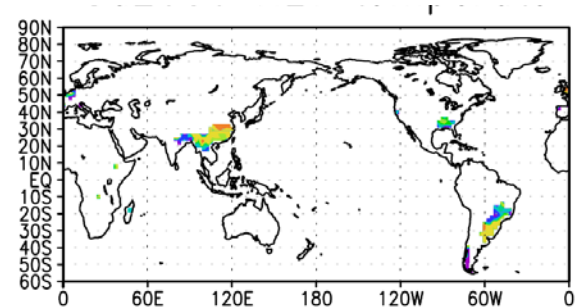
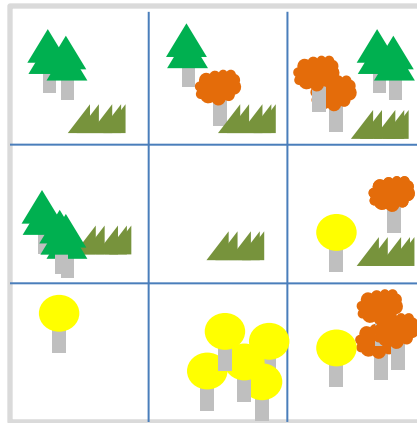


Estimating Vegetation Distribution in the 21st Century - the Role of Meteorology in Plant Migration -



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[Motivation and research question]

- In predicting natural vegetation distribution, plant migration is a key process in controlling shifts in forests and shrub transition. However, the current CLM-DGVM assumes FREE plant migration.
 - A plant type can migrate freely in any land part of the globe and grow if the climate condition becomes favorable to the type
- Ignoring seed constraints could potentially lead to:
 - Overestimation of vegetation carbon sequestration capacity¹⁾
 - Lagged response of trees and taiga²⁾
- We develop a more comprehensive treatment of plant migration using meteorological data in order to provide more explicit representation of plant migration process in the current CLM-DGVM
- Does climate mitigation policy impact, and if so how, the local and migratory response of natural ecosystem?

[Tool] Temperate and Boreal Forests disperse seeds by Wind

Broadleaf Deciduous Temperate tree
e.g. Maple tree



Broadleaf Deciduous Boreal tree
e.g. Willow tree

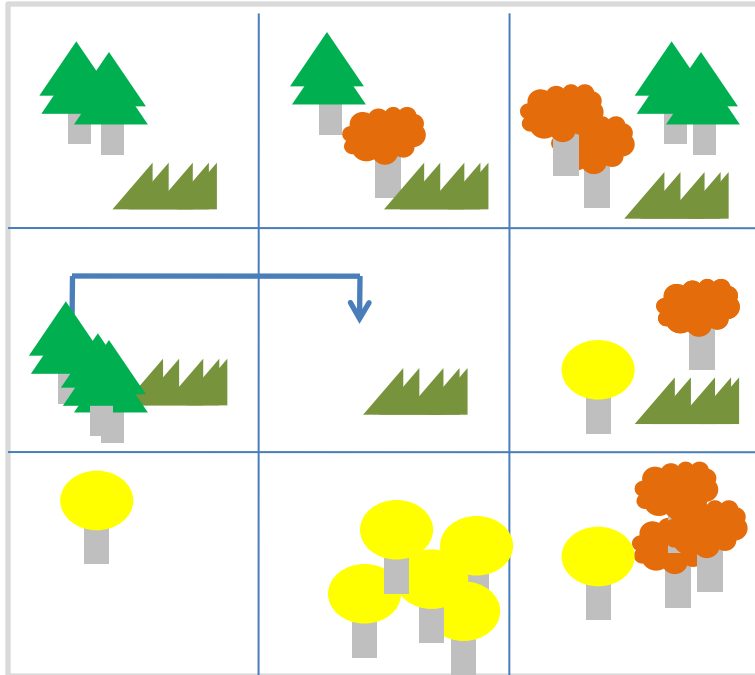


Above: <http://www.flickr.com/photos/86953562@N00/150700450>
Below: Natural Resources Canada/ Canadian Forestry Service
http://www.atl.cfs.nrcan.gc.ca/frontliners/Bernie_Daigle/images/catkins.htm

Note) For tropical forests and grasses,
Wind-dispersal is not a dominant
mechanism

| PFT | Seed dispersal mechanism in SEED |
|-----------------|----------------------------------|
| NET temperate | Seeds by wind dispersal |
| NET boreal | Seeds by wind dispersal |
| BET tropical | Seeds from neighboring grids |
| BET temperate | Seeds by wind dispersal |
| BDT tropical | Seeds from neighboring grids |
| BDT temperate | Seeds by wind dispersal |
| BDT boreal | Seeds by wind dispersal |
| C3 Arctic grass | Free migration |
| C3 Grass | Free migration |
| C4 Grass | Free migration |

[Tool] MIT CLM-DGVM-SEED: quantitative approach



Step 1) Scan vegetation composition (i.e. existing plant types) of eight adjacent grids to decide if their seeds are mainly wind-dispersed (i.e., boreal and temperate forests)

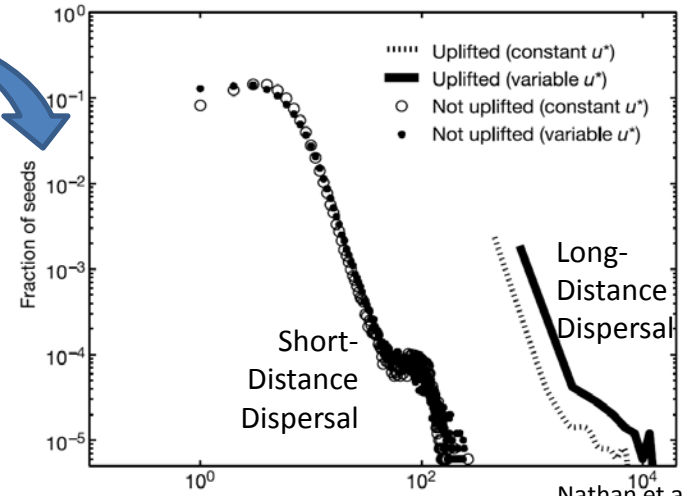
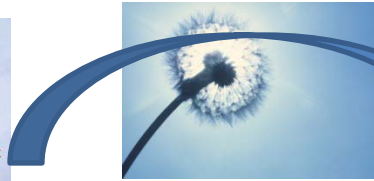
Step 2) Count days of favored wind toward the center grid of the fall season

Step 3) Compute number of seeds that can cover more than 1% of the land-cover of the center grid with density of 1 germinated seed / m²

Step 4) Allow seeds of boreal and temperate trees from only these neighboring grids

of potentially germinated seeds, dispersed by wind
= function of (fecundity, efficiency of LDD, # of days of favored wind, germination rate)

[Tool] Probabilistic approach for Seed availability

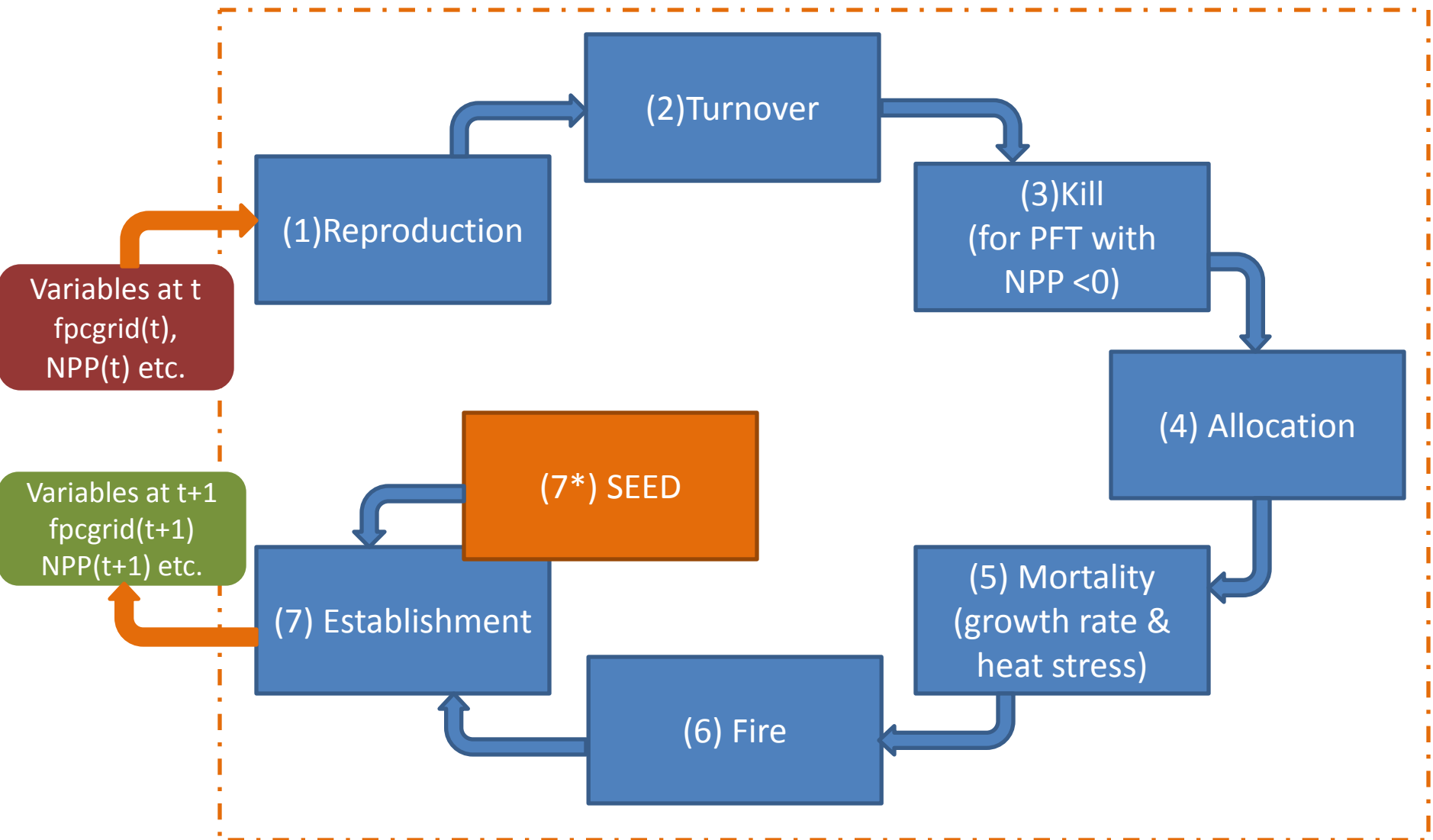


Flowering and ripening to give out seeds
Oct-Dec (3 months)

Long Distance Dispersal (LDD)
(seed uplifting probability: 1~5%)

- # of potentially germinated seeds, dispersed by wind per m^2
- = fxn (fecundity, efficiency of LDD, # of days of favored wind, germination rate)
- = 10^4 seeds per tree per year * # of trees * foliar projective cover on a grid cell
- * 0.01 of LDD efficiency
- * # of days of favored wind per total days for seed dispersal
- * 0.7 of germination rate
- > 1 seed / m^2 and to occupy at least 1% of the land cover
- => Allow germinated seed for the type

[Tool] Seed availability constraint added to CLM-DGVM

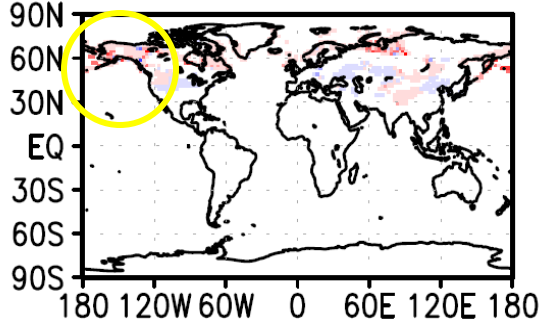


[Evaluation] Test the SEED model behavior

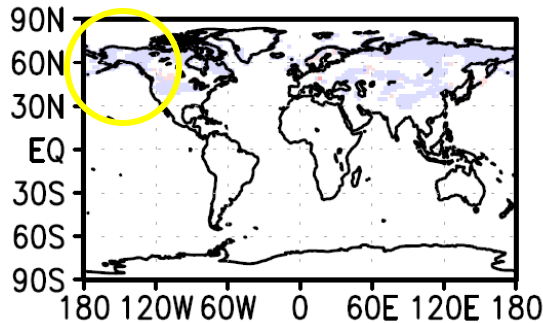
- Climatology and wind profile
 - NCEP Corrected by CRU (NCC) data
 - NCEP reanalysis wind
- Spin-up for 200 years (1951-1970 climate repeated 10 times)
- Run for 30 more years
 - 1971-2000 – NCC climatology

[Evaluation] 63N, 158.75W

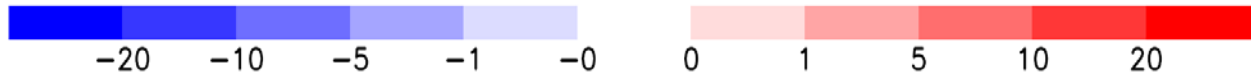
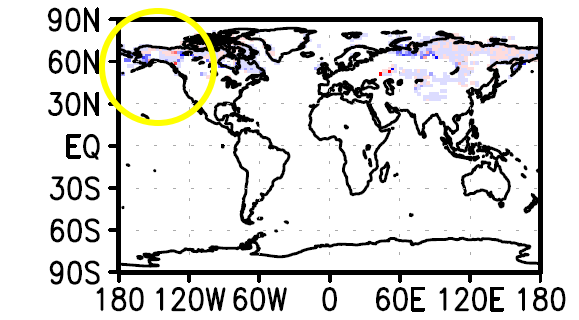
Δ (SEED - FREE) NET boreal



Δ (SEED - FREE) BDT boreal

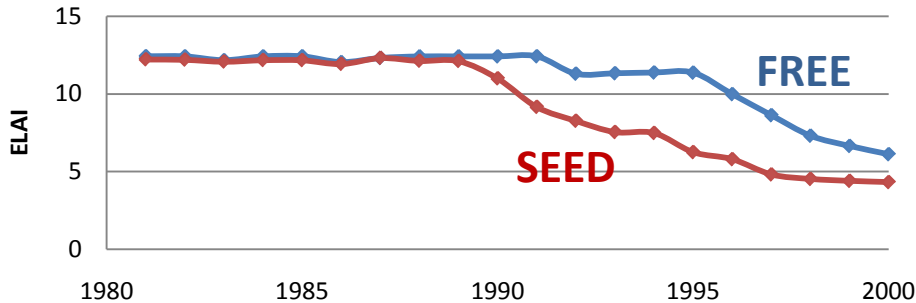


Δ (SEED - FREE) C3 grass Arctic

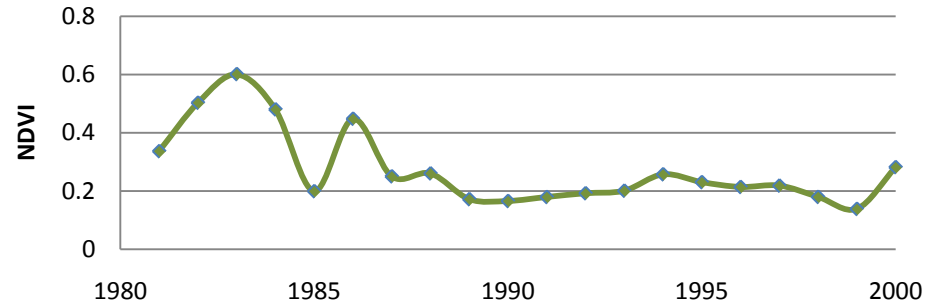


At 63N and 158.75W in year 2000,
more NET boreal forest and less C3 grass Arctic are estimated from SEED

Model Exposed Leaf Area Index (ELAI)



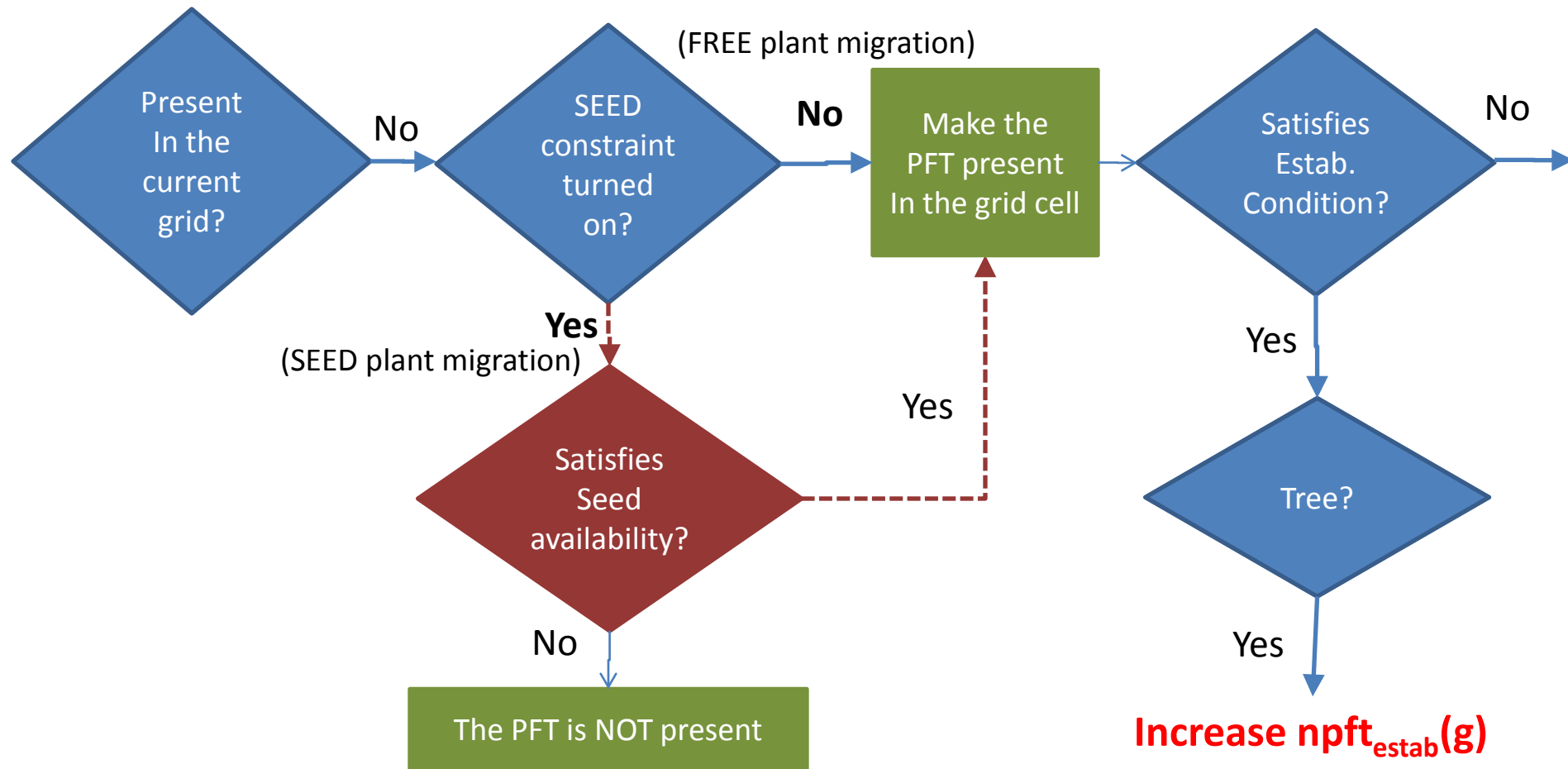
Obs NDVI



Better correlation
 Between LAI and NDVI
 Using SEED

FREE vs Obs SEED vs. Obs
 0.328 0.496

[Evaluation] counterintuitive? SEED scheme alters establishment rate



$$\text{Estab.rate}(p) = \text{Estab}_{\max} * [1 - \exp(5 * [\text{fpc}_{\text{treetotal}}(g) - 1]) / (\text{npft}_{\text{estab}}(g))]$$

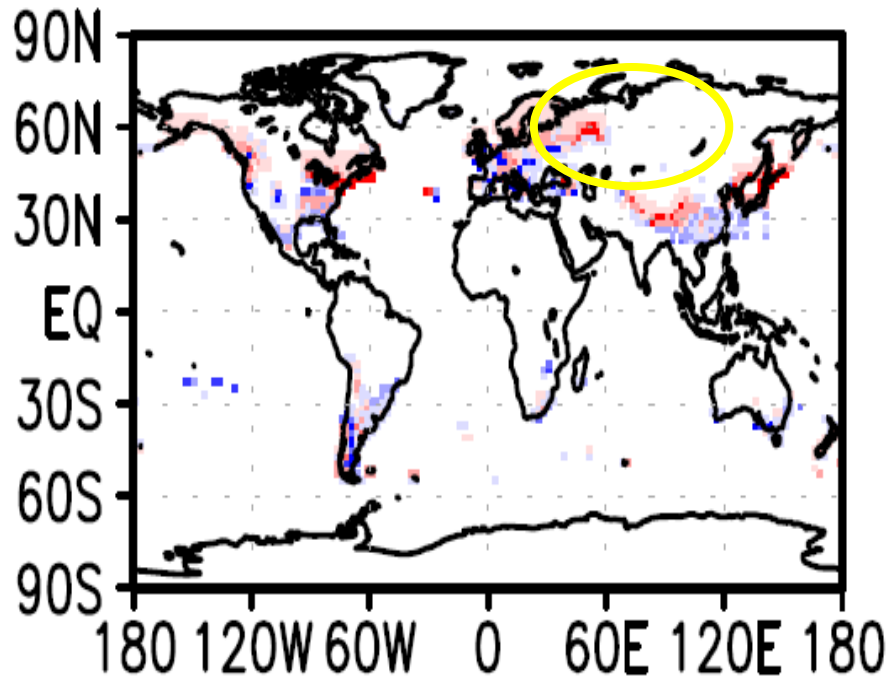
$$\text{Estab.grid}(p) = \text{Estab.rate}(p) * (1 - \text{fpc}_{\text{treetotal}}(g))$$

[Application] Simulation w/ IGSM climate for the 21st century

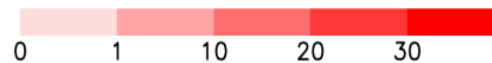
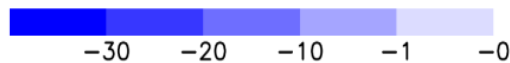
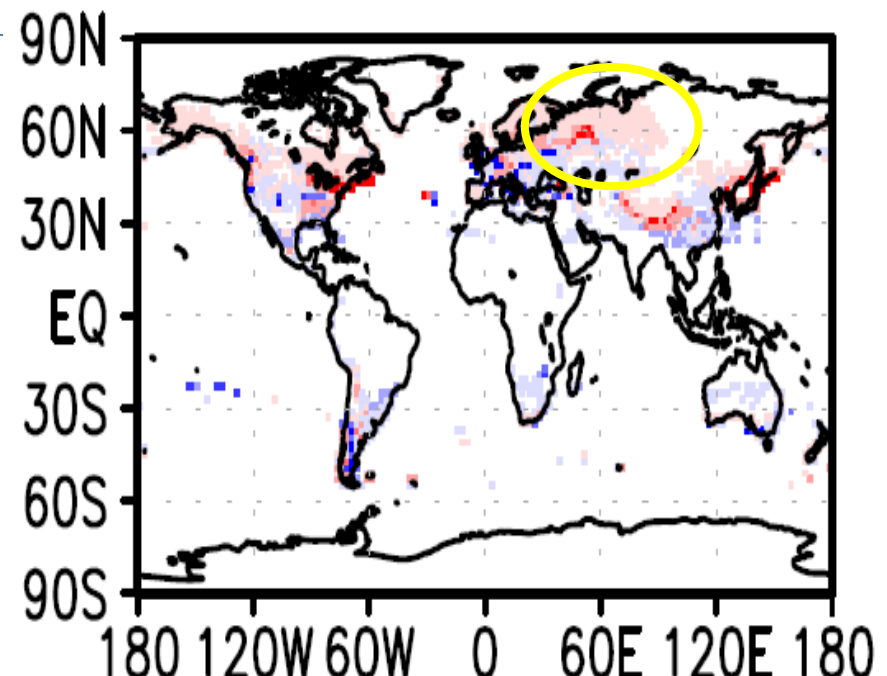
- MIT Integrated Global System Modeling (IGSM) Framework
- Climatological mapping of precipitation and temperature (zonal distribution patterns); but with zonal trends applied.
- High Transient Climate Response (Sensitivity = 5.6 °C)

(Example) Estimated BDT temperate forest : less gain in the Western Siberia

SEED Δ BDT temperate (yr2100 - yr2020)



FREE Δ BDT temperate (yr2100 - yr2020)



[Application] Estimating future vegetation distribution

By 2100, under No-policy scenario:

- [Mid- and high- latitude regions, where wind-dispersed seed availability constraint applied for boreal and temperate forests]
 - Competitions among boreal forests and temperate forests for habitats.
 - By considering availability of wind-blown seeds, BDT temperate forest cover will shrink (0.07%), while NET boreal forest, NET temperate forest, and BET temperate forest may take up its habitat.
- [Low latitude region, where neighbor-limited seed availability constraint applied for tropical forests]
 - In a warming world, BET tropical forest (winner) takes the habitat of BDT tropical fores
 - Increase in BET tropical forest coverage is significantly suppressed using neighboring approach

Thank you!!



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