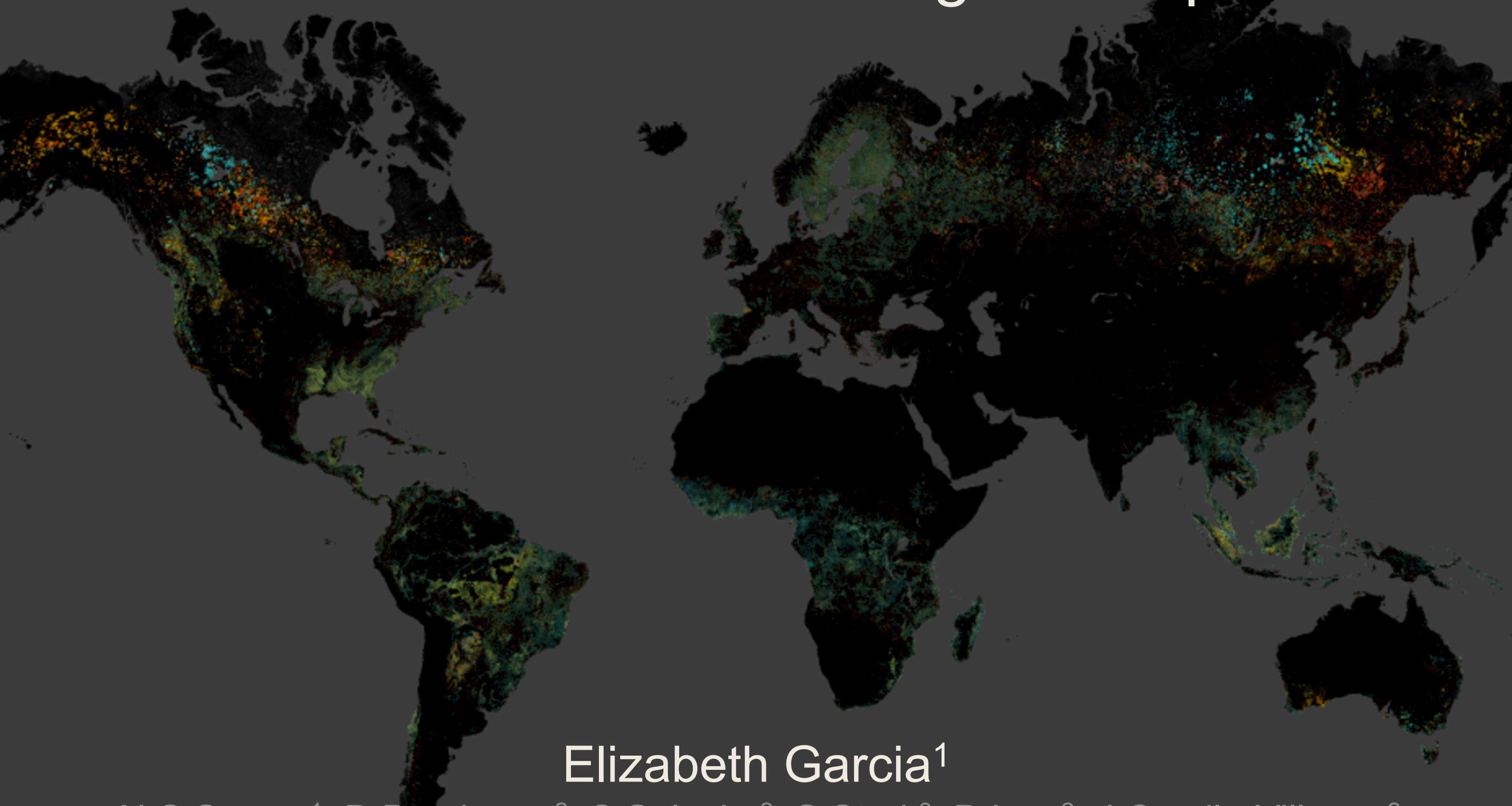
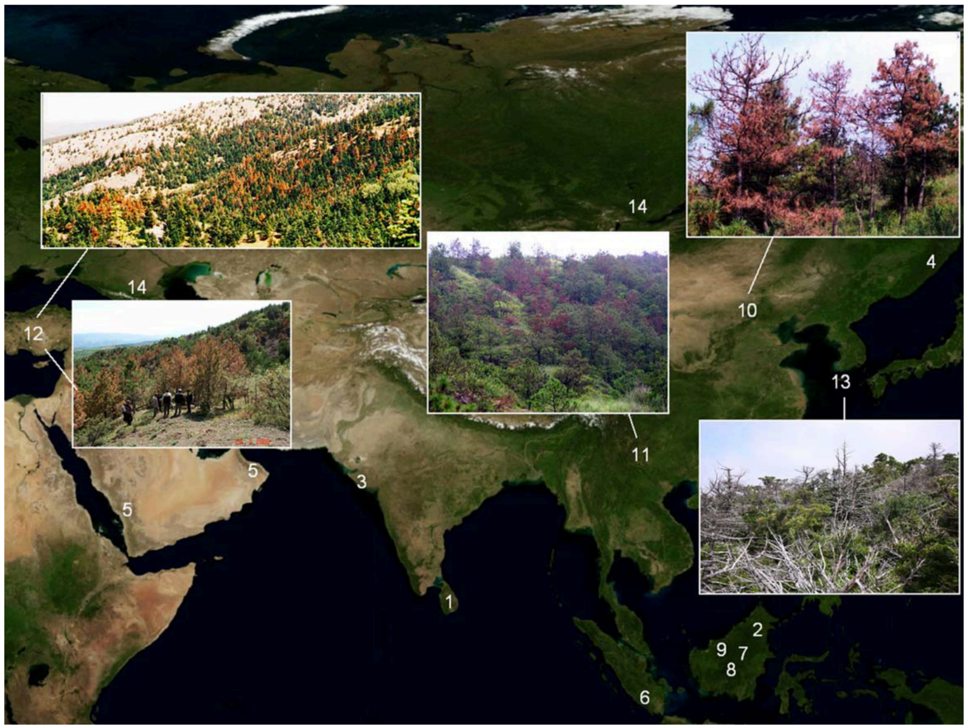
Extending assessment of climate teleconnections to account for diverse ecological responses

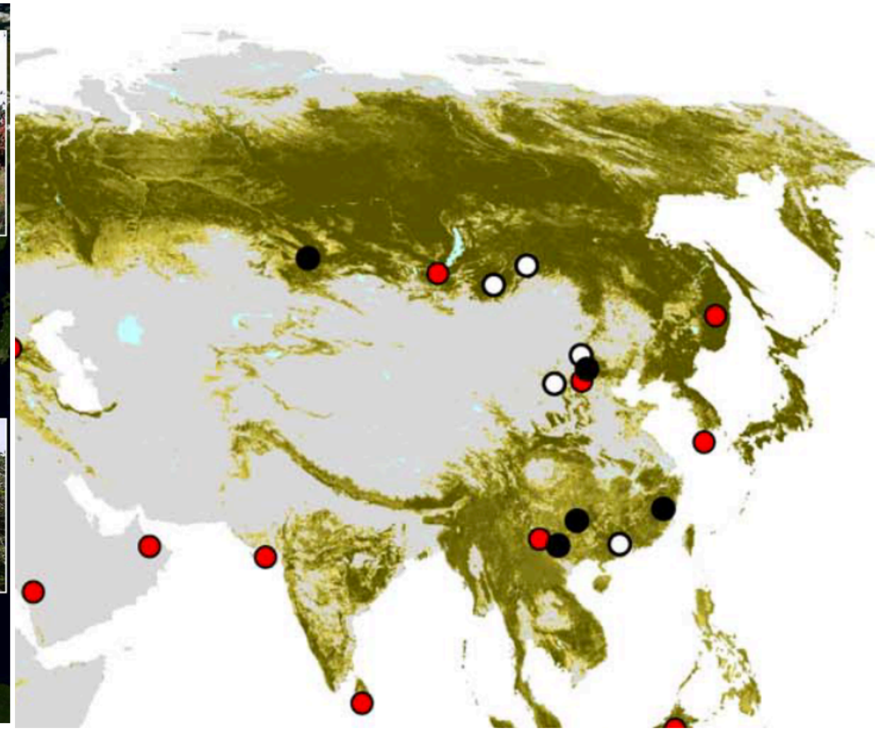


Elizabeth Garcia[1]
ALS Swann[1], D Breshears[2], S Saleska[2], S Stark[3], D Law[2], J Camilo-Villegas[2]
[1]University of Washington, [2]University of Arizona, [3]Michigan State University
NSF EF-1340649
Hansen et al., 2013

Increasing rates of forest loss due to

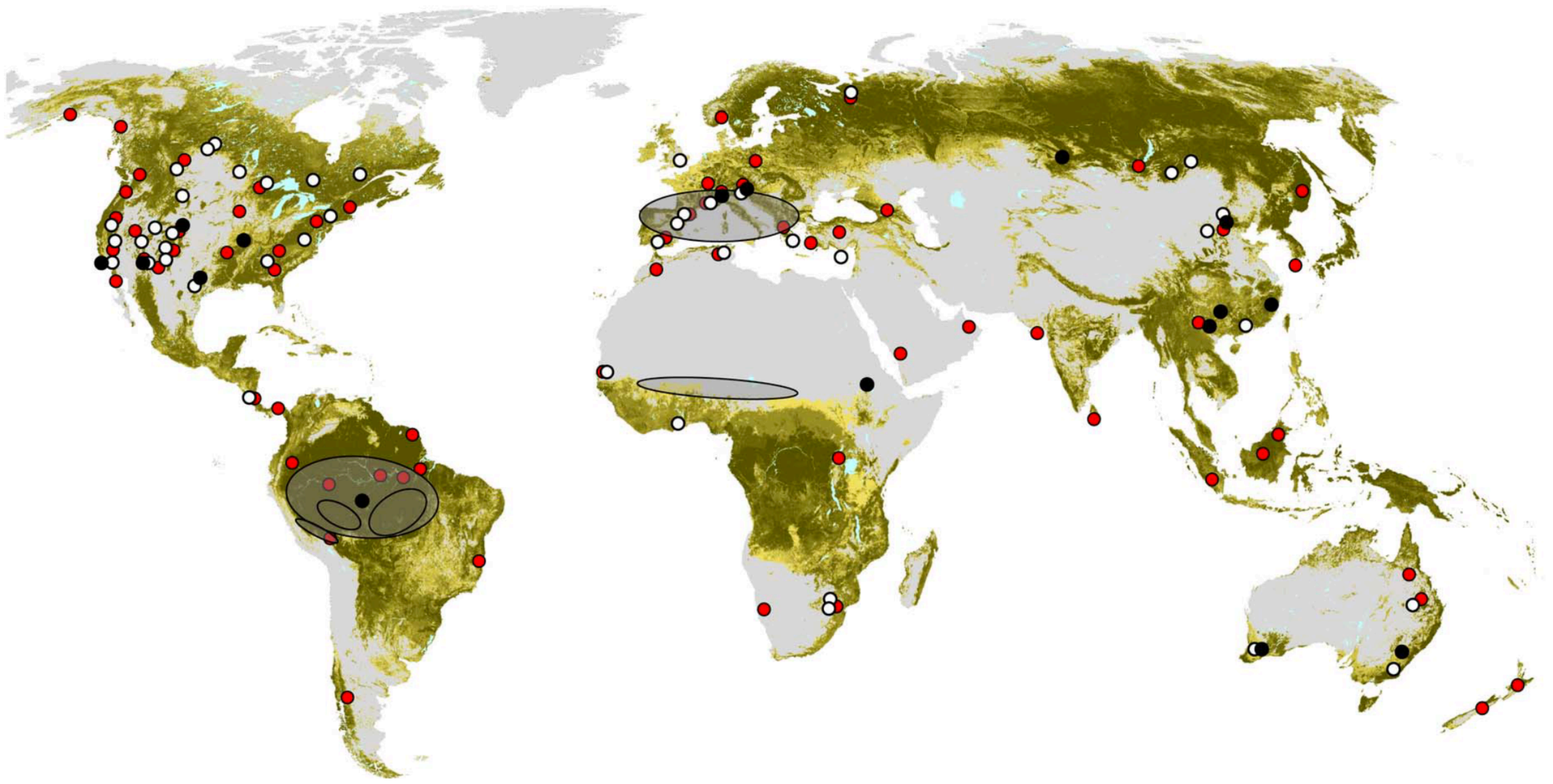
- Climate change (hotter, drier)
- Climate related disturbances (fire, bugs)
- Conversion for urban expansion/agriculture





Allen, Breshears, and McDowell. 2015. Ecosphere
Allen, et al. 2010. Forest Ecology and Mgmt.

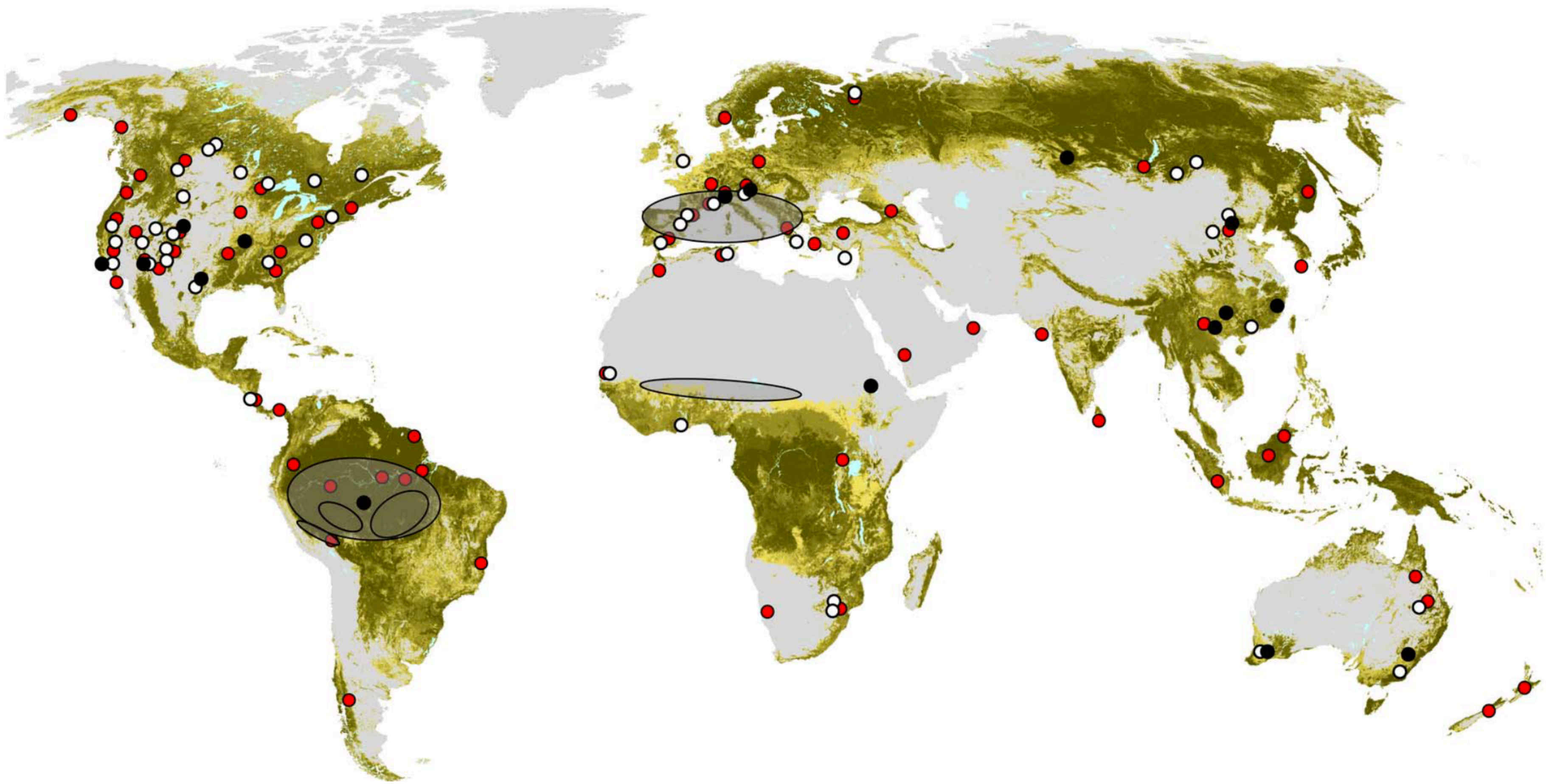
Accelerating forest loss → occurring worldwide



Allen, Breshears, and McDowell. 2015. Ecosphere

Accelerating forest loss → What are the global climate impacts?

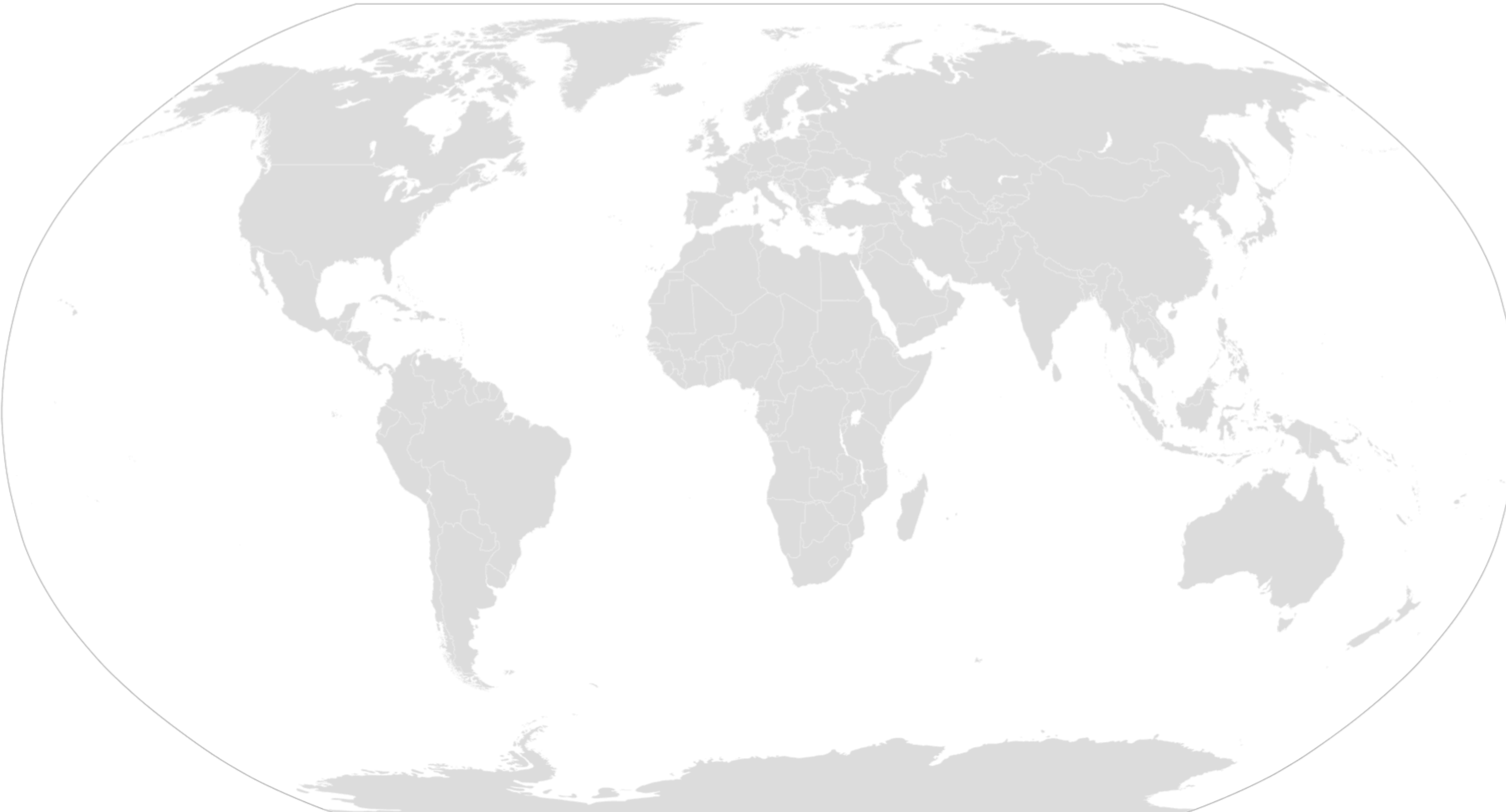
How does **regional** forest loss influence global climate and, consequently, **remote ecosystems' productivity**?



Allen, Breshears, and McDowell. 2015. Ecosphere

Forest loss influences global climate

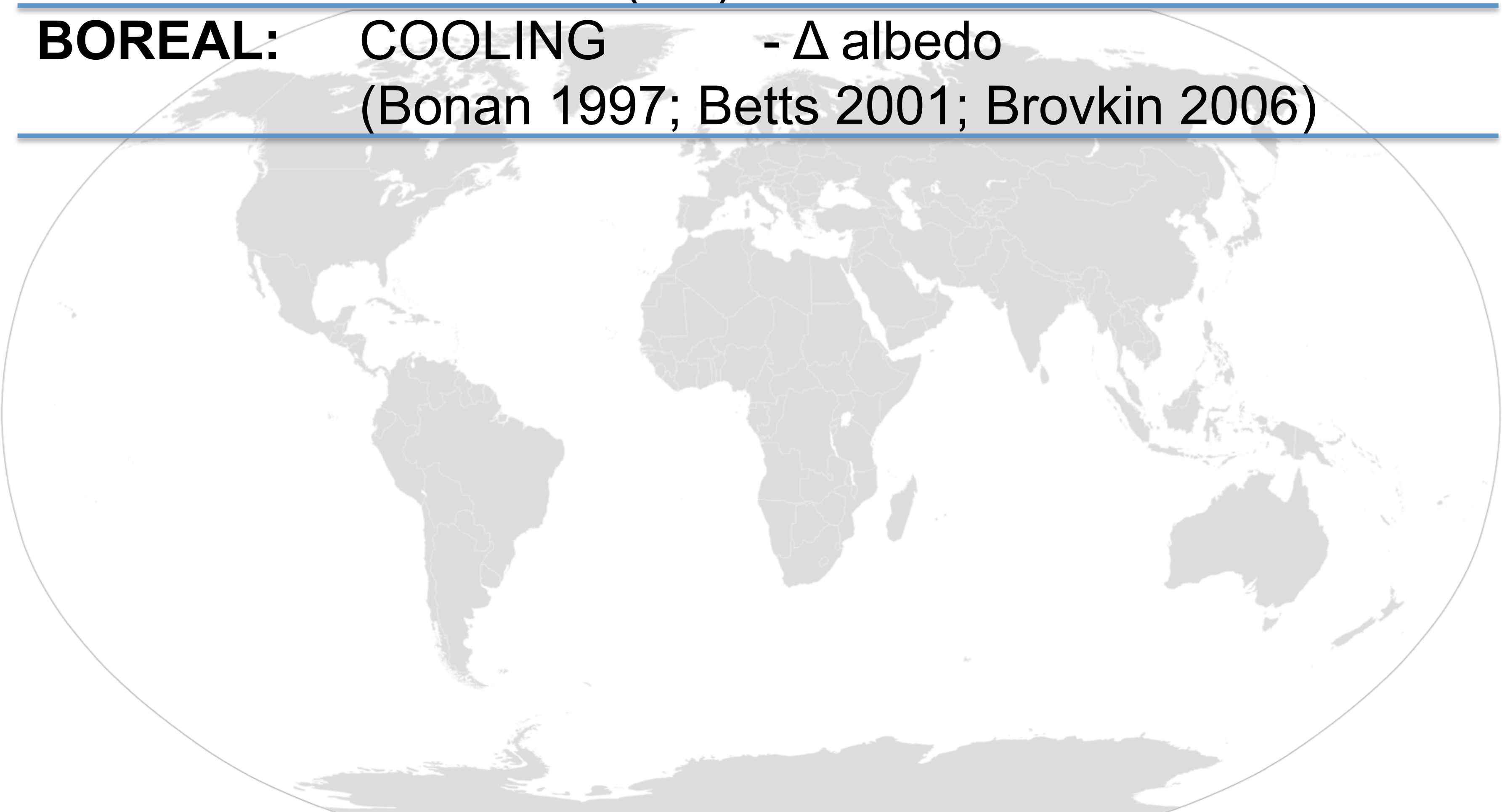
GLOBAL: COOLING (net) - Δ albedo



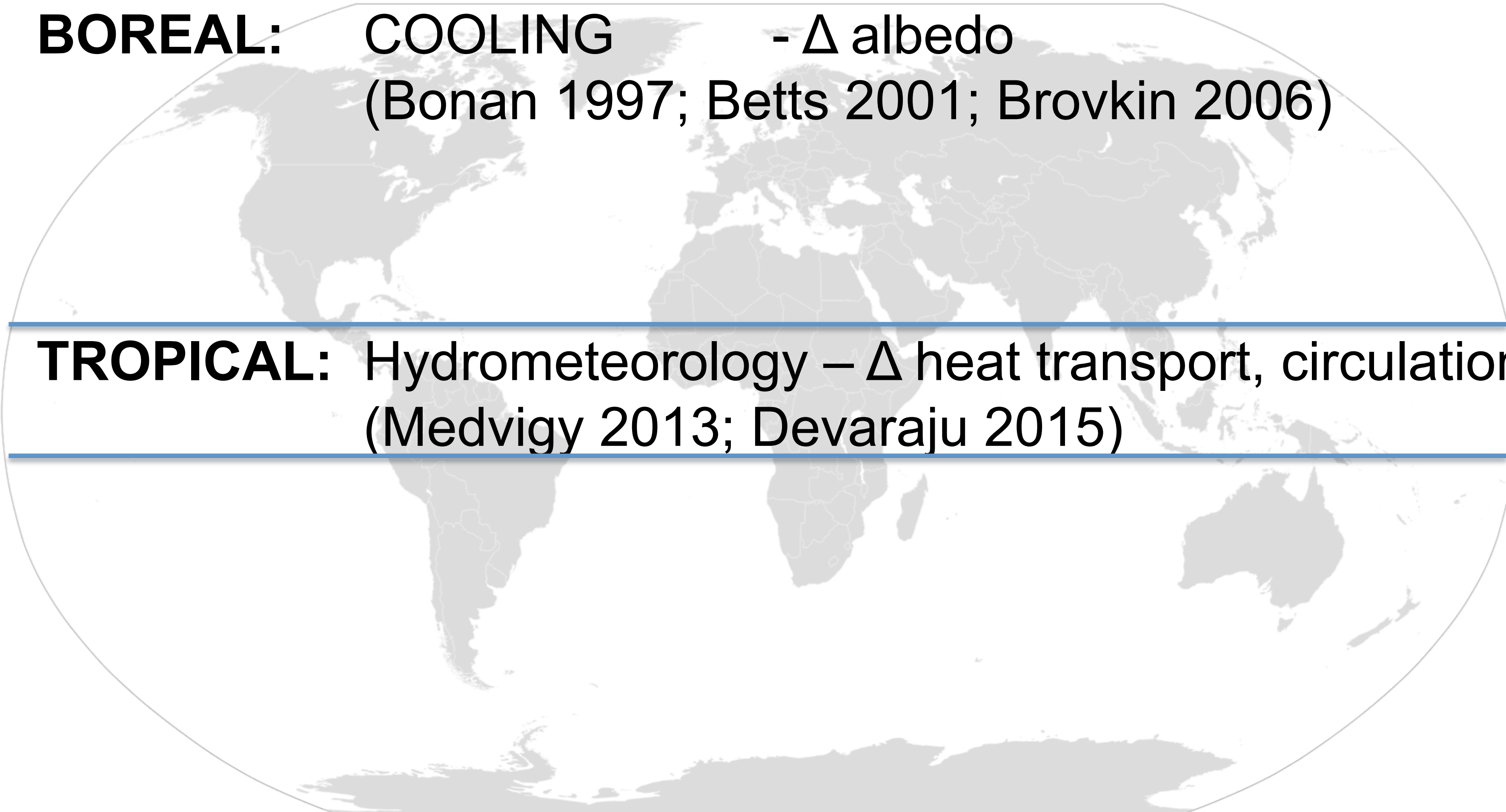
Boreal forest loss → net global cooling

GLOBAL: COOLING (net) - Δ albedo

BOREAL: COOLING - Δ albedo
(Bonan 1997; Betts 2001; Brovkin 2006)



Tropical forest loss → shifts in hydrometeorology



GLOBAL: COOLING (net) - Δ albedo

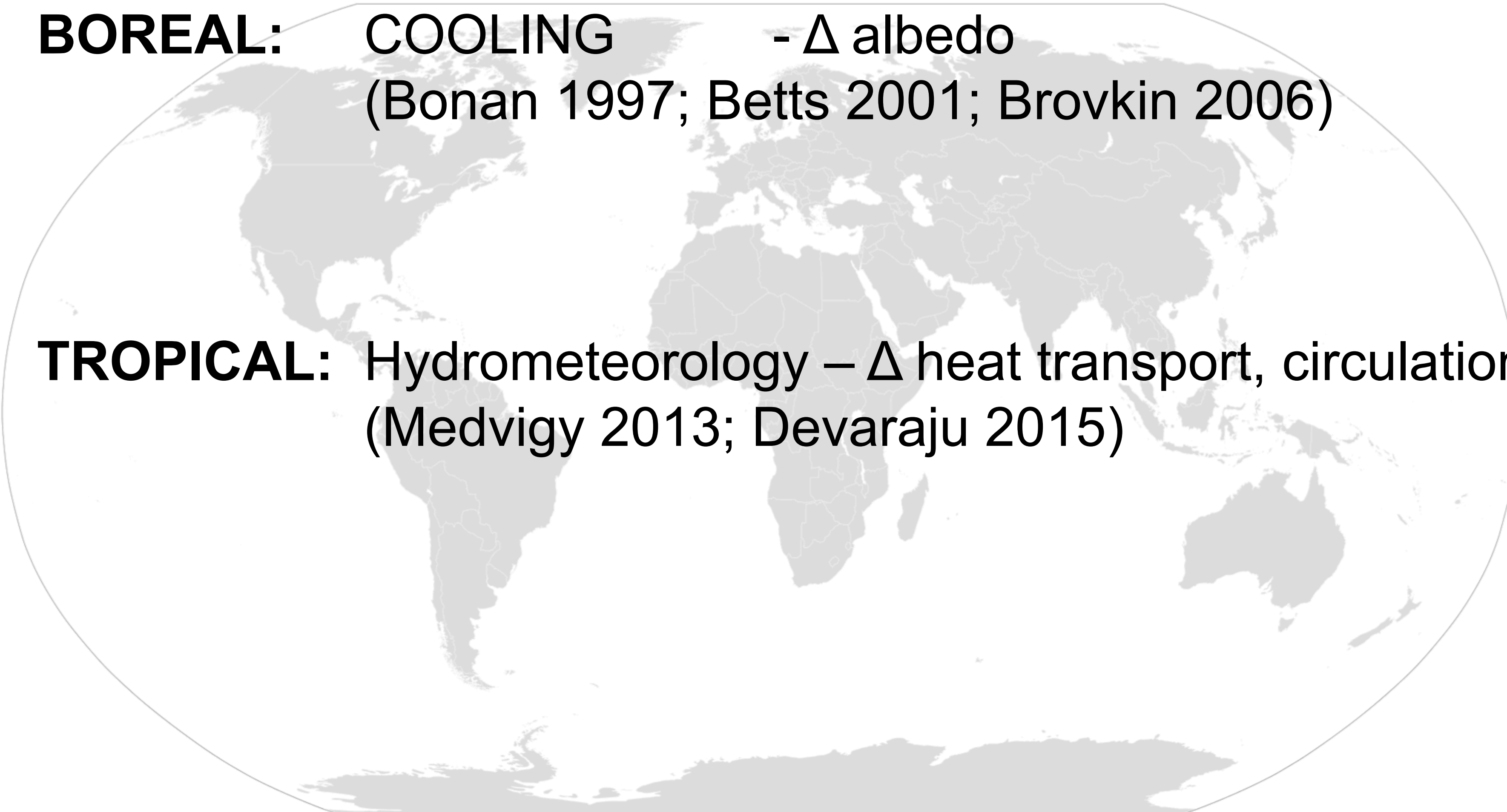
BOREAL: COOLING - Δ albedo

(Bonan 1997; Betts 2001; Brovkin 2006)

TROPICAL: Hydrometeorology – Δ heat transport, circulation

(Medvigy 2013; Devaraju 2015)

Location of disturbance matters for type of climate response

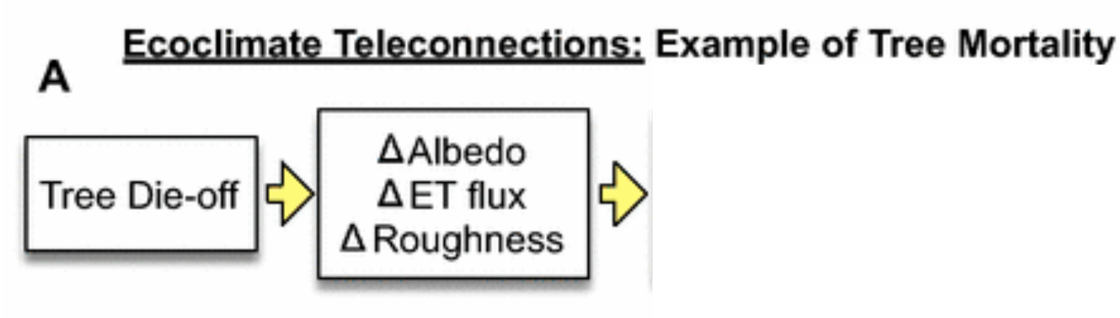


GLOBAL: COOLING (net) - Δ albedo

BOREAL: COOLING - Δ albedo
(Bonan 1997; Betts 2001; Brovkin 2006)

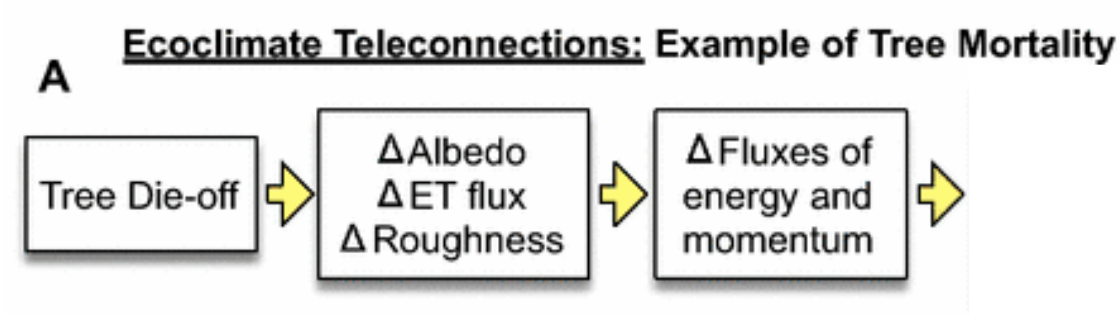
TROPICAL: Hydrometeorology – Δ heat transport, circulation
(Medvigy 2013; Devaraju 2015)

Climatic propagation of land surface change



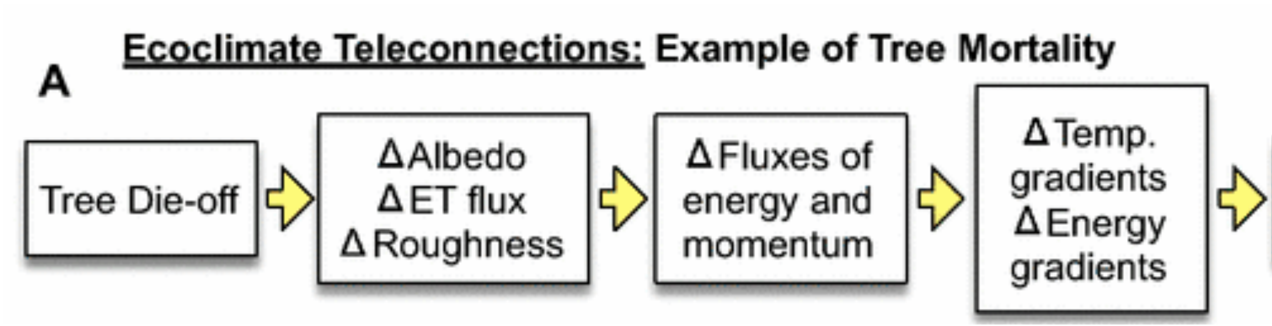
Swann et al. 2012 PNAS
Stark et al. 2016 Landscape Ecology

Ecoclimate teleconnection – atmospheric mechanism connecting land surfaces



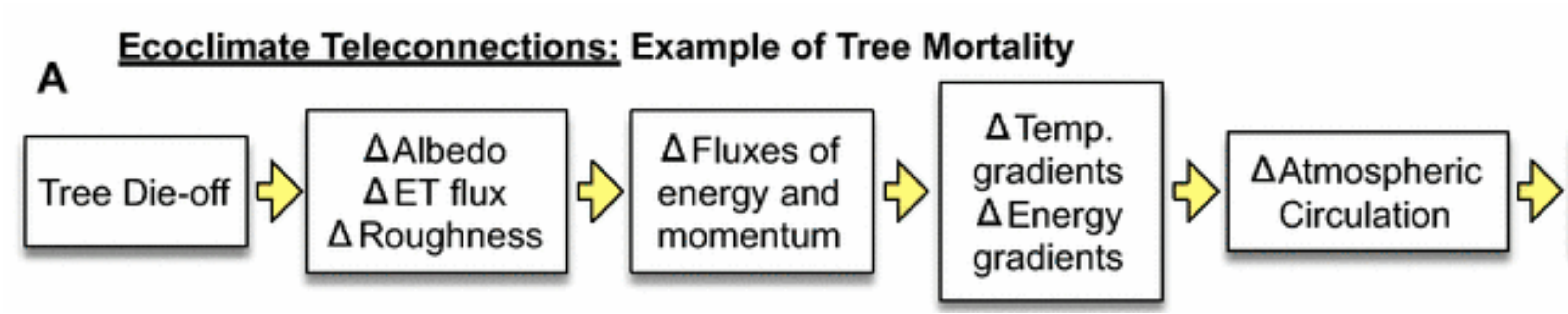
Stark et al. 2016 Landscape Ecology

Ecoclimate teleconnection – atmospheric mechanism connecting land surfaces



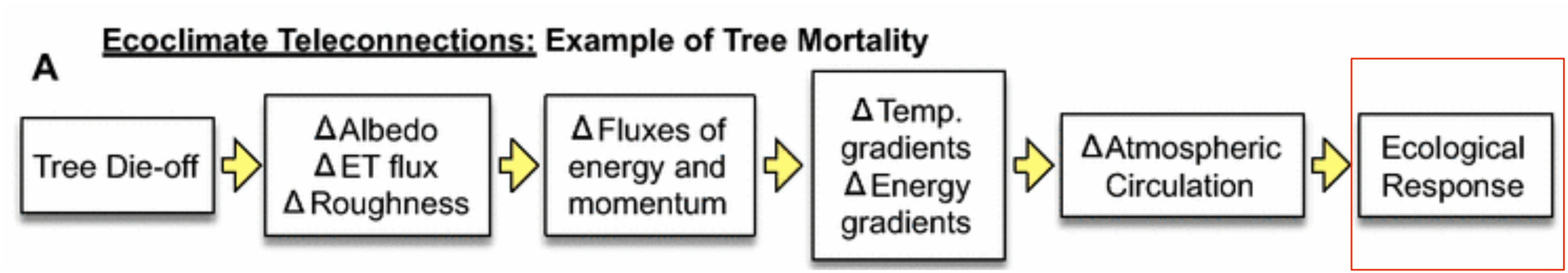
Stark et al. 2016 Landscape Ecology

Ecoclimate teleconnection – atmospheric mechanism connecting land surfaces



Stark et al. 2016 Landscape Ecology

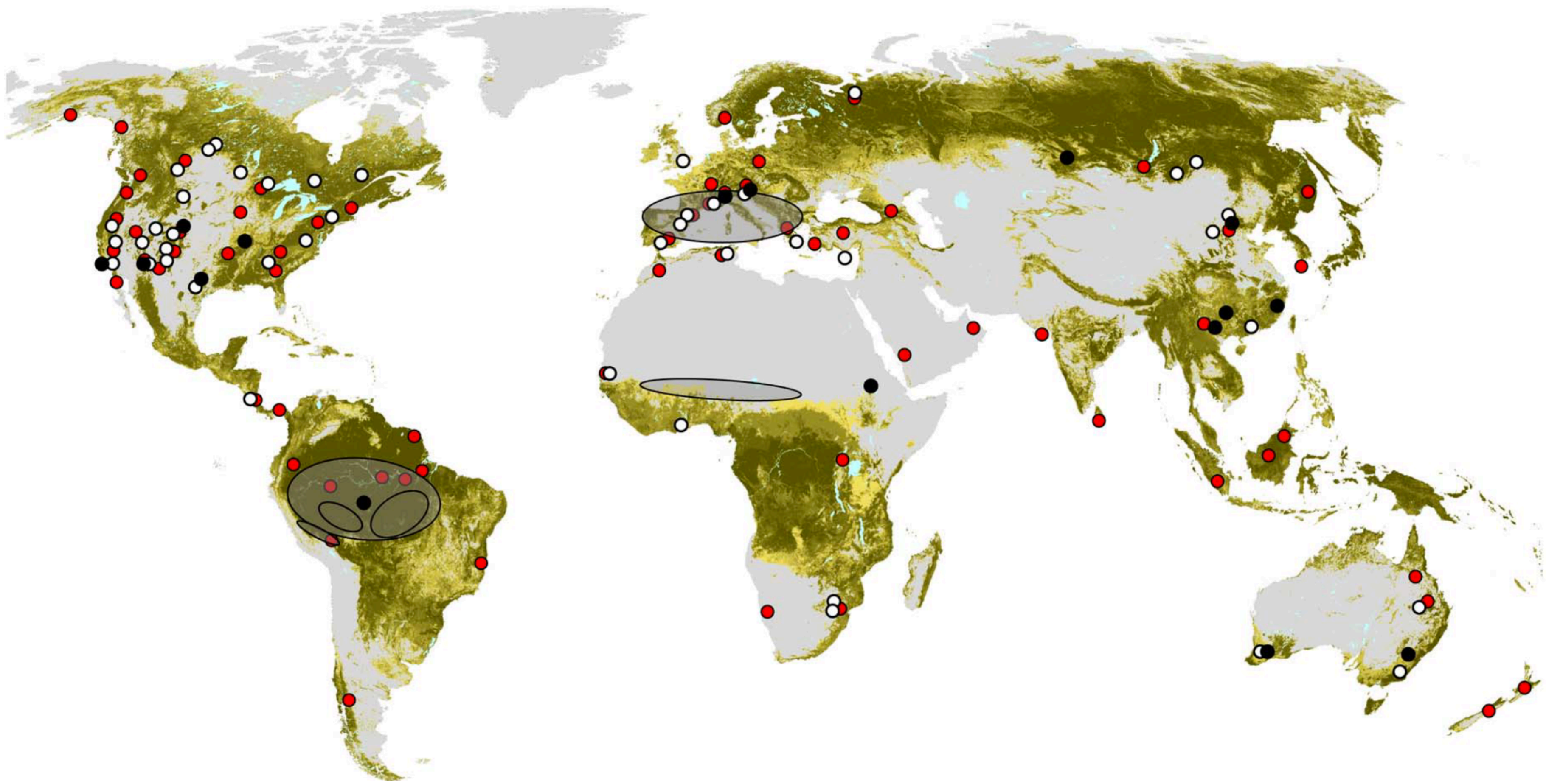
Ecoclimate teleconnection – atmospheric mechanism connecting land surfaces



What are the implications of climate change due to disturbance for remote ecosystems?

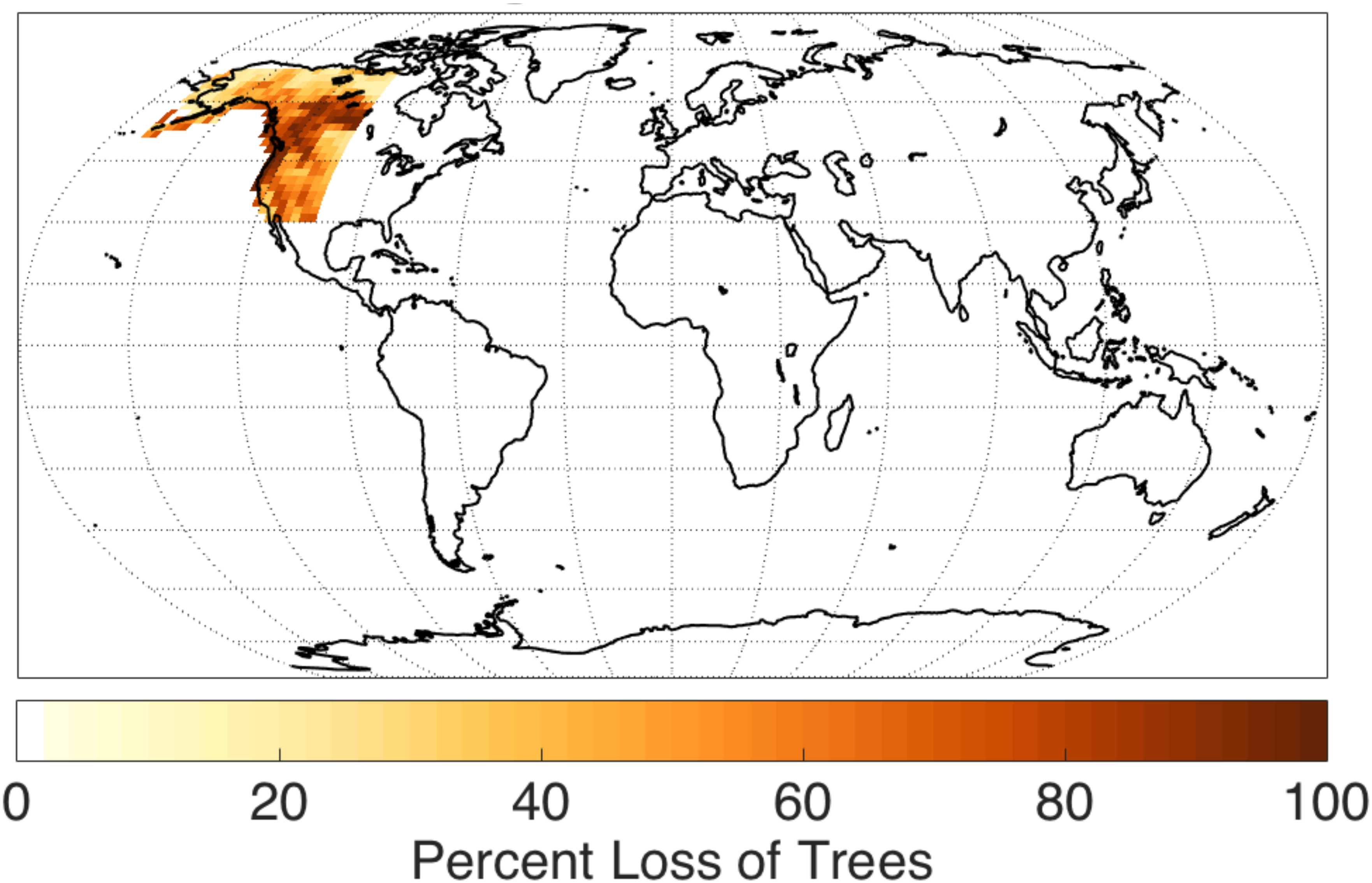
Stark et al. 2016 Landscape Ecology

How does **regional** forest loss influence global climate and, consequently, **remote ecosystems' productivity**?

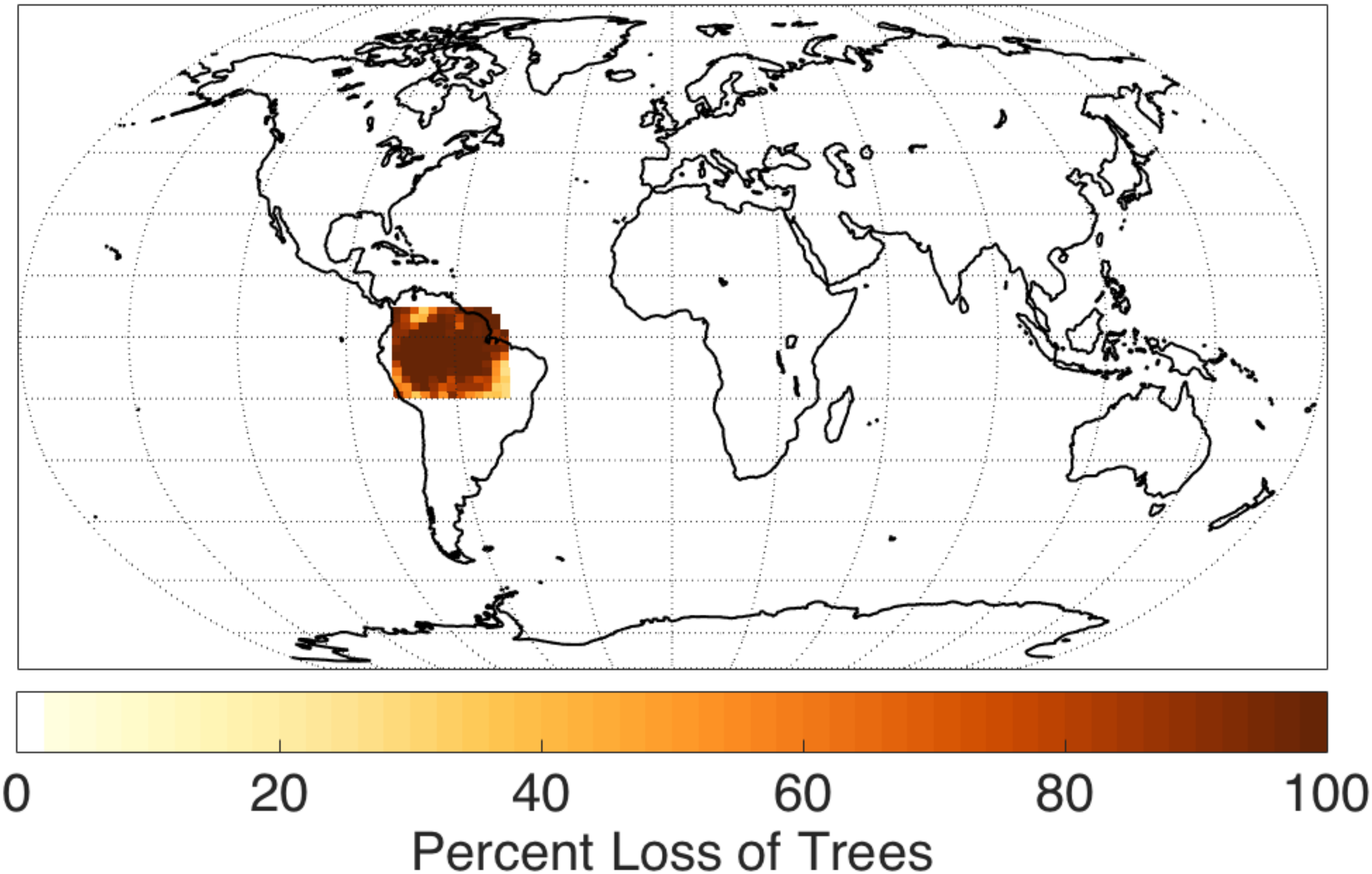


Allen, Breshears, and McDowell. 2015. Ecosphere

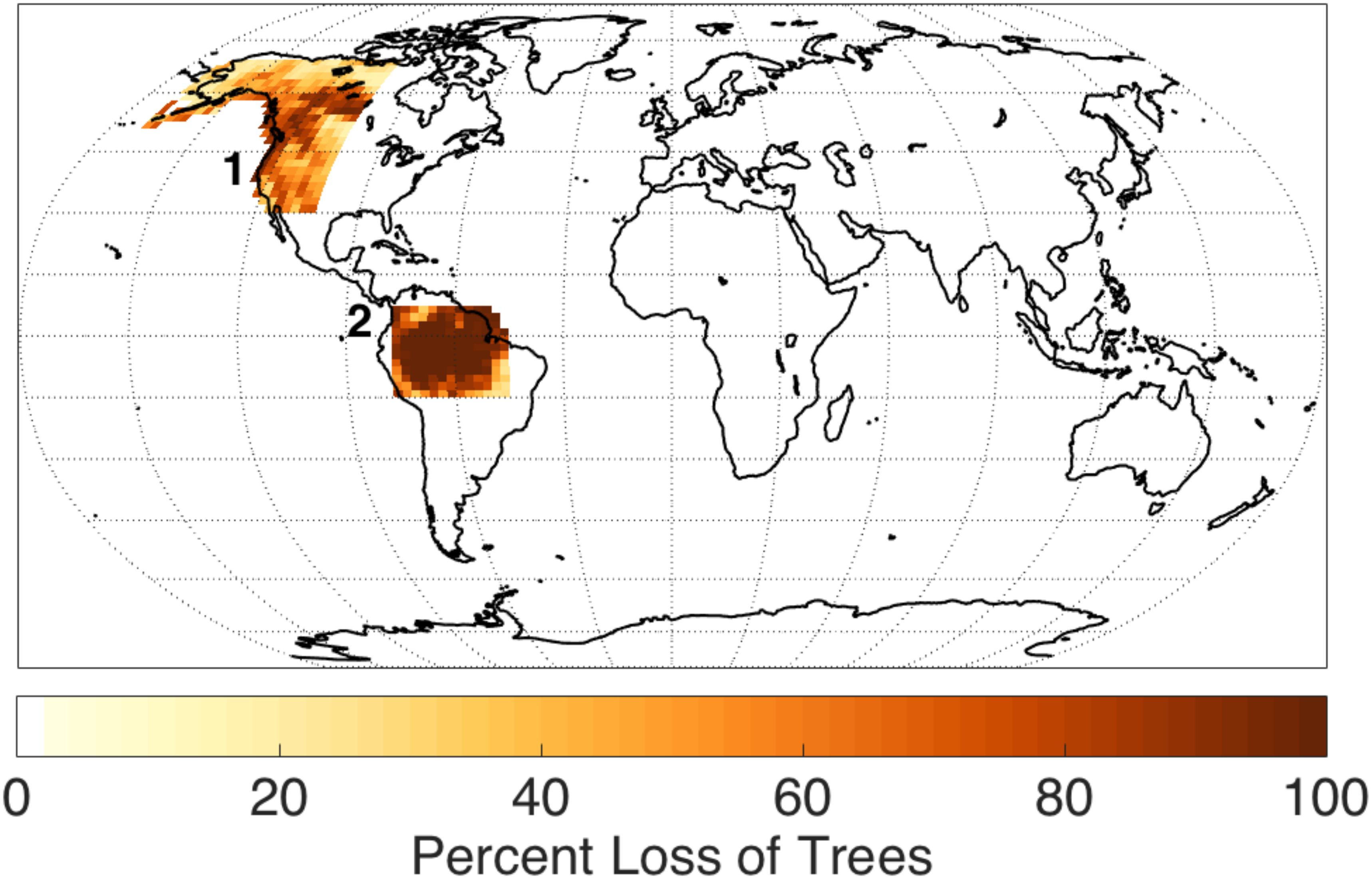
Two vulnerable forests: Western North America (WNA) (temperate/boreal)



Two vulnerable forests: Amazon (tropical)



Two vulnerable forests: WNA + Amazon
Individual and Combined Impacts

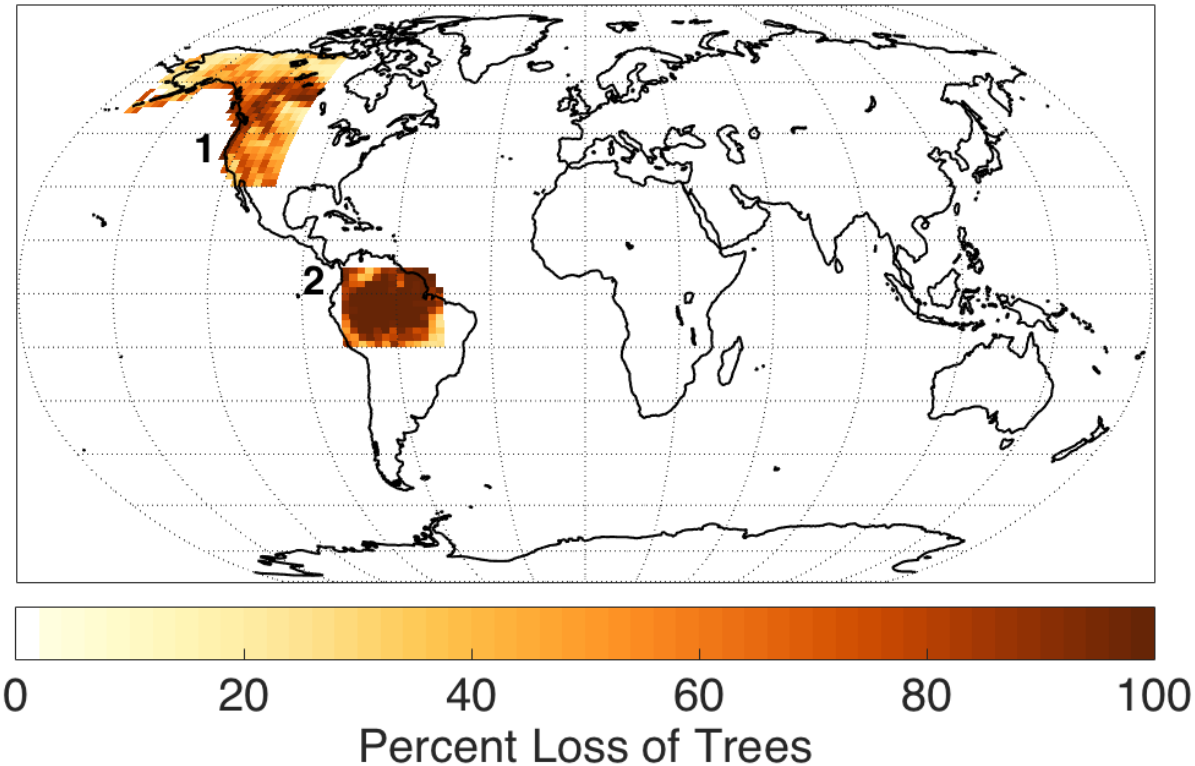


Methodology

3 cases:

- WN. America + Amazon
- WN. America
- Amazon

Compared to Control



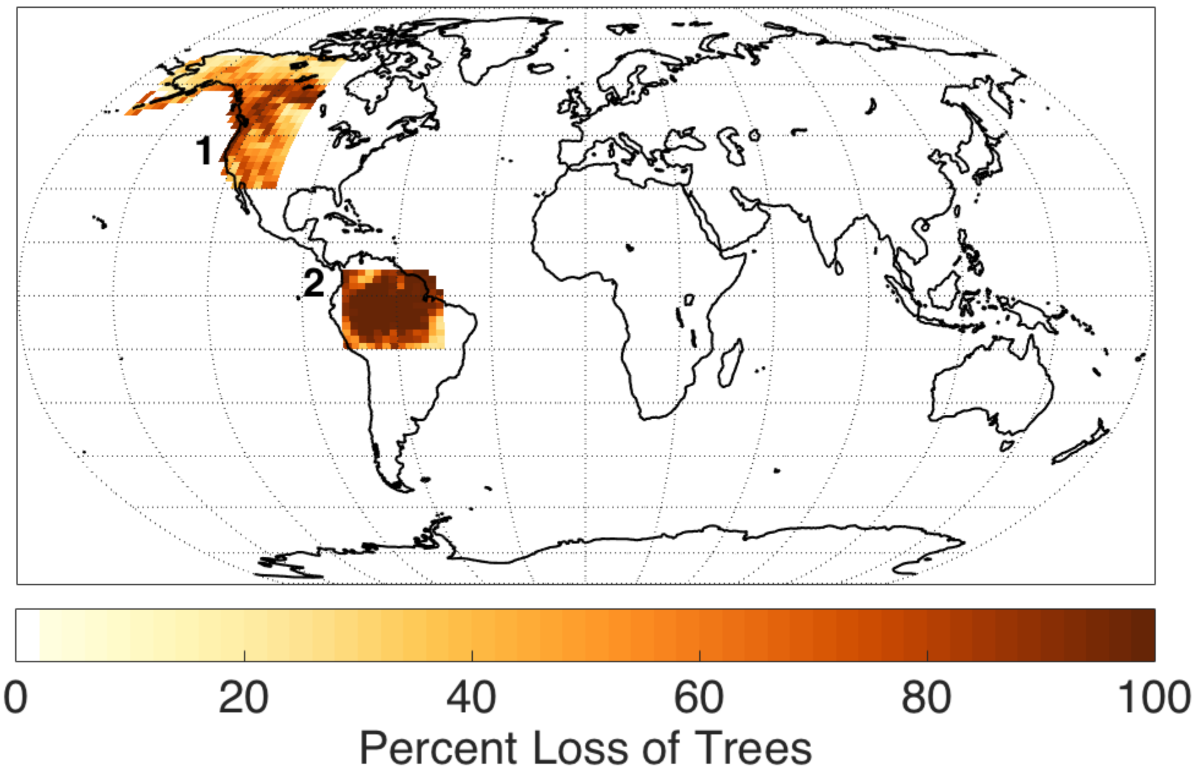
Methodology

3 cases:
- WN. America + Amazon
- WN. America
- Amazon

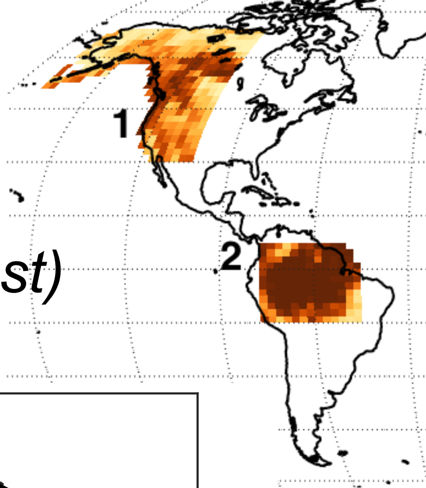
Compared to Control

Modeled with CESM1.3
- CAM5
- CLM4.5
- CICE
- Slab Ocean

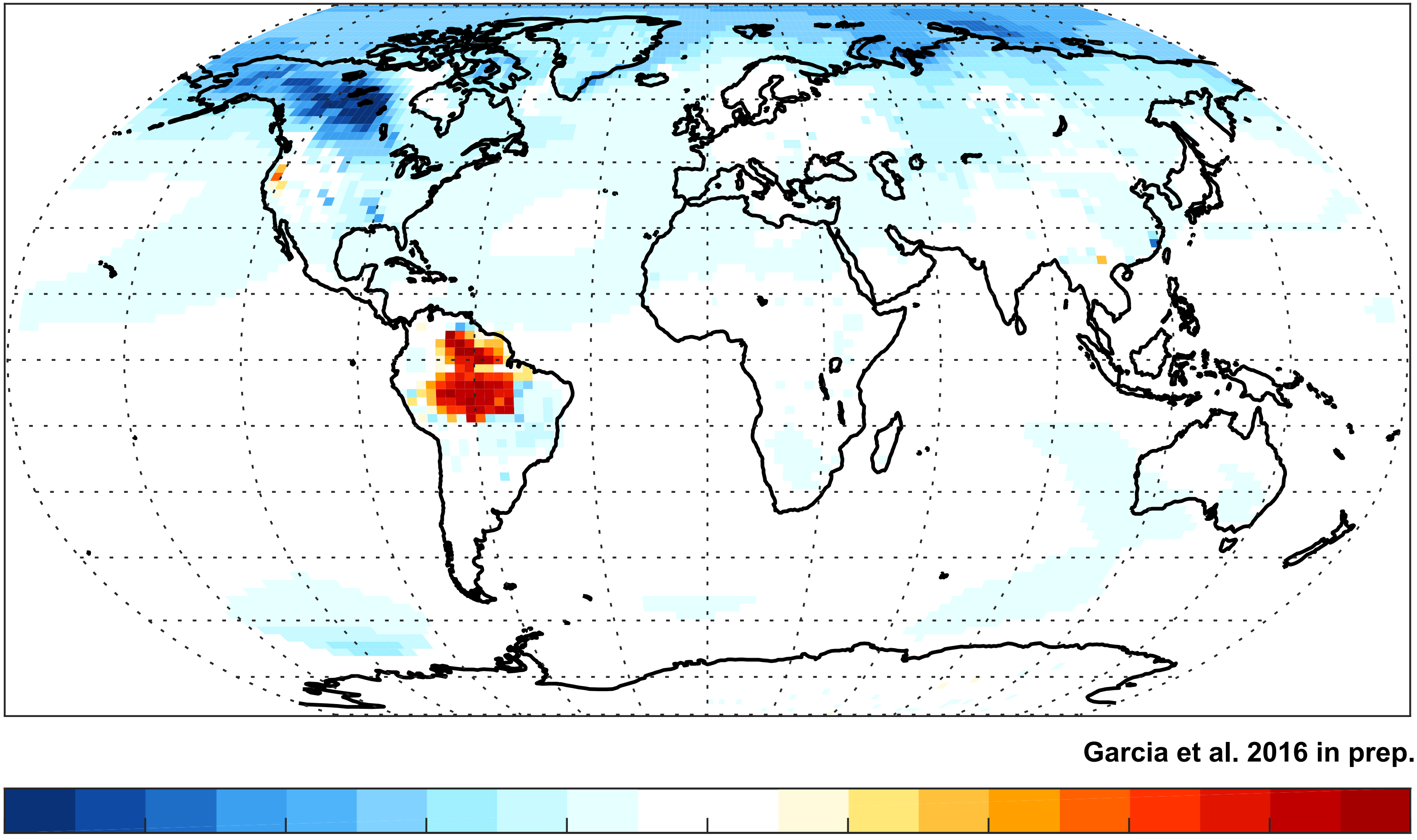
80 yrs – 20 yrs of spinup



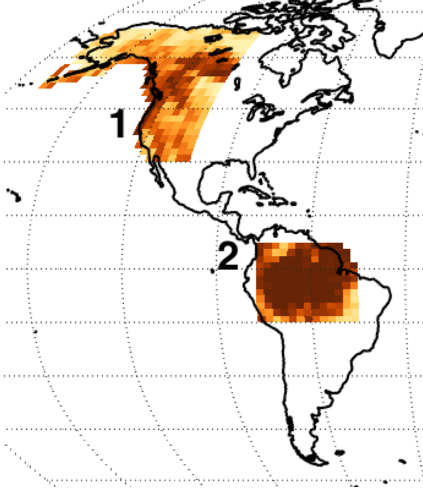
Forest loss in WNA + Amazon → Average Global Cooling

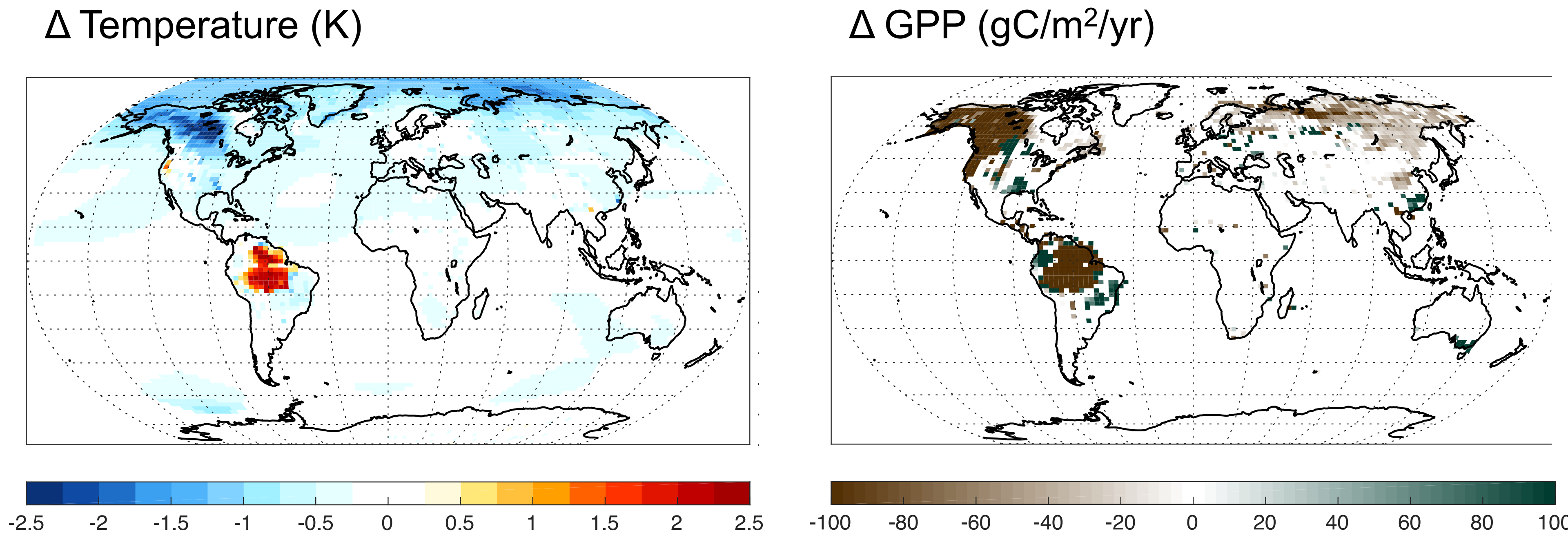


Experiment – CONTROL, Results significant to 95% (*t-test*)
Δ Temperature (K)



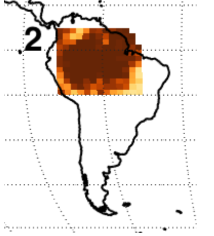
Forest loss in WNA + Amazon → Cooling + Remote Δ GPP



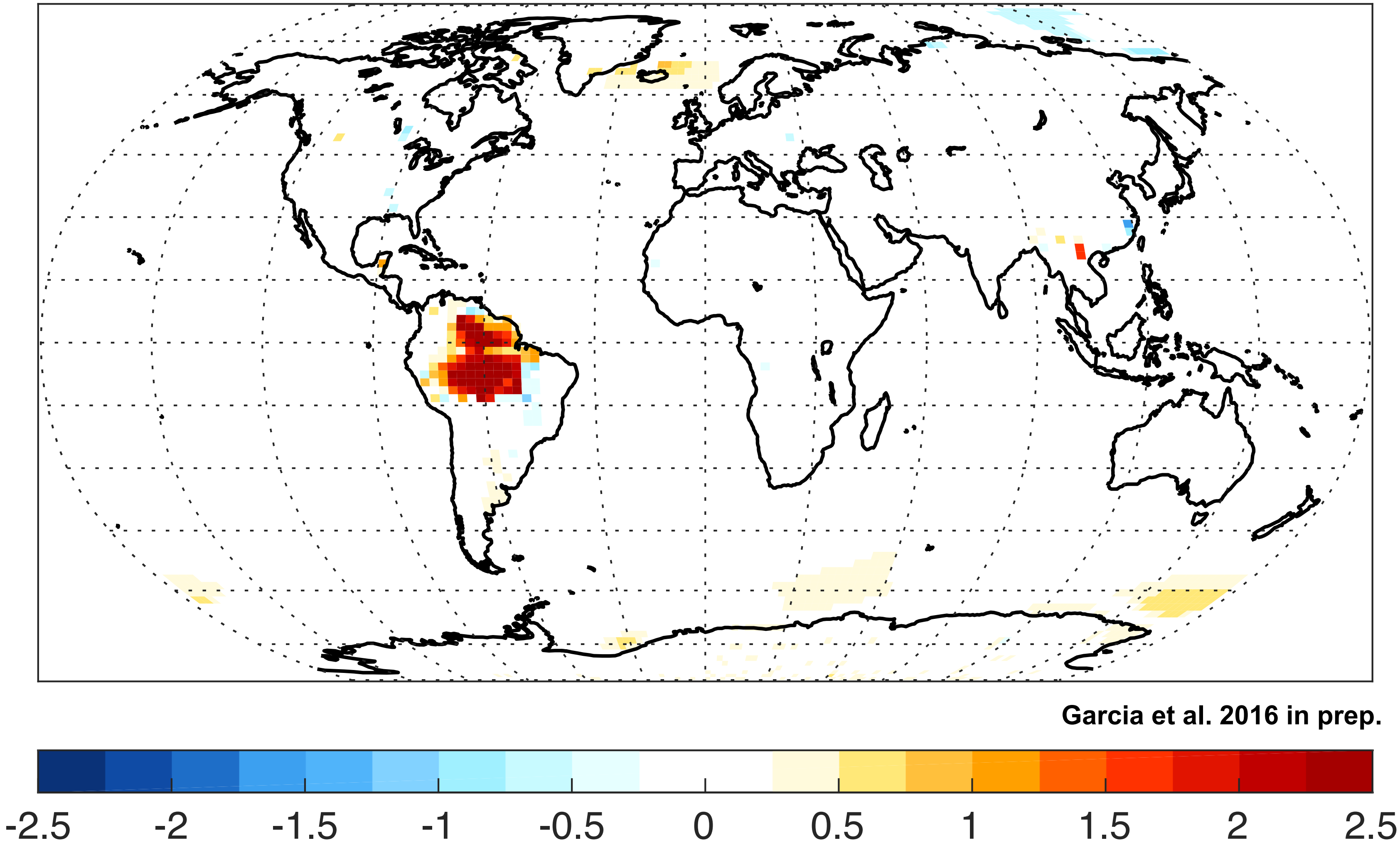


Garcia et al. 2016 in prep.

Forest loss in Amazon → Less Remote Δ T and Δ GPP

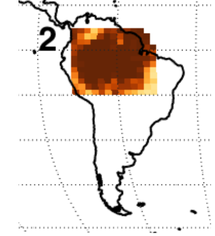


Δ Temperature (K)

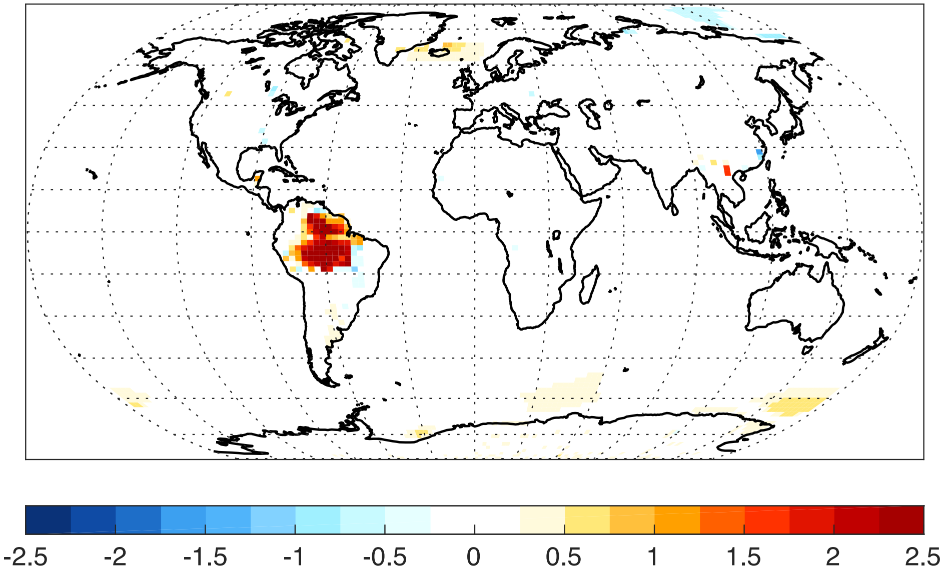


Garcia et al. 2016 in prep.

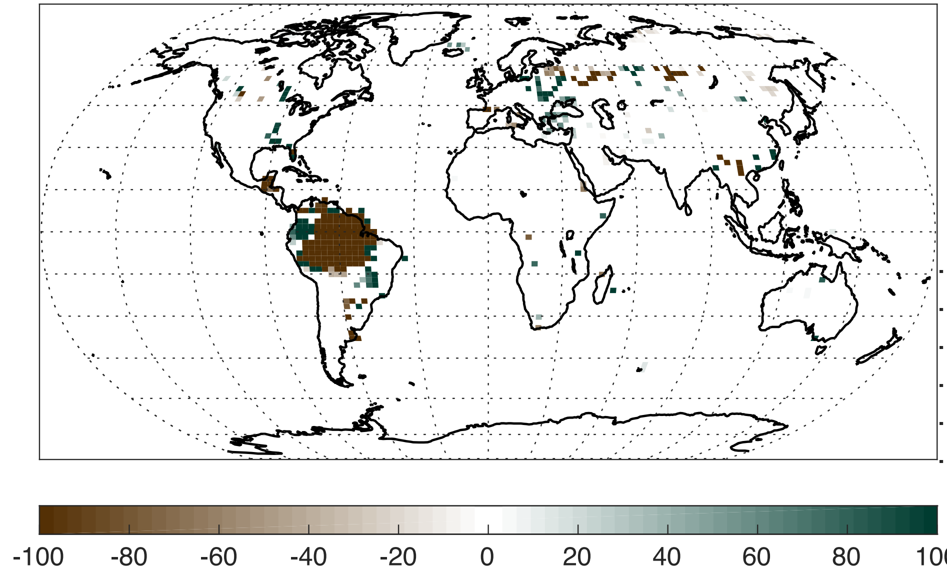
Forest loss in Amazon →
Less Remote Δ T and Δ GPP



Δ Temperature (K)

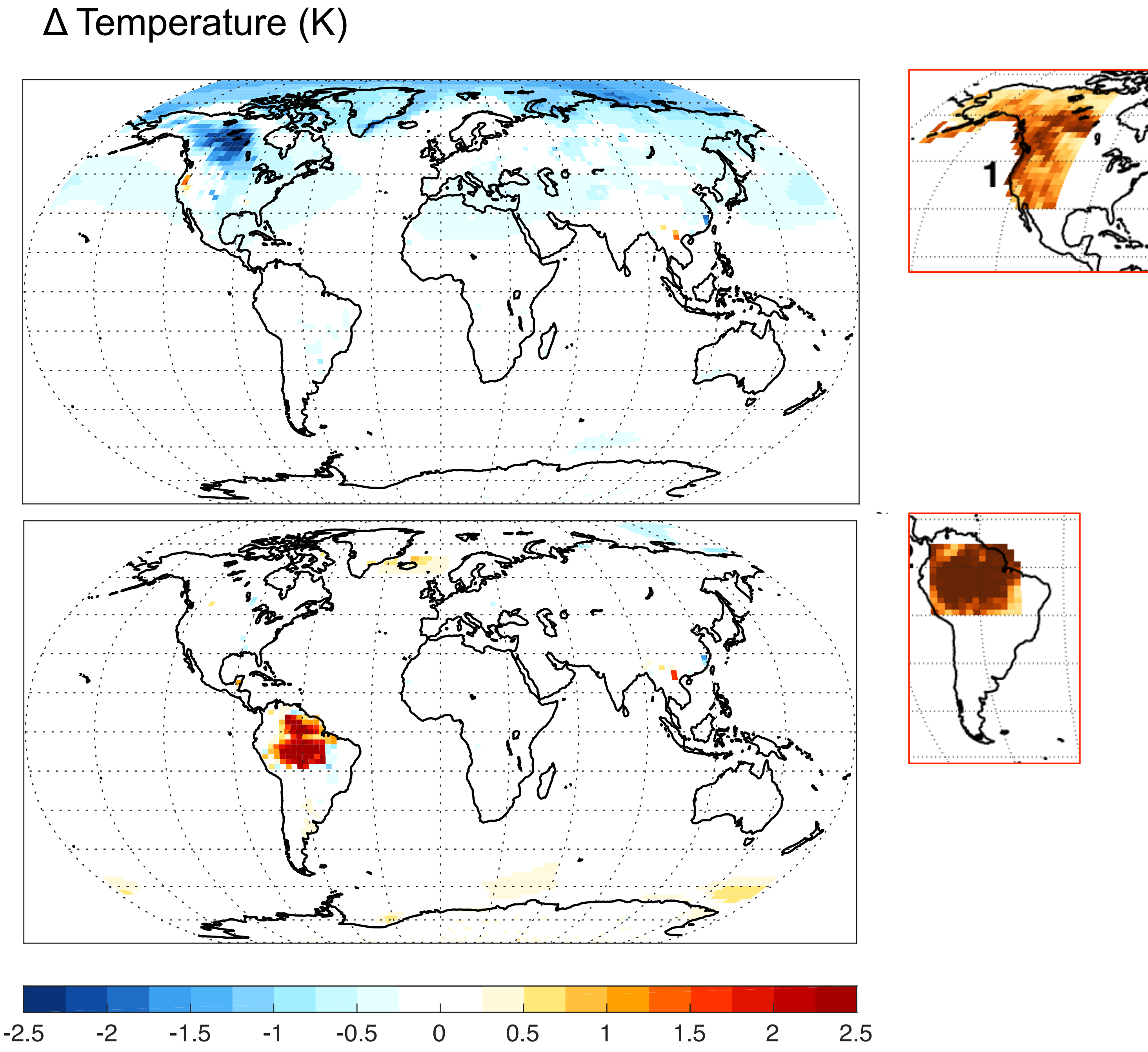


Δ GPP (gC/m²/yr)



Garcia et al. 2016 in prep.

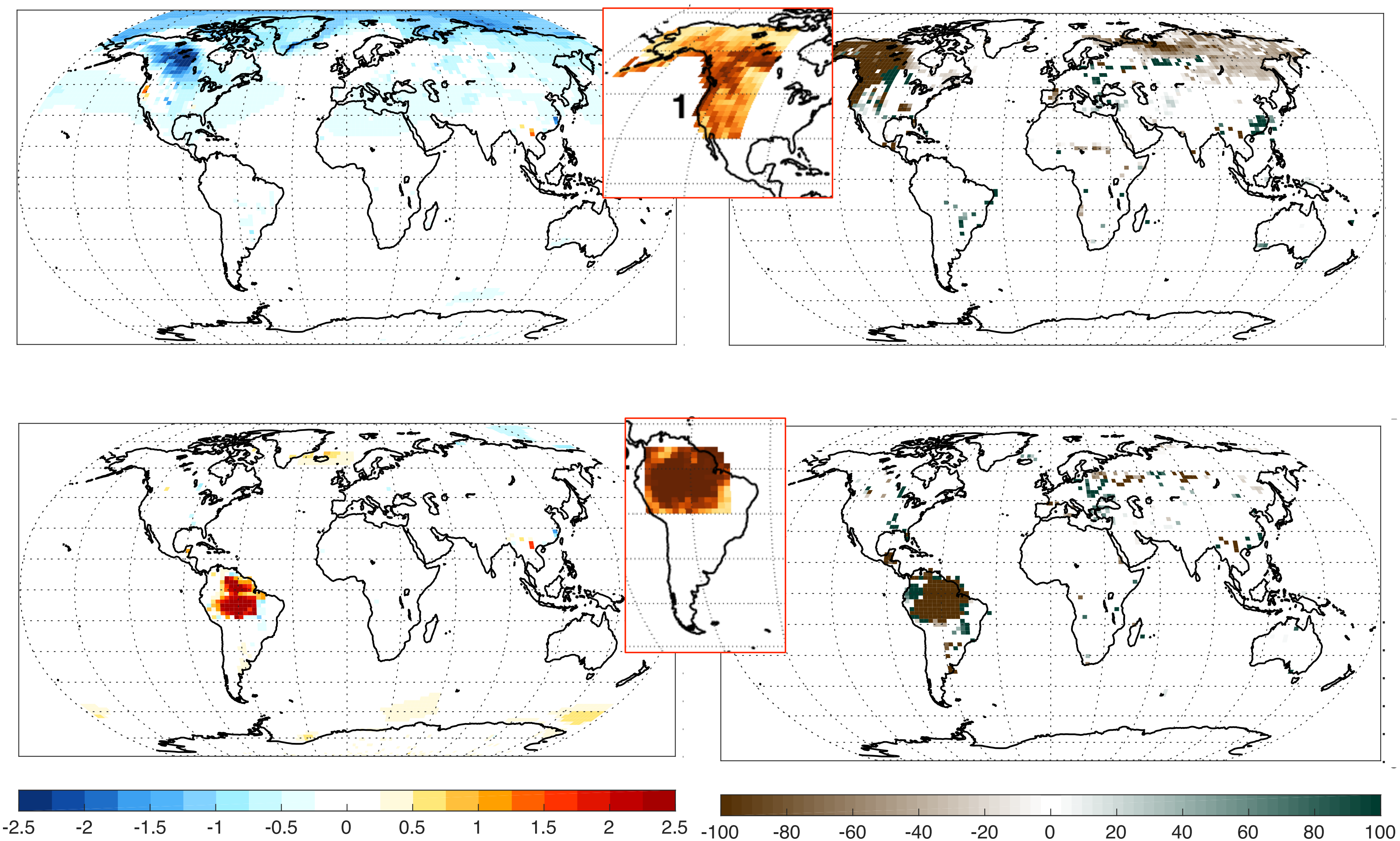
Climate response depends on where forest is lost.



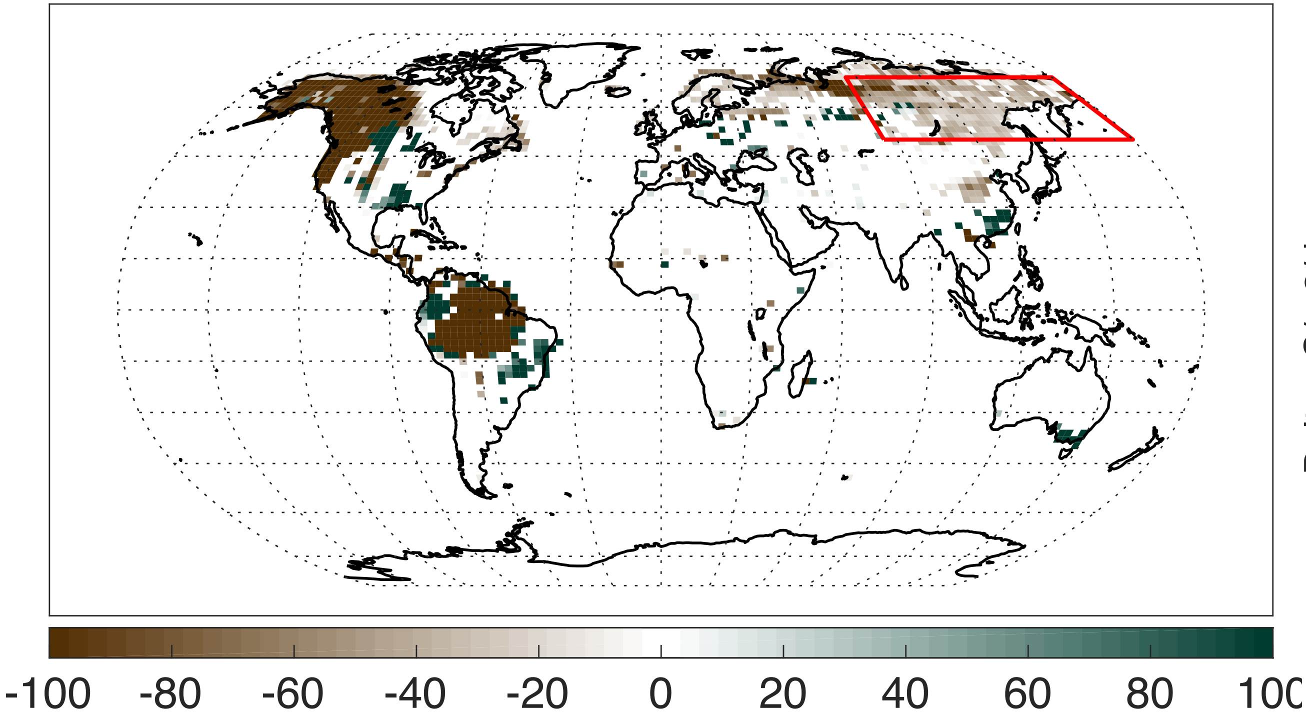
Garcia et al. 2016 in prep.

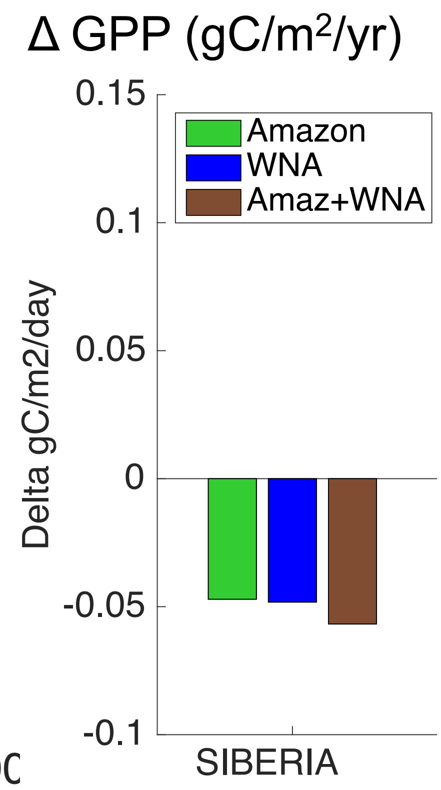
Climate response depends on where forest is lost. GPP, too!

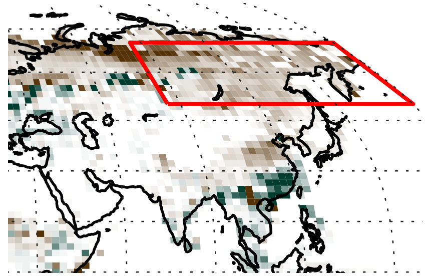
Δ Temperature (K) Δ GPP ($gC/m^2/yr$)



Regional Example: Siberia
Largest Remote Declines in GPP

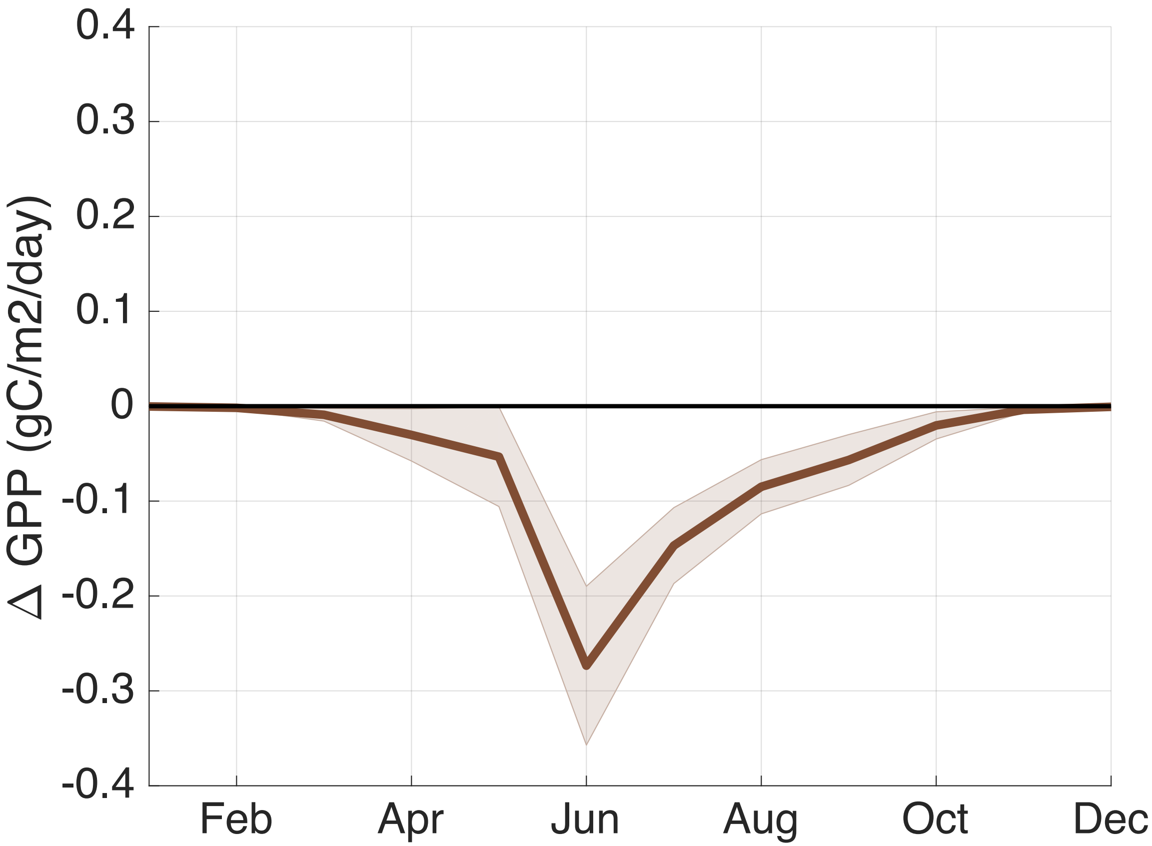


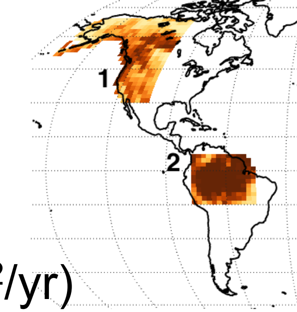


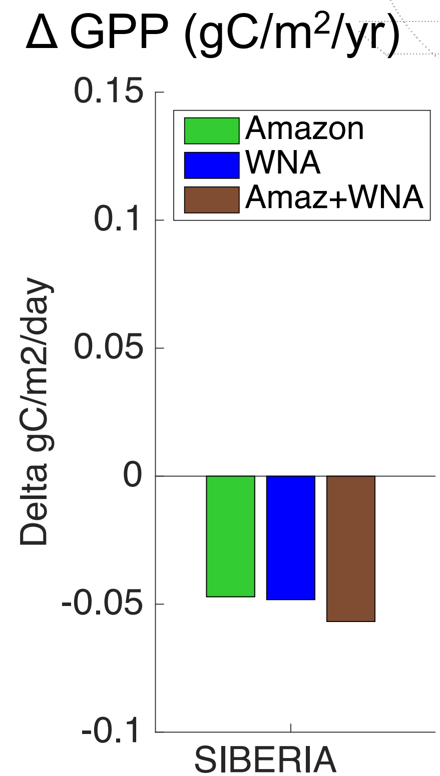


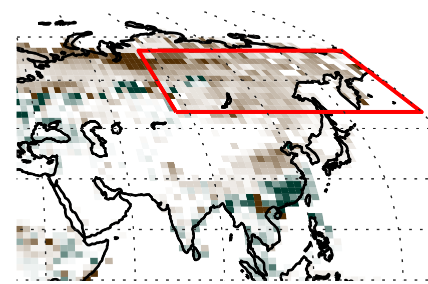
Siberia Monthly ΔGPP (gC/m²/day)

Largest declines during growing season



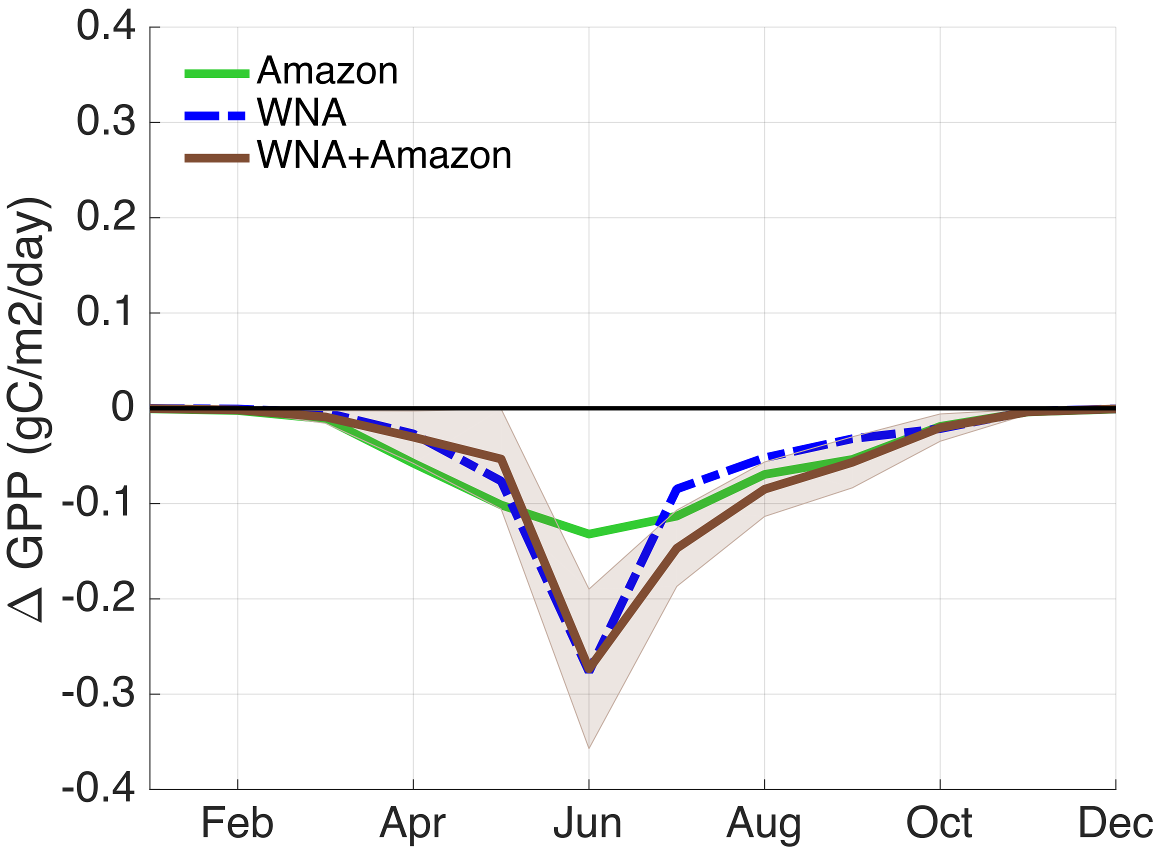


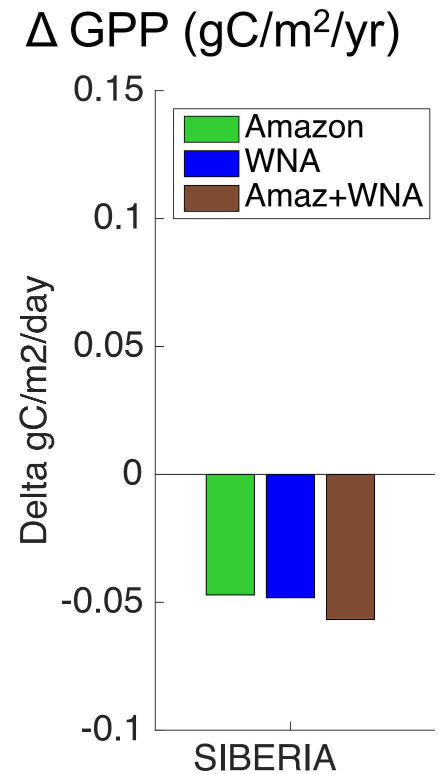


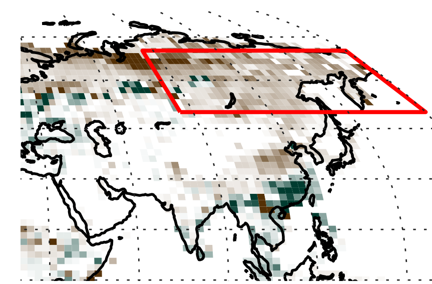


Siberia Monthly ΔGPP (gC/m²/day)

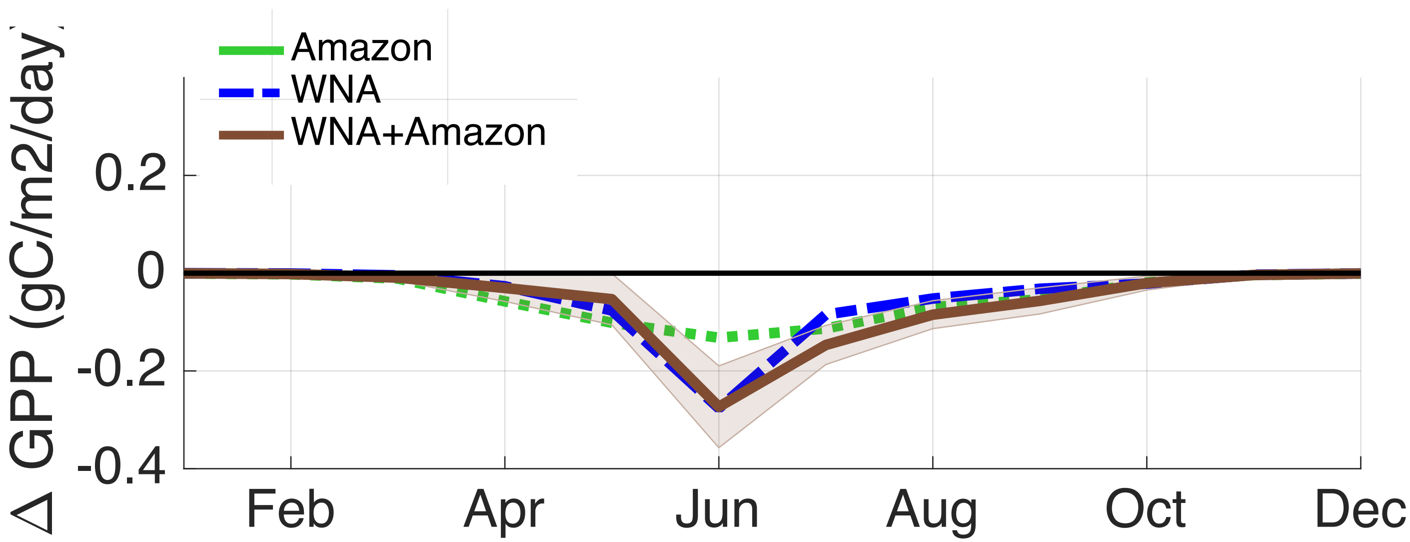
Largest declines during growing season



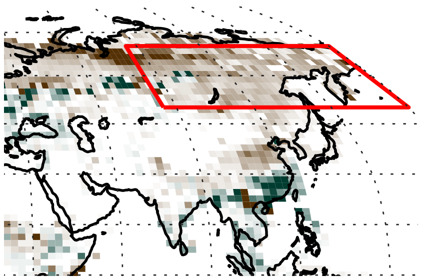




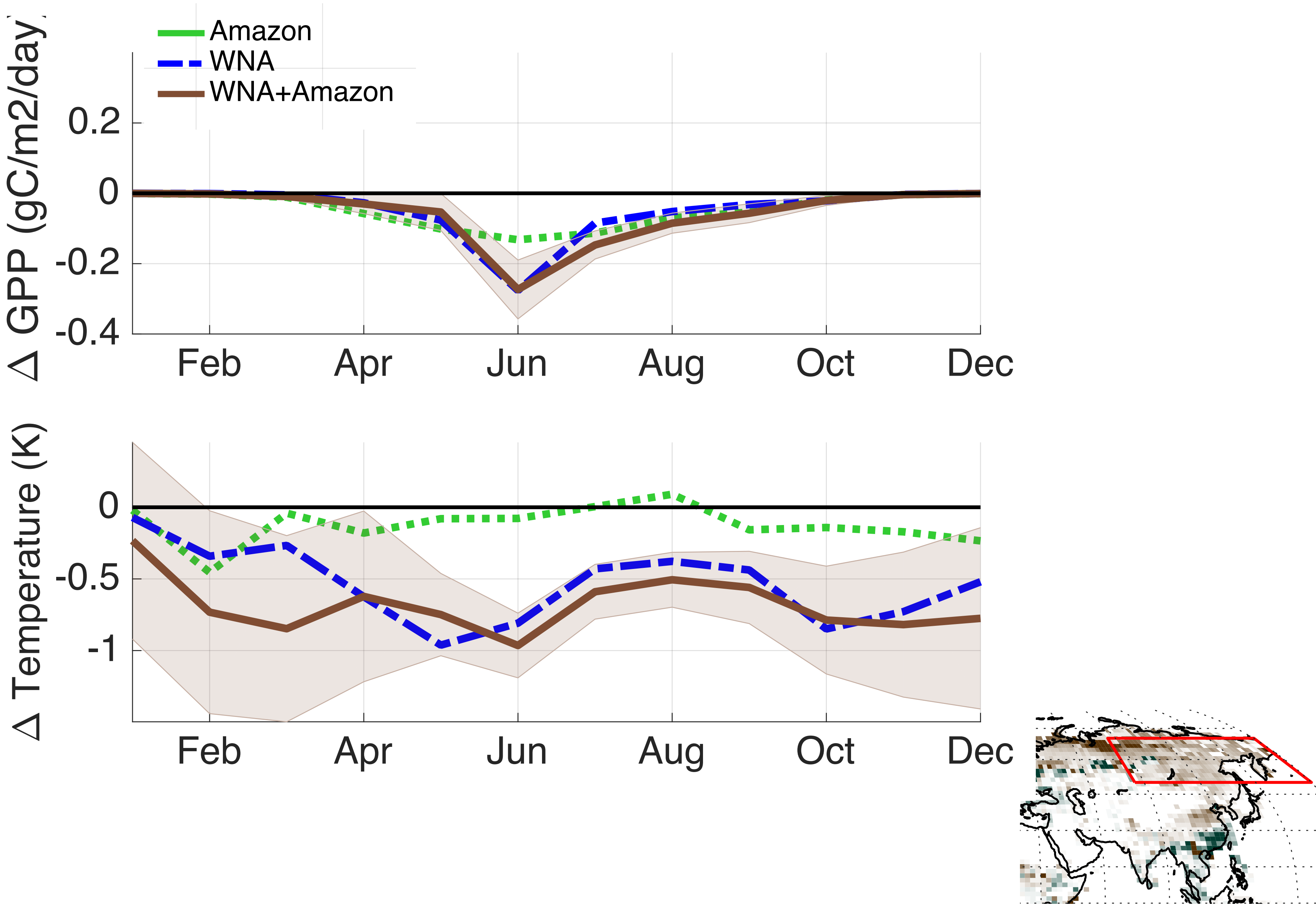
Siberia ↓GPP

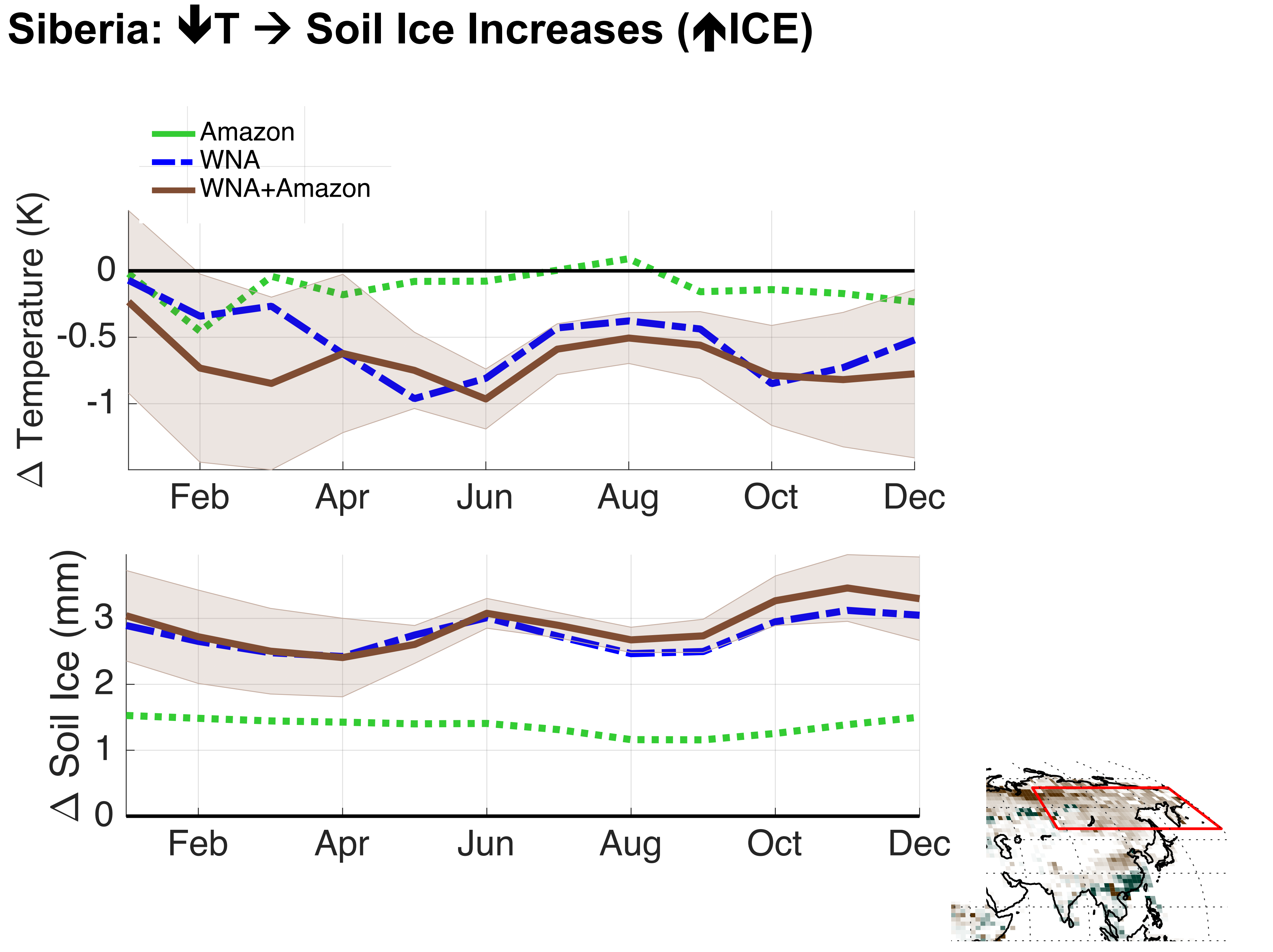


Amazon
WNA
WNA+Amazon
Δ GPP (gC/m2/day)
0.2
0
-0.2
-0.4
Feb
Apr
Jun
Aug
Oct
Dec



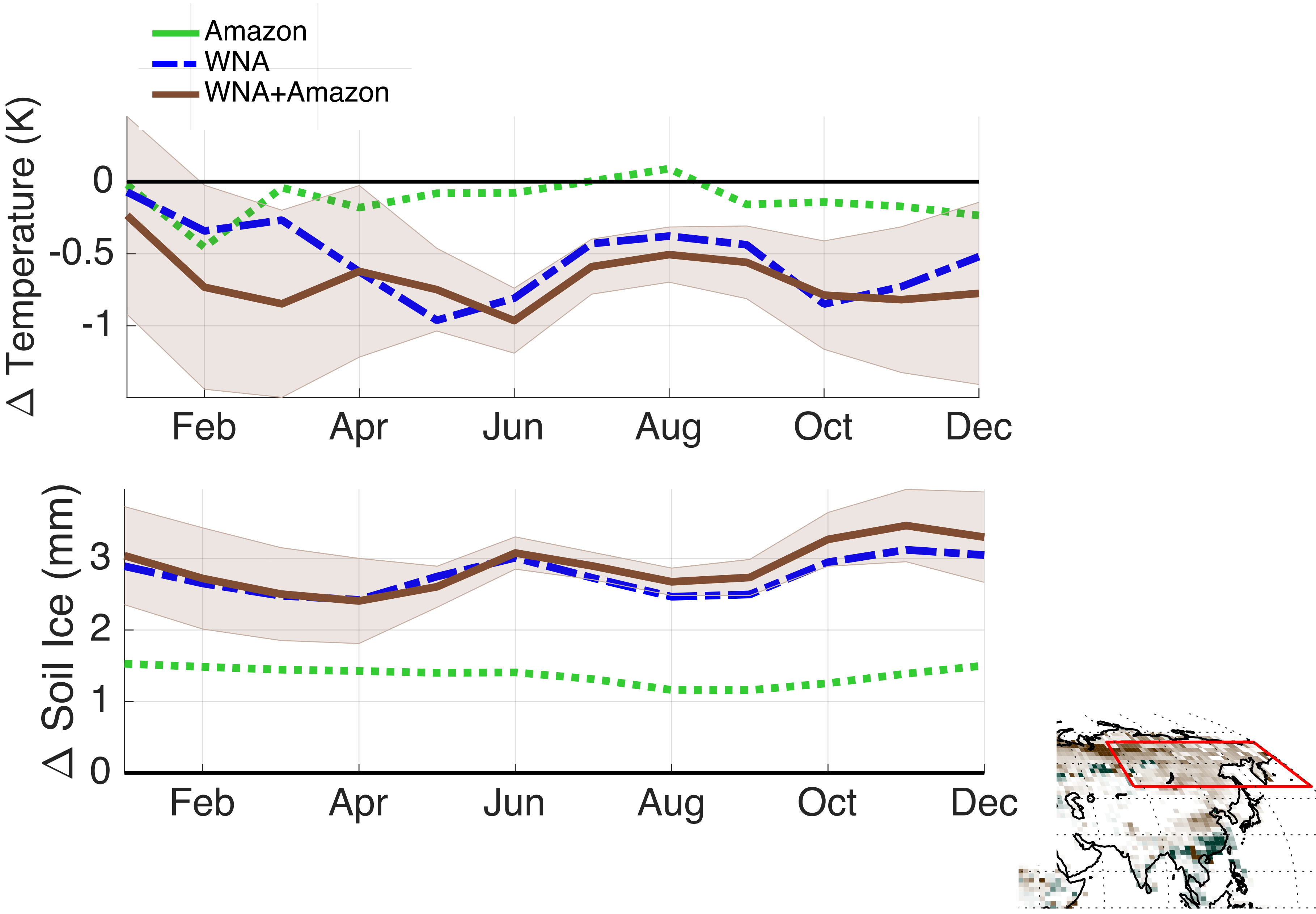
Siberia: Temperature Decreases (↓T)



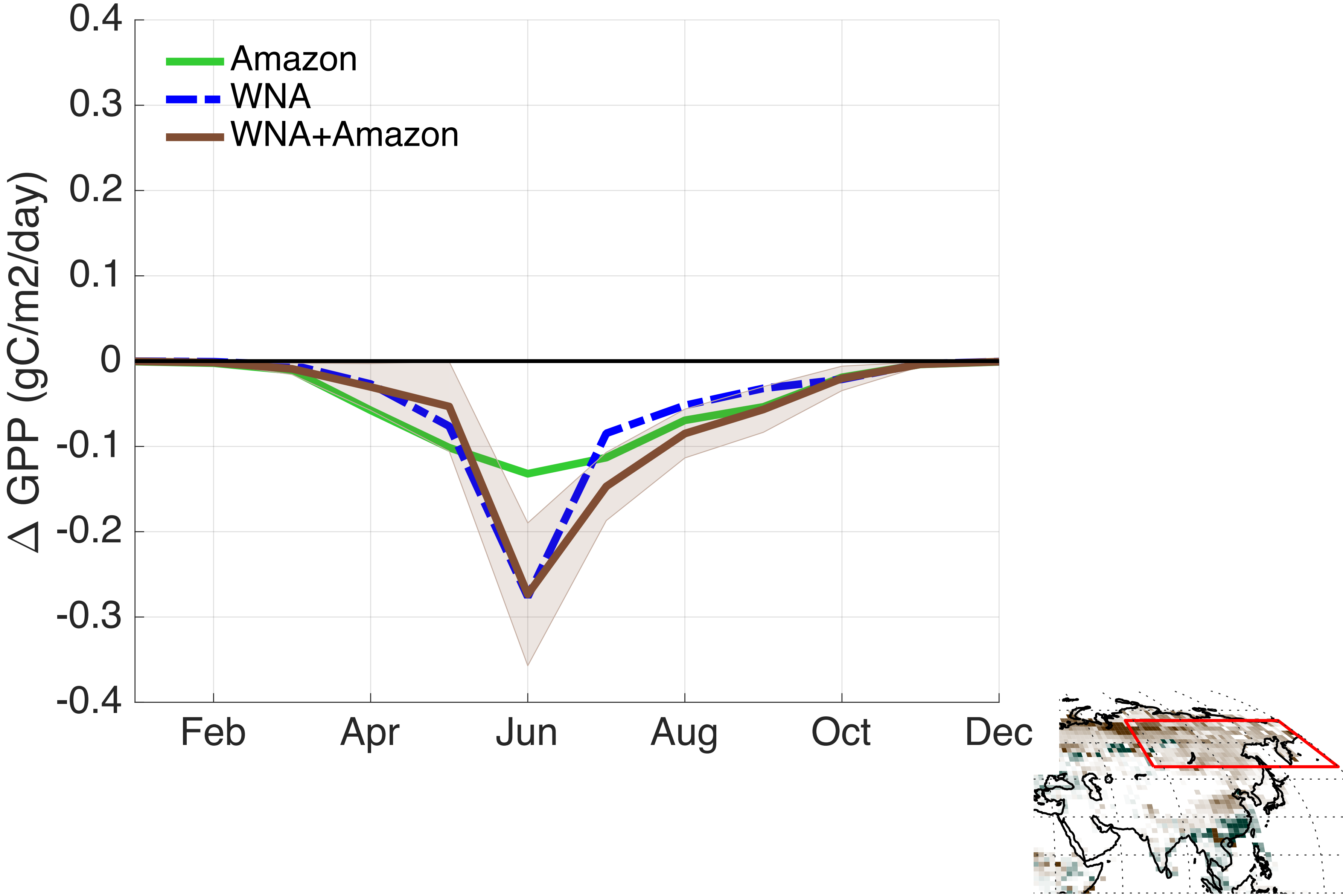

Siberia: ↓T → Soil Ice Increases (↑ICE)
Amazon
WNA
WNA+Amazon
Δ Temperature (K)
0
-0.5
-1
Feb
Apr
Jun
Aug
Oct
Dec
Δ Soil Ice (mm)
3
2
1
0
Feb
Apr
Jun
Aug
Oct
Dec

Siberia: ↓T → Soil Ice Increases (↑ICE)

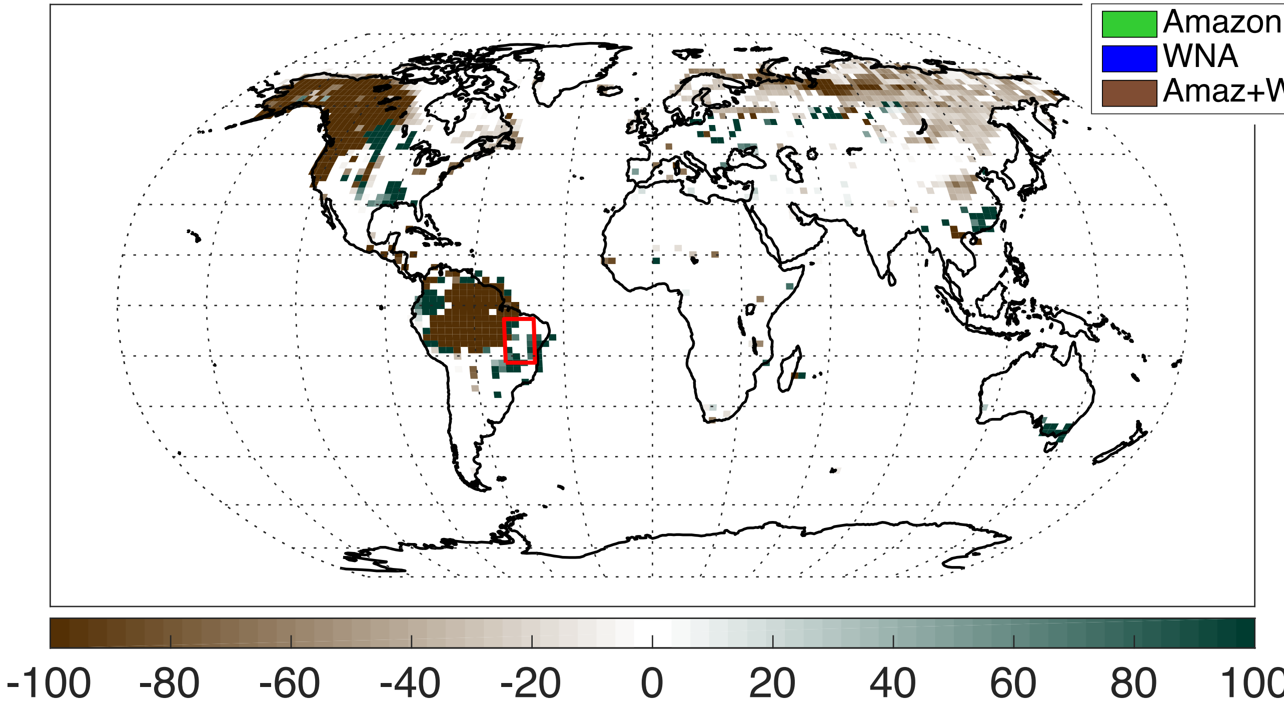
No change in precipitation

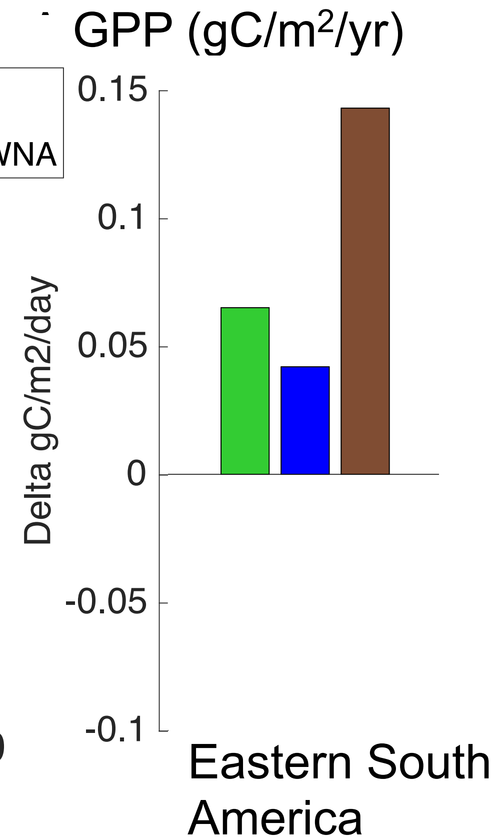


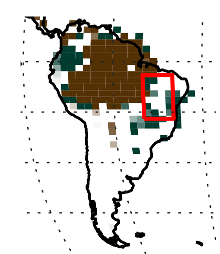
Siberia: ↓T → ↑ICE → WATER LIMITATION → ↓GPP



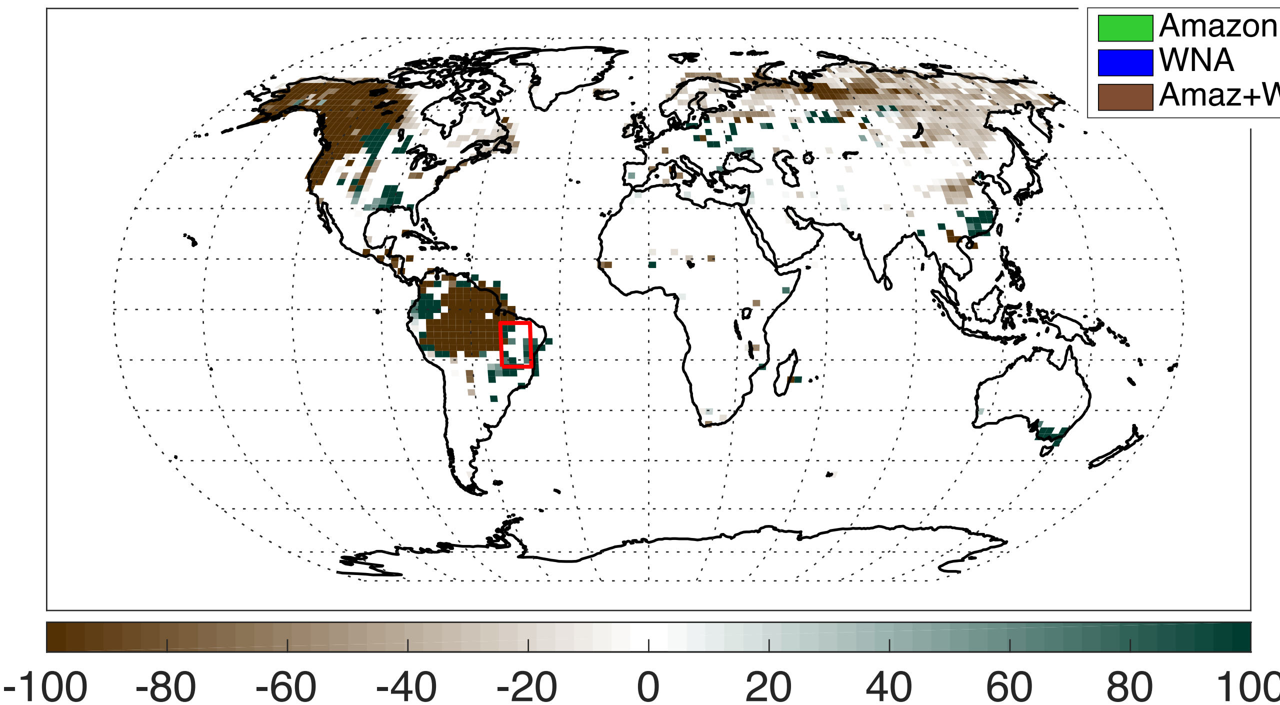
Regional Example: eastern South America
Remote Increases in GPP

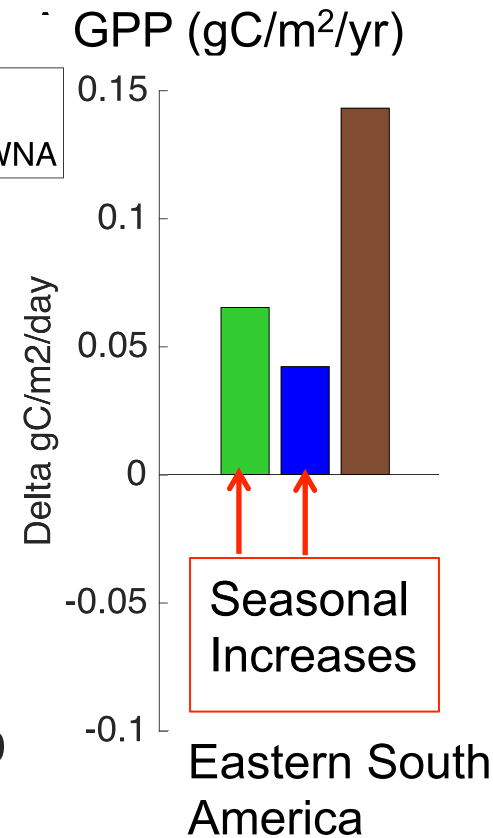


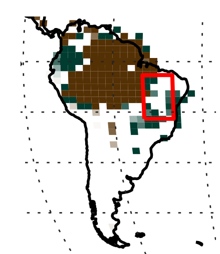




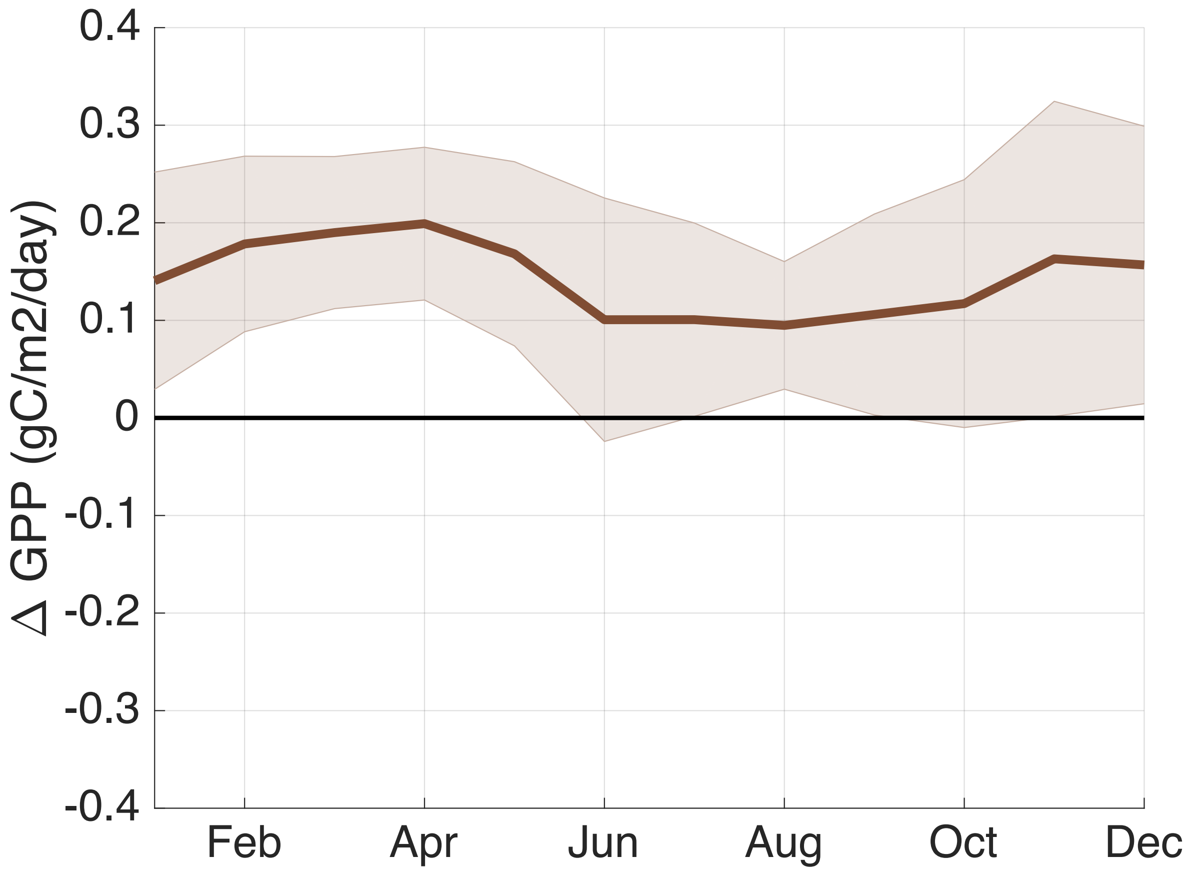
Regional Example: eastern South America
Remote Increases in GPP

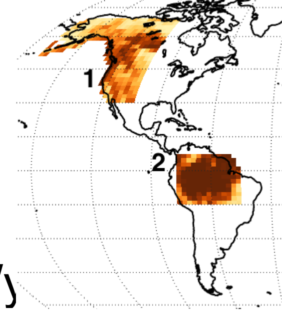


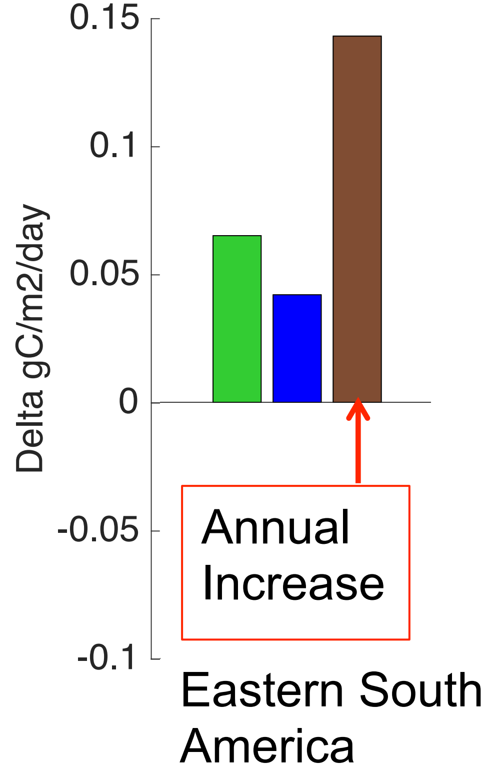


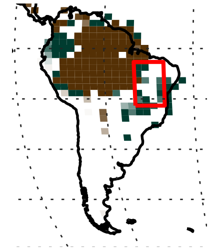


Regional Example: eastern South America
Remote Increases in GPP

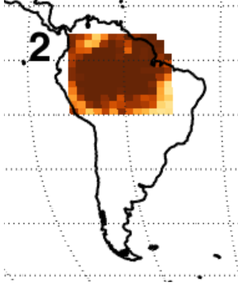


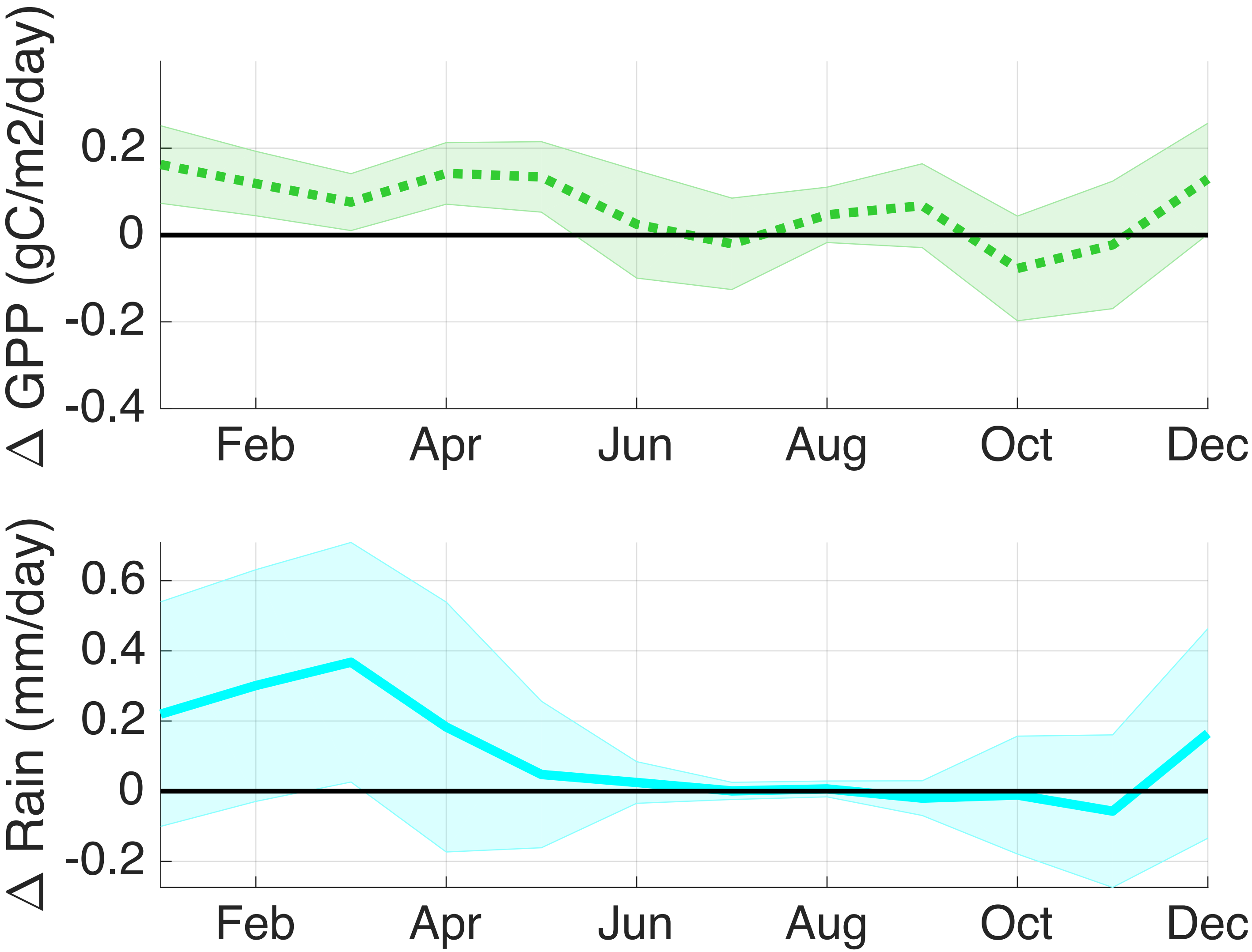


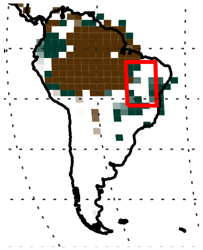




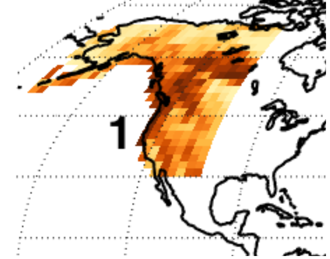
Amazon Loss: More Precipitation (↑P) Jan-Mar

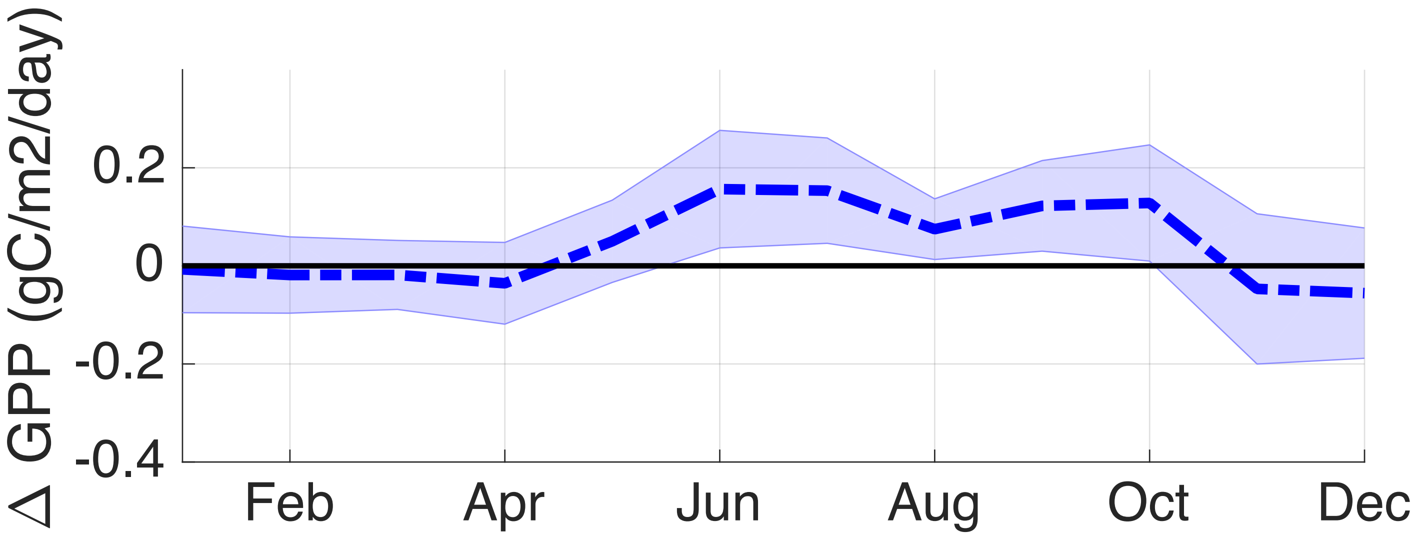


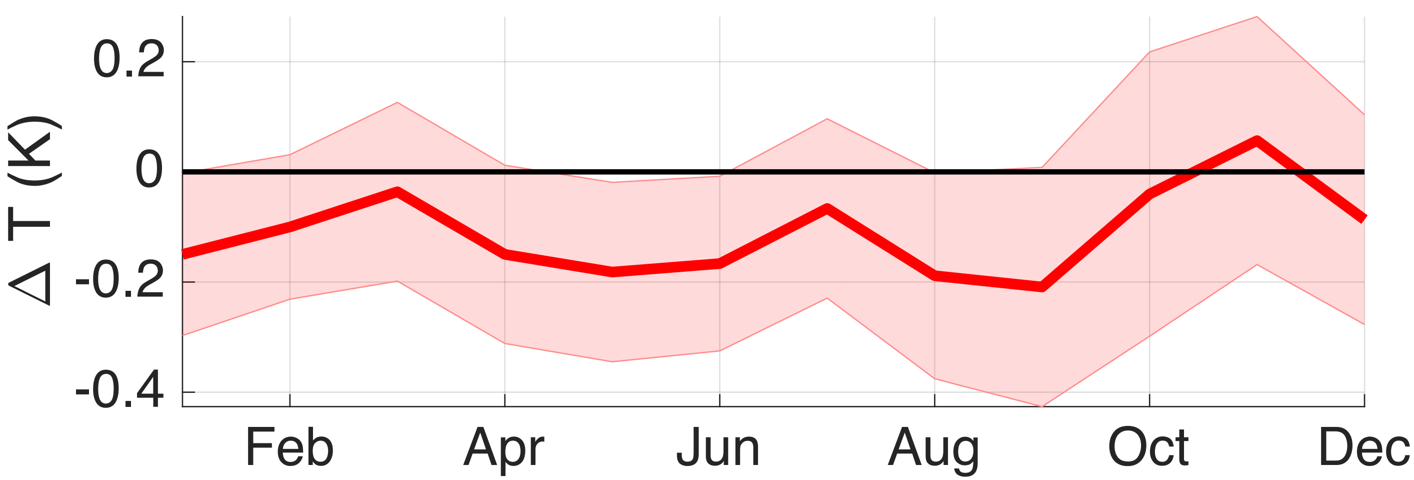


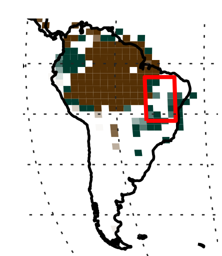


WNA Loss: Cooler Temps (↓T) May-Oct

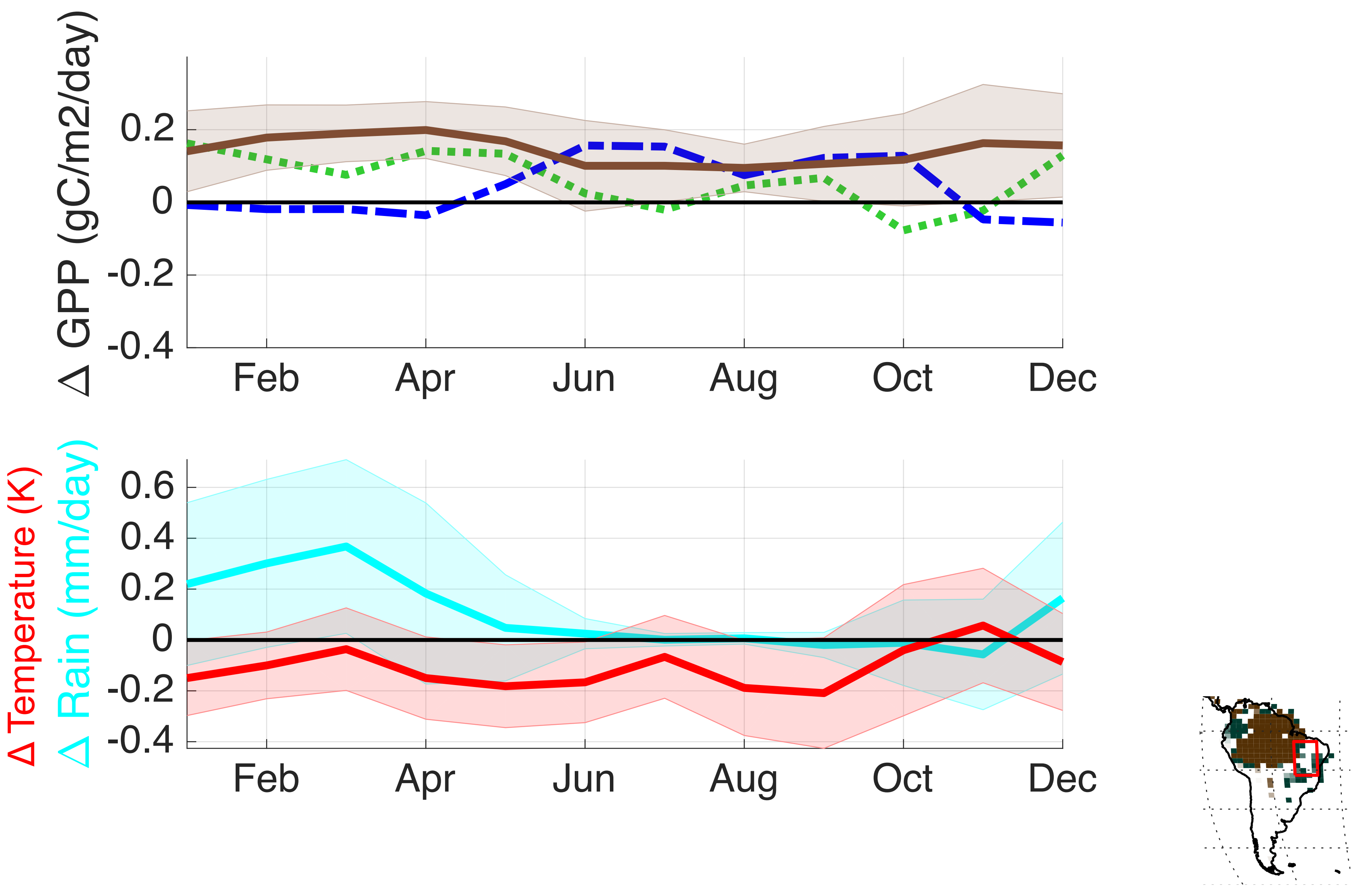








WNA+Amazon Forest Loss: ↑P + ↓T → ↑GPP all year



Regional forest loss—impacts to global climate and remote ecosystem productivity

Global climate feedbacks associated with regional forest loss
→ climate response differs depending on where disturbance occurs

Two Remote Regional Examples

Siberia: Cooler temps led to water limitation [freezing]

↓T → ↑SOILICE → ↓H2O → ↓GPP

Eastern S. America: Amazon Loss, Rain + WNA, Cooling

↑RAIN (Dec-May) → ↓T (Jun-Oct) → ↑GPP WNA+Amazon

-Seasonal responses depend on where disturbance occurred

<u>Land surface are dynamically connected through ecoclimate teleconnections</u>

Caveats

Everything else held constant – increasing $CO_{2,}$ regrowth/ LULCC

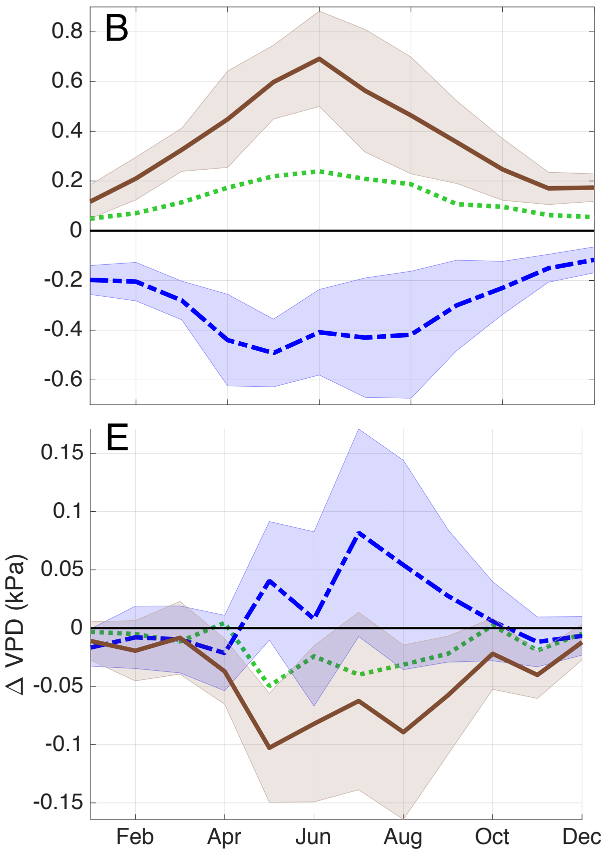
Future Directions

Does a more "realistic" magnitude of forest loss lead to teleconnections?

How do mechanisms controlling vegetation responses to teleconnections relate to bioclimatic regions in source/sink areas?

Link surface energy budget measurements to demography model that characterizes changes in vegetation structure

Extra Slide.



Southeastern N. America
wNA:

$$\downarrow VPD \Rightarrow \uparrow g_s \Rightarrow \downarrow GPP_{SENA}$$

wNA+Amazon, and Amazon cases:

$$\uparrow VPD \Rightarrow \downarrow g_s \Rightarrow \uparrow GPP_{SENA}$$