Changes in the Brewer-Dobson Circulation in JRA-55

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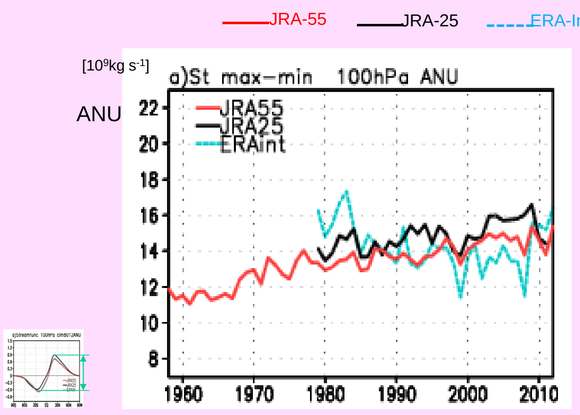
Summary

- *Future projections by climate models suggest that the Brewer-Dobson circulation (BDC) will be intensified as a result of rising GHG concentrations.*
- *In this study, we diagnosed the changes of the BDC based on reanalyses.*
- *In JRA-55, the annual mean tropical upwelling shows a significant increasing trend in the lower stratosphere during the last three decades, which indicates an intensification of the BDC.*
- *However, the trend of the wave activity pattern in JRA-55 does not consist with the greenhouse gas-induced change shown in previous model studies.*
- *The increasing trend of the tropical upwelling in JRA-55 is caused by the different reason from GHG-induced climate change.*

Data and Method

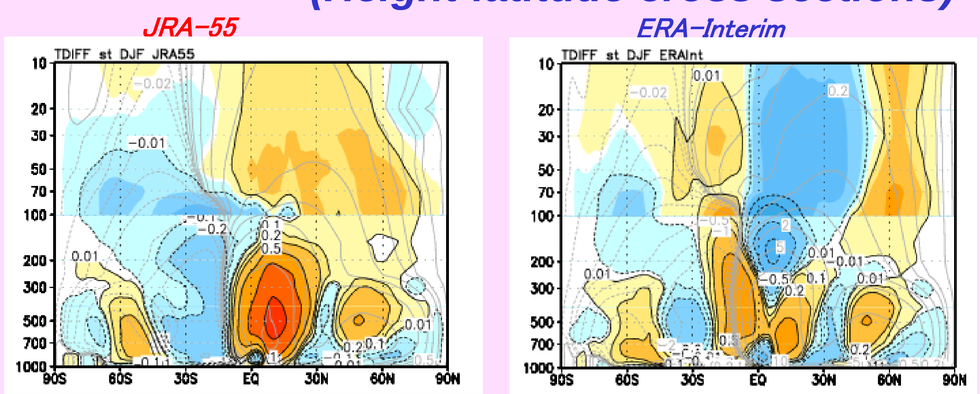
- Atmospheric reanalysis:
  - JRA-55[Kobayashi et al., 2015]
  - JRA-25[Onogi et al., 2007]
  - ERA-Interim[Dee et al., 2011],
- Data period: 1979-2012
- Climatology period: 1981-2010
- Residual mean-meridional circulation diagnosed from the mass-weighted isentropic zonal mean (MIM) meridional velocity [Iwasaki, 1989] as the BDC.
- The trend is calculated as the difference between 2nd (1996-2010) and 1st (1980-1995) half period.

1 Time series of annual mean tropical upwellings at 100hPa (strength of BDC) in Reanalyses



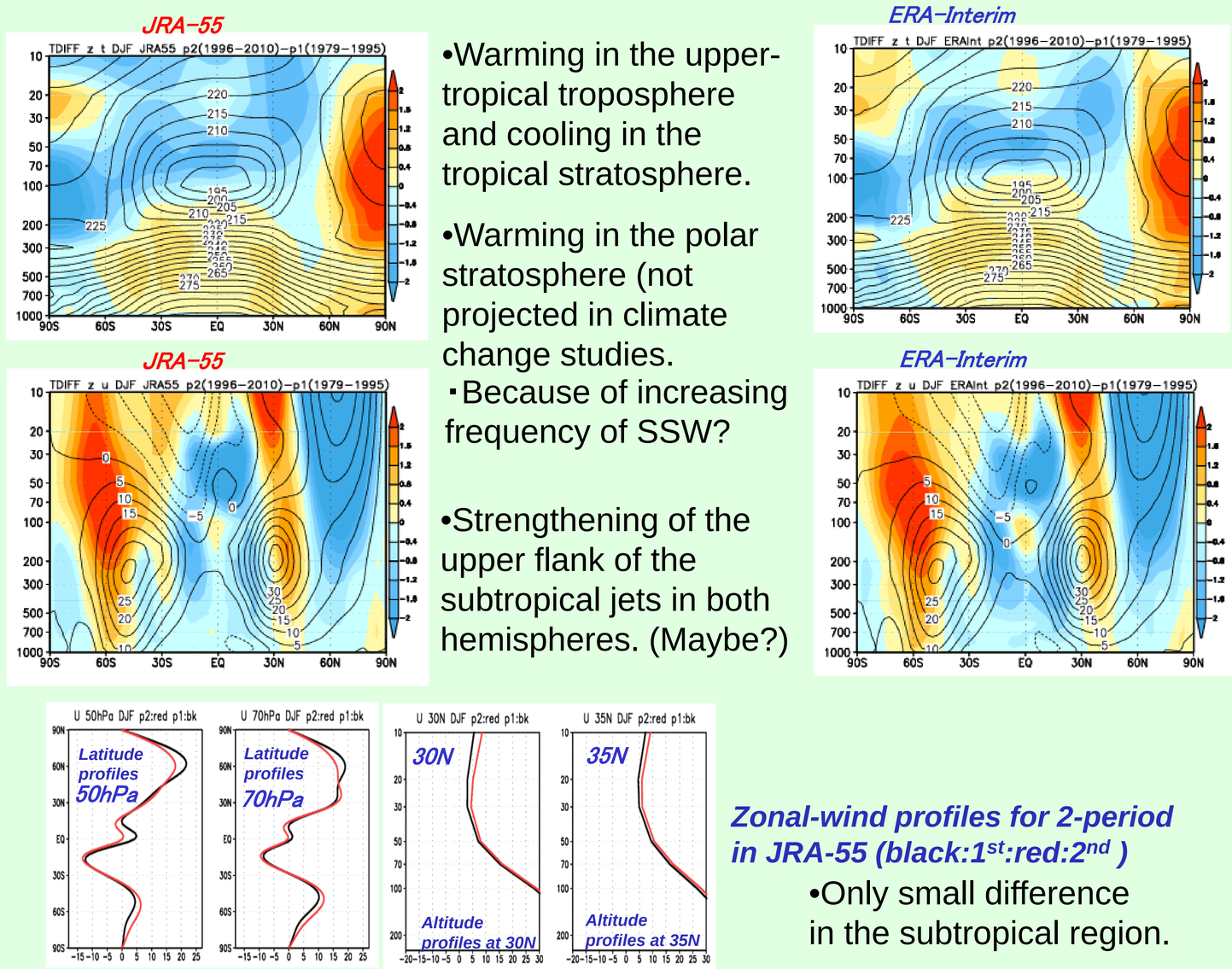
- JRA-55: significant increasing trend (+4%/decade)
- ERA-Interim: decreasing trend

2. Trend of mass streamfunction in DJF (Height-latitude cross sections)



- Meridional circulation intensified in JRA-55, although weakened in ERA-Interim.

3. Trend of zonal mean air temperature and zonal wind in DJF

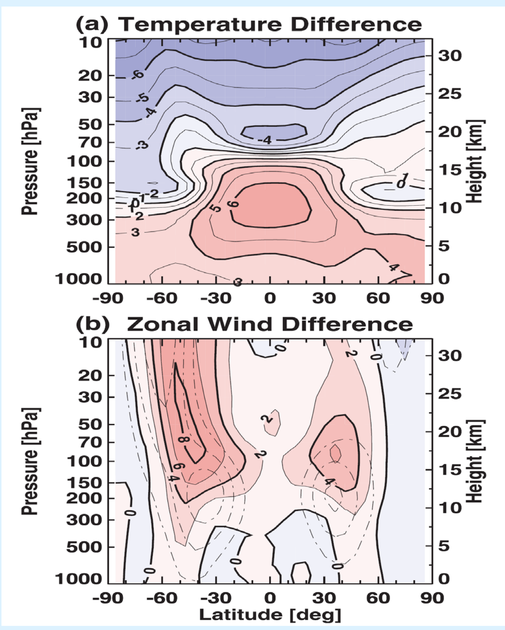


- Warming in the upper-tropical troposphere and cooling in the tropical stratosphere.
- Warming in the polar stratosphere (not projected in climate change studies.
- Because of increasing frequency of SSW?
- Strengthening of the upper flank of the subtropical jets in both hemispheres. (Maybe?)

Zonal-wind profiles for 2-period in JRA-55 (black:1st:red:2nd)

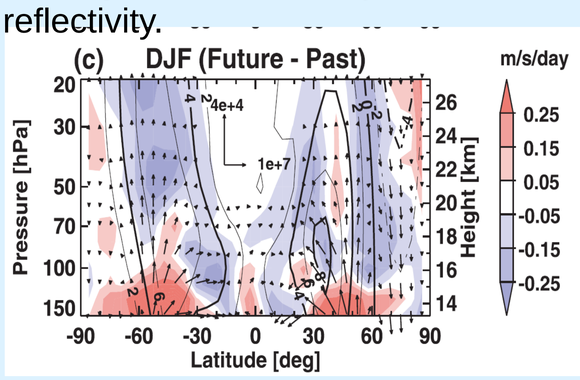
- Only small difference in the subtropical region.

Ref. Mechanism for Strengthening of BDC in response to Climate Change (Shepherd and McLandress, 2011)

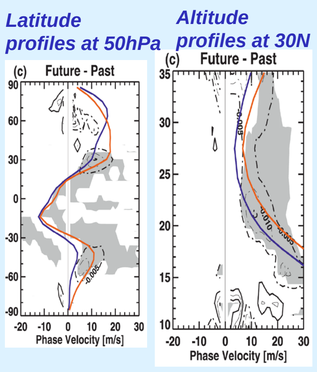


- Warming in the upper-tropical troposphere and cooling in the tropical stratosphere..
- Strengthening of the upper flank of the subtropical jets in both hemispheres
- Change of wave activity and reflectivity.

Difference between the past (1960–79) and the future (2080–99) of the annual- and zonal-mean (a) temperature (K) and (b) zonal wind (m s−1)



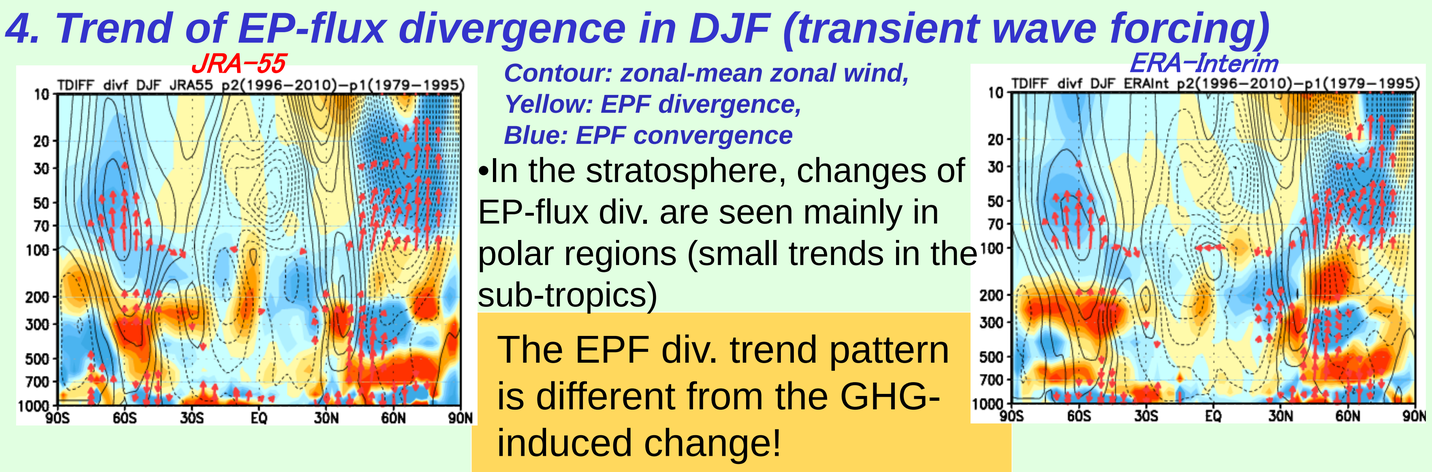
Difference between the past (1960–79) and the future (2080–99) of Zonal-mean zonal wind (contour), EPFD (shade), and EP flux vectors from transient waves for DJF averages



- EP-flux convergence (blue) in lower stratosphere around 30N and 30S produce upward motion in TTL region (downward control principle).

Zonal-wind profiles for the past (blue) and future (red), together with regions where the differences in EPFD for DJF

4. Trend of EP-flux divergence in DJF (transient wave forcing)



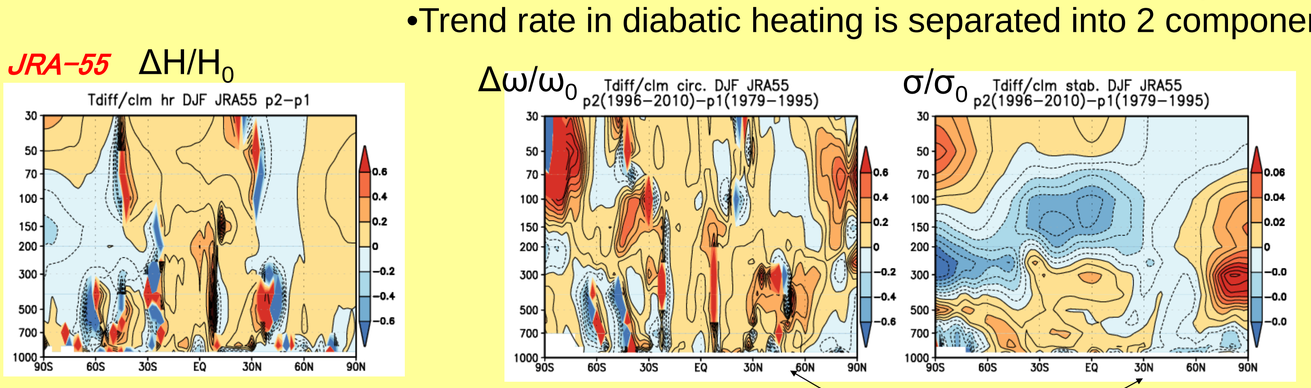
Contour: zonal-mean zonal wind,
Yellow: EPF divergence,
Blue: EPF convergence

- In the stratosphere, changes of EP-flux div. are seen mainly in polar regions (small trends in the sub-tropics)

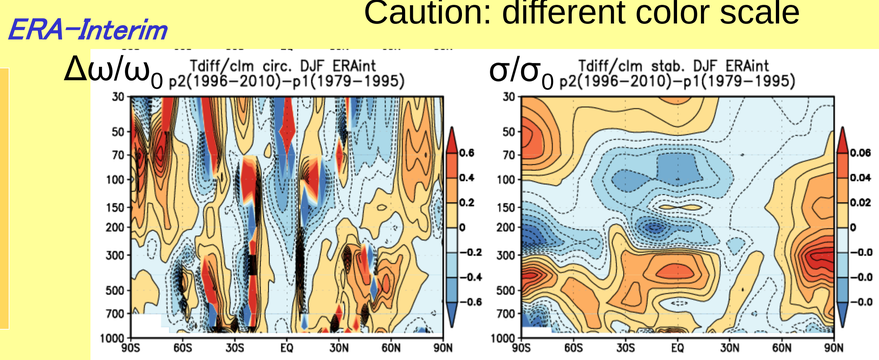
The EPF div. trend pattern is different from the GHG-induced change!

5. Contribution of tropical Diabatic heating

- $H \approx \omega \cdot \sigma$ $(\sigma = \partial\theta/\partial p)$ Thermodynamic eq. ⇨ $\Delta H/H_0 \approx \Delta\omega/\omega_0 + \Delta\sigma/\sigma_0$ (diabatic heating ≈ circulation + static stability)
- Trend rate in diabatic heating is separated into 2 components.



Caution: different color scale



Trend of circulation around TTL is not from stability change but from diabatic heating change