Anthropizing CLM's water cycle

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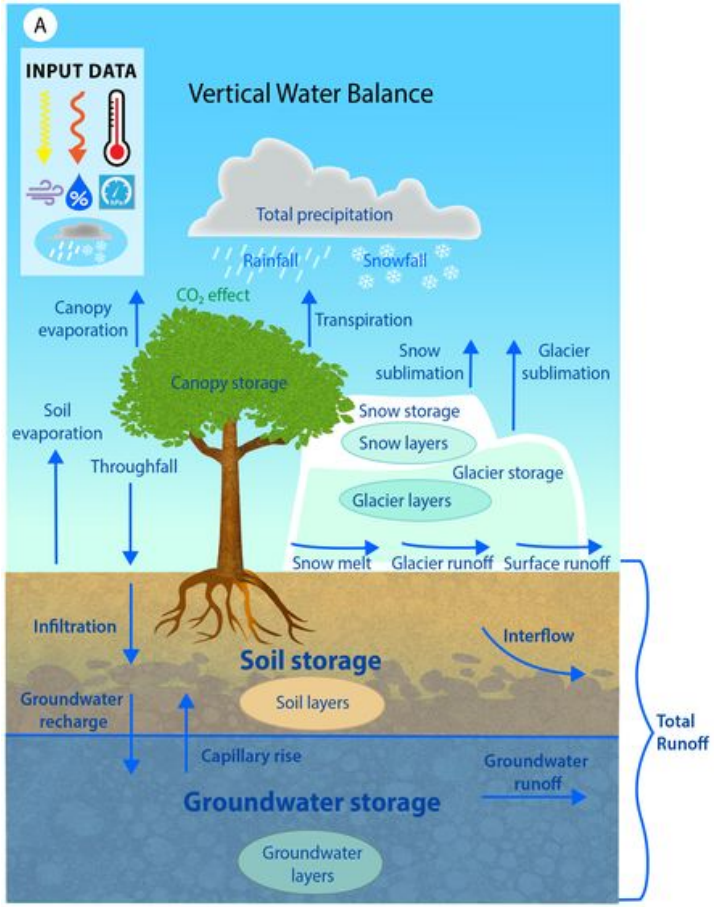
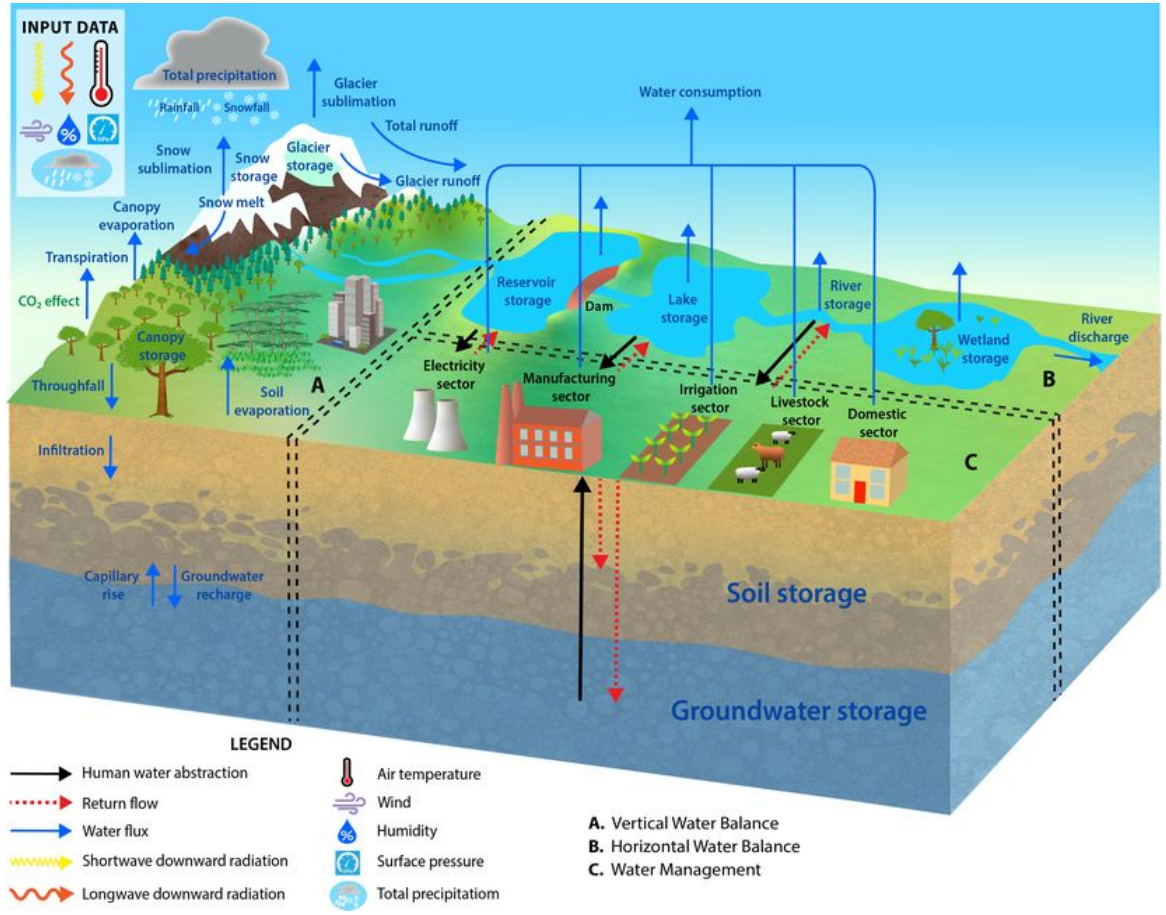
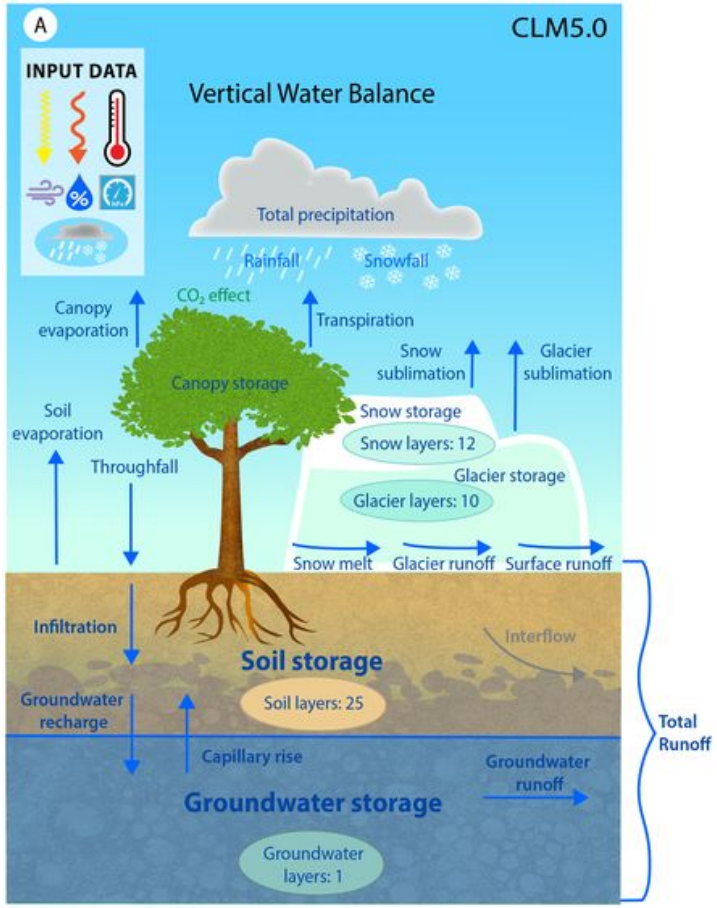
Where we're (hopefully) heading

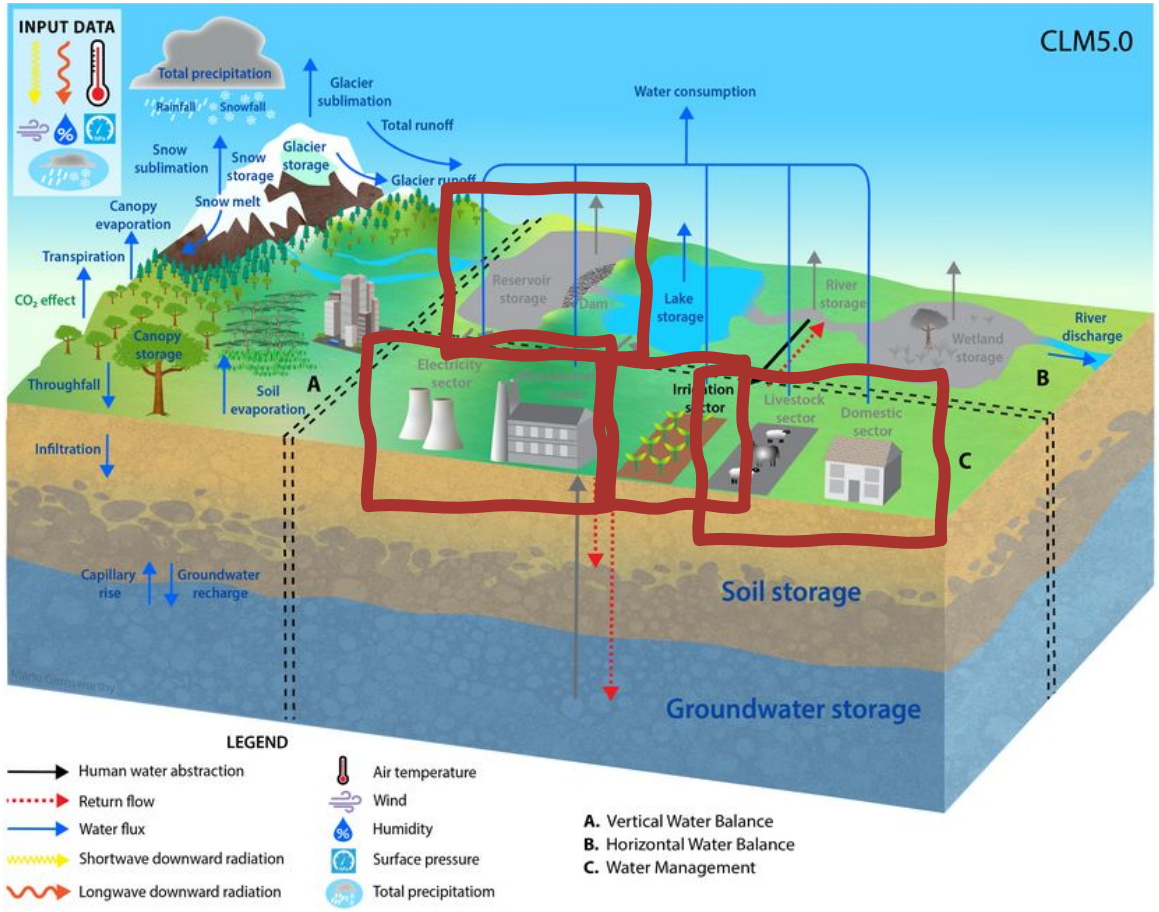




(Telteu et al., 2021 GMD; Müller Schmied et al., in prep.)

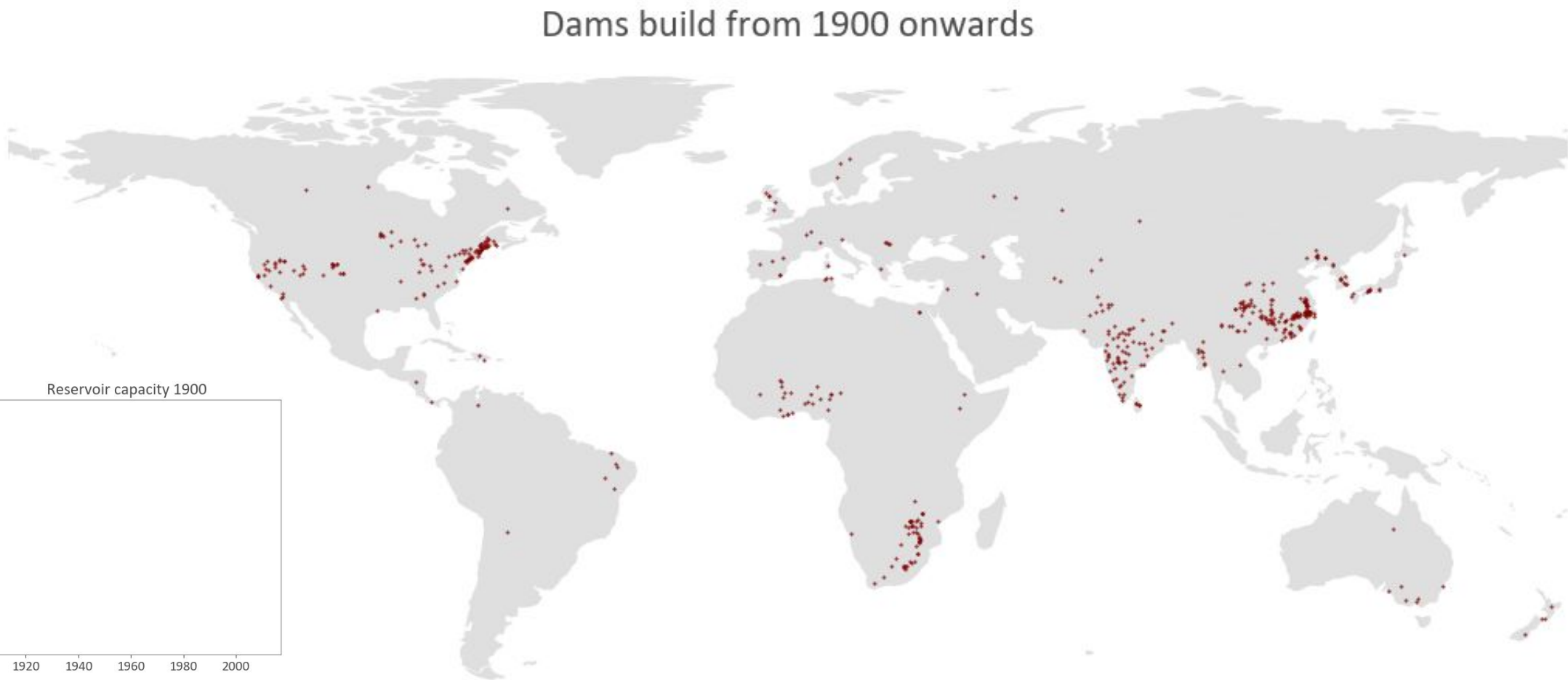
Where we are with CLM5





(Telteu et al., 2021 GMD; Müller Schmied et al., in prep.)

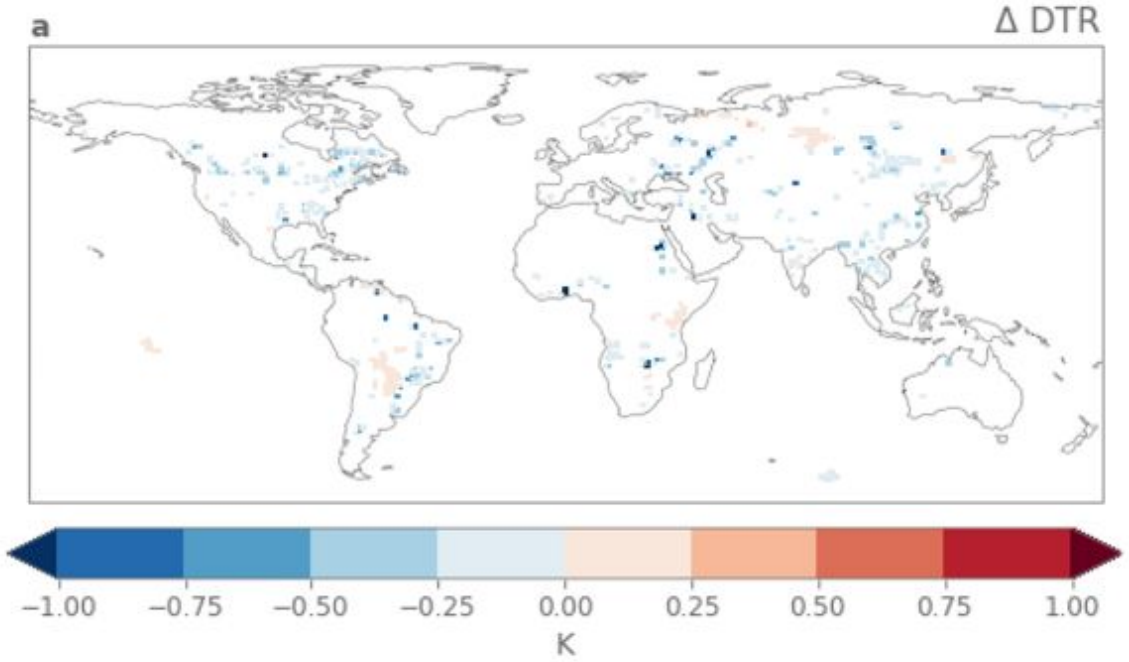
Since the 20th century, humans build 50 000 large dams worldwide

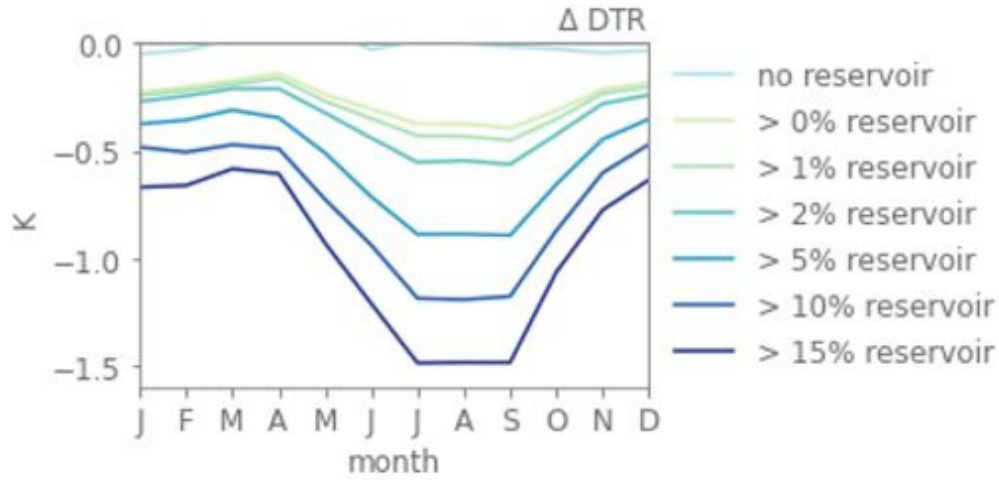


(Courtesy: Inne Vanderkelen)

Coupled experiments: influence of reservoirs on climate

AMIP-style simulations
- 1980-2014, 0.9° by 1.25°
- 5 ens members RES and NORES



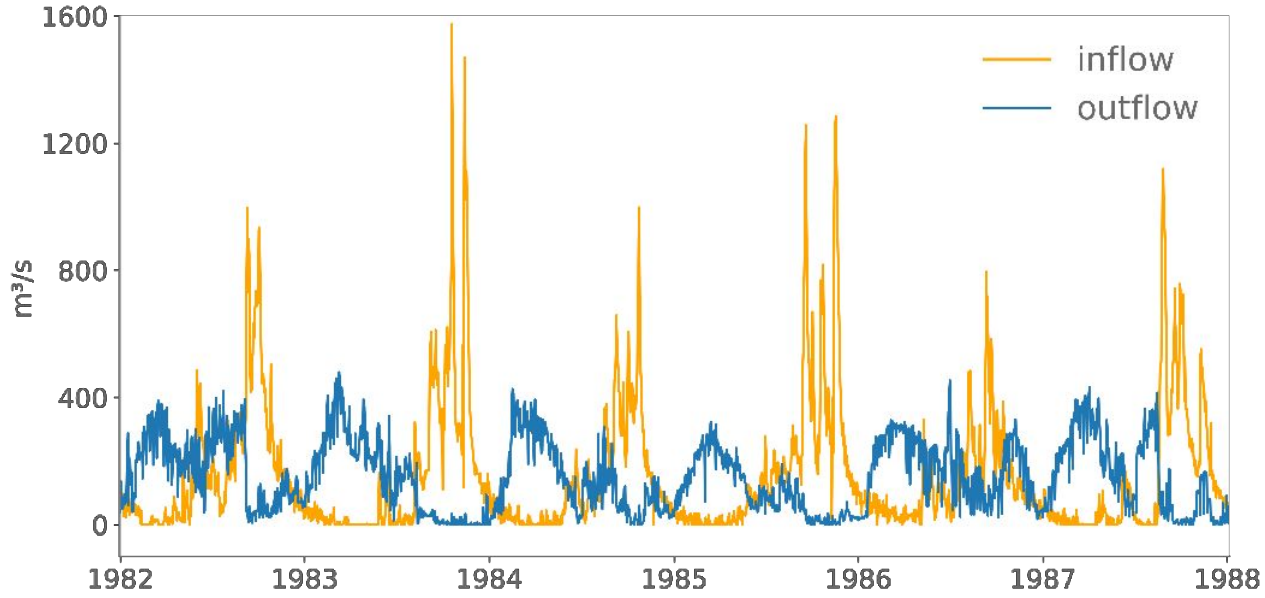


- Reservoirs dampen the daily and seasonal T cycle and T extremes
- Responses localized to reservoir grid cells
- Substantial where reservoirs make up a large fraction

(Vanderkelen et al., 2021 JGR)

Streamflow regulation through dam management

Bhumibol dam, Thailand



(Vanderkelen et al., 2022 GMD)

MizuRoute simulations

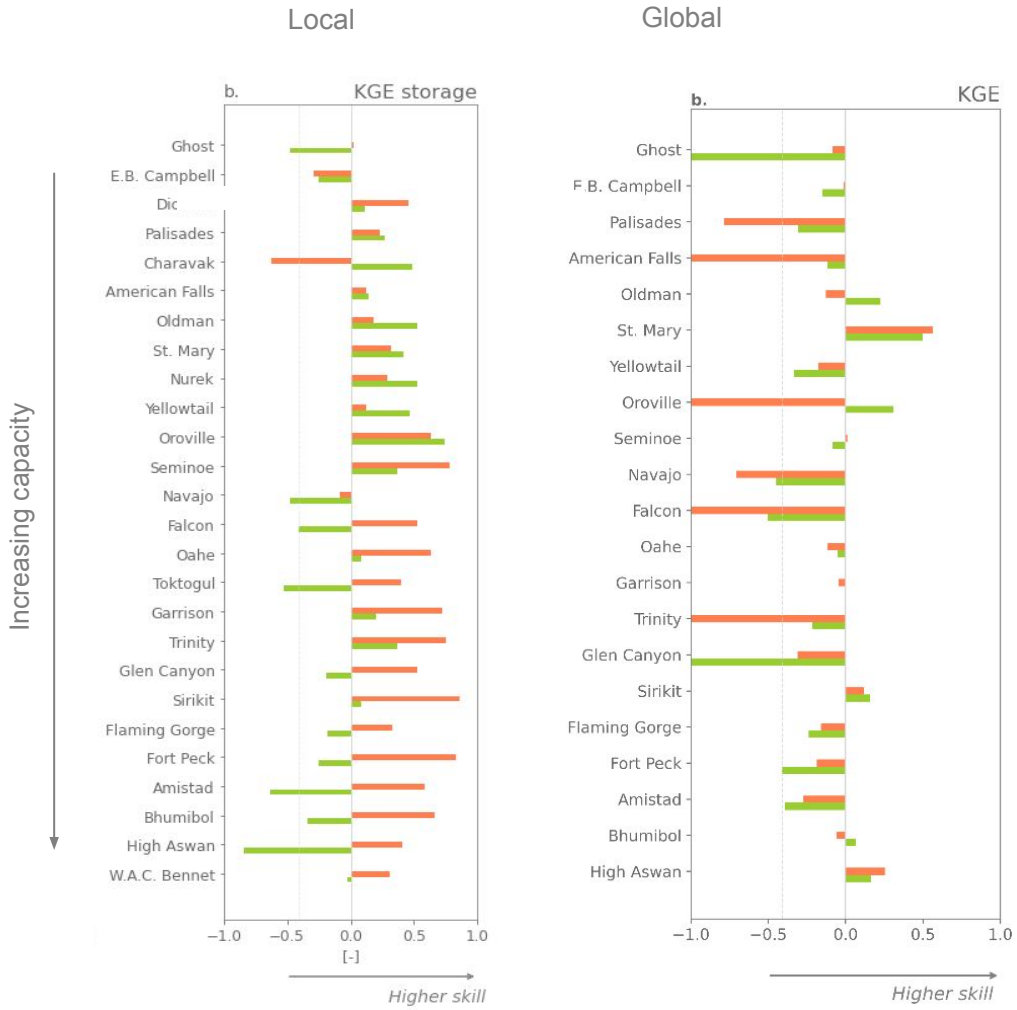
NOLAKES	Run-of-river as outflow
NAT	Natural lake param. of Döll et al, 2003
DAM	Dam param. of Hanasaki, 2006
DAM NOIRR	Dam param. of Hanasaki, 2006; all reservoirs non-irrig

Local simulations

- 26 Individual reservoirs
- Observed reservoir inflows
- Irrigation water demands from CLM and irrigation topology

Global simulations

- HDMA river network with lakes
- 1773 reservoirs, of which 484 irrigation
- Runoff from CTSM

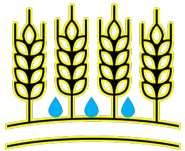


Inconsistency between local and global simulations due to runoff bias in CLM

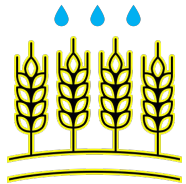
(Vanderkelen et al., 2022 GMD)

Introducing irrigation techniques in CLM

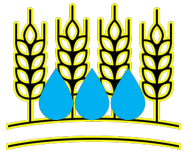
Drip



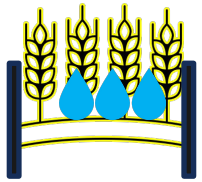
Sprinkler



Flood



Paddy

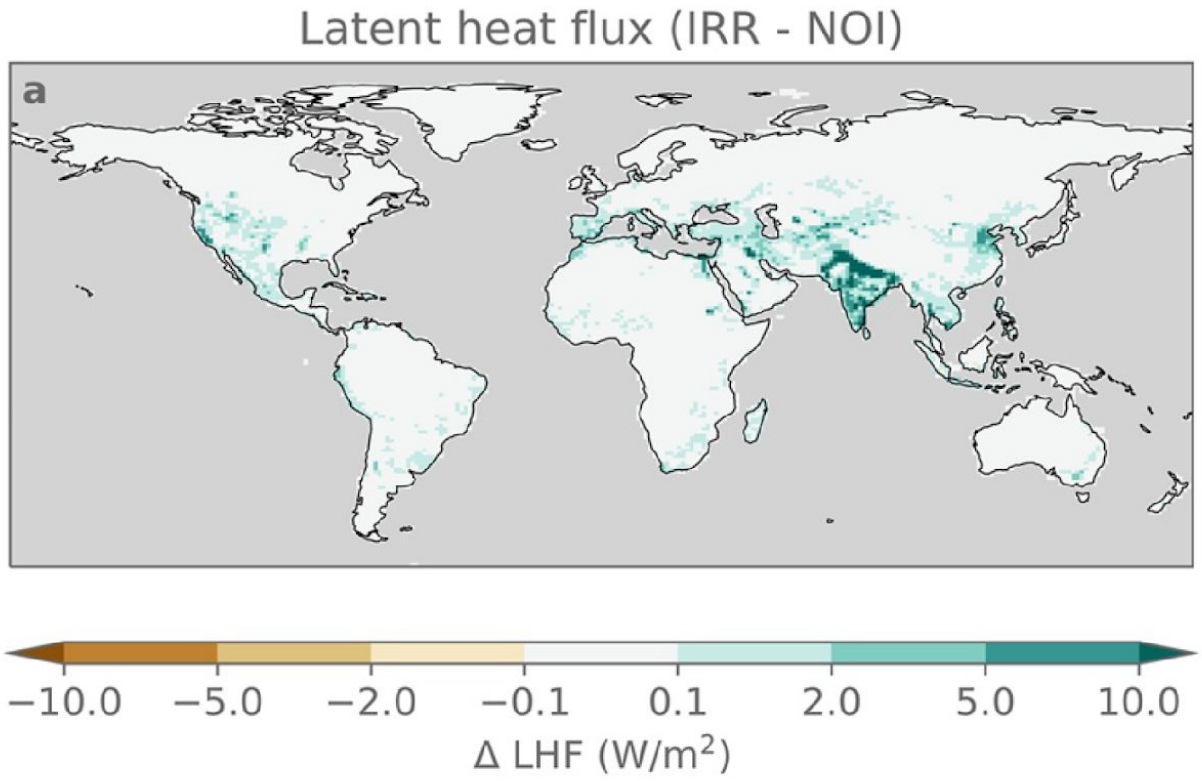


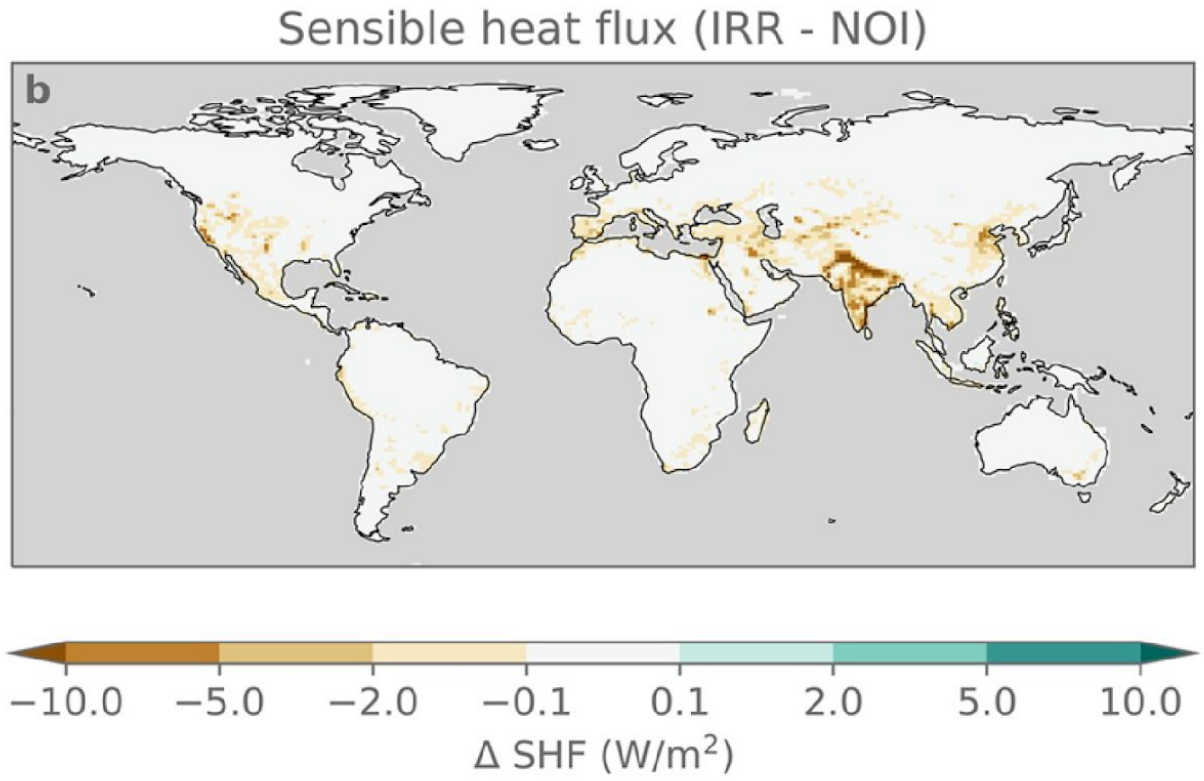
Method	When	How much	Where	Water Ponding
Drip			Under canopy	No
Sprinkler			Over canopy	No
Flood			Under canopy	No
Paddy			Under canopy	Yes

(Yao et al., 2022 JAMES)

Irrigation impact on turbulent fluxes

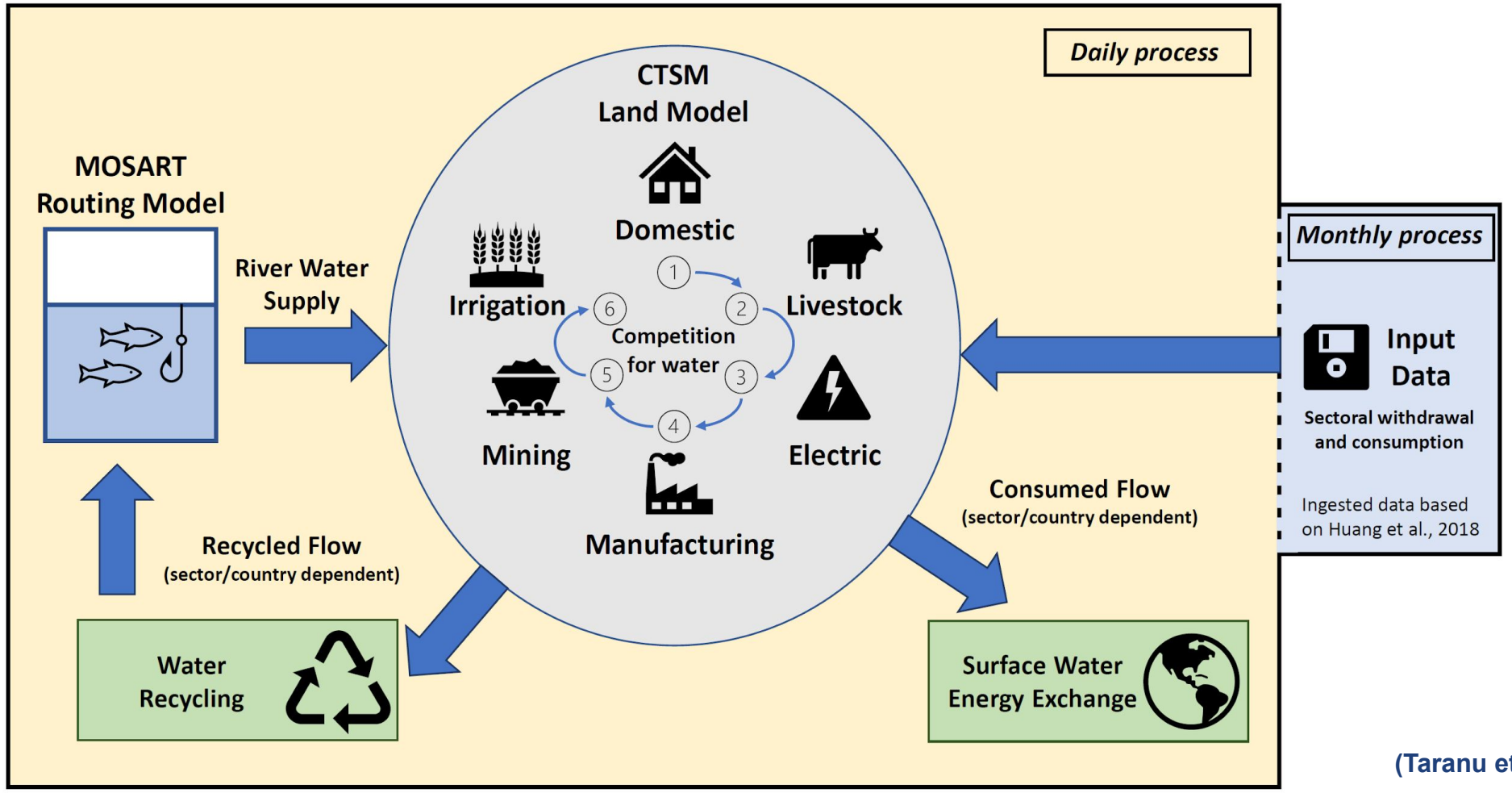
Catch talk by Yi Yao tomorrow





(Yao et al., 2022 JAMES)

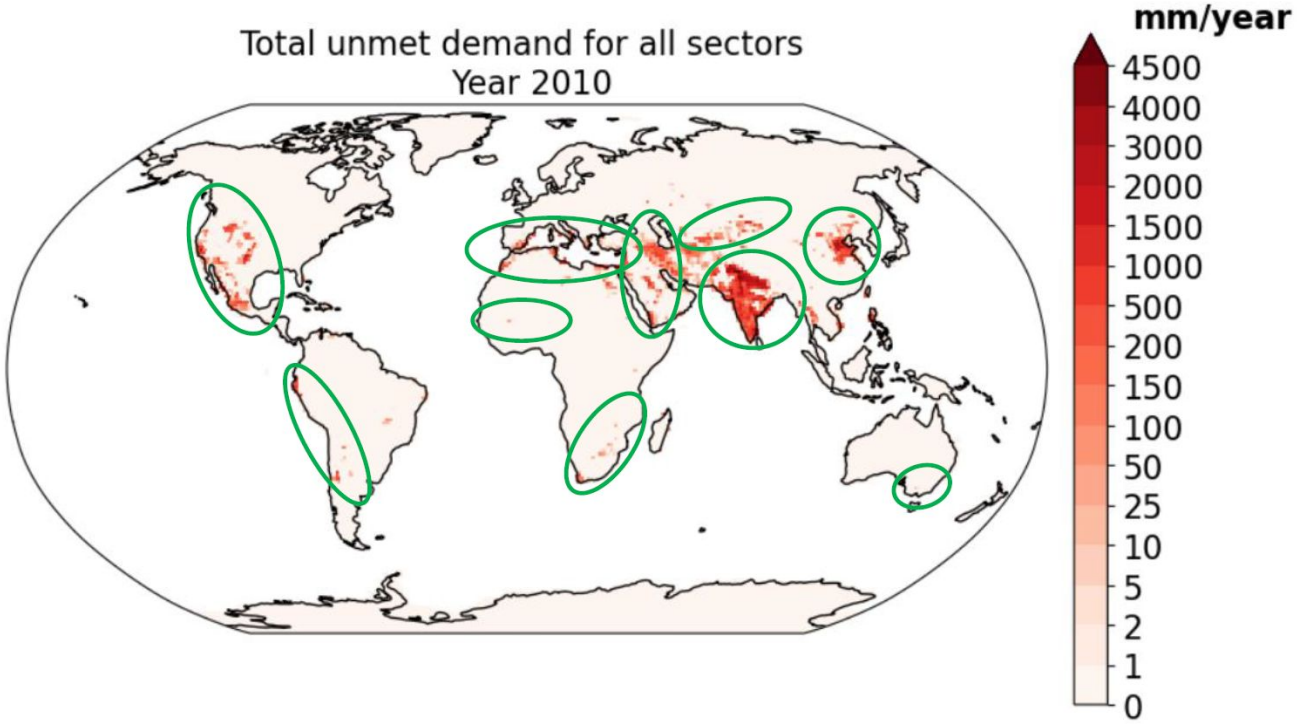
Implementing sectoral water use in CLM



(Taranu et al., in prep.)

Water scarcity in CLM

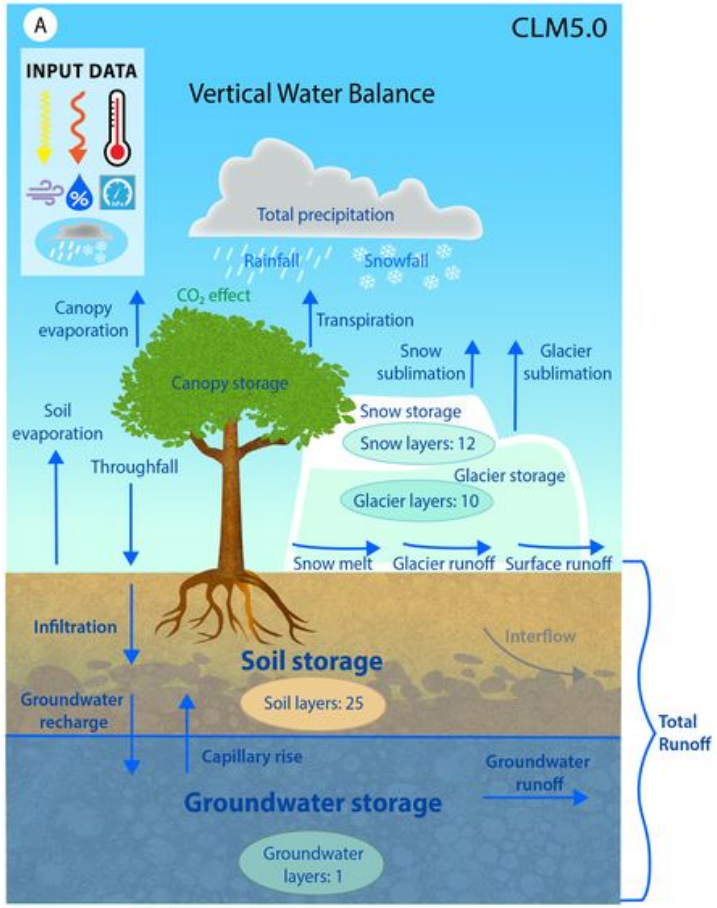
CLM5

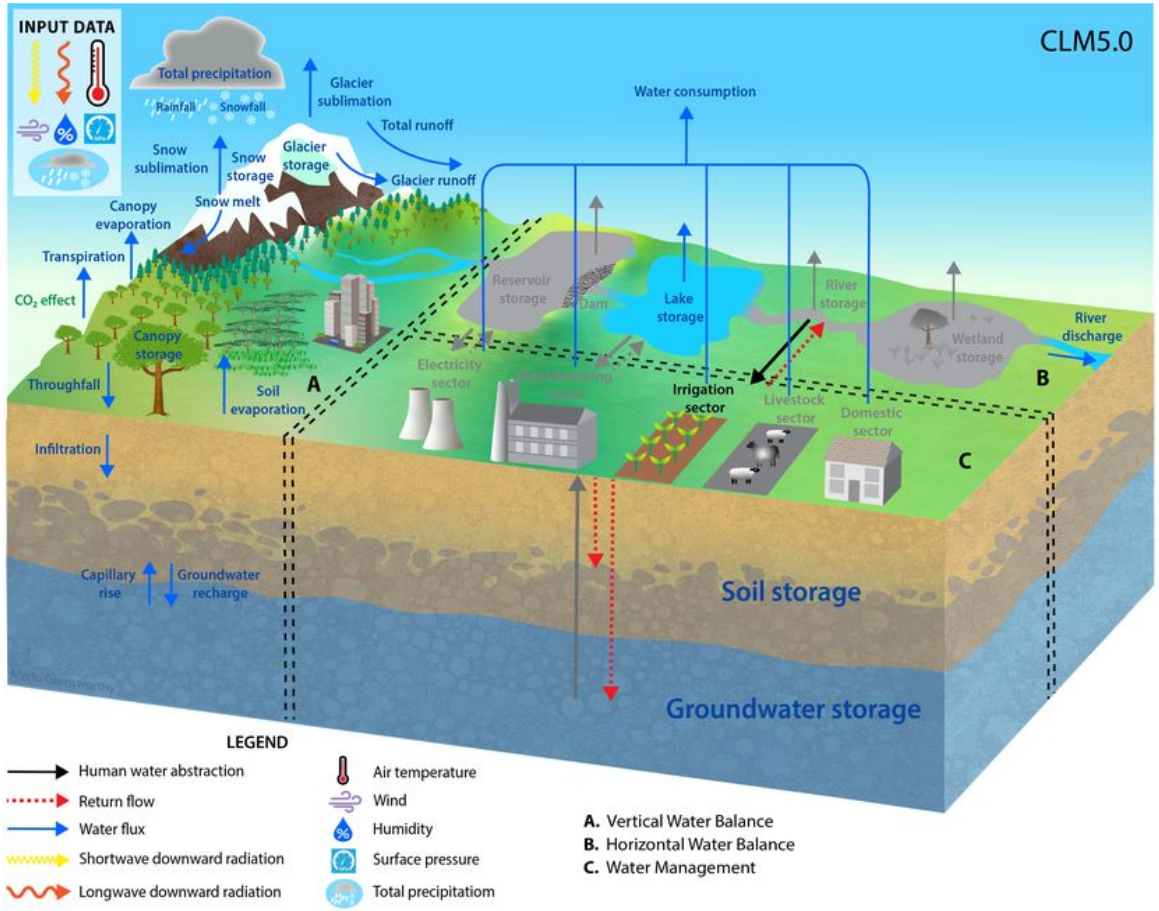


World Resources Institute

(Taranu et al., in prep.)

Where we are with CLM5

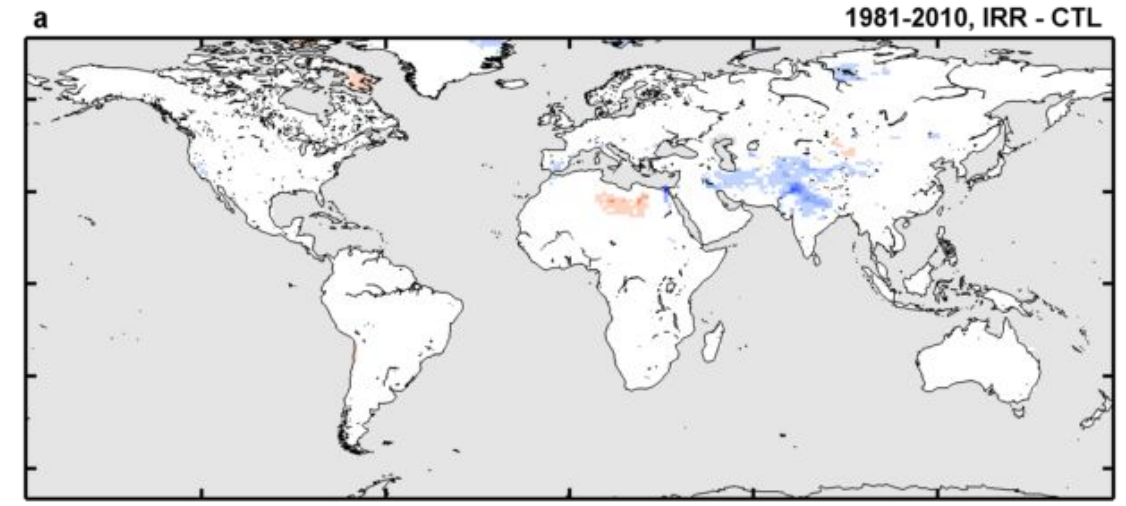




(Müller Schmied et al., in prep.)

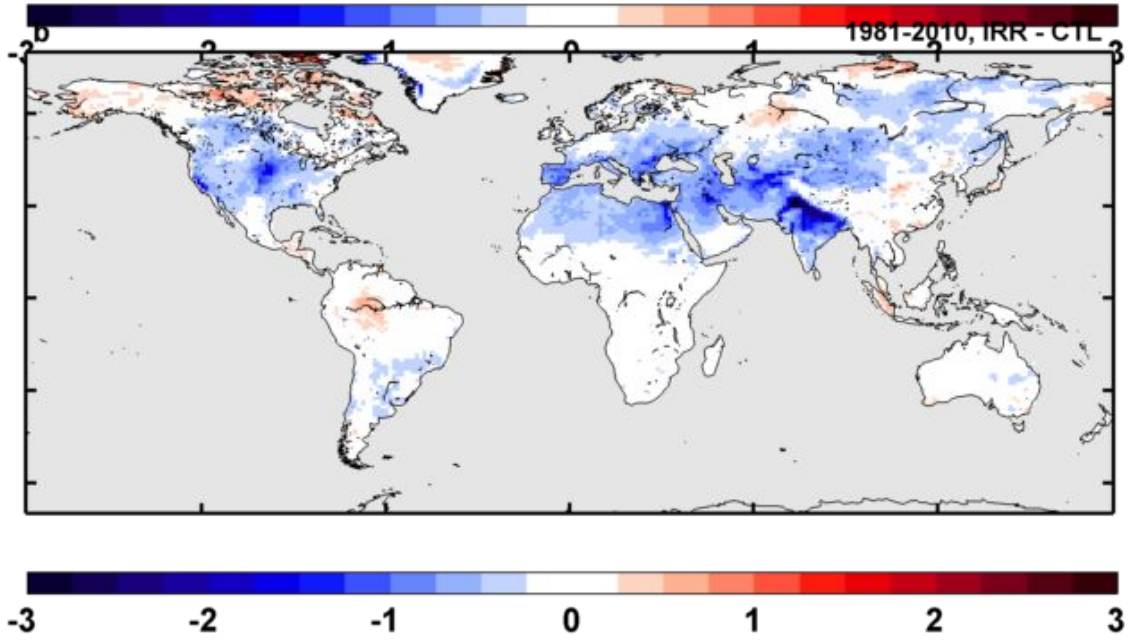

Why does it matter?
(flickr.com)

T_{2m}



(K)

TXx

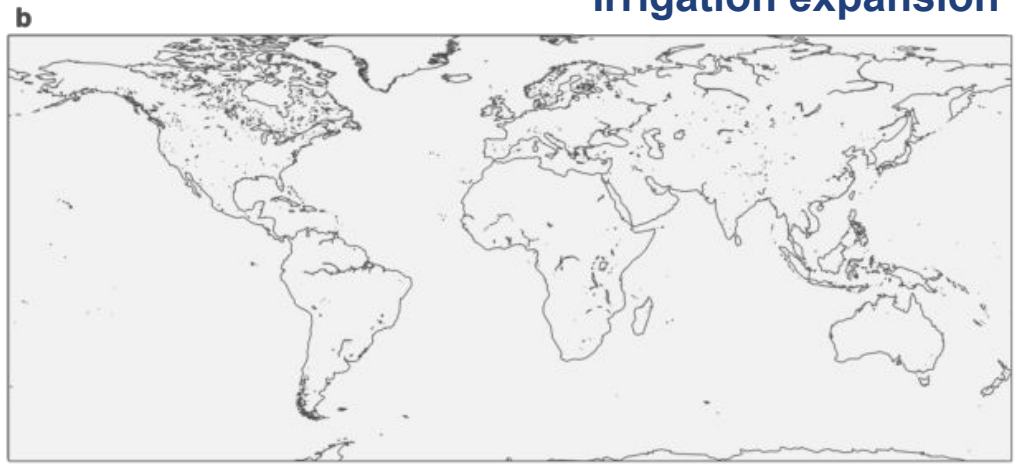


(K)

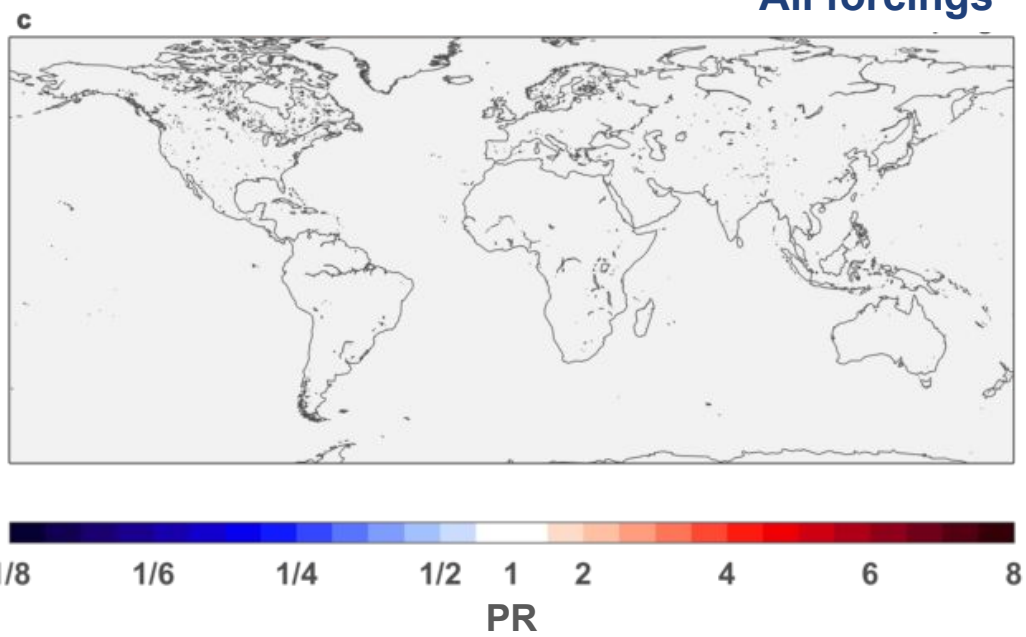
(Thiery et al., 2017 JGR)

All forcings except irrigation

Irrigation expansion

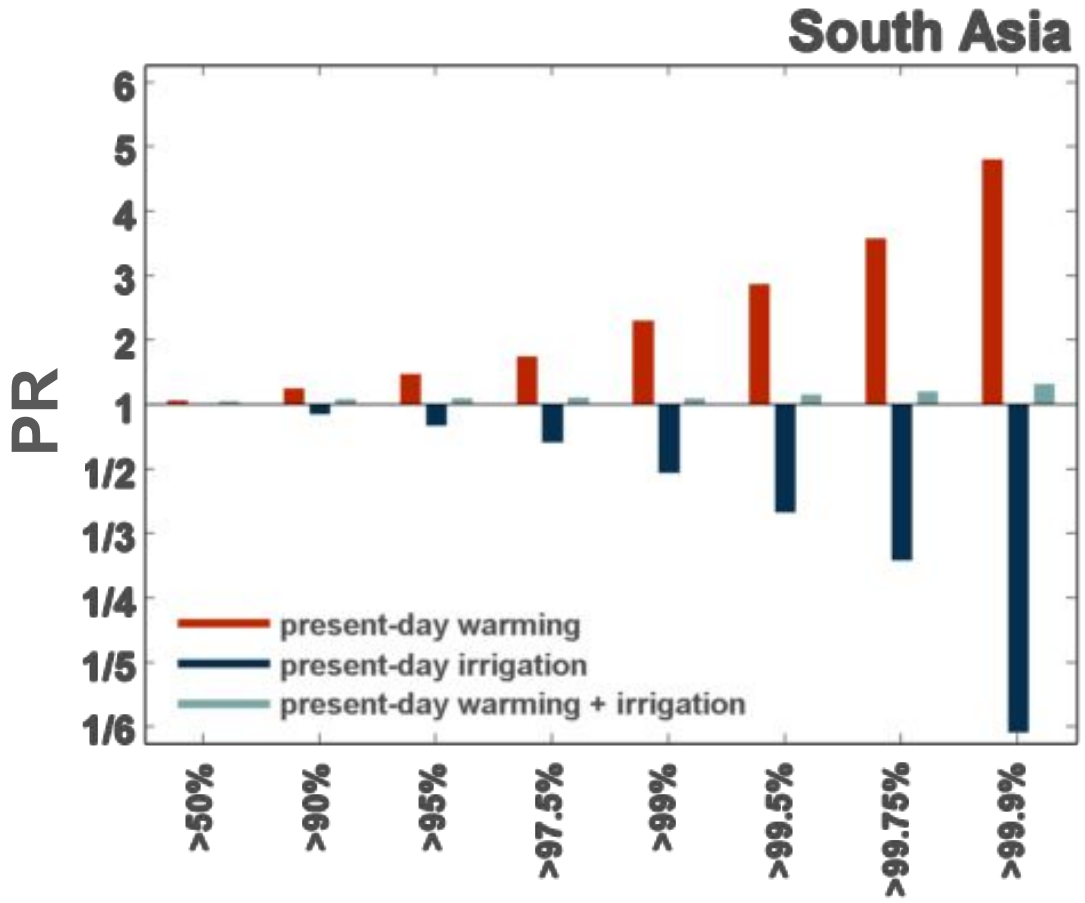


All forcings



(Thiery et al., 2020 Nature Comm.)

Change in probability



Hot extremes more likely

Hot extremes less likely

(Thiery et al., 2020 Nature Comm.)

Six impact categories

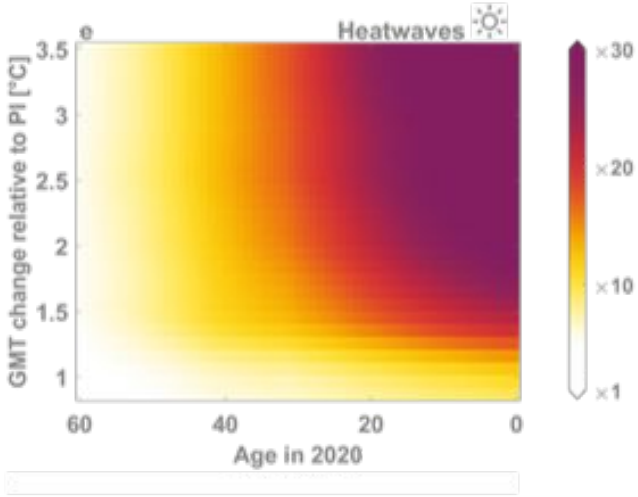
15 ISIMIP2b models, 273 global-scale projections





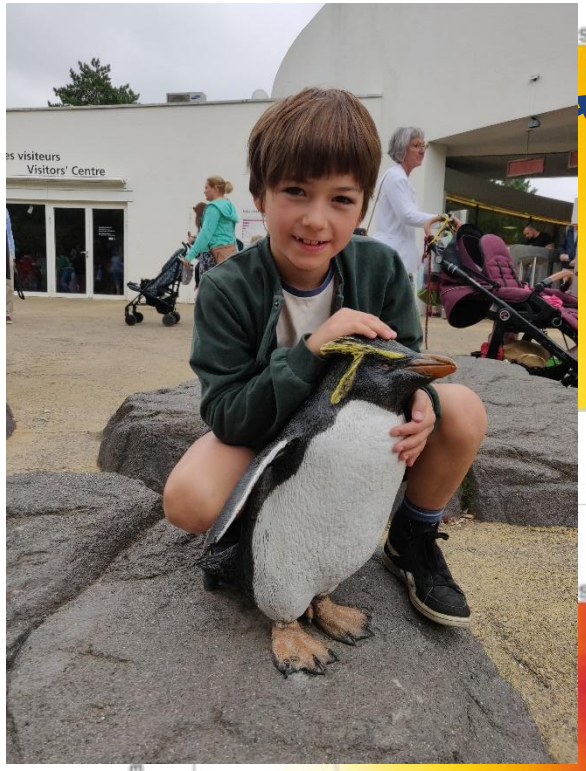

(Lange et al., 2020 EF)

Six burning embers



(Thiery et al., 2021 Science)

The youth is screwed, older generations won't face the risk

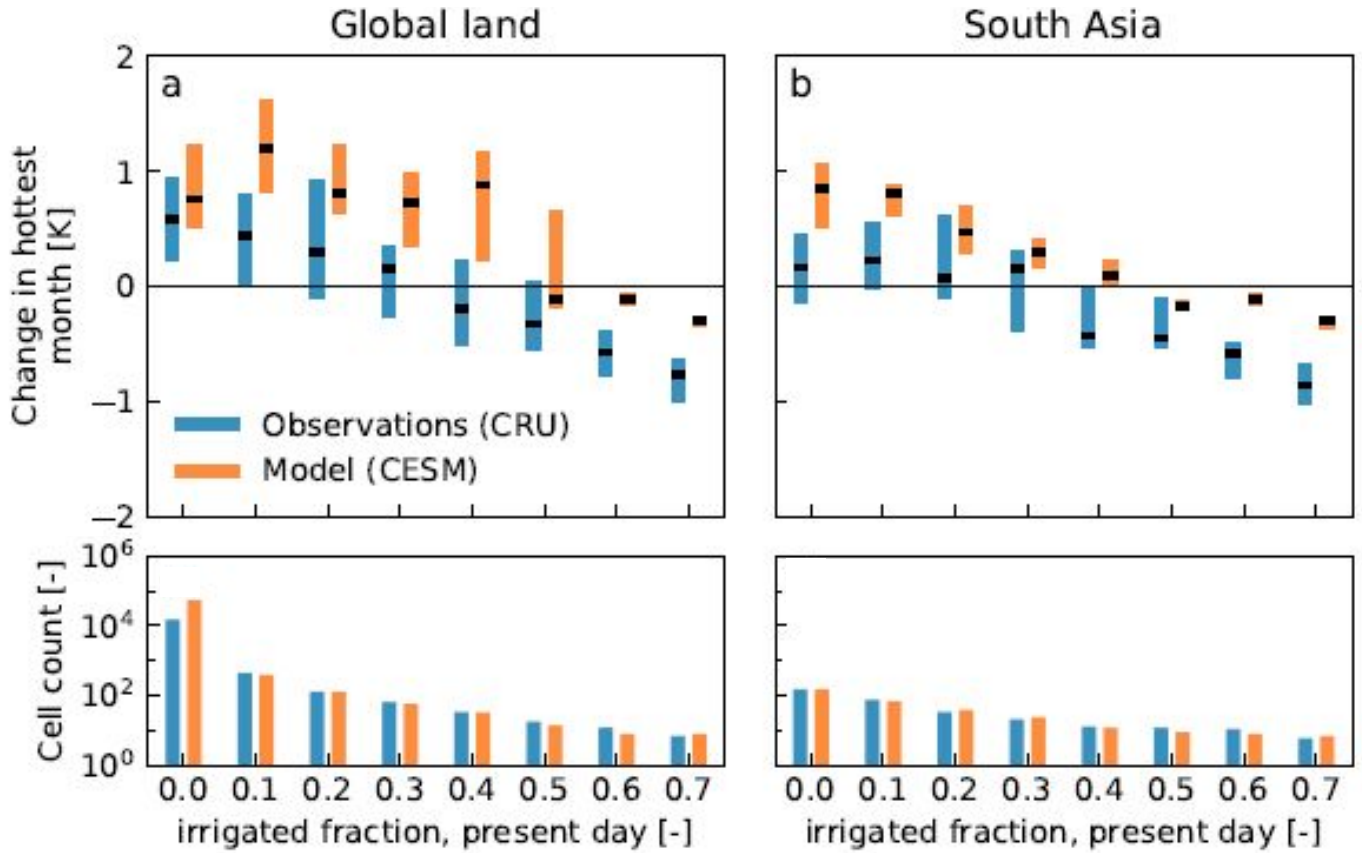


(Thiery et al., 2021 Science)

e.g. 6-yr old under 3°C: wildfires/TCs x2; river floods 3x; crop failure x4; droughts x5, heatwaves x36


Thanks! Questions?
@ThieryWim
(Pixabay)

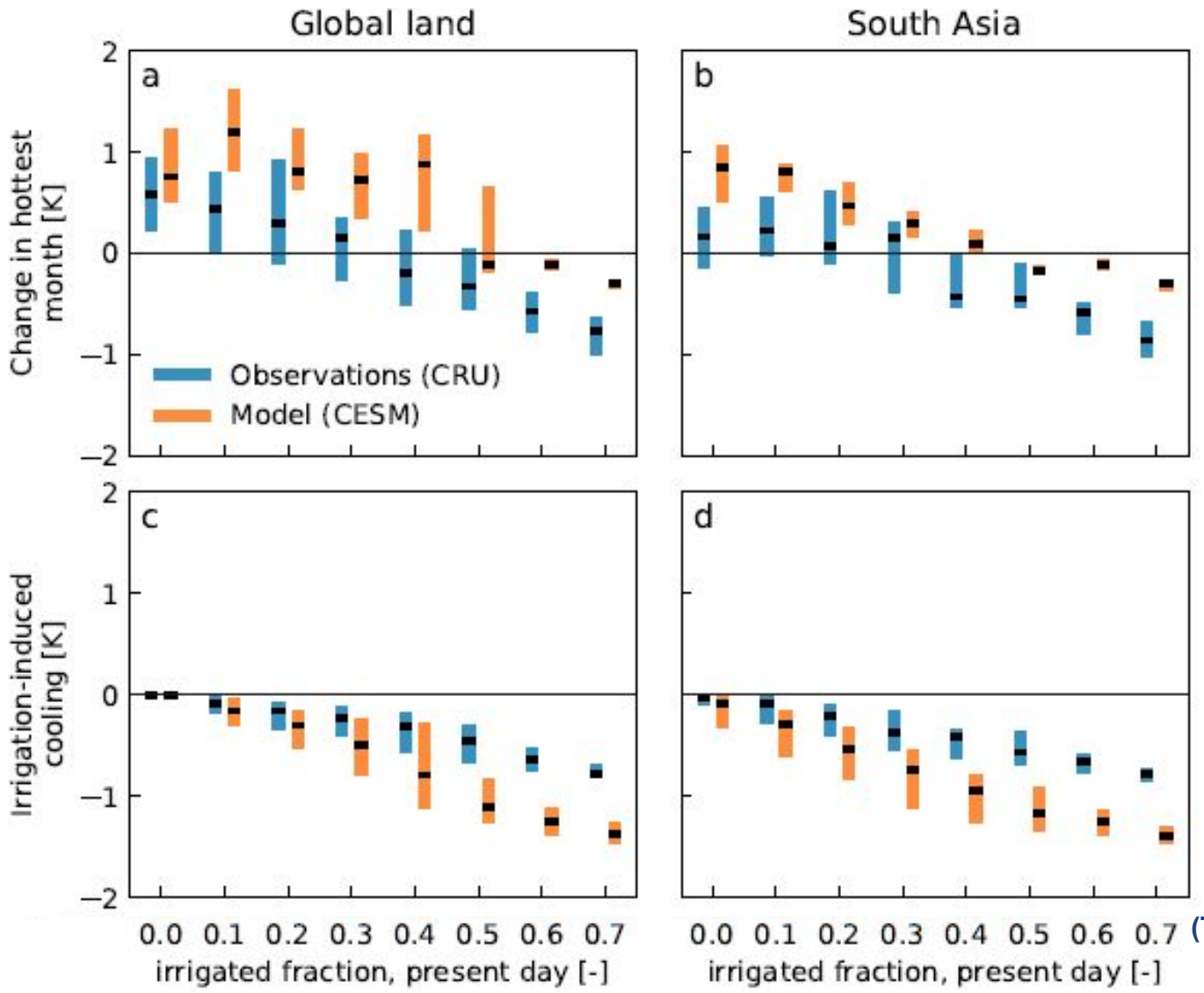
Irrigation-induced cooling?



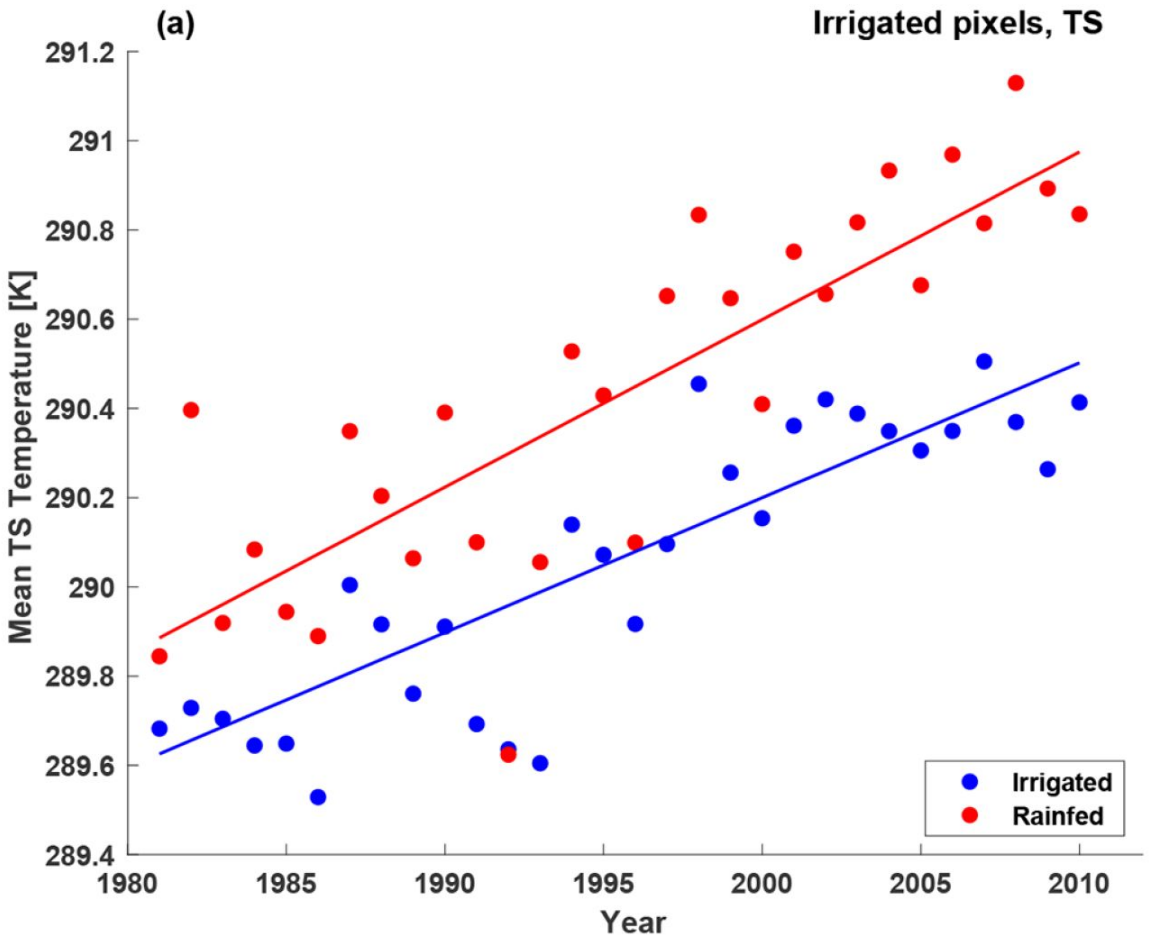
(Thiery et al., 2020 Nature Comm.)

Correlation versus causality

Irrigation-induced cooling!

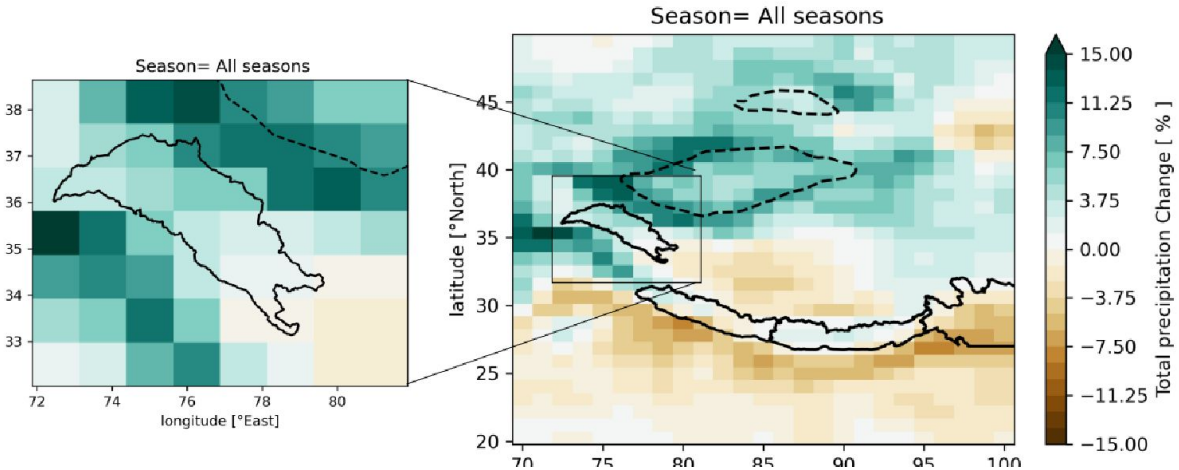


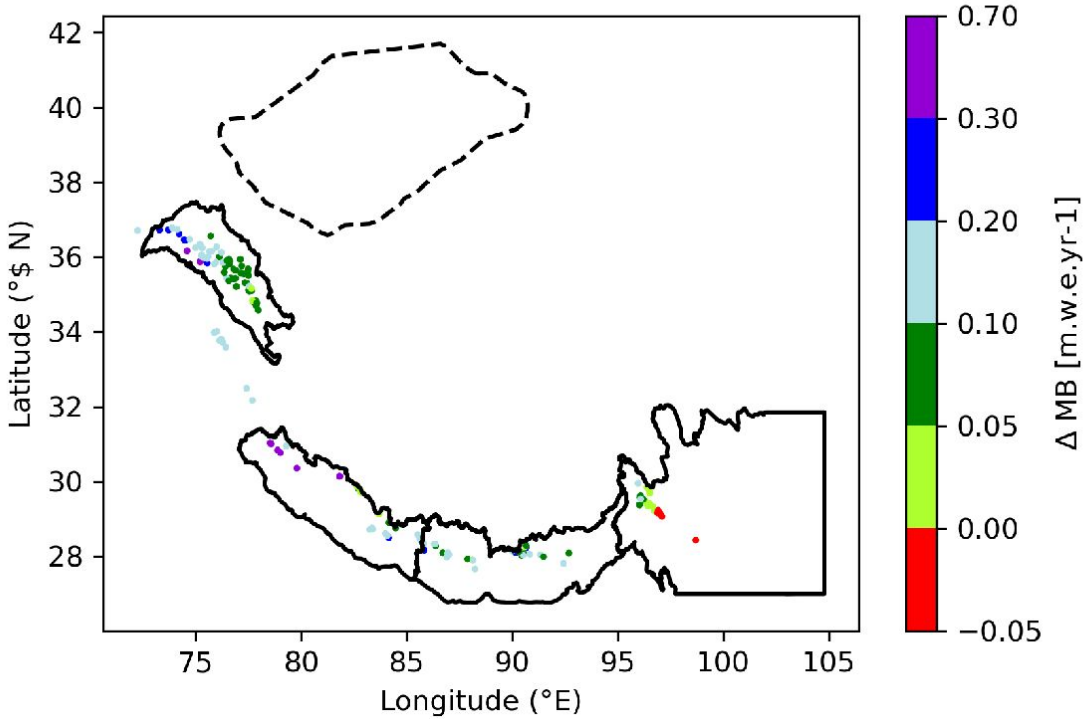
(Thiery et al., 2020 Nature Comm.)



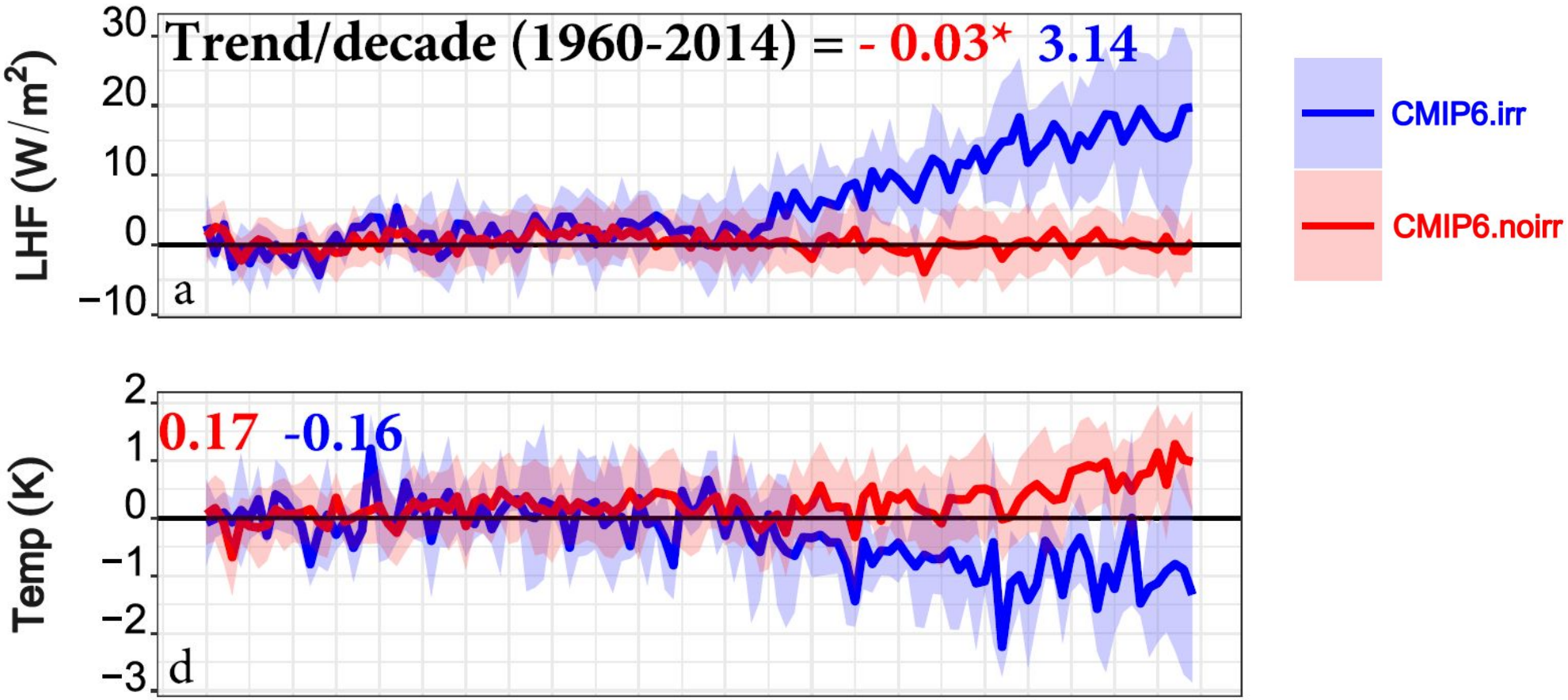
(Gormley-Gallagher et al., 2022 ESD)

Irrigation as explanation of the Karakorum anomaly?





(Vaes et al., in prep.)



(Al Yaari et al., 2022 EF)

Early 20th Century

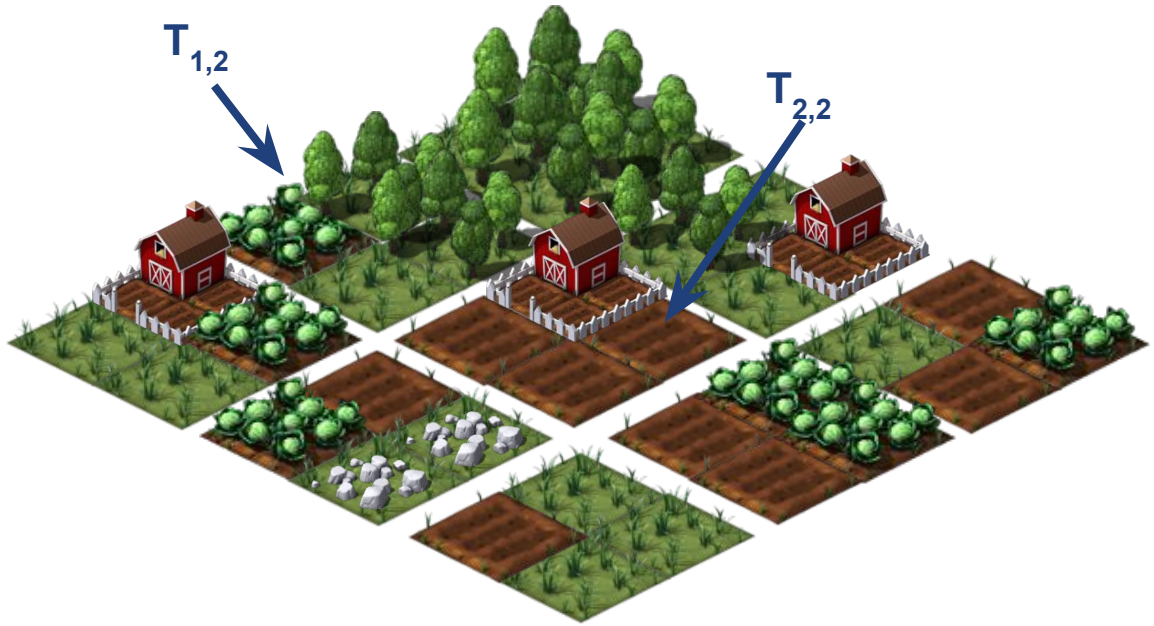
$\overline{T}$

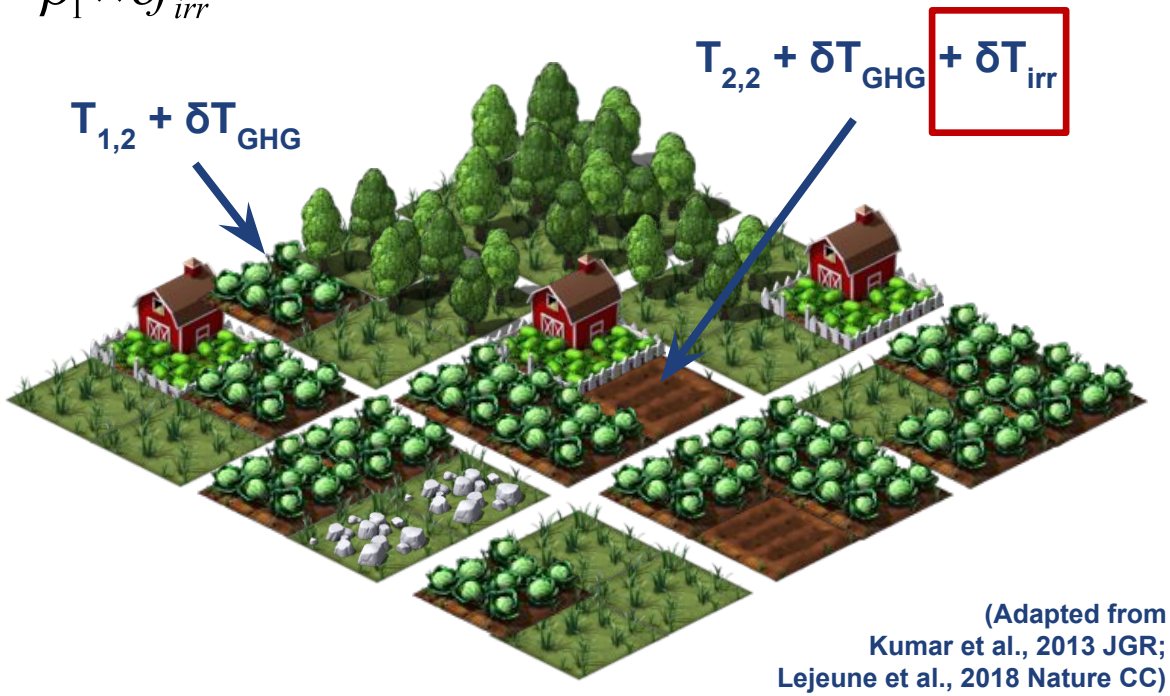
Present-day

$\overline{T} + \overline{\delta T}_{GHG}$

Big Box: $\delta T_{tot} = \beta_0 + \beta_1 \times \delta f_{irr} + \beta_2 \times lat + \beta_3 \times lon + \beta_4 \times elev$

Center pixel: $\delta T_{irr} = \beta_1 \times \delta f_{irr}$





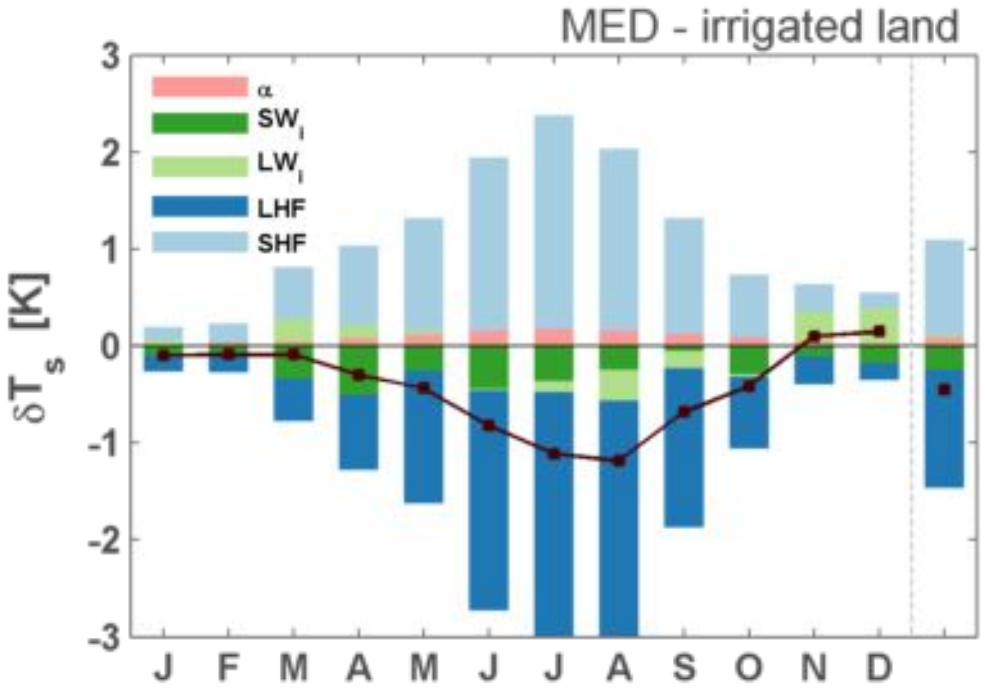
(Adapted from Kumar et al., 2013 JGR; Lejeune et al., 2018 Nature CC)

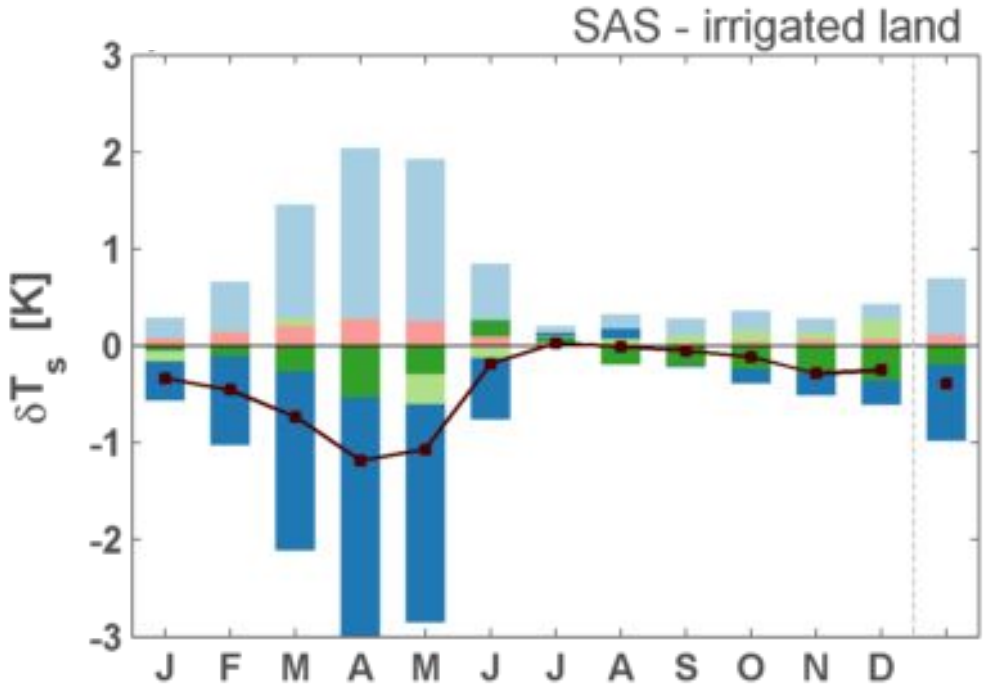
Probability ratio (PR)

$$PR = \frac{P_{new}}{P_{ref}} = \frac{0.5}{0.1} = 5$$

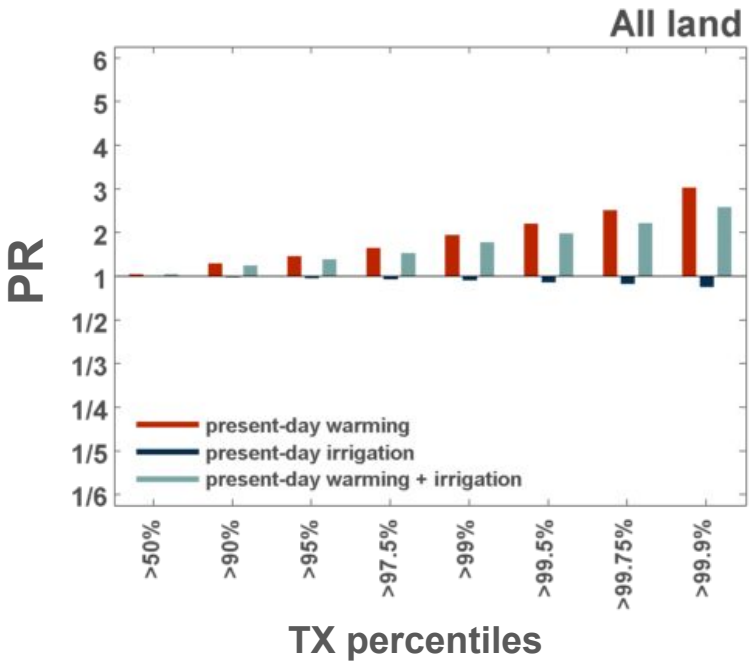
P_{new}: event probability in the new situation
P_{ref} : event probability in the reference situation

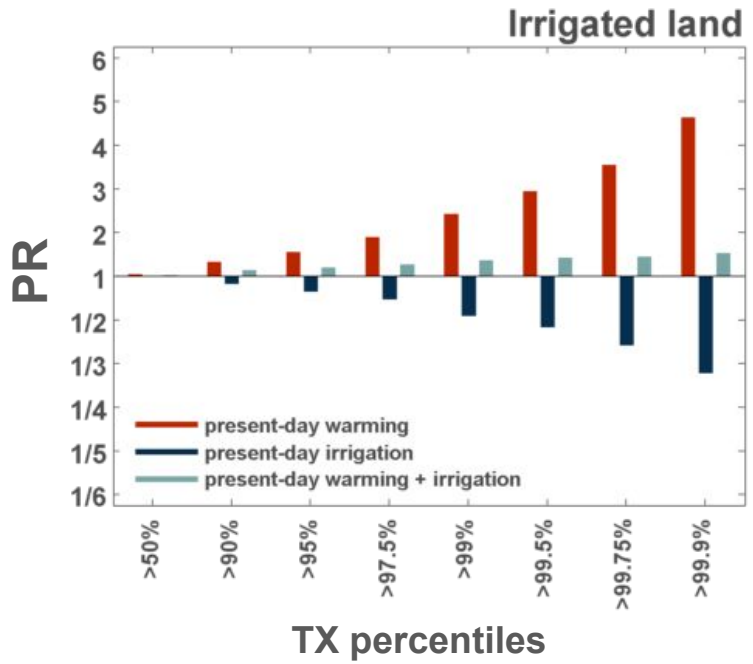
(Fischer and Knutti, 2015 Nature CC)

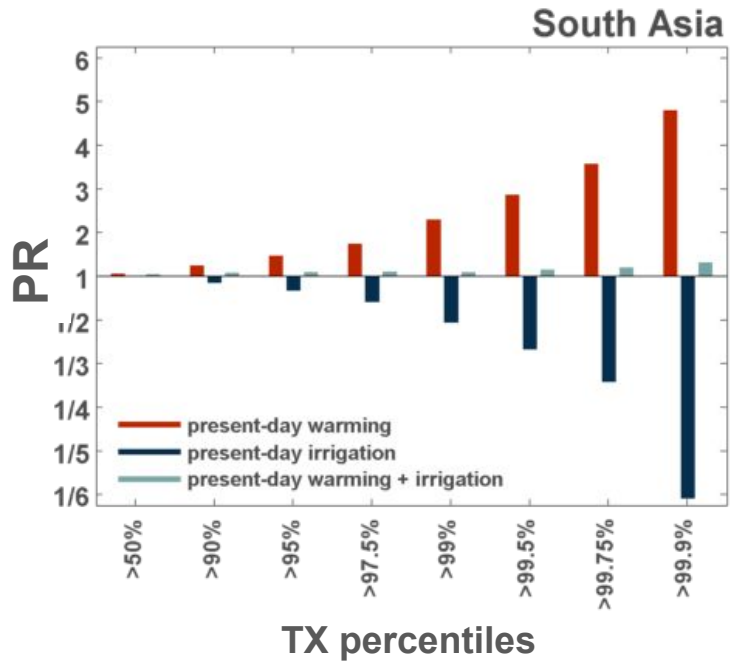




(Thiery et al., 2017 JGR)



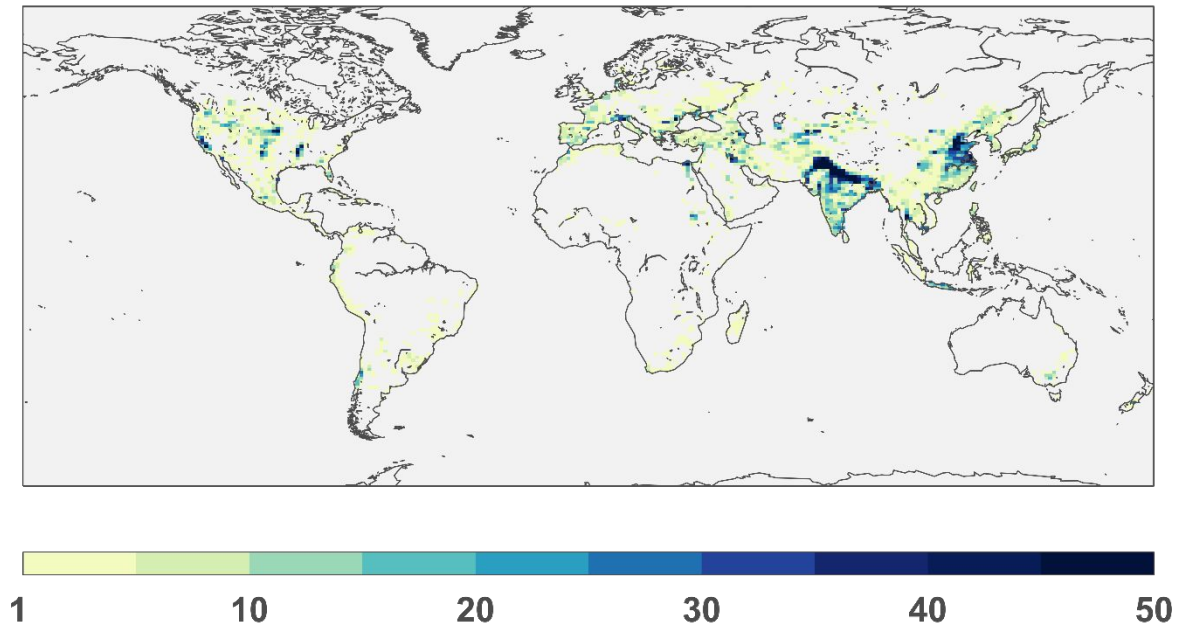


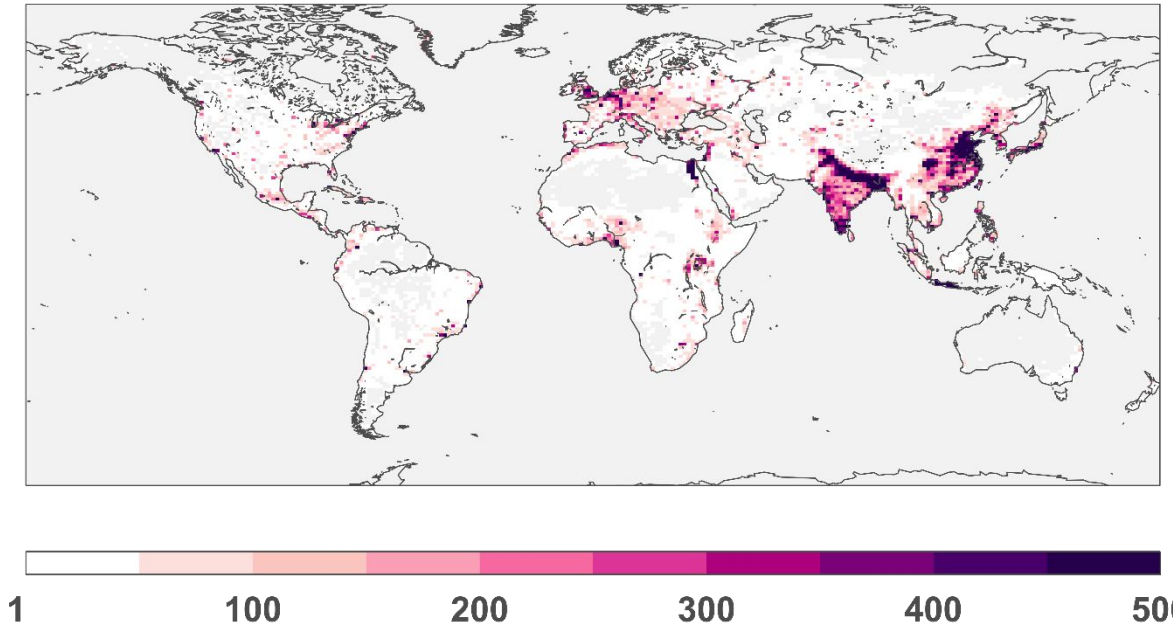


~5 % of all land

~3 % of all land

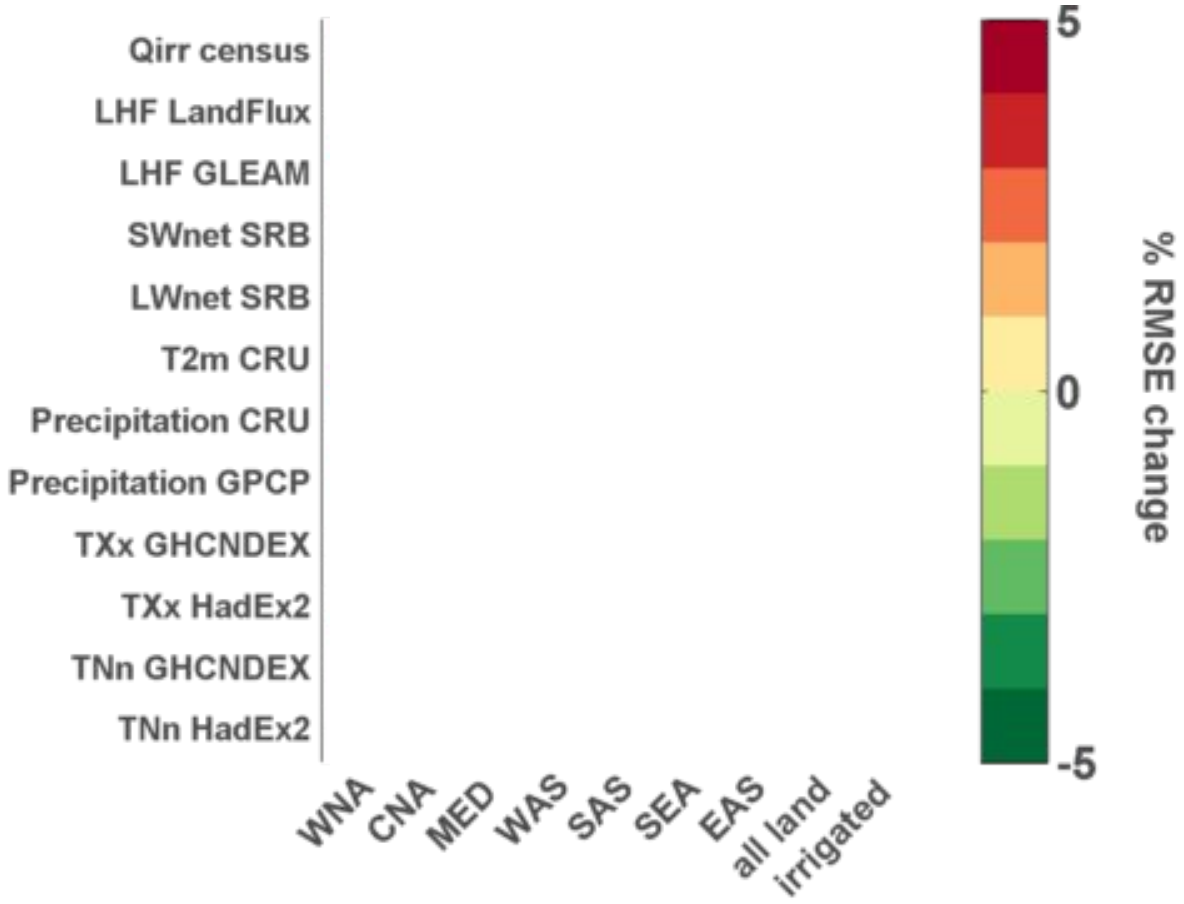
(Thiery et al., 2020 Nature Comm.)





0.79 – 1.29 Billion people less exposed to hot extremes (≠ heat stress)

Added value matrix: changes in spatiotemporal RMSE



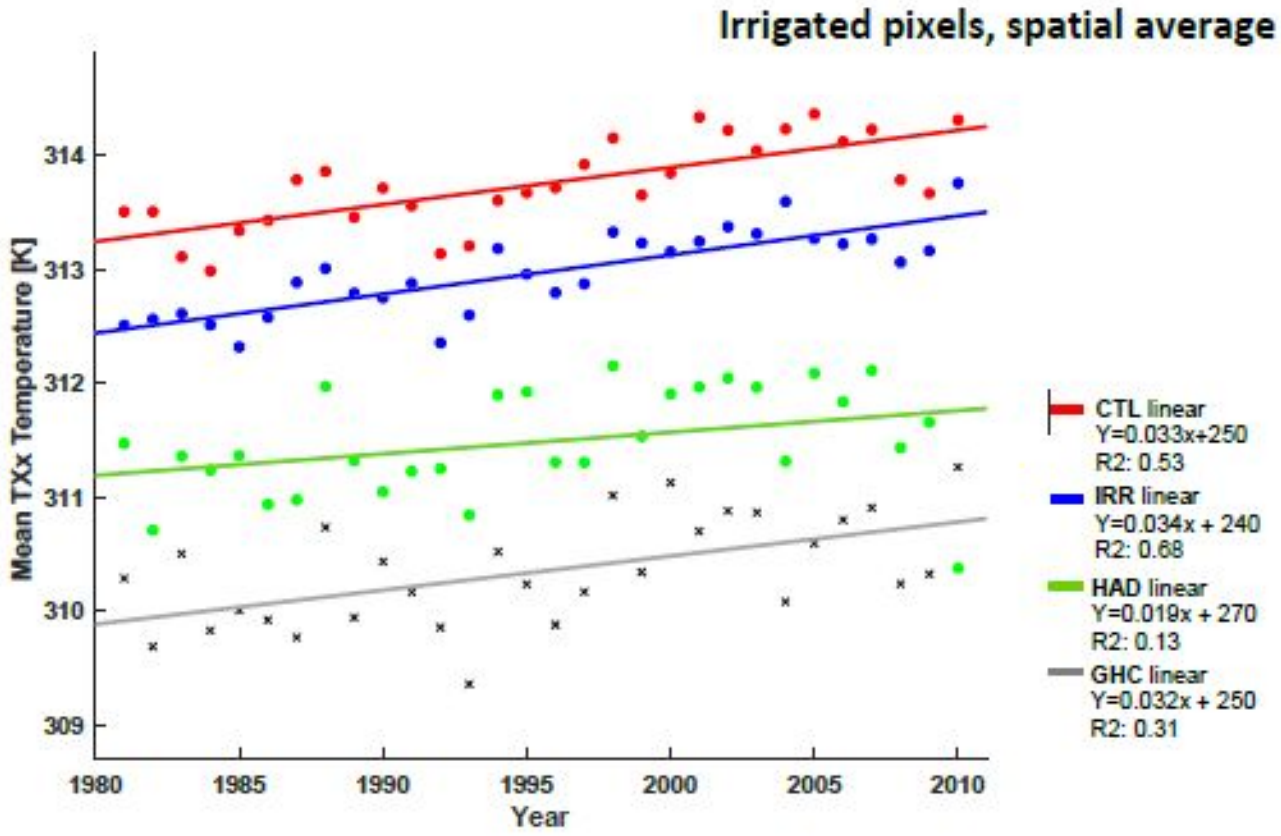
77% of all cells show enhanced skill

(Thiery et al., 2017 JGR)

Irrigation: no effect on recent trends in TXx

instead pulse cooling, so hypothesis that irrigation causes CMIP5 trend bias not corroborated

"We do not find positive trends in the highest maximum temperature of the year in most of India since the 1970s (except spurious trends due to missing data). Decadal variability cannot explain this, but both increased air pollution with aerosols blocking sunlight and increased irrigation leading to evaporative cooling have counteracted the effect of greenhouse gases up to now. Current climate models do not represent these processes well and hence cannot be used to attribute heat waves in this area." (van Oldenborgh et al., 2018 HESS)



(Gormley et al., in prep.)

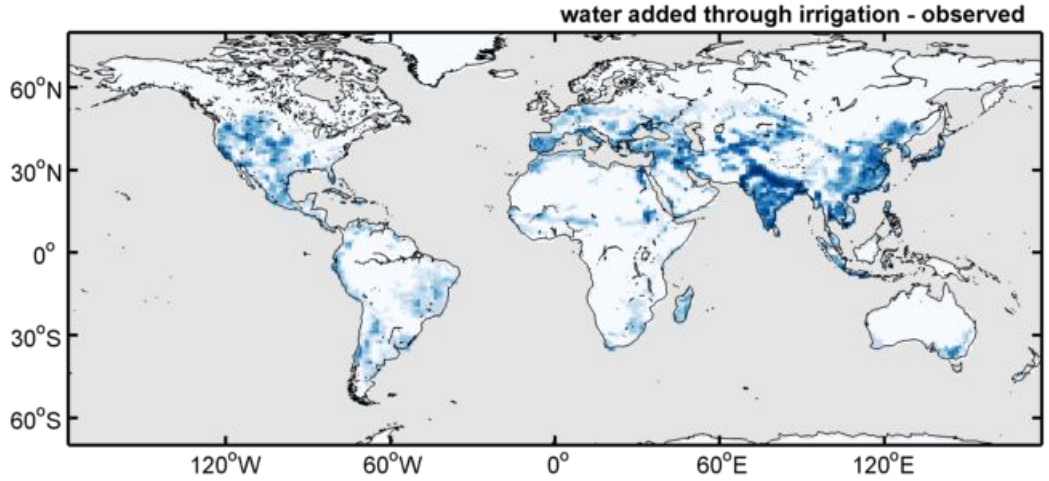
Challenges

- Model instead of prescribe irrigation amounts (but still get realistic numbers)
- Avoid ‘contamination’ of natural SM
- Account for natural variability
- Model evaluation

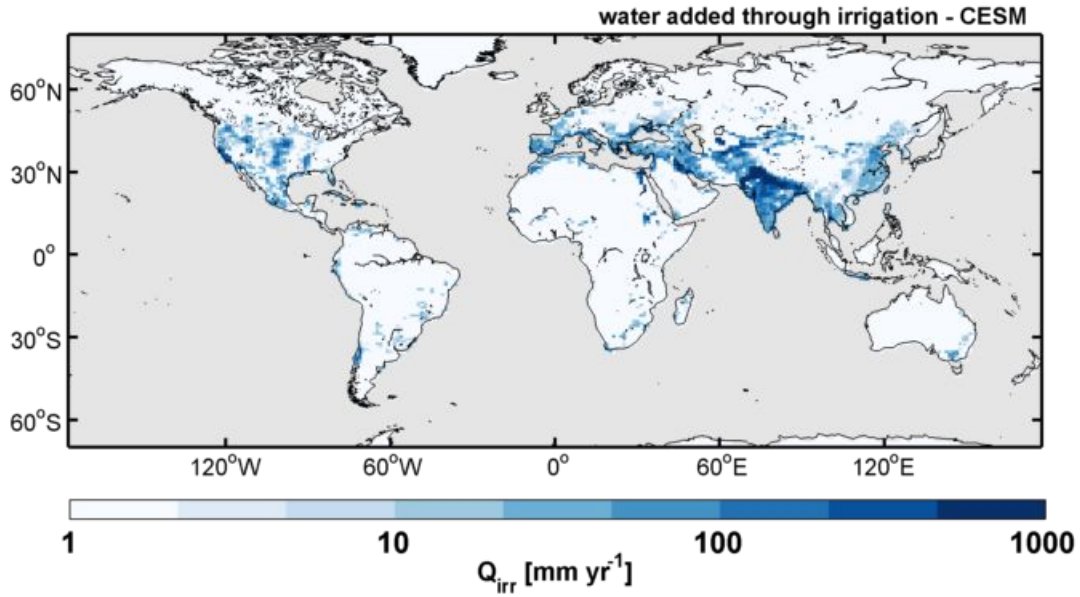
- Focus on extremes
- Quantify contributions from different perturbations of the SEB
- Contrast local effects to grid-cell averages

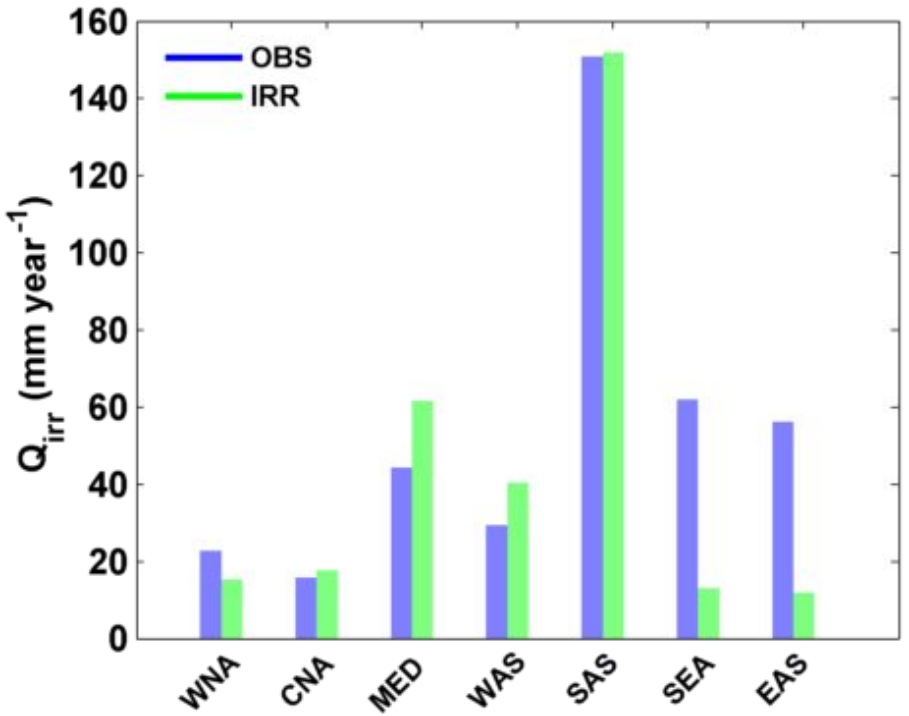
Water added through irrigation

OBS



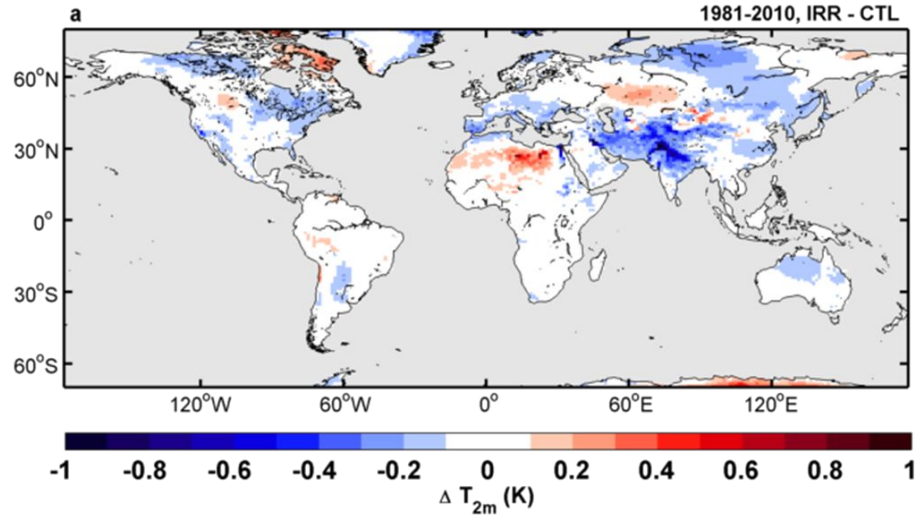
IRR

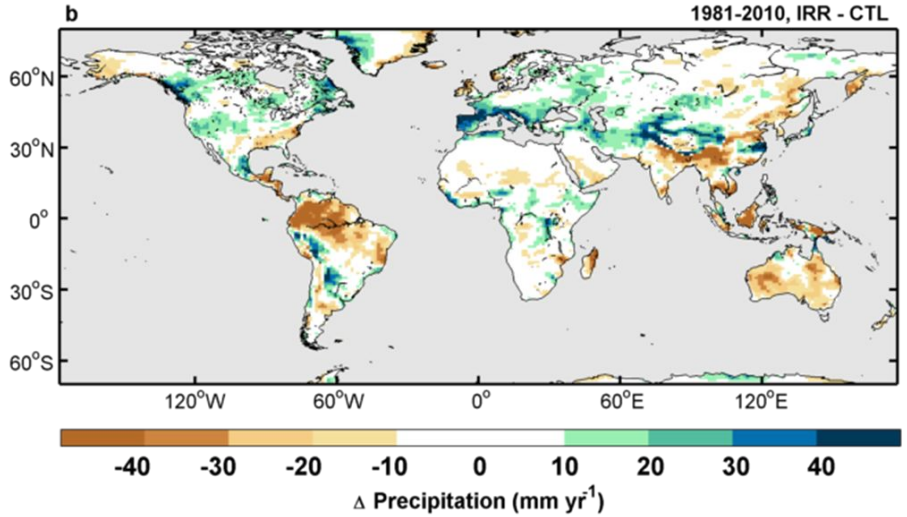


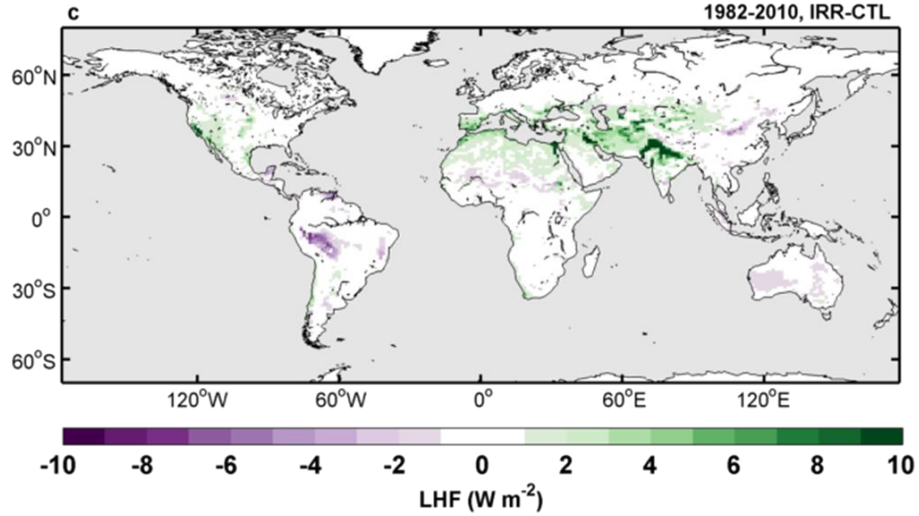


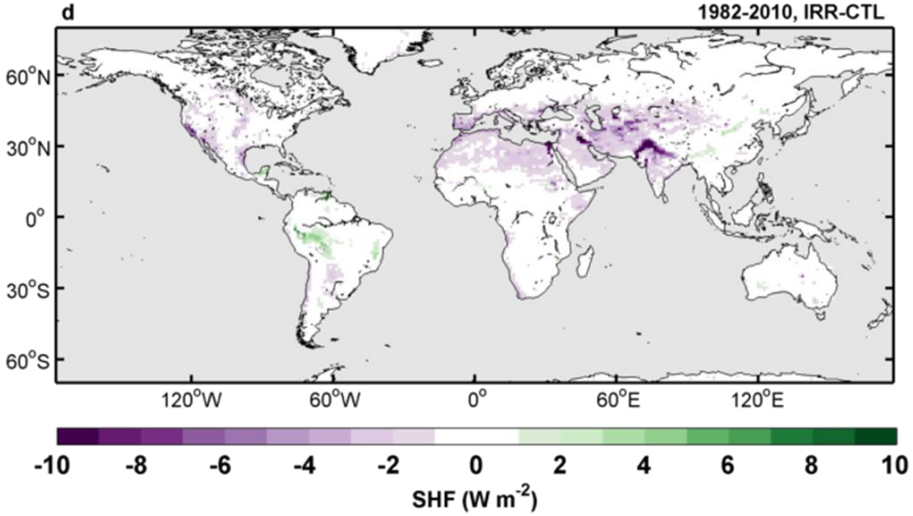
(Thiery et al., 2017 JGR)

Impact on T2m and precipitation



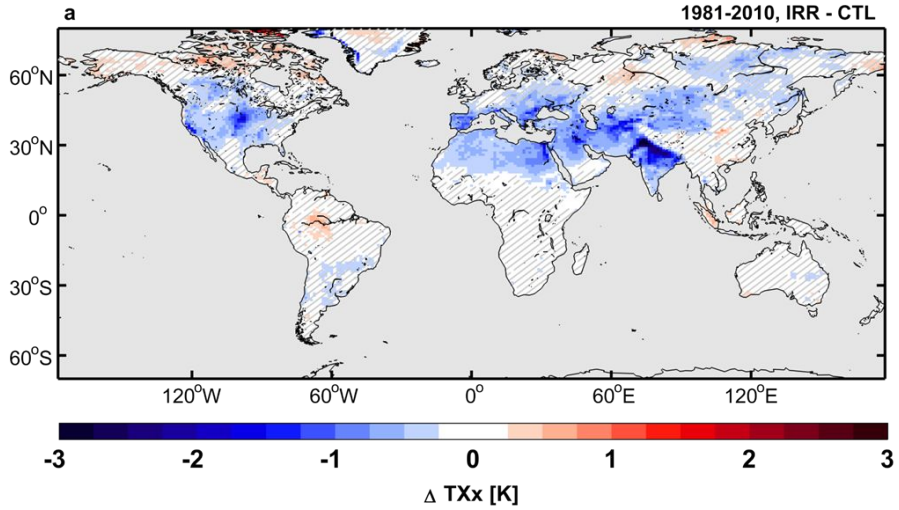


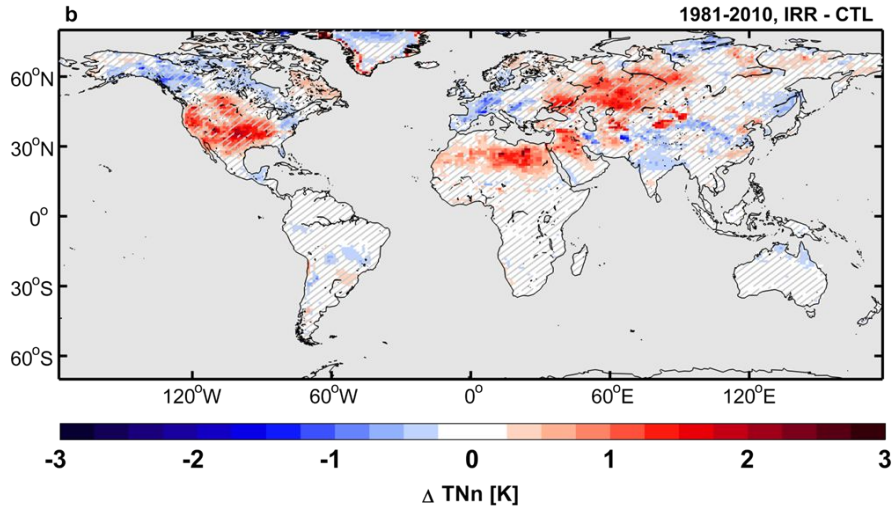


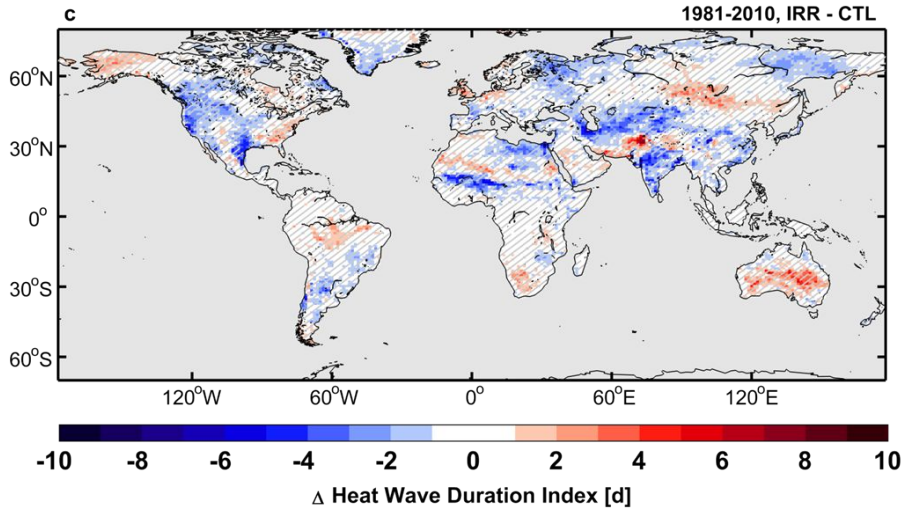


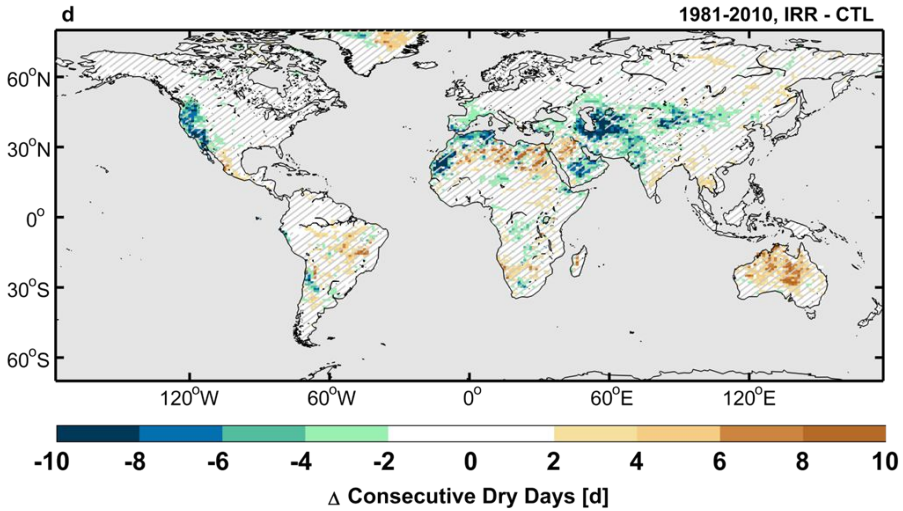
(Thiery et al., 2017 JGR)

Impact on climate extremes



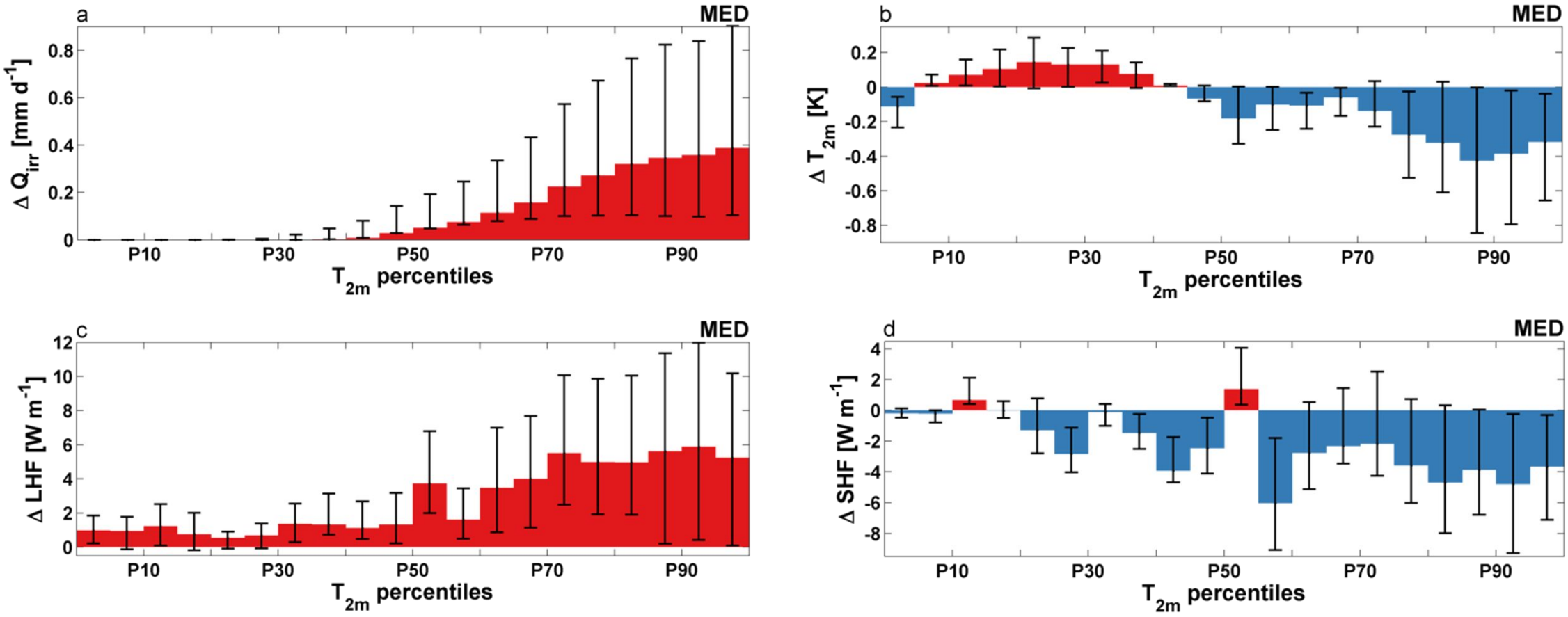






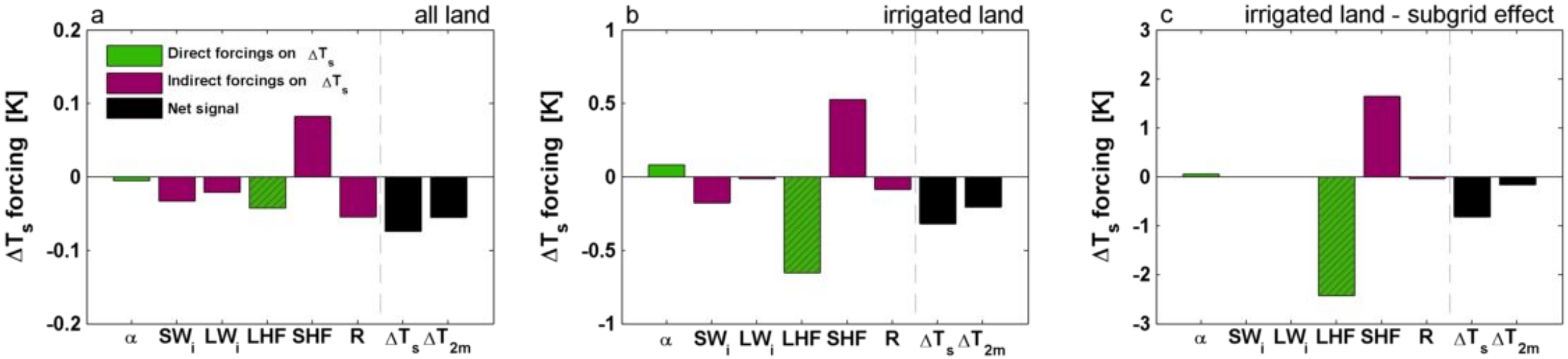
(Thiery et al., 2017 JGR)

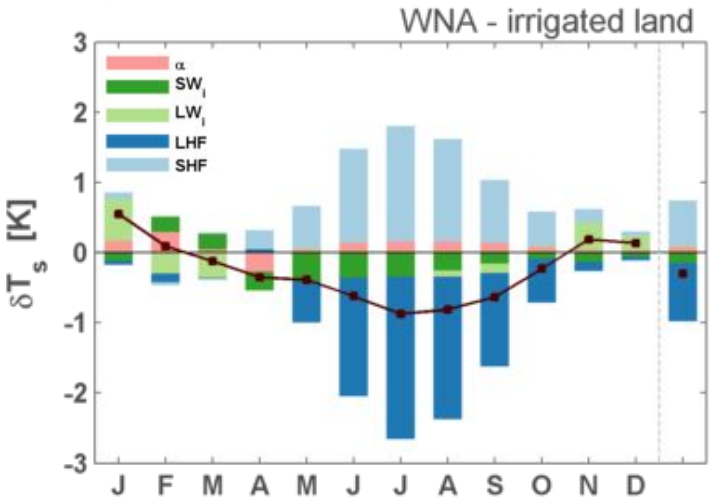
Asymmetric response: Mediterranean

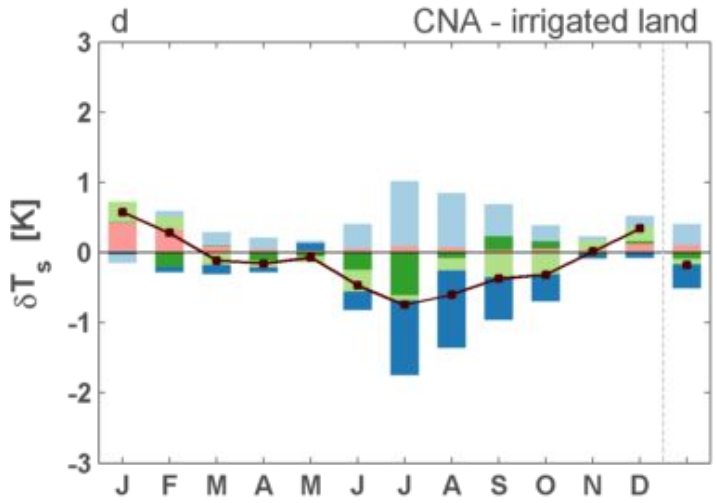


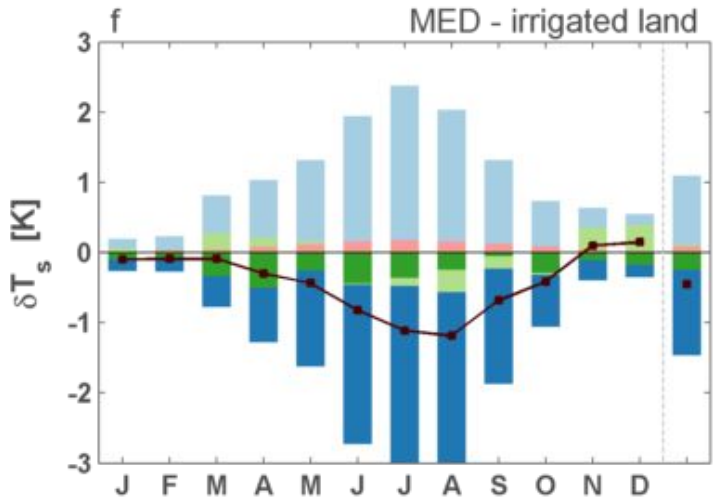
(Thiery et al., 2017 JGR)

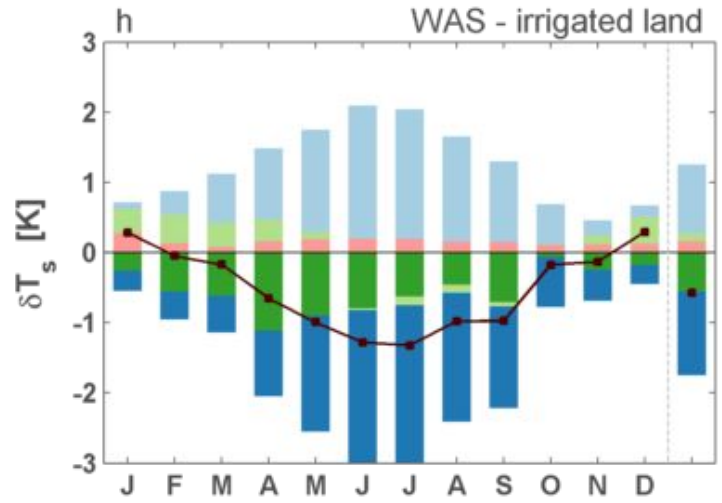
SEB decomposition

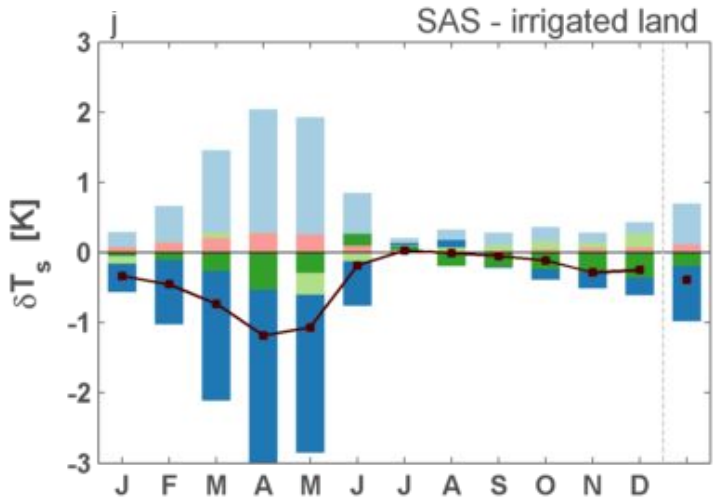


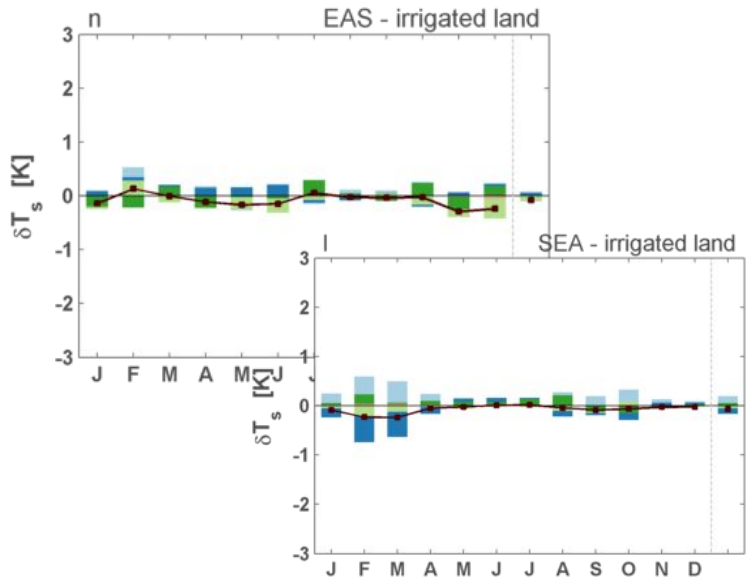

WNA - irrigated land
α
SW↓
LW↓
LHF
SHF
δT_s [K]
J F M A M J J A S O N D

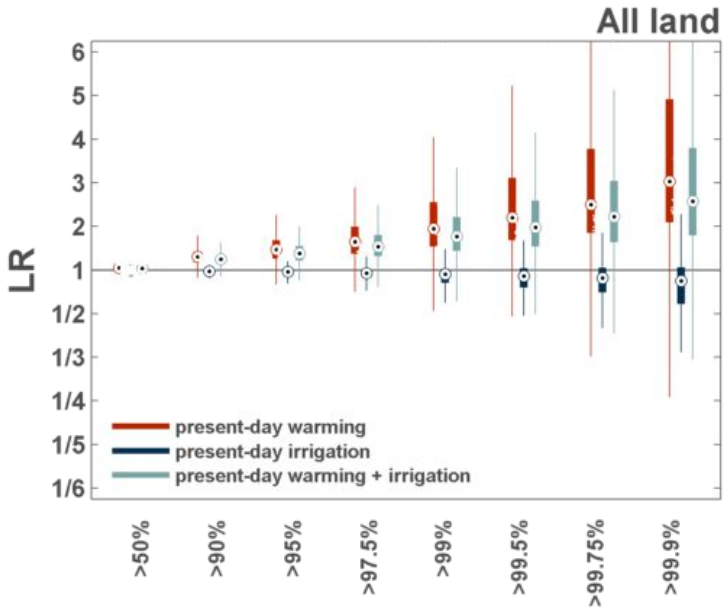

d
CNA - irrigated land
δT_s [K]
J F M A M J J A S O N D

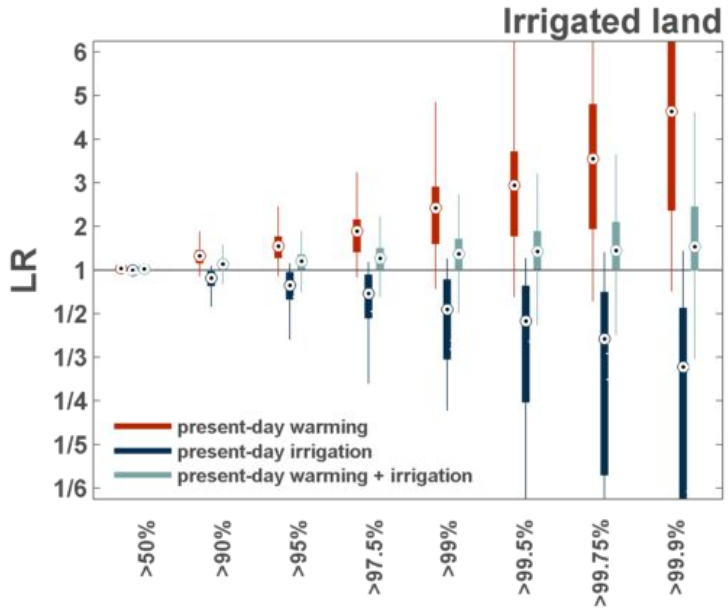

f
MED - irrigated land
δT_s [K]
J F M A M J J A S O N D

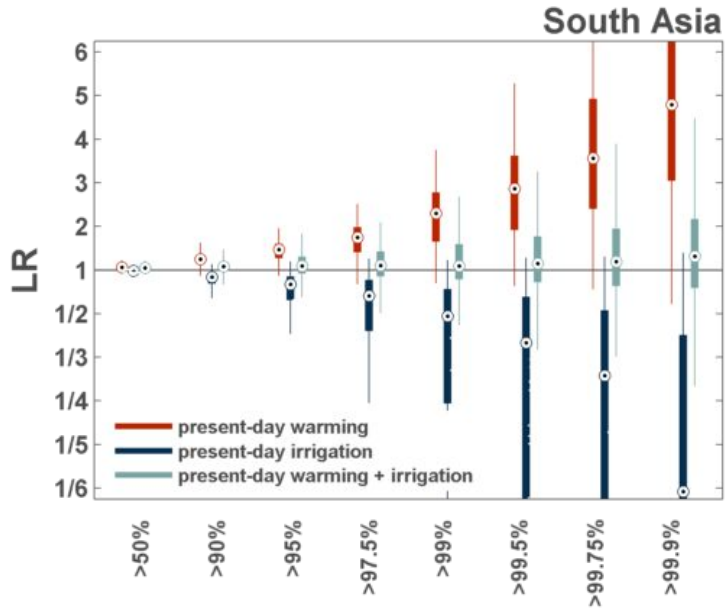

h
WAS - irrigated land
δT_s [K]
J F M A M J J A S O N D


j
SAS - irrigated land
δT_s [K]
J F M A M J J A S O N D


n
EAS - irrigated land
l
SEA - irrigated land
δT_s [K]
J F M A M J J A S O N D



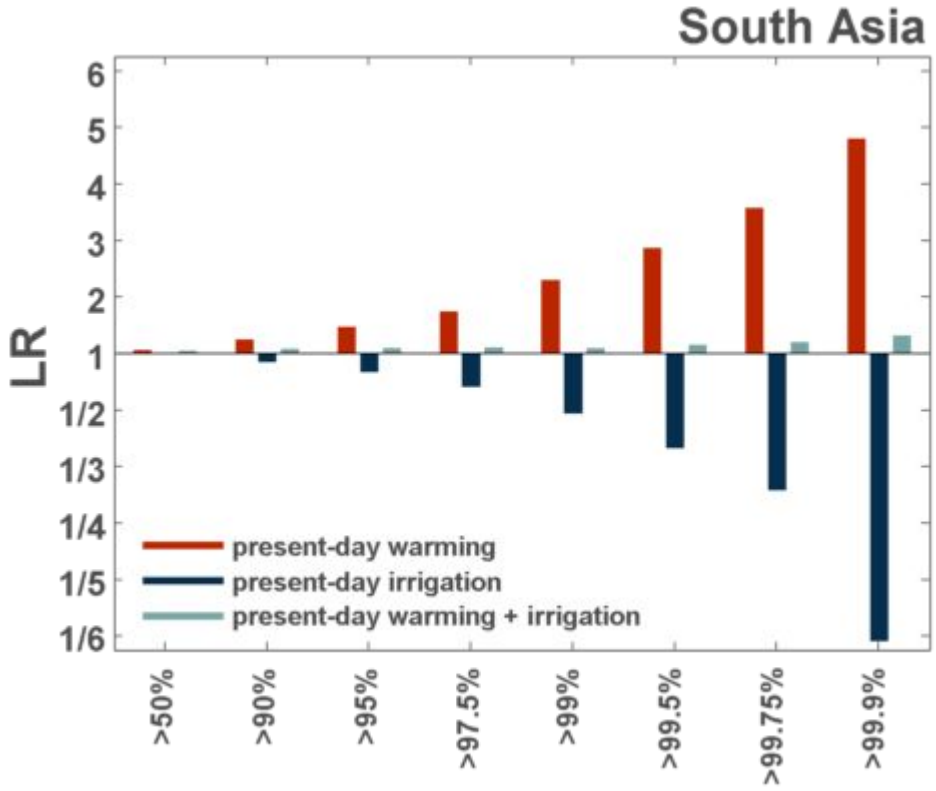


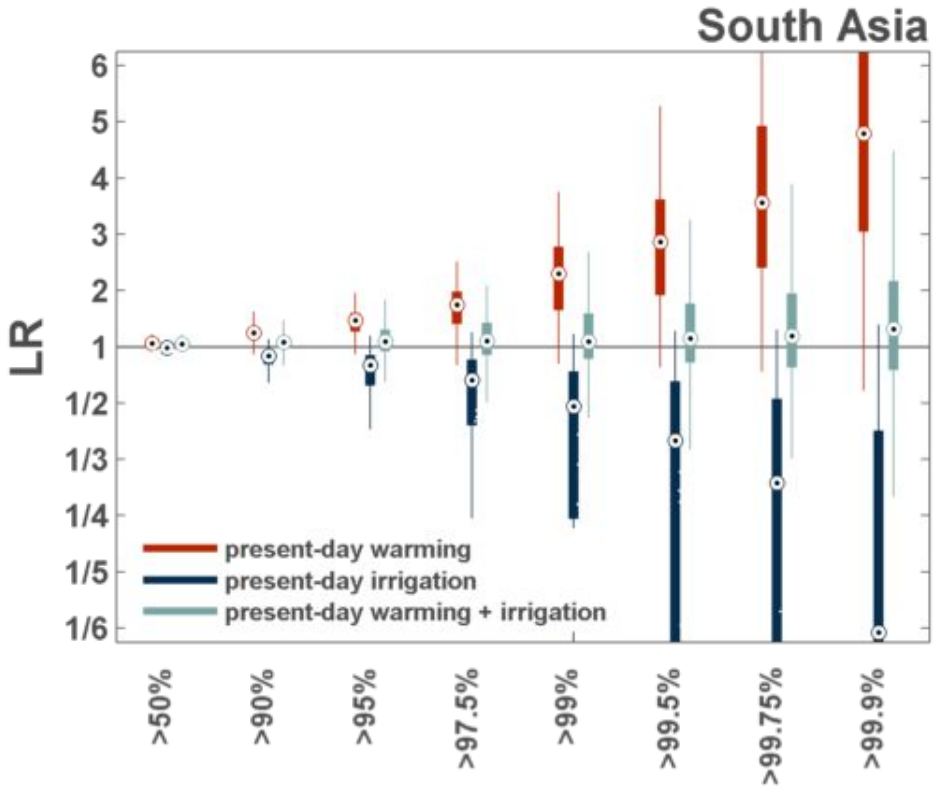


~5 % of all land

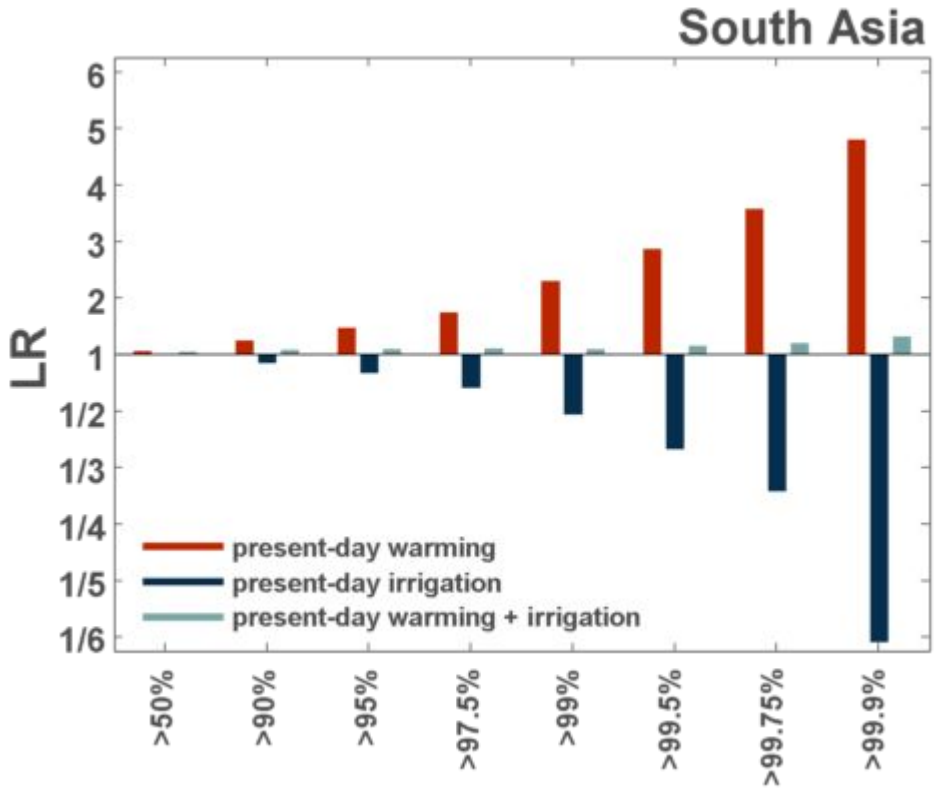
~3 % of all land

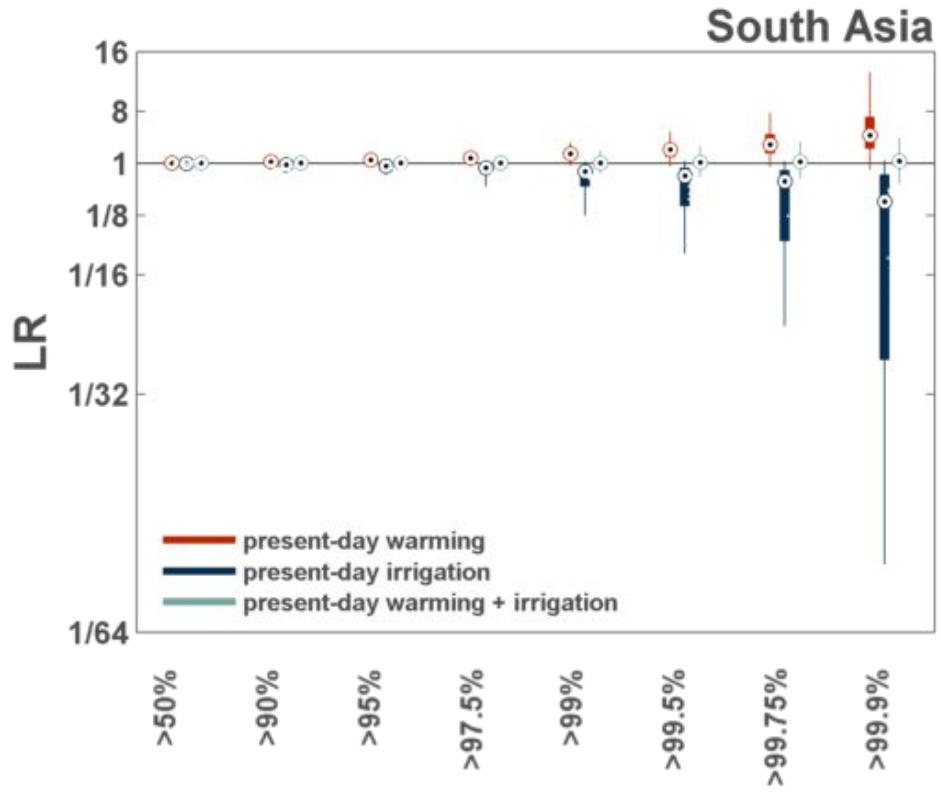
spread


South Asia
LR
6
5
4
3
2
1
1/2
1/3
1/4
1/5
1/6
present-day warming
present-day irrigation
present-day warming + irrigation
>50%
>90%
>95%
>97.5%
>99%
>99.5%
>99.75%
>99.9%

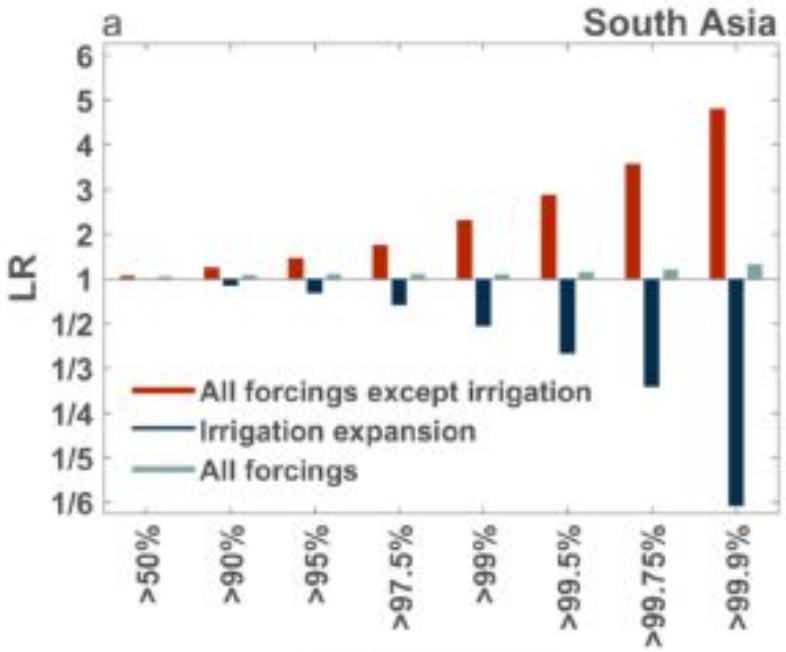

South Asia
LR
6
5
4
3
2
1
1/2
1/3
1/4
1/5
1/6
present-day warming
present-day irrigation
present-day warming + irrigation
>50%
>90%
>95%
>97.5%
>99%
>99.5%
>99.75%
>99.9%

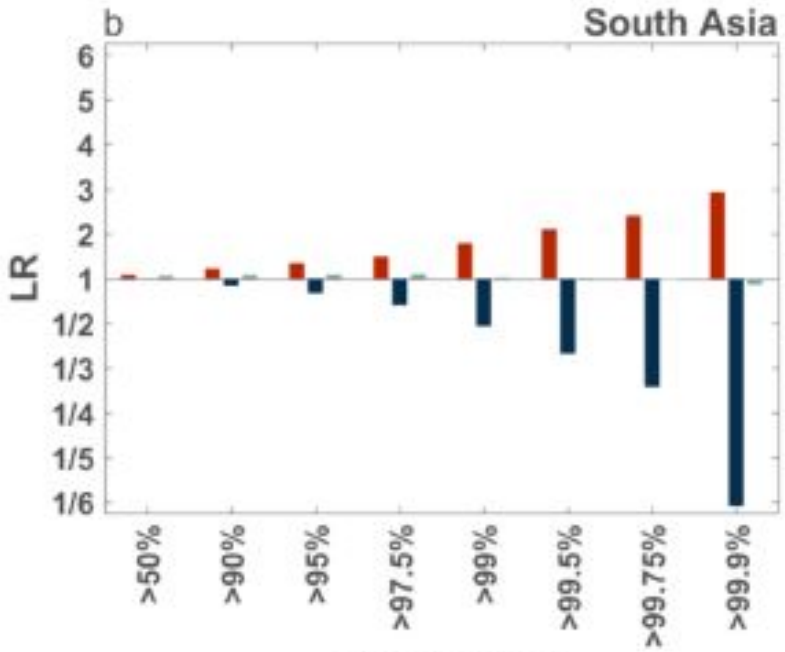
spread

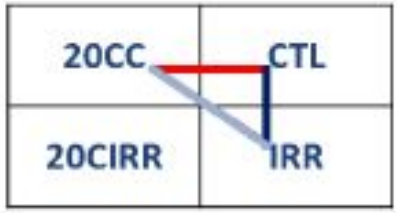

South Asia
LR
6
5
4
3
2
1
1/2
1/3
1/4
1/5
1/6
present-day warming
present-day irrigation
present-day warming + irrigation
>50%
>90%
>95%
>97.5%
>99%
>99.5%
>99.75%
>99.9%


South Asia
LR
16
8
1
1/8
1/16
1/32
1/64
present-day warming
present-day irrigation
present-day warming + irrigation
>50%
>90%
>95%
>97.5%
>99%
>99.5%
>99.75%
>99.9%

Effect of including irrigation in the reference ensemble







SREX regions – all land