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Tsunamis on the Pacific Coast of Canada Recorded in 1994–2007

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Abstract—In the last 15 years there have been 16 tsunami events recorded at tide stations on the Pacific Coast of Canada. Eleven of these events were from distant sources covering almost all regions of the Pacific, as well as the December 26, 2004 Sumatra tsunami in the Indian Ocean. Three tsunamis were generated by local or regional earthquakes and two were meteorological tsunamis. The earliest four events, which occurred in the period 1994–1996, were recorded on analogue recorders; these tsunami records were recently re-examined, digitized and thoroughly analysed. The other 12 tsunami events were recorded using digital high-quality instruments, with 1-min sampling interval, installed on the coast of British Columbia (B.C.) in 1998. All 16 tsunami events were recorded at Tofino on the outer B.C. coast, and some of the tsunamis were recorded at eight or more stations. The tide station at Tofino has been in operation for 100 years and these recent observations add to the dataset of tsunami events compiled previously by S.O. Wigen (1983) for the period 1906–1980. For each of the tsunami records statistical analysis was carried out to determine essential tsunami characteristics for all events (arrival times, maximum amplitudes, frequencies and wave-train structure). The analysis of the records indicated that significant background noise at Langara, a key northern B.C. Tsunami Warning station located near the northern end of the Queen Charlotte Islands, creates serious problems in detecting tsunami waves. That station has now been moved to a new location with better tsunami response. The number of tsunami events observed in the past 15 years also justified re-establishing a tide gauge at Port Alberni, where large tsunami wave amplitudes were measured in March 1964. The two meteorological events are the first ever recorded on the B.C. coast. Also, there have been landslide generated tsunami events which, although not recorded on any coastal tide gauges, demonstrate, along with the recent investigation of a historical catastrophic event, the significant risk that landslide generated tsunami pose to coastal and inland regions of B.C.

Key words: Tsunami records, British Columbia, tide gauge, meteorological tsunami, landslide generated tsunami, tsunami catalogue.

1. Introduction

The Pacific Coast of Canada, in the province of British Columbia (B.C.) extends from approximately 48°N to 55°N, a distance of about 775 kilometres. However, this coast is a complex network of inlets, straits, passes, sounds, and narrows, which has a coastline length, including islands, of approximately 27,300 kilometres (Thomson, 1981).

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Significant parts of this coastline are susceptible to the effects of tsunamis generated within the Pacific basin (Rapatz and Murty, 1987; Murty, 1992; Clague *et al.*, 2003). Geological and geophysical evidence gathered along the western coastline of Vancouver Island, as well as on the Washington and Oregon coasts, show that major Cascadia earthquakes accompanied by destructive tsunamis have an average recurrence interval of about 500 years (Clague and Bobrowsky, 1999; Clague *et al.*, 2003). Trans-Pacific tsunamis caused by major earthquakes elsewhere in the Pacific "Rim of Fire" can also significantly affect the B.C. coast (Murty, 1992; Clague, 2001). The March 1964 Alaska earthquake with magnitude $M_w = 9.2$ produced a catastrophic tsunami which swept southward from the source area in Prince William Sound along the B.C. coast causing about $10 million in damage (Wigen and White, 1964; Clague, 2001; Clague *et al.*, 2003). According to Rapatz and Murty (1987) and Hebenstreit and Murty (1989) for the coast of British Columbia there is also a high potential risk of destructive tsunamis caused by local major earthquakes. The coasts and underwater slopes of B.C. contain significant amounts of unstable material, so submarine and subaerial landslides, slumps and rock falls and associated tsunamis are often the secondary effects of earthquakes (Evans, 2001; Rabinovich *et al.*, 2003).

Until the mid-1980s all tide gauges on the B.C. coast were analogue. Records of reasonably high quality were collected (Wigen, 1983), but with the exception of a very rudimentary automated warning system at Tofino and Langara, sea-level records were not available for real-time analysis in response to potential tsunami events. Basic information could be obtained from gauge attendants by radio or telephone, but the record could only be analysed and digitised days or weeks after the event. The accuracy of these instruments was a few centimetres and Wigen (1983) was able to identify some tsunami as small as 6 cm. Given that the typical range of tide at these stations is about 5 metres it was impossible to identify any events with tsunami wave heights smaller than that. In the 1980s the Canadian Hydrographic Service (CHS) began to operate both digital and analogue gauges at key stations on the B.C. coast. This provided access to the data in real-time by either telephone modem or Meteor Burst communication. For the most part though, on-site data storage and throughput considerations limited the data sampling interval to 15 minutes.

The destructive tsunamis of the last decade (e.g., Shikotan tsunami of October 4, 1994) initiated a major upgrade of the existing Tsunami Warning and Permanent Water Level Network (PWLN) stations on the B.C. coast (see Fig. 1). The new digital instruments were designed to continuously measure sea-level variations with considerably higher precision than earlier analogue gauges, and to store corresponding sea-level samples every minute; a significant improvement from the previous digital instruments. During the period 1999–2001 near-continuous series of high-quality 1-minute sea-level data were collected at all stations and two weak tsunamis (the trans-Pacific Peru tsunami of June 23, 2001 and the local Queen Charlotte tsunami of October 12, 2001) were recorded (Rabinovich and Stephenson, 2004). These two observed tsunami events, and the high quality of the data from the new instruments, initiated a review of tide gauge records for the period 1981–1998. The review identified four events in the 1990s in