Dynamically motivating the definition of sudden stratospheric warmings

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1. Introduction

The polar stratospheric vortex impacts the stratospheric ozone and couples with surface weather and climate. Its most profound dynamics – sudden stratospheric warmings (SSWs) – are not fully understood. Many authors alter the subjective thresholds of the World Meteorological Organization (WMO) definition while presuming to discuss a similar set of events.

Research Questions

1. Does altering the definition of SSWs impact the number and type of events identified?
2. Can the dynamical evolution of the polar vortex motivate the WMO thresholds?

2. WMO definition and variants

Major SSWs must exhibit both (McInturff 1978):

- Circulation reversal at 60N, 10 hPa
- Reversed temperature gradient from 60N to pole

Common variants:

Latitude: 60N, 65N

Pressure level: 10 hPa, 10 hPa or below, at or near 10 hPa

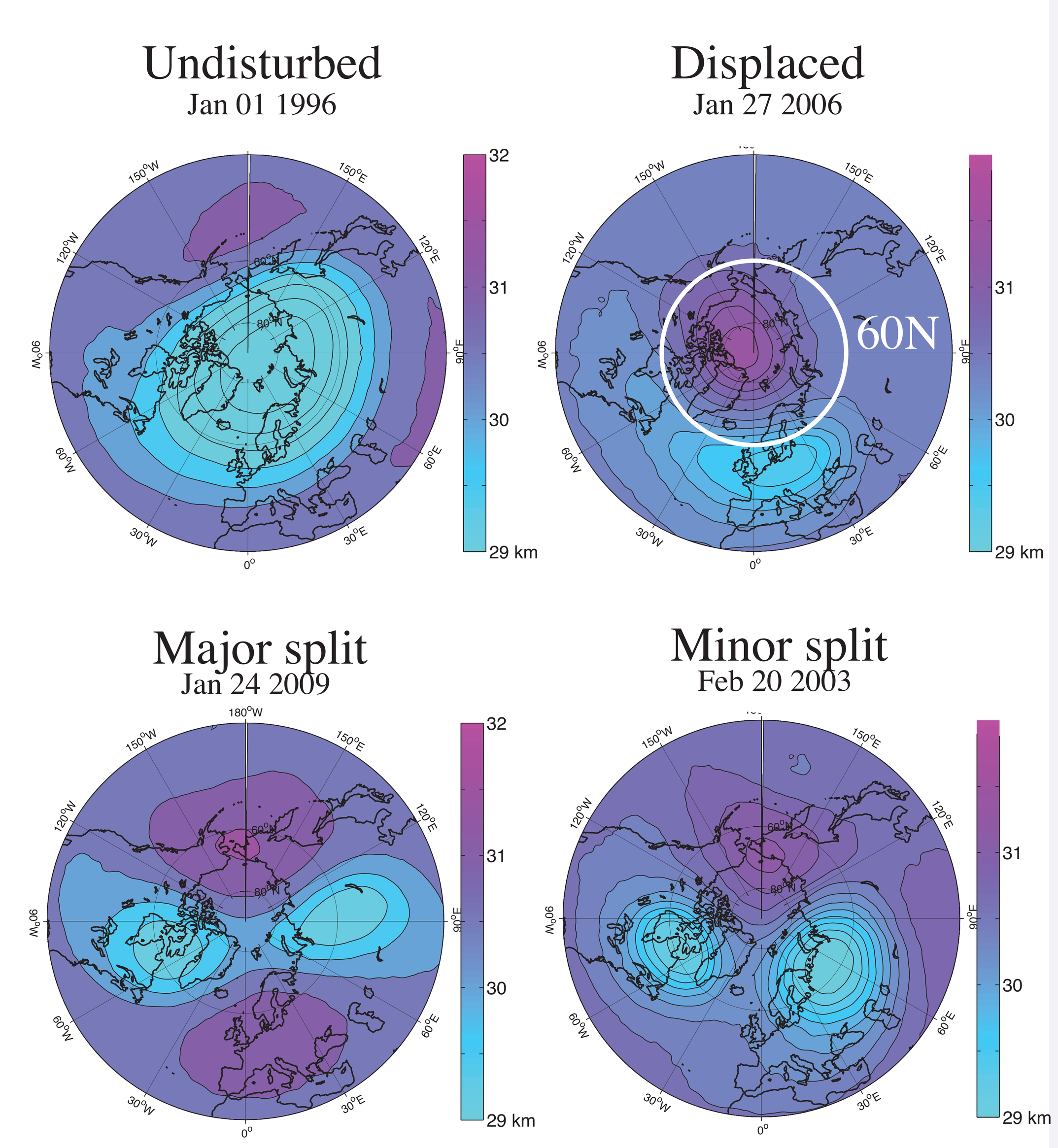
Temperature: Positive gradient, increases at pole, +25K in one week, no temperature-related condition

Persistence: 5 day duration, no persistence condition

Coherence: poleward reversal required, no coherence condition

3. Polar vortex

- The polar vortex forms during polar winter.
- SSWs = split or displacement of the polar vortex.

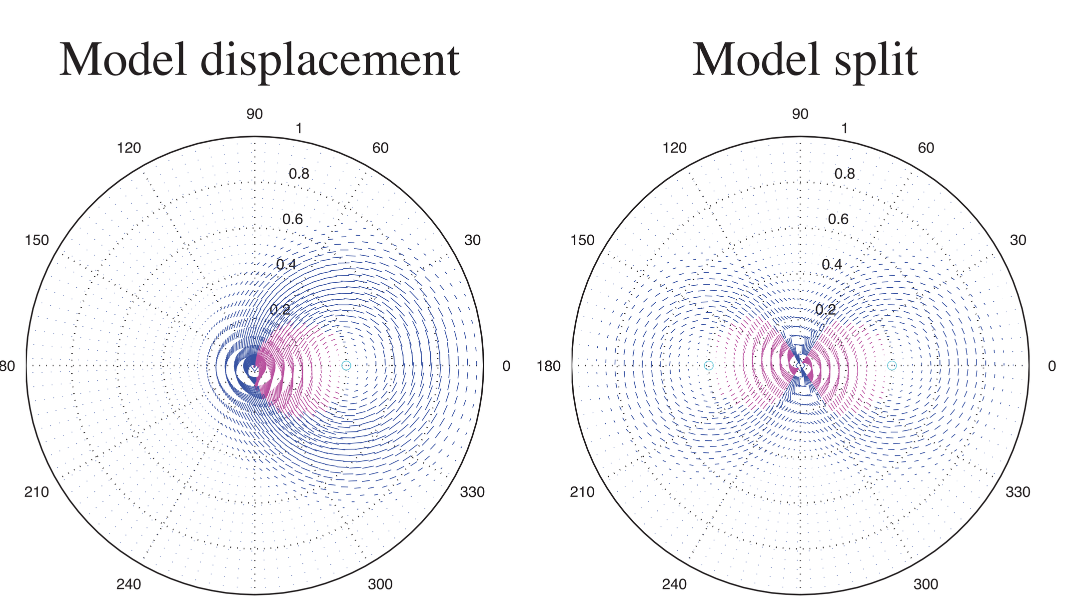


Polar stereographic plot of 10 hPa geopotential heights.

Major warming: Vortices displaced equatorward of 60N

Minor warming: Vortices remain poleward of 60N

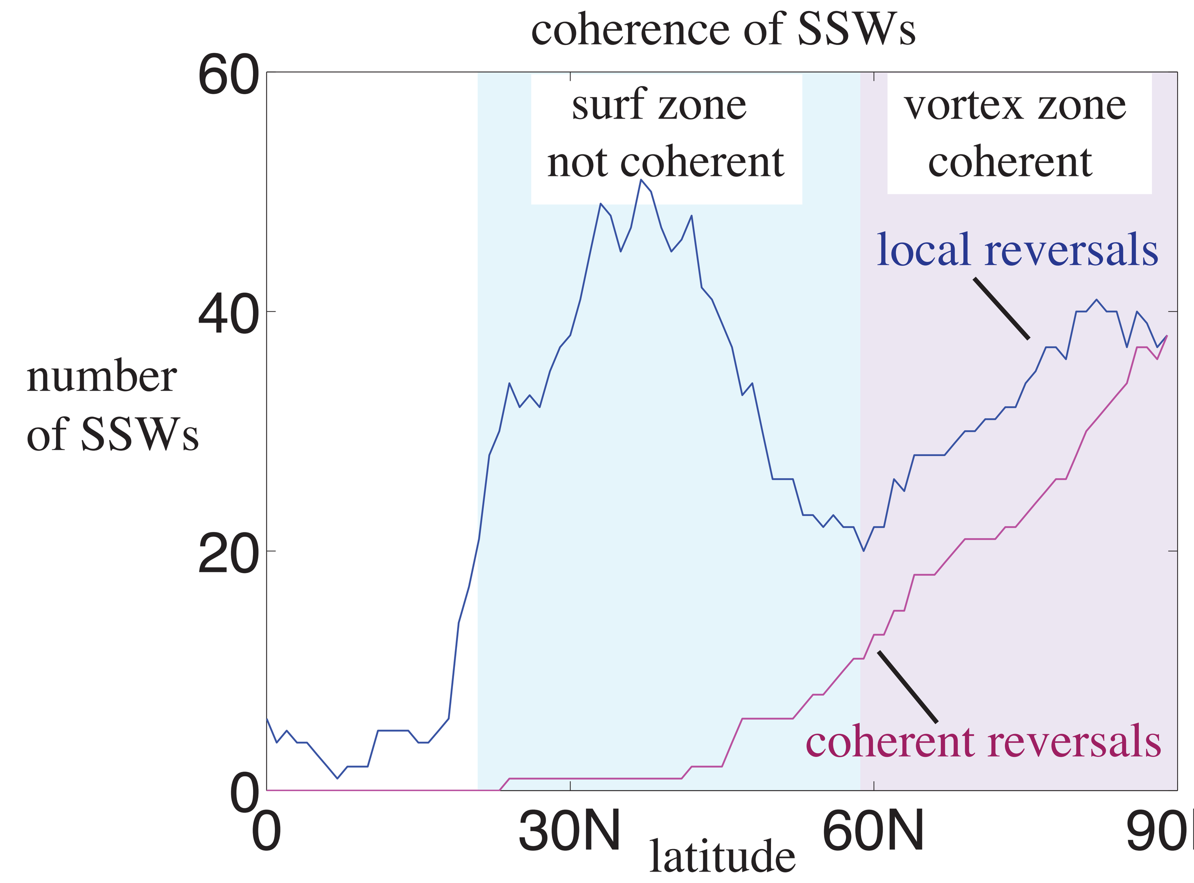
But: If the 65N latitude threshold variant was used, both splits (above) would be identified as major SSWs.



Idealized geometric vortex model with easterlies and westerlies (on a planar disc)

- Winds poleward of the vortex center are easterly.

4. Transition to surf zone



Number of SSWs varies with poleward reversal criterion.

Blue line:

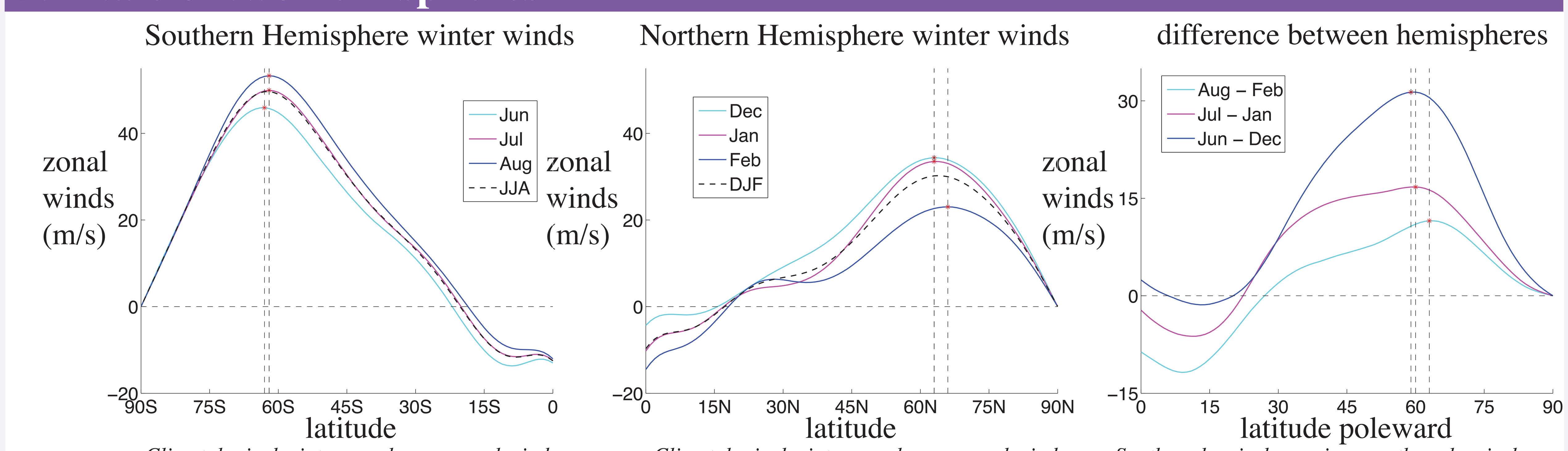
- Local circulation reversal at 10hPa at given latitude

Magenta line:

- Circulation reversal at 10 hPa at given latitude, and
- Circulation reversal everywhere poleward

- Coherent warmings comprehensively reverse Arctic circulation.
- Surf zone (McIntyre and Palmer, 1984) "SSWs" only reverse local circulation.
- 60N demarcates the vortex and surf zone regimes.
- At 60N, poleward reversal condition excludes 9/22 (40%) of events.
- 65N threshold counts six (27%) more reversals than at 60N.

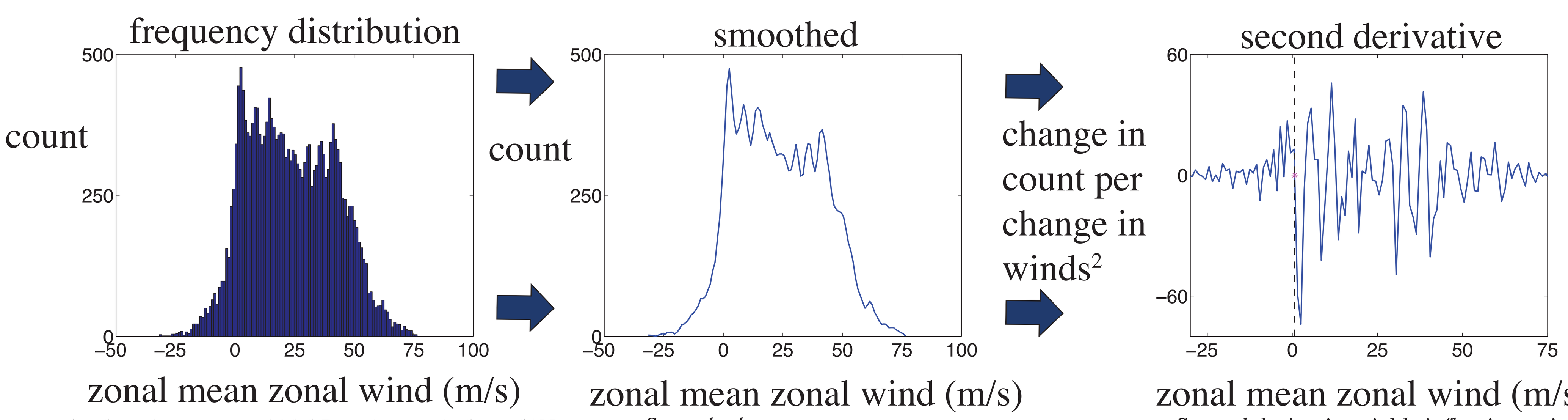
5. A tale of two hemispheres



Climatological winter zonal mean zonal winds · *Climatological winter zonal mean zonal winds* · *Southern hemisphere minus northern hemisphere climatological winter zonal mean zonal winds*

- The strongest winds of the vortex are located near 60 degrees in both hemispheres.
- SSWs fuel the difference between the northern and southern hemispheres, which is maximized near 60 degrees.

6. Circulation reversal as inflection point

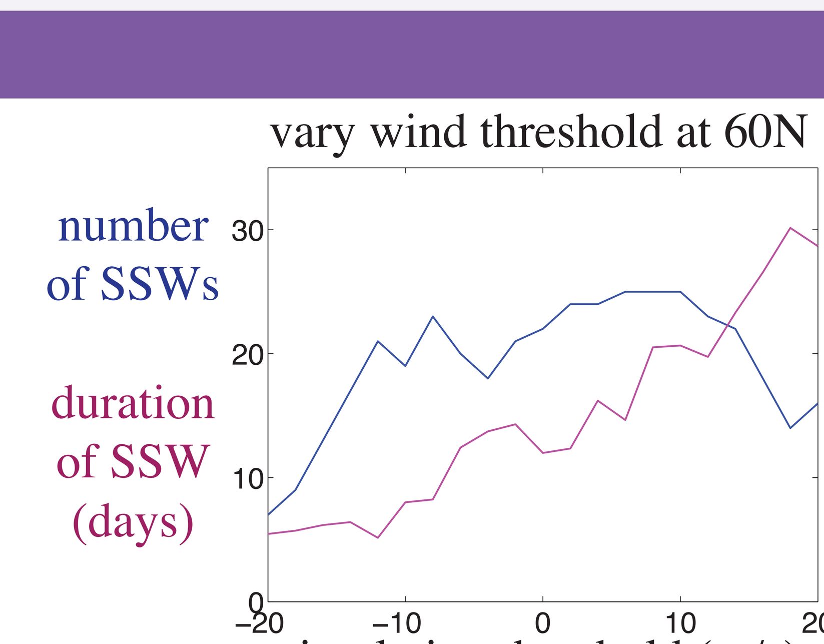


Absolute frequency of 10 hPa winter winds at 60N. · *Smoothed.* · *Second derivative yields inflection point.*

- 0 m/s occurs at the inflection point of the averaged wind frequencies from 50-70N.
- Wind reversals block wave propagation.

7. Open questions

- What are sensible pressure level, persistence, and temperature thresholds?
- How do the geometry and dynamics of the anticyclone affect SSW identification?
- Do the count and duration of SSWs motivate a sensible circulation threshold?



SSWs at various wind thresholds.

- Blue line: Number of SSWs at different circulation thresholds
- Magenta line: Mean duration of warming events at each circulation threshold

8. Conclusions

- Major SSWs occur when vortex center(s) are displaced equatorward of the latitude threshold.
- Latitude variants alter the number of major SSWs identified by 27% and identify warmings of varying degrees of displacement and intensities.
- 60N is a sensible part of the SSW definition because:

(1) 60N marks the edge of the polar vortex.

(2) 60N is maximally affected by vortex dynamics.

(3) 60N marks the transition from the coherent vortex zone to the surf zone.

- Coherence variants alter the number of major SSWs identified by 40% and identify warmings of varying coherence and intensity.
- Circulation reversal is a sensible part of the SSW definition because:

(1) it marks the inflection point of the wind distribution.

References

McInturff, Raymond M. Stratospheric Warmings: Synoptic, Dynamic and General-Circulation Aspects. Washington, D.C.: National Meteorological Center, 1978.

McIntyre, M.E., Palmer, T.N., 1982: The 'surf zone' in the stratosphere. J. Atmospheric and Terrestrial Physics, 46, 825-849.

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