Introduction to Upper-Level Waves

Atmos 5110 Synoptic–Dynamic Meteorology I

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Suggested reading: Lackmann (2011), section 1.5.3

Holton and Hakim (2013), section 5.7

Definitions

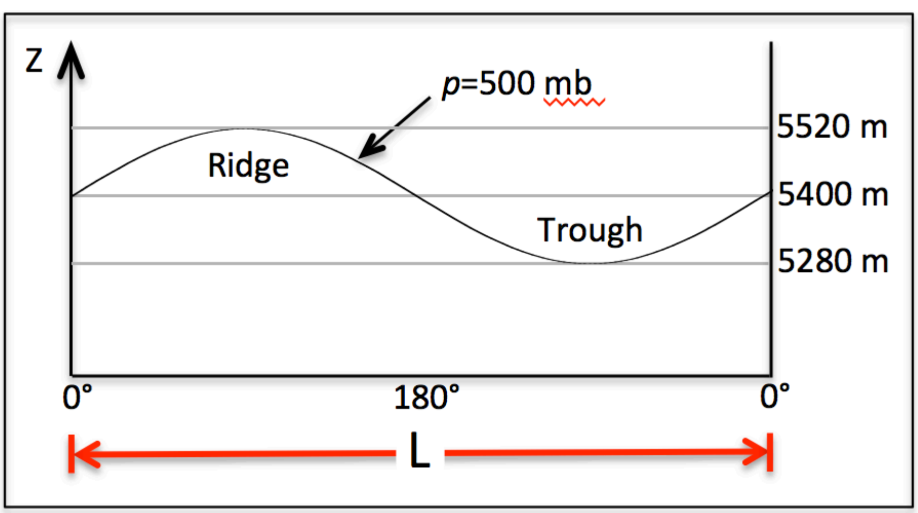
Upper-level ridge: A pressure or geopotential height ridge in the middle and upper troposphere

Upper-level trough: A pressure or geopotential height trough in the middle and upper troposphere

Upper-level wave: A series of upper-level troughs and ridges

Wavelengths and wavenumbers

Consider a zonal cross section around the globe of 500 mb geopotential height



$$L_x = \frac{2\pi a cos\phi}{n}$$

where

L_x = Zonal wavelength

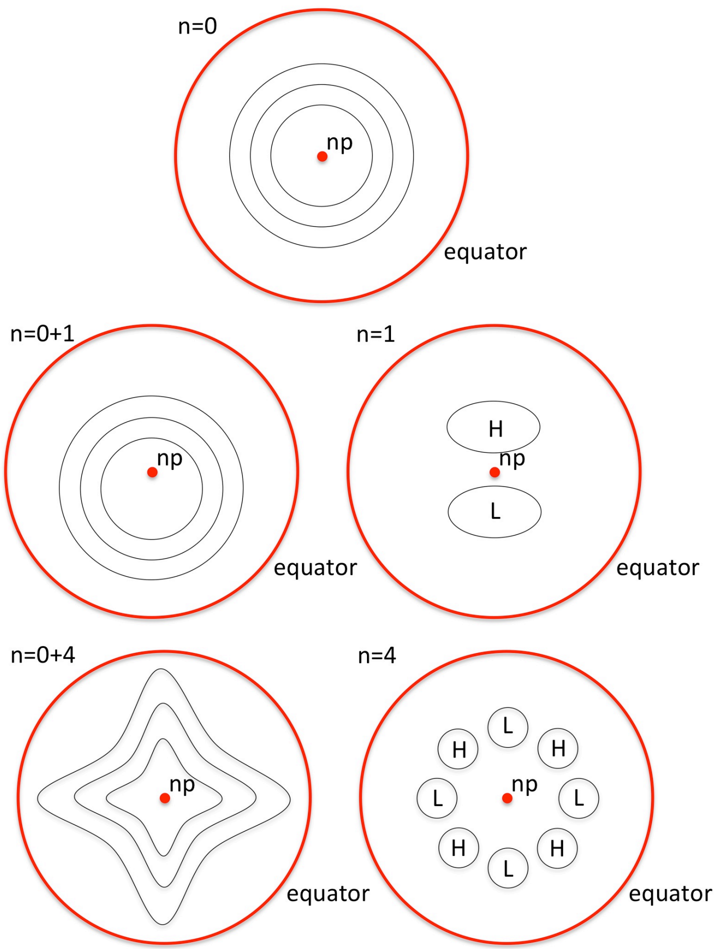
a = radius of the Earth

ϕ = latitude

n = non-dimensional zonal wave number

Non-dimensional zonal wave number: Number of wave cycles (i.e., full wavelengths) around a latitude circle

Zonal wavenumber examples (ugly and not quite correct!)



We use the nondimensional wave number, rather than wavelength, because the wavelength of a given wave varies with latitude. For example, what is the wavelength of a wave number 3 wave at 30°N and 60°N?

$$L_x = \frac{2\pi a cos\phi}{n} = \frac{2\pi(6370\ km)\cos(30)}{3} = 11{,}554\ km \text{ @ 30°N}$$

$$L_x = \frac{2\pi a cos\phi}{n} = \frac{2\pi(6370\ km)\cos(60)}{3} = 6{,}671\ km \text{ @ 60°N}$$

<u>Dimensional wave numbers</u>

It is possible to determine the dimensional wave number of a wave, although it also varies with latitude. Nevertheless, it is sometimes use to describe wave characteristics.

$$k = \frac{2\pi}{L_x} = \frac{2\pi n}{2\pi a cos\phi} = \frac{n}{a cos\phi}\ (units\ m^{-1})$$

<u>Wave characteristics based on synoptic experience</u>

- Long waves: Upper-level waves with low wave numbers (e.g., n=0–5) and large zonal wavelengths that tend to progress (move downstream, typically eastward in midlatitudes) slowly or retrogress (move upstream, typically westward in midlatitudes). Typically planetary-scale waves.

- Short waves: Upper-level waves with higher wave numbers (e.g., n > 5) and short zonal wavelengths that tend to progress more rapidly and are “steered” by the long waves. Typically synoptic-scale waves.

<u>Terminology caveats</u>

1. Usually the term long wave is used for any larger-scale wave that moves slowly and the term short wave is used for any synoptic scale wave that is moving through the longer-wave pattern. There are times, however, where the distinction is ambiguous.

2. Many meteorologists use the term "short wave" to describe what should be a short-wave trough (ditto for short wave ridge). It's best to be specific. Use the term "short wave trough" and not "short wave" when one is referring to a short wave trough.
3. Many meteorologists refer to vorticity maxima as "short waves" although in some instances vorticity maxima exist with little curvature in the height field. Here to, use "vort max" instead of short wave.

Class activity

Using the IDV Global-10day bundle and the GFS wave-number diagnostic available by entering "modelloop gfs004 WN NH" on the command line, examine the movement of long and short waves over the past 10 days and as forecast for the next week.