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# MODEL PREDICTIONS OF GULF AND SOUTHERN ATLANTIC COAST TSUNAMI IMPACTS FROM A DISTRIBUTION OF SOURCES

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## ABSTRACT

The West Coast and Alaska Tsunami Warning Center now issues tsunami warnings for the US Gulf and US /Canadian Atlantic coasts. Because there is less historical data for these regions than for the Pacific, numerical models have been used to make predictions of wave amplitudes, travel time, and "reach". Hypothetical tsunami sources are placed in the Atlantic, the Gulf of Mexico, and in the Caribbean, with the resulting waves advanced forward in time 12 to 24 hours. Model results are presented in relation to warning center procedures.

# MOMENTUM AS A USEFUL TSUNAMI DESCRIPTOR

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## ABSTRACT

In looking at the videos of the Indonesian tsunami coming ashore at various locations, I thought, “That’s a lot of water with a lot of momentum, and that’s what does the damage.” Perhaps the momentum of a tsunami might be a physical quantity to focus on. Only external forces on the designated body of water create its momentum. Within the body of water, turbulence, internal friction and laminar flow involve internal forces and are not relevant.

This could be particularly useful in the generating area. There could be external forces on a designated body of water from a landslide, a pyroclastic flow, an explosion, from steam generation and from chunks of matter falling into the ocean. The horizontal components of those forces result in horizontal momentums. Ultimately when the wave moves out from the generating area and the internal turbulence and laminar flow get dissipated by friction, in the remaining long wave motion the wave height is simply related to the horizontal momentum. The horizontal momentum contribution to the directionality of the wave would be narrower than that due only to the initial vertical displacement.

Focusing on the momentum description of the tsunami introduces many new kinds of physical problems that are interesting in themselves.

# FINITE VOLUME METHODS AND ADAPTIVE REFINEMENT FOR GLOBAL TSUNAMI PROPAGATION AND LOCAL INUNDATION.

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## ABSTRACT

The shallow water equations are a commonly accepted approximation governing tsunami propagation. Numerically capturing certain features of local tsunami inundation requires solving these equations in their physically relevant conservative form, as integral conservation laws for depth and momentum. This form of the equations presents challenges when trying to numerically model global tsunami propagation, so often the best numerical methods for the local inundation regime are not suitable for the global propagation regime. The different regimes of tsunami flow belong to different spatial scales as well, and require correspondingly different grid resolutions. The long wavelength of deep ocean tsunamis requires a large global scale computing domain, yet near the shore the propagating energy is compressed and focused by bathymetry in unpredictable ways. This can lead to large variations in energy and run-up even over small localized regions.

We have developed a finite volume method to deal with the diverse flow regimes of tsunamis. These methods are well suited for the inundation regime—they are robust in the presence of bores and steep gradients, or drying regions, and can capture the inundating shoreline and run-up features. Additionally, these methods are *well-balanced*, meaning that they can appropriately model global propagation.

To deal with the disparate spatial scales, we have used adaptive refinement algorithms originally developed for gas dynamics, where often steep variation is highly localized at a given time, but moves throughout the domain. These algorithms allow evolving Cartesian sub-grids that can move with the propagating waves and highly resolve local inundation of impacted areas in a single global scale computation. Because the dry regions are part of the computing domain, simple rectangular cartesian grids eliminate the need for complex shoreline-fitted mesh generation.

# TSUNAMI PROPAGATION ALONG TAGUS ESTUARY (LISBON, PORTUGAL) PRELIMINARY RESULTS

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## ABSTRACT

In this study we present preliminary results of flood calculation along Tagus Estuary, a catastrophic event that happened several times in the past, as described in historical documents, and that constitutes one of the major risk sources for Lisbon coastal area. To model inundation we used Mader's SWAN model for the open ocean propagation with a 2 km grid, and Imamura's TSUN2 with a 50 m grid covering the entire estuary. The seismic source was computed with the homogeneous elastic half space approach. Modelling results agree with historical reports. Synthetic flood areas correspond to the sites where there are morphological and sedimentary evidences of two known major events that stroke Lisbon: 1531-01-26 and 1755-11-01 tsunamis.

# TSUNAMIGENIC SOURCES IN THE BAY OF PLENTY, NEW ZEALAND

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## ABSTRACT

New Zealand sits in a precarious position astride the boundary between the Pacific and Australian Plates. There is a wide range of potential tsunamigenic sources in this area including fault movements, submarine landslides, volcanic activity, and other mechanisms. In addition, considerable prehistoric information indicates that large tsunamis have inundated the coastline several times in the past. A part of our work has been directed toward using historic and prehistoric tsunami data to evaluate possible sources. Several types of dislocation models and submarine landslide models are used to simulate the displacement of the sources. A finite element numerical model is used to simulate generation, propagation and runup of the resultant tsunami. As an example, we present results for the Bay of Plenty, northeast coast of the North Island, New Zealand. The range of source types includes local faults, subduction zone rupture, volcanic eruptions, sector collapse of seamounts, and submarine landslides. A likely major source is a subduction zone event along the Tonga-Kermadec Trench. Data from paleotsunami deposits have guided the model in determining appropriate source characteristics and establishing the most significant event for this region.

# THE POTENTIAL OF TSUNAMI GENERATION ALONG THE MAKRAN SUBDUCTION ZONE IN THE NORTHERN ARABIAN SEA. CASE STUDY: THE EARTHQUAKE AND TSUNAMI OF NOVEMBER 28, 1945

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## ABSTRACT

Although large earthquakes along the Makran Subduction Zone are infrequent, the potential for the generation of destructive tsunamis in the Northern Arabian Sea cannot be overlooked. It is quite possible that historical tsunamis in this region have not been properly reported or documented. Such past tsunamis must have affected Southern Pakistan, India, Iran, Oman, the Maldives and other countries bordering the Indian Ocean.

The best known of the historical tsunamis in the region is the one generated by the great earthquake of November 28, 1945 off Pakistan's Makran Coast (Balochistan) in the Northern Arabian Sea. The destructive tsunami killed more than 4,000 people in Southern Pakistan but also caused great loss of life and devastation along the coasts of Western India, Iran, Oman and possibly elsewhere.

The seismotectonics of the Makran subduction zone, historical earthquakes in the region, the recent earthquake of October 8, 2005 in Northern Pakistan, and the great tsunamigenic earthquakes of December 26, 2004 and March 28, 2005, are indicative of the active tectonic collision process that is taking place along the entire southern and southeastern boundary of the Eurasian plate as it collides with the Indian plate and adjacent microplates. Tectonic stress transference to other, stress loaded tectonic regions could trigger tsunamigenic earthquakes in the Northern Arabian Sea in the future.

The northward movement and subduction of the Oman oceanic lithosphere beneath the Iranian micro-plate at a very shallow angle and at the high rate is responsible for active orogenesis and uplift that has created a belt of highly folded and densely faulted coastal mountain ridges along the coastal region of Makran, in both the Balochistan and Sindh provinces. The same tectonic collision process has created offshore thrust faults. As in the past, large destructive tsunamigenic earthquakes can occur along major faults in the east Makran region, near Karachi, as well as along the western end of the subduction zone. In fact, recent seismic activity indicates that a large earthquake is possible in the region west of the 1945 event. Such an earthquake can be expected to generate a destructive tsunami.

Additionally, the on-going subduction of the two micro-plates has dragged tertiary marine sediments into an accretionary prism - thus forming the Makran coastal region, Thick sediments, that have accumulated along the deltaic coastlines from the erosion of the Himalayas, particularly along the eastern Sindh region near the Indus River delta, have the potential to fail and cause large underwater tsunamigenic slides. Even smaller magnitude earthquakes could trigger such underwater landslides. Finally, an earthquake similar to that of 1945 in the Makran zone of subduction, has the potential of generating a bookshelf type of failure within the compacted sediments – as that associated with the “silent” and slow 1992 Nicaragua earthquake – thus contributing to a more destructive tsunami. In conclusion, the Makran subduction zone has a relatively high potential for large tsunamigenic earthquakes.

# 2006: STATUS OF TSUNAMI SCIENCE RESEARCH AND FUTURE DIRECTIONS OF RESEARCH

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## ABSTRACT

In 2005, Dr. Robert Wiegel compiled "Tsunami Information Sources". The compilation has been made available via a website and has been published as an issue in *Science of Tsunami Hazards*. The compiled references have been assigned keyword descriptions, and compiled in order to review the breath and depth of Tsunami Science publications.

The review indicates that tsunami research involves eight major scientific disciplines: Geology, Seismology, Tsunami Science, Engineering, Disaster Management, Meteorology and Communications. These disciplines were subdivided into many topical subjects and the results were tabulated.

The topics having the largest number of publications include: tsunamigenic earthquakes, numerical modeling, field surveys, engineering models, harbor, bay, and canal modeling and observations, energy of tsunamis, workshops, tsunami warning centers, instrumentation, tsunami catalogs, tsunami disaster mitigation, evaluation of hazards, the aftermath of tsunamis on humans, and AID provided to Tsunami Damaged Communities.

Several areas of research were identified as likely directions for future research, including: paleotsunami studies, risk assessments, instrumentation, numerical modeling of earthquakes and tsunami, particularly the 2004 Indian Ocean event. There is a dearth of recent publications available on tsunami hazards education for the general public.