SPACE CLIMATE

Climate in Space and on Earth

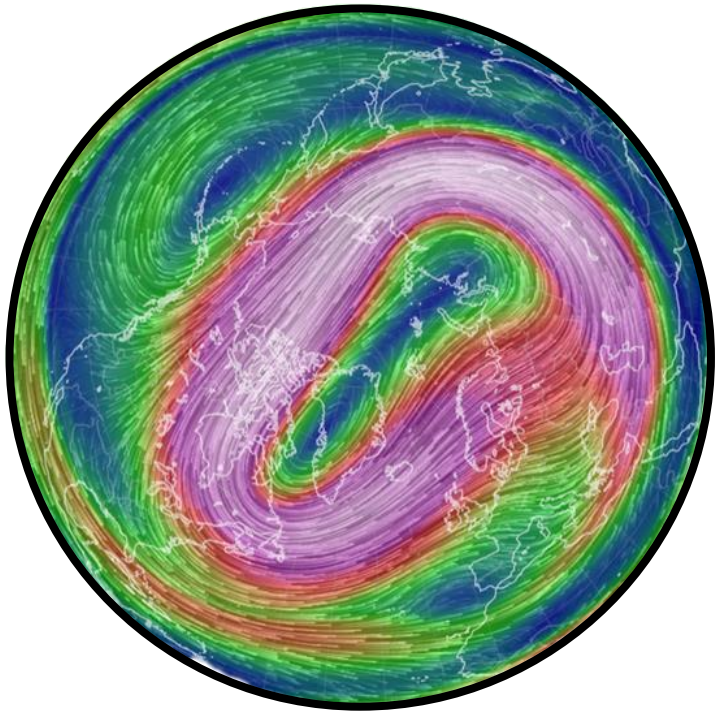
Long-term prediction of Sudden Stratospheric Warmings with Geomagnetic and Solar Activity

Mikhail Vokhmianin, Timo Asikainen, Antti Salminen, Kalevi Mursula
Space physics and Astronomy research unit, University of Oulu, Oulu, Finland

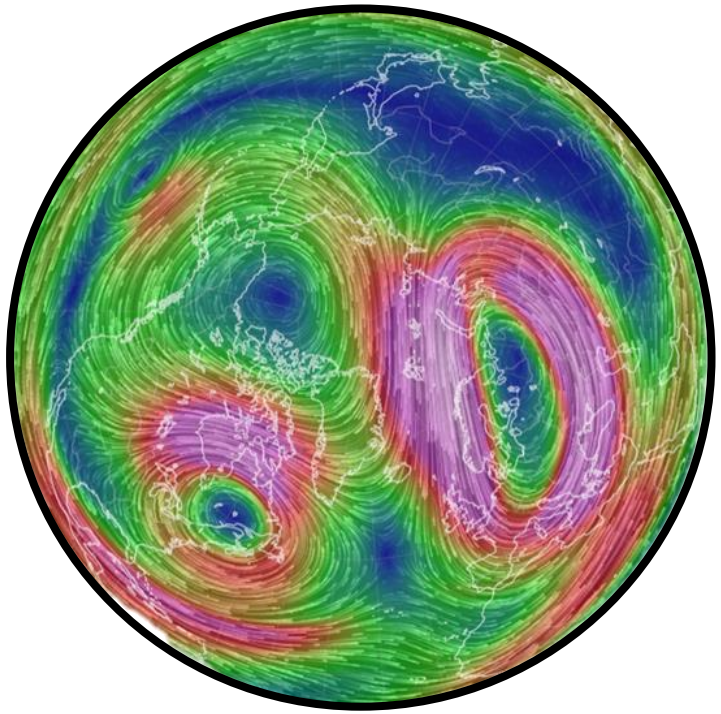
mikhail.vokhmianin@oulu.fi UNIVERSITY OF OULU

Sudden Stratospheric Warmings (SSW)

Northern Hemisphere wind at 10 hPa



10 Dec 2018



5 Jan 2019

- Polar vortex is a jet of westerly winds in the winter polar stratosphere
- Sometimes the vortex weakens or even reverses by the action of planetary waves
- SSW happens every other winter or so (irregularly) and have a

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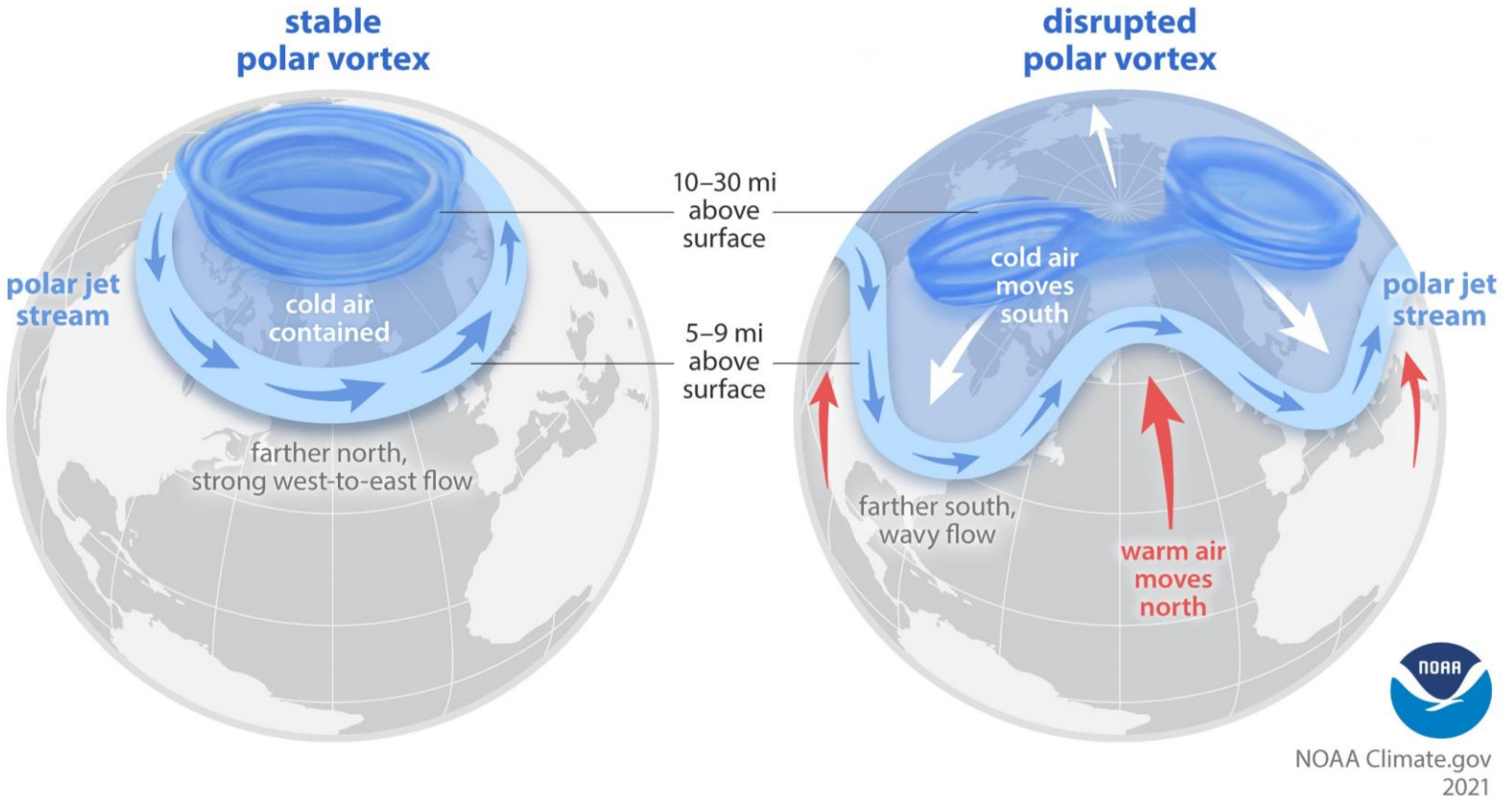
mikhail.vokhmianin@oulu.fi

Sudden Stratospheric Warmings (SSW)



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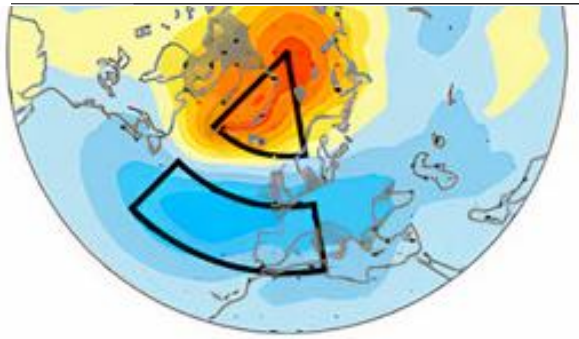
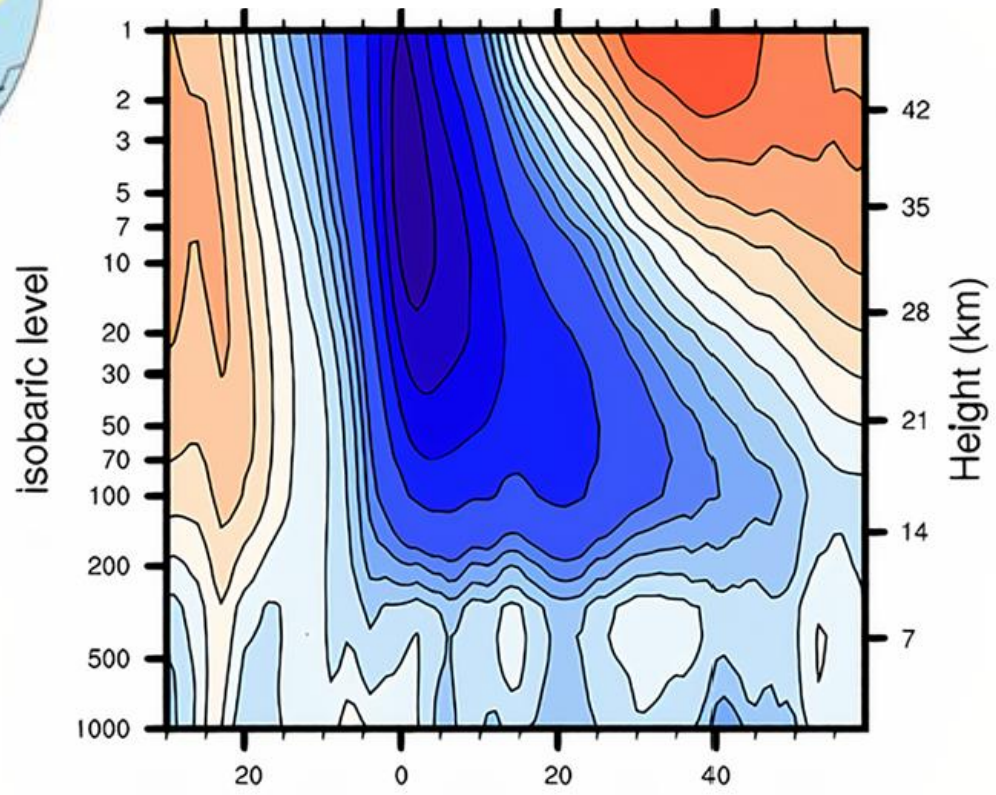
SSW: surface impact



North-Atlantic Oscillation (NAO, difference in SLP anomalies)



Oehrlein et al. 2021

- Weakening of the vortex is usually followed by negative NAO (NAM) climate variability modes and affects wintertime weather in Europe and North America

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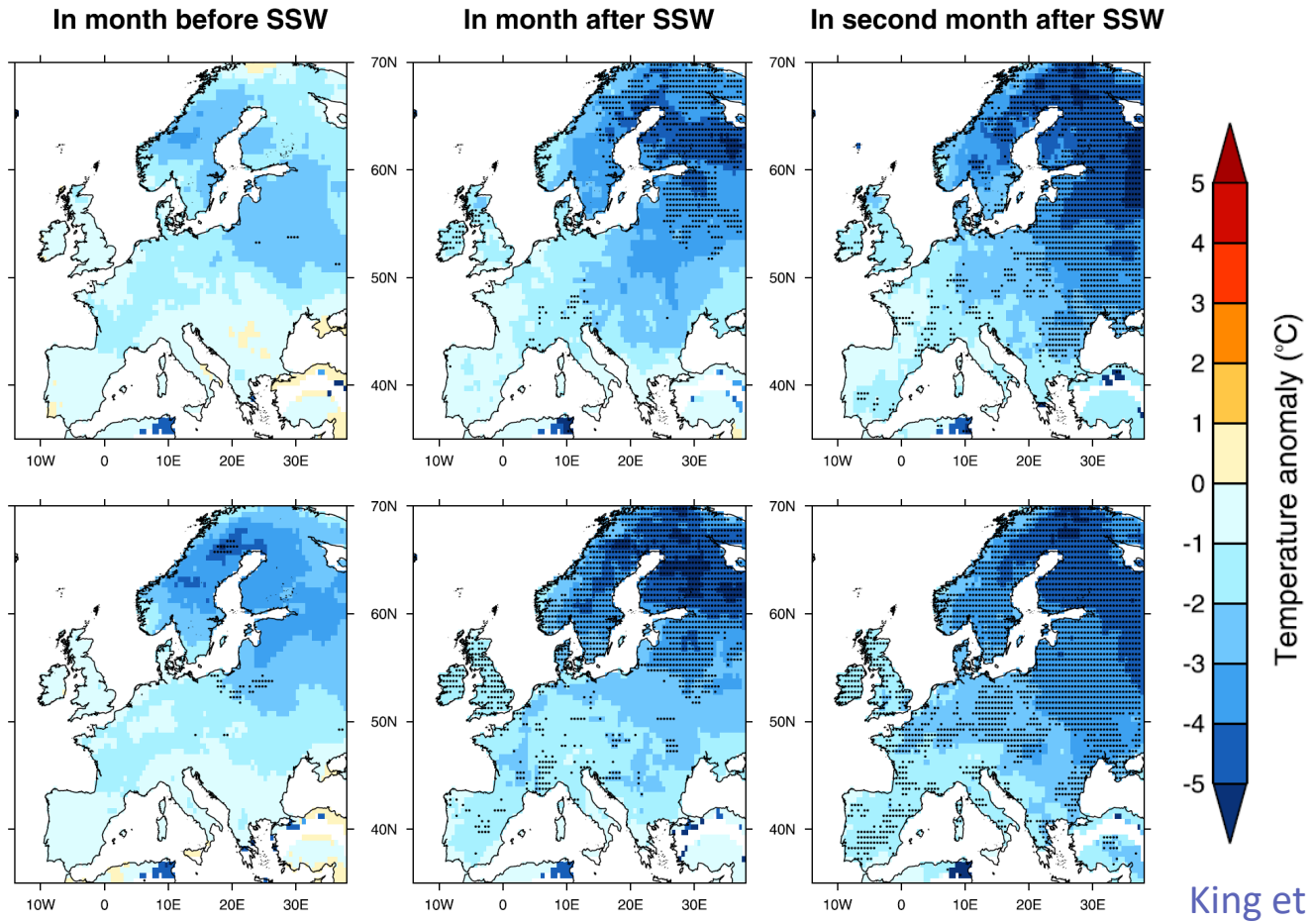

King et al. 2019

- Weakening of the vortex is usually followed by negative NAO (NAM) climate variability modes and affects wintertime weather in Europe and North America
- Winters with SSWs are on average at least 1 °C cooler, but the coldest day and night of winter is on average 3-5 °C colder than in non-SSW winters.

mikhail.vokhmianin@oulu.fi

SSW: surface impact

theconversation.com by R. Hall

Beast from the East 2? What 'sudden stratospheric warming' involves and why it can cause freezing surface weather

Published: January 11, 2021 1.36pm GMT

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A "sudden stratospheric warming" event took place in early January 2021, according to the Met Office, the UK's national weather service. These events are some of the most extreme of atmospheric phenomena, and I study them as part of my academic research. The stratosphere is the layer of the atmosphere from around 10km to 50km above the Earth's surface, and sudden warming up there can lead to very cold weather over Europe and Siberia, with an increased

theguardian.com

Sudden stratospheric warming set to bring lengthy cold snap to UK

Huge rise in air temperature above north pole will allow chilly winds from eastern Europe to blast UK, Met Office warns

Cold weather in Cumbria in 2016. The Met Office said an easterly breeze would bring cold air towards Britain from the middle of next week. Photograph: WittWooPhoto/REX/Shutterstock

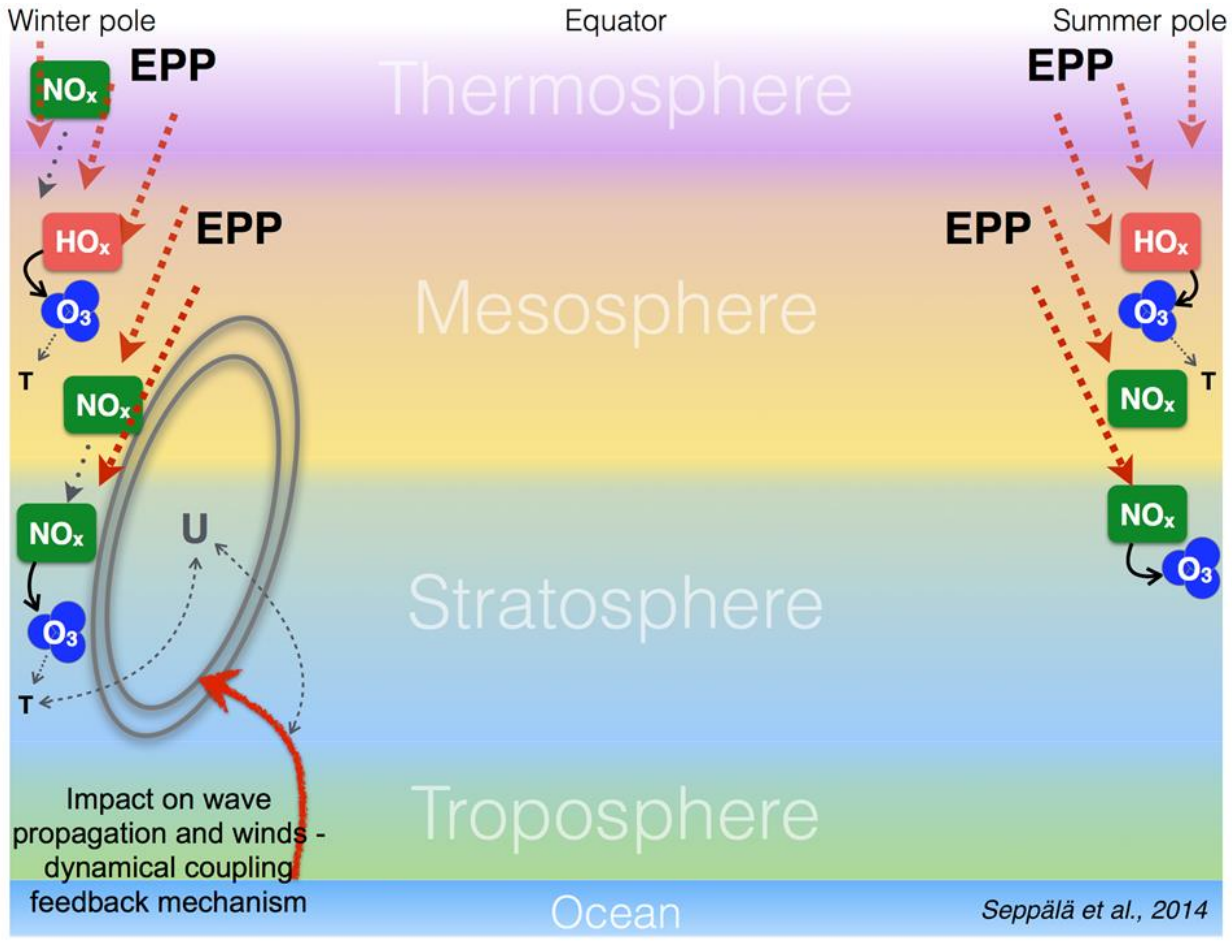
Britain will be gripped by a potentially lengthy cold snap as sudden stratospheric warming looks poised to cause temperatures to tumble.

Snowy Northern Ireland, just after the Beast from the East had passed through in 2018.

mikhail.vokhmianin@oulu.fi

Energetic electron precipitation (EEP) effect

- EEP produces NOx's and HOx’s
- During polar night NOx descend to the stratosphere and catalytically destroy ozone (up to 10% average decrease)
- Ozone variations affect radiative and thermal balance in the mesosphere and stratosphere
- In the lower stratosphere, the vortex becomes stronger due to EEP



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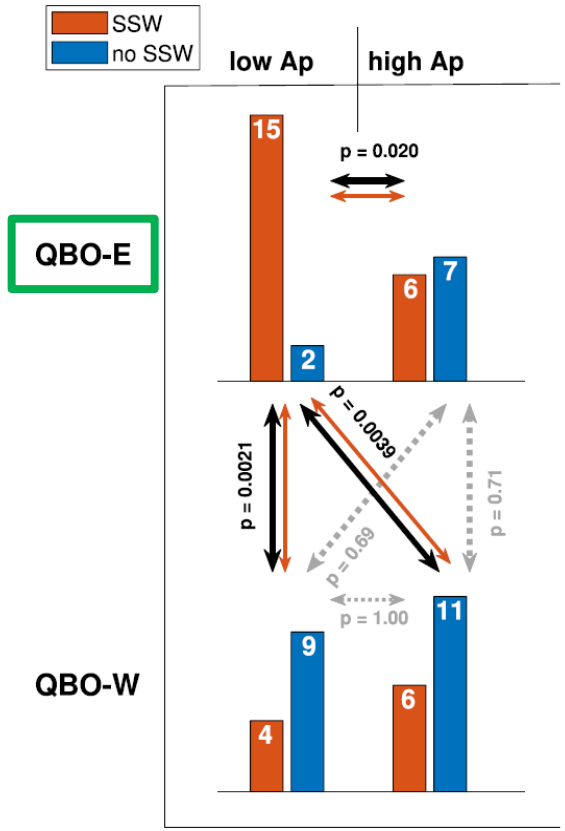
SSW occurrence is modulated by EEP → possibility for the long-term SSW forecast



Salminen et al. 2020

Holton-Tan effect:

QBO – Quasi-Biennial Oscillation of the equatorial stratosphere wind direction

If QBO is in the easterly phase more planetary waves are guided into the polar vortex region → more SSWs

Salminen et al. 2020:

SSWs occurred in

- 88% winters preceded by the easterly QBO in September when December geomag. activity (Ap) was low
- 46% winters preceded by the easterly QBO in September when December geomag. activity (Ap) was high

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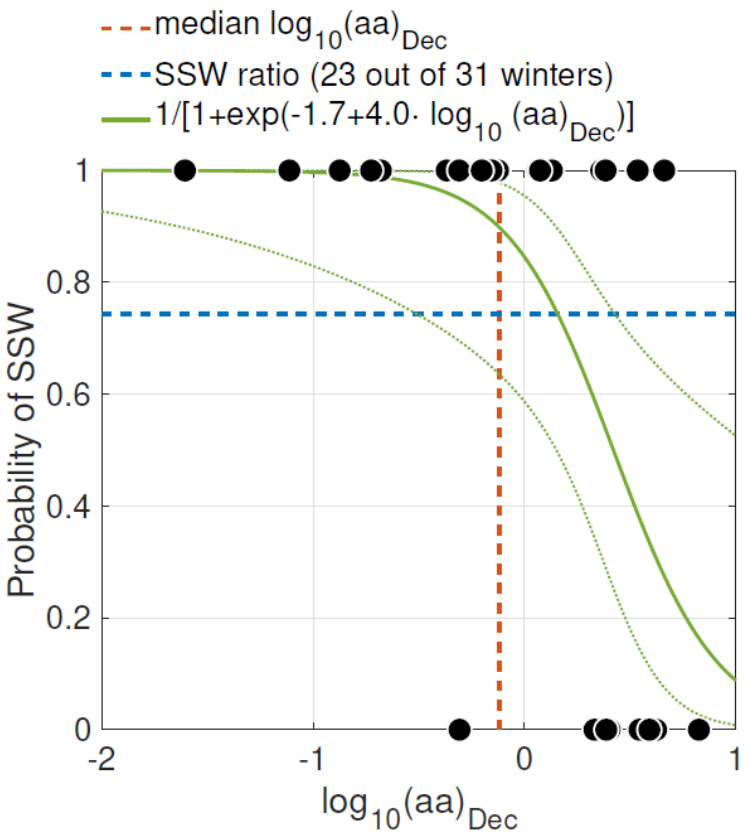
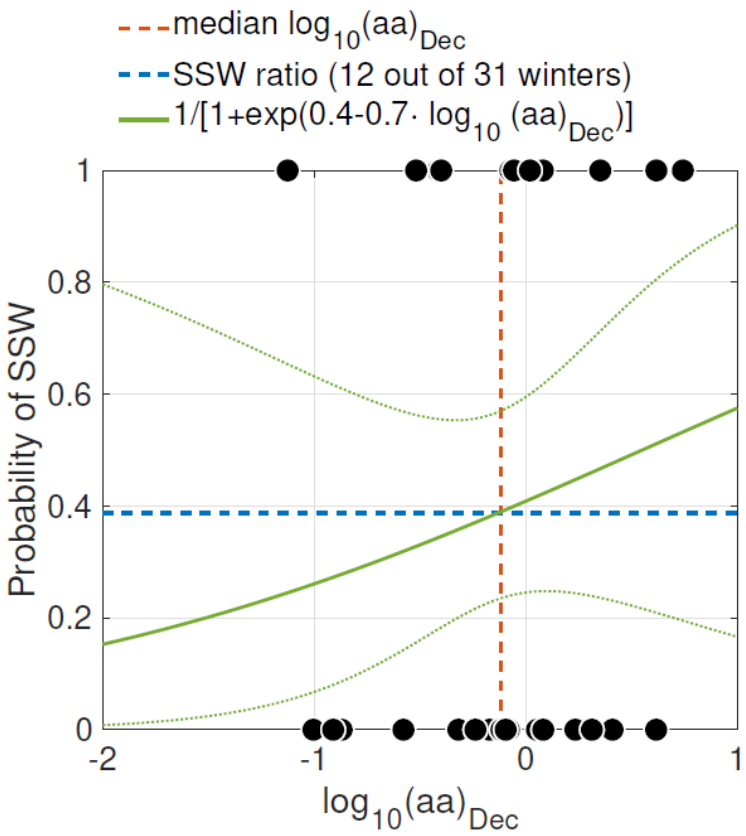
Logistic regression model of the SSW occurrence

easterly QBO



westerly QBO



$$P = \frac{1}{1 + e^{-a - b \cdot X}}$$

This approach helps to:

- Find a combination of the QBO and aa which best separates the SSW/no-SSW winters
- Provide continuous probability of SSW occurrence depending on aa

* SSW list was obtained from ERA5 reanalysis based on definition by Charlton & Polvani (2007)

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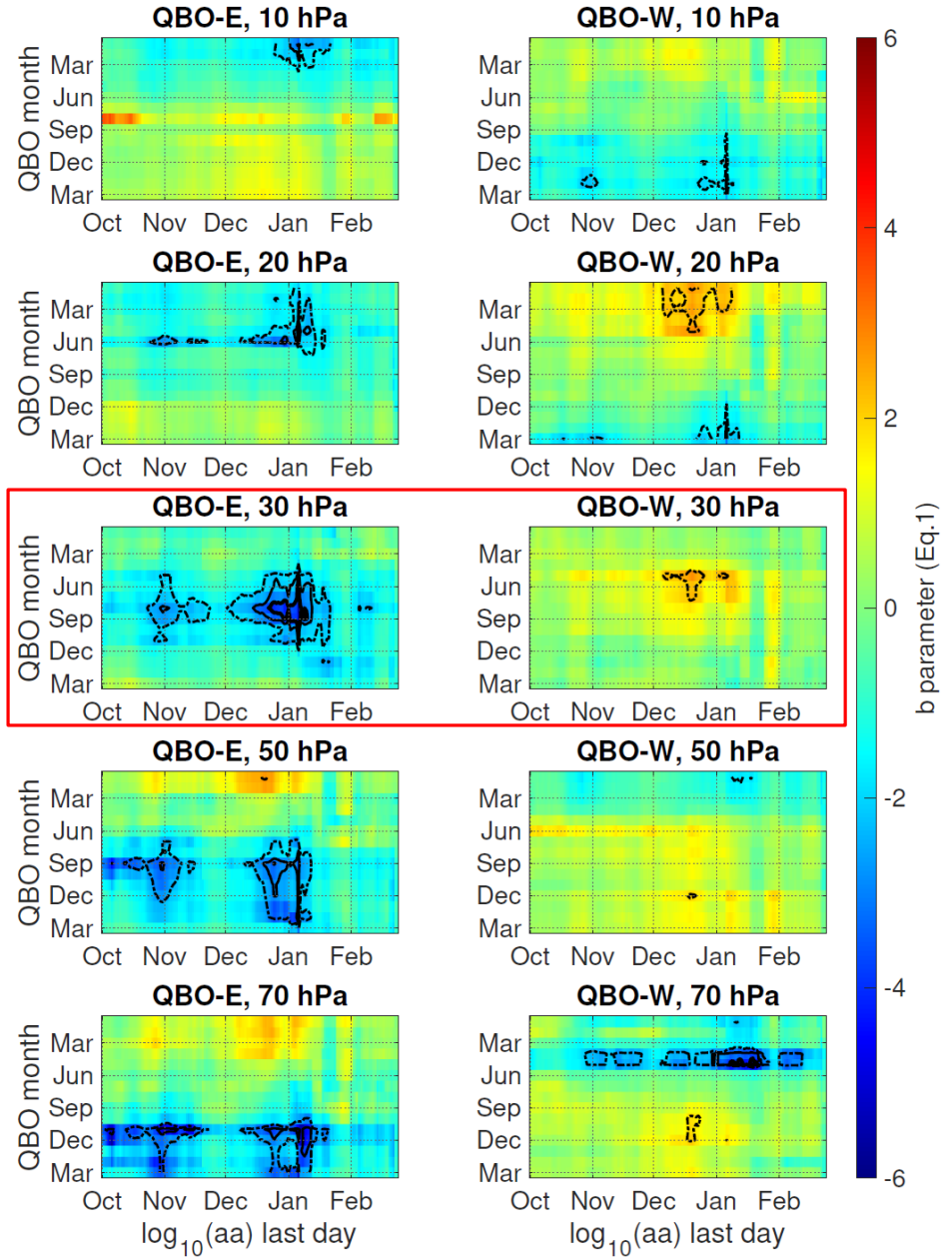
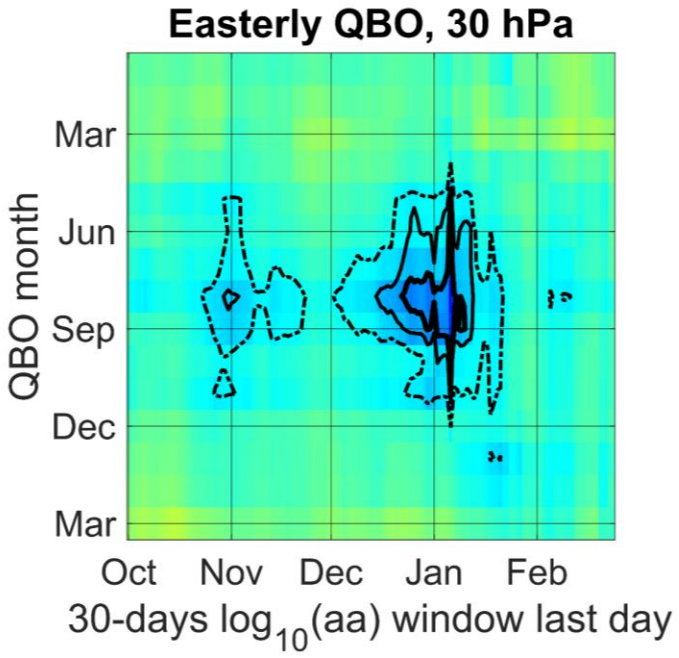
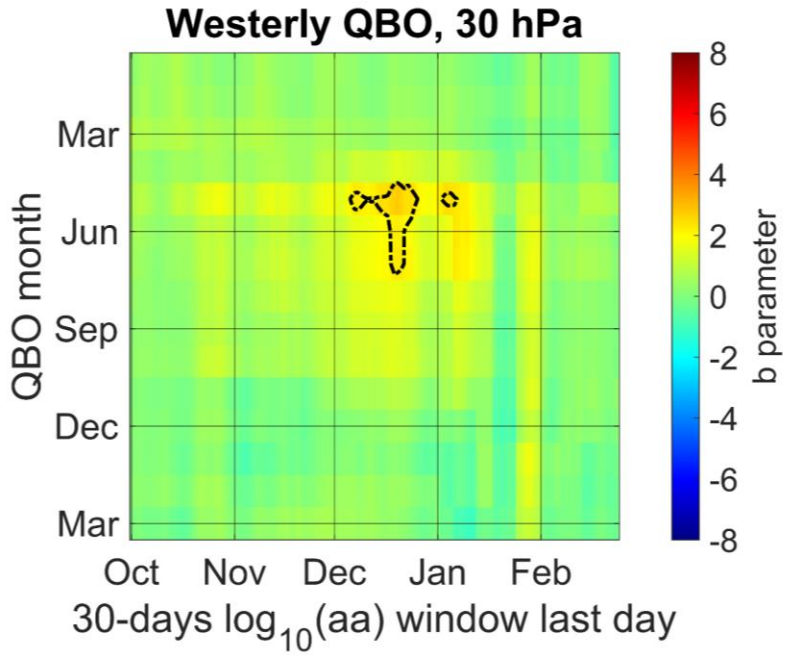


Optimal QBO/aa combination

- The strongest modulation of the SSW occurrence is found for the easterly QBO in August and geomagnetic activity (aa index) from December to the beginning of January.
- No effect for the westerly QBO





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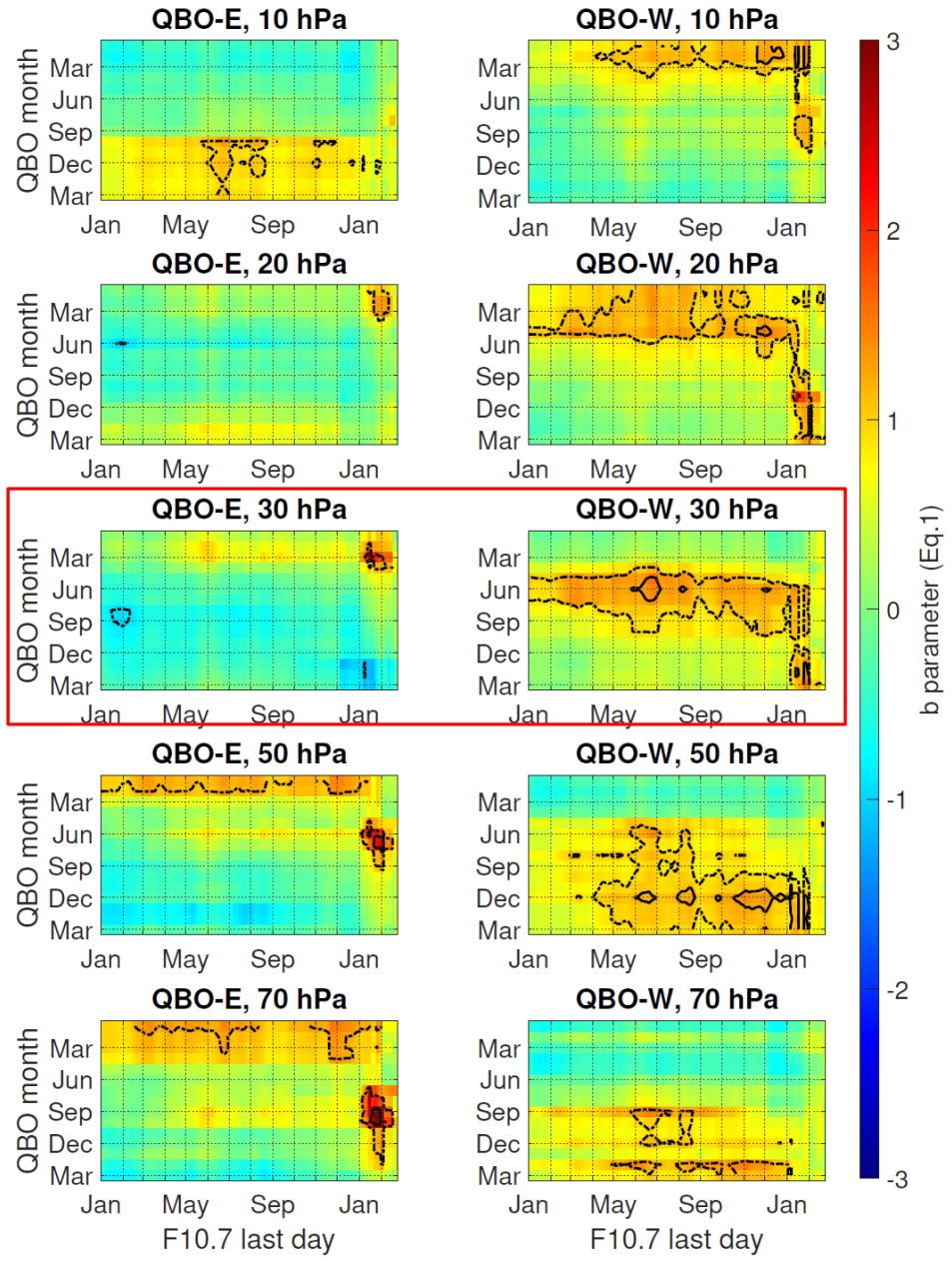
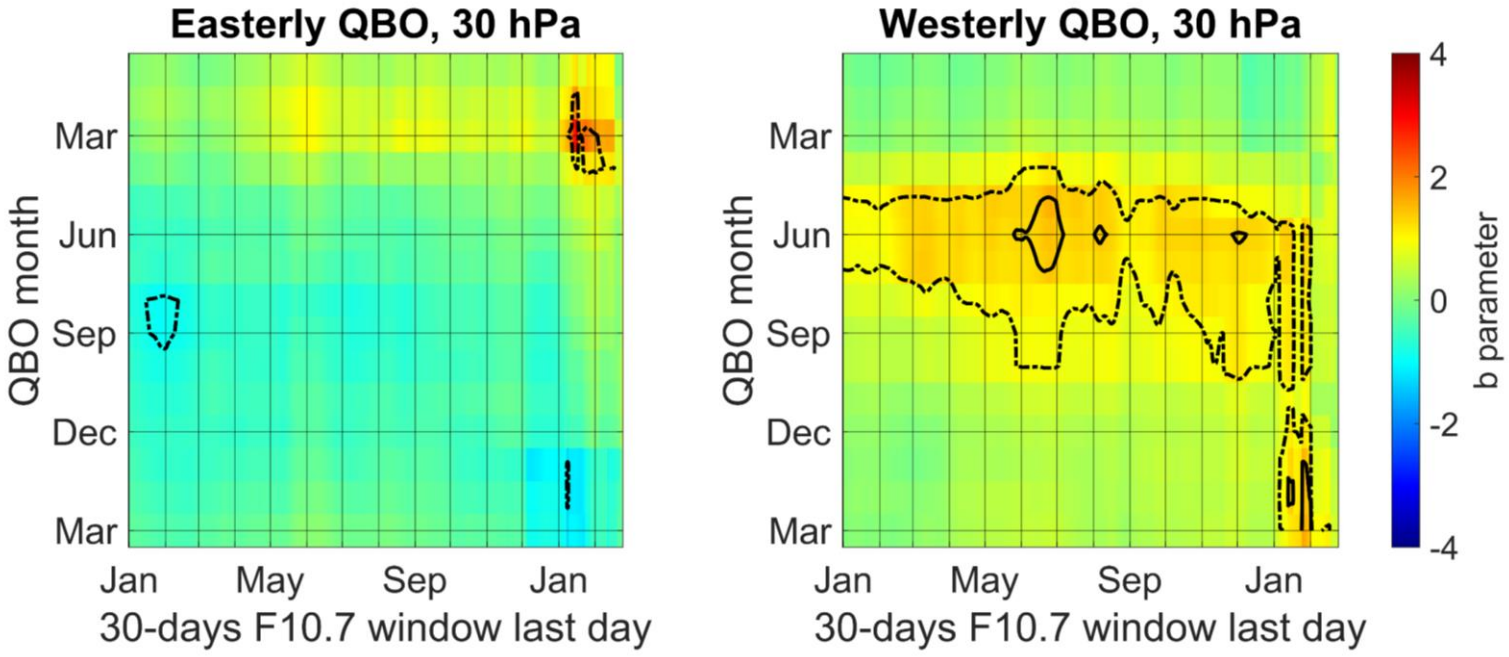


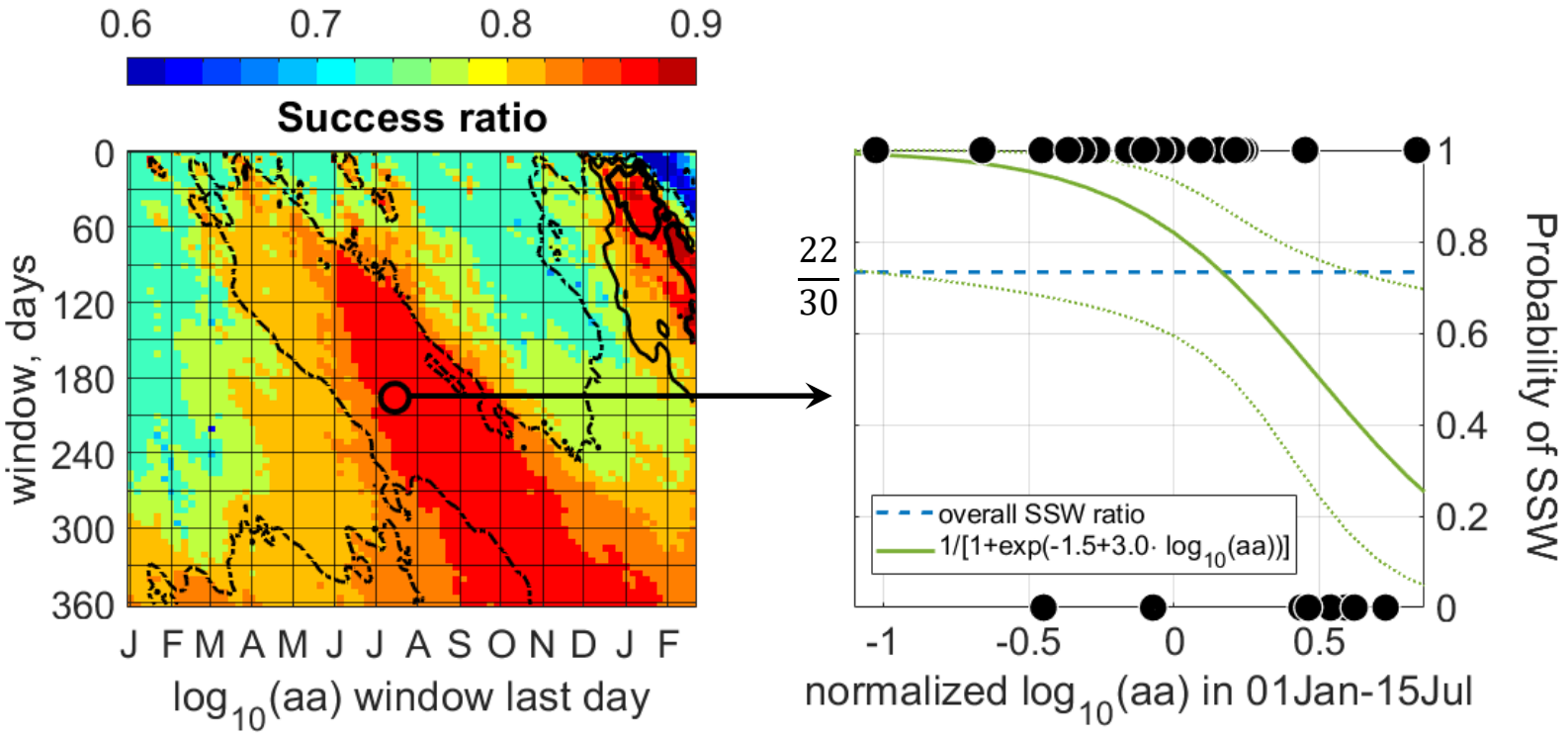
Optimal QBO/F10.7 combination

- F10.7 index effect on the SSW occurrence was found for the winters preceded by the westerly QBO [in accordance with Labitzke & van Loon, 1988] and F10.7 during summer



mikhail.vokhmianin@oulu.fi

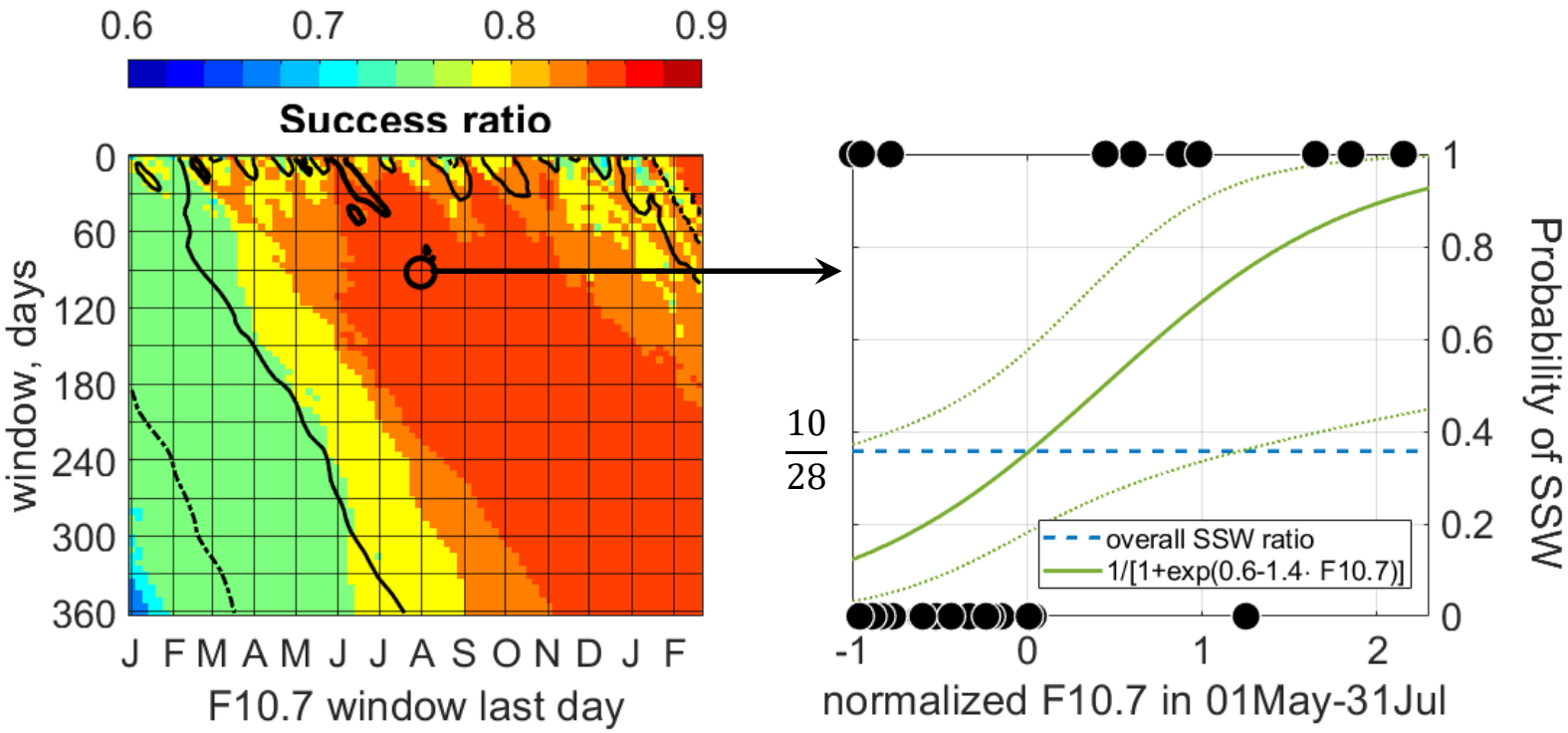
Aa window for the SSW forecast



- The most significant modulation effect is seen under easterly QBO (30 hPa) in August taking aa index from 12 December to 8 January
- Owing to the autocorrelation of the long-term geomagnetic activity, we can use average aa index found in the first half of the year to predict SSW/no-SSW in the following winter

mikhail.vokhmianin@oulu.fi

F10.7 window for the SSW forecast



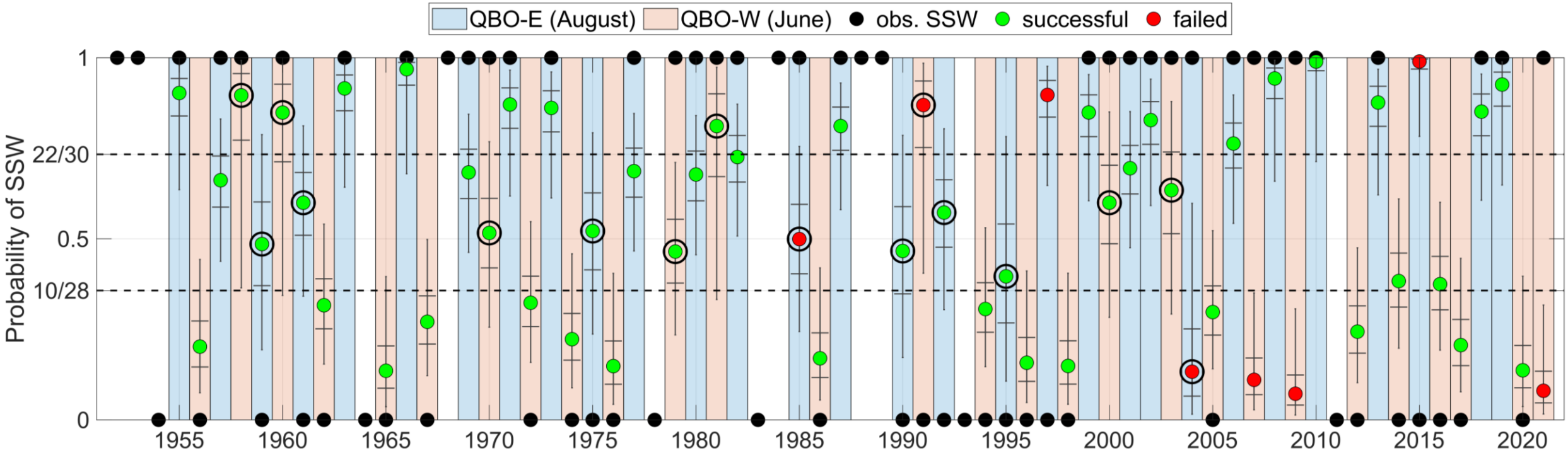
- No exact window was found for the F10.7 index
- We chose westerly QBO in June and F10.7 index from 1 May to 31 July

mikhail.vokhmianin@oulu.fi

SSW backcast

black circles: ones – winters with SSW, zeros – without SSW **green circles** – successful prediction by the model, **red** - failed

Prediction models based on the QBO phase and geomagnetic/solar activity data predict the SSW occurrence in the next winter, 5-6 months in advance, with **86% success**



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Summary

- The SSW occurrence depends on geomagnetic in early winter preceded by easterly QBO and on solar activity in winters preceded by westerly QBO.
- Average geomagnetic activity evaluated from the start of the year until mid-July produces almost an equally successful prediction model for the SSW probability of the subsequent winter season
- Together the aa and F10.7 indices with the QBO phase allow for a good prediction (86% success) of the SSWs well before the upcoming winter.
- Solar-related factors improve wintertime weather predictability

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