24th June, 2008, Hokkaido University, Sapporo
Symposium: Drastic Change in Earth System during Global Warming

# Model analysis of terrestrial response and feedback to global warming

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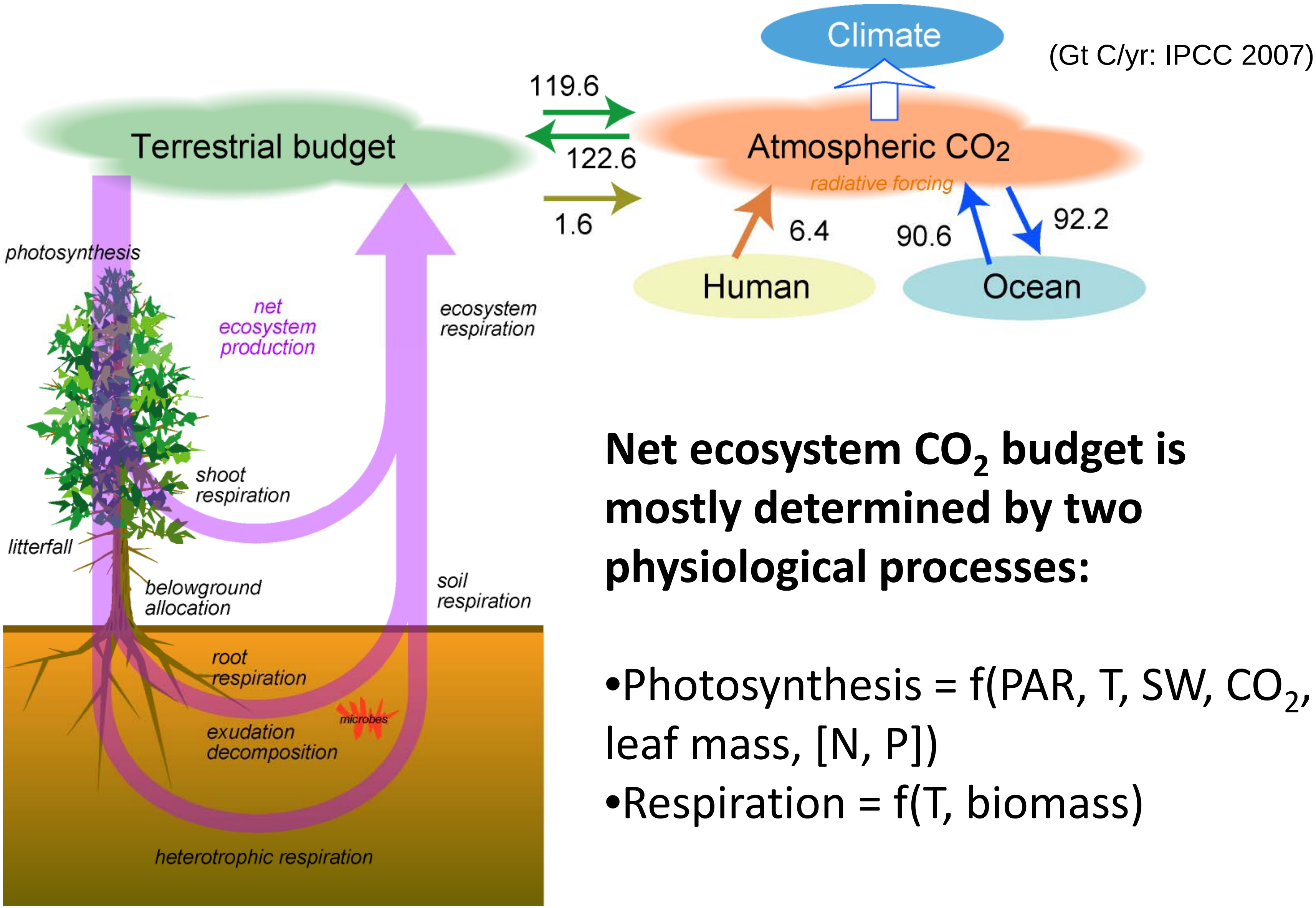
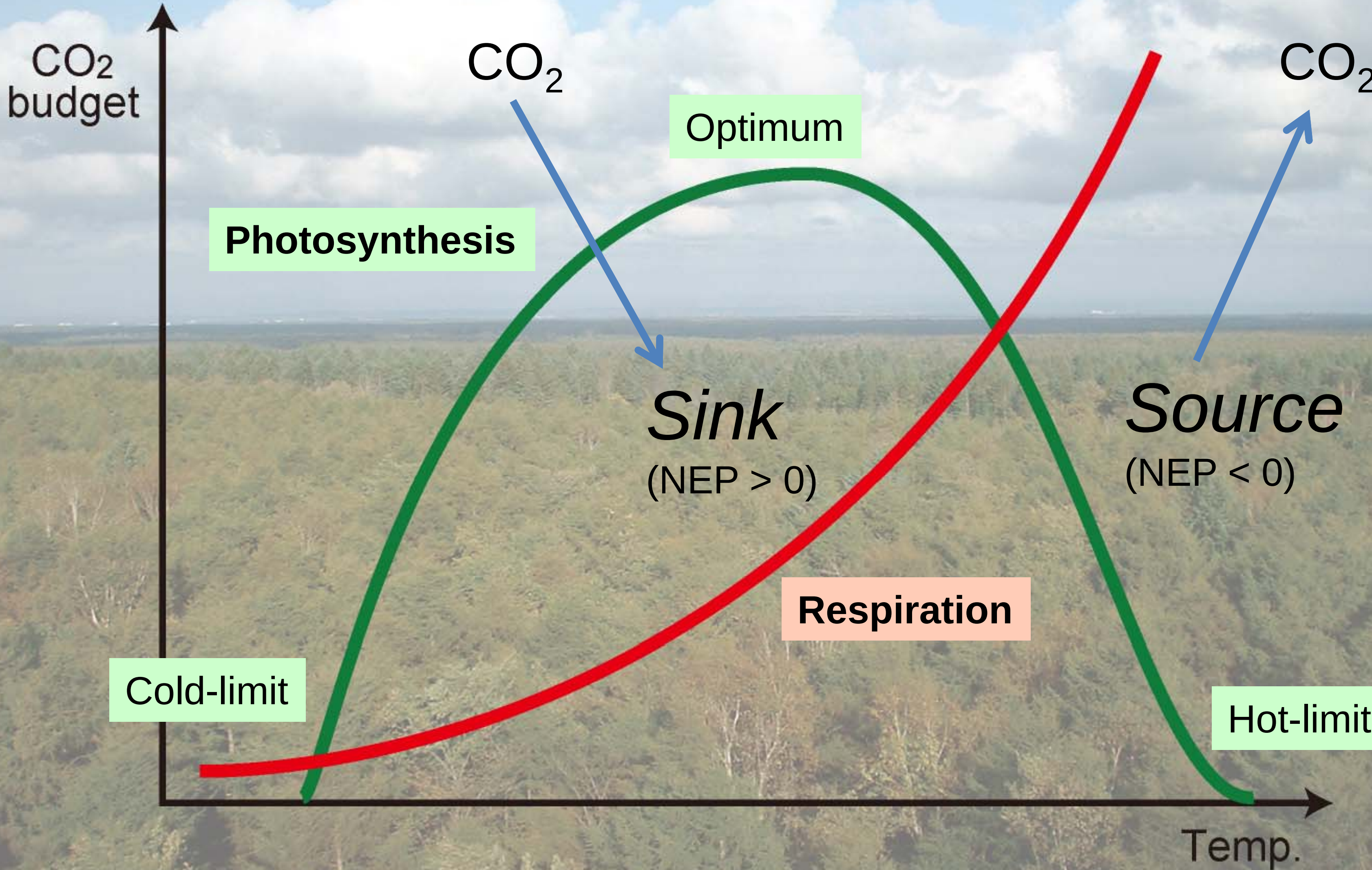
# Ecosystem Carbon Budget




**Net ecosystem $CO_2$ budget is mostly determined by two physiological processes:**

- Photosynthesis = f(PAR, T, SW, $CO_2$, leaf mass, [N, P])
- Respiration = f(T, biomass)

# *Response to warming: physiology*



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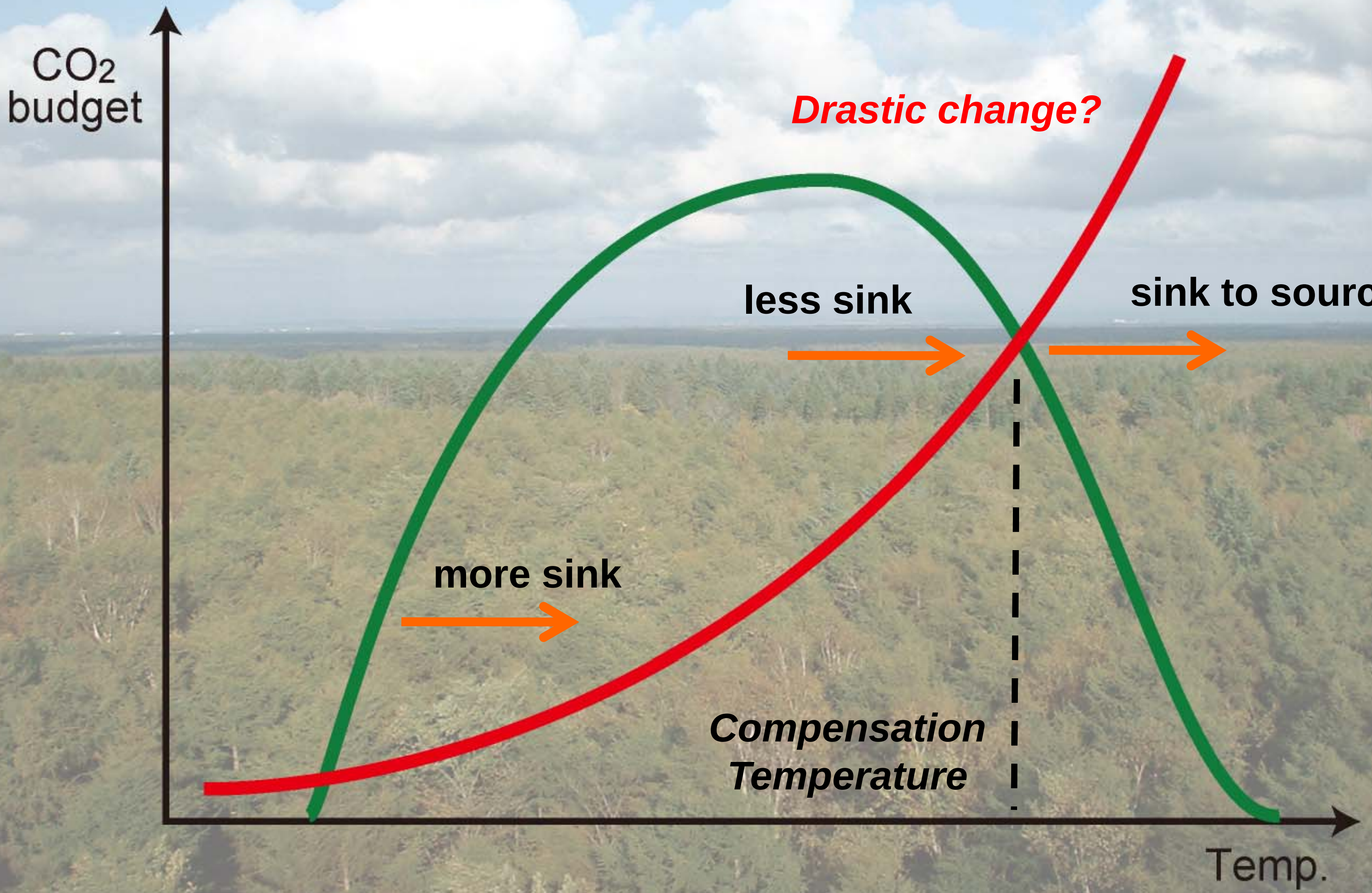
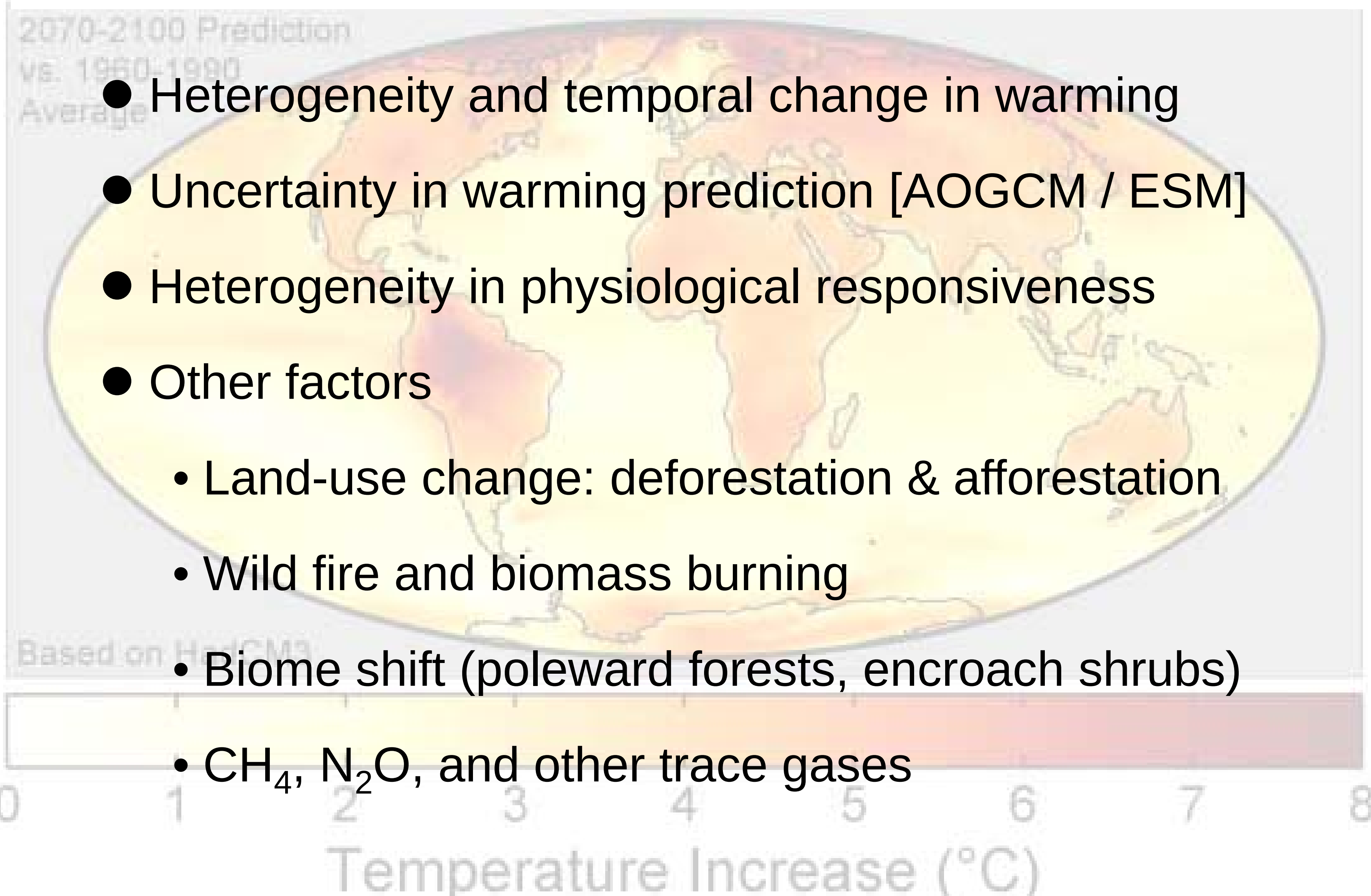
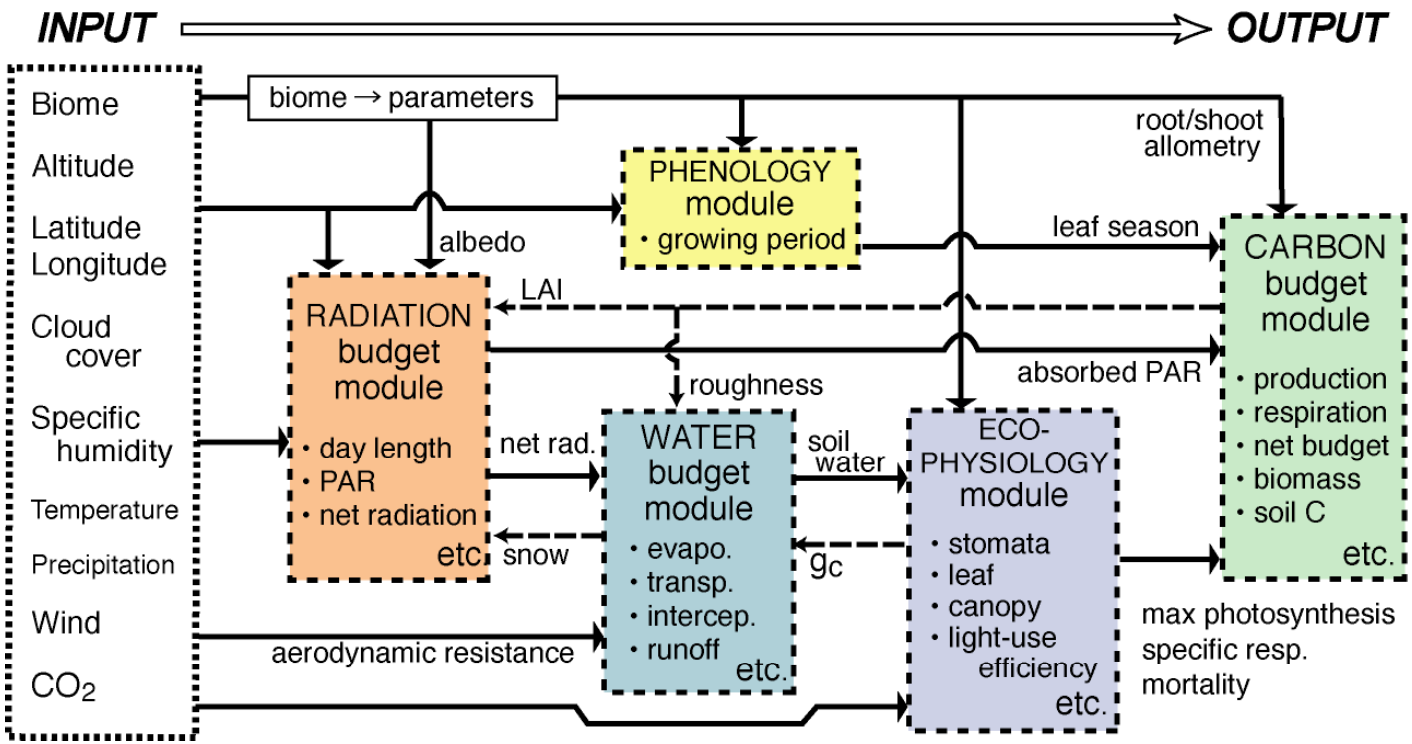


# *Difficulties*




- Heterogeneity and temporal change in warming
- Uncertainty in warming prediction [AOGCM / ESM]
- Heterogeneity in physiological responsiveness
- Other factors
  - Land-use change: deforestation & afforestation
  - Wild fire and biomass burning
  - Biome shift (poleward forests, encroach shrubs)
  - $CH_4$, $N_2O$, and other trace gases

# *Current Modeling*



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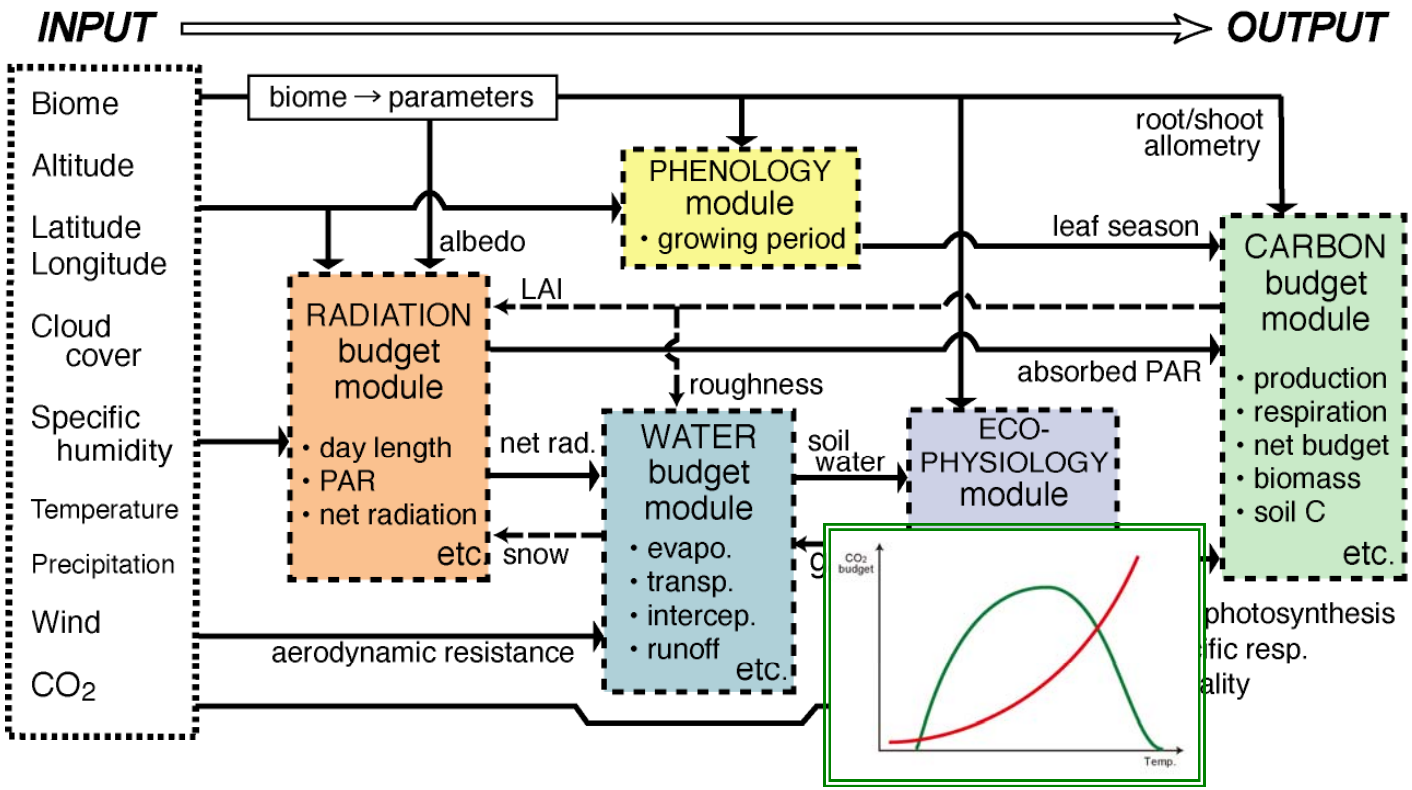

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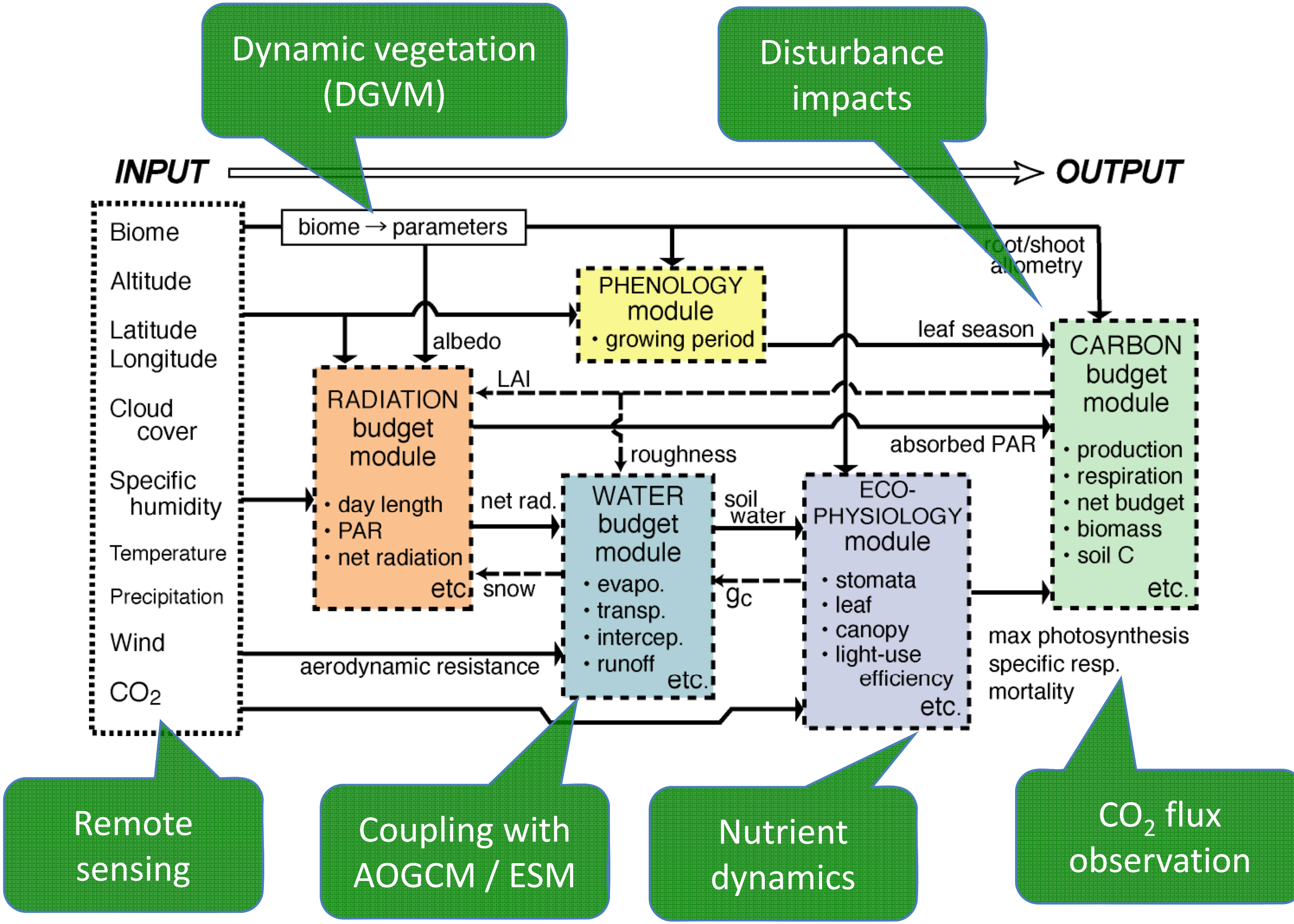
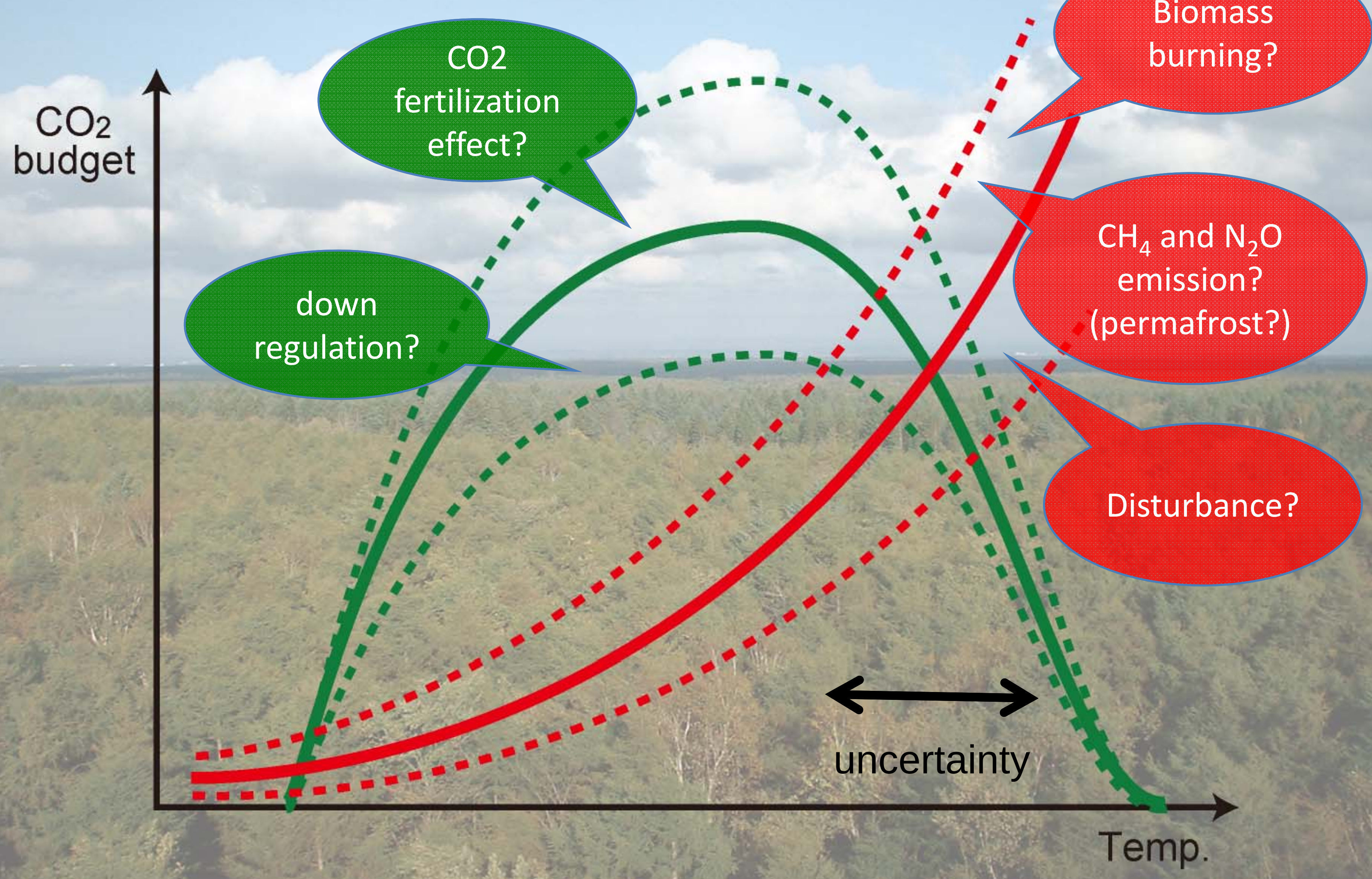
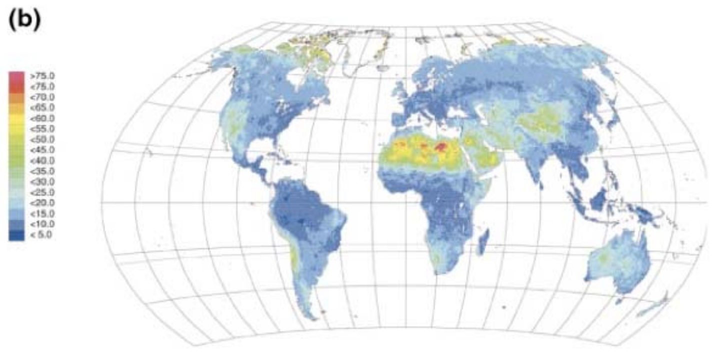


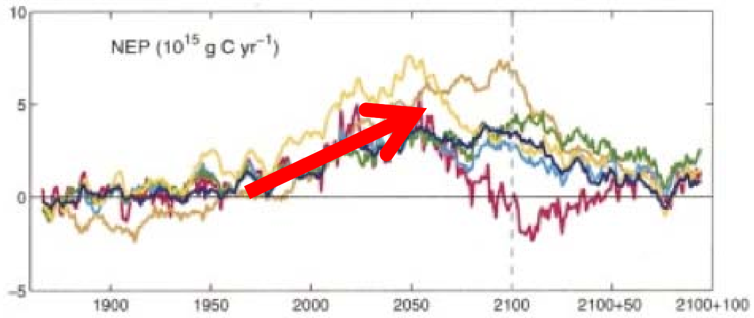
# *Other factors*



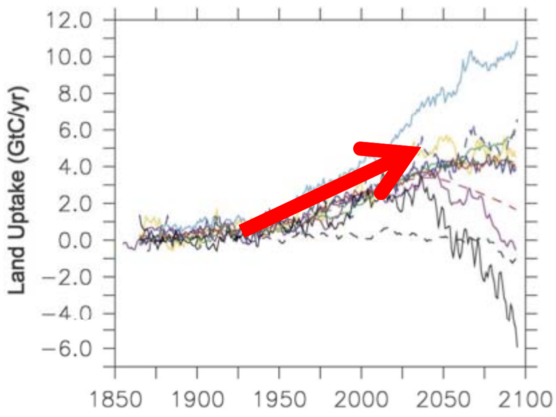
# *Model uncertainty*




Cramer et al. (1999)
17 model NPP estimations:
30 – 80 Gt C / yr

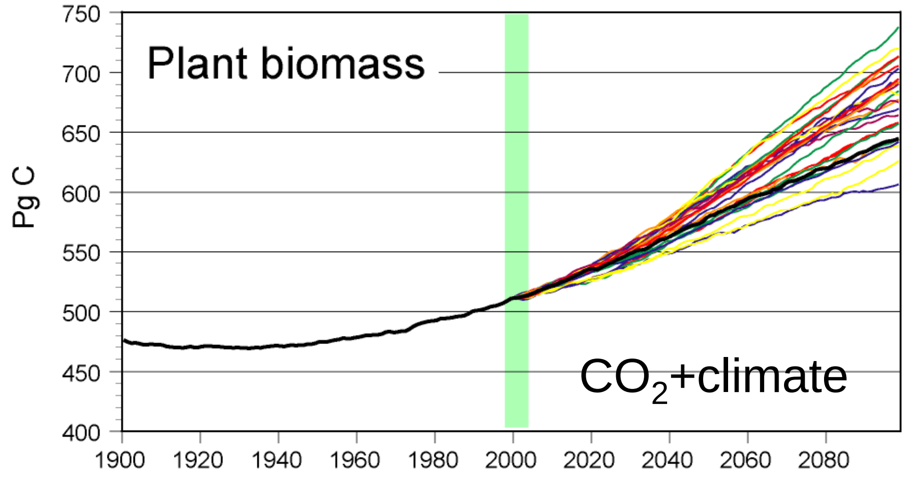


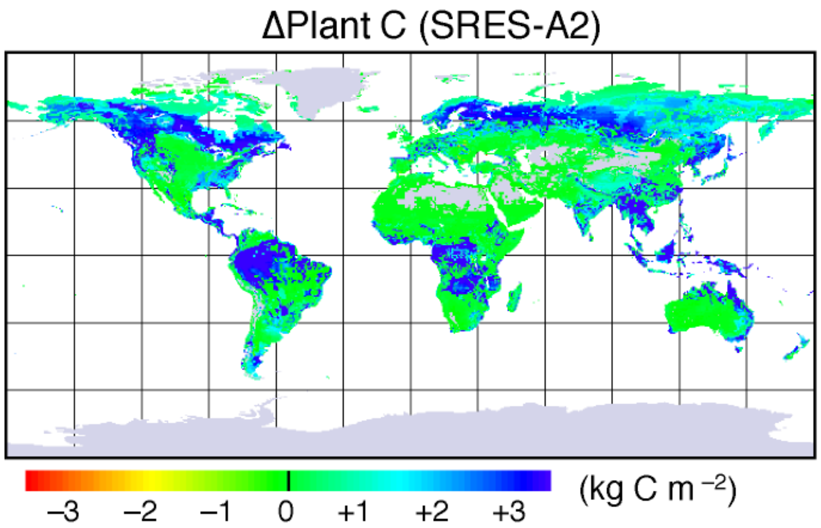

Cramer et al. (2001)
6 DGVMs:
different NEP & biome shift

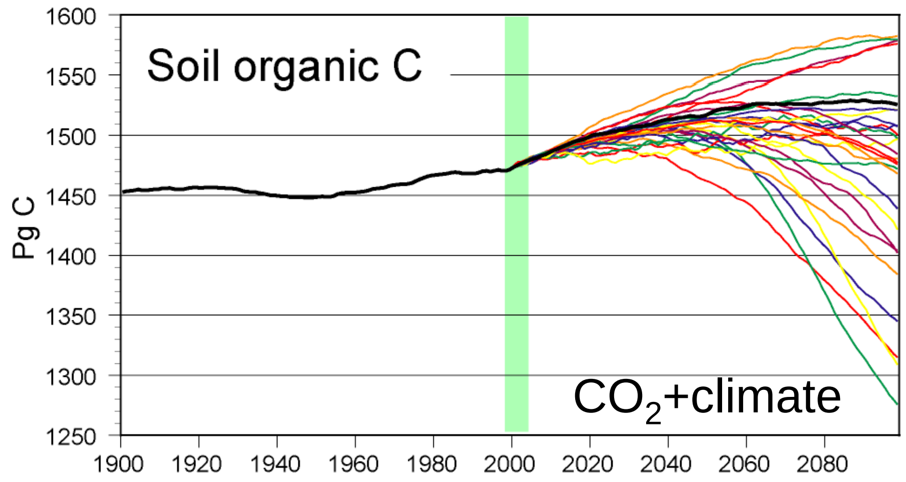


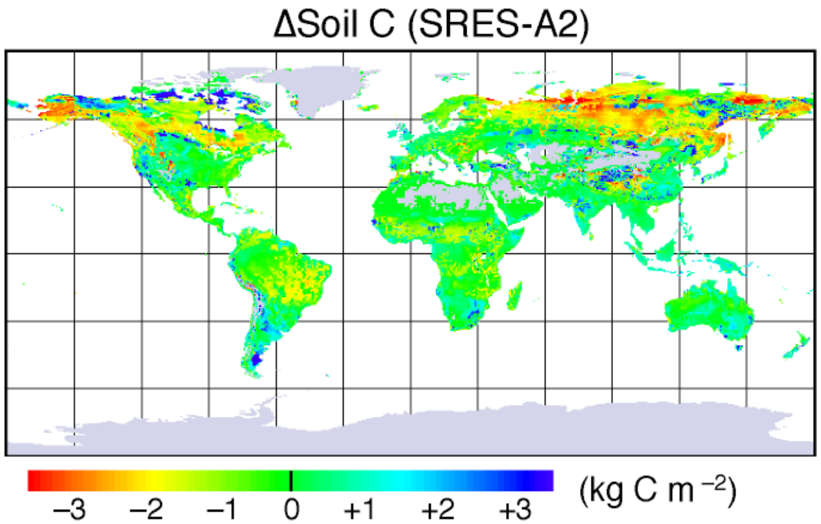

Friedlingstein et al. (2006)
11 climate-carbon cycle models:
different carbon feedbacks

# *Physiological Response*




Model: SimCYCLE-VISIT (Ito, 2005)

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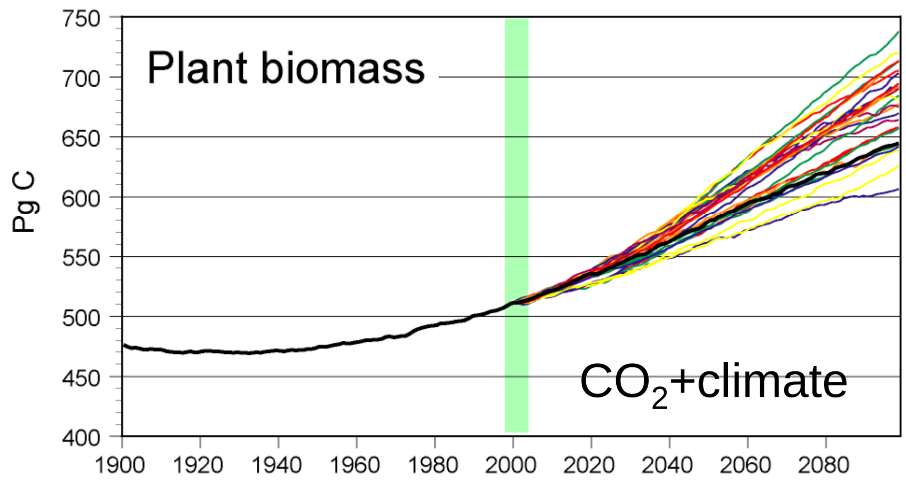
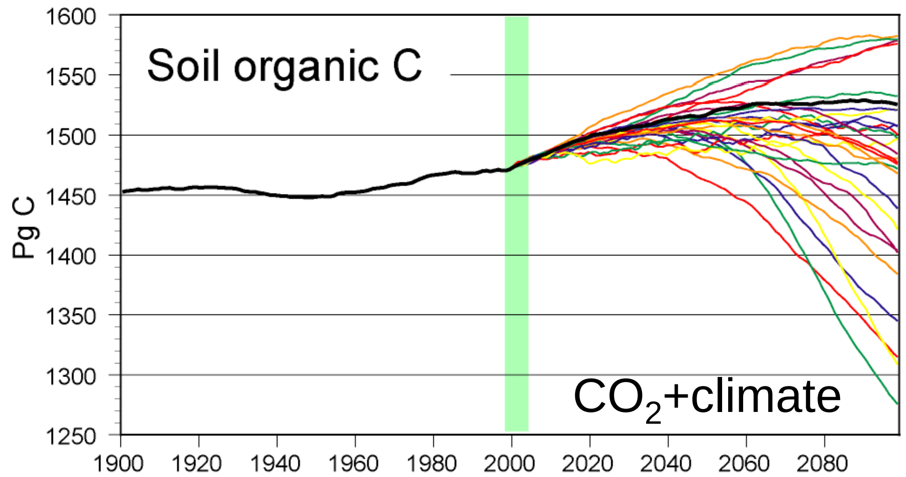
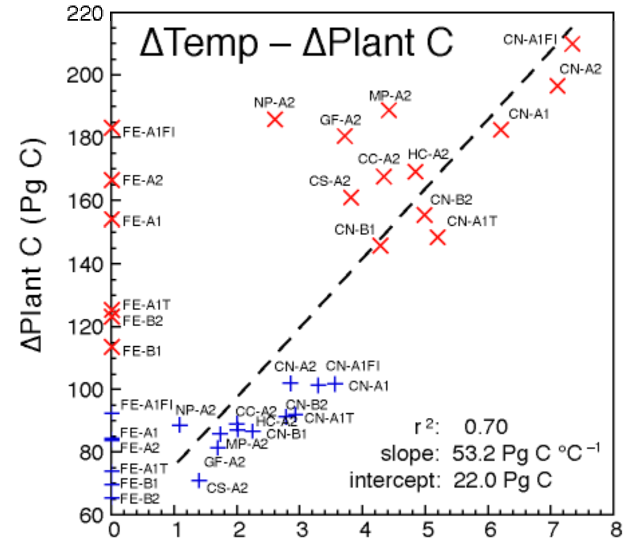
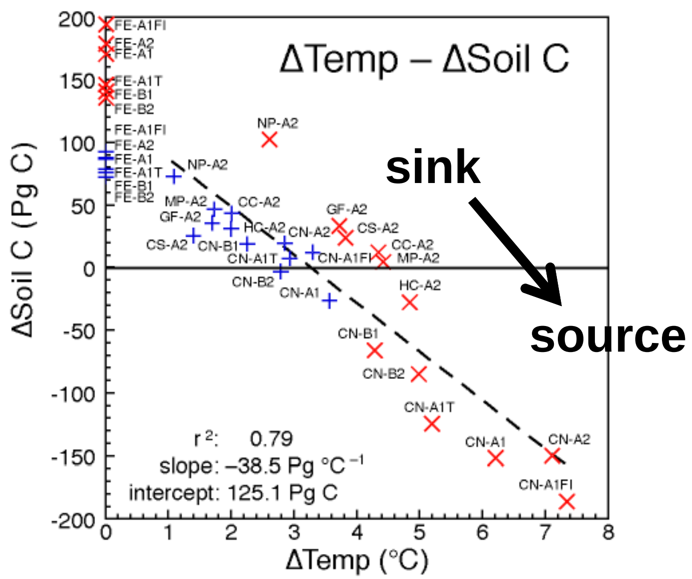


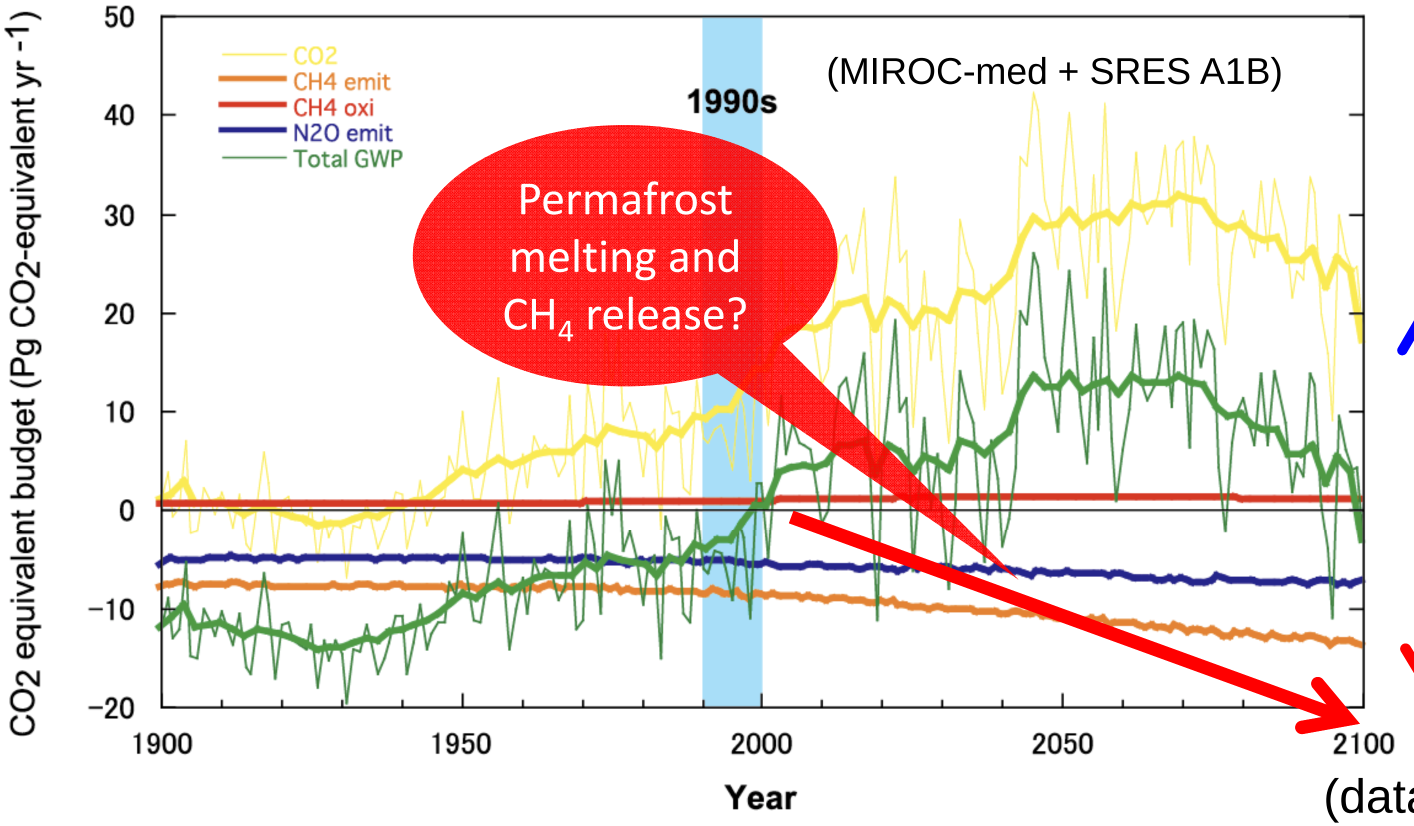




Model: SimCYCLE-VISIT (Ito, 2005)

# *Effects of $CH_4$ and $N_2O$*

Biogeochemical exchange of non-$CO_2$ greenhouse gases ($CH_4$ and $N_2O$) is potentially important. The total budget of Global Warming Potential (GWP) can be different from NEP.




100-year GWP
$CO_2$: 1
$CH_4$: 25
$N_2O$: 298

(data: M.Inatomi)

# Disturbance: local but drastic

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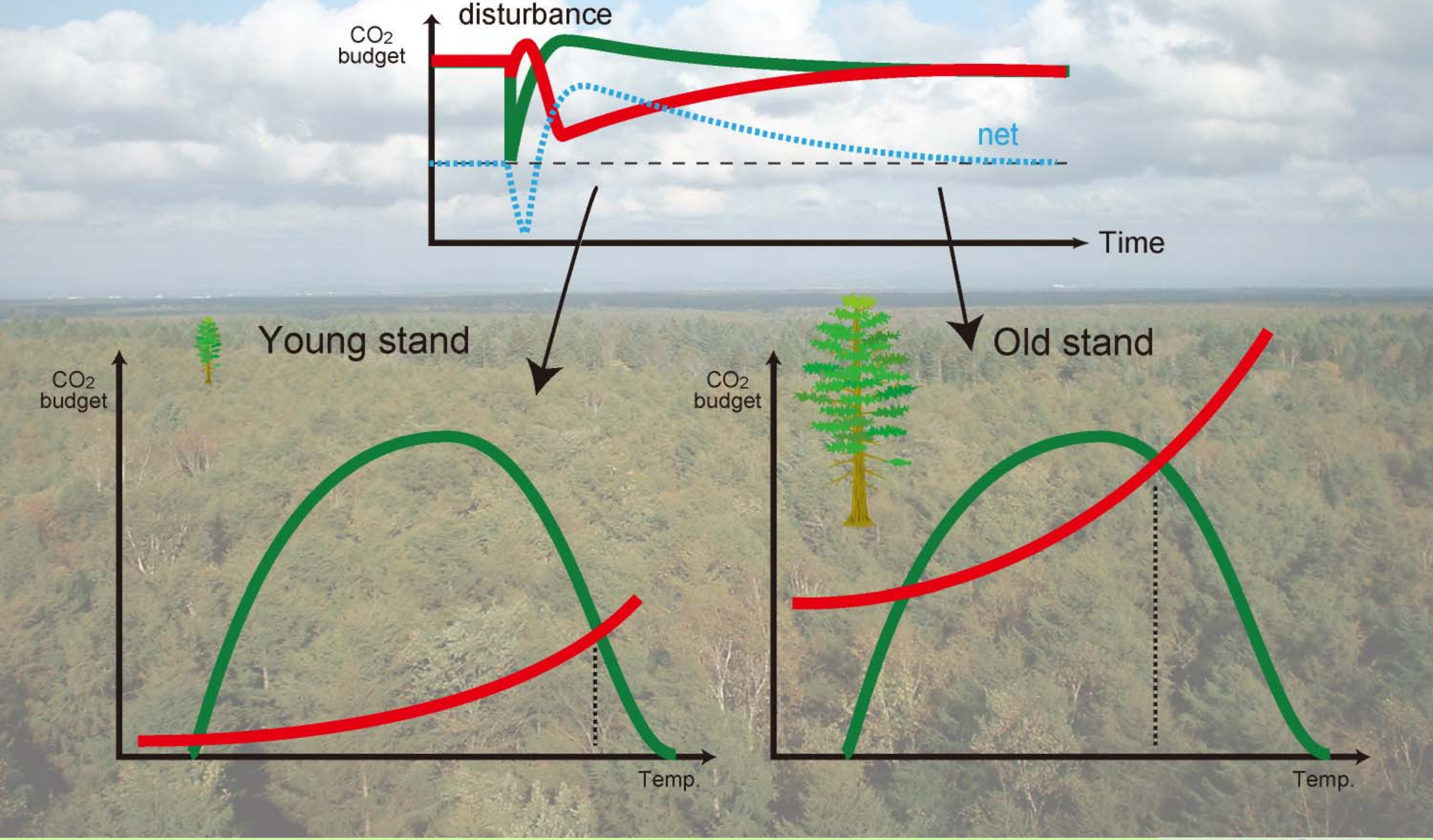


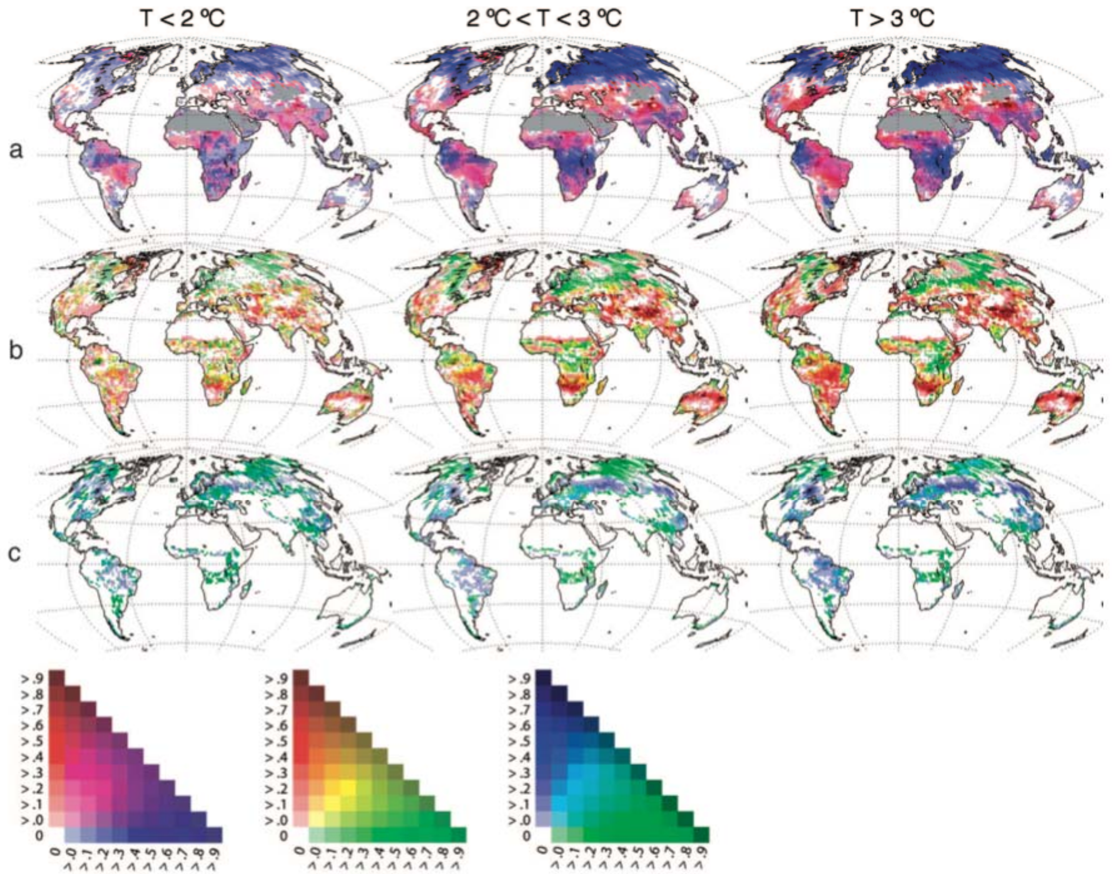
# *Ecological Risk Assessment*

Probabilistic evaluation based on multiple scenarios.

Runoff increase

Carbon release

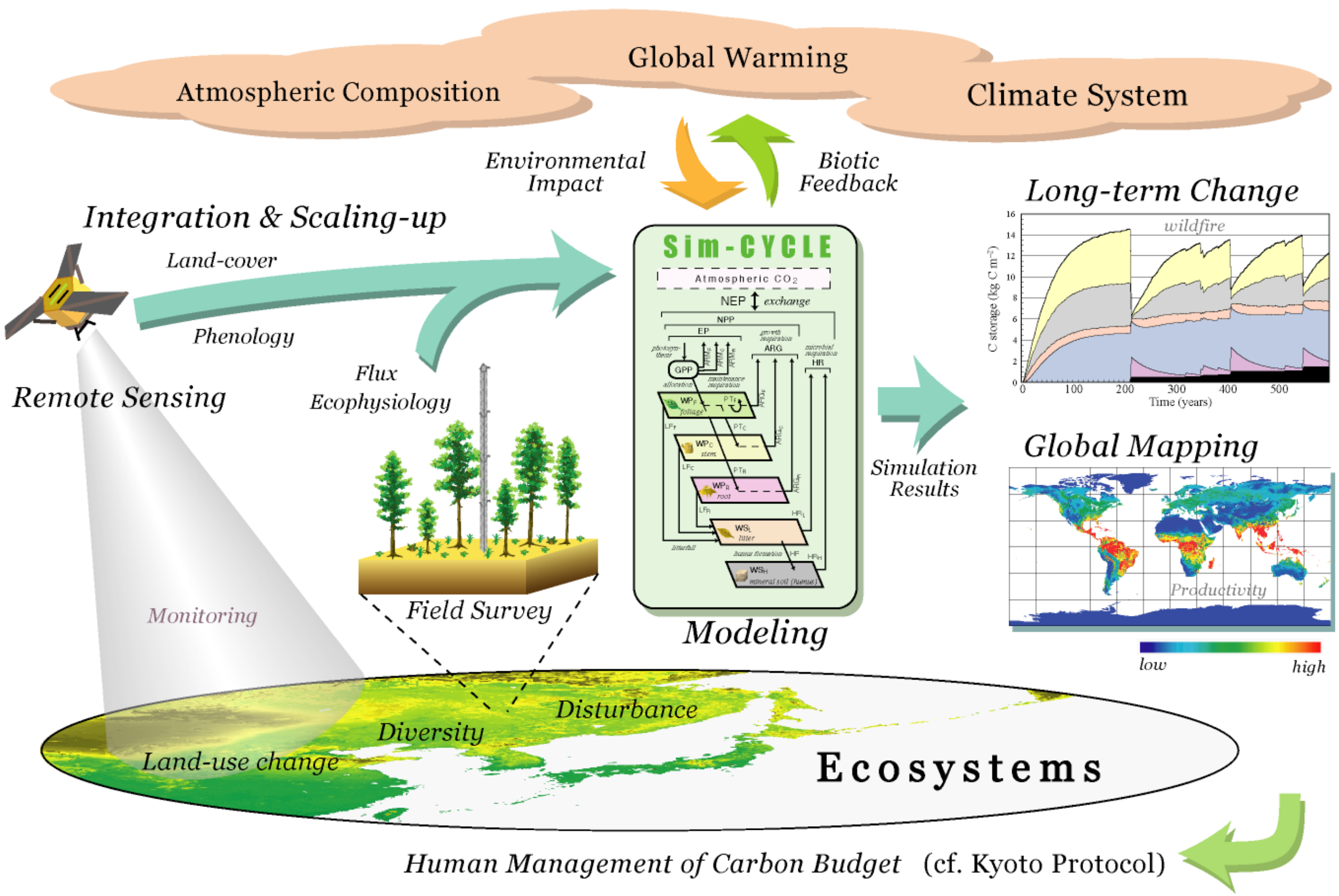
Forest decrease




Scholze et al. (2006): Using LPJ model, ecological risks under climate change were investigated: high risk of river floods, carbon source, and biome shift.

# *Integrated Research*

## *Intimate linkage between observation and modeling*



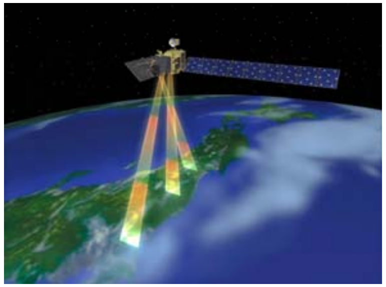
# Earth Observations

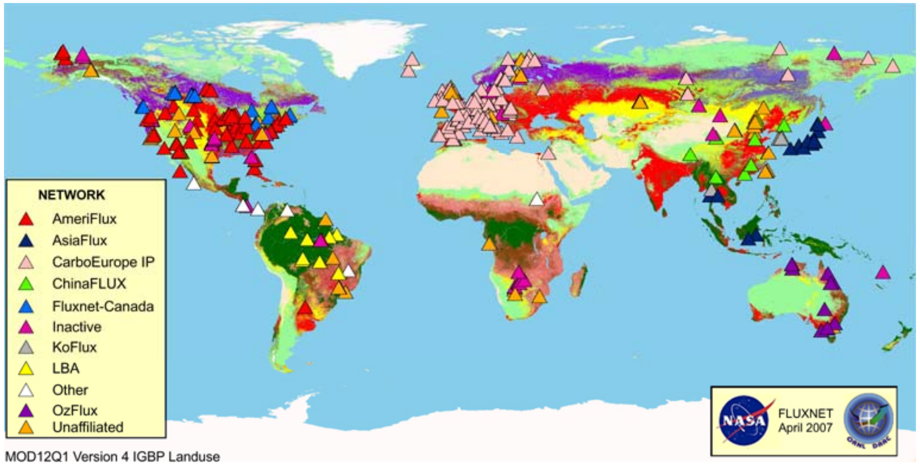
**Flux measurement – bottom-up**

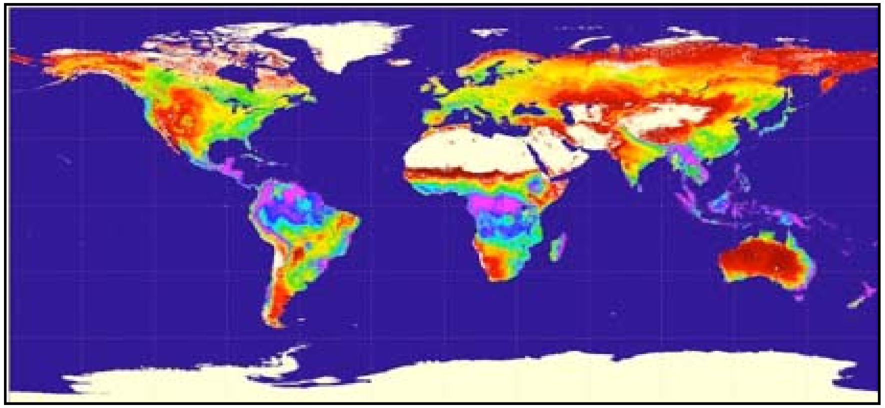
- global coverage (over 500 sites)
- site scale ($km^2$)
- long-term continuous (max. 15 years)
- NEE (GPP / Re)

**Satellite observation – top-down**

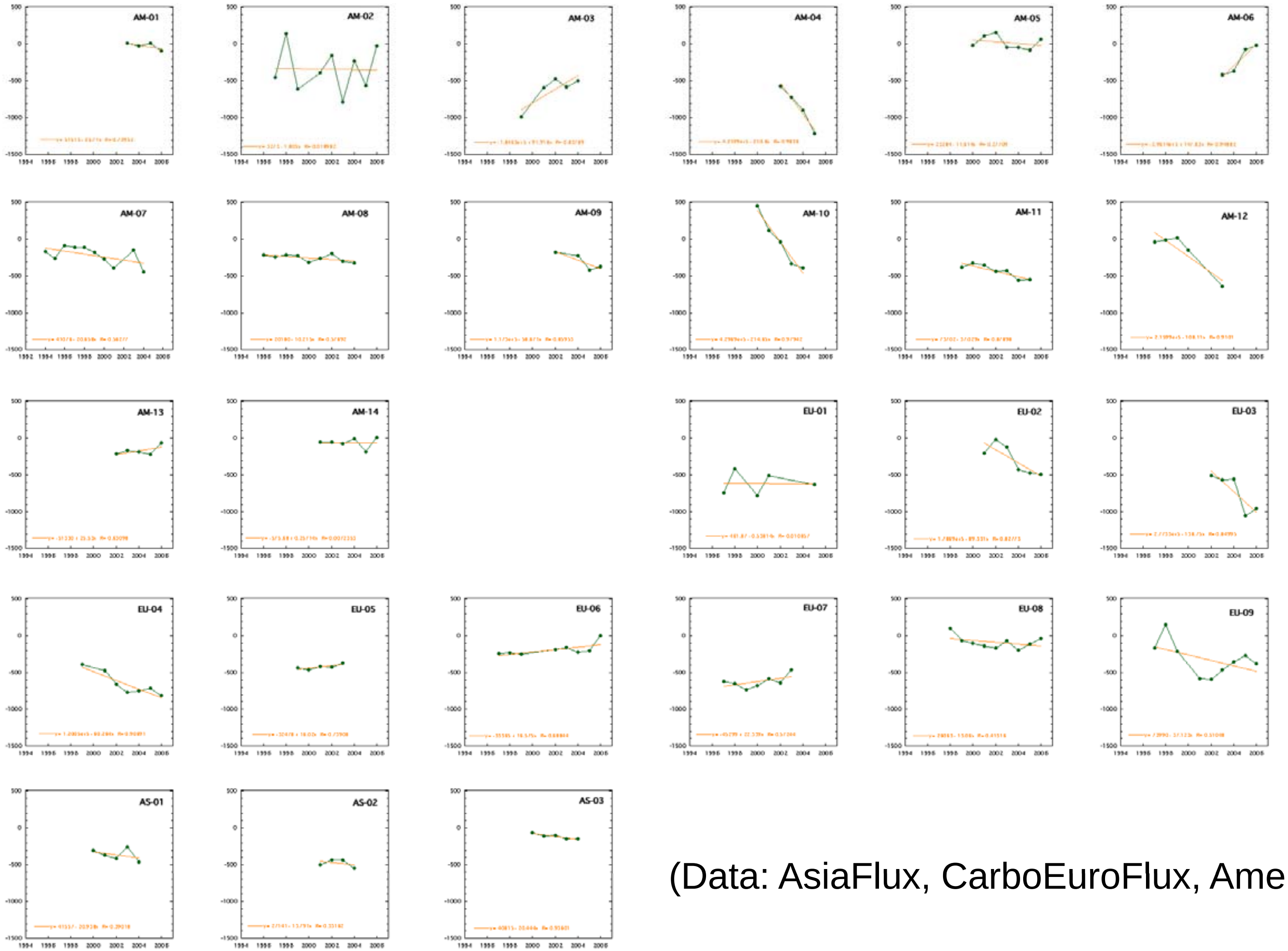
- global coverage
- global scale ($10^8$ $km^2$)
- long-term continuous (max. 25 years)
- NDVI, LAI, fAPAR, NPP, land cover etc.

# *Observed $CO_2$ Budget*




(Data: AsiaFlux, CarboEuroFlux, AmeriFlux)

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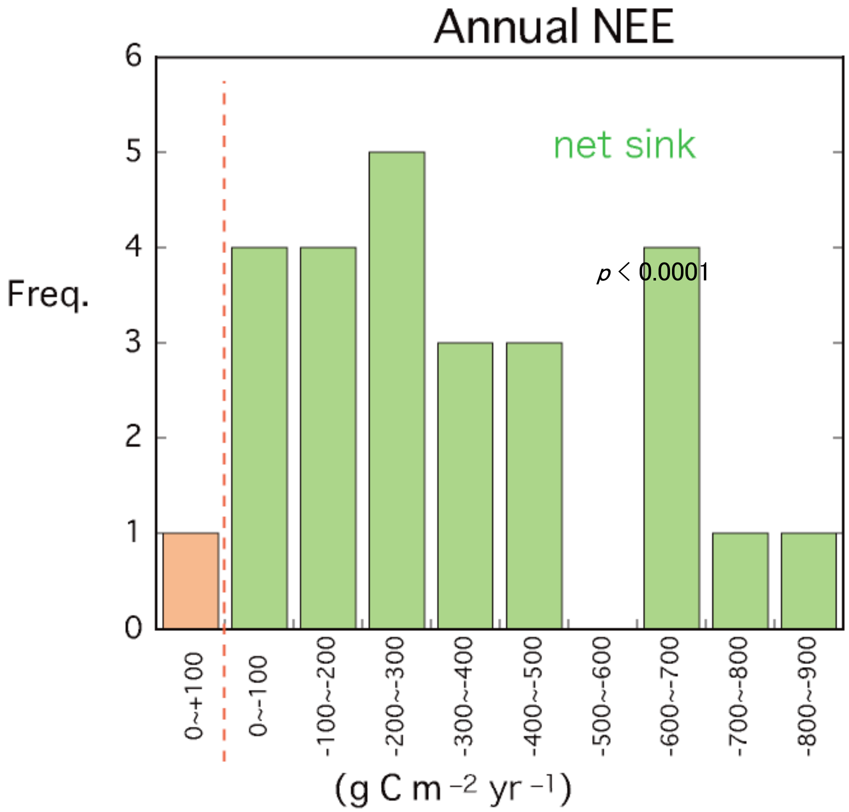


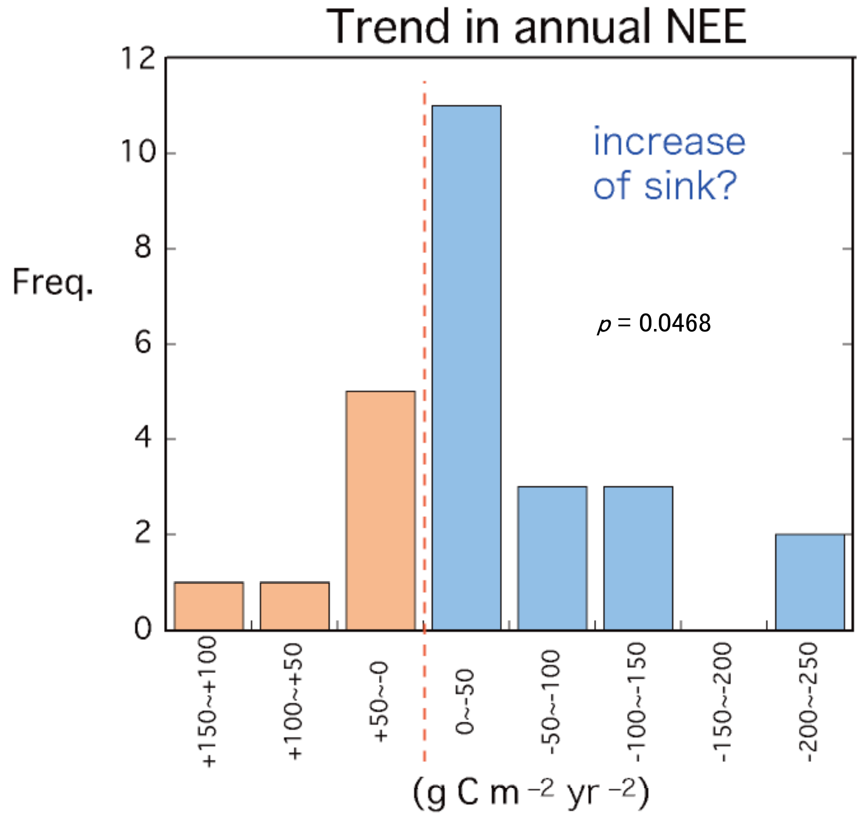

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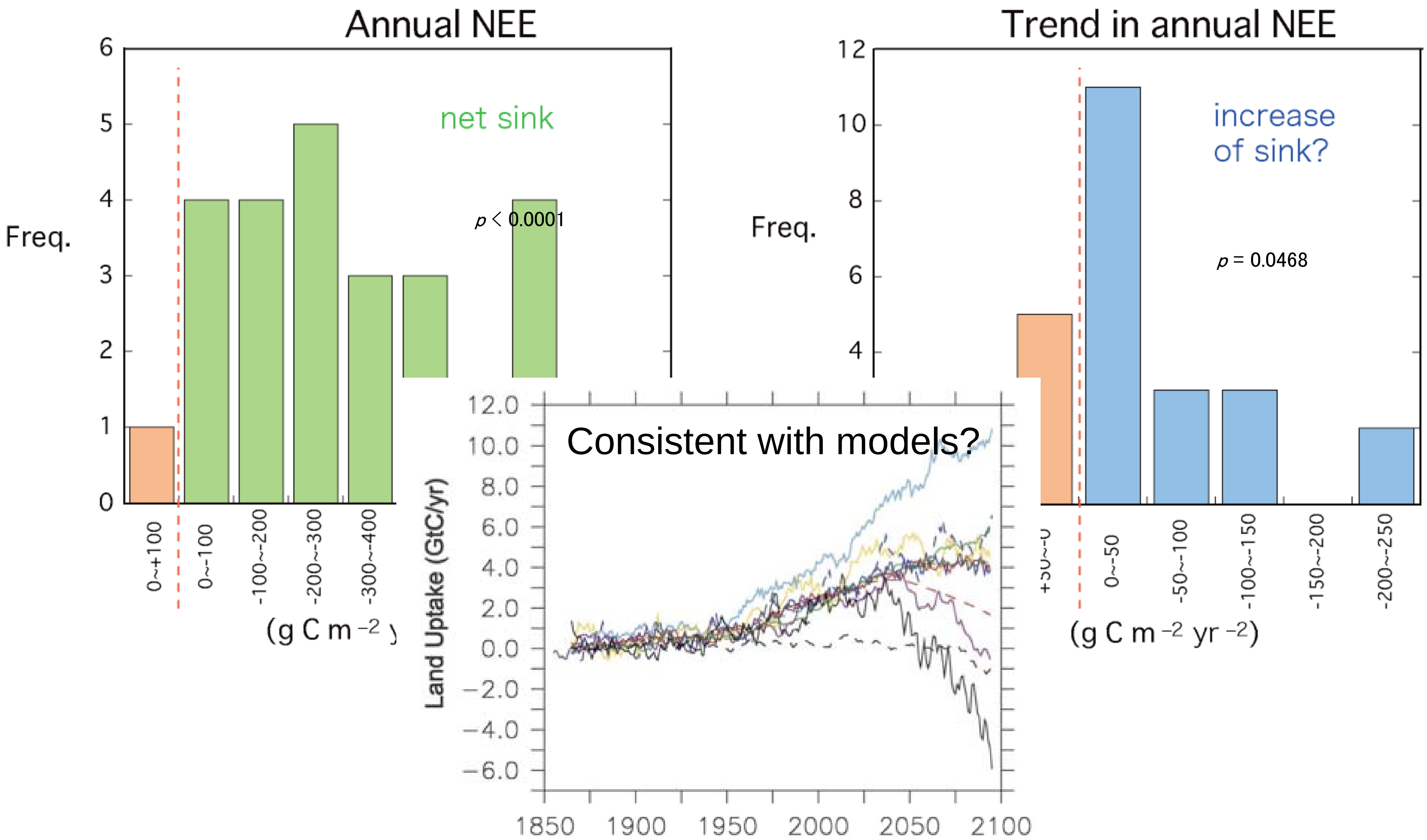
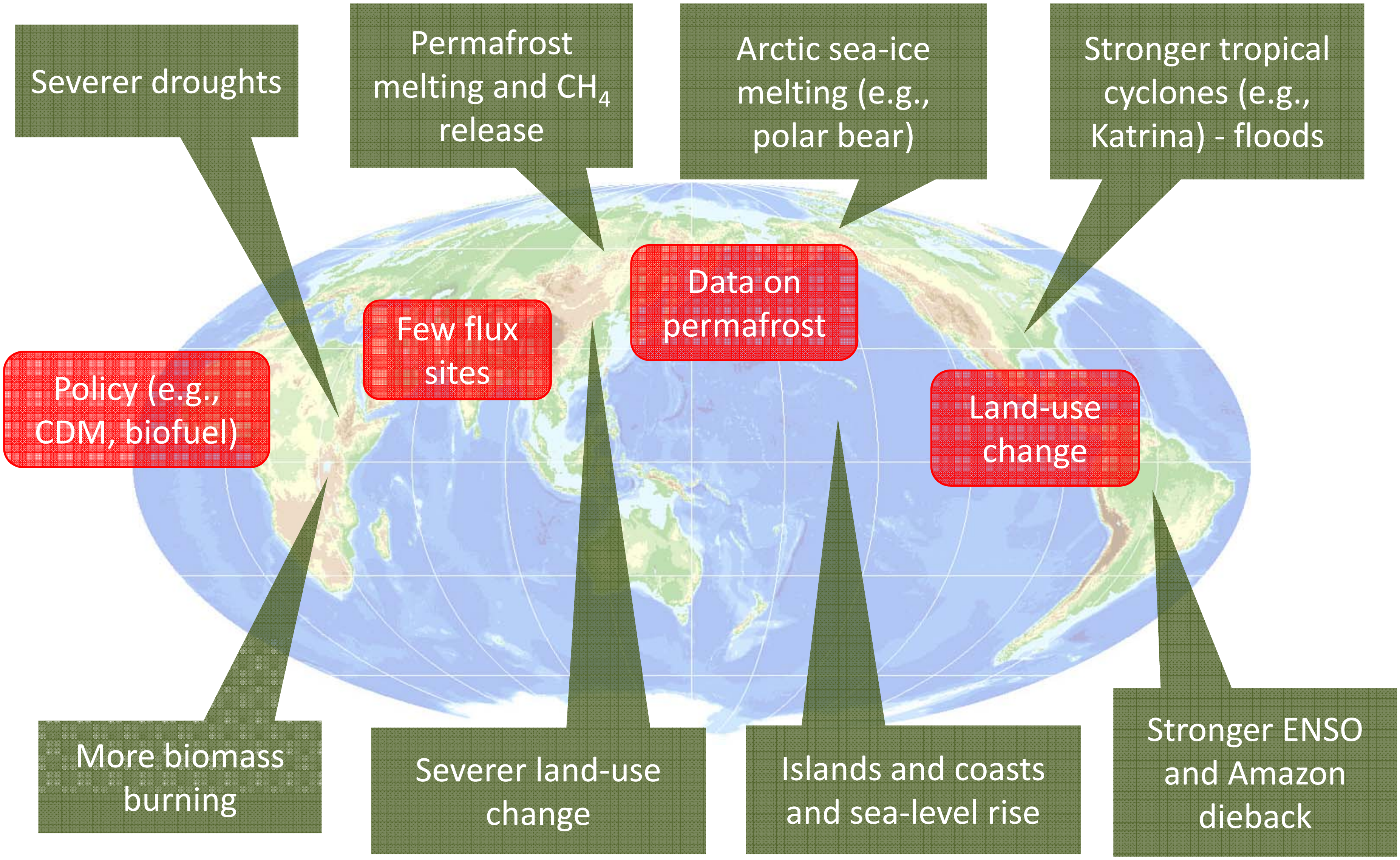


# Key Vulnerabilities & Gaps



# *Concluding Remarks*

- Because of $CO_2$ fertilization and climatic warming, terrestrial ecosystems would act as a net carbon sink (negative feedback) by ca. 2050, but turn to a net source by the end of 21$^{st}$ century.

- There remain large uncertainties in responsiveness to elevated $CO_2$, temperature, and precipitation change.

- Additional processes such as $CH_4$ and $N_2O$ exchange, land-use change, and biomass burning may not be negligible but can strongly affect net response (feedback) to global warming.

- Further studies, especially Earth Observations, are required to understand ecosystem dynamics under global change, improve models, and make more reliable predictions.


Thank you