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Study of Climatic Models to check the Quality of Water

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Abstract - *Climate change describes the changes into the behavior of climate that may be extended for a period of decade or longer. Its impact on the environment is devastating if the same trend of carbon emission is followed (IPCC 2021). Therefore it necessitates finding out the effect of climate change in future, certainly 30 years in future. Climatic models such as General Circulation Models (GCMs) are used to check this impact on the ocean. Dissolved Oxygen is one of the most important parameter which decides the pollution level of the water. Water quality along the coast line of major cities across the world is at its worst due to the addition of unwanted pollutants to the sea water. Therefore in the present study it is proposed to assess the quality of ocean water by checking the Dissolved Oxygen (DO) Concentration. The general circulation models used for this study are taken from CMIP5 and CMIP6 projects. CanESM5 and NCAR CESM1-1-CAM5-CMIP5 models for hind-cast period of 1980-2010 and 2017-2027 respectively have been used for this study.*

Key Words: *IPCC, General Circulation Models (GCMs) , Dissolved Oxygen, CMIP5 and CMIP6*

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations. Its job is to advance scientific knowledge about climate change caused by human activities. The World Meteorological Organization (WMO) and the United Nations Environment programmed (UNEP) established the IPCC in 1988.

The IPCC has chosen a trajectory for greenhouse gas concentrations (not emissions), known as the Representative Concentration Pathway (RCP). For the 2014 IPCC Fifth Assessment Report (AR5), four research and simulation pathways were employed. Various climate scenarios are depicted in the pathways, all of which are thought to be feasible given the level of greenhouse gas (GHG) emissions in the years to come. The RCPs are named after a potential range of radiative forcing levels in the year 2100 (2.6, 4.5, 6, and 8.5 W/m2, respectively). The original RCPs were RCP2.6, RCP4.5, RCP6, and RCP8.5. The original routes and Shared Socioeconomic Pathways, as well as new RCPs including RCP1.9, RCP3.4, and RCP7, have been taken into consideration since AR5.

The greenhouse effect simply is a natural process to balance greenhouse gas concentration throughout the atmosphere. However, due to anthropogenic activities, this natural effect becomes an environmental problem for the entire world. It tends to occur global warming. The world's climate always varied naturally, but the climate change largely variates due to the concentration of "greenhouse gases" in the earth's atmosphere since the industrial revolution began. Now overriding this natural variability and leading to irreversible climate changes. If no climate policy interventions are implemented or modified, future climate changes will be caused by harmful effects on Sri Lanka islands. This study focuses on discussing the Sri Lankan contribution to global warming from industries. Here mainly discussed four industries' GHG emission sources and further aim to discuss the Sri Lankan rules and regulations and implementation options

A potentially disastrous process is being aided by rising atmospheric carbon dioxide levels in addition to the effects of climate change. With a capacity to hold around one-third of all manmade carbon dioxide emissions, the oceans constitute the planet's largest carbon sink. More CO2 is absorbed by the ocean as air concentration rises, which results in a drop in seawater's pH and an increase in its acidity. Coral reefs, shellfish, and the plankton that serve as the foundation of the ocean's food chain are already in danger due to the changing chemistry of the ocean, which will also impact some marine species' capacity to create shells and skeletons. (See Orr et al., "Anthropogenic Ocean acidification over the twenty-first century and its influence on calcifying species," Nature 437:681-86.)

The trend of oxygen depletion is around two to three times more rapid than what it is anticipated from the decline in solubility caused by the warming of the ocean. The heating of the near-surface waters and melting of the polar ice are most likely to blame for the changes in ocean circulation and mixing.

More dissolved gas can be held in cold water than in warmer water. Therefore, it follows that as ocean surface temperatures rise, so does its ability to dissolve oxygen. However, the study's findings revealed that melting polar ice was interfering with the ocean currents that mix highly oxygenated water with subterranean water. As a result, oxygen was finding it more challenging to dissolve in the water.

1.1 General Circulation Model

GCM stands for "General circulation model". General circulation model is one of the most important tools in climate science. What if you know about our future climate is based on this model so it is important to understand how they are made, how they are tested & how they are used. Models are essential tools in science, it allows to use data to make predictions about processes that can directly measure such as, things shall happen in future or things were happened in the past. GCM are built on well understood physical principles, they use complex map and computer algorithms to predict how energy and matter interact. GCM are temporal models meaning that they who predict changes urban time. Time interval can vary year to year or to minute to minute. For the small interval the prediction should be more precise. GCM are also special model because they predict conditions on all areas of the plan, grid size is very important. The smaller the grid size the more precise prediction for given location. GCMs are also has probabilistic meaning that the predicted outcomes come from the models are associated with a percent likely heard again heard right. In general, the better the data to a government model the more accurate the model will be. The most advanced tools now available for predicting how the global climate system will respond to rising greenhouse gas concentrations are general circulation models (GCMs), which simulate physical processes in the atmosphere, ocean, cryosphere, and land surface.

1.2 CMIP5 (Coupled Model Intercomparison Project Phase 5)

It is a comprehensive set of experiments created by the World Climate Research Programme's working group on coupled modelling. Numbers of GCMs are available on this site. This methodology enables a broad group of scientists to approach the systematic analysis of GCMs. CMIP5 is meant to provide a framework for coordinated climate change experiments for the next five years.

1.3 CMIP6 (Coupled Model Intercomparison Project Phase 6)

CMIP6 is the upgraded version of CMIP5. It is a comprehensive set of experiments created by the World Climate Research Programme's working group on coupled modelling In terms of the number of modelling groups involved, the number of potential future scenarios considered, and the number of various experiments carried out, CMIP6 represents a significant improvement over CMIP5. A set of common simulations are created by CMIP and then executed on each model.

1.4 IPCC (Intergovernmental Panel on Climate Change)

An international organization under the United Nations is the Intergovernmental Panel on Climate Change. Its role is to increase scientific understanding of how human activity is causing climate change. Every year the working group of people publishes the report on climate change.

1.5 RCP (Representative Concentration Pathway)

RCP means Representative Concentration Pathway. One must forecast our behavior in order to understand how our climate could alter in the future. In RCPs, a wide range of potential climate change-related problems are described, including greenhouse gases, air pollutants, emissions, and land use. In a number of ways, RCPs have made history. Some of the greatest and lowest greenhouse gas emission scenarios lately explored by the field of climate science are included in them. Unlike the Special Report of Emission Scenarios (SRES), which focuses solely on a no-climate-change strategy, they contain scenarios that mitigate climate change. Fig1 shows the Representative Concentration Pathway with the emission.

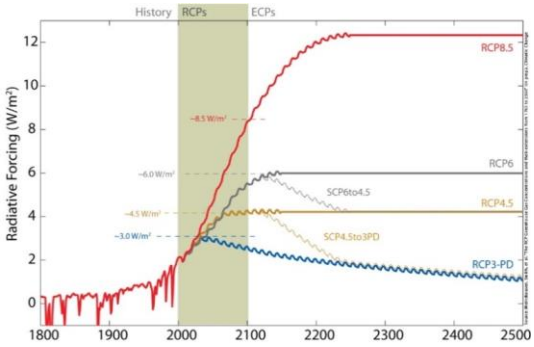

Fig1. RCP Calculations and Data

2. LITERATURE SURVEY

The extreme literature survey has been done on the summary of previous research on General Circulation Model. Through this it has been found the different parameters which are used in GCM.

R. L. Wilby et.al (1998) evaluated the Statistical downscaling of general circulation model output which has the Objective as four statistical downscaling methods were applied to the CMIP6 GCM to execute the different statistical downscaling by given data. There were many GCM models, major is HadCM2 general circulation model, also there are 2 artificial neural network approaches ANN1, ANN2 where ANN2 was majorly used because it was temperature predictor. Other two methods were based on airflow (B-Circ and C-Circ). So these downscaling are calibrated using data prediction method. And these methods exhibited the greatest proportional changes at the sites. The results were compared by GCM-derived predictor variables and by standard sets using a standard suite of diagnostic statistic. Once the downscaling methods are evaluated, the future projections for the drought-related indicators are derived from the methods. D. A. Sachindra, F et.al (2014) have

worked on the Statistical downscaling of general circulation model outputs to catchment scale hydro climatic variables: issues, challenges and possible solutions which have displayed the Outputs of a downscaling study mainly dependent on quality and length of the record of field observations. As it is observed that Greenhouse Gases (GHG) are increasing which can cause anthropogenic climate change. In future the data of GHG and other gases emission scenarios is observed so it needed to downscale the data in regional manner so RCM is the factor used to downscale data regionally. The uncertainties that are observed to the outputs of a statistical downscaling study due to different statistical downscaling techniques are less in comparison to the uncertainties arising from GCMs and greenhouse gas emission scenarios. Statistical downscaling study should be used as indications rather than exact predictions.

Andrew D. Polasky et.al (2022) looked over the CC downscaling which was an open-source Python package for multivariable statistical climate model downscaling V1.0 So It is method for obtaining high-resolution climate or climate change information. As the climate change information tends to grow so to downscale this data there are some applications for this like CC downscaling package that provides number of downscaling methods. It is an open-source framework, the code is created to accommodate new methods for future users. The code is basically written in python language as it is widely used in both the Atmospheric Science and Machine Learning communities. It has several methods and metrics for evaluating the skill on several variables important for different downscaling applications. Using Self-Organizing Maps (SOM) so it can be examined the projected impacts of climate change. SOM method includes two particular training metrics quantization and topological error. Second used is Scikit-Learn which develop machine learning-based downscaling models to determine impacts of atmospheric warming on regional weather 90 and climatic conditions. The analytical solution of the model is found accelerating need for predictable and highly localized data for climate change scenarios led to the development of software. Jolene Cook et.al (2022) at EPSRC were always ready to dedicate time and energy to the needs of the team. BEIS also organized the venue hosting the core team for the 14th Session of IPCC WG III. Mitigation of Climate Change is found to be the third section of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) and it was created by Working Group III. The report presents an up-to-date assessment of worldwide emissions from all sources and industries, which includes actual and projected levels. Mitigation tactics used to reduce emissions and remove greenhouse gases from the atmosphere, and advancements in achieving climate goals. Three guiding principles served as the basis for the WG III contribution to AR6 that improved the synthesis between higher-level and bottom-up insights into technologies and other for reducing emissions; they used social science disciplines more broadly, mainly for gaining insight into problems of lifestyle, behavior, consumption for better connect climate change mitigation to other fields of study.

Bryson Bates and Zbyszek Kundzewicz (2008) have found that number of changes in the large-scale hydrological cycle, includes the increase in atmospheric water in amount of vapor content, altered precipitation patterns, intensities, and extremes, decreased snow cover and widespread ice melting, and adjustments to soil moisture and runoff, it have been linked to observed warming over the past several decades. Freshwater resources are found to be in danger of being severely impacted by climate change. The ability to predict future changes in hydrological variables and their impacts on systems and sectors is constrained by uncertainty at all stages of the assessment process. Uncertainty is influenced by a number of factors, like the range of socioeconomic development possibilities, the range of climate model forecasts for a specific scenario, the downscaling of climate effects to local and regional scales, impacts assessments, and feedback from adaptation and mitigation efforts. M. A. Chamberlain1 et.al (2012) presented a study of Boundary currents and eddies which are examples of ocean characteristics that are currently resolved by global climate models used for project climate change. That has accurately forecasted the marine implications of climate change. Ocean model baseline conditions and surface fluxes were combined with climate change to create a time-slice prediction for the ocean in the year 2060. Here, the downscaling model is ocean-only and does not take into account how changes in the state of the ocean will affect the atmosphere and air-sea fluxes. To simulate real-ocean feedback on heat and maintain steady salinity, it has been stated to use restoration of the sea surface temperature and salinity.

Daisuke Kozaki et.al (2017) have Determined the Water Quality Degradation Due to Industrial and Household Wastewater in the Galing River in Kuantan which have the western side of the Galing River had higher levels of human activity, including an influx of commercial, residential, and untreated raw sewage effluent, and recorded lower class levels than the eastern side in terms of ammoniacal nitrogen, COD, and DO. To understand the influence of the source on water quality, studies have monitored both typical parameters and heavy metal species in industrial, raw sewage, and domestic wastewaters that have discharged from all areas of the Galing River basin area. It is been recommended to look into the evaluation of the water quality data using specific Kuantan city statistics (business type, population of each lot, etc.). Additionally, it is vitally crucial to build a new water treatment plant, sewage system, and thoroughly examine industrial wastes in the western part of the Galing River basin area. B. B. Cael et.al (2022) have demonstrated that how ocean colour measured by remote sensing reflectance exhibits a more rapid emergence of climate change trends due to its multimodal nature and the low inter annual variability of specific wavebands. Following sample collection, DO was locally measured using

a portable DO meter. After the samples were collected, the pH values were determined in the lab using a desktop pH meter. A UV-visible detector was used to calculate COD.

In arid and semi-arid nations like the United Arab Emirates, the future projection of air temperature and precipitation due to climate change has a significant impact on how water resources management strategies are developed (UAE) have been studied by Abubaker El Hakeem et.al (2015) .The outputs of the coarse global circulation models (ocean atmosphere global climate models, or OAGCMs) typically understate the impact of local topography, land use, and sea land differences. To enhance future forecasts, statistical downscaling (SD) links and OAGCM outputs (predictors) are found to be more precise local observed weather data .The Hadley Model (HadCM3) predictors are downscaled in this study using local observations at two stations that reflect the main bioclimatic zones in the UAE. The article suggests a thorough and organized process to direct the choice of dominating predictors in the suggested methodology is used for the UAE, however it is easily adaptable to other regions. By 2080 at the studied stations, the calibrated model, which was used to estimate future scenarios in the area, showed a range of increases in annual mean maximum temperature and a range of decreases in annual precipitation. In light of the revised predictions for temperature and precipitation, the effects of climate change on the management of the UAE's water resources are examined. The impacts of temperature are particularly substantial because a significant portion of the water resources are used for agriculture. At the national level, however, the effects of precipitation are rarely noticeable. The effects of less precipitation, however, will have a more localized influence on mountainous areas that are critically dependent on precipitation for water resources.

3. SELECTION OF GCM

This present study consists of parameter named O2 (Dissolved Oxygen concentration). So the data has been taken from CMIP 5 and CMIP6 sites. Table 1 shows the details about the GCM downloaded from IPCC Model IDs.

Table 1. GCM Downloaded

Title	IPCC MODEL ID	PRIMARY REFERENCE
CCCma CanESM5 model output prepared for CMIP6 DCPP dcppA-hindcast (1980-2010)	CCCma CanESM5	Sospedra-Alfonso, Reinel; Lee, WooSung; Merryfield, William J. et al. (2019)
NCAR CESM1-1-CAM5-CMIP5 model output prepared for CMIP6 DCPP dcppA-hindcast (2017-2027)	NCAR CESM1	Danabasoglu, Gokhan (2019)

4. DOWNLOADING OF GCM

The General circulation model has been downdoaded from CMIP6 and CMIP5 site for the O2 (Dissolved Oxygen concentration). The downloaded GCM files have been given in the fig 2 below.

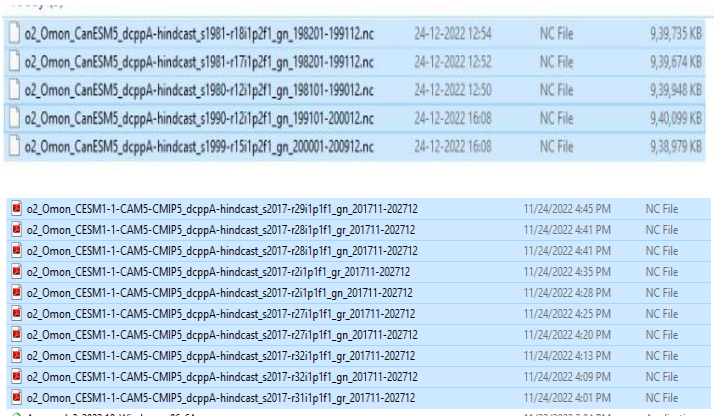

Fig 2. GCM files

5. USE OF DOWNLOADED GCM

The GCM that have downloaded used for the analysis of O2 (Dissolved Oxygen Concentration) from the ocean by the help of downscaling methods for the prediction of O2 level in water from the ocean. This data helps to study climate change impact on water due to rise in water pollution. This downloaded GCMs are need to extract for the further studies by using extracting tools. The Panoply tool (Fig3) which has developed by NASA has used for extraction of the GCMs from .NC file format to text or csv.

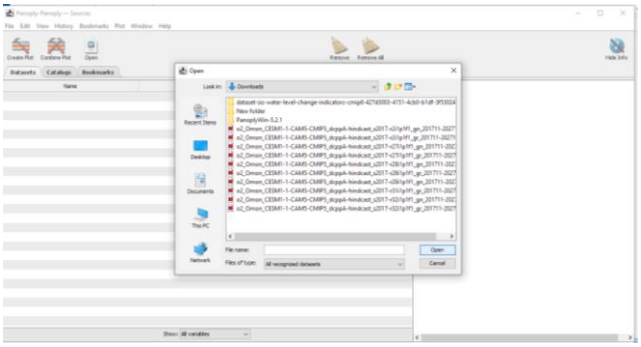

Fig 3. Panoply interface

6. DOWNSCALING

High-resolution climate or climate change information can be obtained by downscaling from General Circulation Models with comparatively low resolution. For the GCM file Downscaling is the important stage to focus on particular region from the globally collected data. From the downscaling method got the proper readings for our region for the study. Downscaling can be done by the various methods like Statistical Downscaling and Dynamic Downscaling. Fig4. Show the downscaling from Global Climate Model.

Statistical Downscaling: Simple method for Downscale the GCM extracted files to give accurate readings or data. The statistical downscaling approach use statistical regressions for translation. Such techniques can be as simple as multiple regressions, which connect local variables to specific GCM drivers, or as sophisticated as support vector machines and neural networks, which use multilayer, input-output configurations.

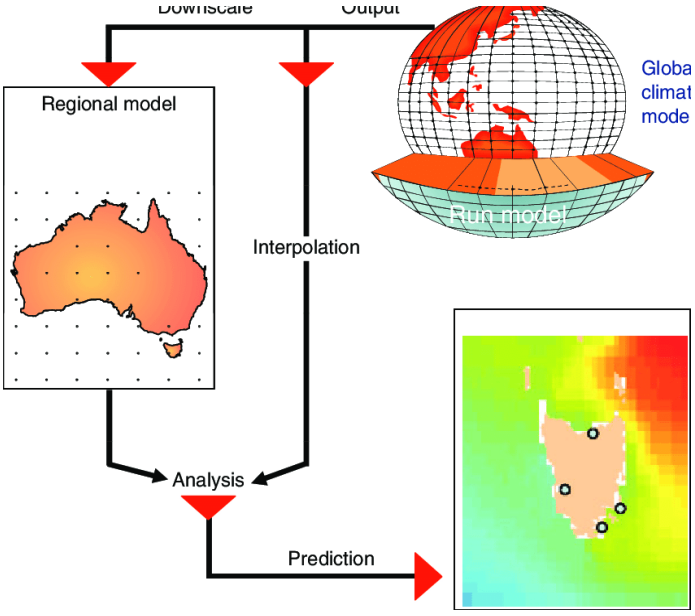

Fig 4. Downscaling from Global Climate Model

This method, sometimes referred to as empirical downscaling, is mostly data driven. In general, the process starts with determining the connection between global factors and regional climatic conditions. Once this link has been established for the present, it may be used to future predictions. The Statistical Downscaling done with software like ANN, MATLAB, PYTHON, etc.

Dynamic Downscaling: It is another method of downscaling of GCM. This is the Advance level of Downscaling method. It needs high-level supercomputer or massively parallel computer for the high-resolution climate change data.

7. CONCLUSION

From this study it has been acknowledged that how climatic change affects the water quality especially in the oceanic regions. There is a major importance of the general circulation model (GCM) because it played an important role that how it has affected the water quality and climatic change. It has found that the number of GCM's used, the parameters are affecting the climatic and oceanic regions. Majorly the parameter that have used is DO (Dissolved Oxygen) which cause Fish and other aquatic species depend on it to survive. As the waste water from the various parts entering into the oceans the Fish and other aquatic species cannot survive when the dissolved oxygen level is too low.

Along with DO other parameters are also important but here mainly here the concerned about DO as BOD and COD are directly connected with DO. While searching the GCM models it has been found that many models which are based on DO variable from CMIP5 and CMIP6 sites. These sites information is been displayed in the previous parts of our report.

8. FUTURE SCOPE

From this study one can go for Statistical Downscaling technique as that of the dynamic downscaling technique because Statistical downscaling techniques can be used for much higher resolutions, up to station-scale, and are computationally cheap and much faster than dynamical downscaling techniques. As it has also found out that statistical downscaling has again major area in the field of ANN, MATLAB and also by using Python Code that can downscale the data that have been collected globally to regional area.

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