

How disturbances are (or are not) represented in CMIP5 Earth System Models

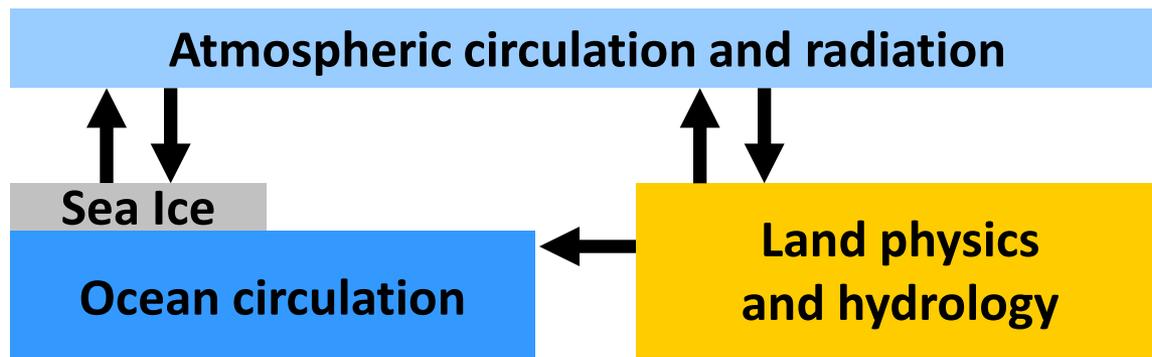
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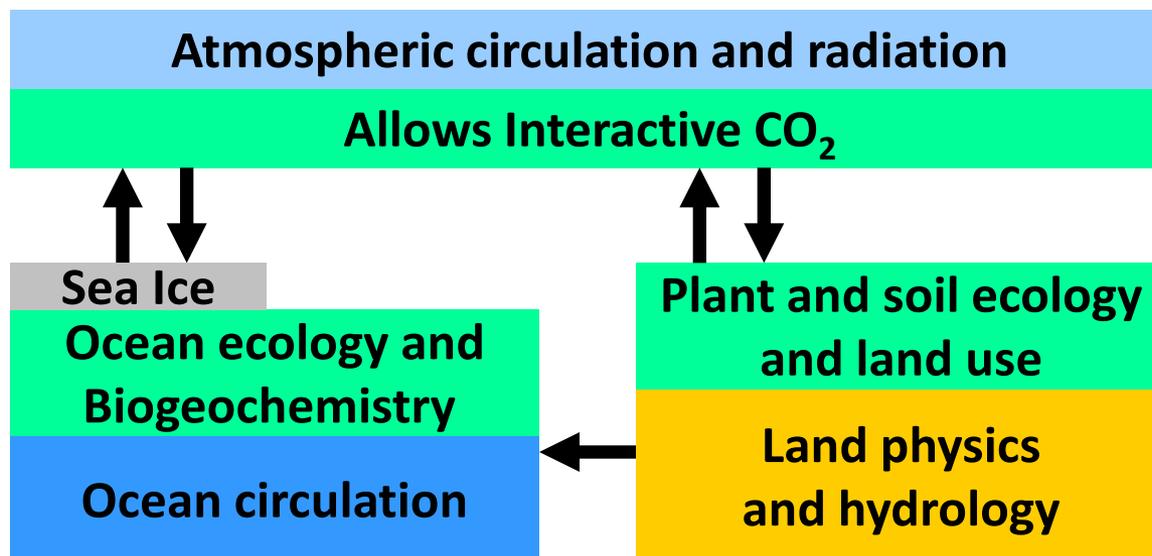


Earth System Models* close the carbon cycle

Climate Model



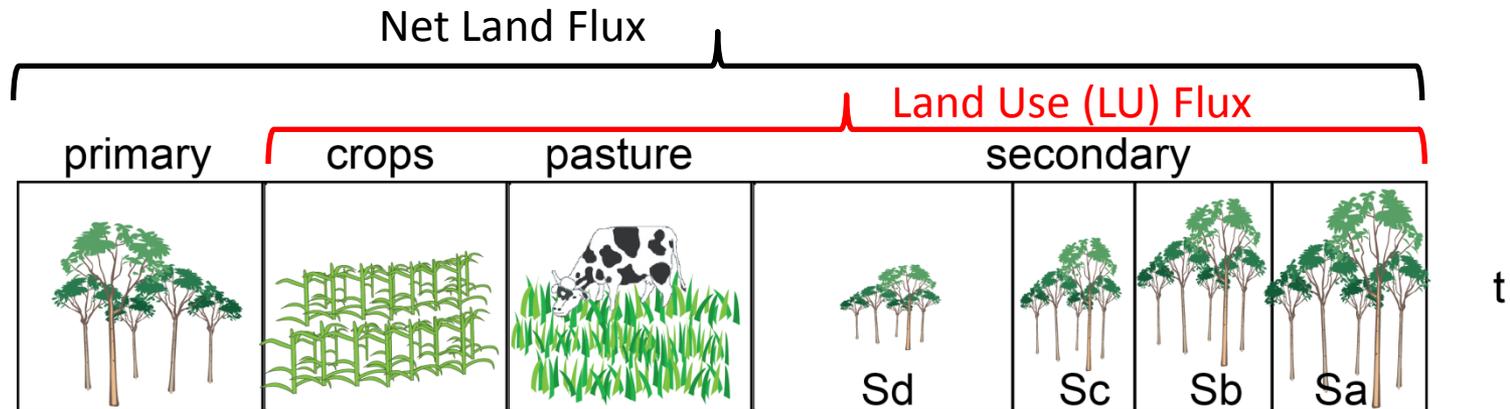
Earth System Model*



*CMIP5 definition; many other definitions of an ESM possible



LM3 Sub-grid-cell heterogeneity and age structure



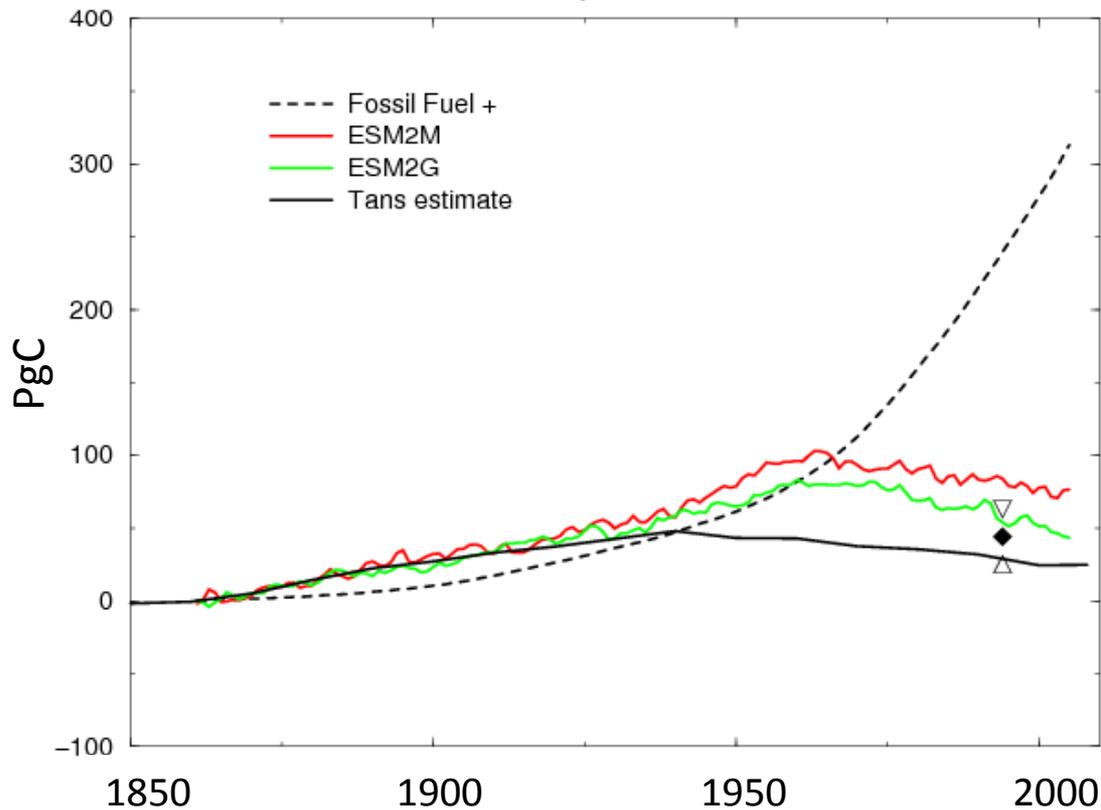
- Typical grid size 1 degree \approx 100 km
- Disturbances occur at much smaller scales
- LM3 uses independent land tiles within each grid cell
 - Primary forest, secondary forest, pasture, crops are separate tiles
 - Multiple tiles represent secondary forest age structure
 - New secondary tiles generated by wood harvesting and ag abandonment
 - Each tile has independent vegetation, soil, hydrology and atmospheric fluxes
 - Light competition and canopy changes are not explicitly simulated

Implementation of disturbance varies by ESM

| Model | Dynamic Veg | Harvest | Fire | Other mortality | Age structure |
|--------------|-------------|---------|------|--|---------------|
| BCC-CSM1.1 | N | N | N | ? | N |
| CanESM2 | N | N | Y | Bioclimatic limits | N |
| CESM1-BGC | N | Y | Y | Includes heat stress, bioclimatic limits | N |
| GFDL-ESM2G | Y | Y | Y | Constant | Y |
| GFDL-ESM2M | Y | Y | Y | Constant | Y |
| HadGEM2-ES | Y | N | N | Constant | N |
| IPSL-CM5A-LR | N | N | Y | Includes heat stress, bioclimatic limits | N |
| MIROC-ESM | Y | Y | N | Includes heat stress, bioclimatic limits | Y |
| MPI-ESM-LR | Y | Y | Y | Includes wind | N |
| NorESM-ME | N | Y | Y | Includes heat stress, bioclimatic limits | N |

Biggest area for improvement: natural mortality rates

Cumulative Land Carbon Flux into Atmosphere



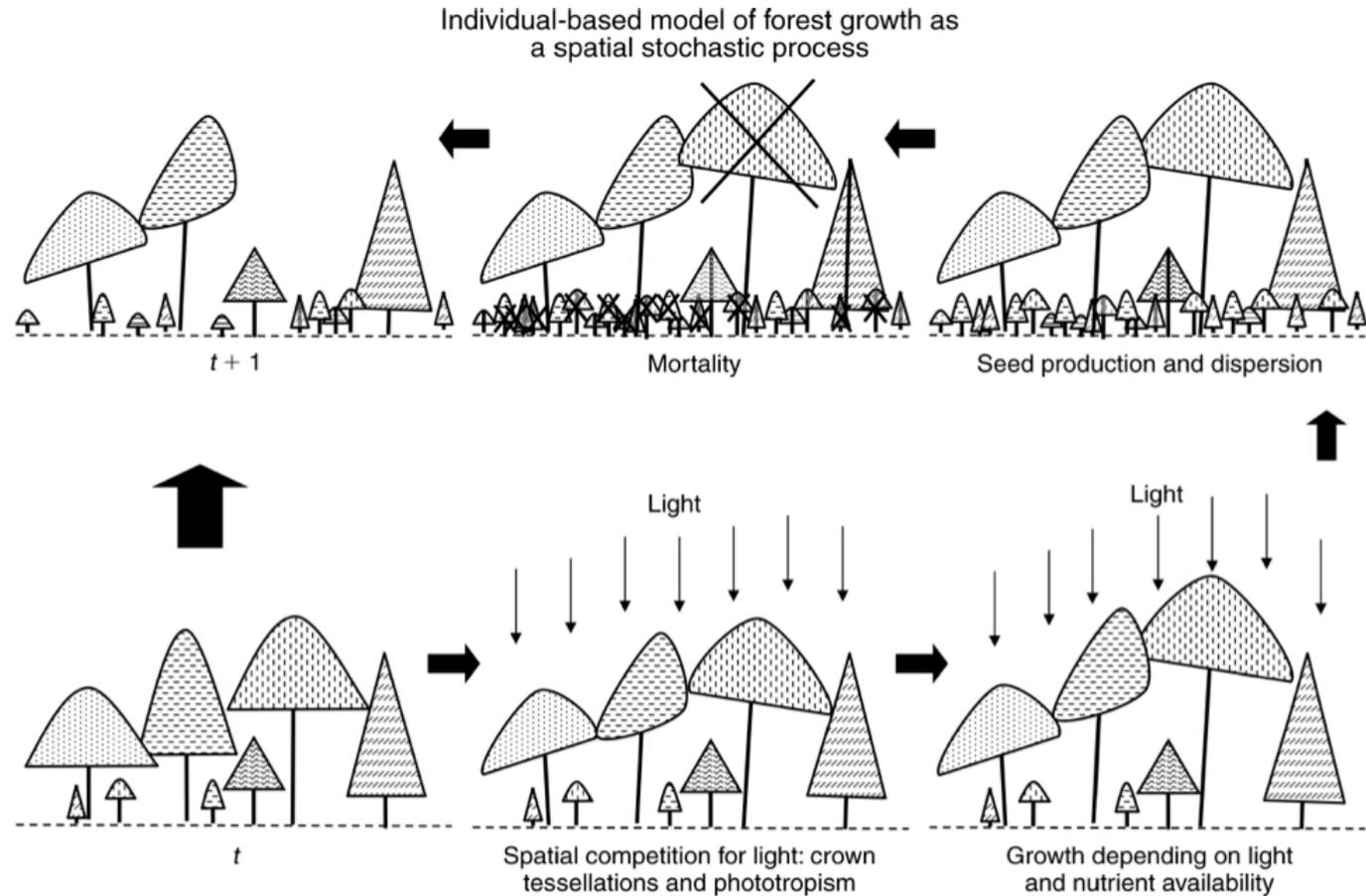
Tans = Tans 2009 estimate

Fossil fuel + = FF+cement = Boden et al. (ORNL)

- Green and red lines represent two ESM versions
- Value of natural mortality rate parameter was only major difference between land models
- We need better disturbance parameterizations
 - Age structure dependence
 - Climate dependence
 - Fire suppression scenarios
 - Wind and insect disturbances

Next generation of models

- Canopy dynamics
- Competition between individuals and species
- Effects of disturbance on forest structure



From Strigul *et al.* (2008)