

Re-cap of Part 1

- Angular momentum balance (not energy balance) controls the stratospheric circulation
 - persistent meridional motion requires a torque
 - no constraint on vertical motion since rad'n relaxational
- The applied torque comes from angular momentum transfer by waves - "wave drag"
 - in extratropical stratosphere, wave drag is mainly from planetary Rossby waves
 - Rossby waves carry negative angular momentum
- Rossby-wave drag drives a poleward circulation
 - induces tropical upwelling and extratropical downwelling (mass conservation), which is accommodated radiatively by tropical cooling and extratropical warming
- Circulation is dominantly in winter hemisphere (since Rossby waves prohibited in summer)

QUESTION: Could Rossby waves induce eastward flow in summer to create their own conditions for propagation?

- Circulation stronger in NH winter than SH winter
 - Arctic vortex warmer and weaker than Antarctic
- Episodes of intense wave drag over the pole lead to "sudden warmings" associated with wave-driven descent
 - almost never in SH - except 2002!

Re-cap of Part 2

- Brewer-Dobson (transport) circulation consists of:
 - { vertical (adiabatic) circulation (to 1st approx)
 - { horizontal mixing
 - mixing in stratospheric "surf zone", spatially inhomogeneous
- Brewer-Dobson circulation is seasonal and leads to winter-spring buildup of mid-lat and polar ozone
 - variability in planetary-wave drag leads to variability in BD circulation, and thus in ozone
- There are global-scale patterns of coupled chemical-dynamical variability
 - variability is ultimately dynamical in origin (chaos)
- Antarctic ozone hole usually controlled by halogen loading
- Arctic springtime ozone controlled much more by meteorological variability
 - low PWD \Rightarrow low O_3 , dynamically and chemically (about 50:50)
 - similar issues at midlatitudes, but attribution unclear
- With climate change, upper stratosphere will cool, increasing ozone
- The main wild card for column ozone is response of PWD
 - nothing can be said with any confidence