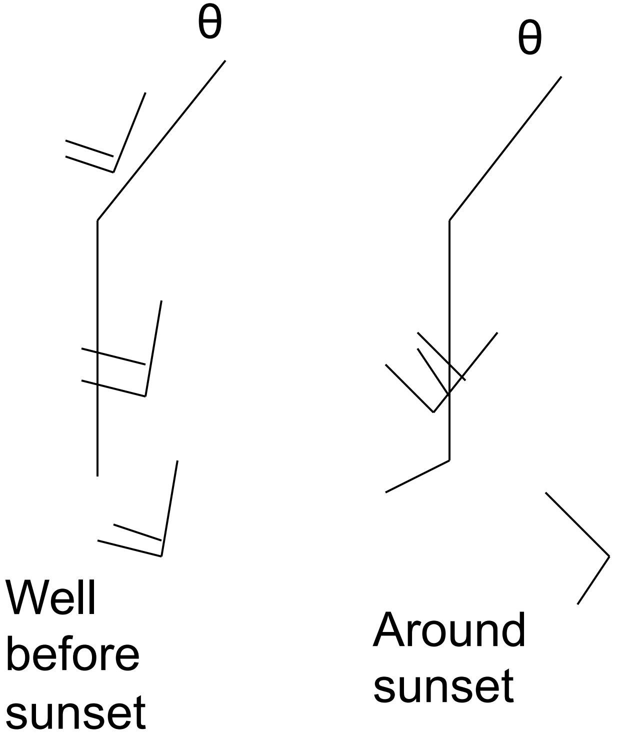
Low Level Jet

Occurrence

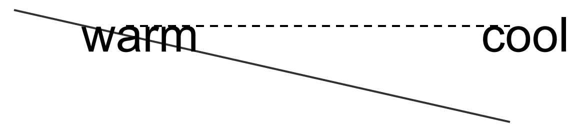
- Most common in late spring and early summer
- Direction is usually from S or SW
- Nocturnal maximum in speeds at least twice that of afternoon minimum (peaks usually reach 30-50 knts at around 925 mb height)
- Important ingredient for MCCs, 75% of all squall lines

Causes

- Inertial Oscillation due to frictional decoupling in early evening



- Baroclinicity produced in inclined boundary layer



•Air currents blocked by Rockies
•Large-scale baroclinicity
•Interactions between upper-level jet streaks and diabatic processes associated with cyclogenesis

Notes

- Isallobaric component due to lee cyclogenesis
- Heating causes pressure gradient to change
- Soil moisture has an impact along with moisture gradients along sloping terrain (dry ground leads to increased speeds but less upward motion at end due to less clouds)

Simple solution for low-level jets

- Begin with horizontal equations of motion:

$Du/dt = -1/\rho \partial p/\partial x + fv$

$Dv/dt = -1/\rho \partial p/\partial y - fu$

Assume the p.g.f. is constant in time

Break the wind into geostrophic and ageostrophic components: $u=u_g+u_a$, $v=v_g+v_a$

- Then we can rewrite the momentum equations as
- $d/dt(u_g+u_a) = -1/\rho\partial p/\partial x + fv_g + fv_a$
- $d/dt(v_g+v_a) = -1/\rho\partial p/\partial y - fu_g - fu_a$
- Recall the geostrophic wind components are given by:

$u_g = -1/\rho f\partial p/\partial y$ since $1/\rho f\partial p/\partial y = -fu_g$

$v_g = 1/\rho f\partial p/\partial x$ since $1/\rho f\partial p/\partial x = fv_g$

And since we assumed the pgf is constant, the geostrophic wind must be constant as well ($du_g/dt = dv_g/dt = 0$)

- Then we can substitute for the pgf in the momentum equations to get:
- $Du_a/dt = -fv_g + fv_g + fv_a = fv_a$
- $Dv_a/dt = fu_g - fu_g - fu_a = -fu_a$
- We can reduce this system to one eqn in one unknown by defining the complex wind vector **V**=u+iv. Then we have:
- $d\mathbf{V}/dt = d/dt\,(u+iv) = du/dt + i\,dv/dt$
- So we get dV/dt by multiplying the 2nd eqn by i an adding to the first

- In terms of this complex vector, ignoring a,

$du/dt = fv$

$+idv/dt = -ifu$

$(du/dt + idv/dt) = -f(iu-v)$

$= -if(u+iv)$ (note $(-if)(iv) = fv$)

Or $D\mathbf{V}/Dt = -if\mathbf{V}$

Integrate $d\mathbf{V}/\mathbf{V} = d(\ln\mathbf{V}) = -ifdt$

$\ln(\mathbf{V}(t)/\mathbf{V}_0) = -if(t-t_0)$

Assume $t_0=0$ is our initial time; then exponentiate to get $\mathbf{V}(t) = \mathbf{V}_0 e^{-ift}$

What does this solution look like?

- Recall the Euler relations:

$e^{i\alpha} = \cos(\alpha) + i\sin(\alpha)$

$e^{-i\alpha} = \cos(\alpha) - i\sin(\alpha)$

Here we have $\alpha=ft$. Then we could rewrite the solution as:

$\mathbf{V}(t) = \mathbf{V}_0[\cos(ft) – i \sin(ft)]$

So $u=u_0\cos(ft)$ and $v=v_0\sin(ft)$

We can see that…

- The amplitude is conserved
- The solution oscillates such that the original phase is recovered at $ft = 2\pi, 4\pi$, etc

Then the period τ of the oscillation is given by $f\tau=2\pi$ or $\tau=2\pi/f$. This is referred to as the inertial period. We see that τ varies with latitude since f varies with latitude. Recall $f=2\Omega\sin\Phi$; while $\Omega=2\pi/\text{day}$. Then we have $\tau=2\pi/f = 2\pi(\text{day})/4\pi\sin\Phi = 1\ \text{day}/2\sin\Phi$. So the inertial period is 1 day when $\sin\Phi=1/2$; ie $\Phi=30^o$

- Numerous other processes have been cited to explain the LLJ. Research has shown that the LLJ is associated with the development of surface cyclones. This in turn can be caused by:

  * lee side troughing

  * adjustment to mass redistribution by upper level jet streaks

Application of equations

- If we know τ and V_a, we can figure out how the LLJ will behave overnight.
- Assume at sunset, V is 10 ms^{-1} from 135^o and V_g is 20 ms^{-1} from 180^o.
- First, need to determine V_a. We need to do this using vector subtraction (break V and V_g into components)

$u_g=0$, $v_g=20$, $u=-7.1$, $v=7.1$

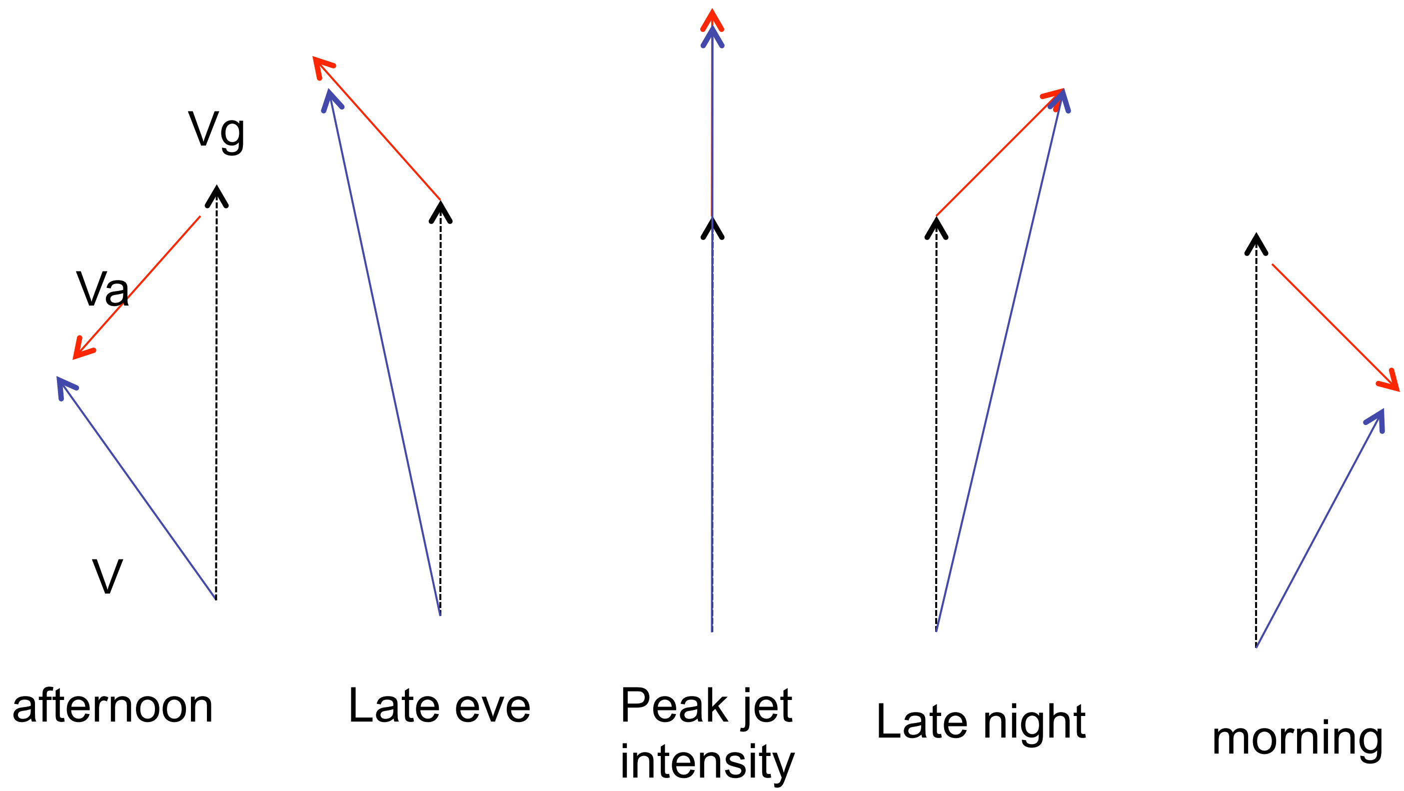
- Thus $u_a = u - u_g$ = -7.1 – 0 = -7.1 m/s
- $V_a = v - v_g$ = 7.1-20 = -12.9 m/s
- So V_a is (-7.1**2 + -12.9**2)**0.5 = 14.5 m/s

and direction is $\tan^{-1}(u_a/v_a) = 29^o$.

τ = 1day/2sinΦ = 18.7 h, so V_a will swing around and make a circle in that time.

- When will the peak wind be? It will be when V_a is in the same direction as V_g. V_g was from 180, so it has to rotate 151 degrees. This will happen in (151/360)*(18.7 h), or about 8-9 hours after sunset.
- What will the peak speed be? Add V_g and V_a. It would be 20 m/s + 14.5 m/s = 34.5 m/s.

Picture what is happening with the ageostrophic wind (and thus LLJ)



Note the LLJ veers during the night and since it is the source of heat/moisture for thunderstorm systems, they also veer in their path overnight too