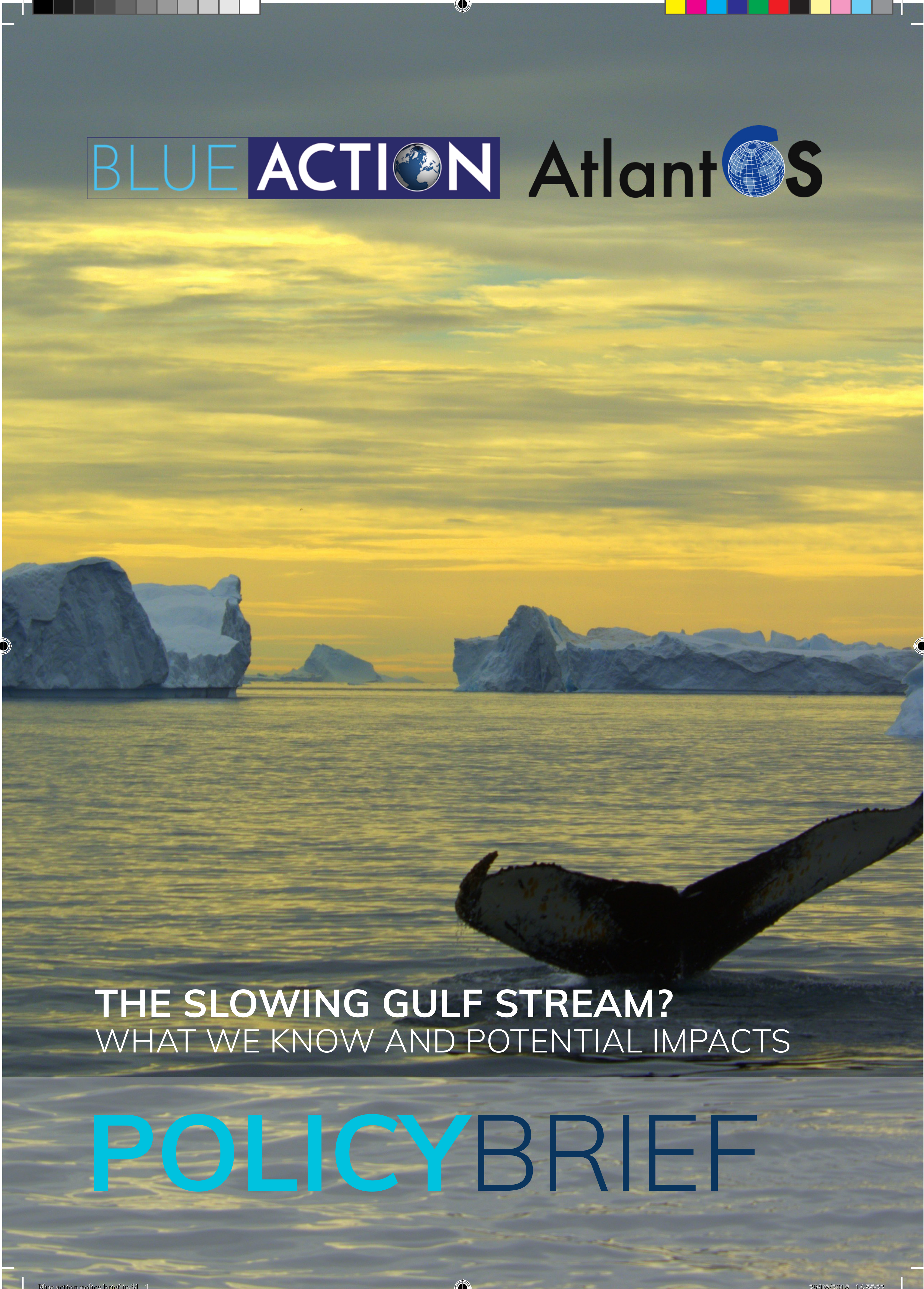

THE SLOWING GULF STREAM?

WHAT WE KNOW AND POTENTIAL IMPACTS

POLICYBRIEF

ABOUT BLUE-ACTION:

Blue-Action aims to improve our ability to describe, model, and predict Arctic climate change and its impact on Northern Hemisphere climate, weather, and their extremes, and to deliver valuated climate services of societal benefit. Blue-Action contributes to the implementation of the Trans-Atlantic Ocean Research Alliance, to the EU's Blue Growth Agenda, and to a long-term strategy to support sustainable growth in the marine and maritime sectors as a whole. Blue-Action supports the implementation of the Galway and the Belem Statements and the achievement of UN SDG 8, 9, 13.

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- The North Atlantic Ocean has a significant influence on Europe's weather and climate. This is related to the sea surface temperature and heat transported by ocean currents.
- Recent research suggests that we could use our understanding of the North Atlantic Ocean to predict winter temperatures in Europe and Arctic sea ice extent 5-10 years in advance.
- To improve predictions of weather and climate in the future, and to better understand how climate change could affect Europe, we must continue to pursue trans-national research that links oceanography, climate and atmospheric sciences.
- Early-warning indicators for approaching climate impacts, fit-for-purpose ocean observing systems, and development of mitigation strategies should be prioritised.
- Investments in ocean and atmospheric sciences are essential to Europe's global leadership in weather and climate science and for safeguarding regions and communities from the risks posed by a changing climate.

It is becoming increasingly apparent that Europe's climate is linked to the physical characteristics of the Atlantic Ocean. The Gulf Stream is an ocean current that forms part of the Atlantic overturning circulation. It transports heat northwards from the tropics, and is largely responsible for the relatively mild climate of Western Europe. A reduction in overturning circulation could lead to lower temperatures in the North Atlantic Ocean, which would affect the climate in Europe.

However, the pathways and processes that govern the link between Europe's climate and the North Atlantic Ocean are not well understood. This makes it challenging to accurately predict weather and climate outcomes for Europe months or decades in advance. By observing and understanding how Atlantic overturning circulation varies naturally, we should be able to extend our prediction horizon for weather and climate in Europe.

Why is this important?

Skilful predictions of weather and climate offer many benefits to society. They can help businesses plan for future weather and climate risks to their operations, enable new business sectors to develop, help governments plan for weather- and climate-related risks to infrastructure and human health, and inform policymakers to govern in ways that help societies to adapt to forthcoming climate changes and impacts.

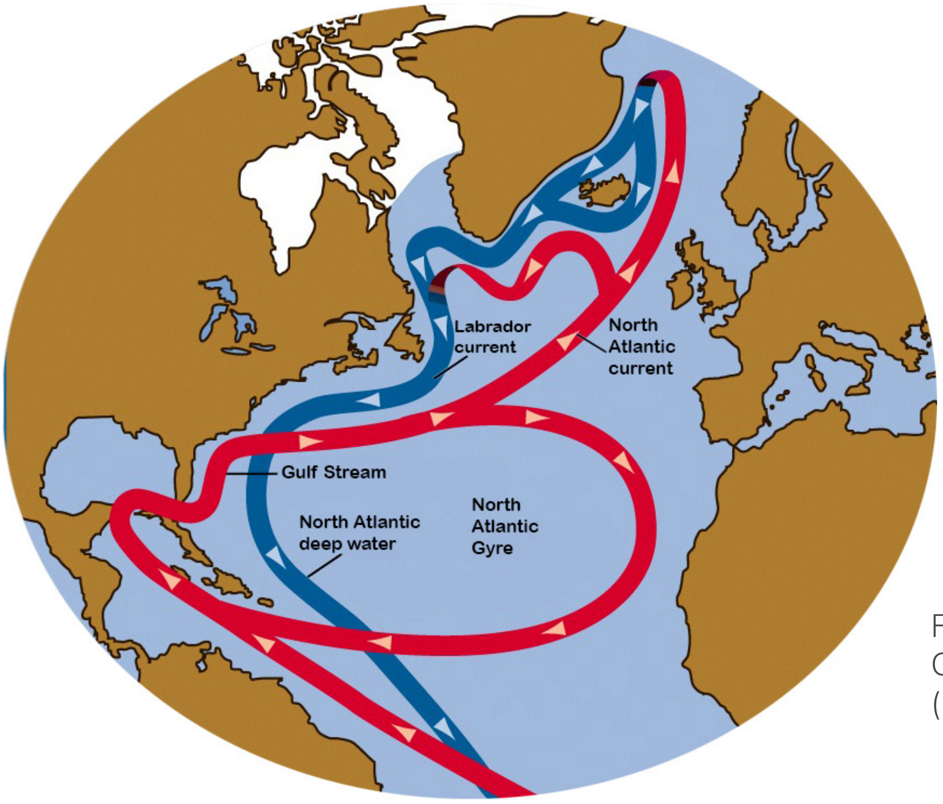


Figure 1: North Atlantic Overturning Circulation. (Image: ESA eduspace)

The Challenge

While the link between Atlantic Ocean temperatures and the European climate is clear, the pathways and processes that control this link are not. Two key knowledge gaps are:

- Understanding how and why the Atlantic overturning circulation has changed over time, and how it will change in the future
- Understanding the processes that link ocean temperature with European climate, and how they will change in a warming world

Global warming is shifting the planet's water cycles, accelerating glacier and sea-ice retreat, and increasing melting of the Greenland Ice sheet. There has been some speculation that circulation in the North Atlantic Ocean could reach a 'tipping point' in response to these changes, and that the heat- and salt-related component of the circulation could slow or shut down. Such a slowing or shut down could have a substantial impact on the weather and climate in Europe. It is imperative that we better understand these ocean and atmospheric processes to quantify the risks of change, and to develop early-warning indicators and fit-for-purpose ocean observing systems.

Blue-Action is supporting scientific research and transatlantic cooperation to assess how the physical conditions in the North Atlantic Ocean govern the weather and climate in Europe. As an important transporter of heat northwards, and the cause of Europe's relatively mild climate, the stability of the Atlantic overturning circulation is of particular interest.

Measuring the Atlantic overturning circulation

As part of the Global Ocean Observing System, international programmes are measuring overturning circulation in the North Atlantic Ocean, supported in part by Blue-Action and other EU programmes. Transport mooring arrays measure changes in overturning circulation over time, and enable researchers to identify and understand the physics of ocean circulation. Climate model development depends on the understanding derived from these observational studies. Blue-Action researchers are observing the overturning circulation at 26°N (the RAPID array, www.rapid.ac.uk, since 2004), at 57°N (the OSNAP array, www.o-snap.org, since 2014), and at other areas including the Greenland-Scotland Ridge (Figure 2).

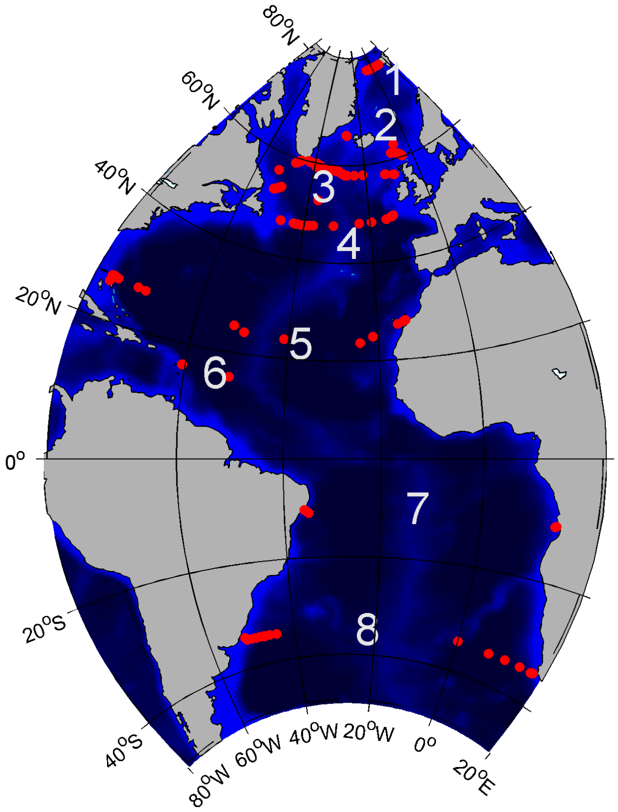


Figure 2: Transport mooring arrays installed in key locations in the Atlantic represent an important part of the Atlantic observing system. These arrays measure long time series of volume, heat, and freshwater fluxes in locations of strong flows.

Image: AtlantOS/OceanSITES

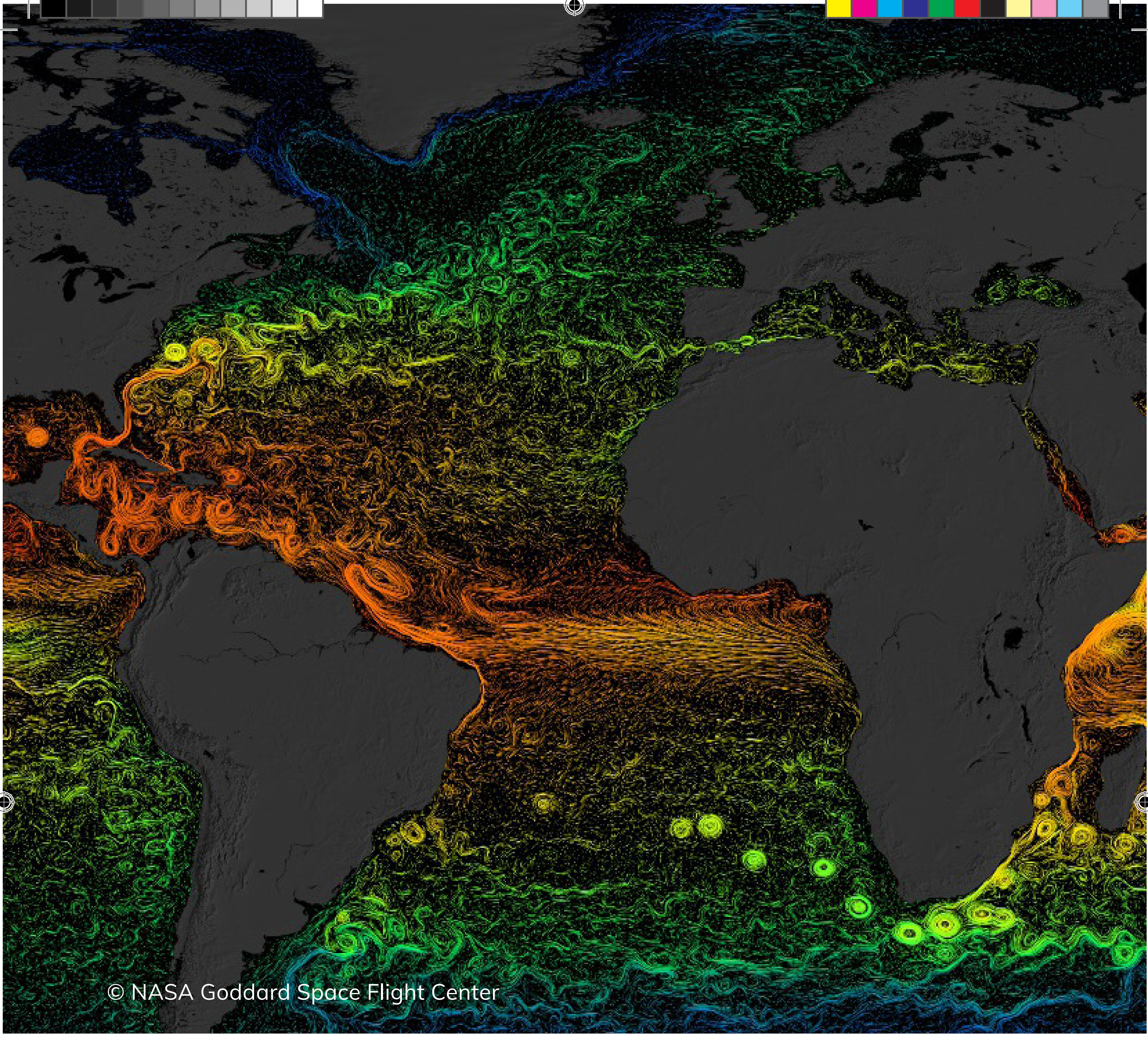
(1) Fram Strait.
(2) Greenland Scotland Ridge.
(3) OSNAP Overturning in the Subpolar North Atlantic Program.
(4) NOAC North Atlantic Changes.
(5) RAPID-MOCHA-WBTS Rapid Climate Change Meridional Overturning Circulation Heat-flux Array Western Boundary Time Series.
(6) MOVE Meridional Overturning Variability Experiment.
(7) 11˚S.
(8) SAMBA-SAMOC South Atlantic Meridional Overturning Circulation.

Is there a slow-down in Atlantic overturning circulation?

A slow-down in Atlantic overturning circulation has been observed in some areas of the North Atlantic Ocean, but not in others. For example, data from the array of instruments spanning the Atlantic at 26°N suggest that the Atlantic meridional overturning circulation has been in a state of reduced overturning since 2008 as compared to 2004-2008. (Smeed et al, 2018).

The Nordic Seas are an important area for another part of the overturning circulation, and have a strong impact on the climate of North West Europe. The warm salty waters of this limb of the overturning circulation cross the Greenland Scotland Ridge separating the Norwegian Sea from the North Atlantic Ocean. Flows across this ridge have been observed since the mid 1990s, and show no long term trend in volume transports (Berx et al. 2013, Hansen et al. 2015), indicating that this branch of the overturning circulation is very stable (Olsen et al. 2008).

Ocean temperatures and salinities measured at the Greenland Scotland Ridge show large variability on inter annual to decadal time scales. Historically, these measurements have tended to vary together, but recently a sudden decrease in salinity was not reflected in recorded temperatures. This discrepancy could be an early indicator of changes in this part of the overturning circulation.



Warmer summers are increasing the risk of a shut down of ocean convection

The Labrador and Irminger Seas around Greenland are important areas driving the overturning circulation because this is where warm, salty Atlantic water mixes with colder, fresher Arctic water, and cools and sinks. There are signs that this mixing process is changing because of warmer summers that are characterised by increased sea surface temperatures, freshwater concentrations, and ice melt. In the subsequent winters, more heat is retained and surface water stays more buoyant, meaning that freshwater does not mix down into deeper water, delaying convection (Oltmanns et al. 2018). This build-up of freshwater on the surface may be amplified by melting of the Greenland ice sheet.

Research led by Blue-Action suggests that these processes could drive a slowing or shutdown of ocean convection in the subpolar North Atlantic (Oltmanns et al. 2018), one of the important drivers of the Atlantic overturning circulation. This could have substantial consequences for the climate of Europe.

Linking the North Atlantic Ocean to Europe's weather

By linking ocean and atmosphere, Blue-Action scientists and partners have, for the first time, assessed the causes of variability in air temperatures over Europe on a regional basis, over different timescales (Årthun et al. 2018). This provides a higher-resolution picture of the different processes and mechanisms influencing the weather in different regions. For example, we now know that the climate of Eastern Europe is dominated by 10 year patterns of variability in large-scale atmospheric circulation (known as the North Atlantic Oscillation). Meanwhile, the climates of Northern and Southern Europe vary on longer time scales, associated with North Atlantic Ocean temperature changes carried into the region by dominant westerly winds. As ocean temperatures in the North Atlantic are predictable several years in advance, European climate could also be predictable (Årthun et al. 2017).

Summary

To make progress in understanding how the ocean influences Europe's weather and climate we must combine observational programmes with model development. Observations of the overturning circulation have revolutionised our understanding of the physical processes and natural variability in the system. In the last 20 years, observations of the northern parts of the overturning circulation which flow between Greenland and Scotland suggest that circulation remains stable. In other locations, observations suggest a downward shift in the strength of the overturning circulation in recent years, which could be linked with climate change. Research led by Blue-Action suggests that warmer summers in the sub-polar North Atlantic could be contributing to changes in overturning circulation.

Looking forward

Our ability to provide regional predictions of anomalous or extreme temperatures for Europe is limited by current climate model technology. However, oceanographers are able to predict the surface temperatures of the North Atlantic Ocean up to a decade in advance, though crucially depending on adequate ocean observations. This suggests that by understanding how the North Atlantic Ocean temperatures influence the climate of Europe, we could extend our prediction horizon to up to a decade in the future. At even longer timescales, a better understanding of physical processes of the North Atlantic Ocean through observational programmes and model development will enable us to anticipate potential abrupt changes to ocean circulation and consequences for the climate in Europe.

This would enable communities, businesses, health services, and policymakers to plan and adapt to future changes in climate and weather years, if not decades in advance, to ensure future prosperity across the region.

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