HYDROLOGY AND EVAPORATION: WHAT SHOULD WE USE?

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Meet the experts in hydrology - The mystery of evaporation
SC14/HS11.1 – EGU 2015

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What is hydrology?

Oxford dictionary:

The branch of science concerned with the properties of the earth's water, and especially its movement in relation to land.

British Hydrological Society:

Hydrology has evolved as a science to try and understand the complex water systems of the Earth, **to study and predict how water will behave under different circumstances as it moves through the land phase of the water cycle**.

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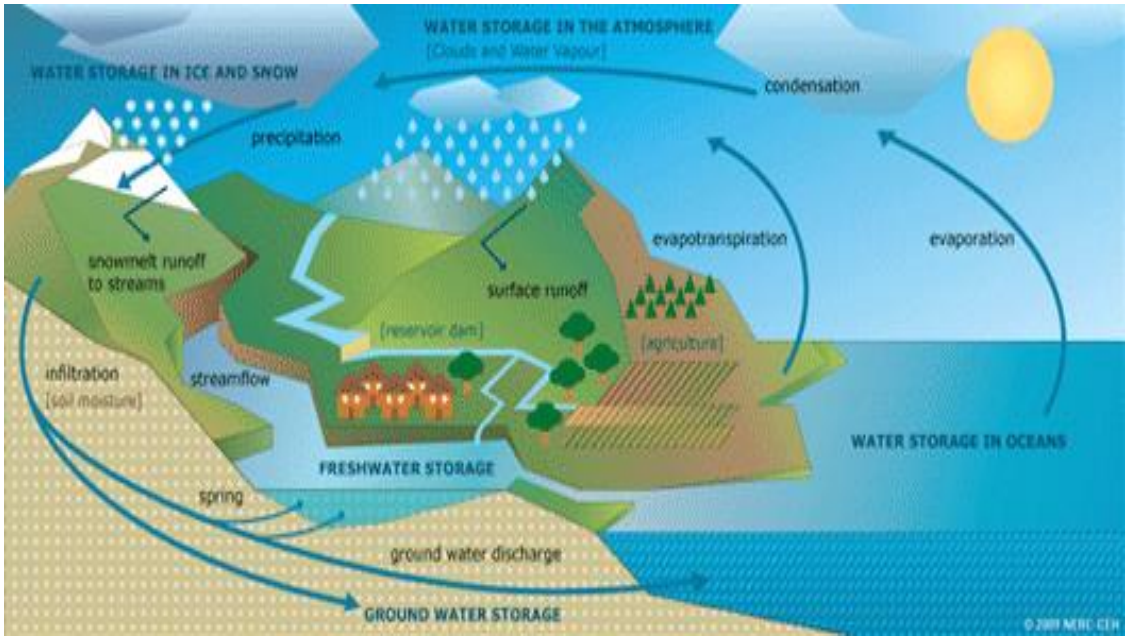
How do we do that?



The hydrology cycle

Source: http://www.waterandclimatechange.eu/

Precipitation

Total evaporation and transpiration from area

$$S = P - Q - E - G$$

Water storage in the area

Stream discharge from the area

Subsurface outflow

The water balance equation

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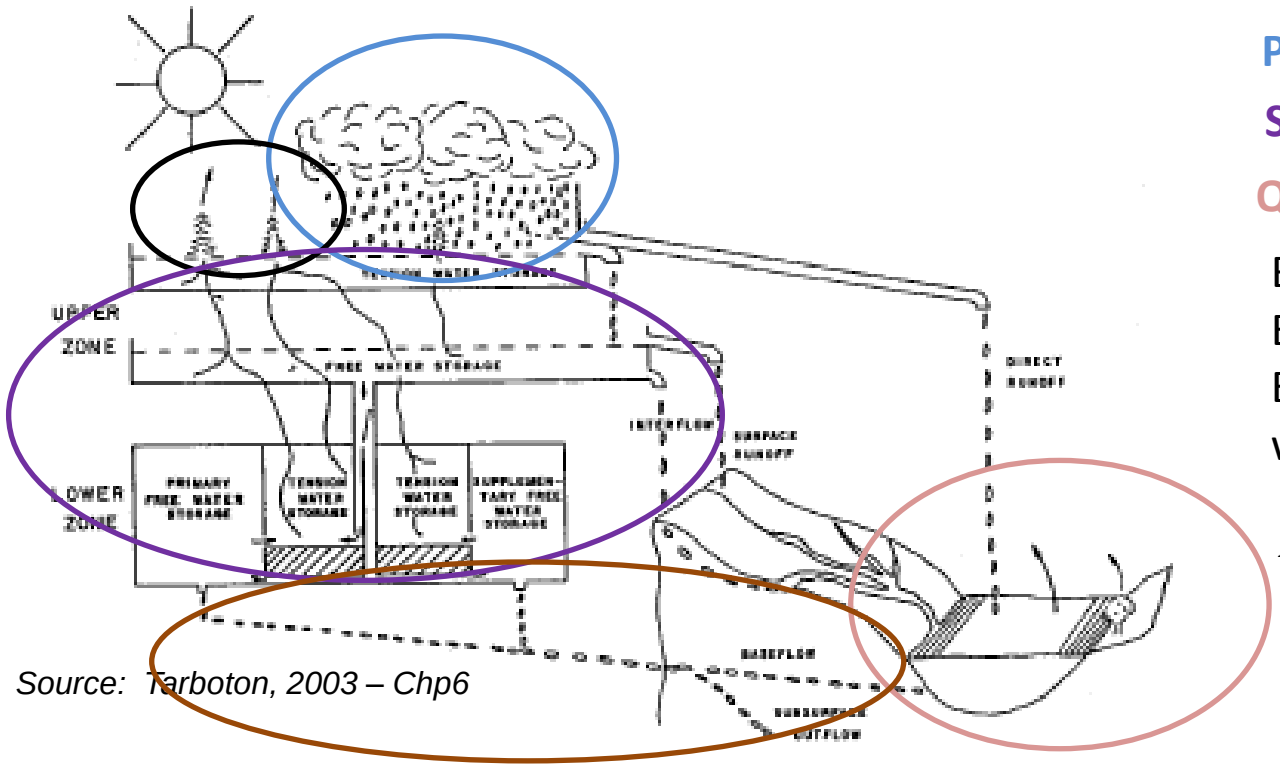
(Conceptual) hydrological modelling



Source: Tarboton, 2003 – Chp6

P and E: Input variables

S and G: Internal variables

Q: Output variable

But….
E used: ETp
ETa: function of ETp and water availability in soil

$$ET_a = ET_p\left(\frac{SMT}{SMC}\right)$$

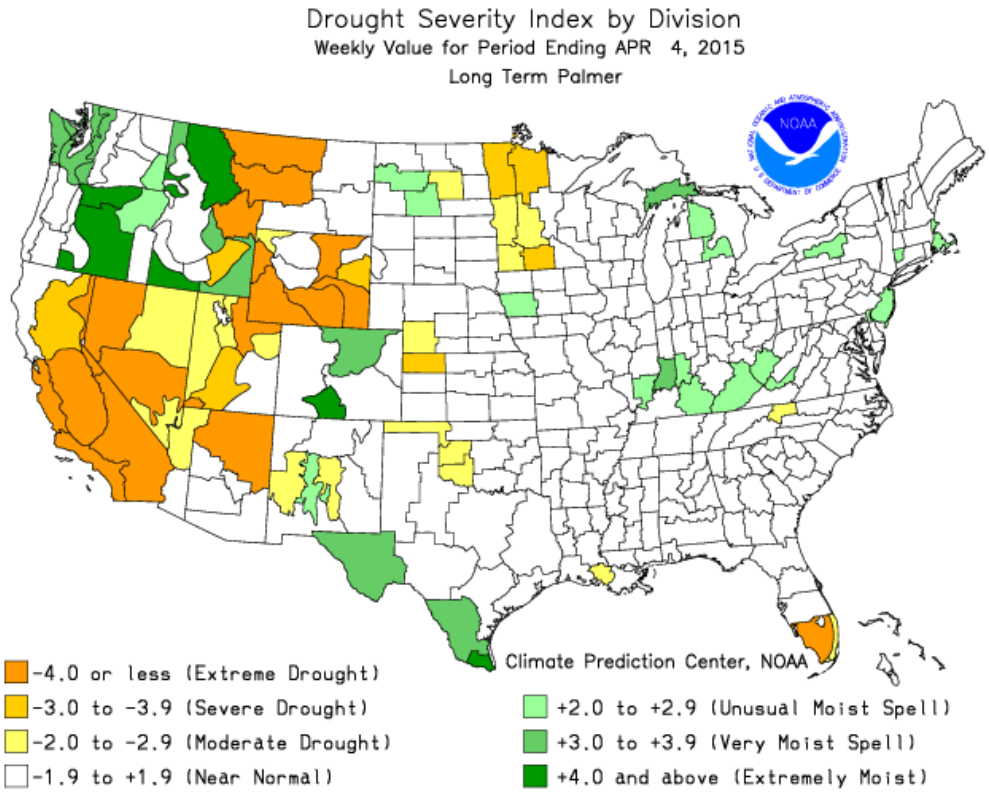
Source: Zhoa et al., 2013, doi: 10.1007/s11442-013-1015-9

$$S = P - Q - E - G$$

The water balance equation

Drought severity assessment

- Drought = period of lack of water
- Many drought indices; water balance used in Palmer Drought Severity Index (1965)
- PDSI has been used in US to initiate drought relief
- ETa ~ ETp(T)
- Data: temperature precipitation



US Drought Portal

http://www.drought.gov/drought/content/products-current-drought-and-monitoring-drought-indicators/palmer-drought-severity-index

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Why ETp?

- Designed for practical water resource management

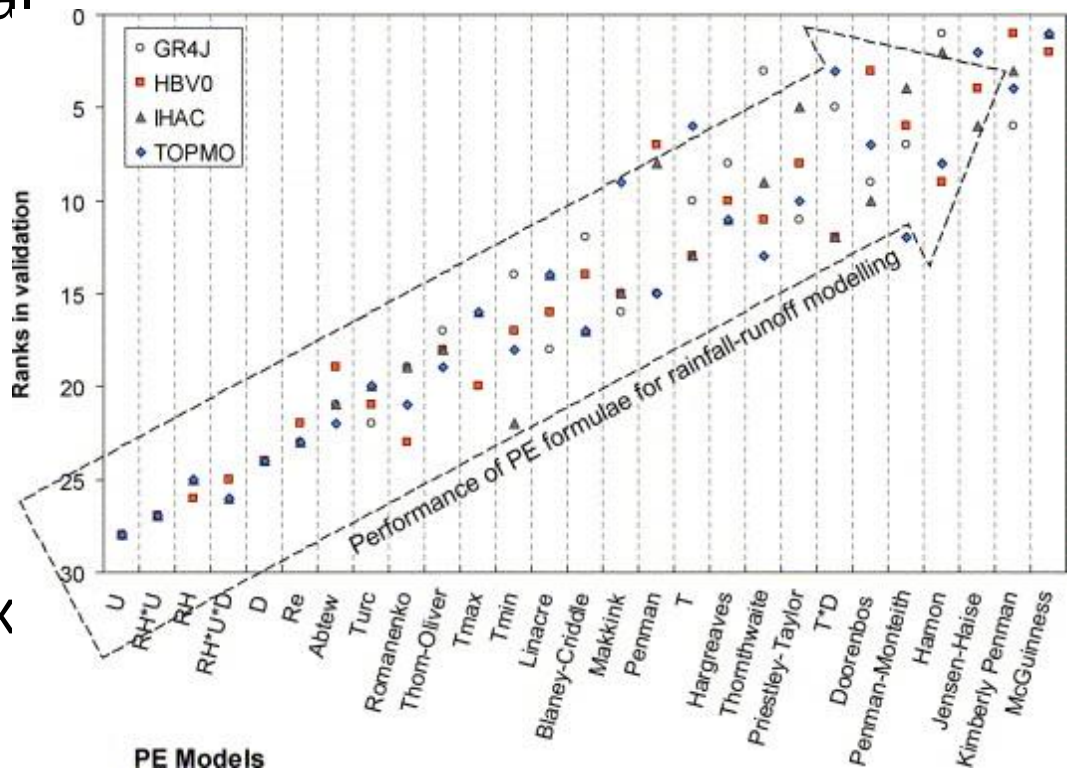
$$crop\ water\ need = ETp - ETa$$

- Conceptually comprises
  - Energy to generate evaporation (radiation/ temperature)
  - Factors influencing dissipation of water from surface (wind/ humidity)

- Many different equations and data requirements
  - Air temperature only for simplest equations
  - Wind speed, long and short wave radiation (linked with cloudiness) and air humidity data

Does ETp equation matter in hydrology?

- Oudin tested 4 conceptual models and 27 ETp equations on >300 sites
- All models calibrated with each equation
- Model performance not much better with complex equations
- Temp. equation best for simplicity and data availability



Oudin et al., 2005, DOI: 10.1016/j.jhydrol.2004.08.206

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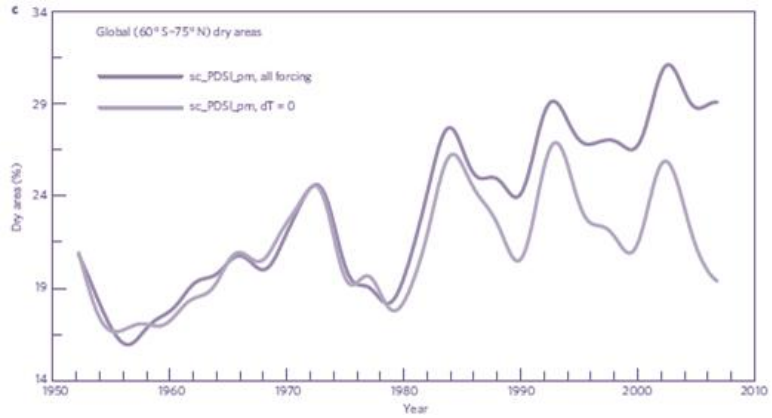
Does ETp matter to estimate drought?

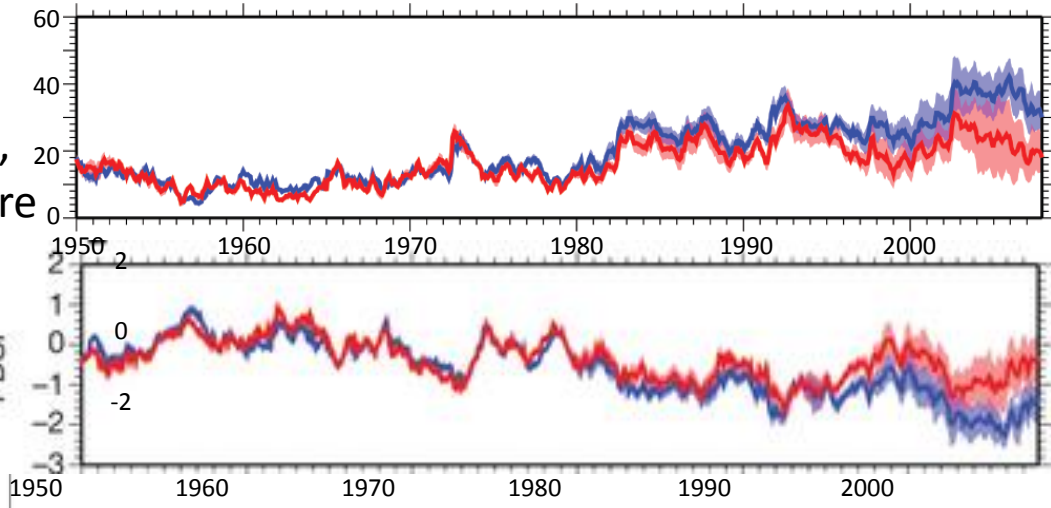


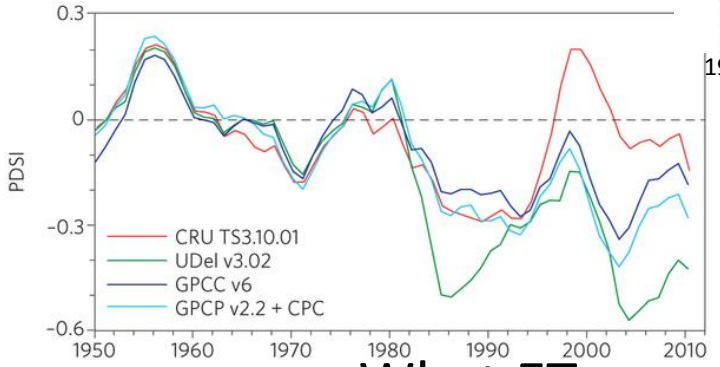
Percentage of global dry area (PDSI-PM<-2.0) including (dark) excluding (light) observed surface warming

(Dai, 2013, Nature CC, DOI:10.1038/nclimate1633)

Percentage of global dry area (PDSI-PM<-3.0, top) and PDSI-PM (bottom) using temperature only (blue) combined Potential Evapotranspiration (red) with uncertainty

(Sheffield et al., 2012, Nature, DOI:10.1038/nature11575)





Time series of 5-year smoothed global-mean annual scPDSI_PM, calculated using four different precipitation data sets

(Trendberth et al., 2013, Nature, DOI:10.1038/nclimate2067)

- What ETp equation should we use?
- (question to evaporation experts)

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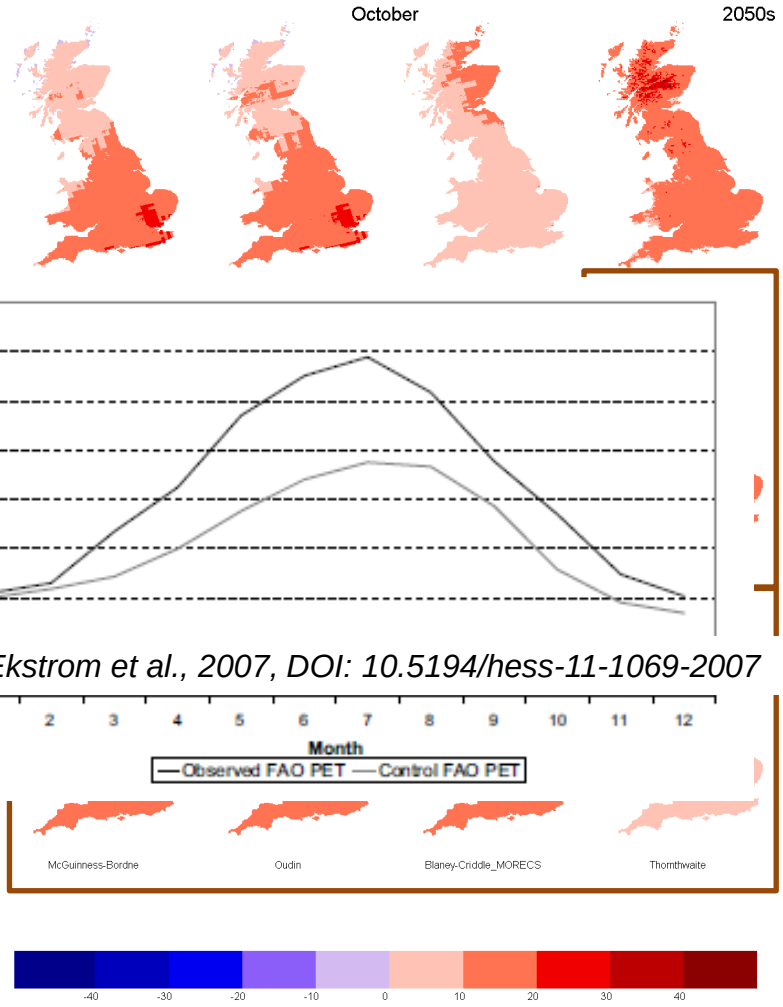
What about future projections?

- Trends in range of climate variables can compensate for T rise (example of drought)
- Different simplifications ➔ different projections
- But
- Can Global Climate Models accurately estimate all climate variables?
- Do we need to bias-correct the variables? Can we do that independently?
- (questions to climate modellers…)



Ekstrom et al., 2007, DOI: 10.5194/hess-11-1069-2007

Prudhomme & Wilkinson, 2013
DOI: 10.5194/hess-17-1365-2013

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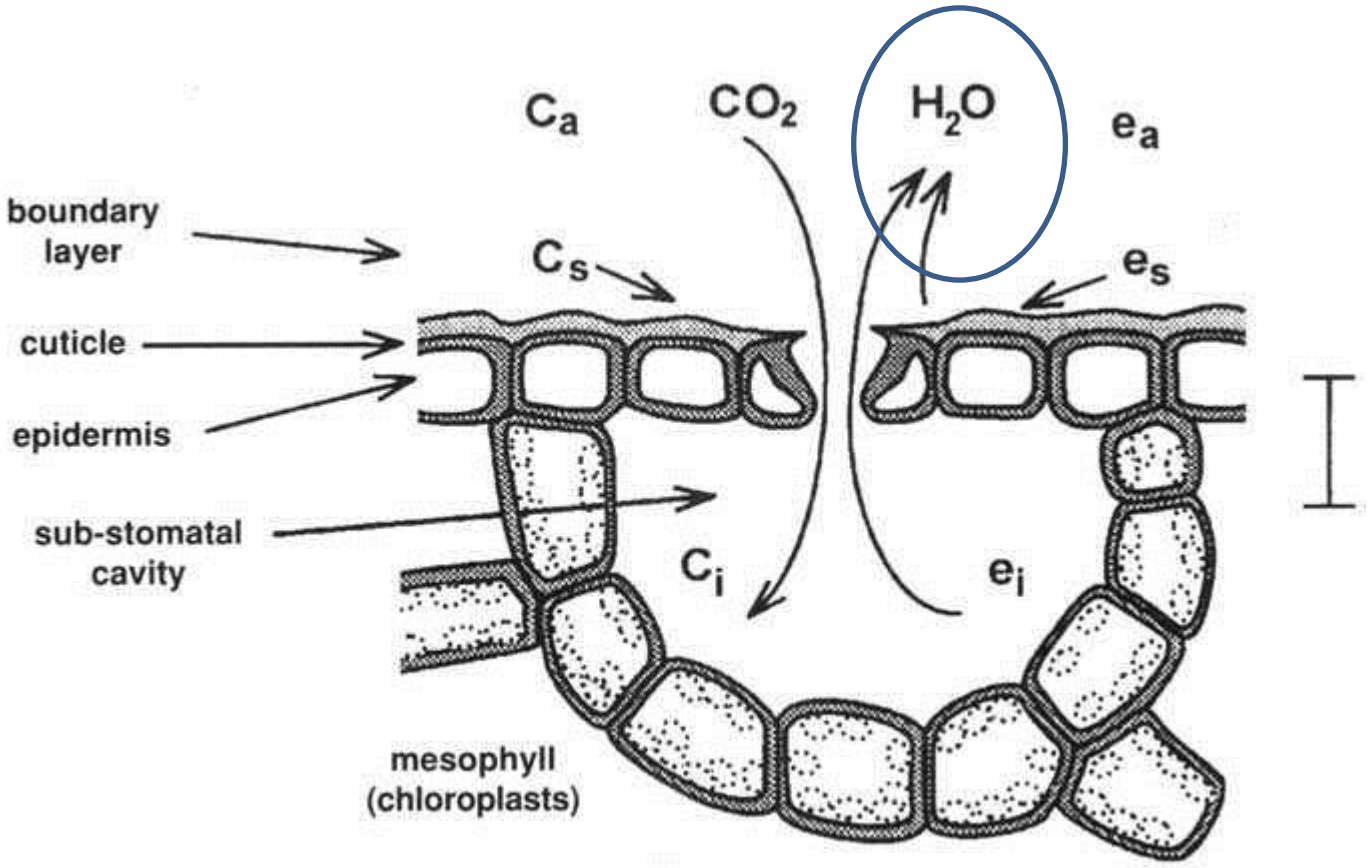
What about CO_2 in the atmosphere?



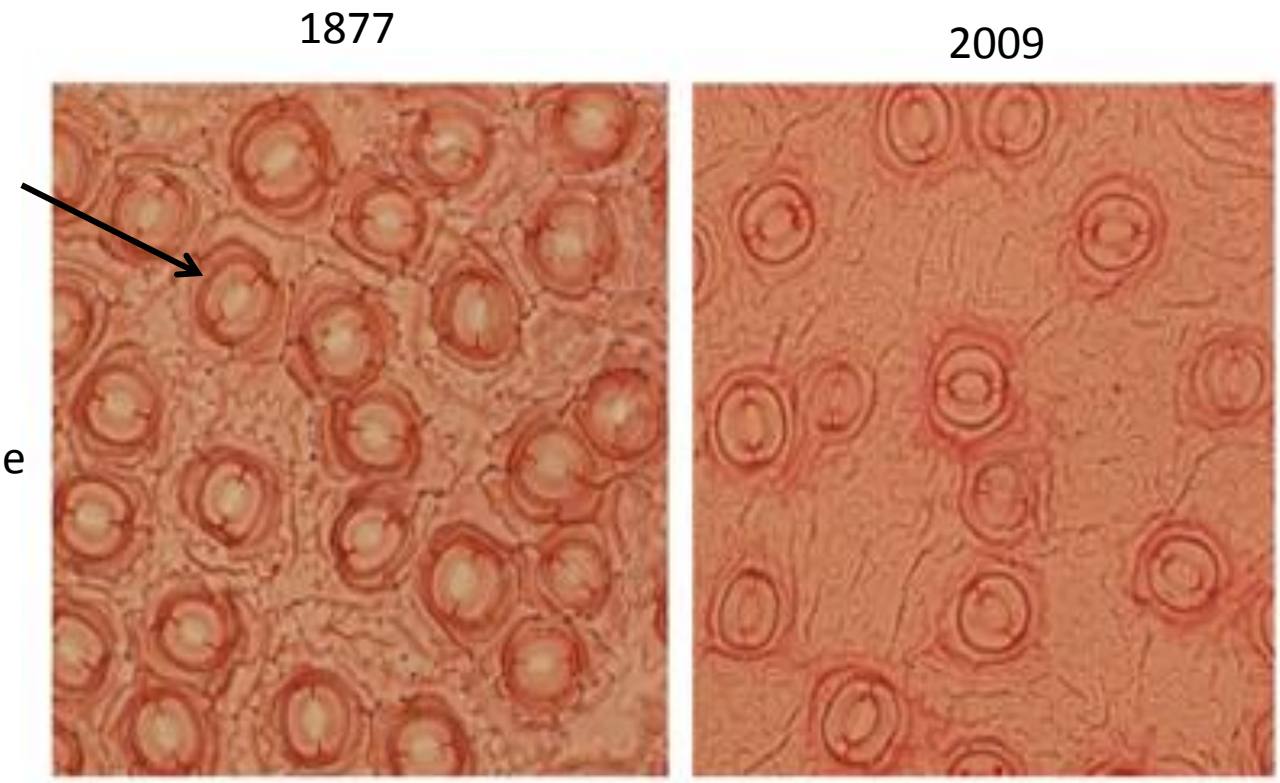
Source: S. Van de Geijn & J. Goudriaan, FAO
http://www.fao.org/docrep/w5183e/w5183e07.htm

Adaptation of plants to increased CO_2

Stomatas

Structures that allow plants to exchange gases with the air

While doing that plant loses water



Fewer stomata in Florida

This results in reduced transpiration

Microscopic images of two leaf fragments of the subtropical shrub dahoon. (image courtesy Emmy Lammertsma).

Lammertsma et al., PNAS, 2011, 10.1073/pnas.1100371108
Jan de Boer et al., PNAS, 2011, 10.1073/pnas.1100555108

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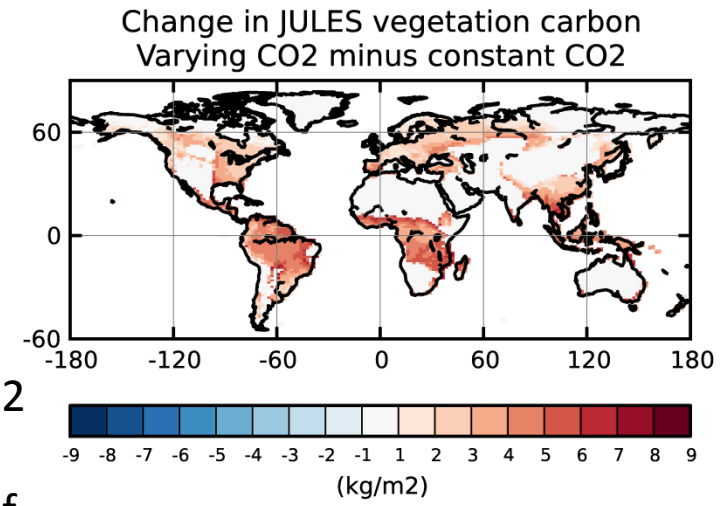
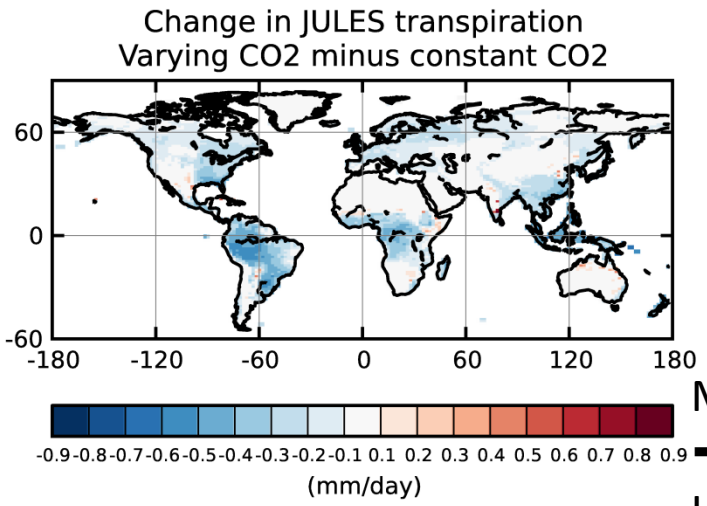
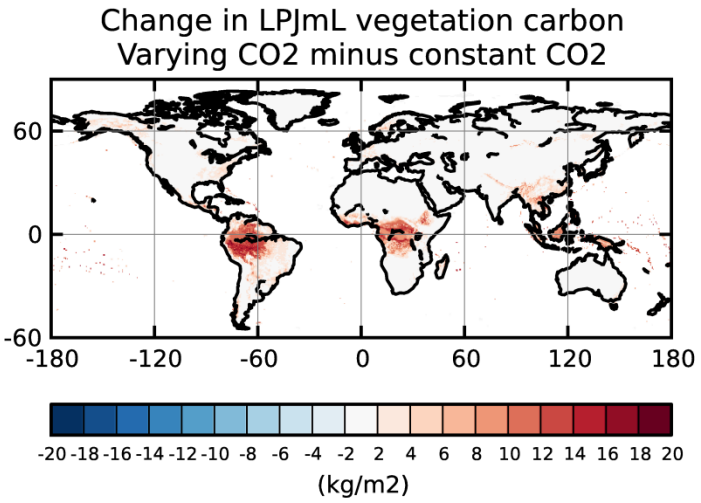
CO_2 fertilisation effect in Global Impact Models

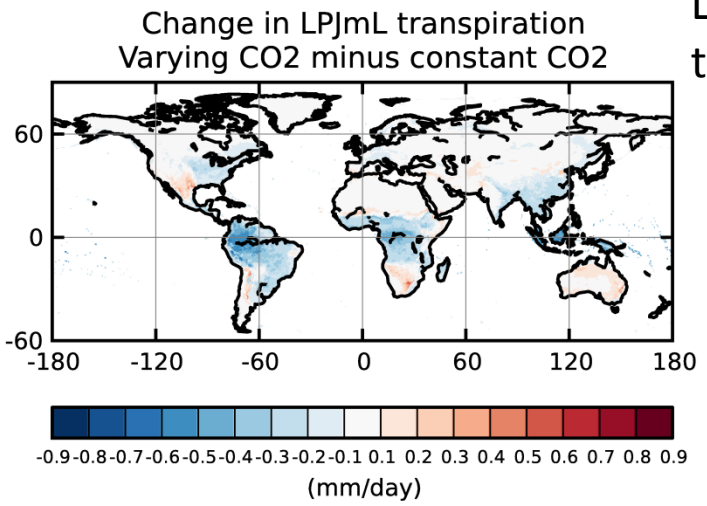
More CO2 ➔ More leaf area





More CO2 ➔ Less transpiration





Prudhomme et al, PNAS, 2014, 10.1073/pnas.1222473110

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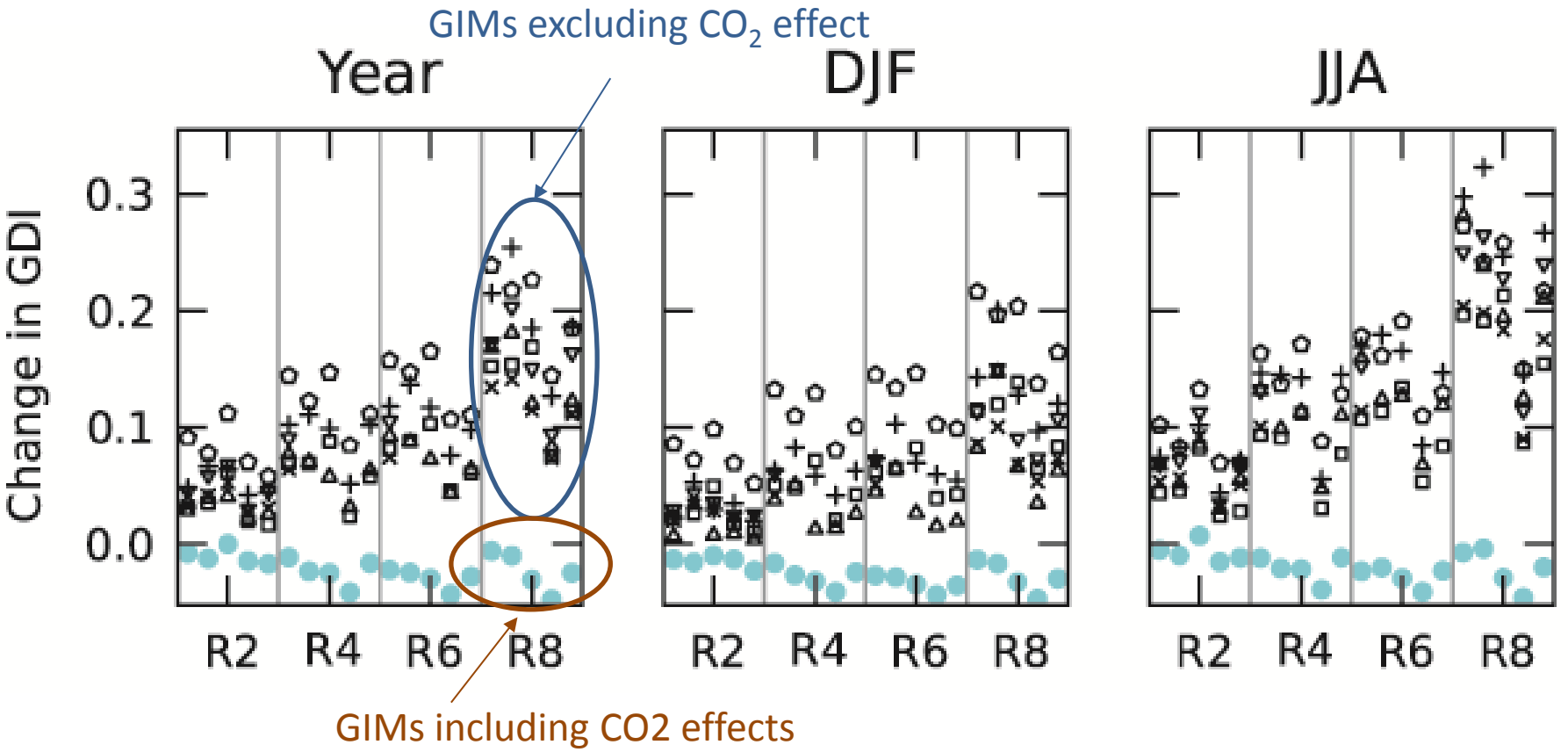
Change in Global Drought extent by 2080



Prudhomme et al, PNAS, 2014, 10.1073/pnas.1222473110

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To summarise…

- 👍 ETp(T) OK for hydrol modelling (calibration)
- 👍 ETp(T) fewer data constraints (T better coverage than radiation and/or wind)
- 👎 ETp(T) too sensitive to warming (overestimation?)
- 👎 Current ETp formulations ignore CO_2 fertilisation effects

(Some) Research questions

- Are there any alternative to ETp in hydrology that is realistic anywhere any time? ➔ use for historic reconstruction; data sparse regions; short, medium and seasonal prediction?
- Is CO_2 forcing as significant as climate forcing in evap processes?
- Can ETp equations evolve to include CO_2 effect?
- Are conceptual hydrological models the right tools to assess impact of climate change on hydrology?

Thank you

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