# A global view of concurrent wildfires, droughts, heatwaves, and air pollution: impacts and risks

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## Objectives

- ❑ **What is the spatial distribution of H, D, F, and P compound event global hotspots?**
- ❑ **Characteristics of compound H, D, F, and P on 6 continents (N-AM, S-AM, EURO, AFRI, ASIA, OCEA;**
- ❑ **Impacts of hot and dry events (heatwave + drought) on FRP;**
- ❑ **Impacts of hot, dry, and fire events (heatwave + drought + FRP) on air quality ($PM_{2.5}$);**

# Data

Heatwaves (H), droughts (D), fires (F), and pollution (P)

The horizontal resolution is preset at **0.75º × 0.75º**, and the time window is between **2003 and 2022 at a daily basis**.

**ERA5** – hourly **T** (1991 – 2022) → daily **Tmax** (1991 – 2022)
hourly **P** (2002 – 2022 → daily acum **P** (2002 – 2022)

**Heatwave (H)** is defined as an event during which 2-metre daily Tmax is above its climatological 90th percentile (P90) for three days or more.

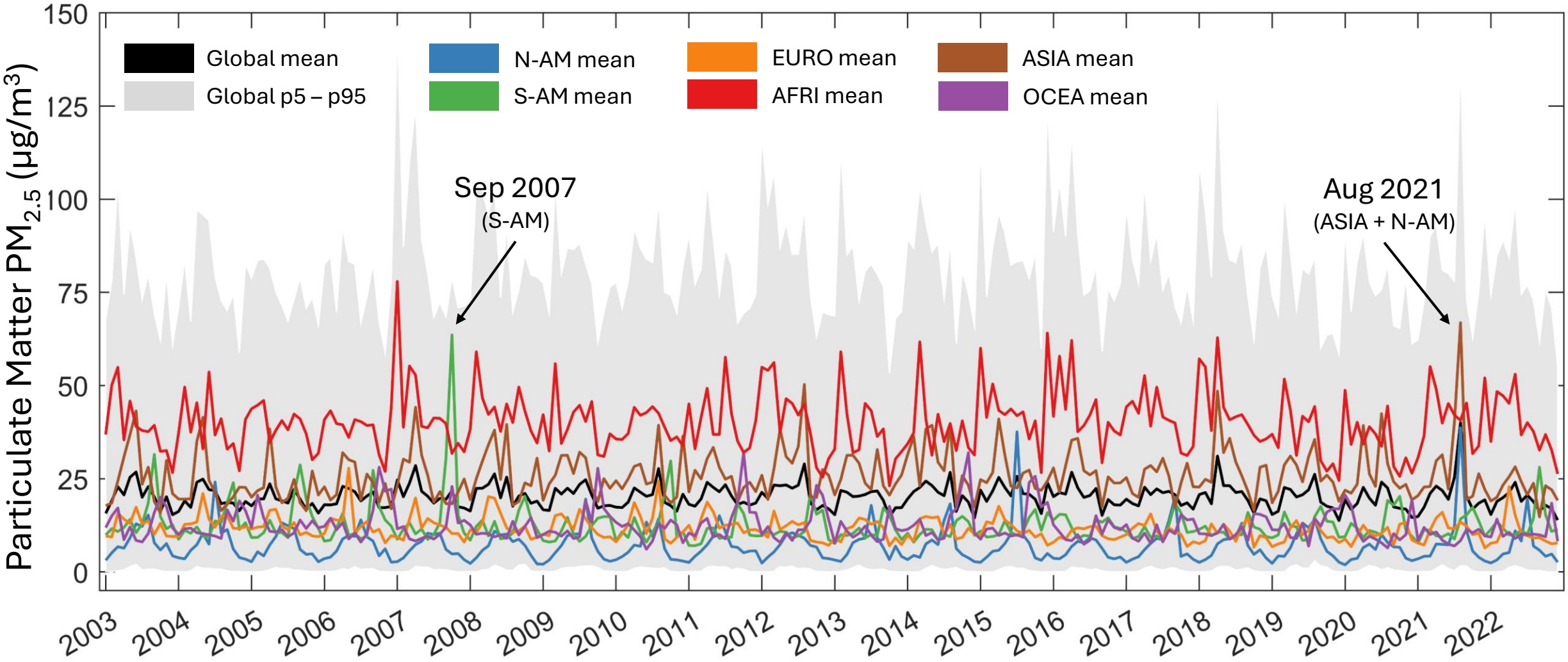
For **droughts (D)** we use daily SPI (Careto et al., 2024), with a timescale = 180 days (6-month).

The **FRP (F)** dataset originates from NASA's FIRMS, containing data on **hotspot location**, **date**, **FRP estimates**, and corresponding **confidence levels** for 88,688,984 FRP estimates. FRP is in MW. For each 0.75º × 0.75º cell, **the maximum FRP with confidence above 80 % is selected** if fire occurrences are observed, and for cells where no occurrences are detected a value of 0 is assigned.

**Air quality (P)** data is retrieved from the Copernicus Atmosphere Monitoring Service (CAMS) global reanalysis (EAC4). Surface **particulate matter with diameter < 2.5 µm** (hereafter **PM2.5**) at the global scale is obtained in intervals of 3 hours at a horizontal resolution of 0.75º × 0.75º degrees for the period spanning **2003 – 2022**. A daily average is then performed, using the 8 hourly values available in each day. Unit of PM2.5 is **µg/m3**.

# Data

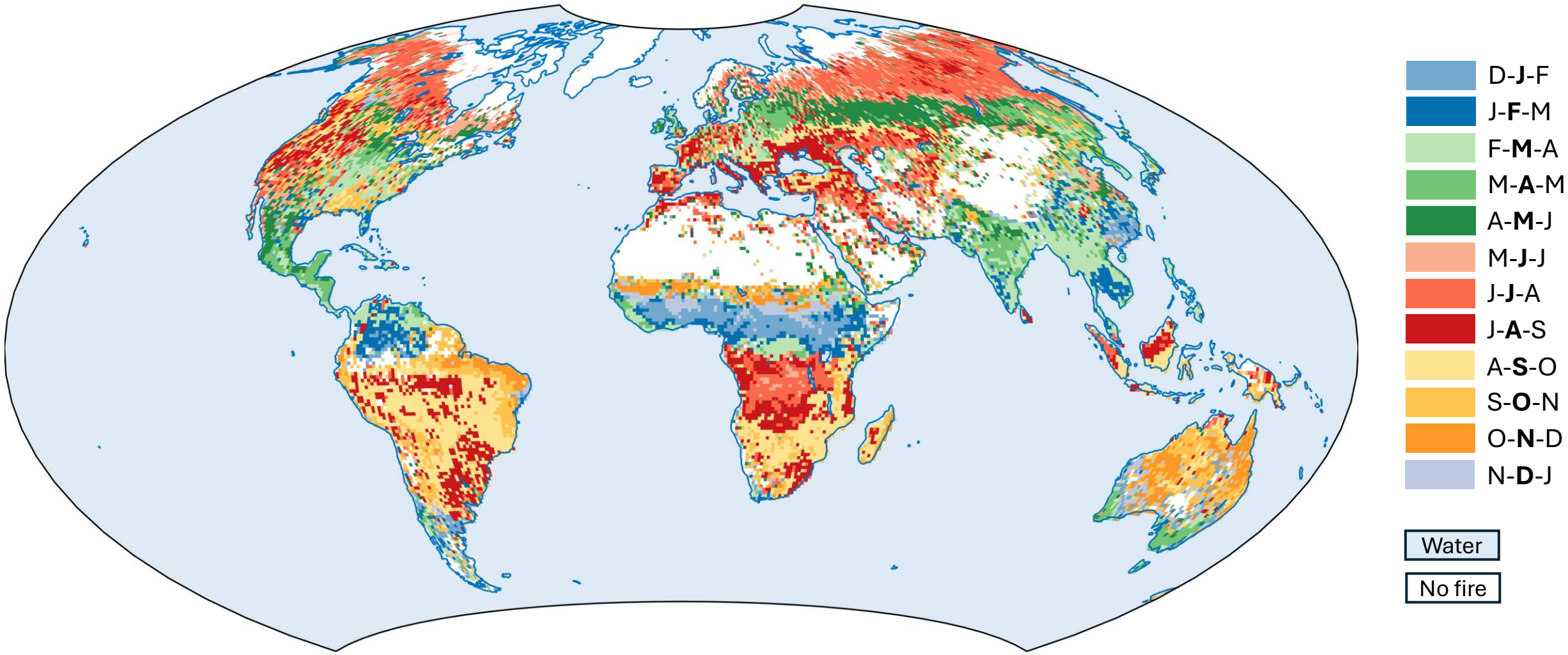
Analysing PM2.5



# Data

Analysing Fires

Characterization of FRP; season of maximum mean FRP (3-month moving window). For each grid-cell and each Julian day of a given season, the mean of 2003 – 2022 is performed. Then, the mean of the season is performed. The season of maximum FRP is selected.



# Methods

## Defining Compound Events

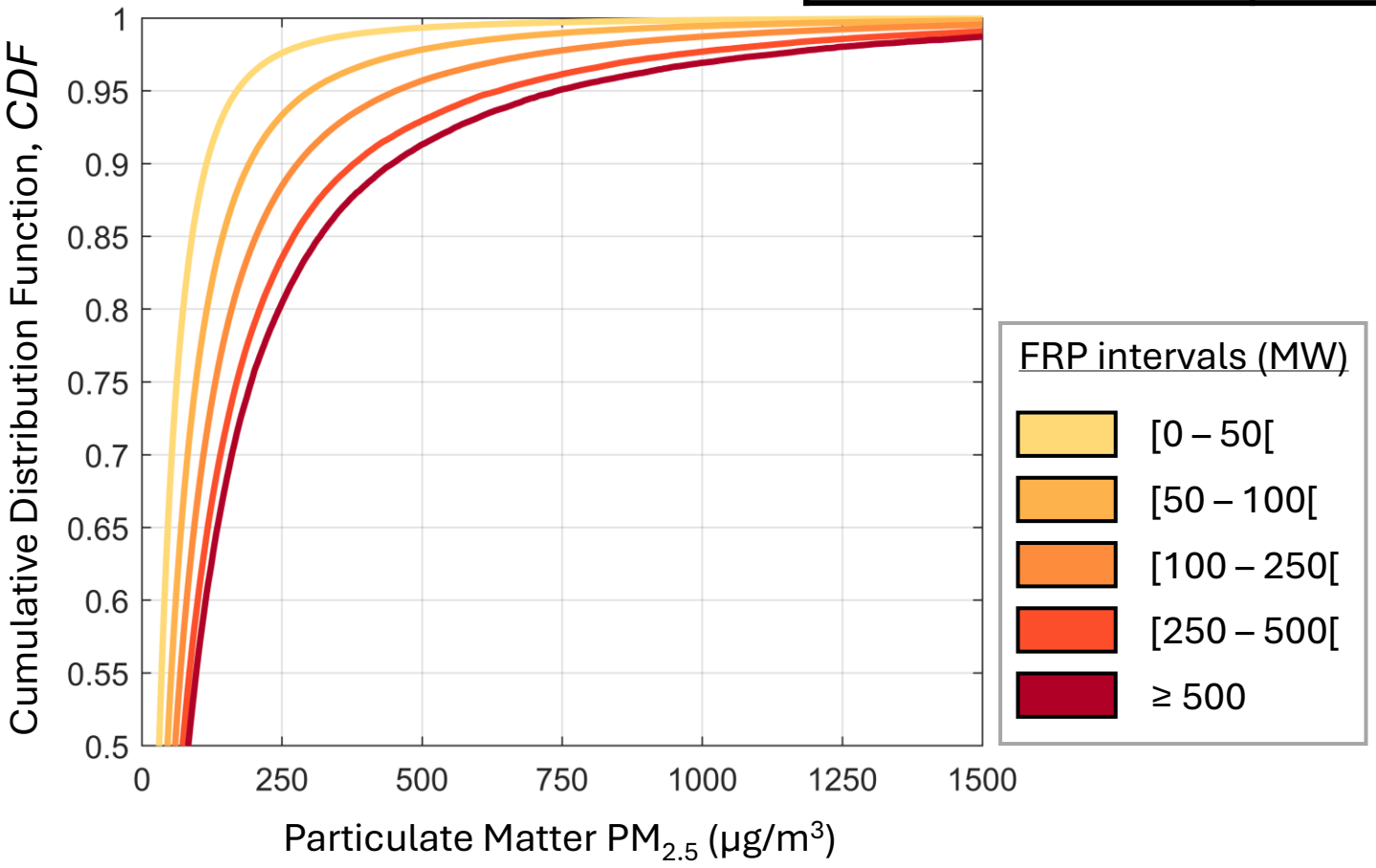
Regarding the PM2.5 threshold **to consider an event of pollution**, the World Health Organization (WHO) new recommended global air quality guideline (AQG) levels and interim targets (IT) are taken, i.e., a **daily average limit value of 75** (IT1), **50** (IT2), **37.5** (IT3), **25** (IT4), and **15** (AQG) μg/m3.

| Value | Hazard | | | | Explanation |
|---|---|---|---|---|---|
| | P | H | D | F | |
| 0 | | | | | No hazard |
| 1 | ■ | | | | Single hazard P |
| 2 | | ■ | | | Single hazard H |
| 4 | | | ■ | | Single hazard D |
| 8 | | | | ■ | Single hazard F |
| 3 | ■ | ■ | | | Compound of P-H |
| 5 | ■ | | ■ | | Compound of P-D |
| 6 | | ■ | ■ | | Compound of H-D |
| 9 | ■ | | | ■ | Compound of P-F |
| 10 | | ■ | | ■ | Compound of H-F |
| 12 | | | ■ | ■ | Compound of D-F |
| 7 | ■ | ■ | ■ | | Compound of P-H-D |
| 11 | ■ | ■ | | ■ | Compound of P-H-F |
| 13 | ■ | | ■ | ■ | Compound of P-D-F |
| 14 | | ■ | ■ | ■ | Compound of H-D-F |
| 15 | ■ | ■ | ■ | ■ | All concurrent events |

# Test

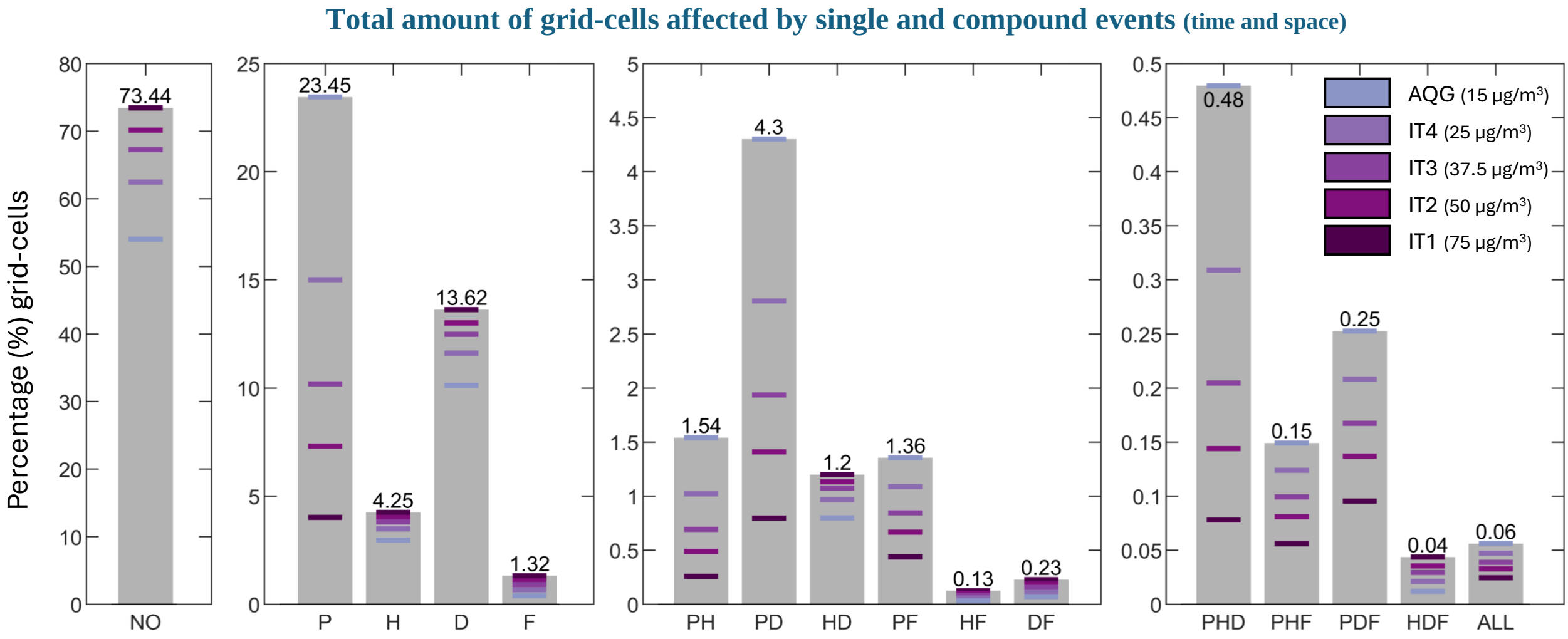
PM2.5 vs. FRP

| | $PM_{2.5}$ | IT1<br>75 µg/m³ | IT2<br>50 µg/m³ | IT3<br>37.5 µg/m³ | IT4<br>25 µg/m³ | AQG<br>15 µg/m³ |
|---|---|---|---|---|---|---|
| **FRP** (MW) | 0 – 50 | 20 | 32 | 43 | 57 | 74 |
| | 50 – 100 | 33 | 47 | 57 | 70 | 83 |
| | 100 – 250 | 42 | 56 | 65 | 76 | 87 |
| | 250 – 500 | 49 | 62 | 70 | 80 | 89 |
| | > 500 | 53 | 65 | 73 | 82 | 90 |



# Results

Global frequency of compound




*Based on Sutanto et al., 2020*

# Methods

Defining hotspots

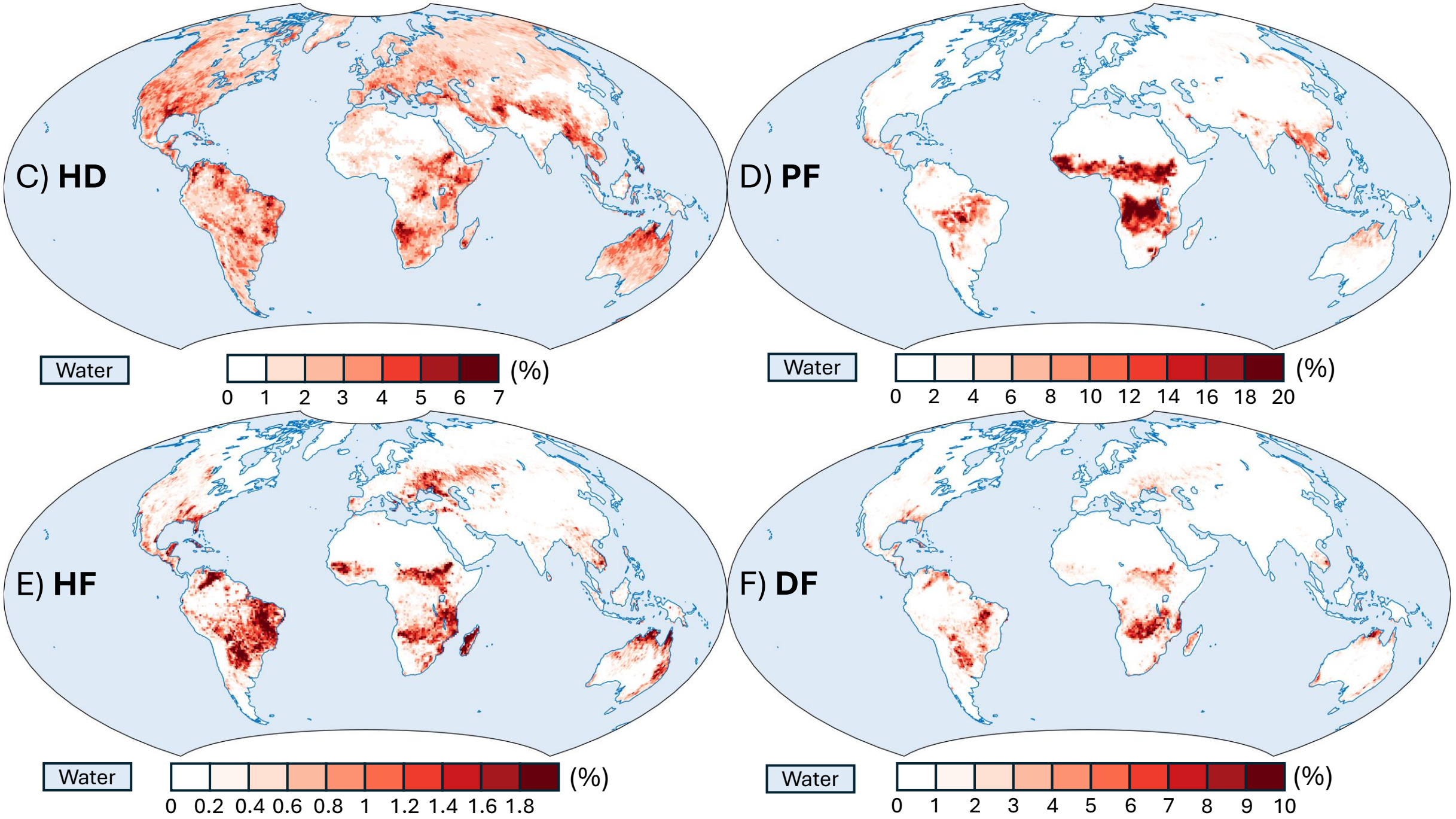
**Hotspot**: P90, in %, of yearly number of compound days for each year/total number of days (365 days) × 100).

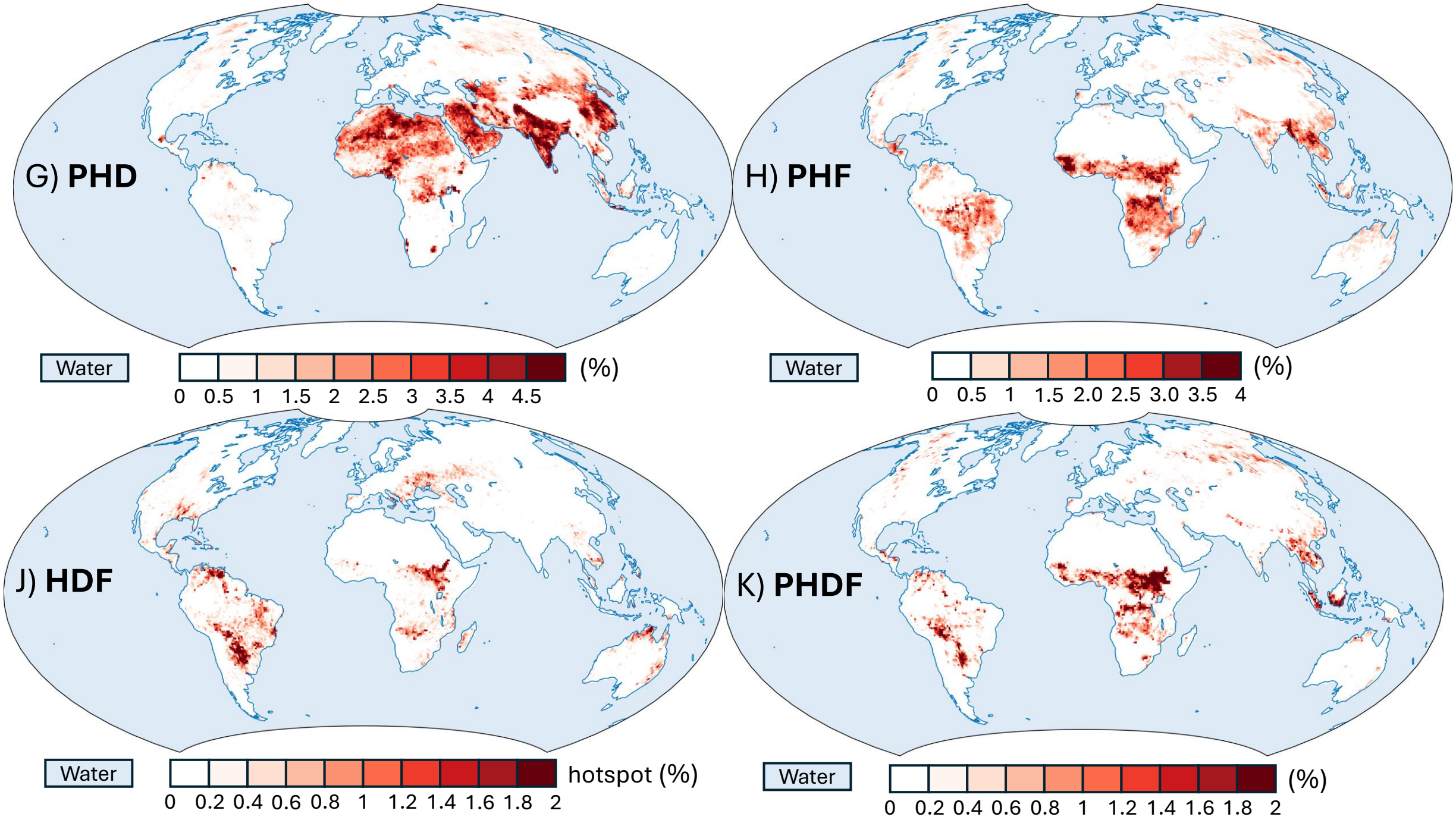
Hotspots of compound events are estimated as the extreme compound hazards in the period **2003 – 2022** for each grid cell.

Here, the 90th percentile of the yearly number of days where a given combination of compound hazards occur divided by the total number of days per year is estimated.

This analysis produces a total of **11 hotspot global maps** (representing each of the compound possibilities, i.e., values except 0, 1, 2, 4, and 8).

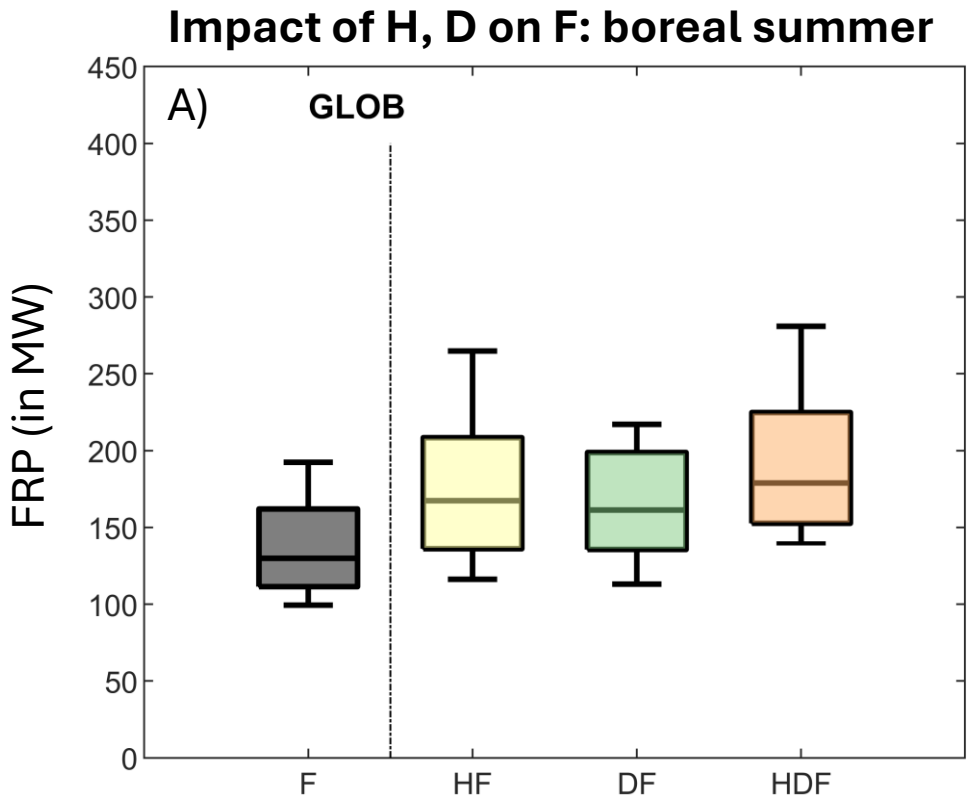
*Based on Sutanto et al., 2020*

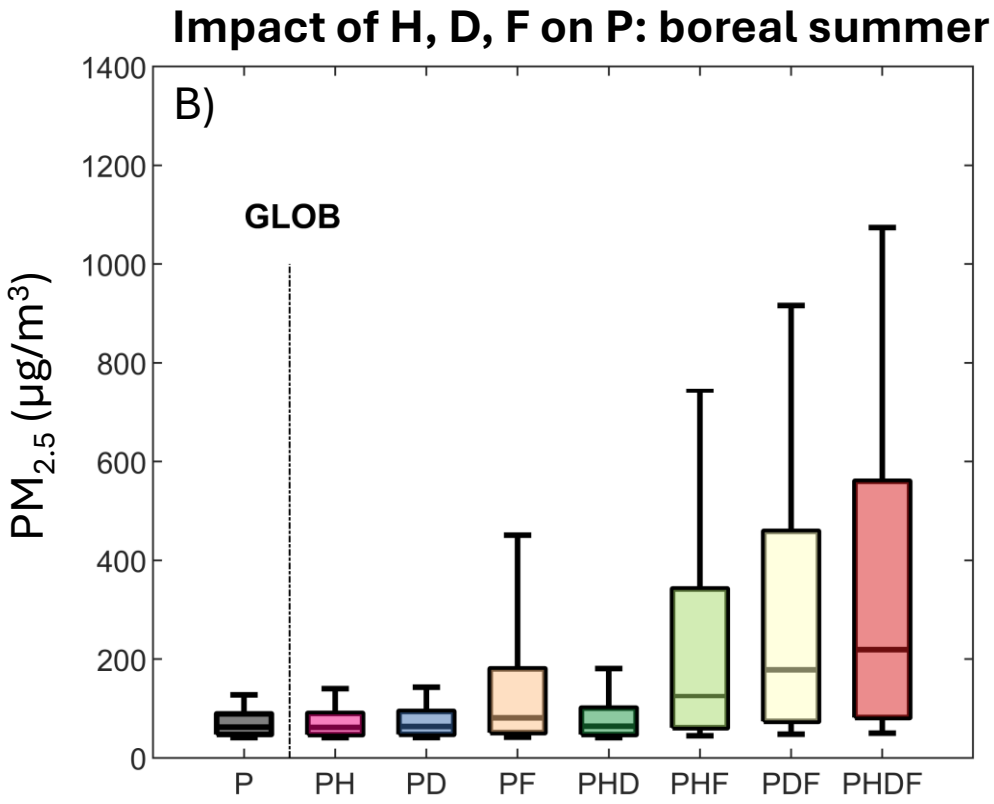

C) HD
Water
0 1 2 3 4 5 6 7
(%)
D) PF
Water
0 2 4 6 8 10 12 14 16 18 20
(%)
E) HF
Water
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8
(%)
F) DF
Water
0 1 2 3 4 5 6 7 8 9 10
(%)


G) PHD
Water
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5
(%)
H) PHF
Water
0 0.5 1 1.5 2.0 2.5 3.0 3.5 4
(%)
J) HDF
Water
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
hotspot (%)
K) PHDF
Water
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
(%)

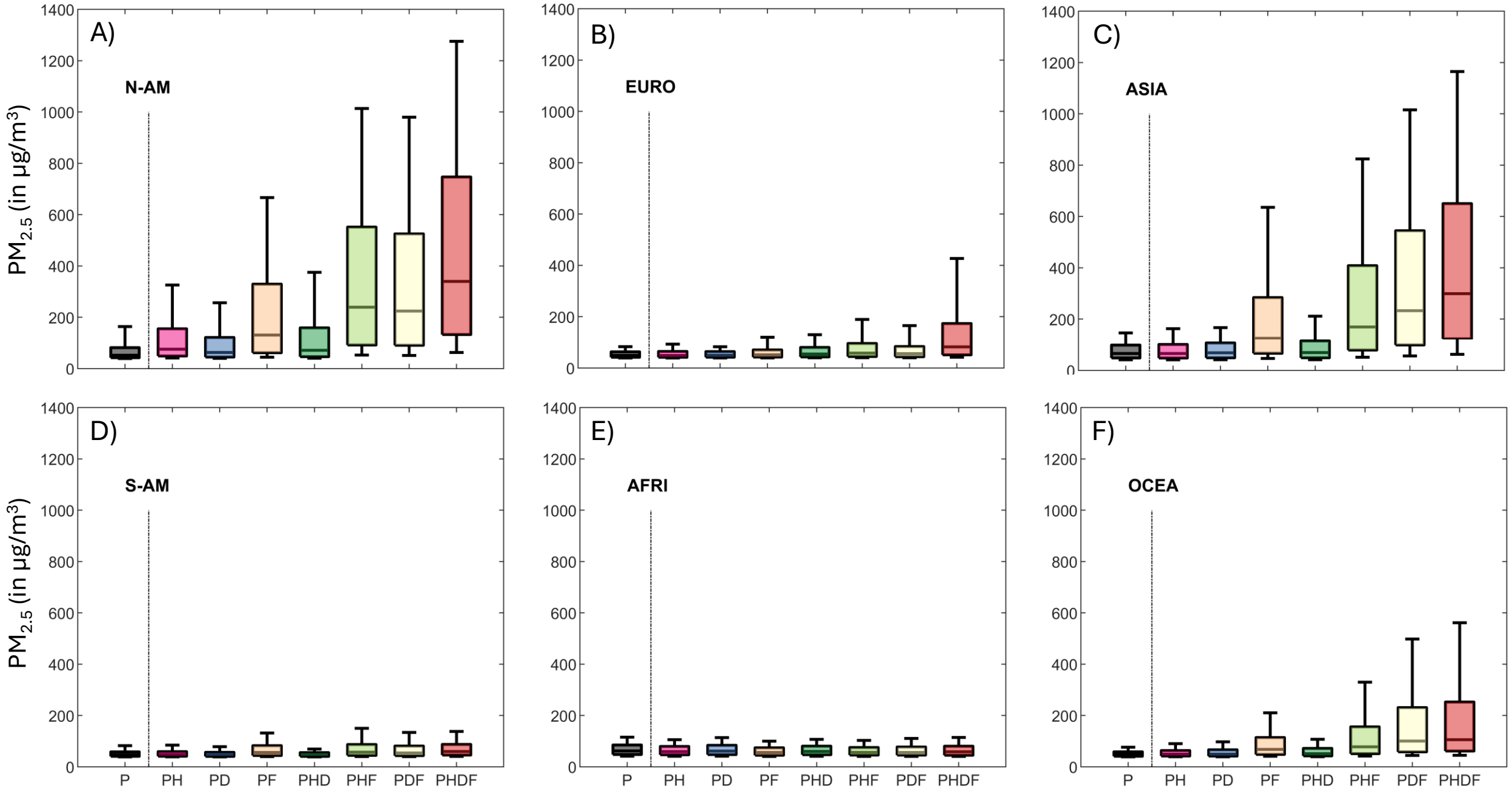
# Results

Impact of compound on FRP and PM2.5



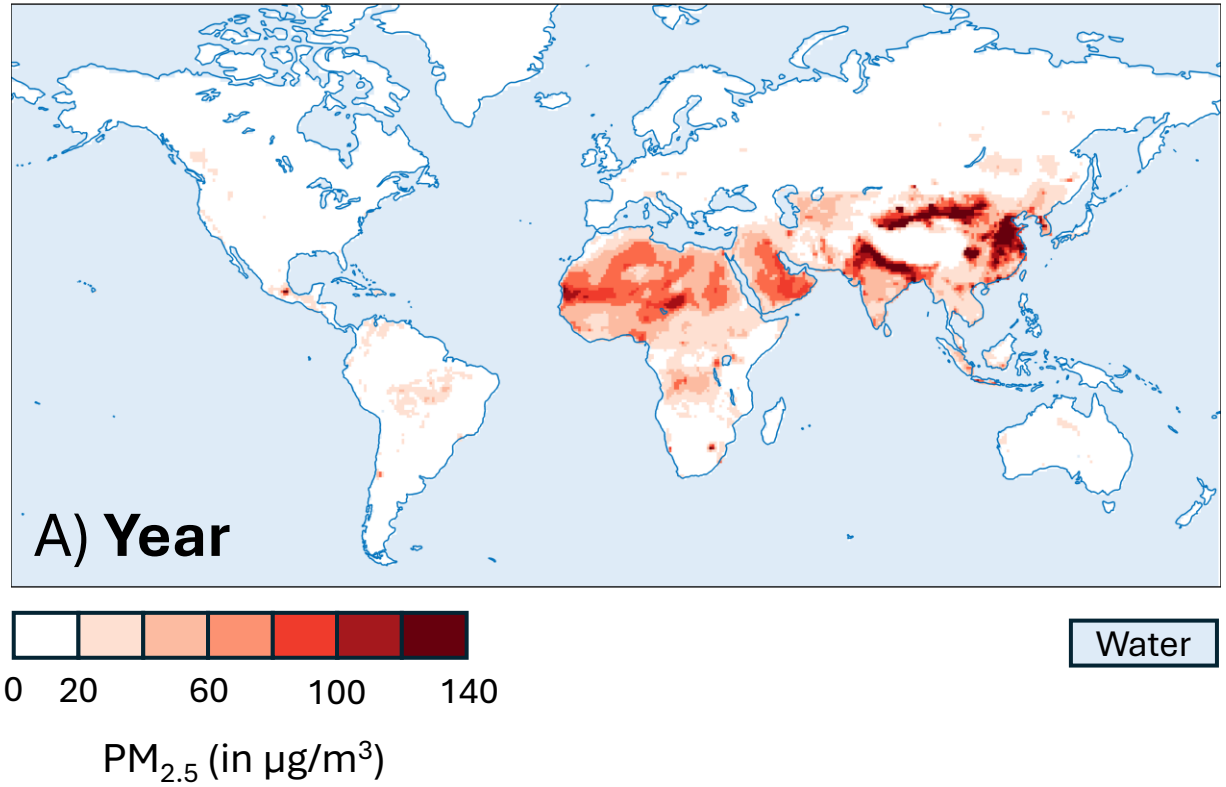
# Impact of H, D, F on P: boreal summer



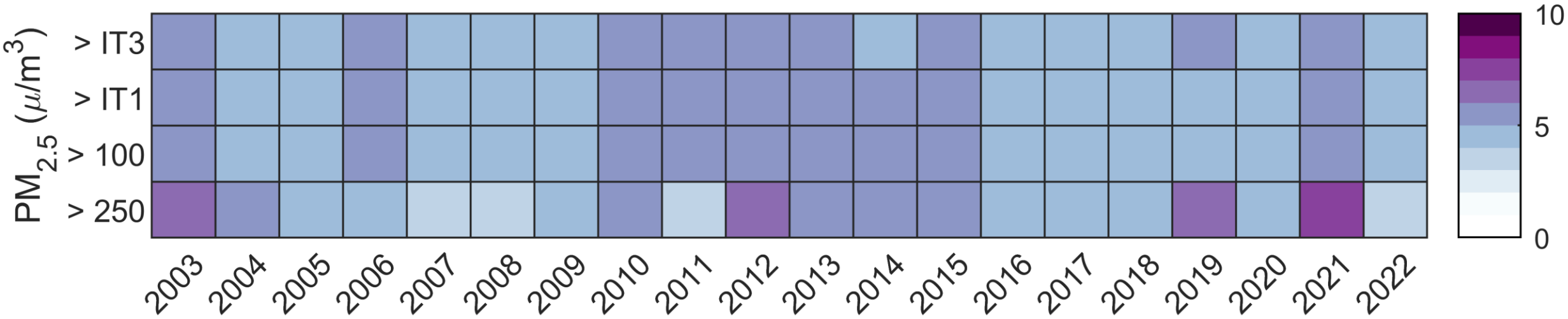
# Results

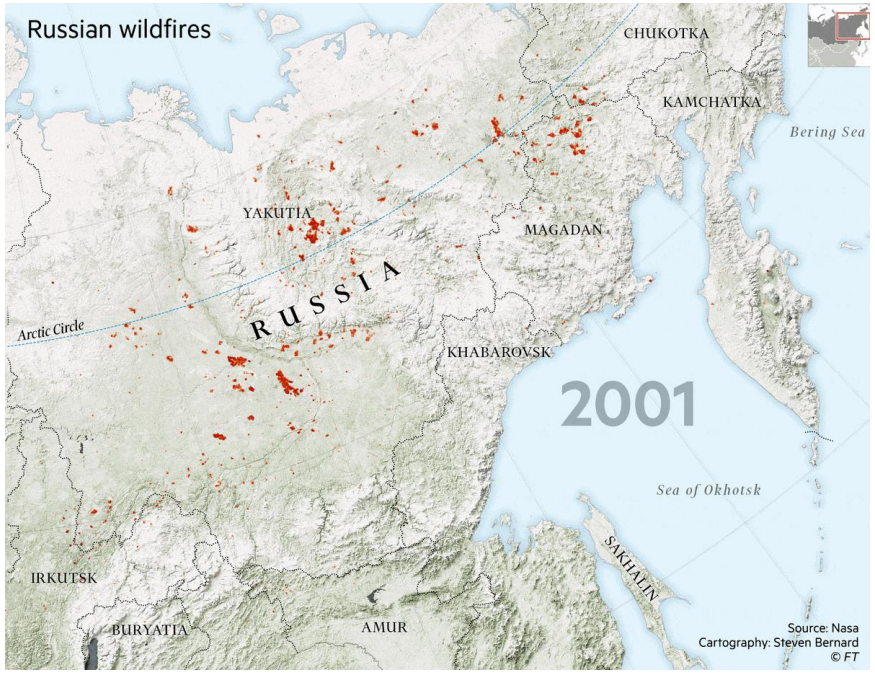
The mystery of N-AM and ASIA

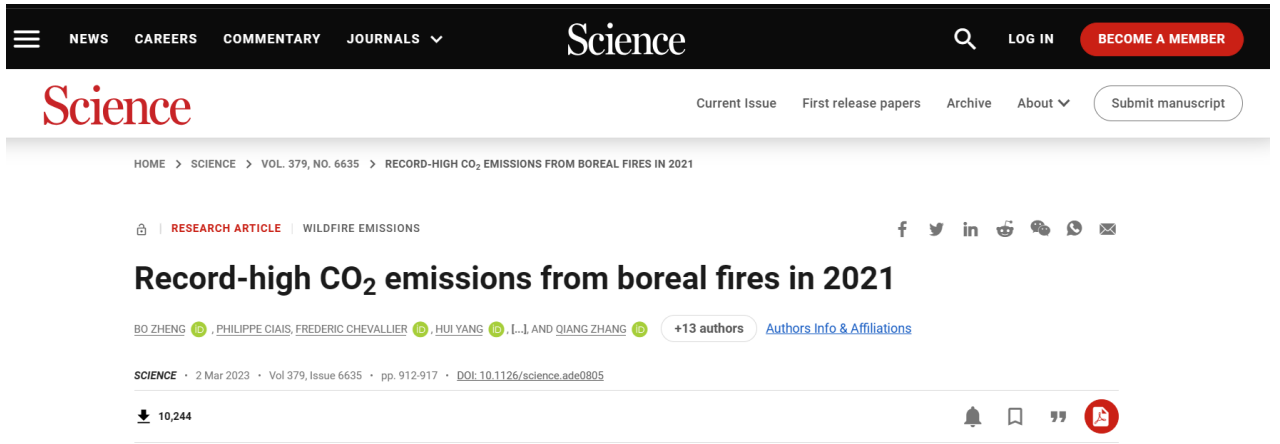
$PM_{2.5}$ 20-year average



# Distribution of the years with grid-cells with PM2.5 above a given threshold



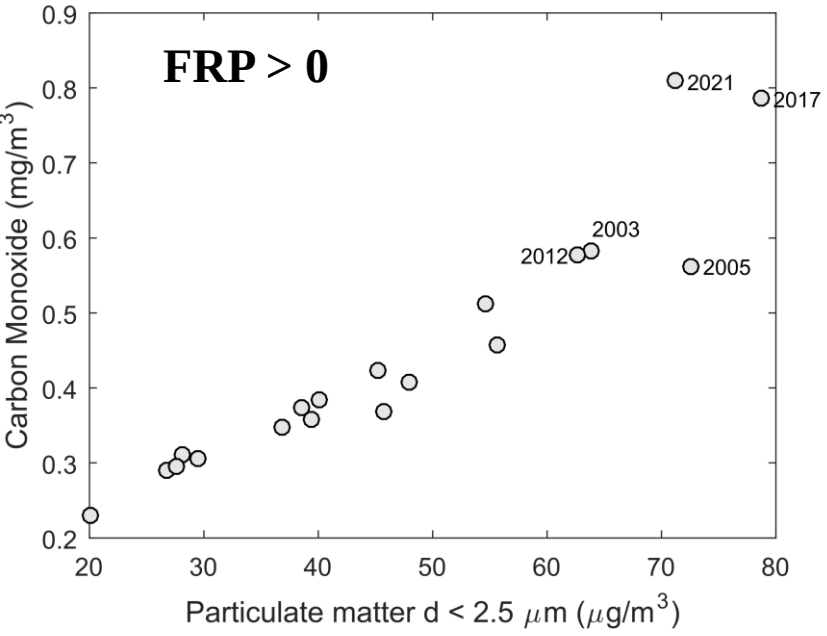



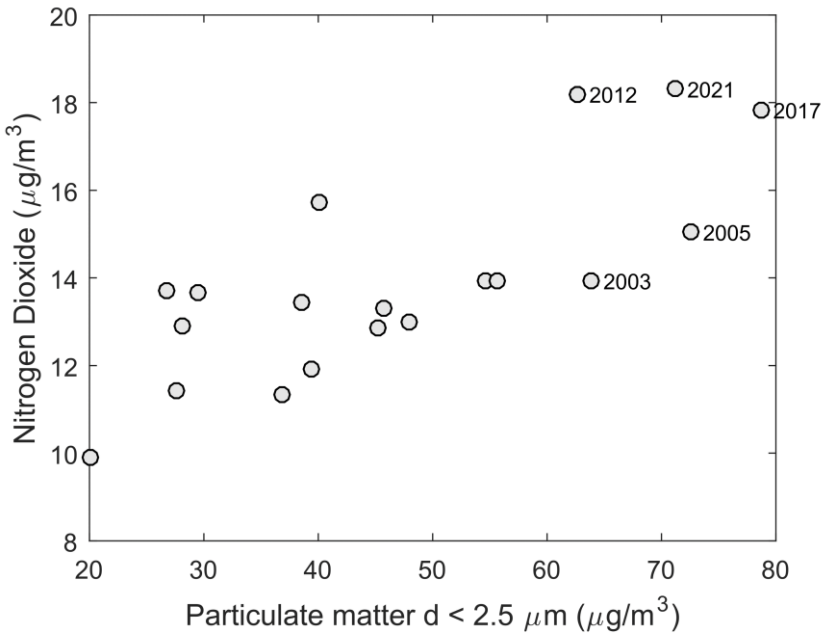



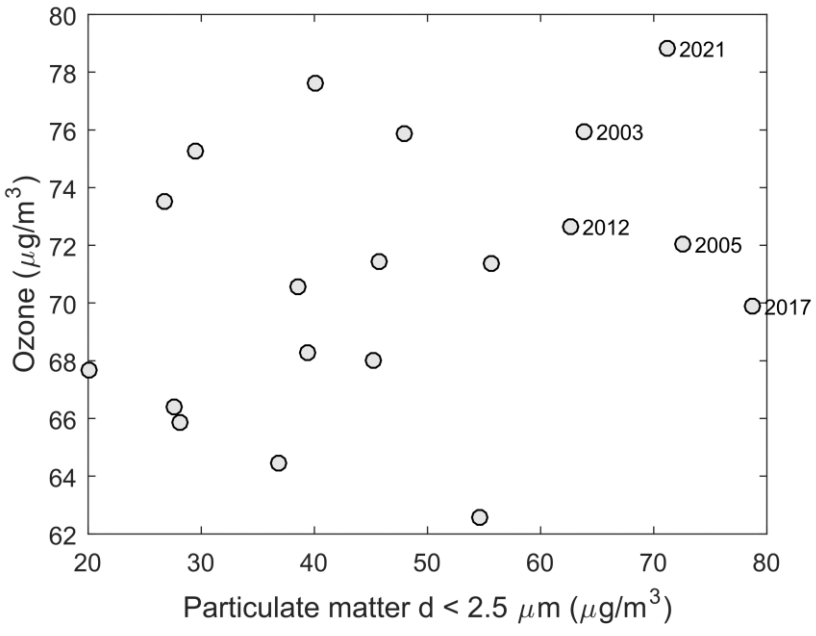
# Where are we going from here?

- ❑ **Paper is being written; first draft almost finished.**
- ❑ **Plume dynamics?**

**2003 – 2021, iberia**



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- ❑ **Risk?**

Risk = Hazard x Exposure x Vulnerability

**Hazard**

| | **1** (slight danger) | **2** (some danger) | **3** (danger) | **4** (great danger) | **5** (extr. danger) |
|---|---|---|---|---|---|
| *NHD* | 0 – p25 | p25 – p50 | p50 – p75 | p75 – p90 | > p90 |
| *SPEI-6* | > 0 | -1 – 0 | -1.5 – -1 | -2 – -1.5 | < -2 |
| *Max. FRP* | = 0 | 0 – p50 | p50 – p75 | p75 – p90 | > p90 |
| *PM2.5 > t1** | - | - | - | - | - |
| *PM2.5 > t2** | - | - | - | - | - |
| *PM2.5 > t3** | - | - | - | - | - |

**Exposure**

| | **1** (slight expo.) | **2** (some expo.) | **3** (exposed) | **4** (great expo.) | **5** (extr. expo.) |
|---|---|---|---|---|---|
| *Pop. density* | 0 – p25 | p25 – p50 | p50 – p75 | p75 – p90 | > p90 |

**Vulnerability**

| | **1** (slight vuln.) | **2** (some vuln.) | **3** (vulnerable) | **4** (great vuln.) | **5** (extr. vuln.) |
|---|---|---|---|---|---|
| *HDI* | 0 – p20 | p20 – p40 | P40 – p60 | p60 – p80 | > p80 |
| *GDP per cap.* | 0 – p20 | p20 – p40 | P40 – p60 | p60 – p80 | > p80 |
| *Total GDP* | 0 – p20 | p20 – p40 | P40 – p60 | p60 – p80 | > p80 |

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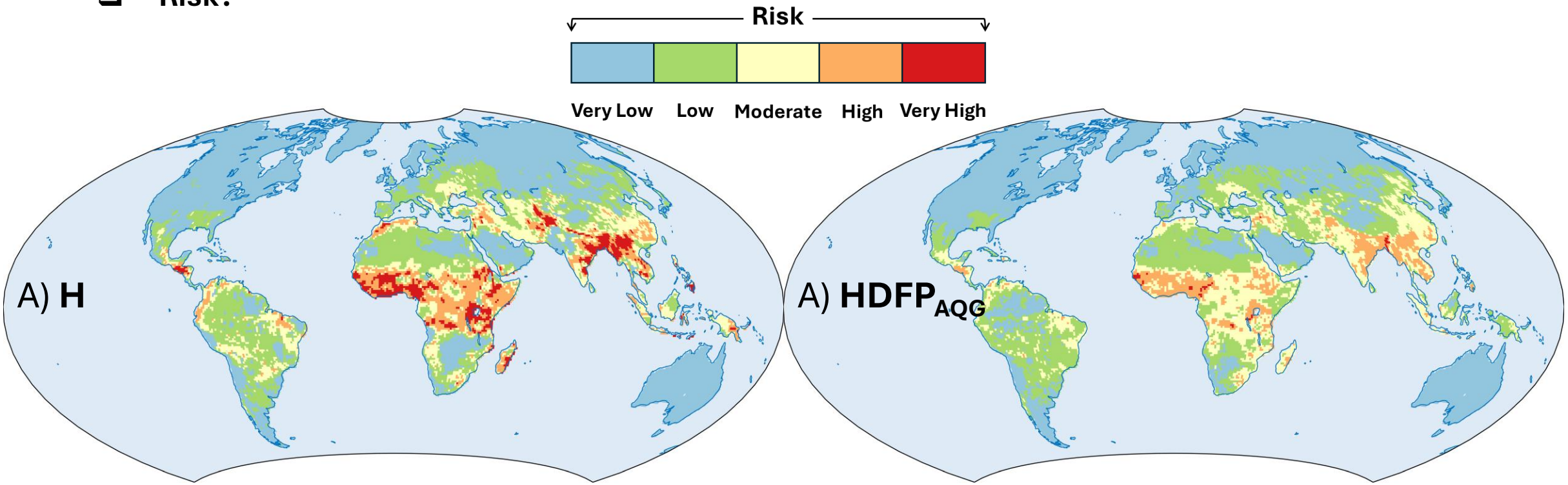

## Main Findings

- ❑ **Hotspot distribution (several key results)**
- ❑ **AFRI and ASIA have larger number of days with compound: particularly PD (ASIA, AFRI), PF (AFRI), and PDF (AFRI)**
- ❑ **Clear impact of HD on F and HDF on P; larger values of FRP on HDF, and larger values of P on PHDF**
- ❑ **EURO pollution substantially increases with PHDF**
- ❑ **N-AM and ASIA pollution due to Boreal Forest Fires**

# Thank you.

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