Hydrodynamic modelling of coastal inundation

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Background

Impacts to the built environment from natural hazards such as riverine flooding, storm surges or tsunami are critical in understanding the economic and social effects on our communities. In order to simulate the behaviour of water flow from such hazards within the built environment, Geoscience Australia and the Australian National University are developing a software modelling tool (called ANUGA) for hydrodynamic simulations. The software will eventually be released under an Open Source license.

Model description

The software implements the finite-volume method for solving the Shallow Water Wave equation. An advantage of this method is that the study area can be represented by an unstructured mesh with variable resolution to suit the particular problem. ANUGA uses a triangular mesh and solves the governing equations within each cell to determine the water depth and horizontal momentum over time. An important capability of the software is that it can model the process of wetting and drying as water enters and leaves an area. This means that it is suitable for simulating water flow onto a beach or dry land and around structures such as buildings.

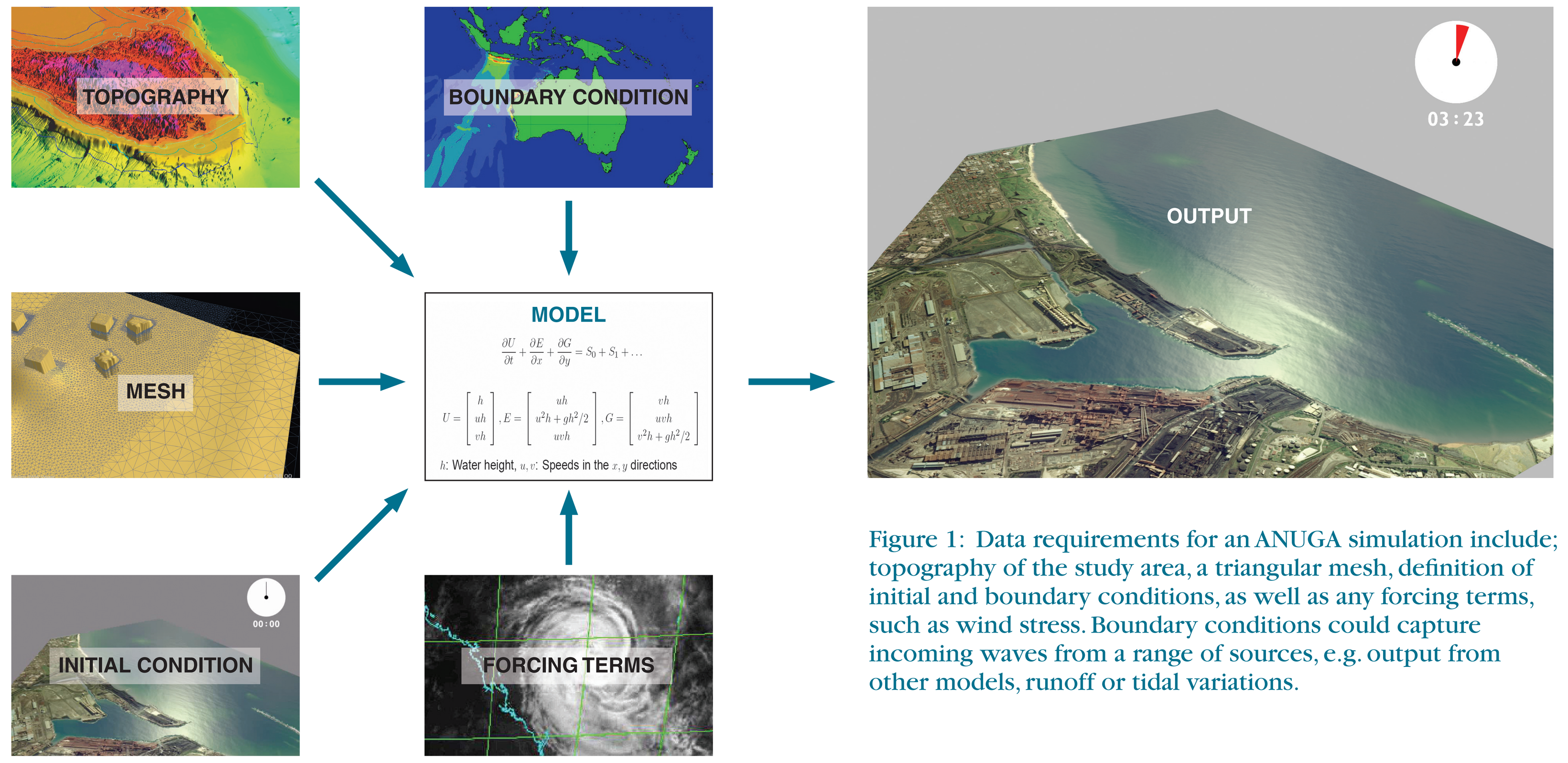


Figure 1: Data requirements for an ANUGA simulation include; topography of the study area, a triangular mesh, definition of initial and boundary conditions, as well as any forcing terms, such as wind stress. Boundary conditions could capture incoming waves from a range of sources, e.g. output from other models, runoff or tidal variations.

Programming

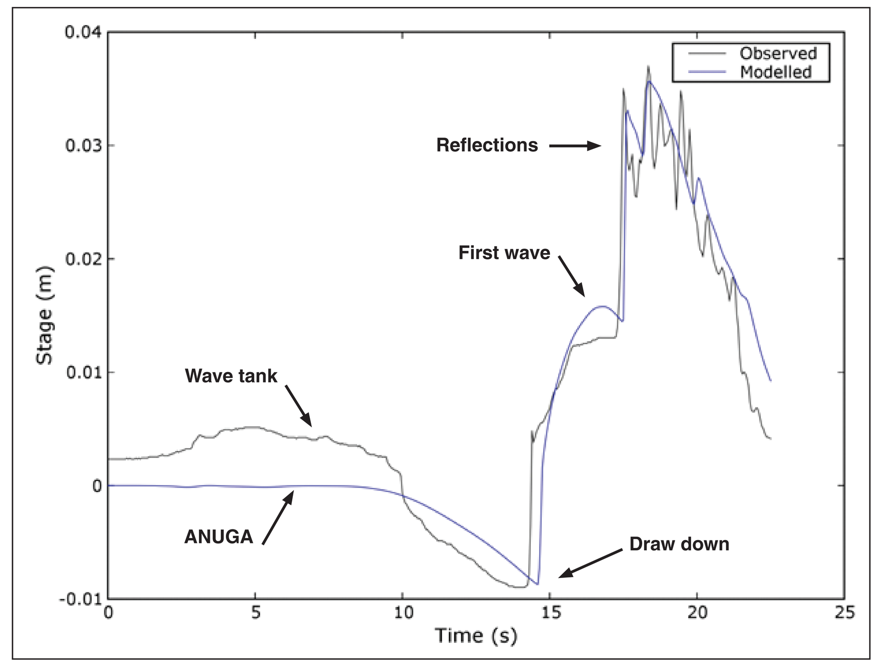
ANUGA is written in the object-oriented programming language Python. Software written in Python can be readily adapted to changing requirements throughout its lifetime allowing for a flexible and easy to use interface. Computationally intensive components are written for efficiency in C routines working directly with the Numerical Python structures.

Model Validation (Okushiri 1993)

ANUGA has been validated against measured results from a wave tank simulation of the 1993 Okushiri Island tsunami off Hokkaido, Japan (Matsuyama and Tanaka, 2001). A significant feature of this tsunami was a maximum run-up of 32 m observed at the head of the Monai Valley. The wave tank dataset provided bathymetry and topography along with initial water depth and the wave specifications. The dataset also contained water depth time series from a wave gauge situated offshore from the simulated inundation area.

Figure 2 compares the observed wave tank and modelled ANUGA water depth at the gauge. The plots show good agreement between the two time series, with AnuGA closely modelling the initial draw down, the wave shoulder and the subsequent reflections. The discrepancy between modelled and simulated data in the first 10 seconds is due to the initial condition in the physical tank not being uniformly zero. Additionally, ANUGA replicates exceptionally well the 32 m Monai Valley run-up, and demonstrates its occurrence to be due to the interaction of the tsunami wave with two juxtaposed valleys above the coastline, see Figure 3.

Figure 2: Time series comparison of the measured experimental results with the ANUGA simulation at one of the gauges.



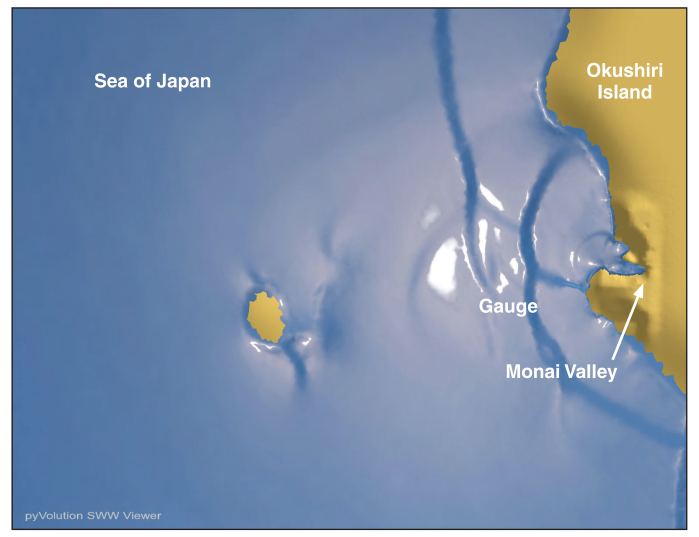


Figure 3: Visualisation of ANUGA output illustrating the capability to capture complex, interacting behaviour, such as the 32 m Monai Valley run-up.

Tsunami Impact Applications

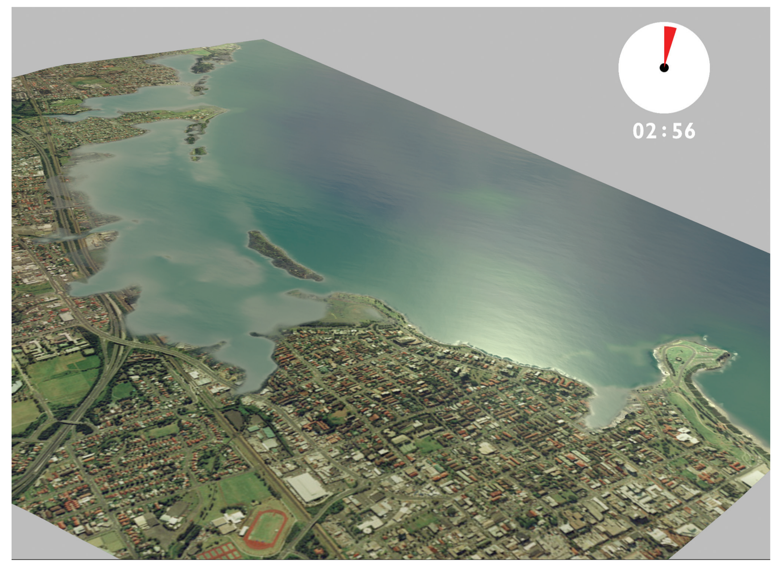


Figure 4: Visualisation of ANUGA hypothetical scenario simulation illustrating coastal inundation. The maximum inundation map is calculated from this output.

Figure 5: Simulation incorporating infrastructure to illustrate ANUGA's capability to model water flow around buildings.

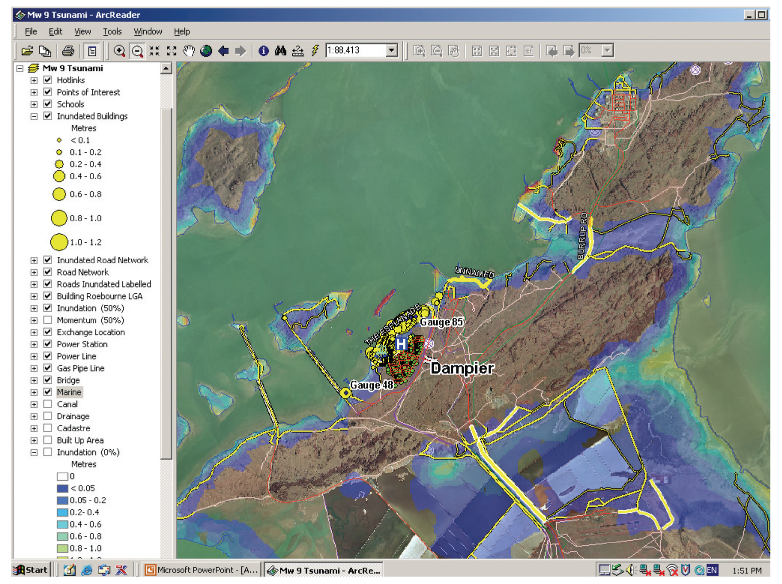


Figure 6: Example of inundation map provided to emergency managers. Here, the map is embedded in a GIS product enabling emergency managers to use the output as a "decision support tool".

ANUGA is currently being applied in a number of projects where impacts from potential tsunami events on coastal communities are simulated, examples are shown in Figures 4 and 5. Predicting the impact from a tsunami is not only important for effective warnings and disaster management, it is also integral to the quantification of risk to infrastructure, buildings and communities. A range of plausible tsunami events are being simulated using the Method of Splitting Tsunami (MOST) method (Titov, 1997) which models the genesis of a tsunami event and propagates the wave in deep water. ANUGA then "picks up" the MOST output near a coastline under scrutiny and propagates the wave through the shallow water and onshore. In this way, the MOST output becomes the boundary condition for the ANUGA simulation.

As ANUGA calculates the water depth and horizontal momentum throughout the simulation, a map of the maximum water depth is easily developed and provided to emergency managers, see Figure 6.The momentum and velocity data, as well as the time series of water depth at key locations, adds increased detail to the estimation of risk and finer detail to evacuation plans. Current projects include Tsunami Impact Modelling for Western Australia and support to the Australian Tsunami Warning System.

References

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