Experiences with a strong outflow case in HARMONIE

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Since 6 July 2007 HARMONIE, the non-hydrostatic model being developed by the HIRLAM-ALADIN consortium, is running pre-operationally at the Royal Netherlands Meteorological Institute (KNMI), producing a 24 hours forecast once a day starting at 0 UTC and using the HIRLAM model as host model. The horizontal resolution is 2,5 km and 40 levels are employed in the vertical. During this period several instances of so-called fireworks have been identified. During such an event the model produces a too strong outflow, often coinciding with too heavy precipitation. A typical example of such model behaviour is presented in Fig. 1. It shows the anomalous wind vector pattern with the too strong outflow based on a 12 hours forecast started from 9 July 2007 at 0 UTC and surrounding the 1 hour accumulated precipipation between 11 and 12 hours lead time. In an explorative study a series of HARMONIE experiments have been performed to investigate to what extent the outflow depends on certain parameters. In particular changes in horizontal diffusion, evaporation rate and advection scheme will be considered. It turns out that for all experiments the outflow appears to be maximal for the 12 hours forecast.

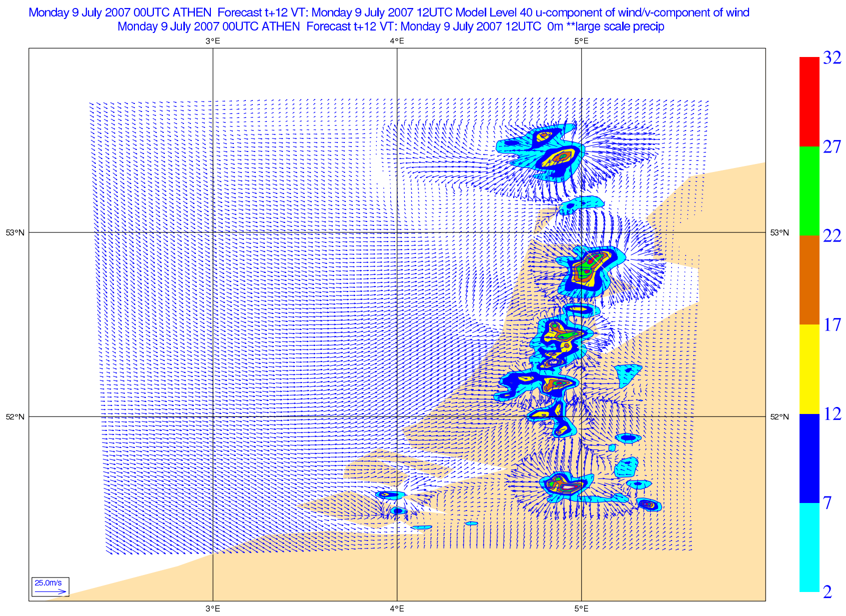

Figure 1: *Wind field at the lowest model level for a 12 hour HARMONIE forecast starting from 9 July 2007 at 0 UTC and the 1 hour accumulated precipitation between 11 and 12 hours lead time. The wind field is plotted every 2,5 km with a unit wind vector of 25 m/s.*

Horizontal diffusion

Four experiments were performed based on HARMONIE model version 33h1. These experiments were are identical apart from the settings of the parameters, which control the horizontal diffusion, see Table 1. From HARMONIE 32h3 to 33h1 the horizontal diffusion was lowered, which intuitively would strenghten the outflow. Experiment 33h1old will explore this. It is a 33h1 forecast, but with the old 32h3 settings for horizontal diffusion. In addition to a default 33h1 forecast, two other experiments HIGH1 and HIGH2 were performed with increasing horizontal diffusion. Note that the horizontal diffusion depends on the control parameters in a reciprocal manner. Figs 2 (upper left and right panels) reveal that lowering the diffusion has indeed increased the magnitude of the outflow, both in size and strength. On the other hand, increasing the horizontal diffusion compared to the 33h1old set-up clearly weakens the outflow. This becomes even more pronounced when plotting the difference fields between two experiments as shown in Fig. 3

Table 1: Parameter settings for four experiments with different horizontal diffusion. The six parameters change diffusion on vorticity (VOR), divergence (DIV), temperature (T), specific humidity (Q), vertical divergence (VD) and pressure departure (PD).

	33h1old	33h1	HIGH1	HIGH2
RDAMPVOR	5.	20.	0.5	0.2
RDAMPDIV	1.	20.	0.5	0.2
RDAMPT	5.	20.	0.5	0.2
RDAMPQ	5.	20.	0.5	0.2
RDAMPVD	1.	20.	0.5	0.2
RDAMPPD	5.	200000.	200000.	200000.

Evaporation

Again four experiments were performed. Now the parameter, which controls the evaporation rate, was changed. The impact on the outflow and precipitation was as one would expect. Going from low to high values of evaporation rate, the amount of precipitation becomes smaller but at the same time the extent of the outflow area increases, see Fig. 4. Associated with this strengthening of the outflow, the model produces a stronger and colder downdraft. This results in too cold surface temperatures as compared to observations, see Fig. 5. It is pointed out that already the default 33h1 forecast exhibits this behaviour (top left panel).

Advection scheme

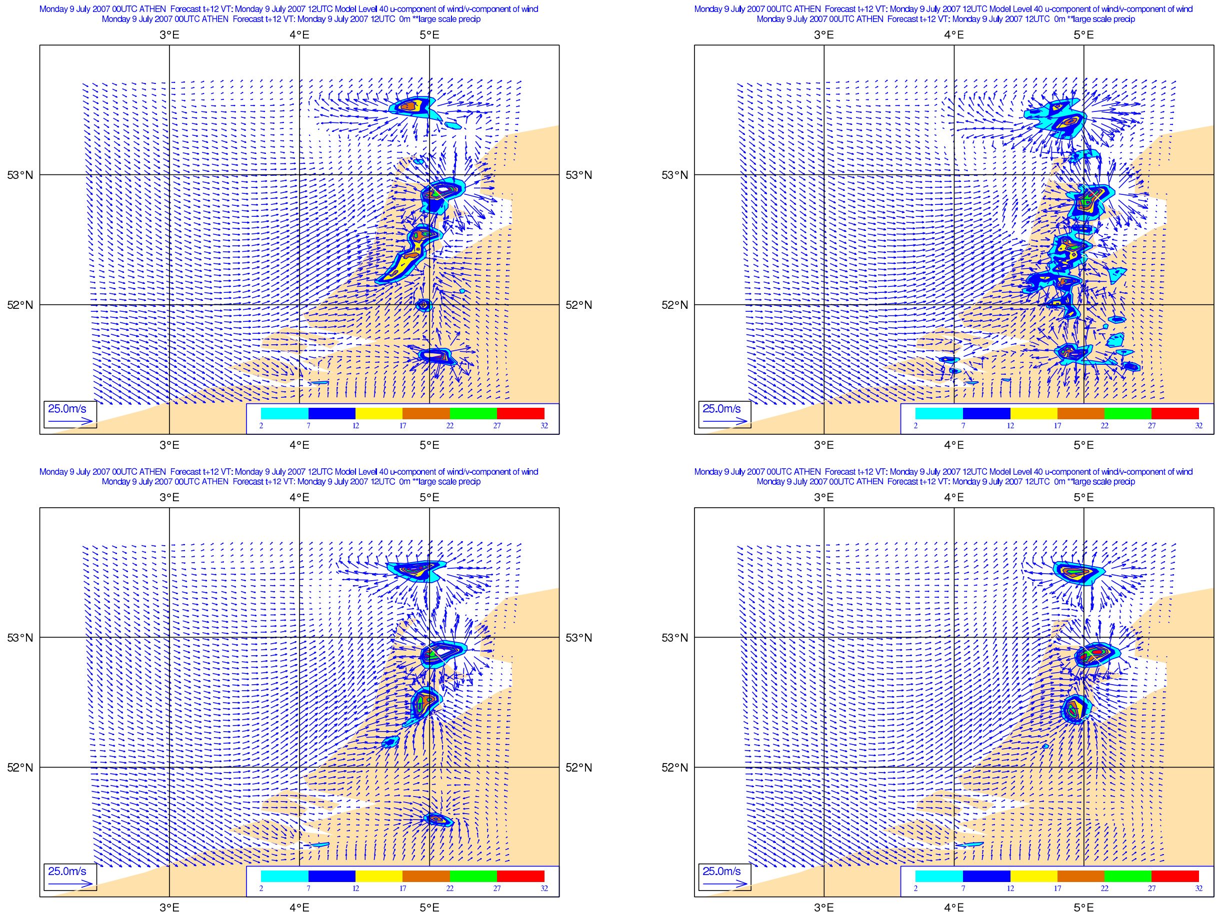

Figure 2: *As Fig. 1 but with a set-up for horizontal diffusion as specified in Table 1: 33h1old (top left), 33h1 (top right), HIGH1 (bottom left), and HIGH2 (bottom right). The wind field is plotted every 5 km.*

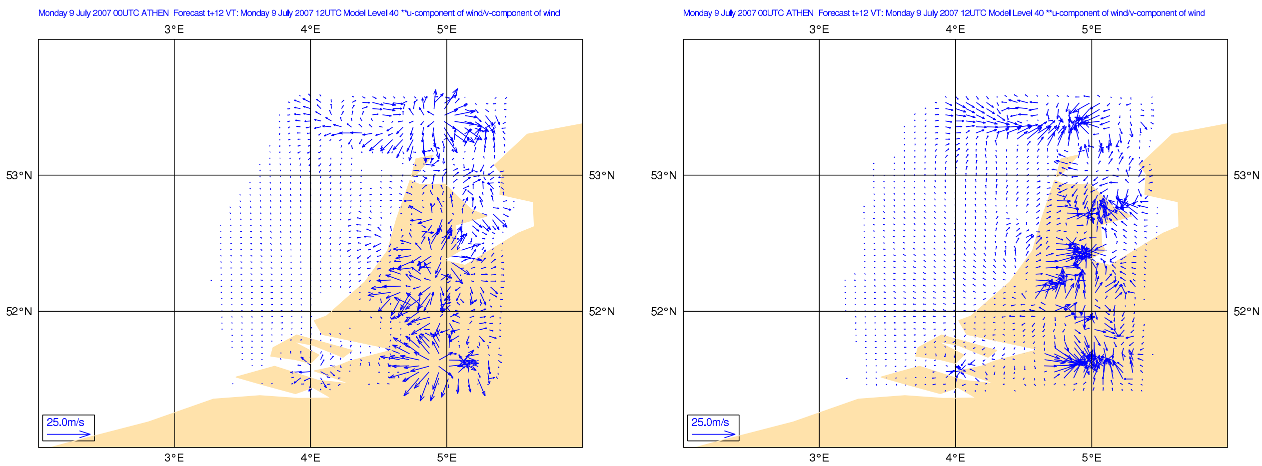

Figure 3: *Difference of the wind fields as shown in Fig. 2 between experiments 33h1 and 33h1old (left), and HIGH1 and 33h1old (right). Unit wind vector is 25 m/s.*

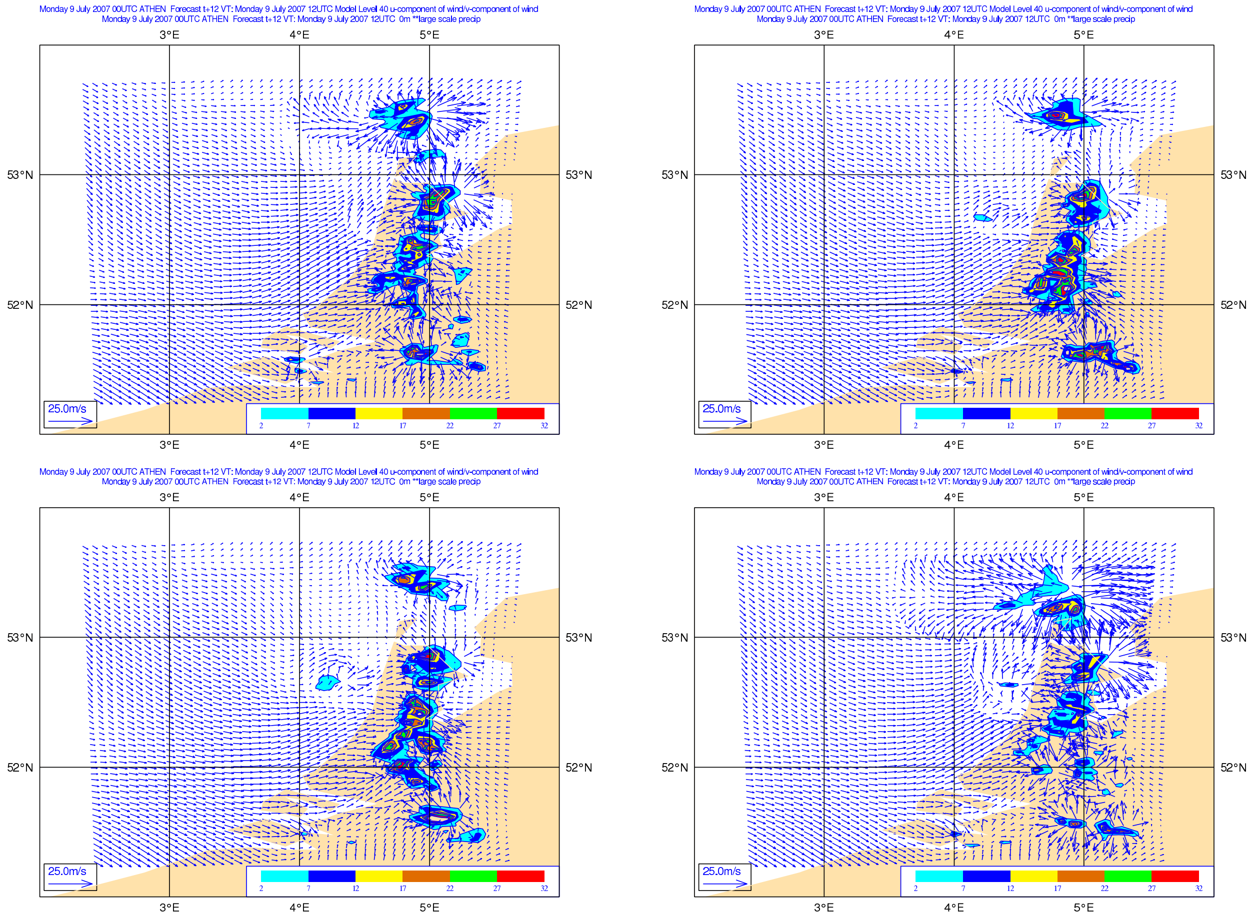

Figure 4: *As Fig. 2, but with four different evaporation rates: 33h1 (top left), factor 10 smaller (top right), no evaporation (bottom left), and factor 10 larger (bottom right).*

To investigate whether the advection scheme has anything to do with the occurence of fireworks, a run with the Eulerian advection scheme was performed. Because of instabilities present in the 33h1 Eulerian scheme, however, it was necessary to revert to model cycle 35h1. The semi-Langrangian outflow behaviour is very similar to 33h1 though (see Fig. 7, left panel). From an operational point of view the Eulerian scheme is not really feasible as it requires substantially more computation time due to the smaller time step of 10s compared to the 60s time step for default semi-Langrangian scheme. The outflow in the Eulerian run proved to be even larger (not shown), probably due to the less diffusive character of the Eulerian scheme. The Eulerian run also produced more intense precipitation distributed over smaller scale structures. Fig 6 shows the instanteneous rain rate for the two advection schemes at 12 hours lead time for the lowest model level. In order to bring the semi-Langrangian run closer to the Eulerian set-up, the advection of all hydrometeors, apart from specific humidity, was switched off together with the semi-Langrangian horizontal diffusion (controlled by LADV and LSLHD respectively). As shown in Fig. 7 (right panel) this has quite some impact on the outflow. In particular the outflow north of 53°N or south of 52°N has decreased substantially.

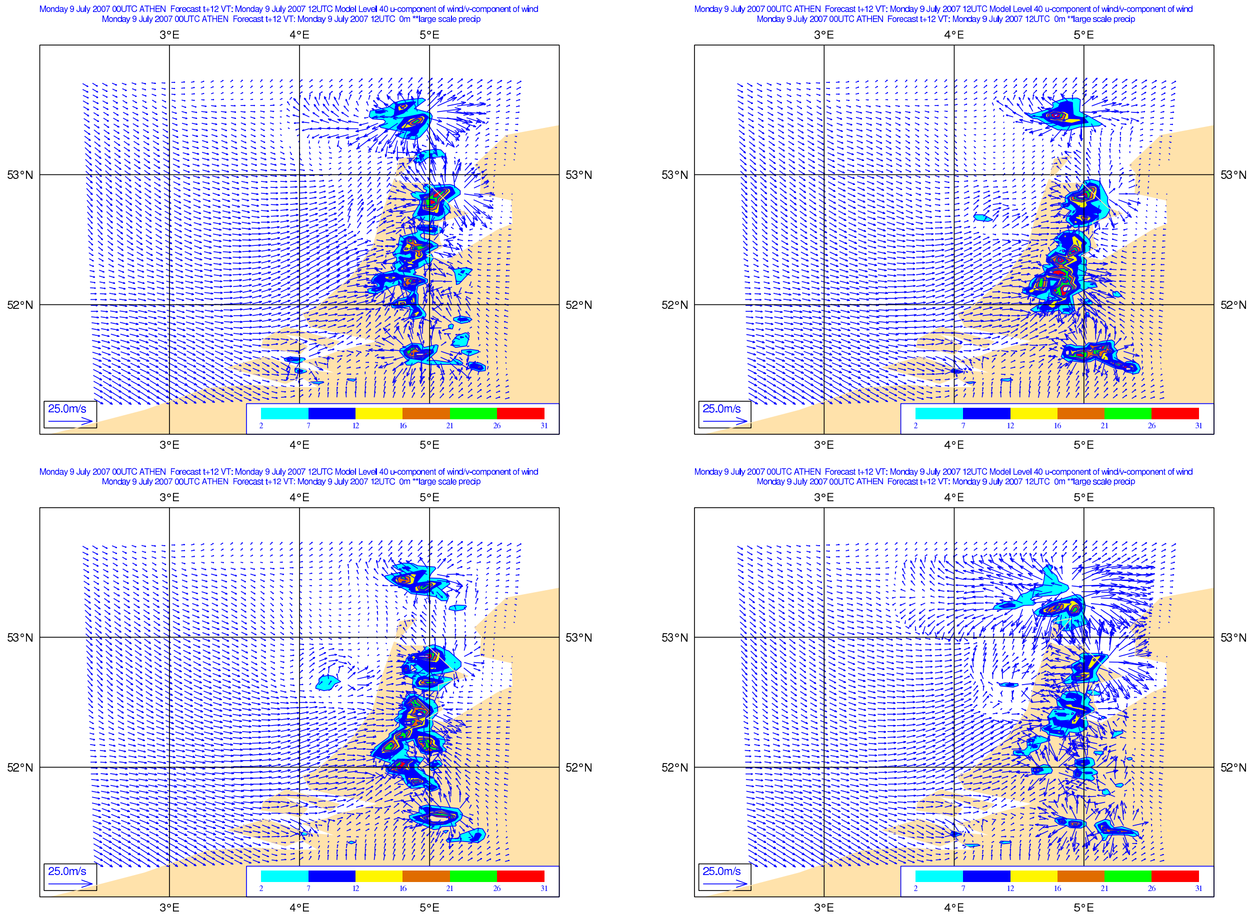

Figure 5: small *As in Fig. 4, temperature at the lowest model for four settings of the evaporation rate.*

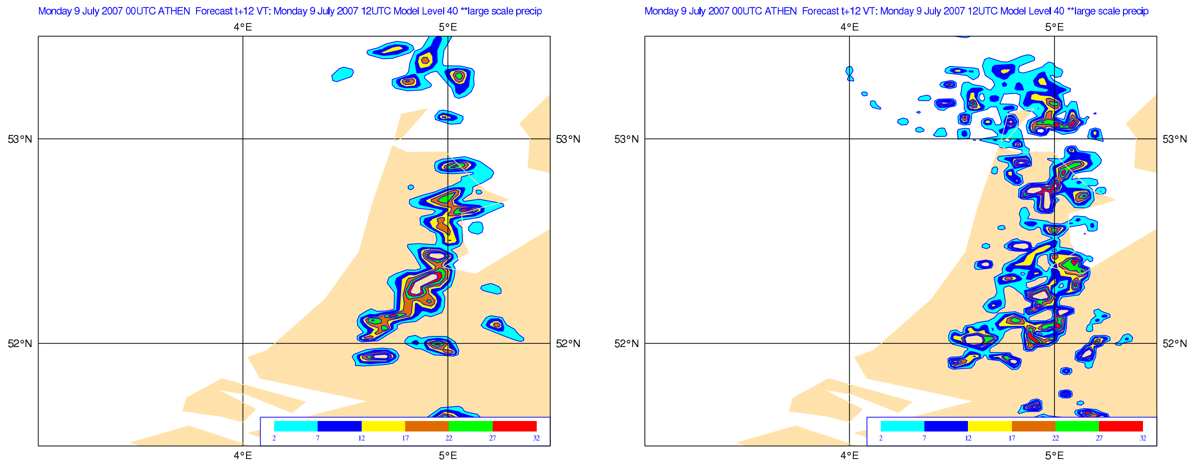

Figure 6: *Instantaneous rain rate at the lowest model level for a 12 hours forecast with the semi-Langrangian (left) and Eulerian (right) advection scheme.*

Resolution

To investigate how the HARMONIE microphysics would respond to increased resolution a forecast at a 500m grid resolution was performed. Various changes to the default semi-

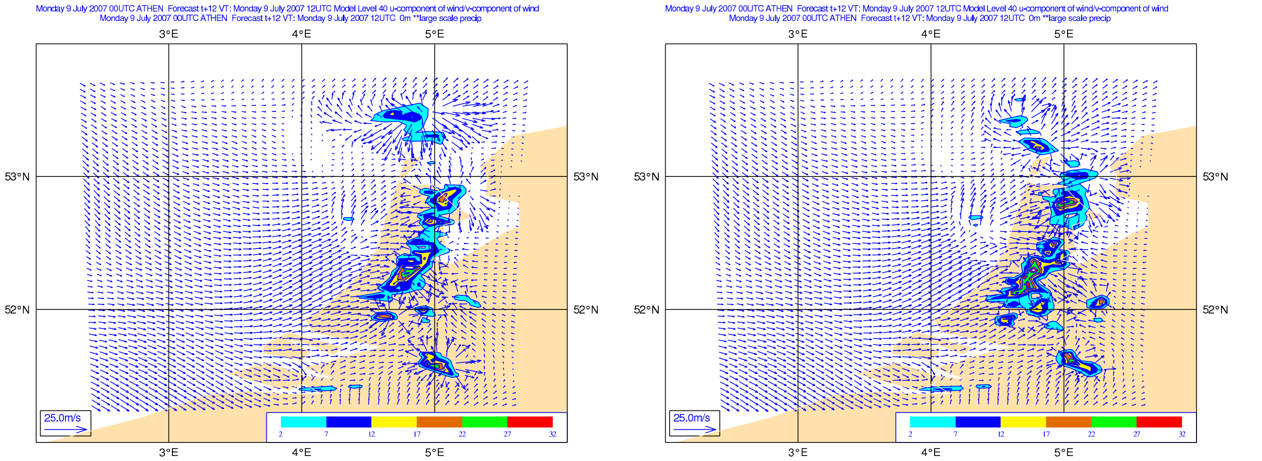

Figure 7: *As 2 but now for default 35h1 (left) or without advection of hydrometeors and semi-Langragian diffusion (right)*

Langrangian set-up were necessary, mainly to ensure stability. For example, the time step was reduced to 10s and, more importantly, the direct advection of vertical wind (LGWADV=.true.) turned out to be essential. Figure 8 shows a 12 hours forecast, which differs entirely from the previous 2,5km runs regarding the wind field and the amount of precipitation. Note that a 2,5km forecast for this sligtly smaller integration area yielded similar results as shown in Fig. 7 (left panel).

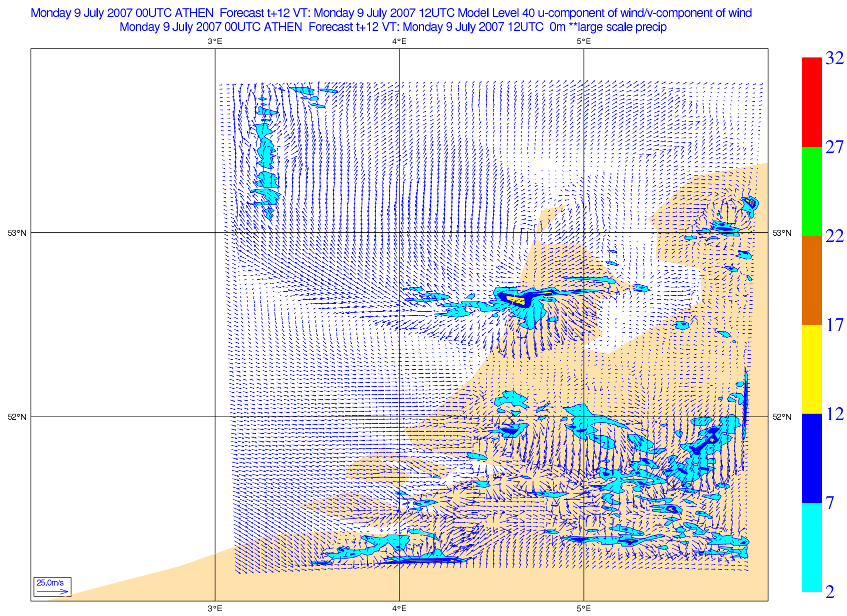

Figure 8: *As Fig. 2 but now for a forecast at 500m grid resolution. Wind vectors are plotted every 2,5km.*

Concluding remarks

The above experiments are merely a first step in understanding the reason why and how frequently fireworks occur in HARMONIE/AROME. It is clear that certain parameters like horizontal diffusion, evaporation rate, but also advection of hydrometeors may have substantial impact on the extent of the outflow. Next step will be to investigate how this sensitivity of the outflow is associated with e.g. different convection behaviour due to different parameter setting or a subtle interaction between physics and dynamics. To that end controlled (so-called warm bubble) experiments will be performed in an idealized model environment.

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