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Meteorology 454 Waves Project Analysis

Rossby waves, or planetary waves, are a product of the Coriolis force and the conservation of absolute vorticity. If a chain of particles is horizontally aligned and then undergoes a meridional displacement, the Coriolis force and conservation of vorticity affect the wave pattern so that it moves westward as air parcels oscillate about their equilibrium latitude. The restoring force for Rossby waves is the meridional gradient of absolute vorticity.

Planetary wave data was gathered daily from August 22, 2005 to November 11, 2005. Data parameters gathered included the wave number (K), the amplitude (A), the wave propagation speed (C), the 500 hPa wind speed (U-500) and the upper tropospheric wind speed (U-upper). The analysis of the relationships of these parameters in both the northern and southern hemisphere as well as how the waves reacted to the change of seasons are presented here.

a. Average wave speed

The average wave speed per day in the northern hemisphere from was +6.25º/day. Waves in general moved from west to east at approximately half the speed as the southern hemisphere. Traveling at the average +6.25º/day it would take about 58 days for wave crest/trough to go around the 50º N latitude circle providing it remained intact.

The average wave speed per day in the southern hemisphere over the same time period was +12.14º/day. Waves again moved from west to east but at twice the wave speed than in the northern hemisphere. With the wave traveling at the average +12.14º/day it would take about 30 days for wave crest/trough to go around the 50º S latitude circle providing it remained intact.

b. Wave speed vs. zonal wind speed

The wave propagation speed in the northern hemisphere was 8.04 m/s and the average zonal (500 hPa) wind speed was 23.66 m/s at an average latitude of 69º N. The propagation of the waves was slower than the zonal winds so the relative velocity of the wave speed to the wind speed was negative and in a westward moving direction.
The comparison of wind speed at 69º N was calculated below:

Radius of the earth=$6.37*10^6$ m
($6.37*10^6$ m cos 69º)*sin 21º = $8.95*10^5$ m
$8.95*10^5$ m * 2 π = 5.63 *10^6 m
5.63 *10^6 m / 23.66 ms^{-1} = $2.38*10^5$ s = 2.75 days

Compare this to the wave propagation at which took 58 days to complete a trip around the earth at 50º S.

In the southern hemisphere, the wave speed was 15.61 m/s and the average zonal (500 hPa) wind speed maximum was 32.89 m/s at an average latitude of 53º S. The propagation of the waves was slower than the zonal winds so the relative velocity of the wave speed to the wind speed was negative and in a westward moving direction. The comparison of wind speed at 53º S and was calculated below:

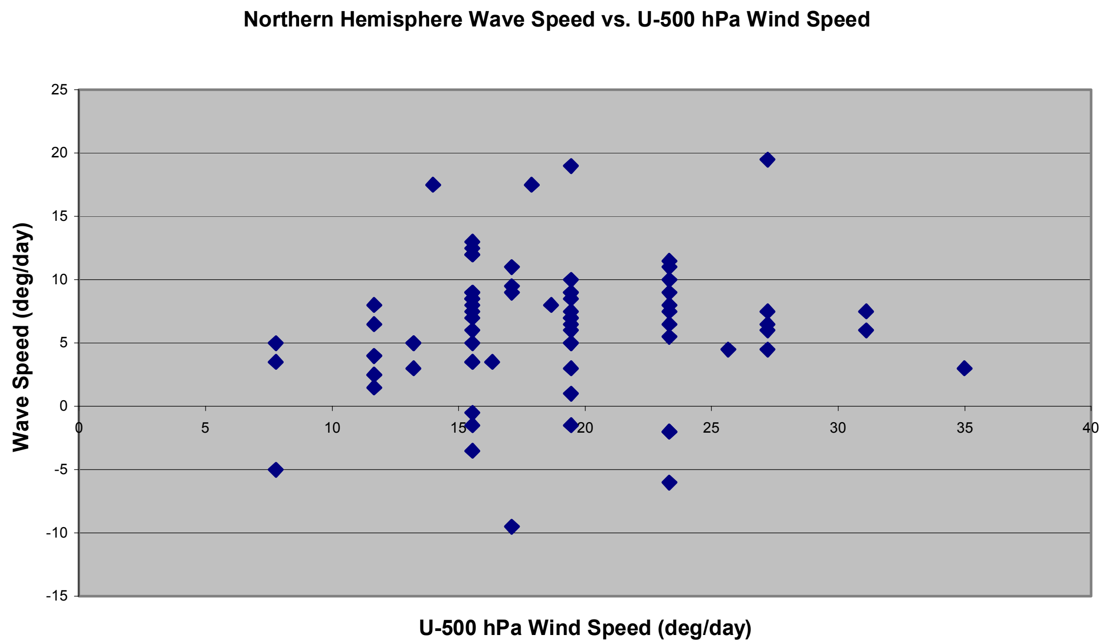
Radius of the earth=$6.37*10^6$ m
($6.37*10^6$ m cos 53º)*sin 37º = $2.31*10^6$ m
$2.31*10^6$ m * 2 π = $1.45*10^7$ m
$1.45*10^7$ m / 32.89 ms^{-1} = $4.41*10^5$ s = 5.10 days

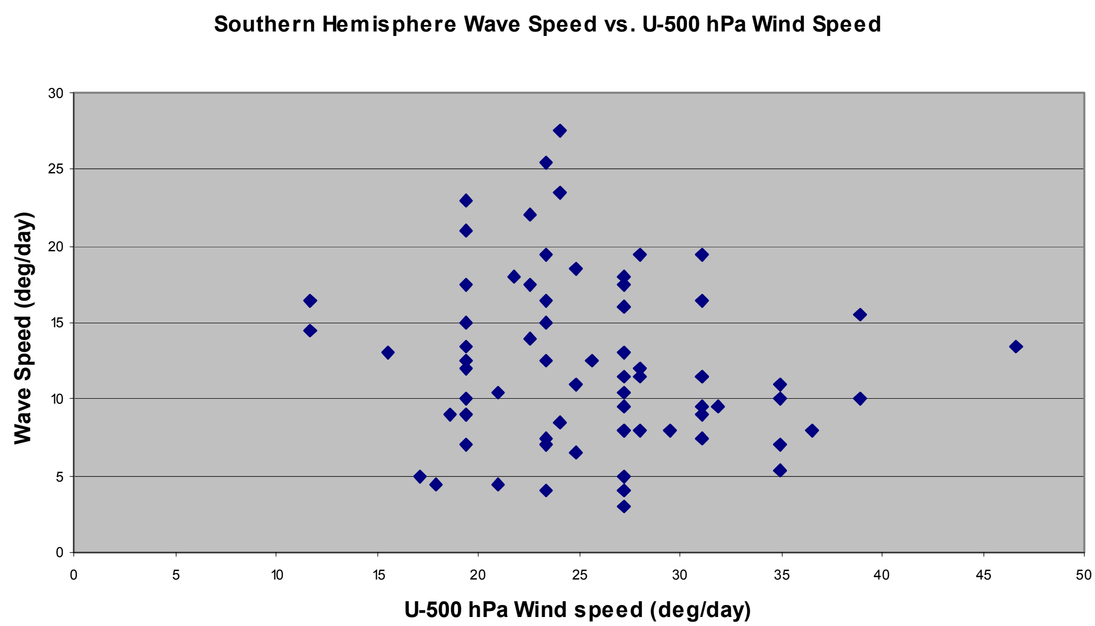
Compare this to the wave propagation at which took 30 days to complete a trip around the earth at 50º S.

c. Wave speed vs. U-500 hPa wind speed

Below are plots of the northern and southern hemisphere wave speed versus the U-500 hPa wind speed. There doesn't seem to be much of a relationship between the two in terms of a linear or polynomial fit, but it generally shows that the U-500 hPa wind speed is greater than the wave speed (for both northern and southern hemispheres).

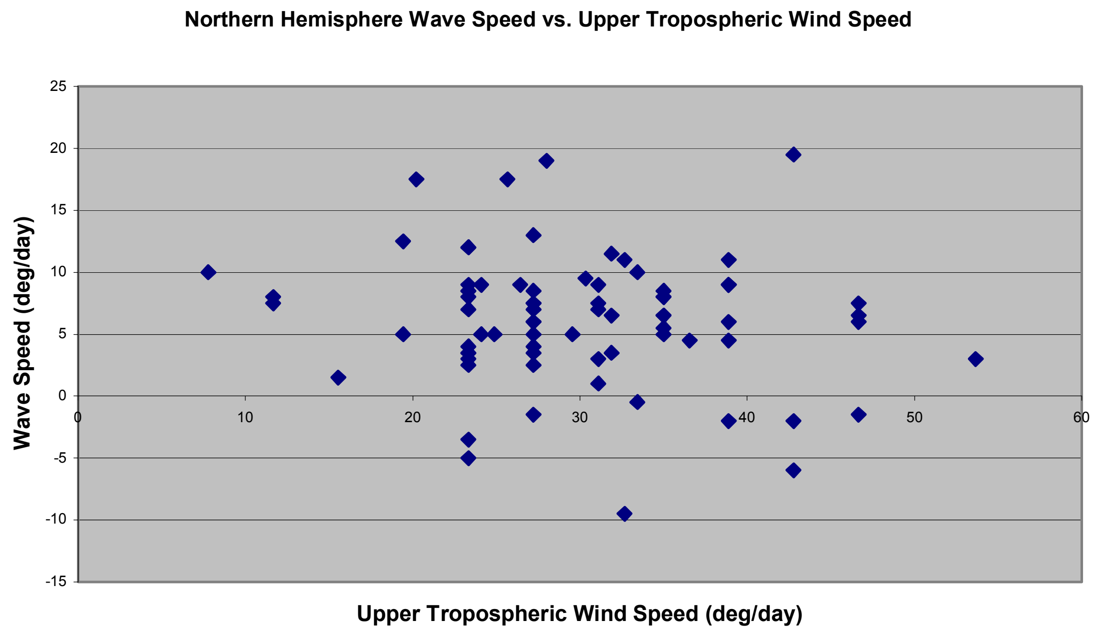
The Rossby wave theory helps explain this because Rossby waves dampen the wave propagation speed. Also, further from the equator in either direction, the greater the difference between the wave and wind speeds. At the average northern latitude for U-500 hPa maximum wind (69º N), waves propagated 6.25 º/day and the wind speed was 18.40 º/day. At the average southern latitude for U-500 hPa maximum wind (50º S), waves propagated 12.14 º/day and the wind speed was 25.58 º/day. This means that the further away from the equator that you go, the more dampening of the wave speed occurs. The phase speed dispersion relationship is $c - \bar{u} = -\beta / K^2$ and so the further that you get away from the equator, the larger the planetary vorticity gradient β (which is d*f*/dy). The result is that there's a greater difference between the wave speed *c* and the wind speed $\bar{u}$.

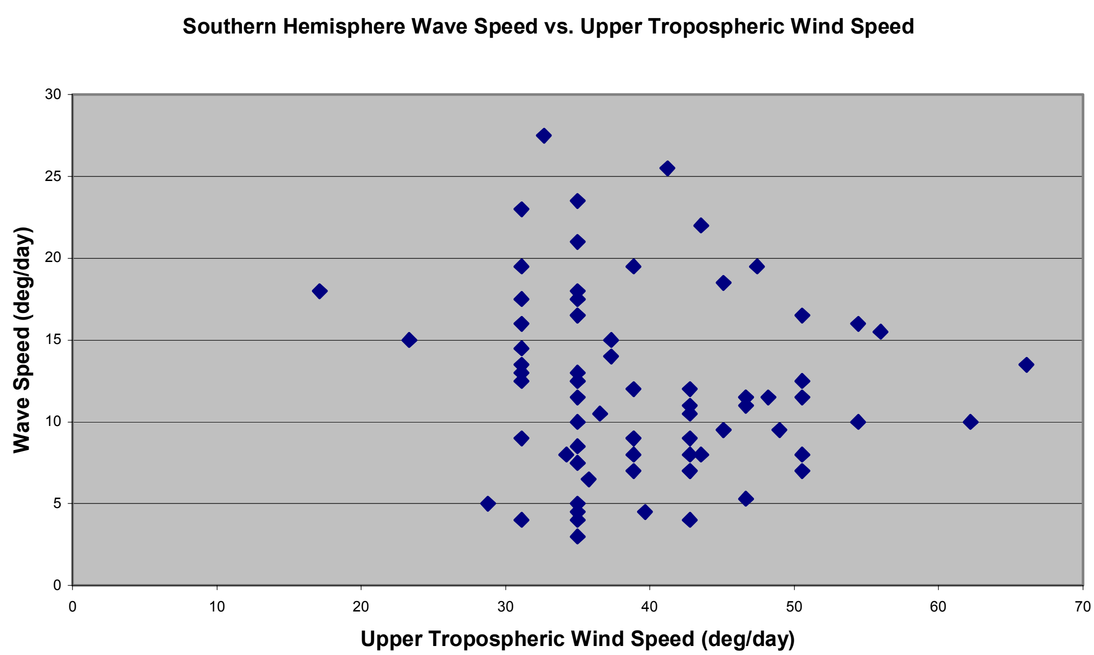




d. Wave speed vs. upper tropospheric wind speed

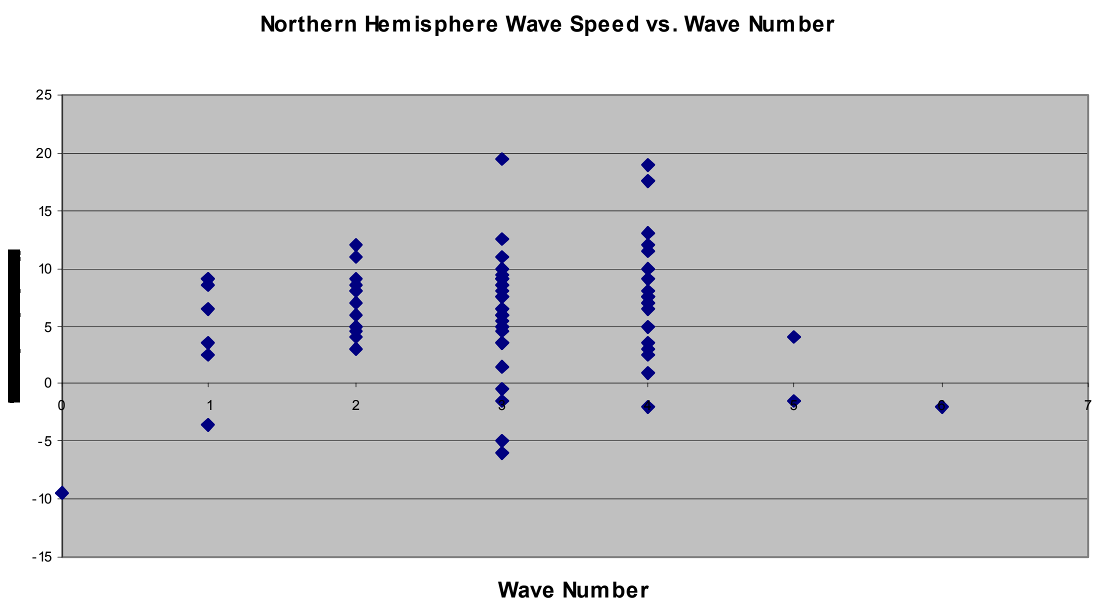
Below are plots of the northern and southern hemisphere wave speed versus upper tropospheric wind speed. Again, no linear or polynomial fit, but it generally shows that the upper tropospheric winds is greater than the wave speed. At the average northern latitude for upper tropospheric wind maximum (67º S), waves propagated 6.25 º/day and the wind speed was 39.67 º/day. At the average southern latitude for upper tropospheric wind maximum (55º S), waves propagated 12.14 º/day and the wind speed was 39.67 º/day. By relative comparison, the upper tropospheric winds and wave speed showed a greater spread than the U-500 hPa winds and the wave speed. So there is more dampening of the upper tropospheric wind speed so the right side of the equation $c-\bar{u}=-\beta/K^2$ must get larger.

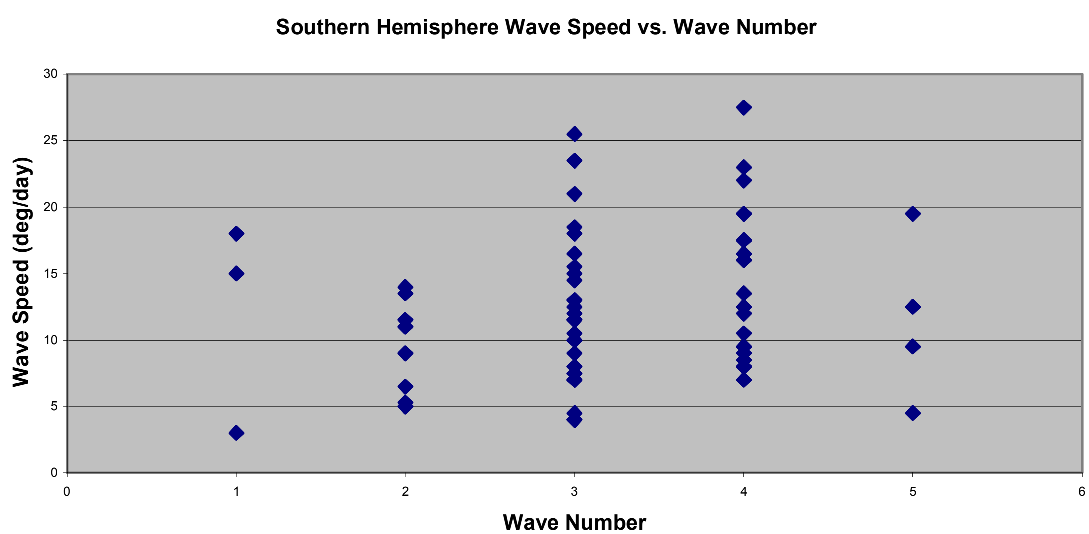




e. Wave speed vs. wave number

Speed varies by wave number in the northern and southern hemispheres by a very little amount if any indicated by the graphs. There's a greater spread for wave numbers 3 and 4 for the northern and southern hemispheres, but also more data points to consider. The southern hemisphere also displayed greater variance in the wave speed than the northern hemisphere. Rossby wave theory says that wave speed changes with the wave number and can be seen by the equation $c - \bar{u} = -\beta / K^2$. Assuming winds are constant, the wave speed is inversely related to the square of the wave number. How this plays a role in how the graph looks we were not able to come to any conclusion.

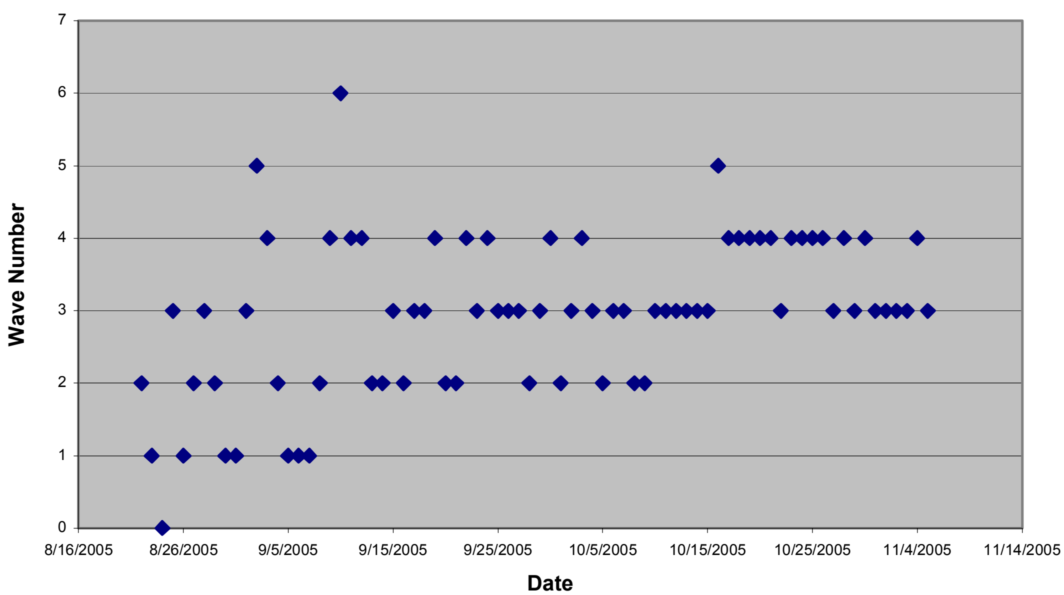




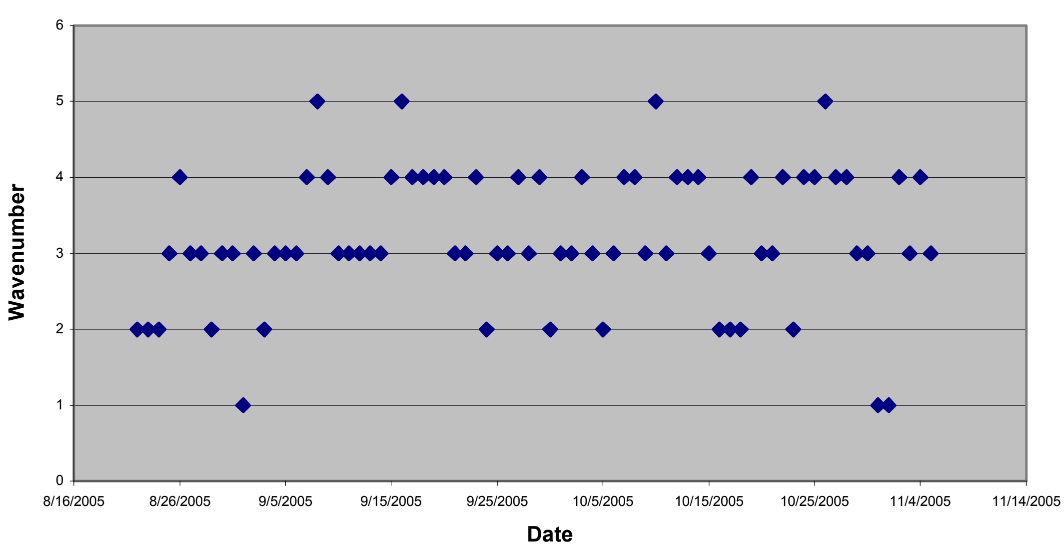
f. Wave number vs. date

Plotted below are the wave number/time series relationships. Observing the northern hemisphere first, from about September 10 until the end of the data gathering, the wave numbers only once changed more than one wave number on consecutive days. Before then, the wave numbers did vary more on a day-to-day basis. The synoptic time scale is approximately one day. So, in the northern hemisphere, wave numbers during the fall did not fluctuate by more than + or –1 wave number on a synoptic scale timeframe. The southern hemisphere had a few more instances of jumping more than one wave number on consecutive days, but did typically follow the northern hemisphere's characteristics.

Northern Hemisphere Wave Number vs. Date

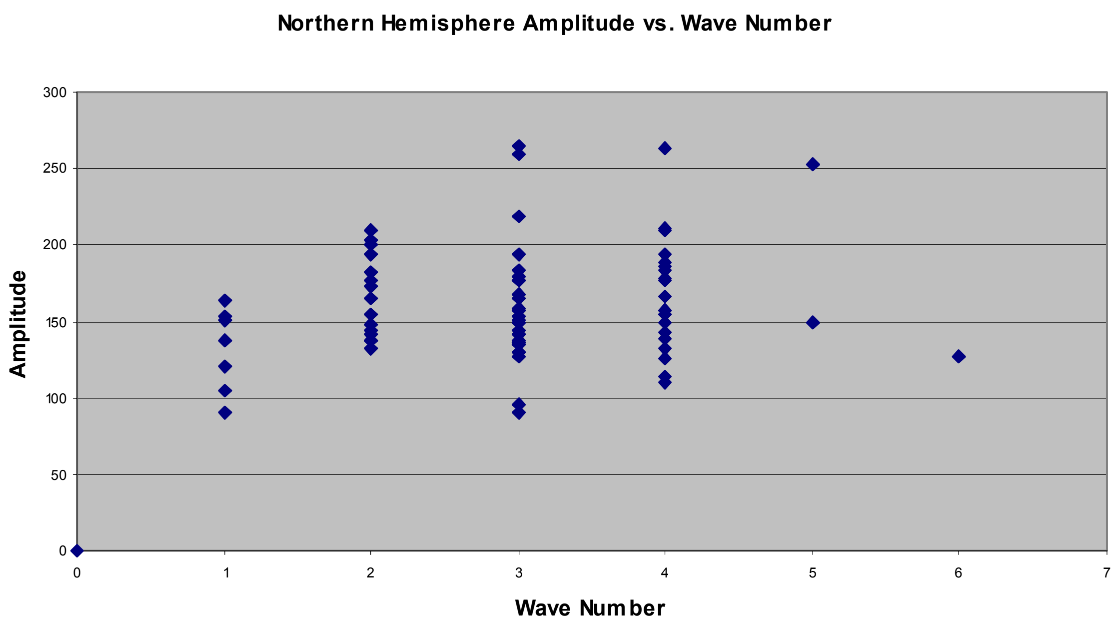


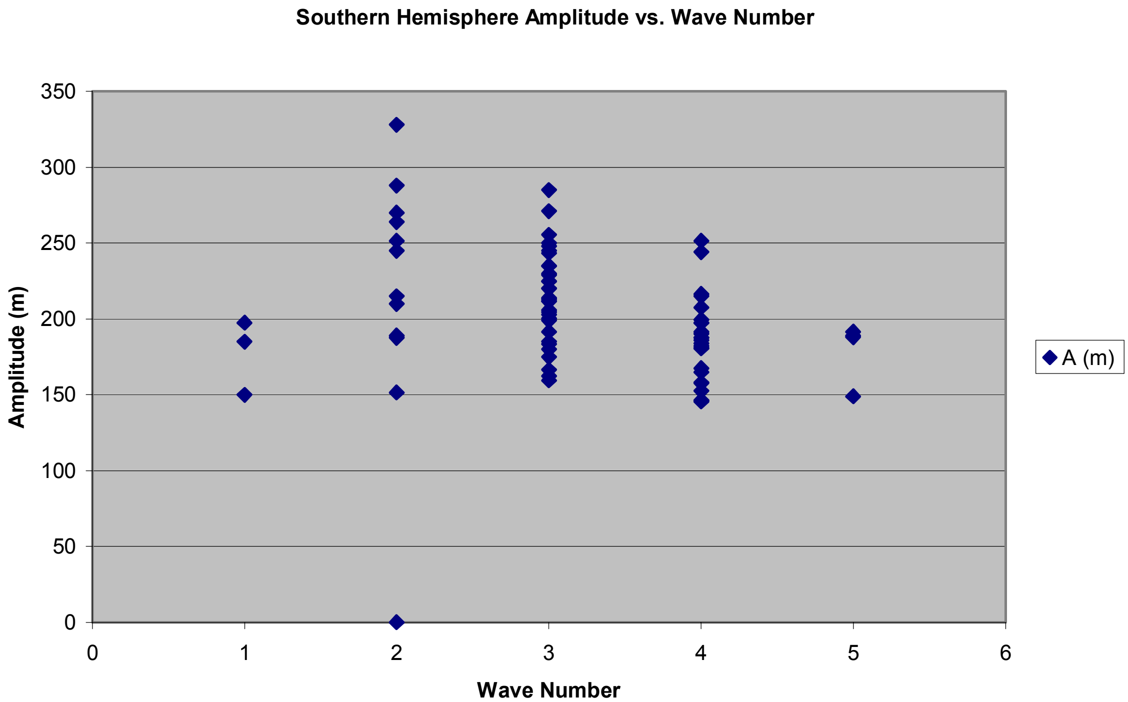
Southern Hemisphere Wave Number vs. Date



g. Amplitude vs. wave number

Below are the northern and southern hemisphere plots for wave amplitude and wave number. Shorter waves have more wave numbers and longer waves have less wave numbers. In the northern hemisphere, wave number patterns 3 and 4 had the largest amplitudes. In the southern hemisphere, wave number patterns 2 and 4 had the largest amplitudes. Although it's close, the longer waves tended to have the largest amplitudes. This was probably due to the fact that the larger waves had larger perturbations from the 50º-latitude line. A small wave would have to have a strong north-south component to have a large perturbation which isn't as common as a shallower trough would be.

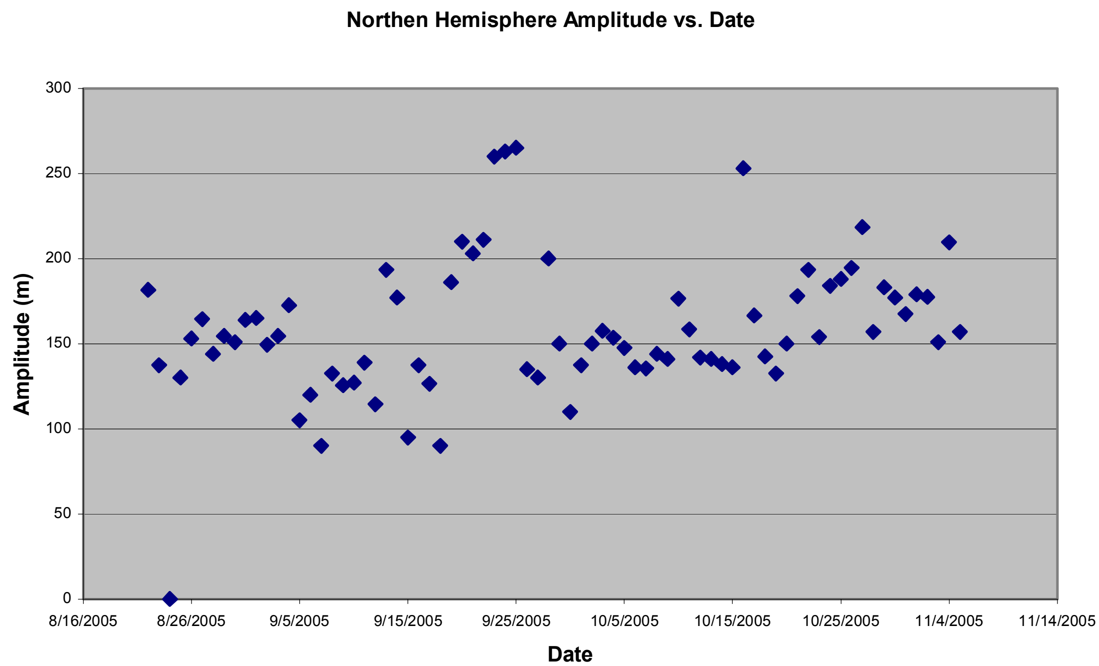


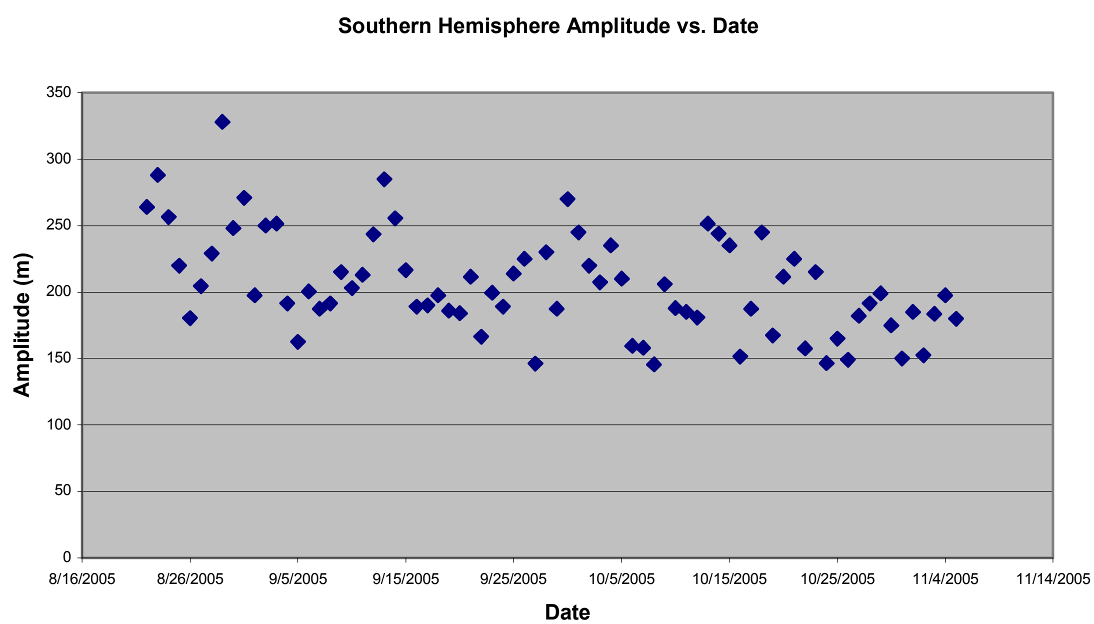


h. Amplitude vs. date

These two plots show a fairly good relationship. In the northern hemisphere, as the seasons change from summer to fall, a slight upward trend (13 % increase) in the amplitude can be seen. In the southern hemisphere, as winter turns into spring, a slightly more dramatic downward trend (28% decrease) in wave amplitude can be observed. There's not a smaller timeframe of significant increase or decrease to note for either the northern or southern hemispheres. Any large perturbations returned back after 1-3 days.

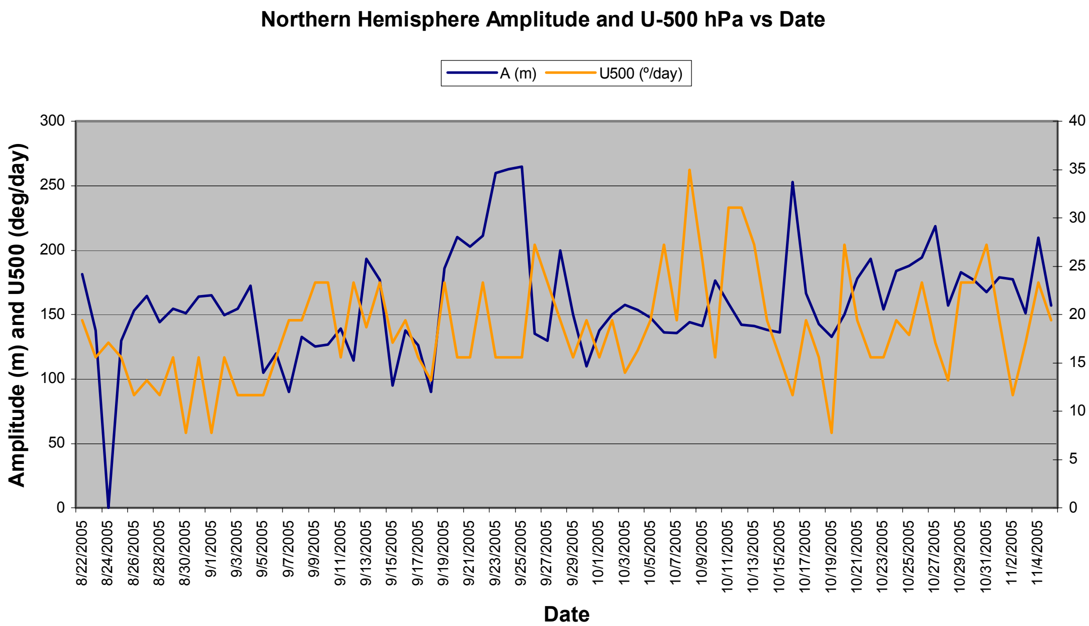
NH: (170-150)/150 = .13 (increase)
SH: (180-250)/250 = -.28 (decrease)

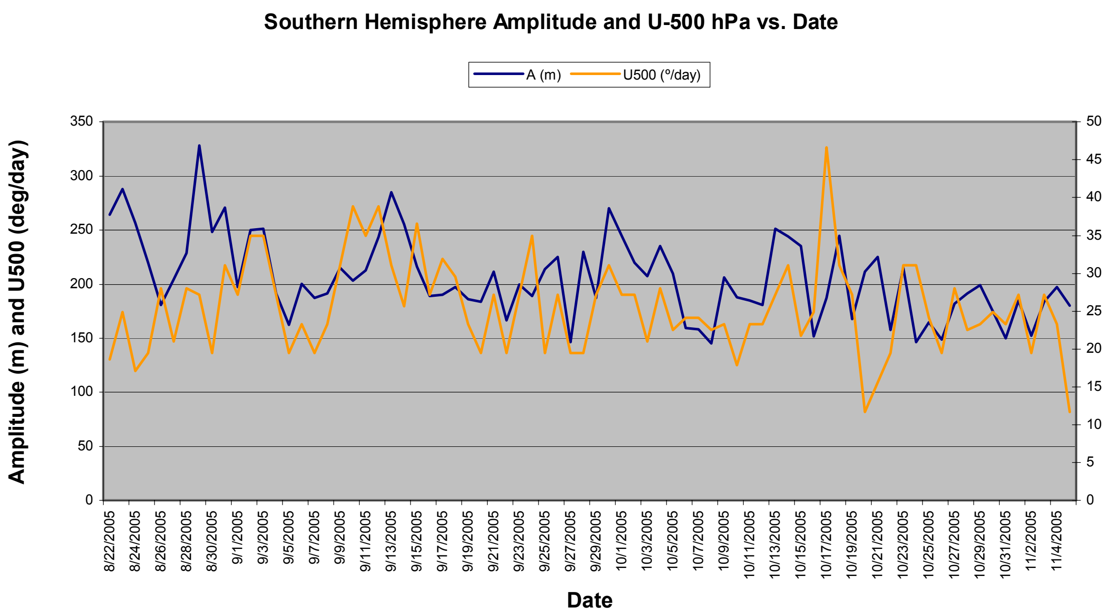




i. U-500 wind speed/Amplitude vs. date

There is a distinct oscillation in wave speed throughout the period. However, there seems to be an overall sinusoidal pattern in both Northern and Southern Hemispheres. There is a positive correlation between the U500 wind and Amplitude. For the Northern Hemisphere, this is a slight relationship between the U500 wind and the Amplitude. This relationship is more distinct in the Southern Hemisphere. We believe this could be because of the difference in landmass between the two hemispheres.





j. Overall

The Rossby Wave Theory, $c - \bar{u} = -\beta / K^2$, helps explain the overall evolution of large-scale waves because Rossby waves dampen the wave propagation speed. There appears to be an approximate agreement between the Rossby Wave Theory and our observations. Factors that could be missing in the model that may potentially improve the relationship between the theory and the observation are location on the longitude axis, the fact that the atmosphere is not always in geostrophic balance, and the region we took our observations from is a more baroclinic than barotropic atmosphere.