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The climatology of the Brewer–Dobson circulation and the contribution of gravity waves

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Key points

1. The climatology of the BDC and the GW contribution are examined for the annual mean state and both equinoctial and solstitial seasons using four modern reanalysis datasets.
2. GWs contribute to the shallow branches at low latitudes and poleward extension of the deep branches, which is essential to determine the turn-around latitude.
3. The autumn circulation is stronger and wider than the spring one. This asymmetry is attributable to the zonal wind tendency, likely owing to the angular momentum transport by radiatively-driven circulation.
4. Plausible deficiencies of current GW parameterizations are discussed by comparing the potential GW contribution and the parameterized GW forcing.

Sato, K. and S. Hirano (2019), The climatology of the Brewer-Dobson circulation and the contribution of gravity waves, Atmospheric Chemistry and Physics, 19, 4517-4539. doi:10.5194/acp-19-4517-2019

Methodology

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- **The definition of** $(\overline{v}^*, \overline{w}^*)$ and **the zonal momentum equation is used.** GWD is estimated as an unknown parameter.

$$\frac{\partial \overline{u}}{\partial t} - \hat{f}\overline{v}^* + \overline{w}^* \frac{\partial \overline{u}}{\partial z} = \frac{1}{\rho_0 a \cos\phi} \nabla \cdot \boldsymbol{F} + \mathrm{GWD} + \overline{X}$$

ignored ($\overline{X}$)

$$\Psi_{dU/dt}(\phi, z) \equiv -\cos\phi \int_z^\infty \left[\frac{\rho_0}{\hat{f}} \frac{\partial \overline{u}}{\partial t}\right]_{\overline{m}} d\zeta$$

$$\Psi_{\mathrm{total}}(\phi, z) \equiv -\cos\phi \int_z^\infty \rho_0 \overline{v}^* \, d\zeta$$

$$\Psi_{\mathrm{RW}}(\phi, z) \equiv \int_z^\infty \left[\frac{\nabla \cdot \boldsymbol{F}}{a\hat{f}}\right]_{\overline{m}} d\zeta$$

$$\Psi_{\mathrm{GW}}(\phi, z) = \Psi_{\mathrm{total}}(\phi, z) - \Psi_{\mathrm{RW}}(\phi, z) - \Psi_{\frac{du}{dt}}(\phi, z)$$

- Note that parameterized GW drag for GWD was not used, because **GW parameterizations do not accurately express real GWs** (Geller et al., J. Climate, 2013).
- Four reanalysis datasets, MERRA-2, MERRA, ERA-Interim, and JRA-55 for 30 years of 1986–2015 were used and similar results are obtained. Here only results from MERRA-2 are shown.

Annual mean climatology (MERRA-2)

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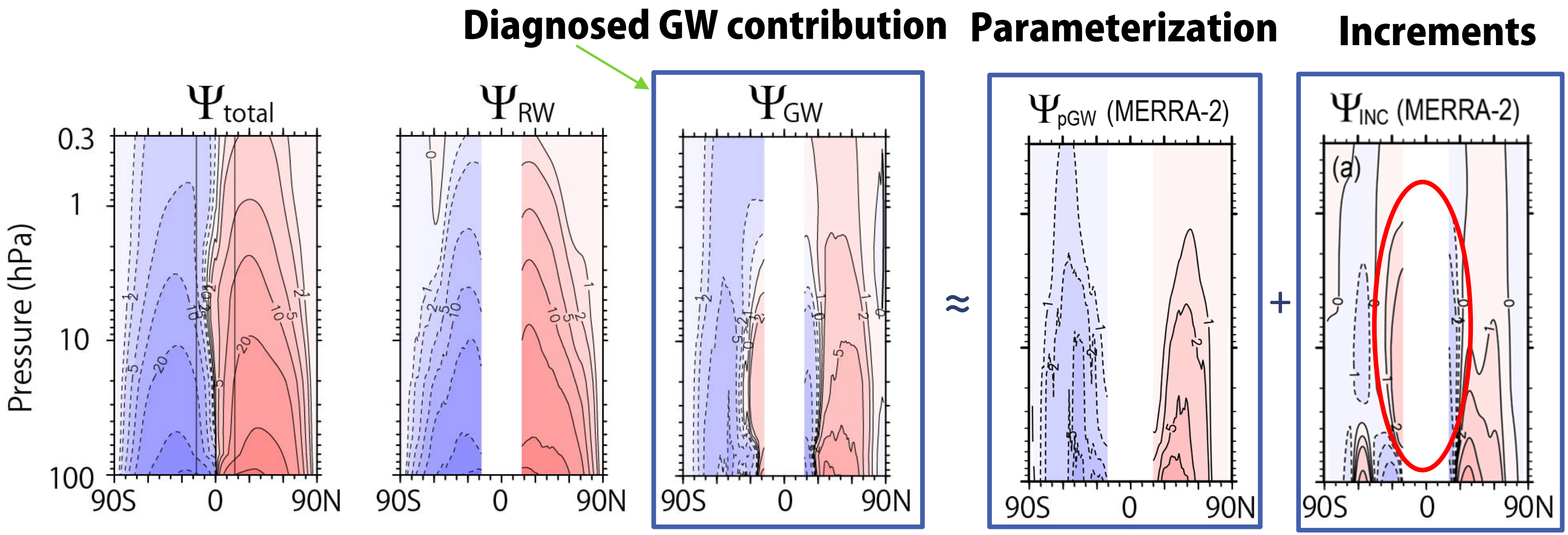

- Ψ_{total} is mainly composed by RWs. However, $\Psi_{\mathrm{total}} \neq \Psi_{\mathrm{RW}}$
- Ψ_{GW} is poleward at mid-to-high latitudes, and equatorward at low latitudes, which is consistent with previous observations and model studies showing dominance of GW westward (eastward) forcing at mid-to-high (low) latitudes.
- The equatorward circulation is not expressed by the GW parameterization, but evident in the increment.

JJA climatology (MERRA-2)

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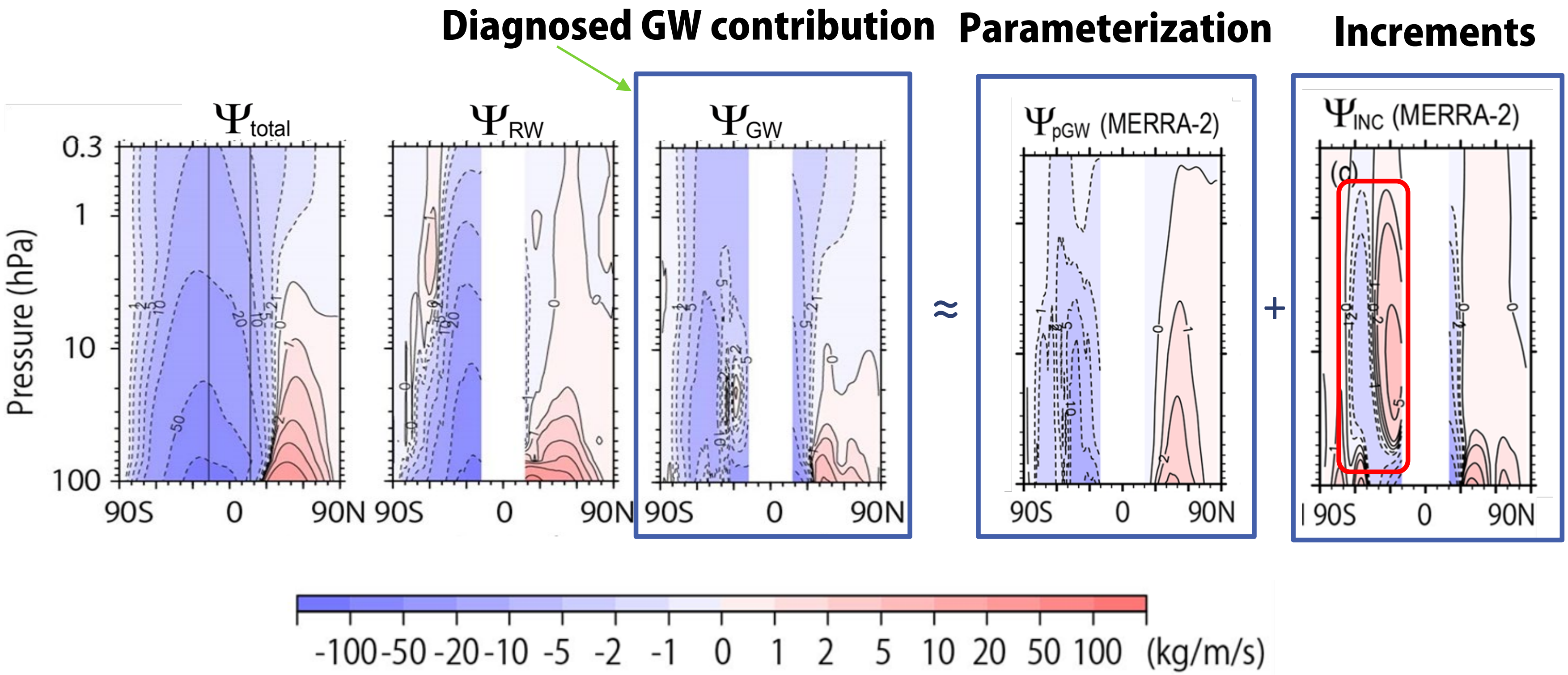

- GW largely contributes to the summer hemispheric part, and the winter mid-latitude part of the winter circulation.
- More westward forcing at ~60S and eastward forcing at SH low latitudes are needed in JJA, suggesting lateral propagation of GWs toward the polar night jet (see Sato et al., GRL, 2019).

MAM climatology (MERRA-2)

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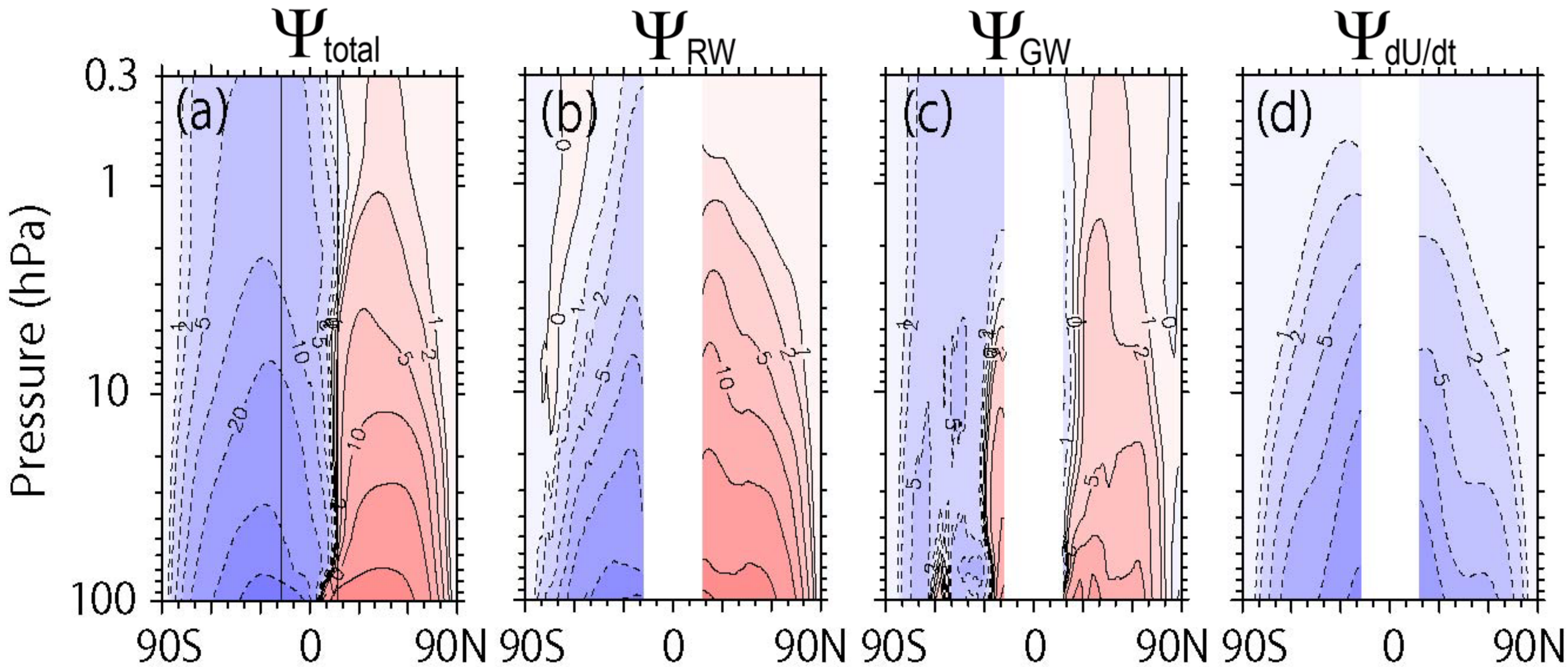

- Even in equinox seasons, the circulation is not symmetric around the equator: The autumn circulation is larger than the spring one.
- This asymmetry comes from zonal wind tendency.
- $\Psi_{dU/dt}$ corresponds to the angular momentum (AM) transport: Westerly (easterly) acceleration in autumn (spring) hemisphere.