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DEVELOPING A DYNAMIC DATA BASE FOR CLIMATE CHANGE IN EGYPT (ROBUST TOOL FOR INTRODUCING CLIMATE CHANGE)

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ABSTRACT

Developing a Dynamic Data Base system for climate change (DBCC) could be associate for enhancing scientific Knowledge in how climate change is predicted and support a new innovation and scientific researches, improve the climate information and water related measures and then support the decision makers to build strategies that cope with climate disaster with related water impacts. This study aims to develop dynamic database (DBCC) system as robust tool to support decision maker for sustainable development projects. This tool is depending on the future projections of climate models and climate scenarios taking in consideration the analysis of extremes climate indicators, trends, and frequency of occurrence of some hazards. In This tool, projections of climate change up to year 2100 for many regional climate models and examples of 40 General circulation models (GCM) with different climate scenarios have been stored, rather than historical data for more than 30 years in daily basis. The future projections of climate models were downloaded dynamically and statistically and biased corrected before stored in DBCC system. In this paper the applied analysis, algorism and the features of the dynamic database with detailed design criteria's and methodologies have been presented. This tool is applied at Wadi El-Natron area that lies at the west of Nile Delta which characterized with low area and suffered from many extremes' events. MYSQL engine with java, python, and net programs languages are used for deployment of this system with user friendly interface. This tool is flexible and dynamic for adding and enhancing for other climate models, parameters or another pilot area.

KEY WORDS : Dynamic Data base management system, Climate change, Climate model

INTRODUCTION

Wadi El-Natron area lies to the west of Nile Delta and it is considered the natural extension of Nile Delta. It is generally a landform depression locating in El-Behera Governorate, Egypt. It is a town with the same name. The name indicates that there are eight different lakes in the area that produce Natron salt. In Christian literature, it is known as "Scetis". Wadi El-Natron is one of the three early Christian monastic centers locating in the desert of the northwestern Nile Delta. The other two monastic centers are Nitria and Kellia. Now, Scetisis called Wadi El Natrun, which is the best known today because it is the most ancient monasteries remain in use, unlike Nitria and Kellia which have only archaeological remains. Figures (1 and 2) show some photos for some monasteries that are located inside the boundary of Wadi El-Natron. The Nitria Desert is sometimes used to refer to the entire region in which the monasteries are located. It can also refer to the vicinity around Nitria and Kellia, where the area around Wadi Natrun is called then more specifically as Scetis Desert. Wadi El-Natron has religious and historical importance because it is recipe sanctification in Christianity for the passage of the holy family. The region is known by several names best known such as the salt field and Sheahat (Scetis), Alasagat and Bir Hooker. The first monastic Christian gathering on the territory of the Valley of Natron is back to the fourth AD Century at the hands of the big St. Magar, which established the monastery of St. Magar, which is still in operation the monastery of Amer yet next to three other monasteries, namely: the monastery of St. Bishoy and Paramos Monastery and the Monastery of Syriacs. The area contains about 700 monasteries in the second half of the fourth AD Century. So, the region is considered as the most important holy areas for followers of the Coptic Orthodox Church.

In addition, Wadi El-Natron area has always been confined as possible area for reclamation and utilization due to its location and the presence of water resources (groundwater) in suitable quality for irrigation. It has about 1.1 Million Feddan cultivated land including 140,000 Feddan are cultivated by wheat. Wadi El-Natron, as a part of Egypt, is vulnerable to climate change. In 2015, a torrentialstorm caused huge damage especially the monasteries which is considered an effective recourse for religious tourism in Wadi El-Natron as shown in Figure 3. Therefore, it is vital to create and originate a dynamic database (DBCC) for Wadi El Natroon region to predict the extreme events that will happen and how to adapt with their effects. Thus, assessing the impacts of climate change is highly required.

BASIC REQUIREMENTS FOR WADI EL NATRON AREA

Owing to the importance of Wadi El Natron area, the main objective and requirement of the current study are to develop a tool that can be used to assist the decision makers and investors to draw a clear future vision for investment in Wadi El Natron in terms of the expected climate changes within the boundary of Wadi El-Natron area. Accordingly, it is proposed to develop a dynamic database for climate conditions (DBCC) and prediction of climate change up to the year 2100. This can be achieved through three main activities; Collecting and analyzing the historical climate data (max. temperature, min. temperature and precipitation) for Wadi El Natron, Predicting the climate parameters (max. temperature, min. temperature and precipitation) up to 2100 using regional climate modeling approach under different emission scenarios, and developing dynamic database containing observed climate parameters from 1979 to 2015 and predicted climate parameters from 2016 to 2100.

HISTORICAL CLIMATE DATA

The study area is covered by 20 climate points as shown in Figure 4. All historical and predicted climate data was presented in each point. Acquire and analyze in daily climate data (max. temperature, min. temperature, precipitation, humidity, ...etc.) from a period of 1979 to 2015 for Wadi El Norton using WATCH Forcing Data ERA-Interim (WFDEI)[1] were analyzed and archived in dynamically data base.

The WATCH project has produced a large number of data sets which should be a considerable use in regional and global studies of climate and

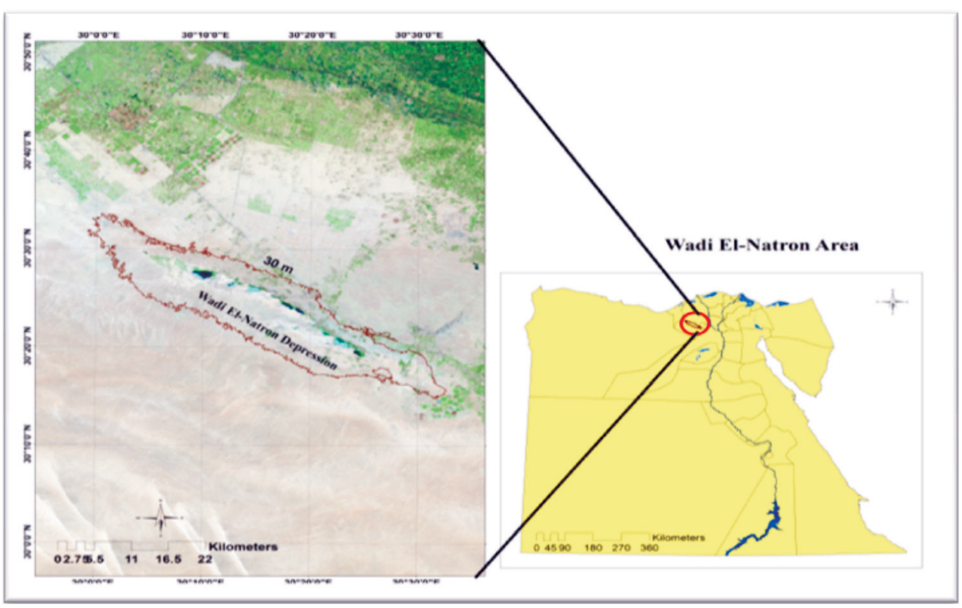

Fig. 1. Location of Wadi El Natroon region

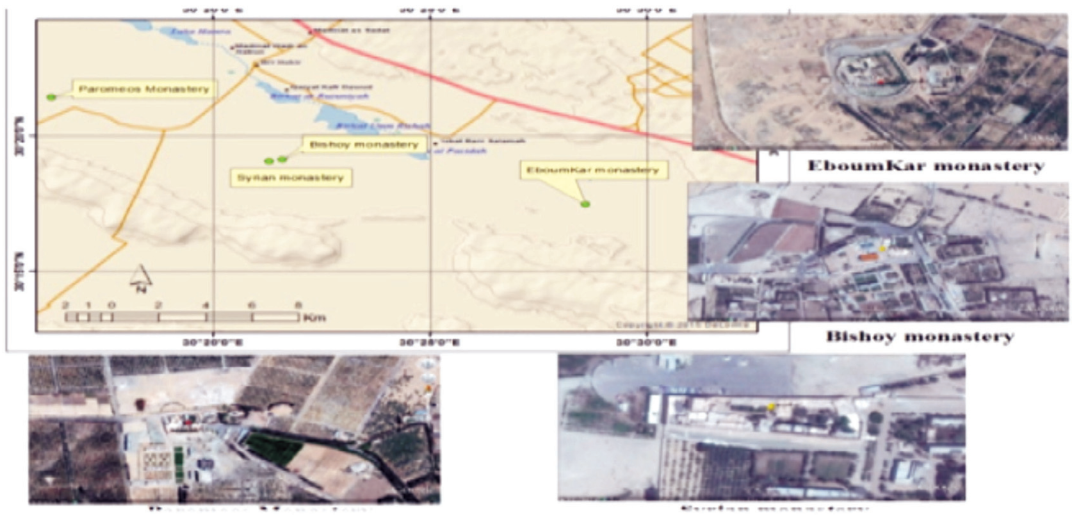

Fig. 2. Main monasteries in Wadi El Natron region

Fig. 3. Destructive effect of the storm in Wadi El Natron region, November, 2015

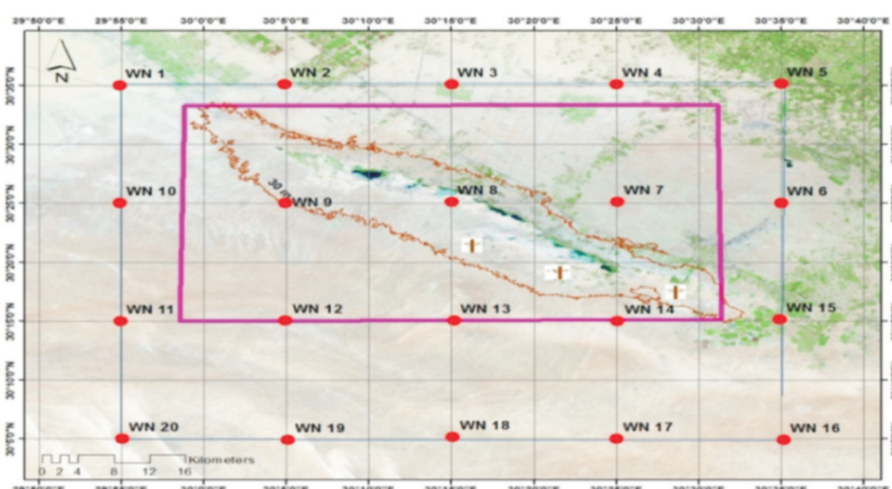

Fig. 4. Investigated climate points

water sectors. It is including data sets for meteorological data that is used by global hydrological or land surface models and model outputs for the 20th and 21st Centuries. The data were derived from the ERA-Interim reanalysis product via sequential interpolation to half-degree resolution, elevation correction and monthly-scale adjustments based on Climatic Research Unit (CRU) (corrected-temperature, diurnal temperature range, cloud-cover) and GPCC (Global Precipitation Climatology Centre) monthly observations combined with new corrections for varying atmospheric aerosol-loading and separate precipitation gauge corrections for rainfall and snowfall. ERA-Interim uses an extensive suite of satellite, atmospheric sounding, and surface observations and provides substantial improvement in surface meteorological variables. The temporal and spatial resolution of WFDEI is daily which makes the data ideal to perform bias correction on daily output from the climate models. Compared to the CRU database WFDEI starts in the year 1979 (starting date of ERA-Interim) and is only available for land grid boxes. Database was established for climate conditions and prediction of climate change up to year 2100.

TREND ANALYSIS FOR RAINFALL, MAXIMUM TEMPERATURE AND MINIMUM TEMPERATURE

The climate parameters were analyzed during the historical period of 1979: 2015 for rainfall, maximum and minimum temperatures at all design climate network for Wadi El Natron area. The present result showed that the maximum rate of rainfall was 228 mm at the year of 2000 and the minimum rate was 11 mm at the year of 1999 as shown in Figure 5 and Table 1.

Maximum and minimum temperatures as most important climate parameters were investigated. The maximum maximumtemperature was 36.6 C° at August 2010 and minimum maximum temperature was 17.1 C° at February 1992 as shown in Figure 6. While the maximum minimum temperature was 25.6 at August 2010 and the minimum minimum temperature were 6.2 at February 1992, as shown in Figure 7. All climate parameters could be analyzed,

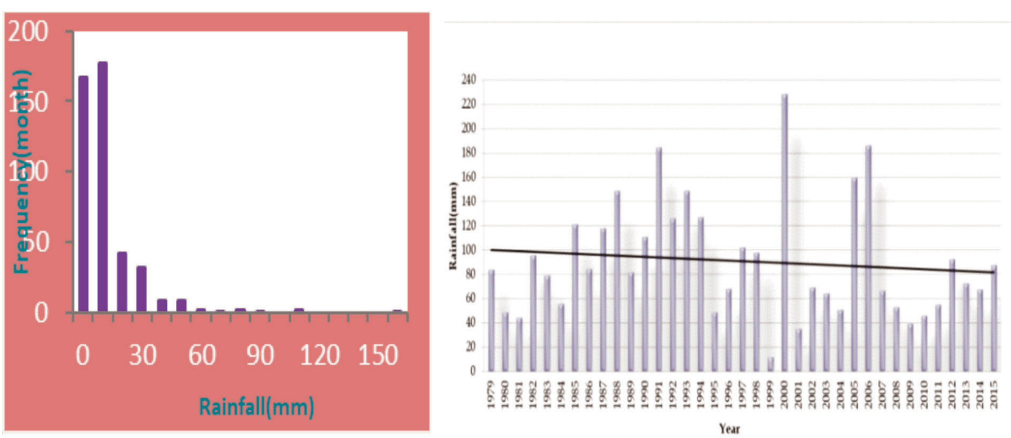

Fig. 5. Historical annually rainfall over Wadi El Natron area from 1979 to 2015

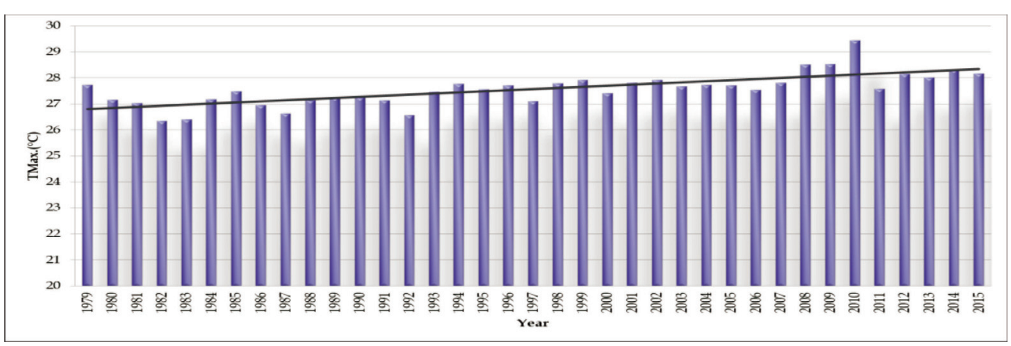

Fig. 6. Historical annually max. Temperature over Wadi El Natron area from 1979 to 2015

stored archived in this dynamically data base as rainfall and temperature with related indicators, extremes analysis and aggregated statistical function as well.

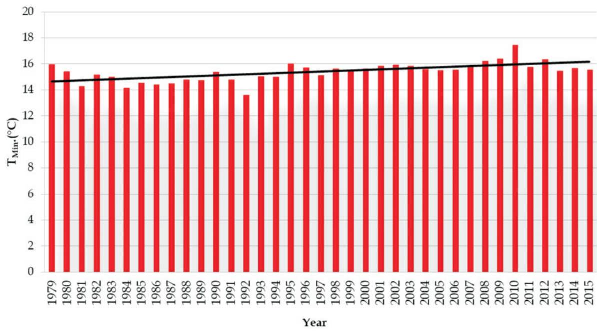

Fig. 7. Historicalannually min. temperature over Wadi El Natron area from 1979 to 2015

Table 1. Rainfall frequency at sample of climate network for historical period 1979:2015

Rainfall Rate (mm)	Frequency
0	167
10	177
20	42
30	32
40	8
50	9
60	2
70	1
80	2
90	1
100	0
110	2
120	0
130	0
140	0
150	0
160	1

ASPECTS OF GLOBAL AND REGIONAL CIRCULATION MODELS

The main method to study the impact of greenhouse gas concentrations on future climate is through the use of climate models. Climate models are numerical models simulating the interactions of the atmosphere, oceans, land surface and ice. They discretize and solve the full equations for mass and energy transfer and radiant exchange within the Earth's climate system. The models also contain parameterizations for processes—such as convection—that occur on scales of too small to be resolved directly.

To model all the interactions within the Earth's climate, a General Circulation Model (GCM) was used by Taylor *et al.* (2012). This model covers the whole globe but has limited spatial and temporal resolution. To get more detailed data for a specific area or continent a Regional Climate Model (RCM) was used. The regional model uses boundary conditions from the global model and a more detailed land cover as shown in Figure 8. RCMs can therefore provide information on much smaller scales supporting more detailed impact and adaptation assessment and planning, which is vital in many vulnerable regions of the world.

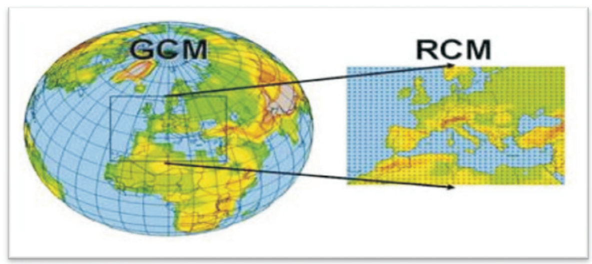

Fig. 8. Schematic depiction of the Regional Climate Model nesting approach

BIAS CORRECTION METHODS

Raw GCM data generally exhibit biases and therefore must be bias-corrected prior to impact assessment applications. Bias correction will compensate for differences in means, preferably on a monthly or seasonal basis. Also, a correction should ideally compensate for differences in variability with respect to historical data but not precluding future changes in variance. Bias correction is generally based on the 1961-1990 or 1971-2000 historical temperature and precipitation data.

Two alternative methods (Fig, 9) were used that have all the above characteristics and will be summarized below:

1. The Delta approach that is very suitable for corrections of e.g., temperature, wind component (u and v), pressure, etc., and
2. The scaling approach for precipitation and wind speed.

A) Delta approach

The following corrects for biases by subtracting the differences found between observed and modeled values:

$$X'_{i,t} = X_{i,t} - \overline{X}_{i,m} + \overline{X}_{i,o} \quad .. (1)$$

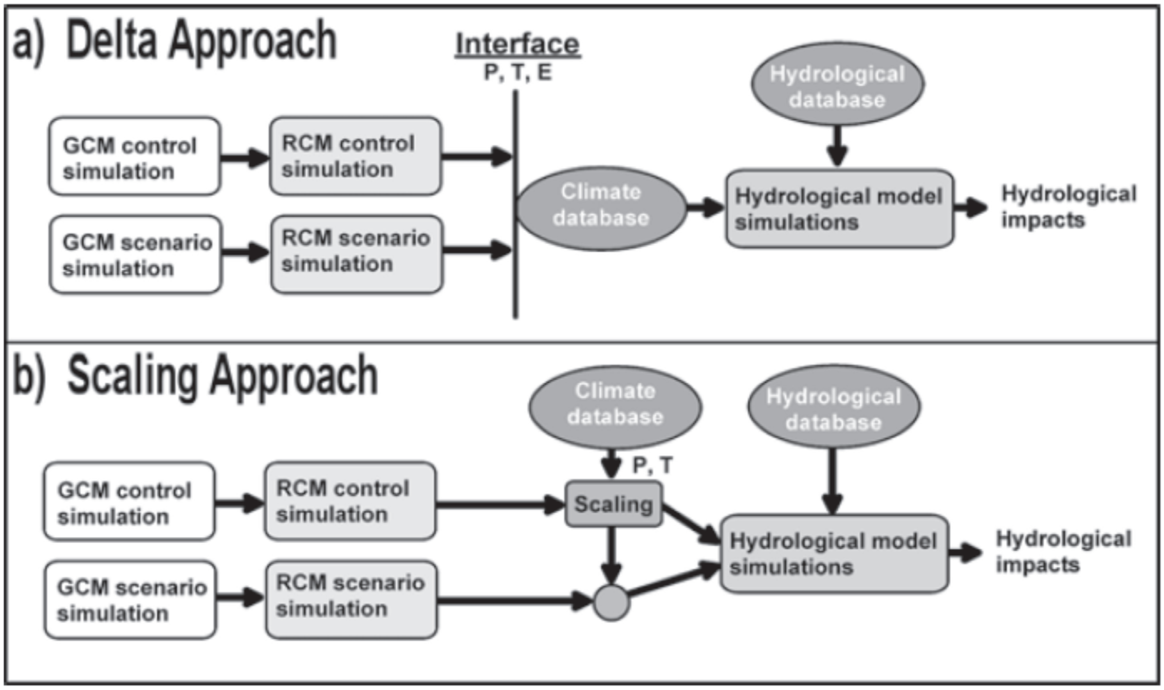

Fig. 9. Aalternatives approaches

In the above equation, $X_{i,t}$ is the model prediction for season or month i of year t, $X_{i,}$ is the 30-year baseline model mean for season or month i, $X_{i,0}$ is the 30-year baseline observed seasonal average, and $X'_{i,t}$ is the bias-adjusted model series. X is temperature or another variable (like u, v or pressure) at the pixel of interest.

The previous adjustment corrects for mean bias. A second adjustment is also made to the model results to conform to the variability of the historical data. This procedure takes the sequence of anomalies and scales them consistently with the observed historical variability as follows:

$$\Delta_{i,t} = X'_{i,t} - \overline{X}'_{i,t} \quad .. (2)$$

$$X''_{i,t} = \Delta_{i,t}\left(\frac{\sigma_{i,o}}{\sigma_{i,m}}\right) + \overline{X}'_{i,t} \quad .. (3)$$

In the above equations, $\Delta_{i,t}$ is the data anomaly for season i of year t, $X'_{i,t}$ is the model mean trend in season i, $\sigma_{i,o}$ is the historical sequence standard deviation during the baseline period, $\sigma_{i,m}$ is the standard deviation for the model data over the same period, and $X_{i,t}$ is the fully adjusted model data. The final adjusted model sequences exhibit the appropriate baseline mean and variance with respect to the observed data. Unlike the commonly used delta-approach (IPCC, 1999), which imposes the historical variance on the future climate, this approach does not preclude future changes in variability.

The scaling approaches

The following equation is used to correct biases by scaling with the ratio of observed and modeled values of Mitchell (2003).

$$X'_{i,t} = X_{i,t} \times \frac{\overline{X}_{i,o}}{\overline{X}_{i,m}} \quad .. (4)$$

Obviously, this approach does not preclude future changes in variability, but still biases in variance can be corrected as before.

PREDICTION OF THE CLIMATE CHANGE UNTIL 2100 FOR DIFFERENT SCENARIOS

Climate change scenarios were used in the framework of climate models for the future development of factors such as governance, social structures, future population growth, technical development and agriculture. These descriptions are essential to model the future climate. Four Relative Concentration Pathways (RCPs) have been defined, named after the radiative forcing that eventually will be reached: RCP2.6, RCP4.5, RCP6 and RCP8.5. They work both forwards towards climate modeling and backwards to analyze what future world development is needed to achieve a certain level of anthropogenic influence on the climate. This allows development of mitigation scenarios as shown in Figure 10.

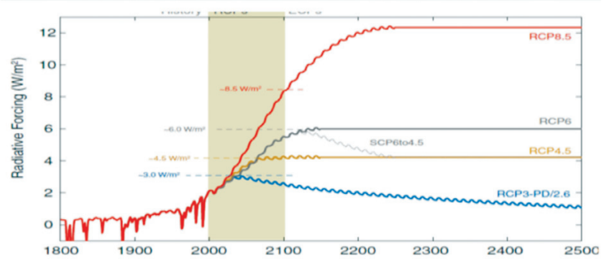

Fig. 10. Graphical representation of four various RCP-scenarios

The RCPs are a set of four new pathways developed for the climate modeling community as a basis for long-term and near-term climate modeling experiments. The four RCPs together span the range of radioactive forcing values (cumulative measure of human emissions of GHGs from all sources expressed in Watts per square meter) found in the open literature, from 2.6 to 8.5 W m^{-2} for the year 2100. The RCPs is the result of an innovative collaboration between integrated assessment modelers, climate model makers, terrestrial ecosystem designers and emissions inventory experts. The product result forms a comprehensive data set with high spatial and sectoral resolution for the period up to the year 2100. Land use, air pollutant emissions, and greenhouse gases are mostly reported with a spatial resolution of 0.5 * 0.5 °, with air pollutants are also provided for each sector (for well mixed gases), A coarser precision is used). The core integrated land use assessment model output, emissions and atmospheric concentration data are coordinated across models and scenarios to ensure consistency with historical observations while maintaining individual scenario trends. For most variants, RCPs cover a wide range of existing literature. The PCRs are complemented by extensions (Extended Concentration Pathways, ECPs), which allow climate modeling experiments up to 2300. The RCPs are an important development in climate research and provide a potential basis for further research and evaluation, including emission mitigation and impact analysis.

The words "concentration pathway" are intended to emphasize that these RCPs are not the new and fully integrated scenarios (i.e, they are not a complete package of socioeconomic, emissions and climate projections), but are instead internally consistent sets of expectations from the radiative forcing components that are used in the later stages. The use of the word "concentration" instead of "emissions" emphasizes that the concentrations are used as a primary product of RCPs, which are designed as inputs into climate models. Coupled carbon-cycle climate models can calculate associated emissions levels (which can be compared to original emissions of Integrated Assessment Models - IAMs). In total, a set of four paths are produced leading to radiative forcing levels of 8.5, 6, 4.5 and 2.6 W/m^2 by 2100. Each RCPs covers 1850 - 2100 periods, and extensions for the subsequent period are formulated "up to 2300"[5].

The RCPs were chosen to represent a wide range of climate outcomes, based on a review of the literature, neither predictions nor policy recommendations, and while each RCP relies on an internally consistent set of socioeconomic assumptions, the four RCPs cannot be treated together as a set with internal socioeconomic logic. consistent. For example, RCP8.5 cannot be used as a socio-economic reference scenario that does not follow climate policy for other RCP programs because the assumptions for RCP8.5 are socio-economic, technological, and biophysical assumptions that differ from the assumptions of other RCPs. Through the present study, RCP4.5 and RCP8.5 have been implemented.

Referring to Regional Climate Models, all simulations performed with RCMs were coordinated within the CORDEX framework (CORDEX: Coordinated Regional climate Downscaling Experiment). The Coordinated Regional Downscaling Experiment (CORDEX) was set up by the World Climate Research Programme (WCRP) in 2009 to coordinate Regional Climate Downscaling and provide a set of high-resolution regional climate projections for the majority of global land regions. The vision of CORDEX is to advance and coordinate the science and application of regional climate downscaling through global partnerships. Within CORDEX, the world has been divided into 14 regions for which simulations with RCMs are executed. In this study we will use the results which have been generated with a selection of RCMs within the CORDEX-AFRICA framework.

From the present study, a set of 40 global circulation models as well as two regional circular models (RegCM4 model and EC-EARTH RCA4) were applied. Climate parameters were predicted from 2010 through 2100 using RCP4.5 and RCP8.5. In addition, the official information has been identified for extreme weather events.

DATABASE SYSTEM

Several data base engines can be used to build up database management systems such as Oracle, MS SQL server, Access, MySQL …etc. In this current study, MySQL was used because this software is free and achieves all the requirements in terms of speed, data storage, security and technical support. Regarding to the programming language, Java and Python was used where these languages was used in the current DBCC. The produced program was written by NET technology. A special Graphical User Interface was designed in such a way to have enough flexibility to present for decision makers and technical or non-technical users according to their requests that deals with map information system within the boundaries of the project area. Main window showed DSS tool main tabs with the main sub-systems; basic climate data that including "climate scenarios, climate models, and climate stations network", alternatives for models, data import and climate data as well asmain data visualization as shown in Fig. 11.

Fig. 11. Main window for Decision Support System tool

DATA BASE FEATURES

The main feature of data base is illustrated in this section; ***Basic Data:***which is a window allows the user to manage and control basic data with (**View**, **Add**, **Edit** and **Delete**) functions: **View**: at the left side shows the new item values and the right side shows the list of saved items; **Add**: fill all required data at the left side then click "**Add**" button to save new item; **Edit**: for select item from the right side then click "**Edit**" button to automatic fill the fields at the left side with selected item values then to save changes it should be clicked "**Add**" button; **Delete** for select item from the right side then click "**Delete**" button then accept the confirmation message to be deleted. ***Climate Alternative*** that assigns relate specific climate scenario to specific climate model at one unique climate alternative as shown in Figure 12 and 13.

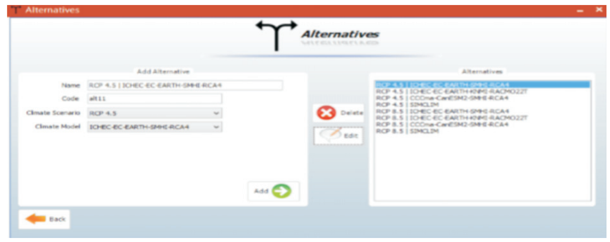

Fig. 12. Wwindow of Basic model data and alternative scenarios

Chart plotting area: that apply by **a.** Use data filter options to filter table data and **b.** Use toggle buttons at bottom to control data querying of: i. All parameters by most of aggregatestatisticssuch average or sum; ii. Selected alternative or all alternatives; iii. Current station or all stations and iv. Monthly or daily data.

DATA ANALYSIS AND EXPORT

The data and analysis could be exported by using the window options area and use buttons to export data to Excel, print preview and export in tables form or chart in image file as shown in top left side for Figure 13.

DATABASE RESULTS AND ANALYSIS

Through this dynamic database, it is available to choose from the historical or the predicted period, thus the selected period and parameters can be used in further analysis. The results and applications of the dynamic data base is varying between displaying the trend whatever it is historical or future projections under different climate models or different socioeconomic and growing population scenarios as presented at figures (14), (15). Meanwhile, comparative between different parameters at many time slices in annually, monthly and daily basses is applicable at the dynamically data base for historical or predicted periods.One can select one station or group to conduct and display analysis as shown as shown in figures (16) and (17). Different aggregate statistical analysis for climate parameters and climate indicators especially for

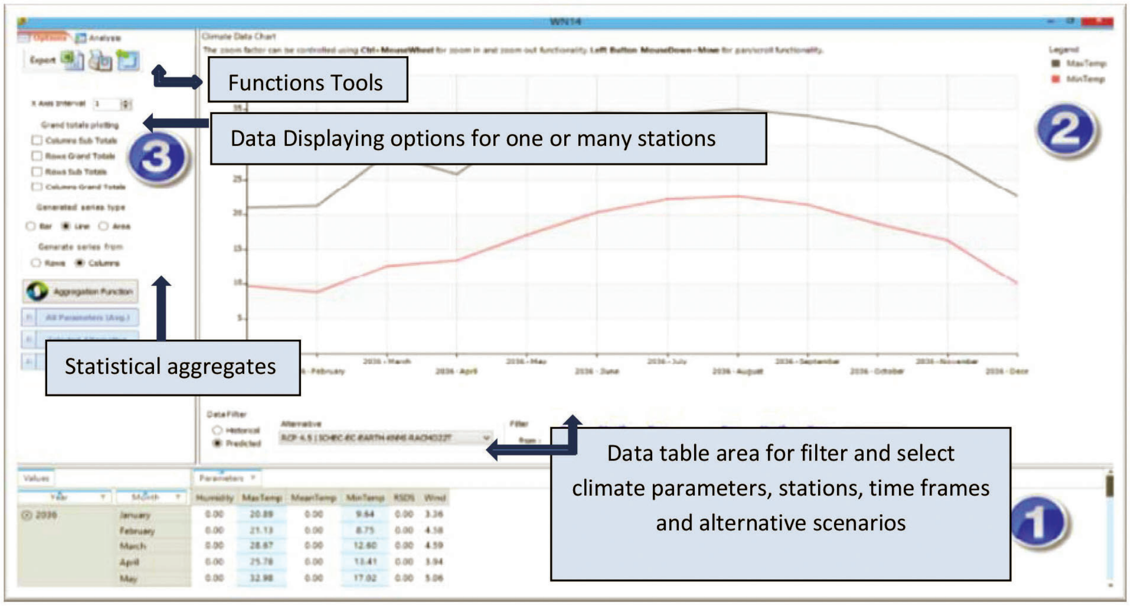

Fig. 12. Window for main functions of Climate Alternatives analysis

extremes events (max., min., standard deviation, frequency analysis, etc.) could be conducted as well. The criterions and limit of extremes values of climate parameters that describe the target area were archived in data base for further analysis which are (min. temperature <0, min. temperature >20, max. temperature > 35:40, precipitations values between (1:5), (5:20), (10:20), and >20 mm as well as wind >7m/s as shown in Fig. 20.

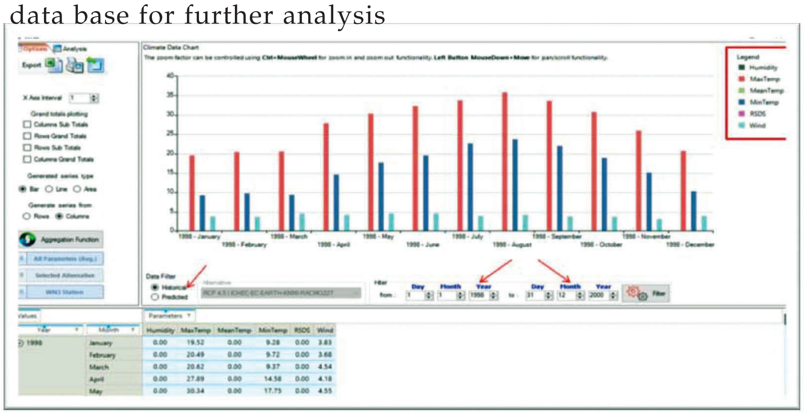

Fig. 13. Display Available parameters

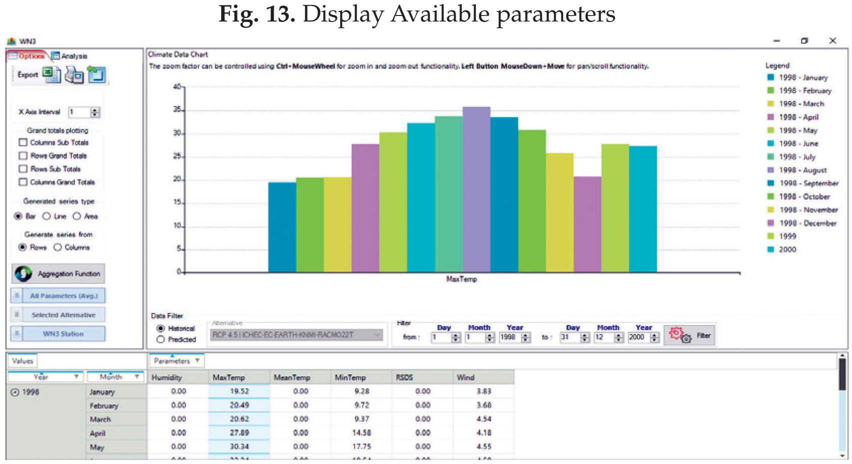

Fig. 14. Certain parameter through multi-time frames

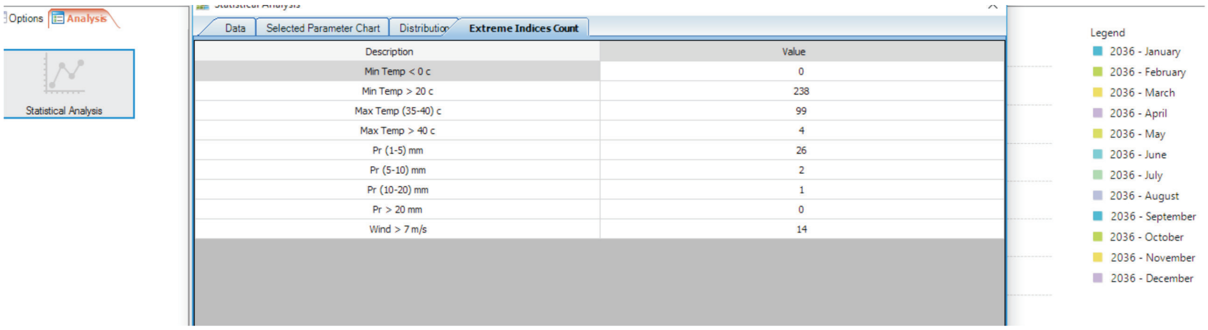

Fig. 15. Calculation for Extreme indices for multi or certain period

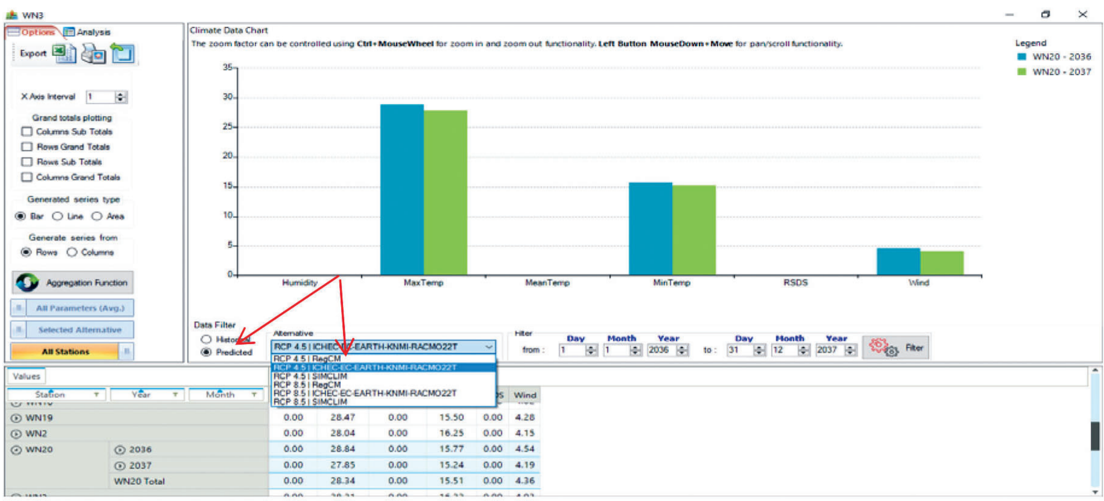

Fig. 16. Comparison between many stations for Multi models with different RCPs scenarios

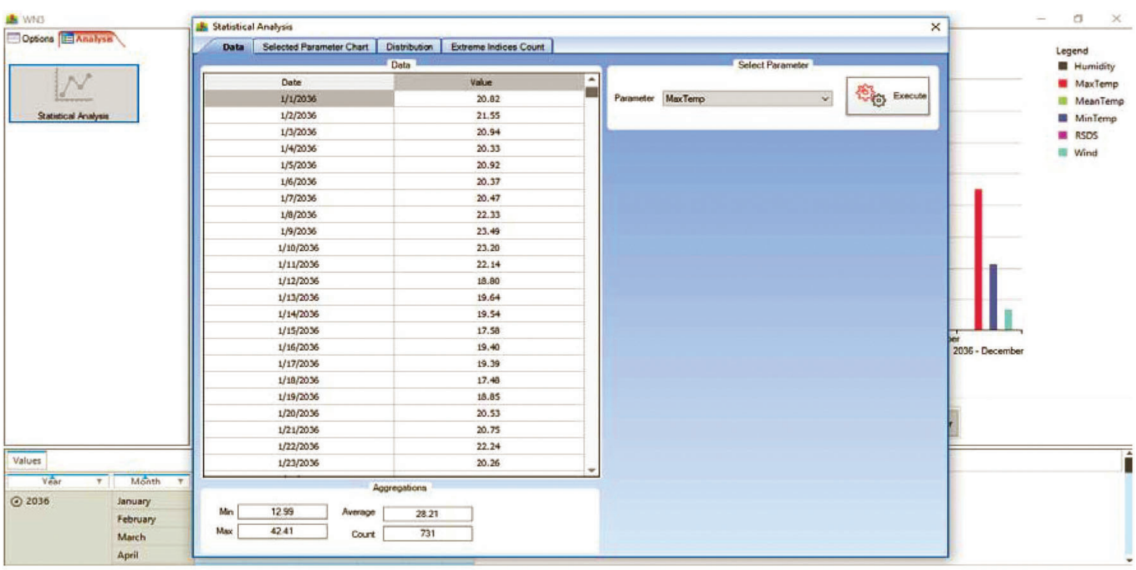

Fig. 17. Aggregate Data setfor required analysis

CONCLUSION

This dynamic Data base is a robust decision supporting system designed to detect the climate hazard at Wadi El Natron area as one of the vulnerable areas in Egypt that suffer from climate change and extremes events. This DBCC system has a historical climate data for more than thirty years

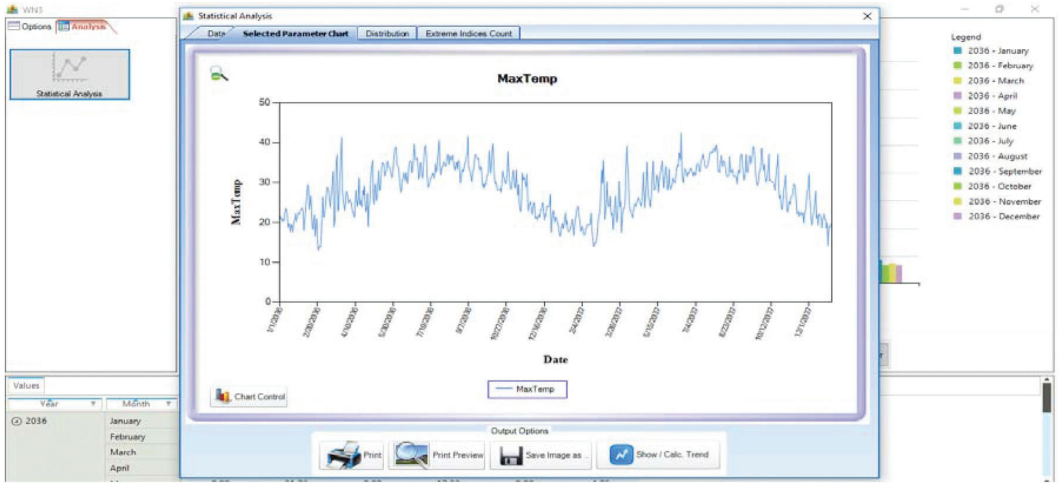

Fig. 18. Statistical analysis and trend for selected parameter at certain period and RCPs scenarios

rather than the projections for many climate models under different socio economic and development future projection scenarios for most climate parameters till 2100. MYSQL engine with java,python, and net programs languages are used for deployment of this system. The stored Historical and future projected data are in daily, monthly and annually basis with the capability for analyzing the important statistical and related indicators. All climate parameters in DBCC could be also investigated, displayed, exported, saved, stored or even printed in graphical, maps and tabular forms for all climate stations network, any selected time farms with different time basis. Such analysis is Frequency for occurrences, distributions and tend for climate parameters (rainfall and temperatures,) for projection represented pathway scenarios that can be analyze rather than the indicators of extreme events and climate index criteria. This tool could be supporting the decision maker in most development projects to meet sustainable goals at target area. This tool is flexible and dynamically for adding and enhancing for other climate models, parameters or another pilot area

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