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Evaluation of NCEP Climate Forecast System Reanalysis (CFSR) against surface observations over Egypt

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Abstract

Egypt experiences from a lack of meteorological weather stations, so it needs new weather ground stations to be established, to cover different locations and well distributed along its area. So the aim of this study is to evaluate the available global reanalysis datasets with different spatial and temporal resolution against surface observations from different ground weather stations distributed all over Egypt. Based on the results of this evaluation, it could be very useful for Egypt to depend on this global dataset to be used as compensation in case of lack of in-situ observations. In this study, the dataset from National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) will be used for this purpose. In this study our evaluation has been done for CFSR against some meteorological parameters such as maximum and minimum temperature at two meters (Tmax) and (Tmin) respectively, mean temperature at two meters (T), dew point temperature at two meters (Td), pressure mean sea level (Pmsl), relative humidity (RH) and total cloud cover (Cld), which collected from 23 weather surface stations over Egypt. The results gave a good agreement between the CFSR and ground station measurements through twenty three stations. The differences between CFSR and observations were very small compared to each other. Also the values of MB, RMSE were within the acceptable range and represented a good agreement between CFSR and observations over most of the Egyptian weather stations. Most correlations were highly correlated except very few stations. The results proved that, it is acceptable to use the CFSR dataset in case of lack of measured meteorological parameters for most weather stations, but the dew point temperature and relative humidity estimated from CFSR need improvements for few weather stations.

1. Introduction

Egypt is a country in the Middle East and North Africa (MENA), has a total land area about one million square kilometers and located between 22^o to 32^o North and 24^o to 37^o east. It is bordered by Libya from the west, the Mediterranean Sea from the north, Sudan from the south and the Gaza Strip and Red Sea from the east as shown in figure (1).

Egypt's climate is semi-desert characterized by hot and dry summers, moderate winters and very little rainfall. Egypt like many developing countries experiences from lack of meteorological weather stations, so it needs new weather ground stations to be established, to cover different locations and well distributed along its area. This needs huge financial support to buy and install these stations, but the country has a big economic problem. To overcome this problem, it is proposed to evaluate the available reanalysis datasets from different sources against the surface observations from ground weather stations distributed over different regions over Egypt.

The National Centers for Atmospheric Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) have created and developed different reanalysis global meteorological datasets. The aim of these datasets is to generate global datasets for a long time period for different meteorological parameters. This reanalysis is created with a numerical weather prediction (NWP) model similar to the one used for operational weather predictions in different climate centers along the globe. The lateral boundary conditions of this model are measured data from different sources, including observations from surface weather stations, ships, aircrafts, radiosondes, and satellites in addition to other observations. This model generates homogeneous data that can be used for long term climatic studies.

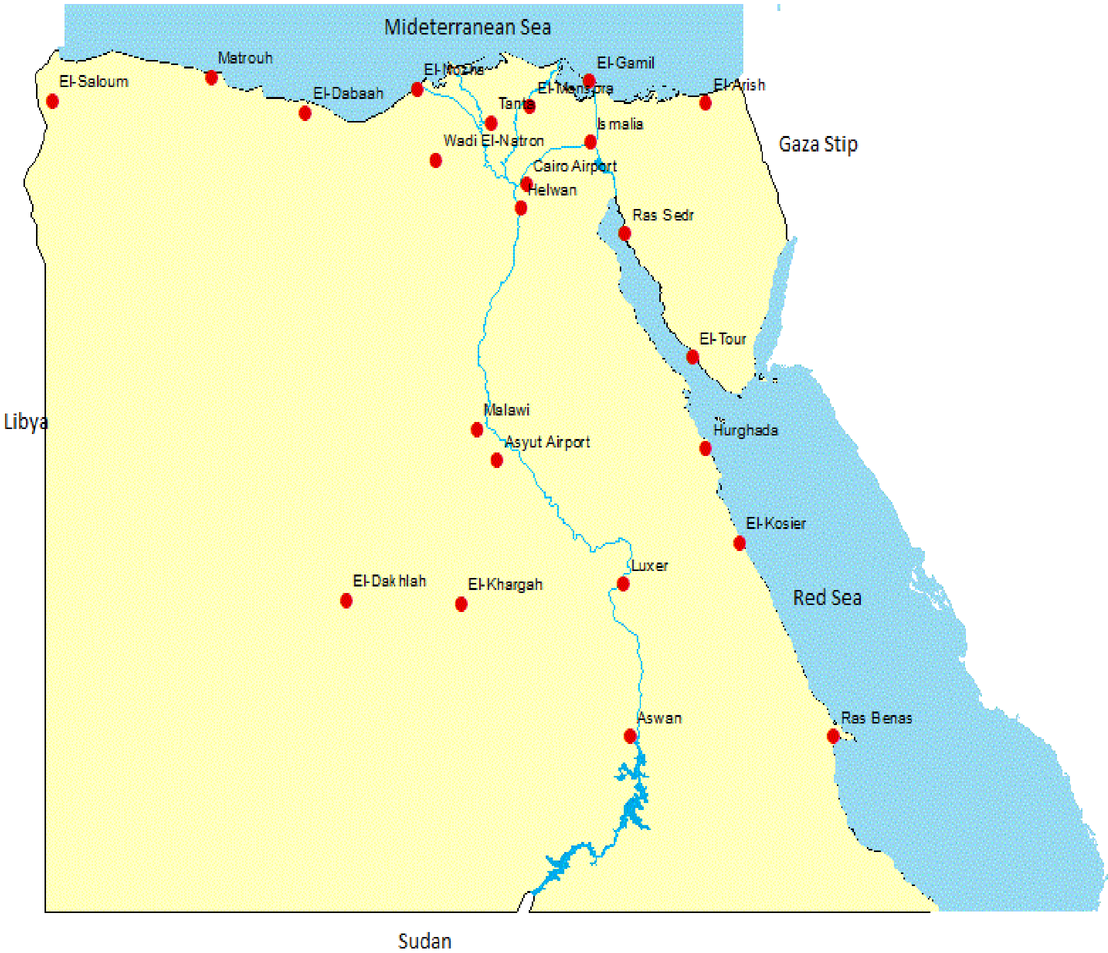

Figure 1. *Egypt map including the meteorological stations used in this study.*

The first generation of reanalysis datasets has been released in the 1990s, as a joint collaboration between the National Center for Atmospheric Research (NCAR) and the National Centers for Environmental Prediction (NCEP) called NCEP/NCAR Reanalysis I. This dataset provides different meteorological parameters starting from 1948 to the present with temporal resolution every 6 hours on a three dimensional grid with a horizontal resolution of approximately 250 km.

This free dataset is updated continuously and has therefore many users distributed all over the world. A subsequent release, Reanalysis II, fixed some errors and updated parameterizations of physical processes but retained the same grid (Kanamitsu et al, 2002). In the past several years, a number of third-generation reanalysis data sets have become available for all end-users whom interested in long term climate studies. The first one is the Climate Forecast System Reanalysis (CFSR), it is based on the Climate Forecast System, the NCEP global forecast model. It is horizontal resolution is approximately 38 km and spans from1979 to the present. On one hand, most meteorological parameters are available every 6 hours and on the other hand selected variables are available every one hour (Saha et al. 2010). This dataset is available for direct download free of charge from this website: http://rda.ucar.edu/pub/cfsr.html. The second one is the Modern-Era Retrospective Analysis for Research and Applications (MERRA). This dataset is based on the National Aeronautics and Space Administration (NASA) global data assimilation system (GEOS-5). Its horizontal resolution is approximately 55 km (0.5° latitude, 0.66° longitude) and starts from 1979 to the present (Rienecker et al. 2011). Most meteorological parameters are available every 6 hours, but the selected ones every one hour. It is available through its website for download free of charge from this website: http://gmao.gsfc.nasa.gov/merra. The third package is the ERA reanalysis datasets from the European Center for Medium-Range Weather Forecasts (ECMWF) reanalysis series (including ERA-15, ERA-40, and ERA-Interim). ERA-Interim represents the most current and up to date dataset. It's based on the Integrated Forecast System (IFS), the main ECMWF global forecasting model. The horizontal resolution of ERA is approximately 80 km (0.75°) and starts from 1979 to the present (Dee et al. 2011). Most meteorological parameters provided every 3 hours. It can be downloaded free of charge too from its website http://www.ecmwf.int/en/research/climate-reanalysis/era-interim.

So the aim of this study is to evaluate the available global reanalysis datasets with different spatial and temporal resolution against surface observations from different ground weather stations distributed all over Egypt. Based on the results of this evaluation, it could be very useful for Egypt to depend on this global dataset to be used as compensation in case of lack of in-situ observations.

There is reason to hope that with their high spatial resolution, as well as improvements in data assimilation methods, the new datasets will perform better against ground observations over Egypt.

In this study, the dataset from National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) will be used for this purpose. It was initially completed over the 32-year period from Jan-1979 to Dec-2010, which uses a high-resolution fully coupled model (Saha et al 2010). The CFSR dataset used the second generation global medium-range ensemble reforecast to improve the skills of the dataset (Hamill et al. 2013). The NCEP/CFSR dataset was evaluated with observations from eleven radiosonde network stations at Tibetan Plateau (that were not assimilated in CFSR), which represents for the first time, and the results showed a good agreement between CFSR dataset and the radiosonde observation with a small root mean square error (RMSE) and small relatively mean bias (MB) compared with the datasets predecessor (Bao and Zhang 2013).

Climate variability in CFSR was analyzed for a set of surface variables including precipitation, surface air temperature at two meters height, soil moisture, sea surface temperature, and surface heat flux, with observations not assimilated directly in the CFSR in different regions, such as Indian ocean, Maritime Continent, and Western Pacific, and the results showed that the data successfully reproduced the mean observation for most parameters, while few deficiencies in the long-term variations were identified in the CFSR Wanqiu et al. (2010).

Kaicun and Robert (2013) compared the CFSR downward long wave radiation on the surface with ground-based observations, satellite retrievals and other reanalysis datasets with different resolutions at 169 global land sites from 1992 to 2010, and found an acceptable mean bias.

Keller et al. (2011) pre-processed the CFSR data in a series of steps, and Perez algorithm was employed to extract the direct normal irradiance (DNI) from global horizontal irradiance (GHI) and a new web dataset with different format was produced. This dataset has become one of the best datasets to be used as a replacement of ground observations.

Decker et al. (2012) evaluated the CFSR and other reanalysis datasets produced at the various centers around the globe, flux tower observations of temperature, wind speed, precipitation, downward shortwave radiation, net surface radiation, and latent and sensible heat fluxes are used to evaluate the performance of various reanalysis products and found that at monthly time scales, the bias term in the reanalysis products are the dominant cause of the mean square errors, while at 6-hourly and daily time scales the dominant contributor to the mean square errors is the correlation term. Also, it is found that the hourly CFSR data have discontinuities present due to the assimilation cycle, while the hourly MERRA data do not contain these jumps.

Zib et al. (2012) was evaluate and Inter-comparison of Cloud Fraction and Radiative Fluxes in CFSR and other reanalysis datasets over the Arctic using 15 years (1994–2008) of high-quality Baseline Surface Radiation Network (BSRN) observations from Barrow (BAR) and Ny-Alesund (NYA) surface stations. BSRN Surface Observations, and CFSR performed the best in reanalyzing surface down welling fluxes with annual mean biases.

2. Data and Methodology

In this study, some of the surface meteorological parameters extracted from CFSR will be evaluated against its related measured parameters collected by the Egyptian Meteorological Authority (EMA) for 23 surface ground stations over Egypt. These parameters are, maximum and minimum temperatures at two meters (Tmax) and (Tmin), mean temperature at two meters (T), dew point temperature at two meters (Td), pressure mean sea level (Pmsl), relative humidity (RH) and total cloud cover (Cld). Data were downloaded in GRIB format (Gridded Binary, is an international, public, binary format for the efficient storage of meteorological/oceanographic variables) from the CFSR dataset website http://rda.ucar.edu. As the resolution of the CFSR is too big compared to the ground stations, simple interpolation techniques of these percentages have been applied to fit the station sites.

Table 1. *Selected Surface Stations over Egypt.*

Station Name	Start	End	Obs.	Lon.	Lat.
El-Salloum	1993/08	2006/12	161	25.08	31.07
Mersa-Matrouh	1979/01	2006/12	336	27.22	31.33
El-Dabaa	1979/01	2006/12	336	28.47	30.93
El-Nozha	1979/01	2006/12	336	29.95	31.20
El-Gamil-Airport	1979/01	2006/12	336	32.23	31.28
El-Arish	1979/06	2006/12	331	33.80	31.03
El-Mansoura	1979/01	2006/12	336	31.45	31.00
Tanta	1979/01	2006/12	336	30.93	30.82
Wadi-El-Natroon	1979/01	2006/12	336	30.20	30.40
Cairo-Airport	1979/01	2006/12	336	31.40	30.13
Helwan	1979/01	2006/12	336	31.33	29.87
Malawi	1991/9	2006/12	184	30.75	27.40
Assiut-Airport	1979/01	2006/12	336	31.02	27.05
Luxor	1979/01	2006/12	336	32.70	25.67
Aswan	1979/01	2006/12	336	32.78	23.97
El-Dakhla	1979/01	2006/12	336	29.00	25.48
El-Kharga	1979/01	2006/12	336	30.53	25.45
Ismailia-Airport	1979/01	2006/12	336	32.25	30.60
Ras-Sedr	1979/01	2006/12	336	32.72	29.58
El-Tour	1984/03	2006/12	274	33.62	28.20
Hurghada-Airport	1979/01	2006/12	336	33.80	27.18
El-Kosseir	1979/01	2006/12	336	34.25	26.13
Ras-Benas	1979/01	2006/12	336	35.50	23.97

Table 1, shows all information about the 23 surface stations that will be used during the course of this study. Also it includes the starting, ending date of these observations and the number of available observations in addition to the longitude and latitude of each station.

The download site offers the option to subset the data based on an area of interest. Some programs were used to create the descriptor files and to create an index files for the data. A custom script was developed to extract the data for the desired stations using distance weighted four point interpolations. All these tools are included in the Grid Analysis and Display System (GrADS) Berman et al. (2001). The CFSR datasets were based on monthly averages to be compatible with the observed data from the ground stations.

Since the CFSR data are continuous time series data and as shown from Table (1), there are many missing data from surface observations. So, the corresponding data from CFSR dataset will be deleted to ensure the compatibility of both CFSR and observational data. Also for enhancing the quality of the results, all unacceptable data as negative values for both relative humidity and cloud cover will not be considered.

Root Mean Square Error (RMSE) is a good overall measure of model performance. The weighting of (prediction-observation) by its square tends to inflate RMSE, particularly when extreme values are present. With respect to a good model, the root mean square error should approach zero.

The mean bias (MB) is the degree of correspondence between the mean prediction and the mean observation. Lower numbers are best and values less than zero indicate under-prediction. The equations for RMSE, MB are given by the following equations:

$$RMSE = (\sum_{i=1}^{n} (X_i - X_o)^2 / n)^{0.5}$$

$$MB = \sum_{i=1}^{n} X_i - X_o / n$$

Where n is the number of observations, X_i and X_o represent predicted and observed values respectively.

3. Results and Discussion

In this section, the evaluations of CFSR dataset will be done for each meteorological parameter individually against the surface observations. Also the statistical calculations for RMSE, MB and the correlation will be introduced.

3.1. Maximum Temperature

Table 2 reports on the statistical indicators of the differences between the monthly means of maximum temperature from CFSR dataset and in-situ observations respectively, mean bias (MB), root mean square error (RMSE) and the correlations for all surface stations. One may notice that, the maximum underpredicted mean bias is -4.47 °C and registered at Ras Benas while the minimum one is -0.1 and registered at El Gamil station. The maximum mean bias is 2.74 °C and registered at El Salloum while the minimum one is 0.08 ^{0}C and registered at Aswan. Also, it can notice that the total monthly average of the maximum teperature for all stations is 28.36 °C while the estimated one from CFSR is 28.28 °C for the same period. So the mean bias average of all stations compared to CFSR is -0.07°C which is very small value. On the the other hand, the minimum and maximum values for root mean square error are 0.63°C and 4.89 °C at El Gamil and Ras Benas respectively while the average RMSE for all stations is 1.91 °C which represents small value. From Table(2), it is noticed that the minimum correlation is 0.949 and registered at Ras Benas but the maximum one registered at Assuit station with value 0.998. So it can deduced that the the average correlation for all stations is 0.988 which represents a very high correlation between the CFSR datasets and the observations from all stations. From these results, one may conclude that the CFSR datasets proved a very high correlations and compitability with observations for the maximum temperatures along all surface stations in Egypt. Also, it can be used as a compensation intead of meaurements especially in the areas which have not surface ground stations.

3.2. Minimum Temperature

Table 3 reports on the statistical indicators of the differences between the monthly means of maximum temperature from CFSR dataset and in-situ observations respectively, mean bias (MB), root mean square error (RMSE) and the correlations for all surface stations. One may notice that, the maximum underpredicted mean bias is -5.89 °C and registered at Aswan while the minimum one is -0.46 and registered at Malawi station. The maximum mean bias is 2.85 °C and registered at Mersa Matrouh while the minimum one is 0.39 ^{o}C and registered at El Dabaa. Also, it can notice that the total monthly average of the minimum temperature for all stations is 16.12 °C while the estimated one from CFSR is 14.46 °C for the same period. So the mean bias average of all stations compared to CFSR is -1.67°C which represents very small value. On the the other hand, the minimum and maximum values for root mean square error are 1.09 °C and 6.04 °C at El Dabaa and Aswan respectively while the average RMSE for all stations is 2.54 °C which represents resonable value. From Table(3), it is noticed that the minimum correlation is 0.898 and registered at El Nozha but the maximum one registered at El Salum station with value 0.994. So it can deduced that the the average correlation for all stations is 0.977 which represents a very high correlation between the CFSR datasets and the observations from all stations. From these results, one may conclude that the CFSR datasets proved a very high correlations and compitability with observations for the minimum temperatures along all surface stations in Egypt. Also, it can be used as a compensation instead of meaurements especially in the areas which have no surface ground stations.

Table 2. *Maximum Temperature Comparisons.*

Station name	Missing Obs.	CFSR °C	Obs. °C	MB °C	RMSE °C	Correlation
El-Salloum	0	27.2	24.46	2.74	3.53	0.979
Mersa-Matrouh	0	22.46	24.2	-1.74	1.82	0.994
El-Dabaa	0	26.27	24.82	1.45	2.2	0.984
El-Nozha	0	23.94	24.71	-0.77	0.97	0.992
El-Gamil-Airport	15	24.13	24.23	-0.1	0.63	0.993
El-Arish	13	27.47	26.11	1.36	1.94	0.991
El-Mansoura	12	28.18	27.23	0.95	1.51	0.993
Tanta	12	28.84	26.91	1.93	2.41	0.992
Wadi-El-Natroon	12	28.69	28.35	0.34	1.25	0.997
Cairo-Airport	12	28.79	27.74	1.05	1.59	0.997
Helwan	12	27.8	27.99	-0.18	1.43	0.987
Malawi	12	29.57	29.23	0.34	1.51	0.993
Assiut-Airport	12	29.87	29.57	0.31	0.82	0.998
Luxor	13	32.08	33.55	-1.47	1.62	0.997
Aswan	13	33.58	33.5	0.08	0.78	0.995
El-Dakhla	20	30.01	32.27	-2.26	2.55	0.993
El-Kharga	12	31.66	32.99	-1.32	1.5	0.997
Ismailia-Airport	12	29.15	28.22	0.93	1.47	0.996
Ras-Sedr	12	28.77	28.09	0.69	1.76	0.989
El-Tour	12	28.55	27.89	0.66	1.74	0.985
Hurghada-Airport	13	27.95	29.57	-1.62	2.87	0.963
El-Kosseir	13	27.43	27.95	-0.52	3.07	0.963
Ras-Benas	13	28.12	32.59	-4.47	4.89	0.949
Average		28.28	28.36	-0.07	1.91	0.988

***Table 3.** Minimum Temperature Comparisons.*

Station name	Missing obs.	CFSR°C	Obs.°C	MB°C	RMSE °C	Correlation
El-Salloum	0	13.3	14.27	-0.97	1.21	0.994
Mersa-Matrouh	0	18.14	15.29	2.85	2.98	0.988
El-Dabaa	0	15.54	15.15	0.39	1.09	0.988
El-Nozha	0	13.99	16.01	-2.02	3.1	0.898
El-Gamil-Airport	15	17.14	18.26	-1.12	1.58	0.984
El-Arish	13	14.8	14.1	0.69	1.2	0.987
El-Mansoura	12	11.6	13.7	-2.11	2.47	0.973
Tanta	12	11.72	13.33	-1.61	1.9	0.98
Wadi-El-Natroon	12	13.73	14.81	-1.09	1.29	0.993
Cairo-Airport	12	12.79	16.38	-3.6	3.71	0.986
Helwan	12	13.33	15.62	-2.29	2.41	0.988
Malawi	12	12.32	12.78	-0.46	1.42	0.975
Assiut-Airport	12	11.29	14.64	-3.36	3.5	0.988
Luxor	13	11.06	16.24	-5.18	5.35	0.983
Aswan	13	13.42	19.31	-5.89	6.04	0.982
El-Dakhla	20	13.71	14.77	-1.06	2.18	0.966
El-Kharga	12	14.62	16.53	-1.91	2.13	0.993
Ismailia-Airport	12	11.81	15.33	-3.52	3.83	0.974
Ras-Sedr	12	12.6	15.92	-3.32	3.5	0.982
El-Tour	12	16.14	18.04	-1.9	3.03	0.911
Hurghada-Airport	13	18.19	19.32	-1.13	1.41	0.992
El-Kosseir	13	20.07	21.11	-1.04	1.37	0.983
Ras-Benas	13	21.19	19.96	1.23	1.67	0.988
Average		14.46	16.12	-1.67	2.54	0.977

3.3. Mean Temperature

Table 4 reports on the statistical indicators of the differences between the monthly means of mean temperature from CFSR dataset and in-situ observations respectively, mean bias (MB), root mean square error (RMSE) and the correlations for all surface stations. One may notice that, the maximum underpredicted mean bias is -5.34 °C and registered at Ras Benas while the minimum one is -0.09 and registered at Tanta station. The maximum mean bias is 0.88 °C and registered at El Arish while the minimum one is 0.28 ^{o}C and registered at El Nozha. Also, it can notice that the total monthly average of the mean teperature for all stations is 22.11 °C while the estimated one from CFSR is 20.86 °C for the same period. So the mean bias average of all stations compared to CFSR is -1.23°C which is very small value. On the the other hand, the minimum and maximum values for root mean square error are 0.56°C and 6.04 °C at El Mansura and Ras Benas respectively while the average RMSE for all stations is 1.91 °C which represents small value. From Table(4), it is noticed that the minimum correlation is 0.878 and registered at Ras Benas but the maximum one registered at Cairo Airport, Helwan,Luxor and El Kharga stations with value 0.997. So it can deduced that the the average correlation for all stations is 0.983 which represents a very high correlation between the CFSR datasets and the observations from all stations. From these results, one may conclude that the CFSR datasets proved a very high correlations and compitability with observations for the mean temperatures along all surface stations in Egypt. Also, it can be used as a compensation intead of meaurements especially in the areas which have no surface ground stations.

3.4. Dew Point Temperature

Table 5 reports on the statistical indicators of the differences between the monthly means of dew point temperatures from CFSR dataset and in-situ observations respectively, mean bias (MB), root mean square error (RMSE) and the correlations for all surface stations. One may notice that, the maximum underpredicted mean bias is -9.74°C and registered at El-Kosseir while the minimum one is -0.09 and registered at Hurghada Airport station. The maximum mean bias is 2.46 °C and registered at Ras Benas while there is no minimum one registered at at any station. Also, it can notice that the total monthly average of the dew point teperature for all stations is 11.81°C while the estimated one from CFSR is 8.64°C for the same period. So the mean bias average of all stations compared to CFSR is -3.17°C which is relatively high value. On the the other hand, the minimum and maximum values for root mean square error are 0.73°C and 24.98°C at El Nozha and El Kosier respectively while the average RMSE for all stations is 5.1°C which represents relatively high value. From Table(5), it is noticed that the minimum correlation is 0.215 and registered at El Kosier but the maximum one registered at El Nozha station with value 0.99. So it can deduced that the the average correlation for all stations is 0.85 which represents a resonable correlation between the

CFSR datasets and the observations from all stations except El-Kosseir and El-Salloum . From these results, one may conclude that the CFSR datasets proved a good correlations and compitability with observations for the dew point temperatures along all surface stations in Egypt except El-Kosseir and El-Salloum stations. Also, it can be used as a compensation intead of meaurements especially in the areas which have not surface ground stations.

Table 4. *Mean Temperature Comparisons.*

Station name	Missing obs.	CFSR°C	Obs.°C	MB°C	RMSE°C	Correlation
El-Salloum	0	19.59	19.03	0.55	1.15	0.988
Mersa-Matrouh	0	20.07	19.66	0.41	0.83	0.994
El-Dabaa	0	20.43	19.83	0.6	0.9	0.991
El-Nozha	0	20.5	20.27	0.23	0.76	0.994
El-Gamil-Airport	0	19.99	21.36	-1.37	1.94	0.964
El-Arish	0	20.7	19.82	0.88	0.99	0.996
El-Mansoura	0	19.66	19.95	-0.28	0.56	0.996
Tanta	0	19.54	19.63	-0.09	0.88	0.99
Wadi-El-Natroon	0	20.49	21.06	-0.57	0.92	0.993
Cairo-Airport	0	20.86	21.77	-0.91	1.29	0.997
Helwan	0	21.01	21.56	-0.55	1.03	0.997
Malawi	0	20.46	20.68	-0.23	0.98	0.995
Assiut-Airport	0	20.21	22.15	-1.94	2.1	0.993
Luxor	0	21.33	24.72	-3.39	3.44	0.997
Aswan	0	22.77	26.37	-3.61	3.67	0.996
El-Dakhla	8	20.98	23.45	-2.47	2.95	0.973
El-Kharga	0	22.45	24.99	-2.54	2.6	0.997
Ismailia-Airport	0	20.46	21.9	-1.44	1.88	0.978
Ras-Sedr	0	20.56	21.92	-1.36	1.82	0.985
El-Tour	0	22.78	23.12	0.35	1.26	0.986
Hurghada-Airport	1	23.6	24.48	-0.88	1.03	0.996
El-Kosseir	0	20.27	24.53	-4.26	4.83	0.931
Ras-Benas	6	21	26.33	-5.34	6.04	0.878
Average		20.86	22.11	-1.23	1.91	0.983

Table 5. *Dew point Temperature Comparisons..*

Station name	Missing obs.	CFSR°C	Obs.°C	MB °C	RMSE °C	Correlation
El-Salloum	0	8.73	14.87	-6.14	17.79	0.294
Mersa-Matrouh	0	13.11	13.56	-0.45	1.3	0.971
El-Dabaa	0	11.97	13.18	-1.22	1.57	0.983
El-Nozha	0	13.73	14.04	-0.31	0.73	0.99
El-Gamil-Airport	0	13.7	15.28	-1.59	1.75	0.988
El-Arish	0	11.87	13.69	-1.82	2.06	0.982
El-Mansoura	0	11.16	13.65	-2.49	2.8	0.967
Tanta	0	10.75	12.94	-2.19	2.51	0.969
Wadi-El-Natroon	0	9.67	11.18	-1.49	2.77	0.897
Cairo-Airport	0	8.25	11.89	-3.63	3.97	0.961
Helwan	0	7.47	10.75	-3.28	3.58	0.957
Malawi	184					
Assiut-Airport	0	3.68	6.2	-2.51	3.26	0.885
Luxor	0	2.05	8.79	-6.74	7.04	0.811
Aswan	0	1.82	4.16	-2.34	2.92	0.836
El-Dakhla	8	2.39	6.5	-4.11	4.9	0.726
El-Kharga	0	2.43	8.89	-6.45	7.06	0.735
Ismailia-Airport	0	9.61	12.42	-2.81	3.16	0.956
Ras-Sedr	0	6.07	12	-5.93	6.32	0.888
El-Tour	0	6.9	13.66	-6.76	7.51	0.879
Hurghada-Airport	1	9.67	9.76	-0.09	1.19	0.968
El-Kosseir	0	10.63	20.37	-9.74	24.98	0.215
Ras-Benas	6	14.44	11.98	2.46	2.98	0.849
Average		8.64	11.81	-3.17	5.10	0.85

3.5. Pressure at Mean Sea Level

Table 6. *Pressure at mean sea level Comparisons.*

Station name	Missing obs.	CFSR mb	Obs. mb	MB mb	RMSE mb	Correlation
El-Salloum	0	1015.62	1016.01	-0.39	0.59	0.992
Mersa-Matrouh	0	1015.34	1015.54	-0.2	0.45	0.993
El-Dabaa	0	1015.06	1013.97	1.09	1.16	0.995
El-Nozha	0	1014.67	1014.6	0.06	0.42	0.994
El-Gamil-Airport	0	1014.13	1013.98	0.15	0.65	0.986
El-Arish	0	1014.22	1013.96	0.26	0.65	0.987
El-Mansoura	0	1015.4	1014.46	0.94	1.53	0.943
Tanta	0	1015.3	1013.92	1.38	1.94	0.93
Wadi-El-Natroon	0	1014.46	1014.74	-0.28	0.64	0.99
Cairo-Airport	0	1014.29	1014.31	-0.02	0.59	0.989
Helwan	0	1014.12	1014.05	0.06	1.23	0.949
Malawi	0	1013.61	1013.46	0.05	0.27	0.994
Assiut-Airport	0	1013.64	1013.65	-0.01	0.47	0.995
Luxor	0	1012.32	1011.78	0.54	0.74	0.994
Aswan	0	1014.99	1011.24	3.75	4.4	0.857
El-Dakhla	8	1013.91	1014.24	-0.33	0.84	0.983
El-Kharga	1	1013.16	1012.44	0.72	1.09	0.982
Ismailia-Airport	1	1014.16	1014.52	-0.36	0.64	0.99
Ras-Sedr	0	1013.9	1013.52	0.39	0.78	0.985
El-Tour	1	1015.29	1010.84	4.44	4.97	0.872
Hurghada-Airport	1	1011.96	1011.52	0.44	0.65	0.994
El-Kosseir	0	1011.26	1011.93	-0.67	0.92	0.99
Ras-Benas	6	1014.71	1009.51	5.2	5.85	0.798
Average		1014.15	1013.40	0.75	1.37	0.964

Table 6 reports on the statistical indicators of the differences between the monthly means of pressure at mean sea level from CFSR dataset and in-situ observations respectively, mean bias (MB), root mean square error (RMSE) and the correlations for all surface stations. One may notice that, the maximum underpredicted mean bias is -0.67 mb and registered at El Koseir while the minimum one is -0.01 and registered at Assiut airport station. The maximum mean bias is 5.2 mb and registered at Ras Benas while the minimum one is 0.05 mb and registered at Malawi. Also, it can notice that the total monthly average of the pressure at mean sea level for all stations is 1013.4 mb while the estimated one from CFSR is 1014.15 mb for the same period. So the mean bias average of all stations compared to CFSR is 0.75mb which is very small value. On the the other hand, the minimum and maximum values for root mean square error are 0.27 mb and 5.85 mb at Malawi and Ras Benas respectively while the average RMSE for all stations is 1.37 mb which represents very small value. From Table(6), it is noticed that the minimum correlation is 0.798 and registered at Ras Benas but the maximum one registered at El Dabaa and Assuit stations with value 0.995. So it can deduced that the the average correlation for all stations is 0.964 which represents a very high correlation between the CFSR datasets and the observations from all stations. From these results, one may conclude that the CFSR datasets proved a very high correlations and compitability with observations for the pressure at mean sea level along all surface stations in Egypt. Also, it can be used as a compensation intead of meaurements especially in the areas which have not surface ground stations.

3.6. Relative Humidity

Table 7 reports on the statistical indicators of the differences between the monthly means of relative humidity from CFSR dataset and in-situ observations respectively, mean bias (MB), root mean square error (RMSE) and the correlations for all surface stations. One may notice that, the maximum underpredicted mean bias is -25.64% and registered at Malawi while the minimum one is -0.57 and registered at Wadi El Natroon station. The maximum mean bias is 9.57% and registered at Ras Benas while the minimum one is 0.42% and registered at Assuit. Also, it can notice that the total monthly average of the relative humidity for all stations is 55.82% while the estimated one from CFSR is 51.39% for the same period. So the mean bias average of all stations compared to CFSR is -4.43% which is very small value. On the the other hand, the minimum and maximum values for root mean square error are 3.41% and 27.02% at El-Nozha and Malawi respectively while the average RMSE for all stations is 9.21% which represents very small value. From Table(7), it is noticed that the minimum correlation is 0.113 and registered at El-Kosseir but the maximum one registered at Aswan station with value 0.97. So it can deduced that the

the average correlation for all stations is 0.669 which represents an average correlation between the CFSR datasets and the observations from all stations. From these results, one may conclude that the CFSR datasets proved an average correlations and compitability with observations for the relative along all surface stations in Egypt. Also, it can be used as a compensation instead of meaurements especially in the areas which have not surface ground stations but under some resyerictions for some areas.

Table 7. *Relative Humidity Comparisons.*

Station name	Missing obs.	CFSR %	Obs. %	MB%	RMSE %	Correlation
El-Salloum	0	55.81	67.13	-11.32	15.1	0.251
Mersa-Matrouh	0	66.83	69.33	-2.5	7.97	0.323
El-Dabaa	1	61.77	67.4	-5.63	7	0.468
El-Nozha	1	67.6	68.92	-1.31	3.41	0.571
El-Gamil-Airport	1	67.82	69.16	-1.34	3.77	0.458
El-Arish	1	62.65	70.32	-7.67	8.41	0.654
El-Mansoura	0	64.96	70.08	-5.11	7.45	0.683
Tanta	0	62.41	68.69	-6.27	8.27	0.683
Wadi-El-Natroon	0	56.69	57.26	-0.57	8.87	0.452
Cairo-Airport	0	51.99	57.42	-5.43	8.83	0.699
Helwan	0	48.72	54.29	-5.57	7.79	0.876
Malawi	0	41.08	66.72	-25.64	27.02	0.792
Assiut-Airport	0	40.3	39.88	0.42	6.62	0.921
Luxor	0	34.1	39.83	-5.73	7.14	0.96
Aswan	0	30.89	27.1	3.79	5.55	0.97
El-Dakhla	8	33.81	37.24	-3.43	7.26	0.9
El-Kharga	0	32.49	39.89	-7.4	9.78	0.859
Ismailia-Airport	0	57.36	58.89	-1.53	7.36	0.618
Ras-Sedr	0	46.54	56.07	-9.53	12.6	0.647
El-Tour	274					
Hurghada-Airport	1	44.85	41.65	3.2	4.31	0.911
El-Kosseir	0	47.44	55.81	-8.37	17.18	0.113
Ras-Benas	6	54.5	44.93	9.57	10.88	0.906
Average		51.39	55.82	-4.43	9.21	0.669

3.7. Total Cloud Cover

Table 8 reports on the statistical indicators of the differences between the monthly means of total cloud cover from CFSR dataset and in-situ observations respectively, mean bias (MB), root mean square error (RMSE) and the correlations for all surface stations. One may notice that, the maximum underpredicted mean bias is -0.98 oktas and registered at El Nozha while the minimum one is -0.04 oktas and registered at El Gamil airport and Tanta stations. The maximum mean bias is 0.82 oktas and registered at Luxor while the minimum one is 0.07and registered at Cairo airport. Also, it can notice that the total monthly average of the total cloud cover for all stations is 1.35 oktas while the estimated one from CFSR is 1.4 oktas for the same period. So the mean bias average of all stations compared to CFSR is 0.06 octas which is very small value. On the the other hand, the minimum and maximum values for root mean square error are 0.38 octas and 1.31 oktas at Malawi and El Nozha respectively while the average RMSE for all stations is 0.71which represents very small value. From Table(6), it is noticed that the minimum correlation is 0.664 and registered at Ras Benas but the maximum one registered at El-Mansoura station with value 0.931. So it can deduced that the the average correlation for all stations is 0.861 which represents a good correlation between the CFSR datasets and the observations from all stations. From these results, one may conclude that the CFSR datasets proved a good correlations and compitability with observations for the total cloud cover along all surface stations in Egypt. Also, it can be used as a compensation intead of meaurements especially in the areas which have no surface ground stations.

Table 8. *Total Cloud Cover Comparisons.*

Station name	Missing obs.	CFSR okta	Obs. okta	MB okta	RMSE okta	Correlation
El-Salloum	0	1.73	1.92	-0.18	0.66	0.871
Mersa-Matrouh	0	1.75	2.54	-0.79	0.96	0.918
El-Dabaa	0	1.78	2.56	-0.78	1	0.893
El-Nozha	0	1.79	2.77	-0.98	1.31	0.80
El-Gamil-Airport	0	1.85	2.25	-0.04	0.85	0.827
El-Arish	0	1.54	1.85	-0.31	0.6	0.898
El-Mansoura	0	1.9	1.64	0.26	0.64	0.931
Tanta	0	1.78	1.82	-0.04	0.58	0.908
Wadi-El-Natroon	0	1.62	2.02	-0.4	0.77	0.833
Cairo-Airport	0	1.52	1.45	0.07	0.57	0.89
Helwan	0	1.43	1.28	0.15	0.68	0.81
Malawi	0	1.06	0.96	0.1	0.38	0.914
Assiut-Airport	0	1.03	0.46	0.57	0.79	0.849
Luxor	0	1.51	0.69	0.82	1.14	0.916
Aswan	0	0.9	0.65	0.26	0.44	0.856
El-Dakhla	8	0.9	0.48	0.42	0.64	0.843
El-Kharga	0	0.88	0.65	0.23	0.44	0.889
Ismailia-Airport	0	1.68	1.57	0.1	0.56	0.892
Ras-Sedr	0	1.47	0.85	0.62	0.89	0.827
El-Tour	0	0.93	0.73	0.21	0.46	0.882
Hurghada-Airport	1	1.01	0.68	0.32	0.55	0.87
El-Kosseir	0	0.95	0.73	0.23	0.5	0.838
Ras-Benas	6	1.1	0.51	0.6	0.82	0.644
Average		1.40	1.35	0.06	0.71	0.861

4. Overall Results

Figure (2) shows the average mean bias for all meteorological parameters along all surface ground stations compared to the estimated ones from the CFSR datasets. One may notice that, the values of the mean bias are negative values and can be arranged from high to low values as follow: relative humidity, dew point temperature, minimum temperature, mean temperature and maximum temperature. So CFSR for the previous parameters are under prediction or estimation but it lies within the acceptable ranges for the mean bias. Also it is noticed that the mean bias for pressure at mean sea level was little bit more than zero, it means CFSR can overestimate it within the satisfaction values of mean bias. The value of the mean bias of total cloud cover may reach to zero that is mean CFSR can estimate it with very high confidence.

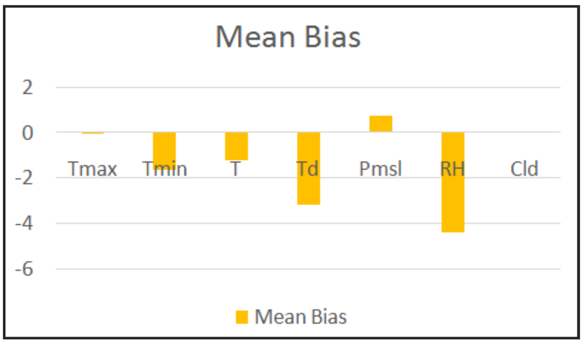

Figure 2. *Average Mean Bias for all parameters.*

Figure (3) shows the average root mean square error for all meteorological parameters along all surface ground stations compared to the estimated ones from the CFSR datasets. One may notice that, the values of the root mean square error can be arranged from high to low values as follow: relative humidity, dew point temperature, minimum temperature, mean temperature, maximum temperature, pressure at mean sea level and total cloud cover.

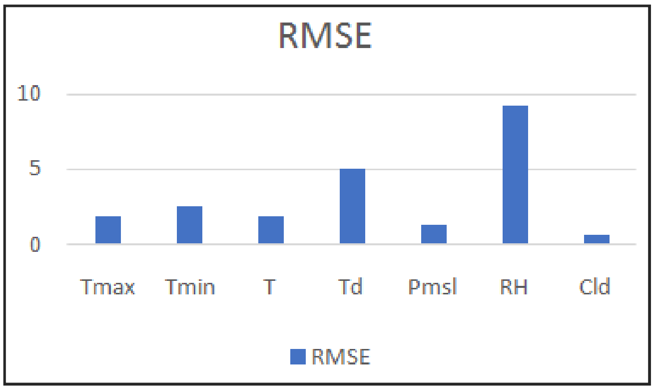

Figure 3. *Average RMSE for all parameters.*

Figure (4) shows the average correlation for all meteorological parameters along all surface ground stations compared to the estimated one from the CFSR datasets. It is noticed that the maximum correlation ranged from the highest to the lowest values for the parameters as follows: maximum temperature, mean temperature, minimum temperature, pressure at mean sea level, total cloud cover, dew point temperature and relative humidity. Hence one may conclude that the CFSR datasets can be used as substitutions of meteorological parameters especially in areas which have not covered by meteorological ground stations in Egypt.

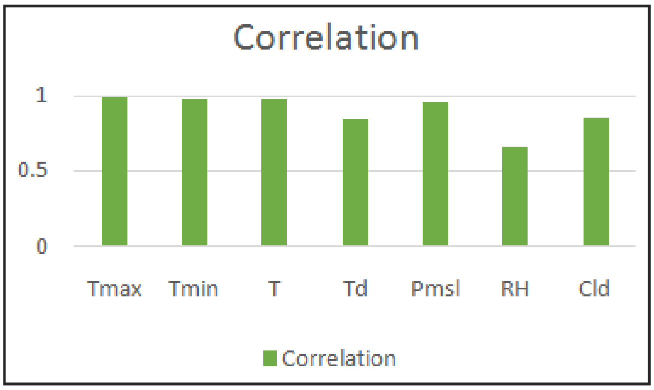

Figure 4. *Average Correlation for all parameters.*

5. Summary and Conclusions

In this study, the evaluation of the CFSR dataset against the ground observation stations over Egypt investigated through different statistical calculations. This research introduced general description of CFSR dataset for the period from 1979 to 2010.

Our evaluation has been done for CFSR against some meteorological parameters such as maximum and minimum temperature at two meters (Tmax) and (Tmin) respectively, mean temperature at two meters (T), dew point temperature at two meters (Td), pressure mean sea level (Pmsl), relative humidity (RH) and total cloud cover (Cld), which collected from 23 weather surface stations over Egypt. The evaluation for CFSR was done using different statistical calculations such as MB, RMSE and the correlation.

The results gave a good agreement between the CFSR and ground station measurements through twenty three stations. Hence, it is concluded that the differences between CFSR and observations were very small compared to each other. Also the values of MB, RMSE were within the acceptable range and represented a good agreement between CFSR and observations over most of the Egyptian weather stations. Most correlations were highly correlated except very few stations. The previous results proved that, it is acceptable to use the CFSR dataset in case of lack of measured meteorological parameters for most weather stations, but the dew point temperature and relative humidity estimated from CFSR need improvements for few weather stations.

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