

1. Using the closed system model of Fig 4.21 as a guide, estimate the following energy-related quantities. The "box" is 800 mb deep and is a rectangle with sides: 2000 km in the east-west direction and 1000 km in the north-south direction.

Assume these things about the **eastern half** of the domain:

the surface low exactly covers only the eastern half of the domain.

it is entirely located over ocean.

the volume average virtual temperature is 264 K.

the average surface P = 1000 mb on the eastern side;

the average top pressure is 200 mb on the eastern side

the volume average efficiency factor is $\epsilon = 0.02$

the horizontal average rain rate is 1.5 cm/day.

the eddy wind components are given by $v' = G(p,t)\sin(\gamma)$ and $u' = -G(p,t)\cos(\gamma)$ where γ is a compass angle measured from true north. If p is in mb, then $G(p,t) = U(t) \left(\frac{p-600}{400} \right)$.

a. Estimate the total latent heat energy release rate (Q) in the eastern half of the domain. You may use latent heating and density of liquid water at 0°C. Q has units J/s.

b. Estimate the volume average heating rate (q) in the eastern half of the domain. q has units K/s. The following formula is helpful:

$$Q \text{ (from part 1a)} = \iiint C_p q \, dM = C_p q \iiint dM$$

c. Using q from part b, estimate the volume average T change over 24 hours.

d. Assume that **half** the diabatic energy conversion from the rainfall is simultaneously converted into kinetic energy. Estimate the volume average vertical velocity (ω) above the surface low. Note that using (4.31), we are assuming that:

$$\epsilon Q/2 = -\epsilon \omega/g \iiint \alpha \, dP \, dx \, dy$$

(Your answer should be in Pa/s.)

e. Using (4.34) as a guide, set the local derivative of eddy KE in the eastern half equal to the baroclinic conversion ($=\epsilon Q/2$, from part d). Assume that the storm is initially weak, with wind magnitude $U(0)=3$ m/s. What is the wind magnitude $U(\tau)$ after 24 hours? Express your answer in m/s.

f. Assume that the rain continues even as the low reaches maturity (fig 4.22). To simplify matters, assume that the information is the same as above with these three exceptions: $\epsilon = -0.02$ (since the low now has a cold core); $U(0) = 23$ m/s; and the vertical structure is barotropic: $G(p,t) = U(t)$. What is the wind magnitude (U) after 24 hours in this case?