

Dynamical Characteristics and Mechanism of Midlatitude Sudden Stratospheric Warming in the Southern Hemisphere

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Introduction

Sudden stratospheric warming (SSW) is a well-known phenomenon with a rapid temperature increase in the stratosphere from late winter to early spring. The polar-region SSW (PSSW) is mainly caused by a strong wave forcing (e.g., Matsuno, 1971). PSSW mainly occurs in the Northern Hemisphere (NH) twice per 3 years (Charlton & Polvani, 2007). In contrast, it rarely occurs in the Southern Hemisphere (SH).

However, recent study on inter-hemispheric coupling showed that **stratospheric warming occurs in the SH midlatitudes once every two years** (Koshin & Sato 2024). There are many issues to be studied, such as its life cycle, underlying dynamics, and impacts on the troposphere. The **aim of this study is to elucidate the dynamical characteristics, mechanisms and similarity with PSSW of the midlatitude SSW (MSSW).**

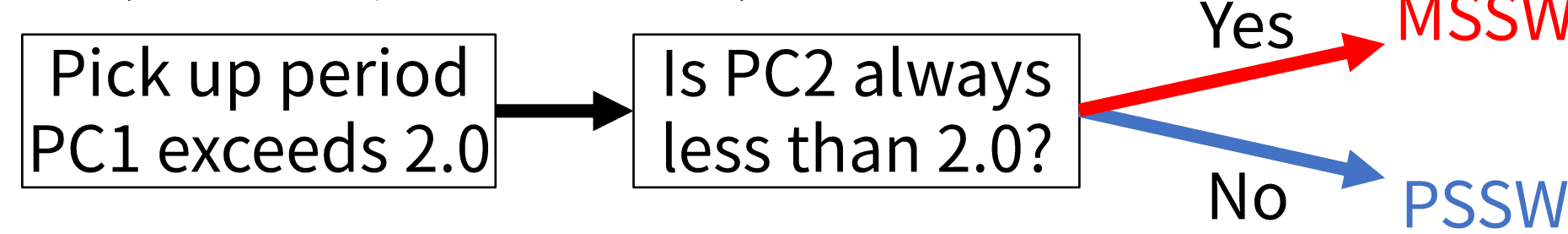
Methodology

Dataset

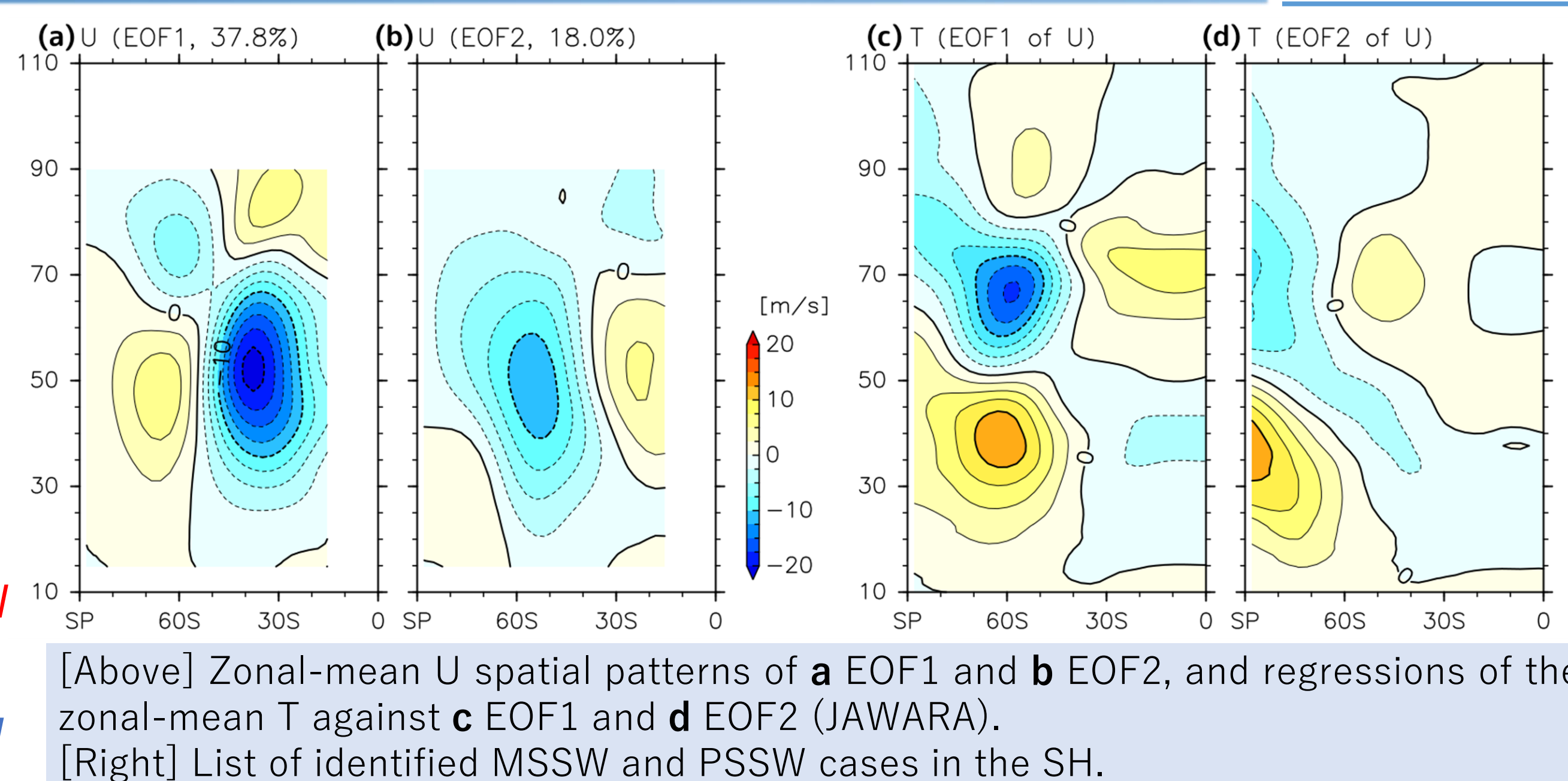
- JAWARA (Sato & Koshin, 2025)
 $\Delta x = 2.8125^\circ$; $\Delta z \sim 1$ km (top: ~ 110 km); $\Delta t = 1$ h
June-September, 2005-2024
- MERRA2 (Gerald et al. 2017)
 $\Delta x = 1.25^\circ$, 42 levels (top: 0.1hPa); $\Delta t = 6$ h
June-September, 1980-2024

Event Definition Method

EOF analysis on the zonal-mean zonal wind (30S-90S, $z=15$ -90 km)



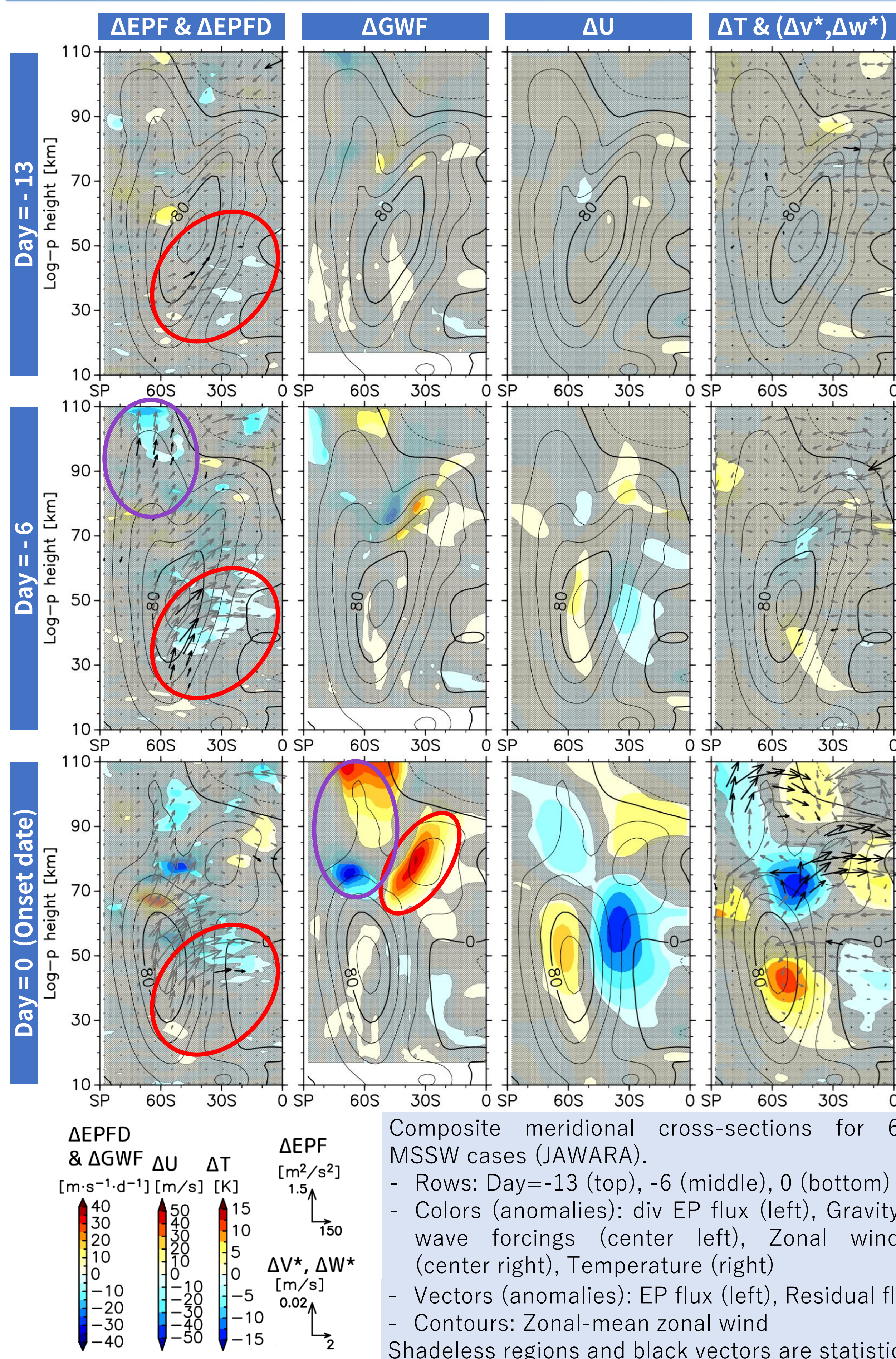
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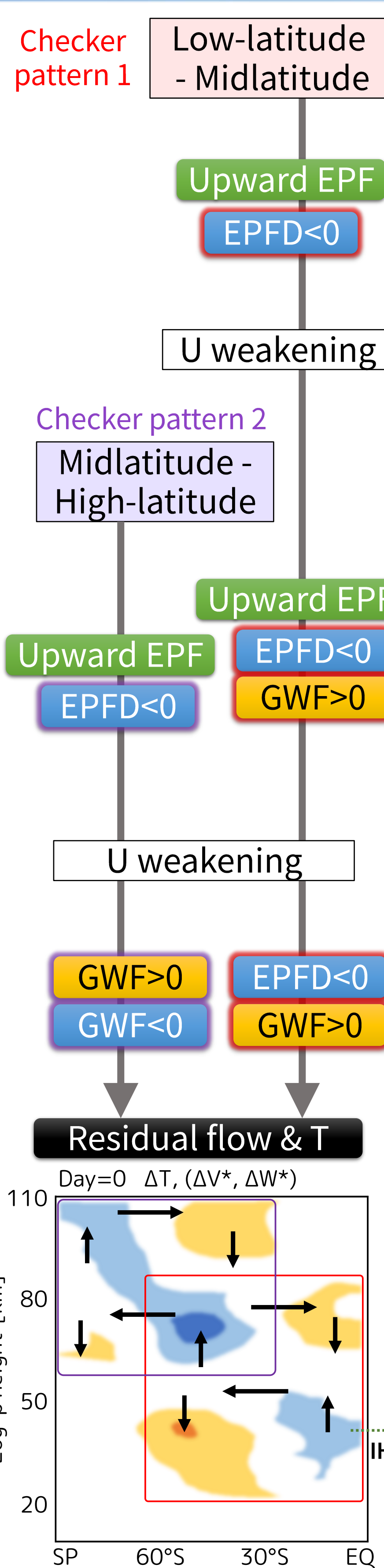
[Above] Zonal-mean U spatial patterns of **a** EOF1 and **b** EOF2, and regressions of the zonal-mean T against **c** EOF1 and **d** EOF2 (JAWARA).
[Right] List of identified MSSW and PSSW cases in the SH.

Year	JAWARA		MERRA-2	
	Type	Onset date	Type	Onset date
1986			MSSW	August 13
1988			MSSW	July 21
1992			MSSW	July 1
1996			MSSW	July 2
1997			MSSW	August 21
2002			MSSW	June 11
2005			MSSW	August 5
2006	MSSW	August 22		
2007	MSSW	July 16	MSSW	July 14
2010	(PSSW)		(PSSW)	
2012	MSSW	July 19	MSSW	July 17
2014	MSSW	July 20	MSSW	July 20
2017	MSSW	July 24	MSSW	July 24
2019	(PSSW)		(PSSW)	
2023	MSSW	July 23	MSSW	July 22
2024	(PSSW)		(PSSW)	

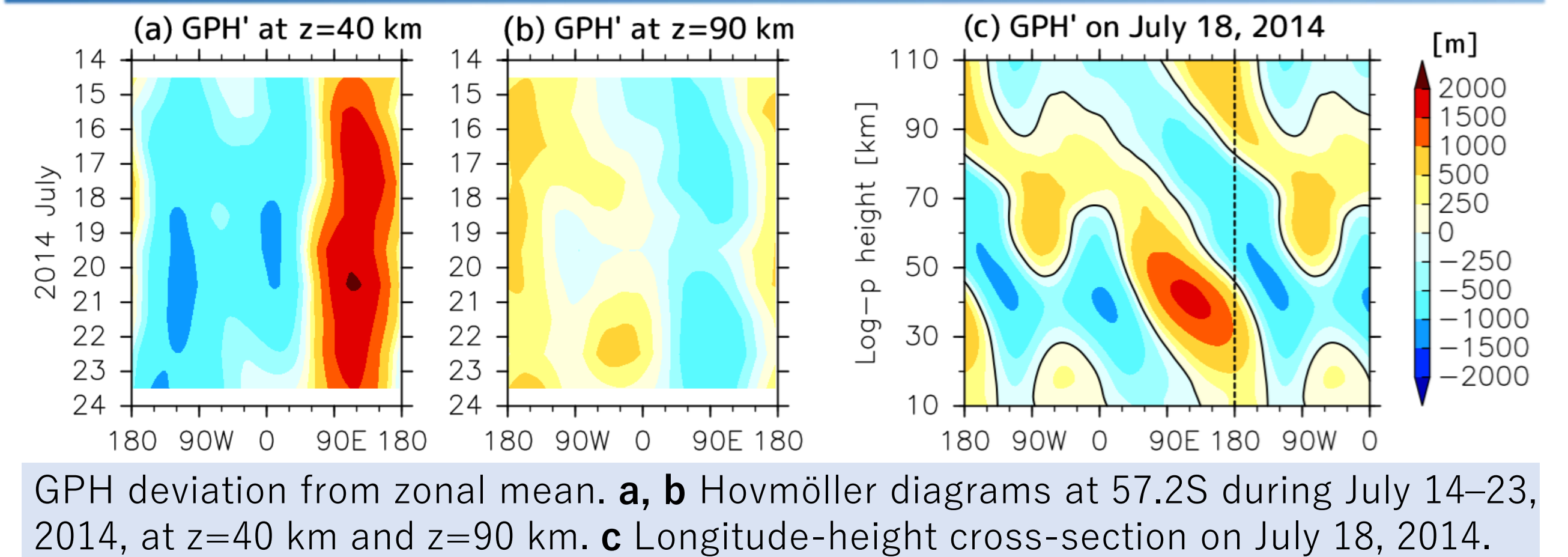
Life Cycle of Midlatitude SSW



Composite meridional cross-sections for 6 MSSW cases (JAWARA).
- Rows: Day=-13 (top), -6 (middle), 0 (bottom)
- Colors (anomalies): div EP flux (left), Gravity wave forcings (center left), Zonal wind (center right), Temperature (right)
- Vectors (anomalies): EP flux (left), Residual flow (right)
- Contours: Zonal-mean zonal wind
Shadeless regions and black vectors are statistically significant (t-test / t^2 -test).

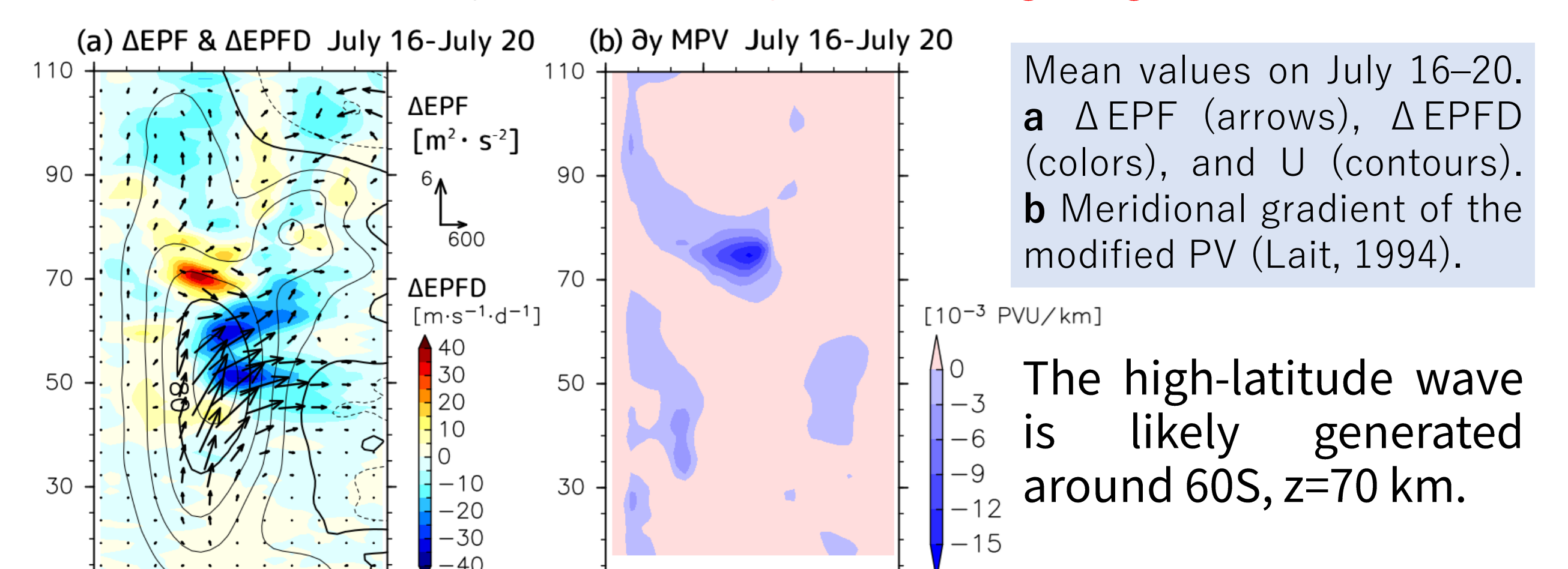


Resolved Waves in Two Regions



GPH deviation from zonal mean. **a**, **b** Hovmöller diagrams at 57.2S during July 14-23, 2014, at $z=40$ km and $z=90$ km. **c** Longitude-height cross-section on July 18, 2014.

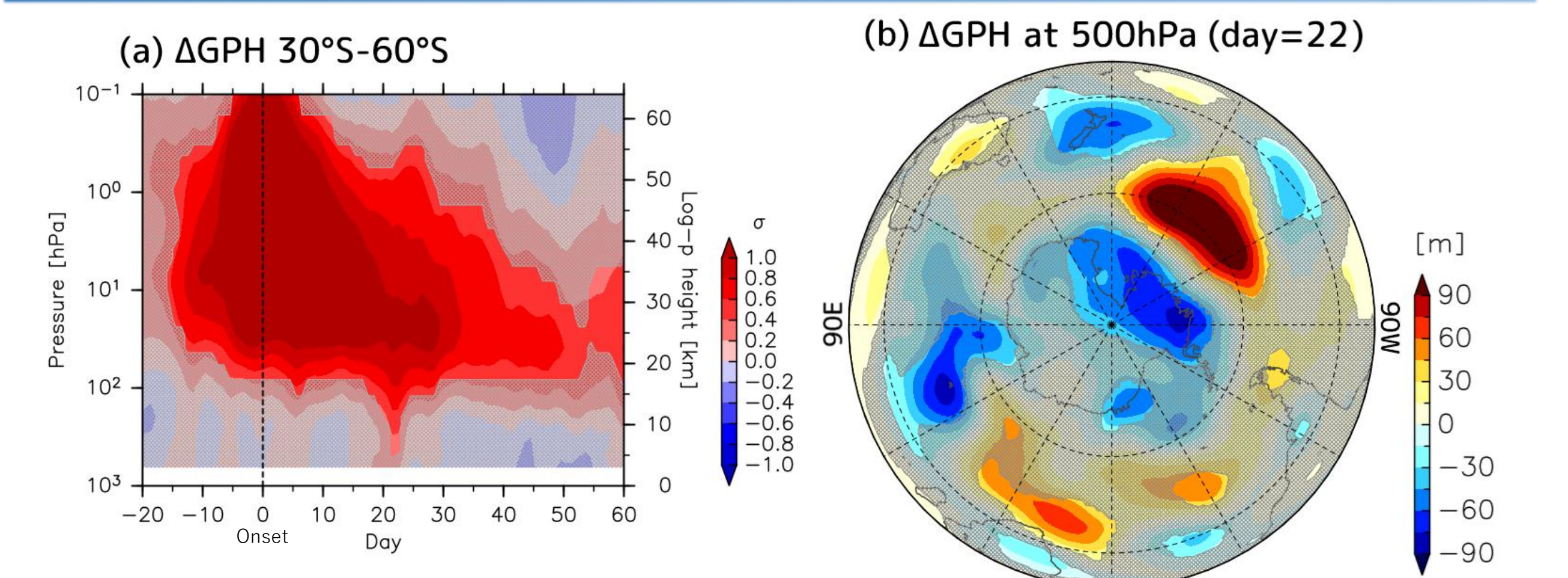
These waves in the high latitudes of mesosphere to lower thermosphere and in the low latitudes of stratosphere to mesosphere have **planetary scale of $s=1-2$** , and they are **stationary** and **propagating upward**.



Mean values on July 16-20. **a** ΔEPF (arrows), $\Delta EPFD$ (colors), and U (contours). **b** Meridional gradient of the modified PV (Lait, 1994).

The high-latitude wave is likely generated around 60S, $z=70$ km.

Impacts on the Troposphere



Composites of the ΔGPH from the climatology for the MSSWs (MERRA-2).

a Normalized ΔGPH averaged over 30S-60S.
b Horizontal distribution at the 500 hPa isobaric surface on Day = 22. Shadeless regions are statistically significant (t-test).

Statistically significant ΔGPH s in the troposphere were observed.

Concluding Remarks & Future Research

Characteristics on recently discovered midlatitude sudden stratospheric warming (MSSW) in the Southern Hemisphere (SH) have been examined. Dominant planetary waves in the midlatitude stratosphere and high-latitude mesosphere and gravity waves play crucial roles in the MSSW. The MSSWs are associated with several significant temperature anomalies in the SH, forming two regions of checker patterns.

It is necessary to closely examine the characteristics of the planetary waves in the polar-region mesosphere to lower-thermosphere, and impacts of MSSW, especially on the troposphere.

References

- Charlton & Polvani (2007). *J. Clim.*, **20**
- Gerald et al. (2017). *J. Clim.*, **30**
- Koshin & Sato (2024). *JGR Atmos.*, **123**
- Lait (1994). *J. Atmos. Sci.*, **51**
- Matsuno (1971). *J. Atmos. Sci.*, **28**
- Sato & Koshin (2025). [Dataset]

Links

Preprint of the paper



Shibata's webpage