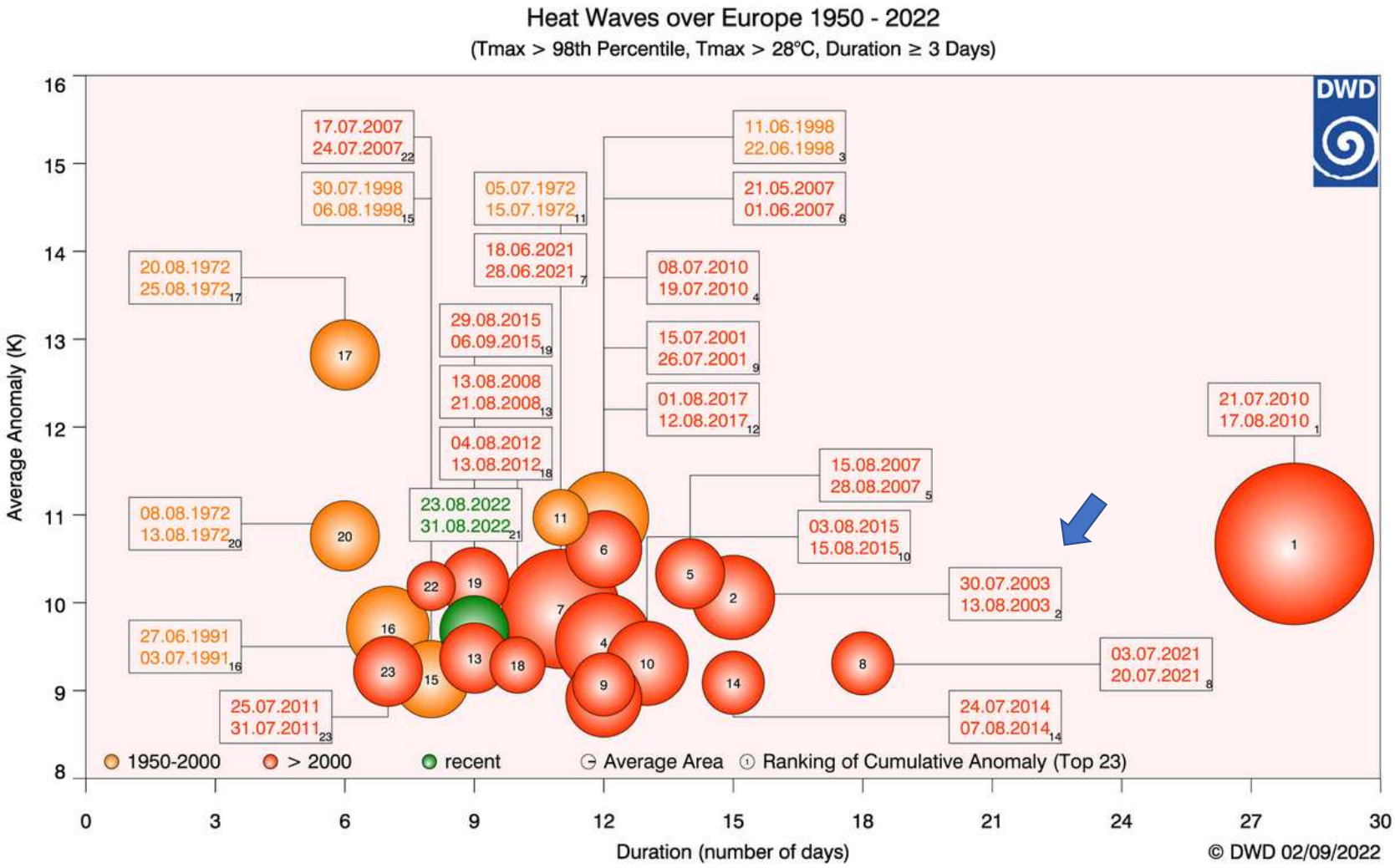
Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

Sources, propagation and sinks of Europe's major heat waves: a complex network analysis of heat extremes

Irene Garcia-Marti
Gerard van der Schrier
Florian Polak

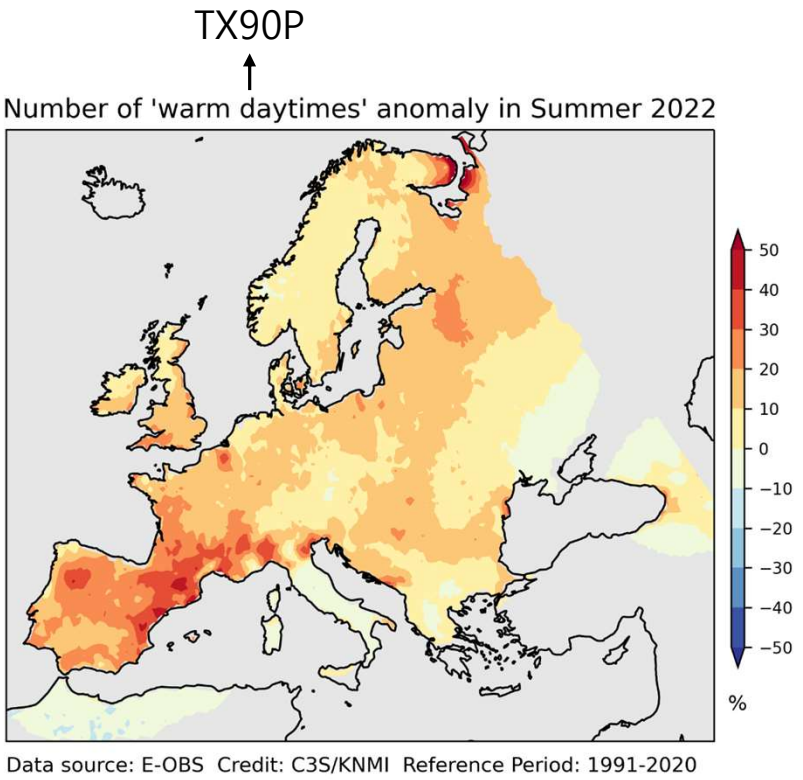
CL2.5 - Extreme Climate Events: Variability, Mechanisms, and Prediction
EGU Annual Meeting

24th April 2023


Heat Waves over Europe 1950 - 2022
(Tmax > 98th Percentile, Tmax > 28°C, Duration ≥ 3 Days)
DWD
Average Anomaly (K)
Duration (number of days)
17.07.2007 24.07.2007 22
30.07.1998 06.08.1998 15
20.08.1972 25.08.1972 17
08.08.1972 13.08.1972 20
27.06.1991 03.07.1991 16
25.07.2011 31.07.2011 23
05.07.1972 15.07.1972 11
18.06.2021 28.06.2021 7
29.08.2015 06.09.2015 19
13.08.2008 21.08.2008 13
04.08.2012 13.08.2012 18
23.08.2022 31.08.2022 21
11.06.1998 22.06.1998 3
21.05.2007 01.06.2007 6
08.07.2010 19.07.2010 4
15.07.2001 26.07.2001 9
01.08.2017 12.08.2017 12
15.08.2007 28.08.2007 5
03.08.2015 15.08.2015 10
30.07.2003 13.08.2003 2
03.07.2021 20.07.2021 8
24.07.2014 07.08.2014 14
21.07.2010 17.08.2010 1
1950-2000
> 2000
recent
Average Area
Ranking of Cumulative Anomaly (Top 23)
© DWD 02/09/2022

Motivation

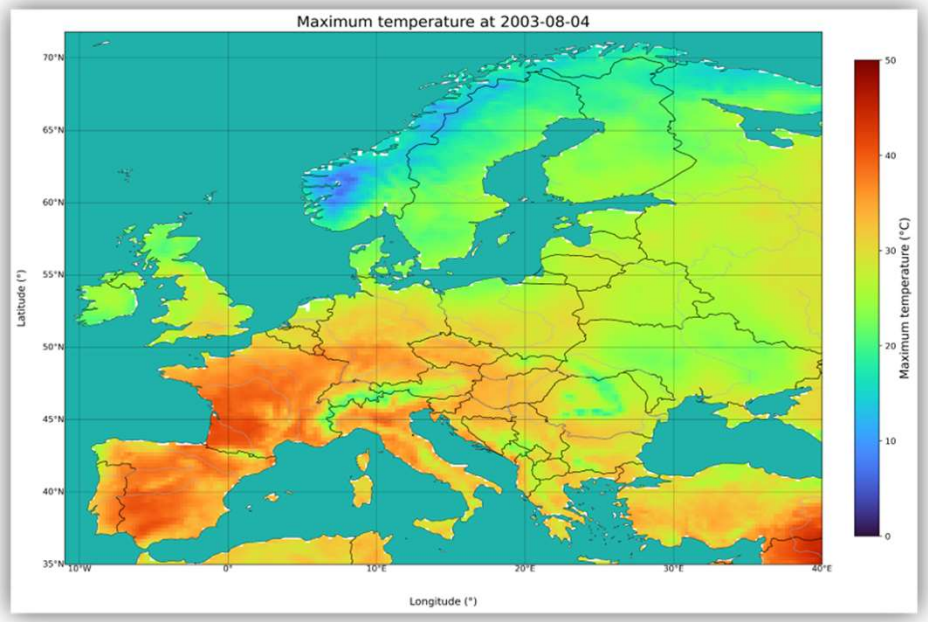
- What are the propagation characteristics of heatwaves?
- Where do heatwaves originate? Where do they wither away?
- What are their preferred paths as they transverse the continent?
- Where are the areas most frequently hit by heatwaves?



State of the Climate bulletin (20/04/23)
https://climate.copernicus.eu/esotc/2022

Data

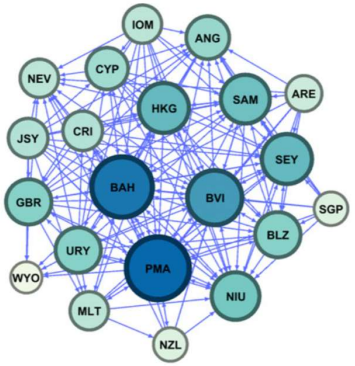
- European Climate Assessment & Dataset project (ECA&D): https://www.ecad.eu/
- E-OBS European gridded daily weather variables
  - Time series: 1950 - today
  - Bonus: 1920 – 1950 available in 'research mode'
  - Variables: TN, TX, RR, PP, FG, HU, QQ
- What do we use in this project?
  - Maximum temperature (TX)
  - Period: 1991 – 2020
  - Spatial resolution: 0.5 deg



Methodology

Two-cents on Complex Networks

- Graph theory, data-driven, used for visualization purposes
- Computationally expensive, hence low-res (i.e. 0.5deg) used in this project
- Common usage in the Social Sciences or Economy to explore relationships and connections
- Reach out for details!



The network structure of global tax evasion evidence from the Panama papers ☆

Garcia Alvarado Fernando [a] ✉, Mandel Antoine [b] 👤 ✉

E-OBS tmax (1991-2020, summer)

Part of heatwave?

- What is our **event**? **TX90p**
- Defined by WMO ETCCDI

Calculate Event Synchronization

- Calculates strength, delay, and adjacency matrices

Modelling with complex networks

- Computes coefficients depicting movement characteristics of heatwaves

Visualization

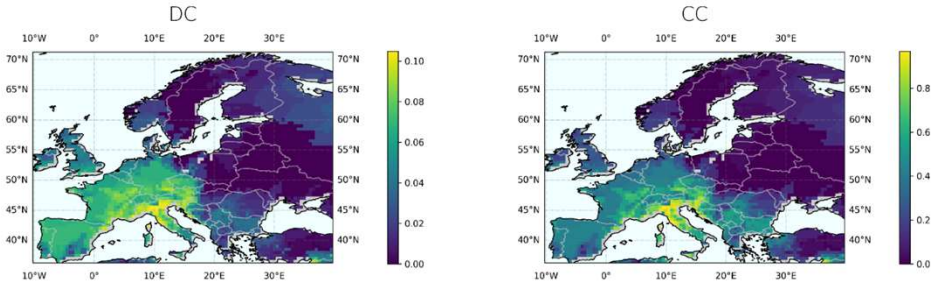
- Turn network output into maps
- Calculate summary statistics

Let's explore the heatwave of 2003!

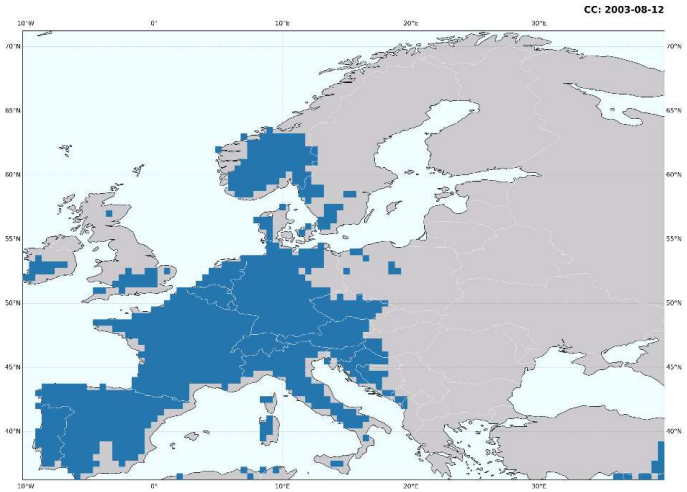
Results

- Dates: Jul 28th to Aug 18th, 2003
- Note: This is the **movement** of the heat!
- Network coefficients:
  - Degree of centrality: **spread** of heatwave
  - Clustering coefficient: **core** of heatwave

Heatwave 2003 (Aug)



monthly means



daily exploration of coefficients

Results

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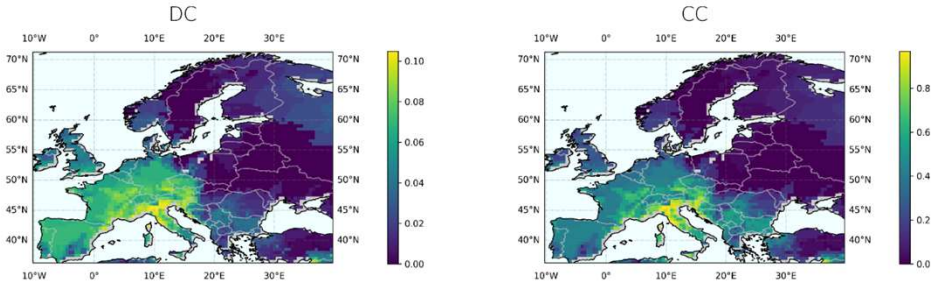
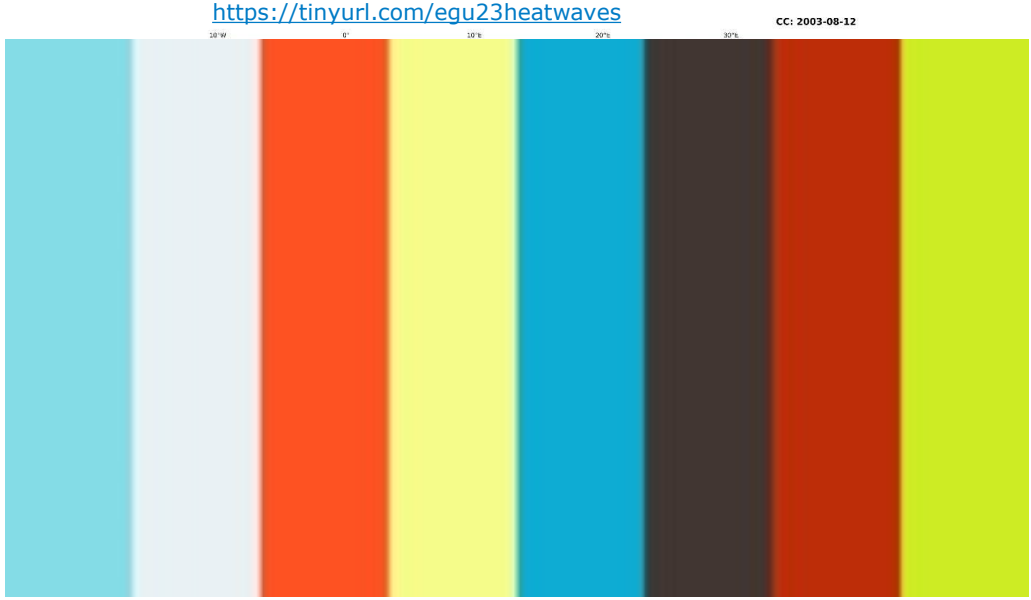
Heatwave 2003 (Aug)



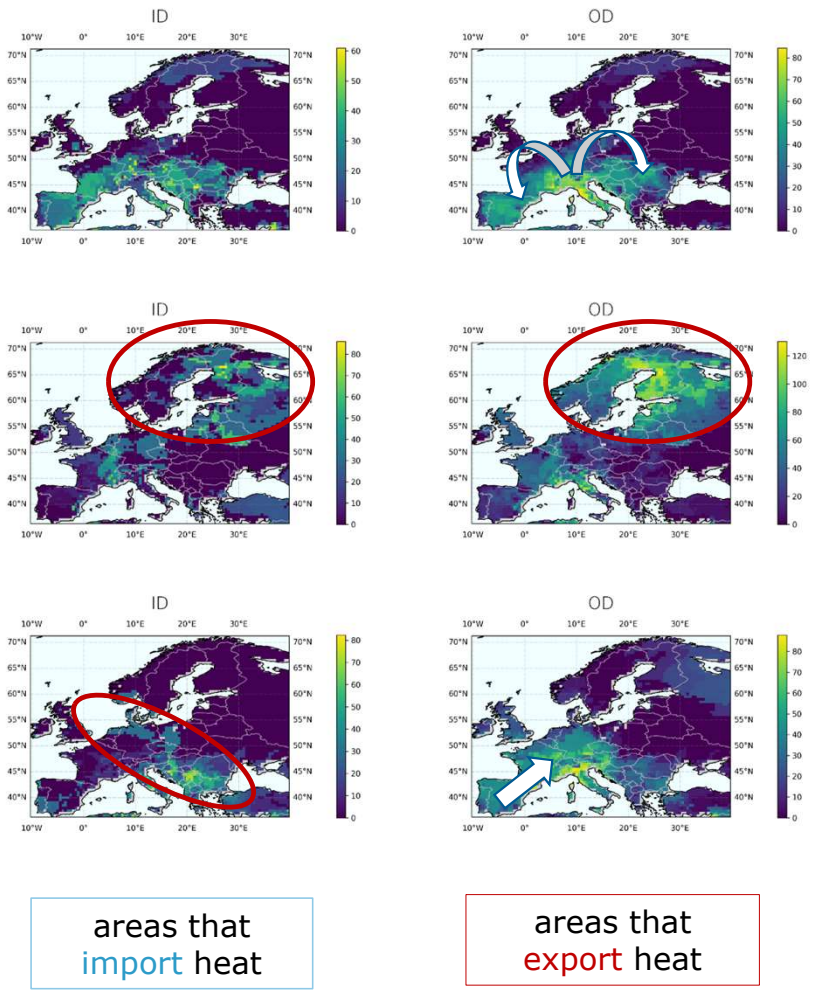
Video available at:
https://tinyurl.com/egu23heatwaves



Results

- Network coefficients:
  - Input degree: number of **inward** connections
  - Output degree: number of **outward** connections
- Highlights:
  - **Jun:** warm spell originates in north Italy/SE France and spreads to Balkan and Iberia
  - **Jul:** warm spell in Scandinavian countries – and heatwave stays there
  - **Aug:** heat develops in Iberia and spreads over the continent, to Denmark, Central Europe & Balkan

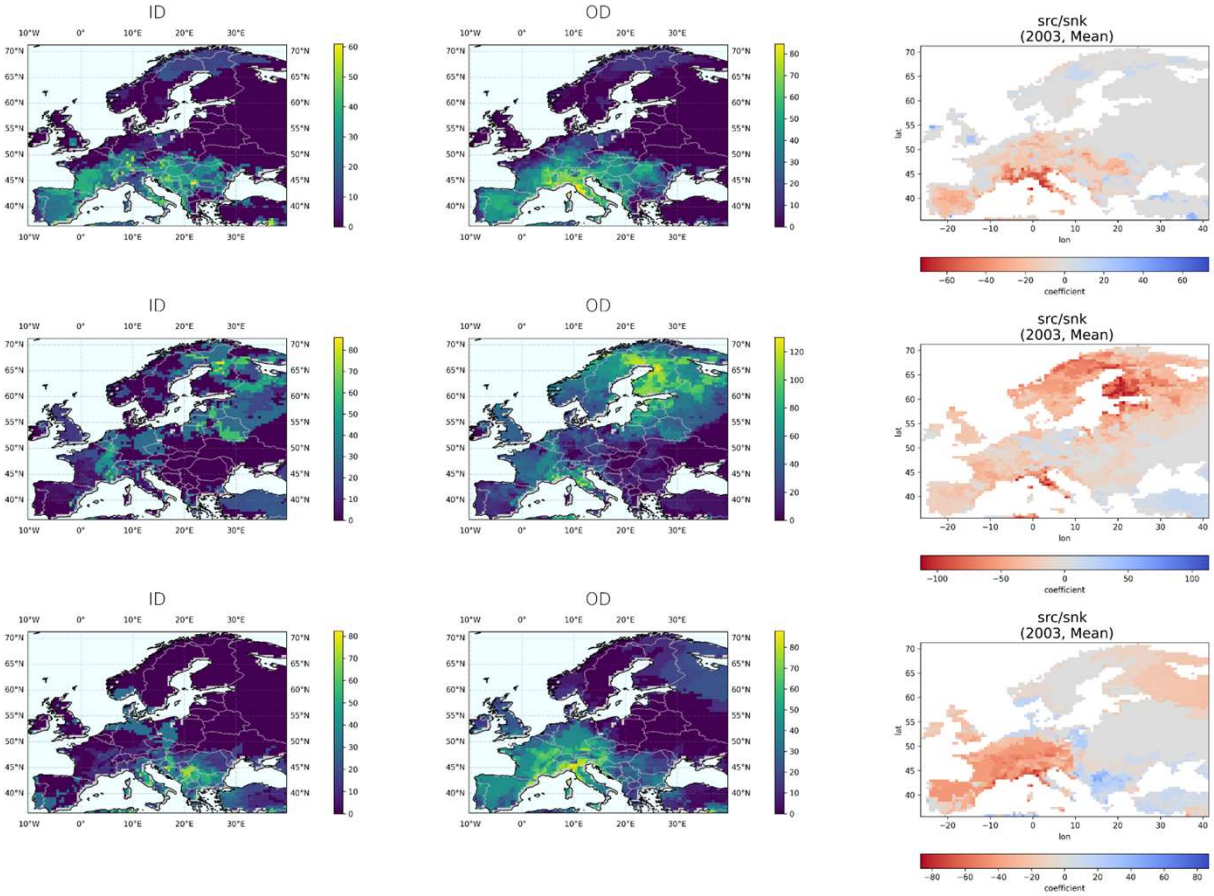
Heatwave 2003



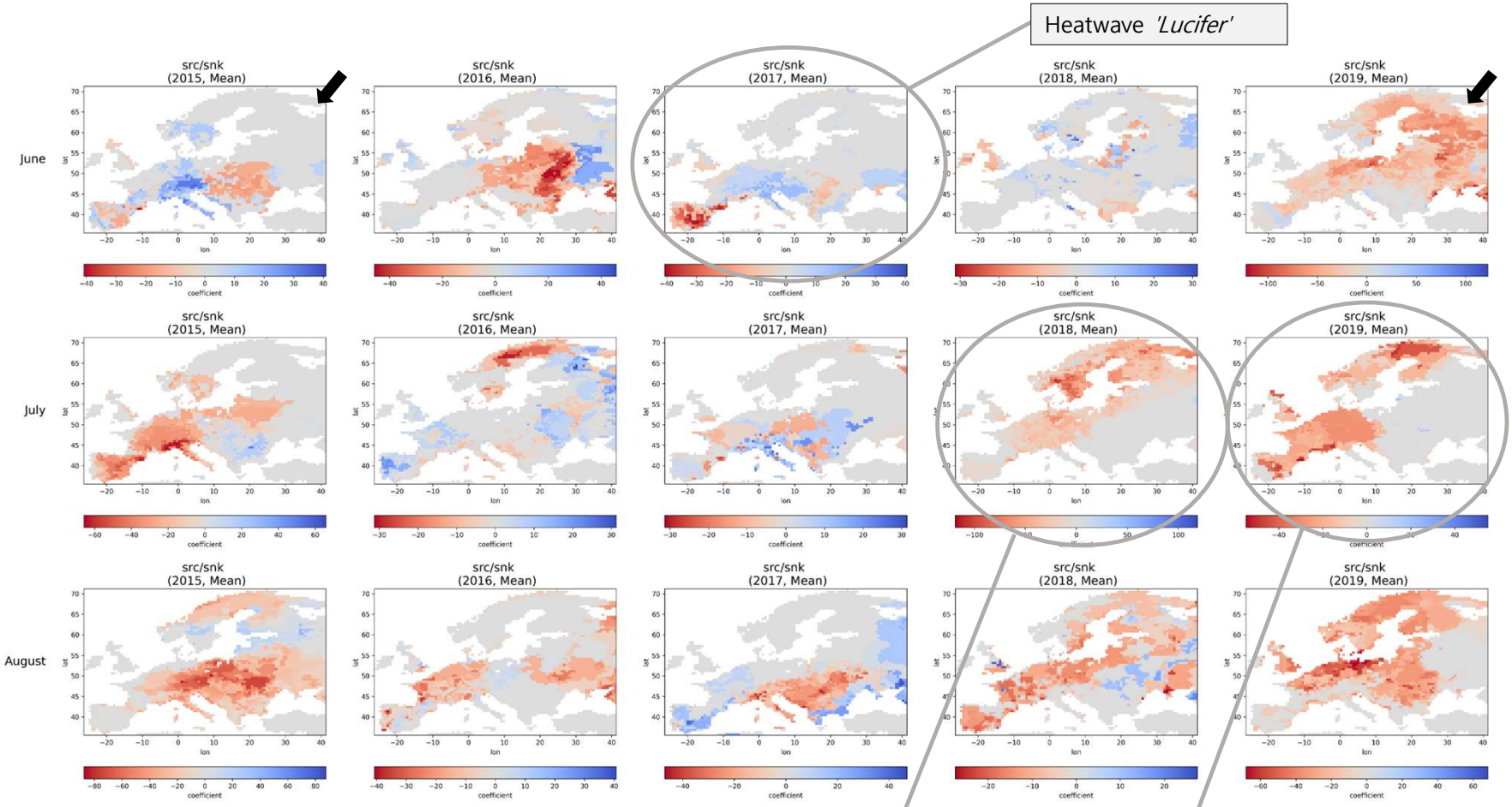
Results

- Moving towards identifying **sources** and **sinks** of heat
  - **Subtracting** input degree and output degree allows a combined view of the heatwave movement

Heatwave 2003 – Sources and Sinks



Heatwaves 2015-2019 – Sources and Sinks



~~Conclusions~~

Challenges ahead

Data technology

Team-up with developers!

- Speed-up computations: parallelization, refactoring
- Create a new higher-resolution product

Scientific

Climatology of the dynamic of heatwaves

Identifying the various types of heatwaves

Social alignment

Issuing weather warnings tailored to regions:

- Improves social preparedness, guide decision-making process
- Increases response capacity when heatwaves hit a region

Thanks! ☺

Feel free to contact:

garciamarti@knmi.nl

@igarciamarti