National Oceanic and Atmospheric Administration (NOAA)

National Center of Environnement Prediction (NCEP)

Africain Desk

Climate Prediction and Monitoring for Tunisia

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I want to especially thank and express my gratitude to Dr. Vadlamani Kumar, my supervisor during my study, for his invaluable knowledge and guidance given to me. I also thank Mr. Endalkachew Bekele for his help and advice.

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Last but not the least; I give thanks to my fellow African Desk visitors for all the support, advice and care rendered to me during my time at the African Desk. I hope we continue to collaborate even when we get back home.

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Introduction :

It is more and more obvious that our climate is changing and these changes are affecting all sectors which concern human life: agriculture, health, environement ..ect. Several studies are conducted in this topic in order to better describe and assess changes. That why the international community try to do a cooperative work in global scale in term of studies and formation.

My internship at the National Center for Environmental Prediction (NCEP / NOAA) is included as part of efforts done by the World Meteorological Organization WMO in Africa to involve capacity building weather services of member countries.

In this center, I had the opportunity to discover the various products and tools used and manipulate them for monitoring and diagnosis of climate in Tunisia.

I had also the chance to assist in many presentation in NCEP in the following topics :

- RFE : Rainfull Estimates ;
- ENSO : El Niño-Southern Oscillation ;
- NAO : North Atlantic Oscillation ;
- MJO : Madden/Julian Oscillation.

In addition, African Desks offer me the occasion to visit, for a week, the International Research Institute for Climate and Society IRI. In the IRI, I attended a training lessons which cover:

- Lecture on the scientific basis for seasonal climate prediction (mechanisms through which SST anomalies can tilt the odds for specific climate anomalies) and sing CPT for seasonal predictions.
- Lectures on methodologies for hydrologic seasonal outlooks.
- Climate Risk Management in the Health Sector.
- Agriculture Sector : Linking Advanced Climate Information for Crop-Yield Forecasting.
- Environmental Monitoring: Remote Sensing as a tool to manage environmental data.

I. Climate Monitoring Tools:

To better understand the variability of rainfall in Tunisia, it was evident to treat series of data of around tens years. And to do this I used a set of Fortran programs and scripts Grads to represent a historic of 30 years of daily rainfall over the period 1978-2007 from 12 stations of the observing networks in Tunisia.

This step allowed me to find the rainfall average for the various stations studied and to diagnose the state of precipitation from these averages.

Below is an example of the graphs obtained from Tunis-Carthage station for the period December 1, 2005 to January 31, 2006. In this graph the average rainfall is represented by red line, above the average colored green and below the average colored brown.

The second curve illustrates the precipitation (green) over the same period indicated above and the normal period (red).

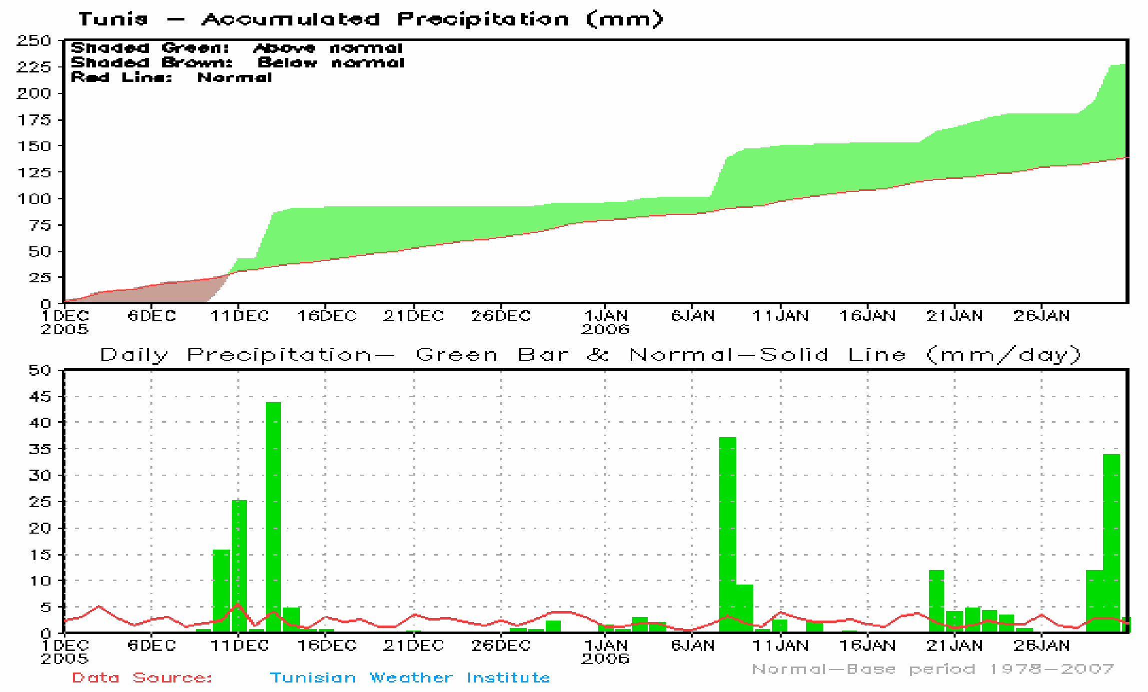

Figure.1: Accumulated (up) and Daily precipitation (down) for the station of Tunis December 1, 2005-January 30, 2006

The following curve shows also the evolution of precipitation and deviation from normal for the same period but this time with smoothing.

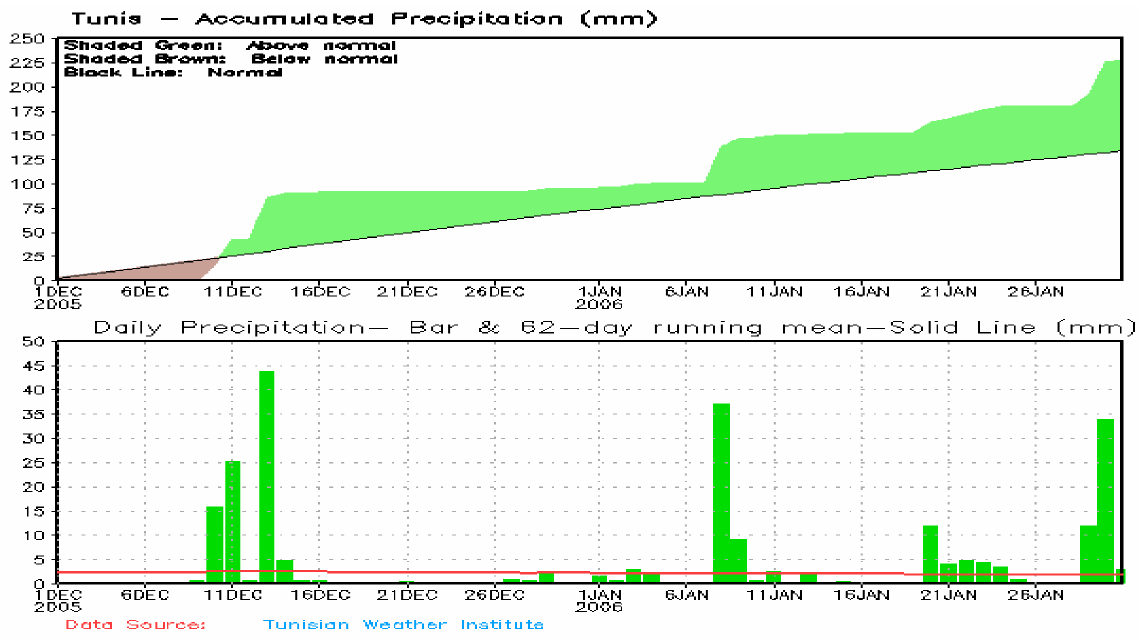

Figure.2: smoothing accumulated (up) and Daily precipitation (down) for the station of Tunis December 1, 2005-January 30, 2006

After representing each station alone, I have tried to identify the spatial distribution of precipitation on Tunisia using scripts on Grads which make interpolations for points in which measures are not available to better simulate and present distributions of precipitation.

Both to identify the status of rainfall compared to average conditions, I tried to represent the climatology of the studied period.

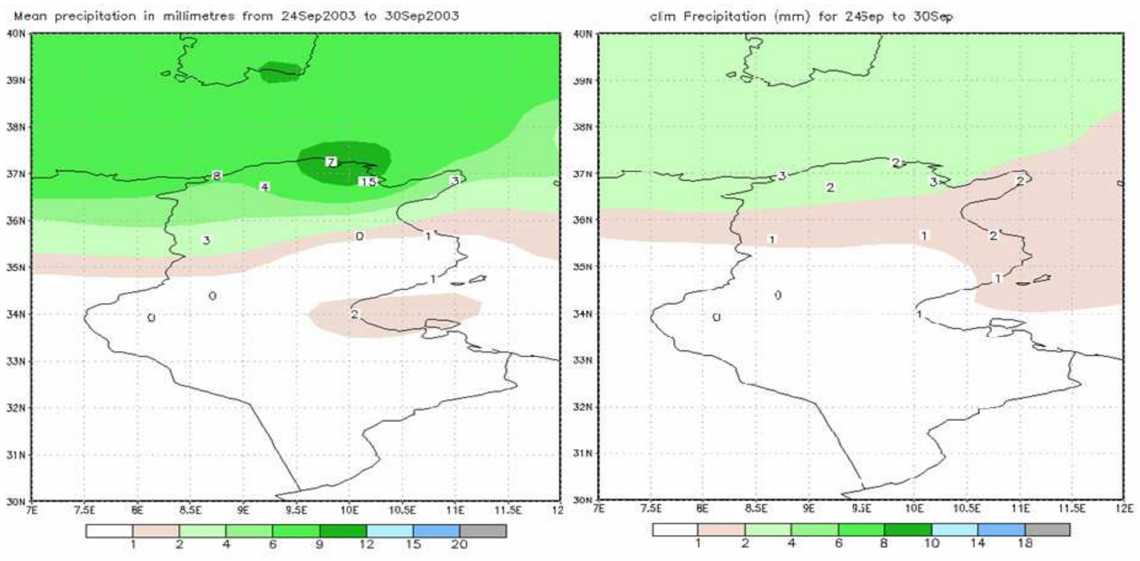

Figure.3: 7 day Mean (left) and climatology precipitation in Tunisia September 24-September 30, 2003

Quantification of deviations in rainfall compared to normal climate is illustrated by the following two curves: one of which shows the anomaly of precipitation and the shows the percentage of anomaly and their spatial distributions on Tunisia.

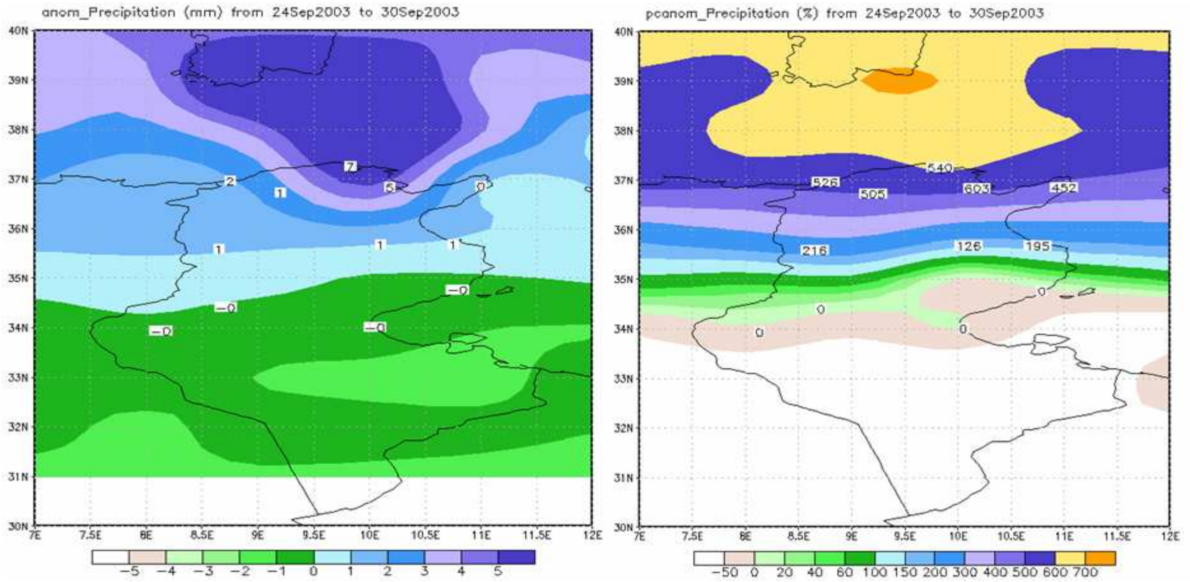

Figure.4: 7 day anomaly (left) and percentage anomaly precipitation in Tunisia
September 24-September 30, 2003

I used a script on Grads to generate time series of daily anomalies and percentage of anomalies for the different stations and below is an example of the resort of Tabarka. This curve allows us to monitor rainfall at this station and this information can be useful for water ressources management in each station.

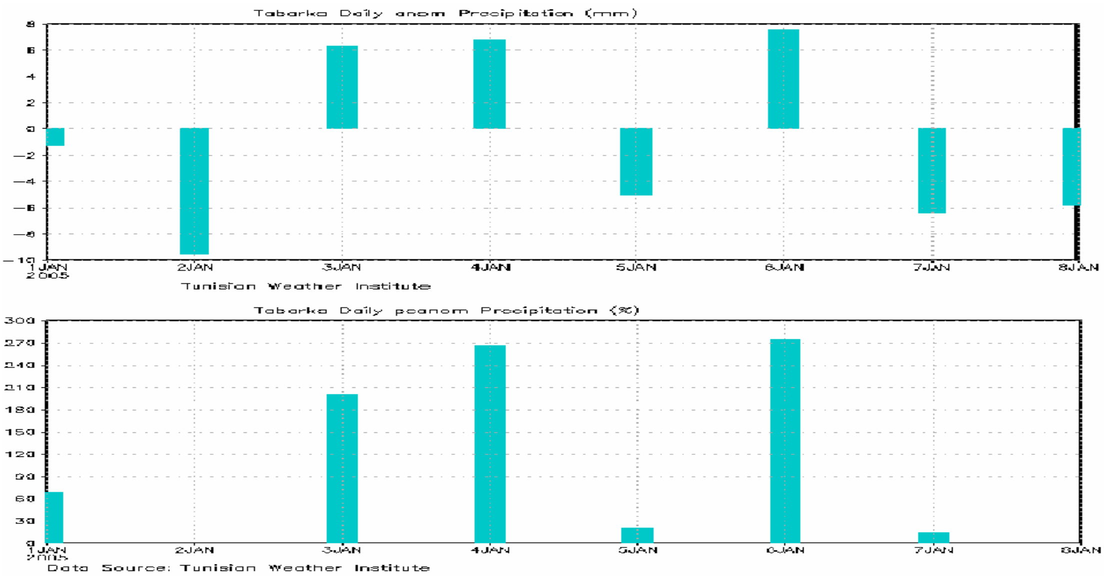

Figure.4: time series daily anomaly (up) and percentage anomaly (down) precipitation for the station of Tabarka
January 1 to January 8, 2005

II. Diagnostics

1. Rainfall estimates

Africa has a limited network of rain gauge stations and for diverse reasons, such as economic with a low perceived relevance of weather services a large number of existing rainfall records is incomplete. On the other hand rainfall is crucial for climate research and for the monitoring of agricultural and water resources. In addition, there is a steady decline of the standard observation network, which is a strong limitation for climate related research as well as for operational agricultural monitoring. Because of these limitations in the availability and quality of measured data, rainfall estimates, which generally depend on climate circulation models and satellite observations, are used. Among the most common estimated rainfall data currently available for Africa is the rainfall estimates (RFE) produced by the Climate Prediction Centre (CPC) of the National Oceanic and Atmospheric Administration (NOAA).

The RFE is a rainfall estimate of NOAA's Climate Prediction Centre currently used by FEWS-NET and several United Nations agencies such as the Food and Agriculture Organization (FAO) and World Food Programme (WFP) for agricultural monitoring in a large number of African countries. It basically uses satellite imagery from the geostationary Meteosat Second Generation (MSG) and estimates convective rainfall as a function of top of cloud temperatures (the so called cold cloud duration model or CCD) and using GTS stations for calibration. There exist two RFE versions (RFE 1.0 and RFE 2.0) produced with slightly different methodologies and different input data at a 0.073° resolution.

Les figures suivantes présentent des exemples des produit de RFE pour un domaine centre sur la Tunisie à savoir le cumul, le normal, l’anomalie et le pourcentage d’anomalie de précipitations pour une période de 7 jours. Ces mêmes produits sont disponibles pour des périodes de 10, 30, 60, 90, 120, 150 et 180 jours. L’estimation de précipitations nous donne une idée sur l’état du sol en termes de quantités d’eau et ceci est utile pour l’agriculture aussi bien pour la gestion des ressources en eau.

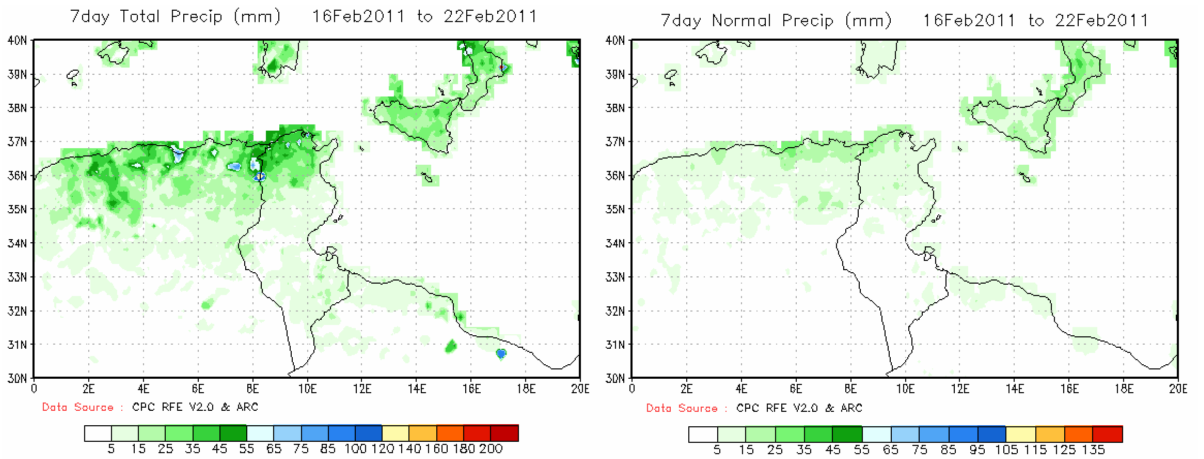

Figure.5: 7 day Total (left) and Normal (right) Precipitation in Tunisia (RFE)
February 16 to February 22, 2011

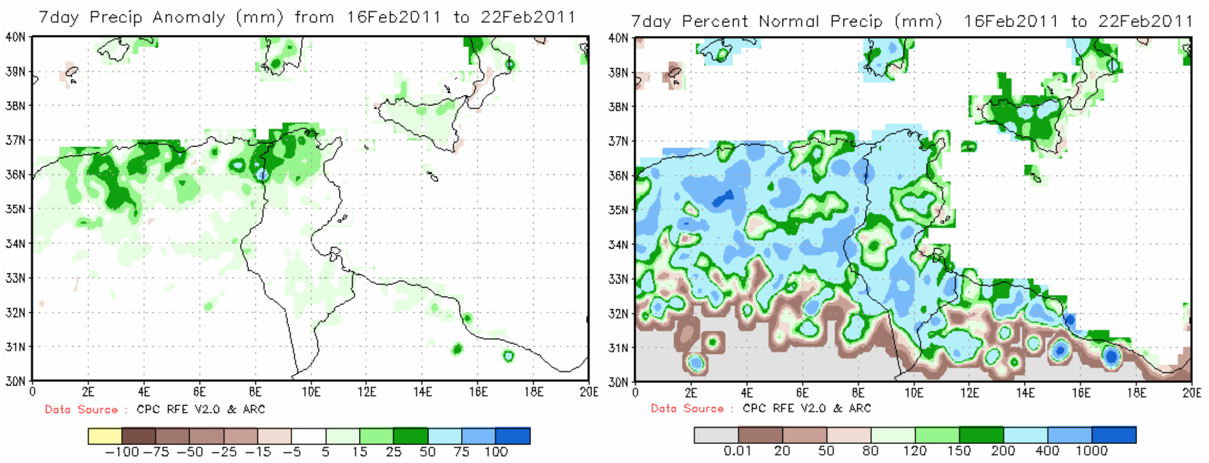

Figure.6: 7 day anomaly (left) and percent normal (right) precipitation in Tunisia (RFE)
February 16 to February 22, 2011

2. *Composite Analysis*

a. Definition of CFSR:

The NCEP Climate Forecast System Reanalysis (CFSR) was completed for the 31-yr period from 1979 to 2009, in January 2010. The CFSR was designed and executed as a global, high-resolution coupled atmosphere–ocean–land surface–sea ice system to provide the best estimate of the state of these coupled domains over this period. New features of the CFSR include:

- Coupling of the atmosphere and ocean during the generation of the 6-h guess field,

- An interactive sea ice model,
- Assimilation of satellite radiances by the Gridpoint Statistical Interpolation (GSI) scheme over the entire period.

The CFSR global atmosphere resolution is ~38 km (T382) with 64 levels extending from the surface to 0.26 hPa. The global ocean's latitudinal spacing is 0.25° at the equator, extending to a global 0.5° beyond the tropics, with 40 levels to a depth of 4737 m. Most available in situ and satellite observations were included in the CFSR. Satellite observations were used in radiance form, rather than retrieved values, and were bias corrected with “spin up” runs at full resolution, taking into account variable CO2 concentrations.

CFSR atmospheric, oceanic, and land surface output products are available at an hourly time resolution and a horizontal resolution of 0.5° latitude × 0.5° longitude. This reanalysis serve many purposes, including providing the basis for most of the NCEP Climate Prediction Center's operational climate products by defining the mean states of the atmosphere, ocean, land surface, and sea ice over the next 30-yr climate normal (1981–2010); providing initial conditions for historical forecasts that are required to calibrate operational NCEP climate forecasts (from week 2 to 9 months); and providing estimates and diagnoses of the Earth's climate state over the satellite data period for community climate research.

After having identified the variability of rainfall at stations in the observing network in Tunisia, I have tried to identify the average configurations of the general atmospheric circulation that creates a dry year or wet year for Tunisia in term of precipitation.

Given the scale of Tunisia, it is represented by a single point on a global grid of CFSR reanalysis. I started doing the spatial average daily precipitation of all stations in order to obtain a single observation point for Tunisia. Then I generated the monthly averages for the new values of spatially averaged precipitation.

After the monthly averages, I calculated seasonal averages for every three consecutive months. For each season, I calculated the average standard deviation and the percentage of anomaly. The curve below shows the percentage of anomaly for the season December, January and February (DJF) over the studied period 1979-2007.

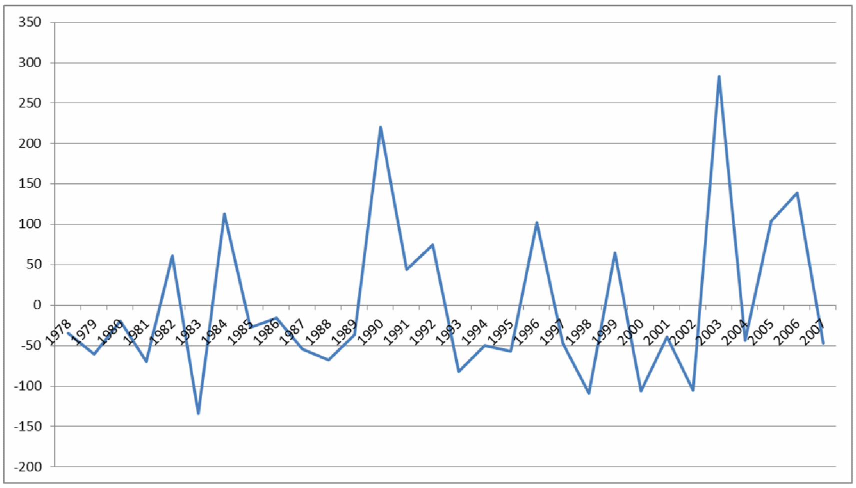

Figure.7: Anomaly percentage precipitation in Tunisia for December-January-February (DJF)

This step allowed me to identify the dry and wet years for all seasons refer to averages over the period of study. We chose to consider a wet year, the year on which the percentage of anomaly is greater than 80% and a dry year, the year on which the percentage of anomaly is less than -80%.

After having selected the dry and wet years, I tried to represent the average configuration of the general atmospheric circulation for each year by using a shell script and CFSR reanalysis.

This process allowed me to know the position of the different systems that directly affect the climate in Tunisia, namely the Azores high and Icelandic Low. Below, the mean configuration of the general atmospheric circulation, respectively, for dry and wet years.

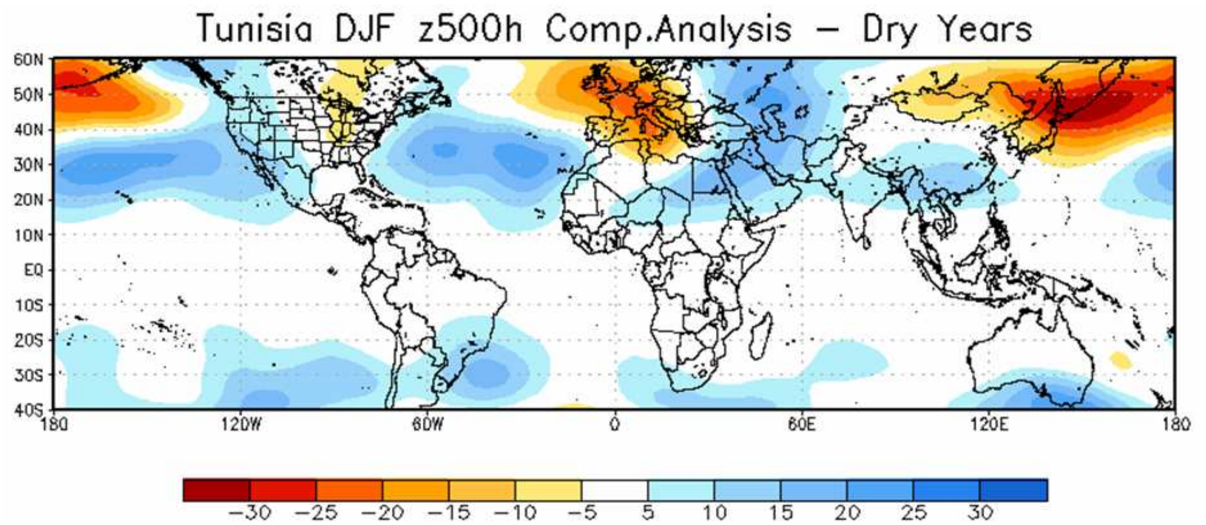

Figure.8: 500 hPa composite analysis for dry years for December-January-February (DJF)

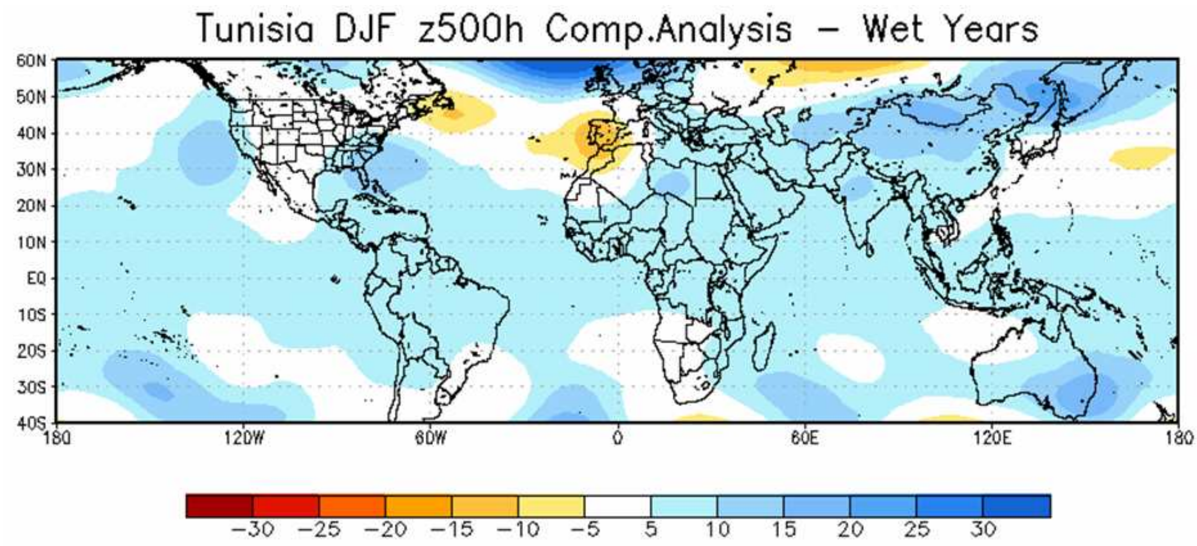

Figure.9: 500 hPa composite analysis for wet years for December-January-February (DJF)

Using CFSR reanalysis also allowed me to represent the average configuration of the mean sea level pressure MSLP for both categories of years. These averages configurations can be useful as reference states to make such a seasonal forecast.

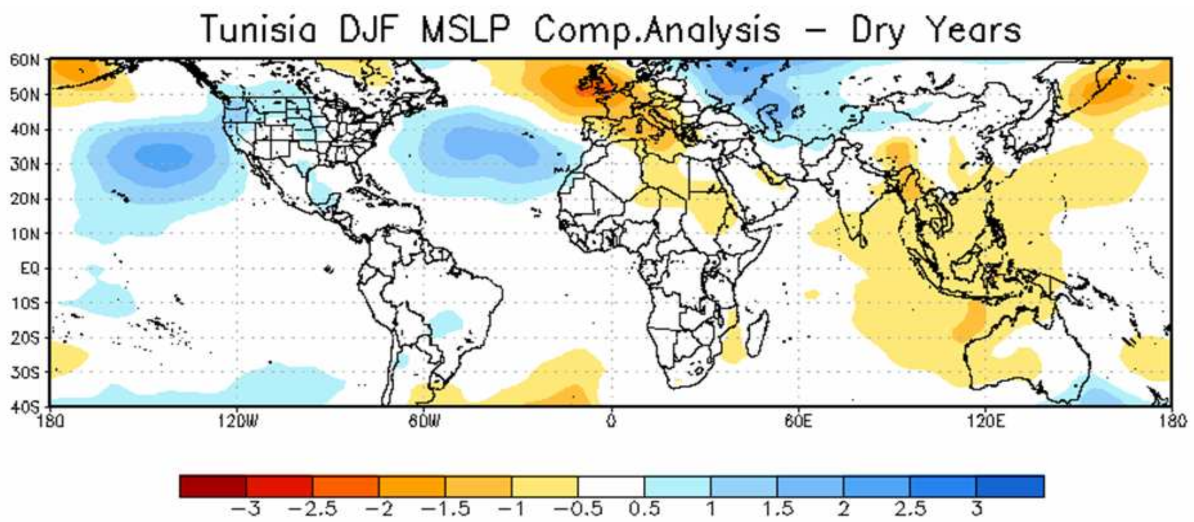

Figure.10: MSLP composite analysis for dry years for December-January-February (DJF).

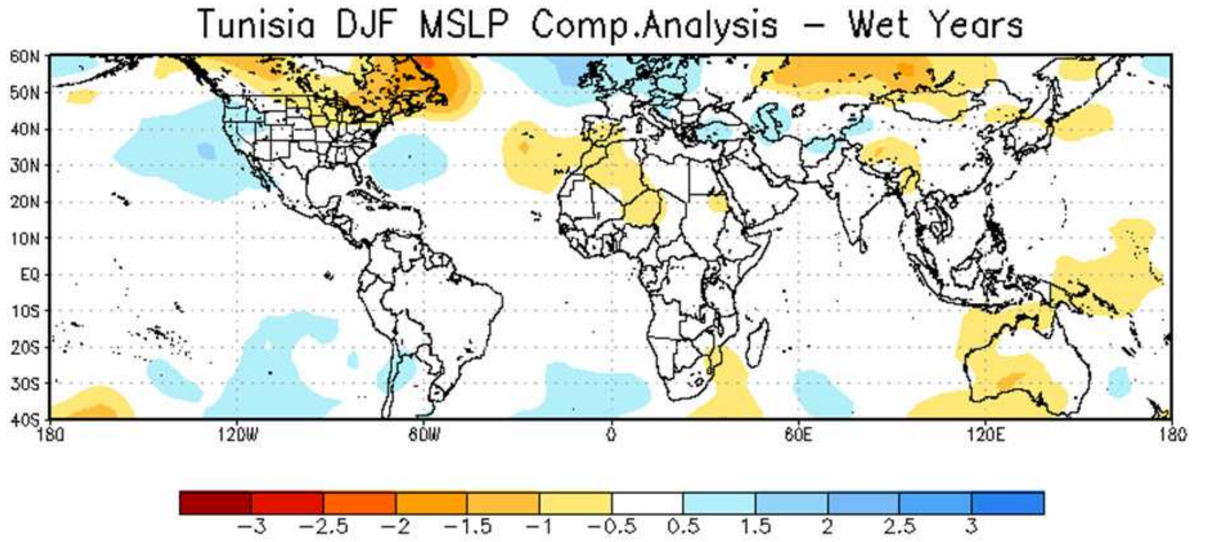

Figure.11: MSLP composite analysis for wet years for December-January-February (DJF).

3. Correlation

A very important step in diagnosis is to identify the determining factors of climate in Tunisia. For this purpose, I used an example of the season : December, January and February (DJF).I calculated the correlation between the normal of the Sea Surface Temperature (SST) on blobal scale for the month of November and the normal rainfall for the season studied. This correlation is represented in the following figure illustrates the low correlations between SST and rainfall in Tunisia for this period.

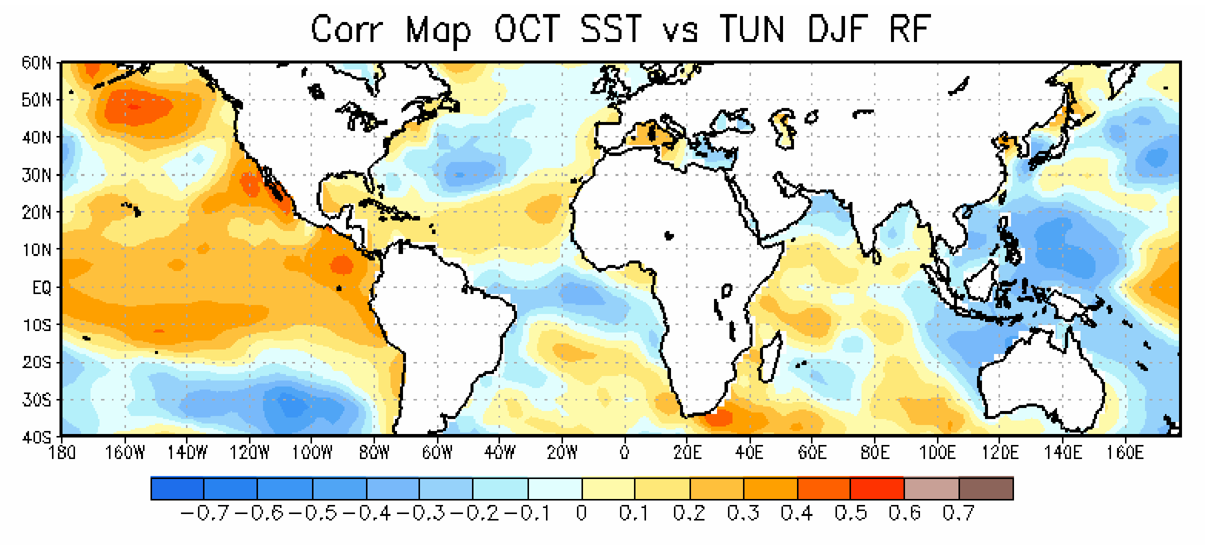

Figure.12: Correlation between SST on October and DJF precipitation in Tunisia.

III. Seasonal Predictions

1. Climate Predictability Tool (CPT) and Methodology of Making Forecasts :

The two techniques, which are used in the CPT, are Principal Components Regression (PCR) and Canonical Correlation Analysis (CCA). Each of these techniques can be used to address more than one kind of problem. This involves data that represent predictors, and data that represent what is to be predicted (predictands). Often, the predictor data is set up to occur earlier than the predictand data, with each spanning a historical period, so that predictive relationships become detectable and describable, and can be used for real-time forecasts. However, the predictor and predictand data can also be set up to occur at the same time, not staggered, so that the techniques describe diagnostic relationships between them, as may be desired for their own sake in climate research, perhaps preceding a study of predictive relationships.

The CPT is designed to use the prediction of a dynamical model (often called atmospheric general circulation model, or AGCM) as the predictor to make possible forecast of rainfall as a predictand. In an ideal world the prediction of the AGCM would be the best tool to use for the rainfall forecast, without needing to use CPT. However, today's best dynamical models are far from perfect. They have systematic errors. What it can do CPT is to identify model errors that are characteristic, and correct the forecasts in such a way as to maximize their average accuracy over the long historical period for which there are samples of model forecast data along with the corresponding actually observed data. Thus, CPT calibrates, or corrects, model forecasts. This process is the same as what is commonly known as model output statistics, or MOS.

In this model correction design, and regardless of whether the CCA or the PCR tool is selected for the analysis, CPT does its job in the same basic manner. The way it works is that the predictand (the y variable) is related to the predictor (the x variable) linearly. The simplest case of a linear relationship is when there is one x and one y, such as the North Atlantic Oscillation Index (NAO) for x, and the rainfall at a station (or the average rainfall over several stations)for y:

$$y = bx + a$$

Here y is predicted by getting the value of the predictor, x, multiplying it by some factor b, and then adding a constant number a. In general, the prediction of y from x is not perfect: in some instances y is over-predicted while in others it is under-predicted. In linear regression, upon which both CPT techniques are based, a and b are determined such that the sum of the squared errors over all of the historical cases used to make the equation is minimised. Squared errors rather than the absolute value of the errors are minimized because this nicely fits the huge collection of linear statistical theory. A consequence of this is that possible large errors heavily govern the formation of the equation, while the possible small or moderate errors exert much less influence. While this has both advantages and drawbacks, regression techniques remain very widely used. This simple form of linear regression, $y = bx + a$, is the basis of the much more complex versions of linear regression used in the CCA and PCR tools provided by CPT. In particular, in both CPT techniques, x is extended from a single scalar variable to an entire set of variables, X, that can form patterns in space and/or time, and y can either remain a single scalar (or a single average value of several elements) as in PCR, or be a second set of variables having patterns, Y, as in CCA. It should be noted that in PCR, even though only one predictand element is treated at a time, the technique can be many times applied repeatedly to each such predictand element (e.g. rainfall at each station) and results can be presented together such as on a map. In handling each predictand element separately, the relationships among the predictand elements are not explicitly used in making an overall forecast as it is in CCA.

A number of different varieties of linear regression can be identified, and can be classified using various criteria. One criterion that helps to describe the two techniques used in CPT is the level of complexity of the predictor and predictand data. Three commonly recognized levels can be identified:

- simple regression: a single predictor and a single predictand
- multiple regression: two or more predictors, and a single predictand

The PCR tool in CPT is in this category of regression, with the x's themselves being defined in a special way in order to need much fewer of them.

- multivariate (pattern) regression: two or more predictors, two or more predictands (**Y**, **B** and **X** are matrices; can be CCA)

The CCA tool in CPT is in this category of regression, with the x's and the y's themselves being defined in a special way in order to need much fewer of each.

The categorization above identifies the PCR technique as a kind of multiple regression that uses a set of predictors to predict one predictand element at a time, and the CCA technique as a kind of multivariate regression, using a set of predictors collectively to predict a set of predictands collectively, such that both predictors and the predictands possess many patterns amongst themselves as well as in their linkages with one another. In both techniques, the prediction rules are determined by analyzing the set of predictors and predictands over a historical period. In climate diagnostics and prediction, often each case of corresponding predictors and predictand come from one year for a specific season, so that there are as many cases as there are years. Short histories are less effective in identifying the best prediction rules, since every year contains extraneous or random variations; thus the more years that are available, the greater the likelihood that the consistent and robust relationships outweigh the random behaviors and appear clearly in the analysis results.

The CPT software was initially designed for use in forecast development by national meteorological services, especially in Africa (most commonly in the Southern African Regional Climate Outlook Forums), to simplify the production of seasonal climate forecasts.

It can be used in any region, and for diagnostic research as well as forecasting. It can be used to perform CCA or PCR on any pair of data sets, for any application.

2. *Tunisia case:*

Forecasting of seasonal rainfall for some parts of the North Africa has been studied before. The behavior of the seasonal precipitation in this region is not well understood .It is also necessary to point out that the rainfall prediction in this region is difficult, due to the fact that the rainfall in this zone can be generated by the north sub-polar depressions or by a south-west flow coming from the Atlantic Ocean. This step attempts to enhance the knowledge of the most important meteorological parameter, which is the rainfall, in Tunisia, and aims to contribute to predict the seasonal rainfall some months in advance. This study concerns the precipitation in the boreal winter season (December to February), because it is estimated that it is the most rainy season in this region. This work is mainly, using CPT, based on statistical Technic CCA to identify the degree of correlation between rainfall in Tunisia and several variables available in the library of the IRI namely Sea Surface Temperature SST, Mean Sea Level Pressure MSLP, 500 hPa and precipitation from CFS and CFSR. The results are presented in the following figure:

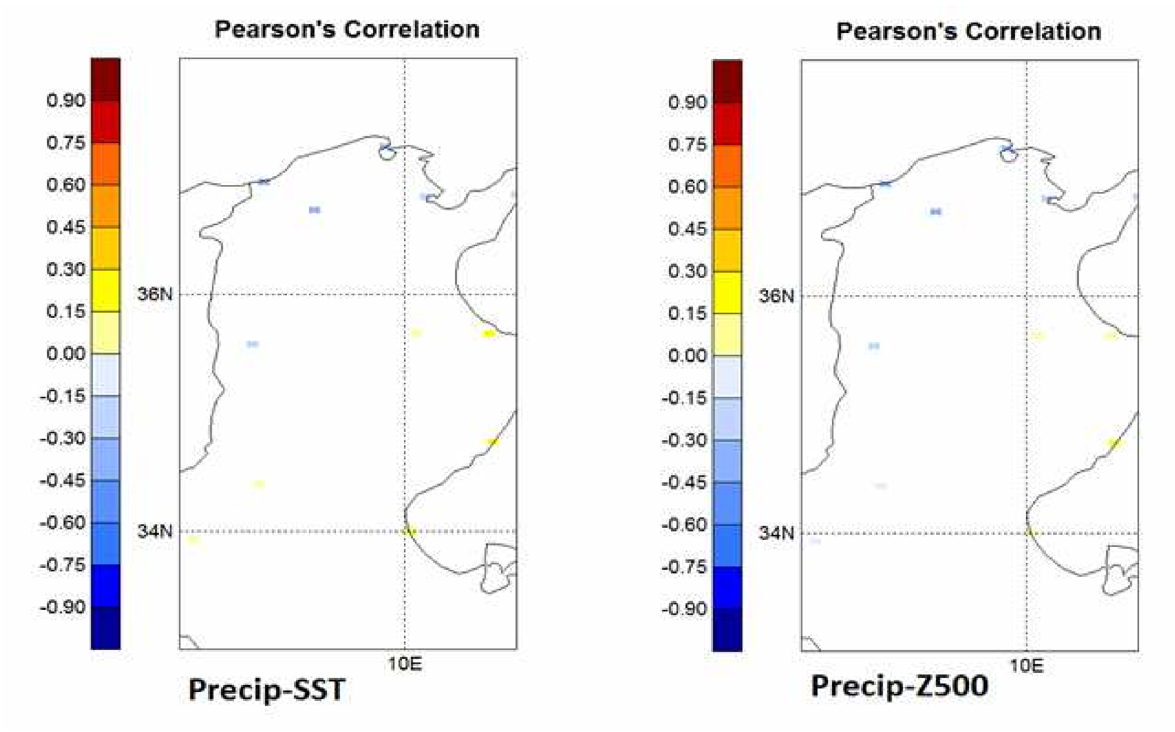

Figure.13: Skill map SST (left) and Z500 (right) with precipitation in Tunisia (DJF).

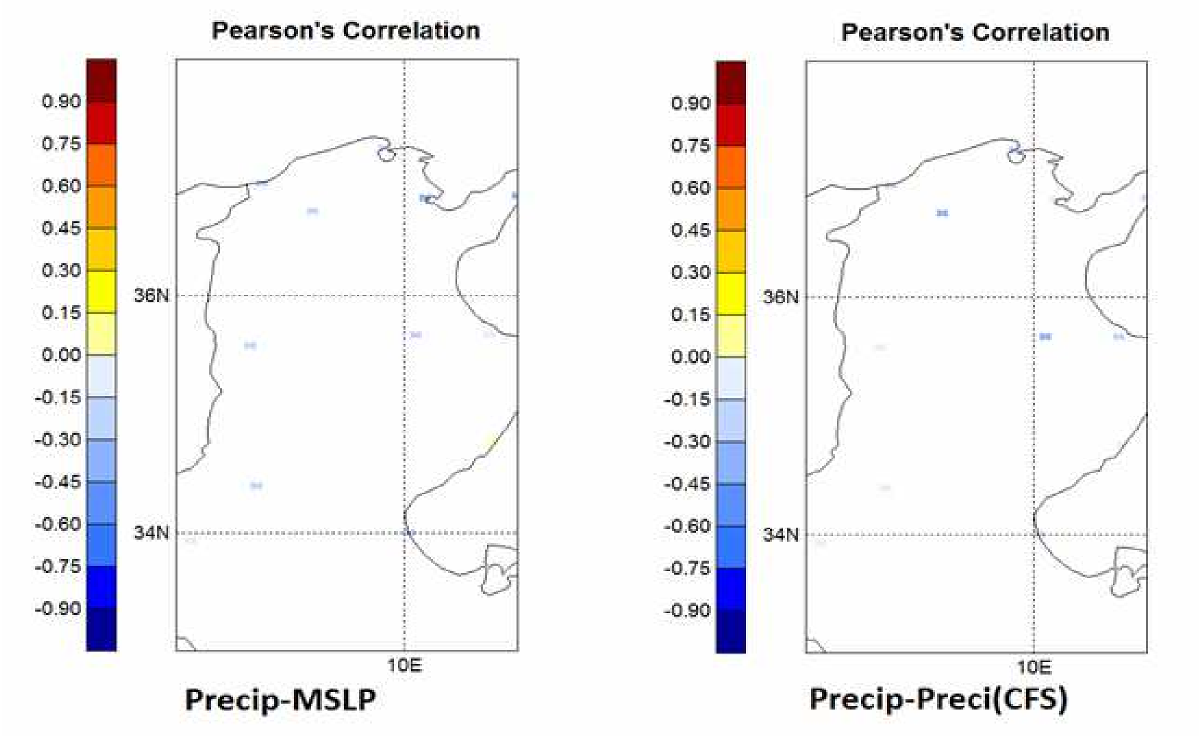

Figure.14: Skill map MSLP (left) and Precipitation from CFS (right) with precipitation in Tunisia (DJF).

The preliminary results presented here are not encouraging; maybe it is due to the number of stations studied and suggests that this research should be redone by using longer climate periods and a larger number of stations. However, it was also due to climate characteristics of this region in North Africa.

Conclusions and Recommendations:

During the course of my internship, at African Desks in NCEP. I had the opportunity to work with many essential tools for monitoring and forecasting climate and discover the various products provided by NCEP, which can be useful for different applications in Tunisia. The work achieved has been very enriching of my professional experience especially at the beginning of my career.

In fact, the work done with CMT can be reintroduced in Tunisia as a weekly or 2 times per month bulletin for monitoring precipitation in Tunisia. This bulletin could constitute a contribution to the applications of agriculture and water resources management…

Last but not least, the use of CPT can be restored by using the full observation network in Tunisia over a long period both by dividing the domain of study on zones that have the same geographic and climatic characteristics.

Such effort would serve as a source for developing regional climate information policy and give information to different users in the socio-economical sector for decision making.