# Greenland climate/ice sheet change, extreme weather and global climate links/impacts

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Arctic Climate & Weather Extremes (Aspen) workshop, 17 May 2022

# Outline

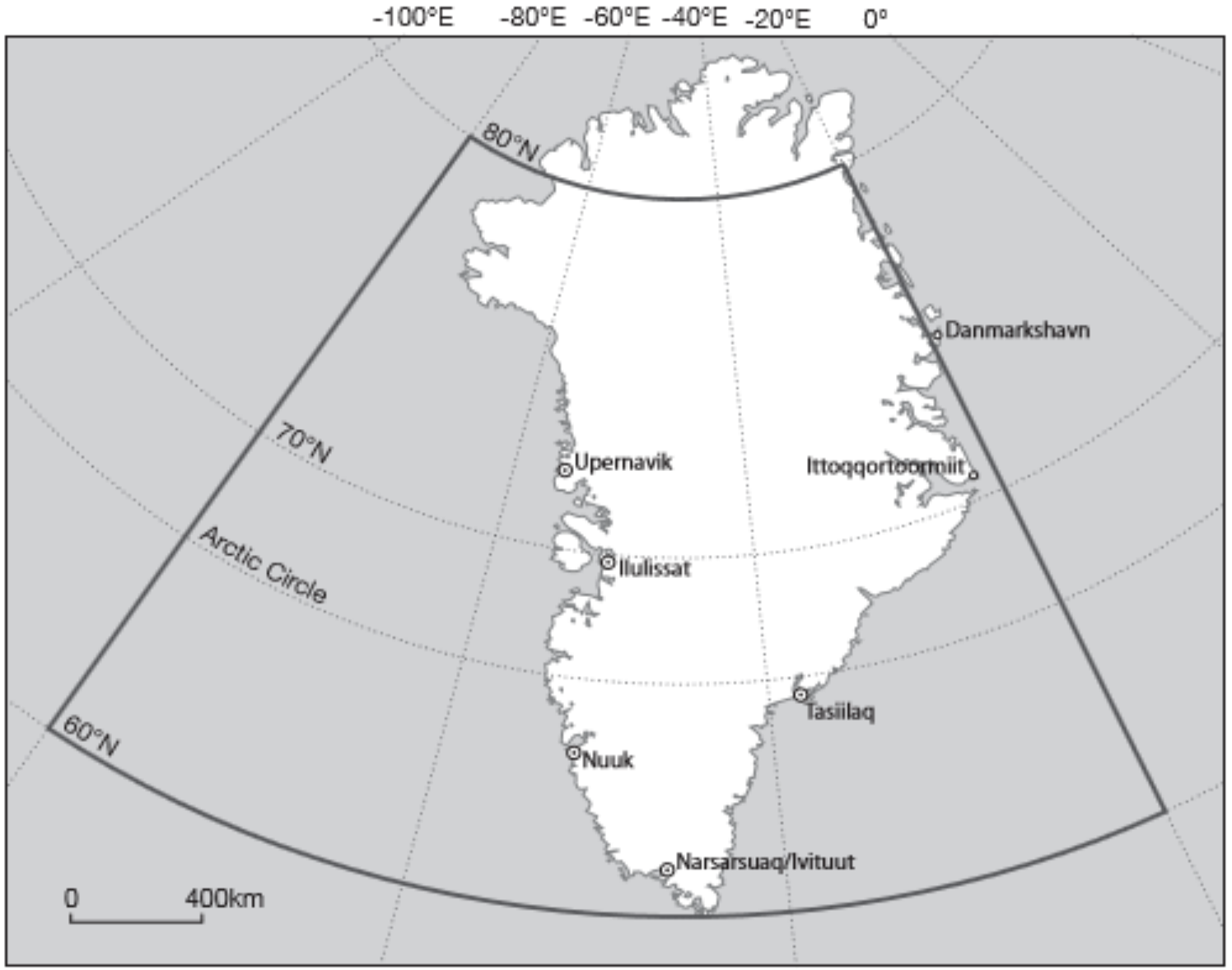
*Greenland climate change gauged through Greenland Blocking Index: definition, update and longer perspective on recent extreme blocking events and trends

*Wider impacts and feedbacks linked to Greenland climate change

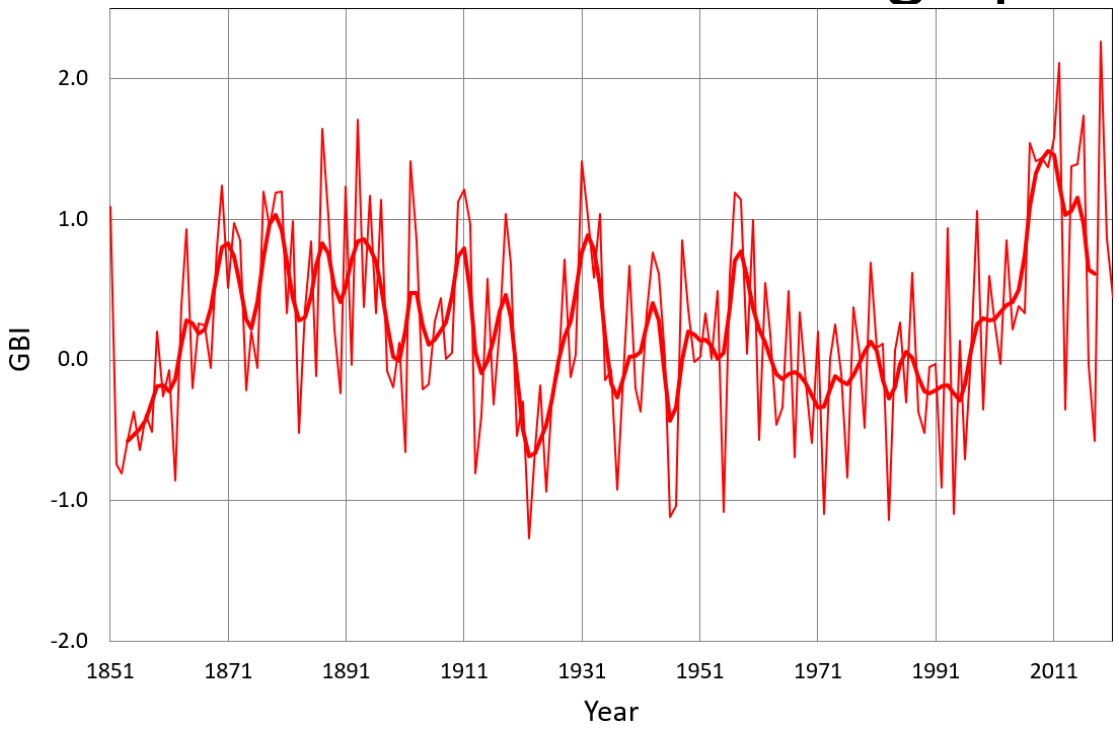
*Greenland Ice Sheet mass change & extreme events

*Suggestions for further work

**Greenland Blocking Index (GBI/GB1)** (Fang 2004, Hanna et al. 2013) is normalised mean 500 hPa (mb) geopotential height over this region (60-80°N, 20-80°W). **GB2** is GB1 minus 60-80°N hemispheric zonal GPH500 mean.



# Recent record summer high pressure over Greenland



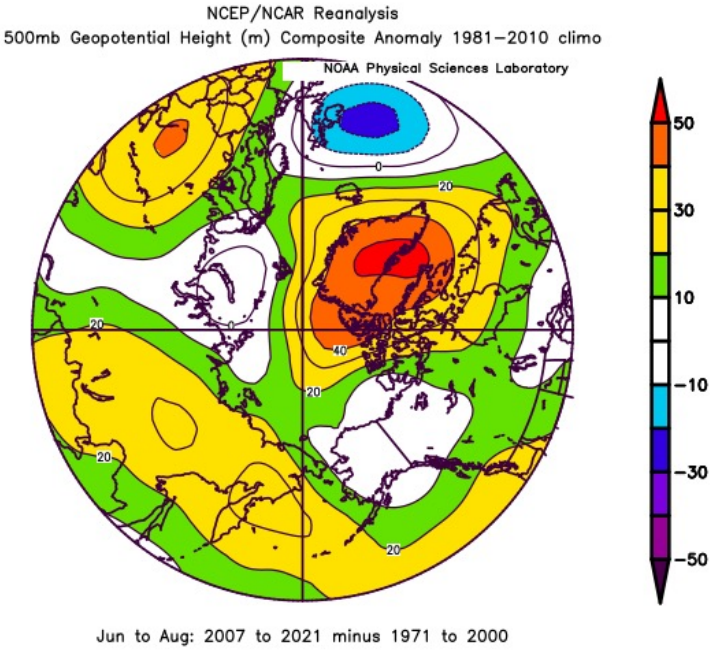
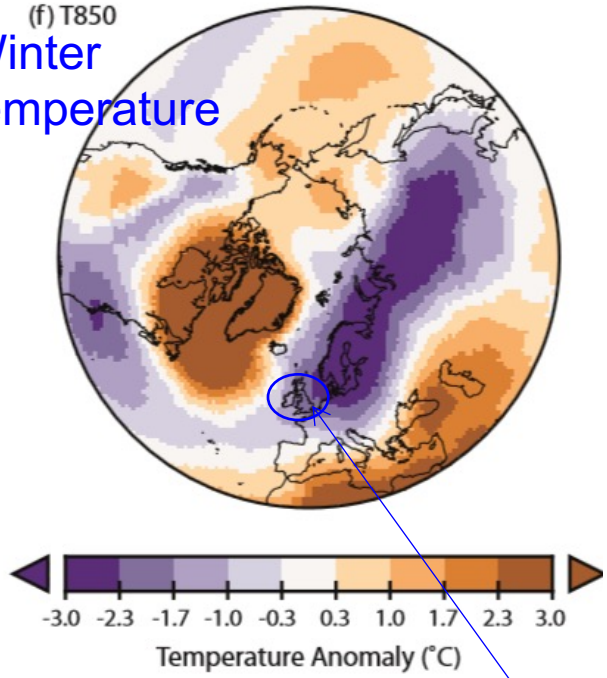
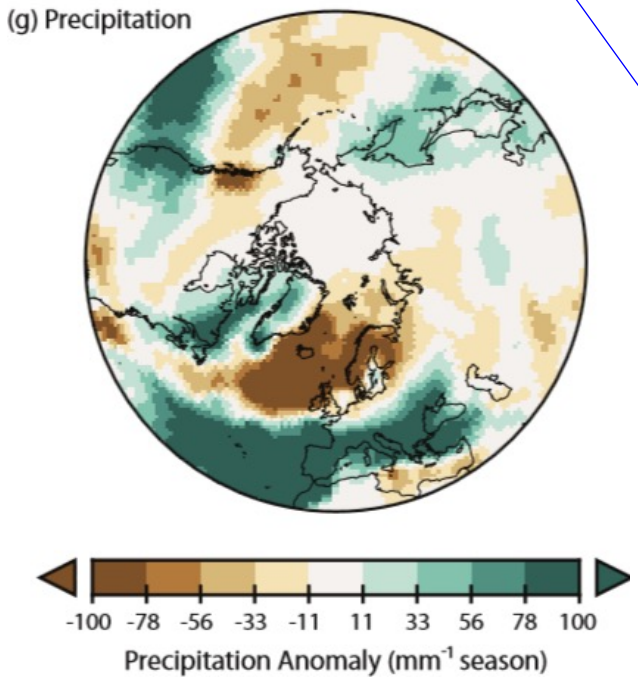




**Figure I** (left) shows yearly values of summer Greenland Blocking Index (GBI) for 1851-2021 fitted with 7-point binomial filter (bold red line), showing the striking significant increase since ~1990. Our updated GBI data are archived by NOAA at: https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/GBI_UL/

(right) shows 500 hPa geopotential height anomaly difference for summer (mean of June, July, August) 2007-2021 minus 1971-2000, showing region used to calculate GBI. This shows the recent increase in geopotential heights/air pressure/blocking over the Greenland region and accompanying decrease over the UK region.

Winter temperature

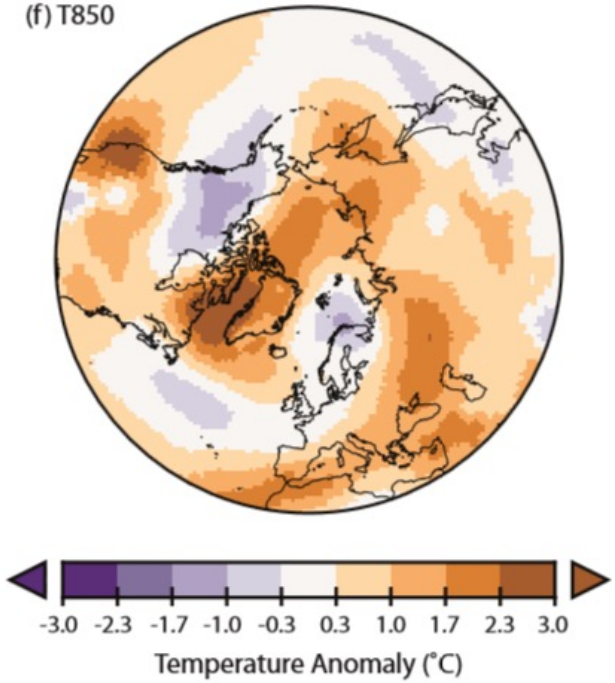


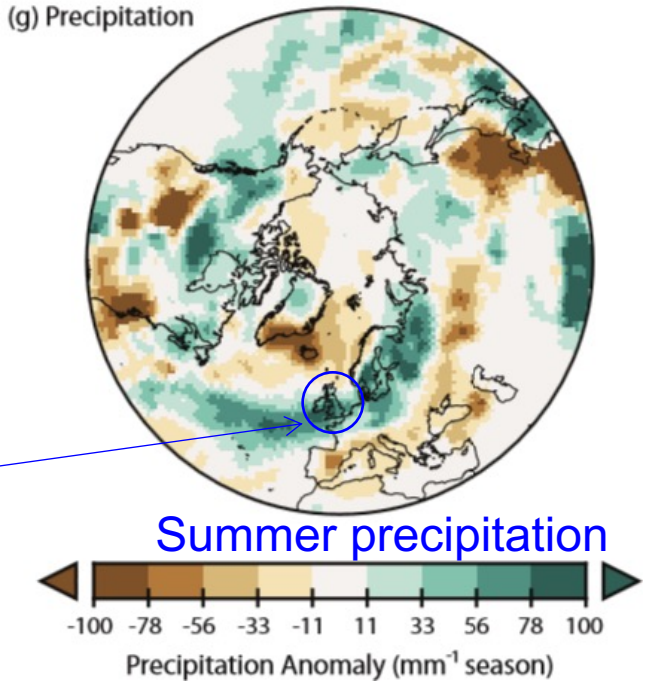




Greenland Blocking (GBI) impacts on mid-latitude weather: *Near-surface temperature (top)* and *precipitation (bottom)* anomalies for **winter (left)** and **summer (right)** for 10 highest minus 10 lowest Greenland Blocking years during 1851-2015. Based on Twentieth Century Reanalysis v2c data.

Note cold winters & wet summers over UK.

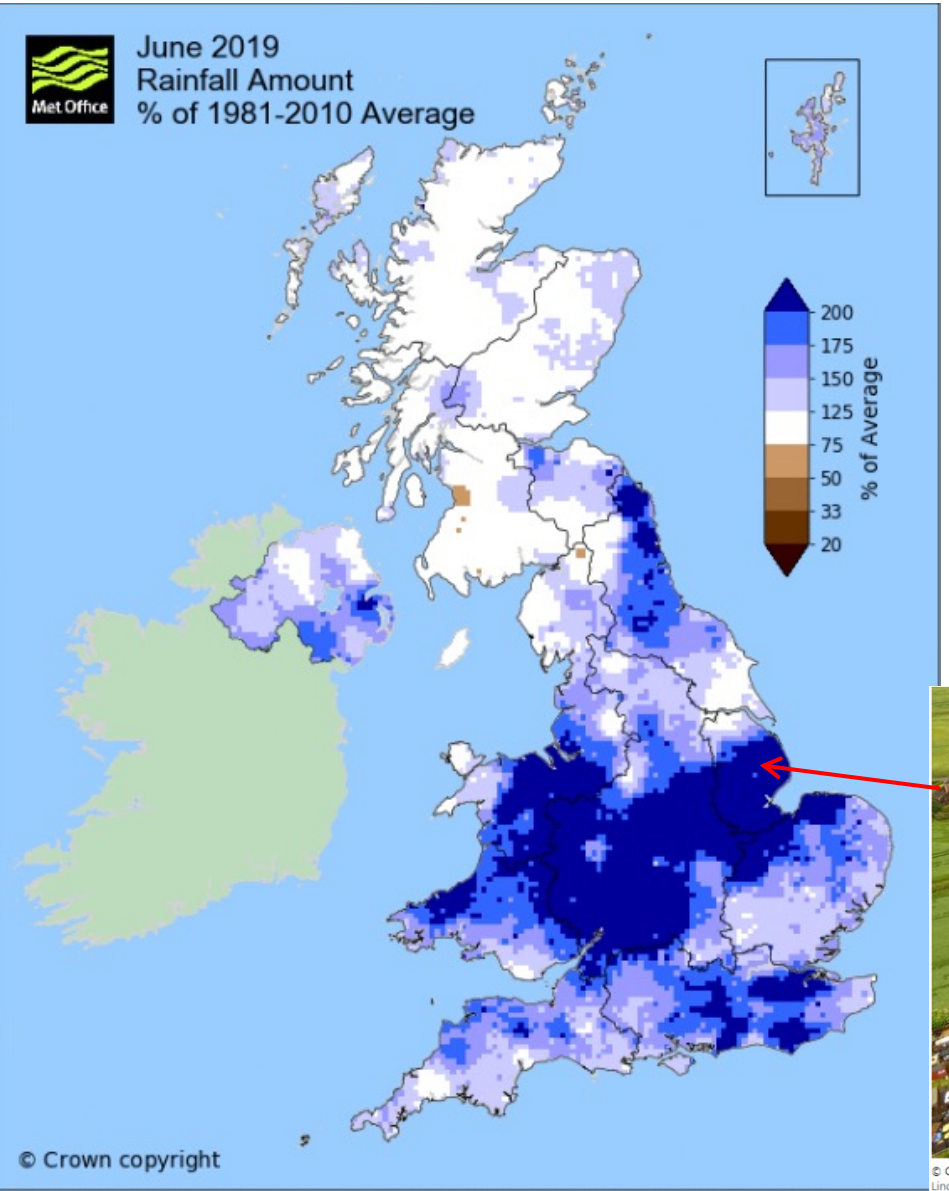
Hanna et al. (2016)

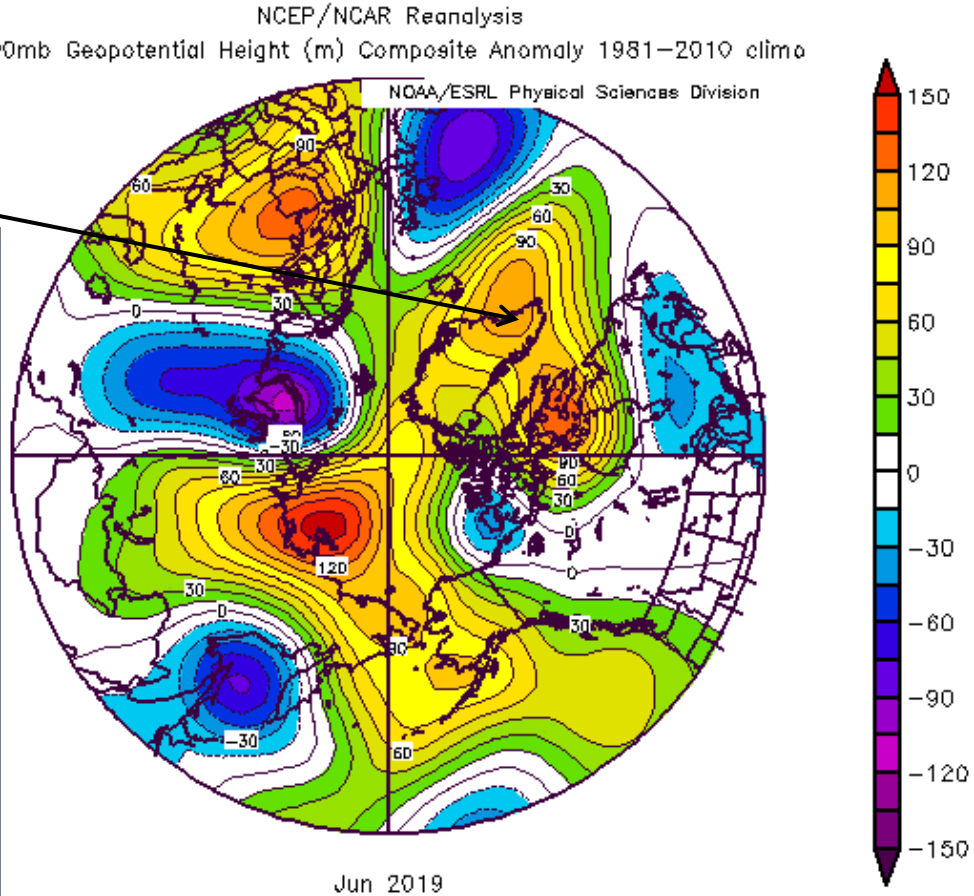



Summer precipitation

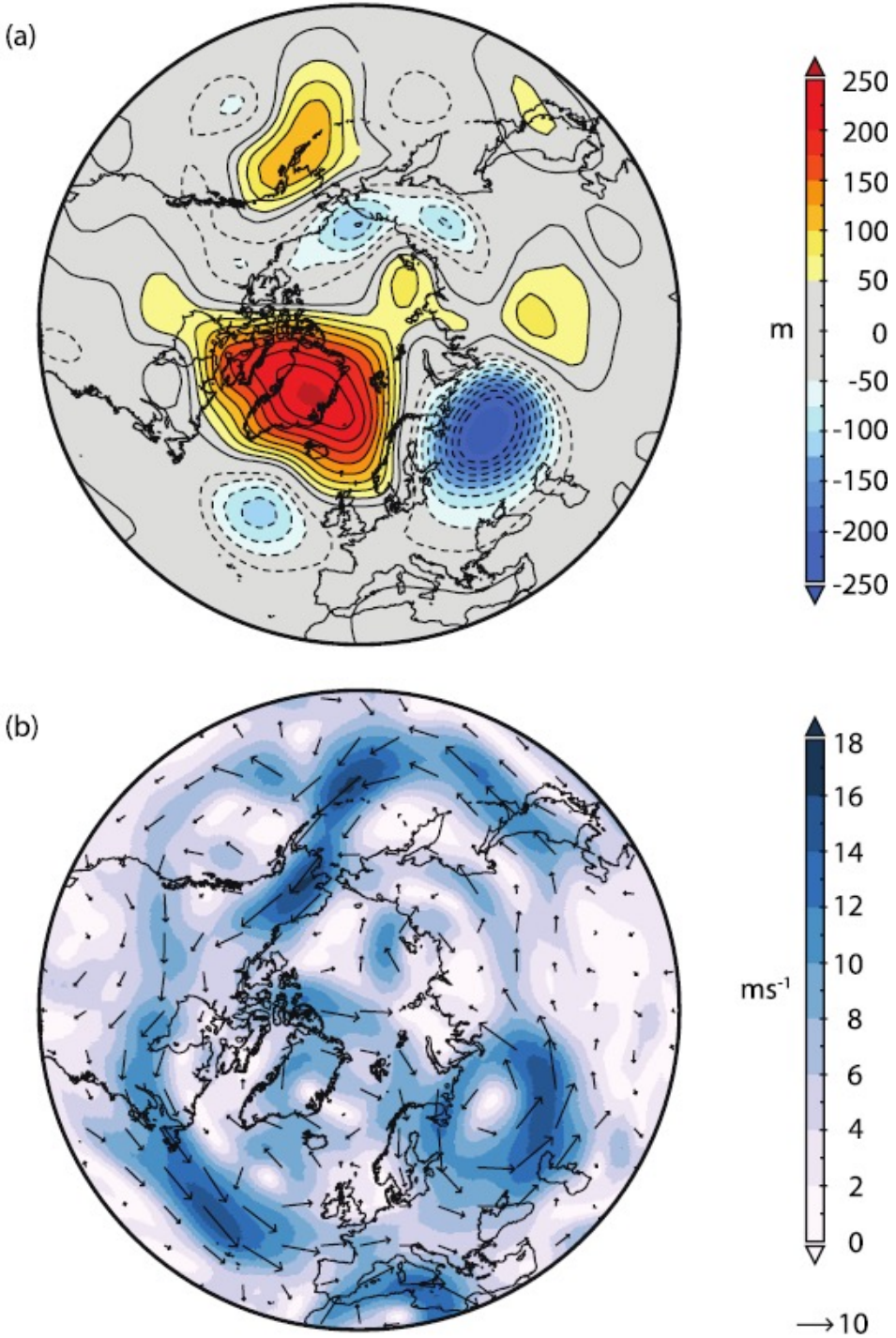
June 2019: = 2nd strongest anticyclone (high air pressure) over Greenland in June since 1948.





Wainfleet, Lincs.



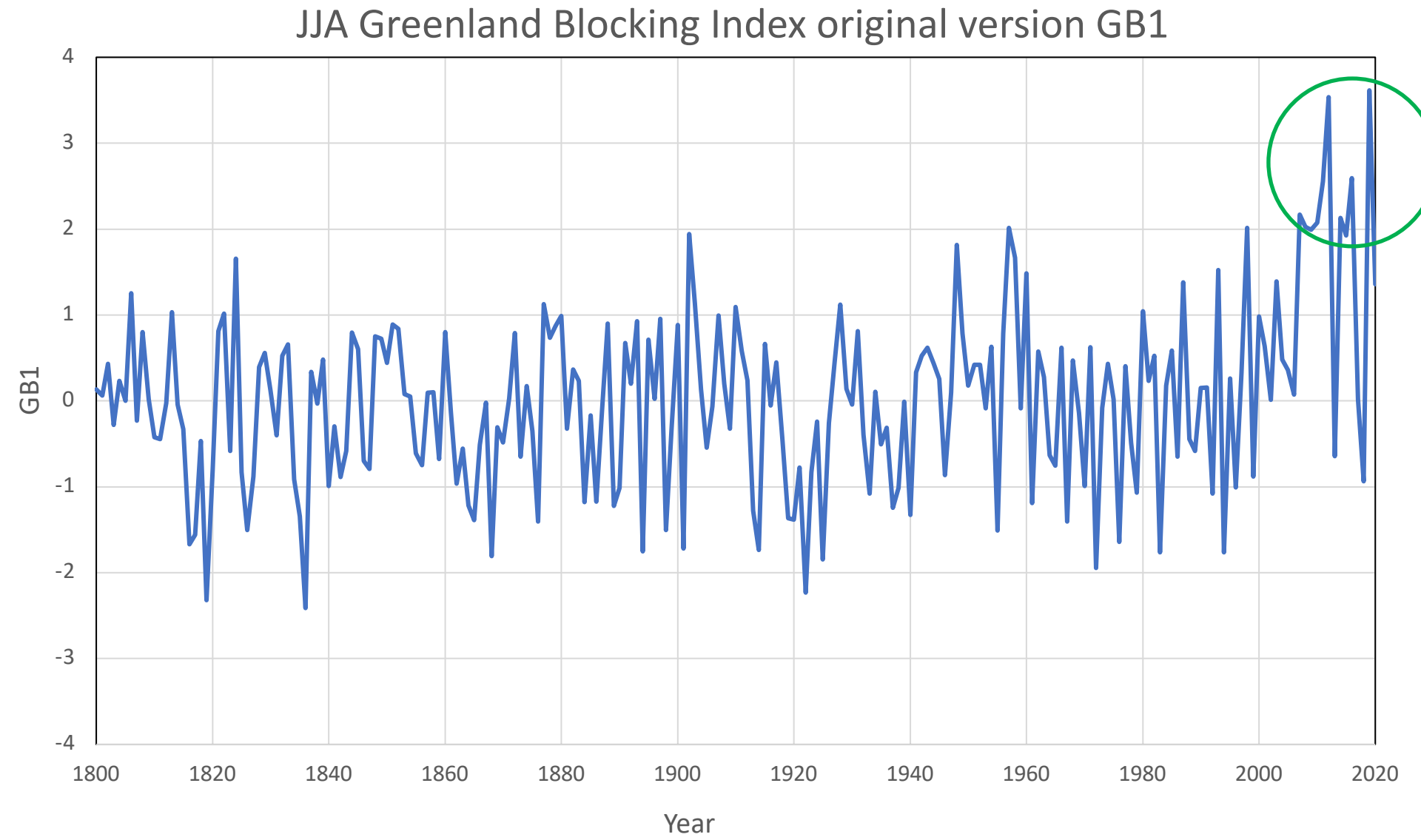

NCEP/NCAR Reanalysis v1 mean

(a) 500 hPa geopotential anomalies;

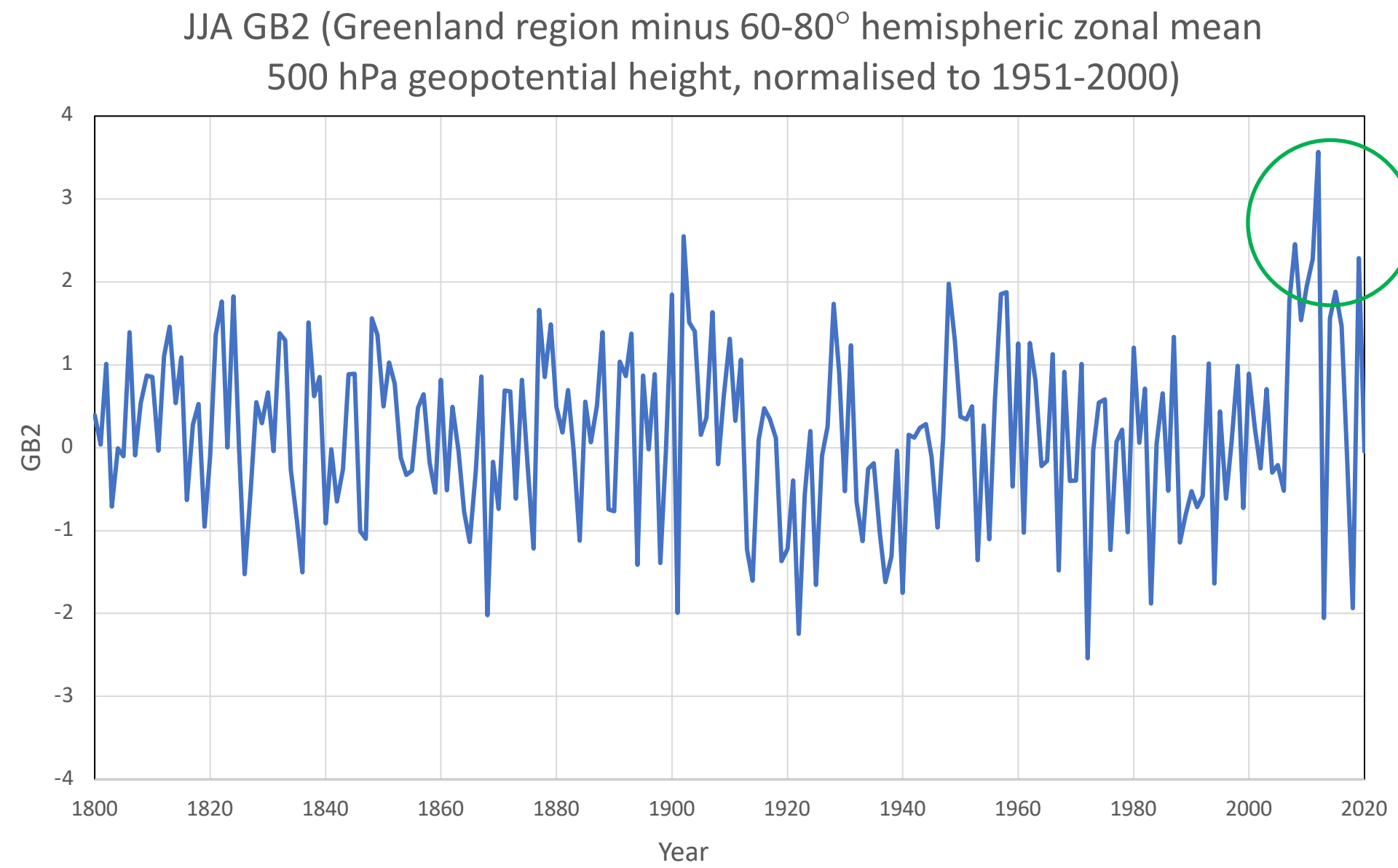
(b) 700 hPa vector winds indicating direction of **anomalous south-easterly airflow over Greenland during the high Greenland Blocking (GB) and high ice-melt episode from 30 July to 4 August 2019**, during which consecutive daily GB anomalies were all >2σ.

For panel (a) negative contours are dotted and the zero contour is omitted.

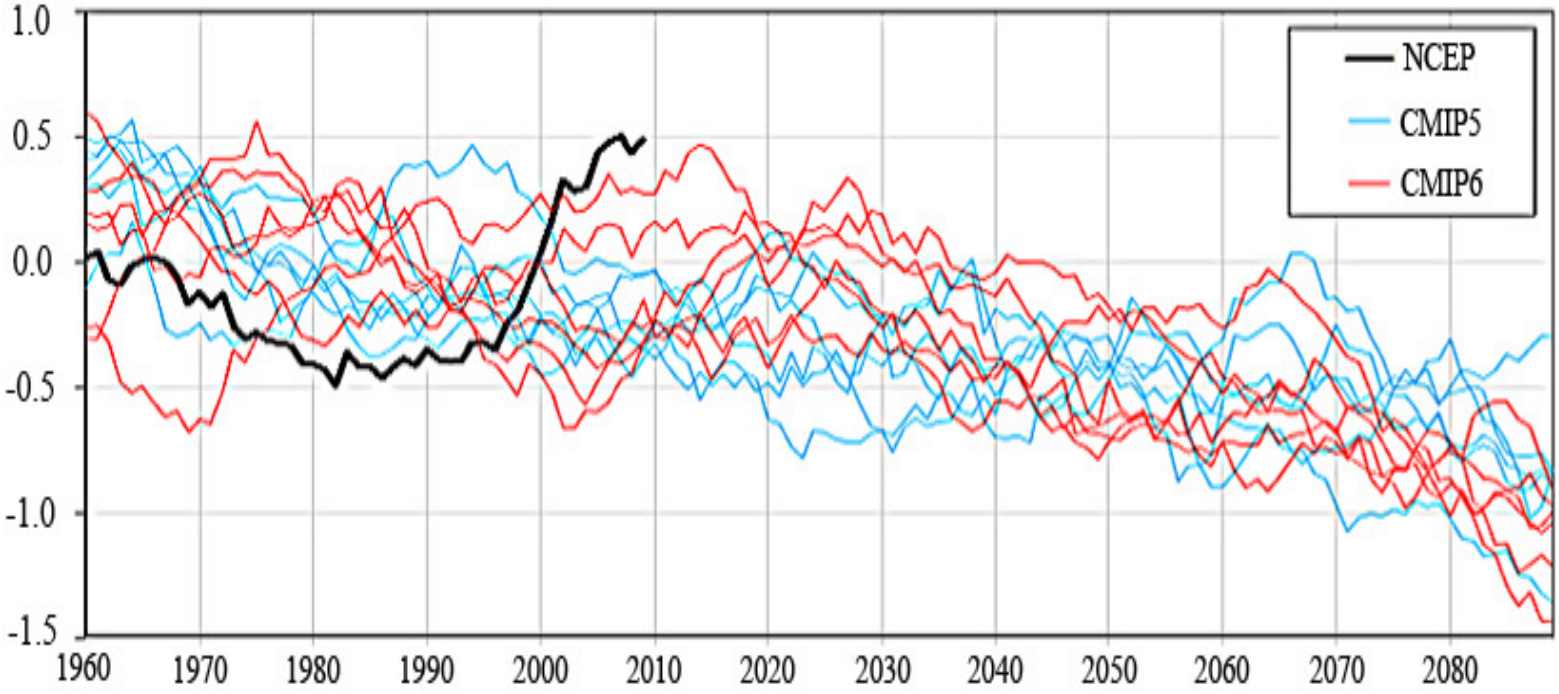
Hanna et al. (2021, *International Journal of Climatology* 41, E1336-E1352)

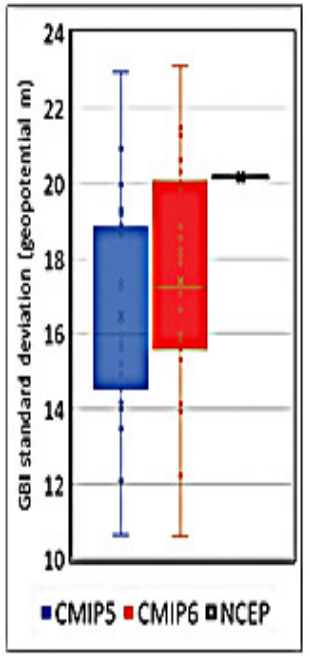



*For JJA GB1 ensemble mean series, 8/10 highest values occurred since 2007 (2019, 2012, 2016, 2011, 2007, 2014, 2010 & 2008). Cumulative probability of getting $P(X \geq 8)=10^{-9}$ , with corrected p-value~$10^{-8}$. All 30 ensemble members have at least 6/10 highest values since 2007 -> $P(X \geq)$~$4 \times 10^{-6}$ -> corrected p-value ~$3 \times 10^{-5}$. Also significant increase in GB1 since 1800.



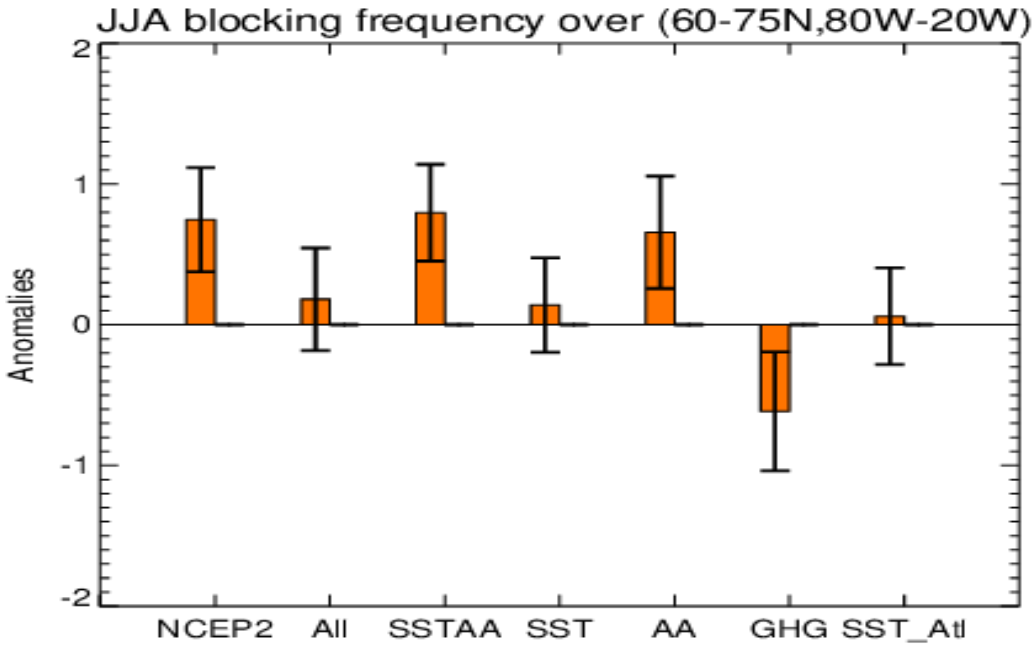

*For JJA GB2 ensemble mean series, 6/10 highest values occurred since 2007 (2012, 2008, 2019, 2011, 2010, 2015). Cumulative probability of getting $P(X \geq 6) = 4 \times 10^{-6}$ , with corrected p-value~$3 \times 10^{-5}$. 27/30 ensemble members have at least 4/10 highest values since 2007 -> $P(X \geq 4) = 0.00173$` -> significant corrected p-value ~0.014. Linear trend not significant.




**Left:** 21-year running means of GBI summer (JJA) time series during 1960–2100, as simulated by NCEP reanalyses (black line) and selected CMIP5 (blue lines) and CMIP6 models (red lines) for which RCP8.5 & SSP585 scenario runs were respectively available. For CMIP time series, historical scenarios are used over 1950–2005 (CMIP5) and 1950-2014 (CMIP6). CMIP5 and CMIP6 models (six in each case) are selected on the basis of showing greatest interannual variability in historical GBI. All values are normalised using 1950-2019 as the reference period.

**Right:** interannual standard deviation of GBI JJA values 1950-2019 from CMIP5/6 and NCEP.




Blocking frequency summer (JJA) climatology observed changes (NCEP2) and Met Office MetUM-GA6 atmosphere and land model simulated seasonal mean responses in blocking frequency climatology to different forcings between the periods 1964-1981 and 1994-2011[16]. Bars show modelled blocking responses to changes in all forcings (All), sea-surface temperature/sea-ice extent and anthropogenic aerosols (SSTAA), sea-surface temperature/sea-ice extent (SST), anthropogenic aerosols (AA), greenhouse gases (GHG), and Atlantic sector sea-surf. temperature/sea-ice extent (SST_Atl). Figure courtesy of Dr. Buwen Dong, University of Reading, adapted from material used in:

Dong, B. & R.T. Sutton (2021) Recent trends in summer atmospheric circulation in the North Atlantic/European region: is there a role for anthropogenic aerosols? *Journal of Climate* 34, 6777-6795.

# New 639,000 GBP "GreenBlock" NERC grant, 2022-2025

## Lincoln-led with Exeter, Oxford, Reading, Sheffield & Met Office

**Causes and impacts of Greenland Blocking changes: Description of the Proposed Research**

**1. Overall aim** This project aims to provide a step-change in understanding the causes of atmospheric circulation (specifically blocking) changes over Greenland, their relation to variations in the North Atlantic atmosphere and oceanic circulation systems, their consequences for climate change and extreme weather conditions over Greenland and the wider North Atlantic region, and their impacts on the Greenland Ice Sheet mass balance and global sea-level rise. This is a revision of a proposal that achieved an Excellence Score of 8/10 in the January 2019 NERC SG round. In this re-organised proposal we provide new pilot-study evidence and include further model analysis tasks (in WP2.2, WP2.3 & WP3.1) by an expanded world-class research team to address the Panel's sole criticism regarding the adequacy of coupled climate models for the proposed work.

**2. Objectives**

**A.** Determine how well current state-of-the-science global climate models (GCMs) represent recent seasonal changes in Greenland Blocking (GB), particularly in summer (WP1).

**B.** Decipher the causes and impacts of extreme GB episodes and GB changes, emphasising the links between synoptic and climatological timescales (WP2.1), and assess the effect of climate-model biases on their simulation of GB variability and trends (WP2.2).

**C.** Produce observationally constrained projections of seasonal GB to year 2100 and associated storylines of their possible impacts on North Atlantic/European weather and climate (WP2.3 & WP3.1), and on the Greenland Ice Sheet melt and global sea-level rise (WP3.2).

**Greenland Ice Sheet total mass change (Gt) from April 2002 to August 2021** determined from GRACE (2002-2017) and GRACE-FO 920128-present) satellite data. From Moon et al. (2021, Arctic Report Card).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## Fire Fury Future (repeat)

Posted on Aug, 25, 2021, by Radio Ecoshock

Should we fear a new burst of warming and extreme weather due to record wildfires? I ask atmospheric scientist John C. Lin from Utah. From the UK, Dr. Edward Hanna says unusual air pressure over Greenland can ruin European summers and pump up ...

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Context

Climate change

United Nations

Climate change refers to long-term shifts in temperatures and weather patterns, mainly caused by human activities, especially the burning of fossil fuels.

Forces behind Greenland melting —Edward Hanna on global warming—Radio Ecoshock 2019-09-04

328 views • 3 Apr 2020

26 DISLIKE SHARE SAVE ...

Hanna *et al*. (2015, updated) *Int. J. Climatol.* Analysis of the **North Atlantic Oscillation** Index = strength of westerly winds reaching UK

Graph shows December NAO values from 1899-2020

**Milder, wetter, stormier**

**Colder, drier**

GBI monthly and daily time series 1851-2021 are available from NOAA:

https://psl.noaa.gov/gcos_wgsp/Timeseries/GBI_UL/

Updates with the new longer series will be posted here.

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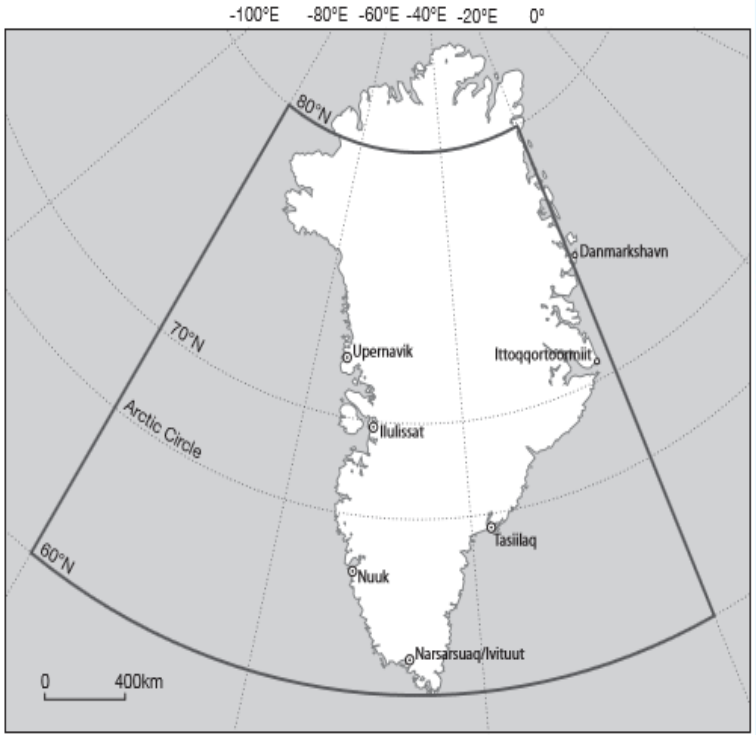


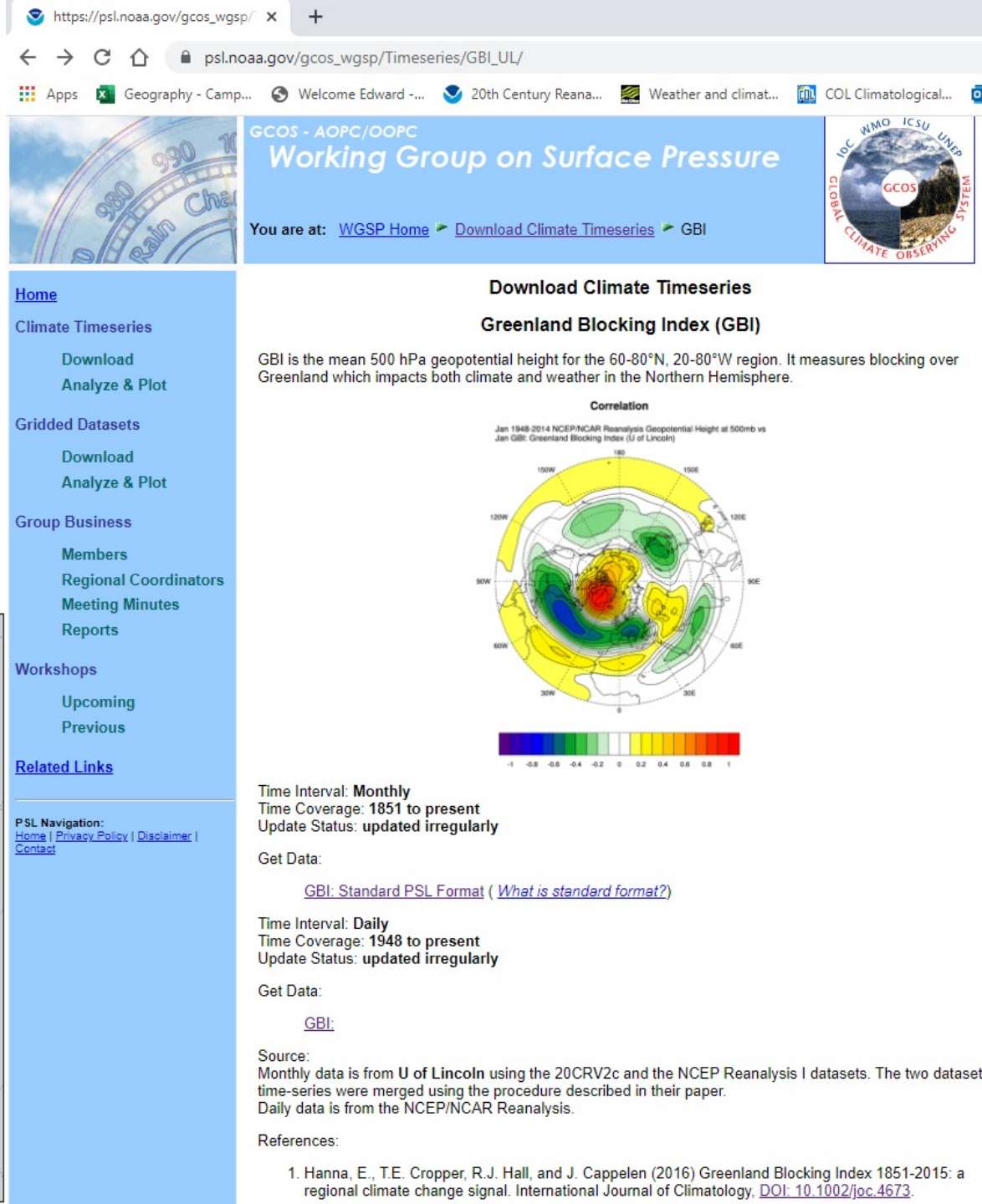

# Summary

*Greenland Blocking (closely linked with North Atlantic polar jet stream changes) has major impacts on climate and extreme weather over Greenland and the wider North Atlantic region (e.g. UK summer rainfall), and on Greenland Ice Sheet mass change.

*New 1800-2021 Greenland Blocking Index (GBI) series from merged (spliced) reanalyses (EKF400v2 & ERA5) datasets where these were checked against long-running/extended climate weather station records (e.g. SW Iceland, Gibraltar).

***Significant increase in GBI/GB1 in summer** is robust feature of the new longer series, based on analysis of individual EKF400v2 reanalysis ensemble members as well as ensemble mean. Despite **no significant overall linear trend in summer GB2**, **BOTH GB1 & GB2 show significant recent clustering (since 2007) of extreme high Greenland Blocking summer seasons.**

*Summer GBI increase is not well represented by most CMIP models.

*New NERC grant will explore Greenland Blocking (changes, mechanisms and wider impacts) in models and observations.

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RESEARCH ARTICLE

International Journal of Climatology RMetS

# Brief communication: CMIP6 does not suggest any atmospheric blocking increase in summer over Greenland by 2100

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**Abstract**

The Greenland blocking index (GBI), an indicator of the synoptic-scale circulation over Greenland, has been anomalously positive during most summers since the late 1990s. Such changes in atmospheric circulation, favouring anticyclonic conditions, have led to an increase in Greenland summer temperatures, a decrease in cloud cover and larger surface melt. The GBI is therefore a key indi-



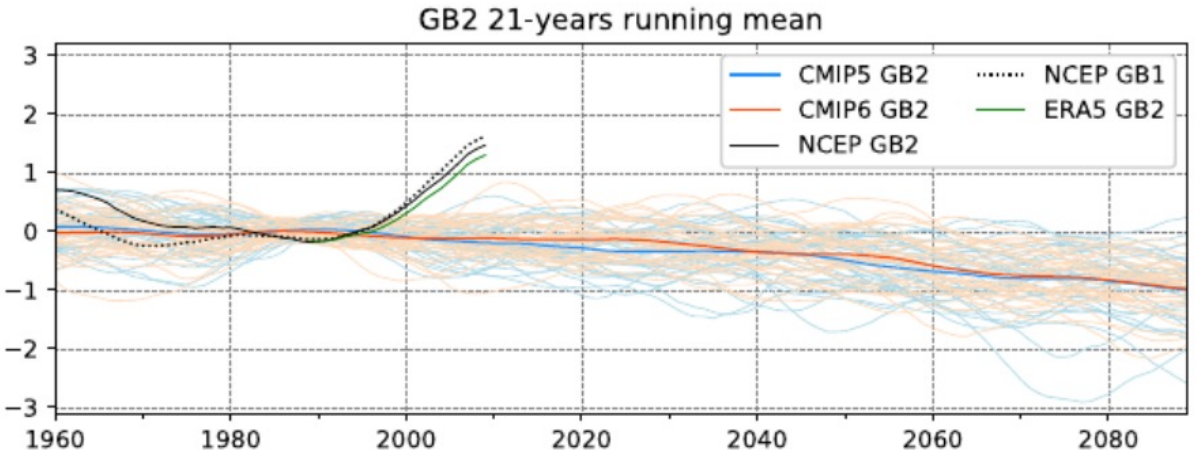
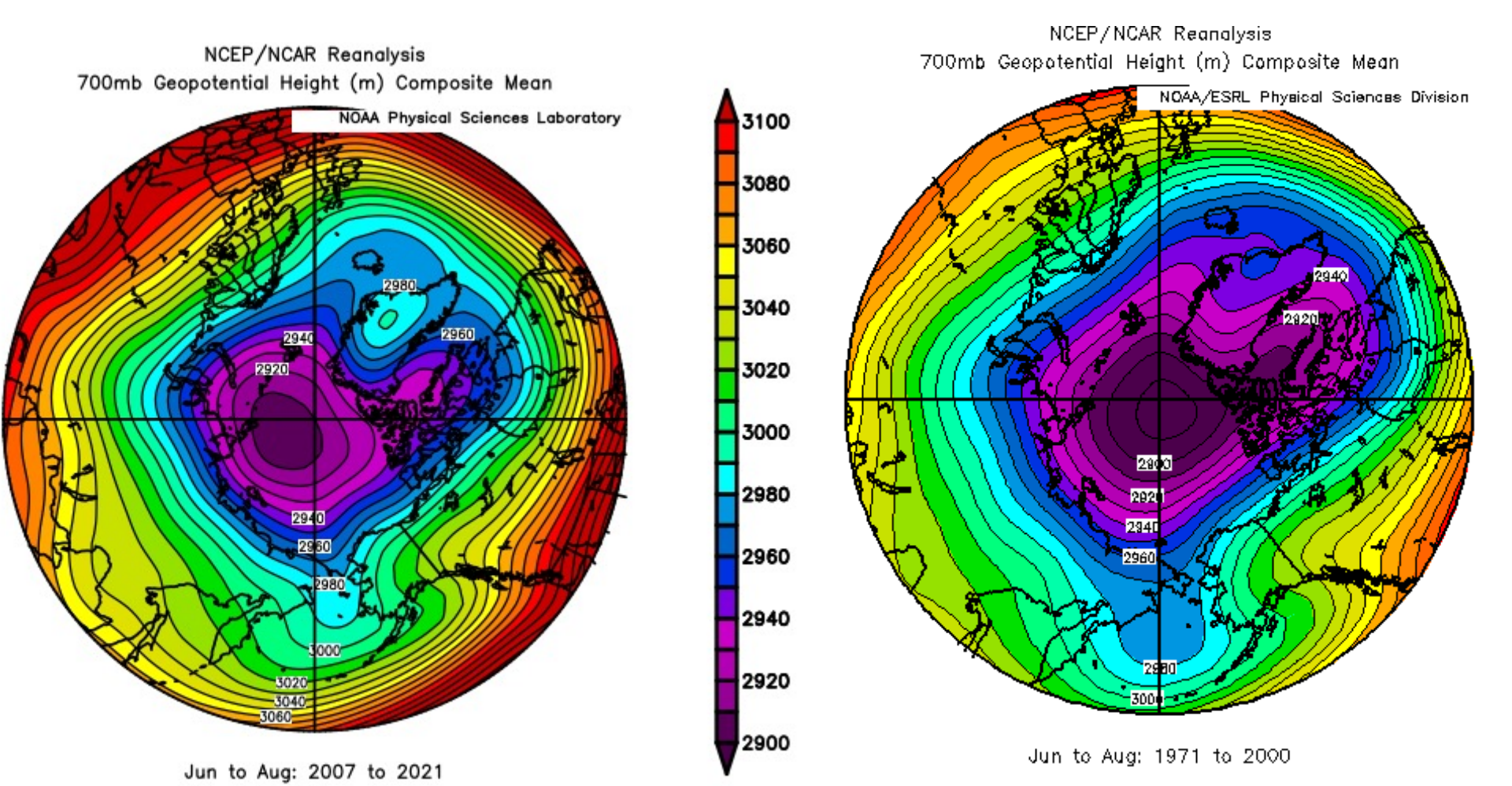



**FIGURE 2** JJA GB1 (dashed black line) and GB2 (solid black line, defined in Equation (2)) indices over 1950–2100 as simulated by NCEP/NCAR Reanalysis 1, ERA5 Reanalysis (green line), as well as by all the CMIP5 models (RCP8.5 scenario, blue lines) and the CMIP6 models (ssp585, red lines). Lighter lines represent the normalized GB2 for each model while the mean of CMIP5 and CMIP6 models are represented by the thicker lines. The historical scenario is used from 1950 to 2005 for CMIP5 and 1950 to 2014 for CMIP6, while RCP8.5 and ssp585 are respectively used afterwards. Finally, a 21-year running mean has been used to smooth the time series, and values have been normalized using 1980–1999 as the reference period




**Wavier jet-stream pattern in North Atlantic sector in last 15 summers**

**2007-2021** (left) compared with climatology (1971-2000, right).

Units = metres of 700 mb geopotential height.

Data: NCEP/NCAR Reanalysis via NOAA/Earth Systems Research Laboratory.

*Overland, Francis, Hanna, Wang (2012, Geophys. Res. Lett.), adapted/updated.*