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Homework 1

Aug. 31 , 2023

AATM 529 – Air Sea Interactions

Problem 1

(a) Resketch figure 1.7 without any shading.

(b) Next, shade on your figure those regions where the lapse rate is superadiabatic.

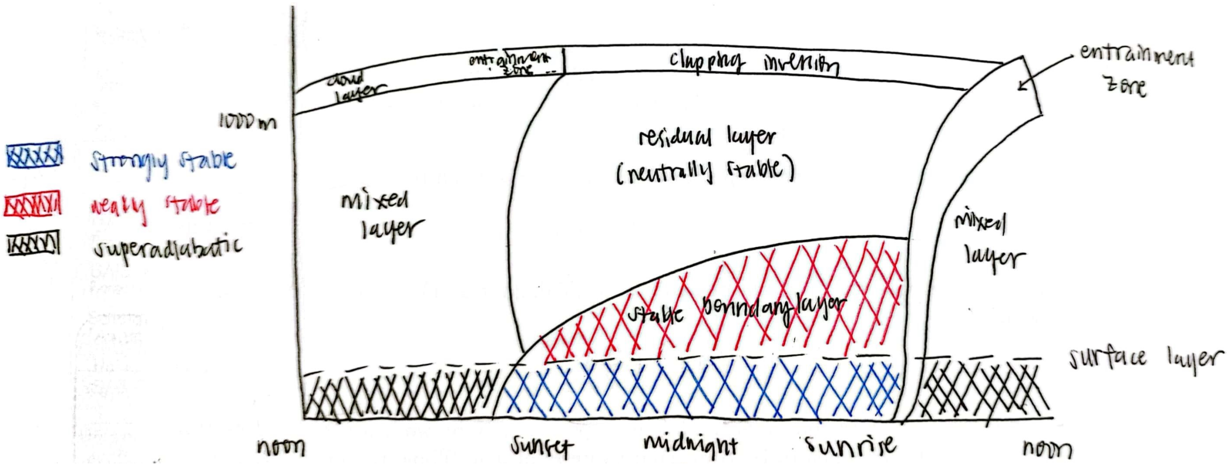
(c) In a different color, shade those regions that have a strongly stable lapse rate.

(d) With a different color, shade those regions that have a weakly stable lapse rate.

(e) Leave the nearly adiabatic lapse rate regions unshaded.

Solution.

The final figure is shown below.



□

Problem 2

From your answer above, we see that a large portion of the mixed layer and the residual layer have nearly adiabatic lapse rates. Nevertheless, there is a difference between the two. Comment on this difference. How would smoke disperse in these regions?From your answer above, we see that a large portion of the mixed layer and the residual layer have nearly adiabatic lapse rates. Nevertheless, there is a difference between the two. Comment on this difference. How would smoke disperse in these regions?

Solution. The mixed layer is statically unstable, while the residual layer is statically neutral. If a smoke plume reaches the residual layer, it disperses and remains on top of the stable boundary layer at night. The stable boundary layer prevents the smoke from dispersing, but only advected upwards and downwind from its source, which is known as **lofting**. After sunrise, the mixed layer begins to grow and overtake the residual layer. Since the mixed layer is unstable, smoke reaching this layer begins to disperse everywhere, and mixed towards the surface. This is known as **fumigation**.

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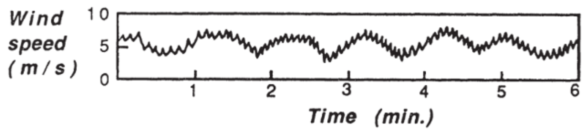
Problem 3

If you observed the following measurement of wind speed on a strip chart, then what diameter (in meters) are the major eddies?



Solution.

Taylor's hypothesis in terms of the mean horizontal wind and time period is given by

$$P = \lambda/M \tag{3.1}$$

where P is the time period, M is the mean horizontal wind speed, and λ is the eddy's diameter. From the plot, the period is about $P = 1\ min = 60\ s$, and the mean wind speed is about $M = 6\ m/s$. Thus, the eddy's diameter is about

$$\lambda = PM = (60\ s)(M = 6\ m/s) = 360\ m \tag{3.2}$$

□

Problem 4

Would there be a boundary layer on a planet that had an atmosphere, but that did not experience a diurnal variation of net radiation at the ground?

Solution. Yes, this planet can still have a boundary layer. However, since it doesn't have a diurnal variation in net radiation, it won't be as turbulent or mixed as the boundary layer in our planet. The mixing in the boundary layer is convectively driven, so without variations in the net energy flux at the ground, turbulence and mixing severely weakens. The boundary layer responds to the planet's surface, and while diurnal changes in net radiation aren't present, other forcings may still be present to drive the boundary layer. Examples of these forcings caused by the surface are frictional drag, terrain, and pollutant emissions. Pollutant emissions (such as aerosols) scatter, absorb, reflect, and transmit radiation which can change the energy budget within the boundary layer.

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Problem 5

Add five items to the list in section 1.8 regarding the significance of the boundary layer.

Solution.

- Studying the energy budget of solar radiation affected by the boundary layer processes (such as aerosol scattering, cloud albedo effects, transmission, and reflection) are important to determine the causes and effects of climate change.
- Studying the boundary layer is important for local agriculture. Changes in dew, frost, temperature, wind gusts, etc. that characterize local climatology can dictate how to better take care of crops and can determine which crops can survive in certain environments.
- The local behavior of wind (such as the land/sea breeze cycle and proximity to mountainous regions) in the boundary layer dictate how wind farms or windmills can effectively harness natural energy.
- Observation sensors such as radars, telescopes, and land/space satellites need to take into account turbulent noise and cloud cover perpetuated in the atmosphere. This is most prevalent within the very turbulent boundary layer.
- Since the daily weather we experience are primarily dictated by the boundary layer's behavior, its processes are necessary to monitor adjustments we need to make to overcome extreme weather (e.g. wearing more layers during freezing winters, hydrating and cooling ourselves during heatwaves).

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