Tsunami-detecting DART buoys deployed offshore of New Zealand

Jose Borrero, eCoast Ltd

In mid-December 2019, the New Zealand Government announced that the first four of an anticipated 12 tsunami-detecting DART buoys were deployed offshore of New Zealand.

So, what is a DART buoy, where are they, and how do they work?

DART stands for **D**eep-ocean **A**ssessment and **R**eporting of **T**sunamis. The technology was developed by the National Oceanic and Atmospheric Administration (NOAA) of the US Government and was first introduced in 2001 with a six-buoy array deployed mostly in the North Pacific Ocean. By 2008 there were 39 stations deployed around the Pacific Rim and in the Indian and Atlantic Oceans (see Figure 1). Real time data from these stations can be viewed online at: www.ndbc.noaa.gov/dart.shtml

Each DART buoy consists of two main components: a sea floor mounted bottom pressure recorder (BPR) and a floating surface buoy. Temperature and pressure data (used to determine the sea surface height), are collected by the BPR every 15 seconds and transmitted to the buoy via an acoustic link. The buoy processes the raw data and transmits the information via satellite to a data centre in either the USA or Australia (or, more recently, now in New Zealand). Under normal conditions, the buoy transmits data every 15 minutes, however when large earthquakes occur in the vicinity of a particular buoy, it converts to 'event mode' and begins transmitting data every minute.

The genius of the DART system is its ability to distinguish a tsunami from the chaos of ocean waves on the high seas. A quick look at the DART locations reveals that these buoys are deployed in some of the stormiest seas on Earth. How then can the system distinguish between a tsunami wave, which may only be centimetres high, when the swell and wind waves are tens of metres high?

The secret lies in the clever algorithm developed by scientists at NOAA that determines the amplitude of the pressure signal at tsunami frequencies and compares it to threshold values. Remember, pressure can be used as a proxy for water depth and therefore wave height. Since tsunami waves have very low frequencies (or long periods, generally tens of minutes to hours) while wind and swell waves exist at much higher frequencies (shorter periods, up to 20 or so seconds), one can filter out the effects of the shorter period wind and swell waves and look only at the underlying tsunami signal.

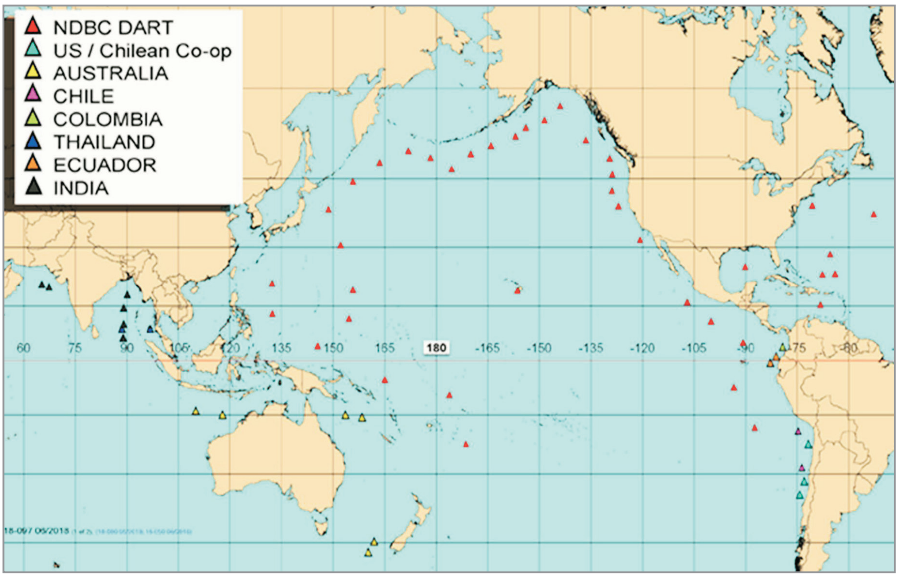

Figure 1: Locations of existing DART buoys prior to the New Zealand array (National Data Buoy Center, NOAA).

Recall however that these BPRs are measuring variations in water depth of millimetres over total depths of more than 5,000 metres! Thus the accuracy and reliability of these instruments is remarkable. More details on this algorithm can be found here: www.ndbc.noaa.gov/dart/algorithm.shtml

Ultimately, the benefit of DART technology is that the system measures tsunami waves directly and much sooner than relying on data from coastal tide gauges or the analysis of data from the earthquake itself. Because tsunamis are 'long' waves, their propagation speed is entirely dependent on the water depth, travelling faster in deeper water. With the buoys positioned in deep water adjacent to the tsunami source zones, a tsunami can reach the nearest DART buoy within minutes of the causative earthquake allowing the warning centres to assess an event's destructive potential within 15-30 minutes of arrival at the buoy.

While this can speed up the issuance of warnings or guidance by several hours, it is also important to note that the technology can be used to call off warnings and avoid unnecessary evacuations, which are both costly and potentially dangerous.

DARTs around New Zealand

Figure 2 shows the locations of the recently deployed DART buoys and locations of planned future deployment sites. The instruments are to be deployed largely along the Tonga-Kermadec Subduction Zone (TKSZ), including the southern extension (Hikurangi Trough), with additional instruments to be deployed in the vicinity of Vanuatu and the New Hebrides subduction zone. Note that the DART stations are mostly located on the eastern side of the TKSZ, for the 'deep water' reasons described above.

Even so, the time for detecting and analysing a tsunami and ultimately making a decision on whether or not to evacuate can be quite short. For example, peak wave heights from a tsunami generated near location 'E' in Figure 2 would reach the eastern shore of Great Barrier Island in about one hour, Whangarei in two hours, and Auckland in

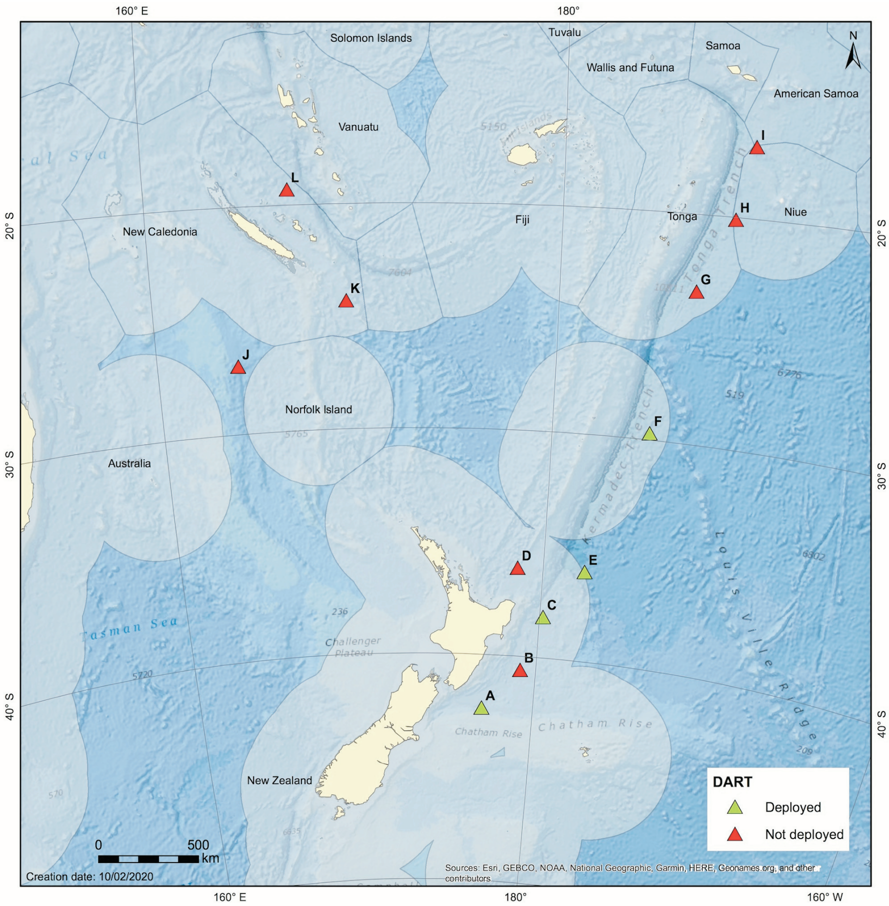

Figure 2: Locations for the 12 planned DART buoys to be installed offshore New Zealand and in the southwest Pacific. The four installed stations are indicated with the green triangles. Map courtesy of Bill Fry, GNS Science.

less than two and a half hours. Response times are even shorter for Gisborne and Hawke's Bay, where a tsunami generated directly offshore could begin affecting the coast quite quickly with peak tsunami heights arriving in approximately 30 minutes. For events such as the January 1976 tsunami – caused by an earthquake near location 'F' in Figure 2 and which caused significant damage to boats and piers in Tutukaka Harbour – the tsunami arrived in just over two hours. For events occurring further afield, in southern Vanuatu, the Solomon Islands or Tonga, there is slightly more time – two hours from Vanuatu and three to four hours for waves from either the Solomons, Tonga or Samoa to reach Cape Reinga.

However, these source regions have been shown, through modelling and actual data, to be less hazardous to New Zealand relative to tsunami generated directly east of us on the TK or Hikurangi Subduction Zones (Power et al., 2011). Thus, even under a best-case scenario where everything runs smoothly, confirmation of a destructive tsunami may only come as tsunami surges are already affecting sections of the coast. Therefore, we must continue to focus on community-based education and awareness efforts such as 'Long or Strong, Get Gone' to get people to heed natural warning signs and prompt self-evacuation.

New Zealand's DART array will also provide some peace of mind to our friends around the Pacific as the readings from our buoys can be used to verify whether or not a damaging or destructive tsunami was generated off our coast. This will also be particularly useful for Chile (and to some extent Australia) who are in the direct line of fire from a tsunami generated along the TKSZ.

If (when?) these new DARTs are put to the test, it won't be the first time that DART technology was used to forecast a tsunami's impact in New Zealand. On the evening of March 11, 2011, immediately following the great earthquake offshore of the Tohoku region of Japan, I used a tsunami source model derived from data recorded on DART stations located offshore of Japan to accurately forecast tsunami heights in New Zealand waters. Model results were available some three to four hours after the earthquake (nine to ten hours prior to arrival in New Zealand) and the information was delivered to duty officers at GeoNET, who used it to adjust the tsunami threat levels and issue warnings guidance to the country (Borrero et al., 2012).

Data access

At this time data from the New Zealand DART buoys are only available to the National Geohazards Monitoring Centre (NGMC) and GNS Science. This is in contrast to the rest of the global DART array, where data can be viewed online by anyone (see the weblink on page 3). During a tsunami event, duty officers at the NGMC, in conjunction with the Tsunami Experts Panel (TEP), will analyse the data and make recommendations to the National Emergency Management Agency who will then advise regional and local civil defence and emergency management (CDEM) groups.

While it has been suggested that the intention is to make the data more widely available, this has not happened yet and it is not clear when it will. Of particular importance is that the data be accessible to New Zealand based tsunami experts as well as scientists at NOAA (the original developers of the system) so that the information can be used to make real time estimates of the tsunami source and provide accurate forecasts of the tsunami effects throughout the Pacific Basin – the very technique that allowed accurate, 'faster than real time forecasting' to benefit New Zealand during the 2011 Japan event.

References

Borrero, J, et al. (2012). Observations, effects and real time assessment of the March 11, 2011 Tohoku-oki Tsunami in New Zealand. *Pure and Applied Geophysics*. https://doi.org/10.1007/s00024-012-0492-6

Power, WL, et al. (2011). Tsunami hazard posed to New Zealand by the Kermadec and southern New Hebrides subduction margins: An assessment based on plate boundary kinematics, interseismic coupling, and historical seismicity. *Pure and Applied Geophysics*. https://doi.org/10.1007/s00024-011-0299-x