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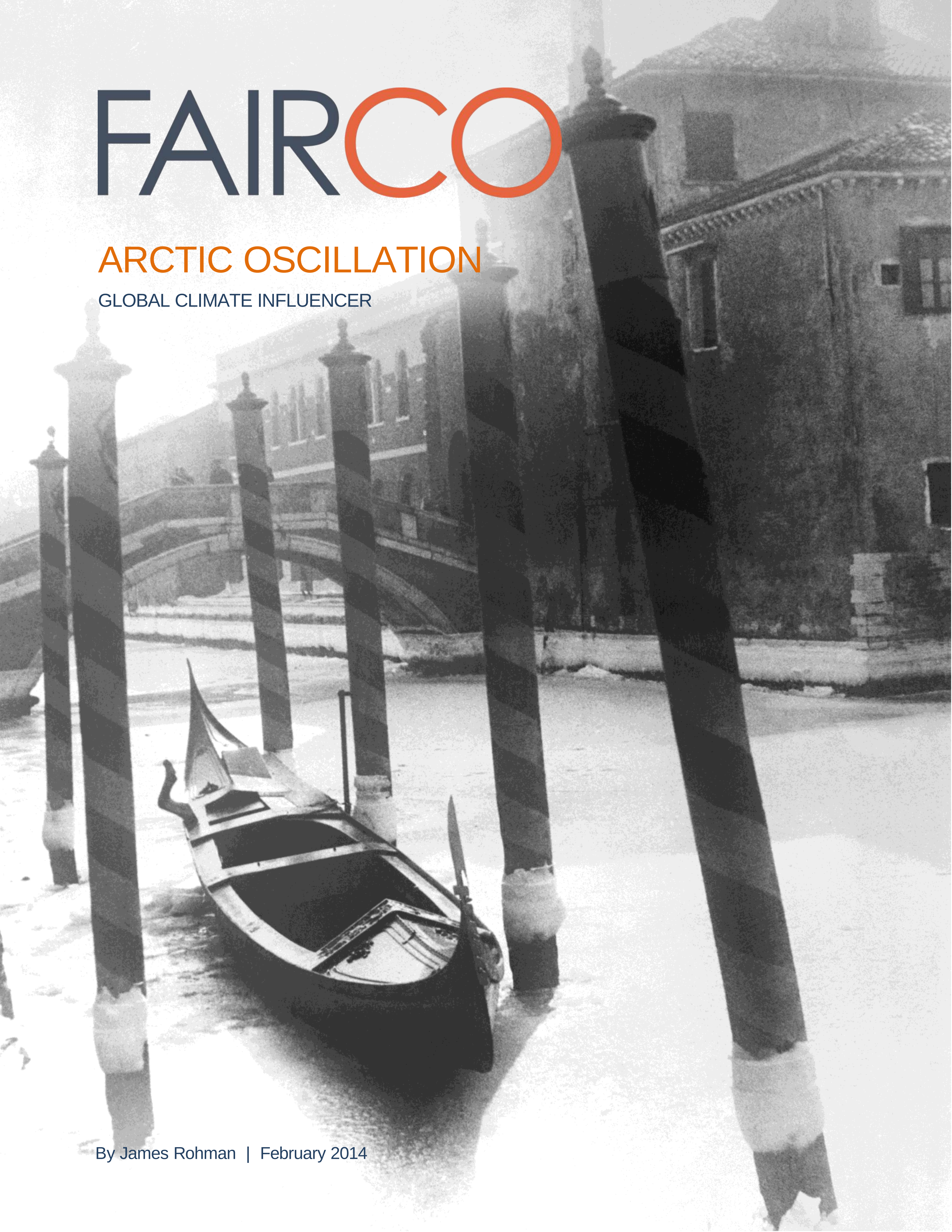
ARCTIC OSCILLATION

GLOBAL CLIMATE INFLUENCER



By James Rohman | February 2014

Figure 1. A satellite image of the jet stream.

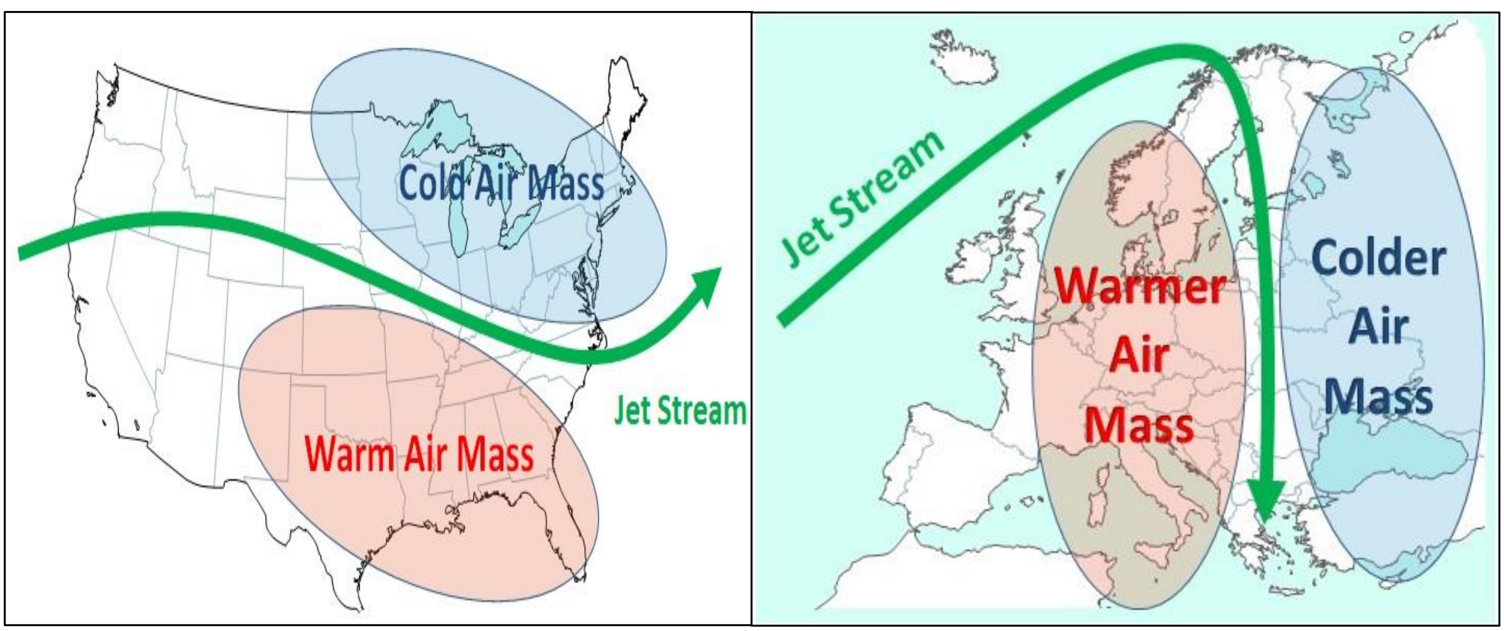


Figure 2. How the jet stream/Arctic Oscillation might affect weather distribution in the Northern Hemisphere.

Introduction

There are a number of recurring climate events that impact the global distribution of weather patterns. One of the more significant climate indexes for the Northern Hemisphere is the Arctic Oscillation (AO).

AO indicates the difference in sea-level pressure between the North Pole and the northern mid-latitudes. It impacts weather patterns in the Northern Hemisphere through the positive and negative phases of the cycle.

AO helps define the extremes of the eccentricities in the jet stream. When there is a strong AO negative phase, the jet stream slows down and takes large meandering loops. During AO positive phases, the jet stream will maintain a straighter east-west orientation.

Because the jet stream marks the boundary between cold Arctic air to the north and warm subtropical air to the south, understanding the location, strength and movement of the jet stream is imperative.

The differences in the shape of the jet stream and distribution of cold and warm air masses during AO positive and negative phases is a driving component in variability of extreme weather in the Northern Hemisphere, typically above 23.5°N.

This paper seeks to introduce the general reader to the Arctic Oscillation, how it works, how it is being impacted by climate change, and what opportunities and threats derive from those developments.

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Arctic Oscillation

The Arctic is home to a semi-permanent low pressure circulation known as the polar vortex. That vortex is in constant opposition to (and therefore represents opposing pressure to) the weather patterns of the northern middle latitudes (i.e. northern North America, Europe and Asia).

The Arctic Oscillation (AO) measures the variation in the strength, intensity and size of the jet stream as it expands, contract and alters its shape. It is measure by sea pressure anomalies, either positive or negative, and by opposing anomalies (negative or positive) in latitudes 37°N-45°N.

During the **'negative phase'** of AO, **sea-level pressure is high in the Arctic while low sea-level pressure develops in the northern middle latitudes.** On the other hand, during AO **'positive phase', high sea-leel pressure develops in the northern middle latitudes, and sea-level pressure is low in the Arctic.**

Dr. James E Hansen, a NASA climatologist, describes AO thus:

'The degree to which Arctic air penetrates into middle latitudes is related to the AO index, which is defined by surface atmospheric pressure patterns. When the AO index is positive, surface pressure is low in the polar region. This helps the middle latitude jet stream to blow strongly and consistently from west to east, thus keeping cold Arctic air locked in the polar region. When the AO index is negative, there tends to be high pressure in the polar region, weaker zonal winds, and greater movement of frigid polar air into middle latitudes.'

Why is it important?

Low polar air pressure tends to keep freezing Arctic air contained above the Arctic Circle, while high polar air pressure allows more of that frigid air to seep south into North America and Eurasia.

The location and strength of the Arctic sea level pressure anomaly influences weather patterns in the Northern Hemisphere, where dense populations and heavily insured value reside.

Developing a greater understanding of the science of the Arctic Oscillation and jet stream can therefore assist insurance underwriters in understanding regional weather patterns and their subsequent impact on insured exposures.

Effects on North America and Europe

During the **positive phase, a strong polar vortex will confine cold air across Polar Regions**. Arctic air is kept in the north, resulting in **colder winters for Canada, Greenland, northern Scandinavia and Russia**, but keeping the mainland US and most of Europe relatively warm.

Resultantly, **extratropical storms are flung further north**. **AO positive creates stormy weather in Alaska, the UK and Scandinavia,** while the **Southwest US and Mediterranean remain dry**.

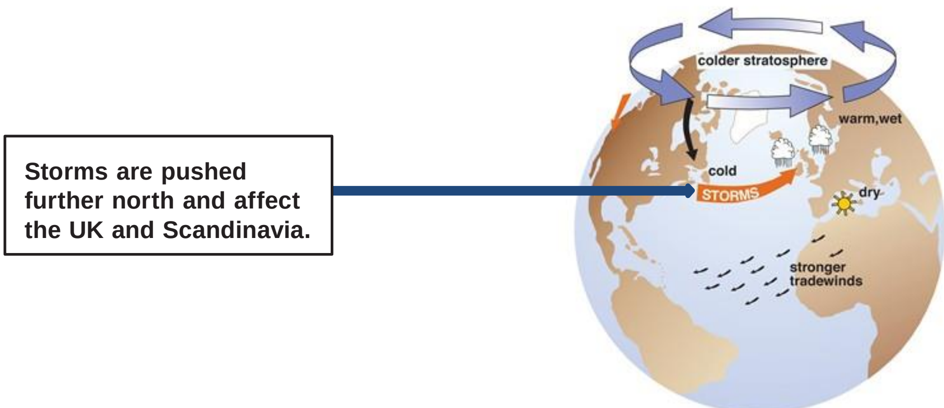

Figure 3. Positive phase of Arctic Oscillation.

During the **negative phase**, the polar vortex is weakened by influxes of warm air from Siberia. **Cold air migrates south with the meandering jet stream**. **Arctic air masses freeze over North America, Europe and Asia, and Mediterranean countries experience stormy winters.**

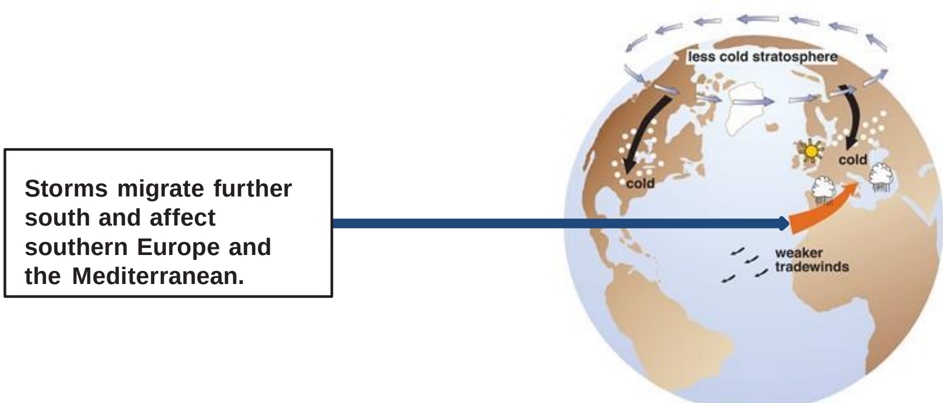

Figure 4. Negative phase of Arctic Oscillation.

Practical Effects

Extreme European Cold Weather, December 2009

AO affects weather patterns over Europe because its proximity to the Arctic Circle. AO often creates blustery conditions and directly contributes to the genesis of winter storms.

December 2009 saw cold Arctic air sweeping across Europe. Frigid winds interacted with warm tropical Atlantic waters, resulting in icy conditions and two major snowstorms. **The harsh weather was attributed to the highly negative AO**. **A strong ridge of high pressure, known as a 'blocking system', funneled cold Arctic air to towards Europe**. Europe was not the only area affected by AO - much of the US experienced snowstorms and freezing temperatures December 2009.

'Snowmageddon', Eastern US, February 2010

In February 2010, the AO reached its most negative monthly value in 60 years of record keeping. That month there were **three discrete large snowstorms**: 25" (February 5-6) and 19.5" (February 9-10) in Baltimore, MD, and 20.9" (February 25-26) in New York. **Such clustering of severe storms is unprecedented, as extreme as the AO reading itself.**

Deadly Cold in Europe, February 2012

February 2012 saw Europe locked in the grips of deadly cold air, **with more than 650 deaths attributed to the Arctic outbreak**. Millions of people in Italy, Bosnia and Romania were stranded due to heavy snowfall and power outages. **93 stations** from the Czech Hydrometeorological Institute reported **all-time low temperature recordings, with one station bottoming out at –49.7^{o}F**. The Danube River froze, closing navigation on the second-longest river in Europe and halting much commercial trade. The iconic canals of Venice froze over, too.

With reported snow depths of 1 meter at sea level and 4 meters in mountain valleys, **the prodigious snowfall was the heaviest in 60 years**. Even the Roman Coliseum closed due to falling masonry and ice.

The cold weather **emanated from an extremely negative AO and blocking pattern over Scandinavia and northwest Russia**. Airflow around the colossal blocking front transported freezing Arctic air into Europe.

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Superstorm Sandy, Eastern US, Halloween 2012

Sandy developed as a tropical cyclone fueled by high sea surface temperatures (SSTs), which hit record highs off the mid-Atlantic and New England coasts during summer 2012. However, **Sandy was also strongly influenced by a blocking pattern parked just south of Greenland, and a jet stream with huge ridges and troughs created during an AO negative phase.**

The colossal dome of high pressure and jet stream worked together to steer Sandy into the mid-Atlantic. **The sharp left turn toward New Jersey was unprecedented in historical databases.**

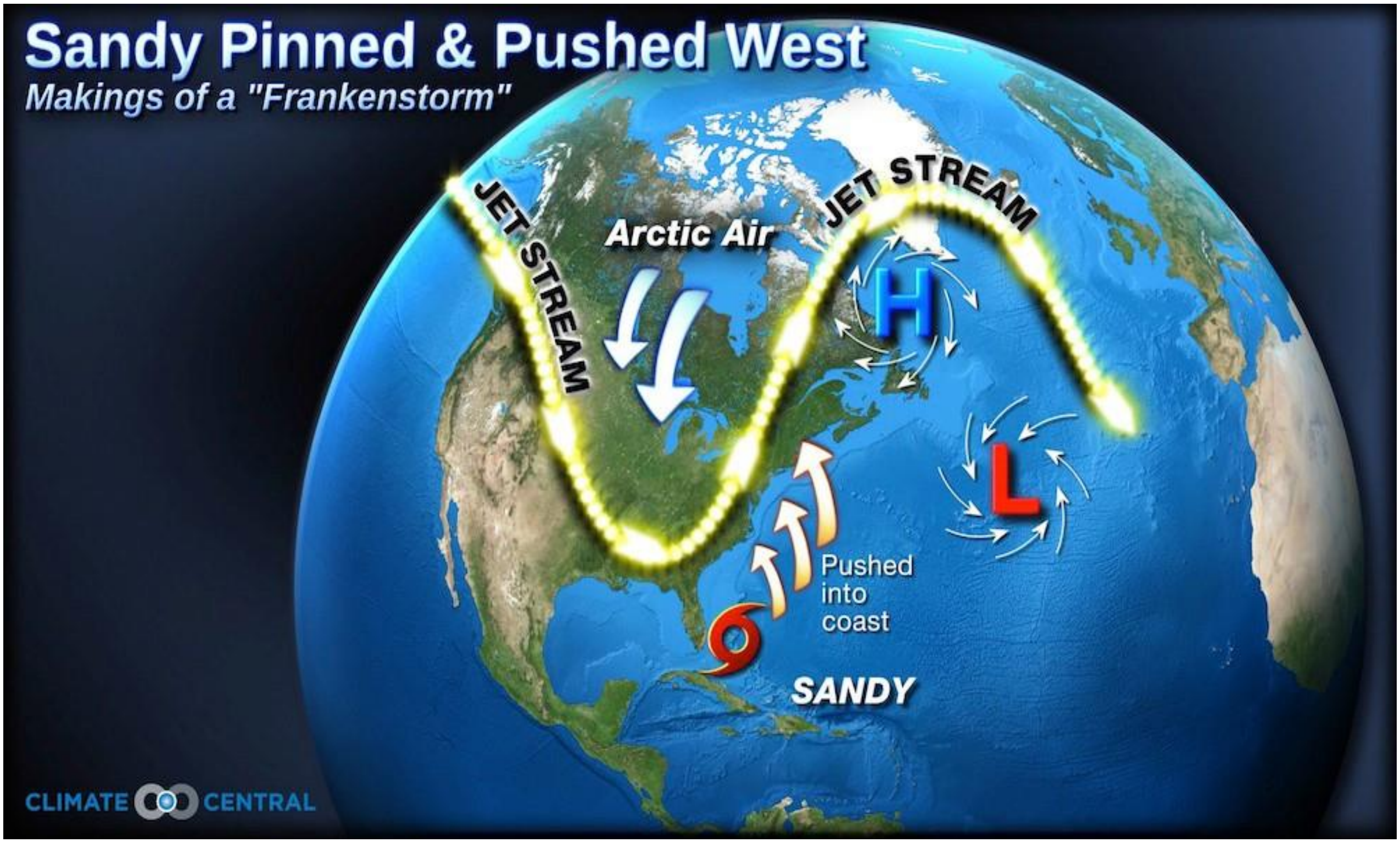

Figure 5. The polar jet stream and blocking pattern over Greenland steered Sandy into the mid-Atlantic region during a negative AO phase.

The strong blocking pattern and altered jet stream were a direct result of the AO negative phase. The storm would have traveled out to open sea had the jet stream been straighter, or had the blocking pattern not existed. In this instance, we can see how a **negative AO resulted in nearly $30 billion in insured loss within the United States.**

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Bitter Cold, March 2013

Extreme cold in March 2013 came from a shift in the AO Index. AO went from weakly positive to strongly negative. The Arctic Oscillation reached the **6th lowest monthly recording in 63 years of record keeping**.

This resulted in the **coldest March in Europe since 1952**.

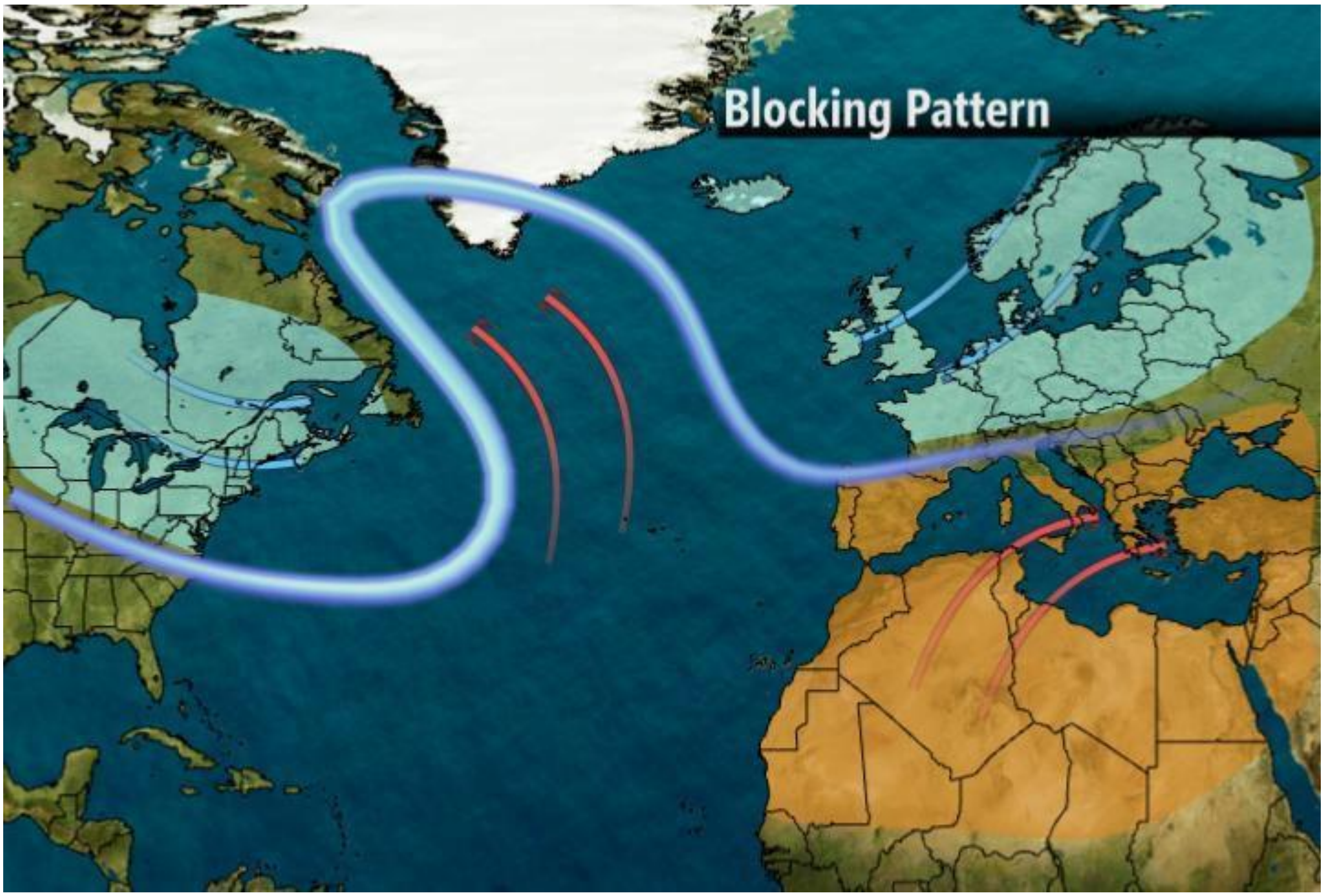

Figure 6. A visual of the pronounced north and south swings of the jet stream during an AO negative phase, with a blocking pattern near Greenland that would steer weather into Europe and North America.

The image shows how a negative AO, a blocking pattern and a wavy jet stream can combine to bring cold Arctic air into Europe and North America, similar to the events of March 2013.

Freezing Conditions, January 2014

In the first full week of January 2014, the US experienced the coldest air outbreak since 1994. Blasts of Arctic air spilled down from the North Pole, smashing many daily low temperature records across the Northeast, Mid- Atlantic, Southeast and Midwest.

The culprit, as with almost every extreme cold event in the northern hemisphere**, is the southerly migration of the polar vortex**. In the winter, near 24 hour darkness permits the development of intensely cold and strong winds over Canada and around the Arctic Circle. The chaotic flow at times allows **the jet stream to dip into North America, allowing the vortex to travel further south into the United States.** This anomaly can send cold Arctic air as far south as Texas.

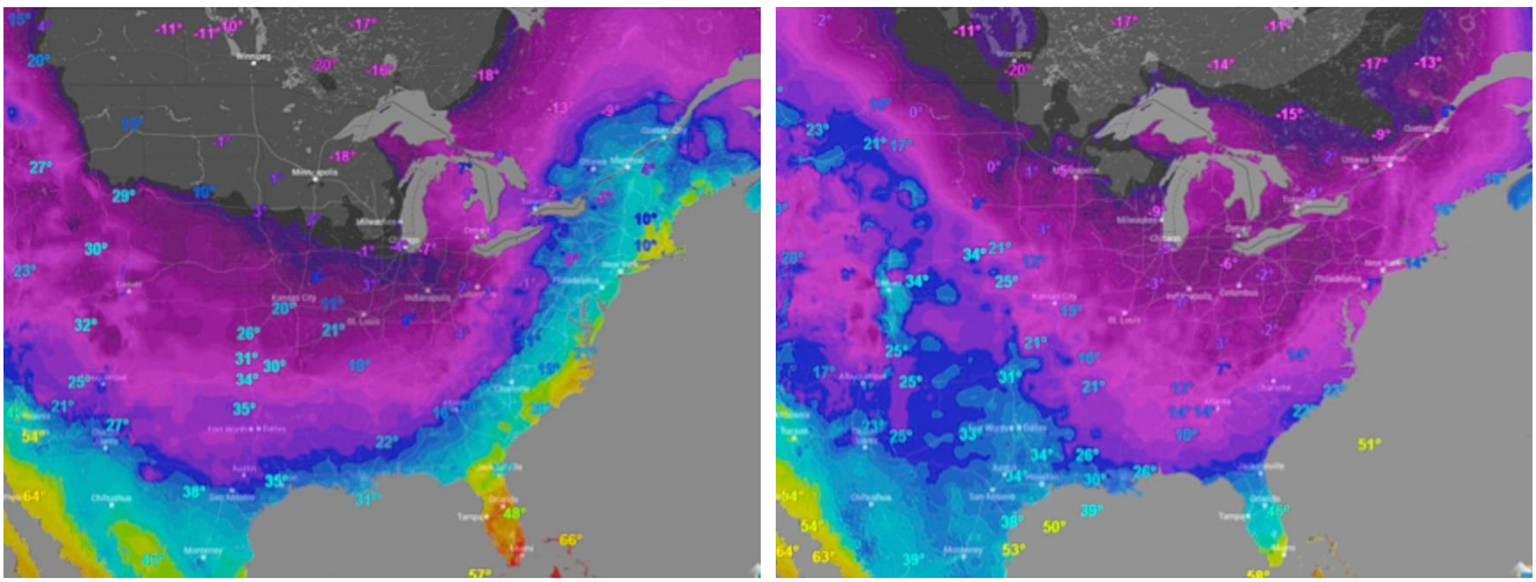

Figure 7. With January 6 on the left and January 7 on the right, images of temperature distribution from Weather Underground show how the jet stream's track influences the spread of cold weather in the continental United States. Notice the distinct eastward movement of the jet stream/cold air, from the 6th to the 7th of January.

The **low temperatures in New York City on January 7th (4°F with wine chill of -5°F) were preceded by a warm phase on January 6th (with temperatures around 50°F)**. This is a testament to the track of the jet stream, and the strong correlation between the migrations of the jet stream and the distribution of cold air across the Northern Hemisphere.

Summary of Conditions

The following table shows a summary of expected forecasts for different regions based on the prevailing phase of the Arctic Oscillation.

Table 1. Summary of conditions expected from each phase of AO.

Phase of AO	Region	Expected Forecast	Associated Climate Condition
Positive	Eastern United States	Above-average temperatures.	Strong westerlies keep cold Arctic air further north.
	Western United States	Warm, dry conditions.	Strong westerlies keep cold Arctic air further north.
	Northeast Canada & Greenland	Below-average temperatures.	Cold Arctic air extends down to this region.
	Northern Europe & Asia	Increased storminess and variability in weather.	Strong westerlies push warmth and precipitation towards northern Europe.
	Mediterranean	Drought-like conditions.	Moisture from Atlantic is pushed towards Northern Europe.
Negative	Eastern United States	Colder winters and increase in Nor'easters.	Cold Arctic air extends down to southerly latitudes.
	Western United States	Cooler weather.	Shape of jet stream allows Arctic air south.
	Northeast Canada & Greenland	Mild air warms western Greenland and eastern Canada.	Jet stream extends north, inviting warm air to flow up sub-tropical regions.
	Northern Europe & Asia	Onset of frigid temperatures.	Cold Arctic air seeps south because of weakened polar vortex.
	Mediterranean	Increased storminess and variability in weather.	Strong westerlies push warmth and precipitation towards Mediterranean region.

The Future

Every winter, **Arctic sea ice grows to the size of the United States; half melts every summer.** The ice-pack that is so critical to the climate system is **highly vulnerable to climate change.** A number of feedbacks – high albedo and Arctic amplification - **compound global climate changes,** and in turn, **influence large portions of the Northern Hemisphere with extreme weather.**

What has changed?

The past thirty years have seen the **Arctic Ocean warm twice as fast as the global average.** Over the same time period, and linked to this warming, the area covered by **average summertime sea ice has shrunk by 75 percent.**

What does it mean?

If Arctic ice continues to melt at accelerating rates, there will be some positive local benefits. As the fabled 'Northwest Passage' becomes an annual reality, so shipping routes between Europe and Asia become significantly shortened, thus freeing up the Panama and Suez Canal from bottlenecks. Exploration for natural resources becomes easier as the local environment conditions become more 'hospitable'.

However, **changes to the Arctic climate have a number of significant consequences in the Northern Hemisphere.** Arctic summer heat waves alter the track of the jet stream. With larger troughs and ridges, the **jet stream's shape is wavier than ever before.** As weather patterns are drawn into the jet stream, they travel east at a slower rate, **This causes all weather systems to persist for longer,** whether extreme or not.

AO impacts the track of extratropical storms in Europe. During periods when the polar vortex is strong and cold air is confined to the Arctic Circle, the **AO positive phase forces storms to track further north into the UK and Scandinavia**. When the polar vortex is weaker and cold air can travel south into Europe and North American during **AO negative, storms typically change route and make landfall in southern Europe and the Mediterranean.**

Climate change in the Arctic also influences the genesis and location of blocking patterns, which, as covered before, can steer the direction of storms into landmasses. Arctic warming can influence weather far beyond the Arctic Circle. **The frequency of extreme weather will likely increase in the Northern Hemisphere accordingly.**

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Glossary

Albedo – The reflective power of a surface. Refers to the high amount of heat reflected by sea ice.

AO Negative – Phase of AO where cold, Arctic air blasts down to northern North America and Eurasia.

AO Positive – Phase of AO where cold, Arctic air is more confined to the Arctic Circle because of the strength of the polar vortex.

Arctic Amplification – Refers to greater temperature increases in the Arctic compared to the rest of the earth, as a result of internal feedback systems.

Arctic Oscillation (AO) – An index of the dominant sea-level pressure variations between the North Pole and 45°N.

Atmospheric Air Pressure – Force per unit exerted on a surface exerted by the weight of air above that surface of the earth. Helps define AO patterns.

Blocking Pattern – Large-scale atmospheric field that is nearly stationary, with the effect of redirecting migratory cyclones and weather patterns.

Boreal – Of or relating to the Northern Hemisphere.

El Niño Southern Oscillation (ENSO) – The oscillation in the Pacific Ocean between anomalously warm and cold water phases. Affects 60% of global weather patterns.

Jet Stream – The fast flowing, narrow air currents found in the atmosphere of many planets, including earth. Shape and location of the jet stream can influence the movement of local weather patterns.

Madden-Julian Oscillation (MJO) - Major part of intraseasonal (30-90 days) variability in the tropical atmosphere. Travels east from Indian Ocean.

Polar Vortex – The semi-permanent and large-scale cyclone located near the planet's geographical poles.

Sea-Level Pressure – Atmospheric pressure at sea level.

South American Monsoon System (SAMS) – The seasonal pattern of prevailing wind that corresponds to changes in precipitation in South America. Most distinct effects are seen in Southeast Brazil.

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Professor Mike Wallace, Professor Emeritus, Department of Atmospheric Sciences, University of Washington

Weather Underground

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