Evaluation of regional hydroclimate variability and links to the hydrology and saltwater intrusion in South Florida

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Topics of Study

Drought Phase and Variabilities in Miami Area

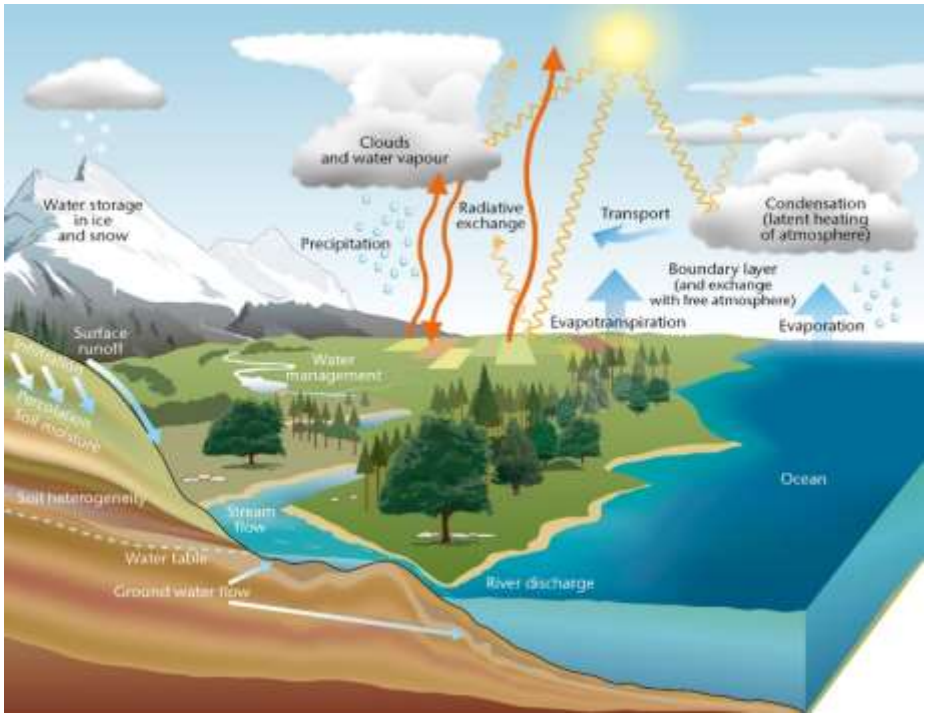
Implications to future freshwater availability and saltwater intrusion

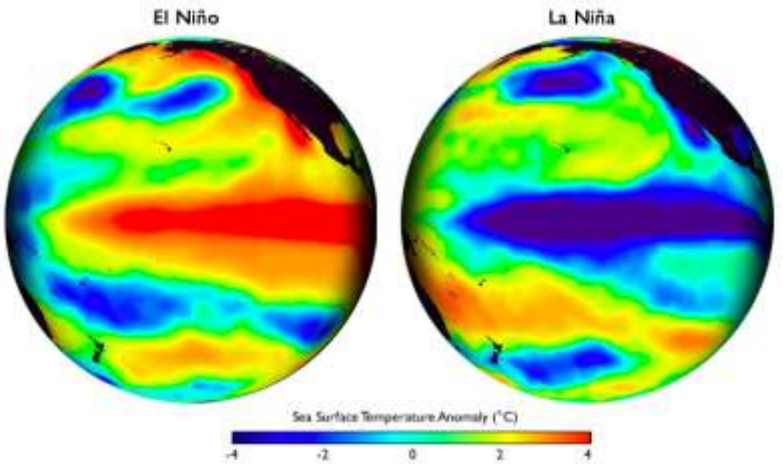
Outline

- Introduction
- Gap
- Objective
- Methodology
- Result and Discussion
- Conclusion and Recommendation

The Atmosphere Hydrosphere Continuum

In South Florida, the dry season rainfall is highly associated with ENSO oscillations (Abtew et al., 2010)



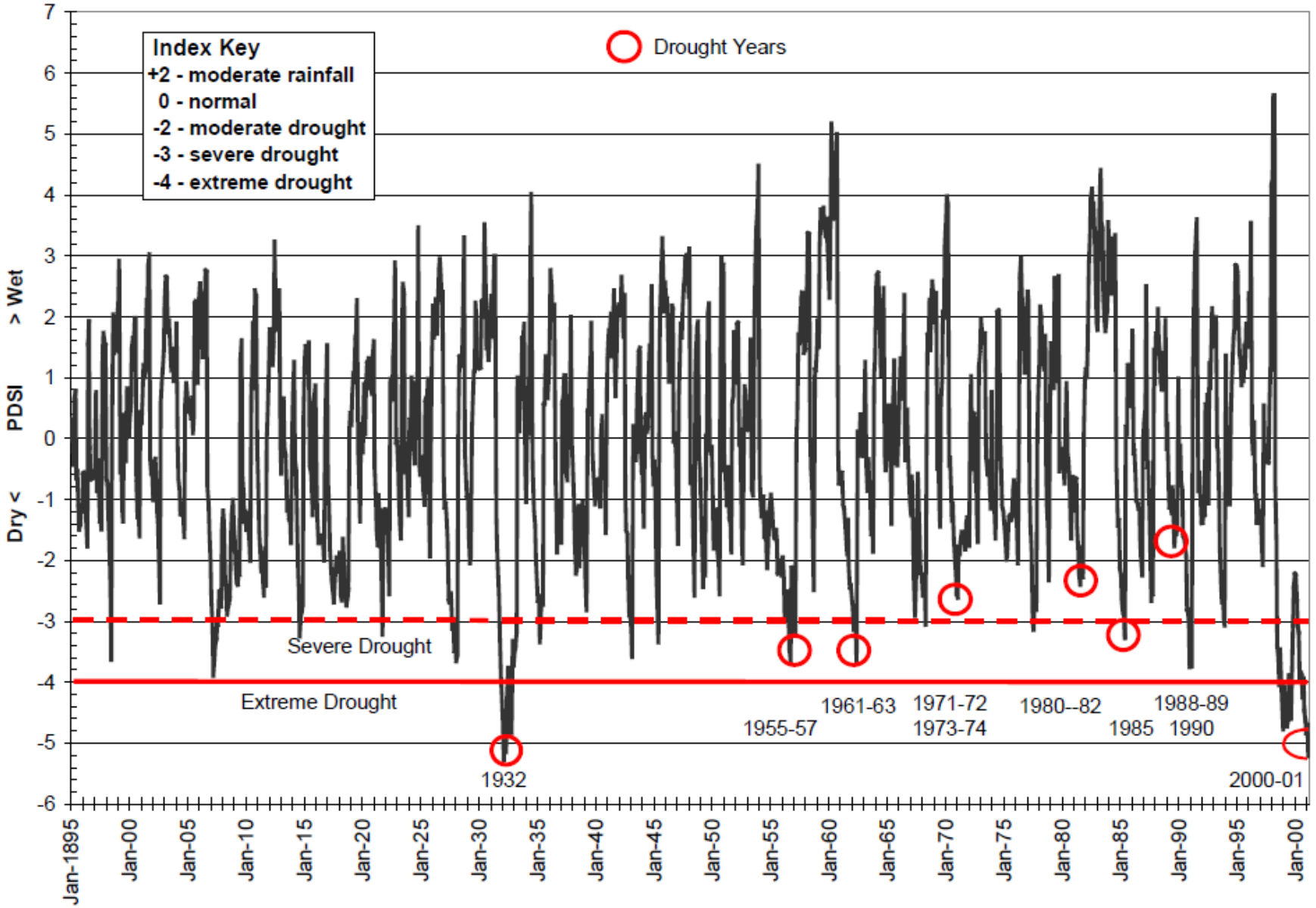


- El-Nino Presents wetness
- La-Nina presents **drought**

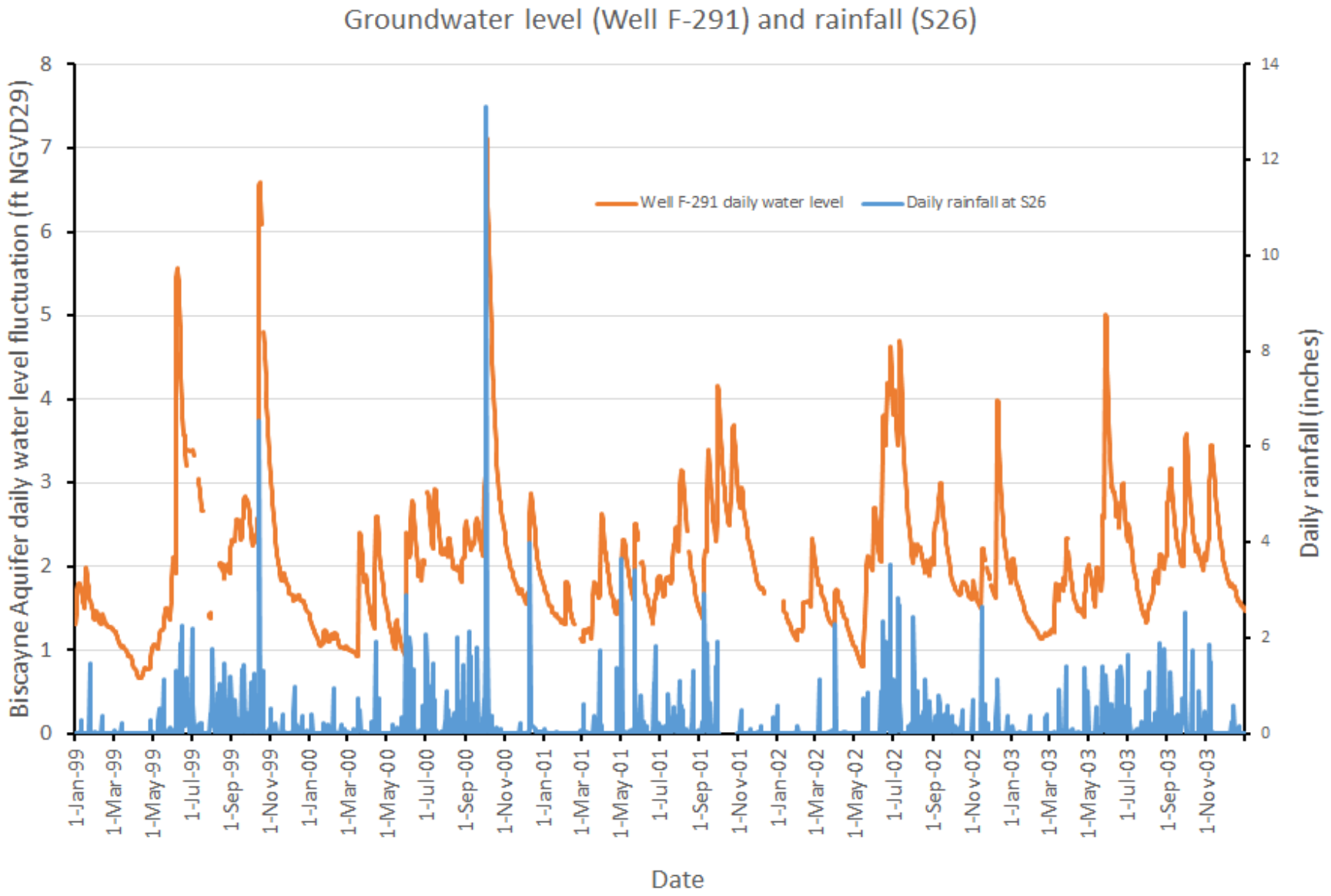
Drought

- **Meteorological**: dry weather patterns
- **Agricultural**: Soil moisture deficit,
- **Hydrological**: Rainfall deficit below normal
- **Managerial**: dryness due to water operations

Drought in South Florida



Groundwater Response to rainfall Biscayne Aquifer



Hydrological Drought

- Groundwater recharge decrease
- Surface water availability decrease
- Groundwater demand increase
  - ➢ Fresh groundwater head decline
    - Hydraulic gradient decrease, even changes its direction
    - Saltwater intrusion?
- Freshwater availability decreases

Problem

The effect of drought on water resources availability and saltwater intrusion is not clearly established

Objectives

The objectives are to:

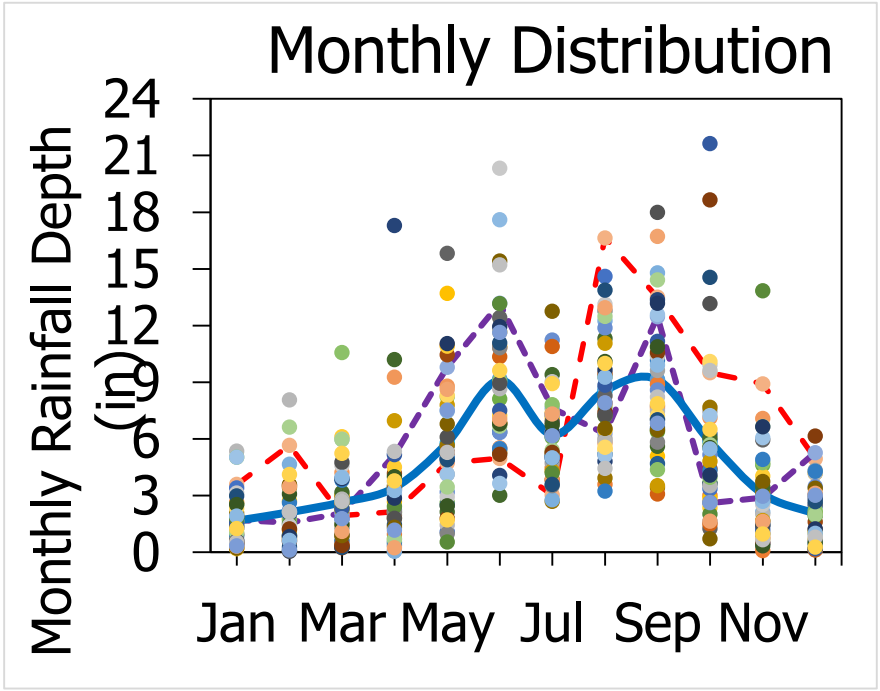
- Evaluate hydrological drought in Miami area

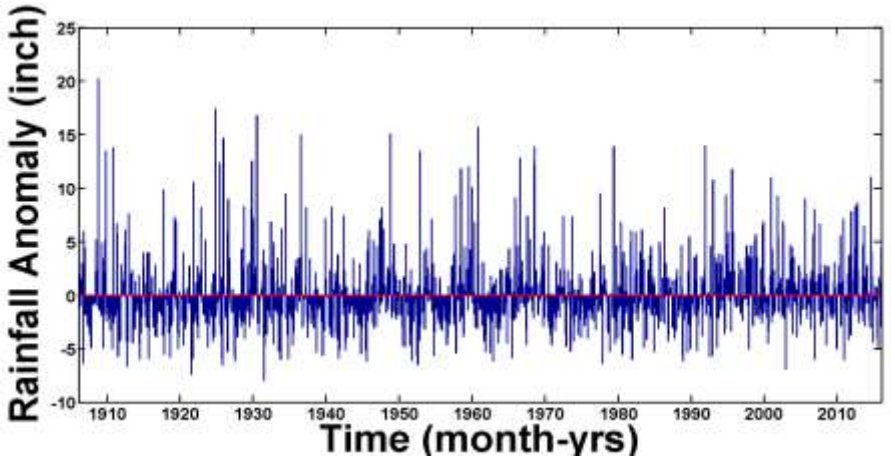
- Develop implications to current and future water availability

Rainfall Data

- Miami Dade county long-term (110 years),

  1906 to 2016, Monthly, From Florida climate center





Approach

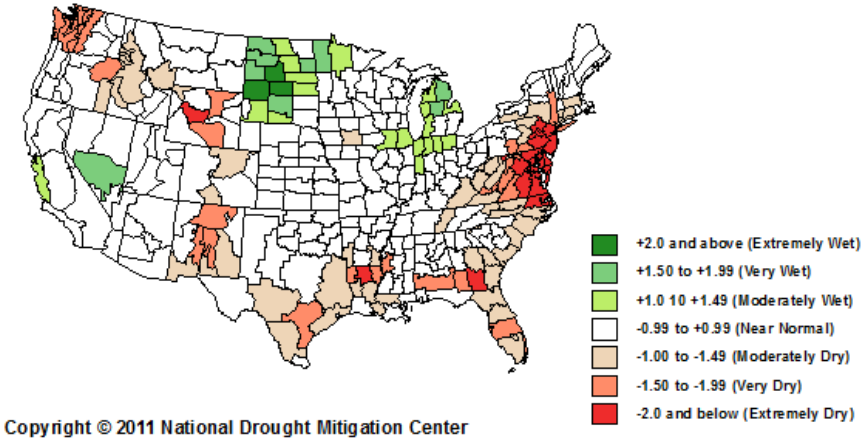
- Time domain
  - **Standardized Precipitation Index (SPI-x)**

- Frequency domain
  - **Fourier transform**

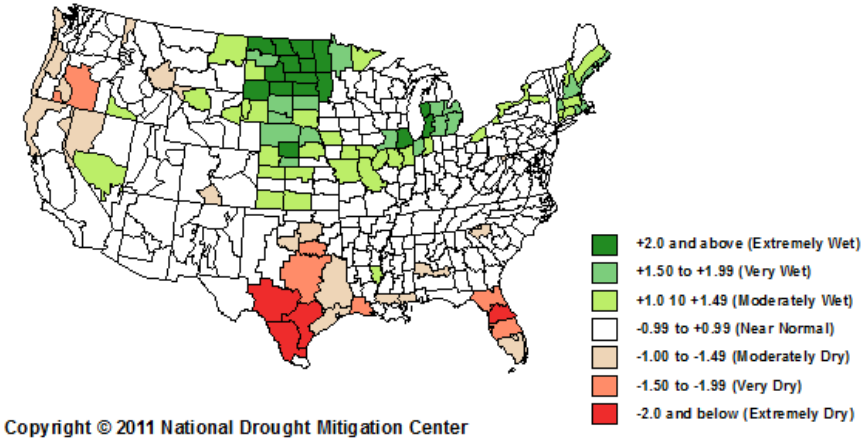
SPI-x

- Widely used for hydrological drought evaluation
- Measures drought at differed time window
- Allows to evaluate the cumulative effect

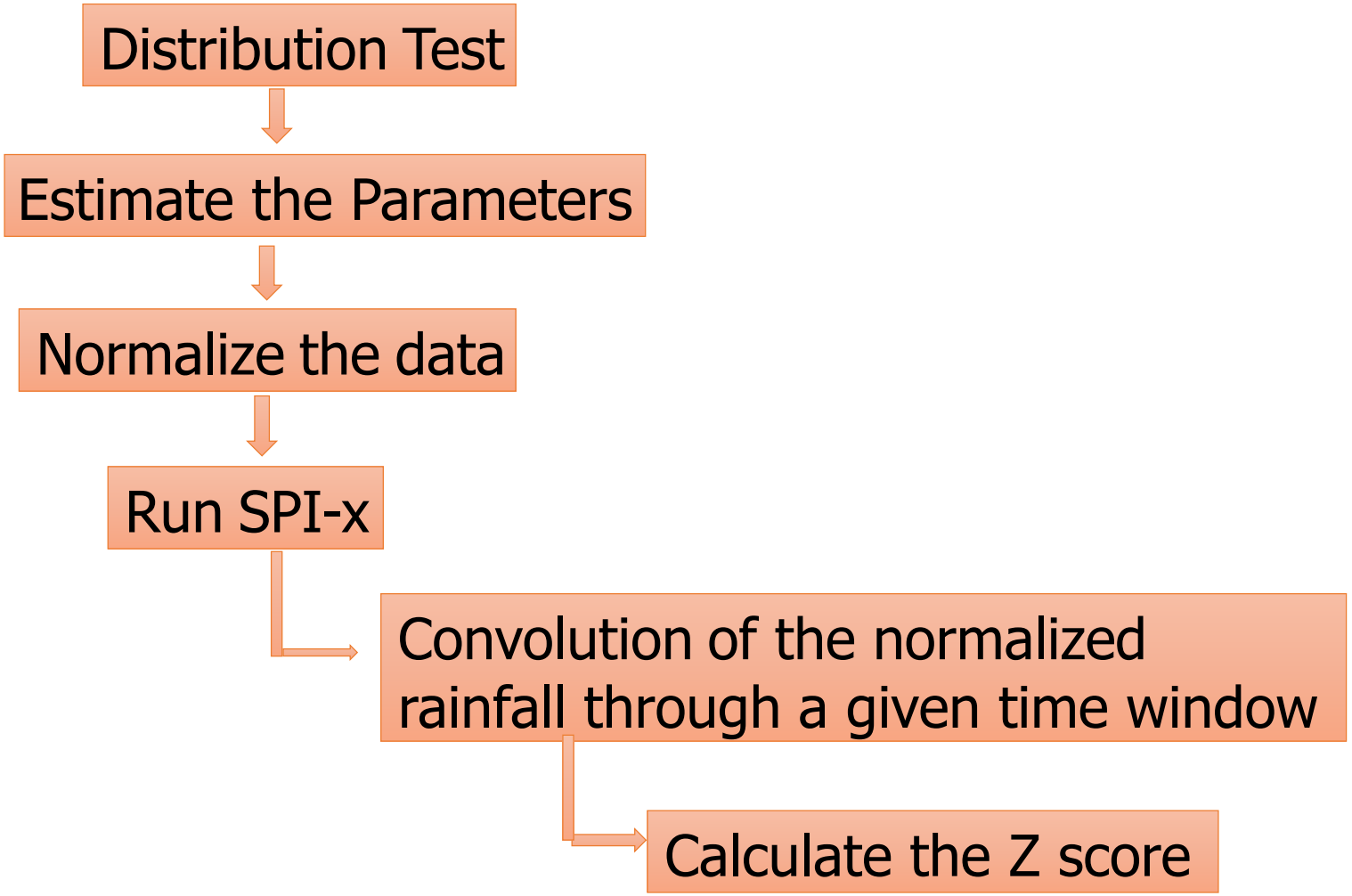
1-month SPI through the end of February 2009



6-month SPI through the end of February 2009



Standardized Precipitation Index (SPI-x)

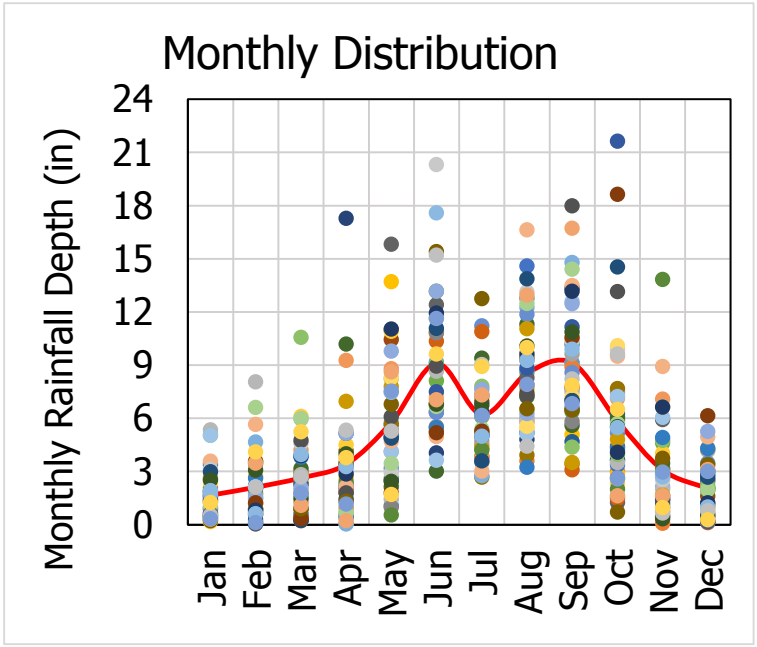


Standard Precipitation Index

Gamma

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} X^{\alpha-1} e^{-x/\beta}$$

$\Gamma(\alpha)$ is the ordinary gamma function of α (Thom, 1966).



$$SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right) \quad \text{when } 0 < H(PRE) \le 0.5$$

$$SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right) \quad \text{when } 0.5 < H(PRE) < 1 \qquad (1)$$

$$t = \sqrt{\left(\ln\left(\frac{1}{(H(PRE))^2} \right) \right)} \quad \text{when } 0 < H(PRE) \le 0.5$$

(2)

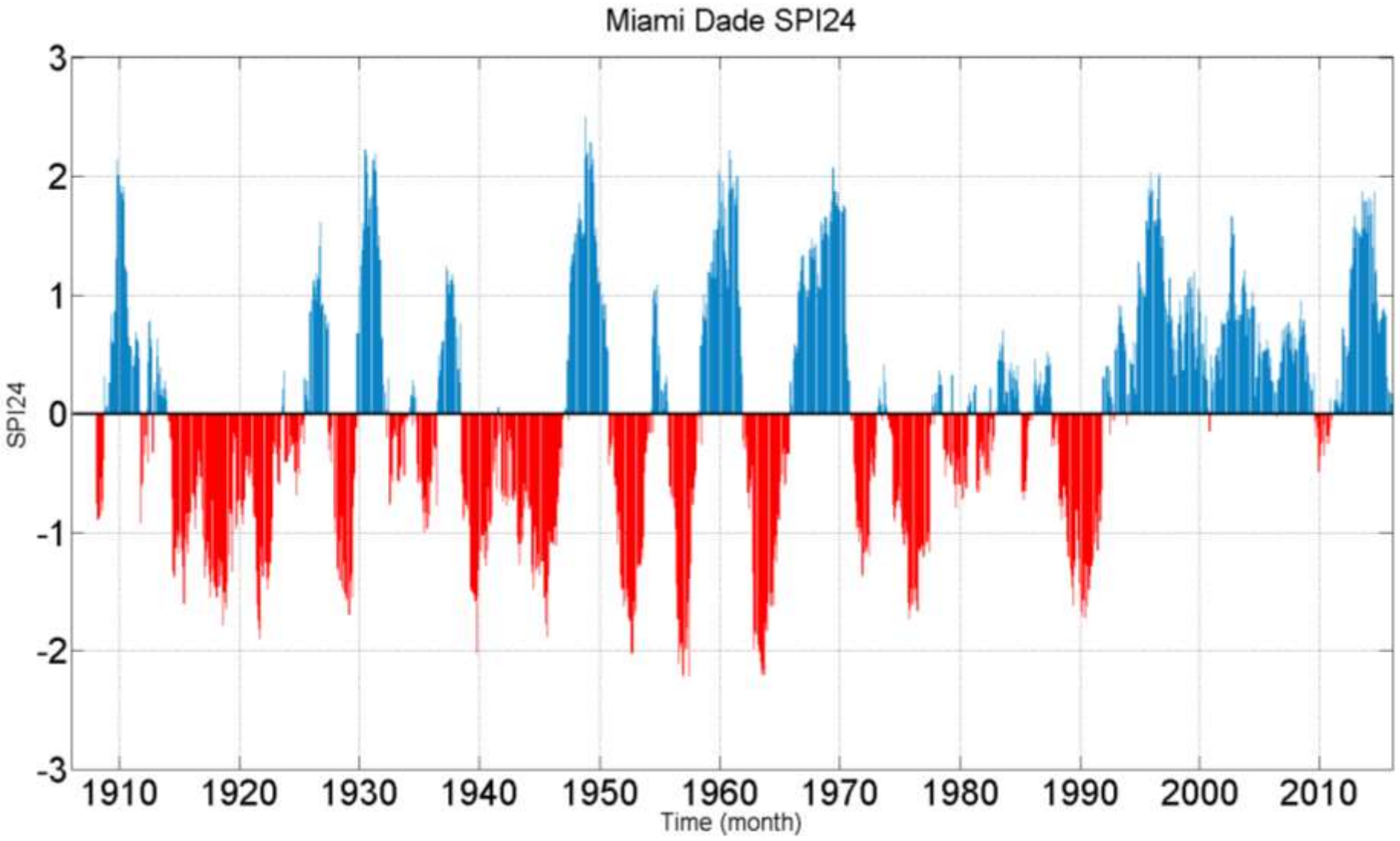
$$t = \sqrt{\left(\ln\left(\frac{1}{(1 - H(PRE))^2} \right) \right)} \quad \text{when } 0.5 < H(PRE) < 1$$

$c_0 = 2.515517$
$c_1 = 0.802853$
$c_2 = 0.010328$

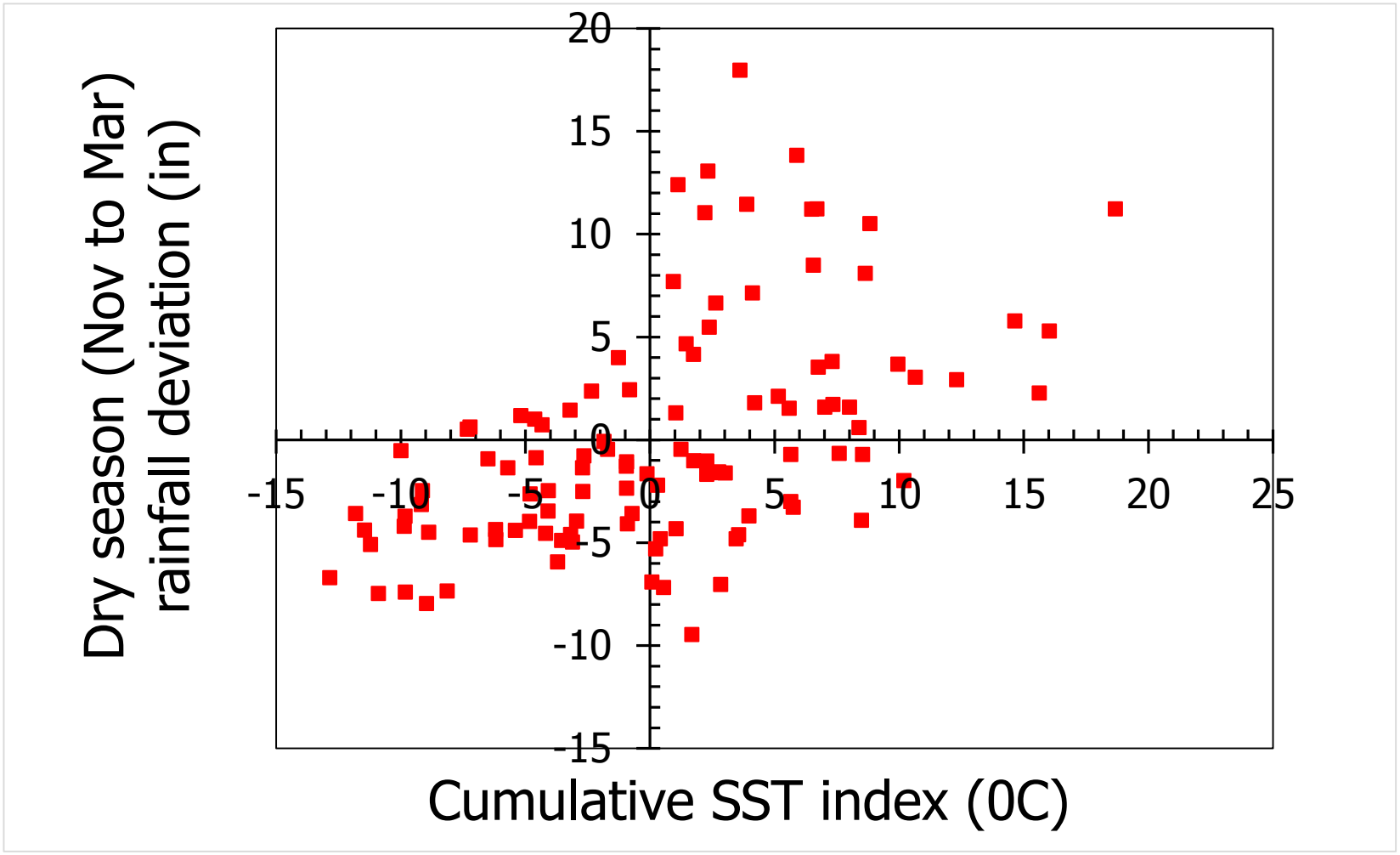
$d_1 = 1.432788$
$d_2 = 0.189269$
$d_3 = 0.001308$

McKee et al. (1993)

Standardized Precipitation Index (SPI-x)



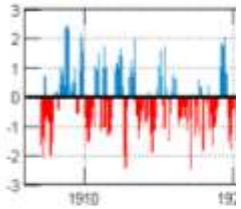
The dry season rainfall anomaly is strongly linked with ENSO fluctuations



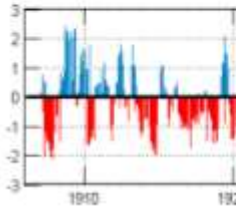
Data source: NOAA: Nino 3.4

Standardized Precipitation Index (SPI-x)

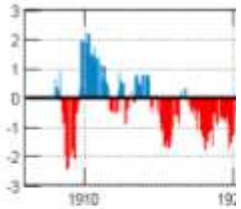
SPI 3



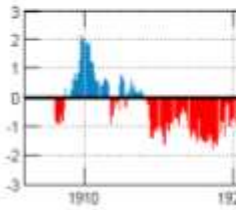
SPI 6



SPI12

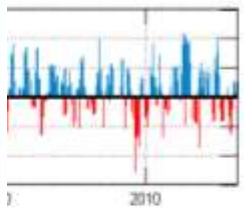


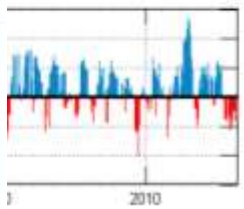
SPI24

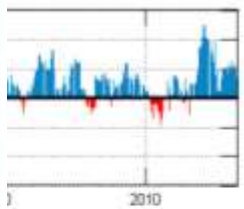


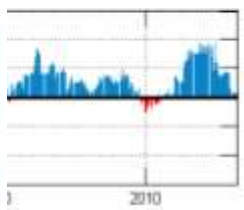
Drought severity based on SPI 12

Start	End	SPI24	Drought Duration (months)
1907.38	1908.62	-19.6	16
1910.71	1911.21	-3.3	7
1911.79	1912.4	-1.8	4
1912.29	1912.38	-0.3	2
1913.46	1915.38	-20.8	24
1915.88	1919.29	-39.0	42
1920.12	1922.62	-30.5	31
1923.79	1924.71	-14.0	12
1927.38	1929.12	-27.2	22
1931.46	1932.46	-12.0	13
1933.46	1934.29	-3.9	10
1934.79	1936.12	-14.6	17
1937.46	1946.29	-37.8	107
1950.21	1953.38	-38.6	39
1955.29	1957.46	-36.3	27
1961.71	1964.54	-46.9	35
1970.54	1972.21	-21.7	21
1973.38	1977.29	-35.3	48
1978.46	1979.62	-11.7	15
1980.29	1982.21	-7.5	24
1983.88	1984.29	-3.4	6
1985.21	1985.96	-4.6	10
1987.21	1988.46	-11.3	16
1988.71	1991.71	-33.2	37
1992.79	1992.96	-1.5	3
1996.88	1997.12	-0.2	4
2000.46	2000.88	-1.1	4
2004.88	2005.38	-2.2	7
2009.12	2010.12	-5.6	13
2015.46	2015.88	-4.7	6



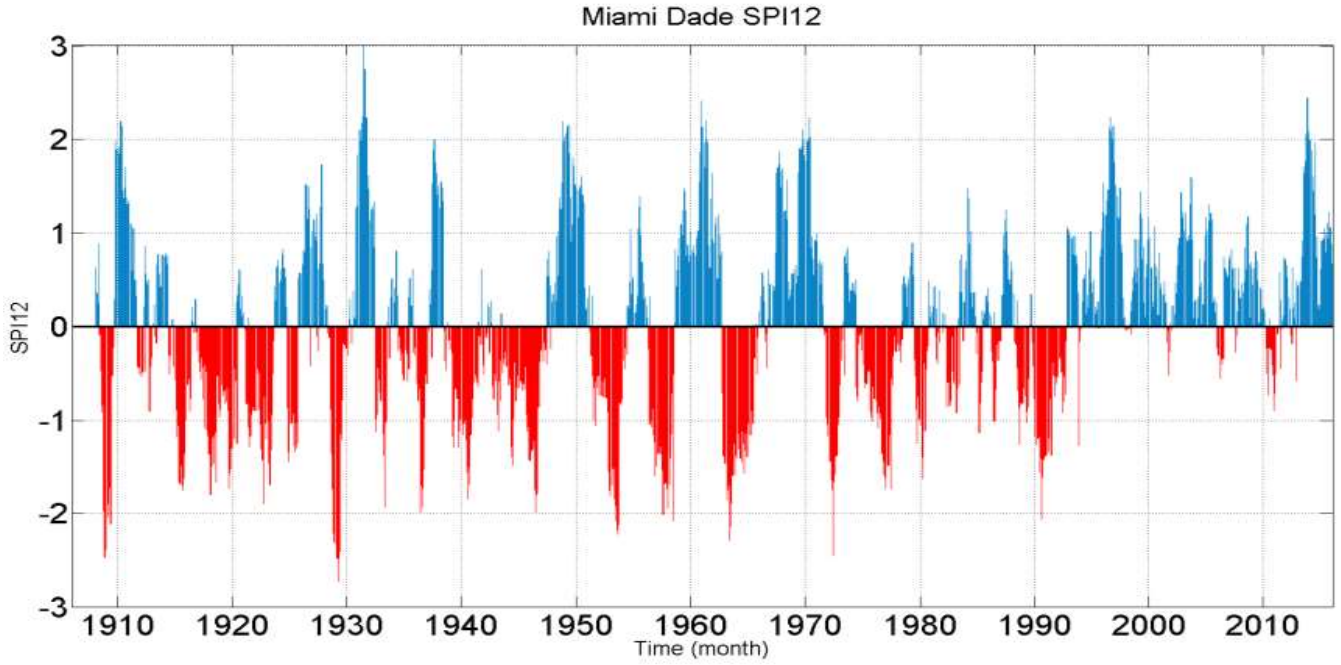




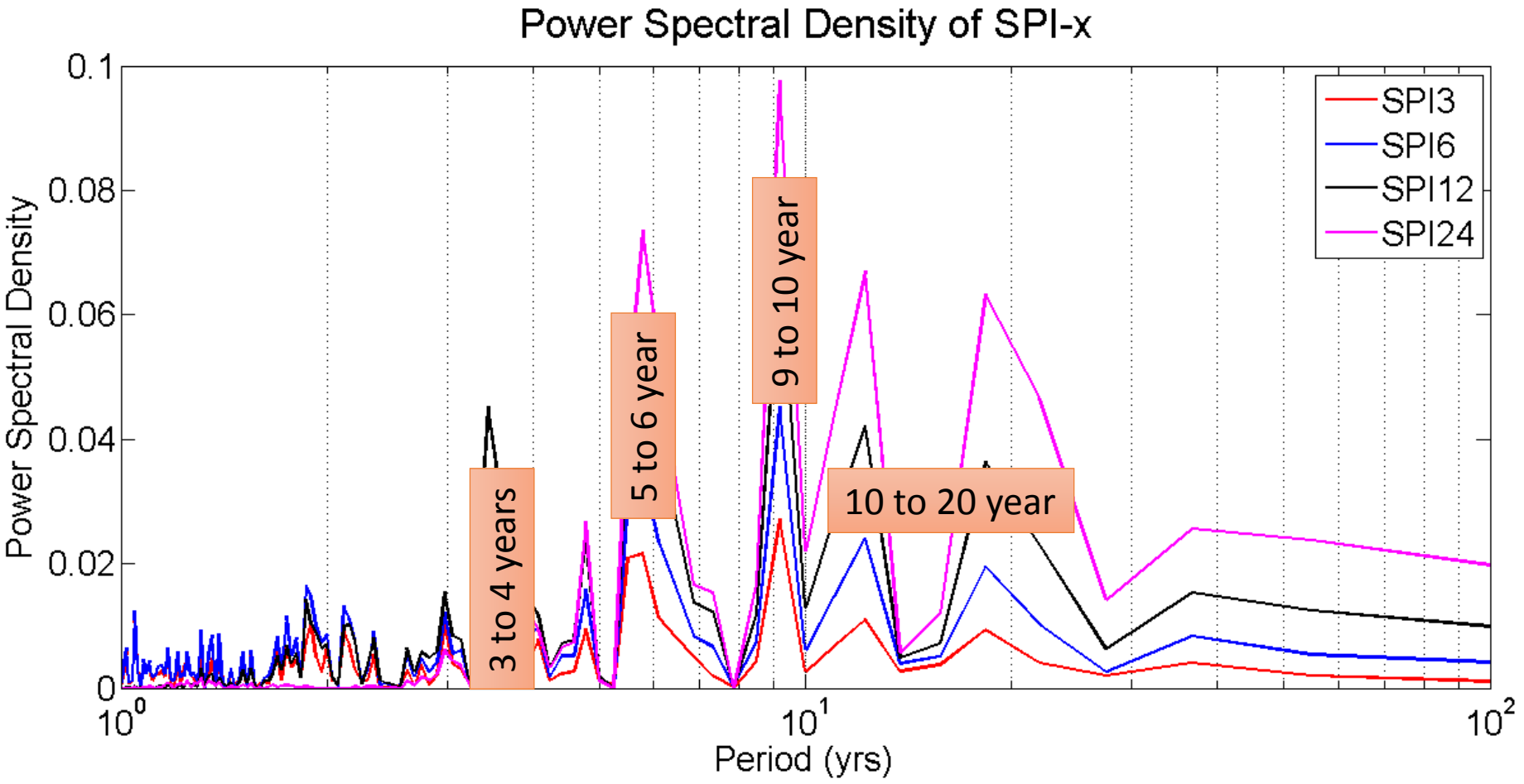


Discussions

- There is a systematic fluctuation of SPI index values with time,
- SPI 3 and 6 indicate seasonal fluctuations
- The SPI12 and SPI24 indicates:
  - Long-term fluctuations
  - A longer wet phase of the fluctuation



Miami droughts in frequency domain



Conclusion

- SPI24 indicates that we are in the wet phase of the fluctuation
- The drought severity is a function of rainfall deficit and duration
- The central drought has a ten-year cycle

- Overall, the Biscayne aquifer is sensitive to rainfall
- Prolonged drought could result in saltwater intrusion

- Hence, recharge deficit management due to drought should be considered to enhance the sustainability of freshwater availability in the area.

Thank you