

## 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

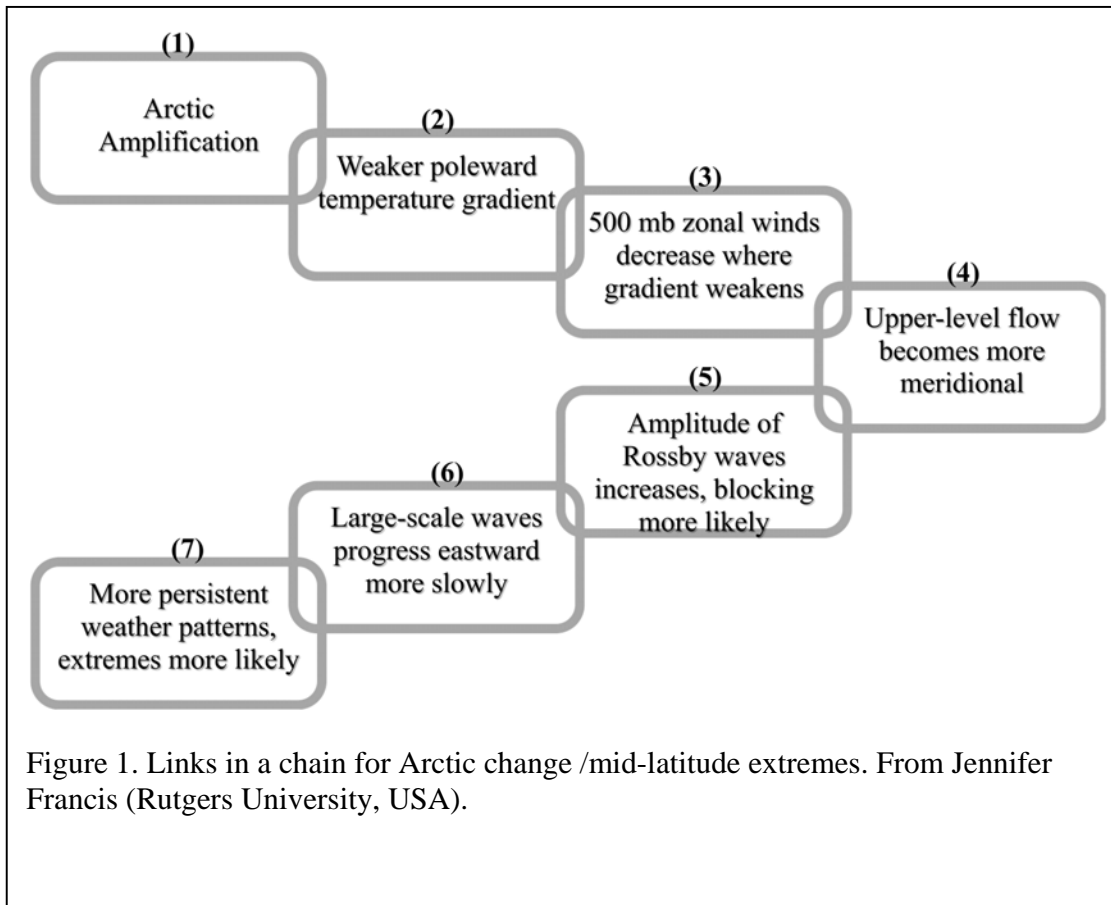
output; research needs to move to more mechanistic studies as a way forward. There is a need to look at forcing beyond just sea ice and snow to a full suite of possible factors.

- \* 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.

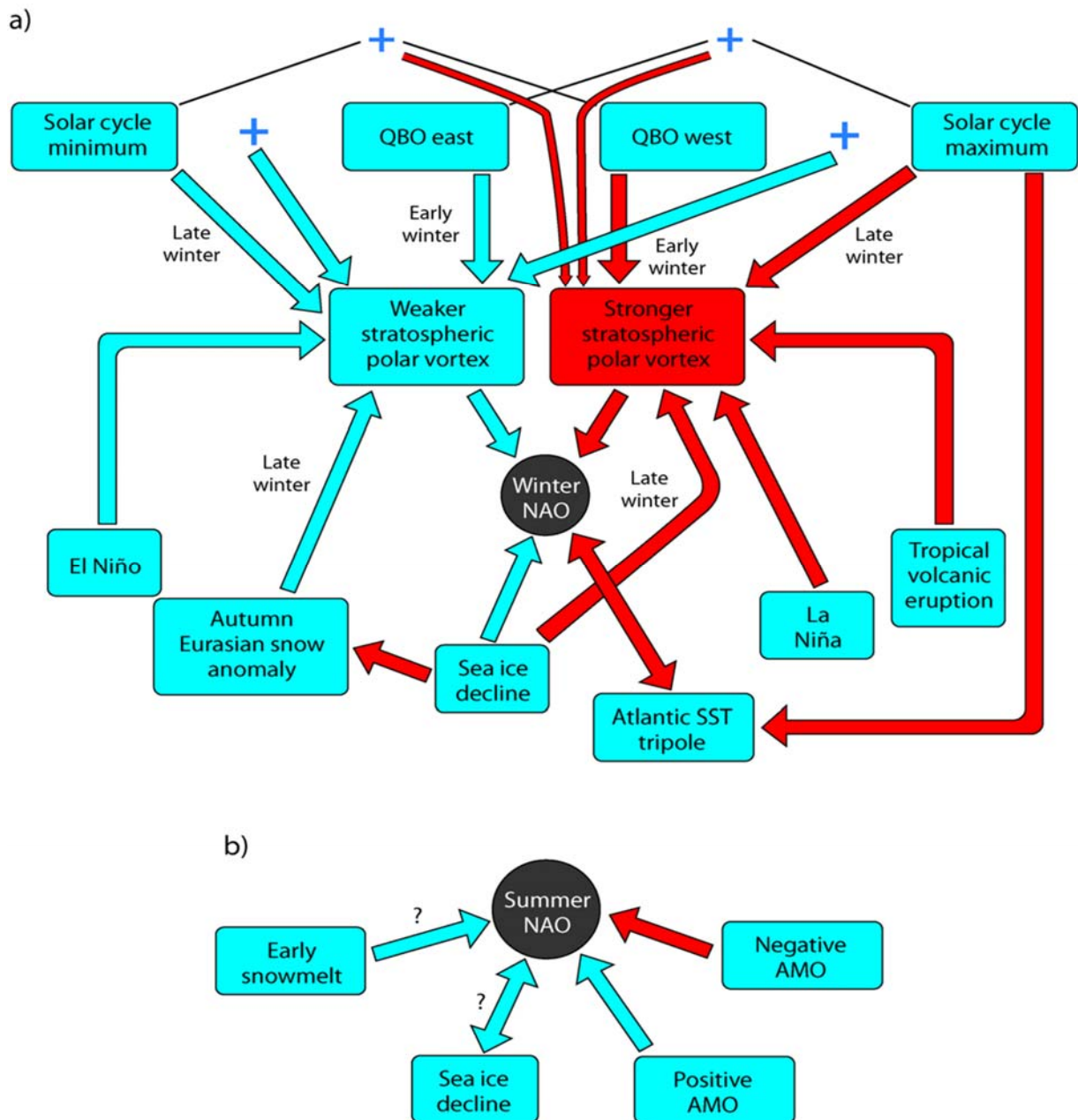


Figure 2. Potential influences on the shift from a positive to negative North Atlantic Oscillation (NAO). A red arrow indicates a strengthening of the target box, while a blue arrow indicates a weakening. From Richard Hall (University of Sheffield, UK).

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