Effect of Large-scale Circulation Patterns on the Water Level in Reservoirs

A Hydroinformatics Approach

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SCINOVA CONSULTING

Our Background

- Scinova Consulting Ltd

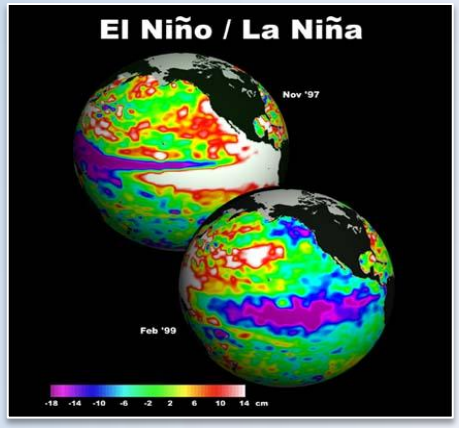
  "Innovative Solutions through Research"
- Team Members
  - Prakash Khedun (PI)
    - PhD in Water Management & Hydrological Science, Texas A&M University
  - Kreshna Gopal
    - PhD in Computer Science, Texas A&M University
    - Computational Intelligence, Bioinformatics, Statistics
  - Anoop Sohun
    - BSc in Computer Science, University of Mauritius
    - Software Engineer

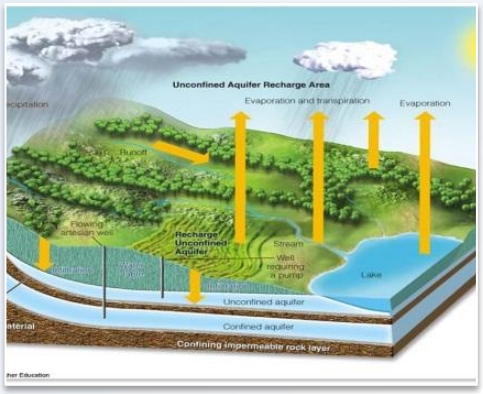
Water Problems in Mauritius

- As per UNDP definition, Mauritius is water stressed[1]
- Forecast supply for 2020 is 970 m^3/person/day
  - Water scarce category[2]
- Recent major droughts
  - 1998-1999 – MUR 2 Billion loss in GDP
  - 2010-2012 – Loss in GDP, social unrest, etc.
- Precipitation is influenced by large-scale circulation patterns (e.g. El Niño, IOD)
- Climate change will influence these phenomena

[1] Less than 1700 m^3/person/day
[2] Less than 1000 m^3/person/day

Hypothesis





Large-scale Circulation Patterns

- ENSO
- IOD

Hydro-meteorological Parameters

- Precipitation
- Temperature
- Evaporation
- Wind
- Streamflow, etc.

Consumption Losses, etc.

Water Levels in Reservoirs

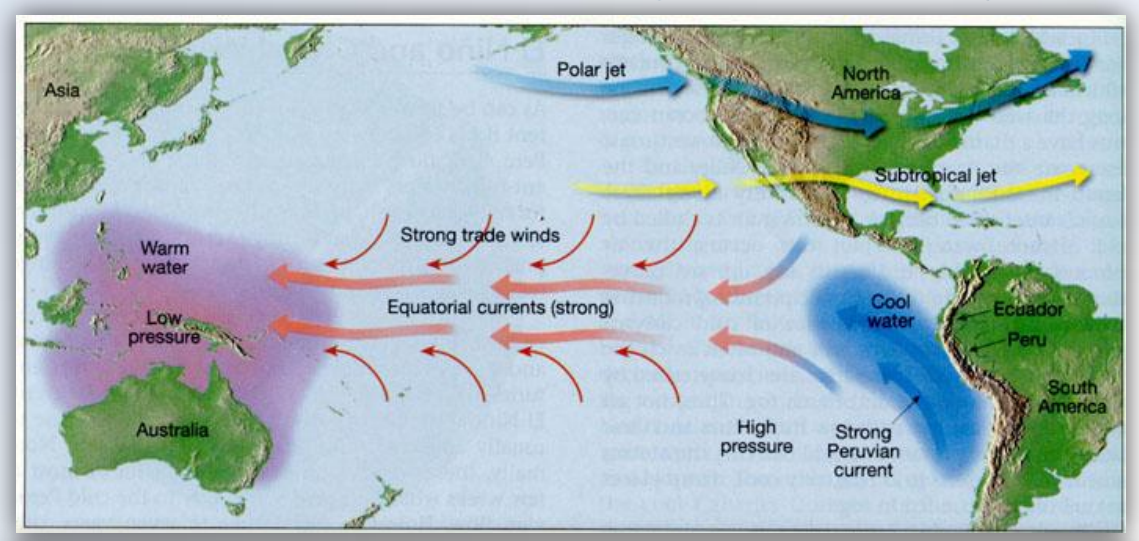
Our Approach

- Hydroinformatics
  - Hydrology, atmospheric science, computer science, statistics, and machine learning
- Time-series Analysis
- Computational Intelligence
  - Artificial Neural Network
  - Support Vector Machine

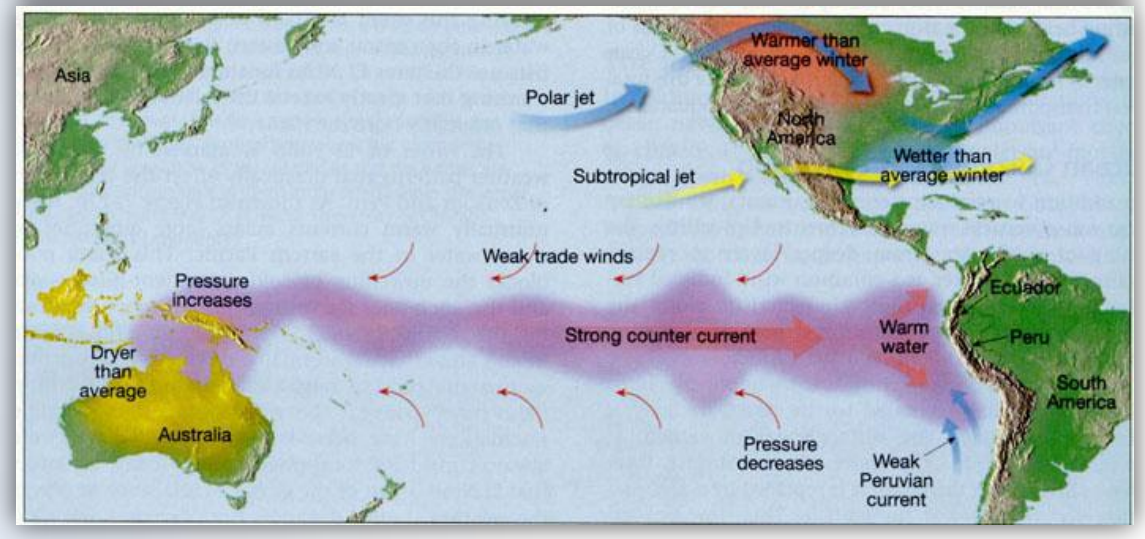
LARGE-SCALE CIRCULATION PATTERNS

El Niño Southern Oscillation (ENSO)

Normal Conditions



El Niño Conditions

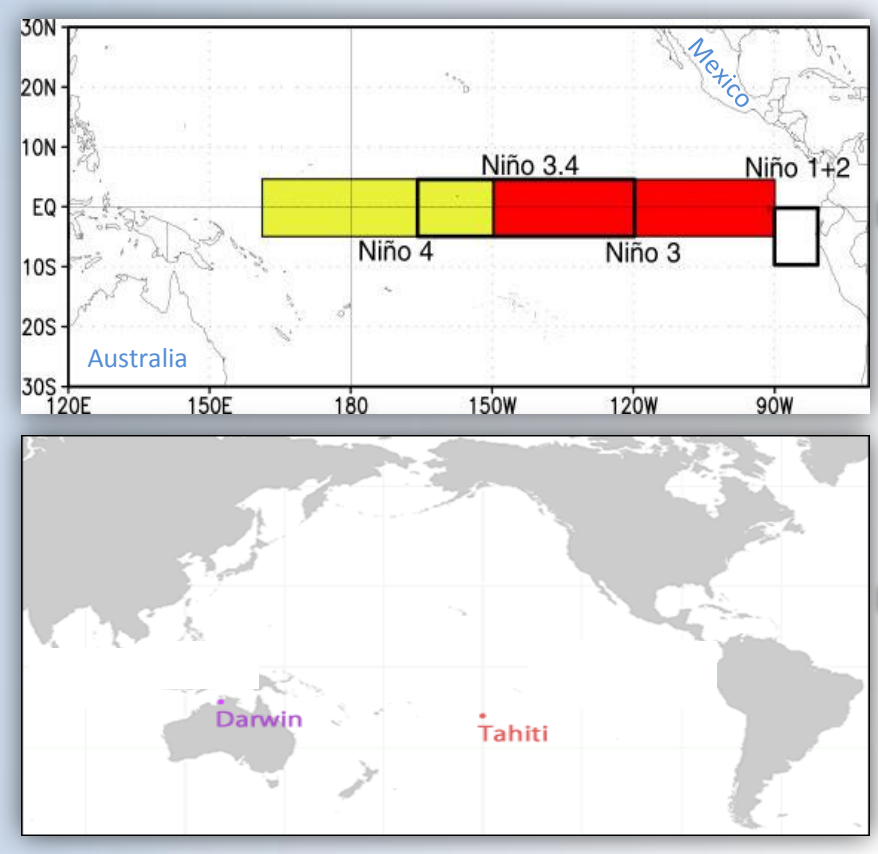


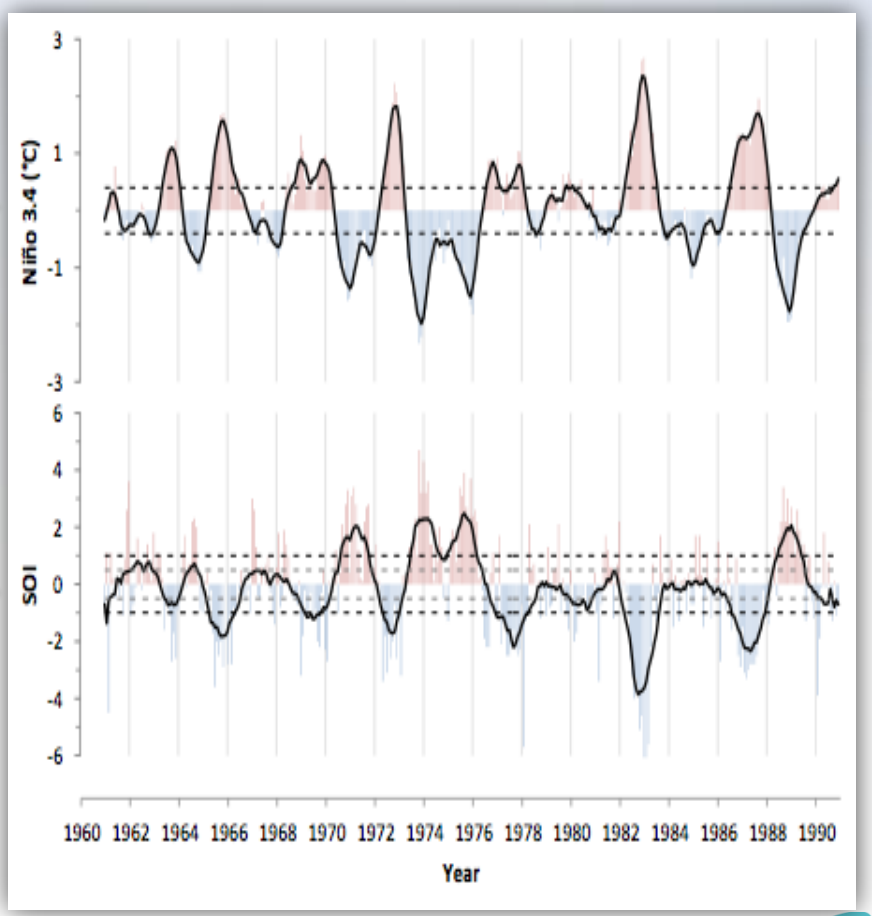
[Madl, 2000]

ENSO

- El Niño Southern Oscillation (ENSO)
  - Most dominant large-scale circulation pattern
  - Affects the hydrological cycle around the globe
  - Recurrence pattern of 3 – 6 years
  - Normally lasts for around a year
- ENSO: coupled ocean-atmosphere phenomenon
  - Sea surface temperature anomaly
    - Niño Indices (Niño 3, 4, 3.4, etc.)
  - Sea-level pressure difference
    - Southern Oscillation Index (SOI)

ENSO: Niño 3.4 & SOI





(Source: National Oceanic and Atmospheric Administration)

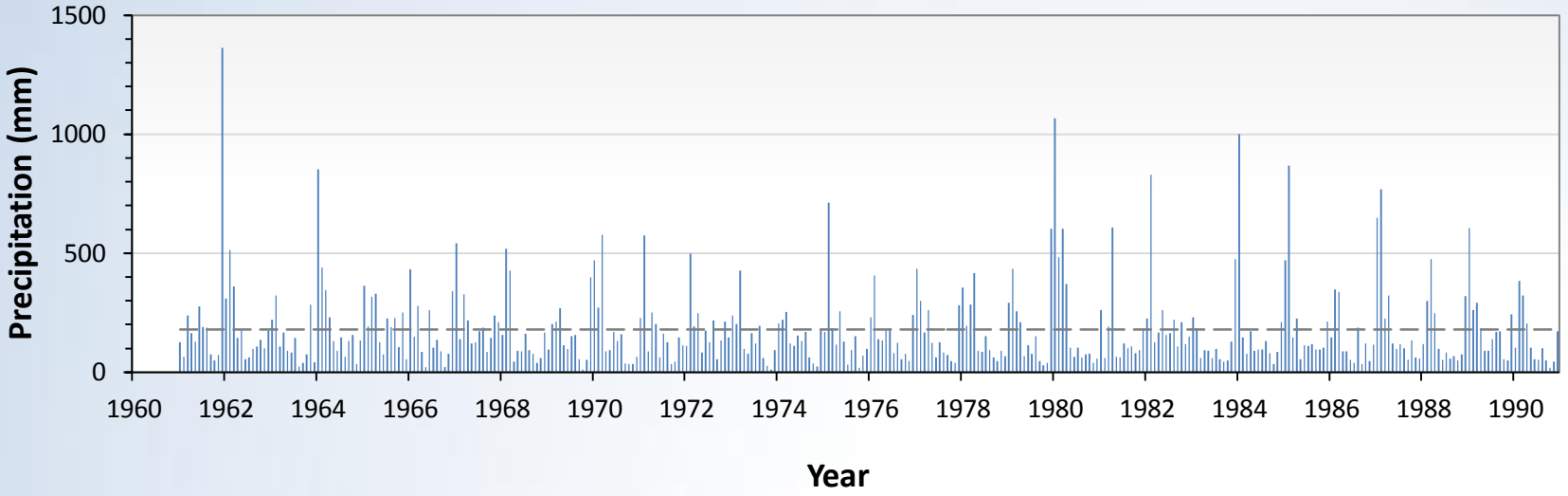
- Is there an official definition for Mauritius?

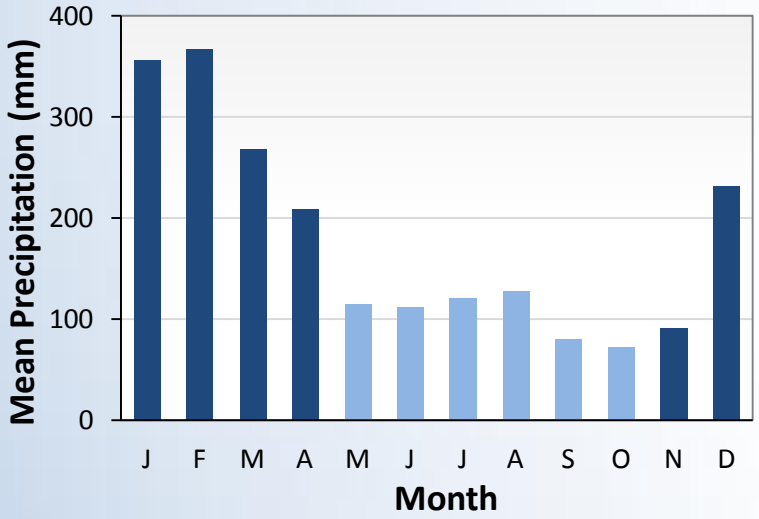
PRELIMINARY RESULTS

Data

- Precipitation for Vacoas station (GHCND:MP000061995)
  - Currently 1961 – 1990 (National Climate Data Center)
  - To be extended to 1900 – 2012
- Niño 3.4
  - Source: International Research Institute
- Southern Oscillation Index
  - Source: National Center for Atmospheric Research

Precipitation @ Vacoas

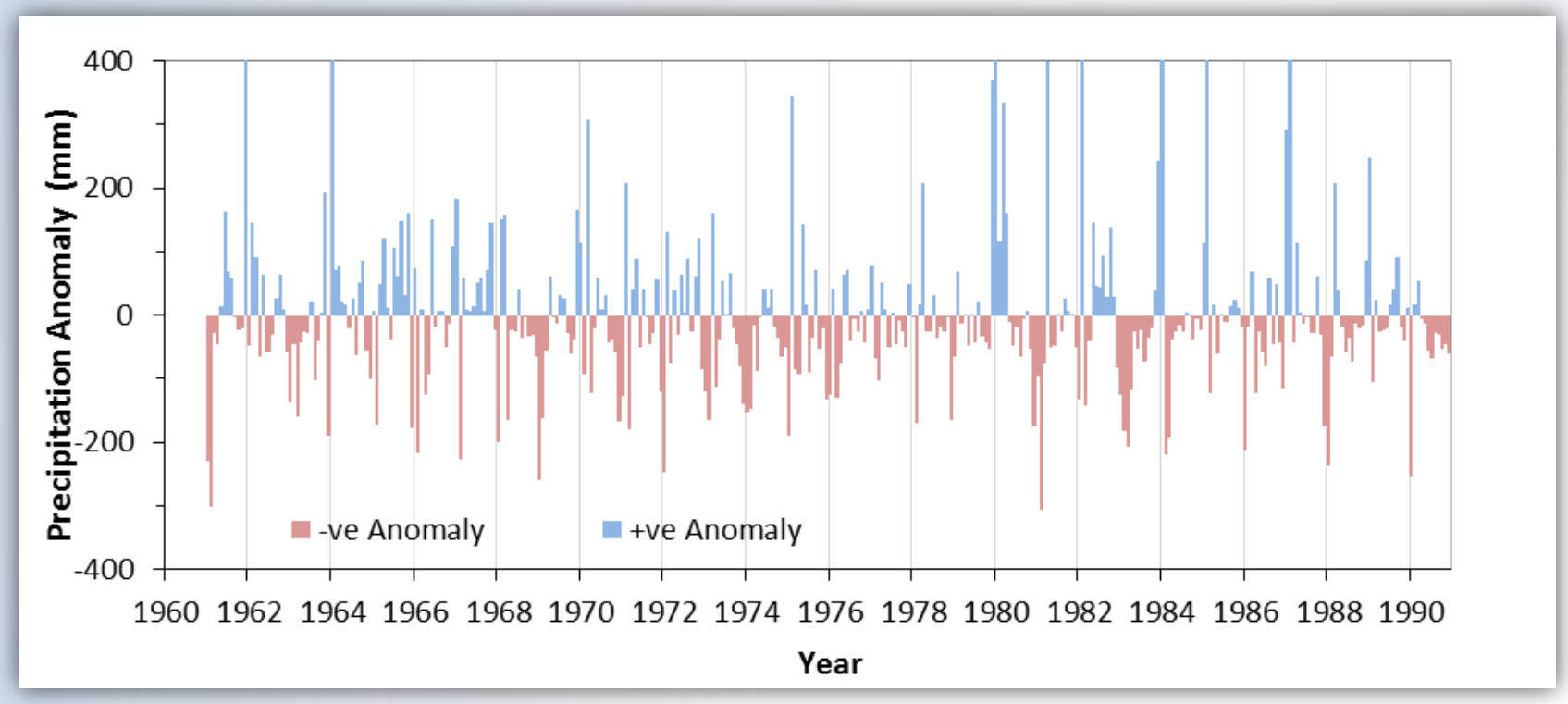




- Seasonal patterns
- Mostly below average precipitation spells

HOW DO WE DEFINE DROUGHTS?

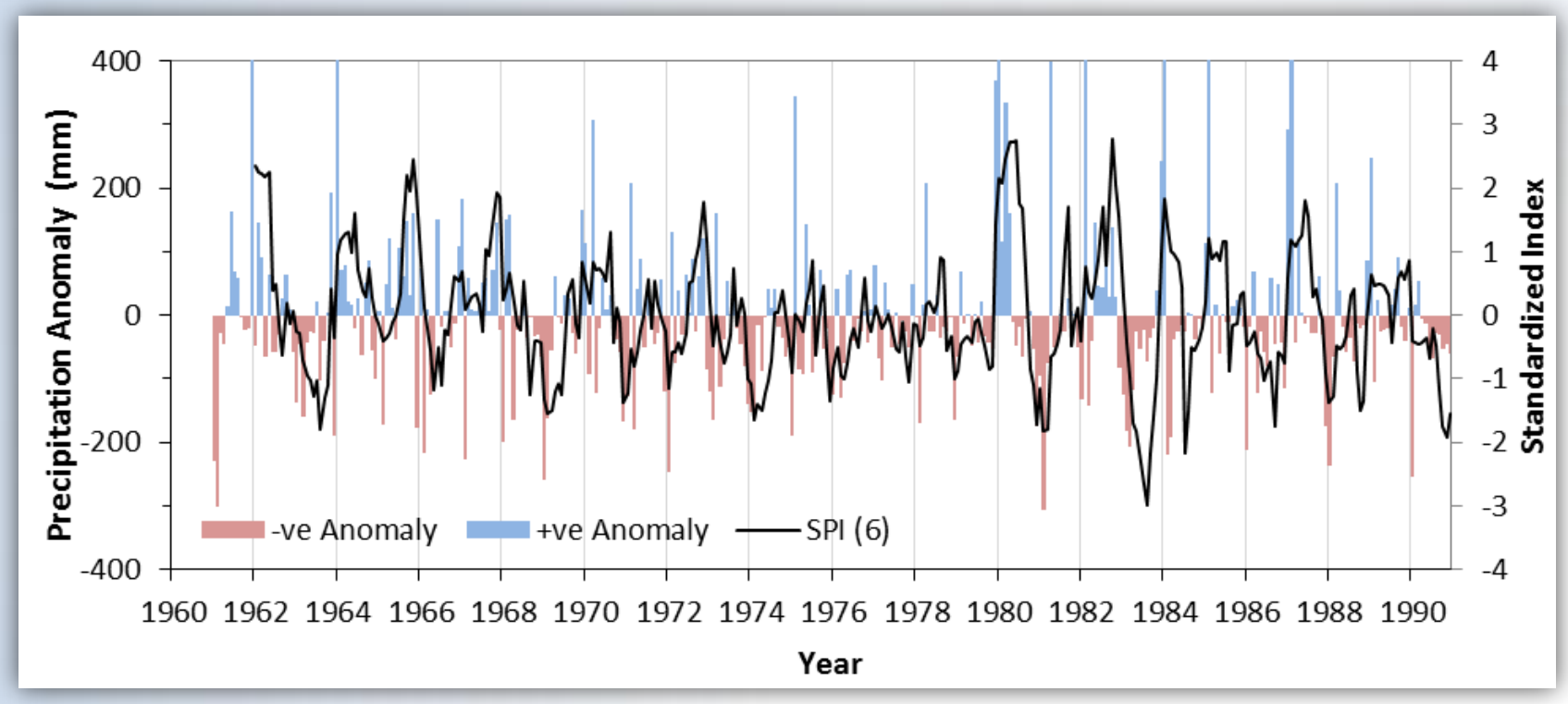
Rainfall Anomaly @ Vacoas



Standardized Precipitation Index (SPI)

- SPI [*McKee et. al*, 1993] is one of the numerous drought indices
  - Uses only one variable (precipitation)
  - Easy to calculate
- Better representation of abnormal wetness and dryness
- Spatially invariant quantity
  - Allows meaningful comparison across regions
- Different timescales
  - Groups of 3, 6, 9, 12, 24, 48 … months
  - In this project SPI(6) is used
    - Seasons are 6 months long

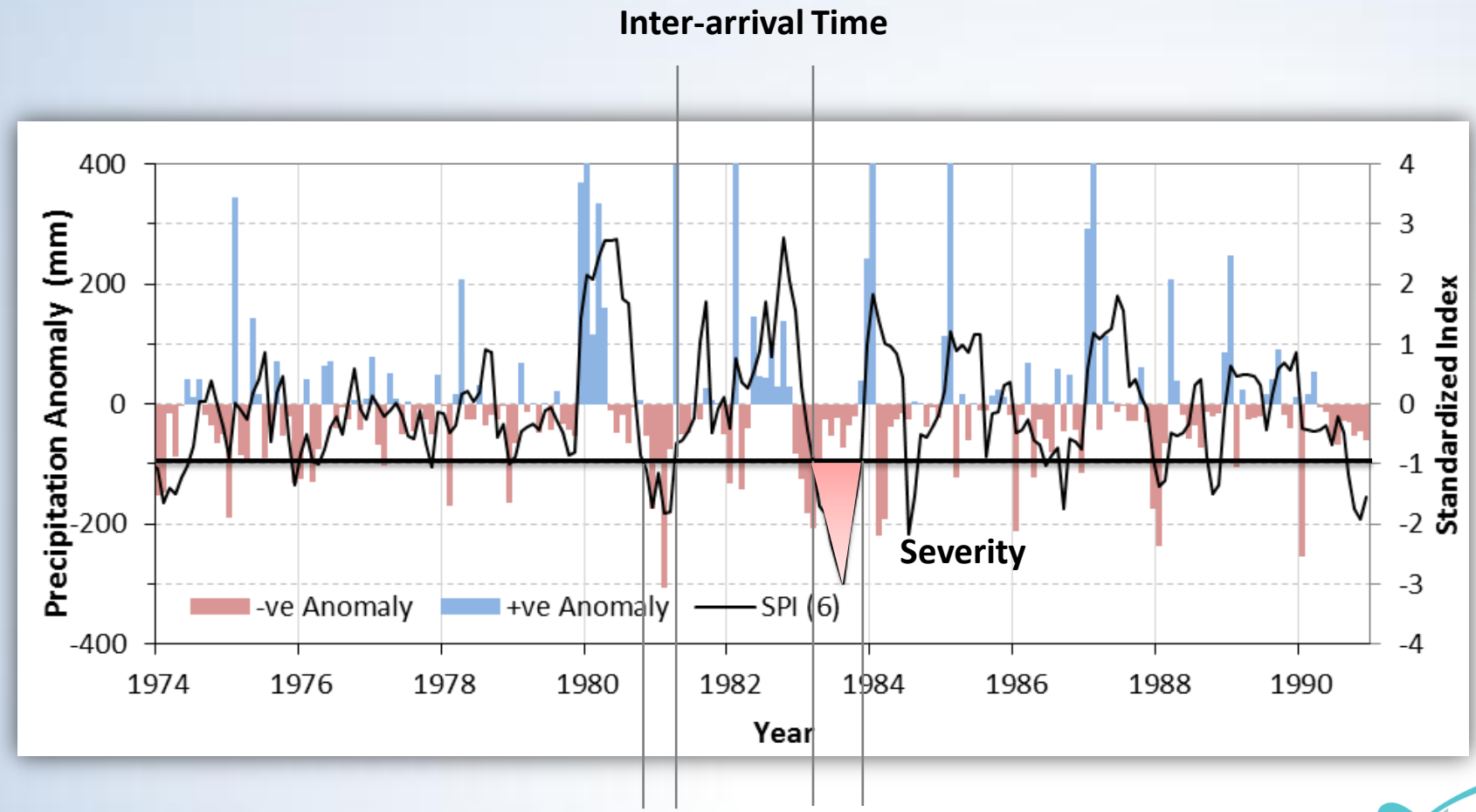
SPI (6) @ Vacoas


Precipitation Anomaly (mm)
400
200
0
-200
-400
Standardized Index
4
3
2
1
0
-1
-2
-3
-4
-ve Anomaly
+ve Anomaly
SPI (6)
1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
Year

Interpreting SPI

SPI Values	
≥ 2.0	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Neutral or near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
≤ -2.0	Extremely dry

Drought Identification



PRECIPITATION PREDICTION

Correlation Between ENSO & Precipitation

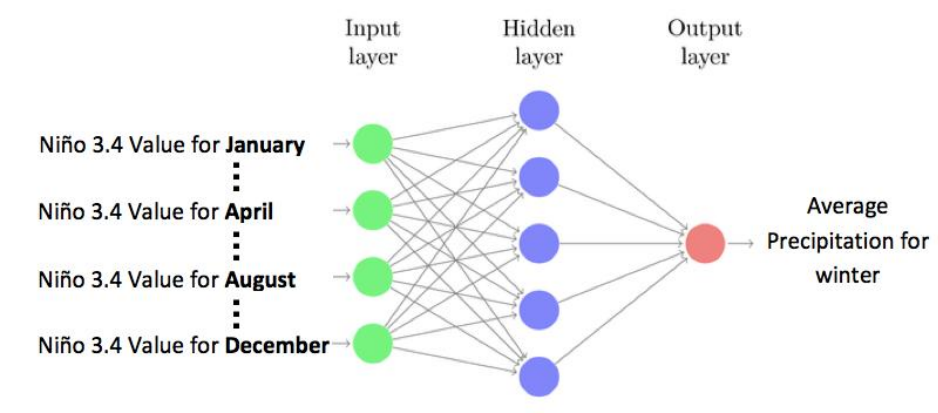
- Precipitation, Niño 3.4 & SOI data were divided into two series
  - Winter: May to October
  - Summer: November to April
- Averaged over each season
- Pearson correlation

Index	Winter	Summer
Niño 3.4	0.237	0.031
SOI	-0.329	-0.015

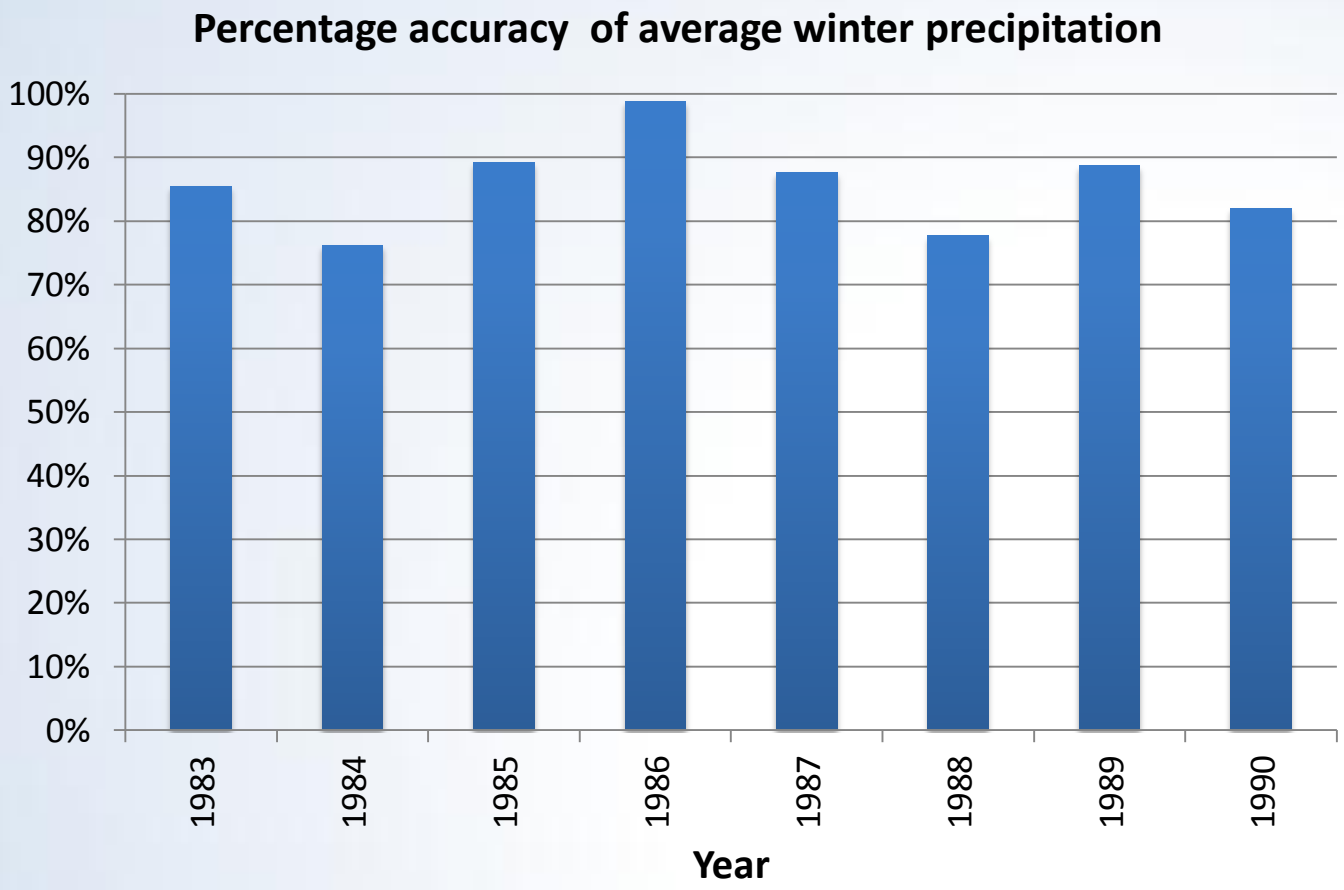
Artificial Neural Network

- Inspired by structure of biological neural networks in the brain
- Predict output based on inputs
  - Training phase
- Multi-Layer Perceptron
  - Three layers: input, hidden, and output

- Inputs
  - Monthly ENSO for one year
- Output
  - Average winter precipitation for following year



ANN: Results

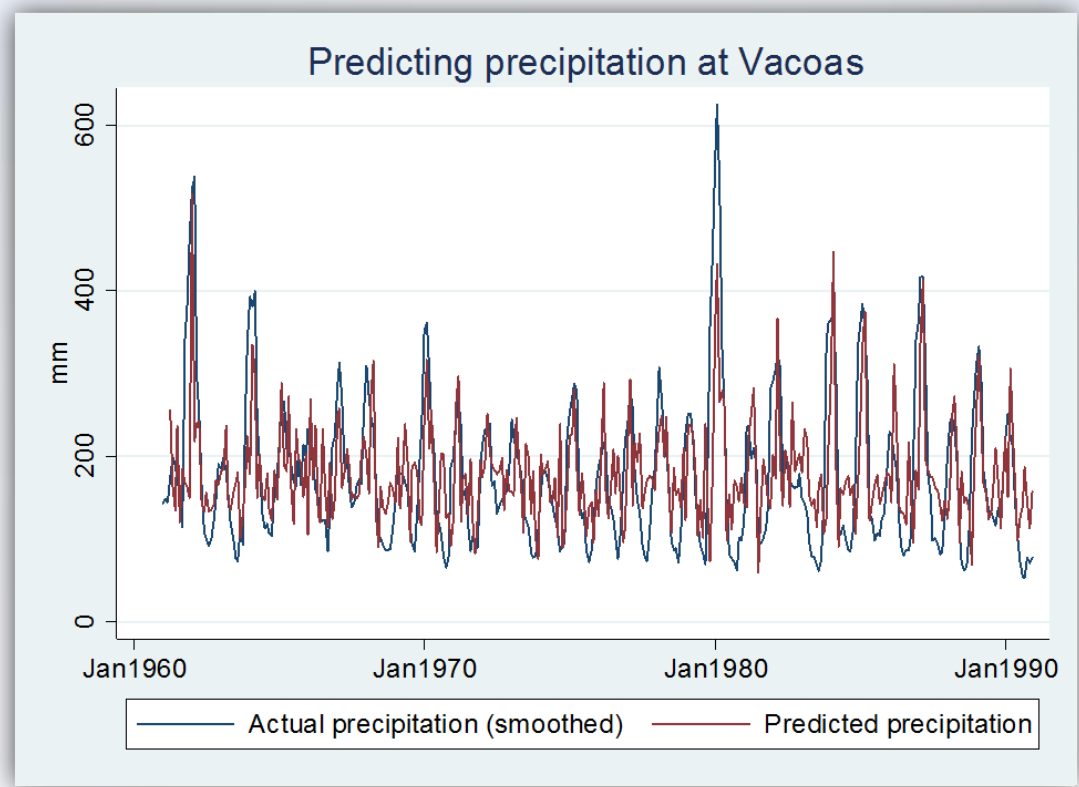

Percentage accuracy of average winter precipitation
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1983
1984
1985
1986
1987
1988
1989
1990
Year

Time Series Analysis & Forecasting

- Currently
  - Auto regressive integrated moving average (ARIMA)
  - Regression Analysis (ENSO, IOD, etc. to predict precipitation and water level)
- Future analysis
  - Data from 1900 to 2012

Time Series Analysis
Multiple Linear Regression

- Explanatory variables
  - Lagged Niño 3.4
  - Lagged SOI
  - Lagged precipitation
- Response variable
  - Precipitation



Summary

- Water problem in Mauritius
  - Efficient management of water resources
- State of the art techniques
  - Hydroinformatics
  - Time Series Analysis
  - Computational Intelligence
- Relationship between large scale circulation patterns and precipitation
- Definition of drought
- Precipitation prediction models

Thank You

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