Assessment of Future Drought in Southwest China based on CMIP5 Multimodels Projections

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Outline

1. **Introduction**
2. Data and methodology
3. Projected changes in precipitation, evaporation and droughts
4. Summary

Introduction

In the last decade, a series of severe and extensive droughts have swept across Southwest China, resulting in tremendous economic losses, deaths, and disruption of society.

- The summer of 2006
- The autumn of 2009 to the spring of 2010
- The late summer of 2011

Study on SW drought

The historical variation in dry/wet conditions over Southwest China in the past 50 or 100 years.

The atmospheric circulation mechanism responsible for causing droughts

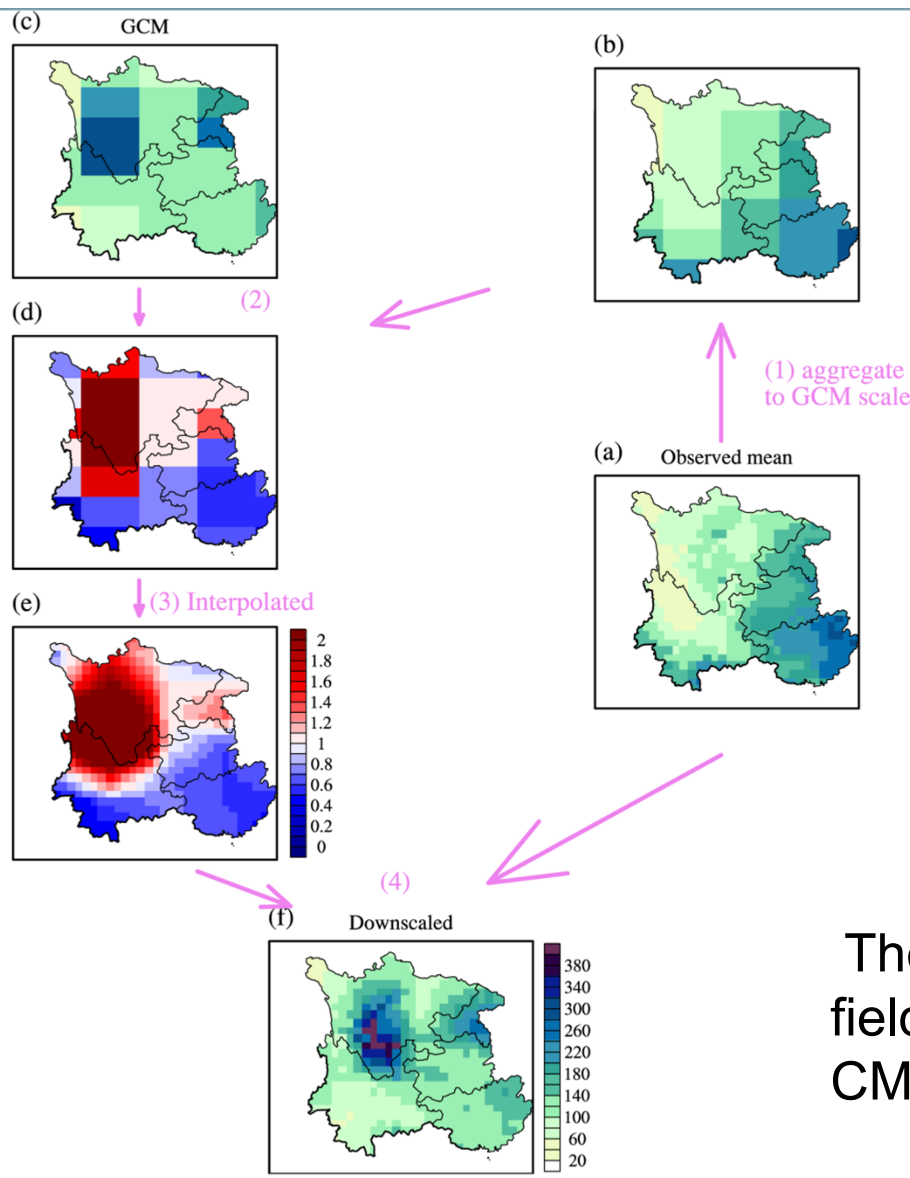
- Summer of 2006:
  - westward shift and intensification of the western pacific subtropical high;
  - northward shift of midlatitude westerlies
- The autumn of 2009 to the spring of 2010:
  - an extremely negative phase of the Arctic Oscillation plays an important role in bringing the track of cold air invasion eastward
- Summer of 2011:
  - weak moisture transport from the Bay of Bengal
  - a positive geopotential height anomaly

few studies have focused on the future changes in drought risk in Southwest China under global warming

Data

- Observational data
  - Precipitation dataset from National Meteorological Information Center
  - Potential Evaporation dataset from CRU TS3.2
- Model data (23 models from CMIP5)
  - 1961-2099
  - RCP4.5 and RCP8.5
  - Variables:
    - Precipitation
    - near-surface air temperature(including mean, minimum, and maximum)
    - surface pressure
    - wind speed at 10 meters
    - surface shortwave and long wave radiation
    - near-surface relative humidity

Spatial disaggregation as downscaling tech



Streamflow forecast:

Wood et al. (2002, 2004)

Climate studies:

Hayhoe et al. (2008), Wang and Chen (2013)

- Use GCM precipitation as a predictor
- monthly GCM precipitation and PET for all climate models (RCP4.5 and RCP8.5) are downscaled to a resolution of 0.5, identical with that of observations

The downscaled precipitation field is constructed from IPSL-CM5A-LR outputs for May 1986.

SPEI procedure

•Calculation of the climatic balance

$$D_i = P_i - PET_i$$

where P(mm) is monthly precipitation and PET(mm) is potential evaportranspiration calculated by the method of Penman-Monteith.
Creation of cumulative series at the desired time scale

$$D_n^k = \sum_{i=0}^{k-1} (P_{n-i} - PET_{n-i}), \quad n \geq k$$

where k(months) is the time scale of the aggregation and n is calculation number

•Fitting the D_n^k (during calibration period) to a probability distribution function

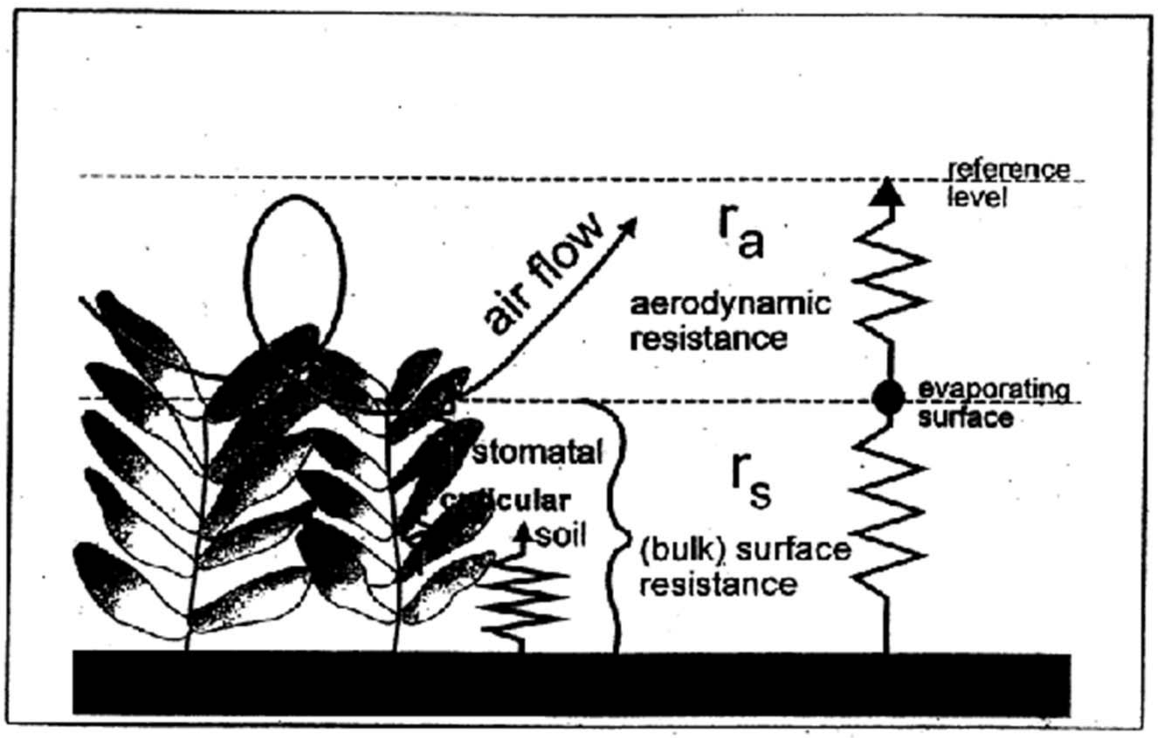
•Transforming the data into (standardized) z- values

$$\int_{-\infty}^{D_i} f(x)\mathrm{d}x = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Z} e^{-x^2/2}\mathrm{d}x$$

Penman-Monteith PET

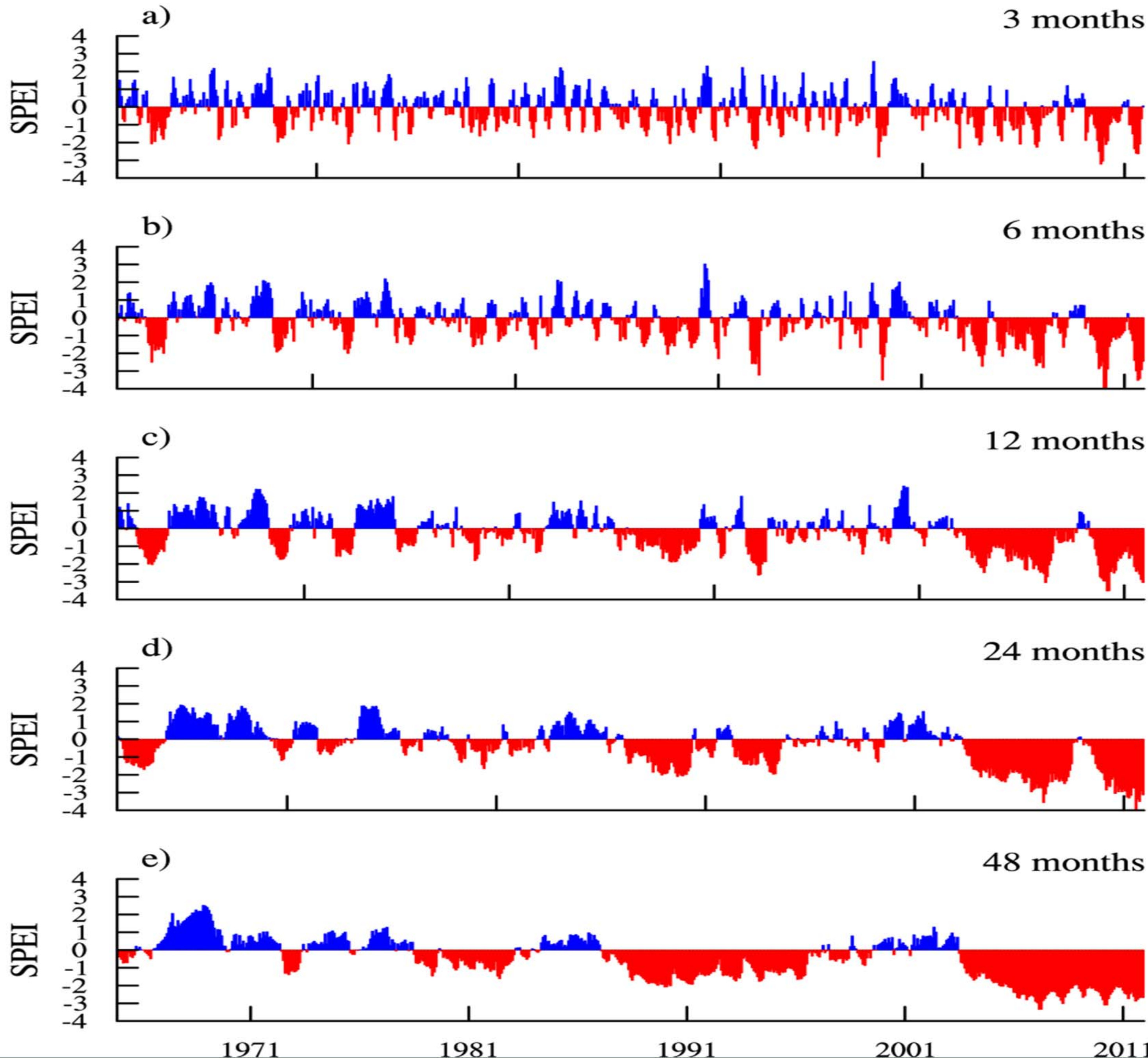
Penman-Monteith PET is recommended by the Food and Agriculture Organization (FAO)

$$PET = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_a - e_d)}{\Delta + \gamma(1 + 0.34 U_2)}$$



Classification of drought according to SPEI

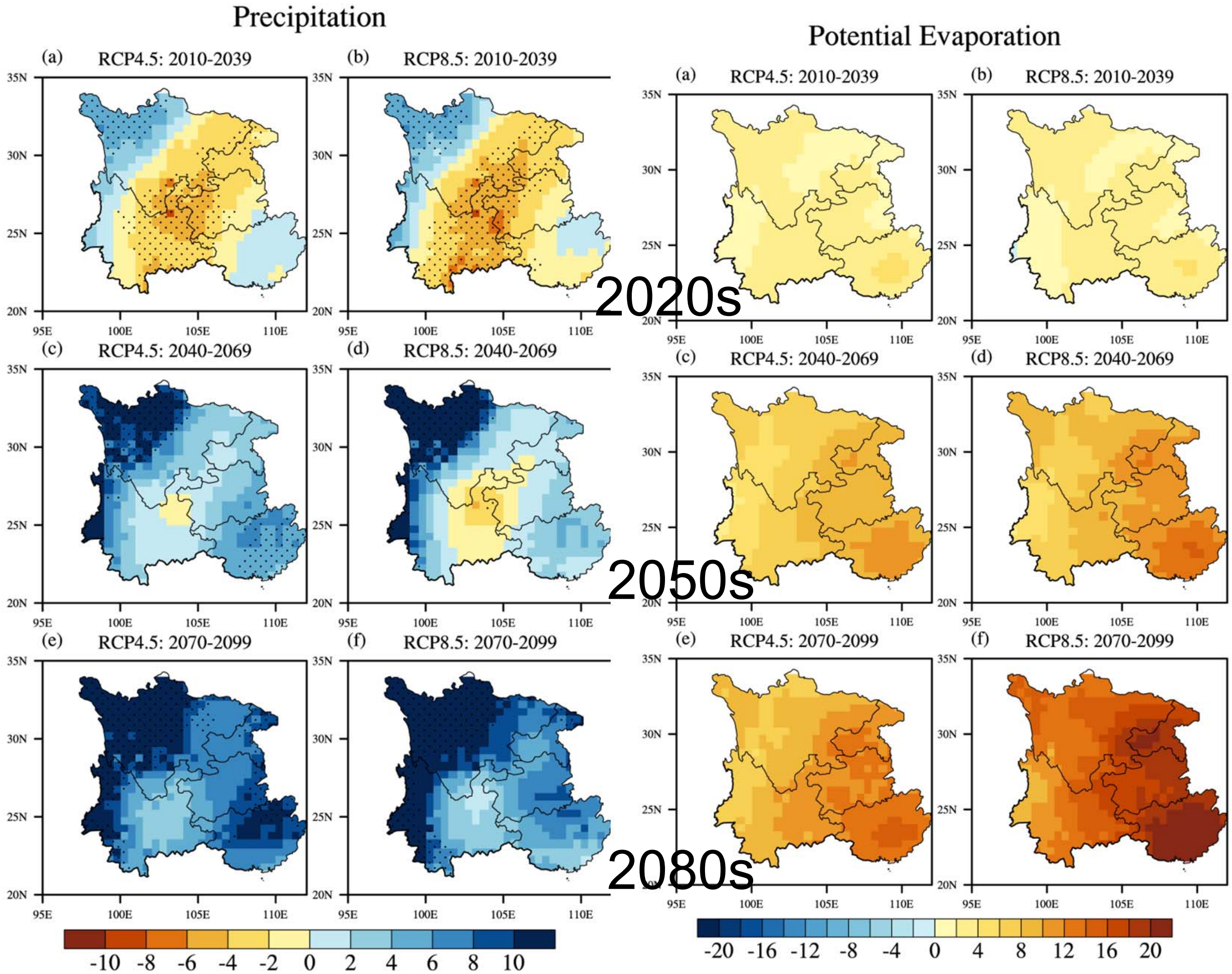
SPEI values	Drought category		Probability (%)
2.0 and above	extreme wet		2.3
1.5 to 1.99	severe wet		4.4
1 to 1.49	moderate wet		9.2
0 to 0.99	mild wet	Near normal	34.1
0 to -0.99	mild drought		34.1
-1 to -1.49	moderate drought		9.2
-1.5 to -1.99	severe drought		4.4
-2 and less	extreme drought		2.3


a)
3 months
b)
6 months
c)
12 months
d)
24 months
e)
48 months
SPEI
4
3
2
1
0
-1
-2
-3
-4
1971
1981
1991
2001
2011

Projected changes in precipitation and PET

The stippling indicates where at least 70% (16 out of 23) of all GCMs agree on the sign of the mean change in a given grid cell.

The GHG forcing scenario has no substantial impact on the projected Precipitation, and its impact on PET response appears after 2050s.



Regional average

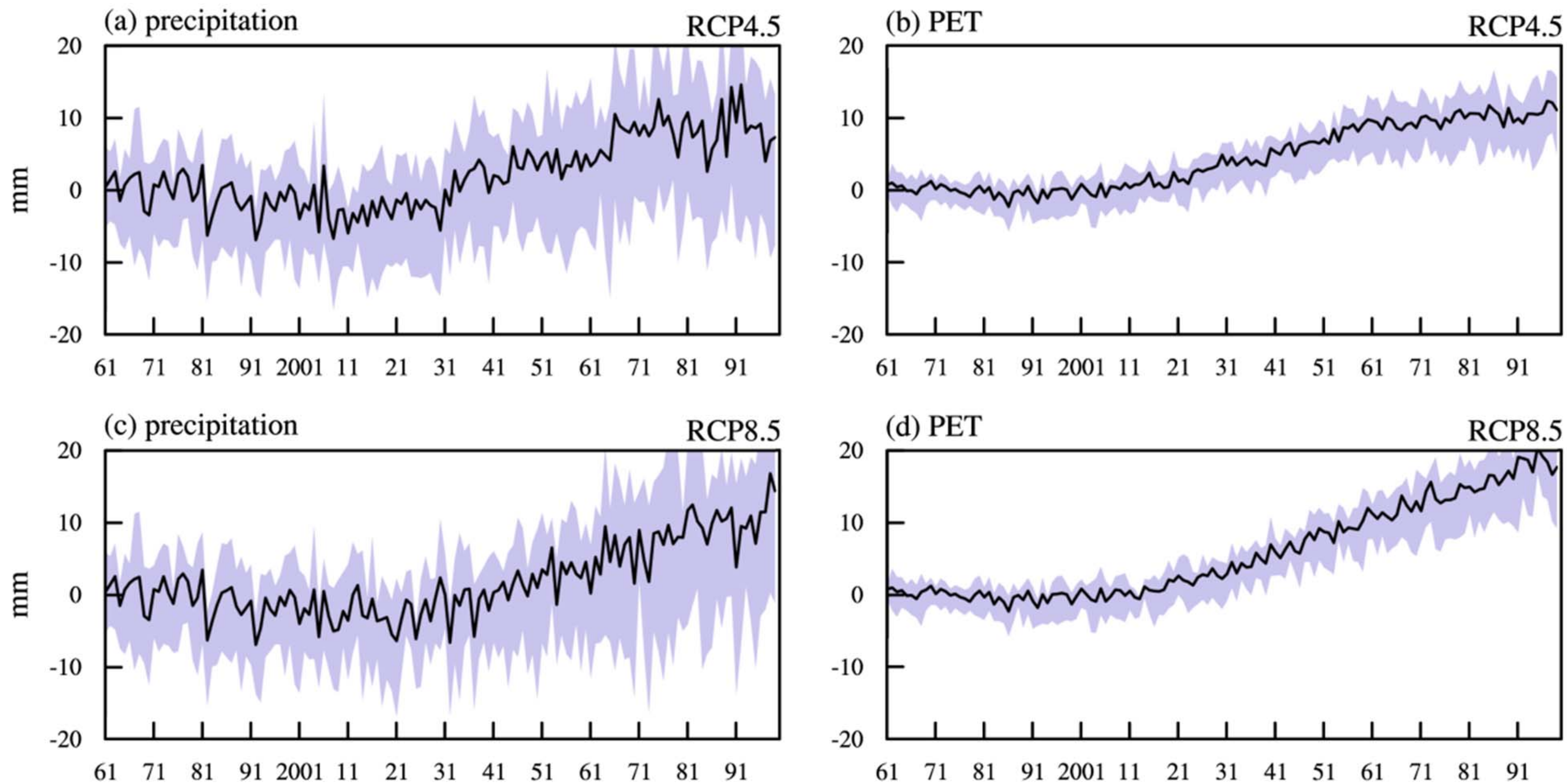


Figure | Anomalies of annual mean precipitation (a, c) and PET (b, d) under RCP4.5 and RCP8.5 averaged over Southwest China from 1961 to 2099 relative to the 1961 to 1990 average. The black line and blue shading denote the ensemble mean and interquartile range across all GCMs, respectively.

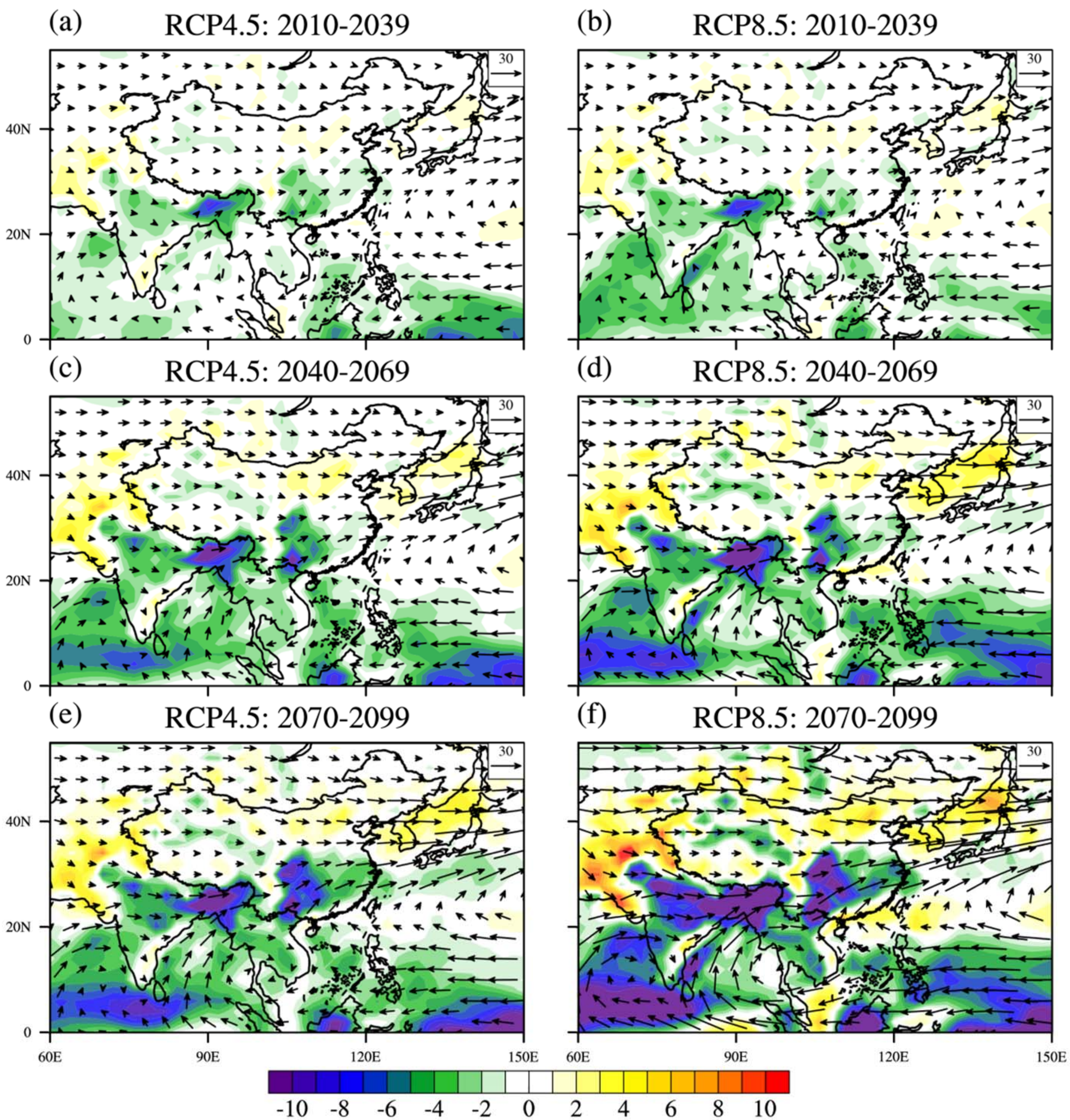


Figure | Spatial pattern of the climatological change in vertically integrated water vapor flux over a depth from the surface to 300 hPa (vectors, in units of kg s^{-1} m^{-1}) and moisture divergence (shaded, in units of 10^{-6} kg s^{-1} m^{-2})

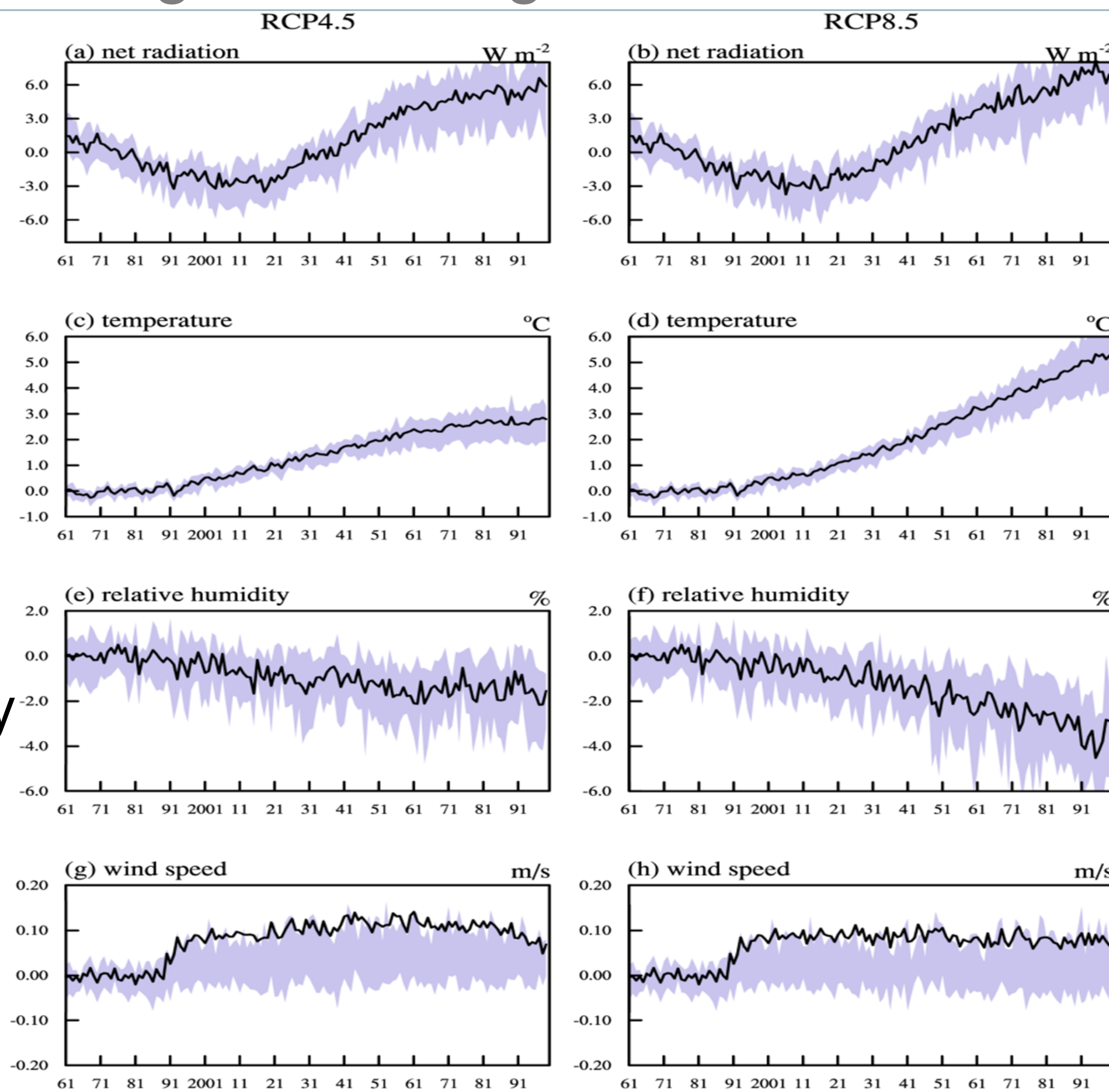
Factors causing PET change

Net radiation

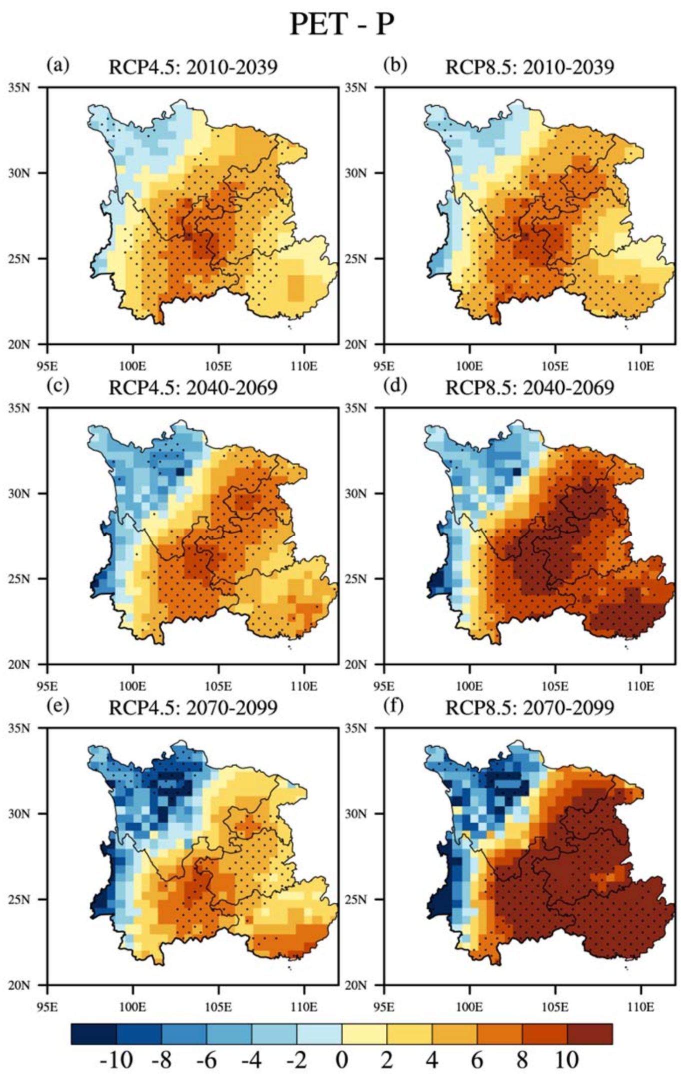
temperature

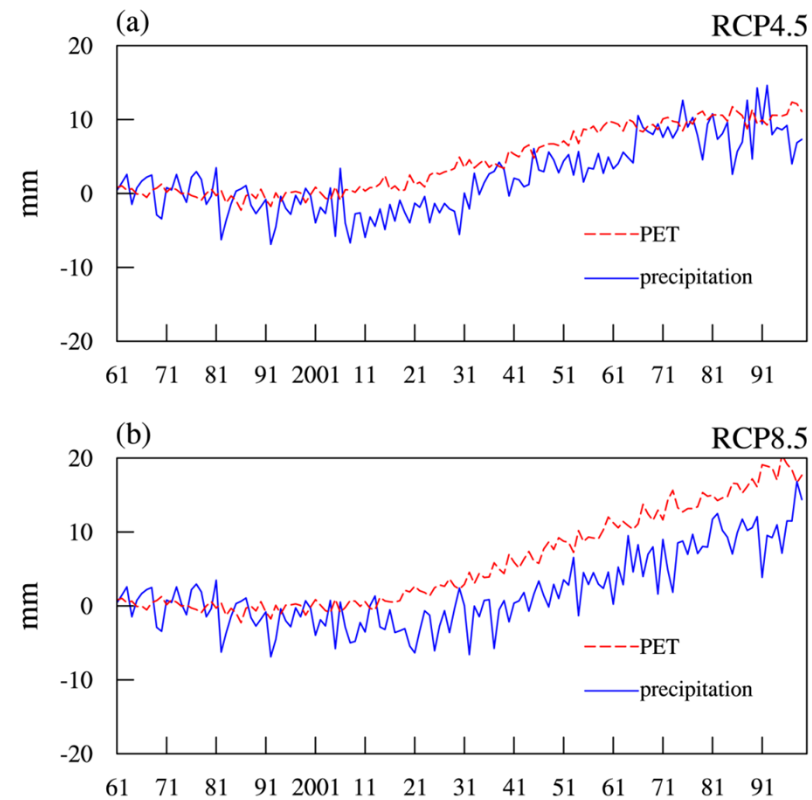
Relative humidity

Wind speed



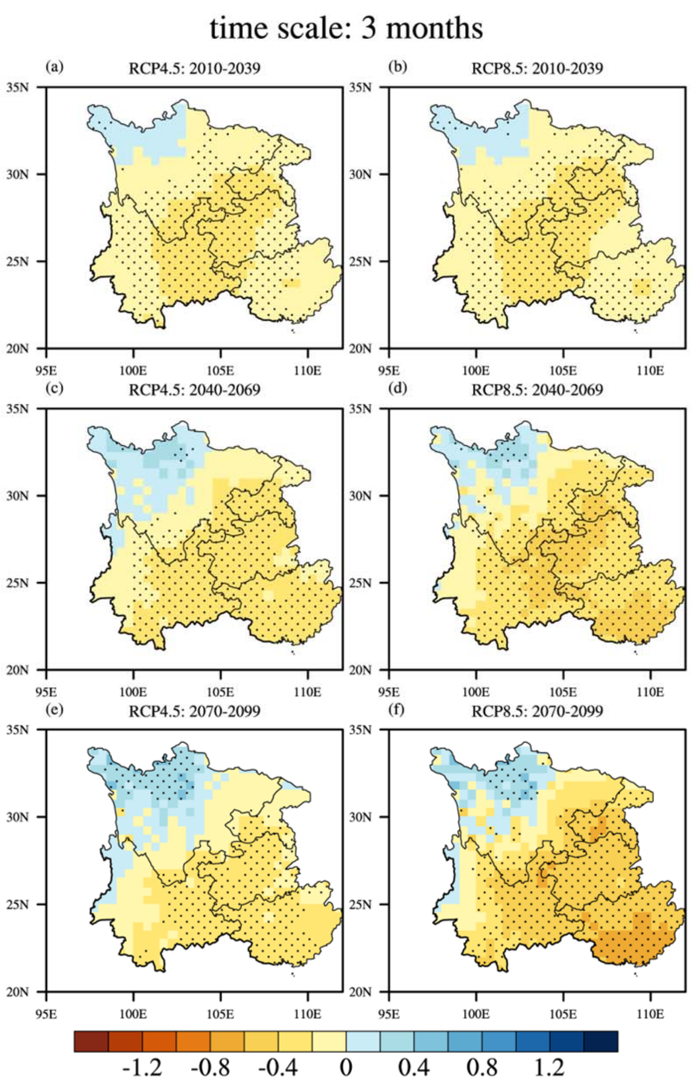
PET - P

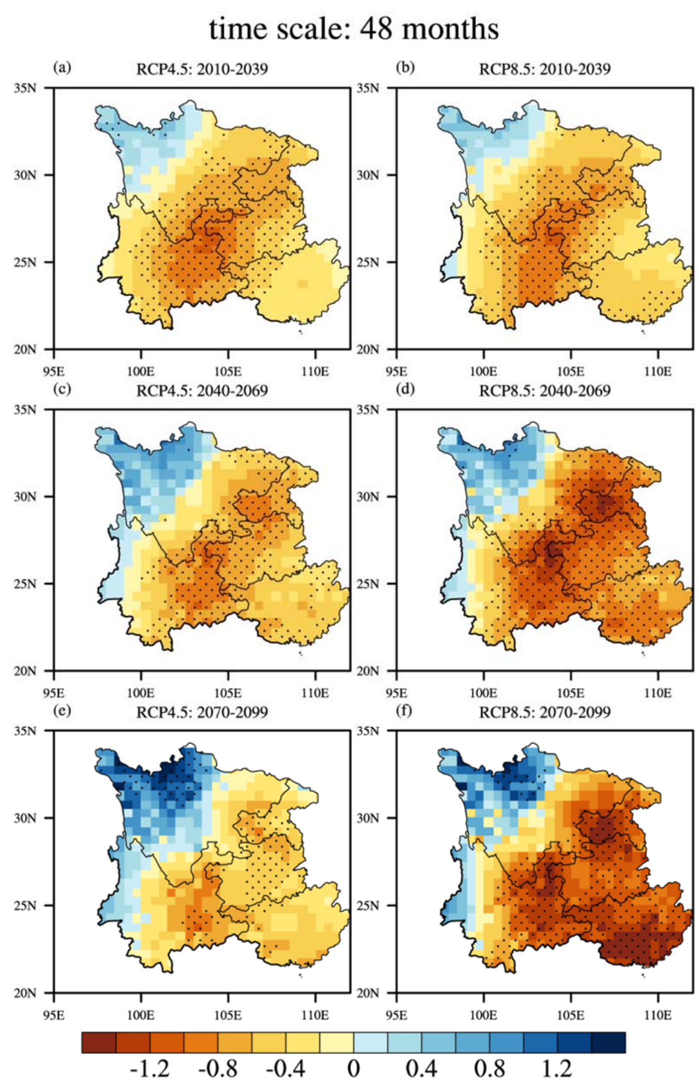




Even with increased PET, the mountainous region in the northwest appears to become wetter and wetter

Changes in SPEI





Future drought scenarios depend on the timescale: the SPE at 48mon is nearly twice as great as that at 3mon.

The drying/wetting tendency at longer timescales is stronger than that at shorter timescales.

At 3mon: a consistent spatial pattern and magnitude, a limited GHG forcing.

At 48mon:significant change in magnitude, cumulative effect of drought

Changes in extreme events

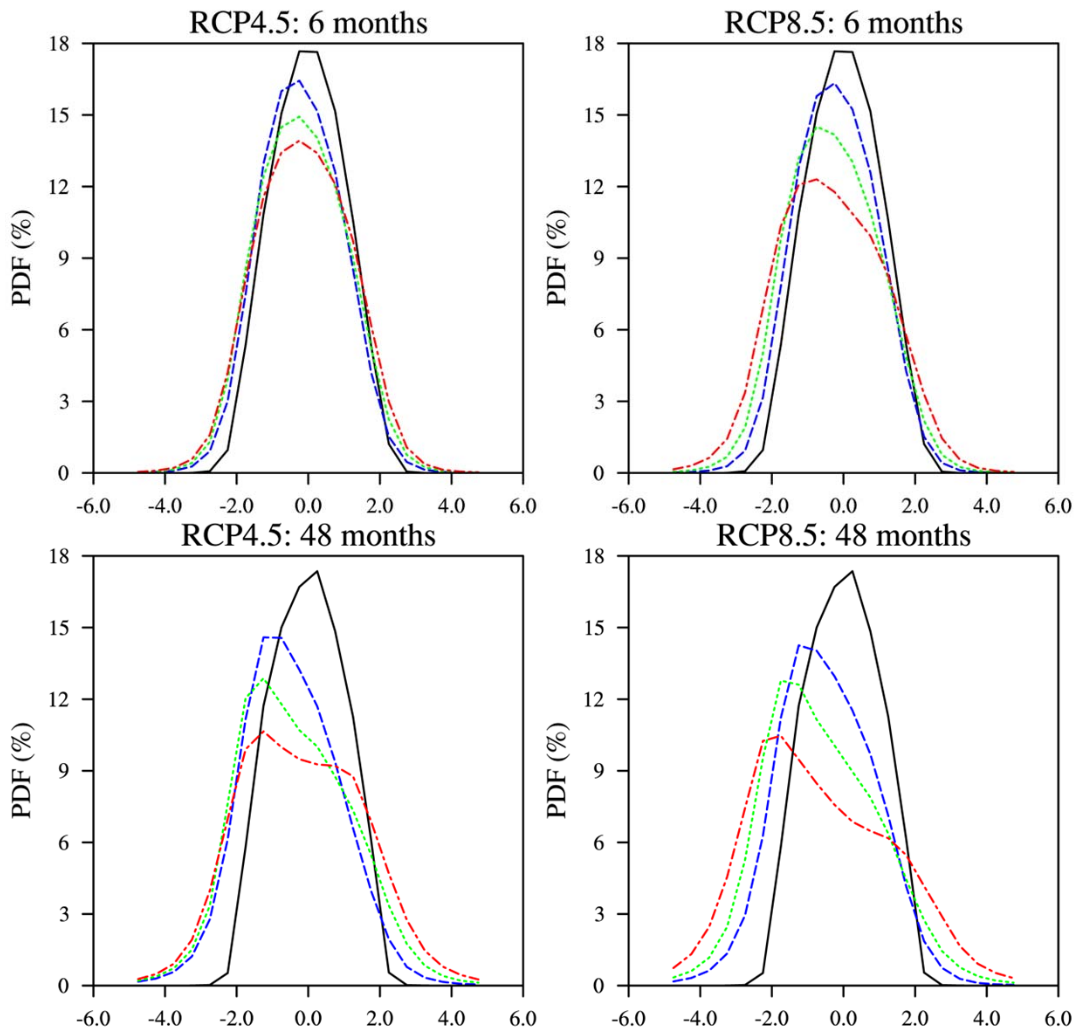


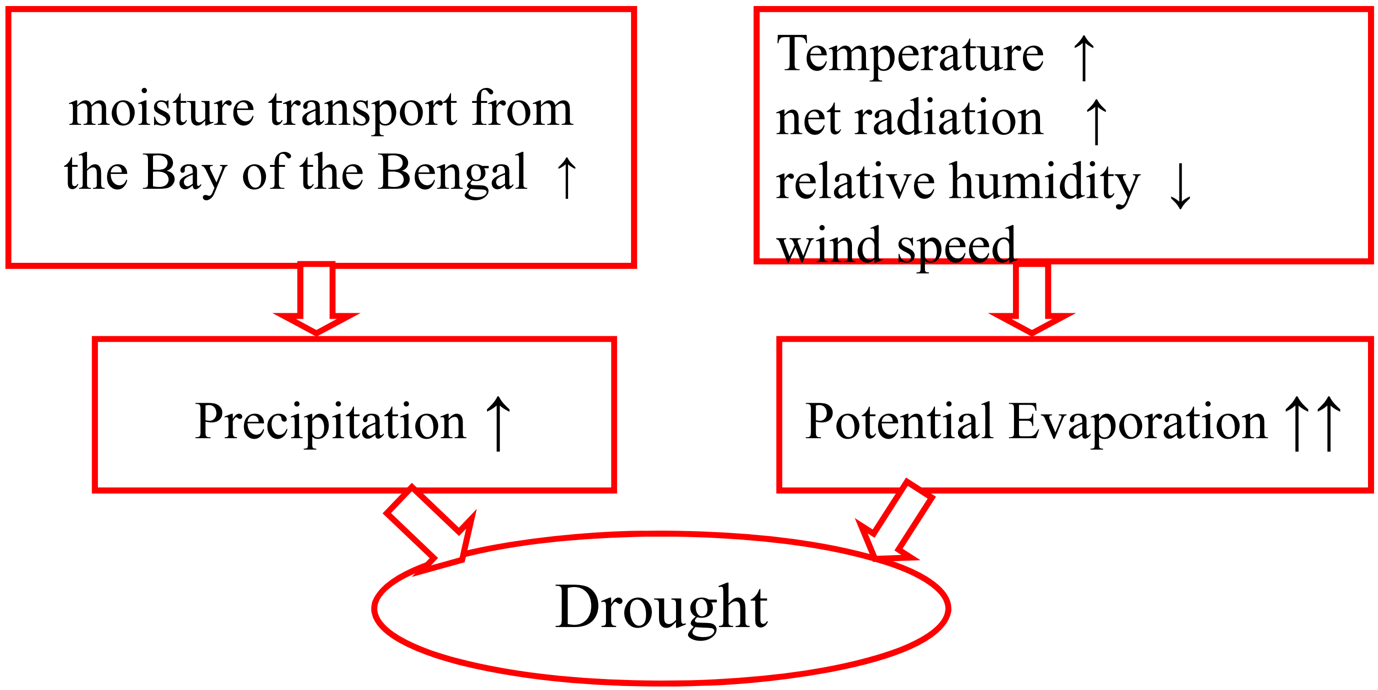
Figure | Probability distributions of SPEI at the time scales of 6 and 48 months under RCP4.5 and RCP8.5

Severe persistent drought will become the norm in 2080s.

The change of extreme events in extreme drought/ flooding will rise rapidly in the future , from 6.6% in 2020s to 22.8% in 2080s

Black : 1961-1990
Blue : 2010-2039
Green : 2040-2069
Red : 2070-2099

Summary

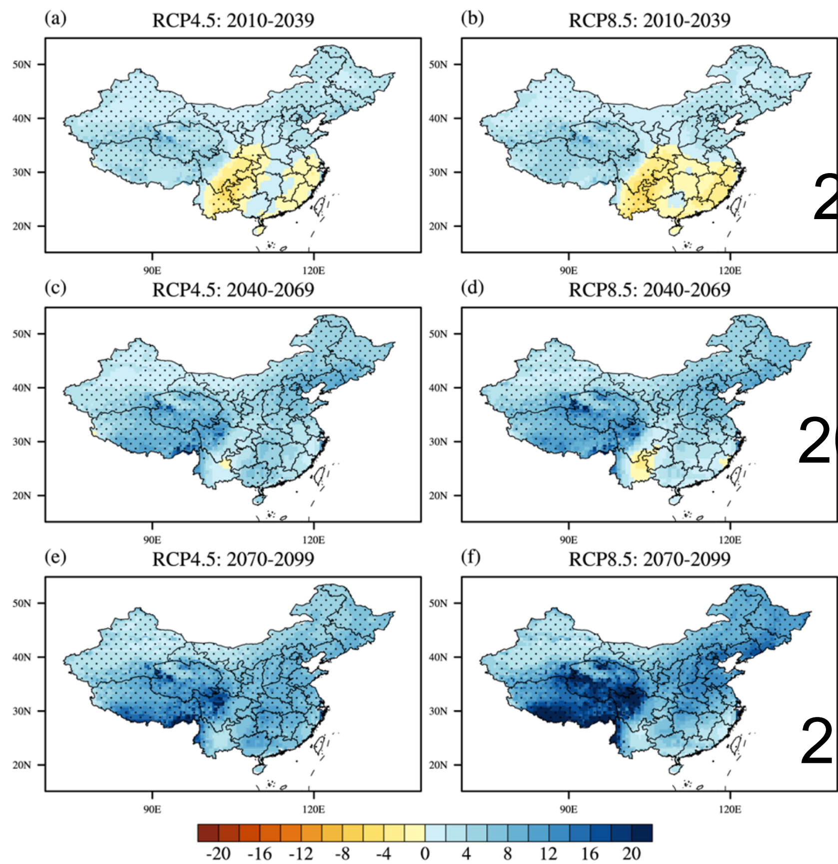


- drying tendency will be in the southeast portion
- Droughts classified as moderate/severe according to historical standard will become the norm in the 2080s under RCP4.5/RCP8.5
- Future drought changes will manifest different characteristics depending on the time scale
- extremely wet events will also become more probable

Nationwide scale—precipitation/drought change

Precipitation

RCP4.5 RCP8.5



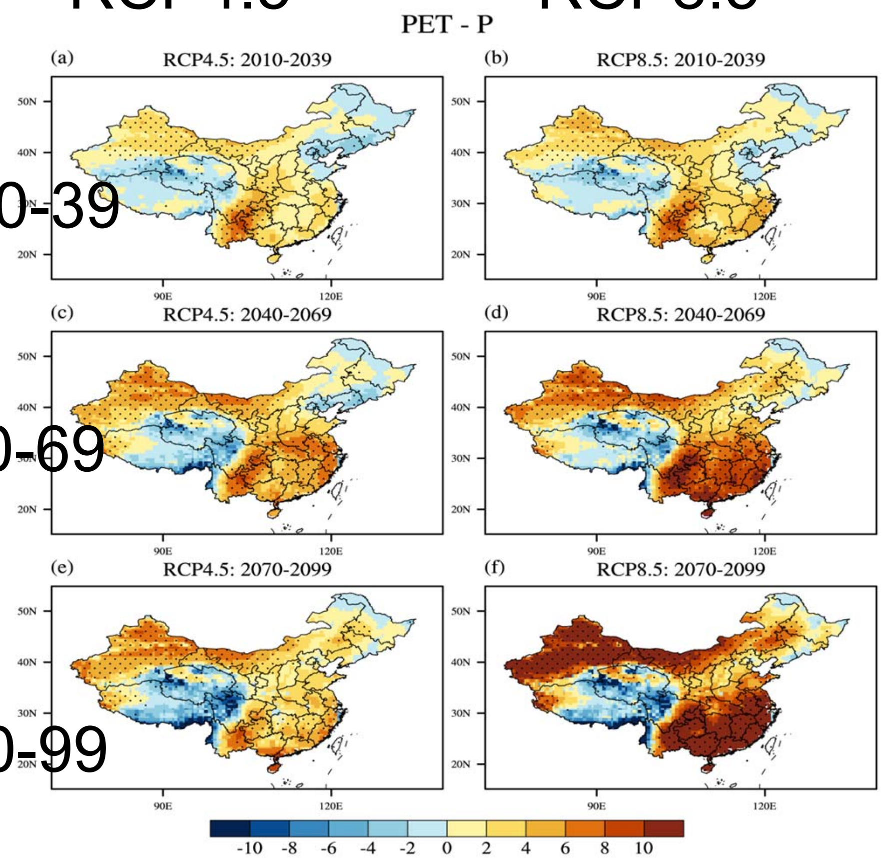
2010-39

2040-69

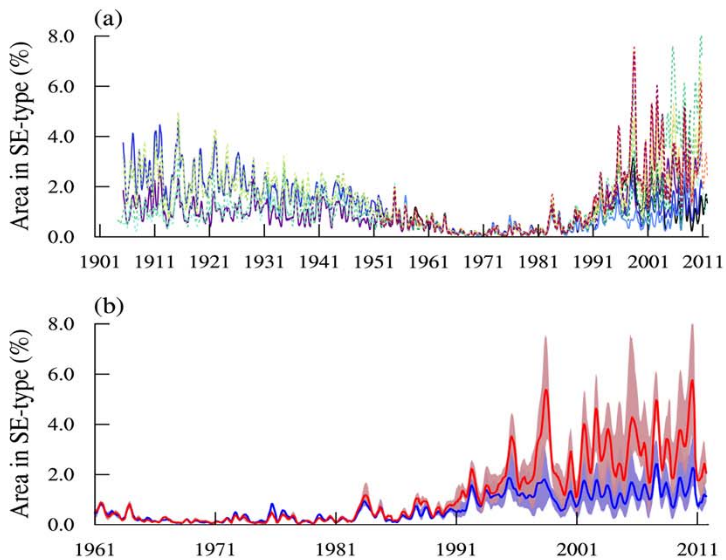
2070-99

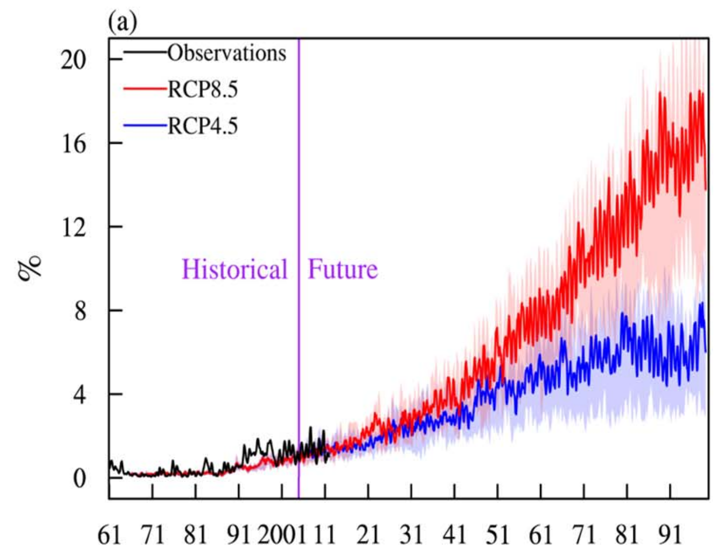
PET-P

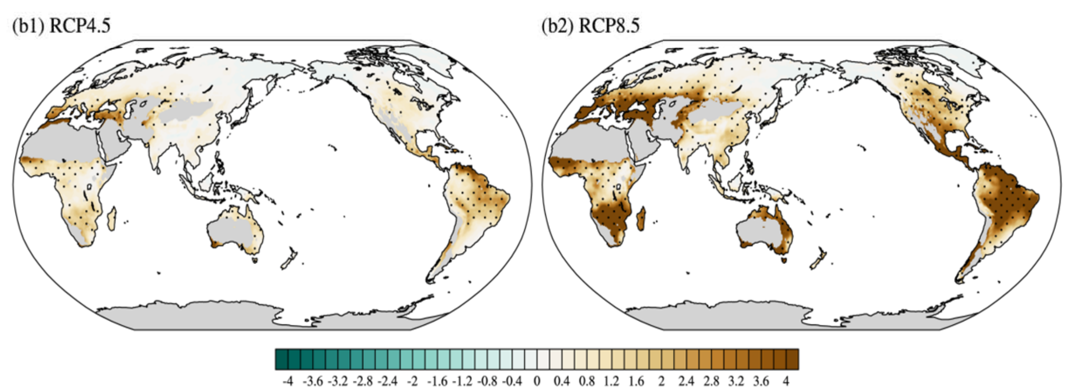
RCP4.5 RCP8.5



Historical and future projected changes in global catastrophic drought



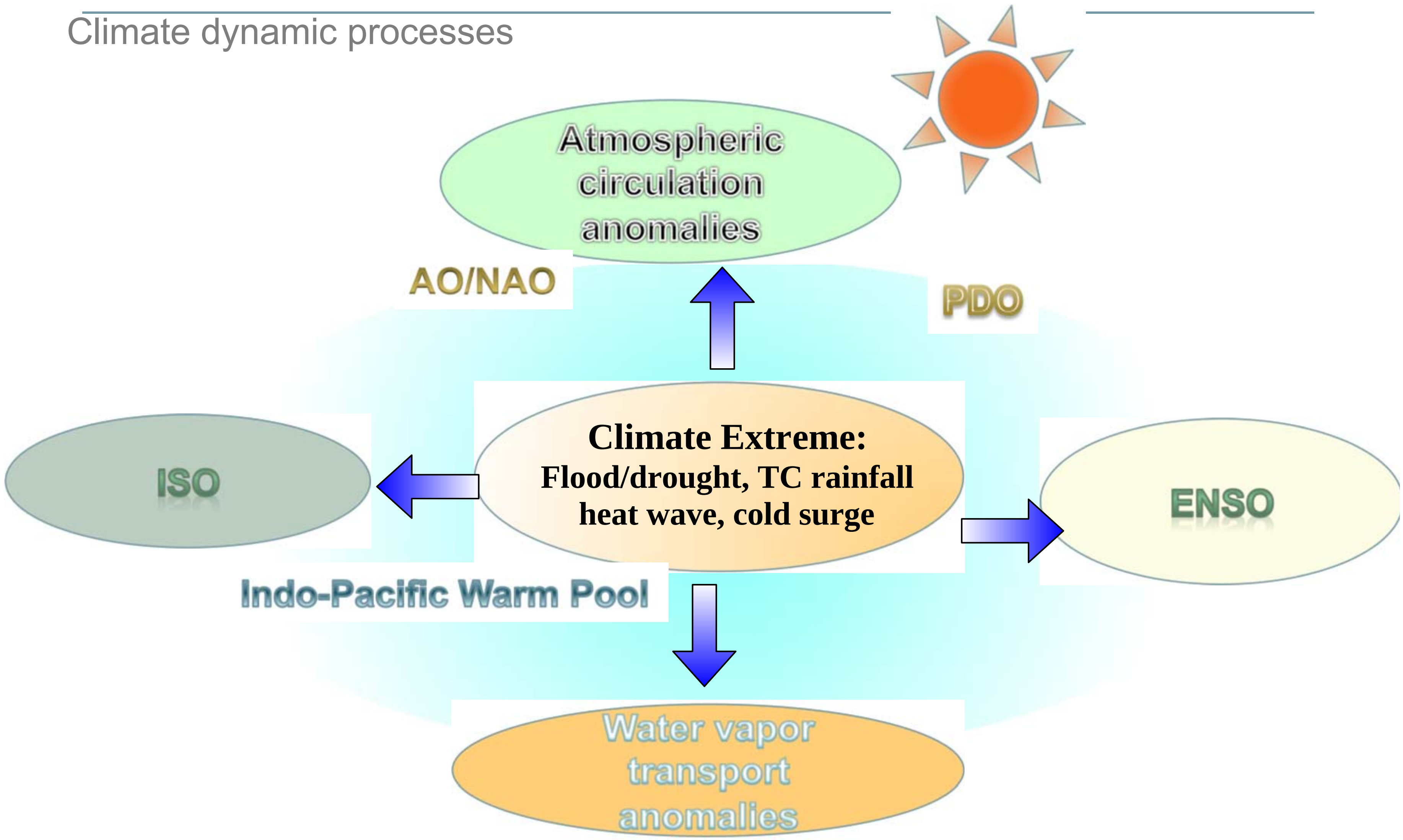




There is a decreasing trend in catastrophic drought until 1960 and a basically flat trend during 1961–1990, followed by a rise to 1.3% of global land in the last two decades.

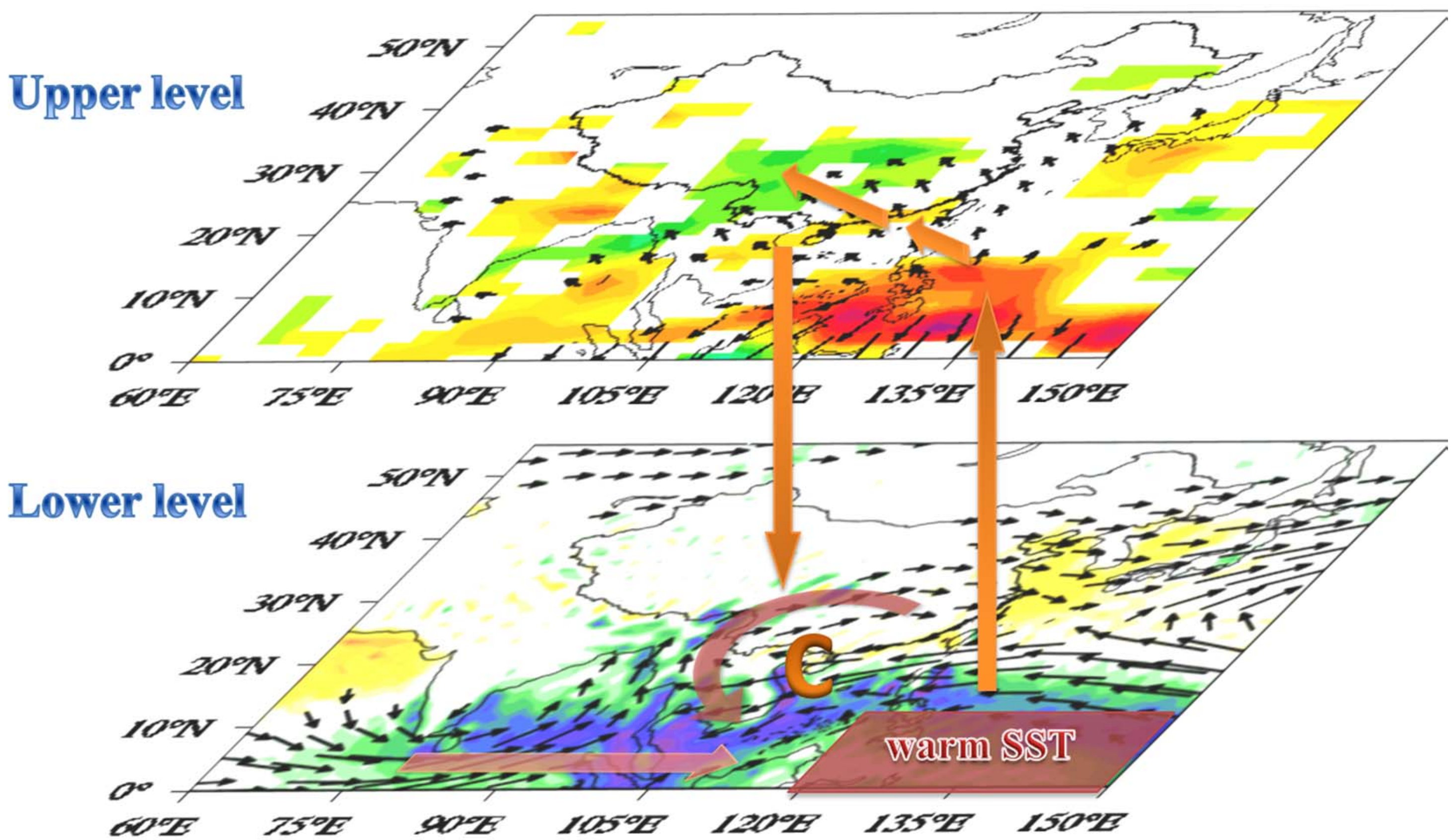
The land area affected by catastrophic drought is projected to increase to 6% and 16% at the end of the 21st century under RCP4.5 and RCP8.5.

Climate dynamic processes



Possible mechanism

Teleconnected influence of tropical Northwest Pacific sea surface temperature on interannual variability of precipitation in SW China

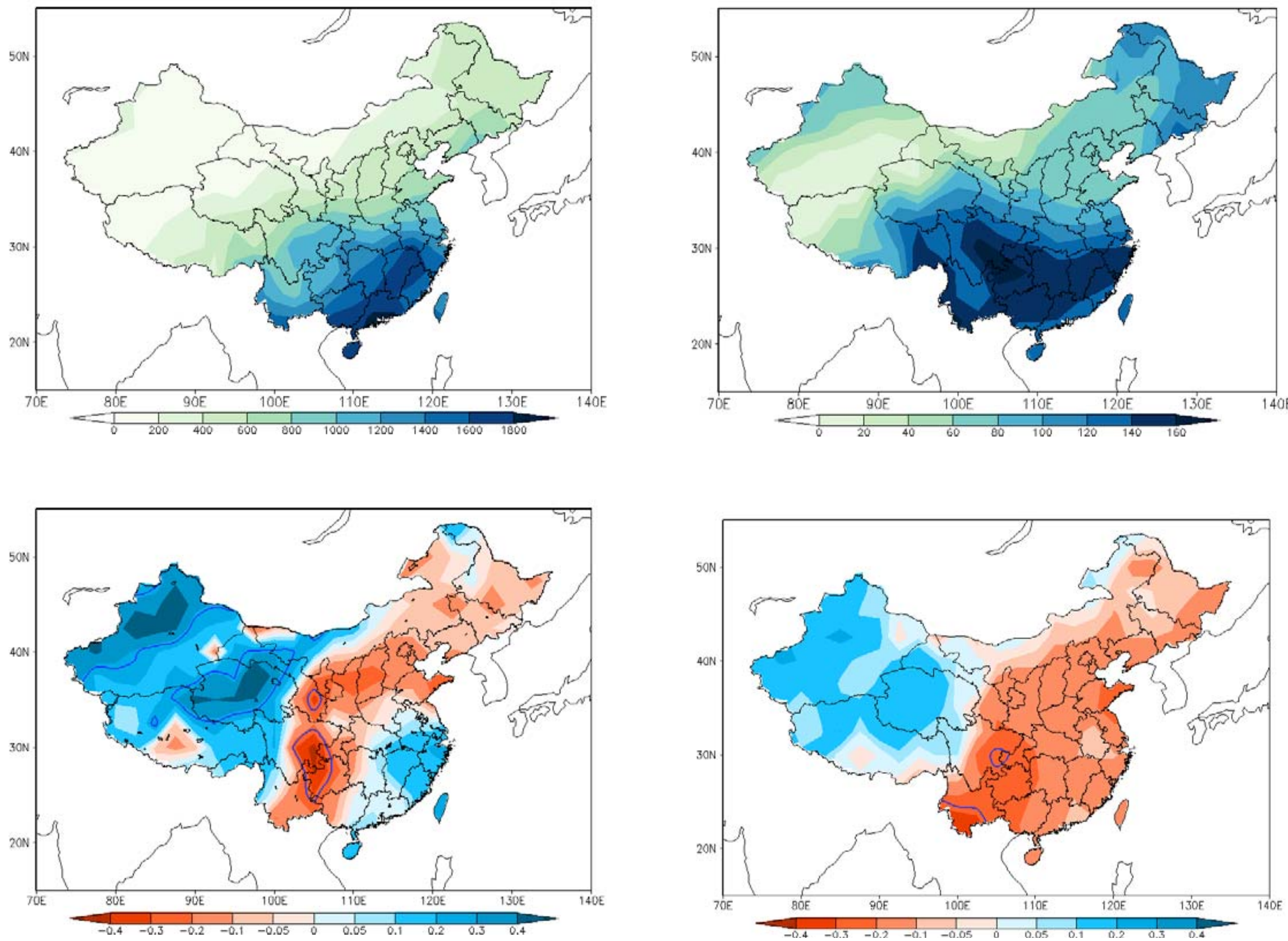


Annual rainfall and rainy day in China

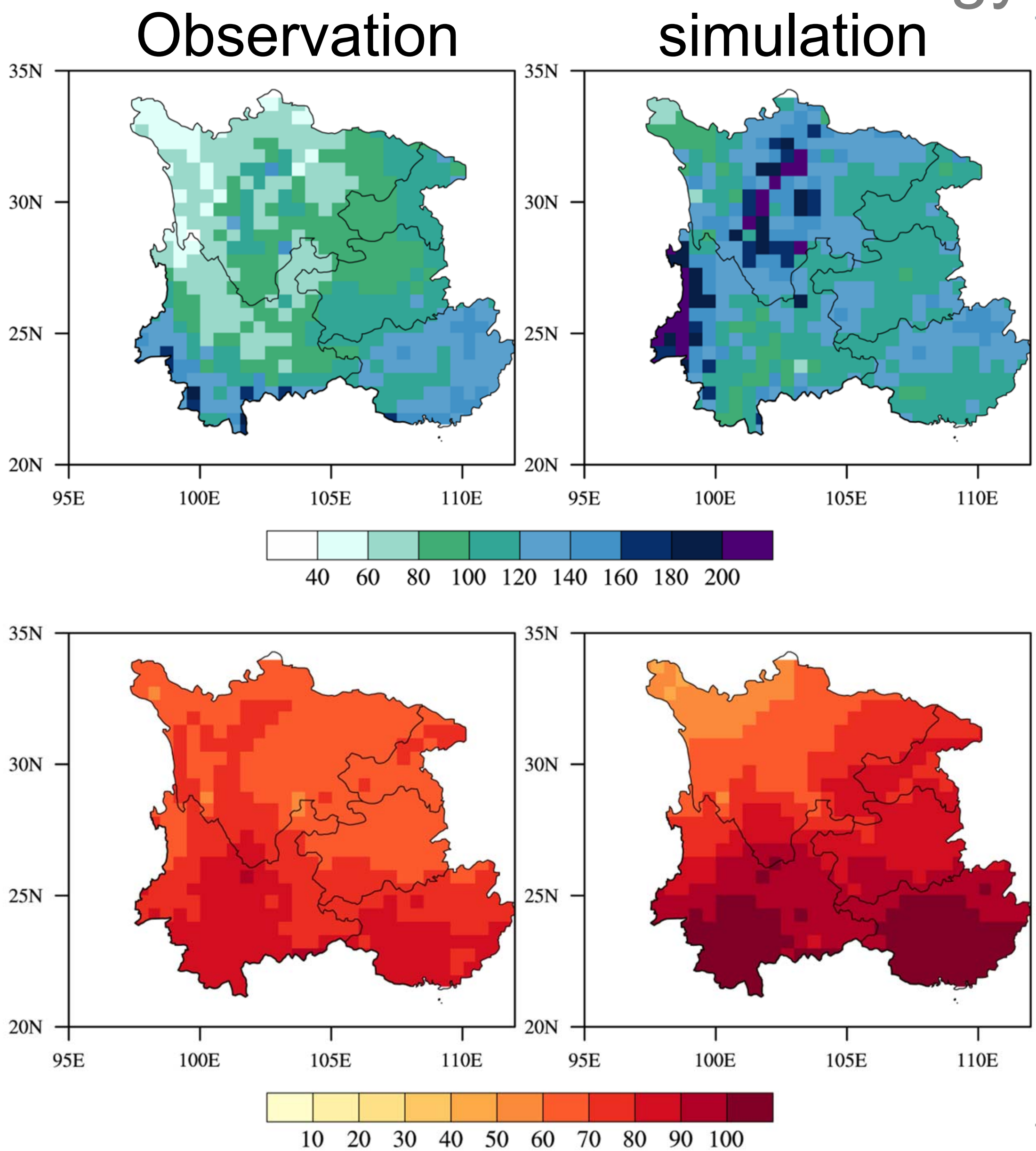
Annual rainfall | Annual rainy day

Climate mean

Trend



Model evaluation—climatology



precipitation

PET