A New Integrated Storminess Indicator for Marine Hazards for Forecasting

Norman J. Shippee, David Atkinson, and Laura Eerkes-Medrano

Department of Geography

University of Victoria

Overall Project Focus

A user-directed research project in the eastern Beaufort Sea region.

➞ travel on the water in all sizes of boats

-- **subsistence**

Inuvikphotos.ca

Overall Project Focus

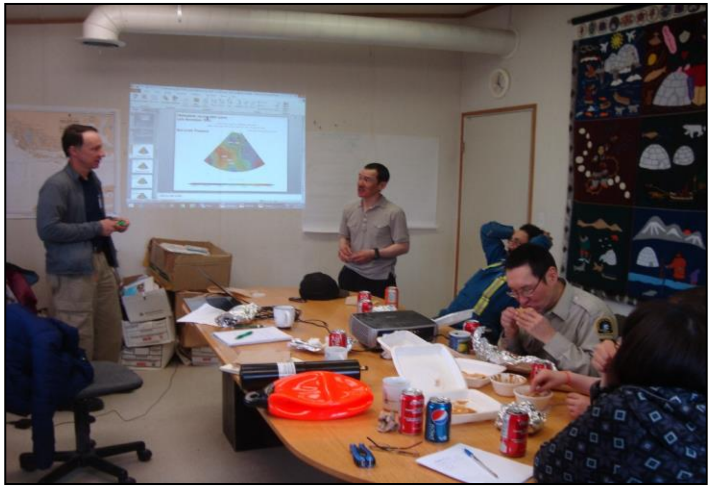
> Community resupply - **barges**

> Tourism – **cruise ships**

> **Coast Guard** activities

Methods: Overview

User-directed research – emphasizes result and product delivery



Methods: User-directed research - How is it done

By working closely with:

Communities

Industry

Response groups

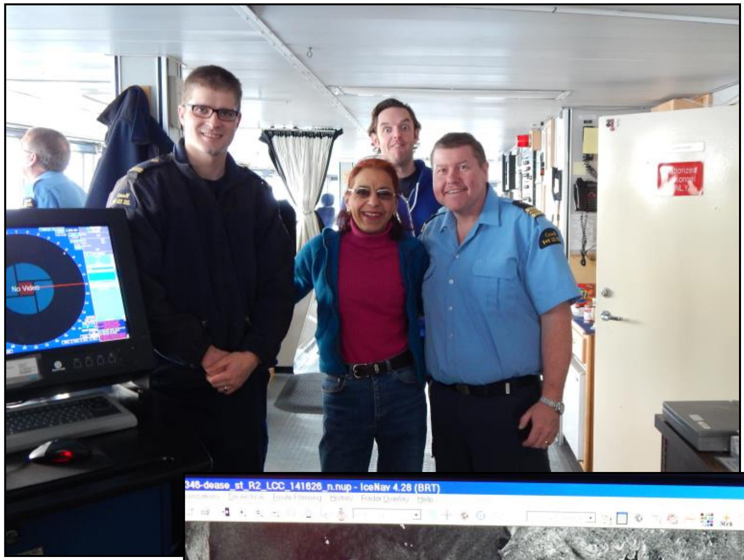
Methods: User-directed research: Industry

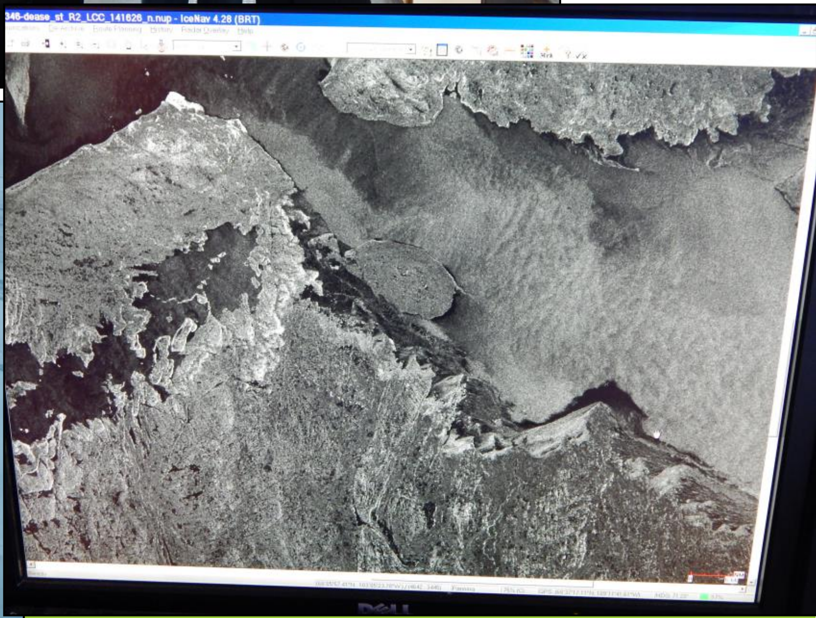
> Transportation and resupply – Northern Transportation Co Ltd and Island T&B

> Oil and gas (with GNWT liaison)

Methods: User-directed research: operational

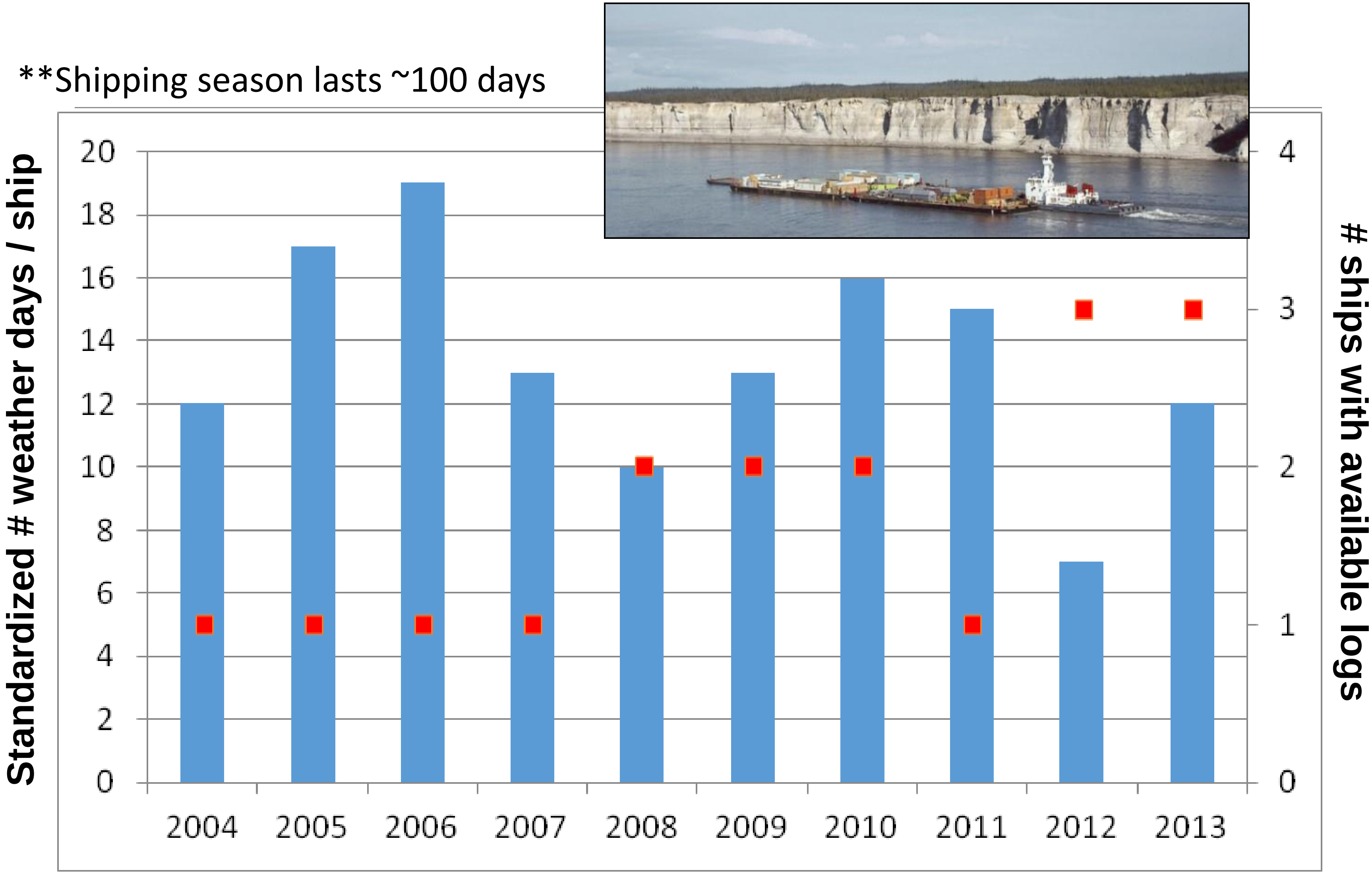
> Response groups
  – CCGS Sir Wilfrid Laurier
  – CCGS Louis S St. Laurent





Preliminary results from NTCL logbooks: weather impacts on tug and barge activity

**Shipping season lasts ~100 days



Some Motivation and the Impetus for this Work

2011 Nome Superstorm

Photo by Nadja Cavin

STORM WATCHERS— East Front Street in Nome bore the brunt of last week's storm that pummeled Northwestern Alaska. Curious Nome residents came out to watch the high water event and ventured beyond the barricades set up by Nome emergency services volunteers.

Nome recovers after super storm

By Diana Haecker

There is nothing like a good-sized storm that gets Nomeites out on Front Street for a walk near the beach. As waves crashed over the seawall armor rock on East Front Street, depositing rocks, driftwood and other debris on the road, people came out in droves to view the spectacle and take video and photos of the angry Bering Sea on a backdrop of a colorful sunset.

The high winds that battered Nome with peak gusts of 66 mph on Tuesday night had subsided by Wednesday afternoon. The Tuesday night blizzard blew six inches of snow on Nome, which accumulated in huge snowdrifts in some areas while other areas were blown clear of any speck of snow.

After the winds died down and visibility returned, the threat of a massive storm surge worried city officials most. Low lying areas like River Street, F Street and Belmont Point flooded. Dry Creek was wet and looked like a lake all the way to Chicken Hill. The storm surge peaked on Wednesday evening with 9.95 feet above the mean low water level. In comparison, a very high tide measures two feet above that level.

However, the anticipated severity of the massive storm did not materialize because the center of the 948-millibar low moved further west over Kamchatka and the wind direction during the main wind storm shifted to the east, blowing across the tundra as opposed to coming from the south as projected, which would have caused the water to surge much higher than it did. Jerry Steiger, meteorologist in charge at the Nome NWS said that the easterly winds pushed the storm-driven waves parallel to the shoreline. "We felt ex-

continued on page 6

Photo by Diana Haecker

IN AWE— Nome Ambulance volunteers Jessica and Charlene Saclamana take a break to witness the storm on Wednesday afternoon at Front Street.

City declares disaster after Bering Sea storm hits Nome

By Sandra L. Medearis

The Nome Common Council is hoping that winds clocked at 66 mph on Nov. 9 along with a sea surge of 10 feet that produced flooding and evacuation of parts of Nome adjacent to the seawall and at Belmont Point will add up to emergency money coming from the state and federal sources to help pay for repairs.

Tuesday a federal and state team was to land in Nome to assess damage here and in the region to coordinate and ascertain the need for relief that could come in three forms: public assistance to repair public facilities, relief to individuals for damages to property and money to establish temporary housing.

Monday night in a special meeting, the Council talked to emergency relief coordination officials via telephone at a special meeting at Nome City Hall and followed up unanimously passing a resolution declaring a disaster delivered by the Bering Sea storm that wham-bammed Nome Nov. 8 and 9. The resolution holds the disaster concept only, City Manager Josie Bahnke said. True costs and complete costs of damage to Port of Nome, utilities and City facilities remain to be gathered. The resolution asks for money for estimates and cost refinement work.

The local declaration is the first step to money for storm cost relief; next, the state will consider a disaster declaration at that level. Even then, there is no guarantee that the Federal Emergency Management Agency—FEMA—will participate. The state Department of Transportation and public facilities will handle damage to the Nome-Council Road. If the damage exceeds $1 million, federal highway programs will be-

continued on page 4

Impacts not always immediate …

Photo by Diana Haecker

ICE RIDGE— Cold winds from the north hastened the freezing of the ocean in Norton Sound, and brought the northern ice pack to the region. New ice was pushed up by the ocean currents to form a ridge of symmetrical ice chunks at East Beach near the Stampeders sign.

The Nome Nugget©

Alaska's Oldest Newspaper

• USPS 598-100 • Single Copy Price - 50 Cents in Nome •

VOLUME CXI NO. 48 DECEMBER 1, 2011

Sea ice blocks fuel barge delivery to Nome

Photo by Diana Haecker

HISTORIC— The U.S. Coast Guard icebreaker *Healy*, right, and the Russian tanker T/V *Renda* parked in the Nome Roadstead, made history when they delivered 1.3 million gallons of fuel to Nome in the midst of winter.

Marine Context - Indicator

Extratropical cyclones (ETCs) generate high-impact weather

- Particularly in the North Pacific, Alaska, and Arctic.

Storm definitions vary widely based on application and perspective

- Pragmatic versus theoretical perspectives

Marine Context - Indicator

Many regions of the circum-Arctic are serviced by tug-and-barge style marine transport that operates during the limited ice-free shipping season (AMSA 2009)

Highly impacted by the marine state

- Tug-and-barge operations require lower wind speed (which impacts sea state)
  - which allows for safe transport of materials.

Interviews with stakeholders indicate:

- ***Breaks between*** wind events are important for marine operations
- Length of window depends on quite a few things
  - Typical safe operating window: 36 and 48 hours.

Methods

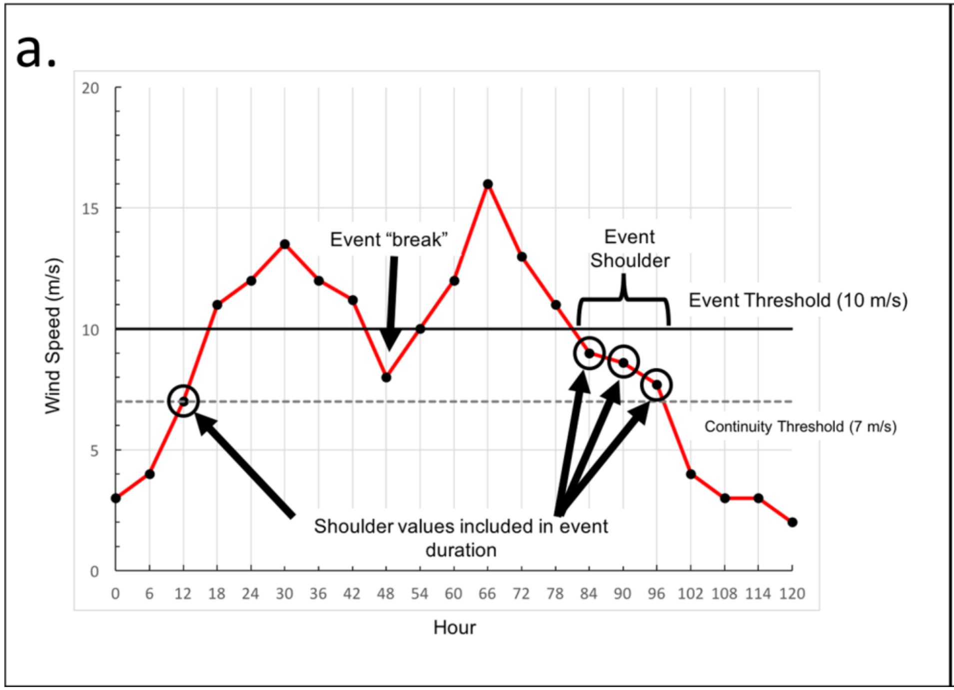
Lull/Storm Winds (LSW) Indicator

- Wind events – The wind speed and duration thresholds for event identification were set to 10 ms^{-1} for at least a 6-hour duration, independent of wind direction
  - Wind speed is allowed to decrease temporarily to as low as 7 ms^{-1} during a 6-hour break
  - Duration of event includes a “ramp-up” and “ramp-down” – until wind speed decreases below the continuity threshold (7 ms^{-1})

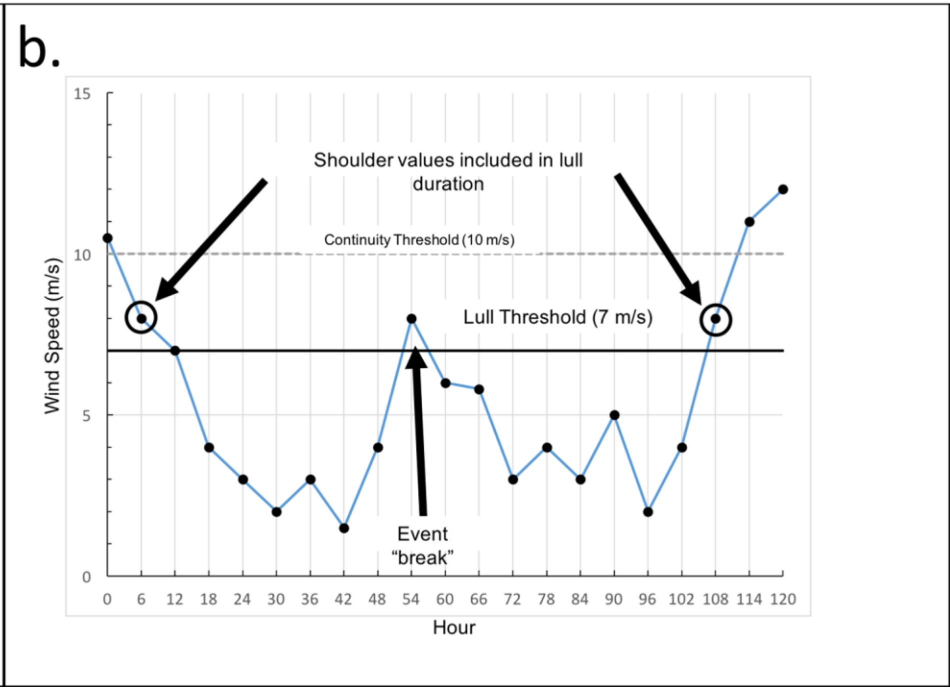
- Lull events – The lull speed and duration thresholds for event identification were set to 7 ms^{-1} or less for at least a 6-hour duration, independent of wind direction
  - Wind speed is allowed to increase temporarily to as high as 10 ms^{-1} during a 6-hour period (over main threshold)
  - Similarly, duration of event includes ramp-up and ramp-down

Algorithm Description - Schematics

Wind Event

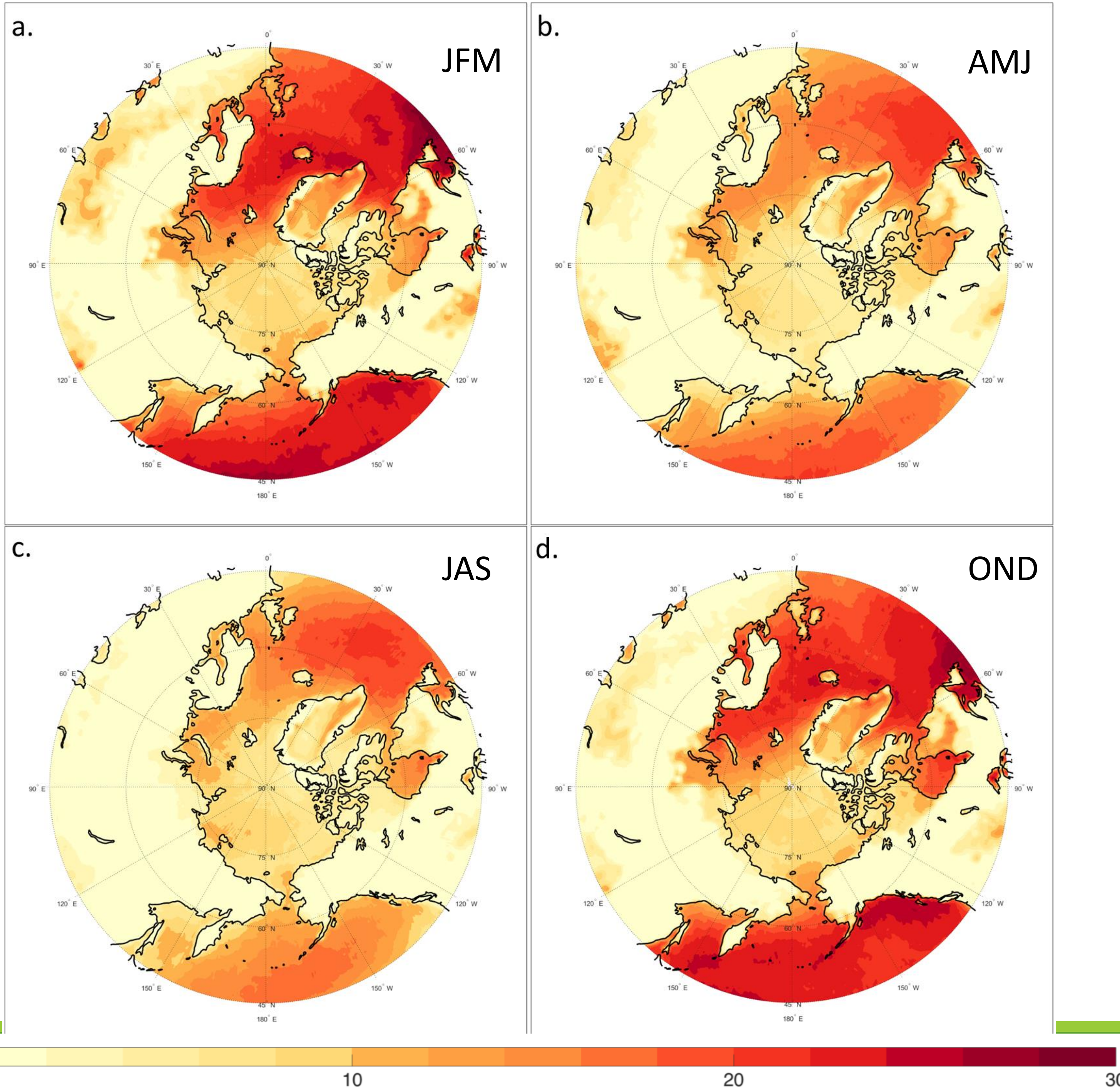


Lull Event



Results – Wind and Lull Events

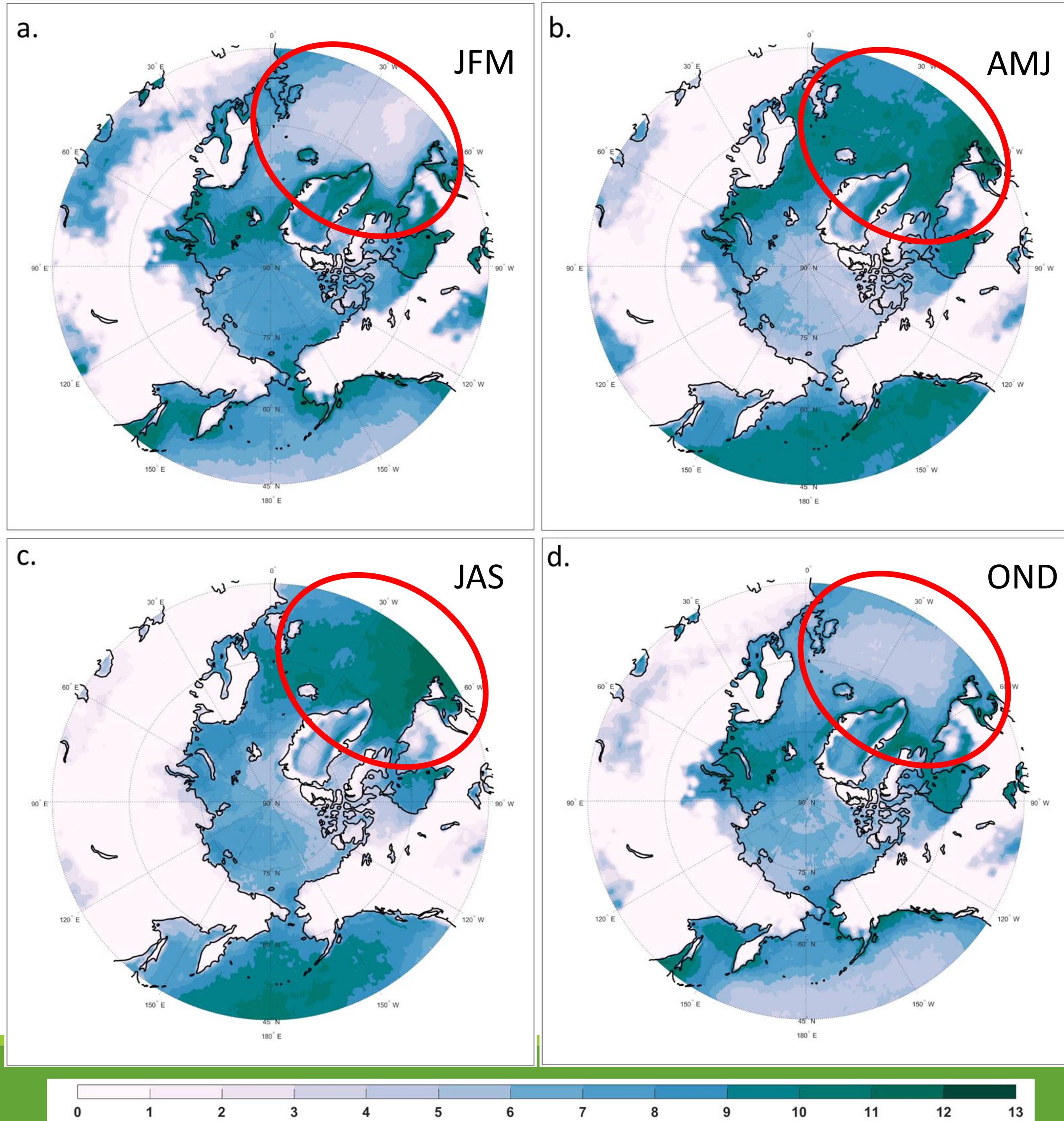
Wind Events


a.
JFM
b.
AMJ
c.
JAS
d.
OND
0
10
20
30

Lull Events

Primary regions of activity – Atlantic:

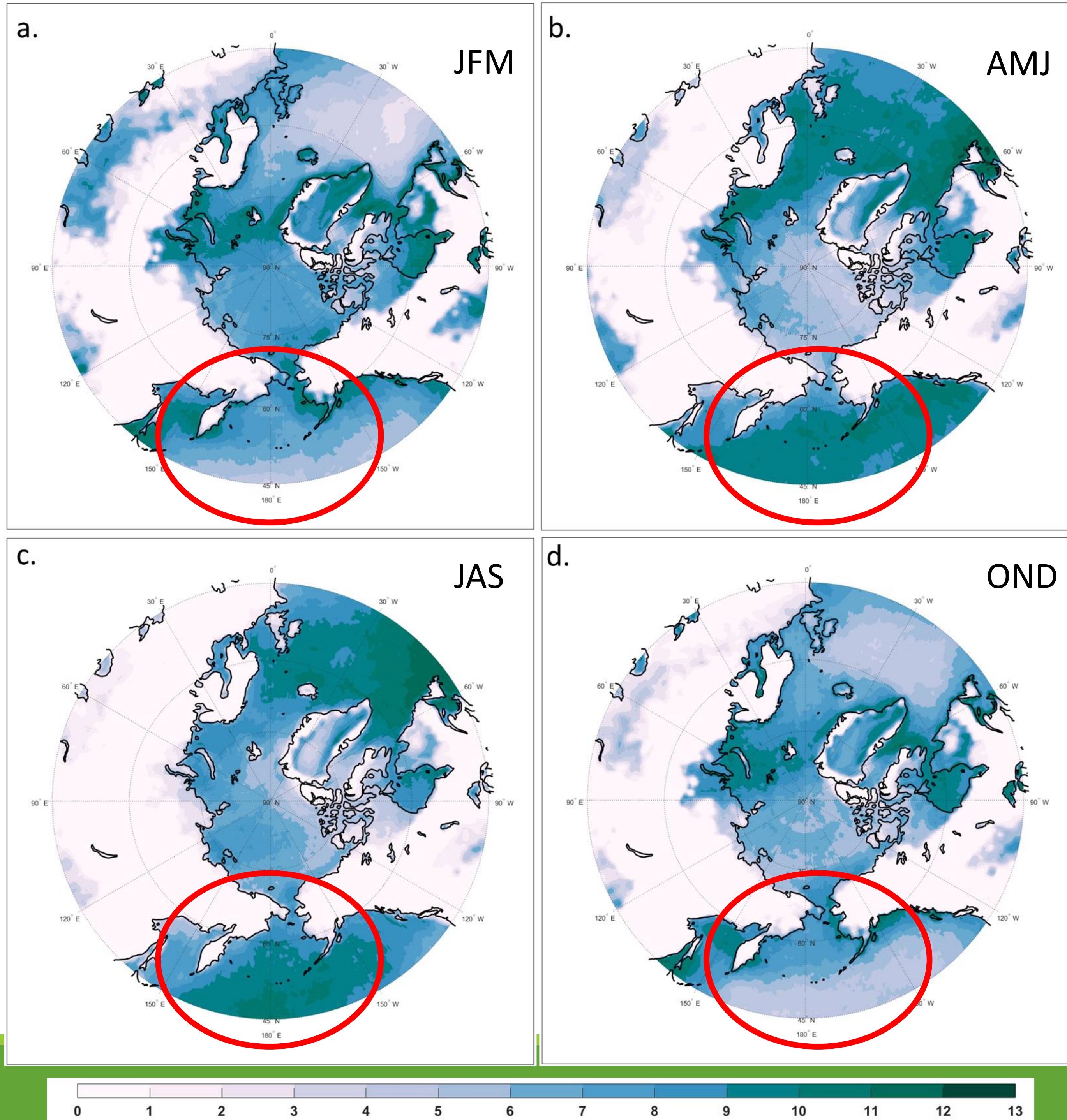
- Max number of lulls of 48-hours or greater found in the spring and summer
  - Fewer overall wind events
- Minimum during the winter and fall seasons
  - 2 – 5 events
- Coastal regions of Newfoundland and Labrador see a small increase
- Spring and summer seasons
  - 10 – 13 events across most of the Atlantic
- Relative max also exists across the Hudson Bay region throughout the year
  - 5-9 events per season


a.
JFM
b.
AMJ
c.
JAS
d.
OND
0
1
2
3
4
5
6
7
8
9
10
11
12
13

Lull Events

Primary regions of activity – Pacific:

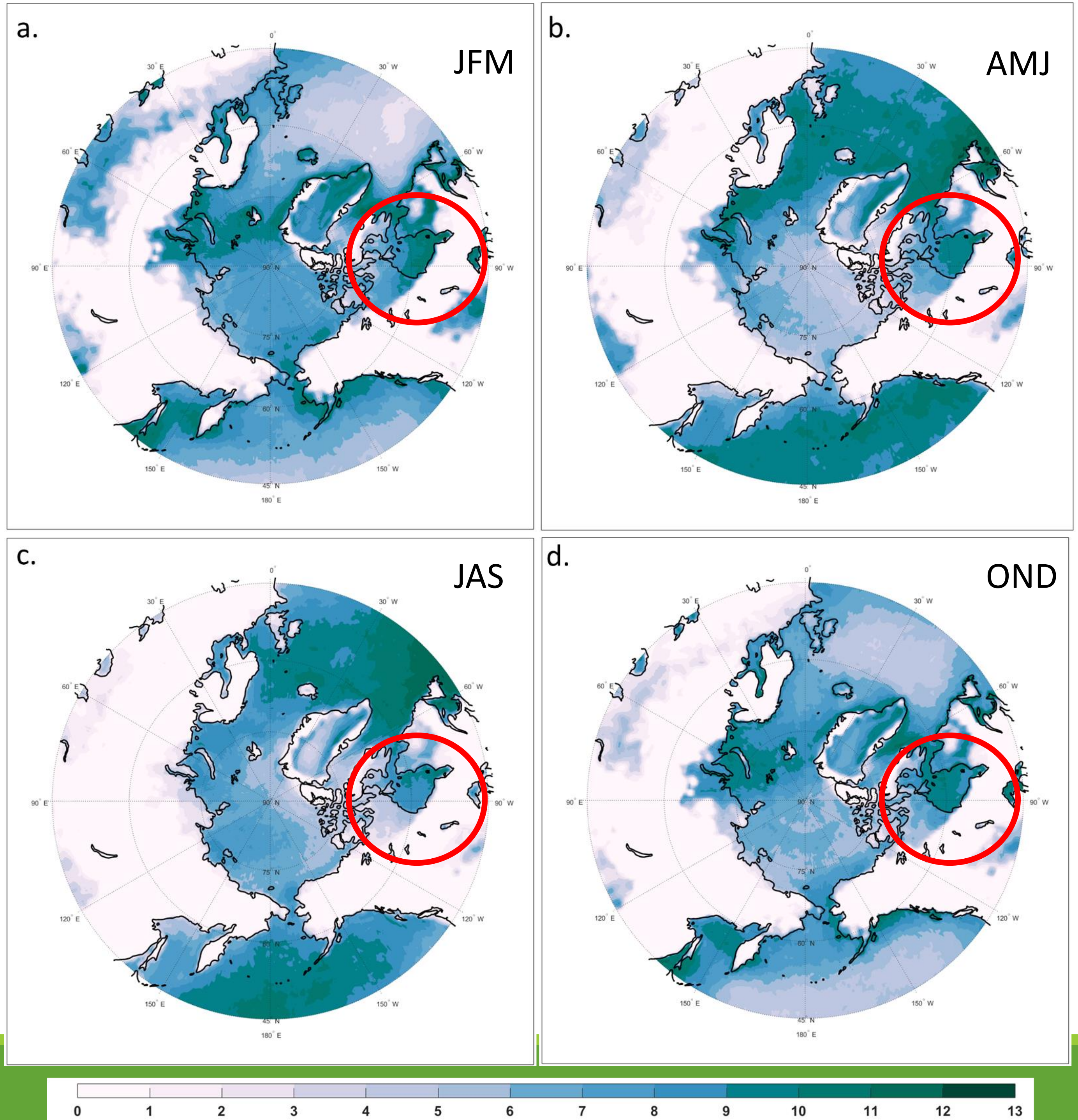
- Similarly, lull activity is at its lowest during the winter and fall seasons
- The highest frequency of lull events in the winter and fall seasons
  - Gulf of Alaska and AK coast
  - 8 – 10 events during both of the seasons
- Spring and summer seasons
  - Increase in the number of lulls is observed
- Coastal areas in the Pacific region tend to show the most inter-season consistency
  - 6 – 10 events per season


a.
JFM
b.
AMJ
c.
JAS
d.
OND
0 1 2 3 4 5 6 7 8 9 10 11 12 13

Lull Events

Primary regions of activity – Arctic:

- Both the Atlantic and Pacific sides of the Arctic, the greatest number of lulls occur in the winter and summer seasons, with 6 – 9 events on average.
- The maximum frequency of lulls in the winter and fall is located near the Atlantic entrance to the Arctic.
- The location of maximum events shifts in spring and summer
  - Closer to the Eurasian continent


a.
JFM
b.
AMJ
c.
JAS
d.
OND
0
1
2
3
4
5
6
7
8
9
10
11
12
13

Trends – Period Breakdown

One interesting result from this study

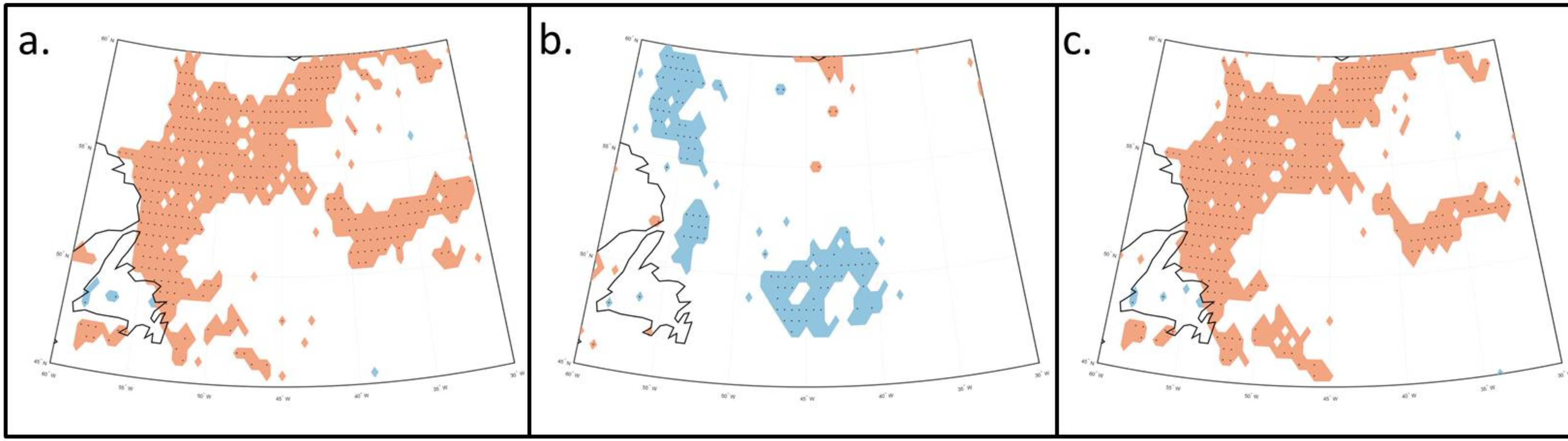
- Some regions with a decreasing trend of lull events lasting 48-hours+ have opposing trends when considering lulls of durations between 6-48 hours.

- This suggests a shift to more frequent short duration lulls, indicating an increase in windiness at these locations.
  - This pattern is prevalent in the North Atlantic region during the winter season
  - Wind event trends in this region show a similar increase in frequency in the winter season.

Wind Event Trends

48-hr + Lull Trends

All Duration Lull Trends



Storminess Percentage

***Storminess Percentage* (SP)** is defined as the percent of time at a given grid point spent in wind event criteria with respect to the total number of hours in that season (approximately 2160)

***Lulliness Percentage* (LP)** is defined using the same methodology.

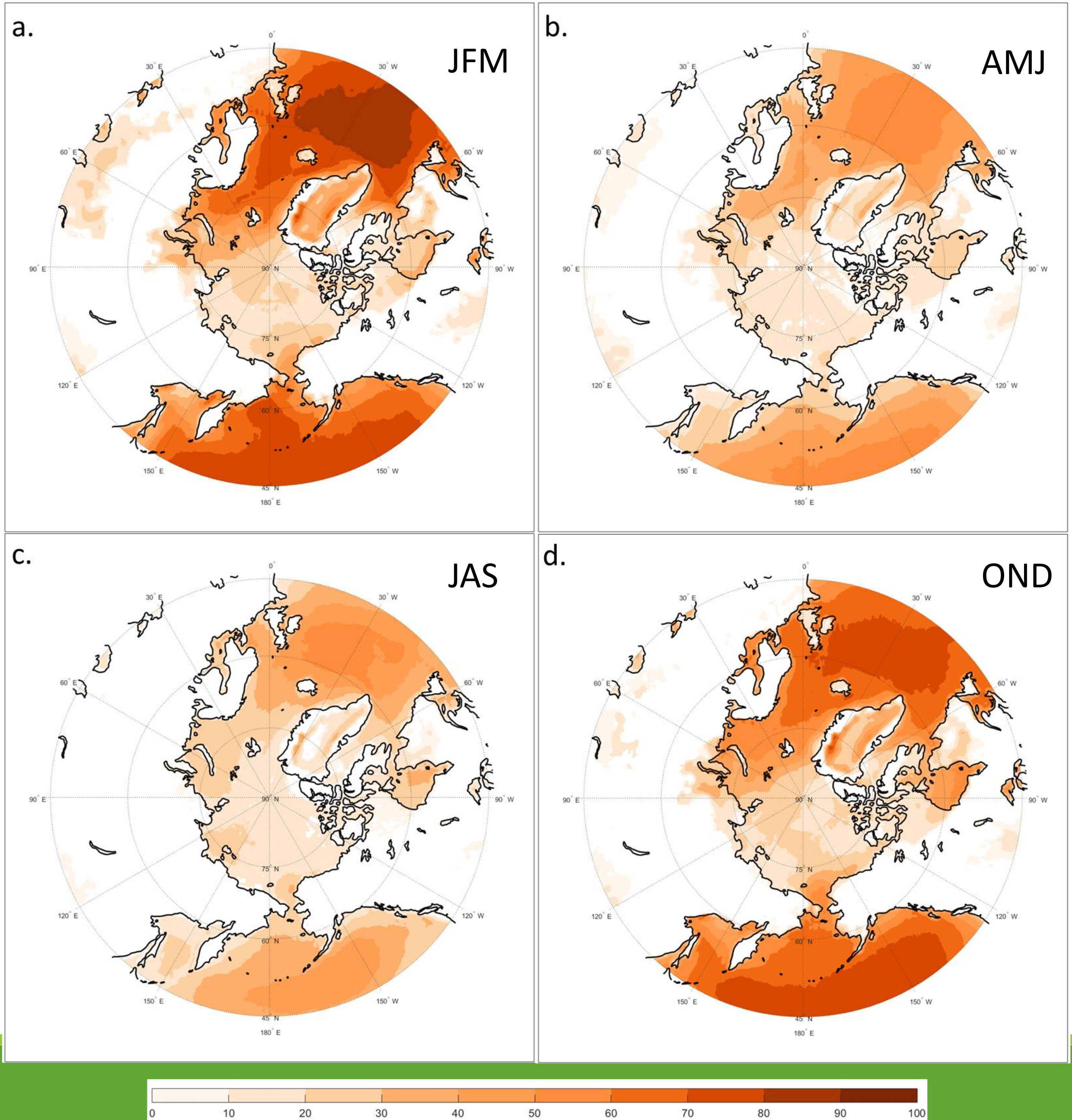
$$SP = \frac{\bar{e}_n \times \bar{d}_n}{d_{max}}$$

Results expressed in terms of the SP and LP indicators present wind and lull event data in a more usable form for end-users

- Allows for simple determination of the percentage of time that is likely to be spent in adverse wind conditions during a given season.

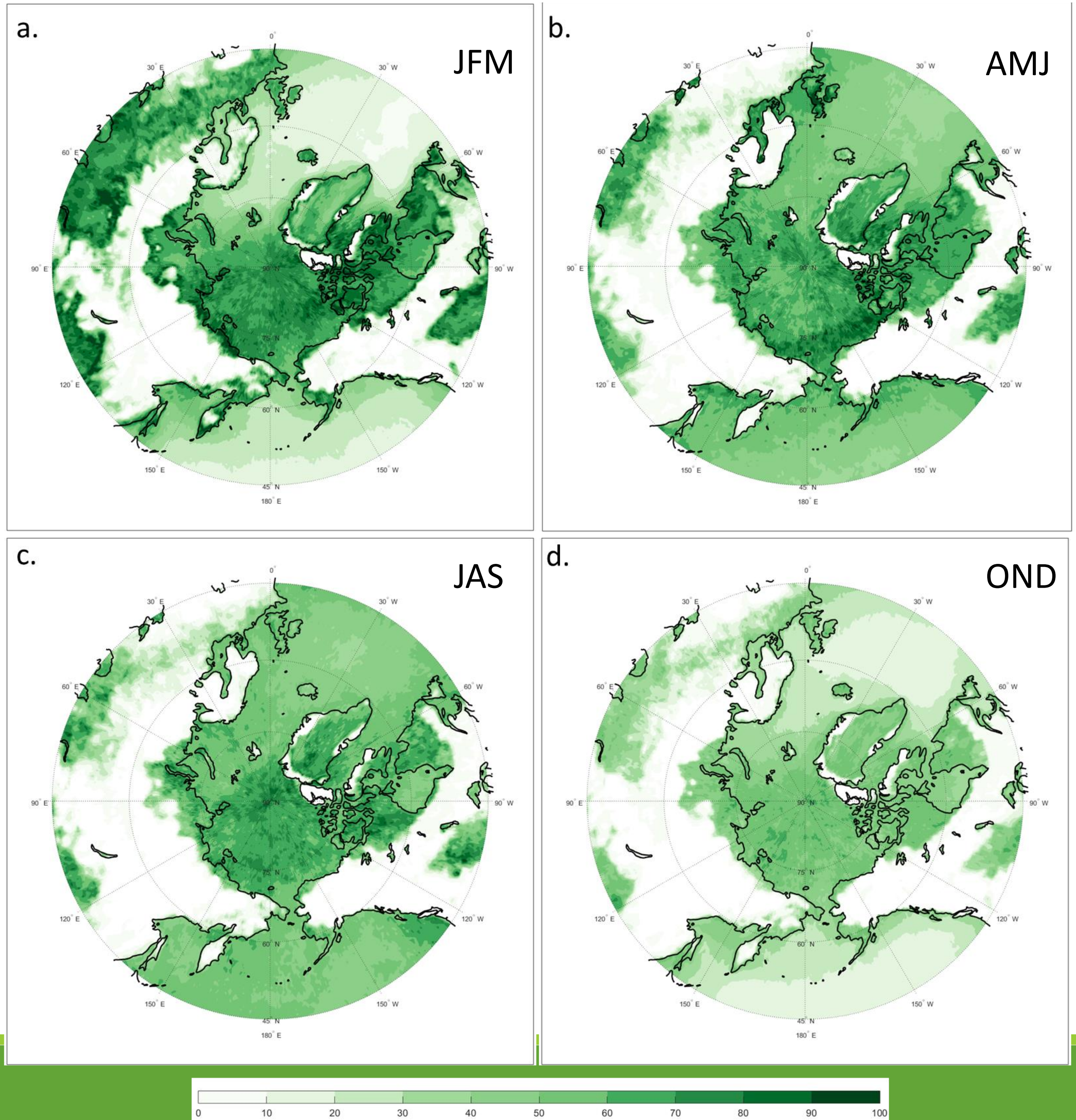
Storminess Percentage Climatology

1979 - 2010



Lulliness Percentage Climatology

1979 - 2010



Next Steps

Forecasting Product – Storminess indicators will be upgraded to convert it to a short- to mid-term forecast product by incorporating forecast model data.

- Currently based off of reanalysis data

Expand the LSW domain

Incorporate the eastern and western seaboards of North America, Gulf of Mexico, and the central North Pacific (including Hawaiian Islands).

Incorporate additional industries

- Thresholds can be easily adjusted, making the algorithm tailorable to any needs of end-users

Tailor results directly to the 100 day shipping season

One Last Thing:

<u>Other Storminess work currently on underway:</u>

- Seasonal predictability of extratropical cyclones in the Canadian Seasonal Forecasting System (CanSIPS)

- Changes in extratropical cyclones and explosive extratropical cyclones in CMIP5 models

- Regional climate model representation cyclones in dynamically downscaled data

- Seasonal predictability of stormininess indicators

<u>Resultant Publications</u>

- Seiler C, Zwiers FW (2015). How will climate change affect explosive cyclones in the extratropics of the Northern Hemisphere?. Climate Dynamics.

- Seiler C, Zwiers FW (2015) How well do CMIP5 climate models reproduce explosive cyclones in the extratropics of the Northern Hemisphere?. Climate Dynamics.

- Shippee, Atkinson, Partain (2016) Enhanced Storm Indicators for the Circumpolar Arctic, JAMC.

Acknowledgements

Funding for this research was provided by NOAA grant NA08OAR4600856 “Social Vulnerability to Climate Change in the Alaskan Coastal Zone” and MEOPAR project 2.3 “User-driven Monitoring of Adverse Marine and Weather States in the Eastern Beaufort Sea.”

We are also grateful for ECMWF providing their datasets in the public domain.

We also thank the captains and crew from Northern Transport Company Limited (NTCL) and Delta Western for their time for interviews and collegues Laura Erkes-Medrano and Vida Khalilian for efforts during the interviews.

References

ACIA, 2005: Arctic Climate Impact Assessment. Cambridge University Press, 1042 pp.

AMSA, 2009: Arctic Marine Shipping Assessment 2009 Report. Arctic Council, 190 pp.

Atkinson, D. E., 2005: Observed storminess patterns and trends in the circum-Arctic coastal regime. *Geo-Marine Lett.*, **25**, 98–109, doi:10.1007/s00367-004-0191-0.

Blier, W., S. Keefe, W. A. Shaffer, and S. C. Kim, 1997: Storm Surges in the Region of Western Alaska. *Weather Forecast.*, **125**, 3094–3108.

Dee, D. P., and Coauthors, 2011: The ERA-Interim reanalysis: configuration and performance of the data assimilation system. *Q. J. R. Meteorol. Soc.*, **137**, 553–597, doi:10.1002/qj.828.

Gilbert, R. O., 1987: *Statistical Methods for Environmental Pollution Monitoring*. John Wiley and Sons, 336 pp.

Hodges, K. I., R. W. Lee, and L. Bengtsson, 2011: A Comparison of Extratropical Cyclones in Recent Reanalyses ERA-Interim, NASA MERRA, NCEP CFSR, and JRA-25. *J. Clim.*, **24**, 4888–4906, doi:10.1175/2011JCLI4097.1.

Kendall, M. G., 1975: *Rank Correlation Methods, 4th Edition.* Charles Griffin, 202 pp.

Lynch, A. H., L. R. Lestak, P. Uotila, E. N. Cassano, and L. Xie, 2008: A Factorial Analysis of Storm Surge Flooding in Barrow, Alaska. *Mon. Weather Rev.*, **136**, 898–912, doi:10.1175/2007MWR2121.1.

MacClenahan, P., J. McKenna, J. a G. Cooper, and B. O'Kane, 2001: Identification of highest magnitude coastal storm events over Western Ireland on the basis of wind speed and duration thresholds. *Int. J. Climatol.*, **21**, 829–842, doi:10.1002/joc.666.

Malloy, J. W., and Coauthors, 2015: A Surface Wind Extremes ("Wind Lulls" and "Wind Blows") Climatology for Central North America and Adjoining Oceans (1979–2012). *J. Appl. Meteorol. Climatol.*, **54**, 643–657, doi:10.1175/JAMC-D-14-0009.1.

Mann, H. B., 1945: Nonparametric tests against trend. *Econometrica.,* **13**, 245-249.

Mason, O. K., D. K. Salmon, and S. L. Ludwig, 1993: THE PERIODICITY OF STORM SURGES IN THE BERING SEA FROM 1898 TO 1993, BASED ON NEWSPAPER ACCOUNTS. *Clim. Change*, 109–123.

Medearis, S., 2011: Sea ice blocks fuel barge delivery to Nome. *The Nome Nugget*., www.nomenugget.net/archives/2011/12.01.11%20nn.pdf. (Accessed January 11, 2016)

Medearis, S., 2012: Nome's first winter fuel delivery comes across the ice. *The Nome Nugget*., www.nomenugget.net/archives/2012/011912nn.pdf (Accessed January 11, 2016)

Mesquita, 2009: Characteristics and Variability of Storm Tracks in the North Pacific, Bering Sea and Alaska. Dissertation, University of Alaska-Fairbanks, 226 pp.

Mesquita, M. S., D. E. Atkinson, and K. I. Hodges, 2010: Characteristics and Variability of Storm Tracks in the North Pacific, Bering Sea, and Alaska*. *J. Clim.*, **23**, 294–311, doi:10.1175/2009JCLI3019.1.

Solomon, S., D. Forbs, and B. Kierstead, 1994: *Coastal Impacts of Climate Change: Beaufort Sea Erosion Study*. Geological Survey of Canada,.

Questions?

Thank You!