High-resolution operational NWP for forecasting meteotsunamis

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http://jadran.izor.hr/~sepic/MESSI/

EWGLAM/SRNWP, Reading, UK, 2-5 Oct 2017

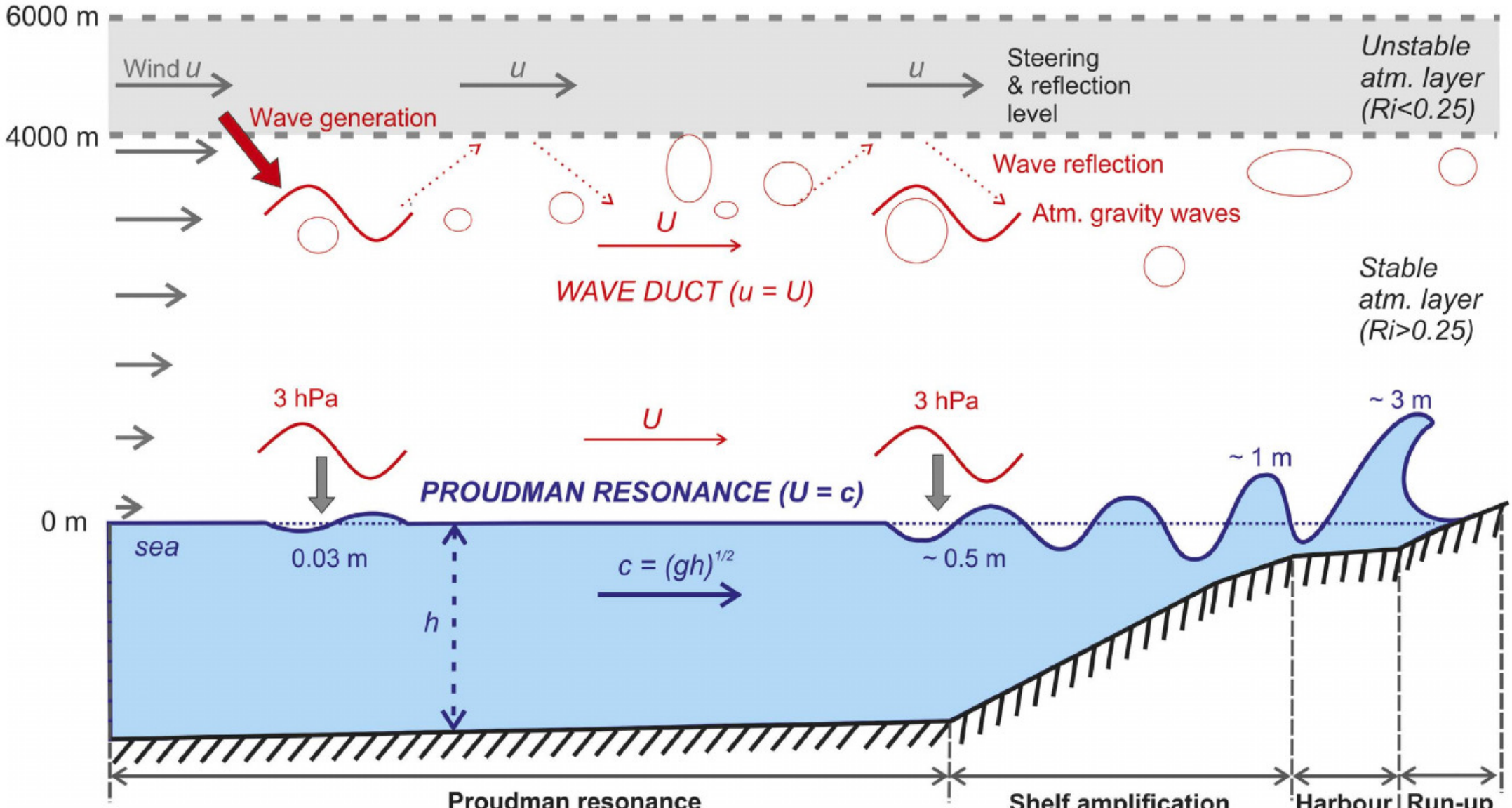
Outline

- What are meteorological tsunamis?
- Which meteorological conditions cause them?
  - Gravity waves
  - Synoptic setting
- Results using 2 km non-hysrostatic ALADIN System ALARO CMC
- Project: “Meteotsunamis, destructive long ocean waves in the tsunami frequency band: from observations and simulations towards a warning system” (MESSI)

Definition

- **A meteotsunami or meteorological tsunami is a tsunami-like wave of meteorological origin.**
- 10% of tsunamis worldwide have unknown origin
- 3% already assigned to meteorological conditions
- atmospheric gravity waves, pressure jumps, frontal passages, squalls ...
- local names: rissaga (Catalan), ressaca (Portuguese), milghuba (Maltese), marrobbio (Italian), abiki (Japanese), šćiga (Croatian)
- It is a rare event, but in Croatia: 28 Jun, 1 and 11 Jul 2017

Mali Lošinj 15.8.2008.

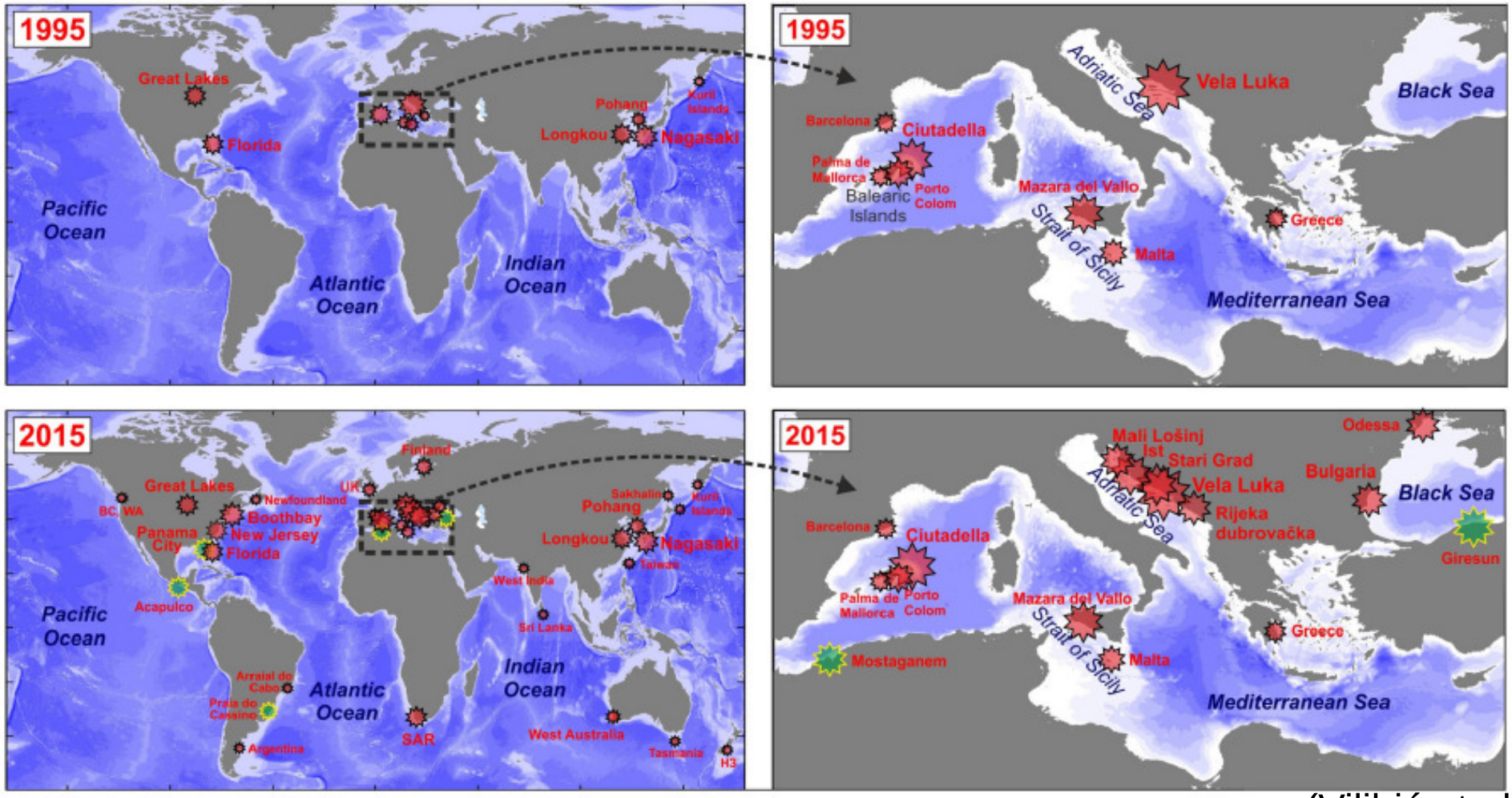


From Šepić et al. | DOI: 10.1038/srep11682

Motivation

- Events:
  - Vela Luka (1978, 6m), Chichago (1954,3m), Nagasaki (1979,5m), Ciutadella (2006,4m), Daytona Beach (1992,3.5m) … Netherlands, Australia, New Zealand, UK, France, Finland
- High waves destroy coastlines, strong currents endanger marine traffic (reduced sea depth during low tide).

Global and Mediterranean meteotsunamis



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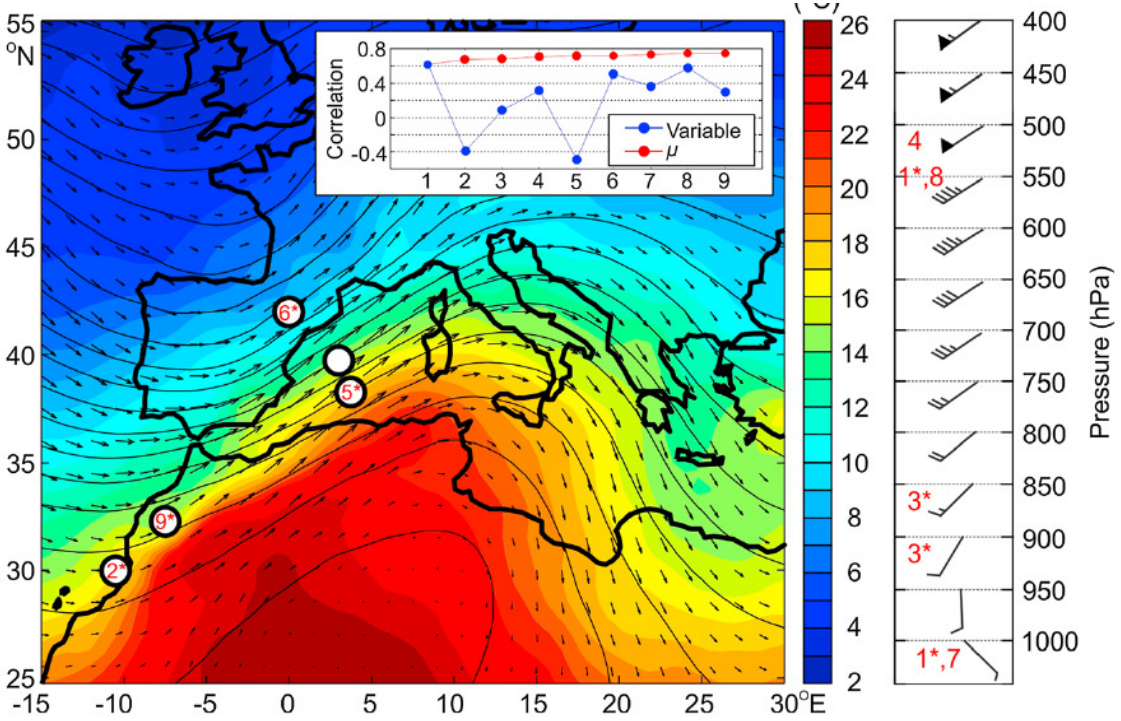
(Vilibić et al. 2016)

Synoptic setting for Ciutadella (Šepić and Vilibić, GRL,2016)



μ1 V^{550}-V^{10m}
μ2 $mslp_C$-$mslp_2$
μ3 T^{850}-T^{900}
μ4 RH^{500}
μ5 $geop^{550}{}_C$-$geop^{550}{}_5$
μ6 $T^{850}{}_C$-$T^{850}{}_6$
μ7 V^{10m}
μ8 228° $V^{550}{}_C$
μ9 $T^{850}{}_C/T^{850}{}_9$

Inset: Correlation coefficient between individual variables and wave heights (blue line), and between μ1–9 and wave heights (red line).
μn is estimated using the first n variables.

Synoptic setting: temperature at 850 hPa and geopotential and wind at 550 hPa, averaged for the 15 strongest events observed at the Ciutadella tide gauge between 1 January 2013 and 1 January 2016. Averaged vertical wind profile during the same 15 strongest event is shown on the right.


Treviso
Trieste
Venice
Velika Gorica
Opatija
Rijeka
Rovinj
Croatia
Slavonski Brod
Pula
Bosnia and Herzegovina
Zenica
Rimini
Zadar
Mali Lošinj
an Marino
Sarajevo
Šibenik
Ancona
Split
Mostar
Makarska
Stari Grad
Vrboska
San Benedetto del Tronto
Vela Luka
Adriatic Sea
Dubrovnik
Terni
Pescara
Hvar
Vasto

Forecasting meteotsunamis on Adriatic requires

- **Synoptic setting**:
  - Inflow of warm air from Africa ~850 hPa
  - SW jet > 20 m/s at ~500 hPa
  - Unstable layer (Ri<0.25) 400-600 hPa
- High resolution: Forecasting a pressure change of more than 1hPa/1min
- Model output every minute
- Pressure disturbance moving
  - in the right direction (direction of SW jet)
  - at the right speed (speed of SW jet)
  - (at the right time)


Mali Lošinj 15.8.2008.

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

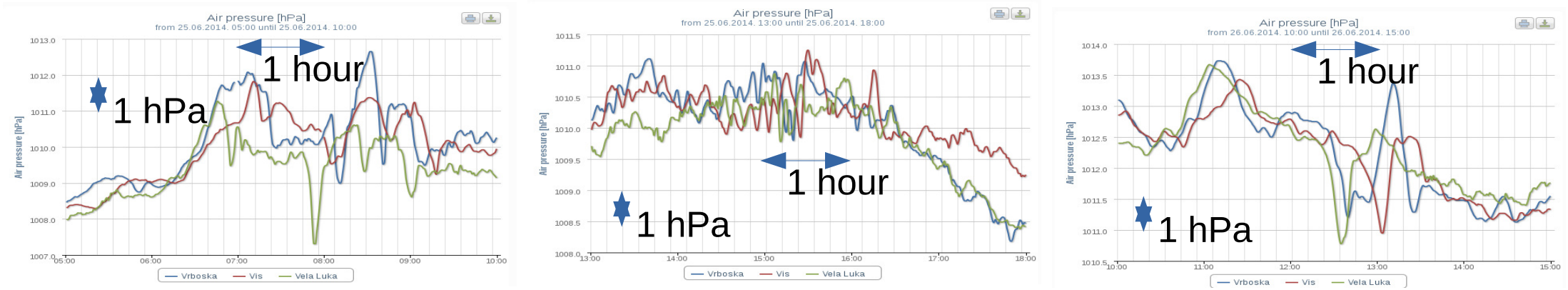
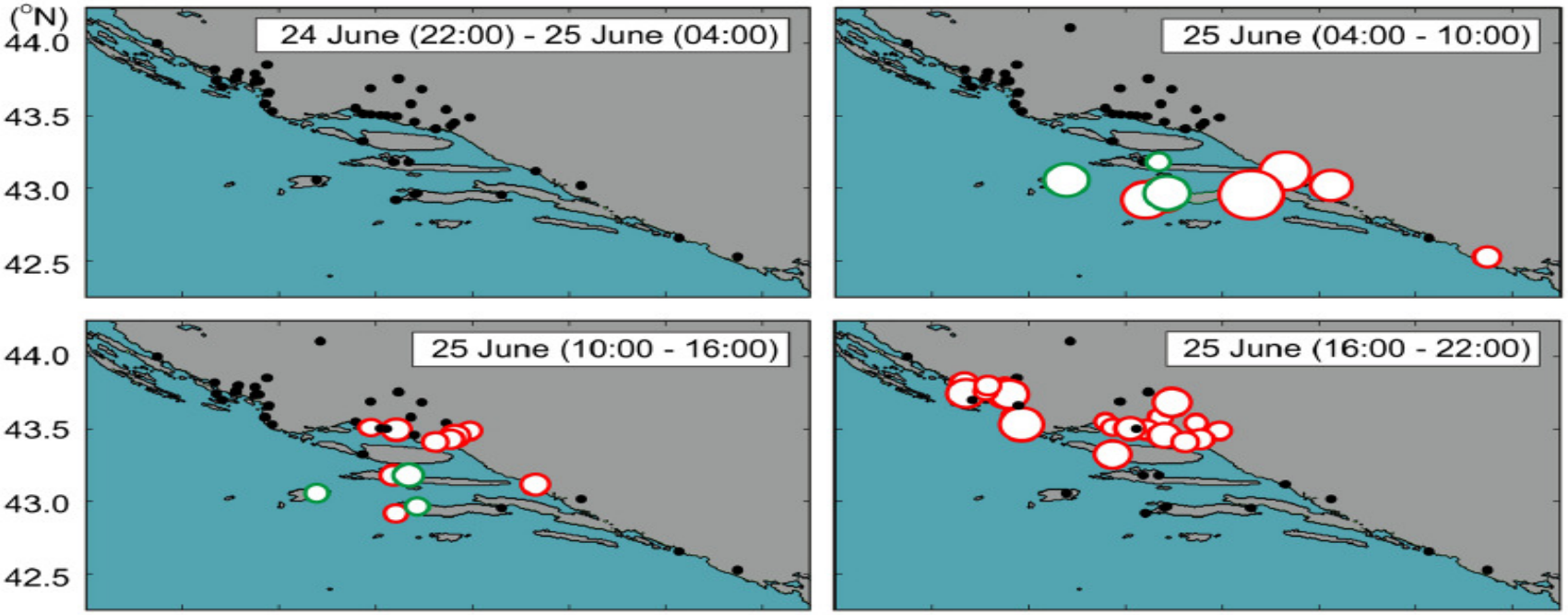


Figure: Air pressure measured on stations Vrboska (blue, Hvar island), Vis (red) and Vela Luka (green) with one second data interval during a widespread meteotsunami event on 25-26 June 2014, maintained by IOF .

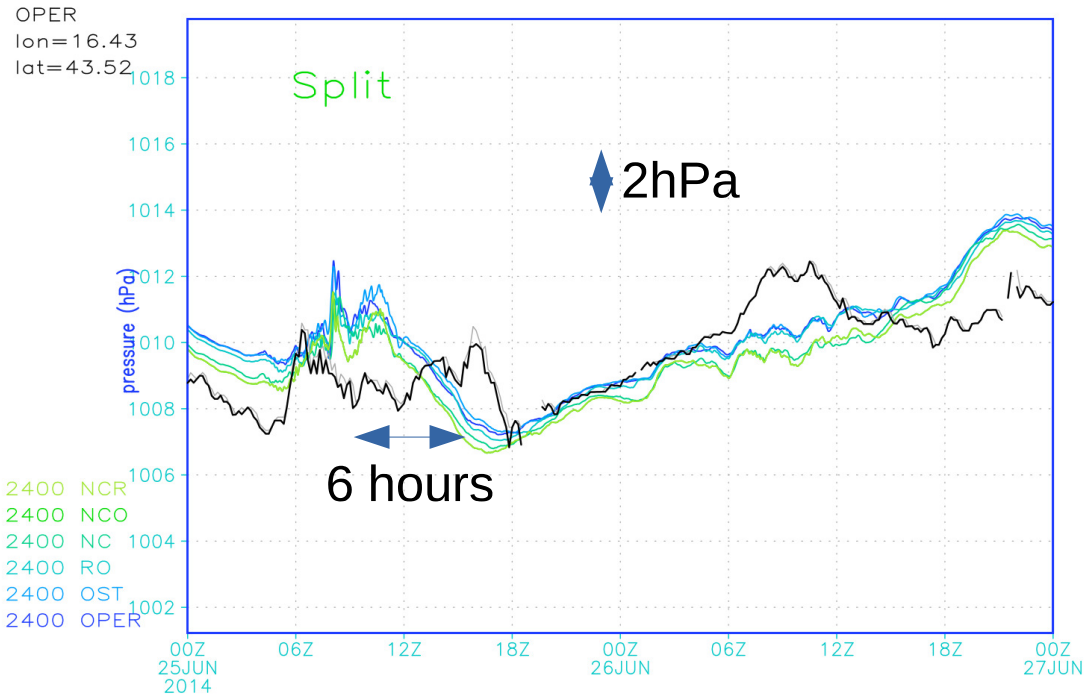
Maximum pressure change in 5 min

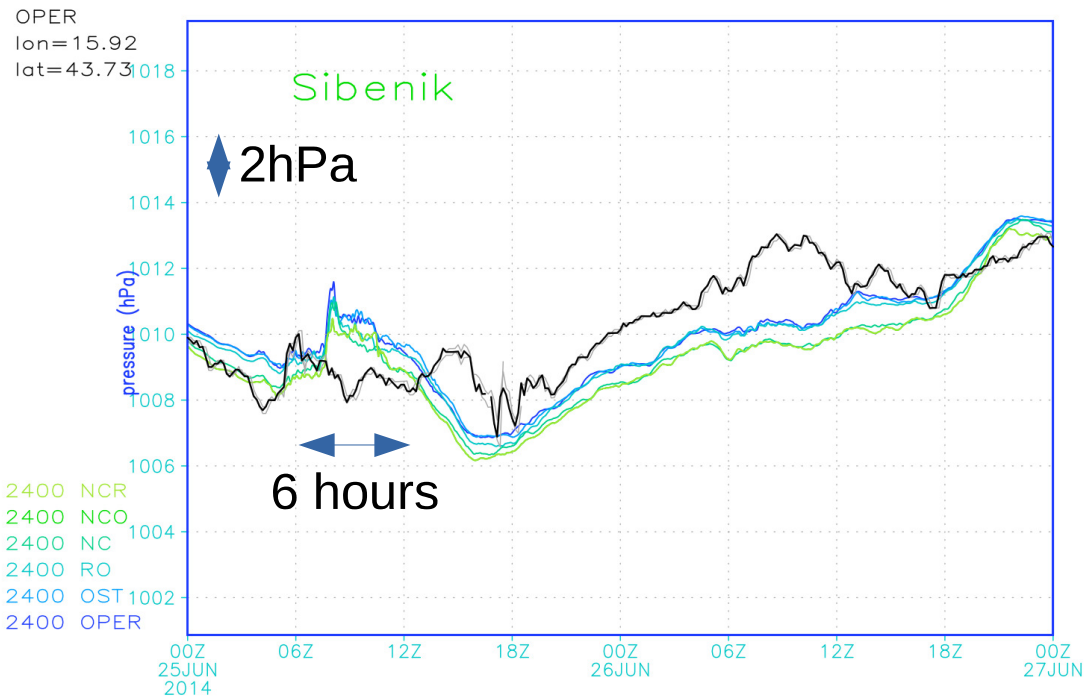


Plots showing intensity and spatial distribution of air pressure disturbances
Black dots - did not surpass 1.0 hPa/5 min.
Red - amateur meteorological stations, and
green - high-quality microbarograph stations

(Šepić et al., PAG, 2016)

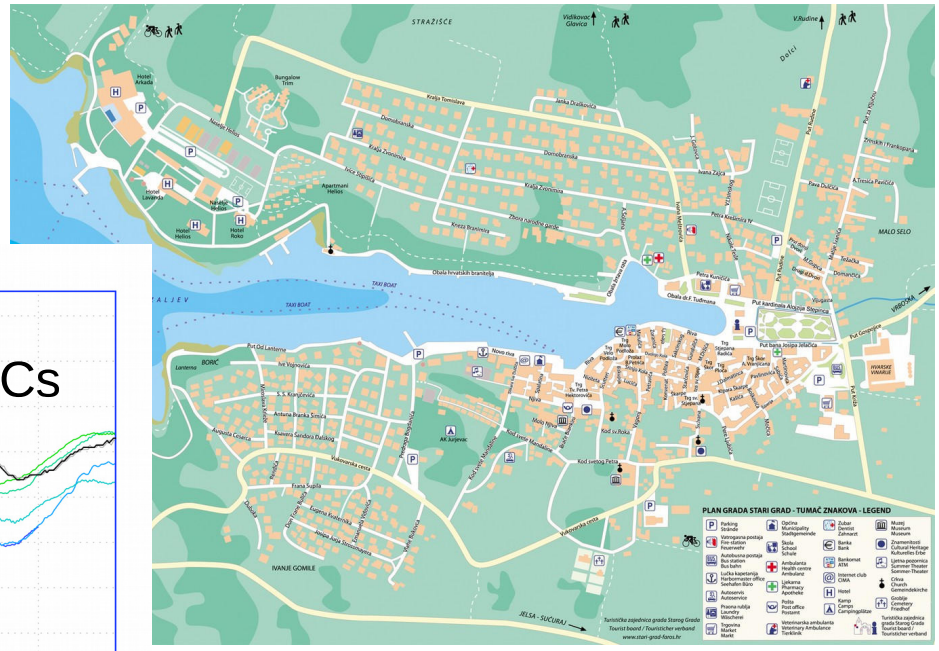
Different SSTs and topography representations

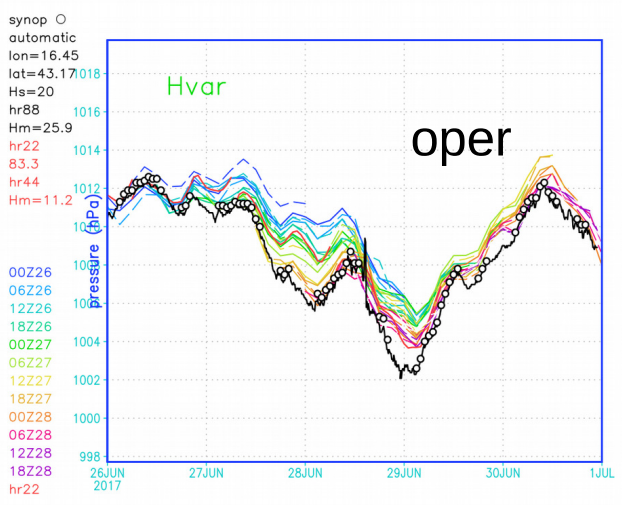


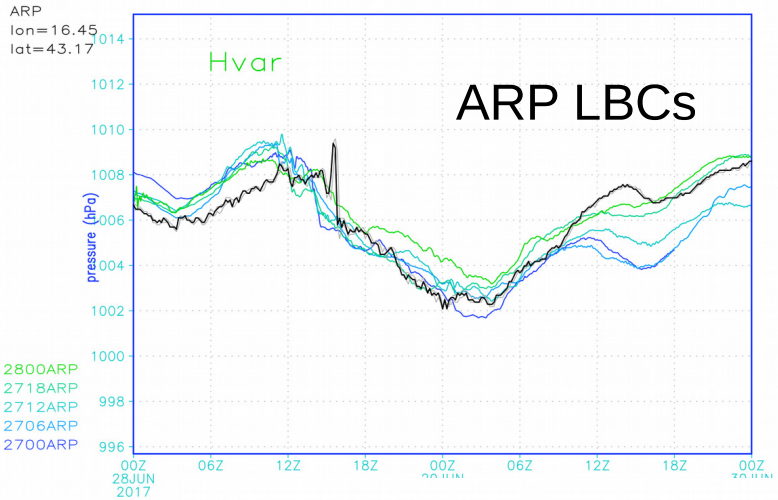


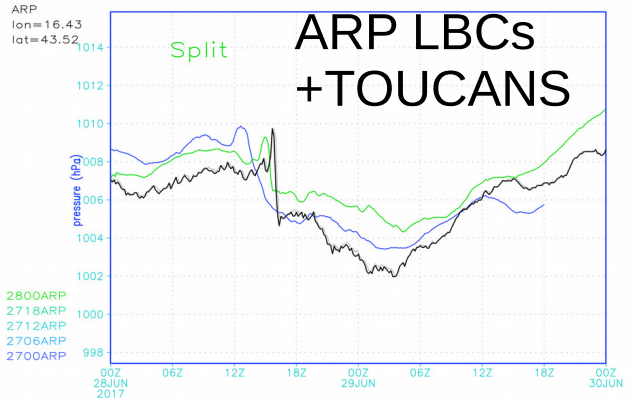
OPER – old topography and z0 IFS SST, OST – using OSTIA SST, RO – using ROMS SST, NC – new topography and z0, NCO – new topo + OSTIA SST, NCR – new topo + ROMS SST.

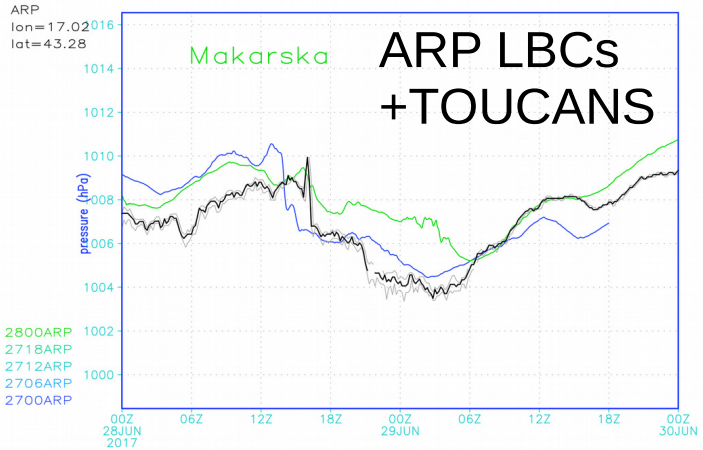
28 June 2017.
Stari Grad



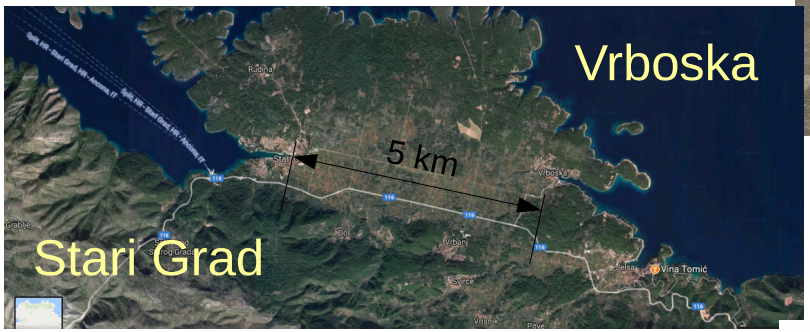




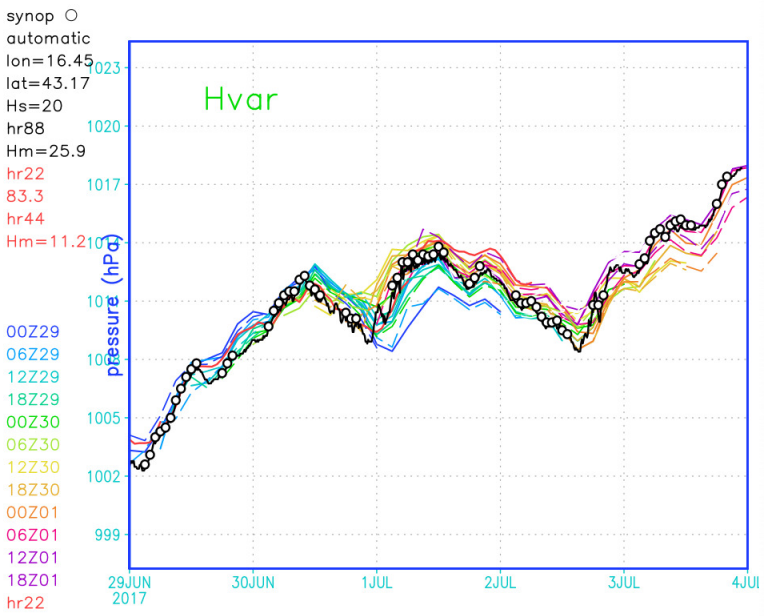


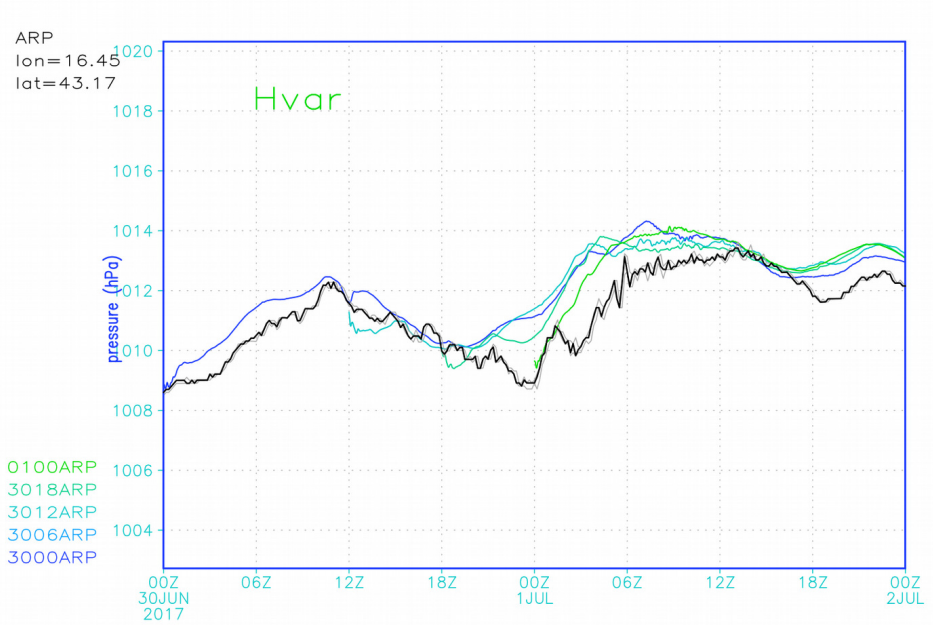


1 July 2017, Vrboska

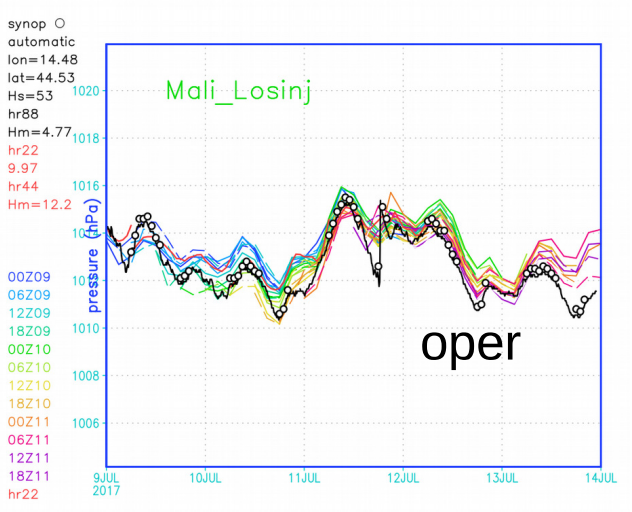


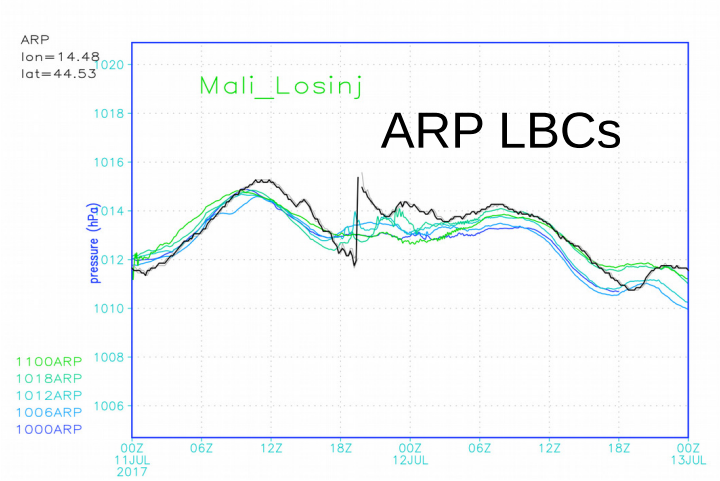
https://www.youtube.com/watch?v=hXp4JidOUbM
https://youtu.be/Kwb4C0_busE

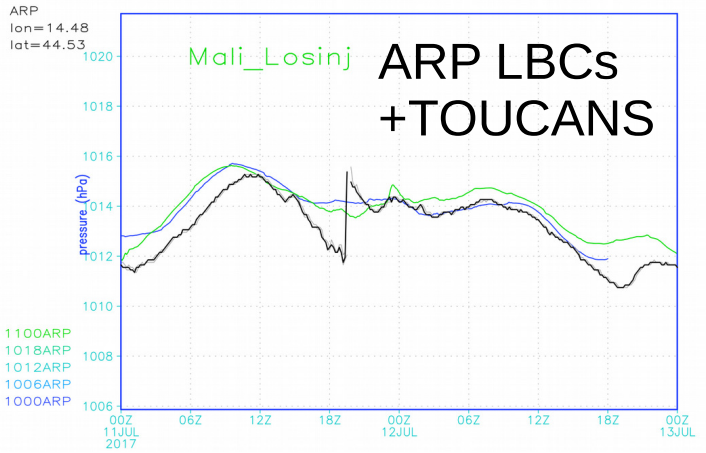


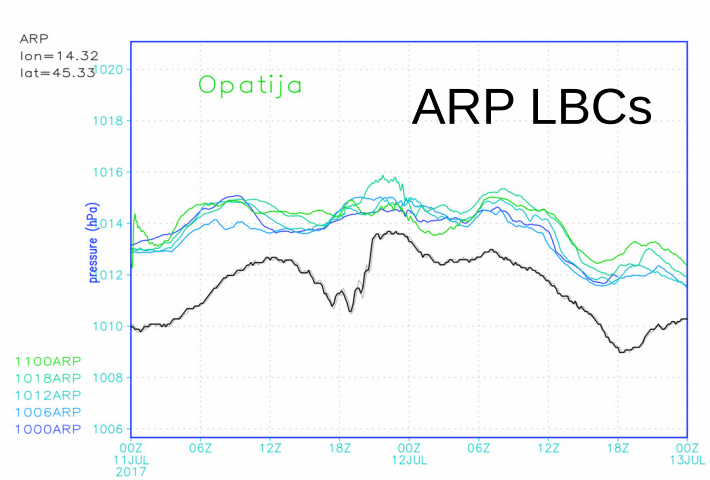


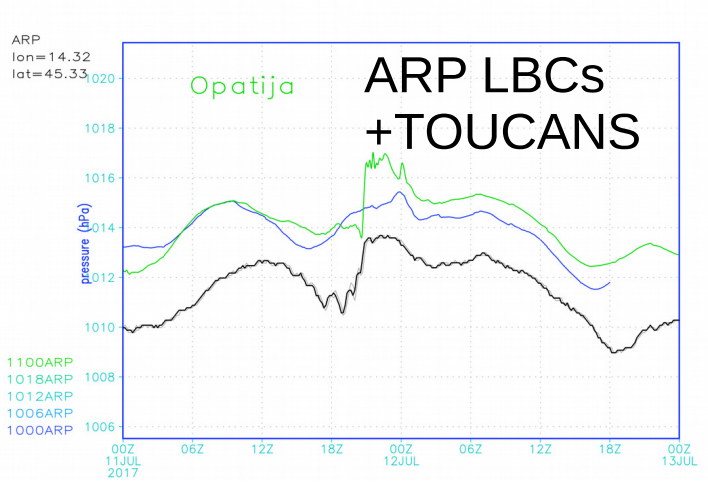
11 July 2017, Mali Lošinj









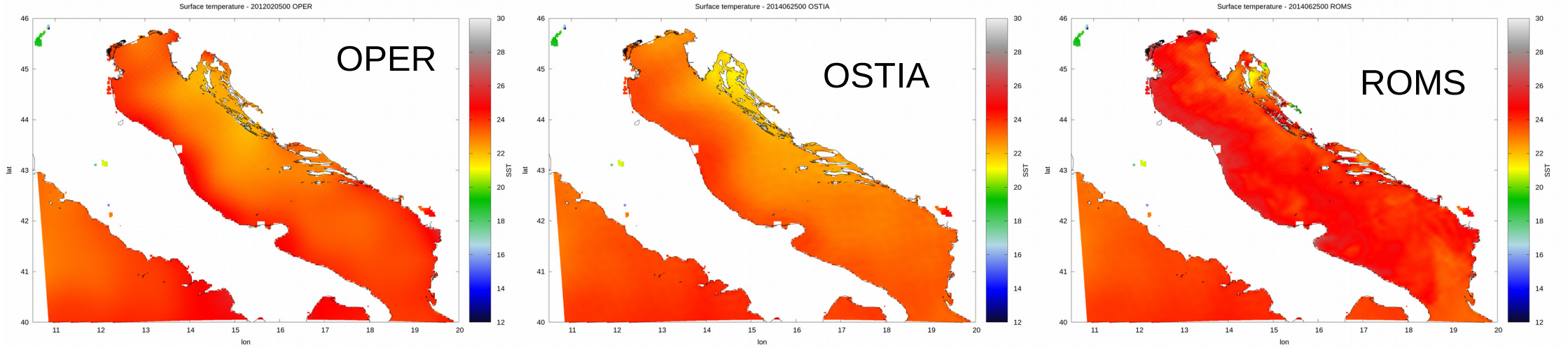


Summary

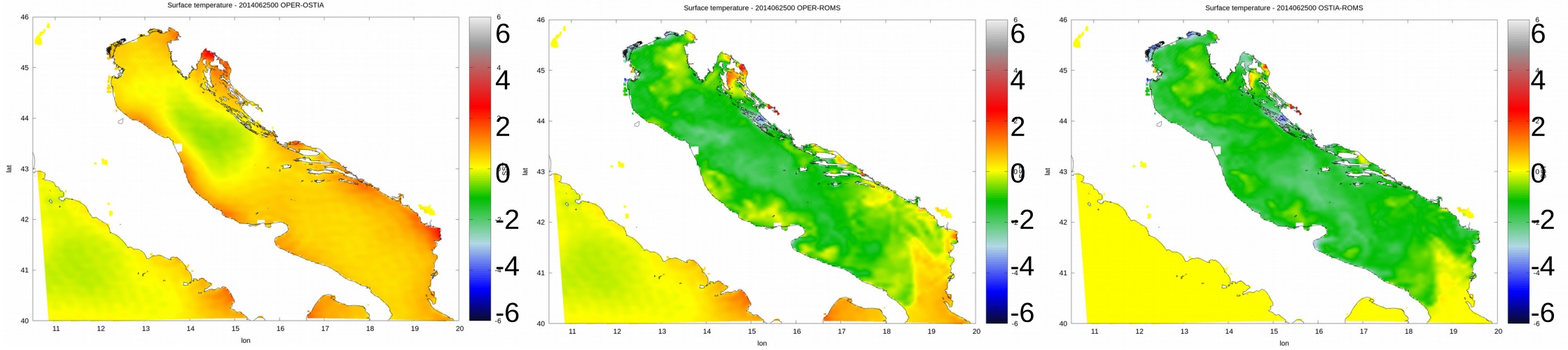
- **Definition: A meteotsunami or meteorological tsunami is a tsunami-like wave of meteorological origin (**atmospheric gravity waves, pressure jumps, frontal passages, squalls)**.**
- Synoptic environment can give an **index** for individual harbour.
- Prediction of the pressuer wave has to be precise for propagation speed and direction.
- Sensitive to LBCs and dynamics and physics set-up, SST and topography representation
- **High resolution forecasts atmospheric waves, low wave amplitude, propagates at different location.**

Publications

- Vilibić, I., Šepić, J., 2017. Global mapping of nonseismic sea level oscillations at tsunami timescales. Scientific Reports, 40818, doi:10.1038/srep40818
- Vilibić, I., Šepić, J., Rabinovich, A. B., Monserrat, S., 2016. Modern Approaches in Meteotsunami Research and Early Warning. Frontiers in Marine Sciences, http://dx.doi.org/10.3389/fmars.2016.00057
- Šepić, J., Vilibić, I., Monserrat, S., 2016. Quantifying the probability of meteotsunami occurrence from synoptic atmospheric patterns. Geophysical Research Letters, doi: 10.1002/2016GL070754
- Šepić, J., Međugorac, I., Janeković, I., Dunić, N., Vilibić, I., 2016. Multi-meteotsunami event in the Adriatic Sea generated by atmospheric disturbances of 25-26 June 2014. Pure and Applied Geophysics, doi: 10.1007/s00024-016-1249-4
- Belušić, D., Strelec Mahović, N., 2009. Detecting and following atmospheric disturbances with a potential to generate meteotsunamis in the Adriatic. Physics and Chemistry of the Earth, 34, 918-927
- http://jadran.izor.hr/~sepic/meteotsunami_catalogue/
- http://jadran.izor.hr/~sepic/MESSI/
- http://jadran.izor.hr/barograf/index_eng.htm



The SST in the operational forecast (left), when using SST from OSTIA (middle) and ROMS (right).



SST differences: in the OPER-OSTIA (left), OPER-ROMS (middle) and OSTIA -ROMS (right).

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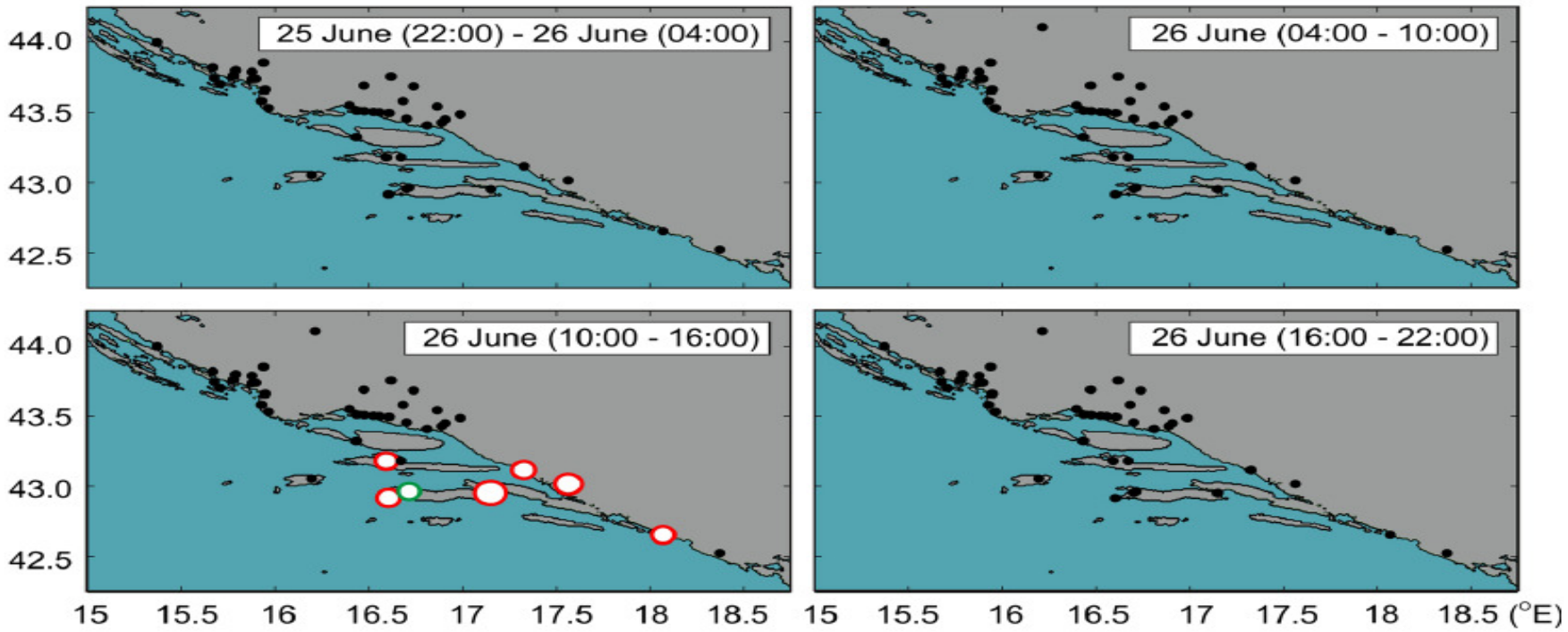
Maximum pressure change in 5 min



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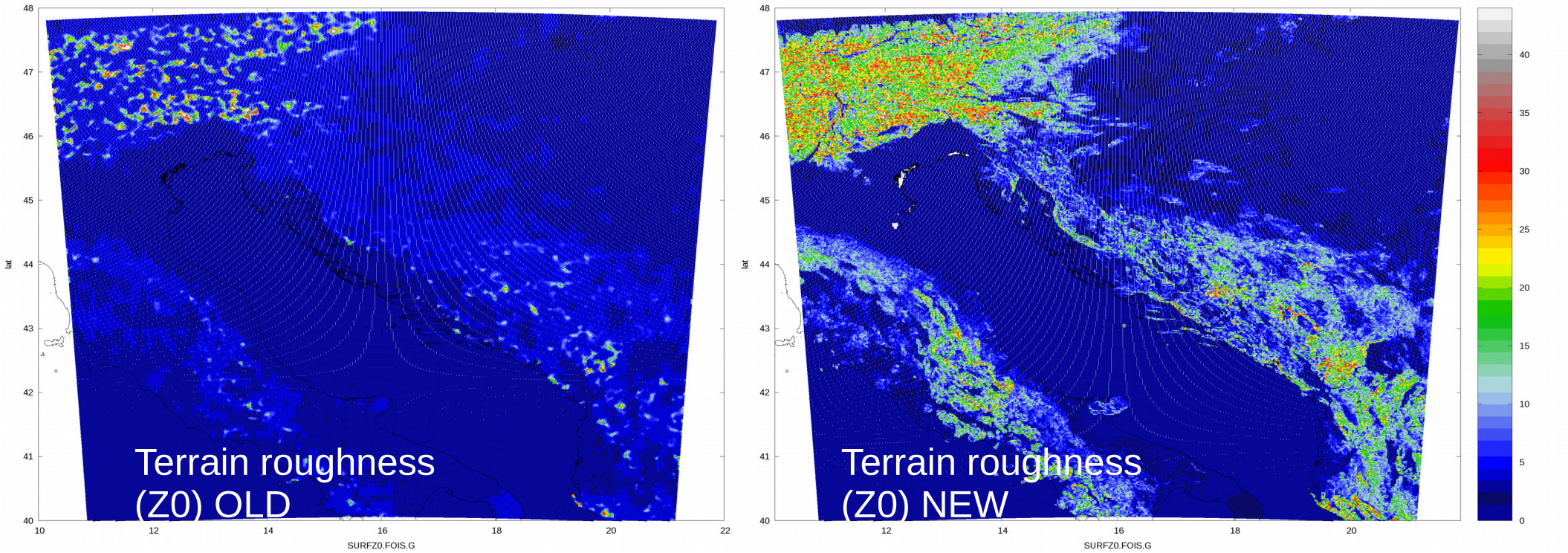
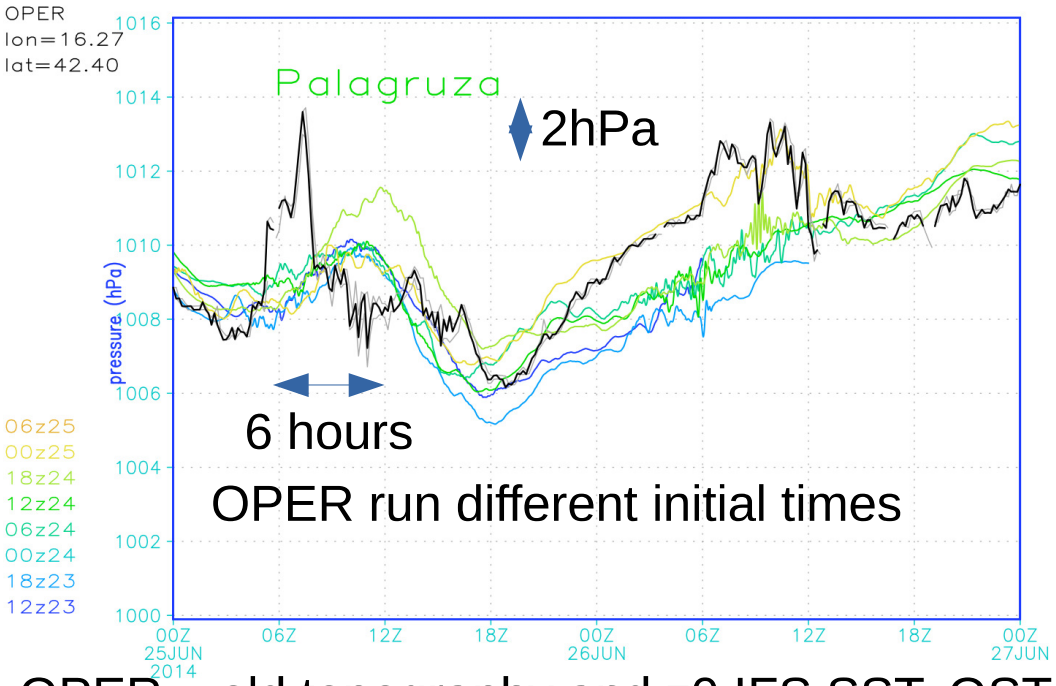
(Šepić et al., PAG, 2016)

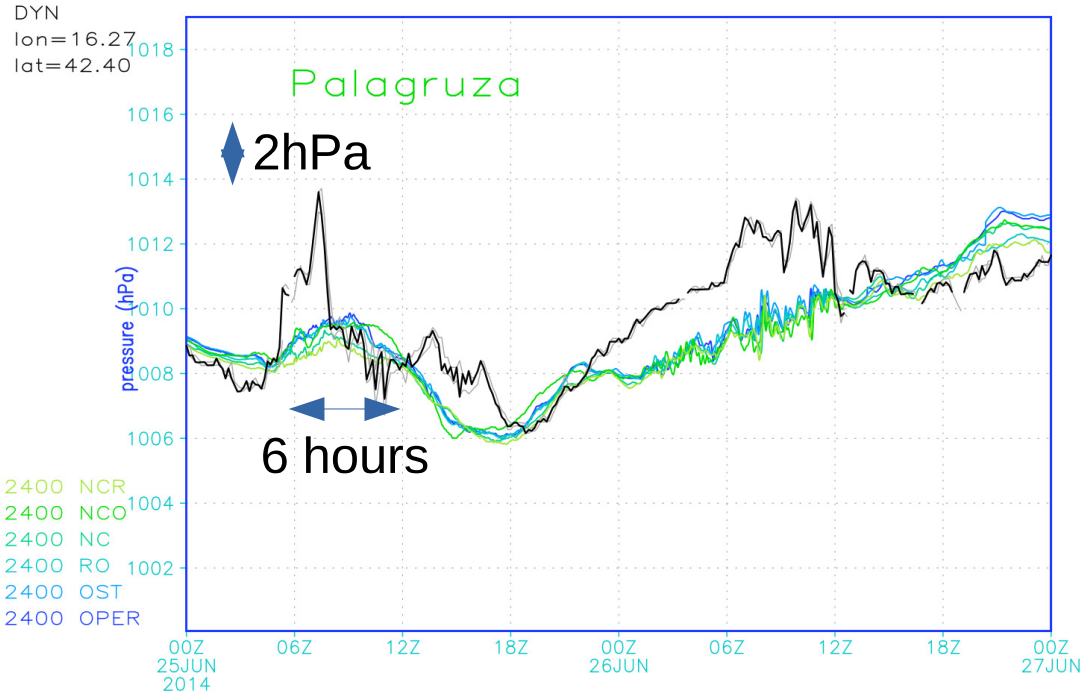
Terrain roughness



Rather smooth terrain over mountains when roughness computed from the old database

Different SSTs and topography representations





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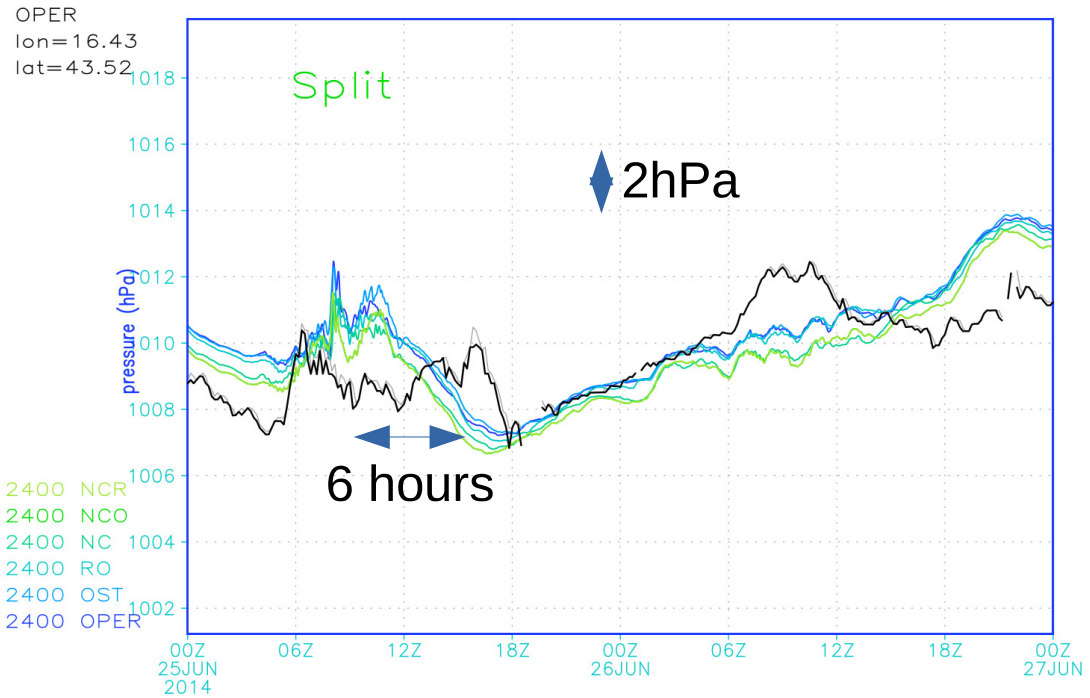

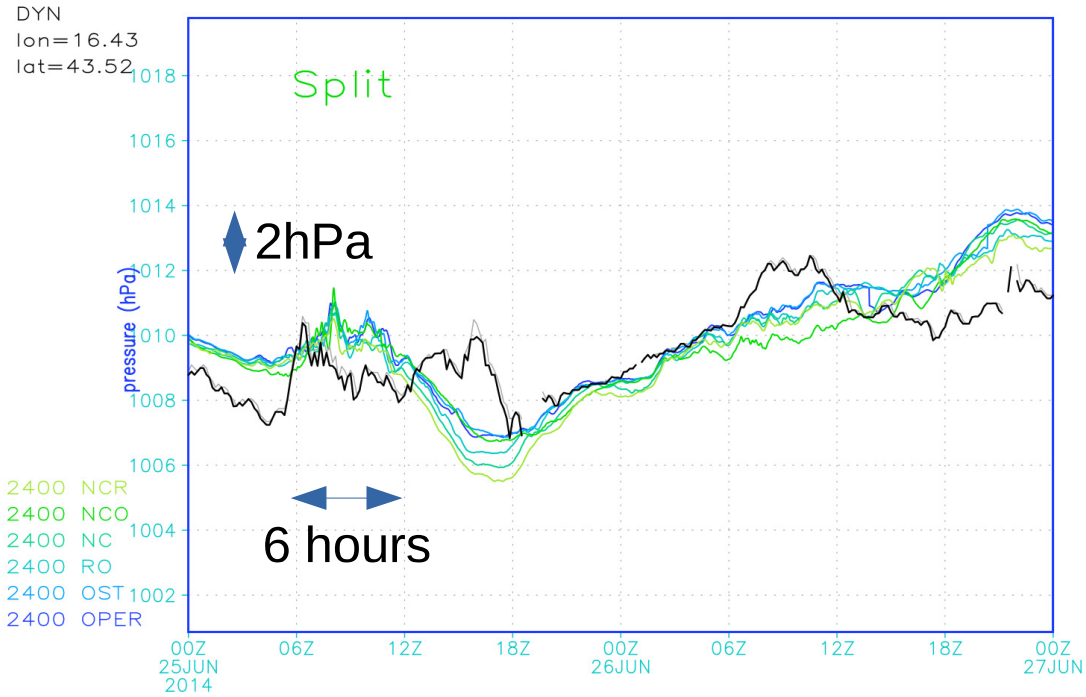

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