SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Open questions: toward improving value of regional water cycle projections

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Royal Society, **Climate change: science, responses and research needs**
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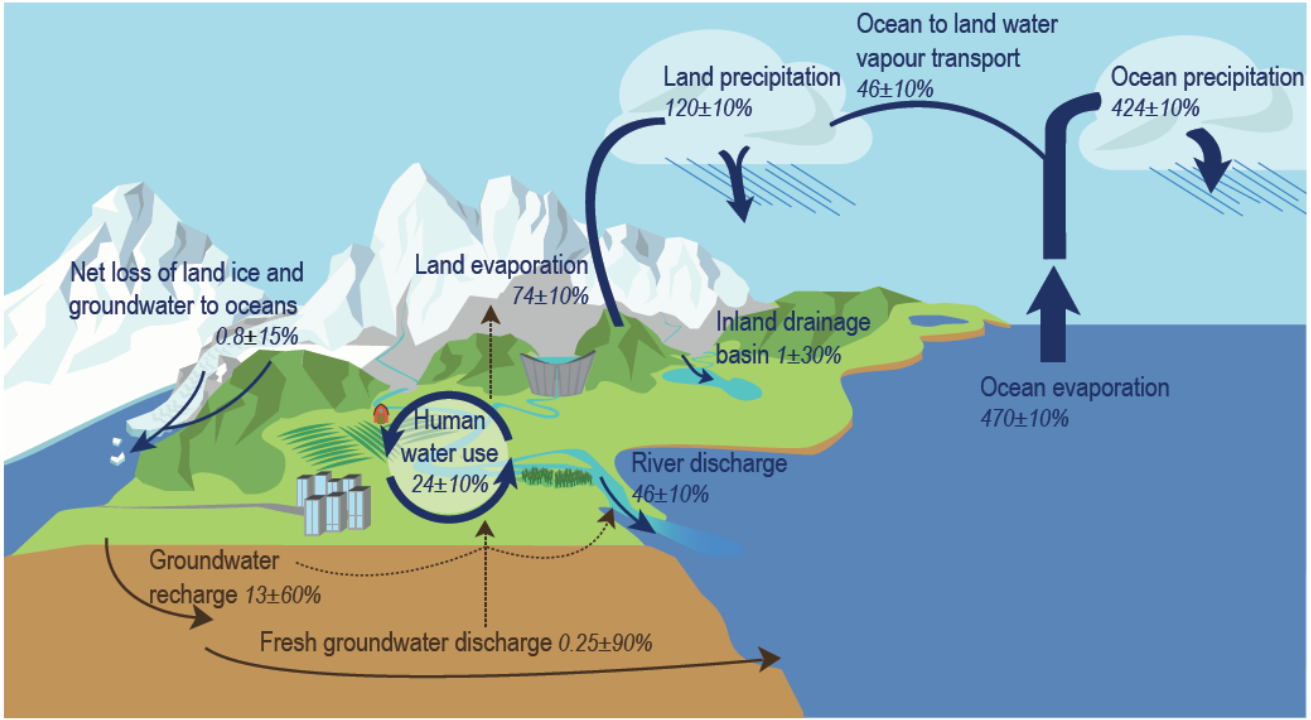
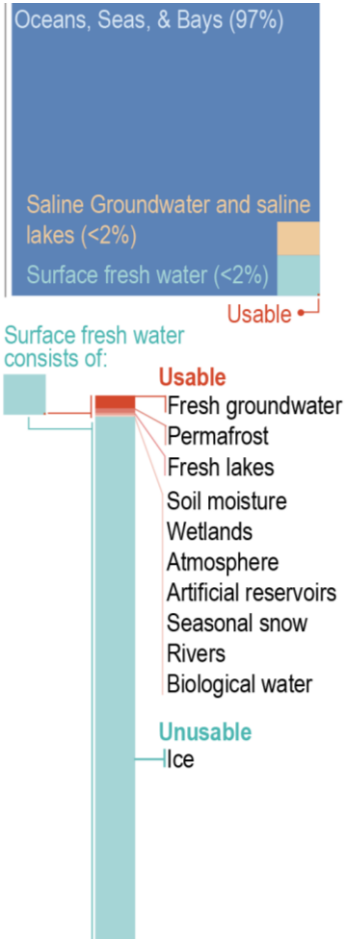
Global water cycle

(b) Water fluxes

Units in thousands of km³ per year



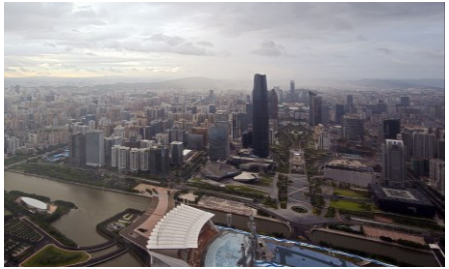


Douville et al. (2021) IPCC, Ch 8 (Fig. 8.1).
See also Allan et al. (2020) NYAS; Abbott et al. (2018) Nature Geosci

> Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events.

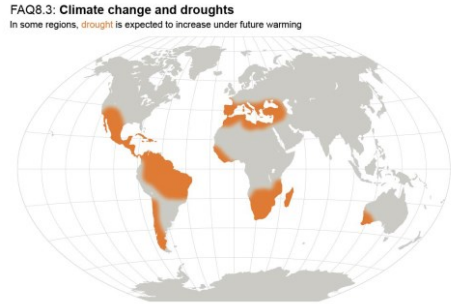
Growing direct human influence on water flows

- Water extraction & use
- Deforestation
- Urbanisation



Causes for concern

- Regional aridification
- Forest dieback, vegetation feedbacks
- Circulation shift (monsoon, storm track, subtropical dry zone, ocean circulation)
- Geoengineering?



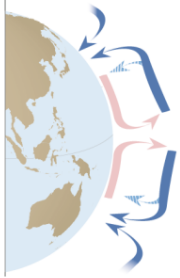
Representation of key physical processes has improved but climate models remain limited in their ability to simulate all aspects of the present-day water cycle and to agree on future changes.

- Convection: double-ITCZ bias; extreme precipitation
- Cloud-aerosol microphysical processes
- Land surface processes including plant water use

- Regional circulation change
  - Forcing (rapid adjustment, warming)
  - Internal variability

Large Scale Circulation projected changes and their effect on the water cycle

Poleward expansion of Hadley Cells

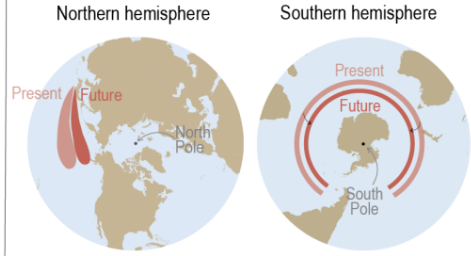


Effect: Broadening of the Hadley Cells and poleward expansion of subtropical dry zones

Regions: Uncertain influence on drying of subtropical land regions that are also controlled by evolving surface temperature patterns

Confidence: Low

Poleward migration of storm tracks



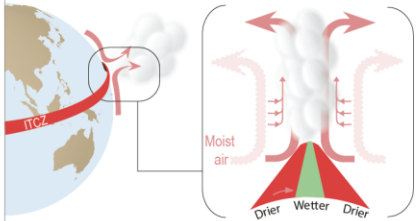
Confidence: Low

Confidence: Medium

Effect: Annual-mean mid-latitude storm tracks shifting polewards.

Regions: Regional storm tracks moving polewards at different rates in different basins. Southern hemisphere storm tracks have moved polewards more clearly, partly driven by ozone depletion. Poleward movement likely to weaken as ozone hole recovers.

Narrowing/strengthening of ITCZ core



Effect: Drying tendency on edges of the ITCZ; moistening tendency in the core, where the wet gets wetter response is expected to be amplified.

Regions: Impacts on individual regions only beginning to be investigated.

Confidence: Medium

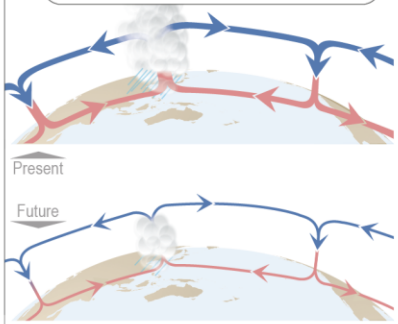
Regional shifts in ITCZ

Effect: Shifts in location of wettest tropical regions, increases or decreases in precipitation amount

Regions: Southward shift 1950-1970s over west Africa due to aerosol cooling of northern hemisphere, recovery since driven mainly by GHGs. Signals of regional shifts emerging.

Confidence: Low

Weaker Walker circulation



Effect: Reduces thermodynamic strengthenir of monsoons and the increasing contrasts between wet and dry regimes

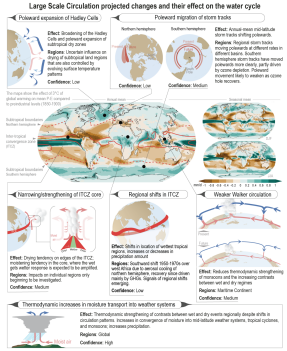
Regions: Maritime Continent

Confidence: Medium

Circulation response crucial for regional water cycle change but low confidence

Evidence emerging e.g. Mamalakis et al. (2021) Nature Clim.; Dong et al. (2022) Nature Comms, etc

WG1
Chapter 8
Fig. 8.21



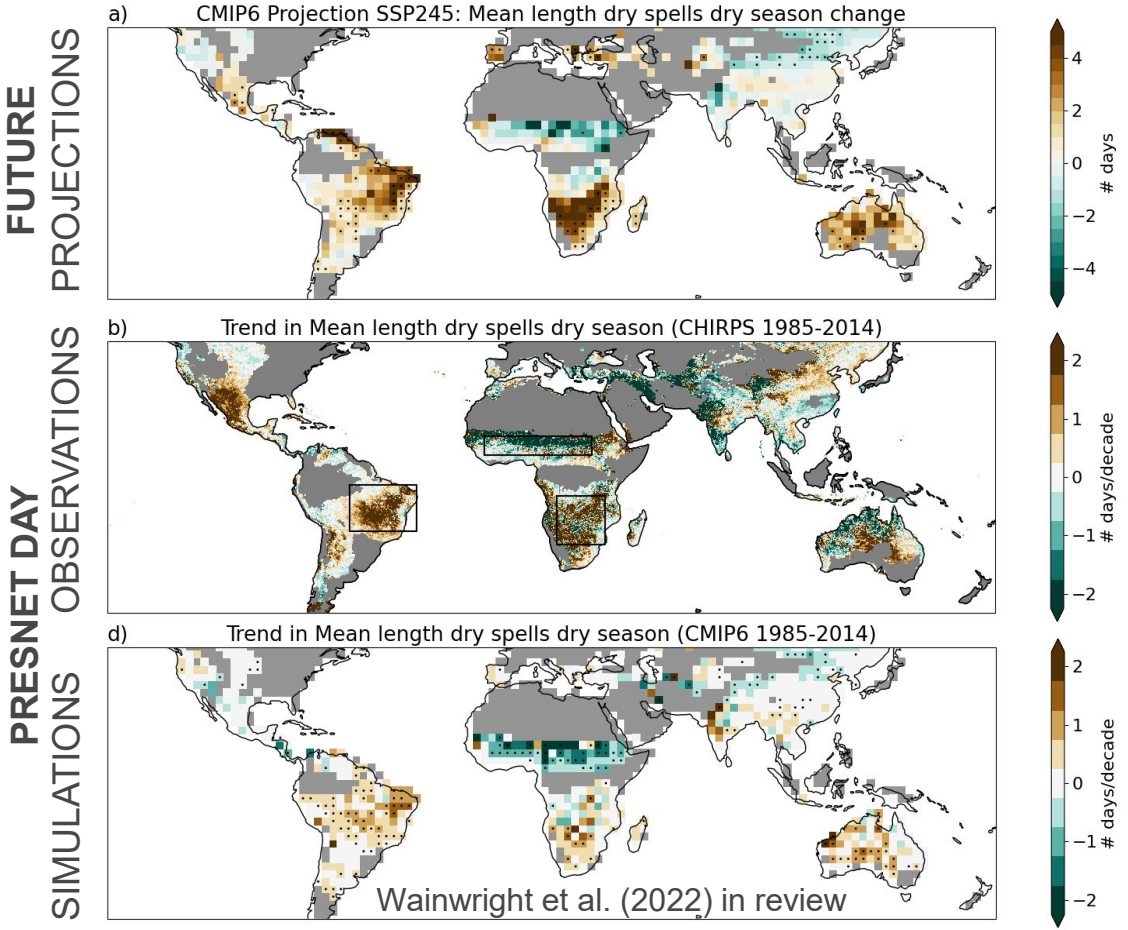
Rumsfeld unknowns

- Vegetation response
- Convection/precip
- Aerosol/cloud
- Circulation change
- …nasty surprises?

Something critical we don't yet know about may become an existential threat if combined with growing water stress from climate change

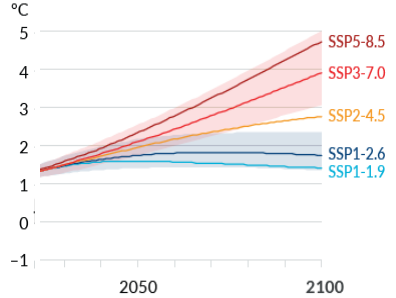
Climate monitoring

- Global observing systems (P, P-E, runoff, storage)
- Emerging Climate Change
  - ➢ Dry season severity e.g. Wainwright et al. (2022) →
  - ➢ Intensity/timing change impacts
  - ➢ Wetland methane emissions Feng et al. (2022) Nature Comm.
- Alarm bells?
  - ➢ Amazon (Boulton et al. 2022 Nature Clim)
  - ➢ AMOC (Boers 2021 Nature Clim)
  - …



Future storylines

- Plausible set of distinct regional outcomes from multiple realisations of future scenarios
- Unlikely but possible high impact climate events (e.g. AMOC shut down, Amazon die back, monsoon failure, huge or clustered volcanoes, etc)
- Regional rivalry aerosol emissions scenario?
- What if 1921 European drought or American dustbowl or Cape Town water crisis conditions occur at 2°C warming?
- What if record breaking wet season or stalling tropical cyclone or intense convective event occurred in 3°C warmer world?



Conclusions

- More intense water cycle: too much, too little problems grow
  - ➢ Increasing direct human impact on water cycle
  - ➢ Limits to prediction (convection, aerosol, vegetation, circulation)
- Opportunities & open questions:
  - ➢ Modelling advances (resolution, ensembles, machine learning)
  - ➢ Improving observing systems
    - ❑ monitoring emerging hydrological climate signals & stores
    - ❑ calibrate future water cycle projections
  - ➢ Early warning of tipping points/abrupt changes in water cycle
  - ➢ Improved early warning of emerging water related crises
    - ❑ Localised flooding, severe wet season/events, emerging & flash droughts/water crises, compound extremes, etc