CEDAR 2018 | CLEMSON PHYSICS AND ASTRONOMY | NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH | NSF

Latitudinal Double-Peak Structure of Stationary Planetary Wave 1 in the Austral Winter Middle Atmosphere & Possible Generation Mechanism

Xian Lu[1], Haonan Wu[1], Jens Oberheide[1],
Han-Li Liu[2], Joe McInerney[2]

[1.] Clemson University
[2.] High Altitude Observatory, NCAR

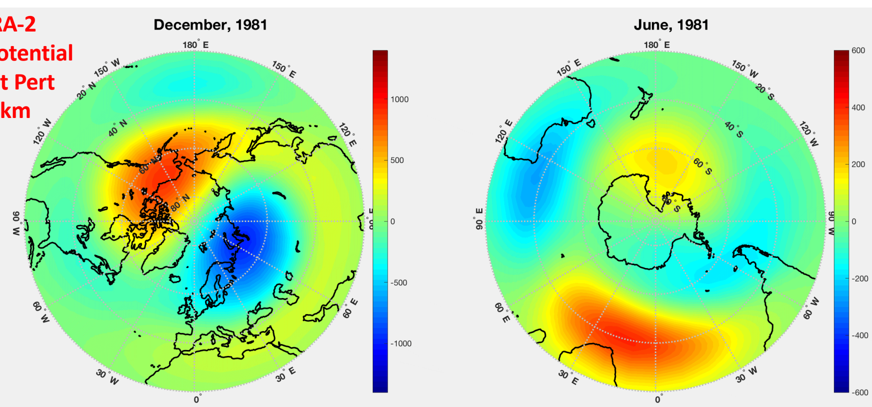
June 27, 2018

1

Introduction

- **(Quasi)-stationary PW: Wave perturbations barely change with time, while have zonal wave structure dominated by wavenumber 1, 2, 3.**
- **Stationary planetary waves (SPWs) are forced by airflow over large-scale topography, planetary-scale differential heating, and averaged effects of synoptic-scale eddies.**
- **Cause Perturbations: Geoh: ± 1 km U(V): ± 50 m/s T: ± 20 K**

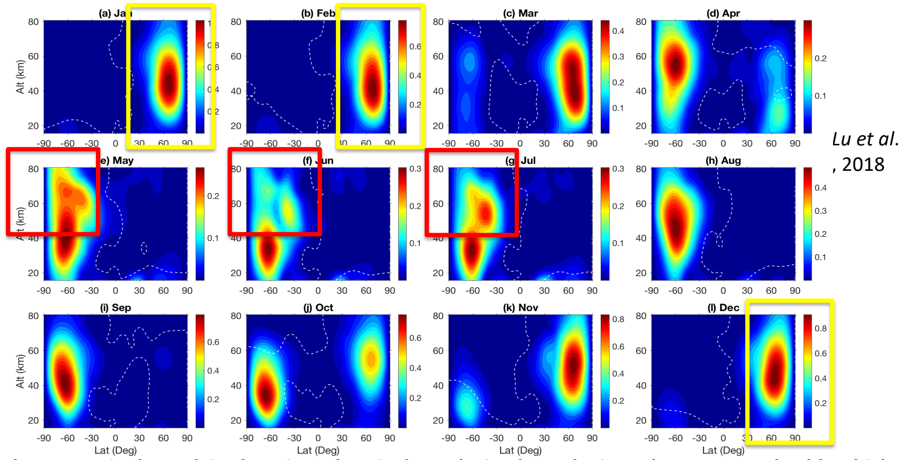
MERRA-2 Geopotential Height Pert @ 50 km



NH SPW structure is dominated by 1-peak, while SH shows 2-peak structure 2

Motivation From MERRA2 (1981-2016)

36 Yearly-Mean (Vector) Monthly-Mean SPW1 Amplitudes



Lu et al., 2018

- Show one single peak in the winter hemisphere during boreal winter (Dec, Jan, and Feb), which is the strongest in a year.
- Latitudinal double peak structure in austral winter (May, Jun, and Jul), which shows weakest magnitude. [Definition: primary high-latitude peak + secondary middle-latitude peak.]
- During equinoxes, wave activities can be found in both hemispheres, where westward winds are prevailing, allowing wave propagation.

3

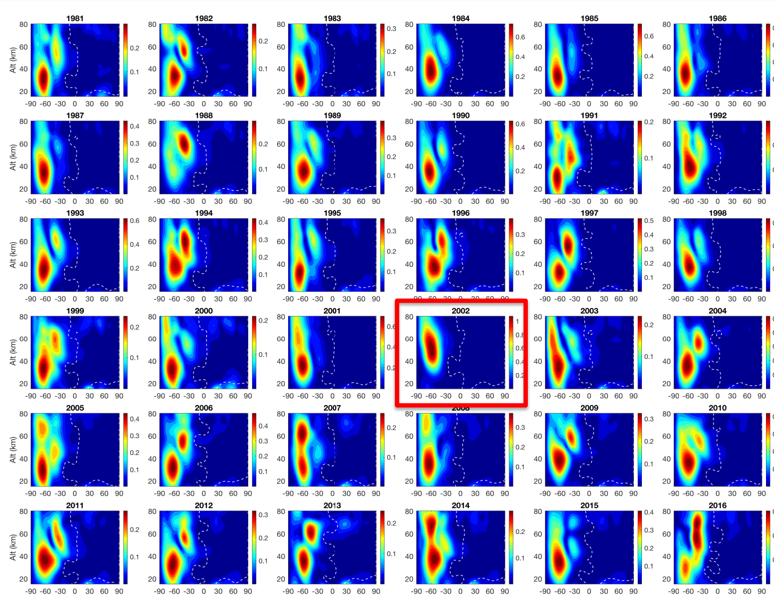
SPW1 Structure Individual Years (1981-2016)

June
Monthly Mean Amplitude

Occurrence Rate: 97%

2002 is an exception dominated by single strong peak

May: 61%
July: 53%
August: 25%



4

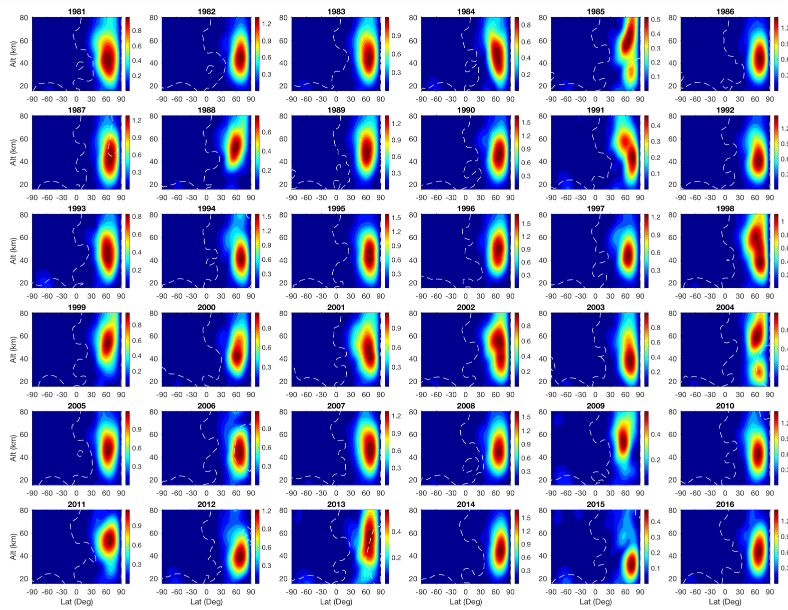
Significant Difference in Jan SPW1

Jan

Month Mean Amplitude

Occurrence Rate: 0%

SPW1 structure has salient inter-hemispheric asymmetry in winter-hemisphere



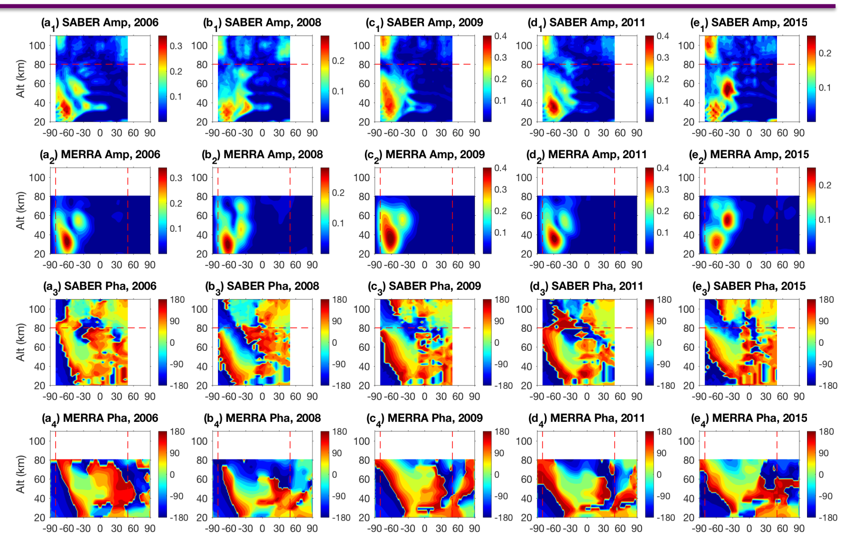
SABER Validating Double-Peak Structure

SABER Amp

MERRA Amp

SABER Phase

MERRA Phase

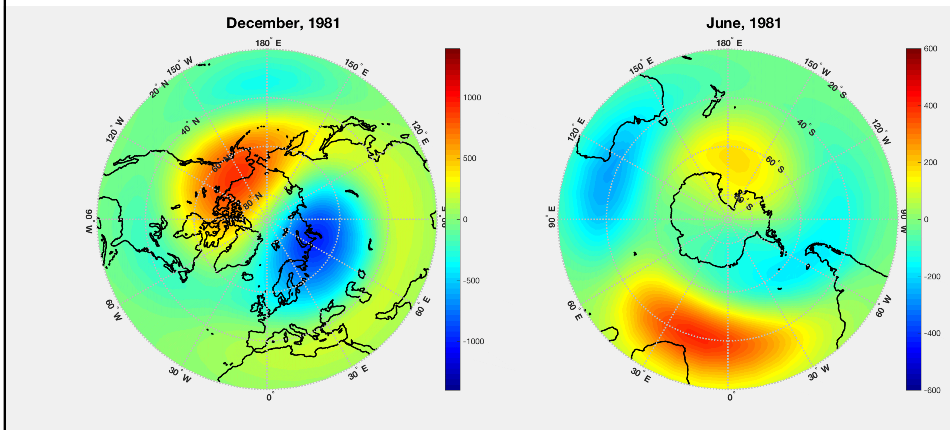


- **SABER and MERRA-2 results are very consistent with each other in terms of SPW1 amplitudes and phases.**
- **The double peak structure is captured by both datasets. Smoother structure shown in MERRA2 is likely due to the larger amount of data samples.**

6

Comparison of NH and SH SPW1

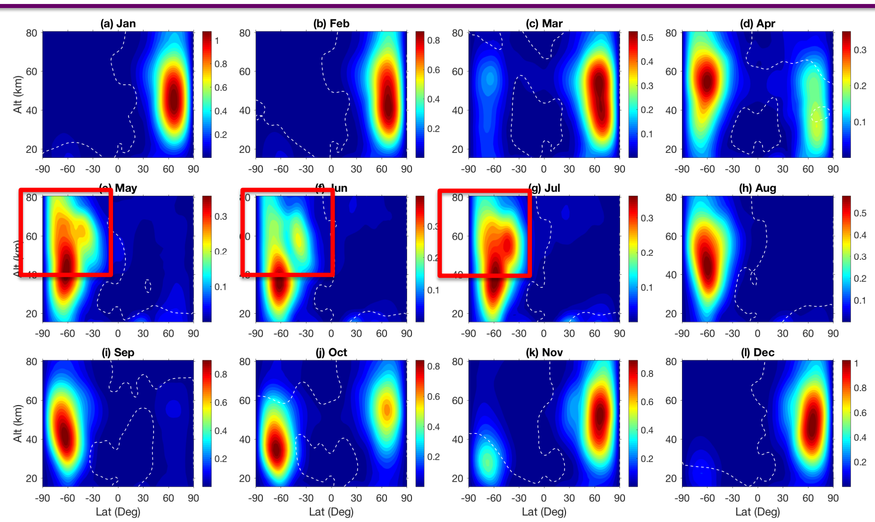
MERRA-2 Geopotential Height Pert @ 50 km



NH SPW1 structure is relative more stable than SH SPW1 structure.

7

36 Yearly-Mean (Absolute) Monthly-Mean SPW1 Amplitudes



- Due to the differences in the occurrence rate of the double-peak structure, the yearly-mean SPW1 structure shows most salient DP feature in June, but not in other months if we simply average the absolute amplitude of each year.

8

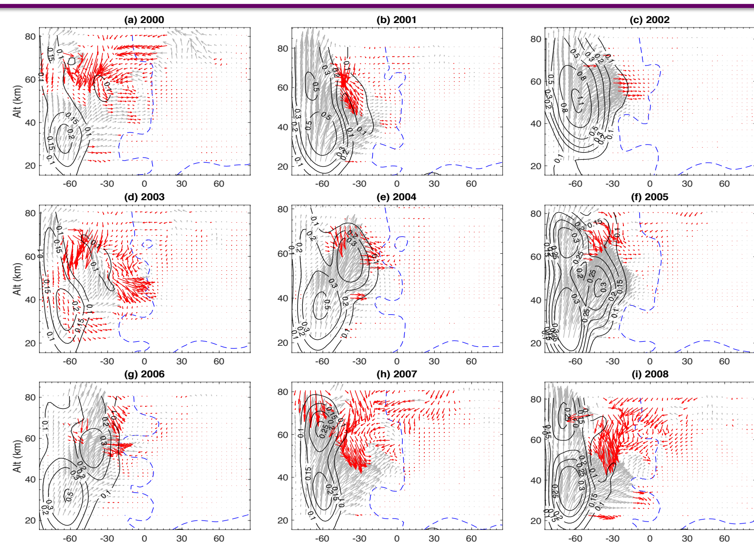
Yearly-Mean Monthly-Mean SPW1 Amplitudes
Absolute .VS. Vector Averaging

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Absolute Ave	$(A_1^1)^a$	1.12	0.89	0.55	0.36	0.37	0.41	0.38	0.60	0.93	0.87	0.93	1.06
Vector Ave	$(A_1^2)^a$	1.07	0.82	0.46	0.31	0.28	0.32	0.32	0.51	0.83	0.79	0.87	0.95
Abs/Vec	A_1^2/A_1^1	0.96	0.91	0.85	0.86	0.75	0.78	0.84	0.85	0.89	0.91	0.94	0.90

- If wave phase does not change from one to the other, we should expect the same results from vector mean and absolute mean.
- Difference (or ratio) from these two averaging methods indicate the variation of phases, or stability of wave structure.
- Wave structure tends to be more stable around austral winter than boreal winter.

9

A Closer Look at EP Flux (Individual year)

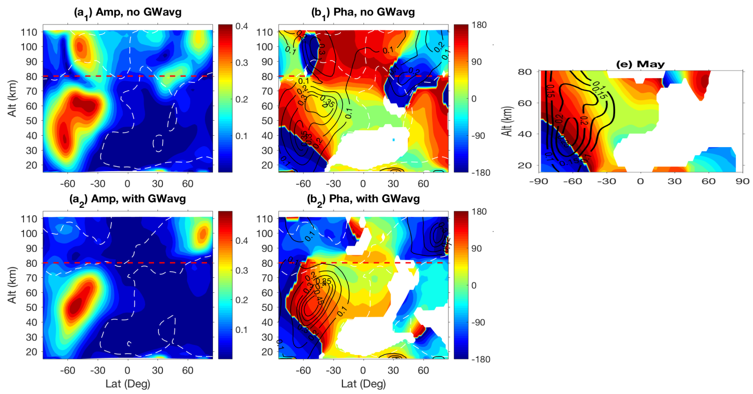


- 2002: No DP feature, dominated by upward and equatorward EP flux
- Other years: Significant downward EP fluxes are located around the secondary peak in middle latitude.

10

Where Do Downward Energy Flows Come From?

WACCM Monthly-Mean SPW1 (May)

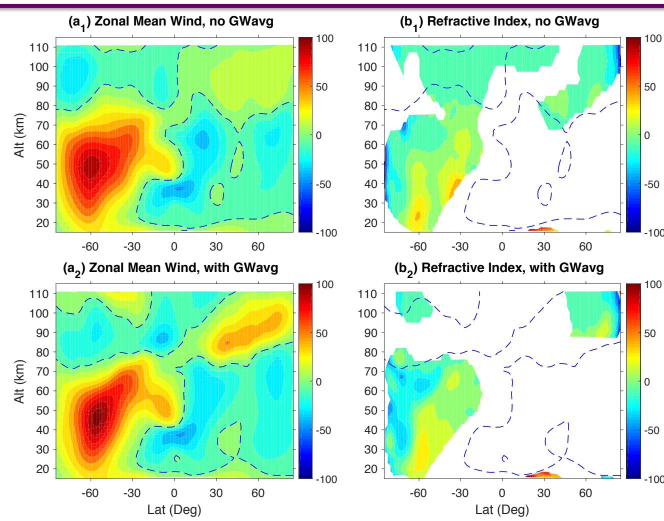


Modified Run: GW drag averaged zonally in WACCM physics module for every time step.

- GW drag forcing is largely responsible for the SPW above 80 km.
- Downward EP fluxes are significantly suppressed after doing zonal mean of GW drag, and DP structure disappears.
- With GW drag being averaged, downward EP flux may originate from wave reflection.

11

What if the zonal mean wind has changed?



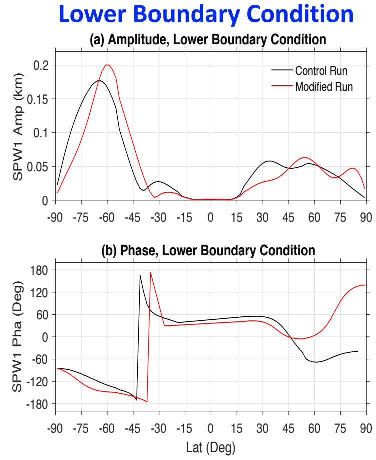
- Zonal mean wind does change from the default to modified WACCM run.
- Refractive index also changes. The question is: how does it impact wave propagation and structure?

12

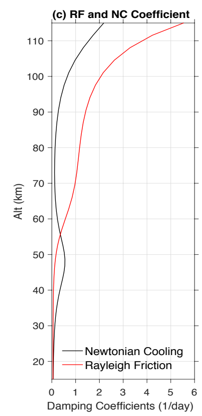
Linear Mechanistic Model

2-D Geopotential (potential vorticity) equation (*Matsuno* [1970] and *Smith and Avery* [1987]): Study how background wind affects SPW propagation and along with dissipation (RF and NC), & how do they determine the overall SPW structure.

Lower Boundary Condition



Friction (Damping)

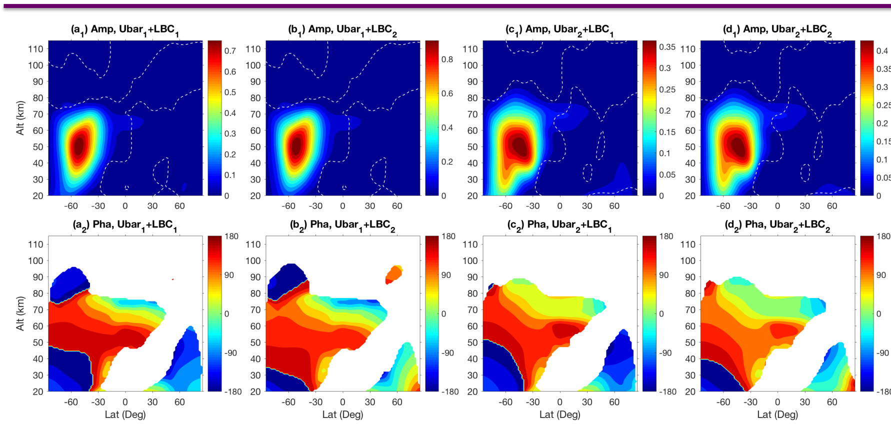


Rayleigh friction (RF) and Newtonian cooling (NC) are incorporated in vorticity and thermodynamic equations, respectively.

- Ubar and lower boundary condition are both obtained from WACCM:
  Differences between WACCM and should be caused by nonlinear wave-mean flow and wave-wave interactions.

13

Linear Mechanistic Model



Credibility of the Linear Mechanistic Model:
1) Sensible vertical and latitudinal structure of SPW1
2) Reasonable phase progression indicating upward wave energy propagation

- Both mean wind fields do not give DP structure directly:
- Wave propagation only dictated by mean wind and wave dissipation can not give double-peak structure in a linear manner.

14

Summary

Observations (MERRA2 + SABER):

1) Latitudinal double-peak structure with polar primary and subtropical secondary peak is a robust feature in austral winter.
2) Downward EP fluxes are often found around the secondary peaks.
3) SPW1 structure is more stable in NH winter than SH winter.

Modeling (WACCM + Linear Mechanistic Model)

→ A possible mechanism:

Filtered GW forcing provides in-situ wave source in the MLT → Downward waves interfere with upward primary waves → wave interference → secondary peak.

❖ Primary wave needs to be weak to have more efficient wave interference, which may explain why this feature doesn't show in NH winter, when SPW1 is strong.

15