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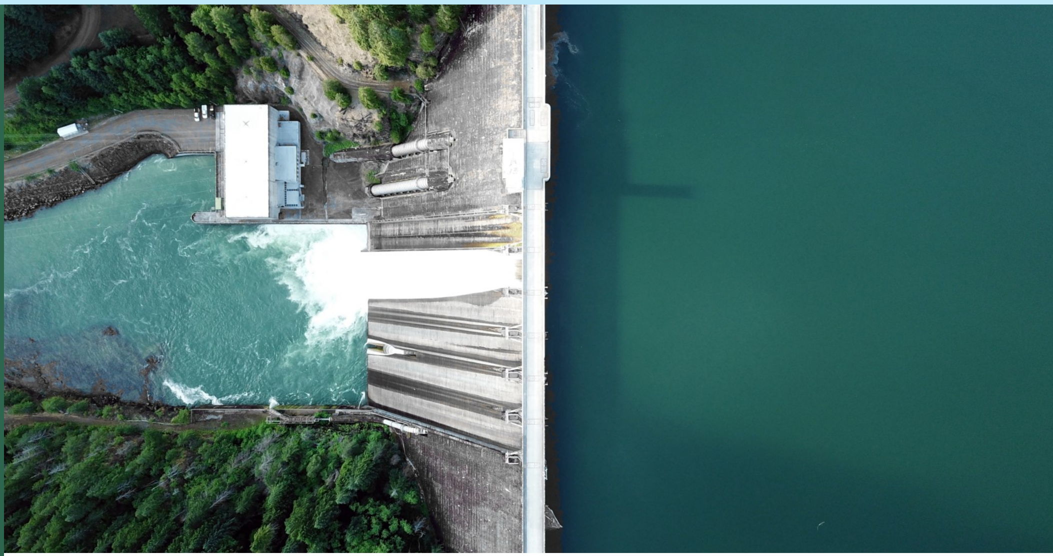
HOW DID ARCTIC SEA ICE AFFECT ENERGY PRODUCTION IN EUROPE IN 2018?



1 January to April low sea ice concentration

Record-low sea ice concentration values in the Bering sea

2 Warm and dry spring

High temperatures and low precipitation in central and northern Europe

3 Impacts on energy and river transport

- Decreased hydro and wind power generation
- Increased solar energy generation
- River transport issues

Spring 2018 was a warm and dry period in the central and northern part of Europe that some energy producers identified as a relevant event affecting their businesses. This period saw high temperatures with low precipitation and wind speed, which impacted renewable power generation. The aim of this case study is to explore whether these weather conditions were associated with extremely low values in *sea ice concentration*[A] observed in the Arctic a few months earlier. The APPLICATE project aims to improve our understanding of the linkages between Arctic sea ice changes and the mid-latitude climate for the benefit of policy makers, businesses and society. Confirming the link between the extremely low sea ice concentrations in 2018 and the subsequent weather conditions over Europe would open an opportunity for short-term and long term planning of European energy systems if similar events become more frequent in the future.

THE EVENT:
Hot and dry spring and early summer 2018

Spring and summer of 2018 in Europe were much warmer than average. During this period, high sea level air pressure conditions were present over the northern half of the continent, which brought clear skies with rather dry and stable weather. This increased the number of sunshine hours typical for this time of the year, but also led to a very small amount of rain in central, western and northern Europe from April to June. A few months earlier, from January to April, the historically lowest sea ice cover in the Bering region of the Arctic was recorded. The almost simultaneous occurrence of these extreme events poses the question of whether the reduction in sea ice had played any role in the development of the high air pressure systems over Europe.

GLOSSARY

A

Sea ice concentration:

The amount of sea ice covering an area, usually written as the percentage of the total area covered by sea ice.

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ENERGY GENERATION AT THE TIME OF THE EVENT: higher than usual solar and lower than usual hydro and wind power generation

The exceptionally warm and dry spring and beginning of summer affected renewable energy sources and their power output, as well as some conventional energy sources. The high temperatures and a very small amount of rain had a big impact on run-of-river hydro-power generation, forcing it to reduce its output, most notably in Germany and Sweden (Agora Energiewende and Sandbag, 2019). The drought conditions also impacted river transport, which affected coal deliveries to power plants and river cooling of nuclear power plants. Spring 2018 was also less windy than usual. This was reflected in a decrease of the energy generation by wind turbines, as illustrated by the decreased capacity factors both for onshore (22%) and offshore wind (36%) (WindEurope, 2019). On the other hand, the high number of sunshine hours allowed for a greater solar energy generation, which hit a record high of 6.7 TWh in Germany in July (Fraunhofer Institute for Solar Energy Systems, 2018).

THE LINK WITH ARCTIC SEA ICE

Extremely low sea ice concentration in the Bering sea

From January until April 2018, the concentration of sea ice in the Bering Sea region of the Arctic reached its lowest values in the last 60 years (Fig.1).

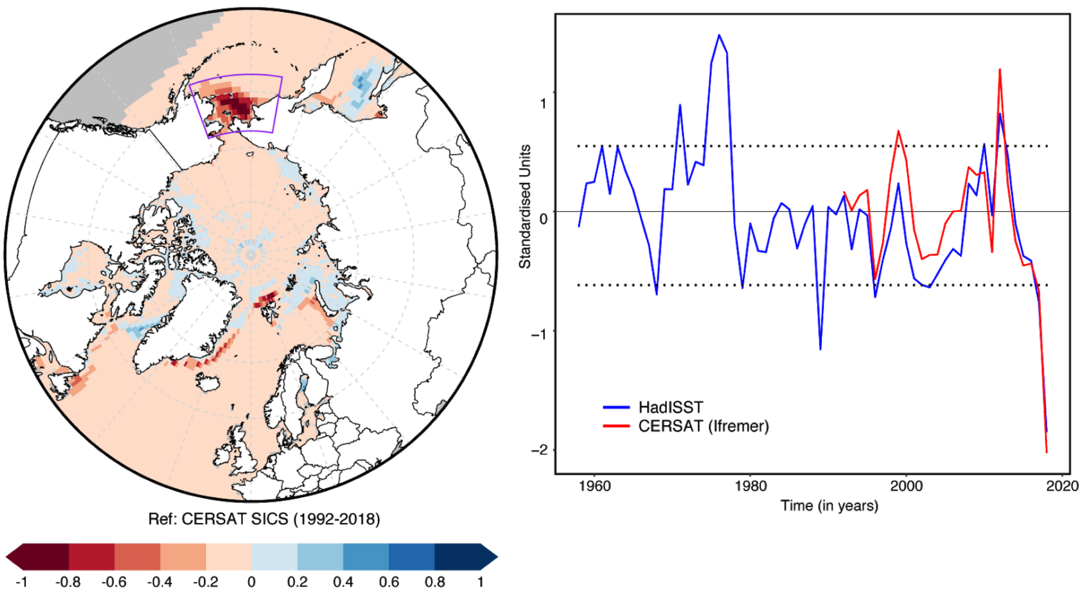


Fig.1. Observed sea ice concentration *anomaly*[B] aggregated for 2 months (March and April) relative to the 1992-2018 average sea ice concentration (left). The darker the red colour, the lower the sea ice concentration in 2018 as compared to the reference period. The purple box marks the Bering Sea area. The figure on the right shows the time series of the sea ice concentration anomaly since 1960, with the two colours marking two different datasets. Source: CERSAT 1992-2018. Credit: Ferran López Martí

B **Anomaly:** The difference between an observation at a given time and its long-term average.

Taking the sea ice observations into account, an analysis method was applied to identify potential linkages between the state of the sea ice in the Arctic and the subsequently observed weather events in Europe. The method consisted in selecting other six years with the lowest sea ice cover in the Bering Sea from February until April, for the period 1958-2017. This corresponds to the top 10% of the years with the lowest sea ice in that period. The 6-year averages of different climate variables (air temperature, surface wind, sea level pressure, precipitation, geopotential height) were then compared to the state of the atmosphere in 2018, focusing on the same variables. If the sea ice over the region played a role in the development of the 2018 weather conditions, a similar atmospheric state should be found between the 2018 case and the 6 year *composite* [C].

The plot of *geopotential height* [D] anomaly shows the state of the atmosphere at a higher altitude (about 6km), two months after the low sea ice concentration was observed in the Bering Sea (Fig. 2). Anomalous high air pressure systems were observed over Europe, parts of North America and Siberia. High pressure is normally associated with clear skies, less precipitation and more solar radiation for the given region.

The left plot shows the anomaly of the year 2018, whereas the right plot shows the anomaly of the average of the 6 years with the lowest Bering Sea ice cover in the period 1958-2017. A *statistical significance* [E] test was done to determine which are the regions with robust patterns of similar atmospheric responses for the 6 selected years. Central and western Europe, Turkey, west coast of the USA, eastern Canada and Siberia show significant (not random) responses. All of them experienced high geopotential values in 2018, thus supporting a potential key role of Bering Sea ice cover. The analysis also showed that, in Europe, the 2018 signal shifted towards Scandinavia, probably reflecting the influence of some additional atmospheric processes.

C

Composite:

An average that is calculated according to specific criteria. For example, one might want a composite for the rainfall at a given location for all years in which the temperature was much above average.

D

Geopotential height:

A variable that approximates the actual height of a pressure surface above mean sea level. For example, pressure of 500 millibars can be found at a height of 5700 metres. It is also called "gravity-adjusted height".

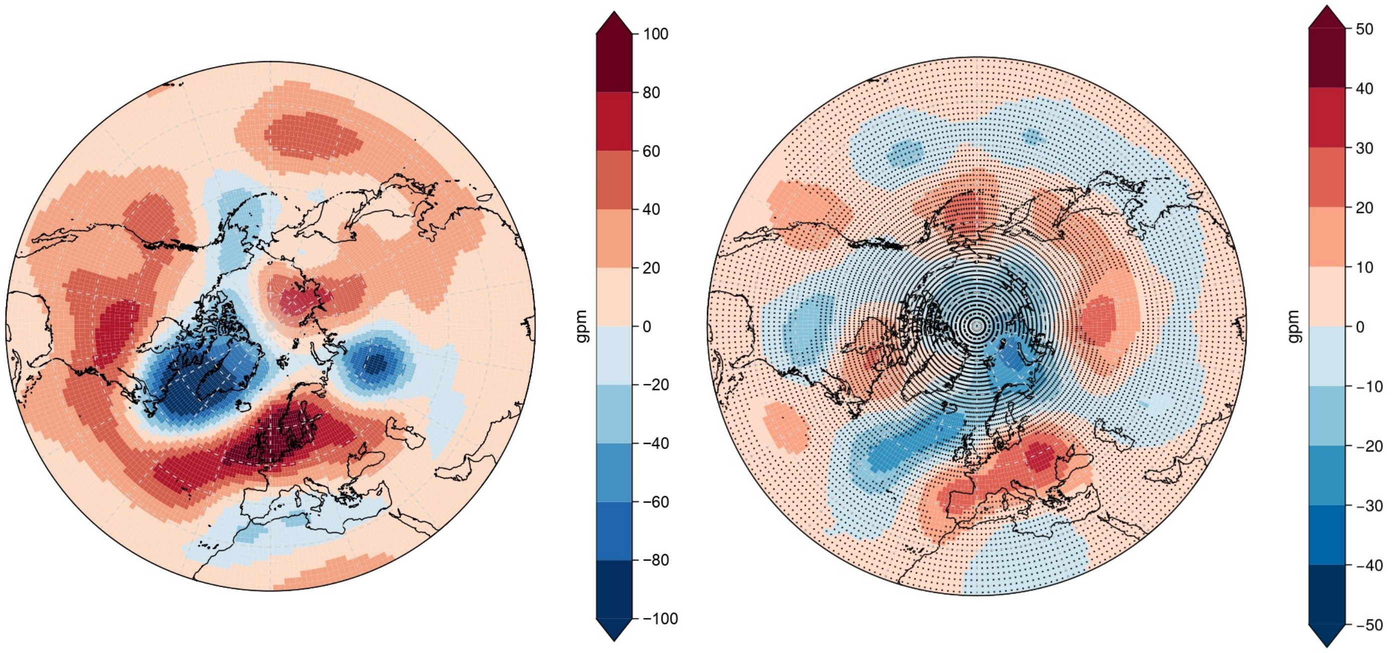


Fig.2. Left - 2018 geopotential height anomaly at 500 mb aggregated for 2 months (May and June), relative to the 1958-2017 average. The darker the red colour the higher the geopotential height as compared to the reference period. Right - composite of the geopotential height anomalies for 6 years with the lowest sea ice concentration in the Bering sea, relative to 1958-2017 average. The absence of black dots marks statistical significance ($p < 0.1$). Source: JRA55 (Japanese reanalysis) Credit: Ferran López Martí

E

Statistical significance:

A statistically significant result is one that is not due to chance.

Potential impact of low Arctic sea ice on Europe

Besides the geopotential height anomaly, another clear climate response was observed for air temperature, which can be related to sunshine duration. During May and June 2018, many parts of Europe had an increase in the number of sunny days, with some areas of central and northern Europe experiencing up to 40% more sunshine hours than average during 2018 (Copernicus, 2019). This had an impact on solar energy generation which increased, especially in Germany.

Europe witnessed positive anomalies in air temperatures during the other 6 years of low Bering sea ice conditions (Fig. 3). The anomaly was obvious in the region where the high air pressure signal, to which the sea ice concentration contributed, was the strongest. Given that this was a very dry period for the region, causing shortfalls in hydro, nuclear and coal, while at the same time increasing the energy demand for cooling, a proper anticipation of the favourable conditions for solar energy production is important for reinforcing the security of European energy systems.

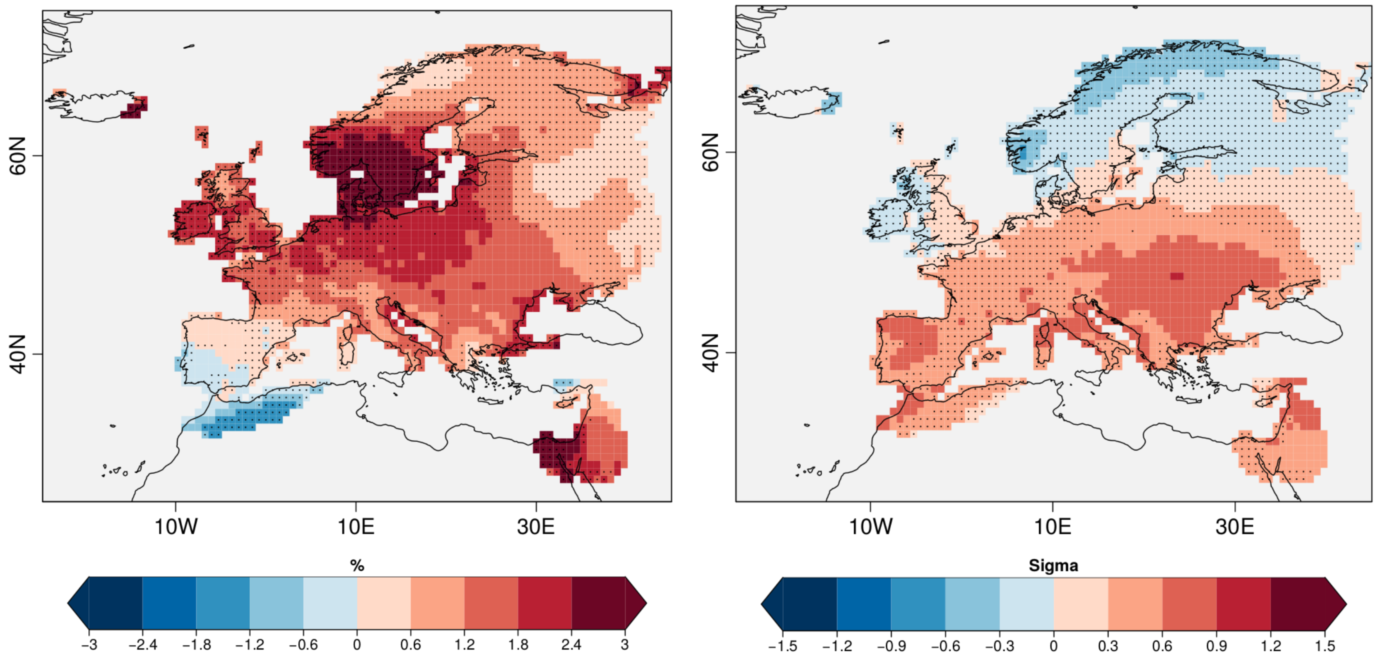


Fig.3. Left - observed 2018 temperature anomaly aggregated for 2 months (May, June) relative to the 1958-2017 average. The darker the red colour the higher the temperature as compared to the reference period. Right - composite of the temperature anomalies for 6 years with the lowest sea ice concentration in the Bering sea, relative to 1958-2017 average. The absence of black dots marks statistical significance ($p < 0.1$). Source: E-OBS gridded dataset (version 19). Credit: Ferran López Martí

A potential response to the preceding sea ice conditions is also found for precipitation (Fig.4). Here, the area where the precipitation changes coincide between the 2018 case and the average of the 6 low sea ice years is smaller than for temperature. In 2018, rainfall was unusually and unevenly spread across Europe, with Southern Europe having more rain than usual, and Northern Europe much less. Below-average rainfall in the northern part of the continent led to low hydropower generation. In Sweden, it was the lowest production in the last six years, and in Germany the lowest this century (Agora Energiewende and Sandbag, 2019).

Besides the reduced hydro potential, the drought in Northern Europe also caused river-cooled nuclear power plants to reduce their output. This is because the water used for cooling the reactors, when discharged to the river, is a few degrees warmer. The increase in temperature leads to more evaporation and has harmful effects on river ecosystems. Therefore during such drought conditions, the regulations require nuclear power plants to reduce their production, in order to minimise the discharge of warm waters. This is especially important for the Rhine river, which is already heavily thermally polluted due to the big number of thermal power plants on its shores.

As the Rhine river is a crucial transport route and its flow was reduced due to the drought, shipped coal deliveries to power plants were hampered as well. The shipping difficulties did not affect only coal deliveries, but all river transport of commodities such as grains, minerals, steel, and industrial goods. The drought started already in the winter months and prolonged into the spring and early summer, affecting much of central and northern European river levels. Therefore, a larger number of ships was needed to transport the same amount of cargo because each ship had to reduce its capacity to prevent getting stranded. This resulted in the waterways becoming more crowded and the freight rates in the Rhine and Danube rivers rising significantly. It also caused millions of tons of goods to be switched to road and rail transport. These conditions caused supply and production problems for many companies in Germany, France, Switzerland and the Netherlands that depend on the Rhine river for transport. These issues could have been better managed if such a dry period had been successfully predicted.

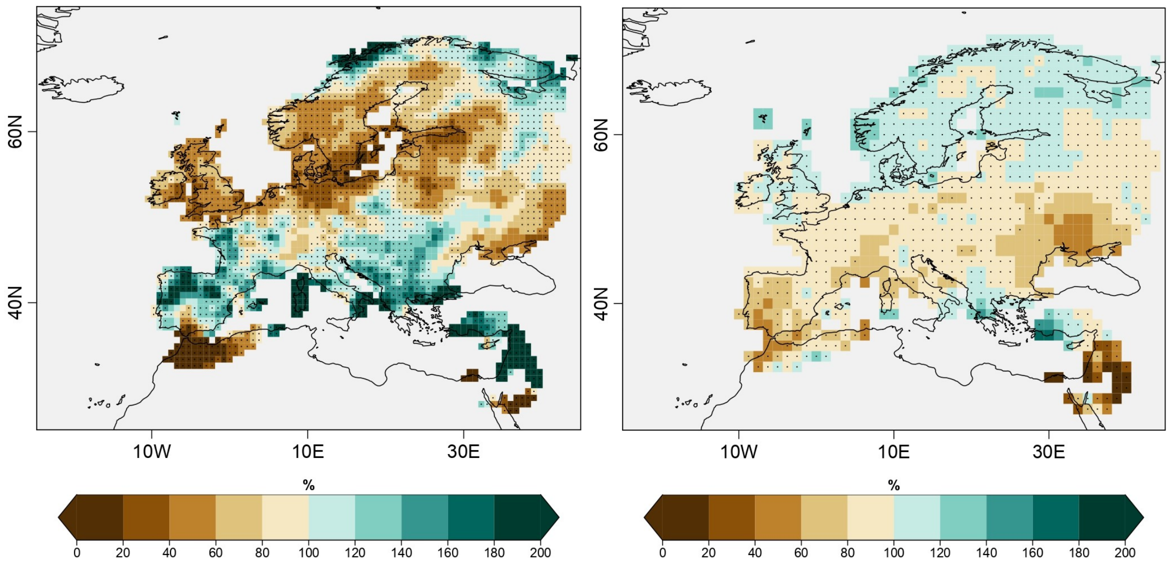


Fig.4. Left - observed precipitation anomaly aggregated for 2 months (May, June) relative to the 1958-2017 average. The darker the brown colour the lower the amount of precipitation as compared to the reference period. Right - composite of the precipitation anomalies for 6 years with the lowest sea ice concentration in the Bering sea, relative to 1958-2017 average. The absence of black dots marks statistical significance ($p < 0.1$). Source: E-OBS gridded dataset (version 19). Credit: Ferran López Martí

The final parameter affecting renewable energy generation was wind. February, April and the rest of the spring and early summer 2018 were less windy than usual. Consequently, there was a reduction in the capacity factors of the wind turbines. However, in this case the analysis could not prove a direct relationship with the low sea ice conditions in the Bering Sea. This is not surprising, as wind conditions are highly variable, and change substantially from one day to another, making it difficult to draw robust conclusions when analysing two or three month averages.

INTERESTING FACT
Despite the reduction in the capacity factors, the share of wind in Europe's total electricity generation for that year, rose by 2% compared to 2017 (bringing it to 14%), but this is in part due to the lower electricity demand at the time, as well as new turbine installations.

CONSIDERATIONS

Although a reduction of Arctic sea ice may impact precipitation, wind speed and solar irradiation, this is only one of the possible contributors, and not necessarily the main driver of the observed climate conditions. Other important components of the climate system, apart from sea ice, also affect European climate. However, the clear pattern identified in this APPLICATE case study, indicates that similar sea-ice situations can trigger similar atmospheric responses over Europe. Seasonal sea ice conditions can, hence, be an important source of information for European climate prediction, particularly in the case of extreme years.

OUTCOMES FROM THE CASE STUDY

The analysis performed in the APPLICATE case study shows that there is indeed a recurrent pattern of similar atmospheric conditions in certain regions for the years with a low sea ice concentration in the Bering sea. Even though this does not imply causality, it means that a relationship between sea ice concentration in the Bering Sea and atmospheric conditions in mid-latitudes exists. Thus, in the future, similar atmospheric responses can be expected over Europe in spring when a similar concentration of sea ice is observed in the Bering sea in winter. The exact physical mechanism linking the sea ice to the climate in the Eurasian continent is currently under investigation using the latest generation of climate models.

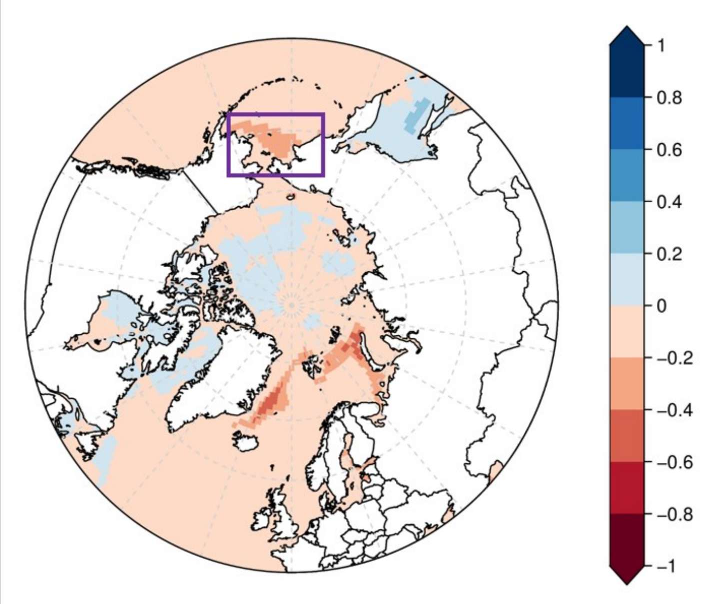
F

Seasonal Forecast:

Probabilistic climate prediction for different climate varibles, for the upcoming seasons.

INTERESTING FACT

Besides observations, we can also use predictions of sea ice. The figure on the right is an example of a *seasonal forecast* G of sea ice concentration for February to April 2018. The forecast was initiated in January 2018. The anomalies were computed using climatology in the 1981-2016 period.
Source: ECMWF SEAS5
Credit: Verónica Torralba



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