Met Office
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Predictions of **future water scarcity**: How important is the **plant physiological response** to rising CO_2?

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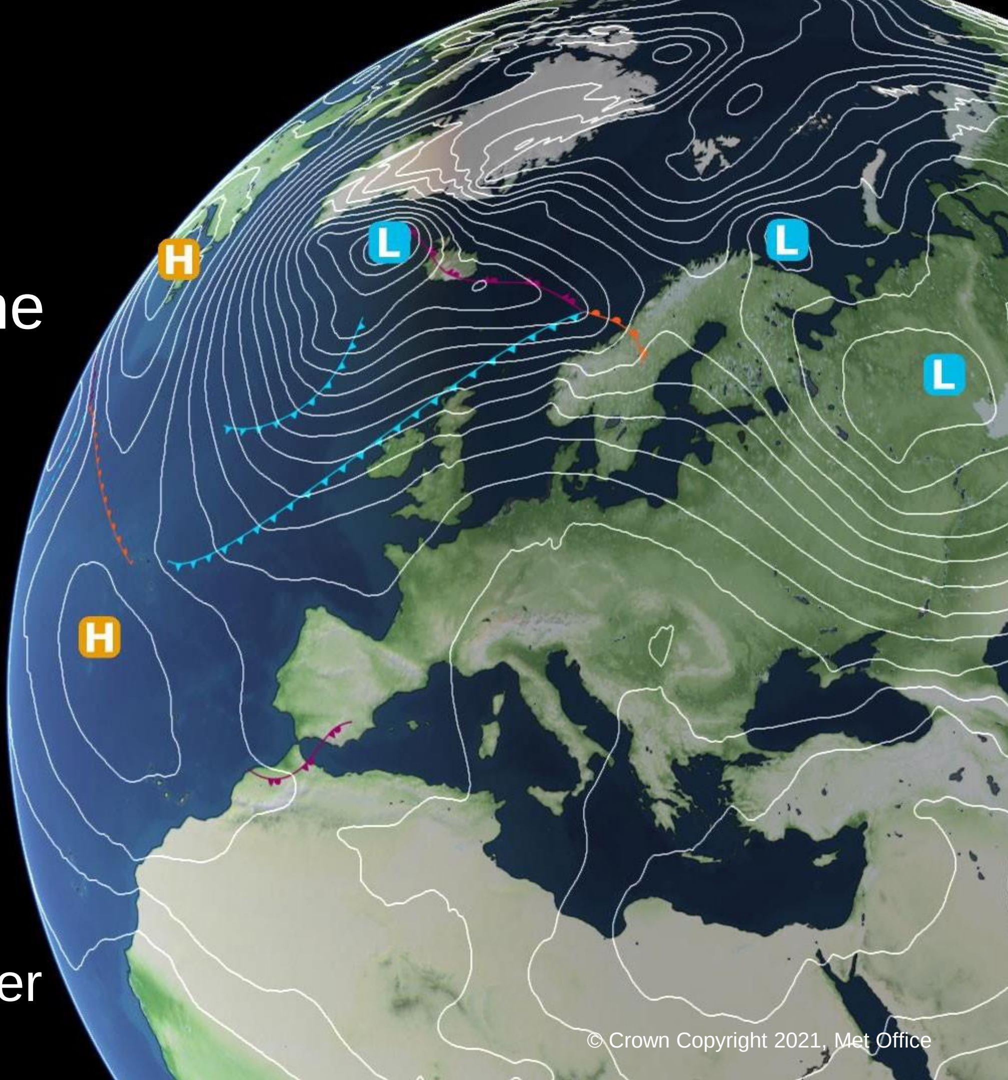


Water scarcity

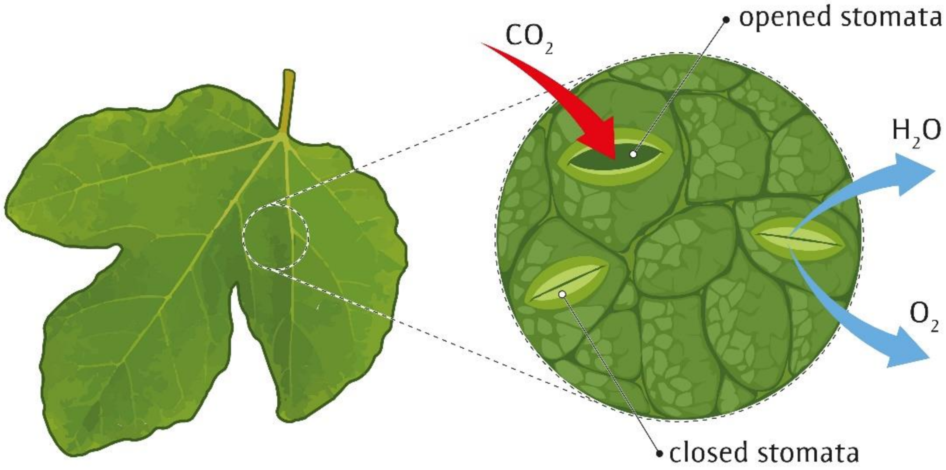
Defined as: When water demand by all sectors (including the environment) outweighs water availability

Roughly **half** of global population experience **severe water scarcity** for at least some part of the year (IPCC AR6)

Worsening global water scarcity

Factors affecting global water scarcity	
Demand	Supply
Population growth and **improving living standards**	**Land cover changes** • Agriculture • Deforestation / Afforestation • Urbanisation **Climate change** • Unpredictable precipitation patterns • Increasing evapotranspiration • Climate extremes • Changing plant water-use efficiency

Plant stomata



Stomatal aperture is a balance between maintaining high rates of **photosynthesis** and low rates of **water loss**

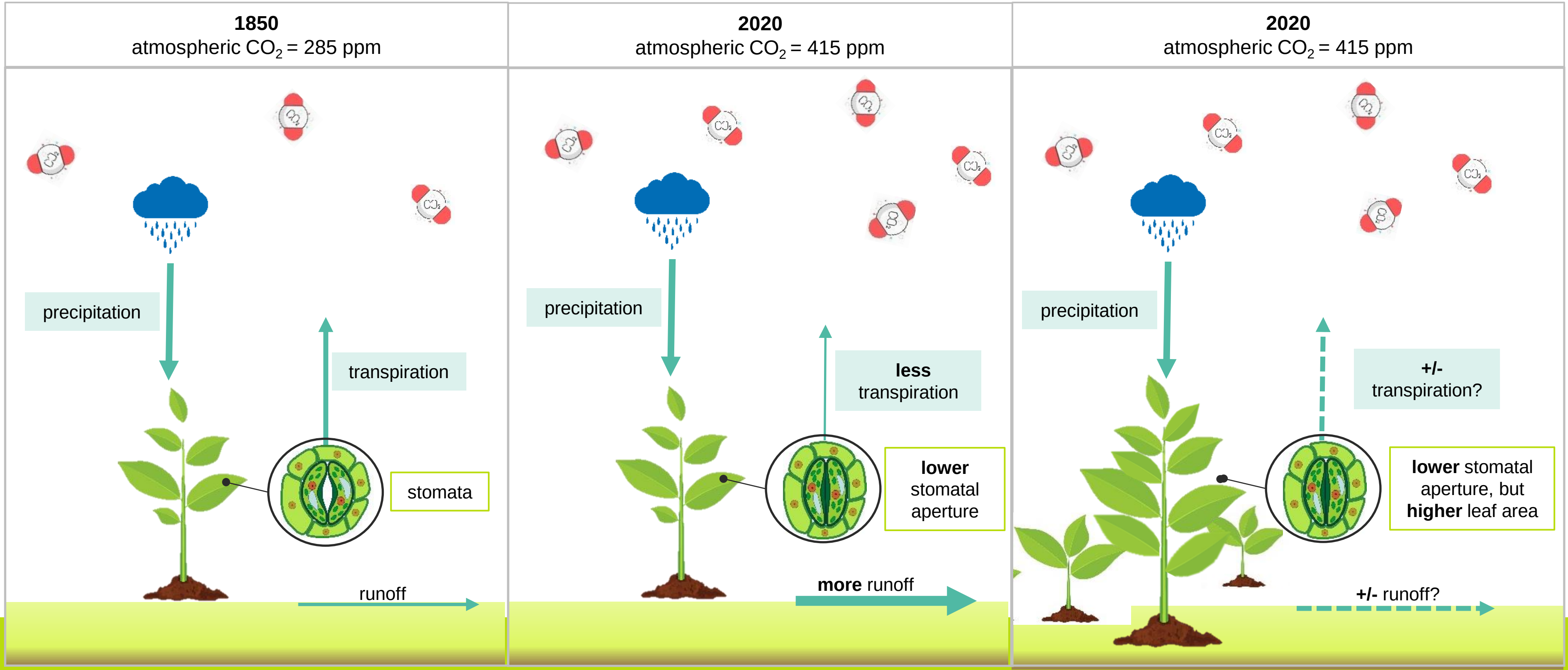
Plant physiology is changing with **rising CO_2**

Contradictory impacts on transpiration and runoff…

(NB we assume precipitation remains constant)

Stomatal response

Stomatal <u>and</u> leaf-area responses



Predicting future water scarcity

- Impact studies should attempt to be **accurate** (as possible) and **useful** to effectively inform long-term adaptation

- Usually based on **hydrology models** run offline driven by **climate model**

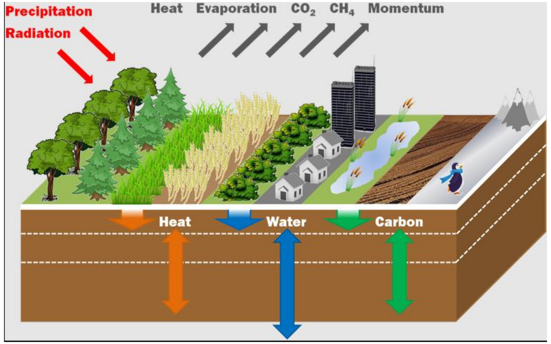
- Many hydrology models negate **the plant physiological response to rising CO_2** – does this matter?

- Numerous studies highlight the influence of plant physiology on **the water cycle**, but those incorporating **socioeconomic factors** are limited

Experimental Design

Earth System Model output
- HADGEM2-ES
- 1861-2100
- RCP60

JULES experiments



Suite u-bk886 (ISIMIP2b)

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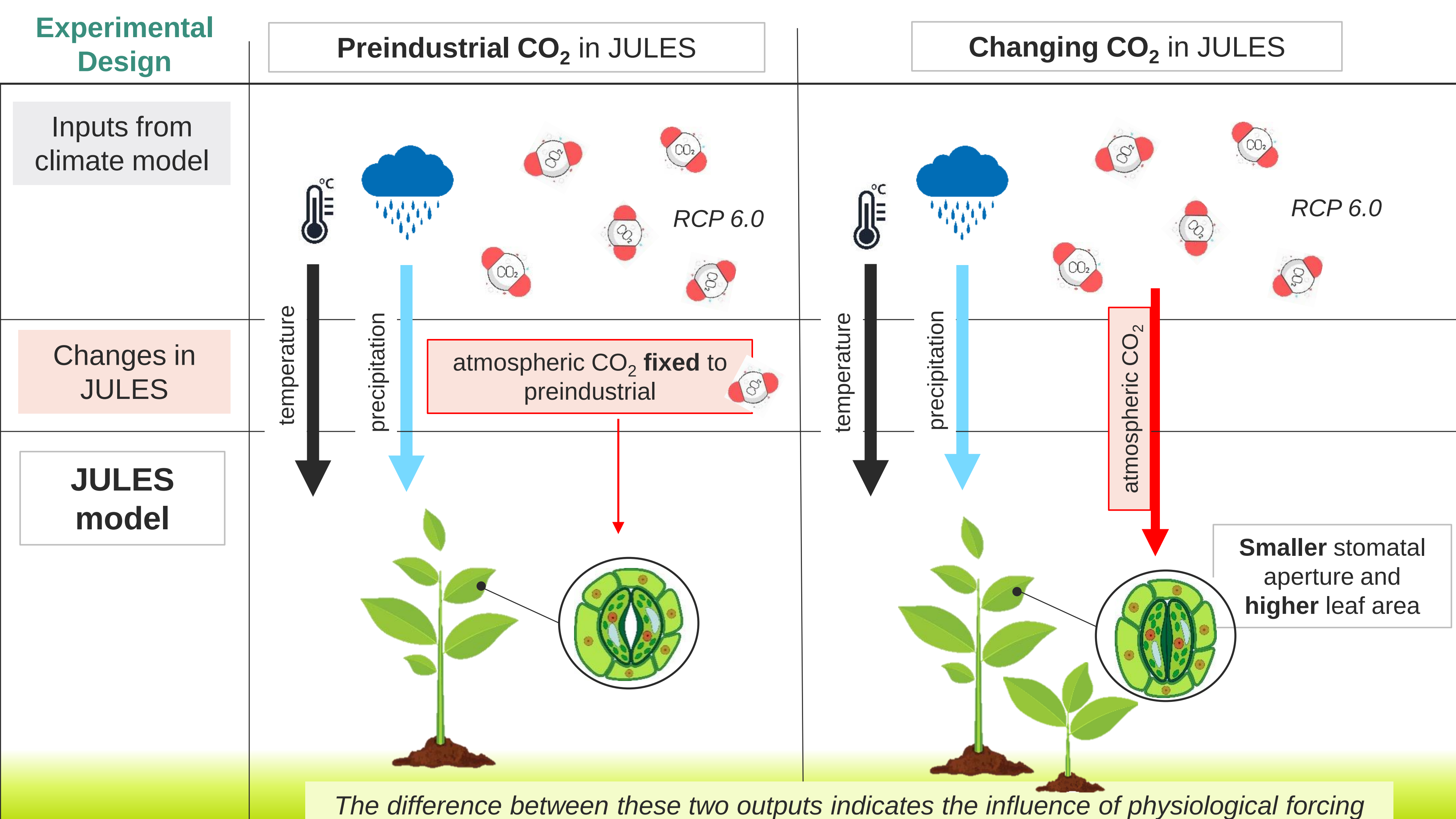
Water cycle variables, e.g., runoff

Water demand data

Water Scarcity

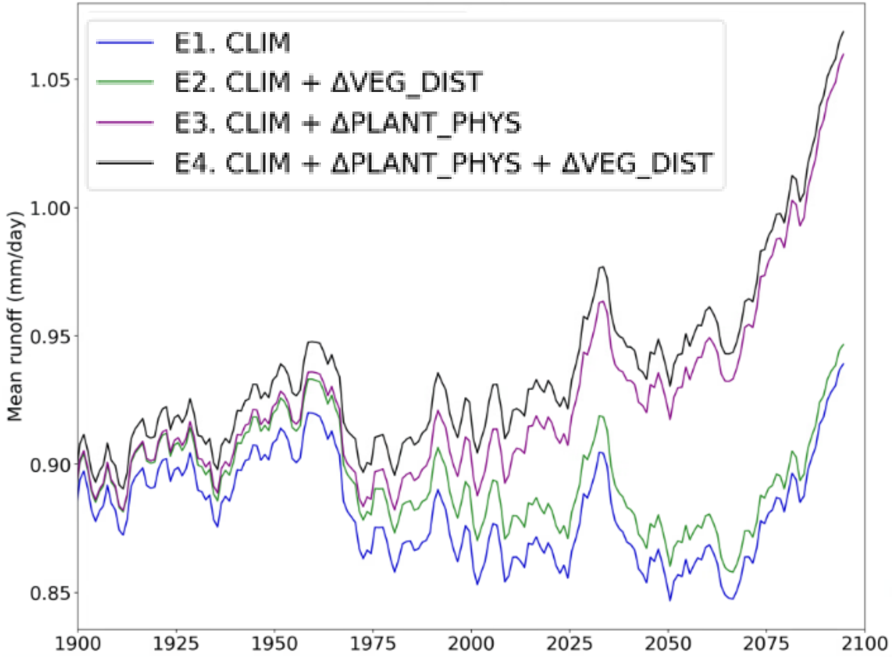
JULES experiments

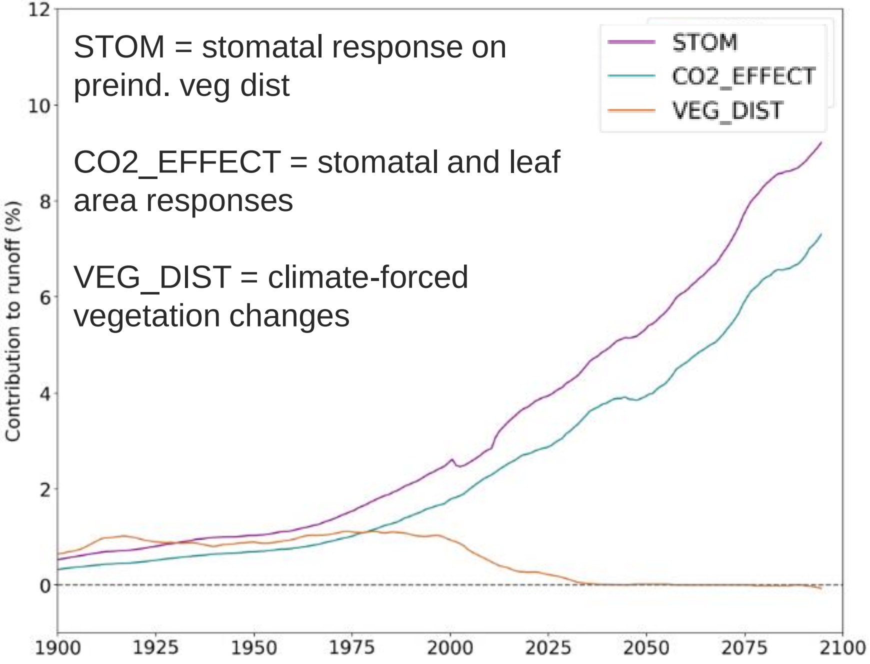
	Preindustrial vegetation distribution (TRIFFID off)	**Dynamic vegetation distribution (TRIFFID on)**	**Difference between experiments estimates influence from:**
Preindustrial CO_2 in JULES	E1. CLIM	E2. CLIM + DYN_VEG_DIST	VEG_DIST: Vegetation distribution changes due to climate and land use changes
Dynamic CO_2 in JULES	E3. CLIM + DYN_CO2	E4. CLIM + DYN_VEG_DIST + DYN_CO2	VEG DIST (+ STOM): Combination of (i) veg. dist. changes due to climate, land use change and leaf area response and (ii) stomatal effect on change in leaf area
Difference between experiments estimates influence from:	STOM: stomatal response only based on preindustrial vegetation distribution	CO2_EFFECT: combination of stomatal response and leaf area increases	



Experimental Design
Preindustrial CO_2 in JULES
Changing CO_2 in JULES
Inputs from climate model
Changes in JULES
JULES model
°C
CO2
RCP 6.0
temperature
precipitation
atmospheric CO_2 **fixed** to preindustrial
atmospheric CO_2
Smaller stomatal aperture and **higher** leaf area
The difference between these two outputs indicates the influence of physiological forcing

Global mean runoff in the four experiments

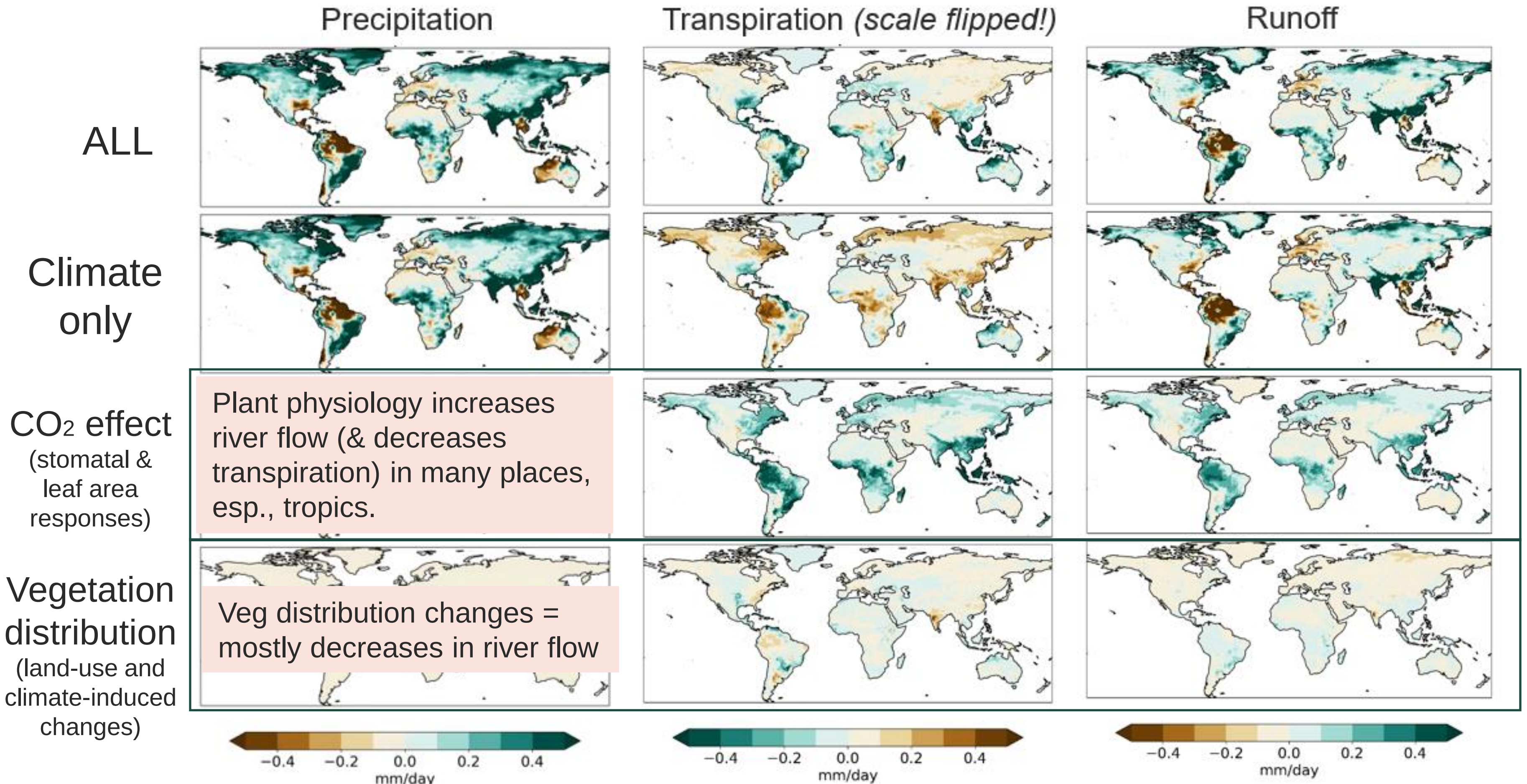




The stomatal response dominates over vegetation distribution changes, increasing global mean runoff by almost 10% by end of century

How does each factor contribute to changes in the **water cycle?**

Mean change from **2010-2029** to **2080-2099**



Plant physiology increases river flow (& decreases transpiration) in many places, esp., tropics.

Veg distribution changes = mostly decreases in river flow

Water Scarcity Index calculation

Water scarcity Index (WSI):

WSI = demand / supply

- *Water scarce > 0.2*
- *Severely water scarce > 0.4*
- *Masked non-water-scarce places (WSI < 0.05)*

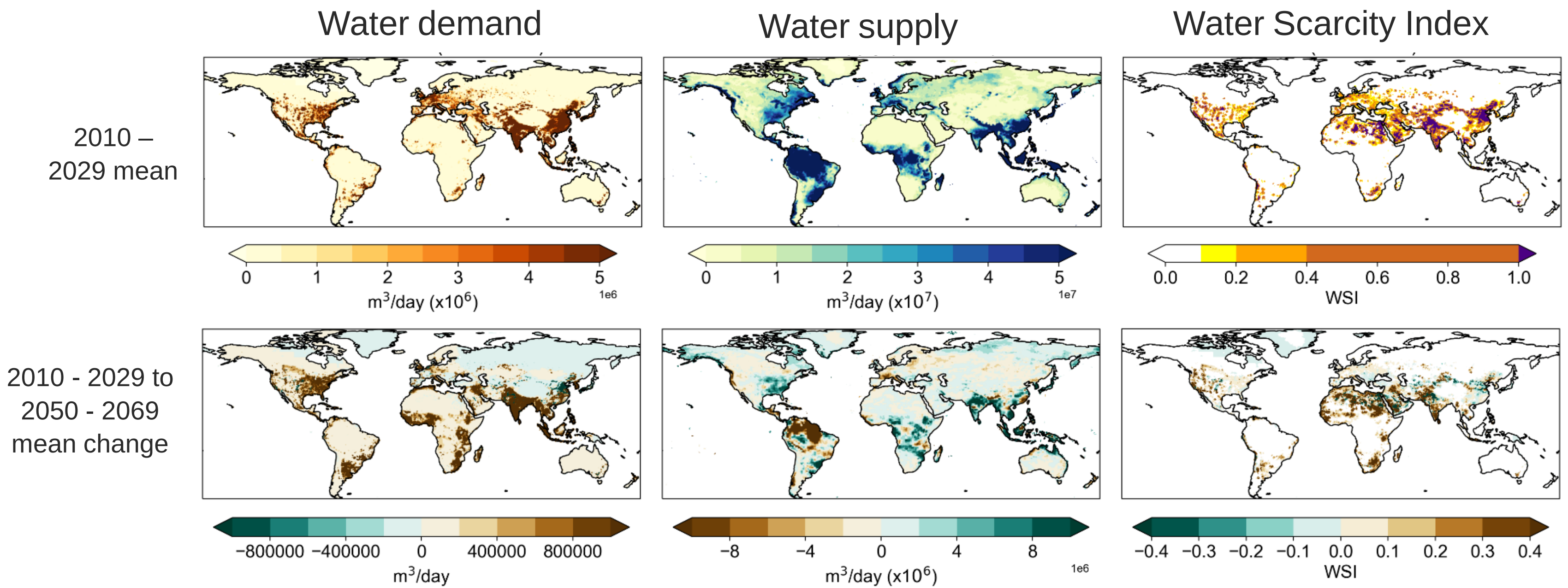
Water demand:

- From ISIMIP database
- Middle of the road (SSP2)
- Total of domestic, industrial & irrigation
- Incorporates population & GDP

Water supply:

- Used **runoff** at gridcell level and **river discharge** at river-basin scale
- TRIPP river routing scheme

Most regions already experiencing water scarcity predicted to worsen in coming decades

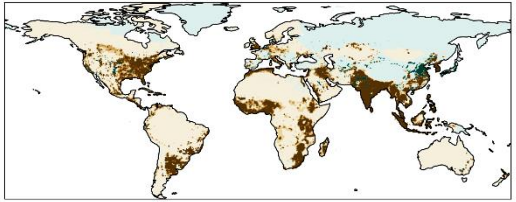


How is each factor contributing to mean WSI change (2010-2019 -> 2060-2069)?

Non water-scarce areas (WSI < 0.05) masked out

	Water demand (SSP2)	**Water supply change**	**WSI change**

ALL



Climate

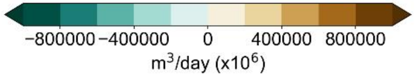
Not applicable

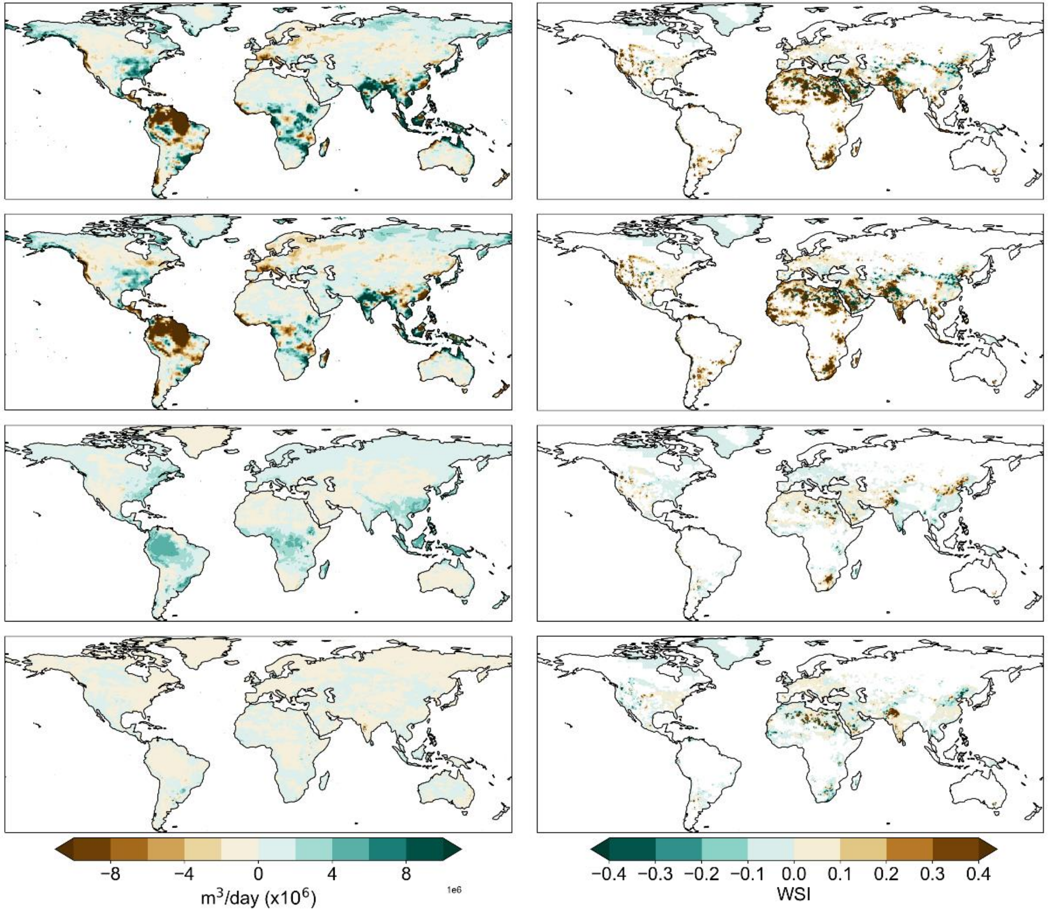
CO2 effect (stomata & leaf area responses)

Small improvements in WSI despite supply increases -> largely in water abundant locations

Vegetation distribution (from climate and land-use)

Vegetation distribution changes appear comparable to CO2





Key points

- Plant physiological response typically **increases global water supply** (stomatal response) but **decreases** seen in more **arid areas** (leaf area increases).

- Plant physiology has **less influence on water scarcity than expected,** since the largest changes are in non-water scarce locations

- Next steps:
  - **Investigate seasonal variation**: Does plant physiology have more of an influence in water scarce months?
  - What is the effect on **population numbers**?

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