CASE STUDY: INFLUENCE OF ENSO ON ARCTIC CLIMATE

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Focus: Hydro-Meteorological hazards

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1. SUMMARY:

One of the most important climatic phenomena on Earth is the El Niño/Southern Oscillation due to generate impacts around the world. Recent studies have found that ENSO - through teleconnections - also has an impact on the Arctic variability modes, such as the North Atlantic Oscillation and the Quasi-Biennial Oscillation, that again have an impact on the Jet Streams and the Polar Vortex. However, the magnitude of the impact through these teleconnections has not been modelled in a realistic way yet**.**

This case study outlines the potential impact of ENSO on the Arctic, through teleconnections and makes a case for increasing knowledge in this topic. It also identifies potential stakeholders that would be interested in potential products like an early warning system for extreme weather as winter storms, sea ice drift, so on.

2. EL NINO SOUTHERN OSCILLATION (ENSO)

One of the most important climatic phenomena on Earth is the El Niño/Southern Oscillation, which affects the ecosystem and human societies [NOAA 2015, EnsoEco]. An increased Sea Surface Temperature (SST) in the equatorial Pacific is called El Niño, whereas El Niña describes a lower SET. These changes of SST are linked to global atmospheric and oceanic circulation (see Figure 1), besides it can cause extreme weather events around the world through teleconnections in the stratosphere (see Figure 2).

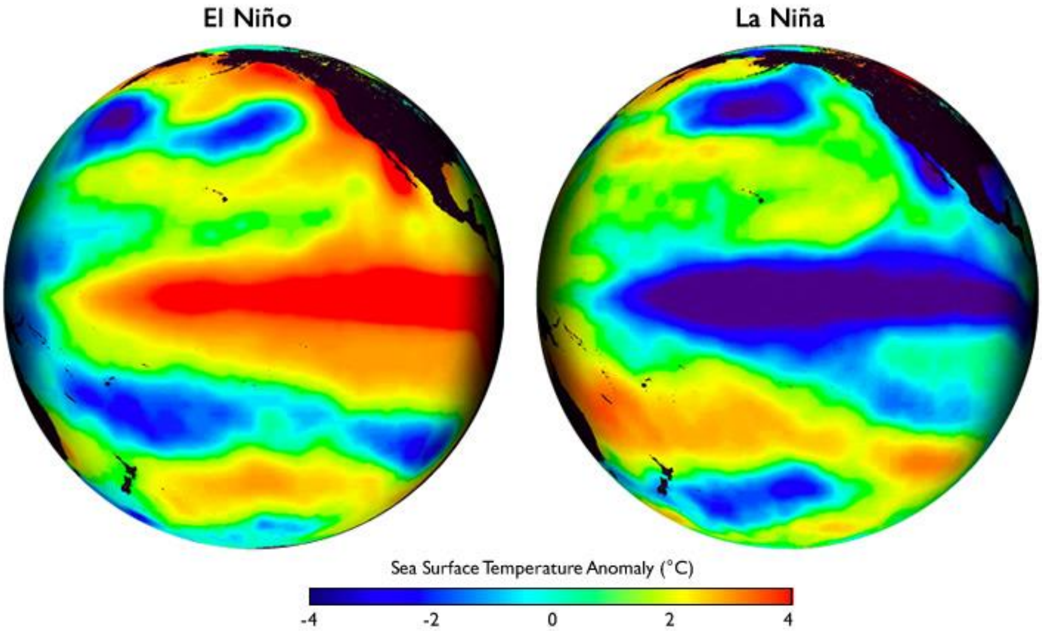


Figure 1: Global maps on the Pacific Ocean show patterns of sea surface temperatures during El Niño and La Niña episodes. Credit: IRI

3. IMPACT OF ENSO

El Niño or la Niña impact are associated with wet and dry events across the world, for instance in South America it generates heavy rainfalls in the coast and dry conditions in the Andes, generally extreme weather that could affect the food security, transport, and so on. On the other hand, recently scientist found the ENSO also has an impact through the stratosphere (see Figure 2).

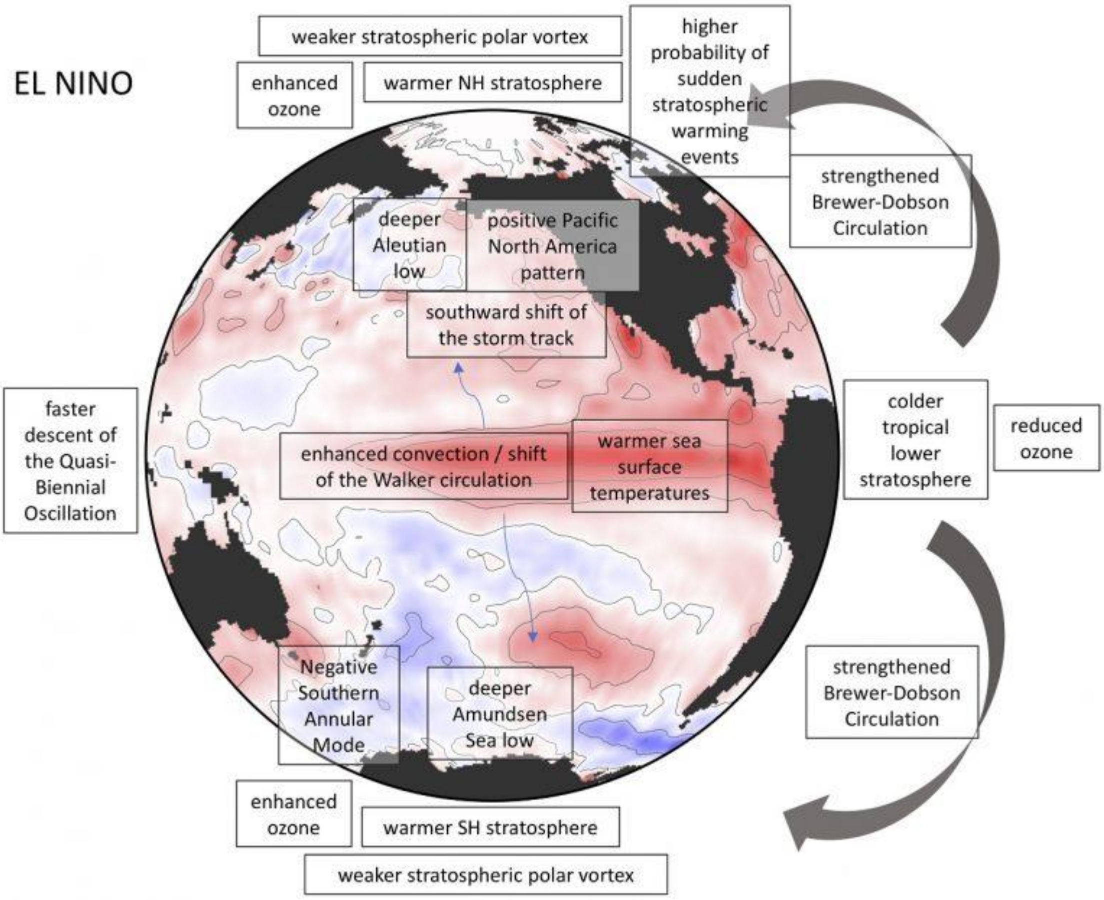
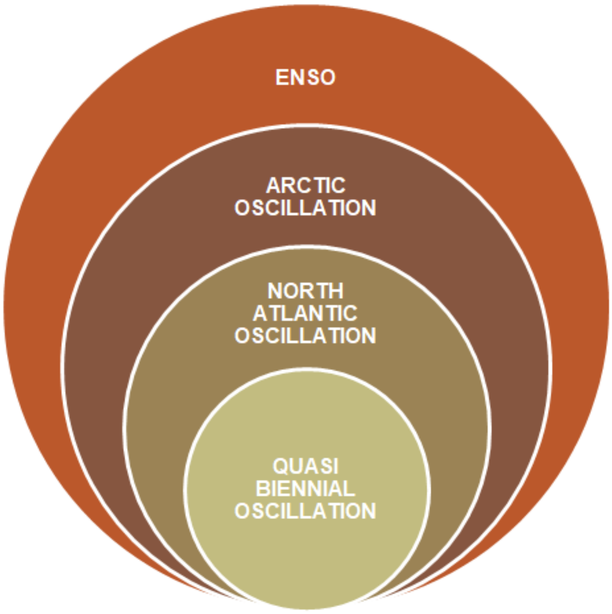


Figure 2: Global impacts in the stratosphere during El Niño events. [Domeisen 2018]

4. ENSO AND THE ARCTIC CLIMATE



a. ARCTIC OSCILLATION AND ENSO

The climate pattern in the Northern Hemisphere is influenced by the Arctic Oscillation (AO): In its positive phase, the AO tends to distribute colder air within the polar region, while in its negative phase, winter storms extend to mid-latitude regions. The swings of the Arctic Oscillation also help control sea ice drift in the Arctic Ocean, leading to year-to-year variability in climate indicators like the Arctic sea ice cover [NSIDC 2012]. In the positive phase, winds are pushing much of the old, thicker sea ice out of the Arctic along the Greenland coast, whereas in the negative phase, this older sea ice is moved and retained within the Arctic. Younger and thinner sea ice is more prone to melt [NSDIC-AO].

> *Walt Meier, NSIDC scientist, noted that the AO is not a sole actor—it works in concert with other large-scale patterns to influence the weather. He said, "The heavy snowfall the last couple years were related to the AO as well as La Niña"* [NSIDC 2012]

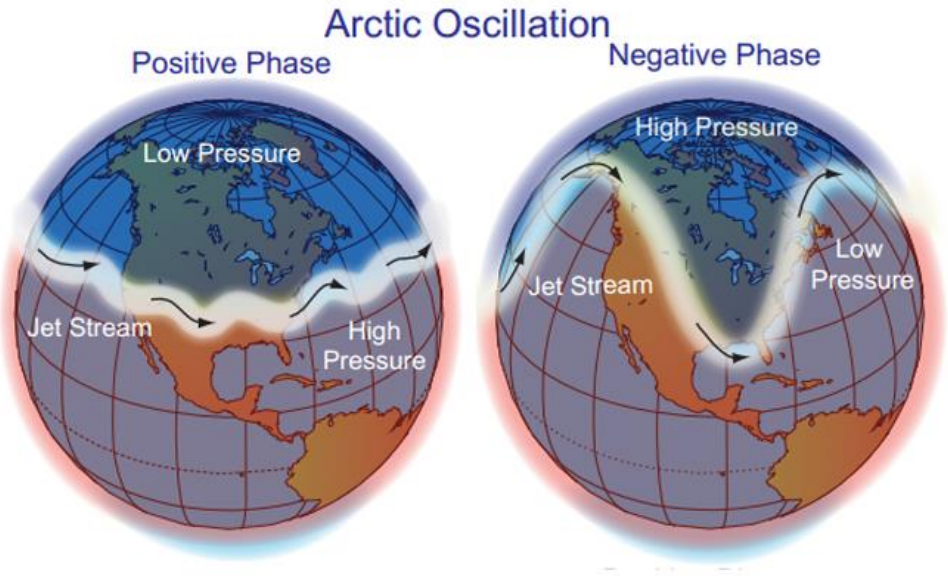


Figure 3: The Arctic Oscillation in its positive and negative phase. Credit: NOAA and NCDC

L'Heureux et al. [HeureuxENSO-AO] state that the strong relations between ENSO and the AO indicate that a part of the predictable signal associated with the AO depends on ENSO, especially at longer lead times. Understanding the skill and predictability of the AO is critical to improving middle- to high-latitude climate outlooks.

b. NORTH ATLANTIC OSCILLATION AND ENSO

The NAO "refers to swings in the atmo-spheric sea level pressure differences between the Arctic and subtropical Atlantic" causing variations in ocean temperature, currents and ocean heat content, as well as variations in precipitation, air temperature and sea ice cover in the Arctic and sub-Arctic, especially in the winter months" [Lifland 2003].

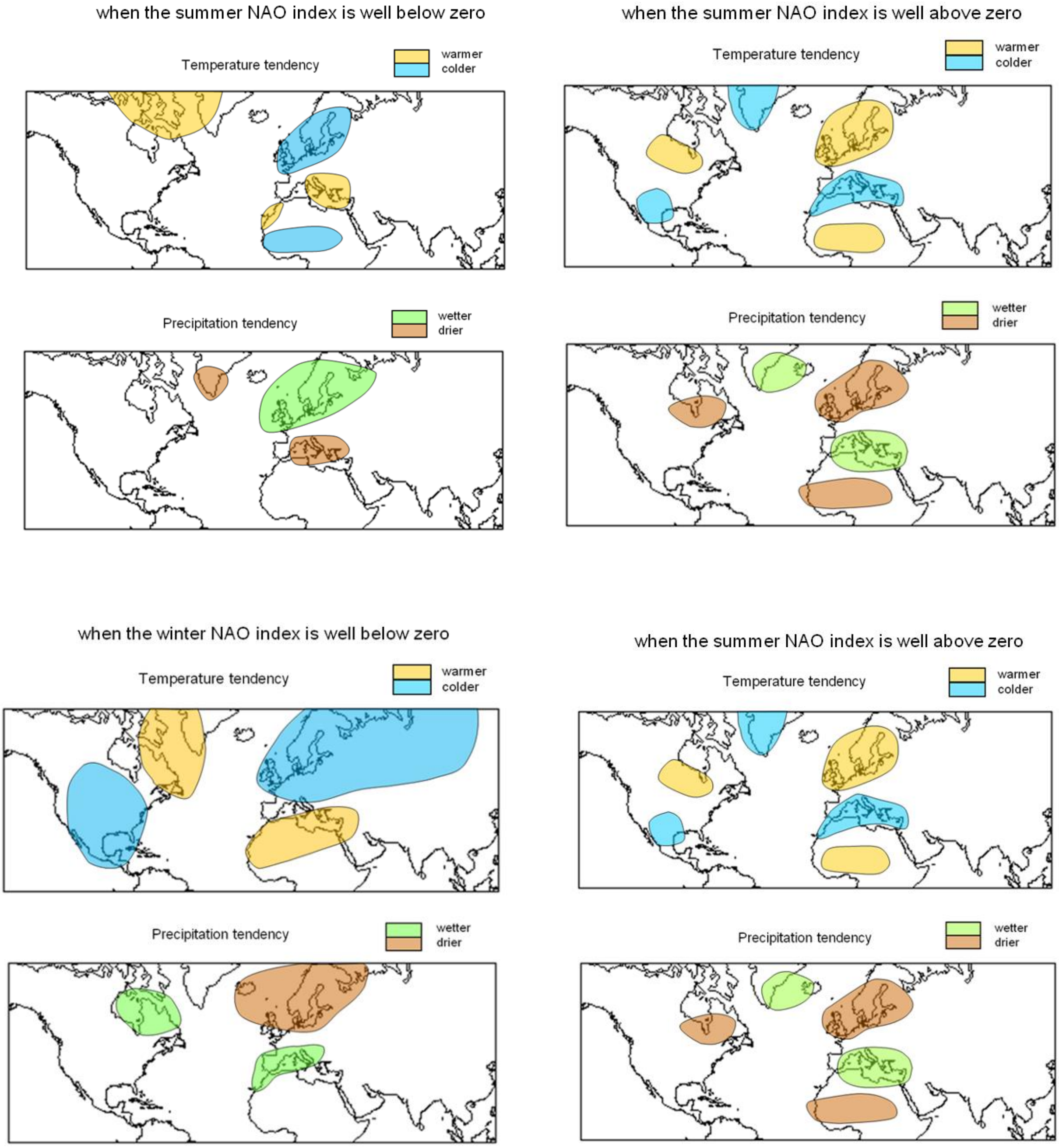


Figure 4: Consequences (obs: schematic) of different winter NAO patterns [MetNAO]

A positive NAO, i.e. a reduction in atmospheric pressure in the North Atlantic, in the summer leads to warming sea around Greenland and North America and a regional rise in sea level due to the 'inverted barometer effect' [ibeGlossary]. Despite the NAO having such a significant impact on Arctic temperatures, wind patterns, ocean currents and sea ice cover, it is still not understood completely which climate processes are governing NAO variability or how it has varied in the past, which also makes it hard to say to which extent it is predictable [Lifland 2003].

To address this issue, better comprehension of the effects on the Arctic of the North Atlantic Oscillation are needed, including a better understanding of its coupling to the Atlantic Multidecadal Oscillation (AMO) and the El Niño Southern Oscillation. The connection between these three factors are often well-visible in climate models (e.g. [HeureuxENSO-AO]). However, the quantification of the climate models does not correspond well to the actual observations. Improving the connection between these factors by themselves, based on actual observations, may be a better measure for predicting extremely high NAO events.

On the other hand, there also seems to be a feedback from NAO to ENSO, which can be observed looking at the coupling between sea surface temperature anomalies and air temperature and variations in salinity leading to changing flow patterns. Another topic that may be relevant in this context is the response to NAO in the troposphere and stratosphere. Here, there has not been carried out a lot of research yet. Models and data describing flow patterns here, would give a more integrated picture of the connections between the phenomena.

Sea surface temperatures for the Arctic can partly be measured through satellite imagery, the same applies for wind patterns (e.g. Aeolus). An improved coverage of the Arctic region would, however, be profitable for quantifying the previously mentioned phenomena. To better assess the flow patterns of the sea and investigate the ecological feedback, a thorough dataset of bathymetry (seafloor mapping) of the North Atlantic would also be of interest, both looking at flow patterns, but also to map coral growth etc.

Looking at climate change, it would also be interesting to investigate how anthropogenic climate change is coming into the picture, which again would encourage stakeholders to take concrete measures [Lifland 2003].

c. ENSO AND QUASI-BIENNIAL OSCILLATION

The quasi-biennial oscillation (QBO) is the dominant mode of stratospheric variability with a period of 22–36 months. It oscillation is characterized by alternating easterlies and westerlies descending from ~1 hPa (~50 km) to ~100 hPa (~16 km) and has been observed to occur in a very similar manner for several decades [Baldwin 2001].

The ENSO affects the stratospheric circulation.Taguchi [2010] mentioned ENSO impacts zonal wind in the tropical lower stratosphere: The wind anomalies associated with the QBO propagate downward more rapidly during El Niño than during La Niña. it is likely that ENSO modulates the waves generated within the troposphere that then propagate up and drive the QBO [Domeisen 2019].

In February 2016, the QBO was disrupted at the same time a very strong Niño and low Arctic sea-ice concentration in the Barents and Kara sea were present [Hirota 2016]. It suggests that all is connected and the cause could inverse.

On the other hand, continue with the stratosphere, the polar vortex. It could be perturbed when large-scale atmospheric waves from the lower atmosphere travel up into the winter stratosphere. When the vortex breaks down, there is an event called a major “sudden stratospheric warming" (SSW), it causes an increase in temperature (~50-70 degrees F in a few days) over the polar stratosphere during these even [Butler et al 2015].

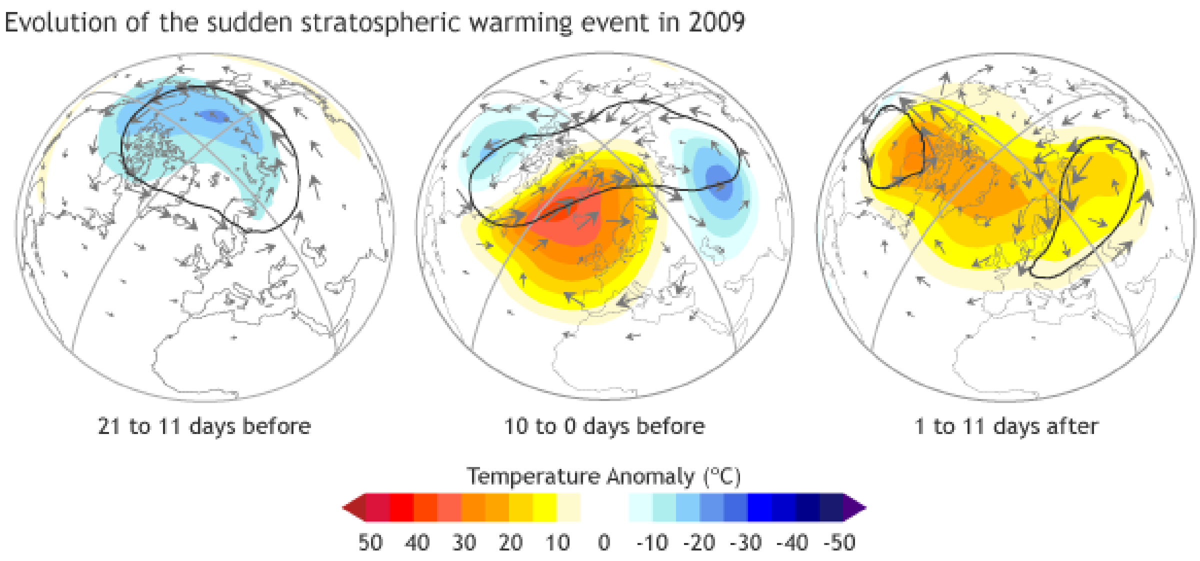


Figure 5: The evolution of a polar vortex collapse in January 2009. Prior the event, the vortex is nearly circular and temperatures are cooler than normal (left). The vortex elongate and temperature warm rapidly (middle). The vortex split in two pieces (right). Credit: NOAA

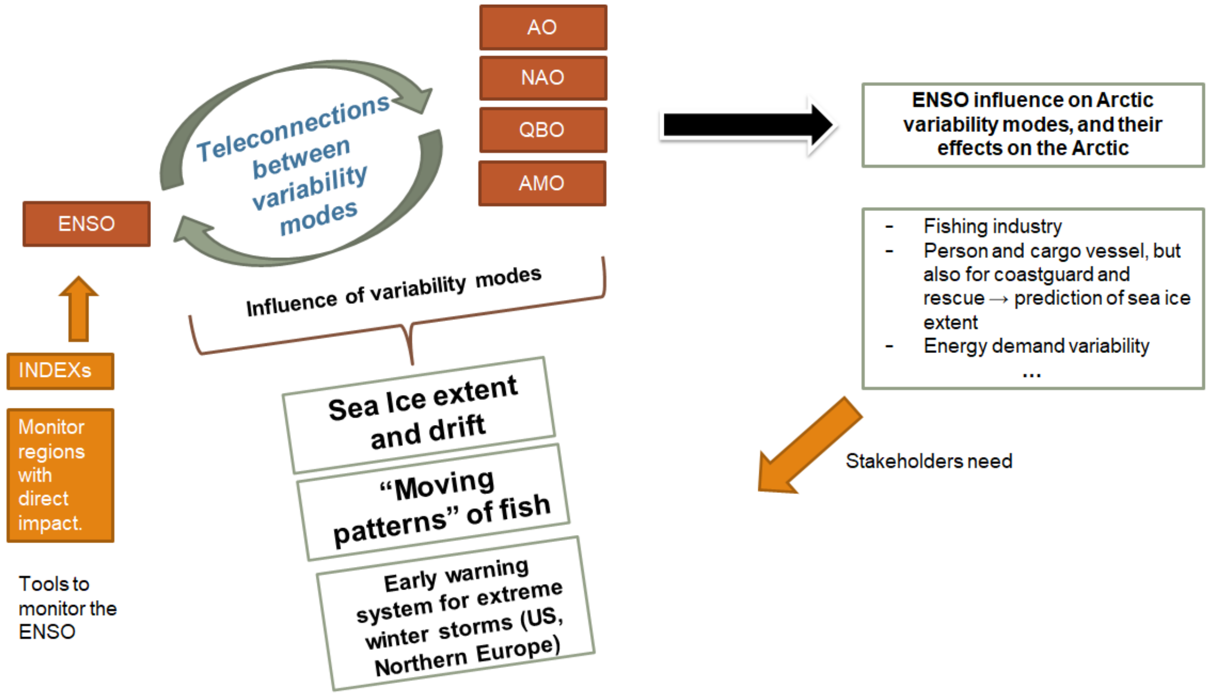
d. UNDERSTANDING THE (TELE-) CONNECTIONS

The climate Arctic could be affected not only by one factor but rather by a combination of several factors, in that case study we want to show how the ENSO is related with the other variability modes (e.g. AO, NAO, QBO) therefore how these teleconnections could affect the Arctic climate. To achieve it we need to aim for:

- Better comprehension of the effects on the Arctic of the North Atlantic Oscillation are needed, including a better understanding of its coupling to the Atlantic Multidecadal Oscillation (AMO) and the El Niño Southern Oscillation.
- Extended knowledge about the impact of ENSO on the Arctic and what is the relation with the other variability modes. Besides, it is important to consider the flavours of El Niño because each one could have different effects.
- Improvement of the forecast of the variability modes and to explore the climate forecast models to know if the relation is recognized or not, with the objective to have better seasonal and interannual forecast.
- Investigation of the impact of extreme ENSO and the modes patterns on the ecosystem to improve the ability of good policy making to preserve a good environment.

Improving knowledge about teleconnections is also one of the topics mentioned in the YOPP modelling plan [YOPP-RP]: Here, a collaboration with the initiative on "Tropics-Midlatitude Interactions and Teleconnections" is mentioned as an opportunity. There will also be carried out relaxation experiments to examine the teleconnections between polar and lower latitudes in a modelling context, and a Polar Amplification Model Intercomparison Project comparing both atmosphere-only and coupled atmosphere-ocean-ice models.

5. WHY IS THIS RELEVANT AND HOW COULD RESEARCH SUPPORT DECISION-MAKING?



In a context of climate change, the frequency of El Niño will be increasing and can therefore impact on the variability modes (section 3) and extreme weather around the world, including the Arctic. Currently, it remains unclear which is the reach of El Niño/ La Niña in the Arctic climate or how the variability of Arctic ice is affecting the global climate.

Biodiversity will be affected by climate change. For instance, Cod larvae can not survive in warmer sea temperatures, a warmer Arctic does impact the population of cod which is important for the local fishing industries [Brockstedt 2019]. It is also talked about that a tipping point is going to be reached, leading the fish population to move northwards [ArcticFish, NewscienceCod], or simply disappear.

Possible adaptation measures as response to better prediction could be to introduce more strict fishing quota in the years where a weaker Niño (and thus a stronger North Atlantic Oscillation) is to be expected.

The extreme weather and climate variability in the Arctic will also impact the energy demand in specific regions due to the warming/cooling variability caused by the NAO.

Sea-ice cover is an important factor for maritime navigation; a better predictability of sea ice extent and spatial distribution would thus also support a more efficient planning for safe and efficient transportation routes, e.g. for cargo and passenger vessels [Copernicus].

Improving the climate prediction, we could support the adaptation measures, for example, establish early warning systems to the Arctic when meteorological or hydrological hazards caused and intensified by one or more variability modes occur. This way, we could stay prepared for the hazard, extreme weather and their consequences on sea and land ice.

6. Bibliography

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