Data Requirement for Empirical Model Development in Climate Prediction

By Omar Baddour for the WMO climate prediction curriculum

I. Introduction:

The Southern Oscillation (SO) was first discovered in 1880-1930, at that time it was clear that seasonal anomalies in the tropical atmosphere were connected (eg droughts in India and Australia were occurring in the same years), this has led subsequently to discover the Elnino-Southern Oscillation (ENSO)phenomena as a main driving force in many of the observed climate anomalies. Furthermore since 70's many work studies and field observations have been conducted to improve the knowledge about ENSO and its impact over world climate. The 1984-1994 TOGA experiment in the Pacific Ocean is the one ever conducted for this purpose. Since then climatic data becomes a great concern within climate research community which led to data quality check and data base organization systems.

The development of computer technology along with the improvement of statistical package have contributed greatly in the development of climate prediction and especially the empirical ones. Various world climate centers such as the national centers of environmental prediction in the US –NCEP-, the united Kingdom Meteorological Office (UKMO), the bureau of meteorology of Australia are issuing regularly experimental long lead forecast based on statistical methods, predicting rainfall, temperature and SST. Regional centers such as the African center of meteorological application for development – ACMAD- , the drought monitoring centers DMCs in Africa are providing also a regular seasonal forecast based on statistical approach. At country level many national meteorological services are also providing long range forecast based on the empirical methods. The need of these methods relays basically on the limitation of applying the dynamical models based on fluid dynamics equation solving to extend the numerical weather prediction range beyond 2 weeks (This has been theoretically demonstrated by Lorenz).

II. Major problems with data

Sampling Problem

The data at hand is only a limited sample in time and space (a tiny portion of what really a real world is), so that the significance of this sample is always a prior question to ask, for which an adequate response should be given before provision of any credible conclusion. As an example of situation in this aspect is the computation of correlation between two variables which lead to the conclusion of whether there is relationship between both variables. If the sample is not large enough, correlation could be a misleading inferential statistics for concluding the existence of such relationship, therefore it is always necessary to conduct statistical tests for the significance of the statistical results. A variety of statistical tests have been developed by statisticians which are adapted for any kind of statistical results. These tests give in probabilistic term the likelihood of the results.

Missing value Problem
Within the sample itself , quality of the data is crucial because the quality of the statistical results depends also upon it. The most important problem statisticians encounter is the missing value problem. In this regards statistician also developed various methods to overcome this problem. The efficiency of these methods however still depends on the extend of the gap in the data sample to be recovered. If this gap represent large portion of the sample, it will be hard for these methods to do the job.
Some of the methods used for data recovery : correlation matrix, Principal Component Analysis, Multiple linear regression. In these methods relationship between various variables in the same data set could be used to recover missing values in some of them.

Outliers problem
Some values in the data set could be largely out of the general behavior (variation) of the data set, these could be natural or artificial outliers. In both cases they should be wisely treated, because a huge outlier could alone influence the results of statistical analysis. Many statistical packages integrate modules and graphics to indicate these outliers. These outliers should be therefore treated so that there influence is minimized. Some of the methods used in this aspect is a log transformation of the variable.

III. Various predictands and predictors used in climate prediction

Empirical methods for climate prediction try to associate two set of climate variables through statistical analysis of their historical time series.

- Set of what we would like to predict called **Predictands Y's**

- Set of What we would like to use as input parameters for prediction called **Predictors X's** or explicative variables

This section gives a list of commonly used predictands and predictors in empirical climate prediction

predictands:
For climate prediction purpose, there is as much possible predictands as climate and other application parameters. Nevertheless, few of them are used for operational or experimental prediction. The main used ones are:

Rainfall and temperature have been the most used ones so far because of their extended impact on various socio-economic aspects: Agriculture (RR and T) , civil protection against floods (RR), energy saving and forest fires fight (T). It remains that for tropical and nearby regions the focus is still on rainfall parameter.
Runoff could be used as predictor. This was done during the 1999 west african climate outlook Forum (see WMO Proceeding on climate prediction and hydrology). This predictor has been found to be very useful for direct application for water resource management aspects, because it has less quality and quantity problems listed above and

for its integration of many aspects of climate variability including : rainfall, evaporation, evapo-transpiration, etc.

Diseases (such as malaria and meningitis) cause many death in tropical region especially in Africa. It is medically shown that they are climate sensitive, parameters like rainfall and temperature have been significantly linked to these diseases. Predictands derived from such diseases could be the number on infected individuals during disease outbreak period . The problem generally that rises for these predictands is the quantity and quality of the data. Very few countries in the infected area get a well organized medical files with enough records and good quality. Generally it is advised to undertake indirect prediction. Such as predicting rainfall and temperature then give a statement on the likelihood occurrence of the disease.

Crop index: The crop index is an index that characterizes the evolution of a crop during a crop season, it is directly affected by several meteorological parameters such as rainfall, temperature, evaporation (water balance) and number and distribution of dry spells during the crop season.

The INSTAT and GENSTAT software generate these index using 10 days meteorological data so that it could be used as a direct predictand and therefore try to predict what would be the crop index at the end of the crop season which leads predict the crop outcome.

Some work have been done in Africa to predict it using sea surface temperature (ACMAD), the work resulted in highly acceptable prediction skill (0.7).

Other Predictands:

Rain onset date : This predictand is very welcome to farmers and agriculture extension units. Especially within areas with short rainy season. Any time saved in the start time to saw would be beneficial for the crop outcome. Such situation happen in the Sahel region in Africa. However very little work has been done to investigate the prediction of start of rainy season. A scheme has been elaborated by Professor J.B. Omotosho from university of ABADAN in Nigeria based on computation of weekly wind shear at 400 and 700 mb, 6 weeks before the start of the rainy season to predict the date (a week) of the onset of the rain in west Africa. Evaluation of the skill of this scheme has not been done yet, efforts at ACMAD was undertaken for such evaluation based on real time skill evaluation.

Hurricane occurrence: some work has been done to link the numbers of hurricanes that hit northern Australia with Southern Oscillation Index.

Predictors

Sea Surface Temperature:

The grid-box sea surface temperature data set have only been available for analysis since the late 1970s. Since 1982, they have been supplemented by satellite estimates. Also moored and drifting buoys (especially tropical Pacific), oil rigs etc. Data are quality controlled, and corrected for changes in instrumental practice. The development of fast computers have permitted a quasi real time data analysis and are put in a quasi-public access files available for monthly climate analysis and long range forecasting purposes. Many international climate centers provide this data in several formats:

- <u>Global formats</u>*:* Global SST files at five days periods and one month period with various spatial resolution ranging from 2.5x2.5 degrees latitude x longitude to 10x10 degrees latitude x longitude. The fields are the output from Global Circulation Model Analysis. The Analysis schemes use ships observation, buoys and satellite data.

- <u>SST indices</u>: Some regions in the ocean play a key role in defining the state of the ocean anomalies and subsequently include most of the information about sea surface temperature anomalies. The identification of these areas was a results of many years of field observations and research. The most important ocean key areas are located in the central tropical Pacific. An index for each area is then computed which is the averaged SST anomaly over the area. Here are key areas for SST indices in the Pacific ocean (from Climate Prediction center):

Nino 1+2 (0-10S)(90W-80W)
Nino 3 (5N-5S)(150W-90W)
Nino 3.4 (5N-5S)(170-120W)
Nino 4 (5N-5S)(160E-150W)

The indices are provided as departure from climatological base mean. The CPC base mean is 1950-1979

Other SST indices:

East Tropical Atlantic index
West Tropical Atlantic index
North West Atlantic index

<u>Table1: Example of extracted data from file containing Pacific SST indices from CPC</u>
<u>Bold zone highlights some of ElNino Or LaNina episode</u>

YR	MONTH	NINO1+2	ANOM	NINO3	ANOM	NINO4	ANOM	NINO3.4	ANOM
50	**1**	**23.49**	**-.84**	**23.97**	**-1.37**	**27.41**	**-.65**	**25.01**	**-1.33**
50	**2**	**24.56**	**-1.25**	**24.51**	**-1.68**	**26.77**	**-1.27**	**24.92**	**-1.69**
50	3	25.59	-.70	26.65	-.21	27.00	-1.08	26.41	-.66
50	4	23.84	-1.58	26.65	-.59	27.12	-1.21	26.75	-.83
50	5	23.41	-.62	25.91	-.81	27.72	-.83	26.30	-1.23
50	6	21.70	-.96	25.64	-.53	27.85	-.69	26.79	-.61
50	7	20.74	-.77	25.17	-.21	27.84	-.62	26.59	-.37
50	8	20.52	-.12	24.51	-.27	27.54	-.81	26.11	-.53
50	9	19.82	-.42	24.12	-.47	27.12	-1.14	25.56	-.84
50	10	20.19	-.37	24.32	-.29	27.64	-.66	26.03	-.42
50	11	20.46	-.96	23.80	-.92	27.13	-1.12	25.42	-.93
50	12	21.92	-.58	24.44	-.42	27.27	-.95	25.54	-.85
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
80	1	24.77	.44	26.06	.72	28.80	.74	27.13	.79
80	2	25.77	-.04	26.54	.35	28.76	.72	27.18	.56
80	3	26.61	.33	26.92	.06	28.66	.57	27.28	.20

80	4	25.80	.38	27.38	.13	28.83	.50	27.86	.28
80	5	24.54	.51	27.13	.40	29.05	.50	27.96	.43
80	6	23.27	.62	26.87	.70	28.99	.45	28.12	.72
80	7	21.52	.01	25.58	.20	28.82	.36	27.32	.36
80	8	20.77	.13	24.70	-.09	28.41	.06	26.59	-.05
80	9	20.66	.42	24.95	.36	28.54	.28	26.60	.20
80	10	20.36	-.19	24.66	.05	28.56	.27	26.51	.05
80	11	21.56	.14	25.12	.40	28.61	.37	26.60	.25
80	12	22.54	.04	25.57	.70	28.45	.24	26.91	.52
81	1	23.48	-.85	25.05	-.29	28.05	-.01	26.11	-.23
81	2	25.21	-.60	25.60	-.59	27.90	-.13	26.16	-.45
81	3	26.31	.02	26.80	-.07	28.17	.09	26.92	-.16
81	4	25.03	-.40	26.94	-.30	28.10	-.23	27.28	-.30
81	5	24.06	.03	26.74	.01	28.43	-.12	27.46	-.07
81	6	22.75	.09	26.24	.07	28.47	-.08	27.41	.01
81	7	21.38	-.13	25.08	-.30	28.21	-.26	26.65	-.31
81	8	20.52	-.12	24.02	-.76	28.06	-.30	26.01	-.63
81	9	19.93	-.31	24.67	.08	28.39	.13	26.57	.17
81	10	20.55	.00	24.92	.31	28.45	.15	26.80	.35
81	11	21.41	-.01	24.79	.07	28.46	.21	26.41	.06
81	12	23.00	.50	25.44	.58	28.42	.21	26.58	.19
82	1	24.34	.08	25.87	.53	28.28	.22	26.71	.36
82	2	25.50	-.24	26.38	.19	28.20	.17	26.68	.06
82	3	25.25	-.93	26.96	.09	28.38	.29	27.17	.09
82	4	24.52	-.79	27.66	.42	28.84	.51	27.97	.39
82	5	24.01	.06	27.76	1.03	29.44	.89	28.51	.99
82	6	22.87	.27	27.46	1.30	29.74	1.19	28.73	1.33
82	7	22.47	1.00	26.47	1.09	29.40	.94	28.10	1.14
82	8	21.74	1.13	26.15	1.36	29.04	.69	27.96	1.33
82	9	21.80	1.59	26.57	1.98	29.18	.91	28.18	1.78
82	**10**	**22.91**	**2.37**	**27.17**	**2.56**	**29.42**	**1.12**	**28.72**	**2.27**
82	**11**	**24.73**	**3.34**	**27.62**	**2.90**	**29.25**	**1.01**	**28.82**	**2.46**
82	**12**	**26.27**	**3.81**	**28.36**	**3.49**	**29.18**	**.97**	**29.17**	**2.78**
83	**1**	**27.60**	**3.34**	**28.94**	**3.60**	**28.95**	**.89**	**29.35**	**3.01**
83	**2**	**28.16**	**2.42**	**29.02**	**2.83**	**28.80**	**.77**	**29.23**	**2.62**
83	**3**	**28.77**	**2.60**	**29.12**	**2.25**	**28.77**	**.68**	**29.06**	**1.98**
83	**4**	**28.76**	**3.45**	**29.16**	**1.92**	**28.85**	**.52**	**28.93**	**1.35**
83	**5**	**28.48**	**4.54**	**29.03**	**2.30**	**29.09**	**.54**	**28.93**	**1.40**
83	**6**	**27.70**	**5.10**	**28.24**	**2.08**	**28.90**	**.35**	**28.30**	**.90**
83	7	26.31	4.83	26.69	1.31	28.67	.21	27.08	.12
83	8	23.98	3.37	25.91	1.13	28.38	.03	26.55	-.09
83	9	22.27	2.06	25.23	.65	28.24	-.02	26.45	.05
83	10	21.82	1.29	24.57	-.04	27.76	-.54	25.84	-.61
83	11	21.83	.44	24.23	-.49	27.77	-.48	25.64	-.72
83	12	22.96	.50	24.43	-.44	27.77	-.44	25.57	-.83
84	1	24.17	-.09	24.81	-.53	27.63	-.43	25.61	-.73
84	2	25.16	-.58	26.18	-.01	27.23	-.80	26.34	-.28
84	3	25.98	-.20	27.10	.24	27.21	-.88	26.83	-.25
84	4	25.21	-.10	27.36	.11	27.72	-.62	27.40	-.18
84	5	23.22	-.72	26.47	-.25	27.94	-.61	27.38	-.14
84	6	21.93	-.67	25.39	-.77	28.11	-.44	26.87	-.53
84	7	21.27	-.20	24.97	-.40	28.33	-.13	26.71	-.25
84	8	20.20	-.41	24.45	-.33	28.17	-.18	26.29	-.35
84	9	20.40	.19	24.30	-.28	28.60	.34	26.41	.01
84	10	20.49	-.05	23.92	-.69	28.26	-.04	25.90	-.55
84	11	21.48	.09	24.04	-.68	27.95	-.29	25.41	-.95
84	12	22.57	.11	23.64	-1.23	27.43	-.78	24.93	-1.46

.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
88	4	24.44	-.87	26.74	-.50	28.16	-.17	27.31	-.26
88	**5**	**23.22**	**-.73**	**25.30**	**-1.43**	**28.36**	**-.19**	**26.50**	**-1.03**
88	**6**	**21.02**	**-1.58**	**24.41**	**-1.75**	**28.13**	**-.42**	**26.10**	**-1.31**
88	**7**	**20.00**	**-1.47**	**23.70**	**-1.68**	**27.87**	**-.59**	**25.58**	**-1.38**
88	**8**	**19.01**	**-1.60**	**23.35**	**-1.44**	**27.63**	**-.72**	**25.22**	**-1.42**
88	**9**	**19.06**	**-1.15**	**23.57**	**-1.01**	**27.59**	**-.67**	**25.40**	**-1.00**
88	**10**	**19.28**	**-1.25**	**23.16**	**-1.45**	**27.09**	**-1.21**	**24.66**	**-1.79**
88	**11**	**20.54**	**-.85**	**23.05**	**-1.67**	**26.77**	**-1.47**	**24.27**	**-2.09**
88	**12**	**21.74**	**-.72**	**23.13**	**-1.74**	**26.70**	**-1.51**	**24.36**	**-2.03**
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
93	7	21.68	.21	25.79	.41	29.19	.73	27.56	.60
93	8	20.87	.26	24.93	.14	28.91	.56	26.87	.23
93	9	20.46	.25	24.92	.34	29.06	.80	26.92	.52
93	10	20.82	.28	25.16	.55	28.87	.58	26.95	.50
93	11	21.29	-.10	25.09	.36	28.90	.66	26.84	.48
93	12	22.11	-.35	25.25	.38	28.87	.66	26.73	.34
94	1	24.16	-.10	25.67	.33	28.37	.31	26.52	.18
94	2	25.71	-.03	26.04	-.15	28.05	.02	26.54	-.08
94	3	25.44	-.74	26.86	.00	28.17	.08	27.17	.09
94	4	24.15	-1.16	27.03	-.22	28.56	.23	27.81	.23
94	5	23.05	-.89	27.00	.27	28.96	.41	28.02	.49
94	6	22.29	-.31	26.45	.28	29.10	.55	27.91	.51
94	7	21.06	-.41	25.17	-.21	29.29	.82	27.31	.35
94	8	19.51	-1.10	24.65	-.14	29.41	1.06	27.31	.67
94	9	19.85	-.36	24.78	.20	29.18	.92	27.02	.62
94	10	21.24	.71	25.42	.80	29.34	1.04	27.38	.93
94	11	22.21	.82	25.80	1.08	29.58	1.33	27.80	1.44
94	12	23.44	.98	26.03	1.16	29.46	1.24	27.83	1.43
95	1	25.15	.88	26.32	.98	29.15	1.08	27.49	1.15
95	2	26.34	.60	26.86	.67	29.01	.98	27.45	.83
95	3	26.00	-.18	27.05	.18	28.92	.83	27.53	.45
95	4	24.28	-1.03	27.07	-.18	28.86	.53	27.90	.33
95	5	22.88	-1.06	26.35	-.38	29.09	.54	27.67	.14
95	6	22.18	-.43	26.10	-.06	29.01	.46	27.52	.12
95	7	21.18	-.29	25.37	-.01	28.76	.30	27.02	.06
95	8	19.89	-.72	24.31	-.48	28.42	.07	26.38	-.26
95	9	20.08	-.13	23.96	-.62	28.21	-.06	25.93	-.47
95	10	20.15	-.39	24.02	-.59	28.03	-.27	25.67	-.78
95	11	21.05	-.34	23.94	-.78	27.94	-.30	25.58	-.77
95	12	22.06	-.40	24.21	-.66	28.06	-.15	25.57	-.82
96	1	23.84	-.42	24.95	-.39	27.88	-.18	25.69	-.66
96	2	25.81	.07	25.70	-.49	27.56	-.47	25.80	-.81
96	3	26.20	.03	26.77	-.10	27.68	-.41	26.64	-.43
96	4	23.74	-1.57	26.78	-.47	28.04	-.29	27.39	-.19
96	5	23.04	-.90	26.32	-.41	28.40	-.15	27.32	-.20
96	6	21.50	-1.10	25.91	-.25	28.54	.00	27.34	-.06
96	7	20.05	-1.42	25.38	.00	28.45	-.01	27.09	.13
96	8	19.62	-1.00	24.59	-.19	28.49	.13	26.55	-.08

96	9	19.28	-.93	24.33	-.26	28.39	.13	26.33	-.07
96	10	19.75	-.78	24.38	-.24	28.35	.05	26.23	-.22
96	11	20.27	-1.12	24.37	-.35	28.28	.04	26.18	-.18
96	12	21.54	-.92	24.14	-.72	28.42	.20	25.97	-.42
97	1	23.64	-.63	24.72	-.62	28.36	.30	25.94	-.40
97	2	25.95	.22	25.87	-.32	28.31	.28	26.37	-.25
97	3	27.22	1.04	27.09	.23	28.52	.44	27.11	.03
97	4	26.59	1.28	27.69	.44	29.32	.98	28.08	.51
97	5	26.86	2.92	28.16	1.43	29.45	.90	28.63	1.10
97	**6**	**26.46**	**3.86**	**28.29**	**2.13**	**29.41**	**.86**	**28.97**	**1.56**
97	**7**	**25.66**	**4.19**	**28.10**	**2.72**	**29.47**	**1.00**	**28.92**	**1.96**
97	**8**	**24.81**	**4.20**	**27.89**	**3.10**	**29.25**	**.89**	**28.84**	**2.20**
97	**9**	**24.32**	**4.11**	**27.85**	**3.26**	**29.31**	**1.05**	**28.93**	**2.53**
97	**10**	**24.61**	**4.08**	**28.15**	**3.54**	**29.26**	**.97**	**29.24**	**2.79**
97	**11**	**25.62**	**4.23**	**28.50**	**3.78**	**29.40**	**1.15**	**29.28**	**2.92**
97	**12**	**26.94**	**4.48**	**28.79**	**3.92**	**29.29**	**1.08**	**29.24**	**2.85**
98	**1**	**28.15**	**3.89**	**28.90**	**3.56**	**29.01**	**.95**	**29.09**	**2.75**
98	**2**	**28.95**	**3.21**	**28.92**	**2.73**	**28.87**	**.84**	**28.86**	**2.25**
98	**3**	**29.14**	**2.96**	**29.13**	**2.26**	**28.65**	**.56**	**28.66**	**1.59**
98	4	28.64	3.33	29.07	1.83	28.53	.19	28.54	.96
98	5	27.70	3.76	28.16	1.43	28.69	.13	28.45	.93
98	6	25.20	2.60	26.01	-.16	28.61	.07	26.72	-.69
98	7	23.44	1.97	25.24	-.14	28.07	-.40	25.94	-1.02
98	8	21.76	1.15	24.63	-.16	27.77	-.58	25.49	-1.15

Oscillation indices:

Southern Oscillation Index, SOI:

This index is the difference between standardized sea level pressure at Tahiti station in the eastern tropical Pacific and the standardized sea level pressure at Darwin station in northern Australia in the western Pacific. This index has been found very useful to monitor ENSO because of its persistence over several months. Significant negative SOI indicates an ElNino episode which is linked with SST warming and sea level pressure decrease in the central and eastern Pacific. Positive SOI is associated with inverted sign anomalies : SST cooling and sea level pressure increase in the central and eastern pacific, which is referenced as LaNINA episode. This index has for long time been used as a main predictor for various climate forecast in the Pacific Region such as in Australia and Indonesia.

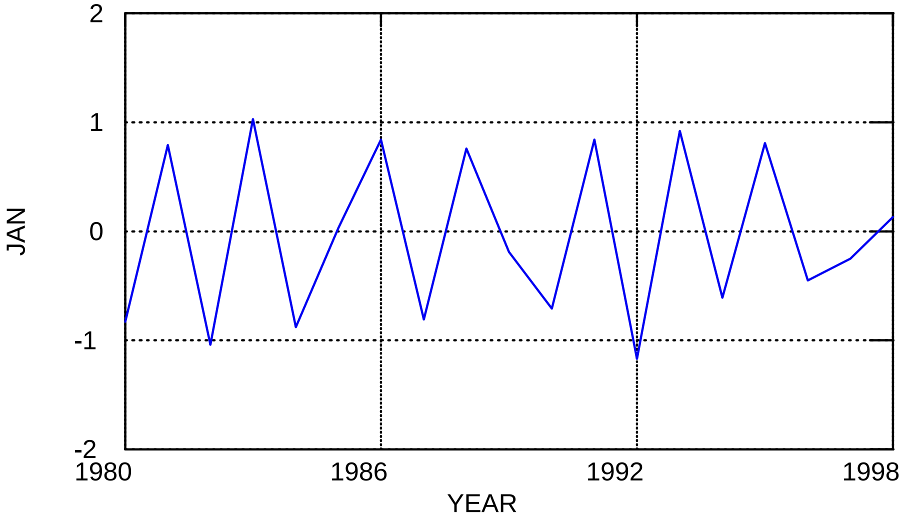
Northern Atlantic Oscillation index, NAOI:

This index is an atmospheric index computed in similar way as SOI. The pressure stations used are Akurery in Island and Ponta delGada in Azores. This index characterizes the northern Atlantic pressure oscillation between Azores high pressure and Island low pressure. Investigation have been conducted in northern Africa (Morocco) to see a predictability potential in this index, unfortunately it does not have similar persistence as SOI.

Quasi-Biennial Oscillation (QBO)

It is an index which characterizes the quasi biennial oscillation observed in the wind field at high altitude between 30 and 50 mb, some investigations -still to be confirmed - have shown that this index could be used as predictor in some tropical regions. The index is being computed using standardized winds over singapore at 30 and 50 mb. A new QBO index has been put in by NCEP which is the zonal wind average over the equator at 30 and 50 mb .

Standardized 30 mb wind



IV. Derived data :

- As Predictands:

Time series for individual stations contain a lot of variability that is either local (i.e ; not connected to large scale climate) or attributable to errors in instrumentation etc. One way to get a clearer picture of climate variability is to calculate area-average rainfall indices. When some stations have missing values, it is best to average anomalies, not actual values. Averaging the percent of normal or the standardized anomalies generally gives an accurate indication of climate variability. Zoning is therefore made to define climatic homogenous area over which the indices are computed. An objective way to do zoning is by applying principal component analysis technique.

Example of rainfall index formula:

Rainfall index = $\frac{1}{K} \sum_{i=1}^{i=K} \frac{R_i - \overline{R}_i}{\sigma_i}$, K: number of stations in the area. The average standard deviation are computed within a reference period such as 1961-1990

Rainfall index is computed for a season or a month.

- ***As Predictors***

Empirical Orthogonal Function (EOF) which represents canonical variables derived from reduction techniques applied on SST fields such as principal component Analysis , Factor Analysis, Eigenvector analysis. These techniques define the leading modes of anomaly of spatial variation in climate data sets. For example, for SST, a leading mode will be El Nino. These patterns are the empirical orthogonal functions or EOFs. Associated with each EOF, the techniques provide a time series that measures the time-variation of the EOF pattern in the observations. For example, the EL Nino EOF time series strong positive values in El Nino years, and strong negative values in La Nina years. The time series could be used as predictors. Global SST's contains three leading modes that are commonly used for climate prediction: EOF1 (could replace NIN03 index), EOF3 which characterizes the north-south difference in SST anomalies, (slowly time varying mode).

Rotation technique is an option made for better geographical interpretation of EOF, one of best known is when rotation applied on the remaining signal after removing the three leading modes from Global SST, the results give the rotated EOF2 that represents the East Tropical Atlantic Variability and could be used as predictor instead of the East Tropical Atlantic SST index.

V. Putting things together into a real world for model development

Basic Computer and software requirement

The development of Personal Computer technology in the second half of 90's made the possibility of having sufficient memory and speed to use large enough data and run sophisticated empirical programs for climate prediction. From the recent past experiences, it seems that the following minimum PC capacity is required for handling global SST data and run statistical methods such as canonical correlation and principal component analysis. The PC is supposed to be a windows machine based.

Hardware requirement:

Pentium II and preferably III (133 Mhz and more)

Hard disk capacity (2 GB)

Software requirement

A statistical package: SYSTAT is one that have been successfully tested in Africa and Latine America,

Graphic Software for mapping such as: Surfer and /or Grads

Data base setup Requirement

- Long enough period (30 to 40 years history) of the data set to ensure statistically significant analysis.
- Many hypothesis in statistics are drawn from hypothesized parametric distributions. Make sure the hypothesis are acceptably respected . Otherwise some transformation are needed to ensure a minimum acceptance of these hypothesis.
- Existence of sound physical hypothesis about the connection between Predictands and Predictors. This could be investigated by GCMs or through statistical analysis of dynamical fields such us winds.

- Data base setup including rainfall data set and SST data in terms of indices, such as NINO3, Equatorial Atlantic, North Atlantic indices plus other SST global patterns based on EOFs, these data sets are ordinary available within various centers (ex: UKMO and NCEP).
- Preliminary Predictor selection for the domain of interest (country level for example) : This is done by looking to the most recent research results referenced in the international reviews. If not Available correlation Analysis should performed to seek for the area of predictors in the Ocean,
- Choice of the Season : Some seasons are more predictable than others, care should be made to define the seasons in order to not overlap months with opposing response to SST's this could dilute the signal and decrease predictability, example in Africa: In Sahel area June responds positively to ENSO Forcing while July and August Respond negatively. Correlation based on individual months could isolate a coherent season and predictability window.

References:

ACMAD and WMO/CLIPS publication, (Baddour,O., Ed.) October 1998 : Climate Forecast in Africa , WMO/TD N°927

Baddour, O. 1985 : Etude de la propagation des ondes de Rossby **à** l'aide du trac**é** des rayons, Note de travail de l'ENM/Toulouse.

Baddour,O. 1992, les m**é**thodes de pr**é**vision saisonnière en Australie et les possibilit**é**s d'adaptation au Maroc, Rapport technique de mission

Folland, C.K., Owen,J.A., Ward,M.N, and Colman, A.W., 1991 : Prediction of seasonal rainfall in the sahel region of Africa using empirical and dynamical methods. J.Forecasting, 10,21-56.

Forum reports from SARCOF and PRESAO meetings , 1998 and 1999.

Grant Branstator, 1983 : Horizontal energy propagation in a barotropic atmosphere with meridional and zonal structure, J.Atm.Science, 1689-1708

Hastenrath, S.,1990 : Decadal-scale changes of the circulation in the tropical Atlantic sector associated with Sahel drought. Int.J.Climatology., 459-472 .

Hoskins, B.J and D.J. Karoly, 1981: The steady linear response of a spherical atmosphere to thernal and orographic forcing. J.Atm. Science 1170-1196

Lamb, P.J., 1978 : large –scale tropical Atlantic surface circulation pattern associated with Subsaharan weather anomalies. Tellus, A30, 240-251

Rowntree,P.R, 1976 : Response of the Atmosphere to a tropical Atlantic ocean anomaly. Q.J.R.M.S, 102,607-625

Ward, M.N., Lamb P.J, Elhamly,M., Sebbari, R. : Climate variability in northern Africa : Understanding droughts in the Sahel and the Maghreb, Chapter 6 in Beyond Elnino : decadal and interdecadal climate variability (A. Navarra, Ed.), Springer, 119-140.