Research Cooperability Program, Crossing Borders Grant – Application Form 2015

Preliminary notices for applicants:

1. **You must read and accept the UKF Guidelines and Procedures - Second Science and Technology Project (STP II) 2015, the respective Call for Proposals and the Research Cooperability Program, Crossing Borders Grant - Instructions for Applicants 2015 – before filling out this form**.
2. *Information on this form is collected in order to make recommendations to the Croatian Science Foundation represented by the Unity through Knowledge Fund's Steering Committee on the allocation of financial support within Second Science and Technology Project Loan Nr. 8258 – HR between Republic of Croatia and International Bank for Reconstruction and Development.*
3. *The information collected may be passed to third parties for assessment purposes. In other instances, information contained in this Proposal can be disclosed without your consent only where authorised or required by law.*

A. Project proposal

1. Project info

a. Project title

Meteotsunamis, destructive long ocean waves in the tsunami frequency band: from observations and simulations towards a warning system (MESSI)

b. Project leader
(first name(s), family name, title, e-mail, address, phone, private address)

Jadranka Šepić, Ph.D., sepic@izor.hr, +385 21 408048

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Private: R. Boškovića 7, 21000 Split, Croatia

c. Duration of the project 24 months

d. Beneficiary (Administering organization)
(full name, address, web address, Personal identification number (OIB), and contact person details)

Institute of Oceanography and Fisheries, Šetalište I. Meštrovića 63, HR-21000 Split, Croatia, URL: http://www.izor.hr, OIB: 86235185568, contact: Jadranka Šepić, sepic@izor.hr

e. Other organizations involved
(full name, address, web address and contact person details)

1. Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Borgo Grotta Gigante 42/C, 34010 Sgonico (TS), Italia, URL: http://www.ogs.trieste.it/, contact: Miro Gačić, mgacic@ogs.trieste.it
2. Meteorological and Hydrological Service, Grič 3, HR-10000 Zagreb, Croatia, URL: http://meteo.hr, contact: Kristian Horvath, horvath@cirus.dhz.hr
3. University of the Balearic Islands, Ctra.Valldemossa, km. 7.5, Palma de Mallorca,

Spain, URL: http://www.uib.eu/, contact: Sebastian Monserrat, s.monserrat@uib.es

4. International Tsunami Research, Inc., 11321 Chalet Road, Sidney, British Columbia, Canada V8L 5M1, URL: http://itrinc.ca/, contact: Alexander B. Rabinovich, a.b.rabinovich@gmail.com

2. Summary of the research project

Word count: ***333***

(*Max. 400 words, add word count)*

a. Description

Flooding due to extreme sea levels can cause extensive damage to coastal areas, especially in low-lying towns and fertile river estuaries, largely present along the eastern Adriatic coastline. Because of predicted sea level rise and non-adapted coastal infrastructure, intensity and frequency of flooding events as well as induced damage are likely to increase further. Particularly dangerous are meteorological tsunamis – several metres high long-ocean waves generated by intense small-scale air pressure disturbances – which occasionally cause substantial damage to coastal towns of the Adriatic Sea (e.g. Vela Luka, Stari Grad, Mali Lošinj) and may raise panic in these highly tourist areas. **The main objective of the MESSI project is to build a reliable prototype of a meteotsunami warning system based on real-time measurements, operational atmosphere and ocean modelling and real time decision-making process, using knowledge acquired from analysis of historical destructive events.** The most prominent and destructive historical meteotsunamis will be investigated by using available atmospheric data and tide-gauge records and reproduced with state-of-the-art numerical ocean (ROMS, SELFE-SCHISM) and mesoscale atmospheric (ALADIN, WRF-ARW) models. Based on output of ocean numerical models, maps of meteotsunami hazard for the Adriatic Sea will be created. Synoptic weather conditions under which meteorological tsunamis typically occur will be classified and quantified. Regional atmospheric climate simulation outputs will be examined for meteotsunamigenic synoptic patterns in the present and future climate, allowing for assessment of meteotsunami potential and its trends. The prototype of a warning system in the middle Adriatic will be based on real-time measurements of key oceanographic and meteorological parameters, creation of operational meteotsunami decision matrix and semi-automatic procedures and protocols for warning of civil protection and local authorities. Such a meteotsunami warning system could present a boost for creation of a still non-existent Adriatic operational oceanographic service. Project outcomes will be highly beneficial for endangered coastal communities, in a sense of rising timely alarms, for planning of construction works along the coastline (roads, marinas, piers, etc.), for the navigation safety, educating people and raising awareness in endangered areas.

b. Project area/field/branch

Geophysics, Physical Oceanography, Meteorology

c. Category of project research (basic, applied or developmental research)

Basic research with strong elements of applied research

d. Project Key words

Meteorological tsunamis, coastal flooding, Adriatic Sea, mesoscale numerical weather

prediction models, ocean modelling, non-standard meteorological measurements, warning systems

3. Composition of the research group

a. Applicants

Main applicant – Project leader		*Co-applicant – Project co-leader*	
Family name:	Šepić	Family name:	Gačić
First name(s):	Jadranka	First name(s):	Miroslav
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Job description within the project	Coordination, project management, dissemination, design of experiments, assessment of results and warning system	Job description within the project	Project management, assessment of results and warning system. Design of meteotsunami monitoring station and warning system prototypes.
Time to be spent (F.T.E.):	0.3	Time to be spent (F.T.E.):	0.2

b. Co-workers

Family name:	Vilibić	Family name:	Kovačević

First name(s):	Ivica	First name(s):	Vedrana
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Job description within the project	Design of experiments, assessment of results and warning system, assessment of historical Adriatic meteotsunamis	Job description within the project	Assessment of historical Adriatic meteotsunamis
Time to be spent (F.T.E.):	0.2	Time to be spent (F.T.E.):	0.2

Family name:	Rabinovich	Family name:	Monserrat
First name(s):	Alexander B.	First name(s):	Sebastian
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Job description within the project	Providing expertise on meteotsunamis, design of scientific experiments, assessment of results.	Job description within the project	Providing expertise on meteotsunamis and meteotsunami warning systems, design of scientific experiments and warning network,

			assessment of results.
Time to be spent (F.T.E.):	0.2	Time to be spent (F.T.E.):	0.2

Family name:	Mihanović	Family name:	Dadić
First name(s):	Hrvoje	First name(s):	Vlado
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Job description within the project	Installation of meteotsunami research and warning network system. Extraction of tsunamigenic synoptic conditions from past and future climate simulations.	Job description within the project	Installation of meteotsunami research and warning network system.
Time to be spent (F.T.E.):	0.2	Time to be spent (F.T.E.):	0.2

Family name:	Beg Paklar	Family name:	Džoić
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Job description within the project	Modelling meteotsunamis with 2D and 3D regional ocean models, set up of operational model. Transfer of modelling knowledge to younger scientists.	Job description within the project	Modelling meteotsunamis with 2D and 3D regional ocean models (ROMS, IOF meteotsunami model), comparison of ocean model outputs.
Time to be spent (F.T.E.):	0.2	Time to be spent (F.T.E.):	0.3

Family name:	Kovač	Family name:	Ivanković
First name(s):	Žarko	First name(s):	Damir
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Job description within the project	Modelling meteotsunamis with 2D and 3D regional ocean model (ROMS, IOF meteotsunami model), comparison of ocean model outputs.	Job description within the project	Dynamic web contents, data processing and database implementation of the warning system.
Time to be spent (F.T.E.):	0.3	Time to be spent (F.T.E.):	0.2

Family name:	Muslim	Family name:	Mašće
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Job description within the project	Construction of a meteotsunami monitoring station prototype, installation of meteotsunami research and warning network.	Job description within the project	Construction of a meteotsunami monitoring station prototype, installation of meteotsunami research and warning network system.
Time to be spent (F.T.E.):	0.2	Time to be spent (F.T.E.):	0.1

Family name:	Tudor	Family name:	Horvath
First name(s):	Martina	First name(s):	Kristian
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Address:	Grič 3, HR-10000 Zagreb, Croatia	Address:	Grič 3, HR-10000 Zagreb, Croatia
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Job description within the project	Operational atmospheric mesoscale models (Aladin/HR), implementation of the warning system.	Job description within the project	Research atmospheric mesoscale models (WRF-ARF), implementation of the warning system.
Time to be spent (F.T.E.):	0.3	Time to be spent (F.T.E.):	0.3

Family name:	TBD
First name(s):	TBD
Title(s):	Ph.D.
Organization:	Institute of

	Oceanography and Fisheries
E-mail:	TBD
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Tel.:	+385 21 408000
Job description within the project	Developing meteotsunami monitoring station prototype, setting up operational atmospheric and ocean models, setting up a prototype of the warning system.
Time to be spent (F.T.E.):	1.0

4. Description of the research project

Word count: 4377

(*Max. 4000 words, add word count)*

a. Rationale and background of the project including the state of the art of the research field

Meteorological tsunamis (meteotsunamis) are rare but hazardous long ocean waves, which have the same frequencies and spatial scales as tsunami waves. Meteotsunamis are, however, not related to seismic activity, volcanic explosions or submarine landslides, but to atmospheric forcing: pressure jumps, atmospheric gravity waves, frontal passages, squalls, etc (Monserrat et al., 2006). Meteotsunami generation process is illustrated in Figure 1. Destructive meteotsunamis are known to occur in Japan (Hibiya and Kajiura, 1982), Spain (Jansà et al., 2007, Vilibić et al., 2008), Great Lakes (Donn and Ewing, 1956), China (Wang et al., 1987), the eastern coast of the USA (Sallanger et al., 1995; Paxton and Sobien, 1998) and other locations (Monserrat et al., 2006). Especially endangered is the eastern coast of the Adriatic Sea where six destructive meteotsunamis have occurred in the past ~30 years (Vilibić and Šepić, 2009). The Great Vela Luka flood of 21 June 1978 is **probably the strongest known meteotsunami in the World**: tsunami-like waves with trough-to-crest heights of up to 6 m and periods of about 20 min suddenly appeared, resulting in one of the greatest marine natural disaster in the modern history of Croatia. with estimated damage of 7 million US dollars at that time, a quarter of annual income of the whole island of Korčula (Vučetić et al., 2009).

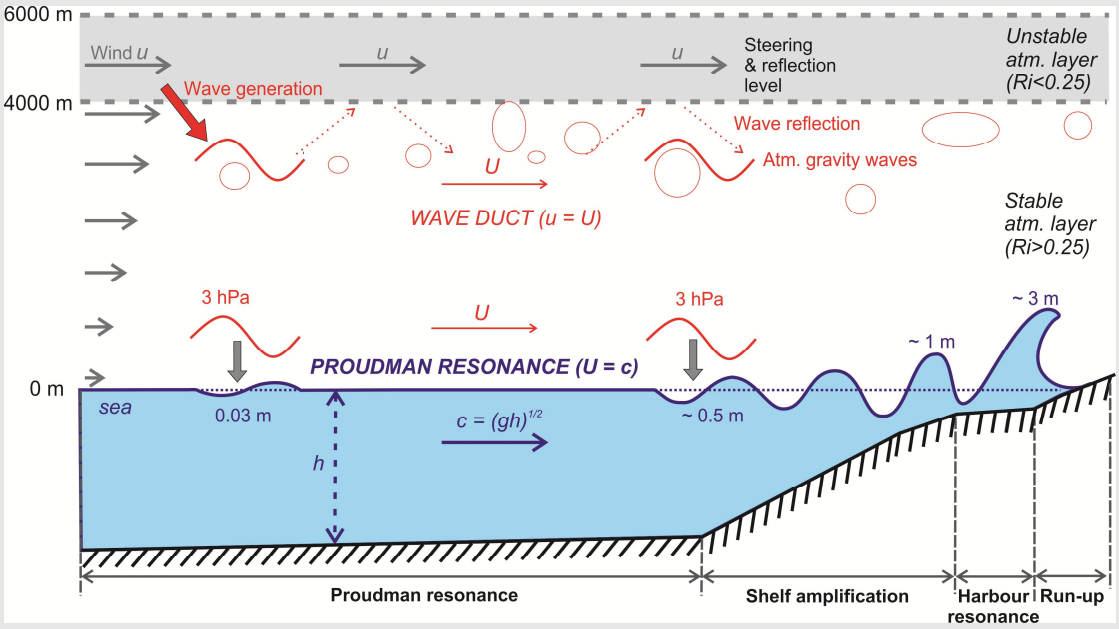

Figure 1. *Illustration of the meteotsunami generation processes. Numerous atmospheric gravity waves (represented by bubbles) are generated at the interface of unstable and stable atmospheric layer at places of strong wind shear. Air pressure change (a surface manifestation of atmospheric gravity waves) generates long-ocean waves which can be amplified through several processes: (1) Proudman resonance (due to matching of long-ocean waves speed and speed of atmospheric gravity wave); (2) shelf amplification (due to shoaling); and (3) harbour resonance (due to matching of frequency of incoming long-ocean waves and harbour eigenperiods). Incoming ocean waves can be amplified more than 100 times before hitting the coast as a destructive meteotsunami (taken from Šepić et al., 2015).*

It is necessary to take into account the threat of meteotsunamis in existing and future

marine tsunami warning systems. Present day tsunami warning systems are based on: (i) monitoring of seismic activity (tsunami source); and (ii) observation and modelling of the propagation of tsunami waves in the deep ocean and at coastal stations (Bernard et al., 2006). Although seismic tsunamis have incomparably larger impact and range than meteotsunamis, the latter seem to occur more often. Only in 2014, meteotsunamis hit: (i) the world's longest beach, the Praia de Cassino beach in Brasil (12 February); (ii) Panama City in Florida (USA) (28 March); and (iii) a number of the Mediterranean and Black Seas locations, including the Adriatic Sea (22-27 June) (Vilibić et al., 2014; Šepić et al., 2015).

Meteotsunami warning systems have so far been developed only for the Balearic Islands (Spain). Several different approaches based on either (i) monitoring of synoptic conditions, (ii) real-time measurements or (iii) numerical modelling have been tested (Jansà et al., 2007; Marcos et al., 2009, Renault et al., 2011). Although relatively reliable in forecasting whether or not a meteotsunami will occur, these systems are not so efficient in predicting strength of an event: a number of non-reliable warnings are thus issued, undermining trust of local population. On 15 June 2006, Ciutadella Harbour (Balearic Islands) was hit by a destructive meteotsunami. More than 130 boats were sunk or damaged, and the total economic loss had an order of several tens of MEuros, in spite of a prompt meteotsunami warning (Vilibić et al., 2008).

It is our intention to build a prototype of a more reliable and efficient meteotsunami warning system. Following Šepić et al. (2015), and Šepić and Vilibić (2011) this system should include: (i) monitoring of meteorological conditions (preconditioning of the event); (ii) observation, tracking and modelling of small-scale air pressure disturbances (monitoring of the meteotsunami source); (iii) observation and modelling of air-sea interaction (meteotsunami generation, propagation and coastal impact); and (iv) establishment of threshold criteria for warnings.

b. Overall objectives, significance and innovation of the research

The main objective of the MESSI project is to build a reliable prototype of a meteotsunami warning system, using knowledge acquired from analysis of historical destructive events. The prototype will be based on real-time measurements, operational atmosphere and ocean modelling and real time decision-making process.

Several **other global and specific objectives** are linked with the main project goal:

1. Supporting, supplementing and directing **operational oceanographic products** and services currently being developed at the national level.
2. Using a novel approach and techniques for **tracking and forecasting potentially hazardous events**..
3. **Collaboration and networking with top-level international scientists, aiming of transfer of knowledge to Ph.D. students and post-docs** - Co-PI (M. Gačić) is one of the leading Mediterranean oceanographers, recently interpreting some of the long-standing questions of the Adriatic oceanography. S. Monserrat and A. Rabinovich are among leading world scientists in the field of tsunami and meteotsunami research.
4. **Interdisciplinarity of the project team** (meteorologists, oceanographers) will allow harmonizing standards and approaches in these two disciplines, a necessity for researching a number of geosciences issues.
5. **Transfer of knowledge to engineers**. OGS engineers are experienced in different operational oceanographic and technological projects and will be available to help with design and construction of a meteotsunami station prototype and setup and implementation of the warning system.

The **significance** of the research comes from the following:

1. Developed prototype of meteotsunami warning system will be an important part of a future fully operational atmosphere-ocean forecasting service in Croatia. Proposed research is **especially important for those local communities which are under high threat of a meteotsunami** (e.g. Vela Luka, Stari Grad, Mali Lošinj, Ist). Collaboration with these communities will be initiated. We plan to maintain warning and research network after the project end.
2. Realisation of the MESSI project will **result in rising knowledge and expertise of Croatian scientists and engineers, enabling them to participate in development of warning systems at other endangered locations** throughout the world ocean. This is rather feasible since the project for building procedures and protocols for meteotsunami warning for the USA east coast, which was financed by the USA national agencies (NOAA), was led by Ivica Vilibić, one of MESSI project members (Vilibić et al., 2014).
3. Adriatic Sea provides **a unique opportunity to examine various aspects of meteotsunamis**. Due to its shallow bathymetry, northern Adriatic is an ideal polygon for study of Proudman resonance (Proudman, 1929). Middle Adriatic, on the other hand, provides a perfect area for research of: (i) generation of meteotsunamis over complex bathymetry, (ii) propagation and interaction of free and forced ocean waves, (iii) refraction and reflection of free waves. Suggested meteotsunami network will be designed in a way which optimizes both warning and scientific possibilities. Findings with **strong scientific relevance publishable in top-level journals** are thus expected.
4. Similar warning systems which combine real-time measurements and ocean models are presently used for several other natural hazard phenomena, like storm surges (e.g. http://kassandra.ve.ismar.cnr.it:8080/kassandra), and tsunamis (e.g. http://ntwc.arh.noaa.gov/). Modelling expertise obtained through duration of the project and established collaboration with the **OGS** may result in **development of other warning and research systems**.

Innovative aspects of the MESSI project are:

1. There is at present no operational oceanographic service with a meteotsunami warning system in the World Ocean based on a combination of real-time measurements and numerical modelling. Therefore, the MESSI project is highly innovative, and it can represent **a prototype warning system for other oceanographic services**.
2. Extracting meteotsunamigenic synoptic patterns from climate simulations is an innovative idea, providing a **new and efficient tool for estimating statistics of extreme events in future**, still not recognized and reproducible by climate models.

c. Proposed approach and methodology

Proposed approach consists of several steps aimed at achieving proposal objectives. These steps are:

1. **Data analysis and numerical reproduction of historic Adriatic meteotsunamis**: (i) the Ist meteotsunami of 22. August 2007; (ii) the Mali Lošinj meteotsunami of 15 August 2008; and (iii) the middle Adriatic meteotsunami of 25-26 June 2014. We plan to reproduce mentioned events with ocean and atmospheric models (aside for the Ist event which was already reproduced with atmospheric model, Šepić et al., 2009). The 2014 middle Adriatic meteotsunami is especially interesting as it was part of an unprecedented chain of meteotsunamis hitting the Mediterranean and the Black Seas in the last week of June 2014. A paper on these interconnected events has been published recently by several project members in the Scientific Reports, one of top-ranked multidisciplinary journals. Extensive atmospheric and ocean data

from Croatian, Italian and Montenegrin stations is available for the 2014 event, and will be studied in detail.

2. **Recognition of meteotsunamigenic synoptic pattern and its extraction from climate simulations**. Meteotsunamis in the Mediterranean typically occur under very specific synoptic conditions (Jansà et al., 2007, Vilibić and Šepić, 2009). We will use a novel neural network technique to extract this pattern from reanalysis data (ERA-Interim atmospheric reanalysis freely available through European Centre for Medium-Range Weather Forecast (ECMWF) web portal), and past and future climate simulations (EUROCORDEX simulations available from http://www.euro-cordex.net/). This will enable us to assess present and projected frequency of meteotsunami favourable conditions. Matching of meteotsunamigenic synoptic conditions in past climate to occurrence of meteotsunamis will be assessed using tide gauge records from Trieste and Dubrovnik.
3. **Reproduction of atmospheric component of meteotsunamis with numerical models.** ALADIN/HR model will be used to assess meteorological background conditions, whereas higher resolution nonhydrostatic ALADIN/HR (NH) and WRF-ARF model (Skamarock and Klemp, 2008) will be used to reproduce specific events and to force numerical ocean model. ALADIN and WRF-ARW models will be fine-tuned with respect to observations (Horvath and Vilibić, 2014).
4. **Reproduction of ocean component of meteotsunamis with numerical model**. Several ocean models will be used: (i) specially developed meteotsunami model (Šepić et al., 2015); (ii) semi-implicit unstructured SCHISM model http://ccrm.vims.edu/schism/); and (iii) Regional Ocean Modelling System model (ROMS, https://www.myroms.org/). Models will be validated with respect to reproduction of historic events and optimal model and settings will be chosen. A series of numerical simulations will be done to determine dependence of maximum sea level height and currents on parameters of atmospheric forcing (type of forcing: wind vs. air pressure; analytical vs. modelled vs. measured time series, amplitude, speed and direction of disturbance), resulting in meteotsunami hazard maps for the Adriatic.
5. **Design and construction of a meteotsunami monitoring station and network prototype**. A non-standard meteotsunami monitoring station consisting of special high-resolution high-quality air pressure sensors, and equipped with data analysis software will be designed and constructed by the IOF engineers. The IOF engineers have a rich experience in building operational monitoring stations. In addition, technological expertise of the Co-PI Institution engineers will be called upon. Monitoring stations will be placed at locations which allow for a timely warning (far off-shore from the vulnerable middle Adriatic communities) and collection of data necessary for improving understanding of meteotsunami generation and propagation: three stations on Italian territory (Tremiti, Ortona, Vieste), at least 100-150 km away from endangered locations; and three on Croatian Islands (likely Palagruža, Šolta, Svetac). This is in addition to already existing microbarographs stations at the islands of Korčula, Hvar, Vis and at the IOF (Split). Tide gauges will be placed in Vela Luka and Stari Grad, and bottom pressure recorders at three off-shore locations at depths higher than 100 m. Bottom pressure recorders will not be on-line, but once they are recovered, they will provide valuable scientific data. Proposed network is illustrated in Figure 2.
6. **Operational procedures**. Operational procedures for a meteotsunami warning system will be established. System will be based on: (i) a forecast of mesoscale meteorological conditions; (ii) coupled atmosphere-ocean model; (iii) data collection; (iv) automatic data analysis; and (v) warning matrix. As a result, two types of hazard estimate will be done: (i) **daily hazard assessment** - based on forecast of synoptic conditions and outputs of atmospheric-ocean coupled model, which will be run once a day, and (ii) **real-time hazard assessment** - based on real-time measurements of

atmospheric parameters.

7. **Dynamic web content and dissemination**. Meteotsunami hazard assessment will be available on the project webpage. Meetings with authorities of vulnerable local communities will be organized, and at the end of the project a stakeholder workshop will be held. All relevant national and local agencies, civil protection agencies, naval offices, local and national decision makers will be invited.

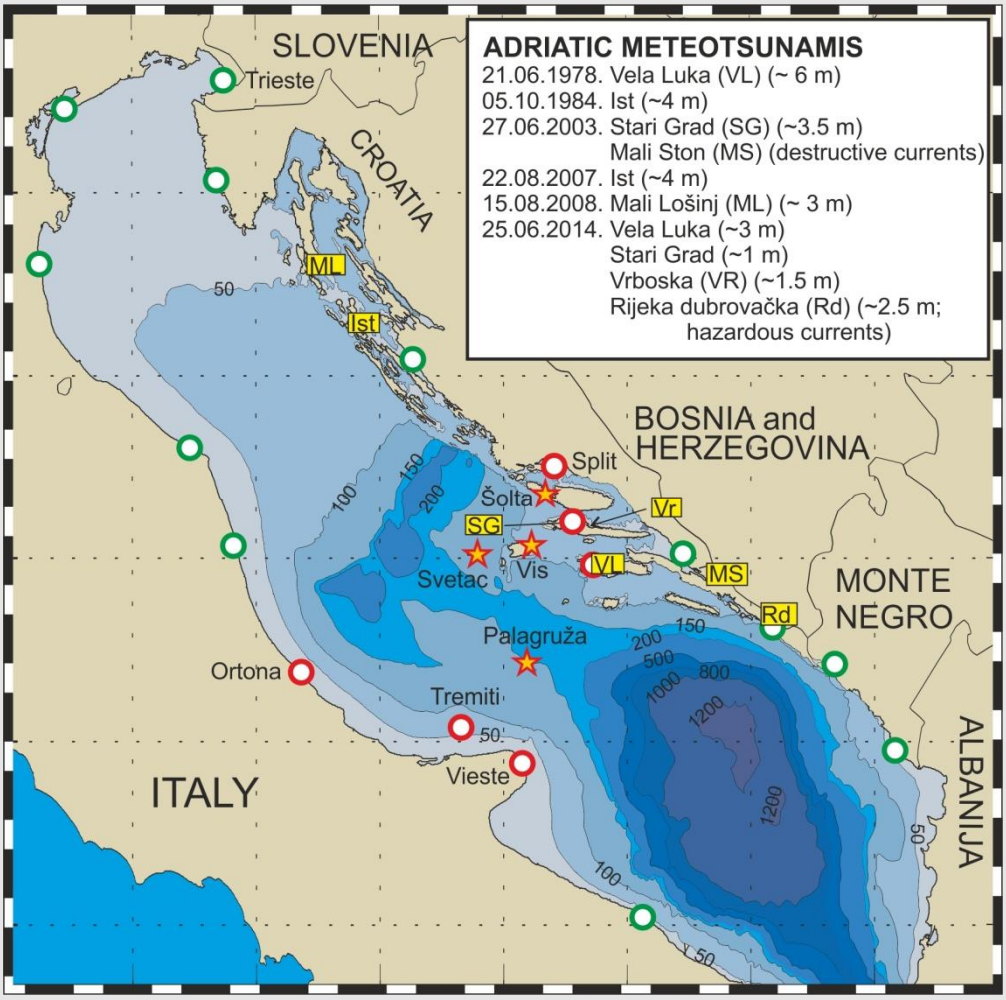

Figure 2. A sketch of the Adriatic research and warning network. Locations hit by the historic Adriatic meteotsunamis are marked with yellow squares. Red circles denote ocean-atmospheric stations, and yellow stars denote atmospheric stations, to be included in the network. Green circles mark additional tide gauges, from which data will be used to assess past meteotsunamis.

d. Expected measurable results and their potential users

A number of **measurable results** are expected from the project. We'll list them here:

1. The **prototype of a meteotsunami monitoring station and warning system** will be developed, based on real-time data acquisition and analysis, and numerical and ocean modelling. The system will become operational following the end of the project. This warning system will present an important part of the planned

operational Adriatic ocean forecast service.

2. **Capacity building and transfer of knowledge** from the collaborating institution **OGS**, Co-PI **Miroslav Gačić** and his team, external expert for high-resolution numerical modelling, and other collaborating Institutions and scientists.
3. **Strengthening numerical modelling groups** - a number of scientists, including two doctorate students, will be involved in numerical modelling of meteotsunamis. This will help strengthen ocean modelling capacity in Croatia.
4. At least **three scientific papers** will be submitted to leading (JCR q1) peer-reviewed international journals, and the project results will be presented at minimum five international scientific/technological conferences.
5. **Communication with local authorities from endangered cities will be initiated**, as a reliable meteotsunami warning system is of their high interest. A stakeholder workshop will be organized towards the end of the project, where results of the project will be disseminated to national and local agencies, civil protection services, and local authorities.

Potential users of the project products are:

1. The **Institute of Oceanography and Fisheries (IOF)** - at which future operational oceanographic service will likely be established. Furthermore, young scientists from the Institute, including a post-doc to be employed on the project, will highly benefit from collaboration with international experts. The **IOF** engineering group will gain expertise through development of monitoring station prototype and installation of research and warning network, all in collaboration with experts from the **OGS**.
2. The **operational NWP research and development department of the Meteorological and Hydrological Service** - new non standard operational forecast products will be developed. This includes automatic recognition of the meteotsunamigenic synoptic pattern from operational and reanalysis/climate atmospheric models, and operational high-resolution ALADIN/HR (NH) model fine tuned to reproduce atmospheric gravity waves over the Adriatic Sea. Developed products will enhance the forecast quality and help **Meteorological and Hydrological Service become more competitive on the international level**.
3. The **Mediterranean, European and world community in operational oceanography** - there is a high international interest for meteotsunami warning systems, as these dangerous waves are known to cause extensive damage and human causalities at a number of worldwide locations. However, at the present there is no fully operational system based on real time data analysis and numerical modelling.
4. **Local authorities** - strongest meteotsunamis in the Adriatic typically occur at particularly vulnerable locations (e.g. Vela Luka, Stari Grad), normally in the summer season (Vilibić and Šepić, 2009) in the high tourist season. Possibility to issue a meteotsunami warning is of high interest to local authorities. It is also necessary to educate local population what to expect and how to behave in a case of a strong meteotsunami.
5. **Various ministries and civil protection agencies**: the Ministry of the Sea, Transport and Infrastructure, the Ministry of Tourism, the Ministry of Science, Education and Sports and the Ministry of Environmental Protection, Physical Planning and Construction of the Republic of Croatia, and a variety of civil protecting agencies (e.g., the Regional Centre for Assistance and Disaster Relief, http://www.rcadr.hr), which are potential governmental users and possible organisers/sponsors for the establishment and maintenance of an operational oceanography centre.
6. **International and national atmospheric and oceanographic researchers** -

meteotsunami research and warning network will be designed enabling research of: (i) generation and propagation of long ocean waves, interaction of free and forced ocean waves, reflection and refraction of ocean waves; (ii) propagation and dispersivness of atmospheric gravity waves; and (iii) interaction of atmospheric gravity waves and long ocean waves. These are all highly interesting scientific topics for a wide scientific community, including meteotsunami researchers, tsunami researchers, and atmospheric researchers specialised in mesoscale meteorology.

e. Relevance and potential benefit of the project to the development of Croatia

The relevance and potential benefit of the MESSI project to Croatia are threefold and interconnected:

1. Creating an operational system with **capacity to provide a timely warning to vulnerable coastal communities**. This is of uttermost importance! Destructive meteotsunami waves, related floodings and strong currents endanger human lives, cause extensive damage to construction works, marine traffic, and marine industries. Education activities in schools and in local communities will increase meteotsunami awareness and preparedness.
2. MESSI project deliverables can serve as a boost to establishment of **future operational oceanographic service**. Unfortunately, Croatia still does not have such a service. One of main reasons for this is a lack of ocean numerical modellers. Through the MESSI project several oceanographic models will be used, and transfer of knowledge from more experienced modellers towards younger scientists is expected. This will allow for creation of a strong modelling group within the IOF which can present a core of a future oceanographic service.
3. Creating a prototype of a meteotsunami warning system will make Croatia **internationally competitive and place it at the top-level of operational warning community**.

f. Proposed communication and outreach of results

The project manager will organize a kick-off meeting within the first month of the project. Semi-annual progress reports will be distributed to all participants. Meetings and project workshops will be organized annually at the **IOF** and **OGS**.

A series of public presentations, aiming at increasing meteotsunami awareness and raising preparedness, will be given at vulnerable local communities, in particular Vela Luka, Stari Grad, Mali Lošinj, and Ist. Special presentations for school children will be organized as well.

A stakeholder workshop will be organised towards the end of the project, when project results and prototype of warning system will be disseminated. The project will have an active web site for publication of project progress reports and outputs. A special session on air-sea interaction with emphasis on meteotsunamis will be organized within 6. International meeting on meteorology and climatology of the Mediterranean (IMMCM), which will be held in Zagreb in 2017. A similar workshop on meteotsunami has already been organized in 2008 in Vela Luka, at the 30th anniversary of the great vela Luka flood of the 1978 (http://jadran.izor.hr/~vilibic/vela_luka/). This workshop resulted in an inspirational exchange of ideas and a special issue of *Journal of Physics and Chemistry of the Earth* on meteorological tsunamis (Rabinovich et al., 2009).

Targeted presentations will be given through various specific meetings, such as the EU Framework Programme Information days and workshops, and specific congresses and meetings of various international operational oceanography programmes and funded projects (MonGOOS, MyOcean, EuroGOOS, NOAA, ...).

At least three scientific papers will be submitted to **top-level journals**. These papers will

likely address one of the following subjects: (i) development and implementation of warning system; (ii) assessment and reproduction of historic Adriatic events, in particular event of 25-26 June 2014; (iii) recognition of meteotsunamigenic synoptic pattern and extraction of this pattern from past and future climate simulations; (iv) comparison of different ocean models; (v) detailed study of data collected from warning network, including assessment of atmospheric gravity waves, and long ocean waves.

Project results will be disseminated on a project web page.

The realisation of MESSI project is also related to other ongoing and past projects and proposals in which project team members participated, such as:

1. **NEURAL, UKF Across border project**, http://jadran.izor.hr/neural/, which ends in October 2015, and whose main objective was to create surface current forecast for the coastal northern and middle Adriatic.
2. **TMEWS, NOAA/NWS project**, http://jadran.izor.hr/tmews/, 2011-2013 - main objective of this project was to build the procedures and protocols for rising of a meteotsunami warning alerts for the USA east coast. Project was led by the MESSI project team member Ivica Vilibić.
3. **Investigations and monitoring systems for the unusual Adriatic dynamics**, national research project, with an aim of researching natural hazards phenomena, including meteotsunamis.
4. **HARFA, Interreg Central Europe project proposal**, http://www.interreg-central.eu/, the project aiming for creation of operational oceanography networks in the Adriatic and Baltic Seas.

We plan to seek extra funding in the future through various project proposals:

1. Horizon 2020 Calls – in particular the calls to be announced under Blue Growth pillar (and BlueMed initiative), which are dealing with ocean monitoring systems and investigations leading to a sustainable growth of the marine areas.
2. Horizon 2020, ERC project – the topic of meteotsunamis fits the purpose of Call for Starting Grants, for which PI is eligible.
3. Interreg Central Europe Calls, http://www.interreg-central.eu/, with annually published calls for regular projects.
4. Interreg Cross-Border Cooperation Calls, http://ec.europa.eu/regional_policy/en/policy/cooperation/european-territorial/cross-border/, where the collaborative projects with Italy and Slovenia are funded.

g. Management of the project

The project will be hosted and managed by the Institute of Oceanography and Fisheries (IOF). Project leader Jadranka Šepić will communicate with the UKF and HRZZ officers, and will be responsible for the scientific and professional content of the deliverables going out of the project. Cost control and monitoring procedures for the project will be set up within the normal cost control mechanism used by the IOF for all internal and external projects. All relevant documents and materials will be stored on the project web pages which will be hosted by the IOF, so the management of the project activities will be transparent and traceable for potential users and for the HRZZ and UKF.

Coordination between all scientists and institutions on the project will be handled by the project leader.

A special effort will be given to the human potential, increasing the capacities in operational oceanography through the employment of one postdoctoral researcher and involvement of several doctoral students on the project.

Kick-off meeting will be organized in month 1 of the project at the IOF, while final project

meeting will be organized in the last months of the project, collocated with the stakeholder workshop.

The project leader will be responsible for dissemination of the project products to the relevant scientific and professional communities, potential users, agencies and international programmes.

Matching fund will be secured from the resources of participating institutions, as the project researches participate in various national and international projects relevant to the MESSI project.

h. Literature references

Bernard, E. N., Mofjeld, H. O., Titov, V., Synolakis, C. E. & González, F. I., 2006. Tsunami: scientific frontiers mitigation, forecasting and policy implications. *Phylosophical transactions of the royal society*, 364, 1989-2006.

Donn, W. L., Ewing, M., 1956. Stokes' edge waves in Lake Michigan. *Science*, 124, 1238–1242..

Hibiya, T., Kajiura, K., 1982. Origin of the Abiki phenomenon (a kind of seiche) in Nagasaki Bay. *Journal of the Oceanographical Society of Japan*, 38, 172–182.

Horvath, K, Vilibić, I., 2014. Atmospheric mesoscale conditions during the Boothbay meteotsunami: a numerical sensitivity study using a high-resolution mesoscale model. *Natural Hazards*, 74, 55-74.

Jansà, A., Monserrat, S., Gomis, D., 2007. The rissaga of 15 June 2006 in Ciutadella (Menorca), a meteorological tsunami. *Advances in Geosciences*, 12, 1−4.

Marcos, M., Monserrat, S., Medina, R., Orfila, A., Olabarrieta, M., 2009. External forcing of meteorological tsunamis at the coast of the Balearic Islands. *Physics and Chemistry of the Earth,* 34, 971−988.

Monserrat, S., Vilibić, I., Rabinovich, A. B., 2006. Meteotsunamis: atmospherically induced destructive ocean waves in the tsunami frequency band. *Natural Hazards and Earth System Sciences*, 6, 1035−1051.

Paulatto, M., Pinat, T., Romanelli, F., 2007. Tsunami hazard scenarios in the Adriatic Sea domain. *Natural Hazards and Earth System Sciences*, 7, 309-325.

Paxton, C.H., Sobien, D.A., 1998. Resonant interaction between an atmospheric gravity wave and shallow water wave along Florida's west coast. *Bulletin of the American Meteorological Society*, 79, 2727−2732.

Proudman, J., 1929. The effects on the sea of changes in atmospheric pressure. *Geophysical Supplement to Monthly Notices of the Royal Astronomical Society,* 2 (4), 197–209.

Rabinovich, A.B., 2009. Seiches and harbour oscillations. In: *Handbook of Coastal and Ocean Engineering*. Ed. Kim, Y.C., World Scientific Publishing Company, Toh Tuck Link, Singapore, 193−236.

Rabinovich A.B., Vilibić, I., Tinti, S., 2009. Meteorological tsunamis: Atmospherically induced destructive ocean waves in the tsunami frequency band. *Physics of the Chemistry of the*

Earth, 34, 891-893.

Renault, L., Vizoso, G., Jansá, A., Wilkin, J., Tintore, J., 2011. Toward the predictability of meteotsunamis in the Balearic Sea using regional nested atmosphere and ocean models. *Geophysical Research Letters,* 38, L10601, doi: 10.1029/2011GL047361.

Sallanger, A.H. Jr, List, J.H., Gelfenbaum, G., Stumpf, R.P., Hansen, M., 1995. Large wave at Daytona Beach, Florida, explained as a squall-line surge. *Journal of Coastal Research*, 11, 1383−1388.

Skamarock, W. C., Klemp, J. B., 2008. A time-split nonhydrostatic atmospheric model for weather research and forecasting applications. *Journal of Computational Physics*, 227, 3465-3485.

Šepić, J., Vilibić, I., 2011. The development and implementation of a real-time meteotsunami warning network for the Adriatic Sea. *Natural Hazards and Earth System Sciences*, 11, 83−91.

Šepić, J., Vilibić, I., Belušić, D., 2009. The source of the 2007 Ist meteotsunami (Adriatic Sea). *Journal of Geophysical Research*, 114, doi: 10.1029/2008JC005092.

Šepić J., Vilibić, I., Rabinovich, A. B., Monserrat, S., 2015. Widespread tsunami-like waves of 23-27 June in the Mediterranean and Black Seas generated by high-altitude atmospheric forcing. *Scientific Reports*, accepted.

Vilbić, I., Šepić, J., 2009. Destructive meteotsunamis along the eastern Adriatic coast: Overview. *Physics and Chemistry of the Earth,* 34, 904−917.

Vilibić, I., Monserrat, S., Rabinovich, A. B., Mihanović, H., 2008. Numerical modeling of a destructive meteotsunami that occurred on 15 June 2006 at the Balearic Islands. *Pure and Applied Geophysics,* 165, 2169−2195.

Vilibić, I., Monserrat, S., Rabinovich, A.B., 2014. Meteorological tsunamis on the US East Coast and in other regions of the World Ocean, *Natural Hazards*, 74, 1-9.

Vučetić, T., Vilibić, I., Tinti, S., Maramai, A., 2009. The great Adriatic flood of 21 June 1978 revisited: an overview of the reports. *Physics and Chemistry of the Earth*, 34, 894–903.

Wang, X., Li, K., Yu, Z., Wu, J., 1987. Statistical characteristics of seiches in Longkou Harbour. *Journal of Physical Oceanography*, 17, 1963−1966.

5. Work plan and timetable of the project

Word count: 1609

(max. *1500 words, add word count)*

a. Milestones (what and when is planned to be done)

The main objective of the MESSI project is to build a reliable prototype of a meteotsunami warning system, using knowledge acquired from analysis of historical destructive events, whilst based on real-time measurements, operational atmosphere and ocean modelling and real time decision-making process. The proposed objective will be achieved through 9 modular tasks. These are:

Task 1. Assessment of historical Adriatic meteotsunamis

The most prominent and devastating historical Adriatic meteotsunamis (the Ist meteotsunami of 22 August 2007, Mali Lošinj meteotsunami of 15 August 2008, and the middle Adriatic meteotsunami of 24-25 June 2014) will be investigated using available atmospheric data and tide-gauge records both from Croatian and Italian Adriatic coast. Historical events will be reproduced with state-of-the art numerical ocean (ROMS, SELFE-SCHISM, IOS meteotsunami model) and weather (Aladin/HR resolution 1-8 km, WRF-ARF) models. Atmospheric waves are more common than meteotsunami since only rare events generate a meteotsunami. The ability of the meteorological models to generate the atmospheric waves should be verified. Applicability of different numerical models will be assessed, and models will be fine-tuned with respect to the in situ and remote (satellite) observations.

Milestone 1. Historical meteotsunamis revaluated and reproduced (month 8).

Milestone 2. Numerical models assessed and fine tuned (month 12).

Task 2. Design and construct a meteotsunami monitoring station prototype

A prototype of meteotsunami monitoring station will be build, requiring non-standard approach and setup. Two station prototypes will be created by the IOF engineers: atmospheric station, and ocean-atmospheric station which will be further equipped with the sea level sensor. The OGS engineers, experienced in different operational oceanography and technological projects, will provide an active support. A special software for storing and sending data and performing rapid detection of meteotsunami favourable conditions will be developed as well.

Milestone 3. Meteotsunami monitoring station prototypes built and ready to use (month 12).

Task 3. Installation of a meteotsunami research and warning network

Meteotsunami monitoring stations will be installed at the selected eastern (Vela Luka, Vis, Stari Grad, Palagruža, Šolta, Svetac) and western middle Adriatic locations (Tremiti, Ortona, Vieste). Bottom pressure recorders will be installed at the open sea. Installations of stations at Italian territory will be organized by the project Co-PI. Locations of stations will be chosen to achieve three main goals: (i) obtaining sea level and air pressure measurements at the most endangered locations; (ii) obtaining atmospheric measurements from locations far-removed from the shore, allowing for a timely warning; (iii) tracking sea level and atmospheric pressure parameters along propagation and generation route of a meteotsunami - enabling relevant scientific research publishable in top journals. Real-time communication and data delivery from stations to the central processing station and project database will be established. Automatic algorithms for estimation of atmospheric disturbance speed and direction will be developed and tested. Preliminary analysis of collected data, including preliminary quantification of air pressure and sea level relationship, will be done as well.

Milestone 4. Meteotsunami research and warning network operational (month 15).

Milestone 5. Preliminary analysis of data collected by the network (month 21).

Task 4. Estimate occurrence rate of meteotsunamis in the past, present and future climate

Favourable synoptic conditions for appearance of meteotsunamigenic air pressure disturbances will be determined using ERA-Interim atmospheric reanalysis available through European Centre for Medium-Range Weather Forecast (ECMWF) web portal. Using state-of-the art pattern recognition methods (e.g. neural networks), favourable synoptic conditions will be extracted from past and future climate simulations, and statistics of occurrence of meteotsunamigenic conditions estimated. Using historic tide gauge records occurrence rate of the past Adriatic meteotsunamis will be verified.

Milestone 6. Favourable synoptic conditions determined (month 15).

Milestone 7. Frequency of meteotsunami events in past and future determined from atmospheric reanalysis and climate models (month 21).

Task 5. Mapping of meteotsunami hazard and creation of meteotsunami warning matrices.

Historic meteotsunami data and numerical ocean model outputs will be used to map meteotsunami hazard over the Adriatic coast. Expected sea level rise and estimated statistics of meteotsunami favourable conditions in future climates will be taken into account, and meteotsunami hazard maps for future climate will be created as well. Maps will include spatial distribution of maximum expected sea surface heights and currents. Meteotsunami warning matrices, associated to presence of meteotsunamigenic conditions and to rate of change, dispersiveness, speed and direction of air pressure disturbance will be created for the most endangered areas.

Milestone 8. Maps of present and future meteotsunami hazard created (month 16).

Milestone 9. Meteotsunami warning matrices created for the most endangered areas (month 20).

Task 6. Setup of operational atmospheric and ocean models

ALADIN/HR mesoscale numerical model will be run operationally at the Meteorological and Hydrological Service. Automatic procedures for recognition of meteotsunami favourable synoptic conditions will be created. A high-resolution non-hydrostatic research ALADIN will be run operationally. Air pressure and wind fields from the ALADIN/HR(NH) model will be used daily to force high-resolution non-structured ocean numerical model SCHISM or ROMS. Sea levels and currents will be obtained from the ocean model.

Milestone 10. An operational atmospheric and ocean model fields available and automatically analyzed in real time for extraction of meteotsunami favourable conditions (month 18).

Task 7. Set up a prototype of warning system

A warning system based on real-time air pressure measurements and results of atmospheric and ocean numerical model will be created in close collaboration with the project Co-PI. Procedures and algorithms for determining a level of danger will be developed. All data will be collected at pre-described time intervals by the central processing unit: daily synoptic conditions, daily simulations of coupled ocean-atmospheric model, measured atmospheric and ocean data. A station which detects a possibly dangerous atmospheric disturbance will notify other stations to enter a burst mode during which continuous data acquisition,

processing and assessing of a meteotsunami threat will be conducted by the central processing unit.

Milestone 11. A prototype of meteotsunami warning system established (month 20).

Task 8. Create dynamic web content with a meteotsunami hazard forecast

Project web pages will be developed at the beginning and updated throughout the project. At its final stage, project web pages will contain real-time data from the warning and research network, relevant outputs of numerical atmospheric and ocean models, meteotsunami warning matrices, and estimates of meteotsunami hazard. The database containing all measurements, and results of numerical simulations will be developed and maintained as well.

Milestone 12. Dynamic web content with meteotsunami danger warning created (month 22).

Task 9. Dissemination towards potential users.

Dissemination of project results will be directed towards: (i) national government authorities, operational services and civil protection agencies, (ii) local authorities, (iii) international programmes and projects. The first and the second will be realized through meetings throughout the project and through organization of a stakeholder workshop at the end of the project. The third will be done through targeted presentations at annual and general meetings of international scientific programmes and projects. Results will be presented at scientific conferences, and at least three scientific papers will be submitted. We'll give lectures for local community, paying a special attention to lectures for children. Project will also be presented through other science outreach activities (e.g., the Festival of Science), and through different public media. Research topics will be offered to masters students of University of Split for doing their thesis work.

Milestone 13. The information on project results and application possibilities will be systematically disseminated to potential users (months 12-24).

Milestone 14. Stakeholder workshop organized (month 24).

b. Key performance indicators (quantitative development towards key project goals – half-yearly achievements). Please show KPI cumulatively, i.e. always add KPI from previous period to new period. E.g. if your KPI in 1st half year is 3 in vivo experiments, in 2nd half-year another 6 in vivo experiments, your KPI in 2nd half-year is 9.

Key performance indicator	1st half-year	2nd half-year	3rd half-year	4th half-year
Number of historical Adriatic meteotsunamis assessed	2	4	4	4
Numerical ocean and atmospheric models set up		1	2	4
Meteotsunami monitoring station prototype built		1	1	1
Meteotsunami research and warning network installed			1	1

Prototype of a meteotsunami warning system set up				1
Number of peer-review research papers submitted		1	2	3
Number of targeted presentations and public lectures		1	3	5
Number of international project proposals submitted, with funding for the IOF equal or higher than the UKF funding for the MESSI project		1	1	2
Special session on meteotsunamis within IMMCM conference held			1	1

c. Assessment of the project risks

Project risks might be related to:

(1) *building of meteotsunami monitoring station prototype and installation of the network*. The **IOF** engineer team members led by **Vlado Dadić** have an extensive experience in development and installation of measuring instruments, real-time data delivery, and visualization of outputs on web pages (e.g. http://jadran.izor.hr/hazadr/). Engineers from the **OGS** are highly experienced in development of technological oceanographic solutions, and will be able to provide additional help. Some of the meteotsunami network instruments are already operative, including: (i) three high-quality microbarograph stations, sending data in real time (http://jadran.izor.hr/barograf/index_eng.htm); and (ii) several Croatian and Italian tide gauges.

(2) *analysis of results and setup of oceanographic and atmospheric models*. Due to competences and strengths of project team, the risk is low. PI and several of the project team members (**Ivica Vilibić, Alexander Rabinovich, Sebastian Monesserat**) are among leading world scientists in research of meteorological tsunamis. Their previous successful cooperation resulted in a number of high-quality publications, an international meteotsunami project, two special issues on meteotsunamis in scientific journals, and a published book. **Miroslav Gačić** is an experienced researcher who recently resolved several of the long standing Adriatic oceanography questions. **Martina Tudor** has the experience in operational NWP model ALADIN inclding the development of the high resolution operational forecast and **Kristian Horvath** has an expertise in simulation atmospheric processes using the research model WRF-ARF. **Gordana Beg Paklar** is a leading numerical oceanographic modeller in Croatia. Finally, three Ph.D. students and one post-doc (fully employed by the project) will analyse results and run numerical models, gaining valuable knowledge and experience while doing so.

6. Partnership, owner structure, IPR and obligations

Word count: 554

(m*ax. 500 words, add word count)*

a. Collaborations and partnership

The **Institute of oceanography and Fisheries (IOF)** is a leading project organisation and **Jadranka Šepić** is the principal investigator, and will be responsible for management and administration of the project. Experienced **IOF** team led by **Vlado Dadić** and **Damir Ivanković** will built a prototype of a meteotsunami warning station and install the warning network. The **IOF** team participated in a number of similar projects (e.g. Adricosm,

SeaDataNet, NASCUM, HAZADR, NEURAL, etc.). **One postdoctoral researcher** will be employed on the project to create necessary procedures and algorithms for warning network, and to do data analysis. Numerical ocean modelling will be carried out at the **IOF** by a team of **two PhD students** supervised by **Gordana Beg Paklar** and **Jadranka Šepić**, who have substantial experience and track-record on that topic. **Hrvoje Kalinić** will be in charge of extracting meteotsunamigenic patterns from past and future climate simulations with use of neural networks, as that is his area of expertise. **Ivica Vilibić** will overlook the project progress, help with design of the network and assessment of data.

Co-PI **Miroslav Gačić** and **Vedrana Kovačević** from the **Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)** will organize and lead installation of meteotsunami stations in Italy, help obtain Italian data necessary for assessment of historical meteotsunamis, as well as real-time sea level data from the existing Italian tide gauge stations in the middle Adriatic. They will also help design warning network, and assess data. The **OGS engineer team** will provide expertise on development of monitoring stations.

The **Meteorological and Hydrological Service (MHS)** of the Republic of Croatia is national operational weather forecasting service, issuing 24/7 day weather forecasts. They run ALADIN/HR operational model four times a day and ALADIN/HR(NH) is currently run once per day. **Martina Tudor** will be responsible for providing outputs of the model. **Kristian Horvath** will run high-resolution non-hydrostatic research WRF-ARW model nested into ALADIN model and capable of reproducing atmospheric gravity waves.

Sebastian Monserrat from the **University of the Balearic Islands** and **Alexander Rabinovich** from the **International Tsunami Research, Inc.** are among leading world experts in meteotsunami research and will provide advice, expertise and knowledge, and help in assessment of scientific results.

b. Owner structure, obligations and intellectual property rights related to the project

The IPR will be in accordance with the UKF Grant Agreement.

B. Financial plan

Please provide the financial plan on separate spreadsheet table (Research Cooperability Program, Crossing Borders Grant – Financial plan.xls 2015). Provide here just totals.

Description/ Source	Year 1	Year 2	**Total in 2 years**
Research Cooperability Program, Crossing borders /UKF	870235	483059	**1353294**
Beneficiary funding / Institute of Oceanography and Fisheries: cash at least 5 % from Interreg Central Europe project	100100	100000	**200100**
Other Croatian public-sector funding / Meteorological and Hydrological Service	50000	50000	**100000**
Other Croatian private funding / please insert source			
Foreign public sector funding / Istituto Nazionale di Oceanografia e di Geofisica Sperimentale	76500	76500	**153000**
Foreign private funding / please insert source			
TOTAL UKF + matching funding (HRK)	**1096835**	**709559**	**1806394**

C. Additional information

7. Suggested evaluators (optional).

Please note that the Steering Committee has no obligations concerning this suggestion. The Steering Committee assumes that applicants will not contact any of the suggested persons in connection with this proposal. See Instructions for details about suggested evaluators.

a.Negative list (maximum 3 names with brief justification)

b.Positive list (minimum 5 names with e-mails and addresses)

1. Eddie Bernard, eddie.bernard@comcast.net, Pacific Marine Environmental Laboratory, NOAA, Seattle, USA.
2. Philip Woodworth, plw@noc.ac.uk, National Oceanography Centre, Liverpool, UK.
3. Danijel Belušić, Danijel.Belusic@monash.edu, Monash University, Australia
4. Marta Marcos, marta.marcos@uib.es, Mediterranean Institute for Advanced Studies, Esporles, Spain
5. Kenji Tanaka, k.tanaka.pb@cc.it-hiroshima.ac.jp, Hiroshima Institute of Technology, Hiroshima, Japan.

D. Annexes

8. CV of the main applicant and co-applicant (project leader and co-leader); Please list names of personnel whose CV's are attached to project proposal

(submitted on the enclosed official Research Cooperability Program – Curriculum Vitae Form 2015)

Jadranka Šepić, PI

Miroslav Gačić, Co-PI

9. Baseline Survey on Research Cooperability Program, Crossing Borders Grant (separate form)

(submitted on the enclosed official Research Cooperability Program, Crossing Borders Grant – Baseline Survey Form 2015)

Attached

10. Please list names, titles and institutions of persons who wrote recommendation letters for the main applicant (project leader)

(max. 1 page each):

Professor Stefano Tinti, DIFA; University of Bologna

Richard E. Thomson, Ph.D., F.R.S.C., F.A.G.U., Institute of Ocean Sciences, Fisheries and Oceans Canada

11. Please list names of a Beneficiary (Administering organization) and Partner Organization(s), which have provided Letters of Commitment

(max. 2 pages each):

1. Institute of Oceanography and Fisheries, Šetalište I. Meštrovića 63, HR-21000 Split, Croatia, URL: http://www.izor.hr, OIB: 86235185568, contact: Jadranka Šepić, sepic@izor.hr
2. Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Borgo Grotta Gigante

42/C, 34010 Sgonico (TS), Italia, URL: http://www.ogs.trieste.it/, contact: Miro Gačić, mgacic@ogs.trieste.it

3. Meteorological and Hydrological Service, Grič 3, HR-10000 Zagreb, Croatia, URL: http://meteo.hr, contact: Kristian Horvath, horvath@cirus.dhz.hr
4. University of the Balearic Islands, Ctra.Valldemossa, km. 7.5, Palma de Mallorca, Spain, URL: http://www.uib.eu/, contact: Sebastian Monserrat, s.monserrat@uib.es
5. International Tsunami Research, Inc., 11321 Chalet Road, Sidney, British Columbia, Canada V8L 5M1, URL: http://itrinc.ca, contact: Alexander B. Rabinovich, a.b.rabinovich@gmail.com

12. Please list attached financial guarantees and legal agreements (Letters of Financial Commitment):

1. Letter of Financial Commitment - Institute of Oceanography and Fisheries, Split, Croatia
2. Letter of Financial Commitment - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Triste, Italy
3. Letter of Financial Commitment - Meteorological and Hydrological Service, Zagreb, Croatia
4. Letter of Financial Commitment - University of the Balearic Islands, Palma de Mallorca, Spain
5. Letter of Financial Commitment - International Tsunami Research, Inc., Sidney, British Columbia, Canada

13. Please list enclosed other relevant annexes

E. Consent of project leader (main applicant) to ensure responsible conduct of research and scientific integrity

The Unity through Knowledge Fund (UKF will take into consideration only those research project applications that conform to the highest international standards of scientific integrity and personal and institutional responsibility in conduct of research and comply with positive regulations of the Republic of Croatia.

Responsible person of organisation and project leader guarantee the implementation and conformity of the research with the stated above in accordance with the UKF Grant Agreement reached with the MSES and Croatian Science Foundation, as well as the project leader by signing both the Project Proposal Form and the Consent of project leader document.

Only research that meets all the listed criteria of scientific integrity, collegiality, protection of human subjects, protection and care of research animals, integrity toward institution, and social responsibility is considered responsibly conducted research.

1. Scientific integrity

a) All researchers on the project are competent in the field of research, as validly substantiated by relevant evidence (letters of reference and curriculum vitae) whose authenticity and validity is guaranteed by the signature of the project leader.

b) The right to research results, intellectual, proprietary and other rights to the amount or to the relative proportion in which the Ministry funds or participates in funding the research project shall be regulated by the Contract.

c) Analysis of the data resulting from the project is correct and in accordance with scientific methodology.

d) Research results in whatever form presented consistently correspond to the research conducted and there is no fabrication, correction or plagiarizing of data, results, ideas, procedures or words in the procedures of proposing, conducting, revising or presenting the research. Research idea and aim stated in the project application are the original work and do not contain in whole or in any part unauthorized appropriation of another person's ideas, data, results or words.

e) Only original copyright work in direct connection with the research shall be considered a research report resulting from the research/project, which excludes any form of scientific misconduct, such as auto-plagiarizing and duplicate publications.

YES / NO, I have read, understood, and accepted all stated criteria on scientific integrity.

2. Collegiality

a) Authors and co-authors of all research reports and published work resulting from the research/project fulfil the following criteria: (i) development of research idea and substantial contribution to the concept and design of the research; (ii) data collection, data analysis, or interpretation of research results; and (iii) writing and designing a research report and published work or providing critical revision and final approval of the research report and published work. Author should fulfil at least one condition from each (i), (ii), or (iii) category.

b) Exchange of information is free, as is use of equipment which is publicly funded.

c) Mentor relationships arising from the research/project and respective obligations of the mentors and mentees rest on mutual respect and agreement on intellectual ownership of results, procedures, patents, and similar.

YES / NO, I have read, understood, and accepted all stated criteria on collegiality.

3. Protection of human subjects

Where possible, a relevant body – institutional ethics committees or similar, should approve every research/project – where adherence to all relevant international and local laws, regulations, and directives on protection of human subjects is required. In addition to the approvals from competent ethics committees, by this Consent the project leader on the project/research guarantees as follows:

a) voluntary participation of all human subjects

b) informed consent from human subjects

c) confidentiality, secrecy, and anonymity of information on human subjects

d) cost/benefit ratio favourable to human subjects

YES / NO, I have read, understood, and accepted all stated criteria on protection of human subjects.

4. Protection/Care of research animals

If experimental animals are used in the research/project, the project leader guarantees the strict abidance to the Animal Protection Act (Narodne novine, No. 135/06) and explicitly describes and confirms the abidance to the Act along with all relevant documentation on procedures, protocols, institution, animal enclosures, manner, and competency in keeping live experimental animals and certificates of competent institutions (ethics committees, authorized veterinarian, and similar).

YES / NO, I have read, understood, and accepted all stated criteria on protection/care of research animals.

5. Integrity in relation to institution

By signing this Consent, the project leaders guarantees as follows:

a) absence of financial or proprietary conflict of interest and absence of conflict of interest in relation to the parent institution

b) absence of conflict of loyalty/commitment to parent institution while conducting the research/project, absence of research conducted for private or public institution the scope of which is broader than the scope of regular work or completely prevents the project leader from performing regular work;

c) familiarity with rules/directions/statutes of the institution proposed as the research site

YES / NO, I have read, understood, and accepted all stated criteria on integrity in relation to institution.

6. Social Responsibility

By signing this Consent, the project leader assumes the social responsibility and:

a) guarantees adherence to the highest ecological norms and provides a detailed description of environmental (and social) impact and treatment of toxic and other waste produced during research

b) guarantees that all procedures and materials used in the research/project are pursuant to the positive regulations of the Republic of Croatia

YES / NO, I have read, understood, and accepted all stated criteria on social responsibility.

I, Jadranka Šepić, the project leader, understand all instructions, obligations, and responsibilities relating to public funding of the proposed research project and hereby oblige myself to conduct the proposed research/project adhering to the highest professional standards of which only some are stated above as well as to all positive legislation, rules, and regulations relating to the area and field and subjects/objects of the stated research.

By signing this agreement and writing YES under the criteria above I confirm that I have read, understood, and accepted everything stated above and that the proposed research/project is in accordance with the

obligations, duties, and responsibilities stated, for which I accept full moral, material, and criminal liability.

Main applicant – Project leader

Name: Jadranka Šepić Signature: Date: 12 June 2015

F. Project applicants' signatures

By signing this proposal I confirm that:

1. YES / NO, I have read, understood, and accepted '**UKF Guidelines and Procedures - Second Science and Technology Project (STP II) 2015'**.
2. YES / NO, The proposed research project is in accordance with the obligations, duties, and responsibilities stated in '**UKF Guidelines and Procedures - Second Science and Technology Project (STP II) 2015'**.
3. YES / NO, I will notify the UKF Secretariat if there are changes to named participant(s) listed in Part A3 after the submission of this Proposal.
4. YES / NO, I will notify the UKF Secretariat if I request support for this research from other organizations or if additional support is granted.
5. YES / NO, To the best of my knowledge, all details provided in this application form and in any supporting documentation are true and complete and no information is false or misleading
6. YES / NO, By submitting this project proposal for UKF funding (even in case my project proposal is not accepted for financing by UKF) I accept to provide the information on the project to the UKF when requested and to be available for subsequent updates within the limits of reasonability for the purpose of evaluating the impact of the program.

Main applicant – Project leader

Name: Jadranka Šepić Signature: ____ Date: 12 June 2015

Co-applicant – Project co-leader

Name: Miroslav Gačić Signature: _____ Date: 12 June 2015

G. Signature of responsible person of Beneficiary (Administering organization)

Notice: The grant will be awarded to a Beneficiary (legal entity). This organization expresses its support with the separate Letter of Commitment signed by the authorized person of an organization. In the case the main applicant is engaged at the organization different from a Beneficiary, that organization should also express its support with separate Letter of Commitment signed by the authorized person of the organization.

By signing this proposal I certify that:

1. YES / NO, My organization supports this Proposal and if successful will provide basic facilities and the items listed in the budget and in the separate letter of commitment.
2. YES / NO, My organization is prepared to have the project carried out under the circumstances set out in this Proposal and in accordance with the **'UKF Guidelines and Procedures - Second Science and Technology Project (STP II) 2015'**, including financial administration, employment of co-workers and reporting according to the law.
3. YES / NO, My organization will undertake all necessary responsibilities and actions concerning the employment of the proposed project's co-workers according to the law.
4. YES / NO, My organization will give the project leader the independence to manage the research project. Independence implies that the project leader has the authority to:
   - apply for funding independently of senior colleagues
   - manage the research funding for the project and make appropriate resource allocation decisions
   - publish as senior author and invite as co-authors only those who have contributed substantially to the reported work
   - supervise team members, including research students or others
   - have access to reasonable space and facilities for conducting the research
5. YES / NO, If they are already employed, the amount of time that the researcher(s) will be devoting to the project is appropriate to existing workloads.
6. YES / NO, My organization will notify the UKF about all conflicts of interest relating to parties involved in or associated with this proposal which may arise after the submission of this proposal.
7. YES / NO, To the best of my knowledge, all details provided in this application form and in any supporting documentation are true and complete and no information is false or misleading.

Name and signature of Beneficiary's (Administering organization's) responsible person:

Legal Entity: Institute of Oceanography and Fisheries

Name and position:	Signature:	Date:
Nedo Vrgoč, director	_____	12 June 2015