

Record-breaking sea levels in the Northern Adriatic on 1 December 2008

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Abstract. An exceptionally strong storm surge affected the Northern Adriatic on 1 December 2008 when high sea level flooded a number of towns in the area. In Venice the sea level rose to 156 cm [1], which is the fourth highest value (*acqua alta*) since 1923. At Bakar the sea level reached 121 cm; this is absolutely the highest level recorded at the oldest Croatian tide gauge. On this occasion not only the Northern Adriatic coast was flooded, but the sea level rose high above

its usual values along the greater part of Dalmatian coast north of Split. The event was a result of fine tuning between the storm surge brought about by a series of synoptic atmospheric disturbances, the tide and the preexisting Adriatic basin-wide seiche, all superimposed on a significant sea level rise due to low-frequency atmospheric disturbance related to planetary waves; the local seiche activity additionally increased the sea level.



Figure 1. Map of the Adriatic showing the position of tide gauges of the Croatian network of permanent stations (*bold*) and some of the flooded towns (*italic*). Photos (left to right) of Venice, Rijeka, Zadar, Vodice and Trogir.

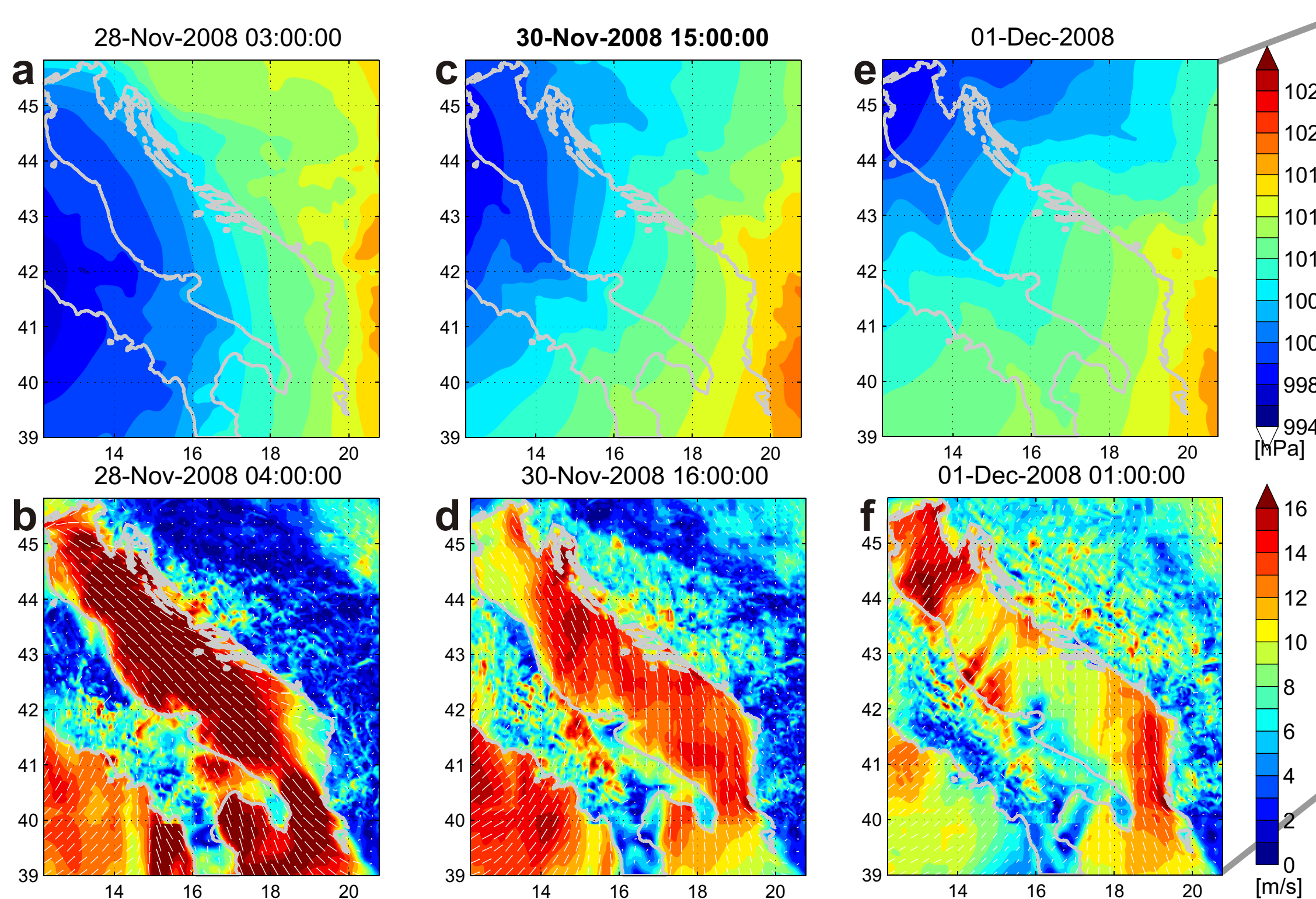


Figure 3. Air pressure (*top*) and wind field (*bottom*) over the Adriatic from ALADIN operational forecast model. Also shown are time series (*right, top*) of air pressure and wind vectors at two grid points (Northern Adriatic, *blue*, Southern Adriatic, *green*) on a transect along the middle of Adriatic and mean wind along the transect (*red*).

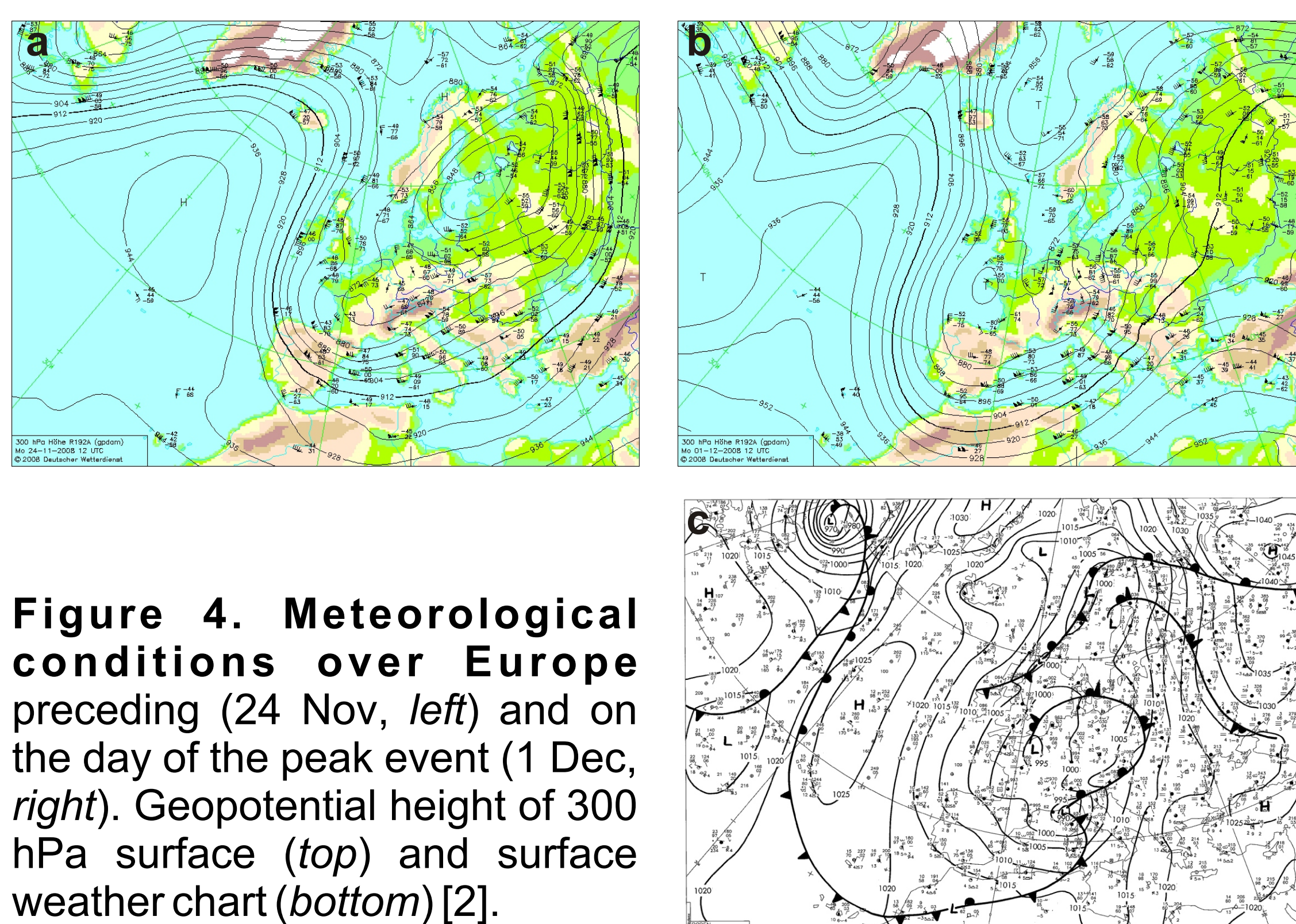


Figure 4. Meteorological conditions over Europe preceding (24 Nov, *left*) and on the day of the peak event (1 Dec, *right*). Geopotential height of 300 hPa surface (*top*) and surface weather chart (*bottom*) [2].

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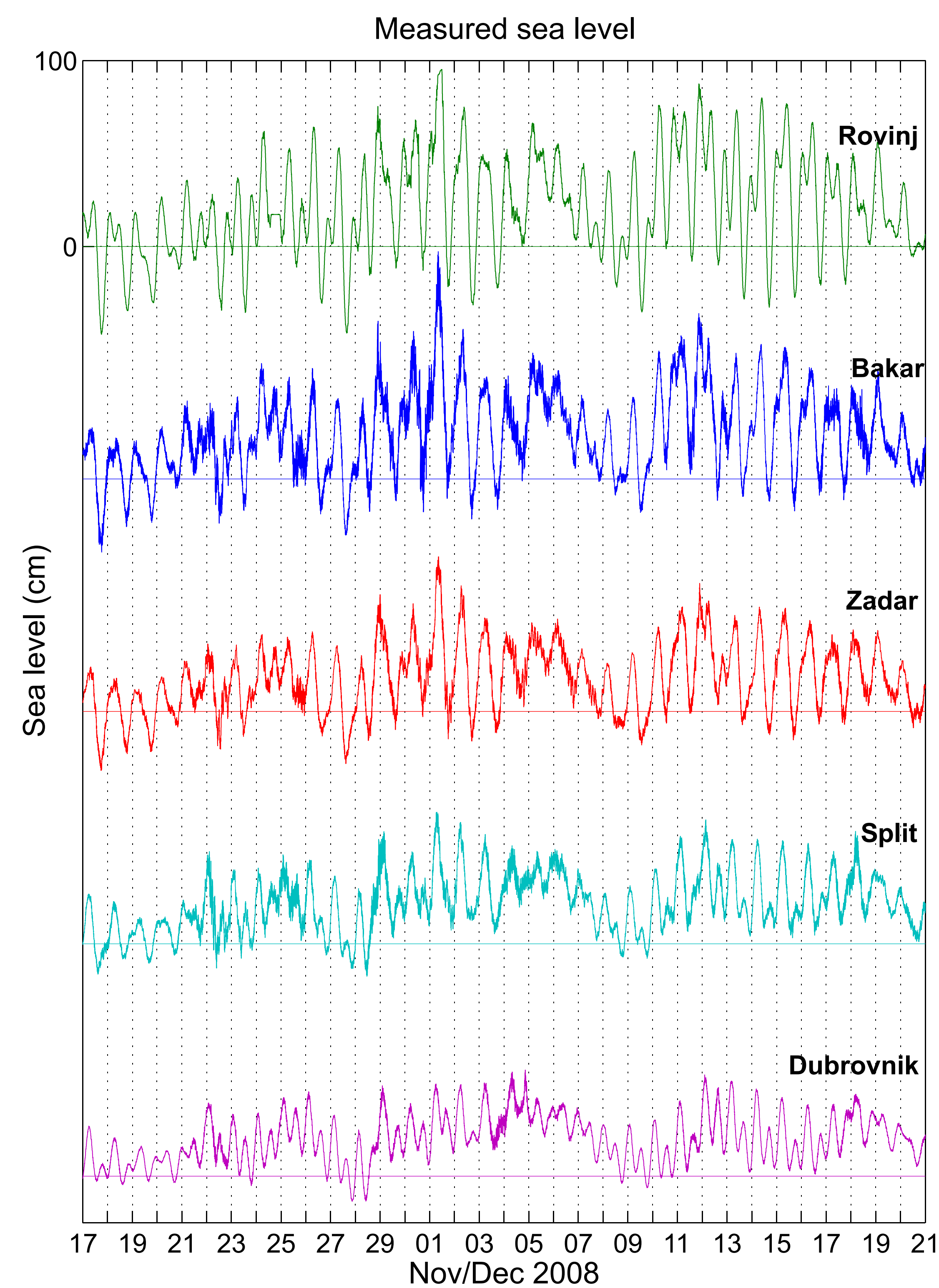


Figure 2. Time series of 1-min sea levels along the east Adriatic coast. The peak event occurred at Bakar at 08:15 CET, with sea level reaching 121 cm; at Rovinj the highest level (95 cm) was recorded at 11:36, at Zadar the maximum (83 cm) occurred at 08:39, at Split it was 71 cm at 07:02, while at Dubrovnik sea level maximum was considerably lower (50 cm).

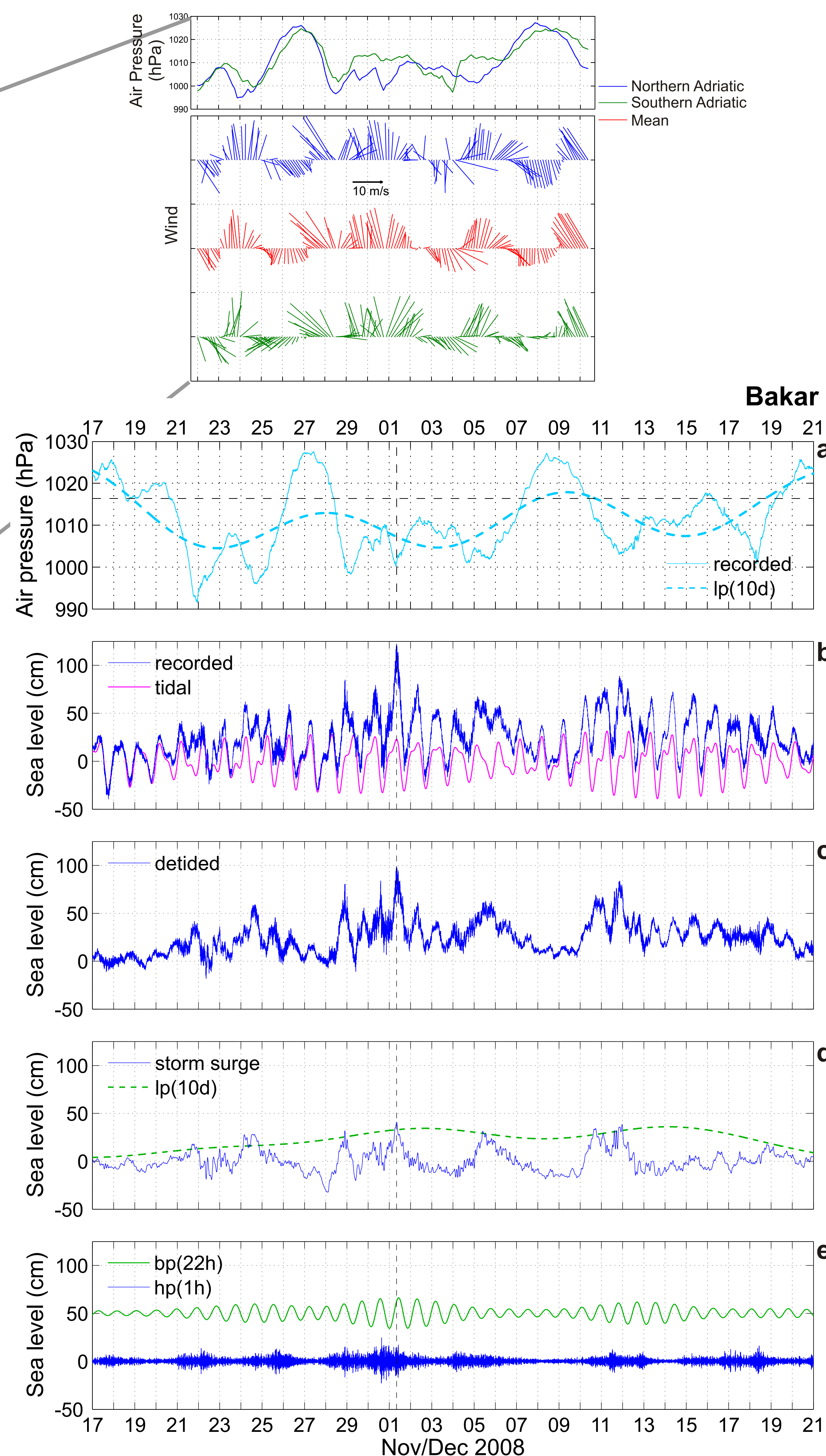


Figure 5. Sea level and air pressure at Bakar. Recorded air pressure and the data low-pass filtered at 10 days (a); the registered 1-min sea level data and the tidal prediction (b); the sea level upon removal of the tidal signal (c); the sea level, low-pass filtered at 10 days and the storm-surge activity related to synoptic atmospheric disturbances (d); sea level, band-pass filtered around 22 hours and high-pass filtered (at 1 hour) time series (e).

The beginning of the episode can be tracked more than a week before the peak event - a large-scale air-pressure disturbance, related to passage of planetary atmospheric waves (**Fig. 4a**), caused sea level to slowly rise (**Fig. 5d**) thus securing preconditions for the occurrence of extreme sea levels [3].

This intensified in the next days when a series of weather fronts passed over the Adriatic, each time triggering off the Adriatic seiche (**Figs. 5c, e**). Three days prior to the peak event a very strong sirocco started to blow (**Fig. 3b**), piling up water in the shallow Northern Adriatic (**Fig. 5d**).

In the morning of 1 December 2008 yet another front passed over the Adriatic (**Fig. 4c**). The air pressure at Bakar (**Fig. 5a**) reached its minimum value at 07:30 CET, just shortly before the tide reached its daily maximum (**Fig. 5b**) and the preexisting Adriatic seiche (**Fig. 5e**) was heading towards its maximum. Hence, when the tide reached its maximum at 08:15 sea level at Bakar went up to its highest level since the start of the uninterrupted measurements in 1949 and also likely since the start of the tide gauge 79 years ago.

This record-breaking level (**Fig. 5**) was a result of fine tuning between the storm surge (~40 cm) brought about by a series of synoptic atmospheric disturbances, the tide (23 cm) and the preexisting Adriatic basin-wide seiche (13 cm), all superimposed on a 33 cm sea level rise due to low-frequency atmospheric disturbance related to planetary waves, whereupon the local seiche activity within the Bakar Bay contributed with additional 10 cm.

References:

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2. Deutscher Wetterdienst, 2008: European Meteorological Bulletin, on CD-ROM.
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