DRY SEASON WATER AVAILABILITY CHANGES ATTRIBUTED TO HUMAN-INDUCED CLIMATE CHANGE

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ETHzürich

CHANGE IN DRY SEASON WATER AVAILABILITY

- Water availability: $P - ET = R + dS/dt$

- Dry season water availability: Month with lowest $P - ET$. $\rightarrow$ one value per year

  - Tropics: minimum of all 12 months.
  - Extratropics (lat>23.5°): minimum of May-Sep in NH and Nov-Mar in SH

- Change in dry season water availability:

$$\Delta(P - ET) = [(P - ET)_{pres} - (P - ET)_{past}] \qquad [mm\ month^{-1}]$$

pres: average from 1985 – 2014
past: average from 1902 – 1950

RECONSTRUCTIONS FROM DATA-DRIVEN MODELS (DDM)

- Observed atmospheric forcing from GSWP-3 (Kim, 2017, DIAS)

- GRUN: Global gridded runoff (Ghiggi et al., 2019, ESSD).

- GRACE-REC: Global gridded terrestrial water storage fluctuations (Humphrey & Gudmundsson, 2019, ESSD).

- Water balance derived water availability estimates:
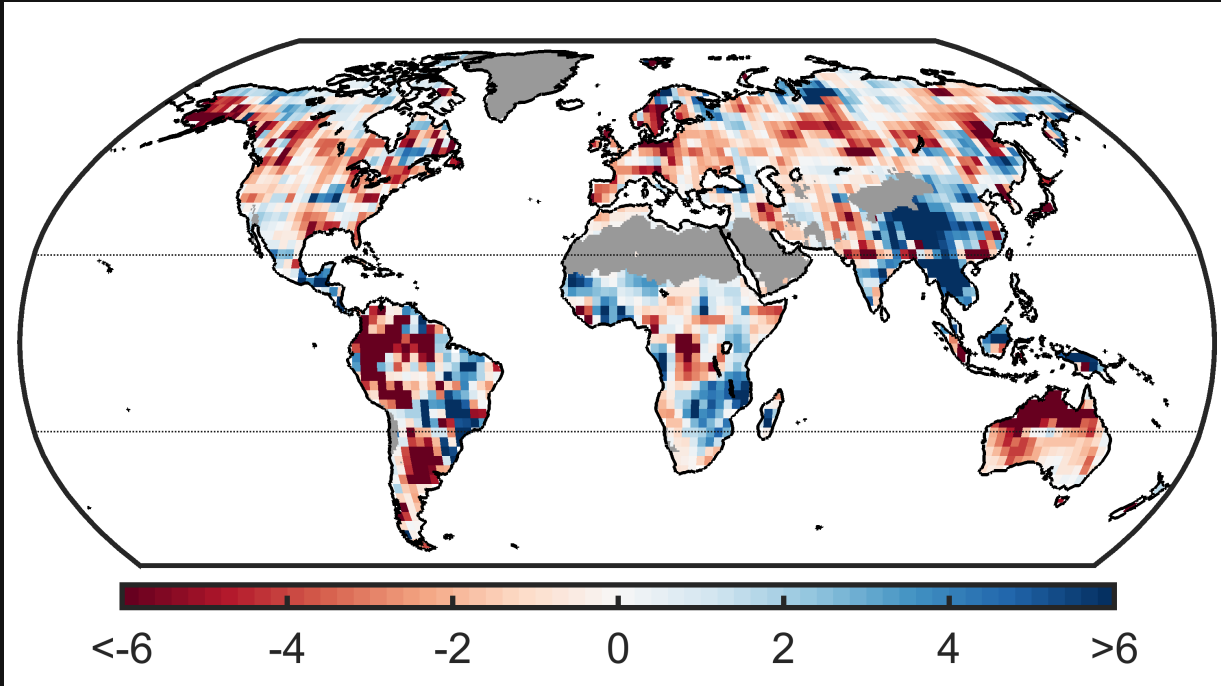
$$R + \Delta TWS = P - ET$$

- Monthly data from 1902 to 2014.

RECONSTRUCTIONS FROM LAND SURFACE MODELS (LSM)

- Observed atmospheric forcing from GSWP-3 (Kim, 2017, DIAS)

- LS3MIP reconstructions:

  ➢ CESM2
  ➢ CMCC-ESM2
  ➢ CNRM-CM6-1
  ➢ CNRM-ESM2-1
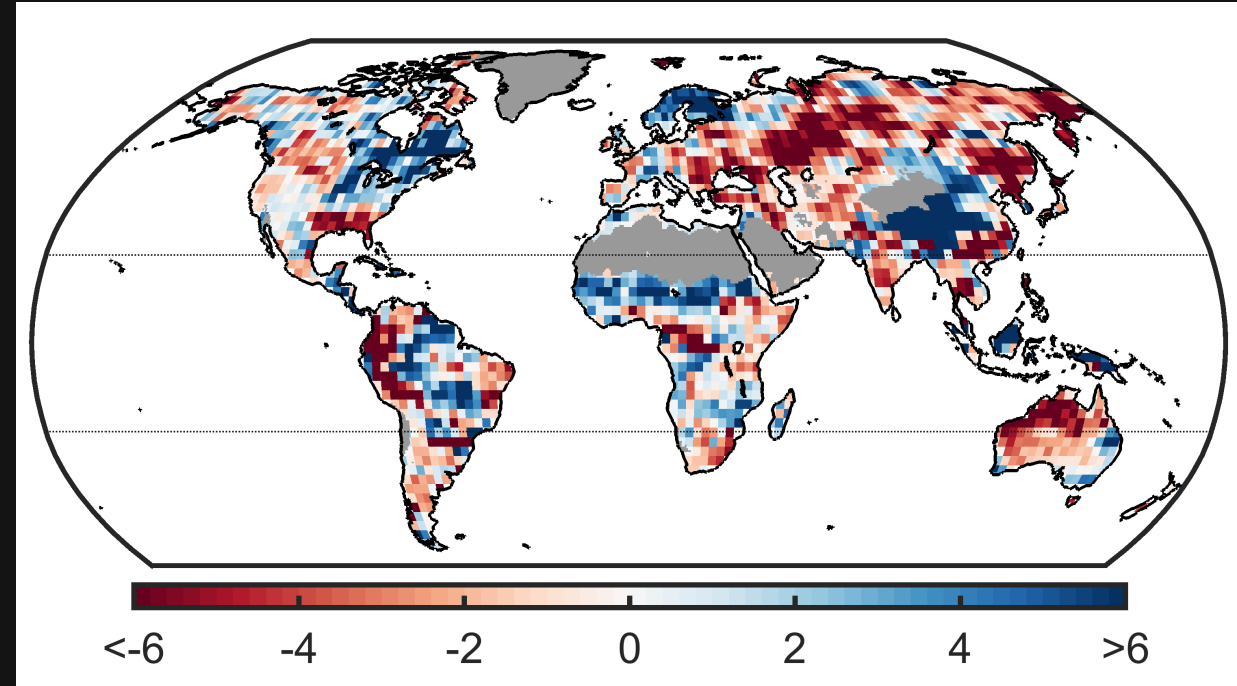 ➢ E3SM
  ➢ IPSL-CM6A-LR

- Monthly data from 1902 to 2014.

PATTERN OF CHANGES IN DRY SEASON WATER AVAILABILITY

Data-driven model reconstruction

Land surface model reconstruction


$\Delta(P - ET)$ [mm month^{-1}]

$\Delta(P - ET)$ [mm month^{-1}]

- 59% agreement in sign of change between DDM and LSM reconstructions.
- 57% of land with drier dry seasons (predominantly at the extratropics): Europe, West North America, North Asia, Southern South America, Australia, Northern Andes and Eastern Africa.

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CAN WE ATTRIBUTE THE PATTERN IN Δ(P − ET) TO CLIMATE CHANGE?

1. CMIP5 simulations with historical forcing *(mdl,hist)* estimate the response of the climate system to the external forcing given by human-induced climate change.

2. Spatial *corr(mdl,hist & obs)* quantifies the similarity between the expected response to climate change and the observed response.

3. Null hypothesis: There is no signal in the observations resulting from climate change, and therefore *corr(mdl,hist & obs)* is **only** a consequence of natural climate variability *(ncv)*.

4. Test requirement: A distribution of *corr(mdl,hist & ncv)*. This is obtained from CMIP5 simulations **without** any external climate change forcing (i.e. pre-industrial conditions).

5. If *corr(mdl,hist & obs)* is greater than almost all estimates of *corr(mdl,hist & ncv)* then the null hypothesis is rejected → Observed response includes a climate change signal.

6. If null hypothesis is not rejected when substituting simulations with full historical forcing *(mdl,hist)* for those with **only** natural historical forcing *(mdl,histNat)* the influence of climate change in the observed response is further confirmed.

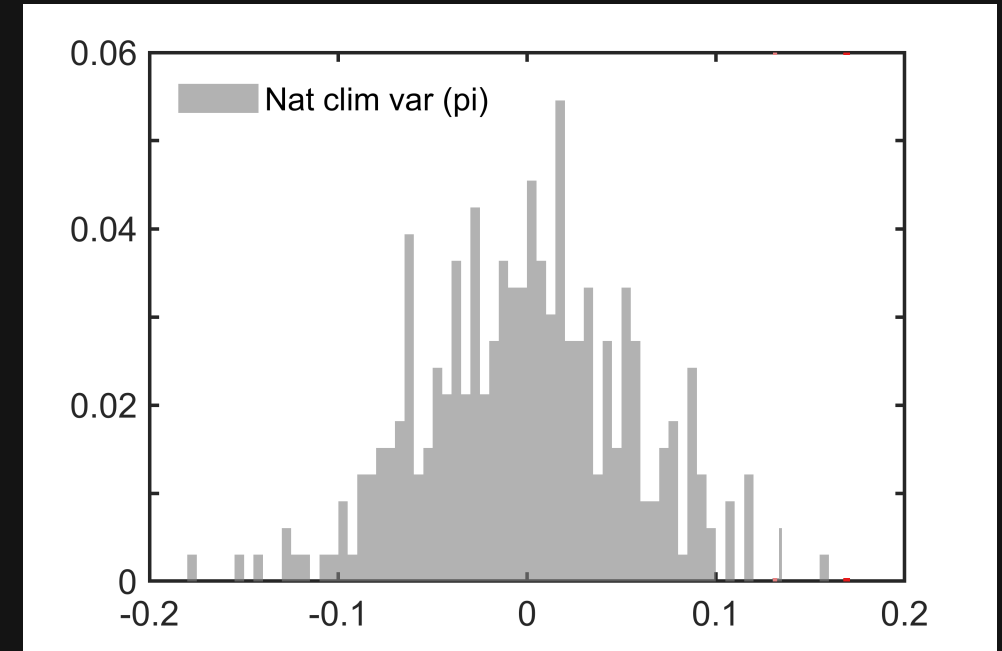Climate change expected historical response
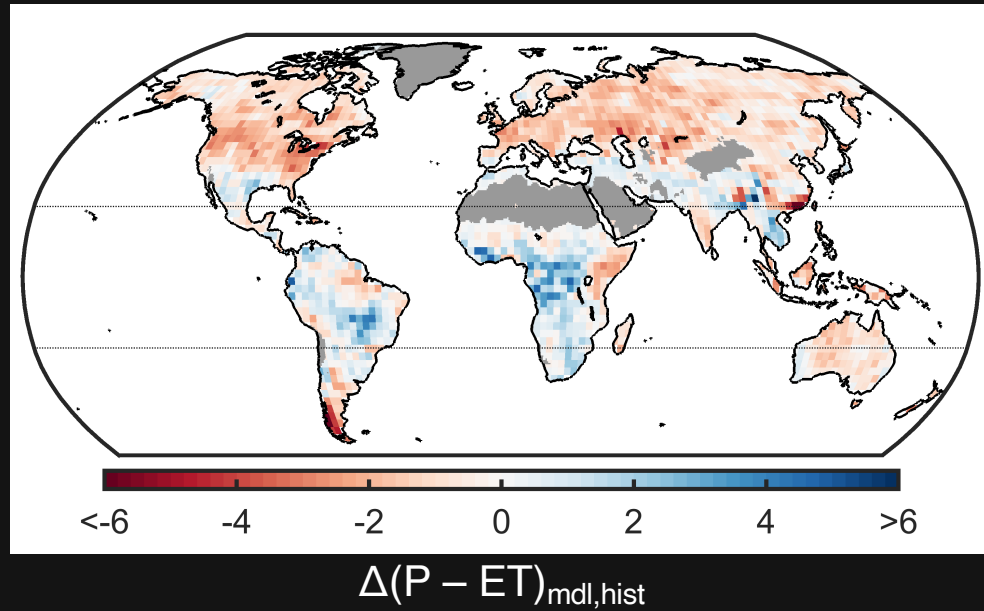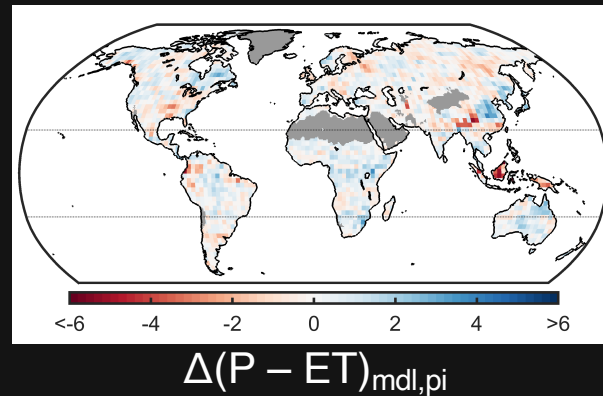
$\Delta(P - ET)_{mdl,hist}$

Correlation with $\Delta(P - ET)_{mdl,hist}$

Nat. clim. variab. response

$\Delta(P - ET)_{mdl,pi}$

Hundreds of estimates

Climate change expected historical response
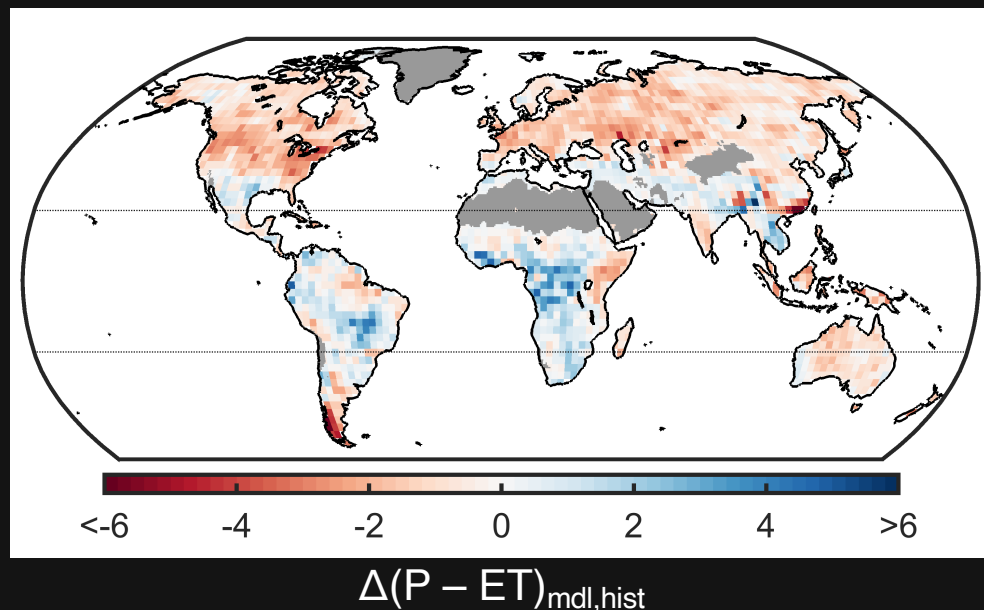
$\Delta(P - ET)_{mdl,hist}$

Observed response
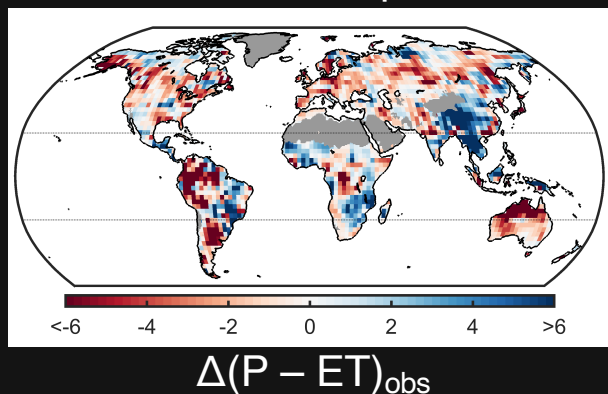
$\Delta(P - ET)_{obs}$

DDM and LSM reconstructions

Nat. clim. variab. response

$\Delta(P - ET)_{mdl,pi}$

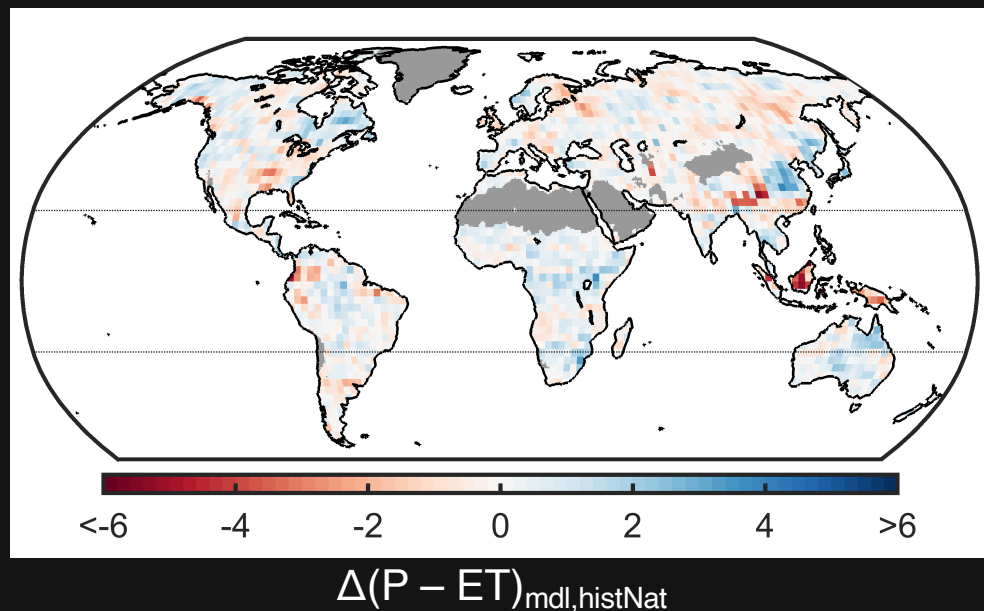Hundreds of estimates

Nat clim var (pi)
Obs. DDM
Obs. LSM
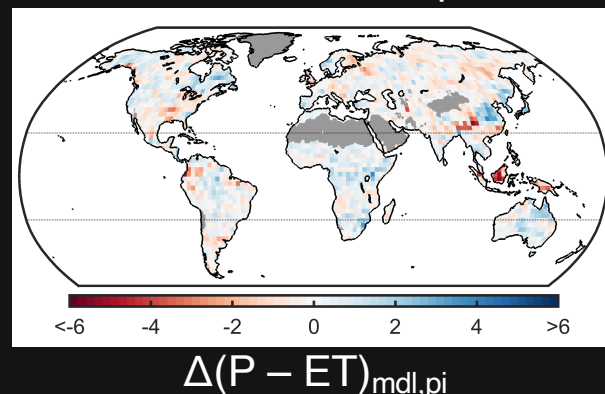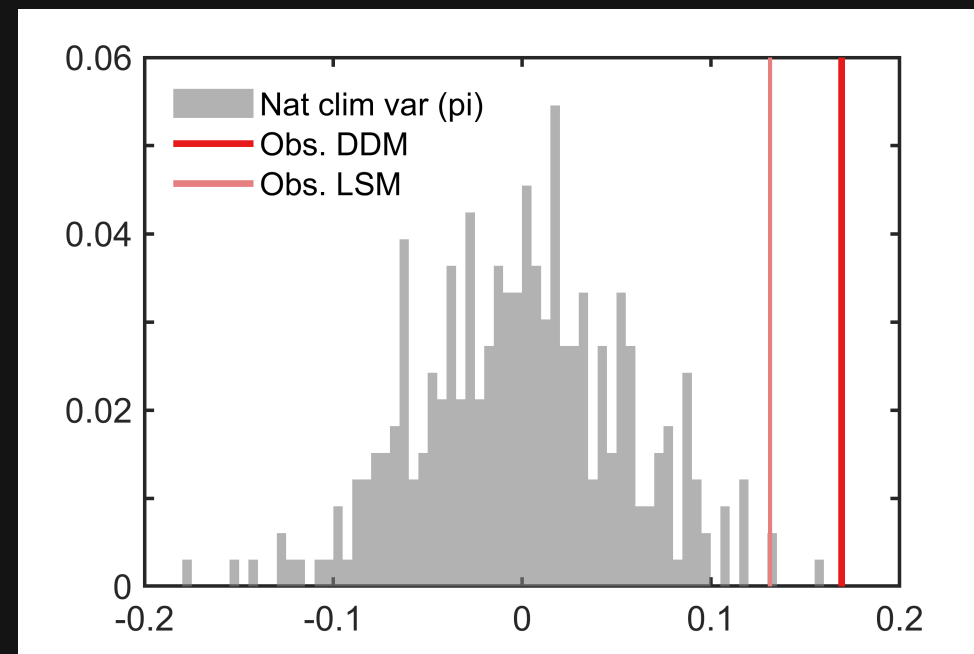
Correlation with $\Delta(P - ET)_{mdl,hist}$

Extremely likely contribution of climate change to $\Delta(P - ET)_{obs}$

Expected historical response **without** human climate change

$$\Delta(P - ET)_{mdl,histNat}$$

Correlation with $\Delta(P - ET)_{mdl,histNat}$

Observed response

$$\Delta(P - ET)_{obs}$$

Nat. clim. variab. response
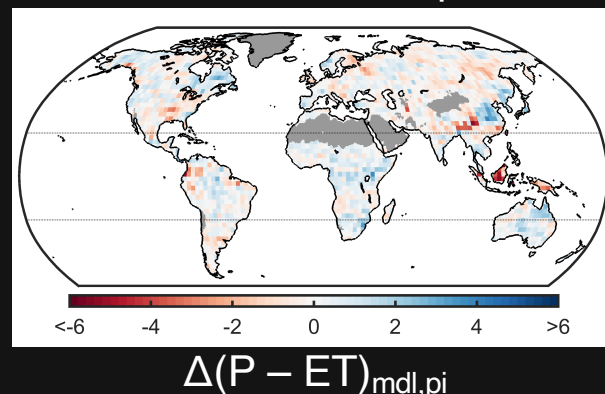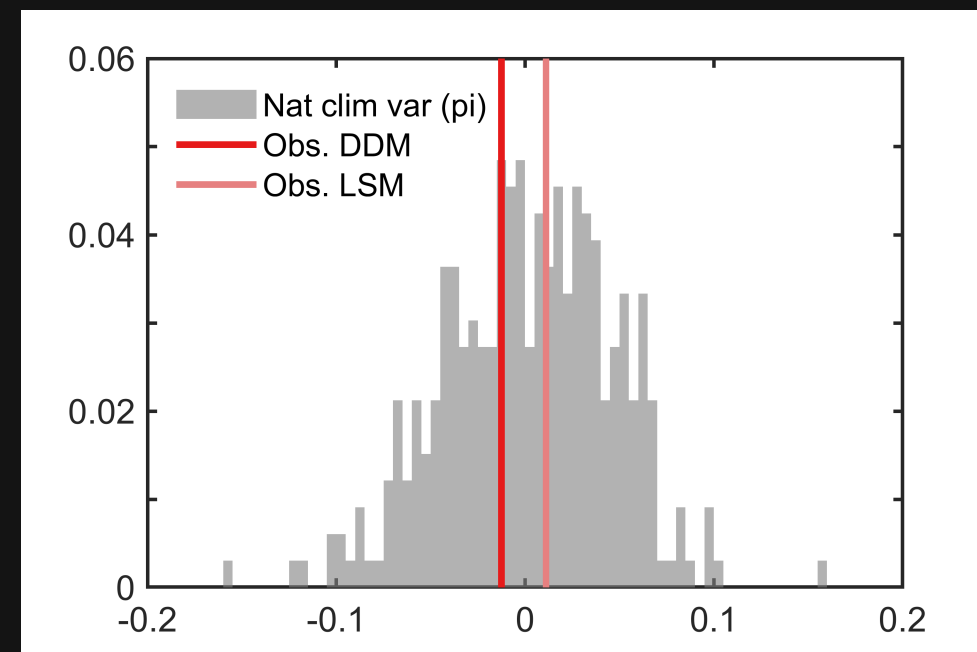
$$\Delta(P - ET)_{mdl,pi}$$

<u>Confirmed contribution of climate change to</u> $\Delta(P - ET)_{Obs}$

DDM and LSM reconstructions   Hundreds of estimates

CONTRIBUTION OF **P** AND **ET** TO Δ(P − ET)

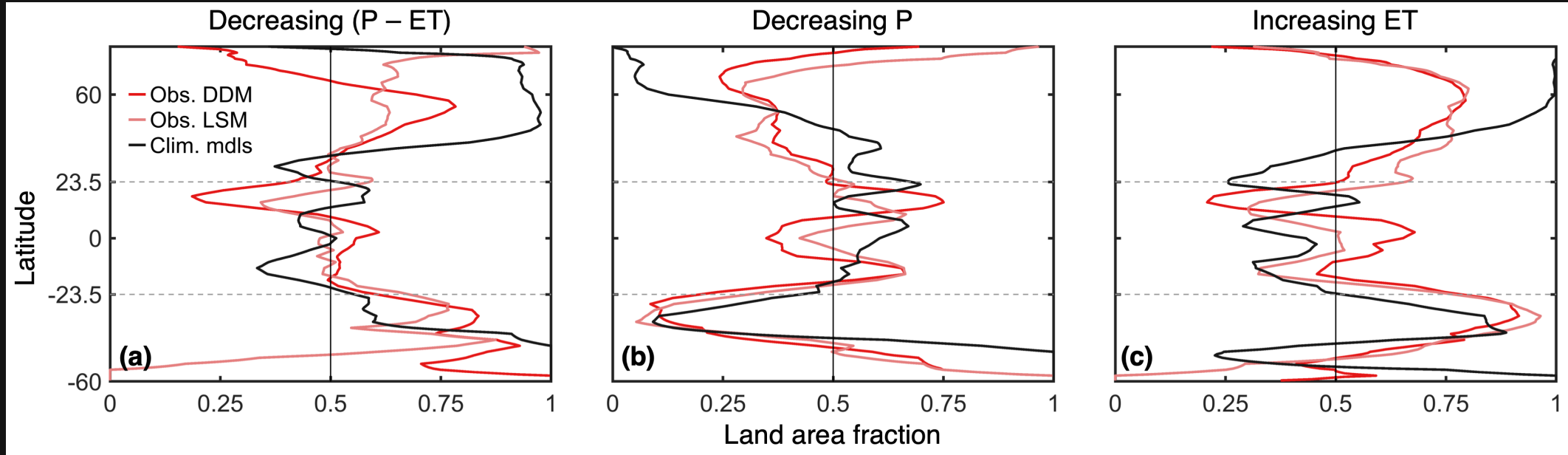$$\Delta(P - ET) = \Delta P - \Delta ET$$

Dominant contribution of increased ET to reduce dry season water availability.

Observations consistent with expected response to climate change.

ΔP contribution to Δ(P − ET)

ΔET contribution to Δ(P − ET)

Obs. based DDM

(a)

(b)

Obs. based LSM

(c)

(d)

Clim. mdls. hist. forcing

(e)

(f)

<-10 -8 -6 -4 -2 0 2 4 6 8 >10
ΔP [mm month^{-1}]

<-10 -8 -6 -4 -2 0 2 4 6 8 >10
− ΔET [mm month^{-1}]
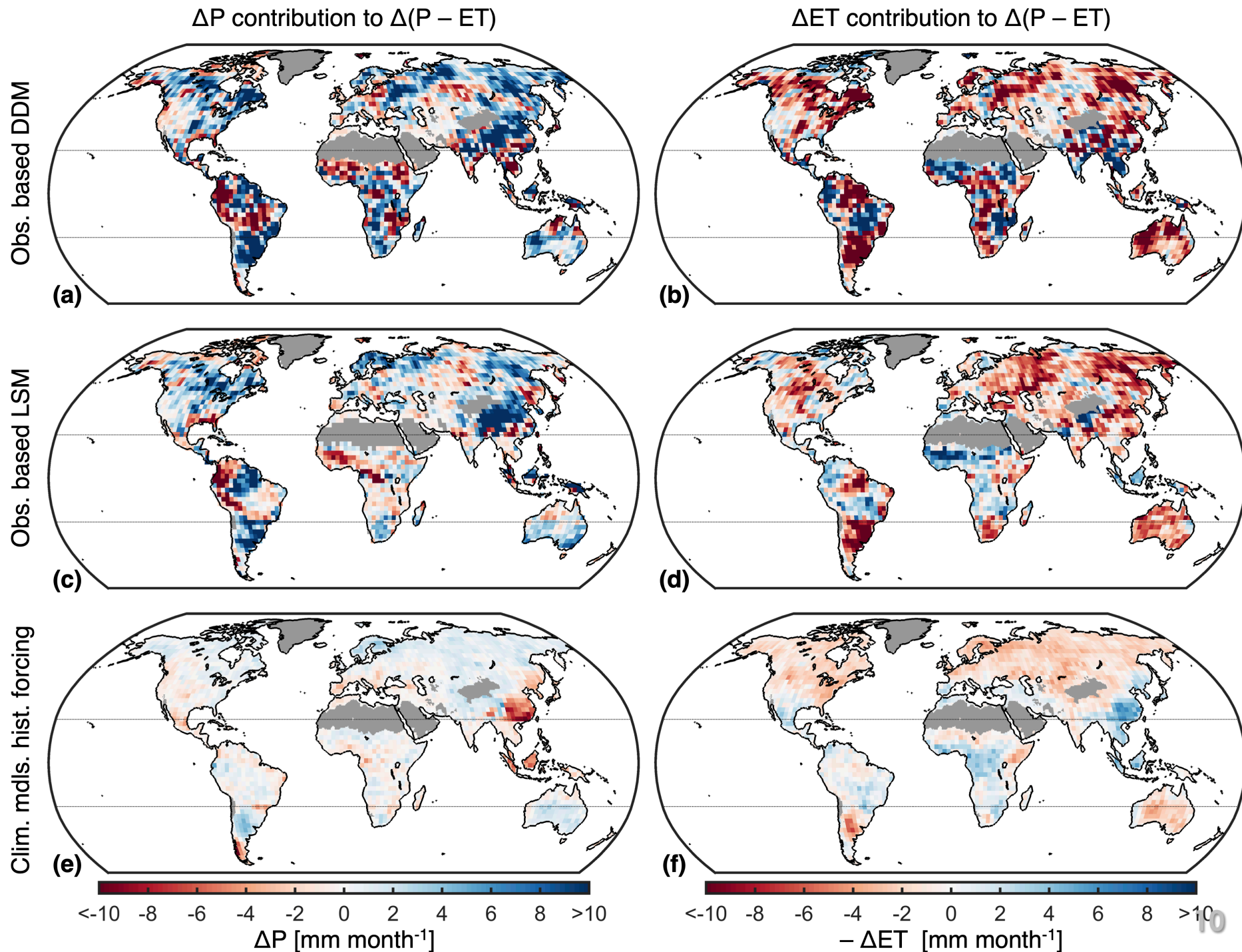
SUMMARY

1. Pattern of changes in Δ(P – ET) from data-driven and land surface models with observed atmospheric forcing.

2. Observed pattern of changes in Δ(P – ET) shows agreement with the expected response to climate change and is not expected from natural climate variability.

3. Observed dominant contribution of increasing ET (rather than decreasing P) to reduce water availability → Also consistent with expected response to climate change.

Conclusion: Multiple lines of evidence indicate that changes in dry season water availability are attributed to human-induced climate change.

COMING SOON:

Padrón, R. S. et al. Observed changes in dry season water availability attributed to human-induced climate change. *Nature Geoscience (accepted)* (2020).

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THANKS!