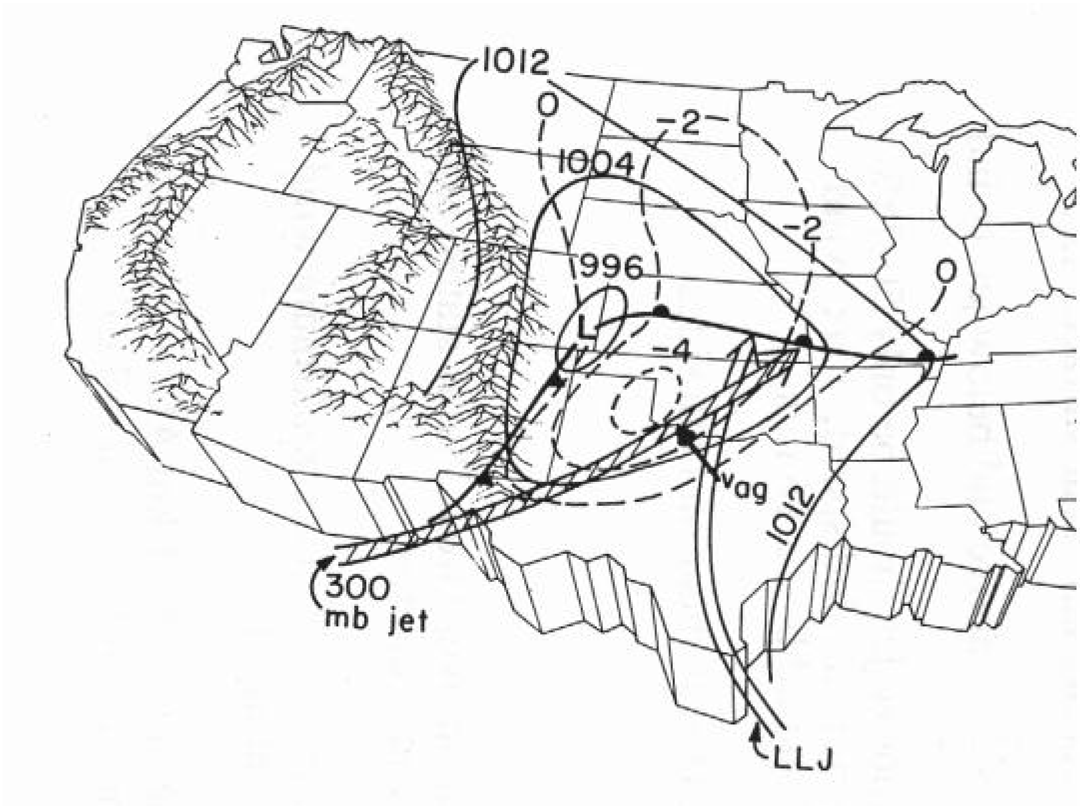
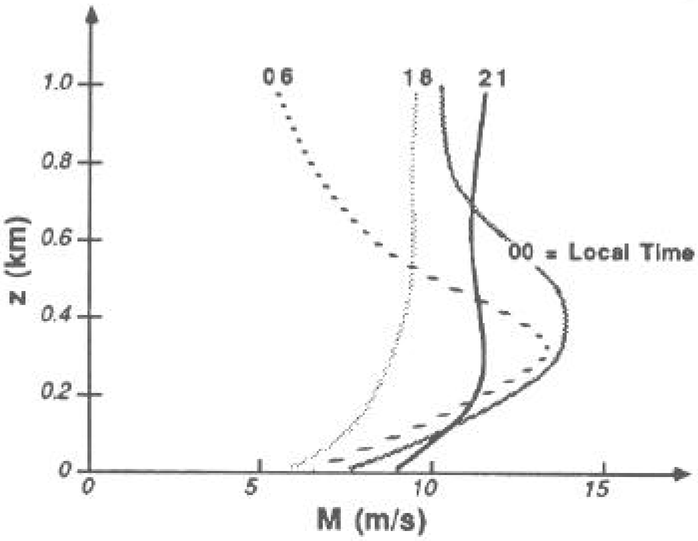
**METR 4433**
**Low Level (Nocturnal) Jet**
Groundhog's Day, 2001
Dr. Keith Brewster

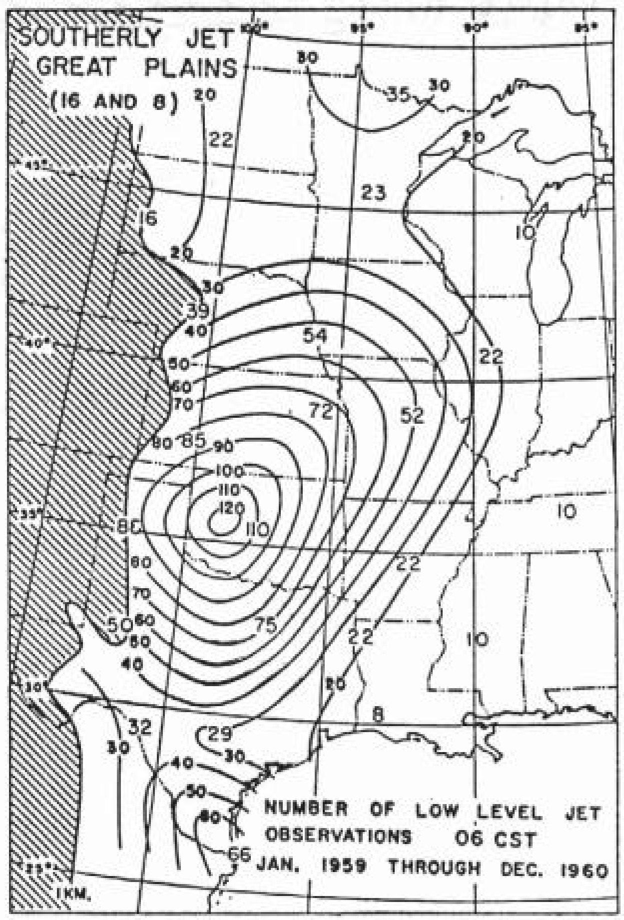



## **Definition:**

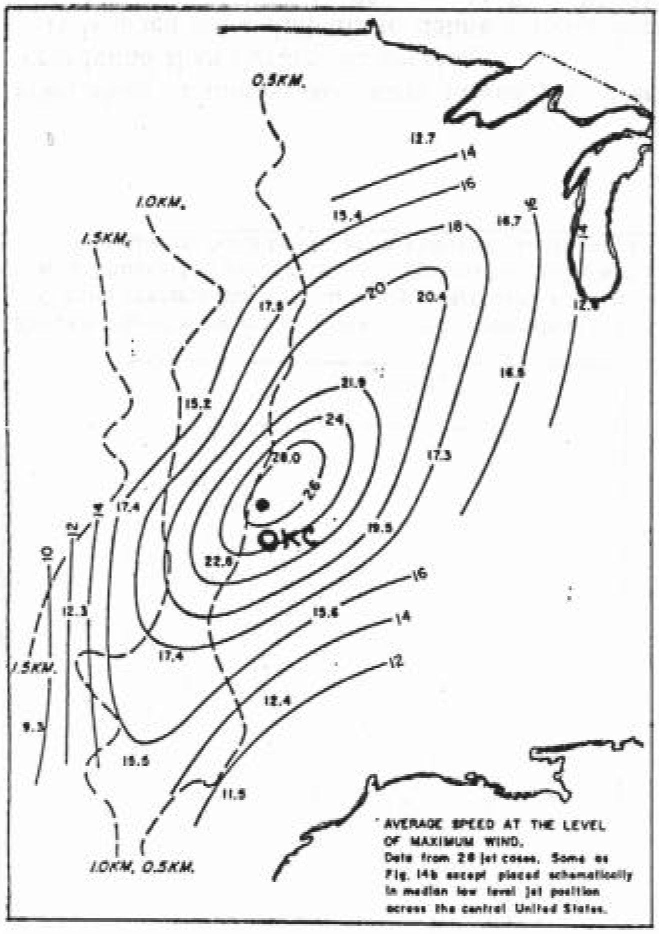
- Fast moving current of air near the surface.
- Large wind shear ($\frac{\partial \vec{V}}{\partial z}$) above and below the jet level.
- Maximum wind speed at least 12-16 m/s (peak speeds up to 30 m/s observed)
- Wind speed above jet 50-75% or less of the maximum.
- Strong lateral shear on both sides. Width typically about 200-300 km.

**Fig. 12.15**
Nocturnal jet evolution during night 13-14 of Wangara. (After Malcher and Kraus, 1983.)

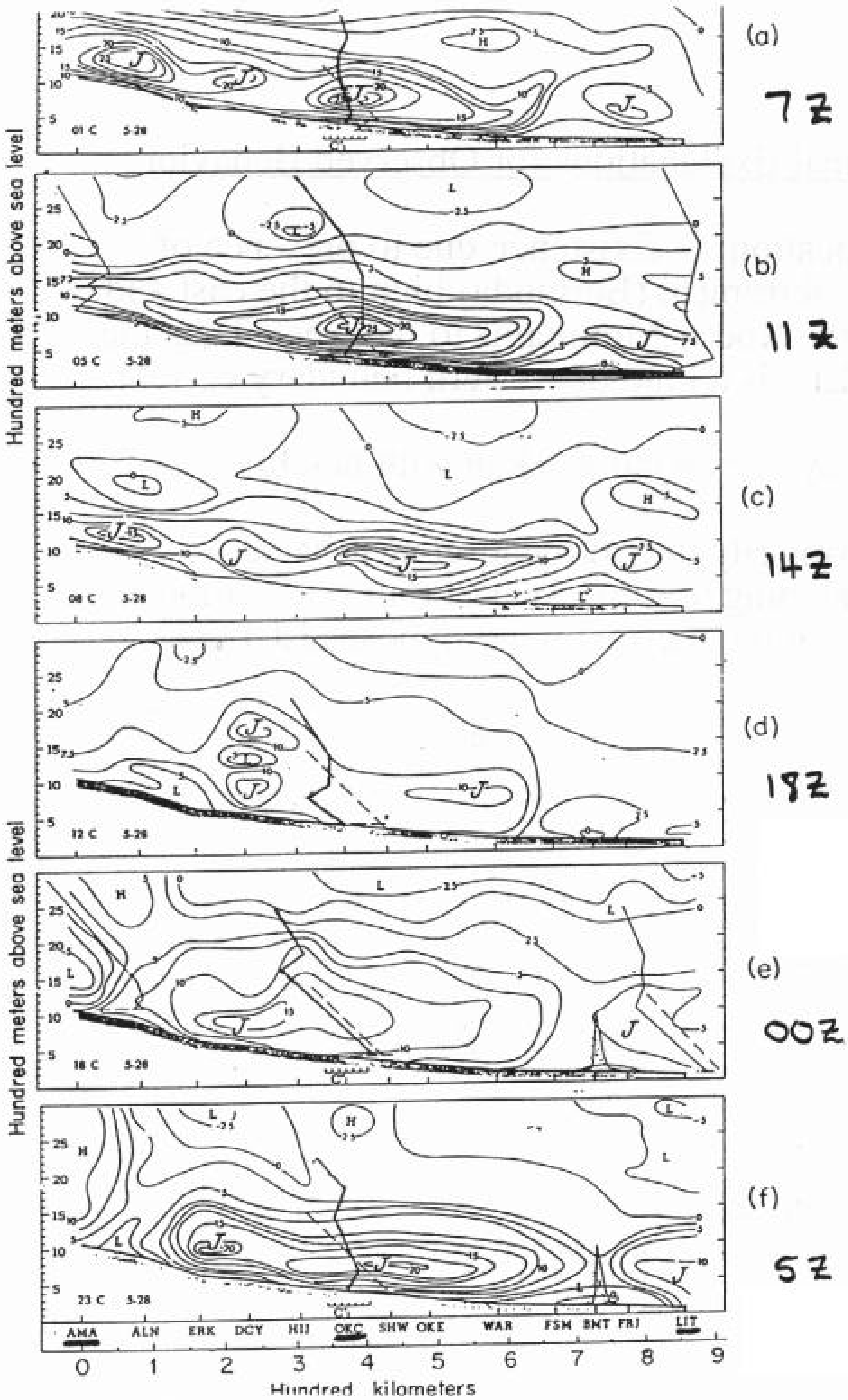





RE 11.—Numbers of Criterion 2 "southerly jet" observations at 06 CST. Two years of data.




RE 15.—Mean isotach pattern (m. sec.$^{-1}$) at the level of maximum wind.



(a)
7Z
(b)
11Z
(c)
14Z
(d)
18Z
(e)
00Z
(f)
5Z
Hundred meters above sea level
01 C 5-28
05 C 5-28
08 C 5-28
12 C 5-28
18 C 5-28
23 C 5-28
AMA ALN ERK DCY HIJ OKC SHW OKE WAR FSM BNT FRI LIT
0 1 2 3 4 5 6 7 8 9
Hundred kilometers

## Climatology: (e.g., Bonner, MWR, 1968)

In the U.S., most common as a southerly jet over the Great Plains, especially in the spring and summer.

Also found, for example, in Australia (Koorin Jet and Southerly Buster) and East Africa (Somali Jet).

For the U.S. Plains version:

Strong diurnal oscillation with strongest wind speeds at night.

Average height 500-1000 m AGL. Near level of nocturnal inversion.

Often the maximum winds are supergeostrophic.

## Meteorological Importance

- Increased northward transport of moisture at jet level.
- Increased low-level convergence at nose of jet.
- Involved in sustaining convection at night – partly responsible for nighttime thunderstorm maximum in Plains.

## Causes:

- Baroclinicity over sloping terrain.
- Inertial oscillation.
- Coupling with return circulation in the jet streak.
- Others

Consider first two causes, as they relate to boundary layer dynamics:

## Baroclinicity Over Sloping Terrain

Thermal Wind Relations:

$$\frac{\partial u_g}{\partial z} = -\frac{g}{f\overline{T}}\frac{\partial \overline{T}}{\partial y}$$

$$\frac{\partial v_g}{\partial z} = \frac{g}{f\overline{T}}\frac{\partial \overline{T}}{\partial x}$$

where $\overline{T}$ is a layer-mean temperature.

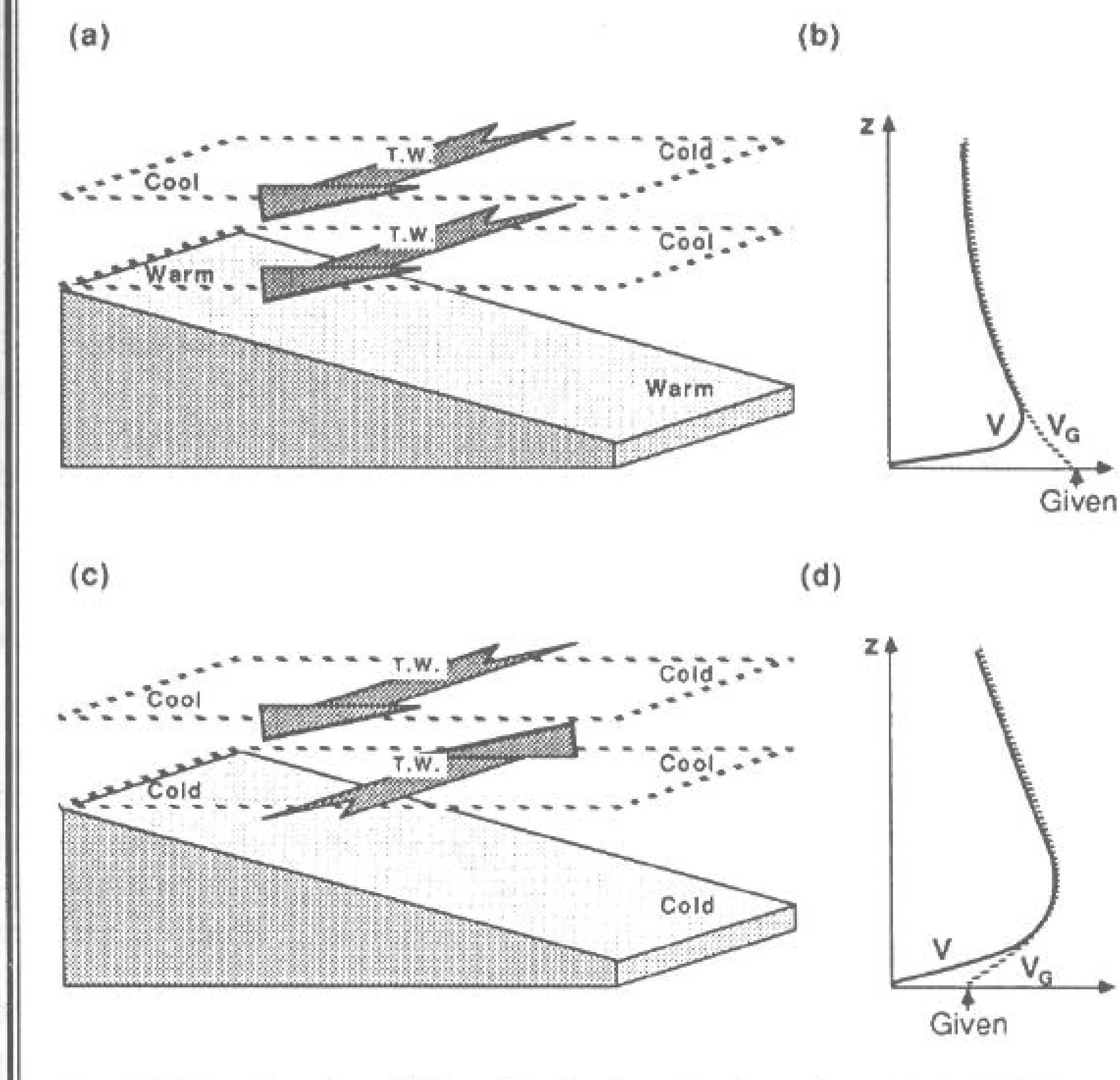


Fig. 12.17 Diurnal oscillation of the low level jet due to thermal wind (T.W.) forcings over sloping terrain.

Daytime (a,b):
Solar insolation warms ground and forms mixed layer with near-adiabatic lapse rate so that west-to-east temperature gradient – measured along a horizontal surface – is negative $\frac{\partial T}{\partial x} < 0$ near the ground and aloft. So thermal wind: $\frac{\partial v_g}{\partial z} < 0$. Mixing is strong during the daytime and tends to blur the effect so that

Nighttime (c,d)

Ground cools more quickly than the air and the gradient is reversed, west-to-east temperature gradient – measured along a horizontal surface – is positive $\frac{\partial T}{\partial x} > 0$ near the ground. So thermal wind: $\frac{\partial v_g}{\partial z} > 0$. Above the level of the inversion the gradient may again reverse such that $\frac{\partial v_g}{\partial z} < 0$. Near the ground frictional forces decrease the wind speed. This leads to the formation of a jet at the level of nocturnal inversion. The stability of the air (lack of mixing) below the inversion helps the jet to persist.

## **Inertial Oscillation**

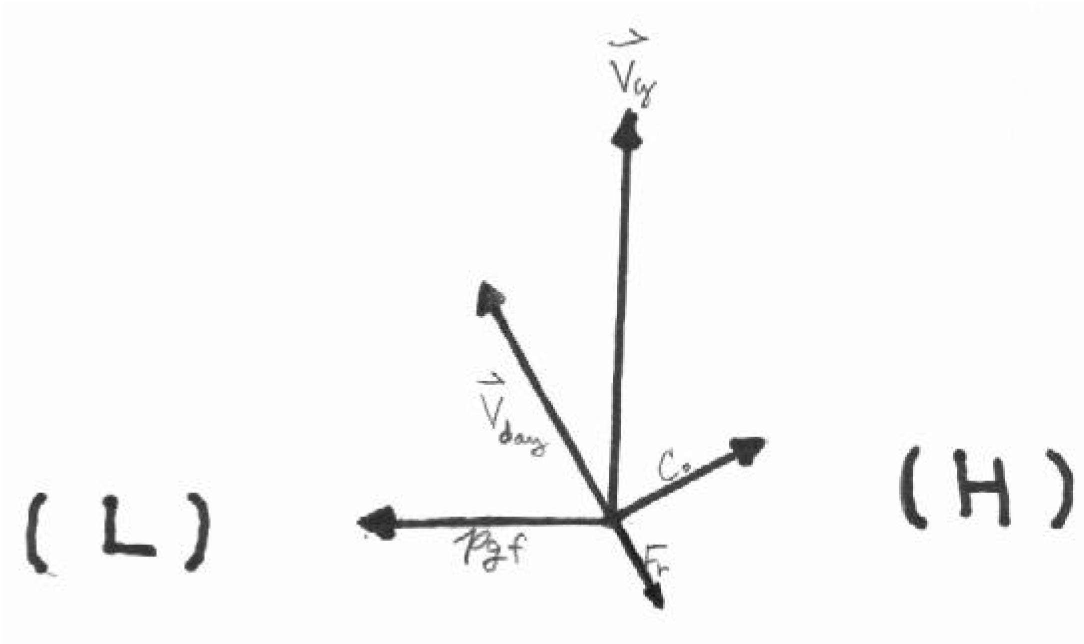
The classic example of an oscillating system is a pendulum. The stable (or balanced) position of a pendulum is pointing straight down. A push of the pendulum to one side will cause it to return to the balance point, but its momentum will carry it past that point, and it will swing up on the other side.

The "Foucault Pendulum" is said to have an inertial oscillation as it swings in a plane which is fixed in an inertial reference frame (fixed in space) while the earth rotates below it – hence demonstrating the Coriolis force.

The behavior of the Low Level Jet has some properties of an inertial oscillation.

Consider the "Balance Point" for atmospheric motion: Geostrophy.

Frictional drag keeps the wind below geostrophy in the mixed PBL during the day.
At night, the stable layer reduces drag to only the lowest tens of meters.
Air above that accelerates as friction is "released".




Mathematically, consider the behavior of the ageostrophic flow, after friction is released:

$$\frac{\partial}{\partial t}\left(u-u_g\right)= f\left(v-v_g\right) \qquad \text{(a)}$$

$$\frac{\partial}{\partial t}\left(v-v_g\right)=-f\left(u-u_g\right) \qquad \text{(b)}$$

Solve this system of equations. Differentiate (a) with respect to time:

$$\frac{\partial^2}{\partial t^2}\left(u-u_g\right)= f\frac{\partial}{\partial t}\left(v-v_g\right)$$

Substitute from (b)

$$\frac{\partial^2}{\partial t^2}\left(u-u_g\right)=-f^2\left(u-u_g\right)$$

Similarly

$$\frac{\partial^2}{\partial t^2}\left(v-v_g\right)=-f^2\left(v-v_g\right)$$

These have solutions of the form:

$$\left(u-u_g\right)= A\sin( ft+a )$$

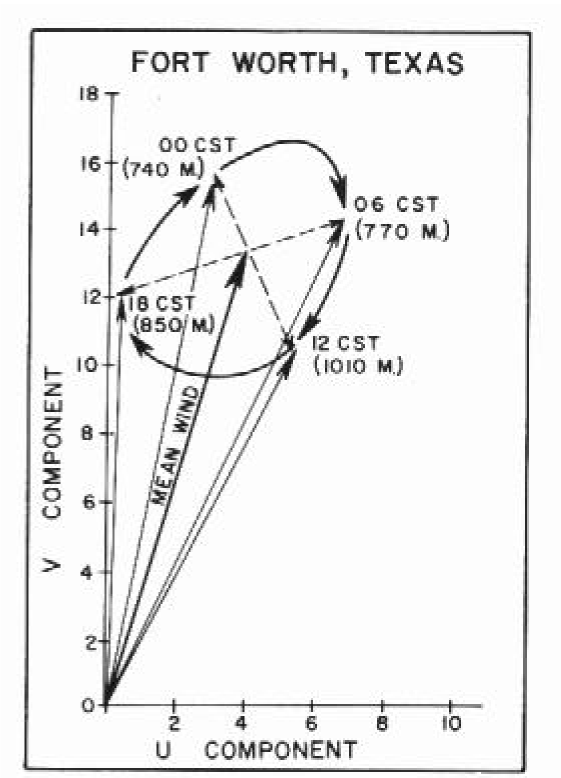
$$\left(v - v_g\right) = A\cos(ft + a)$$

Period T=2π/*f*

Period as a function of Latitude

| *Latitude* | *Period* |
|---|---|
| 20 | 34.9 hr |
| 25 | 28.3 hr |
| 30 | 23.9 hr |
| 35 | 20.9 hr |
| 40 | 18.6 hr |
| 45 | 16.9 hr |
| 50 | 15.6 hr |

A Real Data Case




Low-level convergence resulting from ageostrophic winds associated with nocturnal jet can trigger thunderstorms / convection.