The sensitivity of terrestrial carbon fluxes to temperature and precipitation: a preliminary analysis with ISI-MIP2a

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The Carbon fluxes: terminology

GPP – Gross Primary Production

Ra – Plant Respiration

NPP - Net Primary Production (GPP-Ra)

Rh - Heterotrophic Respiration

NEP - Net Ecosystem Production (NPP-Rh)

Sensitivity analysis: Multiple Regression Approach

$$Y_{Cflux} = \gamma_{Tair} X_{Tair} + \gamma_{Prec} X_{Prec} + \varepsilon$$

Y_{Cflux}: detrended anomaly of annual carbon flux (g C m^{-2} yr^{-1}),
including GPP, NPP, Rh, NEP

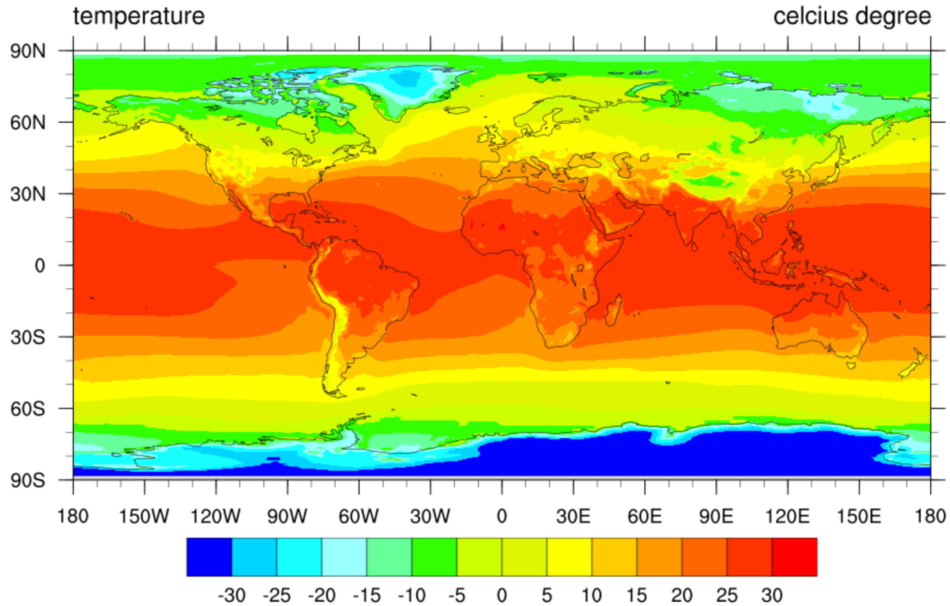
X_{Tair}: detrended anomaly of annual temperature (°C)

X_{Prec}: detrended anomaly of annual precipitation (mm yr^{-1})

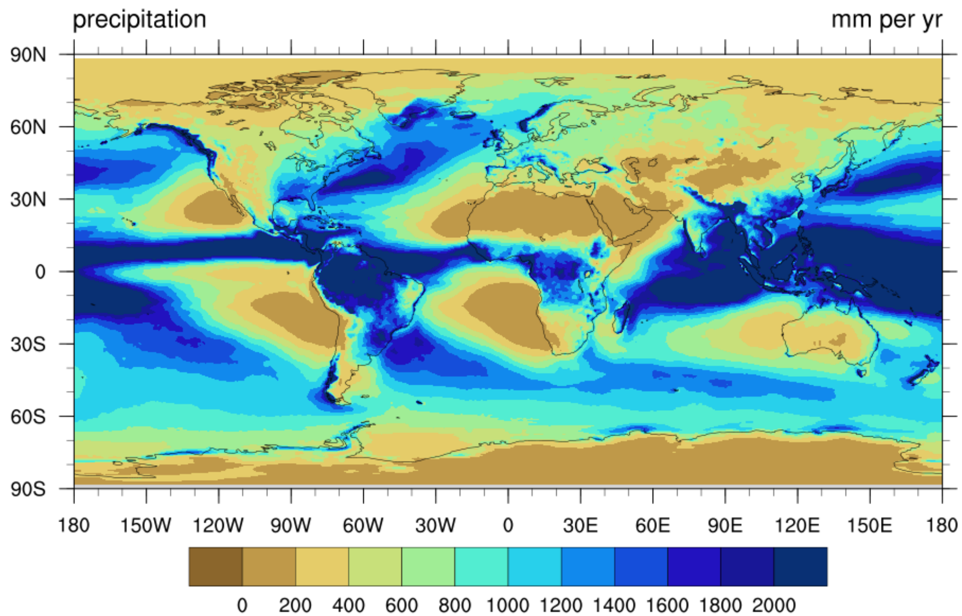
γ_{Tair}: carbon flux sensitivity to interannual variations in temperature
(g C m^{-2} yr^{-1} per °C)

γ_{Prec}: carbon flux sensitivity to interannual variations in precipitation
(g C m^{-2} yr^{-1} per mm yr^{-1})

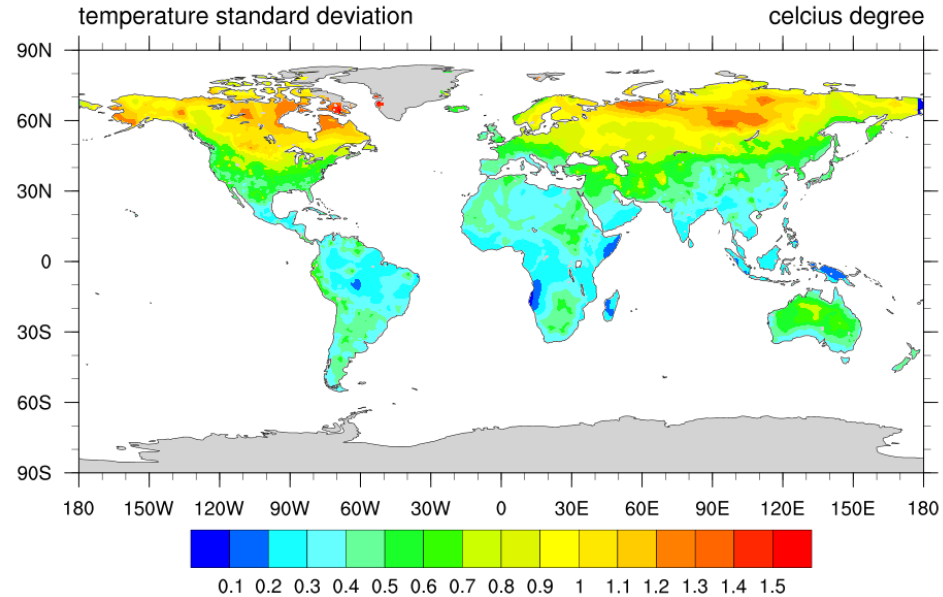
ε: residue error



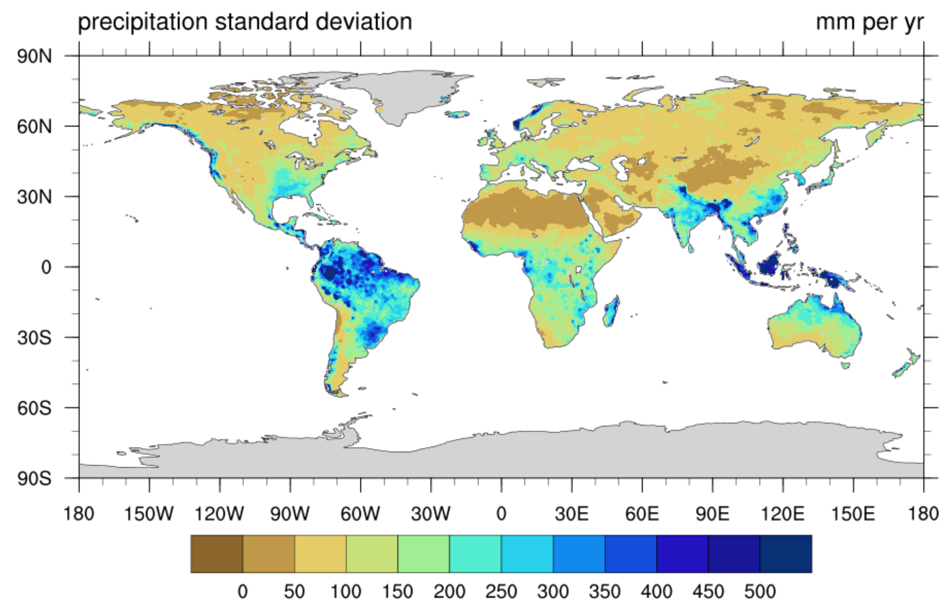
Global average temperature during 1971-2010 based on GSWP3



Global average precipitation during 1971-2010 based on GSWP3

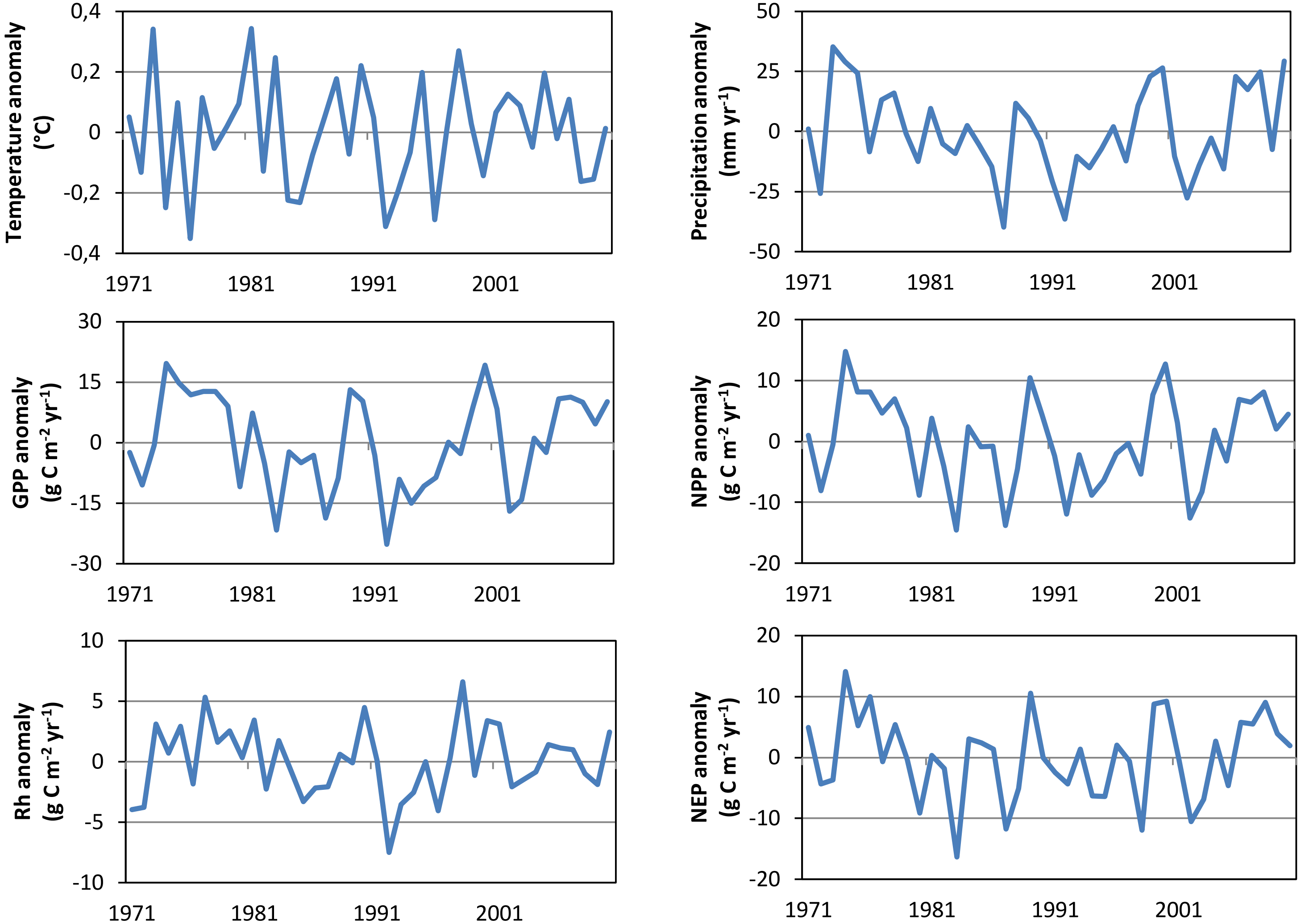


standard deviation of detrended temperature anomaly during 1971-2010 based on GSWP3



standard deviation of detrended precipitation anomaly during 1971-2010 based on GSWP3

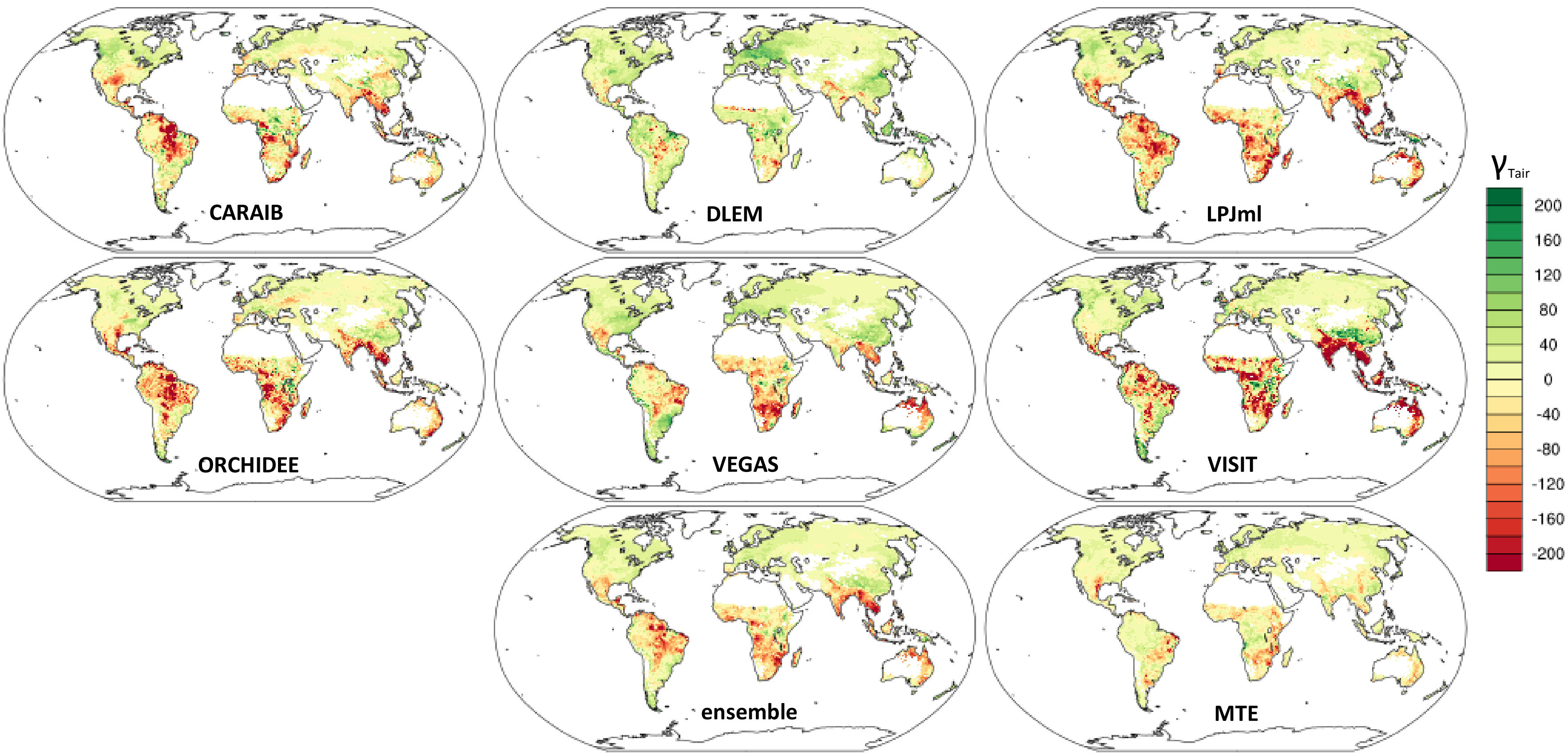
Detrended anomaly of climate and carbon fluxes



Result 1:

The sensitivity of carbon fluxes to temperature variation

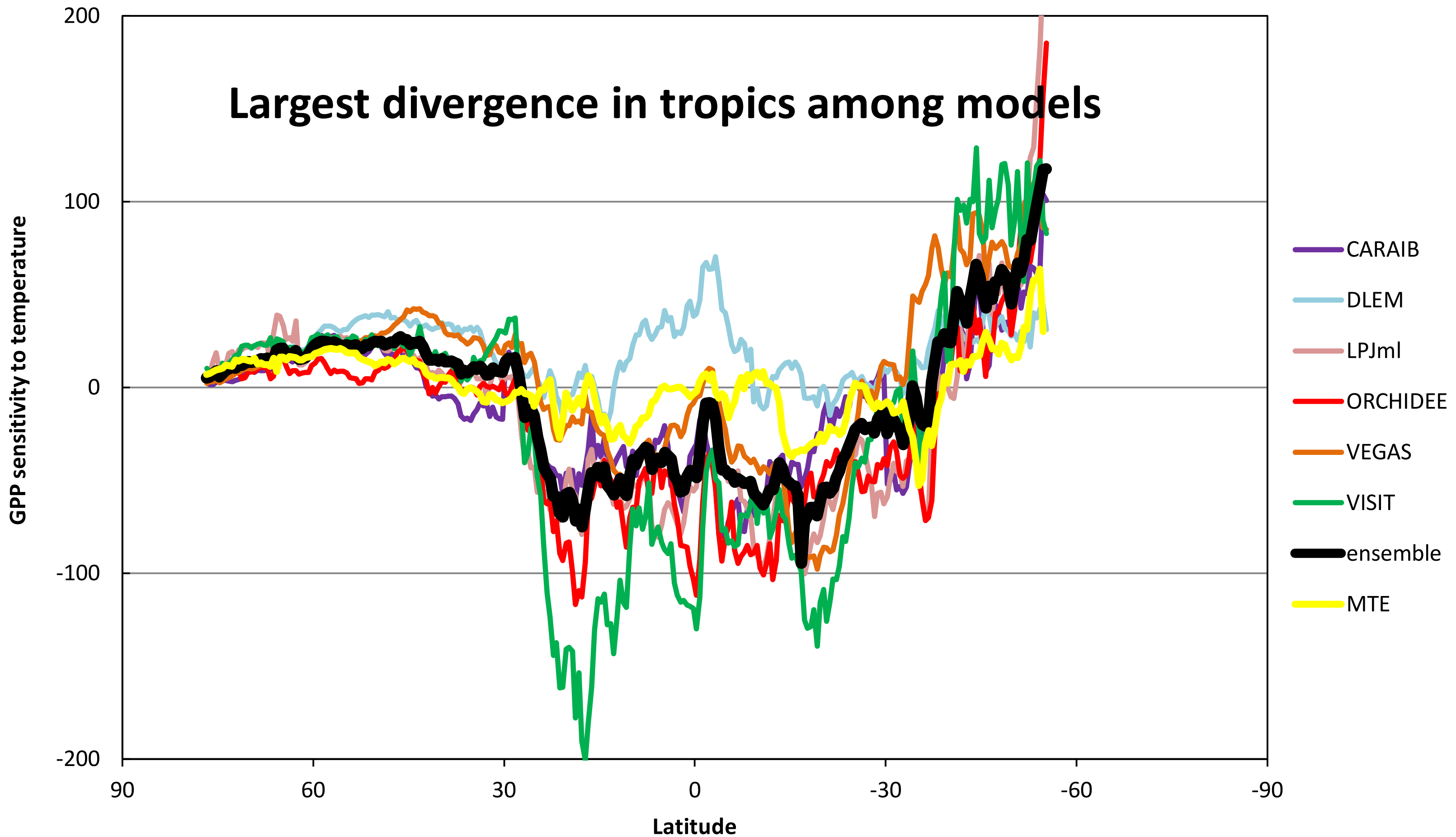
The sensitivity of GPP to temperature variation



GPP sensitivity (g C m^{-2} yr^{-1} per °C) to inter-annual variation in temperature

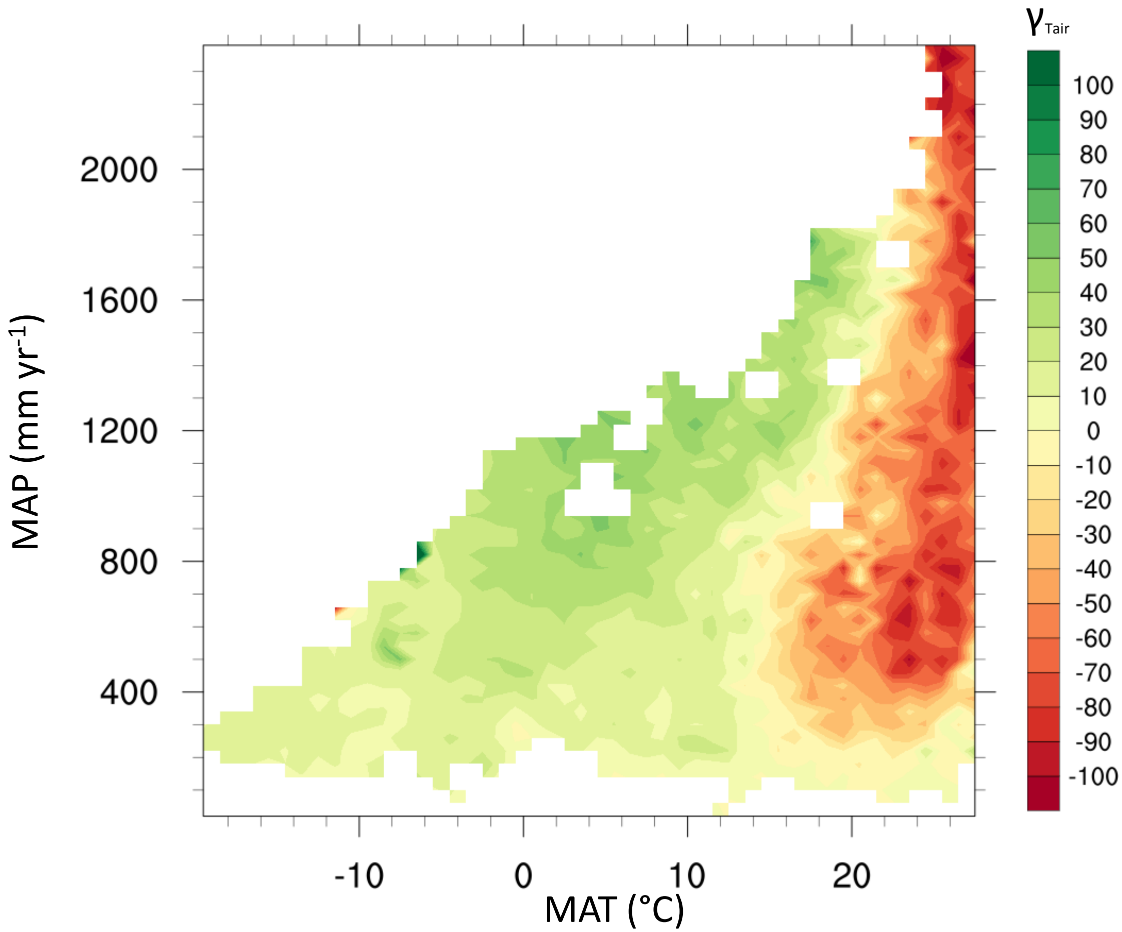
Global average: **-10.5** ± 16.9 g C m^{-2} yr^{-1} per °C

Sensitivity of GPP to temperature variation



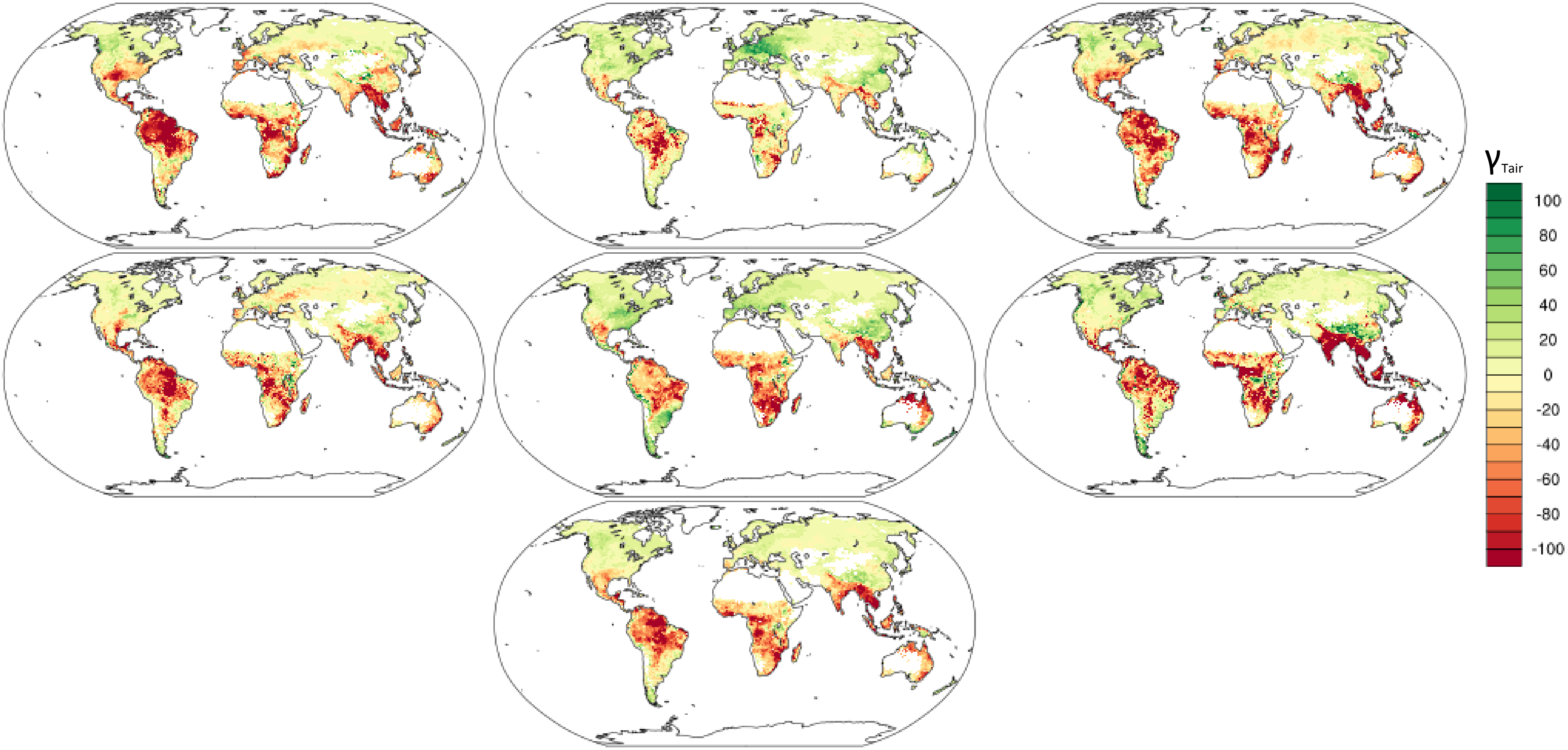
MTE GPP and model ensemble show that GPP is positively correlated with temperature in mid- and high latitudes, but negatively related to temperature in topical region (30°N – 35°S).

Sensitivity of GPP to temperature variation



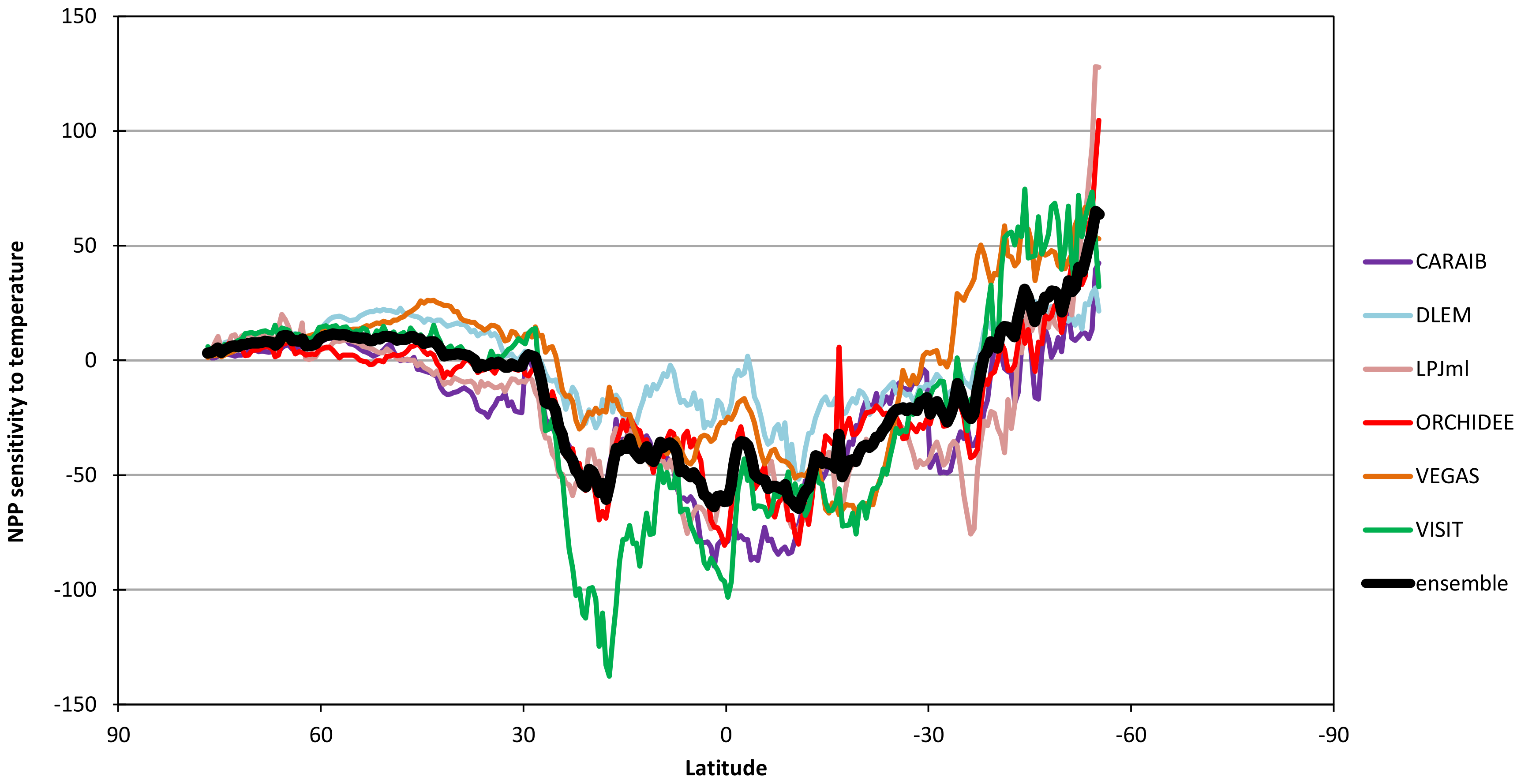
GPP is positively correlated with temperature in low MAT areas, but negatively correlated with temperature in high MAT areas.

Sensitivity of NPP to temperature variation



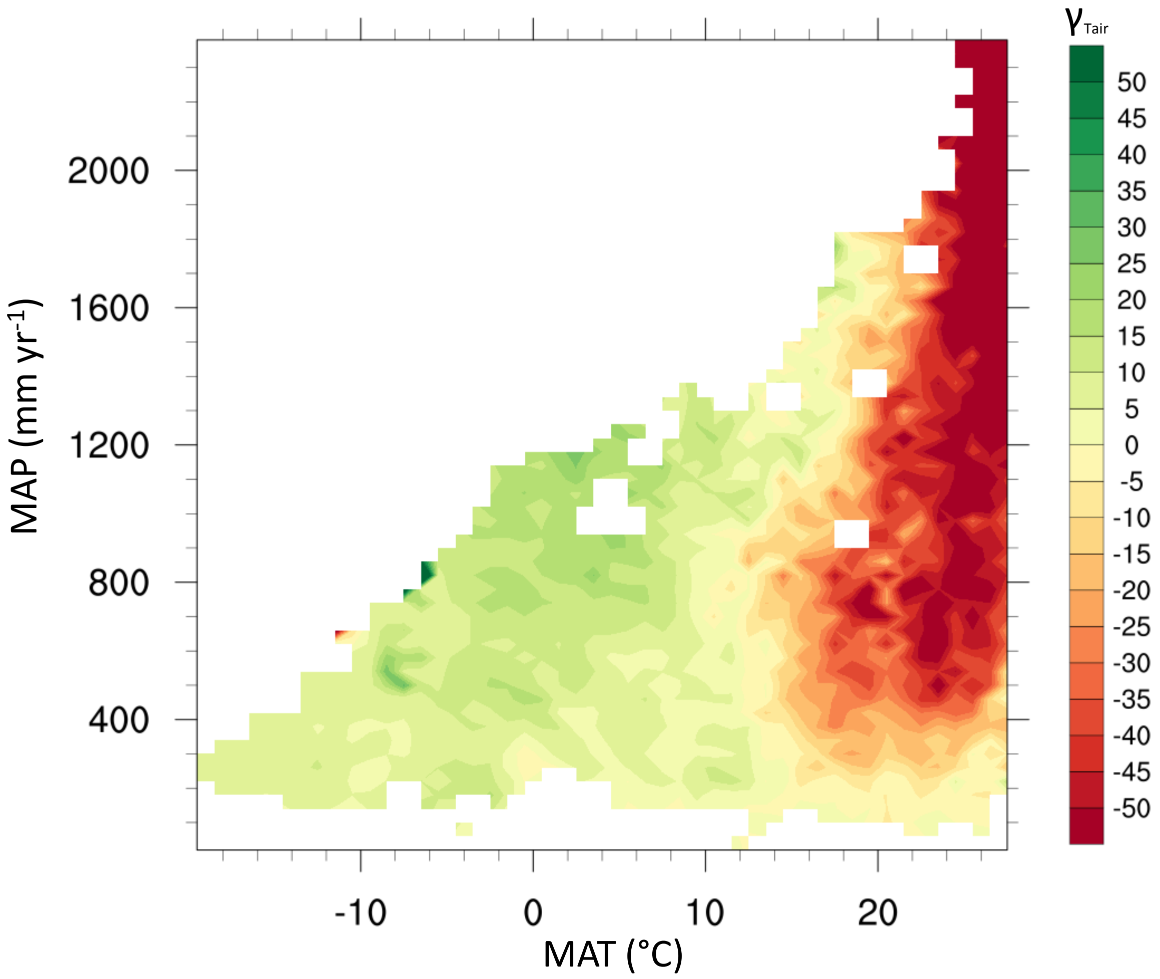
NPP sensitivity (g C m^{-2} yr^{-1} per °C) to inter-annual variation in temperature
Global average: -16.5 ± 9.1 g C m^{-2} yr^{-1} per °C

Sensitivity of NPP to temperature variation

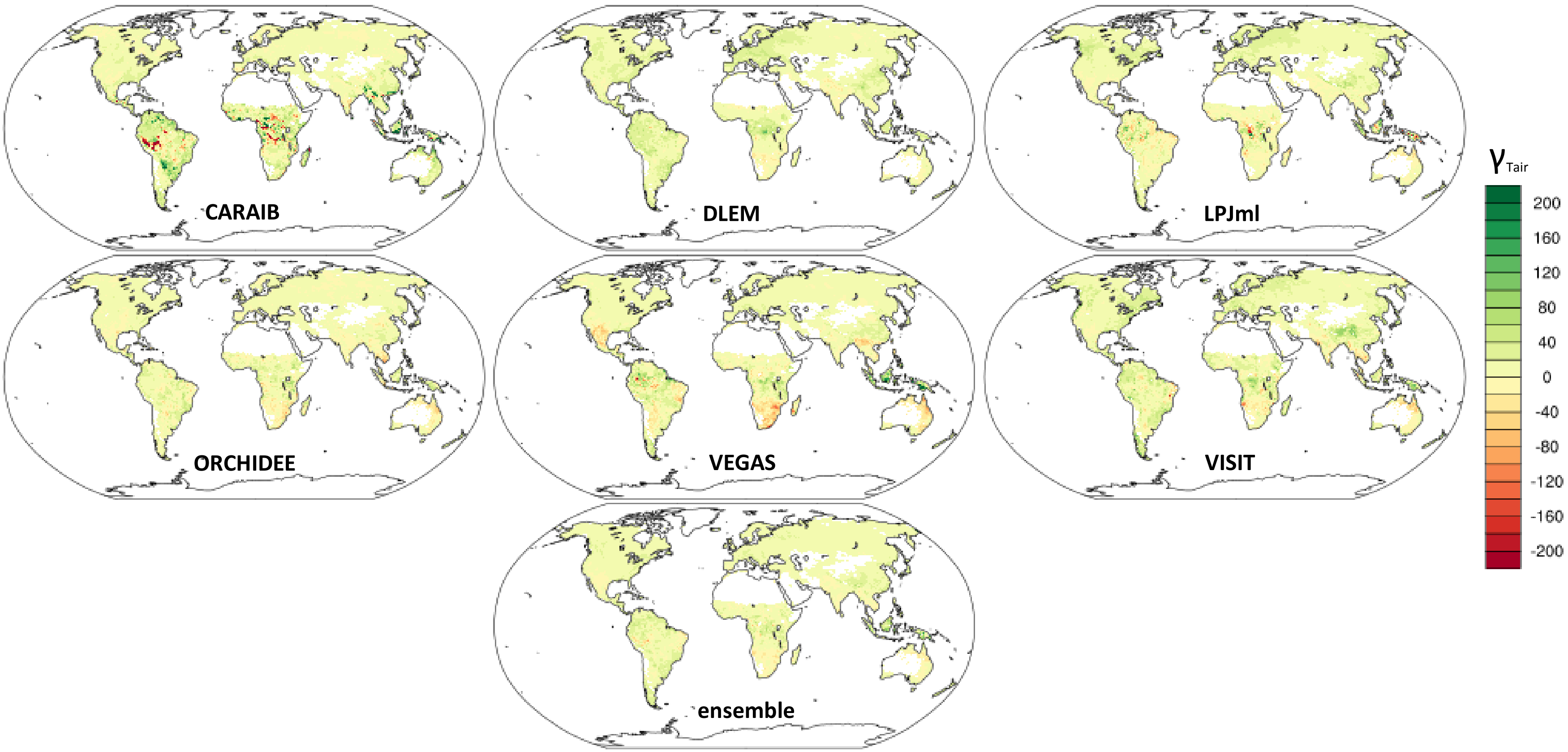


NPP is positively correlated with temperature in mid- and high latitudes, but negatively related to temperature in topical region (30°N – 35°S).

Sensitivity of NPP to temperature variation



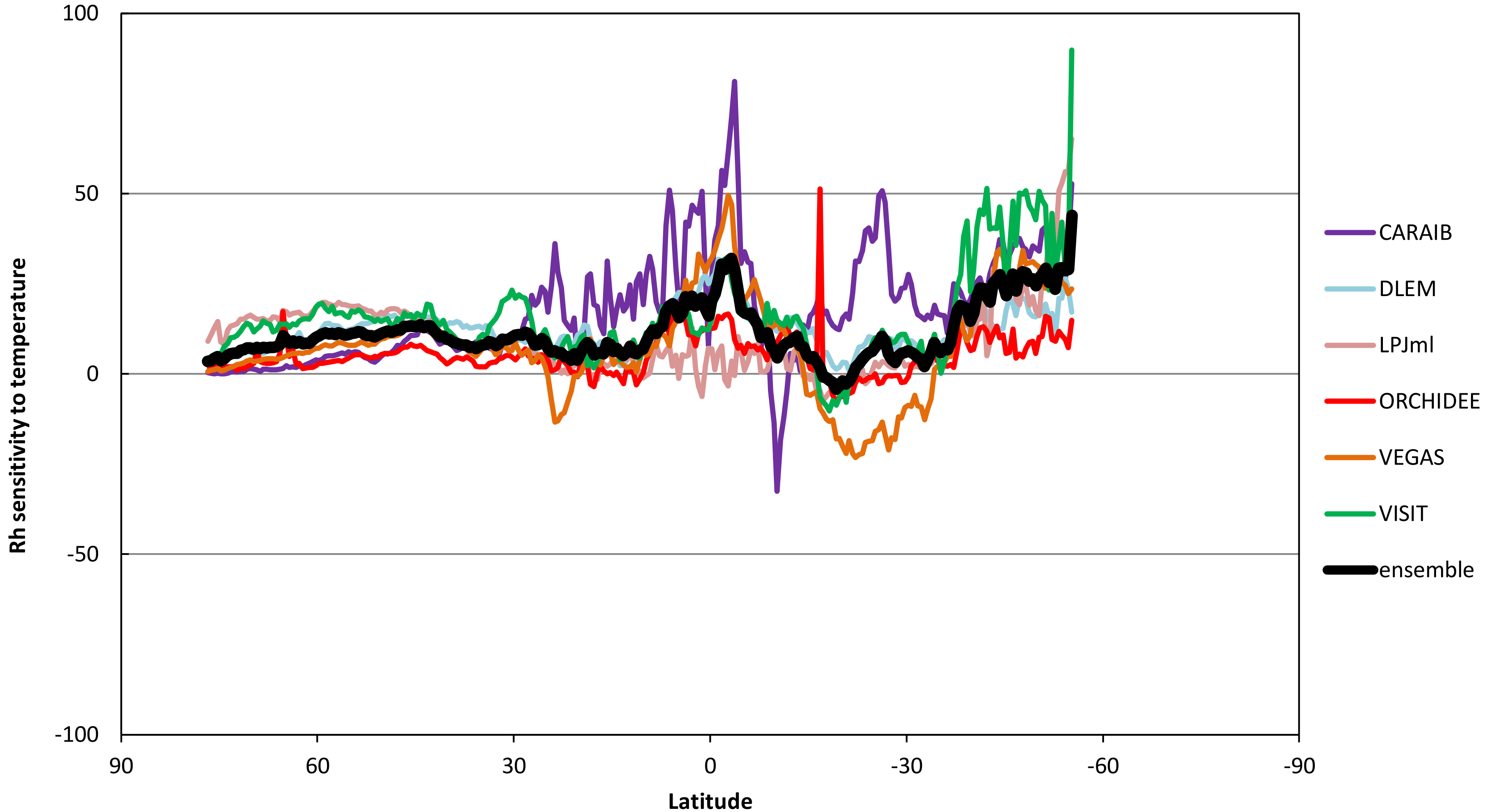
Sensitivity of Rh to temperature variation



Rh sensitivity (g C m^{-2} yr^{-1} per °C) to inter-annual variation in temperature

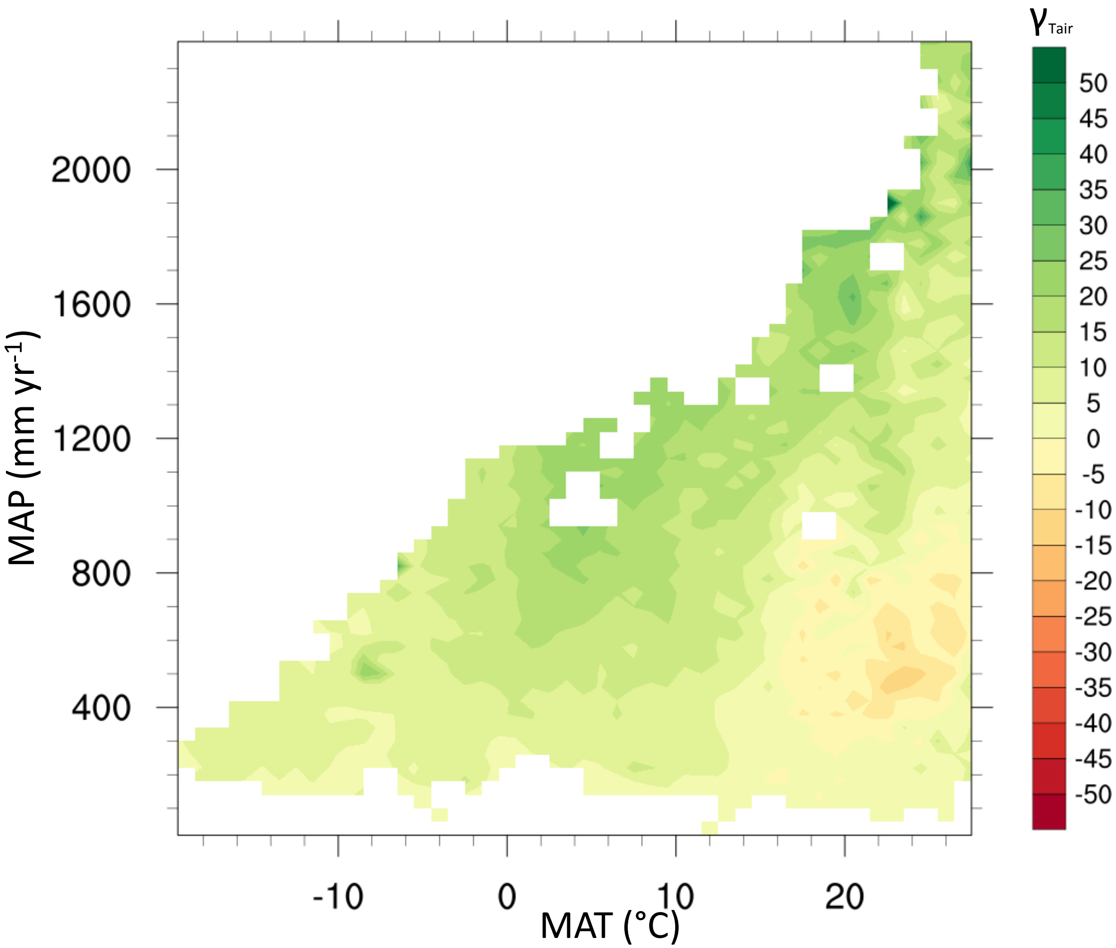
Global average: 11.4 ± 5 g C m^{-2} yr^{-1} per °C

Sensitivity of Rh to temperature variation

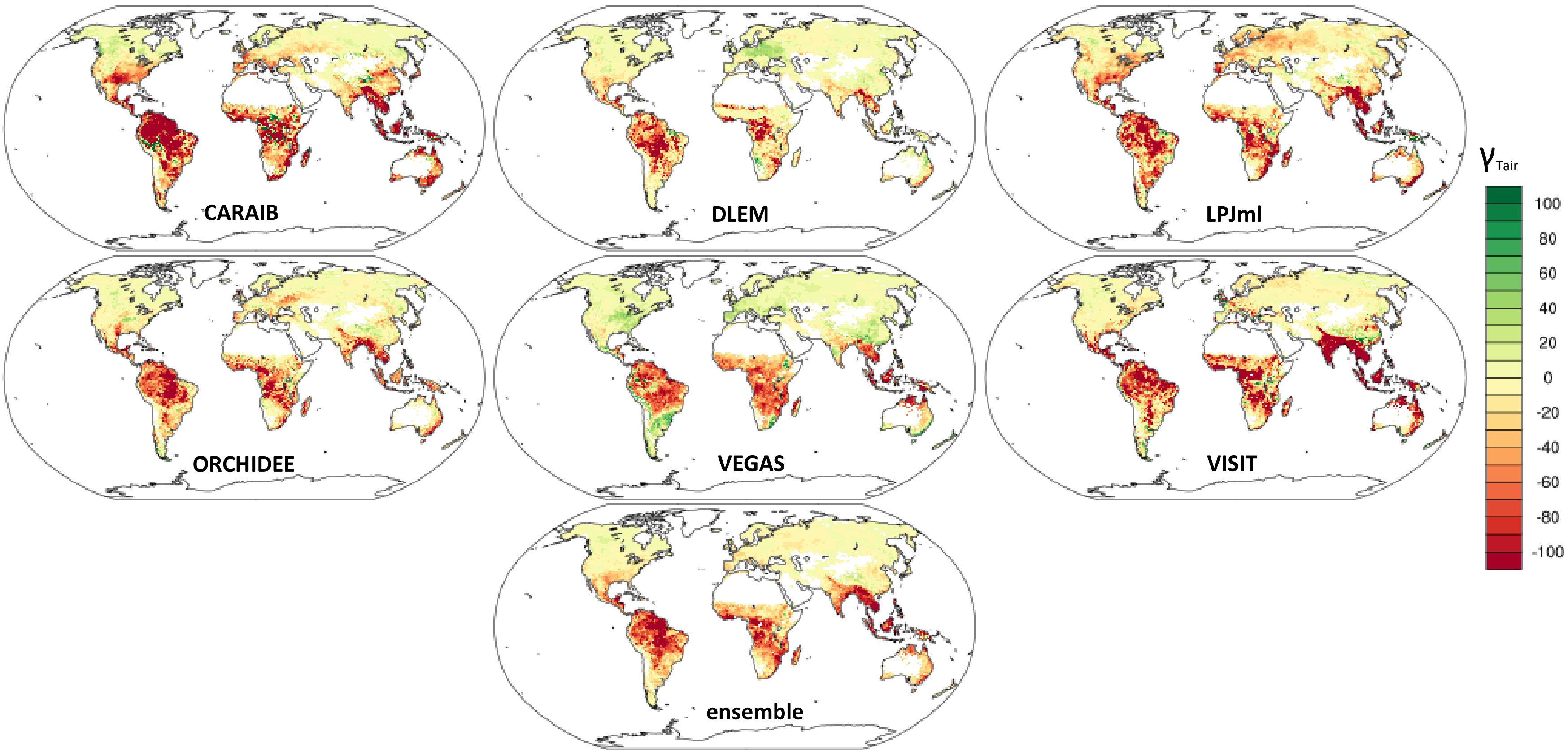


Rh is positively related to temperature almost across all the latitudinal bands, but shows large divergent among models

Sensitivity of Rh to temperature variation

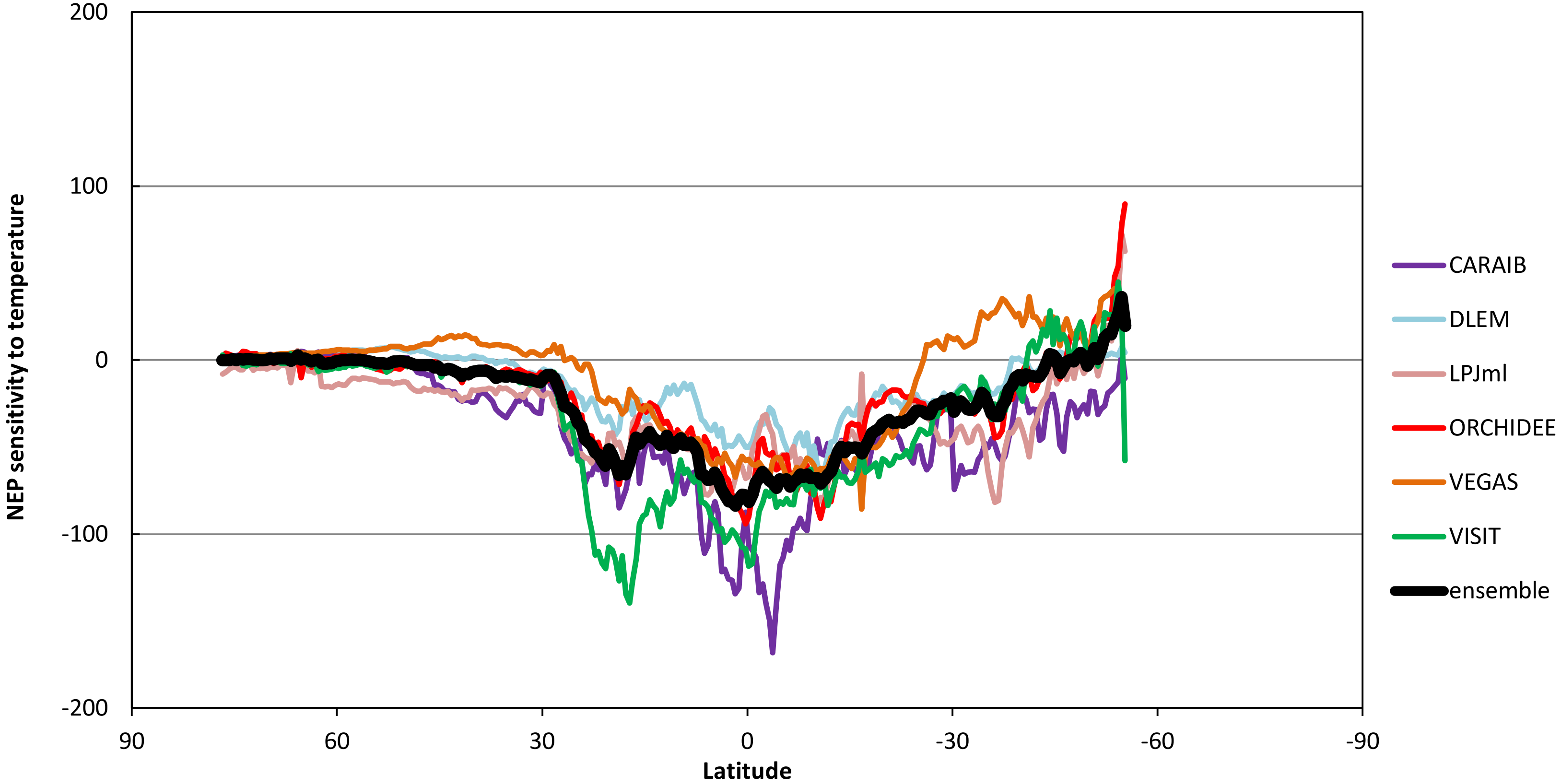


Sensitivity of NEP to temperature variation



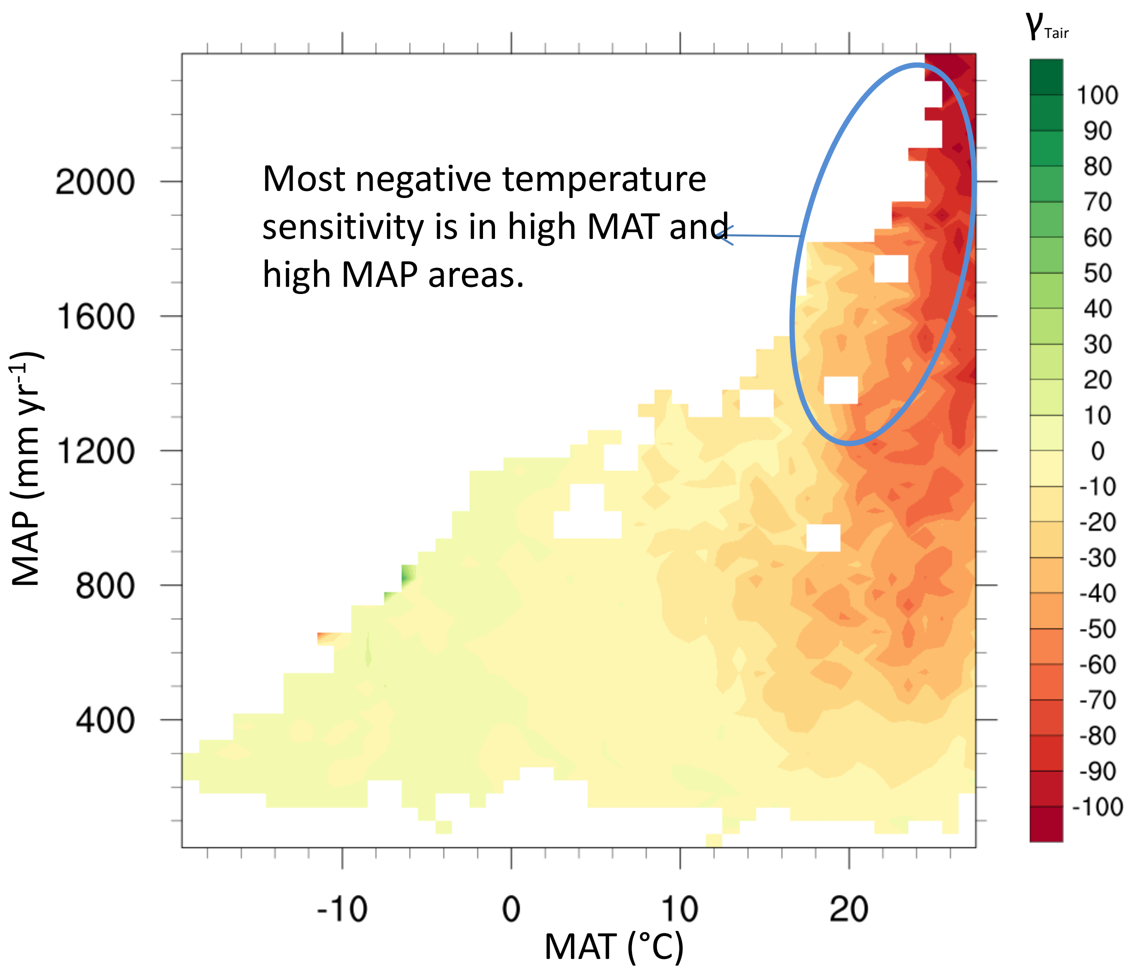
NEP sensitivity (g C m^{-2} yr^{-1} per °C) to inter-annual variation in temperature
Global average: -27.9 ± 11.7 g C m^{-2} yr^{-1} per °C

Sensitivity of NEP to temperature variation

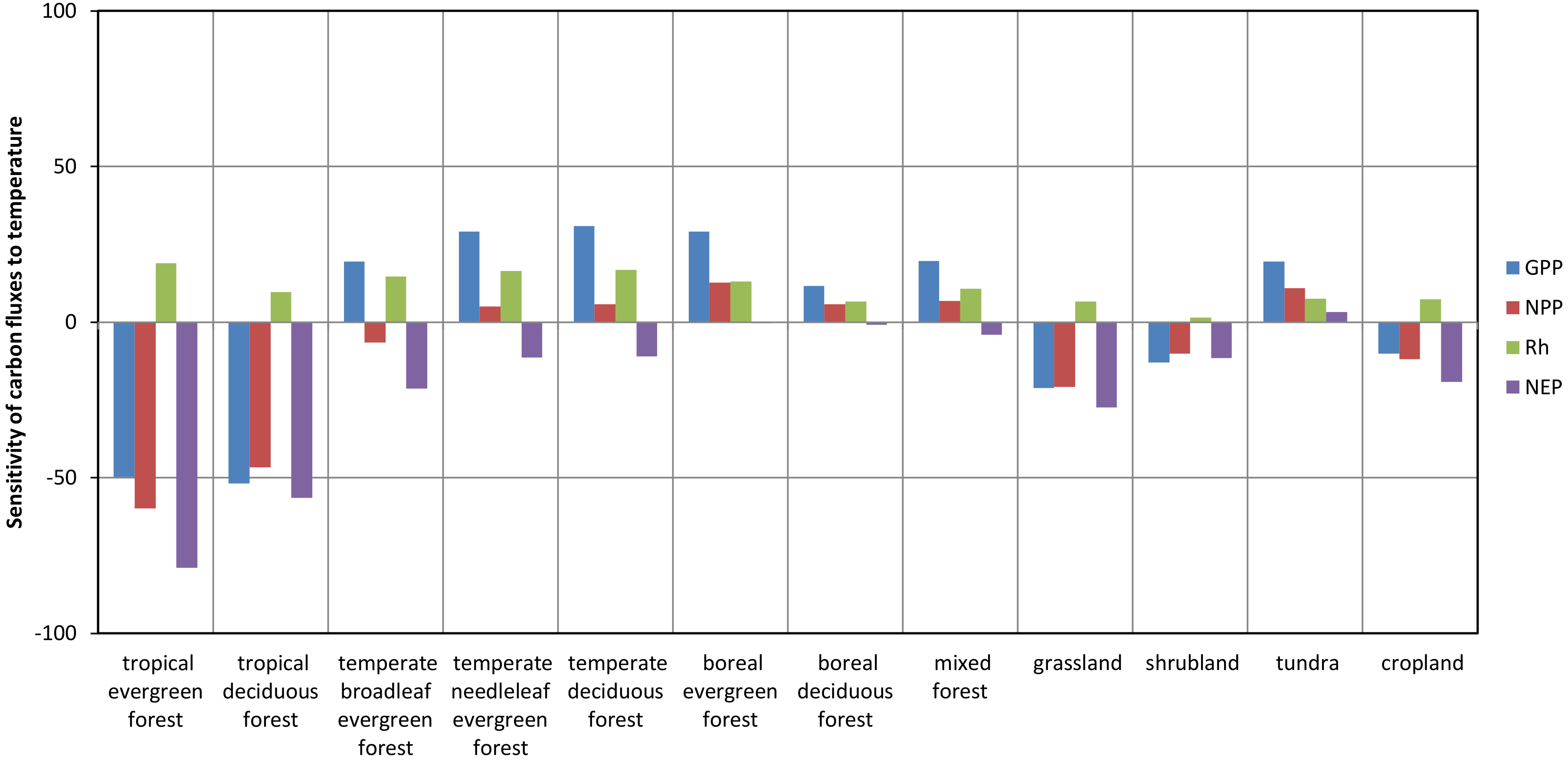


NEP is negatively related to temperature in almost all the latitudinal bands. The most negative sensitivity is in tropical region.

Sensitivity of NEP to temperature variation

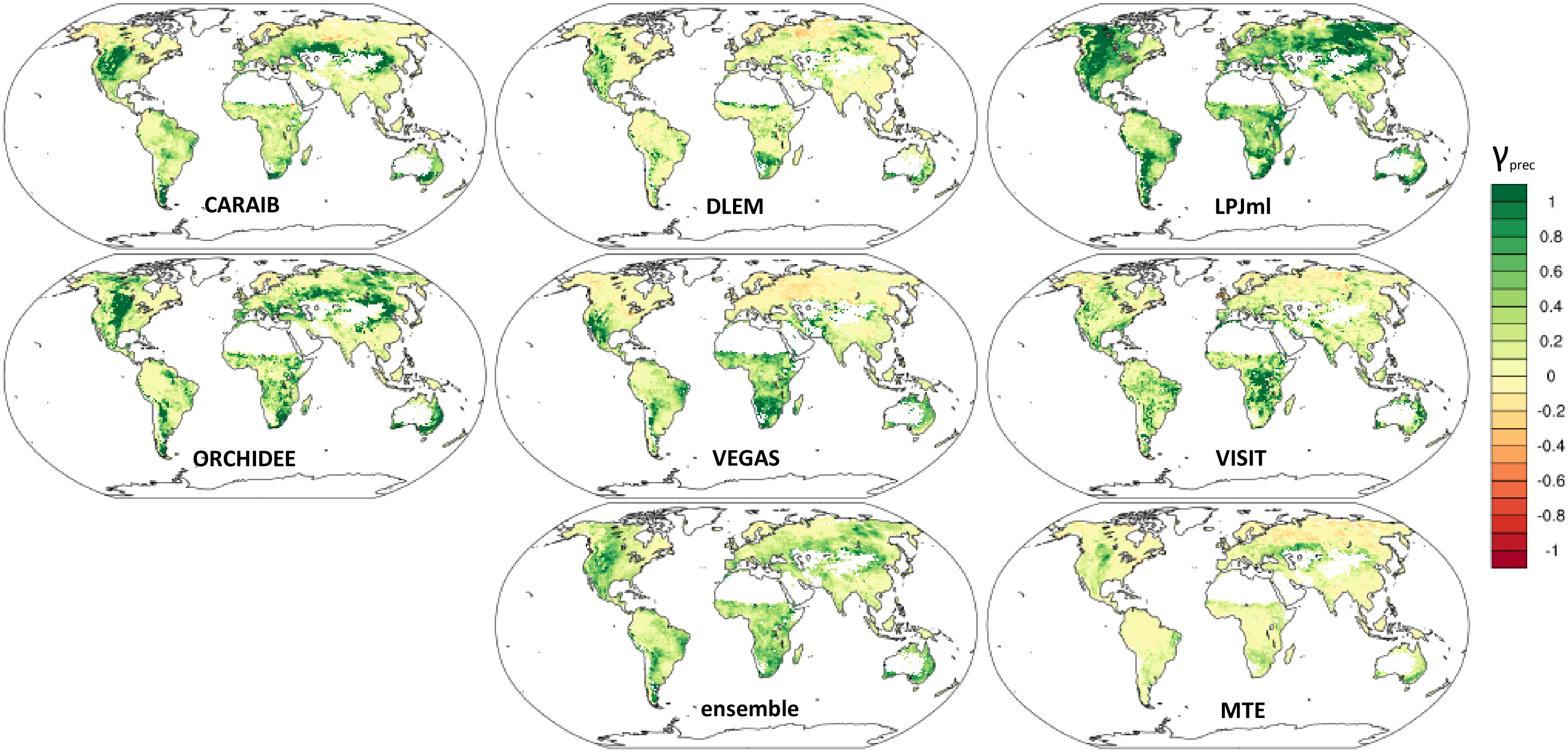


Sensitivity of carbon fluxes to temperature variation



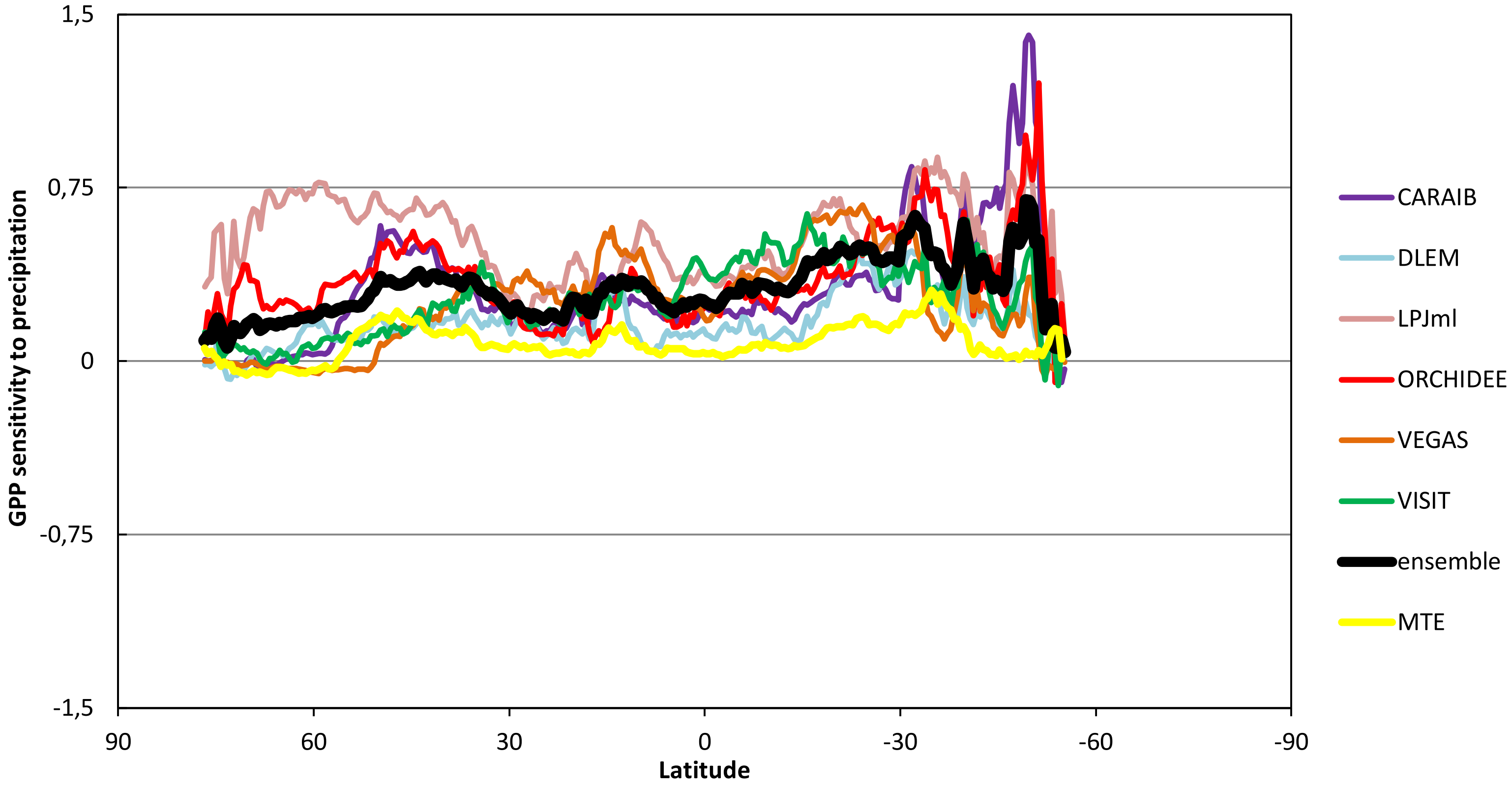
Result 2:
The sensitivity of carbon fluxes to precipitation variation

Sensitivity of GPP to precipitation variation



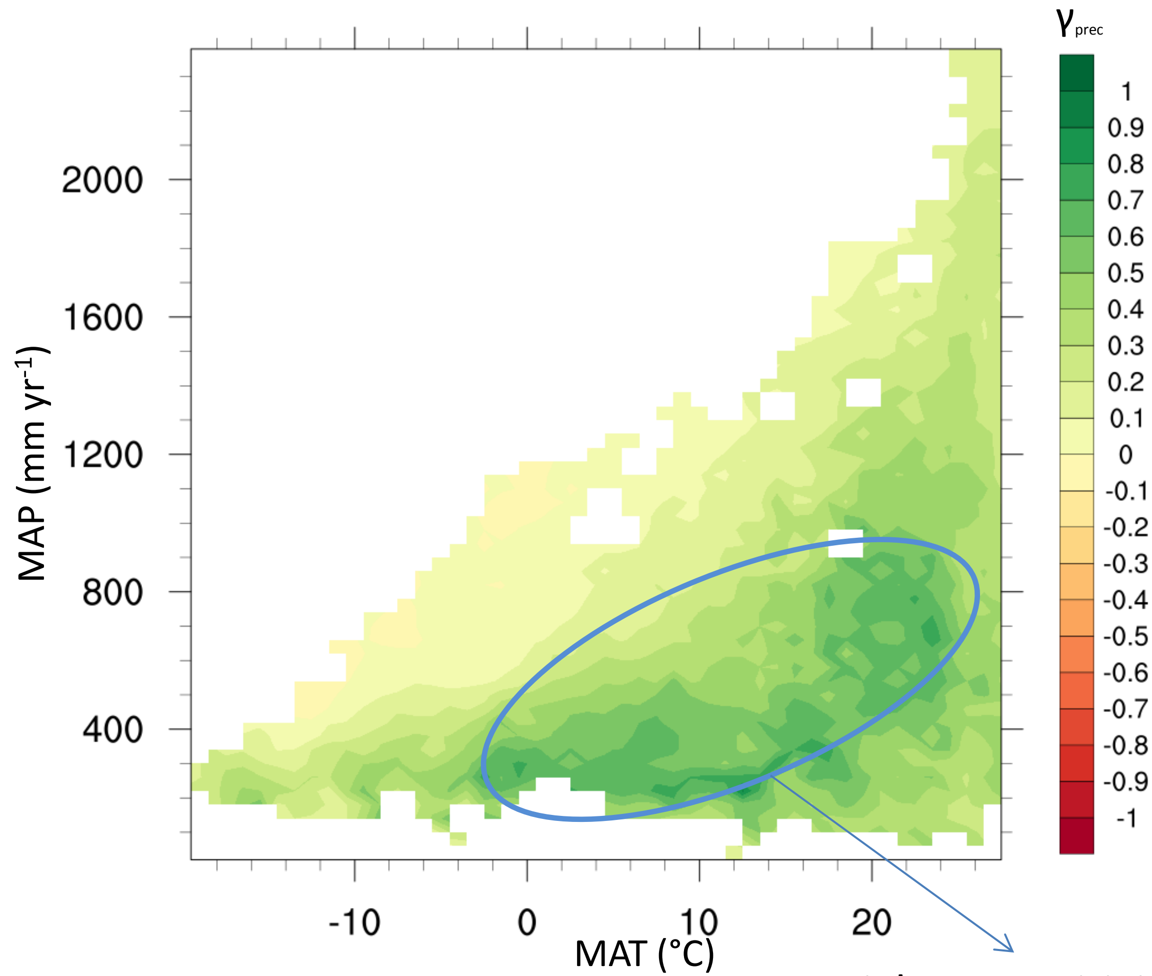
GPP sensitivity (g C m^{-2} yr^{-1} per mm yr^{-1}) to inter-annual variation in precipitation
Global average: 0.3 ± 0.11 g C m^{-2} yr^{-1} per mm yr^{-1}.

Sensitivity of GPP to precipitation variation



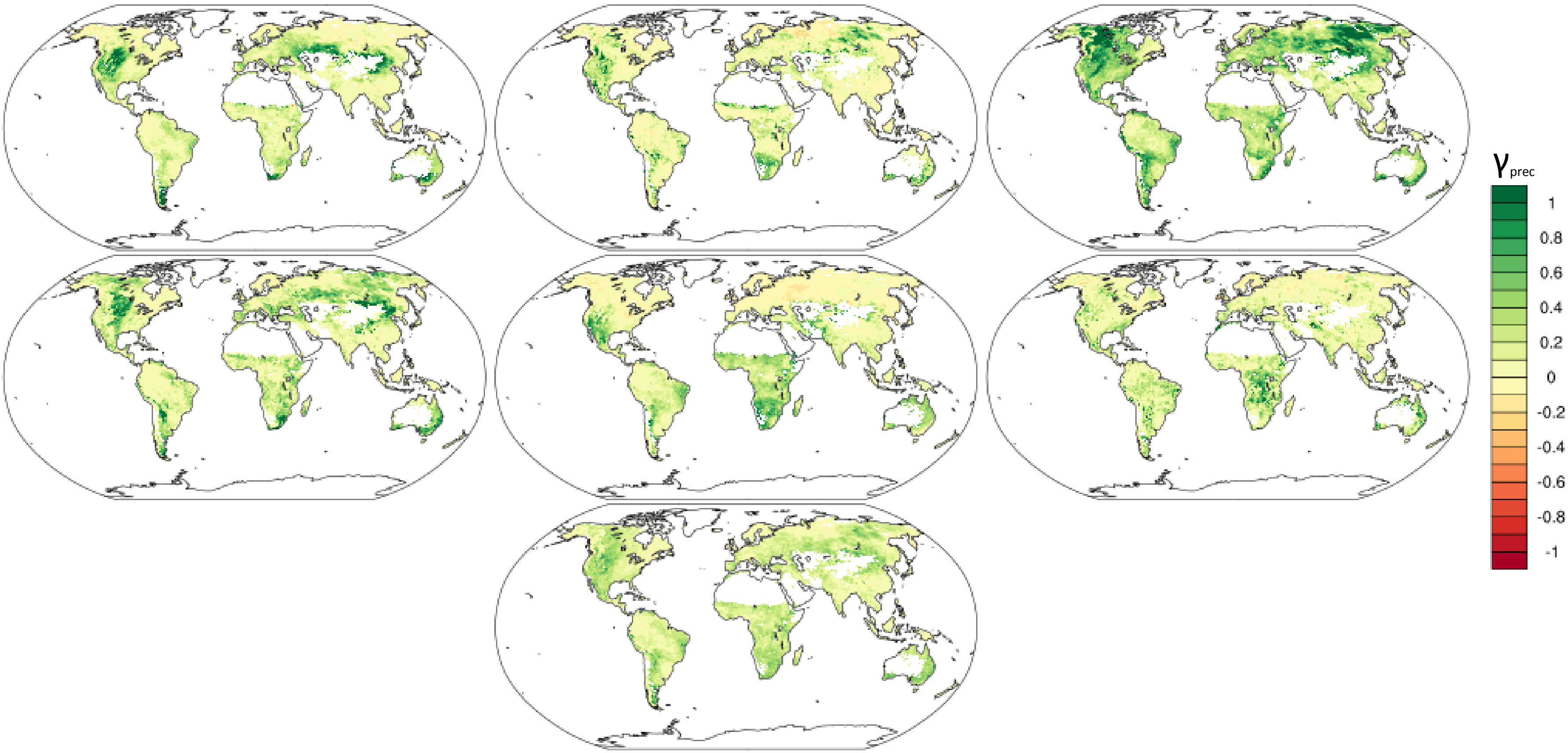
MTE GPP and model ensemble show that GPP is positively correlated with precipitation in almost all the latitudinal bands.

Sensitivity of GPP to precipitation variation



Highest sensitivity is in the low and medium MAP areas.

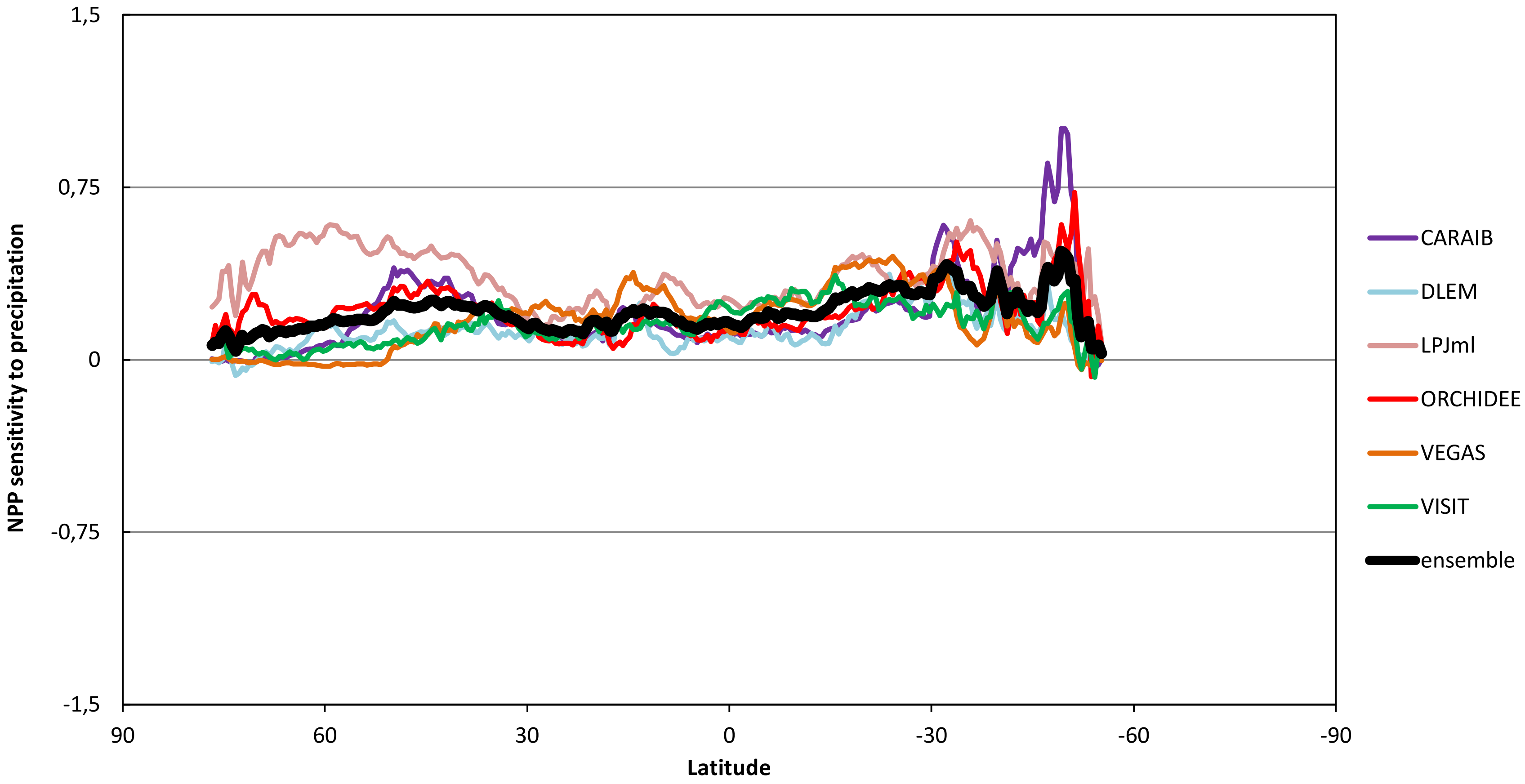
Sensitivity of NPP to precipitation variation



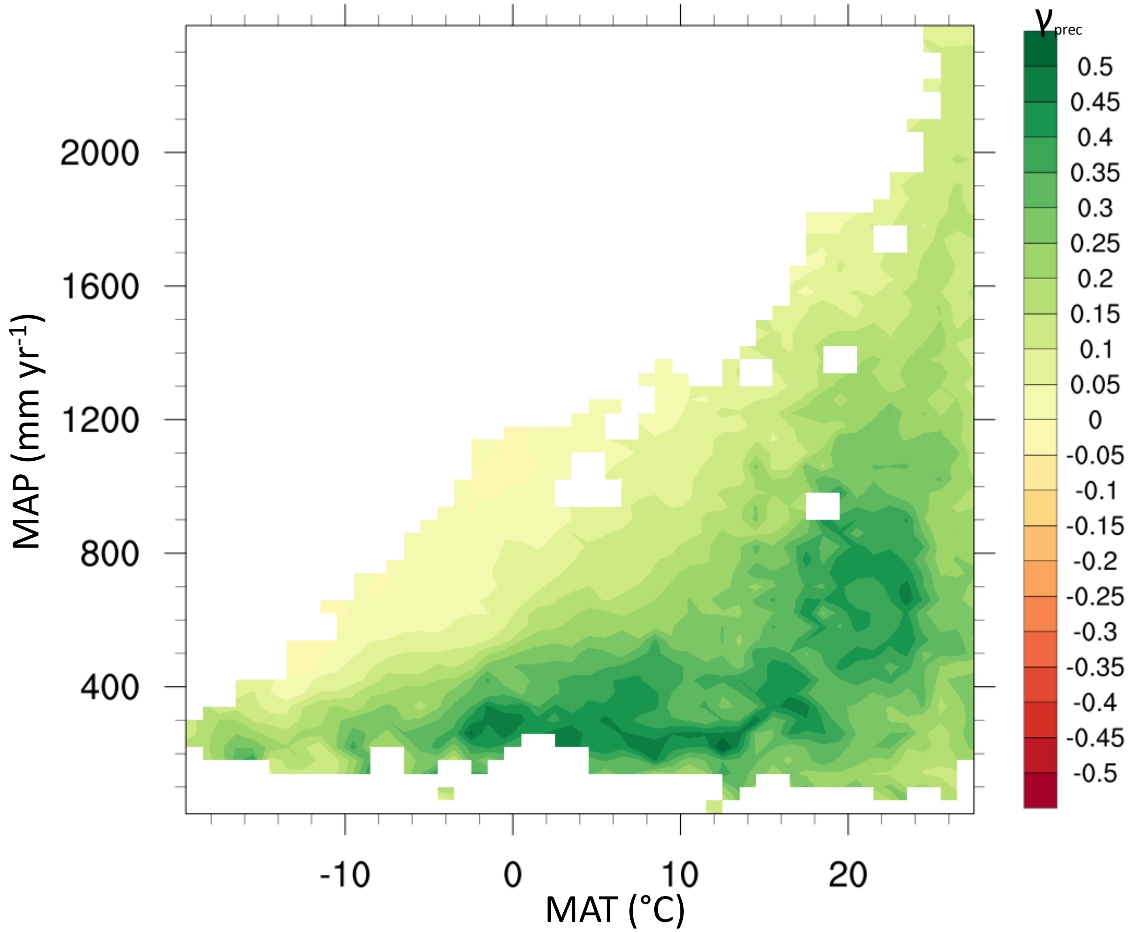
NPP sensitivity (g C m^{-2} yr^{-1} per mm yr^{-1}) to inter-annual variation in precipitation

Global average: **0.2** ± 0.08 g C m^{-2} yr^{-1} per mm yr^{-1}.

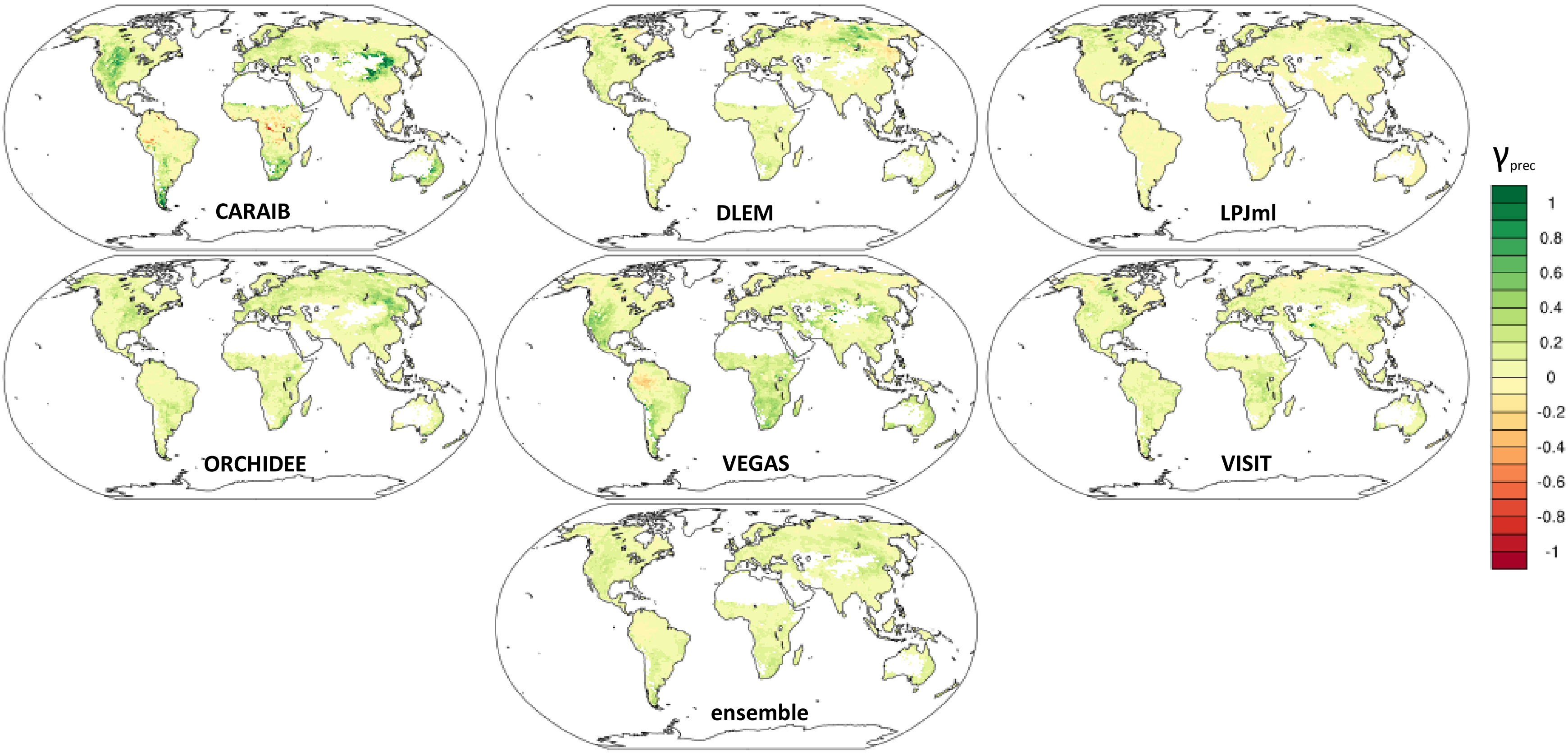
Sensitivity of NPP to precipitation variation



Sensitivity of NPP to precipitation variation



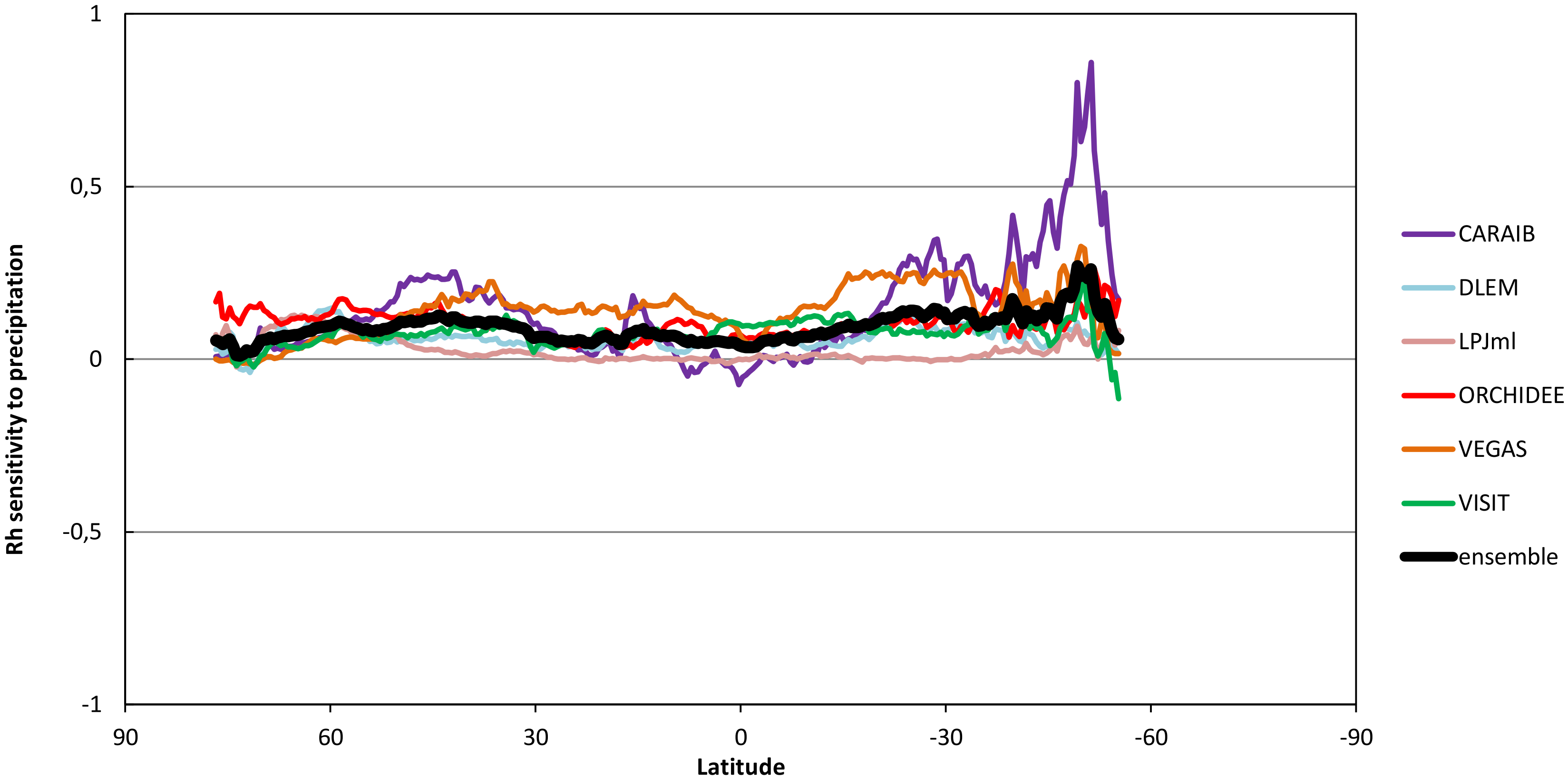
Sensitivity of Rh to precipitation variation



Rh sensitivity (g C m^{-2} yr^{-1} per mm yr^{-1}) to inter-annual variation in precipitation

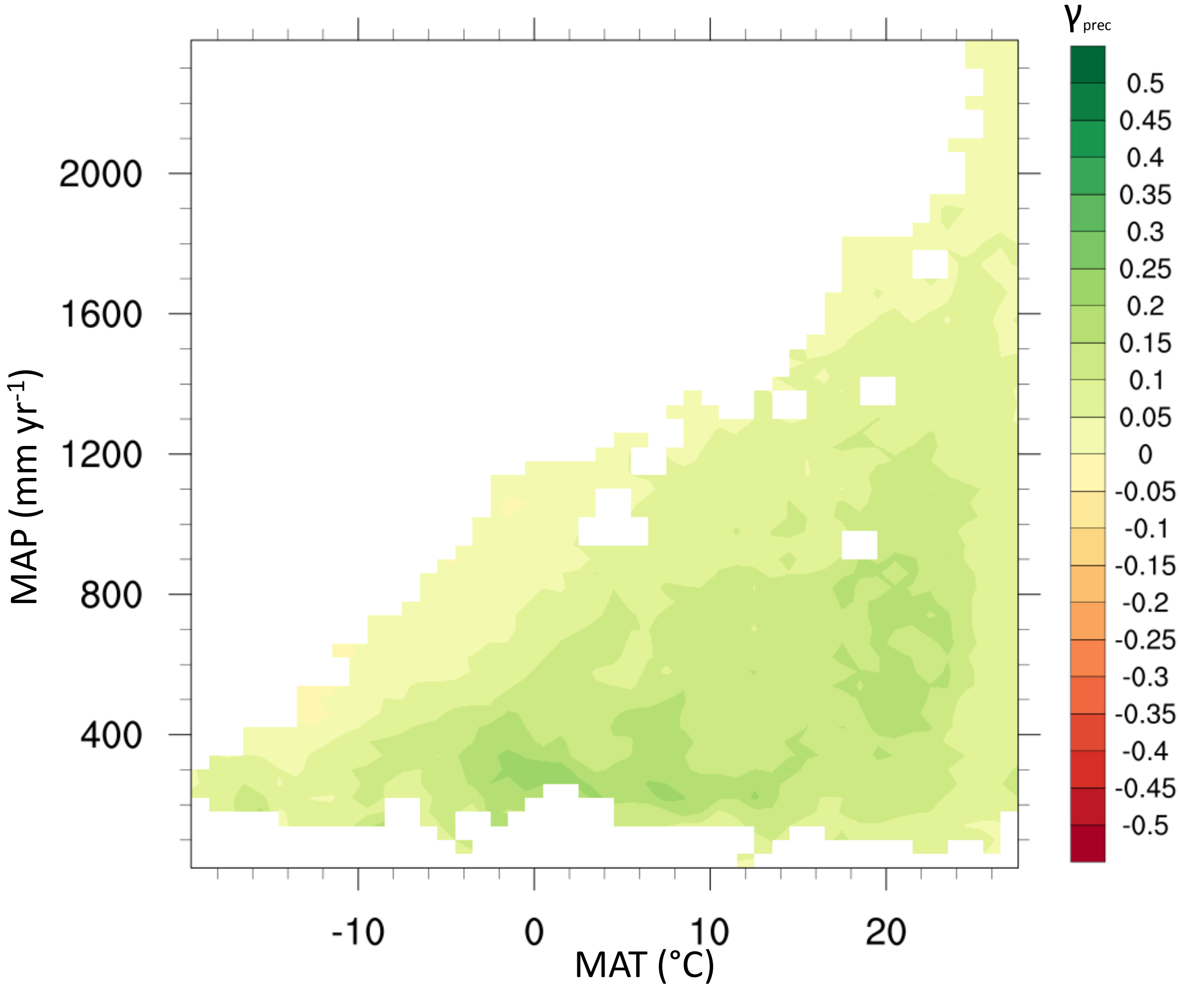
Global average: 0.09 ± 0.03 g C m^{-2} yr^{-1} per mm yr^{-1}

Sensitivity of Rh to precipitation variation

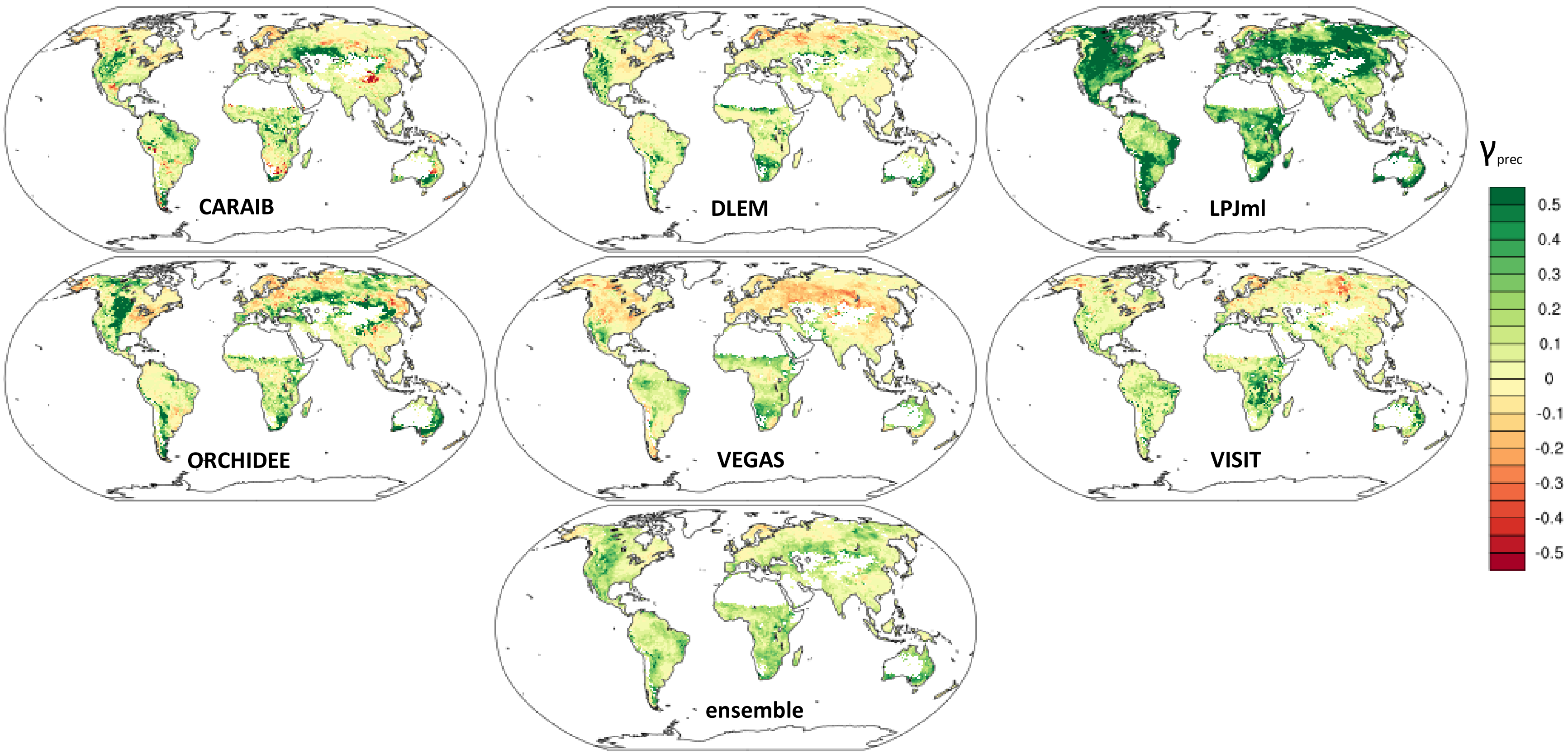


Rh is positively correlated with precipitation in almost all the latitudinal bands.

Sensitivity of Rh to precipitation variation

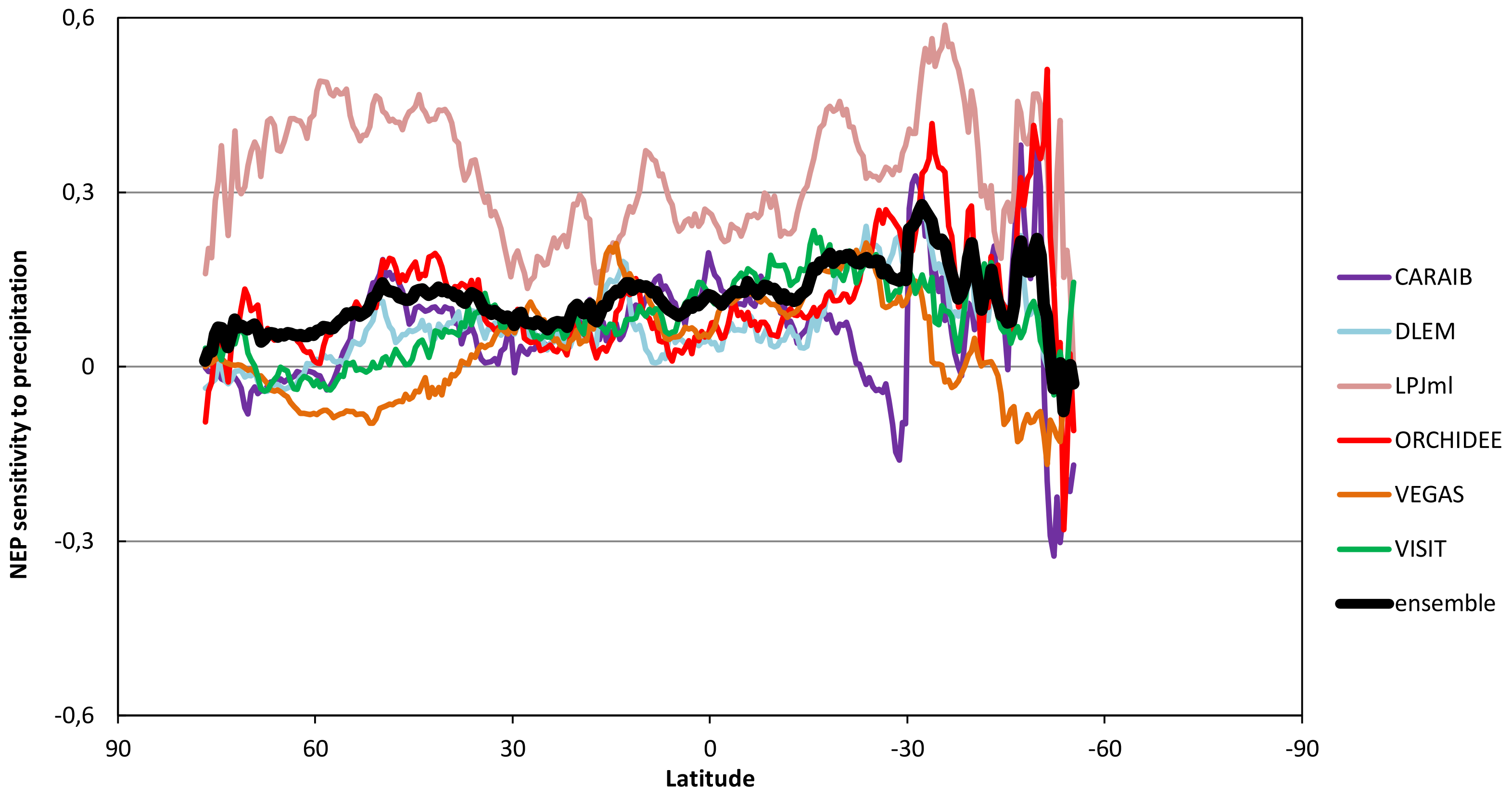


Sensitivity of NEP to precipitation variation



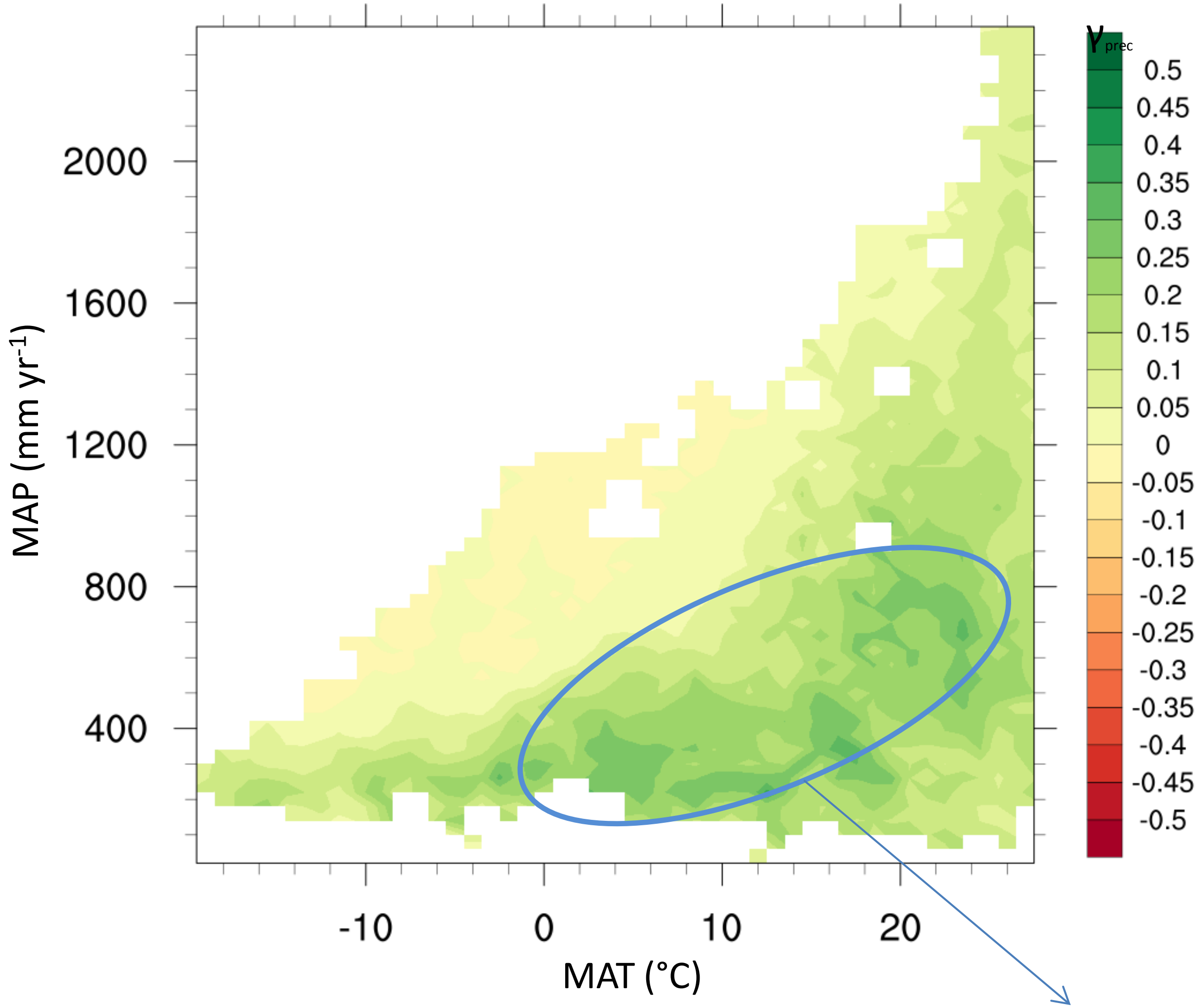
NEP sensitivity (g C m^{-2} yr^{-1} per mm yr^{-1}) to inter-annual variation in precipitation
Global average: 0.11 ± 0.1 g C m^{-2} yr^{-1} per mm yr^{-1}

Sensitivity of NEP to precipitation variation



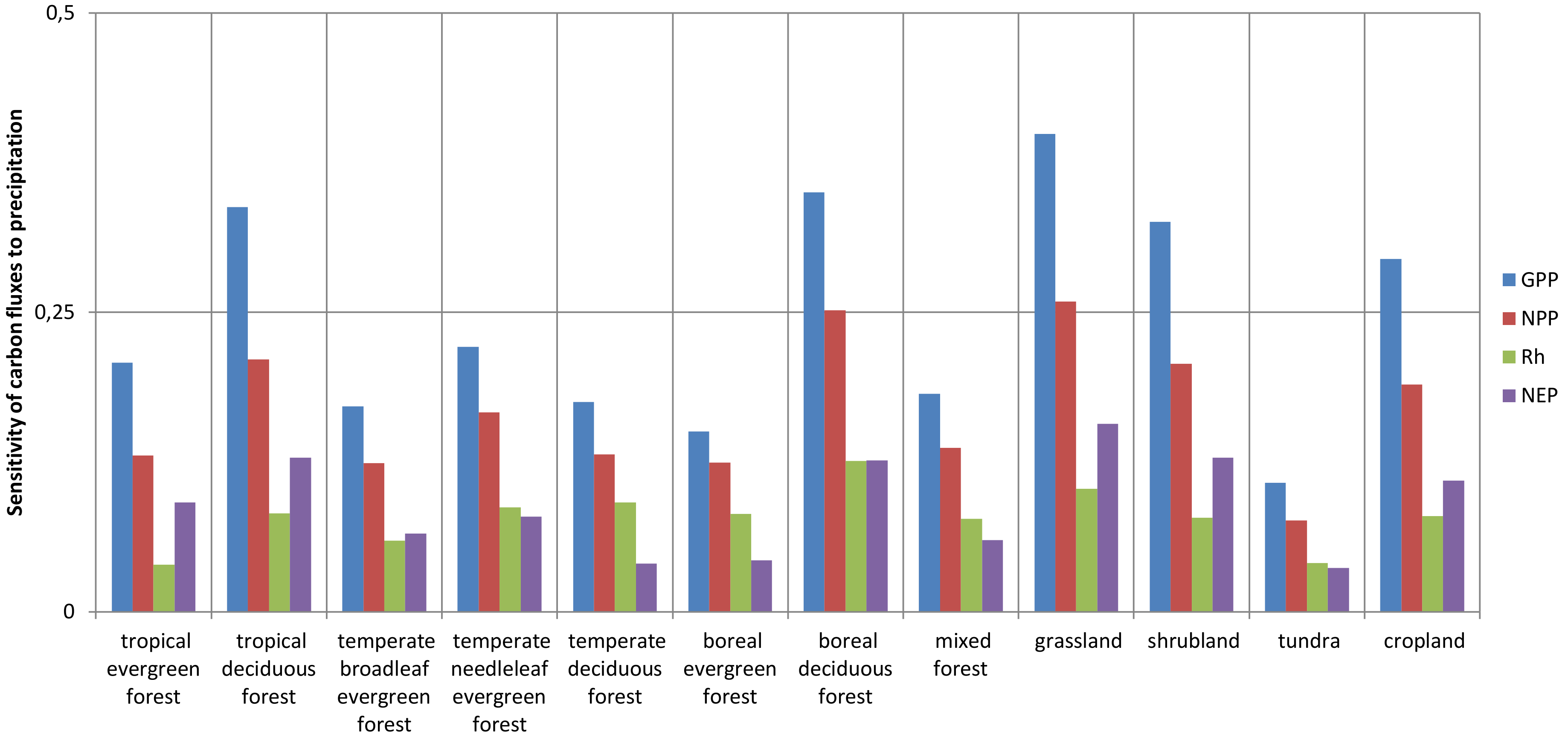
NEP is positively correlated with precipitation in almost all the latitudinal bands.

Sensitivity of NEP to precipitation variation



Similar to GPP sensitivity, highest NEP sensitivity to precipitation is in the low and medium MAP areas as well.

Sensitivity of carbon fluxes to precipitation variation



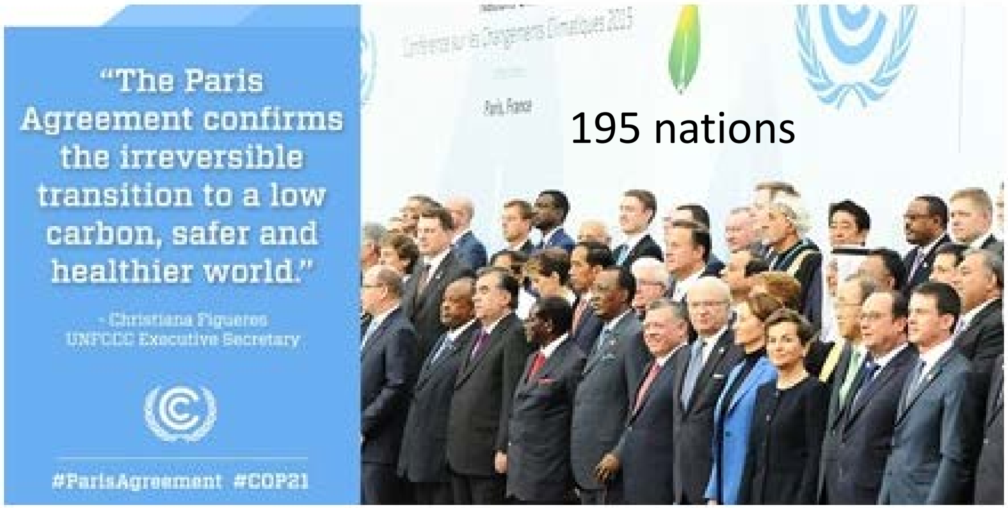
Auburn News

Auburn professor confirms new threshold for climate change mitigation

To curb the rate of climate change and maintain ecosystem services, the increase in surface air temperature must remain below 1.5 degrees Celsius, according to a recently published paper led by Shufen (Susan) Pan, …..

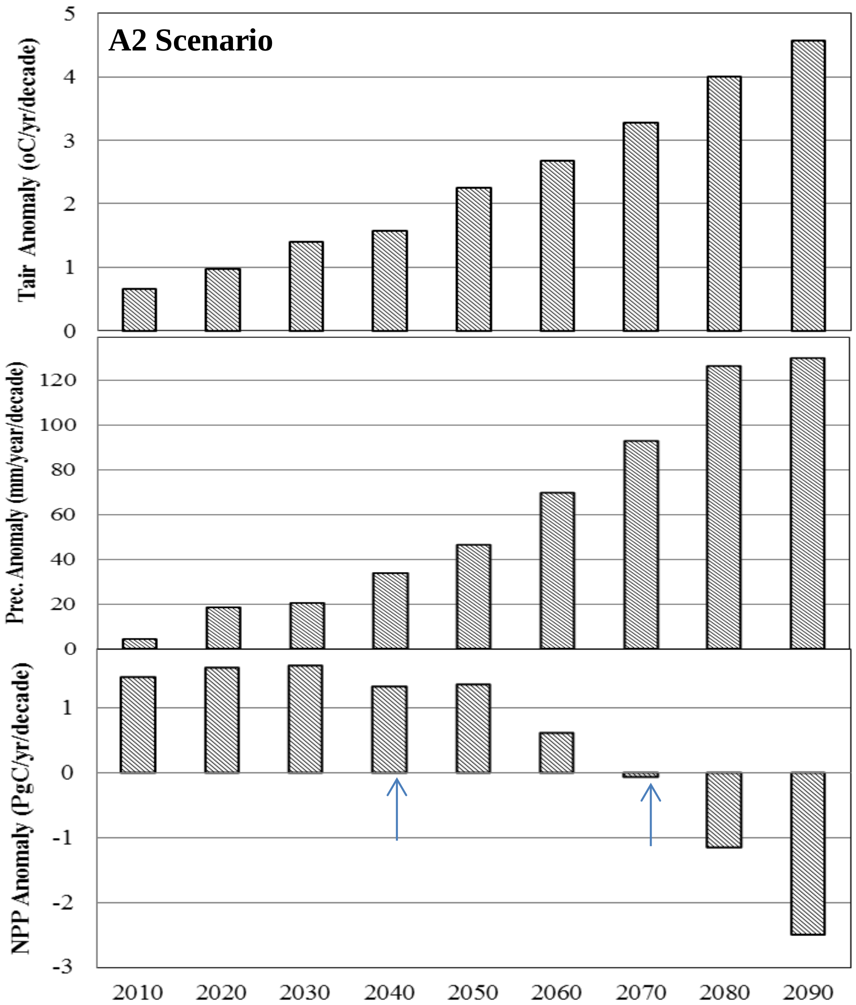
The Paris Climate Agreement: Why 2 Degrees C?

The COP 21 UN Climate change conference



The 1.5 degree Celsius limit is a significantly safer defense line against the worst impacts of a changing climate.

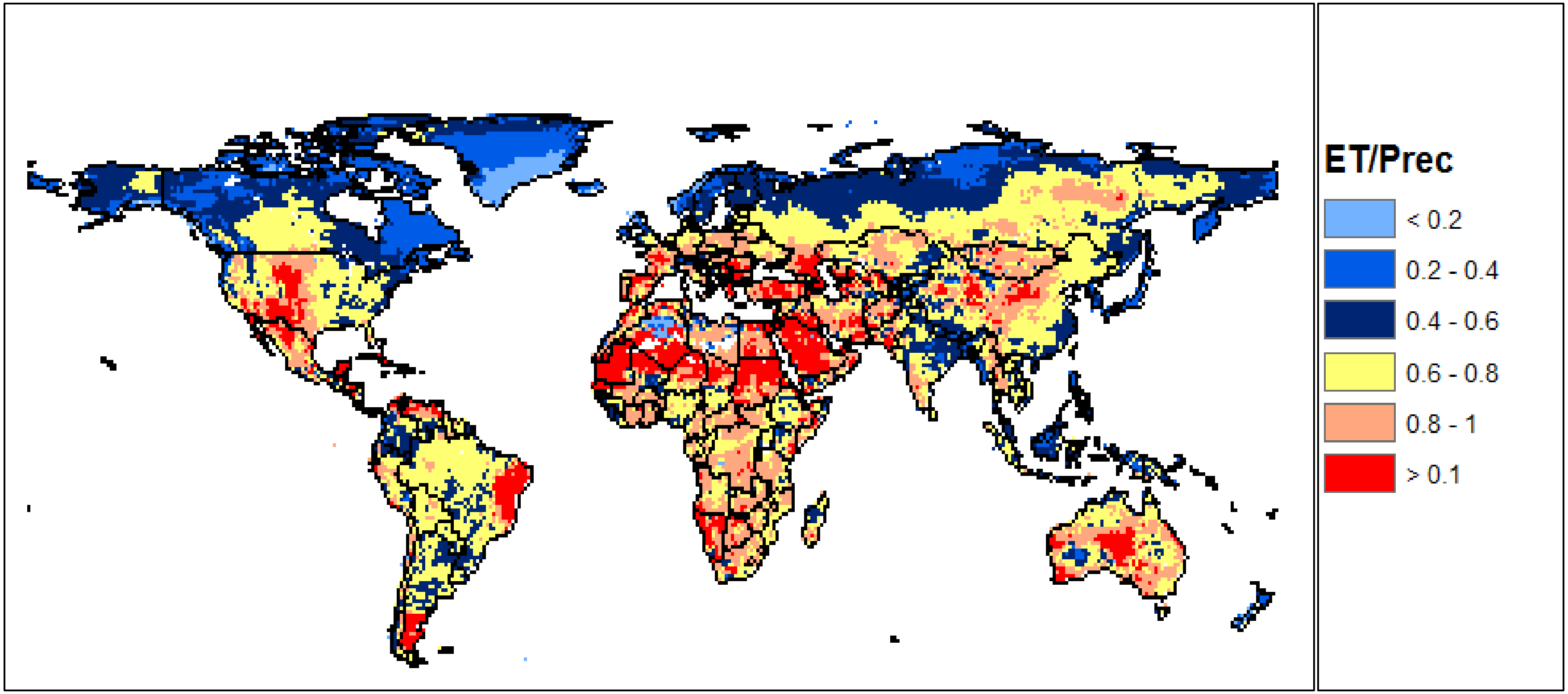
Projection: Impacts of temperature and precipitation changes on Global NPP (2010-2099)



Terrestrial NPP increase until 2050s under high emission scenario; however, NPP would level off or decline after 2050 when temperature increases by more than 1.5°C.

Pan, S. et al. 2014

ET Projection: ET/Precipitation: Water Scarcity



Increase terrestrial ET affecting global water balance especially in the Sahel region, US great plain region, Australia and central Asia (ET/Prec > 1).

Pan, S. et al. 2015

Conclusions

1. Global GPP, NPP and NEP show negative correlation with temperature, but Rh shows positive correlation with temperature. Tropical region is the most sensitive area, also most divergent among models.
2. Precipitation enhanced all the carbon fluxes (GPP, NPP and Rh) and carbon sink (NEP). But there is large divergence among models.
3. As indicated by model ensemble results, 1 degree temperature increase would reduce carbon sink by -27.9 g C m^{-2} yr^{-1}, while 1 mm yr^{-1} precipitation increase would enhance carbon sink by 0.11 g C m^{-2} yr^{-1}.
4. Models could overestimate GPP sensitivity to precipitation across most latitudinal bands, and GPP sensitivity to temperature in tropical region.