Recommendations on improving current work

Incorporating climate change and tracers into water resources studies

Presenters : Nicole Blin &
David Boutt

SOSTENIBILIDAD DE LA INDUSTRIA DEL LITIO:

Monitoreo y desafíos ambientales ante el cambio climático

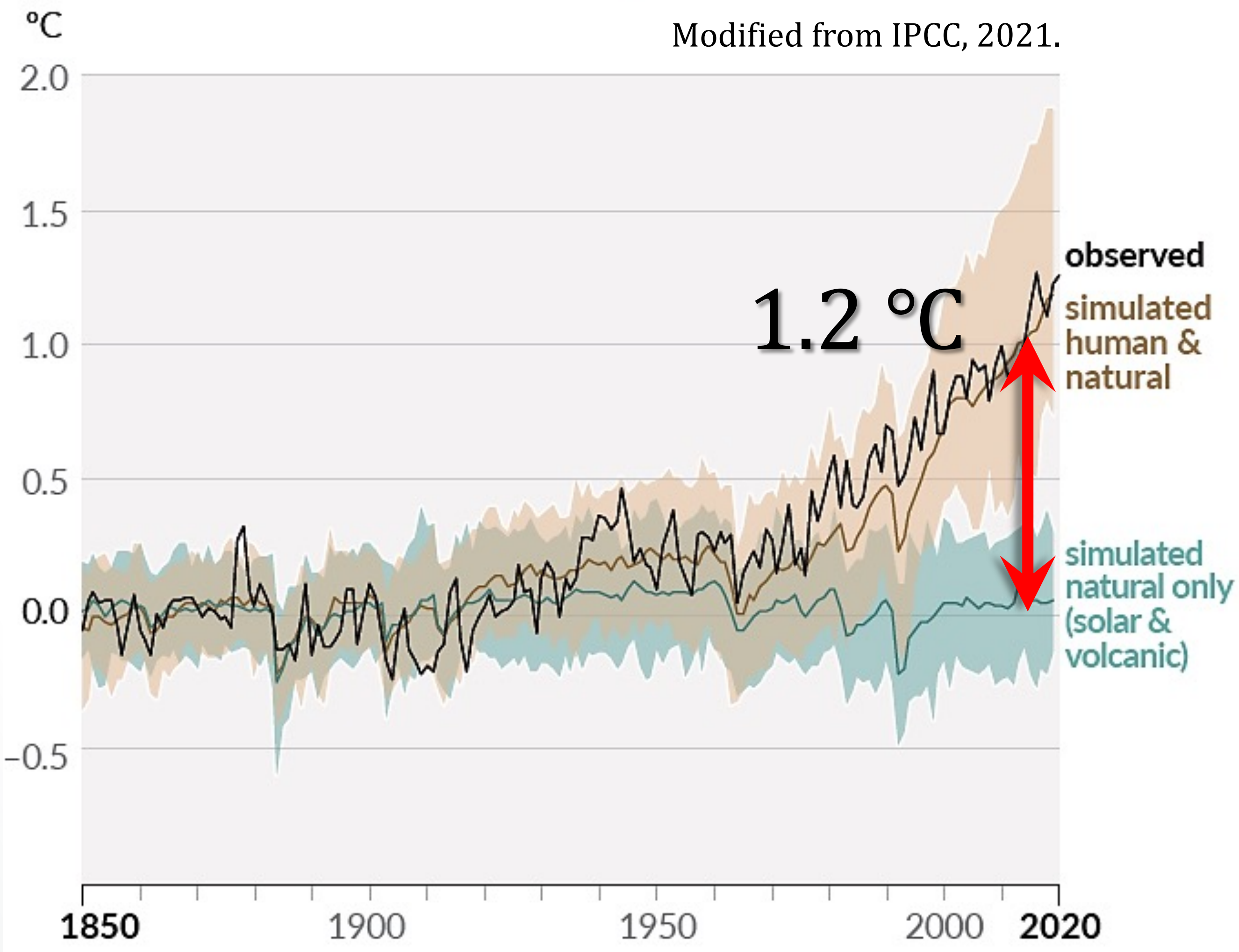
Santiago
15/03/2024

01 Incorporating climate change into water resources assessment studies

Photo by Nicole Blin

climate change

Change in global surface temperature (annual average) as **observed** and simulated using human & nature and only natural factors (both 1850-2020)



Some key concepts

IPCC

Intergovernmental Panel on Climate Change

Future goals

CMIP

Coupled Model Intercomparison Project

Modeling Framework

Climate Change Scenarios

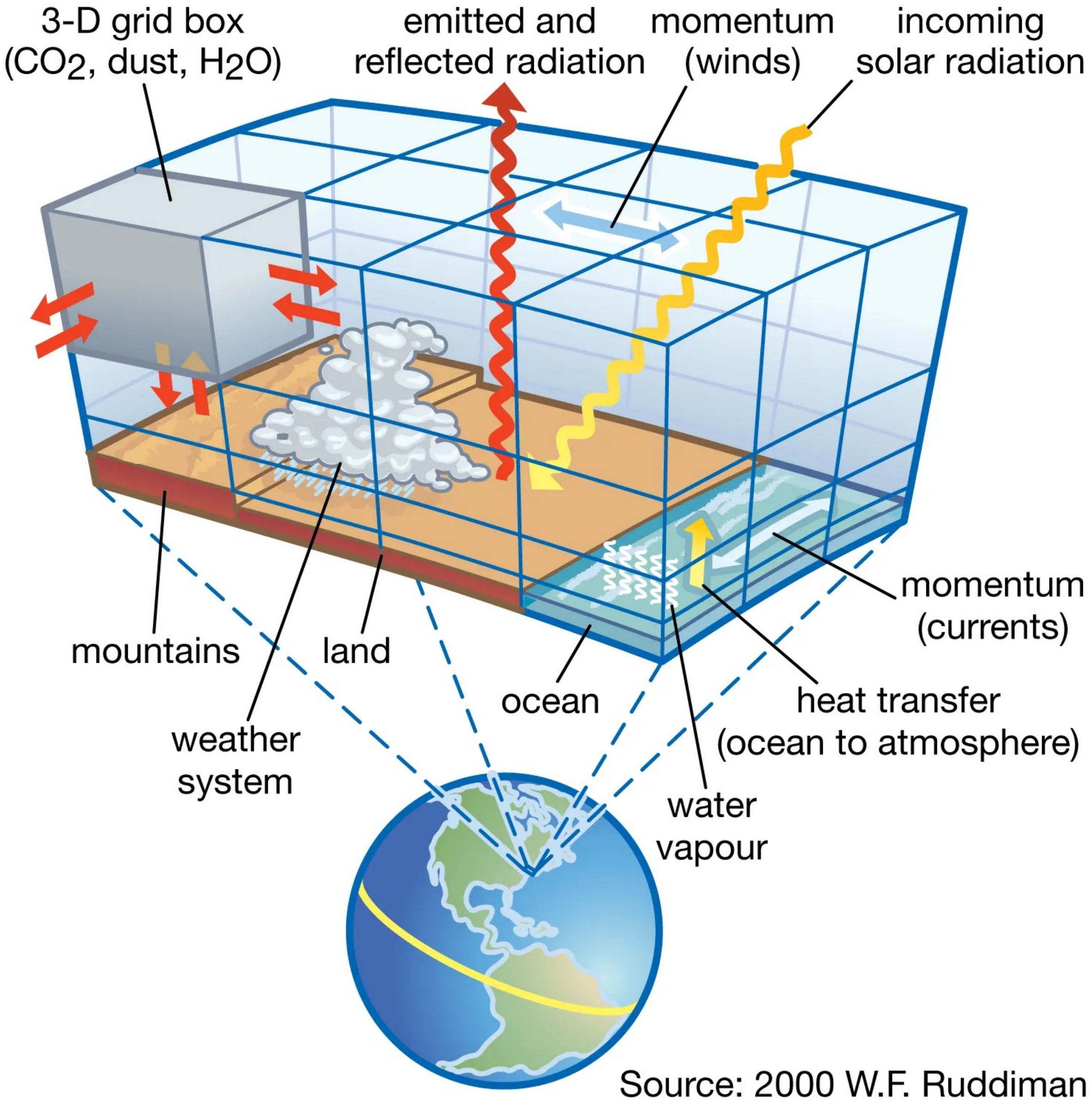
GCMs

GCM: General Circulation Model

GCM

General
Circulation
Model

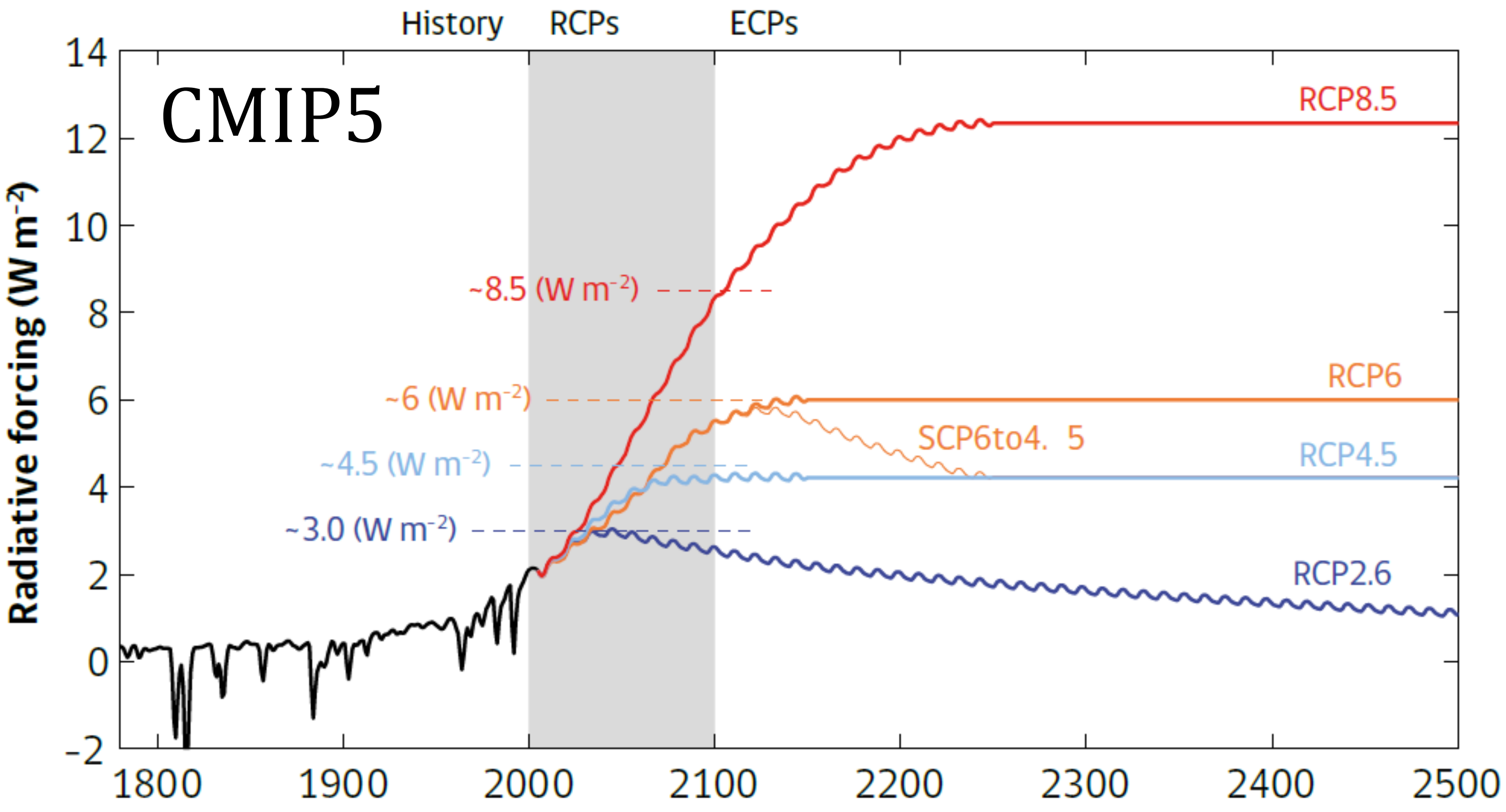
Concept diagram of climate modeling



Source: 2000 W.F. Ruddiman

Climate change scenarios

Representative Concentration Pathways (RCPs)



Cubasch et al. (2013)

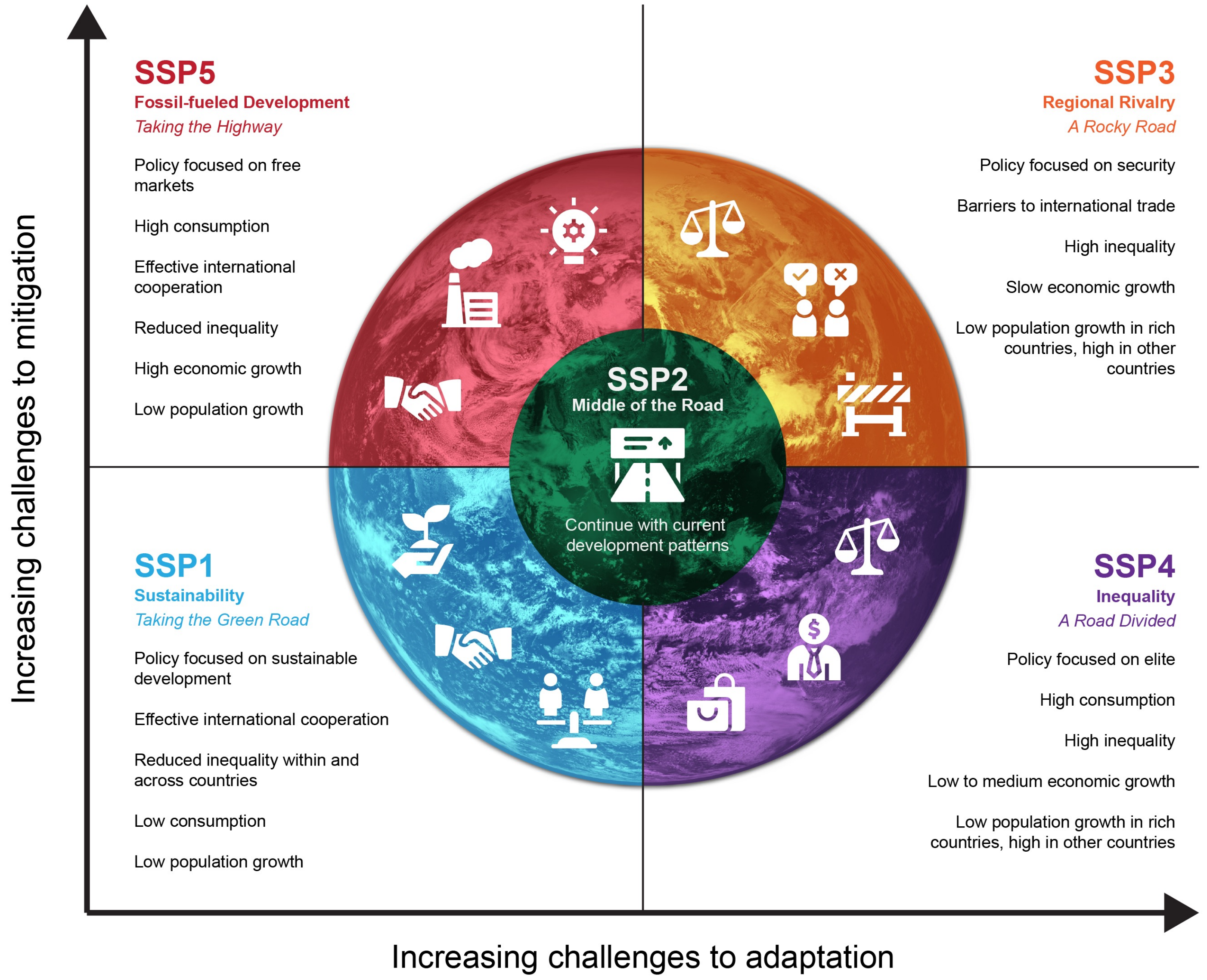
ıelle
etrieved

matehu
ıbs/nort
at-are-
phases-

$$Rad.Forcing = \Delta(E_{in} - E_{out}) \rightarrow \begin{cases} > 0\ planet\ warms \\ < 0\ planet\ cools \end{cases}$$

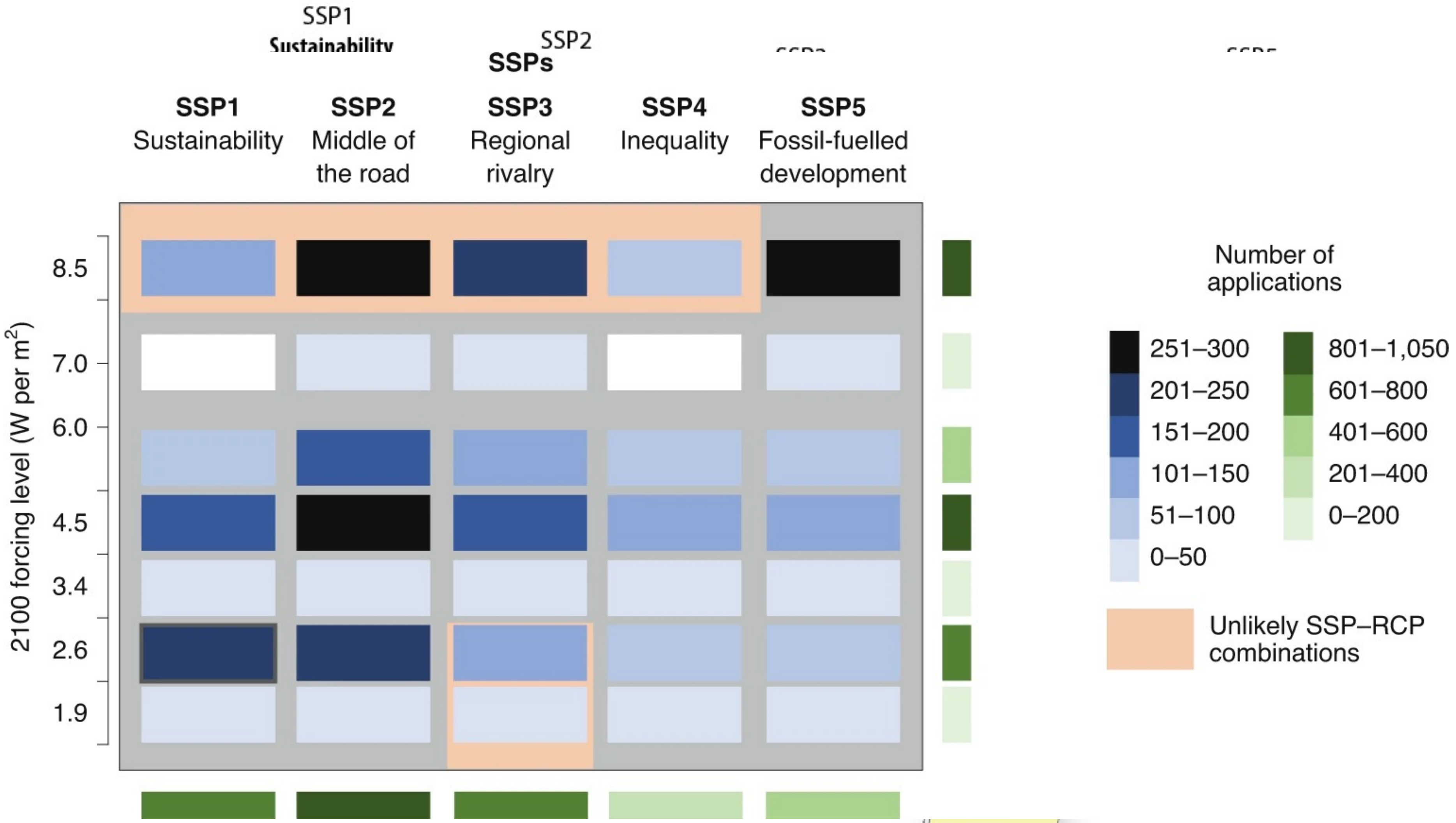
Climate change scenarios

Shared Socioeconomic Pathways



O'Neil et al. (2016)

Climate change scenarios



CMIP6: Combination of SSPs + RCPs

— How could all this be incorporated into water resources assessment studies?

Incorporating climate change into water resources studies

Recommendations

Model selection

- Model performance in study area
- Climate change signal based on raw GCM

Bias-correction

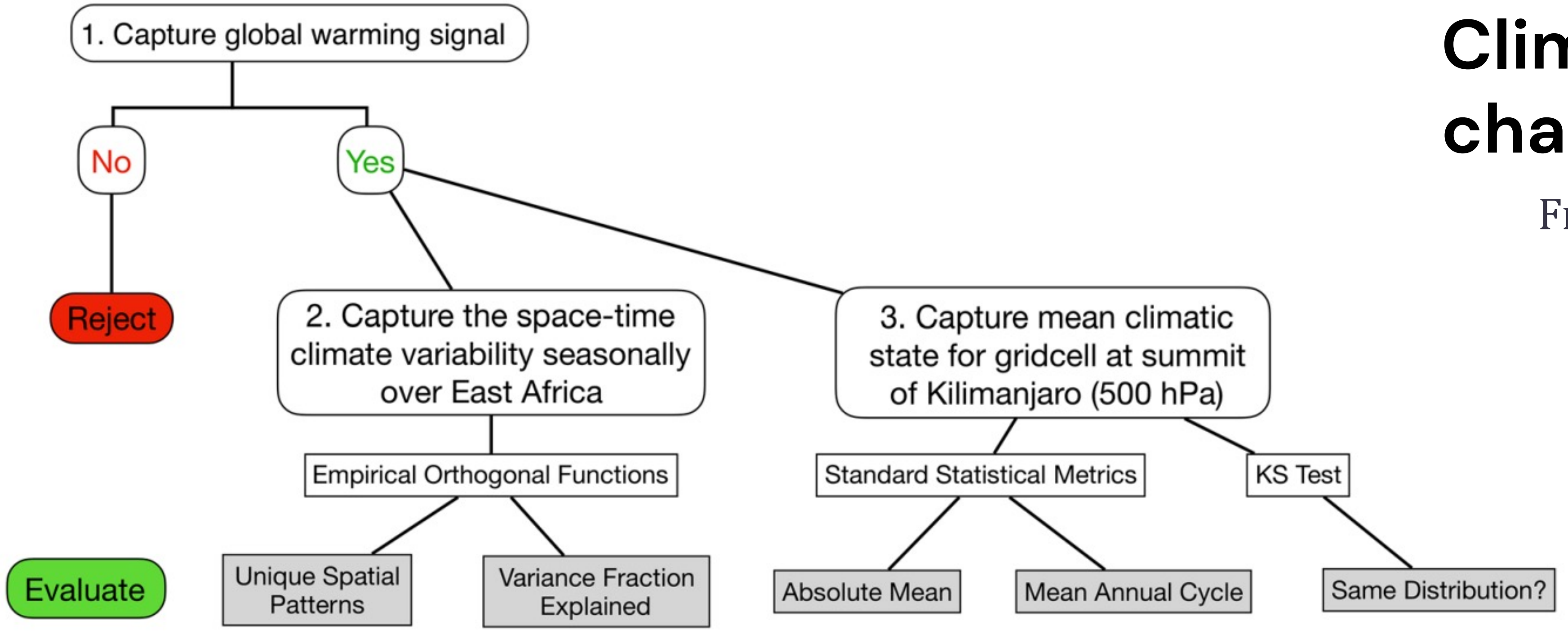
- Statistical vs dynamical methods
- Stat. method based on variable nature

Accounting for uncertainty

- Model ensembles

1. Model selection

Pickler & Molg (2021)



GCM performance

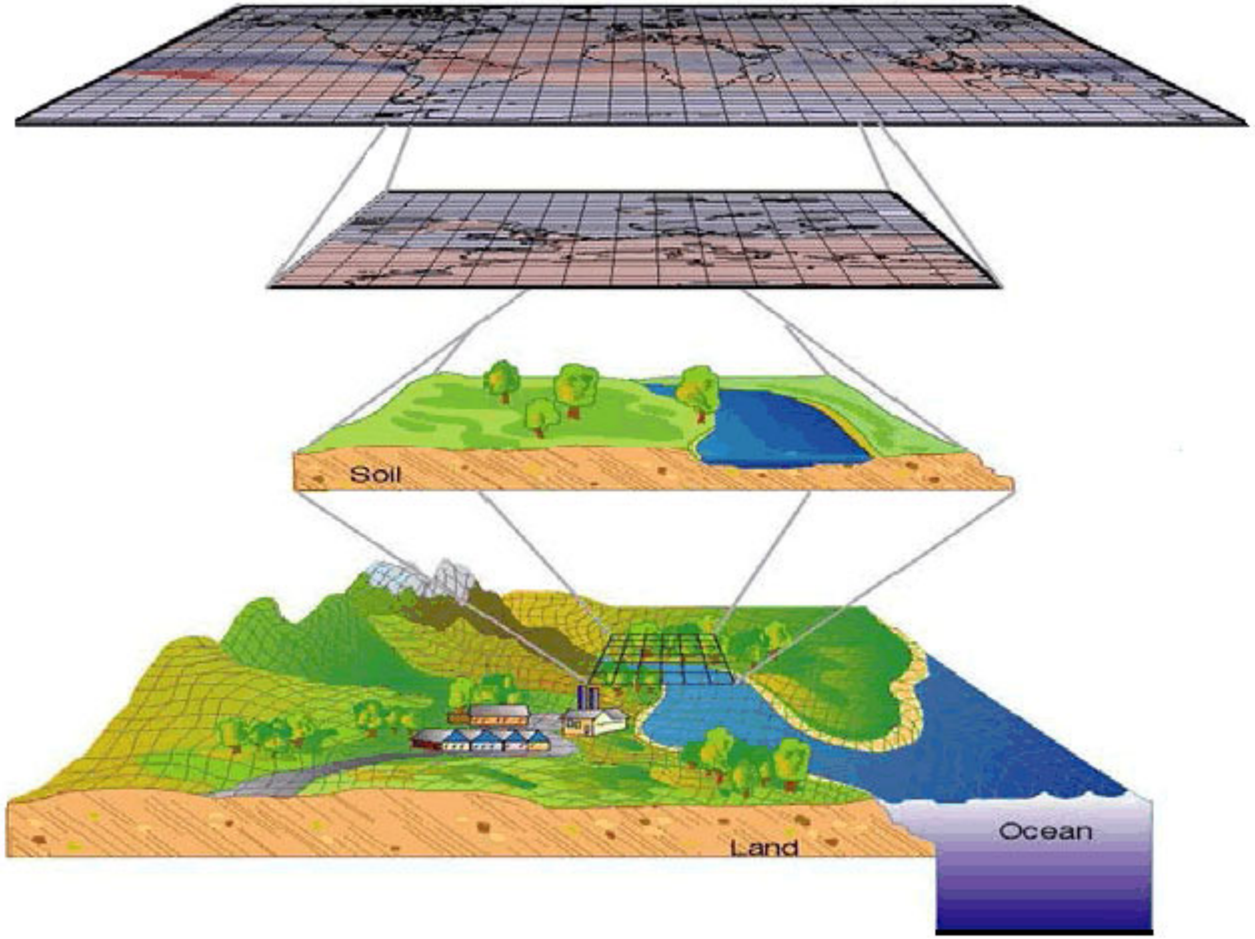
Different based on topography and region

Climate change signal

From raw GCMs

Khan & Pilz (2018)

Why is it necessary?



- GCM resolution
  - Not representative of basin scale dynamics

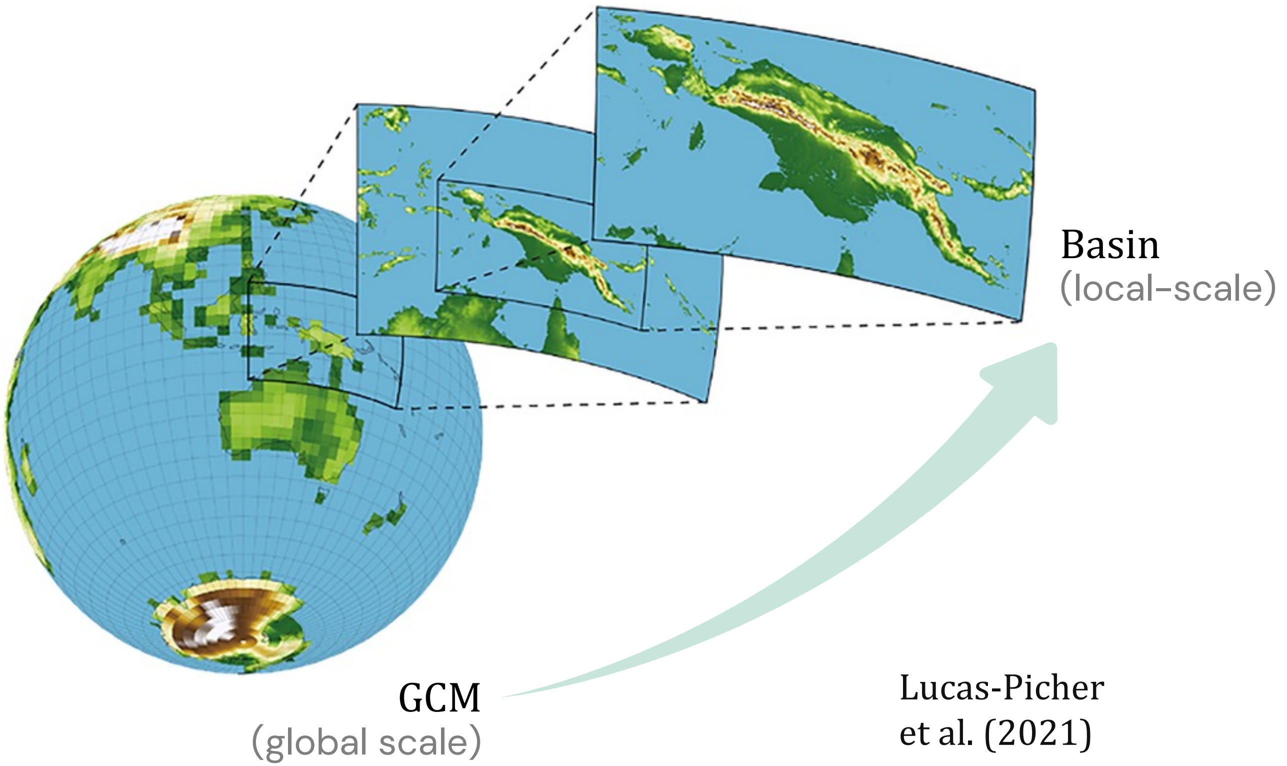
2. Bias-correction

Dynamical methods

using regional climate models (RCMs) or limited-area models (LAMs) to simulate climate processes at a much finer resolution over a specific region of interest

Statistical methods

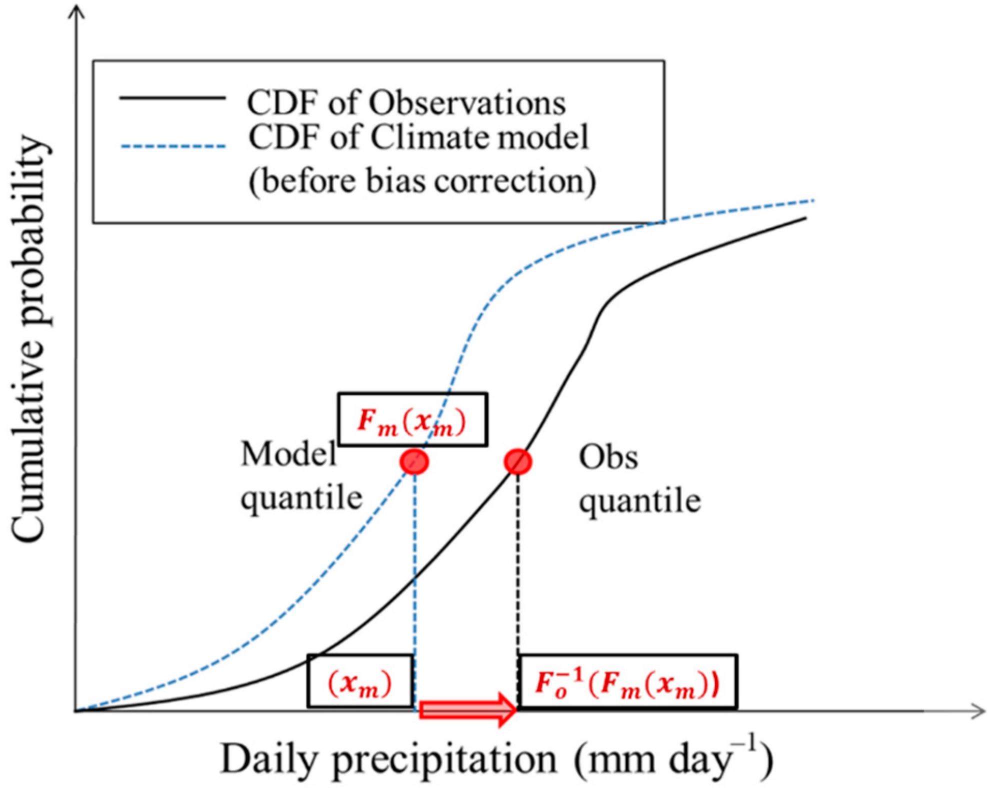
establishes a statistical relationship between large-scale atmospheric variables (from GCMs) and local-scale climate variables based on historical observations



Lucas-Picher et al. (2021)

Statistical methods

Bias-correction of GCMs



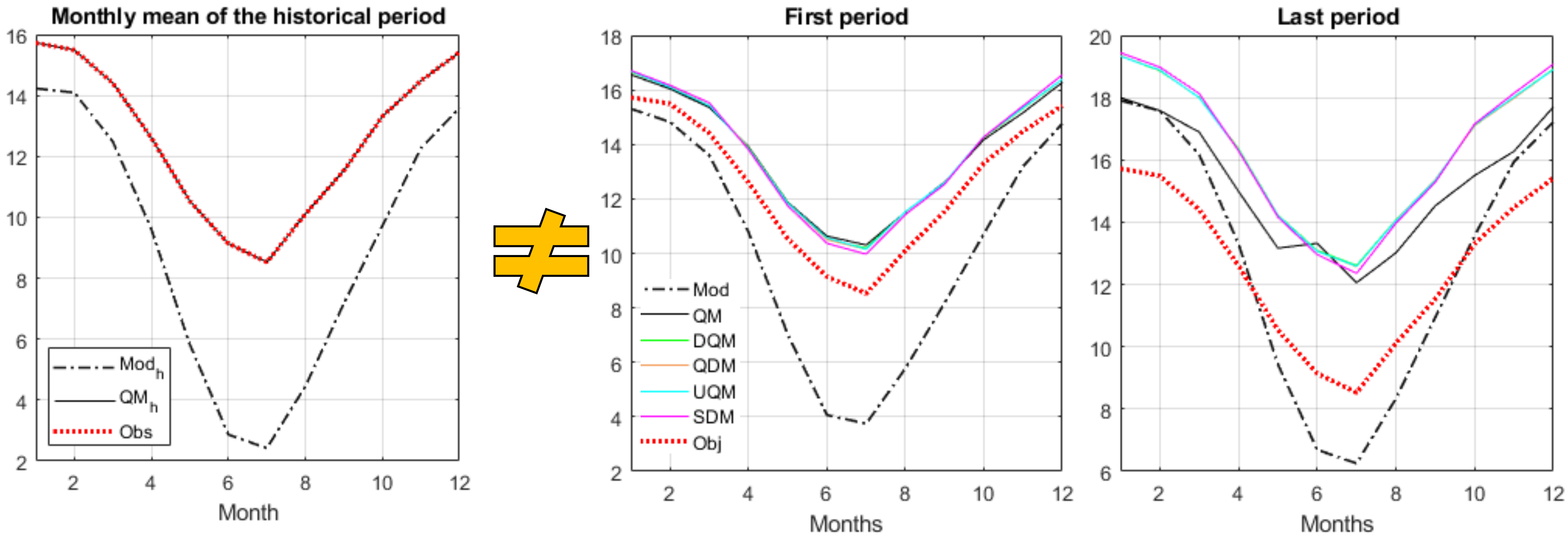
Gupta et al. (2019)

— What method should we use? How could we select the method?

Statistical methods

Bias-correction of GCMs

Performance of the downscaled series is also different in the historical period vs future



Bias-correction method for precipitation in arid regions

Quantile Delta Mapping (QDM)

1. Relative changes in quantiles between future and historical periods of **modeled data**

$$\Delta_m(t) = \frac{F_{m,p}^{(t)-1}[\tau_{m,p}(t)]}{F_{m,h}^{-1}[\tau_{m,p}(t)]}$$

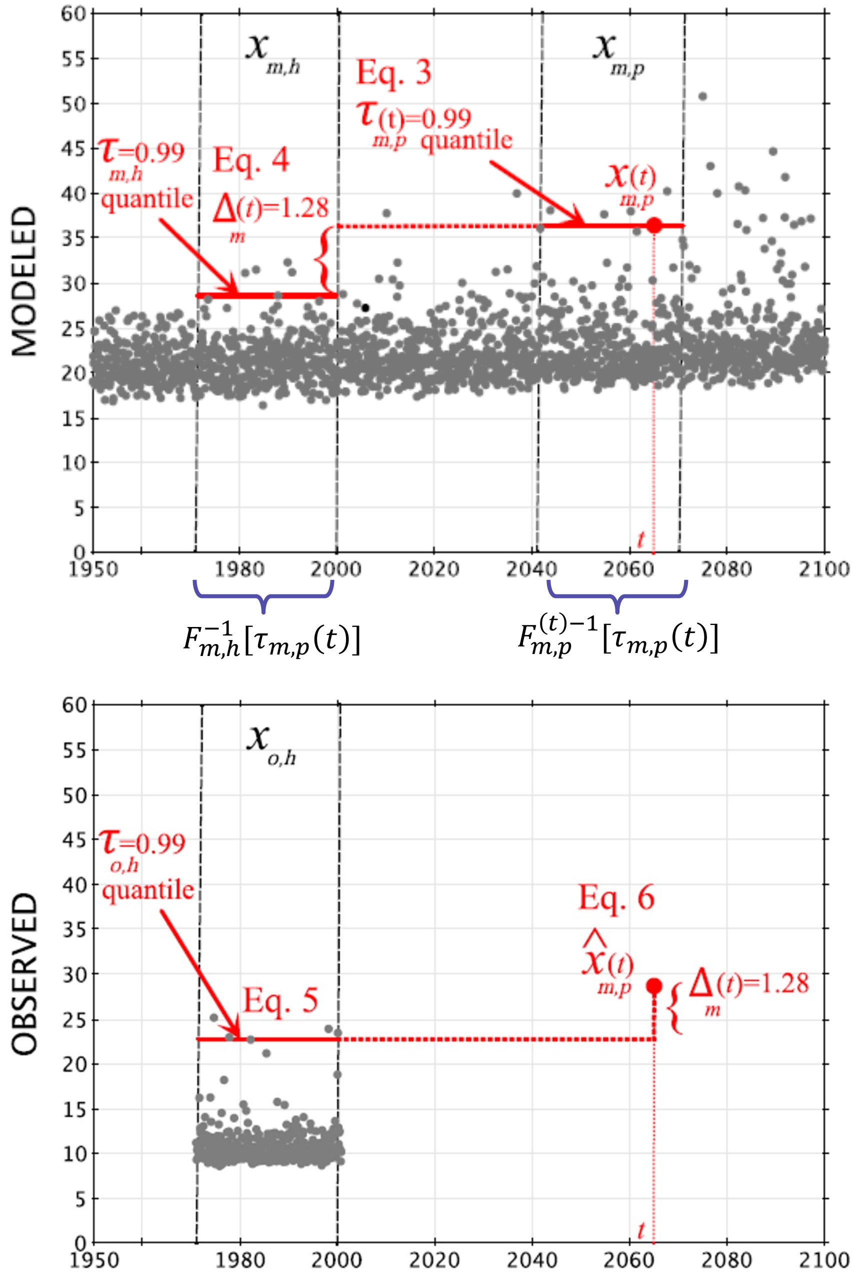
2. Future-period quantiles are bias corrected by the inverse CDF of observations (regular **QM between modeled future** and **obs**)

$$\hat{x}_{o:m,h:p}(t) = F_{o,h}^{-1}[\tau_{m,p}(t)]$$

3. Relative changes in quantiles ($\Delta_m(t)$) are applied to the bias corrected $\hat{x}_{o:m,h:p}(t)$

$$\hat{x}_{m,p}(t) = \hat{x}_{o:m,h:p}(t) \cdot \Delta_m(t)$$

Cannon et al., 2015.



Bias-correction method for precipitation in arid regions

Unbiased Quantile Mapping (UQM)

Preserves GCM changes of the mean and the standard deviation

HYDROLOGICAL SCIENCES JOURNAL
2023, VOL. 68, NO. 8, 1184–1201
https://doi.org/10.1080/02626667.2023.2201450

IAHS AISH

Taylor & Francis
Taylor & Francis Group

OPEN ACCESS Check for updates

Bias adjustment to preserve changes in variability: the unbiased mapping of GCM changes

Cristián Chadwick[a], Jorge Gironás[b,c,d,e], Fernando González-Leiva[b] and Sebastián Aedo[c]

[a]Facultad de Ingeniería y Ciencias, Universidad Adolfo Ibáñez, Santiago, Chile; [b]Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Santiago, Chile; [c]Centro Interdisciplinario de Cambio Global, Pontificia Universidad Católica de Chile, Santiago, Chile; [d]Centro de Investigación para la Gestión Integrada del Riesgo de Desastres, ANID/FONDAP/1522A0005, Santiago, Chile; [e]Centro de Desarrollo Urbano Sustentable, ANID/FONDAP 1522A0002, Santiago, Chile

Tools to support the decision

climQMBC

https://github.com/saedoquililongo/climQMBC

Product Solutions Open Source Pricing

saedoquililongo / climQMBC Public

Code Issues 1 Pull requests Discussions Projects Security Insights

Getting started

Installation or importing

Within the Python, Matlab, and R directories you will find the installation and importing procedure for each programming language.

Quick start

Within the Python, Matlab, and R directories you will find scripts with examples of the capacities of the package and suggestions of its use.

- Python: climQMBC_tester_Python.py
- Matlab: climQMBC_tester_Matlab.m
- R: climQMBC_tester_R.R

Additionally, the Example_notebook.ipynb is a notebook showing the usage of the package in Python and examples of the results of the methods and functions implemented.

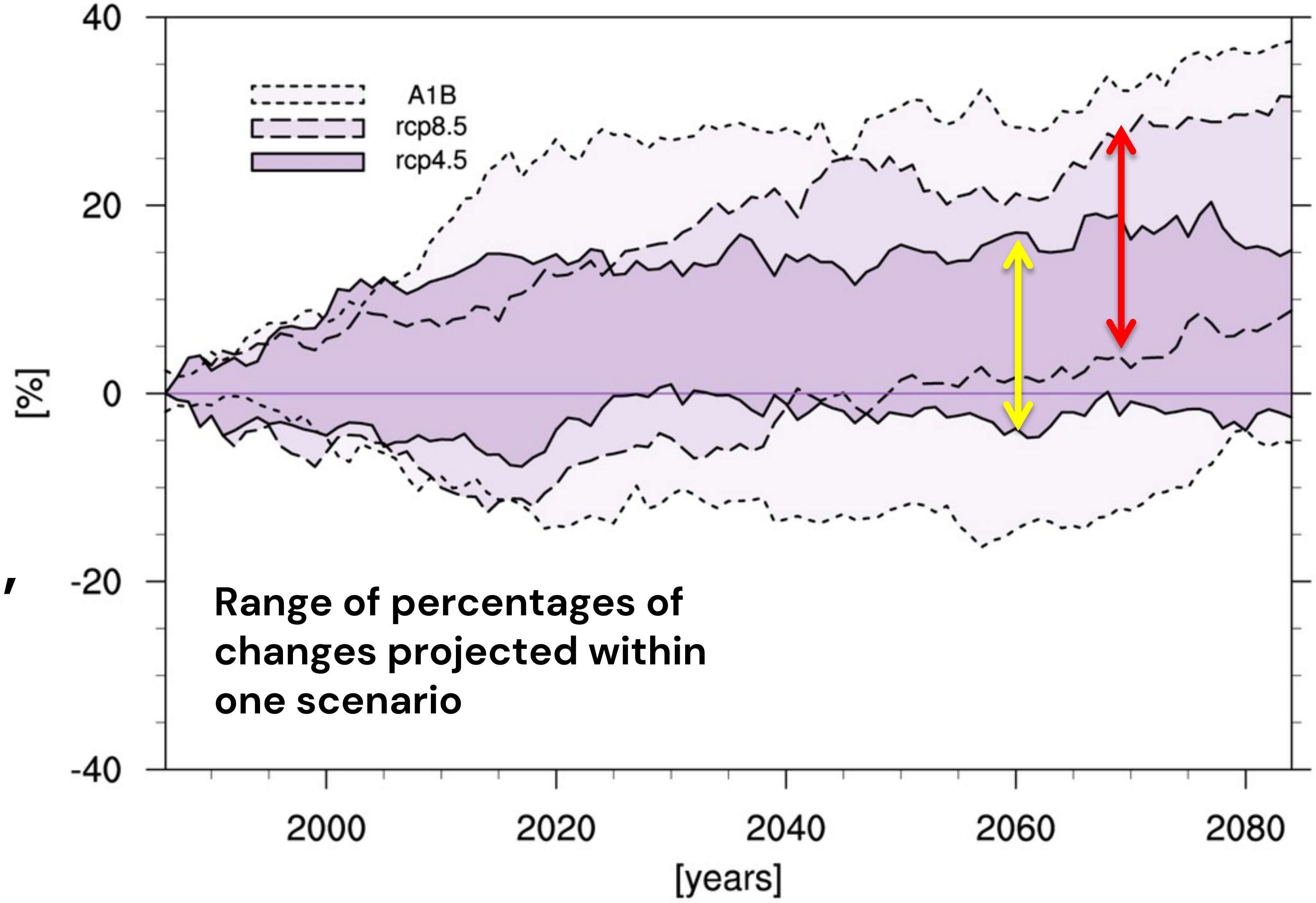
3. Ensembles

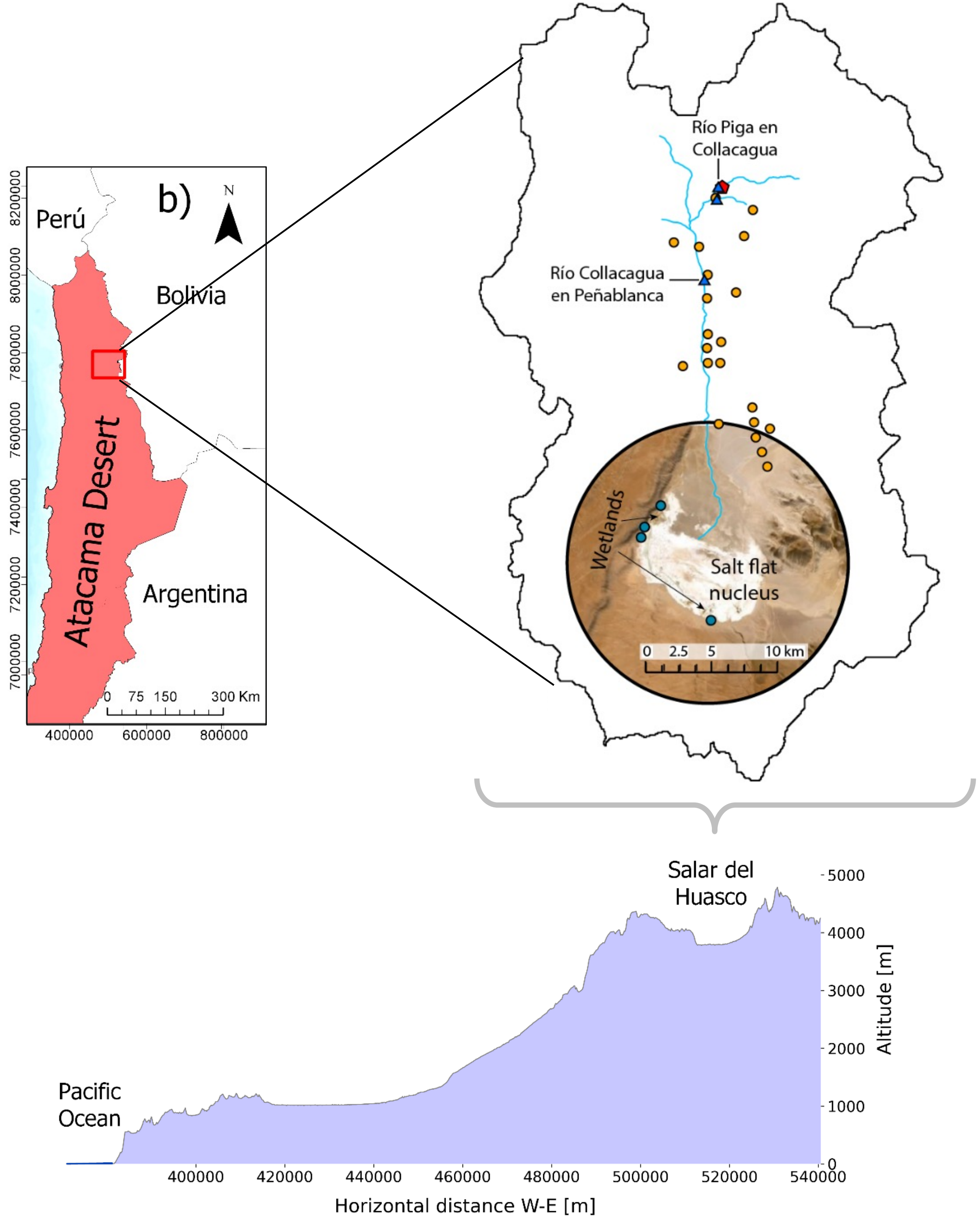
1. There is no recipe
2. The more members the better, but:

Accounting for uncertainty in future projections

3. At least 3 (min, med, max)

Pfeifer et al. (2015)





Ejemplo

Caso de estudio

Salar del Huasco

Climate change
scenarios

— Spectrum of projected outcomes per scenario

SSP2 4.5

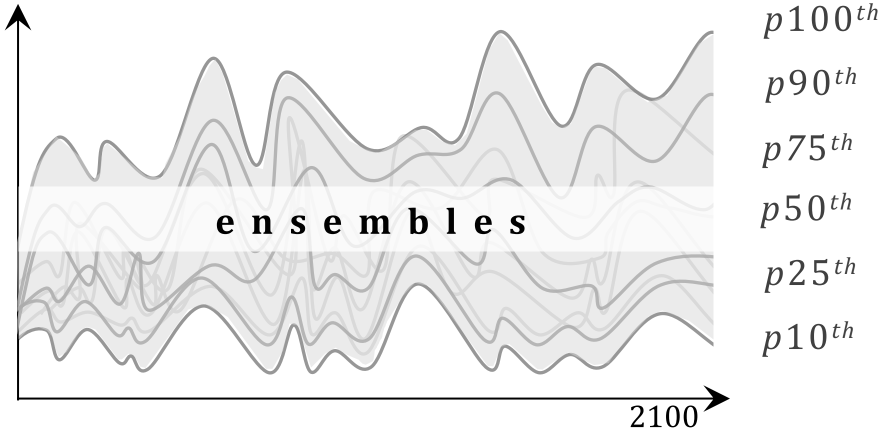
↑2 – 2.9°C

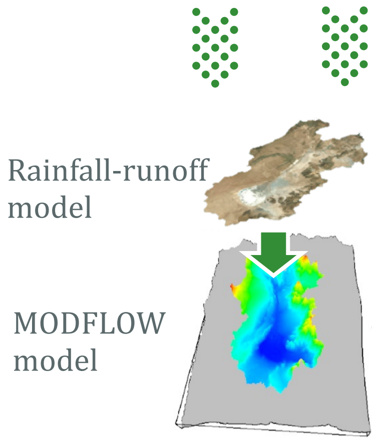
Moderate challenges in mitigation and adaptation

SSP5 8.5

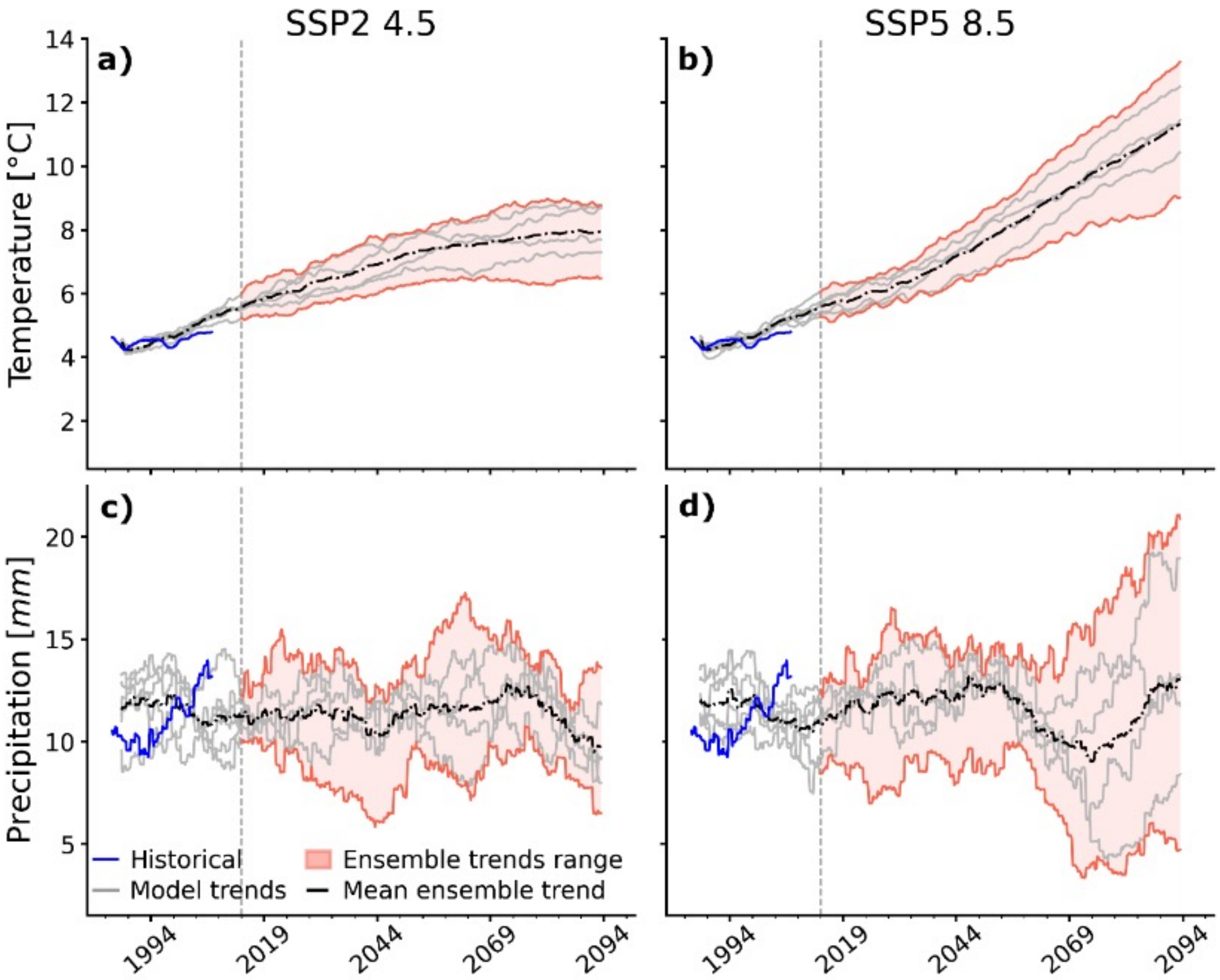
↑4 – 4.3°C

High mitigation challenges

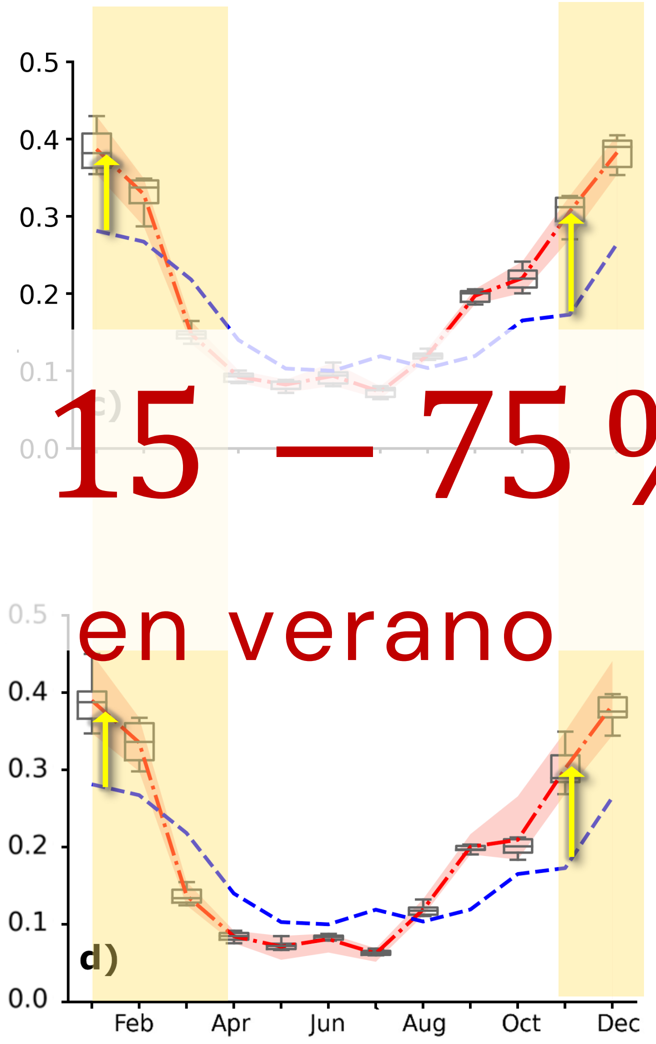




Presenting the results



Evaporación desde la napa



↑ 15 – 75 %

en verano

Key Recommendations

+ + +

- Climate change incorporation into studies:
  - Model selection based on performance and raw GCM signal
  - Bias-correction method based on the nature of the variable in the study area
  - Use of ensembles
  - Provide ranges of change

02 Improving the work done to date

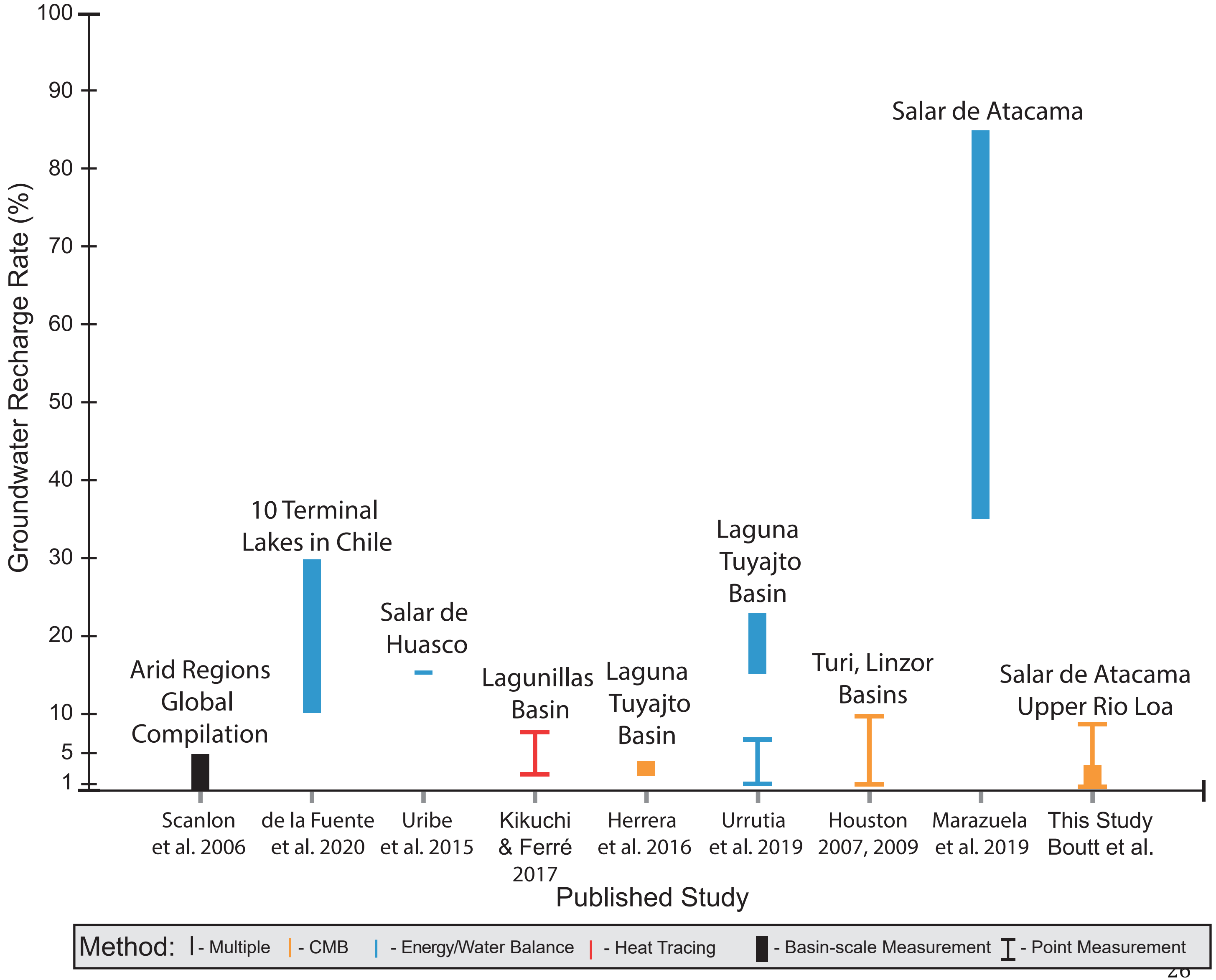
Photo by David Boutt

Constraining Recharge Rates

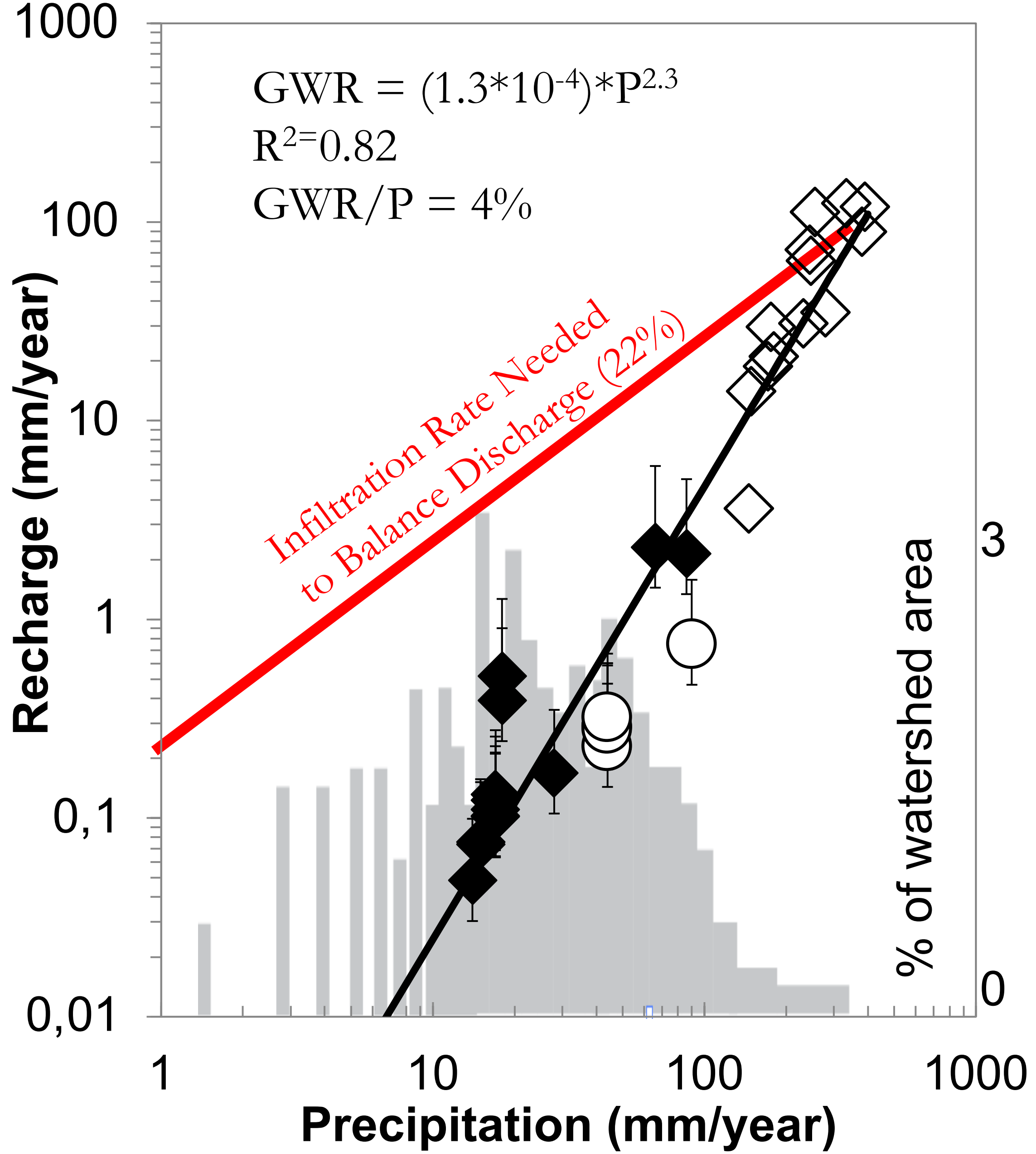
Large Uncertainty in actual basin recharge

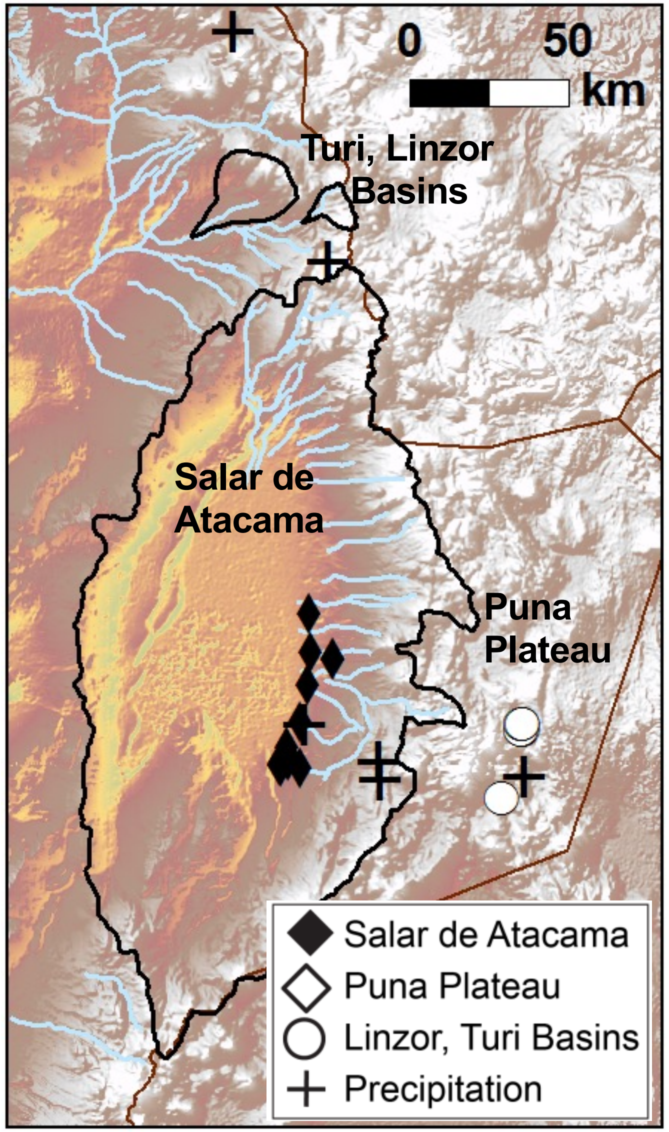
Boutt et al (2021) documents these estimates

Integrated tracer work with infiltration modeling must be explored



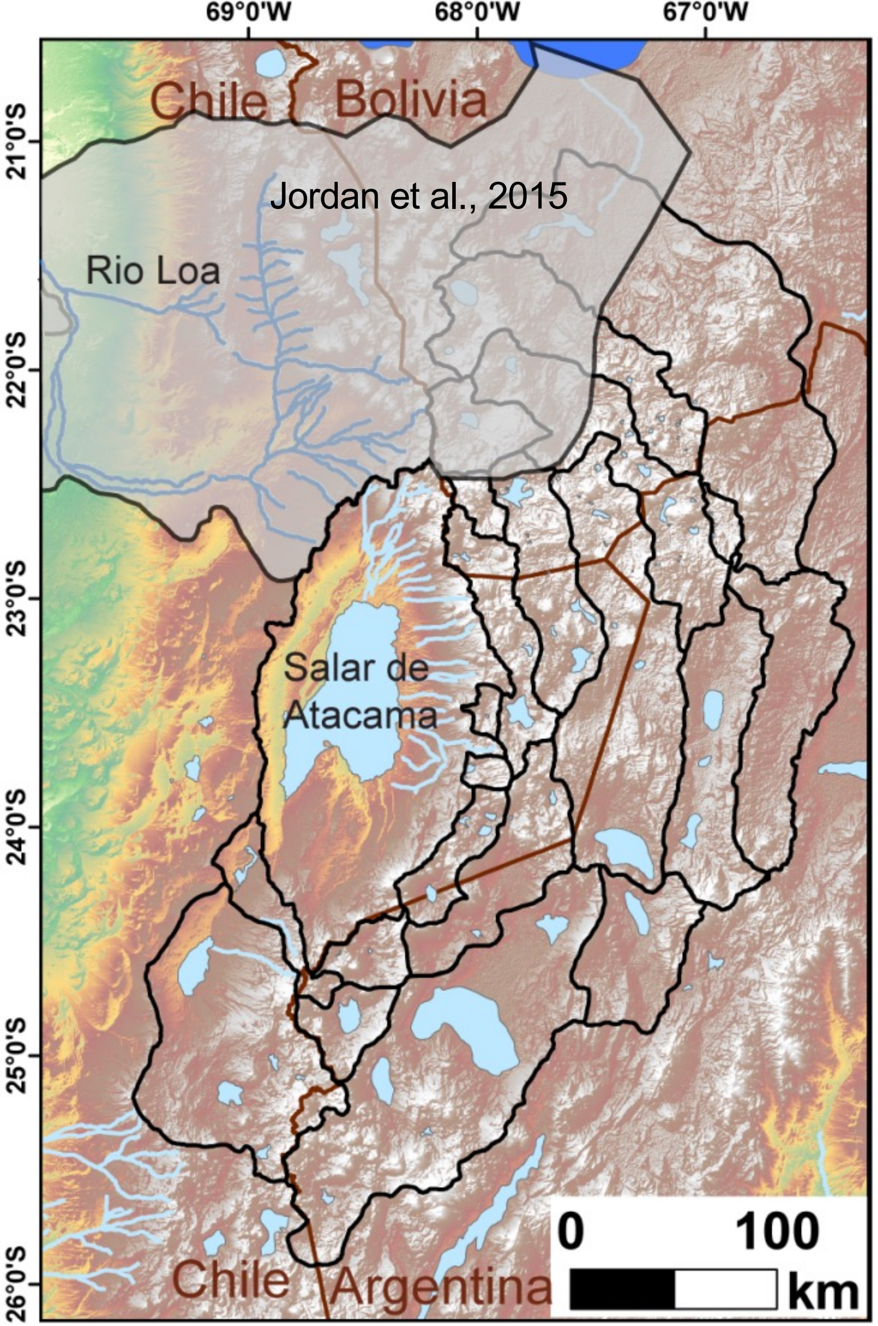
Chloride Mass Balance Recharge Results

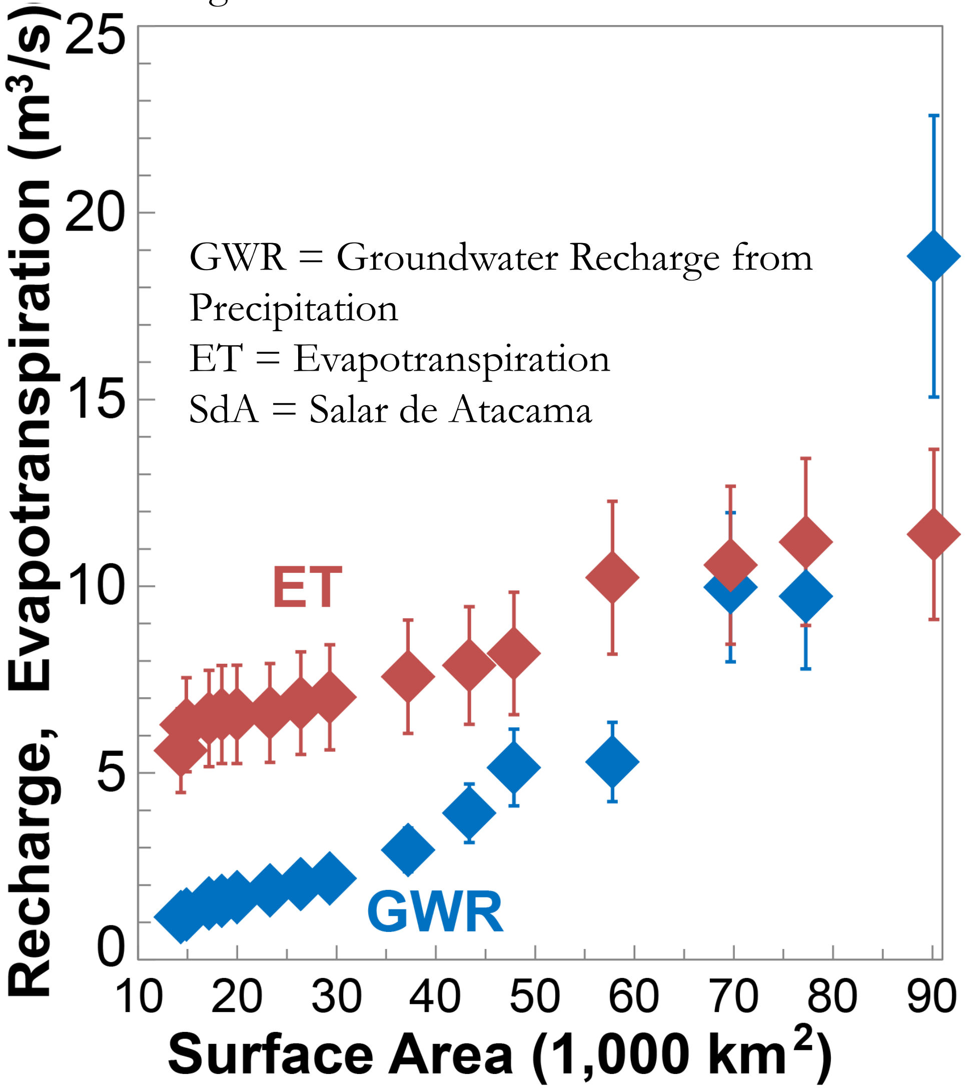




Puna Plateau: *Cervetto*, 2012
Turi and Linzor: *Houston*, 2007, 2009

$GWR - ET_{SdA} - ET_{HighElevSalars} = 0$

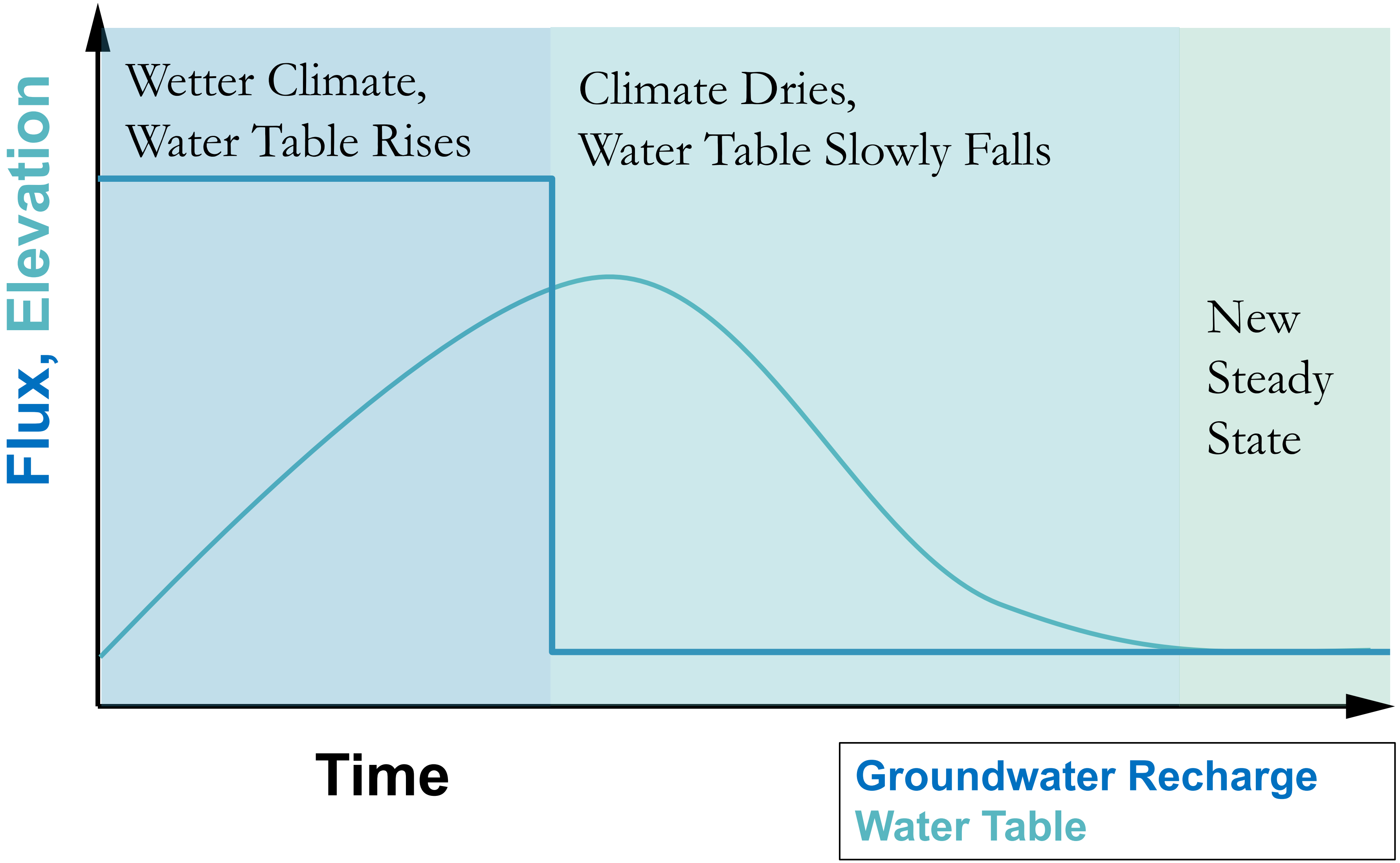




Steady State Regional Flow?

TRANSIENT DRAINING OF STORED GROUNDWATER

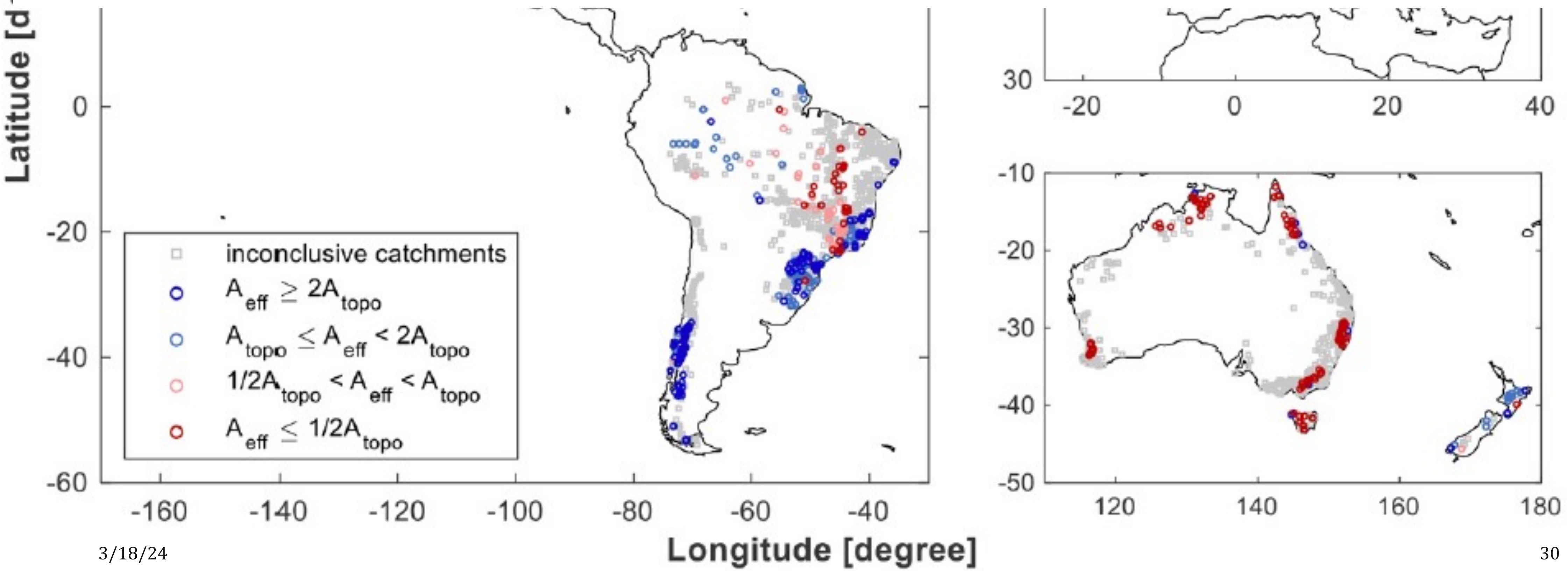
$$GWR - ET = Storage \neq 0$$



What is the hydrologically effective area of a catchment?

Yan Liu[1], Thorsten Wagener[2,3], Hylke E Beck[4] and Andreas Hartmann[1,2]

[1] Chair of Hydrological Modeling and Water Resources, University of Freiburg, 79098 Freiburg, Germany
[2] Department of Civil Engineering, University of Bristol, Bristol, United Kingdom
[3] Cabot Institute, University of Bristol, Bristol, United Kingdom
[4] Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ, United States of America



Recharge Is Most Sensitive To Climate Change


natu
Article
Gr
to
Receive
Accept
Publishe

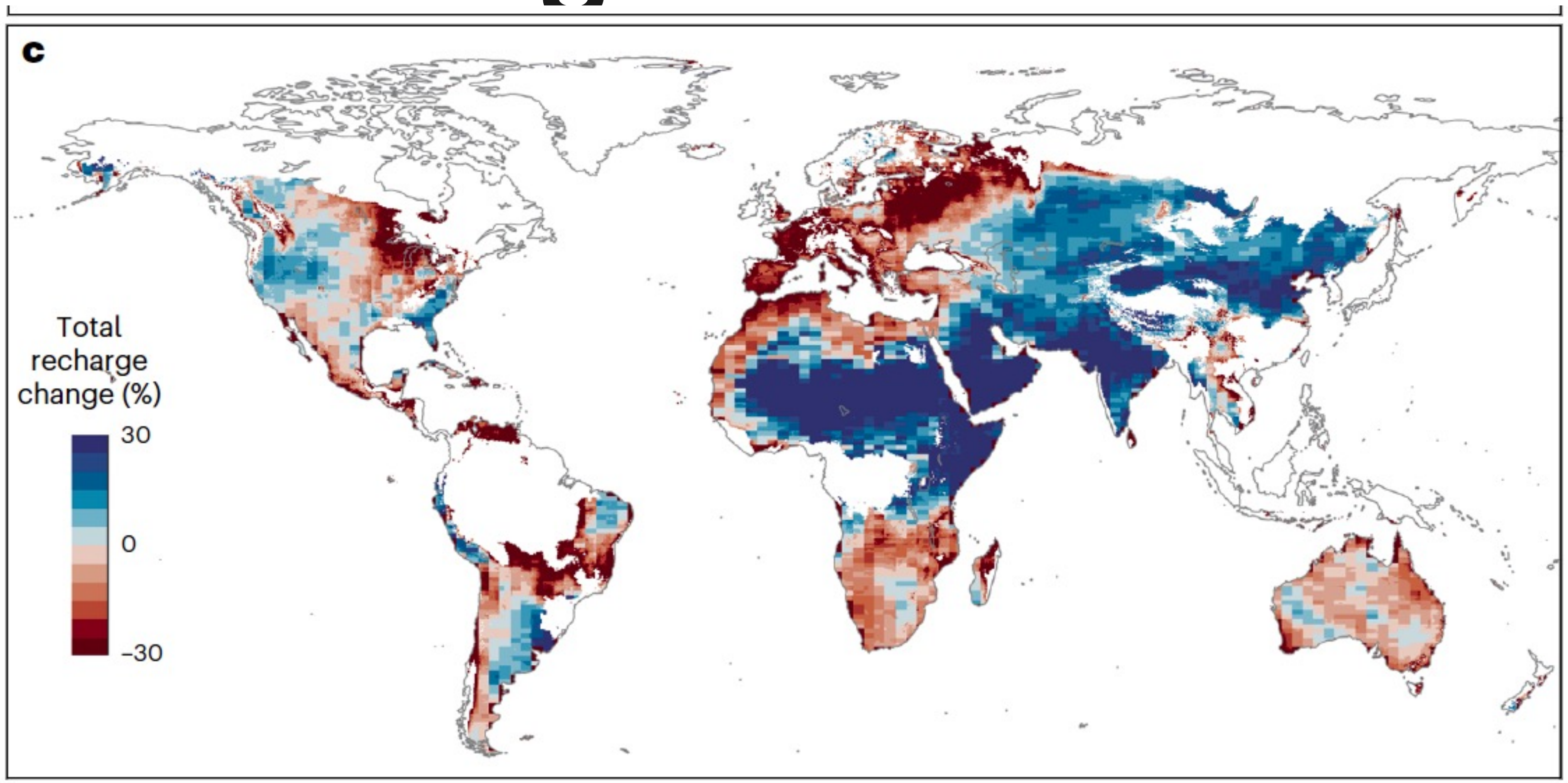
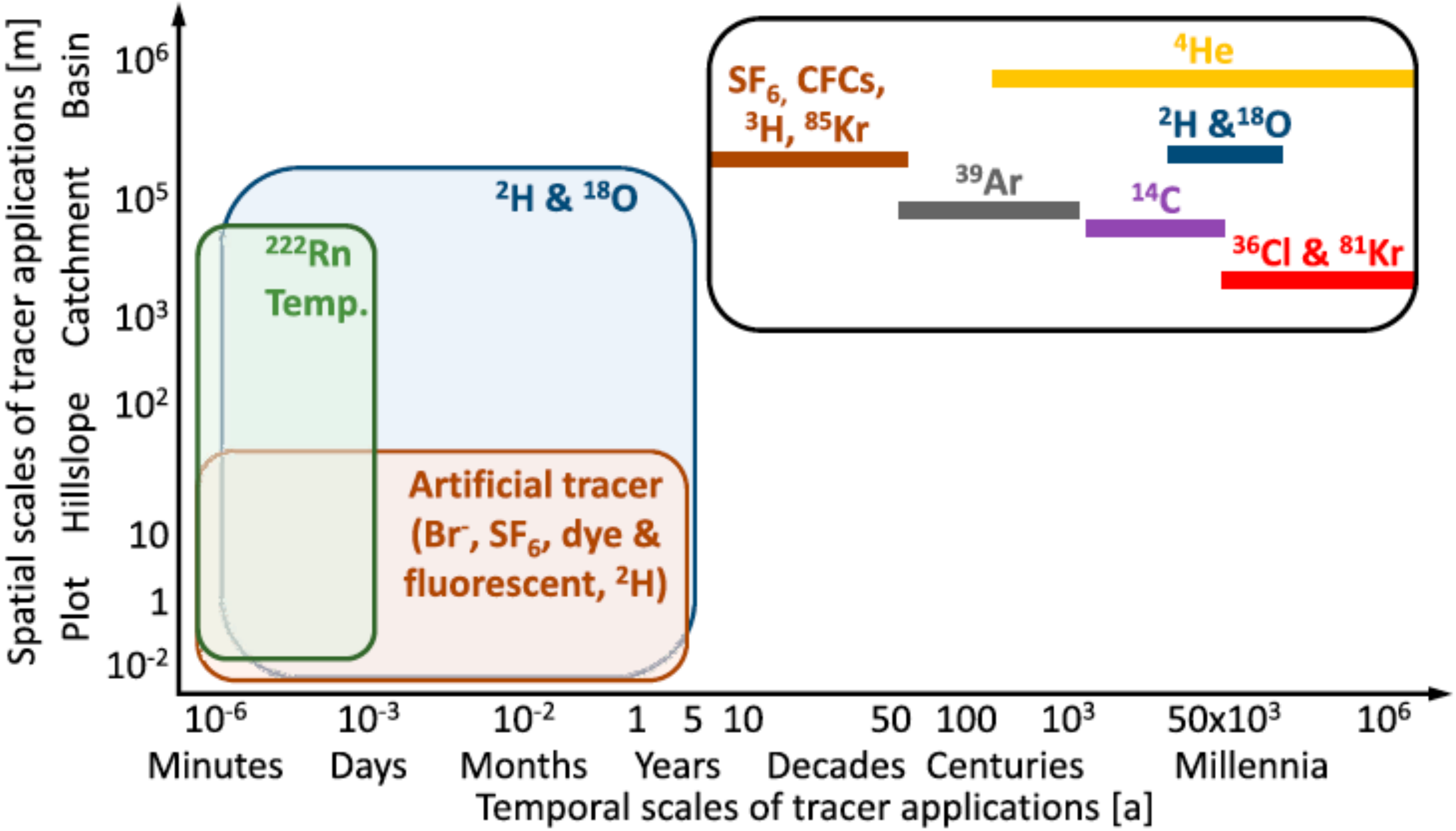
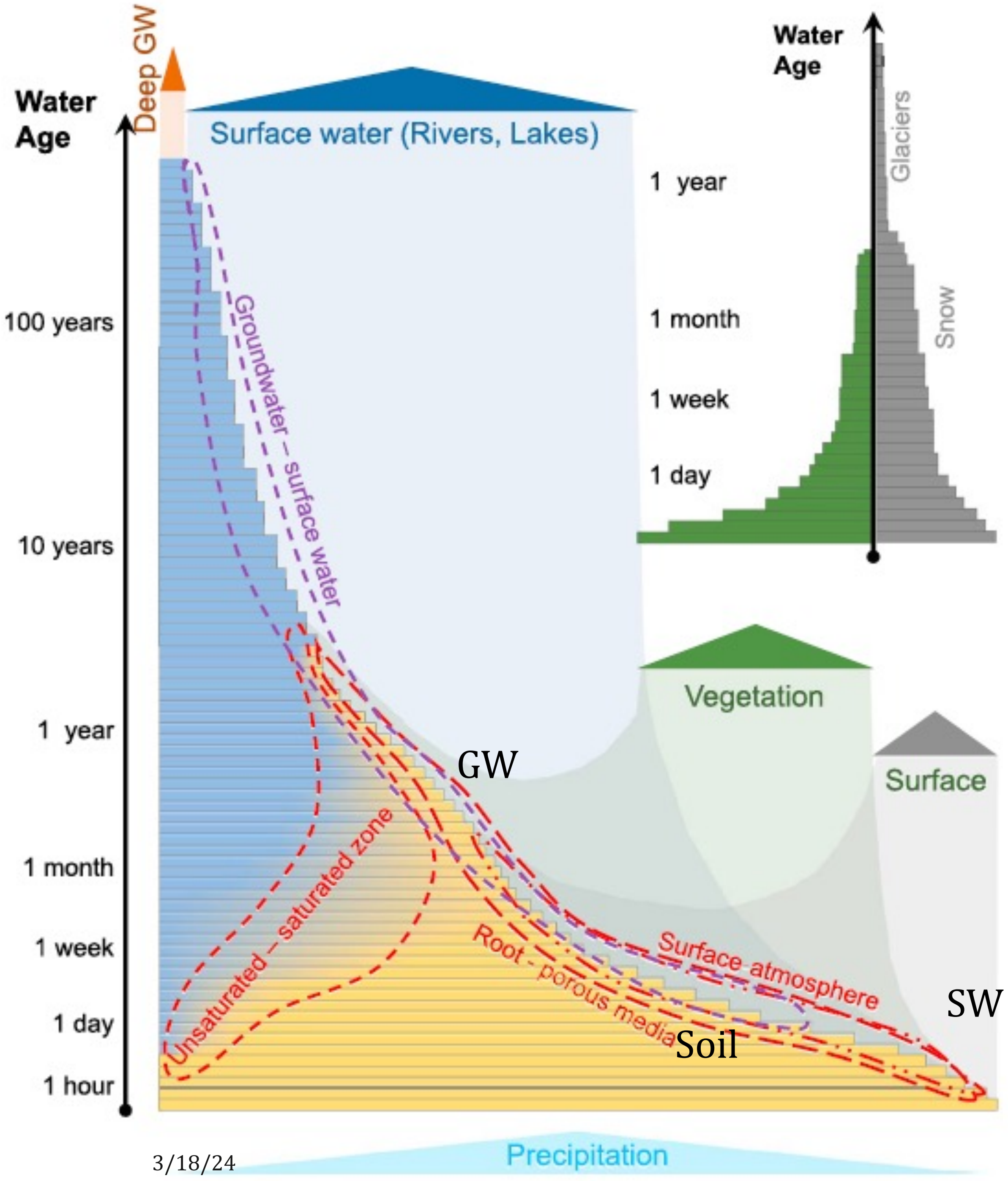


Fig. 4 | Impacts of projected climate changes on groundwater recharge. Projected relative recharge changes (2050–2080 versus 1980–2010) (%) induced by changes in precipitation (**a**), potential evaporation (**b**) and climatic aridity (**c**). Results are depicted for SSP1–2.6, but comparable regional changes occur for other scenarios (SSP5–8.5) (Extended Data Fig. 2), with largely similar regional patterns. Projected precipitation increases are more common in regions with relatively high recharge sensitivity, whereas projected precipitation decreases are more common in areas with a relatively low recharge sensitivity, leading to typically larger relative recharge changes for the wetting regions than for the drying locations.

Common Environmental Tracers



Sprenger, M.et al. (2019). The demographics of water: A review of water ages in the critical zone. Reviews of Geophysics, 57.



WHAT DO ENVIRONMENTAL TRACERS TELL US ABOUT WATER "AGES"?

Sprenger, M. et al. (2019). The demographics of water: A review of water ages in the critical zone. Reviews of Geophysics, 57.

Key Recommendations

+ + +

- Concerted effort must be placed on quantifying recharge to basin
  - Multimethod approach must be used
  - Integrating physical and chemical tracers
  - Developing models that bound possible future recharge scenarios