Climate Change and Drought in a Warmer World

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Drought occurs, resulting in cavitation and/or carbon starvation, followed by increased vulnerability to other disturbances such as insects, fire and growth. In situation (1) soil moisture is sufficient, and the flows of water and carbon are correlated through stomatal conductance (Section 1). Selective mortality and regrowth occurs, coherent with species' strategy (Sections 2 and 3). In situation (2) a severe and prolonged drought affects the terrestrial carbon balance by modifying both gross primary production and ecosystem respiration and net ecosystem exchange; it also results in an increase in mycorrhizal community breakdown (Fig. 1). In situation (3) selective mortality and regrowth occurs, coherent with species' strategy (Sections 4 and 5). Drought affects the terrestrial carbon balance by modifying both gross primary production and ecosystem respiration and net ecosystem exchange; it also results in an increase in mycorrhizal community breakdown (Fig. 1). Drought Impacts

66 million trees killed since 2010 in California, as of August 2016

Drought is NOT just precipitation

Meteorological situation

Meteorological drought

Anomalies in precipitation

Precipitation deficiency

Soil moisture drought

Low soil moisture

Hydrological drought

Low discharge

Low groundwater storage

Socio-economic drought

Impacts

Meteorological drought

Anomalies in temperature

Van Loon (2016), WIREs Water
The Water Budget

warming means more of this...

...and less of this
levels off at about 3
with global temperature as the precipitation signal emerges, but
(black lines). The area fraction with robust projections is increasing
0.8 (fine stippling) for precipitation change is depicted in Fig. 4a
for precipitation, the extent of those is limited, as pointed out
do not agree well (robustness
2025. Regions where most models show significant changes but
are shown in Fig. 4. The stippled area in CMIP3

Heterogeneous precipitation response

Low confidence in some regions

Knutti & Sedlacek (2013), Nature
Soil moisture changes much more widespread

RCP8.5

Why?

IPCC, Fifth Assessment Report (Chapter 12)
Widespread and robust warming, all seasons

Knutti & Sedlacek (2013), Nature
Warming increases atmospheric demand for water
$\Delta P$

$PDSI (2080-2099)$

$\Delta P, \Delta ET$
Central Plains (North America)

Wetter

\[ \Delta P, \Delta ET \]

Drier

\[ \Delta P \]

Legend:
- CanESM2
- CCSM4
- CNRM-CM5
- GFDL-Mk3.6.0
- GFDL-CM3
- GFDL-ESM2M
- GISS-E2-R
- IPSL-CM5A-LR
- MIROC5
- MIROC-ESM
- MIROC-ESM-CHEM
- MRI-CGCM3
- NorESM1-M
Southeast China

Wetter

Drier

$\Delta P, \Delta ET$

$\Delta P$
Europe and the Mediterranean

**Wetter**

**Drier**

### Graph: \( \Delta P, \Delta ET, \Delta P \)

- \( \Delta P \)
- \( \Delta ET \)

**Legend:**
- CanESM2
- CCSM4
- CNRM–CM5
- GFDL–Mk3.6.0
- GFDL–CM3
- GFDL–ESM2G
- GISS–E2–R
- INMCM4.0
- IPSL–CM5A–LR
- MIROC5
- MIROC–ESM
- MIROC–ESM–CHEM
- MRI–CGCM3
- NorESM1–M

**Axes:**
- X-axis: \( \Delta P, \Delta ET, \Delta P \)
- Y-axis: Wetter to Drier

**Observations:**
- The graph indicates changes in precipitation (\( \Delta P \)) and evapotranspiration (\( \Delta ET \)) in different models for the Europe and the Mediterranean regions.
- The models show varying degrees of change in precipitation and evapotranspiration, indicating different climate scenarios.
- The graph suggests that some models predict wetter conditions, while others predict drier conditions.

This graph is crucial for understanding future climate impacts on regions like Europe and the Mediterranean, aiding in informed planning and adaptation strategies.
How robust is the drying across indicators?
How will future droughts compare to the past?
Megadrought Centuries

2050-2099

Wetter

Central Plains

Drier

Southwest
Central Plains

Most drying from increased evaporation

**PDSI**

![Graph of PDSI](image)

**SM-30 cm**

![Graph of SM-30 cm](image)

- **NADA (1100–1300)**
- **Model (1850–2005)**
- **Model (2050–2099)**
Southwest

Doubly hit by increased evaporative demand AND reduced precipitation

- **PDSI**
- **SM-30 cm**

- **NADA (1100–1300)**
- **Model (1850–2005)**
- **Model (2050–2099)**
21st Century Risk of a multidecadal (>35 years) drought increases from 10-15% to >80%
Best Practices for Climate Models & Drought

Consider your drought variable.

What do you care about? Average aridity? Recurrence intervals? Drought severity?

Embrace uncertainty across models, regions, and indicators.

Think probabilistically, not deterministically.
Thank You

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