User-friendly atmospheric blocking detection algorithm helps identification of extreme events

Dhefeus & AIClimate@EU 1st workshop

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Miguel M. Lima

Sousa, P. M, Fuentes-Alvarez, T., Ordoñez, C., García-Herrera, R., Barriopedro, D., Soares, P. M., Trigo, R. M.

Extreme weather events are among the deadliest and costliest natural hazards...

Southern Europe 2022 drought, Galicia, Spain. Source: NBC news

Extreme weather events are among the deadliest and costliest natural hazards…

Temperature and ***hydrological*** extremes are the most impactful continent-wide, with wind- and snow-storms substantially affecting focused regions…

First snow in Rome in 26 years (2012). Source: CNN World

What do these example have in common?

Large-scale dynamic patterns were the main drivers for the prolonged intensity of these events. How so...?

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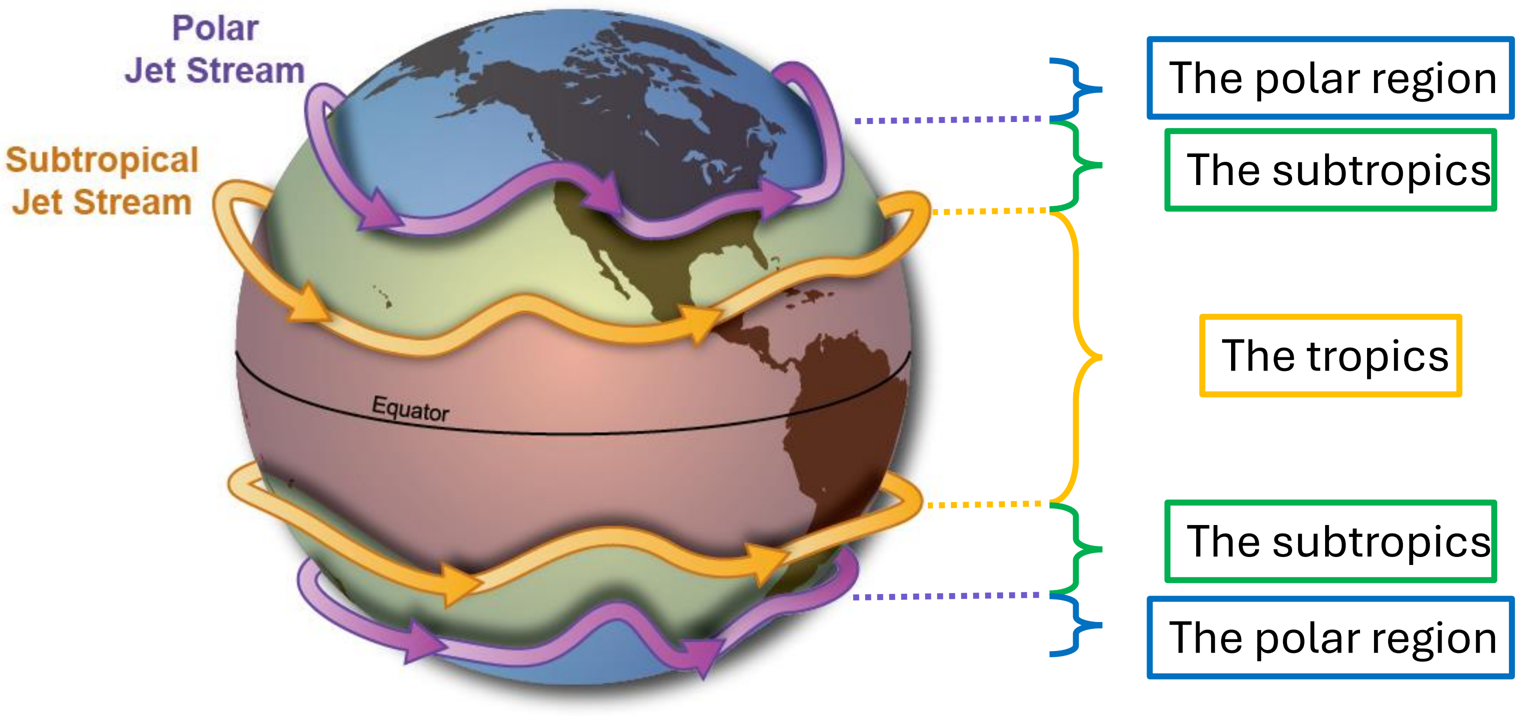
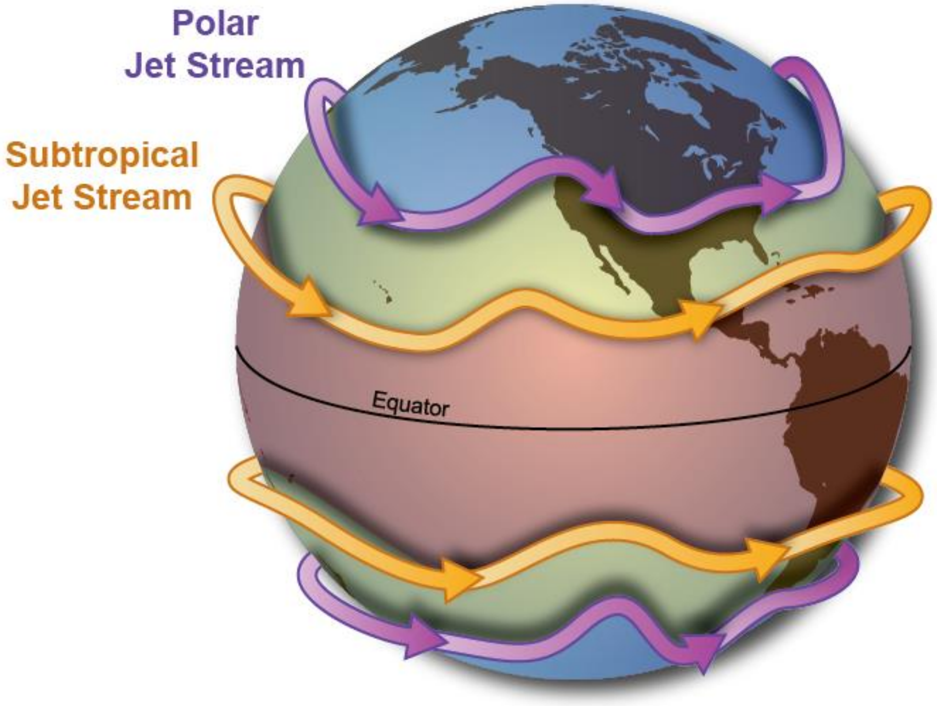
The global circulation can be divided in 3 major latitudinal areas:

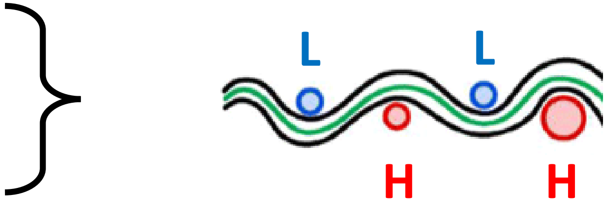


Marking the division between these latitudes, major <u>jet streams</u> are present: The **subtropical** and **polar** jet streams.

Large-scale dynamic patterns were the main drivers for the prolonged intensity of these events. How so…?

These jets can remain stable, modulated by low- and high-pressure systems:

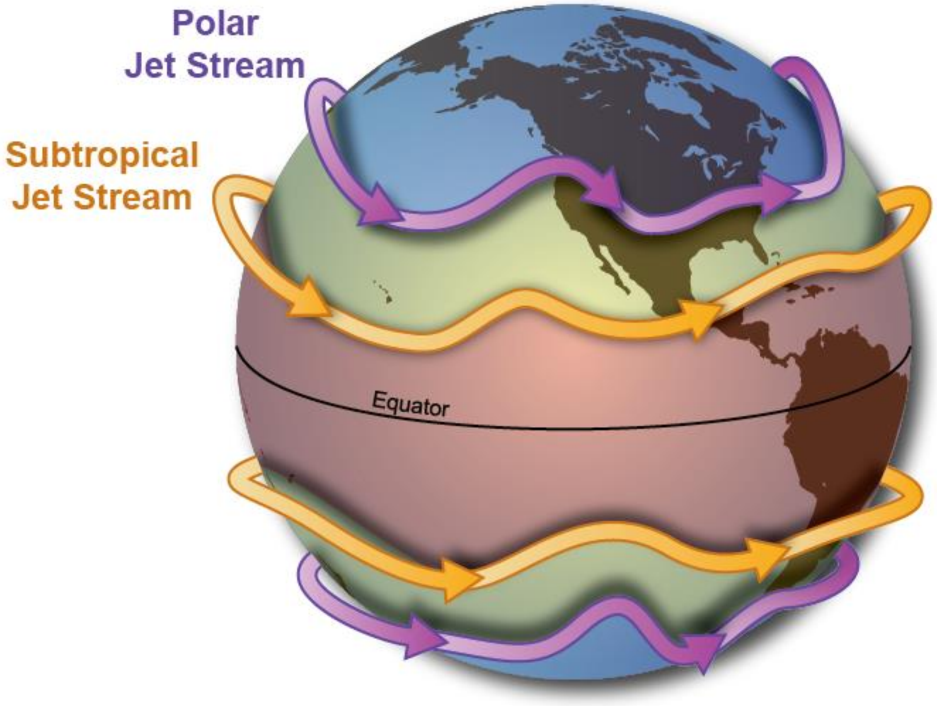


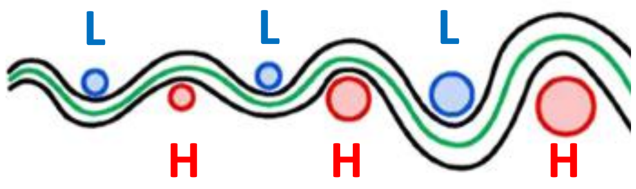


Low pressure: **L**
High pressure: **H**

Large-scale dynamic patterns were the main drivers for the prolonged intensity of these events. How so...?

Often, they are disturbed by these systems or other factors, increasing the instability:

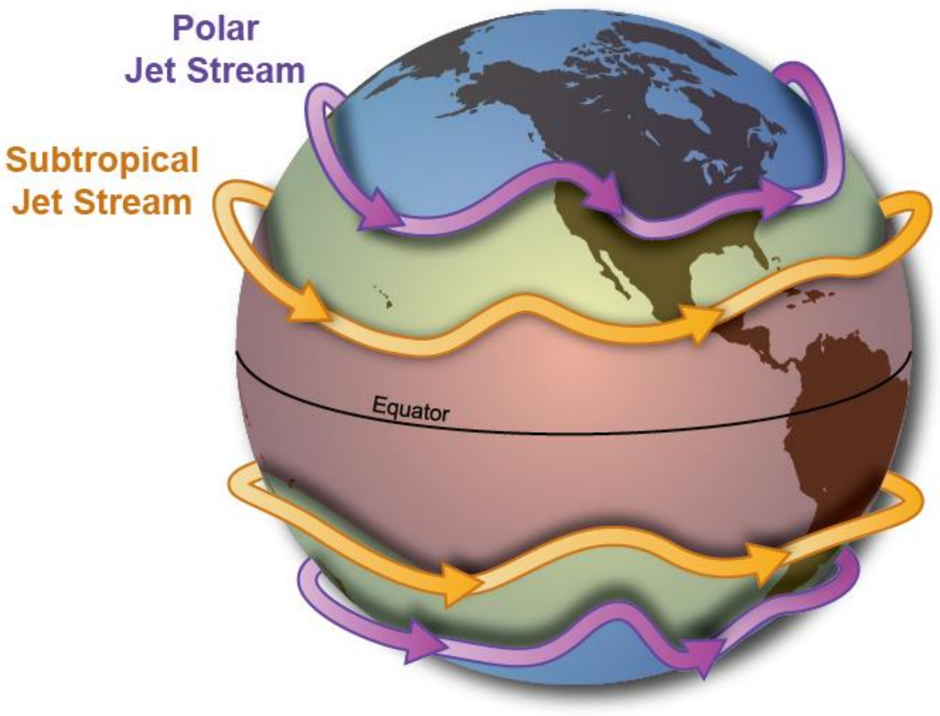


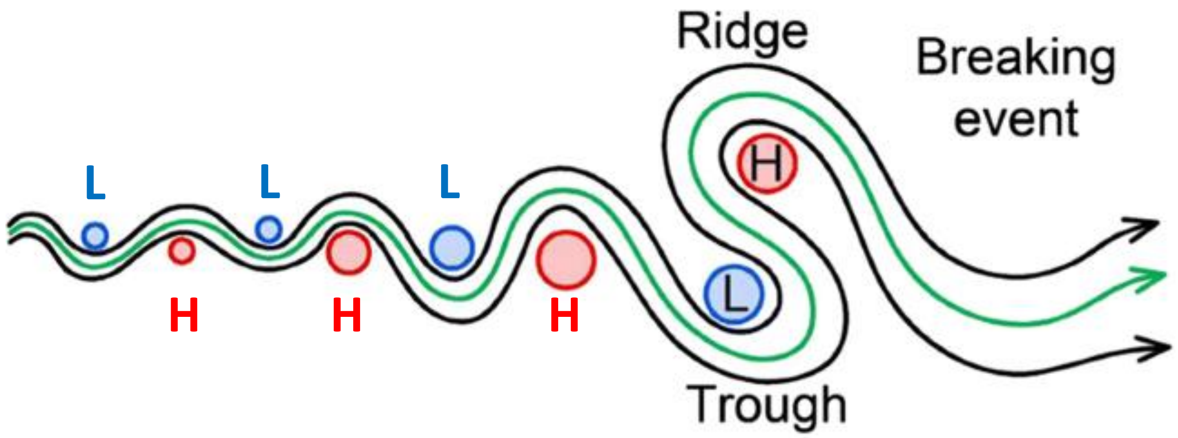


Low pressure: L
High pressure: H

Large-scale dynamic patterns were the main drivers for the prolonged intensity of these events. How so…?

These instabilities can create wave breaking events, leaving large systems:

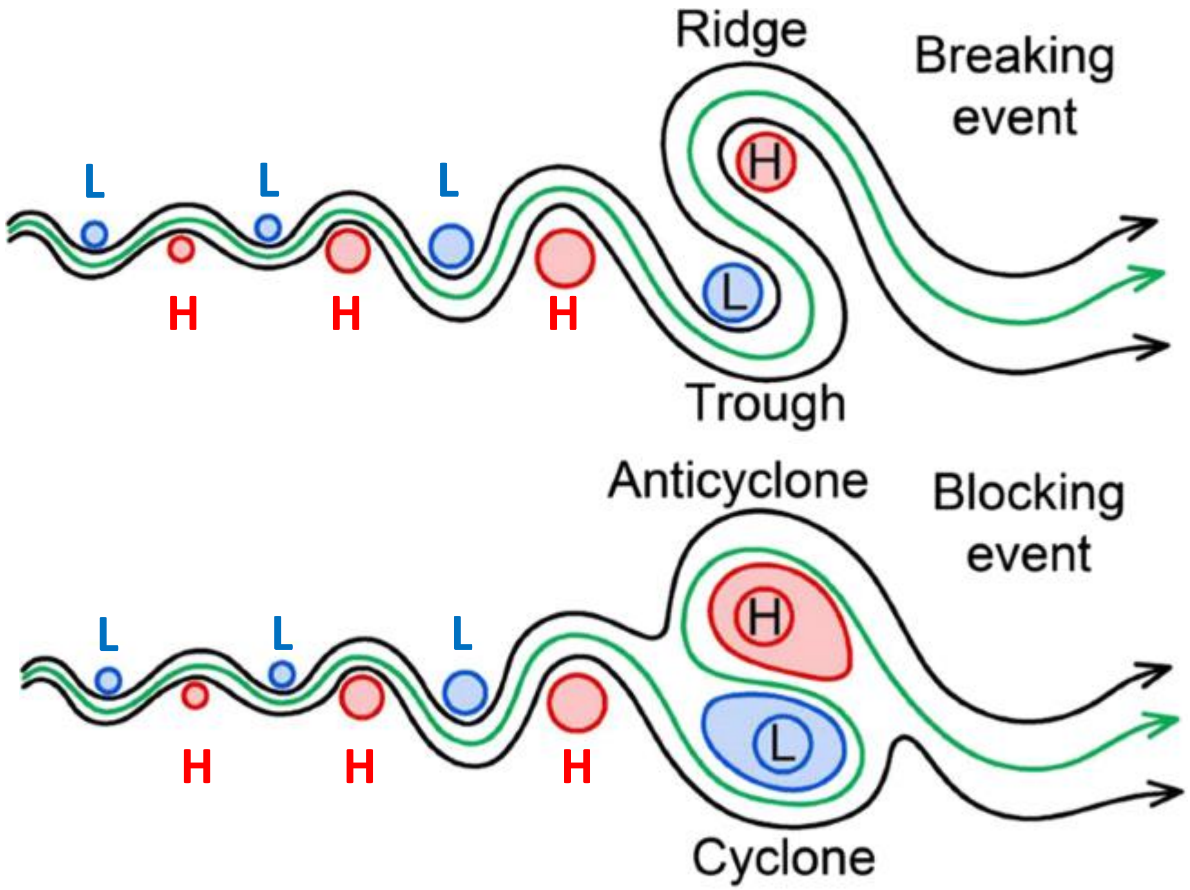




Low pressure: L
High pressure: H

Large-scale dynamic patterns were the main drivers for the prolonged intensity of these events. How so…?

These systems can form in different morphologies and affect areas the size of a continent:



Low pressure: L
High pressure: H

Large-scale dynamic patterns were the main drivers for the prolonged intensity of these events. How so...?

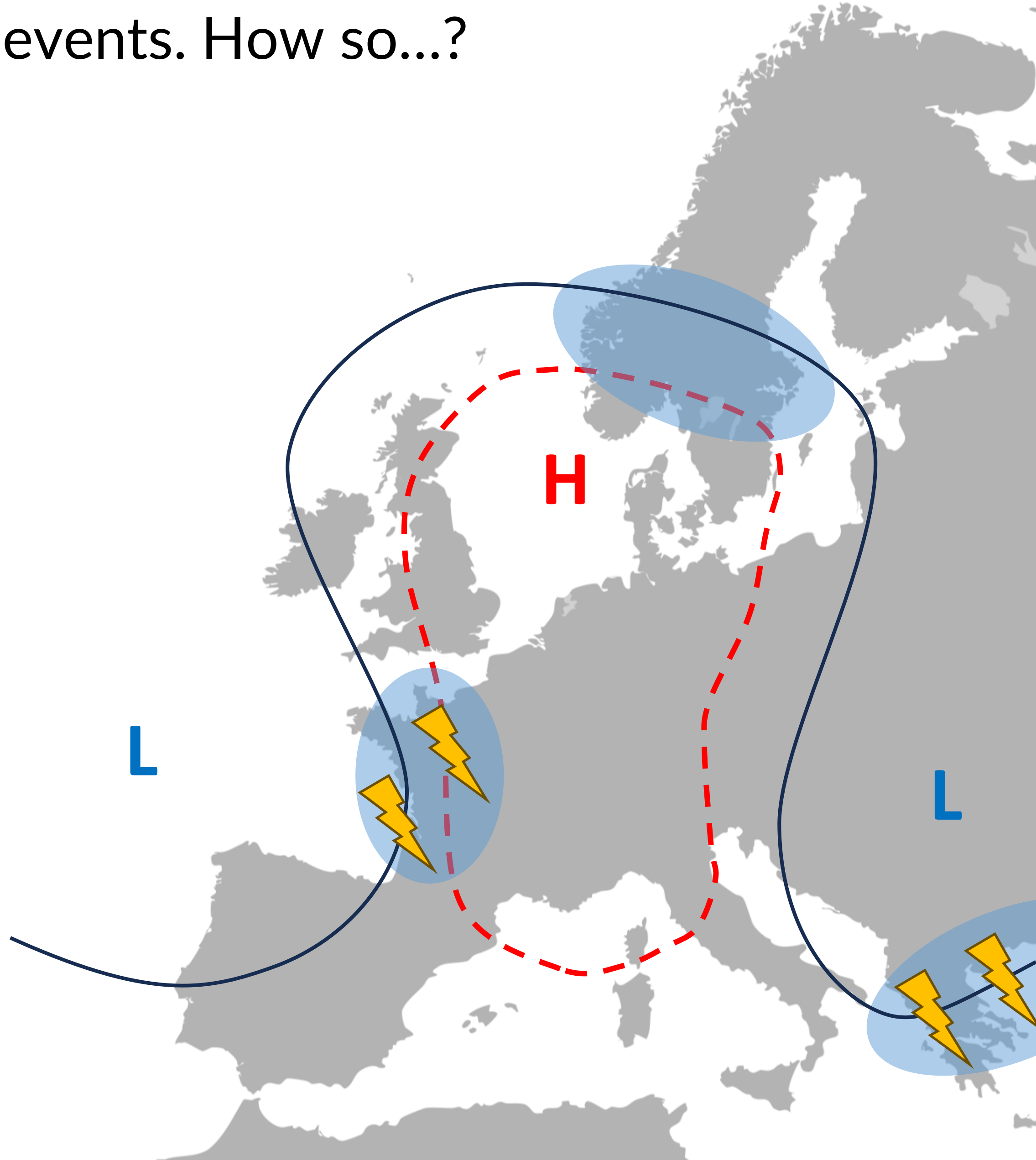
Surface impacts can be varied, including weather extremes:

Warm season

Heat

Heavy precipitation

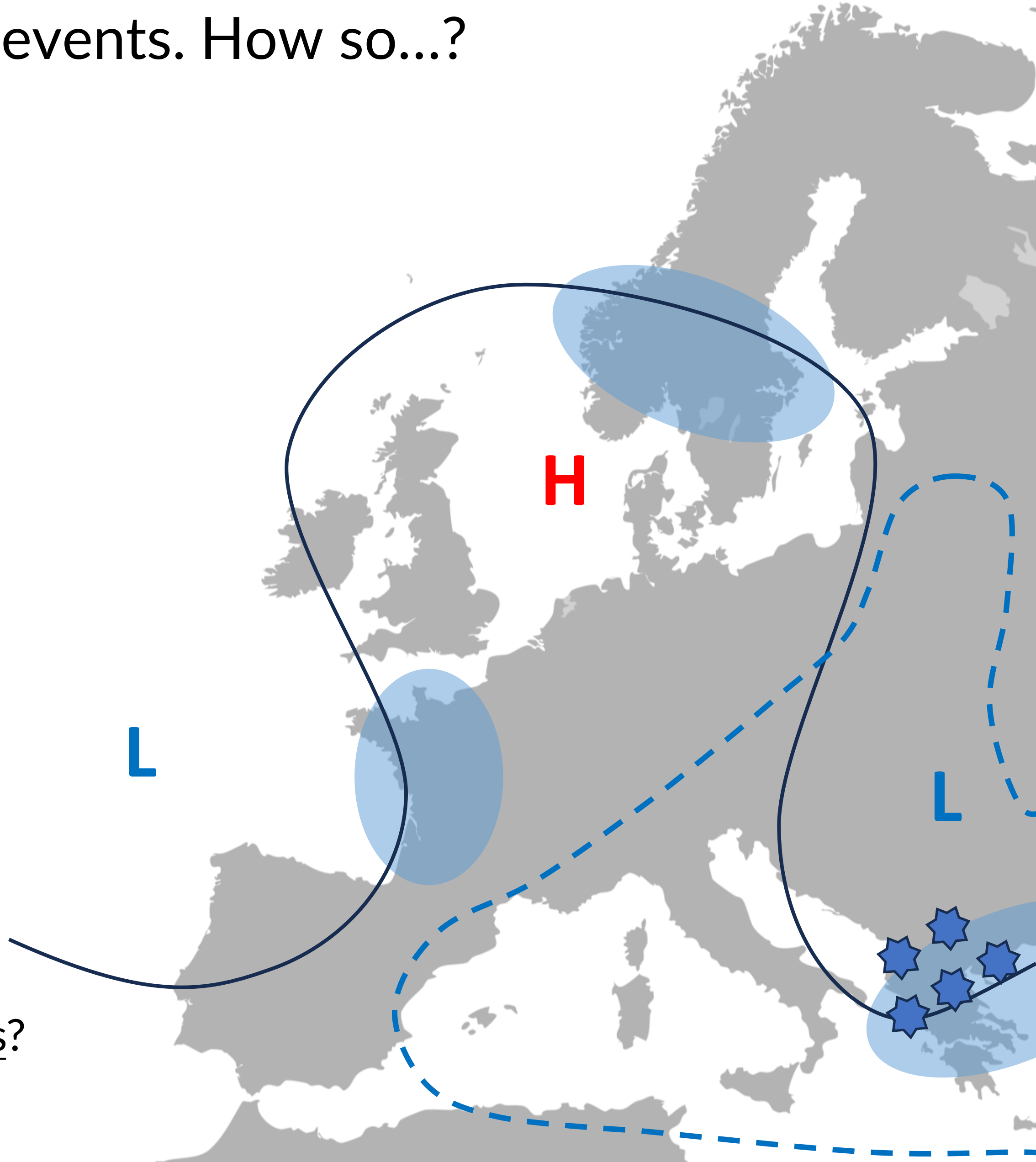
Thunderstorms



Large-scale dynamic patterns were the main drivers for the prolonged intensity of these events. How so...?

Surface impacts can be varied, including weather extremes:

Warm season	Cold season
Heat	Cold
Heavy precipitation	Heavy precipitation
Thunderstorms	Snowstorms



This leaves the question; <u>How can we identify these blockings</u>?

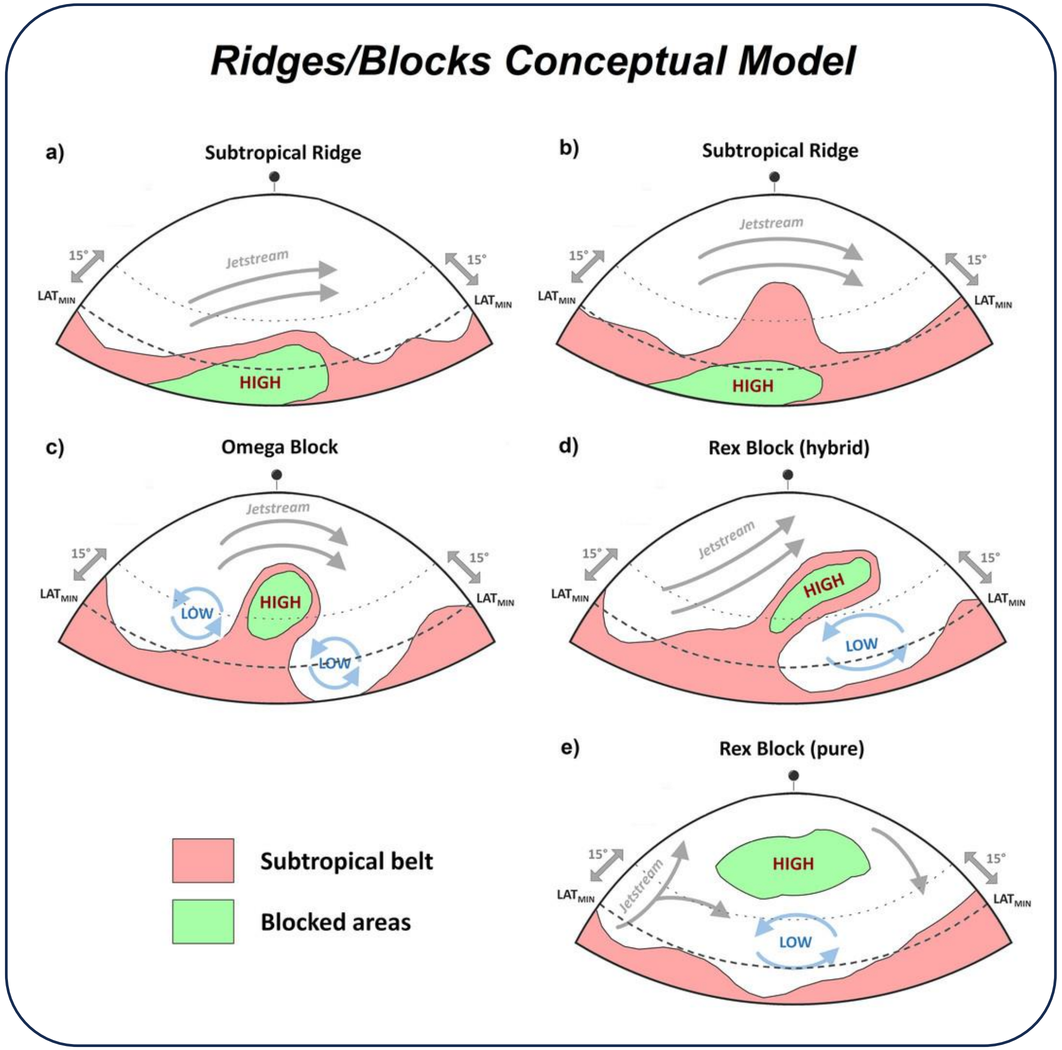
Identification methods: Sousa et al. (2021)

A New Combined Detection Algorithm for Blocking and Subtropical Ridges

PEDRO M. SOUSA,[a,b] DAVID BARRIOPEDRO,[c] RICARDO GARCÍA-HERRERA,[c,d] TIM WOOLLINGS,[e] RICARDO M. TRIGO[a,f]

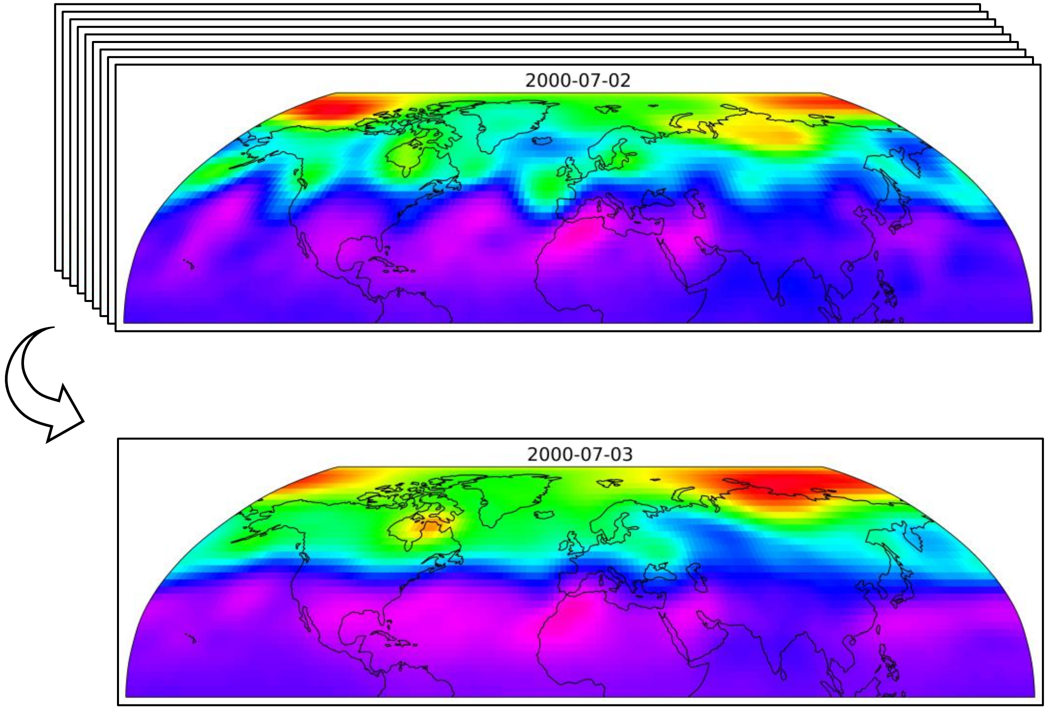
[a] *Instituto Dom Luiz, Faculdade de Ciências, Universidade de Lisboa, Portugal*
[b] *Instituto Português do Mar e da Atmosfera (IPMA), Lisboa, Portugal*
[c] *Instituto de Geociencias, IGEO (CSIC-UCM), Madrid, Spain*
[d] *Departamento de Física de la Tierra y Astrofísica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid (UCM), Madrid, Spain*
[e] *Department of Physics, Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom*
[f] *Departamento de Meteorologia, Instituto de Geociências, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil*

- Z500 gradient methodology;
- Tracks event life-cycle;
- Assimilates low-latitude flow obstructions;
- Can differentiate between different types.

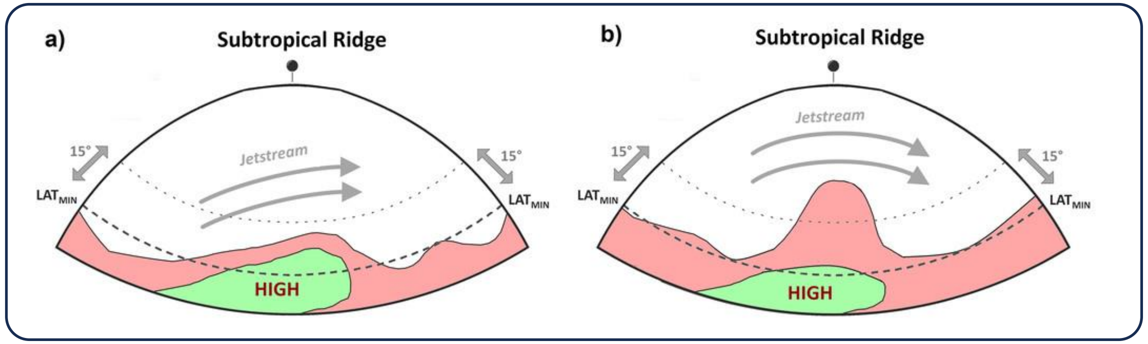


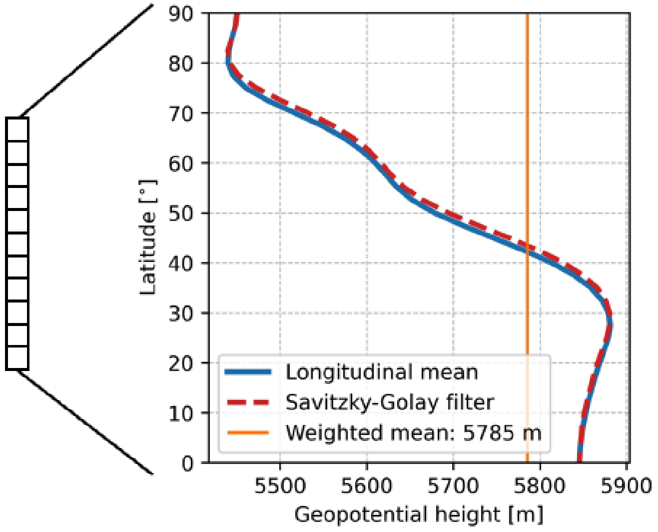
Algorithm overview: Subtropical ridges

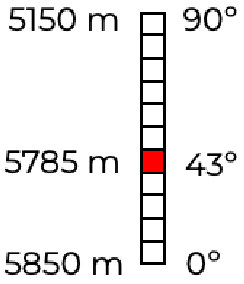
Day N-15 ⇢ Day N-1



Field mean of 15 days before: $\overline{[Z500]}$

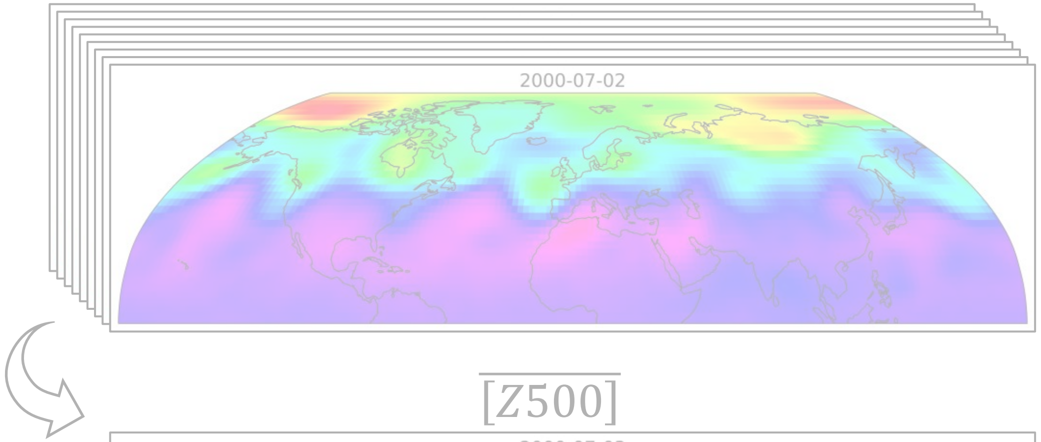




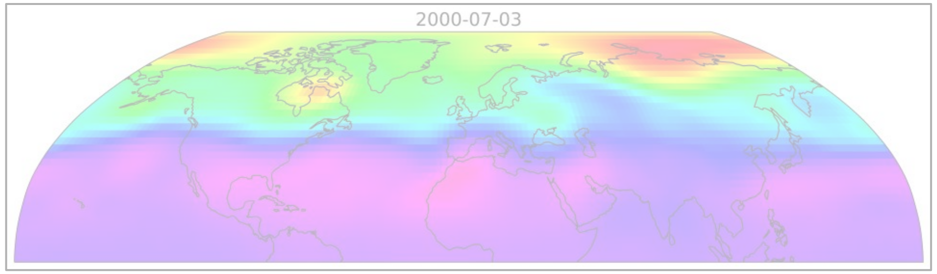


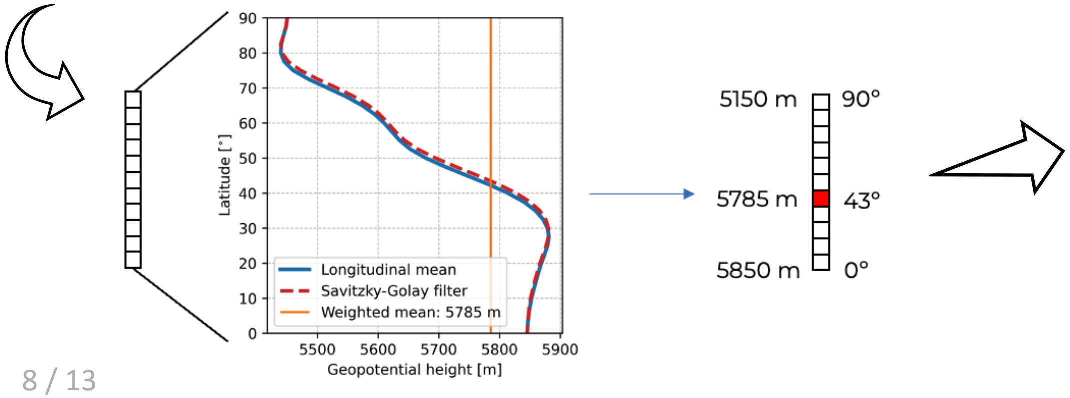
Algorithm overview: Subtropical ridges

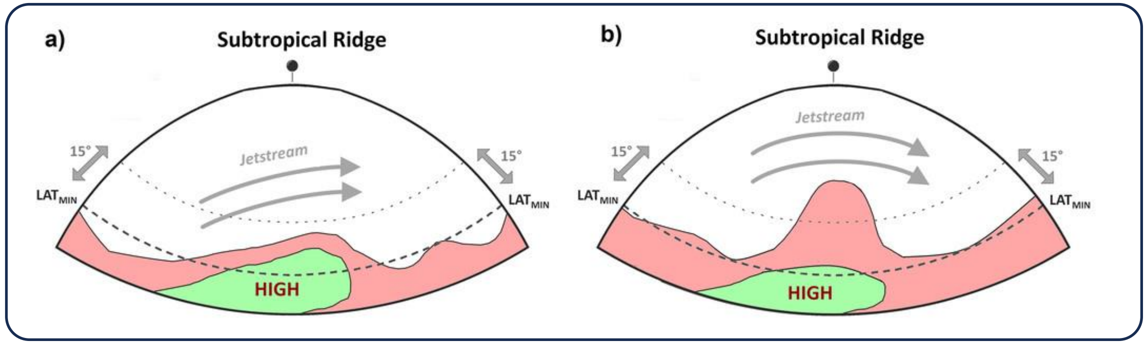
Day N-15 ⇢ Day N-1



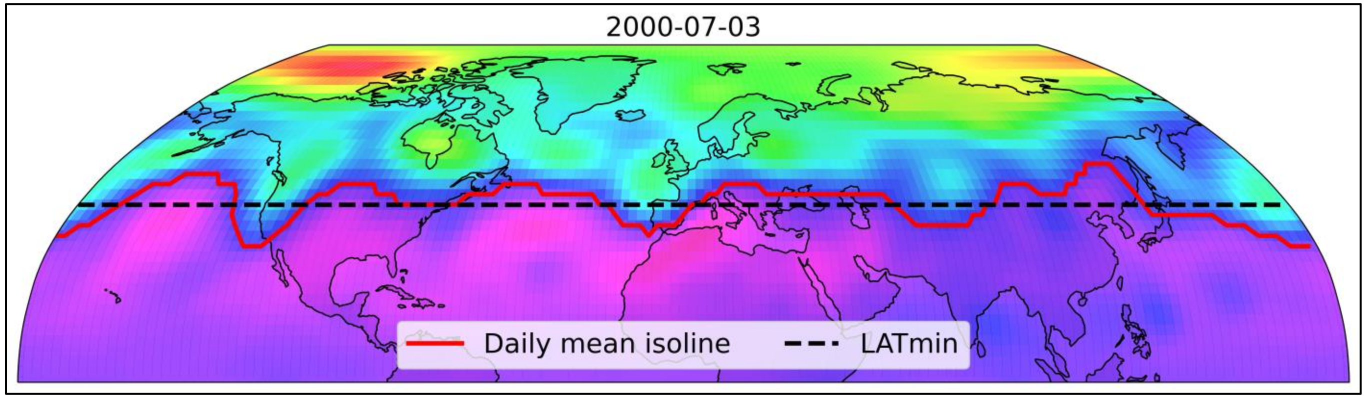
$\overline{[Z500]}$





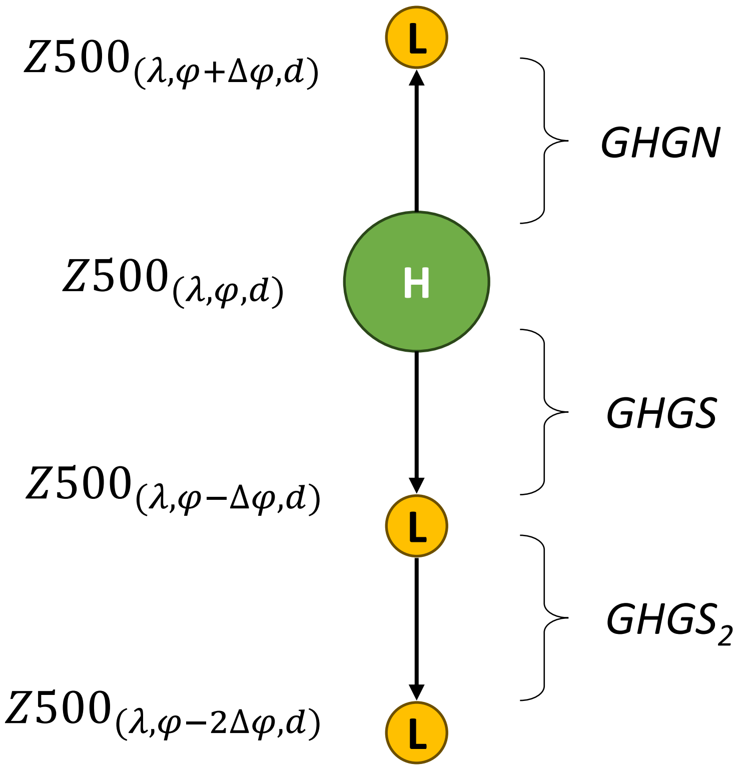


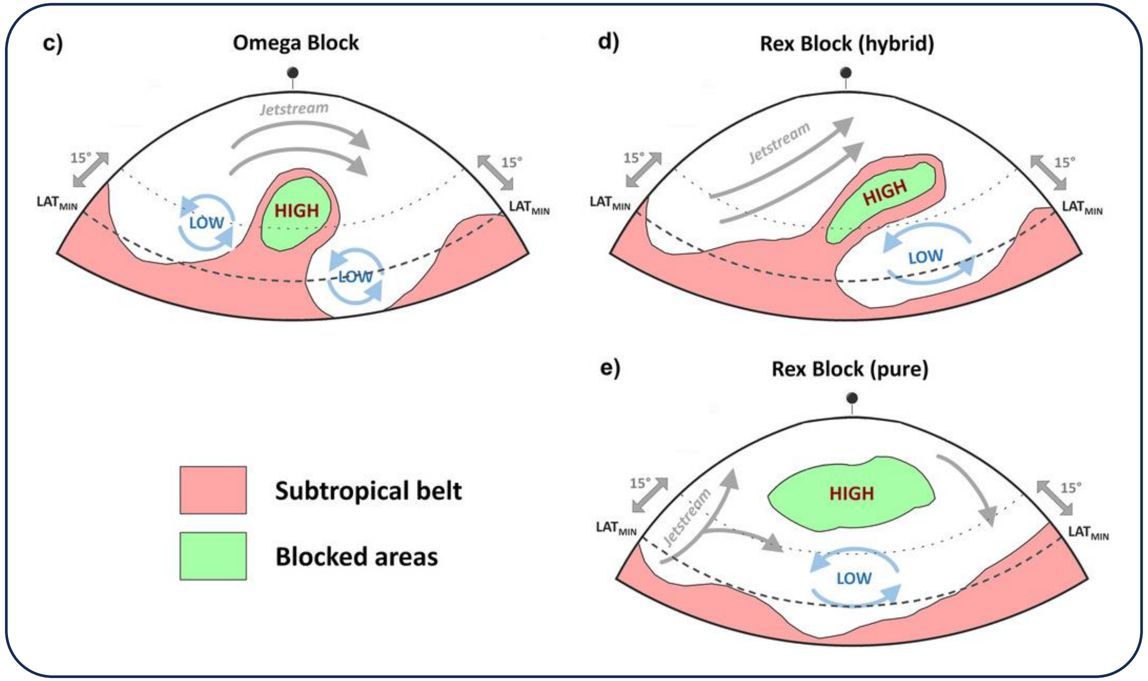
Subtropical ridges are the areas the isoline exceeds the LATmin



Algorithm overview: Z500 gradients

Modified ***Tibaldi-Molteni*** *index:*





- A point is considered blocked if its meridional flanks have lower Z500.
- It can be considered Omega if the southern flank has a weak Z500 gradient.

From algorithm to software: BLOCS

Available on GitHub!

Also scannable on poster outside.

BLOCS

Blocking Location and Obstruction Cataloguing System

Inputs

Geopotential height data

- Daily data;
- Regular gridded dataset (tested with 0.25°, 1°, and 2.5°);
- Admits data for both hemispheres.

Input parameters

- Period of analysis;
- Adapt parameters of identification;
- Changes on structure capturing depending on Sousa et al. (2021) or updated approach.

Identification of structures: Blocked pixels (obeying gradients and ridges rules) that exceed 500.000 km^2 in total area.

Daily structures by type

Subtropical ridges → Omega blocks → Hybrid blocks → Rex blocks → Polar blocks

Identification of events: Overlapping structures in space on consecutive days that exceed 4 days in duration.

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Output

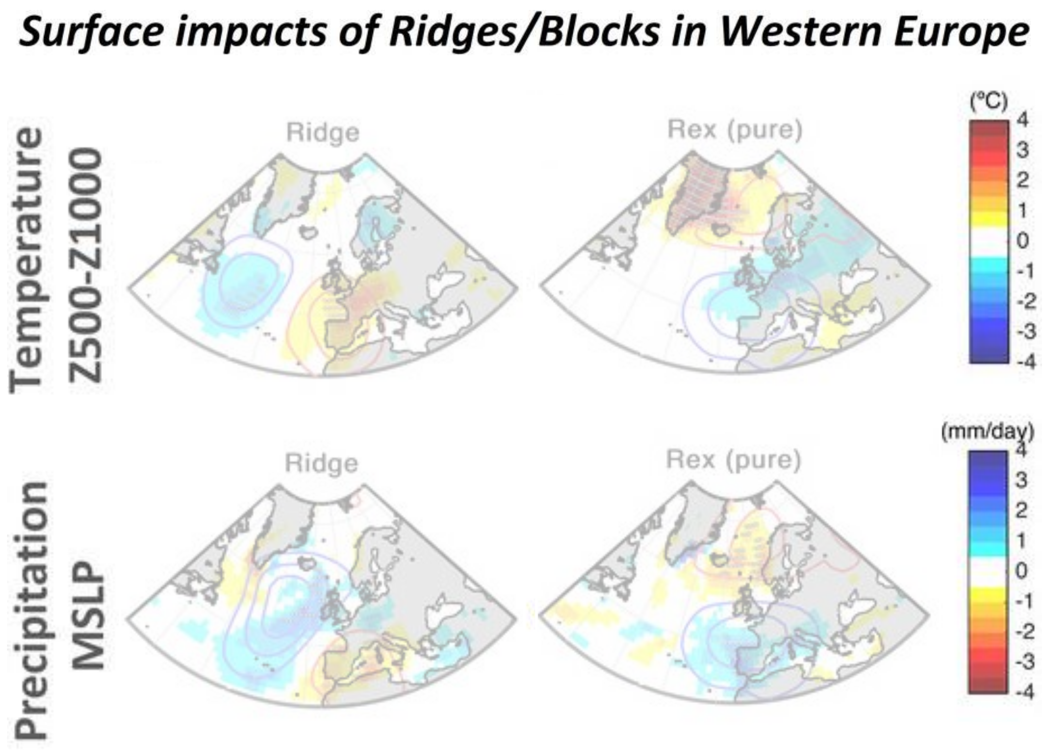
Two *.csv* files:
- Daily statistics (ID, time, weighted centre, area, geopotential, intensity)
- Event statistics (ID, duration, avg. stats., max. stats.)

One *netcdf* file:
- Daily structure masks on regular grid same as input data.
- Blocking intensity per pixel for weighted studies.

Framework to identify extreme events

Field composites of ridge/blocked conditions

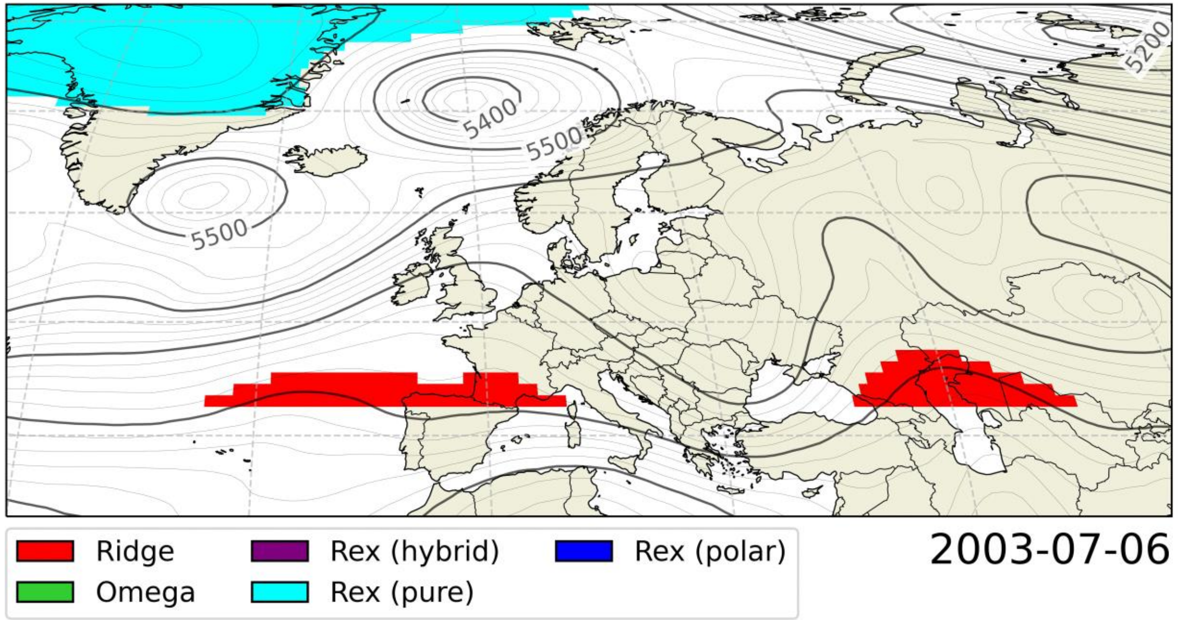
- In western Europe, ridges typically produce **drier and warmer weather**.
- Inversely, **blocked conditions produce wetter and colder days** on average.
- Location of impacts is dependent on specific events.



Source: Sousa et al. (2021)

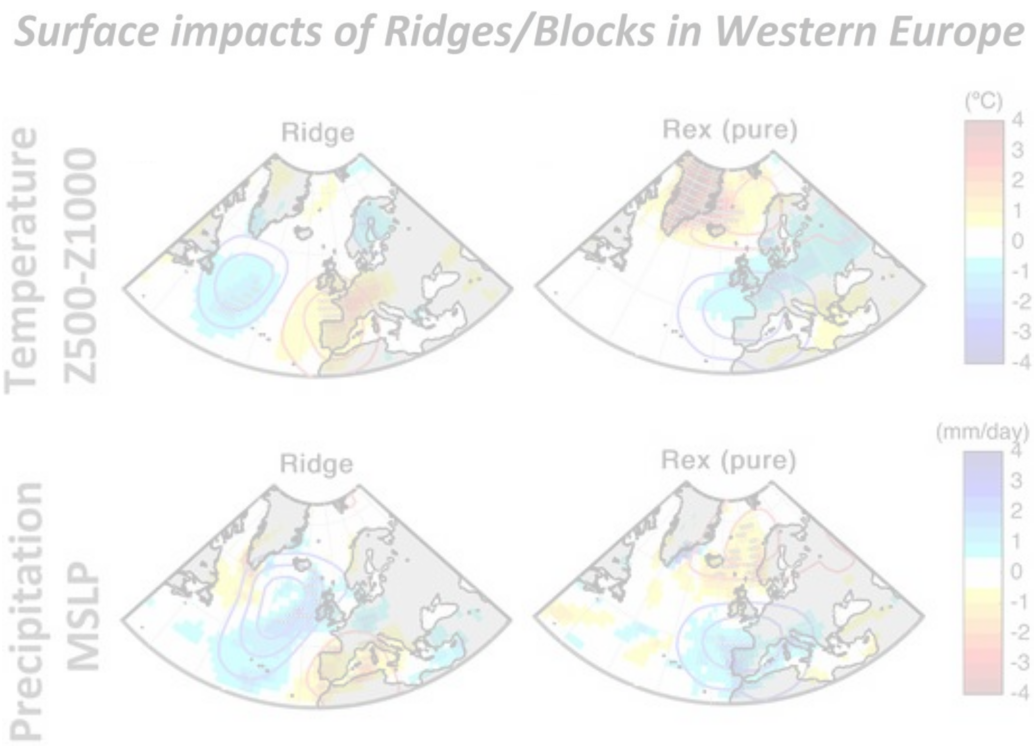
Framework to identify extreme events

Individual extreme weather events: 2003 European heatwave



- Hottest summer since at least 1540.

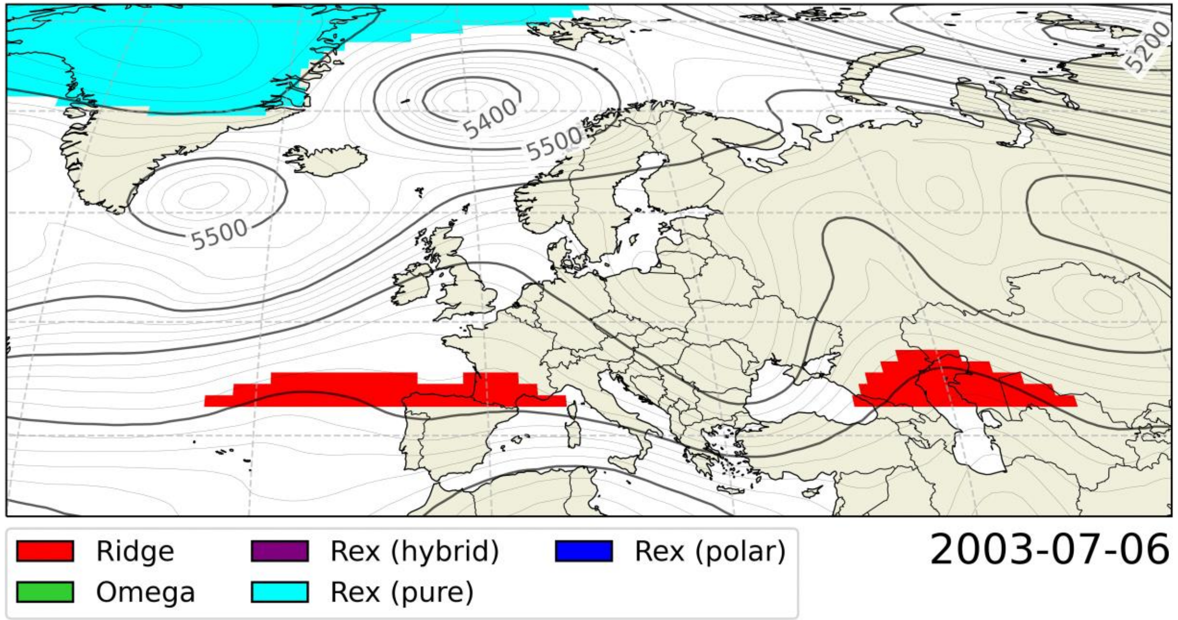
Field composites of blocked/ridge conditions

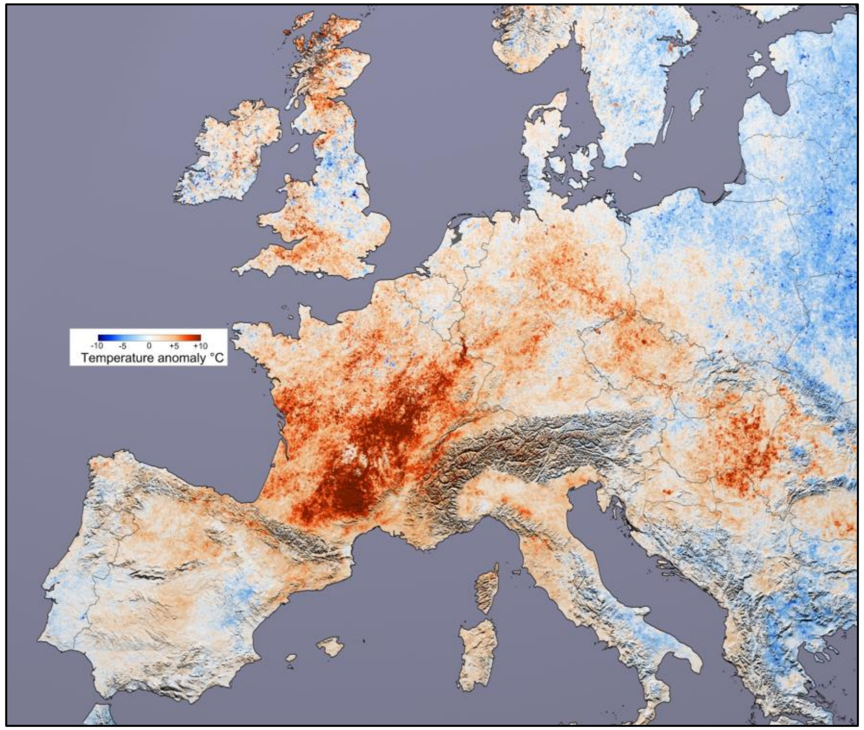


Source: Sousa et al. (2021)

Frameworks to identify extreme events

Individual extreme weather events: 2003 European heatwave





- Hottest summer since at least 1540. **Death toll upwards of 72000**.
- Surge in temperatures influenced the **tragic wildfire season** in Portugal and **drought conditions** in most of Europe.

The bigger picture:

From the 1950s to the present:

> 150.000 fatalities (wars excl.)
> 120 billion €

Temperature extreme events

Type of extreme	Date	Affected region	Blocking region	Damage	References
Heat	Summer 1976	Western Europe	SCAN	23 000 fatalities (in England alone in the first 2 weeks)	Green (1977), Ellis et al. (1980)
	Summer 2003	Central, western Europe	EU (central)	70 000 fatalities, losses of EUR 13 billion	De Bono et al. (2004), Miralles et al. (2014), Kron et al. (2019)
	Summer 2010	Eastern Europe, western Russia	SUBTROP, EU, URAL	55 000 fatalities, losses of EUR 13 billion	Barriopedro et al. (2011), Grumm (2011)
	Summer 2013	Austria, Slovenia	SUBTROP	4 fatalities (alone in Austria)	Lassnig et al. (2014), Lhotka and Kysely (2015)
	Summer 2018	Scandinavia, Germany, France	SCAN	EUR 456 million crop damage (in Germany and Sweden)	Bastos et al. (2020), Spensberger et al. (2020)
Cold	Winter 1941–1942	Europe	EU	260 000 fatalities (also related to war)	Lejenäs (1989)
	Winter 2009–2010	Western, northern Europe	N-ATL	280 fatalities[1]	Cattiaux et al. (2010), Seager et al. (2010), Wang et al. (2010)
	February 2012	Europe	N-ATL, EU	650 fatalities	DWD (2012), de Vries et al. (2013), Planchon et al. (2015)
	January 2017	Balkan Peninsula	SCAN	38 fatalities[2]	Anagnostopoulou et al. (2017)
	March 2018	Europe	N-ATL, SCAN	80 fatalities[3]	Karpechko et al. (2018), Ferranti et al. (2019)

Hydrological extreme events

Type of extreme	Date	Affected region	Blocking region	Damage	References
Droughts	Summer 2003	Central, western Europe	EU (central)	70 000 fatalities, losses of EUR 13 billion	Beniston and Diaz (2004), Ogi et al. (2005), García-Herrera et al. (2010), Kron et al. (2019)
	2004–2005	Iberian Peninsula	N-ATL	EUR 1 billion crop damage[1]	Garcia-Herrera et al. (2007)
	2010	Eastern Europe, western Russia	SUBTROP, EU, URAL	55 000 fatalities, losses of EUR 13 billion	Barriopedro et al. (2011), Lau and Kim (2012)
	2016–2017	Central, western Europe	SUBTROP	losses of EUR 5.8 billion	Aon (2018), García-Herrera et al. (2019)
Thunderstorm	May 2018	Central, eastern Europe	EU (north)	losses of EUR 380 million	Mohr et al. (2020)
Floods	1954	Upper Danube	N-ATL (west)	losses of EUR 886 million	Blöschl et al. (2013), Irwin (2016)
	October 2000	Southern Alps	N-ATL	38 fatalities, losses of EUR 7.5 billion	Kron et al. (2019), Lenggenhager et al. (2019)
	2002	Central Europe	SCAN, EU (east)	39 fatalities, losses of EUR 14.5 billion	Blöschl et al. (2013), Kron et al. (2019)
	October 2011	Switzerland	N-ATL	losses of EUR 52.5 million	Piaget et al. (2015)
	June 2013	Central Europe	SCAN, N-ATL	25 fatalities, losses of EUR 11 billion	Grams et al. (2014), Kron et al. (2019)
Snow event	December 2013	Middle East, Germany	EU (southwest)	5 fatalities, losses of EUR 106 million (Gaza and West Bank)	Erekat and Nofal (2013), Luo et al. (2015)
	January 2019	Alps	N-ATL	7 fatalities[2]	Yessimbet et al. (2022)

- A **user-friendly method** for their identification is important to focus on the study of impacts and determining the dynamics leading to said impacts.
- Possibility of assimilating into *compound event studies*.

Source: Kautz et al. (2022)

Take-home message

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Blocking Location and Obstruction Cataloguing System

User-friendly and open-source **atmospheric blocking** identification algorithm that helps identifying large-scale flow-obstructing conditions.

BLOCS helps in:

- Systematically classifying blocking structures according to type.
- Associating extreme weather to large-scale dynamics.
- Study intricate dynamics leading to high-impact events.

Can be used/extended to:

- ❖ Used with climate models
- ❖ Use for forecasting
- ❖ To train ML algorithms