High Resolution Limited Area Model

HIRLAM

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Partially submerged cars are seen next to boats after heavy rains flooded Silivri on September 8th, 2009 (Picture from Newspaper Todayszamah), see p. 37

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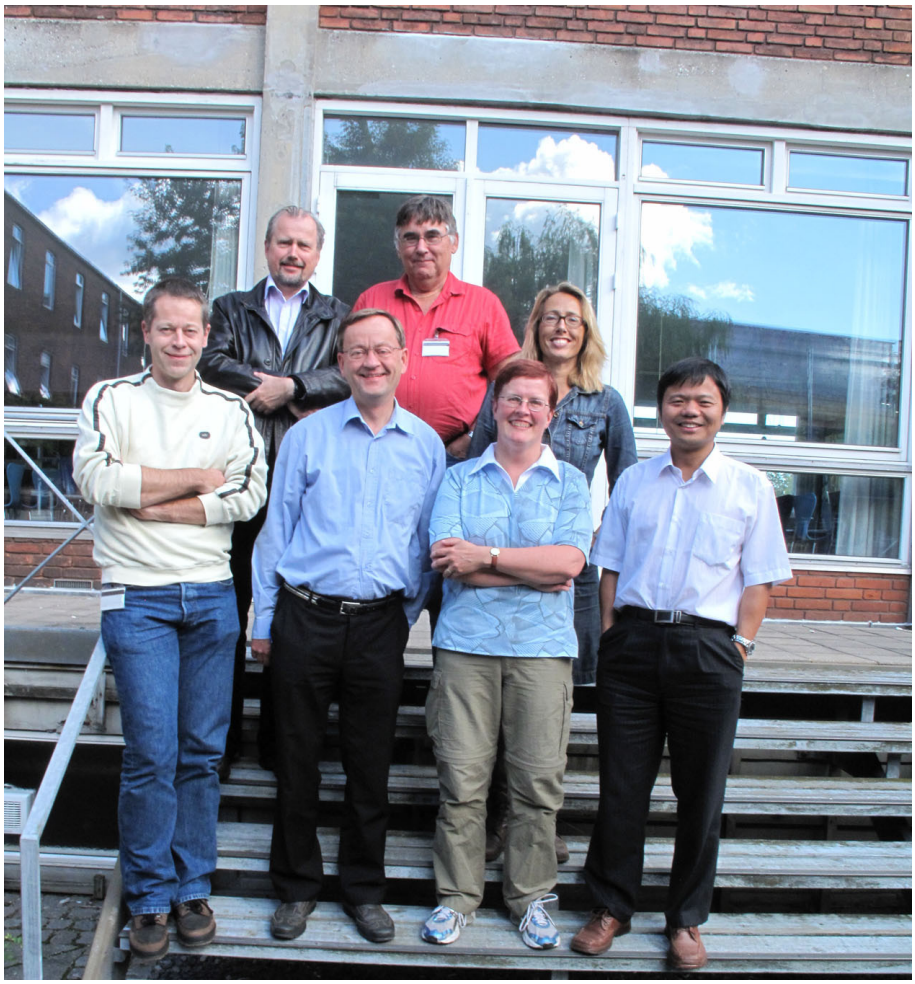
Introduction

Tilly Driesenaar

The first of September this year the HIRLAM program celebrated his 25th anniversary. This occasion nicely coincided with a visit of the management group to DMI, where it all started September 1st 1985. For the occasion a picture was taken of (part of) the management group together with Bent Hansen Sass who also was there at the start 25 years ago.

This Newsletter contains a number of scientific contributions and a few reports of visits to member institutes. It's good to see that the focus is shifting towards Harmonie in the contributions. First we see an article by Magnus Lindskog, Sigurdur Thorsteinsson and Ulf Andrae who compared the 3-dimensional variational data assimilation schemes in HARMONIE and HIRLAM.
The next contribution, also by Magnus Lindskog deals with ALADIN 3D-VAR utilizing a wide extension zone. Then Wim de Rooy tells about the experiences with Harmonie at KNMI.
A revised method to determine the hybrid coordinate in HIRLAM is presented by Per Undén and Huseyin Toros, Gertie Geertsema and Gerard Cats contribute with an evaluation of the precipitation forecasts of HIRLAM and Harmonie for a flash flood event that occurred in Istanbul in September 2009. Then Newsletter is concluded by reports of the visits of the management group to AEMET, FMI and MetÉireann.



Evaluation of Hirlam and Harmonie precipitation forecasts for the Istanbul flash flood event of September 2009

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Abstract
The flash floods of 8 and 9 September 2009 caused 31 deaths and substantial damage in the Istanbul metropolitan area. These events have been simulated with Hirlam and Harmonie. Both models give clear warning signs of the heavy precipitation in the area, but Hirlam in particular still underestimates the amounts. Due to its ability to advect hydrometeors over mountain ridges Harmonie predicts the large amounts with a better position than Hirlam.

1 Introduction

In recent years several severe floods with high economical and social impact occurred in many parts of the world. In the beginning of September 2009 a flash flood in and around the megacity Istanbul caused 31 deaths and resulted in material damage which was estimated to be of the order of 90 million dollars (see figure 1).

The flash flood was caused by a period of two days of intense rainfall in the Thracian region. Under influence of a fast deepening low pressure system, warm moist air was transported from the Black Sea into the Thracian region, resulting in heavy showers and thunderstorms on the 8th and 9th of September.
In this study we have performed Hirlam and Harmonie runs on domains centered at the Thracian region and Istanbul. The precipitation forecasts are evaluated against rainfall observations from some 28 meteorological stations in the region. Both models forecast heavy rainfall in the area, however the locations of the most intense rainfall are off by several tens of kilometers.

2 Observations

2.1 Synoptic Description

On 6 September 2009 a low pressure system with a central sea level pressure of 1005 hPa is located

Figure 1: Partially submerged cars are seen next to boats after heavy rains flooded Silivri on September 8th, 2009. Silivri is a town some 60 km from Istanbul Ataturk Airport. (Picture from Newspaper Todayszaman)

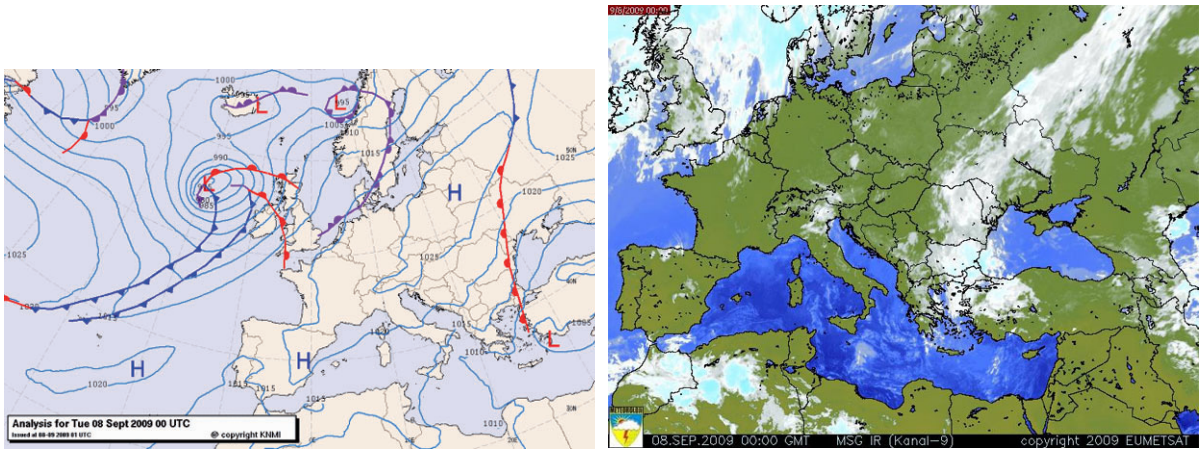


Figure 2: left panel: Weather chart showing the surface analysis for 8 September 2009 00 UTC based on the operational Hirlam analysis (courtesy: KNMI operational service). The panel on the right shows the Meteosat 9 MSG IR image for the same time.

over the Southwest of Anatolia and a high with a centre pressure of 1025 hPa over central Europe. The low pressure system is deepening gradually whilst moving Northwards. On the 7th of September two troughs develop at 500 hPa. The surface analysis for 8 September is shown in figure 2.

2.2 Climate

Istanbul is the business and cultural capital of Turkey and is home to about 13 million people (TUIK, 2010). It has historically been vulnerable to natural disasters. The climate of Istanbul can be characterized as a transition between Mediterranean and Temperate. In the summer months the climate is generally warm and humid with very little rain, whereas the winter months can be cold and wet with some snow. The spring and autumn seasons are mild. Istanbul covers a large area and has a complex topography. The average annual precipitation in the Northwestern part of Turkey, the Marmara Region, is approximately 700 mm with a range from 450 mm to 870 mm.

2.3 Observations

Hourly precipitation data at the 28 stations shown in figure 3 were obtained from the Turkish State Meteorological Service (TSMS) and the Istanbul Metropolitan Municipality (AKOM). Table 2 shows that already on 7 September large amounts of rain had fallen in the area. However this rain fell outside the catchment areas related to the flash flood events. To put the amounts of observed precipitation into perspective we mention that the mean annual precipitation in this area is slightly less than 700 mm. For the 28 stations the average observed precipitation on the two days 8 and 9 September is 84 mm, more than 10% of the mean annual total precipitation. The two day accumulated observed precipitation at station Catalca (id 11) is even 240 mm, approximately one third of the average yearly precipitation.

Figure 1 shows the effect of such heavy rainfall. The picture is taken at Selimpasa, Silivri coast, which is indicated in figure 3. The amount of rainfall was so high that it exceeded the capacity of Ikitelli Ayamama Creek, an important drainage canal for the Istanbul metropolitan area. This creek is also indicated in figure 3.

On 8 September heavy rain falling uninterrupted since the early hours affected the region 50 km west of Istanbul causing flood disasters in many towns. Shop windows crashed, flood water entered businesses and homes, many cars drifted into the sea. Figure 3 indicates the catchment area and the

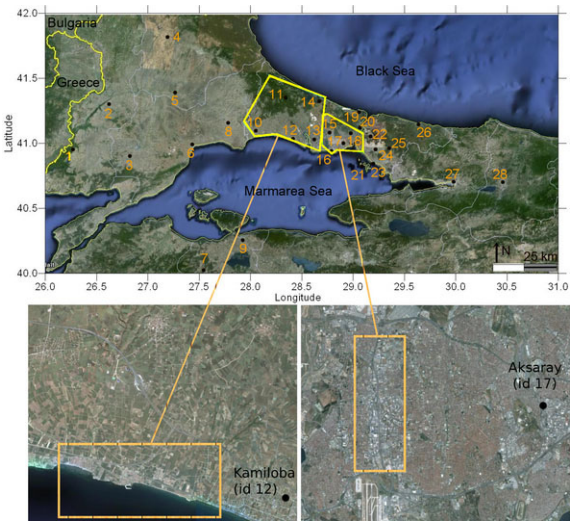


Figure 3: The top panel shows a map with the precipitation statons in the Northwestern part of Turkey (the Marmara Region). The station numbers correspond to those in table 2, the numbering increases from West to East. The rectangles in the bottom panels show the areas of flooding for 8 (left) and 9 (right) September. The polygons in the top panel indicate the relevant catchment areas.

area of flooding. The lower left panel shows Selimpasa, Silivri coast. Silivri is a district of Istanbul Province along the Sea of Marmara, outside of metropolitan Istanbul, containing many holiday and weekend homes for residents of the city.

On September 9 the Ayamama Creek overflowed which resulted in roads almost completely covered by water. The flooded region, Ikitelli, in the Istanbul urban area, is a district with much traffic and industry. Figure 3 also shows the catchment and flooding areas for this event.

3 Model setup

The flood events on September 8-9 were examined using Hirlam and Harmonie. The models were run at ECMWF using the default settings. The number of gridpoints is given in table 1. The model domains are shown in figure 4.

The Hirlam run is initialized at 00 UTC on 6 September with 48-hours forecasts every 12 hours. The Harmonie run is started at 00 UTC on 6 September with analyses every six hours. The forecast length is 24 hours. Both models are nested within ECMWF analyses.

Table 1: Details of the model setup

Model feature	Hirlam	Harmonie
PE	Hydrostatic	Non-hydrostatic
Resolution	11 km	2.5 km
Gridpoints	438x400	389x389 (189x189)

4 Model simulations

The precipitation forecasts for 7 September are also shown in figure 4. According to the Hirlam forecast some 10 to 20 mm can be expected in the region Northwest of Istanbul. Harmonie shows peak values of 70 to 100 mm, which compares well to the observed values. For example the average daysum of stations 4 and 5 is 77 mm. Visual comparison of the model forecasts with the radar information given in figure 5 confirms these conclusions.

The flash floods are mainly due to heavy rainfall on September 8-9. The weather situation leading to these large rainfalls is described by Schipper and Erturk (2009). They found that the upper level low over central Turkey results in the advection of moist unstable air from the Black Sea. Subsequent

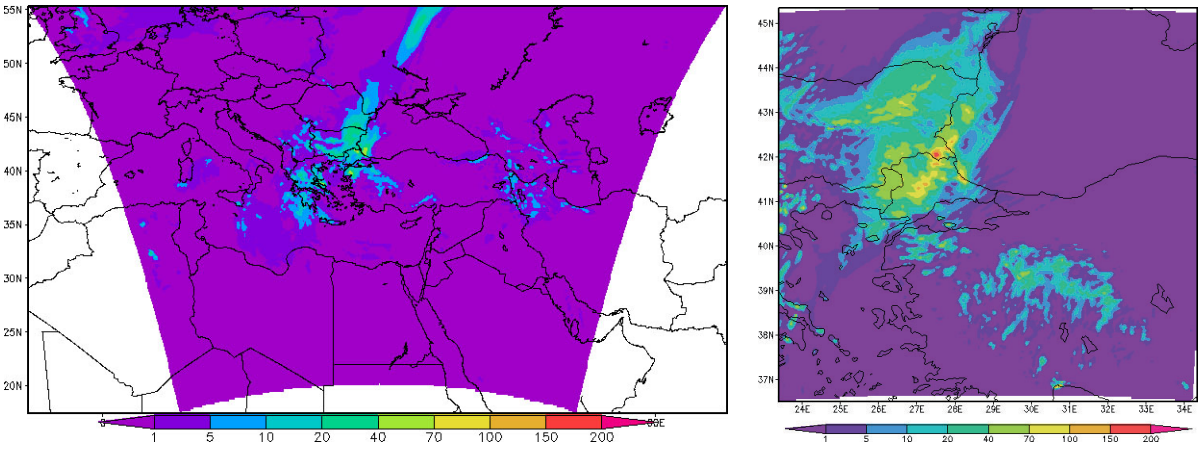


Figure 4: Accumulated 0-24 hours precipitation forecast from 7 September 00 UTC until 8 September 00 UTC. The plotted area shows the model domain. Left panel: Hirlam, right panel: Harmonie.

topographic uplift then results in numerous rounds of showers and thunderstorms in the Marmara Region (west of the Black Sea). The low temperatures found in the upper layers of the cold core low and its contrast to the warm surface causes CB's to grow enthousiastically, producing lots of rain. To achieve accurate short-term precipitaton forecasts in complex terrain, such as in the greater Istanbul

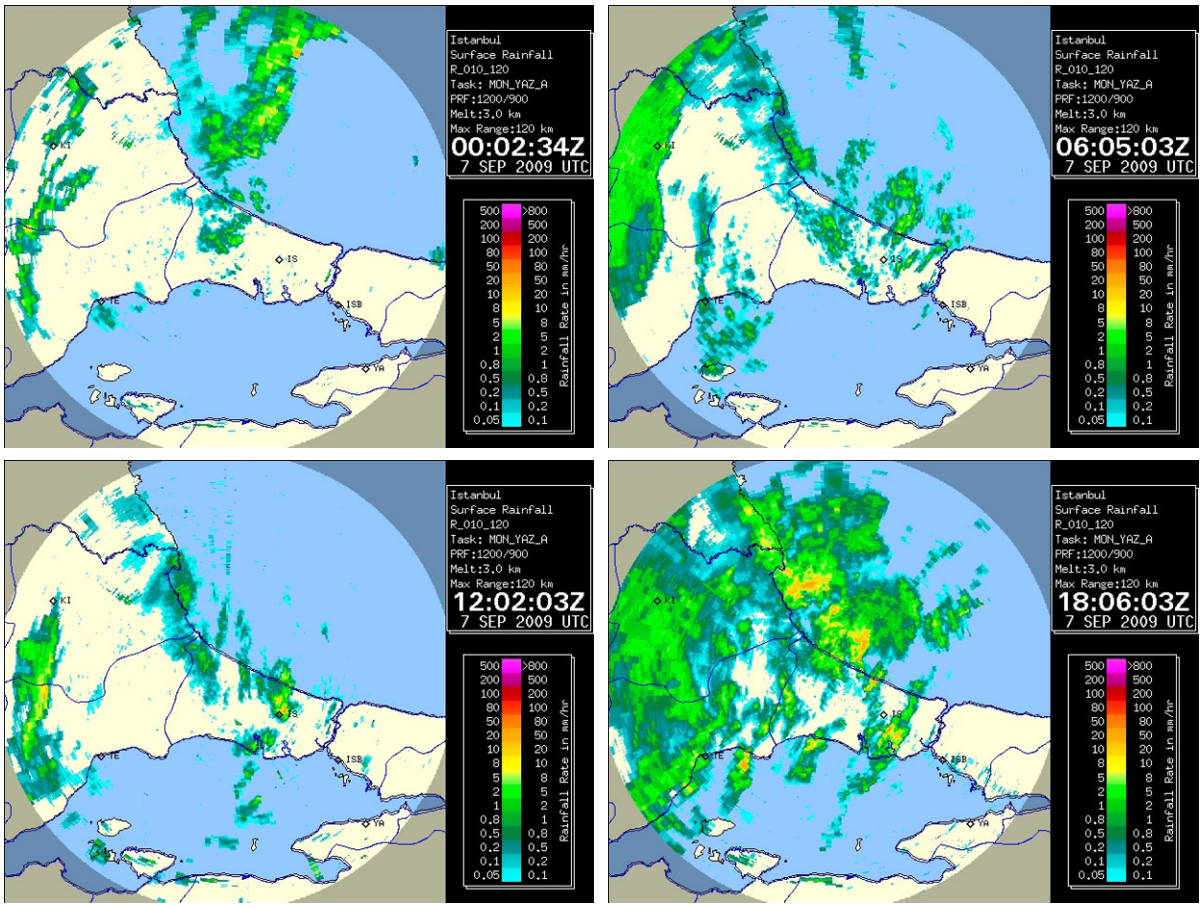


Figure 5: SLI_R radar images are given every six hours starting at 7 September 00 UTC. The Doppler weather radar in Istanbul is operated by TSMS.

area, mesoscale models must include an accurate treatment of the precipitation process and full dynamical interactions driven by the fine-scale variability of topography and atmospheric conditions.

During the heavy rain event (7-10 September), 270 mm has been measured in Catalca in the west of Istanbul. The precipitation on 8 and 9 September averaged over the 28 stations is comparable to long term monthly averages for that region.

4.1 September 8

Figure 8 shows observations of rainfall on 8 September. The rain-gauge observations show large spatial variability between Northwest and Southwest of Marmara region. The highest amounts of rainfall are measured in Catalca (204 mm), Bandirma (122 mm) and Gonen (109 mm). However Bandirma and Gonen are located South of the Marmara Sea and not in the catchment area of the area which was flooded on 8 September. The precipitation value of 49 mm measured at station Terkos (id 14) is most probably a severe underestimation of the true value, because the station did not supply data from 08:00 until 23:00 UTC. The radar image in figure 9 suggests that the rainfall at Terkos may well have been as heavy as at station Catalca (id 11), 204 mm.

The average over all stations is 43 mm. The average over the Silivri flooding area stations (the blue coded stations in table 2) is 81 mm. The bulk of the heavy rain is offshore and over Bandirma (id 9) along with a significant spread along the Southwest of Marmura Sea.

The Hirlam forecast shows two small areas with peak values in the range of 70-100 mm, see figure 8. The peak value area in the middle of the picture is some 20 km Northwest of Catalca (id 11, see fig. 6), at the windside of the model orography (fig. 7).

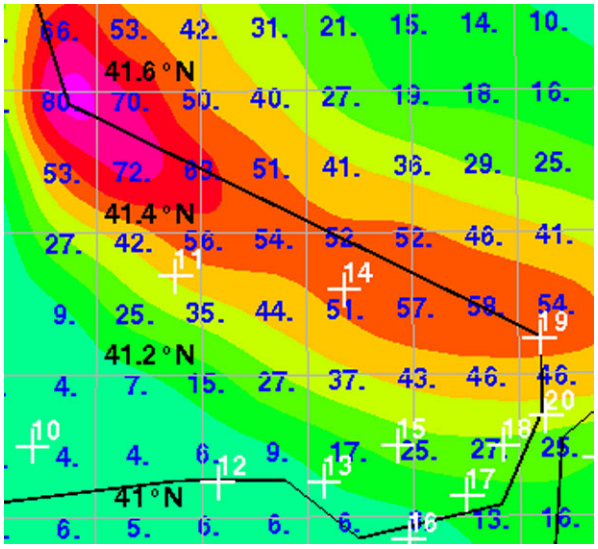


Figure 6: Hirlam grid point values showing the 24-hours precipitation forecast for 8 September (valid at 9 September 00 UT).

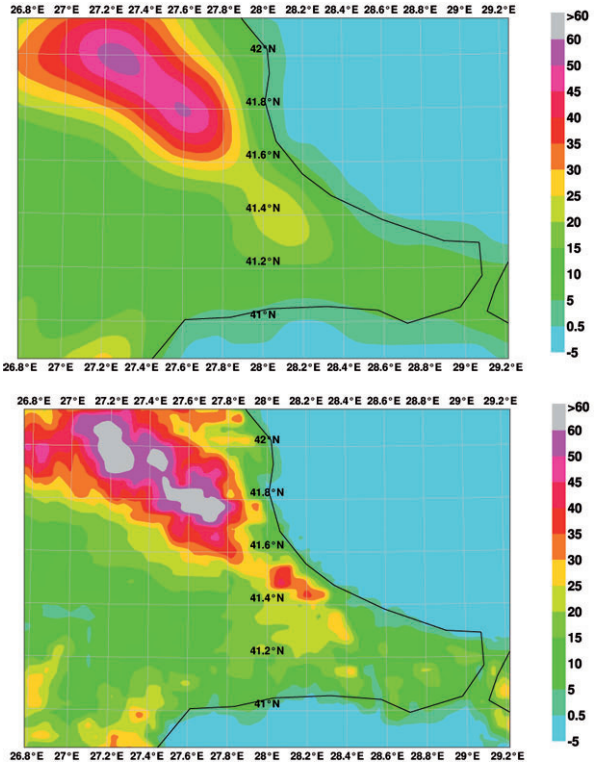


Figure 7: Hirlam (top) and Harmonie (down) orography.

*Table 2: The table gives the station id, name, longitude, latitude, altitude (m), daily total observed precipitation (obs) and the models 24-hour accumulated precipitation forecasts for Hirlam (hir) and Harmonie (har), all in mm. The colors indicate stations which are in the catchment area relevant for 8 (blue) and 9 September (green station names). The * in column 7 indicates that station Terkos (id 14) did not register any data from 08:00 to 23:00, therefore the number given is a 9-hours precipitation sum. The values for Hirlam and Harmonie have been interpolated between grid point values.*

					7 Sep	8 September			9 September		
id	station name	lon	lat	alt	obs	obs	hir	har	obs	hir	har
1	Ipsala	26.37	40.92	10	63.4	50.2	8.4	11.2	0.0	1.6	0.0
2	Uzunkopru	26.69	41.25	52	64.4	33.4	5.4	29.1	0.0	1.7	0.7
3	Malkara	26.91	40.89	207	54.0	28.4	6.7	54.7	5.0	2.2	3.8
4	Kirklarel	27.22	41.74	232	93.0	25.4	4.2	2.1	2.4	4.0	0.8
5	Luleburga	27.31	41.35	46	63.8	37.4	2.6	5.9	10.8	1.8	2.8
6	Tekirdag	27.49	40.99	4	69.2	43.2	3.4	46.0	7.2	7.0	13.2
7	Gonen	27.64	40.11	37	4.2	122.4	31.6	87.2	6.0	25.3	3.9
8	Corlu	27.82	41.15	183	22.6	30.4	4.1	54.4	18.0	9.7	19.7
9	Bandirma	27.99	40.33	63	0.2	109.4	21.4	35.0	144.4	30.0	39.6
10	Canta	28.08	41.10	116	0.8	43.8	4.1	10.5	55.8	7.9	20.8
11	Catalca	28.35	41.34	104	29.4	204.4	36.8	1.8	35.6	30.9	101.5
12	Kamiloba	28.43	41.05	54	3.6	65.0	6.6	22.3	96.6	5.5	33.0
13	Hadimkoy	28.63	41.05	183	5.6	41.0	14.2	43.9	114.2	6.8	15.4
14	Terkos	28.67	41.32	4	64.4	48.6	52.3	5.8	79.8	34.5	29.0
15	Olimpiyat	28.77	41.10	100	15.0	50.2	25.8	42.2	175.2	8.3	33.4
16	Florya	28.79	40.97	37	6.4	28.6	9.1	122.2	78.6	5.1	8.9
17	Aksaray	28.90	41.03	4	0.6	15.0	12.4	146.9	10.6	4.2	12.4
18	Akom	28.97	41.10	88	0.4	33.4	27.2	37.2	38.0	8.0	60.8
19	Kumkoy	29.04	41.25	38	3.8	25.4	55.6	2.7	66.0	35.0	68.3
20	Sariyer	29.05	41.14	59	3.4	65.4	25.0	39.8	41.4	8.7	64.4
21	Buyukada	29.08	40.87	188	0.0	42.2	10.6	65.9	2.2	6.2	20.4
22	Cavusbasi	29.15	41.08	137	0.2	8.0	25.0	61.4	23.4	8.7	39.6
23	Kartal	29.18	40.89	28	0.0	10.4	11.1	72.9	26.6	10.3	30.2
24	Samandira	29.20	40.99	123	0.4	15.2	13.6	78.5	10.6	11.5	37.9
25	Omerli	29.33	41.00	153	4.2	6.8	10.8	43.0	5.0	11.0	49.3
26	Sile	29.60	41.17	83	0.6	2.6	23.2	12.6	13.2	10.6	9.3
27	Kocaeli	29.93	40.77	76	0.0	0.6	11.6	1.6	4.6	5.0	29.2
28	Sakarya	30.39	40.77	30	0.0	4.8	0.1	6.6	69.0	5.0	19.4
				Average	20	42	17	41	41	11	27

The Southern peak value area collocates with station Bandirma. Along the coastline Northwest of Istanbul Hirlam has clear warning sings for large precipitation values, however underestimates the observed values, and has the precipation too much to the North of the catchment area.

The Harmonie forecast is plotted in the bottom panel of figure 8. Harmonie forecasts daysum up to almost 400 mm, which is quite excessive in comparison with the annual precipitation of 700±150 mm, but is in fact only a factor 2 larger than the observed 204 mm in station Catalca. Concentrating on the Istanbul area we see that the peak values of Harmonie are located to the South of the observed peak values.
It is a common feature that Hirlam forecasts the precipitation on the windside of the hill range. Its explanation lies in the fact that in Hirlam precipitation falls vertically. Harmonie, on the other hand,

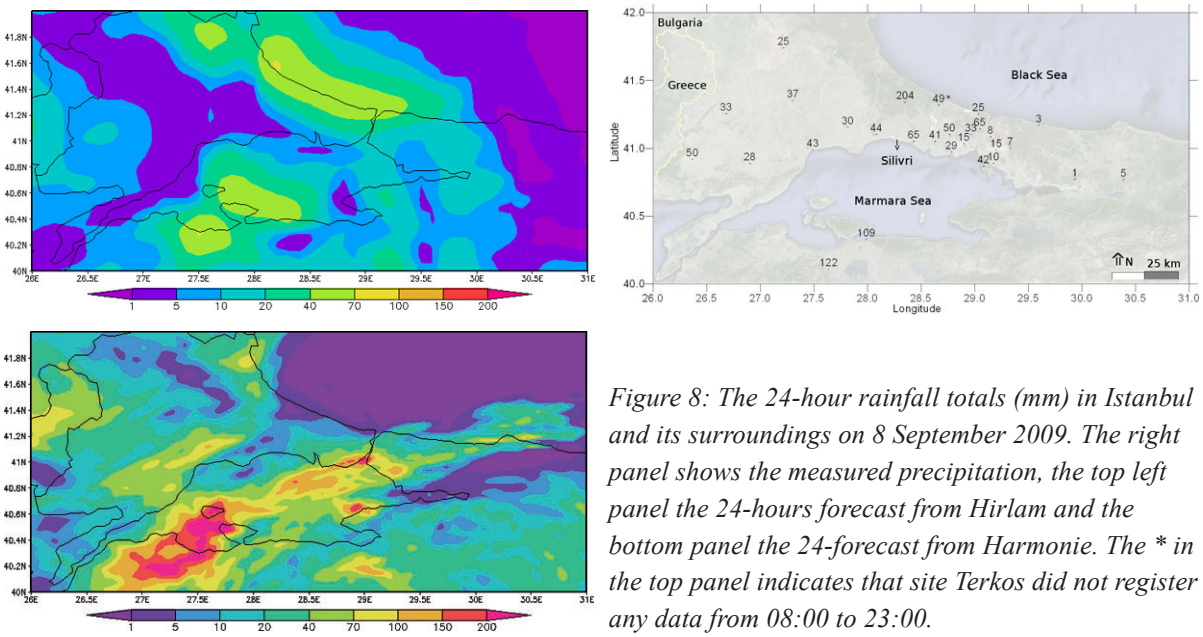


*Figure 8: The 24-hour rainfall totals (mm) in Istanbul and its surroundings on 8 September 2009. The right panel shows the measured precipitation, the top left panel the 24-hours forecast from Hirlam and the bottom panel the 24-forecast from Harmonie. The * in the top panel indicates that site Terkos did not register any data from 08:00 to 23:00.*

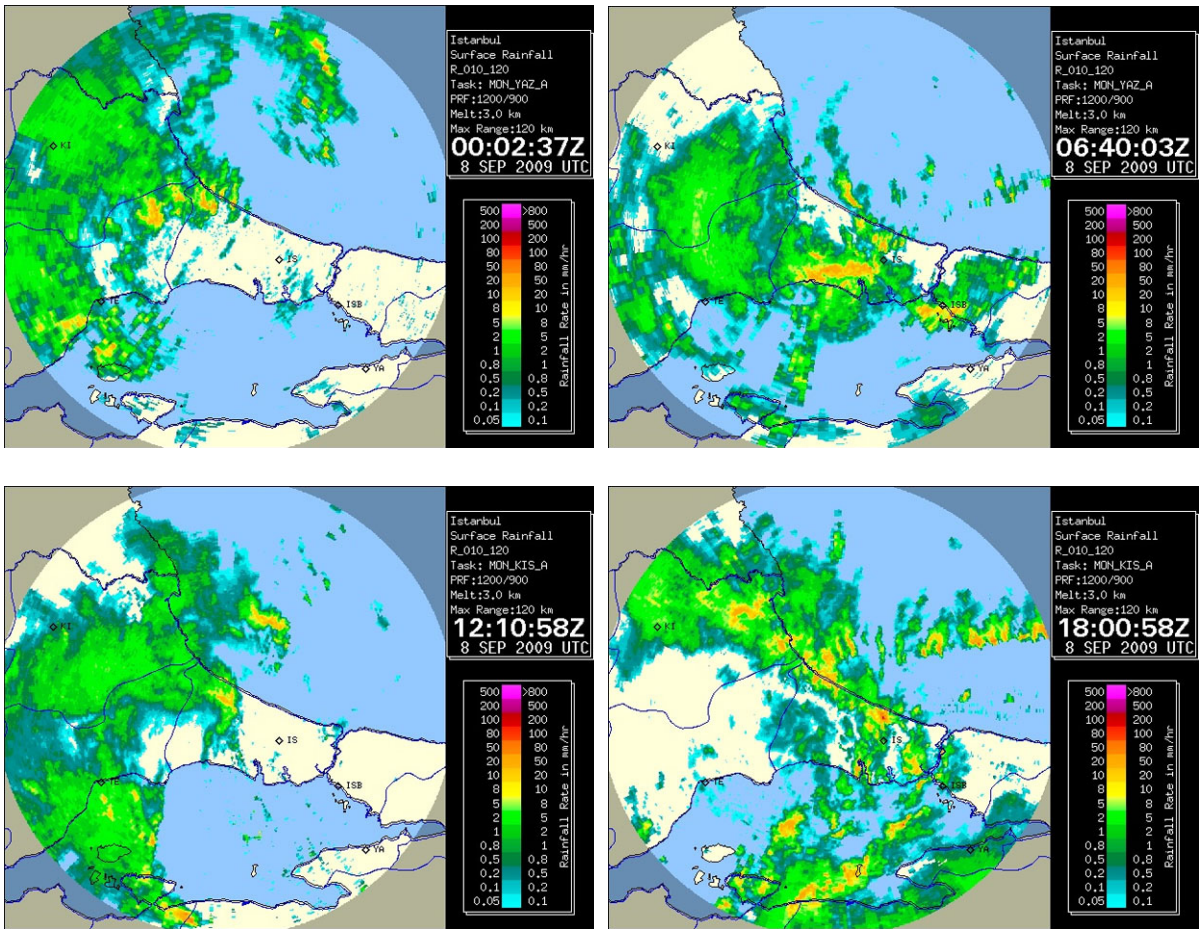
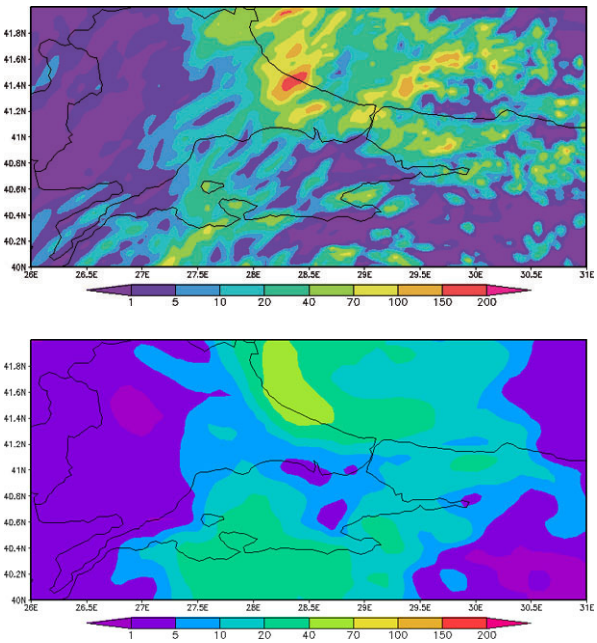


Figure 9: SLI_R radar images are given every six hours starting at 8 September 00 UTC. The Doppler weather radar in Istanbul is operated by TSMS.



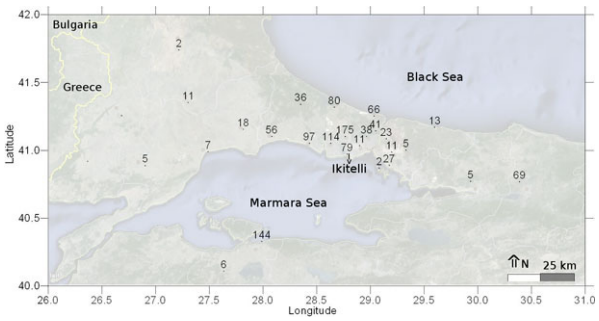


Figure 10: Same as figure 8 for 9 September 2009.

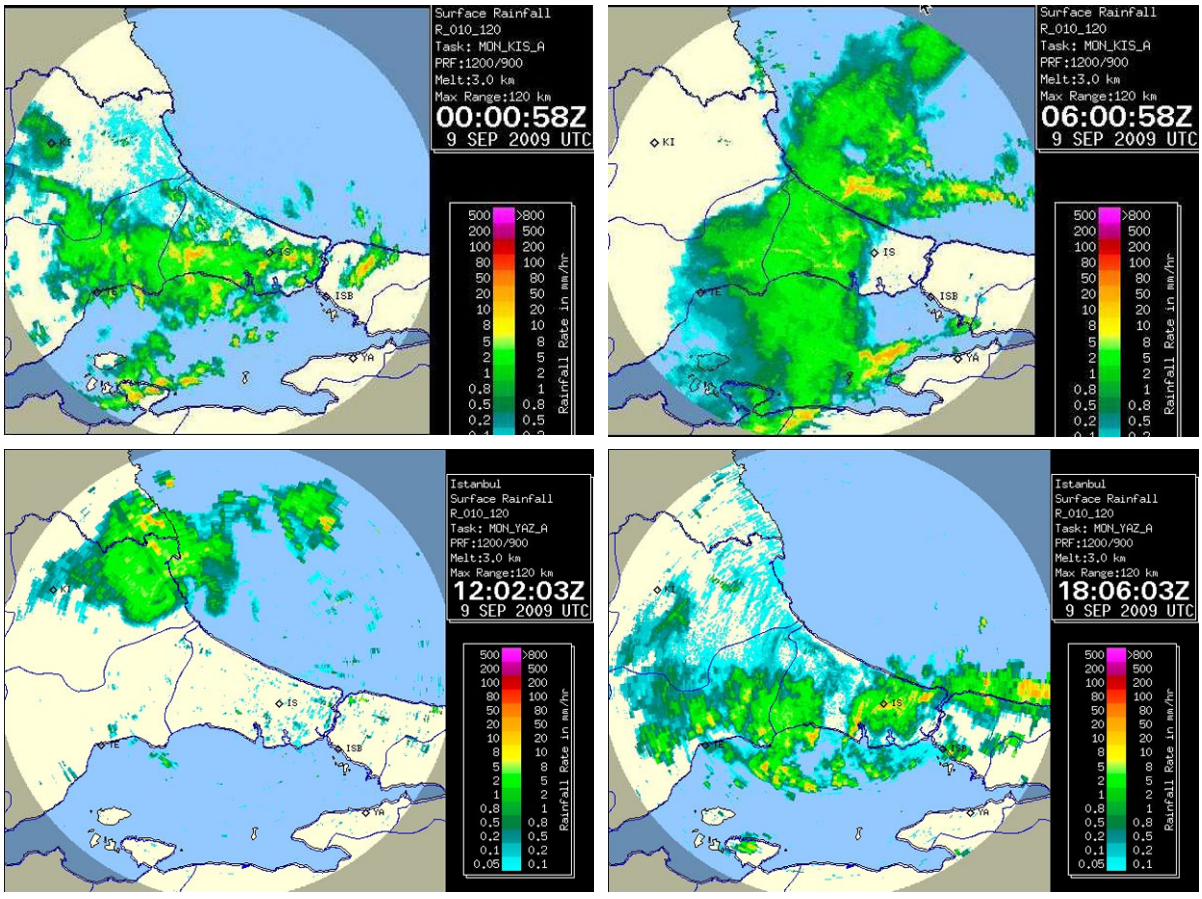


Figure 11: Same as figure 9 for 9 September 2009.

applies advection to a number of hydrometeors, resulting in the possibility that water (in particular if in the form of snow) is advected over the top of the hills. Because the top of the hill range is usually the border of a catchment area, this property of being able to advect precipitation to the leeside is essential to predict proper rainfall amounts for flooding. This advantage of models carrying a range of hydrometeors as prognostic variables has been reported for many other models (e.g. Kunz and Kottmeier, 2006).

4.2 September 9

The rainfall on September 9 is shown in figure 10. The highest rainfall amounts are seen at Olimpiyat (175 mm), Bandirma (144 mm) and Hadimkoy (114 mm). The average over all stations is 40.7 mm. The average for the catchment area is 87.1 mm.

Again, Hirlam forecasts the main precipitation area to the Northwest of the catchment area, with daysum values between 40 and 70 mm approximately 50 km Northwest of the catchment area. The Hirlam 24-hours precipitation forecast gives an average of 10.9 mm for all stations and 6.4 mm for the catchment area. The observed heavy rain South of the Marmara Sea (144 mm at Bandirma, id 9) is also underpredicted by Hirlam.
However it should be remarked that the Hirlam value is an area averaged value while the observation is a point value. At Gonen only 6 mm has been measured. Gonen (id 7) is located less than 25 km Southwest of Bandirma. From the radar images (figure 9) it is clear that in this case the large value observed at Bandirma is not representative for a larger area.

On 9 September 2009 winds blow from the Black Sea over the Istanbul area. There is heavy rain West of the city centre leading to flooding of the area indicated in figure 3. Harmonie forecasts heavy rain (150-200 mm) some 40 km northwest of the flooding area. The average forecast 24-hours precipitation is 27 mm for all stations and 29 mm for the stations in the catchment area, which is quite below the observed values.

Also on this day we observe that Hirlam drops its rain on the windside, and Harmonie, more correctly, on the leeside of the hills.

5 Conclusions

The goal of this experiment was to investigate whether the NWP models Hirlam and Harmonie can forecast the excessive rainfall in the Istanbul area which caused the flash floods on September 8-9 in 2009. The flooded areas were at different locations on the two days. Therefore the two days can be analysed as two different events. Both models are run with the default setting.

The catchment areas for both events are quite small (some hundreds of square kilometers). Hirlam therefore has only some tens of gridpoints in those areas.

The 24-hours accumulated precipitation forecast by Hirlam is quite high as compared to climatology, but still far below observed amounts. Moreover, Hirlam suffers from a location error, due to the vertical falling of rain. Yet, Hirlam gives a clear signal of heavy precipitation in the area, but it needs human interpretation to correct amount and location. Harmonie, on the other hand, gives higher amounts, in particular in the catchment areas. Whether amount and location are good enough to predict flooding should be investigated with a run-off model.

Acknowledgements

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