Predicting ecosystem resilience

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University of
BRISTOL

Robust predictions of ecosystem resilience require

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NB. This talk is focussing on the physiology and **ignoring** fire, demography, pests, etc (see later talks)
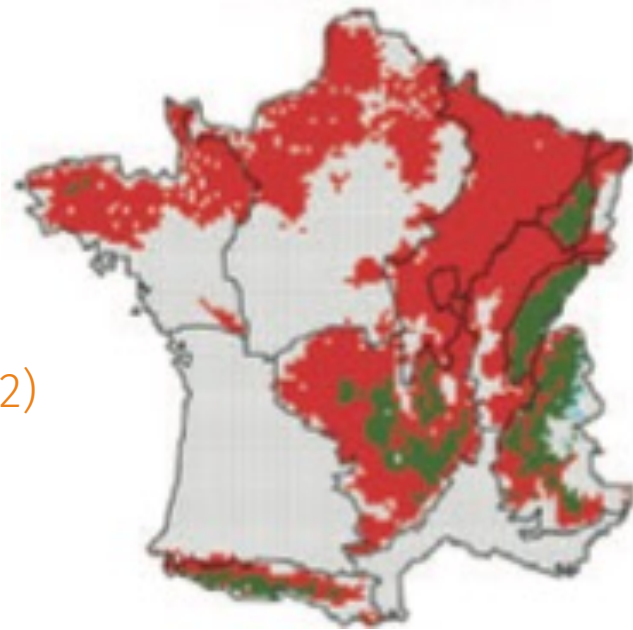
Can we predict ecosystem resilience?

Statistical approach

Predicted beach distribution in 2055

Cheaib et al. (2012) Ecol. Lett.

Eucalyptus range contraction

González-Orozco et al. (2017) Nature Clim. Change

Statistical vs process-based approach
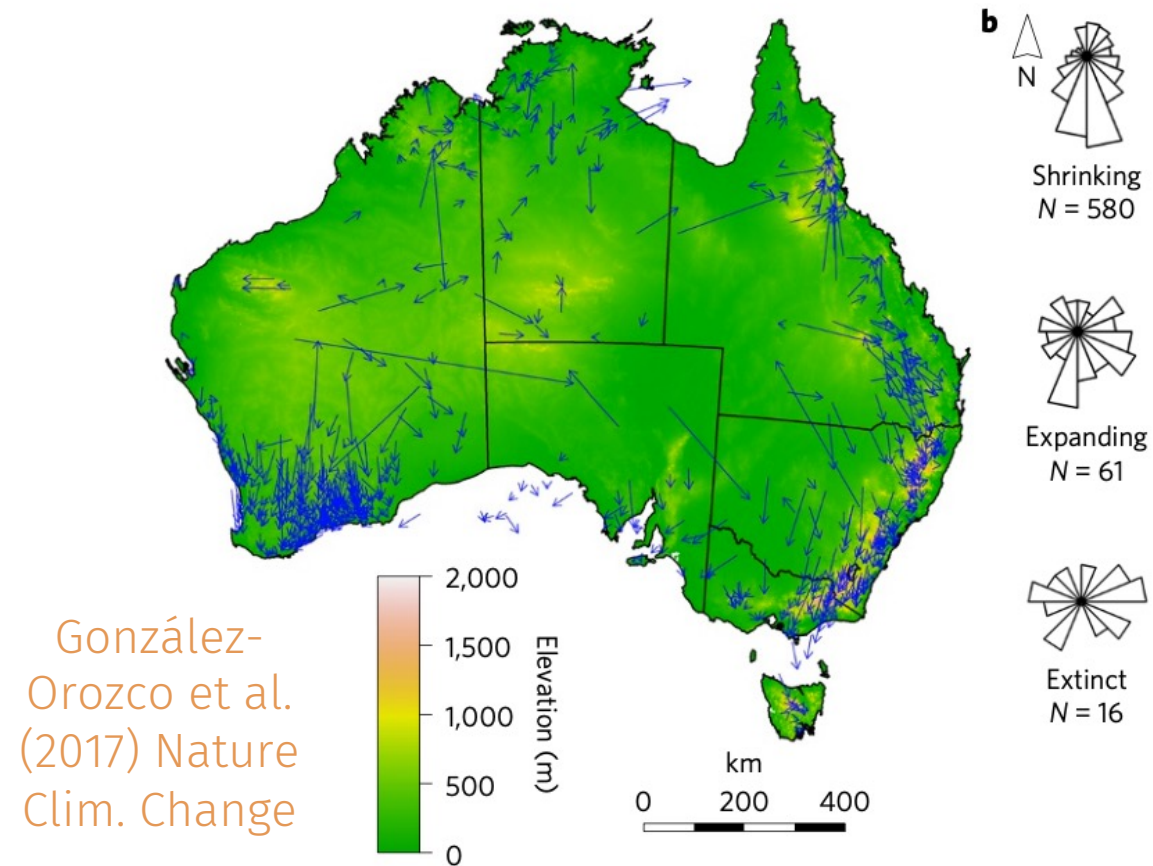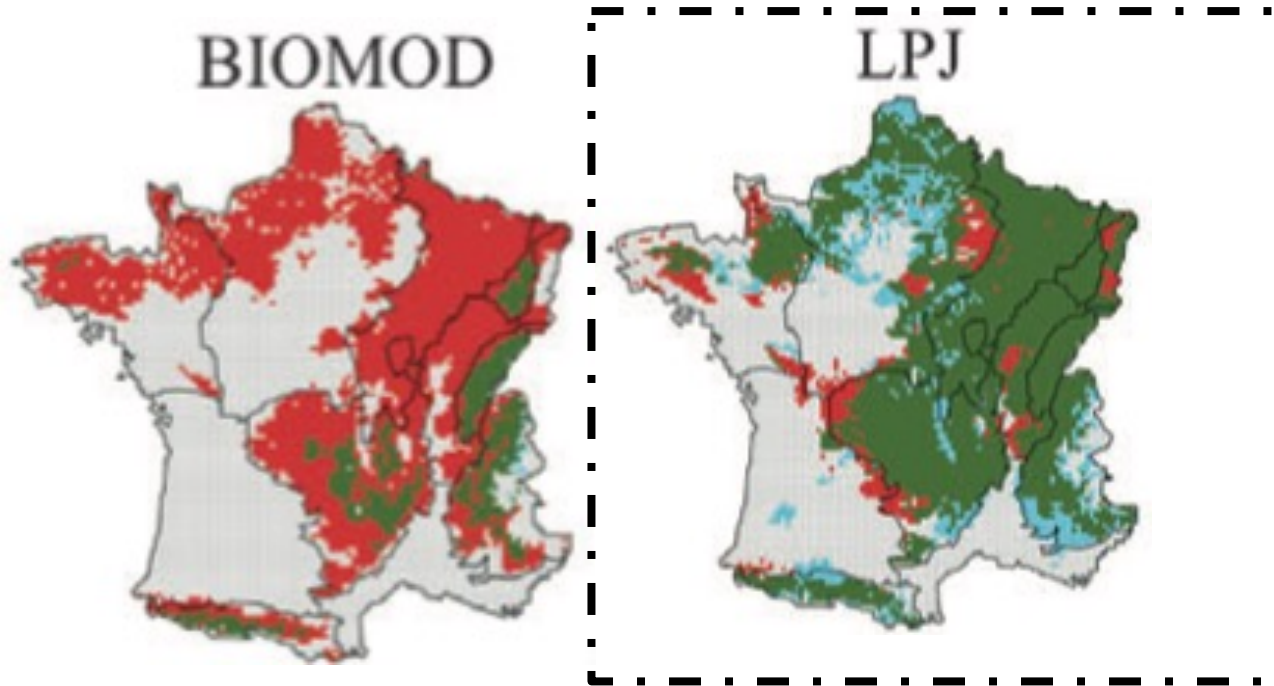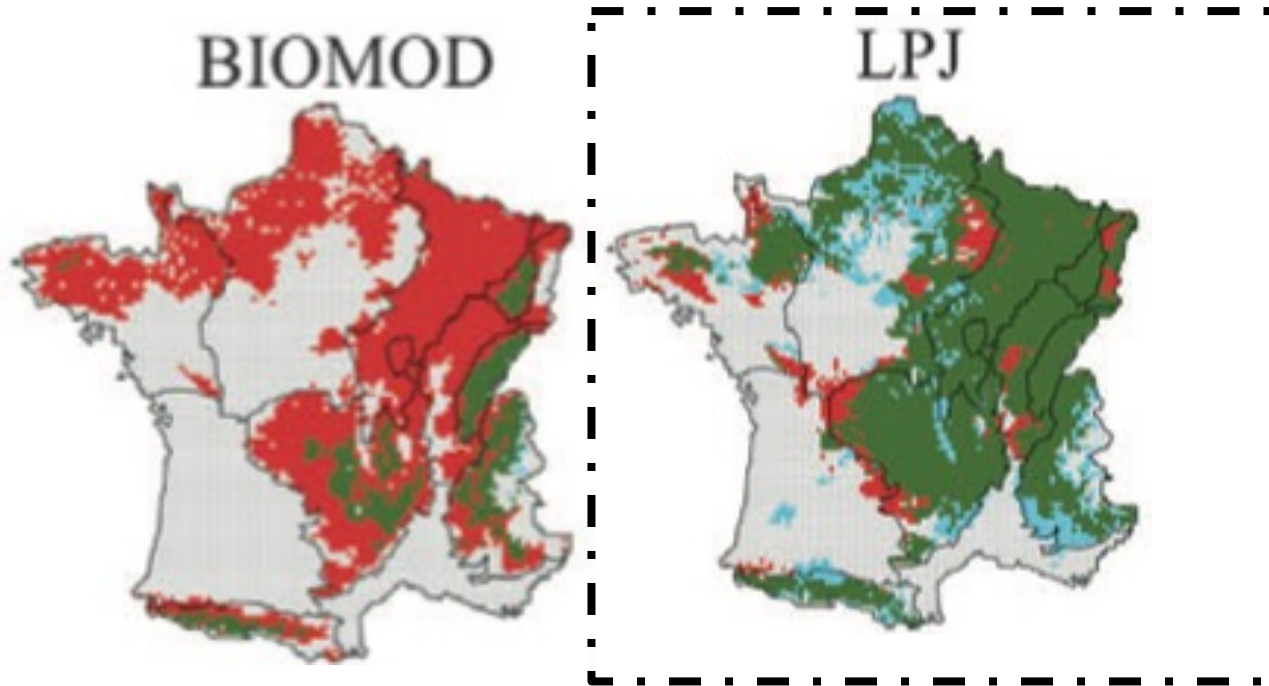
Predicted beach distribution in 2055

BIOMOD   LPJ

Cheaib et al. (2012) Ecol. Lett.

☐ Stable unsuitable area
🟩 Stable suitable area
🟥 Loss of suitable area
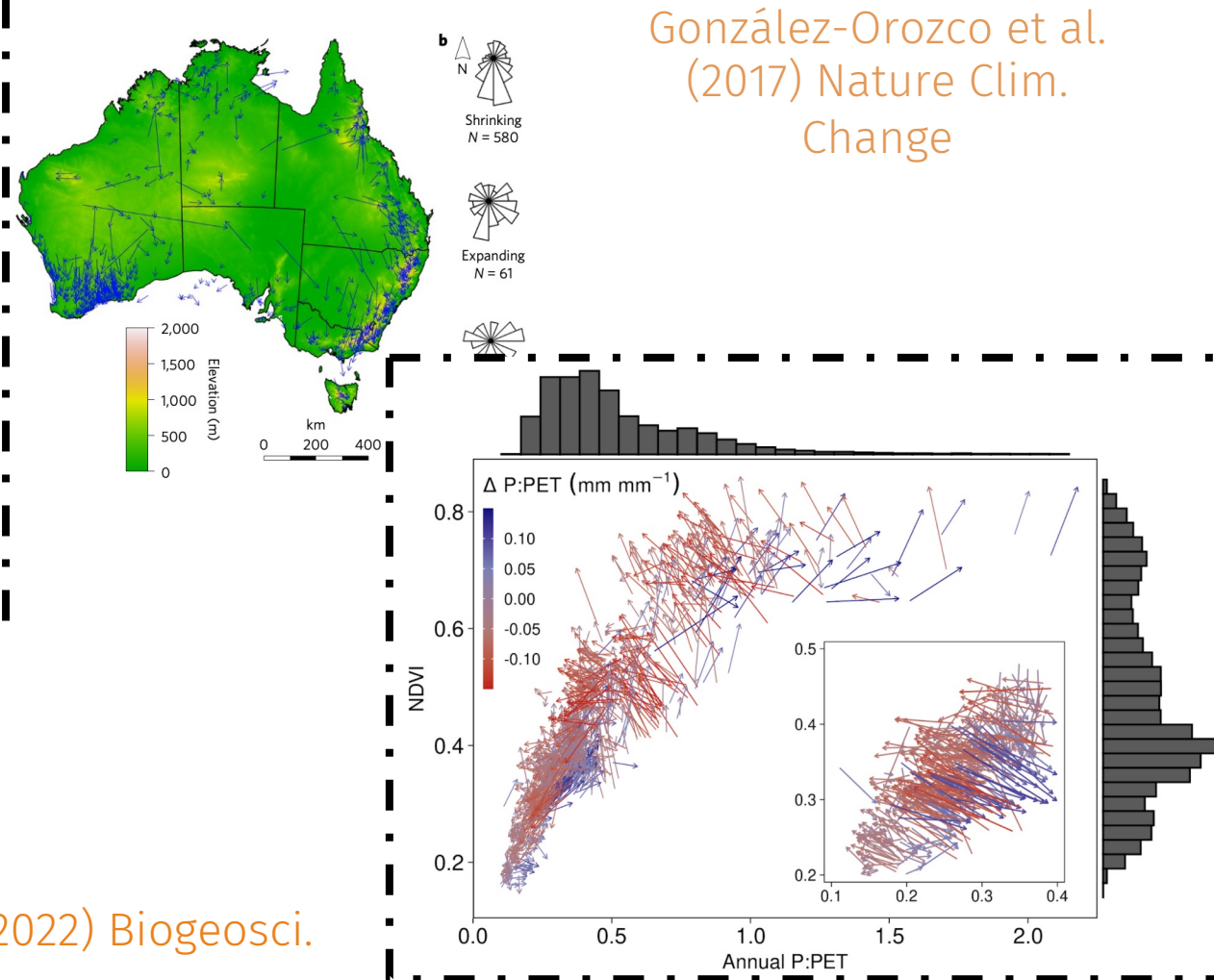🟦 Gain of suitable area

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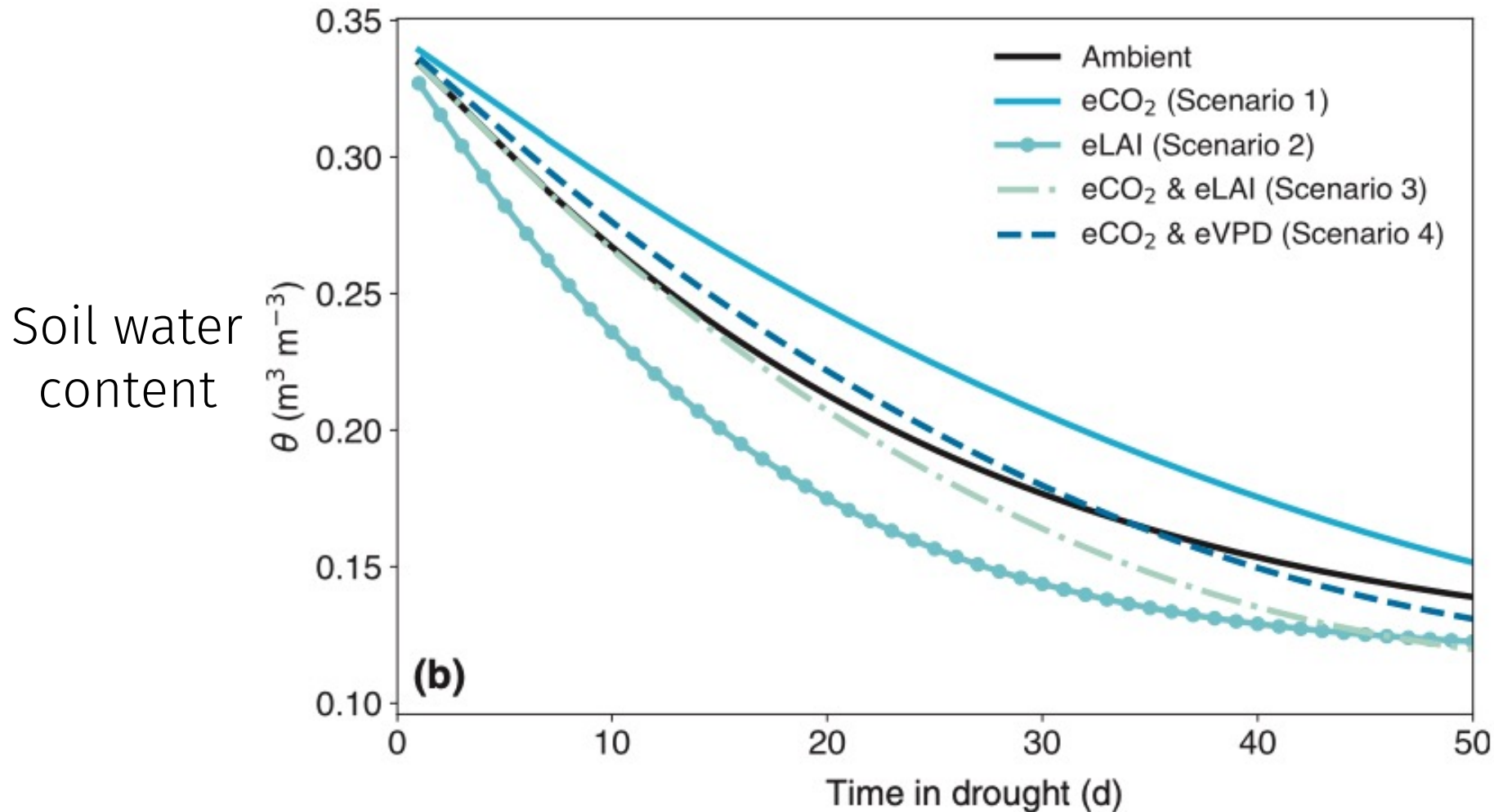
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BIOMOD

LPJ

González-Orozco et al. (2017) Nature Clim. Change

Shrinking
N = 580

Expanding
N = 61

Elevation (m)
2,000
1,500
1,000
500
0

km
0   200   400

Cheaib et al. (2012) Ecol. Lett.

☐ Stable unsuitable area
■ Stable suitable area
■ Loss of suitable area
■ Gain of suitable area

Rifai et al. (2022) Biogeosci.

Δ P:PET (mm mm^{-1})
0.10
0.05
0.00
-0.05
-0.10

NDVI

Annual P:PET

Problem 1: Models are very sensitive to CO_2

Soil water content

(b)

θ ($m^3 m^{-3}$)

Time in drought (d)

- Ambient
- eCO_2 (Scenario 1)
- eLAI (Scenario 2)
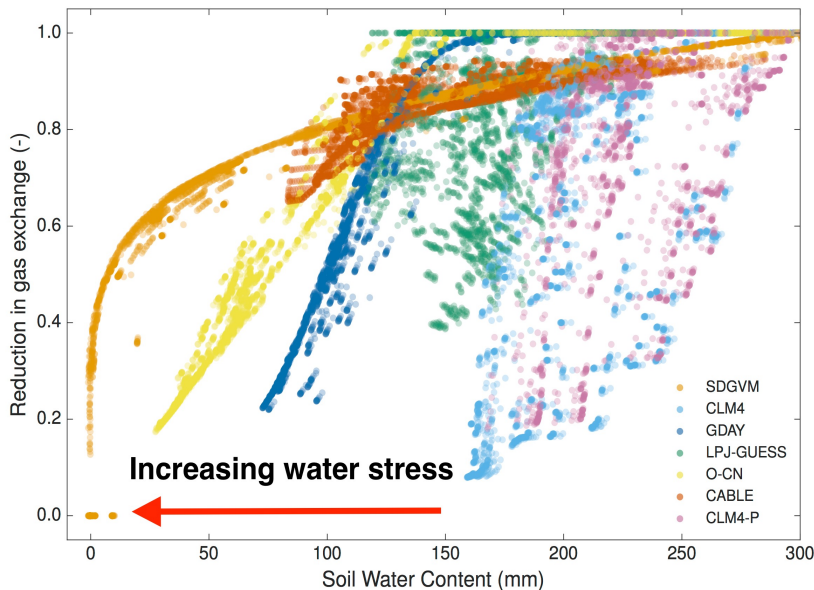- eCO_2 & eLAI (Scenario 3)
- eCO_2 & eVPD (Scenario 4)
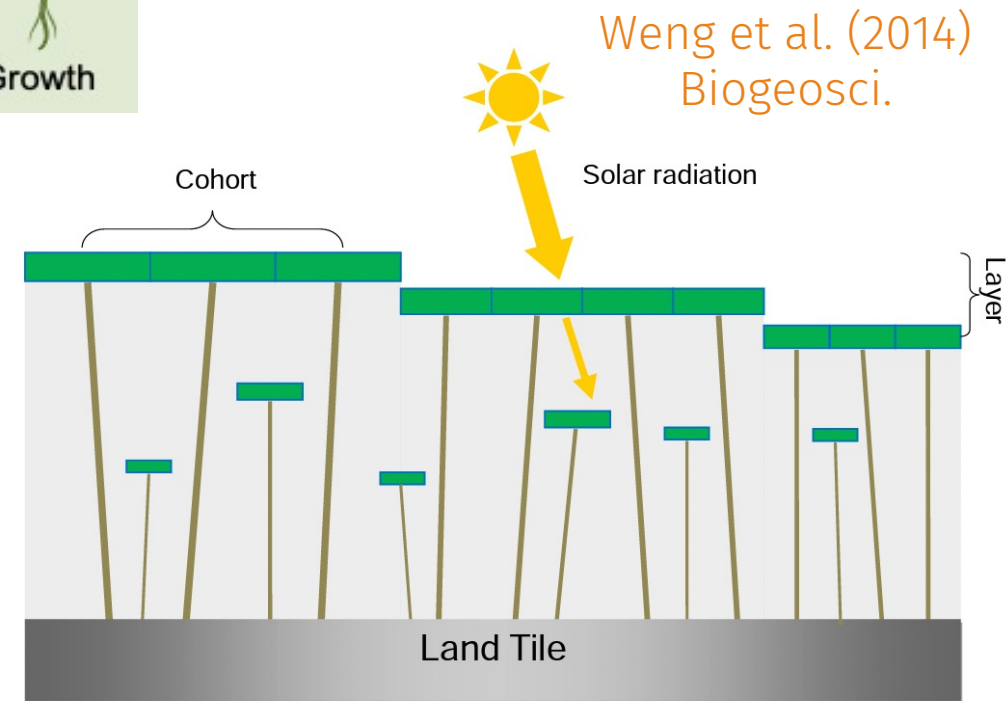
Is this a problem?

Problem 2: Models theory lags observations

Many LSM rely **heavily** on parameterised **empirical tradeoffs**
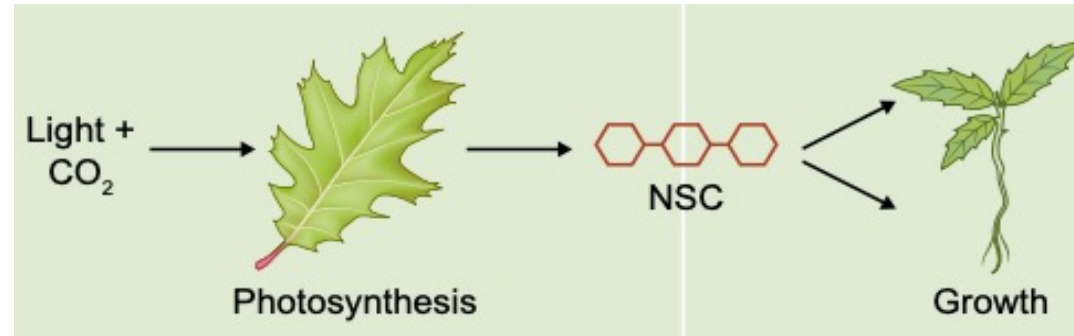
Fatichi et al. (2019) New Phytol.

Weng et al. (2014) Biogeosci.

De Kauwe et al. (2017) Global Change Biol.

Problem 3: How do we capture species diversity?

Challenge: Temperature

Tropical carbon resilience to climate change
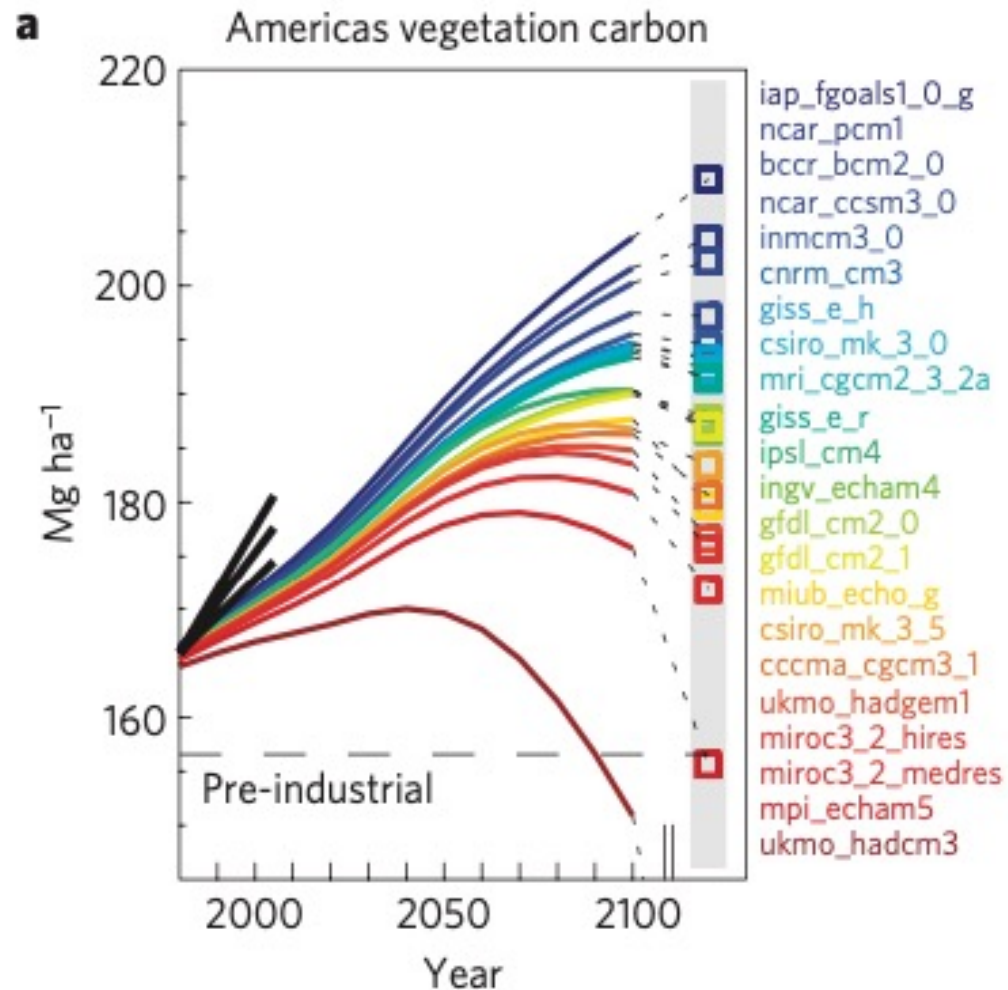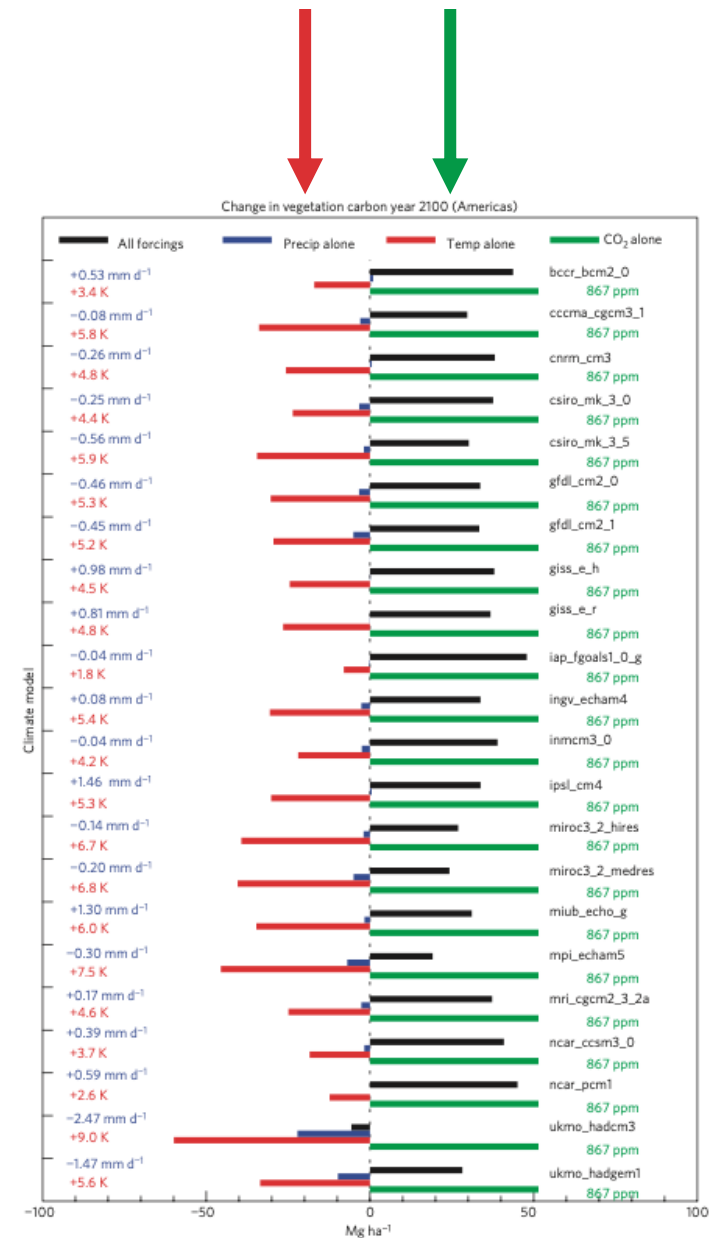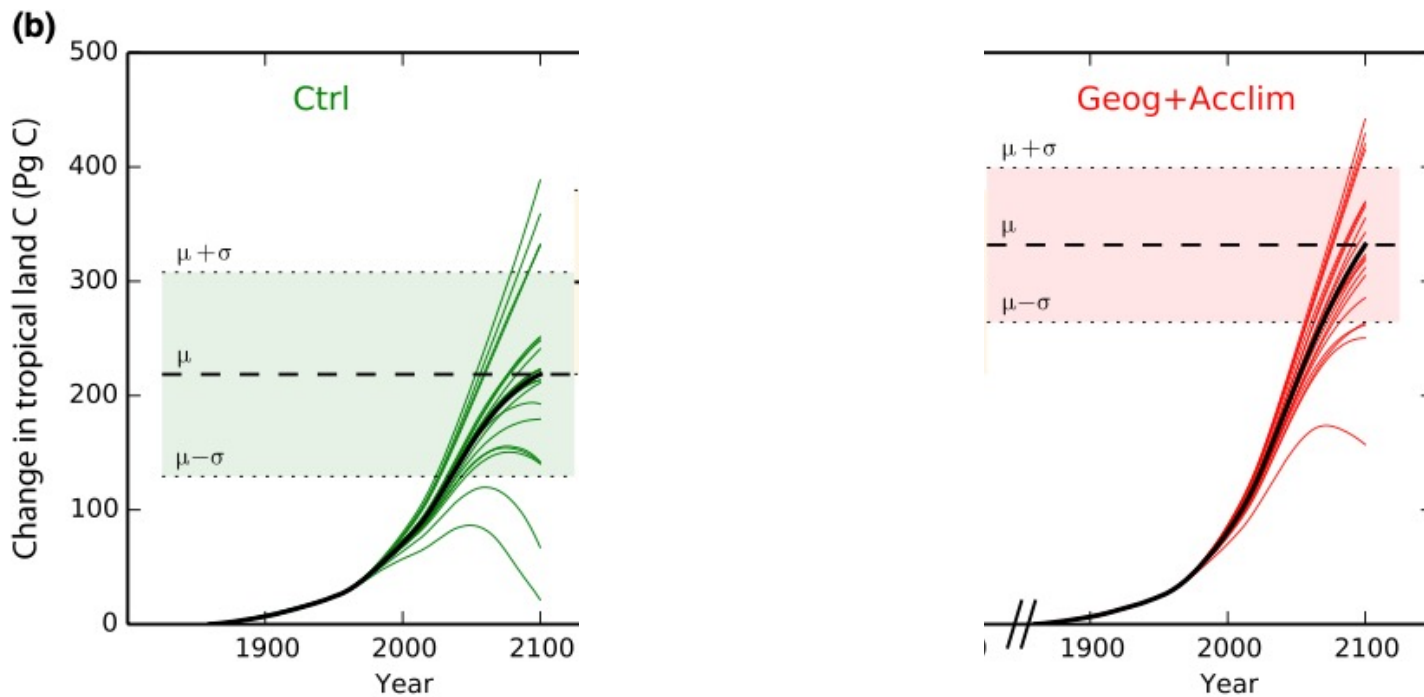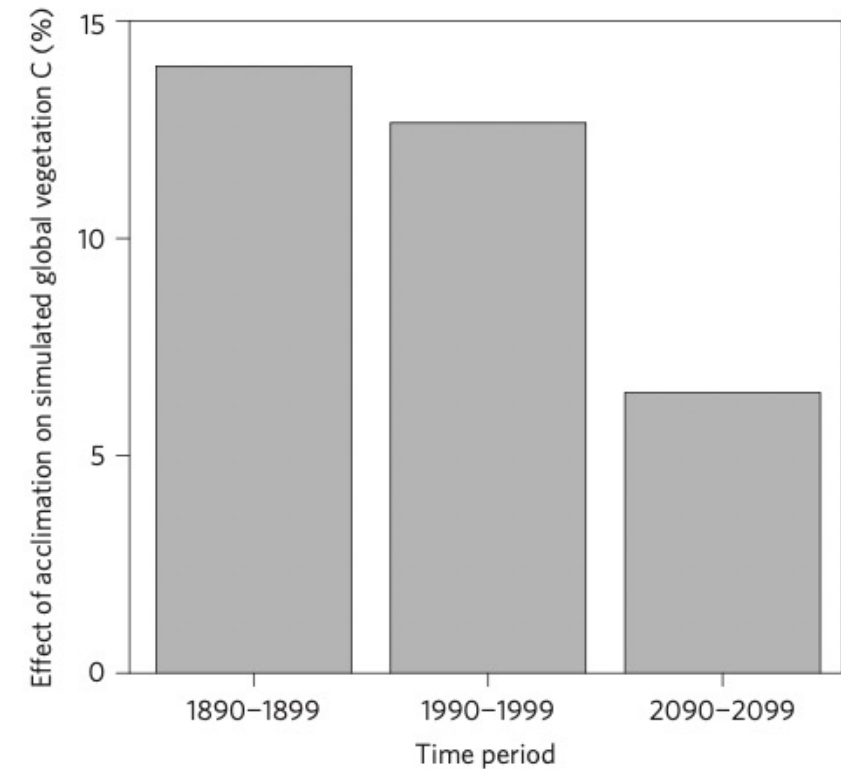

Huntingford et al. (2013) Nature Geosci.

Physiology acclimation to rising temperature

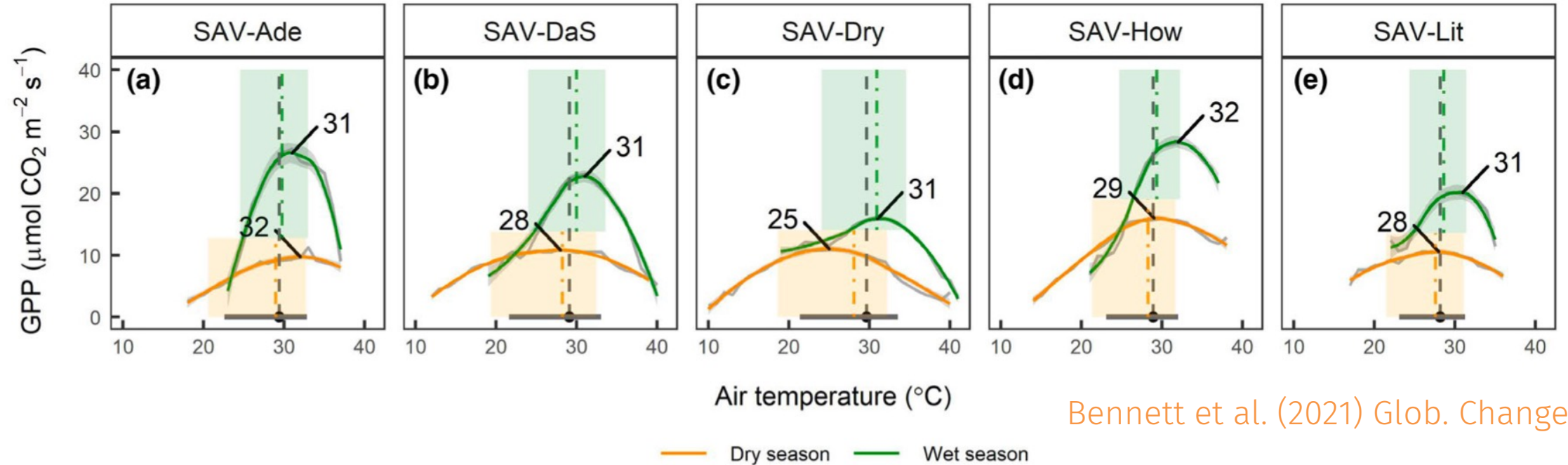**Acclimation:** photosynthesis/respiration physiological adjust to changes in growth temperature
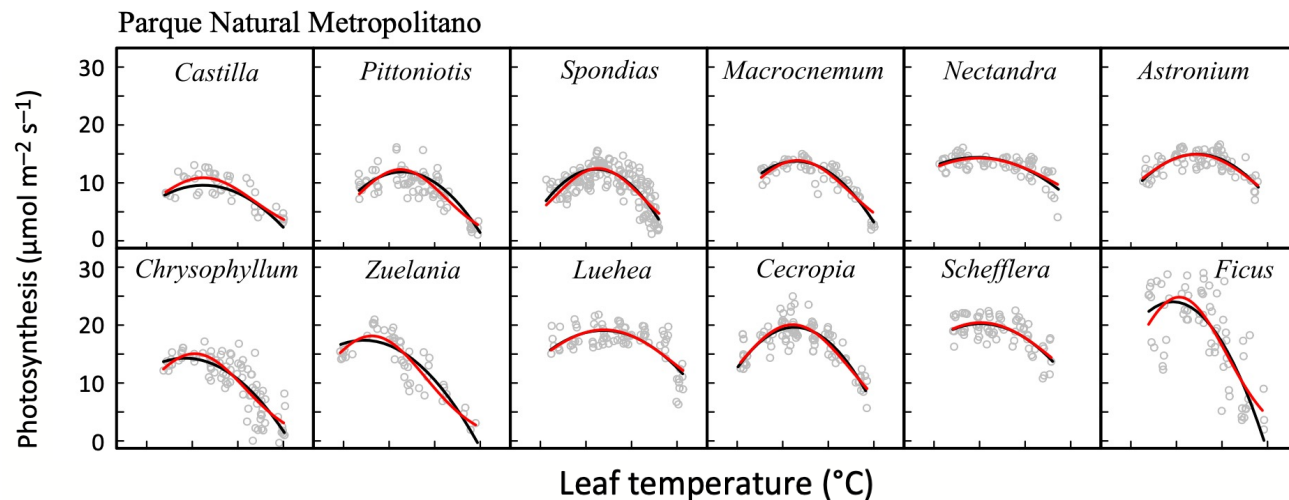

Mercado et al. (2018) New Phytol.

Smith et al. (2016) Nature Clim.

Importance of T_{opt} to carbon fluxes?

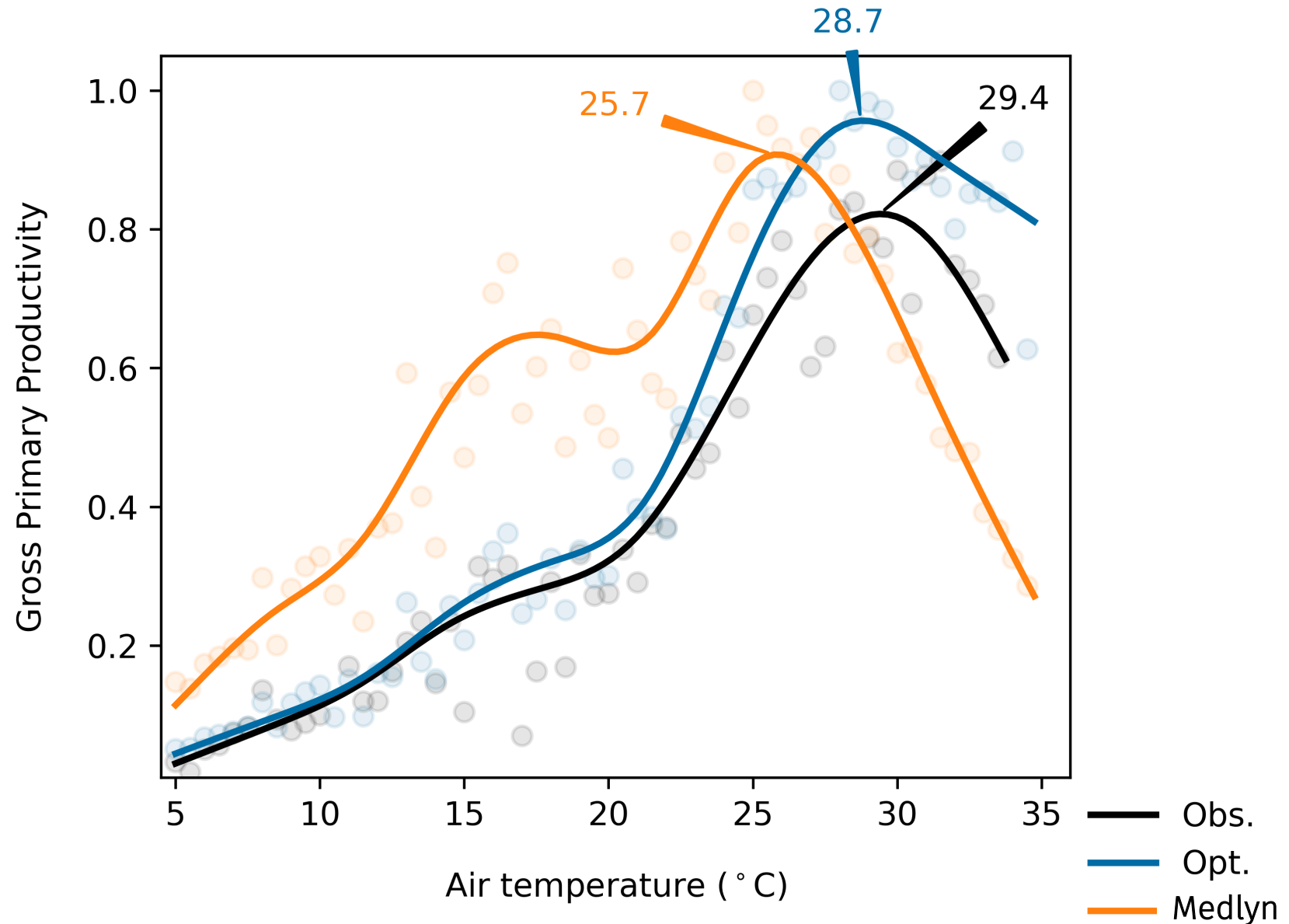Bennett et al. (2021) Glob. Change Biol.

Slot and Winter (2017) New Phyt.

Photosynthesis >T$_{opt}$ more about g$_s$

Temperature response of photosynthetic carbon uptake is **not** just about assumed sensitivities...

Same E$_a$, H$_d$ & ΔS

Challenges

Are models capturing the limitations of temperature & the feedbacks on the carbon cycle?

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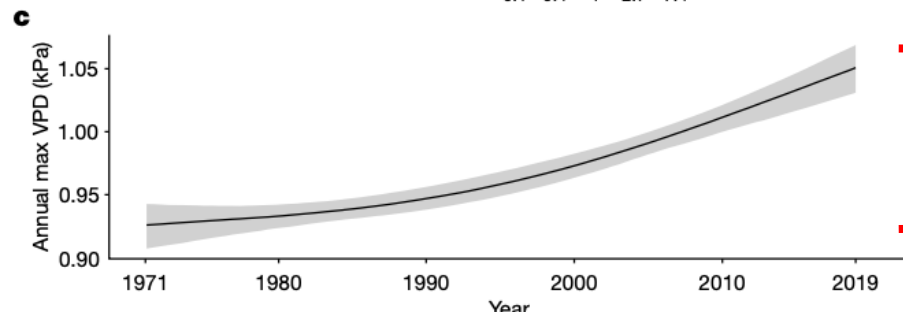
- Can plants acclimate to temperature indefinitely?

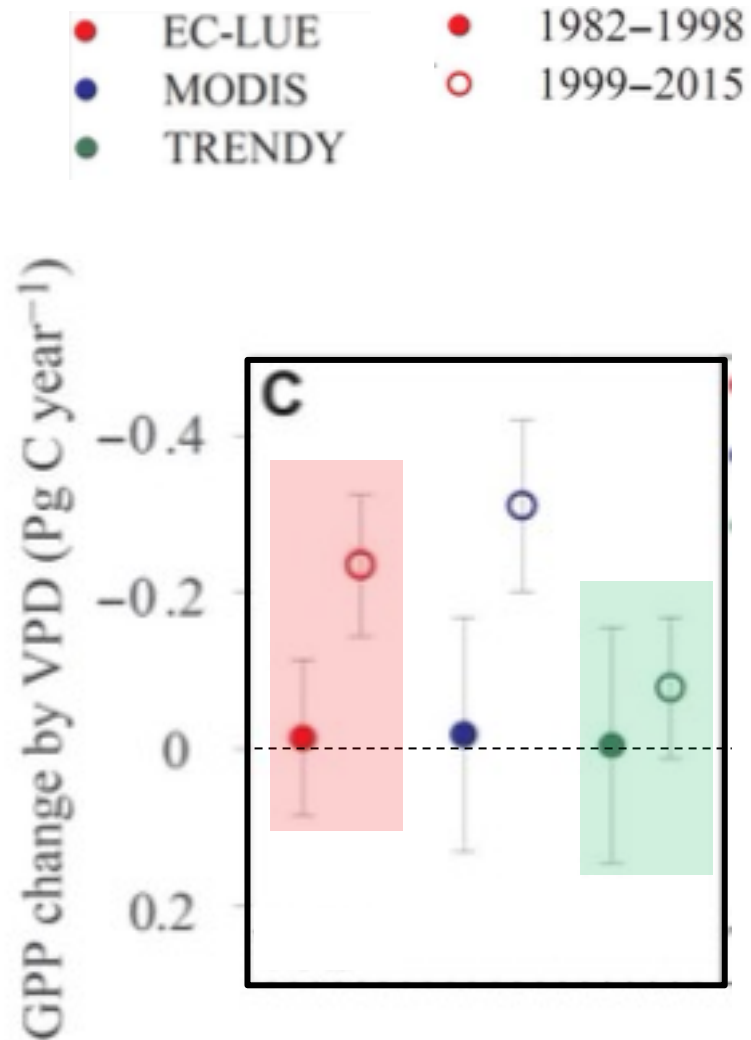# Challenge: VPD

Tropical tree mortality linked to VPD

~15% increase in VPD

Bauman et al. (2022) Nature
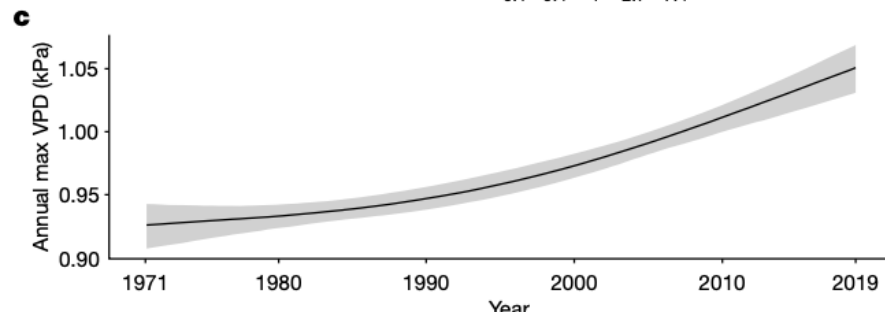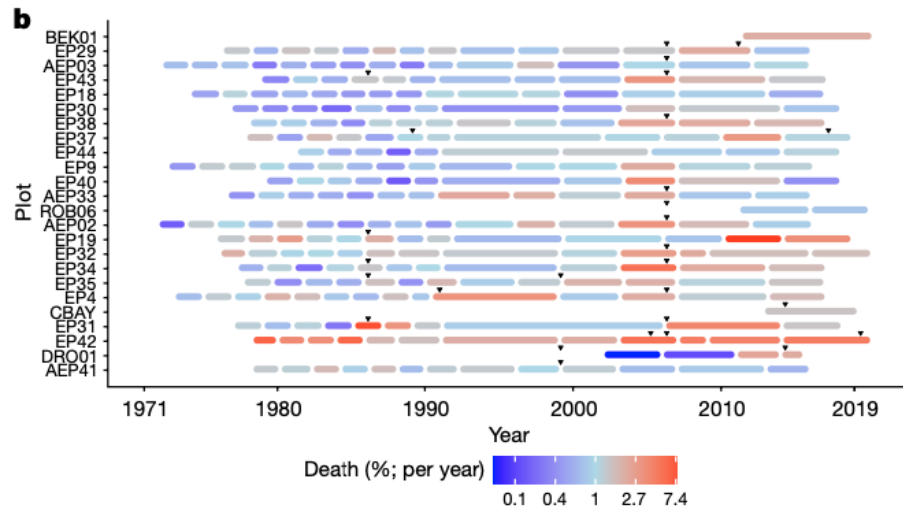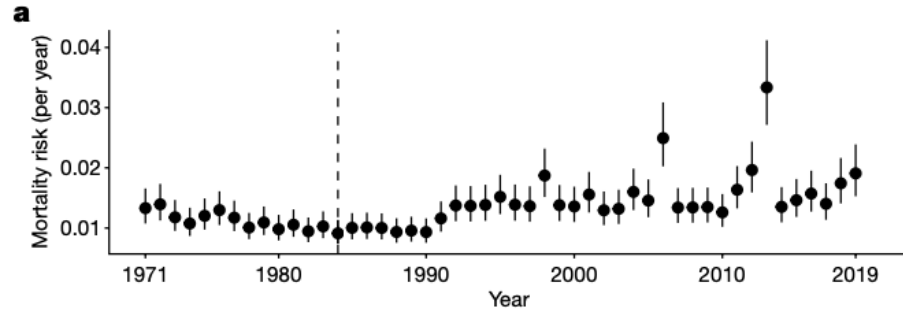
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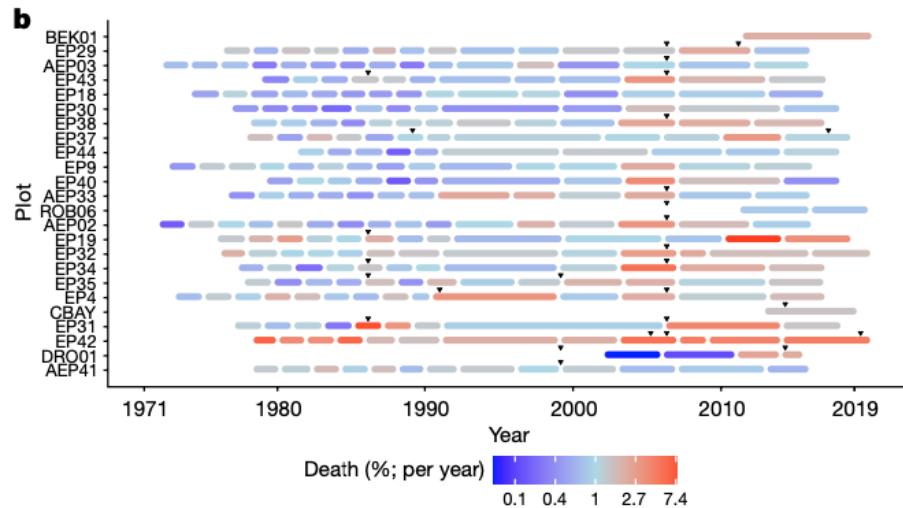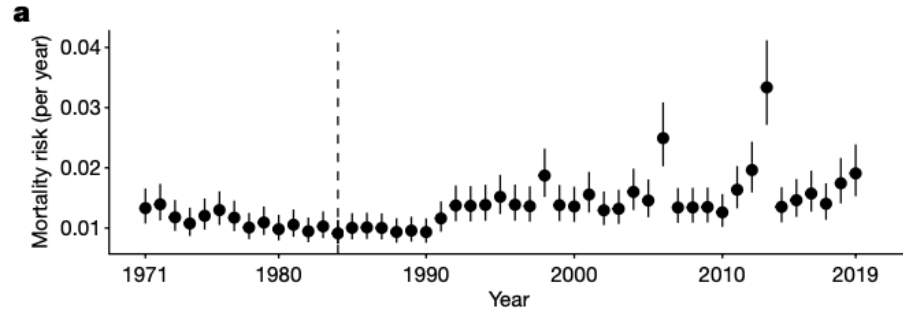
What is the mechanism?

Is it the background change or the response in extreme years?

~15% increase in VPD

Bauman et al. (2022) Nature

Incorrect model sensitivity to VPD?
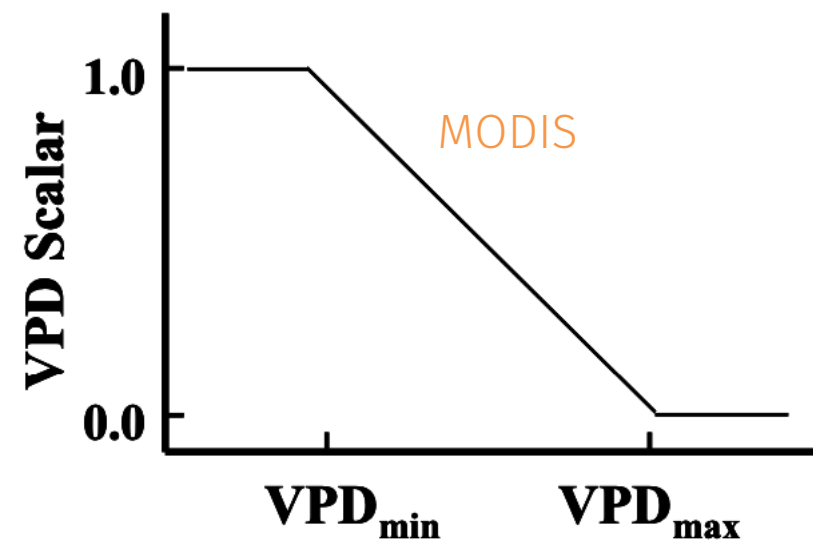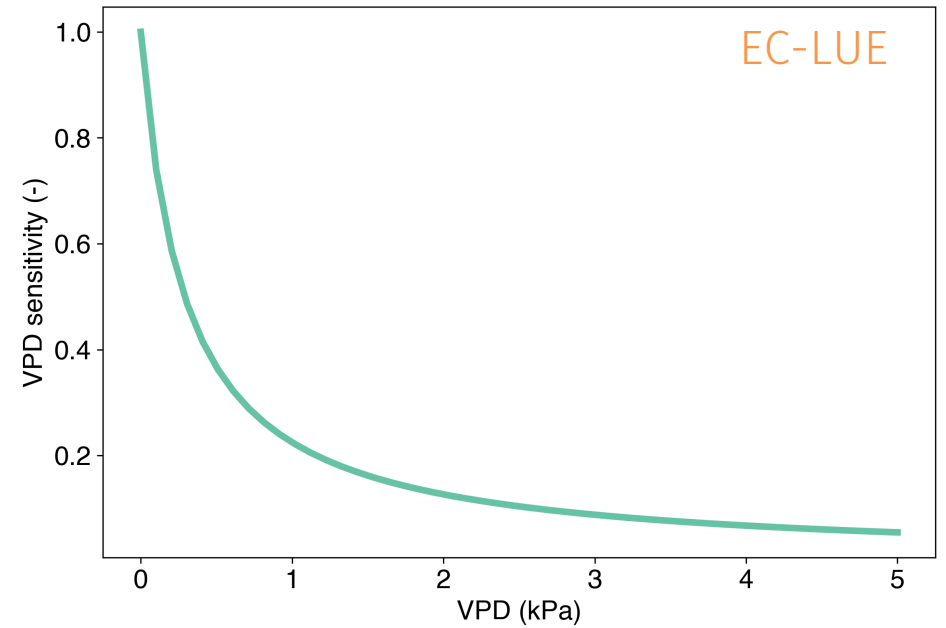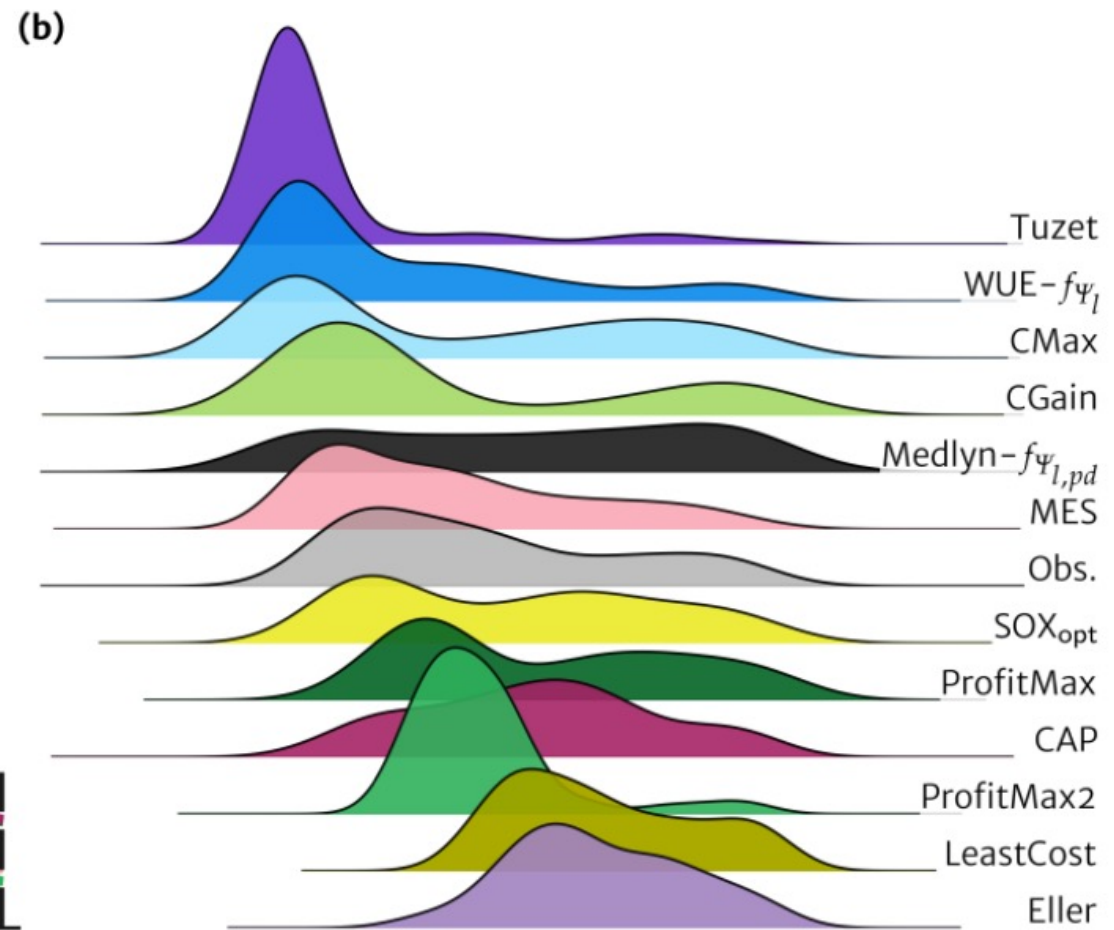

Yuan et al. (2019) Sci. Adv.

Incorrect model sensitivity to VPD?

EC-LUE

MODIS
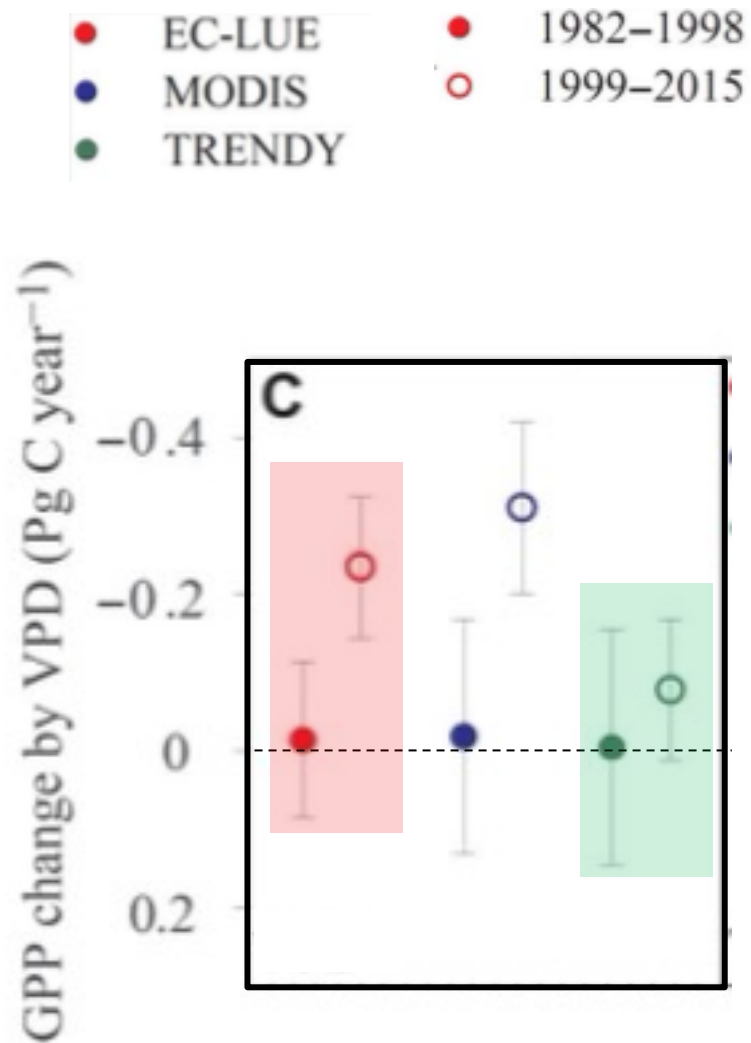
Yuan et al. (2019) Sci. Adv.

What is the **right** sensitivity to VPD?
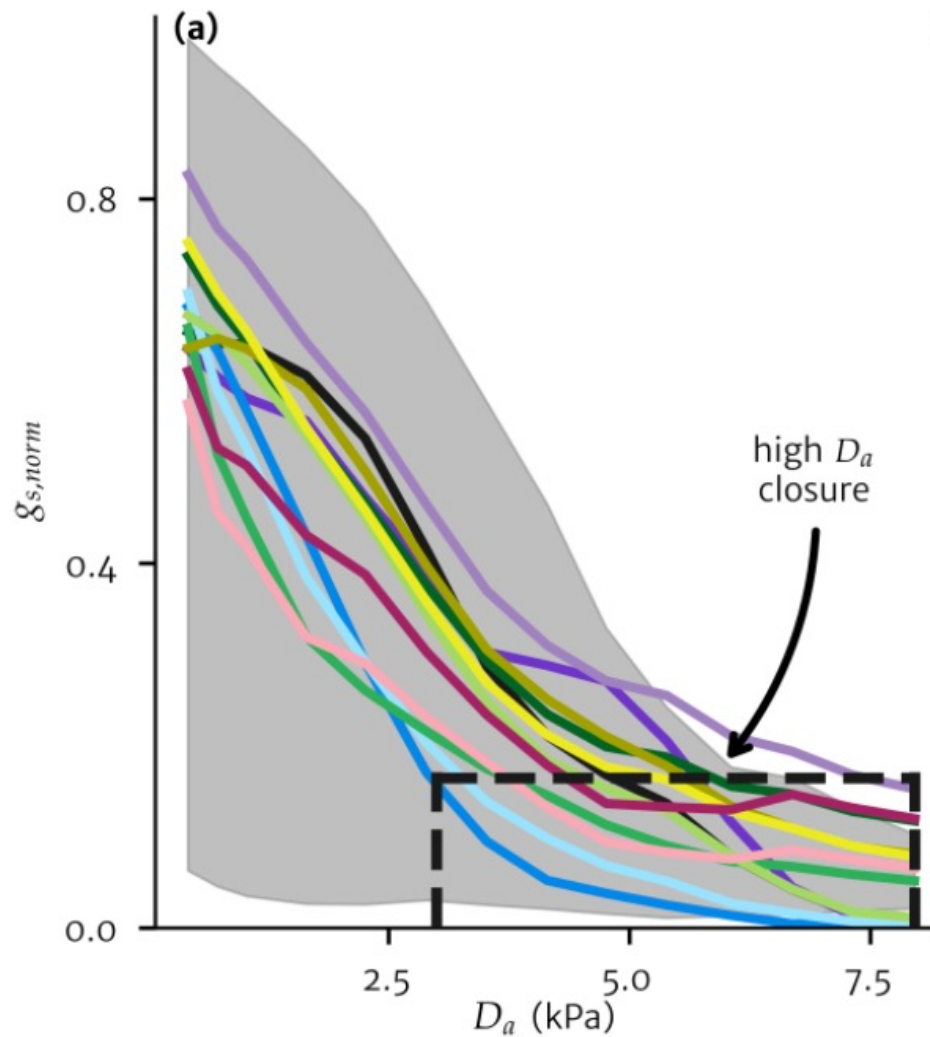
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- Models predict that increased WUE due to CO_2 counteracts increases in VPD to later half of the century...**is this right?**

Challenge: Drought

Predicting species resilience to drought
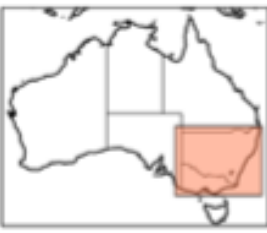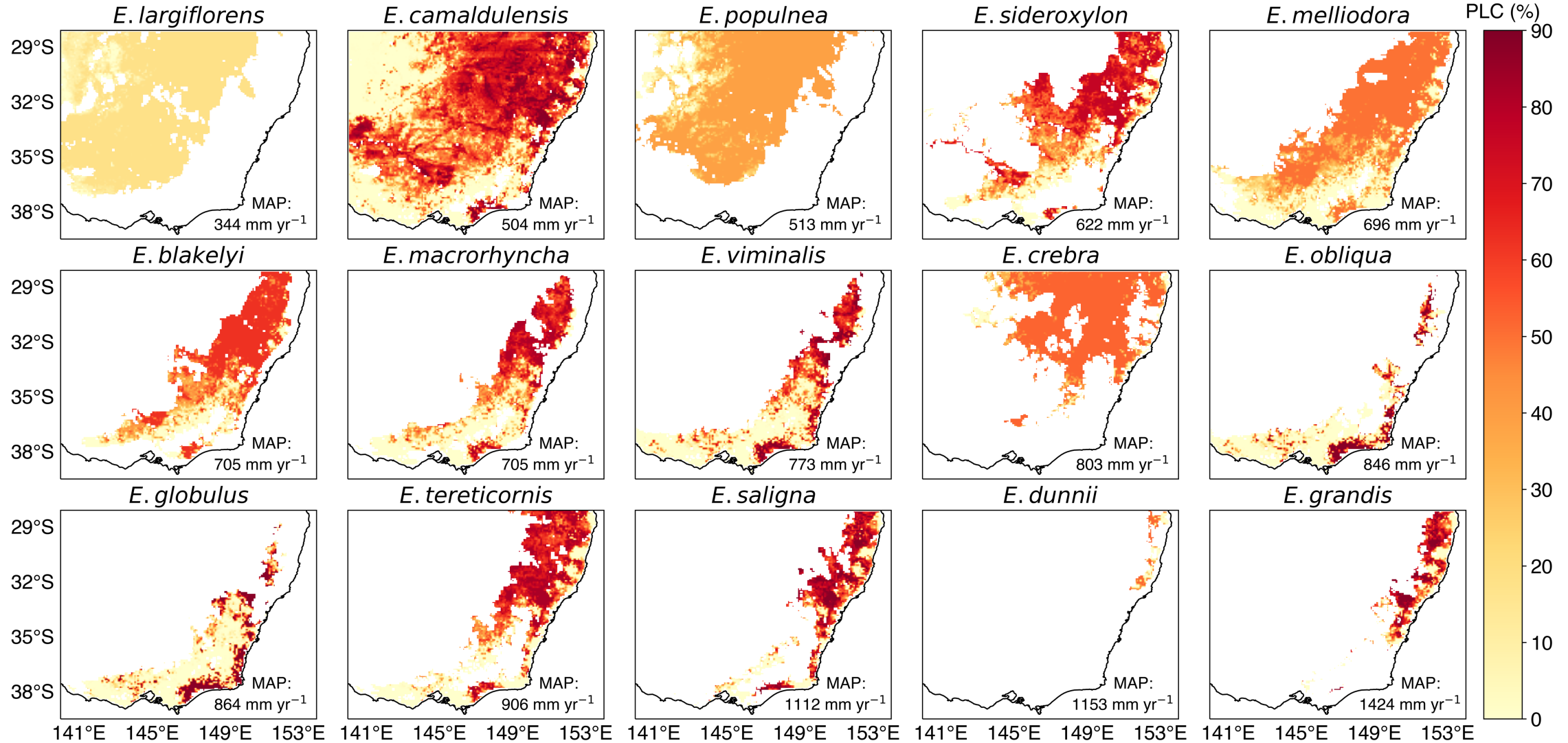
Predicting species resilience to drought

De Kauwe et al. (2022) New Phytol.
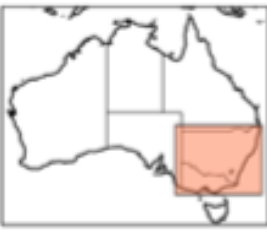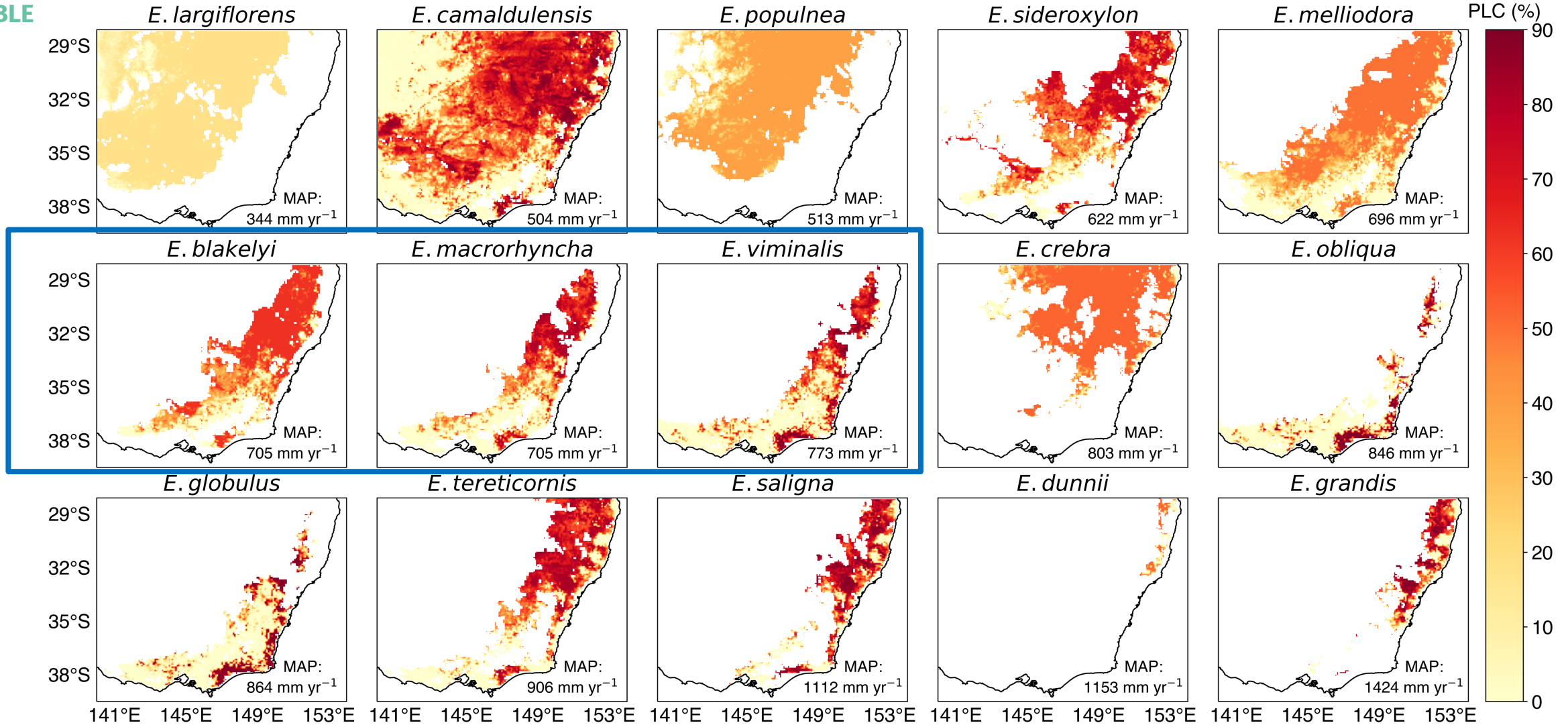
Predictions of future drought mortality

Fagus sylvatica

Current distribution

Predicted mortality
future period (2071-2100)

SurEau-Ecos model

Quercus ilex

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Presence
Absence

Probability of hydraulic failure (%)

0 10 20 30 40 50 60 70 80 90

Ruffault et al. (2022) Geosci. Model Dev

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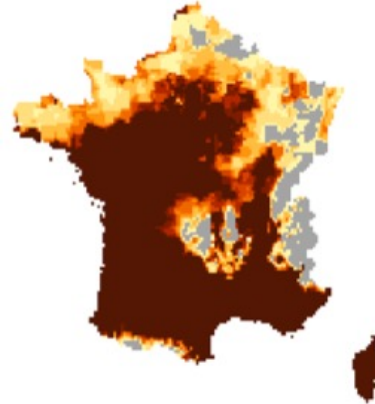
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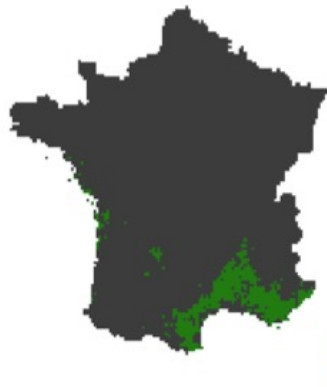
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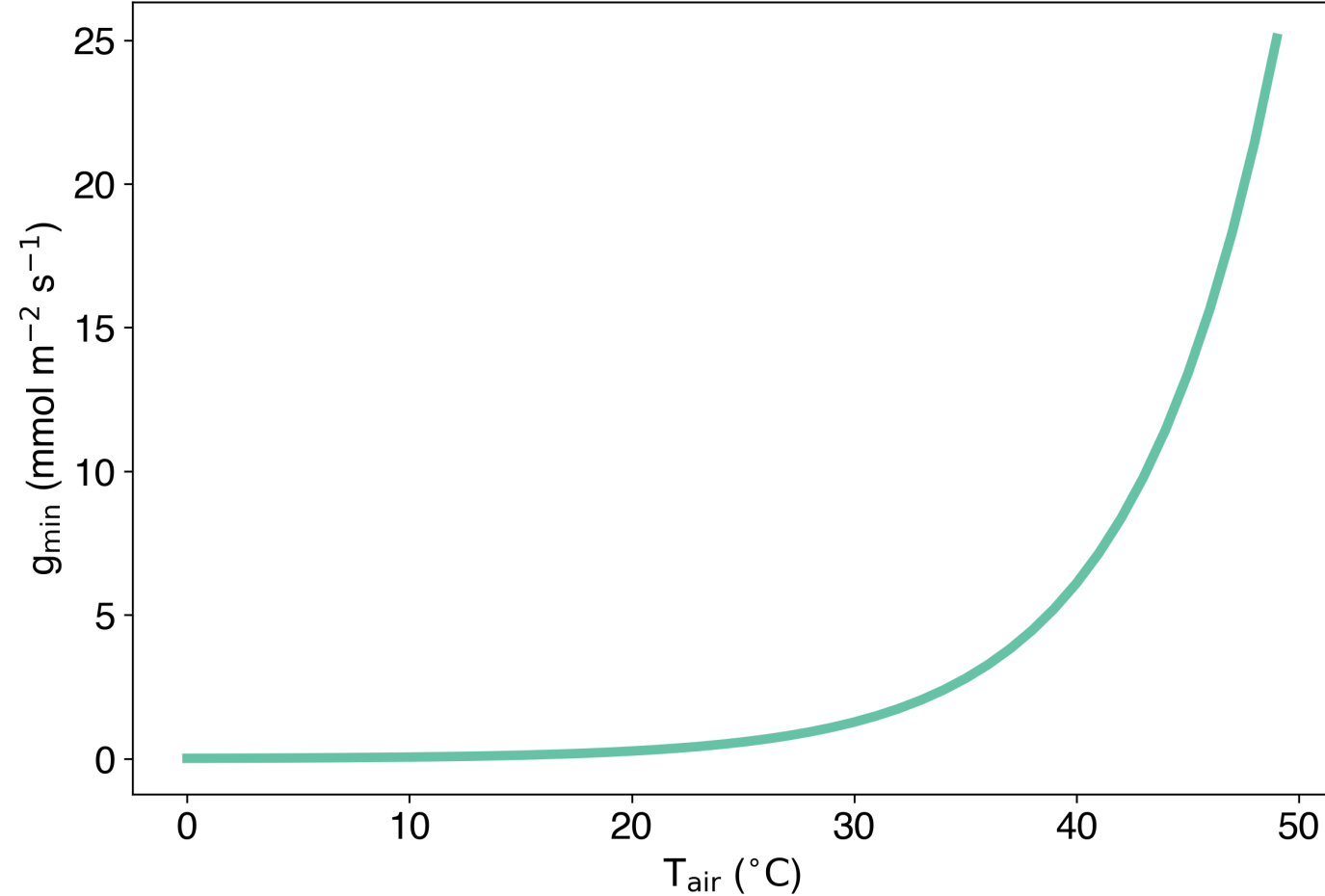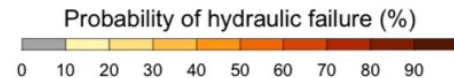
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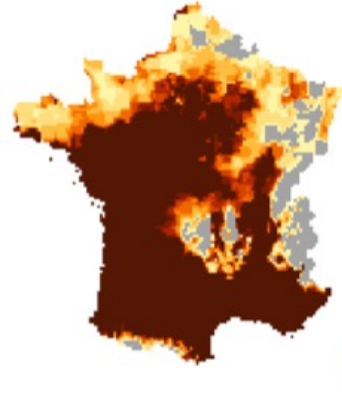0 10 20 30 40 50 60 70 80 90

Ruffault et al. (2022) Geosci. Model Dev

Challenges

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  - *e.g.*, mesophyll conductance sensitivity to drought, loss of root hydraulic conductance, feedback on leaf biomass, *etc*

- We need to better link to sub-surface hydrology
  - *e.g.*, dynamic root uptake, groundwater, *etc*

Challenge: Recovery

Legacy to extremes & recovery

- How long does legacy to extremes persist?
  - Months? Years? Decades?

London, 2022

Legacy to extremes & recovery

- How long does legacy to extremes persist?
  - Months? Years? Decades?

- What **mechanisms** enable recovery?
  - How does the pace of recovery differ among physiological processes?
  - What needs to be included in models?
    - *e.g.*, role of storage, C-cost of recovery, *etc*

London, 2022

Conclusions

- Models have made progress on better simulating **resistance**, but we have a lot of work to do on **recovery**
  - Requires more observations

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Callitris

Eucalyptus

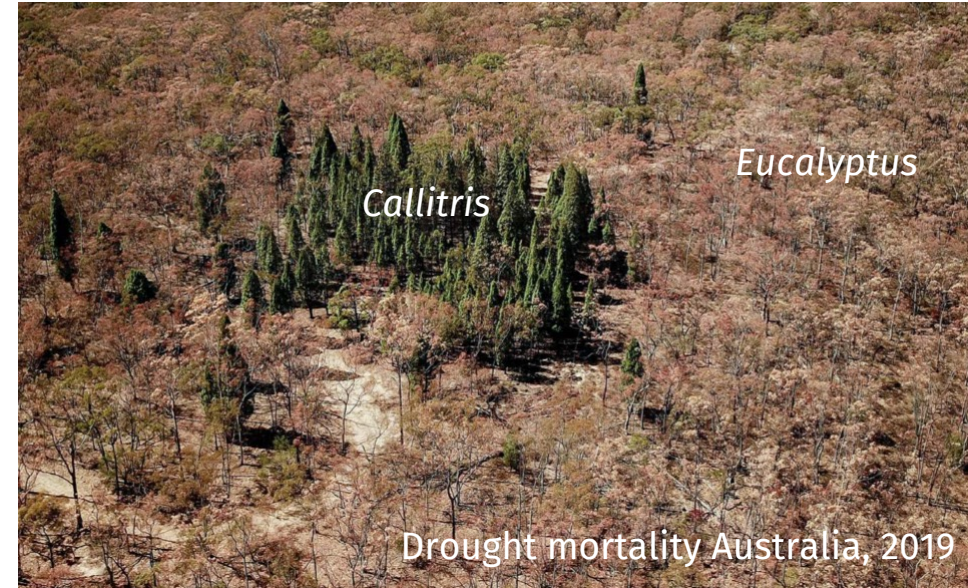Drought mortality Australia, 2019

Conclusions

- Models have made progress on better simulating **resistance**, but we have a lot of work to do on **recovery**
    - Requires more observations

- How do we account for **species** differences in future ecosystem resilience projections?

- Will repeated extremes alter the predictability of ecosystem responses & resilience …?

Callitris

Eucalyptus

Drought mortality Australia, 2019