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# Irrigation techniques in CESM2: from present-day to future

Implementation of irrigation techniques and creation of projected irrigation techniques shares dataset

Yi Yao\*, Wim Thiery et al.

# Deadly heatwaves

COP27

## Europe's heatwave may have caused more than 20,000 'excess' deaths

By Juliette Portala

November 24, 2022 8:46 PM GMT+1 · Updated 7 months ago



A woman covers her head with a bag as she walks at Puerta del Sol square during a hot day as Spain braces for a heatwave in Madrid, Spain, June 10, 2022. REUTERS/Susana Vera/File Photo

## Melbourne to hit 38C and western Sydney 35C as heatwave sweeps parts of Australia

Very warm weather conditions will extend across southern areas and linger until next week, Bureau of Meteorology says

- Follow our [Australia news live blog for the latest updates](#)
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Melbourne was expected to reach a sweltering 35C degrees on Friday as low-level heatwaves settled in over large parts of Australia. Photograph: Con Chronis/AAP

## Climate change is fueling deadly heat waves in India. It's putting the country's development at risk, study says



By Helen Regan, CNN

Published 3:33 AM EDT, Thu April 20, 2023



Prakash Singh/AP/Getty Images/FILE

# What can irrigation do?

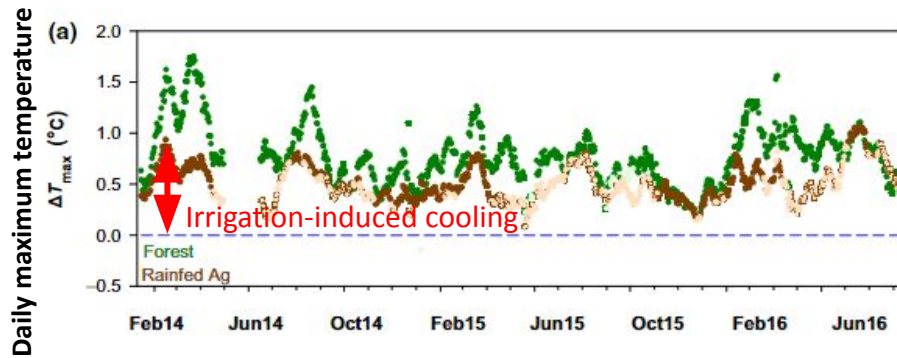
Received: 21 November 2018 | Accepted: 2 May 2019  
DOI: 10.1111/gcb.14725

PRIMARY RESEARCH ARTICLE

Global Change Biology WILEY

## Observation of irrigation-induced climate change in the Midwest United States

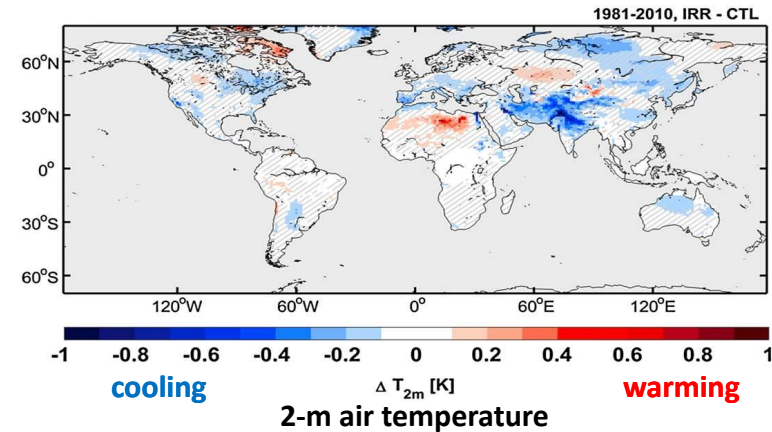
Mallika A. Nocco<sup>1</sup> | Robert A. Smail<sup>2</sup> | Christopher J. Kucharik<sup>1,3</sup>



## Present-day irrigation mitigates heat extremes

Wim Thiery<sup>1,2</sup>, Edouard L. Davin<sup>1</sup>, David M. Lawrence<sup>3</sup>, Annette L. Hirsch<sup>1</sup>, Mathias Hauser<sup>1</sup>, and Sonia I. Seneviratne<sup>1</sup>

<sup>1</sup>Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland, <sup>2</sup>Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Brussels, Belgium, <sup>3</sup>National Center for Atmospheric Research, Boulder, Colorado, USA



Ref:

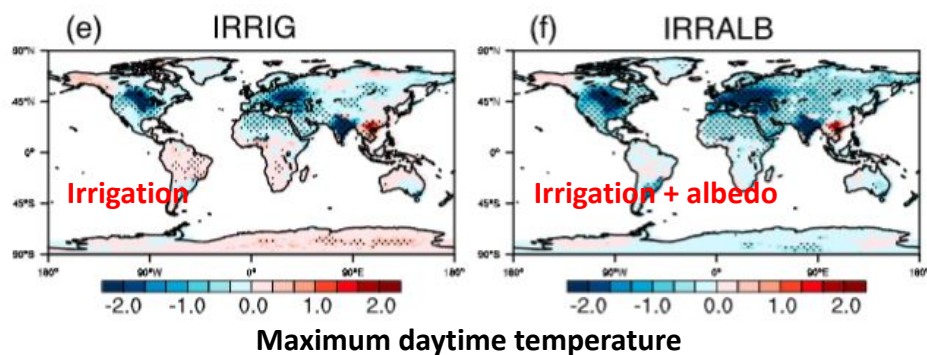
Nocco, Mallika A., Robert A. Smail, and Christopher J. Kucharik. "Observation of irrigation-induced climate change in the Midwest United States." *Global change biology* 25.10 (2019): 3472-3484.  
Thiery, Wim, et al. "Present-day irrigation mitigates heat extremes." *Journal of Geophysical Research: Atmospheres* 122.3 (2017): 1403-1422.

# What can irrigation do?

## Can climate-effective land management reduce regional warming?

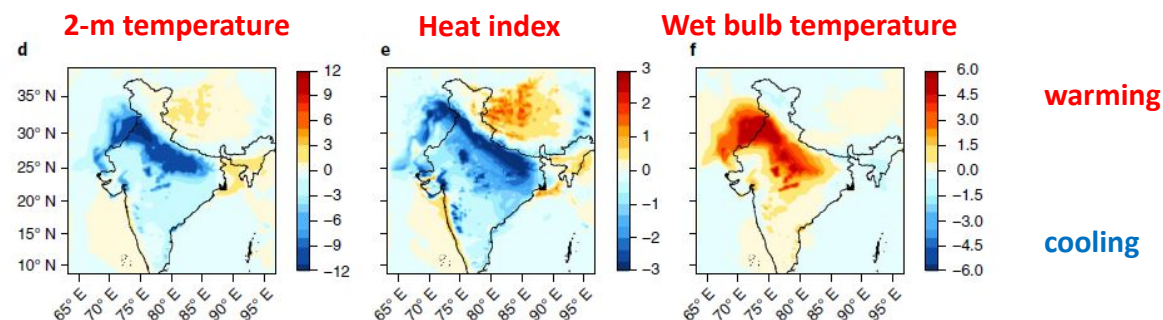
A. L. Hirsch<sup>1</sup>, M. Wilhelm<sup>1</sup>, E. L. Davin<sup>1</sup>, W. Thiery<sup>1,2</sup>, and S. I. Seneviratne<sup>1</sup>

<sup>1</sup>Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland, <sup>2</sup>Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Brussels, Belgium



## Moist heat stress extremes in India enhanced by irrigation

Vimal Mishra<sup>1,2</sup>, Anukesh Krishnankutty Ambika<sup>2</sup>, Akarsh Asoka<sup>2</sup>, Saran Aadhar<sup>1</sup>, Jonathan Buzan<sup>3</sup>, Rohini Kumar<sup>4</sup> and Matthew Huber<sup>3</sup>



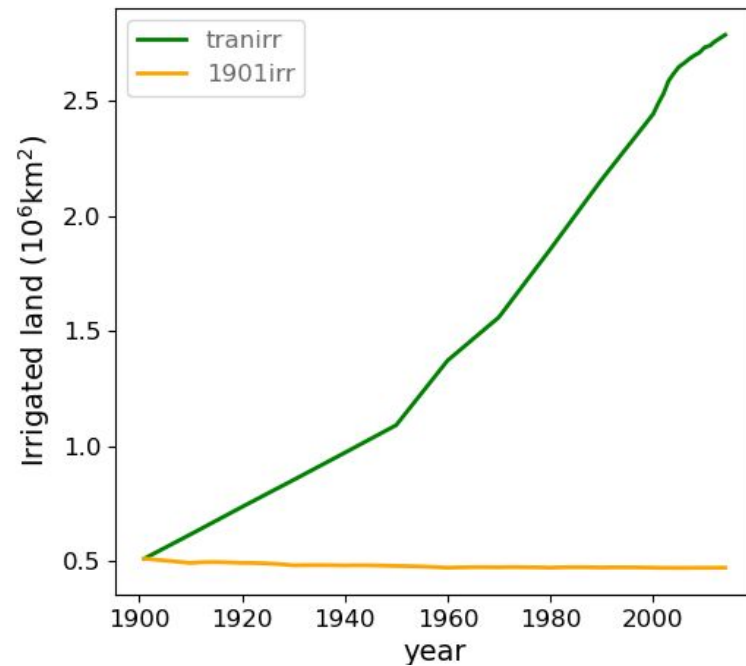
# IRRigation impacts model intercomparison project (IRRMIP)

Objective: impacts of irrigation expansion in 20<sup>th</sup> century on heat extreme events

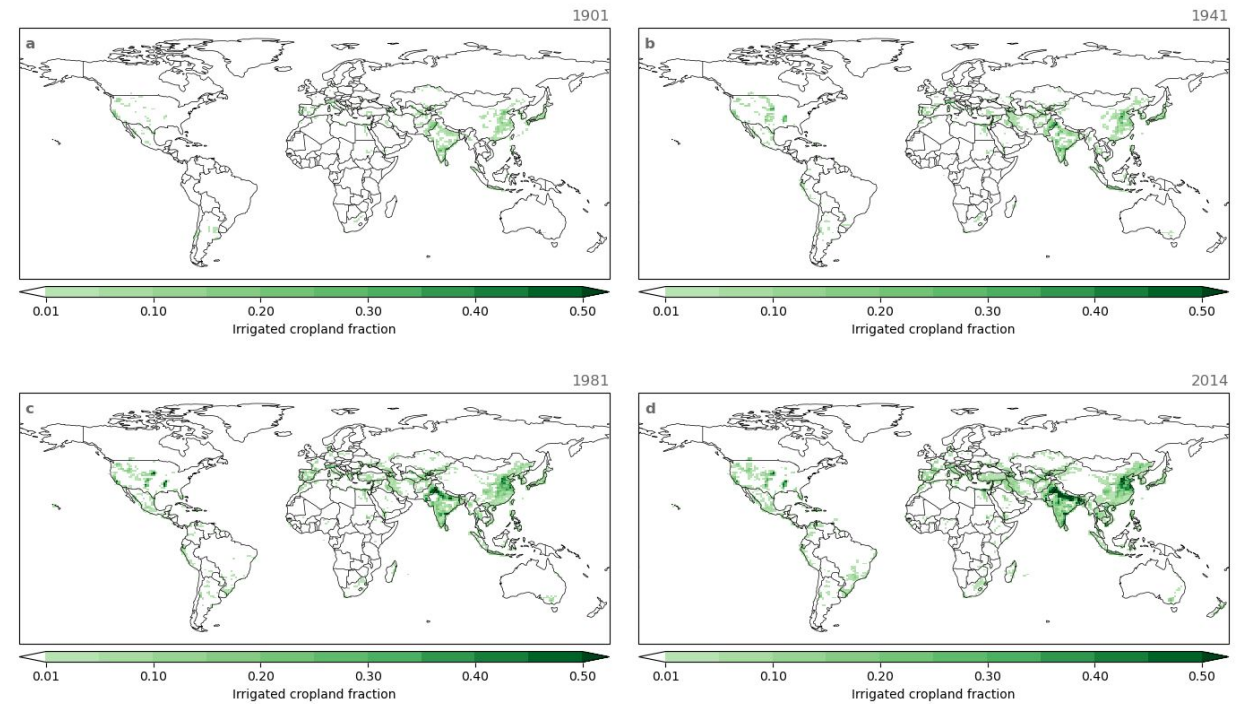
Period: 1901 - 2014

Simulations: tranirr – transient irrigation extent

1901irr – irrigation extent fixed at 1901 level



AMIP





# Data analysis for IRRMIP


$$PR \text{ (probability ratio)} = \frac{\text{Probability}(exp)}{\text{Probability}(ref)}$$

*TSA95%: Events that TSA exceeds 95% percentile during reference period*

*PR > 1: Events happen more likely; PR < 1: Events happen less likely*

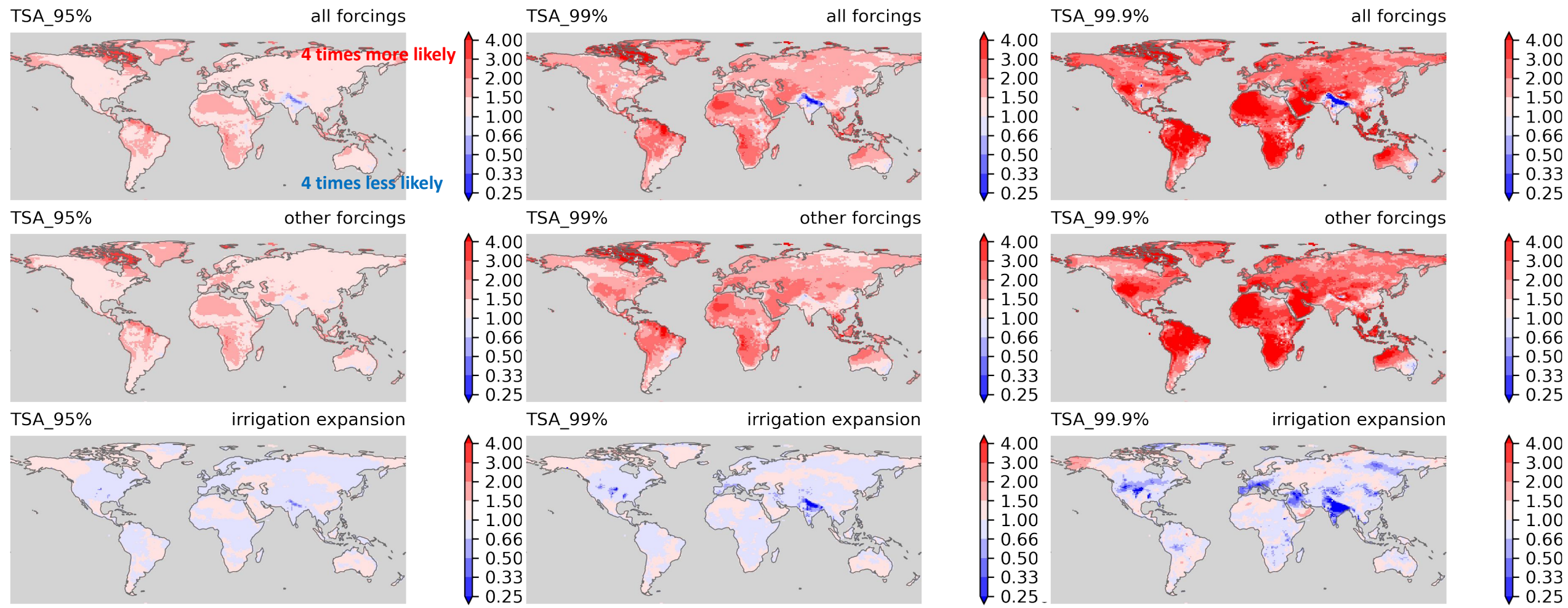
*ref: tranirr 1901 – 1930*  *Impacts of all forcings*  
*exp: tranirr 1985 – 2014*

*ref: 1901irr 1901 – 1930*  *Impacts of all forcings except irrigation expansion*  
*exp: 1901irr 1985 – 2014*

*ref: 1901irr 1985 – 2014*  *Impacts of irrigation expansion*  
*exp: tranirr 1985 – 2014*

# Results from CESM2.1

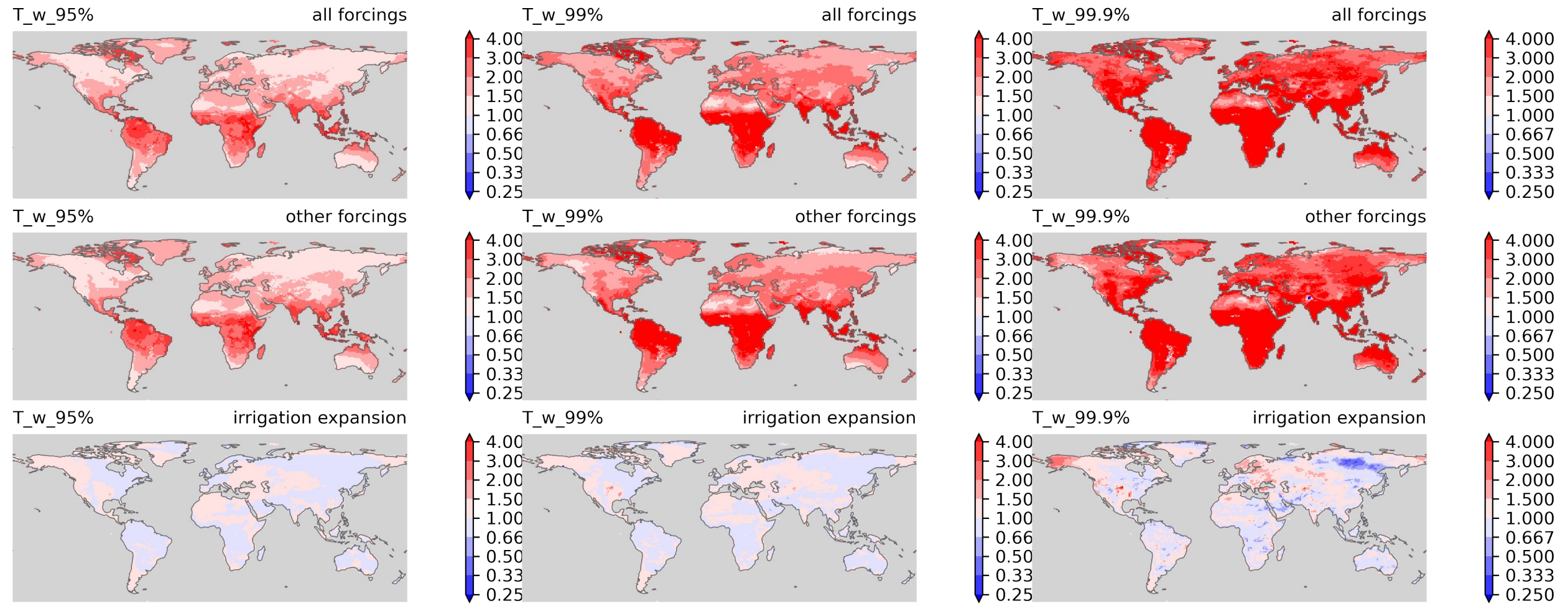
## 2-m air temperature



Irrigation can greatly reduce the frequency of high temperature. The more extreme the temperature is, the more substantial the impacts are.

# Results from CESM2.1.3

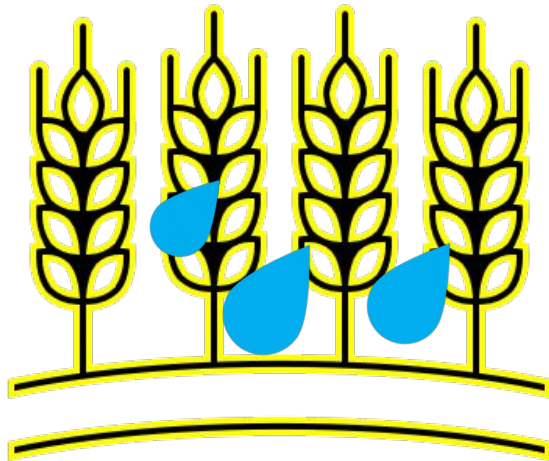
## Wet bulb temperature



After taking moisture into account, irrigation-induced impacts become unclear. However, we didn't see intensified heat extremes in India. Why?



# Representation of irrigation in CESM2.1



**When?** available soil water less than a threshold

$$SW_{avail} < SW_{thresh}$$

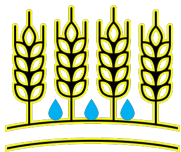
**How much?** target soil water minus available soil water

$$SW_{target} - SW_{avail}$$

**Where?** under canopy = no interception

# Implementation of irrigation techniques in CESM2.2

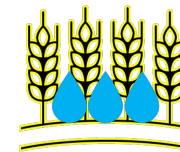
Drip



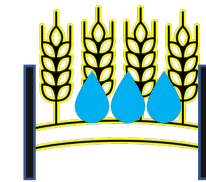
Sprinkler



Flood



Paddy



**Method**

**When**

**How much**

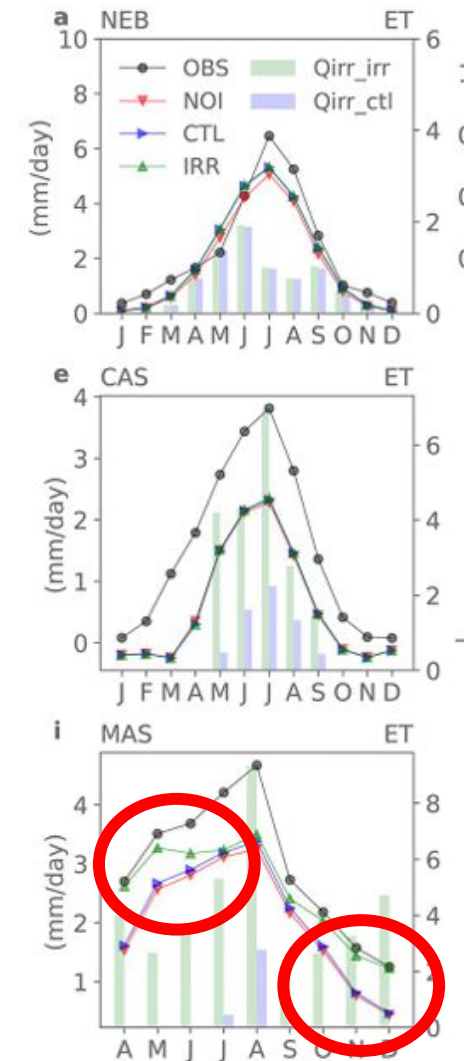
**Where**

**Water Ponding**

Drip				Under canopy	No
Sprinkler				Over canopy	No
Flood				Under canopy	No
Paddy				Under canopy	Yes

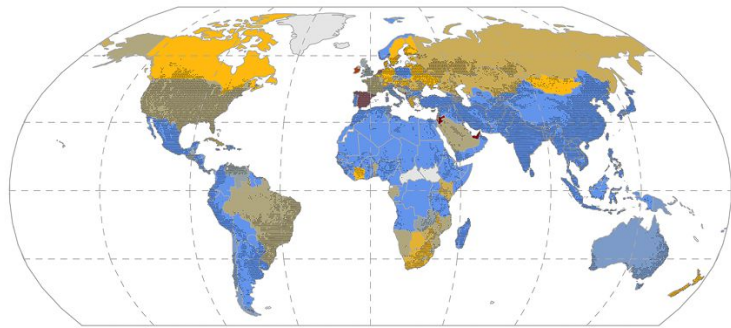
# Evaluation 1: single-point simulations

Simulations	Settings
NOI	No irrigation activated
CTL	With the original irrigation module on
IRR	With the new irrigation module on
NEB:	Nebraska, USA, Maize, Sprinkler
CAS:	Castellaro, ITA, Maize, Flood
MAS:	Mase, JAP, Rice, Paddy

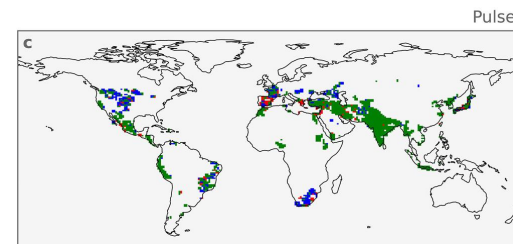
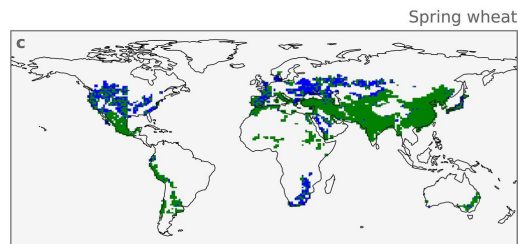
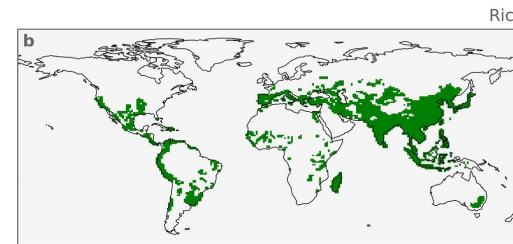
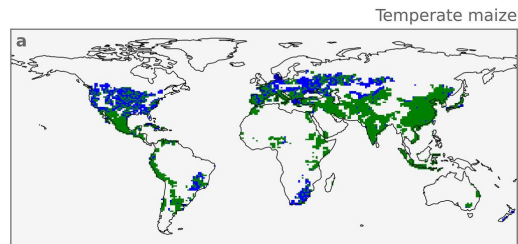
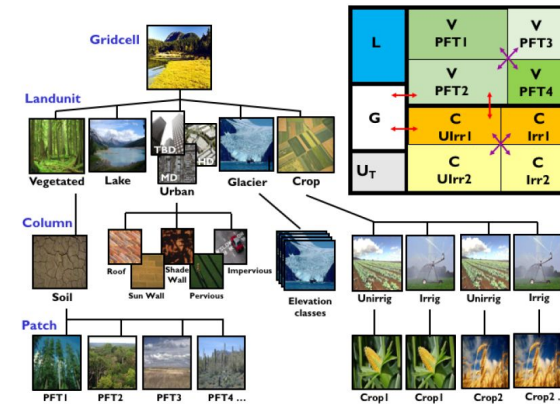
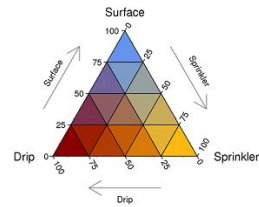


Sprinkler and flood irrigation have negligible impacts on ET, but paddy irrigation greatly reduce the bias during non-peak seasons

# Evaluation 2: global simulations

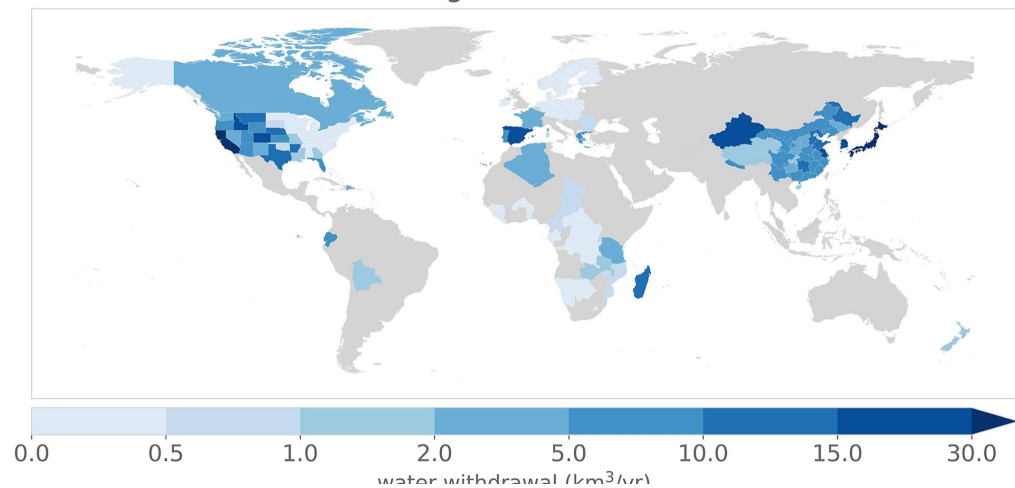


Jägermeyr et al., 2015

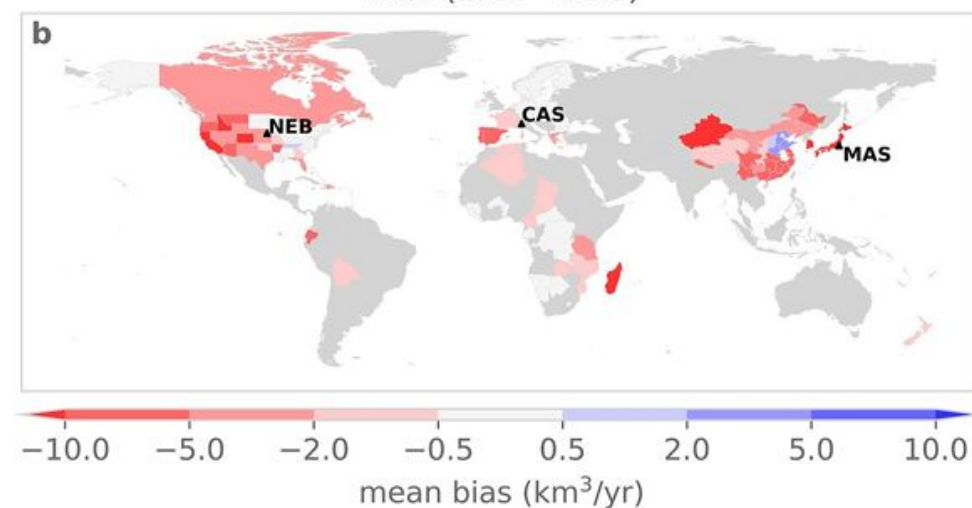


# Evaluation 2: global simulations

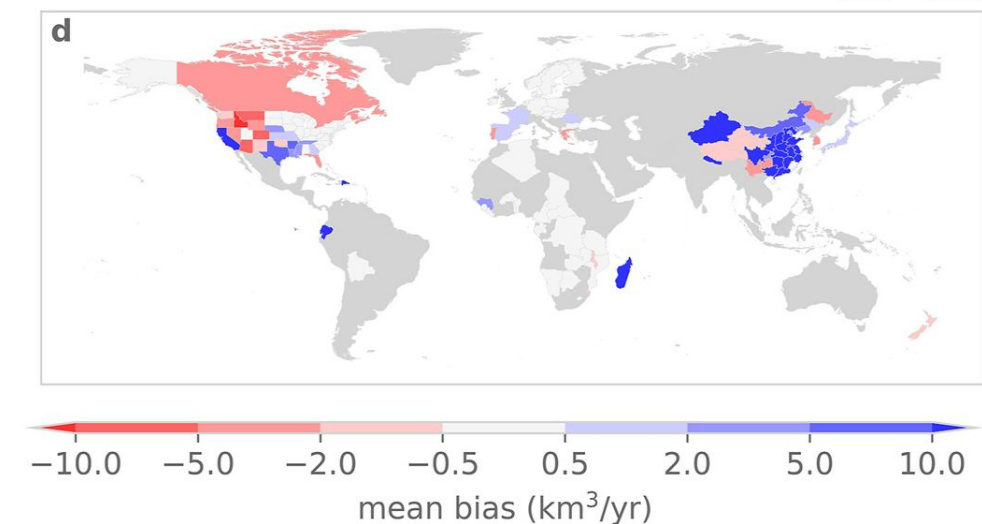
Observed irrigation water withdrawal



Bias (CTL - OBS)



IRR - OBS



CTL	Bias (km <sup>3</sup> /yr)	RMSE (km <sup>3</sup> /yr)	IRR	Bias (km <sup>3</sup> /yr)	RMSE (km <sup>3</sup> /yr)
USA	-10.58	13.42	USA	<b>-0.03</b>	7.94
China	-5.15	7.38	China	22.34	29.84
Other countries	-64.74	78.79	Other countries	<b>-7.67</b>	<b>14.4</b>

New irrigation module substantially improves models' capability of simulating irrigation water withdrawal.







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RESEARCH ARTICLE  
10.1029/2022MS003074

**Key Points:**

- A newly-developed irrigation module considering different irrigation methods is implemented in Community Land Model
- The new irrigation scheme shows a better performance of simulating irrigation water withdrawal against the original module

## Implementation and Evaluation of Irrigation Techniques in the Community Land Model

Yi Yao<sup>1</sup> , Inne Vanderkelen<sup>1</sup> , Danica Lombardozzi<sup>2</sup> , Sean Swenson<sup>2</sup> ,  
David Lawrence<sup>2</sup> , Jonas Jägermeyr<sup>3,4,5</sup>, Luke Grant<sup>1</sup>, and Wim Thiery<sup>1</sup> 

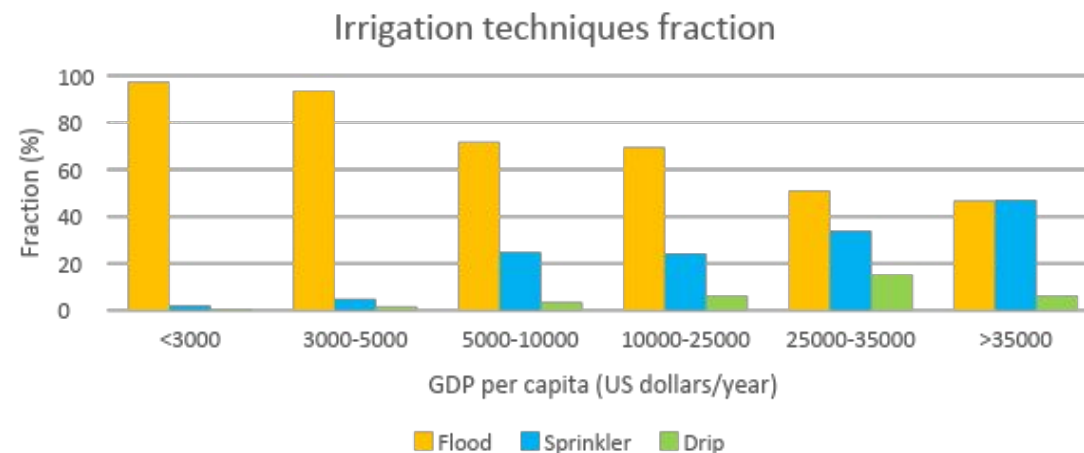
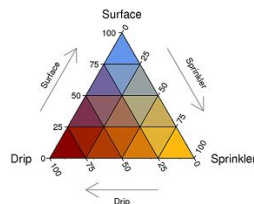
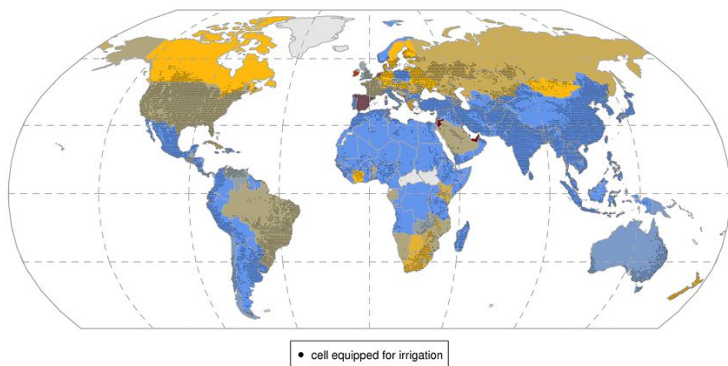
<sup>1</sup>Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Brussels, Belgium, <sup>2</sup>National Center for Atmospheric Research, Boulder, CO, USA, <sup>3</sup>Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Potsdam, Germany, <sup>4</sup>Department of Computer Science, University of Chicago, Chicago, IL, USA, <sup>5</sup>NASA Goddard Institute for Space Studies, New York, NY, USA

**Next:** irrigation-induced impacts on heat extremes under future scenarios

**Issue 1:** there is no projected irrigation techniques shares in line with SSP-RCP

**Issue 2:** this newly developed irrigation module cannot fully address this question

# Projected irrigation techniques shares design



spearman R	Flood	Sprinkler	Drip
GDP	-0.5252***	0.4803***	0.4155***
GOV	-0.5302***	0.4625***	0.4676***
URB	-0.4428***	0.3796***	0.3723***
GII	0.4542***	-0.4104***	-0.3063***

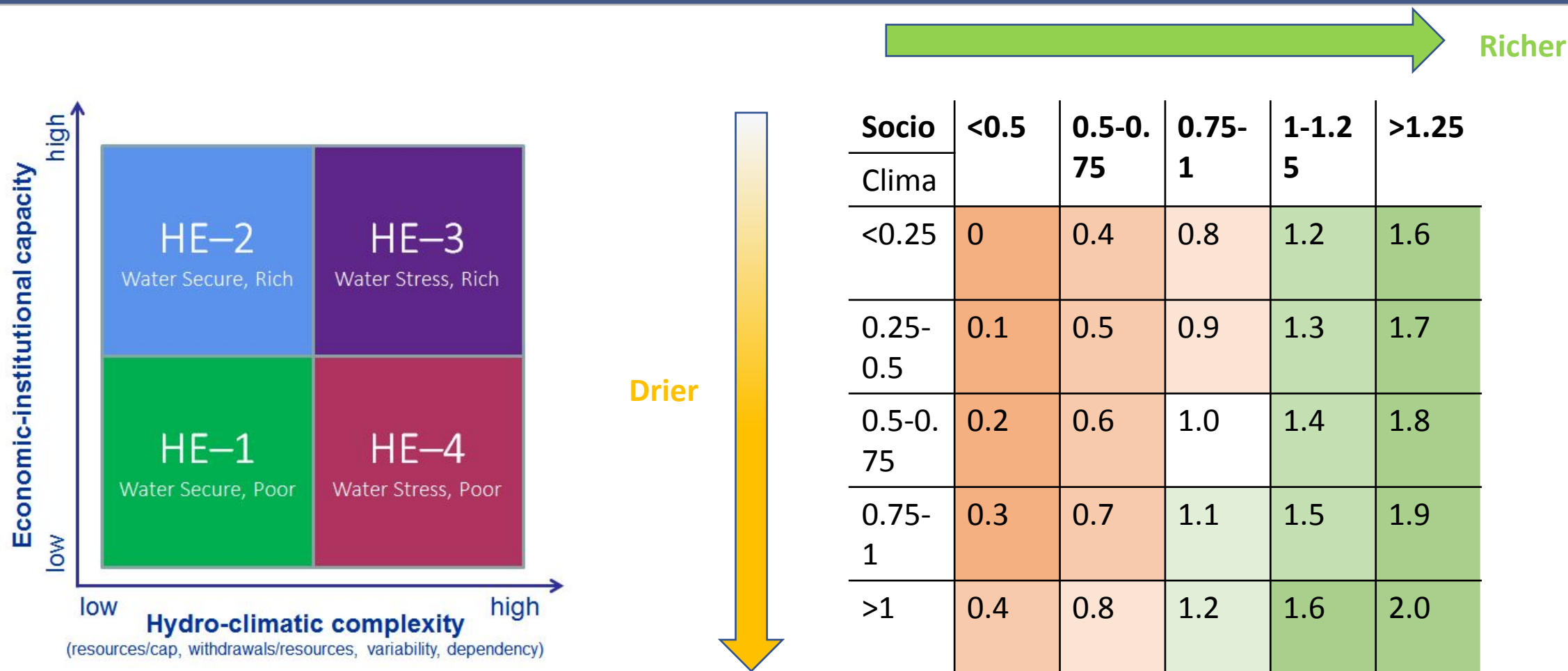
Spearman R	Flood	Sprinkler	Drip
PR	0.2709***	-0.211**	-0.2483***
PPET	-0.0203	0.0761*	-0.1773**
TWS	0.2082**	-0.1353	-0.3112***

Explained variance  
**Socio-economic**

0.782	0.120	0.064	0.034
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Irrigation techniques shares have correlation with GDP, GOV, URB, GII and PR

# Projected irrigation techniques shares design



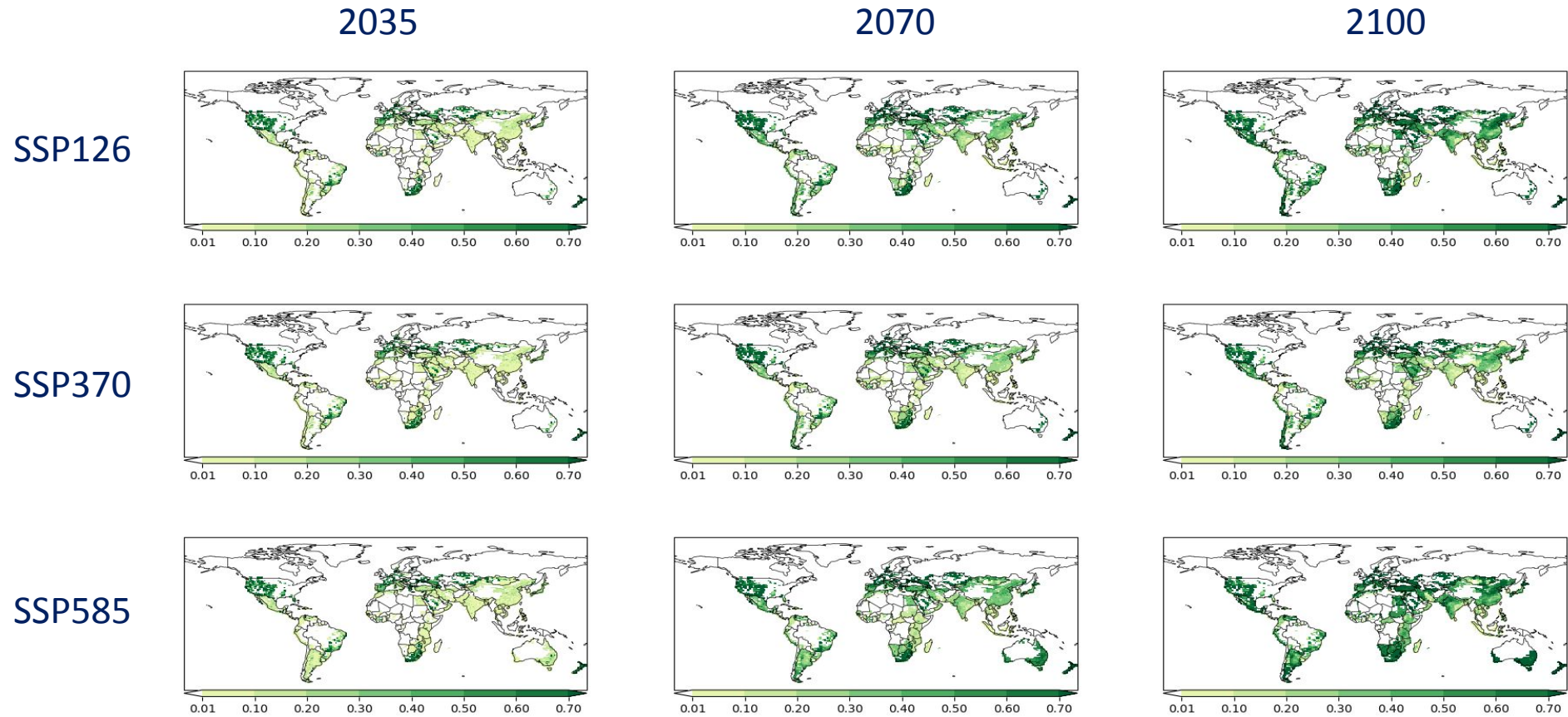
Fischer et al., 2015

We update the speed every five years when we have both data for Socio-economic and hydro-climatic values

Fischer, Günther, et al. "Towards indicators for water security-A global hydro-economic classification of water challenges." (2015).



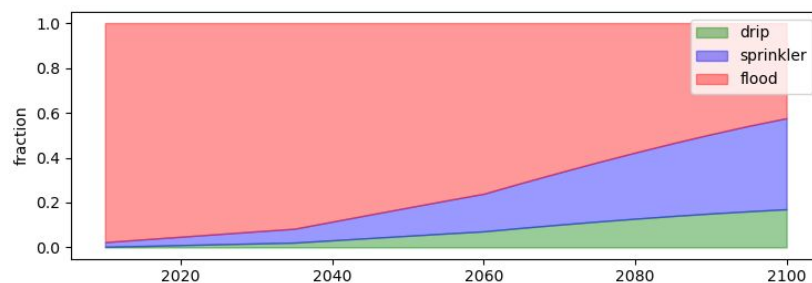
# Example: sprinkler irrigation fraction



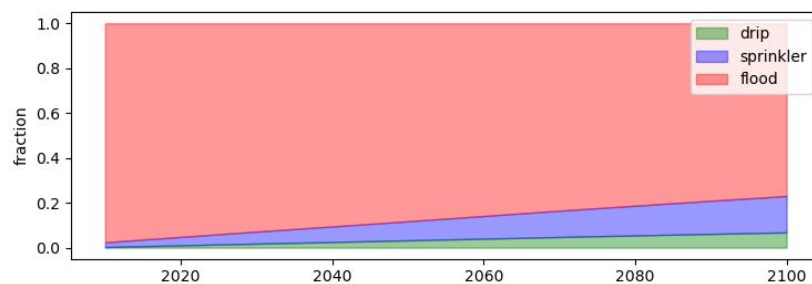
# Example: national irrigation techniques shares for India

## India

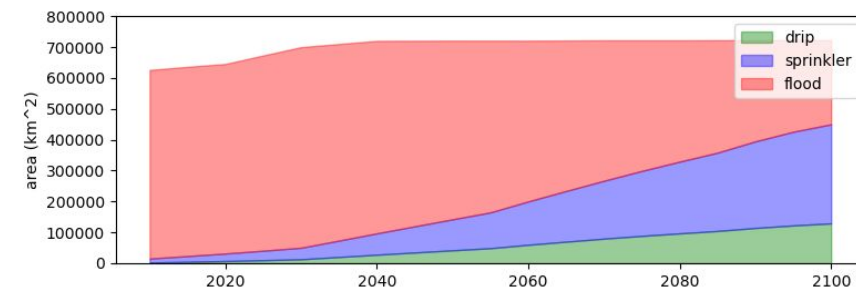
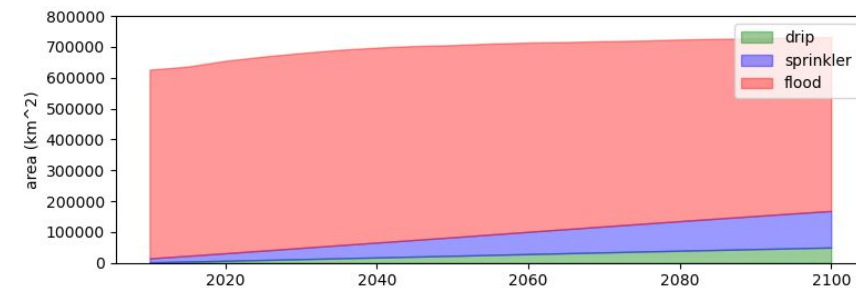
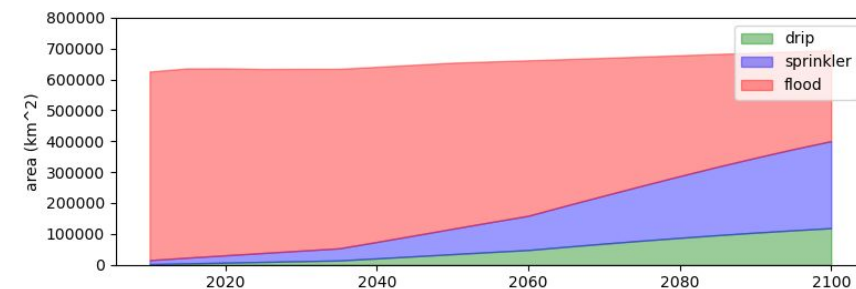
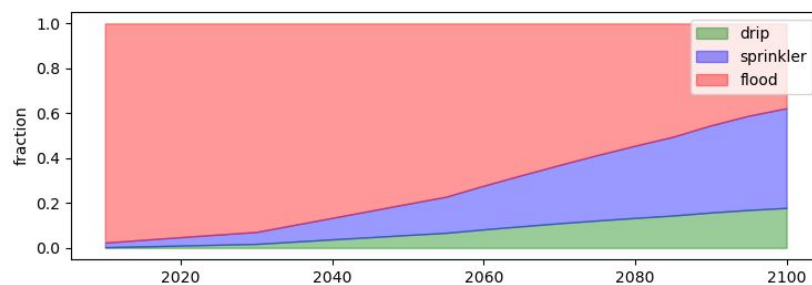
SSP1



SSP3

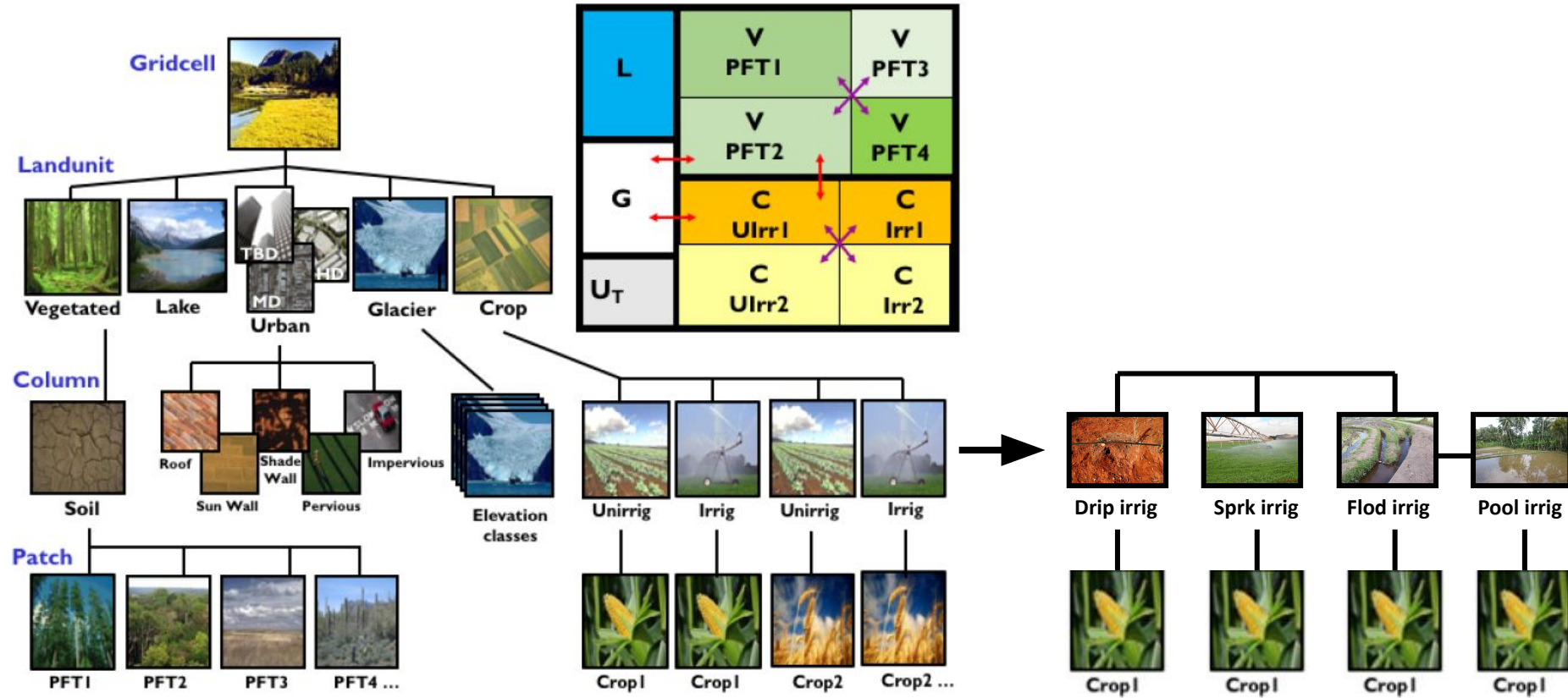


SSP5



These datasets have been implemented in landuse timeseries data for SSP1-2.6, SSP3-7.0 and SSP5-8.5.

# Ongoing development



# Take home messages

1. While taking moisture into account, the impacts of irrigation on heat extremes may be different. A model Intercomparison project (IRRMIP) is ongoing to help us better answer this question.
2. The newly developed irrigation module improve the model both at single-point and global scale. We are working on expanding its ability.
3. A project irrigation techniques shares dataset is created. Feel free to discuss with me ([yi.yao@vub.be](mailto:yi.yao@vub.be)). We anticipate to have the irrigation-induced impacts under future scenarios in few months. (I have to)
4. If you do model development, think carefully what questions you want to address in advance 😞

# Acknowledgement

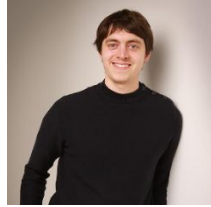
## bClimate CESM group



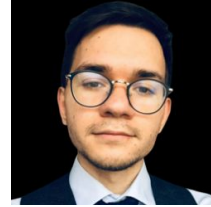
Wim  
Thiery



Inne  
Vanderkelen



Steven  
De Hertog



Sabin  
Taranu

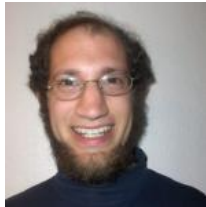
## NCAR



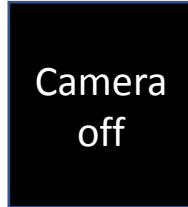
David  
Lawrence



Danica  
Lombardozzi



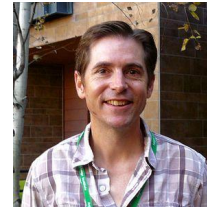
Bill  
Sacks



Sean  
Swenson



Will  
Wieder



Peter  
Lawrence



Erik  
Kluzek



Gary  
Strand