Forecasting air pressure disturbances that cause meteotsunamis

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ABSTRACT

Meteorological tsunamis are long-ocean waves generated by intense small-scale air pressure disturbances. They can be several metres high and cause substantial damage to coastal towns. The main objective of the “Meteotsunamis, destructive long ocean waves in the tsunami frequency band: from observations and simulations towards a warning system” (MESSI) project is to build a reliable prototype of a meteotsunami warning system.

Atmospheric numerical weather prediction models represent one of the main components of any meteotsunami warning system. The non-hydrostatic 2km resolution ALADIN System forecast running operationally in Meteorological and Hydrological Service of Croatia is an obvious candidate. Preliminary analyses of its operational outputs, which have been available since July 2011, reveal the presence of travelling small-scale pressure disturbances capable to excite meteotsunamis. However, the comparison of forecast pressure evolution to the measured data shows that the intensity of the observed pressure disturbances is simulated fairly by the model, but at a slightly different position and time, and propagate with slightly different speed and direction. Meteotsunamis are known to be highly sensitive to these parameters. The recent meteotsunamis are investigated using available atmospheric data and meso-scale atmospheric model ALADIN with ALARO physics package for reproduction of travelling air pressure disturbances during the Adriatic meteotsunami events. Spatial, temporal and spectral properties of the travelling air pressure disturbances are assessed. Here we analyse if using more realistic SST, such as from the ROMS ocean model, and more realistic physiography of the terrain surrounding the Adriatic Sea, can improve the forecast of intense small-scale pressure disturbances that can generate meteotsunamis. One-minute model time-step is used for reproducing the disturbances. This allows for an accurate estimate of the error in the position, shape, variability in space and time, as well as speed and direction of the model disturbances with respect to those know to have generated meteotsunamis. Supplementary, the improvement of the operational forecast is documented, based on the use of more realistic SST, e.g. coming from the ROMS ocean model, and more realistic physiography of the terrain surrounding the Adriatic Sea.

Atmospheric numerical weather prediction models represent one of the main components of any meteotsunami warning system. The non-hydrostatic 2km resolution ALADIN-ALARO forecast running operationally in Meteorological and Hydrological Service of Croatia is an obvious candidate. Preliminary analyses of its operational outputs, which have been available since July 2011, reveal the presence of travelling small-scale pressure disturbances capable to excite meteotsunamis. However, the comparison of forecast pressure evolution to the measured data shows that the intensity of the observed pressure disturbances is simulated fairly by the model, but at a slightly different position and time, and propagate with slightly different speed and direction. Meteotsunamis are known to be highly sensitive to these parameters.

Meteorological tsunamis – several metres high long-ocean waves generated by intense small-scale air pressure disturbances – which occasionally cause substantial damage to coastal towns of the Adriatic Sea (e.g. Vela Luka, Stari Grad, Mali Lošinj)

One-minute model time-step is used for reproducing the disturbances. This allows for an accurate estimate of the error in the position, shape, variability in space and time, as well as speed and direction of the model disturbances with respect to those know to have generated meteotsunamis. Supplementary, an attempt to improve the operational forecast is documented, based on an use of more realistic SST, e.g.coming from the ROMS ocean model, and more realistic physiography of the terrain surrounding the Adriatic sea.

The recent meteotsunamis are investigated using available atmospheric data and meso-scale atmospheric model ALADIN with ALARO physics package. ALADIN-ALARO model is used for reproduction of travelling air pressure disturbances during the Adriatic meteotsunami events. Spatial, temporal and spectral properties of the meteotsunamigenic disturbances (travelling air pressure disturbances) are documented and assessed.

Recently, it has been shown that the physiography fields used by the model are of too low resolution and contain errors in the Adriatic area. These data have been replaced with more accurate data. More importantly, the sea surface temperature (SST) used in the model forecast arrives from the global model that is used for lateral boundary conditions. It has been shown that model SST can be quite far from real values over the Adriatic, especially over the coastal areas, such as in the WAC and Kvarner Bay. Here we analyse if using more realistic SST, such as from the ROMS ocean model, and more realistic physiography of the terrain surrounding the Adriatic sea, can improve the forecast of intense small-scale pressure disturbances that can generate meteotsunamis.

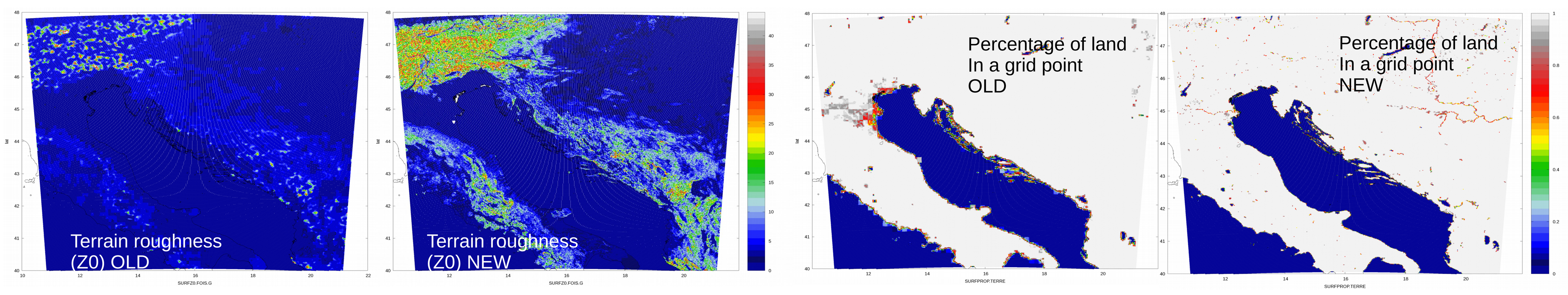

Figure 2: The fields describing the underlying terrain had many flaws. This was operational at the time of June 2014. The new fields are more realistic but also considerably different.

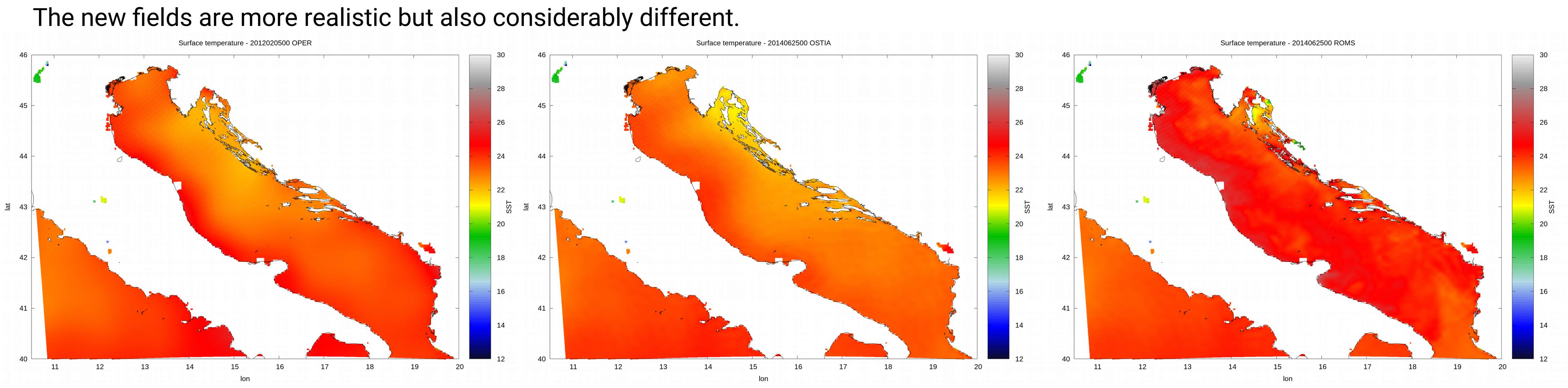

Figure 3: The SST in the operational forecast (left), when using SST from OSTIA (middle) and ROMS (right). SST influences the stability of the lower portion of the troposphere and the possibility of generating and propagating pressure disturbances.

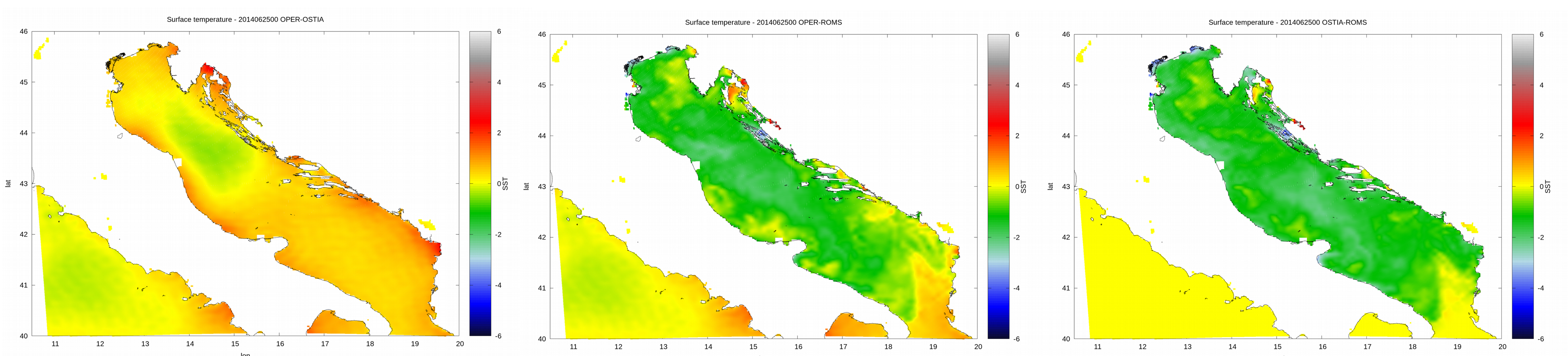

Figure 4: The differences between SSTs: in the operational forecast minus OSTIA (left), OPER-ROMS (middle) and OSTIA -ROMS (right). In this case, ROMS is warmest above open sea and consequently lower layers of troposphere are less stable.

Can these pressure disturbances be forecast by an operational NWP model?

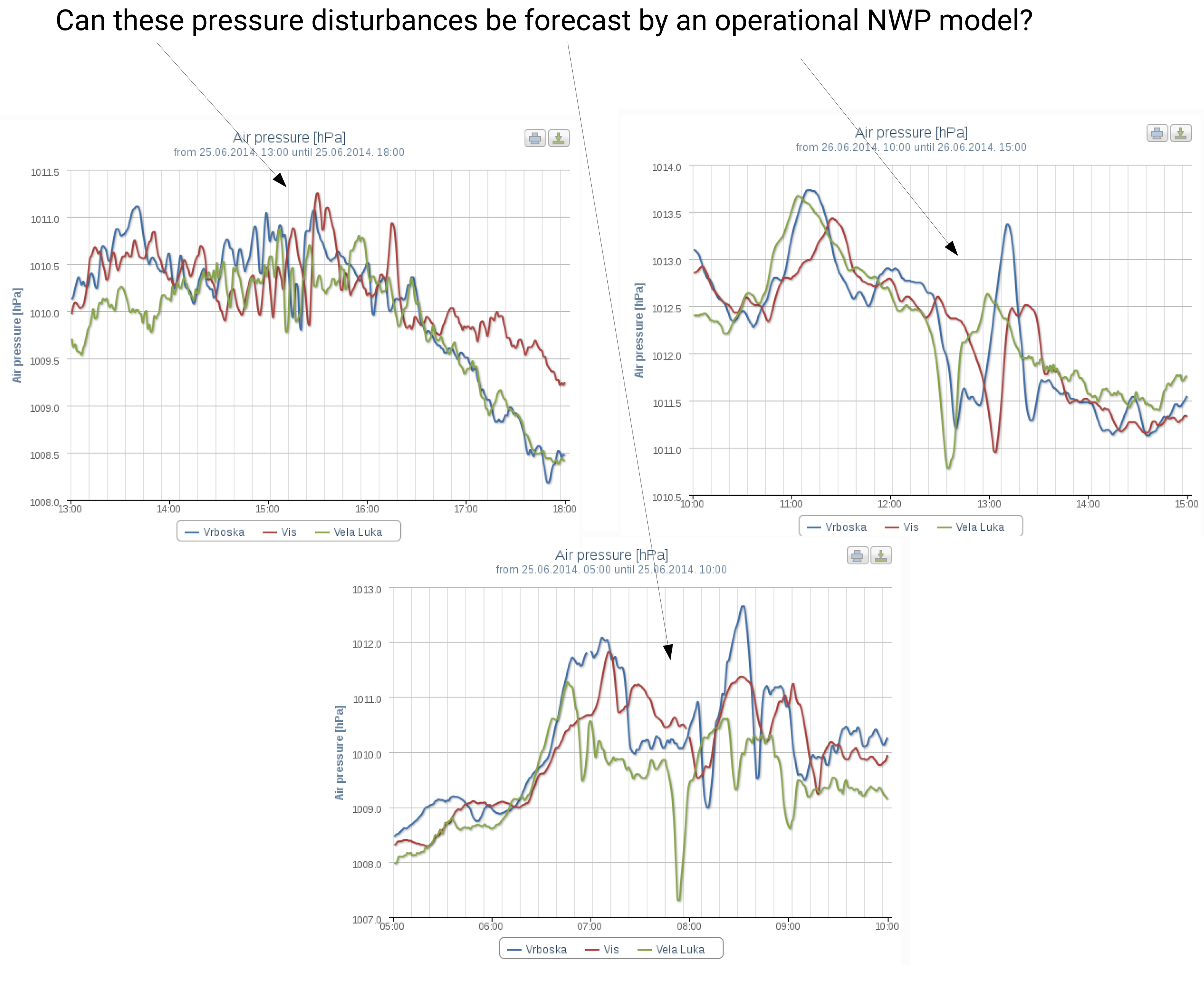

Figure 5: Air pressure measured on stations Vrboska (blue, Hvar island), Vis (red) and Vela Luka (green) with one second data interval during a widespread meteotsunami event on 25-26 June 2014, maintained by Institute fo Oceanography and Fisheries .

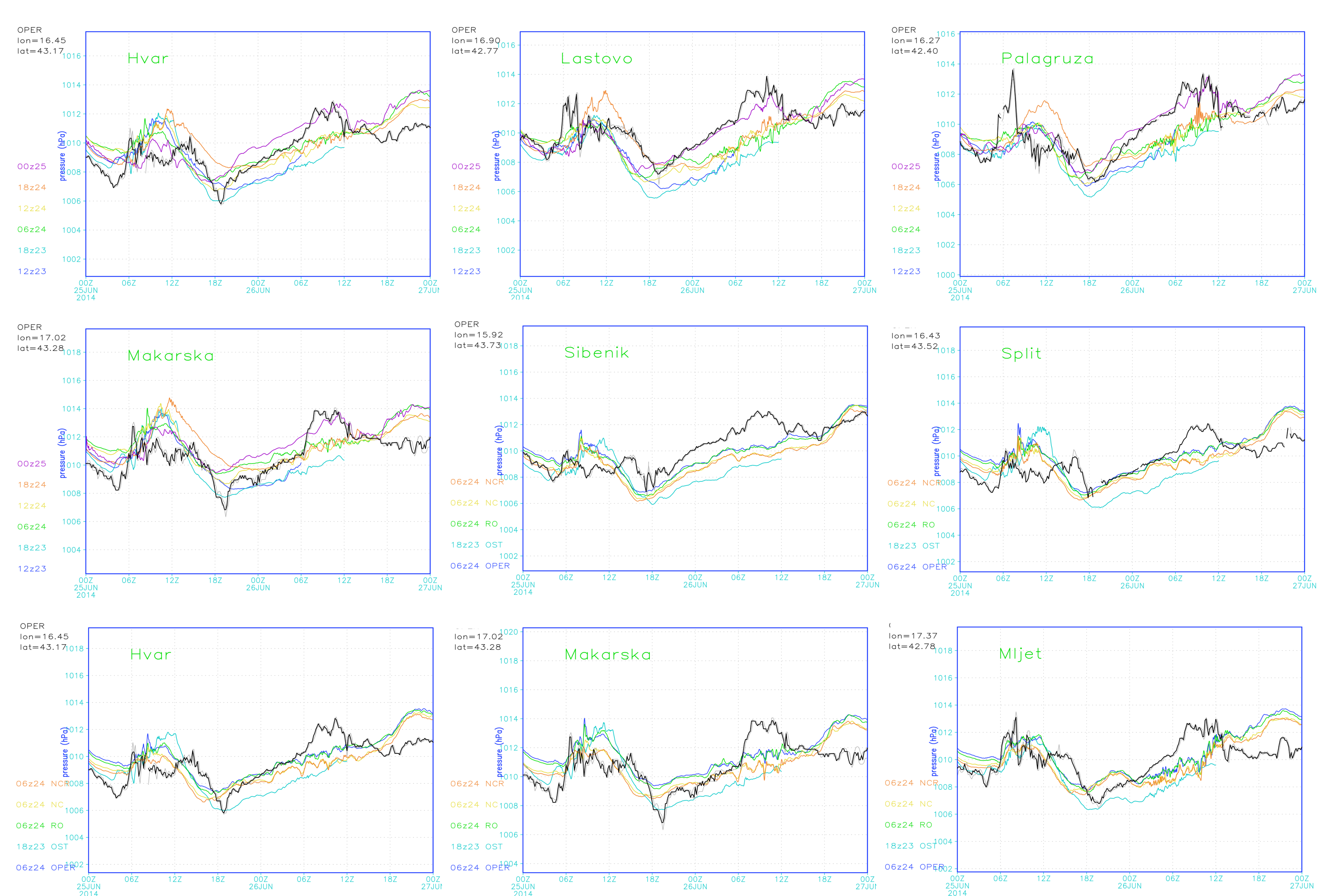

Figure 6: measured pressure (black line, 10 min interval) and output every time step (1 min) from operational run and experiments using SST from OSTIA and ROMS, new surface representation alone and in combination with ROMS. Both SST and roughness of the surrounding land surfaces influence the development, intensity and location of high frequency oscillations in pressure.