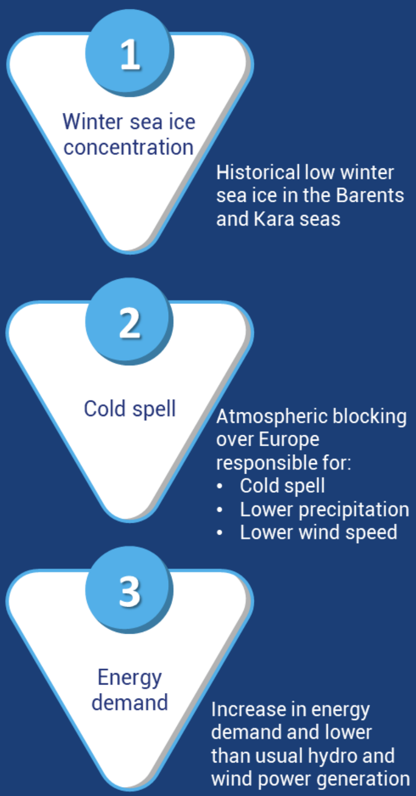
APPLICATE.eu
Advanced prediction in polar regions and beyond

ENERGY CASE STUDY

Effects of Arctic sea ice on energy production in mid-latitudes



CHAIN OF EVENTS

1. Historical low sea ice concentration in the Barents and Kara (BK) seas.

During November and December 2016, extreme warm temperatures were observed in the Arctic. As a result, the total Arctic sea ice extent experienced a historical low value, with negative anomalies[A] in most of the Arctic, but especially strong in the BK seas (Acosta Navarro et al. 2018). According to existing records, a breakpoint in sea ice loss (i.e., an accelerated decline) over the BK seas took place in the early 2000 (Close et al. 2015). In the last decade several studies have found causal links between low Arctic sea ice cover in the late autumn and extreme climate anomalies in the following winter in mid-latitudes (Cohen et al. 2014, Screen et al. 2018). In the framework of the APPLICATE project, retrospective forecasts[B] with the EC-Earth3 climate model (Doblas-Reyes et al. 2013) were performed to attribute the role of extremely reduced Arctic sea ice conditions (mostly over BK) with regard to the extremely low precipitation event in Europe in winter 2016-2017 (Acosta Navarro et al. 2018; see Fig.1).

A

Anomaly: difference between the sea ice extent, area or concentration at a given time and the long-term average. When it is negative, an anomaly indicates there is less ice than average for a given month.

B

Retrospective forecast: refers to a forecast made for a period of the past using only information available before the beginning of the forecast.

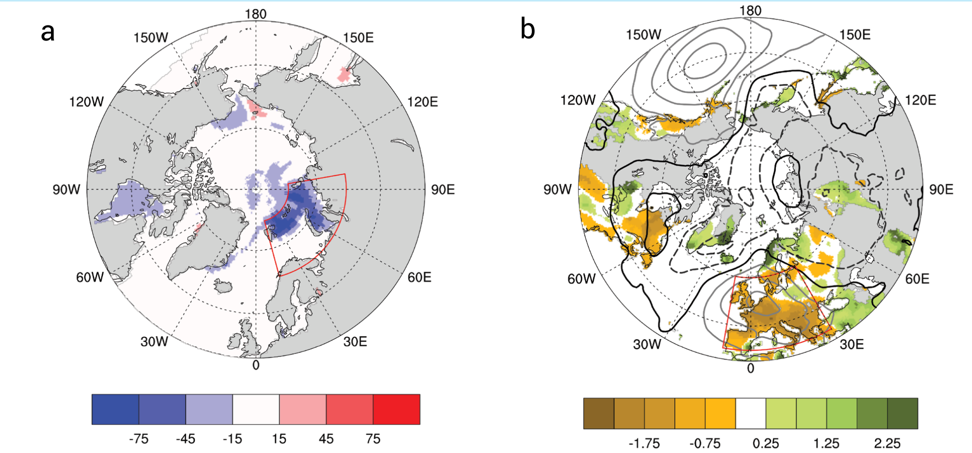


Fig.1. (a) Sea ice concentration anomaly for November-December 2016 relative to the average for 1980-2015. The darker the blue color, the lower the sea ice concentration in 2016, as compared to the period 1980-2015. The red box represents the Barents-Kara region. (b) December 2016 standardized anomalies[C] of total precipitation (colors) and sea level pressure (contours). The darker the orange color, the lower the precipitation in 2016 as compared to the period 1980-2015. Regions with mean precipitation below 1 mm day-1 were excluded. *Source:* observations of monthly mean sea ice concentration 1980-2016 (Cavalieri et al. 1996), observations of European monthly mean precipitation 1901-2016 (Haylock et al. 2008, Harris et al. 2014) and ERA-Interim sea level pressure 1980-2016 (Dee et al. 2011). Credit: Acosta Navarro et al. 2018.

C

Standardized anomaly: refers to the typical variability of a variable and provides useful information of the extreme nature of that variable. Values higher than 1 or lower than −1 only occur 32% of times, while values higher than 2 or lower than −2 are even more unlikely, occurring only 5% of the times.

D

Atmospheric blocking: describes a stable configuration of the mid-latitude atmospheric circulation that yield periods of extreme weather anomalies in large regions ranging from weeks to months. Such situations can lead to heatwaves or cold spells, that can have strong impacts on human activities and health.

2. Atmospheric blocking over Europe.

Cold events in winter are often associated with atmospheric blocking episodes[D] that typically bring cold temperatures, low precipitation and weak wind speeds over the continents. During the particular case of December 2016, a high pressure blocking pattern developed over Europe and led to the lowest total precipitation amount since 1901 (Acosta Navarro et al. 2018). December 2016 was also among the least windy winter months of the last three decades (Vautard et al. 2017).

These anomalies in wind and precipitation were persistent and could be detected over western Europe from December to February 2017, with only one very short interruption (Pechlivanidis et al. 2018). By the third week of January, an abrupt decrease in temperature was detected over northern France, Ireland and the UK, lowering weekly mean temperature close to 0ºC (Fig.2). Such values are very infrequent and represent an extreme expected to occur less than once every 10 years.

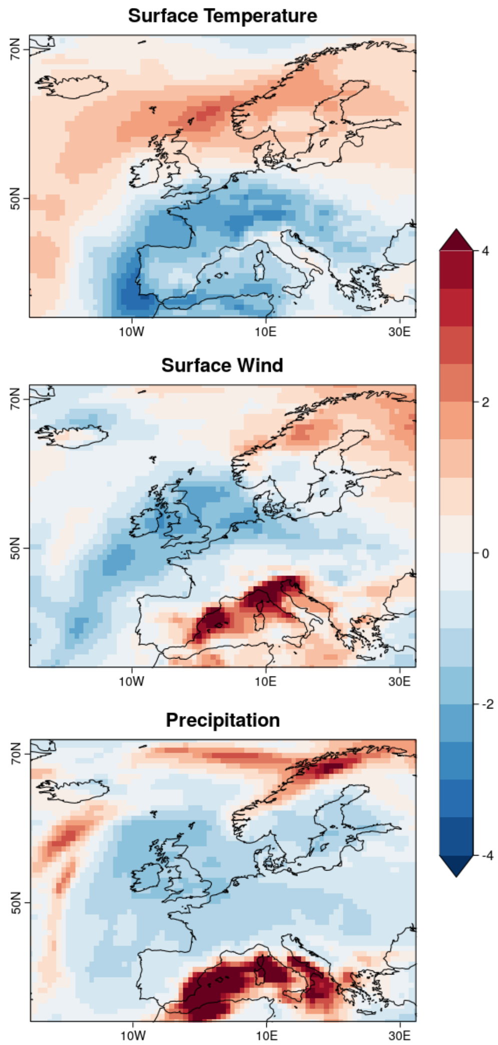


Fig.2. Temperature, precipitation and wind speed anomalies in the third week of January 2017 (17-23 Jan) relative to the average for 1980-2015. Source: ERA-Interim reanalysis. Credit: Pechlivanidis et al. 2018.

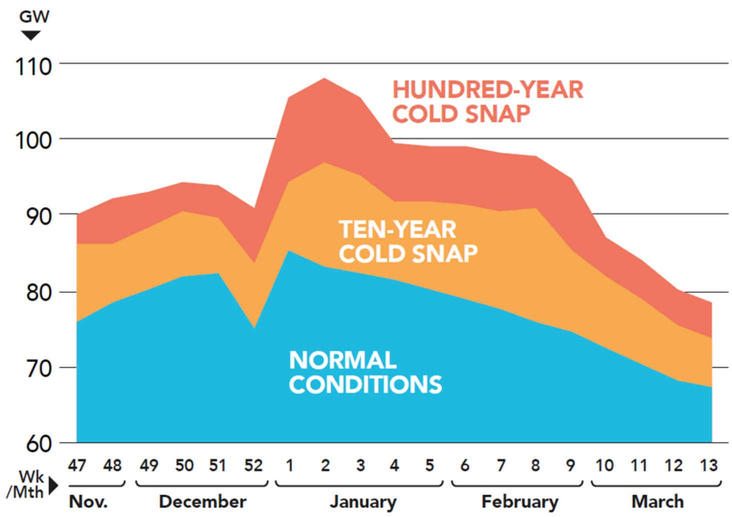
3. Increase in energy demand and lower than usual hydro and wind power generation.

While the cold spell increased energy demand for heating, climatic conditions were not favourable for wind and hydropower generation, which were reduced by the low precipitation and wind in the preceding months. Increase in the demand was especially important in France, where most of the domestic heating systems feed on electricity. Under normal weather conditions for the season, peak demand in France reaches 85 GW in January (RTE 2016).

However, temperature in the third week of January 2017 was 6ºC below normal conditions, an extreme event that only occurs once every 10-years (10-year cold snaps in Fig.3). According to RTE estimates, every 1ºC drop nationwide causes demand to increase by up to 2,4 GW (equivalent to the amount of power consumed in central Paris). Electricity consumption peaked at 94 GW at 7pm on 20 January. This was the third highest peak ever recorded in France (RTE 2017).

The aforementioned climatic situation found France with several nuclear power plants offline, largely for exceptional maintenance and inspection. The cold spell together with the nuclear shutdown created an energy-security risk that required restrictions and energy imports from neighbouring countries (ENTSO-E 2017).

Fig.3. Peak electricity demand (GW) for winter 2016-17 in France distributed according to weeks (Wk) and months (Mth) of the year. The event recorded in the third week of January corresponded to a (once in) ten-year cold snap/cold spell occurrence (orange area). This demand is compared to demand under normal conditions (blue area). Credit: RTE 2016.



Insights from the year 2016 forecasts

The EC-Earth 3.2 model was used in forecast mode to investigate its ability to predict the overall climate conditions around the 2016 event. A first set of forecasts initialized from the observed initial state on the 1st of November 2016 was able to predict with qualitative realism the sea level pressure and precipitation conditions that were observed over Europe in December 2016 (Fig. 1b). These forecasts were then compared with a second set that was initialized from sea-ice conditions representative of the typical climatological state, and the real observed ocean and atmospheric state on the 1st of November 2016. This comparison allowed to single out the specific contribution that the sea ice played over Europe and its predictability, providing evidence that the extremely low sea ice conditions over the Barents and Kara Seas favoured the occurrence of the extreme low precipitation over Europe.

CONSIDERATIONS

Although a reduction of Arctic sea ice may impact precipitation and wind speed over Europe, this is only one of the possible impacts. Other important components of the climate system different from sea ice also affect European climate. In addition, it is important to note that Arctic sea ice impacts over other seasons might be radically different. APPLICATE will give some answers to these considerations through the analysis of additional events that provide new insights.

STAKEHOLDERS

The S2S4E project (Sub-seasonal to seasonal climate predictions for energy) has conducted interviews with various users from the renewable energy sector. Respondents were invited to think about anomalies that were of particular interest to them. As a result of these interviews, the project identified eight relevant case studies presenting different experiences that users had to manage. Energy producers in France and Germany identified the case of the cold spell in winter 2016-17 as a relevant event. Likewise, another extreme event was identified in winter 2017-18, leading to very low temperatures across Europe with effects on the increase in energy consumption dependant on the particular location of the assets.

OUTCOMES FROM THE CASE STUDY

The analysis of this event suggests that a high reduction of Arctic sea ice may have favored a record-breaking low precipitation and wind speed over parts of western Europe. With this case study, APPLICATE contributes to understand the linkages between the Arctic and mid-latitudes. Once these linkages are well-established and understood, future forecasts of extremely low sea ice extent (that also relate with forecasts of electricity demand and power generation) could be potentially valuable for adaptation and for assessing the risk for the European energy systems. The Polar Amplification Model Intercomparison Project (PAMIP)[E] has a dedicate experiment that will be used to address this link in a very systematic manner.

E

PAMIP: coordinated set of numerical model experiments that seeks to improve our understanding of the polar amplification phenomenon, a key aspect of anthropogenic climate change that is responsible for a larger change in surface temperature at high latitudes than the global average.

Find more information on PAMIP in Smith et al. (2019)

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Acknowledgements

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