FINAL REPORT for APN PROJECT

Project Reference Number: CBA2012-01CMY-Abawi

Building Scientific Capacity in Seasonal Climate Forecasting for Improved Risk Management Decisions in a Changing Climate

The following collaborators worked on this project:

Professor Yahya Abawi, Project Leader, University of Southern Queensland, Australia

Mr Ferdie Billones, National Water Resources Board, Philippines

Ms Jovencia B Ganub, Bohol Environment Management office, Philippines

Ms Edna L Juanillo, Philippine Atmospheric, Geophysical and Astronomical Services Administration Philippines

Professor Giashuddin Miah, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh

Mr Abdul Matin, Rural Development Academy, Bangladesh

Mr Abdul Mannan, Bangladesh Meteorology Department, Bangladesh

Mr Adi Ripaldi, Meteorological, Climatological and Geophysical Agency, Indonesia

Ir. Surana, Government Office, Nusa Tenggara Barat, Indonesia

Dr Simon White, University of Southern Queensland, Australia.

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OVERVIEW OF PROJECT WORK AND OUTCOMES

The Asia-Pacific region is highly vulnerable to the impacts of climate variability and climate change due to high exposure and limited institutional capacity. Major limitations to developing effective adaptive capacity to a changing climate in the developing countries of SE Asia are: the limited national capacity for climate monitoring and forecasting; low levels of awareness among decision makers to the local and regional impact of climate variability; and, lack of effective policy responses to climate variability and climate change.

This project was designed to address some of these limitations through targeted training workshops in the use of Seasonal Climate Forecasts (SCF) for leading scientists within meteorological organizations and professionals involved in the agriculture and water sectors. The project also aimed to raise awareness of climate variability and climate change impacts amongst policy makers, researchers, government agencies and farming communities in SE Asia through direct dialogue and seminars.

Keywords
Climate variability, ENSO, SE-Asia, seasonal climate forecasts, risk management, monsoon onset, Indonesia, Philippines, Bangladesh

Objectives

The overall aim of this project is to build local scientific capacity in the use of Seasonal Climate Forecasts (SCF) for leading scientists within meteorological organizations and professionals involved in the agriculture and water sectors through in-country training workshops. The use of SCF forecasts in decision making is best achieved through the development of an operational forecasting system and by demonstrating the value of such forecasts in practical decision making using case studies. Therefore, a key objective of the project was to identify climate drivers that have the most influence on rainfall patterns including the onset of monsoon in the participating countries.

The specific objectives of this project were to:

- conduct training workshops to build local capacity in the theory and operational use of SCF using the SCOPIC and FLOWCAST decision support tools;
- conduct a validation study to identify the relationship between ENSO based drivers and seasonal rainfall using rainfall data for Indonesia, the Philippines and Bangladesh;
- assess the spatial and temporal characteristics of statistical forecasting skill in the region for different ENSO based predictive systems and identify:
- the times of the year when prediction is reliable; and
- potential lead times at which forecasts can be made.

Amount received and number years supported

The Grant awarded to this project was:
US$ 42000 for Year 1:
US$ 28000 for Year 2:

Activity undertaken

Initial in-country visits were conducted in the Philippines, Indonesia and Bangladesh from 10 August–3 September 2011 to meet with project collaborators and decision makers within various government agencies, as well as to deliver a series of seminars on climate risk management and the impact of climate variability and climate change in public seminars. Five seminars with leading agencies were held in the Philippines, Indonesia and Bangladesh (PAGASA, National Water Resources Board, Bohol Environmental Agency, BMKG, and Bangabandhu Sheikh Mujibur Rahman Agricultural University). These seminars were organized by the local collaborators who also arranged meetings with key government officials. In total over 150 people from various government agencies, universities and the public attended the five seminars.

During this visit collaborators from the national meteorological agencies were provided with training in the use of climate prediction software SCOPIC and FLOWCAST, and climate datasets were obtained to conduct a climate validation study.

Following in-country visits, two regional workshops were undertaken for participants from Indonesia, the Philippines and Bangladesh. The first workshop was held from 10-13 January 2012 in Kuala Lumpur, Malaysia, with nine collaborators attending the four day workshop. Training was provided in climate science; data homogeneity testing; validation techniques; forecast skill assessment; and, hands-on training in SCOPIC and FLOWCAST. An outline of the climate validation process with examples from a recently completed study in the Pacific was given and the participants used the methodology from the Pacific study to conduct a validation study for their country (Appendix I). A dedicated spreadsheet to assess the impact of ENSO on the onset and duration of monsoon and relevant training was also provided. Participants used their own data to conduct the validation study in accordance with the objectives of the project and presented their preliminary results during the final day of the workshop.

The second workshop was held from 6-9 January 2014 in Lombok, Indonesia. The gap between the two workshops provided the opportunity for participants to obtain additional data sets and learn more about the operation of the software. All participants have received an unrestricted copy of FLOWCAST software which they can use for further training and research. The second workshop had a similar structure to the first with more time allocated to informal discussions and “hands-on” analysis. A total of 19 people including local staff from BPTP, UNRAM and BMKG from Indonesia attended this workshop. This report is a summary of the analyses and results from the two workshops compiled by a lead author(s) from each country.

Results

Detailed description of data and methodology to complete this study is given in the technical section of this report. While the primary focus of the project was to build scientific capacity in SCF for young scientists in the participating countries, the exercises conducted during the two workshops provided the opportunity to assess the influence of ENSO based predictive systems on rainfall variability and potential for forecasting in the region. The project also allowed the opportunity to engage with public and policy makers through meetings and public seminars. From discussions with senior government officials it was apparent that consideration of climate information in planning and decision making is growing in SE-Asia. Attorney Edgar M. Chatto, the Governor of the Bohol Province in the Philippines, said “Climate variability and climate change is a real challenge for our province. We now incorporate climate variability and climate change projections in all aspects of our planning and environmental management issues”. Discussion with other senior water managers and agricultural practitioners highlighted the importance of seasonal climate forecasts for water allocation, and risk management decisions. Considerable work, however, needs to be done to transfer the findings of this project into practical risk management decisions. This can best be achieved through developing pilot projects in regions where the potential for forecasting is strong and climate variability can significantly improve resource use and other operational efficiencies. An example is the management of Angat Dam in the Philippines which is the main source of water supply for Metro Manila, but is also used for flood mitigation, hydropower production and agricultural use.

Key findings from this project include (for detailed analysis and background refer to the main technical report);

- Impact of ENSO is strong in the Philippines with moderate to high forecasting skill through most of the year particularly for climate type IV (See section 4.1) with lead times of 3-4 months. Niño 3.4 as well as SOI has the strongest relationship with rainfall variability across the whole region. Forecasting skill is poor during the peak rainy season.
- Forecasting of inflow into Angat Dam supplying Metro Manila is possible through most of the year with lead times of up to 4 months. Significant opportunities exist for using stream-flow forecast to optimize competing demand from Angat Dam.
- Onset and duration of monsoon in the Philippines is influenced by ENSO with later onset and shorter duration of monsoon during El Niño years and earlier onset and longer duration during La Niña years. This is particularly pronounced for climate type III (Zamboanga). On average, the onset of monsoon is delayed by up to 38 days in an El Niño years and is up to 35 days shorter as compared to La Niña years.
- Impact of ENSO on the Indonesian rainfall is also strong with moderate to high forecasting skill particularly in eastern Indonesia. Over western Indonesia and Java the effect of ENSO on rainfall variability is less pronounced. In this region the Indian Ocean Dipole may have more influence but was not investigated in this study due to limited resources and data availability.
- Results from eastern Indonesia showed that on average the onset of monsoon tends to be delayed by up to 1 month and have a shorter duration in El Niño years as compared to La Niña years (see section 4.3)
- There appears to be little influence of ENSO on the climate of Bangladesh in terms of the predictability of rainfall, onset and duration of the monsoon season.

All objectives of the original proposal have been met. The validation study has been completed and participants are now confident in the theory of SCF and operational use of software to undertake further research including studies on the application of SCF in risk management decisions across climate sensitive sectors. The project has created lasting network in the region and has strengthened interactions amongst scientists and policy-makers, as well as provided scientific input to policy decision-making.

Relevance to the APN Goals, Science Agenda and to Policy Processes

This project was designed to transfer existing knowledge and information systems developed as part of previous investments in the Asia-Pacific region (ACIAR and AusAID) to other countries in the region. The transfer of knowledge has not only promoted and encouraged activities that will develop scientific capacity and improve the level of awareness on global change issues specific to the region but has also identified present and future needs and emerging challenges and opportunities for the region. Understanding the mechanism of how climate variability is affected in a wider geographic context is essential in developing appropriate response strategies. The project activities aligns strongly with APN Goals and addresses a number of sub-categories under part 107 of the Johannesburg World Summit on Sustainable Development Implementation. Specifically;

- Build greater capacity in science and technology through the use of SCF for sustainable development in the area of water resource management and agriculture;
- Improve policy and decision-making at all levels through improved collaboration between natural and social scientists, and between scientists and policy makers ; and

- Make greater use of integrated scientific assessments, risk assessments and, interdisciplinary and intersectional approaches, via improvements from science-based decision making with greater understanding of climate drivers, their influence and the ability to use SCF in risk management decisions.

Self-Evaluation

Informal evaluation was conducted in relation to the workshop organization, contents and delivery. The feedback was extremely positive with participants expressing high level of satisfaction with their learning experience. Given the complexity of the study during two short workshops and what has been achieved, the enthusiasm and contribution of participants throughout the project is highly commendable. A quote from one collaborator is included below; "*Obtaining a good output using the historical rainfall data of Tagbilaran City was so inspiring. Moreover, I have learned the importance of religiously collecting rainfall data and during the workshop, I have made initial talks with Ms. Edna Juanillo of PAGASA for a partnership with the Provincial Government to ensure that rainfall data is regularly collected and to organize and capacitate (sic) the rainfall observers……. The software is well-developed and it provides guidance to the users on its applications with the HELP option to us participants. Thank you APN for this opportunity from the Province of Bohol*." –Jovencia B Ganub

Potential for further work

Climate change projections suggest higher frequency and magnitude of floods and droughts in the region than what is currently being experienced. The potential for increased risk, as well as the impacts of future changes in climate on agriculture and water resources, demonstrates the need to evaluate current practice for managing climate risks and developing strategies for adapting to future changes in climate. Understanding the impacts of climate on SE-Asian agriculture and natural resources systems and the ability to predict these events with sufficient lead-time for government and farmers to take remedial action, is crucial for policy development and ensuring long-term sustainability and food security in the region. Potential benefits can best be achieved through further work in developing pilot projects in areas where the potential for forecasting is strong and forecasting with sufficient lead time can significantly improve resource use and other operational efficiencies (e.g. Angat Dam management in the Philippines). Furthermore, to develop a better regional understanding of ENSO on the climate of SE-Asia and potential impacts, further studies on the influence of ENSO across other Asian countries (e.g. Lao, Cambodia and Vietnam) is highly desirable.

Publications

Abawi, Y and White, S. (2013) Identifying key climate drivers in South-East Asia to improve climate forecasting and risk management decision-making. APN Science Bulletin, Issue 3, March 2013 Pages 130-134. ISSN 285-761x.

Abawi *et al*. (2014). Predictability of seasonal rainfall and monsoon onset and duration in SE-Asia. (In preparation).

Acknowledgments

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TECHNICAL REPORT

Preface

This report is an output from two workshops held in Kuala Lumpur, Malaysia (10-13 January 2012) and Lombok, Indonesia (6-9 January 2014) as part of the APN CAPaBLE project "Building Scientific Capacity in Seasonal Climate Forecasting for Improved Risk Management Decisions in a Changing Climate". The workshops where held in collaboration with climate scientists and professionals engaged in agriculture and water resources from the Philippines, Indonesia and Bangladesh. The focus of the project was on building scientific capacity in the use of seasonal climate forecasts amongst scientists and practitioners in the region. Through greater understanding of key climate drivers and the operational use of seasonal forecasting systems the risks and opportunities arising from climate variability and change can be better managed.

Table of Contents

1.0 Introduction

The Asia-Pacific region is highly vulnerable to the impacts of climate variability and climate change due to high exposure and limited institutional capacity. Major limitations to developing effective adaptive capacity in SE Asia are: the limited national capacity for climate monitoring and forecasting; low levels of awareness among decision makers to the local and regional impact of climate variability (e.g. ENSO); and, lack of effective policy responses to climate variability and climate change.

The aim of this project was to address some of these limitations through building scientific capacity in the use of Seasonal Climate Forecasts (SCF) for young and leading scientists within meteorological organisations and professionals involved in the agriculture and water sectors in the participating countries. The specific objectives of this project were to:

- conduct training works to build local capacity in the theory and operational use of SCF using the SCOPIC and FLOWCAST climate prediction tools;
- conduct a validation study to identify the relationship between ENSO based drivers and seasonal rainfall, including the onset of monsoon;
- assess the spatial and temporal characteristics of statistical forecasting skill in the region for different ENSO based predictive systems and identify:
- the robustness of each system;
- the times of the year when prediction is most reliable;
- potential lead times at which forecasts can be made; and,
- raising awareness of climate variability and climate change impacts amongst policy makers, researchers, government agencies and the farming communities in SE Asia.

2.0 Methodology

The approach used was through “hands-on” training in the use of seasonal climate forecasting software (SCOPIC and FLOWCAST), climate concepts, forecast verification methodologies, statistical concepts in seasonal climate forecasts, and risk management. These concepts were further re-enforced during the workshops through conducting a validation study where participants conducted a study to assess the impact of ENSO on rainfall variability in their respective countries.

Initial in-country visits were conducted in the Philippines, Indonesia and Bangladesh from 10 August–3 September, 2011, to meet with project collaborators and government officials, as well as to deliver a series of seminars on climate risk management and the impact of climate variability and climate change on water, health, energy and agriculture. Five seminars were conducted in the Philippines, Indonesia and Bangladesh. In total over 150 people from various government agencies, universities and the public attended these seminars.

Following in-country visits, two workshops were conducted for participants from Indonesia, Philippines and Bangladesh. From each country one participant was selected from a climate discipline and one or two from a resource-policy sector. The first workshop was held from 10-13 January, 2012, in Kuala Lumpur, Malaysia with nine collaborators attending the four day workshop. Training was provided in climate science; data homogeneity testing; data patching techniques; validation techniques; forecast skill assessment, climate risk management and hands-on training in SCOPIC and FLOWCAST. A brief description of the software is provided in Section 2.3.

An outline of the climate validation process with examples from a recently completed study in the Pacific was presented and participants used the Pacific approach to assess the impact of ENSO on rainfall variability in their respective countries. A spreadsheet to assess the impact of ENSO on the onset and duration of monsoon with relevant training and examples was given to participants.

The second workshop was held from 6-9 January, 2014, in Lombok, Indonesia. The gap between the two workshops provided the participants the opportunity to obtain additional data sets and learn more about the operation of the software. All participants have received an unrestricted copy of FLOWCAST software which they can use for further training and research. A total of 19 people including local staff from BPTP, UNRAM and BMKG in Indonesia attended the second workshop. This report is a summary of the analysis and results from the two workshops compiled by a lead author(s) from each country. A brief description of climate concepts, statistical analysis and methodology used in the validation study is presented below. Further details are provided in Appendix I.

2.1 Background to Seasonal Climate Forecasting

Seasonal rainfall in the SW-Pacific and SE-Asia is largely driven by the processes of the El Niño Southern Oscillation (ENSO), the Inter-decadal Pacific Oscillation (IPO), the Inter-tropical Convergence Zone (ITCZ), and the Indian Ocean dipole (IOD). Of particular interest is the ENSO phenomenon, which provides the basis for seasonal prediction of rainfall using statistical methods employing atmospheric (SOI) and sea surface temperature (SST) data as proxies for ENSO.

Seasonal Climate Forecasting models fall into two broad categories with regard to the degree to which the models consider physical processes (*empirical* and *dynamical* models). *Empirical models* uses a simple framework to correlate predictor and predictand variables using past observed relationships (e.g. sea surface temperature and rainfall). On the other hand *dynamical models* explicitly stipulate the relationships between climate components and processes in such a way that the model quantitatively describes energy fluxes, mass and momentum. SCOPIC and FLOWCAST uses the *empirical* or "statistical" approach to generate climate forecasts.

Common techniques used in empirical models include; correlation and regression analysis, principal component analysis, cluster analysis, discriminant analysis, analogue or "stratification" method and time series analysis. Discriminant analysis, the methodology incorporated in SCOPIC and FLOWCAST classifies a set of observations into predefined classes to calculate probabilities for these classes (e.g. probability of rainfall terciles for a particular predictor condition).

The predictor time-series used in this study include the Southern Oscillation Index (SOI); Niño 3.4 sea surface temperature anomalies, and EOF of sea surface temperature anomalies derived from a principal component analysis (Drowdowsky and Chambers 1998). A brief descriptions of these predictors are given below.

2.1.1 Southern Oscillation Index

A common measure of ENSO is the Southern Oscillation Index. The index is the difference in surface atmospheric pressure between Tahiti (17° S, 150° W) and Darwin (12° S, 131° E), standardized to a mean of zero and a standard deviation of 1. The score is scaled by a factor of 10. For example, a monthly average SOI value of -10 means the SOI is one standard deviation on the negative side of the long-term mean for that month. A negative value of the SOI suggests higher atmospheric pressure at Darwin compared to Tahiti and often suggests lower than average rainfall over most of eastern Australia, Indonesia and parts of the SE-Asia. Conversely, a positive value of SOI suggests a low-pressure system over Darwin and higher than average rainfall in these region. Monthly indices of SOI from 1876-2014 were used in the analysis (www.bom.gov.au/climate/current/SOIValues.txt)

2.1.2 Sea Surface Temperature Anomalies

Sea Surface Temperature Anomalies (deviation from the long term mean) in tropical Pacific Ocean are important indicators of *El Niño* and *La Niña* conditions. The most common regions are the Niño 1-4 regions (Figure 1):

- Niño 1+2 (0-10S, 80-90W). The region that typically warms first when an *El Niño* event develops.
- Niño 3 (5S-5N; 150W-90W). The region of the tropical Pacific that has the largest variability in sea-surface temperature on *El Niño* time scales.
- Niño 3.4 (5S-5N; 170W-120W). The region that has large variability on *El Niño* time-scales, and that is closer (than Niño 3) to the region where changes in local sea-surface temperature are important for shifting the large region of rainfall typically located in the far western Pacific.
- Niño 4 (5S-5N: 160E-150W). In this region changes of sea-surface temperature exceeding a threshold of 27.5C, are thought to be an important stage in producing rainfall in the western-Pacific.

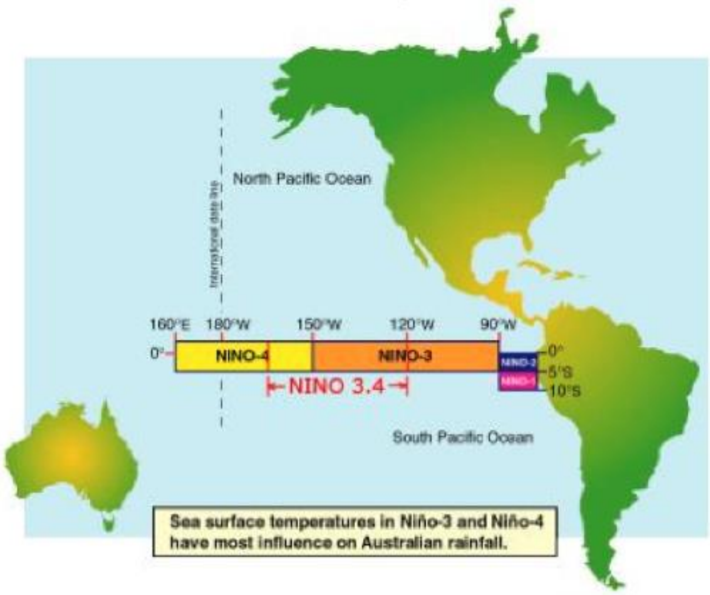


Figure 1. The NINO regions used in the analysis

Niño 3.4 (the region spanning part of Niño 3 and 4) is generally considered a key indicator of rainfall variability in western Pacific, affecting the general circulation of the atmosphere and having a wider influence on the climate of the region. Time series of Niño 3.4 (1982-2014) was used as a predictor in this study.

2.1.3 Sea surface temperature anomaly (SSTa) EOF's

Drosdowsky and Chambers (1998) examining SST predictor data using rotated principal components (EOF's) identified 12 principal components in the Pacific and Indian Oceans that explains about 46% of the total field variance (Figure 2). The first two of these components representing temperature anomalies in the Central Eastern Pacific Ocean (SST 1) and Western Indian Ocean (SST 2) have been used as predictors in generating the outlooks for Australian rainfall and temperature forecasts. Several other EOF's (e.g. 9, 11) have some influence on the rainfall variability in some of the western Pacific countries, but their impact in SE-Asia has not been examined. In this study we examined a time series of SST1, SST2, SST9 and SST11 (1949-2014) as predictors of rainfall. Those results that were found not to be significant are not shown in this report.

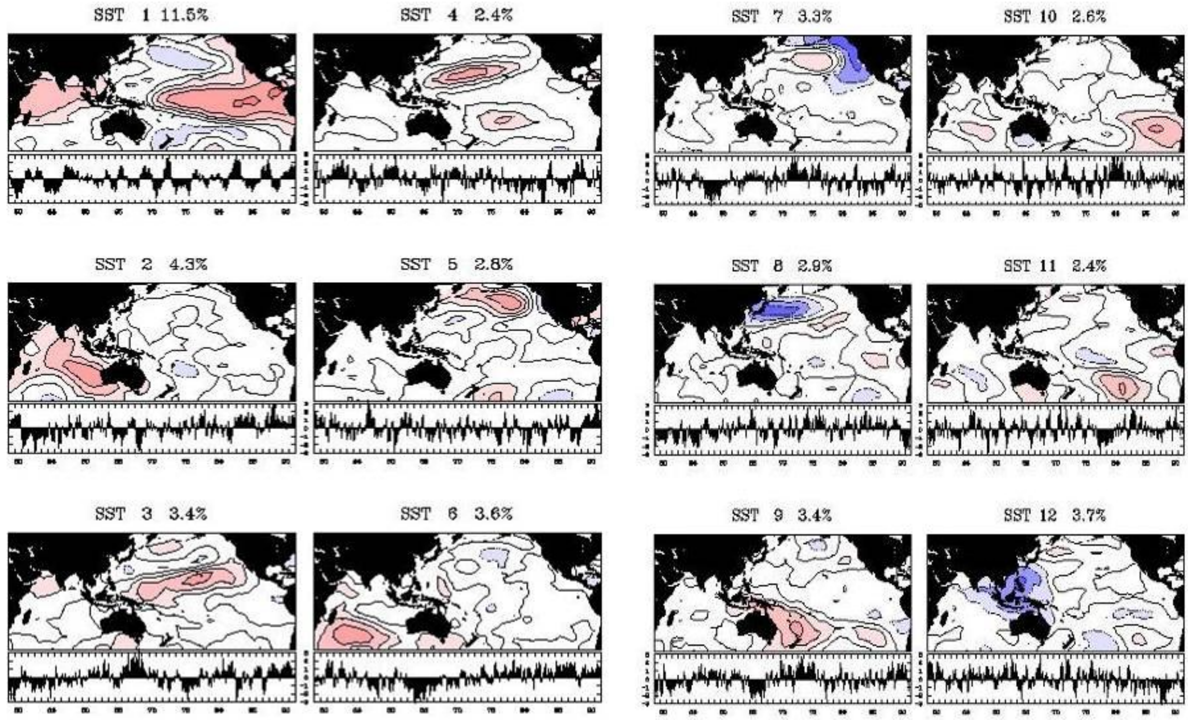


Figure 2. First twelve principal components of sea surface temperature anomalies in the Pacific and Indian Oceans. (http://www.bom.gov.au/bmrc/clfor/cfstaff/wld/RESREP65/rr65.htm#PCA_SST)

2.2 Skill Testing

Skill testing is used to test the "reliability" of forecast systems, based on past performance or trends. Skill tests are usually either regression-based or hind-cast based. Regression-based skill analyses use statistical measures (such as correlation, or non-parametric statistics) to evaluate predictor-predictand relationships. Hind-cast based methods evaluate predictions of past events (hind-casts) against known outcomes using a range of accumulated scoring systems.

An understanding of the "nature" of the forecast-skill is necessary to maximize the effectiveness of the forecasts in decision-making and communication. Analysis typically involves testing different predictors, locations, periods of the year, lead-times and season lengths.

Specifically, objectives of skill testing are to;

- identify which predictors are most suitable for developing seasonal climate outlooks in the study area;
- determine the periods of the year where forecasting skill exists, and those which are not associated with skill;
- determine the range of lead-times where skill exists;
- determine the range of season lengths that can be forecast with adequate skill;
- study how geographical location affects forecasting skill over the study area; *and,*
- determine whether skill is real or artificial.

There are several methods available to evaluate or estimate forecast skill. We have used only two methods in this study. A combined regression and contingency table analysis was used to establish the type and strength of relationship between ENSO and seasonal rainfall. LEPS (Linear Error in Probability Space) scores were calculated to evaluate hind-cast performance using a cross validated approach.

2.2.1 Regression analysis and contingency tables

Scatterplots of predictor-predictand relationships can be used to simultaneously undertake regression analysis (calculating correlations and trends) and contingency table evaluation. Contingency tables (sometimes referred to as cross tabulations) are used to record the predictor-predictand relationship in the form of a frequency distribution in matrix format (Figure 3). The matrix is usually defined using "bins" created by fixed predictor and predictand tercile boundaries. Contingency tables with similar frequency values (counts) in each "bin" typically represent forecast systems with poor predictability. Contingency tables with "zero" or "near-zero" values on one set of matrix diagonals (offset of the "main" diagonal) typically represent systems with high predictability.

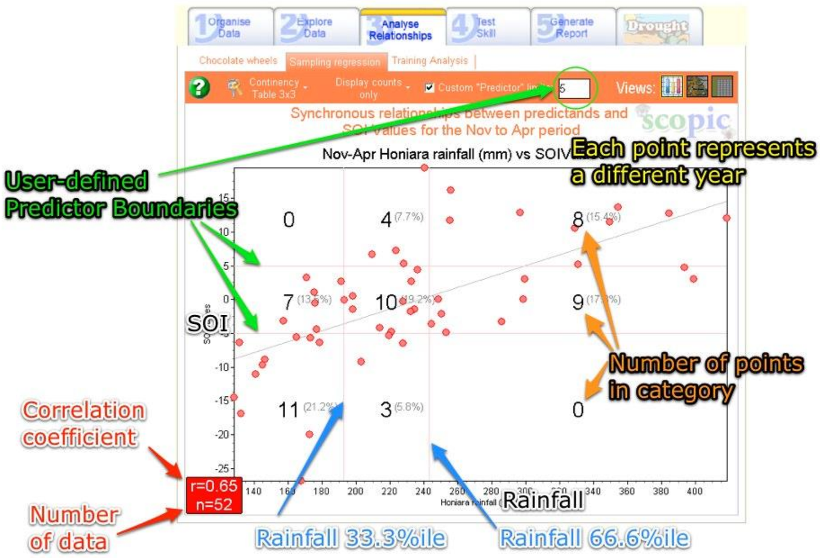


Figure 3. – Example of a contingency table analysis showing data counts in matrix elements. Regression analysis results are also included.

The objective of this analysis was to record the strength and types of relationships between ENSO and seasonal rainfall. That is, to determine what impact ENSO has on increasing or decreasing local seasonal rainfall. In this study, the analysis was performed for the six-monthly periods defined by "wet" and "dry" season to assess the strength of (concurrent) correlation between ENSO and rainfall in each country as well as three monthly rainfalls throughout the year.

2.2.2 Linear Error in Probability Space (LEPS)

The principal measure of forecast repeatability or skill used in this study is a cross-validated hind-cast LEPS skill score test. The skill of the forecast system is expressed in terms of the LEPS score that is described in detail by Potts et al. (1996). The score is derived from a general form $S = 1-|P_f - P_v|$, where P_f and P_v are the cumulative probability of the forecast (or hind-cast) and the verifying observation, so that the score measures the absolute error in terms of the cumulative probability of the forecast and observations. LEPS is analogous to a scoring system that rates the performance of a forecast by rewarding good predictions and penalising poor forecasts, assigning a weighting proportional to the degree of difficulty of a forecast. This is achieved through measurement of the forecast error in probability space as opposed to a measurement (linear) space. The score is normalized so that random forecasts score zero and perfect forecasts at the extremes of the distribution score higher than perfect forecasts in the middle of the distribution. The scores are also scaled so that they decrease uniformly with increasing separation between the forecast and verifying observation. The rationale for this normalization and scaling is discussed in detail by Potts et al. (1996).

SCOPIC and **FLOWCAST** generates "Skill Tables" of LEPS scores for a range of forecast periods and lead-times (Figure 4). The table represents the LEPS results (expressed as a percentage) for 108 separate "hind-cast" analyses (12 periods by 9 lead times). These results are "cross-validated" meaning that the model is trained with all the data except for any from the forecast year, so as not to bias the results. The forecast period is represented on the x-axis; 12 forecast periods (JFM, FMA, MAM,.., OND) with the 9 lead-time (0,1,2,…,8 months) on the y-axis. A lead time of 0 implies a forecast issued just prior to an event while a lead of time 6 implies forecasting an event 6 months ahead of time. The skill score results are assigned colours relative to the magnitude of each score: a blue square denotes forecasting skill greater than climatology (chance); a red square denotes forecasting skill worse than climatology; while a white square denotes skill the same as climatology.

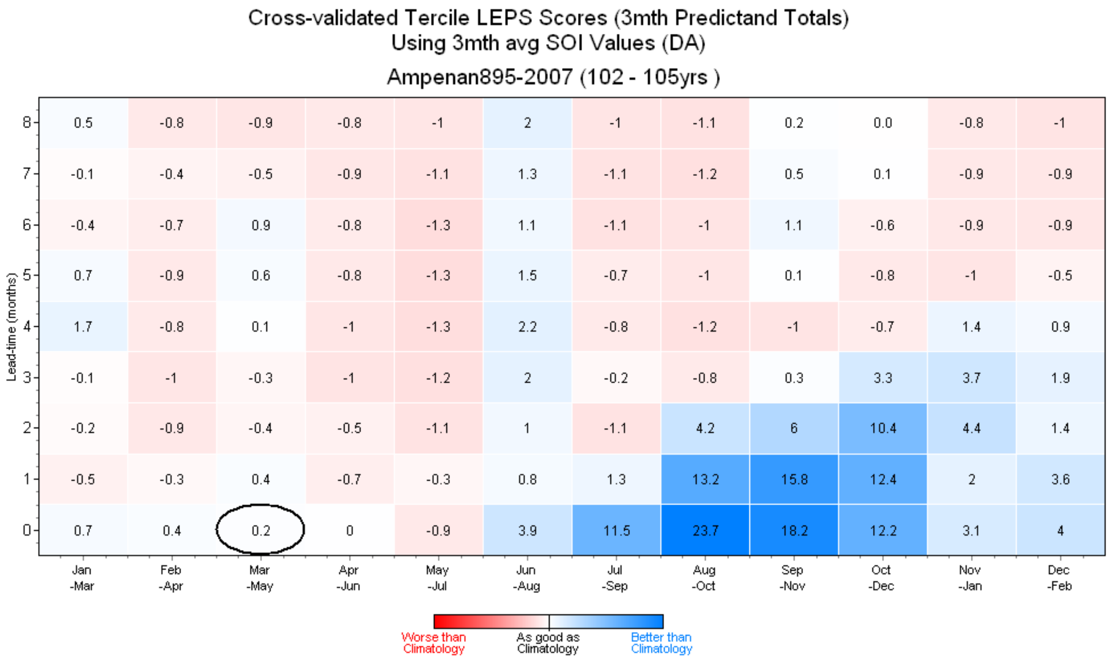


Figure 4. - Skill Map of cross-validated LEPS skill scores showing periods of high skill in blue.

The range of possible LEPS skill scores is from -100% to 100%. In practice, a score of 100% would never be achieved. For this to occur, the "hindcast" analysis would have to be correct every year in the first or third category (tercile forecast) to achieve the maximum reward weighting. Typically LEPS skill score values range non-linearly from -30% to 40%, but this can be influenced by the length of record (LEPS skill score for a 100 year analysis can be about half that of a 50 years analysis), the forecast methodology used (stratification or discriminant analysis), and characteristics of the methodology such as number of phases (for stratification methodology) or number of predictor elements. For this reason, it can be difficult to directly compare LEPS scores across different forecast systems and location. However, individual LEPS skill scores across the table can usually be compared directly with each other and several observations can be made from the resulting patterns:

1. LEPS skill scores generally decrease with increasing lead-time
2. Blocks of “skill” and “no-skill” tend to group together around particular periods of the year. From this, we can determine periods when forecasting is more reliable.

2.3 SCOPIC and FlowCast SCF software

SCOPIC and FLOWCAST seasonal climate forecasting software was developed as an education and training tool for climate services staff in the Pacific and SE-Asia as well as for analysing and generating climate forecasts. Although the two software share the same functionality and methodologies, SCOPIC has a main focus as a training tool whereas FLOWCAST was designed as a research tool with GIS capability. SCOPIC was used in the first year of the project and FLOWCAST for the remainder. Both software employ the discriminant analysis methodology to produce probabilistic forecasts of rainfall and other hydro-climatic variables as well as a range of skill tests including LEPS scores. A sample output of SCOPIC and FLOWCAST is shown in Figure 5.

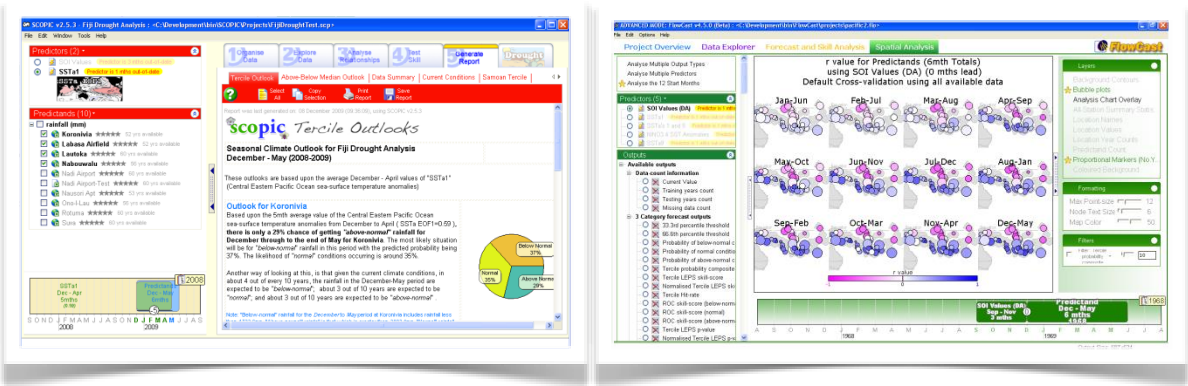
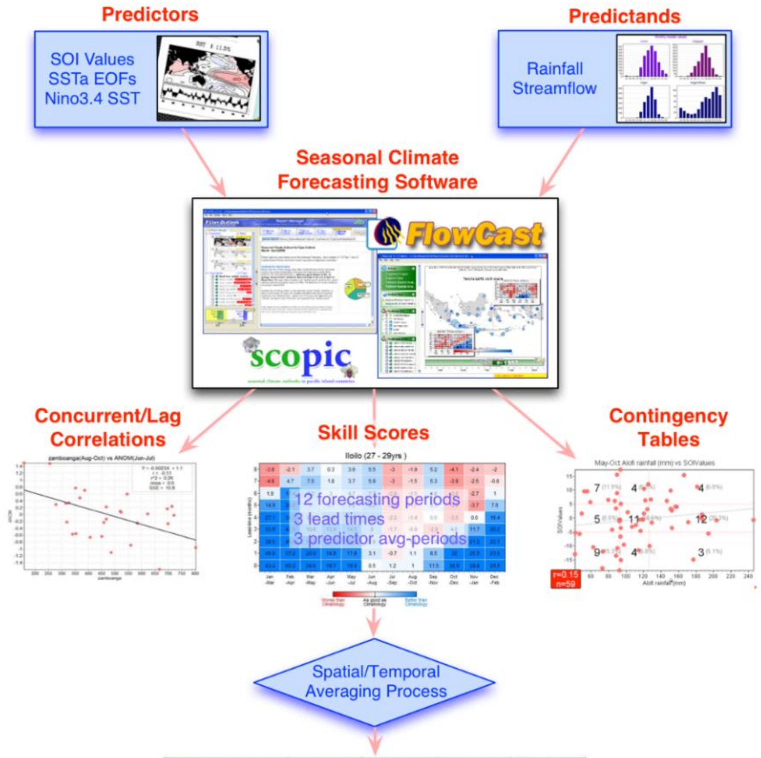


Figure 5. Screenshots of (a) SCOPIC and (b) FlowCast software packages for seasonal climate forecasting and analysis.

3.0 Study Detail

The process used for the climate validations study is shown in Figure 6. A brief descript of each of the component follows;



Climate Region	NINO 3.4	SOI	SST1	SST1&2
Climate Type 1	7.22%	3.46%	1.49%	1.17%
Climate Type 2	16.17%	6.67%	4.18%	6.35%
Climate Type 3	18.77%	10.99%	6.23%	6.56%
Climate Type 4	14.97%	9.33%	6.27%	6.68%
Angat Dam Inflow	14.03%	15.16%	9.73%	9.51%
Angat Rainfall	9.33%	6.09%	3.02%	4.30%

Summary of Average Skill Scores for each Predictor

Figure 6. Flowchart describing the process used in the validation study.

3.1 Data collection and interpretation

Monthly rainfall records covering the major climate regions for each country were collected by country partners (see individual country reports). In the case of Angat Dam in the Philippines stream flow data was also used in the analysis. For the analysis of the onset of monsoon, daily rainfall data (>30 years) was used for selected stations. A spreadsheet was developed to examine the effect of ENSO (El Niño and La Niña) on the onset and duration of Monsoon. All data were quality checked using the “Explore Data” feature in SCOPIC to assess the data record length, gaps and significant outliers. Data from neighboring stations were used to patch missing values using a weighted average triangulation method.

Distribution of average monthly rainfall for each station was used to define six months of “wet” and “dry” periods for each country. The wet and dry period rainfall as well as three monthly rainfall (JFM, AMJ, JAS…OND) were used to conduct synchronous correlation and contingency table analysis between ENSO based predictors and rainfall. Synchronous relationship analysis was conducted using the SCOPIC “Analyse Relationship/ Regression Analysis” feature. Both the trend in regression analysis (positive or negative) between each climate driver (SOI, SST1 and STT2, Niño 3.4, SST9 and SST11) and rainfall/stream flow. Correlation values was recorded and for ease of interpretation, a star rating scale was adopted (1 star for each 0.1 of correlation), with 1 star representing poorly correlated and 5 stars or greater representing good correlation. Rating for all stations and predictors were then tabulated for comparative purposes and to provide an “estimate” of potential forecast skill.

3.2 Forecast Skill

As well as correlation analysis, assessment of forecasting skill was undertaken using the LEPS “Skill Test” function within SCOPIC. All analyses were conducted using tercile forecasts. Using rainfall/streamflow data for each country, a range of ENSO-based statistical forecast systems (Niño 3.4, SOI and SSTs) were tested for each station to calculate a LEPS score for;

- 12 starting periods throughout the year (JFM, FMA, MAM, ..OND)
- 3 lead times (0,1 & 2 months)
- 3 predictor –averaging period (1,2 & 3 month for SST based systems & 2,3 & 4 month SOI based systems)

Longer averaging period for SOI based predictor was used due to inherent volatility in SOI values from one month to next as compared to SST values. To enable a *crude* comparison between alternative ENSO-based systems, the arithmetic average for each county and each climate region was calculated. This average represents the results of 108 separate analyses (12 starting period, 3 lead times and 3 averaging period) as shown in Figure 7.

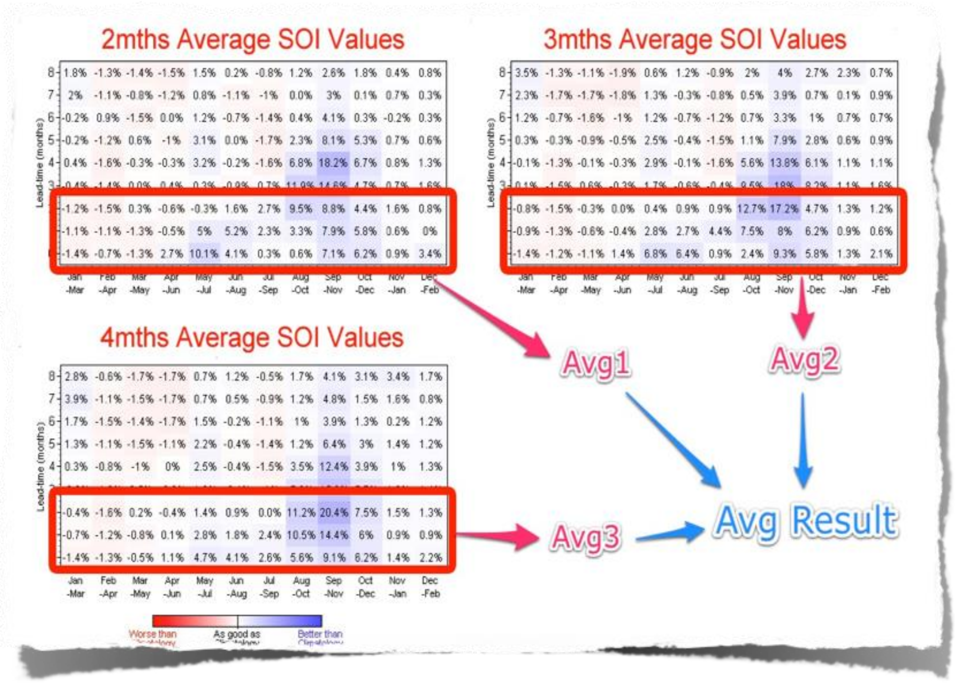


Figure 7. Averaging method used in LEPS skill test.

3.3 Onset of Monsoon

A spreadsheet was used to determine the effect of ENSO (El Niño and La Niña) on the *onset* and *duration* of monsoon in each country. The definition of the *onset* and *duration* of monsoon varied from country to country but was generally defined as the first (last) date where cumulative rainfall over a specified duration (days) exceeded (not exceeded) a certain threshold. For Each ENSO type, these parameters were calculated and the distribution of data plotted. Classification of El Niño and La Niña years were based on Allan 1988.

4.0 Country Reports

The sections below present the results of the study for each country.

4.1 Philippines

4.1.1 Overview of Climate

The Philippines is located in the tropical north western Pacific Ocean. The country is oriented from north to south between 4 to 23° north and 115 to 127° east. The Philippines is composed of about 7,000 islands. The eastern seaboard is the Pacific Ocean while the western seaboard is West Philippine Sea (Figure 8). Two major seasonal wind streams affect the climate of Philippines, the southwest monsoon which dominates during May to September and the northeast monsoon which dominates during November to April. The circulation of the north Pacific high pressure area drives the wind over the Philippines during the transition period (October to April) or when the major wind streams are weak. Ocean currents surrounding the Philippines are responsible for bringing warm currents which play a major role in the climate of the Philippines. The sea surface temperature of the pacific Niño region is known to influence the variability of the seasonal rainfall (National Oceanic and Atmospheric Administration, 2006).

The Philippines can be divided into 4 main climate types based on the seasonality of rainfall within each region (Figure 8). Type I is characterized by two pronounced seasons, dry from November to April and wet during the rest of the year. Peak rainfall occurs from June to September. Type II is characterized by no dry season and a very pronounced rainy period from December to February. Type III is characterized by no maximum rainfall period. This type resembles type I with a short dry season either during December to February or from March to May. Type IV resembles type II with evenly distributed rainfall throughout the year with no dry season. Monthly rainfall distribution for selected stations within each climate type as well as the distribution of monthly streamflow and rainfall for the nearby Science Garden rainfall station are shown in Figures 9 and 10.

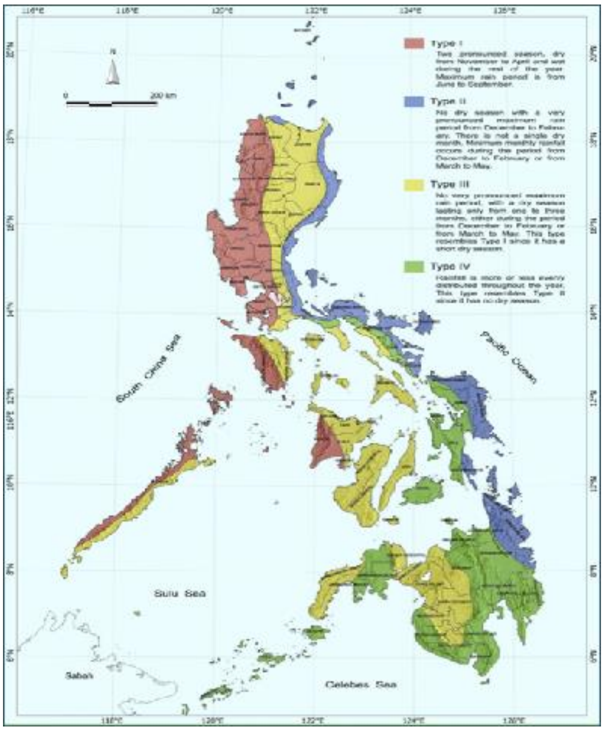


Figure 8. Climate map of the Philippines based on rainfall distribution for 45 synoptic and 66 climate stations (1951-2003). Source PAGASA

4.1.2 Data

Data from three rainfall stations in each of the four climate types were selected for the analyses. Record length and data quality (continuity) were major criteria in the selecting stations within each climate type. Data from the following rainfall stations were used: Type I (Coron, Dagupan, Vigan); Type II (Casiguran, Daet, Tacloban); Type III (Iloilo, Mactan, Zamboanga); and Type IV (Davao, General Santos, Tagbilaran). Relevant information for these stations are shown in Table 1. In addition to rainfall data, monthly inflow into Angat Dam and neighboring rainfall stations (Science Garden and Angat) were also used in the analysis to compare the relative forecasting skill of streamflow and rainfall.

Angat Dam is an important source of water supply for Manila and forecasting of water inflow is very important for the management of the water supply. Angat Dam is located in the province of Bulacan, approximately 58 km north-east of Manila. It is a multi-purpose dam supplying almost 97% of water supply in Metro Manila, generating power to feed the Luzon Grid and providing irrigation water for the province of Bulacan. The dam also serves as flood control facility. The Angat reservoir has a usable storage capacity of 850 million m^3 at an elevation of 217.4 MSL. Average annual inflows is 1,874 million m^3 from the Angat River and Umiray Trans-basin. The Angat catchment receives an average precipitation of 3,037 mm annually. The allocation of water in the Angat Reservoir is the responsibility of the National Water Resources Board (NWRB) and is largely governed by the Operational Rule of the Angat Reservoir agreed between the user agencies such as National Power Corporation (NPC) for power, Metropolitan Waterworks and Sewerage System (MWSS) for water supply and National Irrigation Administration (NIA) for irrigation in coordination with the NWRB.

Agriculture represented by NIA and NPC, has first priority for water use by virtue of being the first appropriators as provided by the Philippine Water Code. However, municipal demand represented by MWSS in times of drought may have the priority over other use, except for recurrent drought where alternative source for municipal purpose must be developed. Although NPC is the owner of Angat Dam, NPC seeks clearances from NWRB regarding water releases.

Table 1: Location of rainfall stations and data quality used in the analyses

Station	Start Date	End Date	Years Length	Quality %	Gaps	Latitude	Longitude
Vigan	Jan-51	Dec-11	60	100	0	17.567	120.383
Dagupan	Jan-51	Dec-11	60	99.7	2	16.05	120.333
Coron	Jan-51	Dec-11	60	95.6	23	12	120.2
Tacloban	Jan-51	Dec-11	60	100	0	11.233	125.033
Daet	Jan-51	Dec-11	60	99.5	3	14.117	122.983
Casiguran	Jan-51	Sep-11	60	98.6	6	16.283	122.117
Iloilo	Jan-51	Aug-10	59	99.7	2	10.7	122.567
Mactan	Aug-72	Dec-11	39	99.6	2	10.3	123.967
Zamboanga	Feb-51	Dec-11	60	98.6	10	6.9	122.067
Tagbilaran	Jan-61	Dec-11	50	100	0	9.633	123.867
Davao	Jan-51	Dec-11	60	99.5	4	7.117	125.65
General Santos	Jan-51	Dec-11	60	96.6	12	6.117	125.183
Science Garden	Feb-61	Dec-11	50	97.5	4	14.65	121.05
Angat Watershed	Jan-62	Dec-99	37	97.4	8	16.417	120.6
Angat (Inflow)	Jan-68	Jul-13	45	100	0	16.417	120.6

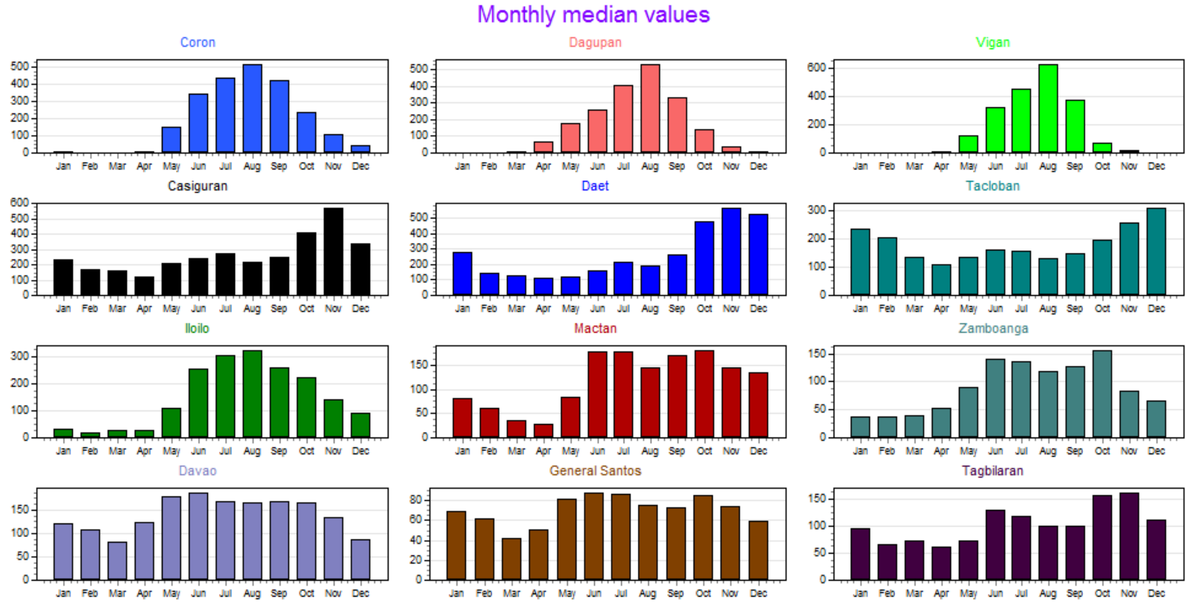


Figure 9. Distribution of rainfall for selected stations within each climate type. Type I-IV (top to bottom)

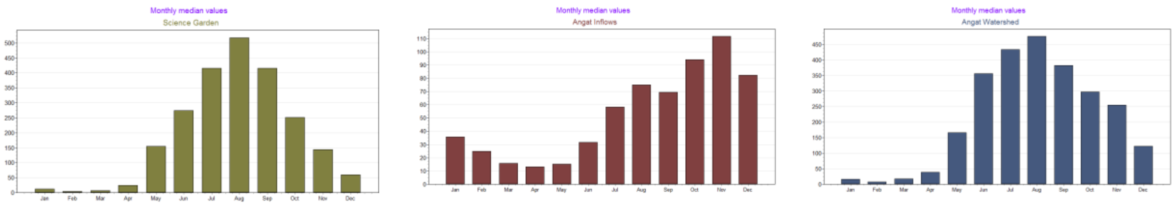


Figure 10. Distribution of rainfall and streamflow for Angat Dam and Science Garden rainfall (Angat catchment).

Based on the distribution of monthly rainfall, suitable periods were selected to define six months of "wet" and "dry" period for concurrent correlation analysis (Table 2). Three monthly periods were also defined for each climate type as shown in Table 3.

Table 2. Selection of 6 month "dry" and "wet" period for each climate type

Station	6months "WET season"	6 months "DRY season"
Type 1 Climate	May - October	November - April
Type 2 Climate	August - January	February– July
Type 3 Climate	June - November	October – May
Type 4 Climate	May - October	November – April
Angat Dam	May - October	November – April

Table 3. Quarterly periods used in the analysis for each climate type.

Station	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Type 1 Climate	Feb – Apr	May – Jul	Aug - Oct	Nov – Jan
Type 2 Climate	Jan – Mar	Apr – Jun	Jul – Sep	Oct – Dec
Type 3 Climate	Mar – May	Jun – Aug	Sep – Nov	Dec – Feb
Type 4 Climate	Feb - Apr	May – Jul	Aug – Oct	Nov – Jan
Angat Dam	Jan - Mar	Apr – Jun	Jul – Sep	Oct – Dec

4.1.3 Synchronous Correlation

Synchronous correlation between ENSO predictors and rainfall was conducted using the FLOWCAST "Analyse Relationship/ Regression Analysis" feature. Both the trend in regression (positive or negative) between climate driver (SOI, SSTa's and Niño 3.4) and monthly rainfall (or inflow) was recorded. Correlation coefficients for stations in each climate type was averaged as shown in Table 4. Individual station correlations are presented in Appendix A. The results for Philippines shows that for most stations, time of the year, and climate types, significant (positive) correlation exists between SOI and rainfall, and negative correlation exists between Niño 3.4 and rainfall. These results show higher rainfalls are expected in the Philippines during the cold phase of ENSO (positive SOI or negative Niño 3.4) and lower rainfall is expected during the warm phase of ENSO (El Niño).

Synchronous relationship between seasonal rainfall for both Niño 3.4 and SOI in the Philippines are strong to very strong in the "dry" season for all climate regions (with the exception of climate type I). In comparison, SSTs (1, 2, 9 and 11) did not have the same level of strength in correlation with "dry" season rainfall, with only a strong to very strong relationship existing for climate types 3 and 4. For the “wet” season a strong to very strong relationship was found for only climate type 2 with Niño3.4 and SOI and again a weaker relationship with SSTs.

The same level of correlation and trend found across the 6 month “wet” and “dry” seasons was also present in the seasonal quarters of the year. SST1 was the only EOF of those tested showing any real strength of correlation to rainfall, with moderate strength existing for seasonal quarter 1 and 4 for climate types 2, 3 and 4. The strength of correlation in the dry season as compared to the wet season was somewhat expected, as the variability of rainfall during the dry season is low and hence more predictable.

It is important to note that although Niño3.4 displays a stronger correlation than SOI, direct comparison cannot be made due to the limited availability of Niño3.4 data (1982-2013) compared with SOI data which dates back to 1876. The longest record used in the analyses was (26-30 years) in the case of Niño 3.4 and 40-60 years for all other predictors. It is also important to note that within each climate region, differences in strength of relationship do exist between stations/locations and the conclusion drawn above is based on the averaging of 3 stations in each climate region of which some have varying lengths of records.

For Angat Dam inflow and catchment rainfall (Science Garden), a strong to very strong synchronous correlation exists during for both Niño3.4 and SOI particularly from January to June.

4.13 LEPS Skill score

As well as correlation analysis, assessment of forecasting skill was undertaken using the LEPS “Skill Test” function within FLOWCAST software. Using rainfall/streamflow data for the Philippines, a range of ENSO predictors (Niño 3.4, SOI and SSTs) were tested for each station to calculate a LEPS score for;

- 12 starting periods throughout the year (JFM, FMA, MAM, ..OND)
- 3 lead times (0,1 & 2 months)
- 3 predictor –averaging period (1,2 & 3 month for SST based systems & 2,3 & 4 month SOI based systems)

An example of cross validated LEPS skill score for 3 month rainfall using a 2 months average predictor period (Niño3.4) for four rainfall stations in the Philippines as well as for Angat Dam inflow and rainfall (Science Garden) are shown in Figures 10 and 11 respectively.

Table 4. Summary of synchronous correlation between Niño 3.4 and rainfall for different climate types in the Philippines.

6m "Wet" Season- NINO 3.4	Relationship	Correlation	6m "Wet" Season Rating
Type 1- Rainfall (May - October)	+ive	0.04	★
Type 2- Rainfall (August - January)	-ive	-0.60	★★★★★★
Type 3- Rainfall June - November)	-ive	-0.40	★★★★
Type 4- Rainfall (May - October)	-ive	-0.29	★★
Angat-Rainfall (May - October)	-ive	-0.28	★★
Angat- Inflow (May - October	-ive	-0.24	★★
6m "Dry" Season- NINO 3.4	**Relationship**	**Correlation**	**6m "Dry" Season Rating**
Type 1- Rainfall (November - April)	-ive	-0.47	★★★★
Type 2- Rainfall (February - July)	-ive	-0.61	★★★★★★
Type 3- Rainfall (October - May)	-ive	-0.71	★★★★★★★
Type 4- Rainfall (November - April	-ive	-0.80	★★★★★★★★
Angat-Rainfall (November - April)	-ive	-0.53	★★★★★
Angat- Inflow (November - April)	-ive	-0.40	★★★★
1st Quarter#- NINO 3.4	**Relationship**	**Correlation**	**!st Quarter Rating**
Type 1- Rainfall (February - April)	-ive	-0.30	★★★
Type 2- Rainfall (January - March)	-ive	-0.70	★★★★★★★
Type 3- Rainfall (March - May)	-ive	-0.63	★★★★★★
Type 4- Rainfall (February - April)	-ive	-0.75	★★★★★★★
Angat-Rainfall (January - March)	-ive	-0.61	★★★★★★
Angat- Inflow (January - March)	-ive	-0.50	★★★★★
2nd Quarter#- NINO 3.4	**Relationship**	**Correlation**	**2nd Quarter Rating**
Type 1- Rainfall (May - July)	-ive	-0.09	
Type 2- Rainfall (April - June)	-ive	-0.55	★★★★★
Type 3- Rainfall (June - August)	+ive	0.02	
Type 4- Rainfall (May - July)	-ive	-0.10	★
Angat-Rainfall (April - June)	-ive	-0.62	★★★★★★
Angat- Inflow (April - June)	-ive	-0.60	★★★★★★
3rd Quarter#- NINO 3.4	**Relationship**	**Correlation**	**3rd Quarter Rating**
Type 1- Rainfall (August- October)	-ive	-0.03	
Type 2- Rainfall (July - September)	+ive	0.04	
Type 3- Rainfall (September - November)	-ive	-0.56	★★★★★
Type 4- Rainfall (August - October)	-ive	-0.23	★★
Angat-Rainfall (July - September)	+ive	0.11	★
Angat- Inflow (July - October)	+ive	0.06	
4th Quarter#- NINO 3.4	**Relationship**	**Correlation**	**4th Quarter Rating**
Type 1- Rainfall (November - January)	-ive	-0.39	★★★
Type 2- Rainfall (October - December)	-ive	-0.55	★★★★★
Type 3- Rainfall (December - February)	-ive	-0.65	★★★★★★
Type 4- Rainfall November - January)	-ive	-0.58	★★★★★
Angat-Rainfall (October - December)	-ive	-0.58	★★★★★
Angat- Inflow (October - December)	-ive	-0.41	★★★★

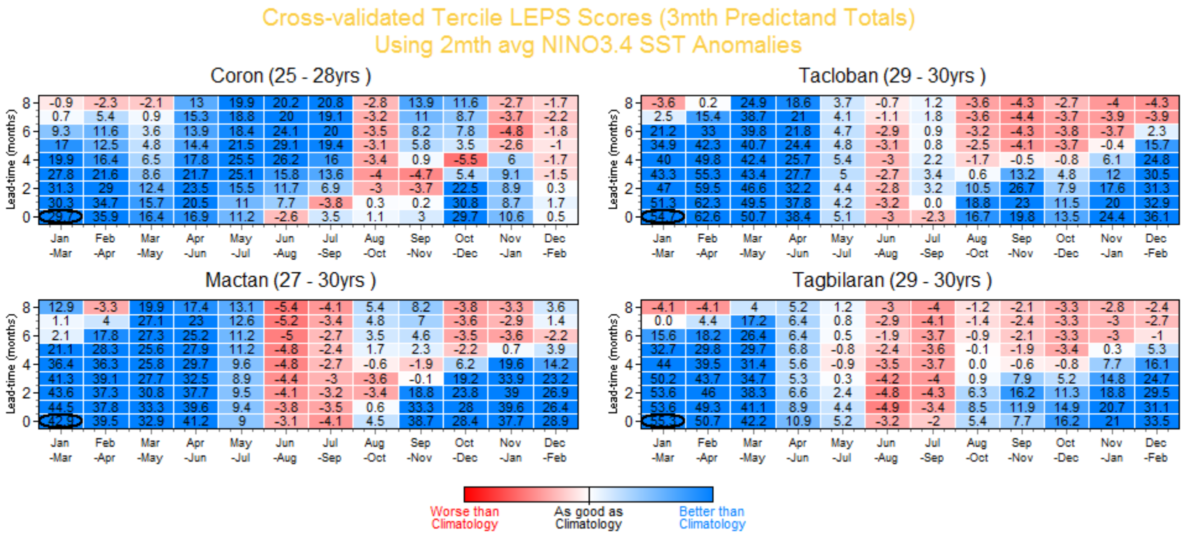


Figure 10. Cross validated LEPS skill score using a 2 month predictor averaging period (Niño3.4) and 3 month predictand (rainfall) for selected rainfall stations in Philippines.

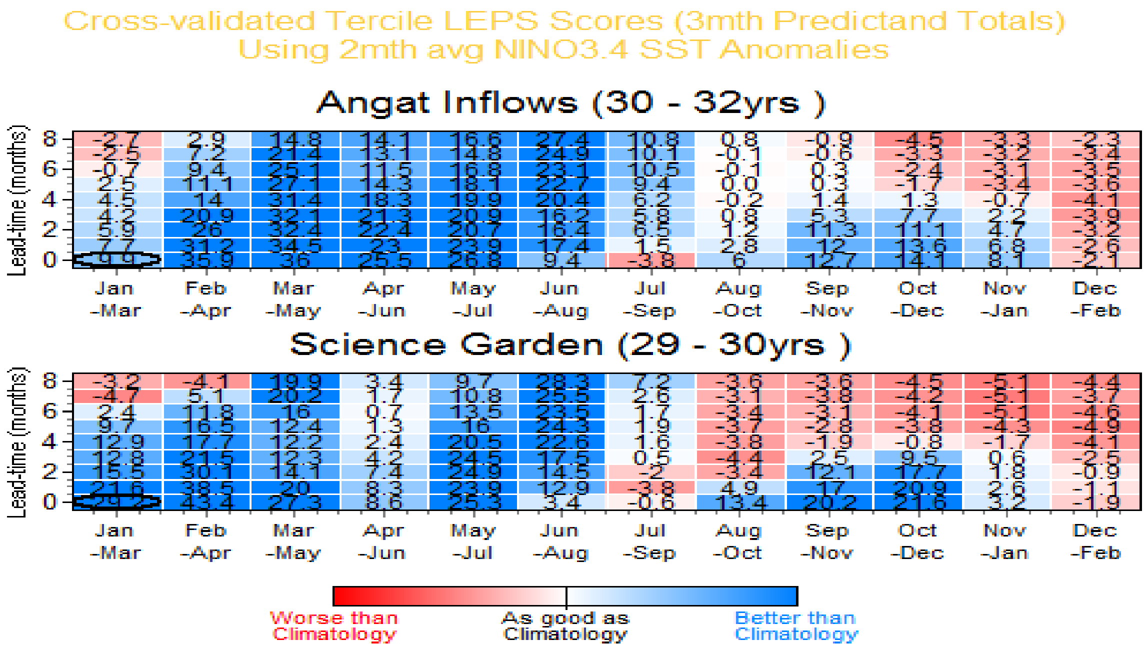


Figure 11. Cross validated LEPS skill score using a 2 month predictor averaging period (Niño3.4) and 3 month predictand (inflow/rainfall) for Angat Dam and neighbouring Science Garden rainfall station.

These results clearly show periods of the year where forecasts have significant skill (dark blue) and period where there is no skill (red shading) and the lead time (months) when reliable forecasts can be made. The results also show that the period of very low skill usually coincide with the peak of the rainfall season when variability is very high.

To enable a *crude* comparison between alternative ENSO-based systems, the arithmetic average of LEPS scores for each rainfall station, is shown Table 5. This average represents the results of 108 separate analyses (12 starting period, 3 lead times and 3 averaging period). The overall average for each climate type is shown in Table 6.

Table 5: Summary LEPS score for each climate type and ENSO predictor

Station	NINO 3.4	SOI	SST1	SST1&2
Coron_Palawan	12.98%	5.09%	2.49%	2.65%
Dagupan City_Pangasinan	6.79%	3.89%	0.85%	0.79%
Vigan,Slocos Sur	1.90%	1.39%	1.13%	0.06%
Casiguran_Quezon	6.63%	4.22%	0.56%	1.15%
Daet_Camarines Norte	16.78%	7.63%	5.52%	5.49%
Tacloban City_Leyte	25.11%	8.16%	6.46%	12.41%
Iloilo City_iloilo	21.14%	6.10%	5.32%	4.29%
Mactan International Airport	23.19%	14.33%	8.81%	8.67%
Zamboanga_Zamboanga del sur	11.97%	12.55%	4.56%	6.72%
Davao City_Davao Del Sur	7.14%	4.65%	1.67%	1.30%
General Santos_South Cotabato	18.46%	9.16%	7.38%	8.79%
Tagbilaran City_Bohol	19.31%	14.18%	9.75%	9.94%
Angat Dam (Inflow)	5.06%	3.68%	3.60%	4.88%
Science Garden	13.60%	8.49%	2.43%	3.71%

Table 6: Summary LEPS score for each climate type and ENSO predictor

Climate Region- Philippines	NINO 3.4	SOI	SST1	SST1&2
Climate Type 1	7.22%	3.46%	1.49%	1.17%
Climate Type 2	16.17%	6.67%	4.18%	6.35%
Climate Type 3	18.77%	10.99%	6.23%	6.56%
Climate Type 4	14.97%	9.33%	6.27%	6.68%
Angat Dam Inflow	14.03%	15.16%	9.73%	9.51%
Angat Rainfall	9.33%	6.09%	3.02%	4.30%

It is worth noting that the skill in forecasting stream-flow is higher than that of rainfall for the same location (Angat inflow and Science Garden rainfall) as reflected in higher LEPS scores for all predictors used (Table 6). Streamflow has an integrating effect (in time and space) of regional climate patterns and is a better indicator of ENSO response than rainfall (Dutta et al. 2006).

The increasing water demand in Metro Manila and the lack of additional sources of water creates an urgent need to optimize the operations of the Angat Reservoir, and rationalize the water allocation to sectors served by the reservoir. The results found in this study and the use of the FLOWCAST software can assist in optimum water allocation and enhance safeguards against shortages of water supply (particularly during El Niño) and risk of over tapping of the dam.

4.1.4 Onset and Duration of the Monsoon

A customized spreadsheet was developed to enable an assessment of the effect of ENSO on the onset and duration of monsoon. Monsoon onset was defined as the first date (after April 1) where cumulative rainfall over 3 days exceeded 25 mm. End of monsoon was defined as the first day (after the start of monsoon) where cumulative rainfall over three successive days was less than 25 mm. After calculating the start and end of monsoon for all years of data, the distribution of onset and duration was plotted for all years as well as the El Niño and La Niña subsets, as shown in Figure 12. Classification of El Niño and La Niña years were based on Allan 1988.

The results clearly shows that ENSO has a significant effect on the onset and duration of monsoon particularly for climate type III (Zamboanga). On average, the onset of monsoon is delayed by up to 38 days in an El Niño years and is up to 35 days shorter duration than during La Niña years. Results for climate type II (Casiguran) and type IV (Tagbilaran) show a delay of approximately 12 days during an El Niño year and shorter duration of about 17 days.

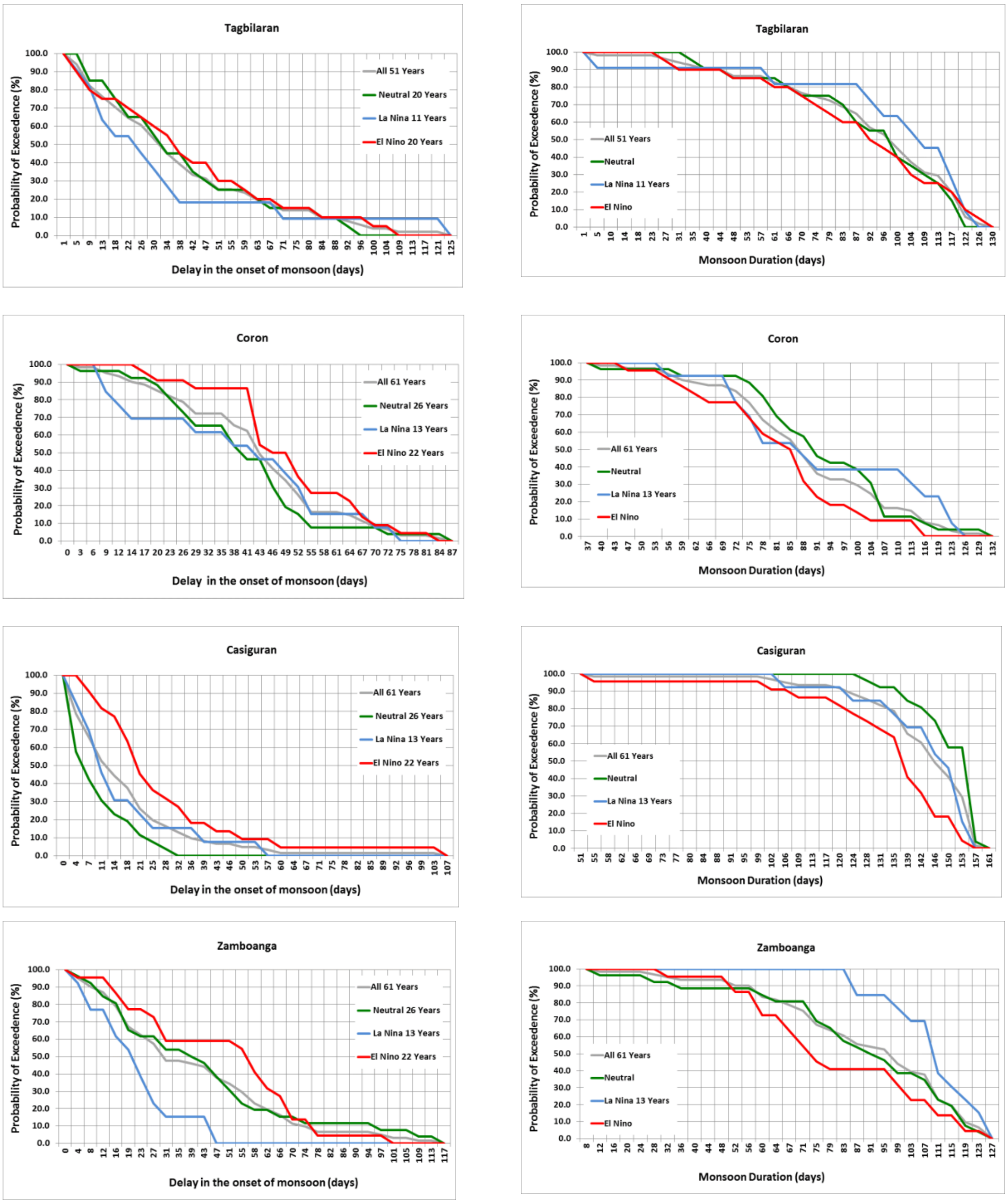


Figure 12. Onset and duration in monsoon for a selected stations located in each of the four climate regions (I - IV, top to bottom respectively) in the Philippines. Monsoon onset defined as 25mm rainfall over 3 consecutive days and monsoon duration defined as monsoon onset to monsoon end (less than 25mm rainfall over 3 consecutive days).

4.2 Bangladesh

4.2.1 Overview of Climate

Bangladesh has a sub-tropical monsoon climate characterized by large variation in seasonal rainfall. The climate of this country can be described by the following four seasons: (a) winter or northeast monsoon (December- February); (b) summer or pre-monsoon (March- May); (c) southwest monsoon or monsoon (June-September); and, (d) autumn or post-monsoon (October-November). Winter season is characterized by very low rainfall over the country with about 2% of annual rainfall occurring in this season. In the summer season inflow of moisture from the Bay of Bengal mixes with the westerly lows and gives rise to local thunderstorm in the late afternoon. These local severe storms are usually called nor'westers which is associated with heavy rainfall. In the pre-monsoon season, about 19% of total annual rainfalls occurs. Monsoon normally reaches the coastal districts of the country by the last week of May to first week of June and engulfs the whole country through June. Generally, heavy to very heavy rain with overcast skies characterize this season. More than 71 % of the total annual rainfall occurs in this season. In the post-monsoon season, rainfall decreases considerably and signals the start of the dry period. Only about 8% of yearly rainfall occurs in the post-monsoon season.

Seasonal climate forecasts with the lead time of one month or longer is essential for Bangladesh. The Bangladesh Meteorological Department (BMD) is responsible for providing weather forecast including seasonal forecast. But BMD cannot satisfy the users as long-term variability of climate is un-predictable most of the times. As a result, the losses due to weather and climate are still significant. A robust seasonal weather forecasting system is highly desirable for BMD and Bangladesh for the welfare of the Bangladesh nation. In this study, an attempt was made to determine the relationship between ENSO and rainfall variability in Bangladesh using the SCOPIC and Flowcast seasonal climate prediction software.

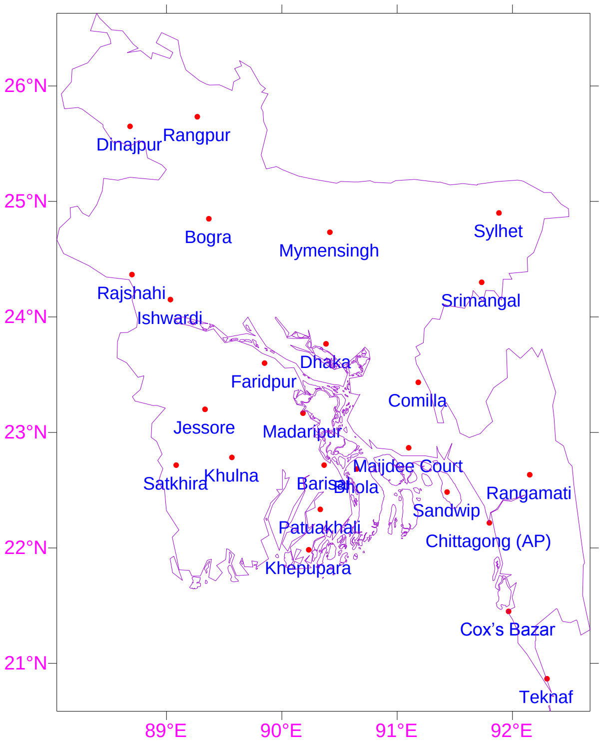


Figure 13. Locations of rainfall stations used in the study.

4.2.2 Data

The methodology used in this study is described in section 3. Monthly rainfall for 25 stations in Bangladesh (Figure 13) was used. The longest periods of data was from 1948 to 2013. However as some of the stations were established after 1948, data length ranged from 36 to 65 years with missing data particularly from 1948-1976 (Table 7).

Monthly rainfall distribution for selected stations are shown in Figures 14a and 14b. The highest rainfall occurs from (June-September) peaking in July. Lowest rainfalls occur during December-February winter season.

Table 7. Location of rainfall stations and data quality used in the analyses

Station	Start Date	End Date	Years Length	Quality %	Gaps	Latitude	Longitude
Barisal	Jan 1949	Dec 2013	64	95.90	9	22.72	90.37
Bhola	Apr 1966	Dec 2013	47	95.80	7	22.68	90.65
Bogra	Feb 1948	Dec 2013	65	97.60	10	24.85	89.37
Chittagong	Jan 1949	Dec 2013	64	98.20	11	22.22	91.80
Comilla	Jan 1948	Dec 2013	65	96.70	4	23.43	91.18
CoxsBazar	Jan 1948	Dec 2013	65	100.00	0	21.45	91.97
Dhaka	Jan 1953	Dec 2013	60	98.40	1	23.77	90.38
Dinajpur	Jan 1950	Dec 2013	63	86.30	5	25.65	88.68
Faridpur	Jan 1948	Dec 2013	65	100.00	0	23.60	89.85
Ishurdi	Apr 1961	Dec 2013	52	91.60	8	24.15	89.03
Jessore	Aug 1948	Dec 2013	65	99.90	1	23.20	89.33
Khepupara	Jan 1974	Dec 2013	39	98.50	5	21.98	90.23
Khulna	Jan 1948	Dec 2013	65	93.80	12	22.78	89.57
Madaripur	Jan 1977	Dec 2013	36	96.20	2	23.17	90.18
MaijdiCourt	Jan 1951	Dec 2013	62	95.80	4	22.87	91.10
Mymensingh	Jan 1948	Dec 2013	65	96.70	4	24.73	90.42
Patuakhali	Aug 1973	Dec 2013	40	92.80	5	22.33	90.33
Rajshahi	Jan 1964	Dec 2013	49	95.30	3	24.37	88.70
Rangamati	Jan 1957	Dec 2013	56	96.50	1	22.63	92.15
Rangpur	Jan 1954	Dec 2013	59	93.60	11	25.73	89.27
Sandwip	May 1966	Dec 2013	57	94.80	5	22.48	91.43
Satkhira	Jan 1948	Dec 2013	65	92.60	21	22.72	89.08
Srimongal	Jan 1948	Dec 2013	65	100.00	0	24.30	91.73
Teknaf	Jan 1977	Dec 2013	36	99.80	1	20.87	92.30

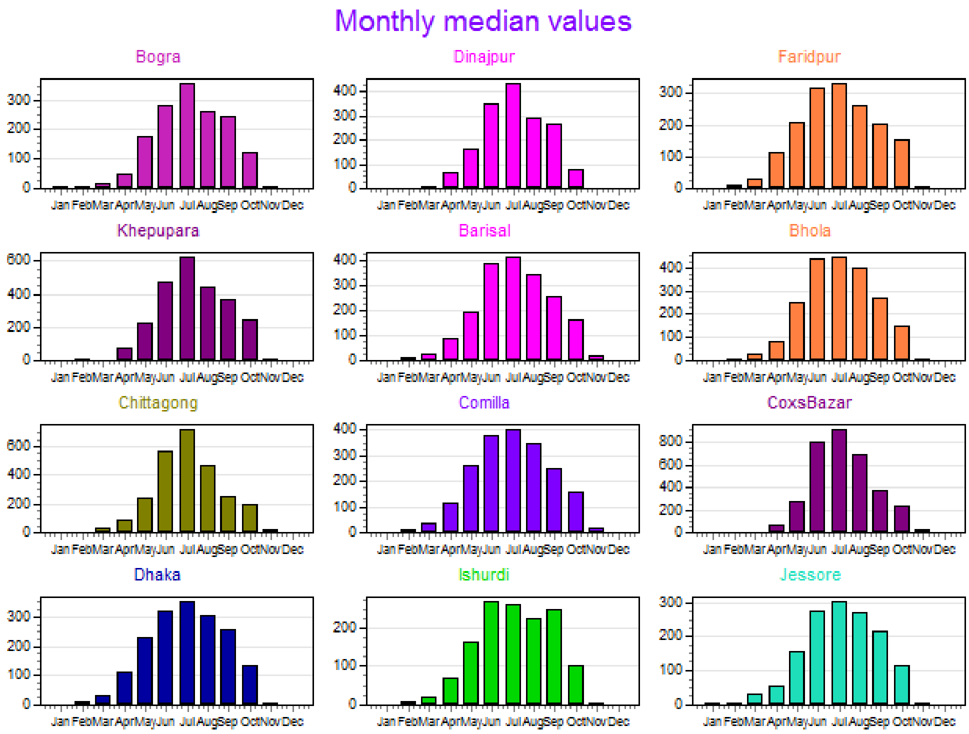


Figure 14a. Distribution of rainfall for selected stations across Bangladesh.

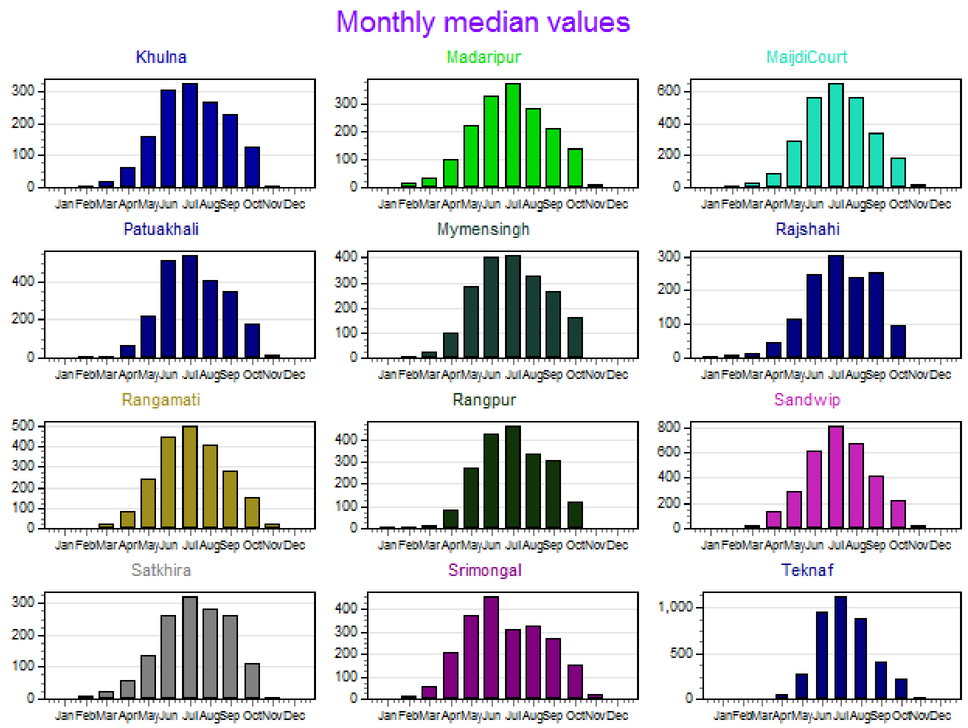


Figure 14b. Distribution of rainfall for selected stations across Bangladesh.

Based on the distribution of monthly rainfall for the selected stations, suitable periods were selected to define six months of “wet” and “dry” and four quarterly periods (winter, pre-monsoon, monsoon and post-monsoon) for concurrent correlation analysis (Table 8).

Table 8. Distribution of annual rainfall in Bangladesh

6months “WET season”	May - Oct
6 months “DRY season”	Nov - Apr
Winter	Dec – Feb
Pre-monsoon	Mar – May
Monsoon	Jun – Aug
Post-monsoon	Sep – Nov

4.2.3 Synchronous Correlation

Synchronous correlation analysis was carried out using the FLOWCAST “Analyse Relationship/ Regression Analysis” feature. The analysis was conducted between all 6 separate rainfall periods (Table 8) and Niño 3.4, SOI, SST1 and 2 predictors. An example of the correlation analysis for Niño 3.4 and 6 month rainfall during the “wet” period is given in Table 9. Average correlation results are given in Table 10. Full results are included in Appendix B.

The results for Bangladesh shows for most stations a nil to moderate (negative) correlation between Niño3.4 and rainfall during the wet season, and a low to moderate positive correlation between Niño 3.4 and rainfall during the dry season. Similar results were found between SOI and rainfall albeit with a negative correlation. No significant correlation was found between SSTa’s (1 and 2) and rainfall. The highest correlation was (r =0.52) found in the first quarter for all predictors. However, this period coincide with the dry season in Bangladesh and the strength of correlation is expected, as rainfall variability during the dry season is low and highly predictable. Of all the predictors tested, Niño3.4 had the strongest correlation for the first quarter rainfall. Although a causative relationship between ENSO and Bangladesh rainfall appears to exist, there is no significant or consistent relationship between ENSO and rainfall across Bangladesh (Appendix B).

Table 9 Synchronous correlation summary for Niño 3.4 and rainfall for selected stations

Station \ NINO 3.4	Relationship	Correlation	6m "WET" Season Rating
Barisal	-ive	-0.14	★
Bhola	-ive	-0.08	
Bogra	-ive	-0.36	★★★
Chittagong	-ive	-0.12	★
Comilla	-ive	-0.12	★★
CoxsBazar	-ive	-0.17	★
Dhaka	-ive	-0.11	★
Dinajpur	-ive	-0.02	
Faridpur	-ive	-0.13	★
Ishurdi	+ive	0.03	
Jessore	+ive	0.14	★
Khepupara	-ive	-0.37	★★★
Khulna	+ive	0.06	
Madaripur	+ive	0.03	
MaijdiCourt	-ive	-0.13	★
Mymensingh	-ive	-0.05	
Patuakhali	+ive	0.01	
Rajshahi	+ive	0.06	
Rangamati	-ive	-0.17	★
Rangpur	+ive	0.01	
Sandwip	-ive	-0.17	★
Satkhira	+ive	0.04	
Srimongal	-ive	-0.13	★
Teknaf	-ive	-0.17	★

Table 10 Average synchronous correlation summary for all stations analysed.

PREDICTOR	6m "WET" Season Rating	6m "DRY" Season Rating	1st Quarter (Dec - Feb)	2nd Quarter (Mar - May)	3rd Quarter (Jun - Aug)	4th Quarter (Sep - Nov)
NINO 3.4	-0.09	0.22	0.27	0.04	0.03	-0.06
SOI	0.05	-0.21	-0.19	-0.04	-0.05	0.13
SST1	-0.08	0.11	0.15	0.07	0.00	-0.07
SST2	0.03	-0.01	0.07	0.07	-0.05	-0.04
SST9	0.06	-0.06	-0.13	0.04	-0.08	0.19
SST11	0.00	0.01	0.06	0.04	-0.06	0.01

4.2.4 LEPS Skill Score

As well as correlation analysis, assessment of forecasting skill was undertaken using the LEPS "Skill Test" function within FLOWCAST software. Based on the geographical location of each station and the years of records available a revised list of 9 stations were selected across Bangladesh and a range of ENSO predictors (Niño 3.4, SOI and SSTs) were tested for each station to calculate a LEPS score for;

- 12 starting periods throughout the year (JFM, FMA, MAM, ..OND)
- 3 lead times (0,1 & 2 months)
- 3 predictor –averaging period (1,2 & 3 month for SST based systems & 2,3 & 4 month SOI based systems)

An example of cross validated LEPS skill score for four stations using 3 months average SOI for 12 starting period (JFM, FMA…DJF) is shown in Figure 15. Individual results are shown in Appendix B.

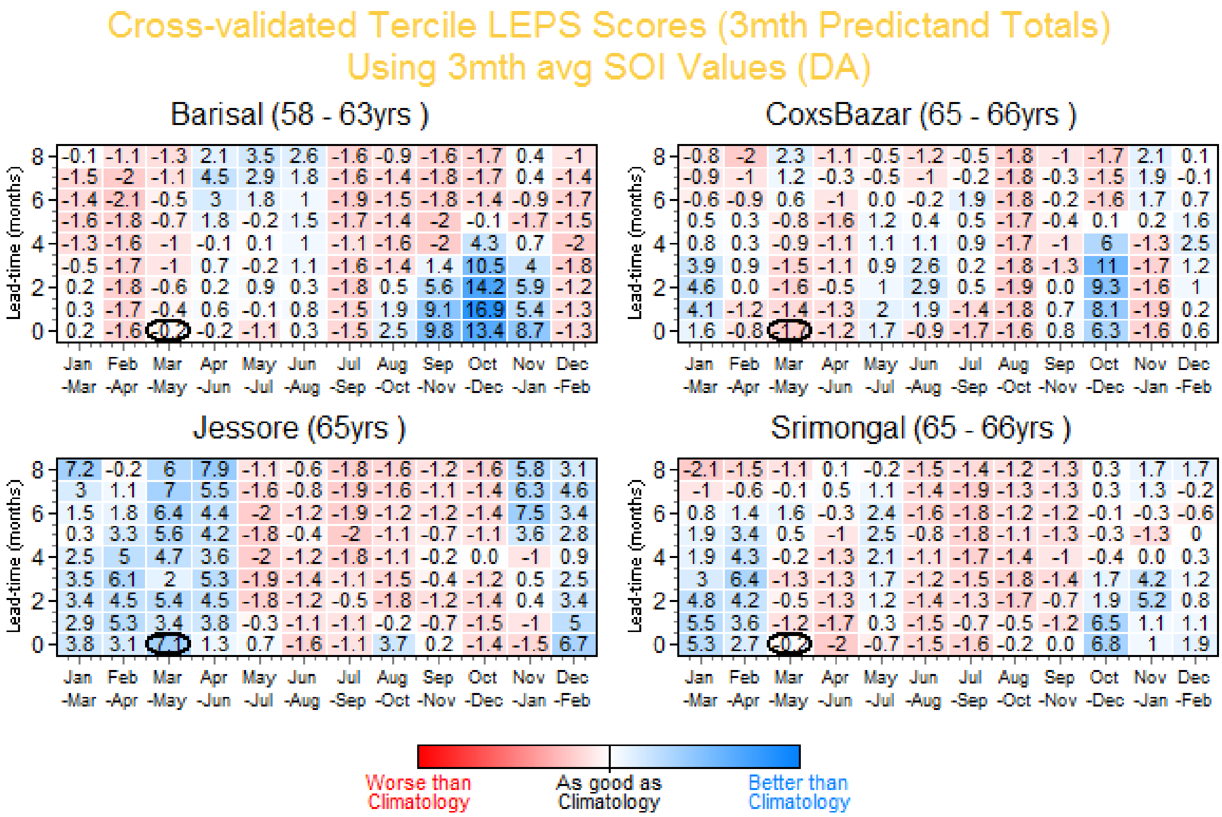


Figure 15. Cross validated LEPS skill score using a 3 month predictor averaging period (SOI) and 3 month predictand (rainfall) for selected rainfall stations in Bangladesh.

These results generally shows very low predictability across the year particularly during the wet months of May to September. To enable a *crude* comparison between alternative ENSO-based systems, the arithmetic average of LEPS for each rainfall station, is shown Table 11. This average represents the results of 108 separate analyses (12 starting period, 3 lead times and 3 averaging period. These results further confirm a lack of predictability of rainfall for all predictors tested.

Table 11: Summary LEPS score (%) for selected stations and ENSO predictor

Station	NINO 3.4	SOI	SST1	SST1&2
Barisal	0.73%	2.22%	-0.52%	-1.67%
Chittagong	0.21%	1.02%	0.42%	-0.30%
Comilla	-0.83%	2.54%	0.88%	2.85%
CoxsBazar	2.06%	0.60%	-0.34%	-0.98%
Dinajpur	-0.01%	1.07%	-0.09%	-0.35%
Faridpur	0.16%	1.01%	0.02%	-0.87%
Jessore	0.46%	1.34%	0.20%	-0.61%
Mymensingh	-0.26%	1.64%	1.09%	-0.04%
Srimongal	-0.16%	4.25%	-0.04%	1.09%

4.2.5 Onset and Duration of the Monsoon

A customized spreadsheet was developed to enable an assessment of the effect of ENSO on the onset and duration of monsoon. Monsoon onset was defined as the first date (after April 1) where cumulative rainfall over fifteen consecutive days exceeded 60 mm. End of monsoon was defined as the first day (after the start of monsoon) where cumulative rainfall over ten successive days was less than 30 mm. After calculating these parameters for all years of data at each location the distribution of onset and duration was plotted based for all years of data and then segregated to El Niño and La Niña subsets. The distribution of monsoon onset and duration for Cox's Bazar is shown in Figures 16 and 17 respectively. No clear distinction in terms of delay in the onset or the duration of the monsoon could be observed between El Niño or La Niña years. Given the low relationship and poor skill previously found from concurrent correlation analysis and LEPs skill testing, this outcome was expected.

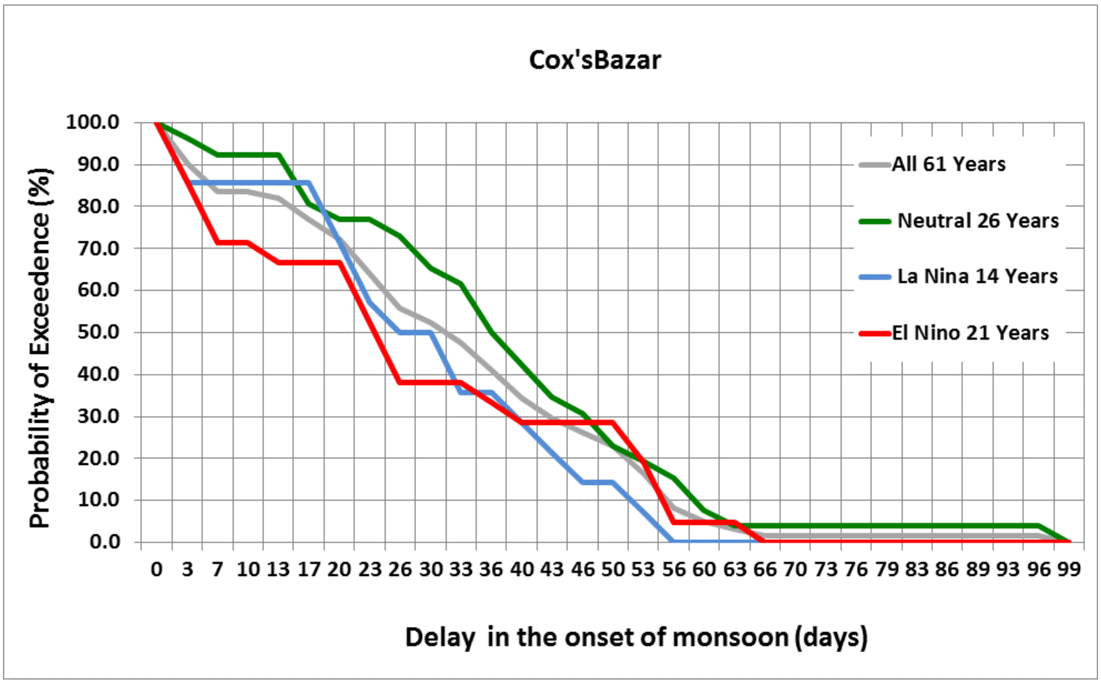


Figure 16. Monsoon onset for Cox's Bazar based on receiving 60mm over 15 consecutive days, shown as days after 1 April.

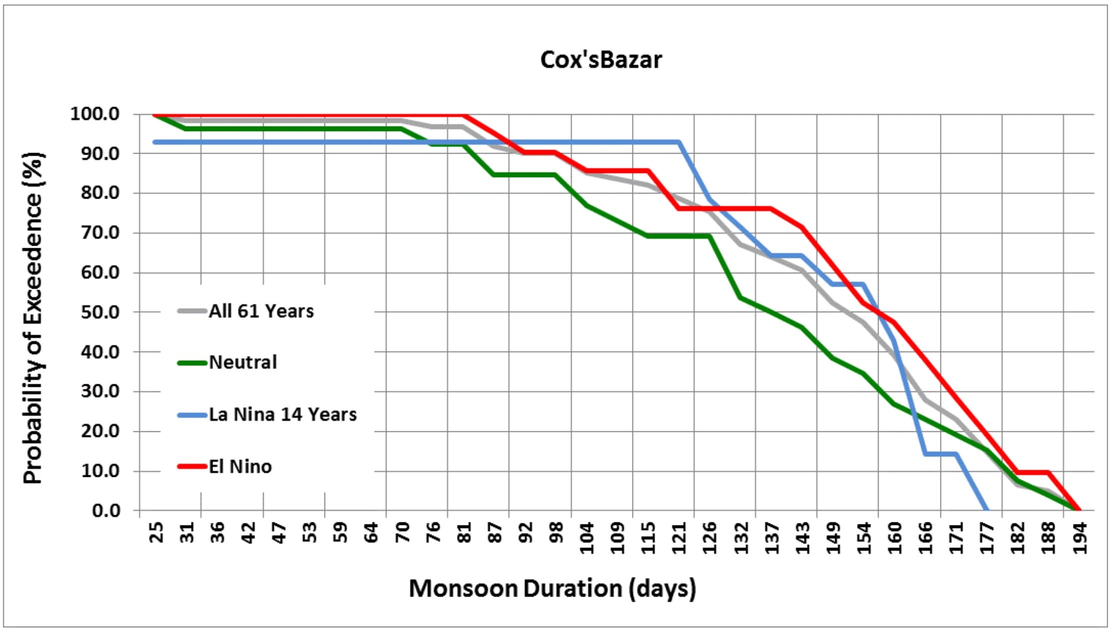


Figure 17. Monsoon duration for Cox's Bazar, shown as days from monsoon onset (60mm rainfall over 15 consecutive days) to monsoon end (less than 30mm rainfall over 10 consecutive days).

The analyses presented above illustrates that seasonal prediction of rainfall in Bangladesh is a challenging task. The synchronous relationship between ENSO predictors and rainfall is poor. Accordingly, the magnitude of LEPS score is low. High scores are irregularly observed but there is no spatial and temporal coherence. The climate of Bangladesh is strongly influenced by orographic effects as well as strong monsoonal rain which masks any influence of ENSO in this country.

4.3 Indonesia

4.3.1 Overview of Climate

Indonesia experiences a typical monsoonal climate system with distinct wet and dry seasons. The annual cycle is dominated by the interaction of the complex topography and the austral–Asian monsoon, and is subject to significant inter-annual variability leading to extremes of drought and anti-drought events generated by conditions in both neighbouring oceans. Aldrian and Susanto (2003) identified three distinct climate regions across Indonesia (Figure 18). Region A experiences a wet NW monsoon during November to March and a dry SE monsoon during May through September. The other regions exhibit quite different rainfall patterns with Region B exhibiting rainfall peaks in October/November and March to May and a distinctive June/July peak for Region C.

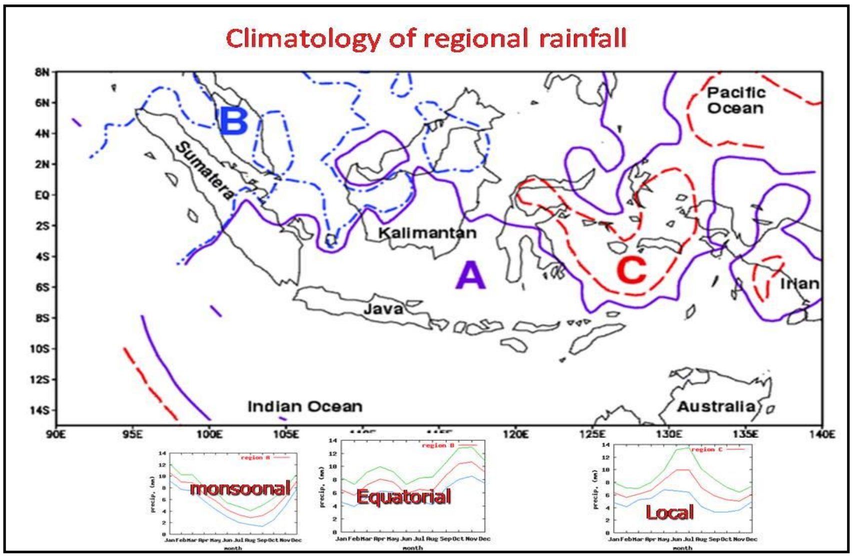


Figure 18. Three Indonesian climate rainfall patterns (a-c). Source: Aldrian and Susanto (2003, p1438–39). Region A: solid line, Region B: short dashed line and Region C:dashed line.

The dominant source of inter-annual climate variability in Indonesia is the El Niño Southern Oscillation (Giannini et al. 2007), estimated to account for about two-thirds of the variance (Haylock and McBride 2001). The remaining variability is driven by Indian Ocean sea surface temperatures (Indian Ocean dipole – IOD) and internal regional processes associated with the monsoon and the Inter-Tropical Convergence Zone (ITCZ). Aldrian and Susanto (2003) identified Region C as being most strongly influenced by ENSO, followed by Region A, with Region B being most influenced by the north/south movement of the ITCZ.

Across Indonesia, including Lombok, drought conditions are associated with warm ENSO events (El Niño) and positive IOD episodes. Anti-drought events are associated with cool ENSO events (La Niña) and negative IOD episodes. The coherency between ENSO and Indonesia reaches a maximum during austral spring (Haylock and McBride 2001; Naylor et al. 2007) and greatly influences the onset of the monsoon with significant impacts on local agriculture. A 30-day delay in monsoon onset is critical to agricultural risk (Naylor et al. 2007). While the onset coincides with the period when ENSO exerts its strongest influence on Indonesian rainfall, the influence of ENSO weakens significantly during the rainy season (December- February) (Haylock and McBride, 2001; Giannini et al. 2007). The onset of the austral-Spring monsoon varies across Indonesia with earlier starts in the north-west and later starts in the south-east of the country (Aldrian and Susanto, 2003; Naylor et al. 2007). Depending on the wind movements across the oceans that influence the monsoon events, the effect of the west monsoon may last up to March.

4.3.2 Data

Ten (10) rainfall stations from three climate types were selected for the analyses (Figure 19) and Table 12. Based on rainfall seasonality in Indonesia, annual rainfall was split into dry and wet seasons according to climate type as shown in Table 13. The longest data set was for Jakarta (1864-2014) and the shortest data set was for Sarmi (1974-2013).

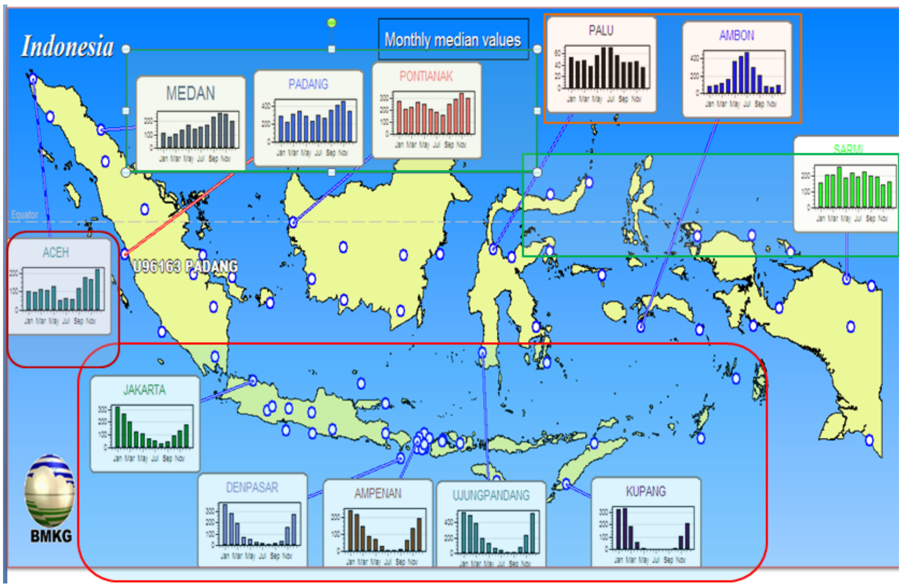


Figure 19. Meteorological station used within the 3 main climate regions of Indonesia (red cycle, green cycle and, brown cycle) Monsoon, Equatorial and Local Climate Type.

Table 12. Meteorological stations used within the 3 main climate regions of Indonesia.

Climate Region Type	Specify station	Start Dat	End Date	Years Ler	Quality %	Gaps	Longitude	Latitude
1. Monsoonal	Aceh	Jan 1952	Jan 2014	62	100%	0	5.52 N	95.42 E
	Jakarta	Jan 1864	Feb 2014	150	100%	0	6.16 S	107.22 E
	Ampenan	Jan 1951	Apr 2014	63	100%	0	8.52 S	116.07 E
	Kupang	Jan 1947	Apr 2014	67	100%	0	10.16 S	124.07 E
2. Equatorial	Medan	Jan 1948	Mar 2011	66	100%	0	3.57 N	99.07 E
	Padang	Jan 1950	Feb 2014	64	100%	0	1.27 S	100.34 E
	Pontianak	Jan 1947	Mar 2014	67	100%	0	0.01 S	109.37 E
	Sarmi	Jan 1974	Dec 2013	39	100%	0	2.2 S	139.13 E
3. Local	Palu	Jan 1954	Dec 2013	59	100%	0	1.07 S	120.13 E
	Ambon	Jan 1950	Dec 2013	63	100%	0	4.09 S	128.07 E

The distribution of median rainfall for each climate type (Monsoonal, Equatorial and Local) is shown in Figures 20a – 20c respectively.

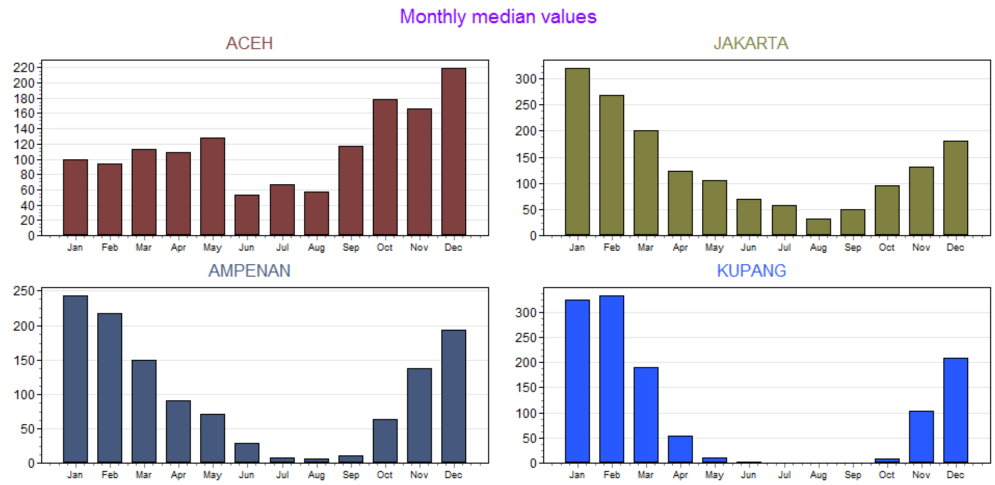


Figure 20a. Distribution of rainfall for selected stations in Monsoon climate region.

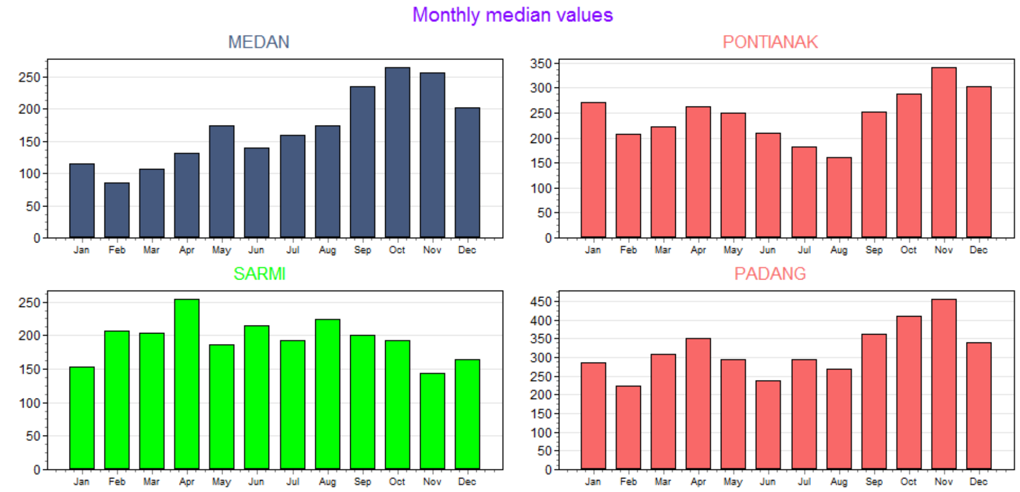


Figure 20b. Distribution of rainfall for selected stations in Equatorial Monsoon climate region.

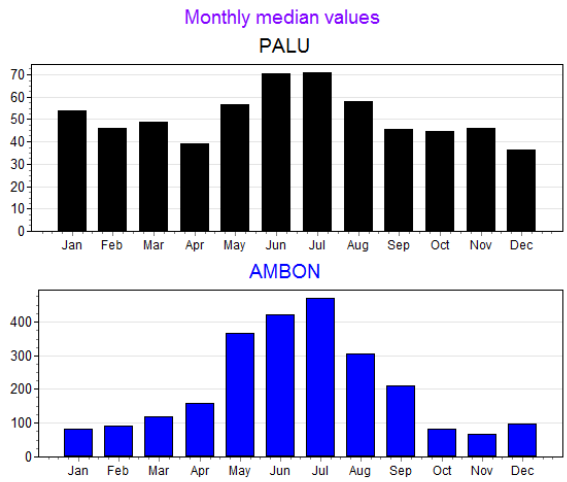


Figure 20c. Distribution of rainfall for selected stations in Local climate region.

In the Monsoon climate type (Aceh, Jakarta, Ampenan and Kupang) the wet season occurs from November to April while the dry season lasts from May to October. In the Equatorial climate type (Medan, Padang, Pontianak and Sarmi) average rainfall exceeds 100 mm throughout the year peaking in October. In the Local climate region (Ambon and Palu) the wet season occurs between May to October while the dry season lasts from November to April. Based on these rainfall patterns, a 6 months "wet" period, 6 months "dry" period and four quarterly periods of 3 months were selected for each of the three climate regions and used in the synchronous correlation analyses (Table 13).

Table 13. Six month and quarterly rainfall periods for the three main rainfall regions in Indonesia

Climate Region Type	6months "WET season"	6 months "DRY season"	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1. Monsoonal	Nov- Apr	May - Oct	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec
2. Equatorial	Nov- Apr	May - Oct	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec
3. Local	May - Oct	Nov - Apr	Nov - Jan	Feb - Apr	May - Jul	Aug - Oct

4.3.3 Synchronous rainfall correlation

Synchronous correlation analysis was conducted using the SCOPIC "Analyse Relationship/Regression Analysis" feature. Both the trend in regression (positive or negative) between predictors (Niño 3.4, SOI and SSTs) and rainfall for each period defined in Table 13 was recorded. An example of the correlation between rainfall and ENSO (SOI and Nino 3.4) for several rainfall stations in Equatorial climate zone is given in Figures 21 and 22. Detailed synchronous results for all climate types and predictors are shown in Appendix C.

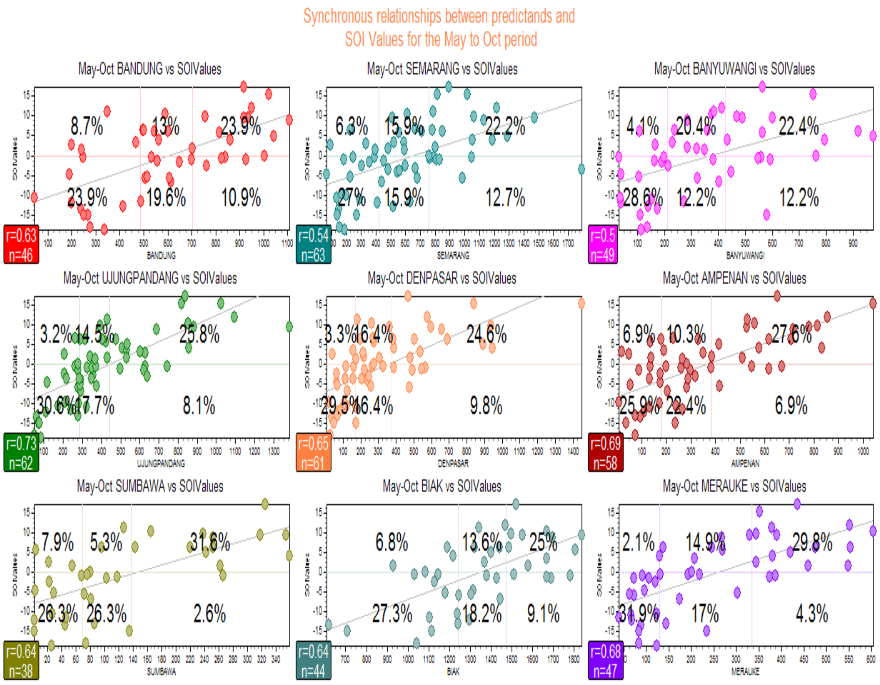


Figure 21. Synchronous relationship between SOI and Rainfall (May-October)

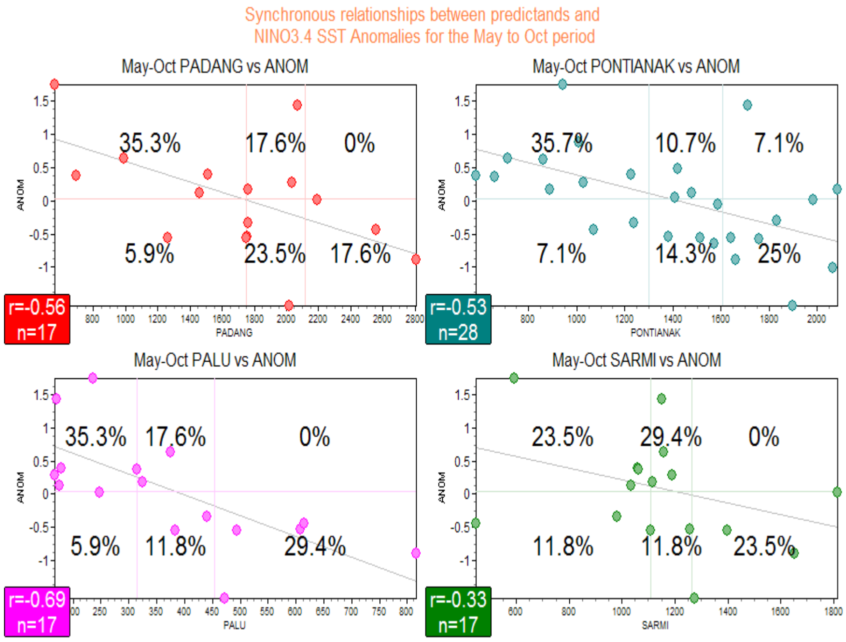


Figure 22. Synchronous relationship between Nino 3.4 and Rainfall (May-October)

Contingency tables and regression analysis show that the synchronous relationship between seasonal rainfall and SOI, Niño 3.4 and SST for the Monsoonal and Local climate type is strong to very strong in the May – October period. This coincides with the dry season for Monsoonal type and wet season for Local climate type. SOI had a positive relationship with higher SOI leading to increased rainfall (La Niña conditions) and Niño3.4 had a negative relationship with higher Niño3.4 leading to reduced rainfall (El Niño condition).

For Equatorial climate type the relationship between ENSO predictors and rainfall is weak. In this region the tropical air masses from both hemispheres converge forming the Inter Tropical Convergence Zone. These air masses are warm and humid with large scale convection resulting in heavy rains during most part of the year.

It is important to note that differences in the strength of relationship exist between stations/locations and conclusions drawn above is based on the averaging of 2-4 stations in each climate region

4.3.4 LEPS Skill Scores

Assessment of forecasting skill was also undertaken using the "Skill Test" function within FLOWCAST. A range of ENSO-based statistical forecast systems were tested for each station to calculate a LEPS score for 3 months rainfall with:

- 12 starting periods throughout the year,
- 3 lead times (0,1 & 2 months), and
- 3 predictor –averaging periods (1,2 & 3 month for SST & Niño3.4 based systems , & 2,3 & 4 month SOI based systems).

An example of cross validated LEPS skill scores for Ampenan is shown in Figure 21. The results show consistent forecasting skill from July to December with poor skill during the peak rainy season (January-April).

To assess an overall level of skill for each predictor, the average annual LEPS score for 108 combinations of predictors, lead times and periods of the year (as outlined above) was calculated for each climate type and rainfall station. The results are summarised in Table 15. The results show similar skill for both SOI and Nino 3.4 particularly for Equatorial and Local climate types. SSTa 1 and 2 also shows similar skill, although not as strong (Table 15).

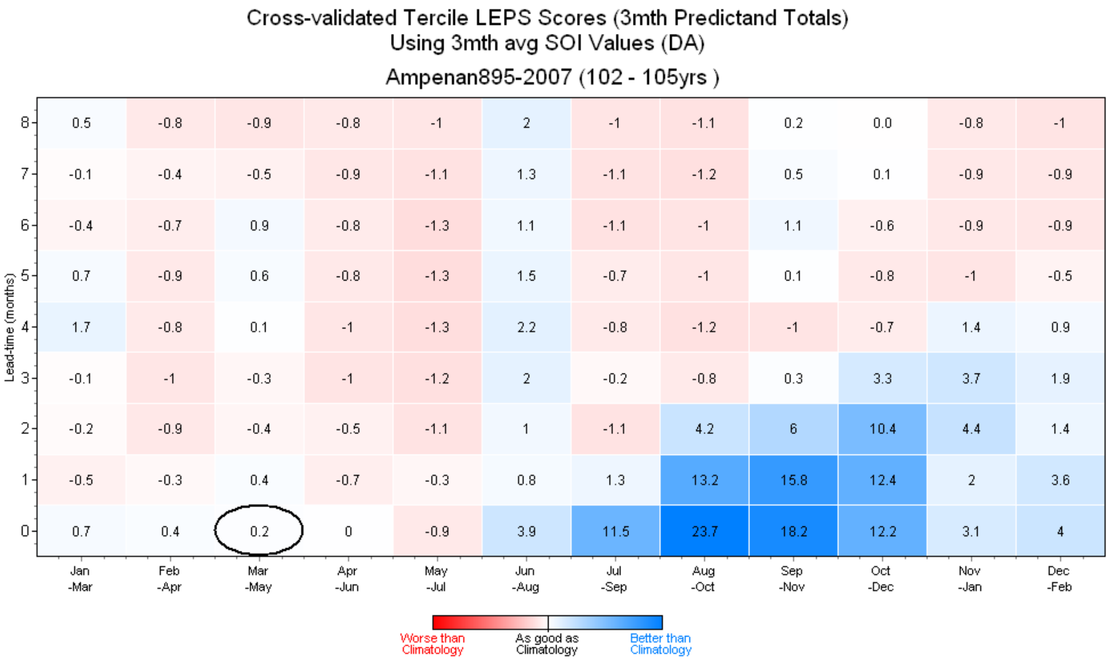


Figure 21. LEPS skill table for using average three month SOI as predictor of rainfall for Ampenan

Table 15. Average annual LEPS score (%) for each station based for a range of predictors

Climate Region Type	Station	Niño 3.4	SOI	SST
Monsoonal	Aceh	11.70%	11.40%	3.20%
	Jakarta	5.70%	5.60%	1.30%
	Ampenan	6.30%	5.40%	3.70%
	Kupang	24.10%	23.50%	9.20%
Equatorial	Medan	20.10%	19.10%	4.10%
	Padang	22.50%	21.60%	12.40%
	Pontianak	11.90%	10.70%	9.70%
	Sarmi	19.00%	18.50%	13.30%
Local	Palu	5.40%	4.90%	5.30%
	Ambon	17.20%	16.40%	9.50%

4.3.5 Onset and Duration of the Monsoon

To assess the effect of ENSO on the onset and duration of monsoon in Indonesia, daily rainfall data for several stations in eastern Indonesia were used in the customized spread sheet. Monsoon onset was defined as the first date (after October 1) when cumulative rainfall over ten consecutive days exceeded 60 mm. End of monsoon was defined as the first day (after the start of monsoon) where cumulative rainfall over fourteen days was less than 25 mm. The distribution of onset and duration was plotted based on all years of data and then segregated into El Niño and La Niña subsets. The distribution of monsoon onset and duration for Ampenan is shown in Figures 22 and 23 respectively. The results show that in La Niña years, 50% of the time the monsoon onset is delayed by 18 days or less, as compared to a delay of up to 42 days in El Niño years. Similarly, 50% of years the monsoon duration in La Niña years is about 45 day compared to 25 days in El Niño years. The distribution of for other rainfall stations in Indonesia is shown in Fig 24.

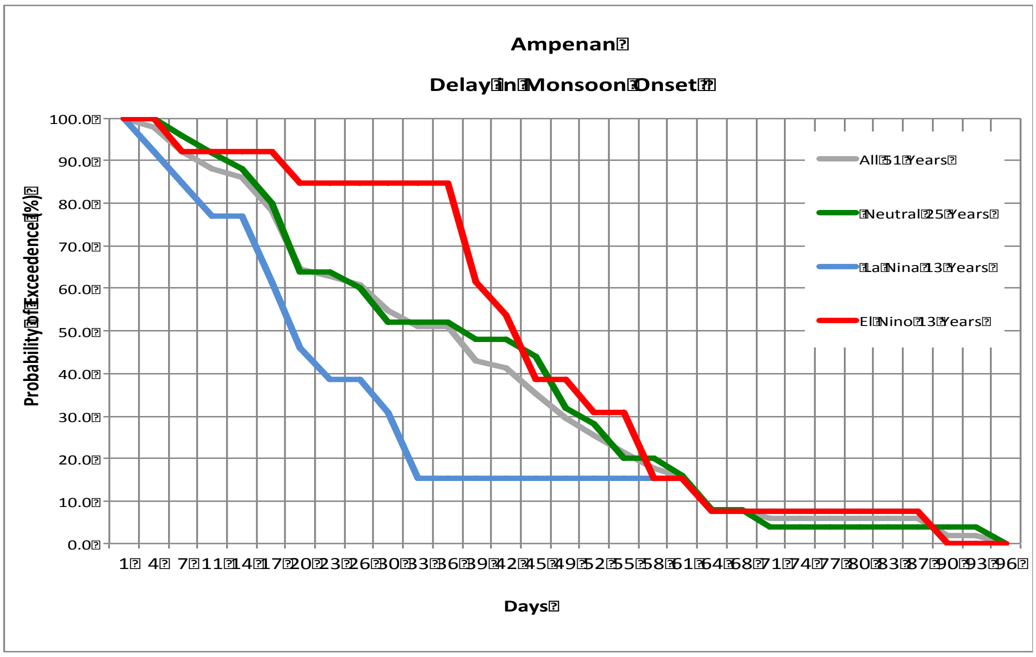


Figure 22. Distribution of monsoon onset for Ampenan during El Niño, La Niña and all years

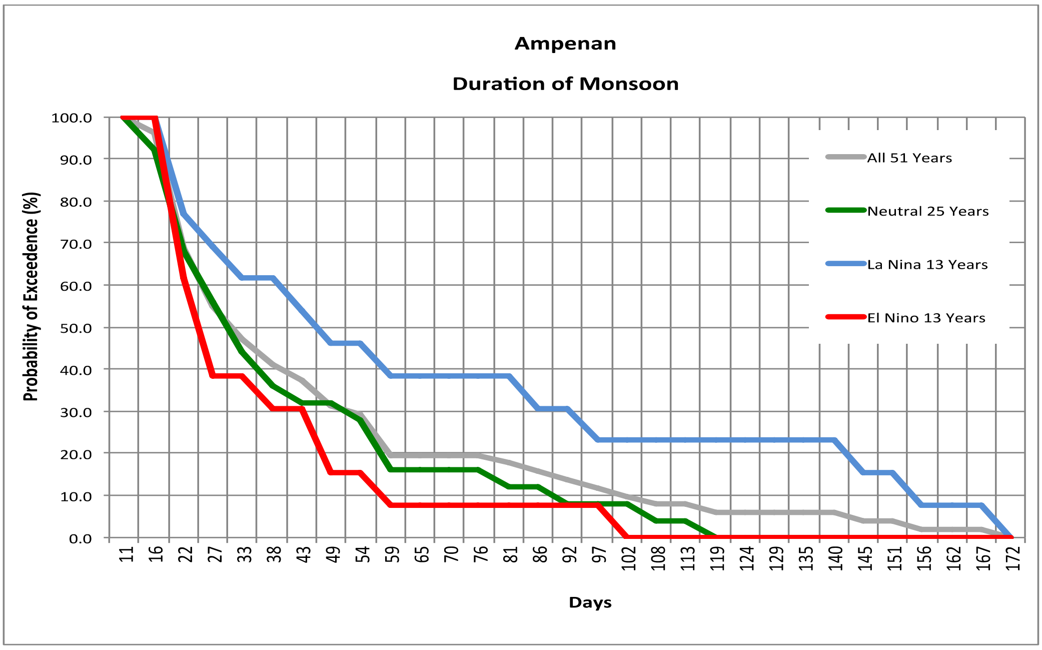


Figure 23. Distribution of monsoon duration for Ampenan during El Niño, La Niña and all years

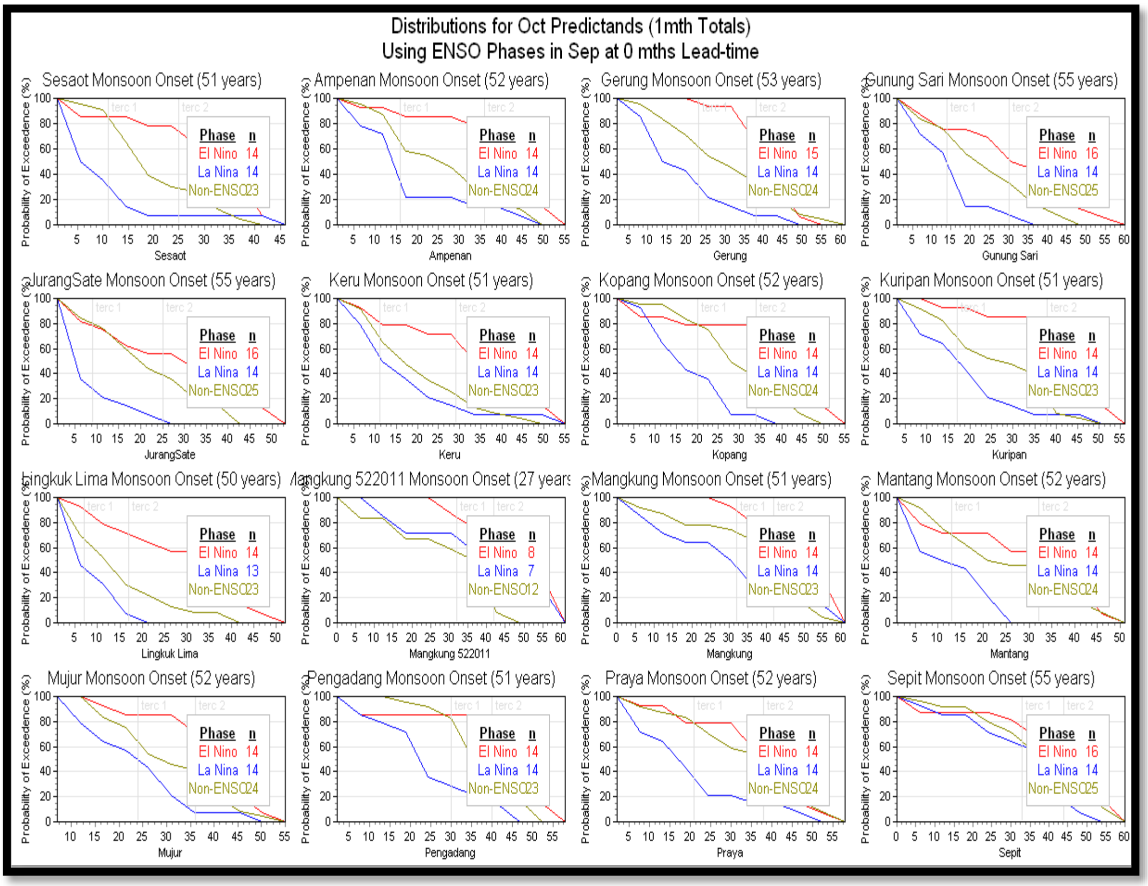


Figure 24. Onset of monsoon displayed as days after 1st October and separated based on Phases of ENSO

5. Conclusion

The following conclusions are drawn from this study:

- Impact of ENSO is strong in the Philippines with moderate to high forecasting skill through most of the year particularly for climate type IV (See section 4.1) with lead times of 3-4 months. Niño 3.4 as well as SOI has the strongest relationship with rainfall variability across the whole region. Forecasting skill is poor during the peak rainy season.
- Forecasting of inflow into Angat Dam supplying Metro Manila is possible through most of the year with lead times of up to 4 months. Significant opportunities exist for using stream-flow forecast to optimize competing demand from Angat Dam.
- Onset and duration of monsoon in the Philippines is influenced by ENSO with later onset and shorter duration of monsoon during El Niño years and earlier onset and longer duration during La Niña years. This is particularly pronounced for climate type III (Zamboanga). On average, the onset of monsoon is delayed by up to 38 days in an El Niño years and is up to 35 days shorter as compared to La Niña years.
- Impact of ENSO on the Indonesian rainfall is also strong with moderate to high forecasting skill particularly in eastern Indonesia. Over western Indonesia and Java the effect of ENSO on rainfall variability is less pronounced. In this region the Indian Ocean Dipole may have more influence but was not investigated in this study due to limited resources and data availability.
- Results from eastern Indonesia showed that on average the onset of monsoon tends to be delayed by up to 1 month and have a shorter duration in El Niño years as compared to La Niña years (see section 4.3)
- There appears to be little influence of ENSO on the climate of Bangladesh in terms of the predictability of rainfall, onset and duration of the monsoon season.

6. Future Directions

The potential for increased risk, as well as the impacts of future changes in climate on agriculture and water resources, demonstrates the need to evaluate current practice for managing climate risks and developing strategies for adapting to future changes in climate. Understanding the impacts of climate on SE-Asian agriculture and natural resources systems and the ability to predict these events with sufficient lead-time for government and farmers to take remedial action, is crucial for policy development and ensuring long-term sustainability and food security in the region. Potential benefits can best be achieved through further work in developing pilot projects in areas where the potential for forecasting is strong and forecasting with sufficient lead time can significantly improve resource use and other operational efficiencies (e.g. Angat Dam management in the Philippines). Furthermore, to develop a better regional understanding of ENSO on the climate of SE-Asia and potential impacts, further studies on the influence of ENSO across other Asian countries (e.g. Lao, Cambodia and Vietnam) is highly desirable.

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Appendix A - Detailed Results for the Philippines

Table A1. Synchronous correlation summary between Niño 3.4 and rainfall (& inflow) for different climate types in the Philippines.

6m "Wet" Season- NINO 3.4	Relationship	Correlation	6m "Wet" Season Rating
Type 1- Rainfall (May - October)	+ive	0.04	★
Type 2- Rainfall (August - January)	-ive	-0.60	★★★★★★
Type 3- Rainfall June - November)	-ive	-0.40	★★★★
Type 4- Rainfall (May - October)	-ive	-0.29	★★
Angat-Rainfall (May - October)	-ive	-0.28	★★
Angat- Inflow (May - October	-ive	-0.24	★★
6m "Dry" Season- NINO 3.4	**Relationship**	**Correlation**	**6m "Dry" Season Rating**
Type 1- Rainfall (November - April)	-ive	-0.47	★★★★
Type 2- Rainfall (February - July)	-ive	-0.61	★★★★★★
Type 3- Rainfall (October - May)	-ive	-0.71	★★★★★★★
Type 4- Rainfall (November - April	-ive	-0.80	★★★★★★★★
Angat-Rainfall (November - April)	-ive	-0.53	★★★★★
Angat- Inflow (November - April)	-ive	-0.40	★★★★
1st Quarter#- NINO 3.4	**Relationship**	**Correlation**	**!st Quarter Rating**
Type 1- Rainfall (February - April)	-ive	-0.30	★★★
Type 2- Rainfall (January - March)	-ive	-0.70	★★★★★★★
Type 3- Rainfall (March - May)	-ive	-0.63	★★★★★★
Type 4- Rainfall (February - April)	-ive	-0.75	★★★★★★★
Angat-Rainfall (January - March)	-ive	-0.61	★★★★★★
Angat- Inflow (January - March)	-ive	-0.50	★★★★★
2nd Quarter#- NINO 3.4	**Relationship**	**Correlation**	**2nd Quarter Rating**
Type 1- Rainfall (May - July)	-ive	-0.09	
Type 2- Rainfall (April - June)	-ive	-0.55	★★★★★
Type 3- Rainfall (June - August)	+ive	0.02	
Type 4- Rainfall (May - July)	-ive	-0.10	★
Angat-Rainfall (April - June)	-ive	-0.62	★★★★★★
Angat- Inflow (April - June)	-ive	-0.60	★★★★★★
3rd Quarter#- NINO 3.4	**Relationship**	**Correlation**	**3rd Quarter Rating**
Type 1- Rainfall (August- October)	-ive	-0.03	
Type 2- Rainfall (July - September)	+ive	0.04	
Type 3- Rainfall (September - November)	-ive	-0.56	★★★★★
Type 4- Rainfall (August - October)	-ive	-0.23	★★
Angat-Rainfall (July - September)	+ive	0.11	★
Angat- Inflow (July - October)	+ive	0.06	
4th Quarter#- NINO 3.4	**Relationship**	**Correlation**	**4th Quarter Rating**
Type 1- Rainfall (November - January)	-ive	-0.39	★★★
Type 2- Rainfall (October - December)	-ive	-0.55	★★★★★
Type 3- Rainfall (December - February)	-ive	-0.65	★★★★★★
Type 4- Rainfall November - January)	-ive	-0.58	★★★★★
Angat-Rainfall (October - December)	-ive	-0.58	★★★★★
Angat- Inflow (October - December)	-ive	-0.41	★★★★

Table A2. Summary of synchronous correlation between SOI and rainfall (& inflow) for different climate types in the Philippines.

6m "Wet" Season- SOI	Relationship	Correlation	6m "Wet" Season Rating
Type 1- Rainfall (May - October)	-ive	-0.08	
Type 2- Rainfall (August - January)	+ive	0.50	☆☆☆☆☆
Type 3- Rainfall June - November)	+ive	0.11	☆
Type 4- Rainfall (May - October)	+ive	0.16	☆
Angat-Rainfall (May - October)	+ive	0.10	☆
Angat- Inflow (May - October	+ive	0.08	
6m "Dry" Season- SOI	**Relationship**	**Correlation**	**6m "Dry" Season Rating**
Type 1- Rainfall (November - April)	+ive	0.32	☆☆☆
Type 2- Rainfall (February - July)	+ive	0.44	☆☆☆☆
Type 3- Rainfall (October - May)	+ive	0.60	☆☆☆☆☆☆
Type 4- Rainfall (November - April	+ive	0.72	☆☆☆☆☆☆☆
Angat-Rainfall (November - April)	+ive	0.54	☆☆☆☆☆
Angat- Inflow (November - April)	+ive	0.37	☆☆☆
1st Quarter# - NINO 3.4	**Relationship**	**Correlation**	**!st Quarter Rating**
Type 1- Rainfall (February - April)	+ive	0.26	☆☆
Type 2- Rainfall (January - March)	+ive	0.55	☆☆☆☆☆
Type 3- Rainfall (March - May)	+ive	0.39	☆☆☆
Type 4- Rainfall (February - April)	+ive	0.64	☆☆☆☆☆☆
Angat-Rainfall (January - March)	+ive	0.57	☆☆☆☆☆
Angat- Inflow (January - March)	+ive	0.34	☆☆☆
2nd Quarter# - NINO 3.4	**Relationship**	**Correlation**	**2nd Quarter Rating**
Type 1- Rainfall (May - July)	-ive	-0.19	☆
Type 2- Rainfall (April - June)	+ive	0.40	☆☆☆☆
Type 3- Rainfall (June - August)	-ive	-0.18	☆
Type 4- Rainfall (May - July)	+ive	0.07	
Angat-Rainfall (April - June)	+ive	0.33	☆☆☆
Angat- Inflow (April - June)	+ive	0.21	☆☆
3rd Quarter# - NINO 3.4	**Relationship**	**Correlation**	**3rd Quarter Rating**
Type 1- Rainfall (August- October)	+ive	0.04	
Type 2- Rainfall (July - September)	+ive	0.01	
Type 3- Rainfall (September - November)	+ive	0.46	☆☆☆☆
Type 4- Rainfall (August - October)	+ive	0.18	☆
Angat-Rainfall (July - September)	-ive	-0.26	☆☆
Angat- Inflow (July - October)	-ive	-0.18	☆
4th Quarter# - NINO 3.4	**Relationship**	**Correlation**	**4th Quarter Rating**
Type 1- Rainfall (November - January)	+ive	0.23	☆☆
Type 2- Rainfall (October - December)	+ive	0.49	☆☆☆☆
Type 3- Rainfall (December - February)	+ive	0.58	☆☆☆☆☆
Type 4- Rainfall November - January)	+ive	0.55	☆☆☆☆☆
Angat-Rainfall (October - December)	+ive	0.49	☆☆☆☆
Angat- Inflow (October - December)	+ive	0.47	☆☆☆☆

Table A3. Summary of synchronous correlation between SSTa's and rainfall (& inflow) for different climate types in the Philippines.

6m "Wet" Season-SST 1	Relationship	Correlation	6m "Wet" Season Rating
Type 1- Rainfall (May - October)	+ive	0.03	
Type 2- Rainfall (August - January)	-ive	-0.37	★★★
Type 3- Rainfall June - November)	-ive	-0.22	★★
Type 4- Rainfall (May - October)	-ive	-0.22	★★
Angat-Rainfall (May - October)	-ive	-0.25	★★
Angat- Inflow (May - October	+ive	0.08	★
6m "Wet" Season-SST 2	**Relationship**	**Correlation**	**6m "Wet" Season Rating**
Type 3- Rainfall June - November)	+ive	0.25	★★
6m "Wet" Season-SST 9	**Relationship**	**Correlation**	**6m "Wet" Season Rating**
Type 1- Rainfall (May - October)	-ive	-0.06	
Type 2- Rainfall (August - January)	+ive	0.21	★★
Type 3- Rainfall June - November)	+ive	0.23	★★
Angat-Rainfall (May - October)	-ive	-0.04	
Angat- Inflow (May - October	+ive	0.17	★
6m "Wet" Season-SST 11	**Relationship**	**Correlation**	**6m "Wet" Season Rating**
Type 4- Rainfall (May - October)	-ive	-0.09	
6m "Dry" Season- SST 1	**Relationship**	**Correlation**	**6m "Dry" Season Rating**
Type 1- Rainfall (November - April)	-ive	-0.28	★★
Type 2- Rainfall (February - July)	-ive	-0.28	★★
Type 3- Rainfall (October - May)	-ive	-0.44	★★★★
Type 4- Rainfall (November - April	-ive	-0.56	★★★★★
Angat-Rainfall (November - April)	-ive	-0.39	★★★
Angat- Inflow (November - April)	-ive	-0.25	★★
6m "Dry" Season- SST 2	**Relationship**	**Correlation**	**6m "Dry" Season Rating**
Type 3- Rainfall (October - May)	-ive	-0.01	
Angat-Rainfall (November - April)	-ive	-0.22	★★
Angat- Inflow (November - April)	+ive	0.05	
6m "Dry" Season- SST 9	**Relationship**	**Correlation**	**6m "Dry" Season Rating**
Type 1- Rainfall (November - April)	-ive	-0.05	
Type 2- Rainfall (February - July)	+ive	0.12	★
Type 3- Rainfall (October - May)	+ive	0.07	
Angat-Rainfall (November - April)	+ive	0.07	
Angat- Inflow (November - April)	+ive	0.02	
6m "Dry" Season- SST 11	**Relationship**	**Correlation**	**6m "Dry" Season Rating**
Type 4- Rainfall (November - April	+ive	0.20	★★

Table A3 continued. Summary of synchronous correlation between SST's and rainfall (& inflow) for different climate types in the Philippines.

1st Quarter- SST 1	Relationship	Correlation	1st Quarter Rating
Type 1- Rainfall (February - April)	-ive	-0.15	★
Type 2- Rainfall (January - March)	-ive	-0.37	★★★
Type 3- Rainfall (March - May)	-ive	-0.36	★★★
Type 4- Rainfall (February - April)	-ive	-0.49	★★★★
Angat-Rainfall (January - March)	-ive	-0.37	★★★
Angat- Inflow (January - March)	-ive	-0.18	★

1st Quarter- SST 2	Relationship	Correlation	1st Quarter Rating
Type 3- Rainfall (March - May)	+ive	0.13	★
Angat-Rainfall (January - March)	+ive	0.10	★
Angat- Inflow (January - March)	+ive	0.12	★

1st Quarter- SST 9	Relationship	Correlation	1st Quarter Rating
Type 1- Rainfall (February - April)	+ive	0.03	
Type 2- Rainfall (January - March)	-ive	-0.01	
Type 3- Rainfall (March - May)	+ive	0.06	
Angat-Rainfall (January - March)	-ive	-0.07	
Angat- Inflow (January - March)	-ive	-0.04	

1st Quarter- SST 11	Relationship	Correlation	1st Quarter Rating
Type 4- Rainfall (February - April)	+ive	0.19	★

2nd Quarter- SST 1	Relationship	Correlation	2nd Quarter Rating
Type 1- Rainfall (May - July)	+ive	0.03	
Type 2- Rainfall (April - June)	-ive	-0.37	★★★
Type 3- Rainfall (June - August)	+ive	0.19	★
Type 4- Rainfall (May - July)	+ive	0.01	
Angat-Rainfall (April - June)	-ive	-0.38	★★★
Angat- Inflow (April - June)	-ive	-0.35	

2nd Quarter- SST 2	Relationship	Correlation	2nd Quarter Rating
Type 3- Rainfall (June - August)	+ive	0.23	★★
Angat-Rainfall (April - June)	+ive	0.10	★
Angat- Inflow (April - June)	+ive	0.12	★

2nd Quarter- SST 9	Relationship	Correlation	2nd Quarter Rating
Type 1- Rainfall (May - July)	-ive	-0.14	★
Type 2- Rainfall (April - June)	-ive	-0.01	
Type 3- Rainfall (June - August)	-ive	-0.09	
Angat-Rainfall (April - June)	+ive	0.05	
Angat- Inflow (April - June)	-ive	-0.03	

2nd Quarter- SST 11	Relationship	Correlation	2nd Quarter Rating
Type 4- Rainfall (May - July)	+ive	0.02	

Table A3 continued. Summary of synchronous correlation between SST's and rainfall (& inflow) for different climate types in the Philippines.

3rd Quarter- SST 1	Relationship	Correlation	3rd Quarter Rating
Type 1- Rainfall (August- October)	+ive	0.11	★
Type 2- Rainfall (July - September)	+ive	0.11	★
Type 3- Rainfall (September - November)	-ive	-0.42	★★★★
Type 4- Rainfall (August - October)	-ive	-0.22	★★
Angat-Rainfall (July - September)	+ive	0.13	★
Angat- Inflow (July - October)	+ive	0.39	★★★
3rd Quarter- SST 2	**Relationship**	**Correlation**	**3rd Quarter Rating**
Type 3- Rainfall (September - November)	+ive	0.04	
Angat-Rainfall (July - September)	-ive	-0.38	★★★
Angat- Inflow (July - October)	-ive	-0.22	★★
3rd Quarter- SST 9	**Relationship**	**Correlation**	**3rd Quarter Rating**
Type 1- Rainfall (August- October)	+ive	0.02	
Type 2- Rainfall (July - September)	+ive	0.03	
Type 3- Rainfall (September - November)	+ive	0.36	★★★
Angat-Rainfall (July - September)	-ive	-0.03	
Angat- Inflow (July - October)	+ive	0.12	★
3rd Quarter- SST 11	**Relationship**	**Correlation**	**3rd Quarter Rating**
Type 4- Rainfall (August - October)	-ive	0.00	
4th Quarter- SST 1	**Relationship**	**Correlation**	**4th Quarter Rating**
Type 1- Rainfall (November - January)	-ive	-0.26	★★
Type 2- Rainfall (October - December)	-ive	-0.36	★★★
Type 3- Rainfall (December - February)	-ive	-0.42	★★★★
Type 4- Rainfall November - January)	-ive	-0.46	★★★★
Angat-Rainfall (October - December)	-ive	-0.49	★★★★
Angat- Inflow (October - December)	-ive	-0.37	★★★
4th Quarter- SST 2	**Relationship**	**Correlation**	**4th Quarter Rating**
Type 3- Rainfall (December - February)	-ive	-0.10	★
Angat-Rainfall (October - December)	-ive	-0.24	★★
Angat- Inflow (October - December)	-ive	-0.15	★
4th Quarter- SST 9	**Relationship**	**Correlation**	**4th Quarter Rating**
Type 1- Rainfall (November - January)	-ive	-0.05	
Type 2- Rainfall (October - December)	+ive	0.20	★★
Type 3- Rainfall (December - February)	-	0.00	
Angat-Rainfall (October - December)	+ive	0.24	★★
Angat- Inflow (October - December)	+ive	0.23	★★
4th Quarter- SST 11	**Relationship**	**Correlation**	**4th Quarter Rating**
Type 4- Rainfall November - January)	+ive	0.10	★

Table A4 Cross validated tercile LEPS skill score table using 1,2 and 3 month averaging Niño 3.4 SST anomalies and 3 month rainfall totals for 12 starting period (JFM, FMA…DJF).

NINO3.4 TYPE 1												
Coron												
1 month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	28.50%	33.20%	15.80%	17.40%	10.00%	-3.90%	14.30%	-0.10%	2.60%	27.80%	11.10%	0.00%
1mths lead	30.60%	36.00%	16.30%	16.20%	11.10%	3.20%	-4.00%	2.40%	3.30%	30.80%	9.80%	1.00%
2mths lead	29.50%	32.90%	15.00%	23.80%	10.70%	11.40%	0.80%	-2.10%	-2.70%	29.70%	7.20%	2.40%
2 months												
0mths lead	29.70%	35.90%	16.40%	16.90%	11.20%	-2.60%	3.50%	1.10%	3.00%	29.70%	10.60%	0.50%
1mths lead	30.30%	34.70%	15.70%	20.50%	11.00%	7.70%	-3.80%	0.30%	0.20%	30.80%	8.70%	1.70%
2mths lead	31.30%	29.00%	12.40%	23.50%	15.50%	11.70%	6.90%	-3.00%	-3.70%	22.50%	8.90%	0.30%
3 months												
0mths lead	29.90%	35.20%	16.20%	20.00%	11.40%	1.80%	-2.60%	0.40%	1.20%	30.40%	9.70%	1.10%
1mths lead	31.50%	31.70%	13.80%	21.60%	14.50%	9.50%	0.90%	-1.10%	-1.50%	26.20%	9.50%	0.70%
2mths lead	29.00%	26.10%	11.00%	22.50%	21.20%	14.80%	10.10%	-3.60%	-4.70%	14.20%	8.70%	-0.10%
Dagupan												
1 month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	18.50%	11.40%	-0.90%	-1.40%	10.80%	17.80%	1.70%	5.40%	16.00%	6.70%	2.00%	-2.20%
1mths lead	14.70%	11.30%	-1.00%	-0.80%	9.10%	21.10%	4.00%	13.50%	11.00%	8.70%	2.70%	-3.50%
2mths lead	10.00%	10.00%	-1.30%	1.00%	8.10%	18.70%	7.40%	1.20%	11.00%	7.20%	4.50%	-2.80%
2 months												
0mths lead	16.80%	11.90%	-0.90%	-1.10%	10.40%	21.00%	3.10%	9.50%	13.80%	7.80%	2.40%	-2.80%
1mths lead	12.50%	10.80%	-1.30%	0.20%	8.60%	20.60%	6.10%	7.50%	11.40%	8.10%	3.60%	-3.20%
2mths lead	10.00%	9.00%	-1.90%	1.30%	8.70%	17.80%	8.50%	0.80%	6.70%	7.40%	4.30%	-2.70%
3 months	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	14.70%	11.40%	-1.30%	-0.20%	9.70%	22.30%	5.00%	7.60%	13.50%	7.80%	3.00%	-2.80%
1mths lead	12.00%	10.00%	-1.90%	0.70%	8.90%	19.30%	7.90%	5.50%	9.20%	8.10%	3.70%	-3.00%
2mths lead	10.30%	7.20%	-2.30%	1.20%	8.70%	18.70%	8.30%	-0.20%	4.10%	7.40%	2.30%	-2.30%
Vigan,ilocos Sur												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	-1.80%	-4.70%	-1.90%	-3.90%	23.50%	6.10%	-3.00%	-2.10%	3.10%	1.90%	-2.90%	-2.30%
1mths lead	-1.50%	-4.80%	-2.40%	-4.00%	20.90%	15.40%	1.40%	-1.80%	0.90%	0.30%	-2.10%	-3.20%
2mths lead	-2.10%	-4.40%	-0.80%	-3.40%	16.00%	18.00%	14.00%	-2.40%	-0.50%	-0.80%	-1.80%	-3.20%
2 months												
0mths lead	-1.70%	-4.90%	-2.20%	-4.00%	23.00%	11.10%	-0.70%	-1.80%	2.00%	1.20%	-2.50%	-2.70%
1mths lead	-1.80%	-4.60%	-1.70%	-3.70%	18.30%	17.60%	7.60%	-3.50%	0.30%	-0.10%	-1.90%	-3.20%
2mths lead	-2.40%	-4.30%	0.20%	-3.70%	15.20%	16.70%	17.10%	-2.50%	-1.30%	-0.90%	-1.90%	-3.20%
3 months												
0mths lead	-1.80%	-4.70%	-1.80%	-3.80%	20.30%	15.20%	4.00%	-3.20%	1.30%	0.70%	-2.20%	-2.80%
1mths lead	-2.00%	-4.50%	-0.80%	-3.90%	16.80%	17.10%	12.90%	-3.10%	-0.40%	-0.40%	-1.90%	-3.10%
2mths lead	-2.30%	-4.30%	0.60%	-3.90%	14.60%	14.80%	18.90%	-2.30%	-1.70%	-0.40%	-2.00%	-3.10%

NINO3.4 TYPE2												
Casiguran quezon												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	3.10%	21.60%	10.10%	17.70%	0.00%	-1.60%	0.80%	17.50%	12.70%	15.30%	2.30%	5.60%
1mths lead	1.20%	22.90%	9.90%	13.40%	2.40%	-1.80%	-0.70%	11.60%	12.40%	16.70%	5.00%	3.40%
2mths lead	-0.20%	18.30%	8.10%	10.40%	1.60%	-2.50%	-1.30%	1.00%	9.70%	16.00%	2.30%	3.40%
2 months												
0mths lead	2.20%	23.00%	10.10%	15.40%	1.40%	-1.40%	0.20%	15.30%	12.80%	16.20%	3.60%	4.60%
1mths lead	0.60%	20.80%	9.30%	11.90%	2.00%	-2.20%	-0.80%	7.10%	11.60%	16.70%	3.70%	3.50%
2mths lead	-0.40%	15.30%	7.30%	9.70%	1.70%	-2.00%	-1.60%	0.00%	6.50%	13.40%	1.40%	2.80%
3 months												
0mths lead	1.50%	21.70%	9.70%	13.50%	1.60%	-1.70%	-0.10%	12.00%	12.50%	16.50%	3.30%	4.30%
1mths lead	0.30%	18.20%	8.50%	10.80%	2.00%	-1.90%	-1.10%	4.60%	9.40%	15.10%	2.70%	3.10%
2mths lead	-0.20%	12.20%	6.70%	8.60%	1.40%	-2.00%	-1.70%	-1.70%	4.80%	9.10%	0.10%	2.00%
Daet camarines Norte												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	50.20%	49.70%	44.60%	24.30%	9.30%	-4.10%	1.30%	4.90%	3.90%	10.40%	11.70%	19.10%
1mths lead	44.40%	49.80%	46.10%	20.70%	7.30%	-3.40%	-2.10%	3.10%	3.40%	7.00%	13.50%	17.60%
2mths lead	45.20%	42.60%	53.40%	16.90%	7.40%	-2.50%	-2.80%	-1.60%	1.10%	5.20%	10.00%	17.10%
2 months												
0mths lead	47.80%	50.10%	45.90%	22.50%	8.50%	-3.90%	-0.20%	4.30%	3.80%	8.80%	12.60%	18.60%
1mths lead	45.20%	46.70%	53.20%	18.80%	7.50%	-2.90%	-2.70%	1.10%	2.40%	6.30%	12.10%	17.70%
2mths lead	45.20%	40.30%	50.70%	15.60%	6.10%	-2.30%	-2.60%	-1.60%	2.50%	3.00%	7.90%	16.00%
3 months												
0mths lead	47.60%	48.30%	52.90%	20.40%	8.20%	-3.50%	-1.60%	2.90%	3.10%	7.90%	12.10%	18.50%
1mths lead	45.60%	44.30%	51.70%	17.20%	6.50%	-2.60%	-2.70%	0.60%	3.30%	4.60%	10.20%	17.00%
2mths lead	45.20%	38.20%	49.40%	15.30%	5.10%	-2.30%	-2.50%	-2.30%	2.70%	0.60%	5.60%	14.60%
Tacloban City leyte												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	55.50%	57.60%	52.30%	37.00%	5.60%	-2.30%	-2.10%	15.70%	18.80%	13.90%	26.90%	37.20%
1mths lead	52.90%	61.90%	48.10%	39.00%	4.30%	-3.20%	-2.10%	16.10%	20.10%	12.70%	20.30%	34.30%
2mths lead	48.60%	61.50%	47.30%	35.90%	4.00%	-3.00%	1.60%	17.50%	24.20%	9.50%	19.10%	29.90%
2 months												
0mths lead	54.70%	62.60%	50.70%	38.40%	5.10%	-3.00%	-2.30%	16.70%	19.80%	13.50%	24.40%	36.10%
1mths lead	51.30%	62.30%	49.50%	37.80%	4.20%	-3.20%	0.00%	18.80%	23.00%	11.50%	20.00%	32.90%
2mths lead	47.00%	59.50%	46.60%	32.20%	4.40%	-2.80%	3.20%	10.50%	26.70%	7.90%	17.60%	31.30%
3 months												
0mths lead	53.50%	63.10%	52.00%	38.00%	4.80%	-3.30%	-0.70%	20.00%	22.20%	12.60%	23.10%	35.10%
1mths lead	50.10%	61.40%	48.60%	34.60%	4.40%	-3.00%	2.00%	14.50%	26.60%	10.10%	18.90%	33.10%
2mths lead	46.20%	58.90%	45.40%	30.40%	4.80%	-2.80%	3.10%	4.70%	21.00%	7.30%	14.90%	31.00%

NINO3.4 TYPE 3

Iloilo City iloilo												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	43.80%	54.70%	24.70%	22.90%	17.80%	-2.80%	5.20%	0.10%	11.50%	36.30%	34.80%	24.40%
1mths lead	42.40%	60.70%	23.10%	18.00%	19.40%	0.40%	-0.60%	-1.90%	13.00%	37.00%	24.80%	24.10%
2mths lead	41.30%	56.00%	22.40%	18.10%	17.30%	5.10%	-0.10%	1.50%	7.60%	32.80%	26.00%	23.10%
2 months												
0mths lead	43.50%	60.80%	24.20%	20.30%	19.90%	-1.60%	2.10%	-0.90%	12.50%	37.40%	30.70%	24.40%
1mths lead	42.20%	59.10%	23.50%	18.30%	18.40%	2.80%	-0.30%	0.50%	10.70%	35.80%	25.90%	24.00%
2mths lead	38.90%	53.90%	18.90%	18.60%	17.00%	4.10%	-0.70%	1.20%	5.10%	27.60%	24.90%	22.50%
3 months												
0mths lead	43.40%	60.20%	24.60%	19.70%	19.40%	0.50%	1.20%	1.00%	11.50%	36.90%	29.80%	24.50%
1mths lead	40.90%	57.20%	20.90%	18.90%	17.80%	3.10%	-0.70%	1.10%	8.50%	32.00%	25.50%	23.60%
2mths lead	38.50%	49.90%	16.30%	17.20%	16.90%	5.80%	-0.90%	1.30%	1.90%	19.50%	21.20%	22.70%
Mactan International Airport												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	41.40%	37.00%	33.40%	41.50%	8.90%	-3.30%	-4.40%	7.50%	40.00%	26.80%	37.60%	30.40%
1mths lead	43.70%	38.10%	31.70%	40.50%	8.40%	-3.30%	-3.70%	1.20%	36.00%	29.40%	36.00%	26.50%
2mths lead	44.50%	36.60%	32.20%	38.20%	10.00%	-4.10%	-3.40%	-0.60%	28.30%	25.50%	42.30%	25.20%
2 months												
0mths lead	42.90%	39.50%	32.90%	41.20%	9.00%	-3.10%	-4.10%	4.50%	38.70%	28.40%	37.70%	28.90%
1mths lead	44.50%	37.80%	33.30%	39.60%	9.40%	-3.80%	-3.50%	0.60%	33.30%	28.00%	39.60%	26.40%
2mths lead	43.60%	37.30%	30.80%	37.70%	9.50%	-4.10%	-3.20%	-3.40%	18.80%	23.80%	39.00%	26.90%
3 months												
0mths lead	44.00%	39.10%	34.20%	40.40%	9.70%	-3.50%	-3.70%	3.40%	36.90%	28.00%	39.60%	28.50%
1mths lead	44.40%	38.20%	32.20%	40.00%	9.30%	-3.90%	-3.40%	-1.70%	27.10%	26.60%	38.60%	27.30%
2mths lead	43.40%	38.70%	29.70%	35.50%	9.70%	-4.30%	-3.20%	-4.50%	8.10%	23.80%	37.90%	24.40%
Zamboanga zamboanga Del Sur												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	26.40%	30.50%	26.80%	4.10%	-1.60%	4.20%	-0.90%	14.20%	8.90%	20.30%	24.90%	11.10%
1mths lead	20.80%	25.70%	24.40%	4.30%	2.60%	-1.80%	4.10%	15.70%	9.40%	24.70%	20.20%	11.10%
2mths lead	21.70%	19.80%	21.00%	4.80%	0.00%	-2.30%	-2.40%	12.10%	8.90%	20.00%	19.80%	11.50%
2 months												
0mths lead	23.80%	29.40%	25.80%	4.30%	0.50%	0.50%	1.40%	15.90%	9.30%	22.80%	23.30%	11.20%
1mths lead	21.40%	22.90%	23.30%	4.60%	1.10%	-2.20%	0.60%	16.40%	9.70%	22.90%	20.40%	11.50%
2mths lead	20.60%	20.10%	19.30%	4.50%	0.30%	-3.20%	-3.50%	6.00%	5.20%	17.60%	18.20%	10.30%
3 months												
0mths lead	23.40%	26.40%	25.30%	4.50%	0.30%	-1.40%	0.50%	17.90%	9.80%	22.40%	22.50%	11.60%
1mths lead	21.00%	22.30%	21.50%	4.40%	0.90%	-2.90%	-2.20%	11.60%	7.90%	20.70%	19.40%	10.90%
2mths lead	18.70%	19.00%	18.50%	4.40%	0.60%	-3.30%	-3.60%	1.20%	1.40%	12.20%	15.50%	8.60%

NINO3.4 TYPE4

Davao City davao Del Sur												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	21.00%	22.40%	17.50%	17.50%	-4.20%	-1.10%	3.20%	-3.50%	-2.50%	-1.80%	9.50%	28.80%
1mths lead	16.60%	16.50%	15.40%	14.70%	-4.10%	-2.40%	-3.70%	-3.60%	-1.40%	-0.50%	12.60%	28.50%
2mths lead	17.30%	12.00%	12.20%	12.30%	-3.70%	-2.80%	-4.70%	-2.30%	2.50%	-1.00%	8.70%	30.30%
2 months												
0mths lead	19.00%	19.20%	16.50%	16.10%	-4.20%	-1.90%	-0.70%	-3.70%	-2.30%	-1.20%	11.10%	28.90%
1mths lead	17.10%	14.40%	13.70%	13.50%	-3.90%	-2.70%	-4.40%	-3.20%	0.60%	-0.60%	10.90%	29.90%
2mths lead	16.60%	11.40%	10.90%	14.30%	-3.40%	-2.90%	-4.30%	-2.20%	1.00%	-2.60%	7.60%	27.60%
3 months												
0mths lead	18.70%	16.90%	14.90%	14.70%	-4.00%	-2.50%	-3.00%	-3.50%	-1.00%	-1.10%	10.60%	30.00%
1mths lead	16.80%	13.40%	12.30%	15.00%	-3.60%	-2.90%	-4.60%	-2.90%	0.60%	-2.00%	9.50%	28.60%
2mths lead	15.50%	10.50%	10.10%	13.50%	-3.60%	-3.10%	-4.00%	-2.10%	1.00%	-3.50%	8.00%	25.40%
General Santos south Cotabato												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	20.50%	62.30%	27.30%	3.70%	-4.50%	-3.50%	2.10%	-0.50%	26.60%	31.60%	33.50%	21.80%
1mths lead	18.60%	64.00%	29.10%	3.80%	-5.20%	-3.70%	14.70%	2.80%	20.00%	31.80%	35.10%	23.80%
2mths lead	22.80%	57.90%	29.80%	4.20%	-5.40%	-4.00%	5.00%	11.40%	24.80%	20.90%	31.40%	24.80%
2 months												
0mths lead	19.70%	63.50%	28.60%	3.80%	-5.00%	-3.60%	8.40%	1.00%	23.90%	32.20%	34.80%	22.90%
1mths lead	20.70%	61.60%	30.70%	4.10%	-5.30%	-3.90%	10.30%	7.90%	23.00%	26.90%	33.90%	24.70%
2mths lead	21.80%	57.30%	28.10%	4.50%	-5.20%	-3.80%	1.90%	11.80%	19.30%	18.30%	27.40%	25.40%
3 months												
0mths lead	20.90%	62.50%	30.90%	4.10%	-5.20%	-3.70%	8.70%	4.30%	25.30%	29.10%	34.40%	23.90%
1mths lead	20.90%	60.50%	29.50%	4.40%	-5.20%	-3.70%	5.90%	11.50%	21.20%	23.60%	30.80%	25.20%
2mths lead	22.00%	54.20%	28.00%	5.30%	-5.10%	-4.00%	1.00%	7.60%	14.80%	12.80%	22.20%	24.10%
Tagbilaran City bohol												
1month	Jan-Mar	Feb-Apr	Mar-May	Apr-Jun	May-Jul	Jun-Aug	Jul-Sep	Aug-Oct	Sep-Nov	Oct-Dec	Nov-Jan	Dec-Feb
0mths lead	56.60%	50.00%	41.40%	11.20%	6.10%	-0.60%	-2.70%	4.90%	6.00%	17.30%	20.60%	34.40%
1mths lead	52.90%	50.60%	42.10%	10.50%	4.00%	-4.70%	-1.40%	5.60%	9.40%	14.90%	20.70%	31.80%
2mths lead	53.50%	46.90%	39.60%	7.50%	4.50%	-4.90%	-4.30%	9.60%	13.90%	14.20%	20.40%	28.90%
2 months												
0mths lead	55.30%	50.70%	42.20%	10.90%	5.20%	-3.20%	-2.00%	5.40%	7.70%	16.20%	21.00%	33.50%
1mths lead	53.60%	49.30%	41.10%	8.90%	4.40%	-4.90%	-3.40%	8.50%	11.90%	14.90%	20.70%	31.10%
2mths lead	53.60%	46.00%	38.30%	6.60%	2.40%	-4.80%	-4.30%	6.30%	16.20%	11.30%	18.80%	29.50%
3 months												
0mths lead	55.50%	50.10%	41.80%	9.50%	5.10%	-4.30%	-2.90%	7.70%	9.70%	16.00%	21.10%	33.00%
1mths lead	54.20%	48.30%	40.00%	7.70%	2.90%	-4.90%	-4.40%	7.40%	14.90%	13.20%	19.80%	31.00%
2mths lead	52.50%	45.50%	36.90%	6.00%	1.30%	-4.40%	-4.30%	3.50%	12.60%	9.30%	17.30%	26.90%

Appendix B - Detailed Results for Bangladesh

Table B1a Synchronous correlation summary between Niño 3.4 and rainfall during “wet” season

Station \ NINO 3.4	Relationship	Correlation	6m "WET" Season Rating
Barisal	-ive	-0.14	★
Bhola	-ive	-0.08	
Bogra	-ive	-0.36	★★★
Chittagong	-ive	-0.12	★
Comilla	-ive	-0.12	★★
CoxsBazar	-ive	-0.17	★
Dhaka	-ive	-0.11	★
Dinajpur	-ive	-0.02	
Faridpur	-ive	-0.13	★
Ishurdi	+ive	0.03	
Jessore	+ive	0.14	★
Khepupara	-ive	-0.37	★★★
Khulna	+ive	0.06	
Madaripur	+ive	0.03	
MaijdiCourt	-ive	-0.13	★
Mymensingh	-ive	-0.05	
Patuakhali	+ive	0.01	
Rajshahi	+ive	0.06	
Rangamati	-ive	-0.17	★
Rangpur	+ive	0.01	
Sandwip	-ive	-0.17	★
Satkhira	+ive	0.04	
Srimongal	-ive	-0.13	★
Teknaf	-ive	-0.17	★

Table B1b Synchronous correlation summary for Niño 3.4 “dry”season

Station \ NINO 3.4	Relationship	Correlation	6m "DRY" Season Rating
Barisal	+ive	0.27	★★
Bhola	+ive	0.32	★★★
Bogra	+ive	0.04	★
Chittagong	+ive	0.21	★★
Comilla	+ive	0.26	★★
CoxsBazar	+ive	0.03	★
Dhaka	+ive	0.21	★★
Dinajpur	+ive	0.31	★★★
Faridpur	+ive	0.15	★
Ishurdi	+ive	0.22	★★
Jessore	+ive	0.29	★★
Khepupara	+ive	0.26	★★
Khulna	+ive	0.53	★★★★★
Madaripur	+ive	0.32	★★★
MaijdiCourt	+ive	0.40	★★★★
Mymensingh	+ive	0.06	
Patuakhali	+ive	0.24	★★
Rajshahi	+ive	0.25	★★
Rangamati	+ive	0.28	★★
Rangpur	-ive	-0.01	
Sandwip	+ive	0.17	★
Satkhira	+ive	0.23	★★
Srimongal	+ive	0.35	★★★
Teknaf	-ive	-0.12	★

Table B1c Synchronous correlation summary for Niño 3.4 (1st Quarter)

Station \ NINO 3.4	Relationship	Correlation	1st Quarter (Dec - Feb)
Barisal	+ive	0.48	★★★★
Bhola	+ive	0.46	★★★★
Bogra	+ive	0.30	★★★
Chittagong	+ive	0.24	★★
Comilla	+ive	0.37	★★★
CoxsBazar	-ive	-0.10	
Dhaka	+ive	0.38	★★★
Dinajpur	+ive	0.27	★★
Faridpur	+ive	0.38	★★★
Ishurdi	+ive	0.21	★★
Jessore	+ive	0.10	
Khepupara	+ive	0.36	★★★
Khulna	+ive	0.49	★★★★
Madaripur	+ive	0.38	★★★
MaijdiCourt	+ive	0.39	★★★
Mymensingh	+ive	0.21	★★
Patuakhali	+ive	0.52	★★★★★
Rajshahi	+ive	0.20	★★
Rangamati	+ive	0.19	★
Rangpur	+ive	0.20	★★
Sandwip	+ive	0.25	★★
Satkhira	+ive	0.36	★★★
Srimongal	+ive	0.10	
Teknaf	-ive	-0.21	★★

Table B1d Synchronous correlation summary for Niño 3.4 (2nd Quarter)

Station \ NINO 3.4	Relationship	Correlation	2nd Quarter (Mar - May)
Barisal	+ive	0.23	★★
Bhola	+ive	0.14	★
Bogra	-ive	-0.08	
Chittagong	-ive	-0.11	★
Comilla	+ive	0.05	
CoxsBazar	-ive	-0.20	★★
Dhaka	-ive	-0.06	
Dinajpur	-ive	-0.11	★
Faridpur	-ive	-0.10	
Ishurdi	+ive	0.19	★
Jessore	+ive	0.31	★★★
Khepupara	+ive	0.14	★
Khulna	+ive	0.36	★★★
Madaripur	+ive	0.17	★
MaijdiCourt	+ive	0.22	★★
Mymensingh	-ive	-0.03	
Patuakhali	+ive	0.42	★★★★
Rajshahi	-ive	-0.22	★★
Rangamati	+ive	0.22	★★
Rangpur	-ive	-0.35	★★★
Sandwip	-ive	-0.05	
Satkhira	-ive	-0.05	
Srimongal	+ive	0.05	
Teknaf	-ive	-0.17	★

Table B1e Synchronous correlation summary for Niño 3.4 (3rd Quarter)

Station \ NINO 3.4	Relationship	Correlation	3rd Quarter (Jun - Aug)
Barisal	-ive	-0.08	
Bhola	+ive	0.10	
Bogra	-	0.00	
Chittagong	-ive	-0.35	★★★
Comilla	+ive	0.01	
CoxsBazar	+ive	0.05	
Dhaka	+ive	0.09	
Dinajpur	-ive	-0.01	
Faridpur	+ive	0.14	★
Ishurdi	-	0.00	
Jessore	+ive	0.09	
Khepupara	+ive	0.21	★★
Khulna	-ive	-0.03	
Madaripur	+ive	0.08	
MaijdiCourt	+ive	0.03	
Mymensingh	-ive	-0.03	
Patuakhali	+ive	0.09	
Rajshahi	+ive	0.13	★
Rangamati	-ive	-0.07	
Rangpur	+ive	0.10	
Sandwip	-ive	-0.07	
Satkhira	+ive	0.13	★
Srimongal	+ive	0.10	
Teknaf	+ive	0.06	

Table B1d Synchronous correlation summary for Niño 3.4 (4th Quarter)

Station \ NINO 3.4	Relationship	Correlation	4th Quarter (Sep - Nov)
Barisal	-ive	-0.05	
Bhola	-ive	-0.17	★
Bogra	-ive	-0.26	★★
Chittagong	-ive	-0.16	★
Comilla	-ive	-0.19	★
CoxsBazar	-ive	-0.20	★★
Dhaka	+ive	0.09	
Dinajpur	-ive	-0.16	★
Faridpur	+ive	0.02	
Ishurdi	+ive	0.11	★
Jessore	+ive	0.20	★★
Khepupara	-ive	-0.22	★★
Khulna	+ive	0.03	
Madaripur	+ive	0.06	
MaijdiCourt	-ive	-0.16	★
Mymensingh	+ive	0.10	
Patuakhali	+ive	0.01	
Rajshahi	-ive	-0.07	
Rangamati	-ive	-0.04	
Rangpur	-ive	-0.07	
Sandwip	-ive	-0.05	
Satkhira	-ive	-0.04	
Srimongal	-ive	-0.10	
Teknaf	-ive	-0.20	★★

Table B1e Synchronous correlation summary for SOI

Station \ SOI	Relationship	Correlation	6m "WET" Season Rating
Barisal	+ive	0.22	★★
Bhola	+ive	0.11	★
Bogra	+ive	0.28	★★
Chittagong	+ive	0.19	★
Comilla	+ive	0.01	
CoxsBazar	+ive	0.10	★
Dhaka	+ive	0.09	
Dinajpur	-ive	-0.04	
Faridpur	+ive	0.17	★
Ishurdi	+ive	0.04	
Jessore	-ive	-0.11	★
Khepupara	+ive	0.24	★★
Khulna	-ive	-0.01	
Madaripur	-ive	-0.11	★
MaijdiCourt	+ive	0.02	
Mymensingh	-ive	-0.03	
Patuakhali	-ive	-0.13	★
Rajshahi	+ive	0.11	★
Rangamati	+ive	0.01	
Rangpur	-	0.00	
Sandwip	+ive	0.10	★
Satkhira	-ive	-0.08	
Srimongal	+ive	0.03	
Teknaf	+ive	0.03	

Station \ SOI	Relationship	Correlation	6m "DRY" Season Rating
Barisal	-ive	-0.09	
Bhola	-ive	-0.13	★
Bogra	-ive	-0.12	★
Chittagong	-ive	-0.13	★
Comilla	-ive	-0.23	★★
CoxsBazar	-ive	-0.08	
Dhaka	-ive	-0.27	★★
Dinajpur	-ive	-0.03	
Faridpur	-ive	-0.23	★★
Ishurdi	-ive	-0.15	★
Jessore	-ive	-0.22	★★
Khepupara	-ive	-0.39	★★★
Khulna	-ive	-0.38	★★★
Madaripur	-ive	-0.41	★★★★
MaijdiCourt	-ive	-0.38	★★★
Mymensingh	-ive	-0.20	★★
Patuakhali	-ive	-0.49	★★★★
Rajshahi	-ive	-0.24	★★
Rangamati	-ive	-0.30	★★★
Rangpur	-ive	-0.04	
Sandwip	-ive	-0.08	
Satkhira	-ive	-0.30	★★★
Srimongal	-ive	-0.25	★★
Teknaf	+ive	0.08	

Station \ SOI	Relationship	Correlation	1st Quarter (Dec - Feb)
Barisal	-ive	-0.03	
Bhola	-ive	-0.17	★
Bogra	-ive	-0.23	★★
Chittagong	-ive	-0.17	★
Comilla	-ive	-0.34	★★★
CoxsBazar	-ive	-0.06	
Dhaka	-ive	-0.23	★★
Dinajpur	-ive	-0.19	★
Faridpur	-ive	-0.13	★
Ishurdi	-ive	-0.18	★
Jessore	-ive	-0.05	★
Khepupara	-ive	-0.39	★★★
Khulna	-ive	-0.34	★★★
Madaripur	-ive	-0.30	★★★
MaijdiCourt	-ive	-0.20	★★
Mymensingh	-ive	-0.20	★★
Patuakhali	-ive	-0.49	★★★★
Rajshahi	-ive	-0.17	★
Rangamati	-ive	-0.20	★★
Rangpur	-ive	-0.17	★
Sandwip	-ive	-0.15	★
Satkhira	-ive	-0.20	★★
Srimongal	-ive	-0.19	★
Teknaf	+ive	0.31	★★★

Station \ SOI	Relationship	Correlation	2nd Quarter (Mar - May)
Barisal	-ive	-0.07	
Bhola	-ive	-0.12	★
Bogra	+ive	0.05	
Chittagong	+ive	0.04	
Comilla	-ive	-0.07	
CoxsBazar	+ive	0.08	
Dhaka	-ive	-0.10	
Dinajpur	+ive	0.08	
Faridpur	+ive	0.04	
Ishurdi	+ive	0.01	
Jessore	-ive	-0.08	
Khepupara	-ive	-0.14	★
Khulna	-ive	-0.08	
Madaripur	-ive	-0.20	★★
MaijdiCourt	-ive	-0.18	★
Mymensingh	-ive	-0.13	★
Patuakhali	-ive	-0.30	★★★
Rajshahi	+ive	0.12	★
Rangamati	-ive	-0.26	★★
Rangpur	+ive	0.21	★★
Sandwip	-ive	-0.04	
Satkhira	+ive	0.05	
Srimongal	-ive	-0.06	
Teknaf	+ive	0.26	★★

Station \ SOI	Relationship	Correlation	3rd Quarter (Jun - Aug)
Barisal	+ive	0.05	
Bhola	-ive	-0.17	★
Bogra	+ive	0.17	★
Chittagong	+ive	0.14	★
Comilla	-ive	-0.08	
CoxsBazar	+ive	0.05	
Dhaka	+ive	0.09	
Dinajpur	-ive	-0.10	
Faridpur	+ive	0.43	★★★★
Ishurdi	-ive	-0.11	★
Jessore	-ive	-0.11	★
Khepupara	-ive	-0.09	
Khulna	-ive	-0.18	★
Madaripur	-ive	-0.17	★
MaijdiCourt	-ive	-0.03	
Mymensingh	-ive	-0.05	
Patuakhali	-ive	-0.36	★★★
Rajshahi	-ive	-0.07	
Rangamati	-ive	-0.06	
Rangpur	-ive	-0.11	★
Sandwip	-ive	-0.07	
Satkhira	-ive	-0.26	★★
Srimongal	-ive	-0.05	
Teknaf	-ive	-0.12	★

Station \ SOI	Relationship	Correlation	4th Quarter (Sep - Nov)
Barisal	+ive	0.32	★★★
Bhola	+ive	0.34	★★★
Bogra	+ive	0.20	★★
Chittagong	-ive	-0.26	★★
Comilla	+ive	0.18	★
CoxsBazar	+ive	0.20	★★
Dhaka	+ive	0.05	
Dinajpur	-ive	-0.01	
Faridpur	+ive	0.23	★★
Ishurdi	+ive	0.20	★★
Jessore	-ive	-0.08	
Khepupara	+ive	0.34	★★★
Khulna	+ive	0.04	
Madaripur	+ive	0.01	
MaijdiCourt	+ive	0.32	★★★
Mymensingh	-ive	-0.03	
Patuakhali	+ive	0.05	
Rajshahi	+ive	0.20	★★
Rangamati	+ive	0.20	★
Rangpur	+ive	0.03	★
Sandwip	+ive	0.14	★
Satkhira	+ive	0.02	
Srimongal	+ive	0.10	
Teknaf	+ive	0.27	★★

Table 2 Synchronous correlation summary for SST 2

Station \ SST2	Relationship	Correlation	6m "WET" Season Rating
Barisal	-ive	-0.13	★
Bhola	-ive	-0.16	★
Bogra	+ive	0.02	
Chittagong	+ive	0.06	
Comilla	-ive	-0.35	★★★
CoxsBazar	+ive	0.16	★
Dhaka	-ive	-0.03	
Dinajpur	+ive	0.06	
Faridpur	-ive	-0.04	
Ishurdi	-ive	-0.17	★
Jessore	+ive	0.14	★
Khepupara	+ive	0.41	★★★★
Khulna	+ive	0.18	★
Madaripur	-ive	-0.23	★★
MaijdiCourt	+ive	0.08	
Mymensingh	-	0.00	
Patuakhali	-ive	-0.06	
Rajshahi	-ive	-0.18	★
Rangamati	+ive	0.18	★
Rangpur	-	0.00	
Sandwip	+ive	0.31	★
Satkhira	+ive	0.11	
Srimongal	-ive	-0.12	★
Teknaf	+ive	0.59	★★★★★

Station \ SST2	Relationship	Correlation	6m "DRY" Season Rating
Barisal	-	0.00	
Bhola	-ive	-0.46	★★★★
Bogra	+ive	0.09	
Chittagong	+ive	0.02	
Comilla	-ive	-0.08	
CoxsBazar	+ive	0.02	
Dhaka	+ive	0.13	★★
Dinajpur	+ive	0.28	★★
Faridpur	+ive	0.02	
Ishurdi	-ive	-0.12	★
Jessore	+ive	0.03	
Khepupara	-ive	-0.16	★
Khulna	+ive	0.09	
Madaripur	-ive	-0.12	★
MaijdiCourt	+ive	0.07	
Mymensingh	+ive	0.05	
Patuakhali	-ive	-0.26	★★
Rajshahi	-ive	-0.01	
Rangamati	+ive	0.08	
Rangpur	+ive	0.29	★★
Sandwip	-ive	-0.13	★
Satkhira	+ive	0.05	
Srimongal	-ive	-0.04	
Teknaf	-ive	-0.18	★

Station \ SST2	Relationship	Correlation	1st Quarter (Dec - Feb)
Barisal	+ive	0.09	
Bhola	-ive	-0.25	★★
Bogra	+ive	0.07	
Chittagong	+ive	0.29	★★
Comilla	+ive	0.26	★★
CoxsBazar	+ive	0.06	
Dhaka	+ive	0.16	★
Dinajpur	+ive	0.12	★
Faridpur	+ive	0.18	★
Ishurdi	-	0.00	
Jessore	+ive	0.11	★
Khepupara	+ive	0.01	
Khulna	+ive	0.22	★★
Madaripur	+ive	0.05	
MaijdiCourt	+ive	0.11	★
Mymensingh	-ive	-0.01	
Patuakhali	+ive	0.10	
Rajshahi	-ive	-0.10	
Rangamati	+ive	0.07	
Rangpur	-ive	-0.21	★★
Sandwip	+ive	0.15	★
Satkhira	+ive	0.06	
Srimongal	+ive	0.10	
Teknaf	-ive	-0.02	

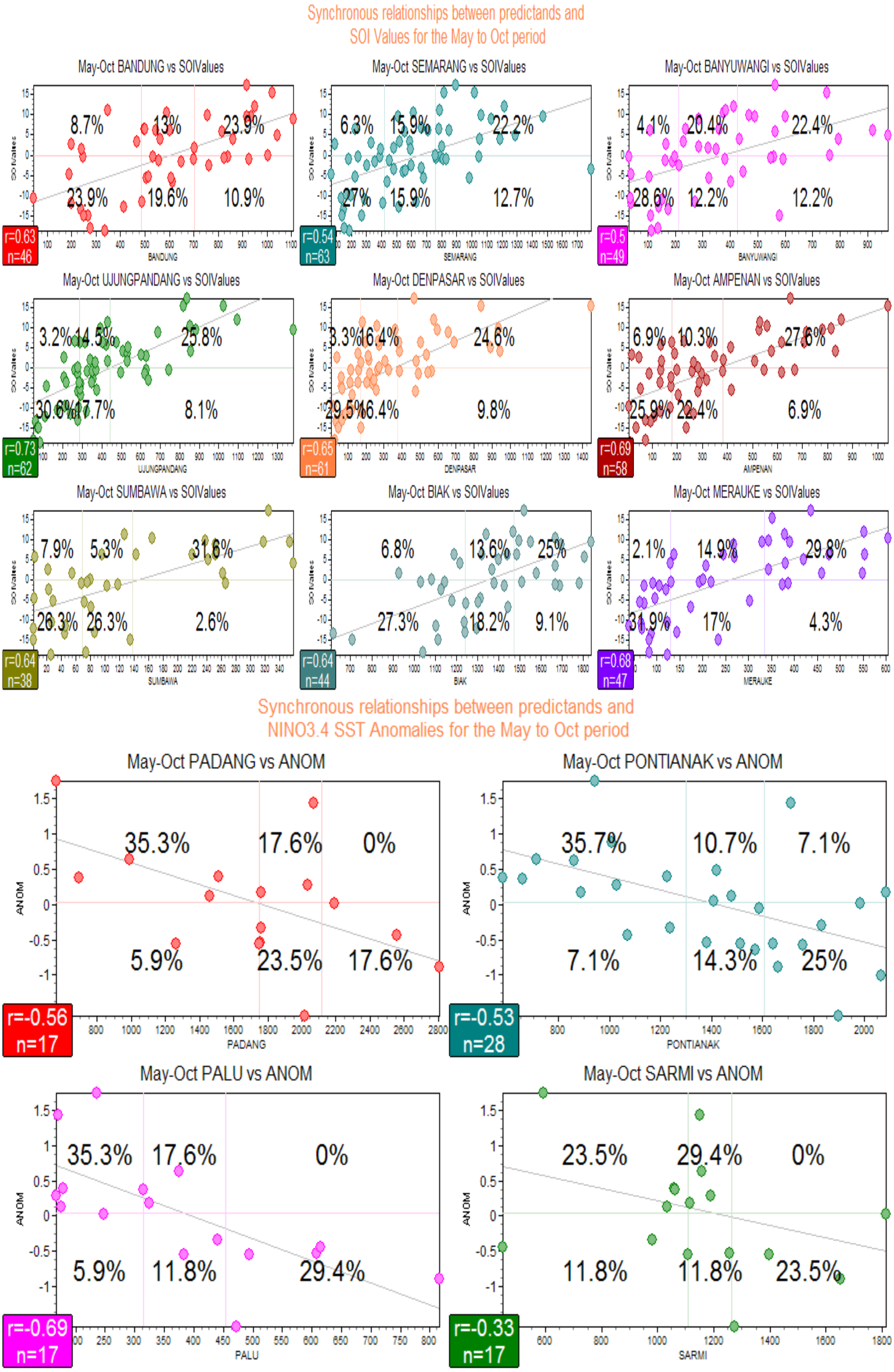
Station \ SST2	Relationship	Correlation	2nd Quarter (Mar - May)
Barisal	+ive	0.09	
Bhola	-ive	-0.25	★★
Bogra	+ive	0.07	
Chittagong	+ive	0.29	★★
Comilla	+ive	0.23	★★
CoxsBazar	+ive	0.06	
Dhaka	+ive	0.16	★
Dinajpur	+ive	0.12	★
Faridpur	+ive	0.18	★
Ishurdi	-	0.00	
Jessore	+ive	0.11	★
Khepupara	+ive	0.01	
Khulna	+ive	0.22	★★
Madaripur	+ive	0.05	
MaijdiCourt	+ive	0.11	★
Mymensingh	-ive	-0.01	
Patuakhali	+ive	0.10	
Rajshahi	-ive	-0.10	
Rangamati	+ive	0.07	
Rangpur	-ive	-0.21	★★
Sandwip	+ive	0.15	★
Satkhira	+ive	0.03	
Srimongal	+ive	0.10	
Teknaf	-ive	-0.02	

Station \ SST2	Relationship	Correlation	3rd Quarter (Jun - Aug)
Barisal	-ive	-0.13	★
Bhola	-ive	-0.21	★★
Bogra	-ive	-0.15	★
Chittagong	+ive	0.06	
Comilla	-ive	-0.42	★★★★
CoxsBazar	+ive	0.11	★
Dhaka	-ive	-0.22	★★
Dinajpur	-ive	-0.09	
Faridpur	-ive	-0.10	
Ishurdi	-ive	-0.11	★
Jessore	-ive	-0.02	
Khepupara	+ive	0.18	★
Khulna	+ive	0.03	
Madaripur	-ive	-0.16	★
MaijdiCourt	-ive	-0.05	
Mymensingh	-ive	-0.07	★
Patuakhali	-	0.00	★
Rajshahi	-ive	-0.32	★★★
Rangamati	+ive	0.03	
Rangpur	-ive	-0.11	★
Sandwip	+ive	0.19	★
Satkhira	+ive	0.12	★
Srimongal	-ive	-0.27	★★
Teknaf	+ive	0.42	★★★★

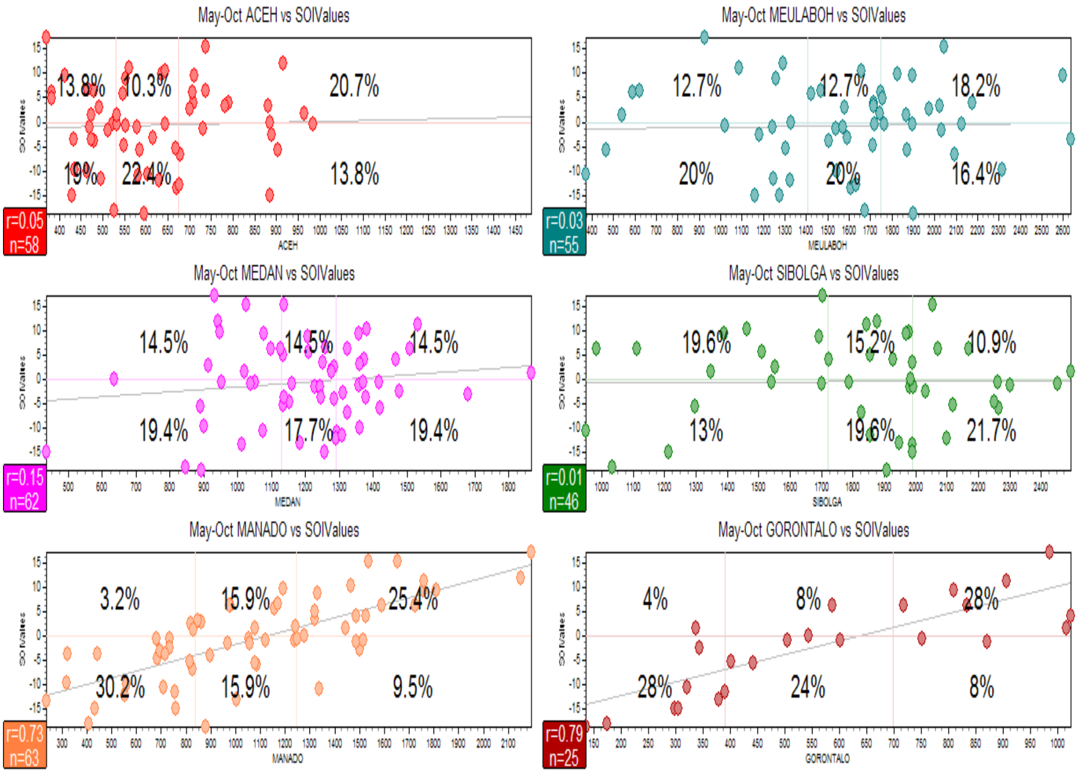
Station \ SST2	Relationship	Correlation	4th Quarter (Sep - Nov)
Barisal	-ive	-0.09	
Bhola	-ive	-0.23	★★
Bogra	-ive	-0.03	
Chittagong	+ive	0.05	
Comilla	-ive	-0.29	★★
CoxsBazar	+ive	0.07	
Dhaka	-	0.00	
Dinajpur	+ive	0.07	
Faridpur	-ive	-0.07	
Ishurdi	-ive	-0.23	★★
Jessore	+ive	0.17	★
Khepupara	+ive	0.04	
Khulna	+ive	0.19	★
Madaripur	-ive	-0.24	★★
MaijdiCourt	+ive	0.01	
Mymensingh	-ive	-0.22	★★
Patuakhali	-ive	-0.25	★★
Rajshahi	-ive	-0.07	
Rangamati	-ive	-0.02	★
Rangpur	+ive	0.13	★
Sandwip	+ive	0.07	
Satkhira	-ive	-0.07	
Srimongal	-ive	-0.11	★
Teknaf	+ive	0.25	★★

Appendix C - Detailed Results for Indonesia

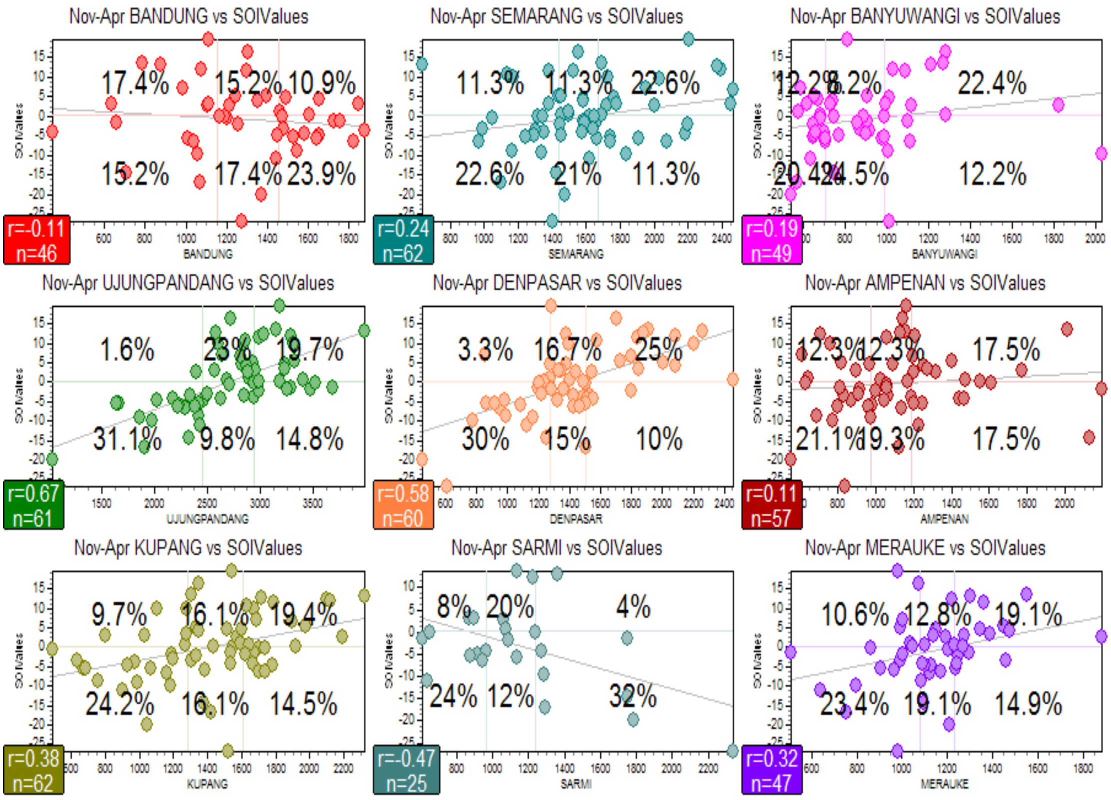
Table C1. Summary of synchronous correlation between Niño 3.4 and rainfall for different climate types in Indonesia



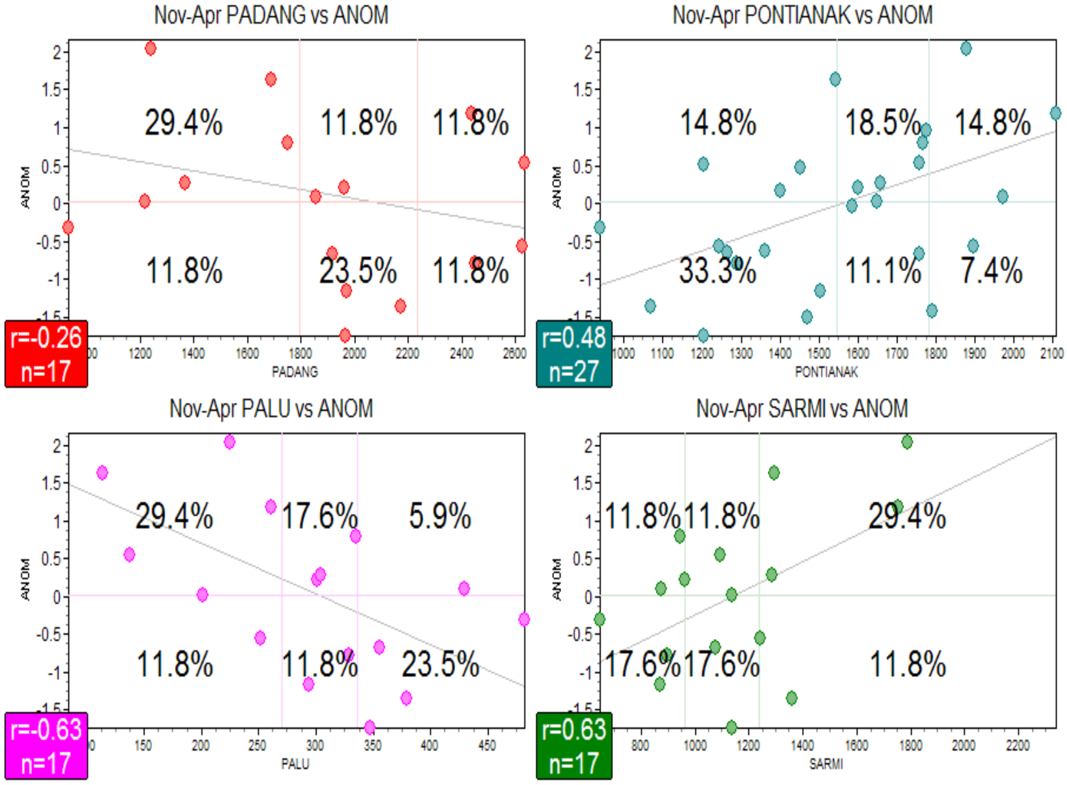
Synchronous relationships between predictands and SOI Values for the May to Oct period



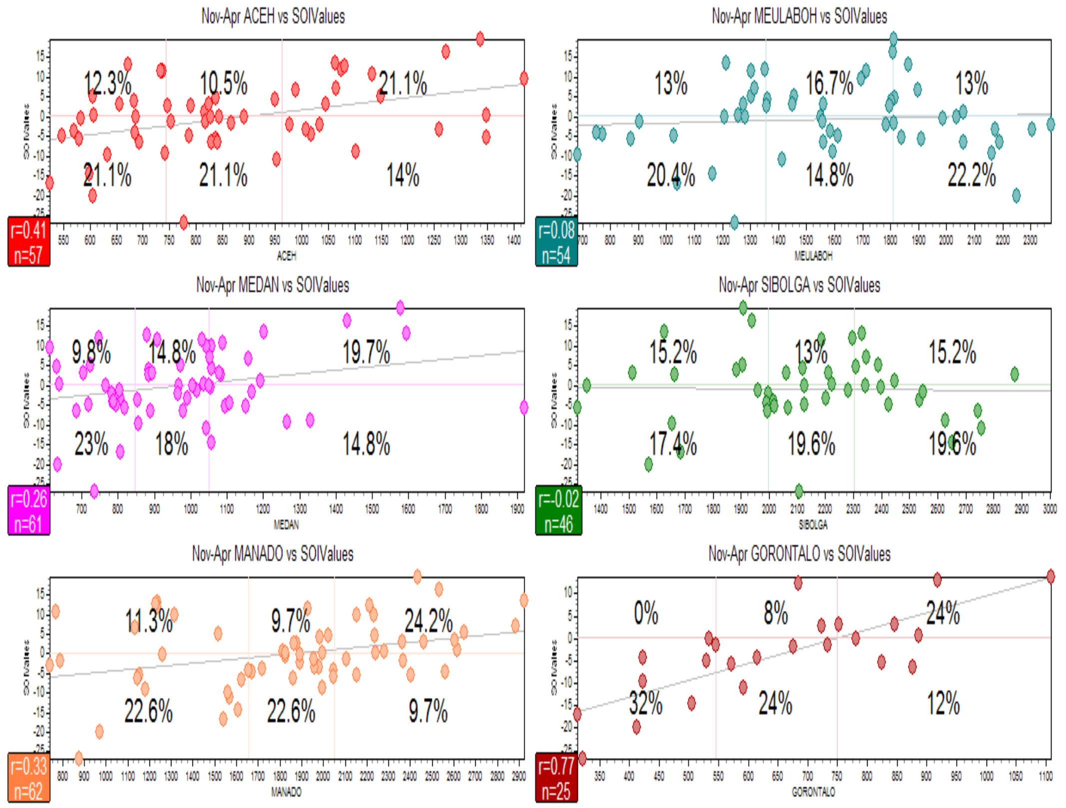
Synchronous relationships between predictands and SOI Values for the Nov to Apr period



Synchronous relationships between predictands and NINO3.4 SST Anomalies for the Nov to Apr period



Synchronous relationships between predictands and SOI Values for the Nov to Apr period



Appendix D - Conferences/Symposia/Workshops

The first workshop was help in Kuala Lumpur Malaysia from 10-13 January 2012. Twelve collaborators from Indonesia, Philippines and Bangladesh attended the workshop. The workshop agenda is attached below;

Asia-Pacific for Global Change Research Project Workshop No:1

"Building scientific capacity in Seasonal Climate Forecasting (SCF) for improved risk management decisions in a changing climate". Hotel Capitol, Kuala Lumpur, Malaysia 10 – 13 January 2012.

Monday 9th January 2012 – Participant Arrive

Tuesday 10th January 2012

9:00 – 10:00	Welcome, APN project objectives and housekeeping Dr Yahya Abawi
10:00 – 10:30	Morning Tea Break
10:30 – 12:30	Getting started with SCOPIC (software revision) – Dr Yahya Abawi
12:30 – 2:00	Lunch
2:00 – 3:00	SCOPIC Hands On (demonstration data set) – All Participants
3:00 – 3:30	Afternoon Tea Break
3:30 – 4:30	Applications of SCF (pilot projects across the Pacific) – Dr Yahya Abawi
4:30 – 5:00	Reflection on day (summary, feedback and comments)

Wednesday 11th January 2012

9:00 – 10:00	Assessing Data Quality (Browser, patching techniques etc) – DR Simon White
10:00 – 10:30	Morning Tea Break
10:30 – 11:30	Validation Study in the Pacific (example of workshop output) – Dr Yahya Abawi
11:30 – 12:30	SCOPIC Hands On (using individual country rainfall data sets) All Participants
12:30 – 2:00	Lunch
2:00 – 3:00	SCOPIC Hands On continued (defining divers of climate)
3:00 – 3:30	Afternoon Tea
3:30 – 4:30	Predicting the Onset and Duration of Monsoon – Dr Simon White
4:30 – 5:00	Reflection on day (summary, feedback and comments)

Thursday 12th January 2012

9:00 – 10:00	Partner Country Presentations- SCOPIC results- Philippines
10:00 – 10:30	Morning Tea Break
10:30 – 11:30	Partner Country Presentations- SCOPIC results - Indonesia
11:30 – 12:30	Partner Country Presentations- SCOPIC results - Bangladesh
12:30 – 2:00	Lunch Break
2:00 – 2:30	Group discussion- SCF for policy development- Indonesia
2:30 – 3:00	Group discussion- SCF for policy development- Bangladesh
3:00 – 3:30	Afternoon Tea
3:30 – 4:00	Group discussion- SCF for policy development- Philippines
4:00 – 4:30	Reflection on day (summary, feedback and comments)
4:30 – 6:00	Break before dinner
6:00 – 8:00	Workshop Dinner (with local guests)

Friday 13th January 2012

9:00 – 10:00	Hands On- Onset and Duration of Monsoon – All participants
10:00 – 10:30	Morning Tea Break
10:30 – 11:30	Report structure (APN requirements), draft report
11:30 – 2:00	Lunch Break
2:00 – 3:00	Informal Partner Country Summary Presentations (20 minutes each)
3:00 – 3:30	Afternoon Tea
3:30 – 4:30	The next step (outcomes to date and advancing pilot projects)
4:30 – 5:00	Workshop closure (results summary and outstanding issues)

The second workshop was held from 5-10 January in Lombok Indonesia. As well as participants from the first workshop, local staff from Indonesian agencies (BPTP, BMKG, UNRAM) also attended the workshop as observers.

Asia-Pacific Network for Global Change Research (APN) Project Workshop No:2

"Building scientific capacity in Seasonal Climate Forecasting (SCF) for improved risk management decisions in a changing climate". CBA2012-01CMY-Abawi

Hotel Jayakarta, Lombok. Indonesia. Jl. Raya Senggigi Km.4, January 5th - 10th , 2014

Sunday January 5th - Participants arrive

Monday January 6th, 2014: Hotel Jakarta Conference Room

9:00 – 10:00	Welcome Address Dr. Ir. Dwi Praptomo S., MS, Head of BPTP NTB APN project and workshop objectives Dr Yahya Abawi, project Leader
10:00 – 10:30	Morning Tea Break
10:30 – 12:30	Review of activities, milestones and achievements (Year 1) Dr Yahya Abawi
12:30 – 2:00	Lunch
2:00 – 3:00	Review of climate forecasting and validation study including key concepts and terminology Dr Yahya Abawi
3:00 – 3:30	Afternoon Tea Break
3:30 – 5:00	Validation Study in the Pacific (A guide for SE_Asia) -Dr Yahya Abawi Introduction to FLOWCASTand comparison with SCOPIC Dr Yahya Abawi and Mr Adi Ripaldi BMKG

Tuesday 07 January 2014: Hotel Jakarta Conference Room

9:00 – 10:00	Assembling new/updated data sets (SCOPIC/FLOWCAST)and assessing data quality (Browser) Dr Simon White
10:00 – 10:30	Morning Tea Break
10:30 – 11:30	Updating rainfall data sets and Climate Indices
11:30 – 12:30	FLOWCAST Hands On (using individual country rainfall data sets)
12:30 – 2:00	Lunch
2:00 – 3:00	FLOWCAST ...... continued (defining divers of climate)
3:00 – 3:30	Afternoon Tea
3:30 – 5:00	Predicting the Onset and Duration of Monsoon Dr Simon White

Wednesday 08 January 2014: Hotel Jakarta Conference Room

9:00 – 10:00	Validation Study (Continued) All Participants
10:00 – 10:30	Morning Tea Break
10:30 – 11:30	Validation continued – interactive session
11:30 – 12:30	Validation Continued – interactive session
12:30 – 2:00	Lunch Break
2:00 – 2:30	Validation (including onset of Monsoon) Continued
2:30 – 3:00	Validation (including onset of Monsoon) Continued
3:00 – 3:30	Afternoon Tea
3:30 – 4:00	Group discussion- policy implications of climate forecasts Identification of case studies –
4:00 – 4:30	Reflection on day (summary, feedback and comments)
6:00 – 8:00	Workshop Dinner (with local guests)

Thursday 09 January 2014: Hotel Jakarta Conference Room

9:00 – 10:00	Report structure – Draft Outline of Final report Planning activities for the remainder of the project
10:00 – 10:30	Morning Tea Break
10:30 – 11:30	Setting deadlines and allocation of tasks – All Participants
11:30 – 2:00	Lunch Break
2:00 – 3:00	Country Presentations (summary of workshop achievements) (20 minutes each)
3:00 – 3:30	Afternoon Tea
3:30 – 4:30	The next step
4:30 – 5:00	Workshop closure (results summary and outstanding issues)

Appendix E - Funding Sources outside the APN

In-kind contribution of US $ 29000 was provided through the Australian Bureau of Meteorology-AusAid for the first year of project for software development. The Indonesian Assessment Institute for Agricultural Technology (Balai Pengkajian Teknologi Pertanian- BPTP) provided US $ 8000 in-kind contribution for administrative support and logistics during the second year of the project. Professor Yahya Abawi (Ariana Consulting Engineers) made himself available as the Project Leader on a *pro-bona* basis.

Appendix F - List of Young Scientists

<u>Indonesia</u>

Name:	Adi Ripaldi (Public Climate Data and Information)
Organisation:	Meteorological, Climatological and Geophysical Agency (BMKG) Mataram
Phone:	+62 370 674134 or +62 81311168130 (mobile)
Email:	rivaldi@bmgk.go.id and rivalntb@yahoo.com

<u>Philippines</u>

Name:	Jovencia B. Ganub
Organisation:	Bohol Environment Management office, provincial,-Bohol Government
Phone:	+63(038) 501-9912
Email:	atzganub@gmail.com

Name:	Ferdie I Billones
Organisation:	Water Resources Assessment Section, National Water Resources Board (NWRB) – Philippines
Phone:	+63-2-9202724
Email:	fibillones2000@yahoo.com

<u>Bangladesh</u>

Name:	Md Abdul Mannan
Organisation:	Bangladesh Meteorology Department (BMD),
Phone:	+881 1 91177004
Email:	mannan@saarc-smrc.org

Appendix G - Glossary of Terms

ACIAR	Australian Centre for International Agricultural Research
APN	Asia Pacific Network for Global Change Research
AUSAID	Australian International Aid Agency (now DFAT)
BEMO	Bohol Environmental Management Office
BMD	Bangladesh Meteorology Department
BMKG	Badan Meteorologi, Klimatologi, Dan Geofisika, Indonesia
BPTP	Badan Litbang Pertanian, Kementerian Pertanian, Indonesia
BSMRAU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
DFAT	Department of Foreign Affairs and Trade
ENSO	El Niño Southern Oscillation
EOF	Empirical Orthogonal Functions
IOD	Indian Ocean Dipole
IPO	Inter-decadal Pacific Oscillation
ITCZ	Inter Tropical Convergence Zone
LEPS	Linear Error in Probability Space
NIA	National Irrigation Administration, Philippines
NPC	National Power Corporation, Philippines
NTB	Nusa Tenggara Barat, Indonesia
NWRB	National Water Resources Board, Philippines
MWSS	Metropolitan Waterworks and Sewerage System, Philippines
PAGASA	Philippines Geophysical and Astronomical Services Administration
RDA	Rural Development Academy, Bangladesh
SCOPIC	Seasonal Climate Outlooks in Pacific Island Countries
SOI	Southern Oscillation Index
SST	Sea Surface Temperature
SSTa	Sea Surface Temperature anomalies
UNRAM	Universitas Mataram
WRB	Water Resources Board NTB, Indonesia

Appendix H - List of Participants

Indonesia

Name: Adi Ripaldi (Public Climate Data and Information)
Organisation: Meteorological, Climatological and Geophysical Agency (BMKG) Mataram.
Phone: +62 370 674134 or +62 81311168130 (mobile)
Email: rivaldi@bmg.go.id and rivalntb@yahoo.com

Name: Ir. Surana (Senior Water Resources Engineer)
Organisation: Government Office, NTB, Mataram
Phone: +62 370 632172
Email: suranamsc@gmail.com

Philippines

Name: Jovencia B. Ganub
Organisation: Bohol Environment Management office, provincial,-Bohol Government
Phone: +63(038) 501-9912
Email: atzganub@gmail.com

Name: Ferdie I Billones
Organisation: Water Resources Assessment Section, National Water Resources Board (NWRB) –Philippines
Phone: +63-2-9202724
Email: fibillones2000@yahoo.com

Name: Edna L Juanillo
Organisation: Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)
Phone: +63-939-4593379
Email: ejuanillo@yahoo.com

Bangladesh

Name: Prof MD. Giashuddin Miah
Organisation: Bangabandhu Sheikh Mujibur Rahman Agricultural University
Phone: +880-2-9205327
Email: giash1960@gmail.com, giashbd@hotmail.com

Name: M. Abdul Matin
Organisation: Rural Development Academy
Phone: +881 7 11875715
Email: mamatin633@yahoo.com

Name: Md Abdul Mannan
Organisation: Bangladesh Meteorology Department (BMD),
Phone: +881 1 91177004
Email: mannan@saarc-smrc.org

Australia

Name: Prof Yahya Abawi
Organisation: Ariana Consulting Engineers
Phone: +61 467001 656
Email: Yahya.abawi@usq.edu.au

Name: Dr Simon White
Organisation: University of Southern Queensland
Phone: + 61 455988302
Email: scwhite78@icloud.com

Appendix I - Introductory Workshop Slides

APN CAPaBLE

Introduction to Empirical Models Including Relevant Statistical Concepts

Professor Yahya Abawi

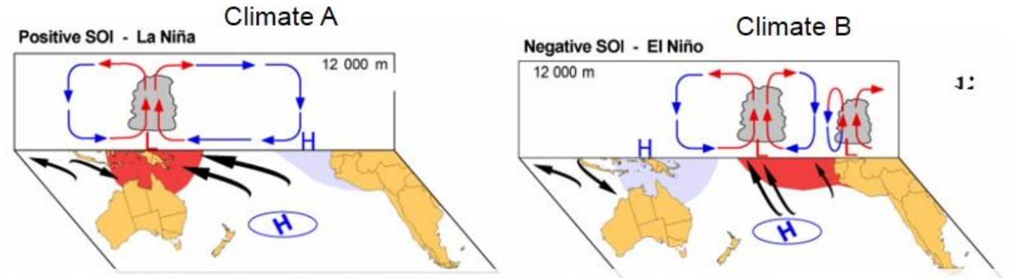
"Building scientific capacity in Seasonal Climate Forecasting (SCF) for improved risk management decisions in a changing climate"
Project: CBA2012-01CMY-Abawi

Types of Climate Models

Climate models fall into two broad categories with regard to the degree to which the models consider physical processes.

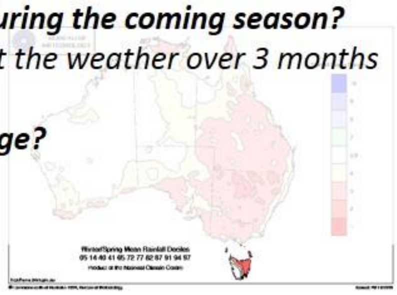
Empirical models: Models that do not embody all the salient physical mechanisms (either not known or not known in sufficient detail to be used). These models employs a convenient but logical framework in order to correlate predictor and predicted variables. Use past observed relationships between slowly varying climate phenomena (such as ocean temperature patterns, e.g., the El Niño) and rainfall, temperature, stream-flows, crop use. History is our guide.
Dynamical models: *Models that specify accurately and explicitly the relationships between climate components and processes. In a such a way that the model quantitatively describe the fluxes of energy, mass and momentum.* Physics is our guide.

How is Climate Prediction Possible?



Imagine you're a farmer in NE Australia and you want to know;

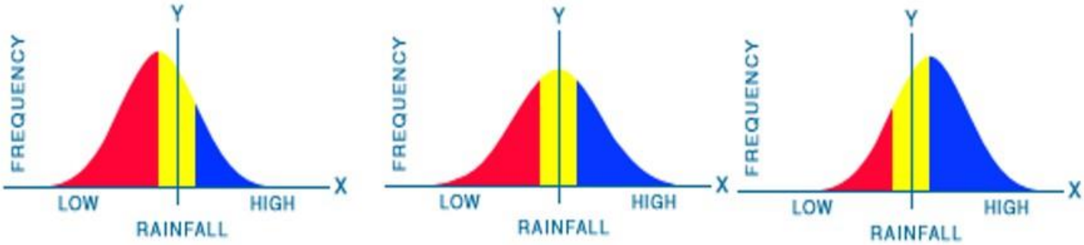
1) ***Precisely, how much rain will you receive during the coming season?***
   Don't know. . Science still cannot predict the weather over 3 months with accuracy.
2) ***Is the season likely to be wetter than average?***
   Very likely if Climate A – the La Niña.
   Very unlikely if Climate B – the El Niño



This is a very simple climate forecast

Empirical Forecasts

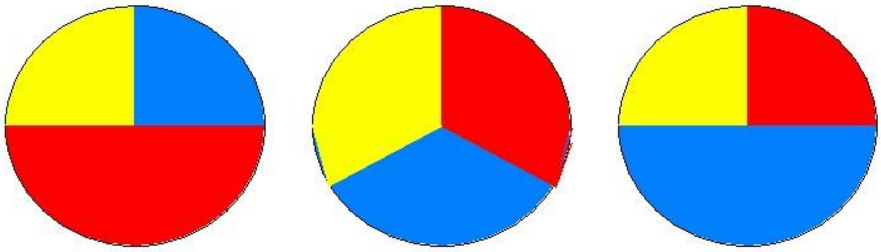
Use the past as a guide to the future.
For a particular location the seasonal rainfall distribution curves may look like:



July SOI < -5 (El Niño) | -5 < July SOI < +5 | July SOI > +5 La Niña

Usually receive low rainfall during El Niño events.

The Rainfall "Chocolate Wheel"

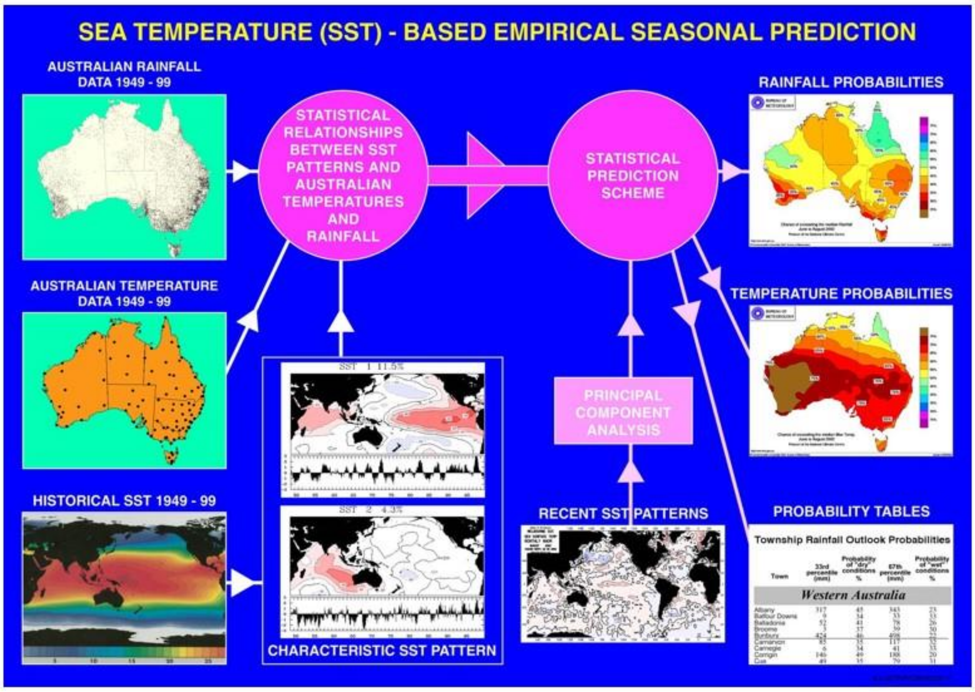


July SOI < -5   -5 < July SOI < +5   July SOI > +5

For this location, if July SOI < -5 , then there is
a 50% chance of receiving "below normal" rainfall,
a 25% chance of "normal" rainfall, and a 25% chance of "higher than normal" rainfall

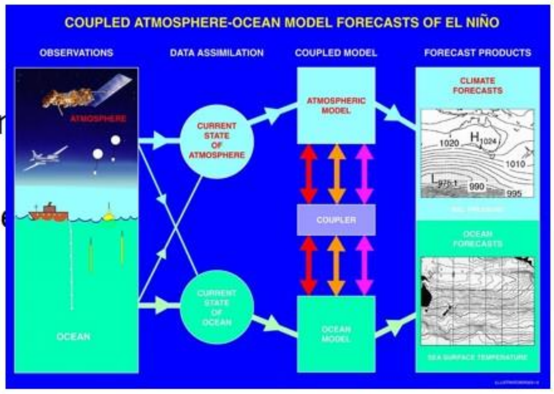
But the wheel must still be spun!

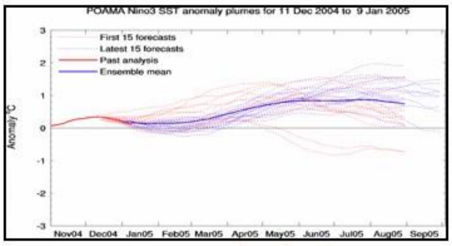
How is Statistical Models Developed ?



Dynamical – Coupled Model - Seasonal Prediction

- Use physical equations to project the climate forwards i time.
- Models do not know about th past; hence they can predict new situations, cope with climate change etc.
- Forecast are still probabilistic, however.
- Require very expensive super computers.





Current Forecast for El Niño

Common Techniques used in Statistical Models

Correlation Analysis
Regression Analysis
Principal Component Analysis
Cluster Analysis
Discriminant Analysis
Analogue method (Stratification)
Time Series Analysis (ARIMA)

Correlation

Correlation is the statistical measure that quantifies the linear relationship between two variables . The sample correlation coefficient (r) between X and Y is :

$$r = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2 \sum_{i=1}^{N}(y_i - \bar{y})^2}}$$

Correlation & Cause

Correlation means that two variables have some type of association with each other, such that as one variable increases, the other also increases, or decreases. But it *does not* mean that one of the variables is the cause of the other.

Example:

It has been argued that there is a high correlation between the increase in **juvenile delinquency** and the *increase in the* **divorce rate** in recent years. This may be so. This does not, however, indicate that the increase in the divorce rate has caused the increase in juvenile delinquency.

Coefficient of Determination r^2

The *coefficient of determination*

gives the proportion of the fluctuation of one variable that is predictable from the other variable. In other words it is the ratio of the explained variation to the total variation.

ranges from $0 \leq r^2 \leq 1$, and denotes the strength of the linear association between *x* and *y*.

If $r = 0.922$, then $r^2 = 0.850$, 85% of the total variation in *y* can be explained by the linear relationship between *x* and *y.*

Regression

Simple Linear Regression and Multiple Linear Regression models

Regression is an extension of correlation analysis that will predict the value of one variable (the dependent variable) based on the values of one or more predictor or 'independent' variables.

$$y = \alpha + \beta x + \varepsilon$$

where: y is the predicted value of the dependent variable
α is the intercept
β is the slope of the line
x is the value of the independent variable
ε is the error or "noise" reflecting other terms that influence the value of dependent variable

Stepwise Linear Regression

Forward Selection: In this procedure, only the best potential predictors that improves the model the most, are examined individually and added into the model equation, starting with the one that explains the highest variance, etc.

Backward Elimination: The regression model starts with all potential predictors and at each step of model construction, the least important predictor is removed until only the best predictors remain.

A stopping criteria should be selected in both cases.

Two Common Statistical Problems in Regression Analysis

Omitted Variables

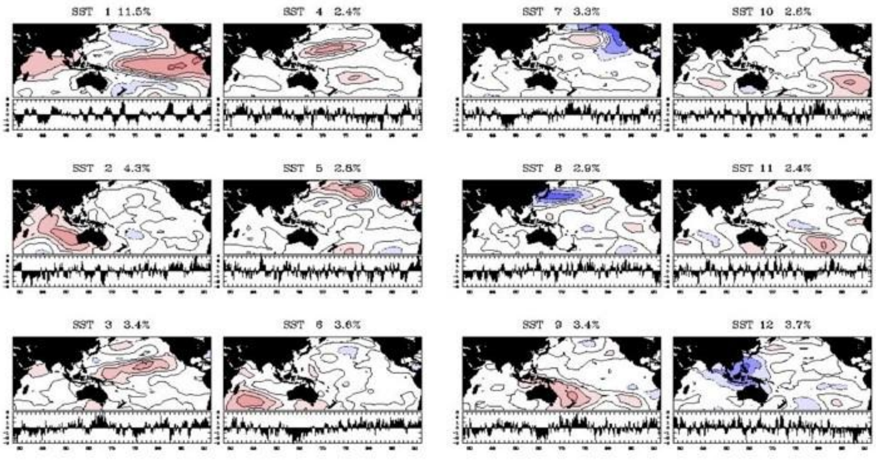
The omission from a regression of some variables that affect the dependent variable may violate the assumption necessary for the minimum SSE criterion to be unbiased estimator. The noise term is assumed to have expected value of zero.

Multicollinearity

Increases the SSE and thus reduces the degree of confidence in the model. The problem arises when two or more independent variables are closely correlated (e.g. SOI and SST).

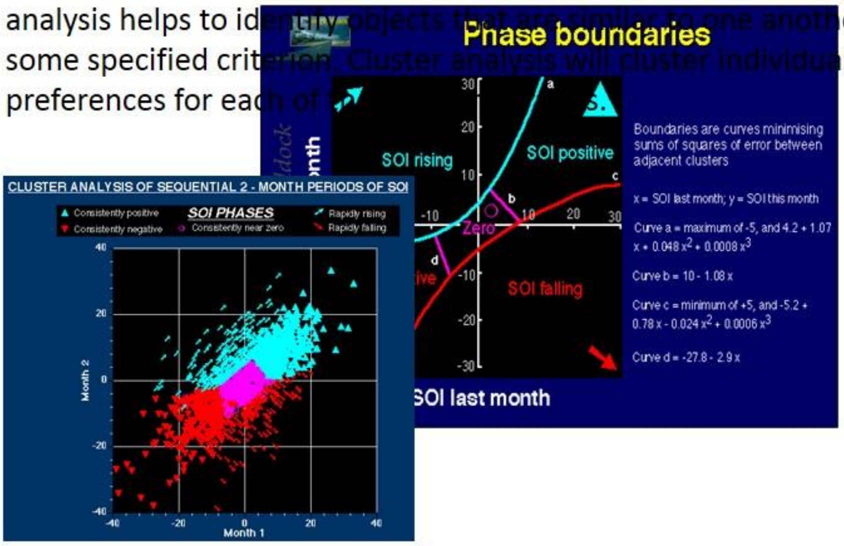
Principal Component Analysis

Factor analysis helps to reduce a vast number of variables to a meaningful, interpretable, and manageable set of factors. A principle component analyses transform all the variables into a set of composite variables that are not correlated to one another..



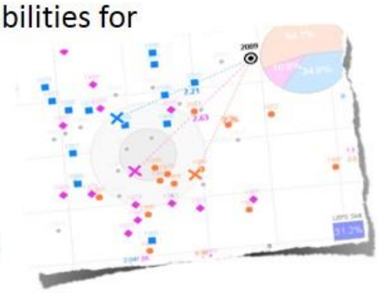
Cluster Analysis

The cluster analysis is used to classify objects or individuals into mutually exclusive and collectively exhaustive groups with high homogeneity within clusters and low homogeneity between clusters. In other words cluster analysis helps to identify objects that are similar to one another, based on some specified criterion. Cluster analysis will cluster individuals by their preferences for each of



Discriminant Analysis

Discriminant analysis helps to identify the independent variables that discriminate a nominally scaled dependent variable of interest. **Discriminant analysis** classifies a set of observations into predefined classes. We can use it to calculate probabilities for these classes for a particular condition



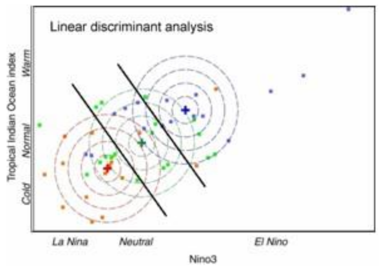
Two Approaches

Class-dependent transformation:

Maximise ratio between class variance to within class variance.

Class-independent transformation:

maximise the ratio of overall variance to within class variance. Each class is considered as a separate class against all others



Baye's Theorem

Used for calculating conditional probabilities for classes defined during discriminant analysis.

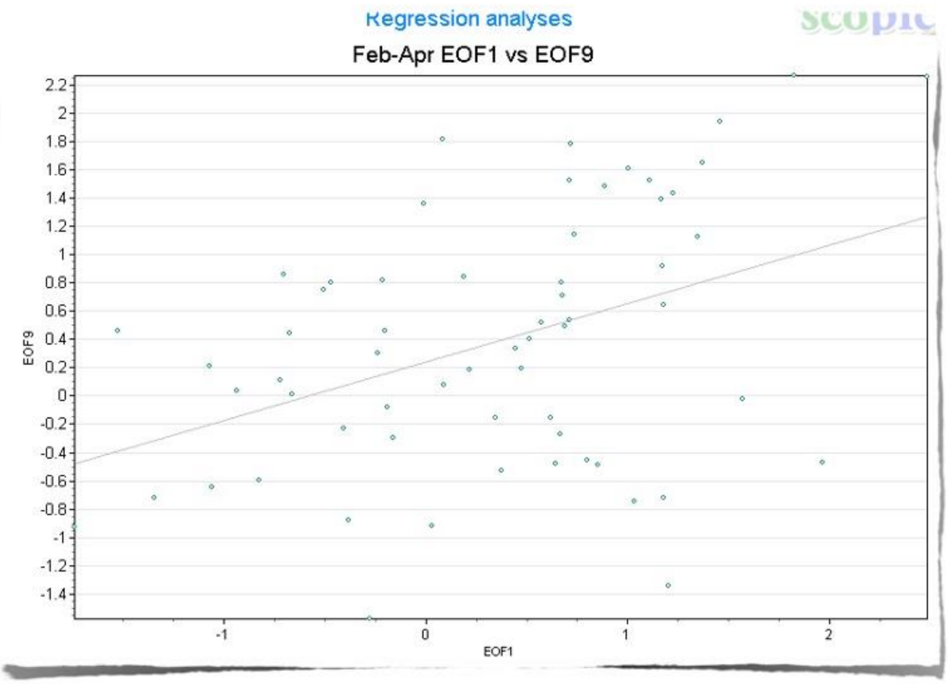
- X = predictor (SSTs or SOI)
- *Y* = predictand (rainfall or temperature)
- Use historical data (e.g. 1950-1999) to devise statistical models (normal or multi-variate normal) for
  - **X** | *Y* above median
  - **X** | *Y* below median
- Use Bayes' theorem to invert the conditionality
  - Pr(*Y* below median | **X** = **x**) = $\rho_1(\mathbf{x}) / (\rho_1(\mathbf{x}) + \rho_2(\mathbf{x}))$
  - Pr(*Y* above median | **X** = **x**) = $\rho_2(\mathbf{x}) / (\rho_1(\mathbf{x}) + \rho_2(\mathbf{x}))$
- Use Linear Discriminant Analysis to calculate forecast probabilities at stations

Steps in Linear Discriminant Analysis

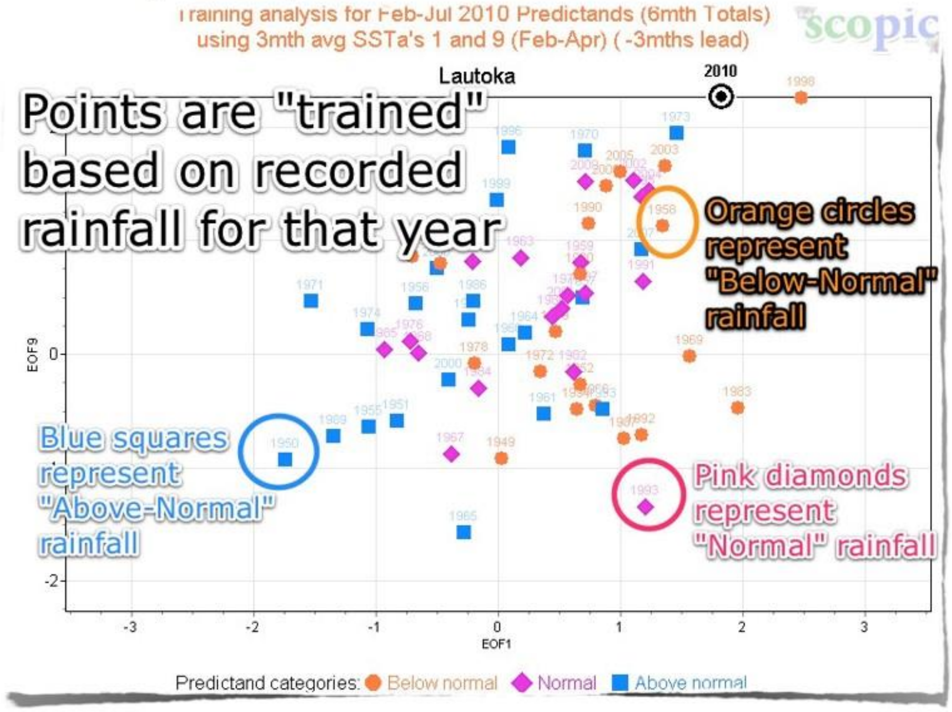
*Consider **a tercile rainfall outlook** using **SSTa1&9** as the predictive system...*

1. SSTa1 is plotted against SSTa9 (i.e. *scatter-plot*)
2. SSTa's are "trained" based on whether rainfall is below-normal, normal, or above-normal.
3. Means of each "trained" tercile group are calculated.
4. Variance and covariance of each tercile group are calculated in each direction... i.e. two variances for **each** group- one for SSTa1 and one for SSTa9
5. The tercile group variances are POOLED (averaged) to calculate the **pooled variances** (*one for SSTa1 and one for SSTa9, and the covariance*).
6. The **distances** from the current conditions to the tercile group means are calculated (*three distances, one for each group*).
7. Bayes' theorem is then used to calculate the probabilities based on a non-linear combination of the **distances** to the means and the **pooled variances**

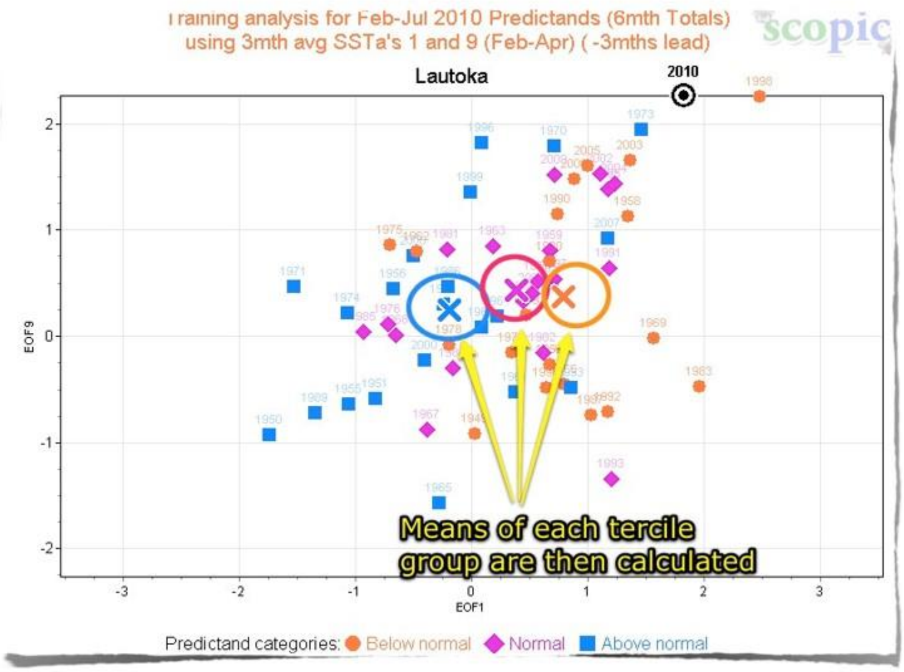
1. SSTa1 is plotted against SSTa9 (i.e. *scatter-plot*)



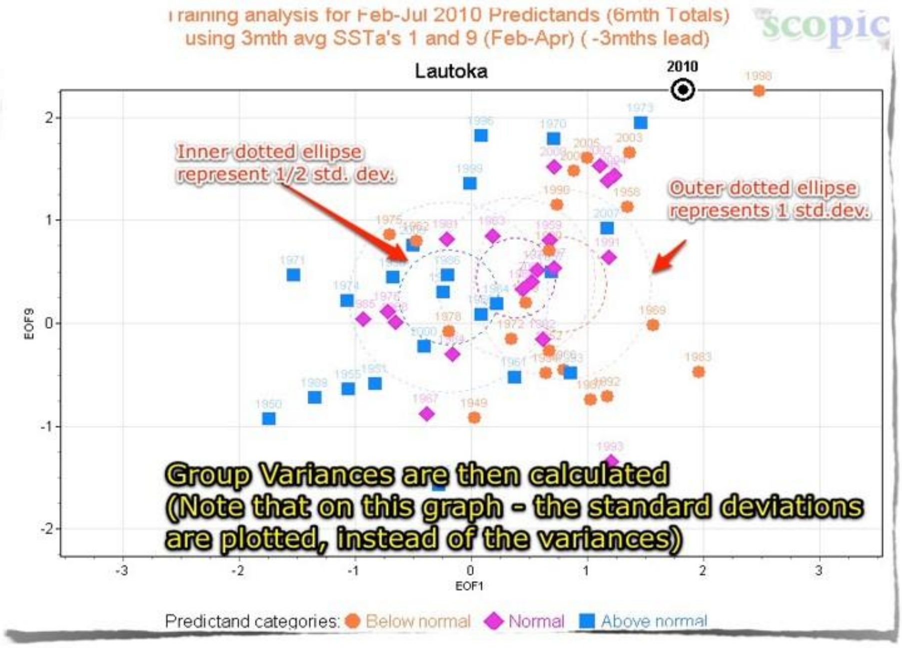
2. SSTas are “trained” based on whether rainfall is below-normal, normal, or above-normal.



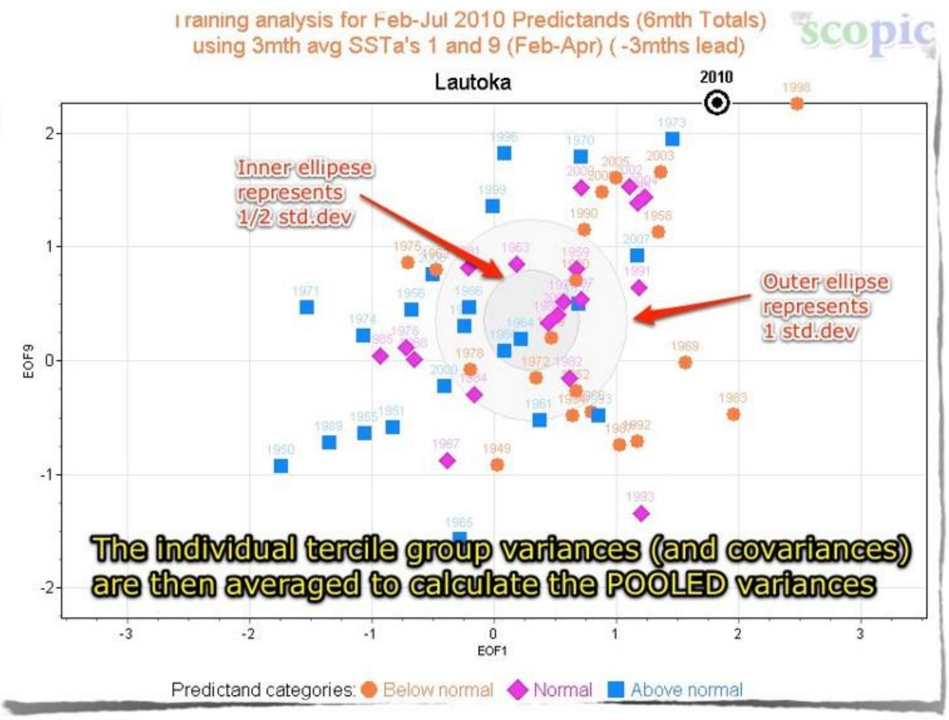
3. Means of each “trained” tercile group are calculated.



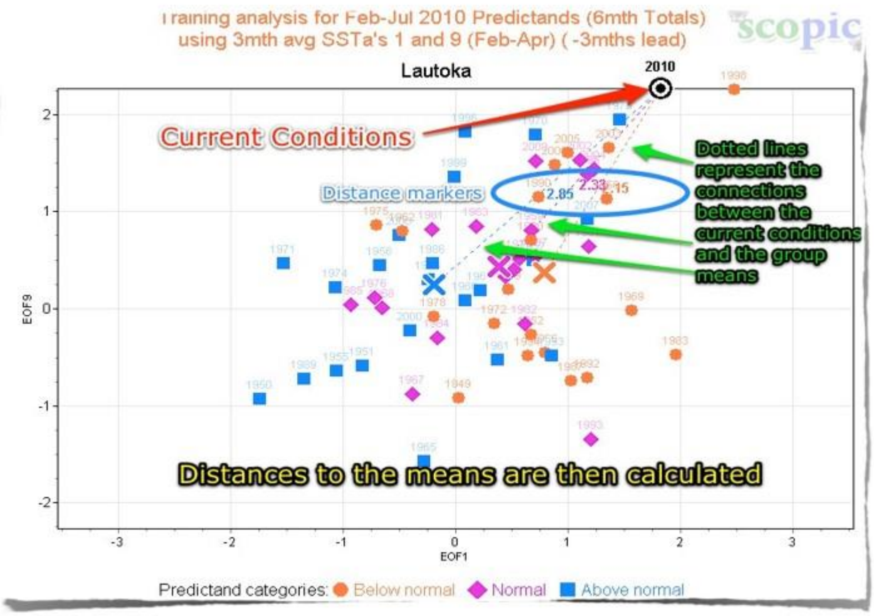
4. Variance and covariance of each tercile group are calculated in each direction.



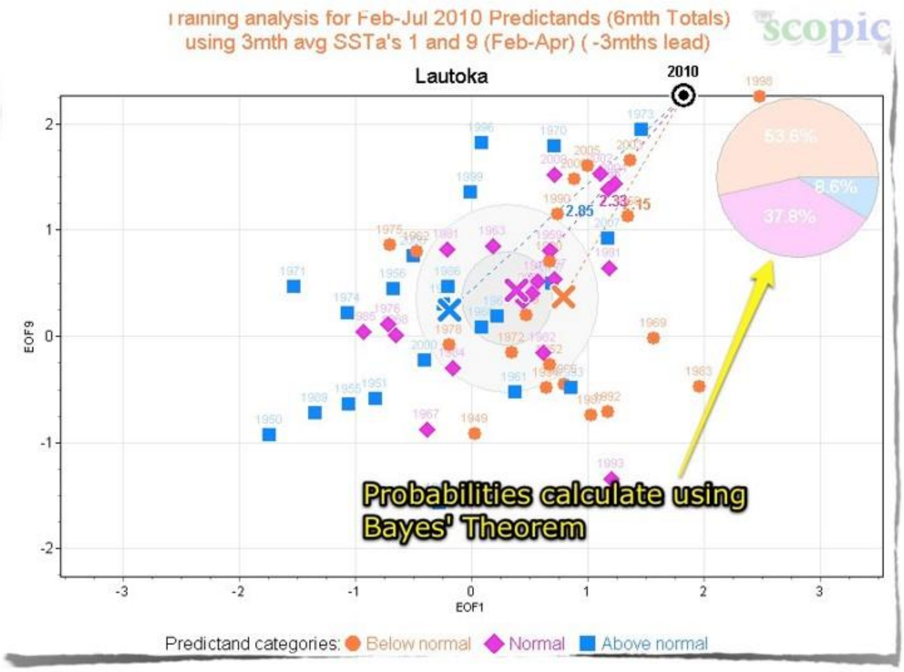
5. The tercile group variances are POOLED (averaged) to calculate the *pooled variance*



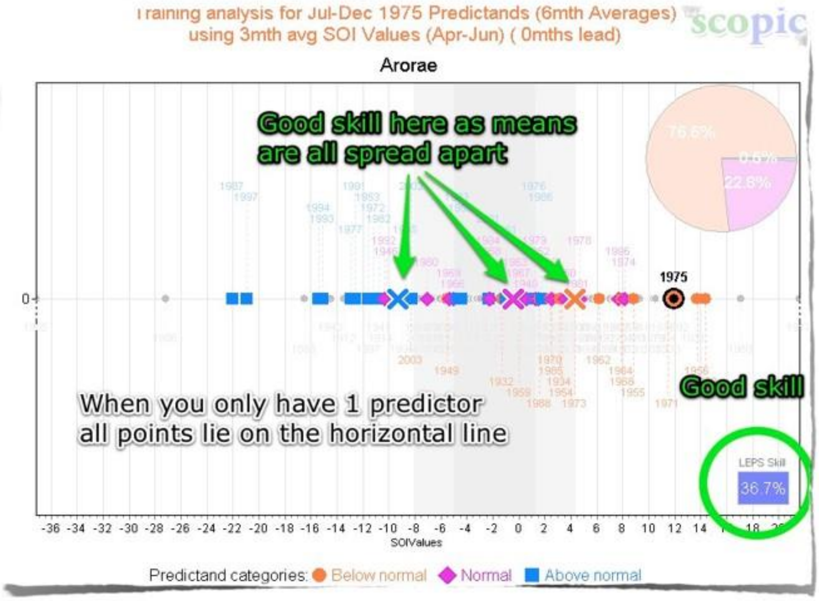
6. The *distances* from the current conditions to each tercile group mean are calculated



7. Probabilities are then calculated using Bayes' Theorem.



Example with one predictor (SOI)



Stratified Climatology Techniques

Climatological probability

- 100 years data; in 25 years, > 100 mm received
- Pr(X > 100 mm) = 0.25
- Pr(X > median) = 0.5

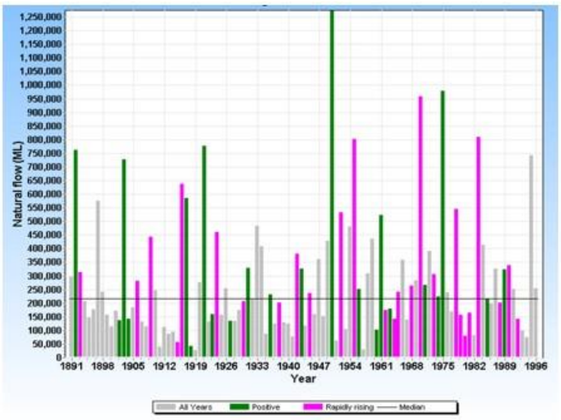
Conditional probability

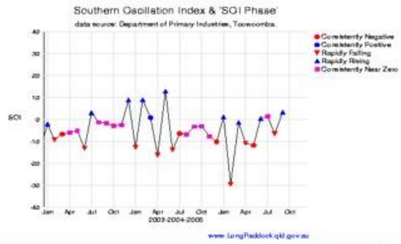
- 40 years with SOI > +4.0; in 20 years > 100 mm received, in 24 years > median
- Pr(X > 100 mm) = 20/40 = 0.50
- Pr (X > climatological median) = 24/40 = 0.60

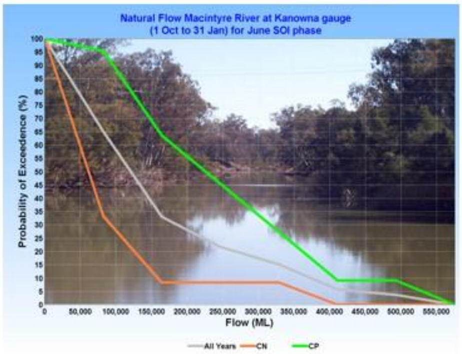
The Analogue Method

Stratified climatology technique where the set of years in the cluster/category varies with the predictor

Need large samples – At least 20 per category







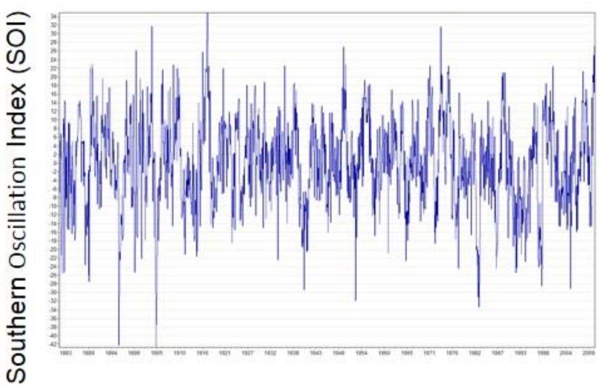
Time Series Analysis

Time series analysis is used to define (understand) the structure (e.g. autocorrelation, trend or seasonal variation) in the observed data. Fit a model and proceeds to forecasting....

Identification phase

Parameter estimation

Model Evaluation



Time Series Analysis

Identifying patterns in time series

Most time series data consists of systematic pattern and random noise. One approach to modelling time series is to decompose the time series into trend, seasonal and residual component

Assumptions

Stationarity

Mean, variance, and autocorrelation should be approximately constant through time.

Non-Seasonality

Periodic fluctuation in time series data. If present must be incorporated in to time series model

Time Series Analysis

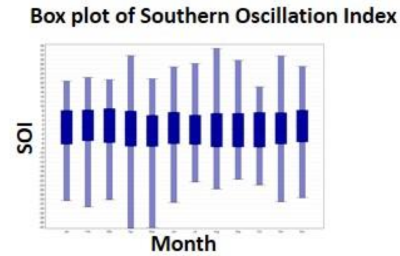
Transformation to achieve Stationarity

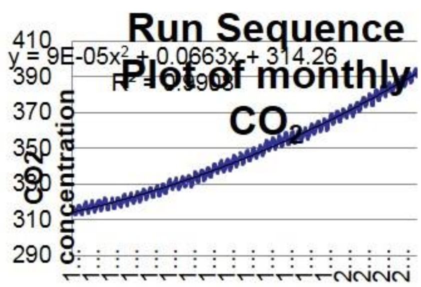
Differencing. Create a new series by lagging the original time series by one or more time period.

Trend Analysis. If data contain a trend, remove by fitting a linear line through the data and then model the residuals from that fit

Non Constant Variance. Transform the data using a log or square root tranformation

Seasonality. A run sequence plot, Box Plot or Autocorrelation Plot can help identify seasonality

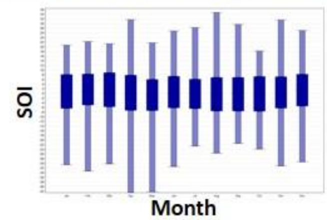




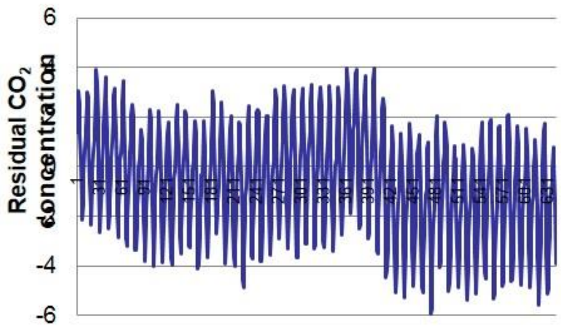
Time Series Analysis

Transformation to achieve Stationarity

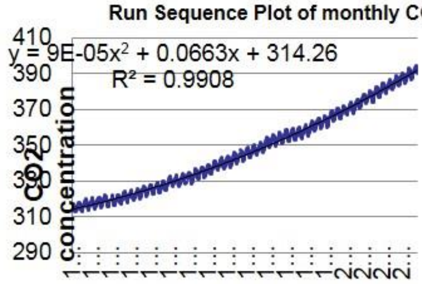
Box plot of Southern Oscillation Index



Detrended CO_2 concentration



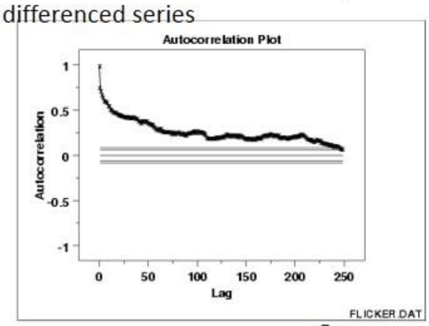
Run Sequence Plot of monthly CO_2



Autocorrelation Plot

Autocorrelation plots at varying time lags are used to check for randomness in a data set. If random, the AC should be near zero for all time lags. If non-random , then one or more of the AC will be significantly non-zero.

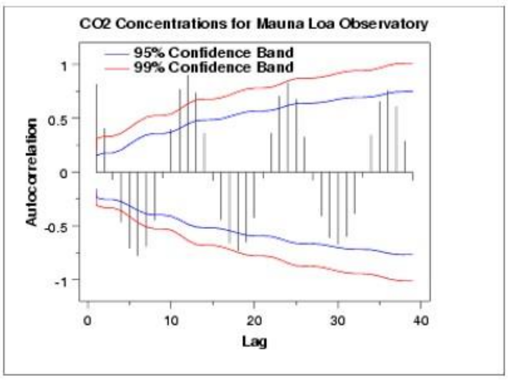
ACF and PACF plots: After a time series has been stationarized by differencing, the next step in fitting an ARIMA model is to determine whether AR or MA terms are needed to correct any autocorrelation that remains in the differenced series



$$Autocorrelation\ coefficient\ R_h = {}^{C_h}/_{C_0}$$

$$Autocovariance\ Function\ C_h = \frac{1}{N}\sum_{i=1}^{N-h}(Y_i - \overline{Y})(Y_{i+h} - \overline{Y})$$

$$Variance\ Function\ C_0 = \frac{1}{N}\sum_{i=1}^{N}(Y_i - \overline{Y})^2$$



ARIMA- Autoregressive Integrated Moving Average

Autoregressive process. Most time series have serially dependent elements. We can estimate a coefficient or a set of coefficients that describe consecutive elements of the series from specific, time-lagged (previous) elements

$$X_t = \alpha + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \beta_3 X_{t-3} + \varepsilon$$

Moving average process. Independent from the autoregressive process, each element in the series can also be affected by the past error that cannot be accounted for by the autoregressive component, that is:

$$X_t = \mu + \varepsilon_t - \phi_1 \varepsilon_{t-1} - \phi_2 \varepsilon_{t-2} - \phi_3 \varepsilon_{t-3} - \cdots$$

Model Identification

(Based on the Shape of the Autocorrelation Function)

SHAPE	INDICATED MODEL
Exponential, decaying to zero	Autoregressive model. Use the partial autocorrelation plot to identify the order of the autoregressive model
Alternating positive and negative, decaying to zero	Autoregressive model. Use the partial autocorrelation plot to help identify the order
One or more spikes, rest are essentially zero	Moving average model, order identified by where plot becomes zero
Decay, starting after a few lags	Mixed autoregressive and moving average model
All zero or close to zero	Data is essentially random
High values at fixed intervals	Include seasonal autoregressive term
No decay to zero	Series is not stationary

Constraints and Limitations of statistical forecasts

Statistical forecast schemes typically assume a "stationary" climate

- interannual variability of training period captures the expected range of outcomes
- can be invalidated by climate change
- most seasonal predictability comes from the tropics (e.g., ENSO)
- predictability is modest and generally explains less than half the variance

- Predictability is greater over longer periods (e.g. 3 months versus 1 month, 2 months), but longer periods less useful
- Predictability drops off rapidly with increased lead time

Basics of forecast verification

Professor Yahya Abawi

"Building scientific capacity in Seasonal Climate Forecasting (SCF) for improved risk management decisions in a changing climate"
Project: CBA2012-01CMY-Abawi

What is forecast verification?

If we take the term *forecast* to mean a prediction of the *future state* (of a variable) then the *forecast verification* is the process of assessing the quality of a forecast.

The forecast is compared, or *verified,* against a corresponding observation of what actually occurred. The verification can be qualitative or quantitative. In either case it gives information about the nature of the forecast errors.

Why verify?

A forecast is like an experiment. We make a hypothesis that a certain outcome will occur. The experiment is not compete until we know the outcome. In the same way a forecast experiment is not complete until we know if the forecast was successful.

What makes a forecast "good"?

Murphy 1993 suggests three types of "goodness".

Consistency. The degree to which the forecast corresponds to the forecasters best judgment about the situation.

Quality. The degree to which the forecast corresponds to what actually happened.

Value. The degree to which the forecast helps a decision maker to realise some benefit from the forecast

Forecast Quality

Key attributes that contribute to forecast quality inlude;

Bias. The correspondence between the mean forecast and mean observation

Accuracy. The level of agreement between the forecast and the observation

Skill. The relative accuracy of the forecast over some *reference* forecast

Reliability. The average agreement between the forecast values and the observed values

Resolution. The ability of the forecast to resolve the set of events into subsets with different frequency distributions

Sharpness. The tendency of forecast to predict extreme values. A forecast of climatology has no sharpness

Discrimination. Ability of the forecast to discriminate amongst observations. Having a higher prediction frequency of an outcome whenever that outcome occurs

Uncertainty. The variability of the observation. The greater the uncertainty, the more difficult to forecast.

Standard Verification Methods

- Methods for Dichotomous Forecasts
- Methods for Multi-Category Forecasts
- Methods for Continuous Variables
- Methods for Probabilistic Forecasts
- Methods for Spatial Forecast
- Methods for Object based Diagnostic Evaluation

Types of Forecasts and Verifications

Nature of Forecast	Examples	Verification Methods
Deterministic	Quantitative precipitation forecast	Visual, Dichotomous, Multi-Category, Continuous, Spatial
Probabilistic	Probability of precipitation, Ensemble Forecast	Visual, Probabilistic, Ensemble
Qualitative	3 day outlook	Visual, Dichotomous, Multi-Category
Space-time Domain		
Time series	Daily maximum temperature	Visual, Dichotomous, Multi-Category, Continuous, Probabilistic
Spatial Distribution	Map of geopotential height	Visual, Dichotomous, Multi-Category, Continuous, Spatial, Probabilistic
Pooled Space and Time	Monthly average global temperature anomaly	Dichotomous, Multi-Category, Continuous, Probabilistic, Ensemble
Specificity of Forecasts		
Dichotomous	Occurrence of fog	Visual, Dichotomous, Probabilistic, ensemble, Spatial
Multi-category	Cold, normal or warm condition	Visual, Multi-Category, Probabilistic, ensemble, Spatial
Continuous	Temperature	Visual, Ensemble, Probabilistic, Continuous, Spatial
Event Based	Tropical cyclone motion and intensity	Visual, Dichotomous, Multi-Category, Continuous, Spatial

Methods for Dichotomous Forecasts

Contingency Table					
		Observed			
		Tornado	No Tornado	Total	
Forecast	Tornado	28 (hits)	72 (false alarms)	100	
	No Tornado	23 (misses)	2680 (correct negatives)	2703	
	Total	51 (observed yes)	2752 (observed no)	2803	

Finley 1884 Tornado Forecast

Contingency Table					
		Observed			
		Tornado	No Tornado	Total	
Forecast	Tornado	28 (hits)	72 (false alarms)	100	
	No Tornado	23 (misses)	2680 (correct negatives)	2703	
	Total	51 (observed yes)	2752 (observed no)	2803	

What fraction of the forecast was correct (accuracy)?

$$Accuracy = \frac{hits + correct\ nagatives}{total} = \frac{28 + 2680}{2803} = 0.966$$

What fraction of the tornados (observed yes) were correctly forecast?

$$Hit\ rate\ (POD) = \frac{hits}{hits + misses} = \frac{28}{28 + 23} = 0.55$$

Heidke Skill Score (Cohen's k)

Contingency Table

		Observed		
		Tornado	No Tornado	Total
Forecast	Tornado	28 (hits)	72 (false alarms)	100
	No Tornado	23 (misses)	2680 (correct negatives)	2703
	Total	51 (observed yes)	2752 (observed no)	2803

What was the accuracy of forecast relative to random chance?

$$HSS = \frac{R - E_{random}}{T - E_{random}}$$

R = Total number of correct forecasts

T = Total number of forecasts

E_{random} = Expected number of correct forecasts due purely to random chance

HSS (Finley's tornado) = 0.36 i.e. there was a 36% improvement in forecast accuracy compared to random chance

Heidke Skill Score

$$HSS = \frac{(A_{11} + A_{22} + A_{33}) - \frac{JM + KN + LO}{T}}{T - \frac{JM + KN + LO}{T}}$$

Forecast Category

	Above-Normal	Near-Normal	Below -Normal	**Total**
Above-Normal	A_{11}	A_{12}	A_{13}	**J**
Near-Normal	A_{21}	A_{22}	A_{23}	**K**
Below-Normal	A_{31}	A_{32}	A_{33}	**L**
Total	**M**	**N**	**O**	**T**

Contingency Table

		Observed		
		Tornado	No Tornado	Total
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	Total	51 (observed yes)	2752 (observed no)	2803

What if we always forecast no tornados? what would be the accuracy?

What will be the problem with forecast?

Contingency Table

		Observed		
		Tornado	No Tornado	Total
Forecast	Tornado	28 (hits)	72 (false alarms)	100
	No Tornado	23 (misses)	2680 (correct negatives)	2703
	Total	51 (observed yes)	2752 (observed no)	2803

What if we always forecast no tornados? what would be the accuracy? {Answer = 0.982}

What will be the problem with this forecast? {Answer = Probability of detecting a tornado (hit rate) will become zero)

Contingency Table				
		Observed		
Forecast		Tornado	No Tornado	Total
	Tornado	28 (hits)	72 (false alarms)	100
	No Tornado	23 (misses)	2680 (correct negatives)	2703
	Total	51 (observed yes)	2752 (observed no)	2803

What is the forecast bias? Ratio of *forecast yes* to *observed yes*.

$$Bias = \frac{hits + false\ alarms}{hits + misses} = \frac{28 + 72}{28 + 23} = 1.96$$

Bias > 1 tendency to over-forecast;
Bias < 1 tendency to under forecast.
(0 ~ ∞; Perfect score is 1).
Tornados were forecast almost twice as often as they occurred

Contingency Table				
		Observed		
Forecast		Tornado	No Tornado	Total
	Tornado	28 (hits)	72 (false alarms)	100
	No Tornado	23 (misses)	2680 (correct negatives)	2703
	Total	51 (observed yes)	2752 (observed no)	2803

What fraction of the predicted events did not actually occur?

$$FAR = \frac{false\ alarms}{hits + false\ alarms} = \frac{72}{28 + 72} = 0.72$$

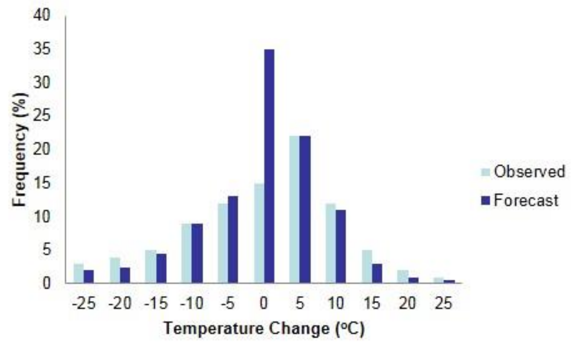
72% of the forecast tornados turned out to be false alarms?

Methods for Multi-Category Forecasts

	Multi-category Contingency Table					
	Observed Category					Total
Forecast Category	i,j	1	2	.....	K	
	1	$n(F_1,O_1)$	$n(F_1,O_2)$	.....	$n(F_1,O_K)$	$N(F_1)$
	2	$n(F_2,O_1)$	$n(F_2,O_2)$	.....	$n(F_2,O_K)$	$N(F_2)$
	......	.....	.....	.....	.....	.....
	K	$n(F_K,O_1)$	$n(F_K,O_2)$	.....	$n(F_K,O_K)$	$N(F_K)$
	Total	$N(O_1)$	$N(O_2)$	.....	$N(O_K)$	N

Histograms

How well did the distribution of forecast category correspond to the distribution of observed category?



Methods for Multi-Category Forecasts

What fraction of the forecasts were in the correct category (Range 0 to 1). Can be misleading as can be influenced by the most common category. Heidke Skill Score

$$Accuracy = \frac{1}{N}\sum_{i=1}^{K} n(F_i, O_i)$$

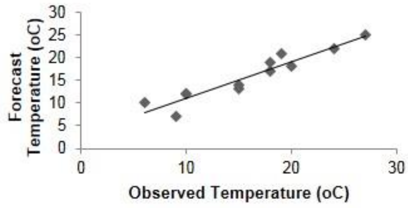
What was the accuracy of the forecast in predicting the correct category, relative to random chance (Range -∞ to 1 ; 0 no skill). Heidke Skill Score

$$HSS = \frac{\frac{1}{N}\sum_{i=1}^{K} n(F_i, O_i) - \frac{1}{N^2}\sum_{i=1}^{K} N(F_i)N(O_i)}{1 - \frac{1}{N^2}\sum_{i=1}^{K} N(F_i)N(O_i)}$$

Methods for forecasts of continuous variables

$$Bias = \frac{\frac{1}{N}\sum_{i=1}^{N} F_i}{\frac{1}{N}\sum_{i=1}^{N} O_i}$$

How does the average forecast magnitude compare to average observed magnitude = 0.994



$$Mean\ Error = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)$$

What is the average forecast error= 0.08 °C
Possible to get perfect score for a bad forecast due to compensating errors

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|(F_i - O_i)|$$

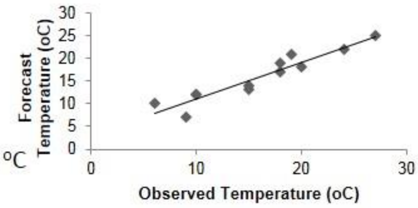
Mean Absolute Error = 1.91 °C
Does not indicate the direction of the deviation

	observed Temp (oC)	Forecast Temp (oC)
1	27	25
2	18	19
3	15	14
4	6	10
5	9	7
6	20	18
7	10	12
8	15	13
9	24	22
10	19	21
11	18	17
12	10	12

Methods for forecasts of continuous variables

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2}$$

What is the average magnitude of forecast error=2.06 °C



$$MSE = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2$$

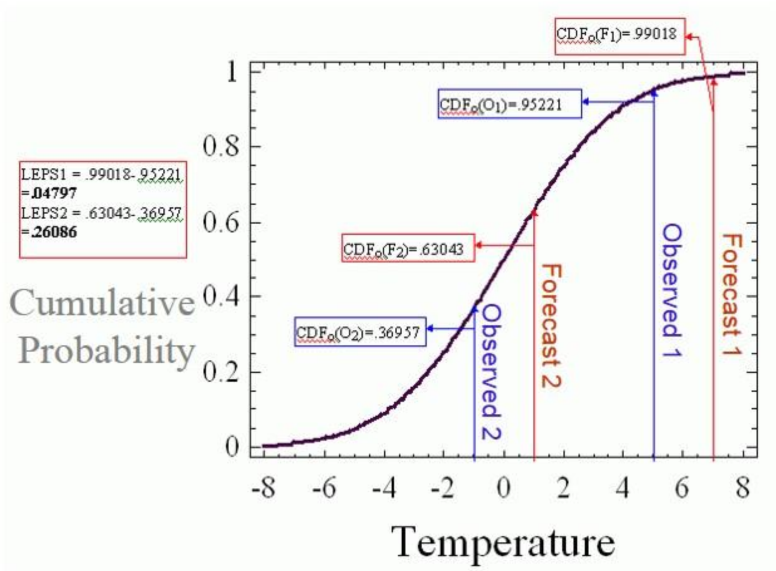
Mean Square Error= 4.25 $°C^2$

	observed Temp (oC)	Forecast Temp (oC)
1	27	25
2	18	19
3	15	14
4	6	10
5	9	7
6	20	18
7	10	12
8	15	13
9	24	22
10	19	21
11	18	17
12	10	12

Linear Error in Probability Space (LEPS)

- Measures the Error in probability space as opposed to measurement space.
- Does not discourage forecasting extreme values if they are warranted.
- Measures the accuracy of one set of forecasts compared to climatology

Linear Error in Probability Space (LEPS)



Penalty weighting…
"Non-LEPS" tercile category weights

	Forecasts		
Observations	Above	Normal	Below
Above	1.0	0	-1.0
Normal	0	1.0	0
Below	-1.0	0	1.0

Penalty weighting…
"LEPS" tercile category weights

	Forecasts		
Observations	Above	Normal	Below
Above	0.89	-0.11	-0.78
Normal	-0.11	0.22	-0.11
Below	-0.78	-0.11	0.89

Weights are optimally defined so that forecasts of climatology AND perpetual forecast of one category AND random guessing have an expected score of zero.

How are LEPS numbers calculated (Example for a Tercile Forecast)

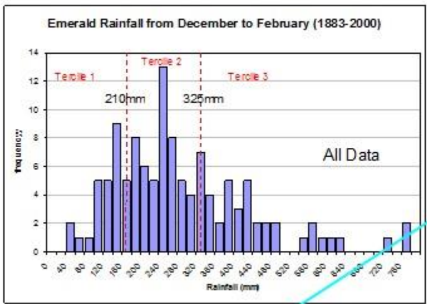
	Forecasts		
Observed	Tercile1 ($p_f=0$ … $p_f=0.33$)	Tercile 2 ($p_f=0.67$)	Tercile 3 ($p_f=1$)
Tercile1 ($p_o=0$)	0.89	-0.11	-0.78
Tercile 2 ($p_o=0.33$)	-0.11	0.22	-0.11
Tercile 3 ($p_o=0.67$)	-0.78	-0.11	0.89

$p_o=1.00$

LEPS are calculated at corners and then averaged

$$LEPS = 3\left(1 - \left|p_f - p_o\right| + p_f^2 - p_f + p_o^2 - p_o\right) - 1$$

Example Calculation for Terciles



	Forecasts		
Observations	Above	Normal	below
Above	0.89	-0.11	-0.78
Normal	-0.11	0.22	-0.11
Below	-0.78	-0.11	0.89

If observed years falls in:

Tercile 3 $p_1 \times 0.89 + p_2 \times -0.11 + p_3 \times -0.78$ = LEPS Score

Tercile 2 $p_1 \times -0.11 + p_2 \times 0.22 + p_3 \times -0.11$ = LEPS Score

Tercile 1 $p_1 \times -0.78 + p_2 \times -0.11 + p_3 \times 0.89$ = LEPS Score

Forecast probabilities

Percentage LEPS score

To Convert to a percentage –
divide by worst case OR best case scenario

i.e. if LEPS score was +ve, divide by the highest category weight.
if LEPS score was –ve, divide by the lowest category weight.

if LEPS score was 0.18 (good forecasting), and observed was in tercile 2, then

LEPS % = 0.18 / 0.22 x 100 % = 81.8%

Highest weighing from table in tercile 2

Forecast performance Via LEPS Score

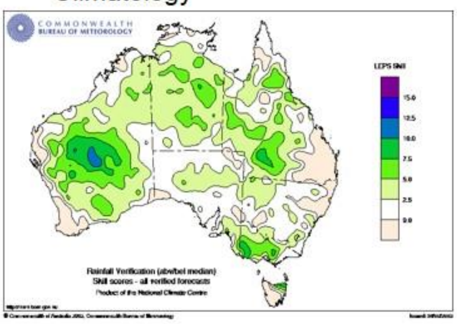
Often expressed as percentage LEPS

-100% 0 100%

Worse than Climatology

As good as Climatology

Better than Climatology



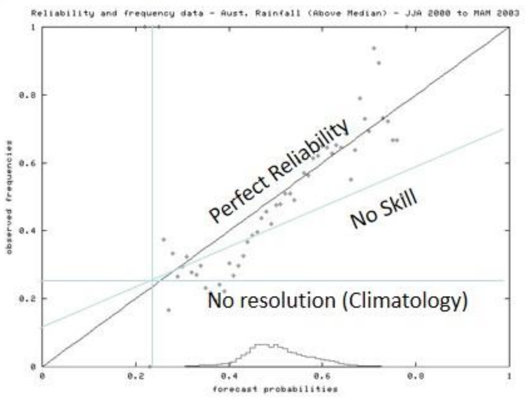
Methods for forecasts of continuous variables

Reliability Diagram
Brier Skill Score (BSS)
Receiving Operating Curves (ROC)
Ranked Probability Skill Score (RPSS)

Reliability Diagram (Attribute Diagram)

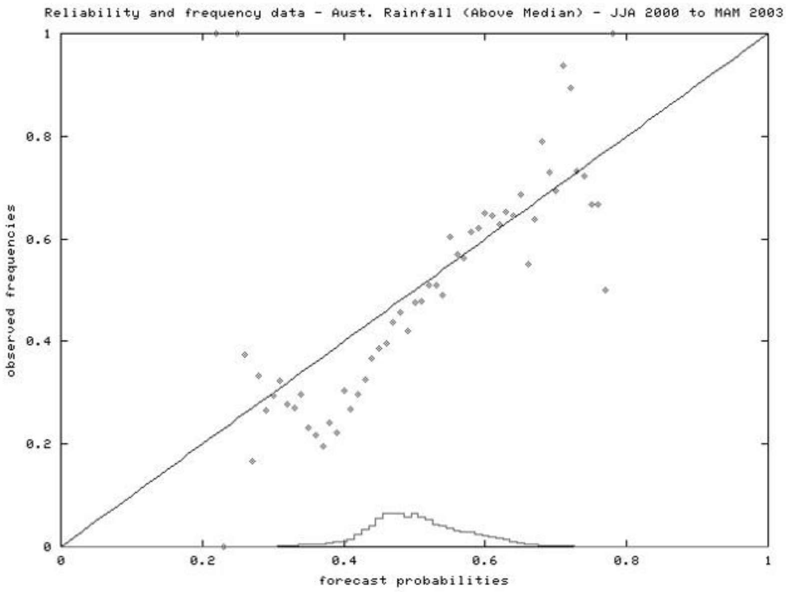
How well do the predicted frequency of an event correspond to their observed frequency?

The reliability diagram plots the observed frequency against the forecast probability, where the range of forecast probabilities are divided into bins (0-5%;5-15%,15-25%,......). The reliability diagram is conditioned on the forecast (given x was predicted what was the outcome?).

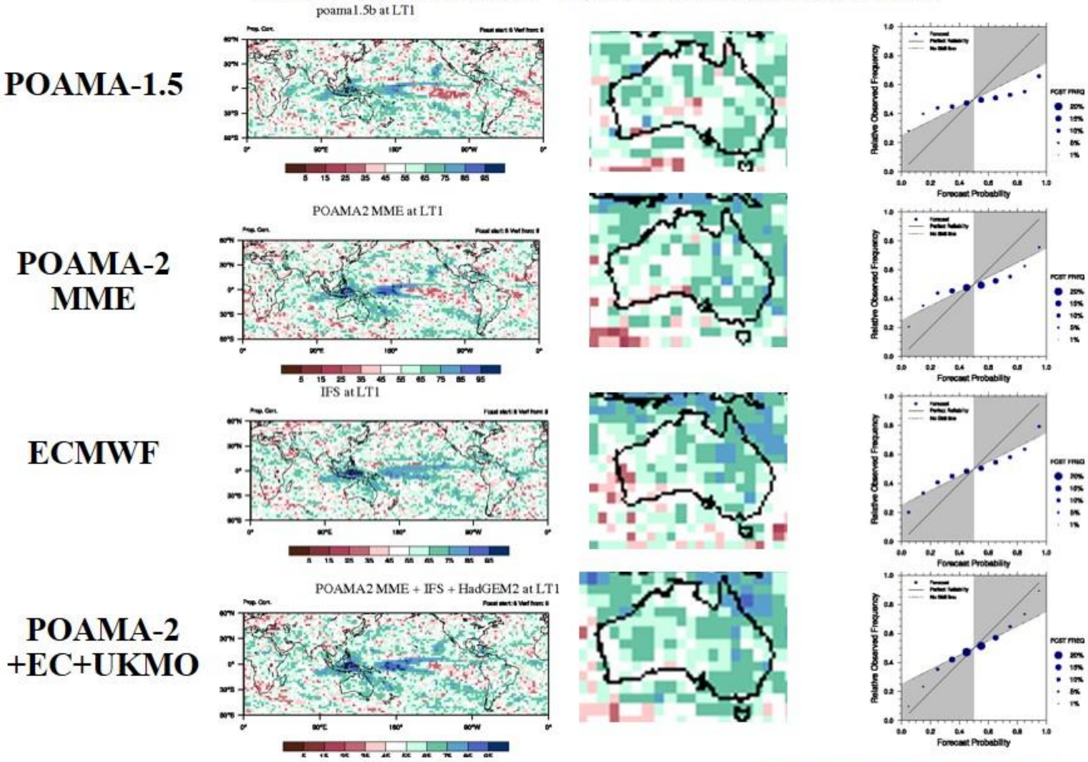


CBA2012-01CMY-Abawi FINAL REPORT

Reliability Diagram
Australian Rainfall (above median)



SON Skill lead 1- above median rainfall



Produced by Eun-Pa Lim

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

Ranked Probability Skill Score

What is the relative improvement of the probability forecast over climatology in predicting the category that the observation fell into?

$$RPS = \frac{1}{M-1}\sum_{m=1}^{M}[(\sum_{k=1}^{m}\rho_k) - (\sum_{k=1}^{m}o_k)]^2$$

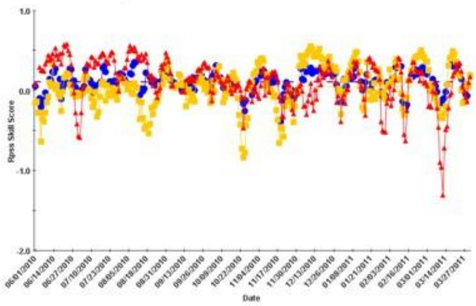
M is the number of forecast categories,
p_k predicted probability in category k
o_k {0,1} for observation in category k

$$CRPS = \int_{-\infty}^{\infty}(P_f(X) - (P_o(X))^2 dx$$

CPRS is for continuous distribution

$$RPSS = \frac{\overline{RPS} - \overline{RPS}_{ref}}{0 - \overline{RPS}_{ref}} = 1 - \frac{\overline{RPS}}{\overline{RPS}_{ref}}$$

Range -∞ to 1; o no skill



Brier Skill Score

Measure the magnitude of Probability Forecast Error. Sensitive to climatological frequency of the event. Can get good Score with out having a real skill

$$BS = \frac{1}{N}\sum_{i=1}^{N}(p_i - o_i)^2$$

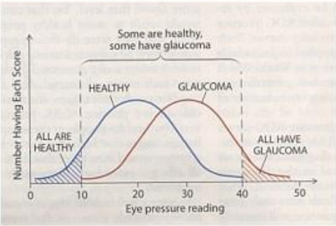
What is the relative skill of probabilistic forecast over that of Climatology in predicting whether or not an event occurred

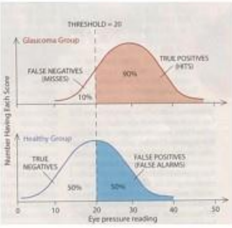
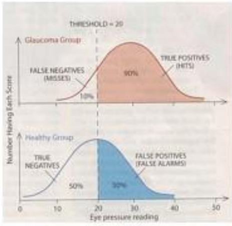
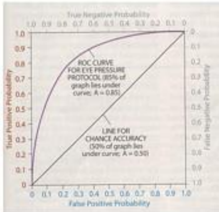
$$BSS = \frac{BS - BS_{ref}}{0 - BS_{ref}} = 1 - \frac{BS}{BS_{ref}}$$

Range -∞ to 1; o no skill

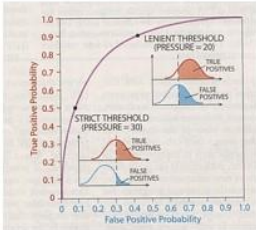
Receiver (relative) Operating Characteristic (ROC)

What is the ability of forecast to discriminate between events and non-events. i.e. measuring resolution



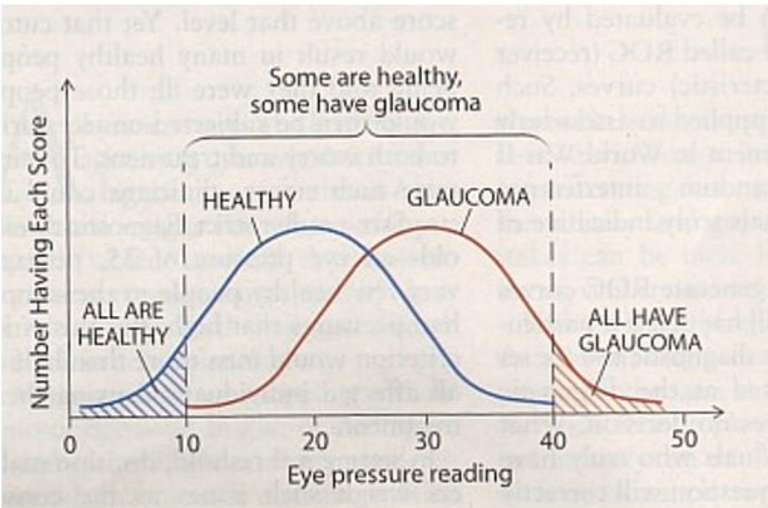
Plots *Hit Rate* (POD) *vs False Alarm Rate* (POFD) using a set of increasing probability thresholds (e.g. 0.05, 0.15,0.25...) to make the yes/no decision. The area under the ROC curve is used as a score



(Glaucoma Example from Scientific American, October 2000)

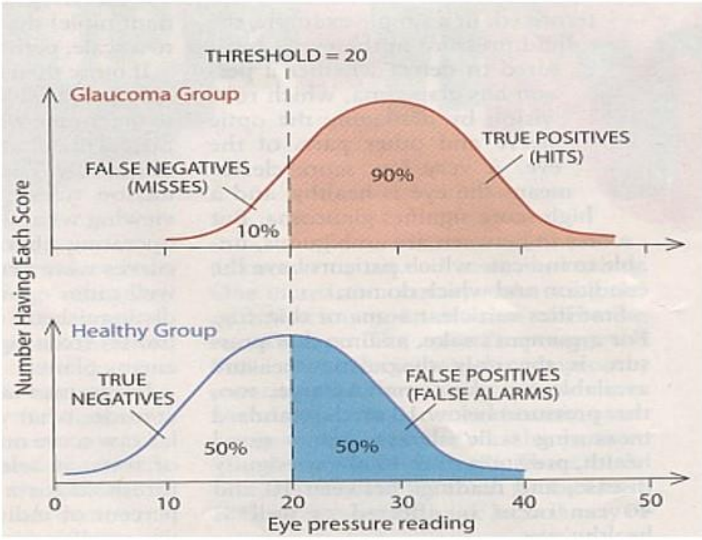
Receiver (relative) Operating Characteristic (ROC)

What is the ability of forecast to discriminate between events and non-events. i.e. measuring resolution

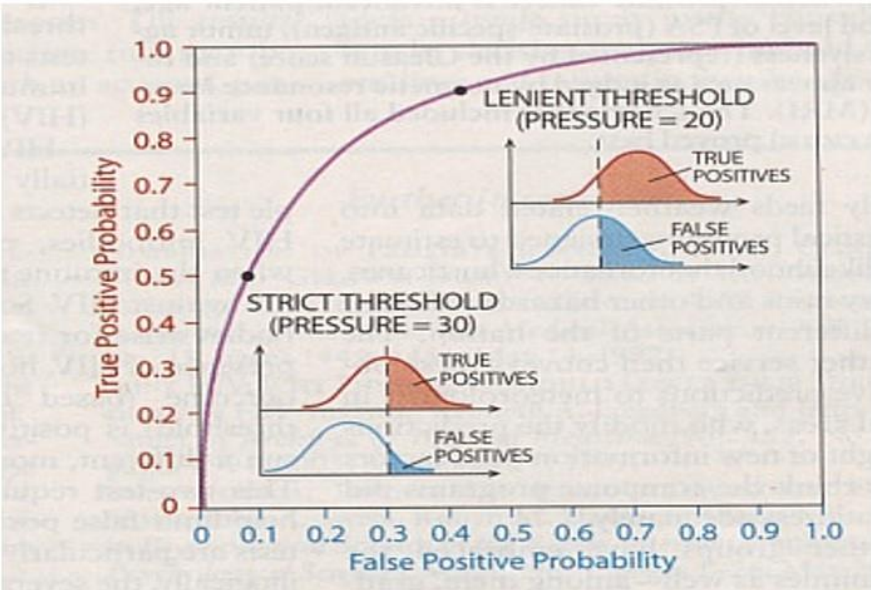


(Glaucoma Example from Scientific American, October 2000)

Receiver (relative) Operating Characteristic (ROC)



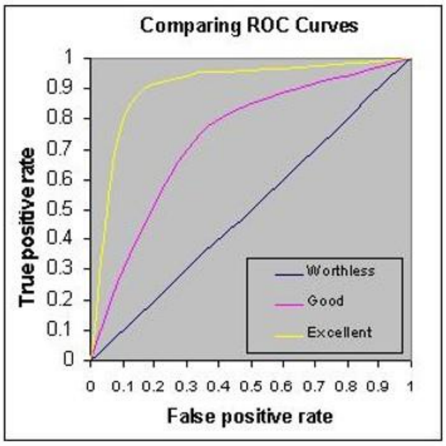
(Glaucoma Example from Scientific American, October 2000)



(Glaucoma Example from Scientific American, October 2000)

Receiver (relative) Operating Characteristic (ROC)

Score	*Rating*
.90 - 1.0	excellent (A)
.80 - .90	good (B)
.70 - .80	fair (C)
.60 - .70	poor (D)
.50 - .60	fail (F)



Validity of verification results

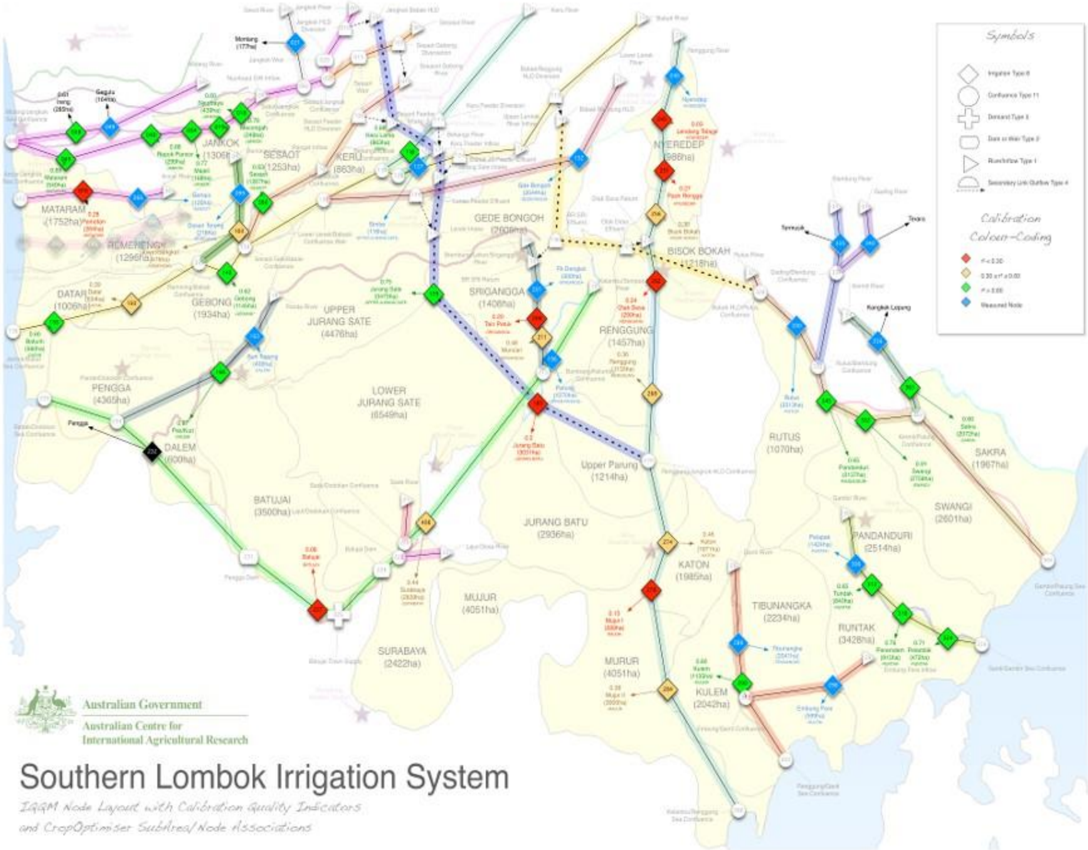
More trustworthy when the quantity and quality of verification results are high

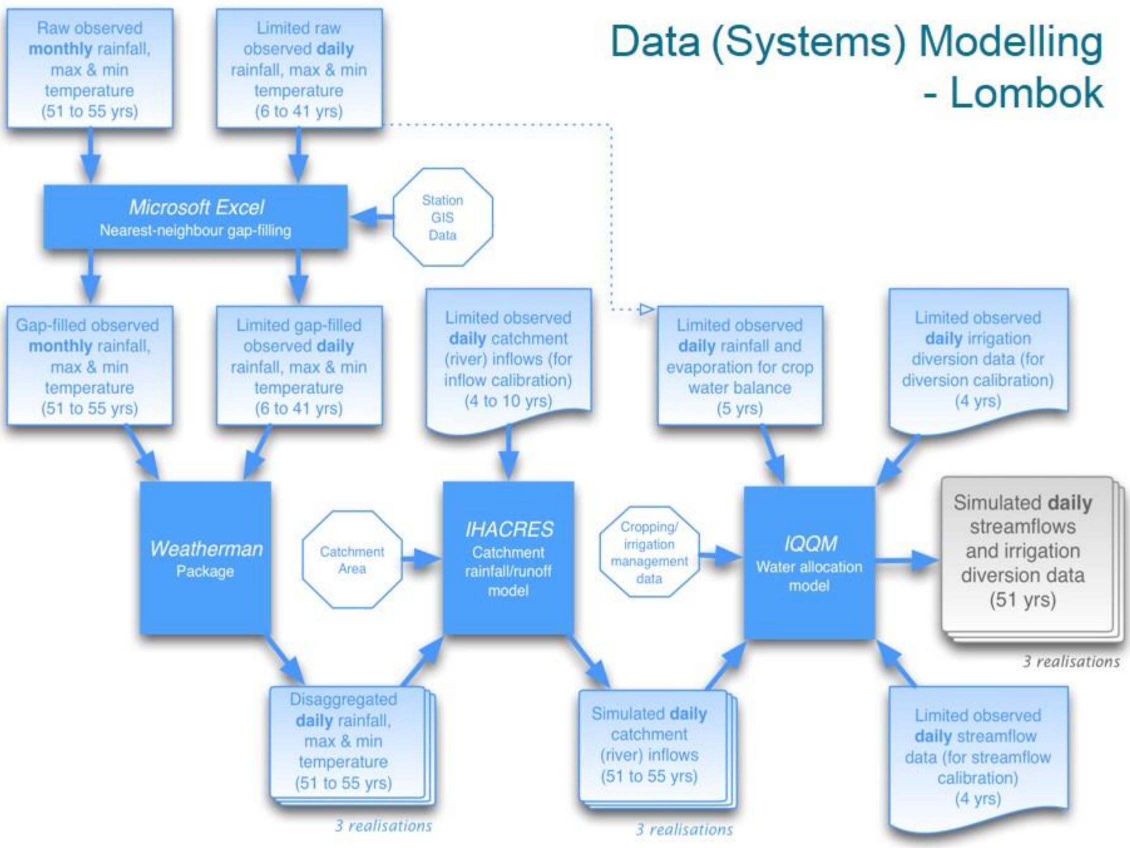
Include error bounds especially when sample size is small and variability is high

Climate Adaptation in the Pacific Islands: Experiences from PICPP project

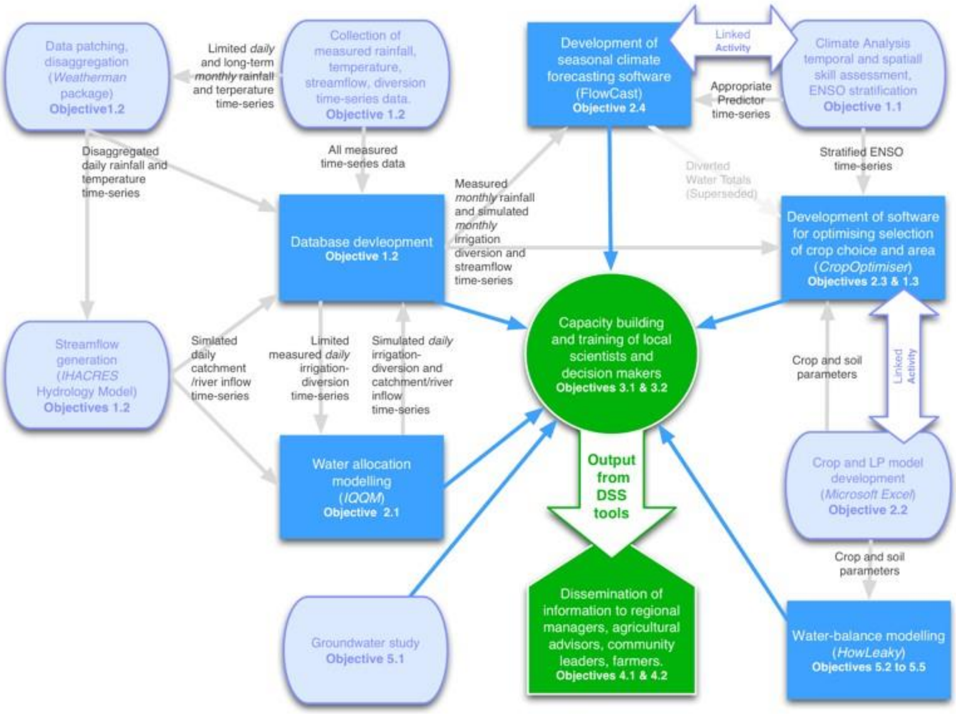
Yahya Abawi

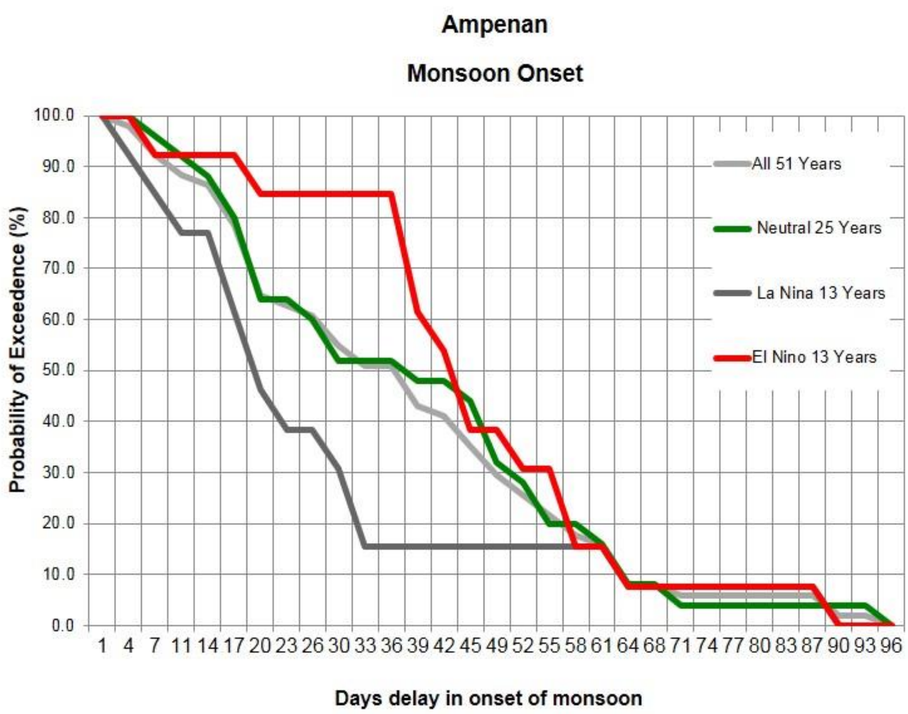
"Building scientific capacity in Seasonal Climate Forecasting (SCF) for improved risk management decisions in a changing climate"
Project: CBA2012-01CMY-Abawi

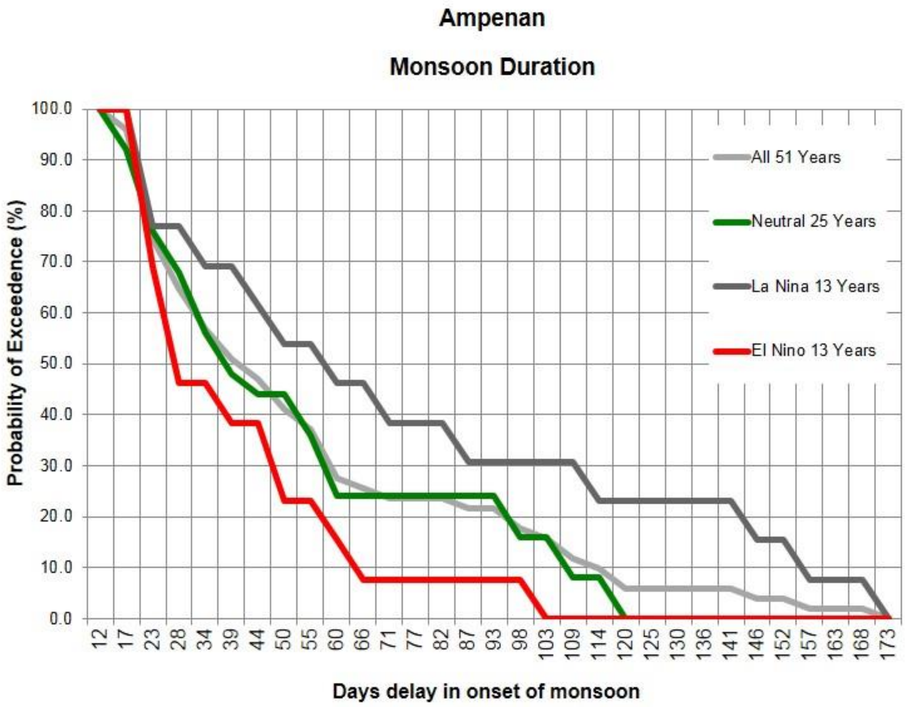

Symbols
Calibration Colour-Coding
Australian Government
Australian Centre for International Agricultural Research
Southern Lombok Irrigation System
IQQM Node Layout with Calibration Quality Indicators and CropOptimiser SubArea/Node Associations

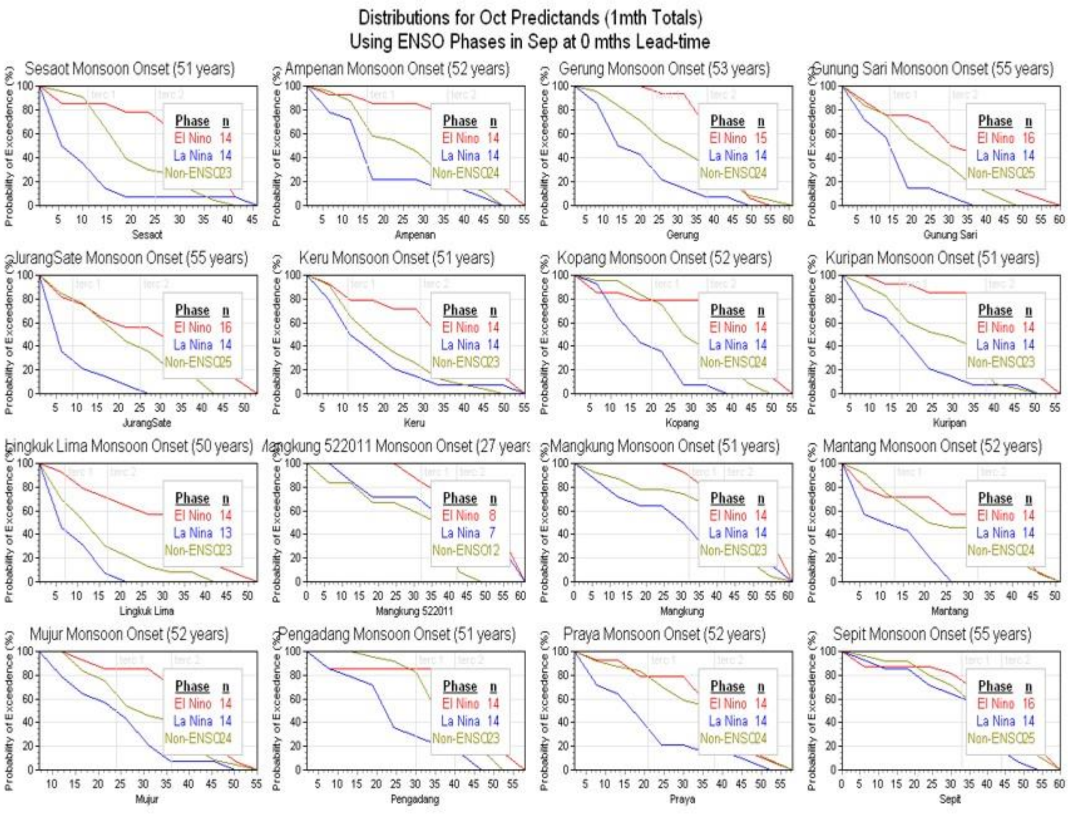

Data (Systems) Modelling - Lombok
Raw observed monthly rainfall, max & min temperature (51 to 55 yrs)
Limited raw observed daily rainfall, max & min temperature (6 to 41 yrs)
Microsoft Excel
Nearest-neighbour gap-filling
Station GIS Data
Gap-filled observed monthly rainfall, max & min temperature (51 to 55 yrs)
Limited gap-filled observed daily rainfall, max & min temperature (6 to 41 yrs)
Limited observed daily catchment (river) inflows (for inflow calibration) (4 to 10 yrs)
Limited observed daily rainfall and evaporation for crop water balance (5 yrs)
Limited observed daily irrigation diversion data (for diversion calibration) (4 yrs)
Weatherman Package
Catchment Area
IHACRES
Catchment rainfall/runoff model
Cropping/irrigation management data
IQQM
Water allocation model
Simulated daily streamflows and irrigation diversion data (51 yrs)
3 realisations
Disaggregated daily rainfall, max & min temperature (51 to 55 yrs)
3 realisations
Simulated daily catchment (river) inflows (51 to 55 yrs)
3 realisations
Limited observed daily streamflow data (for streamflow calibration) (4 yrs)

Lombok "Systems Approach"






Ampenan
Monsoon Duration
Probability of Exceedence (%)
Days delay in onset of monsoon
All 51 Years
Neutral 25 Years
La Nina 13 Years
El Nino 13 Years


Distributions for Oct Predictands (1mth Totals)
Using ENSO Phases in Sep at 0 mths Lead-time
Sesaot Monsoon Onset (51 years)
Ampenan Monsoon Onset (52 years)
Gerung Monsoon Onset (53 years)
Gunung Sari Monsoon Onset (55 years)
JurangSate Monsoon Onset (55 years)
Keru Monsoon Onset (51 years)
Kopang Monsoon Onset (52 years)
Kuripan Monsoon Onset (51 years)
Lingkuk Lima Monsoon Onset (50 years)
Mangkung 522011 Monsoon Onset (27 years
Mangkung Monsoon Onset (51 years)
Mantang Monsoon Onset (52 years)
Mujur Monsoon Onset (52 years)
Pengadang Monsoon Onset (51 years)
Praya Monsoon Onset (52 years)
Sepit Monsoon Onset (55 years)

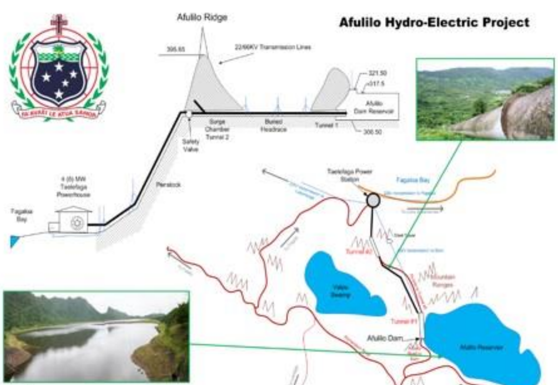
Pacific Islands - Climate Prediction Project

Rainwater management – Tuvalu Case Study
Hydropower – Samoa
Groundwater – Kiribati, Tonga
Surface Water – Cook Islands, Fiji, Vanuatu
Agriculture – PNG, Tonga, Fiji
Malaria study – Solomon Islands

Australian Government
AusAID
Bureau of Meteorology

Pacific Islands – Climate Prediction Project

Hydropower management –Samoa Case Study



Australian Government
AusAID
Bureau of Meteorology

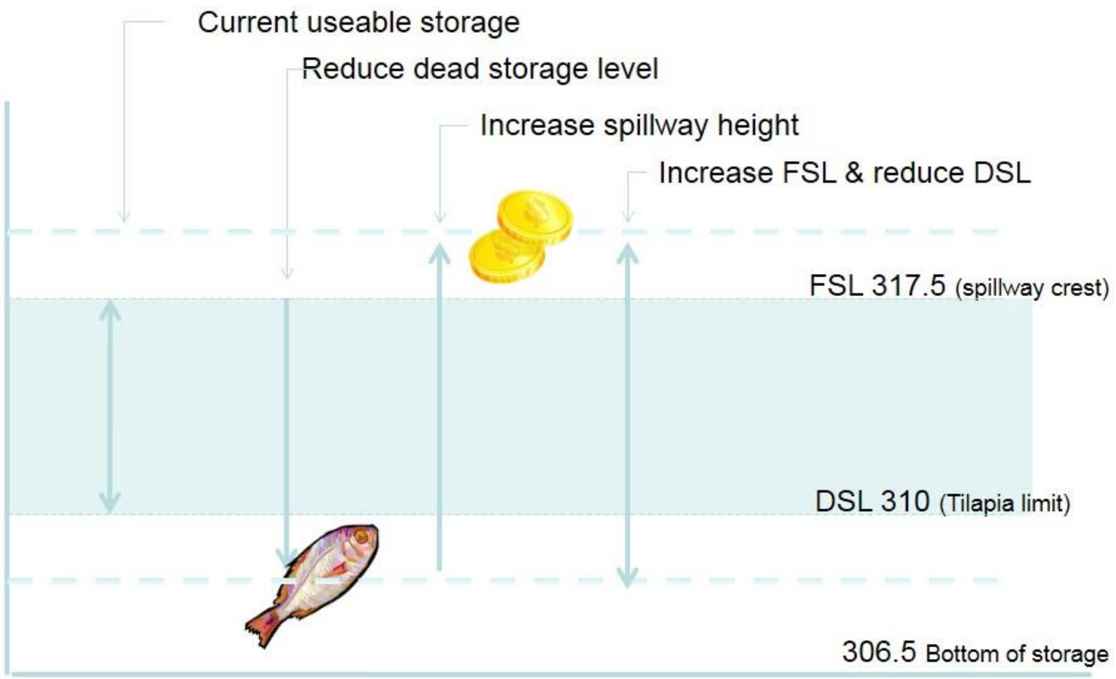
Aims

- **Determine the utility of SCF in the management of hydro-power generation for the Afulilo Dam.**
- **identify management strategies to maximise the use of hydropower generation relative to thermal production.**

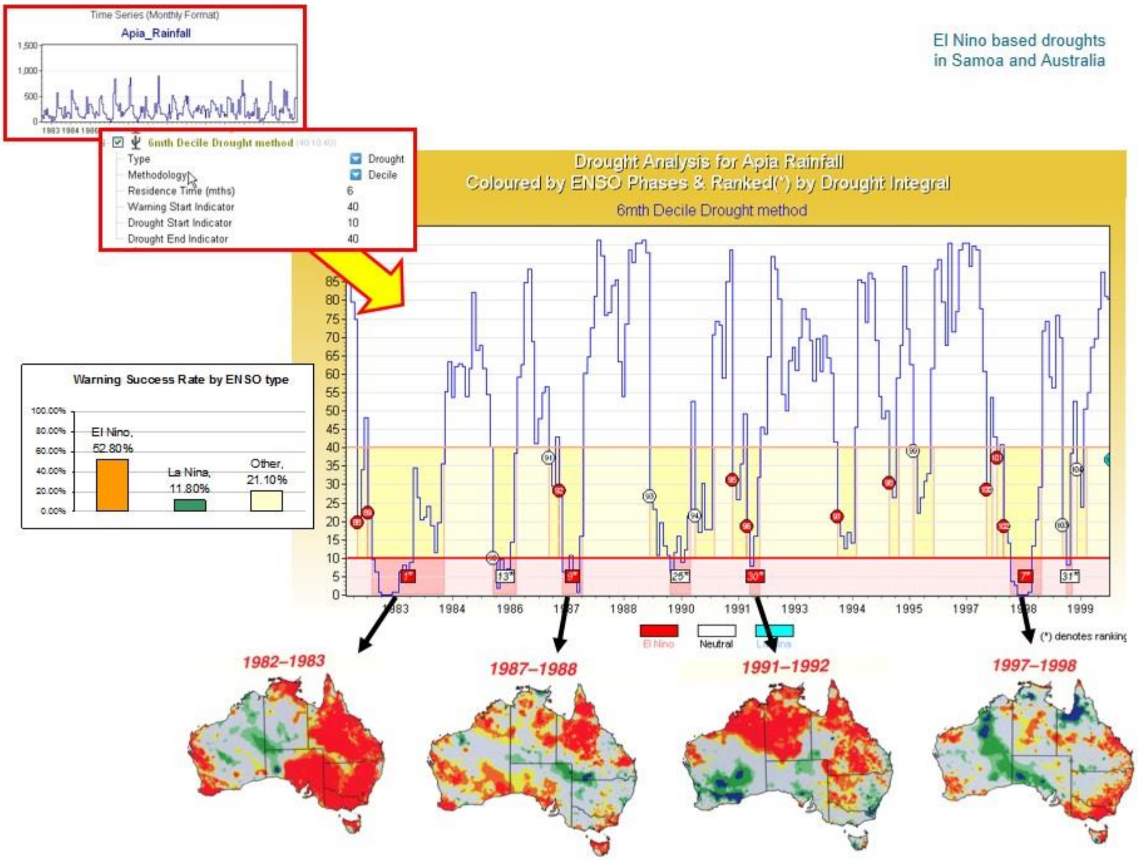
Key points

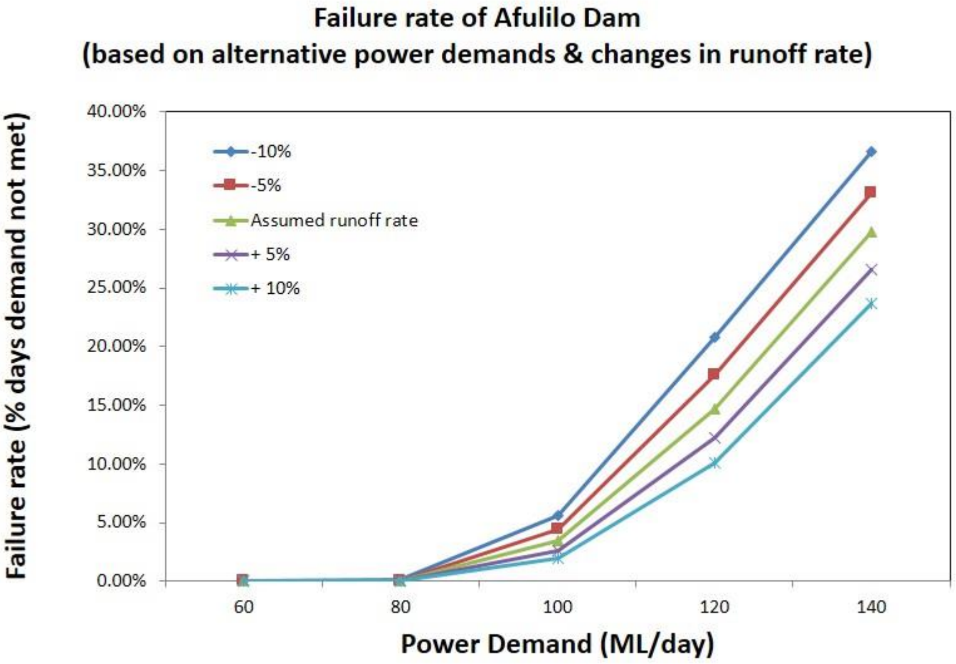
Energy demand increasing 4-5% p.a.
In 1992, Hydropower supplied 80% of demand
Currently 50% of energy demand is sourced from thermal (diesel)

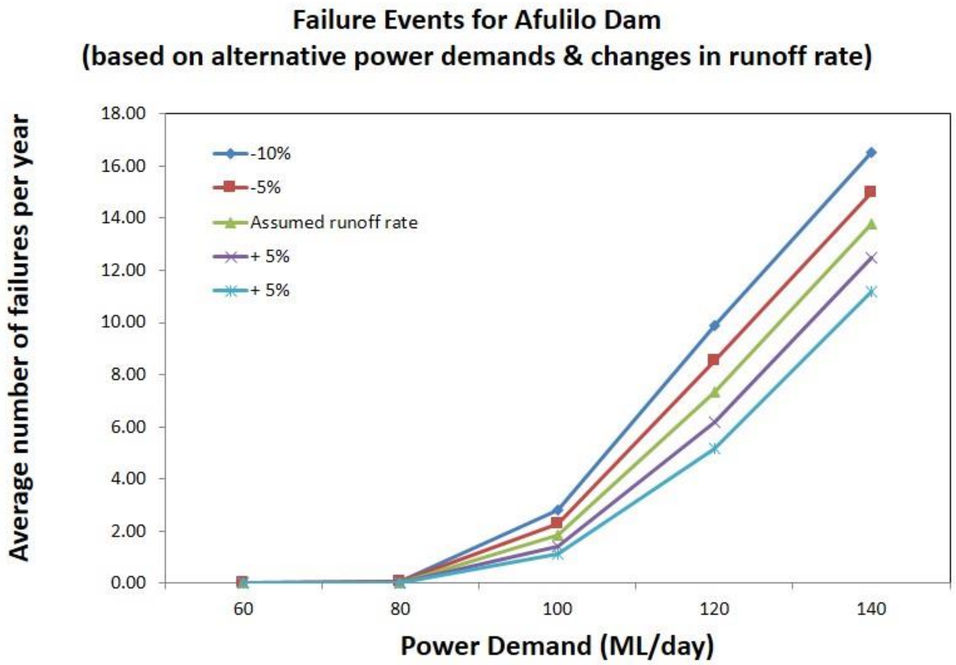
Options to increase usable storage



NB: The 2001 proposed Afulilo power augmentation was to increase the crest by 1.7m and therefore volume by an addition 5,000ML

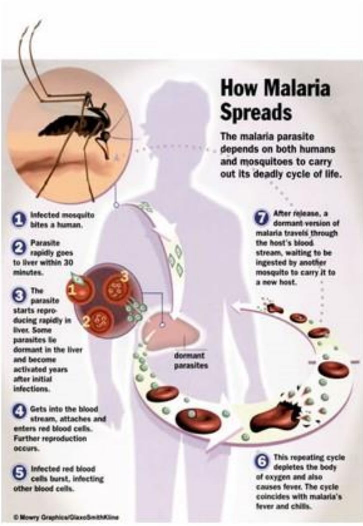



Failure rate of Afulilo Dam
(based on alternative power demands & changes in runoff rate)
Failure rate (% days demand not met)
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
-10%
-5%
Assumed runoff rate
+ 5%
+ 10%
60
80
100
120
140
Power Demand (ML/day)


Failure Events for Afulilo Dam
(based on alternative power demands & changes in runoff rate)
Average number of failures per year
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-10%
-5%
Assumed runoff rate
+ 5%
+ 5%
60
80
100
120
140
Power Demand (ML/day)

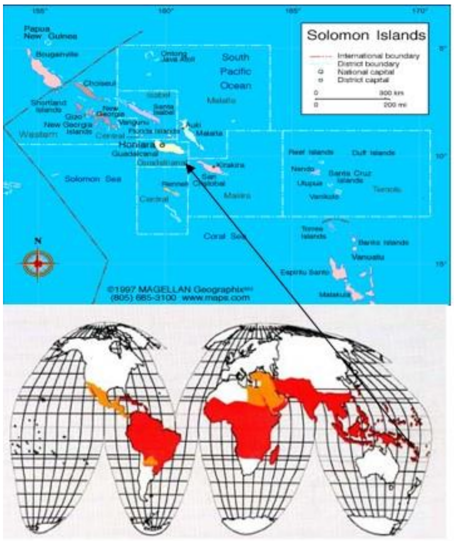
Pacific Islands – Climate Prediction Project

Prediction of Vector-born diseases (Malaria)



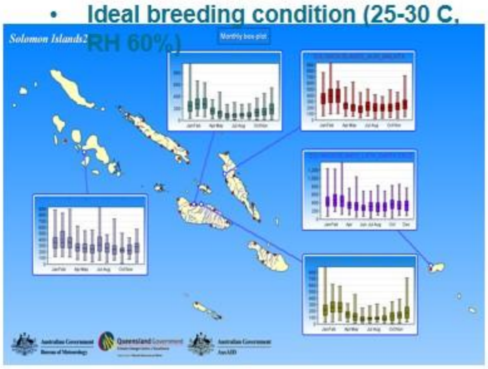
Aims

- **Determine whether malaria epidemics in the Solomon Islands are related to the ENSO, rainfall and other hydro-climatic variables; and**
- **Determine if such relationship can be used as an early warning system for predicting heightened risk of a malarial epidemic and therefore in assisting targeted control strategies.**

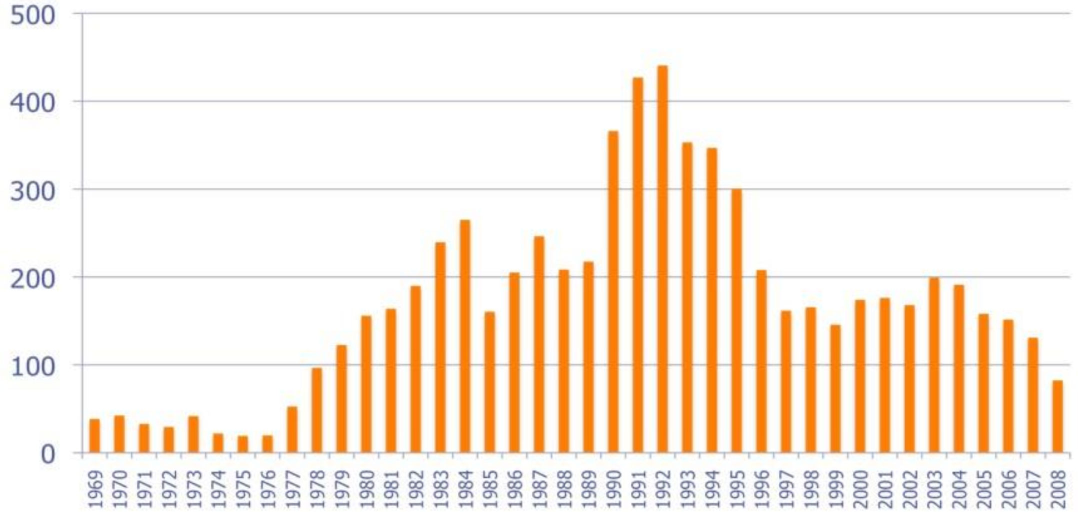


Malaria Snapshot

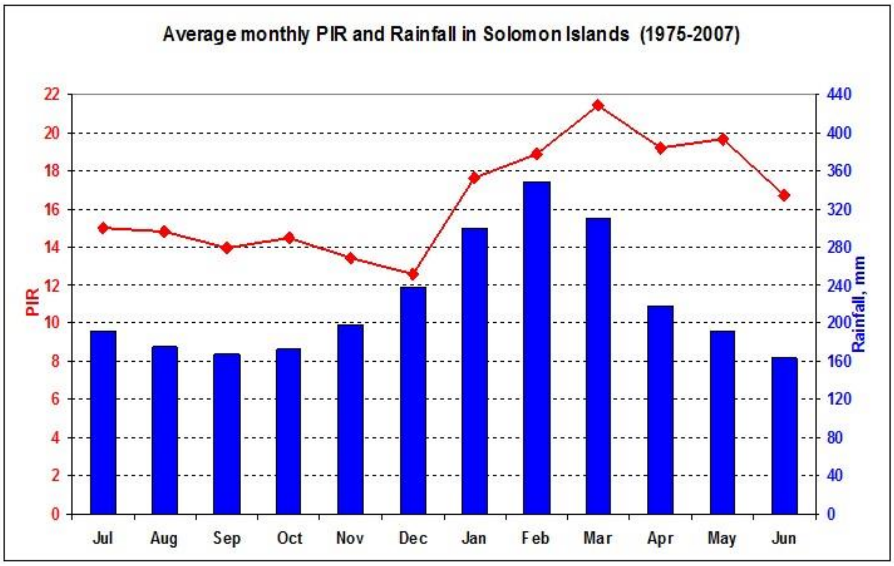
- **100 countries, 40% of world population live in areas where malaria transmission occurs**
- **300 – 500 million cases each year world wide**
- **750,000 – 2 million deaths each year**
- **Plasmodium *falciparum* accounts for 60-70% of all cases in SI. Transmitted by Anopheles Mosquitoes**
- **Ideal breeding condition (25-30 C, RH 60%)**



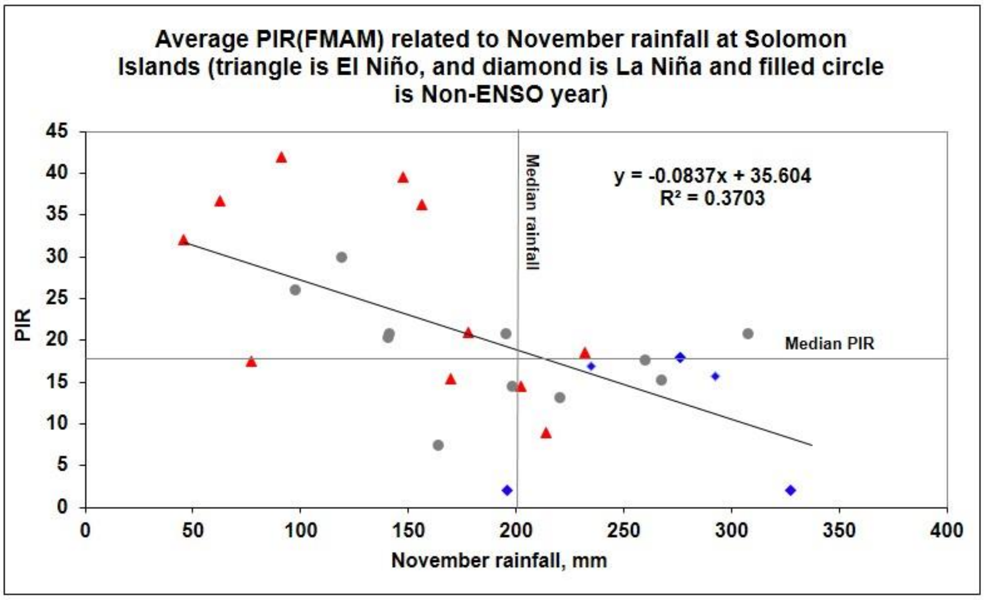
Annual incidence of slide confirmed malaria since 1969 in Solomon Islands



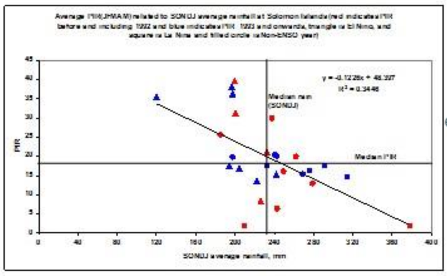
Positive Incidence Ratio (PIR) per 1000 population



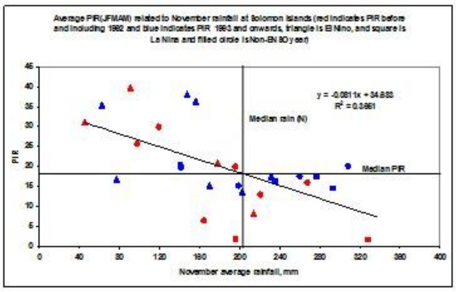
Average PIR (FMAM) is high in the El Niño years when November rainfall is less than long term median rainfall



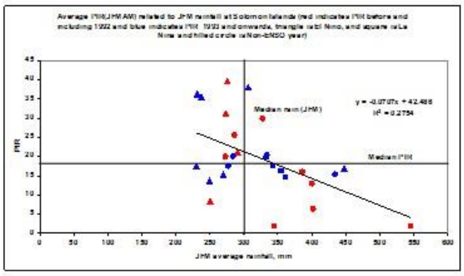
verage PIR(JFMAM) vs rainfall in SONDJ



erage PIR(JFMAM) vs rainfall in September



Average PIR(JFMAM) vs rainfall in JFM



Mosquito life cycle is affected by temperature

Table 1: The effect of mean temperature on the duration of mosquito's life cycle and sporogonic cycle and its effect on the amount of lead time from the availability of breeding sites to the occurrence of malaria cases.

Weather factors	*Stages and duration of mosquito's life cycle and sporogony cycle affected by weather factors*		
Mean temperature (Rainfall temperature)	**Availability of breeding sites ----------------→ Malaria**		
	Mosquito's life cycle*	**Sporogony†**	**Incubation period in human host**
	Larva ------→ Adult(days)	Adult first bite -----→ Infectious bite (days)	
16°C	47	111	**(10–16 days)**
17°C	37	56	
18°C	31	28	
20°C	23	19	
22°C	18	7.9	
30°C	10	5.8	
35°C	7.9	4.8	
39°C	6.7	4.8	
40°C	6.5	4.8	

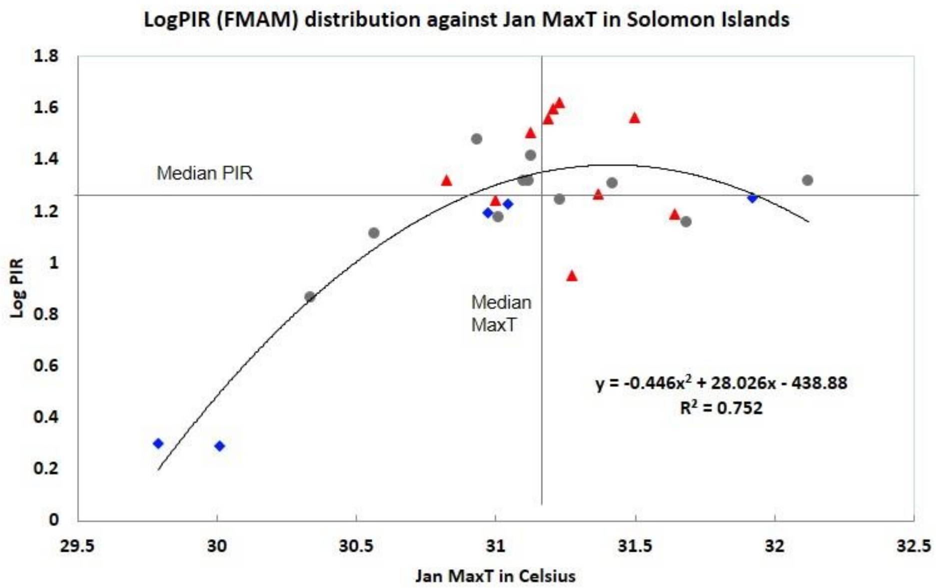
Rueda LM, Patel KJ, Axtell RC, Stinner RE: **Temperature-dependent development and survival rates of Culex quinquefasciatus and Aedes aegypti (Diptera: Culicidae).** *J Med Entomol* 1990, **27**:892-898.

MacDonald G: **The epidemiology and control of malaria.** London: Oxford University Press; 1957.

le Sueur D BLS: **Temperature dependent variation in Anopheles Merus larval head capsule width and adult wing length: implications for anopheline taxonomy.** *Med Vet Entomol* 1991:55-62.

Detinova TS: **Age-grouping methods in Diptera of medical importance, with special reference to some vectors of malaria.** *Monogr Ser World Health Organ* 1962, **47**:13-191.

PIR (FMAM) distribution of malaria as a function of maximum temperature in January in Solomon Islands (Triangle indicates El Niño, Diamond is La Niña and the rest are Non-ENSO years)

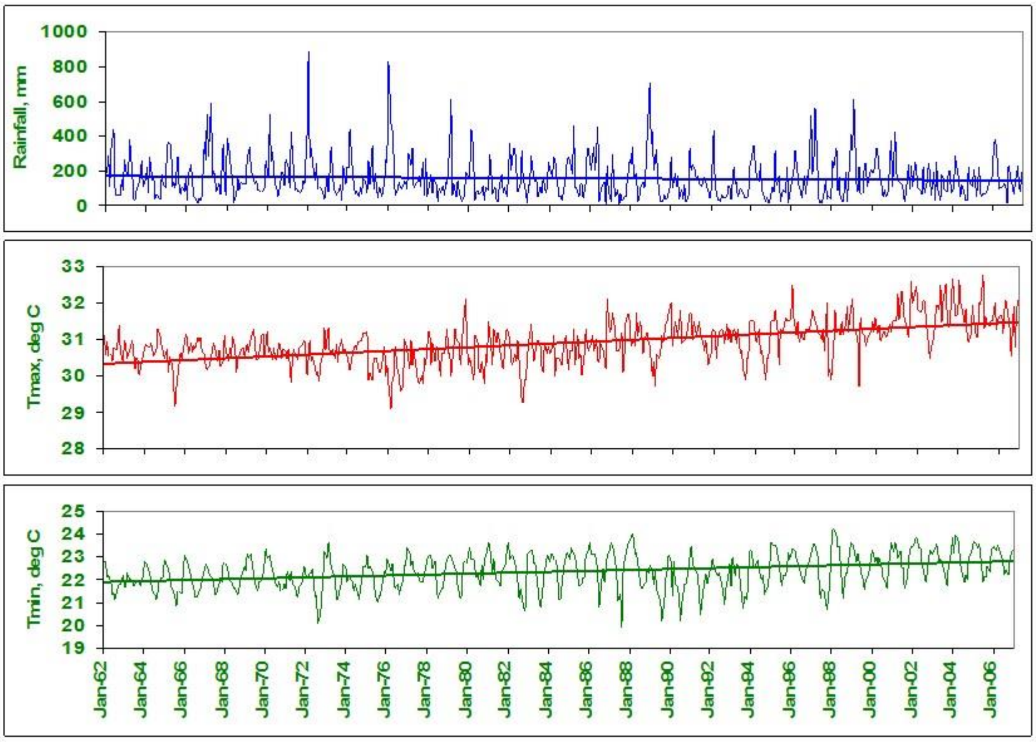


Non-climatic and climate related inter-annual variability in log annual confirmed malarial incidence for Solomon Islands for 1975-2006

Model	Multiple r	r^2	Adjusted r^2	Standard Error
1	0.61	0.37	0.35	0.26
2	0.66	0.44	0.40	0.24
3	0.88	0.78	0.74	0.16

Model 1: JFM average monthly rainfall
Model 2: Model 1 and JFM temperature
Model 3: Model 2 and Policy Intervention

Rainfall, Maximum and Minimum Temperature (Honiara)



Continued support is essential for successful adoption

★LOCAL NEWS

Local activist urges NZ, Aust to reduce emissions

PM to report to Forum on RAMSI partnership

Rarasu Motel assists local church

Today's weather

Climate forecasting can help predict malaria outbreaks

Media Release 14.12.09

Higher incidence of malaria forecast for this summer

A mature El Niño condition is continuing to dominate in the equatorial Pacific Ocean. In the Solomon Islands, El Niño is usually associated with higher temperatures and less rainfall than the long-term average. These conditions are conducive to a heightened risk of malarial infections for the Solomon Islands during the peak infection period of January to May.

The relationship between the incidence of malaria and climatic conditions is currently being investigated as part of the Pacific Islands Climate Prediction Project (PI-CPP), which is funded by AusAid and administered by the Australian Bureau of Meteorology in collaboration with the Solomon Islands National Health Research and Training Institute. This study has shown that malarial incidence peaks during the January to May period, coinciding with the rainy season in the Solomon Islands. Since an El Niño is currently affecting the Solomon Islands, rainfall in this period is likely to be reduced and temperatures increased across most of the Solomon Islands in coming months. Increased temperatures will result in a shorter breeding cycle for mosquitoes and lower rainfall will reduce the flushing of larvae from stagnant water. These factors are likely to contribute to increased mosquito numbers and a higher rate of malaria transmission occurring this summer in the Solomon Islands.

Authorities are reminding residents to be diligent in taking preventative measures such as use of bed nets, especially during the early morning and evening, and where possible remove potential breeding sites such as stagnant pools of water where mosquitos can harbour. If you have any malarial symptoms such as high fever, please report to your local medical officer.

Contact: Mr Lloyd Tahani, National Meteorological Services, Solomon Islands

Use of Climate Forecasting for Rainwater Management -Tuvalu

Australia helps as Tuvalu runs dry - Mozilla Firefox

http://www.smh.com.au/environment/water-issues/australia-helps-as-tuvalu-runs-dry-20111006-1lbrz.html

Environment

Weather | Climate Change | Whale Watch | Animals | Conservation | Water Issues | Energy Smart | Earth Hour

You are here: Home » Environment » Water Issues » Article »

Australia helps as Tuvalu runs dry

Kirsty Needham
October 7, 2011

AUSTRALIA has responded to an SOS from the tiny Pacific nation of Tuvalu, which is days away from running out of water.

The federal government has sent officials and 1000 rehydration packs to Tuvalu's hospital to treat sickness caused by lack of water for sanitation as other governments and the Red Cross send thousands of litres of water.

Speaking from the capital, Funafuti, Tuvalu's disaster co-ordinator, Sumeo Silu, told the *Herald*: "We have less than four or five days. We are rationing water well below the United Nations refugee rate [20 litres per person] with just 40 litres per household. An average household here has 10 to 12 people."

Schools have closed and the government has declared a state of emergency. Australian aid arrived on a New Zealand Hercules aircraft on Wednesday, delivering water, money for fuel for a water supply truck and desalination plants.

The federal government is considering sending an Australian defence aircraft to help.

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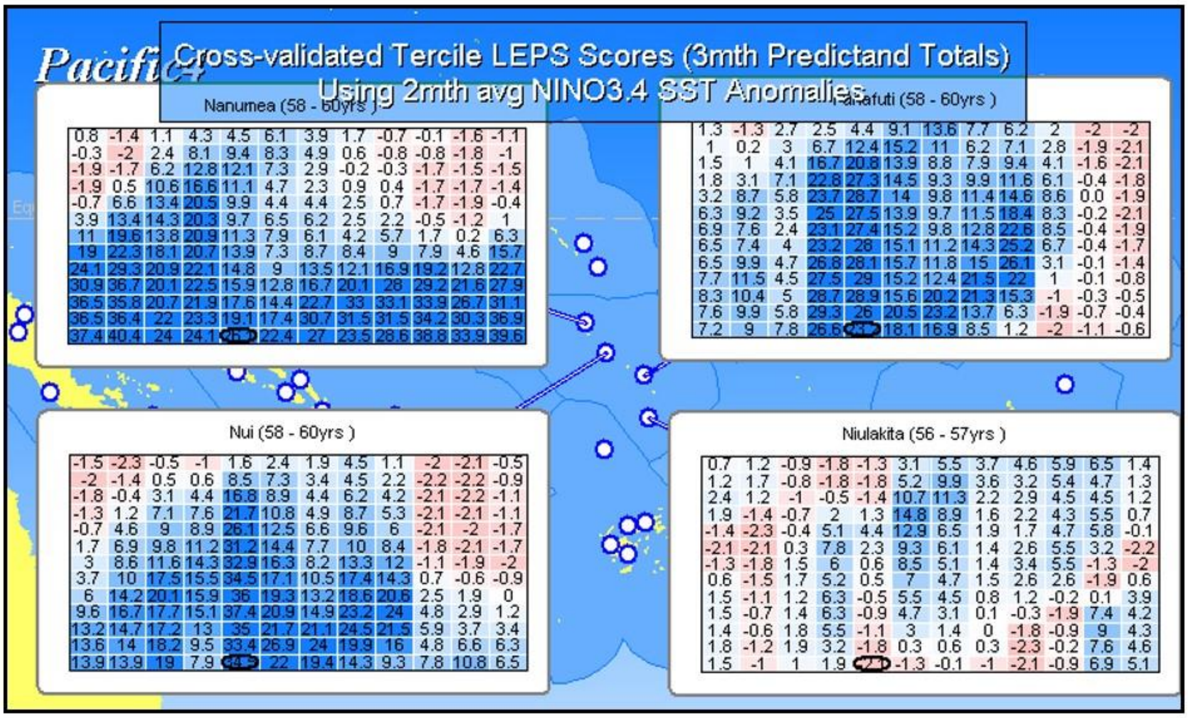
All Climate (3716)
Climate Change (1344)

LEPS – Nino3.4



Nanumea (58 - 60yrs)

0.8	-1.4	1.1	4.3	4.5	6.1	3.9	1.7	-0.7	-0.1	-1.6	-1.1
-0.3	-2	2.4	8.1	9.4	8.3	4.9	0.6	-0.8	-0.8	-1.8	-1
-1.9	-1.7	6.2	12.8	12.1	7.3	2.9	-0.2	-0.3	-1.7	-1.5	-1.5
-1.9	0.5	10.6	16.6	11.1	4.7	2.3	0.9	0.4	-1.7	-1.7	-1.4
-0.7	6.6	13.4	20.5	9.9	4.4	4.4	2.5	0.7	-1.7	-1.9	-0.4
3.9	13.4	14.3	20.3	9.7	6.5	6.2	2.5	2.2	-0.5	-1.2	1
11	19.6	13.8	20.9	11.3	7.9	6.1	4.2	5.7	1.7	0.2	6.3
19	22.3	18.1	20.7	13.9	7.3	8.7	8.4	9	7.9	4.6	15.7
24.1	29.3	20.9	22.1	14.8	9	13.5	12.1	16.9	19.2	12.8	22.7
30.9	36.7	20.1	22.5	15.9	12.8	16.7	20.1	28	29.2	21.6	27.9
36.5	35.8	20.7	21.9	17.6	14.4	22.7	33	33.1	33.9	26.7	31.1
36.5	36.4	22	23.3	19.1	17.4	30.7	31.5	31.5	34.2	30.3	36.9
37.4	40.4	24	24.1	[illegible]	22.4	27	23.5	28.6	38.8	33.9	39.6

Funafuti (58 - 60yrs)

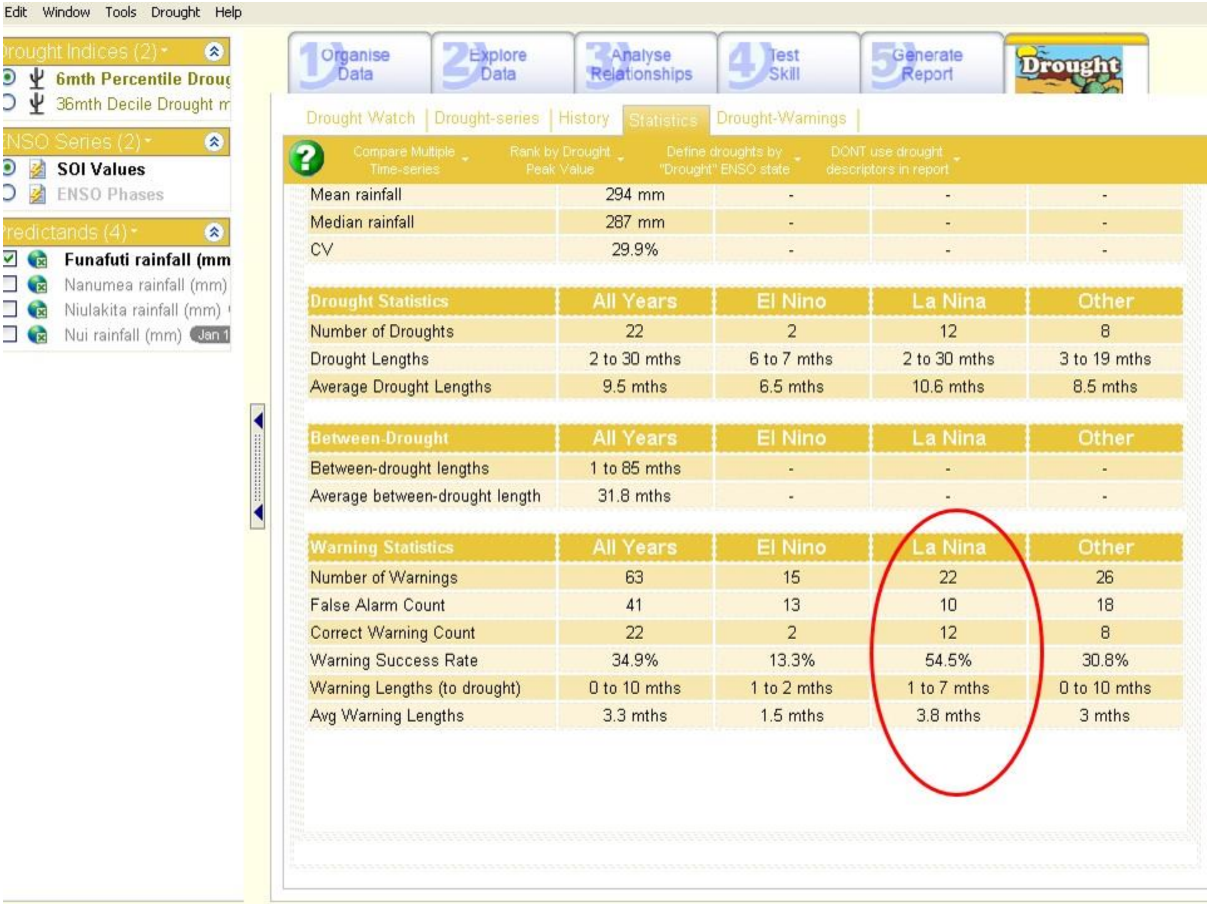
1.3	-1.3	2.7	2.5	4.4	9.1	13.6	7.7	6.2	2	-2	-2
1	0.2	3	6.7	12.4	15.2	11	6.2	7.1	2.8	-1.9	-2.1
1.5	1	4.1	16.7	20.8	13.9	8.8	7.9	9.4	4.1	-1.6	-2.1
1.8	3.1	7.1	22.8	27.3	14.5	9.3	9.9	11.6	6.1	-0.4	-1.8
3.2	8.7	5.8	23.7	28.7	14	9.8	11.4	14.6	8.6	0.0	-1.9
6.3	9.2	3.5	25	27.5	13.9	9.7	11.5	18.4	8.3	-0.2	-2.1
6.9	7.6	2.4	23.1	27.4	15.2	9.8	12.8	22.6	8.5	-0.4	-1.9
6.5	7.4	4	23.2	28	15.1	11.2	14.3	25.2	6.7	-0.4	-1.7
6.5	9.9	4.7	26.8	28.1	15.7	11.8	15	26.1	3.1	-0.1	-1.4
7.7	11.5	4.5	27.5	29	15.2	12.4	21.5	22	1	-0.1	-0.8
8.3	10.4	5	28.7	28.9	15.6	20.2	21.3	15.3	-1	-0.3	-0.5
7.6	9.9	5.8	29.3	26	20.5	23.2	13.7	6.3	-1.9	-0.7	-0.4
7.2	9	7.8	26.6	[illegible]	18.1	16.9	8.5	1.2	-2	-1.1	-0.6

Nui (58 - 60yrs)

-1.5	-2.3	-0.5	-1	1.6	2.4	1.9	4.5	1.1	-2	-2.1	-0.5
-2	-1.4	0.5	0.6	8.5	7.3	3.4	4.5	2.2	-2.2	-2.2	-0.9
-1.8	-0.4	3.1	4.4	16.8	8.9	4.4	6.2	4.2	-2.1	-2.2	-1.1
-1.3	1.2	7.1	7.6	21.7	10.8	4.9	8.7	5.3	-2.1	-2.1	-1.1
-0.7	4.6	9	8.9	26.1	12.5	6.6	9.6	6	-2.1	-2	-1.7
1.7	6.9	9.8	11.2	31.2	14.4	7.7	10	8.4	-1.8	-2.1	-1.7
3	8.6	11.6	14.3	32.9	16.3	8.2	13.3	12	-1.1	-1.9	-2
3.7	10	17.5	15.5	34.5	17.1	10.5	17.4	14.3	0.7	-0.6	-0.9
6	14.2	20.1	15.9	36	19.3	13.2	18.6	20.6	2.5	1.9	0
9.6	16.7	17.7	15.1	37.4	20.9	14.9	23.2	24	4.8	2.9	1.2
13.2	14.7	17.2	13	35	21.7	21.1	24.5	21.5	5.9	3.7	3.4
13.6	14	18.2	9.5	33.4	26.9	24	19.9	16	4.8	6.6	6.3
13.9	13.9	19	7.9	[illegible]	22	19.4	14.3	9.3	7.8	10.8	6.5

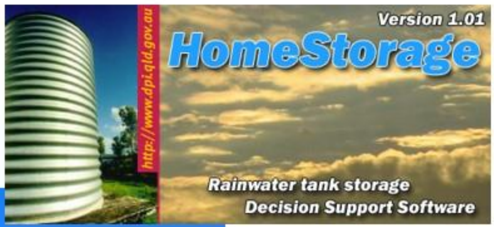
Niulakita (56 - 57yrs)

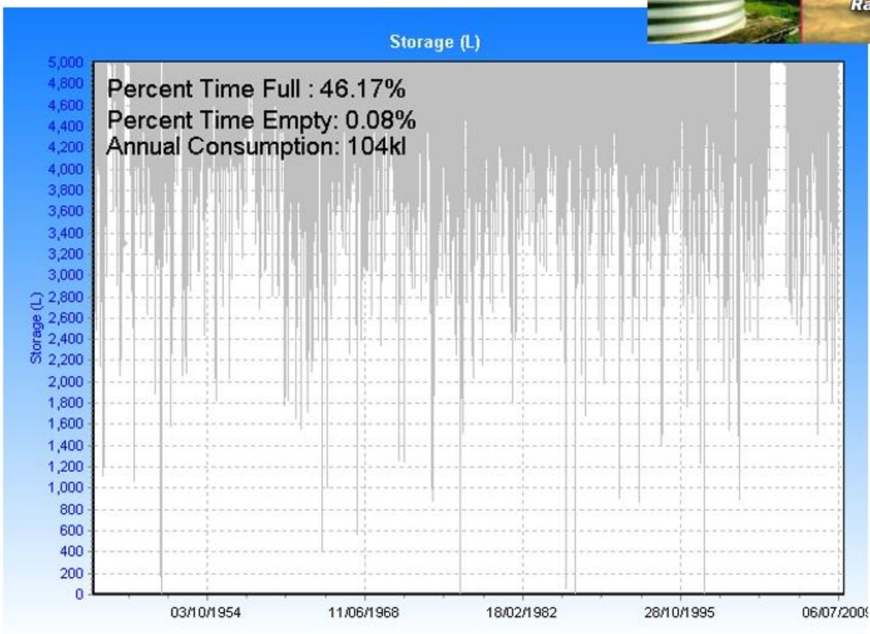
0.7	1.2	-0.9	-1.8	-1.3	3.1	5.5	3.7	4.6	5.9	6.5	1.4
1.2	1.7	-0.8	-1.8	-1.8	5.2	9.9	3.6	3.2	5.4	4.7	1.3
2.4	1.2	-1	-0.5	-1.4	10.7	11.3	2.2	2.9	4.5	4.5	1.2
1.9	-1.4	-0.7	2	1.3	14.8	8.9	1.6	2.2	4.3	5.5	0.7
-1.4	-2.3	-0.4	5.1	4.4	12.9	6.5	1.9	1.7	4.7	5.8	-0.1
-2.1	-2.1	0.3	7.8	2.3	9.3	6.1	1.4	2.6	5.5	3.2	-2.2
-1.3	-1.8	1.5	6	0.6	8.5	5.1	1.4	3.4	5.5	-1.3	-2
0.6	-1.5	1.7	5.2	0.5	7	4.7	1.5	2.6	2.6	-1.9	0.6
1.5	-1.1	1.2	6.3	-0.5	5.5	4.5	0.8	1.2	-0.2	0.1	3.9
1.5	-0.7	1.4	6.3	-0.9	4.7	3.1	0.1	-0.3	-1.9	7.4	4.2
1.4	-0.6	1.8	5.5	-1.1	3	1.4	0	-1.8	-0.9	9	4.3
1.8	-1.2	1.9	3.2	-1.8	0.3	0.6	0.3	-2.3	-0.2	7.6	4.6
1.5	-1	1	1.9	[illegible]	-1.3	-0.1	-1	-2.1	-0.9	6.9	5.1



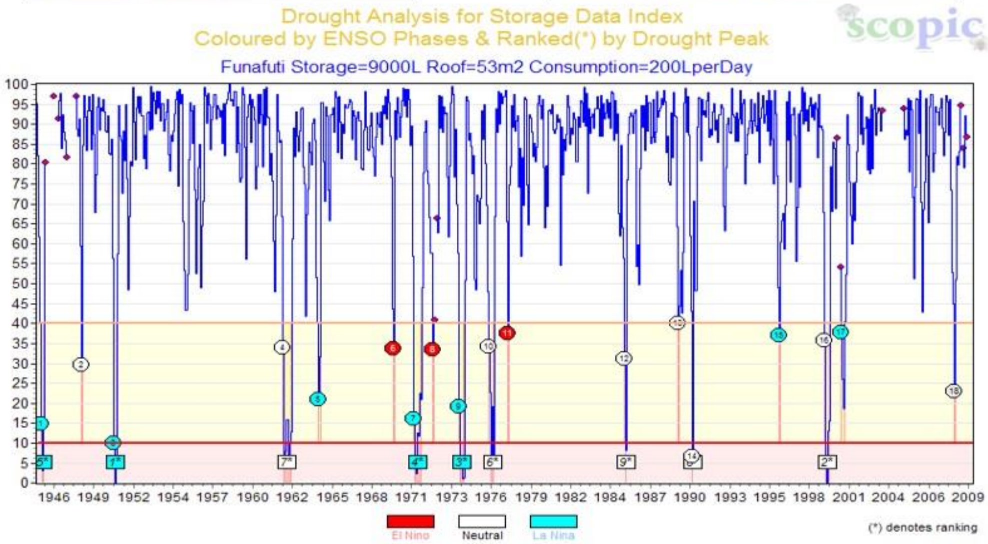
Mean rainfall	294 mm	-	-	-
Median rainfall	287 mm	-	-	-
CV	29.9%	-	-	-
Drought Statistics	**All Years**	**El Nino**	**La Nina**	**Other**
Number of Droughts	22	2	12	8
Drought Lengths	2 to 30 mths	6 to 7 mths	2 to 30 mths	3 to 19 mths
Average Drought Lengths	9.5 mths	6.5 mths	10.6 mths	8.5 mths
Between-Drought	**All Years**	**El Nino**	**La Nina**	**Other**
Between-drought lengths	1 to 85 mths	-	-	-
Average between-drought length	31.8 mths	-	-	-
Warning Statistics	**All Years**	**El Nino**	**La Nina**	**Other**
Number of Warnings	63	15	22	26
False Alarm Count	41	13	10	18
Correct Warning Count	22	2	12	8
Warning Success Rate	34.9%	13.3%	54.5%	30.8%
Warning Lengths (to drought)	0 to 10 mths	1 to 2 mths	1 to 7 mths	0 to 10 mths
Avg Warning Lengths	3.3 mths	1.5 mths	3.8 mths	3 mths

Storage output and statistics





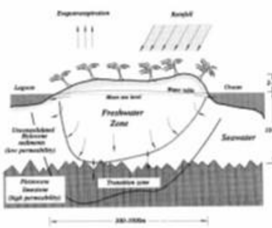
SCOPIC Drought Analysis…

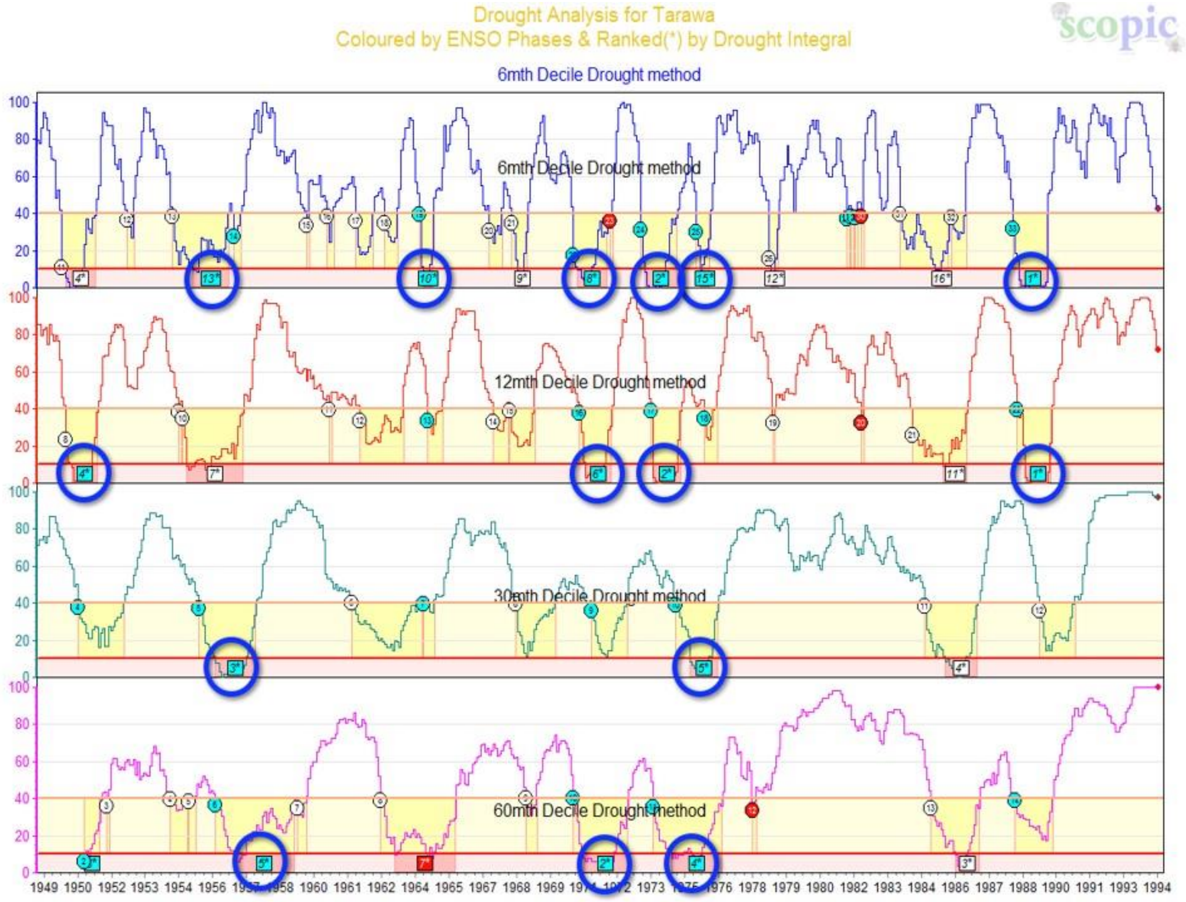


Assessing the potential of seasonal climate forecasting to better manage groundwater resources in Kiribati (and Tonga)

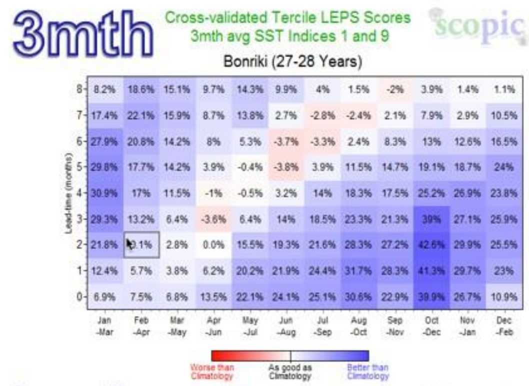
1. **Collect, collate and digitise historical groundwater test data.**
2. **Develop software to transform historical groundwater EC measurements into time-series of freshwater lens volume.**
3. **Assess the forecasting potential of seasonal rainfall and seasonal average freshwater lens volume.**
4. **Develop guidelines for freshwater lens management based on different ENSO conditions using SCOPIC.**

Australian Government
AusAID
Bureau of Meteorology

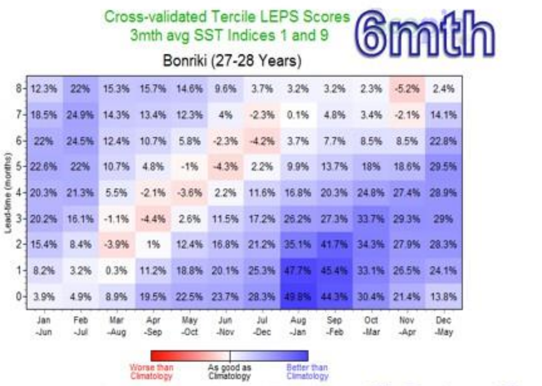




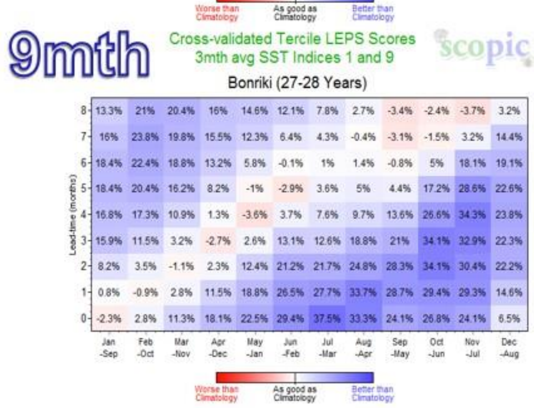
Drought Analysis for Tarawa
Coloured by ENSO Phases & Ranked(*) by Drought Integral
scopic
6mth Decile Drought method
12mth Decile Drought method
30mth Decile Drought method
60mth Decile Drought method



3mth
Cross-validated Tercile LEPS Scores
3mth avg SST Indices 1 and 9
scopic
Bonriki (27-28 Years)
Lead-time (months)
Worse than Climatology
As good as Climatology
Better than Climatology

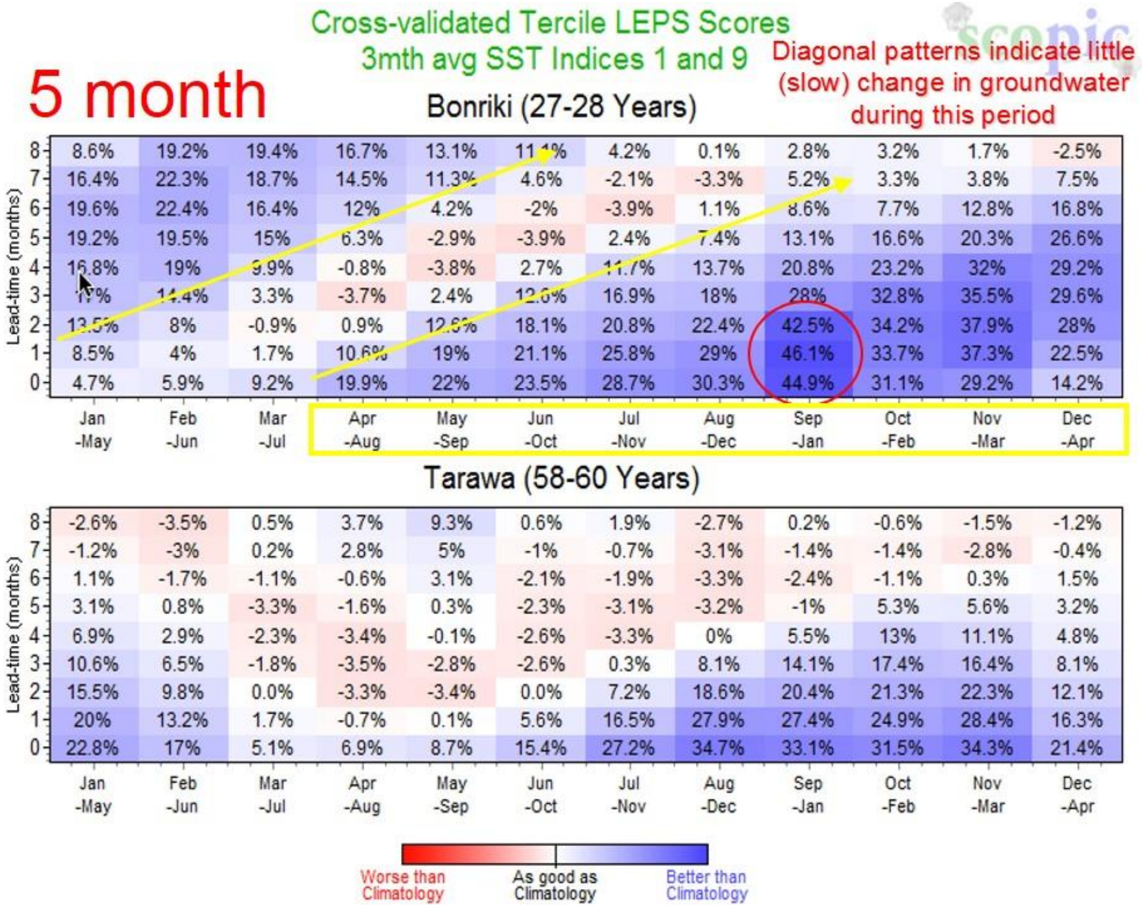


6mth
Cross-validated Tercile LEPS Scores
3mth avg SST Indices 1 and 9
Bonriki (27-28 Years)
Lead-time (months)
Worse than Climatology
As good as Climatology
Better than Climatology



9mth
Cross-validated Tercile LEPS Scores
3mth avg SST Indices 1 and 9
scopic
Bonriki (27-28 Years)
Lead-time (months)
Worse than Climatology
As good as Climatology
Better than Climatology

12mth
Cross-validated Tercile LEPS Scores
3mth avg SST Indices 1 and 9
Bonriki (26-27 Years)
Lead-time (months)
Worse than Climatology
As good as Climatology
Better than Climatology

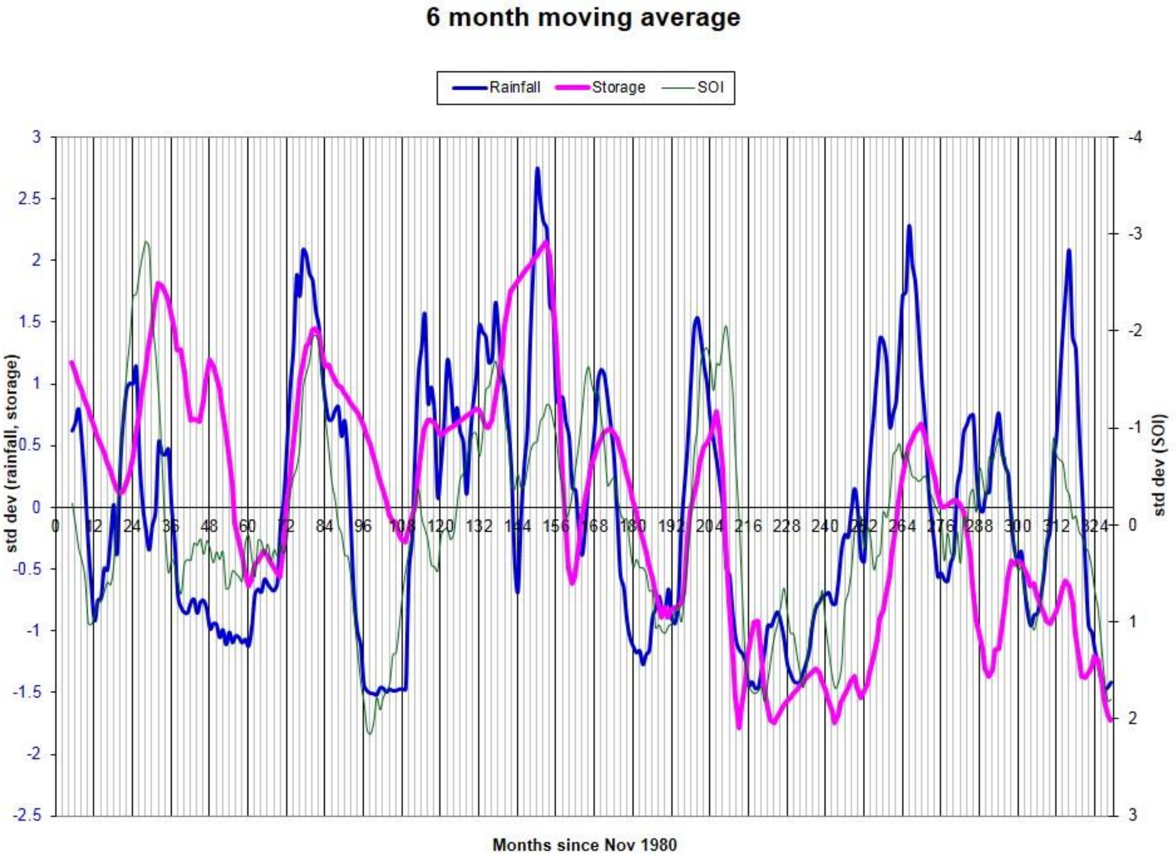


Bonriki (27-28 Years)

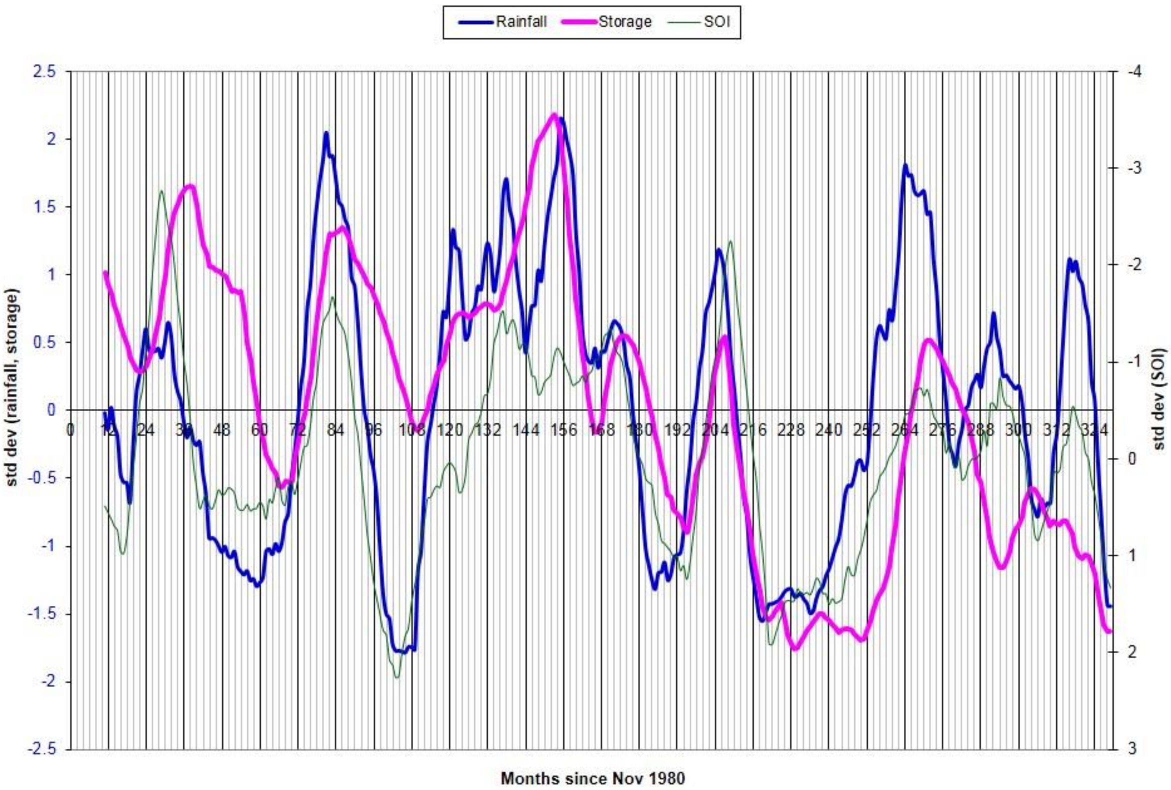
Lead-time (months)	Jan -May	Feb -Jun	Mar -Jul	Apr -Aug	May -Sep	Jun -Oct	Jul -Nov	Aug -Dec	Sep -Jan	Oct -Feb	Nov -Mar	Dec -Apr
8	8.6%	19.2%	19.4%	16.7%	13.1%	[illegible]	4.2%	0.1%	2.8%	3.2%	1.7%	-2.5%
7	16.4%	22.3%	18.7%	14.5%	11.3%	4.6%	-2.1%	-3.3%	5.2%	3.3%	3.8%	7.5%
6	19.6%	22.4%	16.4%	12%	4.2%	-2%	-3.9%	1.1%	8.6%	7.7%	12.8%	16.8%
5	19.2%	19.5%	15%	6.3%	-2.9%	-3.9%	2.4%	7.4%	13.1%	16.6%	20.3%	26.6%
4	16.8%	19%	9.9%	-0.8%	-3.8%	2.7%	11.7%	13.7%	20.8%	23.2%	32%	29.2%
3	[illegible]	14.4%	3.3%	-3.7%	2.4%	12.6%	16.9%	18%	28%	32.8%	35.5%	29.6%
2	13.5%	8%	-0.9%	0.9%	12.6%	18.1%	20.8%	22.4%	42.5%	34.2%	37.9%	28%
1	8.5%	4%	1.7%	10.6%	19%	21.1%	25.8%	29%	46.1%	33.7%	37.3%	22.5%
0	4.7%	5.9%	9.2%	19.9%	22%	23.5%	28.7%	30.3%	44.9%	31.1%	29.2%	14.2%

Tarawa (58-60 Years)

Lead-time (months)	Jan -May	Feb -Jun	Mar -Jul	Apr -Aug	May -Sep	Jun -Oct	Jul -Nov	Aug -Dec	Sep -Jan	Oct -Feb	Nov -Mar	Dec -Apr
8	-2.6%	-3.5%	0.5%	3.7%	9.3%	0.6%	1.9%	-2.7%	0.2%	-0.6%	-1.5%	-1.2%
7	-1.2%	-3%	0.2%	2.8%	5%	-1%	-0.7%	-3.1%	-1.4%	-1.4%	-2.8%	-0.4%
6	1.1%	-1.7%	-1.1%	-0.6%	3.1%	-2.1%	-1.9%	-3.3%	-2.4%	-1.1%	0.3%	1.5%
5	3.1%	0.8%	-3.3%	-1.6%	0.3%	-2.3%	-3.1%	-3.2%	-1%	5.3%	5.6%	3.2%
4	6.9%	2.9%	-2.3%	-3.4%	-0.1%	-2.6%	-3.3%	0%	5.5%	13%	11.1%	4.8%
3	10.6%	6.5%	-1.8%	-3.5%	-2.8%	-2.6%	0.3%	8.1%	14.1%	17.4%	16.4%	8.1%
2	15.5%	9.8%	0.0%	-3.3%	-3.4%	0.0%	7.2%	18.6%	20.4%	21.3%	22.3%	12.1%
1	20%	13.2%	1.7%	-0.7%	0.1%	5.6%	16.5%	27.9%	27.4%	24.9%	28.4%	16.3%
0	22.8%	17%	5.1%	6.9%	8.7%	15.4%	27.2%	34.7%	33.1%	31.5%	34.3%	21.4%



12 month moving average



Assessing the predictability of seasonal rainfall in the south-west Pacific region

Dr Yahya Abawi[1,2] , Dr David McClymont[2] , Dr Simon White[2], Colleagues from the Pacific Island Countries

[1] National Climate Centre Bureau of Meteorology
[2] University of Southern Queensland

Pacific Islands – Climate Prediction Project (PI-CPP)

www.bom.gov.au/climate/pi-cpp/

- **Develop a software called SCOPIC (Seasonal Climate Outlook for Pacific Island Countries) to provide local NMS with the ability to issue seasonal climate forecasts specific to their country**
- **Training in SCF and Risk Management**
- **Conduct pilot project on the impact of climate on vulnerable sectors in each participating country**

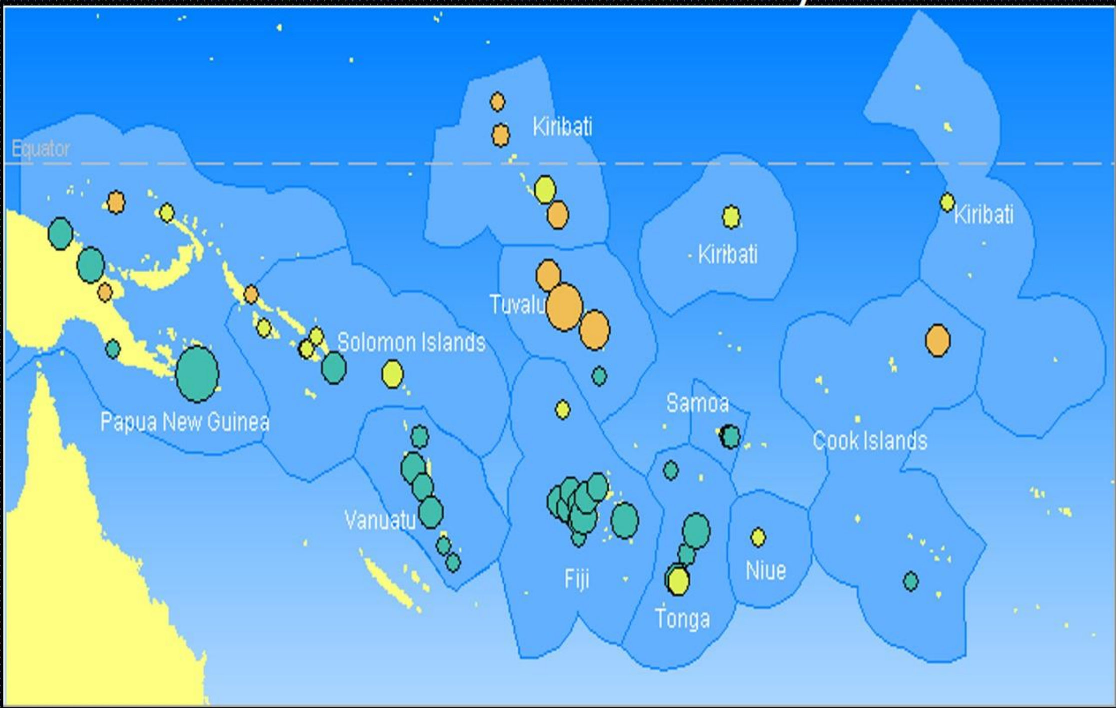
Objectives of Study

1. Analyse the relationship between seasonal rainfall with ENSO for each country.
2. Determine the most robust predictive system(s) for each country.

Drivers of climate in Pacific

- Madden-Julian Oscillation (MJO)
- El Niño Southern Oscillation (ENSO)
- Interdecadal Pacific Oscillation (IPO)
- Intertropical Convergence Zone (ITCZ)
- South Pacific Convergence Zone (SPCZ)

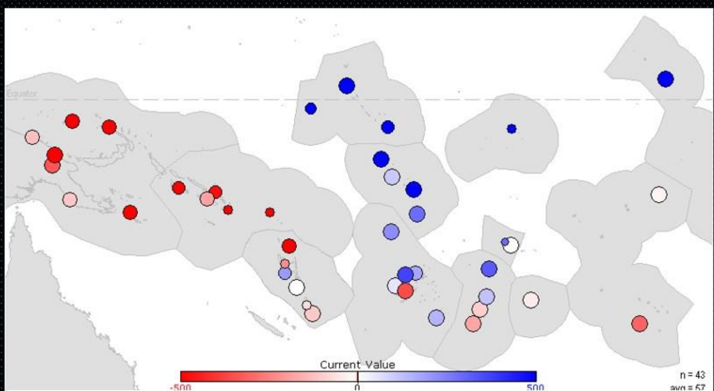
Countries included in the study



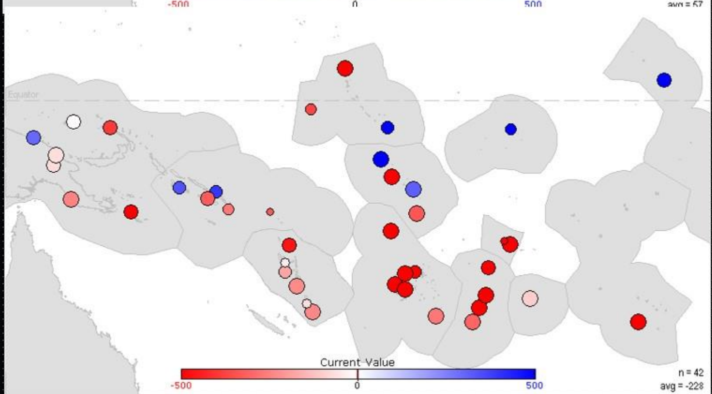
Rainfall Anomalies

1997 El Nino

May – Oct 1997

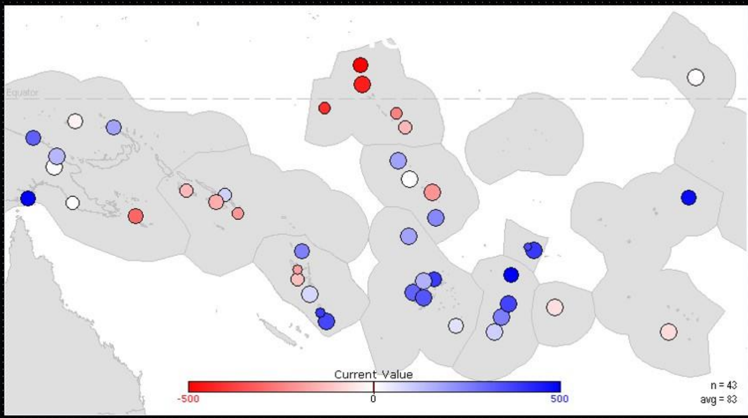


Nov 1997– April 1998

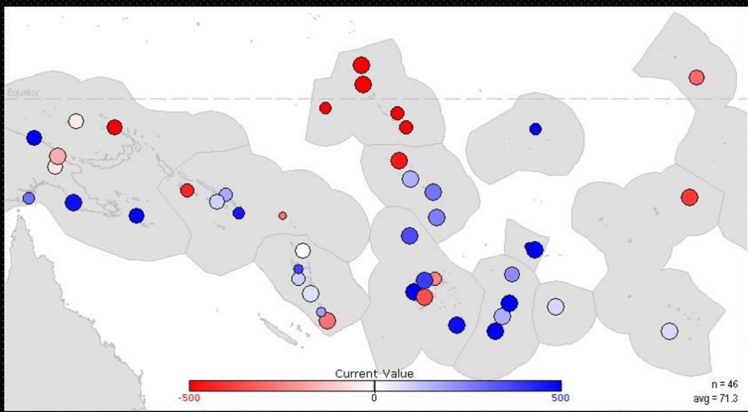


1973
La Nina

May – Oct
1973

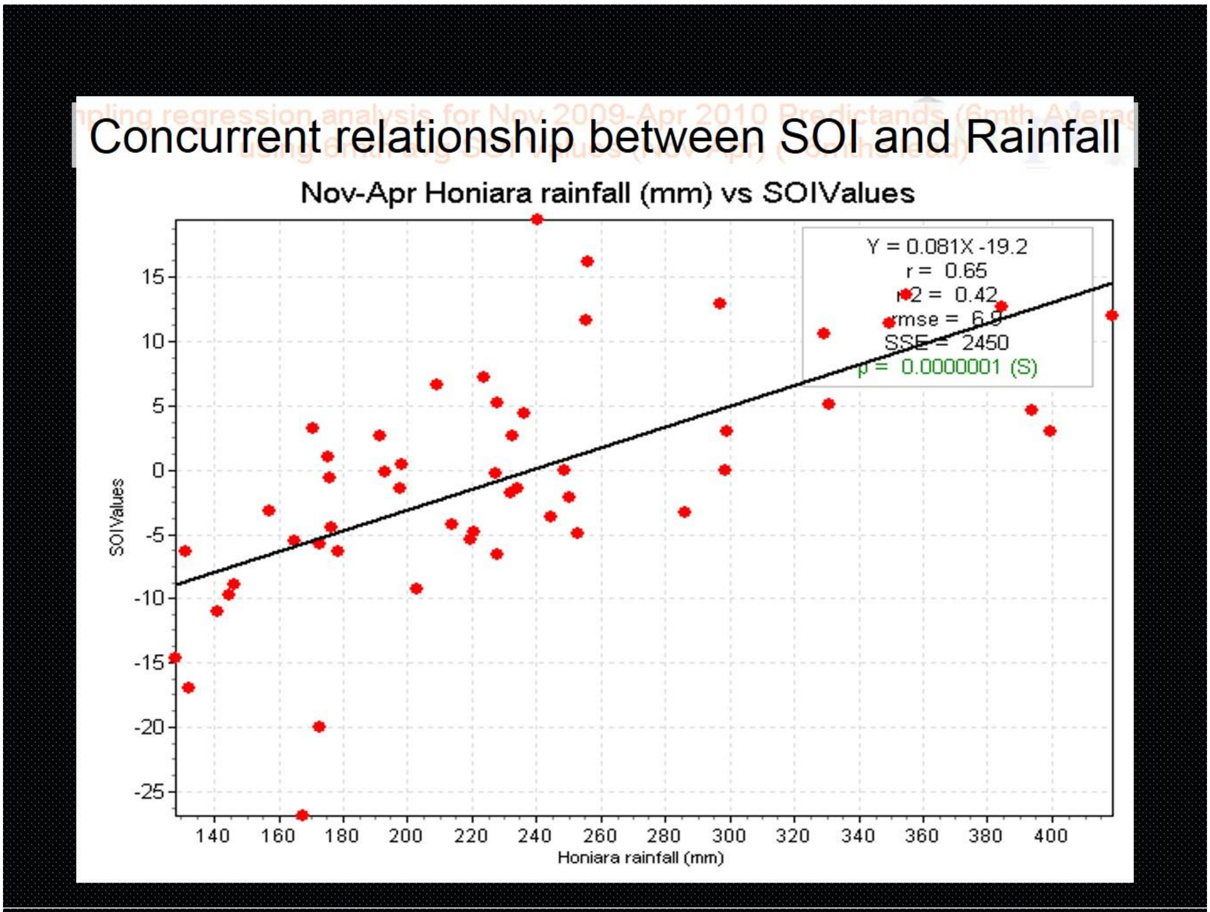


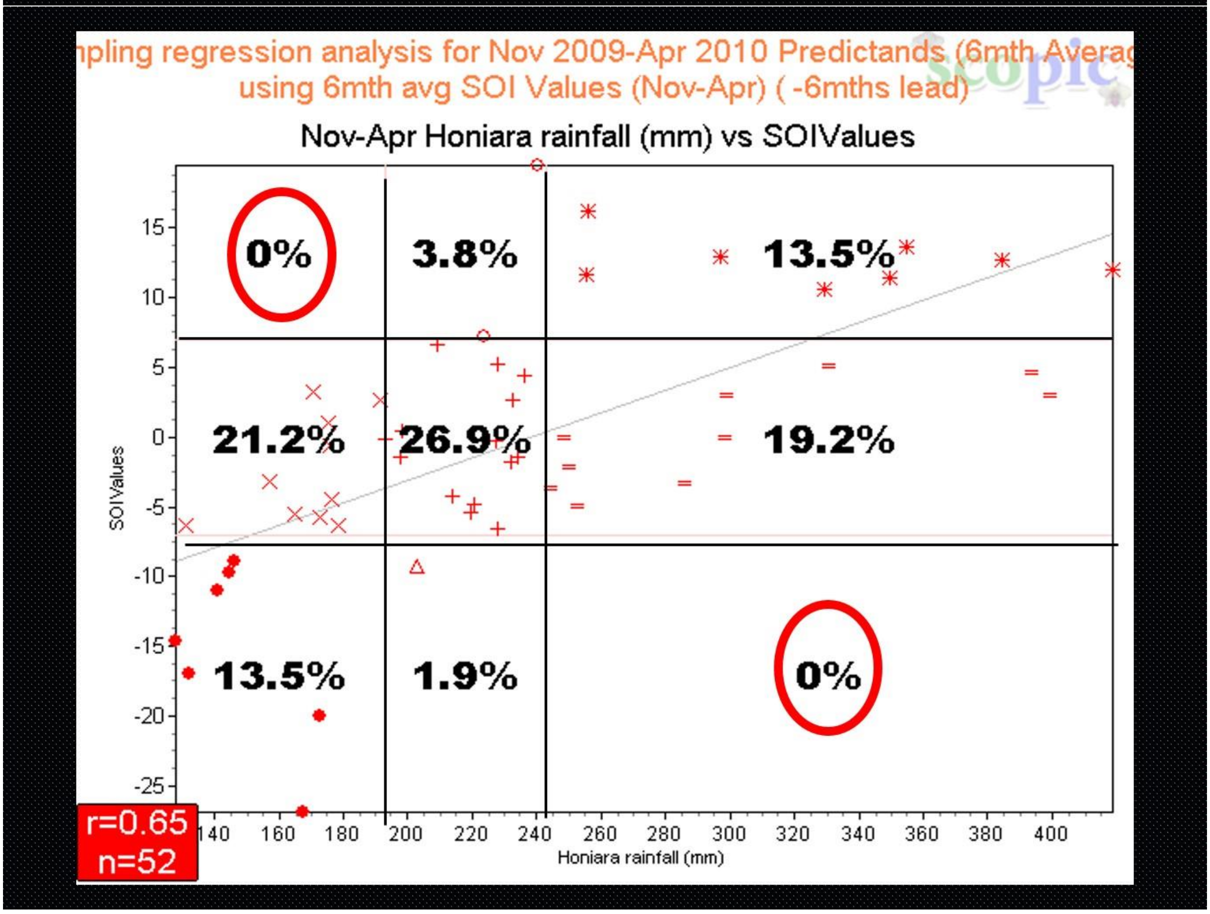
Nov 1973–
April 1973

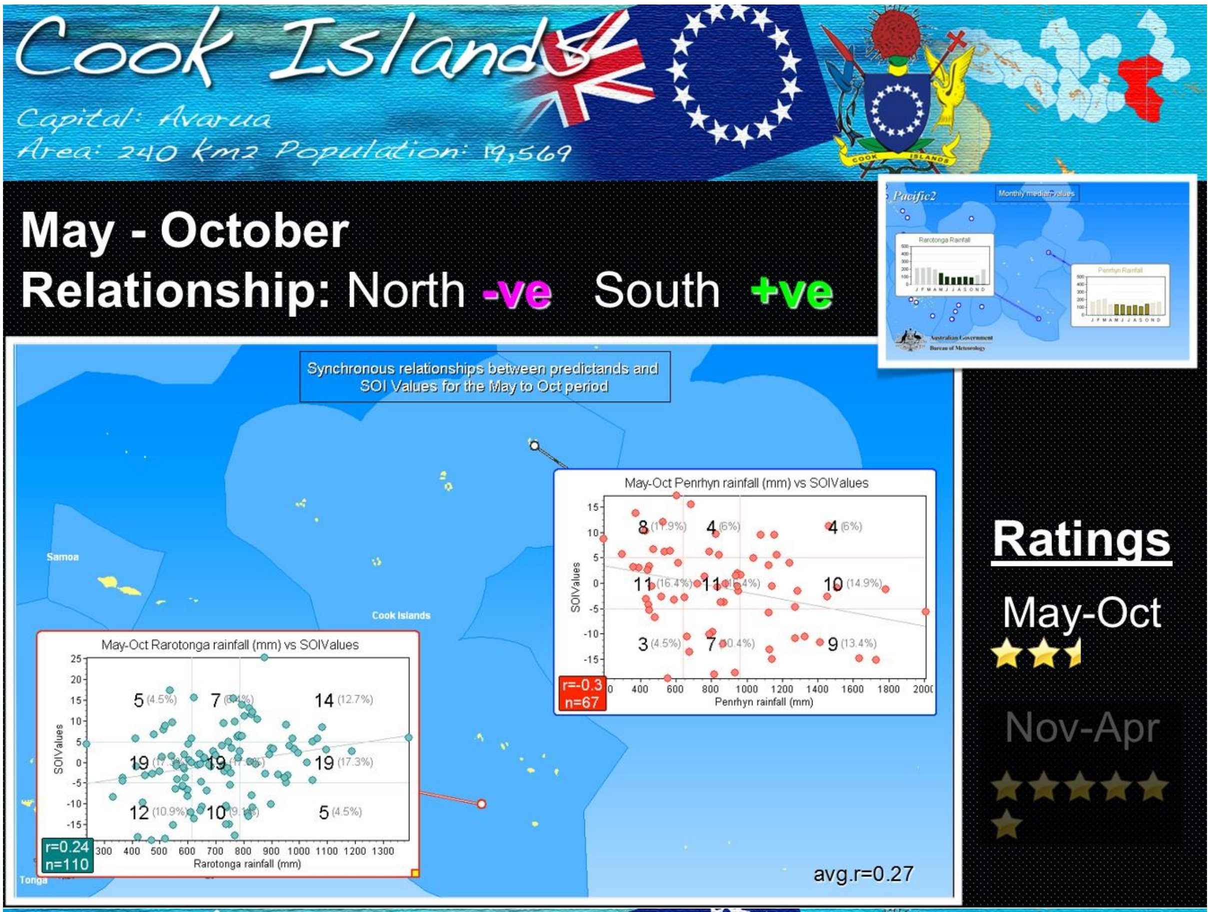


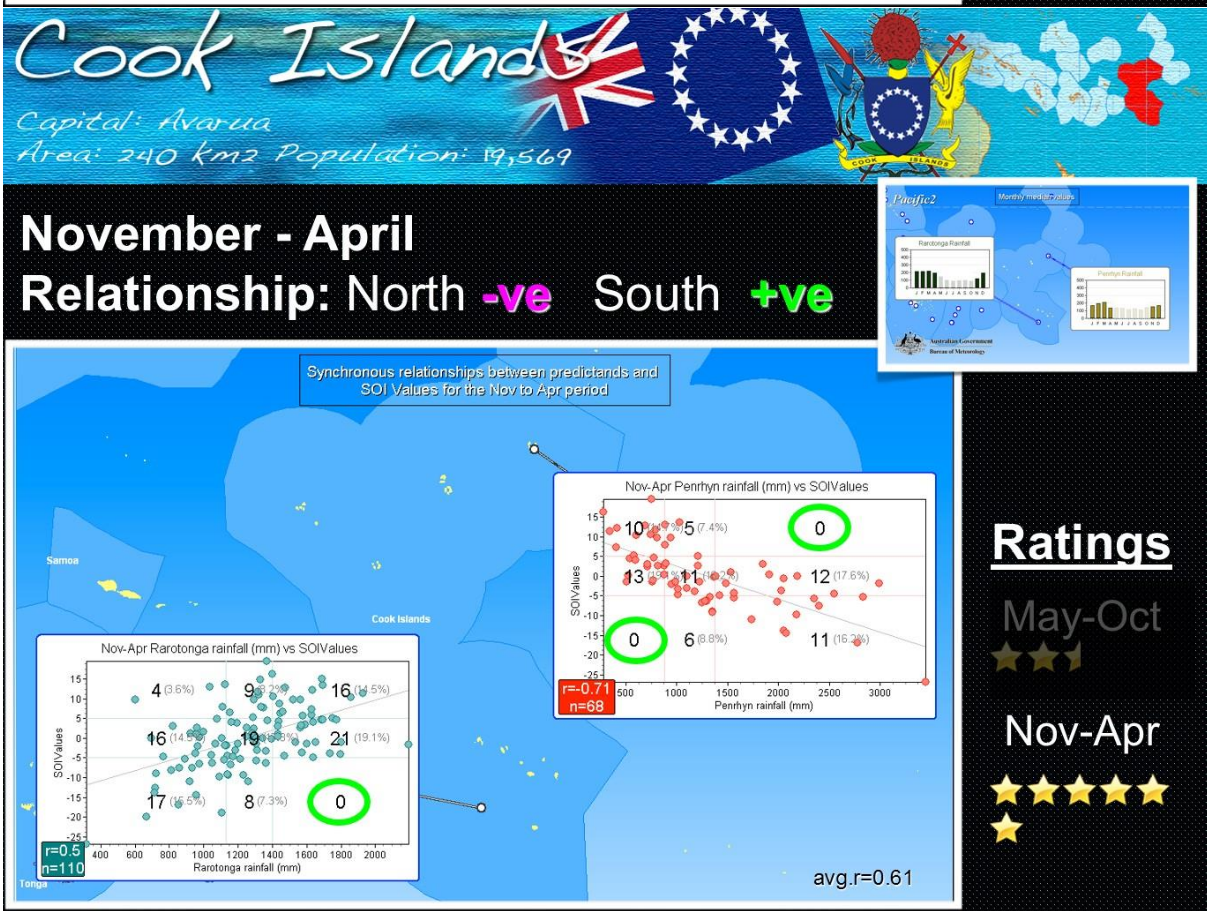
Methodology

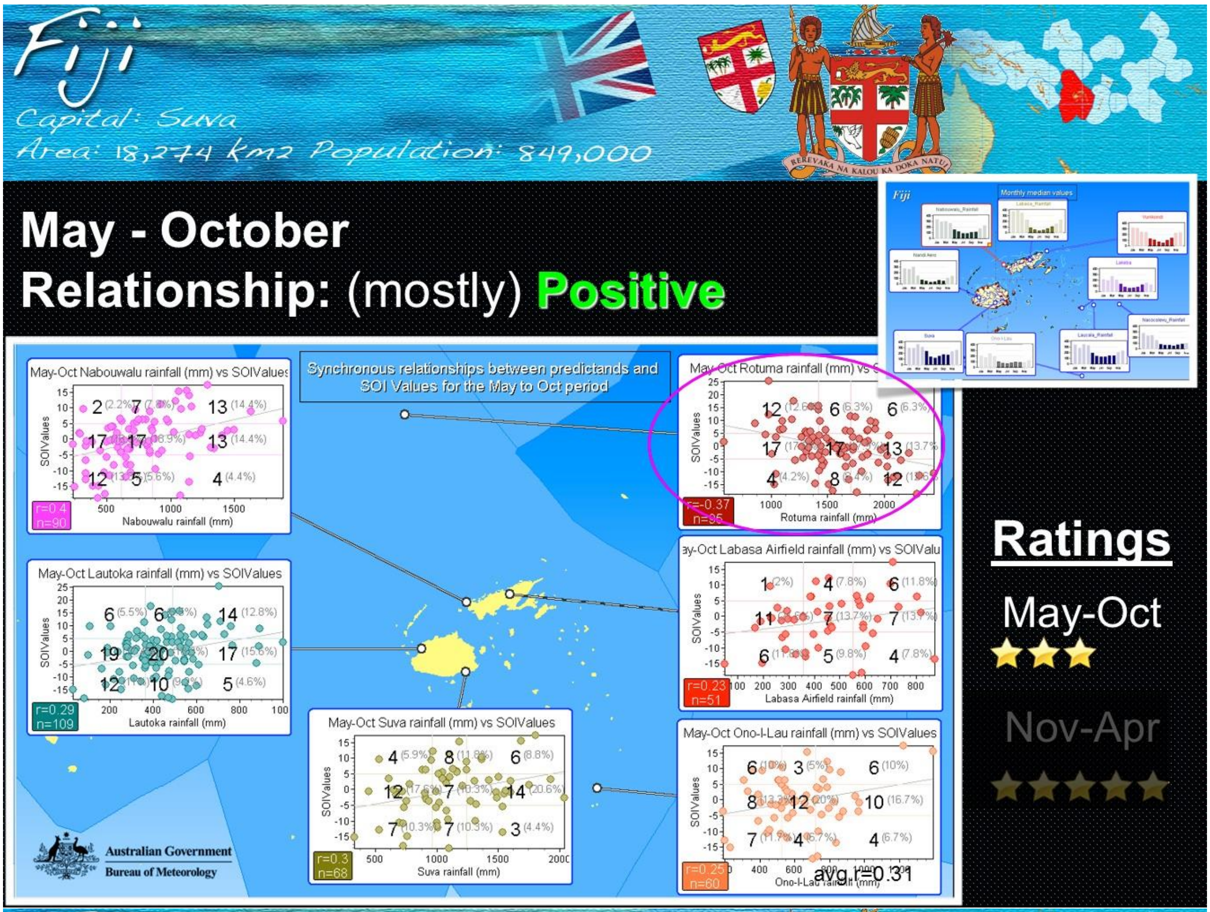
- Use ***SCOPIC's*** regression analysis to compare synchronous SOI and rainfall relationship for periods of:
  - May to October (dry season)
  - November to April (wet season)
- Record relationships (**+ve** or **-ve**)
- Assess correlations using star-scale:
  ⭐ Poorly Correlated ⭐⭐⭐⭐⭐ Highly Correlated

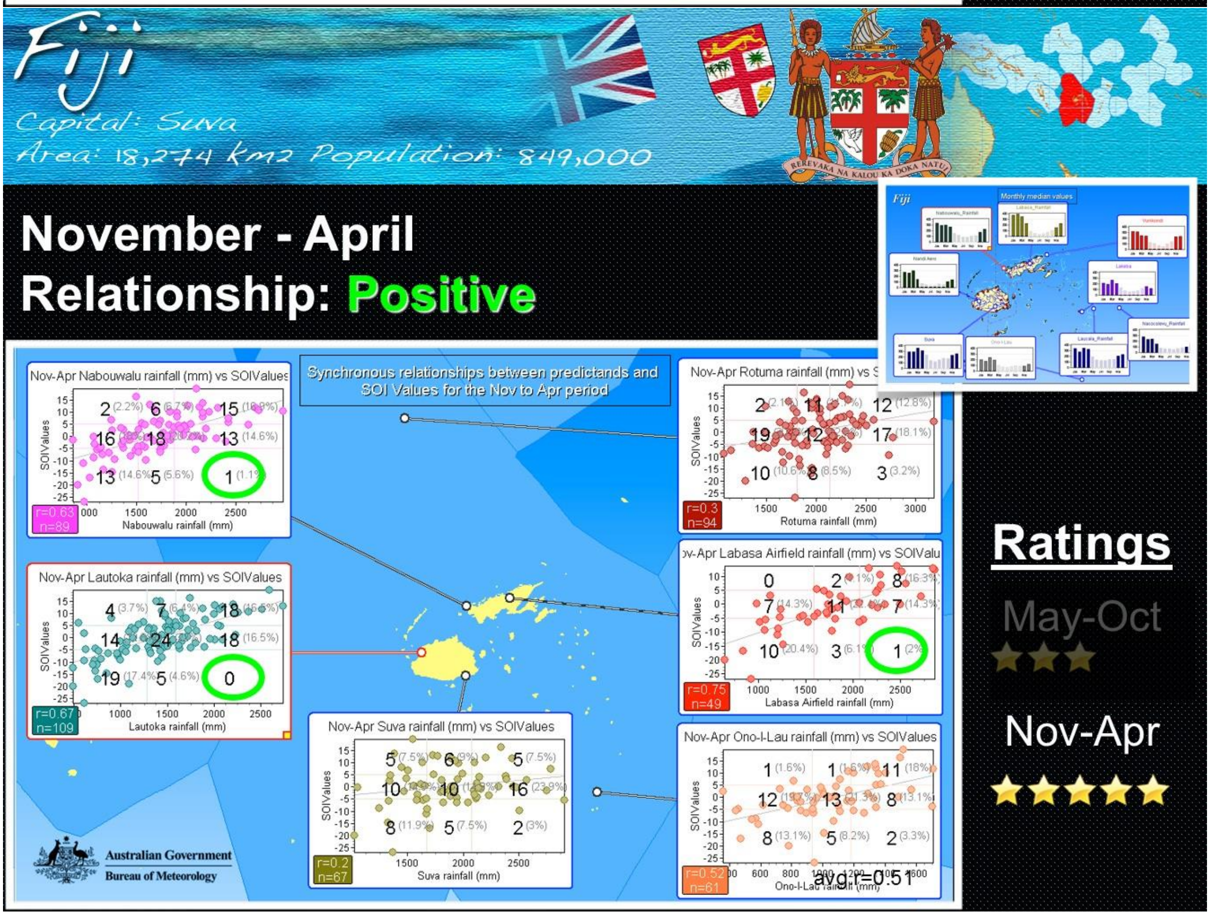

Concurrent relationship between SOI and Rainfall
Nov-Apr Honiara rainfall (mm) vs SOIValues
Y = 0.081X -19.2
r = 0.65
r2 = 0.42
rmse = 6.9
SSE = 2450
p = 0.0000001 (S)
SOIValues
Honiara rainfall (mm)

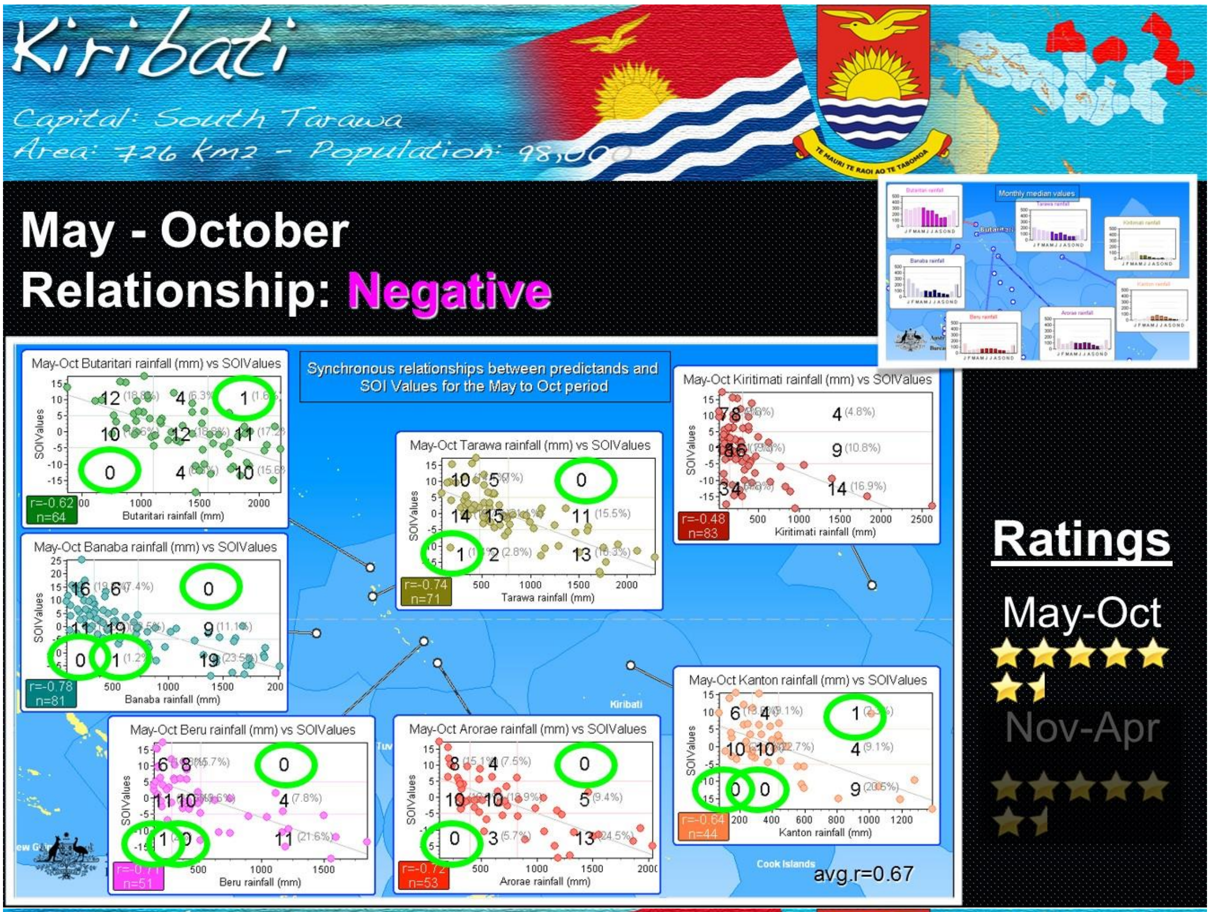

using 6mth avg SOI Values (Nov-Apr) (-6mths lead)
Nov-Apr Honiara rainfall (mm) vs SOIValues
0%
3.8%
13.5%
21.2%
26.9%
19.2%
13.5%
1.9%
0%
r=0.65
n=52
SOIValues
Honiara rainfall (mm)


Cook Islands
Capital: Avarua
Area: 240 km2 Population: 19,569
May - October
Relationship: North -ve South +ve
Synchronous relationships between predictands and SOI Values for the May to Oct period
May-Oct Penrhyn rainfall (mm) vs SOIValues
r=-0.3
n=67
Penrhyn rainfall (mm)
SOIValues
May-Oct Rarotonga rainfall (mm) vs SOIValues
r=0.24
n=110
Rarotonga rainfall (mm)
Samoa
Cook Islands
Tonga
avg.r=0.27
Ratings
May-Oct
Nov-Apr

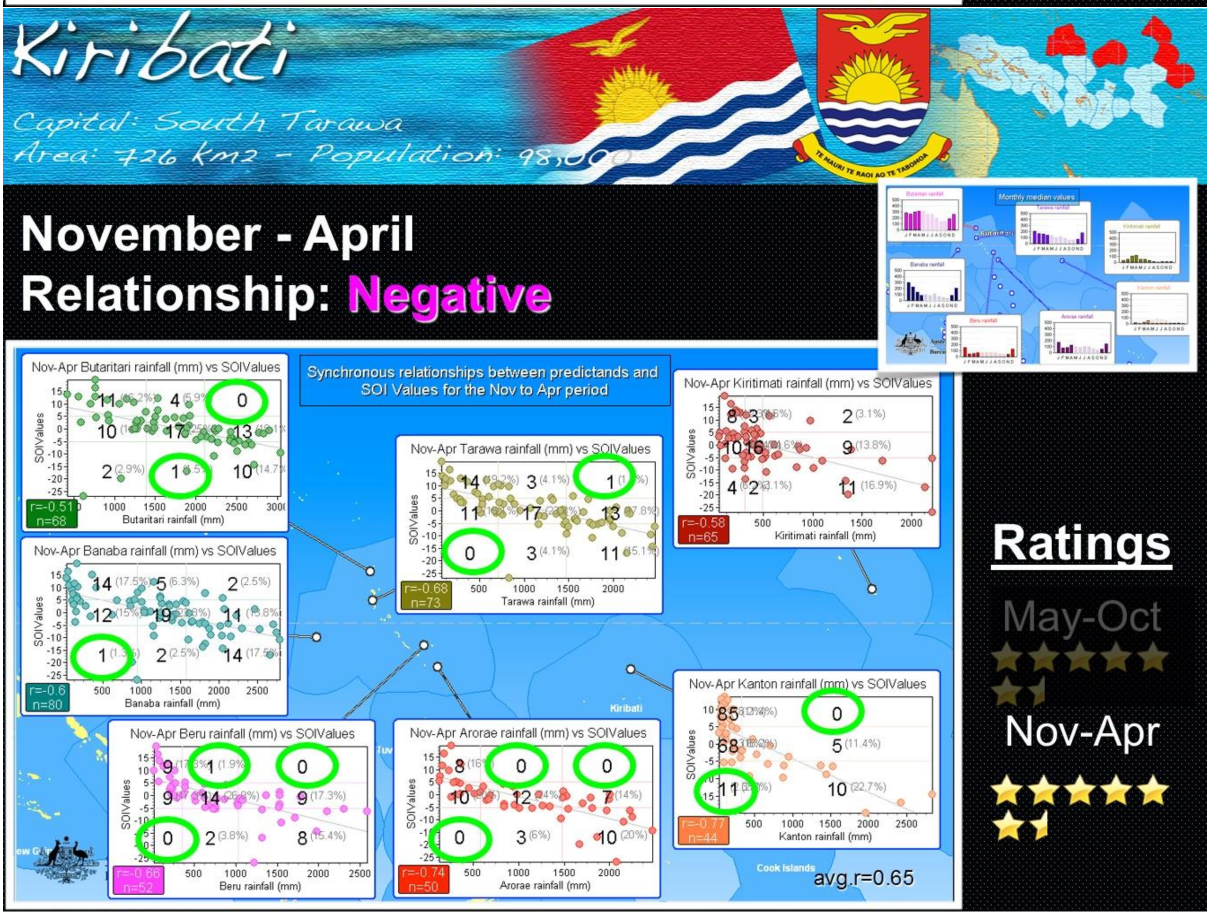

Cook Islands
Capital: Avarua
Area: 240 km2 Population: 19,569
November - April
Relationship: North -ve South +ve
Synchronous relationships between predictands and SOI Values for the Nov to Apr period
Nov-Apr Penrhyn rainfall (mm) vs SOIValues
r=-0.71
n=68
Penrhyn rainfall (mm)
SOIValues
Nov-Apr Rarotonga rainfall (mm) vs SOIValues
r=0.5
n=110
Rarotonga rainfall (mm)
Samoa
Cook Islands
Tonga
avg.r=0.61
Ratings
May-Oct
Nov-Apr


Fiji
Capital: Suva
Area: 18,274 km2 Population: 849,000
May - October
Relationship: (mostly) Positive
May-Oct Nabouwalu rainfall (mm) vs SOIValues
Synchronous relationships between predictands and SOI Values for the May to Oct period
May-Oct Lautoka rainfall (mm) vs SOIValues
May-Oct Suva rainfall (mm) vs SOIValues
May-Oct Ono-I-Lau rainfall (mm) vs SOIValues
avg.r=0.31
Australian Government
Bureau of Meteorology
Ratings
May-Oct
Nov-Apr

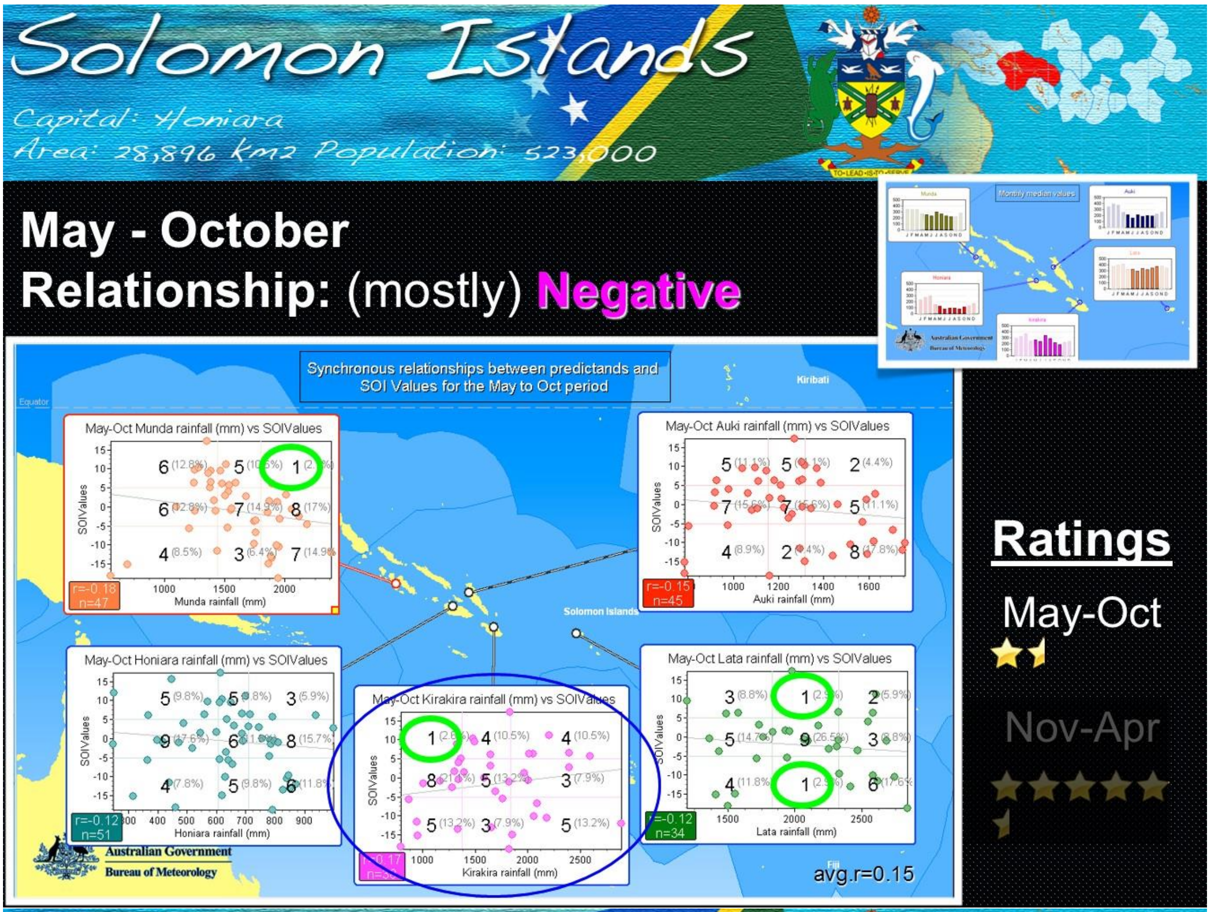

Fiji
Capital: Suva
Area: 18,274 km2 Population: 849,000
November - April
Relationship: Positive
Nov-Apr Nabouwalu rainfall (mm) vs SOIValues
Synchronous relationships between predictands and SOI Values for the Nov to Apr period
Nov-Apr Lautoka rainfall (mm) vs SOIValues
Nov-Apr Suva rainfall (mm) vs SOIValues
Nov-Apr Ono-I-Lau rainfall (mm) vs SOIValues
avg.r=0.51
Australian Government
Bureau of Meteorology
Ratings
May-Oct
Nov-Apr

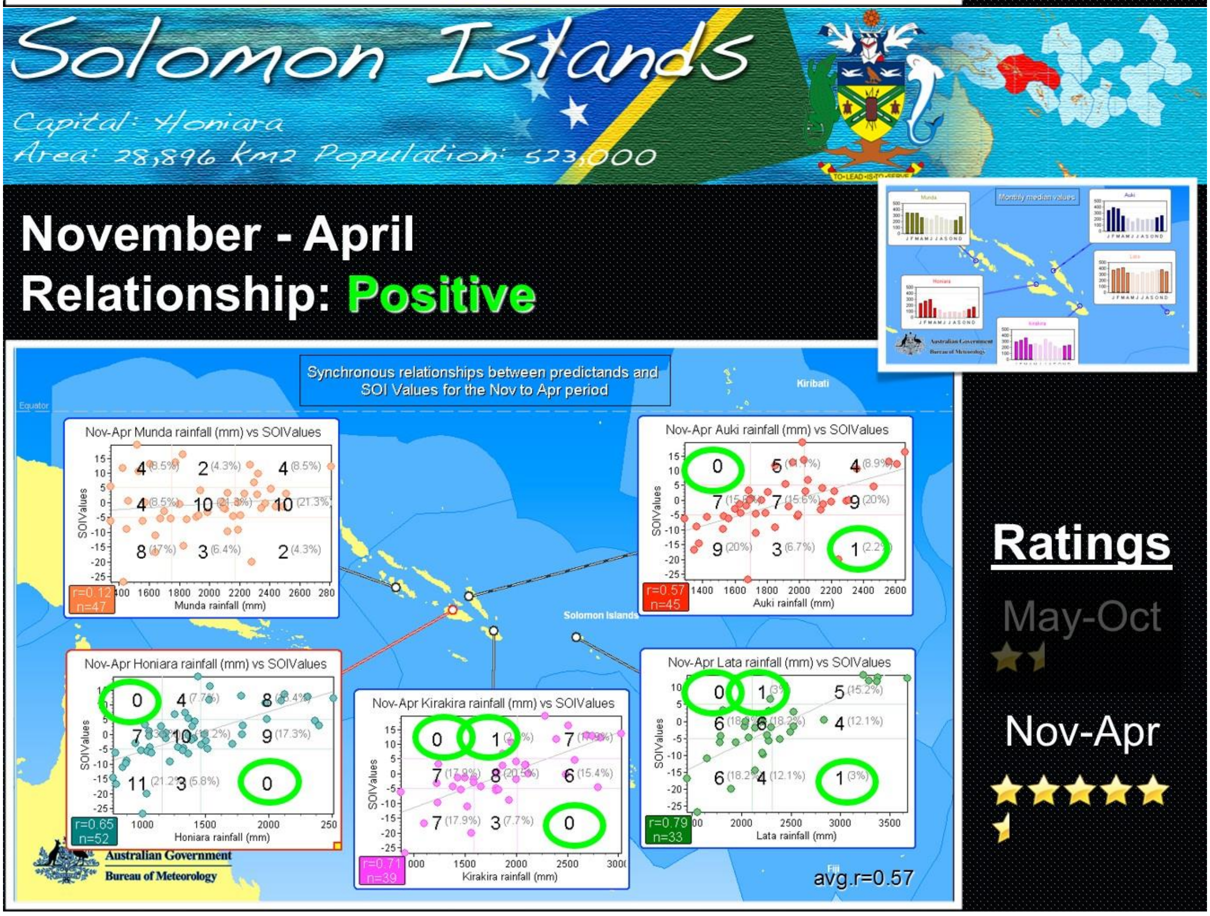


Kiribati
Capital: South Tarawa
Area: 726 km2 – Population: 98,000
TE MAURI TE RAOI AO TE TABOMOA
May - October
Relationship: Negative
Synchronous relationships between predictands and SOI Values for the May to Oct period
May-Oct Butaritari rainfall (mm) vs SOIValues
r=-0.62 n=64
May-Oct Tarawa rainfall (mm) vs SOIValues
r=-0.74 n=71
May-Oct Kiritimati rainfall (mm) vs SOIValues
r=-0.48 n=83
May-Oct Banaba rainfall (mm) vs SOIValues
r=-0.78 n=81
May-Oct Beru rainfall (mm) vs SOIValues
r=-0.71 n=51
May-Oct Arorae rainfall (mm) vs SOIValues
r=-0.72 n=53
May-Oct Kanton rainfall (mm) vs SOIValues
r=-0.64 n=44
avg.r=0.67
Ratings
May-Oct
Nov-Apr



Kiribati
Capital: South Tarawa
Area: 726 km2 – Population: 98,000
November - April
Relationship: Negative
Synchronous relationships between predictands and SOI Values for the Nov to Apr period
Nov-Apr Butaritari rainfall (mm) vs SOIValues
r=-0.51 n=68
Nov-Apr Tarawa rainfall (mm) vs SOIValues
r=-0.68 n=73
Nov-Apr Kiritimati rainfall (mm) vs SOIValues
r=-0.58 n=65
Nov-Apr Banaba rainfall (mm) vs SOIValues
r=-0.6 n=80
Nov-Apr Beru rainfall (mm) vs SOIValues
r=-0.66 n=52
Nov-Apr Arorae rainfall (mm) vs SOIValues
r=-0.74 n=50
Nov-Apr Kanton rainfall (mm) vs SOIValues
r=-0.77 n=44
avg.r=0.65
Ratings
May-Oct
Nov-Apr


Solomon Islands
Capital: Honiara
Area: 28,896 km2 Population: 523,000
May - October
Relationship: (mostly) Negative
Synchronous relationships between predictands and SOI Values for the May to Oct period
May-Oct Munda rainfall (mm) vs SOIValues
r=-0.18
n=47
May-Oct Auki rainfall (mm) vs SOIValues
r=-0.15
n=45
May-Oct Honiara rainfall (mm) vs SOIValues
r=-0.12
n=51
May-Oct Kirakira rainfall (mm) vs SOIValues
May-Oct Lata rainfall (mm) vs SOIValues
r=-0.12
n=34
Solomon Islands
Kiribati
Australian Government
Bureau of Meteorology
avg.r=0.15
Ratings
May-Oct
Nov-Apr


Solomon Islands
Capital: Honiara
Area: 28,896 km2 Population: 523,000
November - April
Relationship: Positive
Synchronous relationships between predictands and SOI Values for the Nov to Apr period
Nov-Apr Munda rainfall (mm) vs SOIValues
r=0.12
n=47
Nov-Apr Auki rainfall (mm) vs SOIValues
r=0.57
n=45
Nov-Apr Honiara rainfall (mm) vs SOIValues
r=0.65
n=52
Nov-Apr Kirakira rainfall (mm) vs SOIValues
r=0.71
n=39
Nov-Apr Lata rainfall (mm) vs SOIValues
r=0.79
n=33
Solomon Islands
Kiribati
Australian Government
Bureau of Meteorology
avg.r=0.57
Ratings
May-Oct
Nov-Apr

Concurrent relationship between SOI and rainfall

Summary

May-October

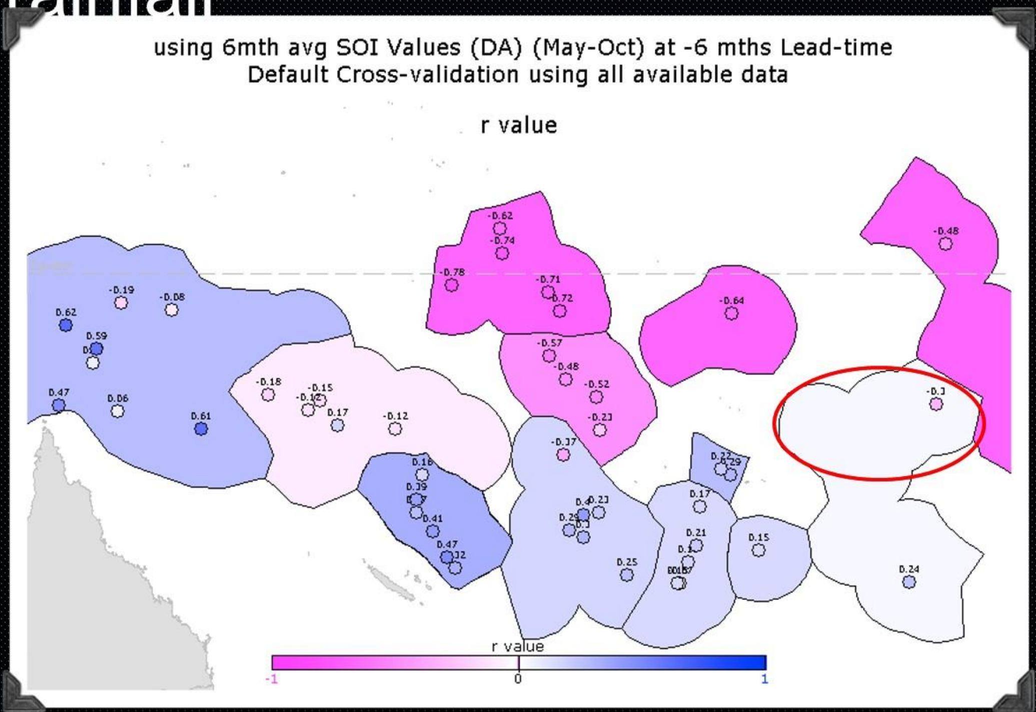
	Country	relationship	correlation
1	Cook Islands	-ve & +ve	★★½
2	Fiji	(m) positive	★★★
3	Kiribati	negative	★★★★★★½
4	Niue	positive	★½
5	Papua New Guinea	(m) positive	★★★½
6	Samoa	positive	★★½
7	Solomon Islands	(m) negative	★½
8	Tonga	positive	★★
9	Tuvalu	negative	★★★★½
10	Vanuatu	positive	★★★½

November-April

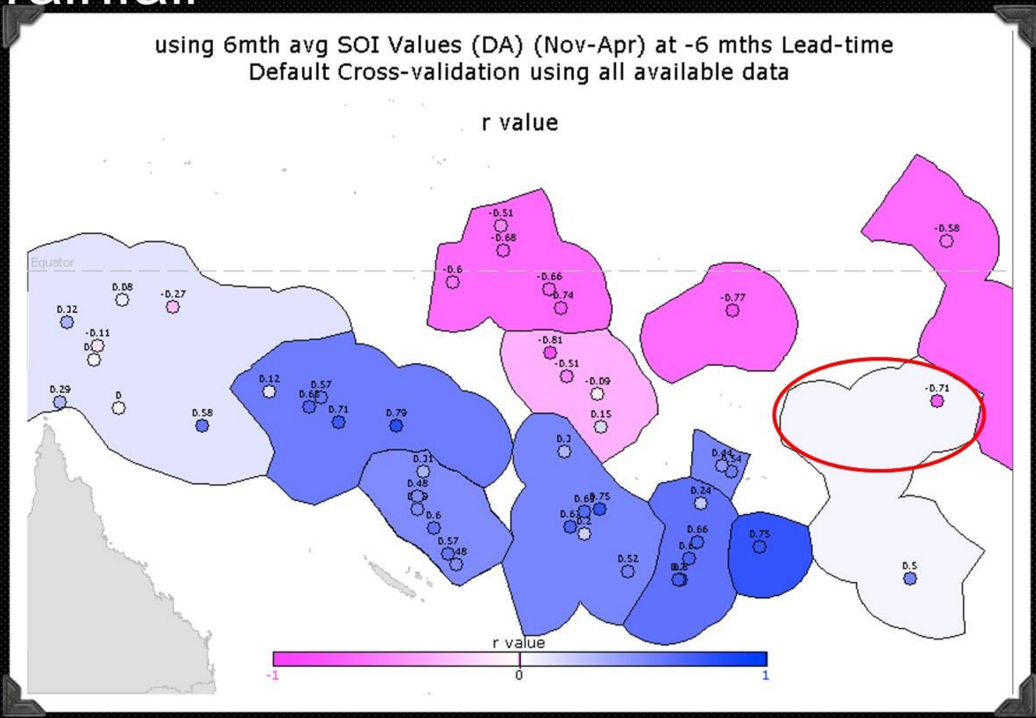
	Country	relationship	correlation
1	Cook Islands	-ve & +ve	★★★★★★
2	Fiji	positive	★★★★★
3	Kiribati	negative	★★★★★★½
4	Niue	positive	★★★★★★★½
5	Papua New Guinea	(m) positive	★★½
6	Samoa	positive	★★★★★
7	Solomon Islands	positive	★★★★★½
8	Tonga	positive	★★★★★½
9	Tuvalu	negative	★★★★
10	Vanuatu	positive	★★★★★

Ratings are for comparative purposes, but also provide an "estimate" of potential forecast skill.

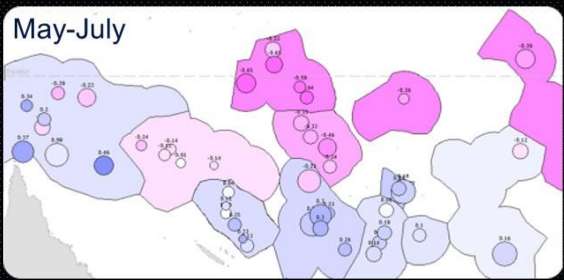
Summary May to October rainfall

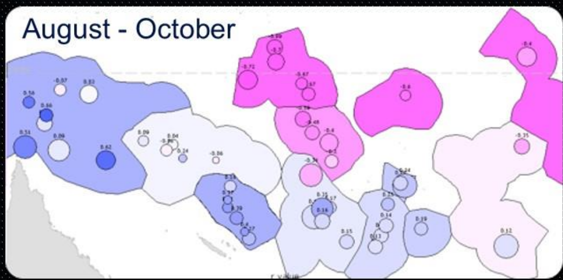


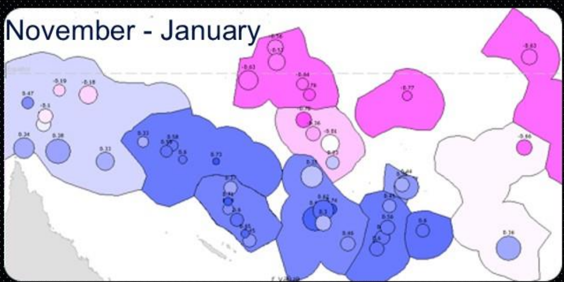
Summary November to April rainfall

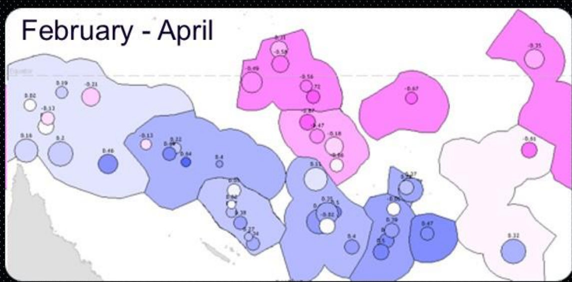


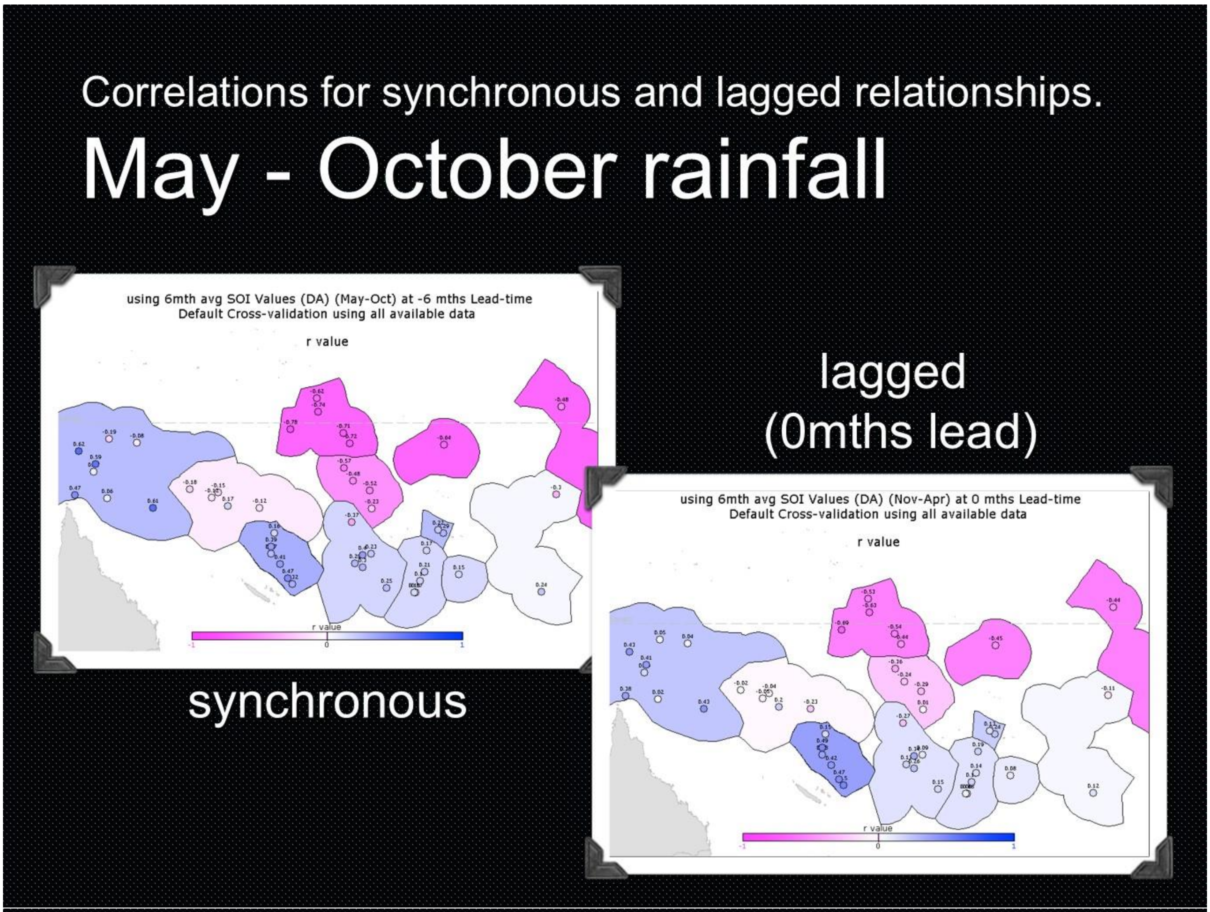
Quarterly Synchronous Relationships

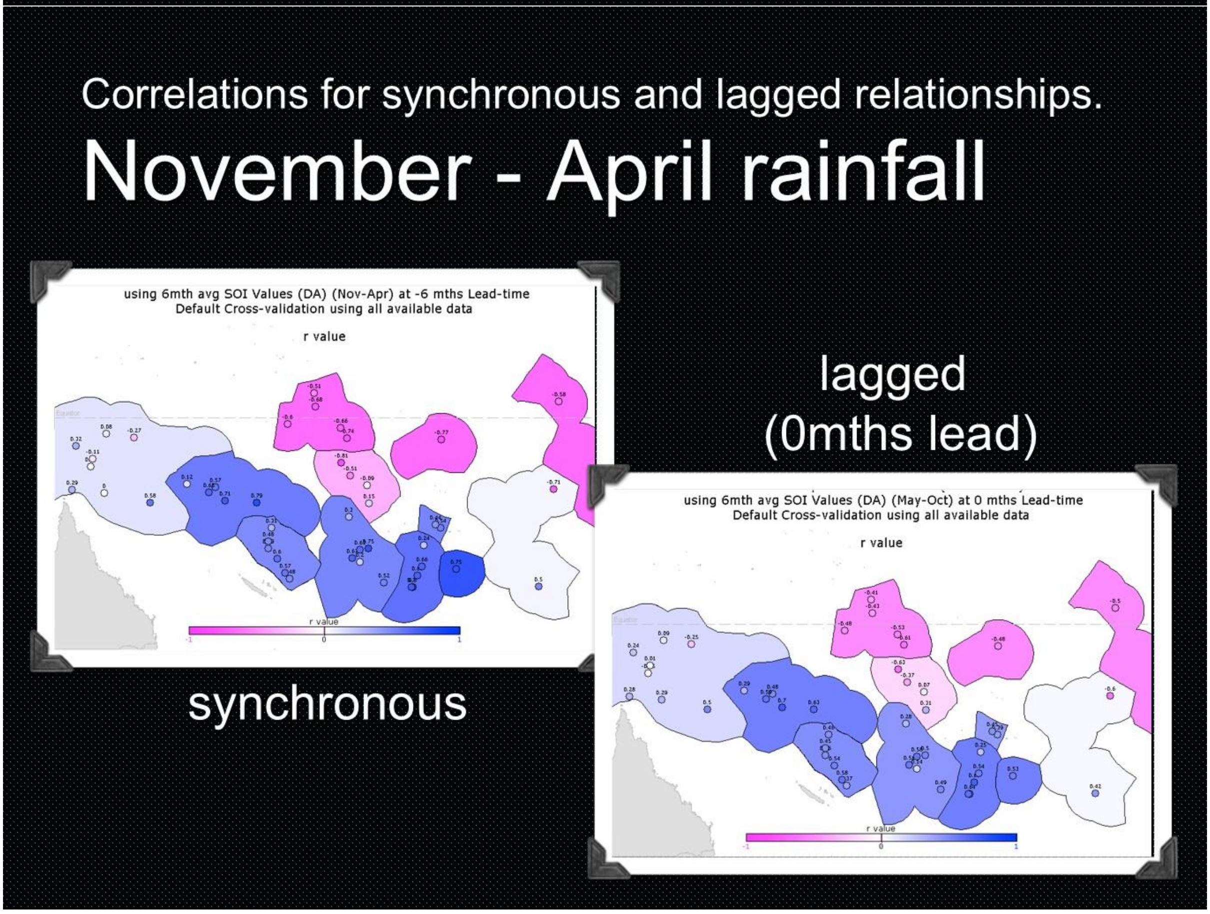









Correlations for synchronous and lagged relationships.
May - October rainfall
using 6mth avg SOI Values (DA) (May-Oct) at -6 mths Lead-time
Default Cross-validation using all available data
r value
synchronous
lagged
(0mths lead)
using 6mth avg SOI Values (DA) (Nov-Apr) at 0 mths Lead-time
Default Cross-validation using all available data
r value


Correlations for synchronous and lagged relationships.
November - April rainfall
using 6mth avg SOI Values (DA) (Nov-Apr) at -6 mths Lead-time
Default Cross-validation using all available data
r value
synchronous
lagged
(0mths lead)
using 6mth avg SOI Values (DA) (May-Oct) at 0 mths Lead-time
Default Cross-validation using all available data
r value

What is the most *robust* predictive system(s) for each country ?

Initial study only focused on SOI. This analysis was later expanded to include other ENSO based predictors

Methodology

- **Evaluate a range of ENSO-based statistical forecast systems (3mth rainfall outlooks) for each country by:**
- Using **FlowCast** to calculate **tercile LEPS scores** and **p-values** for:
  - twelve starting periods of the year
  - three lead-times (0,1 and 2 mths)
  - three predictor-averaging periods
    - 1, 2 and 3mth periods for SSTa based systems
    - 2, 3 and 4mth periods for SOI based systems
- **LEPS scores** arithmetically averaged for each country.
- Significant **p-value** tests counted for each country.
- Evaluate spatial-maps of LEPS Scores

Predictive systems analyzed

- SOI Values (from 1876)
- SOI Values (from 1949)
- SSTa 1
- SSTa 9
- SSTa 1 & 2
- SSTa 1 & 9
- Niño 1.2
- Niño 3
- Niño 3.4
- Niño 4

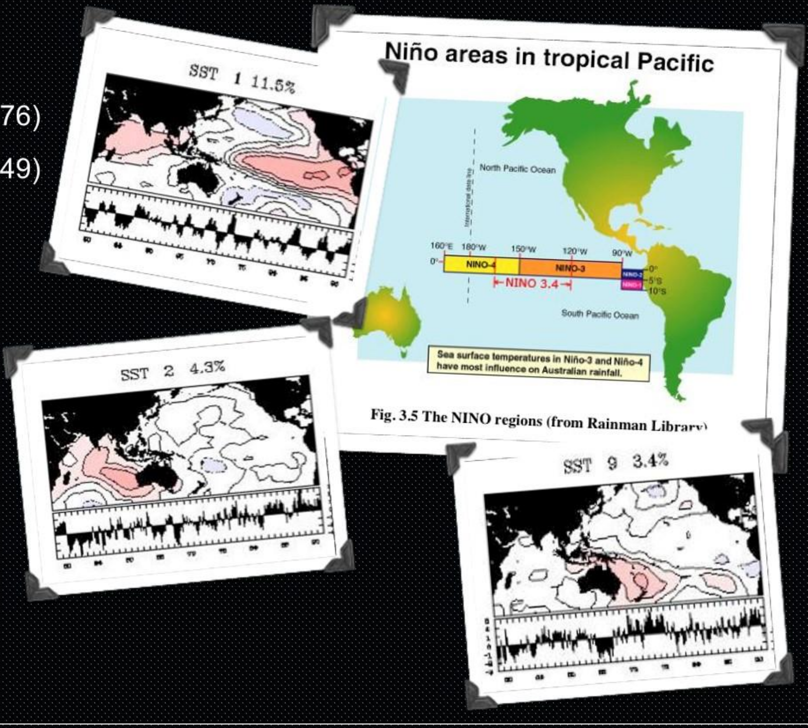


Fig. 3.5 The NINO regions (from Rainman Library)

Rainfall Prediction Skill

Cross-validated Tercile LEPS Scores
3mth avg SOI Values

scopic

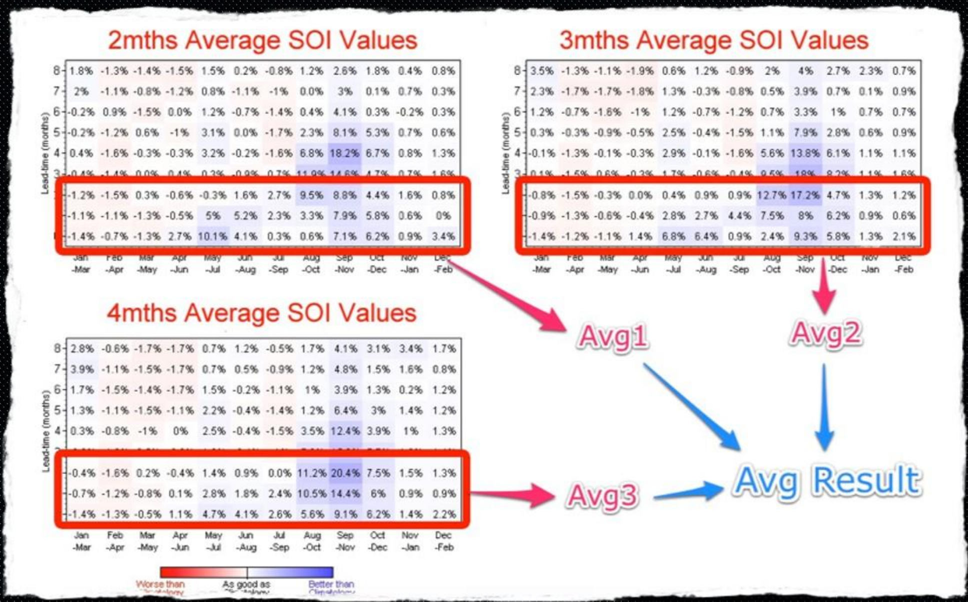
Honiara (51-55 Years)

Lead-time (months)	Jan -Mar	Feb -Apr	Mar -May	Apr -Jun	May -Jul	Jun -Aug	Jul -Sep	Aug -Oct	Sep -Nov	Oct -Dec	Nov -Jan	Dec -Feb
8	-0.9%	1%	7.8%	2.2%	5.9%	-1.9%	-1%	-0.6%	-1.4%	-0.7%	-2.4%	-1.4%
7	1.9%	7.8%	1.7%	1.5%	5.9%	-2.2%	-1.2%	-0.8%	-1.7%	-1.5%	-2.3%	-2.6%
6	6.5%	11.7%	4.4%	2.9%	3.6%	-0.5%	-1.4%	-1.7%	-1.6%	-2.4%	0.4%	0.8%
5	10.3%	22%	6.4%	1.9%	6.2%	0.3%	-1.7%	-1.5%	-1.2%	-0.3%	3.1%	6.6%
4	16.2%	24.8%	7%	2.8%	8.5%	1.3%	-1.4%	-0.5%	0.9%	1.1%	8.7%	11.3%
3	14.7%	27.6%	7%	6.1%	7.8%	0.8%	-1.3%	0.2%	0.8%	3.5%	10.4%	15.1%
2	16.7%	26.7%	11%	6.2%	8%	1.4%	-1.3%	-1.7%	0.0%	4.2%	17.3%	15.3%
1	17.5%	28.9%	9.6%	4.5%	7.3%	2.1%	-1.4%	-2.4%	-1.7%	11.1%	20.5%	18.4%
0	18.2%	25.4%	10.4%	4.5%	10%	-0.4%	-1.6%	-1.8%	-0.5%	16.1%	24.7%	20.3%

Worse than Climatology — As good as Climatology — Better than Climatology

LEPS arithmetic averaging strategy...

108 results averaged to a single result

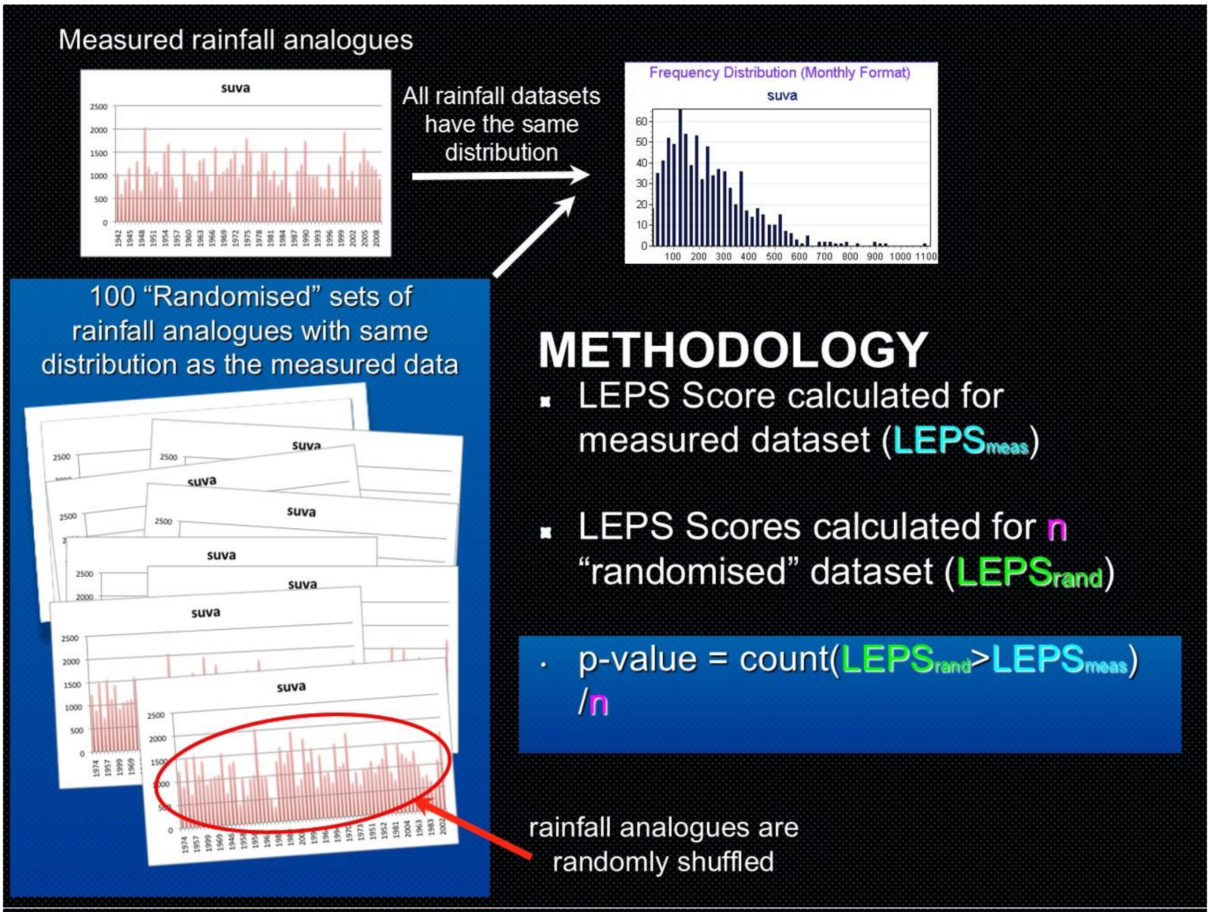


Station results are also averaged for each country.

Significance testing: p-tests

- Tests the **hypothesis** of whether the measured forecast skill (e.g. LEPS score) is greater than what can be obtained by chance.
- Tests measured skill against skill from “randomised” data.
- Uses a pre-defined significance level (e.g. 0.05).
  - Hypothesis is true if less than 5% of “randomised” skill tests have skill greater than measured.

In this study - significant p-test results are “**counted”** for each set of lead-times, averaging periods, and starting periods of the year, and **expressed as a percentage**



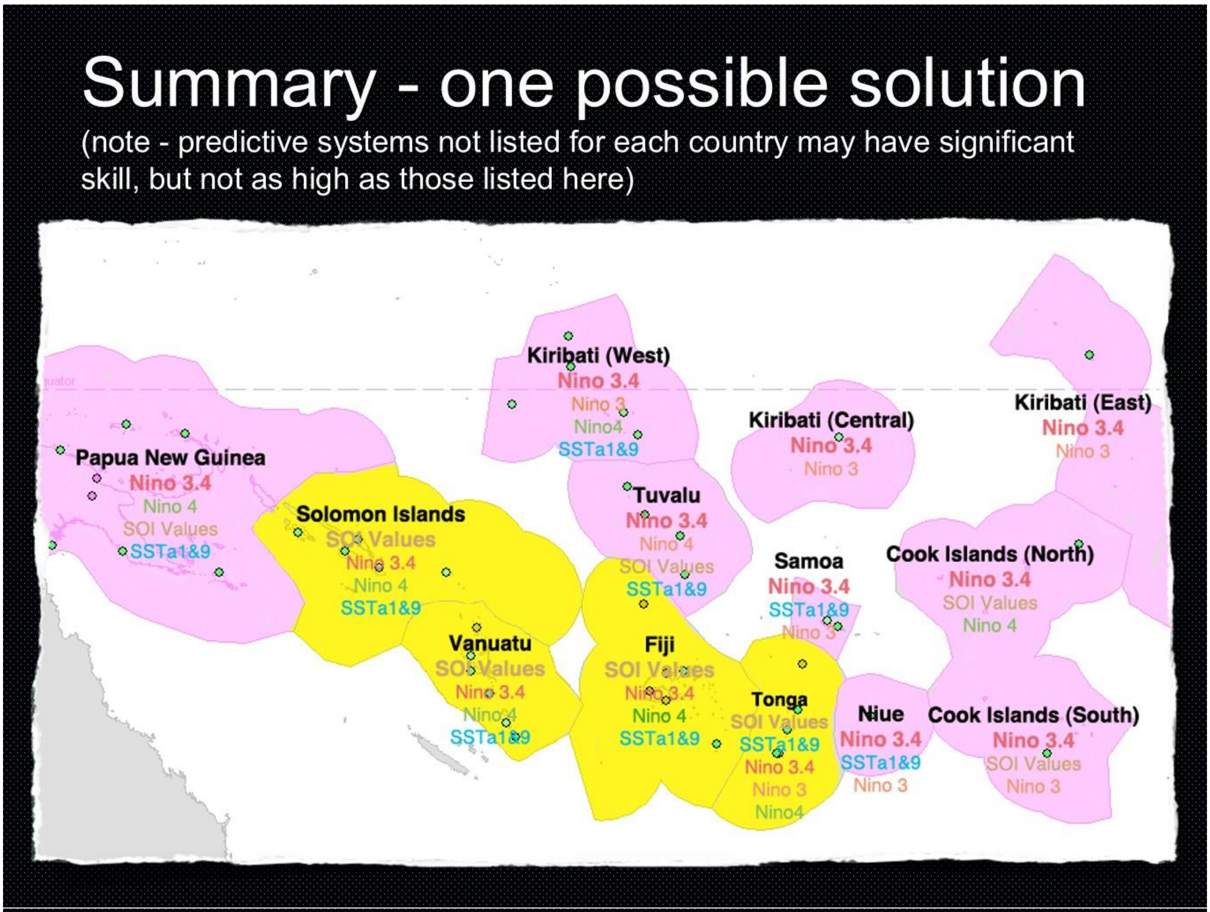
Summary of Results

Percentage of tests (n=108) which have skill above chance (p=0.05)

	SOI	SOI(1949)	SSTa1	SSTa9	SSTa1&9	SSTa1&2	Nino1.2	Nino3	Nino3.4	Nino4
Papua New Guinea	38.3%	35.5%	35.5%	11.0%	36.9%	31.7%	28.5%	38.7%	42.0%	41.2%
Cook Islands (North)	100.0%	99.1%	93.5%	30.6%	92.6%	92.6%	78.7%	89.8%	98.1%	89.8%
Cook Islands (South)	75.0%	49.1%	25.9%	8.3%	19.4%	13.9%	38.0%	60.2%	57.4%	38.0%
Fiji	67.4%	65.3%	51.5%	30.9%	55.1%	44.9%	37.8%	57.6%	59.7%	62.7%
Kiribati (West)	85.4%	80.6%	85.0%	17.2%	86.3%	90.9%	82.2%	88.1%	86.1%	89.1%
Kiribati (Central)	75.9%	75.0%	66.7%	6.5%	65.7%	71.3%	85.2%	85.2%	73.1%	63.9%
Kiribati (East)	56.5%	65.7%	61.1%	9.3%	67.6%	68.5%	66.7%	81.5%	75.9%	63.9%
Niue	41.7%	45.4%	41.7%	28.7%	49.1%	24.1%	59.3%	62.0%	50.9%	44.4%
Samoa	47.7%	25.5%	33.3%	17.1%	31.9%	26.4%	47.7%	51.4%	38.9%	24.1%
Solomon Islands	48.3%	49.3%	31.9%	21.1%	35.9%	29.6%	28.1%	41.1%	44.8%	46.3%
Tonga	58.7%	61.3%	43.1%	31.7%	46.9%	35.9%	48.0%	60.6%	56.1%	47.0%
Tuvalu	73.6%	75.0%	64.6%	20.4%	66.0%	63.2%	50.2%	64.8%	71.8%	76.4%
Vanuatu	72.4%	72.2%	43.7%	29.8%	52.3%	39.5%	32.4%	57.4%	66.2%	67.1%

Average LEPS Score (n=108)

	SOI	SOI(1949)	SSTa1	SSTa9	SSTa1&9	SSTa1&2	Nino1.2	Nino3	Nino3.4	Nino4
Papua New Guinea	5.4	6.2	4.9	0.7	6.3	5.3	3.0	5.4	7.0	6.6
Cook Islands (North)	19.9	19.6	14.6	2.2	16.9	15.1	11.5	16.2	19.5	20.6
Cook Islands (South)	4.1	3.8	2.5	-0.2	2.7	2.0	3.2	5.0	4.8	3.3
Fiji	8.5	9.3	5.7	2.4	8.4	5.4	3.7	6.6	8.9	9.2
Kiribati (West)	16.8	19.3	18.6	1.7	21.3	20.7	14.0	23.0	25.7	24.1
Kiribati (Central)	14.9	15.2	14.0	0.1	15.7	14.4	16.3	20.9	18.9	14.7
Kiribati (East)	8.8	13.1	12.3	1.6	14.0	13.0	10.4	17.4	18.7	14.7
Niue	4.2	4.2	3.3	2.6	5.6	3.9	5.0	6.1	5.3	3.4
Samoa	3.5	3.0	3.4	1.6	4.6	2.9	4.4	5.0	4.4	2.8
Solomon Islands	8.3	8.3	4.1	2.7	6.6	3.8	3.2	5.6	6.8	7.2
Tonga	9.4	9.7	5.4	3.7	8.9	5.5	5.2	8.0	9.0	8.1
Tuvalu	11.6	13.2	10.6	1.2	12.8	11.7	5.9	10.7	14.2	14.4
Vanuatu	10.6	10.6	5.6	3.5	9.8	6.4	3.2	6.7	9.3	10.0


Summary - one possible solution
(note - predictive systems not listed for each country may have significant skill, but not as high as those listed here)
Kiribati (West)
Nino 3.4
Nino 3
Nino4
SSTa1&9
Kiribati (Central)
Nino 3.4
Nino 3
Kiribati (East)
Nino 3.4
Nino 3
Papua New Guinea
Nino 3.4
Nino 4
SOI Values
SSTa1&9
Solomon Islands
SOI Values
Nino 3.4
Nino 4
SSTa1&9
Tuvalu
Nino 3.4
Nino 4
SOI Values
SSTa1&9
Samoa
Nino 3.4
SSTa1&9
Nino 3
Cook Islands (North)
Nino 3.4
SOI Values
Nino 4
Vanuatu
SOI Values
Nino 3.4
Nino 4
SSTa1&9
Fiji
SOI Values
Nino 3.4
Nino 4
SSTa1&9
Tonga
SOI Values
SSTa1&9
Nino 3.4
Nino 3
Nino4
Niue
Nino 3.4
SSTa1&9
Nino 3
Cook Islands (South)
Nino 3.4
SOI Values
Nino 3


SCOPIC v2.6.1 - Samoa : <j:\climate risk transfer folder\03072009 pi-cpp pilot projects\p023_validation report\samoa.scp>
File Edit Window Tools Help
Predictors (4)
NINO3.4 SST Anomalies (2mths)
SOI Values (3mths)
Predictor is 2 mths out-of-date
SST Indices 1, 2 and 9 (1mth)
SSTa's 1 and 9 (3mths)
Predictands (5)
Afiamalu rainfall (mm) 49 yrs available
Apia rainfall (mm) 119 yrs available
Faleolo rainfall (mm) 46 yrs available
Nafanua rainfall (mm) 30 yrs available
Vaipouli rainfall (mm) 62 yrs available
Organise Data
Explore Data
Analyse Relationships
Test Skill
Generate Report
Drought
Skill testing
Skill calendar
Hindcasts
Colour by: Result
Views:
Tercile hindcast analysis for Dec-Feb Predictands (3mth Totals)
3mth avg SOI Values (Sep-Nov) (0mths lead)
scopic
Average Score= (3C+1NC-3I)/n (1.45)
Apia rainfall (mm) (119 years)
Consistent=59 Near Consistent=44 Inconsistent=16
T3
T2
T1
SOI Values Sep - Nov 3mths (-5.83)
Apia Dec - Feb 3mths
2009
2010
2011
O - Observed
P - Predicted
Forecast was inconsistent
Forecast was near consistent
Forecast was consistent
Observed data is missing
Output Size: 800x589

Relative skill of different predictors in each country (default = 1.0)

	Predictors			
Country	3mth avg. SST 1 & 9	1mth avg. SST 1&9	3mth avg. SOI	2mth Nino 3.4
Cook Islands	1.00	1.06	1.12	1.14
Fiji	1.00	1.00	1.04	1.01
Kiribati	1.00	1.06	1.02	1.13
Niue	1.00	0.97	0.94	0.85
PNG	1.00	1.04	1.04	1.13
Samoa	0.98	1.02	1.00	0.94
Solomon	1.01	1.00	1.10	1.01
Tonga	1.00	1.04	0.98	0.99
Tuvalu	1.00	0.99	1.00	1.00
Vanuatu	1.00	1.01	1.08	1.04