Reconsidering the standard definition for sudden stratospheric warmings

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Historical Context of SSW definition

1952: SSW observed by Richard Scherhag

1957/58: IGY program. Major SSW observed.

1964/65: IQSY
WMO STRATALERT program begins, led by Karin Labitzke at FUB.
"When the central temperature of the warm air reaches -30C at 10 mb or -35C at 30 mb" -IQSY

1965-75: Alternative circulation indices are considered by various researchers.
e.g., Johnson et al. 1969

Quiroz 1975 (JAS): *"'Major' will connote that a circulation reversal occurred in the stratospheric polar vortex at an altitude at least as low as the 10-mb level, in association with a reversal of the meridional temperature gradient…"*

1978: Conflicting definitions attributed to WMO:

- *NASA report, R. McInturff: "A stratospheric warming can be said to be major if at 10 mb or below the latitudinal mean temperature increases poleward of 60 degrees latitude and an associated circulation reversal is observed"*
- *WMO CAS report: "major" warmings [are those] with a temperature increase of at least 30 degrees in a week or less at 10 mb or below, or by at least 40 degrees above 10 mb."*

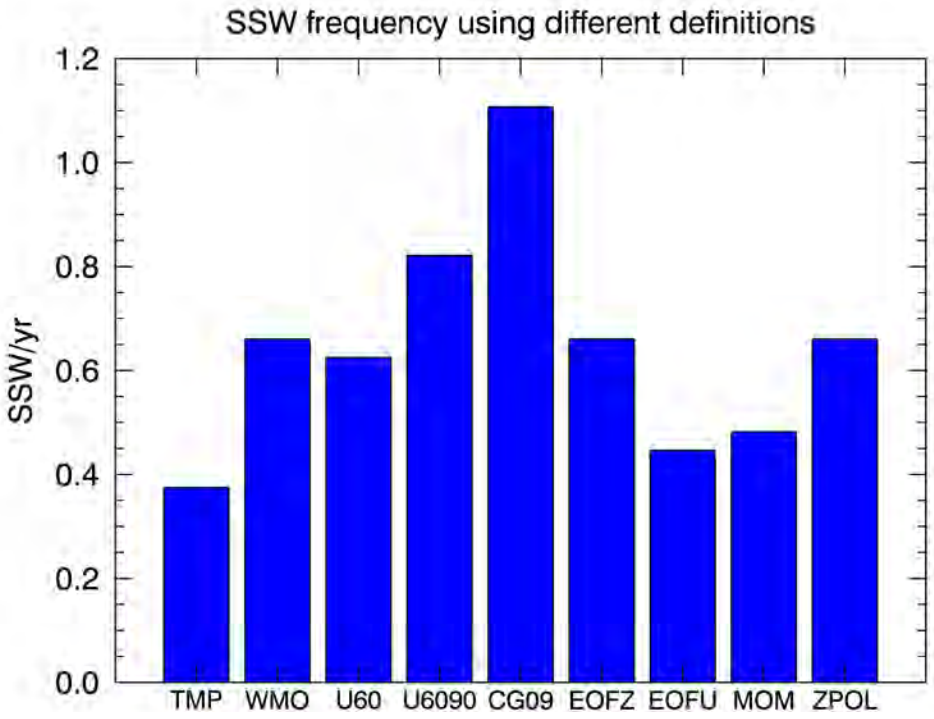
1981-2000s: McInturff 1978 definition adopted in most of the literature (usually just attributed to "WMO")

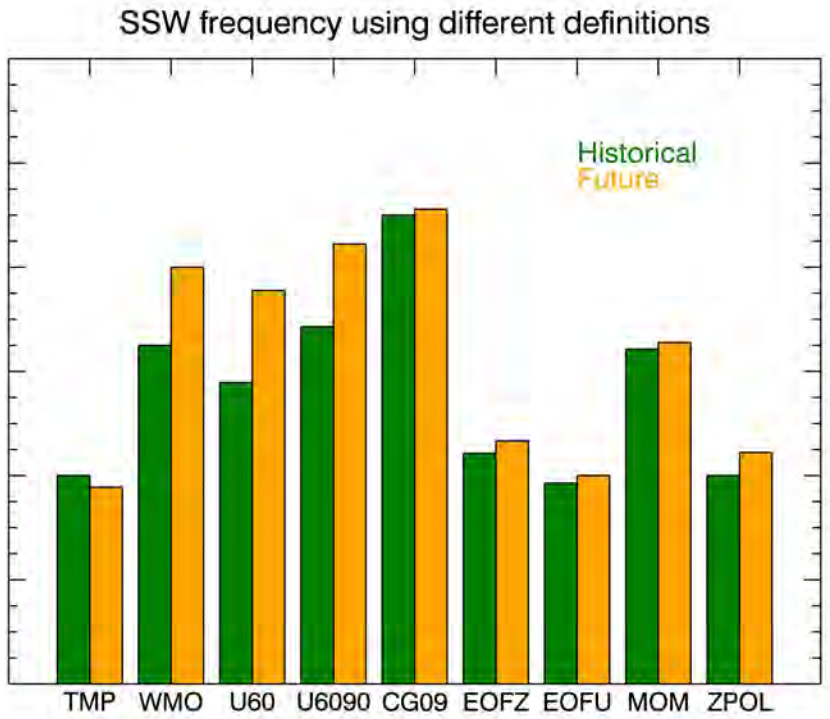
2000s-present: Many new definitions proposed for SSWs, including the commonly used method by *Charlton and Polvani 2007* using zonal-mean zonal winds at 60N

Some definitions in use today

Standard WMO definition (WMO)	*e.g., Quiroz 1975; McInturff 1978; Schoeberl 1978; Labitzke 1981; Andrews et al. 1987; Limpasuvan et al. 2004; Kruger et al. 2005; Kuttippurath and Nikulin 2012*
Zonal mean zonal winds only (U60, U6090)	*e.g., Christiansen 2001; Charlton and Polvani 2007; Charlton et al. 2007*
Empirical Orthogonal Functions (EOFZ,EOFU)	*e.g., Baldwin and Dunkerton 2001; Baldwin 2001; Baldwin et al. 2003; Limpasuvan et al. 2004; Gerber et al. 2008; Baldwin and Thompson 2009; Gerber et al. 2010; Hitchcock and Shepherd 2012; Hitchcock et al. 2013*
Polar cap geopotential height anomalies (ZPOL)	*e.g., Thompson et al. 2002*
k-means clustering (CG09)	*Coughlin and Gray 2009*
Vortex moments (MOM)	*e.g., Waugh and Randel 1999; Hannachi et al. 2011; Mitchell et al 2011, 2012; Seviour et al. 2013*
Supervised learning approach/neural networks	*Blume et al. 2012*

Why is it important to have a standard definition?



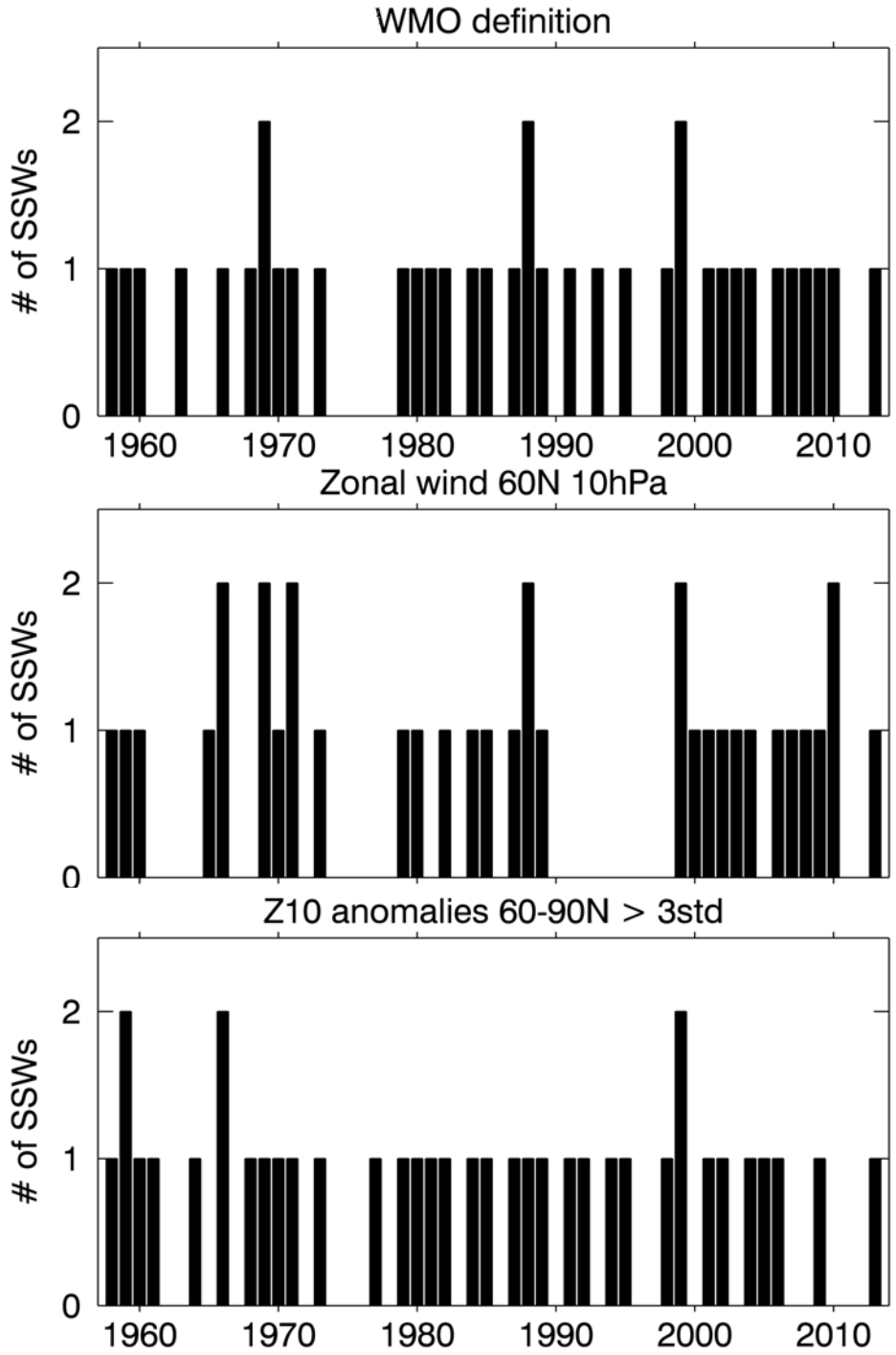


1958-2013,NCEP/NCAR

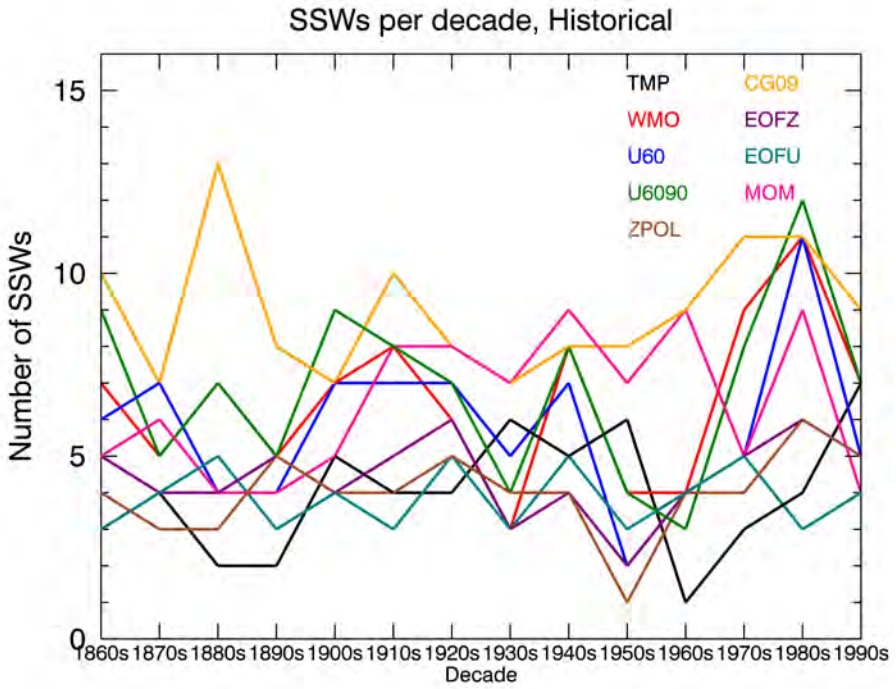
Range: 0.45-1.1 SSW/yr

See also *McLandress and Shepherd 2009*

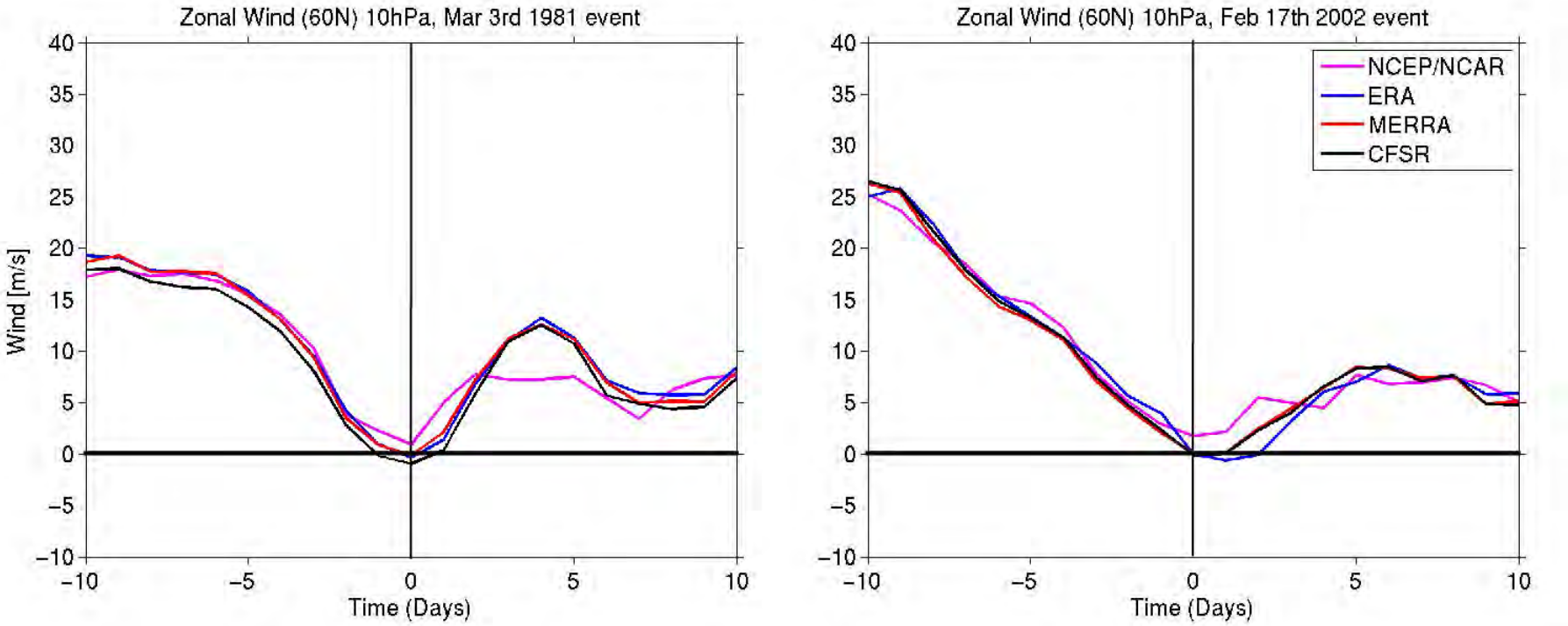
1. Standard set of major SSWs for research purposes
2. Robust metric to assess SSWs in historical and future simulations
3. International efforts for forecasting major SSWs



Sensitivity to decadal variability

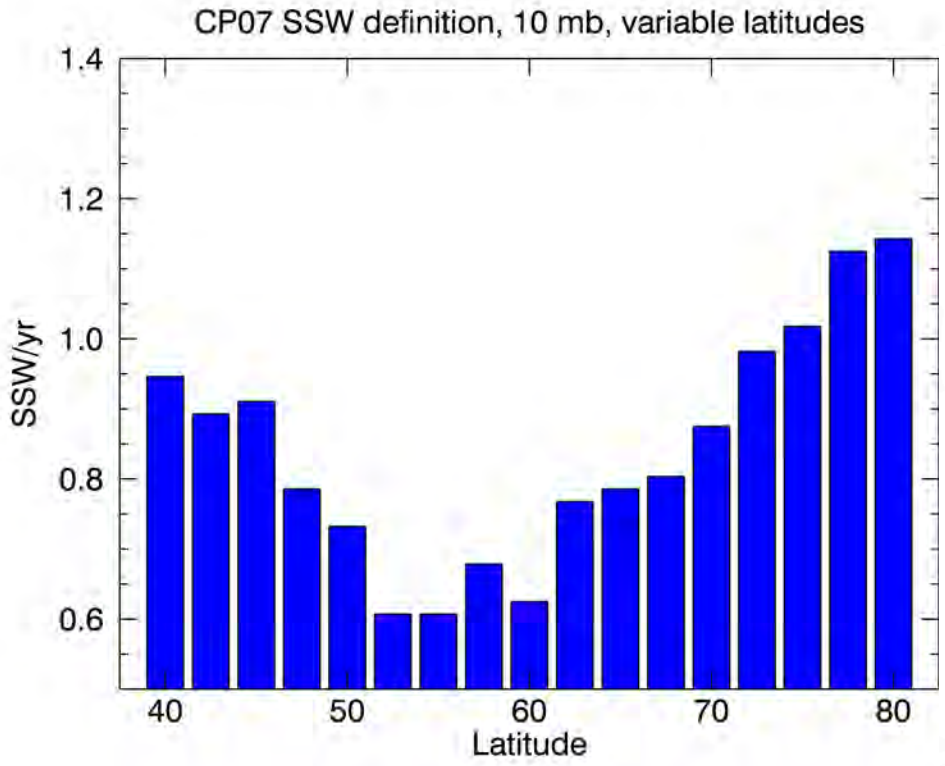


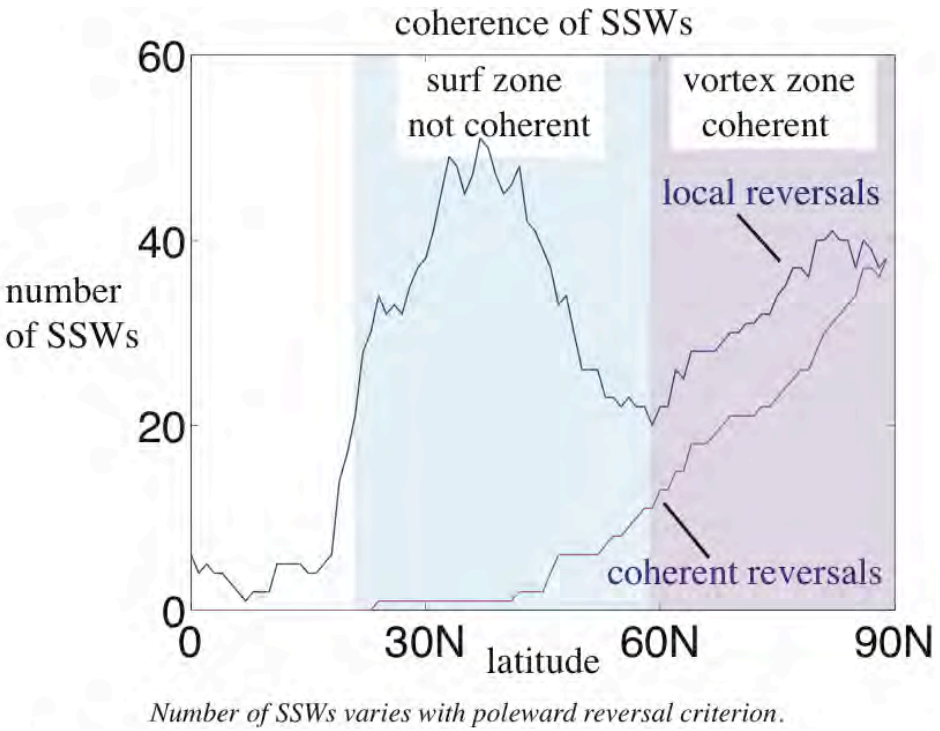
Sensitivity to dataset/threshold



Using the zonal winds at 60N, some SSWs are not classified as major in one or more reanalyses due to differences of less than 2 m/s (definitions using broader areal extent, such as averages from 60-90N, are less sensitive).

Sensitivity to Latitude



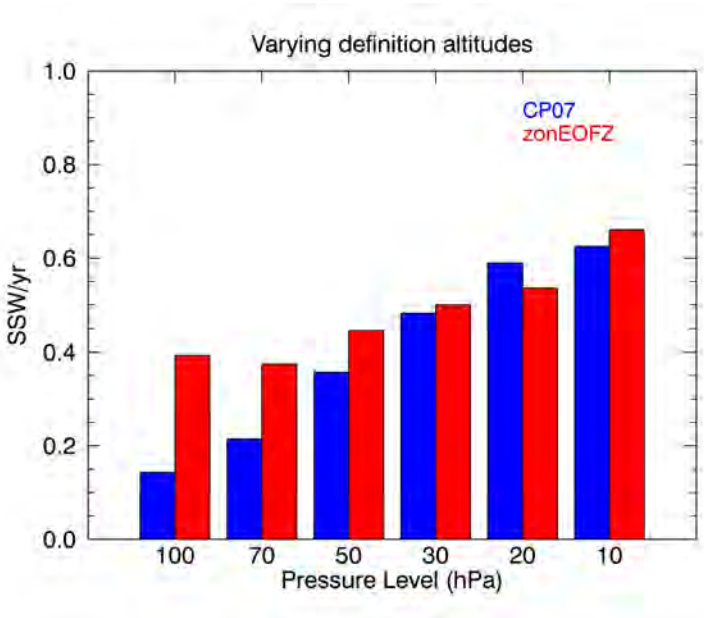


Number of SSWs varies with poleward reversal criterion.

Figure by Aaron Match and Thomas Birner, with permission

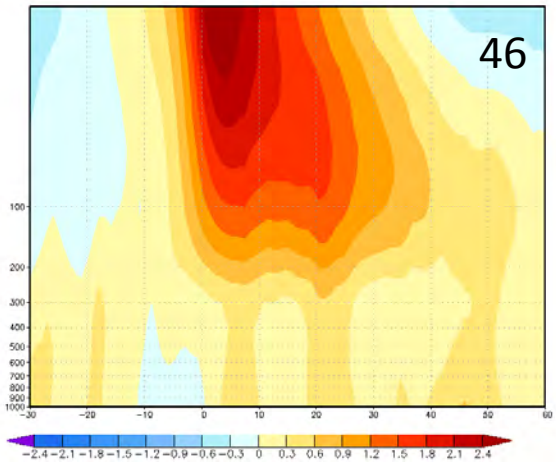
~60N marks transition from surf zone region to coherent vortex region

Sensitivity to Altitude

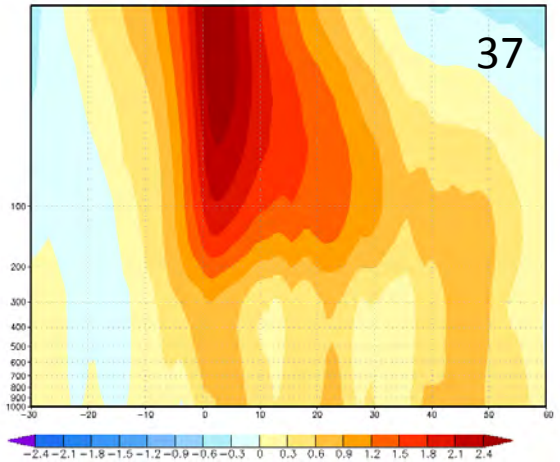


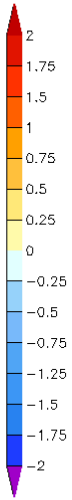
Geopotential Height anomalies

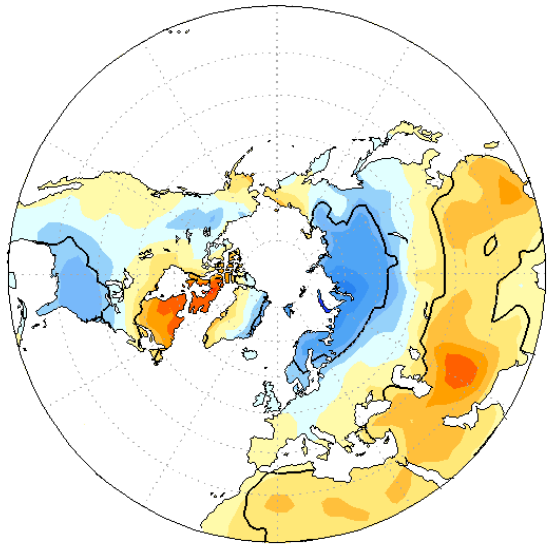
SSWs_U6090, 10 mb

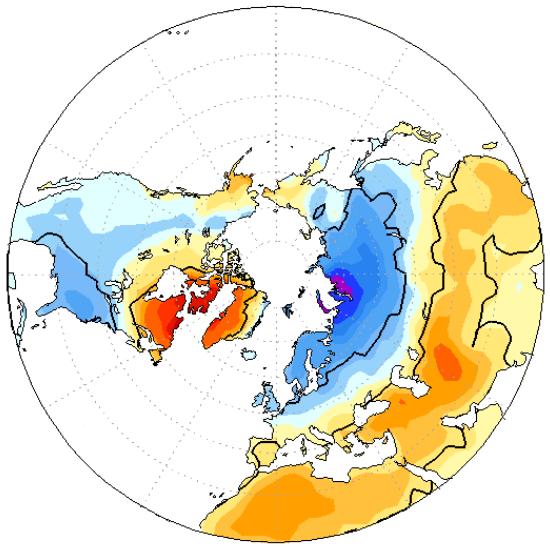


SSWs_U6090, 50 mb









What makes a "good" standard definition?

- Simple.
  - Easily calculated and replicable in both reanalysis and models.
  - Can be applied in real-time (operationally).

- Robust.
  - Should not be highly sensitive to an exact threshold, spatial extent, or pressure level.
  - Not dependent on choice of climatology.
  - Relatively insensitive to changes in the background state (i.e., due to decadal variability or climate change).

- Physical.
  - Ideally, the critical threshold, level, and spatial extent of the definition would be determined based on dynamical understanding.

Recommendations

- Current standard WMO definition is not unreasonable, but improvements should be made (we can do better).

- At the least, specific guidelines should be provided regarding:
  a. Event separation criteria
  b. Final warmings
  c. Split vs displacement-type events

- In addition, we should *consider*:
  a. Vertical or spatial averaging
  b. Specifically defining minor warmings
  c. Changing the focus: stratosphere-troposphere coupling rather than (or in addition to?) best detection of the strongest events at 10 hPa
  d. Sensitivity to the critical threshold
  e. Impacts of climate change on SSW detection. ENSO community has one possible solution…

Next Steps

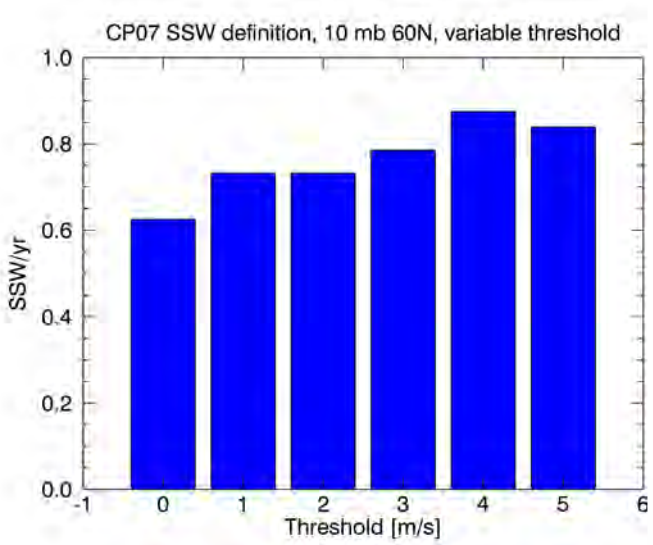
We'd like your input!

Organization committee: Ed Gerber, Dann Mitchell, myself

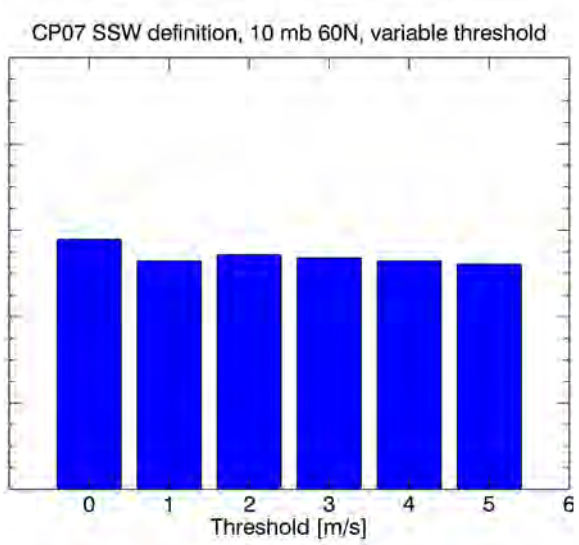
We are starting a SSW definition email list- please email us at wmosswdefinition@gmail.com to get your name on the interest list if you would like to participate. Anyone is welcome!

Sensitivities to critical threshold

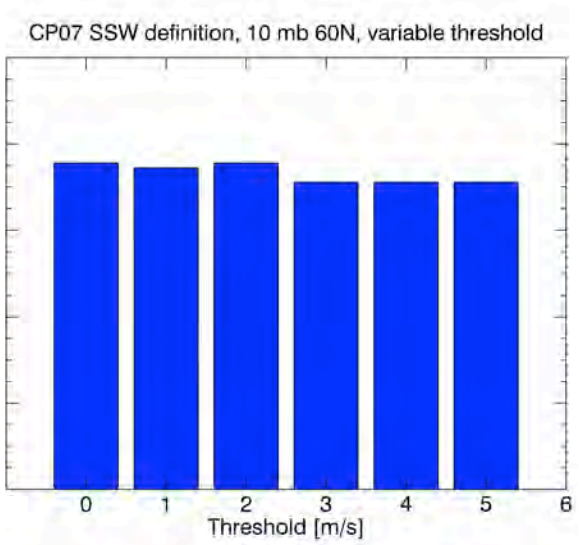
for zonal wind 60N 10 hPa



Observations (1958-2013)



Historical run (1860-1999)



Future run (2010-2099)

- Observations (NCEP-NCAR) more sensitive to threshold than model.
- Changing threshold doesn't drastically change total SSW frequency, because easier detection threshold is balanced by more difficult final warming criteria (wind must return to above threshold for 10 days before April 30).
- Future simulation shows higher SSW frequency for every threshold.