The "CLM-DGVM-SEED": incorporating a meteorological constraint to plant migration in the CLM-DGVM

- introducing wind-driven seed dispersal constraint and sensitivity study -

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Plants migration

- Migration is a key process in controlling shifts such as forest and shrub transition.
- Most of currently existing DGVMs (Dynamic Global Vegetation Models) do not consider plant migration process but assume “simultaneous free dispersal of PFTs.”
  - Trees may experience lagged responses to changes
  - Lagged response in northward shift of taiga may be more realistic (Chapin and Starfield, 1997; Skre et al, 2002)
- Ignoring this process could potentially lead to overestimation of vegetation carbon sequestration capacity (IPCC WG2).
  - For example, in boreal regions, such overestimation occurs due to the high migration rates (Neilson et al. 2005)

Current CLM-DGVM (in CLM 3.5)

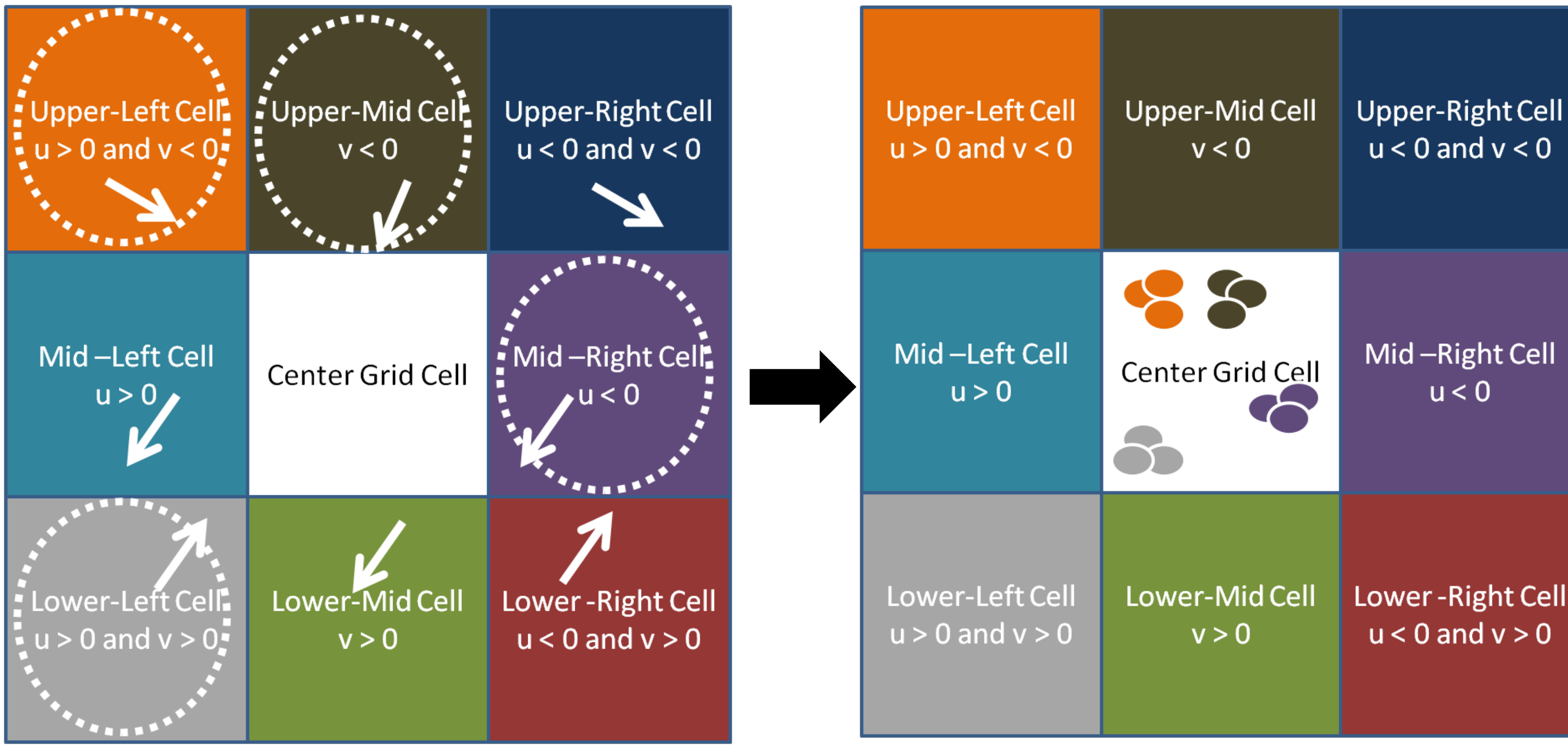
- NPP-based
- In the DGVM Establishment module:
  - Establishment is controlled by climatological variables (Temperature and moisture)
  - Current CLM-DGVM in the CLM 3.5 allows free plant migration as long as establishment condition is satisfied

    (A PFT can migrate freely in any land part of the globe and grow if the climate condition becomes favorable to the type)
- Other constraints to plant migration for more realistic estimation of vegetation cover (i.e., biogeography), and subsequent changes in biogeochemistry and biophysics?

Constraints on Plant migration

- Adding to the climatological constrants (i.e., temp and moisture), what will be the constraints for a better simulation of plant migration?
  - Seed availability
    - By wind (meteorological constraint)
    - By animal
    - By human beings
  - Nutrient limitation
    - Nitrogen in high latitudes
- MIT CLM-DGVM-SEED
  - For a new pft to be established, the pft has to meet both the establishment condition (as in the default CLM) and seed availability constraint from neighboring grids

MIT CLM-DGVM-SEED



Step 1) Scan wind direction and vegetation composition (i.e. existing plant types) of eight adjacent grids

Step 2) Allow seeds only from the neighbors at which wind is blown toward the center grid

Run overview

- Six cases for climate sensitivity (S) test

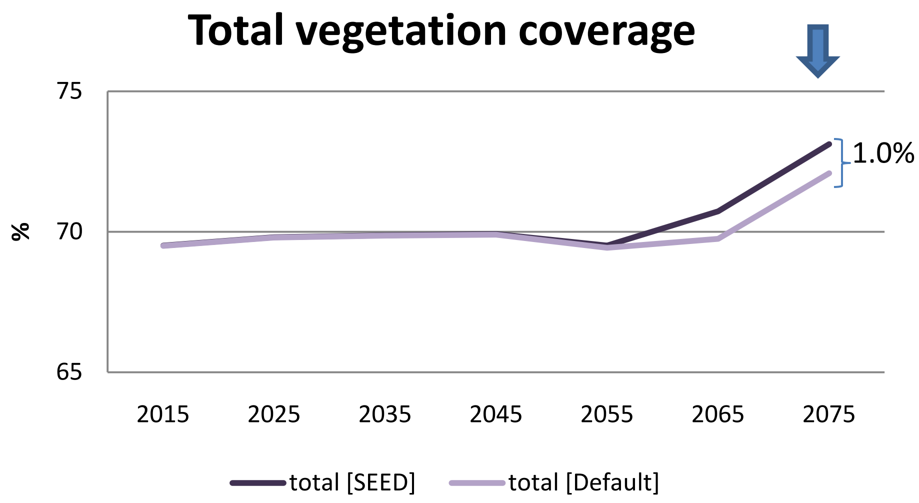
	High sensitivity	Median sensitivity	Low sensitivity
CLM-DGVM-SEED	High, Seed	Median, Seed	Low, Seed
CLM-DGVM-Default	High, Default	Median, Default	Low, Default

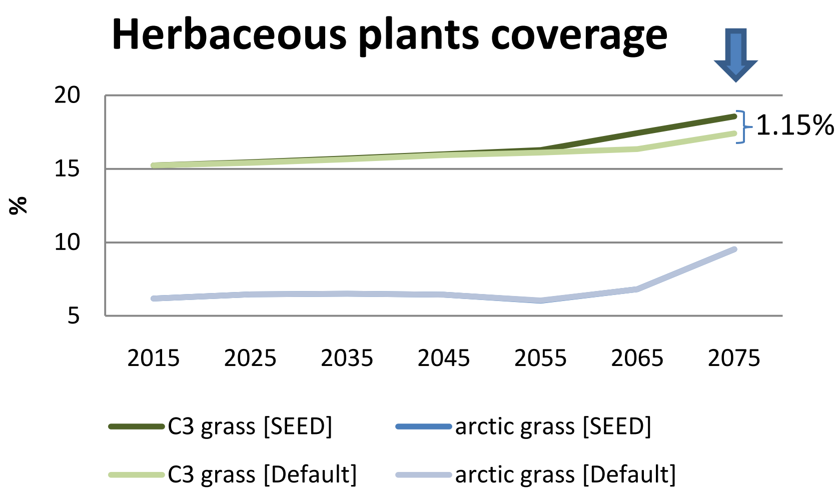
(High S = 5.6 ^{o}C, Median S = 2.9 ^{o}C, Low S = 2.0 ^{o}C)

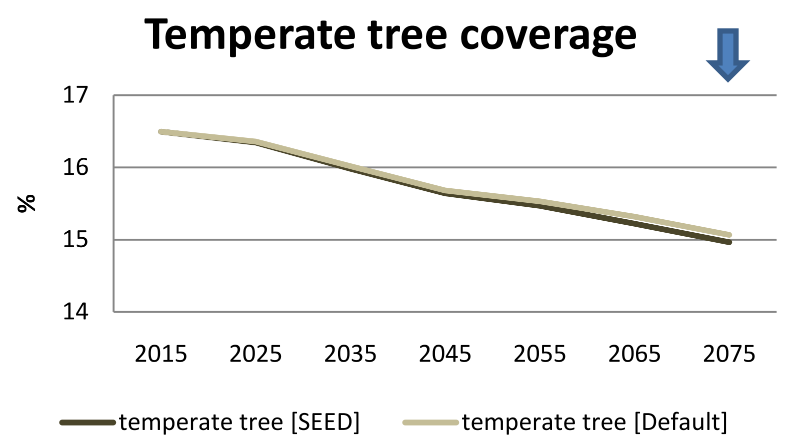
- 2^{o} x 2.5^{o} resolution
- Atmospheric forcing for sensitivity study
  - Climatological mapping of precipitation and temperature
  - Zonal distribution patterns do not change over time; but the trend changes over time
- Spin-up for 150 years (1951-1975 climate repeated)
- Run for 100 years (1976-2075)
- Wind profiles (u and v) from GFDL 2.0, averaged for autumn

Vegetation coverage (yr 2015-2075)

- IGSM High Sensitivity forcing
- Trees (3 categories):
  Tropical, Temperate, Boreal
- Non-trees (2 categories):
  Arctic grass, C3 grass



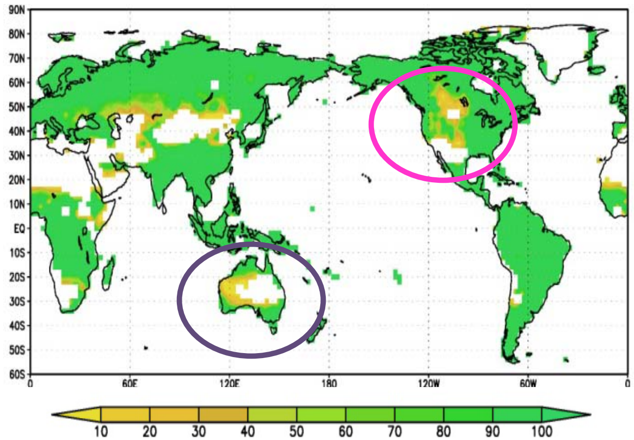




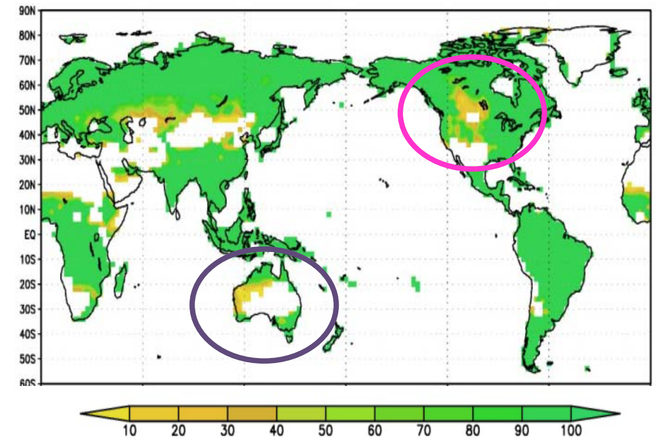
* **More vegetation coverage is expected from SEED, mainly due to the increase in grass coverage**

* **All other types are expected less from SEED than Default, consistently**

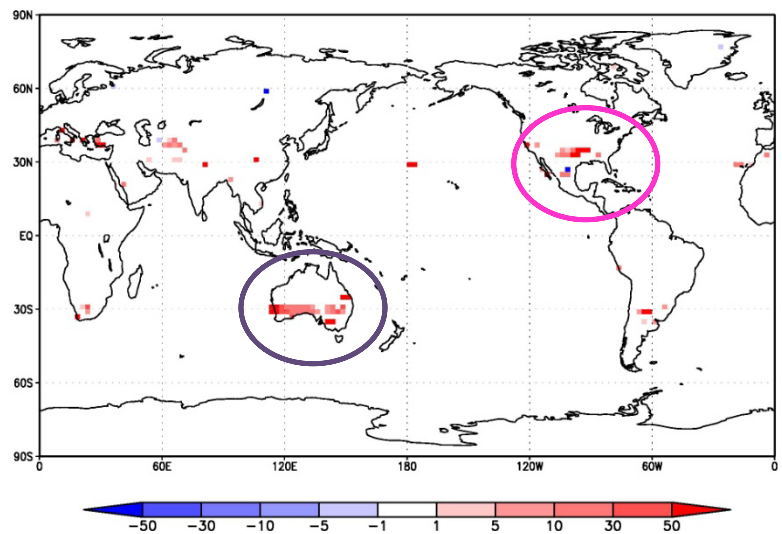
Total vegetation coverage (%) at yr 2075



Total vege cover (%) from DGVM-SEED



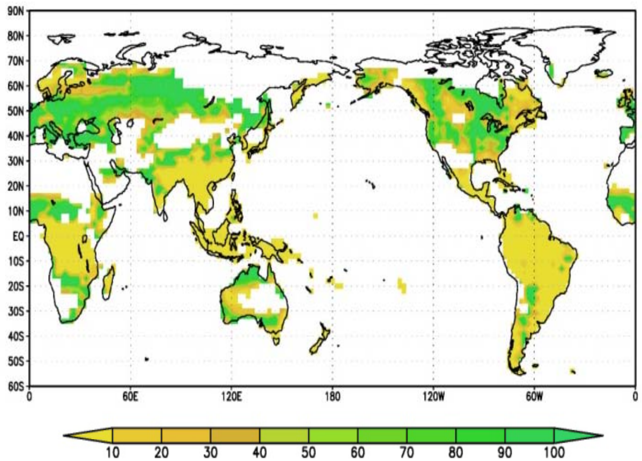
Total vege cover (%) from DGVM-Default



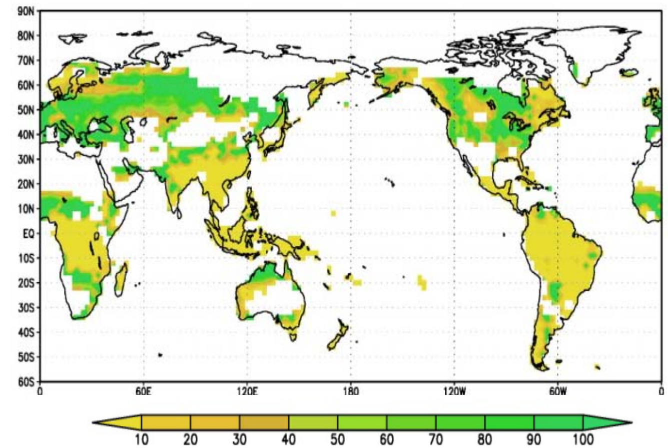
Difference (%) in total vege cover (SEED –Default)

Climate Forcing:
IGSM High Sensitivity

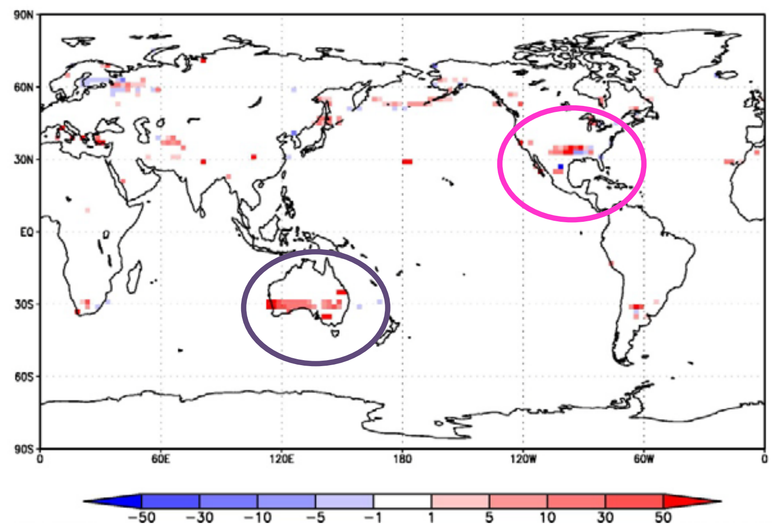
Grass coverage (%) at yr 2075



Grass (%) from DGVM-SEED



Grass (%) from DGVM-Default



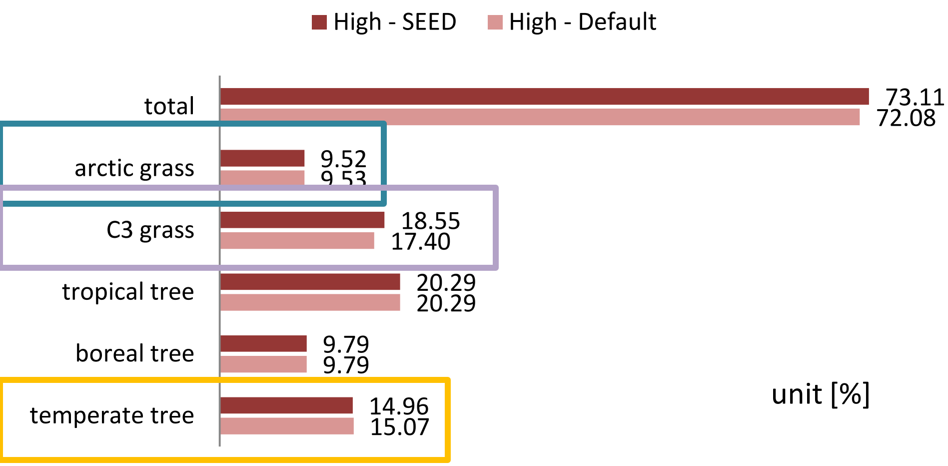
Difference (%) in Grass cover (SEED –Default)

More grass is estimated
with SEED constraint
(Australia & US Southern plane)

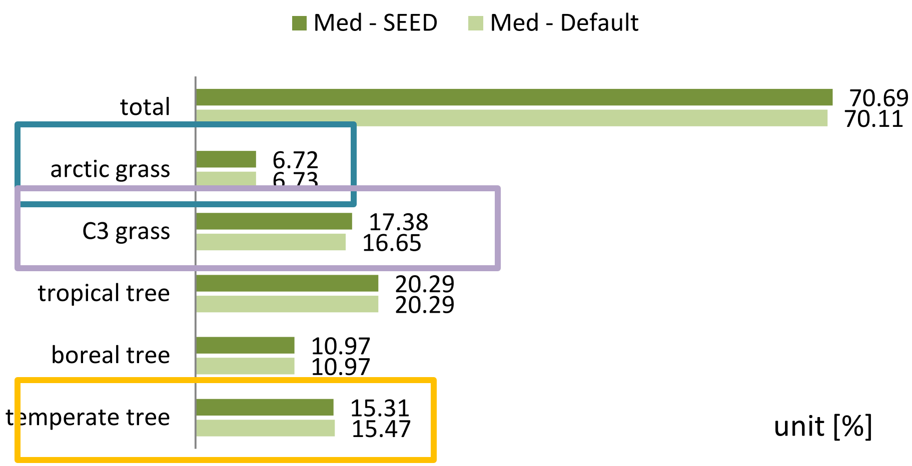
Climate Forcing:
IGSM High Sensitivity

Summary of Global vegetation coverage

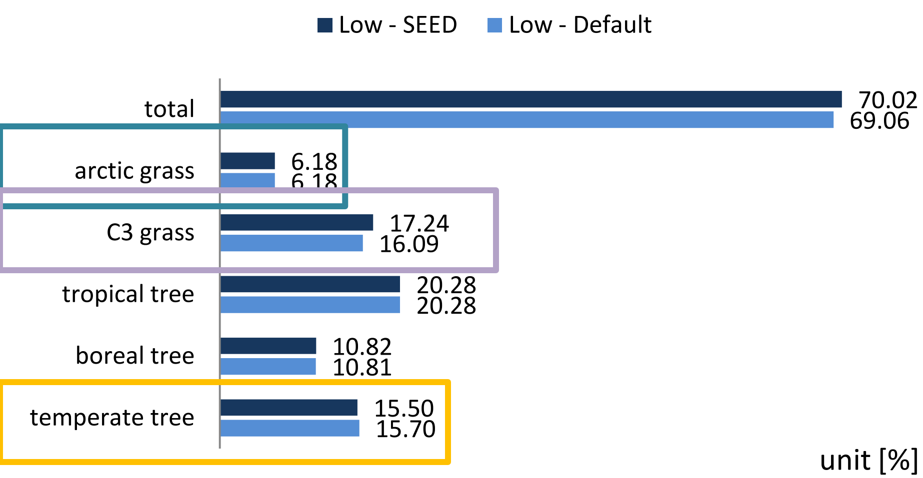
High Climate Sensitivity



Median Climate Sensitivity



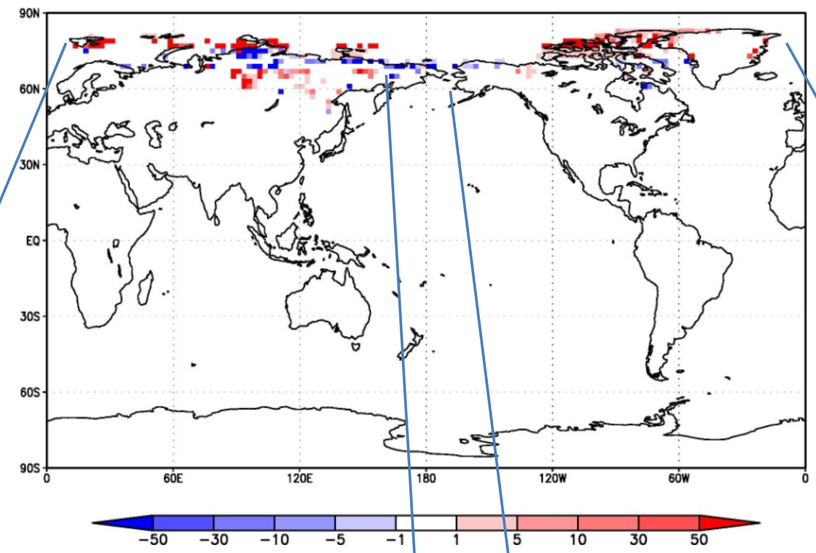
Low Climate Sensitivity



- Global coverage at year 2075
- In all three cases (High, Median and Low),
  - More grass is estimated from SEED
  - Slightly less temperate trees are estimated from SEED

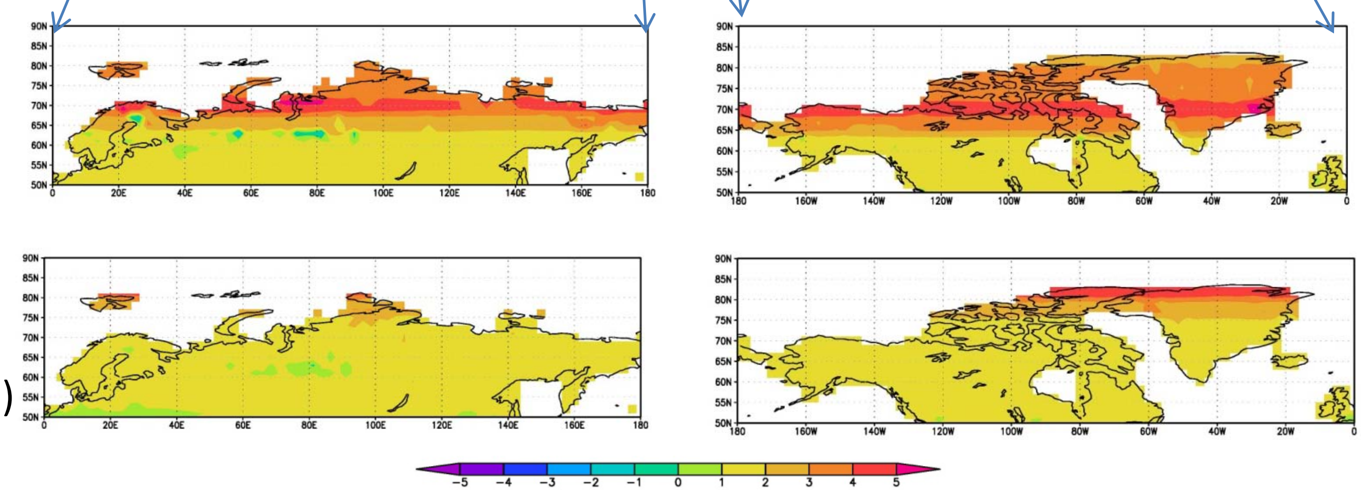
Arctic grass in high and low sensitivities

Difference (%) in
Arctic grass coverage
(High Sensitivity – Low Sensitivity)



Difference (^{o}C) in
atmospheric temperature
(DJF, average of 2066-2075)

Difference (^{o}C) in
atmospheric temperature
(SON, average of 2066-2075)



Our Findings

1. DGVM-SEED vs. DGVM-Default
   - ❑ By adding seed availability constraint to the current DGVM in the CLM 3.5, more grass is expected.
   - ❑ All other types are estimated slightly less with seed availability constraint than in default
2. Sensitivity to climatic forcings
   - ❑ Regional ecosystem changes:
     - Tropical trees are insensitive to either seed availability constraint or different climate forcings.
     - In high latitudes, arctic grass is sensitive to climate change, while grass is sensitive to seed availability constraint

Future work

- Add other constraints to the plant migration
  - Nitrogen limitation (CLM 4?)
- Test sensitivity of migration to assumed wind fields from various GCMs
  - CCSM?
- Use climatic forcing with zonal pattern changed
  - GCM patterns on the IGSM zonal average
  - Tomorrow's talks by Adam Schlosser (MIT)
- Explore more regional impacts
  - High latitudes
  - Mid latitudes