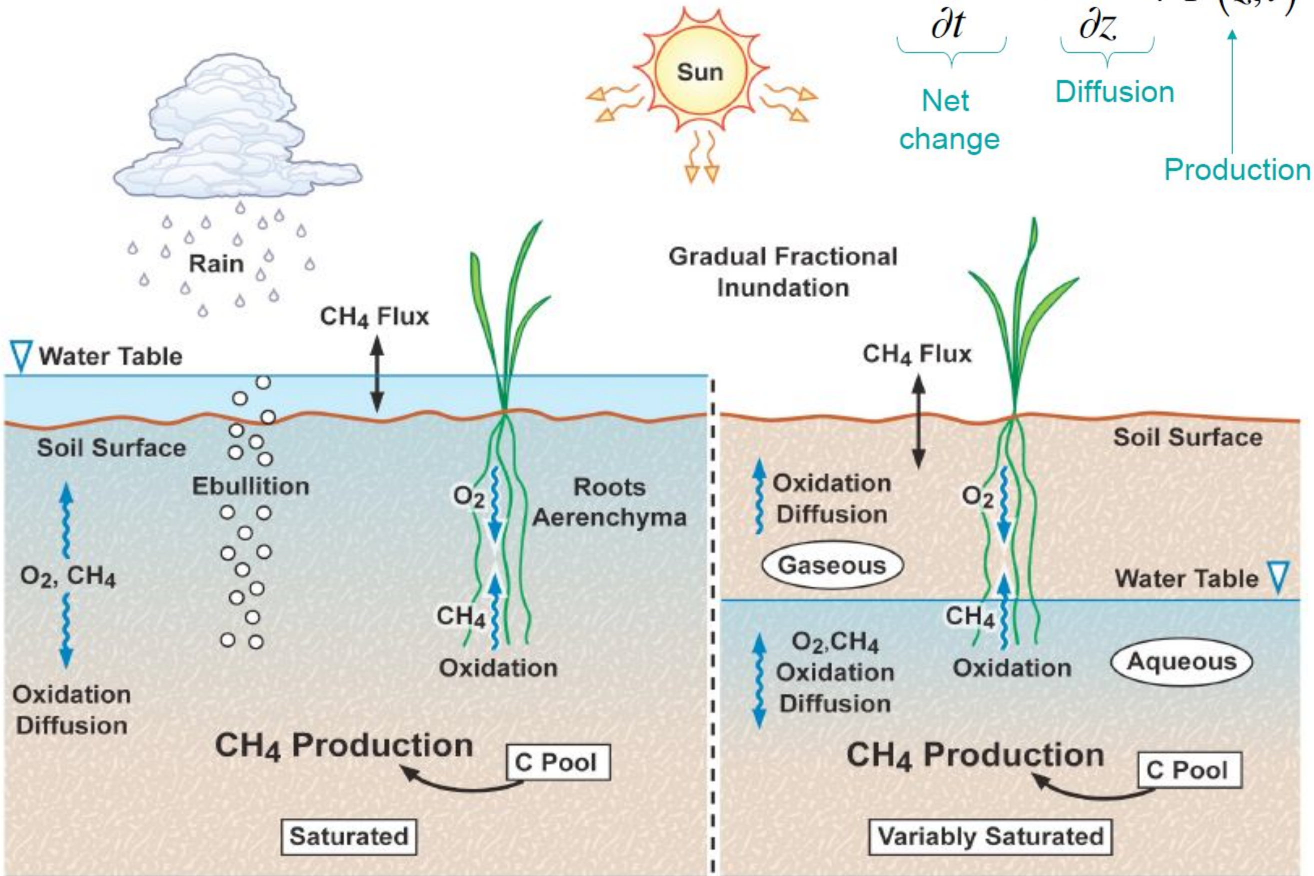




CLM5 is now released

CH_4 in the CLM

$$\underbrace{\frac{\partial(RC)}{\partial t}}_{\text{Net change}} = \underbrace{\frac{\partial F_D}{\partial z}}_{\text{Diffusion}} + \underbrace{P(z,t)}_{\text{Production}} - \underbrace{E(z,t)}_{\text{Ebullition (bubbling)}} - \underbrace{A(z,t)}_{\text{Aerenchyma (tissue)}} - \underbrace{O(z,t)}_{\text{Oxidation}}$$



- Simulates CH4 production and oxidation at saturated and unsaturated areas

From Riley et al. 2011

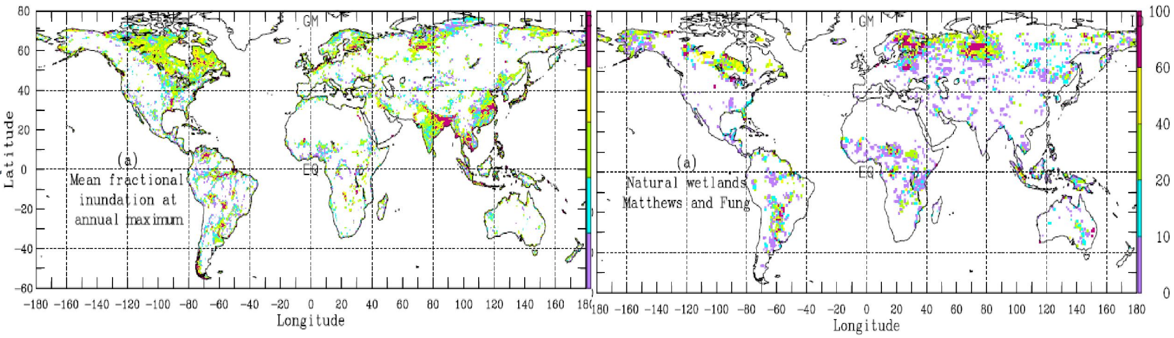
Wetland parameterization in the CLM

› Important to parameterize inundated fraction as CH_4 production is a direct function of surface inundation in the model

› CLM4.5 parameterization in Riley *et al*. 2011 (tuned to fit observations)

- Based on combination of water table and surface runoff
- Not process based parameterization
- $fs = P_1 e^{-zw/P2} + P_3 Qr$
- fs: inundated fraction
- zw: water table
- Qr: surface runoff (mm/s)
- P_1, P_2, P_3: optimized parameters

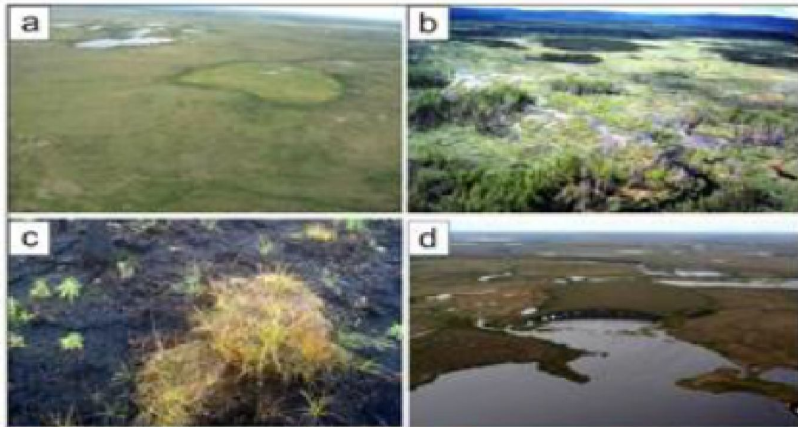
Prigent et al. 2007 | Matthews & Fung 1997



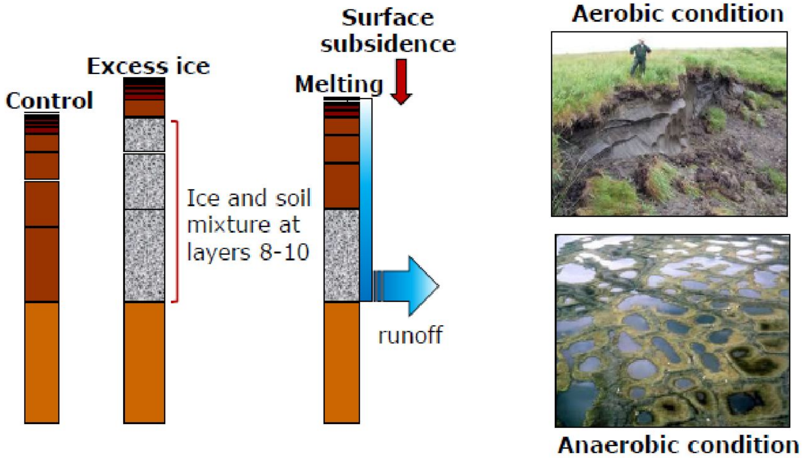
› **Models tuned to fit the current conditions may not predict future conditions accurately under permafrost thaw**

New permafrost parameterization in the CLM

Reality: CH_4 producing wetland formation with permafrost thaw



Model: New parameterization of excess ice in the CLM



New permafrost parameterization in the CLM

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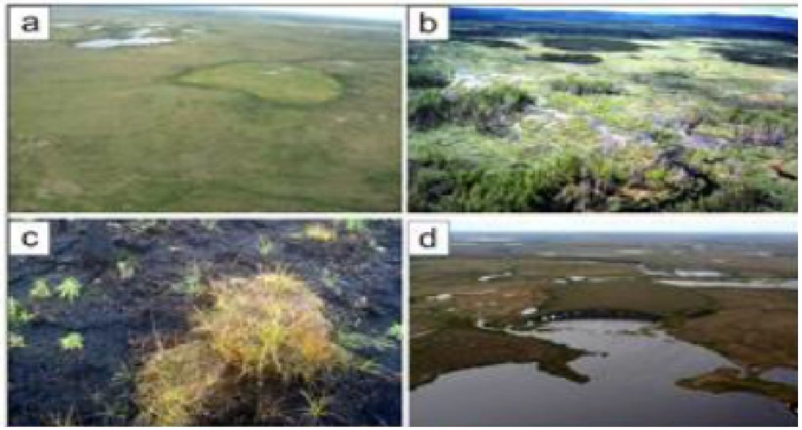
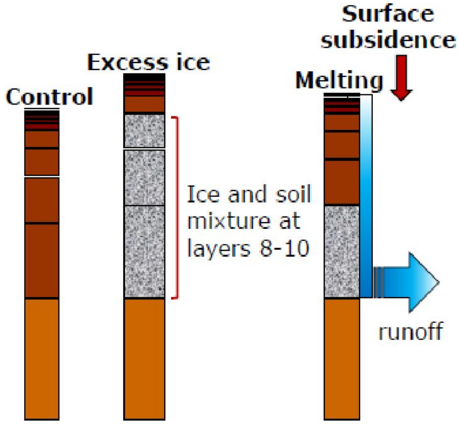


Lee et al. 2014 ERL

- Gridcell mean ice mixture within the soil layers
- Alters local hydrology and ground temperature
- Allows first-order estimation of ground subsidence with thawing permafrost
- **Still not linked to gridcell water distribution and storage**

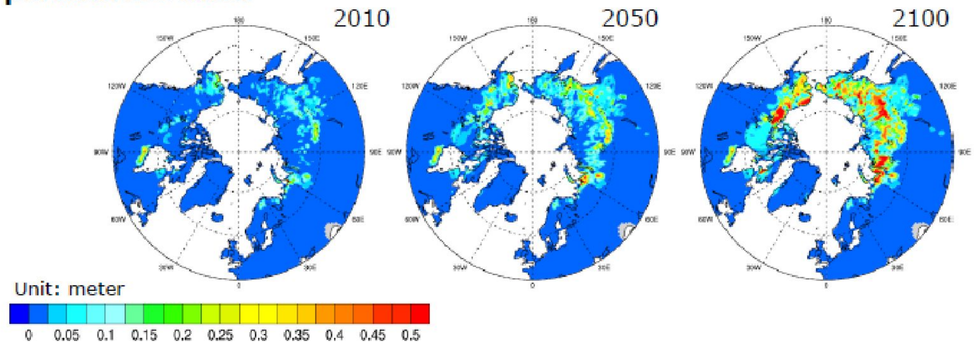
Model: New parameterization of excess ice in the CLM



Aerobic condition

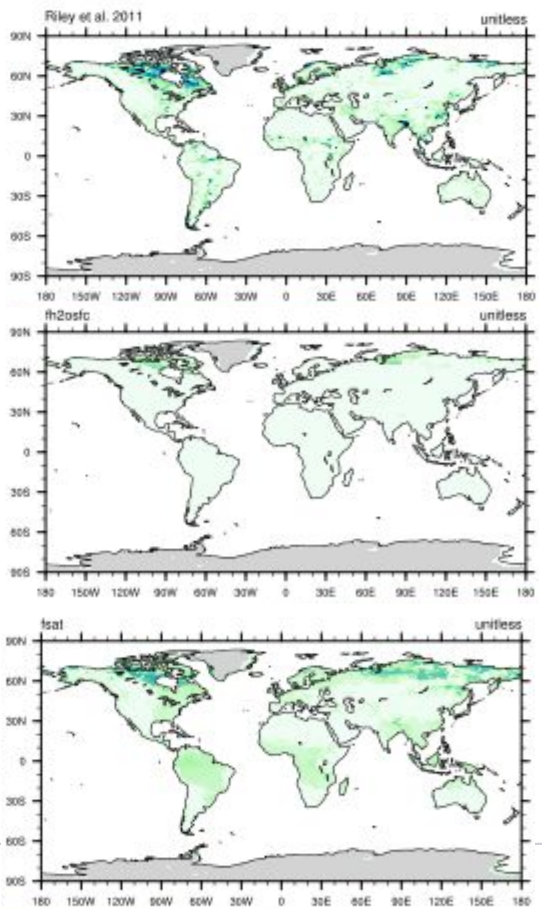
Anaerobic condition

A first order estimation of land surface subsidence with permafrost thaw



Wetland representation in the CLM

- CH4 emissions is a direct function of inundated fraction
- Important to accurately estimate the inundated fraction



- CLM4.5 parameterization in Riley *et al*. 2011

$$f_s = P_1\, e^{-z_w/P_2} + P_3 Q_r$$

  f_s: inundated fraction
  z_w: water table
  Q_r: surface runoff (mm/s)
  P_1, P_2, P_3: optimized parameters

- Inundated fraction set to FH2OSFC

$$f_{h2osfc} = \frac{1}{2}\left(1 + erf\left(\frac{d}{\sigma_{micro}\sqrt{2}}\right)\right)$$

  d: surface water
  σ_{micro}: std of the microtopographic distribution
  erf: error function

- Inundated fraction set to FSAT

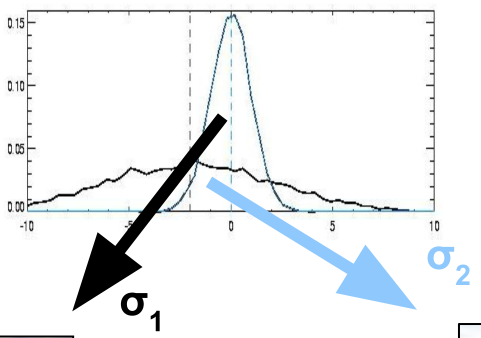
$$f_{sat} = wtfact \times e^{-0.5 \times df \times z_w}$$

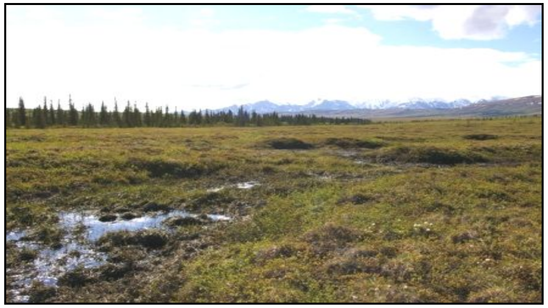
  wtfact: maximum saturated fraction
  df: decay factor

Dynamic microtopography with permafrost thaw and dynamic wetlands

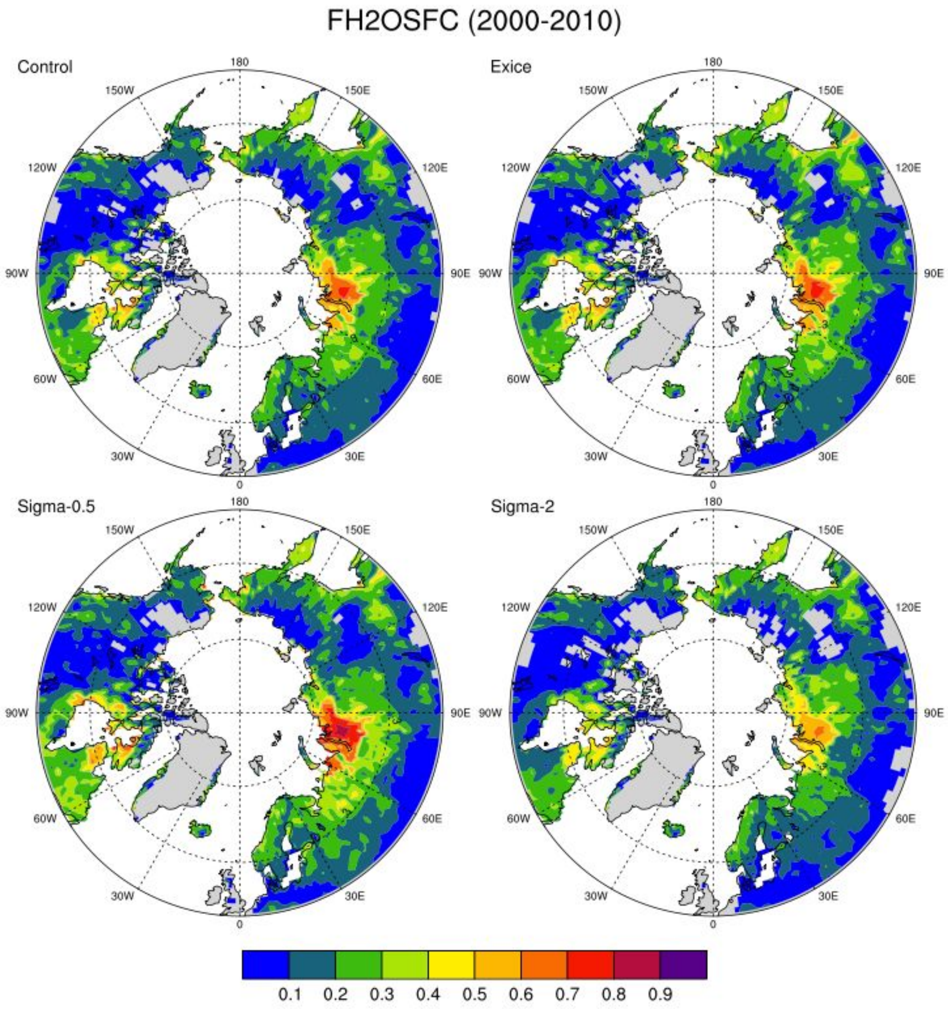
- Simulating thermokarst-like features: use dynamic microtopography to change wetland size and distribution with permafrost thaw
- Surface microtopography coupled to ground subsidence
- Surface wetland fraction calculated with the new microtopography value

Microtopographic distribution





Sensitivity of surface inundation to microtopography parameterization



- Sensitivity of simulated surface wetlands to subsidence-microsigma parameterizations
- Control
- Exice
- micro_sigma x 0.5
- micro_sigma x 2.0

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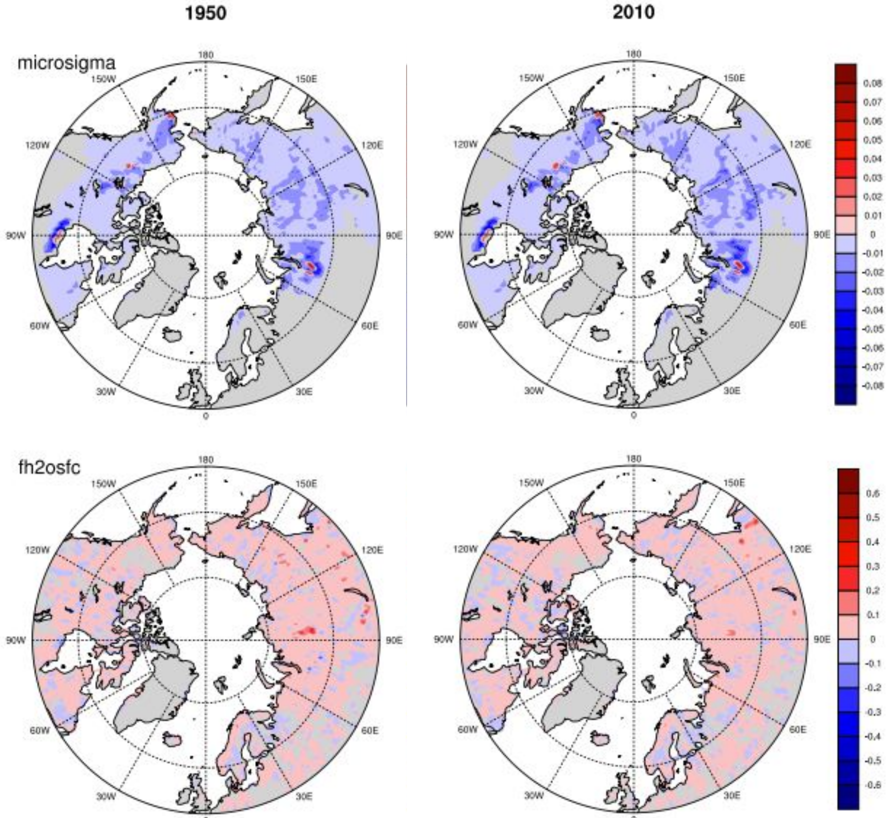
Ground subsidence effects on surface inundation

Exice - Control

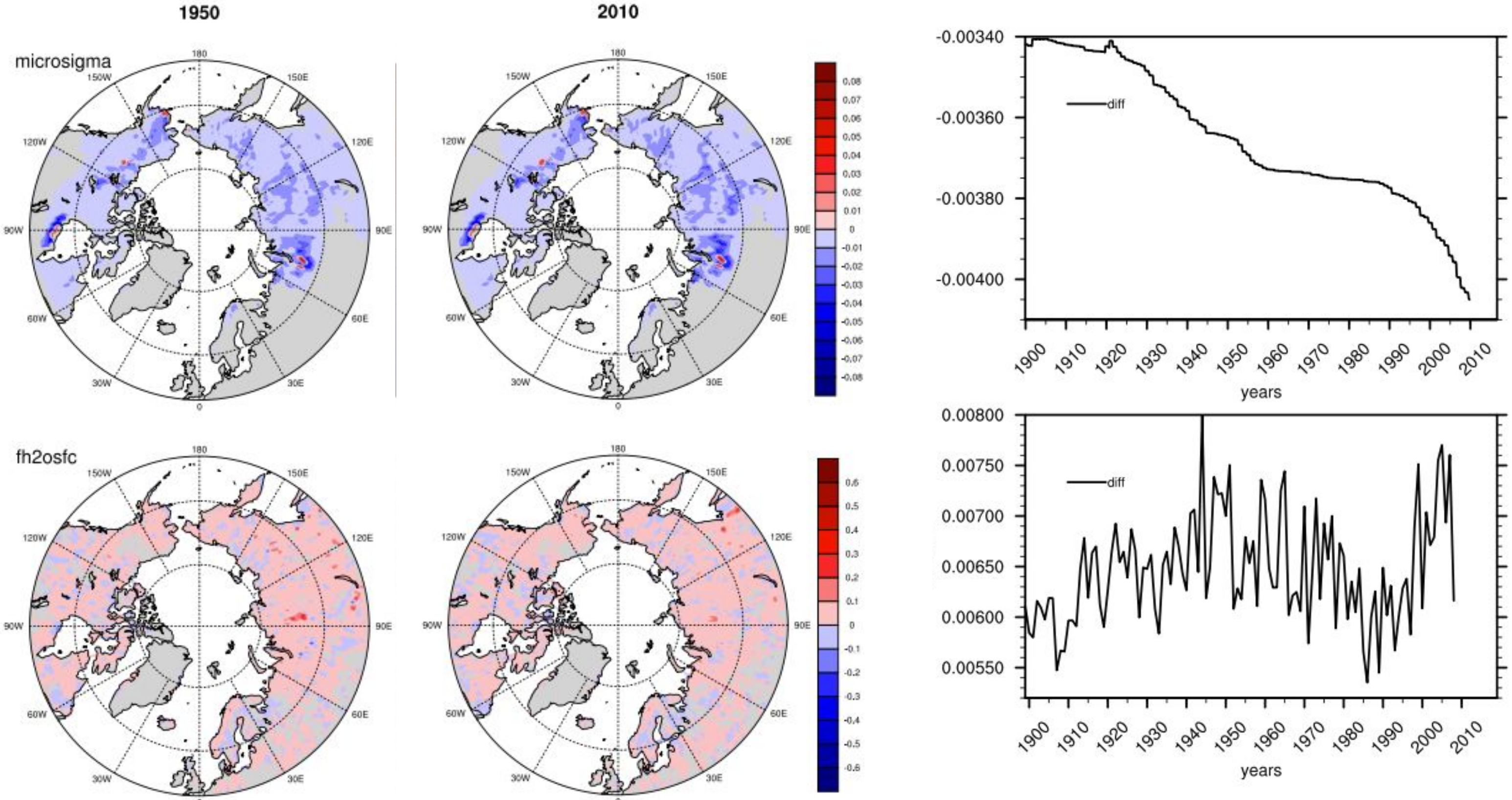


Difference maps of surface microtopography and wetland fraction from Exice and Control experiments for 1950 and 2010.

Ekici et al. In prep.

Ground subsidence effects on surface inundation

Exice - Control



Difference maps of surface microtopography and wetland fraction from Exice and Control experiments for 1950 and 2010.

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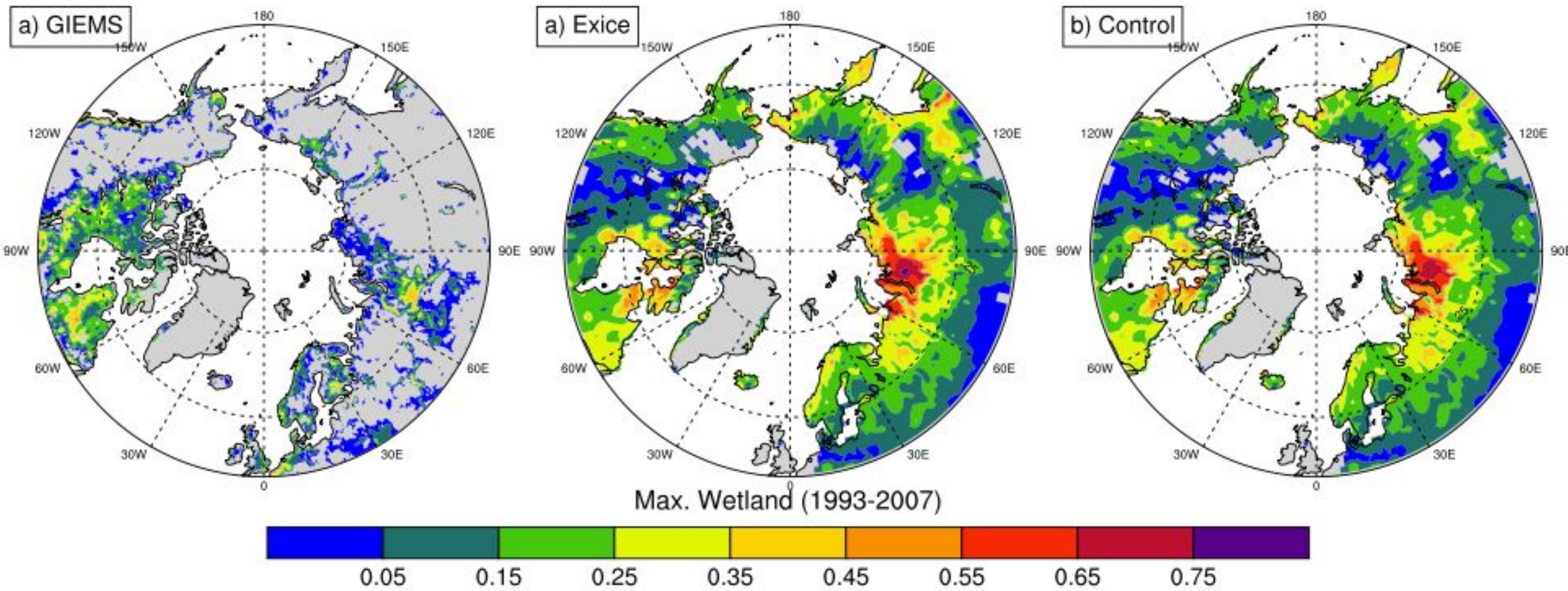
Spatial comparison to satellite driven dataset



› Surface wetland fraction comparison from GIEMS dataset (Prigent et al. 2007) and annual maximum fh2osfc of Exice and Control experiments


How can we represent real world in models?

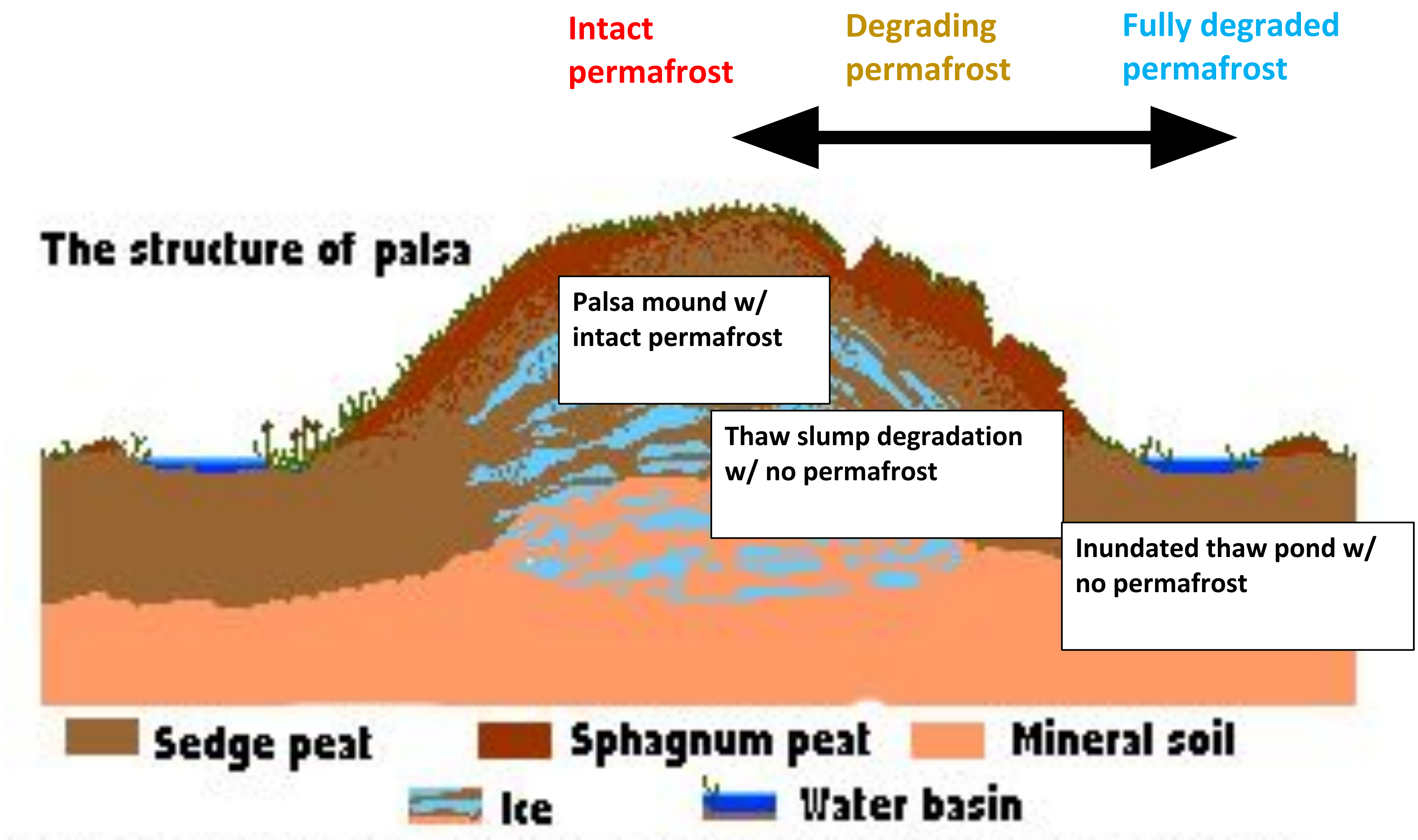
An ongoing project to evaluate modeling with observations

- **Overall goals:**
  - Gain process level understanding on permafrost carbon release under changes in hydrological conditions
  - Use observational data to evaluate models

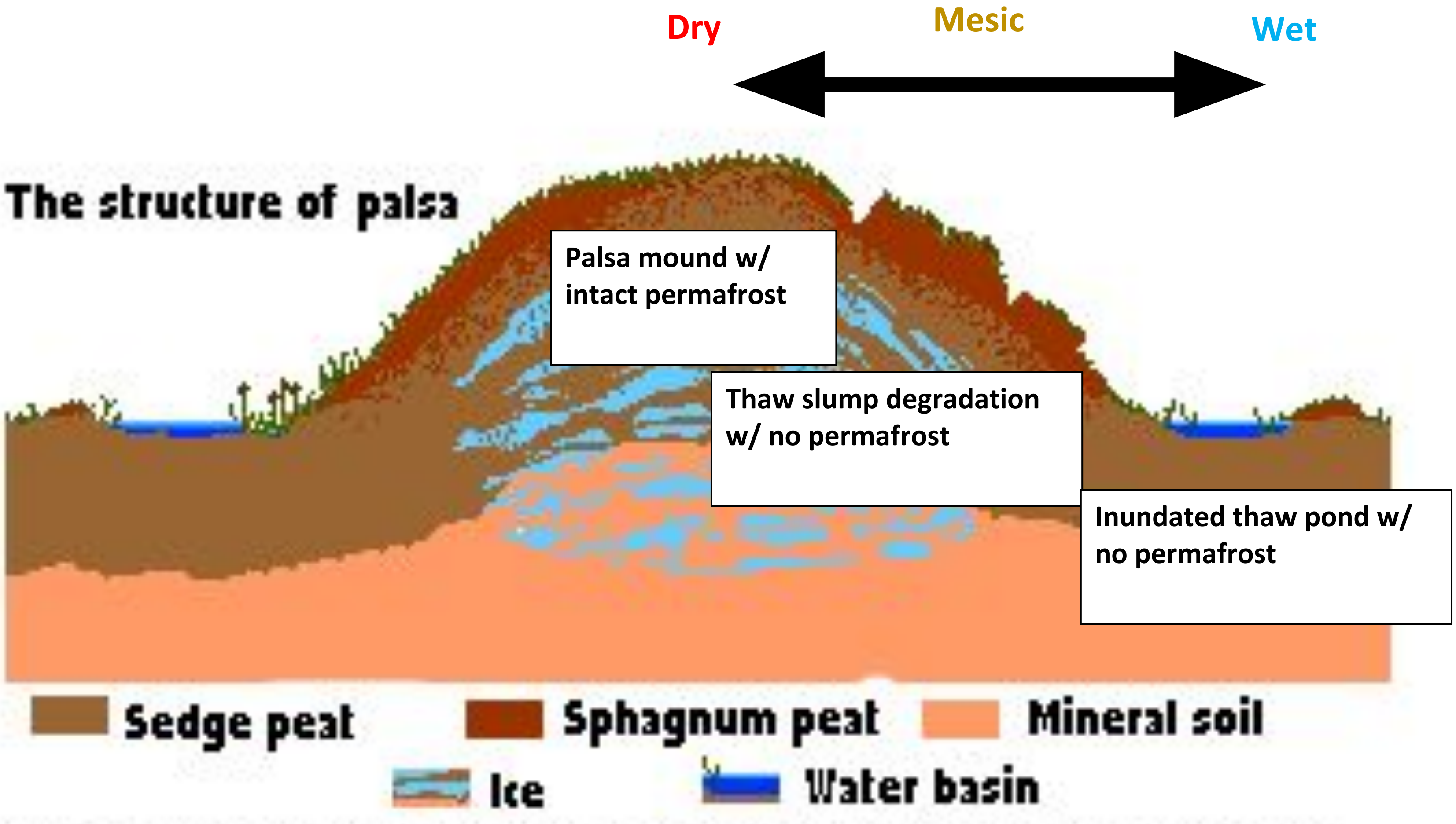
- **FEEDBACK:** Advancing permafrost carbon climate feedback - improvements and evaluations of the Norwegian Earth System Model with observations
  - Funded by the Research Council of Norway
  - Lead: Hanna Lee
  - Includes field observations of CO_2 and CH_4 in soil profiles with other environmental observations to understand processes
  - CLM CH4 module evaluation with in situ data
  - 2016-

- **Collecting CO_2 and CH_4 in soil profiles on high temporal resolution**

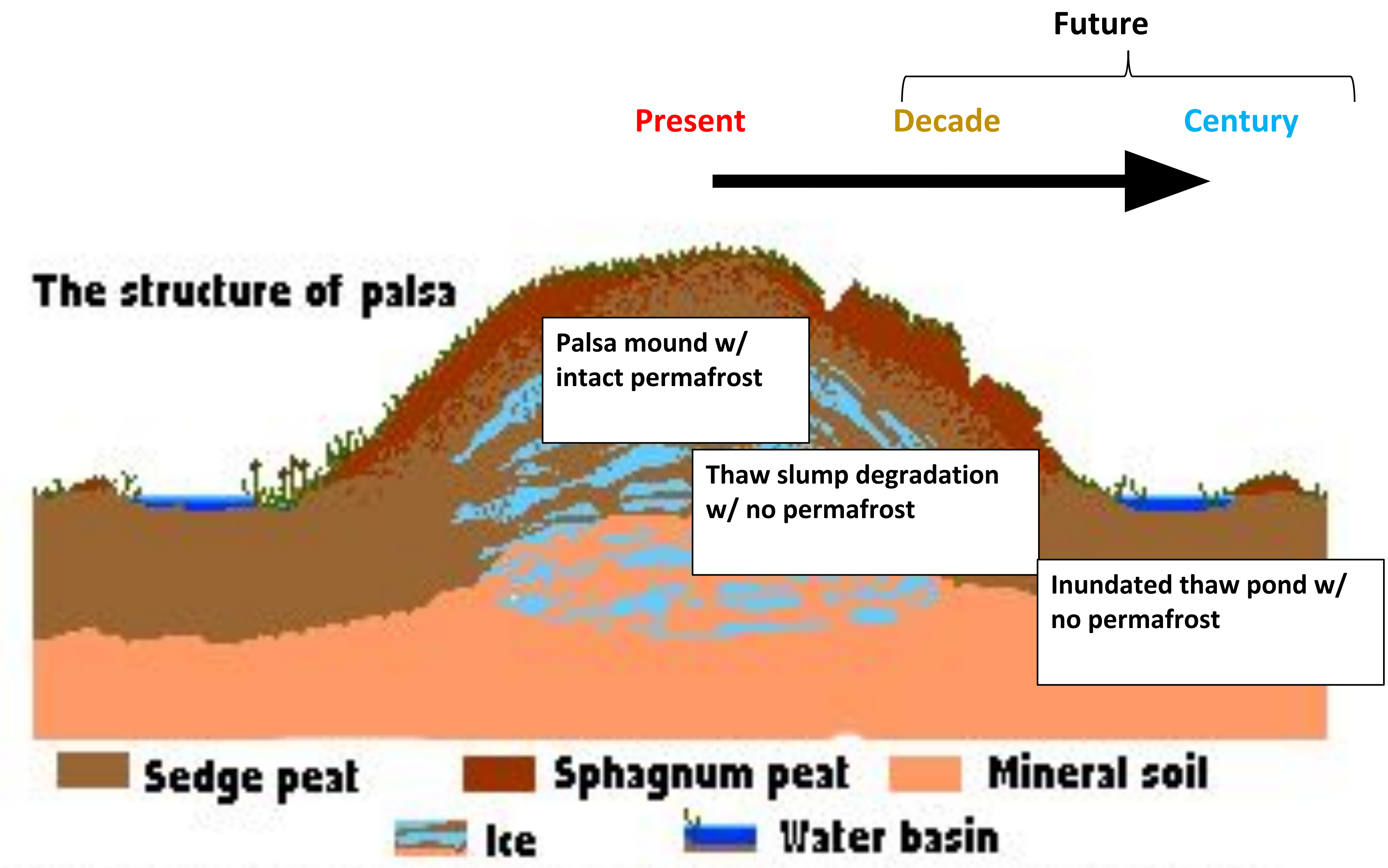
Permafrost thaw gradient



Soil moisture gradient



Chronosequence time scale



Field site setup

Landscape scale CO2 release

Plot scale CO2/CH4 release (includes vegetation and whole soil profile)

Depth-specific soil profile CO2/CH4 production, temperature, moisture, and biogeochemistry at 10, 20, and 40 cm depths

Iskorasfjellet
69.25N, 25.37E
gian Sea
Sweden
Norway
Finland
Baltic Sea
Estonia

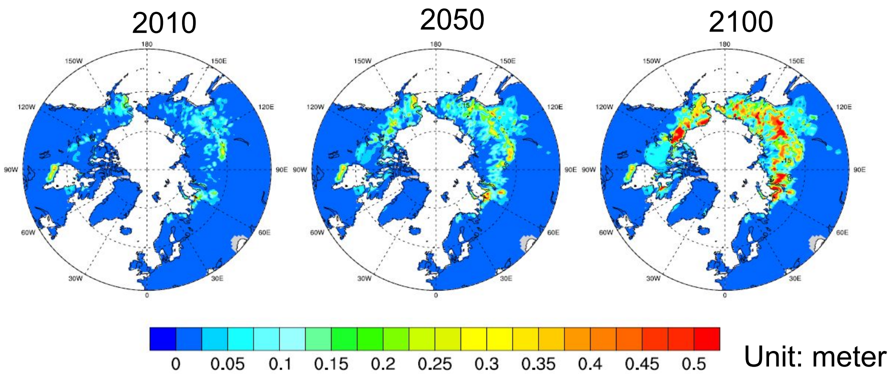
An ongoing project to upscale permafrost processes in NorESM

› **Overall goals:**
  - Model scaling using observations, small scale, finer scale models to improve NorESM
  - Focused on modeling to improve upscaling of permafrost thaw processes
  - 2016-

› **PERMANOR:** Permafrost landscapes in transformation – from local-scale processes to the global model NorESM
  - Funded by the Research Council of Norway
  - Lead: Sebastian Westermann
  - Includes field observations, remote sensing, detailed permafrost modeling (CryoGrid3), regional climate modeling (WRF), and NorESM-CLM

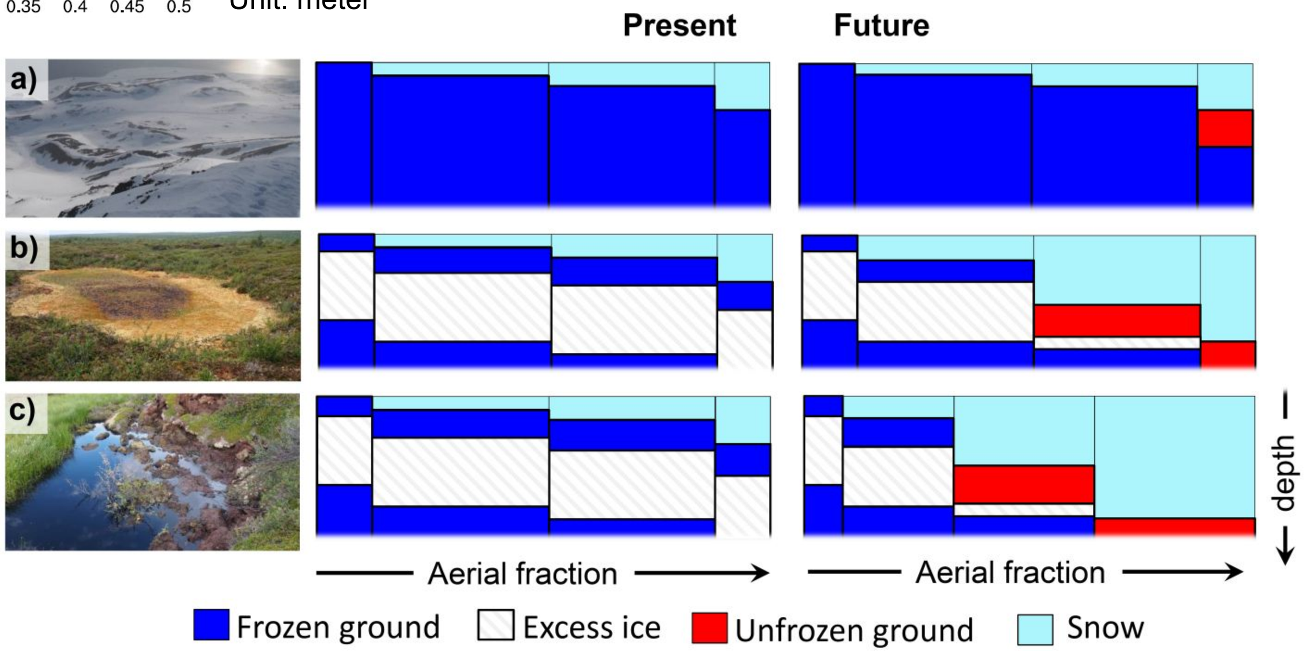
› **Upscaling of permafrost processes**

Representing permafrost thaw processes in models



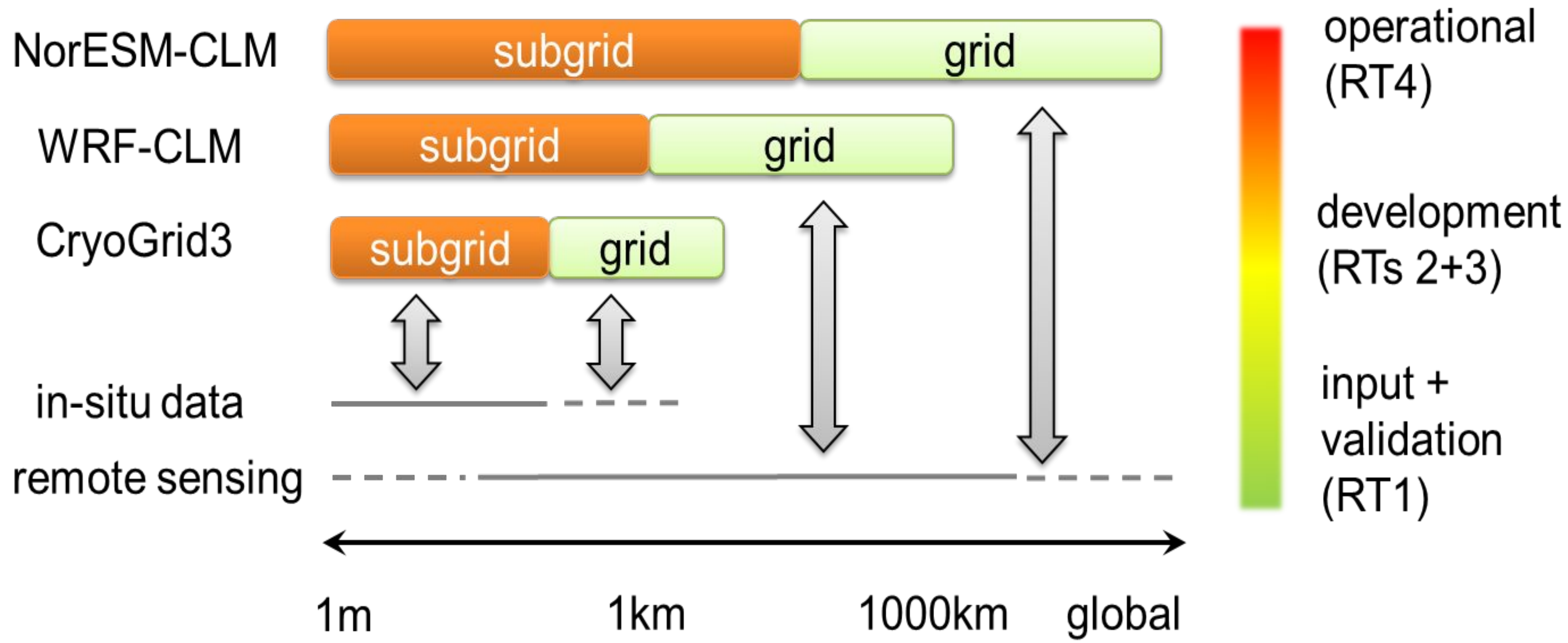
- Model parameterization of permafrost thaw and land surface subsidence
- Can be projected to future climate change scenarios

- Application towards dynamic snow layer and dynamic wetlands modeling



Lee et al. 2014
Westermann et al. 2016

Upscaling permafrost thaw processes in models



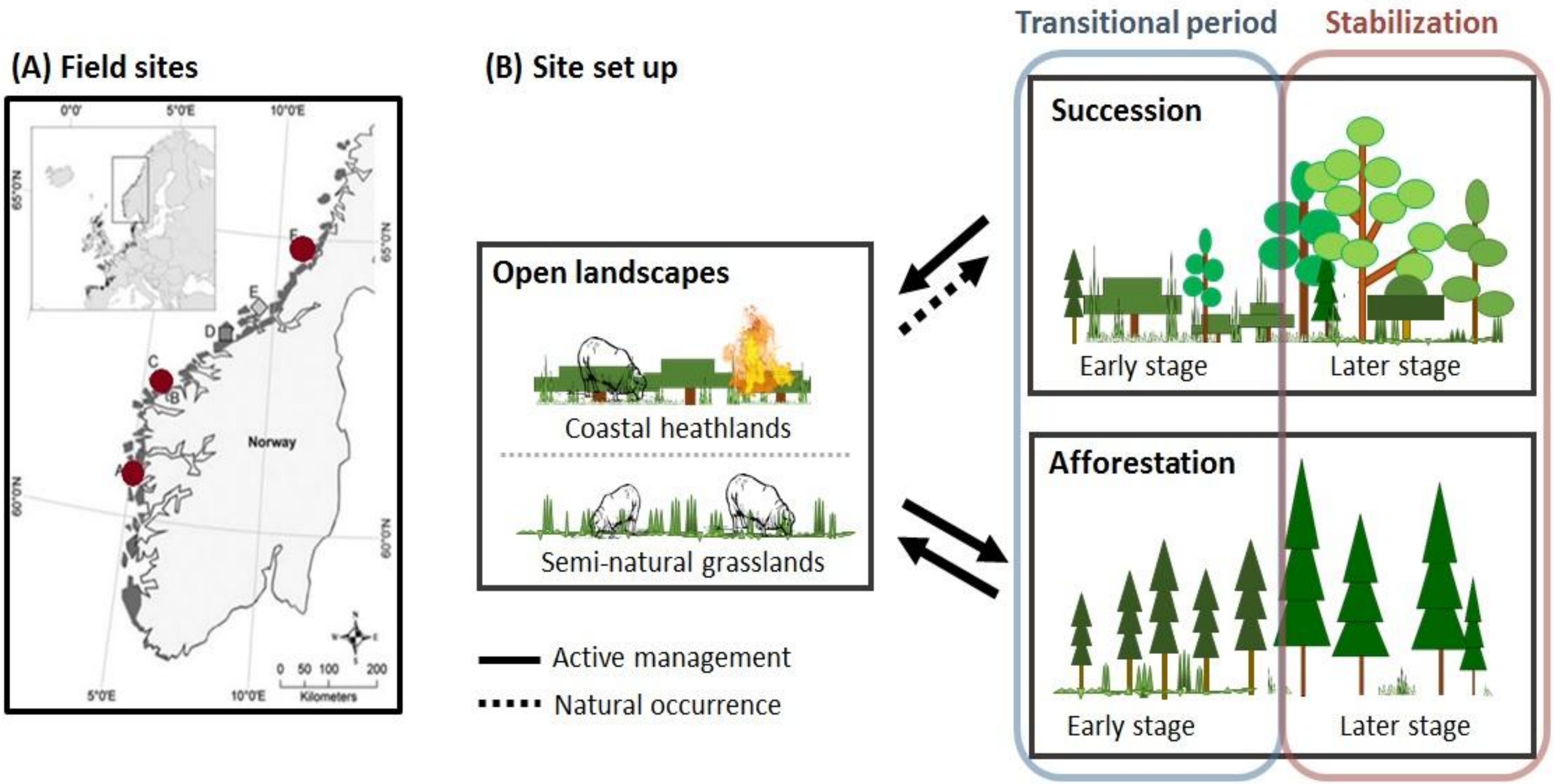
- Upscaling permafrost thaw processes to Earth System Model grid scale using different scale of models
- Focused on process level representation of permafrost

The impacts of afforestation on climate and our lives

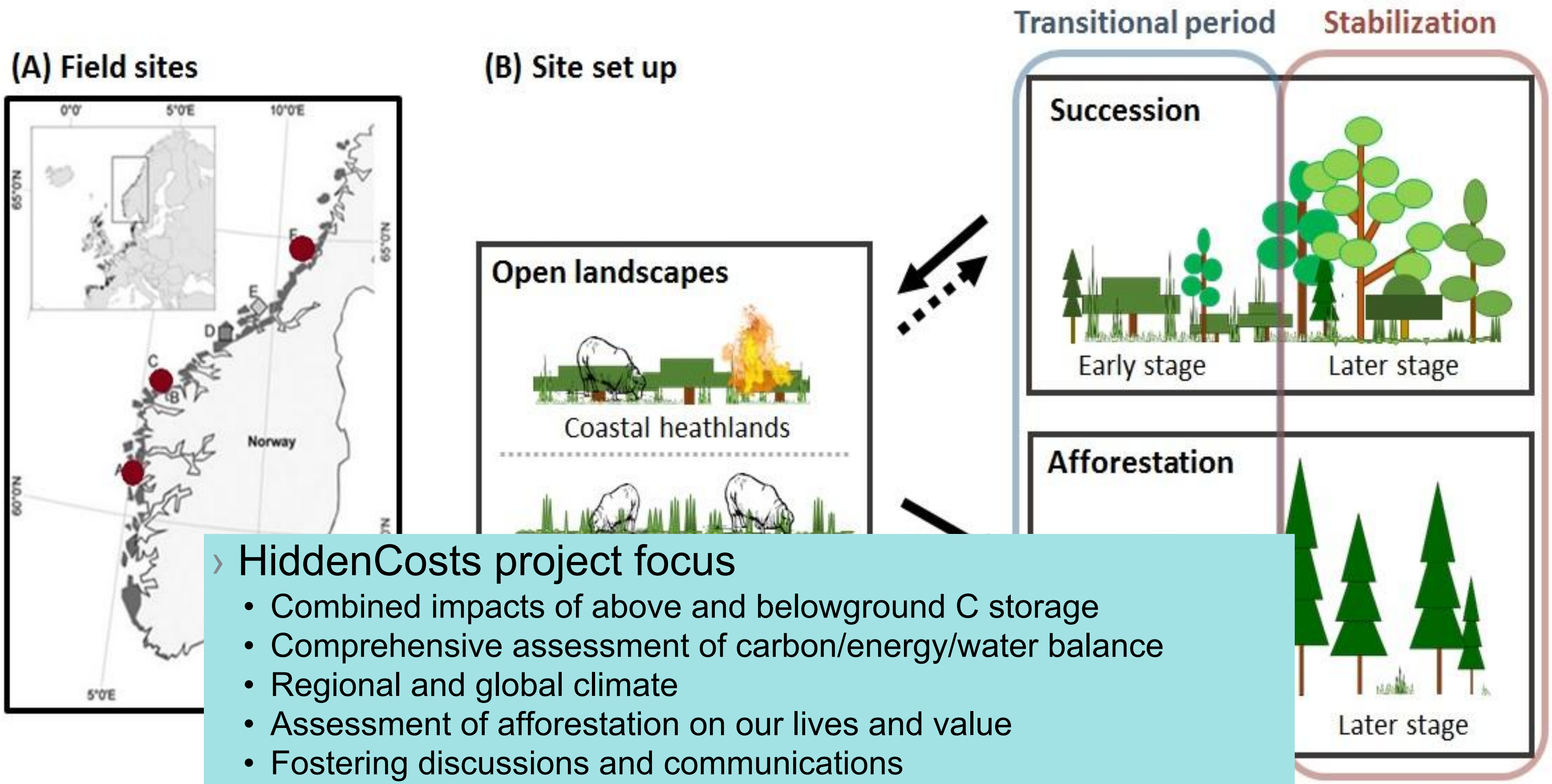
- Hidden costs of implementing afforestation as a climate mitigation strategy: A comprehensive assessment of direct and indirect impacts
  - Funded by the Research Council of Norway
  - 10.9 milNOK
  - 2017-
  - Lead: Uni Klima, Hanna Lee
  - Regional / global impact
  - Biodiversity / ecosystem structure / ecosystem C storage
  - Public valuation / ecosystem services
  - Communications

Climate research to influence decision making

Scenario testing

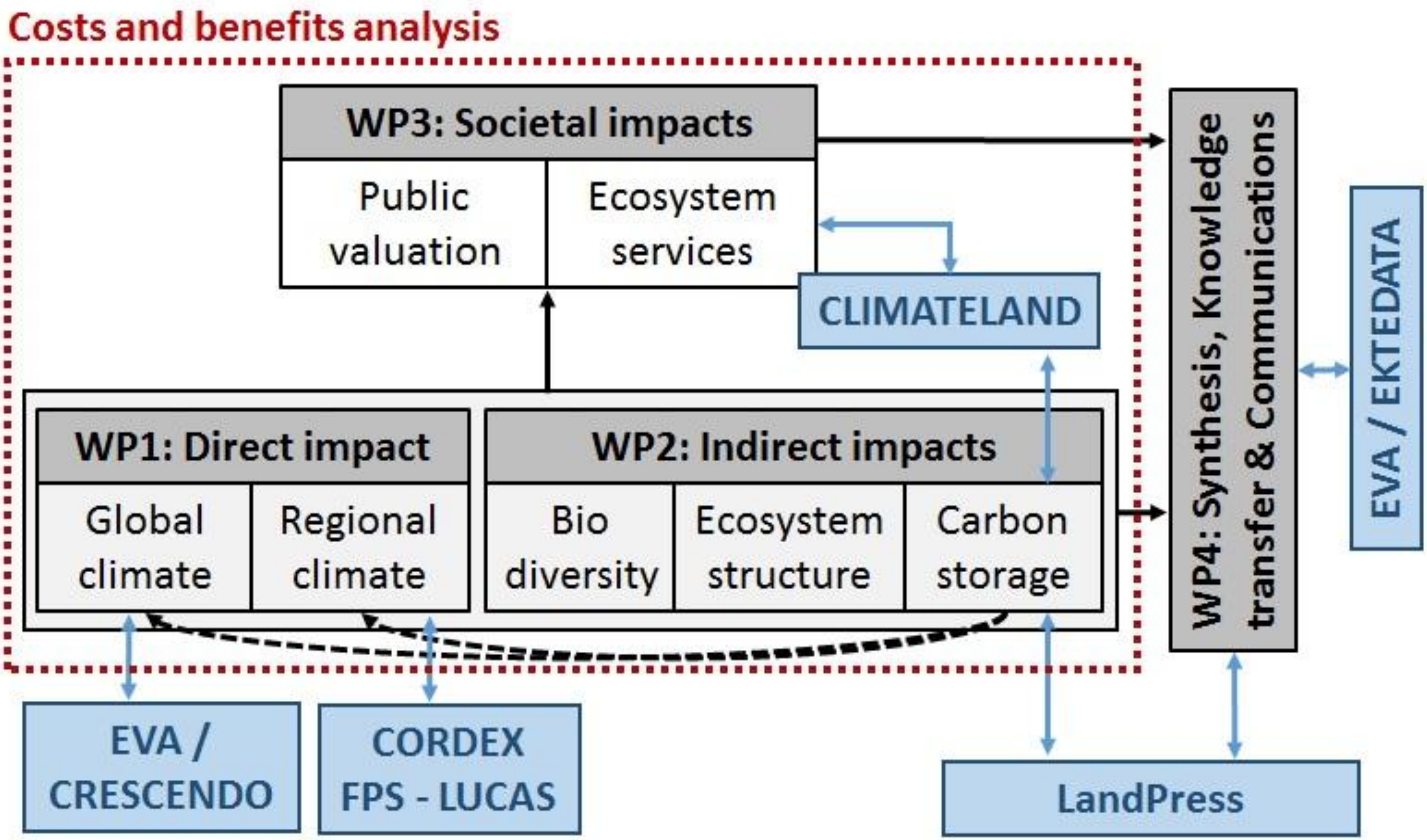


Scenario testing



› HiddenCosts project focus
- Combined impacts of above and belowground C storage
- Comprehensive assessment of carbon/energy/water balance
- Regional and global climate
- Assessment of afforestation on our lives and value
- Fostering discussions and communications

HiddenCosts project organization



Opportunity to collaborate

- Collaborative model development
- Model intercomparison (CRESCENDO project)
- Workshops and exchange
  - Site visits
  - Visiting scholar grant (Bjerknes: 1-2 weeks, RCN: 1-12 months)
  - Workshop organizing grant (RCN: running call up to 10k Euro)