SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2019
Project Title:	PSAS Data Assimilation for the Adriatic Sea using Regional Ocean Modelling System (ROMS)
Computer Project Account:	spcrjane
Principal Investigator(s):	Asst. prof., dr.sc. Ivica Janekovic
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Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	Jan 2018
Expected end date:	Jan 2020

Computer resources allocated/used for the current year and the previous one

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	900,000	94,932	900,000	640,596 (71%)
Data storage capacity	(Gbytes)	4500			

Summary of project objectives (10 lines max)

The aim of the project is to estimate the best possible, and at the same time, dynamically consistent ocean analysis by combining ocean observations and model solving Navier-Stokes equations for the ocean dynamics. I performed one year long experiment assimilating all available observations ranging from multiple satellite (i.e. SST) data to individual vertical profiles of temperature and salinity obtained from many ship observations or dense in space and time sea glider and acoustic Doppler current profiler's ocean currents. Data assimilation successfully minimized mismatch between model estimates and observations but keeping ocean dynamics constrained with model error covariance. There was independent set of observations set aside and not used in the data assimilation to gauge model performance. In my case, I used 4DVar PSAS technique which is available inside ROMS modelling system (Rutgers version).

Summary of problems encountered (10 lines max)

At the start there was a problem with the ROMS model and the advection scheme for tracers that caused unrealistic values when using multiple river sources (in my case 41 river inputs along the coastline of Adriatic Sea basin) that generated strong salinity fronts. This issue was fixed in the new version of the code.

Summary of plans for the continuation of the project (10 lines max)

I would like to continue data assimilation experiment expanding system to include (a) new atmospheric forcing (ECMWF-IFS instead of ALADIN-HR which now days have comparable resolutions) and (b) test the system capabilities for two-way coupled ocean-atmosphere. This looks tricky and active topic of reasearch as ocean model makes/sends increments to the atmospheric model inputs via data assimilation while atmospheric model is 2-way coupled at the same time and sending info back to the ocean model. Assimilation in the ocean model could prove feasible and cheaper but capable to improve atmospheric model as well. Additional development of assimilation in the nested domains could be the next bonus (c) as I am running ocean ROMS model at 2 km resolution with multiple nests (500 m resolution). Boundary conditions are part of the control vector in the data assimilation and they might decouple nest/child domain via data assimilation from the parent (2 km model providing boundary conditions).

List of publications/reports from the project with complete references

Submitted manuscript in May 2019 to the Ocean Modelling journal "Using multi-platform 4D-Var data assimilation to improve modelling of the Adriatic 1 Sea dynamics".

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

The project started almost a year and half ago (the first few months was delayed as needed token arrived late). During the first few months I got familiar with CRAY environment and modules needed to compile and setup the Regional Ocean Modeling System (ROMS) model. During the last year I managed to run whole yearlong Four-Dimensional Variational (4DVar) data assimilation experiment, formulated on the physical-space statistical analysis system (PSAS) algorithm with multiple 4-days cycles producing dynamically consistent re-analysis for the Adriatic Sea. This experiment was performed for the very first time in the Adriatic using advanced 4DVar technique. The High-resolution multi-platform observations were assimilated into ROMS forced by mesoscale atmospheric model ALADIN/HR (Aire Limitée Adaptation dynamique Développement InterNational), including important freshwater river inflows, tides and realistic open boundary conditions for the period between October 2014 and September 2015. The observations included sea surface temperature (SST) measured by satellites, in situ temperature and salinity data measured by various moving (Argo profiling floats, shipborne CTDs, sea glider, towed CTD profiler) and moored platforms, ocean current profiles measured by moored Acoustic Doppler Current Profilers (ADCPs), and daily mean surface sea currents from high-frequency (HF) radars. Three model simulations were integrated: (1) free non-assimilative simulation over the yearlong period – served as baseline simulation; (2) free non-assimilative simulation initiated by the previous assimilation 4-day cycle – served as background simulation for assimilation, and (3) fully assimilative simulation that used all available observations during the each of 4-days assimilation cycle - analysis simulation. The assimilation improved significantly the modelling system performance, especially in SST, with time average RMSE equalled to 0.84, 0.63 and 0.41ºC and bias 0.34, 0.12, 0.01ºC for baseline, background and analysis simulations, respectively. These reductions were mostly achieved during the wintertime outbreaks of a cold and dry bora wind, due to the underestimation of heat and momentum fluxes by the atmospheric model. Those fine adjustments in the northern Adriatic are possibly affecting dense water generation, while in the southern Adriatic analysis simulation suggested weaker gyre that could have multiple impacts on all other physical-related bio-chemical studies. DA model skill compared well against background solution indicating predictability skill of DA for each of the assimilation 4-day windows. Computing the skill for the different types of observations I could measure specifically where DA is performing better (i.e. having smaller rmse than the background simulation). In my case DA skill was found always better; for glider observations 44%, yo-yo towed CTD 38%, CTD stations 37%, SST(Modis) 34%, SST(L3) 28%, HF radar 21% and ADCP 20% in average during the whole year-long experiment compared to baseline solution. This result additionally points capability of DA application for potential operational setup where model skill outperforms “non-assimilation setup”.

All the DA corrections to the control vector (atmospheric forcing, initial state and boundary conditions) seems physical and in the right location and direction. Overall results are in general agreement with the Adriatic Sea dynamics, yet improving many fine scale features which could have profound implications on the long term climatology, dense water formation in the northern regions, deep water convection in the southern Adriatic or inflow through the boundary conditions.