Digital Elevation Models of Garibaldi, Oregon: Data Sources, Processing and Evaluation

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Summary

In the fall of 2012, the NOAA National Geophysical Data Center (NGDC) developed two integrated topographic-bathymetric Digital Elevation Models (DEMs) of the Oregon coast surrounding the town of Garibaldi, Oregon and Tillamook Bay for the NOAA Pacific Marine Environmental Laboratory (PMEL). The DEMs are identical except for the vertical datum to which they are referenced. The first version of the DEM is referenced to the North American Vertical Datum of 1988, an orthometric datum. In order to approximate the maximum spatial extent of inundation, the second version of the DEM is referenced to the tidal datum Mean High Water (MHW). The MHW DEM will serve as input dataset for the Method of Splitting Tsunami (MOST) model developed by the PMEL Center for Tsunami Research to simulate tsunami generation, propagation and inundation. The extent of the DEM, data sources, processing steps and a brief evaluation are described below. Generally speaking, the methodology used in developing the DEM follows the procedures described in NOAA Technical Memorandum NESDIS NGDC-60 (Lim et al., 2012).

DEM Specifications

The DEMs were developed to the specifications listed in Table 1, as provided by PMEL. These DEMs serve to update a previous version created by NGDC in 2007 (Carignan et al., 2009), as many new data were acquired in the region since the initial date of completion.

Table 1. DEM Specification for the Garibaldi, Oregon DEM

Grid Area	Garibaldi, OR
Coverage Extent	123.7º to 124.5º W; 45.1º to 45.9º N
Coordinate System	Geographic Decimal Degrees
Horizontal Datum	World Geodetic System of 1984 (WGS84)
Vertical Datum	North American Vertical Datum of 1988 (NAVD88); Mean High Water (MHW)
Vertical Units	Meters
Cell Size	1/3 Arc-Second
Grid Format	ASCII raster grid

Figure 1 provides a graphic display of the extent of the DEM(s). Garibaldi, Oregon is situated in the center of the bounding box, along the shores of Tillamook Bay. The source data was obtained and processed for a slightly larger area than illustrated in Figure 1 in order to minimize edge-effects during the gridding process.
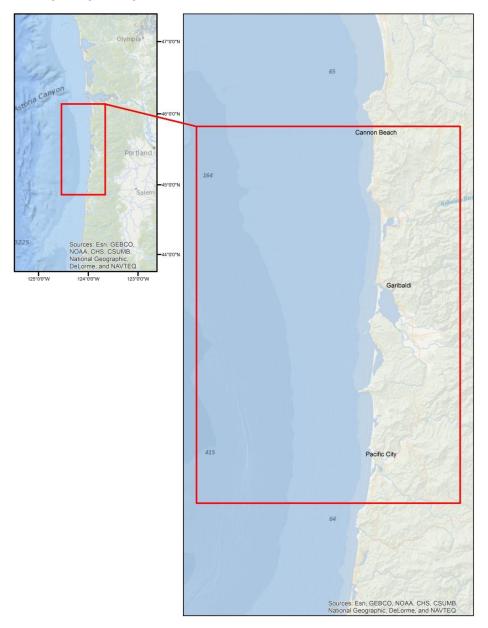

Figure 1. Map of the DEM extent, as indicated by red bounding box.

Data Sources, Processing & Evaluation

The 'best available' bathymetric, topographic, and shoreline data were collected for the study area from a variety of federal and state agencies, including academia (Figure 2). Bathymetric datasets used in the development of the DEM(s) include 8 NOAA gridded multibeam surveys

(BAG), 29 NOAA hydrographic surveys (XYZ sounding data), 1 gridded multibeam survey obtained from the Oregon State University Seafloor Mapping and Active Tectonics Lab and 1 bathymetric lidar survey from the U.S. Army Corps of Engineers Joint Airborne Lidar Bathymetry Technical Center of Expertise (USACE JALBTCX; Table 2).
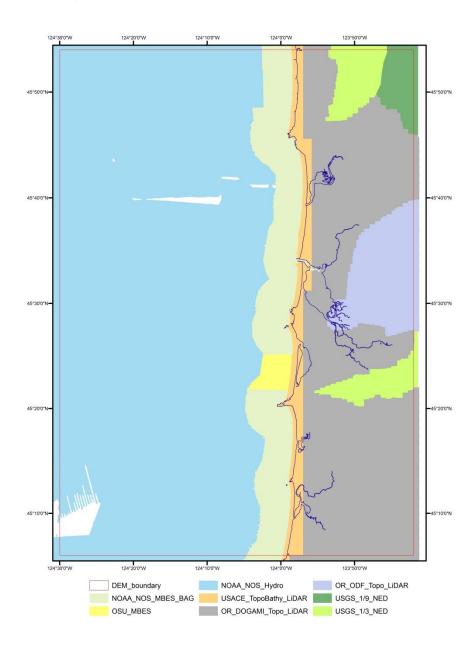

Figure 2. Spatial distribution of datasets used in the creation of the Garibaldi DEM

All bathymetric data were converted to common horizontal (WGS84) and vertical datums (NAVD88). The Proj4[1] Cartographic Projections Library was used to perform the horizontal

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[1] Proj4 is a free standard Unix filter function which converts geographic longitude and latitude coordinates into cartesian coordinates, $(\lambda, \varphi) \rightarrow (x, y)$, by means of a wide variety of cartographic projection functions. URL: http://trac.osgeo.org/proj/

datum adjustments. Vertical datum adjustments from Mean Lower Low Water (MLLW) to the North American Vertical Datum of 1988 (NAVD88) were applied using transformation grids derived from NOAA VDatum[2] software.

Table 2. Bathymetric data sources used in the development of the Garibaldi DEM

Source	Date	Data Type	Spatial Resolution	Original Horizontal Datum	Original Vertical Datum
NOAA	2010	Gridded Multibeam Bathymetry (BAG)	1m – 8m	NAD83 UTM Zone 10 North	MLLW
NOAA	1877-2003	Hydrographic Survey Soundings (ASCII XYZ)	Varies; typical range from <10 m to kilometers	NAD27; NAD83	MLLW
Oregon State Univ.	2010	Gridded Multibeam Bathymetry (ESRI grid)	4m	WGS84	MLLW
USACE	2010-2011	Lidar Point Cloud(LAS)	Typical point spacing for bathymetric lidar is ~3-5m	NAD83	NAVD88

Once common datums were established among disparate bathymetric datasets, a bathymetric 'pre-surface' was generated in order to interpolate or extrapolate values where data coverage was sparse or non-existent. The cell-size of this grid was 1/3 arc-seconds. More recent data (generally the highest resolution) superceded older, lower resolution data in the creation of the bathymetric surface. In order to exclude extrapolated values in 'upland' areas, the 'pre-surface' was clipped using a 'hybrid' shoreline obtained from multiple sources including the Oregon Coastal Management Program and NOAA Coastal Services Center. In some areas, the shoreline was digitized using the most recent Google Earth imagery.

Topographic data used in the creation of the Garibaldi DEM(s) includes lidar data collected by the Oregon Department of Geology and Mineral Resources (DOGAMI), Oregon Department of Forestry (ODF), and USACE JALBTCX (Table 3). The highest spatial resolution data from the United States Geological Survey (USGS) National Elevation Dataset (NED) was used where there was no lidar coverage. Because all of the topographic source data were already referenced vertically to NAVD88, no vertical transformations were necessary. However, Proj4 was used to establish a common horizontal reference consistent among the data.

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[2] VDatum is a free software tool developed jointly by NOAA's National Geodetic Survey (NGS), Office of Coast Survey (OCS) and Center for Operational Oceanographic Products and Services (CO-OPS). VDatum is designed to transform geospatial data between a variety of vertical and horizontal datums. This allows users to convert their data from different vertical references into a common system, which enables the fusion of disparate geospatial data, particularly in coastal regions (NOAA, 2010). URL: http://vdatum.noaa.gov/

Table 3. Topographic data sources used in the development of the Garibaldi DEM

Source	Date	Data Type	Spatial Resolution	Original Horizontal Datum	Original Vertical Datum
DOGAMI (North Coast)	2009	Lidar Point Cloud (LAS)	Point Density: $>= 8\text{pts/m}^2$	NAD83 Oregon Lambert (Intl Feet)	NAVD88
DOGAMI (Yambo Study Area)	2010	Lidar Point Cloud (LAS)	Point Density: $>= 8\text{pts/m}^2$	NAD83 Oregon Lambert (Intl Feet)	NAVD88
ODF	2007	Lidar Point Cloud (LAS)	Point Density: $>= 8\text{pts/m}^2$	NAD83 Oregon Lambert (Intl Feet)	NAVD88
USACE	2010-2011	Lidar Point Cloud (LAS)	Typical point spacing for topographic lidar is ~1-2m	NAD83	NAVD88
USGS	1999-2012	Gridded Topography	1/9–1/3 arc-second	NAD83	NAVD88

After the bathymetric surface was reviewed for anomalies and any necessary edits to the source data were made, an integrated topographic-bathymetric DEM referenced to NAVD88 was generated using MB-System[3]. The relative weighting of the datasets used in the creation of the integrated grid is listed in Table 4.

Table 4. Data hierarchy used to assign gridding weight in MB-System.

Source	Relative Weighting
Multibeam Bathymetry (NOAA & OSU)	100
USACE Topo-Bathy Lidar	100
NOAA Hydrographic Survey Soundings	60
Bathymetric 'Pre-Surface'	40
ODF Lidar	20
DOGAMI Lidar	20
USGS 1/9 Arc-Second NED	20
USGS 1/3 Arc-Second NED	10

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[3] MB-System is an open source software package for the processing and display of bathymetry and backscatter imagery data derived from multibeam, interferometry, and sidescan sonars. The source code for MB-System is freely available (for free) by anonymous ftp (including "point and click" access through these web pages). A complete description is provided in web pages accessed through the web site. MB-System was originally developed at the Lamont-Doherty Earth Observatory of Columbia University (L-DEO) and is now a collaborative effort between the Monterey Bay Aquarium Research Institute (MBARI) and L-DEO. The National Science Foundation has provided the primary support for MB-System development since 1993. The Packard Foundation has provided significant support through MBARI since 1998. Additional support has derived from SeaBeam Instruments (1994-1997), NOAA (2002-2004), and others. [Extracted from MB-System web site.] URL: http://www.ldeo.columbia.edu/res/pi/MB-System

Once the integrated topo-bathy DEM was created, it was reviewed qualitatively for any anomalies. Additionally, the values of the DEM were compared to 137 National Geodetic Survey (NGS) survey monuments located within the boundaries of the DEM to assess the quantitative vertical accuracy of the DEM. All NGS monuments used in comparison were in 'GOOD' or 'MONUMENTED' condition as defined by NGS. The results are shown in Figure 3.

The Root Mean Squae Error (RMSE) of the DEM is 4.57m (Figure 3). It must be noted that for more than half of the NGS monuments (74 of 137), the difference between the published survey elevation and the DEM was within a threshold of 1m, or 10% of the cell size. There are many possible sources of deviation from the 'expected' published values from NGS monuments, including improper classification of the source lidar data used in the creation of the DEM, the influence of DEM spatial resolution on input source measurements (i.e. the averaging of multiple data points with a grid cell) or errors with the published information contained in NGS survey monument data sheets.
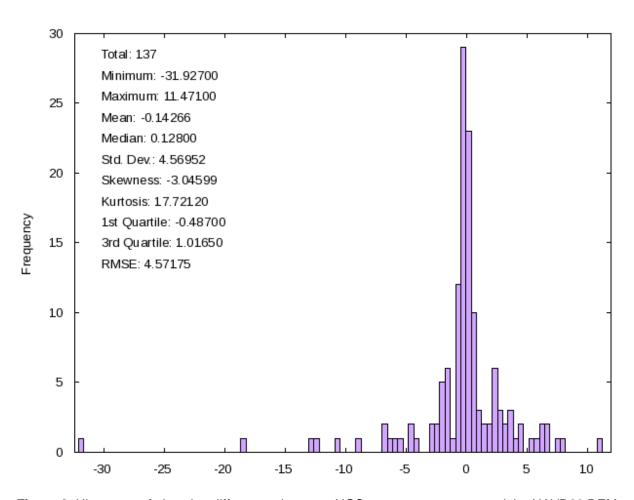

Figure 3. Histogram of elevation differences between NGS survey monuments and the NAVD88 DEM.

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The final NAVD88 grid was converted to MHW using transformation grids derived from NOAA VDatum software. The process of extrapolating MHW inland is described in Section 3.3.4 of Lim et al (2012).

References

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URL: http://www.ngdc.noaa.gov/dem/squareCellGrid/getReport/249

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URL: http://www.csc.noaa.gov/publications/slc_tech.pdf

Appendix 1- NOAA bathymetry used in Garibaldi DEM creation

Survey	Date	Resolution	Original Horizontal Datum	Original Vertical Datum
H01378	1877	N/A	North American Datum of 1983	MLLW
H04612	1926	20000	North American Datum of 1983	MLLW
H04613	1926	20000	North American Datum of 1983	MLLW
H04614	1926	20000	North American Datum of 1983	MLLW
H04633A	1926	120000	North American Datum of 1983	MLLW
H04635	1926	40000	North American Datum of 1983	MLLW
H04636	1926	80000	North American Datum of 1983	MLLW
H04637	1926	40000	North American Datum of 1983	MLLW
H04638	1926	80000	North American Datum of 1983	MLLW
H04639	1926	120000	North American Datum of 1983	MLLW
H04745	1927	20000	North American Datum of 1983	MLLW
H04746	1927	20000	North American Datum of 1983	MLLW
H04747	1927	20000	North American Datum of 1983	MLLW
H04753	1927	120000	North American Datum of 1983	MLLW
H04754	1927	80000	North American Datum of 1983	MLLW
H04755	1927	40000	North American Datum of 1983	MLLW
H04756	1927	40000	North American Datum of 1983	MLLW
H04757	1927	120000	North American Datum of 1983	MLLW
H08346	1956	10000	North American Datum of 1927	MLLW
H08368	1957	5000	North American Datum of 1927	MLLW
H08369	1957	5000	North American Datum of 1927	MLLW
H08370	1957	10000	North American Datum of 1927	MLLW
H08371	1957	10000	North American Datum of 1927	MLLW
H08372	1957	10000	North American Datum of 1927	MLLW
B00019	1985	N/A	North American Datum of 1983	MLLW

Survey	Date	Resolution	Original Horizontal Datum	Original Vertical Datum
B00020	1985	N/A	North American Datum of 1983	MLLW
B00115	1987	N/A	North American Datum of 1983	MLLW
B00116	1987	N/A	North American Datum of 1983	MLLW
H11235	2003	5000	North American Datum of 1983	MLLW
F00571[*]	2010	10000	North American Datum of 1983	MLLW
H12122[*]	2010	20000	North American Datum of 1983	MLLW
H12123[*]	2010	20000	North American Datum of 1983	MLLW
H12124[*]	2010	20000	North American Datum of 1983	MLLW
H12125[*]	2010	20000	North American Datum of 1983	MLLW
H12126[*]	2010	20000	North American Datum of 1983	MLLW
H12127[*]	2010	20000	North American Datum of 1983	MLLW
H12128[*]	2010	20000	North American Datum of 1983	MLLW

[*] Denotes BAG survey