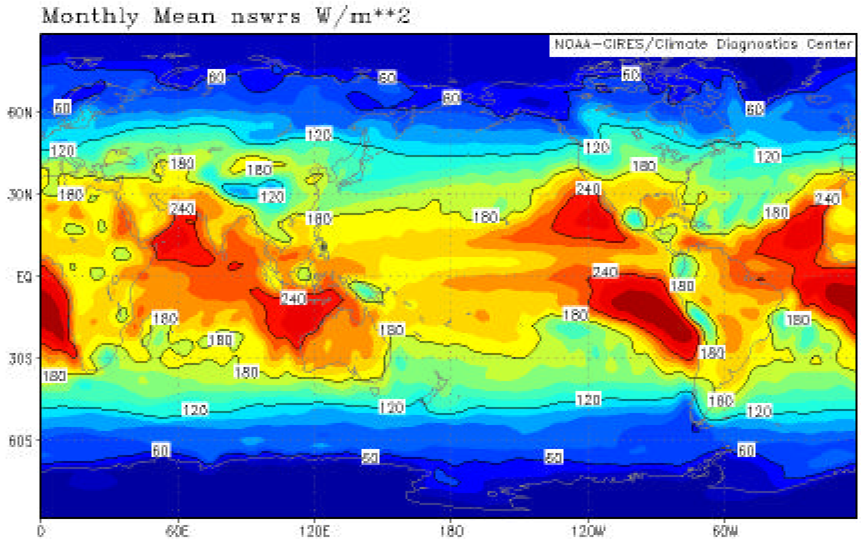
Chapter 11
Global circulation

- Differential heating and heat transport
- Thermal wind and jet streams
- Midlatitude troughs and ridges, and Rossby waves

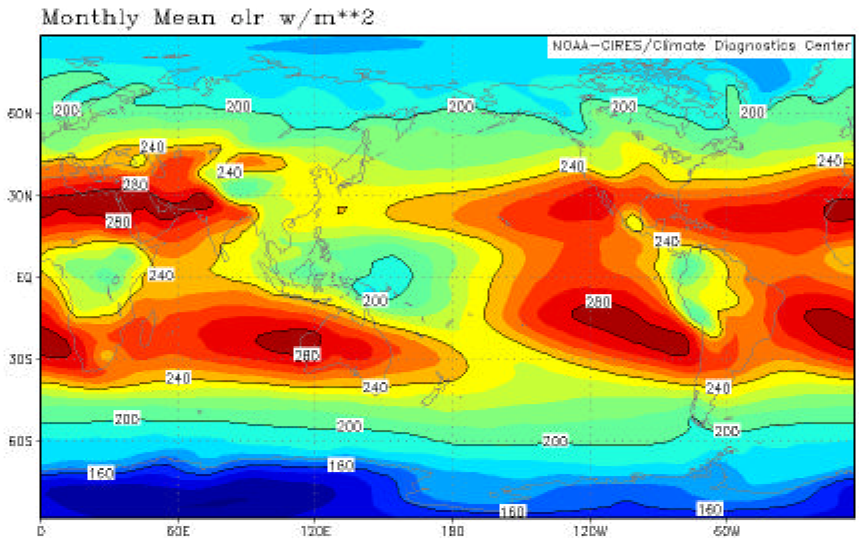
General circulation

- Driving force is meridional temperature gradient (understand pp. 224-7)
  - Biggest in middle latitudes
  - Maintained by radiative forcings
- E_{out} and E_{in} (p. 226)
  - See next slides for actual examples

Incoming radiation



Outgoing radiation



Heat transport needed

- Maximizes at around latitude 40
- Accomplished by atmosphere and ocean circulation systems
- Eddies transport heat poleward and “coldness” to the equator
- Think of eddies as a mixing process that is trying to reduce the meridional temperature difference

Thermal wind

- Thermal wind is the vertical gradient of geostrophic wind (as a vector)
  - $V_{g\ upper}$ minus $V_{g\ lower}$ (vector subtraction)
- Thermal wind is a vertical wind shear
- Parallel to temperature or thickness lines
- Magnitude is proportional to the gradient of temperature or thickness
- Thermal wind is geostrophically related to temp or thickness contours
  - In terms of temperature (eq. 11.10)
  - In terms of thickness (eq. 11.12)

Jet stream and thermal wind

- Understand the relation between Figs. 11.11 a,b,c
  - Horiz temp gradient largest where vertical wind shear largest
  - In stratosphere, where westerlies decrease with height, thermal wind is from the east
  - Note tropopause discontinuity near jet

Relative and absolute vorticity

- Relative vorticity - Met II - eq. 11.18 (ζ_r)
  - Made up of shear + curvature
  - Relative to earth's surface
  - Positive = cyclonic, negative = anticyclonic
- Planetary vorticity
  - Caused by earth rotation
  - Given by $f_c=2\Omega.\mathrm{Sin}\phi$
  - Max at poles, zero at equator
  - Is always cyclonic (direct of rotation)
- Absolute vort = Relative + planetary vort
  - $\zeta_a = \zeta_r + f_c$
  - Cannot be negative, i.e., $\zeta_r > - f_c$

Barotropic instability and Rossby waves

- Based on conservation of absolute vorticity
  - $\zeta_a = \zeta_r + f_c = \zeta_r + 2\Omega.\text{Sin}\phi$ = constant
  - See p. 236-237
- Wavelength, λ, about 6,000 km
- Waves move with speed given by

  $c=U_o-\beta.(\lambda/2\pi)^2$, where $\beta=2.29 \times 10^{-11}.\cos\phi$ and U_o is the mean background flow
  - Thus, short waves move with speeds close to U_o while longer waves move slower
  - Called a dispersion relation

Potential vorticity

- Given by equation 11.21
- Is conserved
- Barotropic instability is a special case
- 11.22 can be re-written as

  $\zeta_r + f_c = \text{PV}.\Delta z$, where PV is constant, so

  $\Delta\zeta_r + \Delta f_c = \Delta(\Delta z)$

  Stretch column (increase Δz) means ζ_r or latitude must increase

Mountain Rossby waves (p. 284)

- Caused by PV conservation as air flows over mountains. See Fig. 13.2
- $\Delta\zeta_r + \Delta f_c = \Delta(\Delta z)$

Changes in: vorticity latitude depth of column

  - A to C - Δz decreases, so ζ_r decreases. Flow turns anticyclonically and heads south
  - C to D - f_c decreases, Δz stays the same, so ζ_r must increase (reduces a/c curvature)
  - D to E - Δz increases so ζ_r continues to increase. Result is lee trough
- Results in ridge upwind, trough downwind