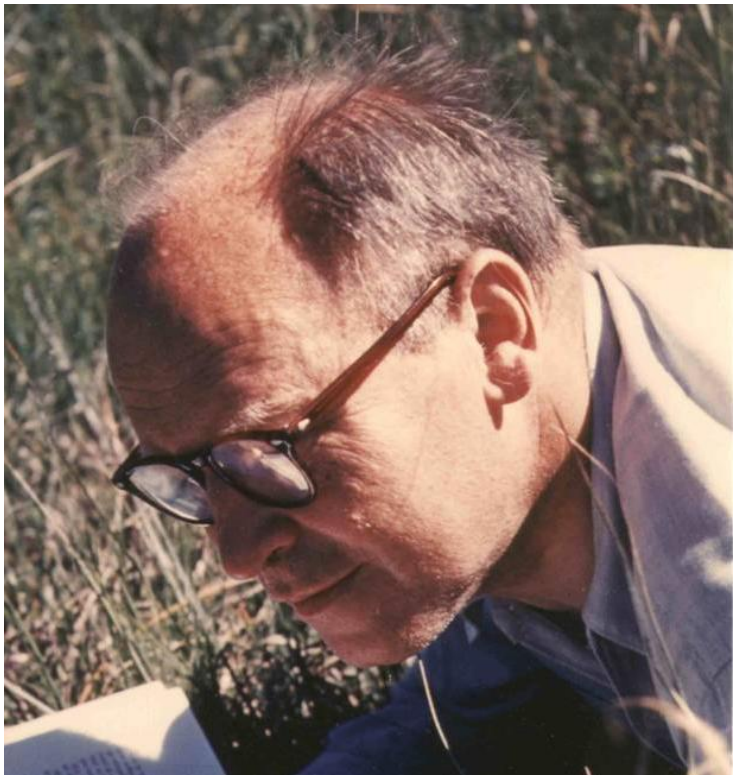
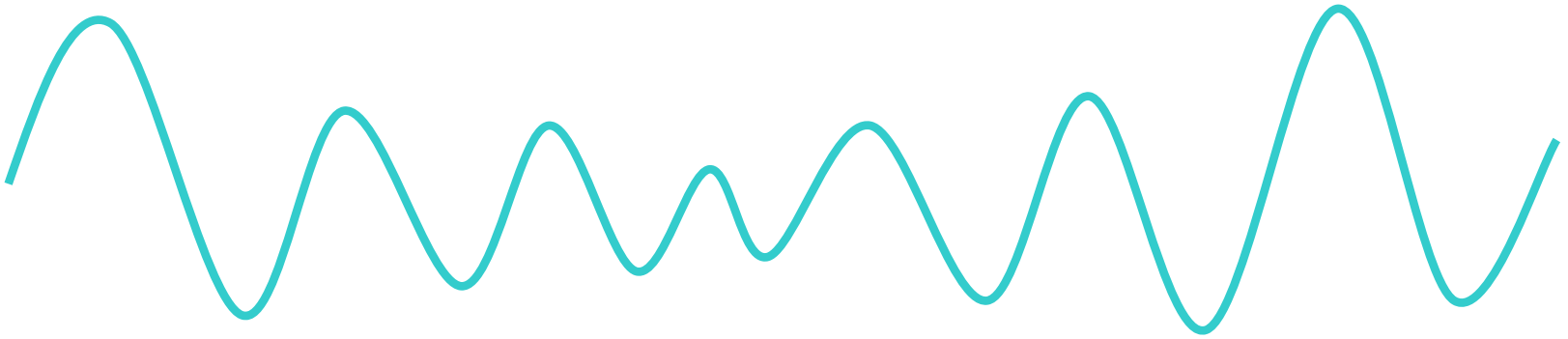
Dynamic meteorology without tears

Group velocity and "downstream development"

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

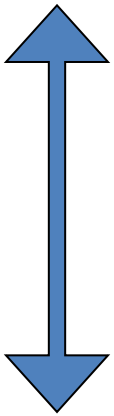
Resting on the beech he could listen to the sound of the incoming waves, their rhythm with a peculiar periodicity, **“The Seventh Wave”** a consequence of **group velocity**





Speed of the weather **patterns** (high and low pressure systems)

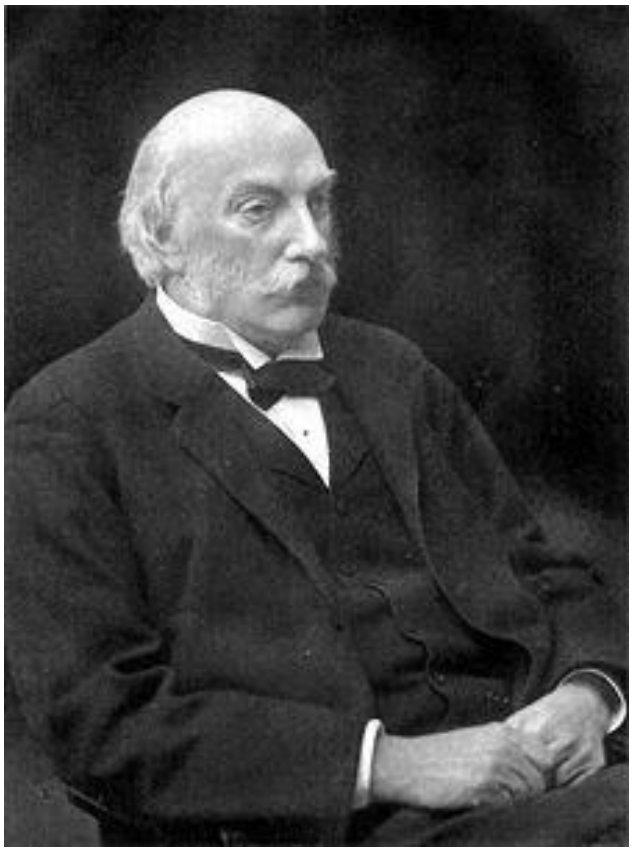
$$c = U - \frac{\beta L^2}{4\pi^2}$$



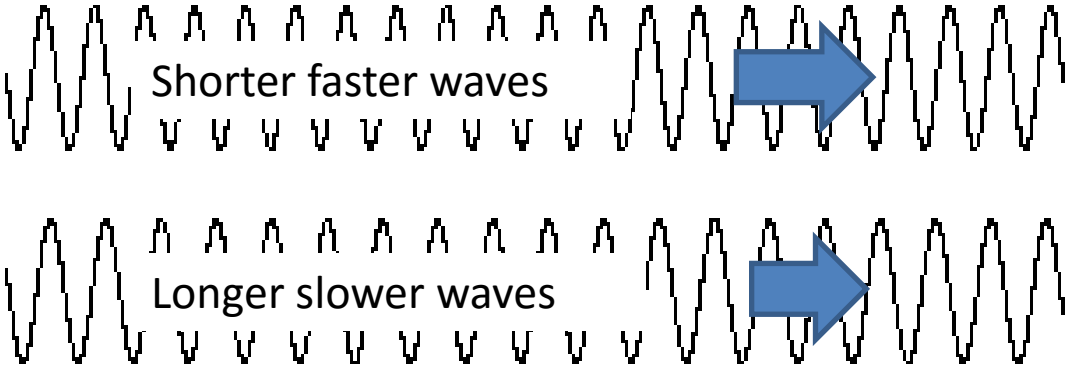
Speed of the **energy** in the weather patterns

$$c_g = U + \frac{\beta L^2}{4\pi^2}$$

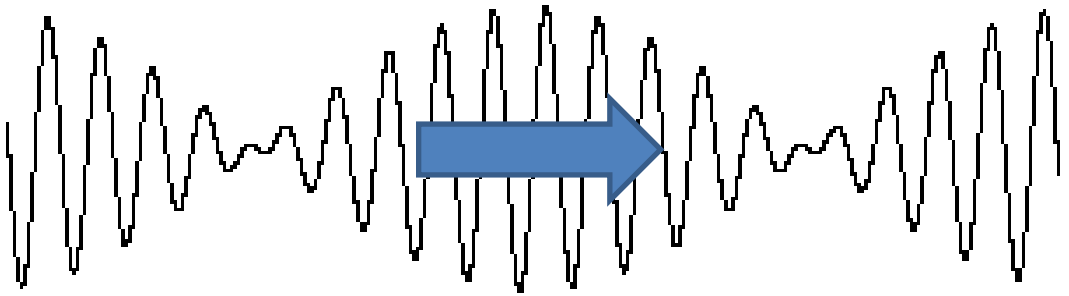
Group velocity is a ***British*** invention



Lord Rayleigh
1842-1919



The modulated electromagnetic wave can be decomposed into a sum of non-modulated waves of different wavelengths and phase speeds



What does it mean?

Group velocity in water surface waves

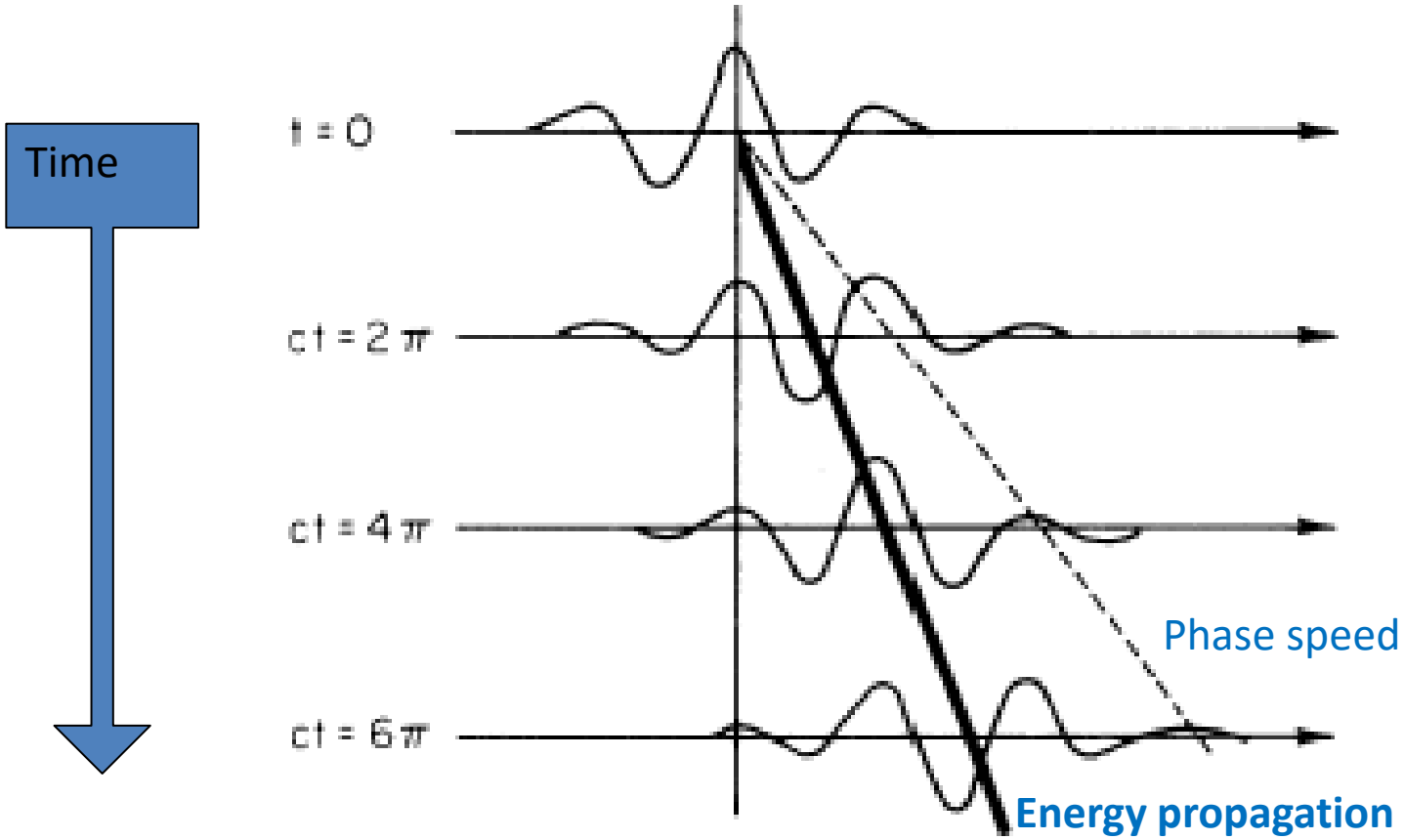


Fig.1 The successive progression of water wave packages. The crest in the centre moves rapidly out, weakens and leaves behind the main energy, into which upstream waves enter and amplify (from Holton, 1992).

Group velocity in the atmosphere

Time

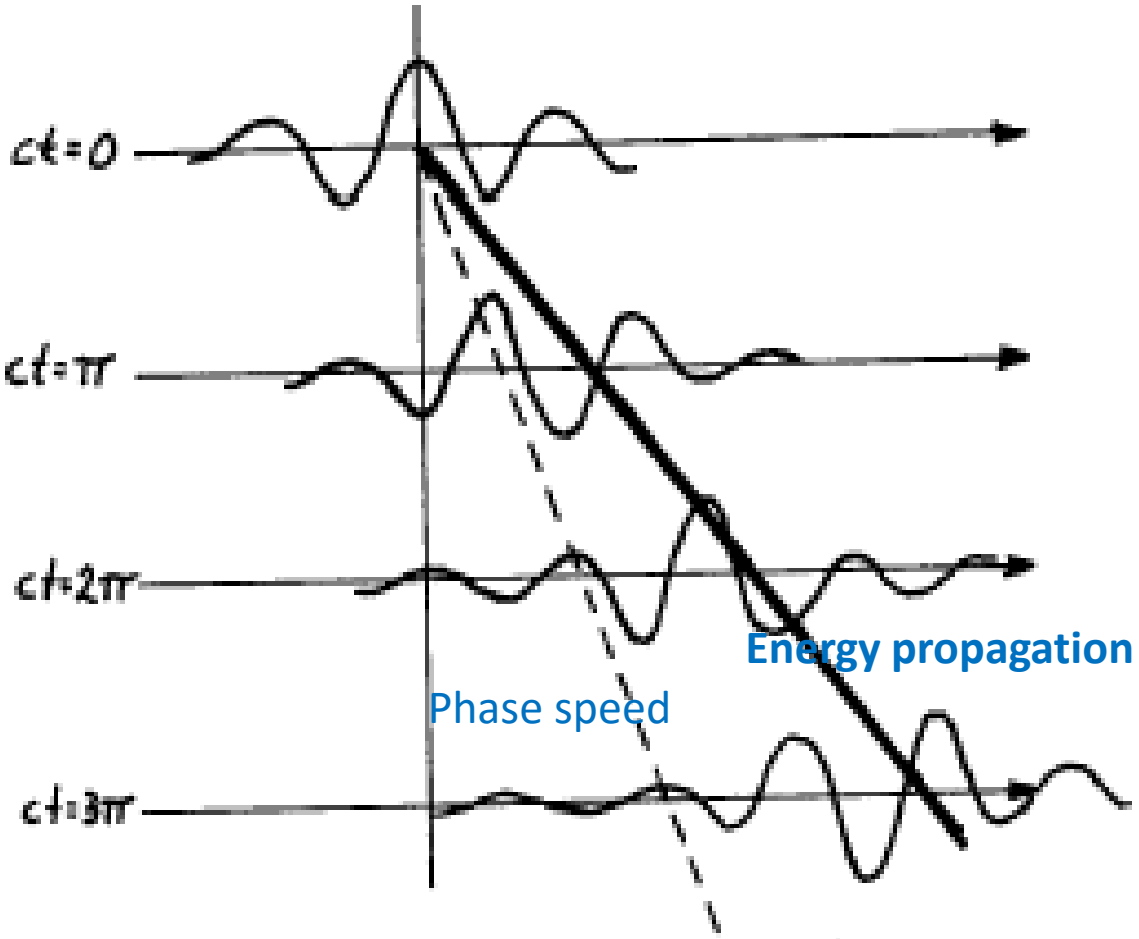
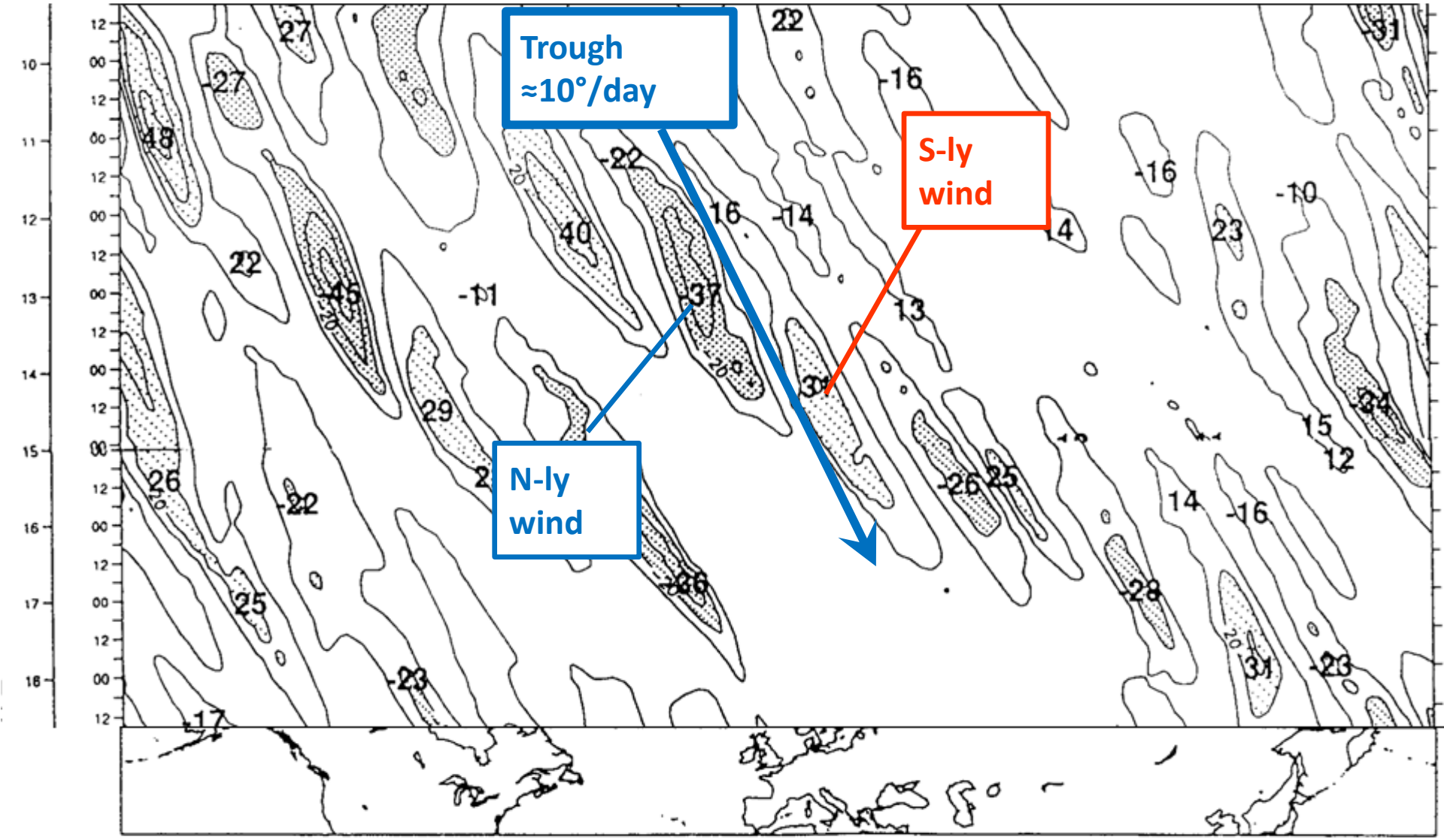


Fig. 2: The corresponding mechanism in the atmosphere: the central wave moves more slowly than the bulk of the energy which propagates downstream amplifying waves on its arrival.

Trough-ridge (Hovmöller) Diagram

of 250 hPa meridional wind component 10-18 September 1993



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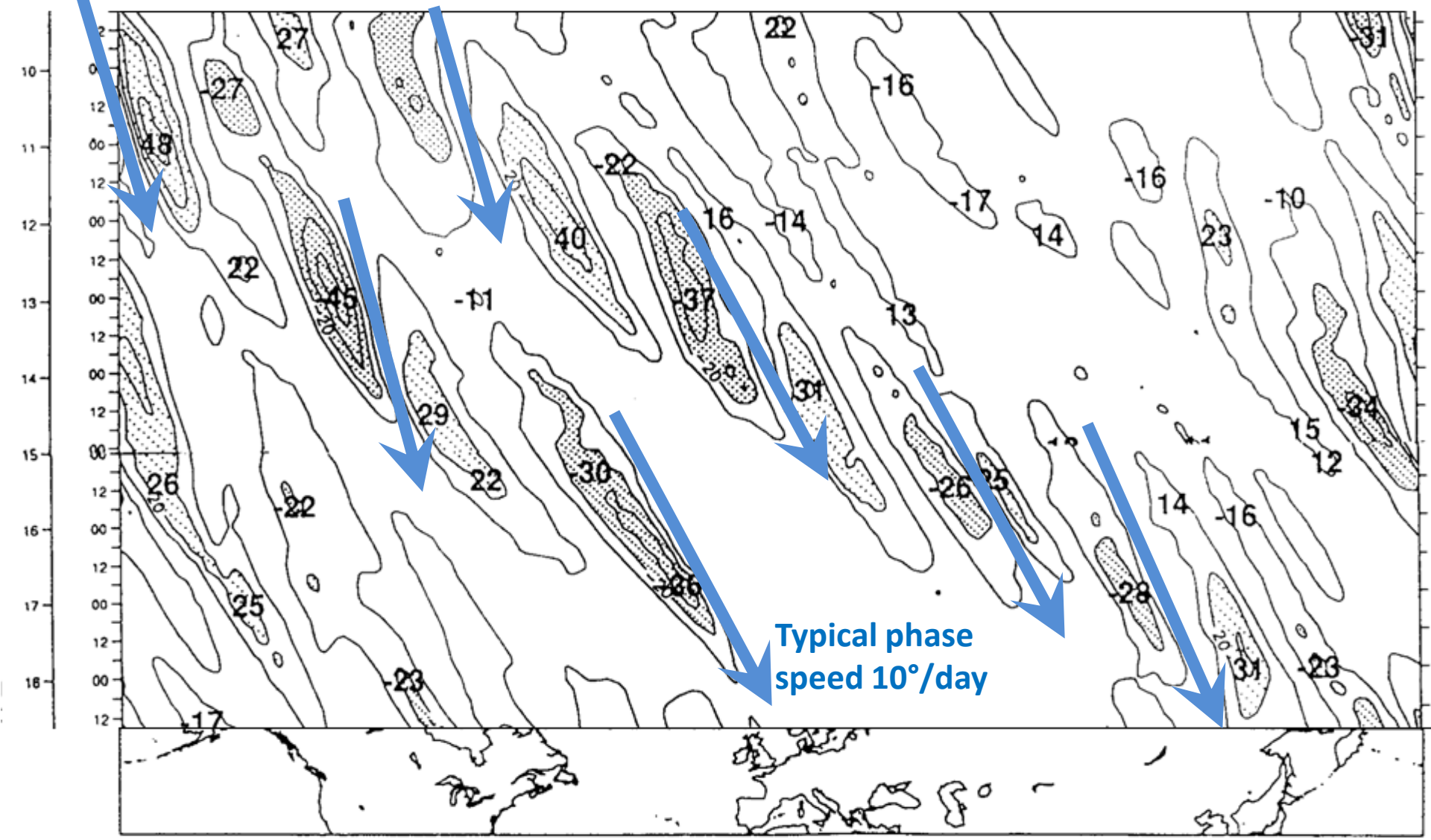

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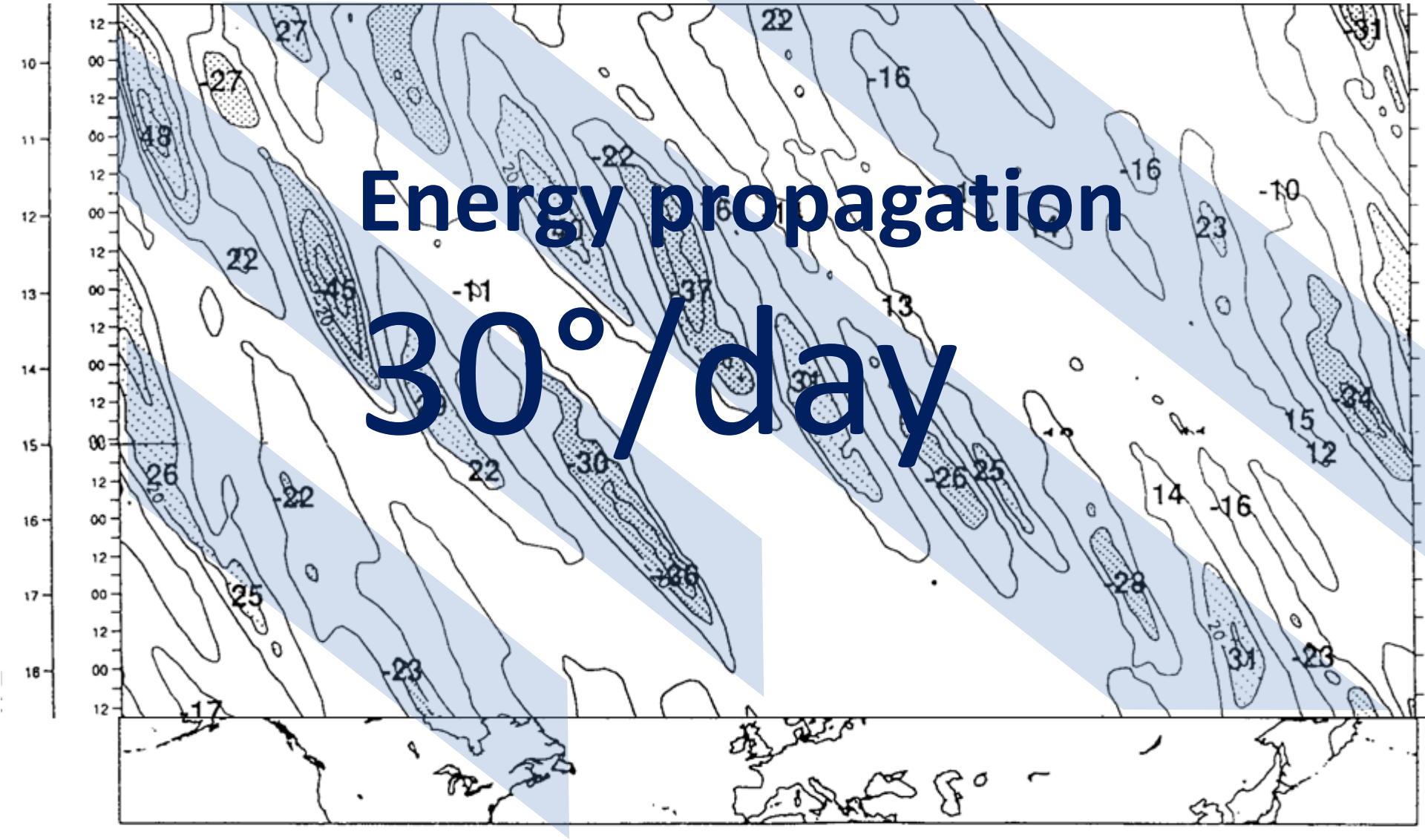
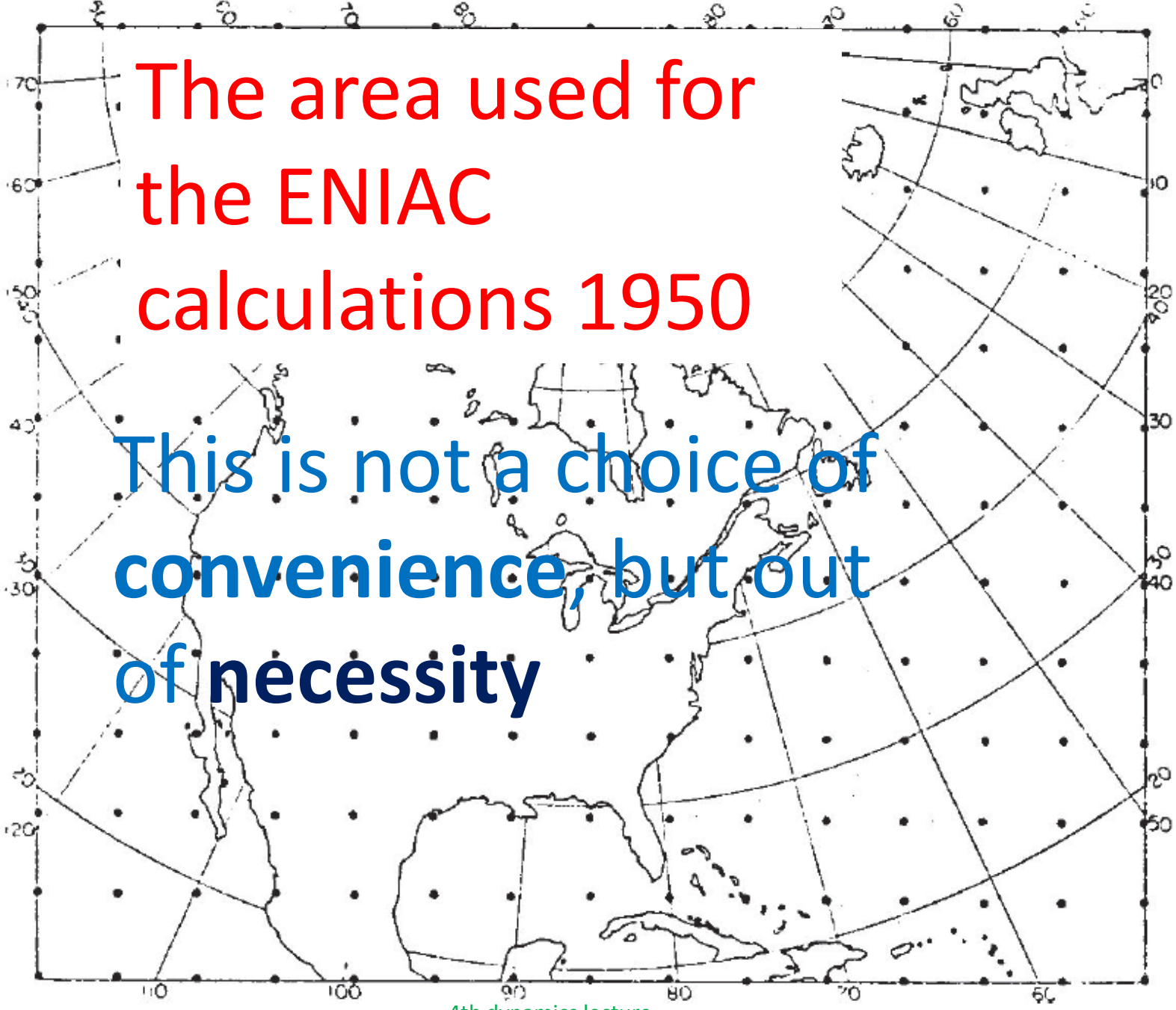


What use can be made of "group velocity thinking"?

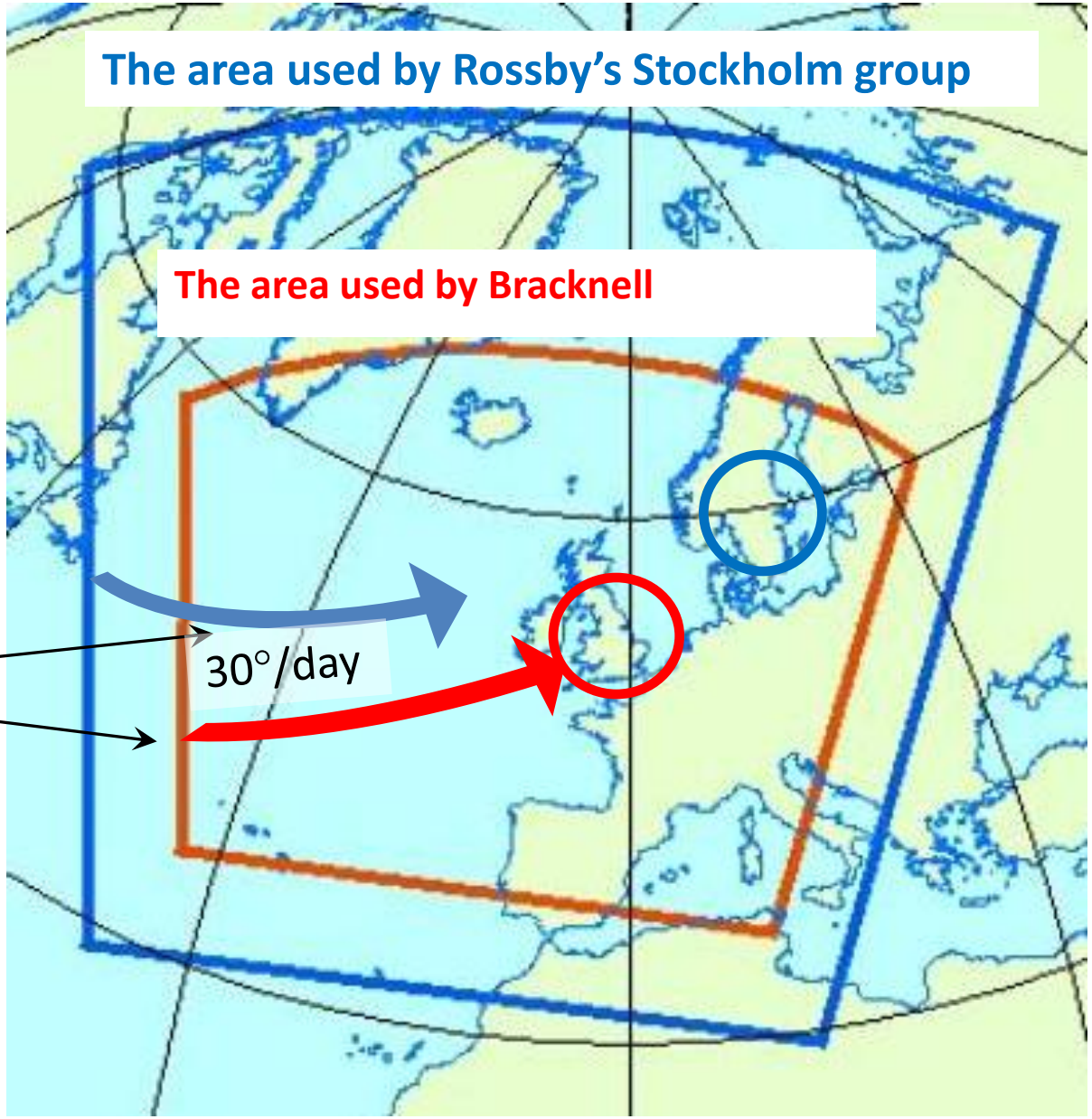
1. In the early days of NWP "group velocity thinking" was used to define the computational area – as it should still be used!



The area used for the ENIAC calculations 1950

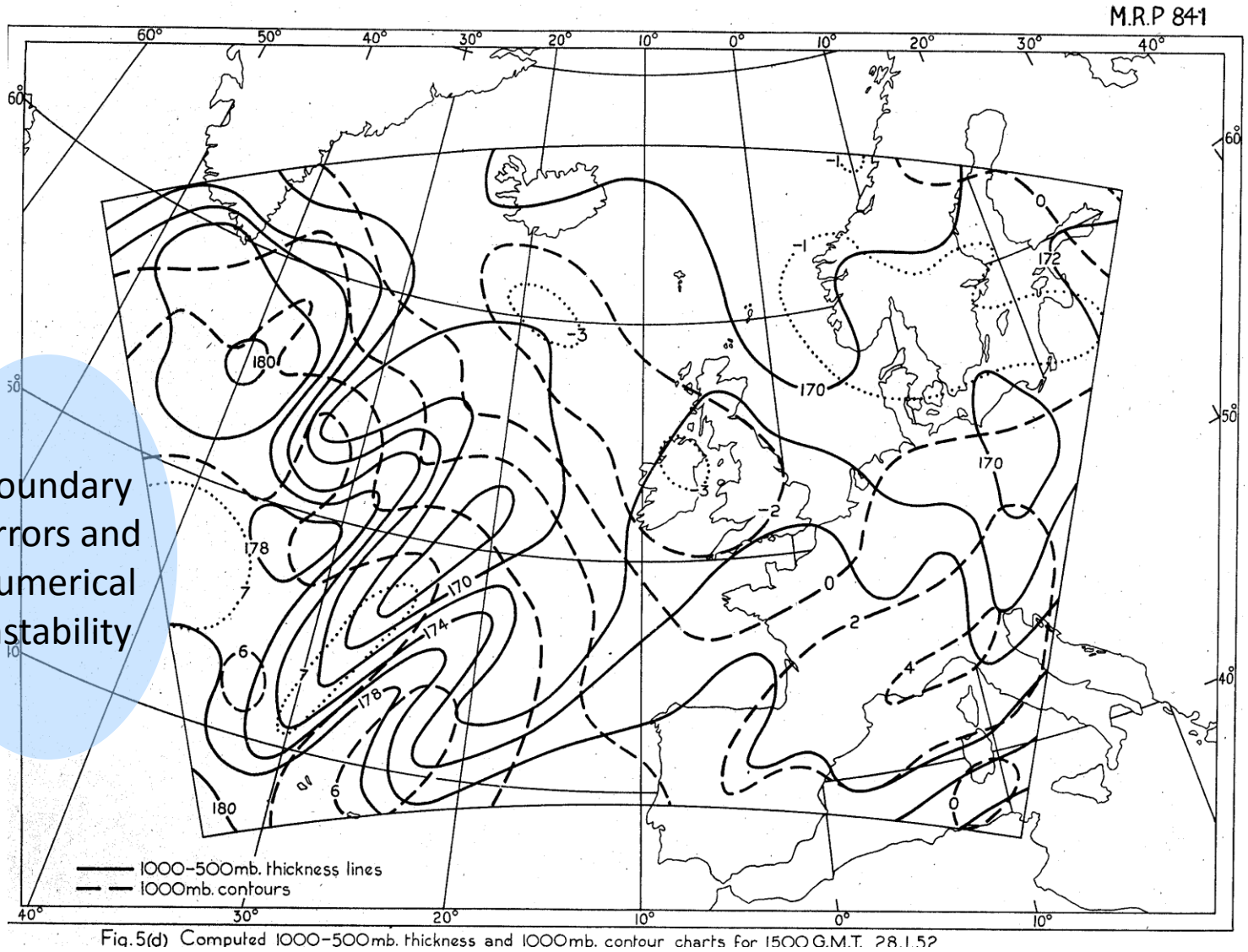
This is not a choice of **convenience**, but out of **necessity**

The effects of the constant boundaries should not reach the forecast heart land



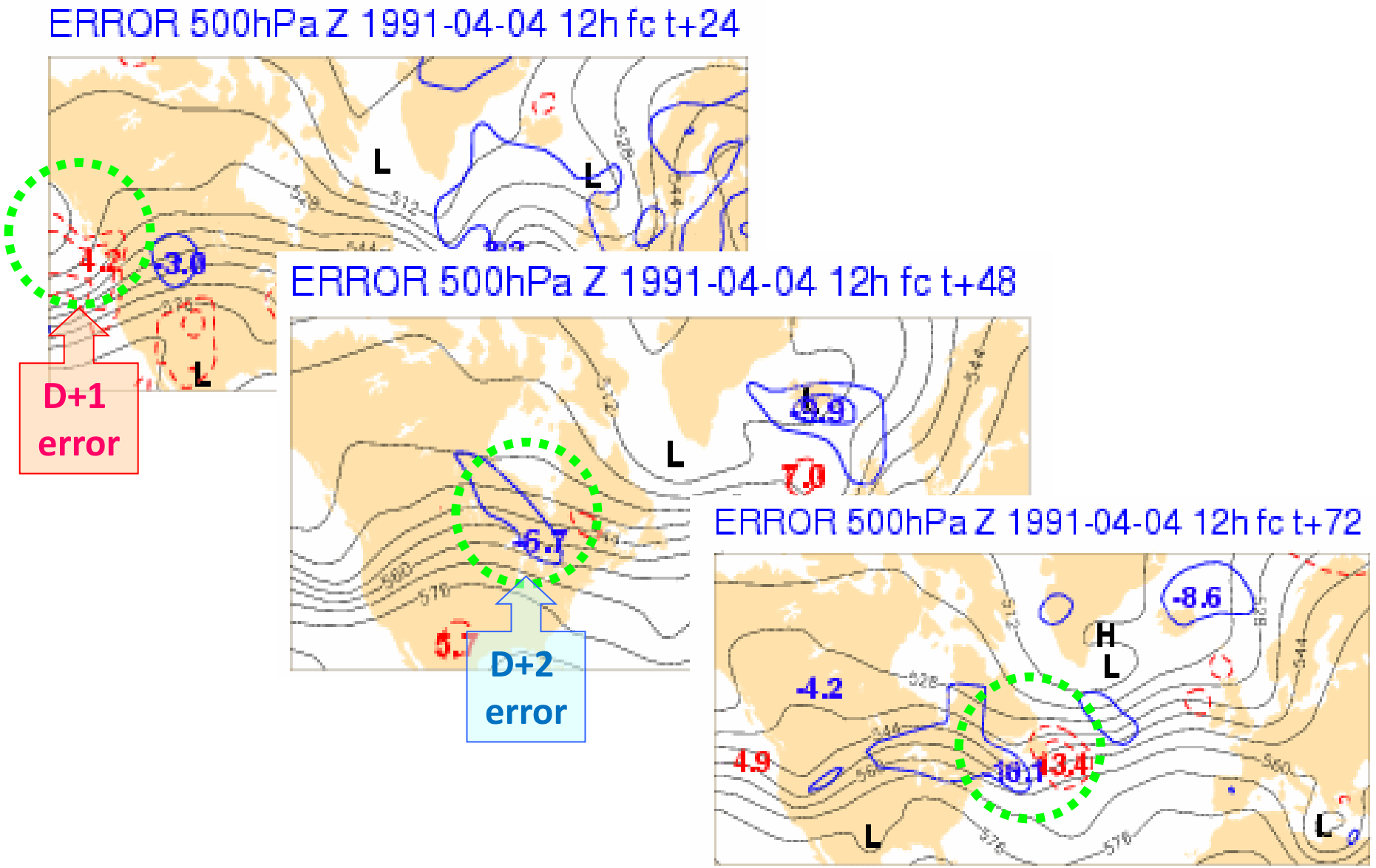
The typical **"group velocity"** is about the same us the upper-tropospheric flow

A +24 hour UKMO forecast 27 January 1952 15 UTC



2. 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



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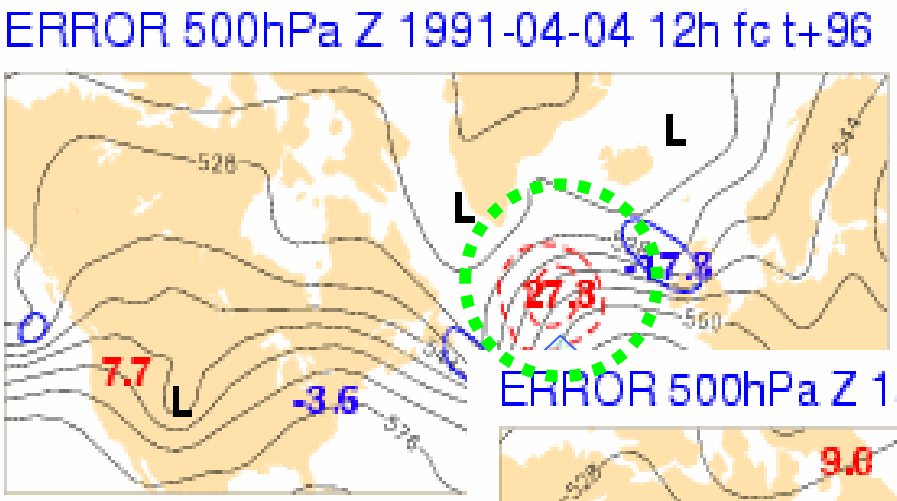
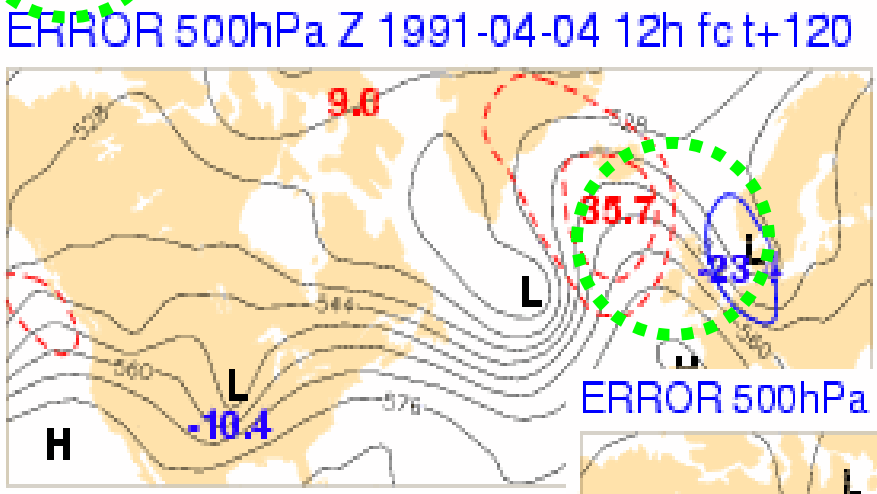
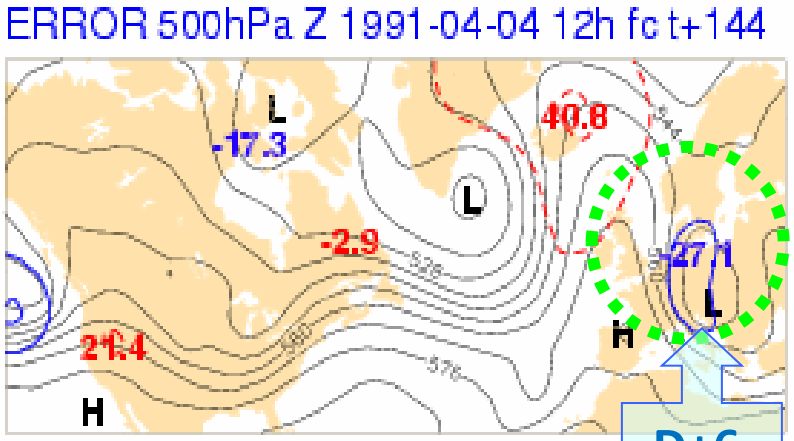


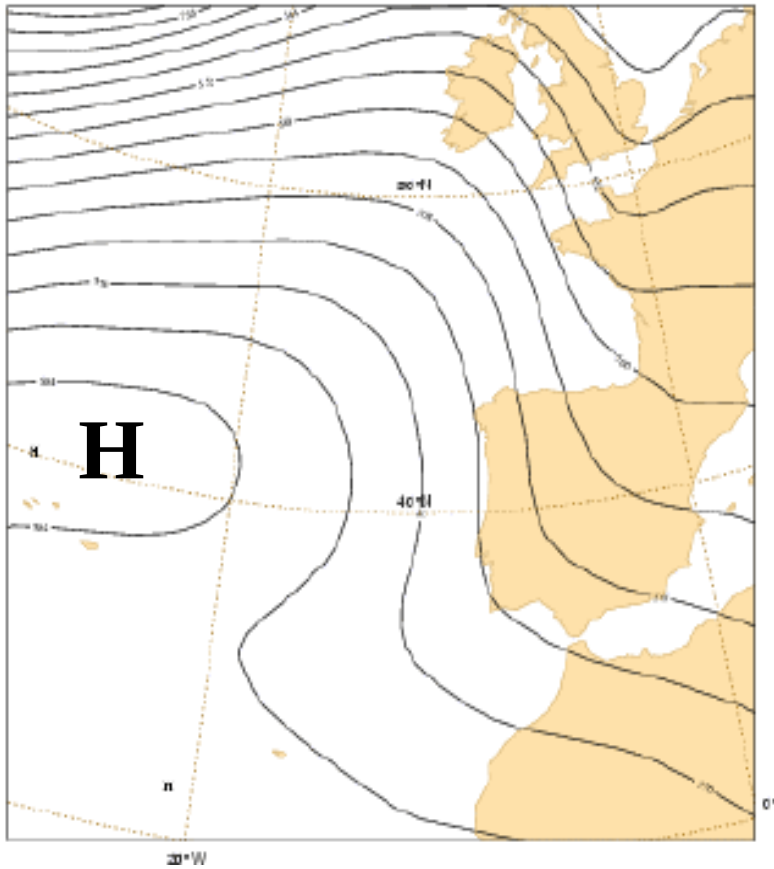




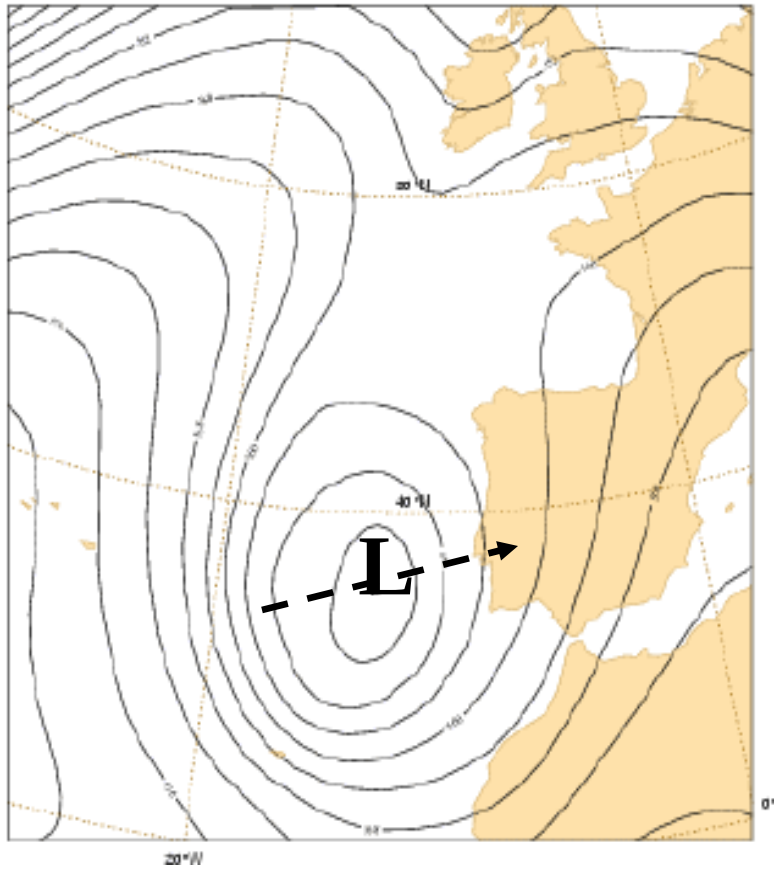
D+6 error

A “jumpy” forecast of a Spanish cut-off

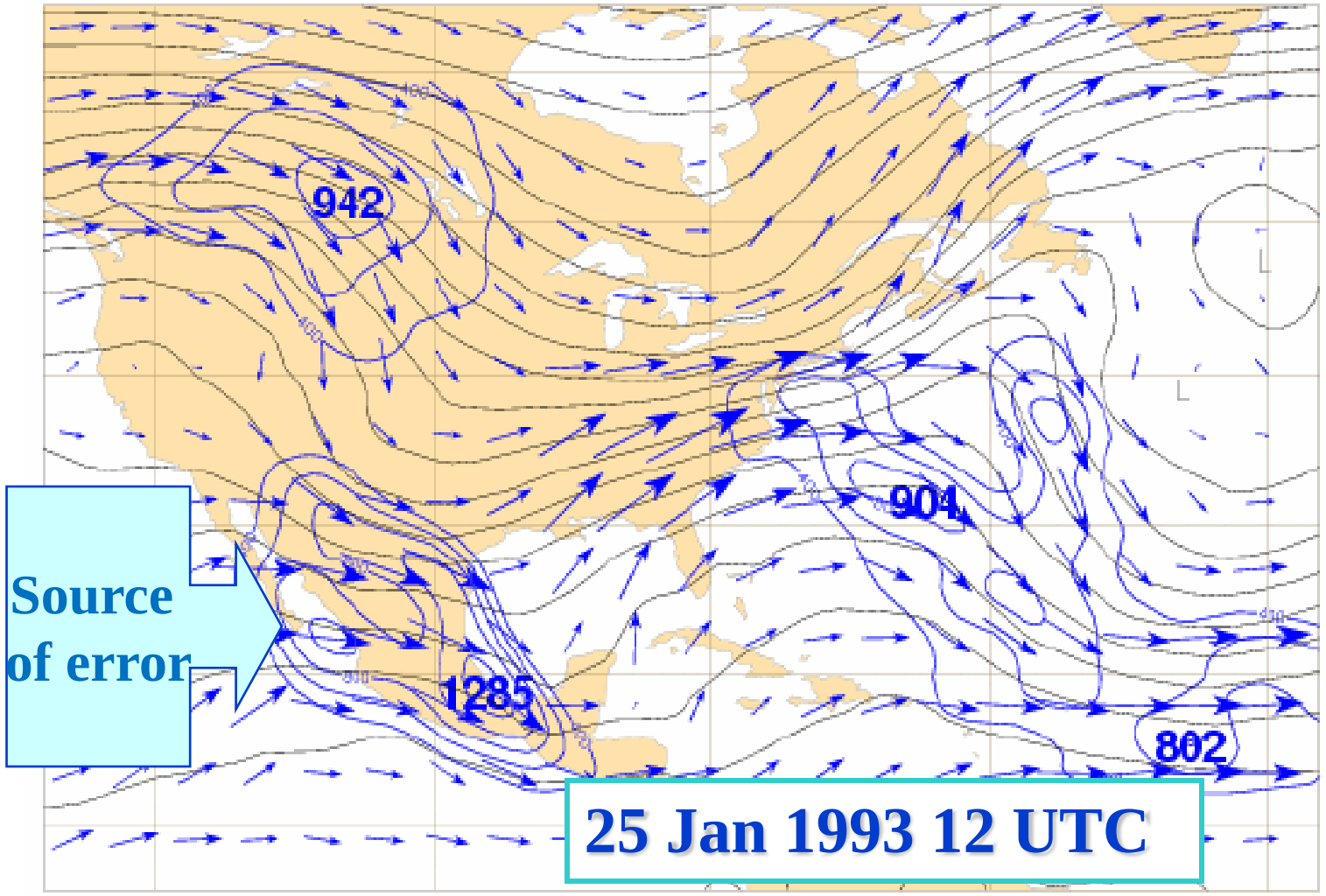
D+5 from 24 Jan 1993 VT 29 Jan



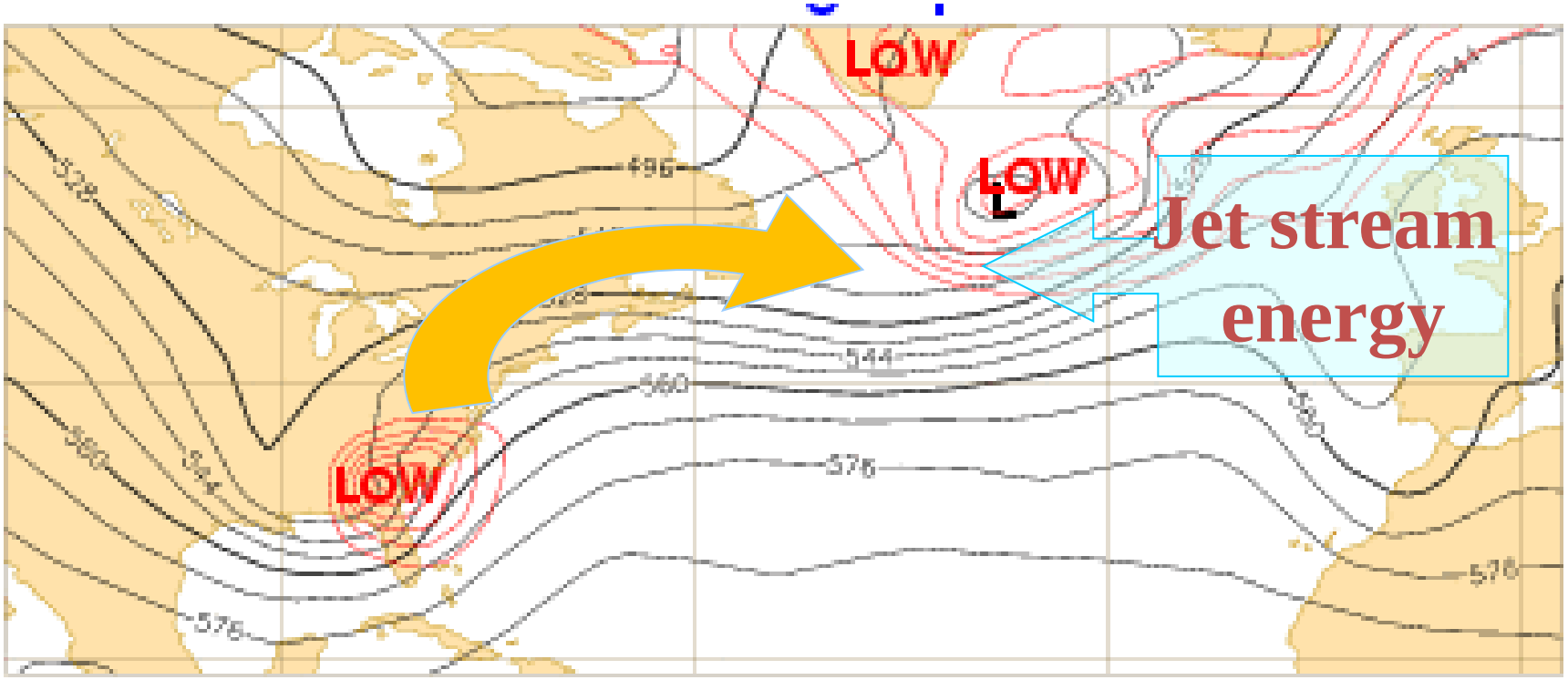
D+4 from 25 Jan 1993 VT 29 Jan



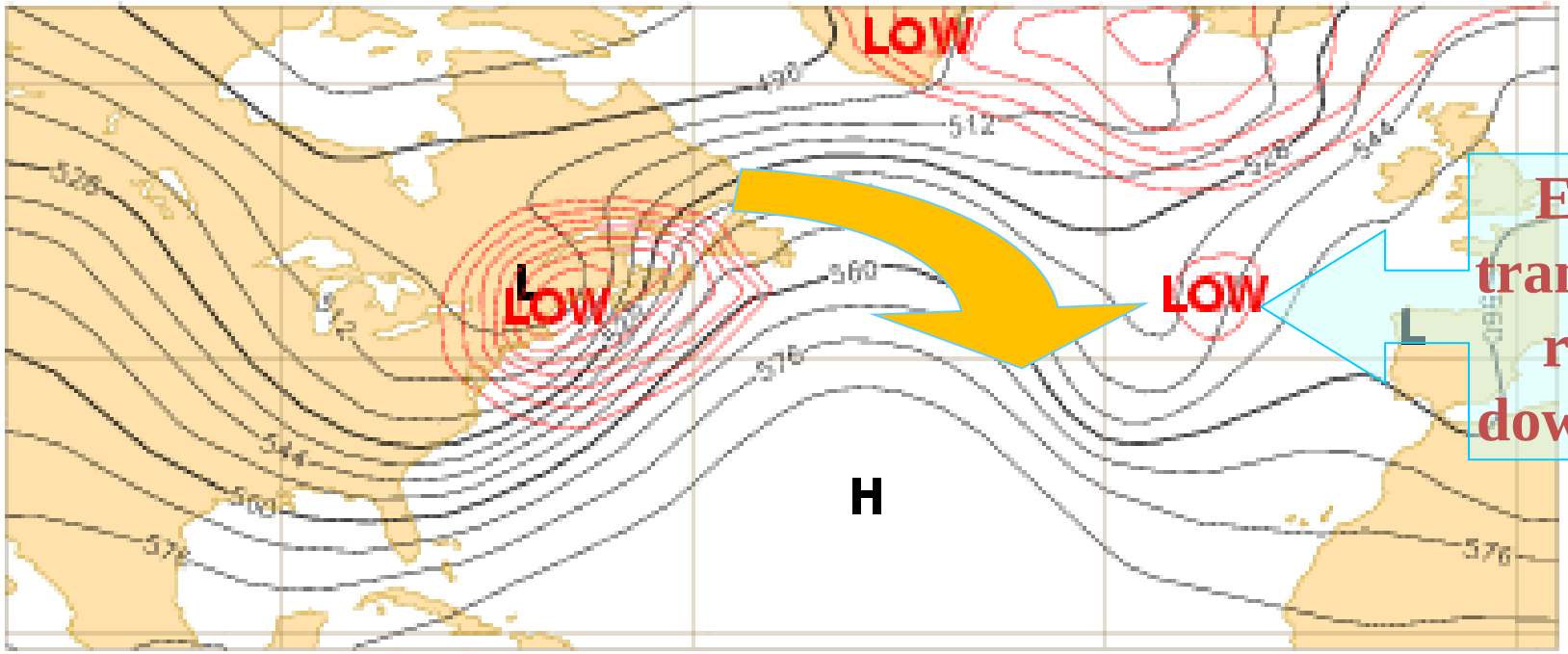
The cause of the "jump" was traced back to the Mexican Gulf where the EPS perturbations confirmed the sensitivity



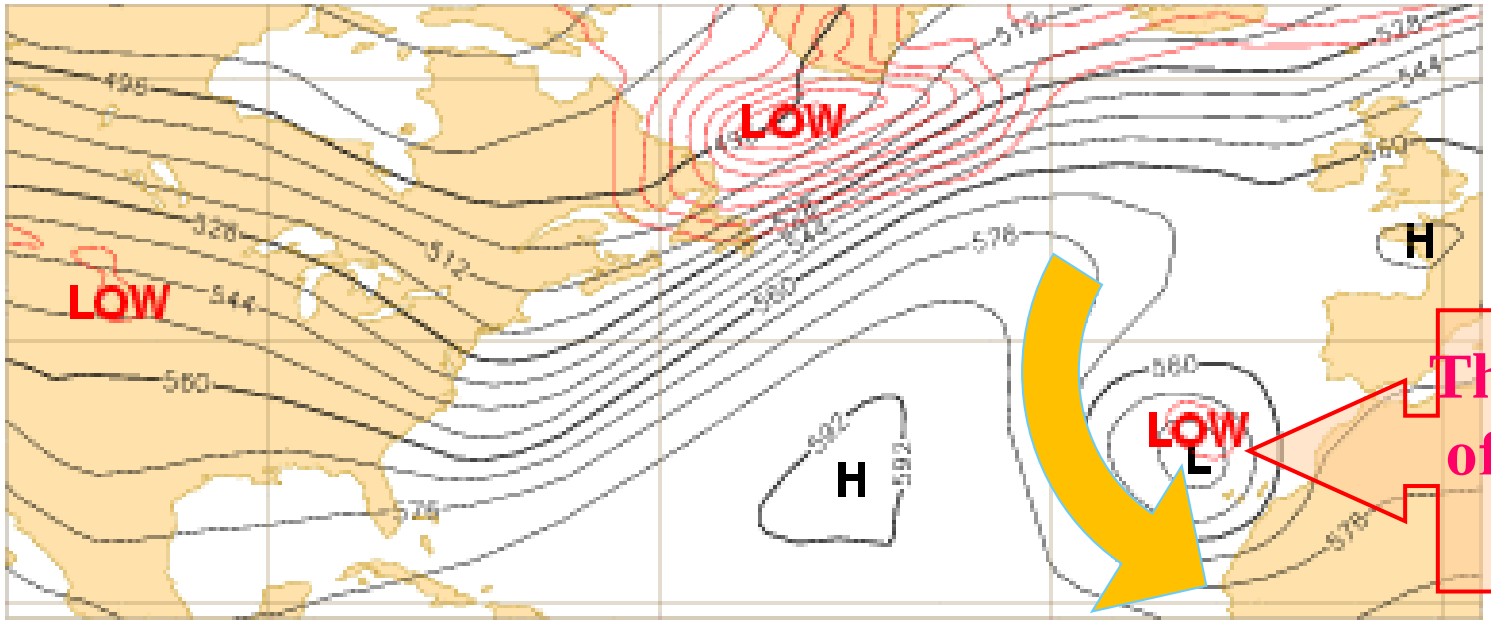
500 and 1000 hPa 1993-01-27 12z

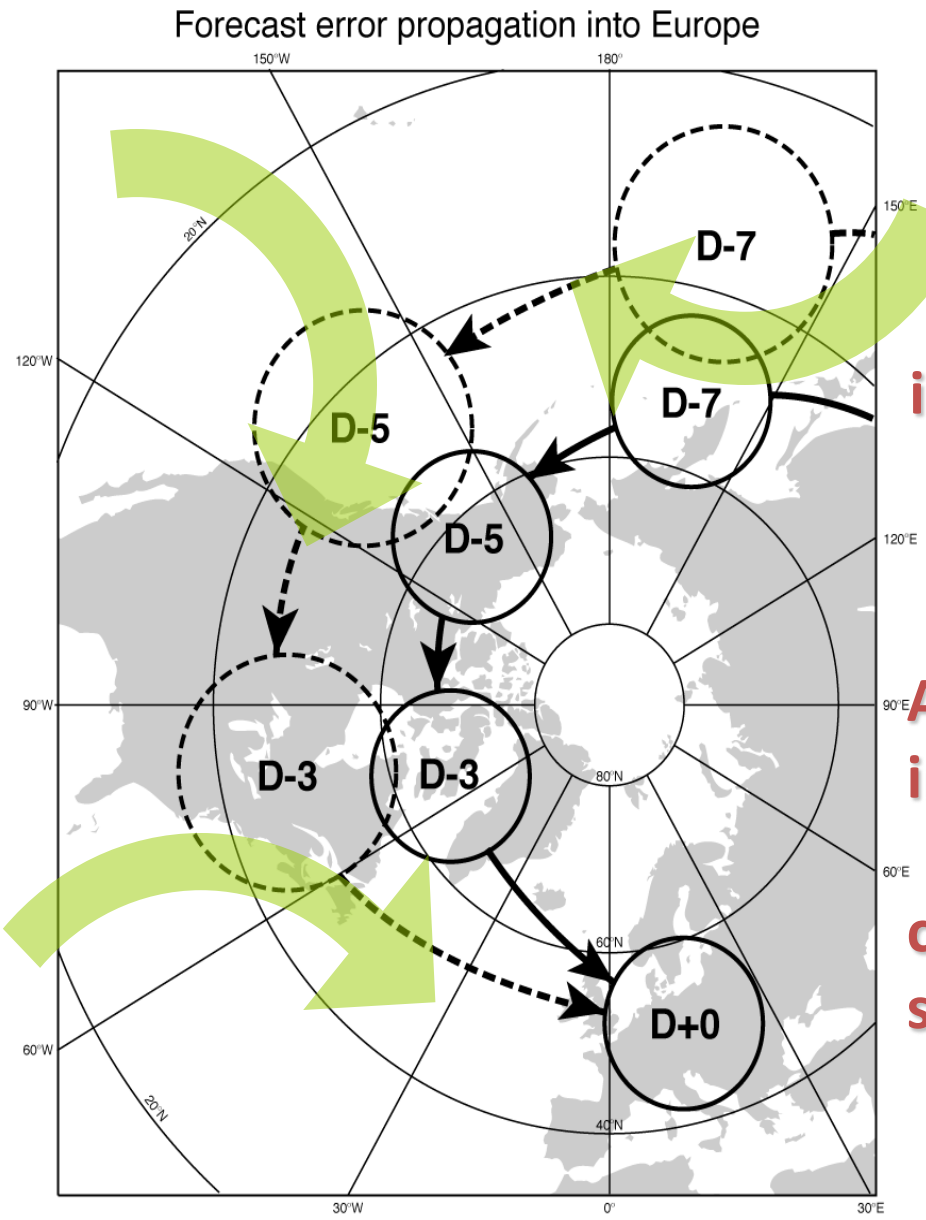


500 and 1000 hPa 1993-01-28 12z



500 and 1000 hPa 1993-01-29 12z





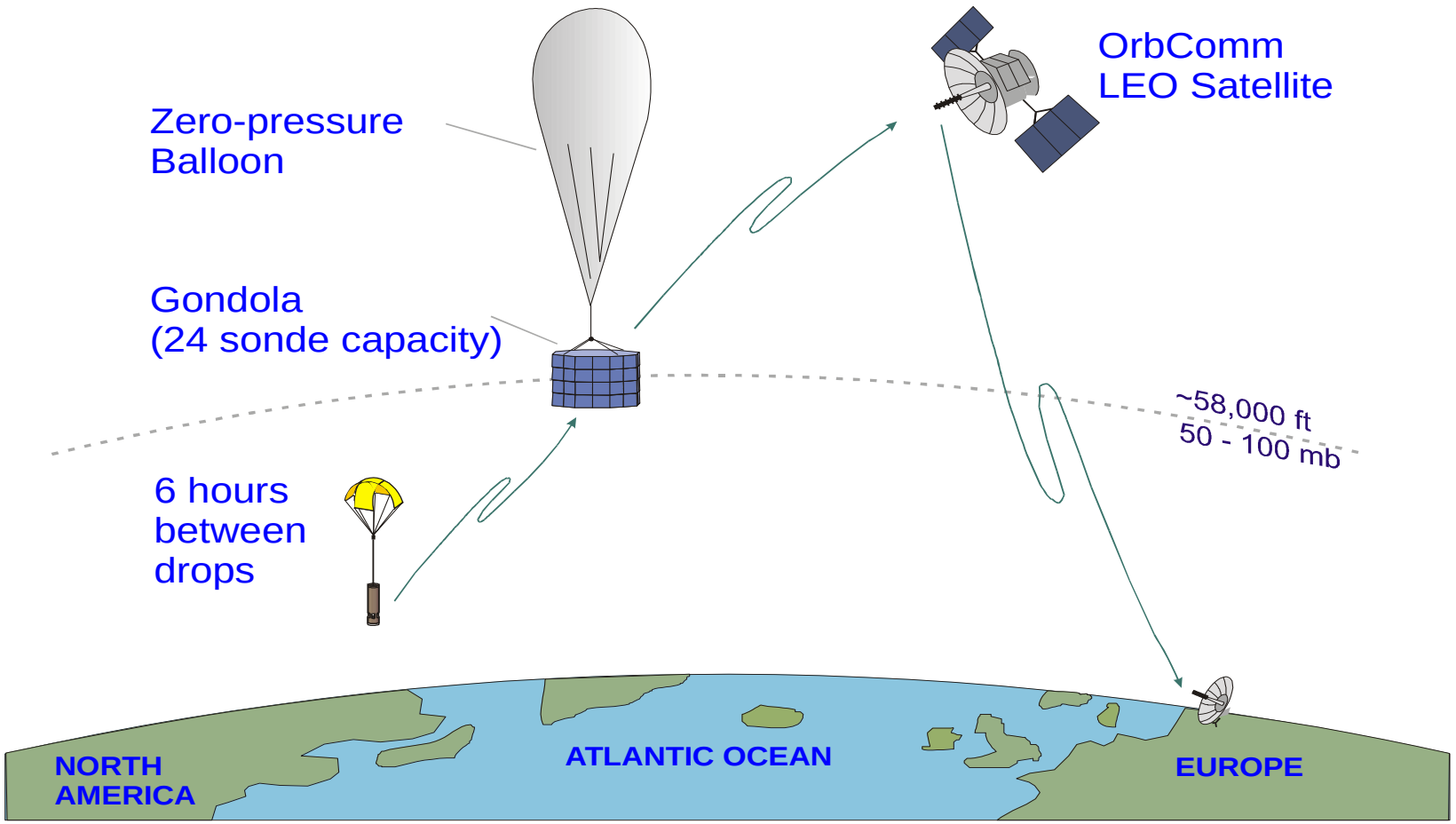
Forecast errors reach Europe with a speed of ~30 longitude deg/day, irrespective of season (thanks to the convergence of the meridians)

Adding to this are the influences

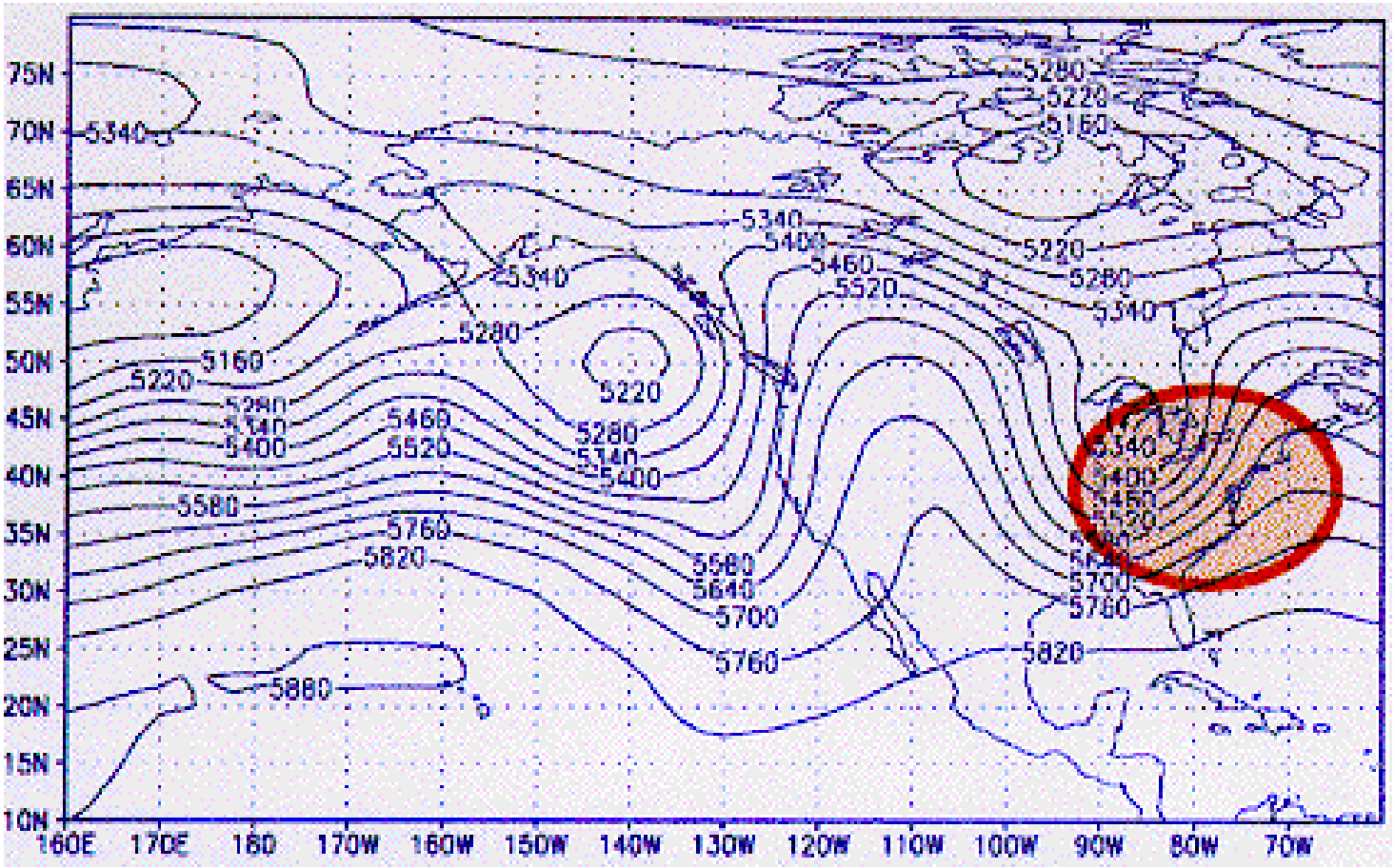
coming from the Tropics at all seasons

3. In particular in the US it is used, or has been used, to define where extra observations should be supplied

Extra observations in the FASTEX experiment 1997

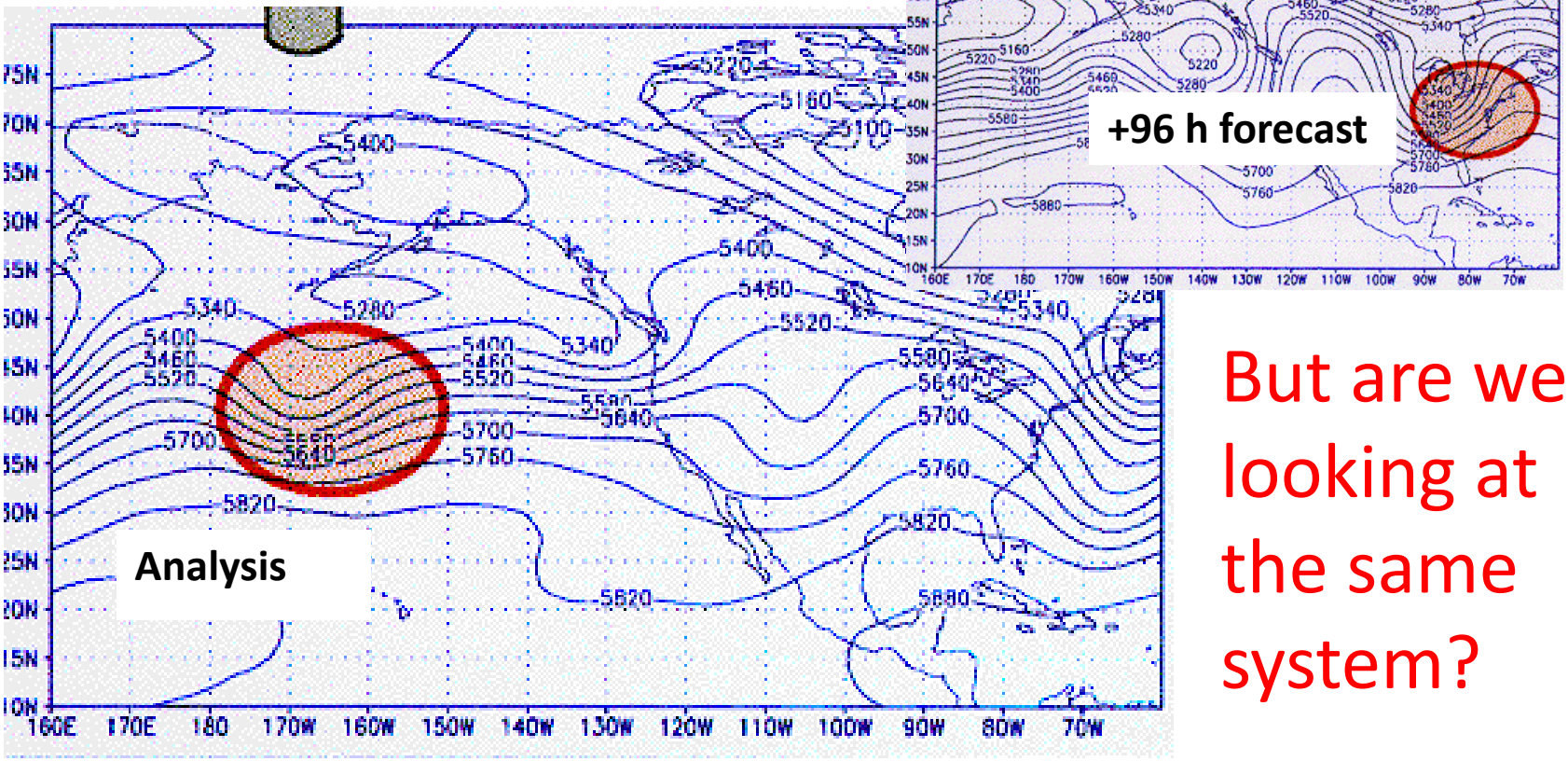


An example from the NCEP by Zoltan Toht



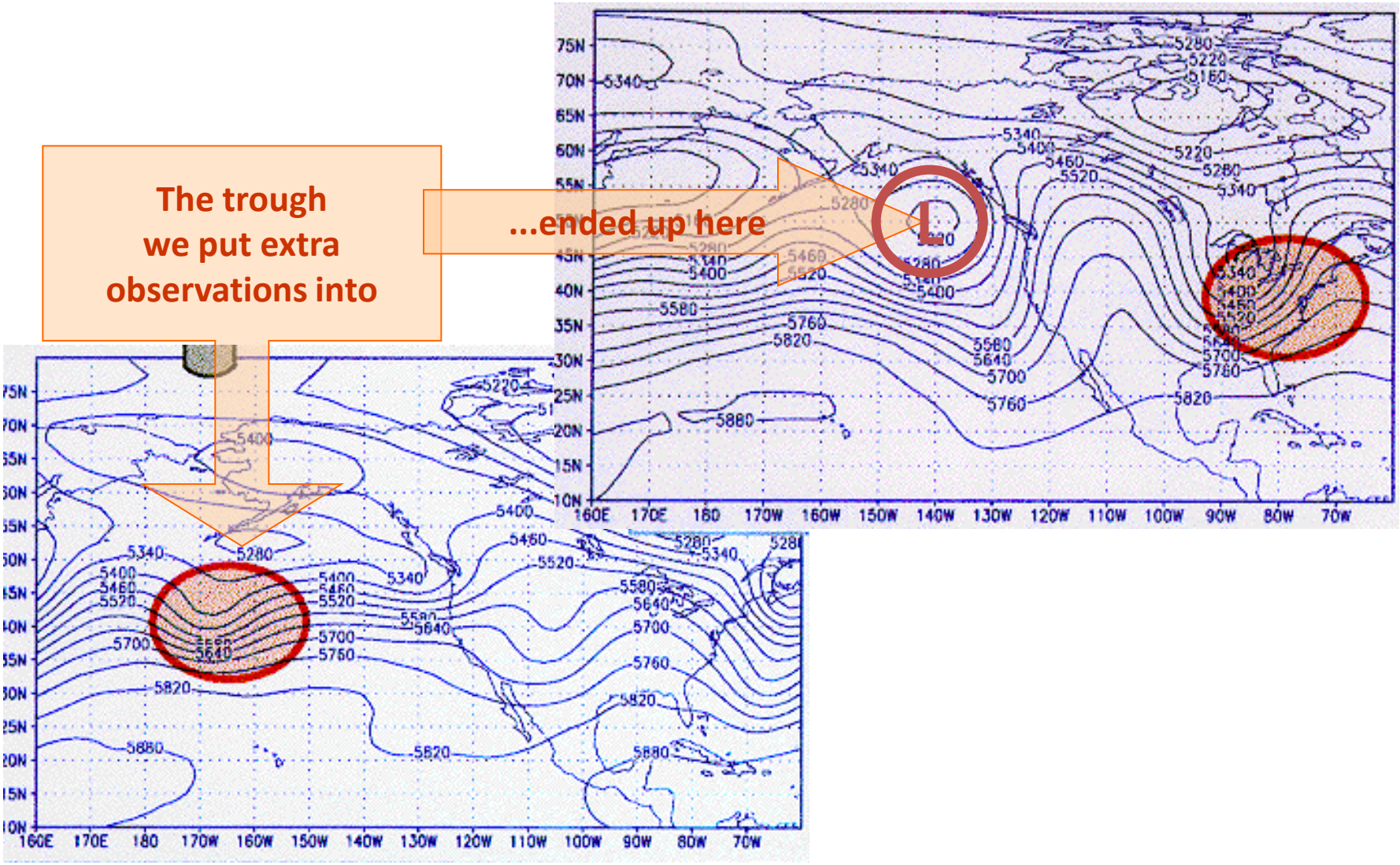
A numerical +96 h forecast indicates a storm over eastern USA in four days time

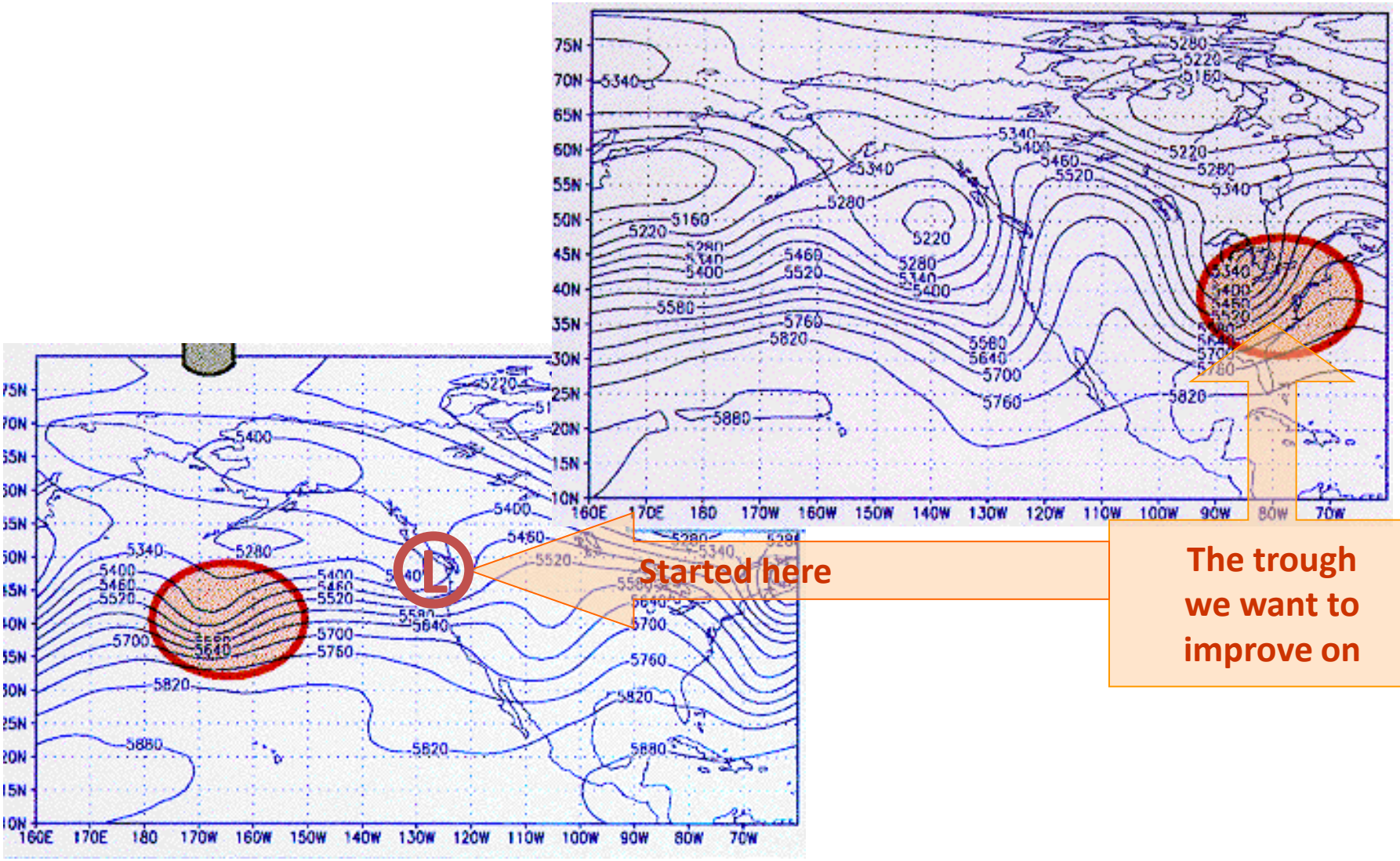
Mathematical (adjoint or sensitivity) analyses point out a trough in the mid-Pacific as the likely target for extra observations. More and better observation here will improve the forecast.



But are we looking at the same system?

The answer is NO




Started here
The trough we want to improve on

"Group velocity thinking"

will help us to

1. Understand "downstream development", the interaction between different synoptic systems
2. Design the size of computational areas in limited area NWP modelling
3. Trace the origin of forecast errors due to problems in initial conditions
4. Know where to put in extra "adaptive" observations
5. Realize the limitations of "PV-thinking" . . . .

End