

Biophysical impacts of forests on temperature: evidence from satellite data and climate models

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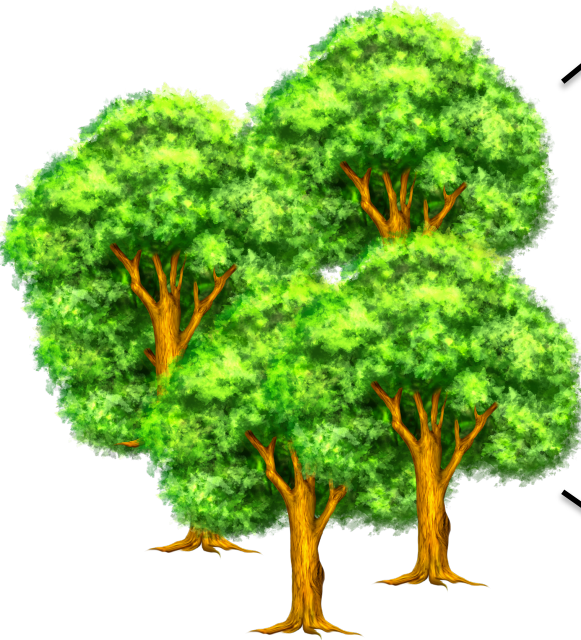
CICS-MD Science Meeting

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ESSIC, College Park, MD



Forest



Biogeochemical

- Carbon cycle
- ~45% of terrestrial carbon
- ~50% of terrestrial net primary production

Biophysical

- Land surface properties:
 - Albedo
 - Evapotranspiration (ET)
 - Roughness

Climate

Fast decline of global forests

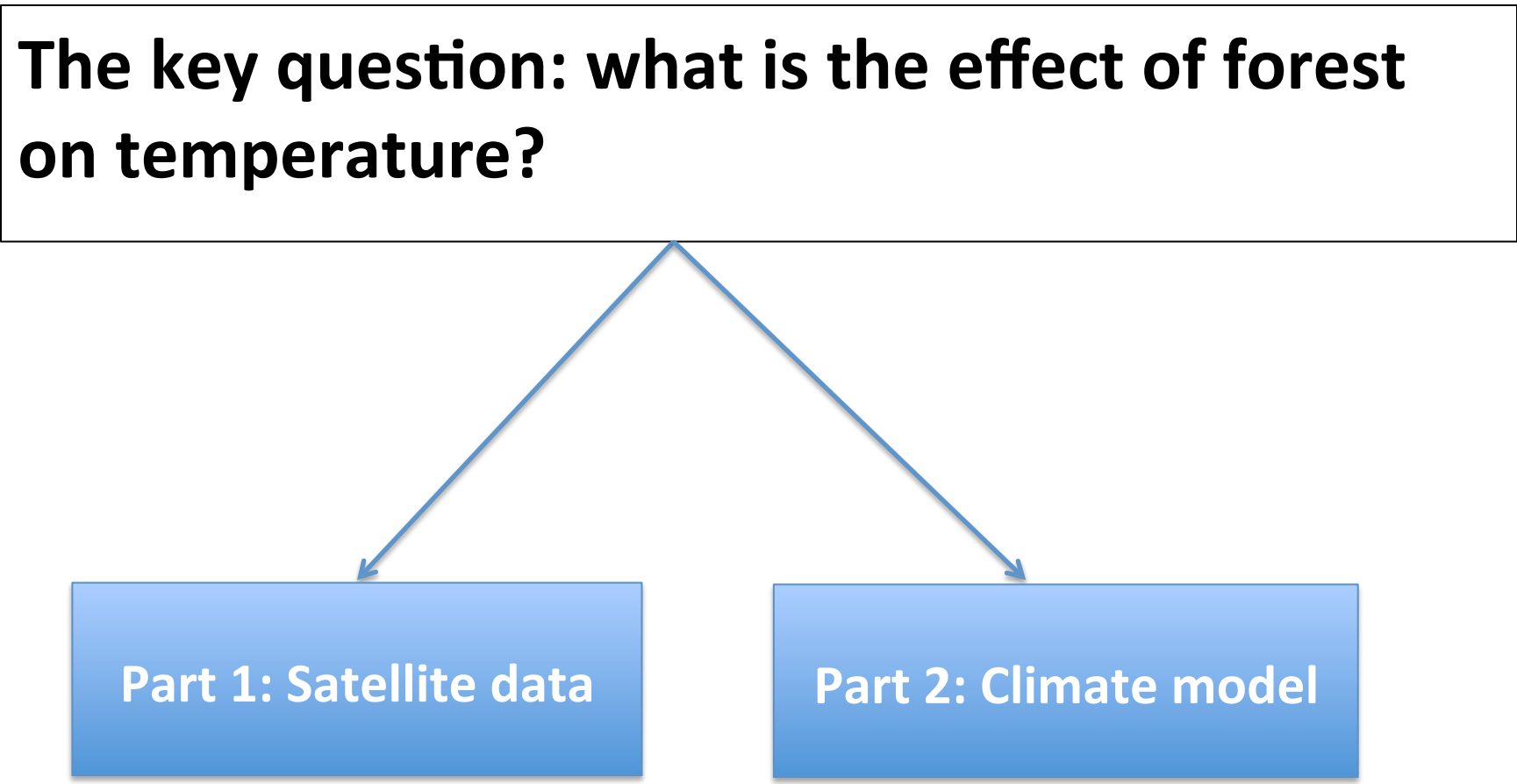
A world map showing the distribution of forest cover, with green areas representing forests. A small icon of a tree with a cloud-like shape next to it is located in the upper left corner, over North America.

**Global deforestation =
13 Million hectares
every year**

Close to the size of West Virginia
~3% of global forest cover

Perspectives from satellite data and simulations

The key question: what is the effect of forest on temperature?



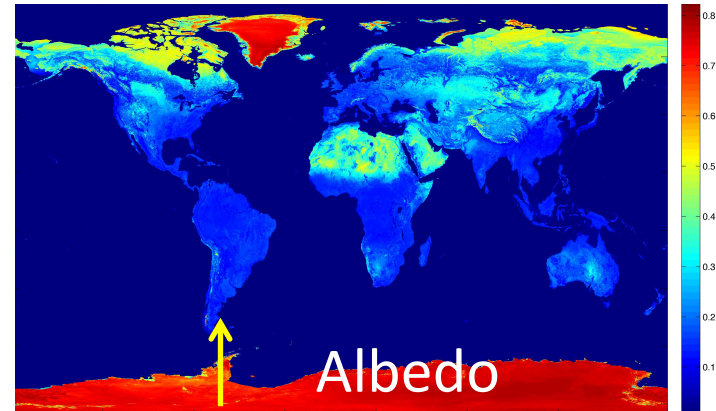
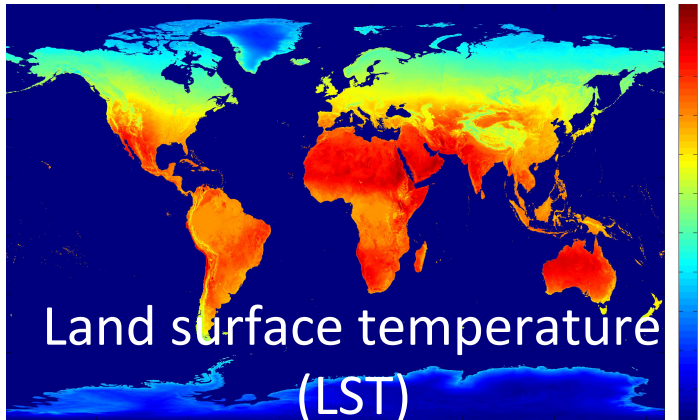
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graph TD; A["The key question: what is the effect of forest on temperature?"] --> B["Part 1: Satellite data"]; A --> C["Part 2: Climate model"]
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Part 1: Satellite data

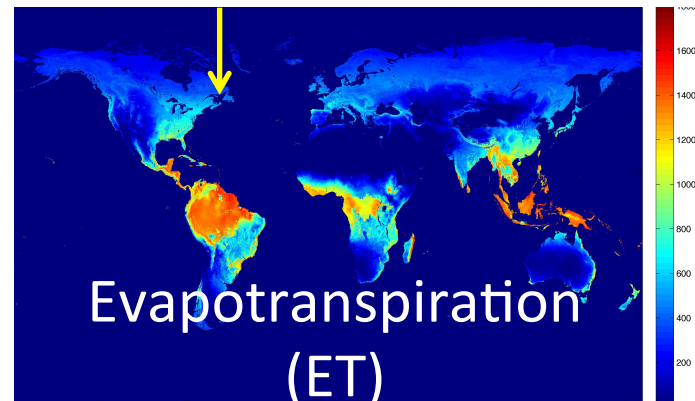
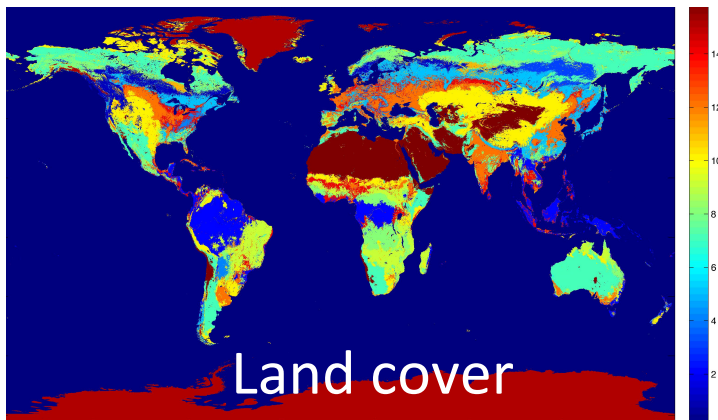
Part 2: Climate model

Part 1. Evidence from MODIS satellite data

Data



Biophysical drivers



Quantify effect of forest on temperature

Method

- Compare **forest** with **nearby open land** (grass and crop) in land surface temperature, albedo, and evapotranspiration (ET).

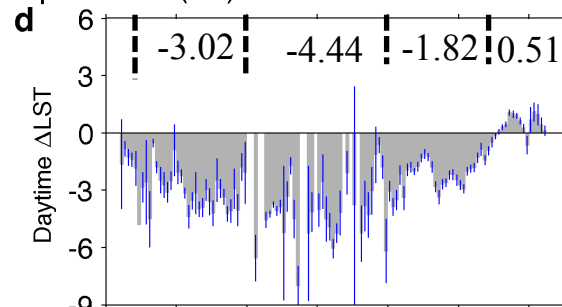
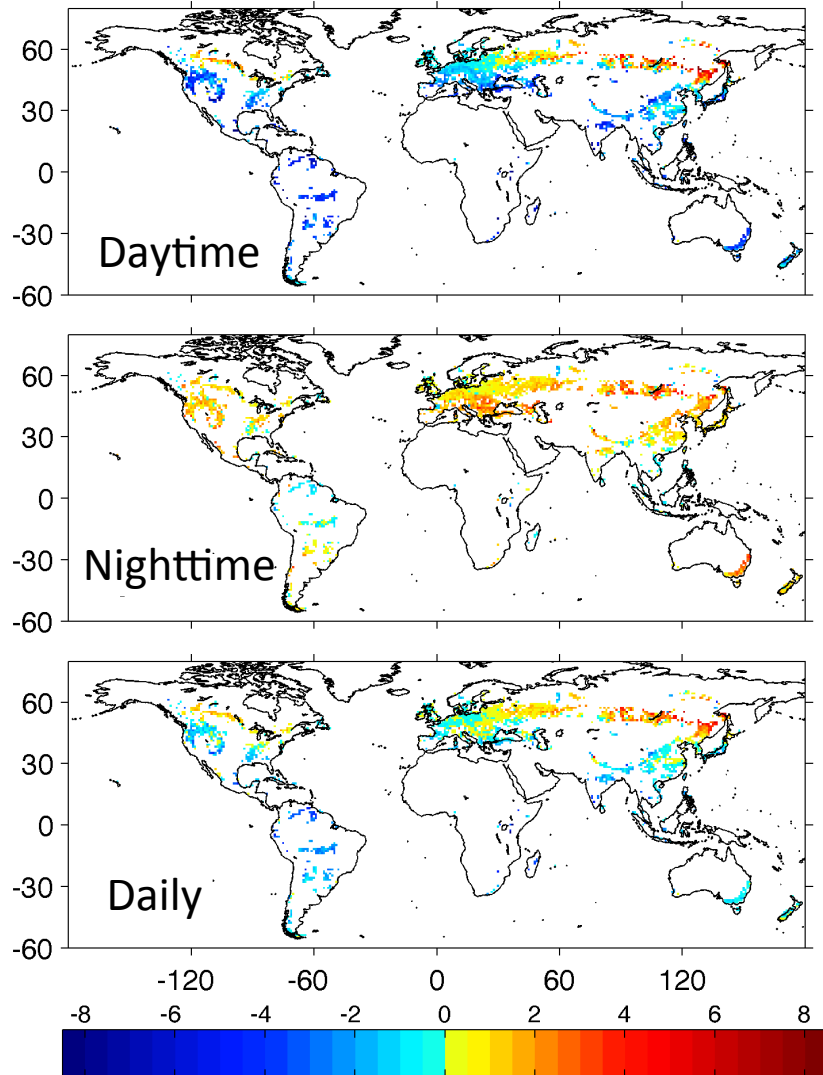
Forest vs. open land

$$\begin{aligned}\Delta LST &= LST_{\text{Forest}} - LST_{\text{Open land}} \\ \Delta \text{Albedo} &= \text{albedo}_{\text{Forest}} - \text{albedo}_{\text{Open land}} \\ \Delta ET &= ET_{\text{Forest}} - ET_{\text{Open land}} \\ &\dots\end{aligned}$$

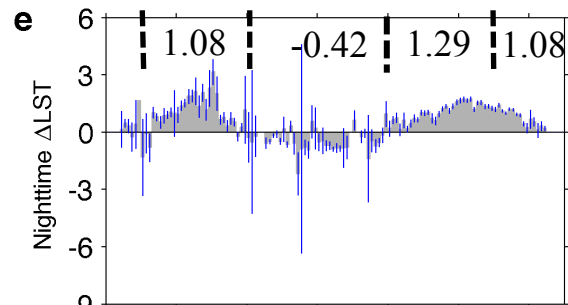
Temperature effects of forests from MODIS data

Annual Δ LST of forest minus open land

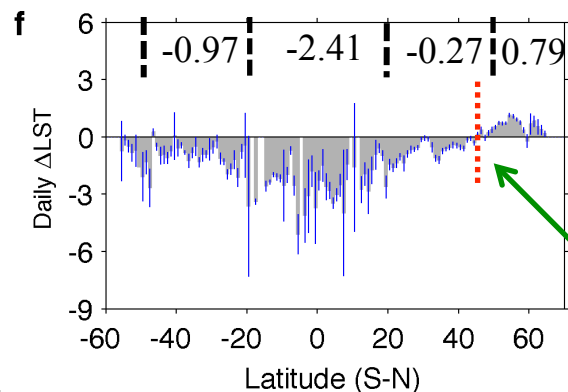
LST differences between forest and open land ($^{\circ}\text{C}$)



Daytime:
Cooling except
high latitude



Nighttime:
Warming except
tropics



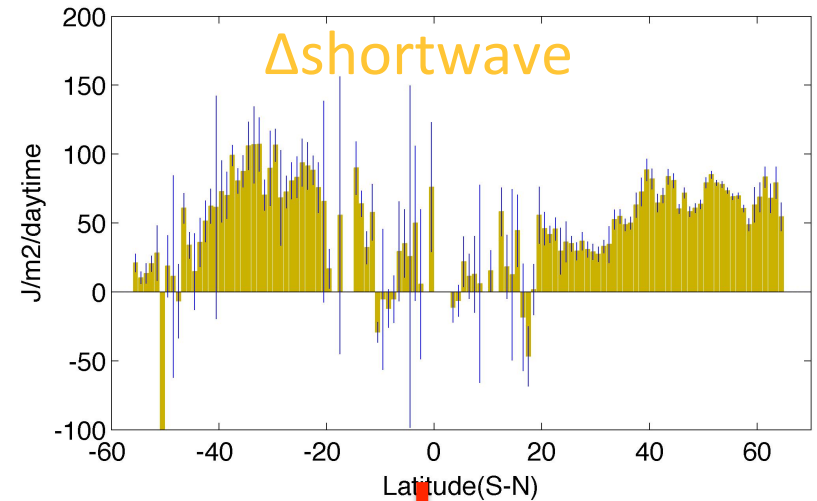
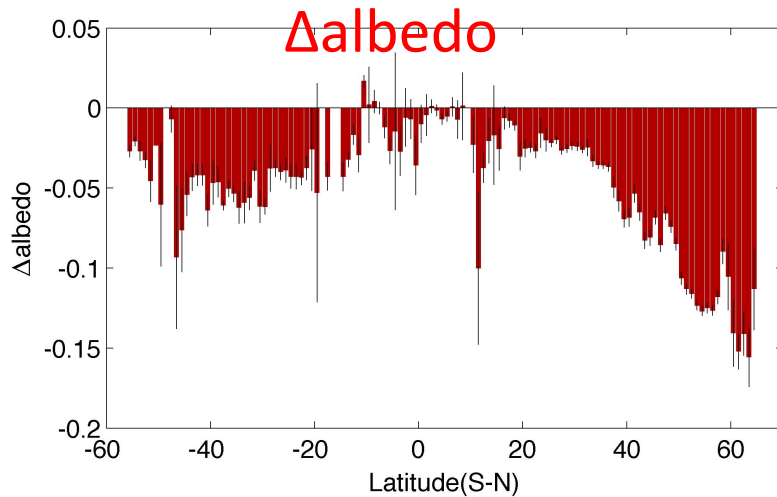
Daytime and
nighttime enhanced
or counteracted

Transitional
latitude at 45N

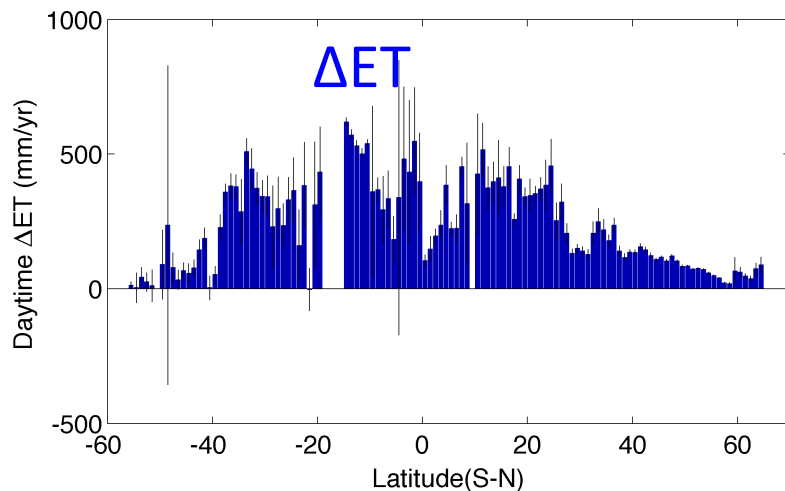
Biophysical factors control the temperature
effect of forests

Mechanisms of Temperature effect: albedo warming vs. ET cooling

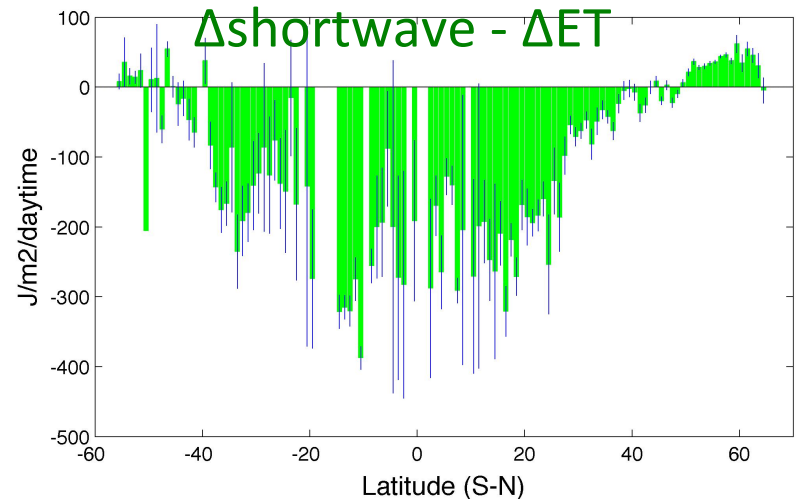
Lower albedo in forest has warming effect More absorbed shortwave energy



Higher ET in forest has cooling effect

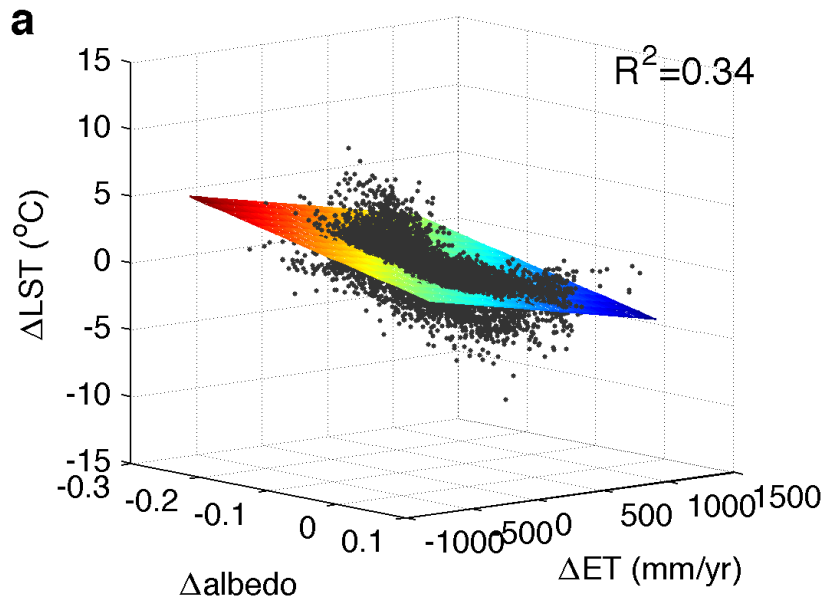


Net effect determine daytime ΔLST



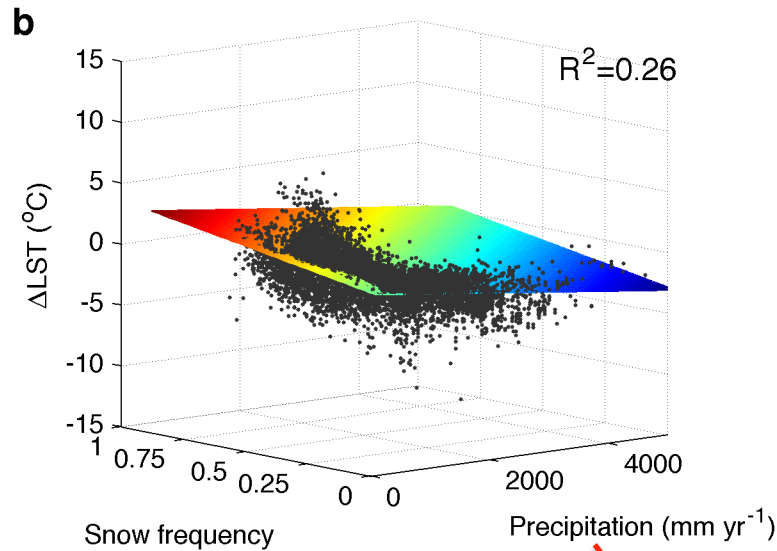
Biophysical effects

	Albedo warming	ET cooling	Net daily effect
Boreal forest	Strong	Weak	Warming
Northern Temperate forest	Moderate	Moderate	Moderate cooling
Tropical forest	Weak	Strong	Strong cooling



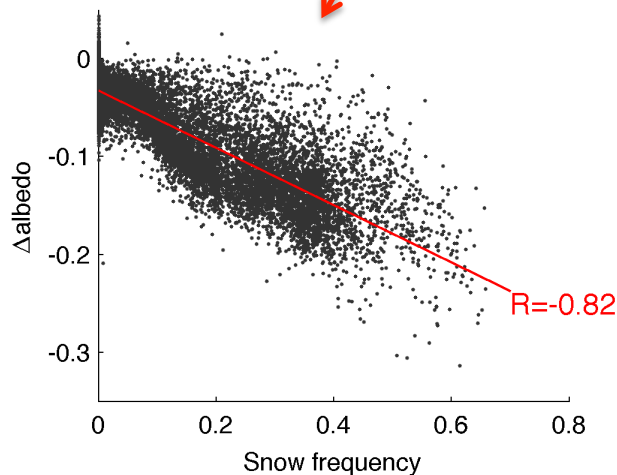
$\Delta albedo$ and ΔET
explain 34% spatial
variance of daily ΔLST

Background climate influences Δ LST through regulating biophysical factors

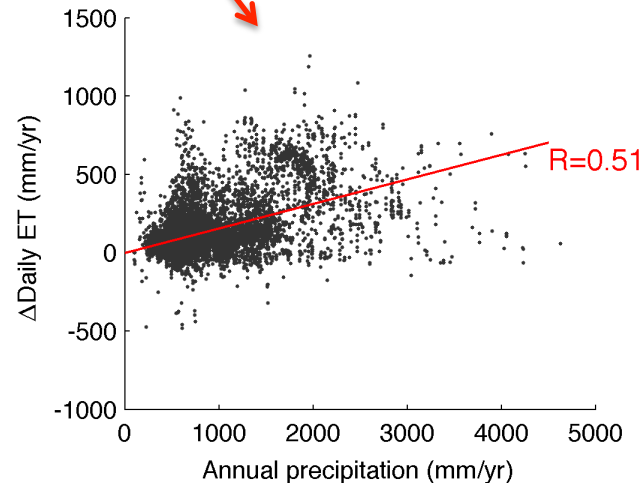


Snow frequency and precipitation explain 26% spatial variance of daily Δ LST

Snow affects Δ albedo



Precipitation affects Δ ET



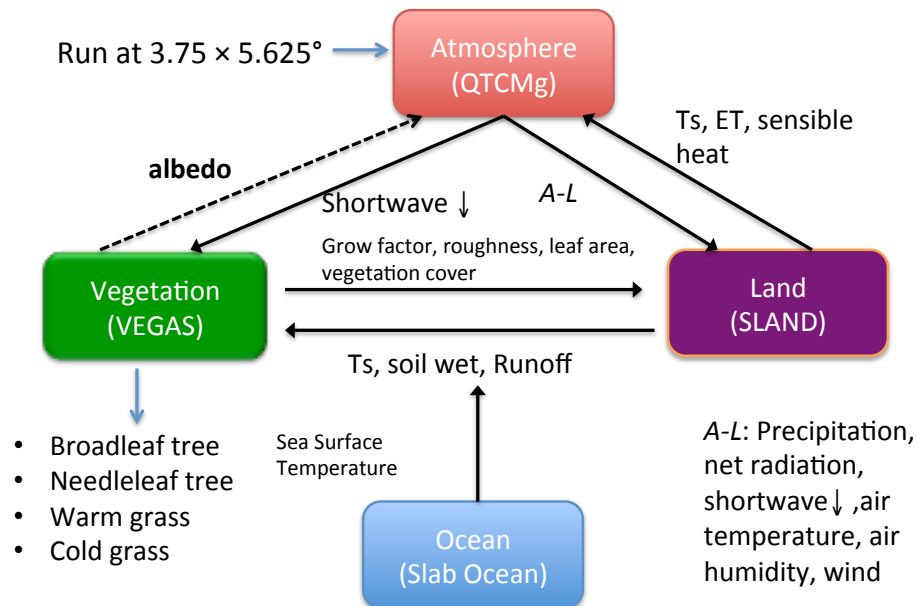
From satellite data, we know

- Biophysical effects of forests on local temperature have considerable **latitudinal and diurnal variations**.
- **Albedo and ET** largely determine temperature effects.
- **Background climate** can regulate biophysical effects

Part 2. Evidence from climate models

- Deforestation experiments with UMD earth system model

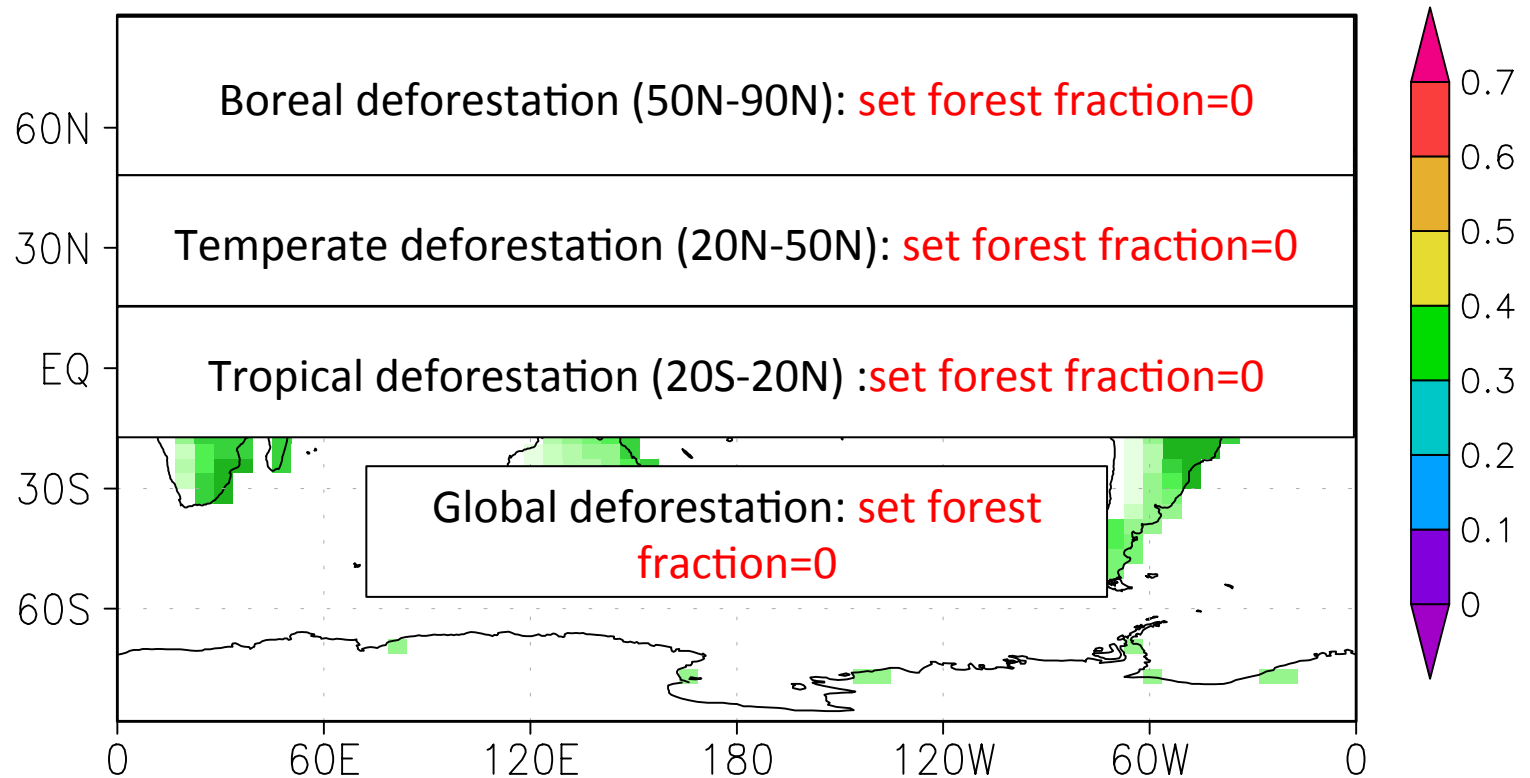
UMD earth system model



Method

Deforestation experiments on potential vegetation:

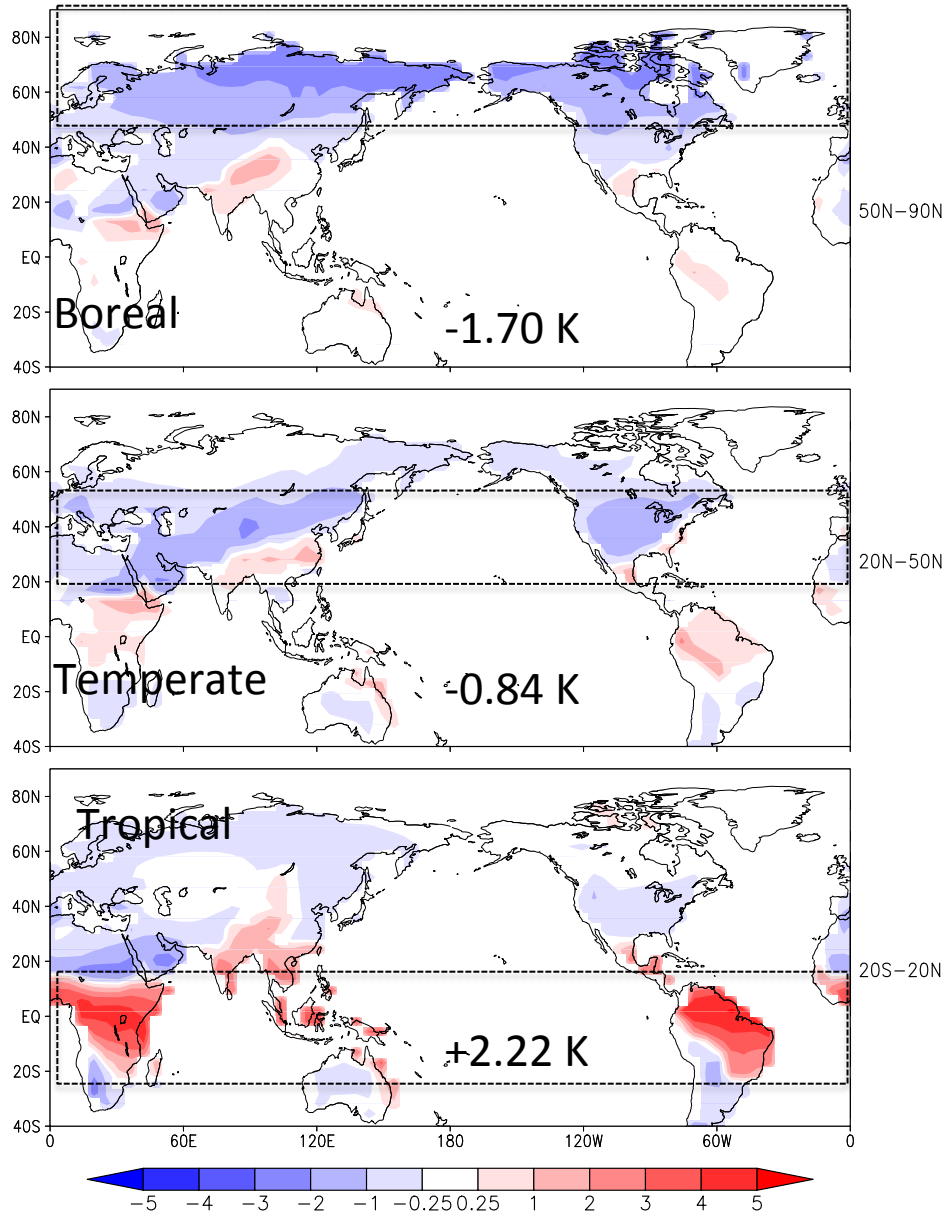
baseline forest fraction



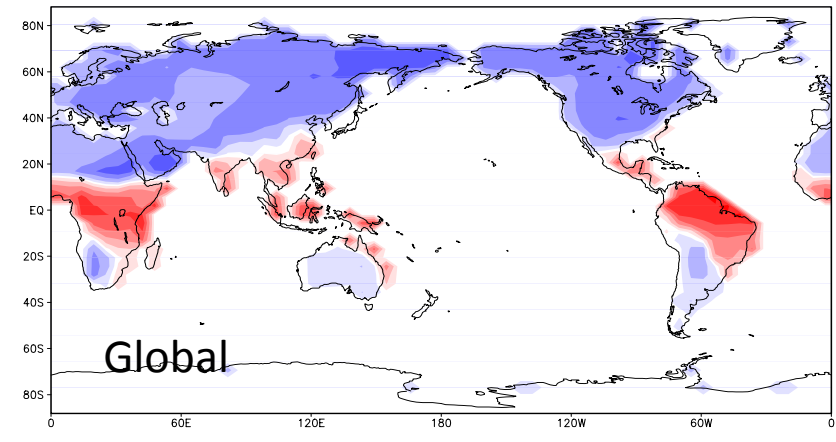
How does deforestation influence temperature?

Impact of deforestation on temperature

Regional deforestation



Global deforestation



Temperature change (K)

Region	Regional deforestation	Global deforestation
Boreal (50N-90N)	-1.70	-2.42
North temperate (20N-50N)	-0.84	-1.56
Tropical (20S-20N)	2.22	2.06

Mechanisms for temperature change?

- Albedo vs. ET effects

Mechanisms behind latitudinal ΔT : albedo and ET effect



Albedo effect

Increased albedo

Decreased shortwave energy (SW)

Cooling mechanism

ET effect

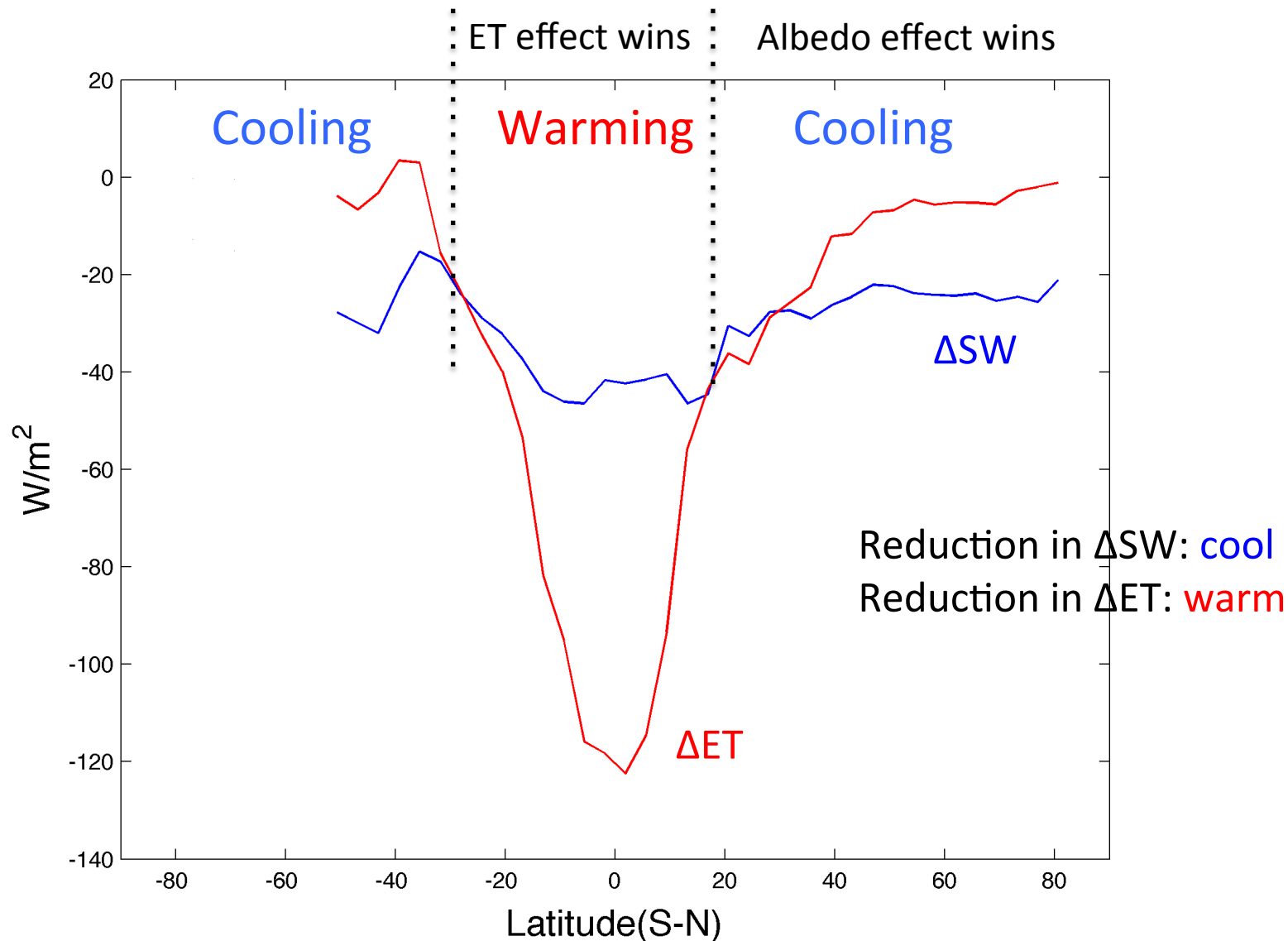
Decreased ET/Precipitation

Warming mechanism

Vs.

$$\Delta T \approx \Delta LW \uparrow = (\Delta SW - \Delta ET) + \Delta LW \uparrow + \Delta H$$

Relative importance of ΔSW and ΔET across latitudes

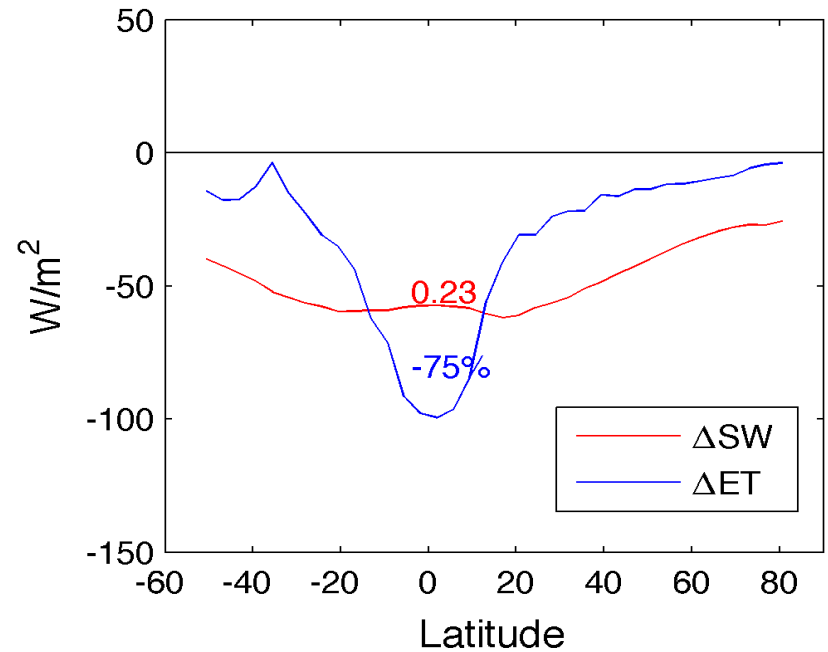
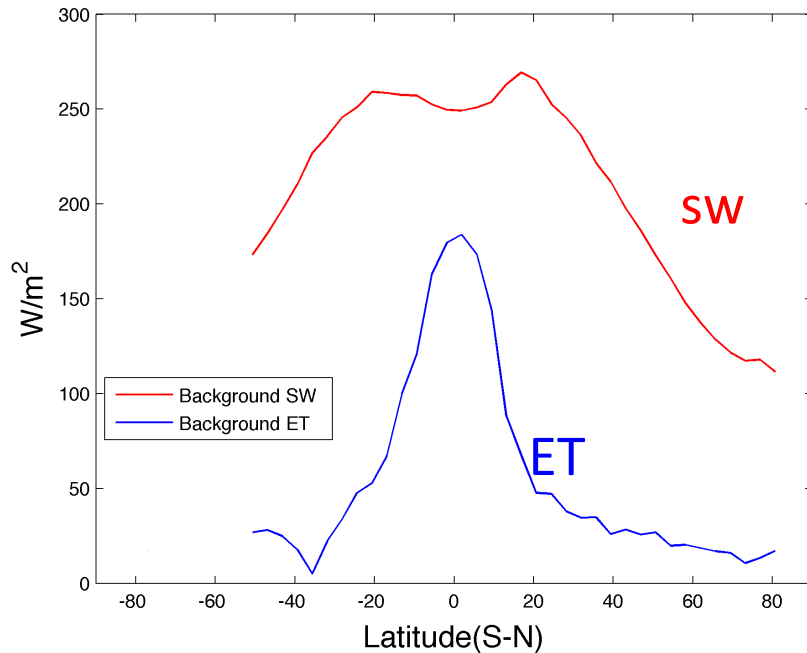


Mechanisms for temperature change

- Background climate

ΔSW and ΔET originated from background climate

Background climatology of SW and ET $\Delta ET = \text{Background ET} \times \text{reduction rate } (-75\%)$
 $\Delta SW = \text{Background SW} \times \text{albedo increase } (0.23)$



Findings from deforestation experiments

- Temperature response to deforestation has **strong latitudinal dependence**.
- **ΔSW and ΔET** largely determine the impact of deforestation.
- **Background climate** sets constrain to biophysical effects

Summary for the biophysical effects of forest

Forests	Evidence	Climate model	Satellite data
Boreal forest	Strong	Warming	Warming
Northern Temperate forest	Mixed	Weak warming	Weak cooling
Tropical forest	Strong	Cooling	Cooling

Considering all the critical roles that forests play in carbon sequestration, ecology, biodiversity, society, and regulating local climate, forests must be protected.