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DYNAMICAL VEGETATION - ATMOSPHERE MODELLING AT THE UNIVERSITY OF OSLO: SOME PRELIMINARY RESULTS

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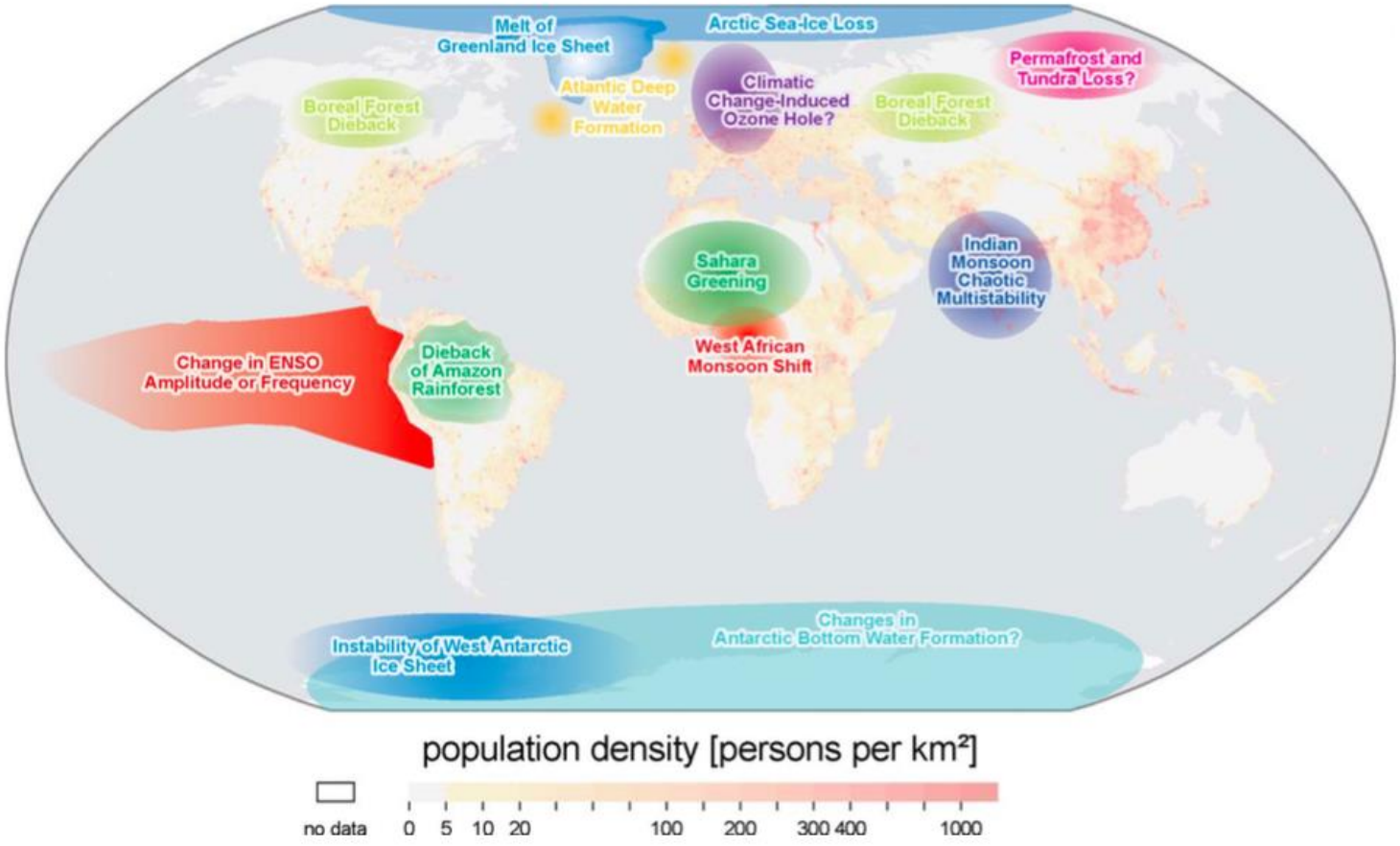
Outlines

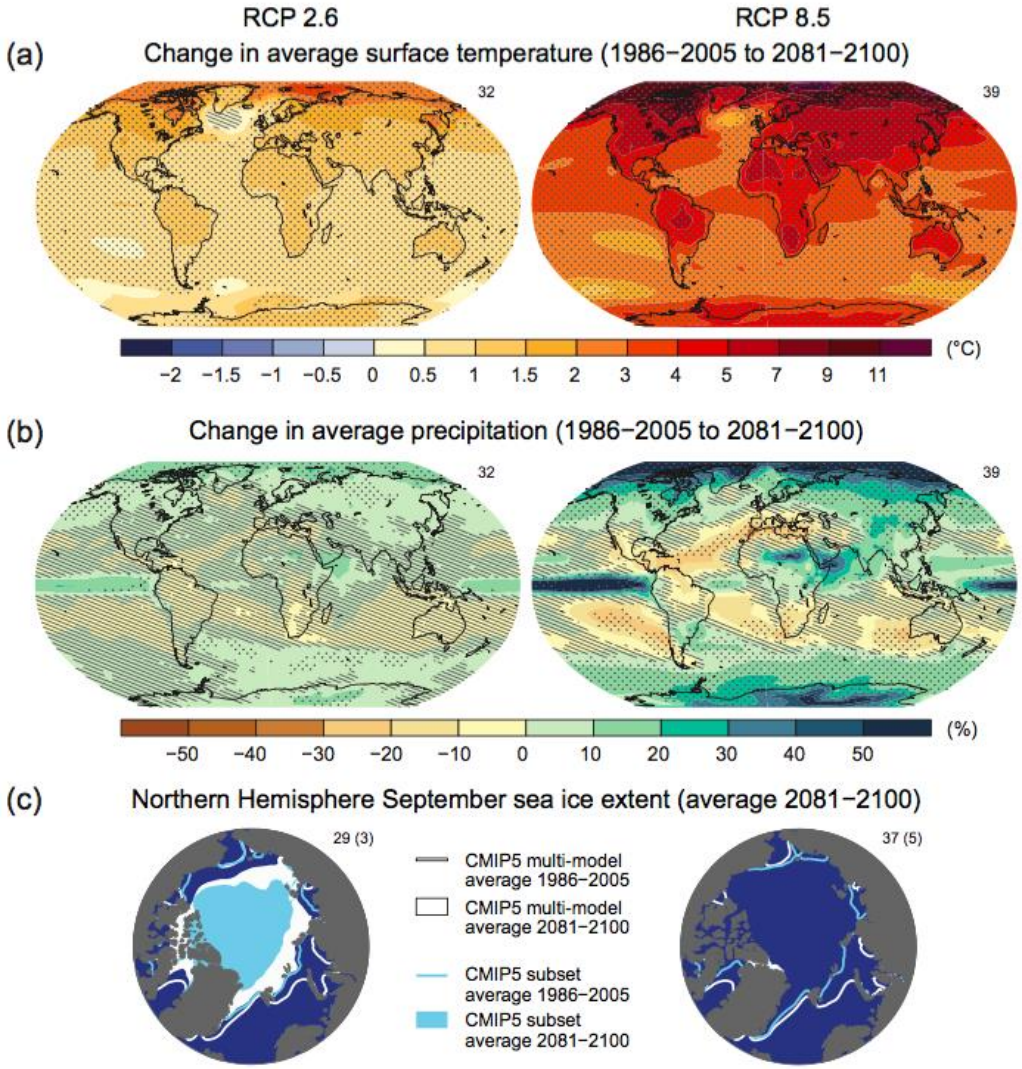
- Research motives
- Dynamic global vegetation model in NorESM: CLM4.5 – BGCDV
- Present-day simulation by NorESM-DynVeg in the Arctic
- Model response to 4xCO2 in NorESM-DynVeg in the Arctic
- Summary and future researches

1. Motive: Arctic vegetation as a tipping element



Lenton et al. 2008

1. Motive: Vegetation feedback NOT in future projections



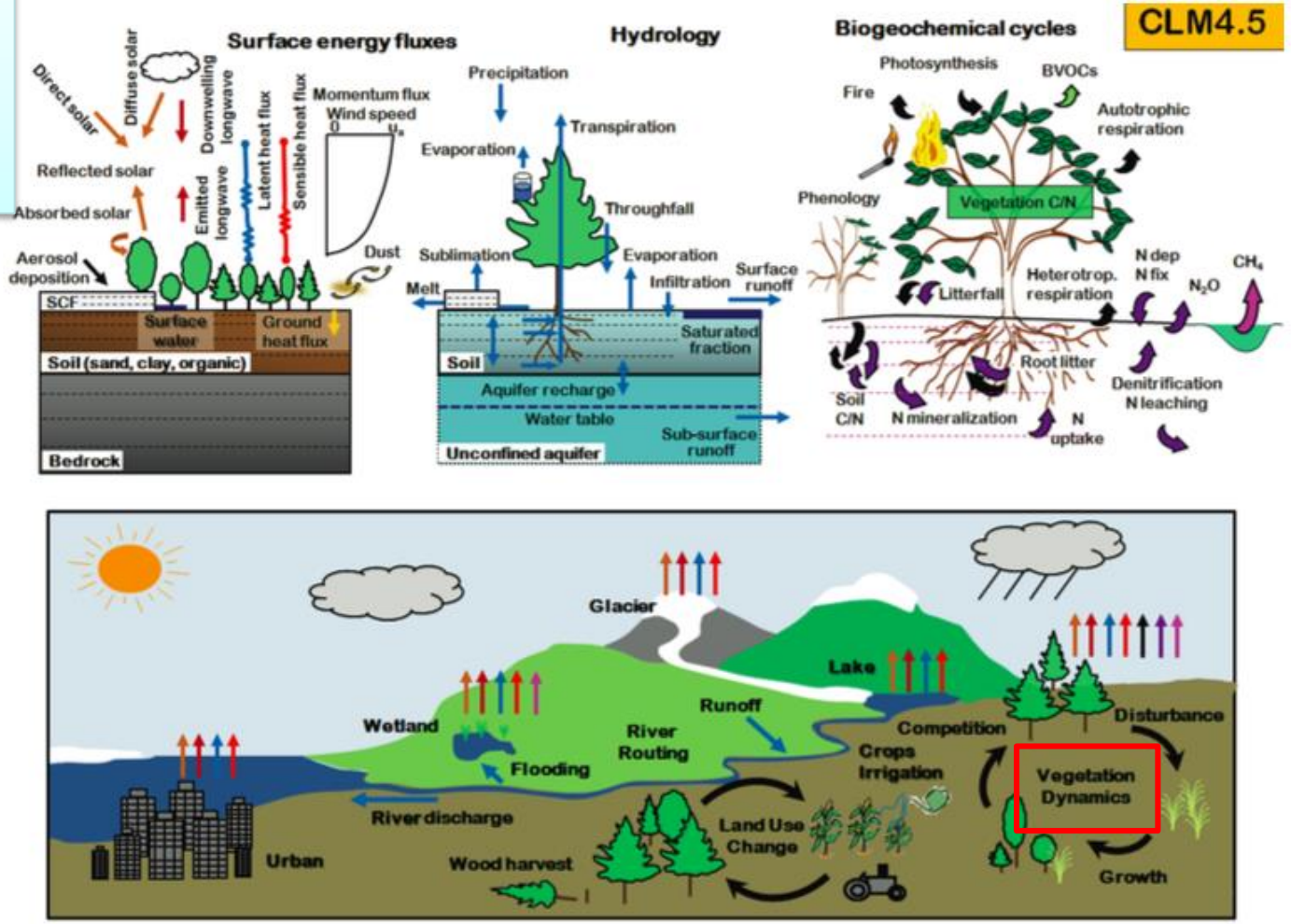
IPCC 2013

1. Motive

- Improve Dynamic Global Vegetation Model (DGVM) to better represent the Arctic vegetation and its response to climate change.
- Improve the coupling of DGVM with climate model to better represent climate-vegetation feedbacks in the Arctic region
- Employ the couple DGVM-climate model to better investigate:
  - Future vegetation changes in the Arctic
  - Biophysical feedback of future vegetation changes in Arctic
    - Polar amplification, snow cover, permafrost
    - Climate extremes
  - Biogeochemical feedback of future vegetation changes
    - Carbon sequestration, Methane emission

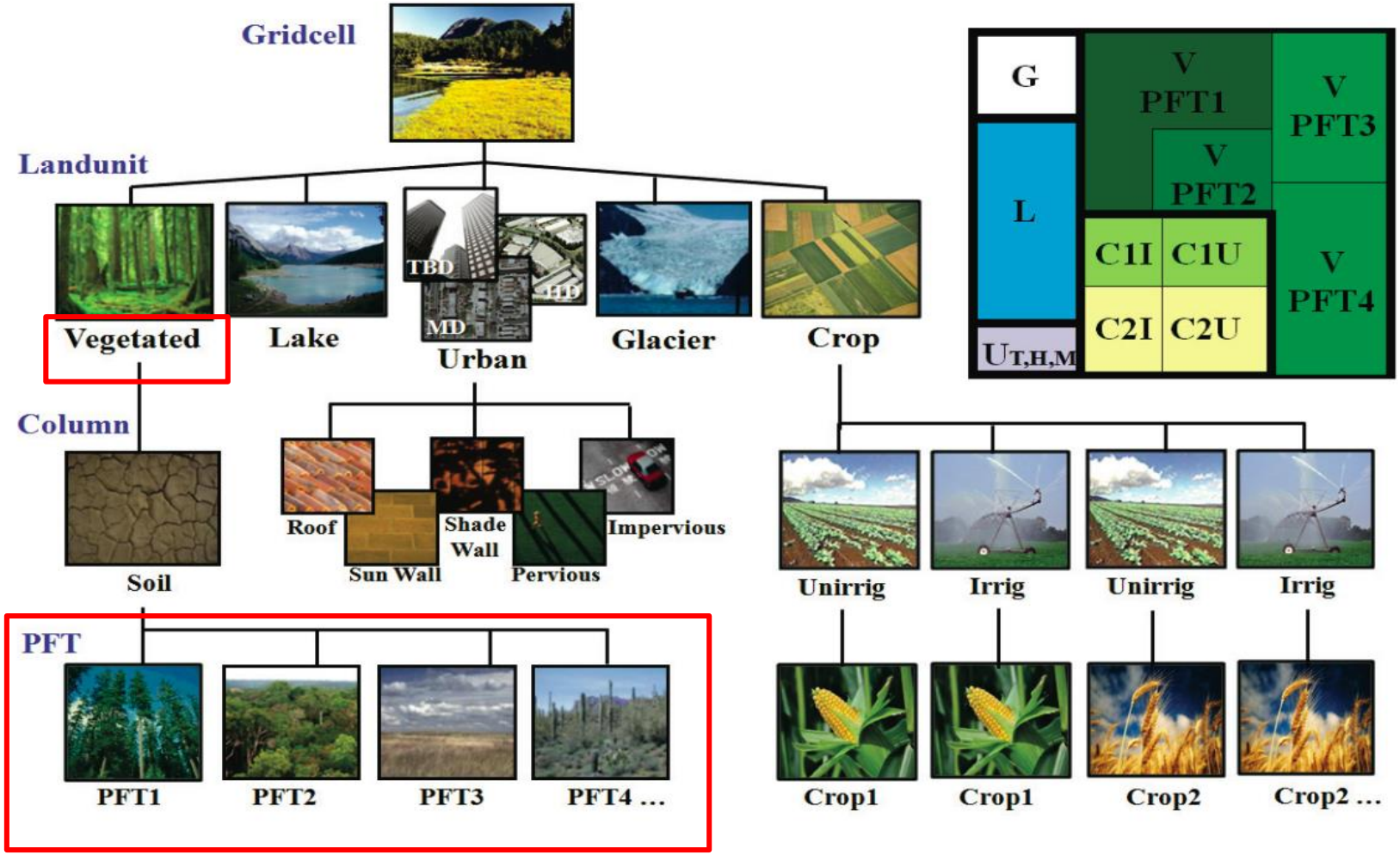
2. DGVM in NorESM: **CLM4.5-BGCDV**

CLM4.5-BGCDV:
- CN cycle
- vegetation dynamics
- vertical soil layer



Oleson et al. 2013

2. CLM4.5-BGCDV: Grid Structure



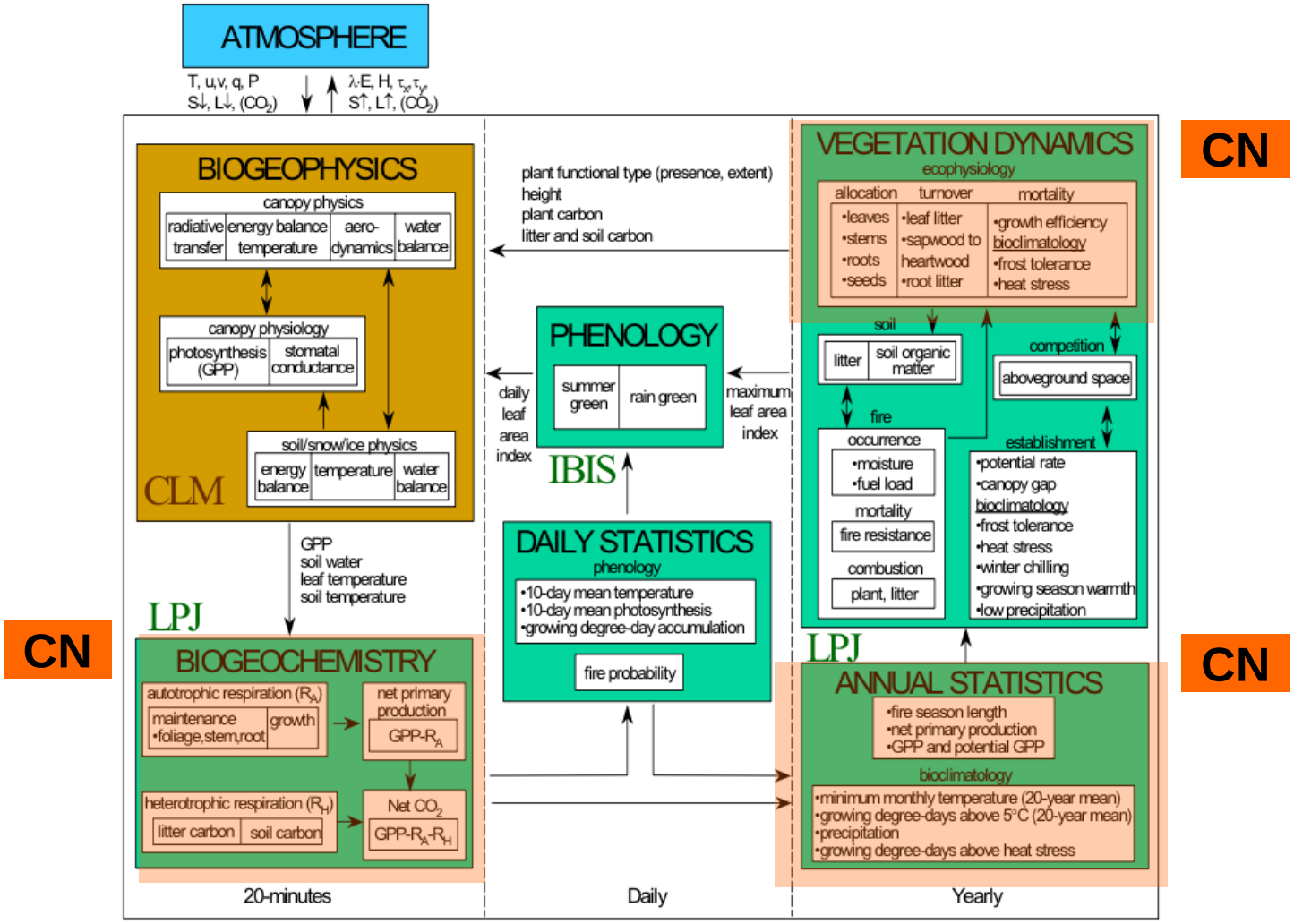
Oleson et al. 2013

2. CLM4.5-BGCDV: **PFTs**

PFT and PFT number corresponding to the list of PFTs in Table 2.1		Survival $T_{c,min}$ (°C)	Establishment $T_{c,max}$ (°C)	Establishment GDD_{min}
Tropical broadleaf evergreen tree (BET)	(4)	15.5	No limit	0
Tropical broadleaf deciduous tree (BDT)	(6)	15.5	No limit	0
Temperate needleleaf evergreen tree (NET)	(1)	-2.0	22.0	900
Temperate broadleaf evergreen tree (BET)	(5)	3.0	18.8	1200
Temperate broadleaf deciduous tree (BDT)	(7)	-17.0	15.5	1200
Boreal needleleaf evergreen tree (NET)	(2)	-32.5	-2.0	600
Boreal deciduous tree	(8)	No limit	-2.0	350
Temperate broadleaf deciduous shrub (BDS)	(10)	-17.0	No limit	1200
Boreal broadleaf deciduous shrub (BDS)	(11)	No limit	-2.0	350
C_4	(14)	15.5	No limit	0
C_3	(13)	-17.0	15.5	0
C_3 arctic	(12)	No limit	-17.0	0

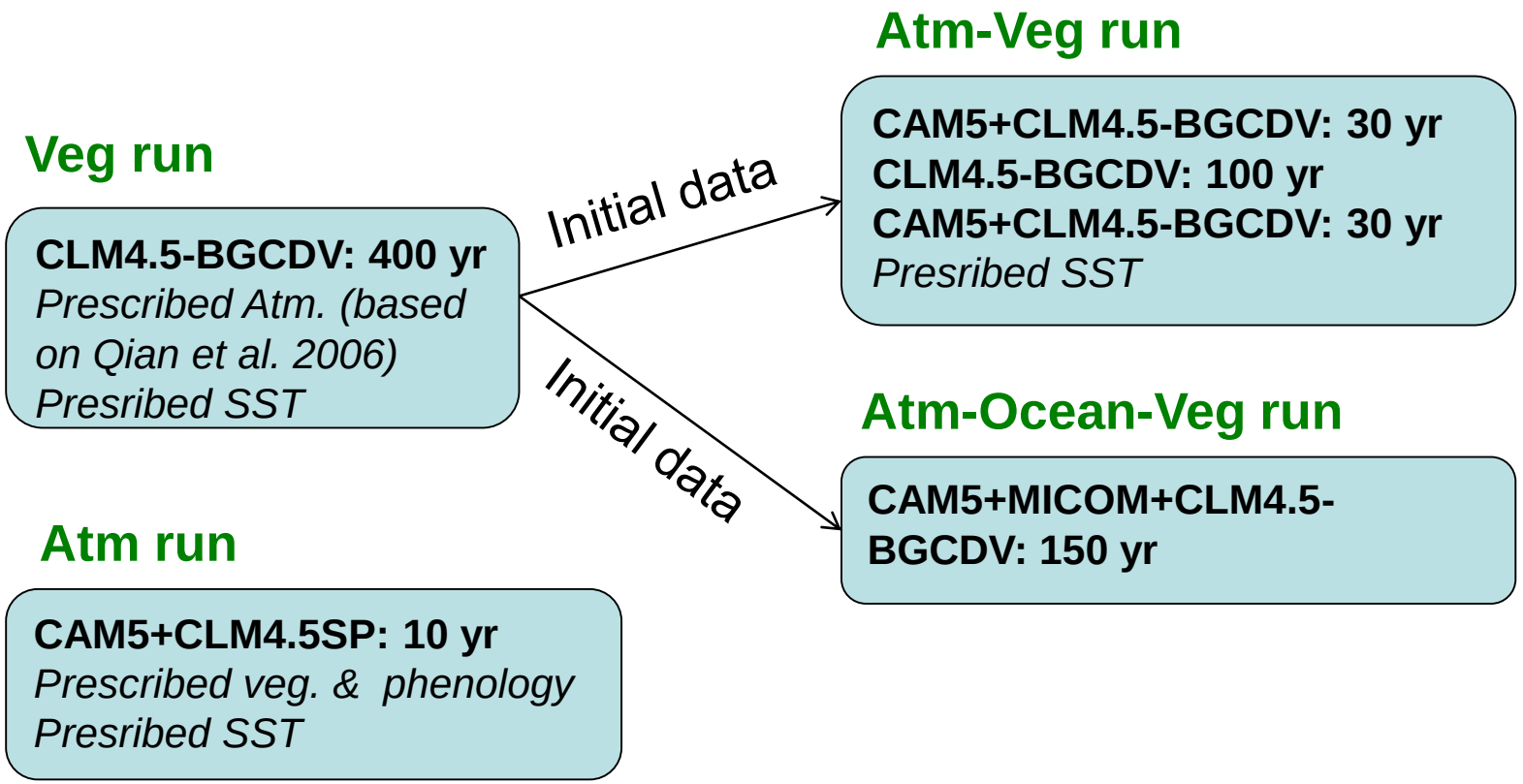
Oleson et al. 2013

2. CLM4.5-BGCDV: vegetation dynamics



Oleson et al. 2013

3. Present-day Simulation: **Experiments**



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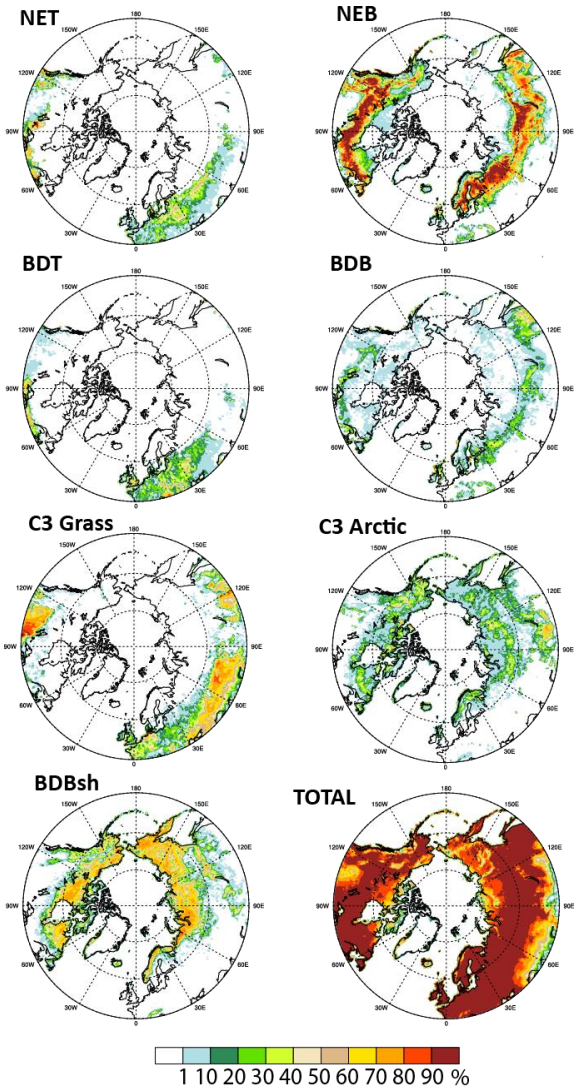
3. Results: Plant cover fraction (%)

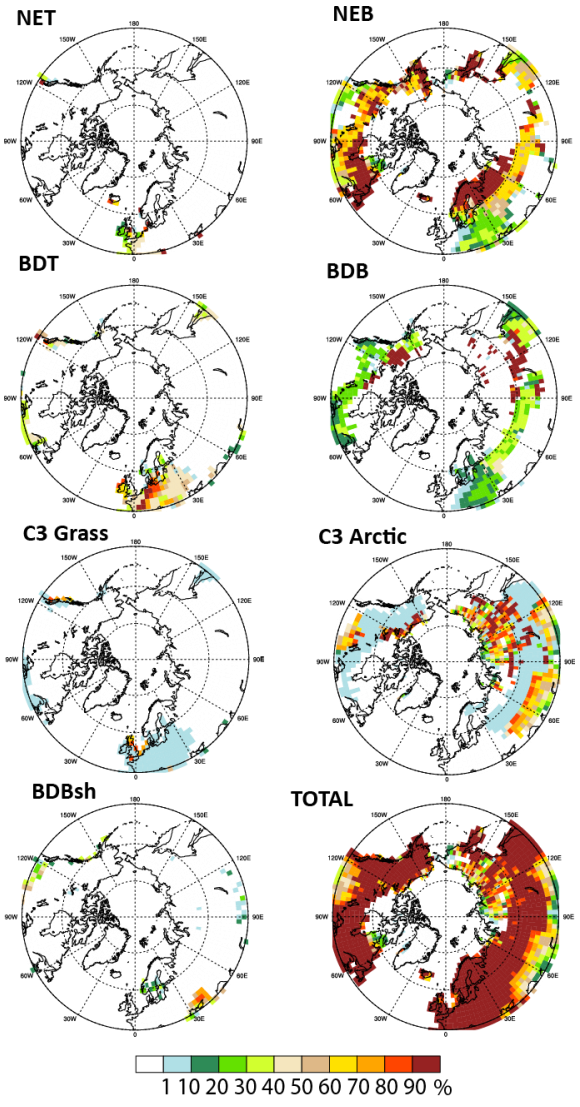
Observation

N: Neadleleaf
B: Broadleaf

E: Evergreen
D: Deciduous

T: Temperate
B: Boreal





Veg run

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3. Results: Plant cover fraction (%)

Observation

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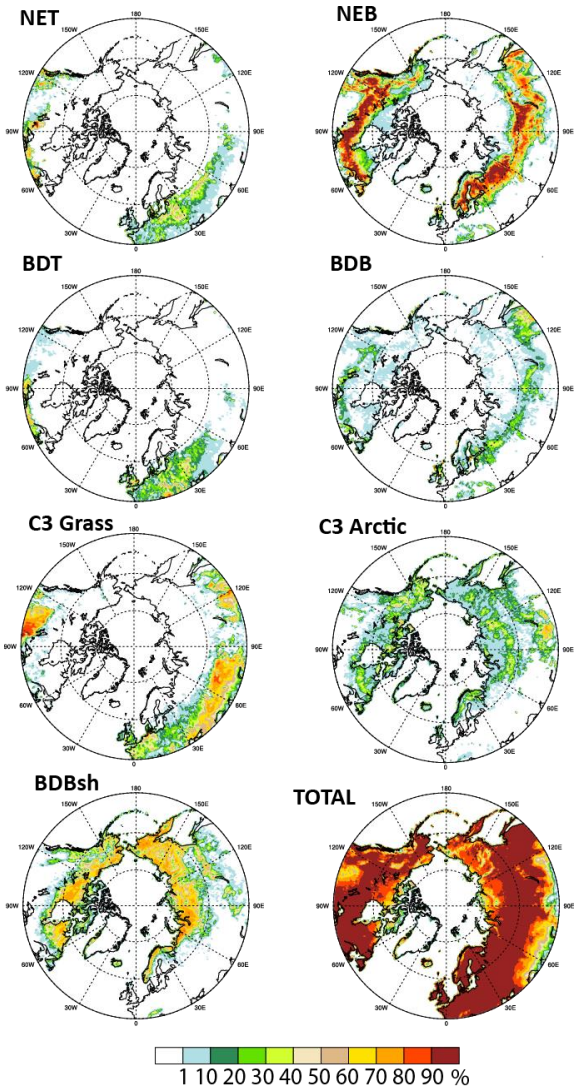
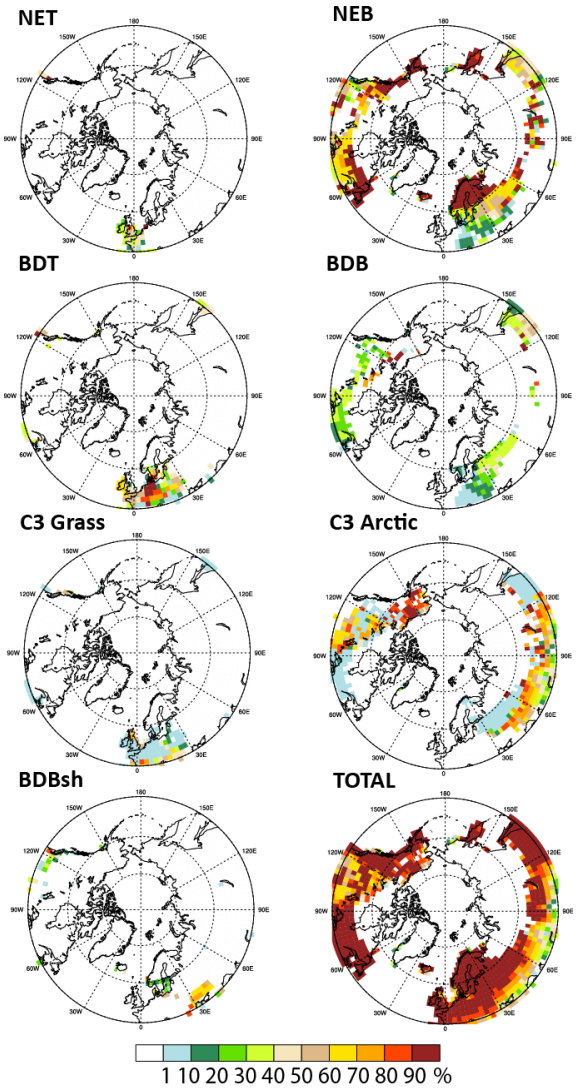
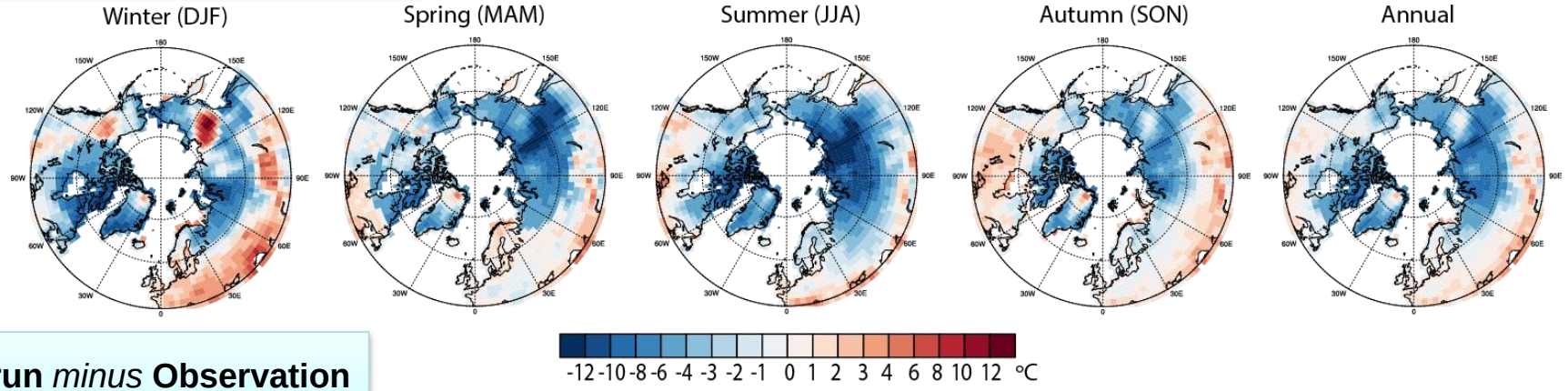




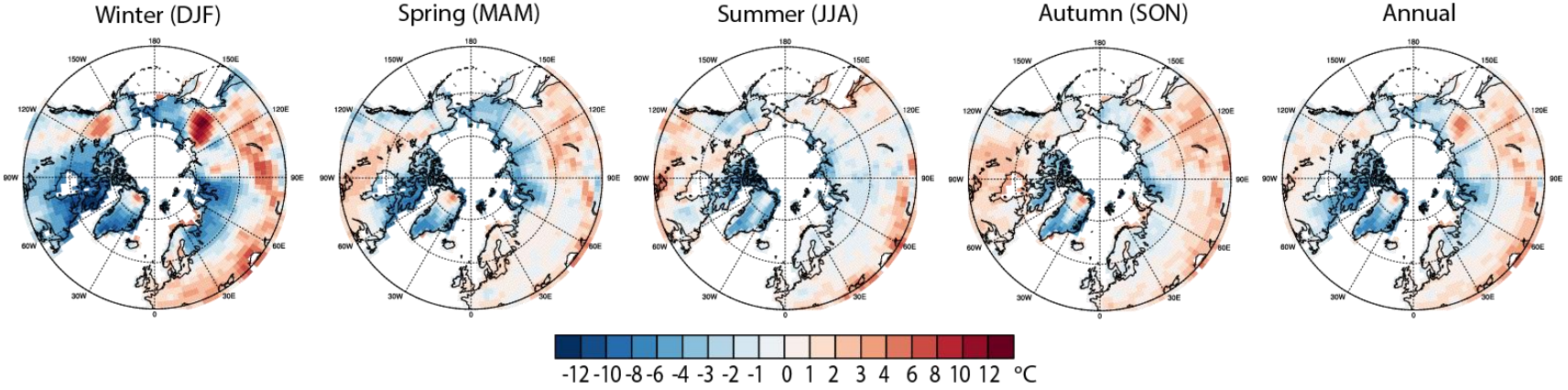
Atm-Veg run

3. Results: Temperature biases

Atm-Veg run *minus* Observation

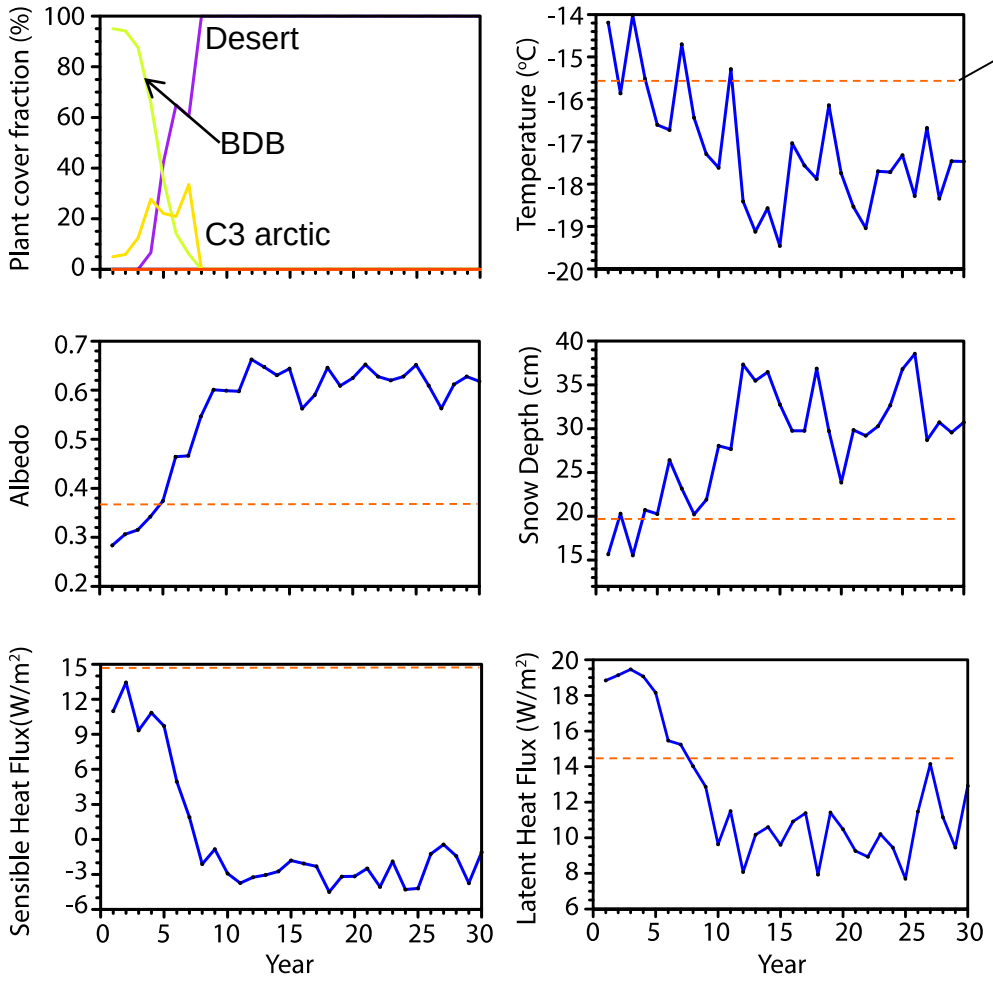


Atm run *minus* Observation



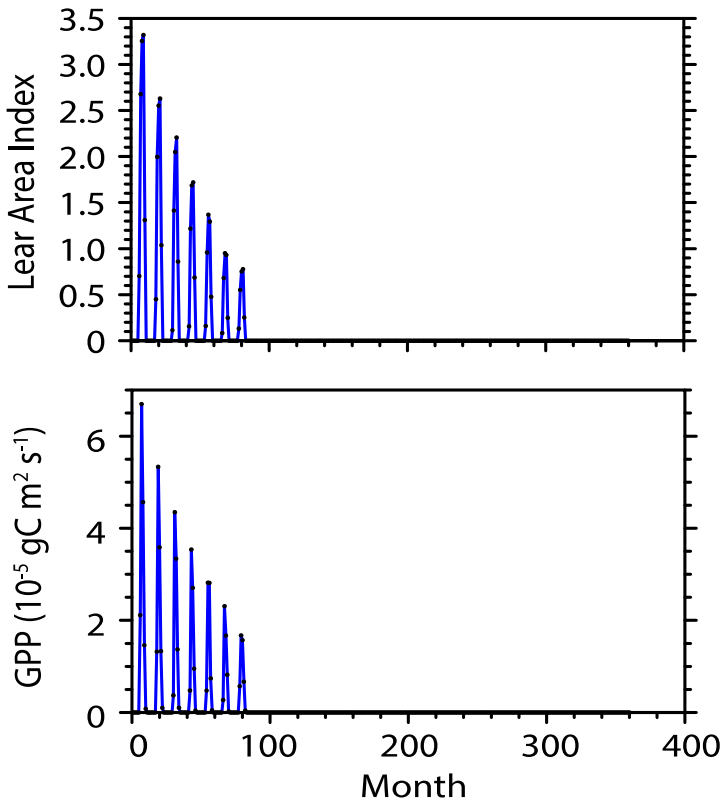
3. Results: Less vegetation amplify cold bias

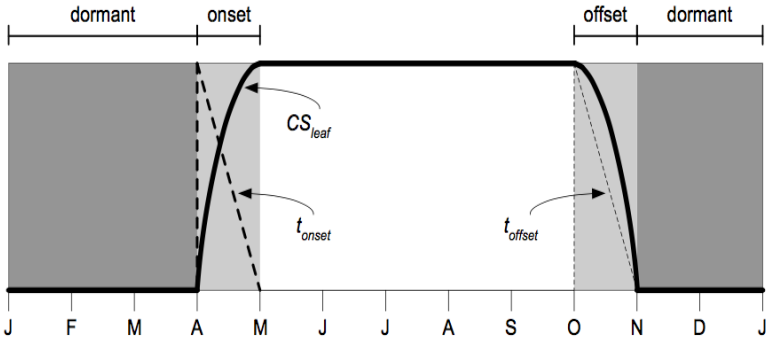
Atm-Veg run
(First 30 year)



3. Results: Cold biases inhibit vegetation growth

Atm-Veg run
(First 30 year)



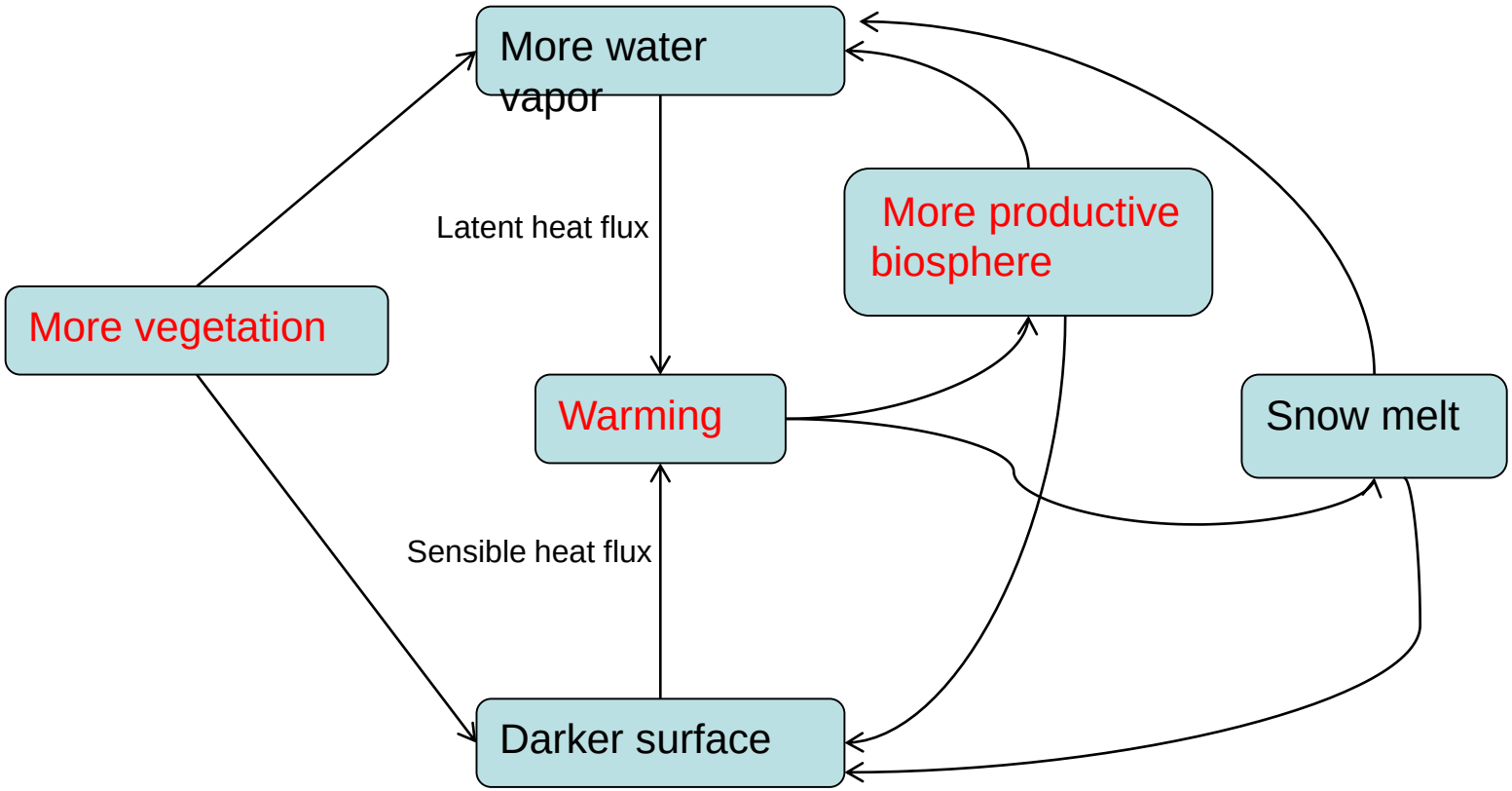


$$GDD_{sum\_crit} = \exp\left(4.8 + 0.13\left(T_{2m,ann\_avg} - TKFRZ\right)\right)$$

$$GDD_{sum}^{n} = \begin{cases} GDD_{sum}^{n-1} + \left(T_{s,3} - TKFRZ\right) f_{day} & \text{for } T_{s,3} > TKFRZ \\ GDD_{sum}^{n-1} & \text{for } T_{s,3} \le TKFRZ \end{cases}$$

- Onset is triggered when **a common degree-day summation exceeds a critical value**, and **the time is before summer solstice**

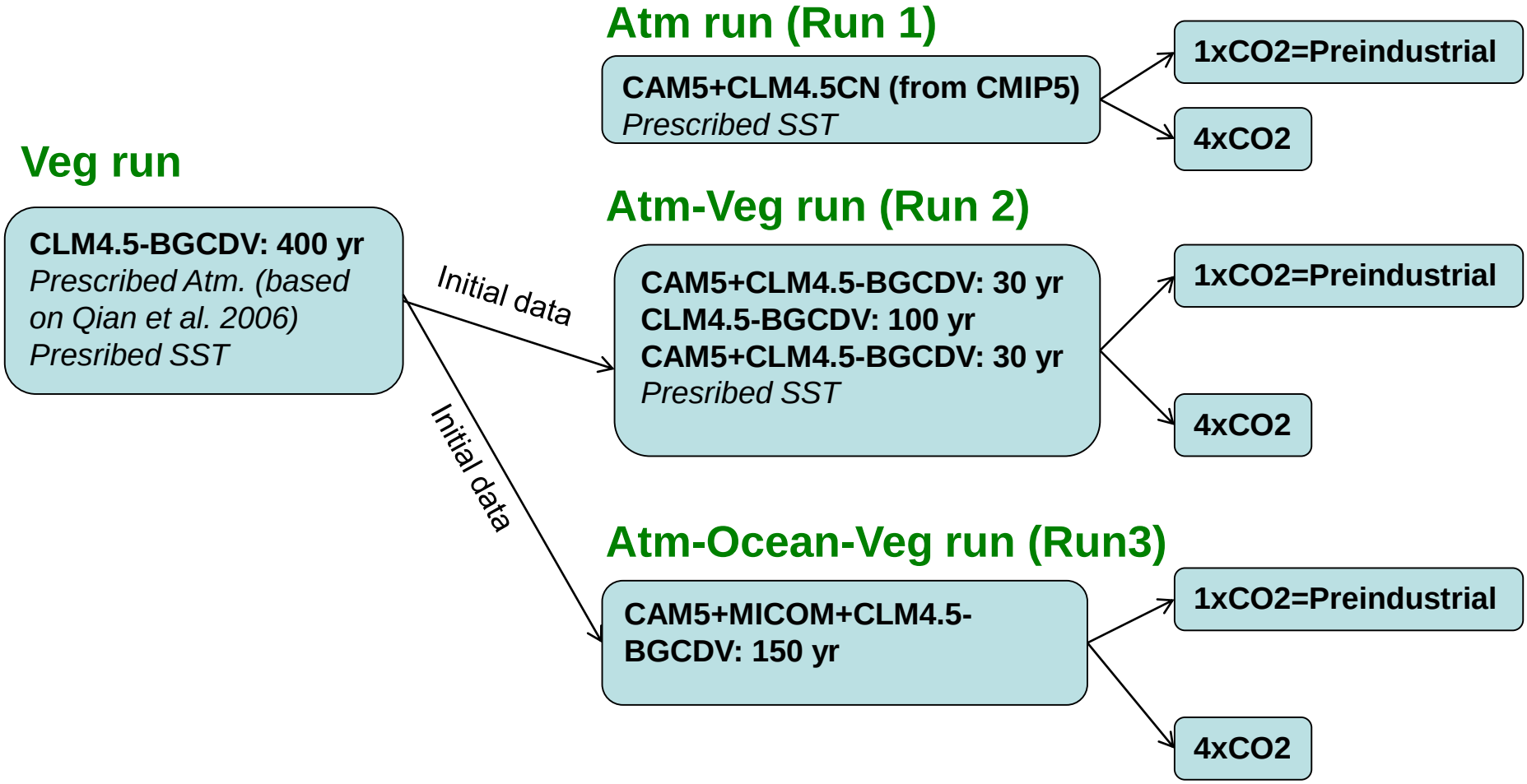
3. Results: Vegetation-temperature feedbacks



3. Present-day Simulation: **Summary**

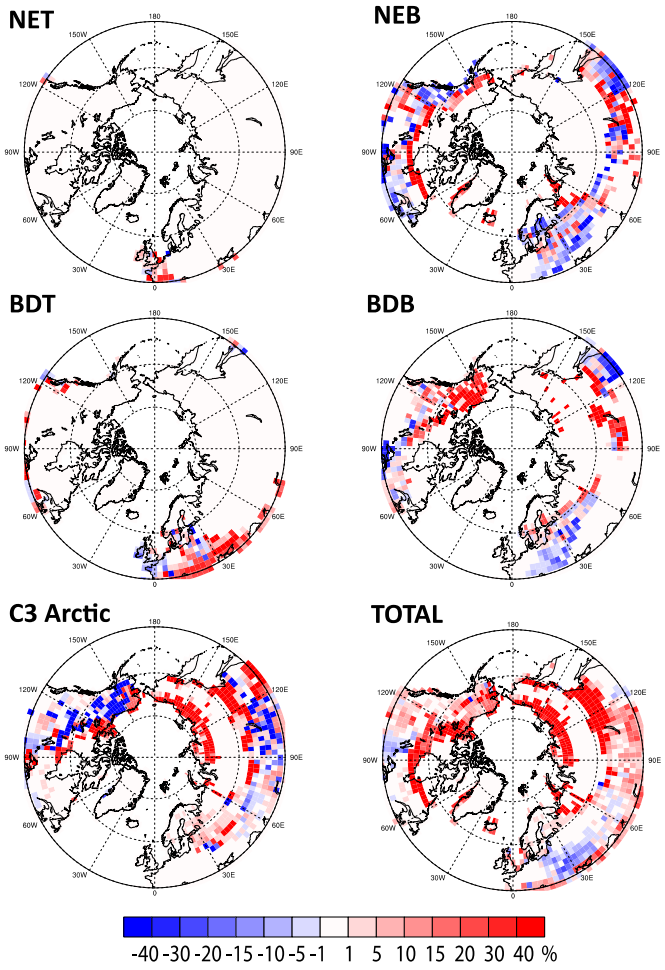
- CLM4.5-BGCDV (***Veg run***) underestimates Arctic shrubs, while overestimates Arctic grass.
- The coupled dynamic vegetation-atmosphere run (**Atm-Veg run**) underestimates Arctic grass, shrub and total plant cover, leading to strong cold biases in the Arctic.
- The positive feedback between vegetation and temperature (i.e., ***more vegetation -> more heating->higher temperature -> more vegetation***) is particularly strong in Arctic, making the coupled vegetation-atmosphere model highly unstable in this region.
- A careful parameterization of vegetation and its interaction with climate is needed for Arctic region.

4. 4xCO2 Simulation: **Experiments**

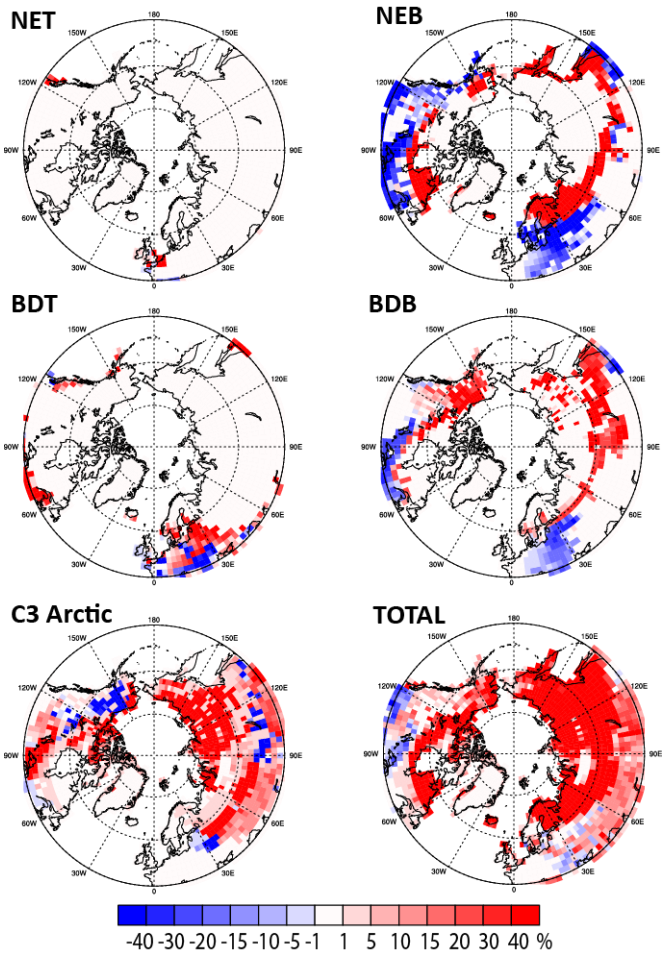


4. Plant cover changes (% points)

Exp4xCO2 – Exp1xCO2
Fixed SST
(run 2)



Exp4xCO2 – Exp1xCO2
Dynamic ocean
(run 3)

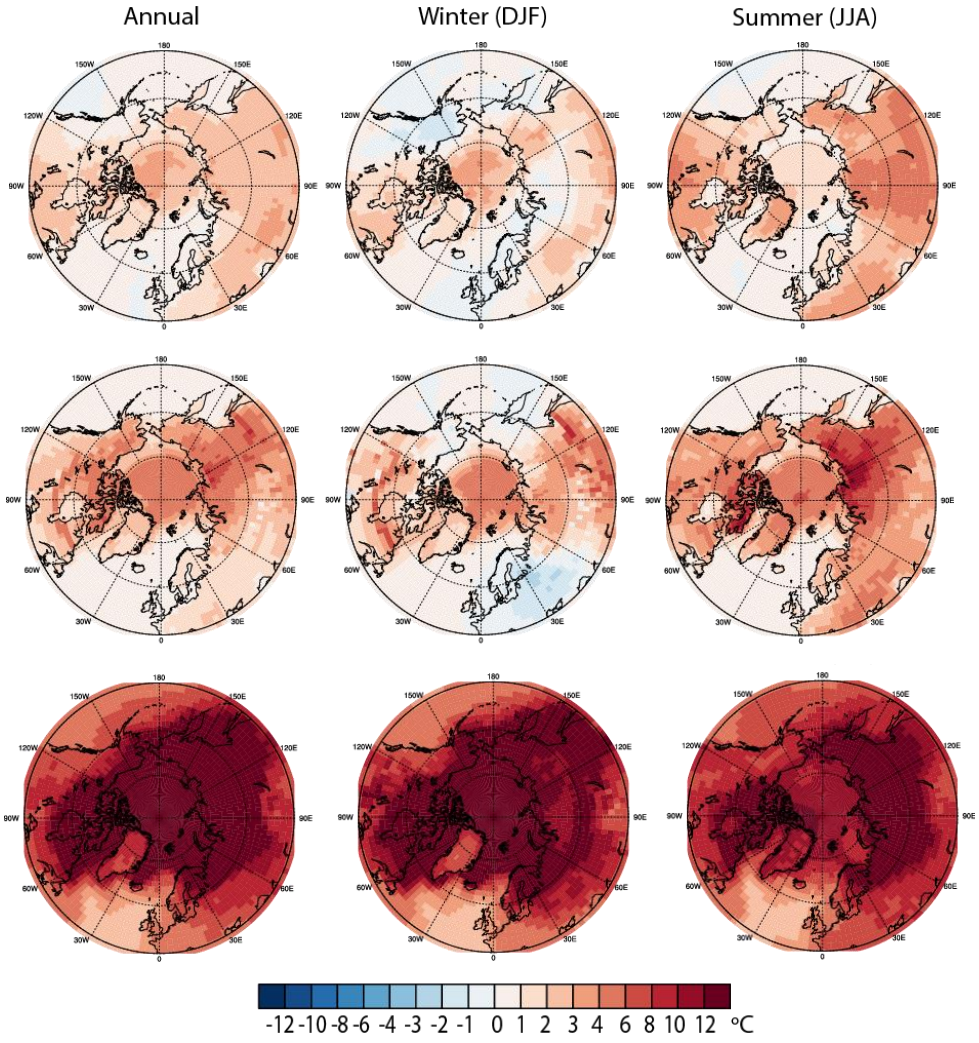


4. Surface temperature changes

Exp4xCO2 – Exp1xCO2
fixed vegetation
(run 1)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)

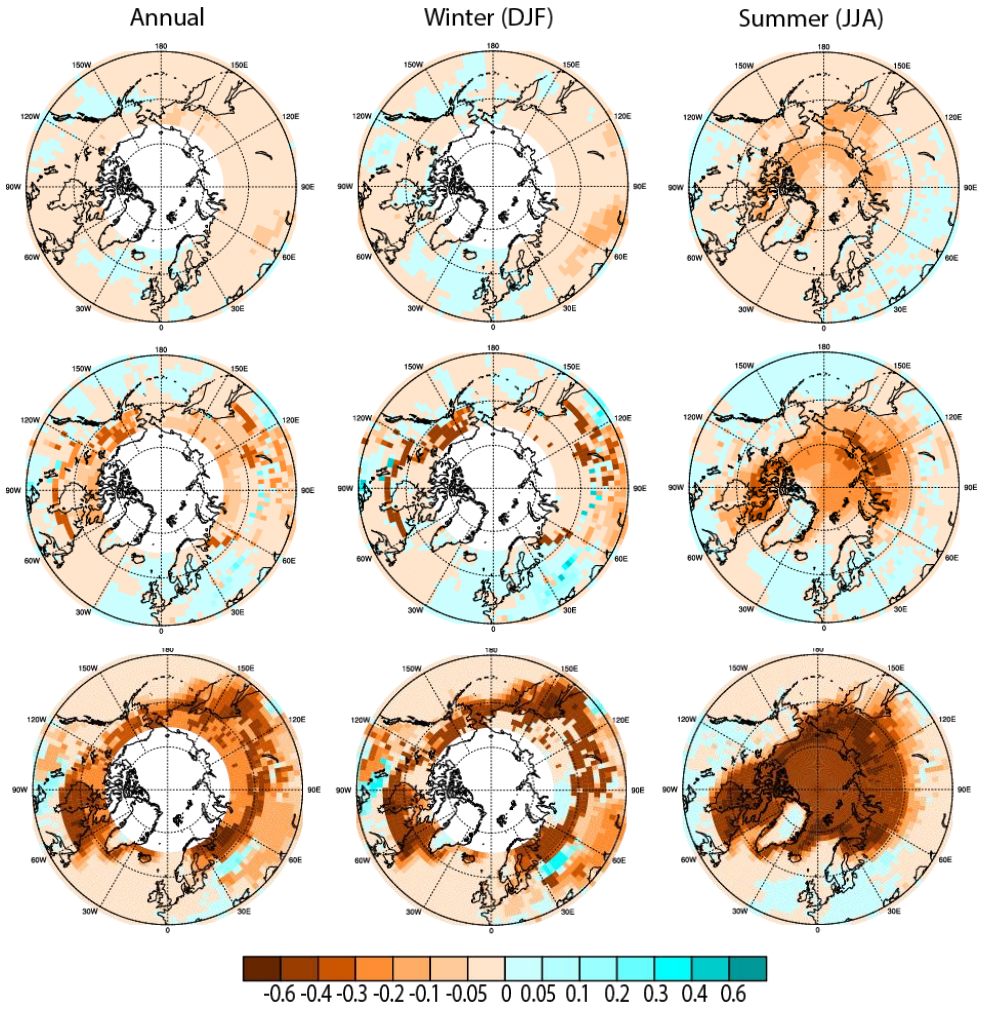


4. Albedo changes

Exp4xCO2 – Exp1xCO2
fixed vegetation
(run 1)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)

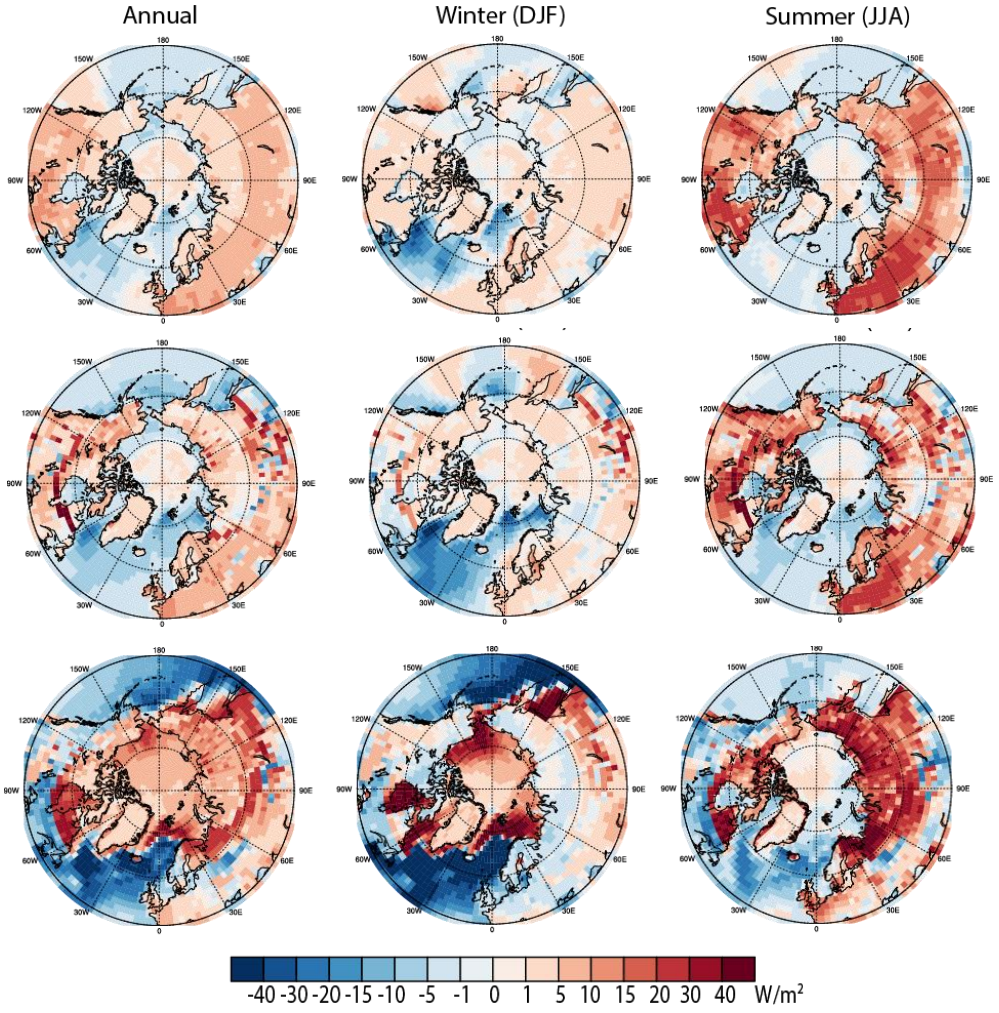


4. Sensible heat flux changes

Exp4xCO2 – Exp1xCO2
fixed vegetation
(run 1)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)

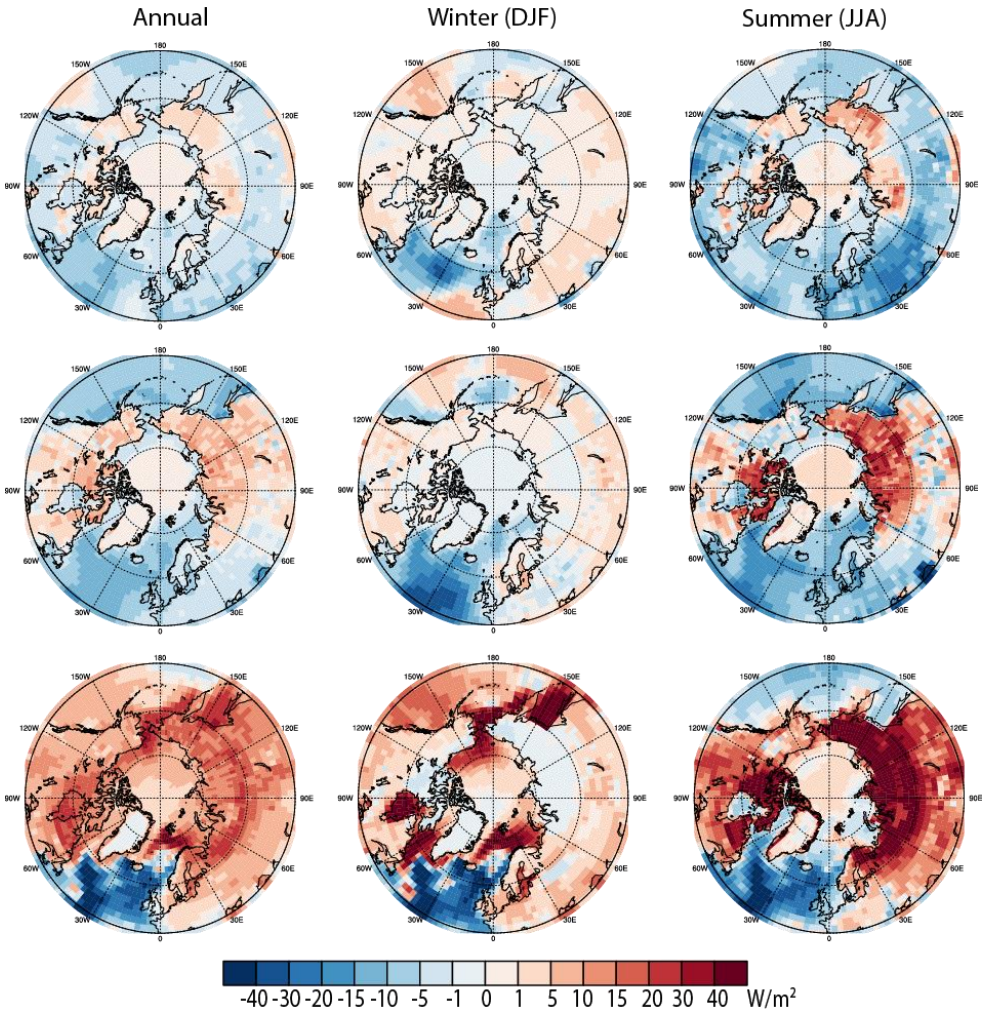


4. Latent heat flux changes

Exp4xCO2 – Exp1xCO2
fixed vegetation
(run 1)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

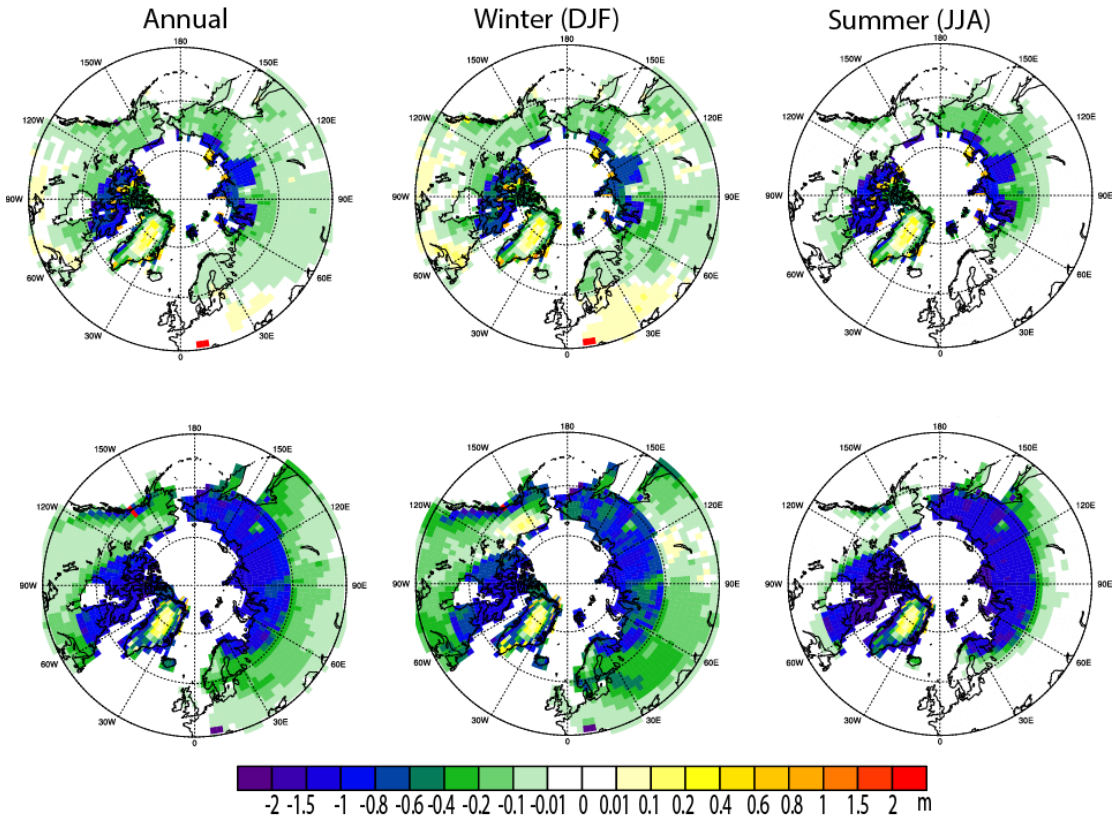
Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)



4. Snow depth changes

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)

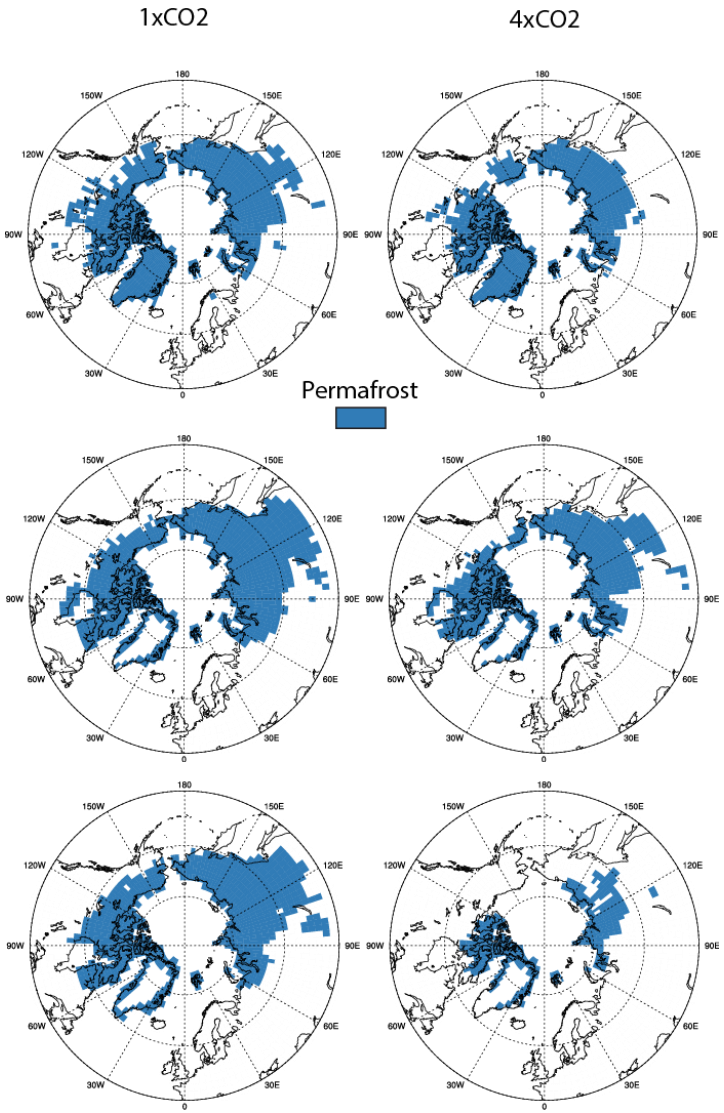


4. Permafrost changes

Exp4xCO2 – Exp1xCO2
fixed vegetation
(run 1)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)

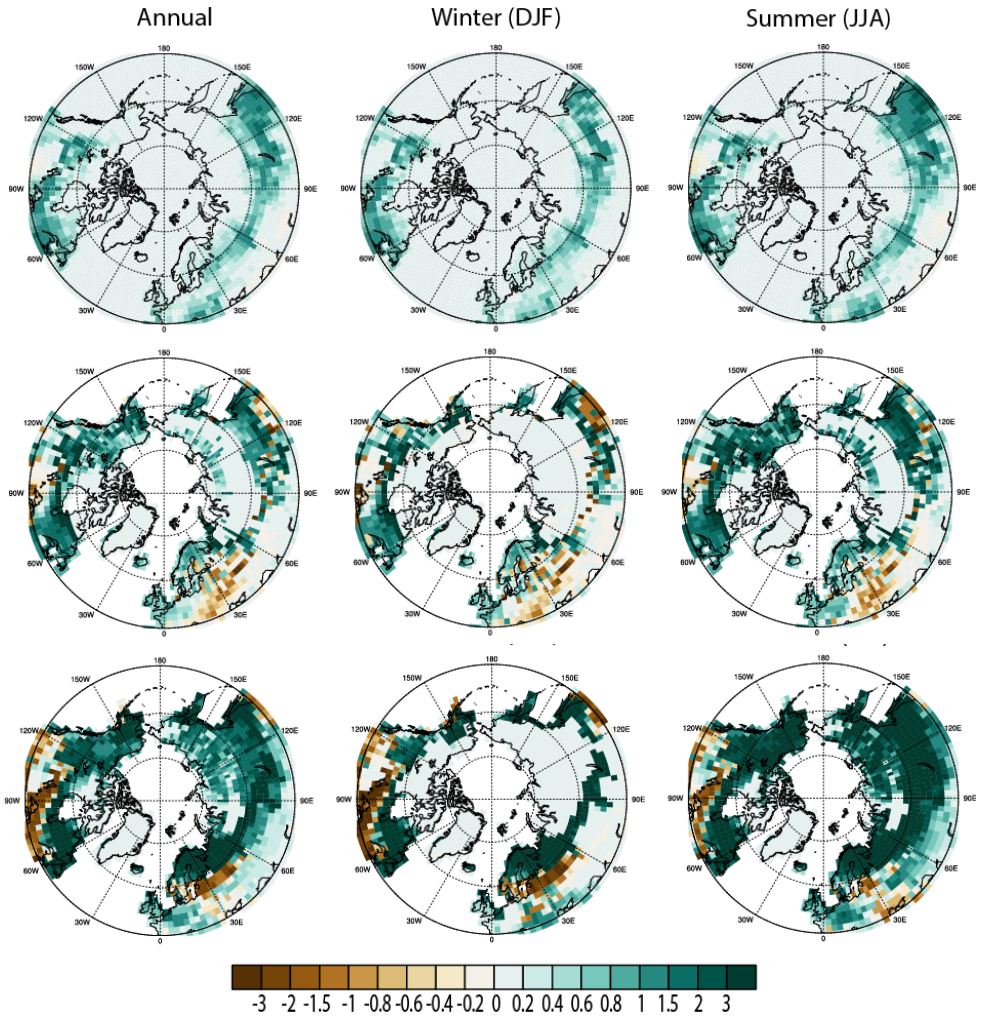


4. Leaf area index changes

Exp4xCO2 – Exp1xCO2
fixed vegetation
(run 1)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)

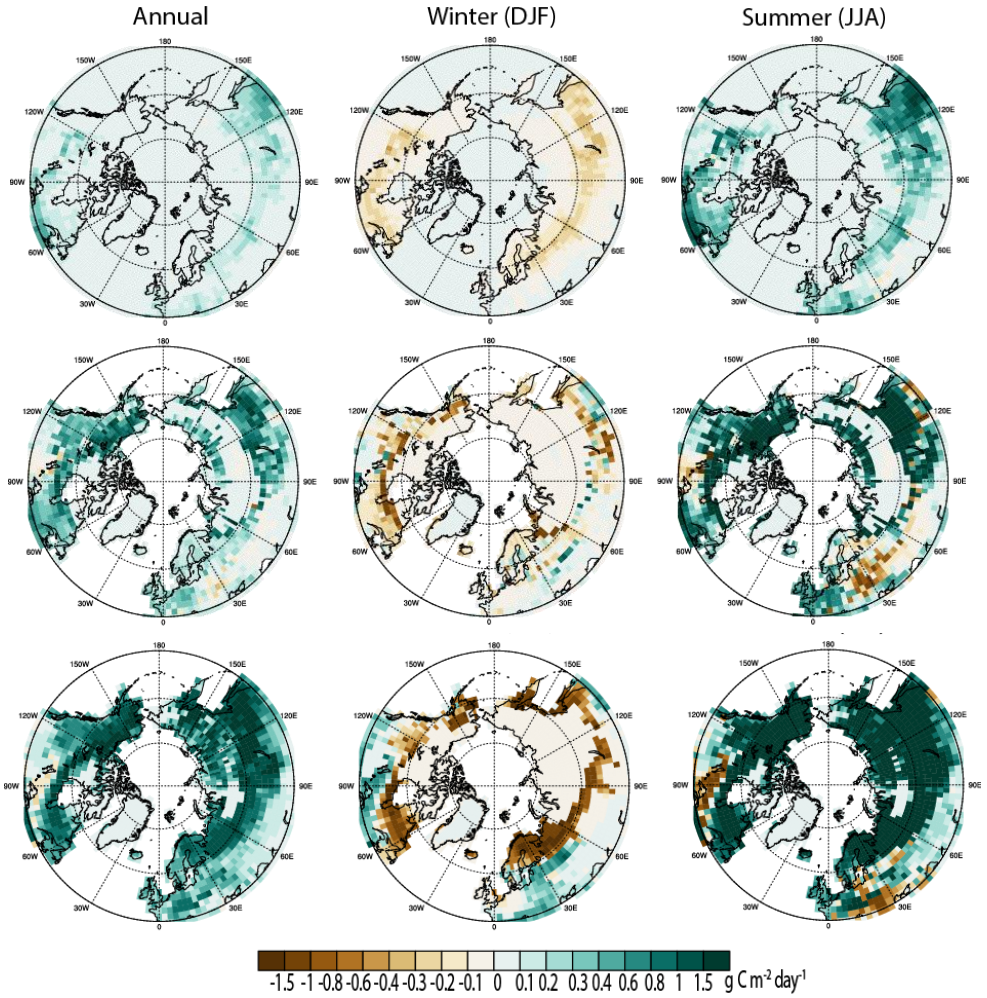


4. Net Primary Production (NPP) change

Exp4xCO2 – Exp1xCO2
fixed vegetation
(run 1)

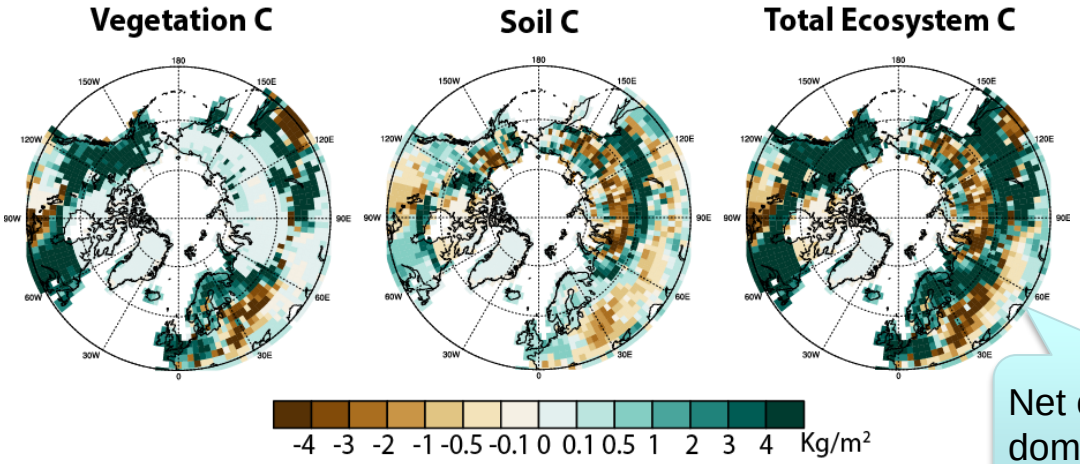
Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)



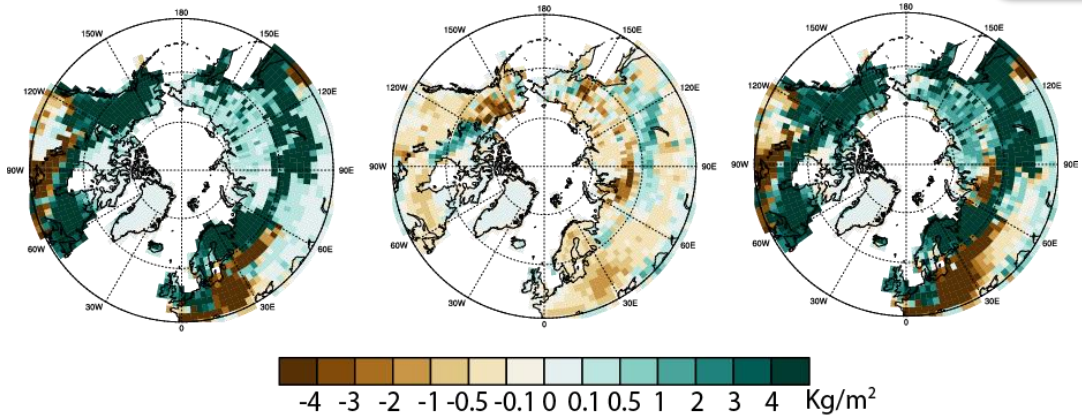
4. Carbon stock changes

Exp4xCO2 – Exp1xCO2
dynamic vegetation
(run 2)



Net carbon sink in domain: ~3kg m^{-2}

Exp4xCO2 – Exp1xCO2
dynamic vegetation
dynamic ocean
(run 3)



4. 4xCO2 Simulation: **Summary**

- The impact of dynamical vegetation in the Arctic under increased CO2
  - **Biophysical feedbacks**
    - **Amplification of the warming (northern Eurasia)**
      - More vegetation, more ET&latent heat, higher LAI&lower albedo, less snow&lower albedo
    - **Dampening of warming (East/Central Europe)**
      - Less vegetation (in particular needle leaf trees), lessET&latent heat, lowerLAI(esp winter)&higher albedo, more snow (winter)&higher albedo
  - **Biogeochemical feedbacks**
    - **Dampening of warming (northern Eurasia)**
      - Increased NPP and carbon stock due to more vegetation
    - **Amplification of warming (East/Central Europe)**
      - Decrased NPP and carbon stock due to higher soil temperatures and plant and soil respiration
      - Especially in winter
- Dynamic vegetation points to changes that vary much between regions
- Most of the changes are attenuated in the case of coupled ocean

5. Future work

- Improve parameterization of current PFTs
  - e.g., the phenology of Arctic PFTs; better description of Arctic shrubs
- Add more PFTs to represent the Arctic vegetation
  - e.g., moss, lichen
- Remote sensing-model integration
- Coupled dynamic vegetation-atmosphere in a regional climate model (WRF-CLM4.5BGCDV):


THANK YOU!
Trollstigen