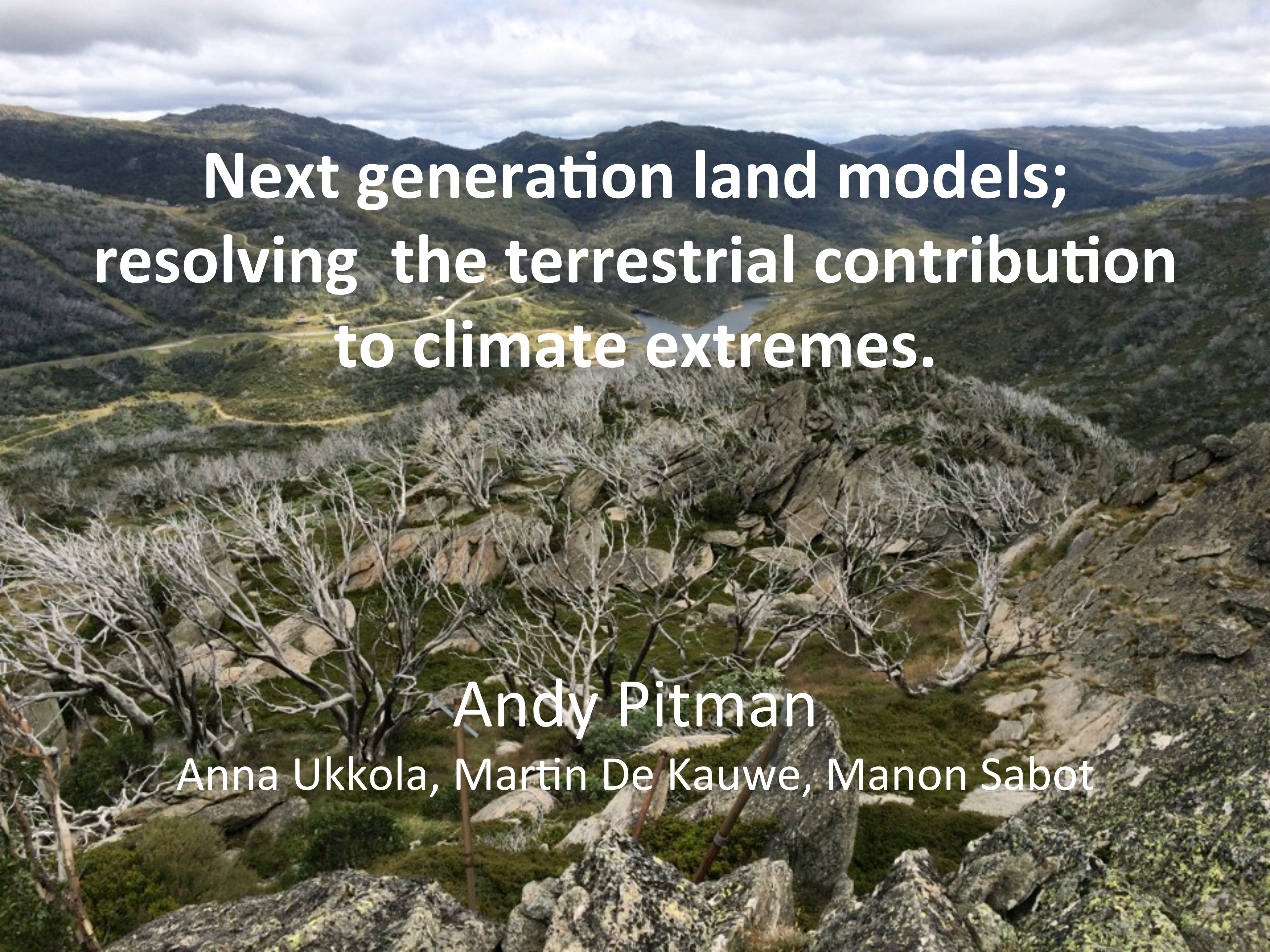
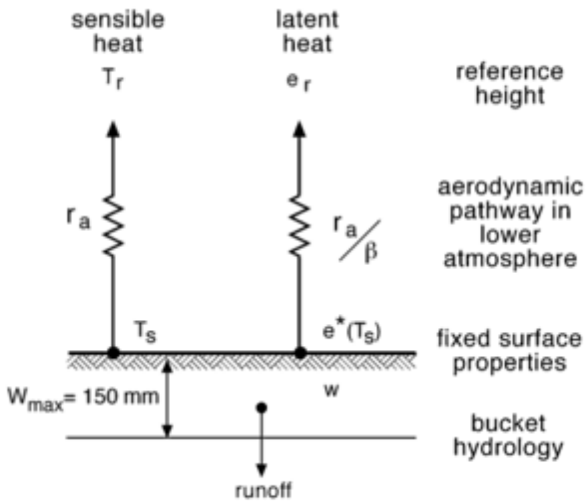


# Next generation land models; resolving the terrestrial contribution to climate extremes.

Andy Pitman

Anna Ukkola, Martin De Kauwe, Manon Sabot

# First generation land surface models




Mikhail Budyko

Syukuru Manabe

No water storage beyond seasonal.

No carbon

Common in 1st, 2nd IPCC reports

Now very rare.

Linked with systematic errors (mid-continental drying)

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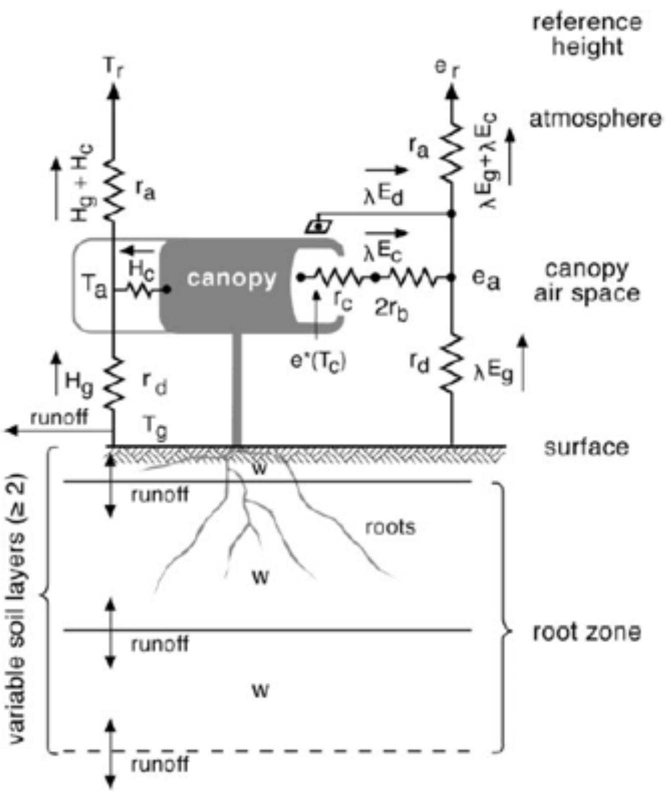
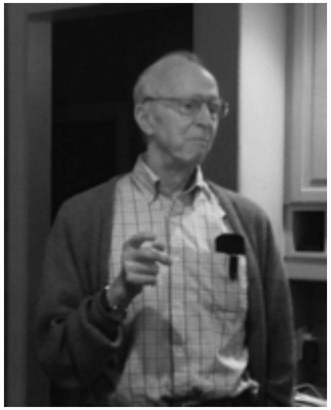
# Second generation land surface models



James Deardorff

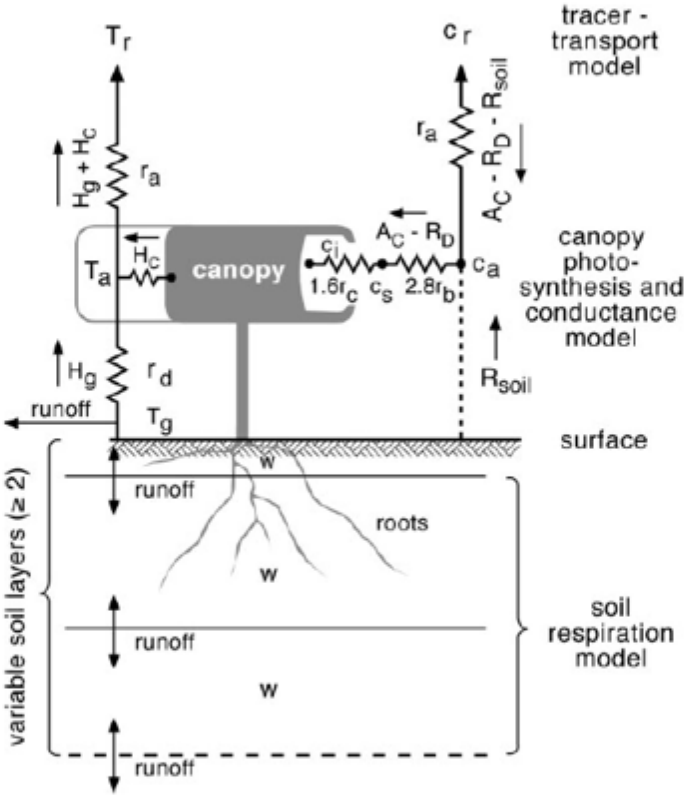
Bob Dickinson

Stomatal conductance empirical

Common in 2nd – 4th IPCC reports

Do not couple energy, water and carbon physically correctly at the stomate

# Third generation land surface models




Piers Sellers

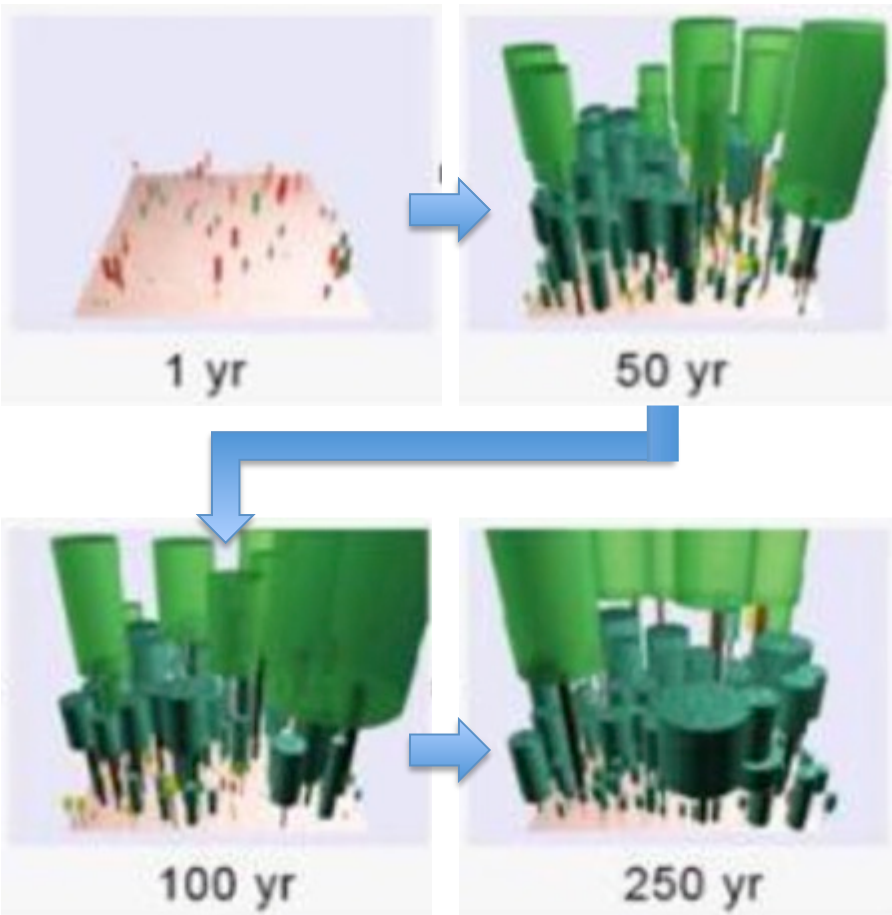
Links energy, water and carbon via stomates

Energy and water storage

Takes carbon and uses it

Common in 4th and 5th IPCC and commonly used

# Fourth generation land surface models




Victor Brovkin

Jon Foley

Adds vegetation dynamics

Focus on longer timescales

See Sellers et al., 1997, *Science* for further details

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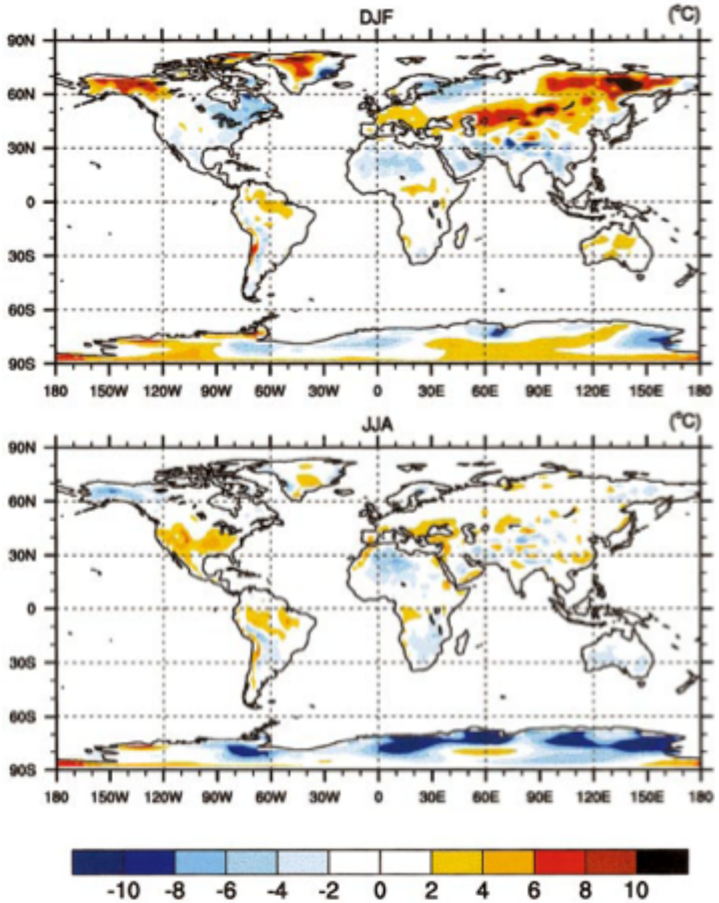
# Land models were developed for large scales and the average state




Bonan et al., 2002, J. Climate

General statements

- Our LSMs are suitable for large time and space scales – the averages
- Now applied to different phenomenon: heat waves and droughts for example
- Are our LSMs fit for these phenomenon?
- We have always had an excuse for not focusing on extremes: little suitable data

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# We now have data

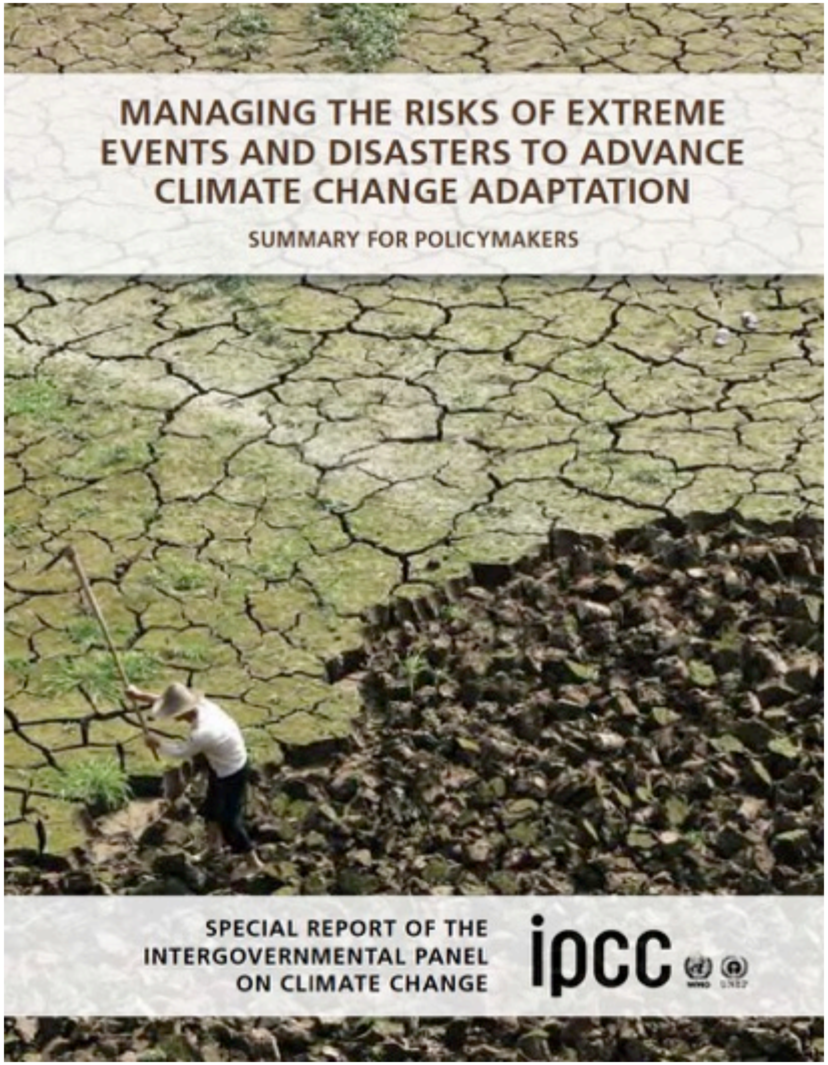
http://fluxnet.fluxdata.org

Ukkola et al., 2017, GMD, provide a netCDF tool

Multiple relevant satellite products

# We now have purpose

http://fluxnet.fluxdata.org

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# To address some awkward questions

[http://fluxnet.fluxdata.org](http://fluxnet.fluxdata.org)

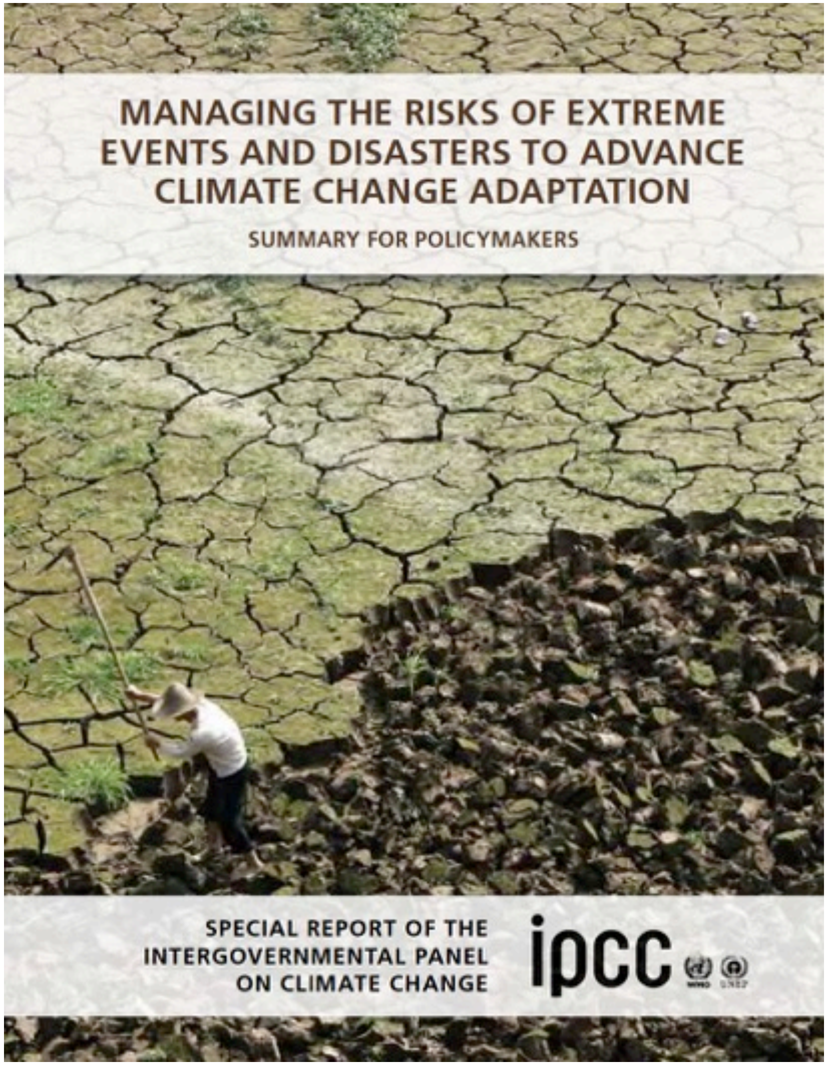
**Questions**

Do we know the sign of the change in future drought?

- Increased evaporative demand
- Increased water use efficiency

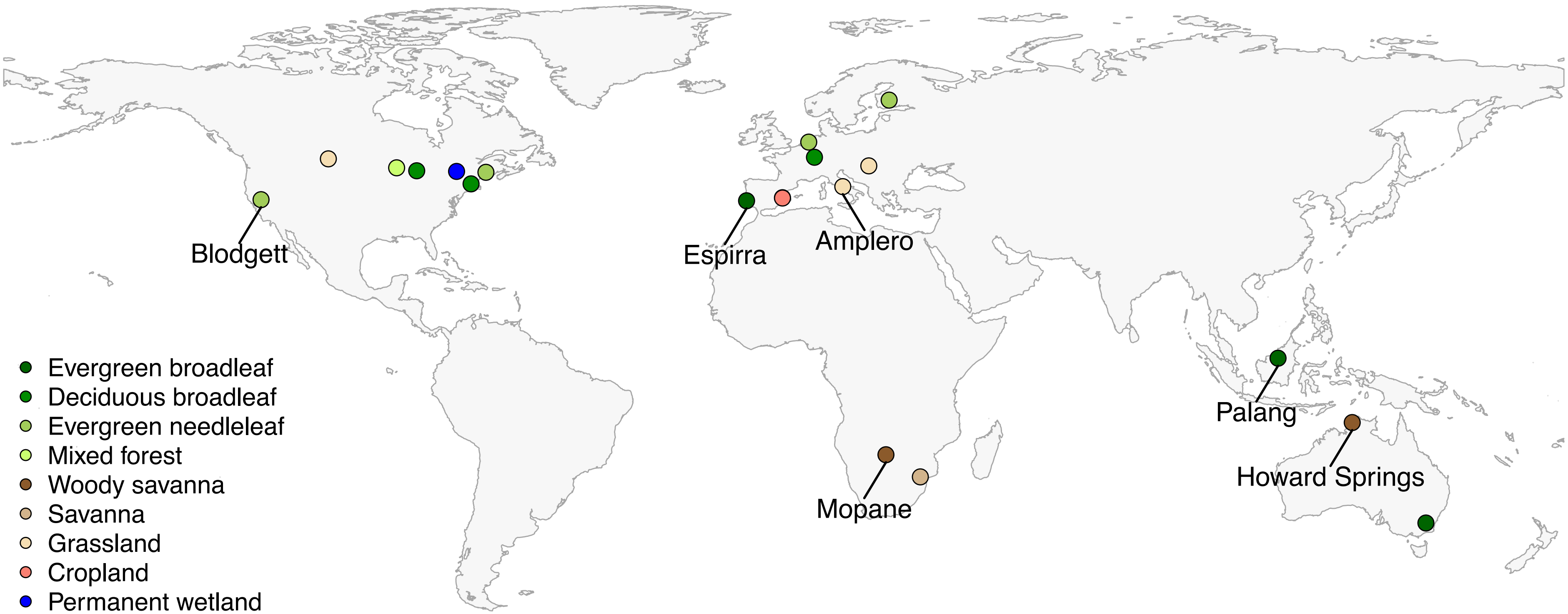
Do we know the magnitude of the land feedback on future heatwaves?

- Do we partition net radiation well under dry down?
- Do we do moisture stress well?



# Lets start with drought …

## Evaluating LSMs at flux tower sites for drought

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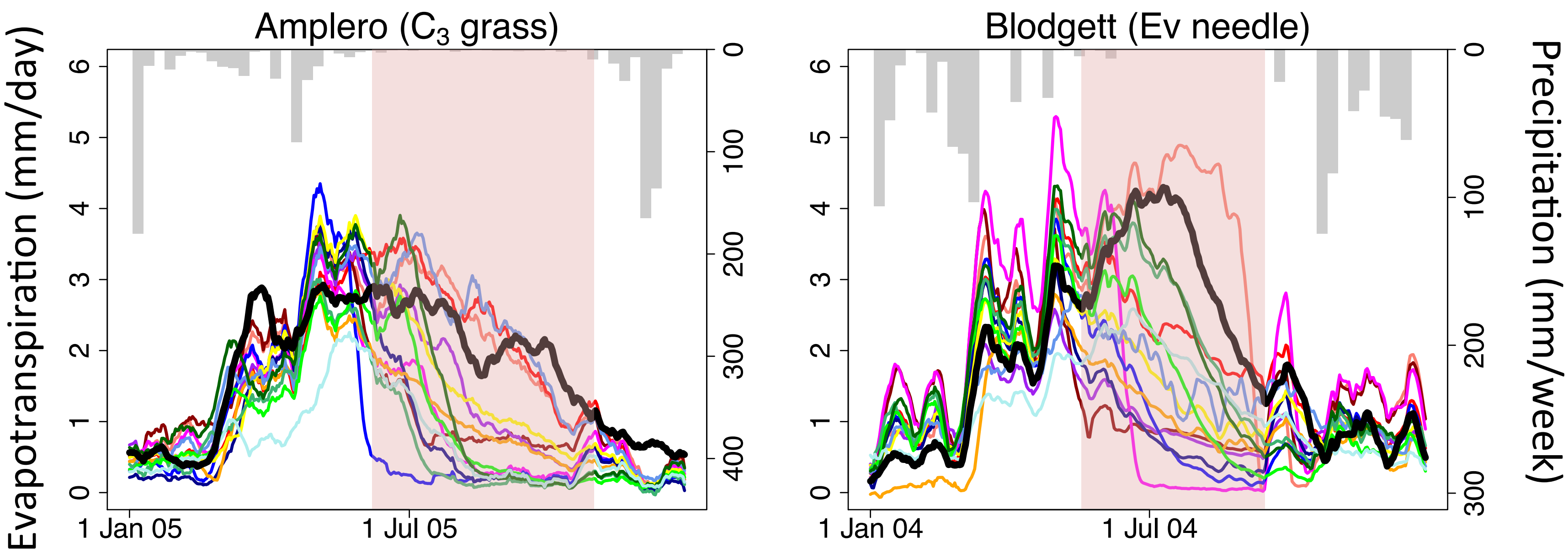
# Lets start with drought …

Ukkola et al, 2016, ERL

**ET simulations**




- Note, for forests, systematic ET bias (too low)
- Very rare that LSMs over predict ET

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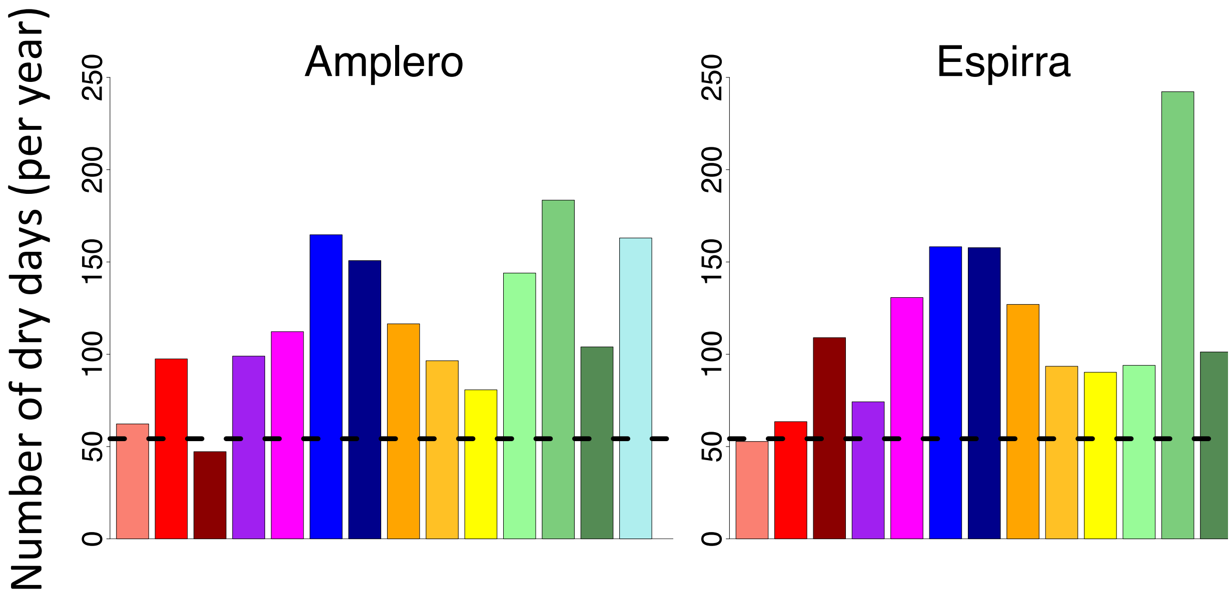
# Drought duration – droughts last too long

Simulated mean:

111 days

Observed mean:

53 days




Various land surface models

Observed (dashed line) and simulated (bars)

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Ukkola et al, 2016, ERL

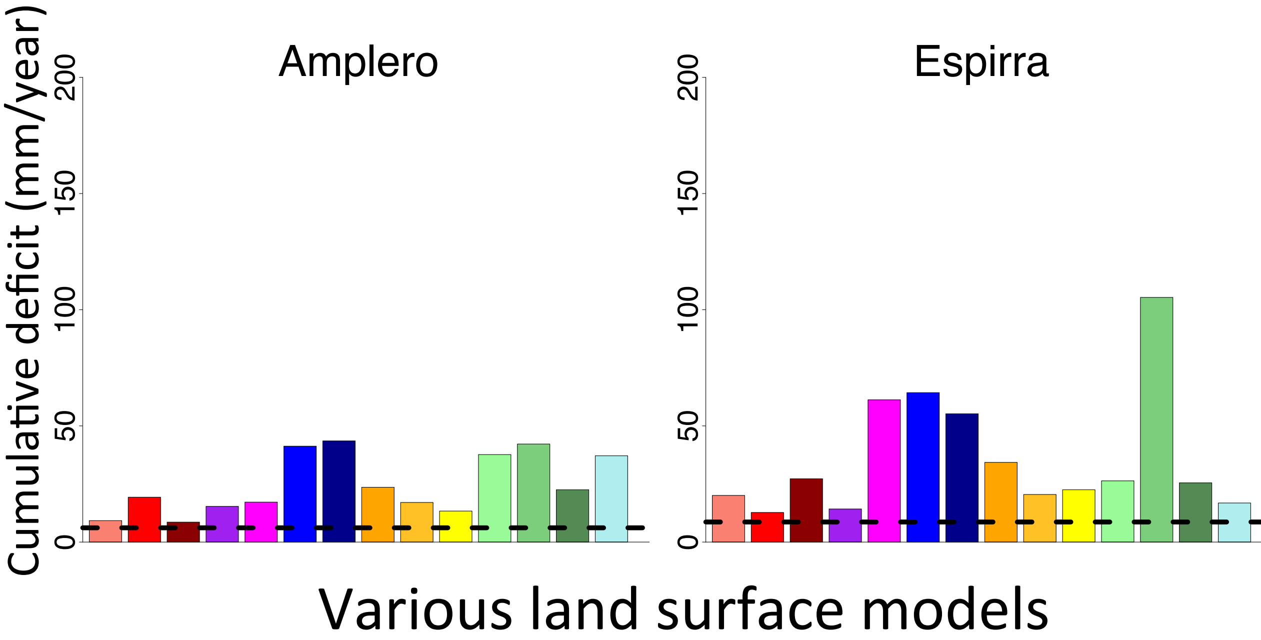
# Drought magnitude – excessive magnitude

Simulated mean:

42 days

Observed mean:

9 days




Observed (dashed line) and Simulated (bars)

Ukkola et al, 2016, ERL

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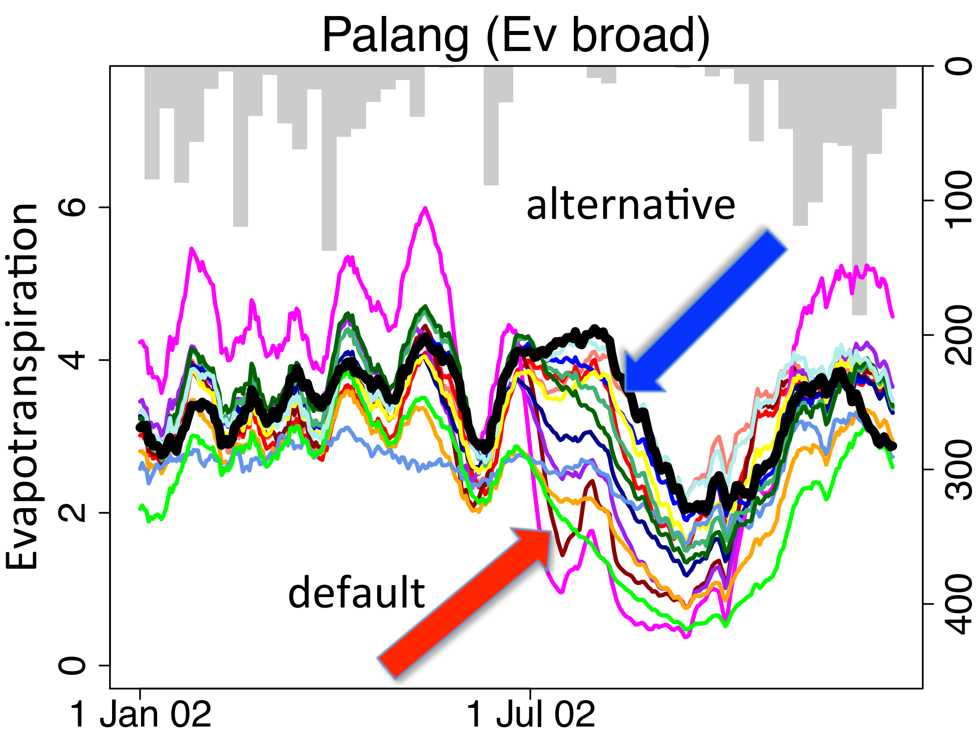
# We could fix the biases in our model




Improvements in CABLE due to:

Pore based soil evaporation

- Decker et al., 2017

Revised stomatal conductance

- De Kauwe et al., 2015, GMD

Revised soil hydrology

- Decker, 2015, JAMES

- Plant water use strategies
  - De Kauwe et al., 2015, Biogeosciences

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# What about heatwaves


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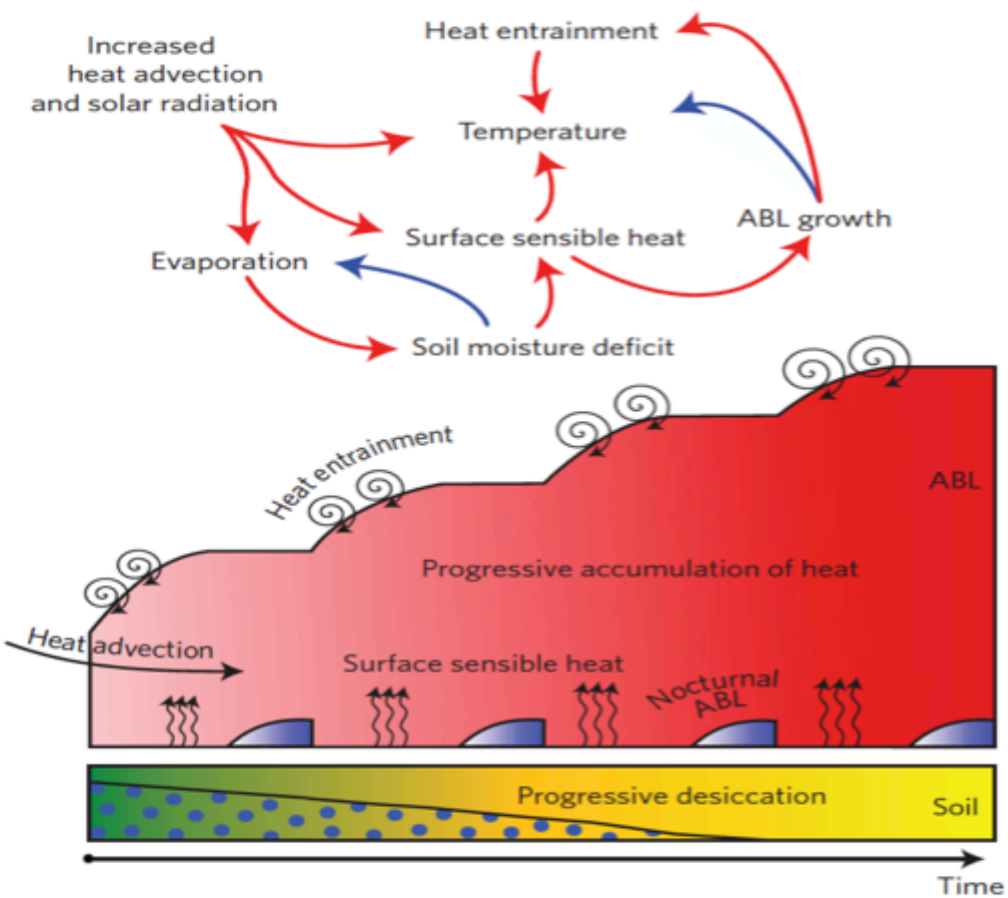
# Role of the land surface on days to seasons

## Land – boundary layer intensification




The key here is, can we get the progressive drying, and the consequences on latent and sensible heat right?

Boundary layer

Surface energy balance

Soil moisture

From Miralles et al., 2014, Nature Geoscience

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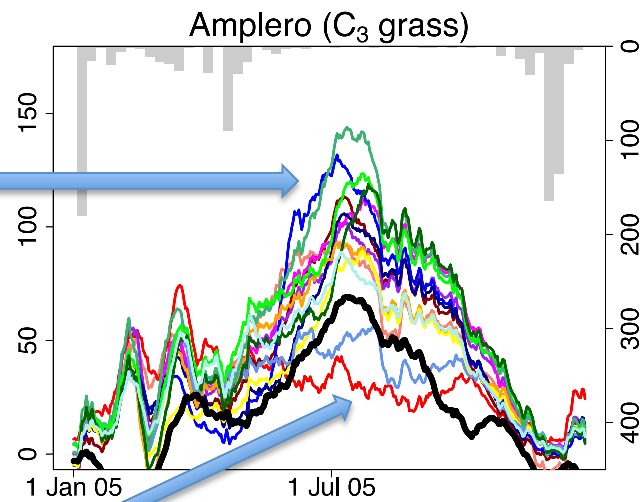
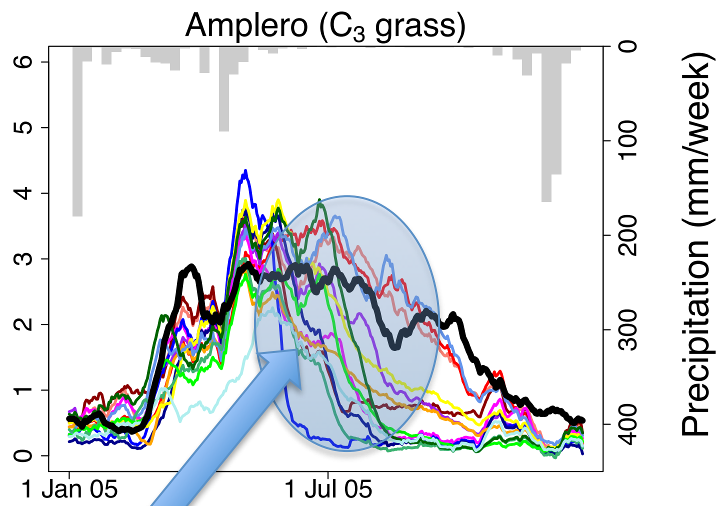
# What about heatwaves

Sensible heat flux W/m²)




Evapotranspiration (mm/d)




Very strong feedback, amplifying heatwave

Very weak feedback, suppressing heatwave

**Strong tendency to dry out too fast and desiccate in summer**

Note - ~10 land models used in CMIP5, identical atmospheric forcing

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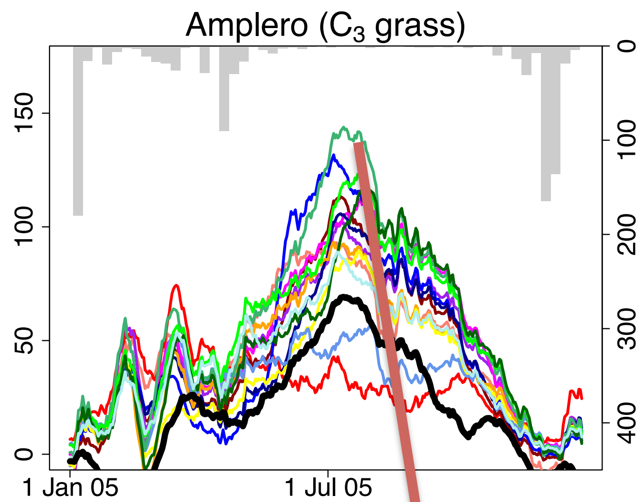
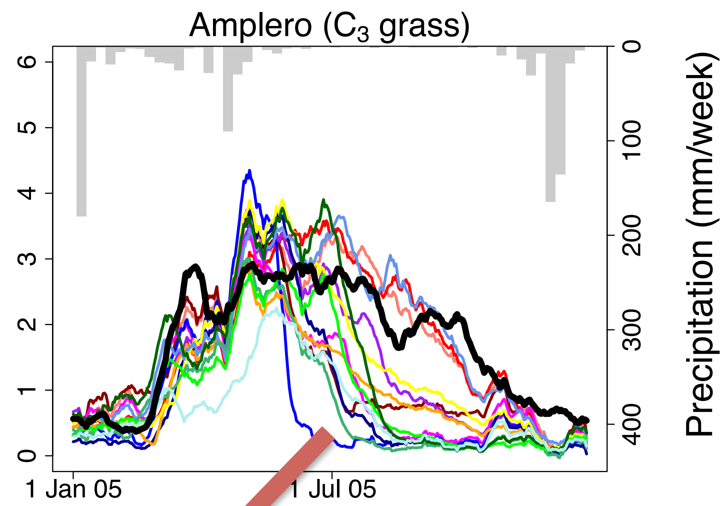
# What about heatwaves

Sensible heat flux W/m$^2$)




Evapotranspiration (mm/d)

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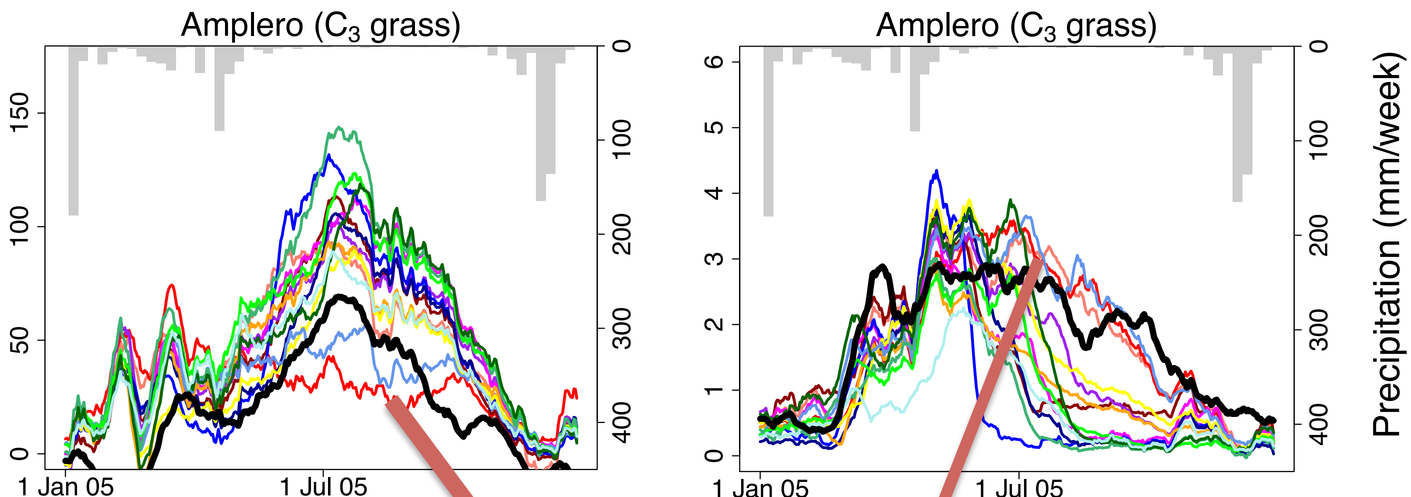
# What about heatwaves

Sensible heat flux W/m$^2$)    Evapotranspiration (mm/d)




**But is this just an off-line result?**

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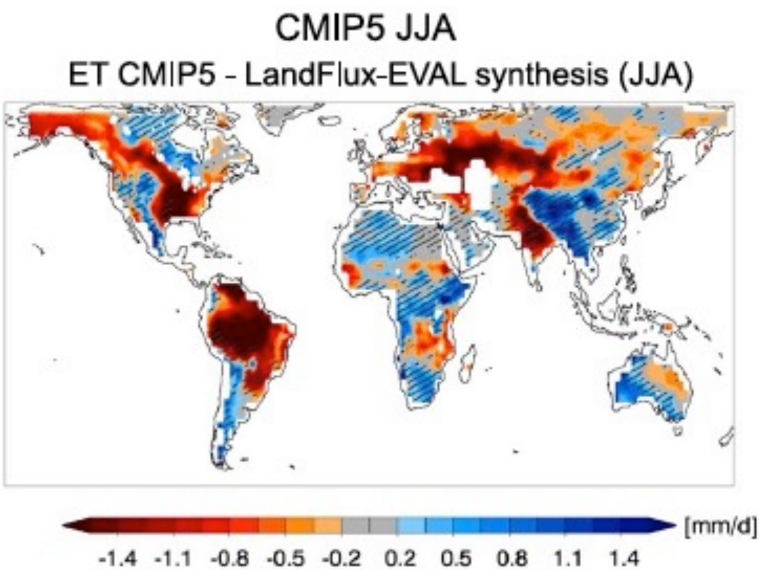
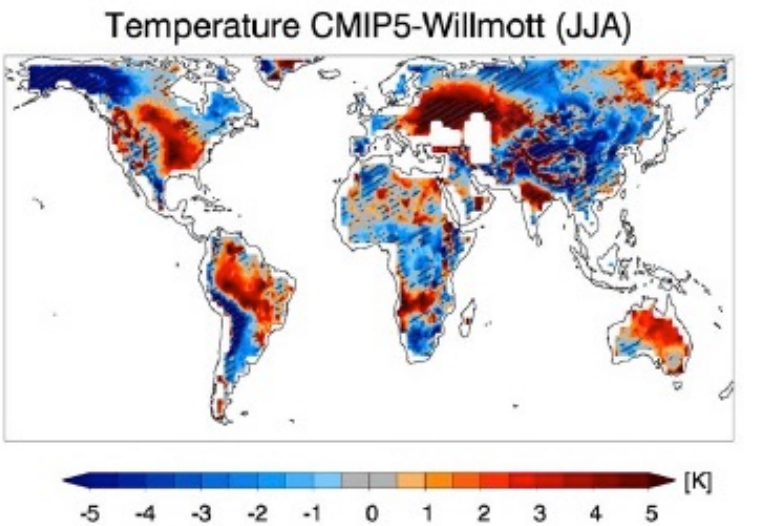
# We see evidence of this in climate models




Strong and common low ET bias in JJA in CMIP5




Strong and common high temperature bias in JJA in CMIP5

Mueller and Seneviratne, 2014, GRL

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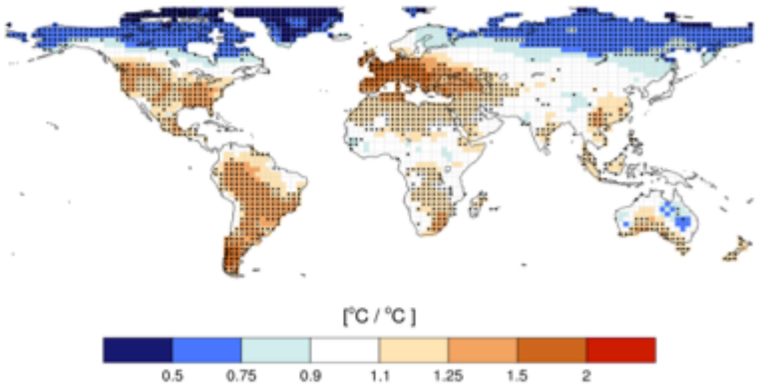
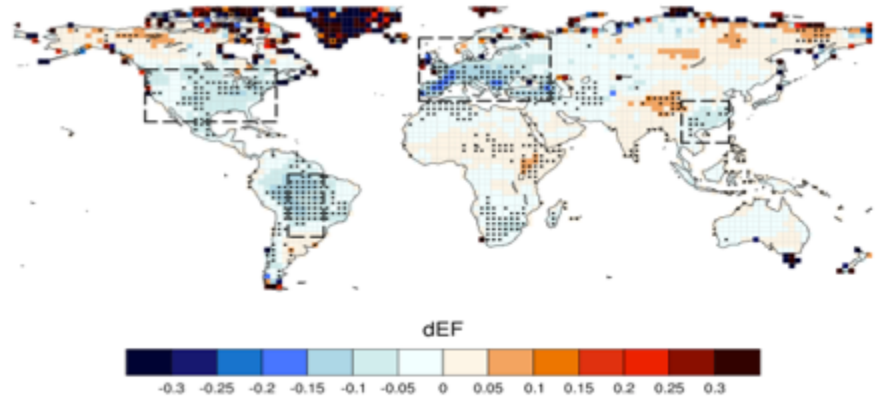
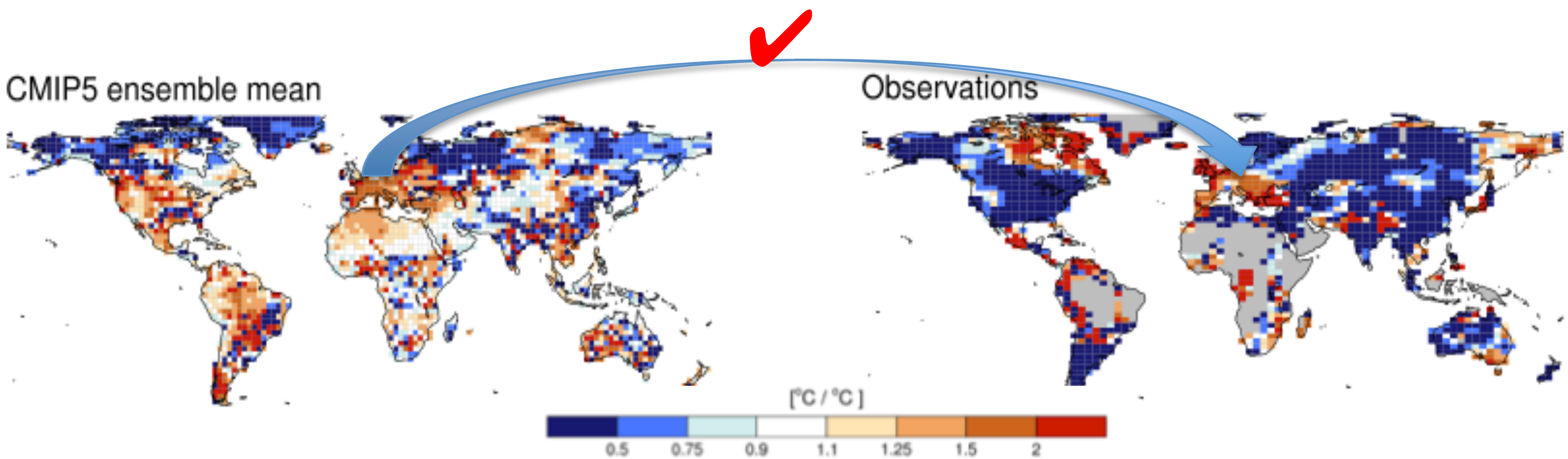
# We see evidence of this in climate models




CMIP-5: TXx / Tmean




CMIP-5 – change in EF (LE / (LE + H))




TXx from HadEX2 and GHCNDEX, Tmean from HadCRUT

Donat et al., 2017, GRL

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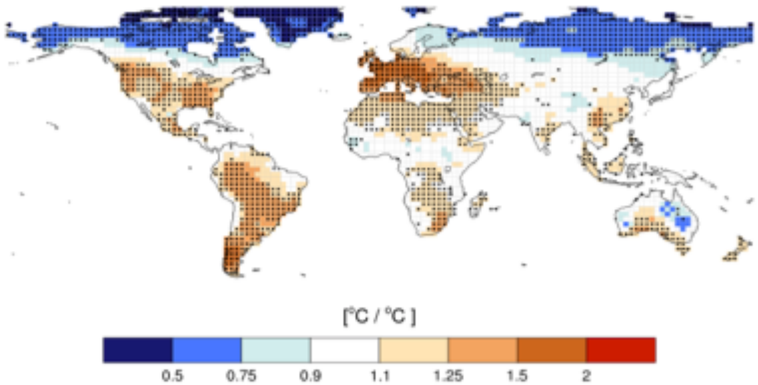
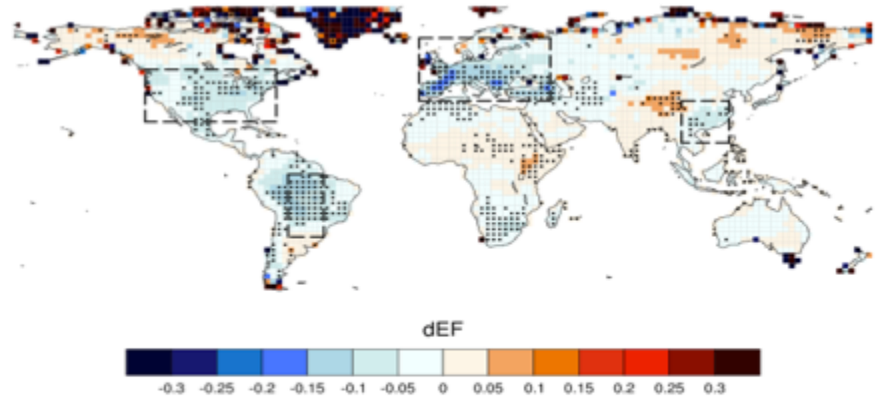
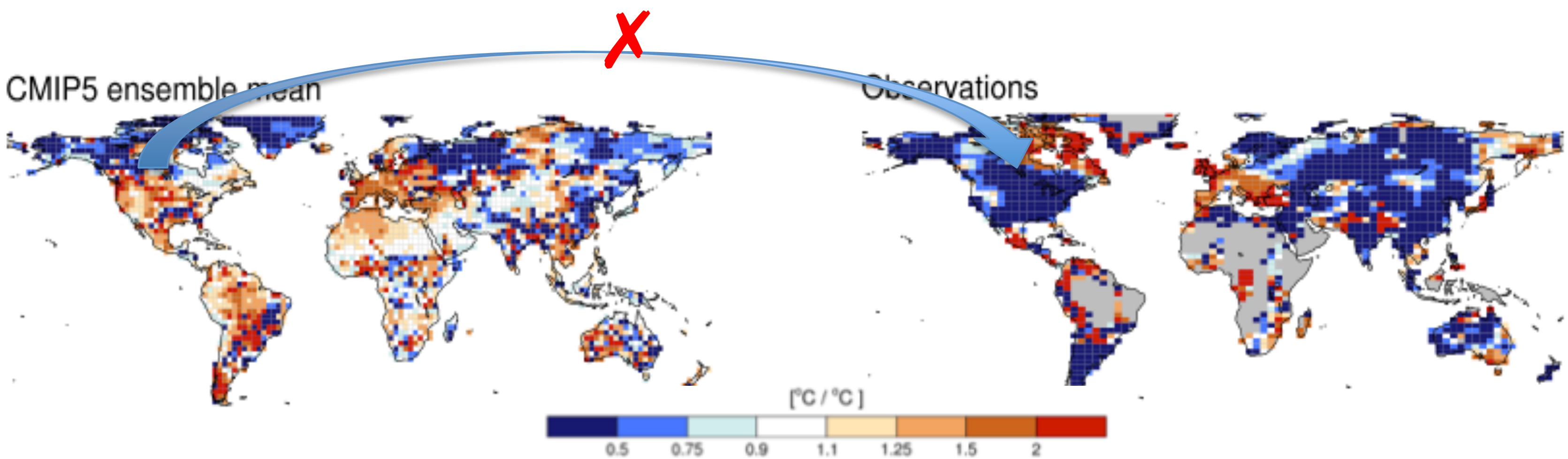
# We see evidence of this in climate models




CMIP-5: TXx / Tmean




CMIP-5 – change in EF (LE / (LE + H))




TXx from HadEX2 and GHCNDEX, Tmean from HadCRUT

Donat et al., 2017, GRL

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# Summary

- While land surface models (may) work well for the purposes for which they were built, they were not built with an eye to extremes
- The evidence that they can simulate droughts, and how droughts affect the atmosphere is limited
- The evidence that they can capture the contribution of the land to heatwaves is limited

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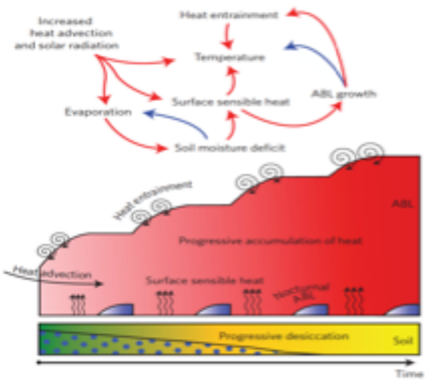
# Ways forward




- Evaluate models with an eye on extremes, e.g. droughts and heatwaves

- Choose data sets with expressions of extreme events
- Co-evaluate the land and PBL if possible
- Explore whether functional relationships are reproduced by your models

- Worry about new evidence (de Kauwe poster)

- Worry about new physical processes, e.g. hydraulics, cavitation, non-stomatal limitation, mortality, tap roots, LAI-water dynamics

- Take part in multi-model evaluations where possible (e.g. PLUMBER-2)

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