

Rain-on-snow events in Svalbard, climatology and trends

By Marius O. Jonassen and Siiri Wickström

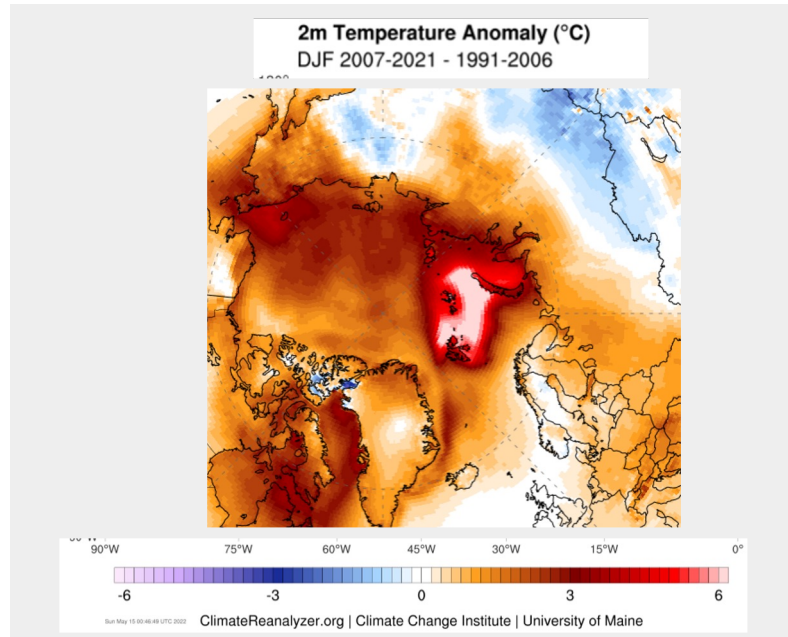
Photo: Ketil Isaksen/MET

BACKGROUND

- Arctic winters have become increasingly warmer and wetter

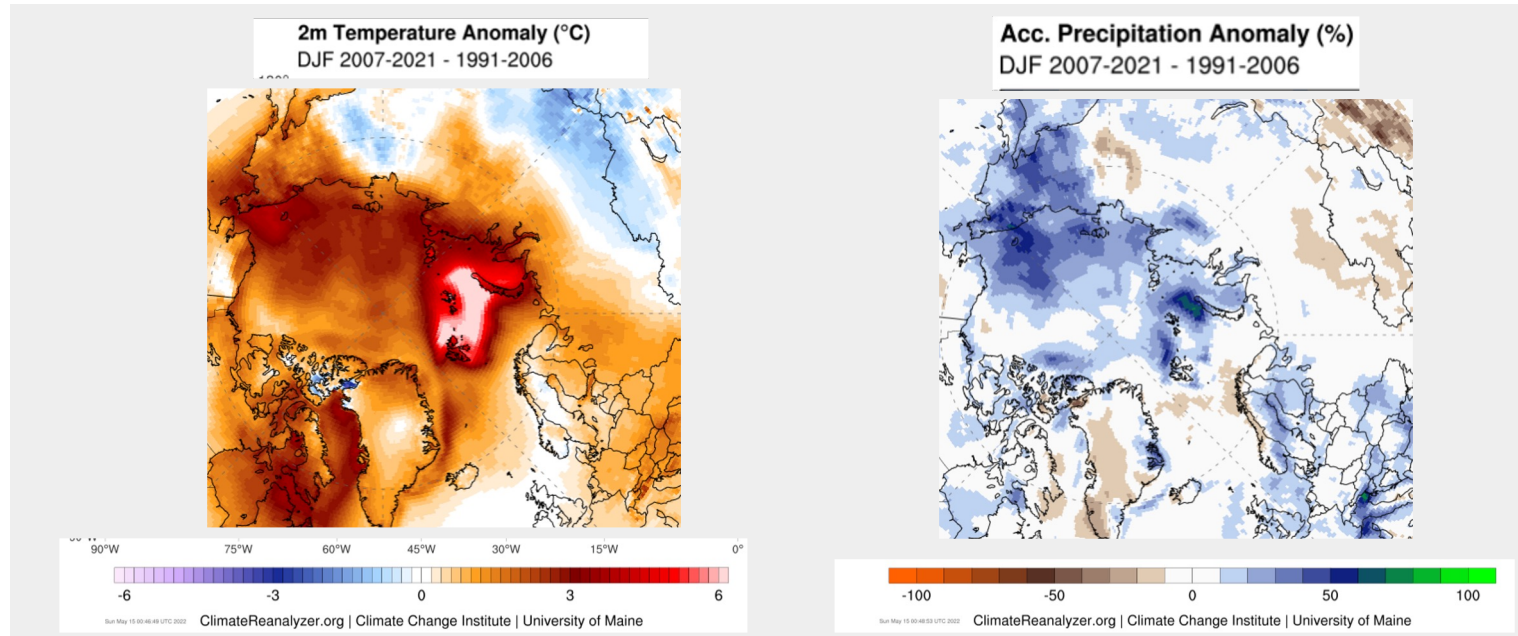
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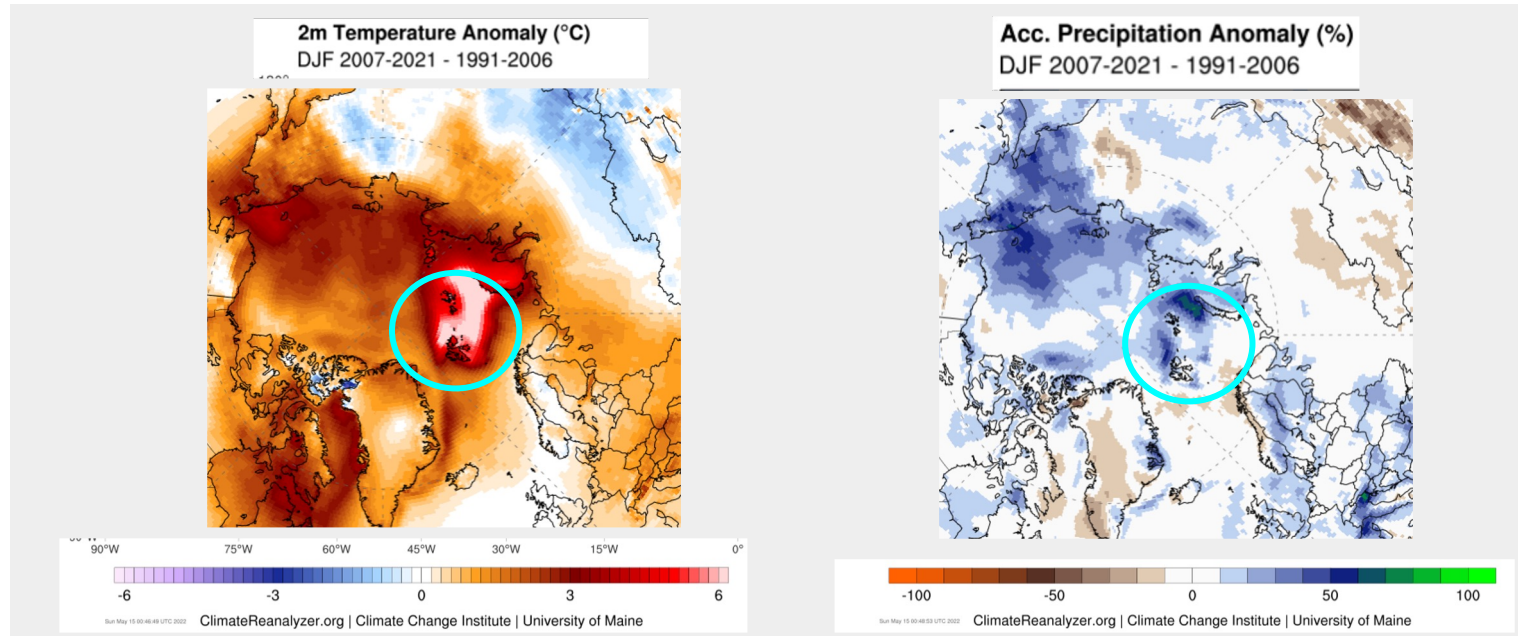
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- **Svalbard is in a hot spot for this climate change**



BACKGROUND

- Arctic winters have become increasingly warmer and wetter
- Svalbard is in a hot spot for this climate change
- **Such change makes “rain-on-snow events” more relevant**
 - *Rain during the winter time while the ground is covered by snow*

BACKGROUND

- *Rain-on-snow (ROS)* may cause:

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- ***Rain-on-snow (ROS)*** may cause:
 - Extensive ice layers at the snow/ground interface where permafrost prevails
 - *Might block access to food resources for herbivores such as reindeer (Hansen et al., 2013).*



Photos: Brage B. Hansen, NTNU Centre for Biodiversity Dynamics

BACKGROUND

- ***Rain-on-snow (ROS) may cause:***
 - Extensive ice layers at the snow/ground interface where permafrost prevails
 - *Might hinder snowmobiles and dogsleds in the field*
Bad for tourism and scientific fieldwork



Photos: mushamna.blogspot.com/

BACKGROUND

- ***Rain-on-snow (ROS)*** may cause:
 - Slush avalanches
 - *Posing a risk to people and infrastructure*



Svalbardposten, 2012



UNIS, 2006

GOALS OF THIS STUDY

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- **Provide a climatology of ROS events in Svalbard**
 - Number of events
 - Duration of events
 - Mean T2 during events
 - Mean precip amount during events

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 - Focusing on the same variables

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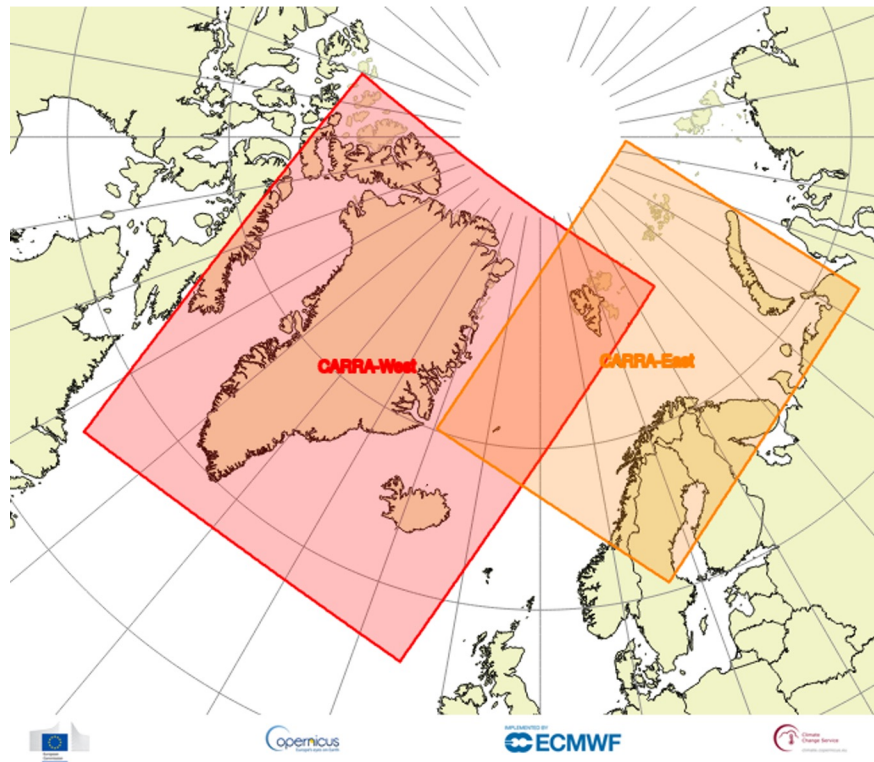
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 - Number of events
 - Duration of events
 - Mean T2 during events
 - Mean precip amount during events
- **Provide trends of ROS events in Svalbard**
 - Focusing on the same variables
- **Look into cases of most extreme ROS events in Svalbard**
 - Showcasing the January 2012 event

DATA and METHODS

DATA and METHODS: *CARRA REANALYSIS*

Copernicus Arctic Regional ReAnalysis project

- 30-years (**1991-2021**) reanalysis for European Arctic
- Two domains; West and **East**
- Horizontal resolution of 2.5 km
- Based on HARMONIE-AROME cy40
- ERA5 forcing on boundaries
- 3-hourly cycling, hourly output



DATA and METHODS: *Flow type data set*

- Flow type data set for Svalbard (Niedźwiedź, 2013)
 - *Manually made based on DWD charts*
 - *Similar to the flow type data set made for the British Isles (Lamb, 1972)*
- 21 different flow types
 - *8 cyclonic*
 - *8 anticyclonic*
 - *5 non-directional*

Our definitions:

ROS = a DJF day that has:

- *daily mean $T_2 \geq 0^\circ\text{C}$*
and
- *daily accumulated precipitation $\geq 1\text{ mm}$*

ROS event: One or more subsequent DJF days when these conditions are fulfilled

RESULTS

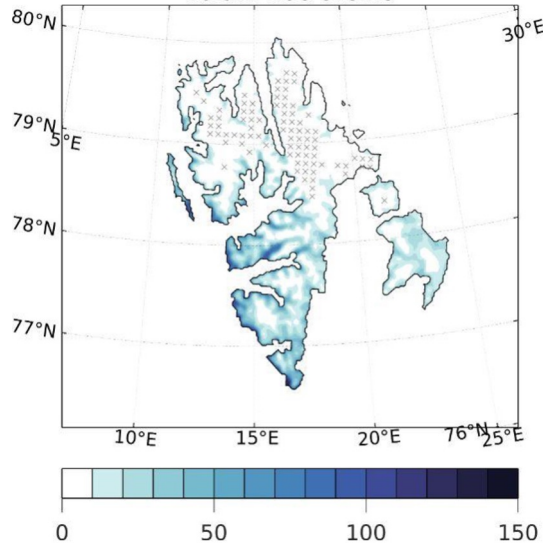
ROS statistics, *climatology*

DJF 1991-2021

ROS statistics, *climatology*

DJF 1991-2021

Total #ROS events

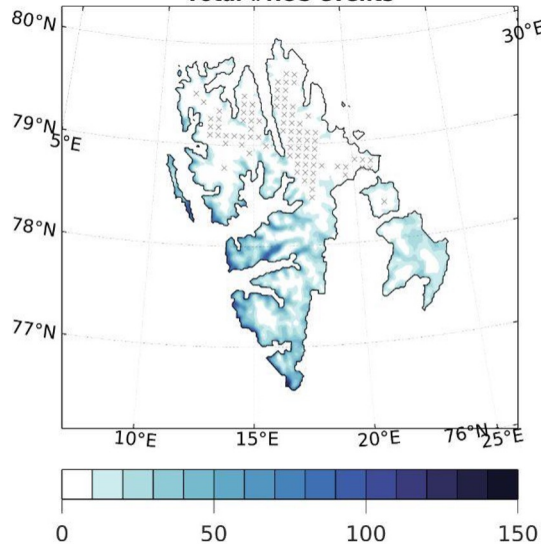


- **Most events (100-120)**
 - *South- and west-coasts*
 - *Central Spitsbergen at lower altitude*

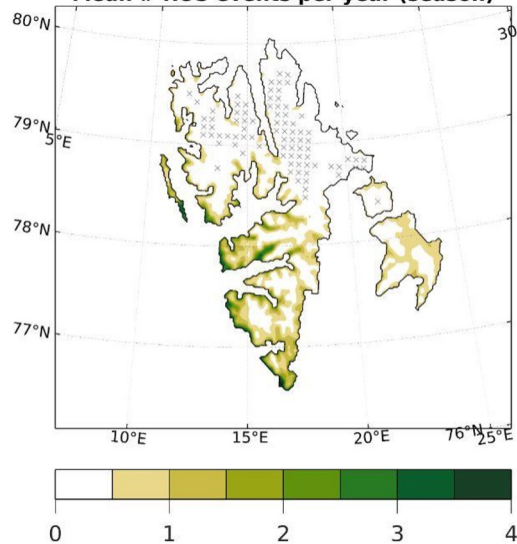
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DJF 1991-2021

Total #ROS events



Mean # ROS events per year (season)

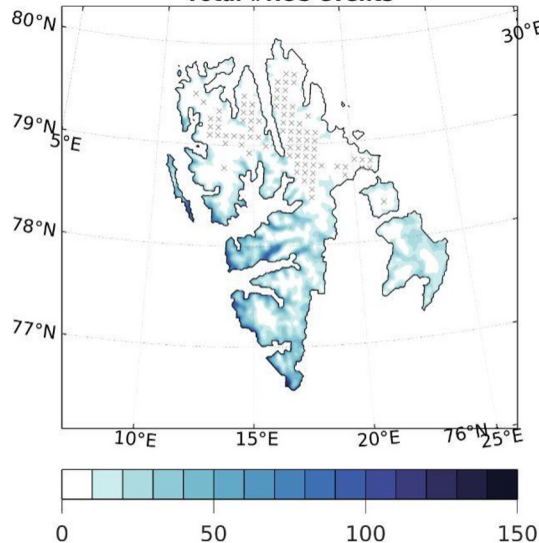


- **Most events (100-120) (2-4 per season)**
 - *South- and west-coasts*
 - *Central Spitsbergen at lower altitude*

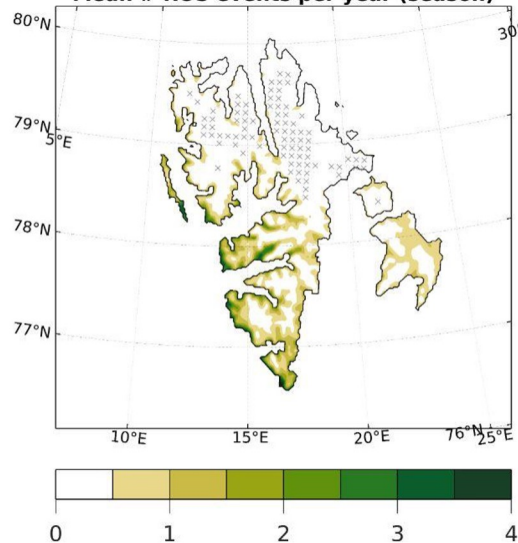
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DJF 1991-2021

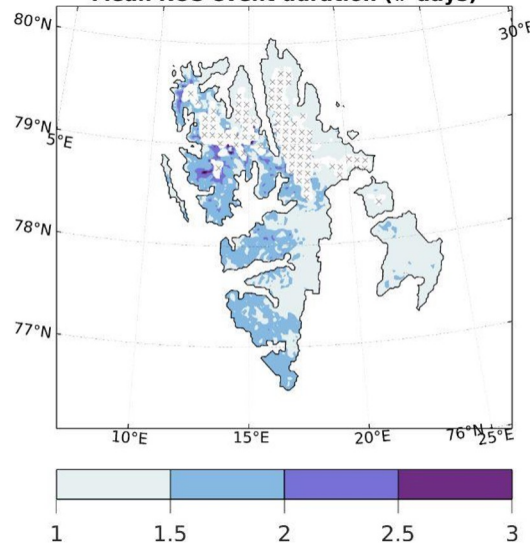
Total #ROS events



Mean # ROS events per year (season)



Mean ROS event duration (# days)

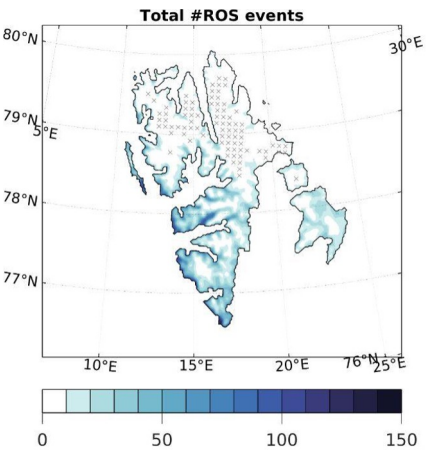


- **Most events (100-120) (2-4 per season)**
 - *South- and west-coasts*
 - *Central Spitsbergen at lower altitude*

- **Longest event duration (2-2.5 days)**
 - *In western half*
 - *In western mountains*
 - *(But few events)*

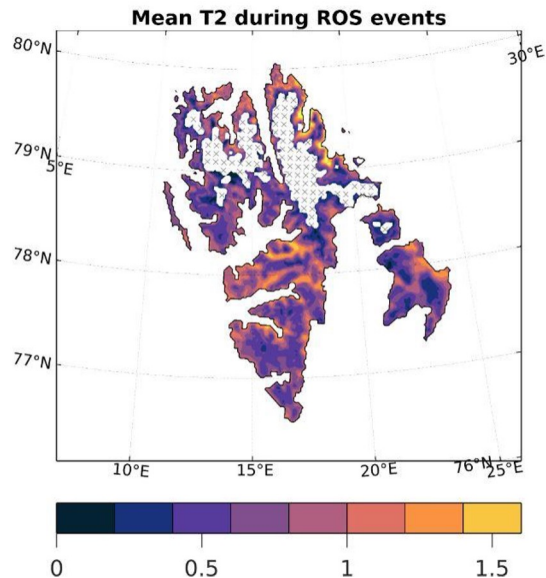
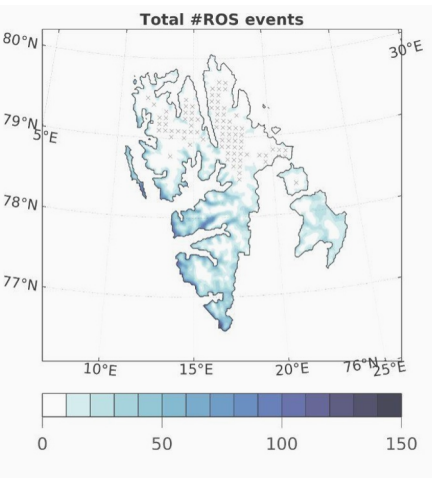
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DJF 1991-2021



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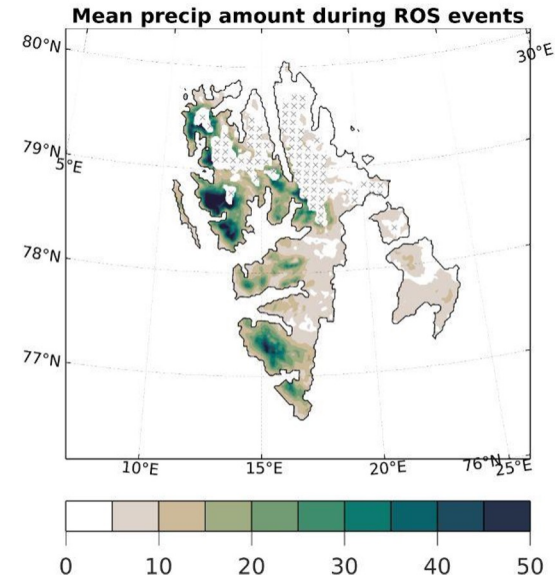
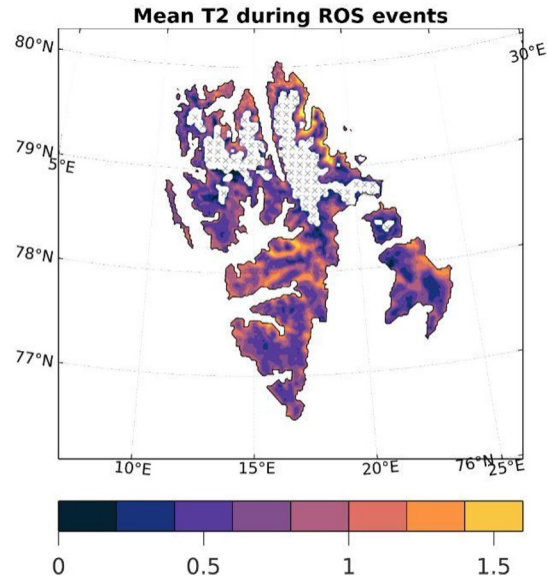
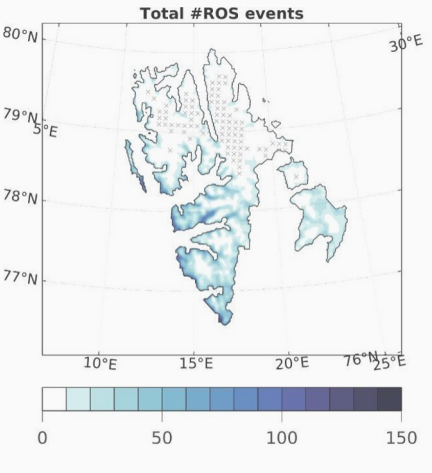
DJF 1991-2021



- **Warmest events (1-1.5 °C)**
 - *At lower altitude*
 - *In the north (but few events)*

ROS statistics, *climatology*

DJF 1991-2021



- **Warmest events (1-1.5 °C)**
 - *At lower altitude*
 - *In the north (but few events)*

- **Wettest events (30-50 mm)**
 - *In mountains:*
 - south + west + central*
 - *(But few events)*

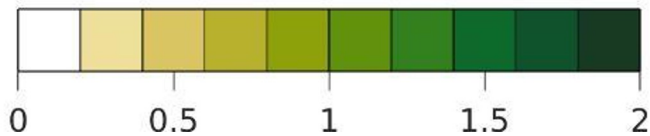
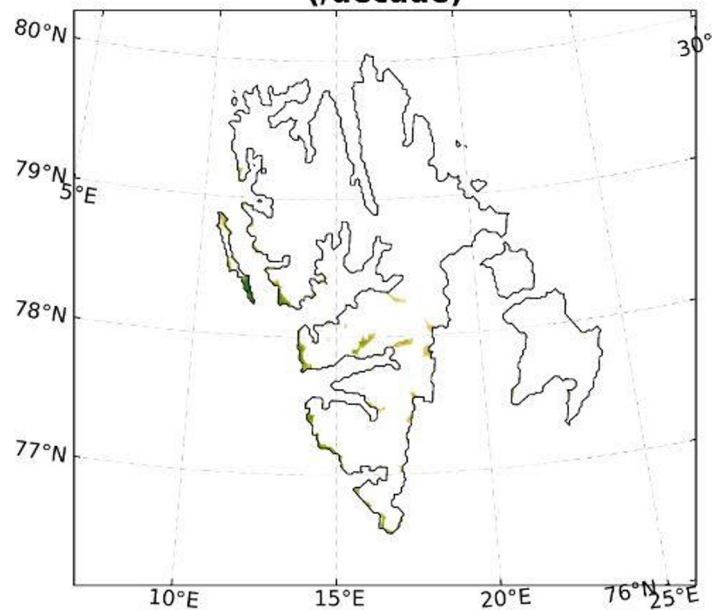
ROS statistics, *trends*

DJF 1991-2021

ROS statistics, *trends*

DJF 1991-2021

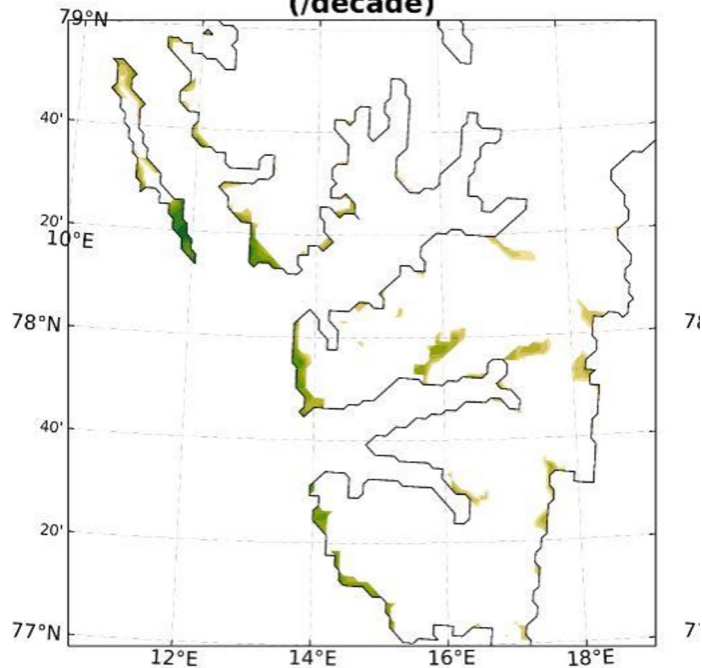
**Trend, #ROS events
(/decade)**



ROS statistics, *trends*

DJF 1991-2021

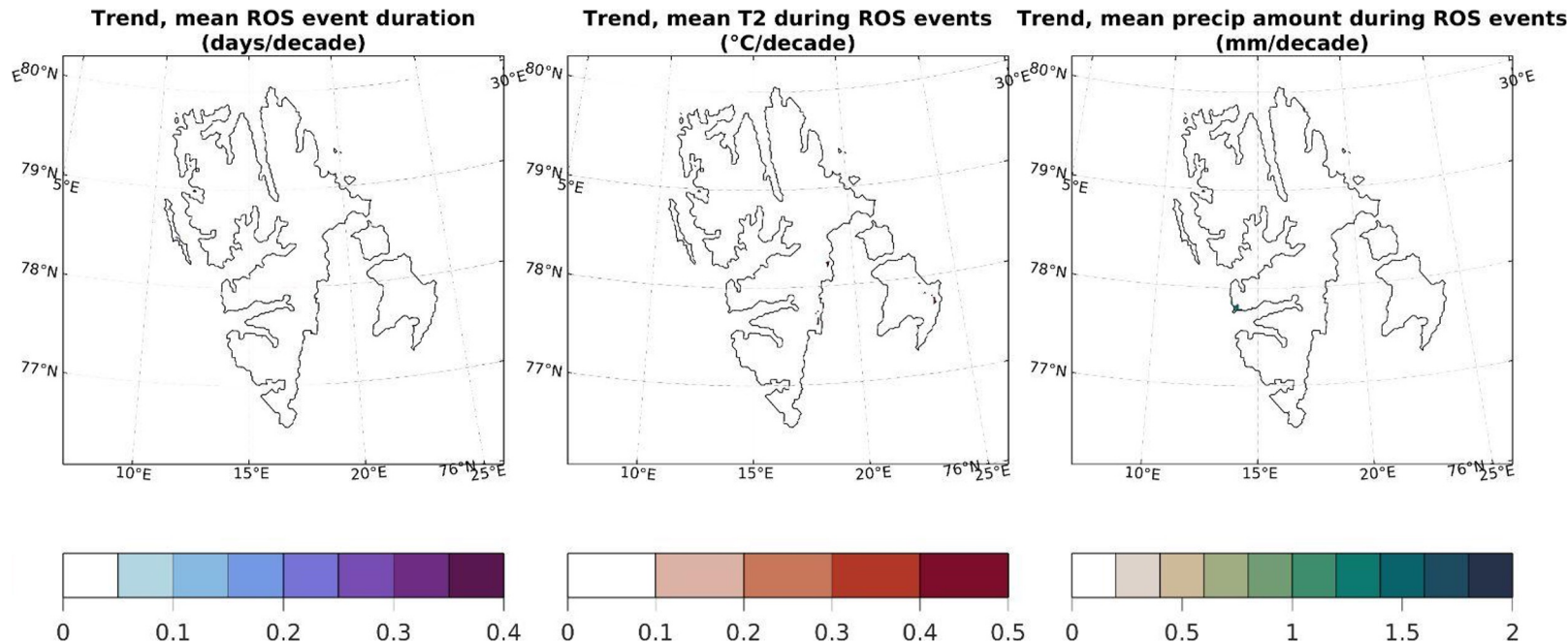
**Trend, #ROS events
(/decade)**



- **Strongest trends (1-2 events / decade)**
 - *South- and west-coasts*
 - *Lower altitude in Central Spitsbergen*

ROS statistics, *trends*

DJF 1991-2021



- **Almost no significant trends in:**
 - *ROS event duration*
 - *Mean T2 during ROS events*
 - *Mean precip amount during ROS events*

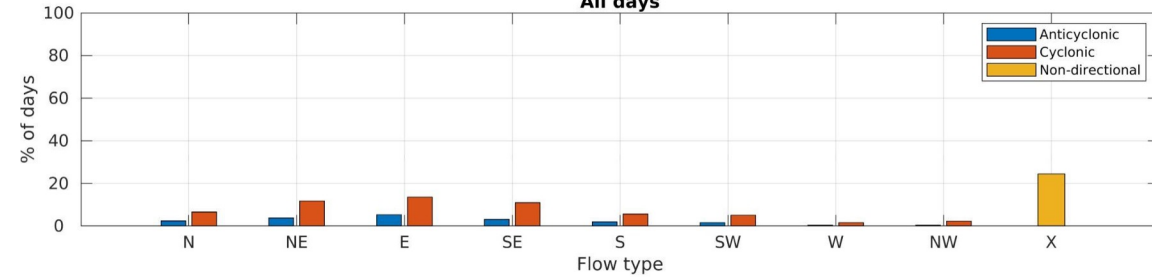
ROS *and flow types*

DJF 1991-2021

ROS *and flow types*

DJF 1991-2021

All days

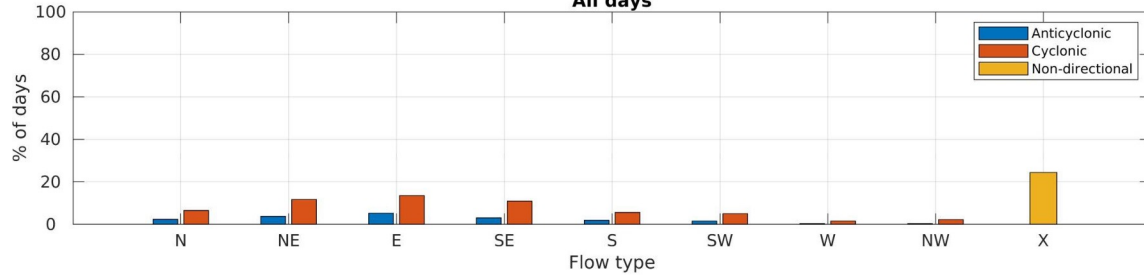


- Cyclonic NE + E + SE
- Non-directional

ROS and flow types

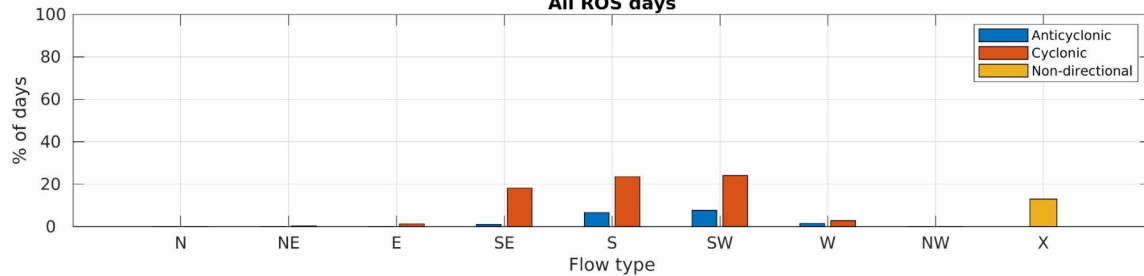
DJF 1991-2021

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- Cyclonic NE + E + SE
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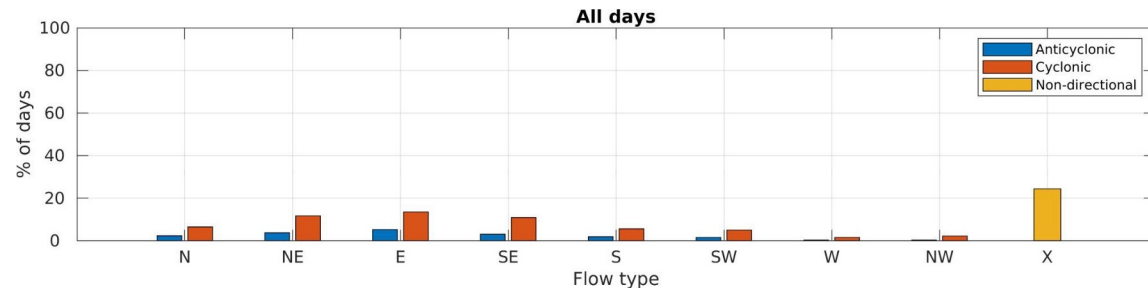
All ROS days



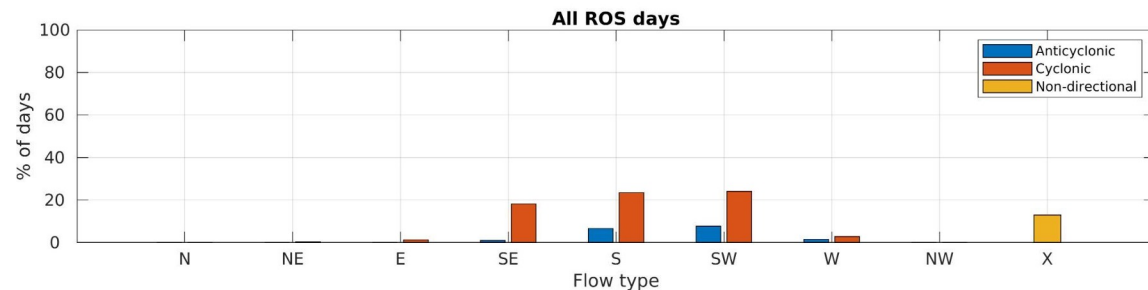
- Cyclonic SE + S + SW
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ROS and flow types

DJF 1991-2021



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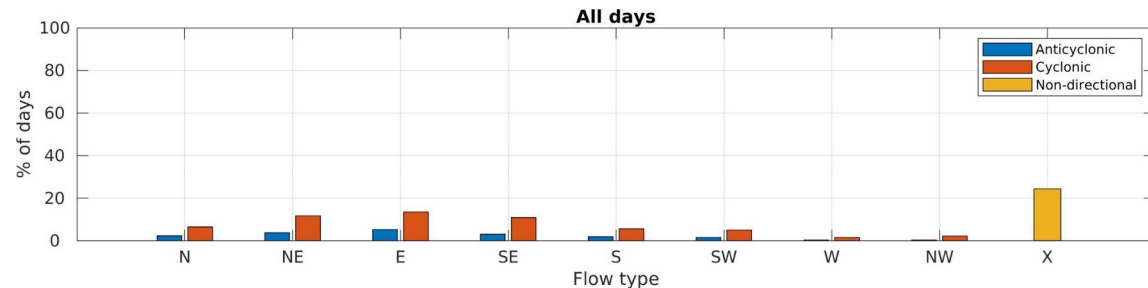


- Cyclonic SE + S + SW
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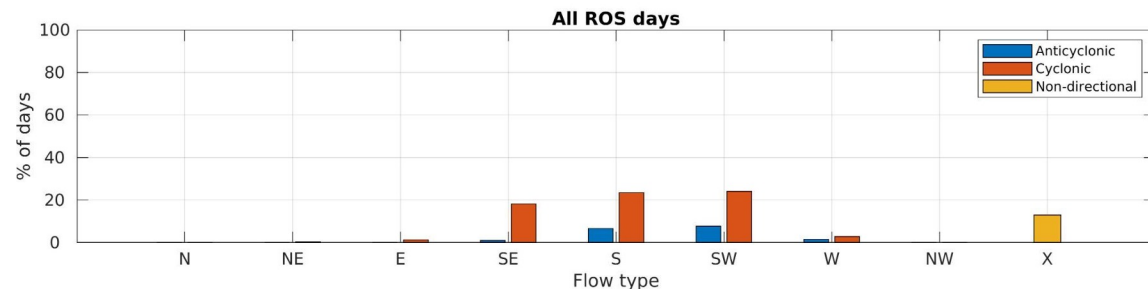
Most extreme ROS?

ROS and flow types

DJF 1991-2021



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- Cyclonic SE + S + SW
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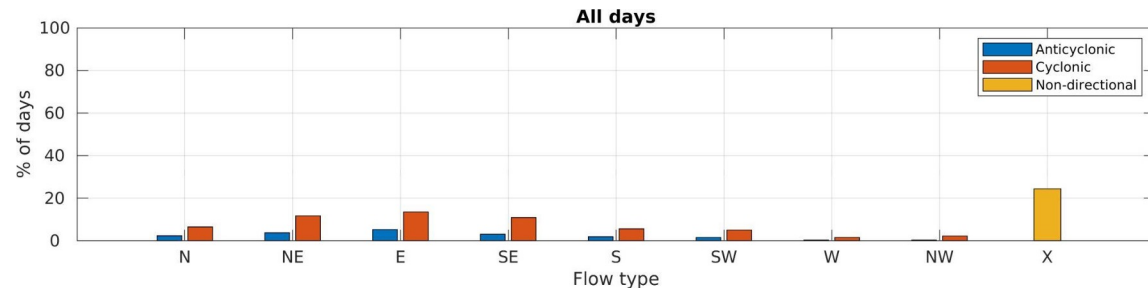
Most extreme ROS?

Extreme index =

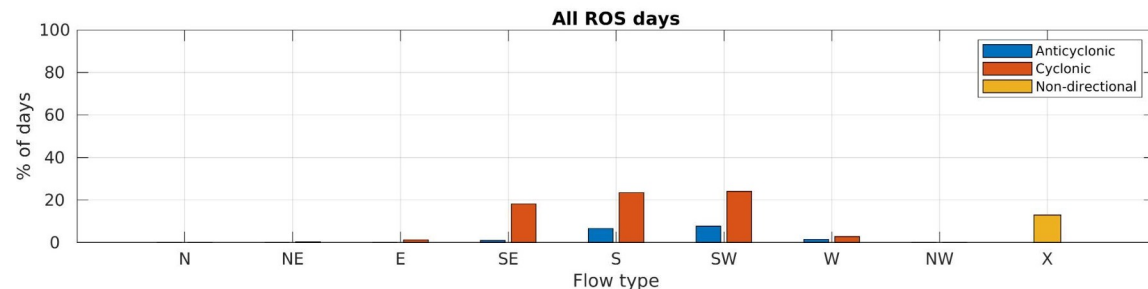
$$\frac{\% \text{grid points} * \text{mean}(\text{norm}(T2))}{\text{mean}(\text{norm}(\text{Precip}))}$$

ROS and flow types

DJF 1991-2021



- Cyclonic NE + E + SE
- Non-directional



- Cyclonic SE + S + SW
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Most extreme ROS?

Extreme index =

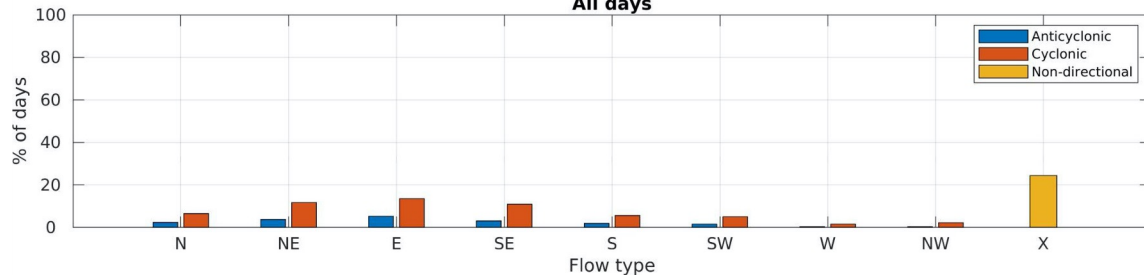
$$\% \text{grid points} * \text{mean}(\text{norm}(T2)) * \text{mean}(\text{norm}(\text{Precip}))$$

Most extreme ROS = 85% percentile of extreme index

ROS and flow types

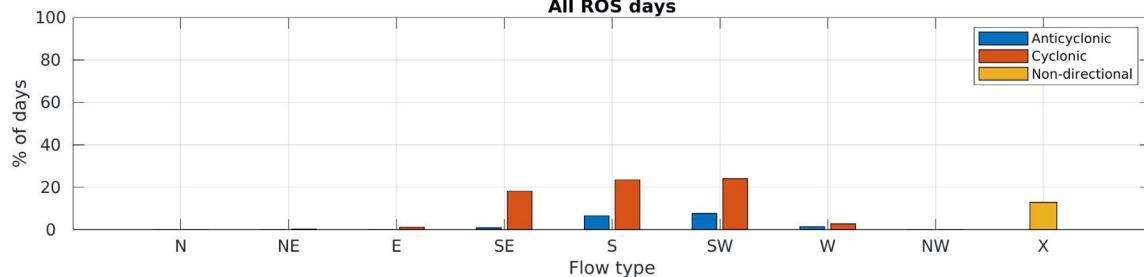
DJF 1991-2021

All days



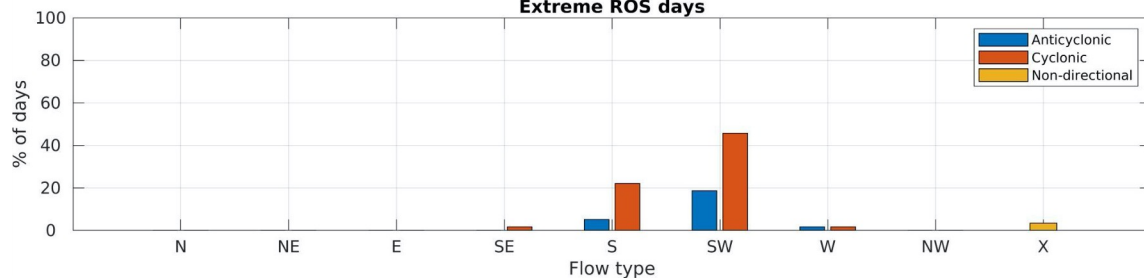
- Cyclonic NE + E + SE
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All ROS days



- Cyclonic SE + S + SW
- Non-directional

Extreme ROS days



- Cyclonic S + SW

ROS, *extreme days*

DJF 1991-2021

Extreme days
($n = 59$)

	'16-Jan-2010'
	'17-Jan-2010'
'24-Dec-1990'	'18-Jan-2010'
'27-Feb-1991'	'25-Jan-2010'
'07-Dec-1991'	'29-Jan-2012'
'01-Dec-1993'	'30-Jan-2012'
'10-Dec-1994'	'31-Jan-2012'
'02-Dec-1995'	'07-Feb-2012'
'03-Dec-1995'	'08-Feb-2012'
'04-Dec-1995'	'06-Jan-2013'
'05-Dec-1995'	'16-Dec-2013'
'18-Jan-1996'	'11-Feb-2014'
'03-Dec-2001'	'22-Jan-2015'
'04-Dec-2001'	'16-Feb-2015'
'03-Dec-2002'	'29-Dec-2015'
'04-Dec-2002'	'30-Dec-2015'
'05-Dec-2002'	'01-Jan-2016'
'06-Dec-2002'	'02-Jan-2016'
'07-Dec-2002'	'03-Jan-2016'
'09-Feb-2005'	'24-Jan-2016'
'16-Feb-2005'	'21-Dec-2016'
'06-Jan-2006'	'05-Feb-2017'
'10-Jan-2006'	'06-Feb-2017'
'15-Jan-2006'	'07-Feb-2017'
'08-Jan-2007'	'08-Feb-2017'
'01-Jan-2008'	'09-Feb-2017'
'02-Jan-2008'	'10-Feb-2017'
'18-Feb-2009'	'12-Jan-2018'
'10-Dec-2009'	'13-Jan-2018'
	'15-Jan-2018'
	'26-Feb-2018'
	'19-Dec-2018'

ROS, *extreme events*

DJF 1991-2021

Extreme events

(3 or more consecutive ROS days)

$n = 6$

'24-Dec-1990'	'16-Jan-2010'
'27-Feb-1991'	'17-Jan-2010'
'07-Dec-1991'	'18-Jan-2010'
'01-Dec-1993'	'25-Jan-2010'
'10-Dec-1994'	'29-Jan-2012'
'02-Dec-1995'	'30-Jan-2012'
'03-Dec-1995'	'31-Jan-2012'
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'16-Feb-2005'	'03-Jan-2016'
'06-Jan-2006'	'24-Jan-2016'
'10-Jan-2006'	'21-Dec-2016'
'15-Jan-2006'	'05-Feb-2017'
'08-Jan-2007'	'06-Feb-2017'
'01-Jan-2008'	'07-Feb-2017'
'02-Jan-2008'	'08-Feb-2017'
'18-Feb-2009'	'09-Feb-2017'
'10-Dec-2009'	'10-Feb-2017'
	'12-Jan-2018'
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ROS, *extreme events*

DJF 1991-2021

Extreme events

(3 or more consecutive ROS days)

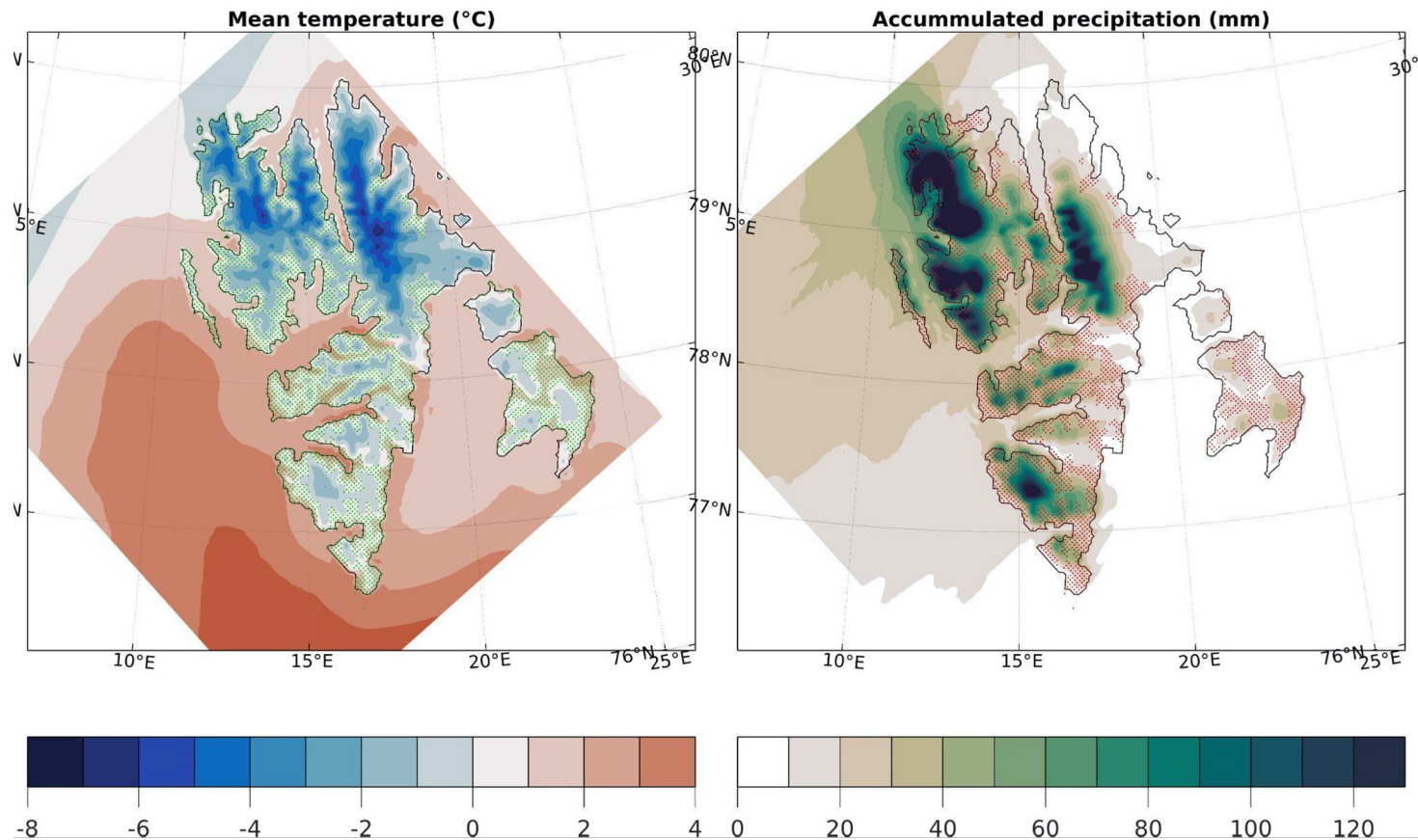
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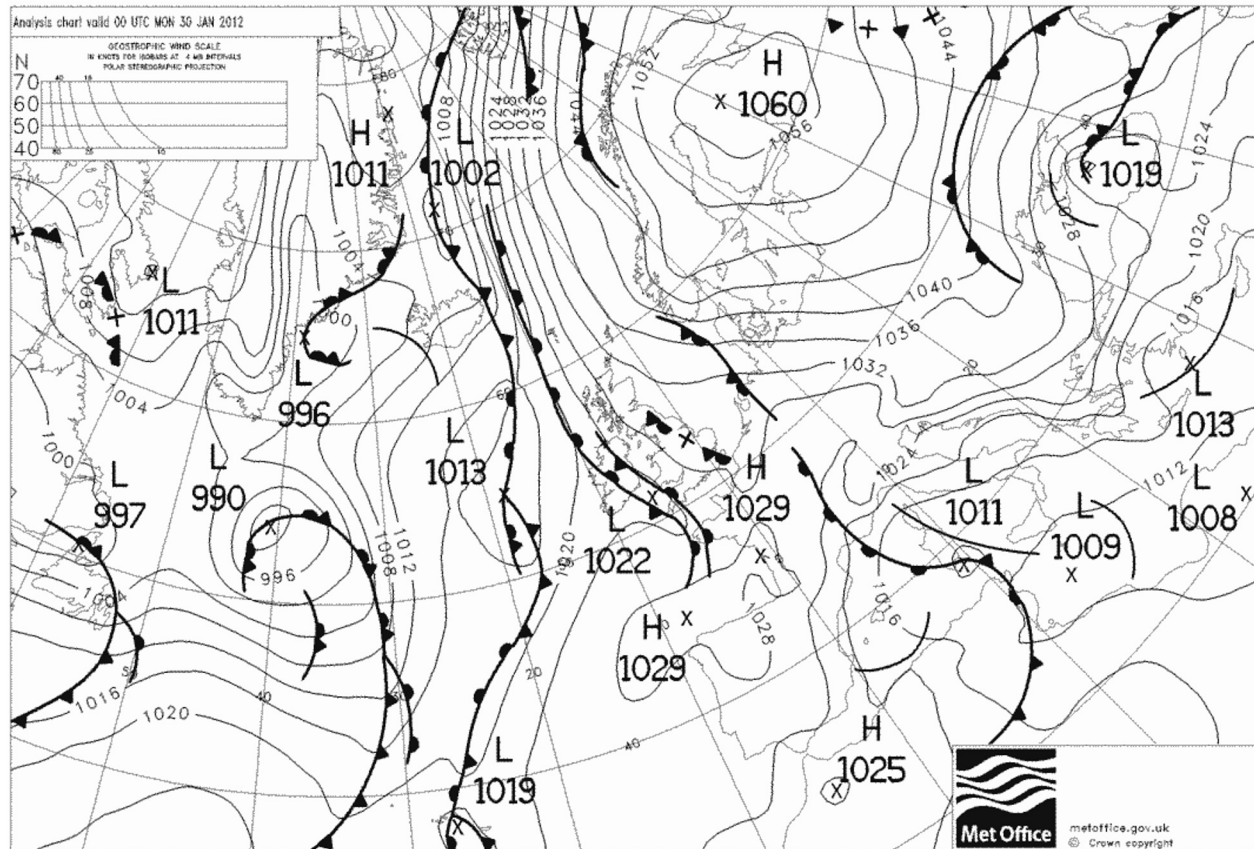
ROS, *extreme event*

29-31 January, 2012



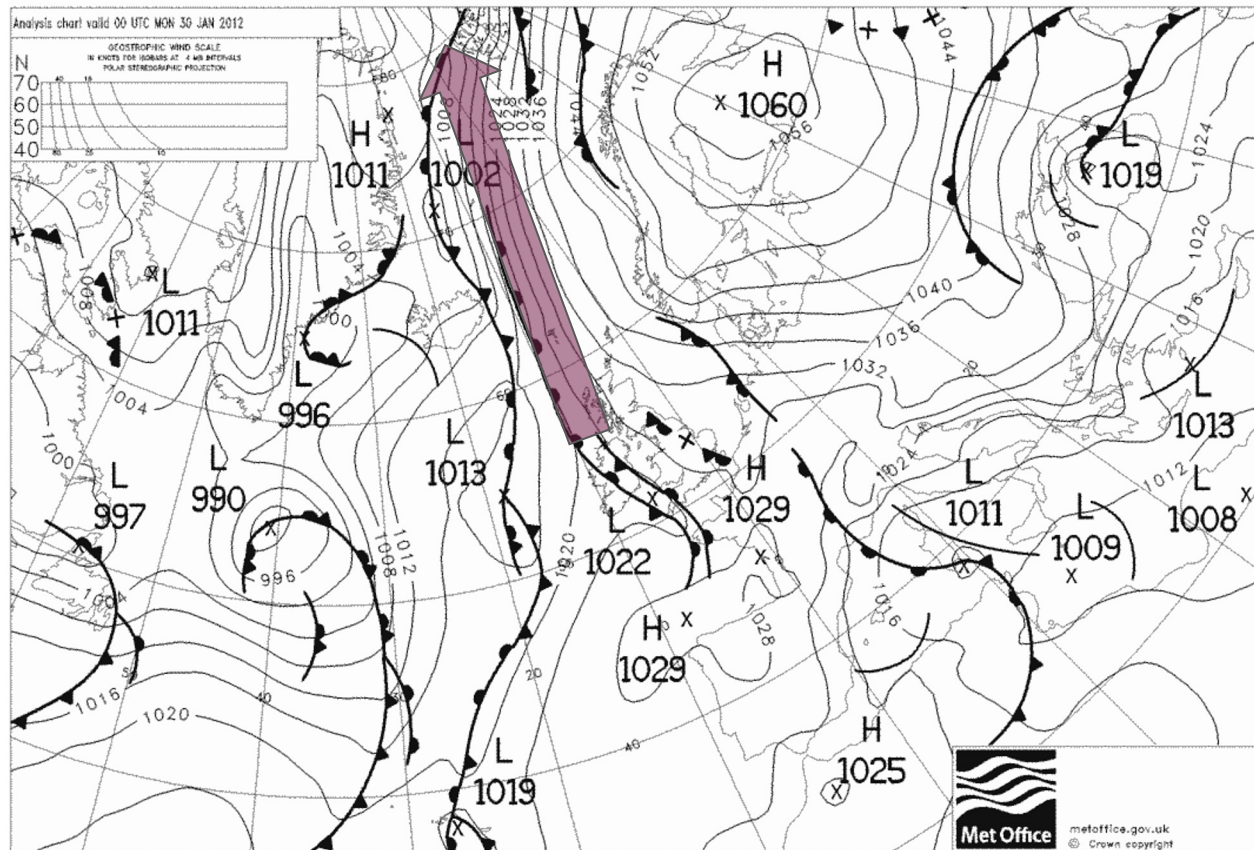
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Brage B Hansen *et al* 2014 *Environ. Res. Lett.* **9** 114021 doi:[10.1088/1748-9326/9/11/114021](https://doi.org/10.1088/1748-9326/9/11/114021)

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- *Temperature up to 7°C*
- *Up to 98 mm rain (in Ny-Ålesund) (every > 500 yrs!)*
- *Slush avalanches*
- *Increased permafrost temperature -> 5m*
- *5-20 cm ground ice cover*
- *Increased starvation-induced mortality of wild reindeer*

Conclusions, *climatology*

Conclusions, *climatology*

During DJF, 1991-2021, ROS events:

- Were most common:
 - On the south- and west-coasts of Spitsbergen
 - At low altitudes in Central Spitsbergen
- Occurred 2-4 times per season on average in these regions
- Lasted on average 1-2 days in these regions
- Had mean 2m temperatures up to 1.5 °C
- Had mean accumulated precipitation up 50 mm

Conclusions, *trends*

During DJF, 1991-2021, ROS events:

- Increased significantly in numbers (1-2/decade)
 - On the south- and west-coasts of Spitsbergen
 - At low altitudes in Central Spitsbergen

- Had no significant trends for:
 - Duration of events
 - Mean 2m temperature during events
 - Mean accumulated precipitation amount during events

Future/Outlook

Look into connections between ROS and:

- Regional/synoptic-scale circulation
 - Storm tracks
 - Climate indices
 - Composites of heat and moisture transport etc

Compare model-based results against observations

Longer-term trends in ROS

- 1979 -> 2022 (Future CARRA data?)
- 2021 -> 20?? (CMIP/CORDEX ...)