Supergeostrophic and Subgeostrophic winds

We now want to compare the wind speed in a trough and ridge against the theoretical geostrophic value.

Recall the gradient wind equation

(1) $$\frac{|\vec{V}|^2}{R} + f|\vec{V}| = -\frac{\partial \Phi}{\partial n}$$

By substituting the geostrophic wind relationship $|\vec{V}_g| = \frac{-1}{f}\frac{\partial \Phi}{\partial n}$ into (1), we get

(2) $$\frac{|\vec{V}|^2}{R} + f|\vec{V}| - f|\vec{V}_g| = 0$$

Dividing by $f|\vec{V}|$ gives

(3) $$\frac{|\vec{V}_g|}{|\vec{V}|} = 1 + \frac{|\vec{V}|}{fR}$$

There are 3 cases to examine: cyclonic flow, anticyclonic flow, and straight flow. Eq. (3) allows us to compare the geostrophic estimate of the wind speed, which neglects curvature of the flow, with the gradient estimate of the wind speed, which includes curvature of the flow.

Cyclonic ($R>0$)	Anticylonic ($R<0$)	straight ($R\to\infty$)
$\lvert\vec{V_g}\rvert / \lvert\vec{V}\rvert > 1$	$\lvert\vec{V_g}\rvert / \lvert\vec{V}\rvert < 1$	$\lvert\vec{V_g}\rvert / \lvert\vec{V}\rvert = 1$
or	or	or
$\lvert\vec{V}\rvert < \lvert\vec{V_g}\rvert$	$\lvert\vec{V}\rvert > \lvert\vec{V_g}\rvert$	$\lvert\vec{V}\rvert = \lvert\vec{V_g}\rvert$
Wind is <u>subgeostrophic</u> in a trough	Wind is <u>supergeostrophic</u> in a ridge	Wind is geostrophic

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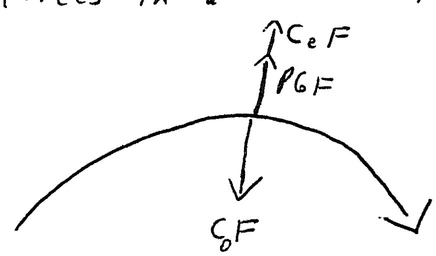
The reason for these differences is that when flow is curved, the centrifugal force becomes important and deviations from $\lvert\vec{V_g}\rvert$ occur.

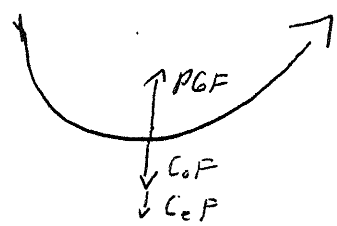
Consider the balance of forces in a ridge



A moving object will continue moving in a straight line unless acted upon by an unbalanced force. But in order to keep the path curved (parallel to isobars) in a ridge, the Coriolis Force must balance both the

Pressure Gradient force and the Centrifugal force. Since CoF is proportional to wind speed, a faster wind is needed for a balance to occur in a ridge than if the air flow was straight with the same pressure gradient. We call this <u>supergeostrophic wind</u>, where $|\vec{V}| > |\vec{V}_g|$.

Now consider the balance of forces in a trough:

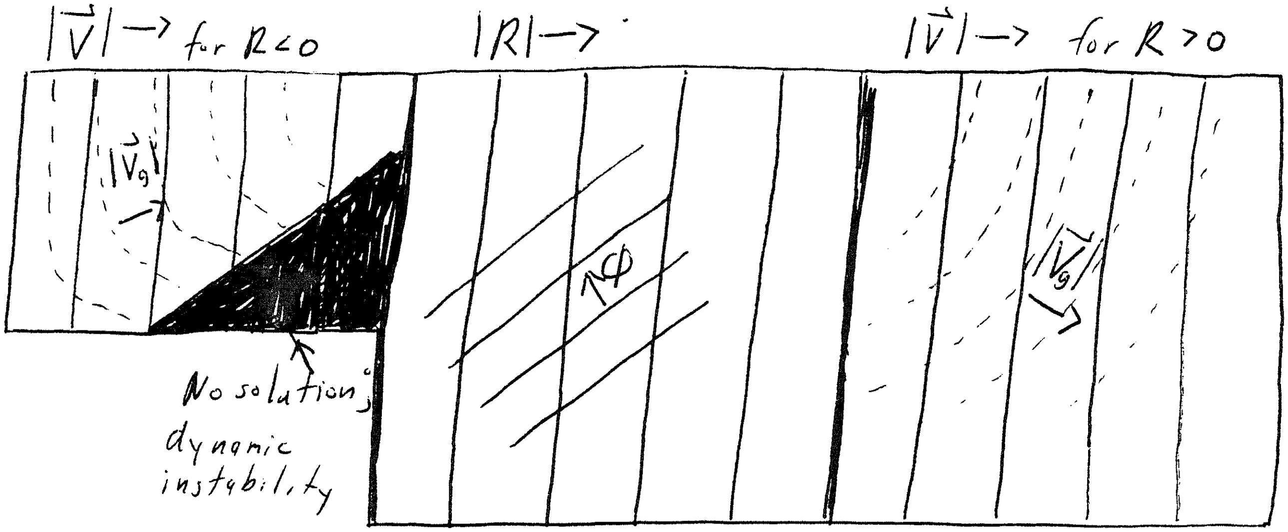


In a trough, the Coriolis and centrifugal terms act together to balance the Pressure Gradient force. In a sense, CoF is "helped" by CeF, and less wind is needed to achieve a balance with PGF than if the air flow was straight with the same PGF. We call this <u>subgeostrophic</u> wind, where $|\vec{V}| < |\vec{V}_g|$.

In actual practice on weather maps, the differences between $|\vec{V}|$ and $|\vec{V}_g|$ are small until the wind speed is high.

Gradient wind nomogram

By solving Eq. (2), graphical comparisons may be done for $R>0$ and $R<0$. (see graphical handout)



Steps:

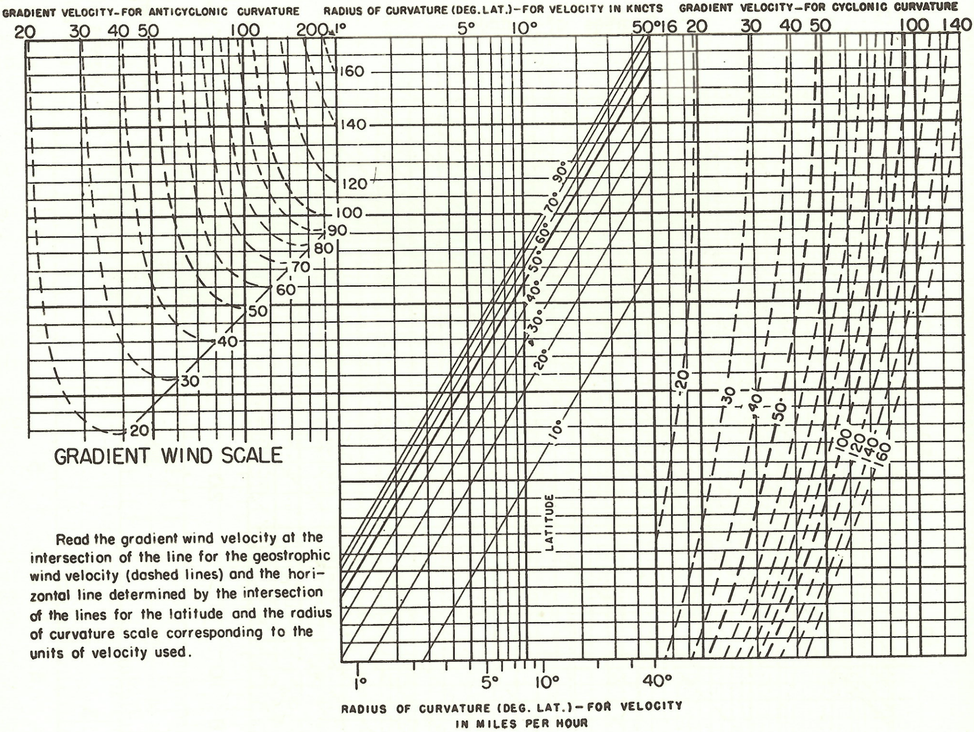
1) Find intersection of $|R|$ and ϕ, where R is the radius of curvature and ϕ is latitude. Compute $|\vec{V}_g|$ on geostrophic nomogram.

2) If $R>0$, go right. If $R<0$, go left. Go to intersection of corresponding $|\vec{V}_g|$.

3) Where $|\vec{V}_g|$ intersects the x-axis value gives the gradient wind $|\vec{V}|$.

Gradient Wind Scale

(After J. C. Bellamy)



Read the gradient wind velocity at the intersection of the line for the geostrophic wind velocity (dashed lines) and the horizontal line determined by the intersection of the lines for the latitude and the radius of curvature scale corresponding to the units of velocity used.

Nomogram example.

Let $R = 10^\circ$ at $\phi = 45^\circ N$. Wind is in knots.

For cyclonic curvature $R > 0$

$\lvert\vec{V}_g\rvert$	20	40	50	100
$\lvert\vec{V}\rvert$	19	35	42	75
difference	1	5	8	25
%	5	13	16	25

For anticyclonic curvature $R < 0$

$\lvert\vec{V}_g\rvert$	20	40	50	
$\lvert\vec{V}\rvert$	23	53	80	
difference	3	13	30	
%	13	25	38	

For fast winds the difference between $\lvert\vec{V}_g\rvert$ and $\lvert\vec{V}\rvert$ are considerable.

For the same $\lvert\vec{V}_g\rvert$, ridges contain larger differences than troughs at the same latitude and with same $\lvert R\rvert$.