

## FINAL REPORT

### *The Northern Hemisphere polar jet stream and links with Arctic climate change* IASC/CliC/IMO/NOAA Workshop held on 13-15 November 2013 at Reykjavik in Iceland

James E. Overland & Edward Hanna, 17 January 2014

The Iceland Workshop was successful with 33 scientists who have recently worked on jet stream and Arctic linkages issues. The workshop consisted of summary talks and extensive time for discussion during the sessions and during breaks and meals provided by IMO. Iceland provided this group of meteorologists and oceanographers with some outstanding weather: a major storm followed by snow. The agenda and list of participants are provided at the end. We appreciated the major support of IASC and CliC, and the hospitality of our hosts at IMO.



Main scientific findings are as follows:

\* Arctic/mid-latitude linkages will be a major topic for the next decade because of the emergence of Arctic climate changes, known as Arctic amplification, and their impact on hemispheric weather and potential for improved seasonal forecasting. However, sorting causality and attribution of linkages is difficult between Arctic forcing and changes in mid-latitude chaotic flow. While evidence increasingly supports increased variability and the possibility of linkages from observed extremes during the last 5-10 years, the record is too short to rigorously/statistically provide sufficient scientific proof. Consequently there is still skepticism and uncertainty in these areas. Most studies have relied on correlation of reanalyses or model

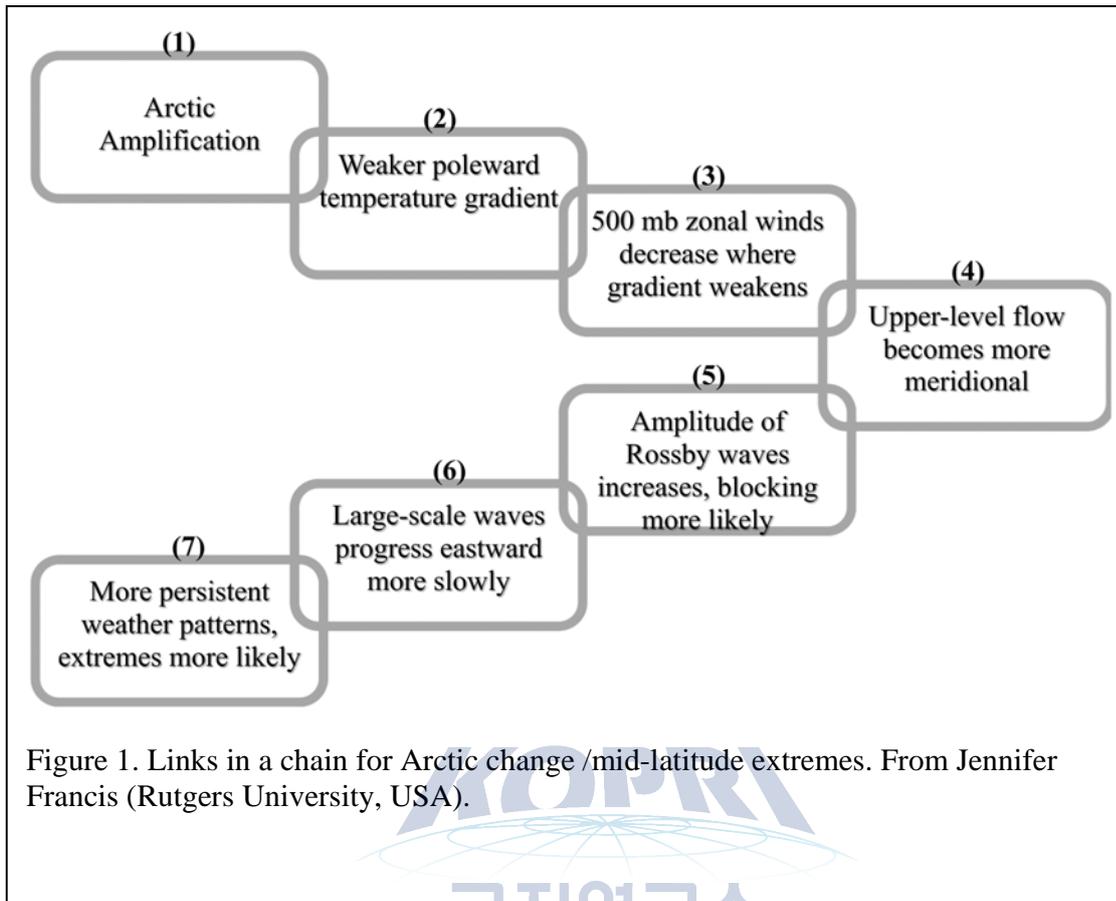
output; research needs to move to more mechanistic studies as a way forward. There is a need to look at forcing beyond just sea ice and snow to a full suite of possible factors.

\* Potential research ideas include further analysis of phase and wave number of the long-wave pattern/blocking, especially east of Urals and west of Greenland. Regional blocking and highly amplified flows often are coincident with Arctic-wide warming patterns. Elucidation of the underlying mechanisms of change may also result from a focus on weekly to monthly time scales and factors driving the negative phase of the Arctic Oscillation (AO).

\* More rigorous hemispheric and regional case studies of changes in jet-stream variability and recent extreme AO/North Atlantic Oscillation (NAO) and Greenland Blocking events like March 2013, winter 2009-2010 and summer 2012 are also needed.

\* Model studies are still rather weak in their support of linkages, especially the climate models that were used in the CMIP5 effort. Using CMIP5 output as an argument that linkages are not present is not a valid argument that linkages are not found in the real world. Increased resolution and examination of multiple individual ensemble members (as opposed to averaging model output across members) is expected to provide a way forward. There needs to be a better understanding of climate-model biases in response to Arctic sea-ice loss, and a clearer attribution of the recent sea-ice decline as well as of extreme weather events. Climate models seem unable to capture the recently observed highly-amplified jet-stream wave pattern, neither do they well represent the stratospheric polar vortex, but a more concerted model and attribution focus on high latitudes would help.

At this stage, the linkage mechanisms are uncertain, but their potential importance is difficult to overstate. Having summarized the present state of knowledge, we need to identify the most fruitful way forward in this rapidly progressing research field, and identify sources of uncertainty in the conceptual models outlined below. Two schematics emerged from the Iceland workshop that help provide a framework for further synthesis and research. The first was provided by Jennifer Francis and shows the set of “links in the chain of connected events” that need to occur for linkages to form between global warming and extreme mid-latitude weather events:



More work is clearly needed on conditions that lead to amplified planetary waves and changes in these. Our proposed approach is to further investigate the assumptions and strength of the processes represented by each link from statistical approaches, case studies, and modelling experiments representing the previous few decades and the projected period of future, more intense Arctic amplification. A body of literature exists on blocking behaviour but it does not include many recent events, a large fraction of which were associated with amplified upper-level flow patterns without a typical block.

So far we have a tantalizing array of possible drivers based on observed correlations, theoretical reasoning and limited modeling work. Next we need better quantification of Linkages drivers, the interaction between them and their response to ongoing greenhouse-gas forcing.

Second, a conceptual model of the North Atlantic Oscillation (NAO), which relates to Greenland blocking events and northern hemisphere polar jet stream changes, was provided by Richard Hall. The approach here is to contrast what might be the role of internal atmospheric processes versus external (forced) processes. Recently observed increasing variance in the NAO index in early winter - especially December - needs further exploration/explanation, as does a better understanding of the intrinsic (unpredictable) component of the NAO/AO versus its forced (predictable) component.

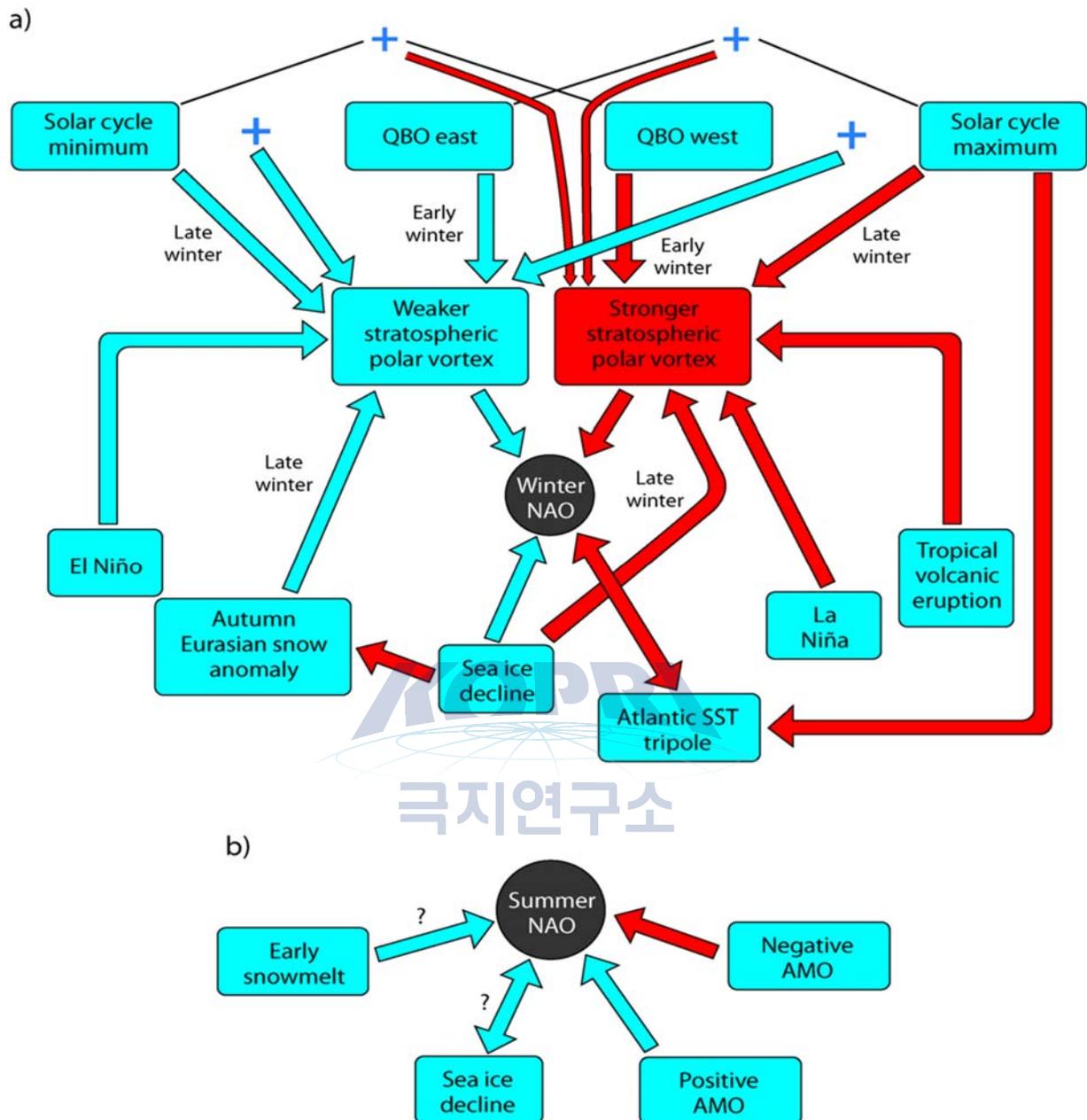


Figure 2. Potential influences on the shift from a positive to negative North Atlantic Oscillation (NAO). A red arrow indicates a strengthening of the target box, while a blue arrow indicates a weakening. From Richard Hall (University of Sheffield, UK).

In the above figure, NAO can be used a surrogate for AO or North Atlantic polar jet-stream variability.

Summing up, linkages is going to be a major topic in climatological research for the next decade that is scientifically challenging but rewarding, and practically beneficial for climate prediction with the potential for scientific breakthroughs and improved seasonal forecasting.

## Wednesday, 13 November

Time	Agenda Item
09:00 – 09:15	<b>Welcome and Introductions</b> - T Jónsson and E Hanna
09:15 – 09:30	<b>Meeting Structure and Overview</b> - J Overland and E Hanna
09:30 – 10:40 09:30 – 09:45 09:45 – 10:05 10:05 – 10:25 10:25 – 10:40	<b>Icelandic Perspective and Hemispheric Overview (Chair: Edward Hanna)</b> Iceland: on the northern flank of the jet stream – T Jónsson Circumpolar Vortex: Calculations and Correlations – P Jones Response of the wintertime atmospheric circulation to current and projected Arctic sea ice decline – G Magnusdottir Group Discussion
10:40 – 11:00	<b>Coffee Break</b>
11:00 – 12:45 11:00 – 11:20 11:20 – 11:35 11:35 – 11:55 11:55 – 12:15 12:15 – 12:35 12:35 – 12:45 12:45 – 14:00	<b>Jet Stream Especially the North Atlantic (Chair: Robert Erdelyi)</b> A long perspective on Atlantic jet variability – T Woollings A comparison of North Atlantic Jet Stream Representation in ERA-Interim and 20th Century Reanalysis Data - R Hall Frozen assets: what can ships' logbooks tell us about Arctic climate change? – D Wheeler Simulations of the impact of Arctic sea ice on the atmospheric circulation: the need for coupled models – D Smith Greenland Blocking and North Atlantic Oscillation changes – E Hanna / J Overland Group Discussion Lunch (after which we move into the <i>matsalur</i> - lunch hall)
14:00 – 15:40 14:00 – 14:20 14:20 – 14:40 14:40 – 15:00 15:00 – 15:20 15:20 – 15:40	<b>Potential Arctic / Mid-Latitude Linkages - North America (Chair: Edward Hanna)</b> The Chain of Events Linking Arctic Amplification to Extreme Weather: Which Links are Made of Steel and Which of Clay? – J Francis / S Vavrus Northern Hemisphere polar jet stream and links with Arctic climate change: large-scale patterns – H Tanaka (by Skype) Northern Hemisphere Atmospheric Response to Variations in Arctic Sea Ice – S Strey Creation and interpretation of climate outlooks: An operational perspective – M L'Heureux Group Discussion
15:40 – 16:00	<b>Coffee Break</b>
16:00 – 17:50 16:00 – 16:20 16:20 – 16:40 16:40 – 17:00 17:00 – 17:15 17:15 – 17:30 17:30 – 17:50	<b>Potential Arctic / Mid-Latitude Linkages – Europe (Chair: Hanna/Jónsson)</b> Recent changes of the atmospheric jets and their link to Northern Hemisphere weather - Petoukhov Tropo- and stratospheric teleconnection response to Arctic sea ice retreat – D. Handorf Influence of Arctic sea ice on European summer precipitation – J Screen A reconstruction of the daily NAO back to 1850 and climatic analysis – T. Cropper ERA Reanalysis and jet stream (TBC) - H. Bjornsson Group Discussion
19:00 -	<b>Group Dinner</b>

## Thursday, 14 November

Time	Agenda Item
09:00 – 10:30	<b>Potential Arctic / Mid-Latitude Linkages - East Asia (Chair: Jim Overland)</b>

09:00 – 09:20	Rapid Arctic Warming in Recent Decades and Its Impact on Climate Change over East Asia - S-J Kim
09:20 – 09:40	Extreme weather in northern mid-latitudes linked to cryosphere loss - Q Tang
09:40 – 10:00	A cause of the AO polarity reversal from winter to summer in 2010 and its relation to extreme hot summer associated with polar jet, summer AO and blocking - Y Tachibana
10:00 – 10:30	Group Discussion
<b>10:30 – 11:00</b>	<b>Coffee Break</b>
<b>11:00 – 12:00</b>	<b>Potential Arctic / Mid-Latitude Linkages – Large Scale (Chair: Jim Overland)</b>
11:00 – 11:20	Large scale linkages between fall Eurasian snow cover and Northern Hemisphere winter climate – J. Cohen
11:20 – 11:40	Moisture injections into the Arctic and associated large-scale circulations – R. Caballero
11:40 – 12:00	Group Discussion
<b>12:00 – 12:30</b>	<b>Regional Breakout Groups (start)</b>
<b>12:30 – 13:30</b>	<b>Lunch</b>
<b>13:30 – 16:15</b>	<b>Regional Breakout Groups (with Coffee from 15:00)</b>
<b>16:30 – 17:30</b>	<b>Workshop Reception at Marine Research Institute, Reykjavik Harbour</b>

## Friday, 15 November

Time	Agenda Item
<b>09:00 – 10:30</b>	<b>Regional Breakout Group Reports (Chair: Jim Overland)</b>
09:00 – 09:20	North America
09:20 – 09:40	Europe
09:40 – 10:00	East Asia
10:00 – 10:30	Large Scale
<b>10:30 – 11:00</b>	<b>Coffee Break</b>
<b>11:00 – 12:00</b>	<b>Next Steps (Chair: Jim Overland)</b>
<b>12:00 – 13:30</b>	<b>Lunch</b>
<b>13:30</b>	<b>Workshop Ends</b>

**Participant list**

<b>Name</b>	<b>Affiliation/Institution</b>	<b>Country</b>
Björnsson, Halldór	Icelandic Met Office	Iceland
Caballero, Rodrigo	Department of Meteorology, Stockholm University	Sweden
Cohen, Judah	Atmospheric and Environmental Research, Inc.	USA
Cropper, Tom	University of Sheffield	UK
Erdelyi, Robert	University of Sheffield	UK
Erlingsson, Björn	Icelandic Meteorological Office	Iceland
Francis, Jennifer	Rutgers University	USA
Hall, Richard	University of Sheffield	UK
Handorf, Doerthe	Alfred Wegener Institute of Polar and Marine Research	Germany
Hanna, Edward	University of Sheffield	UK
Intrieri, Janet	NOAA/Boulder	USA
Jones, Phil	Climatic Research Unit, University of East Anglia	UK
Jonsson, Trausti	Icelandic Met Office	Iceland
Kim, Seong Joong	Korea Polar Research Institute	Korea
L'Heureux, Michelle	National Centers for Environmental Protection	USA
Magnusdottir, Gudrun	University of California - Irvine	USA
Mote, Tom	University of Georgia	USA
Nawri, Nikolai	International Maritime Organization	UK
Ólafsson, Haraldur	Icelandic Met Office	Iceland
Overland, James	NOAA/Seattle	USA
Petersen, Guðrun Nina	Icelandic Met Office	Iceland
Petoukhov, Vladimir	Potsdam Institute for Climate Impact Research	Germany
Screen, James	University of Exeter	UK
Smith, Doug	Met Office Hadley Centre	UK
Strey, Sara	University of Illinois	USA
Sveinbjörnsson, Einar	Veðurvaktin	Iceland
Tachibana, Yoshihiro	JAMSTEC/ Mie University	Japan
Tanaka, Hiroshi	University of Tsukuba	Japan
Tang, Qiuhong	Chinese Academy of Sciences	China
Vavrus, Steve	University of Wisconsin	USA
Wheeler, Dennis	University of Sunderland	UK
Woollings, Tim	University of Reading	UK
Þorsteinsson, Sigurður	Icelandic Met Office	Iceland