Dynamic meteorology without tears

Part V: Rossby's planetary waves

5th Moscow lecture May 2016
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What “is” a Rossby wave?

Lunch discussion at ECMWF around 1995:

Scientist: -What about the weekend weather?

AP: -Oh, Fine!

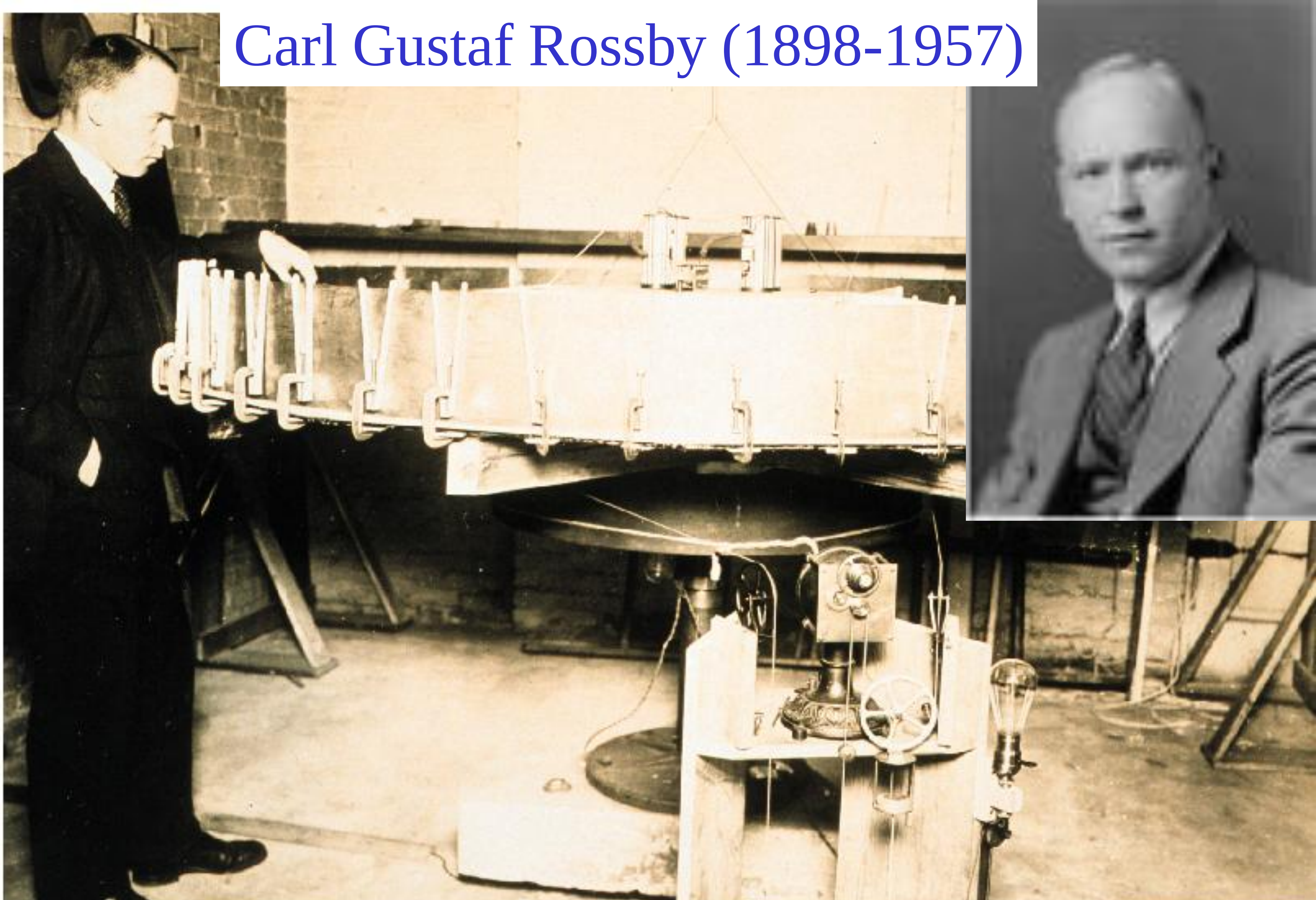
Scientist: -How can you be so sure?

AP: -A big Rossby wave is seen coming in!

Scientist: -But can you *see* a Rossby wave??

AP: -Rossby obviously saw them in the 1930’s!

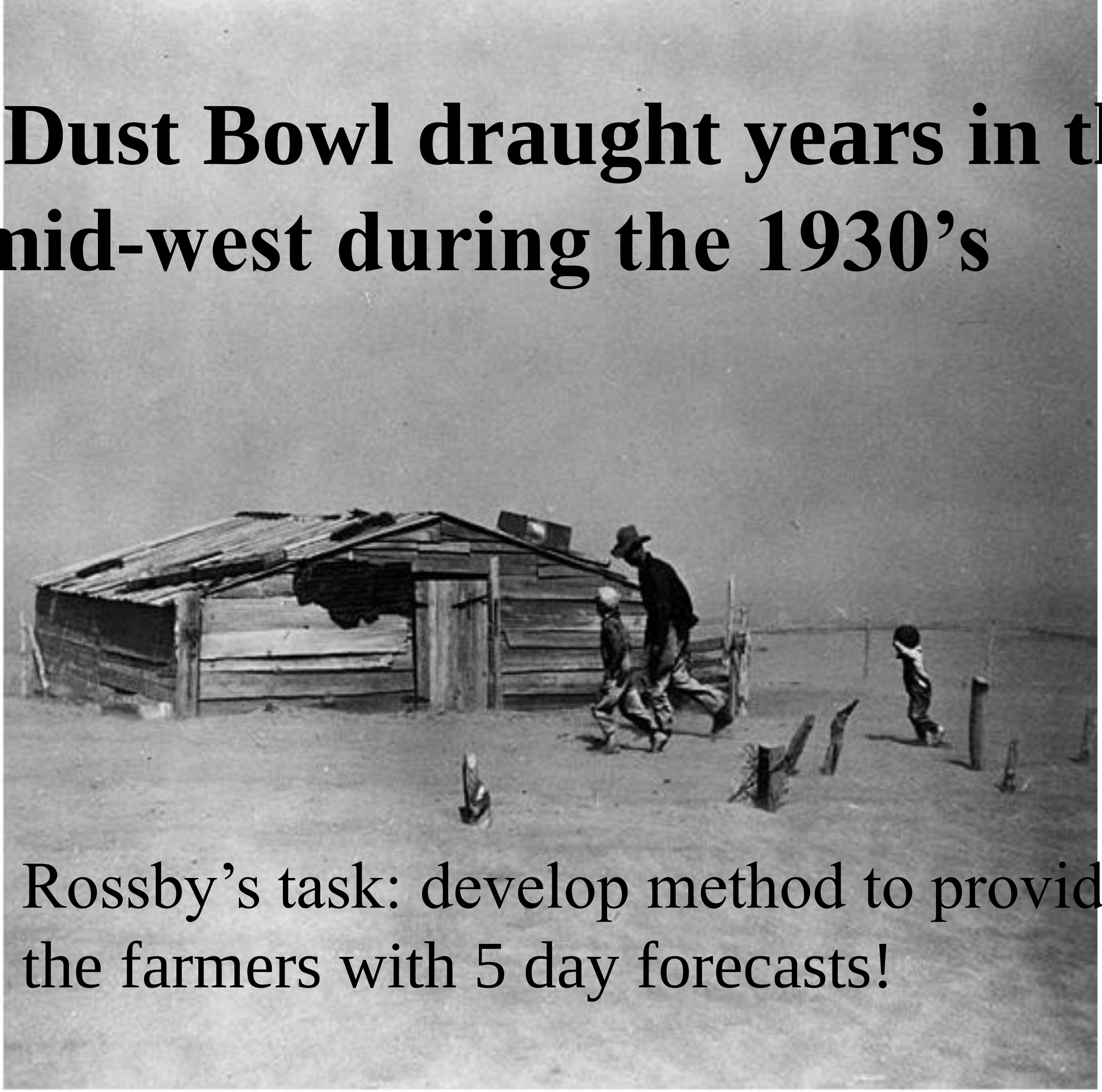
Carl Gustaf Rossby (1898-1957)



Carl Gustaf Rossby (1898-1957)

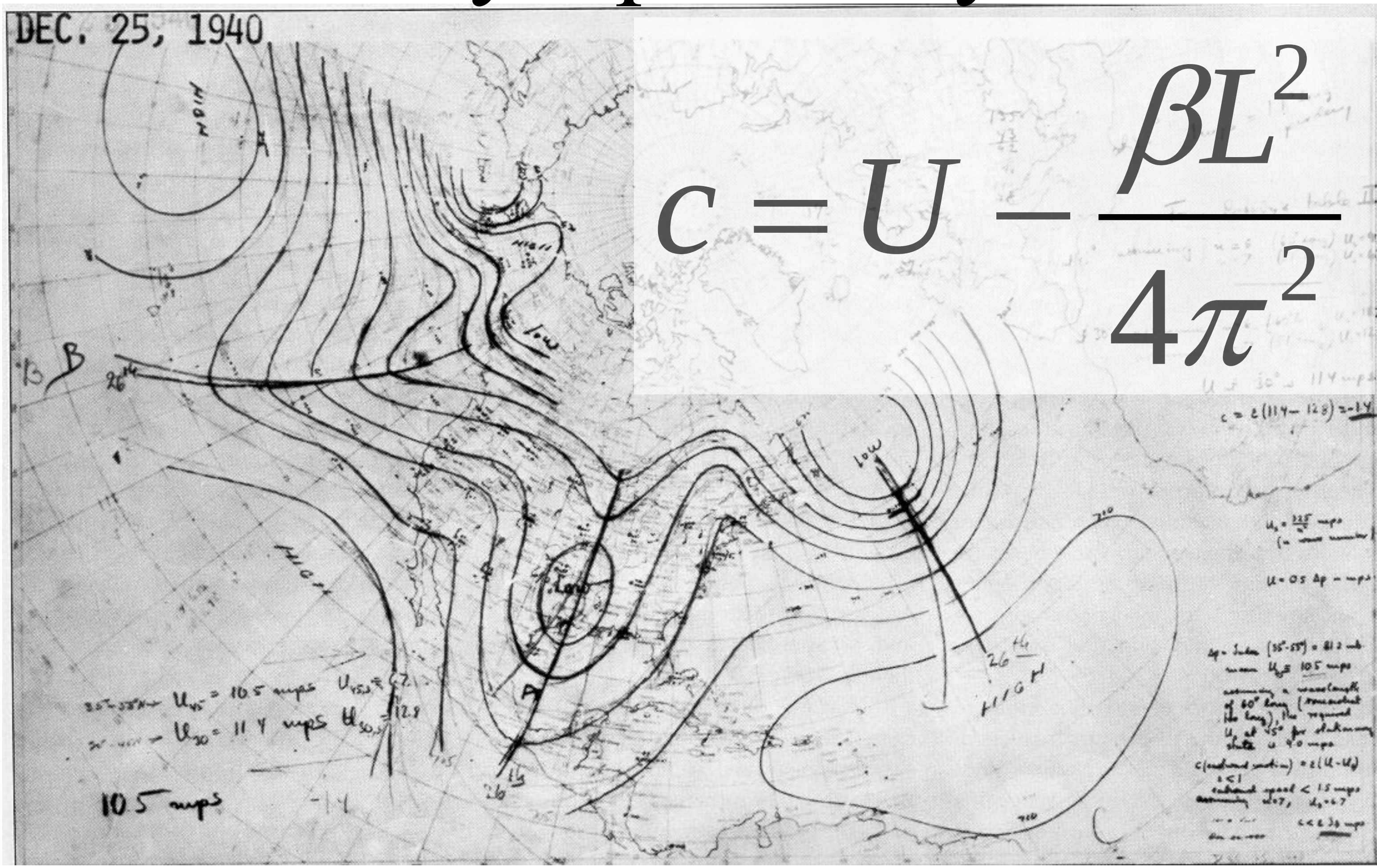
1898	Born in Stockholm, Sweden
1919-20	Bjerknes group in Bergen
1921	Studying aerology in Germany
1922-25	Weather forecaster at SMHI
1926	Moves to the United States of America to spread the Bergen school concept
1936-38	Works on geostrophic adjustment problems
1938-39	Discovers and explains “his” wave

The Dust Bowl draught years in the US mid-west during the 1930’s



Rossby’s task: develop method to provide the farmers with 5 day forecasts!

C-G Rossby's planetary waves



$$c = U - \frac{\beta L^2}{4\pi^2}$$

c = phase speed, U= zonal flow at 5-6 km, L=wave length, β=df/dy

Going west for large L, going east for small L

The wave equation was used in practical forecasting

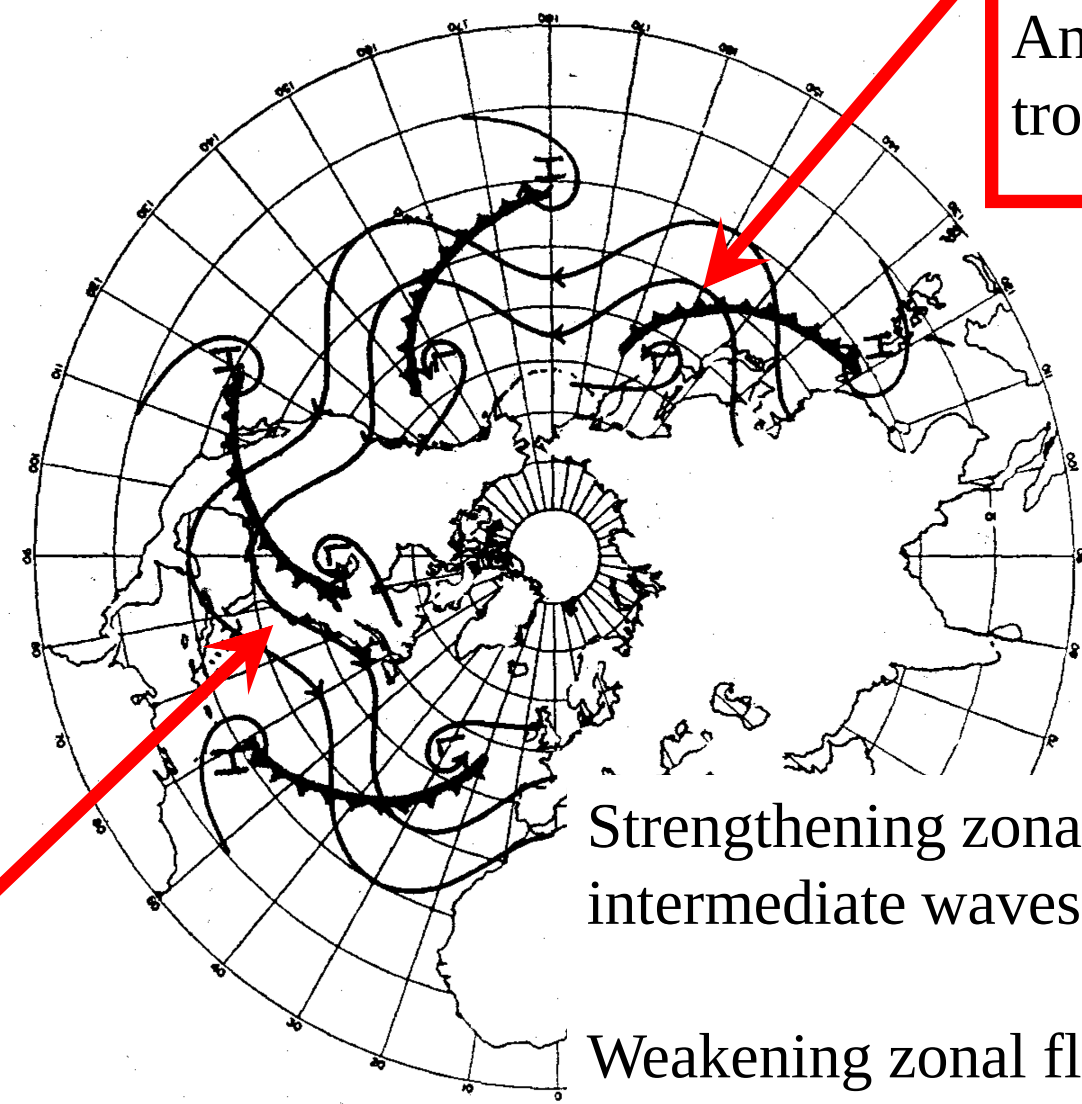
For stationary waves ($c=0$) we can derive their wave length (L_s)

$$L_S = 2\pi\sqrt{\frac{U}{\beta}}$$

Differences between the current wave length (L) and the stationary (L_s) gave indications about re-positionings (c)

$$c = U\left(1 - \frac{L^2}{L_S{}^2}\right)$$

Major troughs on the westernmost side of the big oceans were considered stationary **“anchor troughs”**

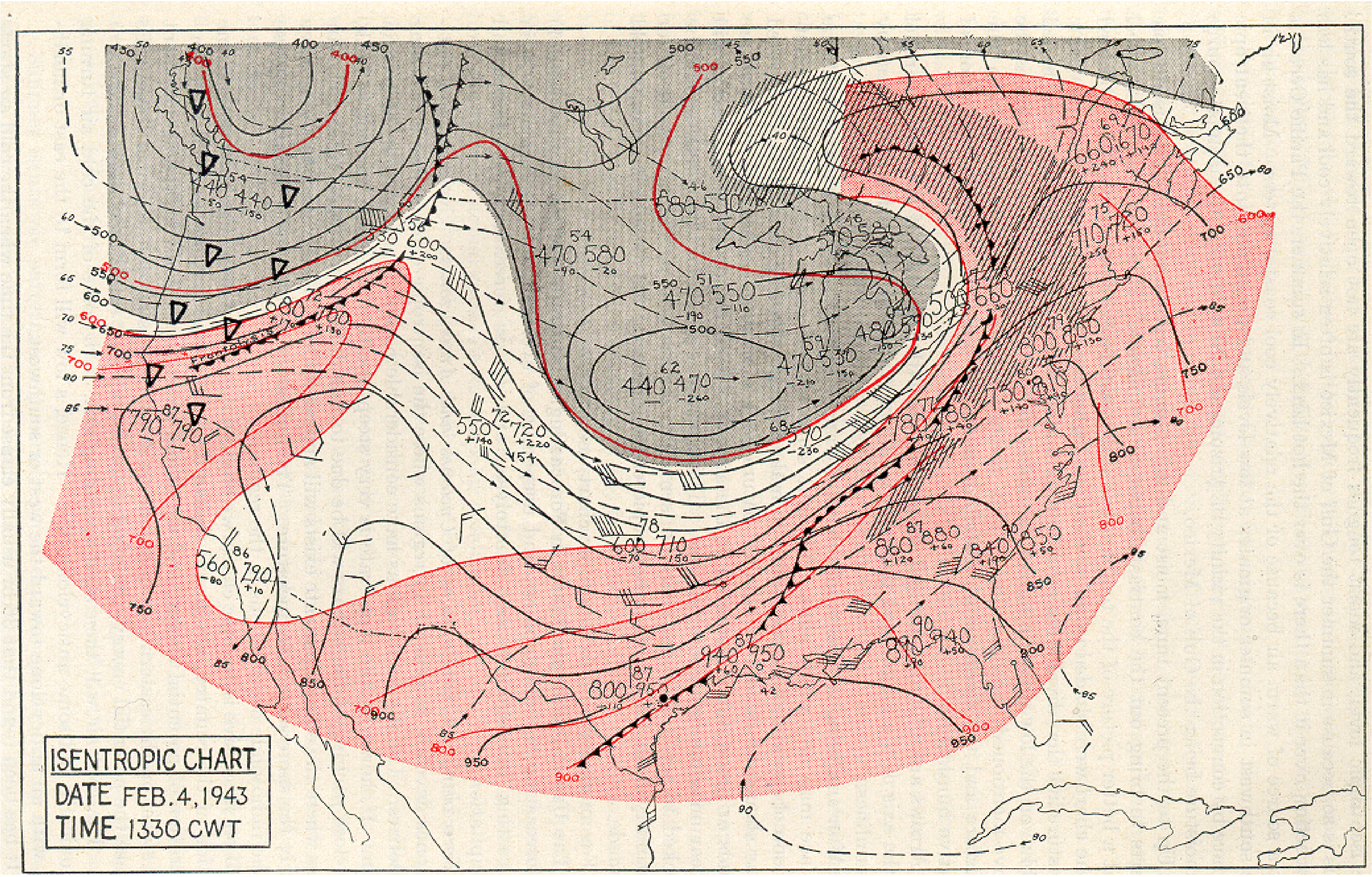


Anchor trough

Anchor trough

Strengthening zonal flow→ intermediate waves disappear

Weakening zonal flow→ more waves appear



The planetary wave approach was combined with isentropic analysis

Five-day forecasts from August 1940

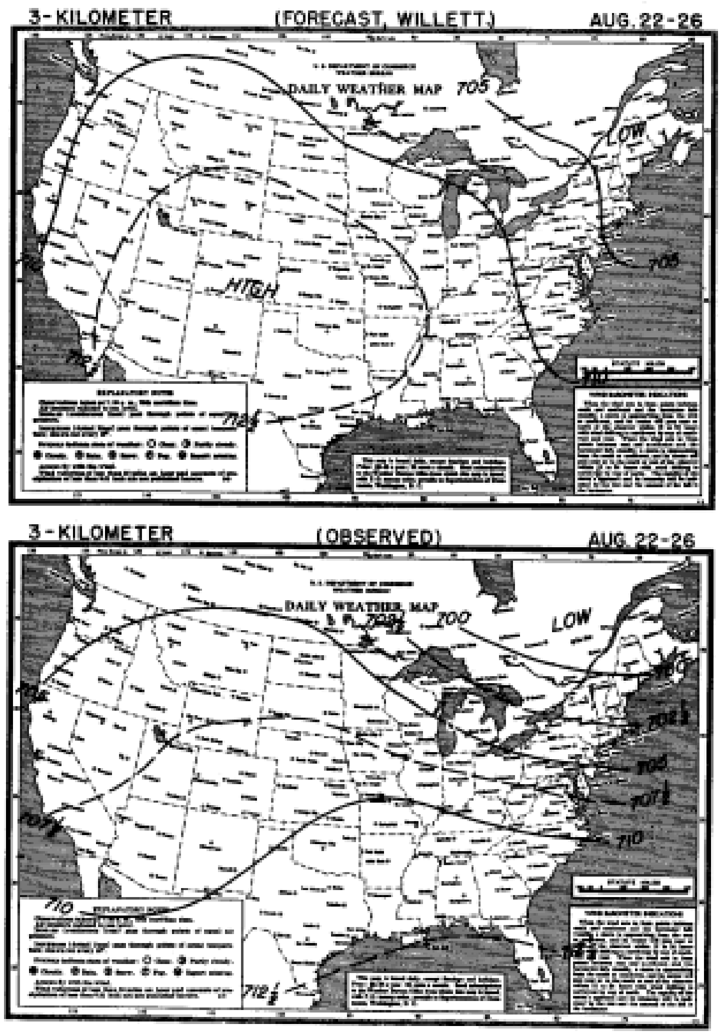


FIGURE 35.—Forecast and verification charts of mean 3-kilometer-pressure distribution (millibars) over the United States for the period August 21–25, 1940.

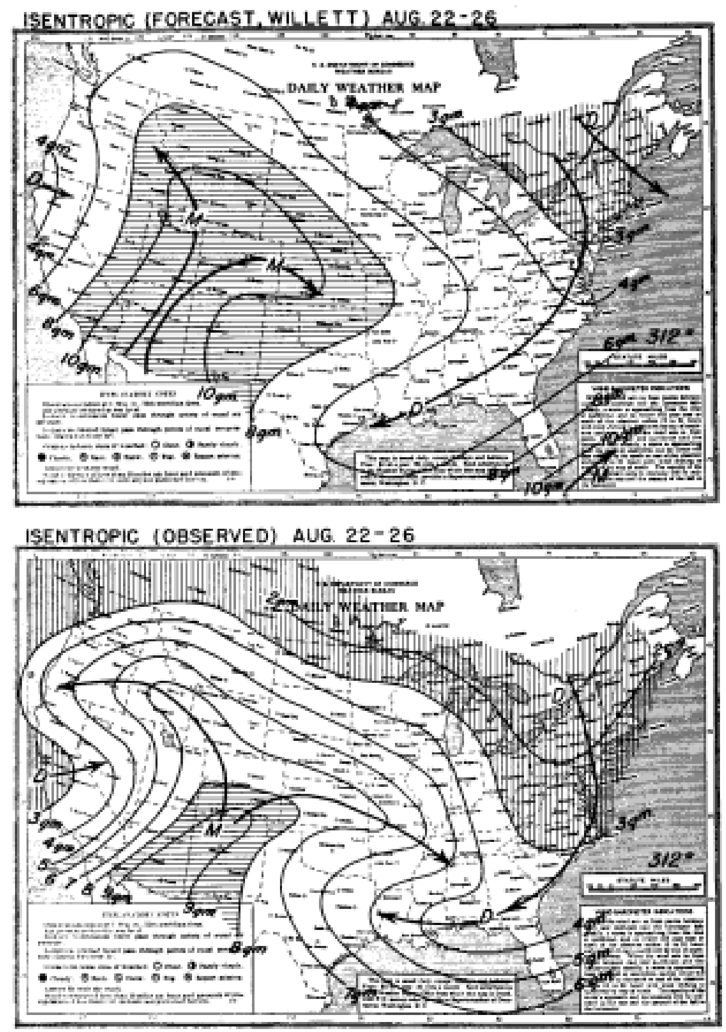
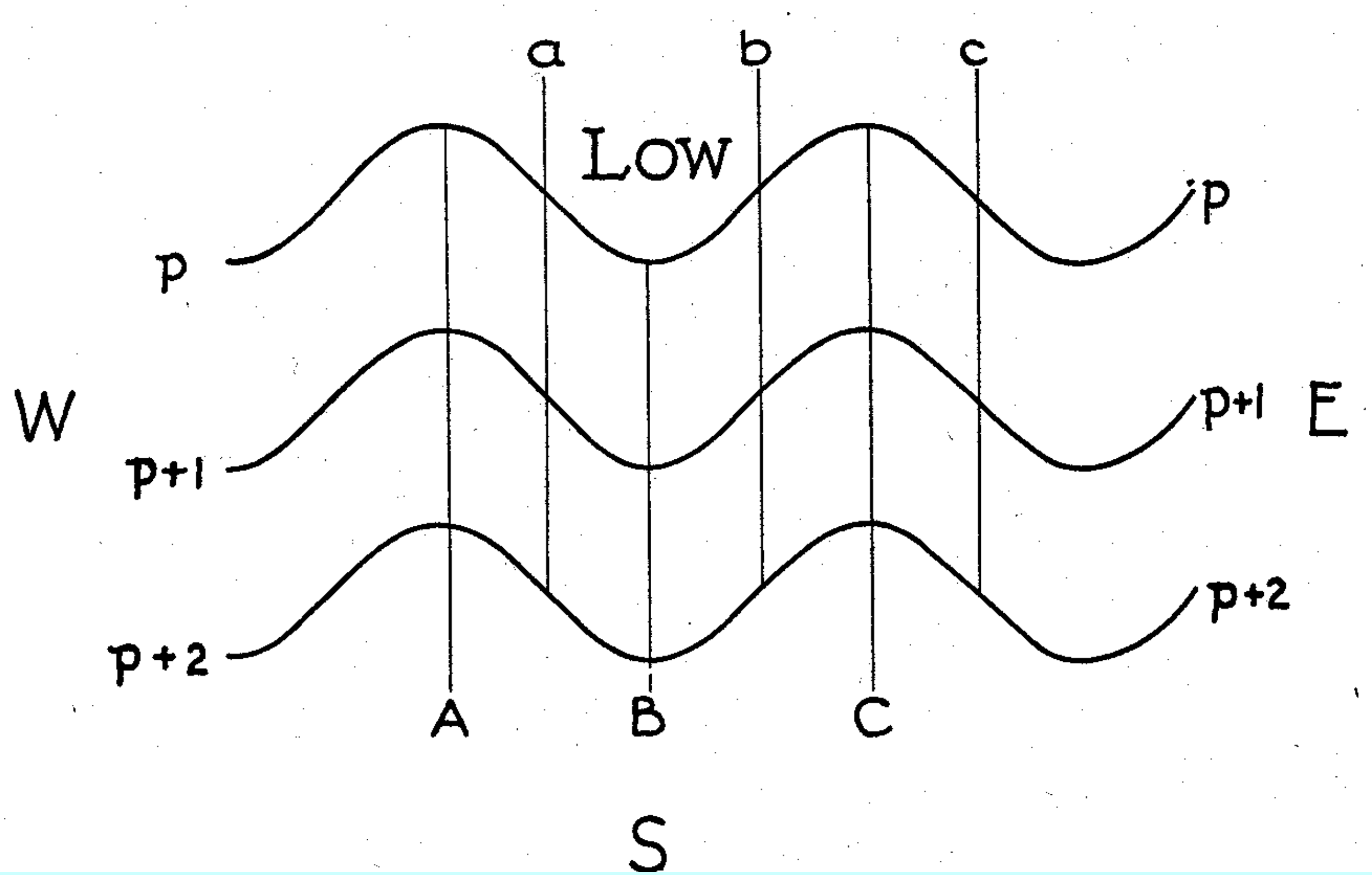
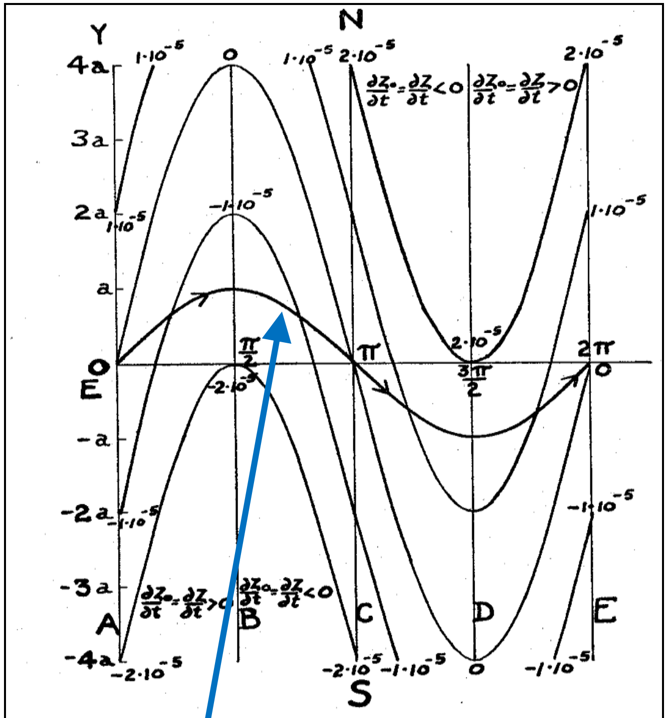


FIGURE 36.—Forecast and verification charts of the mean isentropic-moisture distribution over the United States for the period August 21–25, 1940.

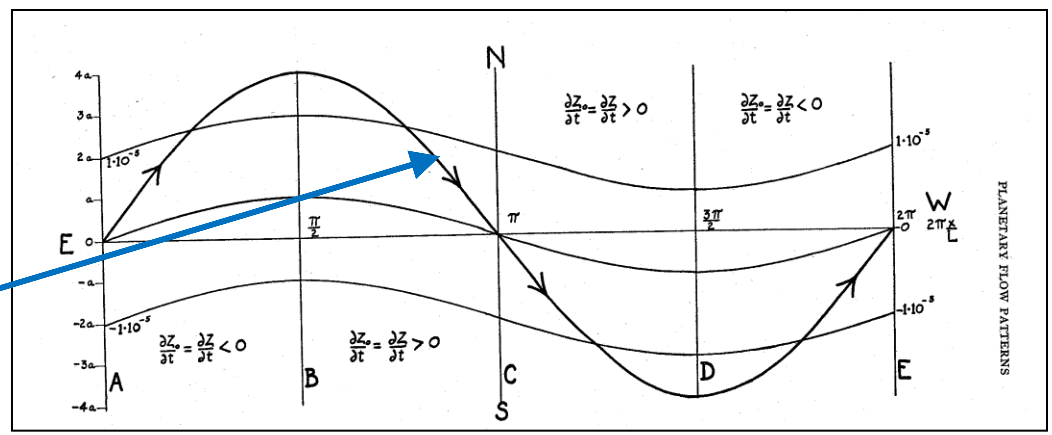
The isobaric channel illustration used by Rossby (1939)



…to which he **wrongly** applied the gradient wind equation and had to publish a new explanation in QJRMS in 1940

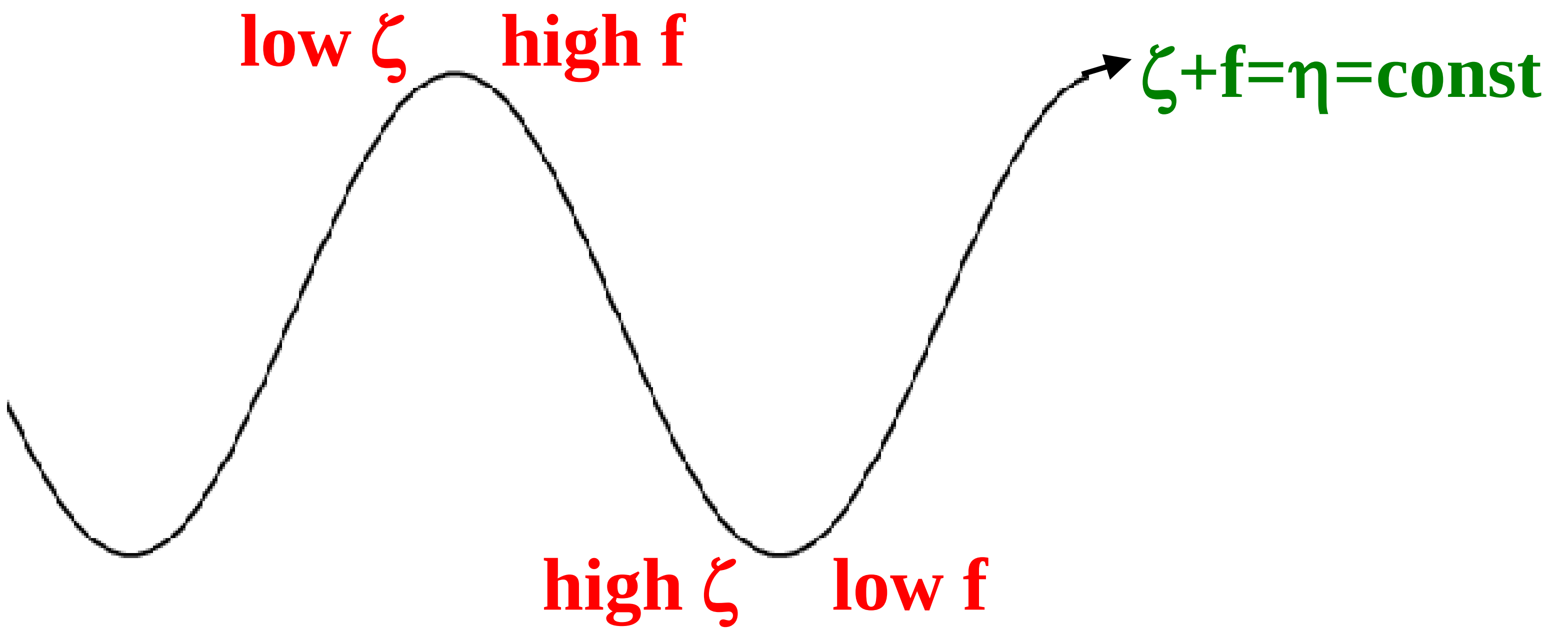


Very few seem to have taken notice of the Rossby (1940) correction - and even fewer understood what he meant



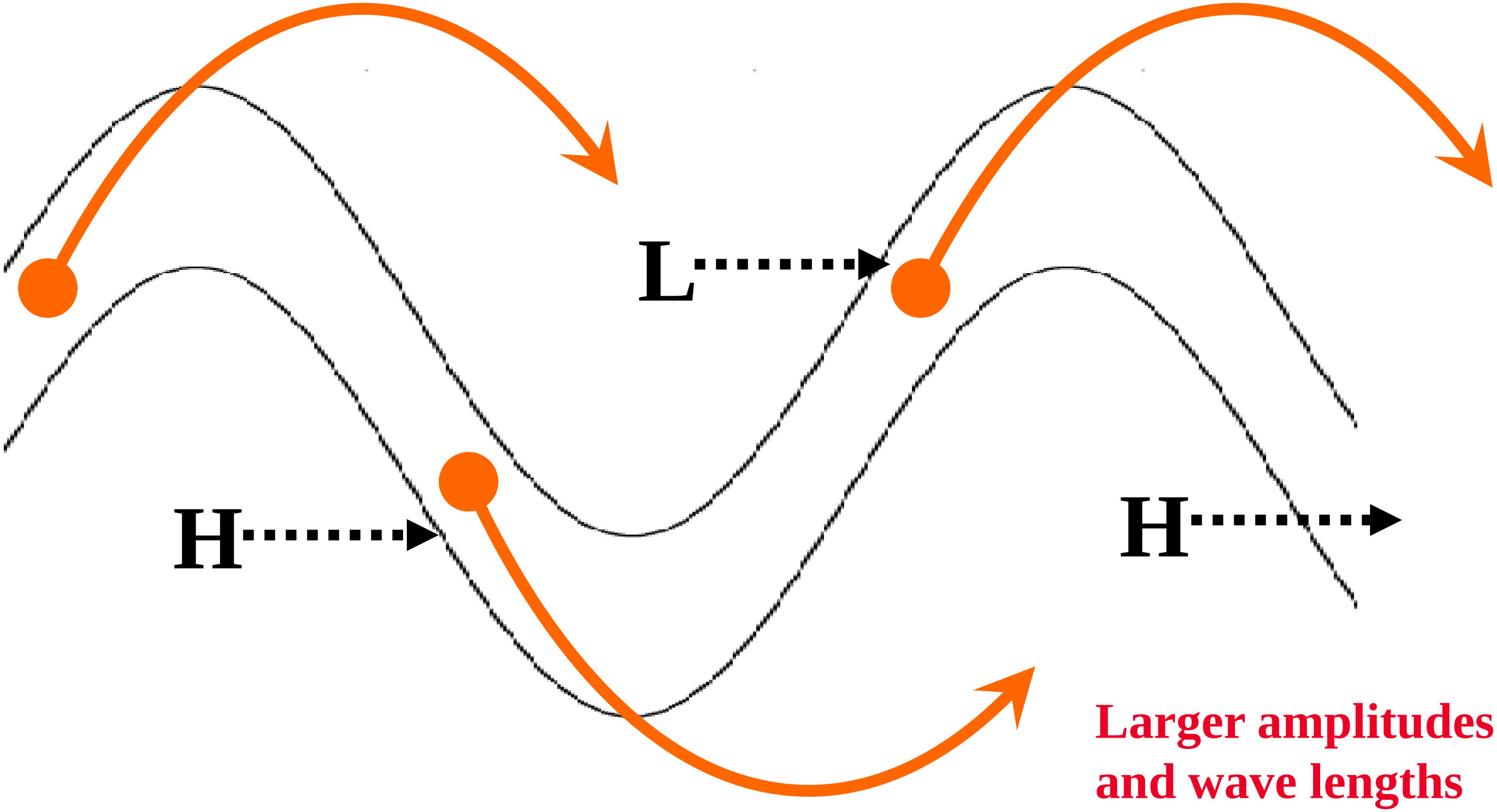
Trajectories and PV isolines

In his new derivation 1940 Rossby made use of conservation of absolute vorticity $\zeta+f=\eta=const$



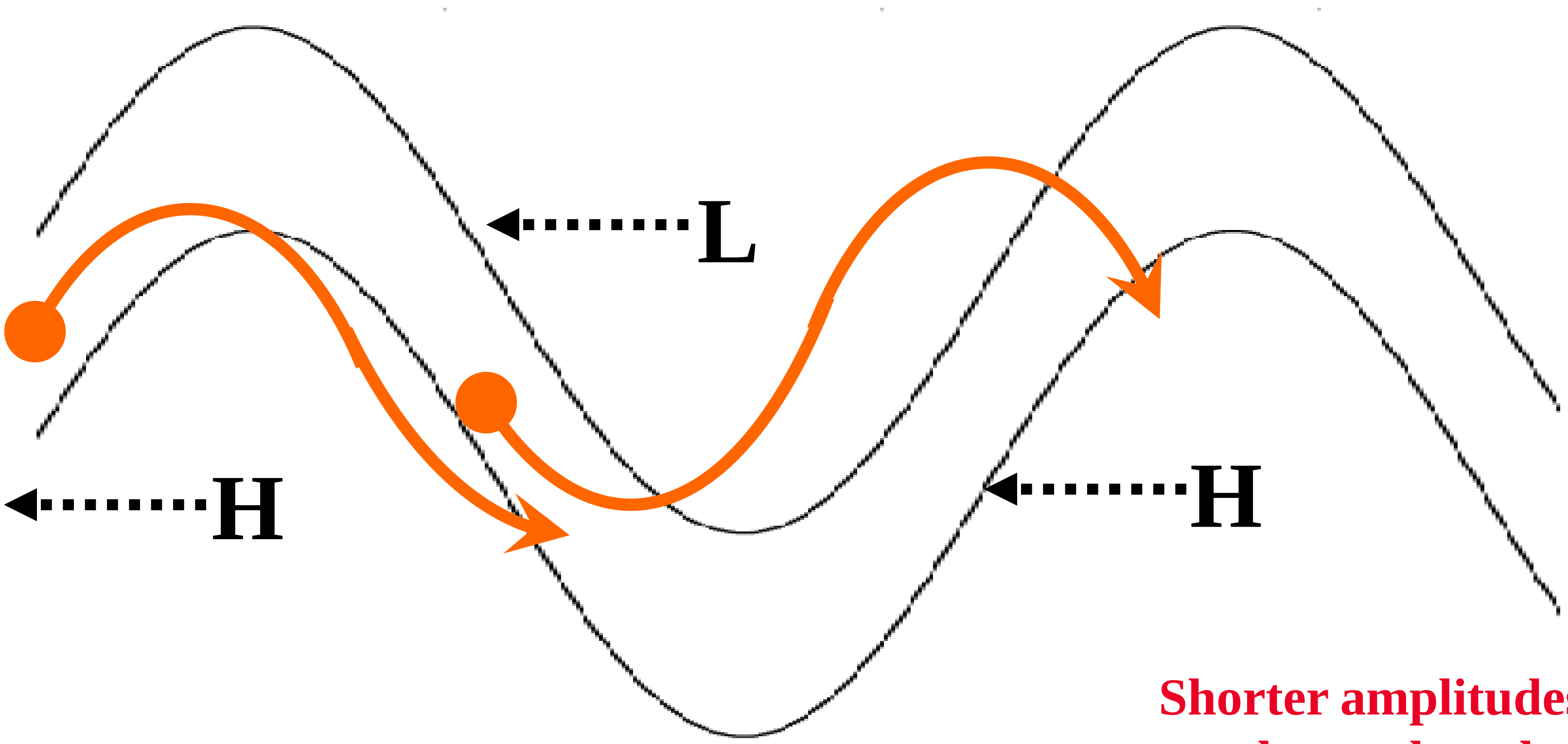
Such a Constant Absolute Vorticity (CAV) **trajectory** is not a “Rossby wave”, as stated in some textbooks

Relation between stream lines and trajectories in a *progressive* flow



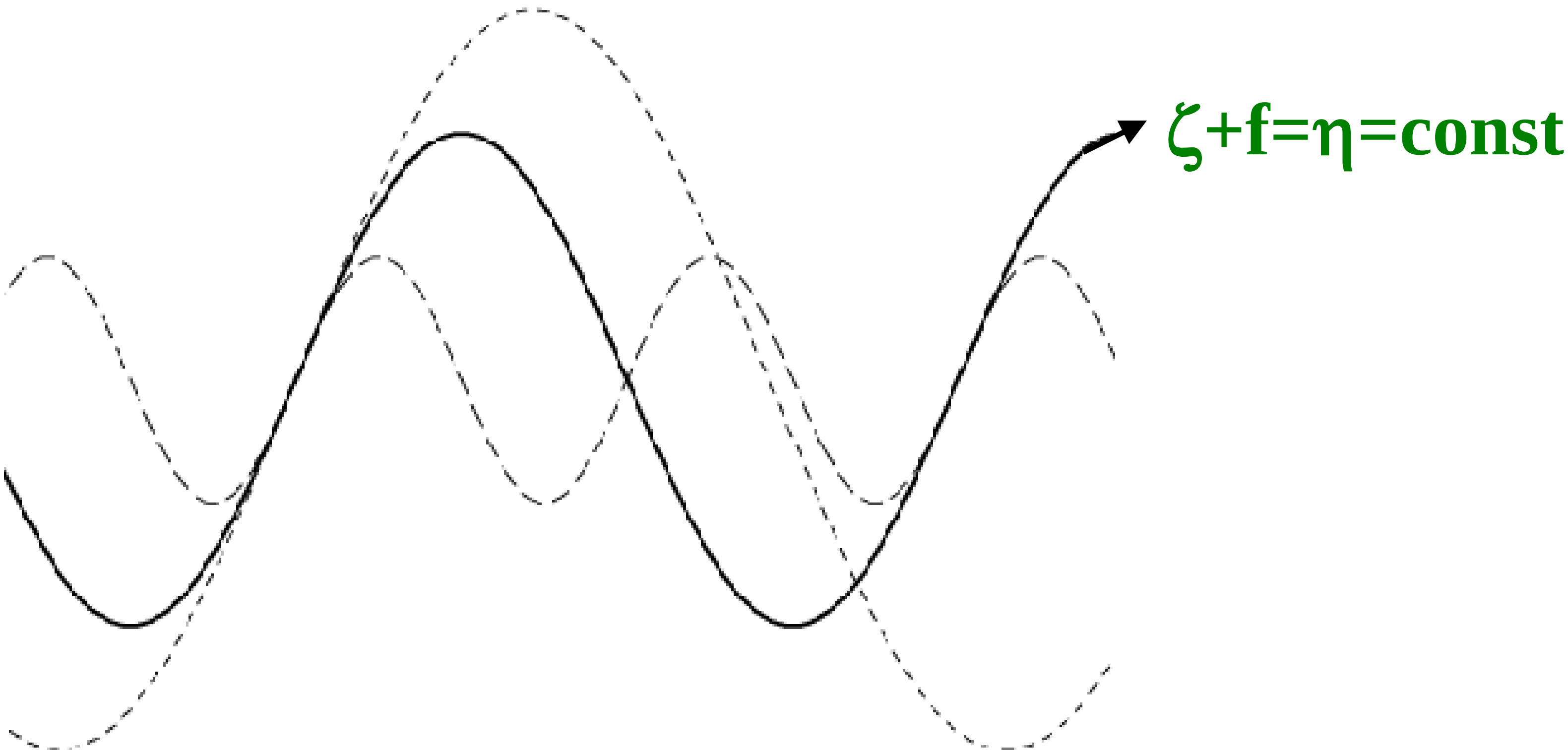
Larger amplitudes and wave lengths

Relation between stream lines and trajectories in a *retrogressive* flow

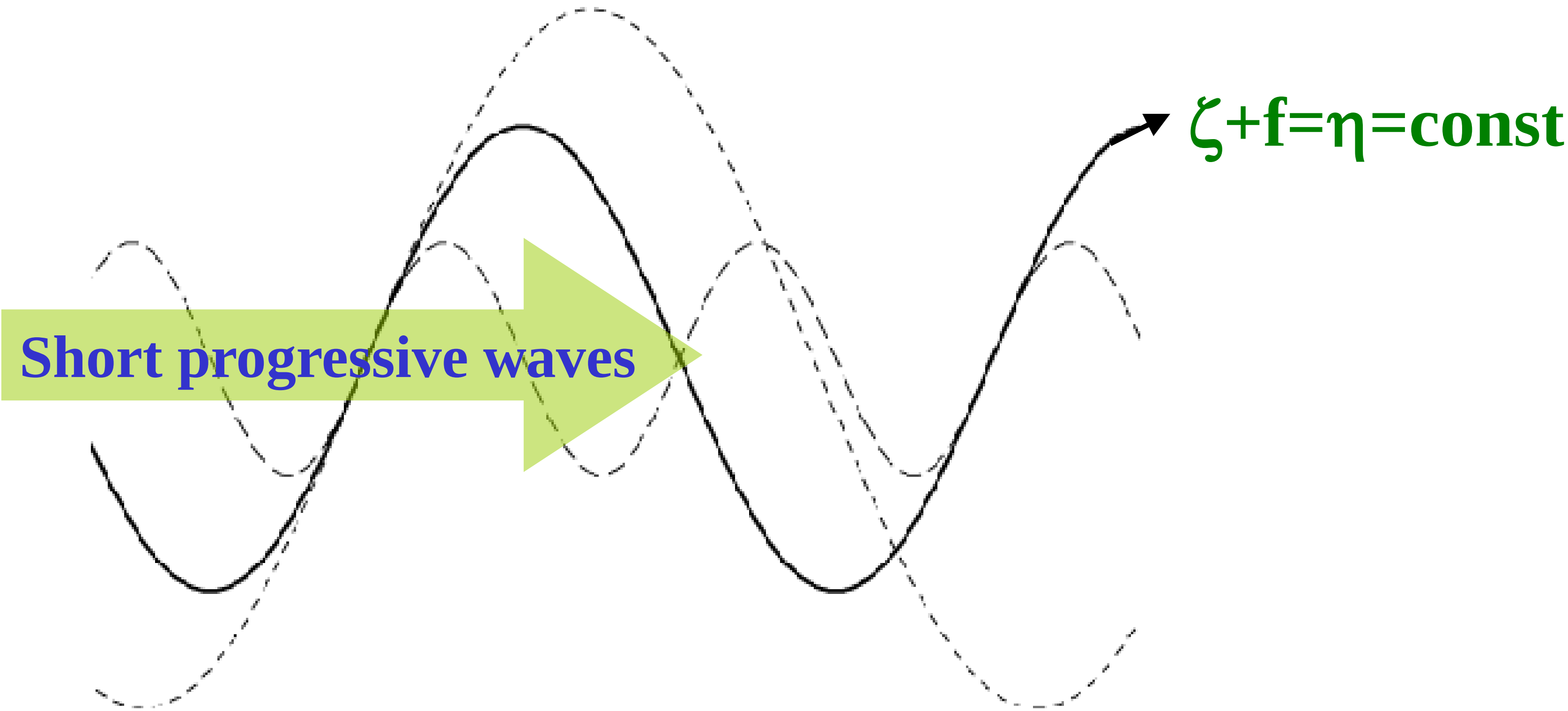


Shorter amplitudes and wave lengths

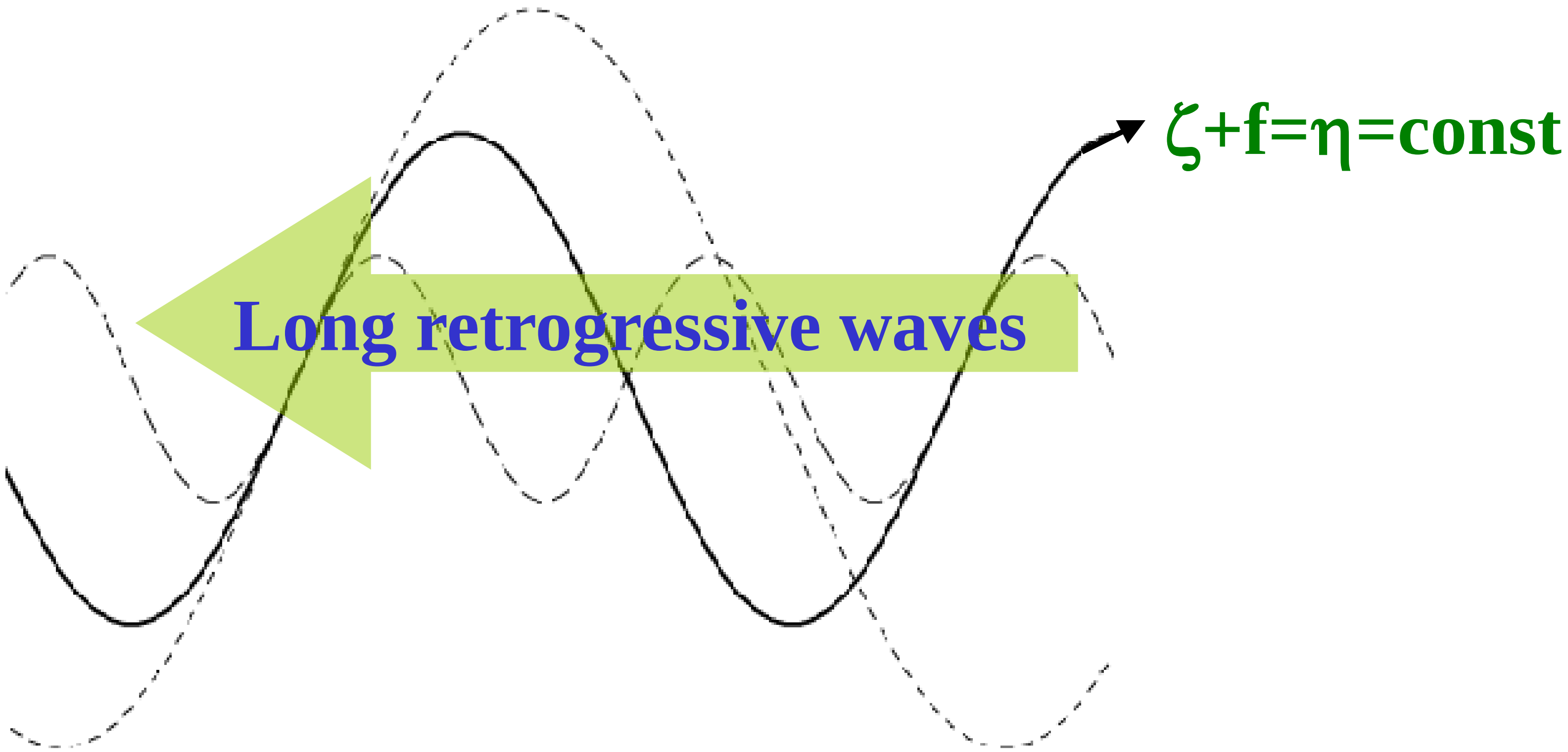
-Rossby (1940) showed that one and the same CAV trajectory satisfies two types of streamlines (waves)



-Rossby (1940) showed that one and the same CAV trajectory satisfies progressive short waves



-Rossby (1940) showed that the same CAV trajectory satisfies retrogressive long waves



Some meteorologists remained sceptical about Rossby's barotropic approach

But the atmosphere is **baroclinic**

R.C.Sutcliffe, UKMO

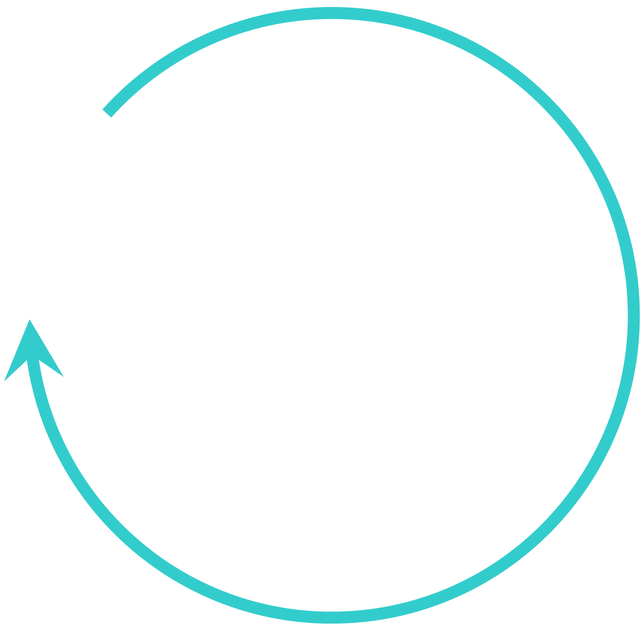
Yes, but it can kinematically be *described* as **barotropic**

C-G Rossby, MISU

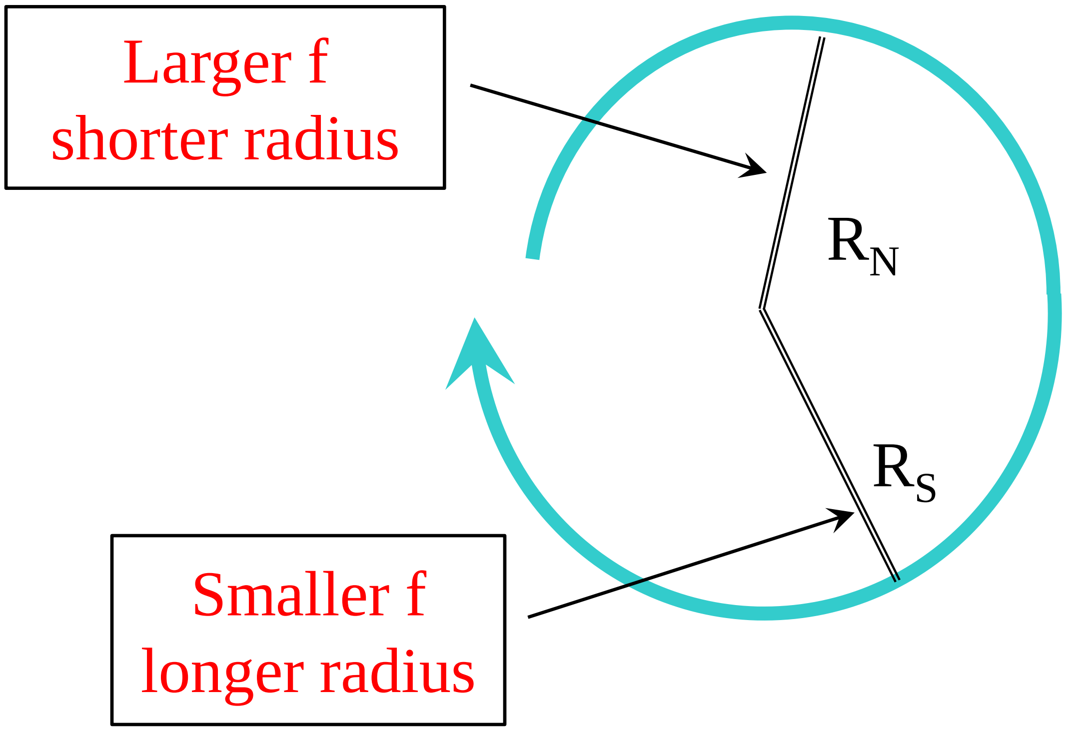
The ”beta-effect”

The Coriolis parameter $f = 2\Omega\sin\varphi$

depends on latitude



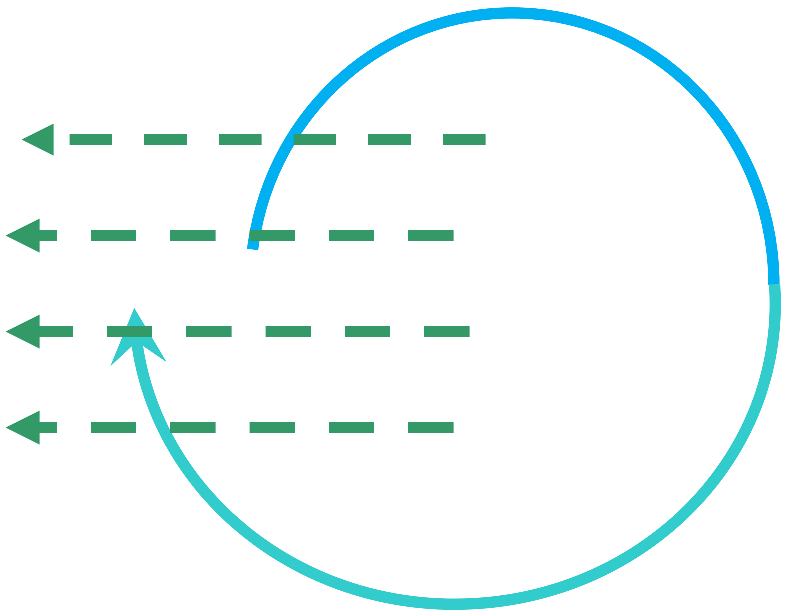
The ”beta-effect”



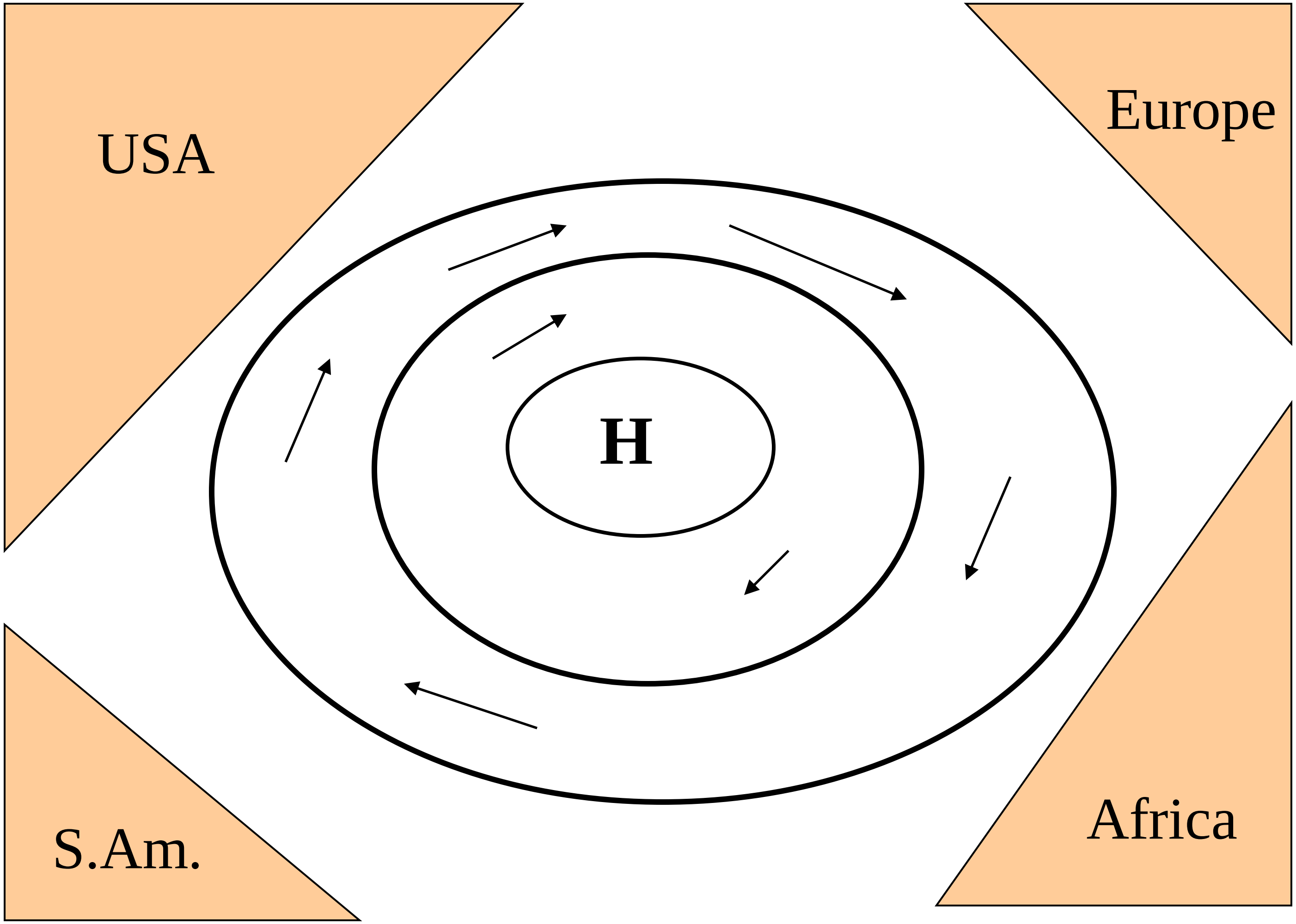
∴ the radius of the inertia circle $R=V/f$

depends on latitude

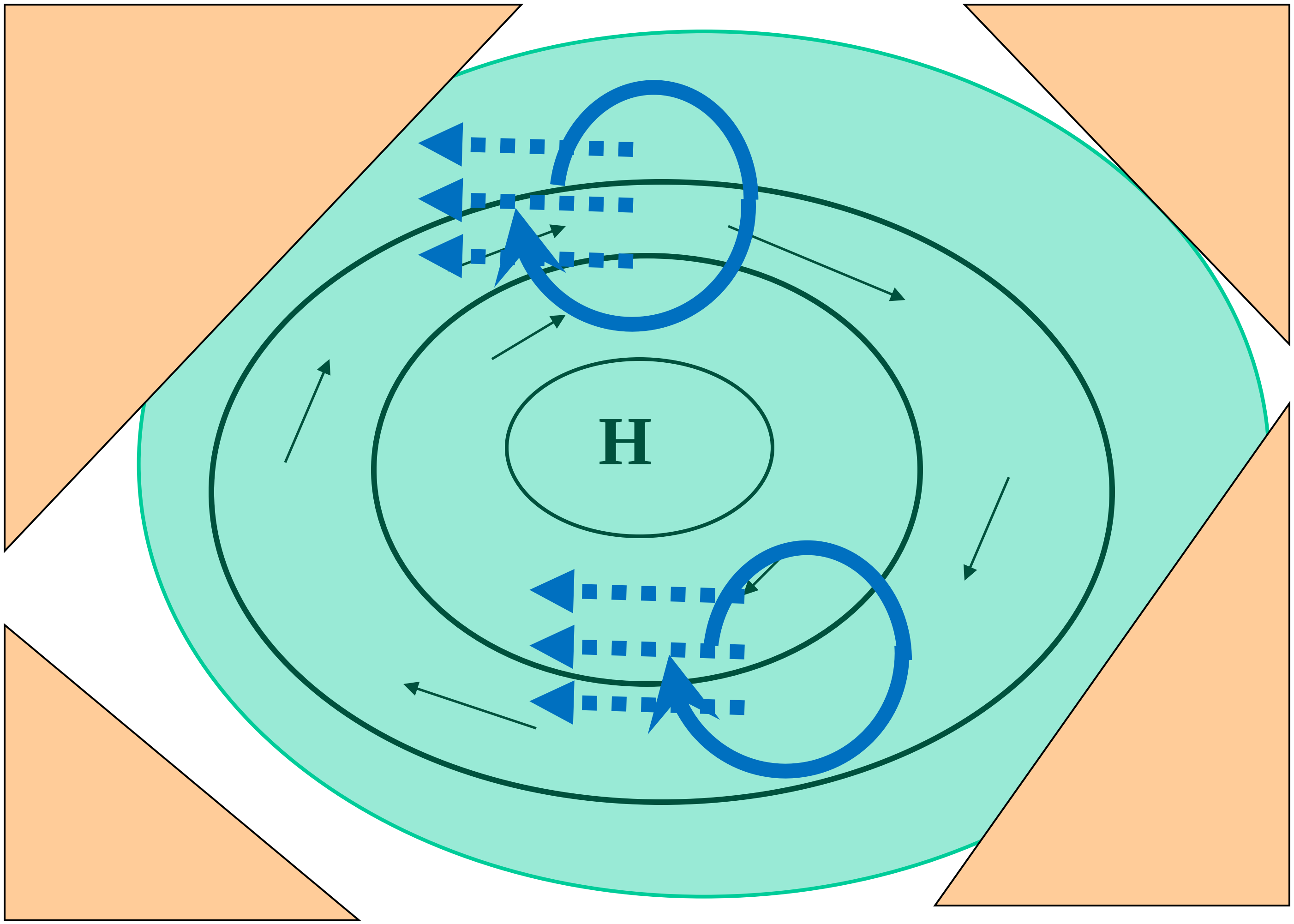
The ”beta-effect” gives rise to a slow westward propagation of mass



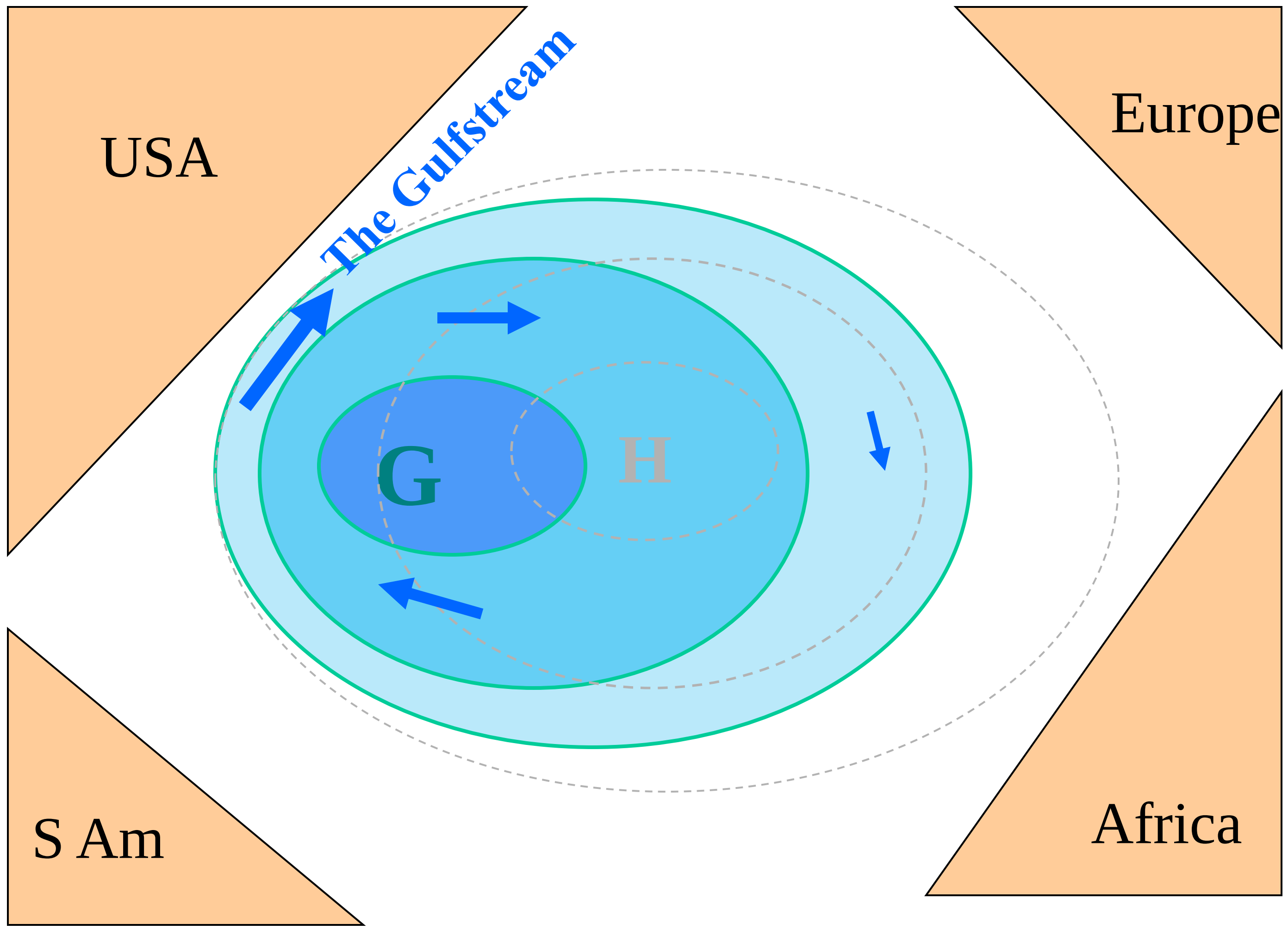
The subtropical high pressure area ("The Azores High")



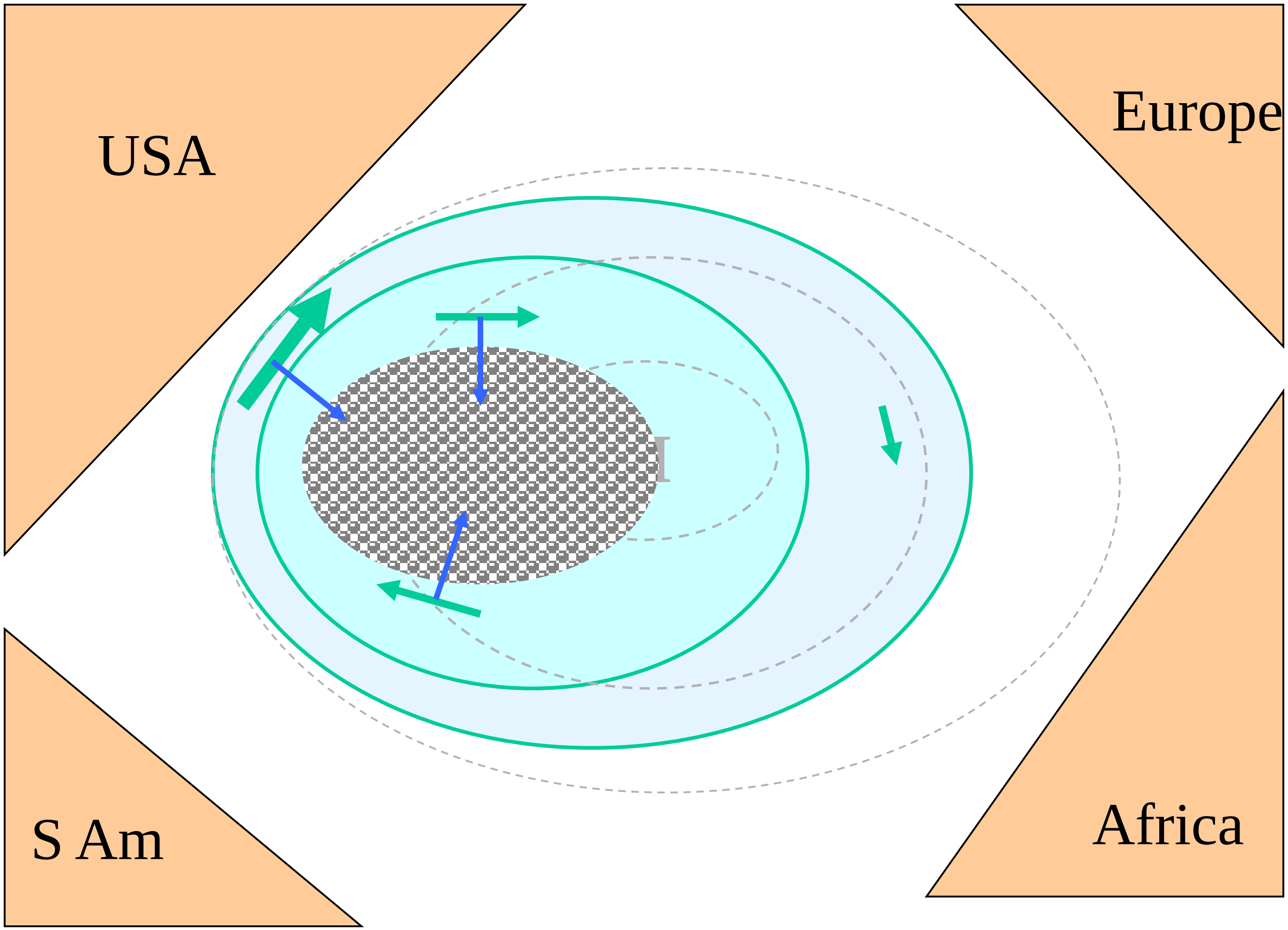
The beta effect drives the water slowly westward



Instead we get an asymmetric Gulf Stream circulation



The Sargasso Sea ("Ekman pumping" of the surface debris)



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