Scale-selective digital-filtering initialization

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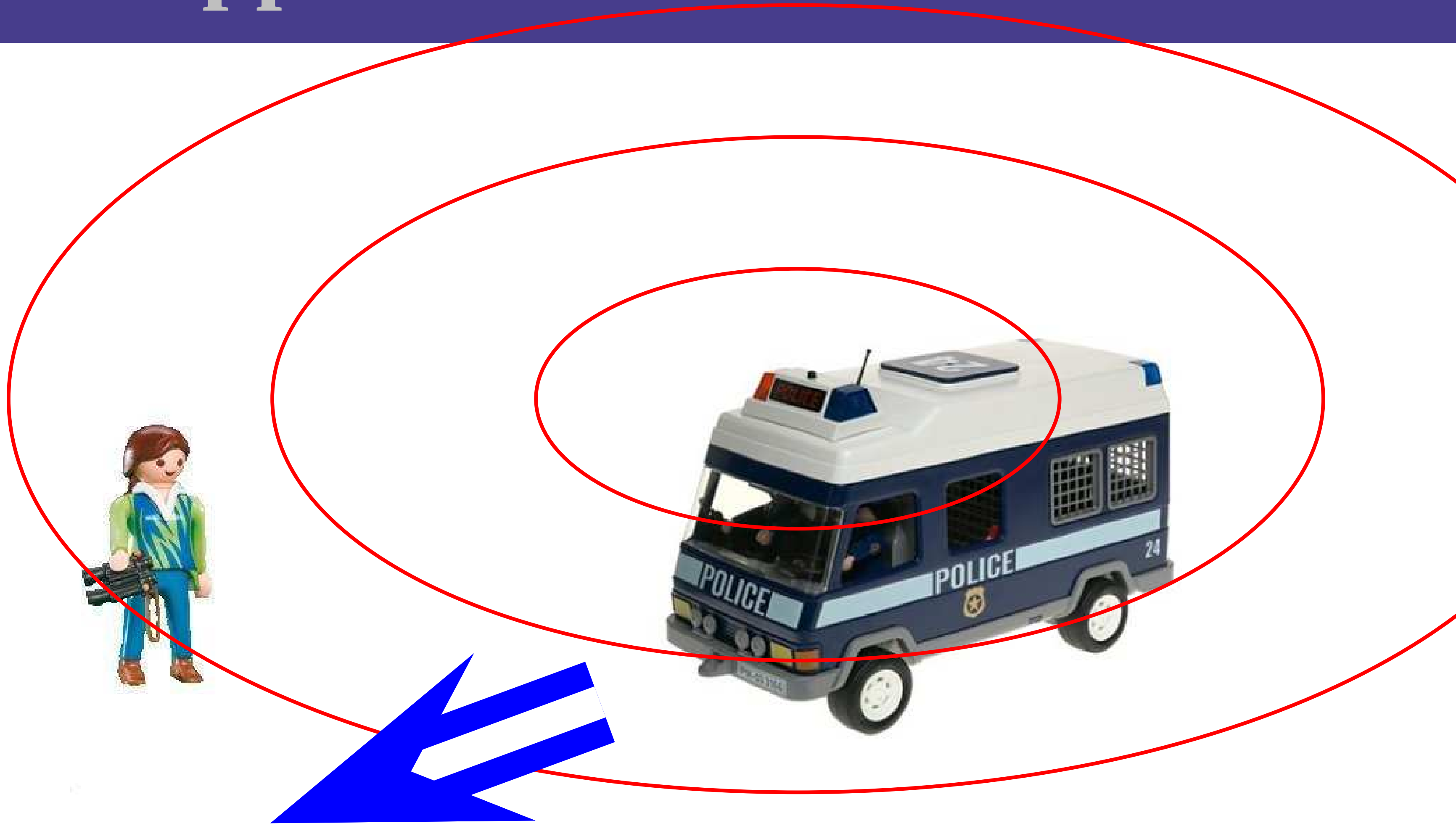
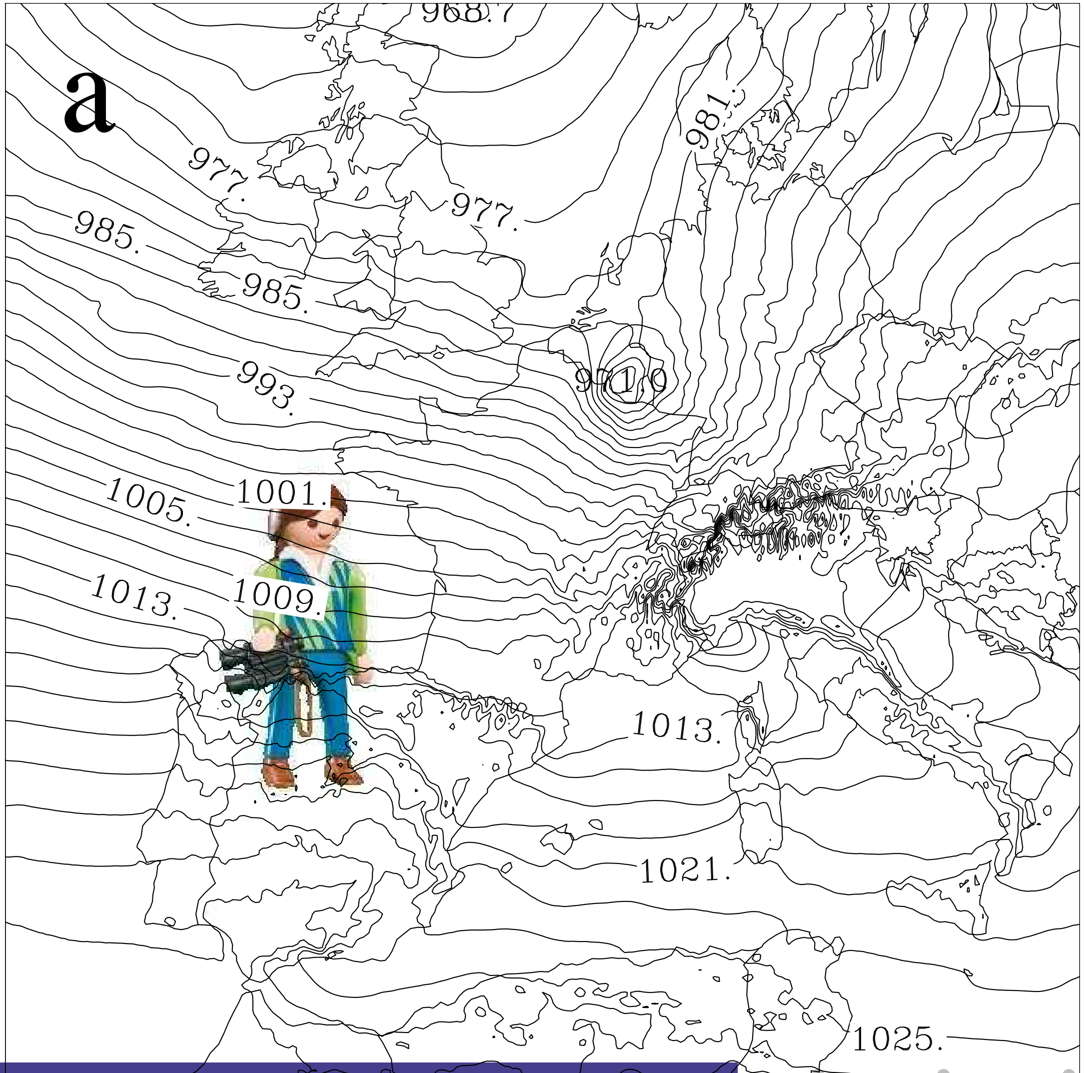
The Doppler effect

The Doppler effect



$$\omega = \omega_{siren} + v\,\kappa \qquad with \qquad \kappa = \frac{2\pi}{L}$$

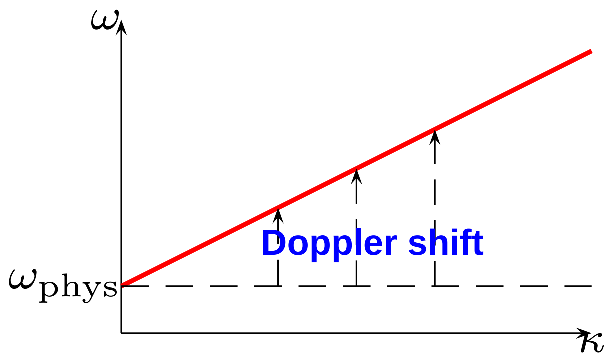
Another extreme case (Lothar)



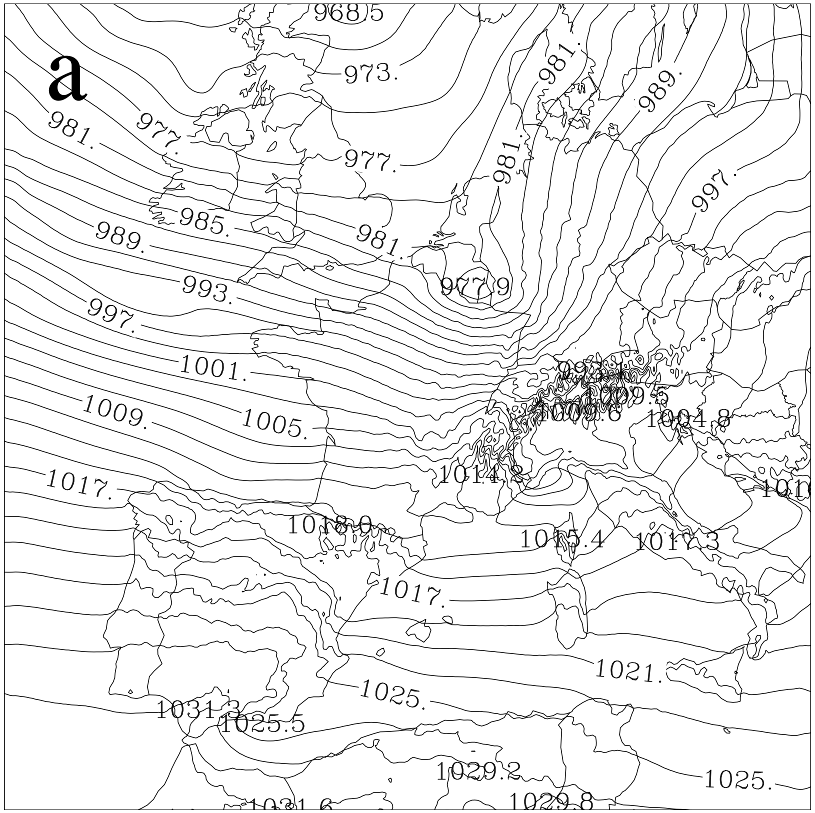
For waves superposed on a large-scale flow, we also have a Doppler effect for each mode

$$\omega = \omega_{\mathrm{phys}} + c\,\kappa$$

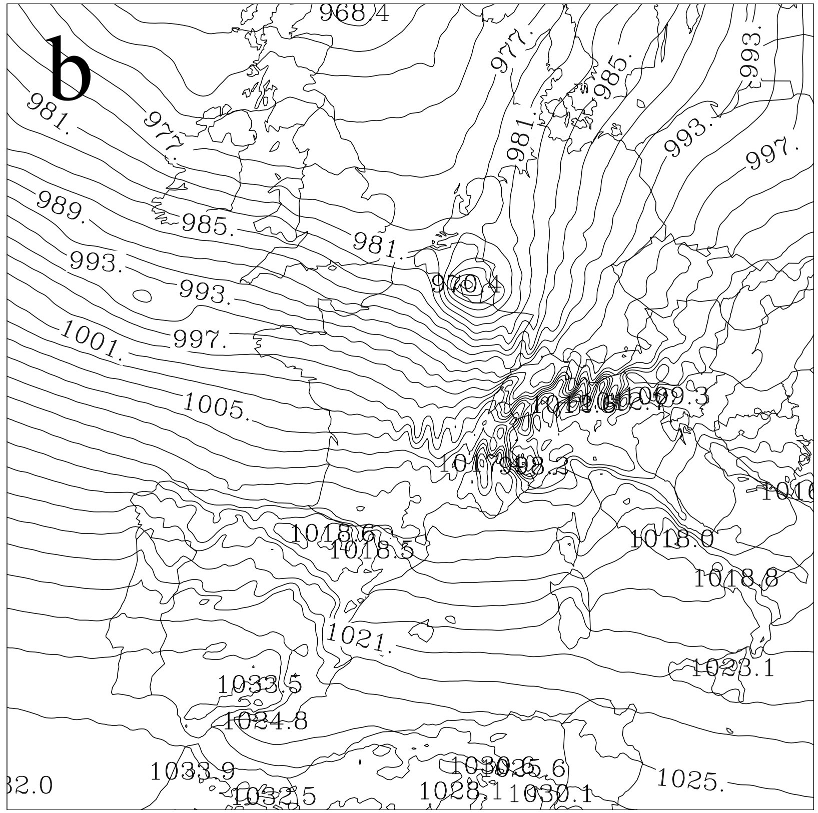
with physical frequency ω_{phys}, the deeping of the storm is a time evolution that gets shifted.



Another extreme case (Lothar)



The result of a standard (operationally) used DFI (**977.9 hPa**).

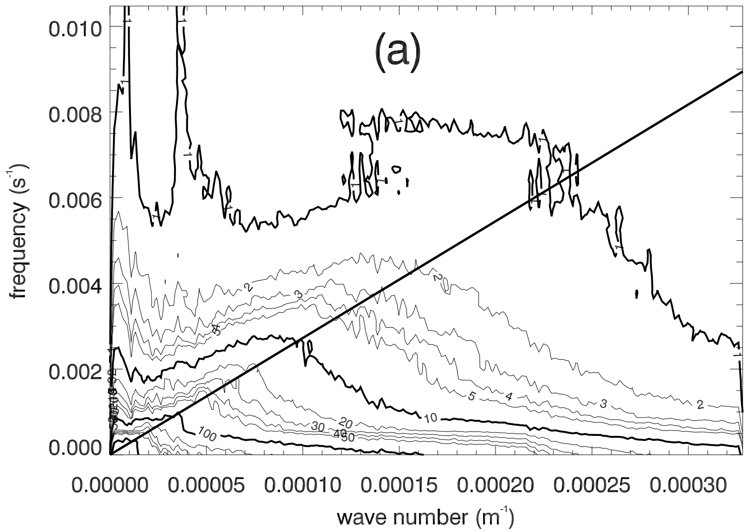


ALADIN forecast after developping for 9 h (**970.4 hPa**).

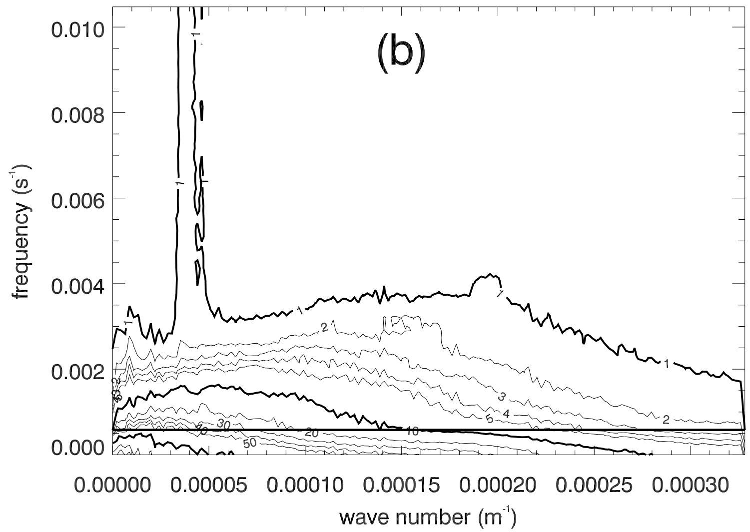
So ...

- DFI filters the waves over the Alps and Central Massif
- but, it also knocks off about 7 hPa from the low of the storm.
- Let us look at the spectrum, ...

spectrum in time AND space

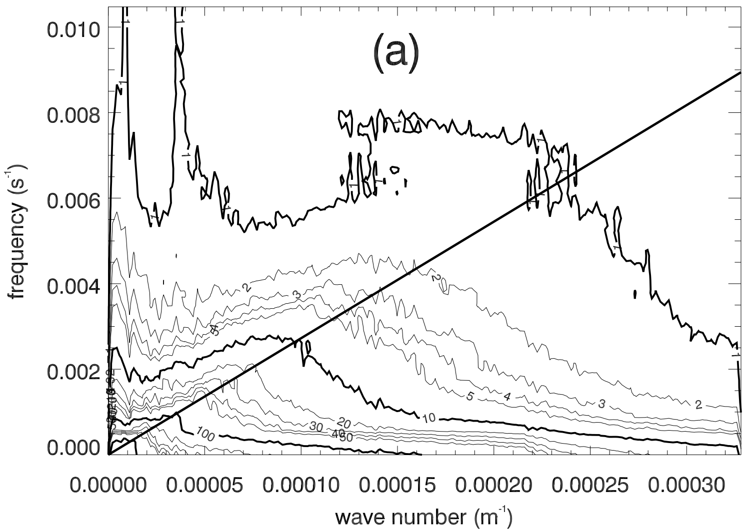


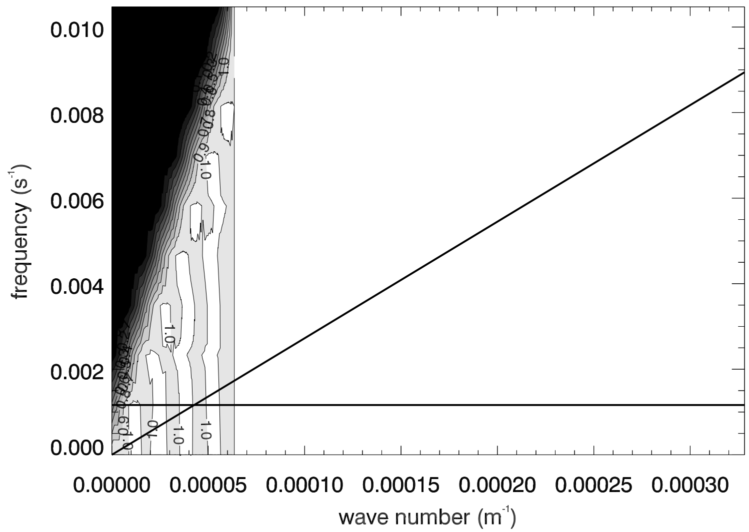
The Lothar storm $\ln p_s$ decomposed between 0600 UTC and 1200 UTC on 28 December 1999. The thick line is the propagation speed of the storm in this time interval: 98 km/h.



$\ln p_s$ decomposed between 0600 UTC and 1200 UTC of an anticyclonic case on 28 December 1999. The thick horizontal line corresponds to a filter cut-off period of 3 h.

Scale-selective low-pass windows



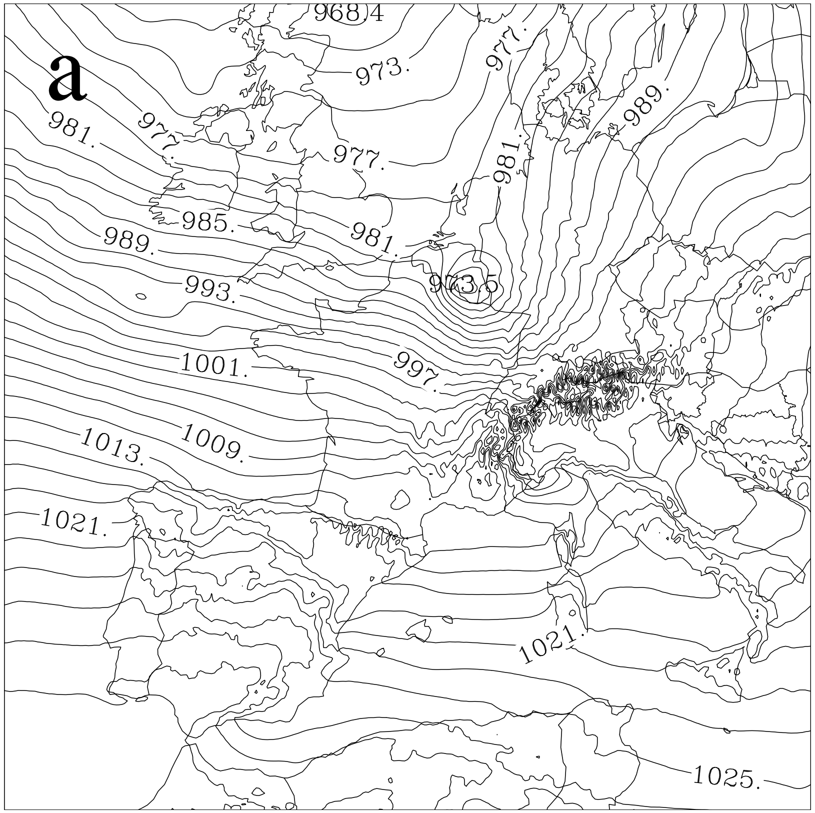


The *scale-selective* cut-off frequency of a low-pass Lancsoz filter:

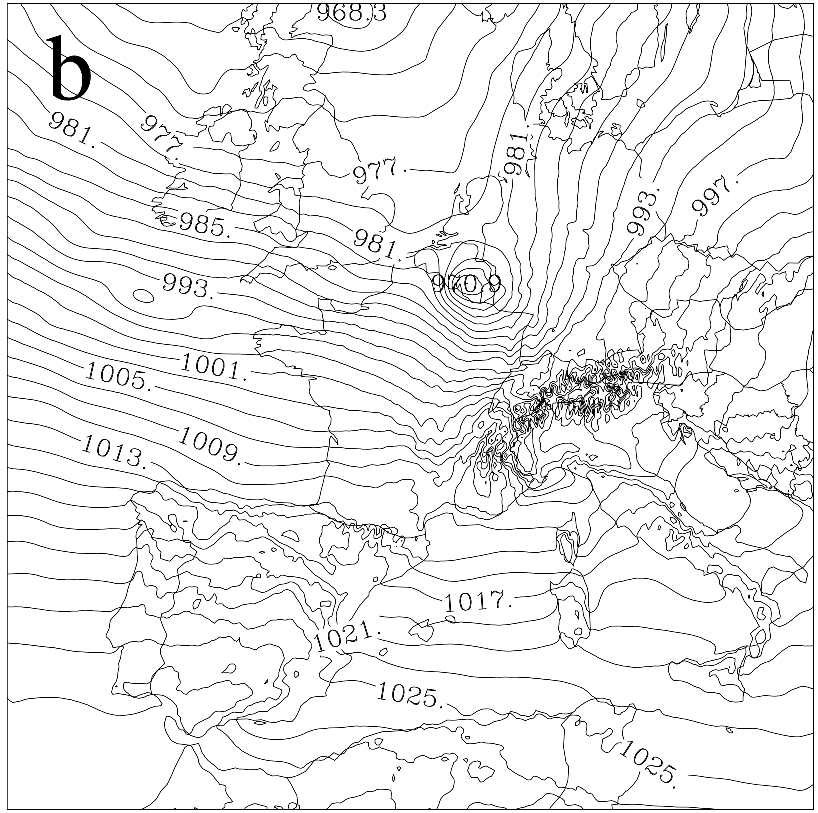
$$\omega_c(\kappa) = \begin{cases} \omega_c^0 + \frac{\kappa}{\kappa_c}\left(\frac{\pi}{\Delta t} - \omega_c^0\right) & \text{if} \quad \kappa \leq \kappa_c \\ \frac{\pi}{\Delta t} & \text{if} \quad \kappa > \kappa_c \end{cases}$$

The cut-ott period is $T_c^0 = 2\pi/\omega_c^0$ while the *slope* of the cut-off frequencies is $c = \pi/(\kappa_c \Delta t)$.

Results:



a run with $T_c^0 = 3h$ (**973.5 hPa**).

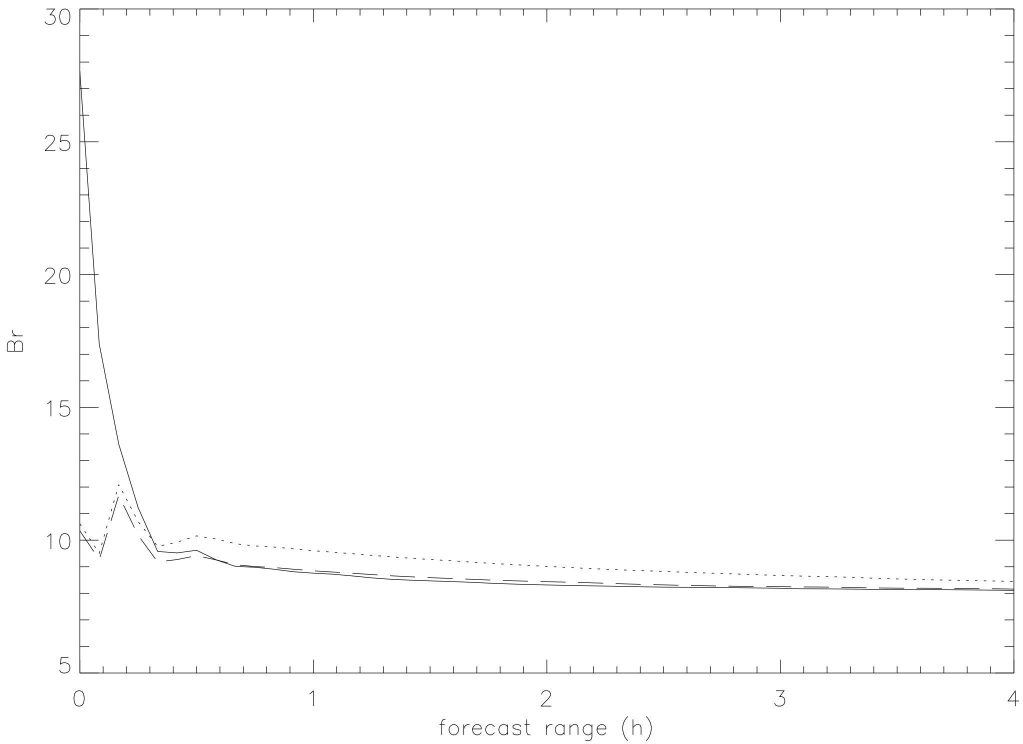


a run with $T_c^0 = 1.5h$ (**970.9 hPa**).

But what about the balance?

Another extreme case (Lothar)

$$Br = 100 \frac{\sum_{IJ} |\sum_L \nabla\cdot\Delta p_L \mathbf{V}_{IJL}|}{\sum_{IJ} \sum_L |\nabla\cdot\Delta p_L \mathbf{V}_{IJL}|}$$ (Lynch and Huang, MWR, 1992)

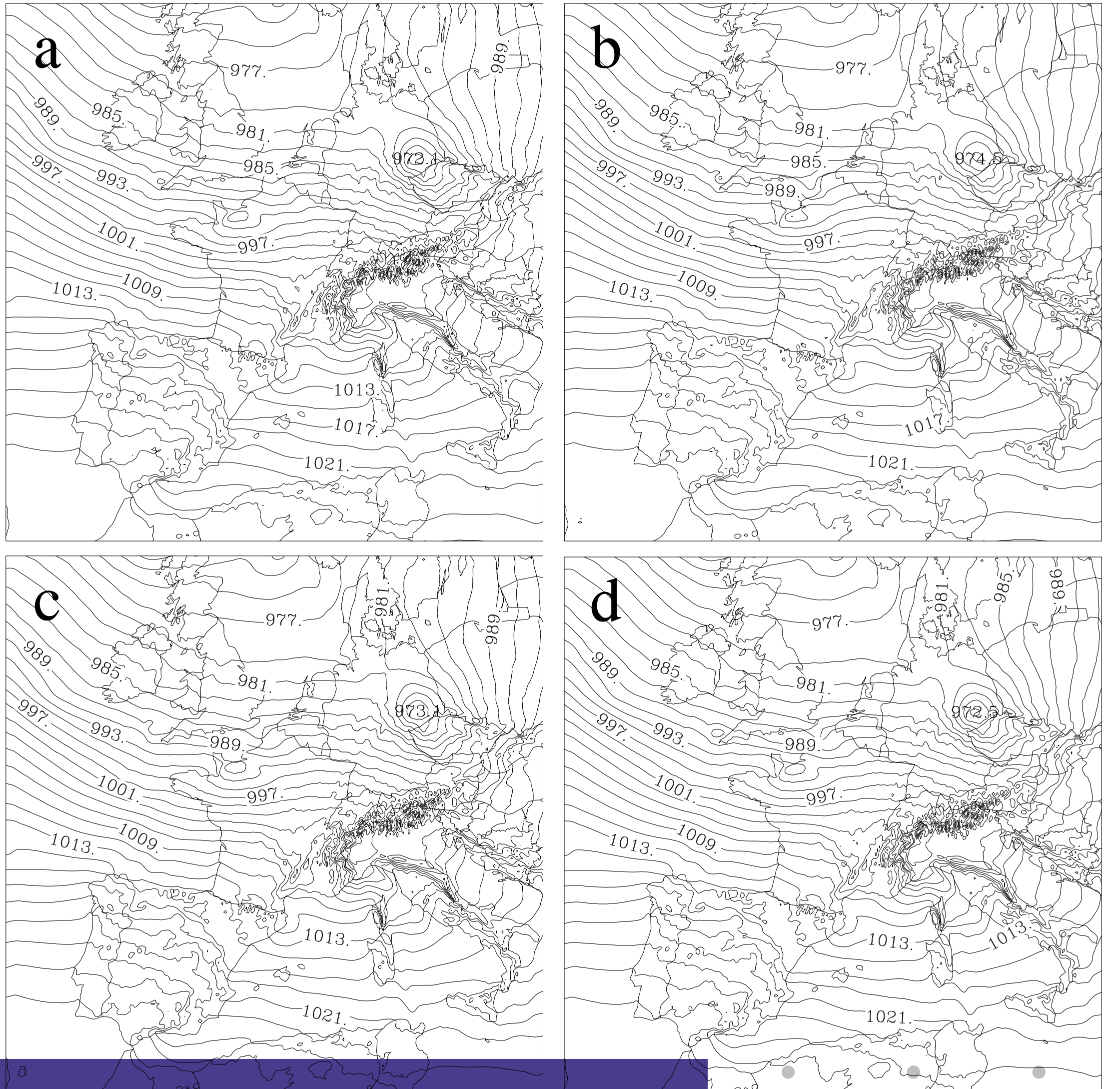


solid: uninitialized
dots: full DFI
dashed: $\mathrm{SSDFI}_{1.5\mathrm{h}}$
There are 2 surprises:

- filtering *less* ($\mathrm{SSDFI}_{1.5\mathrm{h}}$) $\Rightarrow$ *more* balanced!
- but, full DFI is *worse* than uninitialized after *half and hour*!?

DFI actually creates an unbalance in the *slow* part of the part of dynamics! So it needs a longer time to adjust.

After 6 h, i.e. at 1500 UTC 26 Decemb

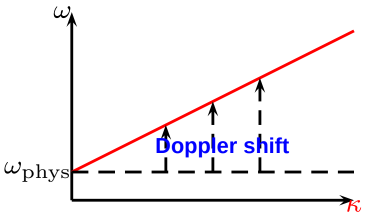


- (a) no initialization (972.4 hPa),
- (b) $\mathrm{DFI}_{3\mathrm{h}}$ (974.5 hPa),
- (c) $\mathrm{SSDFI}_{3\mathrm{h}}$ (973.1 hPa),
- (d) $\mathrm{SSDFI}_{1.5\mathrm{h}}$ (972.5 hPa).

So the improvement carries over later in the forecast.

going to higher resolution

Let us increase the resolution by a factor of 5, e.g. ALADIN$_{10\mathrm{km}}$ $\longrightarrow$ AROME$_{2\mathrm{km}}$.



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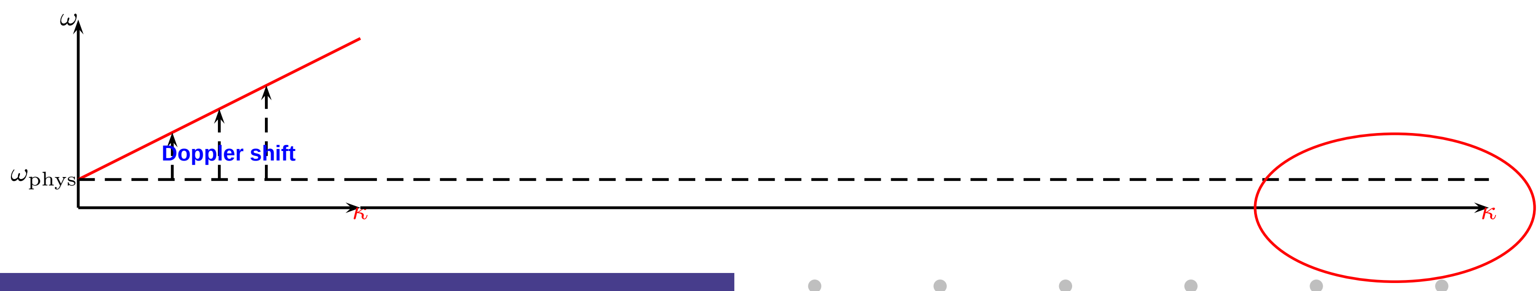
$$\omega = \omega_{\text{phys}} + c\,\kappa$$



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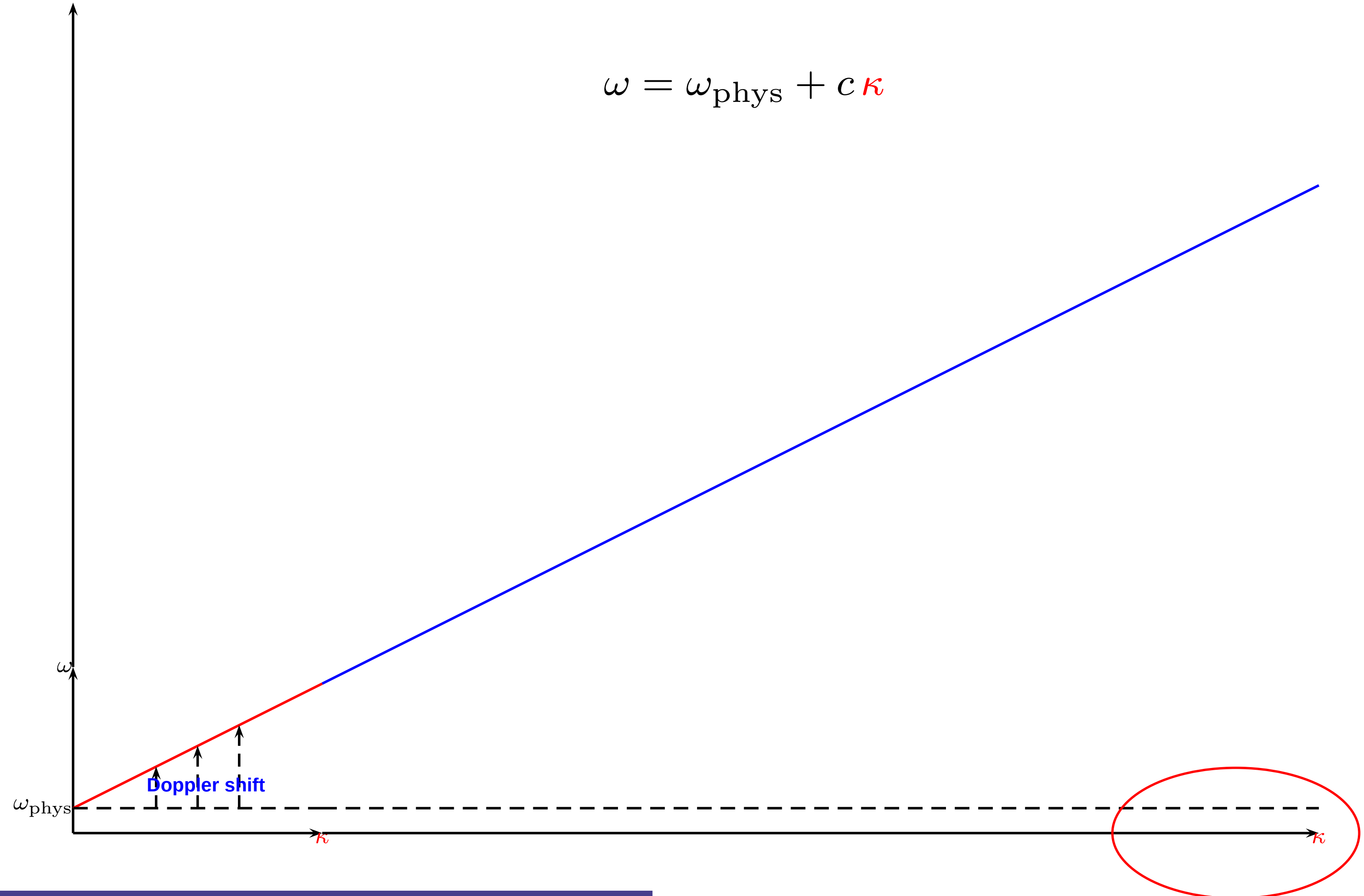

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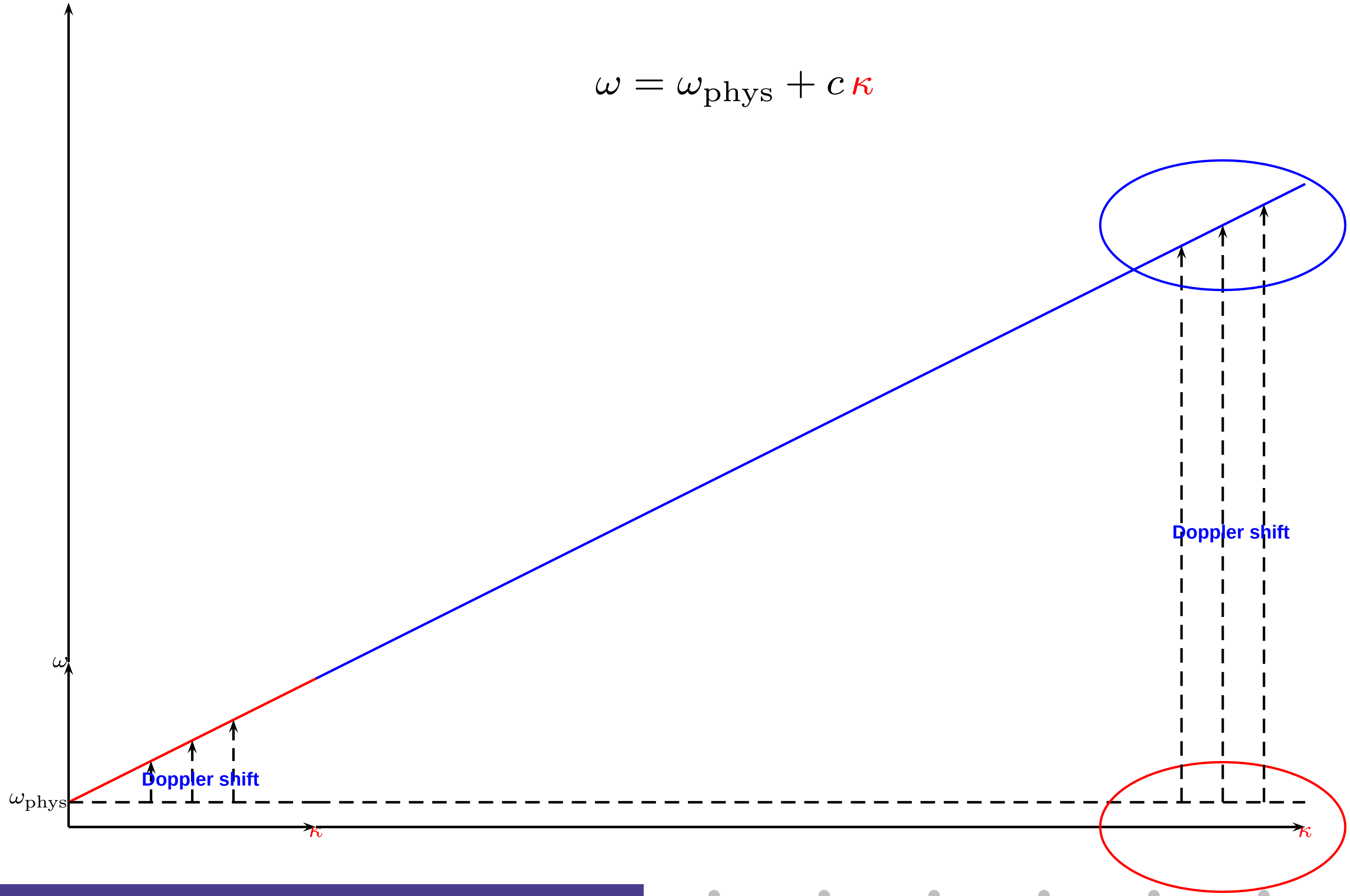

Conclusions

- A Doppler effect can shift *relevant* frequencies into the frequency part of the spectrum that is usually filtered by DFI. There exists at least on case: the Lothar storm. But it is one of the most important ones!
- *SSDFI* can be used to leave the Doppler shifted part of the spectrum *intact*.
- This means actually filtering *less* and one would expect the state to be *less* balanced. Actually, *(not)* surprisingly *the opposite is true*.
- SSDFI was (relatively) easy to implement in the *spectral* ALADIN model. The code exists in ALADIN in (an old) cycle at the RMI, but has not been phased.
- One might expect this Doppler effect to play a bigger role in *kilometer scale phenomena* in kilometer-scale models (AROME). But this should be investigated...
- Should we extend this into a more *sophisticated tool*: space-time spectral analysis combined with some filtering (wavelets)? At least one can use the existing SSDFI with c above the flow speed as a rough tool.