Drylands and Tropical Forests: Determining Which Region Contributes More to Interannual Carbon Flux Variability Across Different Definitions

Liam Bogucki & Dr. Natasha MacBean

Summary

Understanding which region primarily dictates the global interannual variation (IAV) of terrestrial carbon flux is critically important in our understanding of climate change. However, the current literature disagrees as to which global region is primarily dictating the observed IAV. The disagreement is whether regions classified as tropical forests, or regions classified as drylands / semi-arid, are the greatest contributor to IAV. We assessed the importance of four different regional classification schemes across 18 process-based land surface models simulating carbon fluxes from 1970 to 2021, by calculating an IAV contribution score. We found across most models and definitions that drylands provided a greater contribution to interannual variability than tropical forests. However, different regional definitions did lead to different IAV contribution scores. Additionally, when looking at a sub-regional scale, there is mixed results in which sub-region provides the greatest IAV contribution. Our findings demonstrate that regional boundary definitions can influence which region provides a greater IAV contribution, and that drylands are the region which typically provide a greater contribution regardless of definition.

Background

- Terrestrial ecosystems are the largest sink for global airborne carbon emissions.[1]
- Terrestrial ecosystems display interannual variation (IAV) of carbon fluxes, with some years providing a net uptake of carbon, and other years resulting in a net efflux of carbon into the atmosphere.[2]
- Existing analyses of which region primarily dictates the interannual variation in carbon flux provide a conflicting account, with some pointing to drylands and others to tropical forests.[2,3]
- Different analyses have utilized differing regional definitions.[2,3]

Methods

- Regions were represented at 0.5° latitude and longitude scale.
- Four different regional definitions were used (Table 1).
- Sub-regional analysis used MODIS type I land classification.[4]
- The calculation of IAV contributions was adapted from Ahlström *et al.*[5]
- The 18 models used: CLM5, ORCHIDEE, YIBS, IBIS, CABLE-POP, JULES, OCN, JSBACH, VISIT, VISIT-NIES, ISBA-CSTRIP, LPJ-GUESS, LPJWSL, LPX-BERN, CLASSIC, DLEM, SDGVM, and ISAM.[6]

Research Questions:

Do drylands or tropical forests contribute more to the interannual variation in terrestrial carbon flux?

What influence do regional definitions have?

Results

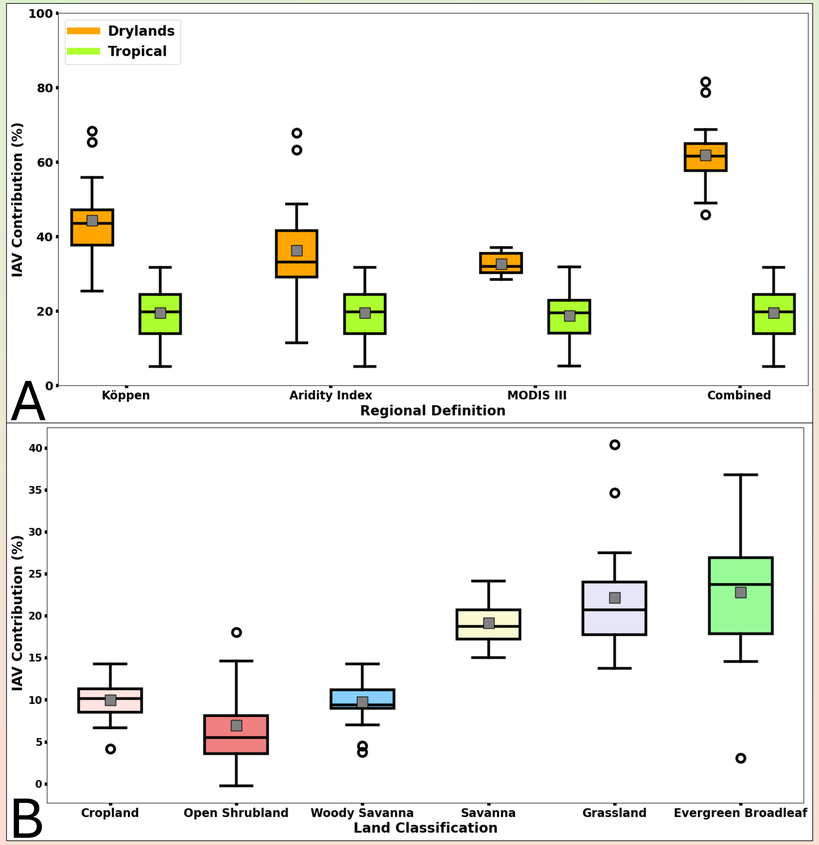

Figure 1. Boxplots of regional and sub-regional IAV contribution scores for 18 process-based land surface models, with mean shown as grey square. A) Comparison of regional IAV contribution scores. **B)** Comparison of sub-regional IAV contribution scores.

Regional Definitions

Table 1. Explanation of four different regional definitions used in analysis.

Regional Definition	Region	Criteria
Köppen	Drylands	▪ Köppen regions: Dry Summer Savanna, Dry Winter Savanna, Hot Semi-Arid, Cold Semi-Arid, Hot Desert, and Cold Desert[7] ▪ Removing land > 90% Bare
	Tropical	▪ Köppen regions: Rainforest and Monsoon[7]
Aridity Index	Drylands	▪ Regions with aridity index (AI) within 0 < AI < 0.65 ▪ At or below 55°N ▪ Removal of Antarctica ▪ Priority forfeited to tropical regions where overlap
	Tropical	▪ Köppen regions: Rainforest and Monsoon[7]
MODIS III	Drylands	▪ MODIS type III savanna and shrub lands < 45°N[4]
	Tropical	▪ MODIS type III forest class where grid cells have a mean monthly temperature that never falls below 18°C from 1940 – 2024[4]
Combined	Drylands	▪ Combination of Köppen, Aridity Index, and MODIS III definition ▪ Priority forfeited to tropical regions
	Tropical	▪ Köppen regions: Rainforest and Monsoon[9]

Results

- All models had higher IAV contribution from drylands using the Köppen and Combined definition.
- One model had a higher IAV contribution from tropical forests using the Aridity Index definition, with all others having drylands.
- Two models had a higher IAV contribution from tropical forests using the MODIS III definition, with all others having drylands.
- 11 models had Evergreen Broadleaf (tropical forest) as the dominant IAV sub-region, six models had Grasslands, and one had Savanna.

Conclusions

- Most models showed drylands contributing more to the IAV in terrestrial carbon fluxes than tropical forests, regardless of which definition system was used.
- When looking at a sub-regional comparison it is unclear which sub-region is the most responsible for contributing to the IAV in terrestrial carbon fluxes
- Definitions have some impact on which region is contributing more to IAV, but overall, drylands are the dominant region.

References

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