The Climatology and Interannual Variability of Upward and Downward Propagation of Rossby Wave Activity Propagation Across the Tropopause

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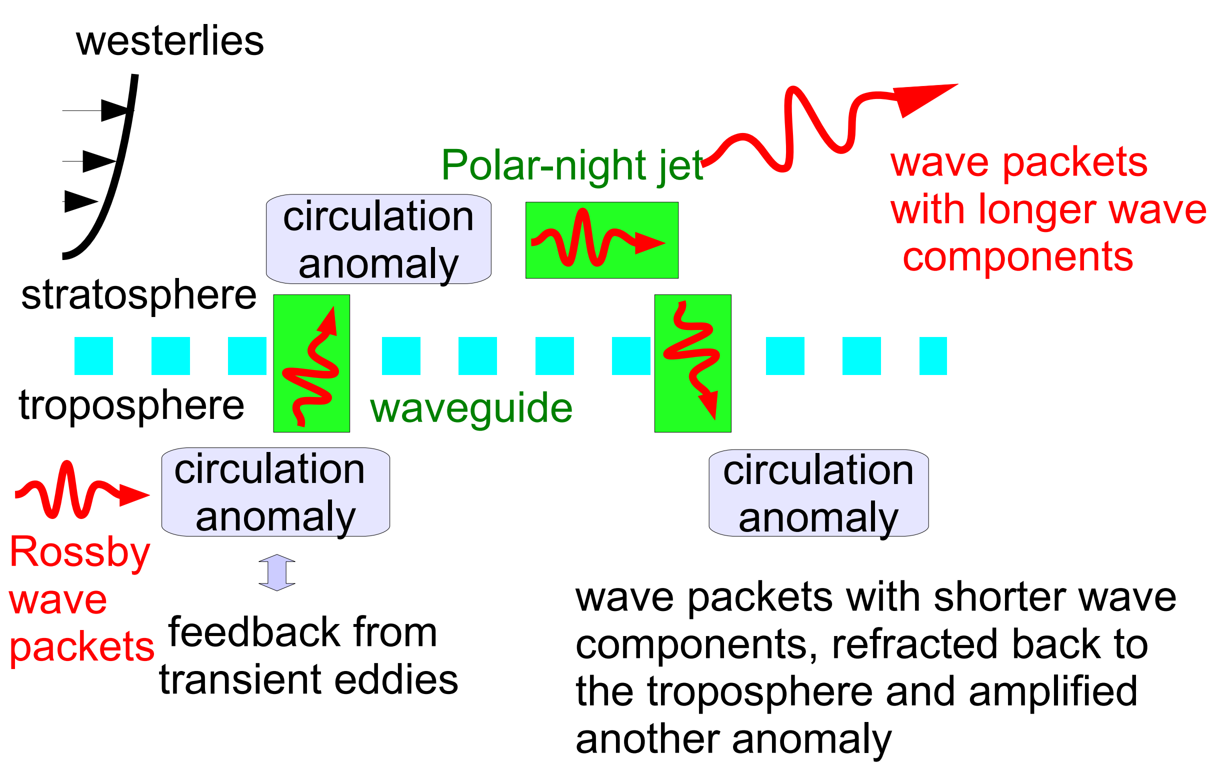
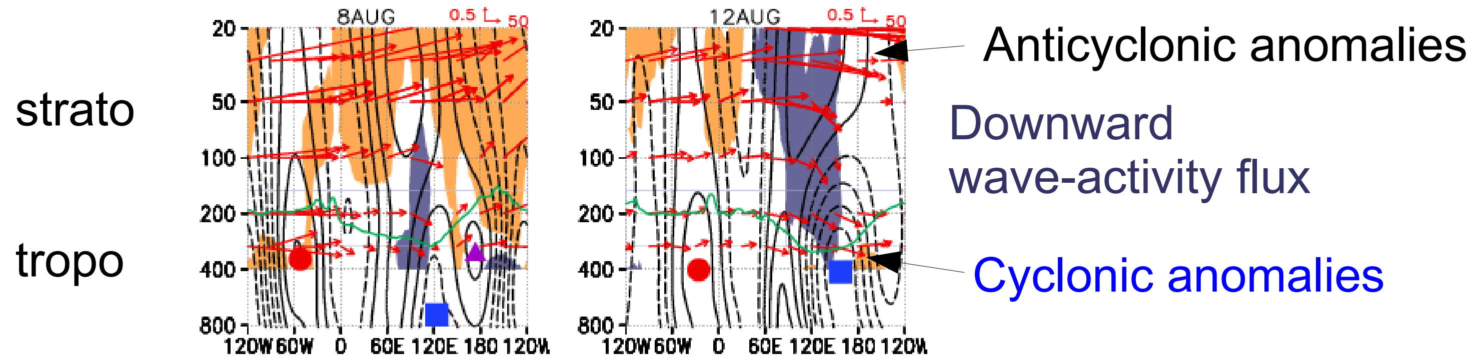
Schematic diagram of upward and downward propagating “wave packets”



1. Introduction

- Previous studies on "downward" propagating planetary waves from the stratosphere into the troposphere.
  - Perlwitz and Harnik (2003, 2004),,,
    - Planetary wave reflection (each zonal wavenumber 1 and 2)
  - Nishii and Nakamura (2005)
    - Downward propagation as a "wave packet" from the strato to tropo associated with amplifying tropospheric localized circulation anomalies
    - A case study observed in the SH late winter of 1997



Amplifying cyclonic height anomalies (dashed line) in the troposphere associated with downward injection of wave-activity flux from 8 to 12 Aug.

- The aim of this study
  - To obtain a picture of climatology and interannual variability of upward and downward propagating wave packets across the tropopause in SH late winter.
  - To obtain the relationship between wave-packet propagation and the zonally-asymmetric stratospheric polar-night jet and tropospheric subtropical jet.

2. Data and analysis method

- NCEP/NCAR reanalysis data set (1979-2003)
- Japan ReAnalysis (JRA25) is also used
- Circulation anomalies associated with waves
  - Submonthly fluctuations (time series with 8-days low-pass filtered and subtracted their 31-day running-mean field)
- Activity of submonthly fluctuations
  - variances of geopotential height anomaly
- Diagnosis of wave packets
  - 3-D wave-activity flux (WAF) defined for zonally asymmetric basic field (Takaya and Nakamura 2001)
  - Parallel with wave-packet propagation

$$W=\frac{p}{2|\boldsymbol{U}|}\begin{pmatrix} U(v'^2-\psi'v'_x)+V(-u'v'+\psi'u'_x) \\ U(-u'v'+\psi'u'_x)+V(u'^2+\psi'u'_y) \\ \frac{f_0 R_a}{N^2 H_0}\{U(v'T'-\psi'T'_x)+V(-u'T'-\psi'T'_y)\} \end{pmatrix}$$

- Proxy for upward and downward wave-packet propagation associated with submonthly fluctuations
  - Taking only positive or negative value of 100-hPa WAF vertical component for each day on each grid. Then averaged within a month.
  - Named “Upward only”, “downward only” propagation, respectively.

2. Data and analysis method (2)

- Interannual variability of the downward wave-packet propagation
  - Taking active and inactive months of “downward only WAF” from August and September 1979-2003, where interannual variability of it is prominent.
    - Over the Atlantic (300-330E, 60-50S averaged)
      - 7 active months (under -0.009[m^2/s^2])
      - 7 inactive months (over -0.0015[m^2/s^2])
    - South of Australia (120-180E, 55-65S averaged)
      - 6 active months (under -0.009[m^2/s^2])
      - 7 inactive months (over -0.001[m^2/s^2])
  - Then making composite maps and taking the difference of them.
- Influence of wind structures on wave-packet propagation is estimated by using “total wavenumber”. The maximum region corresponds to “waveguide”. (based on monthly-mean field)

$$\kappa_s^2 = \frac{|\nabla_H Q|}{|\boldsymbol{U}|} - \frac{f_0^2}{4N^2 H_0^2}\left(1 - 4H_0 N \frac{dN^{-1}}{dz} + 4H_0^2 N \frac{d^2 N^{-1}}{dz^2}\right)$$

$$= k^2 + l^2 + \frac{f^2}{N^2} m^2 = k^2 + n_k^2$$

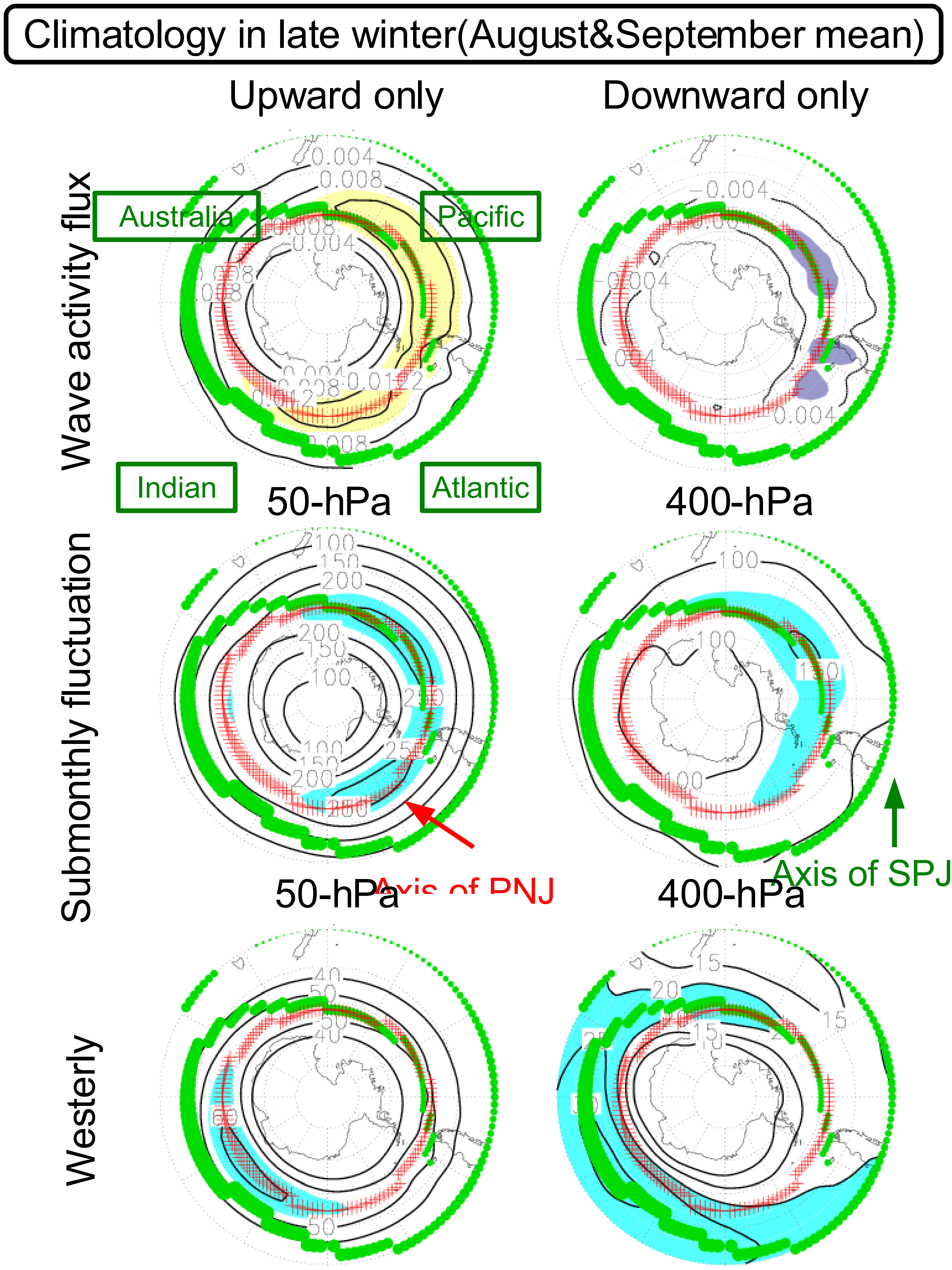
$$\frac{|\nabla_H Q|}{|\boldsymbol{U}|} \approx \frac{Q_y}{U} \approx \frac{\beta - U_{yy} - \frac{f^2}{N^2} U_{zz} + \frac{1}{H} U_z}{U}$$

3. Results

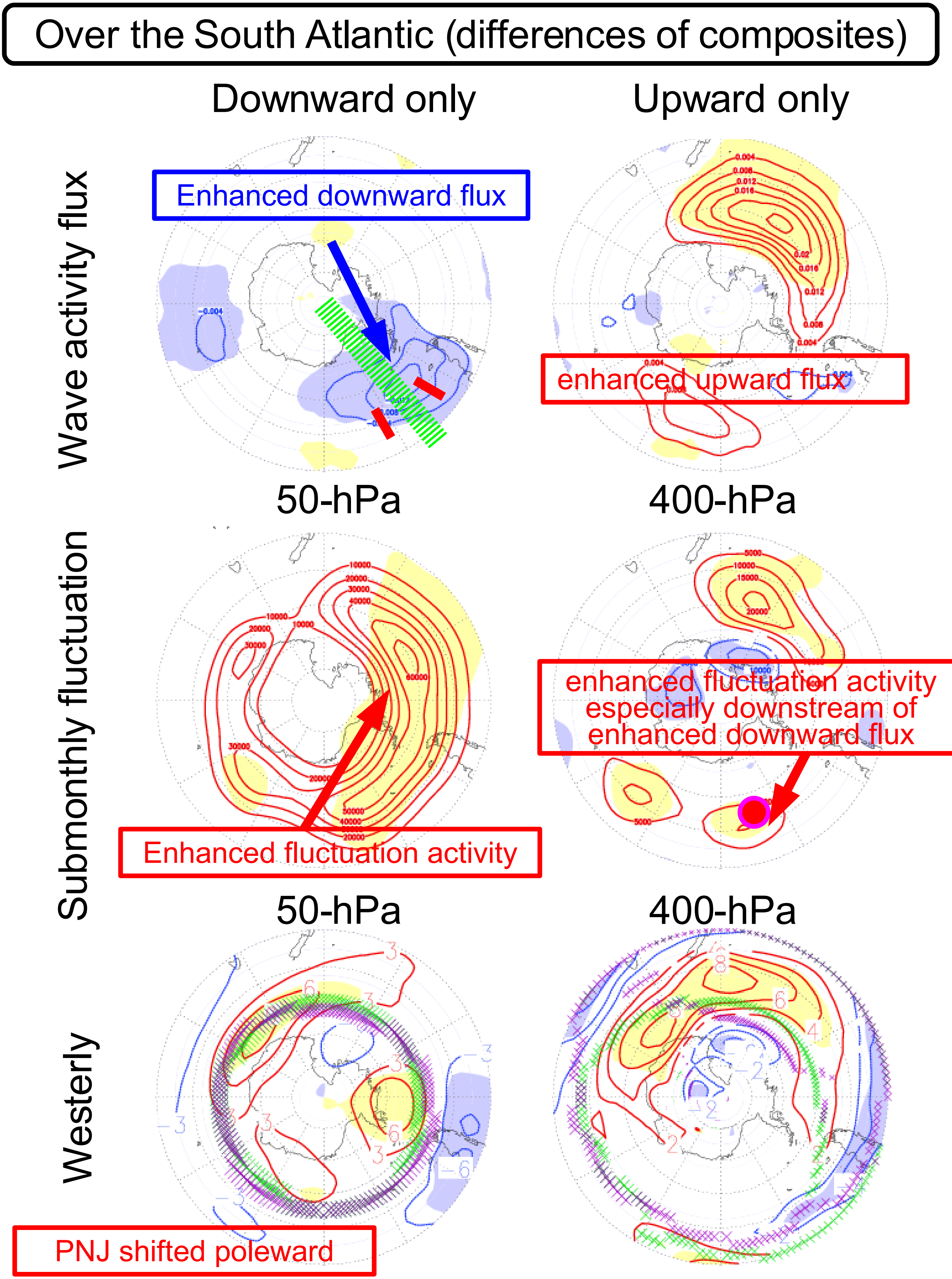
- Climatology
  - (1) Upward wave-activity flux from the trop into strato, (2) downward wave-activity flux from the strato to tropo, (3) stratospheric submonthly fluctuations, and (4) tropospheric submonthly fluctuations, are all prominent over the South Pacific.
  - Axis of the polar-night jet (PNJ) and the subpolar-jet (SPJ) is overlapped there.
  - Over the Indian Ocean, those quantities are not prominent where the PNJ and SPJ are not overlapped.
- Interannual variability of downward WAF over the South Atlantic (300-330E, 60-50S)
  - Upward WAF and submonthly fluctuations in the strato in “active months” are more enhanced upstream of downward WAF .
  - Submonthly fluctuations in the tropo is also more enhanced downstream of downward WAF.
  - Stratospheric PNJ shifts poleward and tropospheric subtropical jet tends to be strengthen.
  - During “active months”, negatively correlated signal in the strato can be observed upstream of enhanced submonthly fluctuation region in the tropo.
  - The wave guide structure expressed as total wavenumber tends to be enlarged.
- To the south of Australia (120-180E, 55-65S)
  - Similar changes to above mentioned region are observed.

4. Conclusions

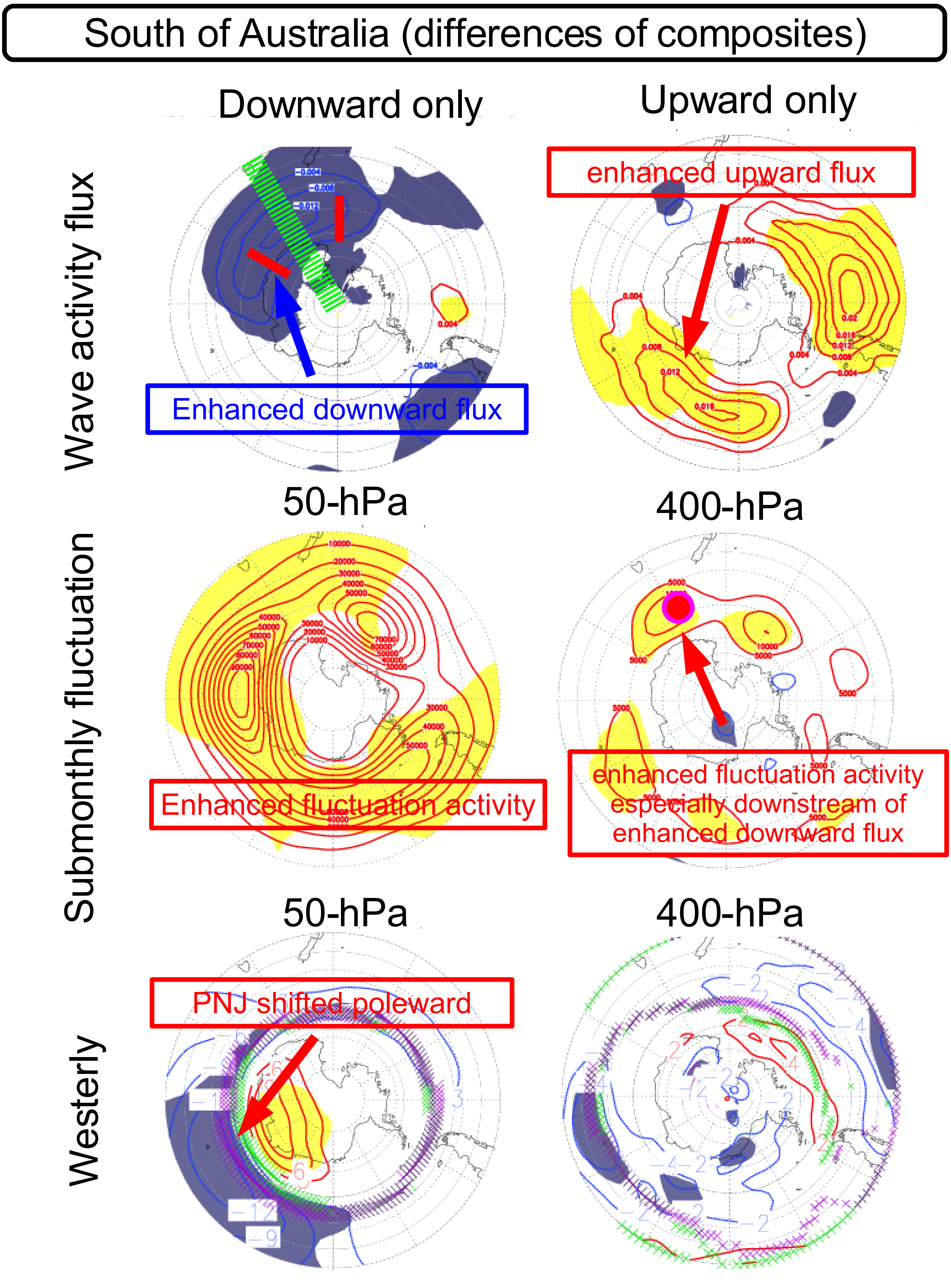
- Climatology and interannual variability of upward and downward propagation of Rossby wave packets in late winter of the SH are studied by using monthly-mean WAF as a proxy.
- Climatology
  - Upward and downward wave packet propagation across the tropopause is suggested to be active over the South Pacific, while not over the Indian Ocean.
  - The former is where submonthly fluctuations both in the tropo and strato are enhanced and SPJ and PNJ are vertically overlapped each other, while the later is not.
- Interannual variability of downward WAF
  - Associated with enhanced downward WAF from the strato, tropospheric submonthly fluctuations downstream of donward WAF are enhanced. The PNJ tends to shift poleward to the south of Australia and over the south Atlantic.
  - Those wind structure change is suggested to give more clear “waveguide” structures around the tropopause there.
  - Downward propagating wave-packet structure can be observed in correlation maps during active months.



Climatology in late winter(August&September mean)
Upward only
Downward only
Wave activity flux
Australia
Pacific
Indian
Atlantic
50-hPa
400-hPa
Submonthly fluctuation
Axis of PNJ
Axis of SPJ
50-hPa
400-hPa
Westerly

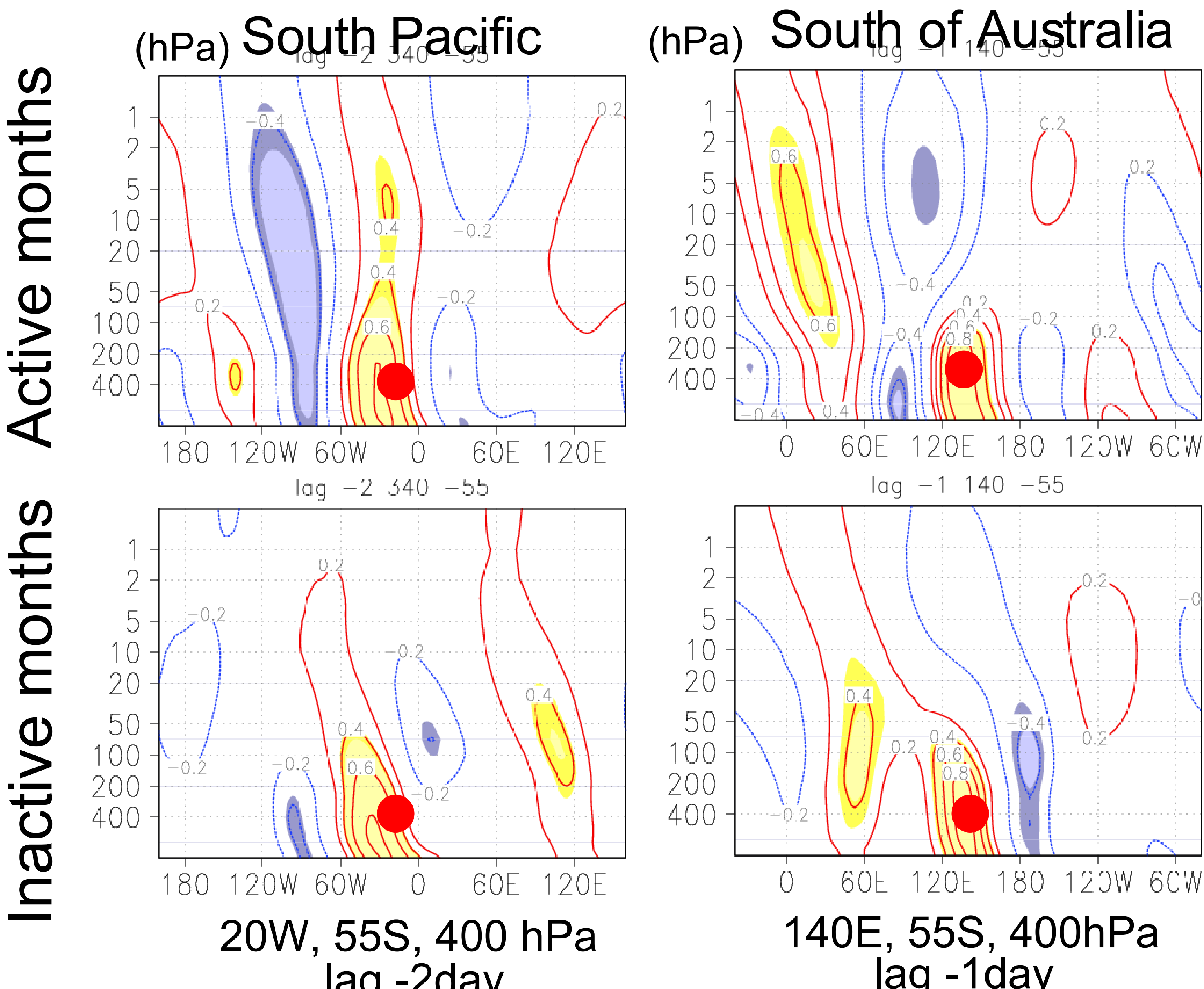


Over the South Atlantic (differences of composites)
Downward only
Upward only
Wave activity flux
Enhanced downward flux
enhanced upward flux
50-hPa
400-hPa
Submonthly fluctuation
Enhanced fluctuation activity
enhanced fluctuation activity
especially downstream of
enhanced downward flux
50-hPa
400-hPa
Westerly
PNJ shifted poleward



South of Australia (differences of composites)
Downward only
Upward only
Wave activity flux
Enhanced downward flux
enhanced upward flux
50-hPa
400-hPa
Submonthly fluctuation
Enhanced fluctuation activity
enhanced fluctuation activity especially downstream of enhanced downward flux
50-hPa
400-hPa
Westerly
PNJ shifted poleward

One-point correlation maps of anomaly based on tropospheric grids downstream of downward WAF



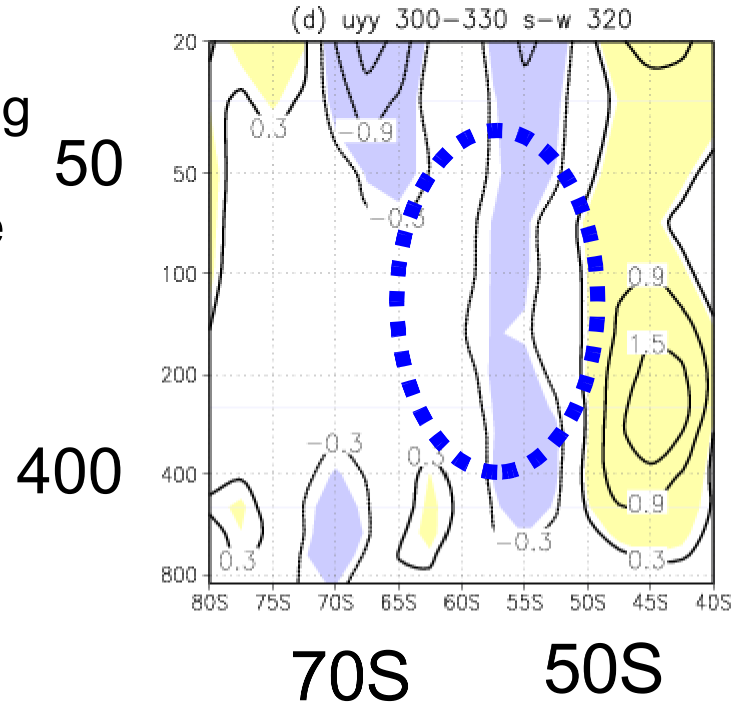
Shading;
90% confidence

(based on JRA25)

Total wavenumber over the South Atlantic (40W cross section)

Difference of Uyy

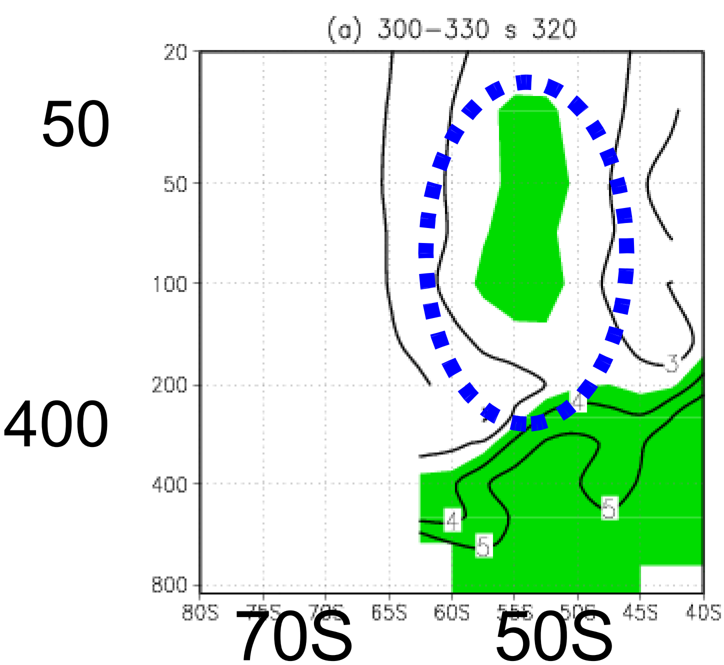
Negative Uyy contributes to enlarging "total wavenumber" in the lower stratosphere

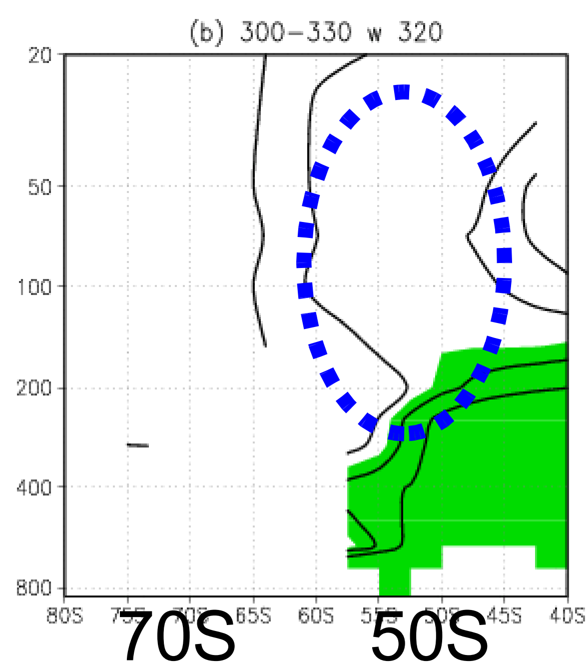


Total wavenumber

active downward flux months

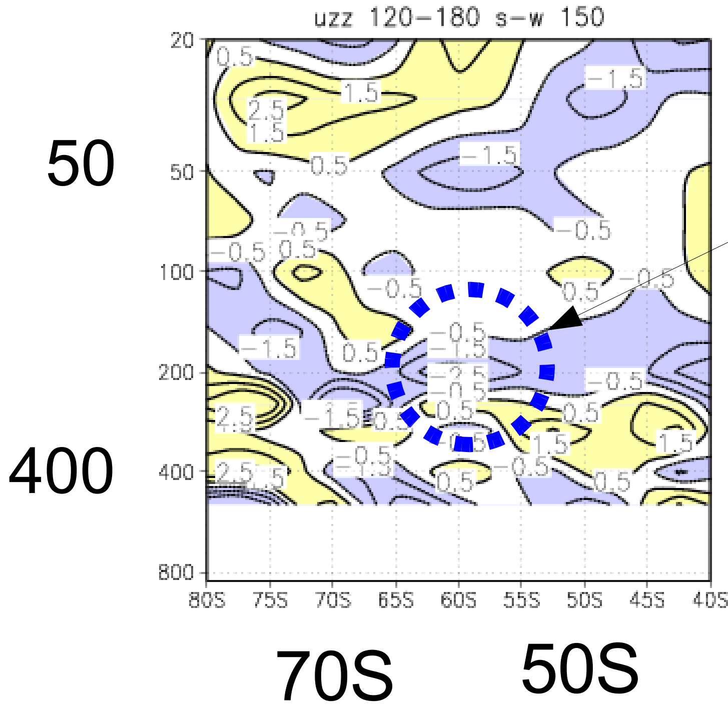
inactive downward flux months





Total wavenumber over south of Australia (150E cross section)

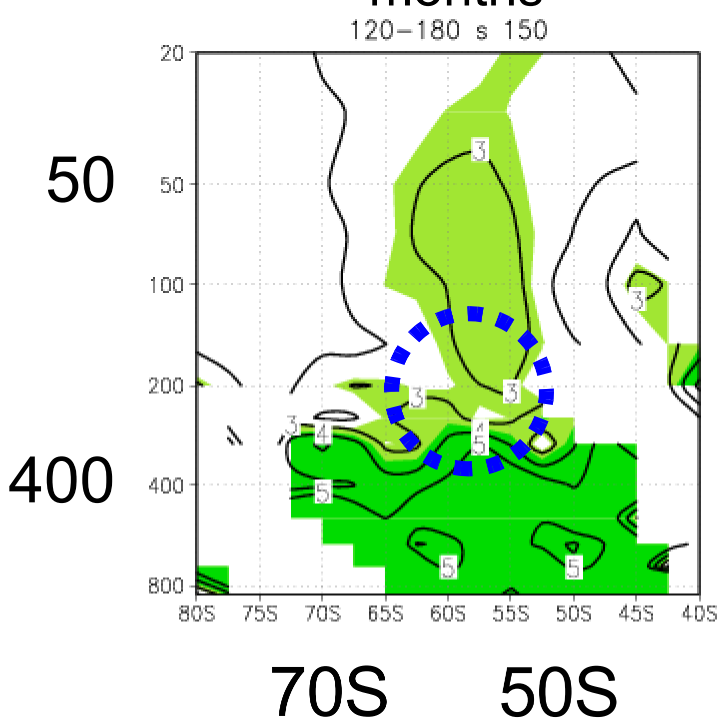
Difference of Uzz



Negative Uzz contributes to enlarging "total wavenumber" around the tropopause

Total wavenumber

active downward flux months



inactive downward flux months