

A Guide to Sudden Stratospheric Warmings in the Southern Hemisphere

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WHY SH SSWs NEED A DIFFERENT LENS

SSW definitions are based on the dynamics and variability of the NH polar vortex. The SH shows different behaviour, while still influencing surface weather and climate. NH definitions fail to detect more than one or two historical events in the SH.

GOAL: Identify dynamically significant SH events, align different onset definitions. Test whether they share a common life cycle and assess surface impact.

10	10	2002, 2019
detection methods	common events 1979-2025	remain special events

METHODS

Different diagnostics target different aspects of vortex disturbance. At first, we tuned parameters so individual methods yield roughly 5–6 events per decade, similar to NH. Common events were then identified as years where at least 9/10 methods detected an event.

Method	Variable	Description	Onset definition	Depth definition	Main reference(s)
DISP, SPLIT	Z	longitude-latitude geometric moments	Centroid lat $\phi > \text{thres}^b$, ≥ 7 days Aspect ratio $r > \text{thres}$, ≥ 7 days	$\max(\phi)$ $\max(r)$	<i>Mitchell et al. (2011)</i> , <i>Seviour et al. (2013)</i>
ZEOF	Z	latitude-longitude EOF1	$\text{PC1} > \text{thres}$	$\max(\text{PC1})$	<i>Thompson and Wallace (2000)</i>
ZPOLAR	$\bar{Z}$	polar-cap Z anomaly	$\langle Z \rangle_a < \text{thresh} [\text{stddev}]$	$\min(\langle Z \rangle_a)$	<i>Baldwin and Thompson (2009)</i>
TPOLAR	$\bar{T}$	Meridional T gradient, polar cap T anomaly	$\nabla T > 0$ for ≥ 5 days, $\nabla T > \text{thres}$, $T_{\text{pc}}^a > 0$	$\max(\nabla T)$	<i>Shen et al. (2022)</i>
UANOM	$\bar{u}$	daily u anomaly	$u_a < \text{thres}$	$\min(u_a)$	<i>Jucker et al. (2021)</i>
UTEND	$\bar{u}$	15-day u tendency	$u_{\text{tend}} < \text{thres}$	$\min(u_{\text{tend}})$	<i>Kim et al. (2017)</i>
UDROP	$\bar{u}$	10-day u tendency, in-window u change	$u_{\text{tend}} < \text{thres}$, $(u_{\text{tend}}^{\max} - u_{\text{tend}}^{\min})/u_{\text{tend}} < \text{ratio}$	$\min(u_{\text{tend}})$	<i>Wu et al. (2022)</i>
FZ	F_z	Vertical EP-flux at 100 hPa, divided by $-1e5$ and detrended, weighted sum of 20–90°S mean	$\langle F_z^{100} \rangle \geq \text{thres}$	$\max(\langle F_z^{100} \rangle)$	<i>Reichler and Jucker (2022)</i>
OZONE	tco3	polar cap averaged total column ozone anomalies	$\text{tco3} > \text{thres}$	$\max(\text{tco3})$	
STCM	$\bar{u}$	month-pressure EOF1	$\text{PC1} > \text{thres}^a$	PC1	<i>E. Lim et al. (2018)</i>

^aWe assign all ST Coupled Mode events an onset date of 1. October, which is when the STCM maximizes at 10 hPa (E. Lim et al., 2018).

^bNote the algorithm works with absolute value of latitude.

COMMON CENTRAL DATE

To align events across definitions, we search for the warmest polar-cap (60-90S) temperature anomaly at 10hPa. This is motivated by the most fundamental definition of SSWs: a warming.

shssw: A COMMUNITY TOOLKIT

As part of the project, we created a python toolkit which includes all tested methods. The user can easily select their preferred method(s), and change relevant parameters. All is done via one function call, and all detailed calculations are done internally.

COMMUNITY CALL: We call for the community to test the toolkit ahead of publication. If you are interested, please email Martin Jucker (martin.jucker@unsw.edu.au).

Thanks to APARC for financial support for necessary code development.

AGREEMENT ACROSS METHODS

Each definition has its own onset date depending on the variable and thresholds used (note STCM does not have any onset date and is here set to 1. October). Below Figure 1 shows event detection from 1979 to 2025 from ERA5, while Figure 2 shows their seasonality. Observations from this first analysis are:

- there is considerable difference between methods, although most events are detected by more than one method (squares vs. circles)
- several methods detect fewer events during the second half of the 1990s and the early 2020s
- 2002, 2017, 2019 are the only events detected by all methods; 2017 is relatively weak, leaving 2002 and 2019 as generally strong and universally detected events

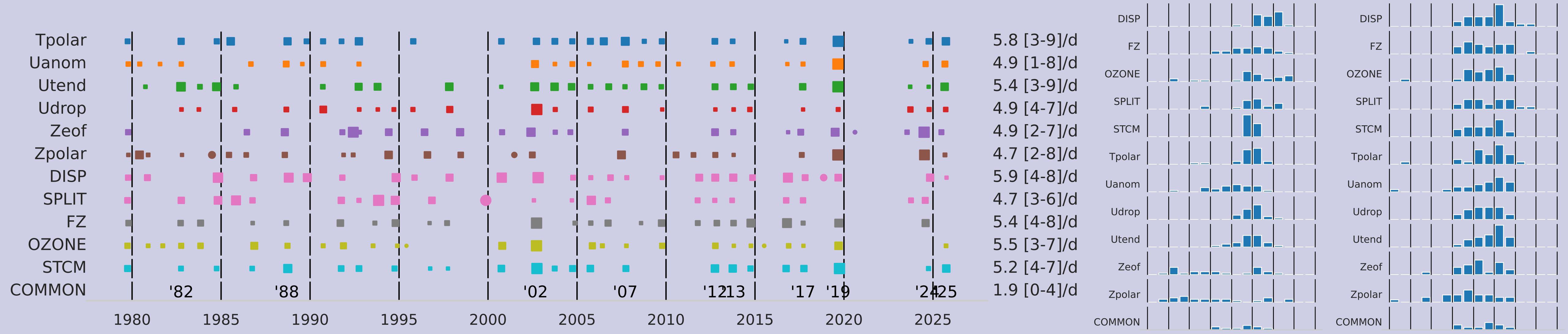


Figure 1: Onset dates for each method. The size of each square denotes the relative strength compared to all other events detected with the same method. The 109 COMMON events (last row) are denoted by their year. They are defined as events where at least 9/10 methods detect an event within 90 days. Events only detected by one method are shown as circles. The overall frequency [events/decade] and range is reported along the right edge.

- most events happen in spring, though there is a considerable number of events in August, and a few events in early winter
- defining a central date based on one common definition (warmest anomaly) creates more agreement between methods

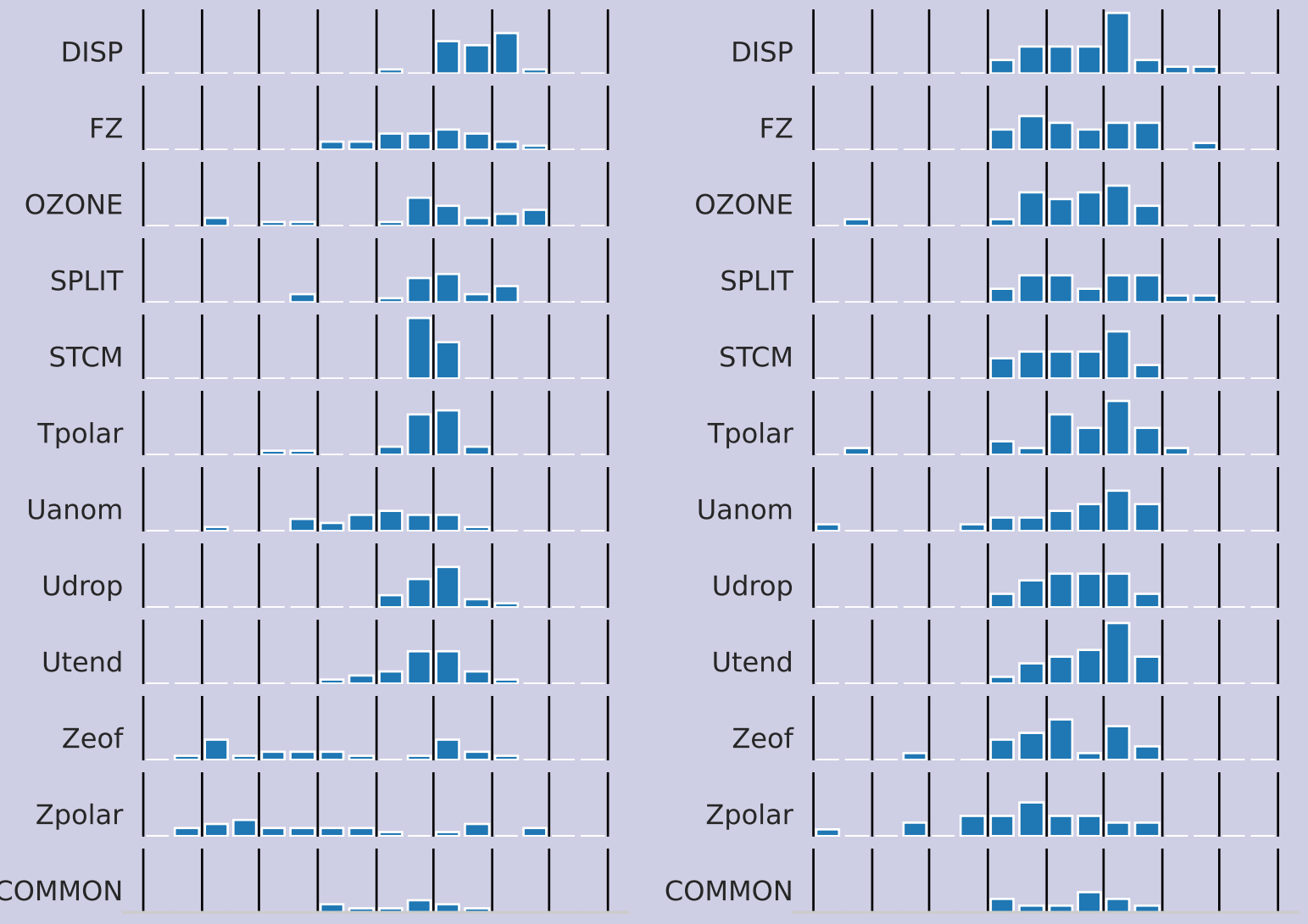


Figure 2: Seasonality of onset dates for each method. The left panel uses individual onset dates, while the right panel uses the central dates.

STRATOSPHERE-TROPOSPHERE COUPLING

Composite evolution of COMMON events follows expected trajectory (Figure 3):

- buildup of strong wave-1 upward wave forcing in extratropics accompanied by planetary-scale surface perturbations
- decreased wave activity post event with Southern Annular Mode like signature at the surface

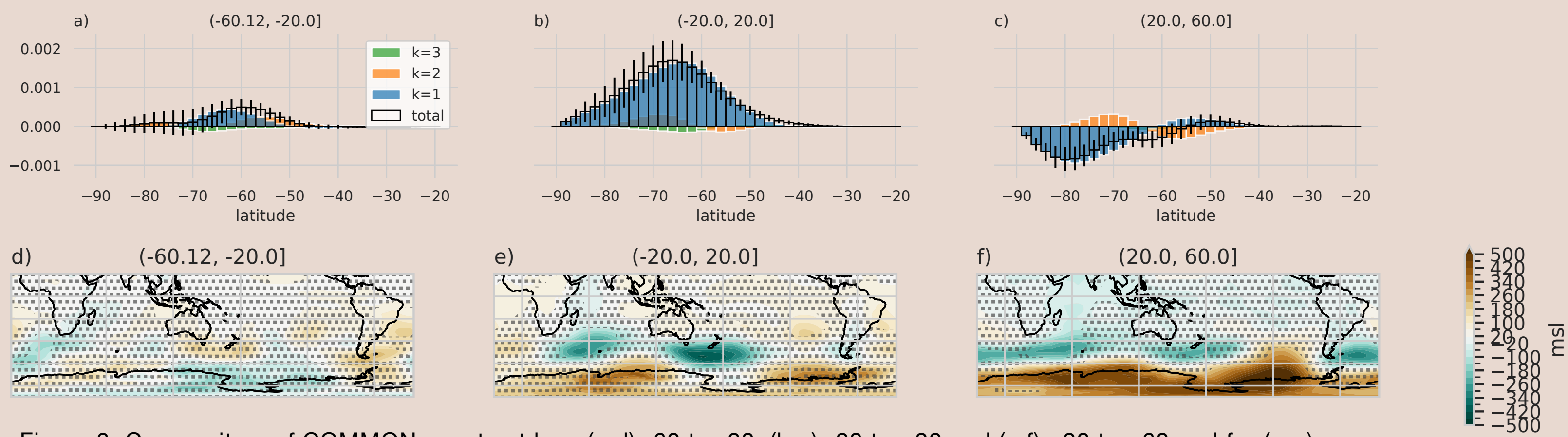


Figure 3: Composites of COMMON events at lags (a,d) -60 to -20, (b,e) -20 to +20 and (c,f) +20 to +60 and for (a-c) anomalous upward Eliassen-Palm flux (wavenumbers 1-3 and total) and (d-f) anomalous SLP (green is negative).

Similarly, time periods with more events (Figure 4, top) have more wave forcing than periods with fewer events (bottom).

In particular, there is more wave-1 forcing, while wave-2 forcing can even be anomalously weak (blue vs orange).

Figure 4: Seasonal upward Eliassen-Palm flux anomalies during (top) 2010-2019 (4 COMMON events) and (bottom) 1990-1999 (0 COMMON events). Anomalies are averaged over rolling three-month periods from June to March.



Baldwin & Thompson *QJRM*S (2009); Jucker et al. *GRL* (2021); Kim et al. *JCLim* (2017); Lim et al. *JGRA* (2018); Mitchell et al. *JAS* (2011); Reichler & Jucker *WCD* (2022); Seviour et al *GRL* (20130; Shen et al. *JCLim* (2022); Thompson & Wallace *JCLim* (2000); Wu et al. *WCD* (2022)