REPRESENTING LAND IN THE CLIMATE SYSTEM

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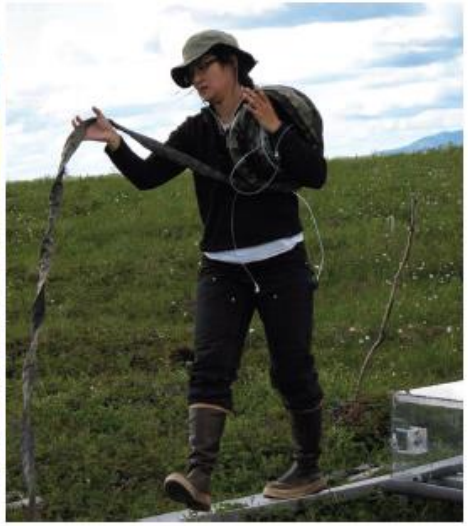
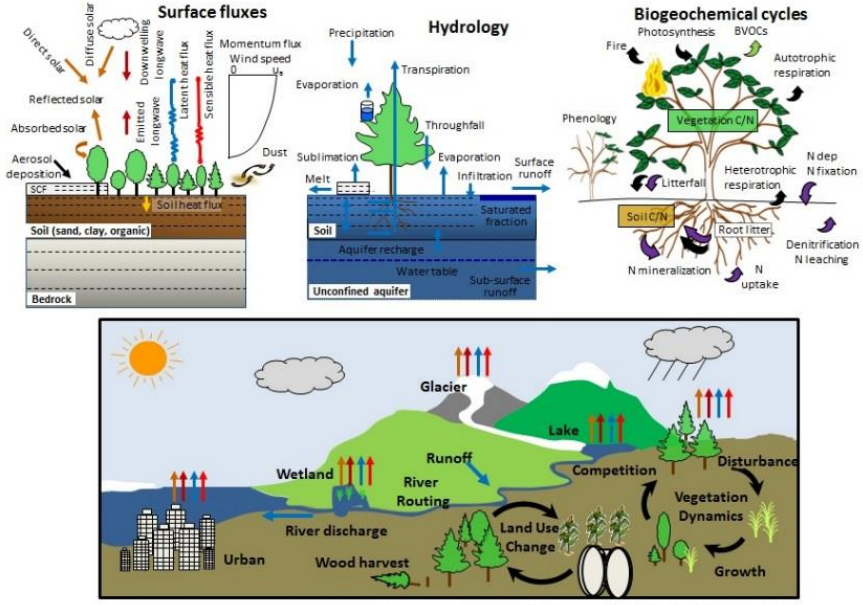
From Ecosystem to Earth System

› Who am I?

- Senior researcher at Uni Research Climate
- Ecosystem Ecologist, Terrestrial Biogeochemist, Earth System Modeler





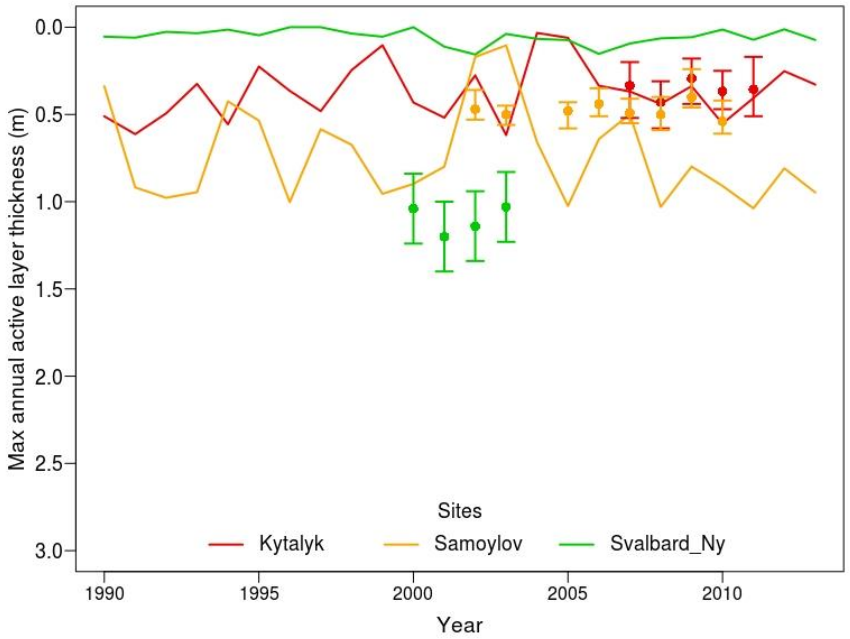
Lawrence et al., Journal Advances Modeling Earth Systems, 2011

Are you a modeler or an observationist?

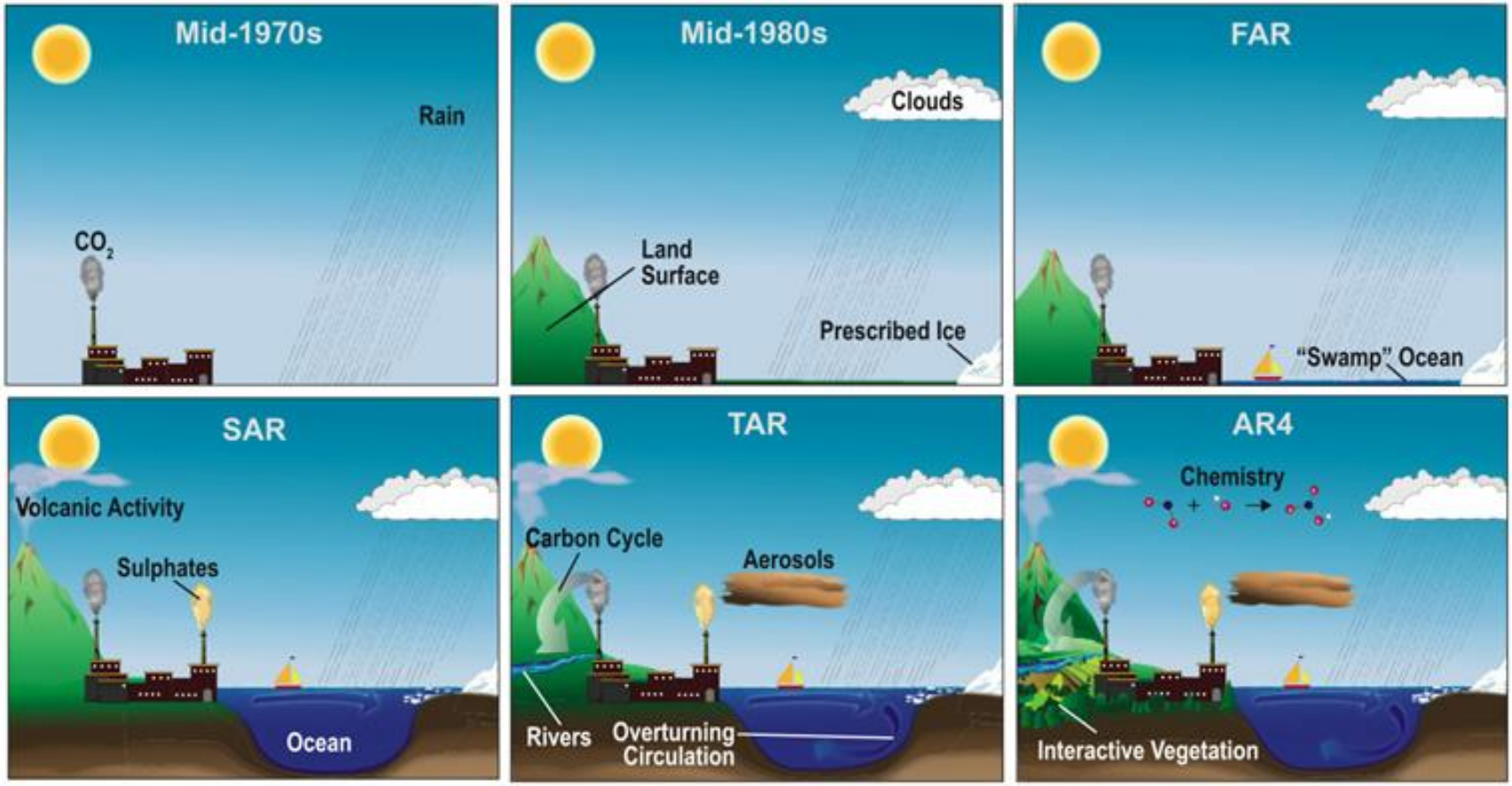
```
            ! from Zhao (1997) and Koren (1999)
            supercool(c,j) = 0.0_r8
            if (lun%itype(l) == istsoil .or. lun%itype(l) == istcrop .or. col%itype(c) == icol_road_perv) then
               if(t_soisno(c,j) < tfrz) then
                  smp = hfus*(tfrz-t_soisno(c,j))/(grav*t_soisno(c,j)) * 1000._r8  !(mm)
                  supercool(c,j) = watsat(c,j)*(smp/sucsat(c,j))**(-1._r8/bsw(c,j))
                  supercool(c,j) = supercool(c,j)*dz(c,j)*1000._r8       ! (mm)
               endif
            endif

            if (h2osoi_liq(c,j) > supercool(c,j) .AND. t_soisno(c,j) < tfrz) then
               imelt(c,j) = 2
               !                tinc(c,j) = t_soisno(c,j) - tfrz
               tinc(c,j) = tfrz - t_soisno(c,j)
               t_soisno(c,j) = tfrz
            endif

            ! If snow exists, but its thickness is less than the critical value (0.01 m)
            if (snl(c)+1 == 1 .AND. h2osno(c) > 0._r8 .AND. j == 1) then
               if (t_soisno(c,j) > tfrz) then
                  imelt(c,j) = 1
                  !                tinc(c,j) = t_soisno(c,j) - tfrz
                  tinc(c,j) = tfrz - t_soisno(c,j)
                  t_soisno(c,j) = tfrz
               endif
            endif

         endif

      end do
   enddo


   do j = -nlevsno+1,nlevgrnd       ! all layers
      do fc = 1,num_nolakec
         c = filter_nolakec(fc)

         if ((col%itype(c) /= icol_sunwall .and. col%itype(c) /= icol_shadewall &
              .and. col%itype(c) /= icol_roof) .or. ( j <= nlevurb)) then

            if (j >= snl(c)+1) then

               ! Calculate the energy surplus and loss for melting and freezing
               if (imelt(c,j) > 0) then
```

From Ecosystem to Earth System

- Interested in the feedback cycles of global climate change and ecosystem carbon cycles
- In situ observations, lab experiments, modeling

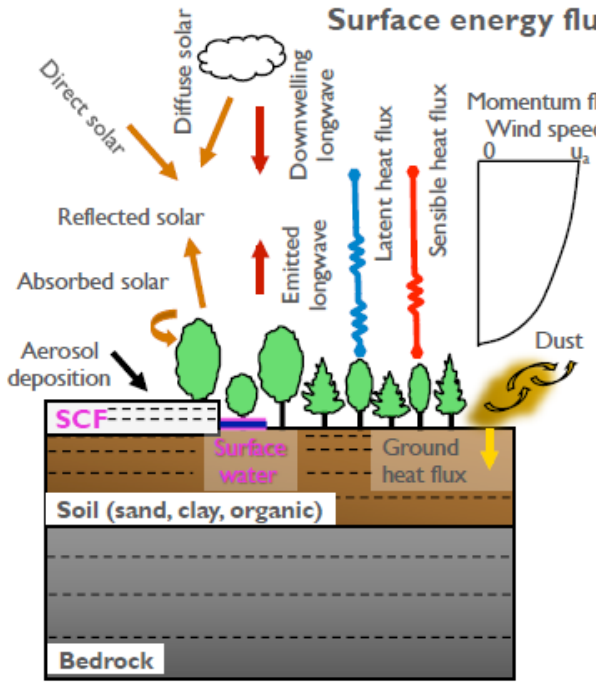


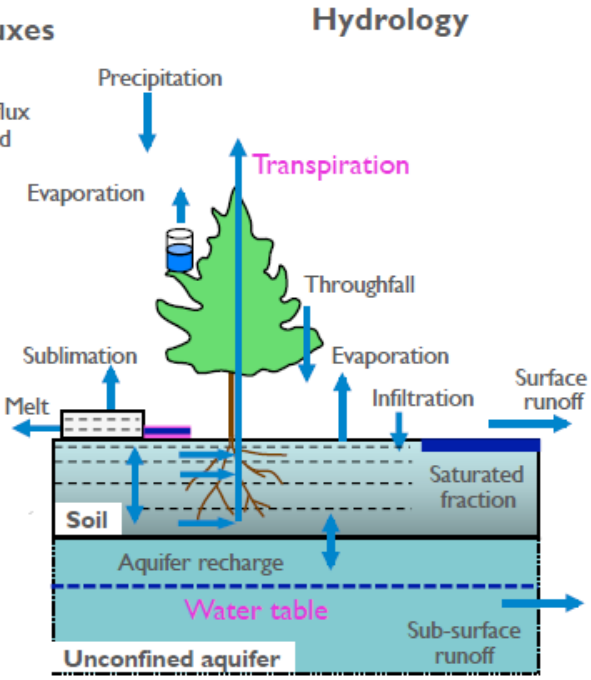
The World in Global Climate Models

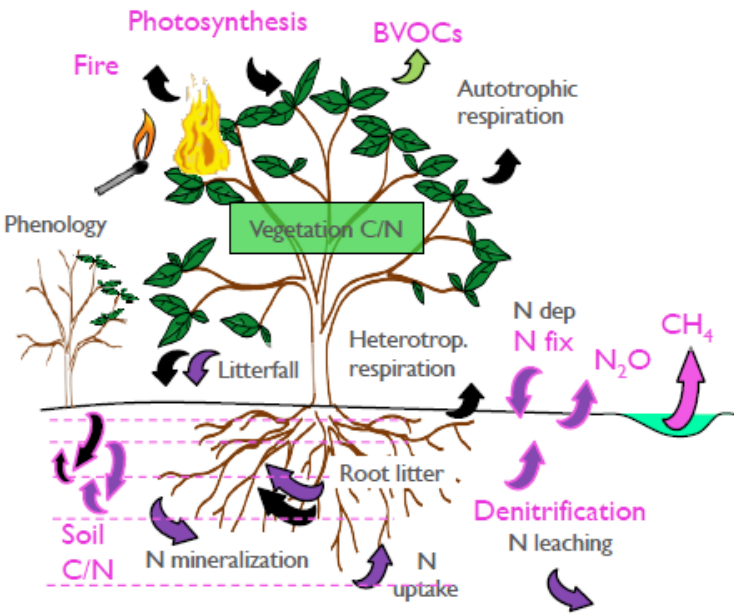


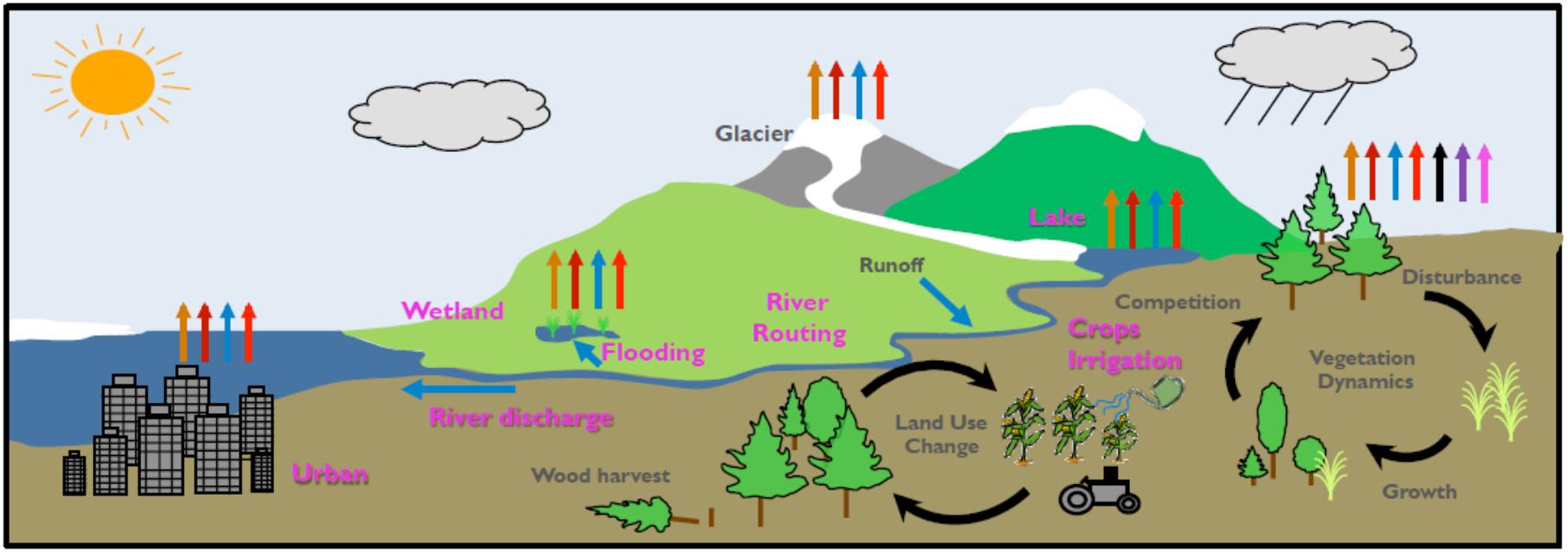
IPCC AR4

CLM4.5


Surface energy fluxes
Direct solar
Diffuse solar
Downwelling longwave
Reflected solar
Absorbed solar
Emitted longwave
Latent heat flux
Sensible heat flux
Momentum flux
Wind speed
0
u_a
Aerosol deposition
Dust
SCF
Surface water
Ground heat flux
Soil (sand, clay, organic)
Bedrock

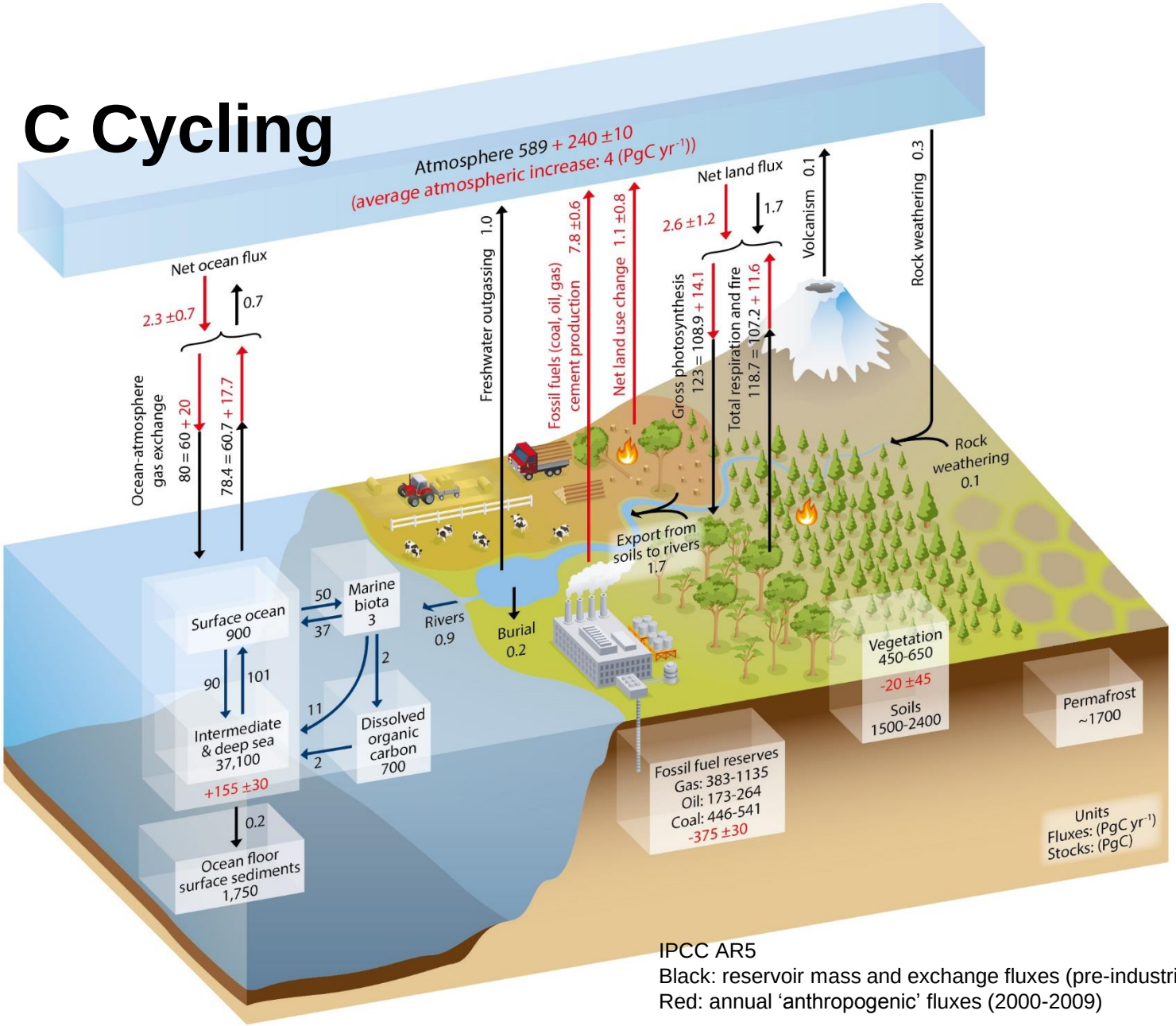

Hydrology
Precipitation
Transpiration
Evaporation
Throughfall
Sublimation
Evaporation
Melt
Infiltration
Surface runoff
Saturated fraction
Soil
Aquifer recharge
Water table
Sub-surface runoff
Unconfined aquifer


Biogeochemical cycles
Photosynthesis
BVOCs
Fire
Autotrophic respiration
Phenology
Vegetation C/N
Litterfall
Heterotrop. respiration
N dep
N fix
N_2O
CH_4
Root litter
Soil C/N
N mineralization
N uptake
Denitrification
N leaching


Glacier
Lake
Runoff
Wetland
River Routing
Flooding
River discharge
Urban
Wood harvest
Land Use Change
Crops
Irrigation
Competition
Disturbance
Vegetation Dynamics
Growth

Bjerknes Centre for Climate Research

Global C Cycling

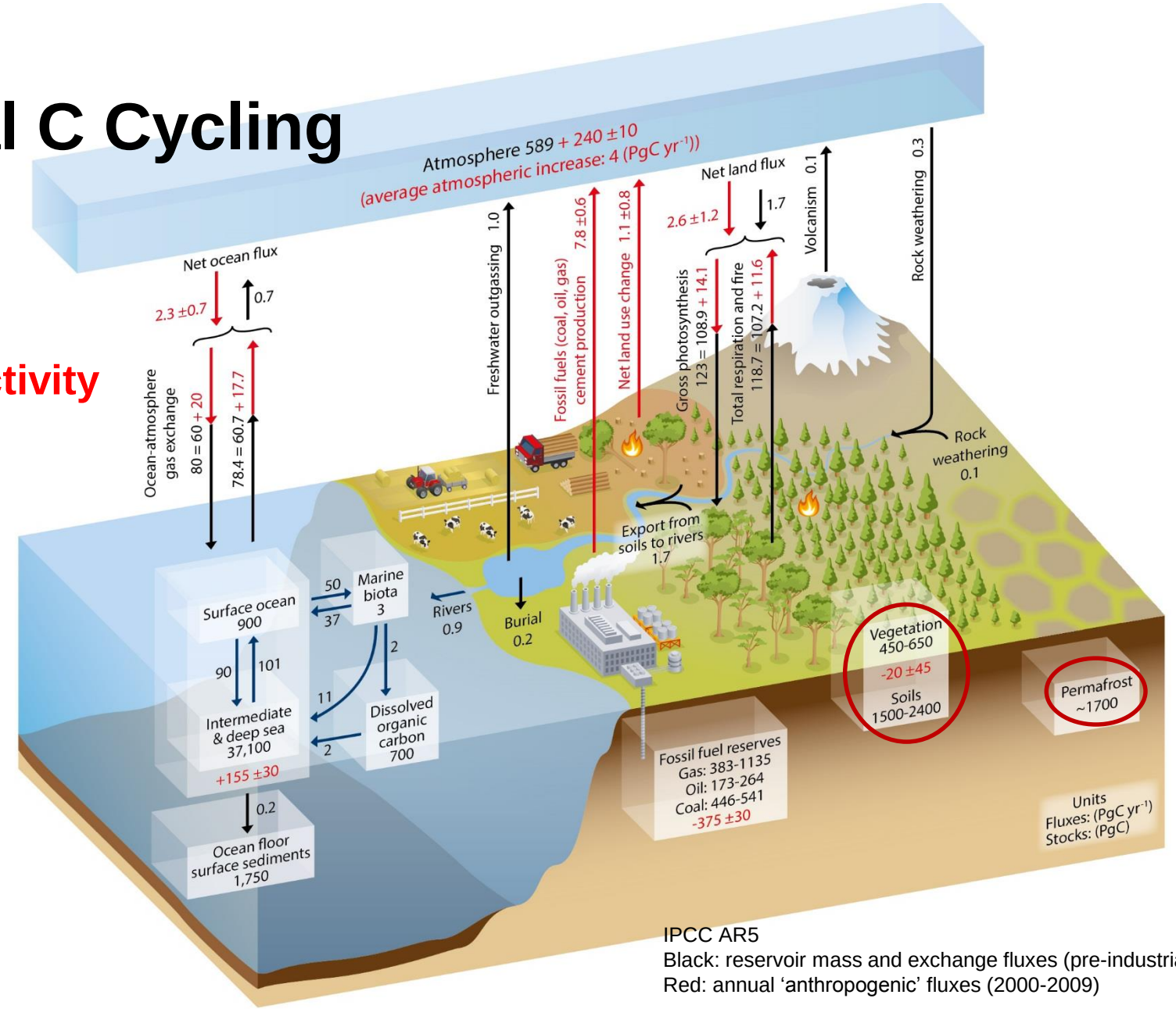


IPCC AR5
Black: reservoir mass and exchange fluxes (pre-industrial)
Red: annual 'anthropogenic' fluxes (2000-2009)

UNIVERSITY OF BERGEN

Global C Cycling

+ Human activity
+ Warming



IPCC AR5
Black: reservoir mass and exchange fluxes (pre-industrial)
Red: annual 'anthropogenic' fluxes (2000-2009)

Permafrost carbon climte feedback

- Over 1600 Pg C storage in permafrost soil
- Large uncertainty in the dynamics of wetlands and CO_2/CH_4 balance

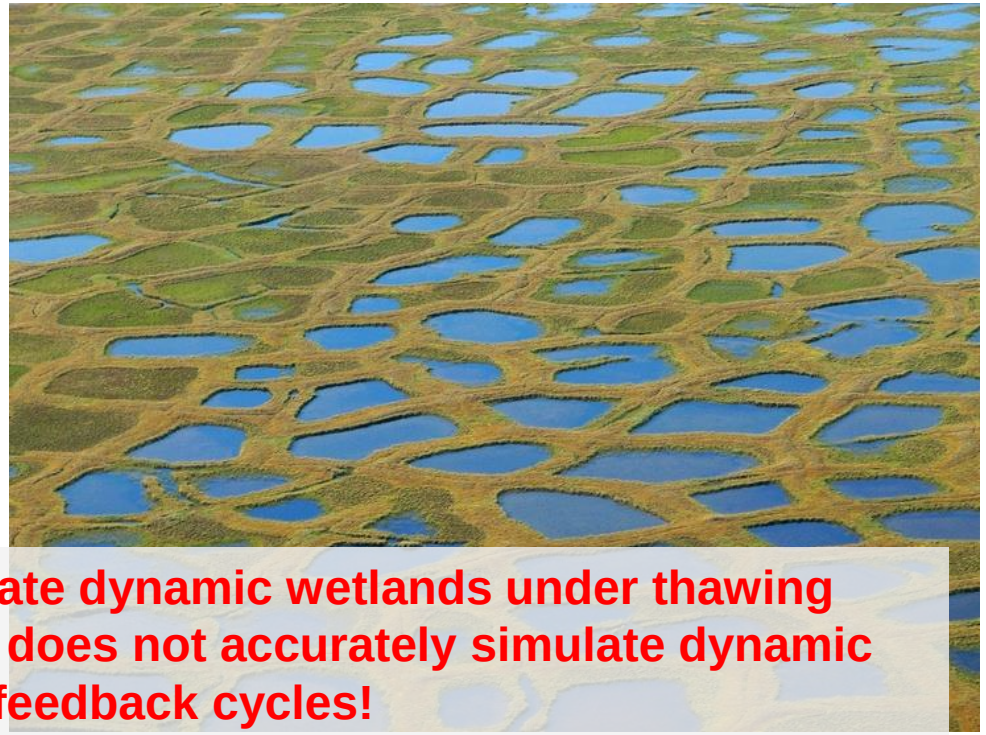
Modeling permafrost carbon climte feedback

- Over 1600 Pg C storage in permafrost soil
- Large uncertainty in the dynamics of wetlands and CO_2/CH_4 balance

It is not 'permafrost' itself that produces CH_4, it is 'wetlands' created from thawing permafrost produces CH_4

Modeling permafrost carbon climte feedback

- Over 1600 Pg C storage in permafrost soil
- Large uncertainty in the dynamics of wetlands and CO_2/CH_4 balance



If the model does not simulate dynamic wetlands under thawing permafrost, than the model does not accurately simulate dynamic permafrost carbon climate feedback cycles!

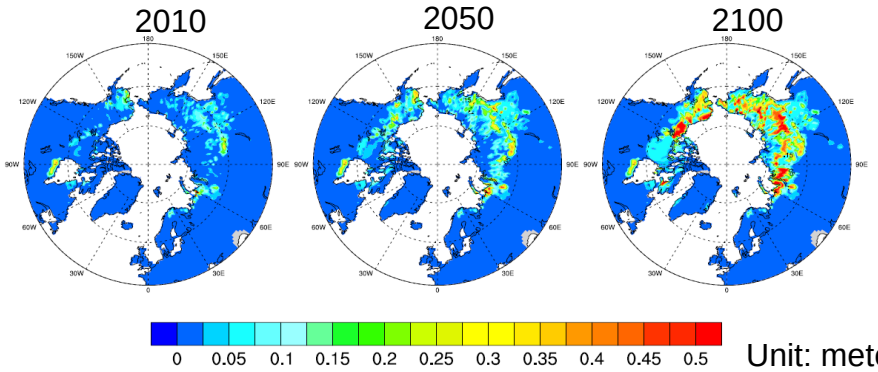
FEEDBACK / PERMANOR projects

- **Two NFR funded projects jointly to Uni Klima & UiO-Geo**

- **PERMANOR:** Permafrost landscapes in transformation – from local-scale processes to the global model NorESM
  - Lead: UiO, Sebastian Westermann
  - Model scaling using observations, small scale, finer scale models to improve NorESM
  - Focused on modeling to improve upscaling of permafrost thaw processes
  - 2016-

- **FEEDBACK:** Advancing permafrost carbon climate feedback - improvements and evaluations of the Norwegian Earth System Model with observations
  - Lead: Uni Klima, Hanna Lee
  - Observation of CO2/CH4 in soil profiles where permafrost is thawing
  - Focused on model evaluation with field observations
  - 2016-

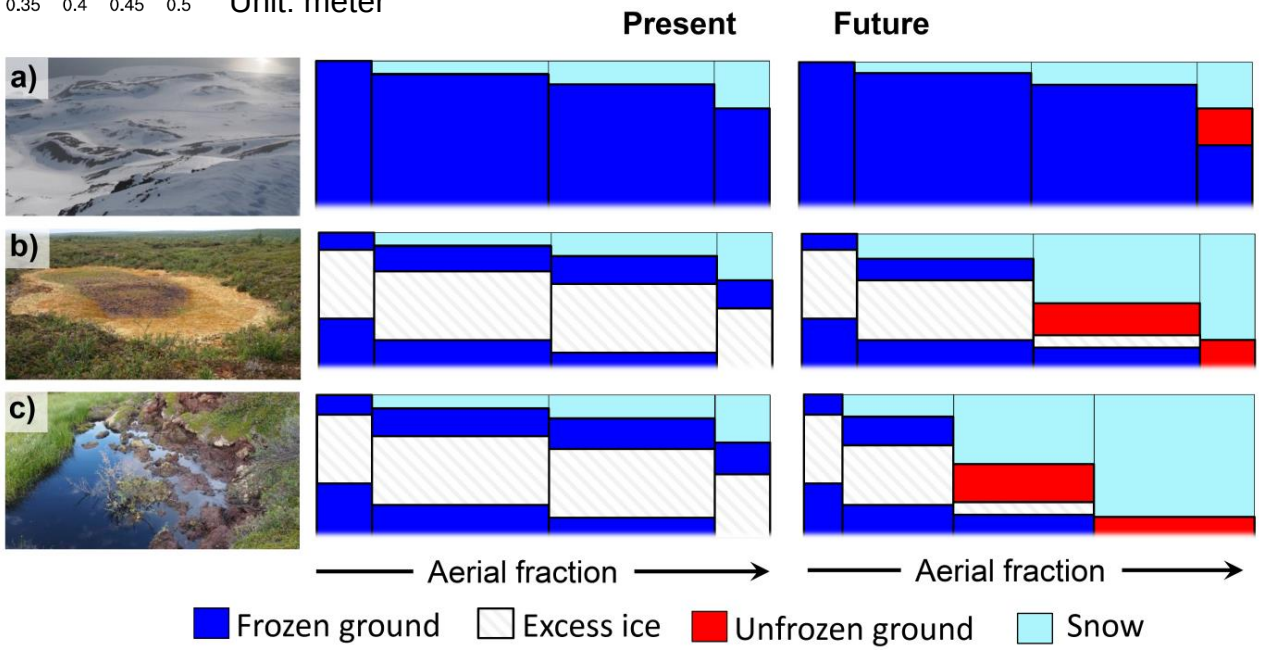
Representing permafrost thaw processes in models



Unit: meter

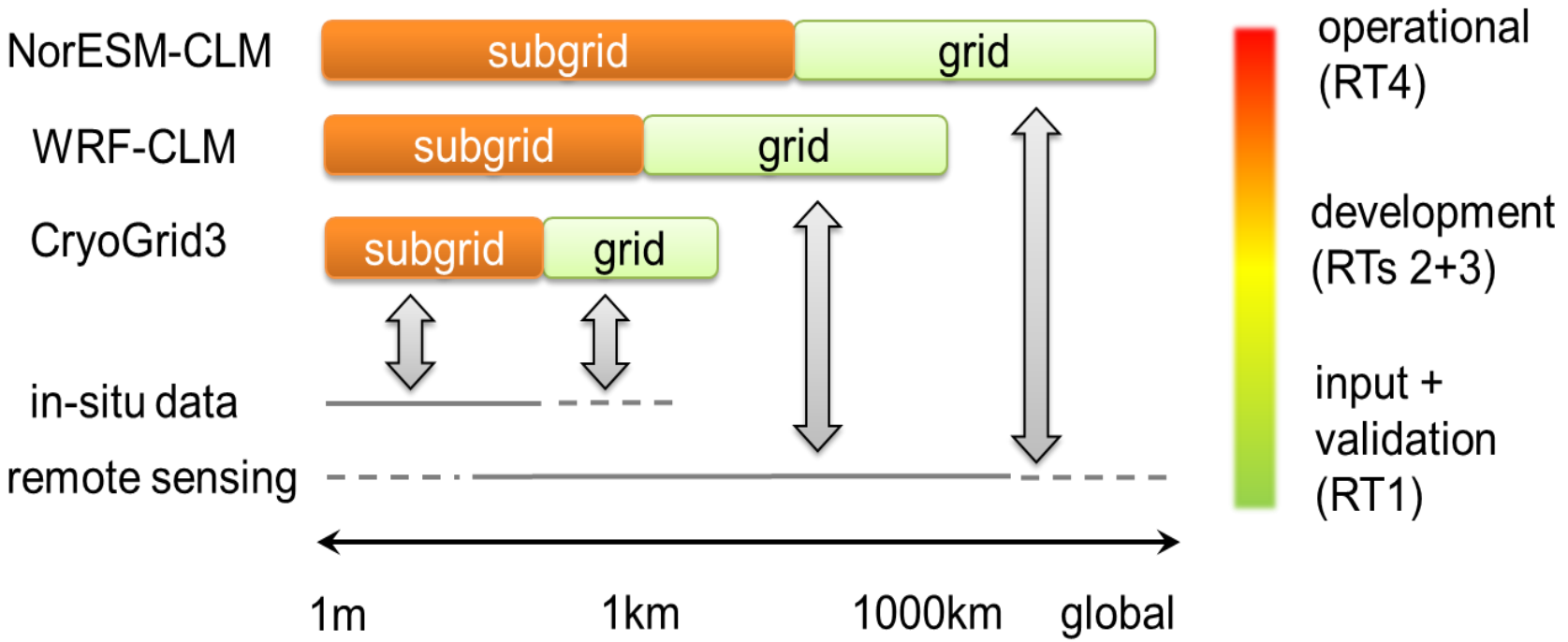
- Model parameterization of permafrost thaw and land surface subsidence
- Can be projected to future climate change scenarios

- Application towards dynamic snow layer and dynamic wetlands modeling



Lee et al. 2014
Westermann et al. 2016

Upscaling permafrost thaw processes in models

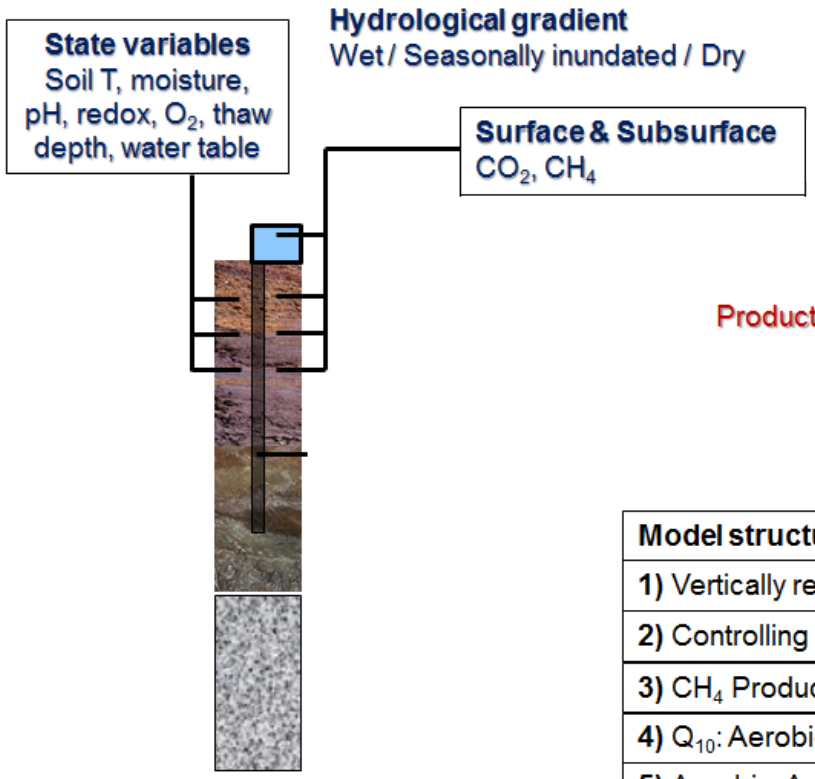


- Upscaling permafrost thaw processes to Earth System Model grid scale using different scale of models
- Focused on process level representation of permafrost

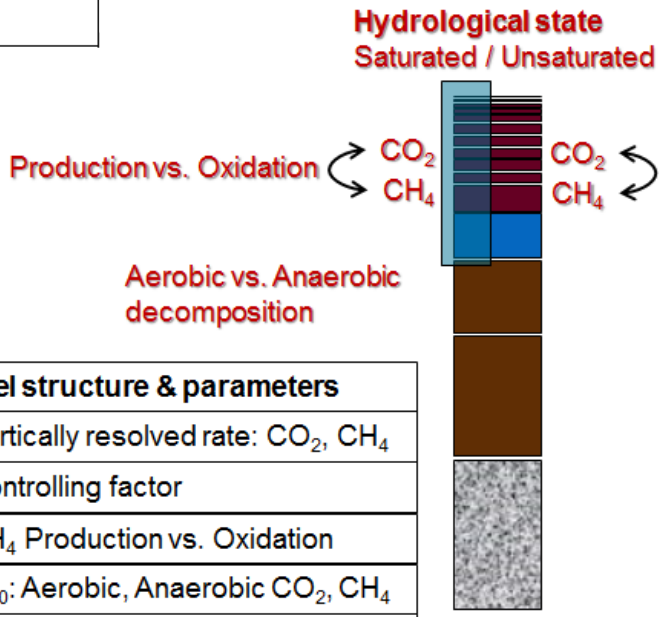
Observations of permafrost carbon release

- Field site selection
  - *Finnmarksvidda, Norway (Iskorasfjellet)*: The plains in the interior of Finnmark, Norway, located in the zone of discontinuous permafrost.
  - Palsa mire with actively thawing permafrost

Using observations to constrain the model



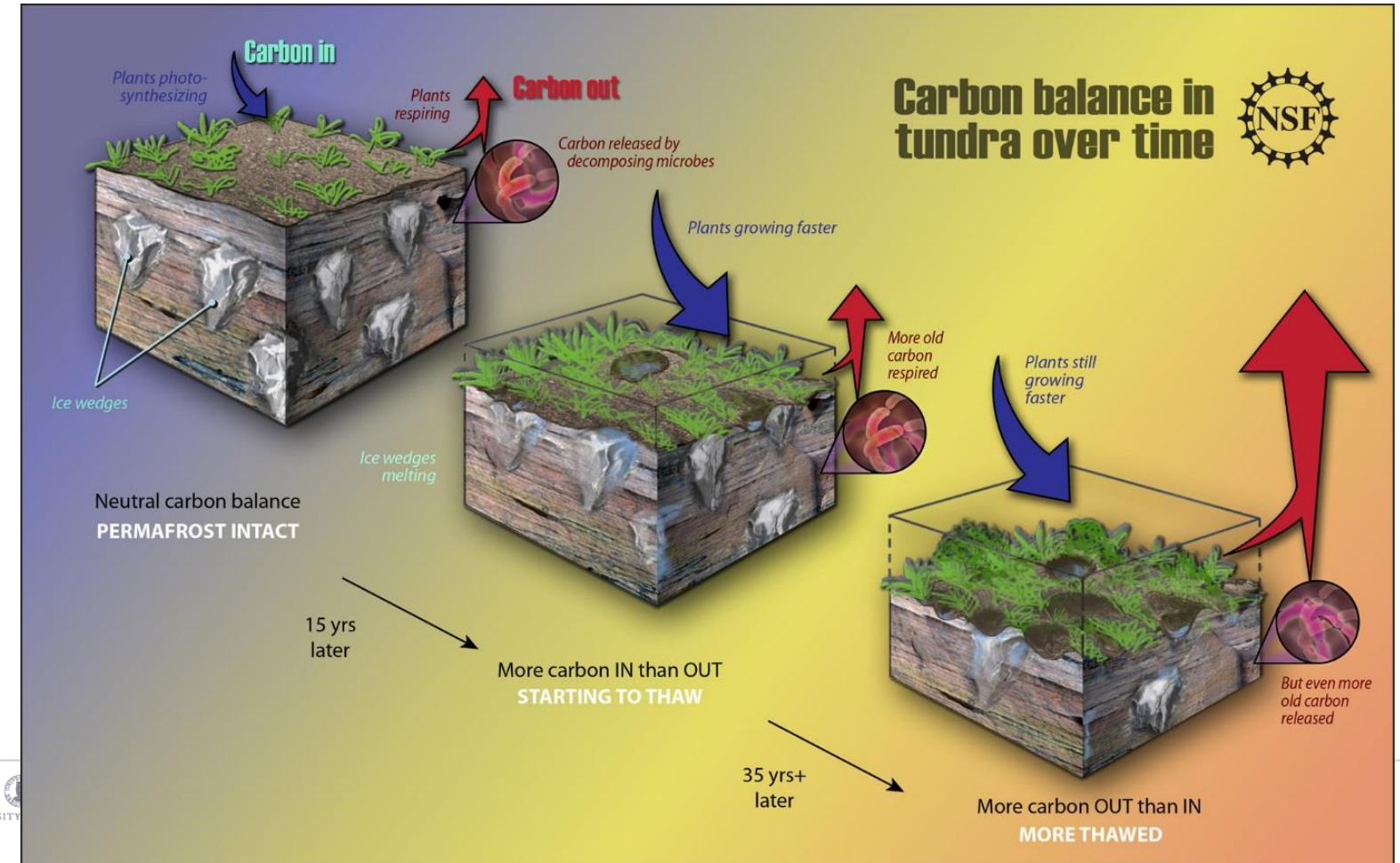
CLM5 model evaluation



Model structure & parameters
1) Vertically resolved rate: CO_2, CH_4
2) Controlling factor
3) CH_4 Production vs. Oxidation
4) Q_{10}: Aerobic, Anaerobic CO_2, CH_4
5) Aerobic, Anaerobic decomposition

Permafrost carbon climate feedback

› The ultimate goal is to understand and simulate permafrost carbon climate feedbacks



Tackling societal challenges

Afforestation is considered 4th viable method in C sequestration

Alf Daniel Moen (t.v.) og Stian Almestad håper skogeiere i Stjørdal melder inn areal til prosjektet med CO2-fangst. **Foto: Jan Erik Sundøy**

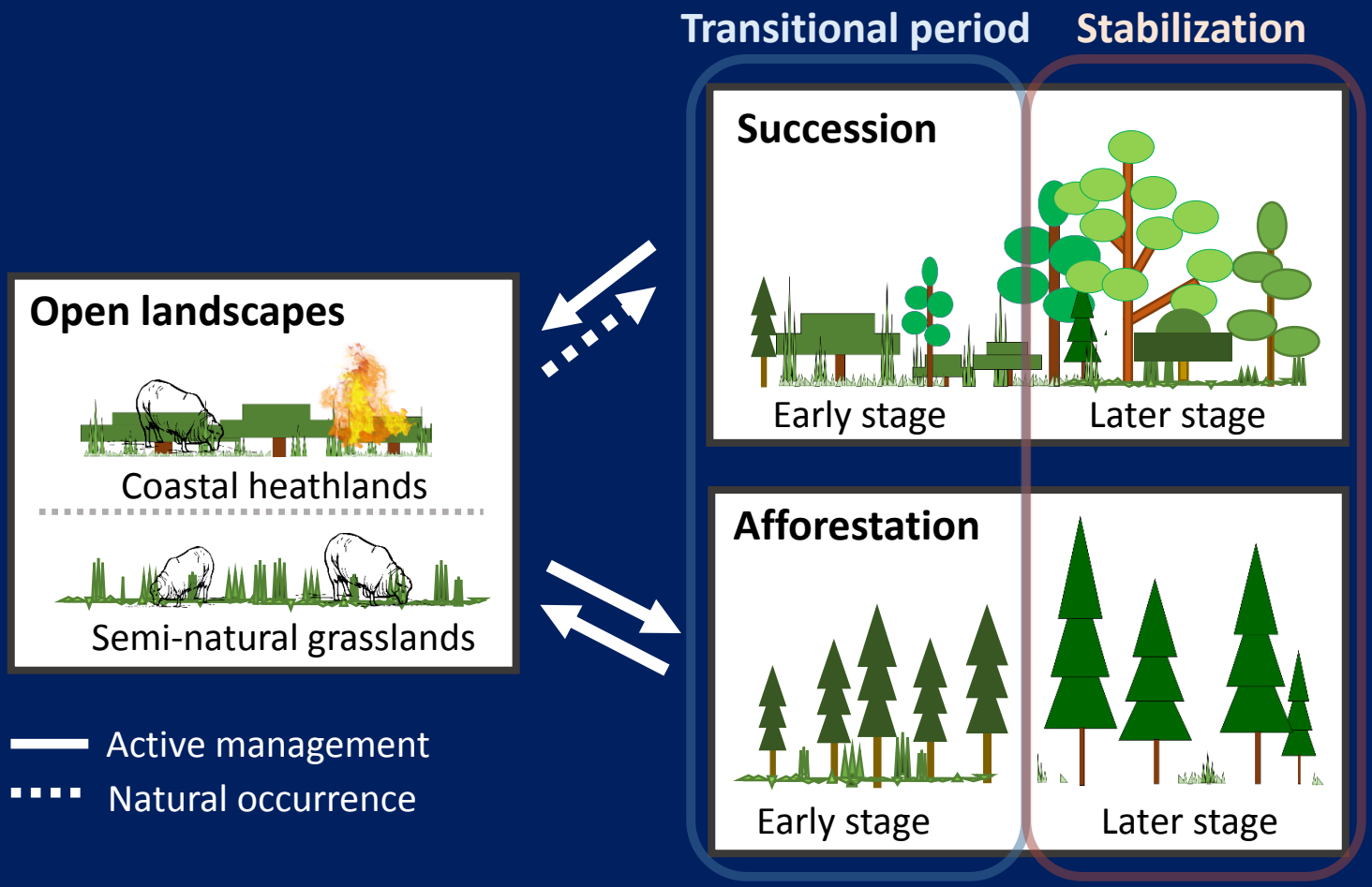
Tilbyr penger til å være med på CO2-fangst

– Har du i dag et uproduktivt areal, igjengrodd, så får du nå gratis hjelp til rydding og skogplanting av arealet.

Afforestation in the high latitudes

- C sequestration is slow
- Soil C storage is neglected
- Cultural landscapes

A more scienific land management scheme and C sequestration



We will evaluate the overall costs and benefits of afforestation in open landscapes by analyzing the direct and indirect impacts of such schemes, thereby gaining overall understandings of **climatic, ecological, and societal impacts of afforestation and the two alternative scenarios, continued management and natural succession**

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
  - 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

Next goal

- Active collaborations
  - Bjerknes Centre
  - LATICE involvement

- Emphasis on education
  - **CHESS funded ‘Land surface modeling course’**
  - Educate and train theories and applications of land-atmospheric interaction and land surface modeling in the framework of the Norwegian Earth System Model
  - Tentative dates: 25-29 September

Thank you

FOR MORE INFORMATION REGARDING COLLABORATIONS, PLEASE CONTACT HANNA LEE (HANNA.LEE@UNI.NO)