

Introduction

The Cyprus coastal ocean forecasting system, known as CYCOFOS has been providing operational hydrodynamical and sea state forecasts in the Eastern Mediterranean since early 2002. Recently, it has been improved with the implementation of new hydrodynamic, wave and atmospheric modeling systems with the objective of targeting larger and higher resolution domains, at regional and sub-regional scales. For the new CYCOFOS hydrodynamic modeling system a novel parallel version of the ocean flow model POM has been developed and implemented using Message Passing Interface (MPI) on Linux clusters. The new flow model covers the entire Eastern Mediterranean with a resolution of 2 km and the Levantine basin with resolution of 500 m, both nested in Copernicus marine environmental monitoring service, CMEMS regional MFS. The CYCOFOS hydrodynamic model is coupled with the latest ECMWF parallel WAM model v.4. The sea surface currents produced from the Copernicus marine service, and CYCOFOS has been incorporated in the wave integration, providing a second independent forcing input, in addition to the winds, for the new wave model. The Weather Research and Forecasting atmospheric model, known as WRF has been implemented in the same domain as SKIRON atmospheric system, in order to provide the backup forcing for the CYCOFOS new modeling systems. This new CYCOFOS modelling system is a contribution for the EU-CISE project.

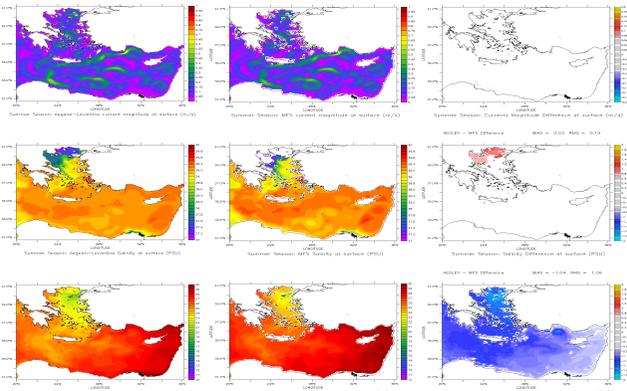


Figure 1: CYCOFOS Aegean-Levantine model (left) against the Copernicus marine service regional MFS (middle), seasonal averaged (top row) magnitude of sea surface currents (in m/s), (middle row) surface salinity and (bottom row) SST July-August 2015.

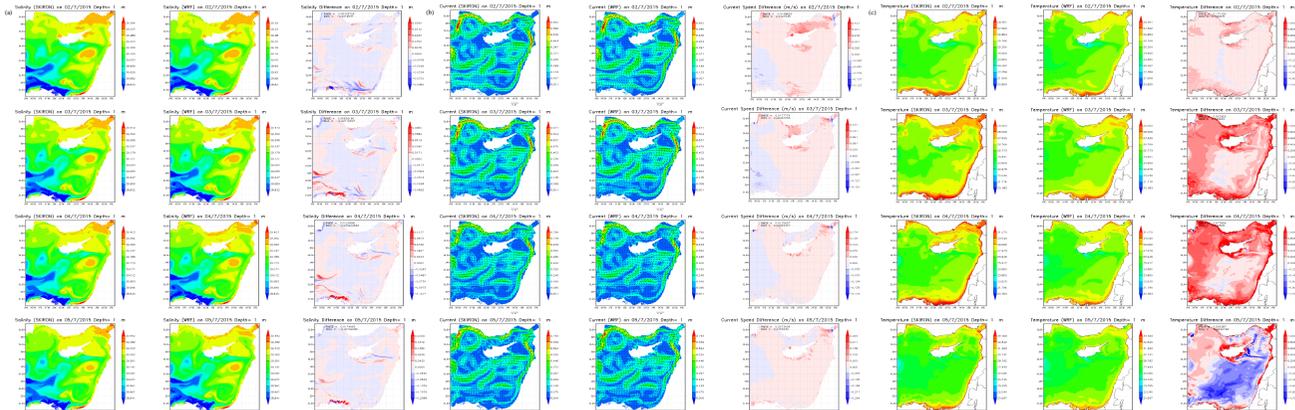


Figure 2: Comparison of SKIRON and WRF atmospheric forcing on CYCOFOS hydrodynamic model for (a) salinity, (b) ocean currents and (c) Sea Surface Temperature for a period of 4 days forecast (2 July 2015).

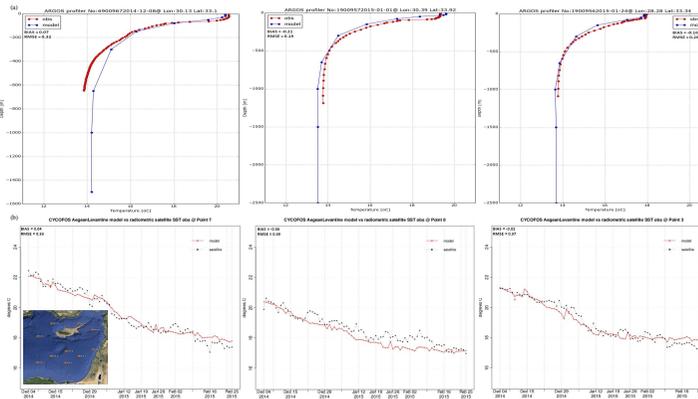


Figure 3: (a) Three arbitrary chosen temperature ARGO floats profiles (red) and CYCOFOS (blue) profiles. (b) Arbitrary selected time series plots of the statistical inter-comparison of CYCOFOS model (red line) with satellite observations (dots) of the sea surface temperature (SST), over the Levantine basin for a period of 3 months, from 4 December 2014 to 25 February 2015.

Evaluation of CYCOFOS hydrodynamic and WAM models

CYCOFOS Aegean Levantine (2 km resolution) was evaluated against:

- Copernicus MFS (7 km resolution) model for surface variables of salinity, SST and sea currents from July to August 2015 (figure 1).
- Satellite (Envisat, NOAA-18, MetOpA, Modis Aqua/Terra, MSG1) infrared measurements of SST (figure 3).
- in-situ data from 88 ARGO floats temperature profiles collected between December 2014 to January 2015 in the Levantine Basin (figure 4).

CYCOFOS WAM (5 km resolution) evaluation during different wind/wave characteristics and seasons (September 2013, October 2013, November 2013 and March 2014), against:

- in-situ wave records obtained from the Hadera station located at the water depth of 27 m (Long: 34.863 Lat: 32.471). November 2013 evaluation is shown on figure 5.
- Satellite (Cryosat-2, Jason-2, SARAL) observations for the whole Mediterranean.

Evaluation of CYCOFOS WRF model

WRF pre-operational evaluation was made at 2 stages. The first stage was a comparison between observational data and reanalysis and the second stage was the comparison with SKIRON atmospheric forcing in order to check the order of similarity. The CYCOFOS WRF model was evaluated for the period between December 2014 to February 2015 against:

- In-situ (METAR) wind speed data collected from 427 stations for the whole Mediterranean (figure 6).
 - ECMWF ERA-interim wind speed data for the whole Mediterranean (figure 7).
- The second stage of evaluation, as it is shown in figure 4, indicates the differences between WRF and the SKIRON forcing in order to evaluate the differences between the 2 different forcing in time figure 2).

Evaluation statistics of WAM and hydrodynamic models Vs observations	Mean Bias	Mean RMSE
WAM vs Satellites (for whole Med sea)	0.148 m	0.44
WAM vs Hadera (for all the examined periods)	0.175 m	0.3125
CYCOFOS Aegean-Levantine model SST vs Satellites (for 10 selected locations)	0.177 °C	0.413
CYCOFOS Aegean-Levantine model SST vs ARGOS float (on 8/DEC/2014) at different water depths	Surface -0.17 °C 100 m -0.27 °C 300 m -0.23 °C Below 300m -0.15 °C average	0.25 0.134 0.119 0.09

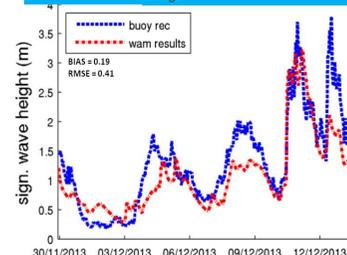


Figure 5: Time Series of the new CYCOFOS WAM modeled and in-situ corresponding measurements significant wave height data from Hadera station, December 2013.

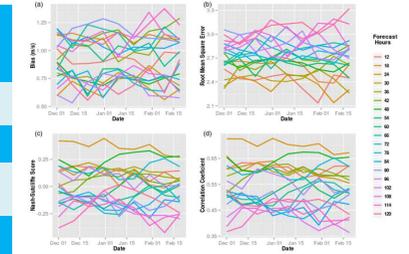


Figure 6: Statistical values for every 6hrs timestep (averaged from December 2014 to February 2015): CYCOFOS WRF Vs METAR stations wind speed: (a) Mean Bias Values, (b) RMSE, (c) Nash-Sutcliffe score, (d) Correlation Coefficient.

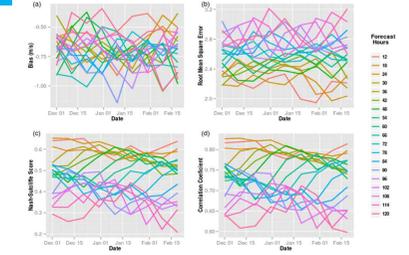


Figure 7: Statistical values for every 6hrs timestep (averaged from December 2014 to February 2015): CYCOFOS WRF Vs ECMWF ERA-INTERIM reanalysis wind speed: (a) Mean Bias Values, (b) RMSE, (c) Nash-Sutcliffe score, (d) Correlation Coefficient.

Conclusions

- The CYCOFOS hydrodynamic model has good agreement with Copernicus marine service regional MFS model for salinity, ocean currents and SST. Better agreement is observed with in-situ and satellite temperature data with BIAS and RMSE values reaching 0.17(absolute) and 0.413 respectively at surface. Also in depth temperature comparisons have very good agreements with Bias and RMSE values not exceeding 0.27 and 0.135 respectively.
- CYCOFOS WAM also performs very well compared to Hadera in-situ data and satellite data from whole Mediterranean with BIAS and RMSE reaching up to 0.175 and 0.44 respectively.
- WRF model wind speed also performs very well compared to ERA-INTERIM reanalysis and METAR data. Comparison between SKIRON and WRF atmospheric forcing on hydrodynamic model are also in good agreement.

References:

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