Study guide for ATMS 545 Midterm

The kinetic energy cycle.

Where does kinetic energy come from? Where does it go?

Why is it advantageous to think of *available potential energy* rather than just plain *potential energy* as the source of kinetic energy?

Interpret the terms in the expression for available potential energy. Why des static stability appear in the denominator.

How is available potential energy generated?

Give four different interpretations of the conversion from available potential energy and kinetic energy, one involving cross-isobar flow and one involving the rising of warm air and the sinking of cold air.

Give four different interpretations of a thermally direct (or thermally indirect) circulation. Give examples of thermally direct (or thermally indirect) circulations in the atmosphere or oceans.

Is the wind-driven ocean circulation thermally direct or thermally indirect? (Justify your answer.)

How does diabatic heating act to generate available potential energy?

Why doesn't the vertical gradient of diabatic heating appear as a source of available kinetic energy in Lorenz's formulation of the kinetic energy cycle?

List some other simplifications inherent in Lorenz's formulation of the kinetic energy cycle.

Assuming that atmospheric motions remain close to a state of geostrophic balance, in what sense does the ratio of available potential energy to kinetic energy change in response to (a) an increase in static stability, (b) an increase planetary rotation, (c) an increase in the horizontal scale of disturbances, (d) an increase in the vertical scale of disturbances. Which has more kinetic energy: a wave with zonal wavenumber 1 or a wave of the same amplitude in the geopotential height field but zonal wavenumber 10?

Can you imagine a class of motions that has kinetic energy but no available potential energy?

Within the planetary boundary layer the dissipation of kinetic energy is much larger than the *in situ* release of available potential energy. How is the energy supplied?

What kind of flux through the tropopause maintains stratospheric motions against frictional dissipation.

In a stratified fluid with horizontal and vertical heating gradients and a thermally direct circulation cell, what happens if the horizontal heating gradient becomes vanishingly small? what happens if the vertical heating gradient becomes vanishingly small?

Describe the kinetic energy cycle in a well mixed swimming pool with surface waves.

Compare the strengths of the reservoirs and conversions in the kinetic energy cycle in the winter and summer hemispheres.

Study guide for ATMS 545 Midterm

The angular momentum balance

What is atmospheric angular momentum?

Why doesn’t the ocean play an important role in the angular momentum balance of the Earth system?

In the tropics, sea level is higher on the western side of the oceans than on the western side.

Atmospheric angular momentum varies in phase or out of phase with variations in length of day? Explain.

List two well posed (steady state) balance requirements for angular momentum, one relating to the atmosphere as a whole and one relating to the air lying within certain latitude belts.

Describe how the mountain torque can act either as a source or sink of angular momentum.

How do we know that the mountain torque doesn’t play a critical role in the global (steady state) angular momentum balance?

Describe the role of the frictional torque in the angular momentum balance

Describe the role of mean meridional circulations in the poleward transport of angular momentum.

Describe the role of mean meridional circulations in the vertical transport of angular momentum.

Describe the mechanisms by which angular momentum is transported poleward across 30° in the Earth’s atmosphere. At what level in the atmosphere is the transport largest?

Compare the partitioning of the angular momentum transport between transient eddies and stationary waves in the Northern and Southern hemispheres.

Describe the balance requirement for the vertical transport of angular momentum in the Earth’s atmosphere? How is the transport accomplished? How do we know which term is dominant?

Ridges and troughs of waves that transport westerly momentum poleward tilt poleward with increasing latitude. Explain using a sketch.

List the dominant terms in the equation for the time rate of change of zonally averaged zonal wind and give a physical interpretation of each of them. Indicate the relative magnitudes and signs of these terms (a) in the boundary layer at 15° latitude; (b) at the jet stream level at 15° latitude, (c) at the jet stream level at 45° latitude; and (d) in the boundary layer at 45° latitude.

What does the angular momentum balance tell us about the relative strengths of the Hadley and Ferrell cells? Explain.

The poleward transport of angular momentum is greater in the winter or summer hemisphere? How do we know?

Study guide for ATMS 545 Midterm

Balance requirements for total energy and water vapor

How do we know that there exists a balance requirement for the poleward transport of total energy by the atmosphere and oceans, with maximum transport across 38° latitude?

How can we infer the ocean transport without actually measuring it (a) using satellite and atmospheric measurements only and (b) using measurements of the fluxes at the air-sea interface? Specifically, what fluxes need to be taken into account in (b)?

Describe how the thermohaline circulation and the wind-driven ocean circulation contribute to the poleward energy transport. In which ocean is the thermohaline contribution largest? At what latitudes is the wind driven contribution largest?

The atmospheric transport partitioned between what three components of energy? Give an interpretation of each of the three components. How does each component figure into the transport? Why is the latent heat flux relatively more important during summer?

The Hadley cell transports sensible and latent heat equatorward, yet it transports total energy poleward. In general, thermally direct circulations in a stably stratified transport total energy down the horizontal temperature gradient and vice versa. Explain.

Explain how the eddy heat fluxes by the stationary waves just above the Earth's surface cool the tropics (equatorward of ~20° latitude) and warm midlatitudes, especially in the summer hemisphere.

Explain how the transient eddies transport latent and sensible heat poleward across the storm tracks at a latitude of ~45°. At what level is this transport strongest?

Is the eddy transport of geopotential across 30° latitude poleward or equatorward? How do we know it is only of minor importance in the transport of total energy at this latitude?

Describe how the annual cycle perturbs the global energy balance with emphasis on how heat storage in the ocean mixed layer reduces the temperature response.

Describe the meridional transport of water vapor by the eddies in the atmosphere with reference to the major wet and dry belts.

Describe the balance requirements for water vapor transport into or out of a prescribed region. Describe the balance requirements for the hydrologic cycle (a) over a prescribed land region including the special case of a closed basin and (b) over a prescribed oceanic region.

On average, there must be a net convergence of water vapor flux onto land. Explain.

Eddies that transport heat poleward tilt westward with height. Explain.

Explain how the equatorward gradient of diabatic heating induces poleward heat fluxes.

The eddies in the lower stratosphere produce a strong poleward eddy heat flux in the absence of a strong meridional heating gradient. Explain how this can occur.

Study guide for ATMS 545 Midterm

Appendix 1 and general knowledge

For each of the following terms, (a) give a physical interpretation, (b) explain, step by step, how it is computed from a table of grid point values of u and v along a latitude circle (rows) sampled at a sequence of times (columns)., and (c) Give two formulas, one with three terms and one with four terms, showing how it contributes to the total transport.

$$\left[\overline{u'v'}\right] \quad \overline{[u]'[v]'} \quad \left[\overline{u^* v^*}\right] \quad \left[\overline{u}^* \overline{v}^*\right]$$

Using the notation introduced in the Appendix, write expressions for the total flux, the flux by the transient eddies, the by the steady mean meridional circulations, the flux by the stationary waves, and the flux by the transient mean meridional circulations.

The above expressions involve both zonal averaging and time averaging. Be prepared to recognize terms arising from decompositions for time averages at a single point and zonal averages at a single time.

Each of the above expressions involve covariances, which can be expressed in terms of the product moment formula (i.e., as the product of the dimensionless correlation coefficient between the two variables and the respective standard deviations. The standard deviation is an indicator of the typical amplitude of the fluctuations in a variable. Be prepared to provide an example with hypothetical numbers.

How long does one need to sample in time to obtain representative general circulation statistics. Does it make sense to separate the data by season.

What distinction might one expect to see between statistics computed for a single winter season and, say, 30 winter seasons 1979-2009 apart from greater statistical reliability of the statistics based on the larger sample?

What distinction might one expect to see between statistics computed for 1979-2009 based on daily data, monthly data, and seasonal-mean data?

What distinction might one expect to see statistics based on data at 2 ° longitude intervals versus, say, 10° longitude intervals?

What are the relative advantages of plotting zonally averaged general circulation statistics using pressure as a linear vertical coordinate versus using height as a linear vertical coordinate?

Why is the horizontal coordinate used in these plots often linear in sine of latitude rather than latitude itself?