Project Title: Towards a meteotsunami warning system along the U.S. coastline (TMEWS)

Federal Agency Name(s): National Weather Service (NWS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce

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REQUIRED SIGNATURES

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Abstract page

Project Title: Towards a meteotsunami warning system along the U.S. coastline (TMEWS)

Project team members: Ivica Vilibić (PI), Sebastian Monserrat (Co-PI), Vlado Dadić, Isaac Fine, Kristian Horvath, Damir Ivanković, Marta Marcos, Hrvoje Mihanović, Stipe Muslim, Alexander Rabinovich, Nataša Strelec Mahović, Jadranka Šepić, TBD (postdoc), TBD (research assistant)

Total proposed costs: $349,987

Budget period: June 1, 2011 – February 28, 2013

Abstract: Meteotsunamis or meteorological tsunamis, atmospherically induced destructive ocean waves in the tsunami frequency band, are found to affect coasts in a damaging way in a number of places in the World Ocean. These destructive waves are not related to any seismic activity, volcanic explosions, submarine landslides or meteorite impacts but to atmospheric forcing: atmospheric gravity waves, pressure jumps, frontal passages, squalls, tropical cyclones, or similar. Meteotsunami waves has been observed and sporadically studied along the U.S. coastline, but no comprehensive and interdisciplinary studies have been performed, especially on the source of meteotsunami waves. Therefore, the first objective of the TMEWS project is to improve the knowledge on the sources and atmospheric characteristics of the U.S. meteotsunamis, its interaction with coastal waters and amplification when approaching and hitting the shoreline. Historical U.S. meteotsunamis, such as Daytona Beach FL in 1992 and Booth Bay MA in 2008, will be investigated by analyzing all available atmospheric and ocean data, and by reproducing of the events with atmospheric and ocean numerical models. The acquired knowledge will be used for the assessment of the processes, parameters and variables that can be used in a timely detection of a meteotsunami. An assessment of the NWS/NOAA observing facilities will be performed, and the applicability and necessary modifications will be proposed in order to fulfill the requirements for the timely detection of a meteotsunami. The final objective of the TMEWS project is to develop decision meteotsunami matrix, associated operational protocols and procedures, and flowchart of the meteotsunami warning system, from its detection on the observational network towards the issuing of meteotsunami alerts. Apart the overall objective of the TMEWS project, to build an efficient meteotsunami warning system, the project realization will impact different groups of users (scientists, coastal engineers, coastal management authorities, etc.) and raise public awareness in high-risk meteotsunami areas, resulting in an increased safety level of coastal population and in a decreased potential damage on properties, goods and service along the U.S. coastline.

1. State-of-the art and objectives

Overall objective of the project proposal "Towards a meteotsunami warning system along the U.S. coastline (TMEWS)" is to build the procedures and protocols for rising of a meteotsunami warning alerts adoptable the U.S. observing capacities, and based on the meteorological and oceanographic characteristics of historical meteotsunamis observed along the U.S. coastline.

Meteotsunamis or meteorological tsunamis are atmospherically generated destructive long ocean waves occurring over a tsunami frequency band (Rabinovich and Monserrat, 1996, 1998; Monserrat et al., 2006; Šepić and Vilibić, 2011). These oscillations are similar to ordinary tsunami waves and can affect coasts in a similar damaging way, although catastrophic effects related to this type of waves are normally observed only in specific bays and inlets, where the waves can reach high of 6 m and more (Fig. 1, Vilibić and Šepić, 2009). At certain places in the World Ocean, these hazardous sea level oscillations of meteorological origin are observed to occur regularly and have specific local names: e.g., 'rissaga' in the Balearic Islands (Gomis et al., 1993), 'abiki' in Nagasaki Bay (Hibiya and Kajiura, 1982), 'milghuba' in the Maltese Islands (Drago, 2009), 'šćiga' in the Adriatic Sea (Orlić et al., 2010), etc. Meteorological tsunamis have been observed and investigated along the U.S. and Canadian coastlines (Sallenger et al., 1995; Mecking et al., 2009; Thomson et al., 2007, 2009), including the Great Lakes (Ewing et al., 1954; Donn and Balachandran, 1969). Fig. 2 displays the places where meteotsunamis have been observed and investigated.

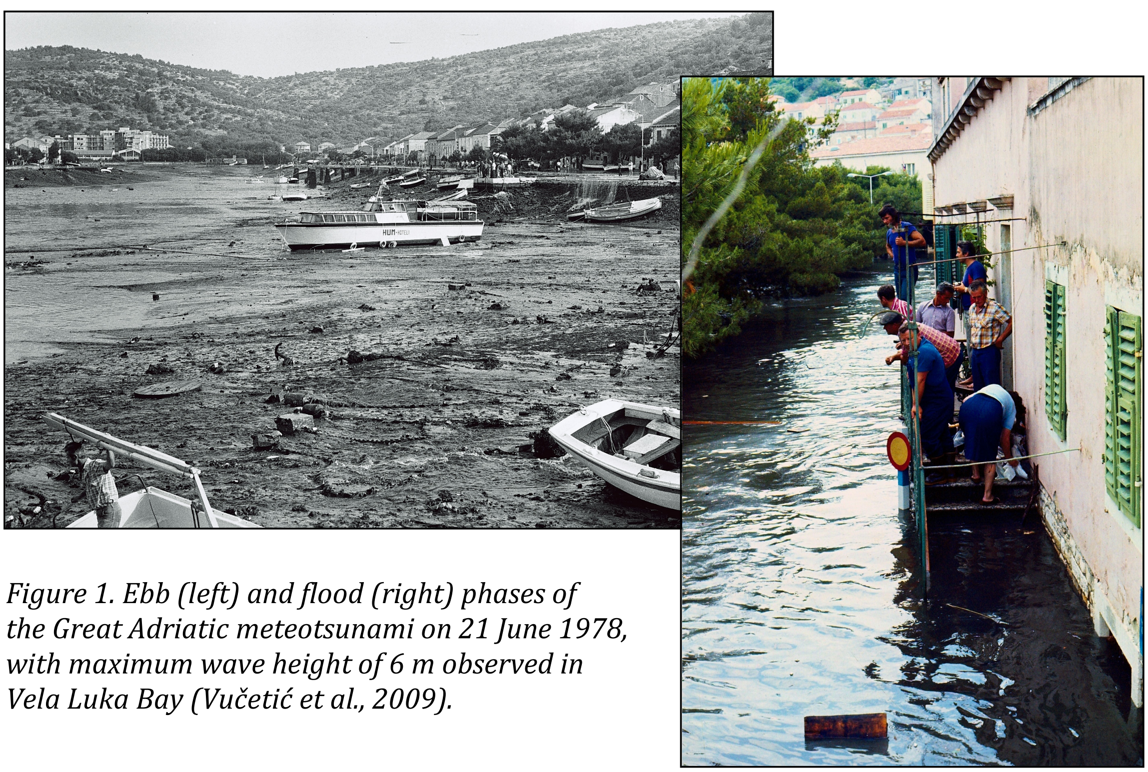

Figure 1. Ebb (left) and flood (right) phases of the Great Adriatic meteotsunami on 21 June 1978, with maximum wave height of 6 m observed in Vela Luka Bay (Vučetić et al., 2009).

Meteotsunamis are generated by traveling atmospheric disturbances, and have several phases necessary for a creation of destructive waves (Monserrat et al., 2006; Rabinovich, 2009): (i) open-ocean energetic and non-dissipative atmospheric disturbances transfers the energy towards the ocean through a resonant process (e.g., through the Proudman resonance – the speed of atmospheric disturbance is equal to the speed of long ocean waves, Proudman, 1929), (ii) generated ocean waves are amplified when shoaling toward the coast, and (iii) incoming ocean waves are being amplified by a coastal resonant process (e.g., harbor resonance, Rabinovich, 2009). All of these components are needed for creation of a destructive meteotsunami.

Due to their relation with atmospheric processes and in particular with air pressure disturbances, meteorological tsunamis could presumably be forecasted more easily and at a lower cost than tsunamis. Meteorological tsunamis are generated by intense, low-dispersive and sharp (one with a high rate of air pressure change, e.g., 5 hPa 10 min^{-1}) air pressure disturbances that can be tracked on the ground (Monserrat and Thorpe, 1992; Vilibić et al., 2008; Thomson et al., 2009; Šepić et al., 2009a; Tanaka, 2010). Such an approach has been used for creation of pilot Adriatic meteotsunami observing network, found to successfully capture meteotsunami events (Šepić and Vilibić, 2011). The pilot network consists of (i) a triangled microbarograph stations with real-time communication towards the centre, (ii) central database for data quality-check and rapid detection algorithms based on estimation of a disturbance intensity, dissipativeness, velocity and direction, and (iii) protocols and meteotsunami decision matrix created for rising of an alert in a future operational meteotsunami warning system. More about the pilot meteotsunami network can be found at http://jadran.izor.hr/barograf/index_eng.htm.

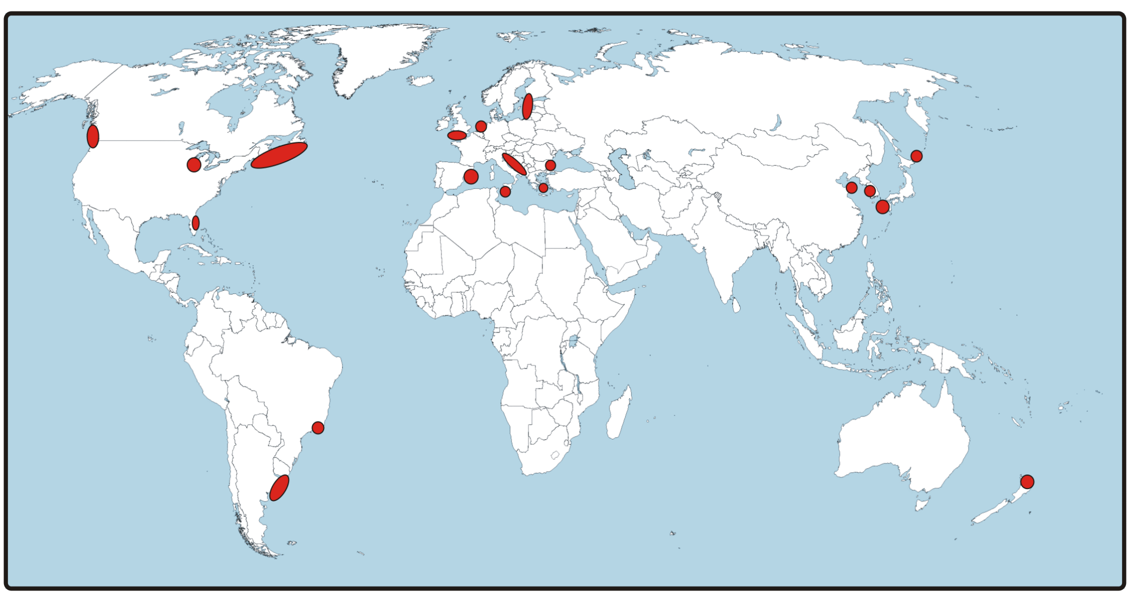

Figure 2. World map of all documented meteotsunami events.

Another feasible approach has been used by the Balearic Meteorological Service (Jansà et al., 2007), which raises a 'rissaga' alert if the synoptic conditions are following the patterns observed during the meteotsunami events. Sea level stations ahead from the most affected area can be used for detection of a meteotsunami (e.g., on the Balearic Islands, Marcos et al., 2009). Moreover, vertical sounding profiles (Vilibić and Šepić, 2009) and satellite images (Belušić and Strelec Mahović, 2009; Vilibić et al., 2010) can be used for detecting favorable conditions for a meteotsunami event, on top of other *in situ* observational systems. Finally, a few meteotsunami events have been reproduced by state-of-the-art mesoscale atmospheric models model (Belušić et al., 2007; Šepić et al., 2009b), improving the knowledge about small-scale processes conductive for generation of a meteotsunami.

All of these approaches will be used when investigating the U.S. meteotsunamis, extracting their common characteristics and assessing them towards the literature and existing systems in the World Ocean. The observed characteristics will be used in definition of the observational systems useful in detection of a meteotsunami, evaluate them versus the observational U.S. meteorological and oceanographic capacities, and define protocols and meteotsunami decision matrix to be tested on the observed and used on the future meteotsunamis along the U.S. coastline.

2. Research plan and timetable of the project

2.1. Project description

The project will fully follow the requests and objectives listed in the Announcement of the funding opportunity. These are: (i) research on the U.S. historical meteotsunamis and identification of the meteotsunami source conditions in the atmosphere and the associated oceanographic conditions, (ii) research on available meteorological and oceanographic observing systems capable for detection of a meteotsunami, including data communication and processing flow requirements, and their validation towards the U.S. observational systems, and (iii) definition of operational protocols and meteotsunami decision matrix to be used in future meteotsunami warning system, altogether tested on a historical U.S. meteotsunami. Accordingly, the project will consist of three tasks, each of them fulfilling one required objective, and each Task will consist of Actions necessary to meet the listed measures in the Announcement.

Detailed breakdown of the work plan (tasks, actions) may be found in the following. Major milestones and timeline of tasks and actions are indicated in the brackets.

Task 1. Investigating the causative forces and pre-cursor environmental conditions conductive to meteotsunami formations

- Action 1.1. Catalogue on historical U.S. meteotsunamis (0-2 months)

The first action is to collect the list of all potential historical U.S. meteotsunamis, apart from the fact that some of them are already known (e.g., Daytona Beach FL in 1992, Booth Bay MA in 2008). However, a number of less dramatic but relevant events should be included as well, and the collaborative work with NOAA and NWS facilities and researchers, plus an assessment of the tsunami catalogues, will be done in order to get as many as potential meteotsunami events.

- Action 1.2. Analysis of weather and ocean conditions during historical meteotsunamis (months 0-7)

The analysis of the weather and ocean conditions will be performed for all catalogued meteotsunamis. The analyses will include the parameters and systems recognized to be useful in the world meteotsunami research studies, such as (i) synoptic conditions during a meteotsunami event (NCEP/NCAR or ECMWF reanalysis fields), (ii) vertical structure and profiles (through the investigations of sounding data available at the University of Wyoming, http://weather.uwyo.edu/upperair/sounding.html), (iii) ground meteorological stations with high-resolution observational possibilities (1 min or less) or charts of enough quality for digitizing and obtaining high-resolution data, (iv) sequential satellite cloud images of high-resolution (Meteosat satellites), (v) meteo and ocean data available in the affected area, and (vi) coastal tide gauges and other stations in the area. Finally, the weather conditions favorable for a meteotsunami in the inter-decadal scale will be examined by extracting characteristic situations from the reanalysis fields.

- Action 1.3. Reproduction of meteotsunami events by atmospheric and ocean numerical models (months 3-8)

Reproduction of the observed meteotsunami source characteristics in the atmosphere will be done by using state-of-the-art Weather Research and Forecast (WRF) mesoscale atmospheric model, used successfully in several meteotsunami studies (Adriatic Sea, Šepić et al., 2009b; East China Sea, Tanaka, 2010). The model will be applied on the most destructive meteotsunami events, in order to get insights to the atmospheric physics underlying the generation and non-dissipative traveling of a ground disturbance. Resonant transfer of the energy towards the ocean, and the interaction of the generated barotropic ocean waves with the ocean topography and coastline will be reproduced by a meteotsunami barotropic model forced by a traveling air pressure disturbance (Vilibić et al., 2004; Šepić et al., 2011). The ocean modeling studies will explore the sensitivity of a coastal area to the meteotsunamis of different intensity, velocity and direction of the generating traveling atmospheric disturbance. The model results will be used for quantification of topographical influence to the generation and amplification of the meteotsunami waves.

- Action 1.4. Explanation of meteotsunami generation and dynamics (months 6-10)

The studies conducted in Actions 1.3 and 1.4 will be thoroughly investigated, in order to acquire common background and source characteristics of a meteotsunami in the atmosphere, which may be useful to monitor by a real-time meteotsunami warning system. This will include (i) common characteristics of the synoptic conditions observed during world meteotsunamis (e.g., inflow of warm and dry air masses in lower troposphere, low Richardson number and instabilities in mid troposphere traveling with speed and direction that may preserve an atmospheric disturbance over long distances, see more in Jansà et al., 2007; Vilibić et al., 2008, 2009, 2010; Vilibić and Šepić, 2009; Šepić et al., 2009c), and (ii) estimation of atmospheric disturbance intensity, dissipativeness, speed, direction and coverage from the ground and satellite data, and atmosphere modeling results (see methodology and examples in Šepić et al., 2009a,b, Vilibić et al., 2010, Šepić and Vilibić, 2011). Ocean measurements and numerical simulation will be assessed for common behavior of the resonantly generated ocean waves, and for the topographical amplification at the most affected area (estimation of a transfer function, amplification and Q-factors of the coastal regions, bays, harbors, see Rabinovich, 2009). Special attention will be paid on extraction of rapid environmental parameters, i.e., of parameters that may be detected and quantified by an observing system with an appropriate latency (e.g., in less than a minute).

Task 2. Defining the observational systems, communications, and processing systems necessary to forecast meteotsunamis

- Action 2.1. Definition of overall standards for real-time detection of a meteotsunami (months 7-11)

Based on the outcome of Action 1.4, i.e., on the common atmospheric and ocean characteristics observed during U.S. historical meteotsunamis, overall standards and protocols for the real-time detection of a meteotsunami will be defined. The standards will include: (i) complete list of atmospheric and ocean parameters (e.g., ground air pressure and wind measurements, satellite measurements) and derived variables which are capable for detection of a meteotsunami, including the recommendations for their temporal and spatial sampling resolution and properties, (ii) the list of the maximum latency in processing different environmental parameters (e.g., latency in estimation of a strength, velocity and direction of a traveling atmospheric disturbance) based on the analyses of historical meteotsunamis, and (iii) the list of communication lines (e.g., GPRS, VHF, satellites) and processing capacities to be used for data acquisition, processing and detecting of a meteotsunami, which will allow for timely decision on eventual rising of a meteotsunami alert to the affected population and relevant agencies.

- Action 2.2. Catalogue of existing meteo and ocean platforms and observing systems, and communication routes capable for detecting a meteotsunami (months 10-15)

Together with the NWS and NOAA researchers and facilities, project team will make the catalogue of all available U.S. measuring systems, their capacities, regional distribution, measured parameters, communication properties, data latency, etc., which may fulfill the requirements given in Action 2.1. This will include (i) ground meteorological stations in coastal areas, (ii) vertical sounding stations, (iii) coastal meteorological and oceanographic stations, (iv) meteo-ocean coastal and open-ocean buoys, (v) satellite facilities, (vi) operational forecasting products (both on synoptic and local scales), and other. Special attention will be given to the availability of operational observing systems in the area where meteotsunamis have been registered.

- <u>Action 2.3. Assessment of U.S. observational meteo and ocean network versus the standards</u> (months 14-17)

Not all of available meteorological and oceanographic observing systems, or some their parts, will be appropriate for use in real-time detection of a meteotsunami. Moreover, not all U.S. coastline is affected equally by meteotsunamis, but some its parts are more exposed due to the complexity of a coastline (wide shelf, bays and harbors with large amplification factors, etc.). Therefore, the assessment of the available U.S. observational systems versus their applicability will take into account the level of meteotsunami risk (taken from Action 3.1), and the level of usefulness of the observing systems (assessment versus different measured parameters) for their eventual use in future meteotsunami warning system. In addition, gaps in observational systems in the areas with highest risk will be identified, and recommendations for their minimization and removal will be proposed.

Task 3. Developing a protocol for issuing meteotsunami warnings

- <u>Action 3.1. Classification of meteotsunami risk areas along the U.S. coast</u> (months 10-13)

Destructive meteotsunamis are generated when several criteria are met together, of which the most important one is bottom topography close to the coastline. The well-intended coastline or the coastline with a broad shelf may have a higher risk for destructive meteotsunamis. Another important delimiter for different meteotsunami risks is the exposure to the meteotsunami sources, which may be different along the U.S. coastline. For example, it is known that tropical depressions and hurricanes may generate meteotsunami waves when traveling offshore (e.g., Mecking et al., 2009). Therefore, the risk to a meteotsunamis will not be the same along the eastern U.S. coastline, prone to the tropical cyclone influences, and along western U.S. coastline, or some their parts. This Action will assess the whole U.S. coastline versus the level for the meteotsunami risk, and the recommendations for monitoring and detection of meteotsunamis in the high-risk areas will be developed in details (Action 2.3).

- <u>Action 3.2. Identification of environmental variables necessary to raise a meteotsunami alarm</u> (months 13-15)

In line with previous actions, the decision on which environmental variables should be included in raising a meteotsunami alarm will be listed. The list will also include derived meteorological variables (e.g., the speed and direction of a traveling atmospheric disturbance) found to detect the meteotsunami generative potential, and ocean variables that detect the arrival of open-ocean meteotsunami waves (e.g., rapid variation of bottom pressure measurements on buoys).

- Action 3.3. Develop a meteotsunami decision matrix and protocols for U.S. coast (months 14-19)

Detailed protocols from detection of a meteotsunami towards the decision on issuing of a meteotsunami warnings will be define. The protocol will include multi-parameter approach, as not all parameters may be available for detecting of a certain meteotsunami in a specific region. The protocol will include two operational modes (i) normal mode, for the areas not affected by meteotsunami favorable conditions and where no atmospheric disturbance and long ocean waves exceeding a certain threshold has been detected, and (ii) burst mode, covering the regions with meteotsunami favorable conditions, when atmospheric disturbance is exceeding a certain threshold in its temporal changes (e.g., 2 hPa over 5 min) over a number of microbarograph stations, and having speed and direction favorable for a meteotsunami generation (e.g., as defined for the middle Adriatic Sea, Šepić and Vilibić, 2011), and when the ocean network detects the long ocean waves over a threshold value. The burst mode will trigger instantaneous investigations of other relevant parameters, e.g., speed of cloud tops from satellite images, if found to be relevant during historical meteotsunami events. All of these procedures, parameters and critical thresholds will be listed in the meteotsunami decision matrix, what will be the basis of the future meteotsunami warning system.

- Action 3.4.Testing the meteotsunami warning system on historical events (months 19-21)

Two real meteotsunami cases will be selected for the testing of the proposed procedures and protocols, to validate the operability of the system. Eventual problems and inappropriate alarms will be documented, including the assessment of the reasons for eventual failures of the systems (problems in data coverage, problems in procedures). Eventual modification of the system will be adopted, and the testing of the system repeated.

3. Project results and outcome

Major outcome and result of the TMEWS project will be fully developed protocols and procedures for the future meteotsunami warning system along the U.S. coastline, based on the analysis of historical meteotsunami events, and adopted to the available and planned meteorological and oceanographic monitoring infrastructure along the U.S. coastline.

Apart from the major outcome, which is precisely defined by the Announcement of the funding opportunity and handled by the project proposal, there will be a number of project results in different research fields. Namely, the project encompasses a research in oceanography, atmospheric sciences, communication, computer and related technical sciences, and the project will have measurable results to be used not by NOAA/NWS only, but by different groups and levels of users. These are:

- A significant increase in knowledge on U.S. meteotsunamis, their sources, generation and dynamics - to be conducted mostly in Task 1 - will be reached through the project. This is not recognized as important and properly investigated in the last 50 years (since the Great Lakes meteotsunamis in the 1950s with human casualties and large damage, Donn and Ewing, 1956; Donn, 1959), but their impact will be increased in the future on top of the projected sea level rise along U.S. coastline (Yin et al., 2009). As the proposed research of the U.S. meteotsunamis will include the analysis of all *in situ* and remote sensing observations and numerical modeling simulations, we intend to disseminate our results to wider scientific community by publishing at least two research papers in high-quality peer-reviewed journals in atmospheric science and oceanography.
- The risk on meteotsunamis will be mapped for the whole U.S. coastline, based on the historical events, atmospheric conditions and bathymetry. A particular attention will be given to the places with the highest meteotsunami risk, where the recommendations for monitoring capacities necessary for timely detecting of a destructive meteotsunami will be advised.
- The research on historical meteotsunamis is highly relevant for the world research of such rare but vigorous events. The knowledge earned on assessing of meteotsunami sources and the dynamics of meteotsunami waves through the ocean may be used for boosting the research in other known hot spot meteotsunami places, and in research of potential meteotsunamis, not recognized or falsely classified in the tsunami catalogues (e.g., the Great Adriatic meteotsunami of June 1978 classified as a four on then Sieberg-Ambraseys tsunami intensity scale was wrongly or not classified in different tsunami catalogues since 2009 (Tinti et al., 2004; Vučetić et al., 2009). Therefore, the acquired knowledge on the U.S. historical meteotsunamis will be used and disseminated towards the various tsunami catalogues.
- The research on assessment of the U.S. observational capacities on detecting potential meteotsunamis, and the associated definitions of protocols, procedures and solutions needed for an operational meteotsunami warning systems, can be used for creation of meteotsunami warning systems in other regions of the world. In fact, the knowledge about source characteristics and dynamics of the world meteotsunamis will be implemented through TMEWS project to the research of U.S. meteotsunamis, and successful realization of this project will allow for opposite knowledge flow – from the U.S. towards the world science.
- Close collaboration between the project team and the NOAA/NWS facilities and scientists will allow for knowledge transfer between an operational agency and a scientific community. As the project team encompasses the researchers with the best world references on the meteotsunami research, their knowledge will be transferred to the U.S. facilities and used for the creation of the meteotsunami warning systems.

4. Project benefits, users and public outreach

4.1. Benefits to the emergency management community

Emergency management community within the U.S. will have direct benefits for the project results, as the project outcome – fully developed procedures and protocols for detection of a meteotsunami and issuing a warning message – will be a basis for developing actions and procedure for raising an awareness, mitigation and protection measures for an area impacted by the hazard. The developed protocols will be based on decision meteotsunami matrix, which will specify a level of meteotsunami danger in an area (e.g., Blue Level – no meteotsunami danger, Green Level - low probability for weak or moderate meteotsunamis, Yellow Level - low probability for strong meteotsunamis or high probability of weak meteotsunamis, Orange Level - low probability for destructive meteotsunamis, or high probability for strong meteotsunamis, Red Level - high probability for destructive meteotsunamis). Once operational within the NWS/NOAA facilities, the meteotsunami warning system will allow the emergency management community to develop contingency and disaster plans for the affected populations and areas, including actions which may lower potential damage on properties, goods and service and prevent human losses and injuries. Such plans should follow and may be merged with already developed and operational plans for tsunamis, which exist from the federal, state, to local levels and communities. For example, harbors/bays are the places exposed to a higher meteotsunami risk if having large amplification factors; in these cases harbor offices may establish appropriate policies to assure that development does not pose unacceptable risks to life or property due to a destructive meteotsunami event or setting modifications to reduce such risks.

Furthermore, a research and environmental impact studies during the construction activities (e.g., harbors) in high-risk meteotsunami area should include a study on amplification of incoming meteotsunami ocean waves, as the incoming meteotsunami waves may become destructive if the harbor has the maximum amplification factor (resonance) at frequencies matching the maximum energy of the incoming tsunami or meteotsunami waves. Our project will result in mapping of high-risk meteotsunami areas along the U.S. coastline as well as increased knowledge about the ocean processes which are favorable for generation of destructive meteotsunamis, and the project results may be used in any assessment study that deals with the coastal and shoreline structures and actions.

4.2. Benefits to the general public

The research activities to be conducted within TMEWS project will significantly increase the knowledge about the U.S. meteotsunami, adding a new component to the existing knowledge on seismic and landslide tsunamis. The knowledge should be disseminated towards the population that are living or working in high-risk meteotsunami area, through a usual communication channels developed for raising awareness on regular tsunamis: various media, targeted courses and seminars, schools, leaflets, documentaries, public lectures or similar. Raising the awareness on a meteotsunami threat will lower the meteotsunami risks, improve the safeness issues, and enable proper and timely actions when high meteotsunami danger will be issued through emergency services for a certain area.

4.3. Other potential users of the project results

International aspects of the TMEWS project results and outcomes are not negligible, as destructive meteotsunamis are endangering a number of coastal regions in the World Ocean (see Fig. 2). Therefore, the concept of a meteotsunami warning systems may be used for creation of similar systems worldwide, disseminating the knowledge towards different research groups and national/international facilities. The users may be different international organizations which are dealing with tsunamis, such as UNESCO Intergovernmental Oceanographic Commission, which has Tsunami Programme set all over the world (http://www.ioc-tsunami.org).

Furthermore, the users will be different research groups, which may build more comprehensive and throughout research on the process on generation and dynamics of meteotsunamis, not covered by the TMEWS project. As the proposed research activities deal with the high-resolution atmosphere and ocean modeling issues, meteotsunami research studies will improve the knowledge on reproduction of small-scale processes in the atmosphere, which may be used in other studies (e.g., climate projection studies are currently downscaling regional climate models to local scales, reproduced by atmosphere and ocean mesoscale models such as WRF and ROMS, and our results may be used in these research studies).

5. Project team members and competences

The TMEWS project will be managed by the Institute of Oceanography and Fisheries (IOF), Split, Croatia, and consist of researchers, staff and experts from different world institutions, being the leaders in the meteotsunami research and possess the majority of the meteotsunami research references.

The project consortium has the experience and references in: (i) the research on meteotsunami sources, both through the analysis of the available meteorological measurements, remote sensing data and through state-of-the-art atmosphere and ocean numerical modeling, (ii), research and knowledge on underlying physics of the phenomenon, done by using and developing theoretical concepts and through data and modeling analyses, (iii) meteorological and ocean observing systems in delayed and real-time operational mode, including data acquisition, processing and archiving in real-time, and tsunami detection systems, and (iv) creation and definition of tsunami and meteotsunami detection and decision protocols, including their testing on real tsunami and meteotsunami cases.

- Institute of Oceanography and Fisheries, Split, Croatia

Institute of Oceanography and Fisheries (IOF, http://www.izor.hr), founded in 1930, is one of the largest and oldest marine scientific institutions along the Adriatic coast as well as the Mediterranean Sea. Scientific activities conducted in the IOF are interdisciplinary, encompassing all aspects of sea exploration: physical, chemical, geological, and biological parameters and fisheries. IOF is national coordination body for the UNESCO Intergovernmental Oceanographic Commission, including their expert groups on tsunamis (ICG NEAMTWS) and data management (IODE), Mediterranean Science Commission (CIESM), different fisheries commissions and other. IOF participated in a number of international projects, including European projects on oceanographic data exchange, standards and protocols (SEA-SEARCH, SEADATANET), and bilateral U.S.-Croatia research projects (EACE, ITHACA) funded by U.S. Federal Agencies and Foundations (NSF). IOF is currently running a number of ocean observing systems, including pilot microbarograph network designed for detection of a destructive meteotsunami events (http://jadran.izor.hr/barograf/index_eng.htm).

IOF project team to be engaged in TMEWS project will include two senior researchers (Ivica Vilibić, Vlado Dadić), one Ph.D. student (Jadranka Šepić), two ocean engineering and computing professionals (Damir Ivanković, Stipe Muslim), one postdoc (TBD) and one expert in oceanography (Hrvoje Mihanović) employed by the project. The team has competences in (i) research of meteotsunami sources, atmosphere-ocean coupling processes and meteotsunami ocean waves dynamics, (ii) ocean monitoring systems (buoys, coastal stations, HF radars), including data flow and processing used in a pilot meteotsunami network, (iii) development of rapid meteotsunami detection and decision algorithms and their application to a monitoring network.

Principal Investigator succinct CV: Ivica Vilibić - Full research scientist, Graduated in 1994, M.Sc. in 1998, Ph.D. in 2002 in the field of physical oceanography. International projects: various FP, Interreg IIIa, bilateral (HR-USA, HR-IT), and national projects. He has published about 60 original peer-reviewed scientific papers, and has presented more than 100 communications to scientific meetings. Reviewer to various high-quality international journals and projects, including *Nature* and *Canadian Foundation for Climate and Atmospheric Sciences*. Membership: AGU, CIESM, IAPSO, national representative in UNESCO IOC ICG-NEAMTWS tsunami group. More to be found in the attached full CV and http://jadran.izor.hr/~vilibic.

- Other project team researchers and experts

Other researchers in the TMEWS project team come from different research and operational organization:

(i) *Mediterraneo de Estudios Avanzados (IMEDEA)*, UIB-CSIC, Balearic Islands, Spain – IMEDEA will be involved in the project trough Sebastian Monserrat, Co-PI, and Marta Marcos, both full time research scientists at the Institute. They will be mainly involved in investigating the general environmental conditions conductive to meteotsunami formations in the USA (Actions 1.1 to 1.4). IMEDEA has major experience in carrying on this specific research in the Mediterranean and most of the results will be extrapolated and adapted to the specific characteristics of the US costs. IMEDEA will also participate in the definition of the overall standards for real-time detection of meteotsunamis at the

US (Action 2.1). Previous experience in defining a similar network at the Balearic Islands will be adapted to specific regions along the U.S. coastline.

The exact terms of IMEDEA participation will be afterwards defined in a "Collaborative Science Agreement" that will be signed between IMEDEA and the leading institution IOF in the case of project approval.

(ii) Alexander Rabinovich and Isaak Fine – experts in the tsunami and meteotsunami research, will be engaged in the TMEWS project, having many references on the world meteotsunamis, also with ocean numerical models and oceanographic instrumentations and systems.

(iii) Kristian Horvath and Nataša Strelec Mahović – expert from operational weather services, and also having knowledge on mesoscale atmospheric models (WRF) and processing of satellite images, of which both are being used in detection and reproduction of atmospheric conditions during various meteotsunami events.

6. Project management

The project will be leaded and managed by the Principal Investigator (PI) Ivica Vilibić and Institute of Oceanography and Fisheries (IOF). IOF and PI will be responsible for managing the coordination of the project team, including authorization of required project reports towards the grant provider and financial aspects of the project. Decision-making body for the project will consist of PI and Co-PI, who will be responsible for proper realization of the project, and for deciding on different demands eventually raised towards the project consortium. Each Task and Action will be executed by a task force appointed for a specific project problem and work to be done. The task forces will include NOAA/NWS staff, which will allow for reaching the objectives listed in the Announcement for this grant.

A kick-off meeting will be organized at the beginning of the project (June 2011). The meeting may be organized in agreement with NOAA/NWS at the Institute of Oceanography and Fisheries, Croatia. Researchers and staff from the NOAA/NWS facilities and centers will participate in the meeting as a user group, in order to discuss and agree on details of the proposed work.

Two more meeting of the whole project consortium together with the NOAA and NWS personnel will be organized in the middle (month 9 to 11) and at the end of the project (month 21). Final project meeting will be merged with a project workshop with tentative title "Workshop on Meteotsunamis and Meteotsunami Warning Systems". Final Workshop will be opened and announced to the wider U.S. and international community, aside the project consortium and NOAA/NWS staff. Middle-term project meeting and workshop may be organized as a side event during Ocean Sciences Meeting, Salt Lake City, February 20-24, 2012.

Aside from the above project meetings, short research visits (up to two months) of project team members to the NOAA/NWS centers will be done throughout the project, depending on the realization of the agreed project tasks and when a request from the project results users (NOAA/NWS) will be raised. Also, the communication line between

TMEWS project consortium and the NOAA/NWS project user group will be opened constantly throughout the project, via email, video-link or voice communication.

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