Date: 23 December 2012

A coastal vulnerability index for the Philippines using remote sensing data

W. R. Clavano

Institute of Environmental Science for Social Change

Correspondence to: wrclavano@gmail.com

Abstract

A quick assessment is made to characterize the vulnerability of the Philippine coastline to sea-level change. Freely available remote sensing data is used to provide values for mean sea-level change, coastal slope, tidal range, and mean significant wave height. By ranking these variables, a coastal vulnerability index (CVI) for the Philippines is produced. Results of this national assessment, which provide a relative measure of risk, is provided here accompanied by the parametric values for each point in a grid cell along the coast. This allows other users to adjust the ranking as they see fit or to adapt the data to more localized contexts. For example, the results of this study could be combined with human factors to produce a more useful index.

1 A coastal vulnerability index

A report by the United Nations Environment Programme (UNEP, 2005) ranked the Philippine coastal zone as highly vulnerable to environmental change when compared to other countries. Many factors contribute to the vulnerability of a particular coast to sea-level change. Along with the mean rate of sea-level change, these include the exposure of the coastal zone to the different physical processes including winds and tides, its geomorphology, as well as land use and other human factors. In the study presented by Clavano (2012), freely accessible remote sensing data is used to construct a coastal vulnerability index (CVI) for the Philippine coastline. Future research will include information on human factors, such as population density and coping capacity, at a more local scale to make the index more relevant to a particular planning area. In the meantime, interested groups (for example, local governments and communities) are welcome to use the data provided here, perhaps complementing it with their own assessments.

The approach here is adapted from the index used by the U.S. Geological Survey (Theiler and Hammar-Klose, 1999), which defines a CVI as the square root of the geometric mean of the different parametric values, r, so that

$$\text{CVI} = \sqrt{\frac{r_1 \times r_2 \times \cdots \times r_n}{n}}$$

where n is the number of factors considered. The factors included in the index here is listed in Table 1, which is 4 out of the 6 factors Theiler and Hammar-Klose (1999) use, minus geomorphology and shoreline change rate.

2 Data used and their sources

Information used to create the CVI is based on remote sensing data and is freely available. Included in this analysis are mean sea-level change, coastal slope, mean tidal range, and mean significant wave height. Pendleton et al. (2010) has found that most of the variability in the results of a CVI based on environmental factors alone can be explained entirely by only four variables: geomorphology, coastal slope, sea-level change rate, and mean significant wave height. In the absence of a geomorphology class, we hope that the inclusion of tidal range can serve as its temporary proxy, representing how much of a coast would be affected by this physical process.

– Coastal slope. Calculated from a blend by W. Smith of the GEBCO (General Bathymetric Charts of the Oceans) and Smith and Sandwell (S2004) combined bathymetry and topography. A link to the data is available from the Applied Modelling and Computation Group of the Department of Earth Science and Engineering at Imperial College London ftp://facon.grdl.noaa.gov/pub/walter/Gebco_SandS_blend.bi2. Other sources are also available, for example, see the Satellite Geodesy website of the Scripps Institute of Oceanography (http://topex.ucsd.edu/WWW_html/mar_topo.html).

– Mean sea level variation. Regional mean sea level trends [mm/yr] from October 1992 to April 2012. Data compiled by CLS/CNES/Legos. Note that the projections do not include variations caused by glacioisostatic adjustment. Available online at http://www.aviso.oceanobs.com/en/news/ocean-indicators/mean-sea-level/.

– Mean significant wave height. Gridded wind/wave products. Produced by Legos and CLS Space Oceanography Division and distributed by AVISO, with support from CNES. Available online at http://www.aviso.oceanobs.com/en/data/products/wind-waves-products/mswhmwind.html.

– Tidal range. FES2004–Finite Element Solution-Global Tide Model. Produced by Legos and CLS Space Oceanography Division and distributed by AVISO, with support from CNES. Available online at http://www.aviso.oceanobs.com/en/data/products/ auxiliary-products/global-tide-fes2004-fes99.html.

– Coastline. GSHHS–A Global Self-consistent, Hierarchical, High-resolution Shoreline Database. Developed and maintained by P. Wessel of SOEST at the University of Hawai'i and W. H. F. Smith of the NOAA Laboratory for Satellite Altimetry and distributed by the NOAA National Geophysical Data Center. Available online at http:// www.ngdc.noaa.gov/mgg/shorelines/gshhs.html.

There is insufficient data about shoreline change rates in the Philippines to include this parameter in the current CVI. Had a geomorphology class been included, it would rank rocky cliffs as very low vulnerability, low cliffs and alluvial plains as moderate, and salt marshes, mud flats, deltas, mangrove areas, and coral reefs, among other things, as high. Thus, the ranking is useful if it is considered as indicative. Alternative sources of information representing geomorphological characteristics sensitive to sea level change is currently under investigation. Similarly, there is not enough data to include shoreline change in terms of erosion or sediment accretion to include it in the ranking. However, equal amounts of erosion or accretion, or no change at all would have moderate vulnerability, accretion areas would be low and erosion areas would be high.

3 Ranking of values

When the ranking of the parametric values are made relative to a region, the resulting CVI becomes more useful. The full range of values along the Philippine coast for each variable is considered and distributed accordingly. For example, the range of mean significant wave heights along the Philippine coast varies between 0.69-2.08m. Fig. 1 (a) shows how the empirical cumulative distribution of the values allows the identification of the lowest 30% of observations and to rank them "very low", the next 20% "low", the following 20% "moderate", another 20% "high", and the highest 10% as "very high." Values for both tidal range and coastal slope are ranked in reverse, that is, the lowest values are ranked "very high" and vice versa. The resulting division of parametric values is presented in Table 1.

Variable values are applied to the ranks: 1, 2, 3, 4, and 5 from "very low" to "very high," respectively. Similarly, we look at the distribution of the resulting indices and divide these into the same percentiles as for the values of each of the factors above to come up with a final ranking. Values for each of factors, their ranks, the CVI, and the overall rank are included in the data file. The final vulnerability ranking can, of course, be changed when a different geographic area is considered or when there is significant alteration to the coastline or its conditions.

4 Results and the data file

Fig. 2 shows the results of the CVI using only environmental data: sea-level change, tidal range, significant wave height, and slope. A 0.5-arcdegree grid is used to identify cells that represent the coastline, which is sufficient for this national assessment. Finer resolutions can certainly be produced for elevation data but compared to the other variables, which are only available at this scale or higher, the cost does not outweigh the benefits.

The data file is provided in ASCII format and is temporarily shared through the link
https://docs.google.com/0B2HxNxQGUtqrNmNlXy1QRjFEODA
Coordinates for each grid cell and its CVI is provided in the file. Also in the file are the values of each of the parameters used to construct the CVI. They have been provided to allow the user adjust the ranking, apply different weights, or focus in on a specific area, with the objective of making the assessment more useful or accounting for changing conditions or priorities (see, for example, Frihy and El-Sayed (2012) and other CVI studies mentioned in UNEP (2005)). Each variable's rank follows that value, the final CVI and its rank occupy the last two columns, respectively. One header line in the text file reminds the user of the values in each column.

```
Longitude Latitude Cslope rc MSL rs MSWH rw Trange rt CVI R
```

5 Summary

Using quickly and freely accessible remote sensing data, a coastal vulnerability index (CVI) can be constructed considering only environmental factors to present an indicative measure of coastal risk at a national level. The ranking is adjusted to the range of values found in a region, which makes the index relative but perhaps also more relevant. Results for the Philippines are provided here in a grid where only cells along a coastline have values. Information is on the geomorphological characteristics the represent shoreline change is not readily available. Including this information would significantly improve the quality and usefulness of this CVI, and is currently under investigation. Users are encouraged to adjust the ranking, revise the values, and/or play with weighting each factor, as well as expand the index by adding human factors such population density and coping capacity, to create a tool that is more useful given a certain context.

Acknowledgements. Support for this research from Assicura Worldwide is greatly appreciated.

References

Clavano, W. R. .: Changing sea levels: the global context and Philippine coastal vulnerability, online, http://ecojesuit.com/changing-sea-levels-the-global-context-and-philippine-coastal-vulnerability/2521/, presented during a conference on internal migration and displacement, Davao City, Philippines, 20–22 May 2012, 30 Apr, 2012.

Frihy, O. E. and El-Sayed, M. K.: Vulnerability risk assessment and adaptation to climate change induced sea level rise along the Mediterranean coast of Egypt, Mitigation and Adaptation Strategies for Global, Online First, doi:10.1007/s11027-012-9418-y, 23pp, 2012.

Pendleton, E. A., Thieler, E. R., and Williams, S. J.: Importance of coastal change variables in determining vulnerability to sea- and lake-level change, Journal of Coastal Research, 26, 176–183, doi:10.2112/08-1102.1, 2010.

Theiler, E. R. and Hammar-Klose, E. S.: National Assessment of Coastal Vulnerability to Future Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast, online, http://pubs.usgs.gov/of/of99-593/, Open-File Report 99-593, 1999.

UNEP: Assessing Coastal Vulnerability: Developing a Global Index for Measuring Risk, http://www.unep.org/DEWA/products/publications/2006/CVI_PM65_Final_05.pdf, United Nations Environment Programme, Division of Early Warning and Assessment, 54pp, 2005.

Table 1. List of factors included in the current CVI assessment along with a ranking of parameter values. These have been scaled to match the ranges currently found in the Philippines and arbitrarily selected from the different distributions as shown in Fig. 1. This results in an index that is region-specific so that relative values can guide the identification, for example, of 10% of the Philippine coastline that are of highest risk.

	Very low	Low	Moderate	High	Very high
Rank value	1	2	3	4	5
Percentage of observations	30%	20%	20%	20%	10%
Slope [%]	$>$1.7	1.7-0.9	0.9-0.4	0.4-0.1	$<$0.1
Sea level change [mm/yr]	$<$6.5	6.5-7.1	7.1-7.7	7.7-8.5	$>$8.5
Mean significant wave height [m]	$<$0.8	0.8-1.0	1.0-1.4	1.4-1.7	$>$1.7
Mean tide range [m]	$>$3.9	3.9-3.3	3.3-3.1	3.1-2.8	$<$2.8

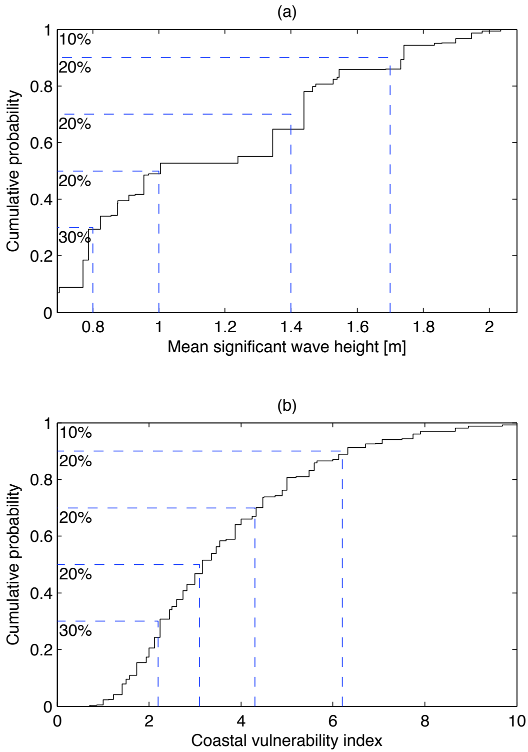

Fig. 1. Division of parametric values and final indices using the empirical cumulative distribution.

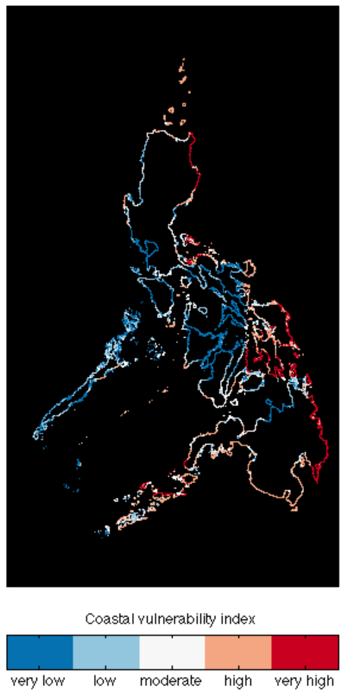

Fig. 2. A CVI map of the Philippine coastline showing the spatial distribution of low and high vulnerabilities. The ranking assesses values of mean sea-level change, coastal slope, tidal range, and mean significant wave height. All the data have been gathered using remote sensing and are freely available online.