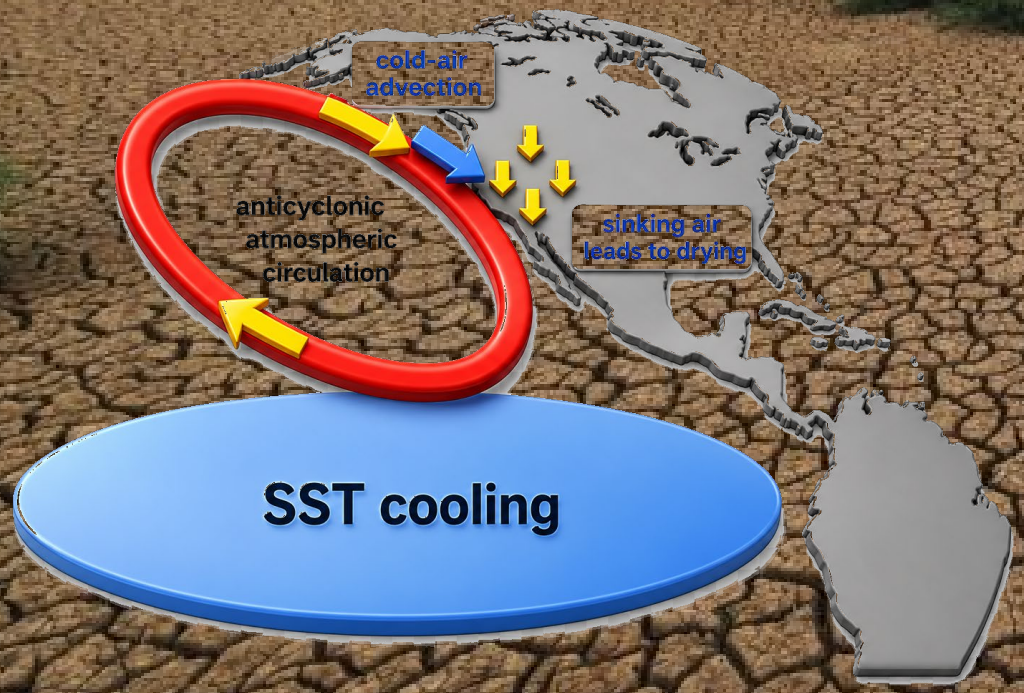
Regional drying over the Western U.S. driven by enhanced atmospheric subsidence amid global moistening from 1980 to 2020

Qinghua Ding (UCSB), Tiffany Shaw(U Chicago), Hailan Wang(CPC), Ian Baxter(U Chicago), Jiang Zhu (NCAR)

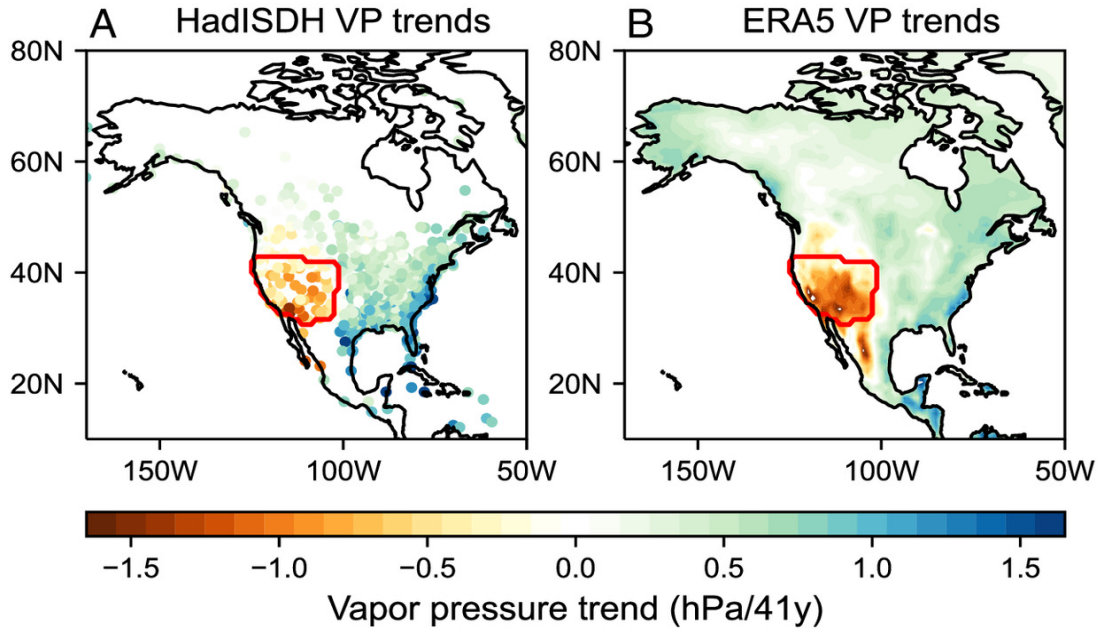


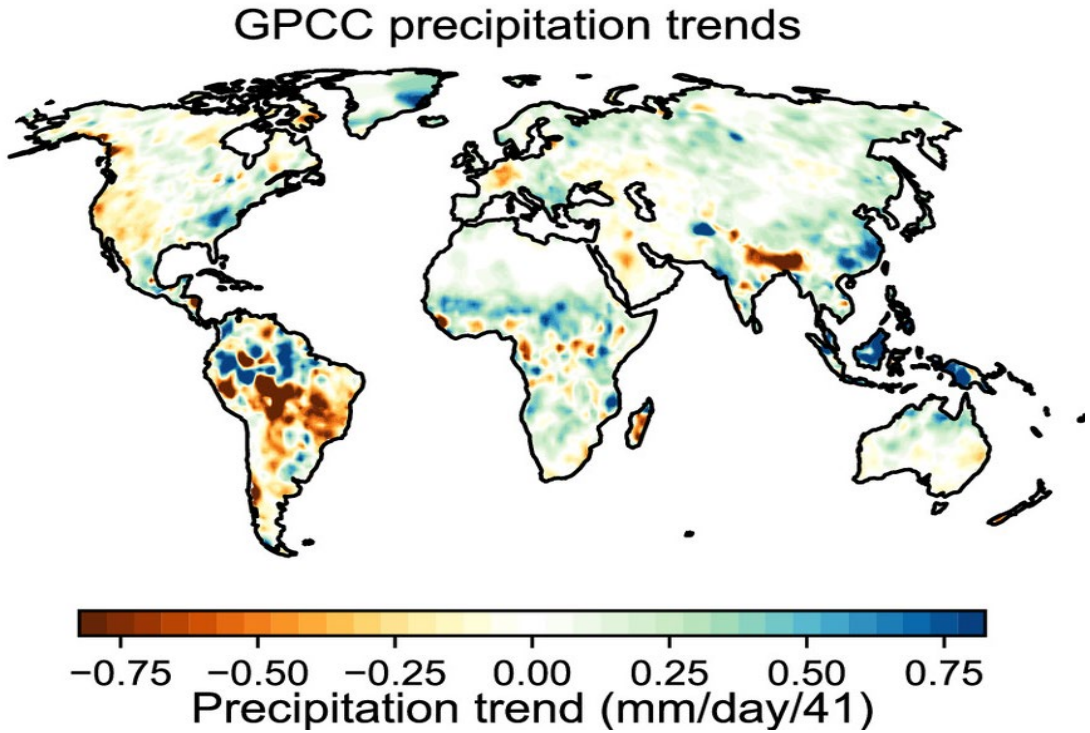
CLIMATE PROGRAM OFFICE

CVP Climate Variability and Predictability

Regional drying across multiple dimensions over the Western U.S from 1980 to 2020

Trends of annual mean fields from 1980 to 2020

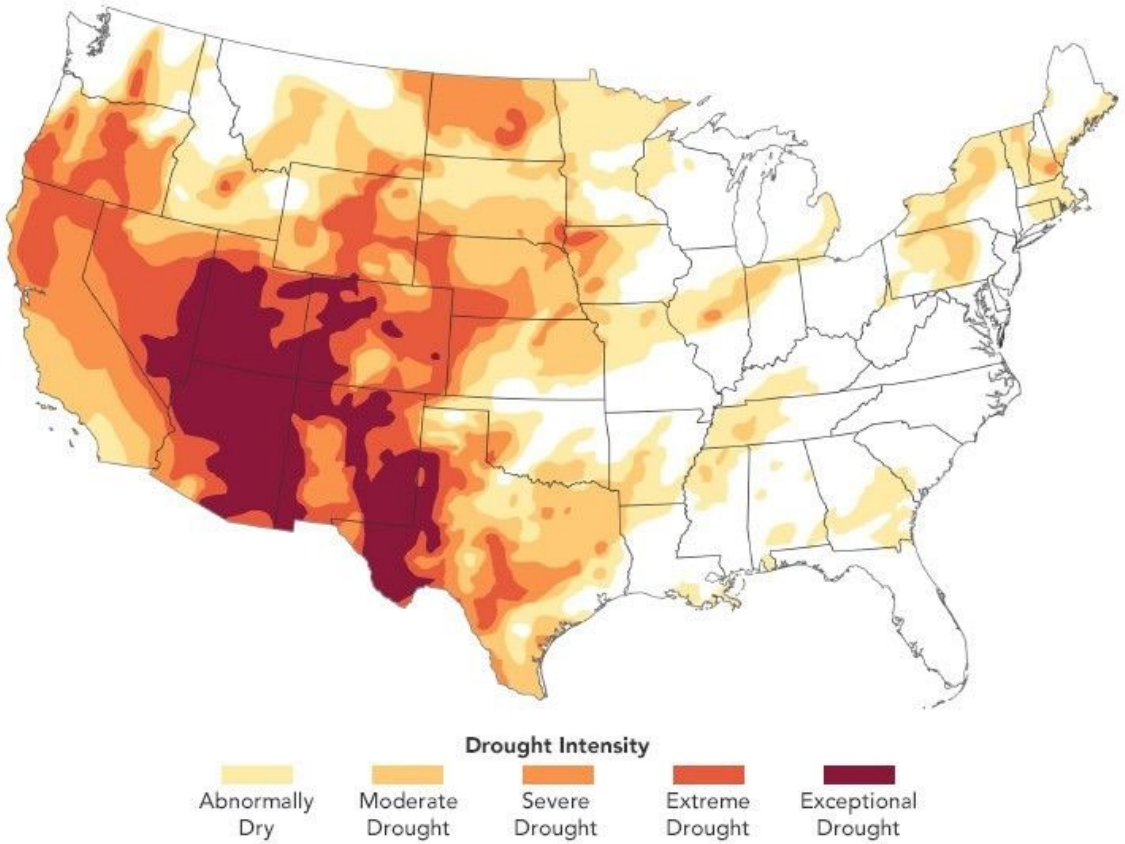




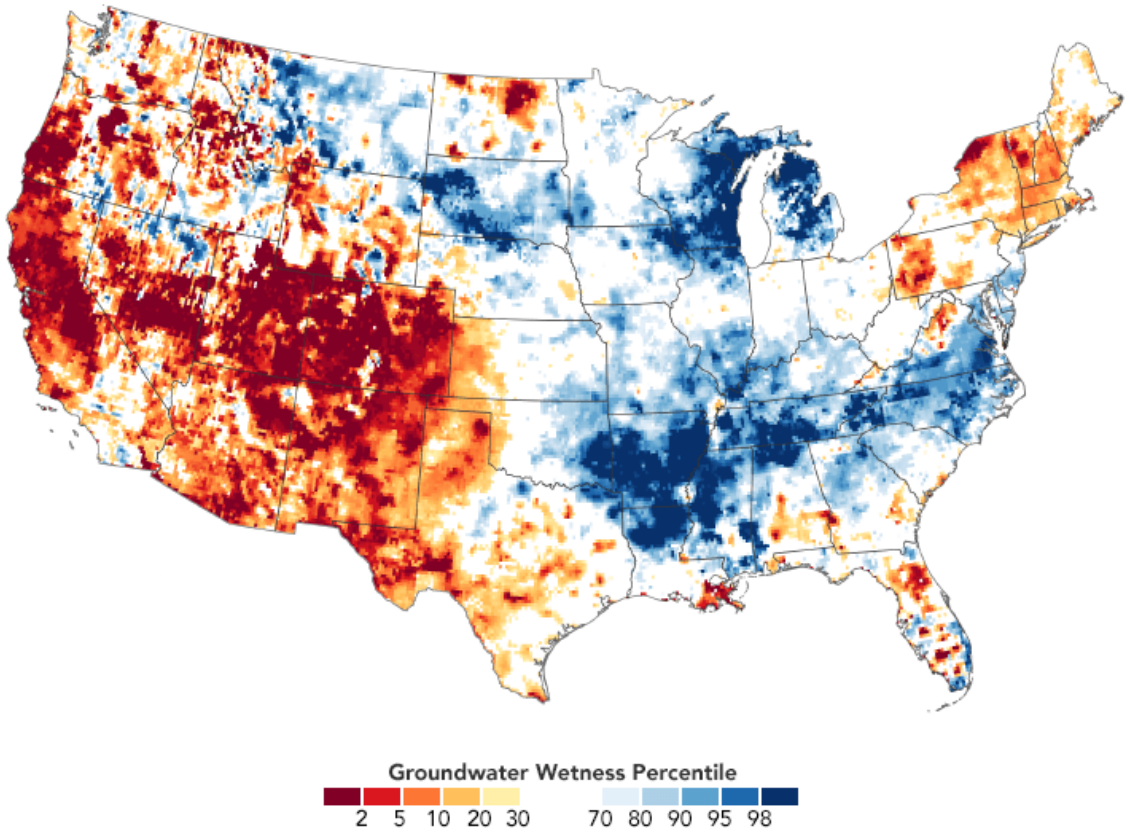
Simpson et al. 2024

The Drying U.S. West

Drought Monitor on 12/8, 2020.



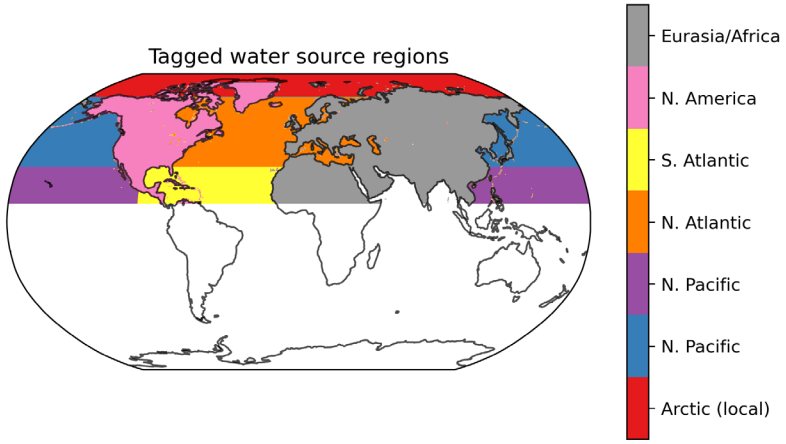
Shallow groundwater storage (GRACE-FO) as of 12/7, 2020

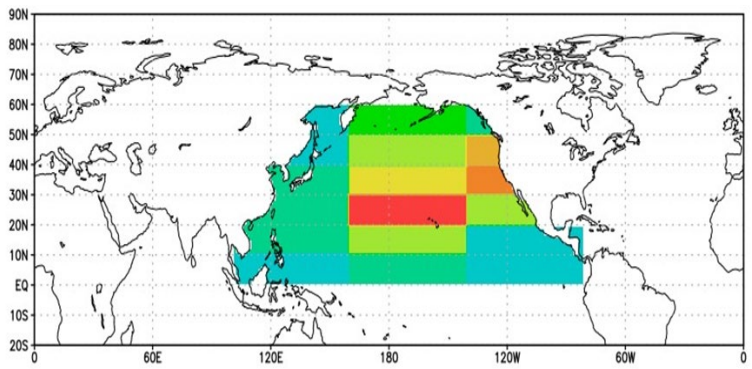


NASA Science

A new tool providing problem-solving capabilities

Flexible in designing our tagging domains





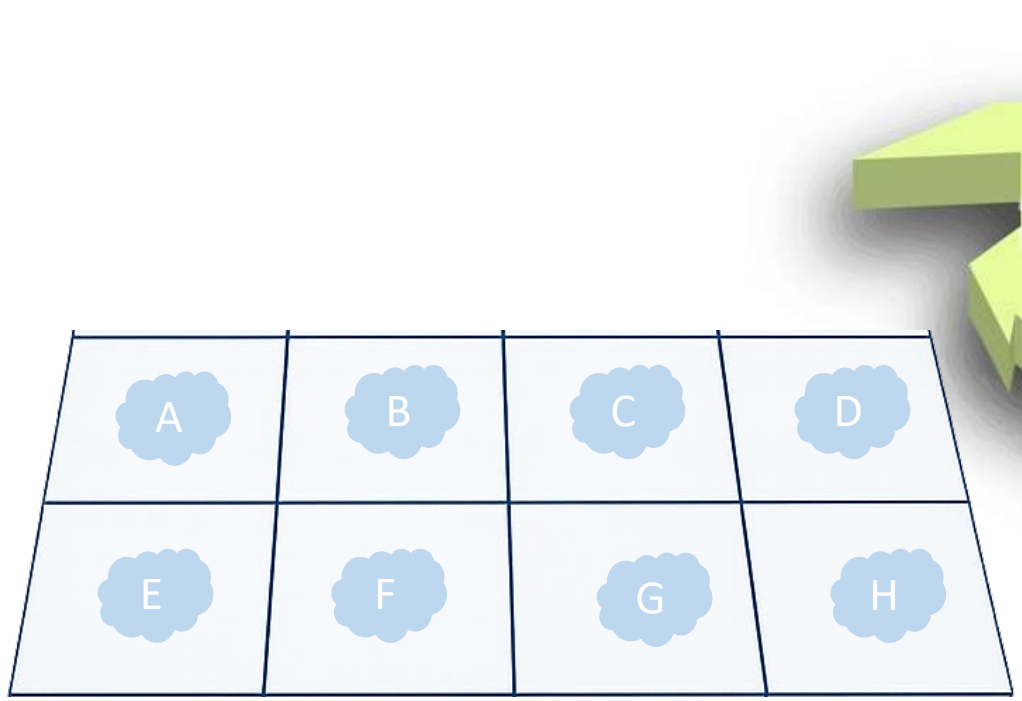
iCAM5 water tagging + nudging

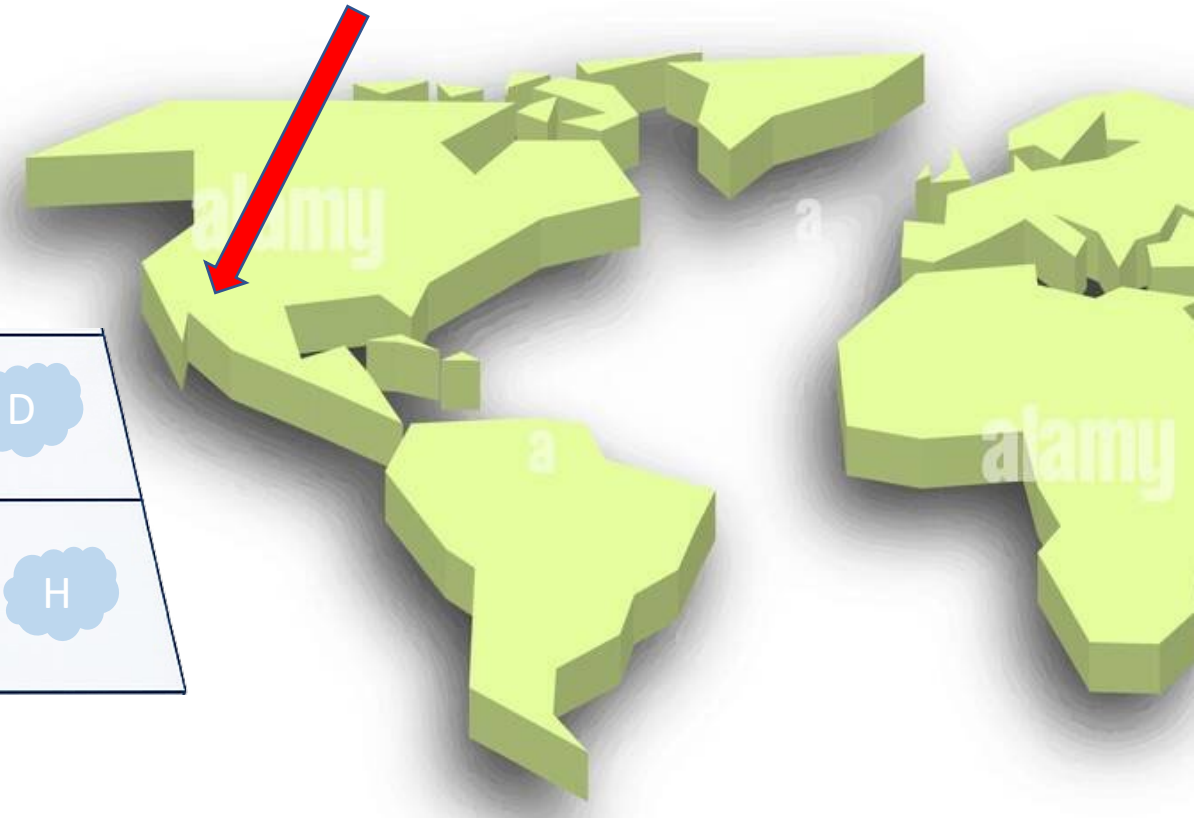
- AMIP-style
  - ERA5 SST/SEAICE (1980-2020)
- Fixed/Varying CO2 concentrations
- ERA5 U, V, T (1980-2020)
- 1 or 2-degree resolution

Goals:

- Replicate hydrological changes from observations using nudging & prescribed boundary conditions
- Characterize variability and trends in local vs. remote moisture contributions to atmospheric humidity and precipitation changes

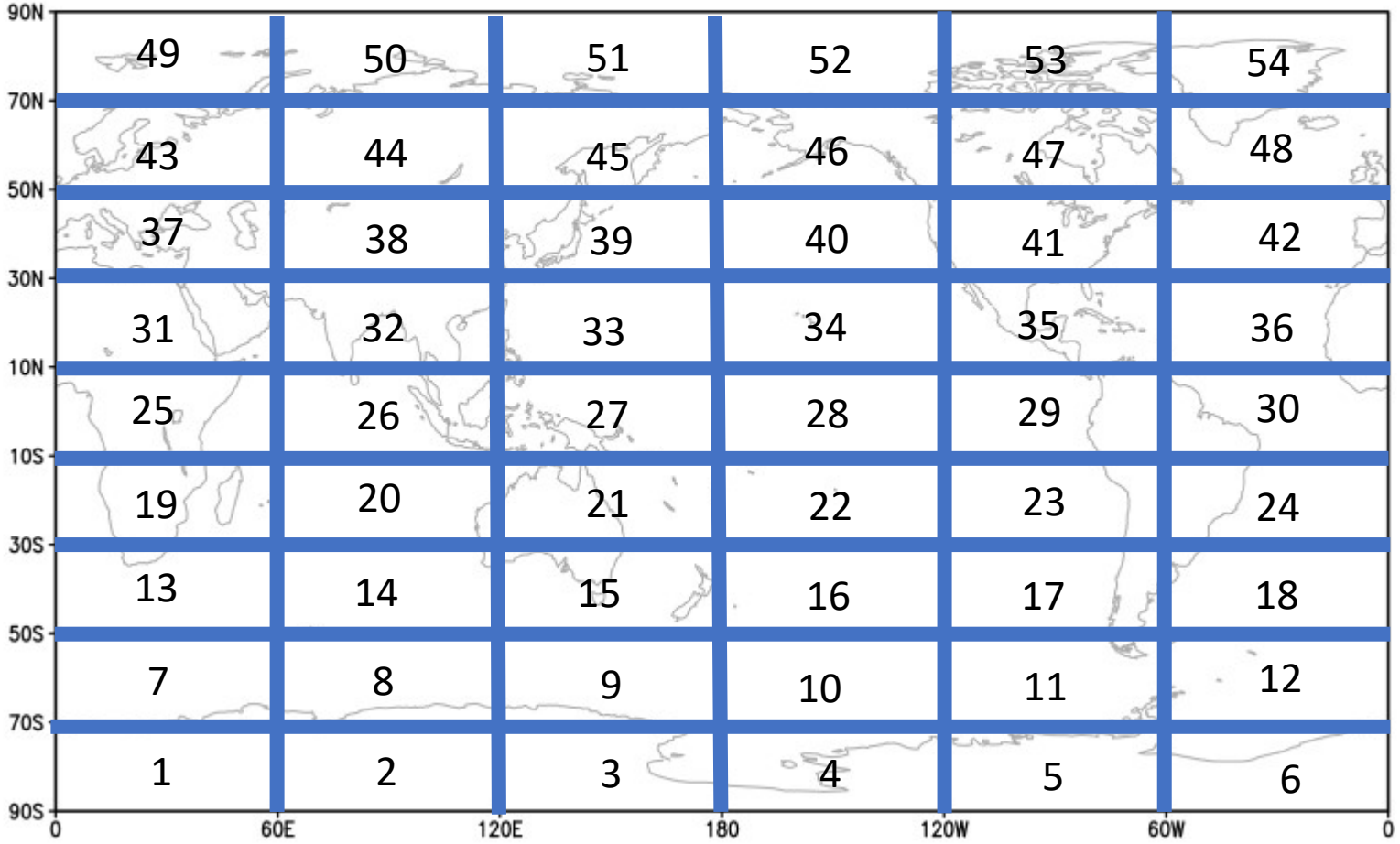
How does it work?



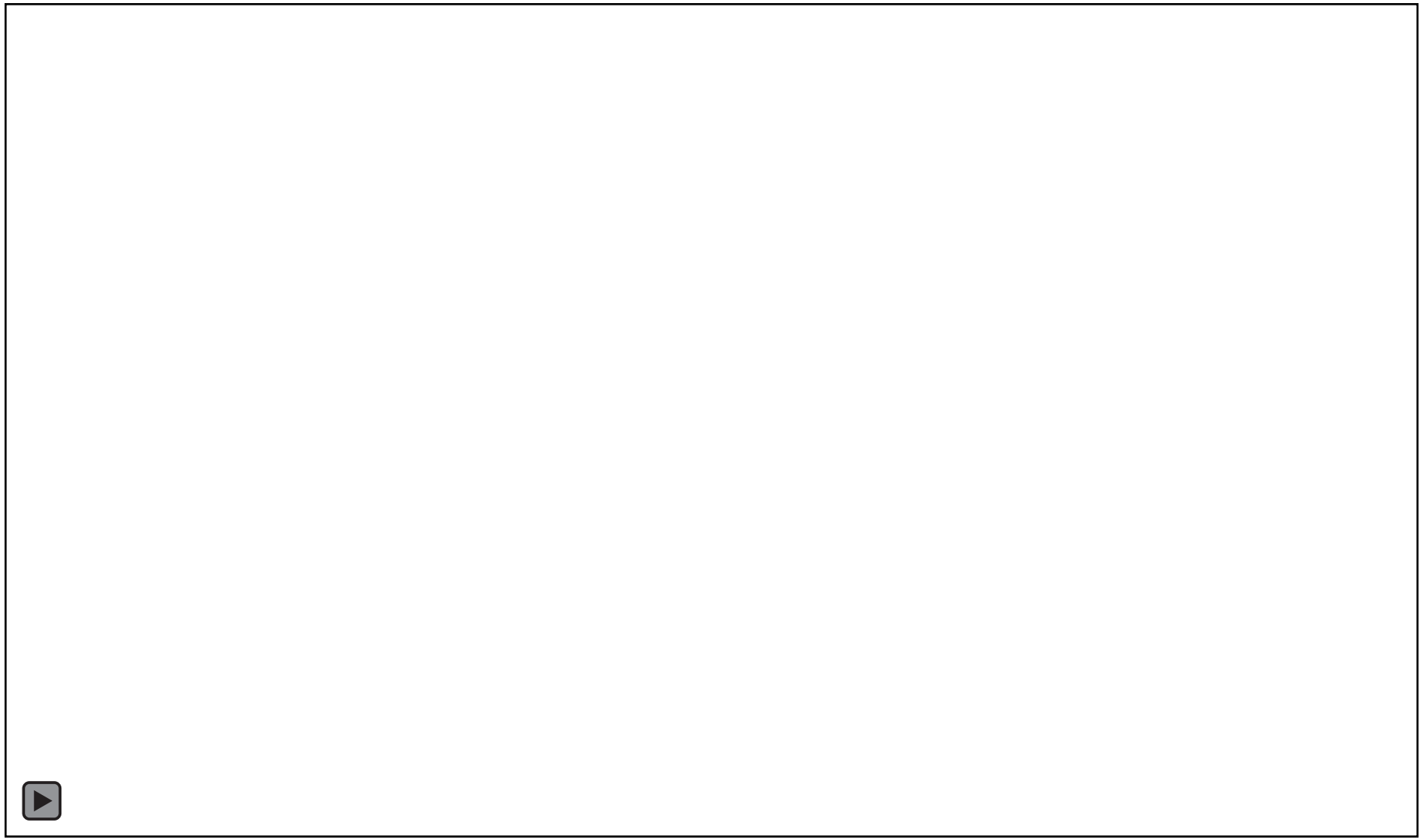


Experiment Design

A set of tagging with seamless global coverage (2-degree resolution)



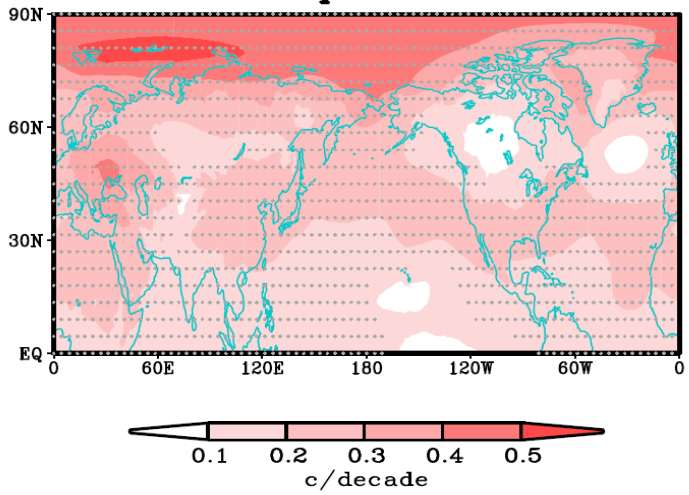
Contribution of each tagging domain to total precipitation in climatology (1980 to 2020)



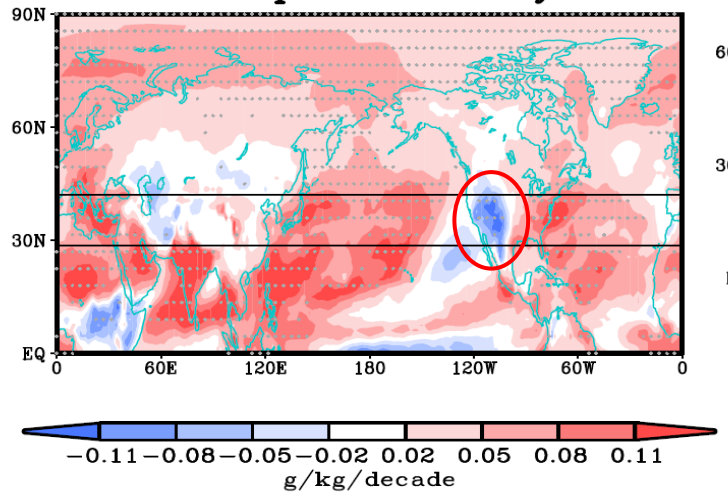
“Moistening hole”: regional drying over the western U.S. amid global moistening from 1980 to 2020

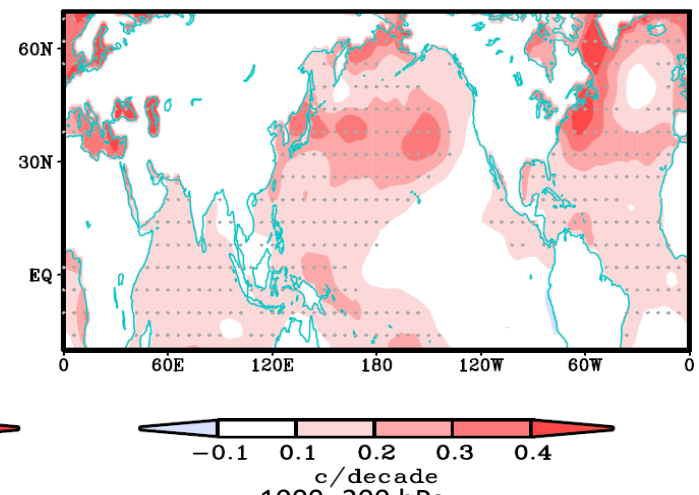
Linear trends of annual mean fields from 1980 to 2020 in ERA5

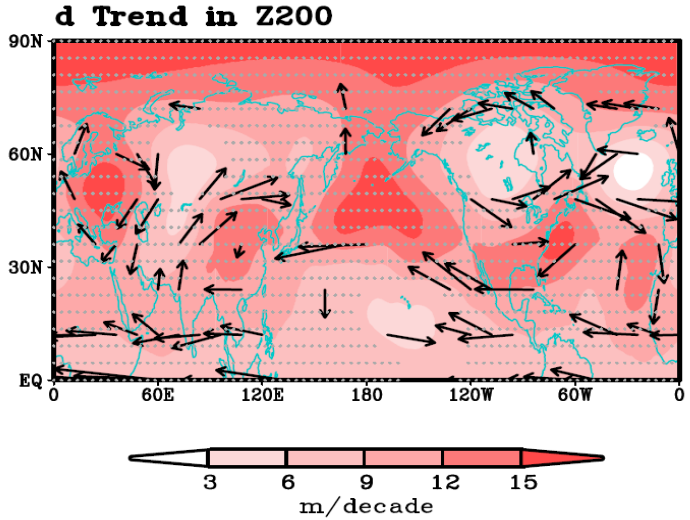
1000- 200 hPa

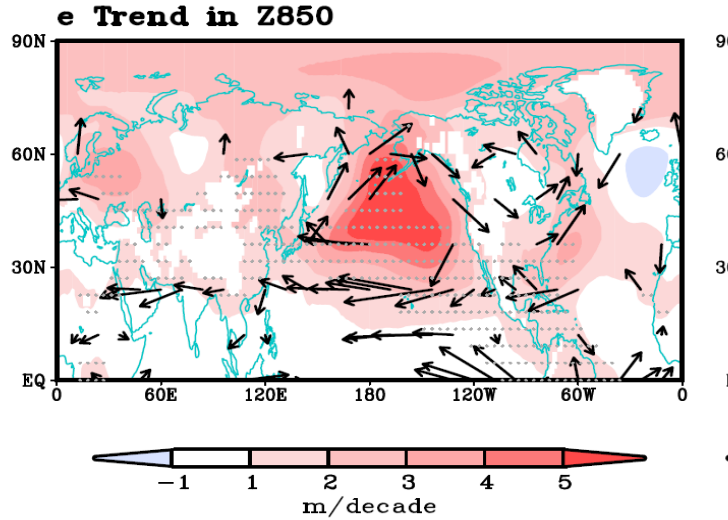


1000-650hPa

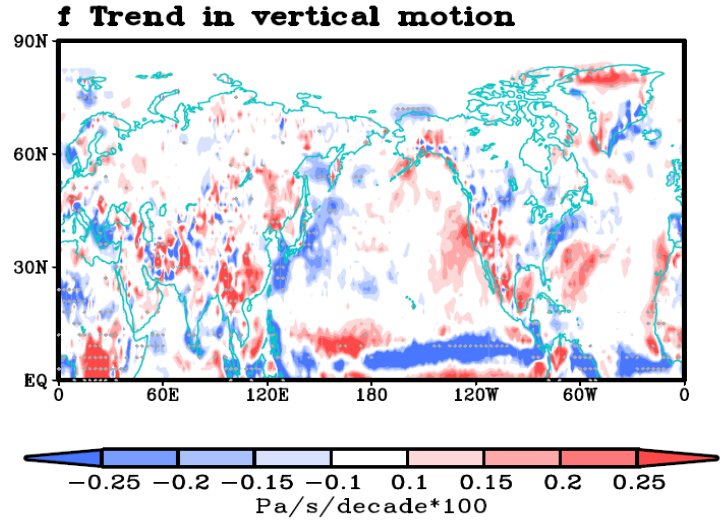




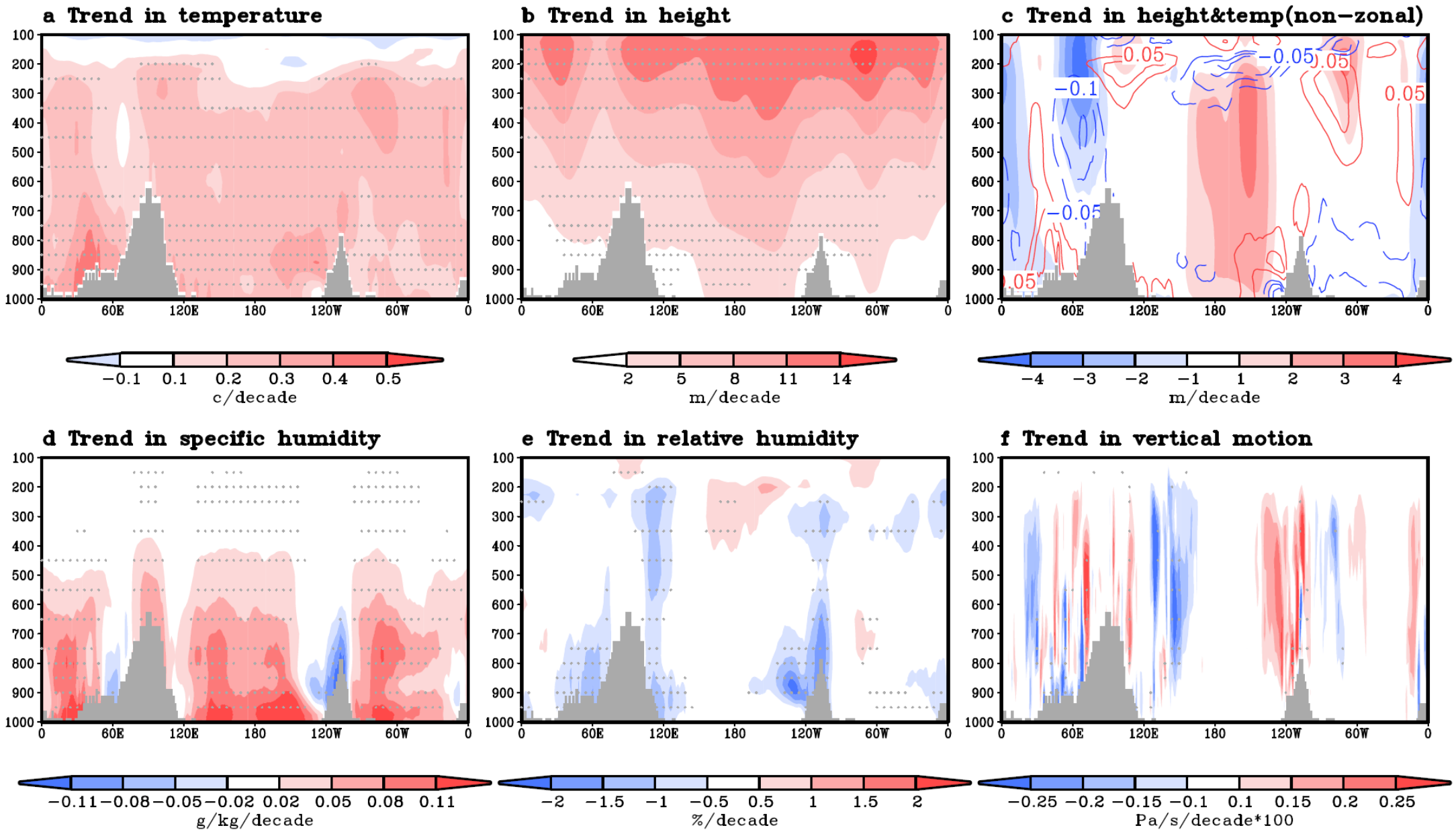




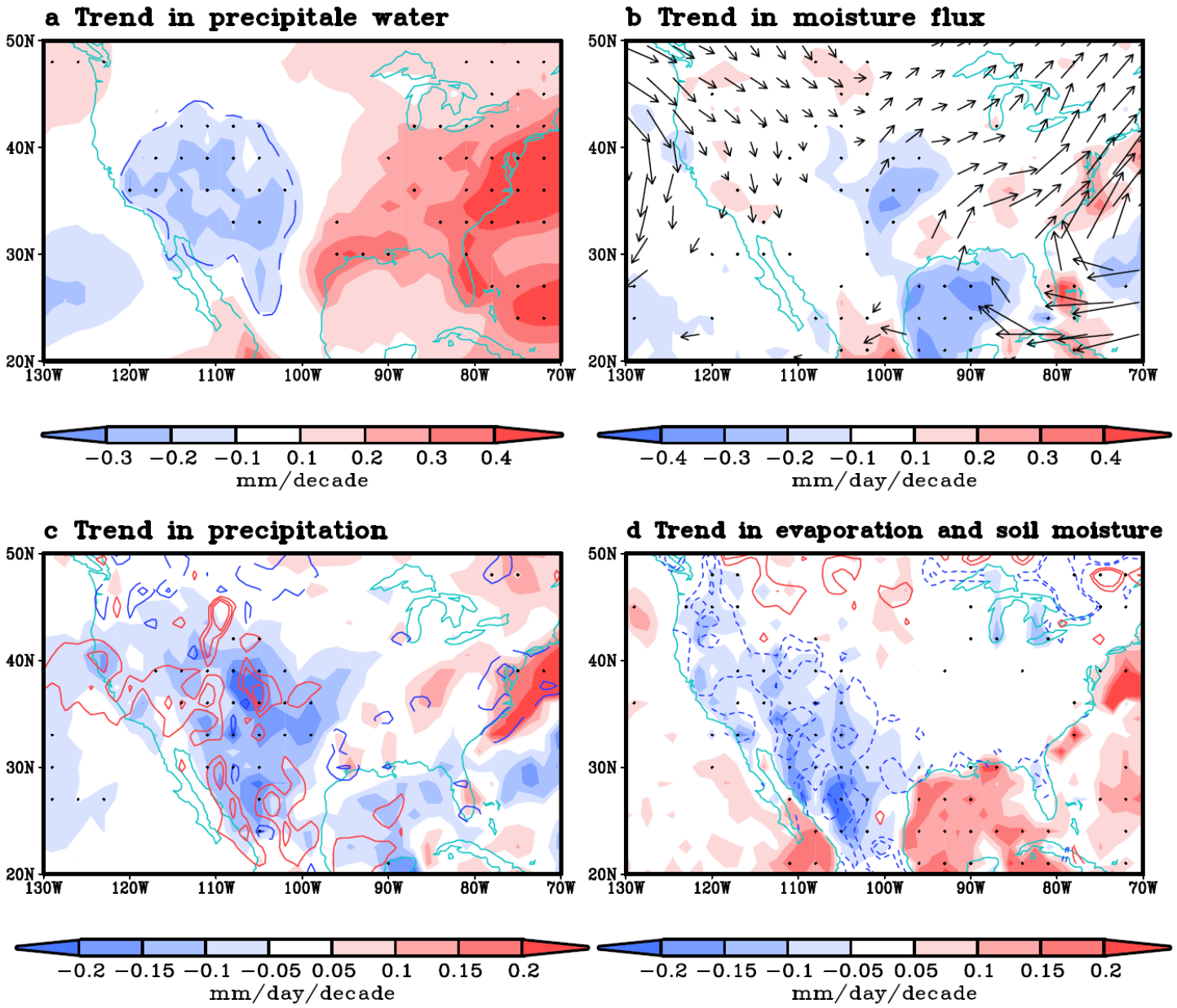
1000- 200 hPa



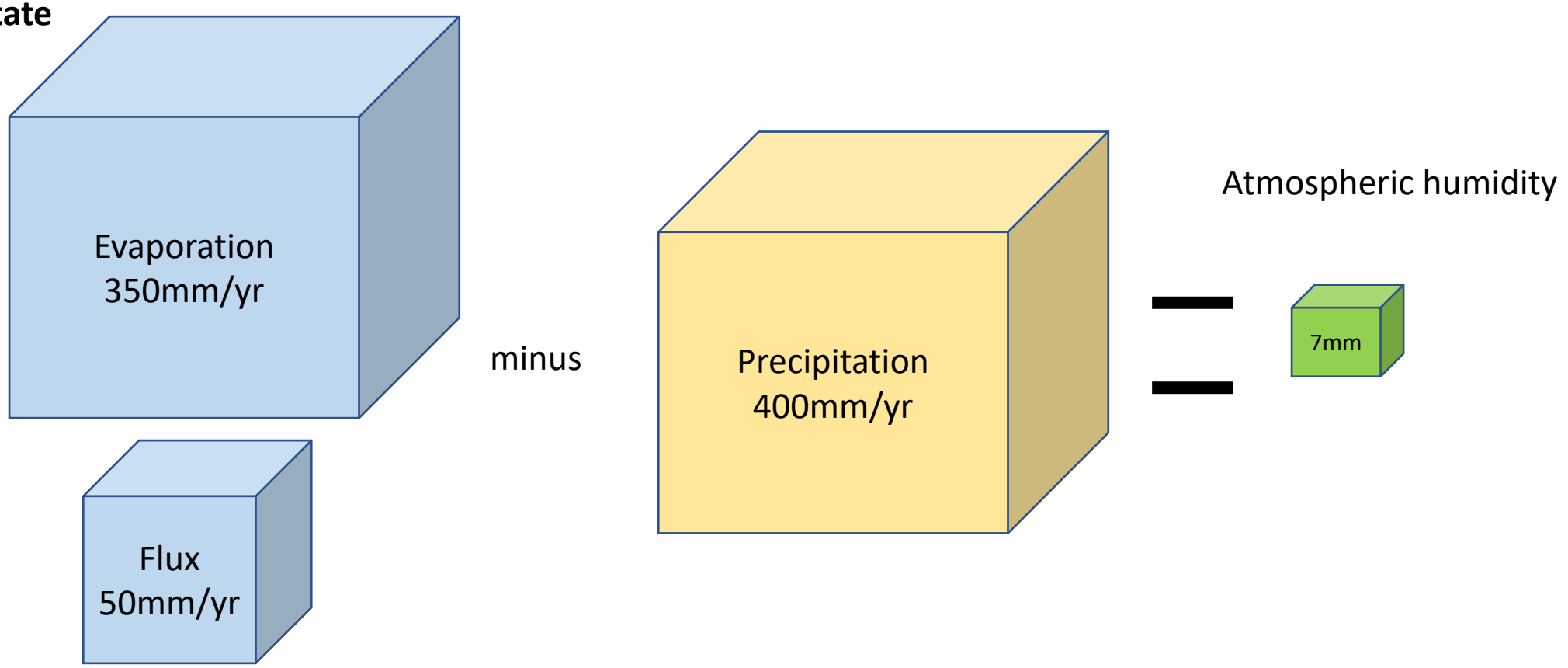
Linear trends of annual mean fields (vertical transect along 30°–40°N) from 1980 to 2020 in ERA5



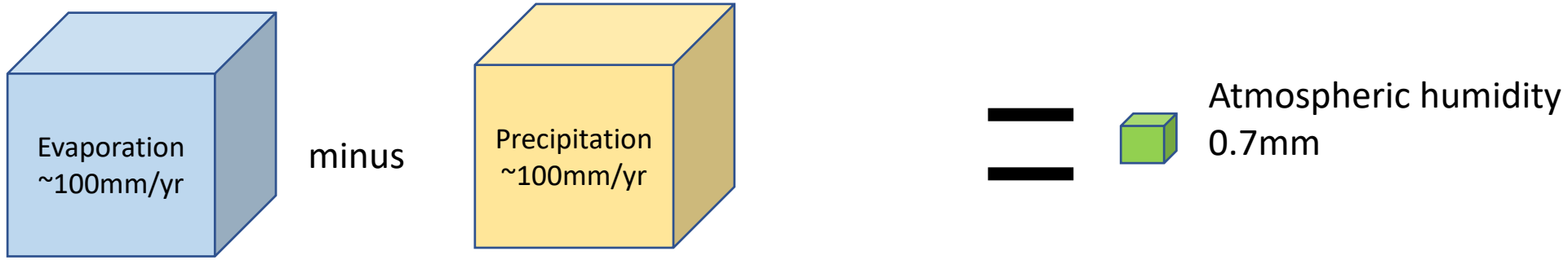
Linear trends of annual mean fields from 1980 to 2020 in ERA5



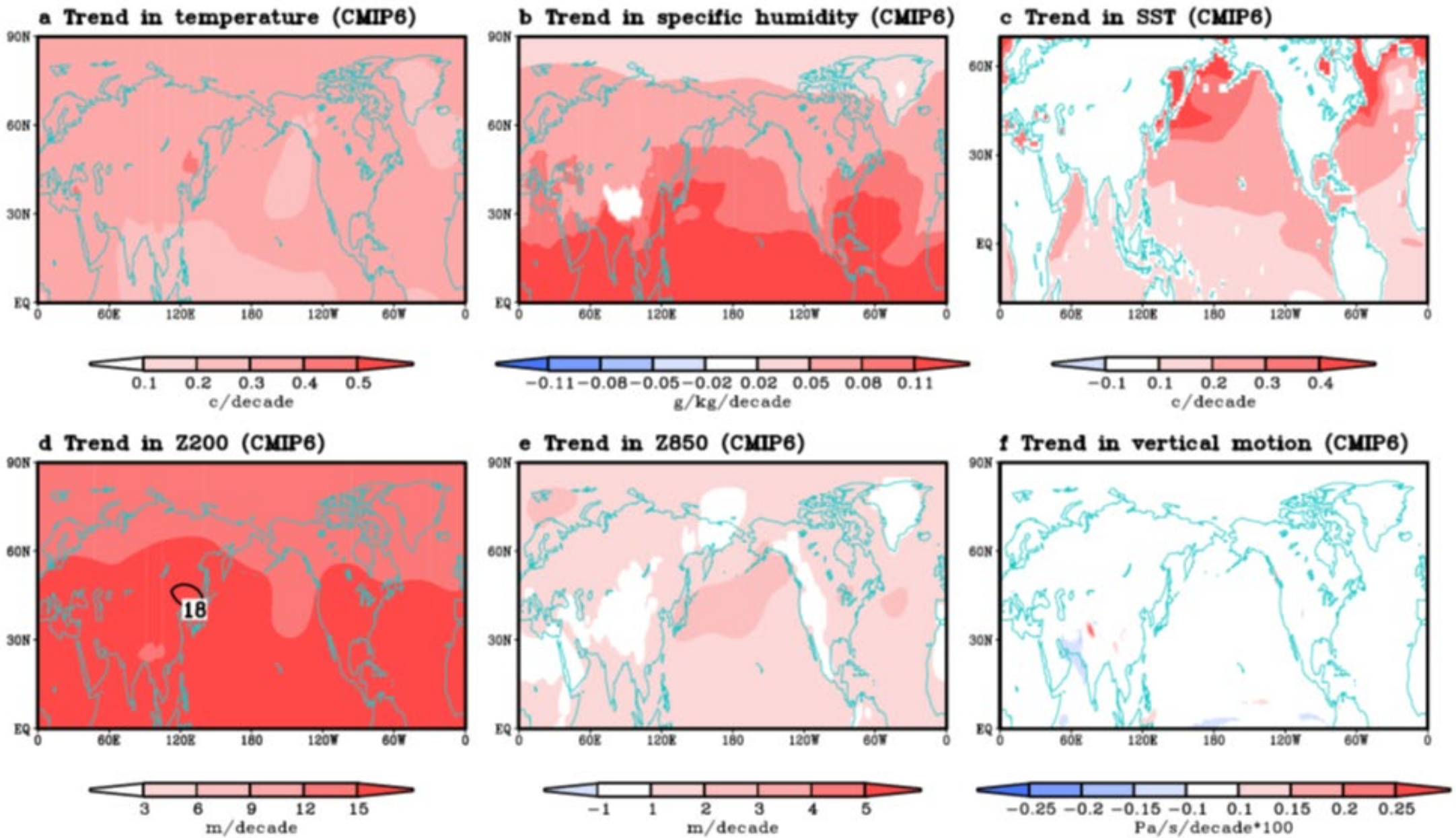
Mean state



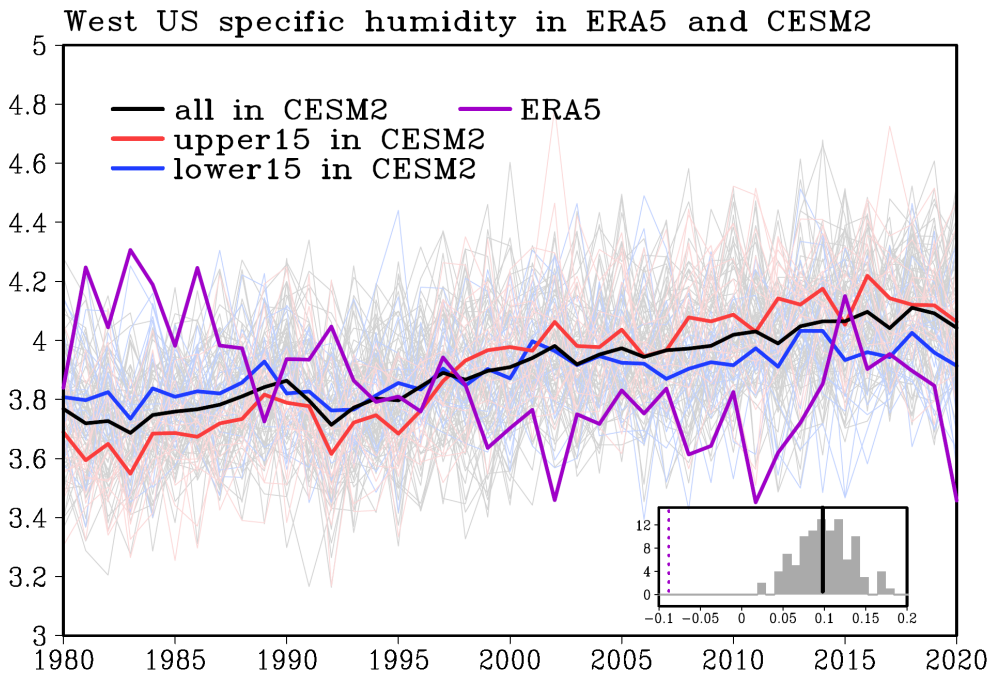
41-yr drying trends from 1980 to 2020 (the reduction part)



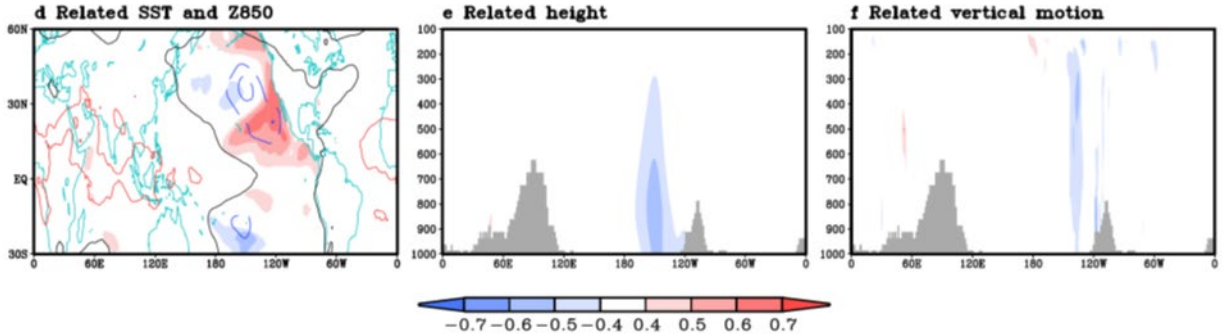
Linear trends of annual mean fields from 1980 to 2020 in CESM2-LEN (anthropogenic forcing)

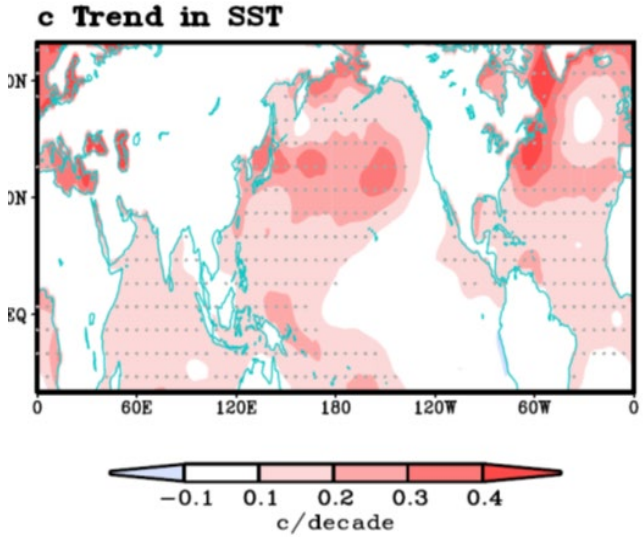


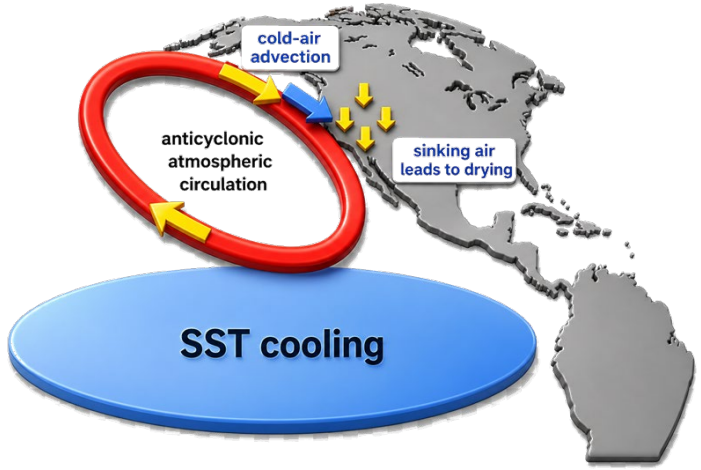
Cooling of tropical eastern Pacific SSTs may contribute to the development of the MH.



MH related large scale patterns in ERA5 (detrended)

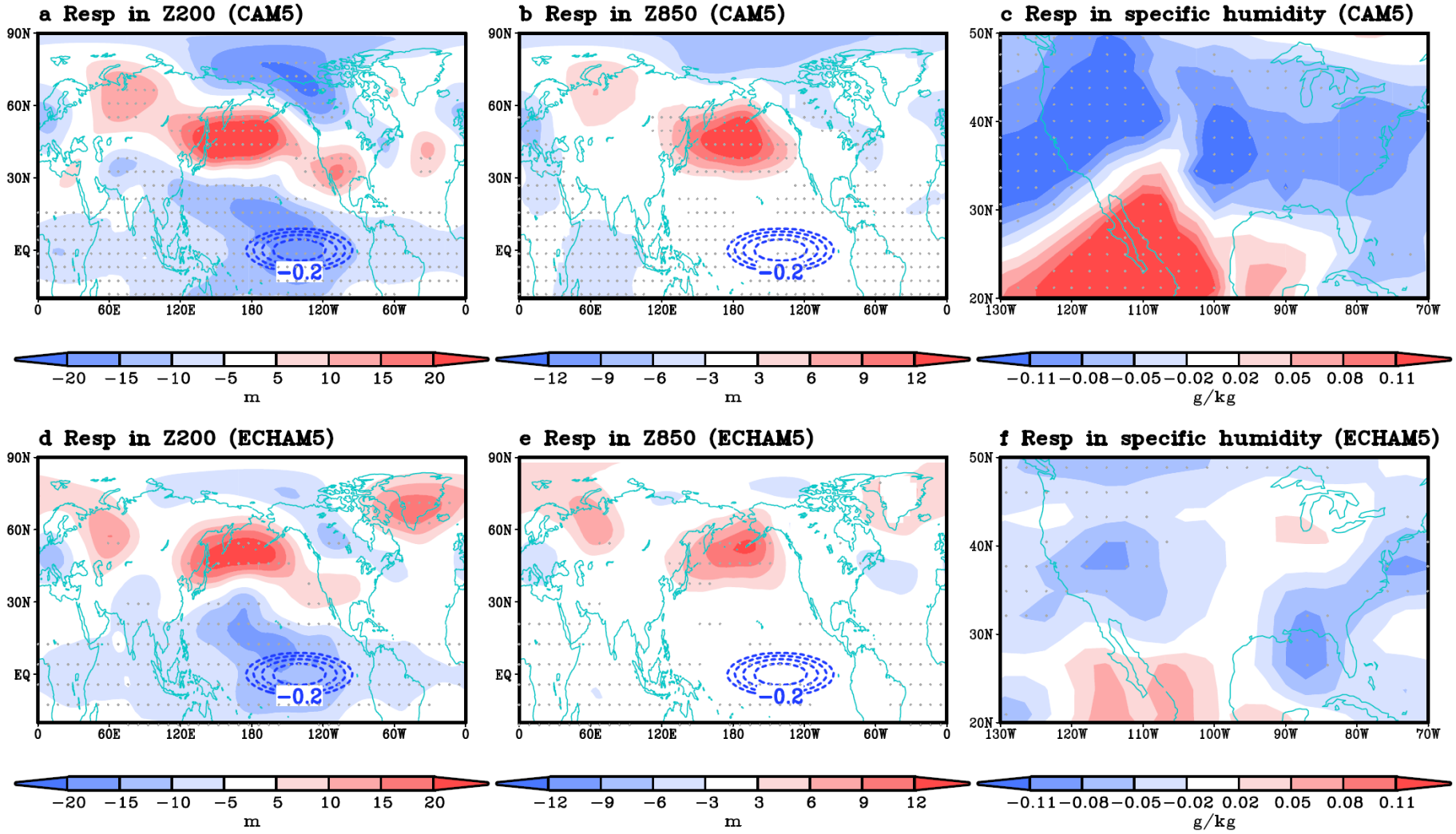






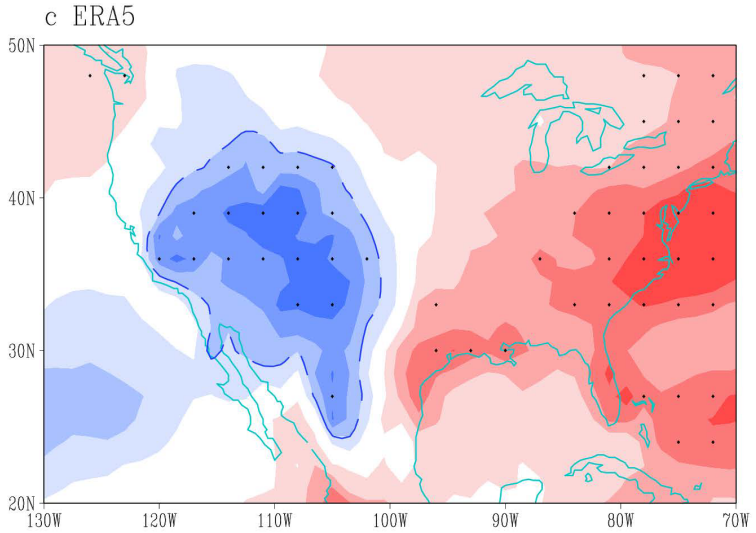
Two AMIP runs support the role of tropical cooling in forming the MH.

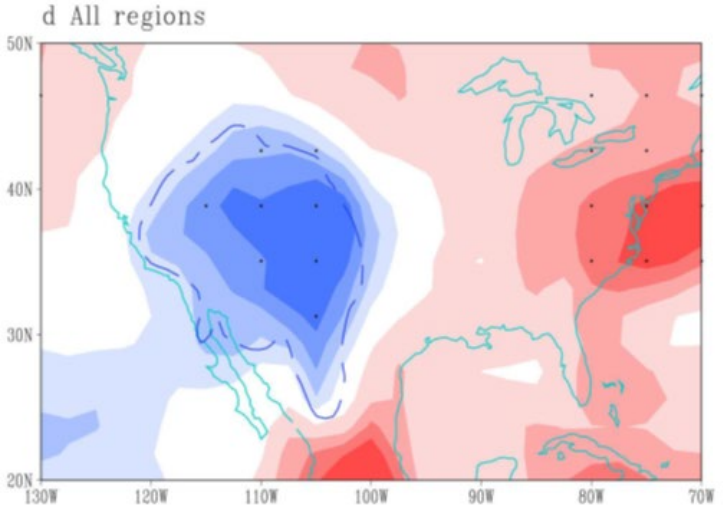
SST run minus control run (annual mean fields, 40 yr)

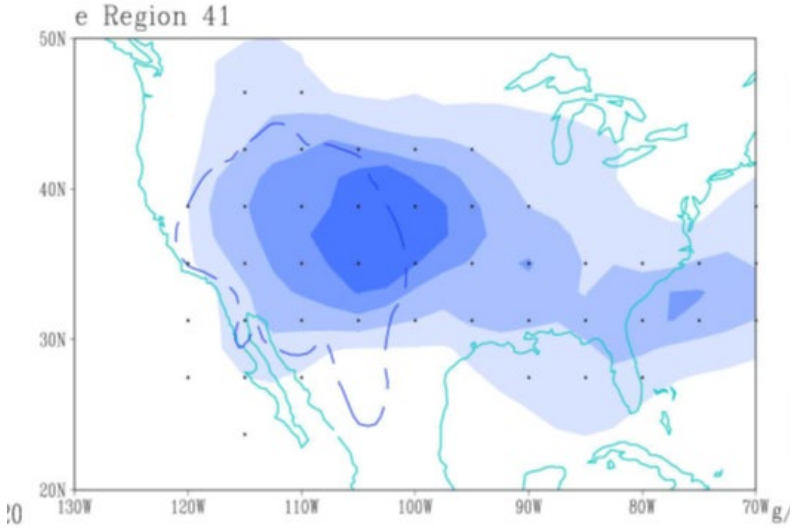


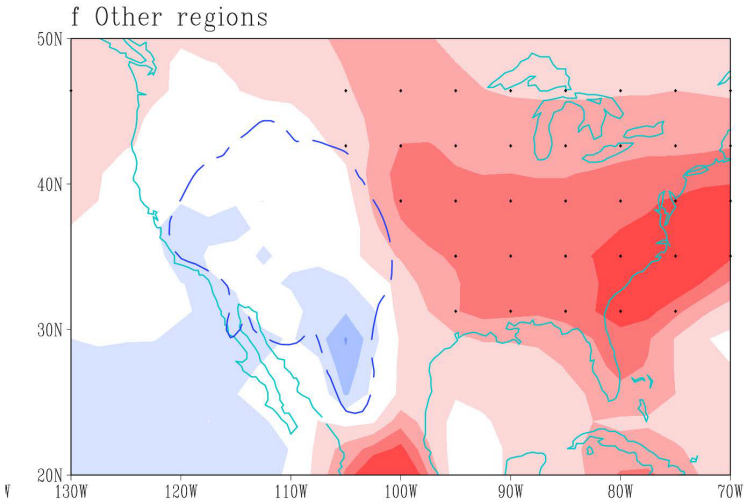
What can we learn from our nudging-tagging simulations?

Linear trends of annual mean specific humidity from 1980 to 2020 (1000-650hPa)

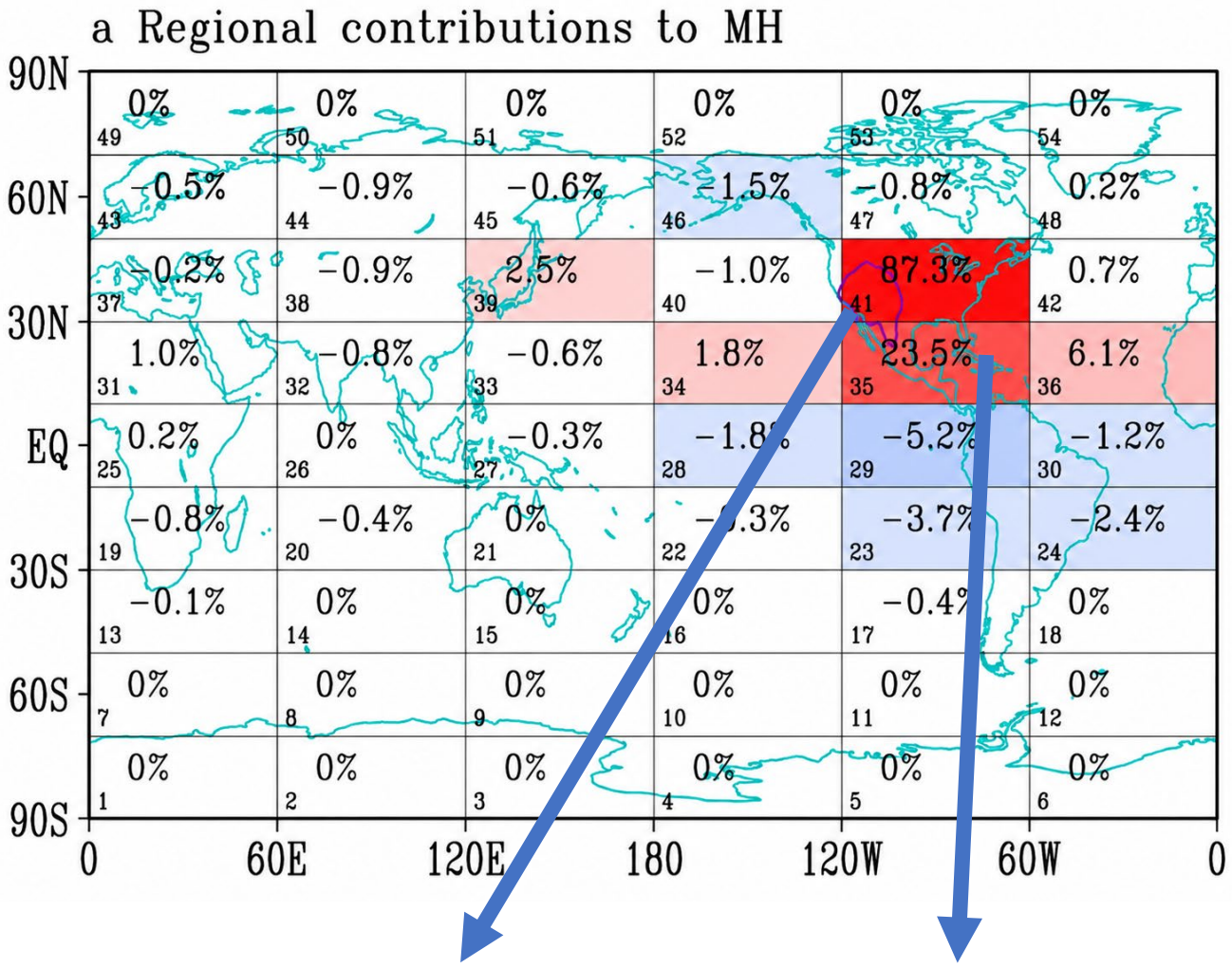






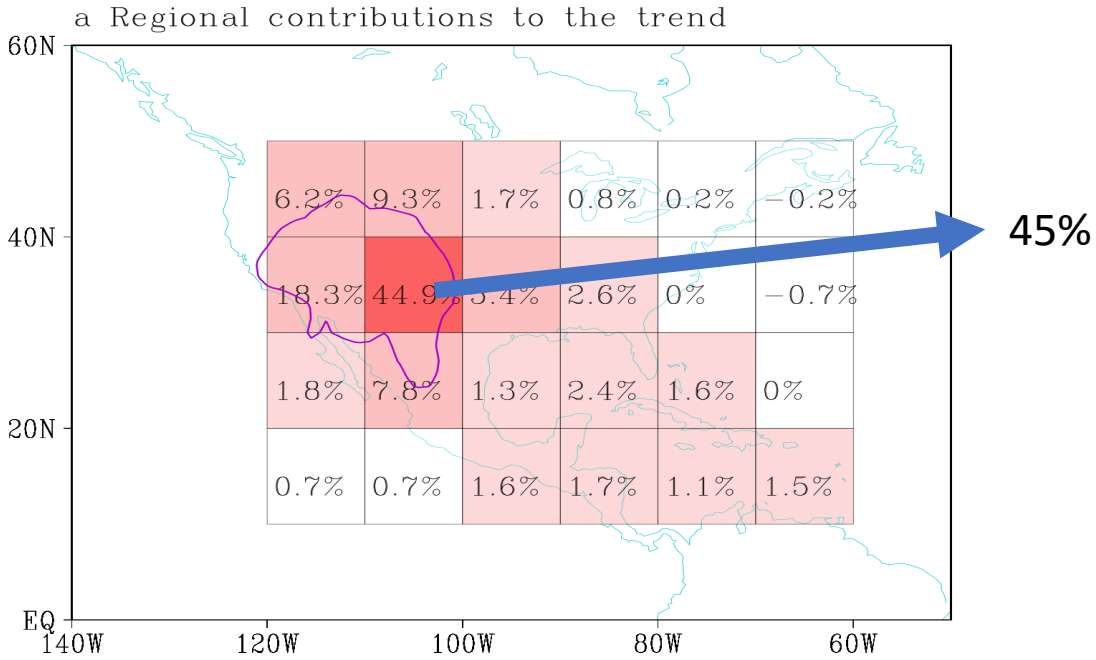


Reduced local evapotranspiration matters most for the MH (long term trends)

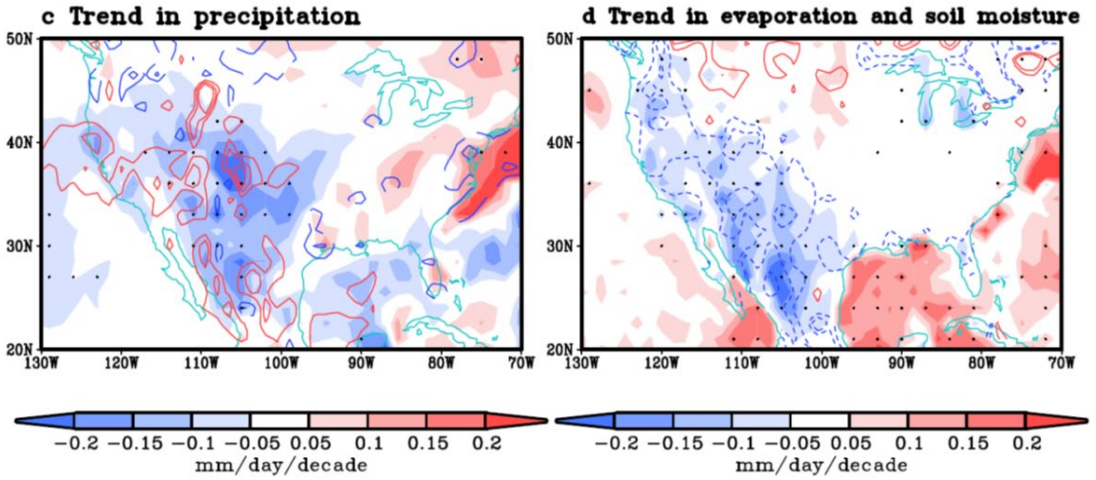


Region 41: 87.3%

Region 35: 23.5%

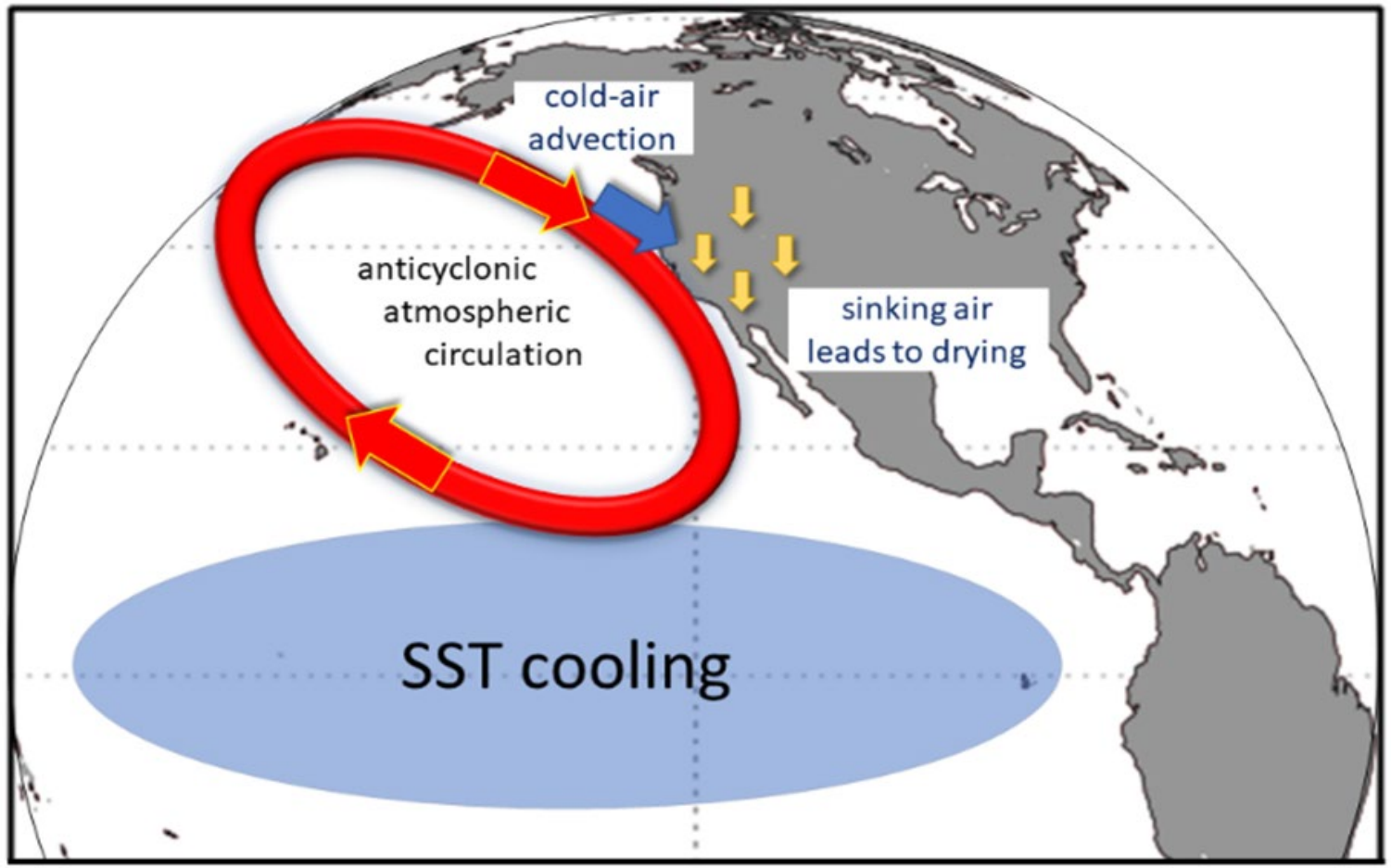


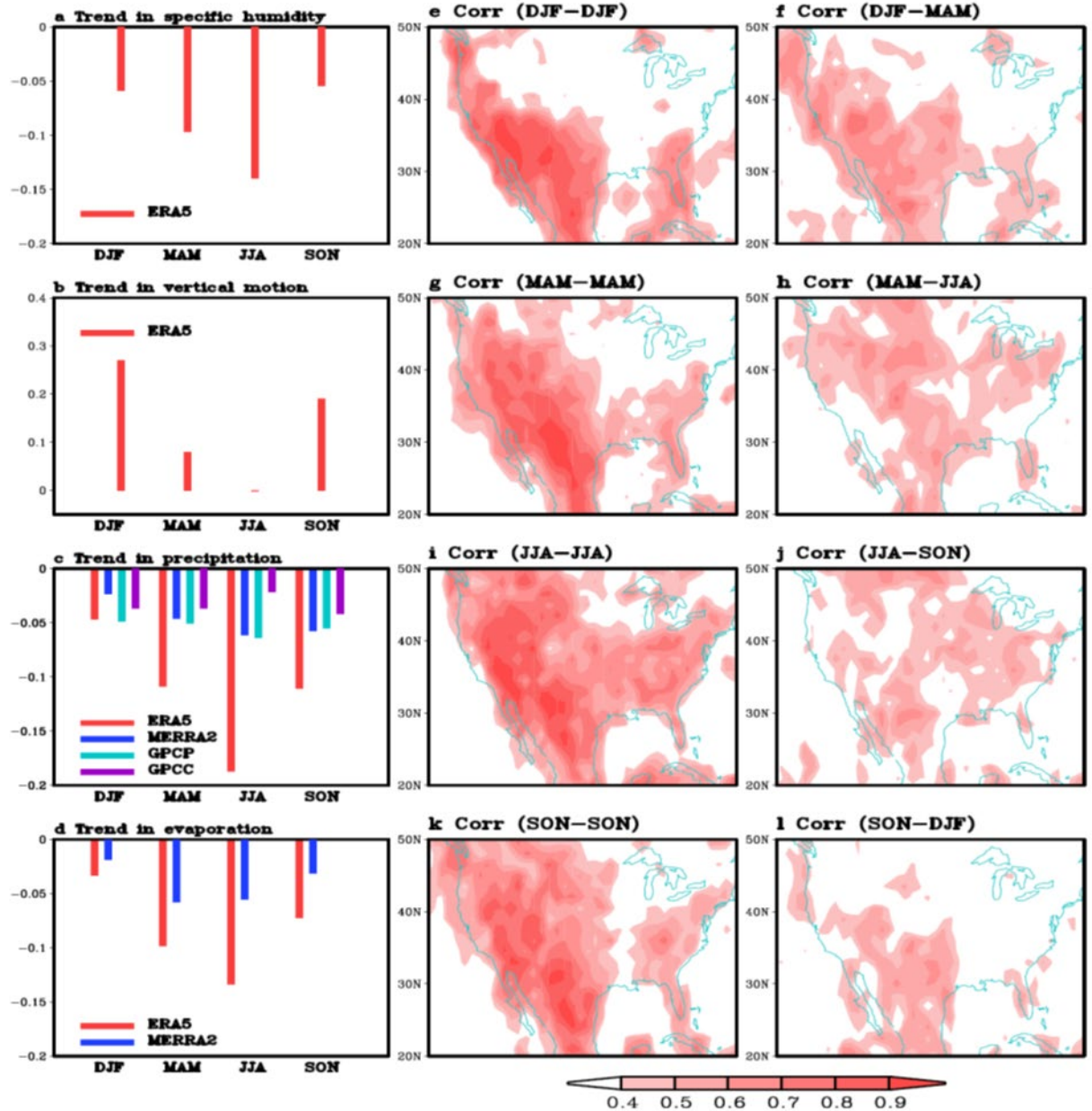
45%



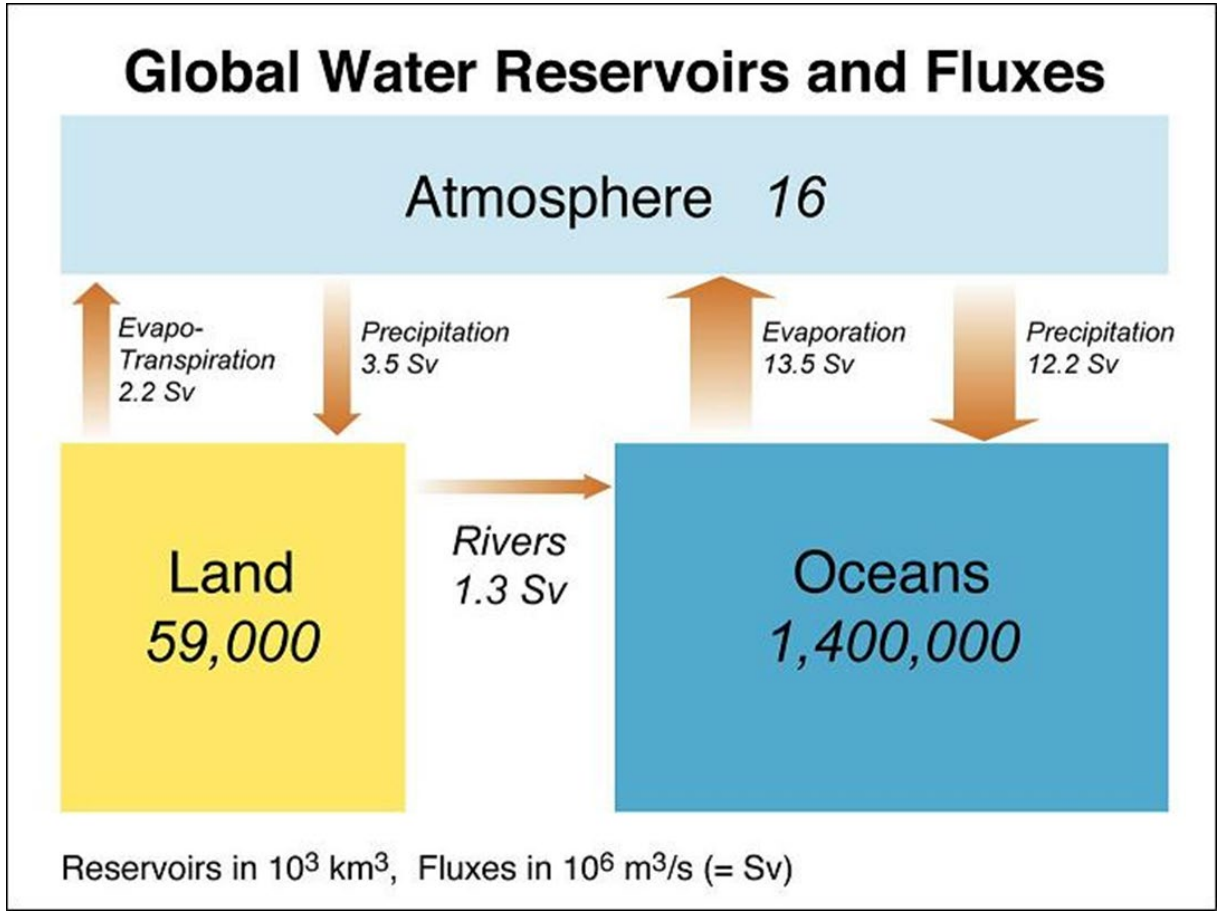
What caused the moistening hole?

Low-frequency changes of atmospheric vertical motion may offer insights
The MH is best viewed as an indicator, rather than a cause, of the broader, multidimensional drought conditions over the Western U.S. in recent decades, which may originate in the tropical Pacific.




a Trend in specific humidity
ERA5
DJF
MAM
JJA
SON
b Trend in vertical motion
ERA5
c Trend in precipitation
ERA5
MERRA2
GPCP
GPCC
d Trend in evaporation
ERA5
MERRA2
e Corr (DJF−DJF)
f Corr (DJF−MAM)
g Corr (MAM−MAM)
h Corr (MAM−JJA)
i Corr (JJA−JJA)
j Corr (JJA−SON)
k Corr (SON−SON)
l Corr (SON−DJF)
50N
40N
30N
20N
0.4 0.5 0.6 0.7 0.8 0.9

Typical time scales for global horizontal transport in the atmosphere



https://www2.whoi.edu/site/globalwatercycle/