

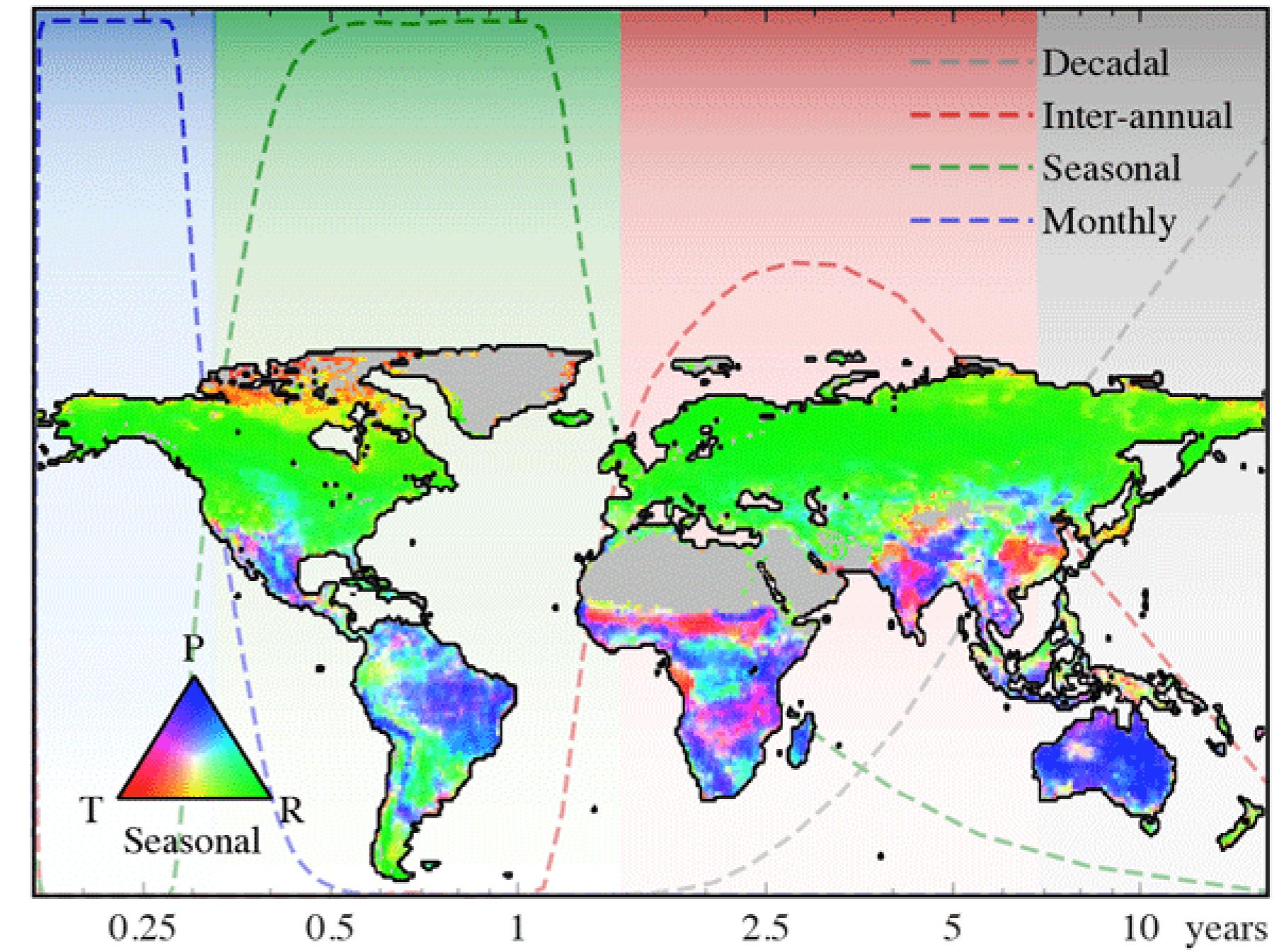
CLIMATIC DRIVERS AND BIOGEOPHYSICAL FEEDBACKS: A CAUSAL INFERENCE APPROACH OVER MULTIPLE TEMPORAL SCALES

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GOAL

- Global climate-vegetation interactions
 - Climate → vegetation
 - Vegetation → climate
- Temporal scales
 - Monthly
 - Seasonal
 - Inter-annually
- Benchmark ESM



CONDITIONAL SPECTRAL GRANGER CAUSALITY

- Extension *Granger causality* to the frequency domain
- Multivariate
- Non-parametric
- For a set of $p + 2$ variables $(X, Y, Z_1, Z_2 \dots Z_p)$, the conditional spectral Granger causality is given by

$$CSGC_{X \rightarrow Y | Z_1, Z_2 \dots Z_p}(f) = \ln \left(\frac{\Gamma_{yy}}{|Q_{yy}(f)\Sigma_{xx}Q_{yy}^*(f)|} \right)$$

where Γ , Q , and Σ can be determined from the transformations
(Fourier, wavelet...) of $X, Y, Z_1, Z_2 \dots Z_p$

CONDITIONAL SPECTRAL GRANGER CAUSALITY

- Fraction of variance in Y explained by X is given by

$$F_{X \rightarrow Y | Z_1, Z_2 \dots Z_p}(f) = \left(1 - e^{-CSGC_{X \rightarrow Y | Z_1, Z_2 \dots Z_p}(f)}\right) = \frac{\Gamma_{yy} - |Q_{yy}(f)\Sigma_{xx}Q_{yy}^*(f)|}{\Gamma_{yy}}$$

→ Allows to calculate how much variance in the target variable is explained by the predictors at each temporal scale

DATASETS

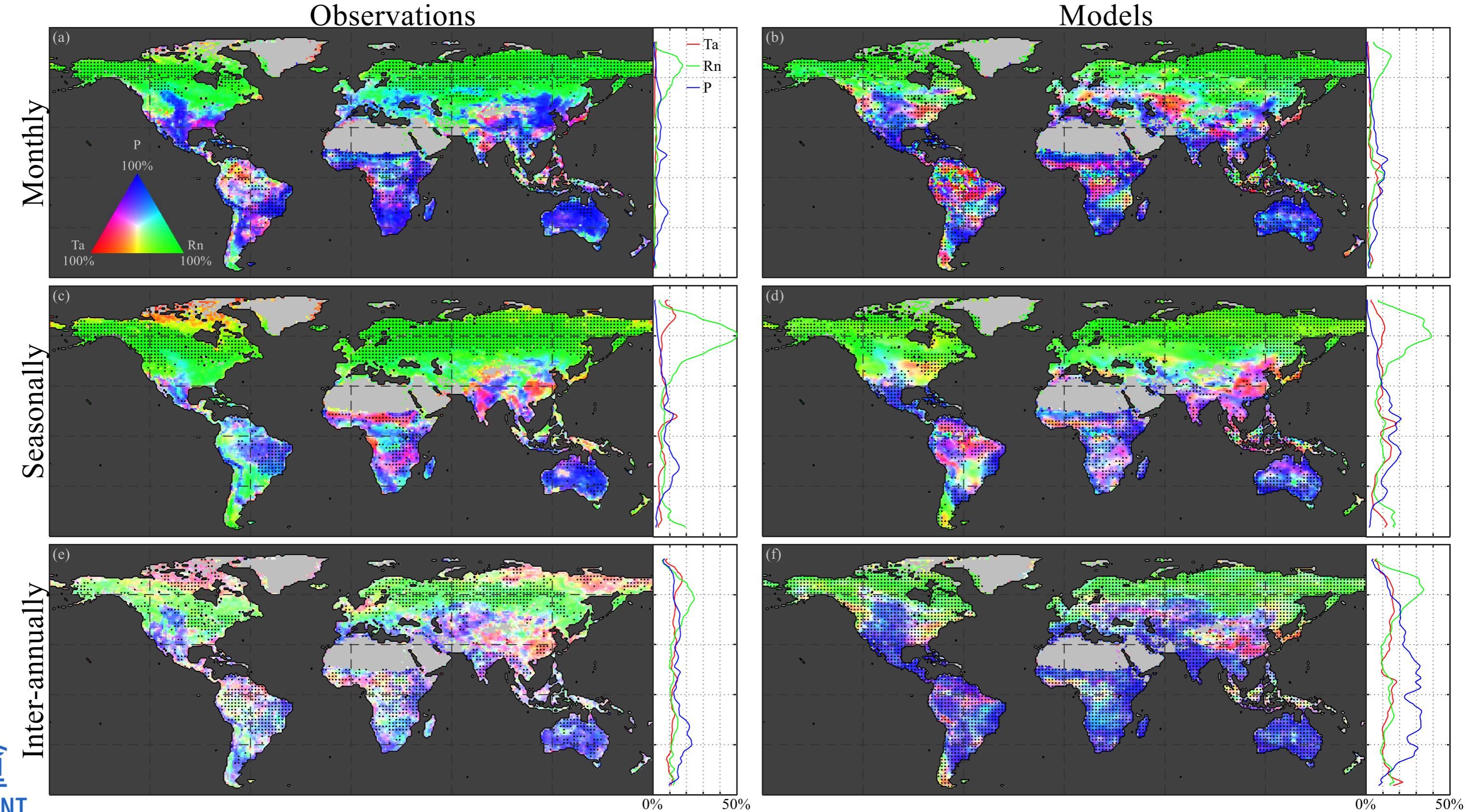
Observations ensemble

- Leaf area index
 - GIMMS3g, TCDR, GLOBMAP, GLASS
- Air temperature
 - ERA5, CRUNCEP
- Net radiation
 - ERA5, CRUNCEP
- Precipitation
 - ERA5, CRUNCEP, GPCC

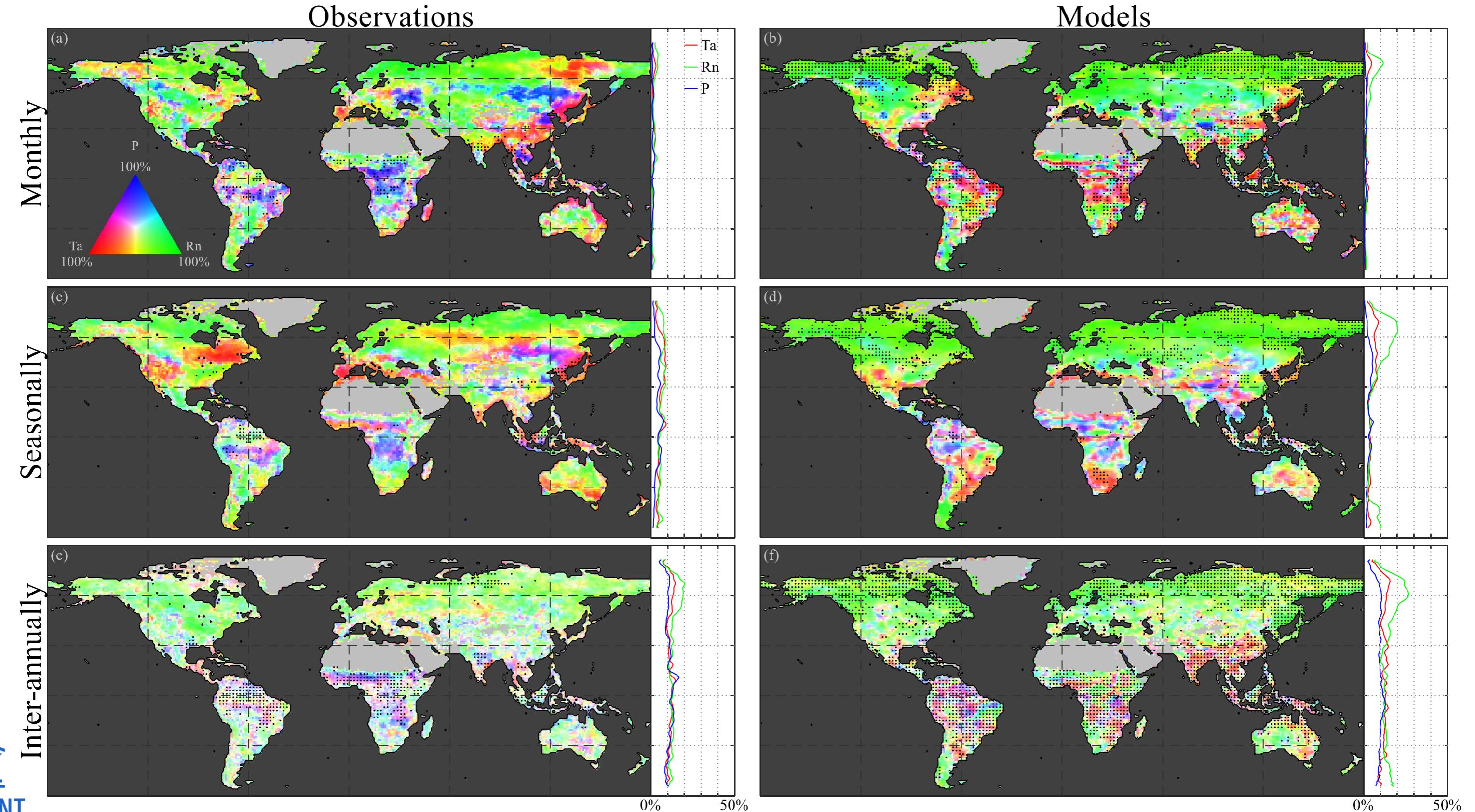
Earth System Models

- CMIP5
 - HadGEM2-ES
 - IPSEL-CM5A-MR
 - NorESM1-M
 - CCSM4

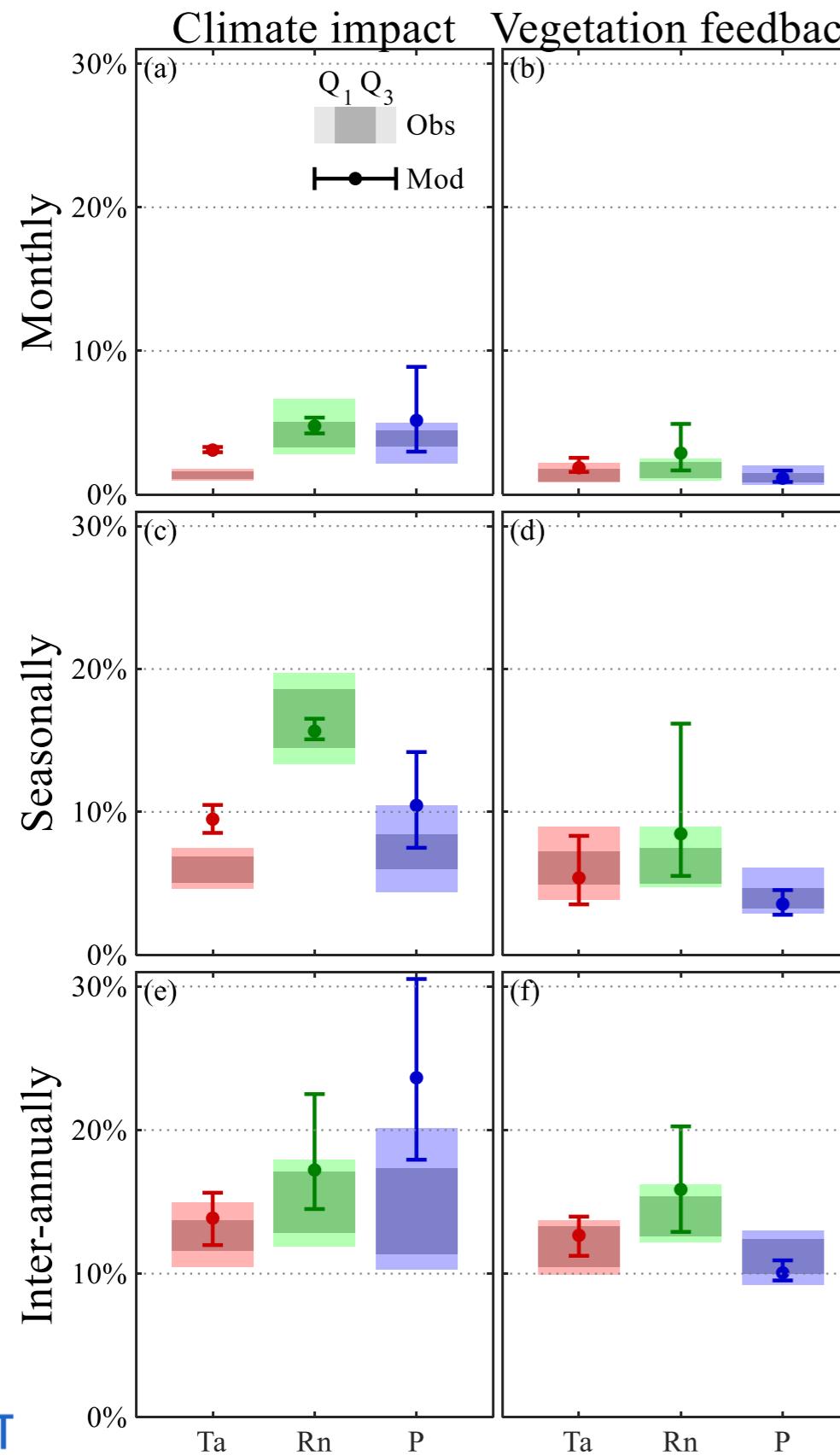
IMPACT OF CLIMATE ON VEGETATION



FEEDBACK OF VEGETATION ON CLIMATE



FEEDBACK OF VEGETATION ON CLIMATE



- Increase with temporal scale
- Impacts > feedbacks
- Overestimation impact precipitation by models?

Challenges

- Causal sufficiency
- Changes over time

More information

Claessen, J., Molini, A., Martens, B., Detto, M., Demuzere, M., and Miralles, D. G.: Global biosphere-climate interaction: a causal appraisal of observations and models over multiple temporal scales, *Biogeosciences*, 16, 4851-4874, <https://doi.org/10.5194/bg-16-4851-2019>, 2019.

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