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ABSTRACTS

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Session 1, Tsunami Instrumentation and Warning Systems

Potential Tsunamigenic Earthquakes in New Zealand

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Tsunami Society International

The earthquakes of 22 February 2011 and of July 24, 2016 near Christchurch in New Zealand, did not appear to have released all their energy. Although the February 22, 2011 event was relatively a mild 6.3 magnitude earthquake, there were at least three factors that made a bad situation worse in the Canterbury Region of South Island. Buildings had been weakened (and not upgraded) by the earlier 7.1 event of September 4, 2010. There were aftershocks of 5.1 on September 8 and of 5.0 on October 19, 2010. Everyone tho,ught that there was no sense of urgency about future events. This was especially painful when the Canterbury Television building collapsed in the February event killing 115. There were two additional effects here - a communications hub was destroyed and the wreckage was a very visible reminder of loss. Subsequently, there was a swarm of earthquakes on December 26, 2010 and on January 21 there was another event described as an aftershock of 5.1 Richter. However, this event was too strong and too far in space and time to be considered as anlso aftershock. Also, a stronger event of about 6.5 was anticipated and if it occurred close enough to the coast and the constricted waters near Wellington (or even offshore) whether it would be capable to generate a local tsunami.

The progression of recent earthquakes in the region, indicates energy transfer to adjacent faults. More earthquakes with local tsunamigenic potential can be expected near South Island with additional adverse impact in the Christchurch and perhaps the in the Wellington area o North Island. Several of the faults that may be present in the area have not been adequately identified. As recently as September 1, 2016, a magnitude 7.2 earthquake occurred off the east coast of North Island. However this quake had a deep focal depth of 99 miles, thus did not pose a threat of tsunami generation or of damage from surface seismic waves. It is believed that another large earthquake similar to the 21 February 2011 event will occur in the near future in New Zealand, perhaps slightly north-west of the 2011 Christchurch event with a magnitude which may range around 6-6.5. Given the nature of the geology of New Zealand, earthquakes along the plate boundary are common, although those of magnitude 7.0 or more are relatively infrequent. The largest recorded earthquake in New Zealand took place in 1855 at Wairapa and had a magnitude of 8.2. Earthquakes of 7.8 magnitude have caused significant damage and some loss of life in 1931, 1929 and 1848. More recently, in July 2009 an earthquake of M7.8 occurred in the South Island's relatively uninhabited west coast region; while the broader region of Canterbury Province experienced major earthquake events in 1929 and 1888. In more modern times, the Canterbury area has been shaken by quakes of M5.9 and M6.7 in 1994. Prehistoric tsunamis have occurred in New Zealand from cascading nuee ardente and pyroclastic volcani flows

Since the region is part of a complex broad plate boundary, the seismicity is relatively low. Because of its proximity to the Alpine fault and the continuous, interactive and large tectonic movements along this great seismic boundary, more earthquakes can be expected.

ADVANCED AND INEXPENSIVE SEA LEVEL MEASUREMENT ACTIVITIES AT THE JOINT RESEARCH CENTRE OF THE EUROPEAN COMMISSION

A. Annunziato. D. Galliano, M. Bavaro, J. Fortuny-Guasch, M. Bonaita

The European Commission Humanitarian Aid and Civil Protection General Directorate (DG-ECHO) aims at saving lives of populations affected by natural disasters and man-made crises; it ensures rapid and effective delivery of EU relief assistance through its two main instruments: humanitarian aid and civil protection. Disaster response both inside and outside the EU requires effective methods to monitor the situation. For this reason the Joint Research Centre, the scientific arm of the European Commission has been requested to support with analytical services and other technical tasks the DG-ECHO and in particular its monitoring centre, named the Emergency Response and Coordination Centre (ERCC).

In this frame, on request of DG-ECHO, JRC developed a relevant activity on Sea Level analysis and measurements, in order to support the Member States of the North East Atlantic and Mediterranean Tsunami Warning System (NEAMTWS) of UNESCO to improve the monitoring capabilities of Tsunami events. The monitoring of sea level becomes also useful in case of important extra tropical stormy events which endanger the European Costs from time to time, mostly during winter periods.

The following activities have been performed and will be described in the report:

- Preliminary results of the installation of a Sea Level Network of Inexpensive Device for Sea Level Measurement (IDSL) in close collaboration with UNESCO/IOC
- In-house development and testing of a new instrument based on a floating differential GPS

The IDSL device is an instrument with the characteristic to be cheap and very effective but its reliability, duration and quality need to be determined and qualified. For this reason a number of experimental campaigns are being conducted and the first year of operation is described in this paper.

The inexpensive GNSS-based sea level monitoring device, recently developed by the JRC, is not yet at the same level of maturity as the IDSL; for this reason a dedicated experimental campaign was organized. The objective of the campaign was to demonstrate the feasibility of using a low cost Differential Global Navigation Satellite System (DGNSS) based sensor to measure and ultimately monitor in real-time the sea level. The results of this initial campaign are shown in the paper.

Some benchmark solutions for the tsunami wave rays and fronts

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For some kinds of bottom topography it is possible to obtain exact analytical formulae which describe wave rays and fronts. For the trivial case of constant depth the trajectories of wave rays will be the straight lines and front lines are presented by circles. Above the sloping bottom, where the depth is proportional to the distance from the straight coastline, the wave rays are the arcs of cycloid. In the case of parabolic bottom relief, when depth is proportional to the squared distance from the straight shoreline, the wave-ray trajectories will be presented by arcs of circles with centers located on this shoreline. Above such a type of bottom relief the initially round-shaped wave front will be a circle through the all propagation process.

These exact formulae must be used for verification of the numerical methods. Moreover, these solutions give possibility to estimate tsunami wave heights within the wave-ray approach. Such estimations for sloping and parabolic bottom reliefs were compared against the height distribution obtained by numerical solution of the shallow-water equations. Both these distributions of the wave height maxima look similar off the shelf zone, where the depth is greater than 200 m.

EARLY PIONEERING RESEARCH IN SUPPORT OF THE TSUNAMI WARNING SYSTEM IN THE PACIFIC OCEAN

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The year 2015 marked the 50th anniversary of operations of the International Tsunami Warning System in the Pacific Ocean - which officially begun in 1965. A previous report in the journal "Science of Tsunami Hazards" described briefly the establishment of early tsunami warning systems by the USA and other countries and the progressive improvements and international cooperative efforts after 1965 by international institutions and governmental organizations, in establishing the International Tsunami Warning System under the auspices of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, with the purpose of mitigating the disaster's impact in the Pacific, but later expanded to include other regions. The present paper provides a brief historical review of the early, pioneering research efforts undertaken mainly in the U.S.A., initially by scientists at the Hawaii Institute of Geophysics of the University of Hawaii, at the U. S. Coast and Geodetic Survey, at the Honolulu Observatory - later renamed Pacific Tsunami Warning Center (PTWC) - at the International Tsunami Information Center (ITIC), at the Joint Tsunami Research Effort (JTRE) and at the later-established Joint Institute of Marine and Atmospheric Research (JIMAR) at the University of Hawaii, in close cooperation with scientists at the Pacific Division of the National Weather Service (NWS) of NOAA. Also, reviewed briefly but to a lesser extent are some of the additional early research projects undertaken by scientists at the U.S. Geological Survey, researchers at different U.S. Universities and at many other national and international governmental and non-governmental institutions.

Keywords: *Tsunami research; Science of Tsunami Hazards; Pacific Tsunami Warning System; International cooperation;*

Tsunami-Prone Source Mechanisms in the Mediterranean Region for Global Tsunami-Modelling System in Joint Research Center (JRC)

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Abstract

Short tsunami arrival times especially require a possible earthquake source parameters data on tectonic features of the faults like strike, dip, rake,and slip in order to minimize real time uncertainty of rupture parameters. Indeed the earthquake parameters available right after an earthquake are preliminary and not enough. Determining which earthquake source parameters would affect the initial height of tsunamis show the sensitivity of the maximum tsunami heights and tsunami time series along the coastal regions. Therefore, tsunami generation models should be performed according to the seismotectonics properties of the different regions. In order to do this, the geometries of the tsunamigenic sources in Mediterranean region have been examined to put in the effect of fault geometry and depths of earthquakes into the European Commission, Joint Research Centre (EU-JRC) global tsunami-modeling system. The system is an integral part of the Global Disasters Alerts and Coordination System (GDACS) which was developed by the EU-JRC.

ECUADOR EARTHQUAKE AND TSUNAMI OF 17 APRIL 2016

George Pararas-Carayannis

Tsunami Society International

Coastal monitoring of Okhotsk Sea using an autonomous mobile robot

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Need of development of modern coastal infrastructure dictates strict requirements to quality of operational and statistical information about the wave modes of a port bay that is impossible without carrying out long high-precision supervision and development of systems of monitoring. Fixed monitoring of the dangerous marine hazards in coastal areas, port bays is of great scientific interest and has the expressed applied aspect connected with safety in zones of marine activities. Results of scientific work shall allow to reduce damage from these phenomena due to the correct planning of business and industrial activity.

In May-June, 2016 at the coast zone of Sakhalin Island were studies of an experimental research of a autonomous mobile robotic (AMR) complex which have allowed to estimate efficiency of the made technical solutions, algorithms of its functioning, and also work of the measuring equipment have been conducted. As the area for carrying out pilot studies with the established set of the equipment the coastline of Sakhalin Island as area with big prospect of use (fig. 1) is chosen. An important aspect in case of an assessment of opportunities of movement of AMR along the chosen routes is preliminary accounting of data on soil surfaces of coastlines of the island.

TSUNAMI EARLY WARNING SYSTEM BASED ON SMARTPHONES

Farzad Azima

Earthquake Early Warning (EEW) systems involve very high Capex. Therefore, EEW systems have been installed in a very limited number of regions. Applying crowdsourcing on humanitarian projects led us to use accelerometers in smartphones distributed all over the globe to detect earthquake shakes. We have implemented Earling, an innovative method of EEW system, utilizing personal smartphone sensors, to detect earthquakes by gathering shake reports. To minimize false alarms, we have devised some special algorithms, called Trust Algorithms (TA). Data sent from smartphones, is analyzed by TA in real time. In communicating with a service, the system can receive shake data from smartphones, analyze and distinguish earthquakes from everyday shakes. Then central unit applies complementary analysis on the results and send an alert to users in the vicinity of the earthquake in seconds.
We have successfully tested some of the recent earthquakes using simulation data around Europe by Earling, at first to detect the earthquakes and then to issue an alert in simulated environment.

Using algorithms embedded in Earling, we can detect epicenter and magnitude of earthquakes, as well as microseisms. Therefore, detecting a massive earthquake in the coastal region means a tsunami may be on its way. Earling can act as a complementary system for traditional early warning networks and following local public-safety policies, issue a tsunami early warning alert, to areas at risk.

Keywords: Tsunami Early Warning System, Earthquake Early Warning System, Smartphone, Public Safety

NOVEL TSUNAMI AND FLOODING PROTECTION BARRIER,

POSSIBLE SOLUTION FOR THE FUKUSHIMA WATER AND WASTE PROBLEMS

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Tsunami hazard can be prevented when the impulse waves are reflected by a stable submerged vertical barrier before the catastrophic high Tsunami waves are formed near the coast. Building of such deep walls of 20 to 30m depth by conventional technology is difficult. Two efficient and economic construction technologies will be described. These are based on lowering two parallel high-strength steel fences into the sea and fixing the fences with rocks or rubble deposited from top. Barriers parallel to the coastline are preferably built as empty triangular cylinders- of 20m to more than 100m length- on land/ in the harbor, provided with heavy foundations, transported by floatation in long rows to the intended site (in advance prepared by dredging), and then lowered by filling with rocks, concrete, grout, sand. These barriers extend above sea level and have concrete walls on top to protect a concrete service road. The top concrete walls are protected against storm surges by replaceable surge stoppers/parapets.

Computer simulation in collaboration with Technical University Braunschweig/Germany has shown that the height of tsunami waves in front of the vertical barrier is doubled. Furthermore, the loads from tsunami impulse waves onto the vertical barrier have been calculated (1).

The barriers protect threatened cities and coastlines against tsunami waves and against highest waves from tropical storms, but also against oil spill and other contamination from the ocean and thus protect flora, fauna and beaches. The construction costs can be compensated with reservoirs between barrier and coast a) by dumps for waste followed by land reclamation, or b) by large-scale fish farming - combined with renewable tidal energy for fresh sea water.

Specific applications proposed for the Fukushima radioactive water and waste problems will be discussed.

(1)Hans J.Scheel, Hisham ElSafti and Hocine Oumeraci, in preparation.

VALIDATION OF NUMERICAL MODELS FOR SIMULATING HYDRAULIC BORE INTERACTIONS WITH NEARSHORE STRUCTURES

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Damage to buildings and critical infrastructure caused by tsunami- or cyclone-induced coastal flooding can have long-lasting and devastating consequences. Past mitigation strategies have primarily considered the establishment of early warning systems, zoning bylaws, and evacuation plans in order to minimize the loss of human life. Although all of these elements are essential to a comprehensive system of protection, critical structures and infrastructure that are required to restore a community to normal operation are left vulnerable to destruction. As coastal cities around the globe continue to increase in population and mitigation strategies based solely on horizontal evacuation become less feasible, a commensurate increase in the demand to construct resilient refuges and infrastructure capable of withstanding the impact of extreme waves is certain to follow.

Previous researchers such as Ramsden (1996) and Linton et al. (2013) investigated the impact and interaction of bores with two-dimensional structures spanning the entire width of a test flume. The insights provided may be useful in the design of structures such as seawalls, but may oversimplify the physical mechanisms at play during flow around three-dimensional structures. The present study explores these mechanisms using an in-depth analysis of results generated by a newly-developed multi-phase numerical model. The results of a physical model investigation including time-series of water surface elevation, vertical pressure distribution, and net base shear force exerted on a structural model by a passing hydraulic bore are used in a quantitative comparison to validate the numerical model. Emphasis is also placed on comparing the performance of two fundamentally different numerical tools (OpenFOAM and SPH) available to engineers for assessing bore-induced loading on nearshore structures. Finally, using this newly developed model, a detailed analysis of the extreme wave loading process is provided where the time-dependent water surface profiles, pressures, and air entrainment are related to the resulting forces experienced by the structure.

THE ROLE OF MUSEUMS IN SAVING THE ENVIRONMENT- KERALA STATE MEMORIAL TSUNAMI MUSEUM

Preetha Saloma George

The Kerala State Memorial Tsunami Museum is a “people’s museum” aimed at public outreach education about the tsunami risk and memorialize those lost to the tsunami on Dec. 26, 2004. Exhibits explain how to respond to warnings of distant tsunamis and how to recognize the signs of a tsunami in order to be prepared for locally generated tsunamis. Content are designed for and aimed toward the general public and includes a significant component specifically created for children. The survivor stories featured includes those of children and local villagers.

The collection of community tsunami memories through video interviews with tsunami survivors is extremely important. The information can be integrated with physical data and thus available for use in better recreating events during the tsunami and it will be possible to better understand the social behavior of individuals in differing cultures when faced with such a disaster. Oral history interviews with survivors can also be used to reconstruct the heights and extent of flooding and thus be of value in defining danger zones. This information is of great value to emergency planners and emergency response personnel as it can be used to define new zoning maps, community road maps, safe evacuation routes and evacuation plans. It is also an extremely effective tool for community and regional disaster preparedness education.The museum will also preserve the social and cultural history of the state and promote economic development. The museum will serve as a living memorial to those who lost their lives in past tsunami events. Because a large portion of the museum is about oral history, the museum will serve as a resource center for community residents who are interested in conducting their own oral history projects. We believe that through education and awareness no one should ever again die due to a tsunami

FLOOD-INDUCED DEBRIS MOTION IN A BUILT-IN ENVIRONMENT

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Recent tsunami, such as the 2011 Tohoku and the 2015 Chilean, have shown that in addition to hydraulic loading, debris loads are a critical load to consider in the design of tsunami resistant infrastructure. The ASCE7 Chapter 6: Tsunami Loads and Effects represents a new standard that addresses the spatial distribution of debris associated with large-scale debris impact, such as shipping containers and shipping vessels. Many of this standard's prescriptions are based on analysis of a limited data set from a post-tsunami field survey following the 2011 Tohoku Tsunami in Japan. This paper presents result of an experimental study dealing with debris motion in tsunami-like flow conditions that analyzes the motion of debris in a built environment comparing the results to the previous debris motion studies and prescriptions of the ASCE7 standard. From the experiments, the authors concluded that the presence of macro-roughness in a built environment caused the loss of momentum of the inundating surge and the trapping of debris resulting in a reduction of the maximum longitudinal displacement of the debris. The study also found that the debris tended to propagate within the deep, high-velocity jets created by the flow constrictions, creating preferred transport paths for the debris.

Keywords: Debris, Tsunami, Physical Modelling, Built Environment, Coastal Engineering

EFFECTIVE COMMUNICATION MODEL FOR GLOBAL TSUNAMI EVACUATION SYSTEM OF SECRET DOCTRINE

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Tsunami waves are killer waves radiating from epicenter slammed into the coastline snatching people out to sea. It is a lifethreatening wave train which will cause severe damage to the population residing at coastal areas. In order to save the life of people, efficient and effective communication mechanism need to be employed to issue warning whenever required. This research paper deals with enhancement of effective communication model to be adopt to evacuate the population by tsunami alert through their mobile and handheld bracelet in case of tsunami. A web Portal has been developed to issue a Tsunami warning through mobile and handheld bracelet based on the tsunami wave prediction and hit time towards the coastal boundaries. By SMPP Protocol, Bulk Warning SMS are sent to group of people who are at coastal area where possibilities of tsunami. The registered device will be tracked to issue warning or alert if the person reaches the danger area of tsunami prone zone. This system also equipped with issue a alert message for fisherman, blind, deaf and other general public towards coastal areas incase of tsunami. The evacuation plan has also been
displayed in the mobile device in coastal region as well as in handheld device which reroute the fisherman to evacuate from the danger prone area to escape from tsunami.

Keywords – Tsunami Early warning System, Tsunami Alert

A SIMPLE PRACTICAL MODEL FOR TSUNAMI-INDUCED SCOUR

Ravindra Jayaratne1, Mara Nicholas2, Takayuki Suzuki3 and Tomoya Shibayama4

Tsunami–induced scour was observed around the edges of most buildings during the 2011 Great East Japan Earthquake and tsunami. The locations of scour holes resulted in significant damage on buildings near the Tohoku coast. It was noted that tsunami-induced scour poses a great threat to the structural performance of buildings, when under tsunami wave loading conditions (Chock et al., 2013). The ASCE 7 Tsunami loads and design standard guidelines suggest that tsunami-induced scour effect determines the design of foundations (Chock, 2015). Chock (2015) also indicated that the general parameters required for the design of foundations against tsunami effects include the scour depth and extent. Hence understanding the pattern of tsunami-induced

Session 4 - Experimental / Numerical Modeling

THE ALGORITHM FOR THE CONVEYER COMPUTATION OF TSUNAMI INSIDE JAPANESE HARBORS USING THE SEQUENCE OF GRIDS

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Tsunami sources of subduction zones are usually located in deep-water areas. Thus, if we want to estimate tsunami parameters near a coastline the computational domain must include both deep and shallow-water areas. A standard stability condition required that the wave advancement during one time step be lesser than a spatial grid-step. In this case we must use a sufficient small time step (for computational stability in deep-water areas of the domain) which makes computations on a shallow shelf with unreasonably small time step be too time consuming. A grid-switching algorithm for computing the tsunami propagation from the initial source to the coastline has been developed. Computations that use Method of Splitting Tsunami (MOST) are carried out on a sequence of grids with various resolutions where one is embedded into another. Tsunami wave parameters are transferred from the larger domain to the embedded smaller one by means of boundary conditions. Computations in the initial large domain and all the subareas start simultaneously. On the final stage of the numerical experiment the computations inside few harbors are carried on. The resolution of grids decreases from the initial value of 280 m down to 8-17 meters for grids that cover the small harbor areas. Comparison of the tsunami wave parameters obtained by computations with switching grids and without it reveals a certain difference of wave length and height inside a harbor. This difference is bigger for smaller sources which generate shorter waves.

ANALYSIS OF THE 17 NOV 2015 CROTONE PORT OSCILLATION DUE TO THE LEFKADA EARTHQUAKE

A. Annunziato

On 17^{th} November 2015, a Mw 6.4 earthquake occurred at Lat/Lon 38.8° / 20.4° close to the Lefkada Island in Greece. The event caused local displacement and relocation with some minor damage to buildings and infrastructure but causing a small wave that propagated in the Ionian Sea. A sea level disturbance was measured in the port of Crotone, Italy, on the other side of the Ionian Sea, with a maximum amplitude of about 12 cm; the peak amplitude was detected about 1 hour and half after the earthquake, much later than the expected travel time from the epicentre to the Crotone port. This amplitude is not coherent with possible focal mechanisms that can be considered and therefore an analysis was performed to understand the reason for this disturbance. It should be noticed that this was the only measurement that showed this trend: other measurements in the area, namely Taranto, did not show similar oscillation. Other previous analyses proposed the occurrence of a non-tsunamigenic oscillation (i.e. a landslide occurred sometime after the main event, in front of Crotone port). Although a number of landslide indeed occurred close to the epicentre, this possibility however was not verified by local submarine survey.

A collection of high resolution bathymetry was performed and dedicated analysis performed. It is demonstrated that an incoming wave of a specific period can be largely amplified by the Crotone port up to 10 times. The form of the originating deformation however must have a specific form in order to justify the 7 min period of the incoming wave. Using a backtracking the expected incoming wave form is identified that could explain the amplification of 12 cm in the port: a curve of a maximum 1 cm wave of a specific period is sufficient to be amplified in the port.

A BRIEF REVIEW ON TSUNAMI EARLY WARNING DETECTION

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Tsunami early warning systems have provided to be the extreme importance after the tsunami that hit Japan in March 2011. This research article presents a case study based on the tsunami detection using Bottom Pressure Rate (BPR) measurement and the post the analysis using the SAR datasets. A final decision based system using BPR has been studied to carry out the measurements of tsunami wave parameters. SAR based study has also been carried out for the post tsunami studies. Wiener filters are utilized to remove the speckle noise presents in imagery. Future scope of this work has also been proposed.

Keywords: Remote Sensing, Tsunami Damage Detection, Epicenter, BPR