IBS Center
for Climate Physics

The First Emergence of Unprecedented Compound Extremes in the Anthropocene

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Water Security: Day Zero Drought Conditions

Cape Town 2018
Largest water reservoir was at 11% capacity

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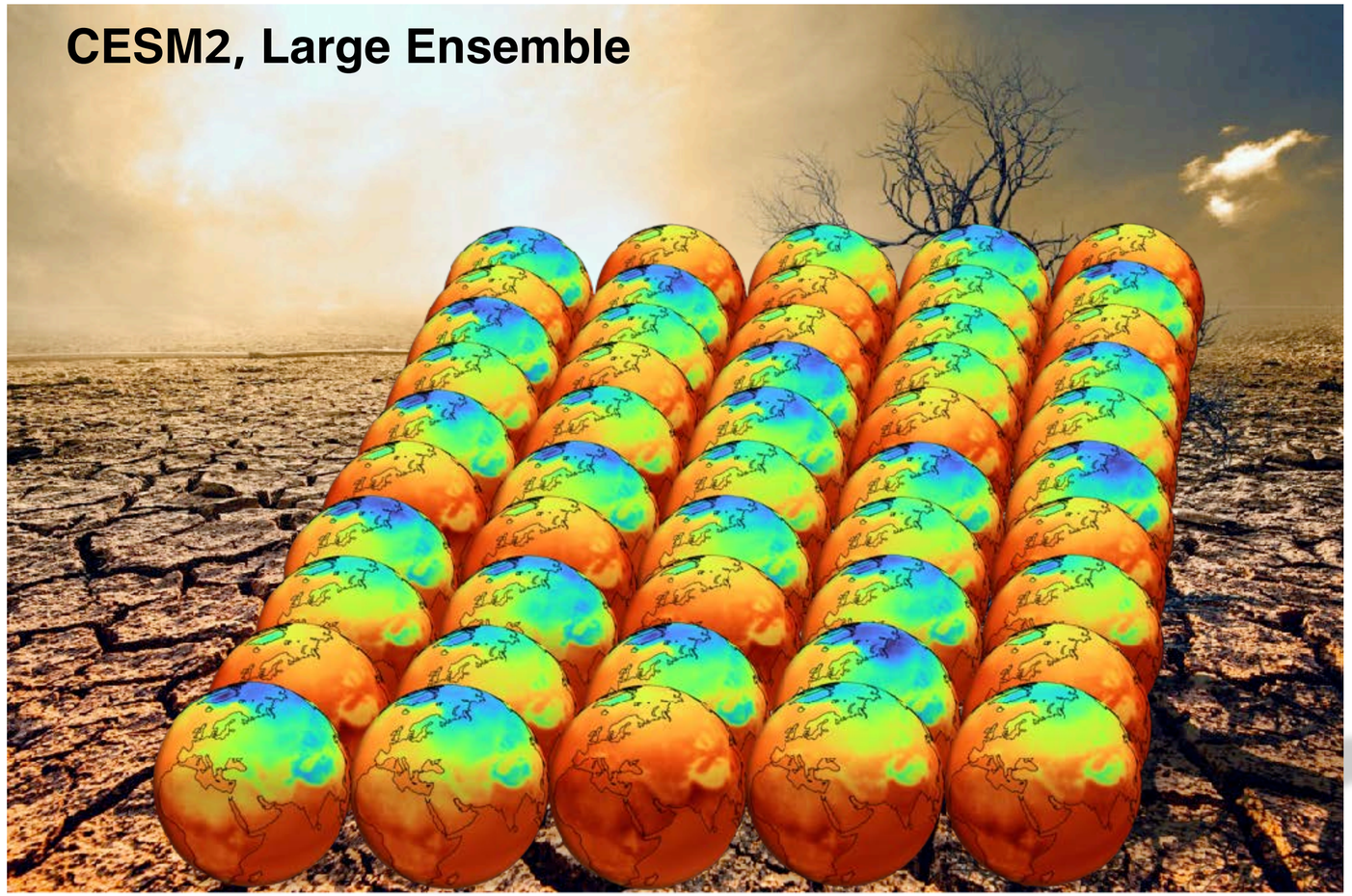
Research Methods

To estimate anthropogenic shifts in the probability distribution of weather and climate and elucidate underlying mechanisms we use the

- ICCP/NCAR Community Earth System Model **CESM2** 100 member Large Ensemble Simulation (Rodgers et al., 2021) using the SSP3-7.0 scenario



Compound DZD Index

- Reservoirs: Global Reservoir and Dams (GRanD) database which includes information on reservoir location, capacity, and the long-term average discharge (1971-2000)
- Water demand: Monthly global gridded water consumption data for sectoral water use from Khan et al. (2023)
- Water Stress:
  - Standardized Precipitation-Evapotranspiration Index (SPEI)
  - Standardized River Flow Index (SRFI)
  - Standardized Water Scarcity Index (SWSI)
- Population exposure: HYDE3.3 for period 1900-2000 and NCAR SSP3 population scenario for period 2010-2100

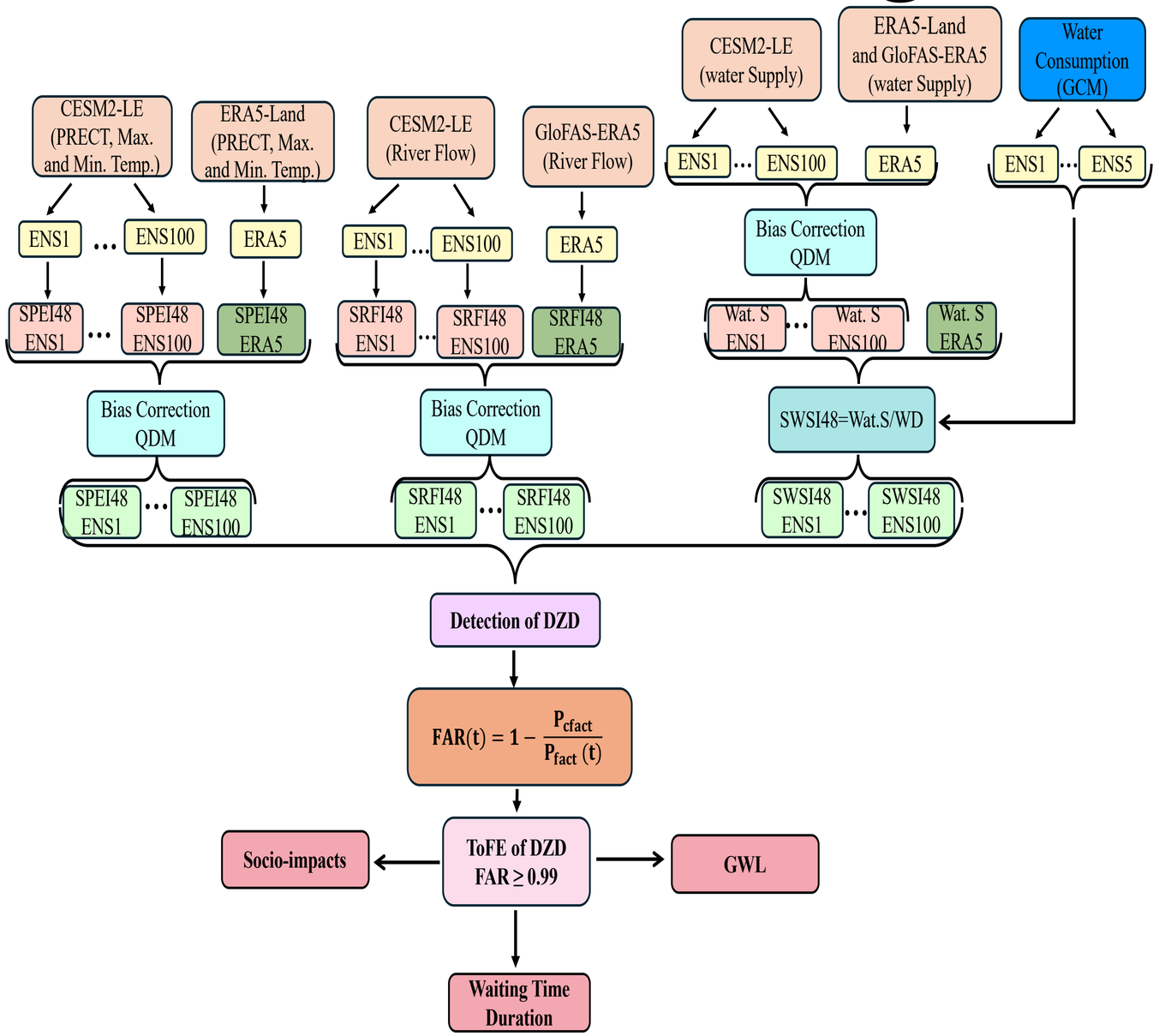
Time of First Emergence

- We use a probabilistic approach based on Fractional Attributable Risk

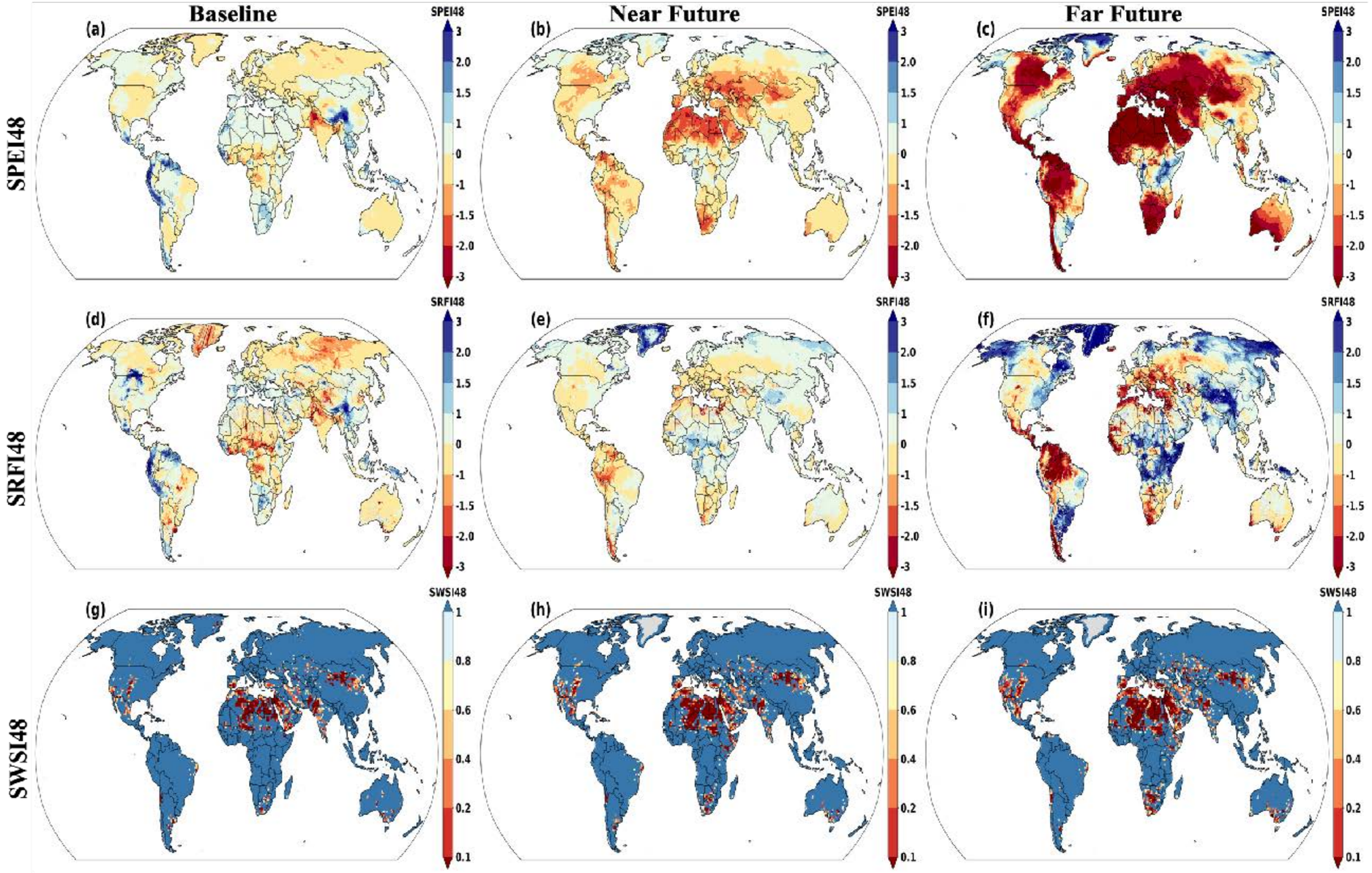
$$FAR\,(t) = 1 - \frac{P_{preindustrial}}{P_{forcing}(t)}\ with\ \begin{cases} P_{preindustrial} = \dfrac{\sum_{ens1}^{ens100} event_{i,preindustrial}(DZD)}{N_{preindustrial}} \\ P_{forcing}\,(t) = \dfrac{\sum_{ens1}^{ens100} event(t)_{i,forcing}\,(DZD)}{N_{forcing}\,(t)} \end{cases}$$

- We define “Day Zero Drought” as
  - DZD occurs if $\begin{cases} \text{SPEI48} \leq -1.5 \cap \text{SRFI48} \leq -1.5 \cap \text{SWSI48} \leq 0.6, \text{dur}_{ce} \geq \text{TRD, if reservoir exists.} \\ \text{SPEI48} \leq -1.5 \cap \text{SRFI48} \leq -1.5 \cap \text{SWSI48} \leq 0.6, \text{if there is no reservoir.} \end{cases}$

Time of First Emergence



Emergence of Day Zero Drought (DZD)



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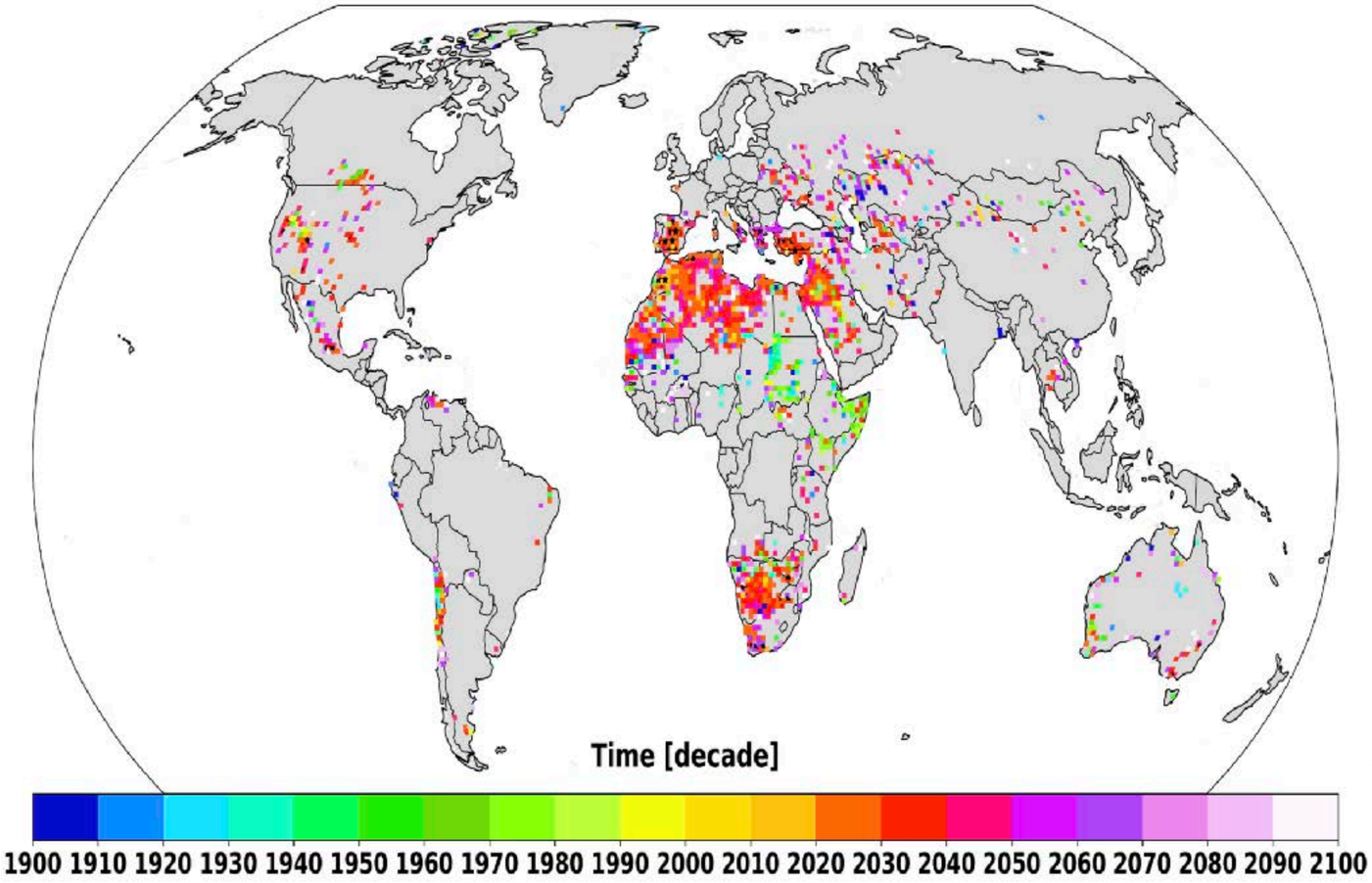
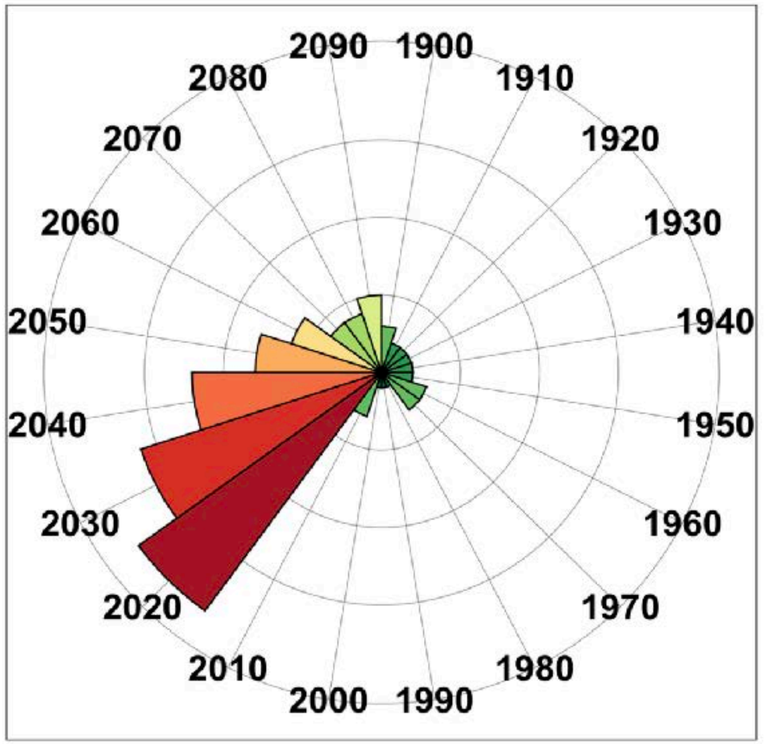


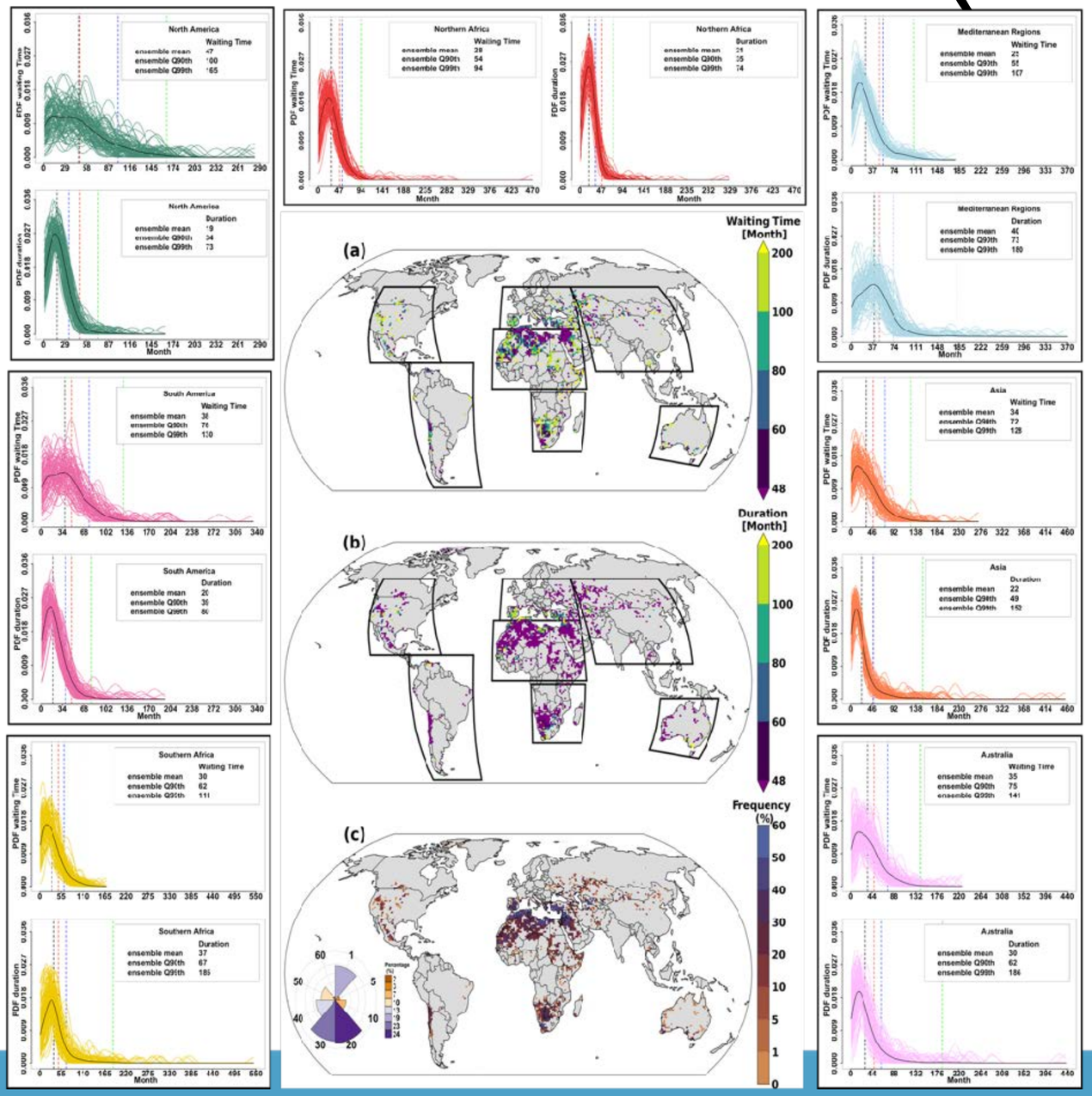


DZD is based on Standardized Precipitation-Evapotranspiration Index, Standardized River Flow Index, Standardized Water Scarcity Index, Time for Reservoirs to Dry

The DZD is introduced here as a compound event, for which certain criteria for extreme conditions related to 4 hydrological variables have to be met

Emergence of Day Zero Drought (DZD)

Distributions of the duration and the waiting times between two events after first emergence



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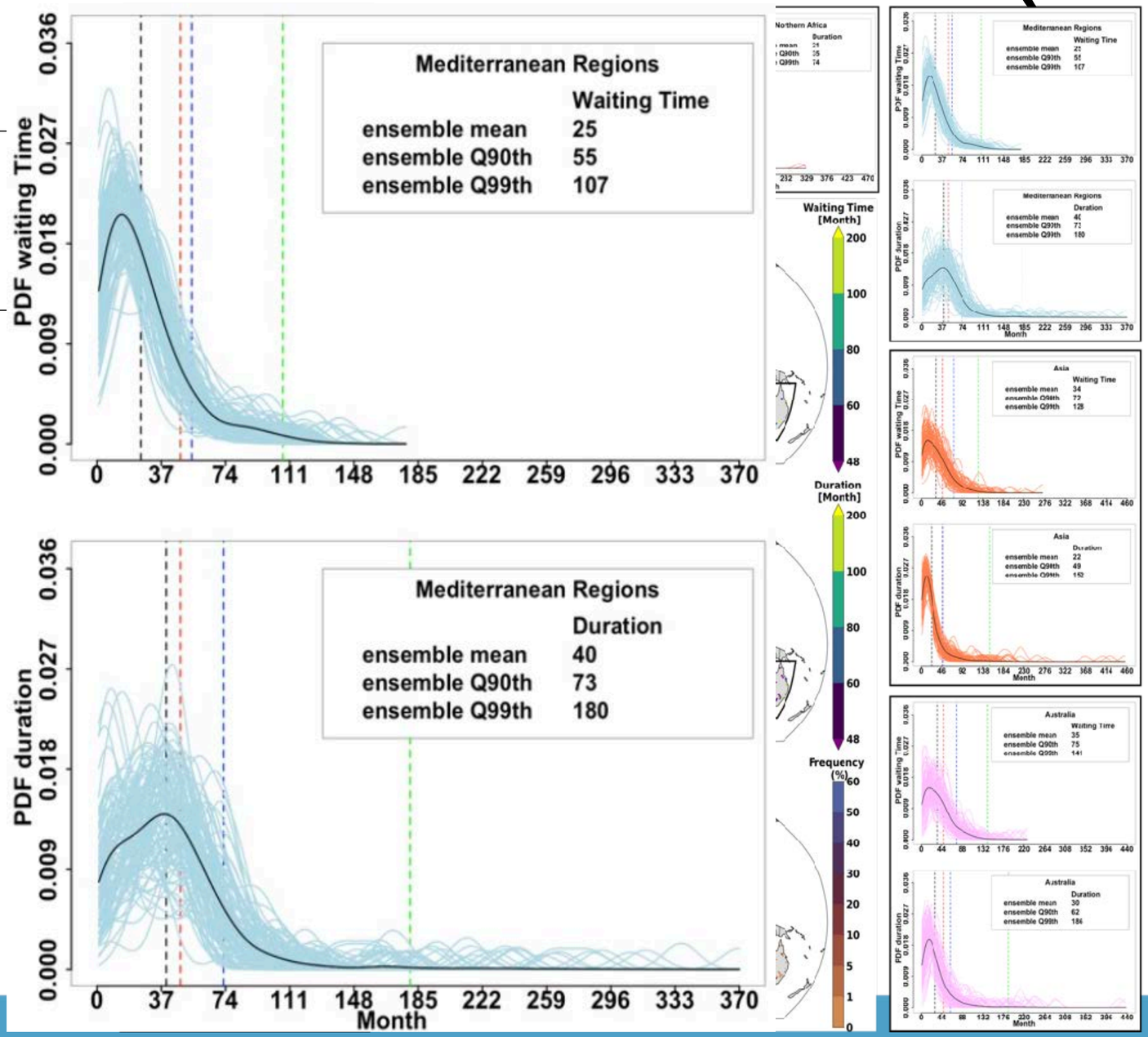

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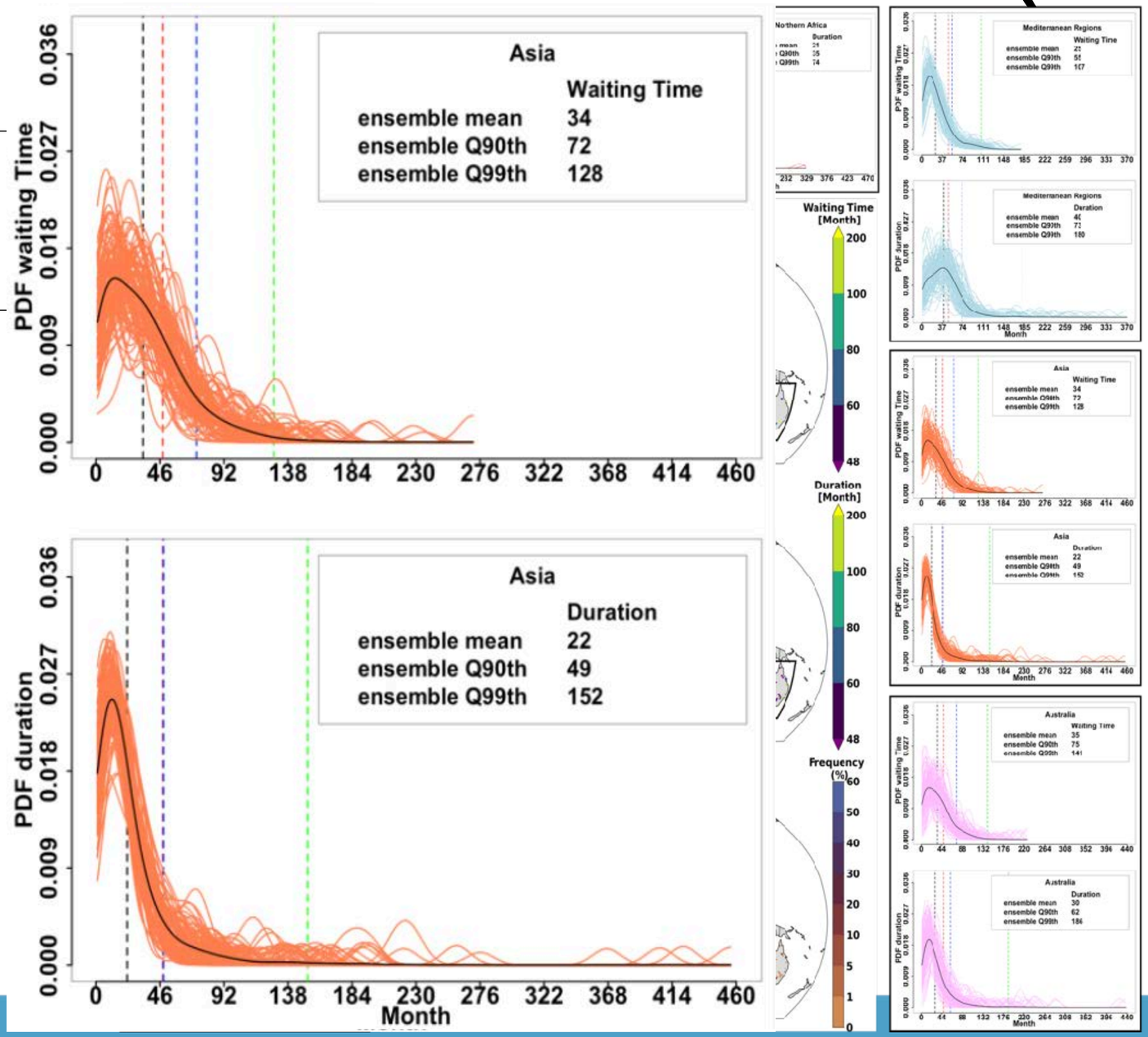

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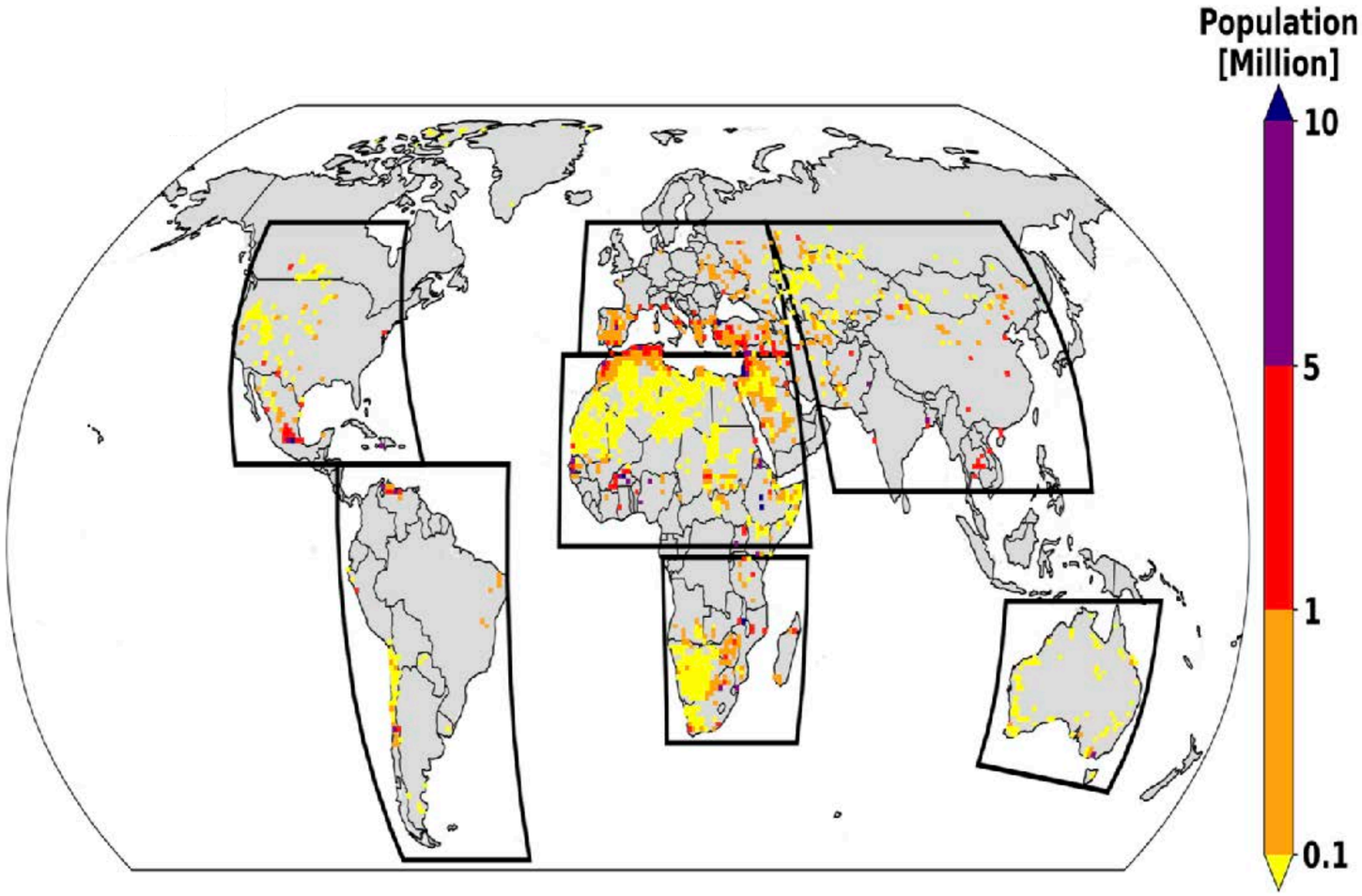
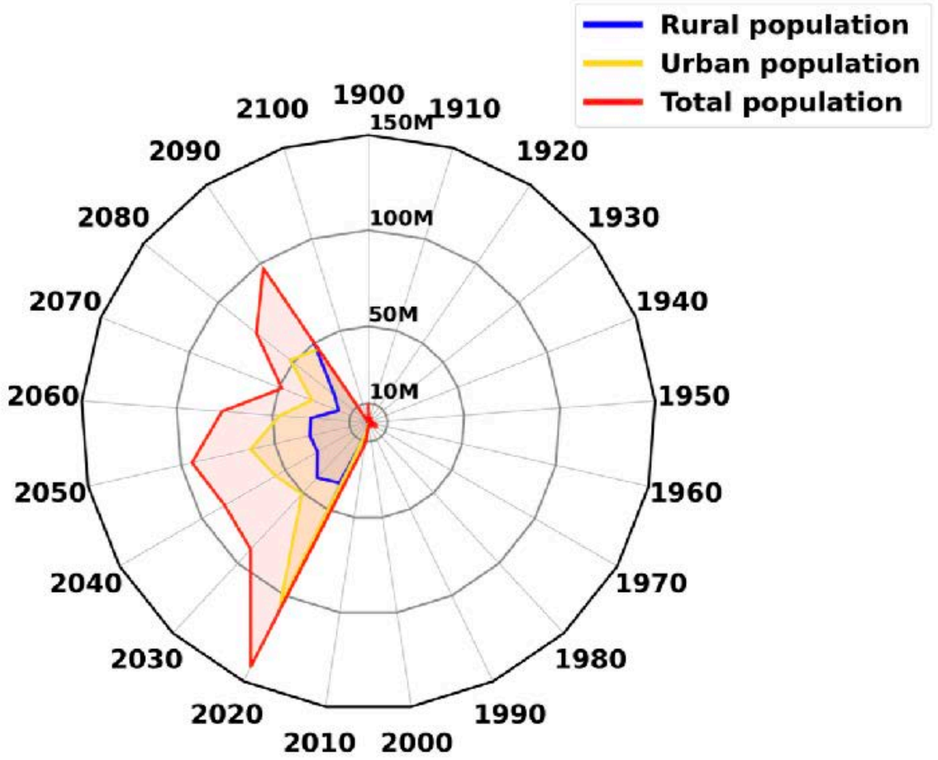
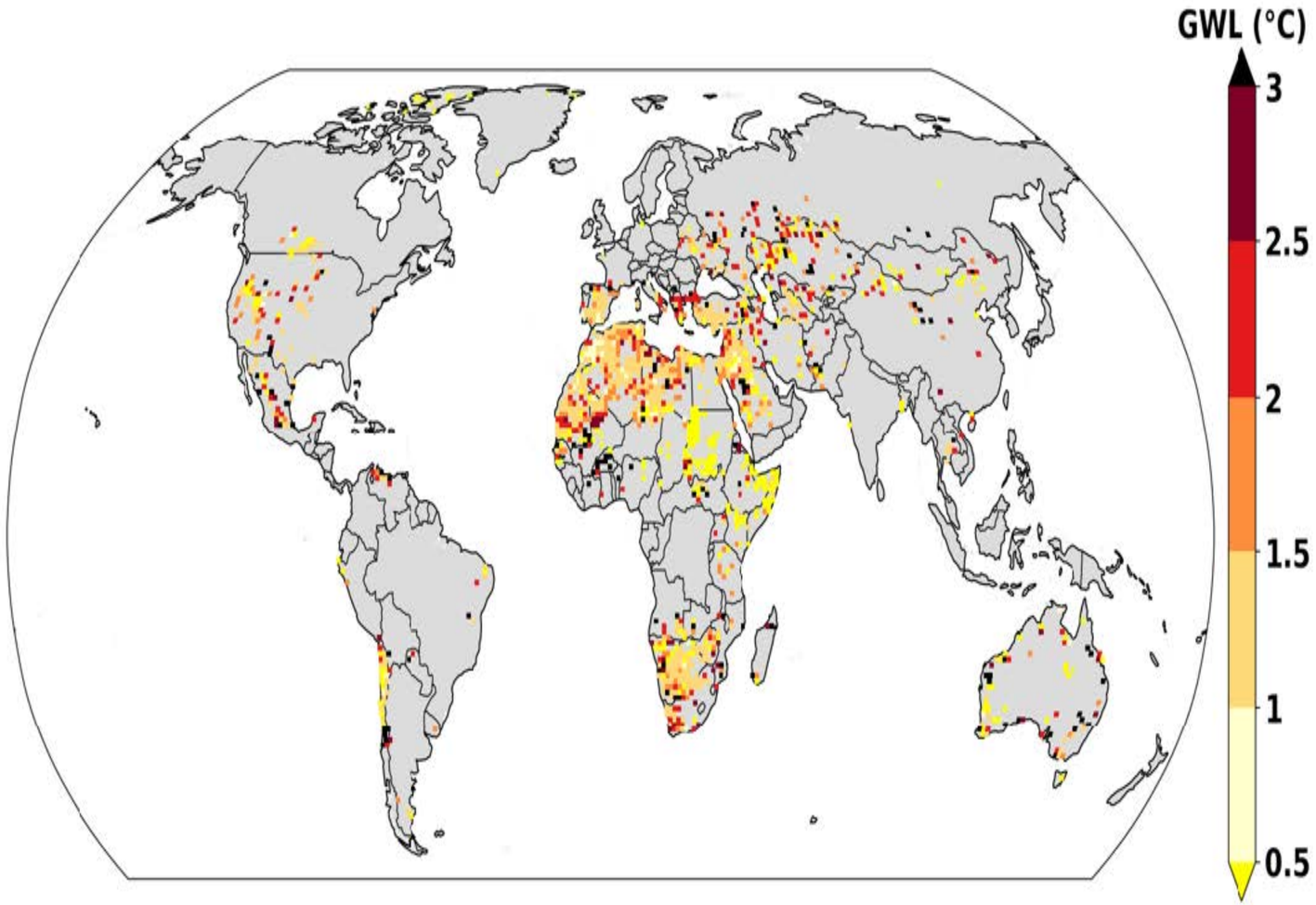


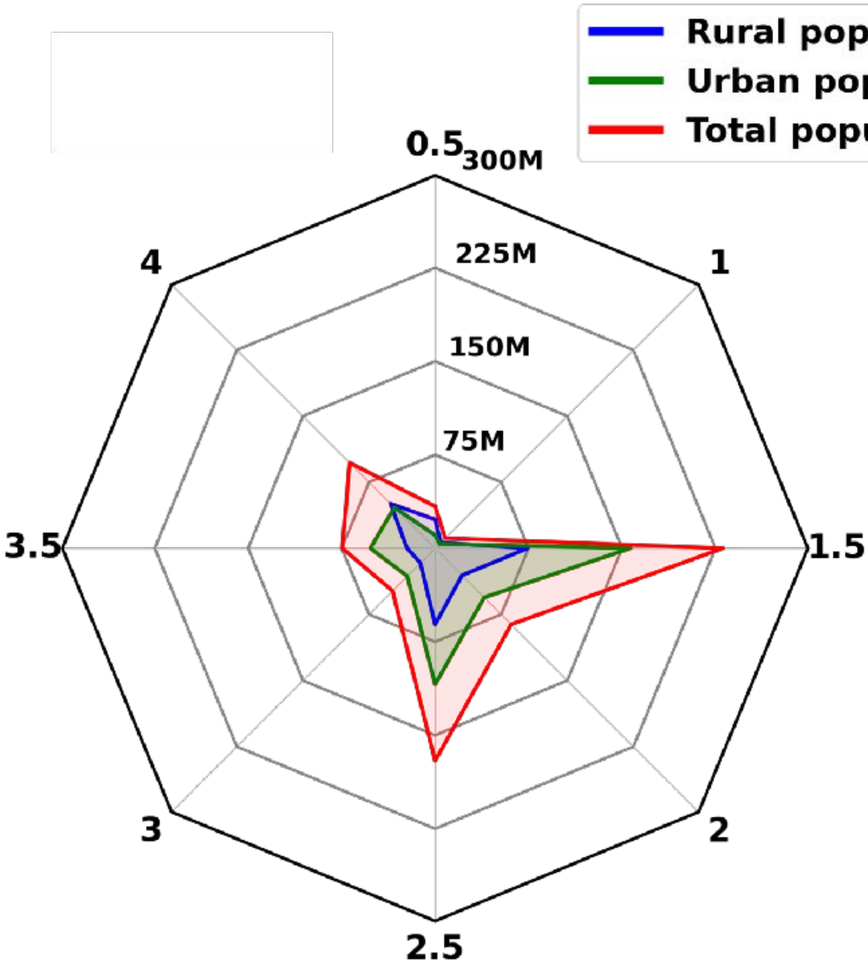


- 753 million people will be exposed to DZD (about 9% of population) till 2100.
- Hotspots for DZD conditions: the Mediterranean and Southern Africa.

In 2030 we expect that about 231 million people will experience their first DZD conditions, most of them in urban areas.

Emergence of Day Zero Drought

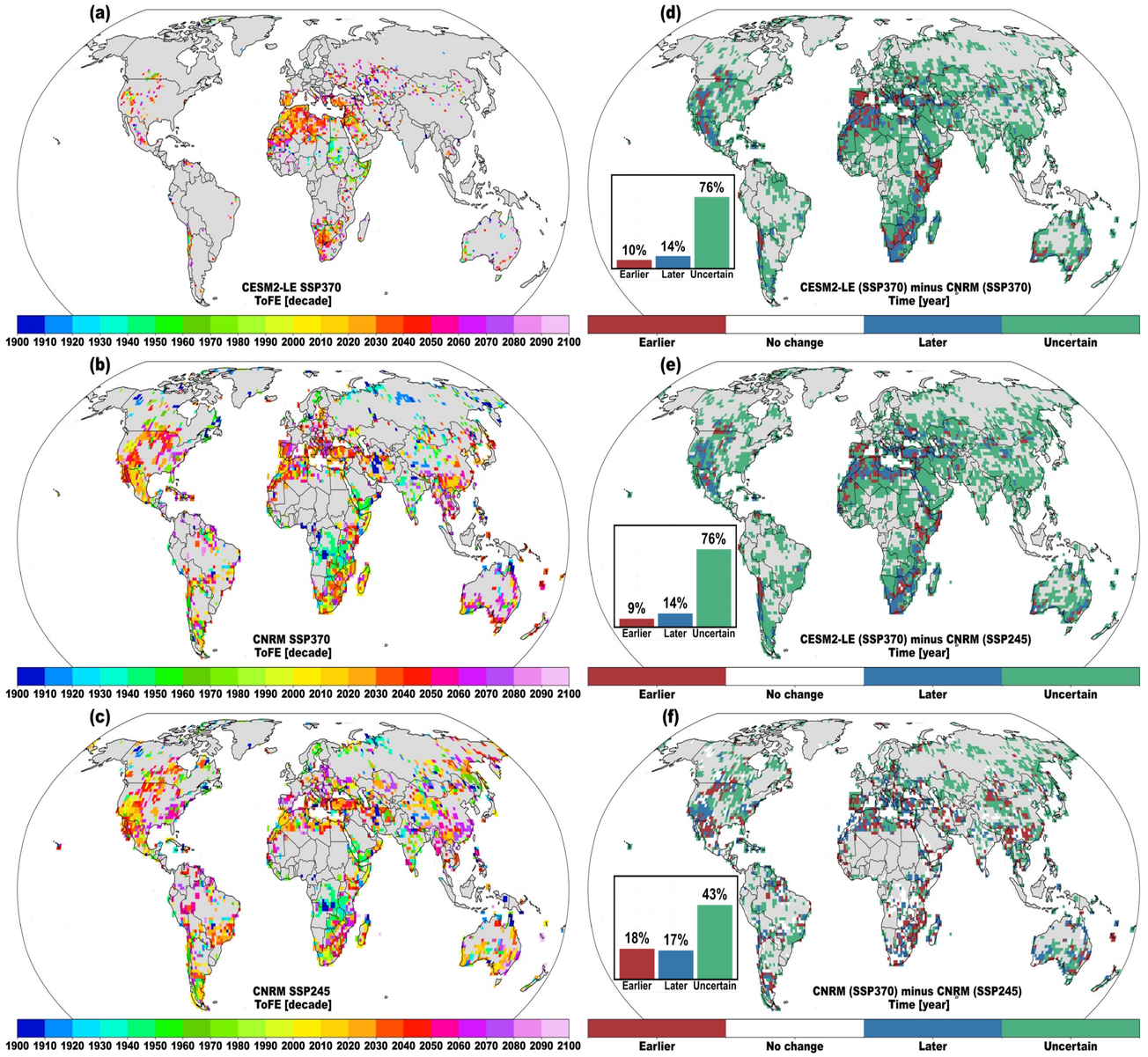




- Our results show that 61% of GWL related to the ToFE of DZD-affected regions are in the range of 1°C to 2.5°C of warming

Model Sensitivity

Comparison with CNRM-ESM2-1



Summary

- Time of First Emergence of drought-driven water scarcity events, “Day Zero Drought” (DZD), by analyzing the simultaneous impact of multi-year water supply deficits and high-water consumption.
- Using a probabilistic framework and a large ensemble of climate simulations, we attribute the timing and likelihood of DZD events to human influence.
- Our findings indicate that 35% of DZD-prone regions will experience the Time of First Emergence by 2020 and 2030.
- The emergence of DZD is expected to potentially drain 14% of global reservoirs and to impact urban population most at the 1.5°C warming level.
- The length of time between successive DZD events is shorter than the duration of DZD, leading to insufficient recovery periods and exacerbating water scarcity risks.
- **Reference**: Ravinandrasana and Franzke, 2025: The First Emergence of Unprecedented Global Water Scarcity in the Anthropocene. Nature Communications in review

Postdoc Position

Postdoctoral Fellow Position – Earth System Variability and Extremes

- Use Earth system models to investigate how interactive fire emissions affect climate variability, climate sensitivity and extreme events.
- Investigate the interactions and long-term variability of fire and vegetation and their impact on compound extremes.
- Employer: IBS Center for Climate Physics
- Location: Pusan National University, Busan, South Korea
- Term: Full Time, 2 year, with possibility for renewal