Analyze of the Anomalously Large Antarctic Ozone Hole in November

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Introduction

- The ozone variability in the polar regions during winter and spring exerts a significant influence on modulating the global climate system by changing atmospheric circulation (e.g. Thompson and Solomon, 2002; Son et al. 2010; Banerjee et al., 2020).
- Although the Antarctic ozone hole areas decrease with time in late spring, the Antarctic ozone holes persist with large size in November in some particular years (e.g. Krueger et al., 1988; Stolarski et al., 1990).
- As the Antarctic is completely illuminated by the sun in November, the large Antarctic ozone holes result in enhanced ultraviolet at the Antarctic surface, which increases the potential risk of biological damage (e.g. Frederick and Alberts 1991; Lee et al., 2001).

Data

- The TCO datasets used in this study are the Total Ozone Mapping Spectrometer (TOMS) dataset from 1979 to 2005 and the Ozone Monitoring Instrument (OMI) dataset from 2006 to 2017.
- The daily meteorological data and ozone mass mixing ratio are derived from the NASA Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2) for the period 1980–2017.
- The SLIMCAT three-dimensional offline chemical transport model (CTM) is used here to explore the effects of chemical and dynamical processes on ozone variability.

Results

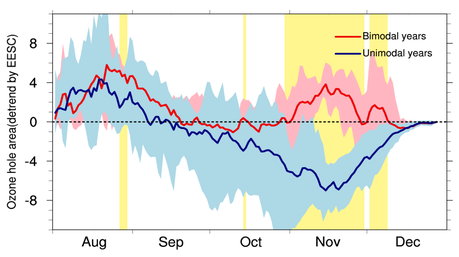

FIG.1 The composite evolution of detrended ozone hole areas (unit: million km^2) in bimodal (red) and unimodal (blue) years. Yellow shadings indicate that the differences of TCO between bimodal and unimodal years are statistically significant at 90% level based on Student's t test.

Dynamical processes play a leading role in the anomalously large Antarctic ozone hole in November.

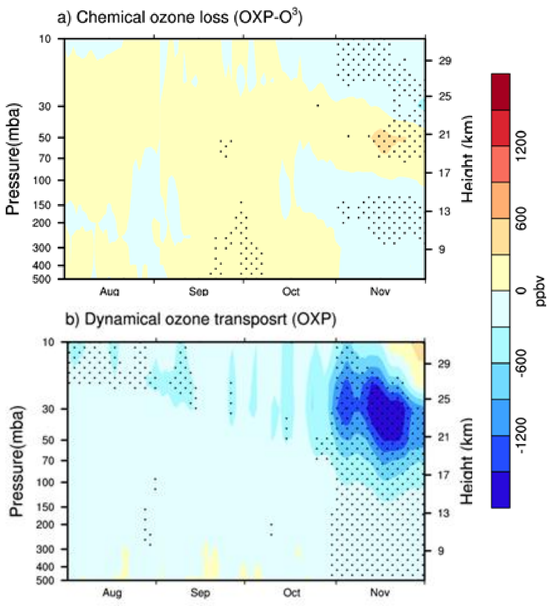

FIG.2 Differences of ozone volume mixing ratio averaged over 60°S to 90°S between bimodal and unimodal years simulated by SLIMCAT model: (a) chemical ozone and (b) dynamical ozone. The dotted regions are statistically significant at 90% confidence level according to Student's t test.

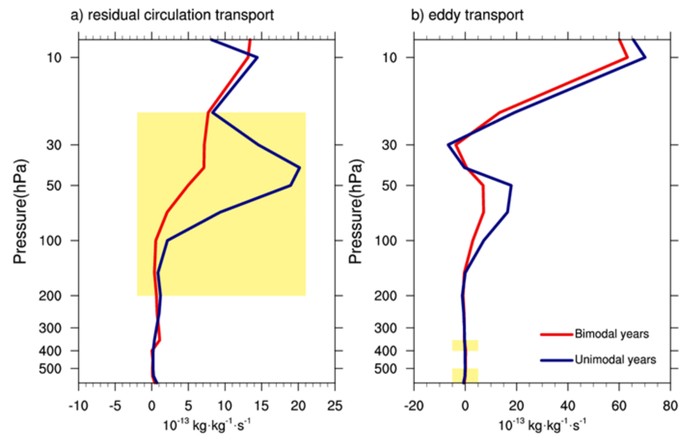

FIG.3 Decomposition of the zonal mean ozone variation into (a) residual mean circulation transport and (b) eddy transport over polar regions (60°–90°S) averaged from November 1 to 20 by utilizing MERRA-2 data.

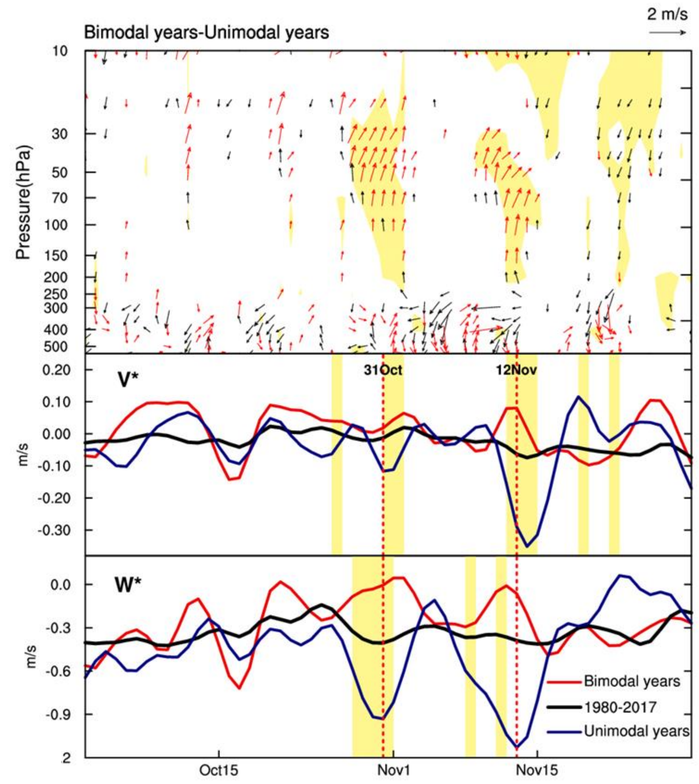

FIG. 4 The difference of the residual circulation averaged from 60°S to 90°S between bimodal and unimodal years as a function of time and height (top). $\bar{v}^*$ (middle) and $\bar{w}^*$ (bottom) averaged over 60°–90°S at 70 hPa as a function of time.

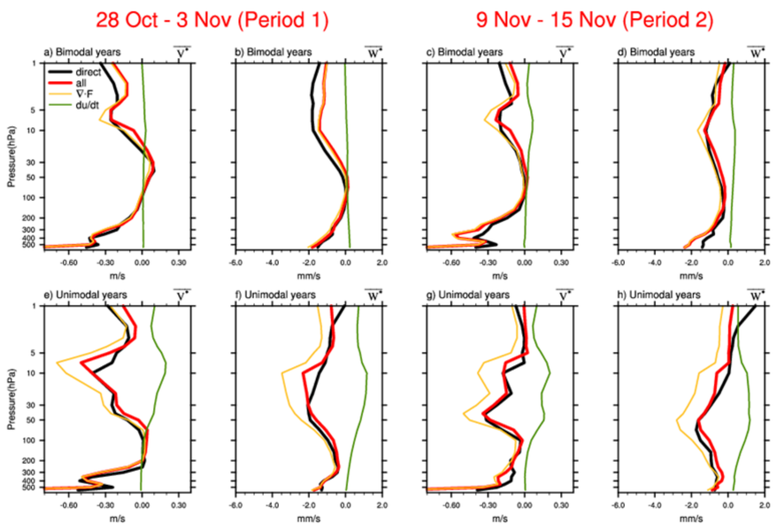

FIG. 5 Composite residual circulation averaged over 60°–90°S as a function of level for the two time periods according to the downward .control principle.

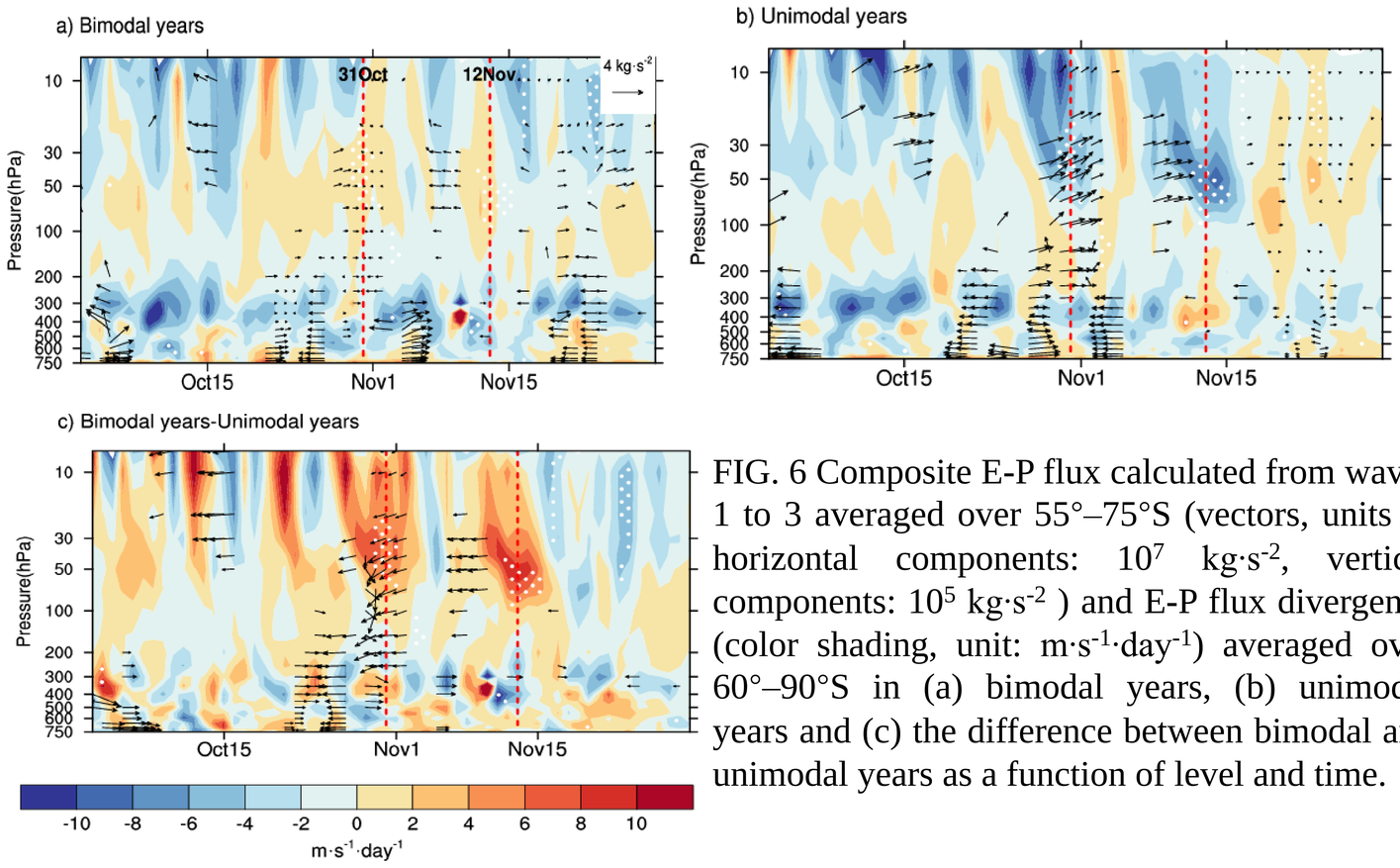

FIG. 6 Composite E-P flux calculated from waves 1 to 3 averaged over 55°–75°S (vectors, units of horizontal components: 10^7 kg·s^{-2}, vertical components: 10^5 kg·s^{-2}) and E-P flux divergence (color shading, unit: m·s^{-1}·day^{-1}) averaged over 60°–90°S in (a) bimodal years, (b) unimodal years and (c) the difference between bimodal and unimodal years as a function of level and time.

Conclusions

- **Dynamical processes** play a leading role in the anomalously large Antarctic ozone hole in November.
- **The residual circulation** is a decisive factor for the less ozone transported to the polar regions in bimodal years.
- **The E-P flux divergence** is the dominant component in modulation of the residual circulation while zonal-mean zonal wind tendency is less important, suggesting that planetary wave changes play a critical role in the formation of the anomalously large Antarctic ozone holes in November during bimodal years.