Marine Structures 37 (2014) 33–53

Contents lists available at ScienceDirect

Marine Structures

journal homepage: www.elsevier.com/locate/marstruc

Changes in the design and operational wind due to climate change at the Indian offshore sites

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A R T I C L E I N F O

Article history:
Received 12 February 2014
Accepted 13 February 2014

Keywords:
Offshore structures
Operational wind
Design wind
Climate change impact
Neural networks

A B S T R A C T

The increasing global warming is most likely to affect the magnitude and pattern of wind at a regional level and such an effect may or not follow the trend predicted at the global scale. Regional level exercises are therefore necessary while making decisions related to engineering infrastructure. In this paper an attempt is made to know the extent of change in design as well as operational wind conditions at two offshore locations along the west coast of India. The design wind speeds with return periods of 10, 50 and 100 years derived for two 30-year time slices in the past and future are compared. In two separate exercises the past and future wind at the local level is simulated by empirical downscaling as well as by interpolation of the general circulation model (GCM) output. Both sets of past and future data are fitted to the Generalized Pareto as well as Weibull distributions using the peak over threshold method to extract long term wind speeds with a specified return. It is noticed that at the given locations the operational and design wind may undergo an increase of around 11%–14% when no downscaling is adopted and 14%–17% when the GCM data are downscaled. Although these figures may suffer from a certain level of statistical uncertainty the study points out to take a relook into the safety margins kept in the design and operation of ocean structures in the light of global warming.

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http://dx.doi.org/10.1016/j.marstruc.2014.02.005
0951-8339/

1. Introduction

The inter-governmental panel on climate change (IPCC), based on sophisticated modeling tools and observations of average air and ocean temperatures over the earth, had confirmed existence of global warming that is most likely due to human interference with the atmosphere [1]. Due to dependency of air pressure on temperature changes in wind speed and its pattern of flow can only be expected as a consequence. An increase in wind could affect other coastal processes as well. For example as per DHI [2] a 10% rise in wind can give rise to 26% higher waves and 40%–100% jump in the rate of sediment transport in general. The stated increase in wave heights may possibly result in case of wind of around 20 m/s generating fully developed seas. A quantitative prediction of such changes with respect to operational and design wind speeds would go a long way in ascertaining safety of various coastal, harbor and offshore structures installed in the sea. The present study is oriented in this direction and it predicts the change in values of daily mean wind speeds corresponding to return periods of 10, 50 and 100 years, typically used in operation and design exercises. The changes are worked out for two offshore locations along the western Indian coastline. Such station-specific studies are necessary because ocean structures are built with local conditions and the regional change may or not follow global trends due to the influence of a variety of local factors like coastal geomorphology, shifting of storm tracks and surface roughness.

The procedure to evaluate the changed wind conditions normally involves use of a general circulation model (GCM) which is a mathematical description of circulations in atmosphere, ocean, and at land boundaries. Based on concepts of mass, momentum and energy balance, it simulates response of climate systems to increasing global temperatures arising out of the rise in green house gas emissions. A GCM typically gives predicted values of climate variables including wind speeds and directions over large spatial grids and time steps. Investigators over the world are continuously experimenting with a variety of GCMs with a view to come up with more and more accurate and reliable versions. Those working under the US based World Climate Research Program have conducted a state of the art modeling exercise called Coupled Model Inter-comparison Project (CMIP) that deals with analysis of coupled atmosphere and ocean general circulation models. The 5-th phase of this experiment called CMIP5 is one of the latest and it involves several multi-model exercises for reliable impact assessments [3].

A GCM is run for possible future scenarios of temperature rise due to a certain increase in greenhouse gas emissions together with world's response to reduce such emissions. The Fourth assessment report, AR4, of IPCC lists six families of warming scenarios, including the high warming scenario: A2. The revised scenarios in the latest Fifth assessment report, AR5, are called Representative Concentration Pathways (RCPs) and these are specified as per their warming potential and societal response encapsulated into a certain radiative forcing, like 4.5 or 6.5 W/m^2, that drives the GCMs. More information regarding the GCMs can be found out in textbooks by Donnor et al. [4] and Randall [5].

The outputs of GCMs are available over large spatial grids and hence may need conversion through a process called downscaling to apply to a specific region. There are basically two alternatives to downscale GCM data, namely, dynamical and statistical. In dynamical downscaling the knowledge of the underlying physical process is utilized while the statistical alternative exploits regression capabilities of various statistical and other approaches like artificial neural networks and genetic programming. The various downscaling models are presented in Prudhomme et al. [6] and Wilby et al. [7]. The standard for downscaling could be observed data or reanalysis data available over a long term. The reanalysis data result from assimilation of observations into GCM predictions, making the latter more reliable. The reanalysis data called ERA-40 of European Centre for Medium-Range Weather Forecasts (ECMWF) is available over a period of more than 40 years in the past. The National Center for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) have created historical wind records of more than 50 years.

Owing to an incomplete knowledge of the physics underlying various atmospheric processes and also due to the application of numerical schemes to solve the governing differential equations, GCM data contains bias or a systematic error. There are various ways to remove such a bias and most of these involve comparison of statistical properties of a given GCM with those of a more reliable long term dataset obtained by other means like observed or reanalysis data.