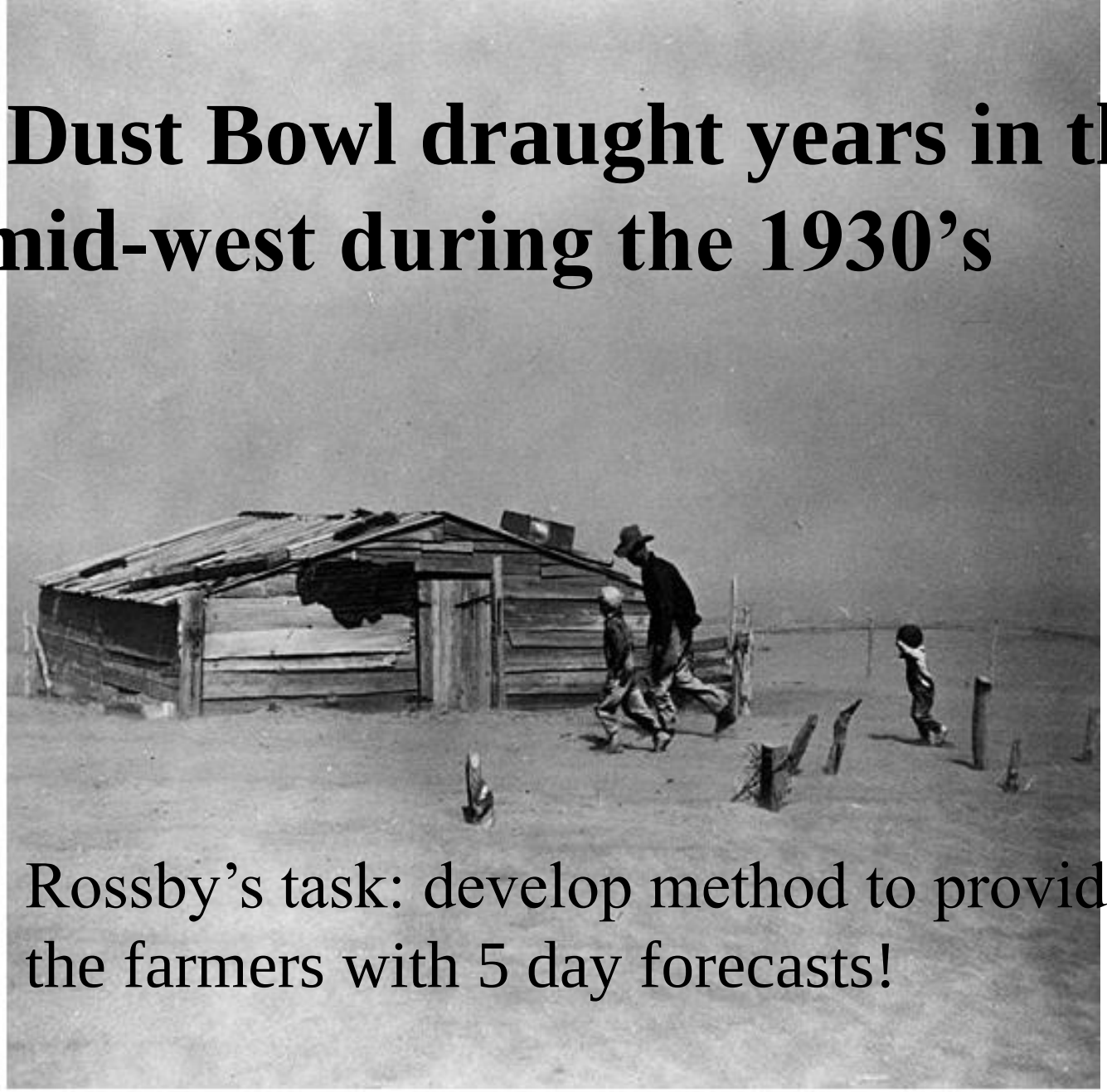
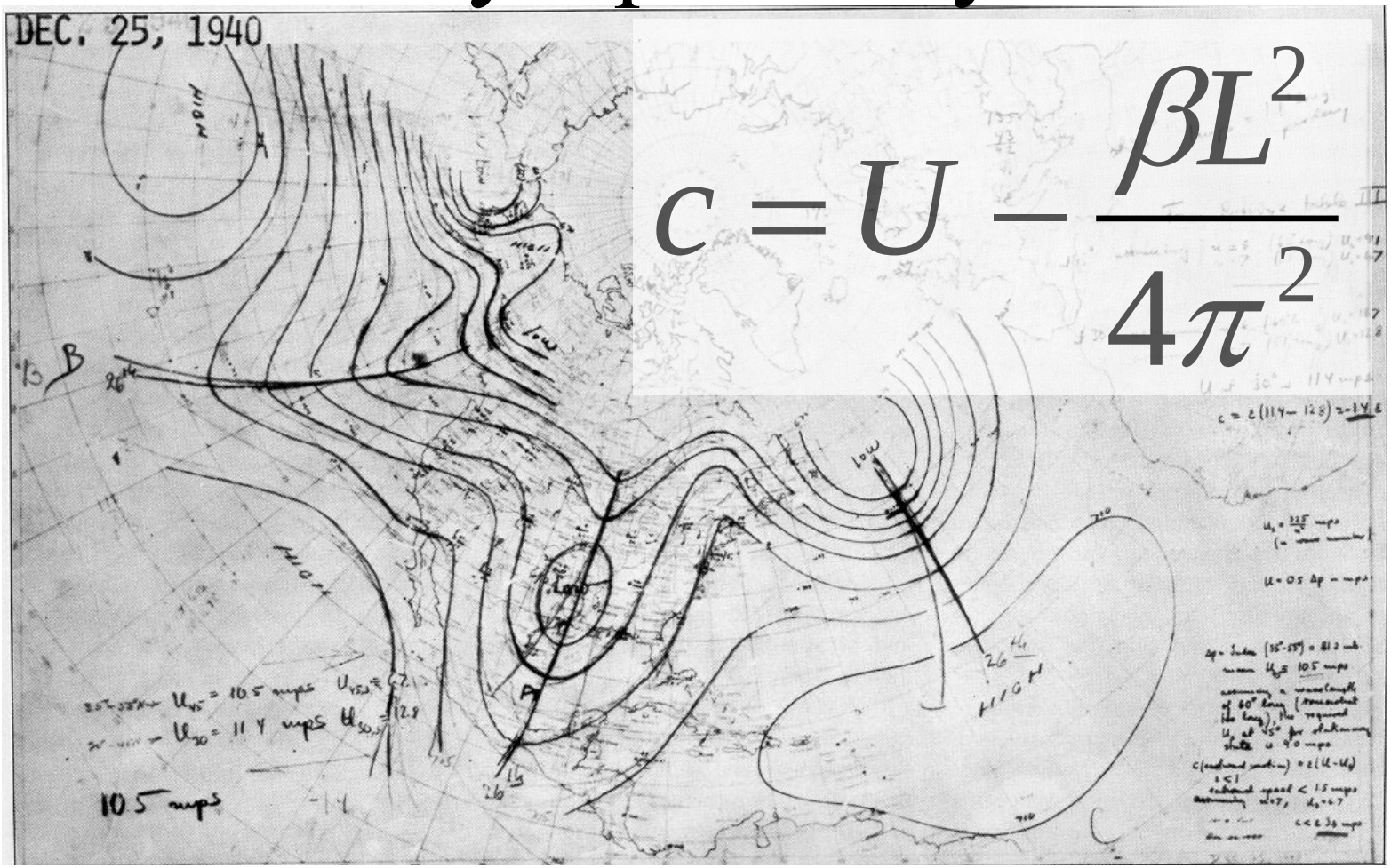
4. Rossby's planetary waves – *and "group velocity thinking"*

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!

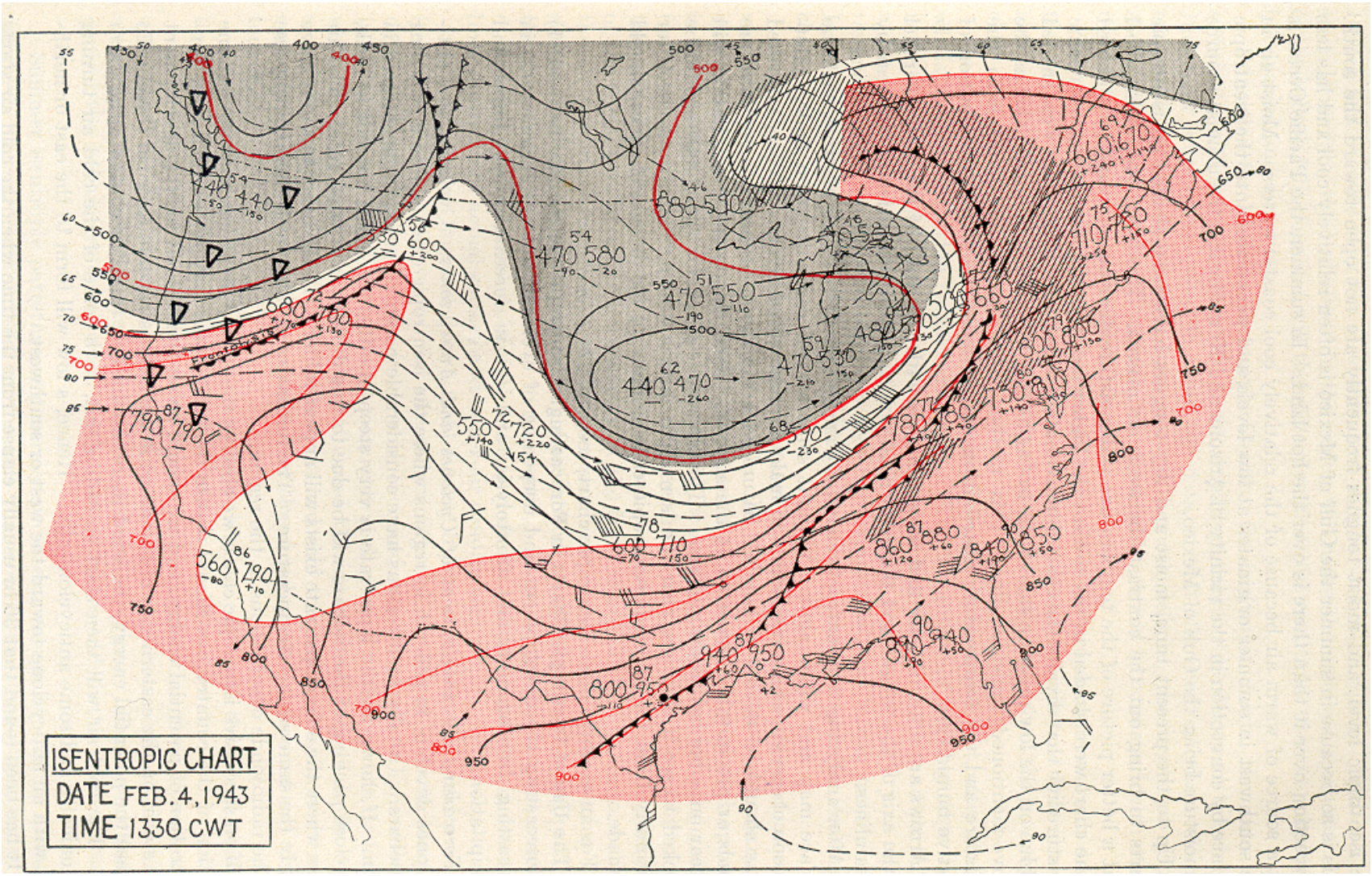
C-G Rossby's planetary waves



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

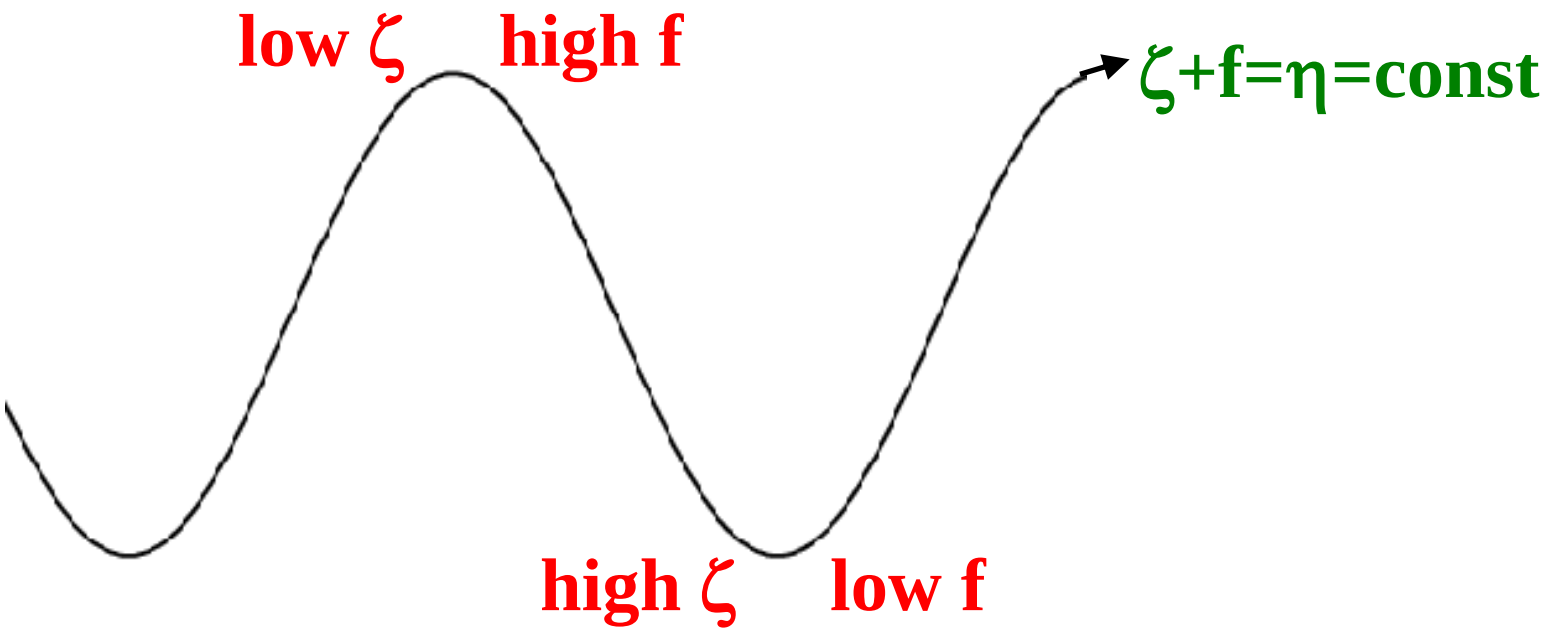
c = phase speed, U= zonal flow at 5-6 km, L=wave length, $\beta = df/dy$

Going west for large L, going east for small L



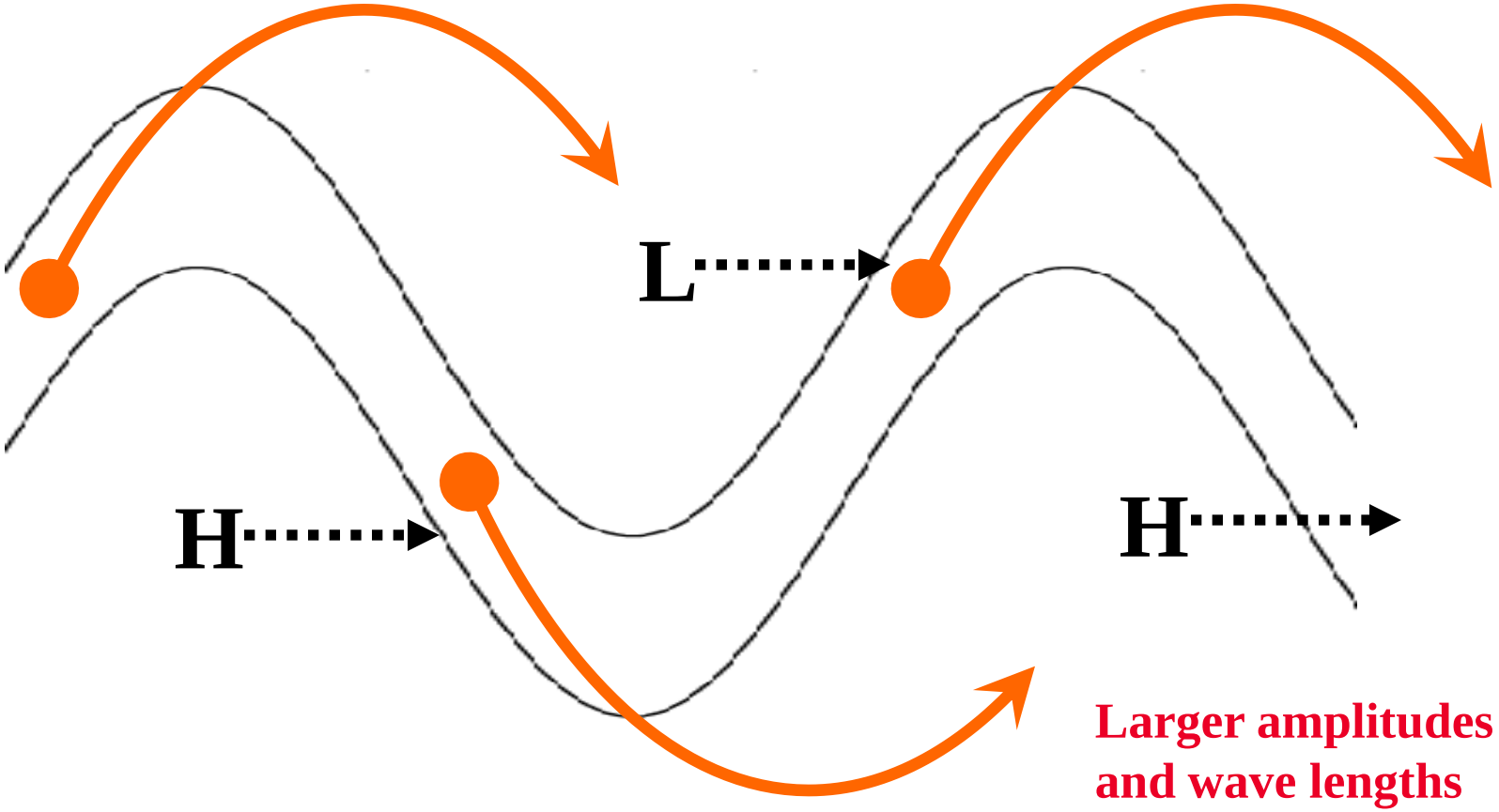
The planetary wave approach was combined with isentropic analysis

In his new derivation 1940 Rossby made use of conservation of absolute vorticity ζ+f=η=const

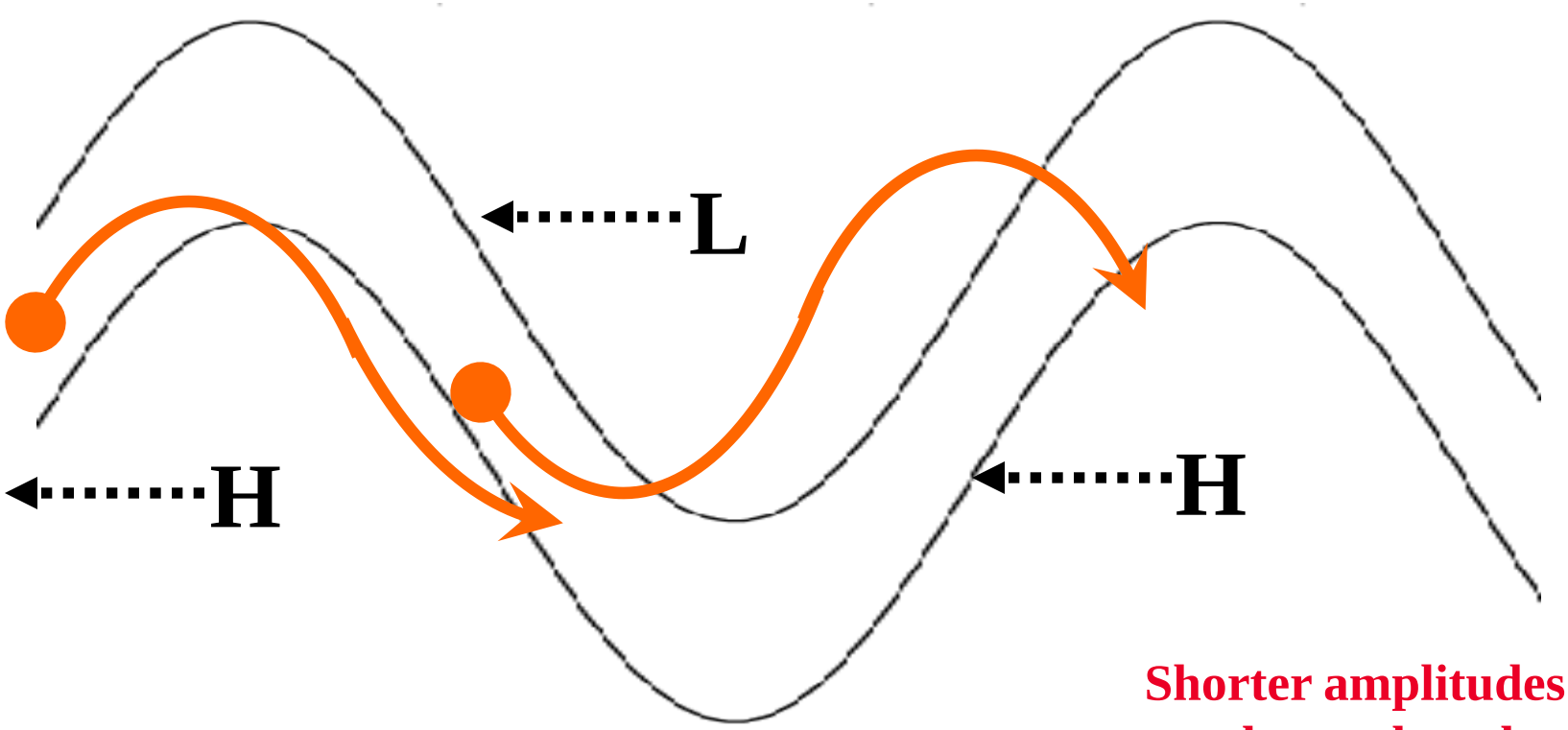


Such a Constant Absolute Vorticity (CAV) **trajectory** is not a "Rossby wave", as stated in some textbooks

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

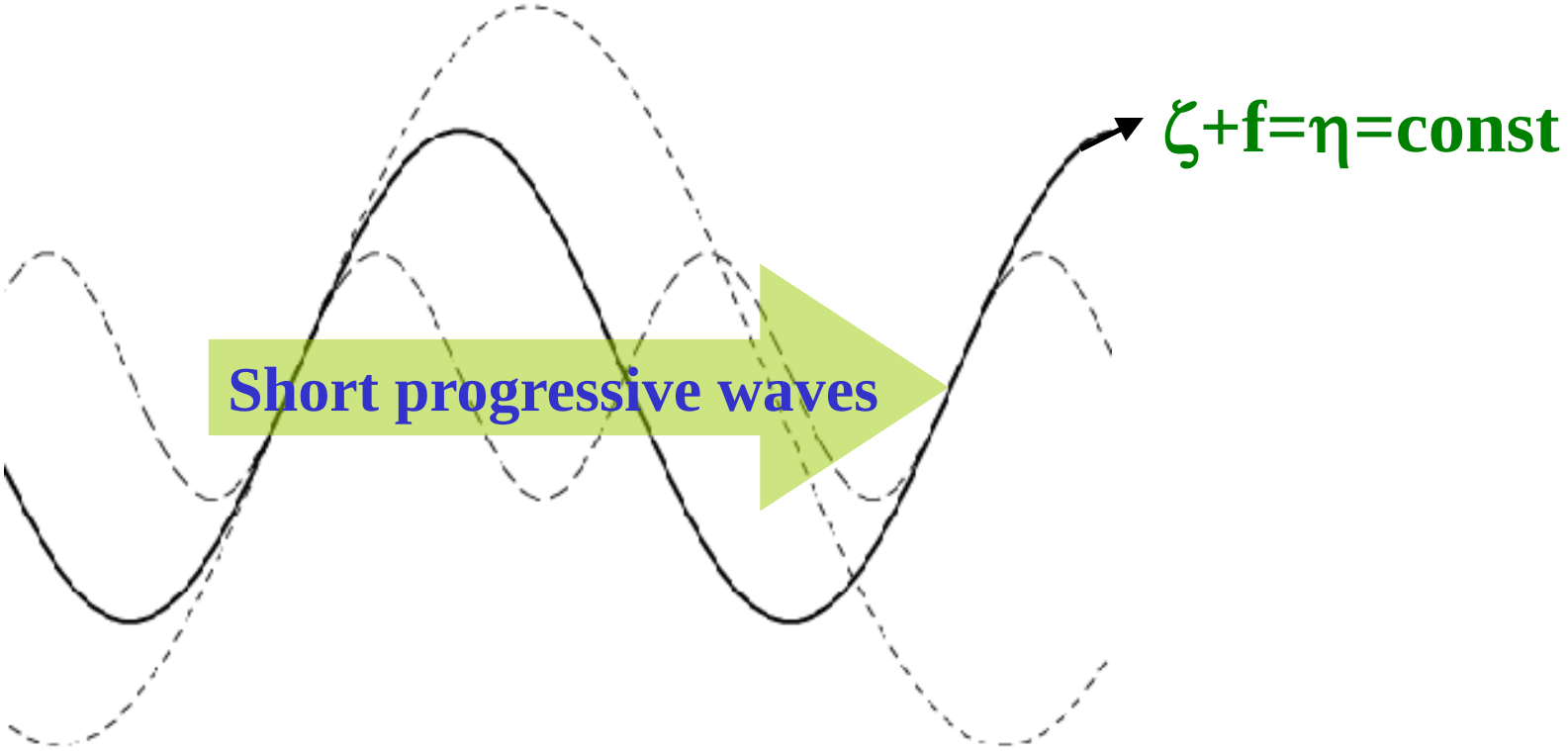


Relation between stream lines and trajectories in a *retrogressive* flow

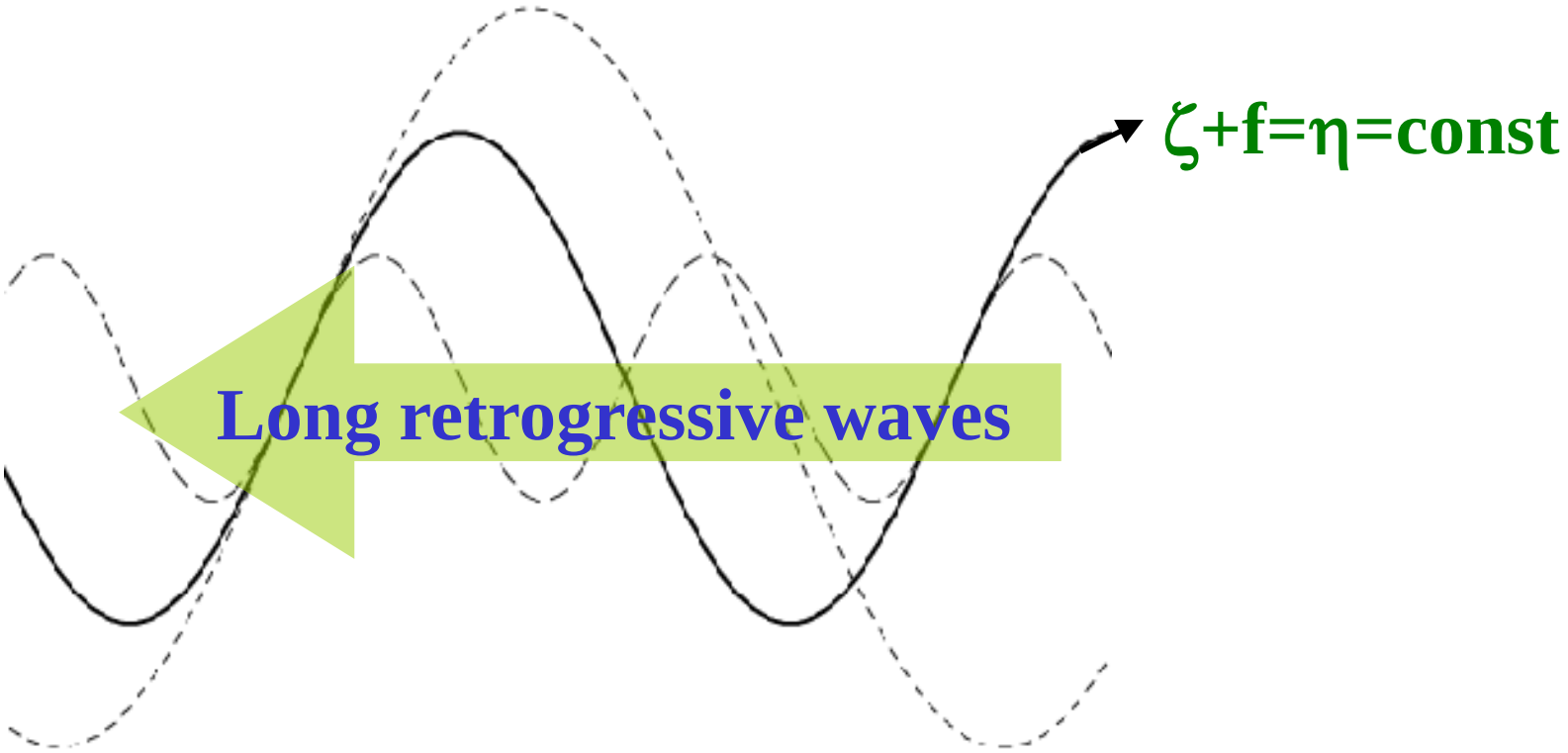


Shorter amplitudes and wave lengths

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

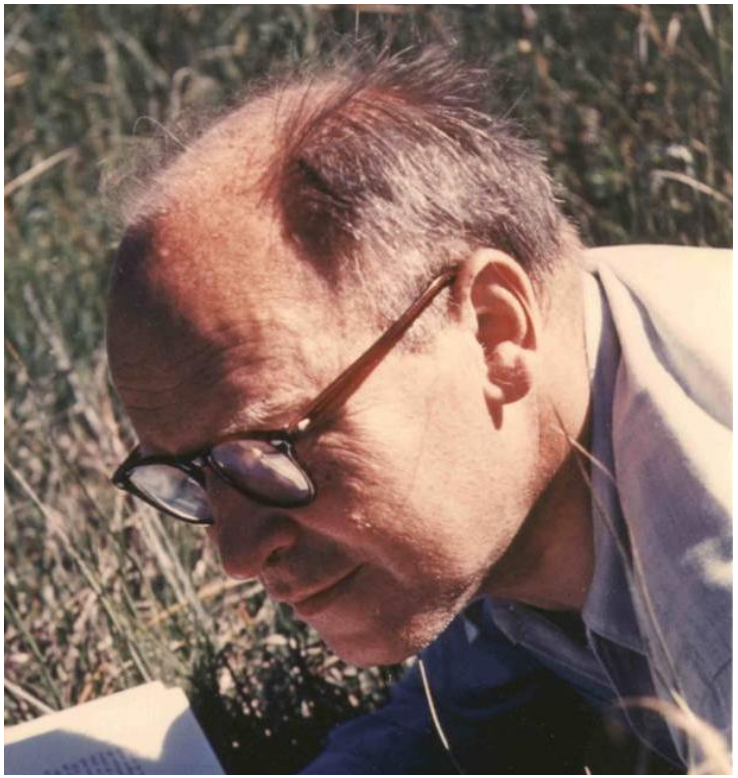


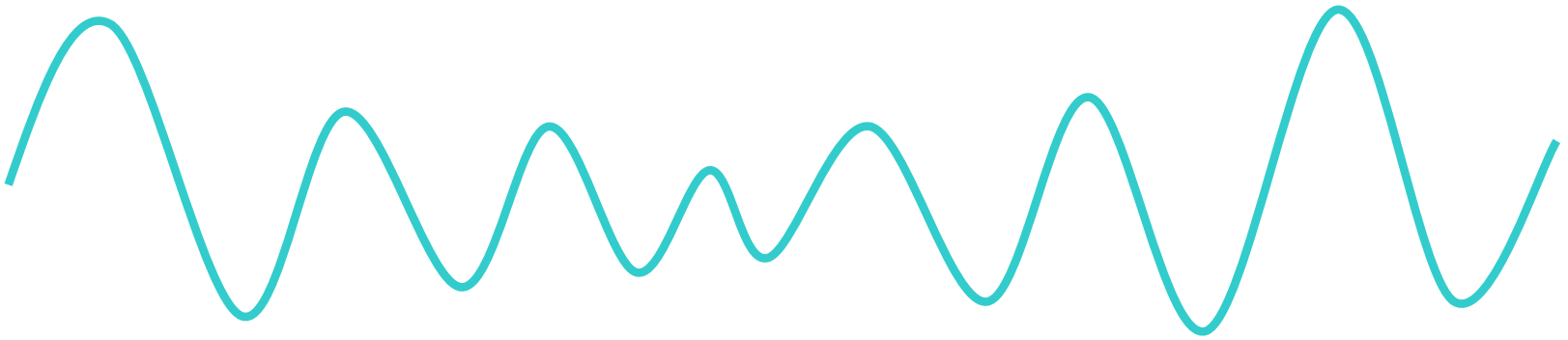
-Rossby (1940) showed that one and the same CAV trajectory satisfies two types of streamlines (waves)



In summer 1944 Carl Gustaf Rossby, then chief meteorological advisor to the US war government, took a vacation in the oceanographic research centre La Jolla in southern California

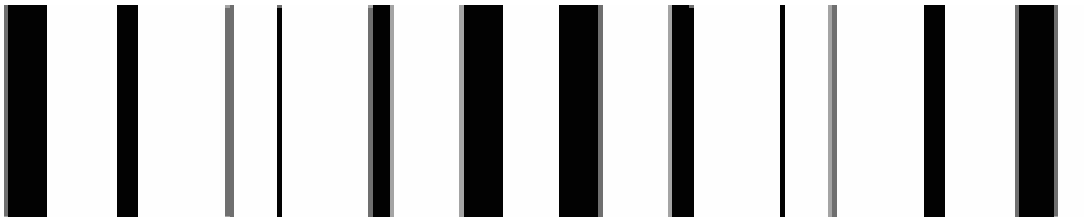
Resting on the beech he could listen to the sound of the incoming waves, their rhythm with a peculiar periodicity, **“The Ninth Wave”** a consequence of group velocity





The concept of group velocity can be illustrated by two combs with slightly different spacing between the tags

The phase speeds of the two wave systems (or comb tags!) are different



Their inference pattern moves with a different velocity, **the group velocity** (in this case *slowly* backwards)

Group velocity in water surface waves

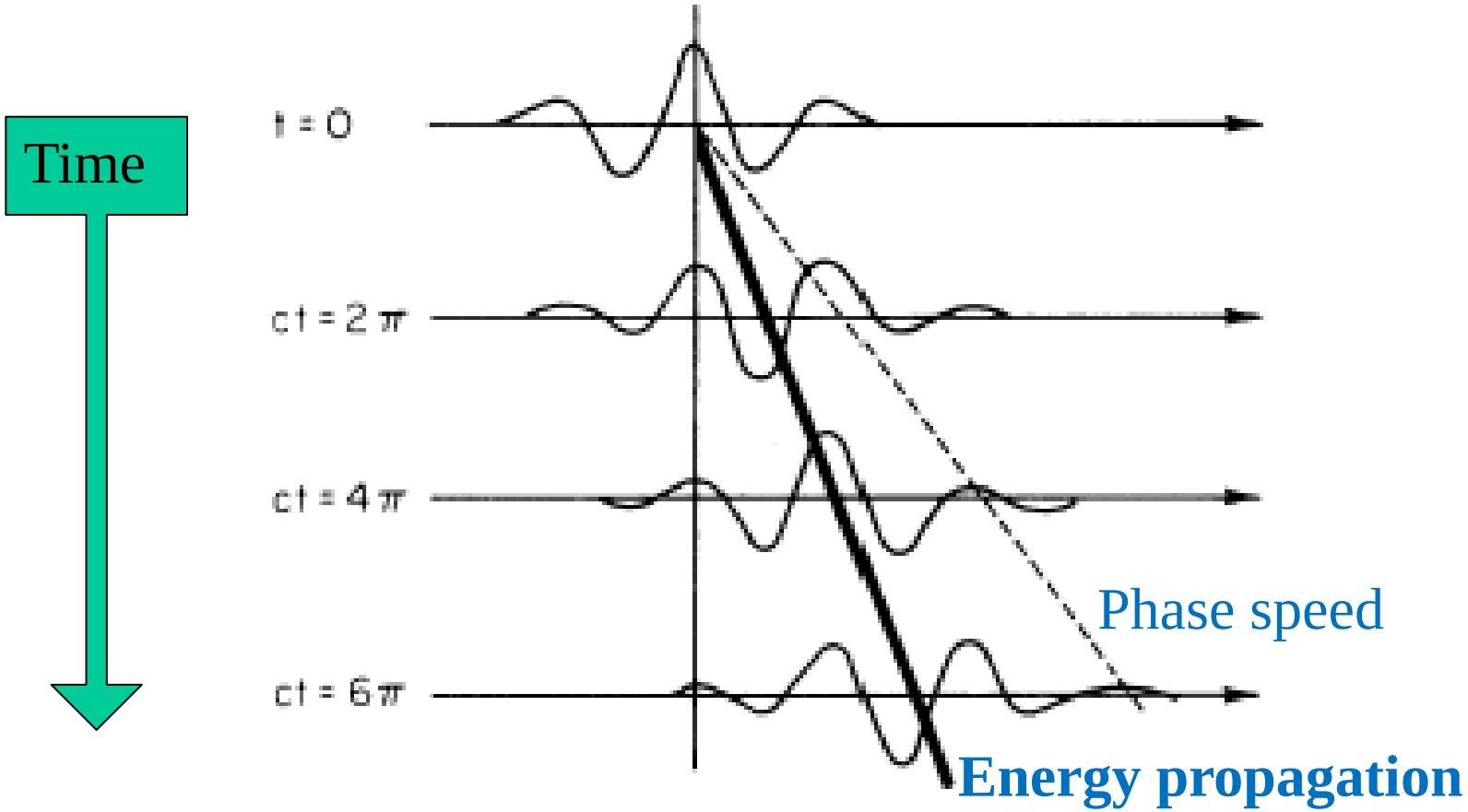


Fig.1 The successive progression of water wave packages. The crest in the centre moves rapidly out, weakens and leaves behind the main energy, into which upstream waves enter and amplify (from Holton, 1992).

Phase speeds ***c*** according to Rossby's wave equation

$$c = U - \frac{\beta L^2}{4\pi^2} \approx 10^\circ / day$$

This wave equation is ***dispersive*** and gives rise to "downstream development" by the ***"group velocity"***

$$c_g = U + \frac{\beta L^2}{4\pi^2} \approx 30^\circ / day$$

propagating energy ("influences") rapidly downstream

Group velocity in the atmosphere

Time

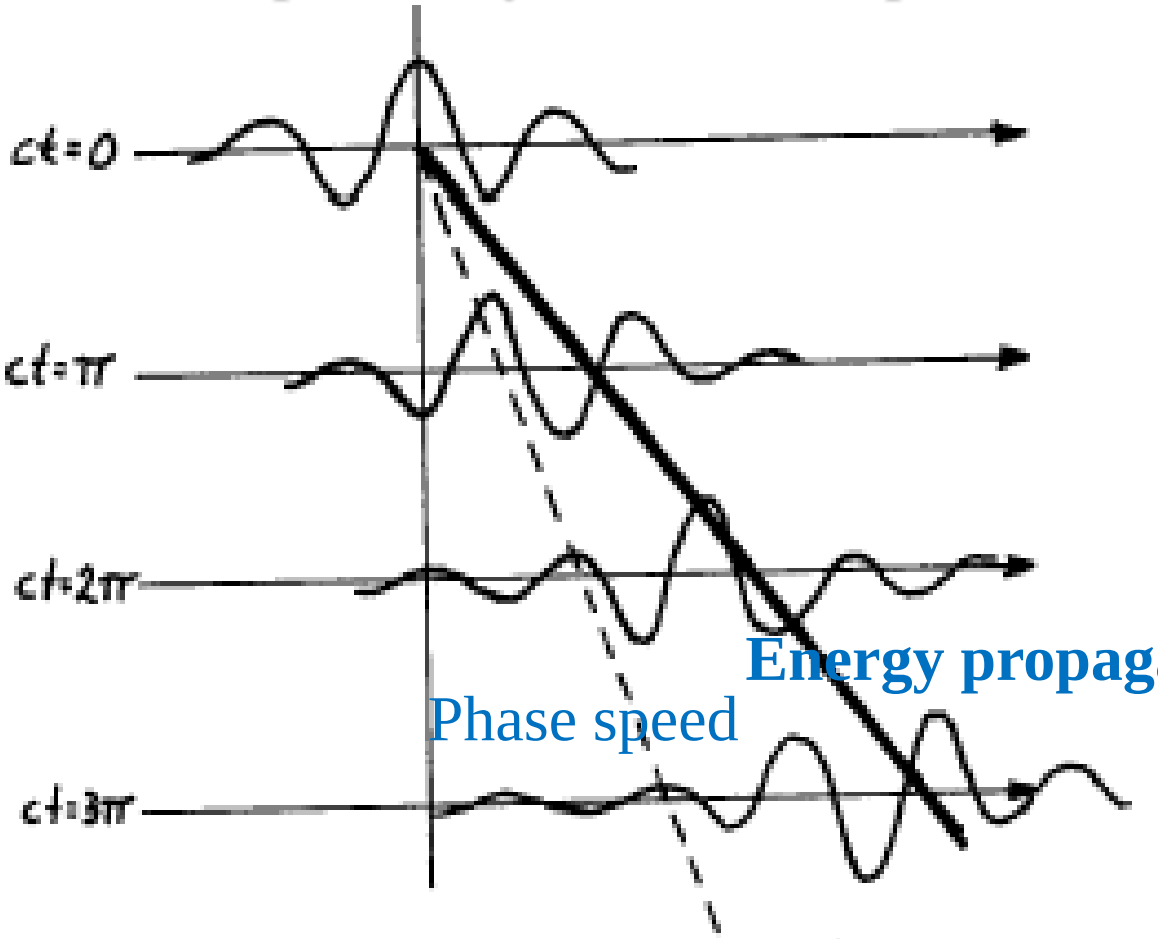


Fig. 2: The corresponding mechanism in the atmosphere: the central wave moves more slowly than the bulk of the energy which propagates downstream amplifying waves on its arrival.

From an upstream baroclinic development the released kinetic energy is transported, through the upper-tropospheric flow, to the next downstream cyclone

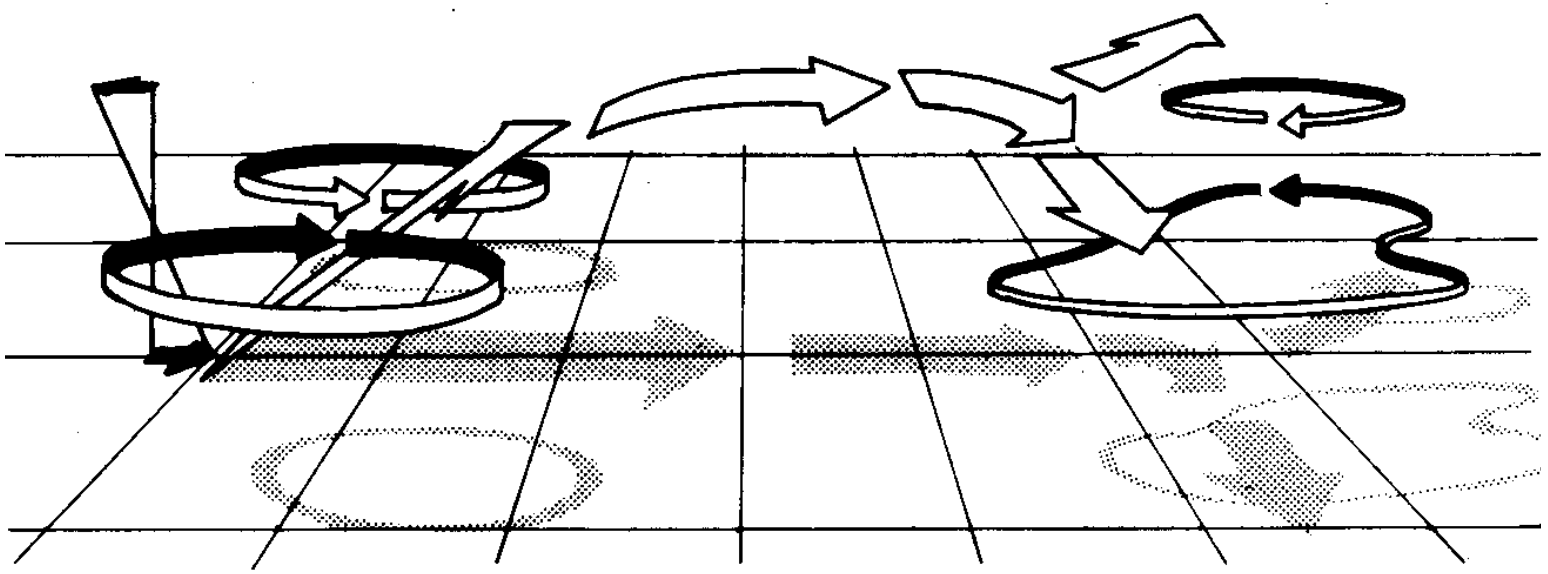
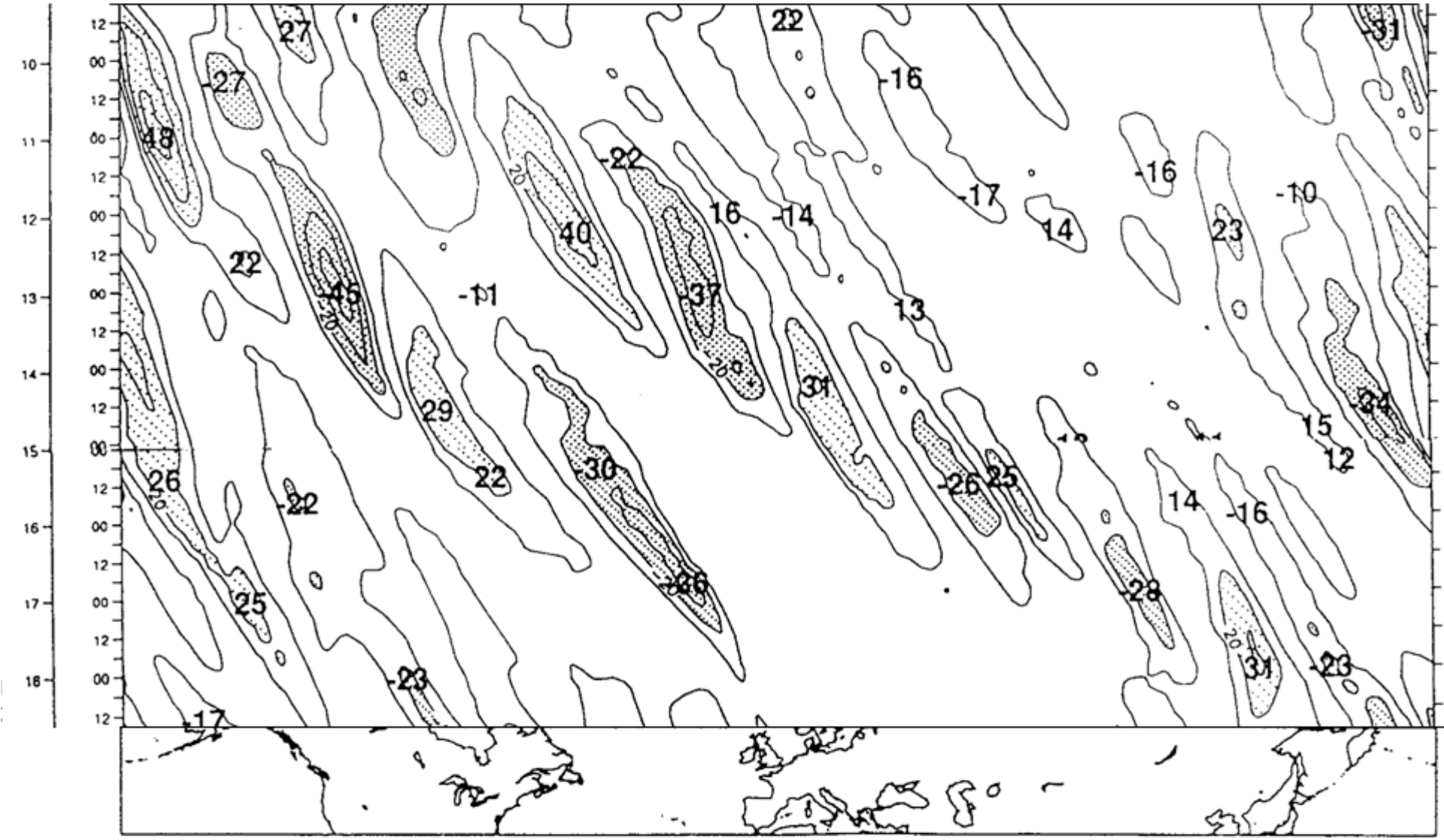


Illustration from Hoskins, James and White (JAS, 1983)

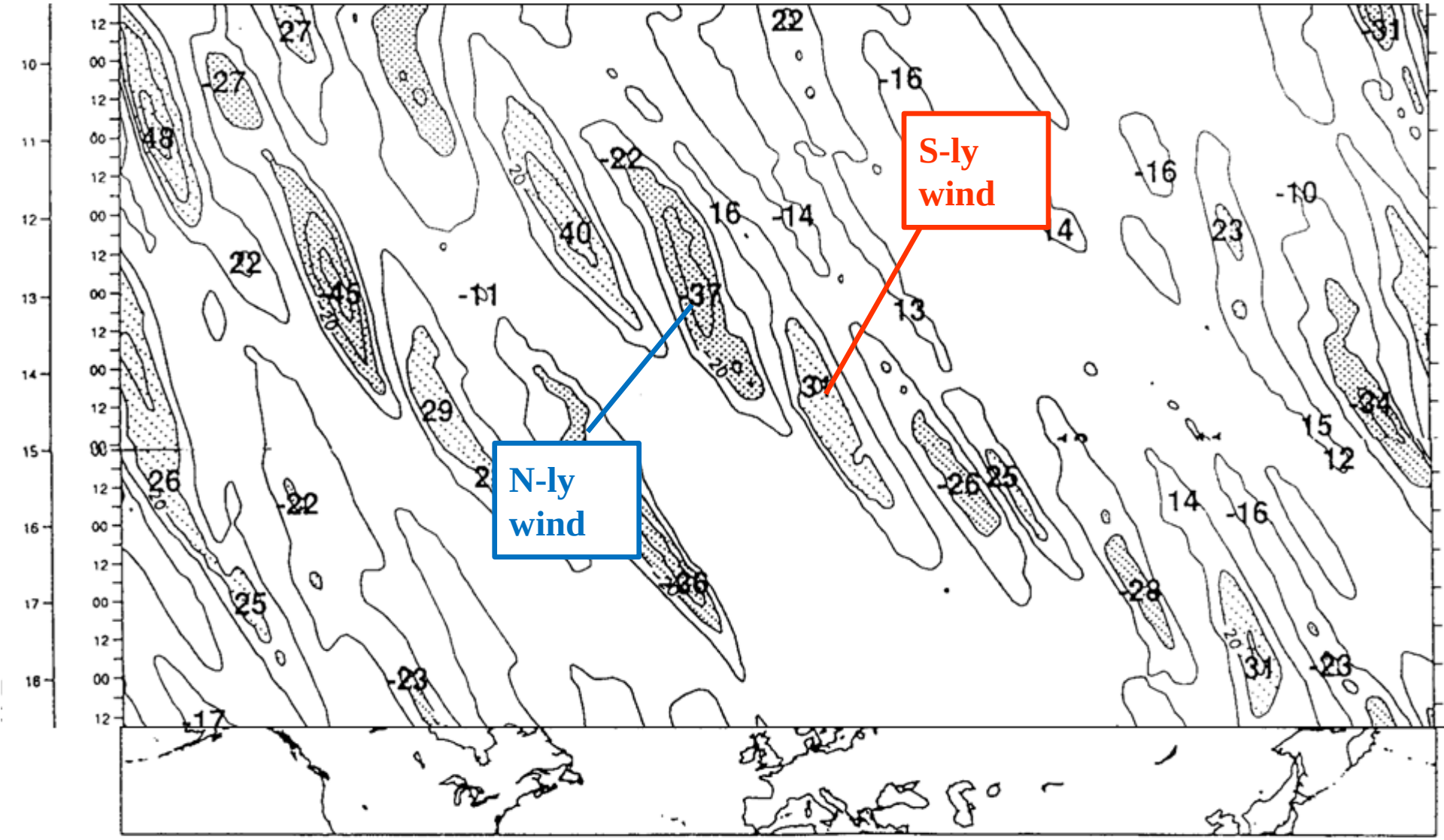
Trough-ridge (Hovmöller) Diagram

of 250 hPa meridional wind component 10-18 September 1993



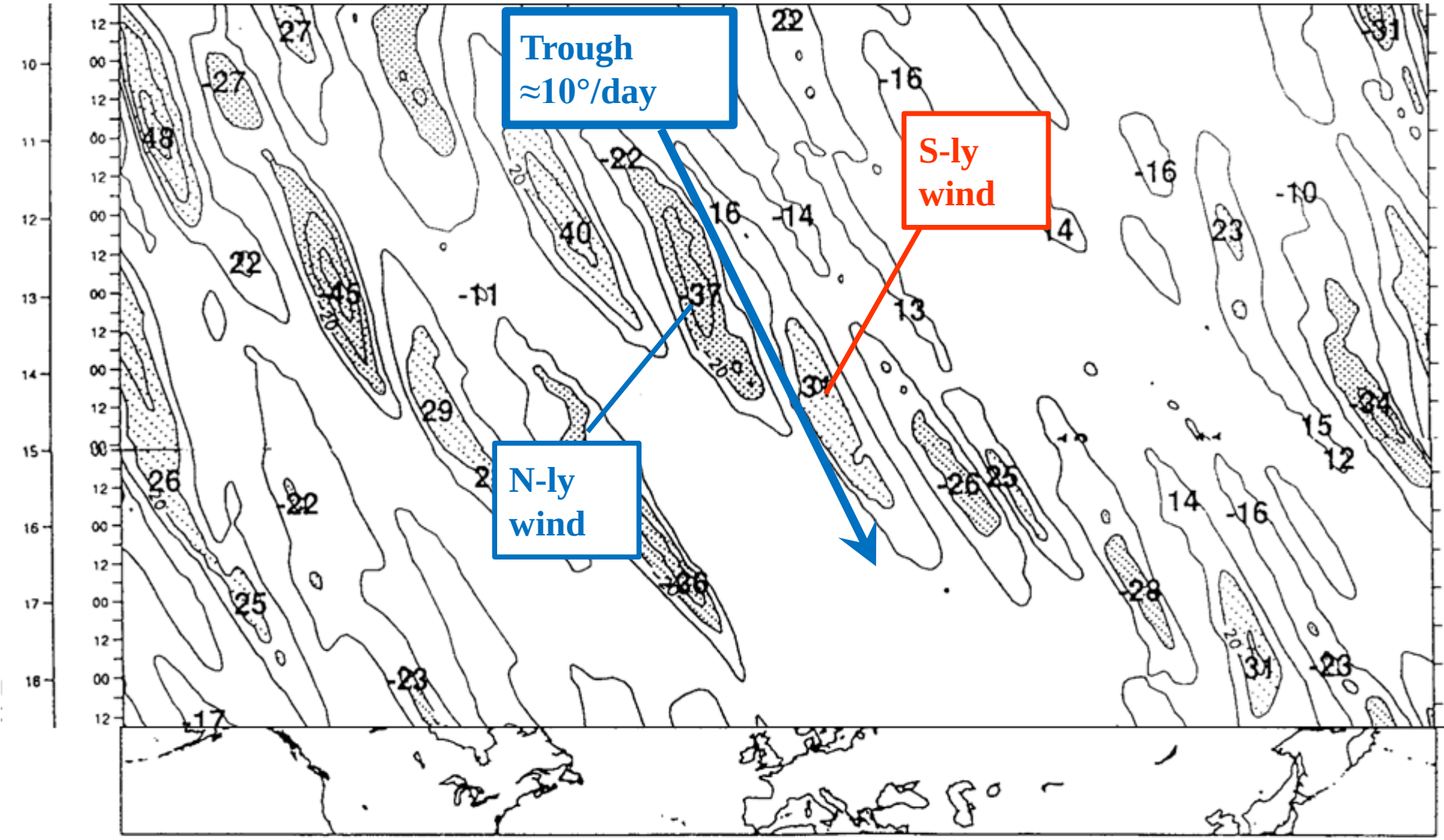
Trough-ridge (Hovmöller) Diagram

of 250 hPa meridional wind component 10-18 September 1993



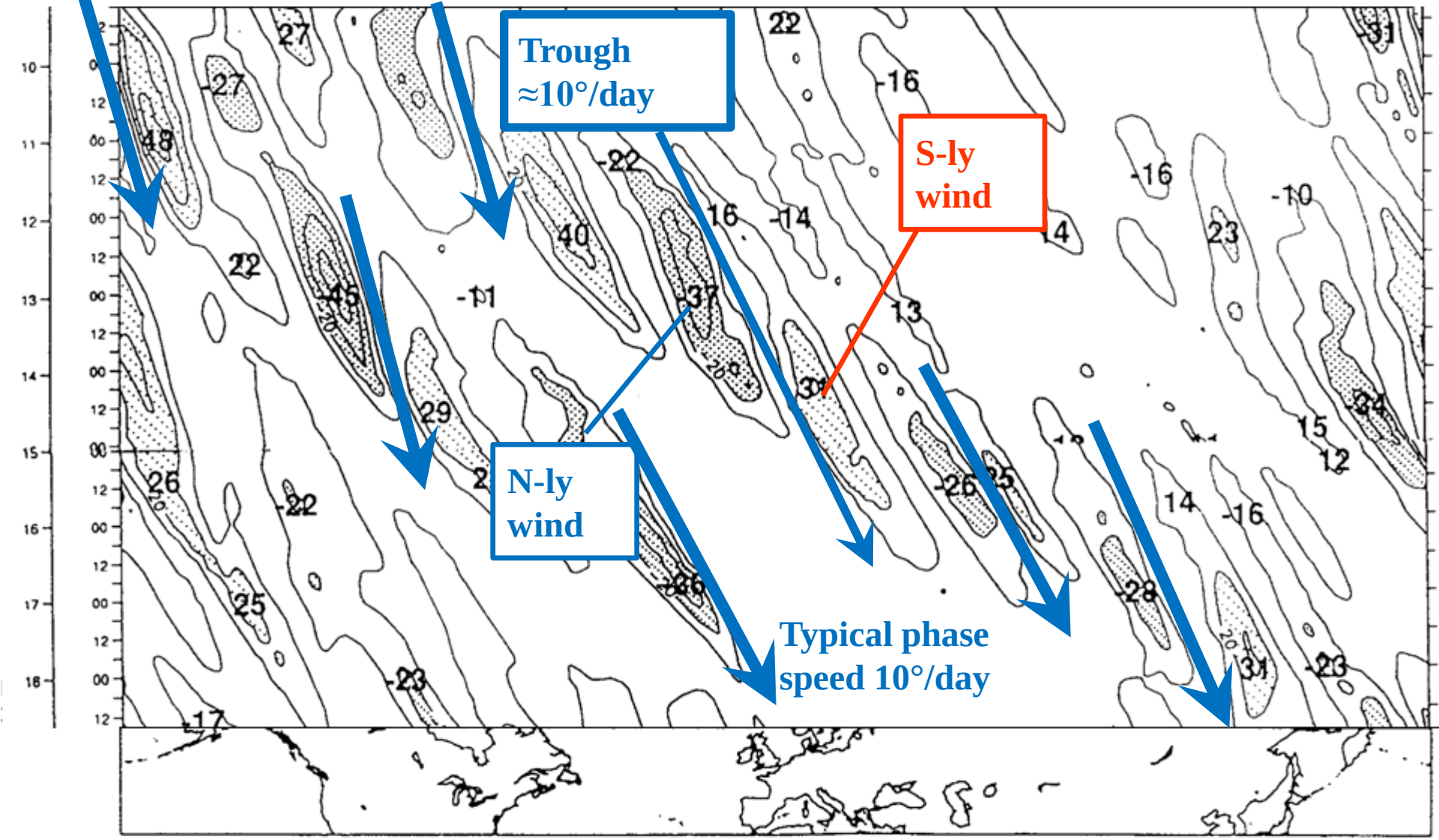
Trough-ridge (Hovmöller) Diagram

of 250 hPa meridional wind component 10-18 September 1993



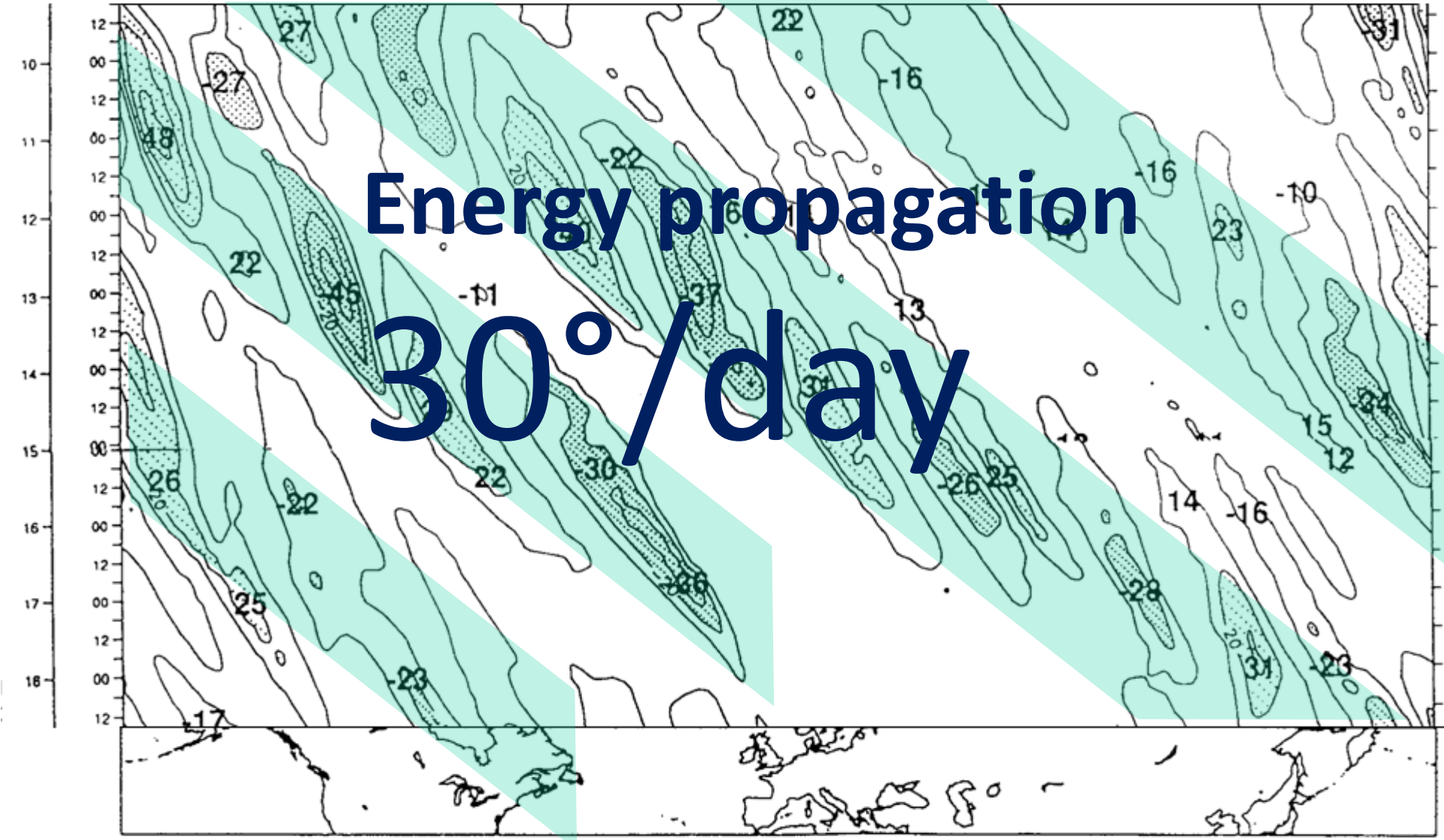
Trough-ridge (Hovmöller) Diagram

of 250 hPa meridional wind component 10-18 September 1993



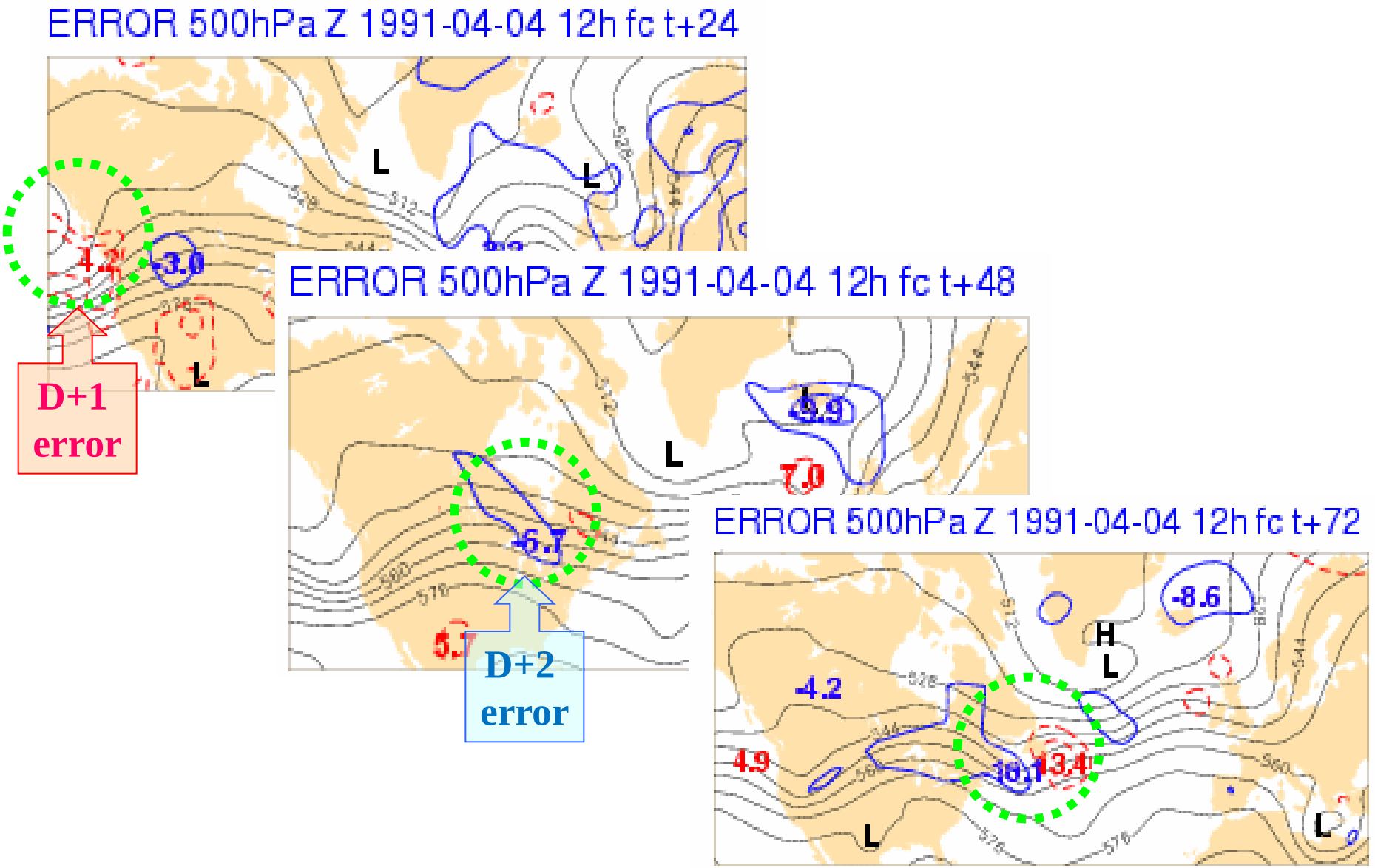
Trough-ridge (Hovmöller) Diagram

of 250 hPa meridional wind component 10-18 September 1993

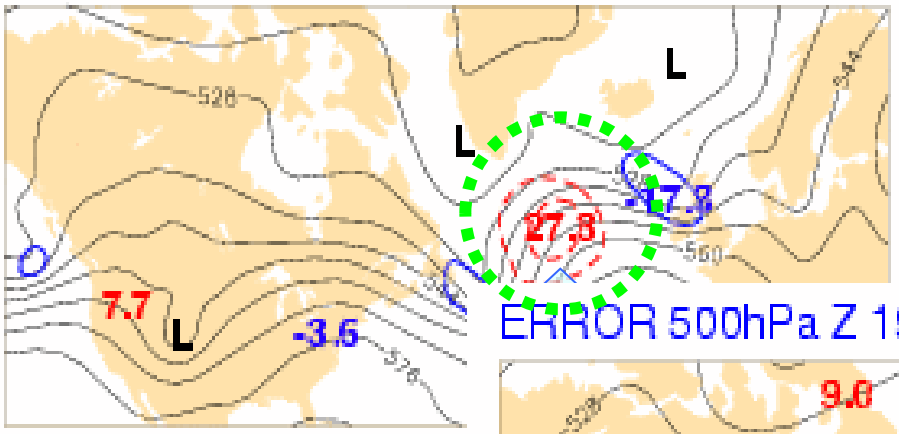


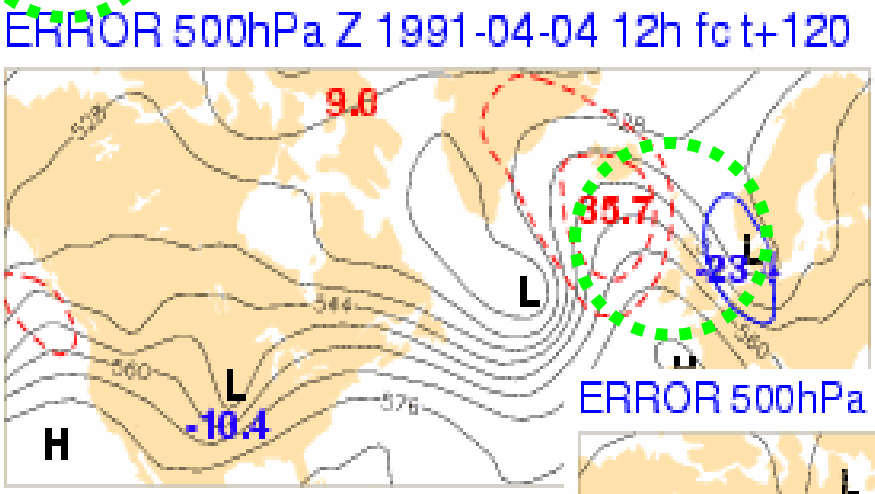
At ECMWF, UKMO and other NWP centres “group velocity thinking” is used to trace the origin of forecast errors (or forecast “jumps”) due to poor initial conditions

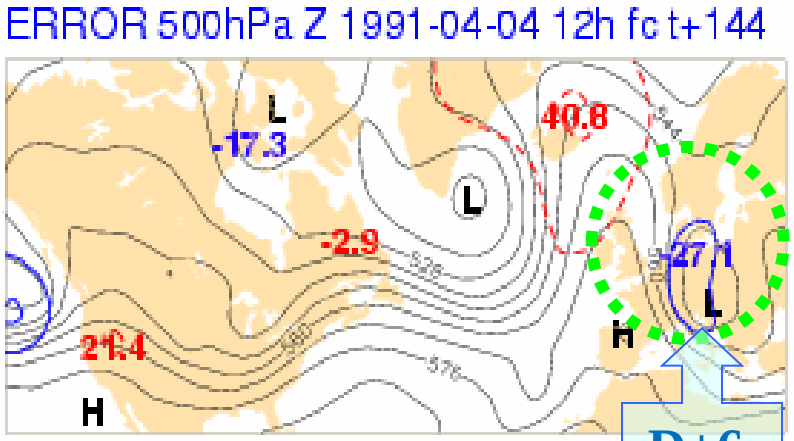
Error tracking from the NE Pacific to Europe in 5 days



Error tracking from the NE Pacific to Europe in 5 days

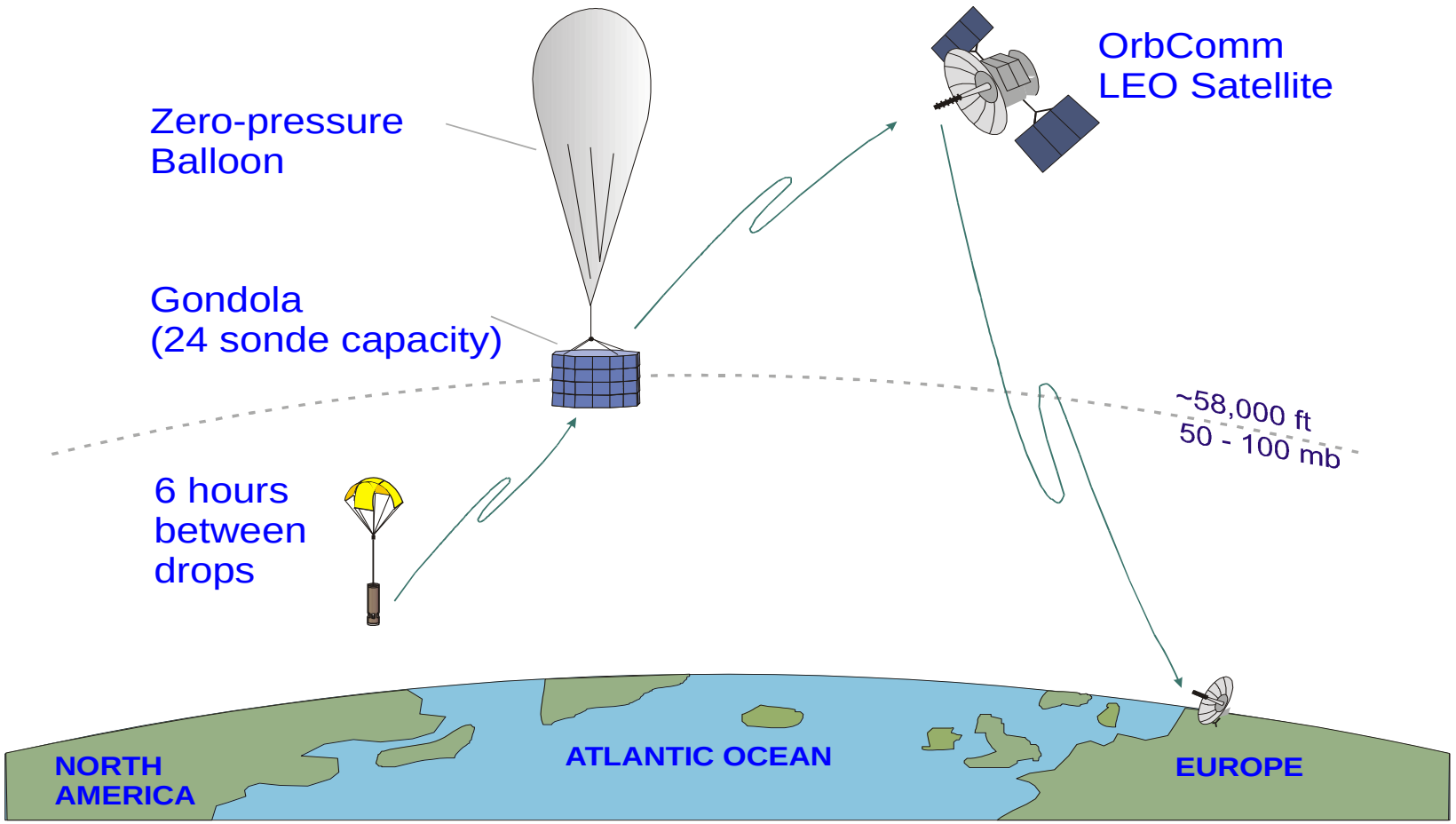




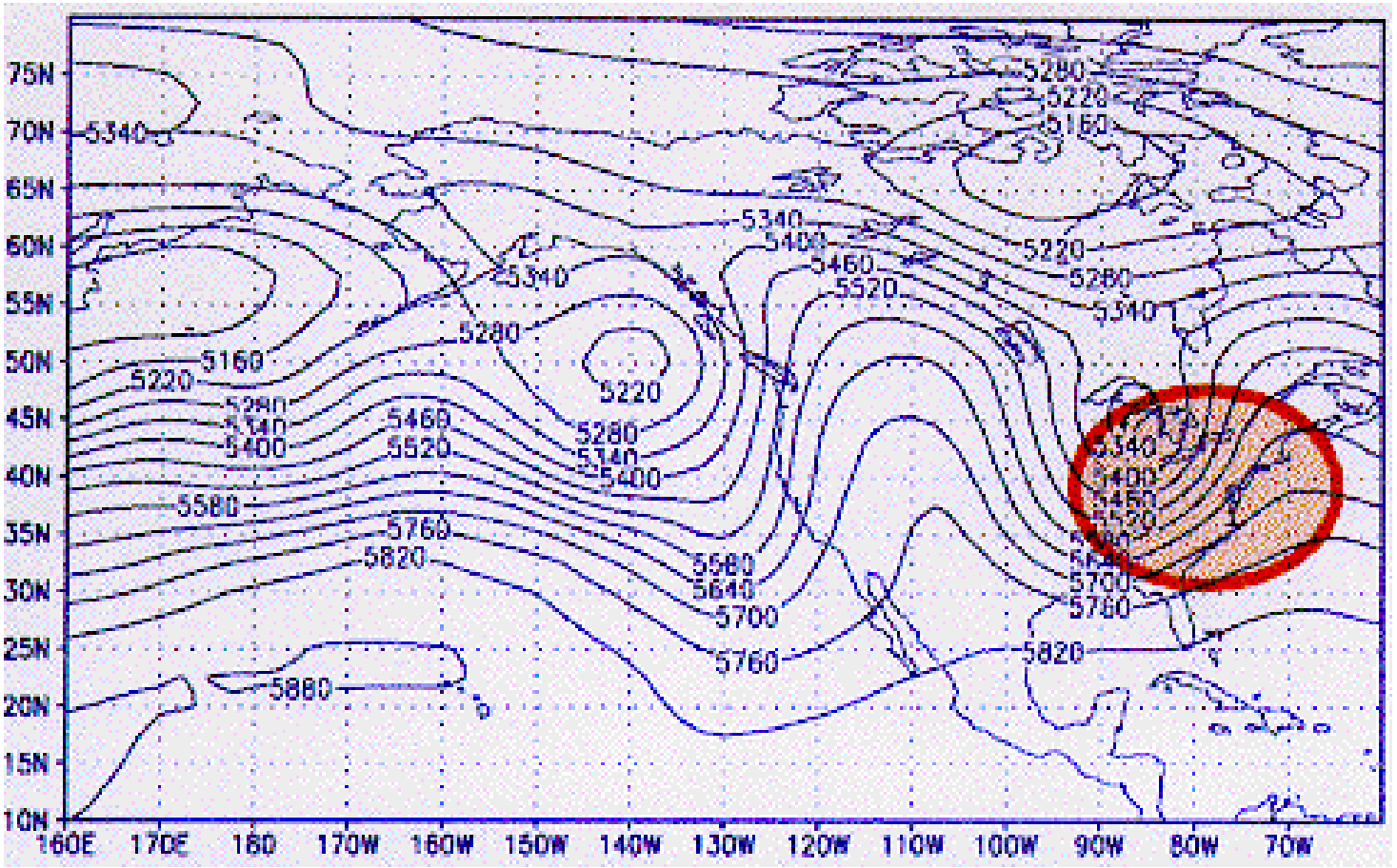


D+6 error

Extra observations in the FASTEX experiment 1997

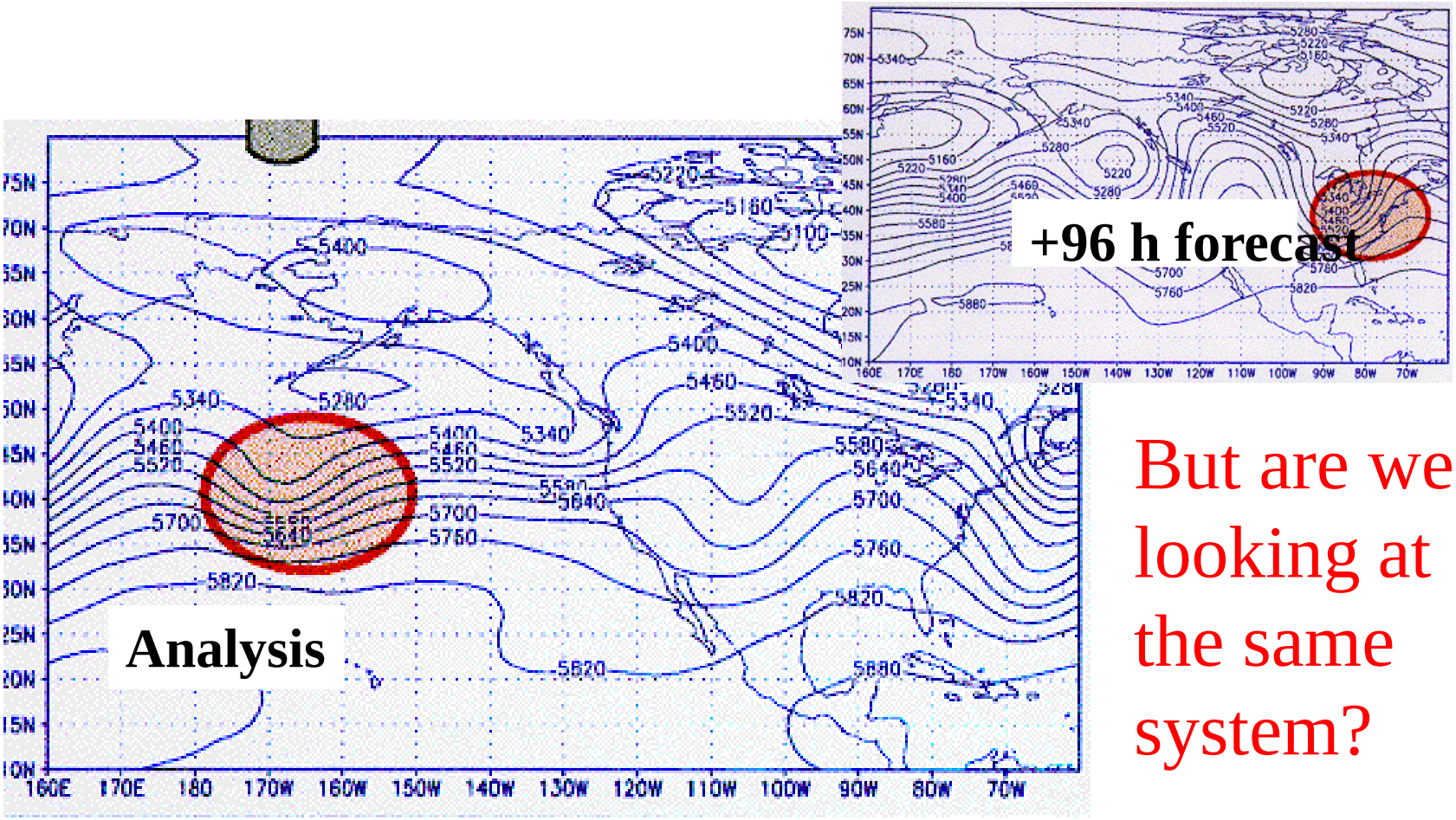


An example from the NCEP by Zoltan Toht



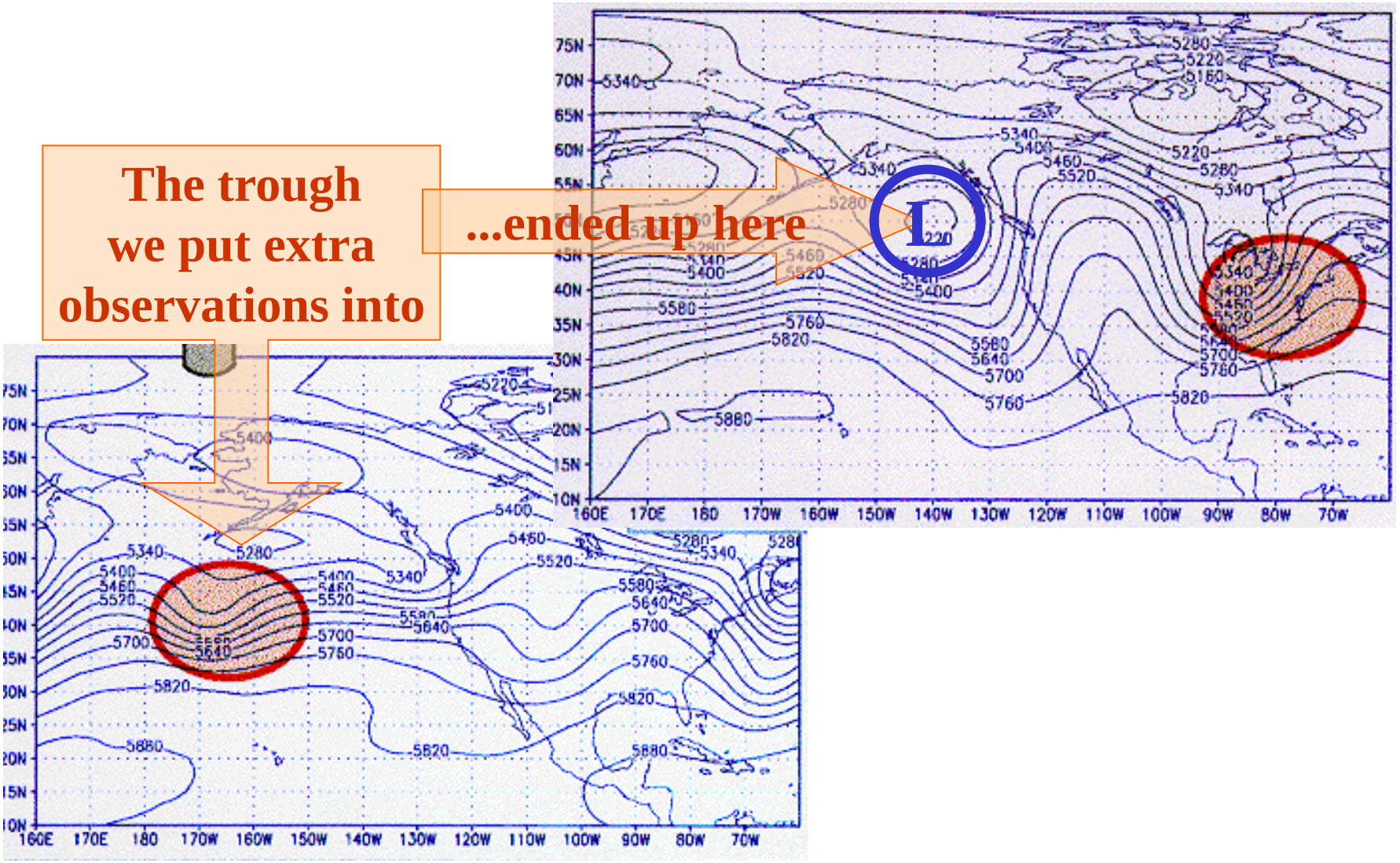
A numerical +96 h forecast indicates a storm over eastern USA in four days time

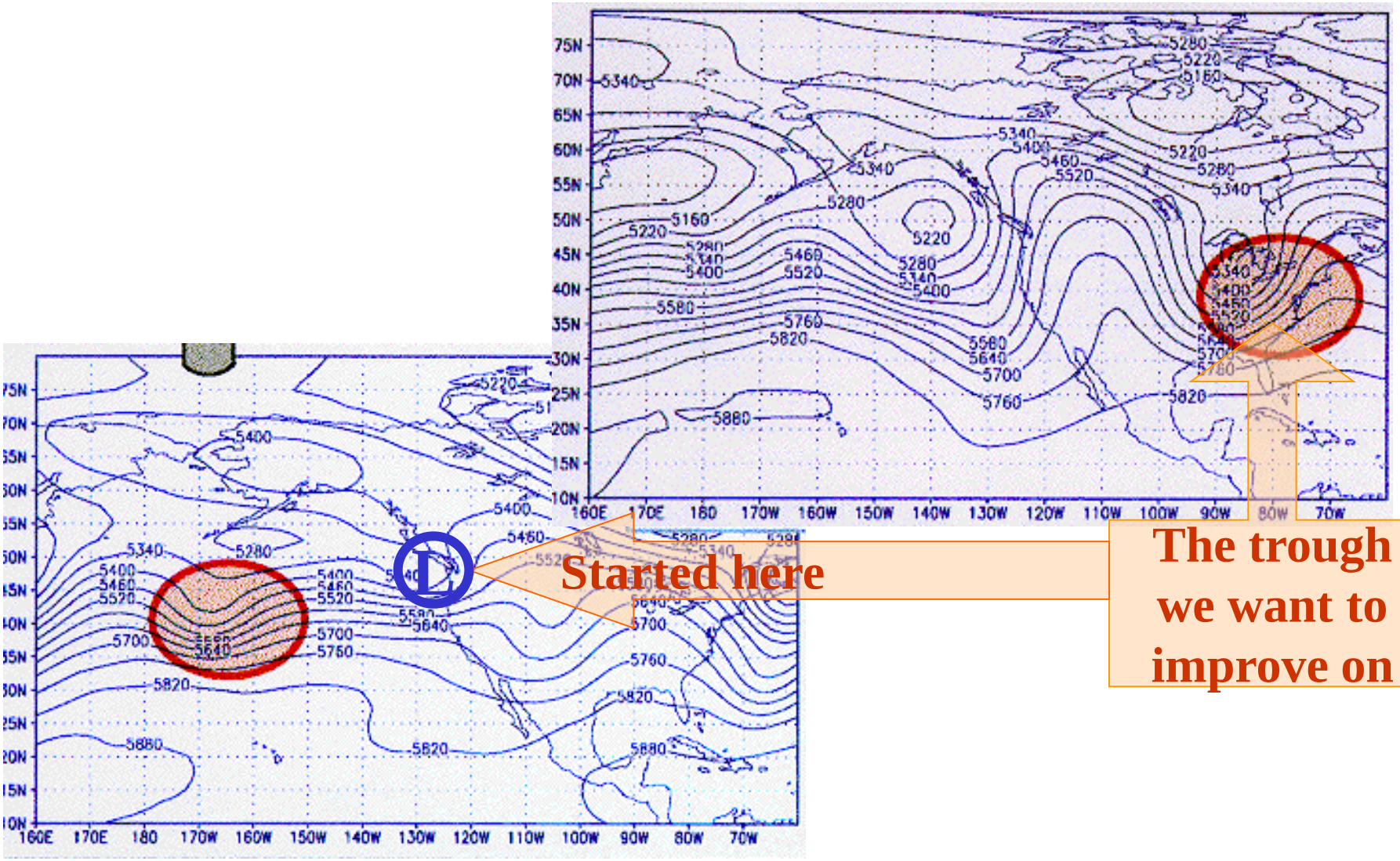
Mathematical (adjoint or sensitivity) analyses point out a trough in the mid-Pacific as the likely target for extra observations. More and better observation here will improve the forecast.



But are we looking at the same system?

The answer is NO




Started here
The trough we want to improve on

End