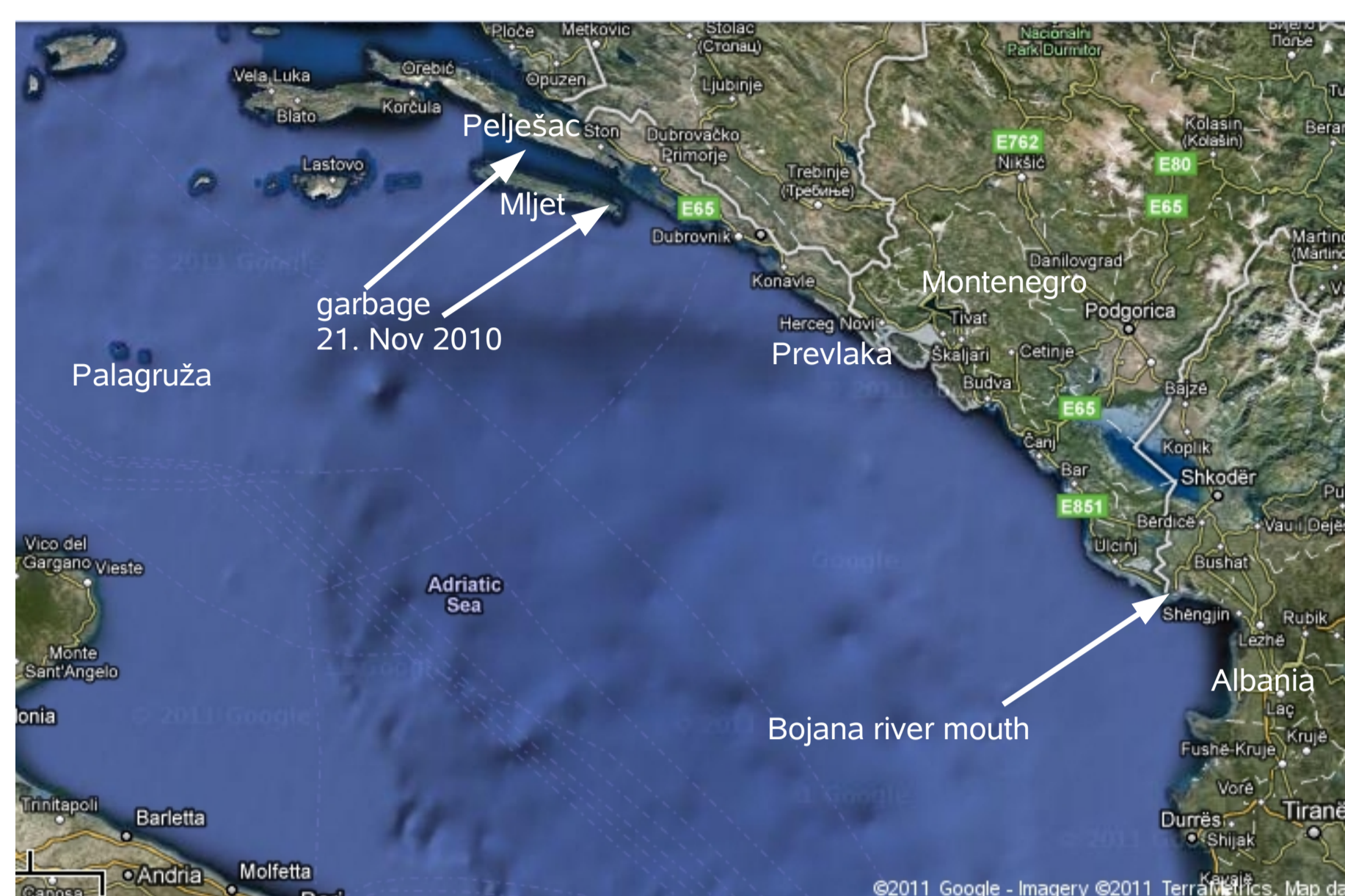


# Analysis of the weather situation prior to the garbage accumulation on the south-eastern Adriatic coast in Croatia

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## Introduction

On 21st November 2010, garbage accumulation has been observed on the southeast coast of Pelješac Peninsula, Mljet, Korčula and Lastovo Islands as well in inlets and beaches in the vicinity of Dubrovnik, Croatia. The heaps of garbage have contained mostly plastic packages, glass, clothes and other typical floating trash. The labels on the garbage items suggested that it arrived mostly from Albania. It is not unusual that a few pieces of garbage from Albania reach Croatian coast in late autumn, but the event was much larger than in other years. It is assumed that strong southeasterly "jugo" (sirocco) wind has intensified the sea current system that brought the floating garbage from Albania. It is further assumed that the garbage was washed into the sea by strong flash floods as a consequence of the torrential rain. This hypotheses are investigated using available meteorological, oceanographic and hydrological data.



## Methods

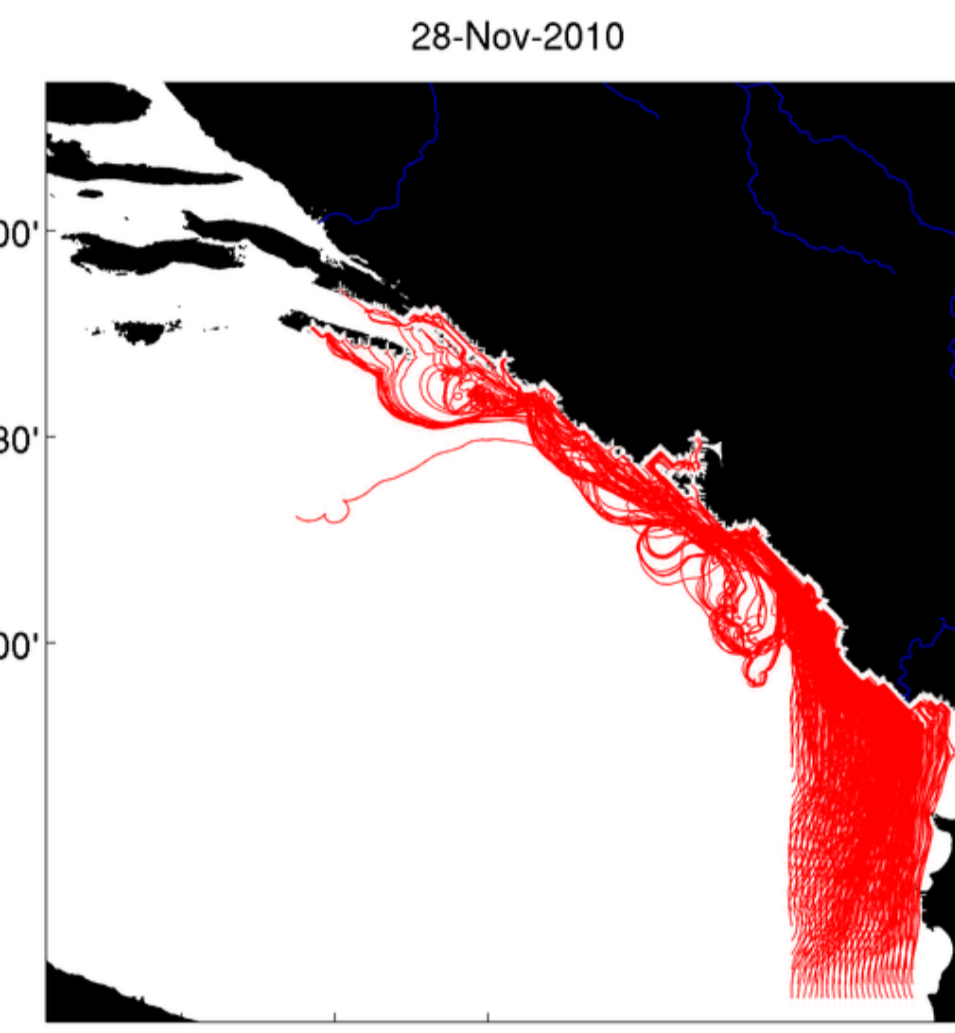
The meteorological conditions are analyzed on available satellite data, in-situ measurements on SYNOP, climatological and rain-gauge measurements from Croatia, Montenegro and Macedonia as well as the NWP model data obtained using ALADIN model on 8 and 2 km resolution. The hydrological analysis in the area is done using the water level measurements on relevant major rivers in Montenegro and Macedonia. The sea currents responsible for pollution transport are computed using ROMS ocean model, forced with ALADIN 8 and 2 km outputs, major Adriatic river inflows and large scale ocean model data at the open boundary. The results from ocean model are used as input to the backward trajectory computations that could reveal the possible origin of the garbage.

In November 2010 there were several heavy rainfall events that could have initiated flash floods in the area. Unfortunately in-situ measurements of rainfall from Albania were not available to the authors. Therefore, available remote sensing satellite data are used to describe the events, supported by the measurements on the meteorological stations from the surrounding areas (Croatia, Montenegro, Macedonia and Greece).

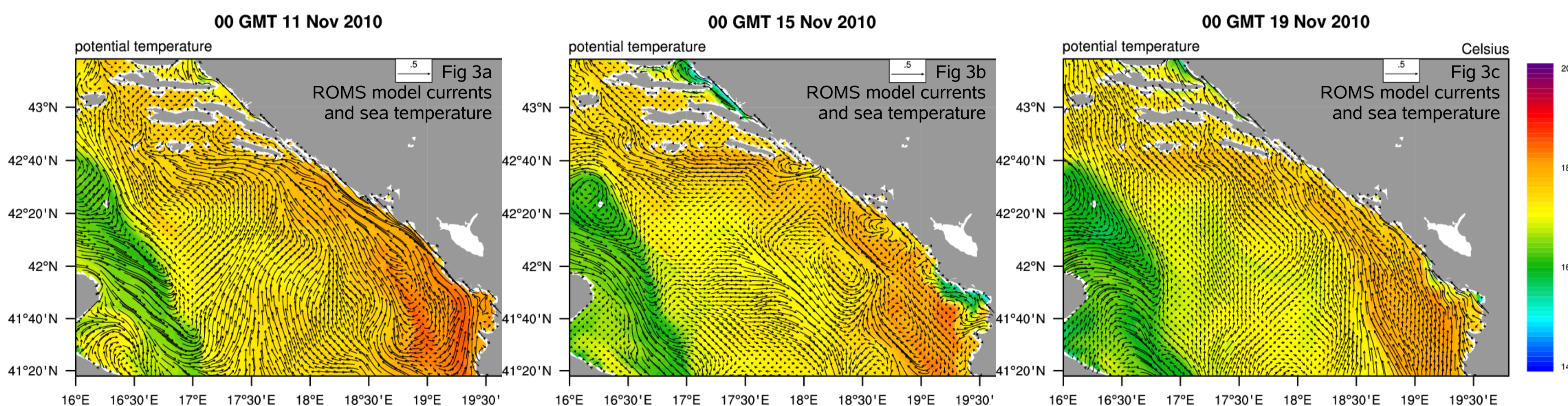
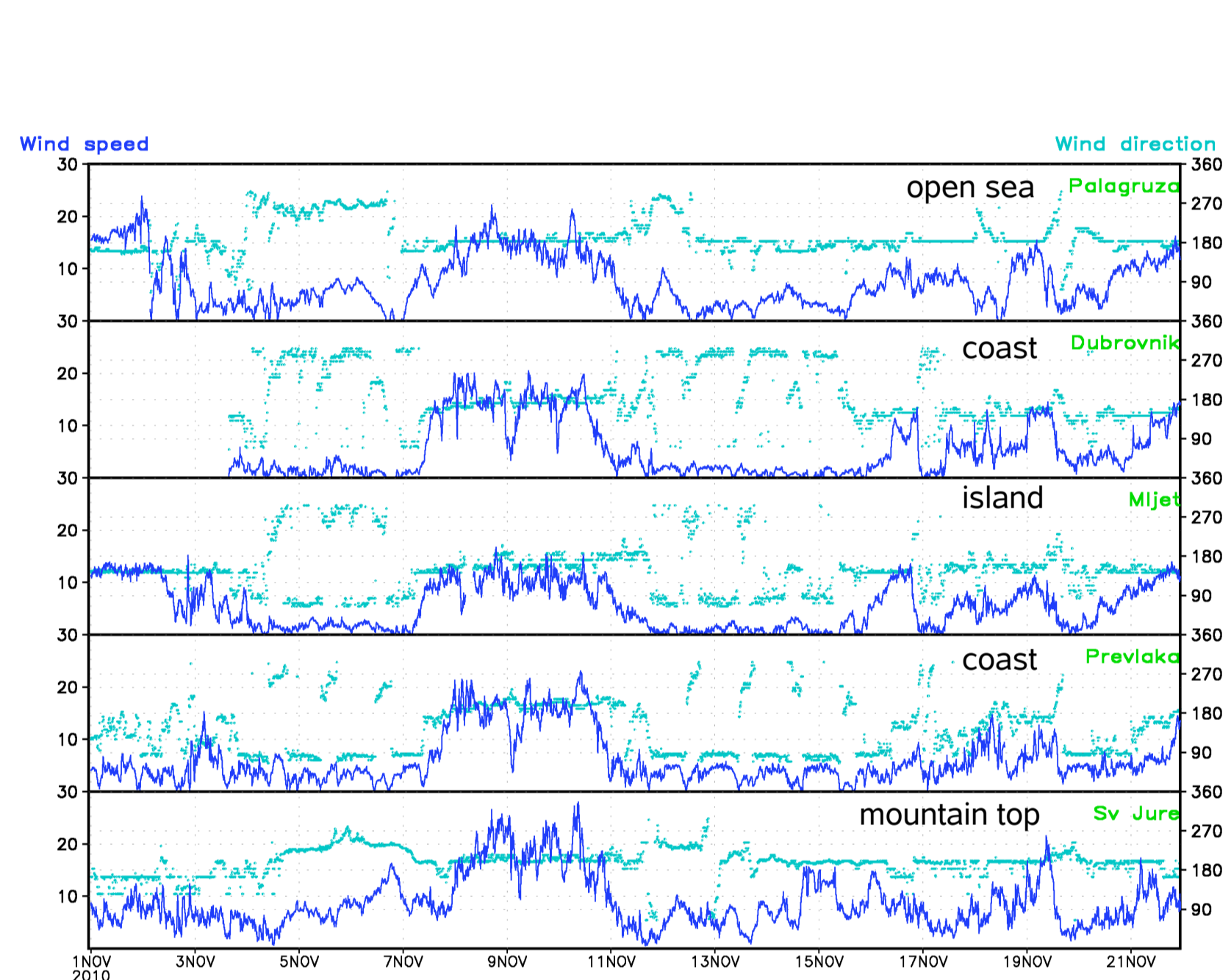
The convective rainfall rate and precipitating cloud derived fields from the Meteosat 9 reveals the cases with strong convection and rainfall over Albania on 8-10 and 17-19 November 2010. Both cases are characterized by strong convection and rainfall in the afternoon and periods with little or no rain in between. The precipitating clouds cover much of the area, while the convective rainfall rate is far more localized, but often very intensive. It is important to note that those fields are available on 6 hour interval, heavy rainfall could have occurred during the sampling interval and easily could have been missed. The operational 8 km resolution ALADIN model did forecast heavy rainfall over Albania for both cases as well as Croatia and Montenegro as observations suggested.

## Conclusions

Measured rainfall and NWP model rainfall show that the rain was more intensive in the event of 8-10 November than in the later one. Measured wind speed and direction show that the episode of strong southeasterly wind was longer in the first event (8-10 Nov 2010) than in the second one. The strength of the southeasterly wind was underestimated by the operational ALADIN model forecast. Measured 10 min wind speed was sometimes 50% larger than the forecast one in several locations. The water level measurements on the rivers that flow into the Adriatic Sea in Montenegro show significant increase in the water level on 9th November 2010 that is followed by an increase in the water level of the Skadar lake as well. The water levels of Skadar lake and Bojana river stayed high until the end of November.



ROMS ocean model data was used for input to the trajectory computations. The trajectories were initiated off the coast of Albania. They stop as soon as they reach a coast. Most of the trajectories starting on 08 Nov 2010 finish on the coast of Montenegro and south-east Croatia by 28 Nov 2010.



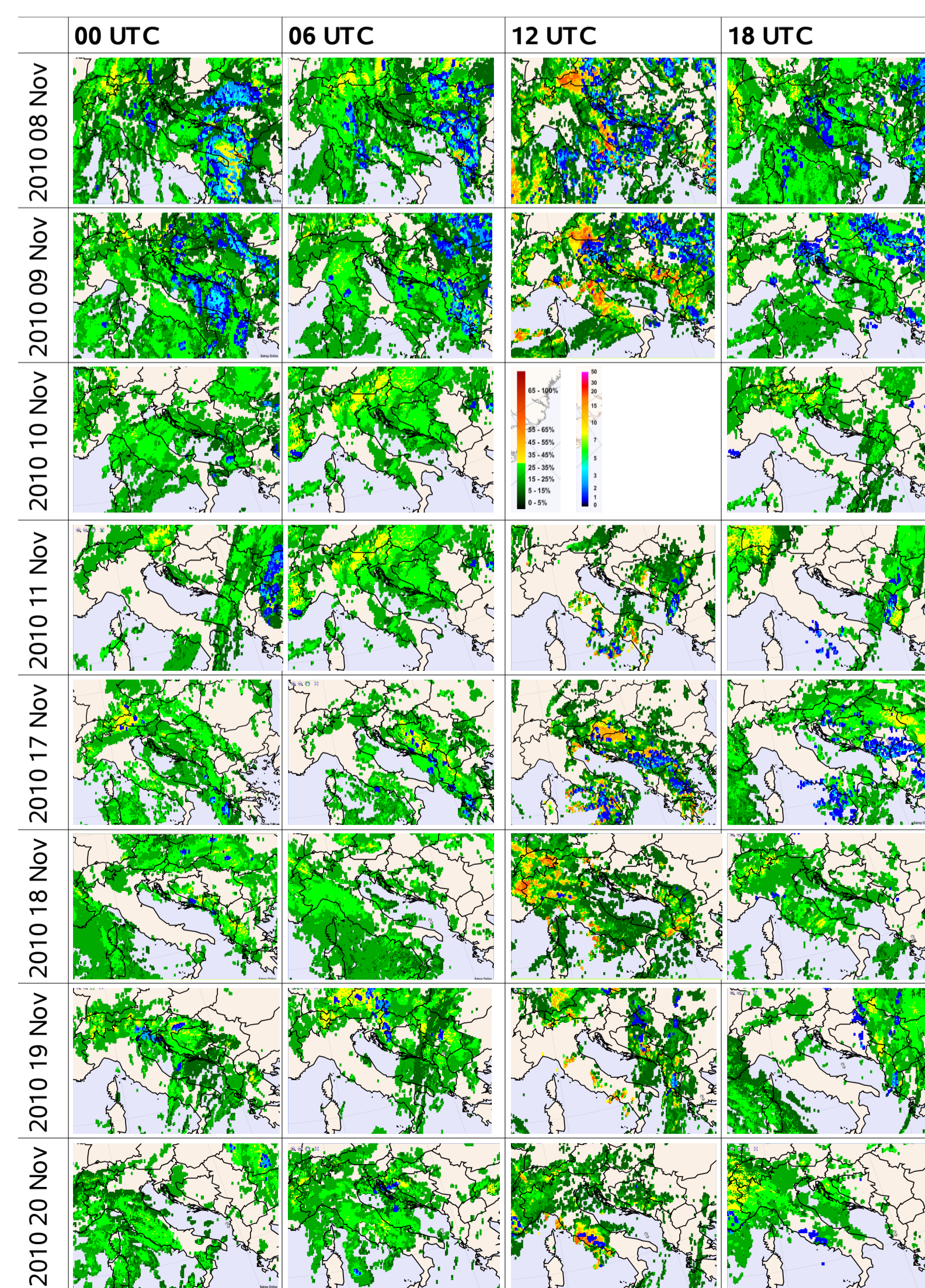
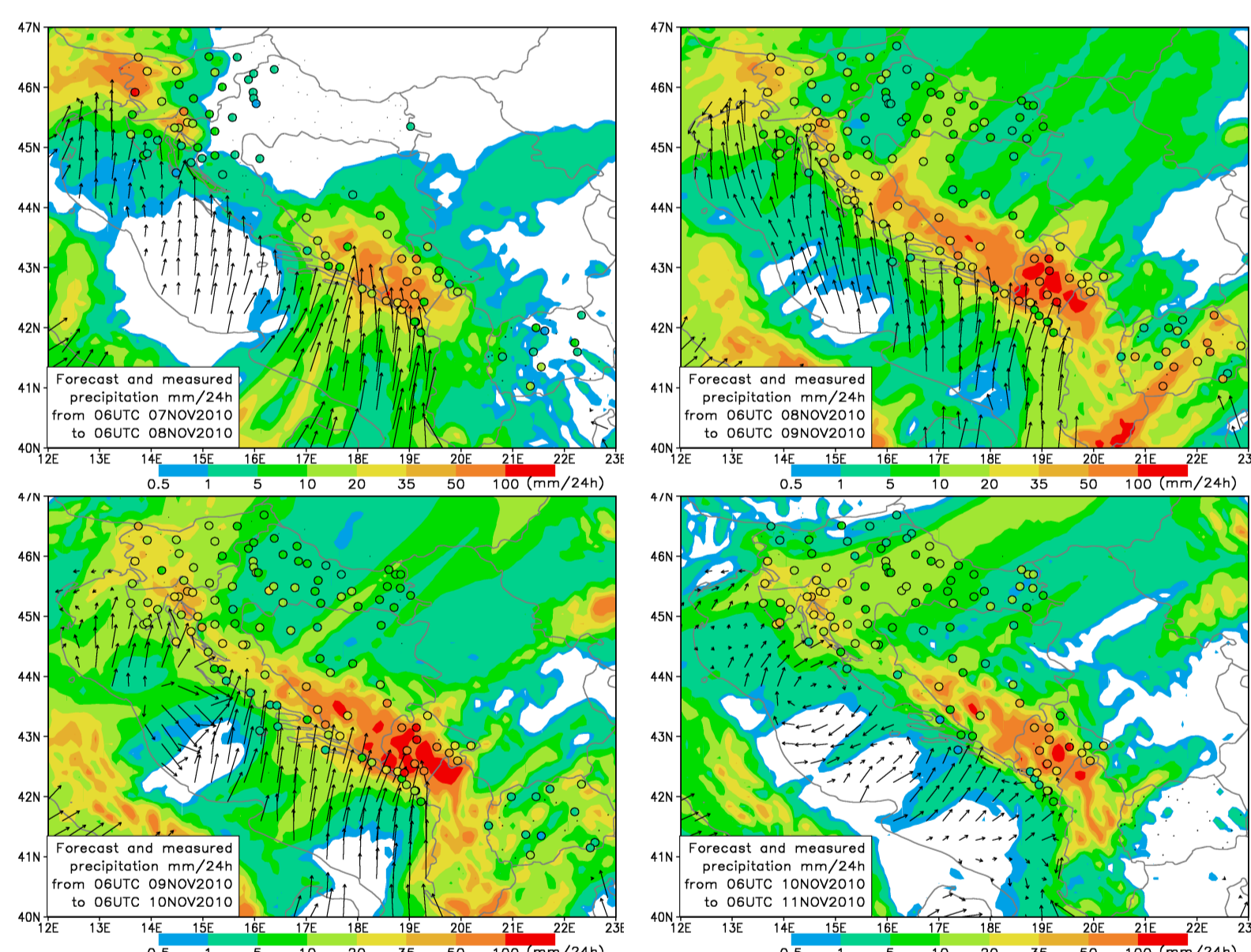
Measured wind speed (dark blue) and direction (light blue) that wind in the episode of 7<sup>th</sup> - 11<sup>th</sup> Nov 2010 was from south and stronger and lasted longer than other strong wind episodes. In that episode wind measured at Palagruža, Dubrovnik and Prevlaka was stronger than predicted and correct at Mljet and Sv. Jure. The wind was stronger on the coast (Dubrovnik and Prevlaka) than off-shore (Mljet), probably as a consequence of channelling by the coastal mountains. In maps of forecast and measured precipitation, wind is shown as arrows for the term of the end of the 24 hour period.

From 11<sup>th</sup> to 15<sup>th</sup> Nov 2010, wind is weak to moderate with direction typical to the sea breeze diurnal cycle. From 16<sup>th</sup> Nov 2010, the wind strengthens and southeast direction prevails in Dubrovnik, Mljet and Prevlaka. This wind episode has finally enhanced the sea currents that have transported the garbage to the shore.

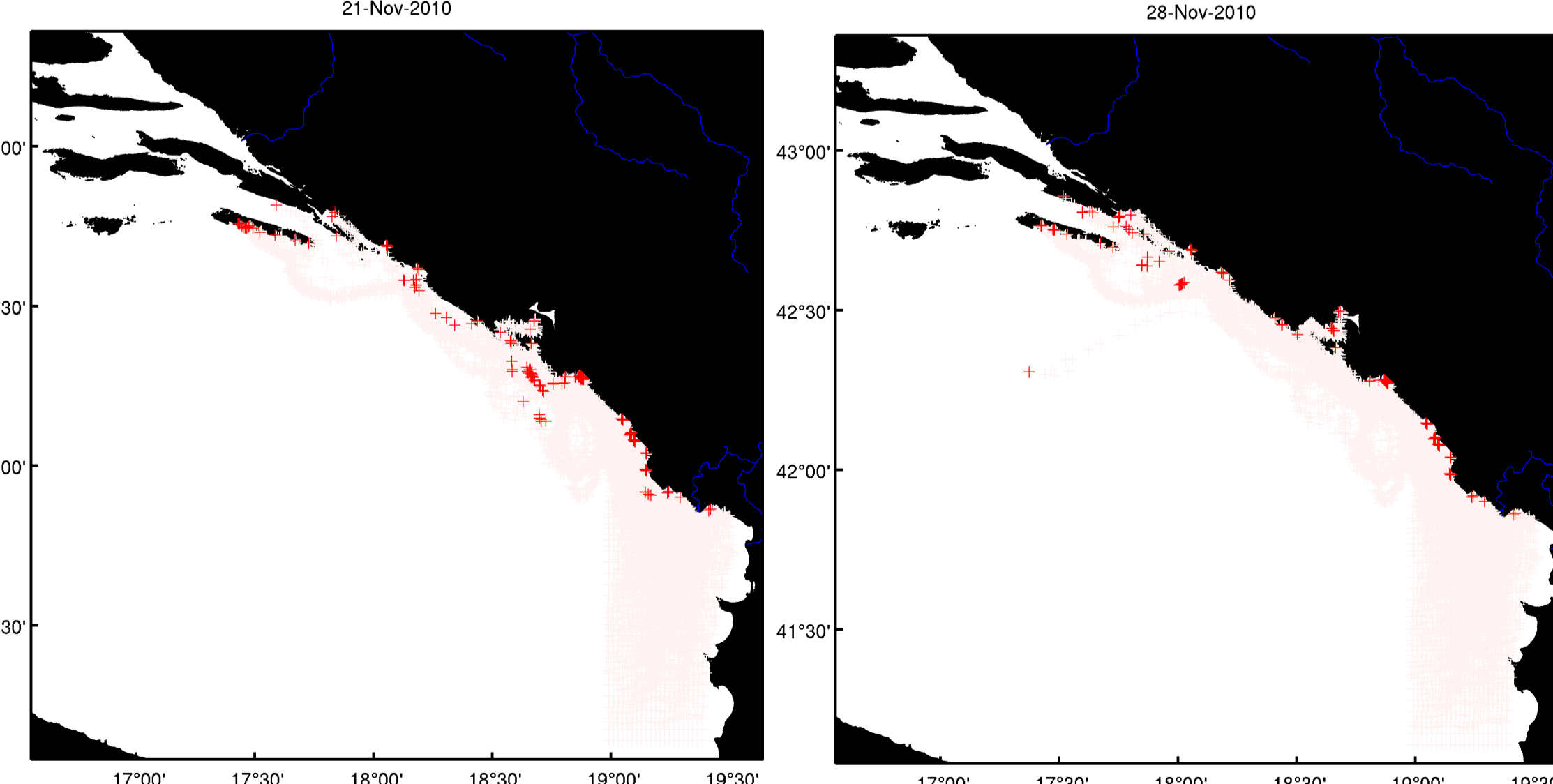
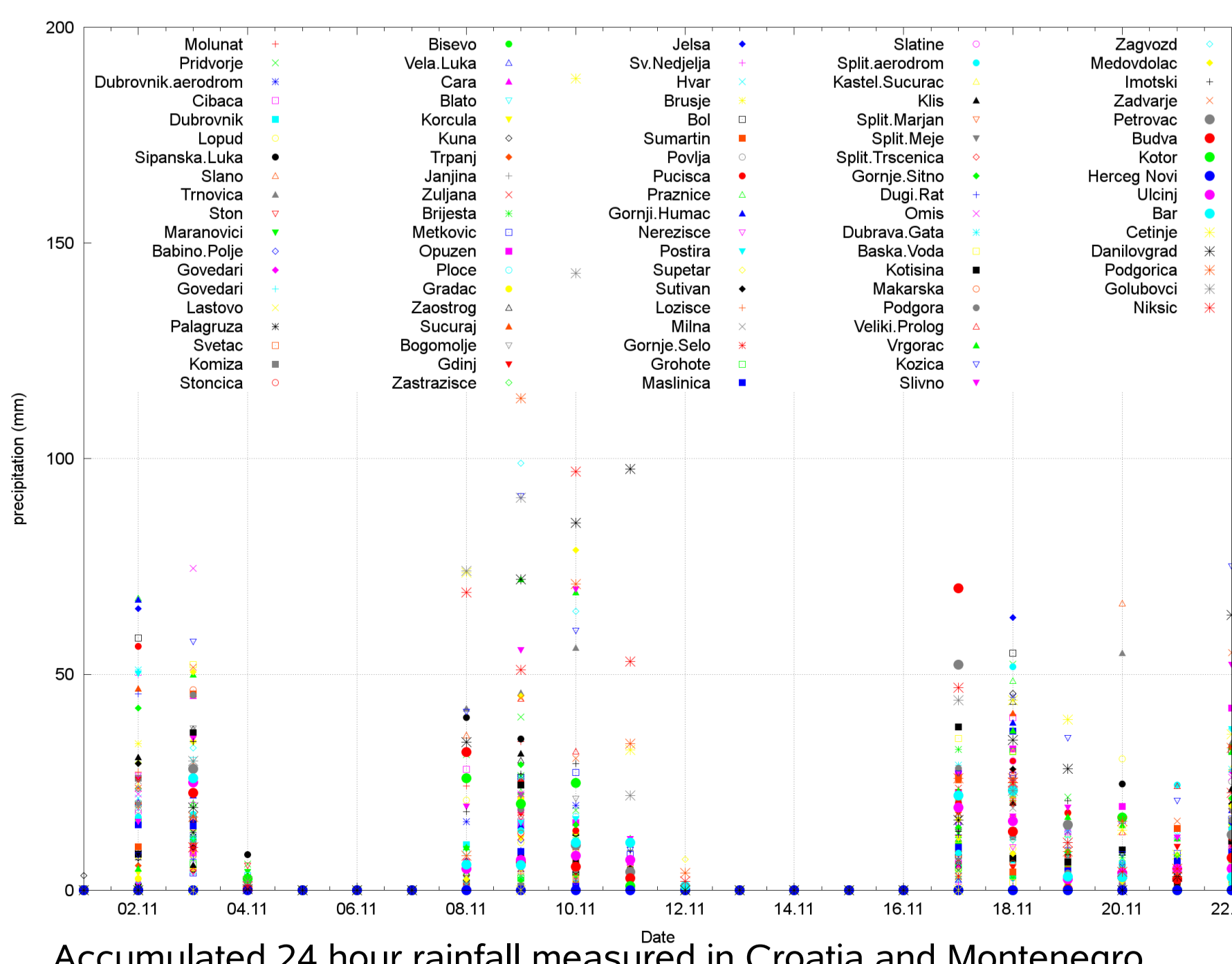
The forecast rainfall exceeded 100mm/24hr on various parts of Croatia, Montenegro and Albania (shaded) for several days in a row. This corresponds to the values measured on rain-gauges (circles) although the model exaggerated slightly the rainfall on the coastline and underestimated the rainfall on several locations further inland. The precipitation fields derived from satellite measurements reveal precipitation and intensive convective activity on south-east Adriatic coast.

The surface sea currents were computed using ROMS model forced with ALADIN meteorological model data (10m wind, 2m temp and relative humidity, sea level pressure, rain, short wave radiation and clouds), climatological values for the river run-off of the east Adriatic rivers and at the open boundary with daily values for temperature, salinity, currents and sea level from AREG (INGV) Mediterranean model. Model results show development of a strong sea current from south-east (north-west current) after jugo episodes and vortices close to the eastern Adriatic coast in weak wind. During November 2010, three periods of different wind conditions can be distinguished. From 7<sup>th</sup> to 11<sup>th</sup>, strong south-east wind initiated strong north-west currents (Fig 3a) followed by a weak wind period when the sea-current transport was weak (Fig 3b) and the period with moderate to strong south-east wind that strengthened the north-west current again.

The trajectories were initiated of the coast of Albania on 8<sup>th</sup> Nov 2010. They reach Mljet by 21<sup>st</sup> Nov 2010, and several reach Pelješac in the following days. The reason could be in too weak south-east wind in the model as well as run-off of the Bojana river used for input. These trajectories have to go through a narrow channel and close the the sea shore (edge of the computational domain) where models do not perform exceptionally well.



In the figures, the precipitating clouds field provides probabilities of precipitation intensities and the convective rainfall rate (mm/hr) is computed assuming that clouds being both high and with a large vertical extent are more likely to be raining. Both products are available at [www.satrepnline.org](http://www.satrepnline.org). Measurements from the rain-gauges show that rainfall in the period 7-11 Nov 2010 was more intensive than in other rainy periods. Stations in Montenegro (larger circles and stars) received more rain than Croatian stations.



Water level measurements on the rivers and lakes in Montenegro that flow to the Adriatic Sea. The event of 7<sup>th</sup> - 11<sup>th</sup> Nov 2010 is connected with the rapid increase in the water levels. The levels of Skadar lake and Bojana river remain high. Table shows annual river run-off distribution for the Albanian rivers varies for an order of magnitude during the year.

