

Statistics of sudden stratospheric warmings using a large model ensemble

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Summary

Using a large ensemble of initialised hindcasts from the Met Office seasonal prediction system, GloSea5 (MacLachlan et al., QJRMS, 2015), we explore various statistics relating to sudden stratospheric warmings (SSWs) for the winter period, November to March.

A) Observations show that SSWs occur at a similar frequency during both El Niño and La Niña winters. This is contrary to expectation, as the stronger stratospheric polar vortex associated with La Niña years might be expected to result in fewer of these extreme events. We show that this similar frequency may have occurred by chance due to the limited sample of years in the observational record.

B) In these hindcasts, winters with two SSWs, a rare event in the observational record, on average have an increased surface impact.

C) Somewhat surprisingly, our analysis indicates a risk, albeit small, of winters with three or more SSWs, as yet an *unseen* event

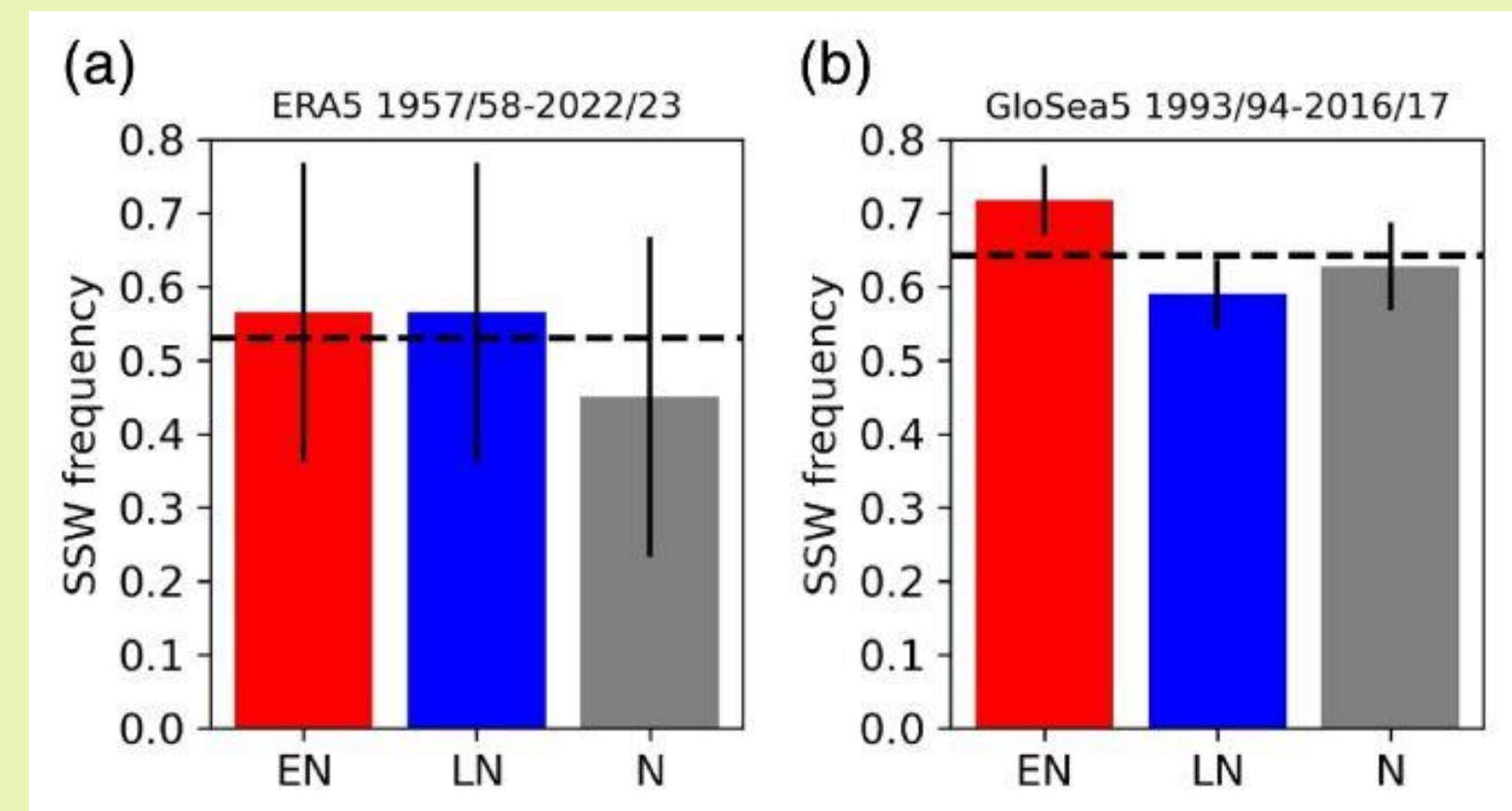
Methods

Use initialised hindcasts from GloSea5-GC2 24 winters from 1993/94 to 2016/17
Hindcast sets initialised on 25/10, 01/11, 09/11, run in 2019 and 2020
1008 realizations of winter in total

Charlton & Polvani, J.Clim., 2007) definition for SSWs is used

- The central date of the warming is the first day on which the daily zonal mean wind at 10 hPa and 60°N transfers to easterly
- An interval of 20 consecutive days of westerlies must exist before another event can be defined
- Cases where winds are easterly and do not return to westerly for at least 10 consecutive days before 30th April are considered final warmings

A. El Niño, La Niña and SSW frequency

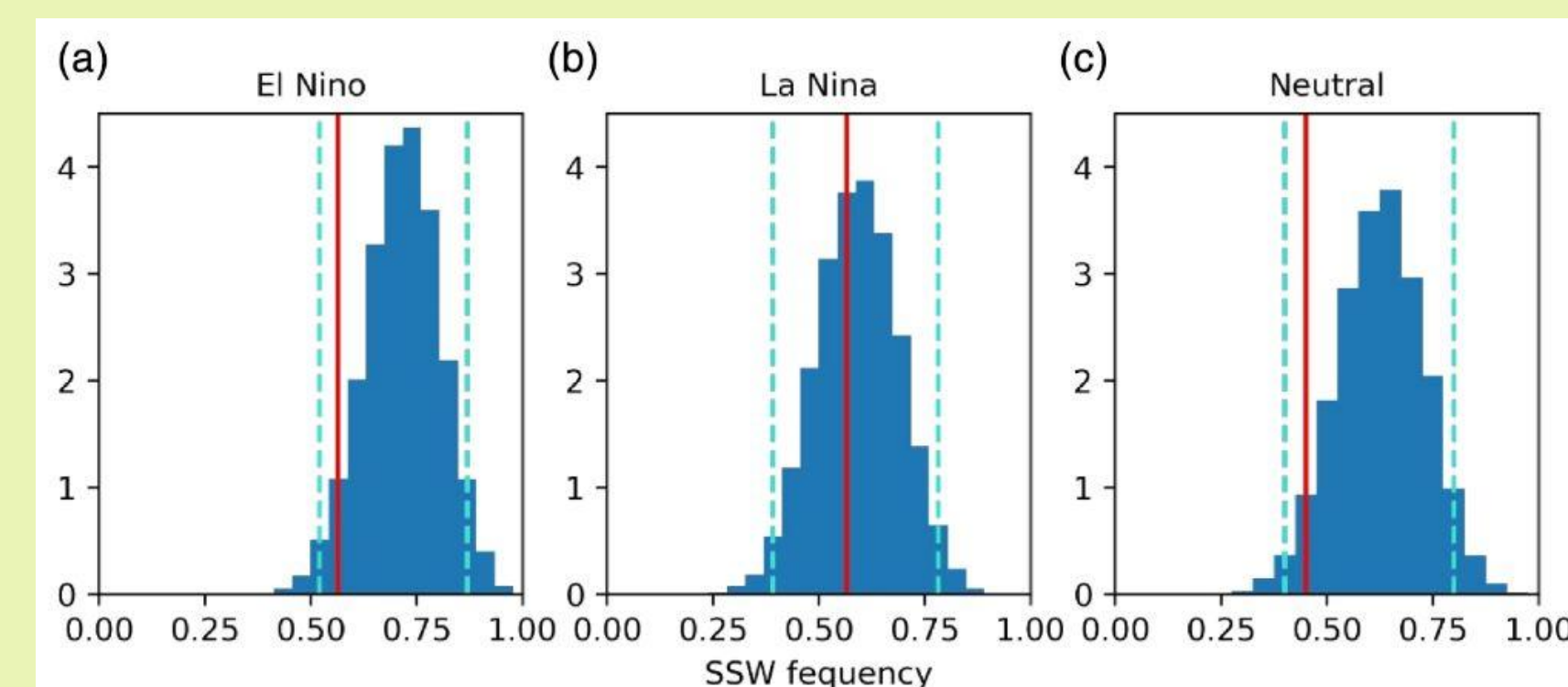


Observed (ERA5) SSW frequency is similar in El Niño and La Niña years (Butler & Polvani, GRL, 2011)

GloSea5 shows the more intuitive result, the highest SSW frequency occurs in El Niño years, the lowest in La Niña

Can the observed frequencies be sampled by chance from the model?

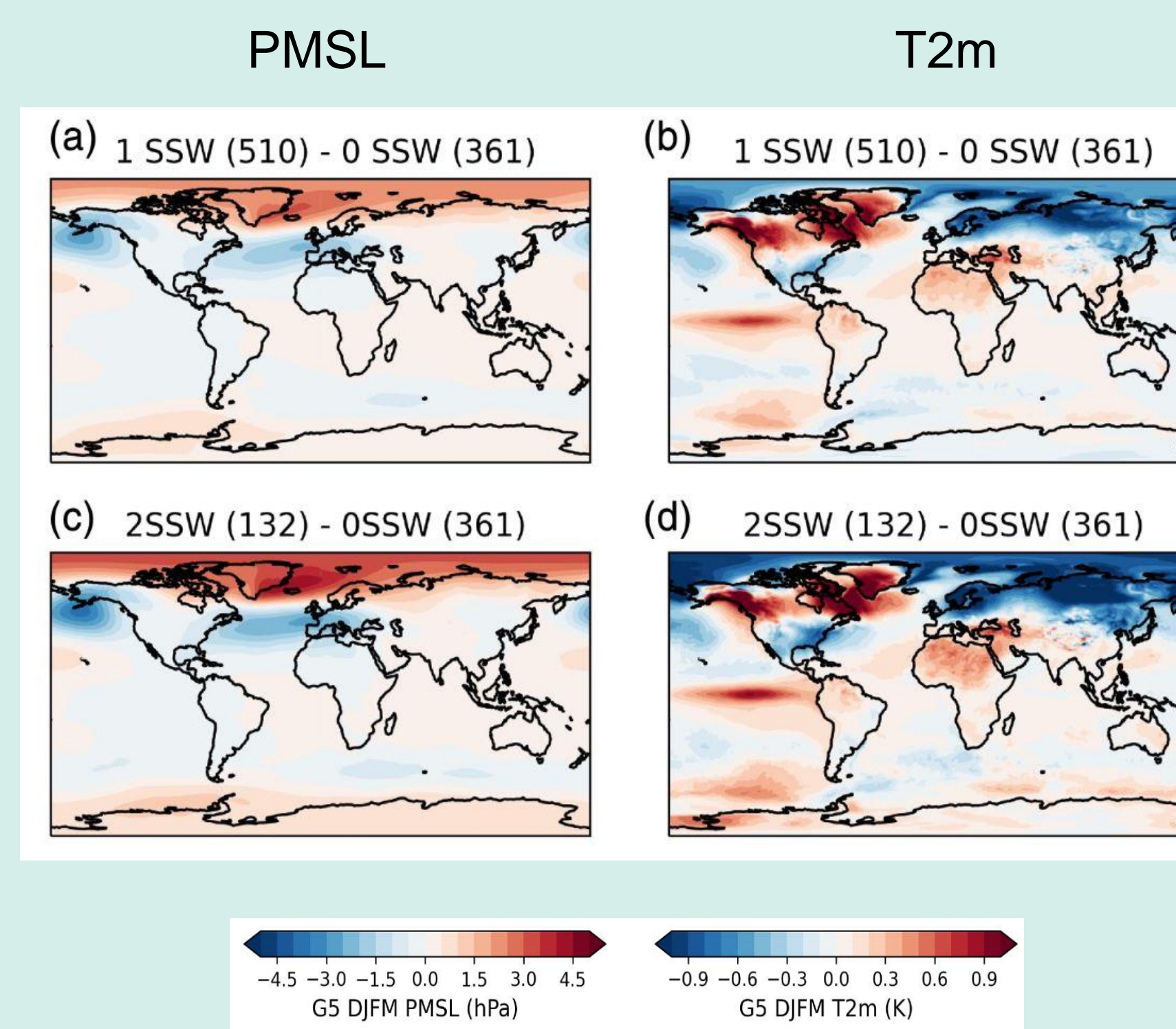
We randomly re-sample the hindcasts based on the observed number of events in each of the ENSO phases



Observations (red) lie within the central 95% of the model distribution (pale blue-dashed), indicating the observed frequencies are consistent with the model.

Hence, the similar El Niño and La Niña frequency could have occurred by chance due to the relatively short historical record (see also Weinberger et al., Clim. Dyn., 2019)

B. Impact of winters with more than 1 SSW



The mean impact of 1 SSW on winter (DJFM) surface pressure and T2m temperature relative to years without an SSW is

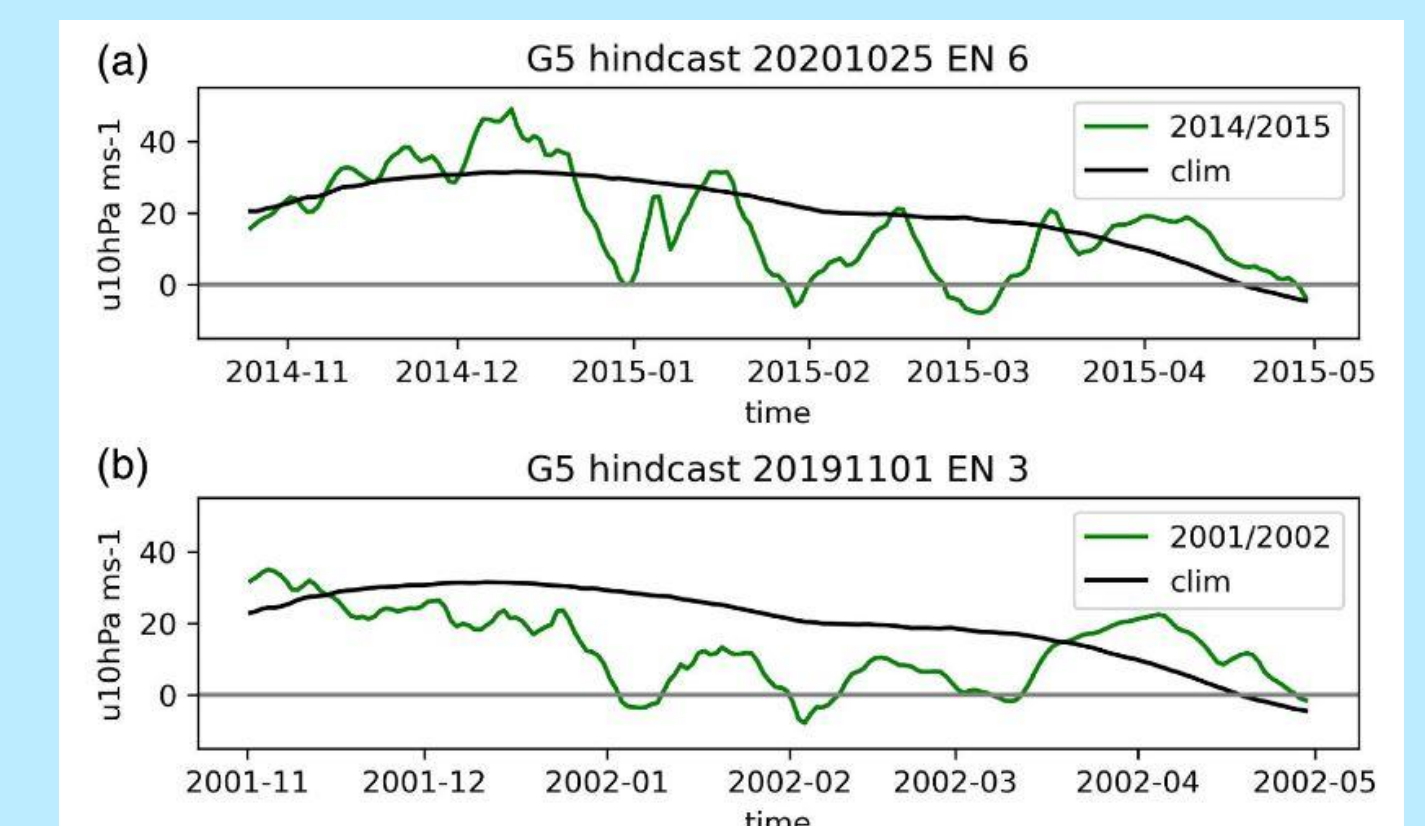
- negative NAO response
- warming over eastern North America and Southern Europe, cooling over southern North America and northern Europe

Winters with 2 SSWs are relatively rare in the observational record (7 in 66 years). Based on a large sample, GloSea5 shows that on average the surface response is amplified

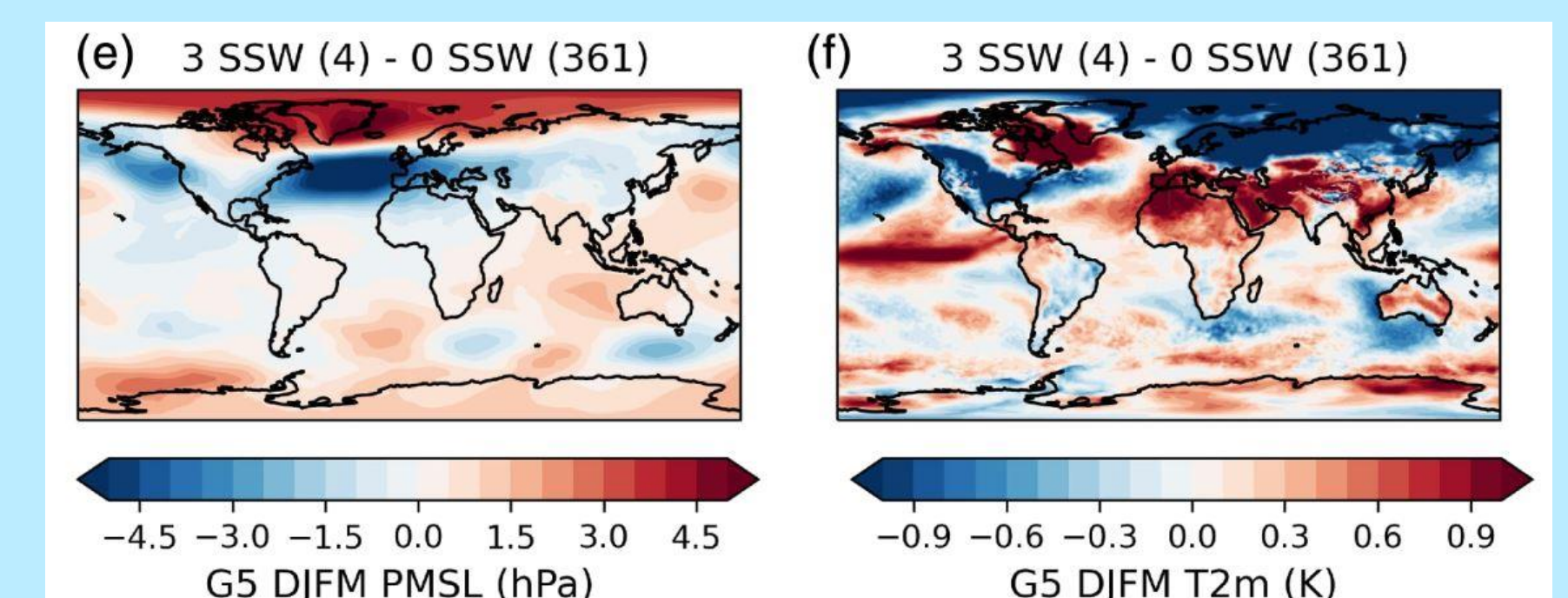
TABLE 1. Difference in mean NAO (DJFM) for various winter SSW counts relative to the climatological NAO for all GloSea5 hindcast winters, 19.92 hPa.

SSW	0	1	2	3
NAO (hPa)	+2.97	-1.26	-2.91	-7.58

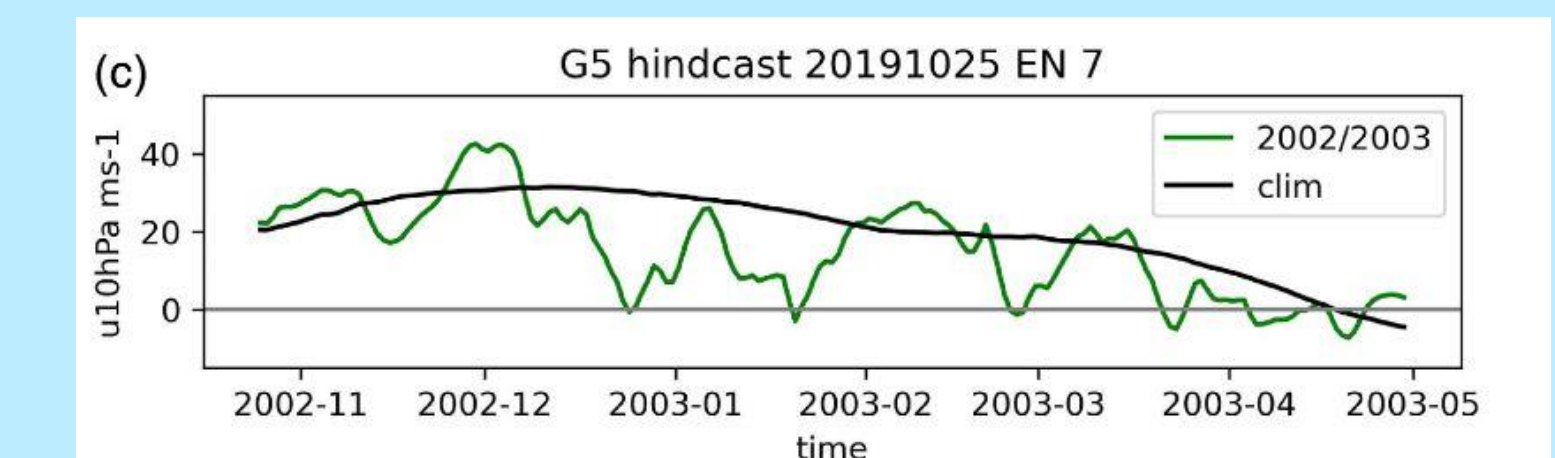
C. Unseen events: Multiple SSWs per winter



On 4 occasions we find model winters with 3 SSWs. This represents ~ 1/250 year event and has never been observed (yet!)



Find surface response enhanced compared to double winters (but note small sample). Potential for extreme impact on surface climate



The algorithm also detects 1 event with 4 SSWs

Winter 2023/24

