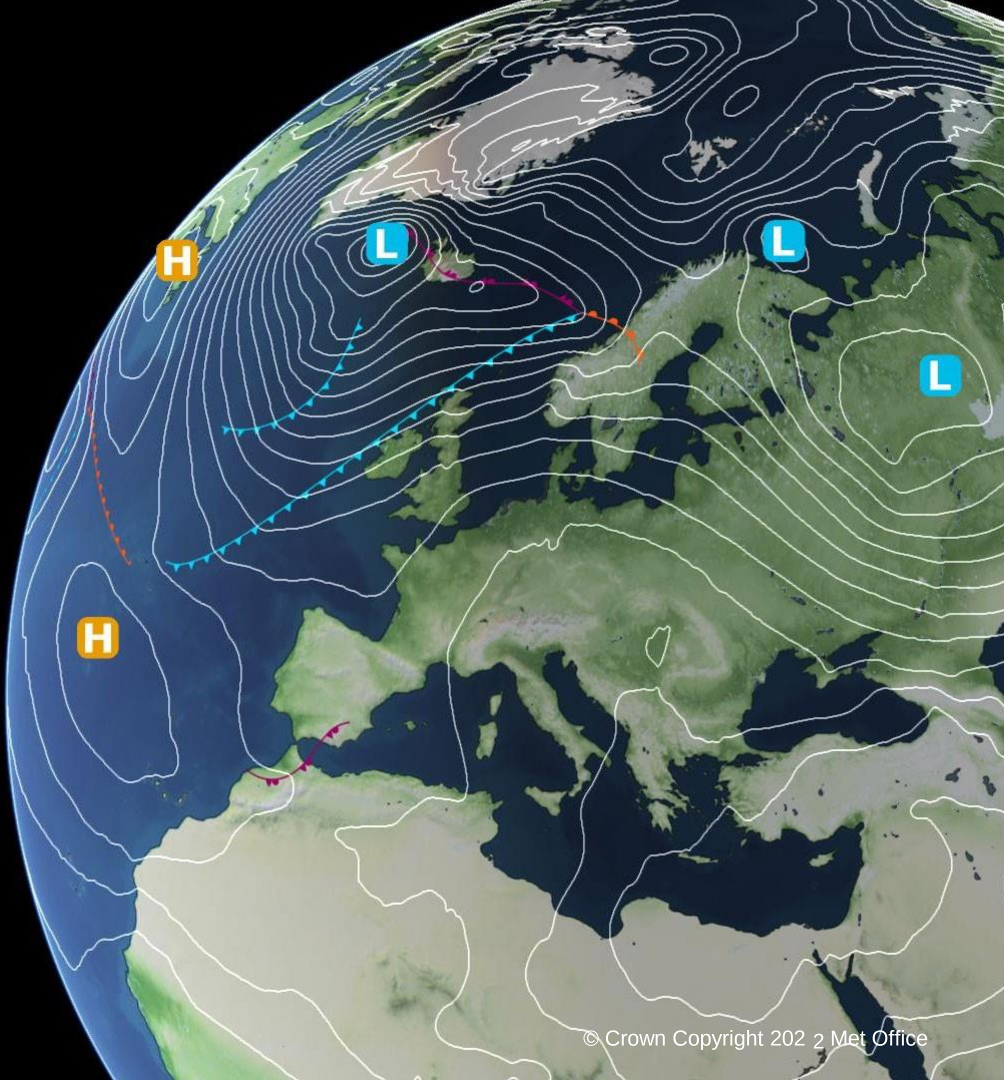
Met Office

Exploring the mechanisms and interactions of extreme weather and large scale atmospheric processes

Prof. Paul Davies

Principal Fellow in Weather and Climate Extremes and Impacts

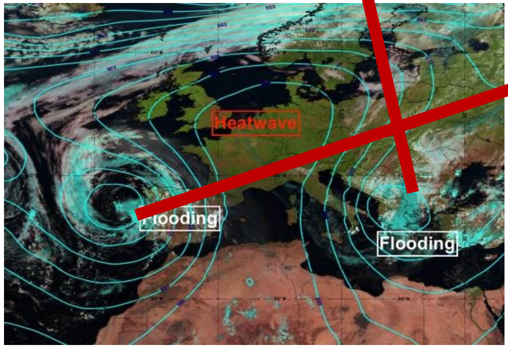


Record-shattering rainfall extremes

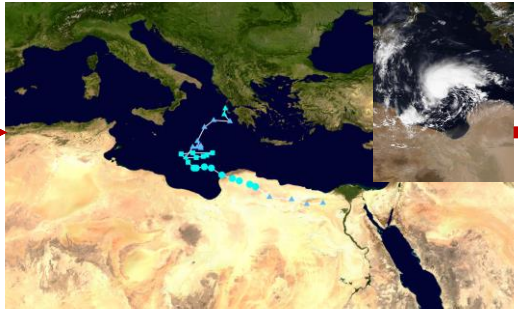
Early September 2023

Greece – Storm Daniel

1092 mm/24h
$2.14 billion
Flooded 730 km^2



Medicane – hurricane-like storm in the Mediterranean



Spain – Storm Dana

243.4 mm/24h

Libya – Medicane Daniel

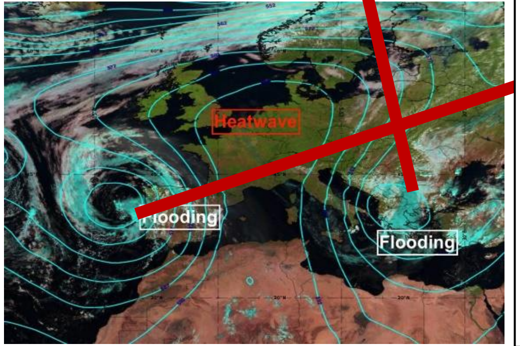
>400 mm/6h
$19 billion
>20,000 deaths

Record-shattering rainfall extremes

Summer/Autumn 2023

Greece – Storm Daniel

1092 mm/24h
$2.14 billion
Flooded 730 km²



Medicane – hurricane-like stc
Mediterranean

Key points

- A blocked wave pattern in September caused slow-moving cut-off lows that drenched Europe; Storm Daniel deposited >1,000 mm rainfall in Thessaly, Greece, over a 24-hour period.
- Tropical cyclones drove extreme rainfall across many global regions; Tropical Cyclone Freddy inundated parts of Mozambique with 400–800 mm rainfall in 24 hours.
- A high number of severe convective storms caused flash flooding in many locations; Hebei Province, China, recorded rainfall totals >1,000 mm in 3 days.

Year in review

Climate chronicles https://doi.org/10.1038/s43017-024-00547-9

Precipitation extremes in 2023

Hayley J. Fowler, Stephen Blenkinsop, Amy Green & Paul A. Davies

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2023 saw a multitude of extreme precipitation events across the globe, causing flash flooding, countless fatalities and huge economic losses. Fuelled by a combination of a strong El Niño, record ocean warmth and anthropogenic warming, these events highlight the ongoing risks posed by extreme precipitation in a warming climate.

Extreme precipitation arises from many atmospheric phenomena, including atmospheric rivers, tropical and extratropical cyclones and convective storms. Its impacts are often catastrophic, with resulting flash floods causing substantial economic damage (which indiscriminately affects developed and developing nations[1]) and countless fatalities. For instance, monsoon-related extreme precipitation across India and Bangladesh in May–June 2022 affected and displaced ~10 million and 250,000 people, respectively; Raigad district in Maha-

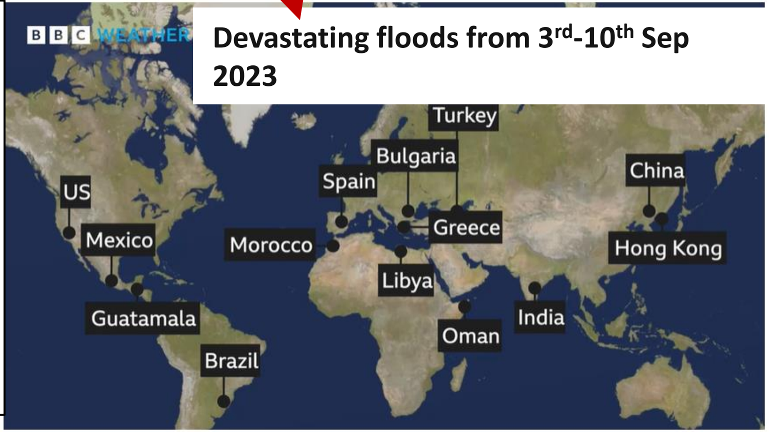
The storm subsequently moved offshore on the 9th September, transitioning into a rare Mediterranean tropical cyclone – a Medicane. The cyclone hit Libya on 10th September, producing ~440 mm rainfall in 6 h that broke two dams above the city of Derna. The resulting 7-m flood wave caused tens of thousands of fatalities and damage totalling an estimated US $19 billion. Anthropogenic climate change made the extreme rainfall 50 times more likely[7].

Low-pressure systems not associated with blocking also caused extreme rainfall events. For example, Emilia-Romagna, Northern Italy, experienced heavy rainfall associated with three distinct low-pressure systems situated over the Tyrrhenian Sea on the 2nd, 10th and 16th May. In 2 weeks, the region received the normal amount of rainfall for 7 months, including 366.4 mm in Modigliana between 8–21 May, with a return period of ~200 years. The rainfall caused the overflow of twenty-three rivers across the region and resulted in 8 fatalities. Anthropogenic climate change had a limited influence on this heavy spring rainfall event.

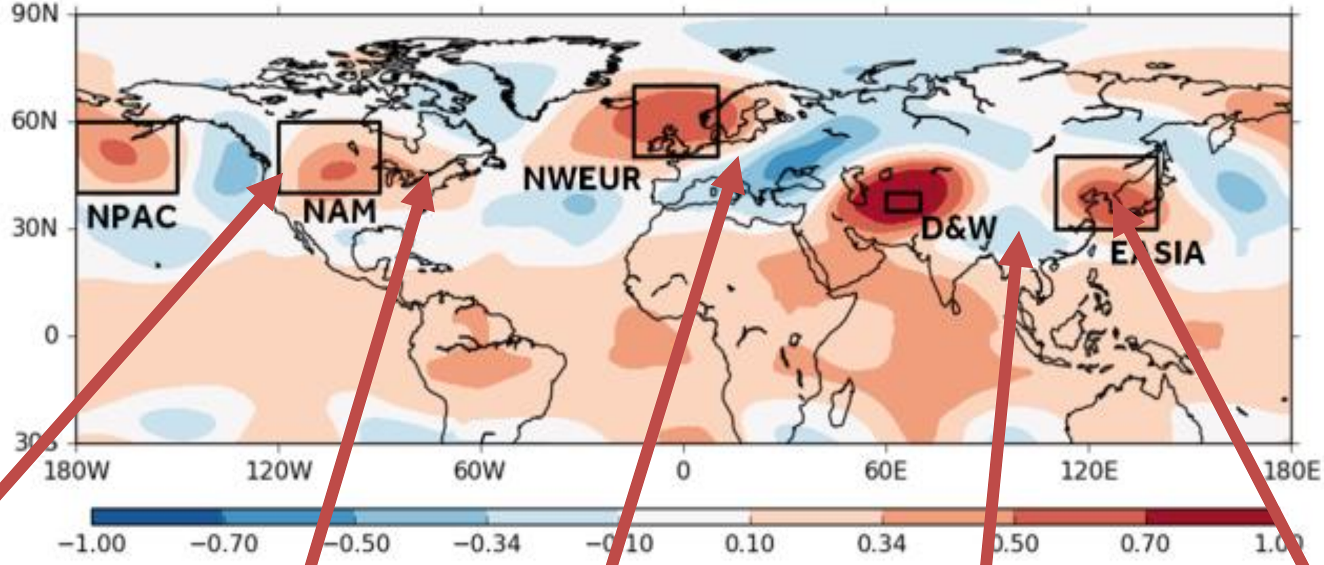
A low-pressure system associated with remnants of Typhoon Haikui also brought record-breaking rainfall in Hong Kong on 7th September. The region received >600 mm rain in 24 h, over a quarter of annual

$19 billion
>20,000 deaths

Devastating floods from 3rd-10th Sep 2023



Blocked Pattern causing persistent weather extremes



200mb seasonal composite anomaly from 1981-2010 climatology for JJA 2021

US/Canadian Heat Dome

New York Floods

80 mm/h

Germany Floods

Large area >150 mm/24h
207 mm/6h

Zhengzhou Floods

201.9 mm/h
617.1 mm/3d

Siberian wildfires

UK Winter extremes 2019/2020

The wet and stormy UK Winter of 2019/20

Paul A. Davies[1]*, Adam A. Scaife[1,2], Mark. McCarthy[1], Jeff R. Knight[1], Nick. Dunstone[1], David Sexton[1], Nikos. Christidis[1], David. Fereday[1].

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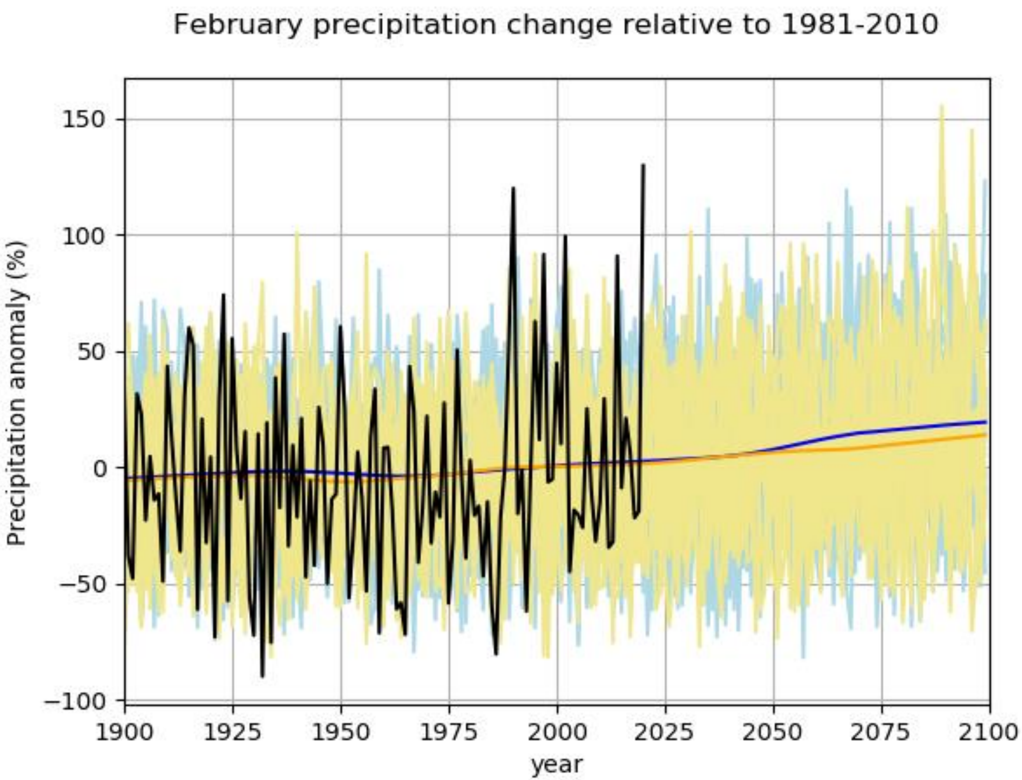
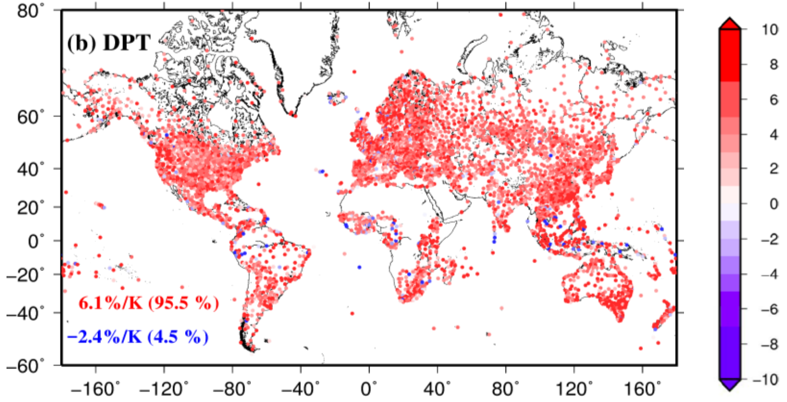
Abstract

The winter of 2019/20 was remarkable on many fronts, the UK experienced its wettest February on record for the UK overall, England, Wales and Northern Ireland, and second wettest for Scotland in series from 1862, and one of the four named windstorms, Dennis was one of the deepest Atlantic depressions on record.

This pattern was primarily the result of a strong and positive North Atlantic Oscillation (NAO). The associated strong north-south surface pressure gradient across the North Atlantic and westerly regime brought a succession of cyclonic systems, persistent heavy rain and associated severe floods to much of the UK. During February, when the UK experienced a peak in rainfall extremes, three named windstorms Ciara (7-8 Feb), Dennis (15-16 Feb), and Jorge (28-29 Feb) accounted for approximately 44% of the February rainfall total.

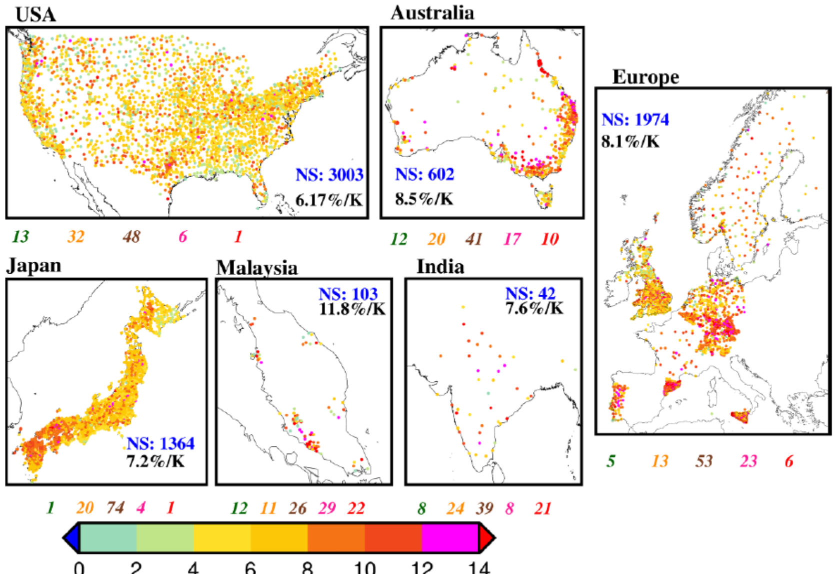


February precipitation anomaly as a percentage of the 1981-2010 average, for observations (black), individual ensemble members of the PPE-15 (light blue), and CMIP5-13 (light orange). The smoothed model ensemble means are shown in dark blue (PPE-15) and orange (CMIP5-13).



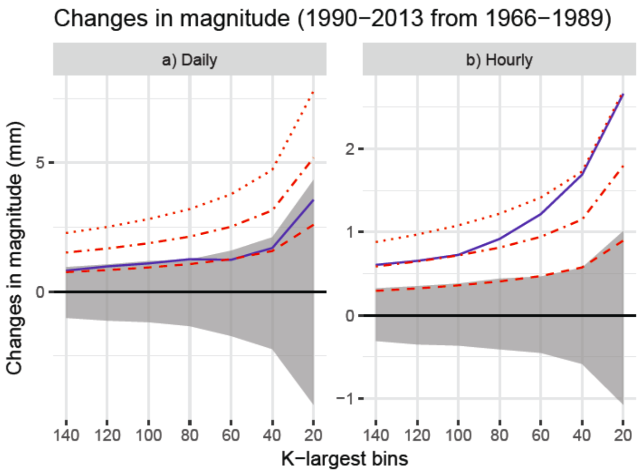
Temperature-precipitation scaling confirmed at 6-7% per °C for daily extreme rainfall

Ali, Fowler and Mishra, GRL, 2018



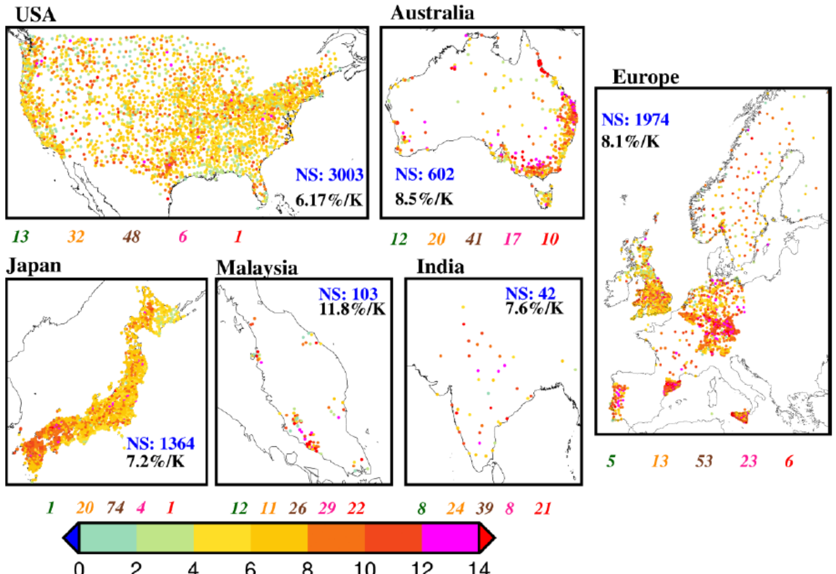
Temperature-precipitation scaling confirmed at 7% per °C or higher for hourly extreme rainfall.

Ali, et al., 2021, GRL



Increase in intensity of daily heavy precipitation is consistent with Clausius-Clapeyron scaling; hourly intensities can have a much higher scaling rate

Fischer and Knutti, Nature Climate Change, 2016
Guerreiro et al., Nature Climate Change, 2018



Temperature-precipitation scaling confirmed at 7% per °C or higher for hourly extreme rainfall.

Ali, et al., 2021, GRL

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Winter 2019/20 extreme weather and large scale atmospheric processes

Met Office

Predictability of European winter 2019/20: Indian Ocean dipole impacts on the NAO

Steven C. Hardiman[1] | Nick J. Dunstone[1] | Adam A. Scaife[1,2] | Doug M. Smith[1] | Jeff R. Knight[1] | Paul Davies[1] | Martin Claus[3,4] | Richard J. Greatbatch[3,4]

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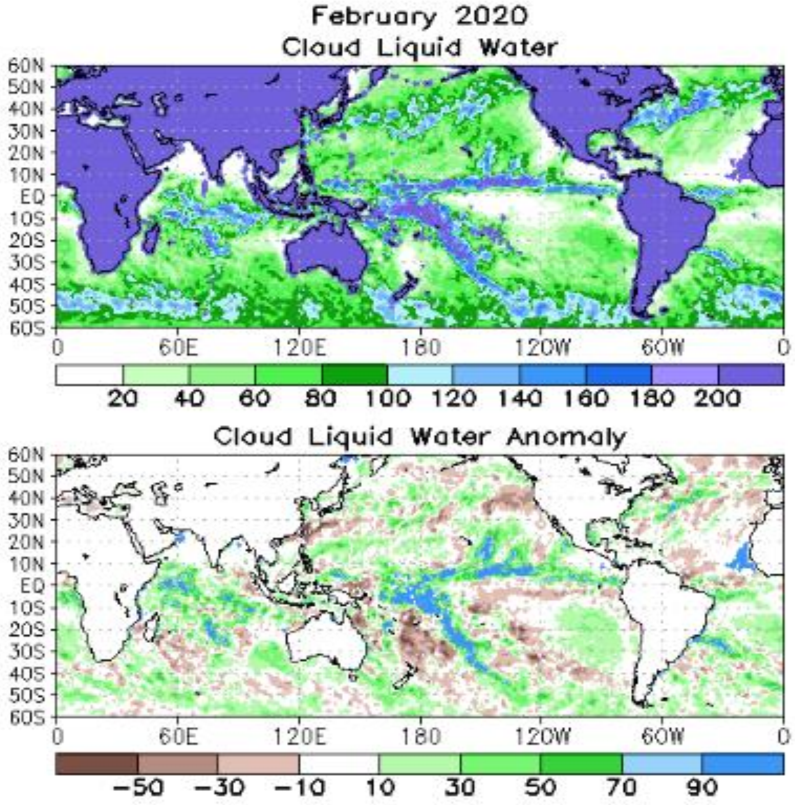
Funding information
Met Office Hadley Centre Climate Programme funded by BEIS and Defra

Abstract

Northern Europe and the UK experienced an exceptionally warm and wet winter in 2019/20, driven by an anomalously positive North Atlantic Oscillation (NAO). This positive NAO was well forecast by several seasonal forecast systems, suggesting that this winter the NAO was highly predictable at seasonal lead times. A very strong positive Indian Ocean dipole (IOD) event was also observed at the start of winter. Here we use composite analysis and model experiments, to show that the IOD was a key driver of the observed positive NAO. Using model experiments that perturb the Indian Ocean initial conditions, two teleconnection pathways of the IOD to the north Atlantic emerge: a tropospheric teleconnection pathway via a Rossby wave train travelling from the Indian Ocean over the Pacific and Atlantic, and a stratospheric teleconnection pathway via the Aleutian region and the stratospheric polar vortex. These pathways are similar to those for the El Niño Southern Oscillation link to the north Atlantic which are already well documented. The anomalies in the north Atlantic jet stream location and strength, and the associated precipitation anomalies over the UK and northern Europe, as simulated by the model IOD experiments, show remarkable agreement with those forecast and observed.

KEYWORDS

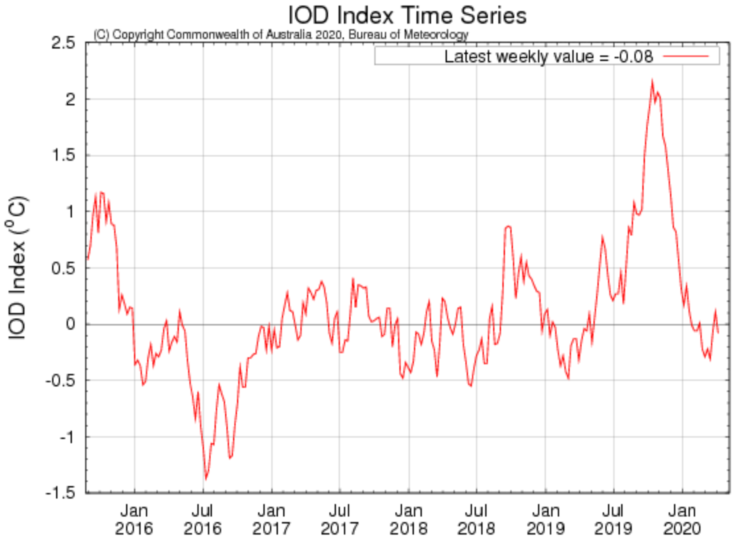
European winter, Indian Ocean dipole, North Atlantic oscillation, seasonal forecasting, teleconnections

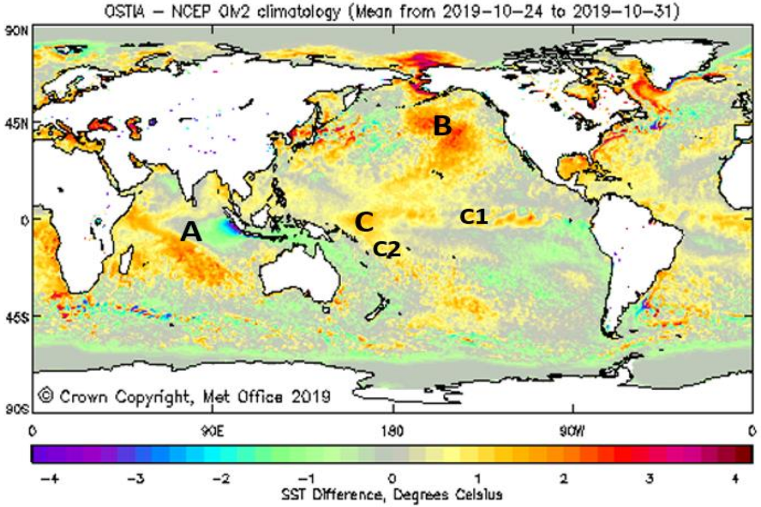


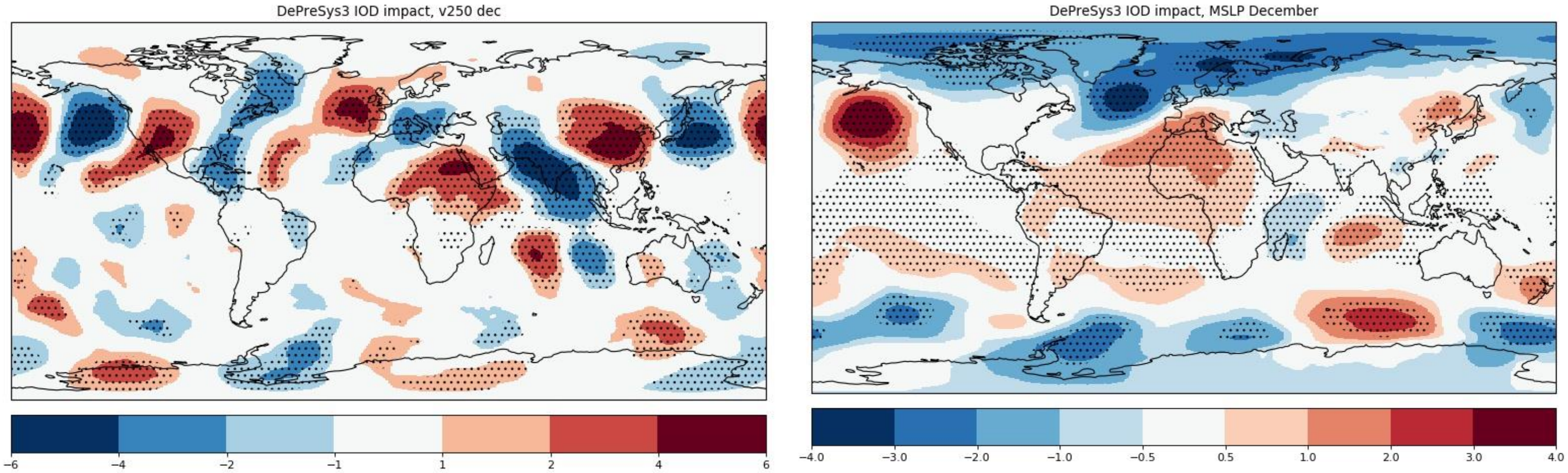
Mean (top) and anomalous (bottom) cloud liquid water (g m-2) based on the Special Sensor Microwave/ Imager (SSM/I) (Weng et al 1997: J. Climate, 10, 1086-1098). Anomalies are calculated from the 1987-2010 base period means.

Met Office

Indian Ocean Dipole







Composite analysis and model experiments, to show that the IOD was a key driver of the observed positive NAO. Using model experiments that perturb the Indian Ocean initial conditions, two teleconnection pathways of the IOD to the north Atlantic emerge: a tropospheric teleconnection pathway via a Rossby wave train travelling from the Indian Ocean over the Pacific and Atlantic, and a stratospheric teleconnection pathway via the Aleutian region and the stratospheric polar vortex.

Windows of opportunities

Windows of opportunity for predicting seasonal climate extremes highlighted by the Pakistan floods of 2022

Received: 19 January 2023

Accepted: 10 October 2023

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Check for updates

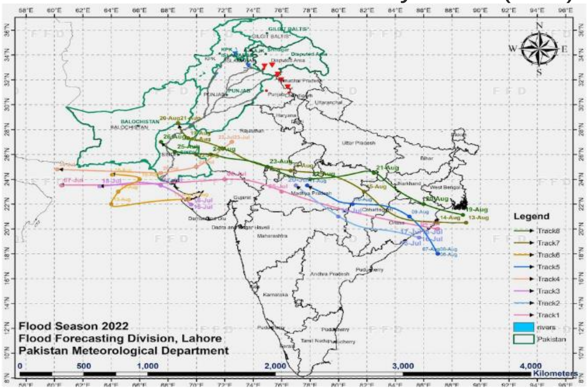
Nick Dunstone[1], Doug M. Smith[1], Steven C. Hardiman[1], Paul Davies[1], Sarah Ineson[1], Shipra Jain[2], Chris Kent[1], Gill Martin[1] & Adam A. Scaife[1,3]

Skilful predictions of near-term climate extremes are key to a resilient society. However, standard methods of analysing seasonal forecasts are not optimised to identify the rarer and most impactful extremes. For example, standard tercile probability maps, used in real-time regional climate outlooks, failed to convey the extreme magnitude of summer 2022 Pakistan rainfall that was, in fact, widely predicted by seasonal forecasts. Here we argue that, in this case, a strong summer La Niña provided a window of opportunity to issue a much more confident forecast for extreme rainfall than average skill estimates would suggest. We explore ways of building forecast confidence via a physical understanding of dynamical mechanisms, perturbation experiments to isolate extreme drivers, and simple empirical relationships. We highlight the need for more detailed routine monitoring of forecasts, with improved tools, to identify regional climate extremes and hence utilise windows of opportunity to issue trustworthy and actionable early warnings.

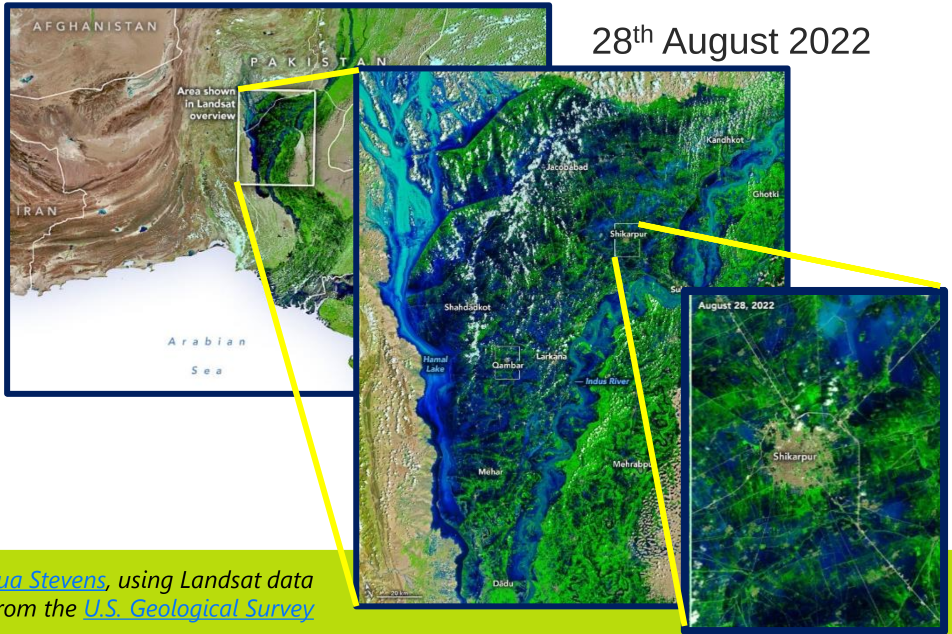
Extreme Pakistan rainfall signals were present in summer 2022 seasonal predictions yet not well signalled by regional forecast outlooks

- Was Pakistan rainfall in summer 2022 a ***window of opportunity*** for more confident and actionable early warning?
- Can we use physical dynamical understanding to build confidence in extreme forecast signals?
- Can we develop new tools to identify and explore extreme forecast signals in real-time?

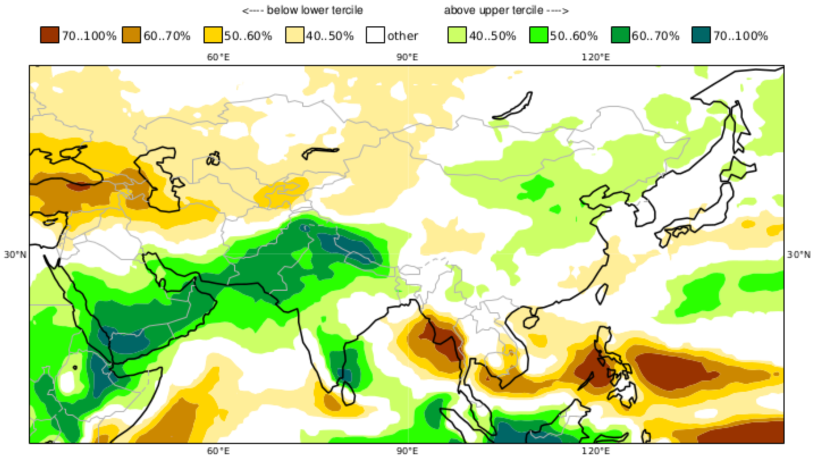
Monsoon Low Pressure Systems (LPS):



28th August 2022



NASA Earth Observatory images by Joshua Stevens, using Landsat data from the U.S. Geological Survey



Multi-model upper tercile >60%

“So you’re saying we’ve got a 2-in-3 chance of being in upper third of rainfall this summer… which we expect 1-in-3 years normally?”

WMO operational seasonal outlooks typically focus on maps of tercile probabilities.

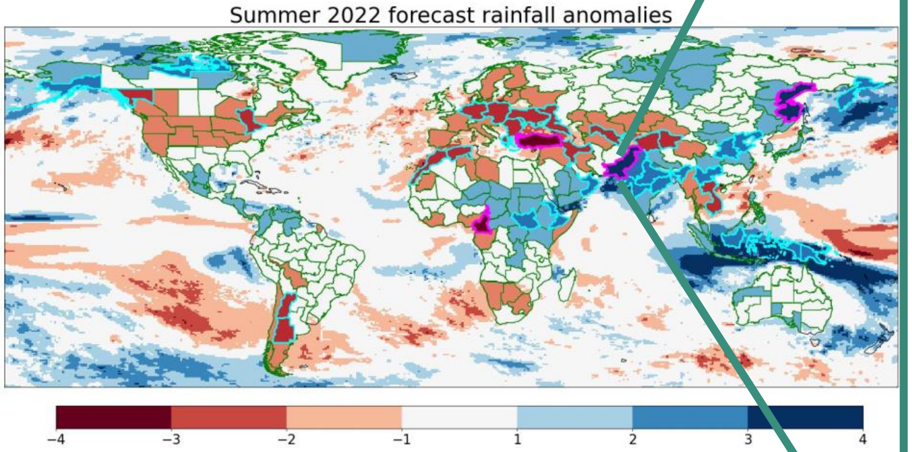
Need to look at **more extreme tail**:
Upper quintile Upper decile


BIG
DATA
SOCIAL
SAN
NAS
SOFTWARE
LARGE
COMPLEX
STORAGE
PAST
MILLION
SETS
INCLUDE
NETWORKS
HYPOTHESIS
SCIENCE
PROCESS
SYSTEMS
VOLUME
DEVELOPMENT
TECHNOLOGY
BILLION
NEW
APPROACH
ANALYTICS
AMOUNT
APPLICATIONS
ANALYSIS
RESEARCH
LEARNING
EVERY
WORLD
VARIOUS
BASED
TIMES
INTERNET
SEARCH
ARCHITECTURE
SHARED
SUCCESSFUL
NEEDED
USES
TERMS
YEAR

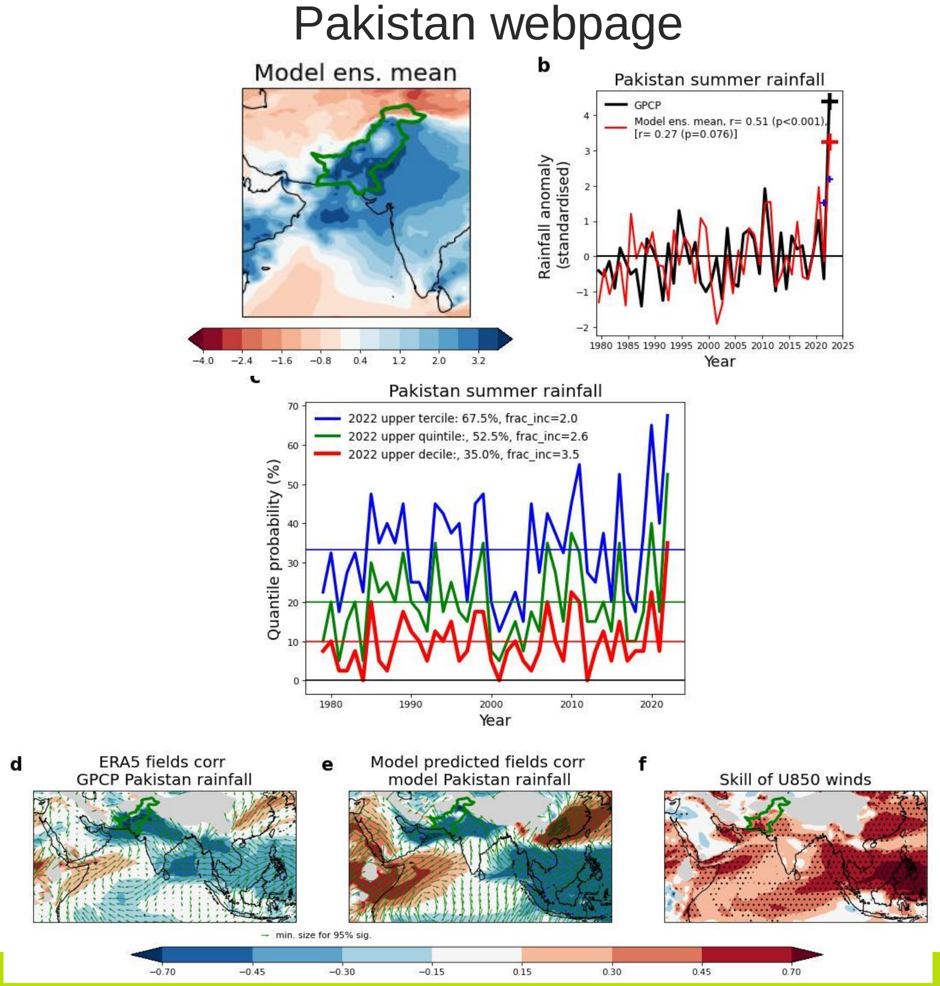
Extremes tool

New interactive tools needed to better identify/explore potential climate extremes and their drivers in real-time

"click"



Divide global land into 0.5 million km^2 regions, along geopolitical boundaries – e.g. Pakistan is one region.



Stone, D.A. A hierarchical collection of political/economic regions for analysis of climate extremes. Climatic Change 155, 639–656 (2019). https://doi.org/10.1007/s10584-019-02479-6

Social and behavioural sciences

Early warning, Early action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SPORTS FINAL

Sunday, October 1, 2023

DAILY NEWS

NEW YORK'S HOMETOWN NEWSPAPER

CONGRESS AVOIDS GOV'T SHUTDOWN

HOUSE & SENATE PASS STOPGAP FUNDING BILL HOURS BEFORE DEADLINE - SEE PAGE 14

Motorists stood knee-deep alongside their stalled cars on flooded FDR Drive Friday.

NO WARNING

- New Yorkers angry over lack of storm notice
- Adams praises city's response to flooding
- Brooklyn hospital forced to evacuate

SEE PAGES 4-5

AFP/GETTY

We need to be a bit better at recognizing the potential for outlier events at actionable lead-times. Conversely, where that's not possible we cumulatively should have excellent short-fuse communication strategies

An example of a first mile / last mile issue? Whether a timely warning is issued is less important than whether everybody, including the most vulnerable and the ones paying least attention, are taking appropriate action

Summary thoughts

- Compound extremes may change more than individual extremes. Often, they are connected by physical processes in sequences across local to large scale atmospheric processes
- Dynamical changes to the atmosphere are important for changing characteristics of extreme weather, but there is a risk we underestimate the changes we are seeing in the real world, esp. the persistence of blocked conditions important for heatwaves and extreme rainfall.
- We should use physical dynamical understanding to build confidence and new tools in extreme forecast signals
- We need to prioritise our science towards societal problems – climate is changing rapidly and the need to target actionable advice when it matters though transdisciplinary collaboration is key.