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Damaging sediment density flows triggered by tropical cyclones

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ABSTRACT

The global network of subsea fibre-optic cables plays a critical role in the world economy and is considered as strategic infrastructure for many nations. Sediment density flows have caused significant disruption to this network in the recent past. These cable breaks represent the only means to actively monitor such flows over large oceanic regions. Here, we use a global cable break database to analyse tropical cyclone triggering of sediment density flows worldwide over 25 yrs. Cable breaking sediment density flows are triggered in nearly all areas exposed to tropical cyclones but most occur in the NW Pacific. They are triggered by one of three sets of mechanisms. Tropical cyclones directly trigger flows, synchronous to their passage, as a consequence of storm waves, currents and surges. Cyclones also trigger flows indirectly, with near-synchronous timing to their passage, as a consequence of peak flood discharges. Last, cyclones trigger flows after a delay of days as a consequence of the failure of large volumes of rapidly deposited sediment. No clear relationship emerges between tropical cyclone activity (i.e. track, frequency and intensity) and the number of sediment density flows triggered. This is a consequence of the short period of observation. However, expansion of the cable network and predicted changes to cyclone activity in specific regions increases the likelihood of increasing numbers of damaging flows.

1. Introduction

Tropical cyclones are common in many regions of the world and affect nearly all tropical areas (Emanuel, 2005). Associated with these meteorological phenomena are extreme winds, torrential rains and subsequent river floods, increased surface run-off and/or landslides, large waves and damaging storm surges leading to coastal flooding (Peduzzi et al., 2012). An often unrecognised hazard is that posed to subsea infrastructure by cyclone-triggered sediment density flows.

Sediment density flows (a generic term used here to encompass turbidity currents, debris flows, hyperpycnal plumes and submarine landslides, etc.) can travel at speeds of up to 19 $m\,s^{-1}$ and runout for several hundreds of kilometres. These flows can damage critical seafloor infrastructure, such as that associated with the offshore hydrocarbon industry or subsea telecommunication cable networks (Carter et al., 2009; Pope et al., 2016). The seafloor telecommunication network currently carries >95% of global intercontinental data and internet traffic making it integral to the global economy and strategic infrastructure for many countries (Carter et al., 2009; Burnett et al., 2013). Determining the timing and triggering of these flows is important for submarine geohazard assessment, especially whether their frequency may change as the oceans warm due to predicted climate change (Stocker, 2014).

Multiple triggering mechanisms have been identified for sediment density flows. These include earthquakes, tsunami and storm wave loading, rapid sediment deposition and oversteepening, direct plunging of dense river water (hyperpycnal flows) and volcanic activity (Piper and Normark, 2009). However, we have limited understanding of the frequency of flows worldwide or how often they are triggered by specific mechanisms because their exact timing and character are often problematic to measure. In most cases where a specific triggering mechanism has been identified, it has been based on cable breaks or damage to other seafloor infrastructure (e.g. Hsu et al., 2008; Cattaneo et al., 2012; see Talling et al., 2013 for more detail). This is particularly true of triggering of sediment density flows by tropical cyclones (Bea et al., 1983; Dengler et al., 1984; Alvarado, 2006; Carter et al., 2012; Gavey et al., 2016).

Using a global database of cable breaks, here we specifically focus on the role tropical cyclones play in triggering damaging

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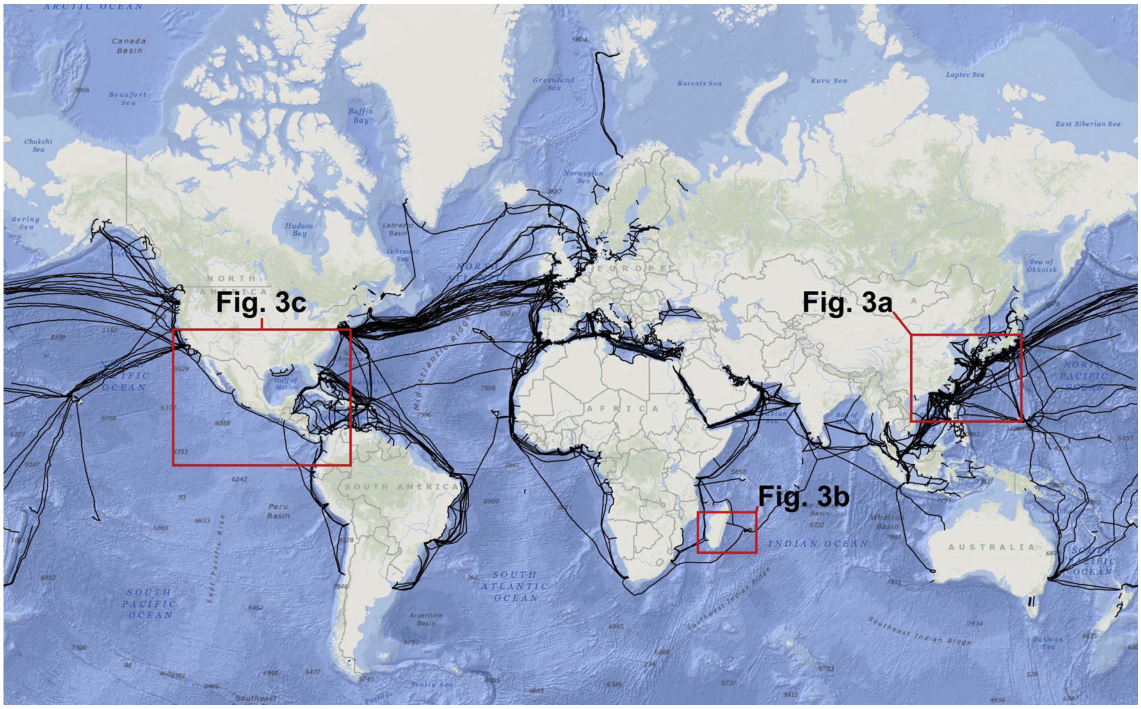

Fig. 1. Map of the submarine cable network used in this study.

sediment density flows. Furthering previous spatially and temporally restricted studies; the use of a global compilation of cable breaks allows the identification of areas where damaging sediment density flows, triggered by cyclones occur and how frequent these events have been globally over a 25 yr time period.

1.1. Aims

Three main questions are addressed. First, how important are tropical cyclones for causing cable breaks on a global basis, and in which settings (submarine canyons, etc.) and water depths do cyclone induced breaks occur? Second, can the mechanisms by which cyclones trigger sediment density flows be identified from cable breaks? For example, are flows triggered by storm waves and currents during the tropical cyclone and/or are flows typically delayed and triggered a few days after the passing of the tropical cyclone (Carter et al., 2012)? Third, is the frequency of cyclone-triggered sediment density flows and cable breaks likely to change due to projected climate change?

2. Data and methods

2.1. Cable break database

This study is based on non-public, aggregated data supplied by Global Marine Systems Limited (UK) on a non-disclosure basis. The database contains information on the location of each subsea cable when it was laid (Fig. 1). It includes other installation information such as seabed type and duration the cable has been in service. Cable breaks within the database are identified and generally related to likely causes, i.e. seismic, trawling, anchor, etc. Each 'break' refers to a break or failure along a section of a specific cable. A 'break' can range from internal damage of the power conductor or optical fibres to the complete physical separation of the entire cable assembly. Each recorded 'break' may therefore also represent multiple breaks along a single section of cable. The timing of a break in the database is recorded to the nearest day.

2.2. Tropical cyclone data

2.2.1. Tropical cyclone track data

Historical tropical cyclone track data were obtained from the National Hurricane Center (NHC) Hurdat-2 "best track" dataset (Landsea et al., 2013). This dataset is an archive compiled every 6 h (at 0000, 0600, 1200, 1800 UTC) and includes reports of storm position and maximum wind speeds.

2.2.2. Tropical cyclone characterisation: ECMWF ERA-interim reanalysis data

The global coverage of ocean buoys recording variables such as surface pressure and wave height is spatially variable, and such data are not always freely available. The same is true of terrestrial weather stations. Thus to analyse specific tropical cyclone characteristics we used global model data in order to homogenise data quality. Records of tropical cyclone characteristics came from ERA-Interim global atmospheric reanalysis produced by the European Centre for Medium-Range Weather Forecasts (Dee et al., 2011). ERA-Interim covers the period from 1 January 1979 onwards, and continues to be extended forward in near-real time. 3-h estimates of surface pressure (Pa), significant wave height (m), total precipitation (m) and surface runoff (m) data were obtained from the ERA-interim model. These data were gridded at a spatial resolution of $0.125° \times 0.125°$.

2.3. Comparison of cable break and tropical cyclone databases

All cable breaks within the database attributed to the following causes were included in our analysis: earthquakes, landslides, chafe under current action, other natural causes, and unknown causes. Among these categories, cable breaks with a known cause unrelated to tropical cyclones were removed, such as those due to earthquakes (Pope et al., 2016). A tropical cyclone was attributed to be the cause of a sediment density flow if the cable break coincided with the passing of a tropical cyclone according to the best-track data and the ERA-interim data, or occurred within 14 days

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