REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE:	CROATIA
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Project Title:	The Adriatic decadal and inter-annual oscillations: modelling component

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☒	NO

Computer resources required for 2018-2020: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	13,000,000	13,000,000	13,000,000
Accumulated data storage (total archive volume)[2]	(GB)	25,000	50,000	75,000

An electronic copy of this form must be sent via e-mail to: *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

June 21st 2017

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.
[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

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Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).

Following submission by the relevant Member State the Special Project requests will be evaluated by ECMWF as well as the Scientific and Technical Advisory Committees. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Large requests asking for 10,000,000 SBUs or more will receive a detailed review by members of the Scientific Advisory Committee.

All accepted project requests will be published on the ECMWF website.

1) State-of-the-art

Thermohaline oscillations of the Adriatic-Ionian System – as well as their biological consequences – have been extensively studied in the last 60 years (Buljan, 1953; Zore-Armanda, 1963; Buljan and Zore-Armanda, 1976; Grbec et al., 2009; Civitarese et al., 2010; Vilibić et al., 2012). In particular, the Adriatic-Ionian Bimodal Oscillating System (BiOS, Gačić et al., 2010), which consists on the decadal reversal of the cyclonic northern Ionian circulation into anti-cyclonic circulation, has been found to strongly affect the thermohaline, biogeochemical, ecological and fishery conditions in the Adriatic Sea (see Figure 1). The BiOS regimes are also related to a wider Eastern Mediterranean oscillatory dynamics (Krokos et al., 2014; Theocharis et al., 2014). In particular, Klein et al. (1999) proved the interplay between dense water formation occurring in the Adriatic and Aegean Seas.

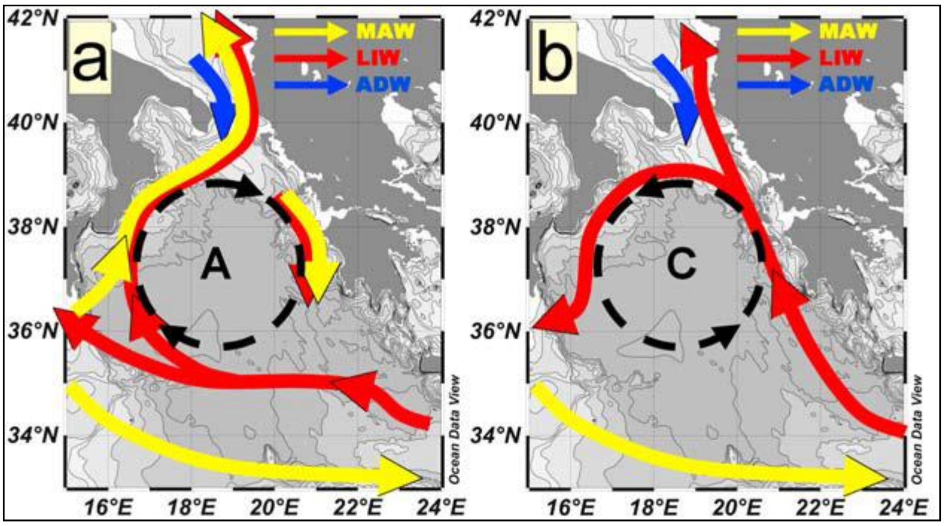

Figure 1: Scheme of Bimodal Adriatic-Ionian oscillation (BIOS) regimes, A- anti-cyclonic, C- cyclonic (taken from Gačić et al., 2010). The cyclonic circulation brings saline Levantine Intermediate Water (LIW) to the Adriatic. The low-salinity Modified Atlantic Water (MAW) freshens the Adriatic basin for anti-cyclonic circulation. The Adriatic Deep Water (ADW) mixes in the southern Adriatic.

However, surprisingly, the physical explanation of the thermohaline oscillations is still under debate as two different theories are opposed. The first theory links the oscillations to the pressure and wind-driven patterns (Grbec et al., 2003). Molcard et al. (2002) and Pinardi et al. (2015) have been recently proving the relationship between wind stress curl and northern Ionian reversals. The second theory correlates the oscillations with the effects of dense water formation (Borzelli et al.,2009; Gačić et al., 2010). In particular, Vilibić and Šantić (2008) and Mihanović et al. (2013) demonstrate the direct link between the oscillations and the dense water formation in the southern and northern Adriatic.

The dense water formation (DWF) in the Adriatic occurs in two areas: the deep Southern Adriatic Pit, through open-ocean convection (Gačić et al., 2002) and the shallow and wide northern Adriatic shelf, through direct cooling of the whole water column (Vested et al., 1998). Both processes are sensitive to spatial and temporal properties of the bora wind, which is found to vary at a minute timescale and over a kilometer spatial scales (Grisogono and Belušić, 2009; Kuzmić et al., 2015). For that reason, the DWF modelling requires the application of mesoscale atmospheric models, whilst ECMWF products are found to underestimate the wind (Cavaleri et al., 1997; Mantziafou and Lascaratos, 2004, 2008). Also, the bathymetry and orography in coastal areas are found crucial for proper reproduction of oceanic processes that may reflect in the overall Adriatic thermohaline circulation (Vilibić et al., 2017).

2) Previous Numerical Modelling Efforts

In addition to the diverging theories, the numerical modelling of the Adriatic-Ionian thermohaline oscillations has only been initiated in the recent years (Theocharis et al., 2014). The two main reasons for this lack of numerical studies are: (1) the need of long term (multi-decadal) simulations to cover enough cycles of the BiOS regimes and (2) the need for high-resolution mesoscale atmospheric and ocean simulations to reproduce the observed ocean dynamics and dense water formation rates in the Adriatic.

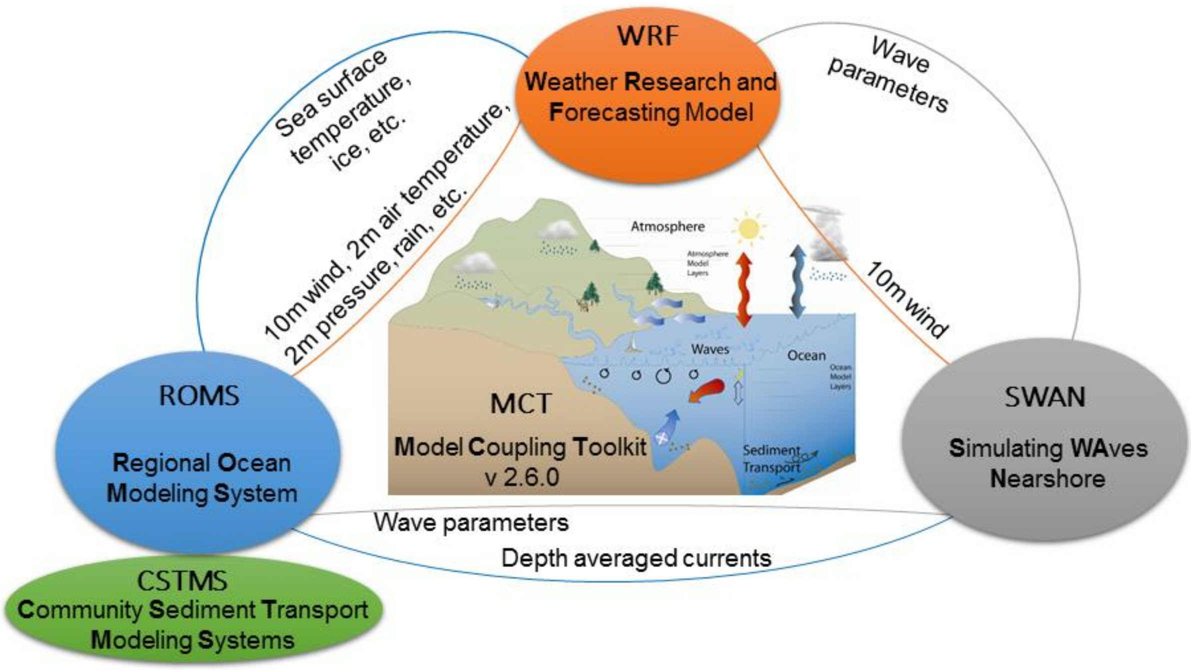

Figure 2: Numerical suite of COAWST model adapted from: http://woodshole.er.usgs.gov/operations/modeling/COAWST/

The available ocean models of the Mediterranean Sea (including the climate simulations undertaken within the Med-CORDEX project) are found too coarse to resolve properly the fine structure of the Adriatic dynamics over climate (multi-decadal) periods, such as generation of dense waters in the northern Adriatic (Dunić et al., 2016).

3) Proposed Work

The proposed work will be achieved in the framework of the ADIOS project, partially funded by the Croatian Science Foundation, and part of a collaborative effort with colleagues from Croatia, France and Italy. The aim is to numerically investigate and quantify the processes driving the inter-annual to decadal thermohaline variations in the Adriatic-Ionian basin with a high resolution Adriatic-Ionian fully coupled atmosphere-ocean model.

The high-resolution modelling strategy is based on the use and development of the Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) Modelling System (Warner et al., 2008; 2010). This model is already widely used and validated by the research community to (1) quantify the regional budgets of water and heat (e.g., Ricchi et al., 2016) and (2) perform regional climate change simulations (Nicholls and Mohr, 2015).

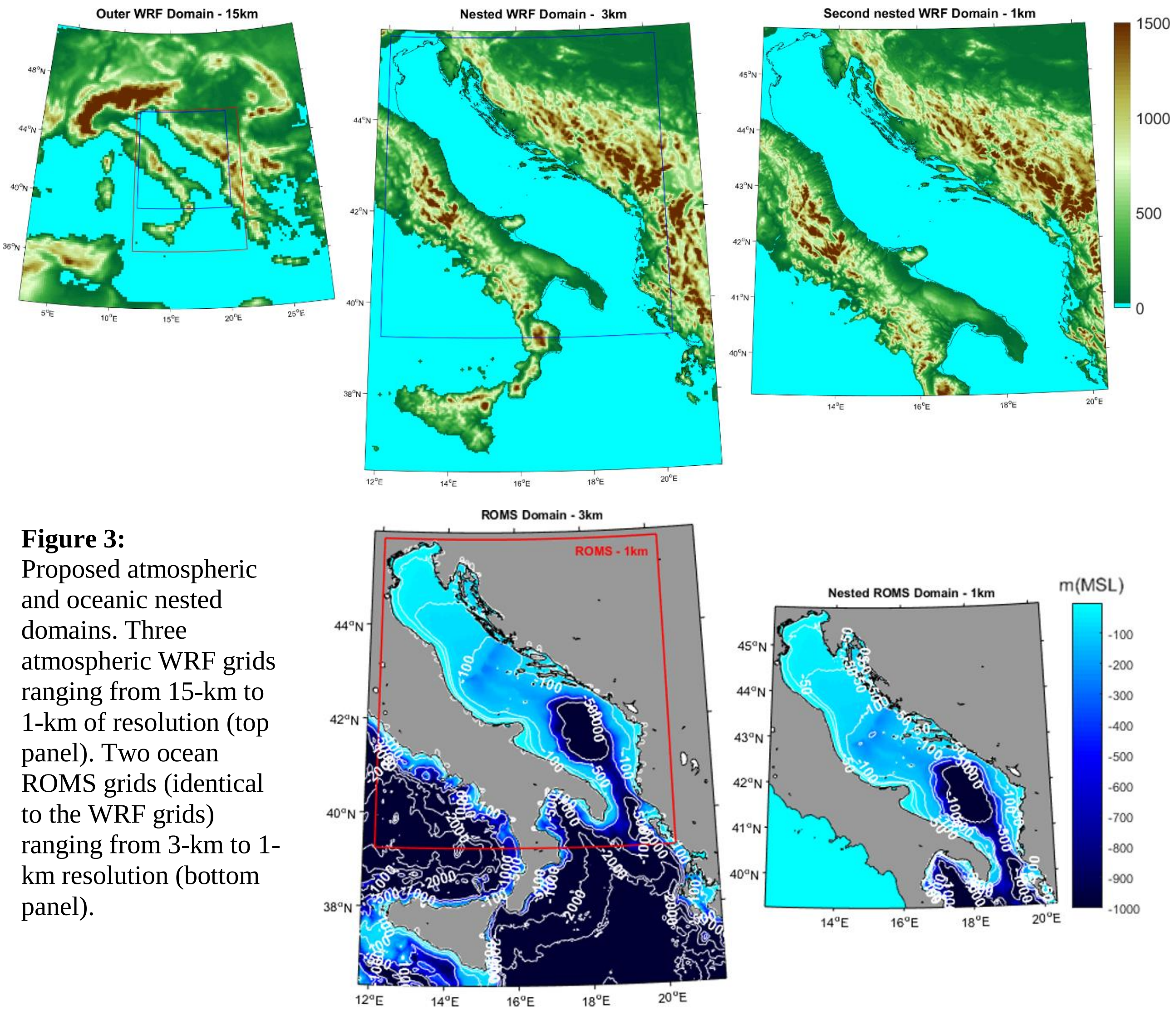

Figure 3:
Proposed atmospheric and oceanic nested domains. Three atmospheric WRF grids ranging from 15-km to 1-km of resolution (top panel). Two ocean ROMS grids (identical to the WRF grids) ranging from 3-km to 1-km resolution (bottom panel).

This numerical system is built around the Model Coupling Toolkit (MCT) which exchanges data fields and dynamically couples the atmospheric model Weather Research and Forecasting

(WRF) with the ocean model ROMS and which dynamically nests grids in order to increase the resolution in the area of interest (see Figure 2). The model is a Fortran based code already installed and fully tested on the ECMWF high performance computing facilities.

The Adriatic-Ionian model will consist in two nested atmospheric grids of respectively 15-km and 3-km resolution and two nested ocean grids of 3-km and 1-km respectively (see Figure 3). The 3-km resolution grids will be identical for both the atmosphere and the ocean. A 1-km atmospheric grid identical to the ocean grid may also be used depending on the performance of the model and the computer resources needed.

Computing resources needed: given the size of the grids (atmosphere: 140x140x58 + 266x361x58 + 676x730x58 – ocean: 266x361x35 + 676x730x35) and based on previous experience with ECMWF resources, the following system should be run with at least **300 CPUs** in order to achieve reasonable time of execution of the model (about 5-year of simulation in one-month real time). The **targeted** use of the ECMWF resources is thus **700,000 SBUs and 1,500GB** of storage **per year of simulation**.

The modelling strategy of the project consists in the following points:

(i) Setup and test/validation of the different coupled models

The regional Adriatic-Ionian model will be forced by existing atmosphere/ocean model products. The choice of the forcing will depend on the performance of the model during a period of 4 years between 2013 and 2016 when several measurements where collected over the studied area.
In addition to the choice of the forcing, the parameterizations of the bottom roughness, the turbulence, the vertical distribution of the model vertical layers, etc… will also be tested in order to define the optimal configuration of the models.
This test/validation phase will also determine the final settings of the models depending on the allocated computer resources (computation time and storage).

Computing resources needed: up to 5 different configurations of the model are planned to be tested. As some of these simulations will be run in parallel on other resources (i.e. Croatian HPC Isabella), about **3,000,000 SBUs** and up to **6,000 GB** are planned to be used for this phase of the ECMWF special project.

(ii) Evaluation run – 30year run

Following the Med-CORDEX initiative, an evaluation run for a period of 30 years using ECMWF ERA-Interim reanalysis products to force the atmospheric model will first be setup.
This is the key run of the project as it will be used to confront the different theories concerning the Adriatic-Ionian thermohaline oscillations.

Computing resources needed:
Following our first estimate, **21,000,000 SBUs** and up to **45,000 GB** will be used in the framework of the ECMWF special project to **fully cover the 30-year run**.

These two first points of the modelling strategy are planned to be achieved during the first and half year of the requested ECMWF HPC resources.

(iii) Future scenario runs

Idealistically the RCP4.5 and RCP8.5 climate change scenarios will also be run with the validated high-resolution Adriatic-Ionian model. Realistically RCP8.5 will most probably be the only scenario simulated. Products from the Med-CORDEX initiative will be used as boundary conditions of the high-resolution regional model. The goal of these simulations is principally to obtain some clues on how climate change may affect the Adriatic-Ionian oscillations and the potential ecological consequences of these changes.

<u>Computing resources needed:</u>
The 100-year simulation of the RCP scenario will only be **partially run** within the ECMWF Special project framework with the remaining **15,000,000 SBUs and 24,000 GB** requested.

The last point of the modelling strategy is planned to be achieved during the last year and half of the requested ECMWF HPC resources.

It is also planned that the model outputs will be disseminated to the research community and users via a LDAP open access server.

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