Analysis of synoptic conditions leading to positive and negative sea level extremes along the coast of the Mediterranean Sea

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Then Moses stretched out his hand over the sea; and the Lord drove the sea back by a strong east wind all night, and made the sea dry land, and the waters were divided. And the people of Israel went into the midst of the sea on dry ground, the waters being a wall to them on their right hand and on their left. [.. .. ..] So Moses stretched forth his hand over the sea, and the sea returned to its wonted flow when the morning appeared.[.. .. ..] The waters returned and covered the chariots and the horsemen and all the host of Pharaoh that had followed them into the sea; not so much as one of them remained.
Authors analyzed large positive and negative storm surges along the Mediterranean coast in a 7-member climate model ensemble covering the period 1951–2050 under the A1B emission scenario. A hydro-dynamical shallow water model (HYPSE, Hydrostatic Padua Sea Elevation model) was driven by 6-hourly meteorological fields produced by the state-of-the-art global and regional climate models that have been used in the CIRCE fp6 project (Climate Change and Impact Research: the Mediterranean Environment). […] the model ensemble mean shows a modest (about -5%), but clear and widespread, decrease of the amplitude of both positive and negative large storm surges along the coast of the Mediterranean Sea.

Ensemble mean storm surge index (cm) for positive (red line, cm) and negative (black line, cm) surges in the present climate in model simulations (top panel). Climate change percent index (%) for positive (red line) and negative (black line) surges. Coastal points are ordered clockwise starting from Gibraltar. Country national borders and some stations used are marked to help locating the different stretches of the Mediterranean coastline.

(a) - Coast Grid Points (National and Regional Borders)

(b) - Coast Grid Points (National and Regional Borders)
The inverse barometer effect

**negative surges**
- high pressure system, anti-cyclone
- negative sea level anomaly

**positive surges**
- low pressure system, cyclone
- positive sea level anomaly

... It is about 1cm per hPa
Questions:
As future projections show similar trends for both positive and negative surges, what have those two opposite phenomena in common? Large positive surges are well known to be caused by intense cyclones. Are also negative surges caused by cyclones?

This analysis is based on SL simulations carried out with a two-dimensional model based on depth averaged currents (HYPSE), implemented on grid covering the whole Mediterranean sea with a 0.2 degs Lat-Lon regular mesh. HYPSE is forced by SLP and surface winds hourly fields, which are provided by the European project HIPOCAS (Sotillo et al., 2005, Ratsimandresy, 2008a et al, 2008), for the period 1958-2001 on a 0.5 x 0.5 degree grid. 9 stations have been selected and 88 events have been considered for each of them.
Is the analysis of the model simulations leading to the correct synoptic conditions?

NEGATIVE SURGES

Composites based on 88 largest simulated surges

ALICA  TOULO  TRIES  DUBRO

Composites based on 88 largest observed surges

ALICA  TOULO  TRIES  DUBRO
Synoptic conditions leading to positive and negative surges

**POSITIVE SURGES**

- ALICANTE
- TOULON
- TRIESTE
- THESSALONIKI

**NEGATIVE SURGES**

- ALICANTE
- TOULON
- TRIESTE
- THESSALONIKI
Density of cyclones producing positive surges

Density of cyclones producing negative surges
NEGATIVE STORM SURGES

STORM SURGE

INVERSE BAROMETER

RESIDUAL

ALICANTE

TOULON

TRIESTE

ALEXANDRIA
Classification of areas of cyclogenesis
negative surges: tracks for cyclogenesis inside the Western Mediterranean

alia

toulo

tries

dubro

thess

isken

gabes

tripo

alexa
positive surges: tracks for cyclogenesis inside the Western Mediterranean
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**Number of cyclogenesis causing positive surges**

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Mean sea level anomaly as function of the cyclone position
Conclusions

• When a cyclone crosses the Mediterranean, its impact on sea level consists of positive and negative anomalies in different part of the basin, depending on the position of the cyclone.
• Western Mediterranean cyclogenesis causes positive surges in the south western Med and negative in the north western Med. Atlantic cyclones produce positive surges in the western Med.
• To a substantial extend negative surges in the Mediterranean are caused by a redistribution of water within the basin.
• During negative surges the Mediterranean Sea behaves partially as a closed basin, as the water flow across Gibraltar is not sufficient to allow the sea level to adjust to the inverse barometer effect.
• It is therefore plausible that in the Mediterranean Sea a future reduction of storminess will determine a reduction of both positive and negative large sea level anomalies.
appendix