Droughts:
Definitions, Monitors and Causes

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Outline

- General Facts
- Definitions
  - Conceptual vs Operational
  - Meteorological, Agricultural, Hydrological and Socioeconomic
- Indices
- Monitors
- PR Drought Events
- Rainfall Patterns, Drought Conditions and Forecast

General Drought Facts

- Droughts are natural events that occur in nearly all climate zones but with widely variable characteristics.

- Drought is a deviation from climate and is quite different from an arid region with low annual precipitation.

- While droughts can be defined as a climate phenomenon, their impacts on humans and the environment can be extreme.

General Drought Facts

Differences in **hydrometeorological** variables and **socioeconomic** factors as well as the stochastic nature of water demands in different regions around the world have become an obstacle **to having a precise definition** of drought.

General Drought Facts

- Yevjevich (1967) stated that widely diverse views of drought definitions are one of the principal obstacles to investigations of droughts.

- When defining a drought it is important to distinguish between **conceptual and operational definitions** (Wilhite and Glantz, 1987).

Drought - *Definitions*

- **Conceptual definitions**, formulated in general terms, help people understand the concept of drought.
  - – those stated in relative terms (e.g., a drought is a long, dry period).

- An **operational definition** of drought helps people to **identify the beginning, end, and degree of severity of a drought**. This definition is usually made by comparing the current situation to the historical average, often based on a 30-year period of record (according to World Meteorological Organization recommendations).

Drought - *Definitions*

Some of the commonly used definitions (conceptual) are:

(i) **The World Meteorological Organization (WMO, 1986)** - *'drought means a sustained, extended deficiency in precipitation.'*

(ii) **The UN Convention to Combat Drought & Desertification (1994)** - *'drought means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.'*

(iii) **The Food and Agriculture Organization (FAO, 1983) of the United Nations** - *'the percentage of years when crops fail from the lack of moisture.'*

Drought - *Definitions*

Some of the commonly used definitions (conceptual) are:

(iv) **The encyclopedia of climate and weather (Schneider, 1996)** - *'an extended period – a season, a year, or several years – of deficient rainfall relative to the statistical multi-year mean for a region.'*

(v) **Palmer (1965)** - *'drought as a significant deviation from the normal hydrologic conditions of an area.'*

(vi) **Linseley et al. (1959)** - *'drought as a sustained period of time without significant rainfall.'*

The droughts are generally classified **(operational definitions)** into four categories (Wilhite and Glantz, 1985; American Meteorological Society, 2004), which include:

Meteorological

Agricultural

Hydrological

Hydrological with respect of the land use

Socioeconomic

Drought – *Operational Definitions*

Meteorological drought is usually defined on the basis of **the degree of dryness** (in comparison to some "normal" or average amount) and the **duration of the dry period**. Definitions of meteorological drought **must be considered as specific to a region** since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region.

Drought – *Operational Definitions*

Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, **differences between actual and potential evapotranspiration**, **soil water deficits**, reduced groundwater or reservoir levels, and so forth.

Drought – *Operational Definitions*

Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., **streamflow, reservoir and lake levels, groundwater**). The frequency and severity of **hydrological drought is often defined on a watershed or river basin scale**.

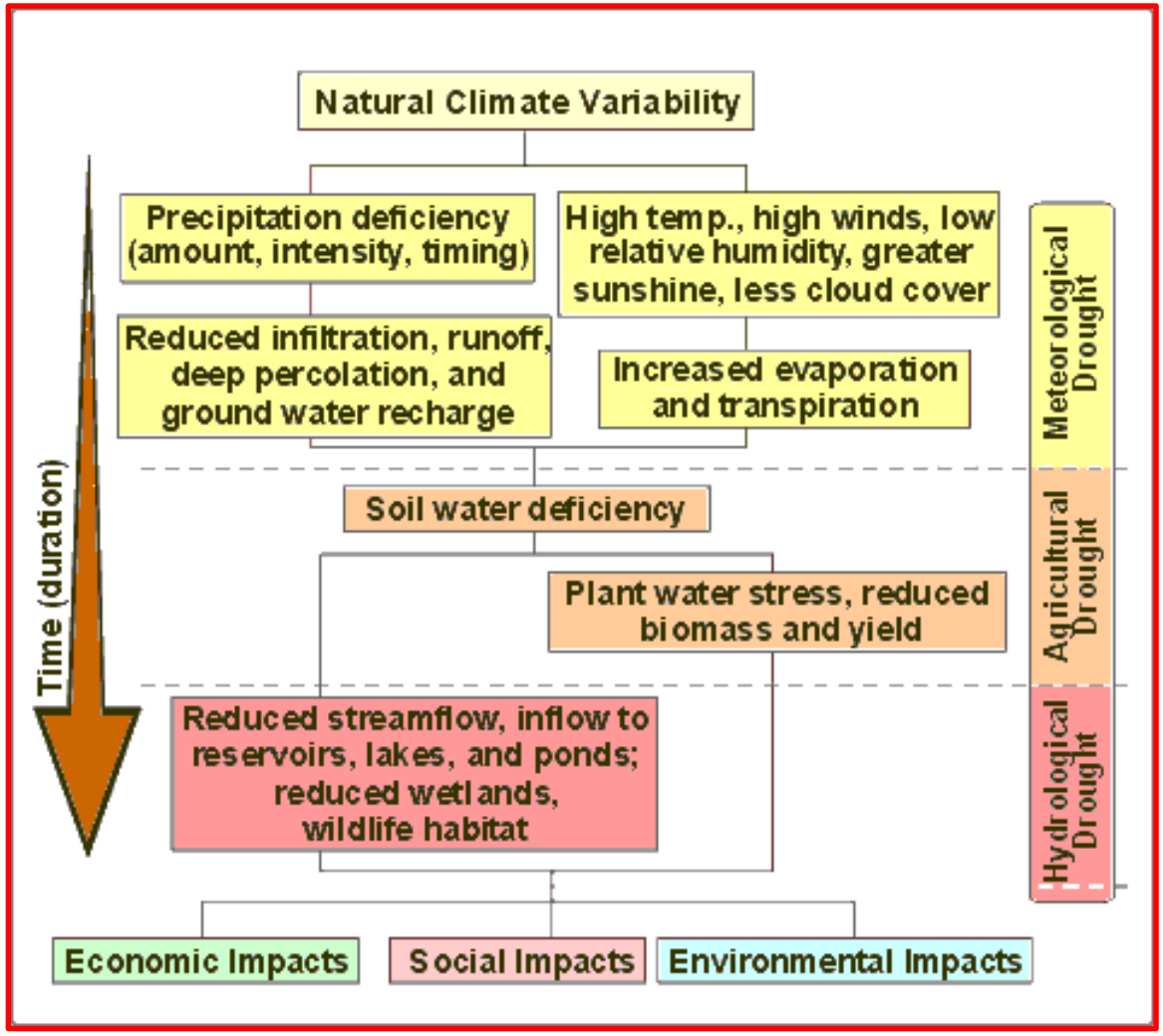
Drought – *Operational Definitions*

Hydrological with respect of the land use - Although climate is a primary contributor to hydrological drought, other factors such as **changes in land use** (e.g., deforestation), **land degradation, and the construction of dams all affect the hydrological characteristics of the basin**.

Drought – *Operational Definitions*

Socioeconomic - This occurs when **physical water shortage starts to affect people**, individually and collectively or, in more abstract terms, most socioeconomic definitions of drought are associated with the supply and demand of an economic good.

In general, meteorological drought onset is first, followed by agricultural, then hydrological. The sequence is similar for recovery.



http://www.noaa.gov/

Drought- *Indices*

A number of different indices have been developed to quantify a drought, each with its own strengths and weaknesses.

- Palmer drought severity index (PDSI; Palmer 1965)
- rainfall anomaly index (RAI; van Rooy, 1965)
- deciles (Gibbs and Maher, 1967)
- crop moisture index (CMI; Palmer, 1968)
- Bhalme and Mooly drought index (BMDI;Bhalme andMooley, 1980)
- surfacewater supply index (SWSI; Shafer and Dezman, 1982)

Drought- *Indices*

A number of different indices have been developed to quantify a drought, each with its own strengths and weaknesses.

- national rainfall index (NRI; Gommes and Petrassi, 1994)
- standardized precipitation index (SPI; McKee et al., 1993, 1995)
- reclamation drought index (RDI; Weghorst, 1996). The soil moisture drought index (SMDI; Hollinger et al., 1993)
- crop-specific drought index (CSDI; Meyer and Hubbard,1995)
- vegetation condition index (VCI; Liu and Kogan, 1996)

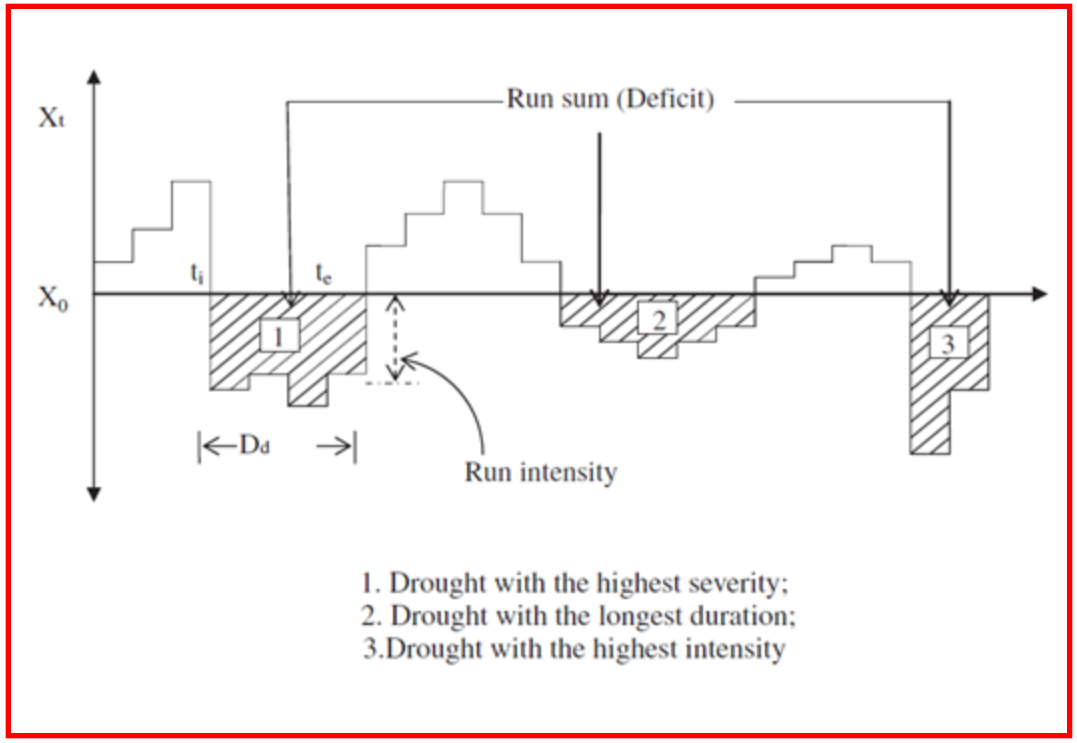
Drought- *Indices*

Most commonly used indices

Percent of Normal Precipitation
Palmer Drought Severity Index (PDSI)
Standardized Precipitation Index (SPI)
Crop Moisture Index (CMI)
Satellite Vegetative Health Index (VHI)

Drought- *Indices*

The method commonly used for identification of drought properties based on drought indices is the ***Run Theory*** Yevjevich (1967).



Drought- *Monitors*

The US Drought Monitor

Because no single index works under all regimes, a number of drought indices and data are considered.

Drought Severity Classification

			Ranges				
Category	Description	Possible Impacts	Palmer Drought Index	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short and Long-term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	3-5	-1.6 to -1.9	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0-2	0-2	-2.0 or less	0-2

http://droughtmonitor.unl.edu/

Drought- *Monitors*

- The U.S. Drought Monitor, established in 1999, is a weekly map of drought conditions that is produced jointly by the National Oceanic and Atmospheric Administration, the U.S. Department of Agriculture, and the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln.

- The U.S. Drought Monitor maps come out every Thursday morning at 8:30 eastern time. The map is based on measurements of climatic, hydrologic and soil conditions as well as reported impacts and observations from more than 350 contributors around the country.

Drought- *Monitors*

The US Drought Monitor

- In addition to indices and data, other outlooks, news accounts, and expert opinions from a broad range of individuals, including federal and academic scientists, are considered.
- Weather Forecast Offices and River Forecast Centers participate in this monitor via e-mail.

Palmer Drought Severity Index

The PDSI was the first index developed in the U.S. (1965). It is a soil moisture algorithm based on precipitation and temperature data, as well as the local available water content of the soil. From the inputs, all the basic terms of the water balance equation can be determined. Negative values depict drought (range -6 to 6).

Strengths: Very comprehensive, places current conditions in an historical perspective, best for long-term drought and homogeneous area

Limitations: Can be slow to respond, does not consider snowpack, need to know the state of the climate

Crop Moisture Index

The Crop Moisture Index was also developed by Palmer (1968), and is a simple water balance index. The CMI responds more rapidly than the Palmer Index and can change considerably from week to week, so it is more effective in calculating short-term abnormal dryness or wetness affecting agriculture.

Strengths: Reflects quickly changing soil conditions for agricultural applications

Limitations: Useful only during the growing season, not a useful long-term drought monitoring tool

Satellite Vegetative Health Index

The Satellite VHI is a combination of the chlorophyll and moisture content in vegetation combined with surface thermal changes. A Vegetation and Temperature condition Index (VT) is produced, with values from 0 to 100 characterizing change in vegetation conditions from extremely poor (0) to excellent (100).

Strengths: Good spatial coverage of vegetative health for agricultural applications; useful for early drought detection; not adversely affected by bad surface observations

Limitations: Useful only during the growing season

Percent of Normal Precipitation

$$\frac{\text{Actual precipitation}}{\text{Normal precipitation}} \times 100$$

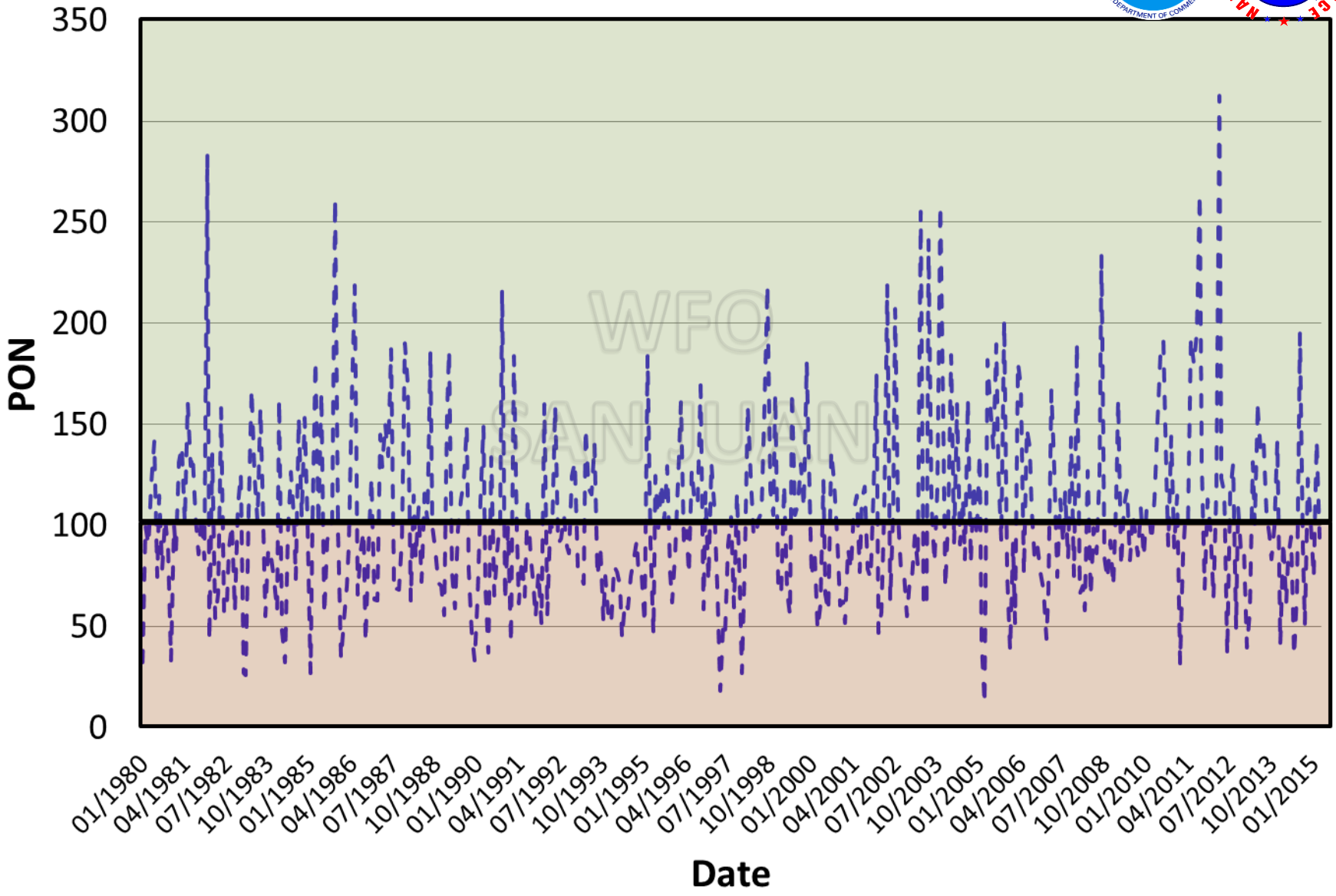
Strengths: Very easy to calculate, regularly generated by various climate software packages, and is generally useful and easy to understand by media and public

Limitations: Often misunderstood as precipitation has a non-normal distribution, which is not taken into account. A station or climate division must have a long record of observations from which a normal can be computed.

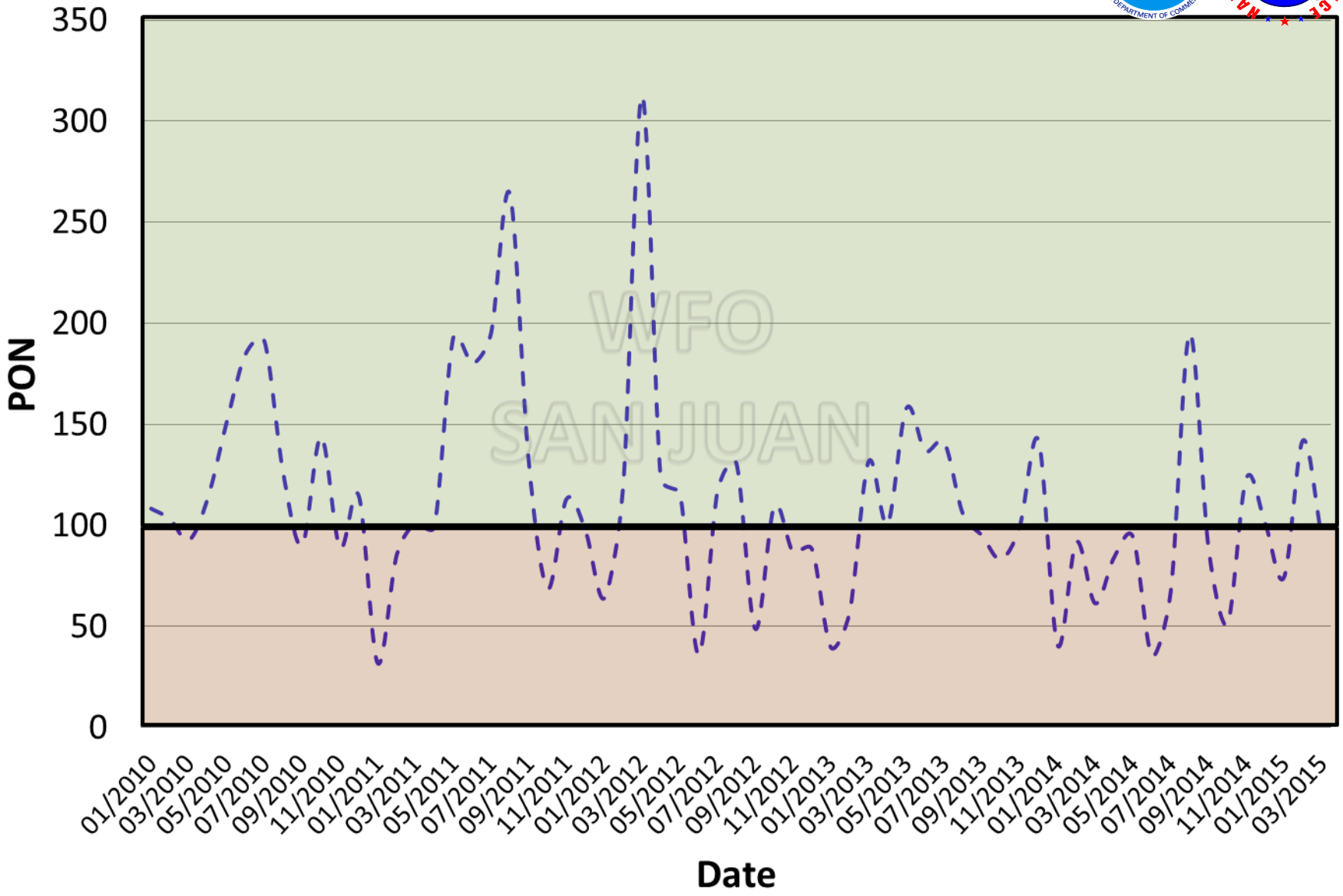
Percent of Normal Precipitation

Percent of normal rainfall based on 1980-2010 National Climatic Data Center (NCDC) Climate Normals and data from National Weather Service COOP stations. **Results based on island wide statistics.**

Percent of Normal Rainfall



Percent of Normal Rainfall



Standardized Precipitation Index

The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (half of the precipitation amounts are below the median, and half above) (Edwards and McKee, 1997). The SPI is negative for drought (index ranges from -2 to 2).

Strengths: Not as complex as the PDSI; can provide early warning of both the onset and end of drought; captures the various time scales of drought

Limitations: Precipitation is the only input - temperature and soil moisture not included, based on preliminary data

Standardized Precipitation Index

- A **3-month SPI** reflects short- and medium-term moisture conditions and **provides a seasonal estimation** of precipitation.

- The **6-month SPI indicates seasonal to medium-term trends** in precipitation. A 6-month SPI can be very effective in showing the precipitation over distinct seasons. Information from a **6-month SPI may also begin to be associated with anomalous streamflows and reservoir levels**, depending on the region and time of year.

Standardized Precipitation Index

- The **9-month SPI provides an indication of inter-seasonal** precipitation patterns over a medium timescale duration. Droughts usually **take a season or more to develop**. SPI values **below -1.5 for these timescales** are usually a good indication that dryness is **having a significant impact on agriculture and may be affecting other sectors as well**.

- The **24-**, and **12-month SPI** at these timescales **reflects long-term** precipitation patterns. SPIs of these timescales are usually **tied to streamflows, reservoir levels, and even groundwater**.

Standardized Precipitation Index

12-month SPI values islandwide for Jan 1940 – Mar 2015 were calculated using National Weather Service COOP stations.

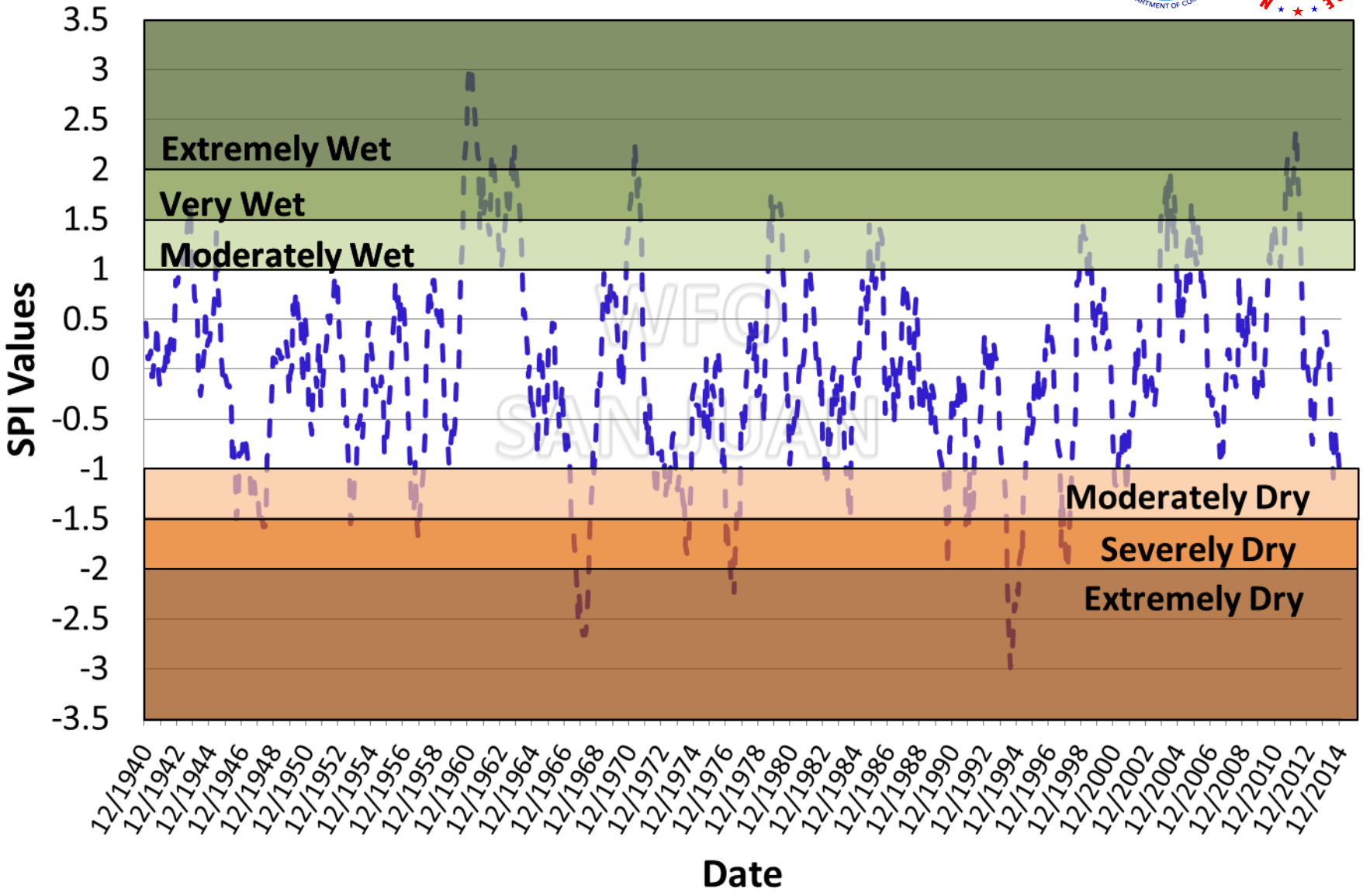
Based on 12-month

Drought with the highest intensity 93-96 followed by 66-69.

Drought with the highest duration 71-76.

2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

12-Month SPI


3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
SPI Values
Extremely Wet
Very Wet
Moderately Wet
Moderately Dry
Severely Dry
Extremely Dry
WFO SAN JUAN
12/1940
12/1942
12/1944
12/1946
12/1948
12/1950
12/1952
12/1954
12/1956
12/1958
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12/2000
12/2002
12/2004
12/2006
12/2008
12/2010
12/2012
12/2014
Date

Standardized Precipitation Index

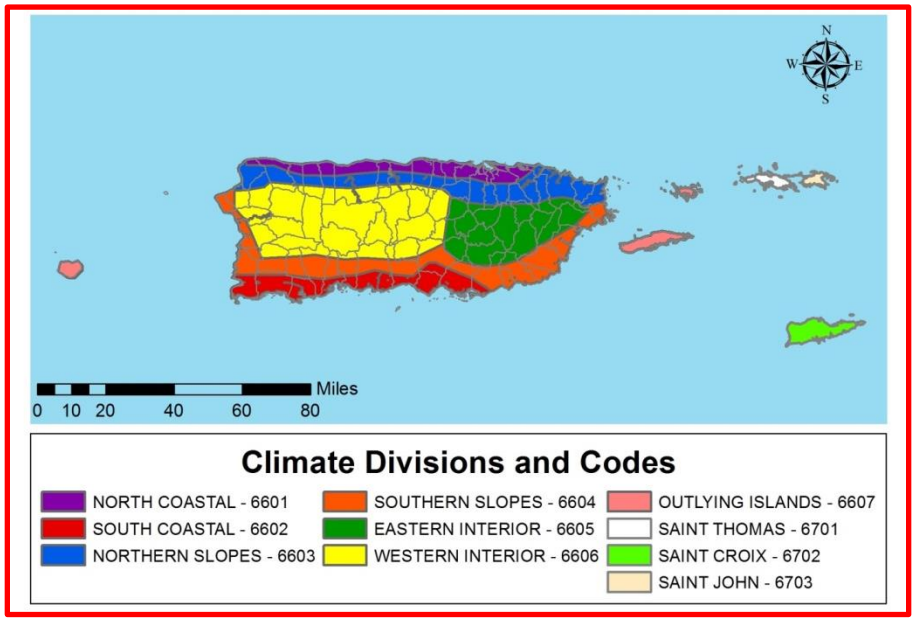
12-month SPI values per climate division for Jan 1941 – Mar 2015 were calculated using National Weather Service COOP stations.

Based on 12-month

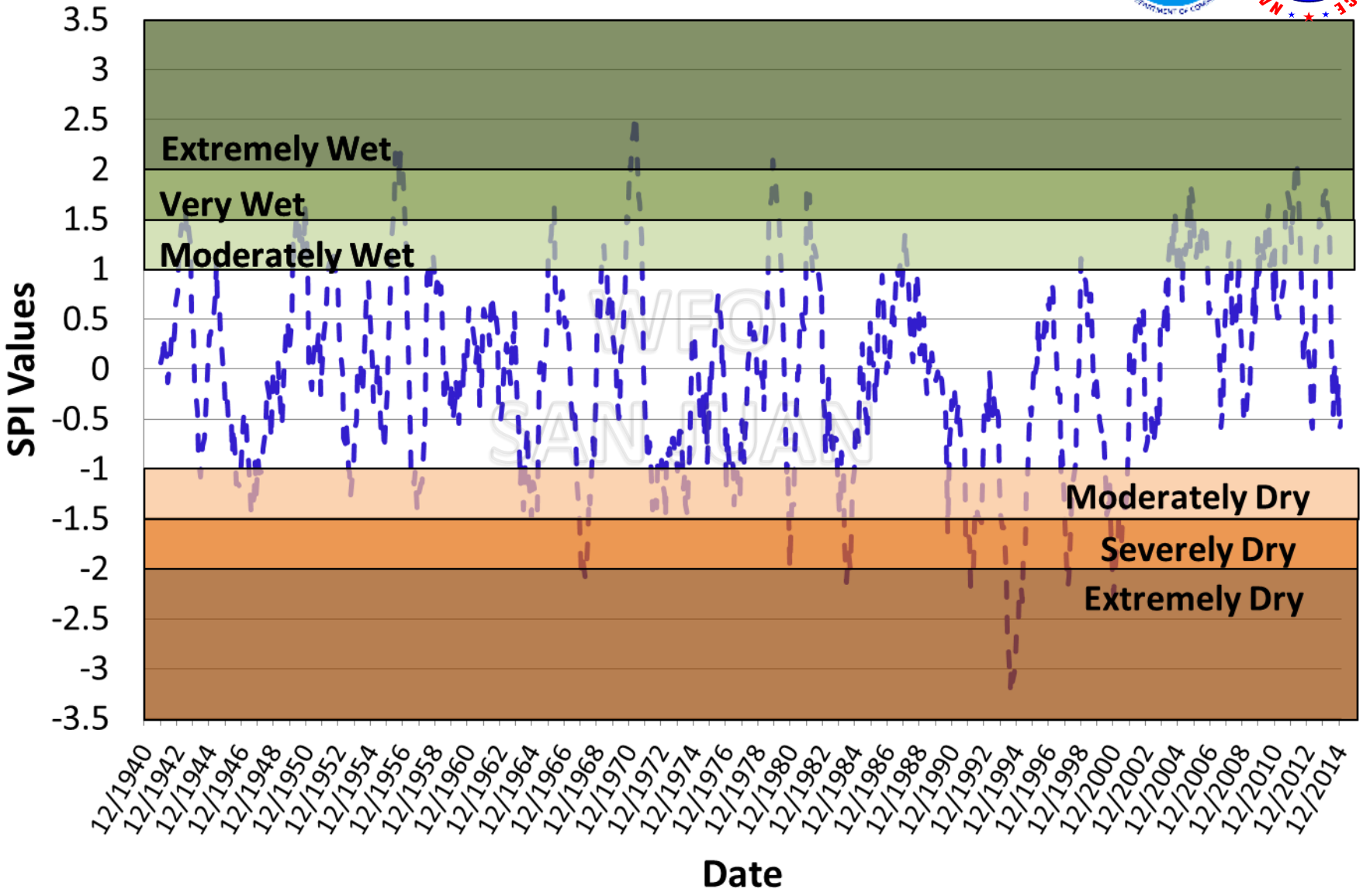
Drought with the highest intensity along the S and E PR; 66-69.

Drought with the highest intensity along N and W PR; 93-96.

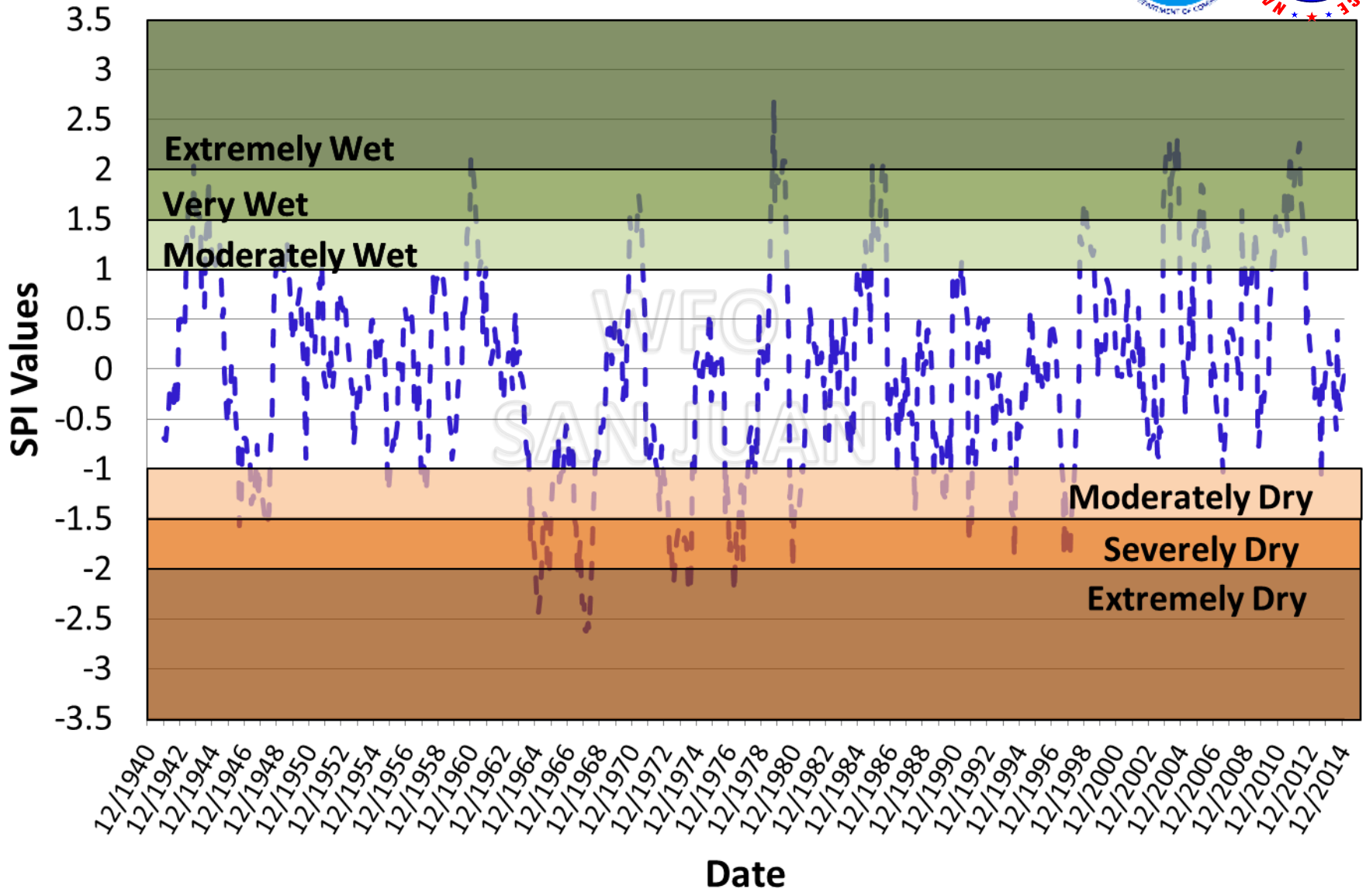
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry



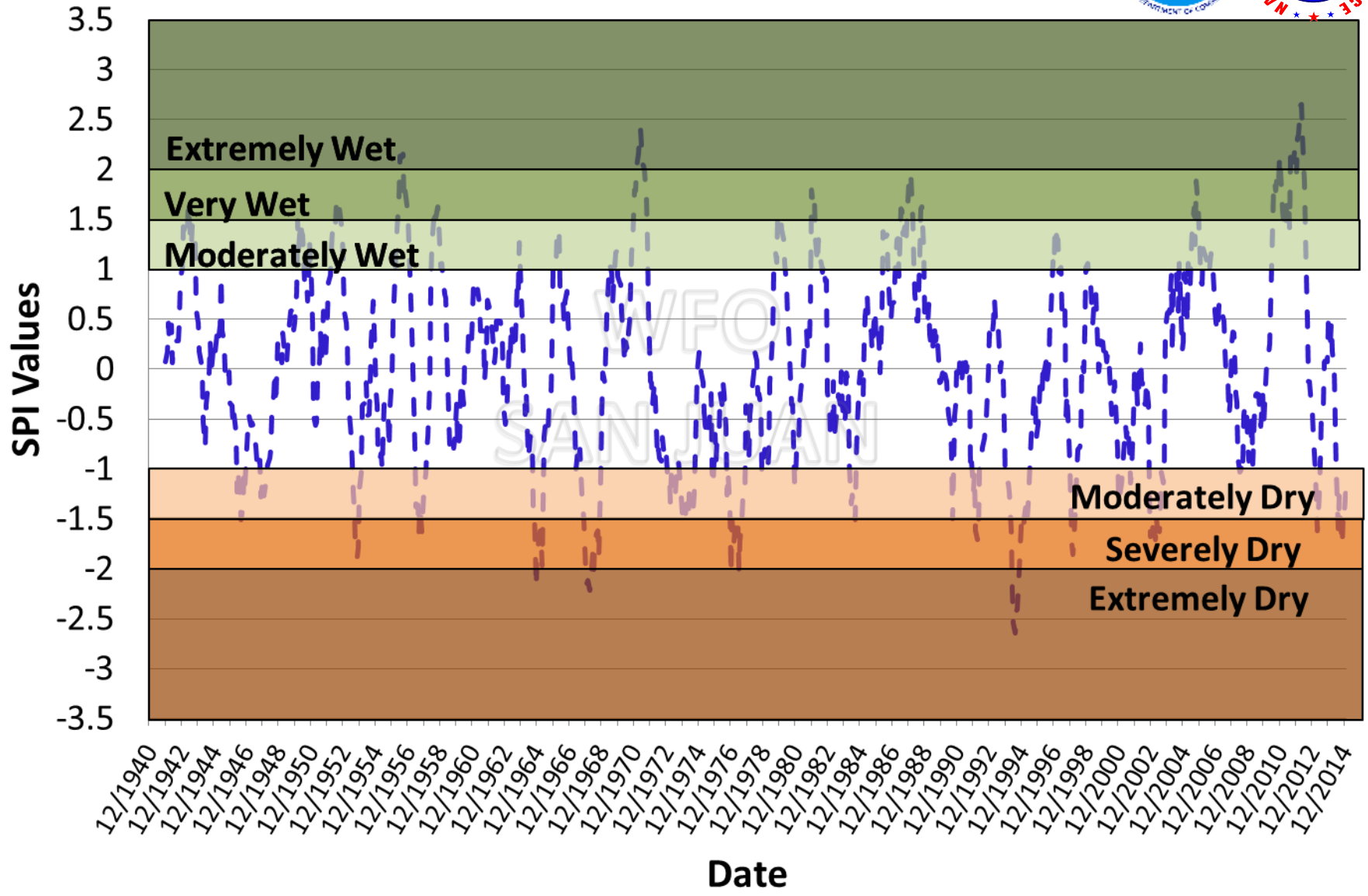
12-Month SPI North Coast



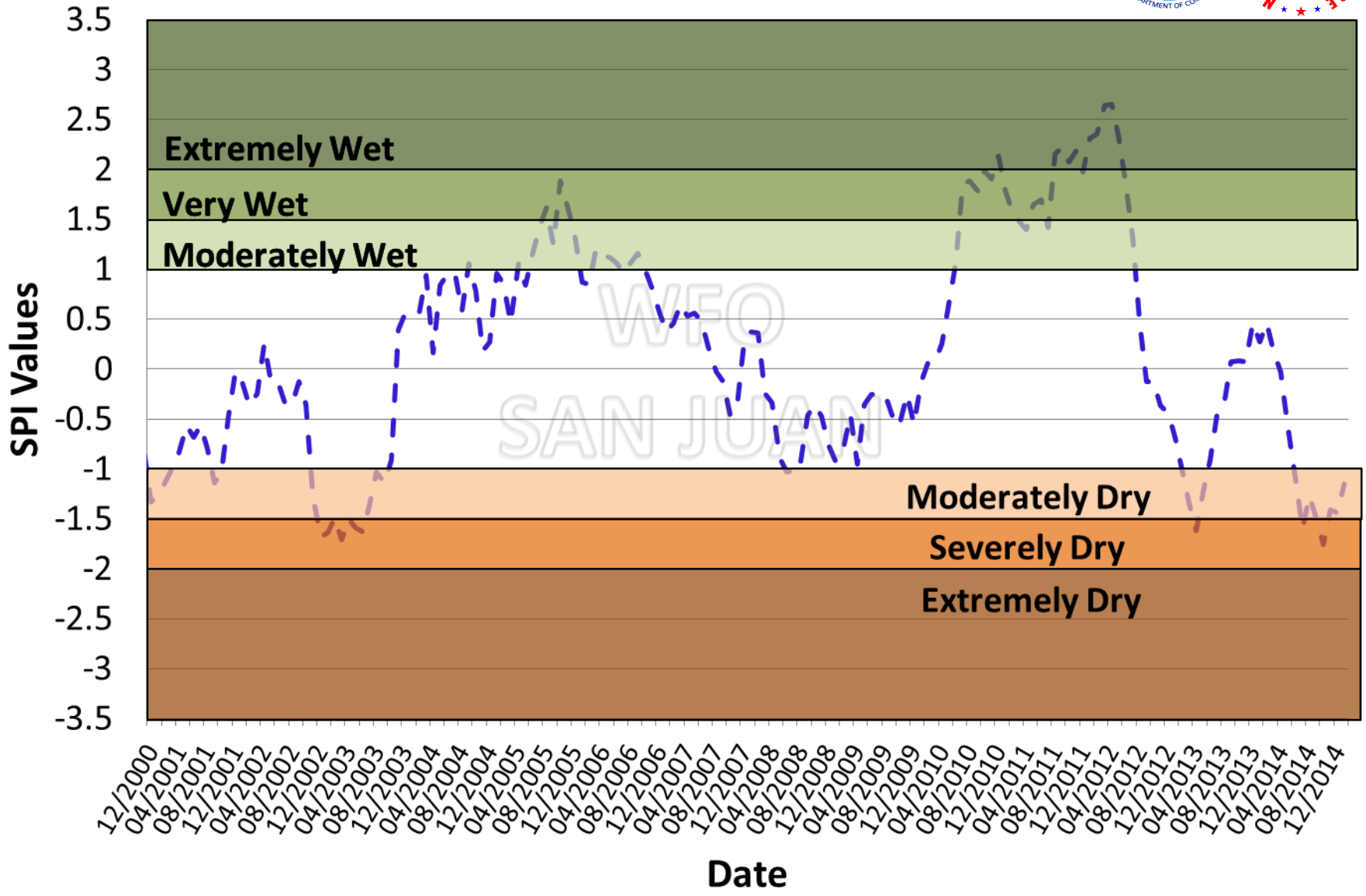
12-Month SPI South Coast



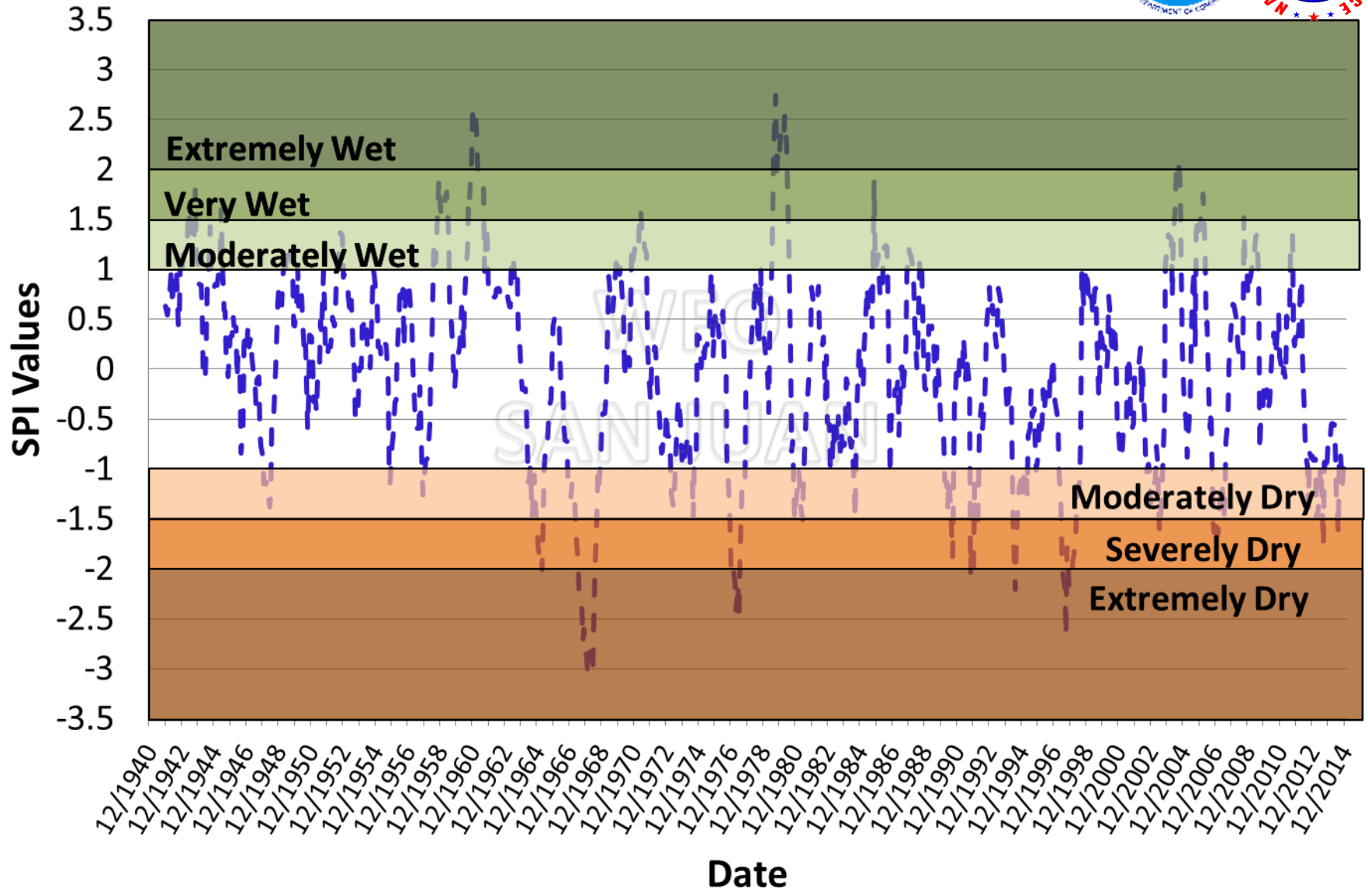
12-Month SPI Northern Slopes



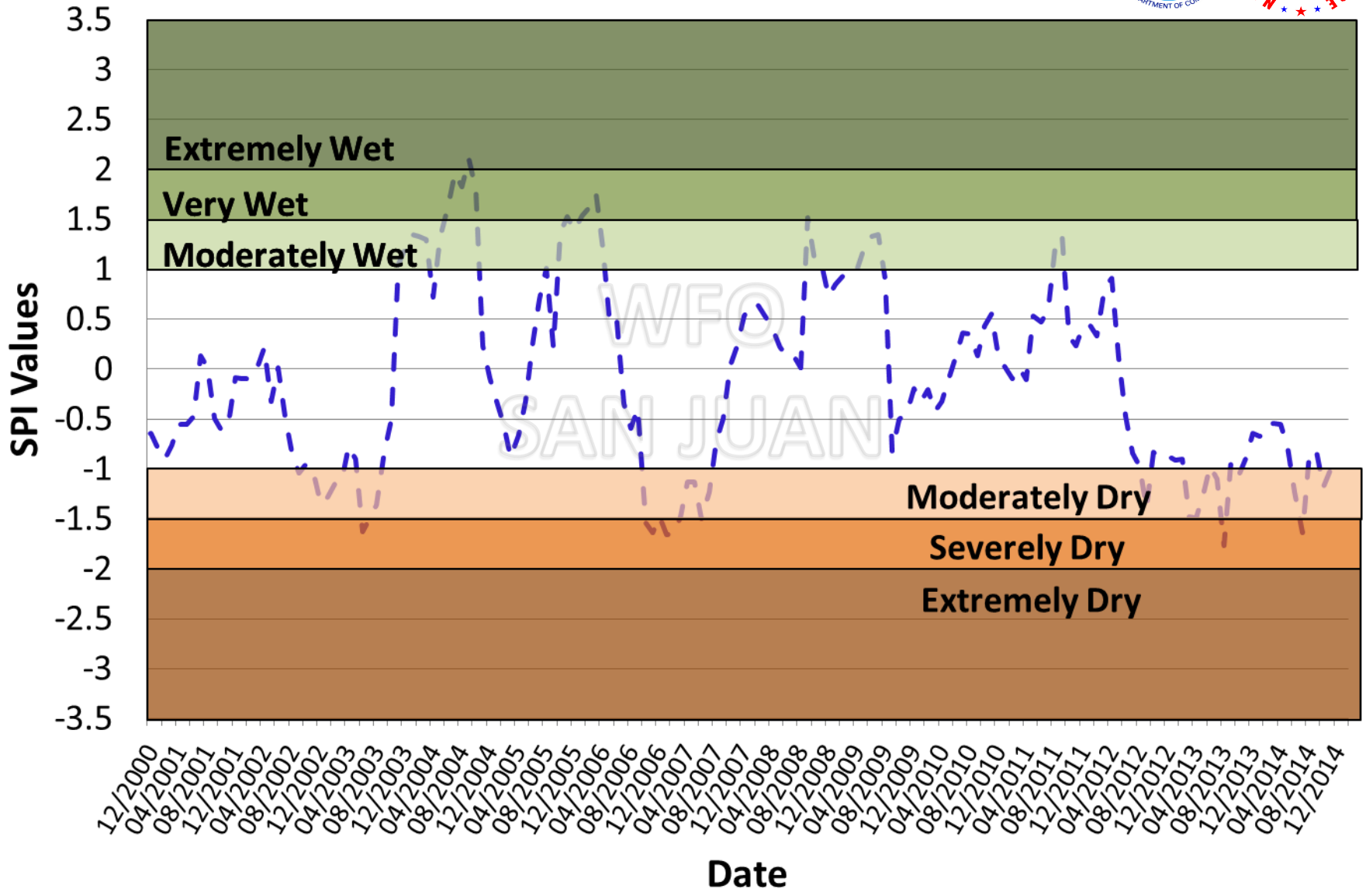
12-Month SPI Northern Slopes



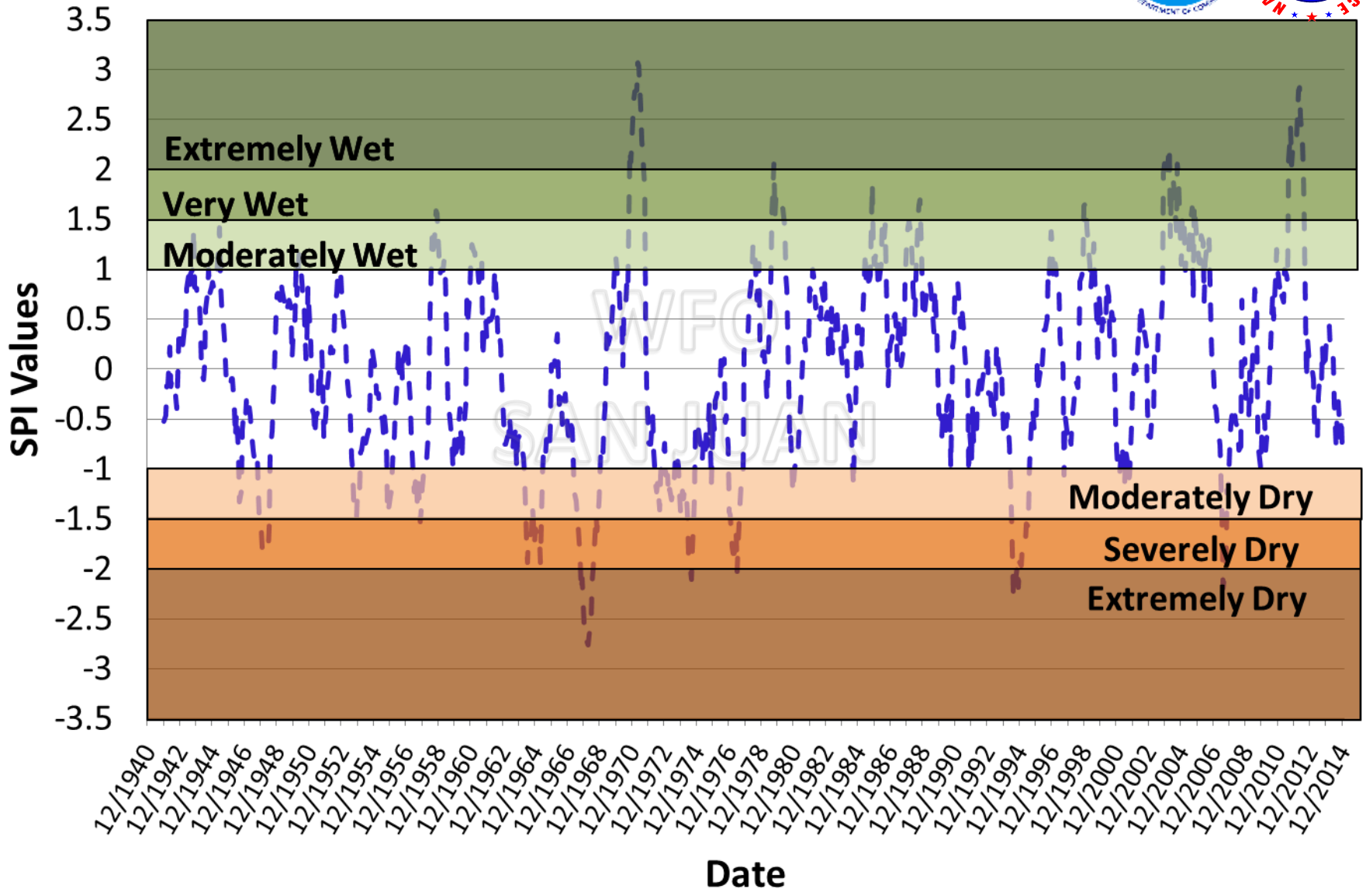
12-Month SPI Southern Slopes



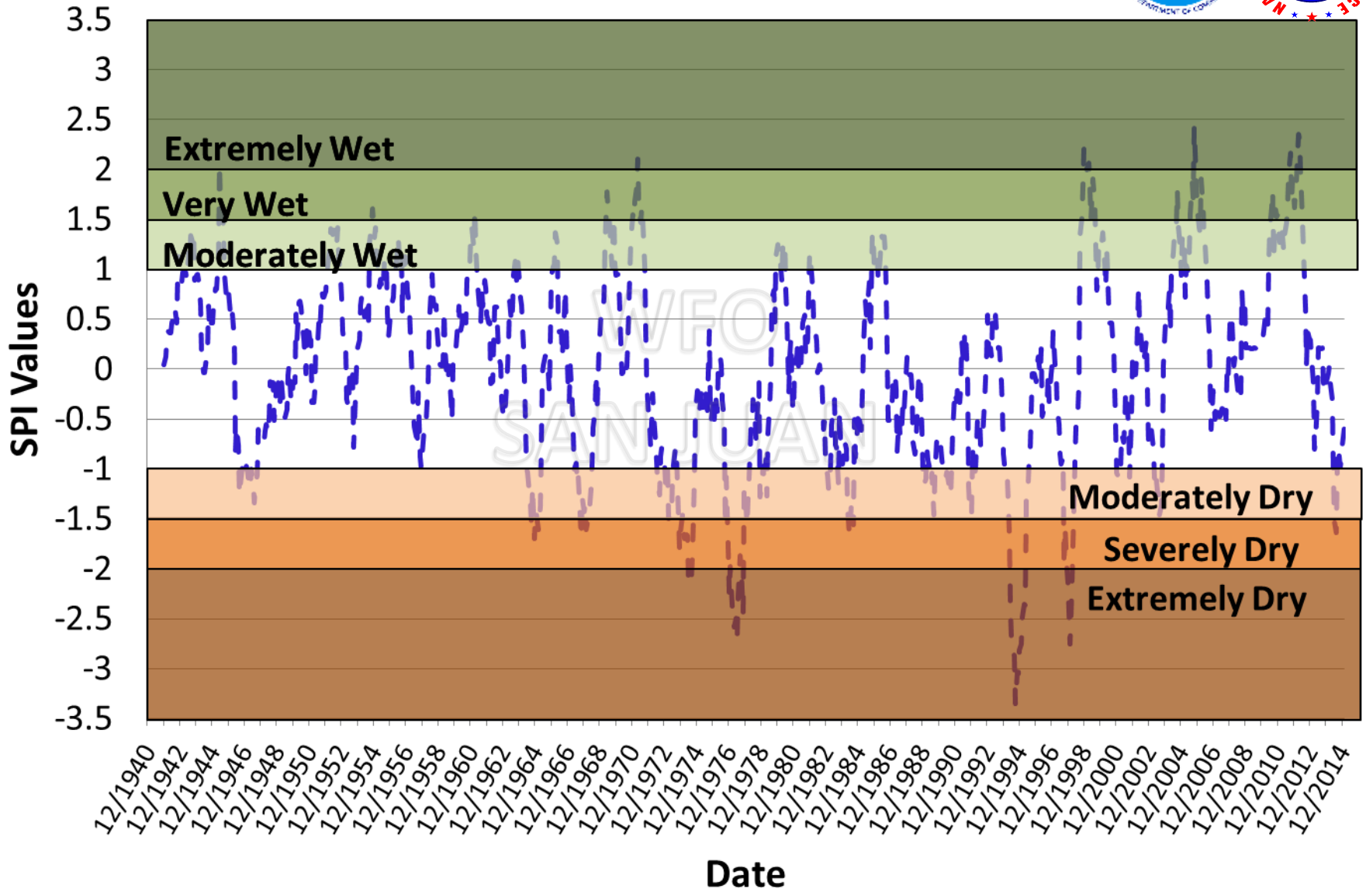
12-Month SPI Southern Slopes



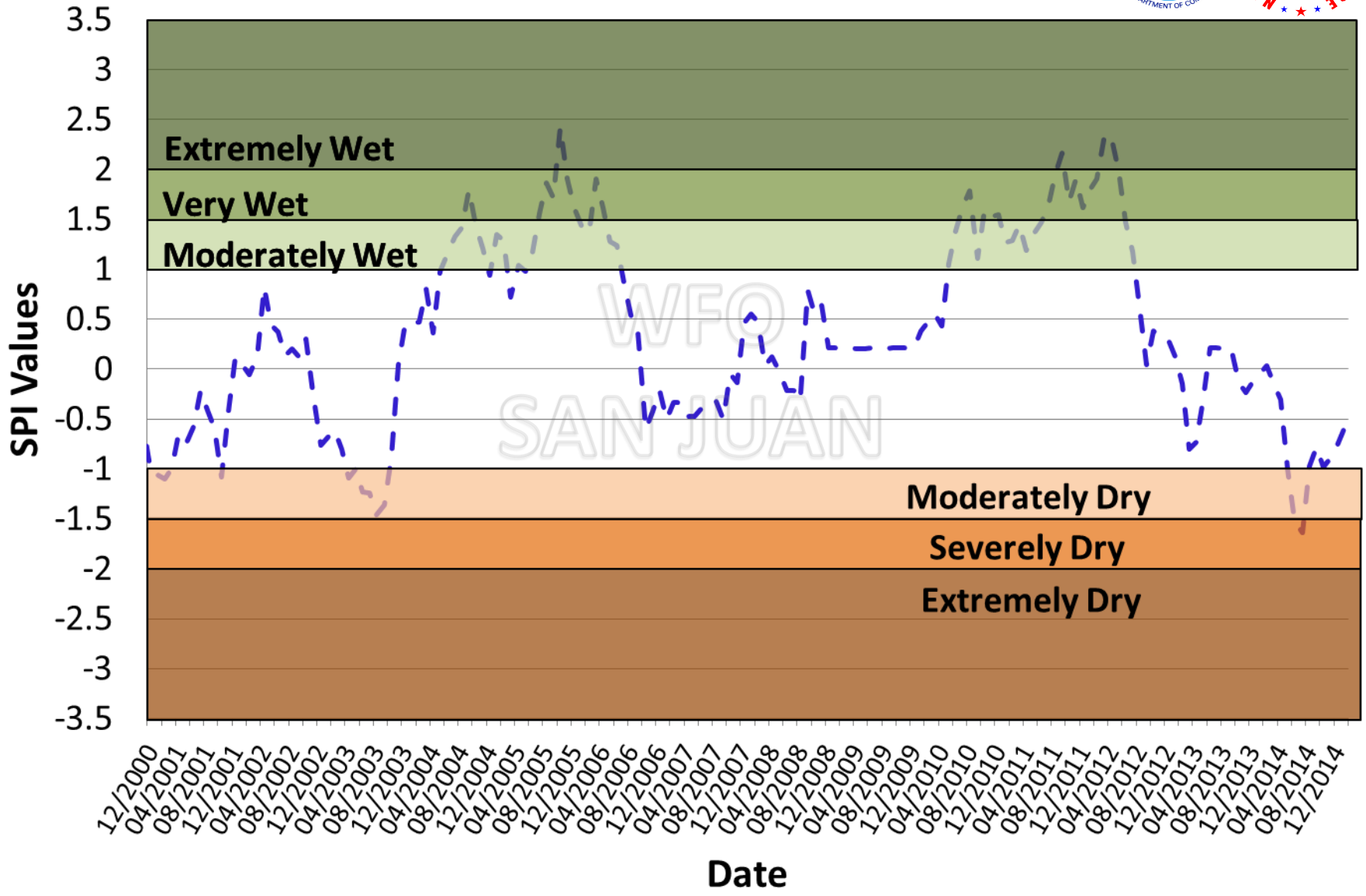
12-Month SPI Eastern Interior



12-Month SPI Western Interior

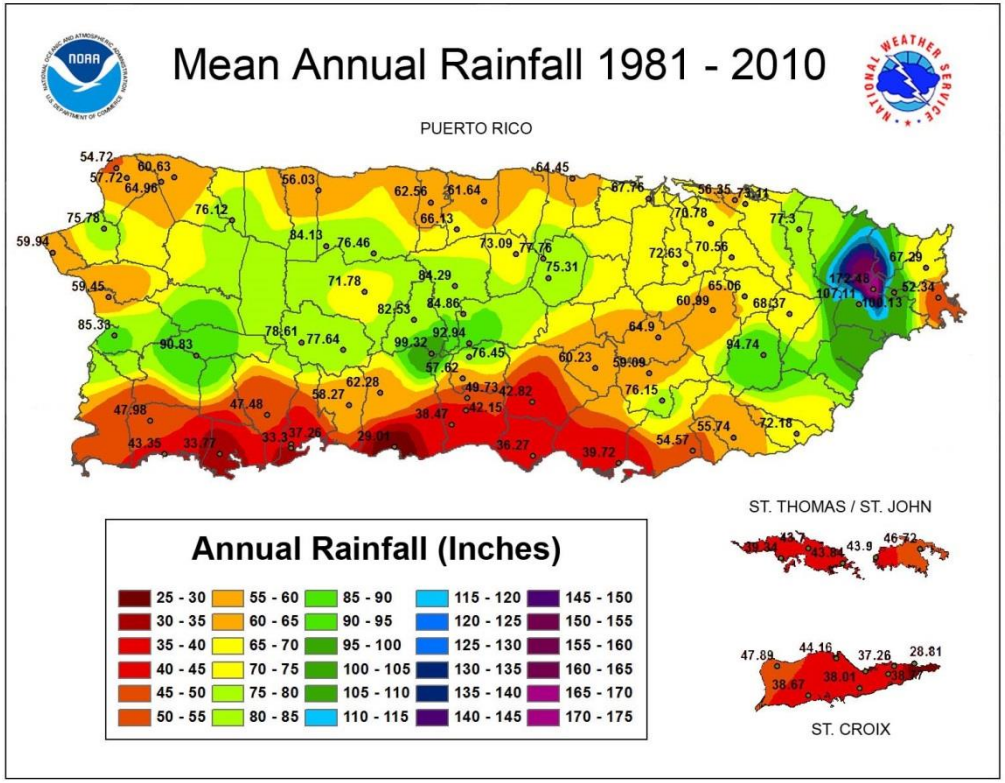


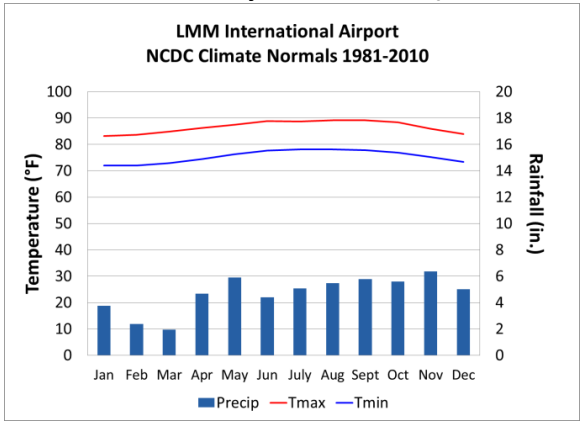
12-Month SPI Western Interior

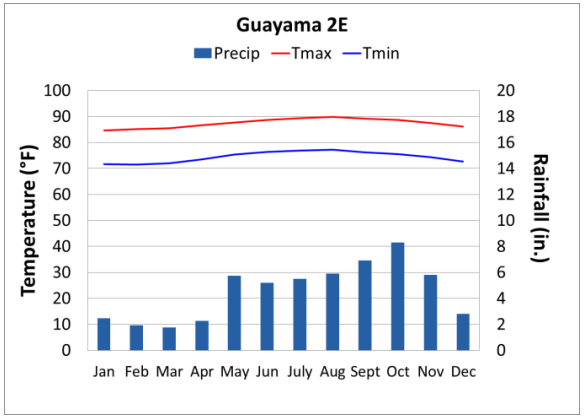


Local rainfall pattern, drought conditions and forecast – "What causes a drought?"

In most parts of the Caribbean, rainfall is bimodal with an initial maximum around May, a relative minimum between Jun-Aug (Mid Summer Drought), and a 2nd peak in Sep-Nov. (Rudloff,1981; Giannini et al ., 2000; Chen and Taylor, 2002)

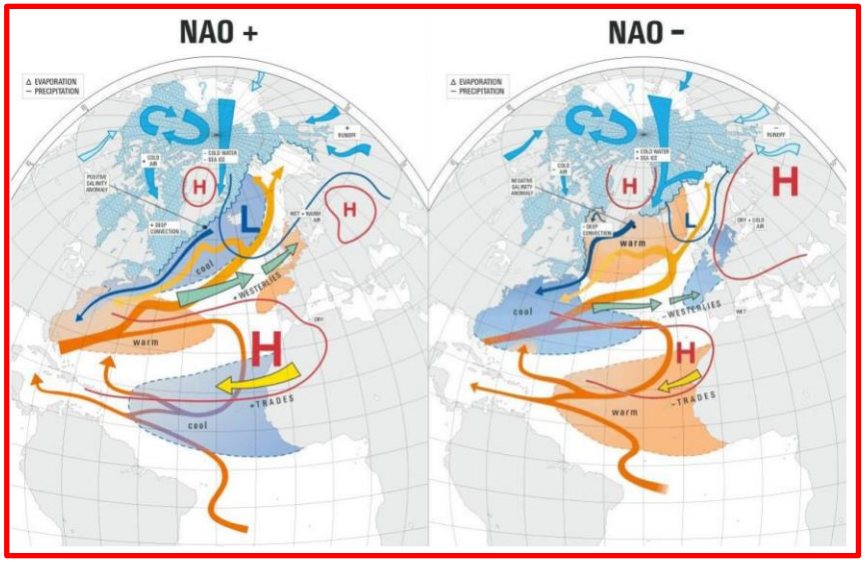






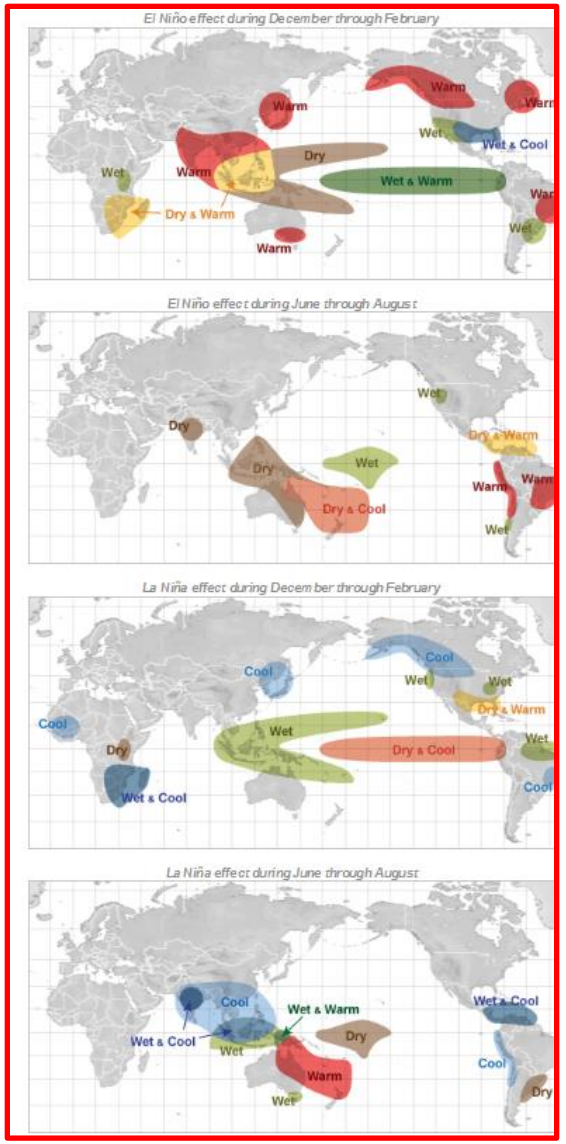
http://www.srh.noaa.gov/sju/

Local rainfall pattern, drought conditions and forecast – "What causes a drought?"



- The dominant synoptic influence for Caribbean precipitation is the North Atlantic subtropical high (NAH), affecting the strength of the trade winds and subsidence (Gamble et al. 2008).
- A positive NAO phase implies a stronger than normal NAH.
- Warm ENSO – rainfall decreases during our wet season
- The phase of the NAO modulates the behavior of warm ENSO events (Giannini et al. 2001). A positive NAO phase implies a stronger than normal NAH, and amplifies the drying during a warm ENSO event.

http://www.noaa.gov/



Local rainfall pattern, drought conditions and forecast – "What causes a drought?"

CFSv2 forecast seasonal Prec anomalies

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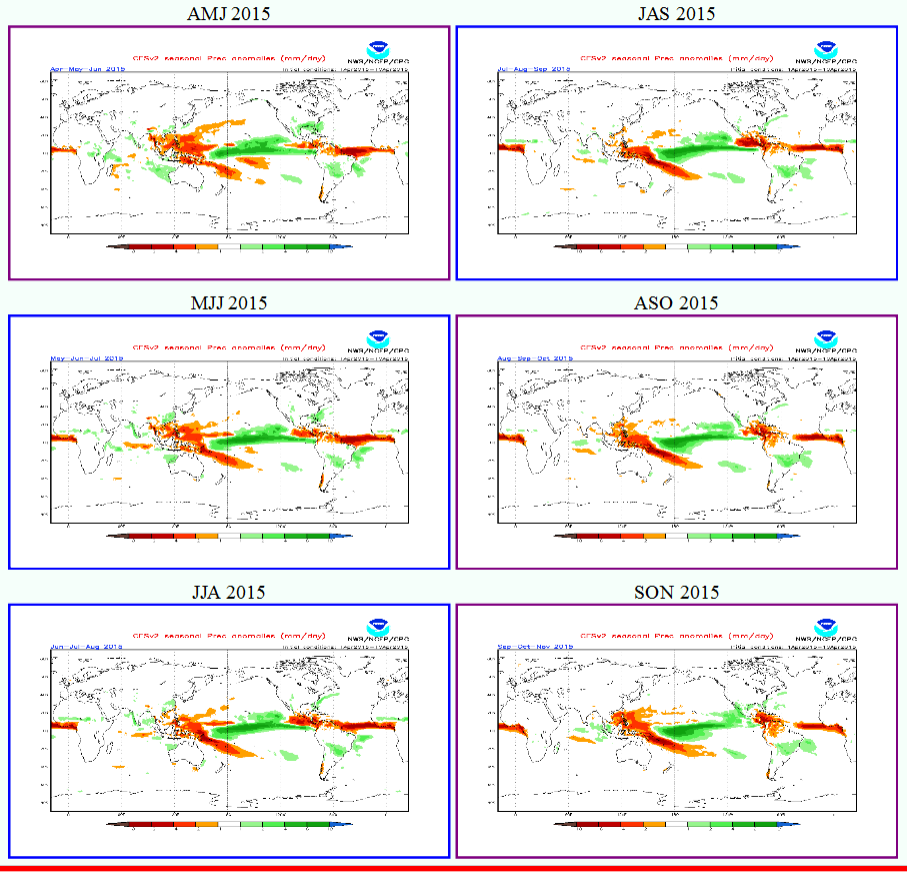

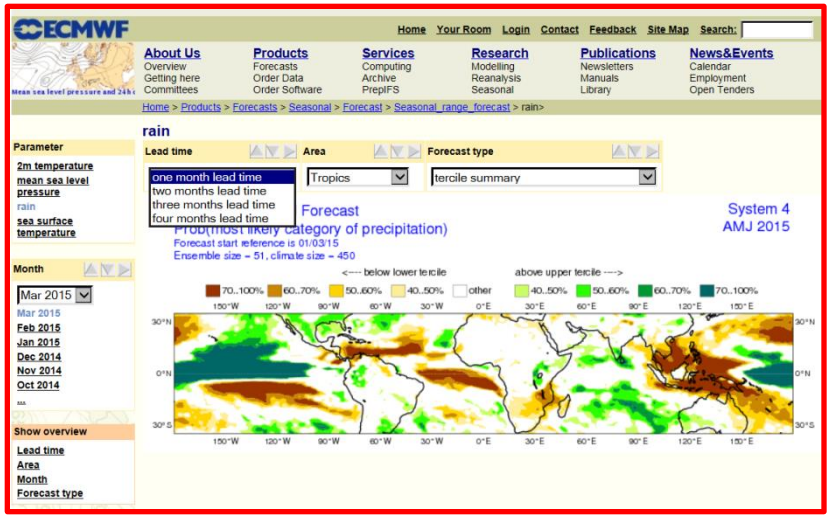

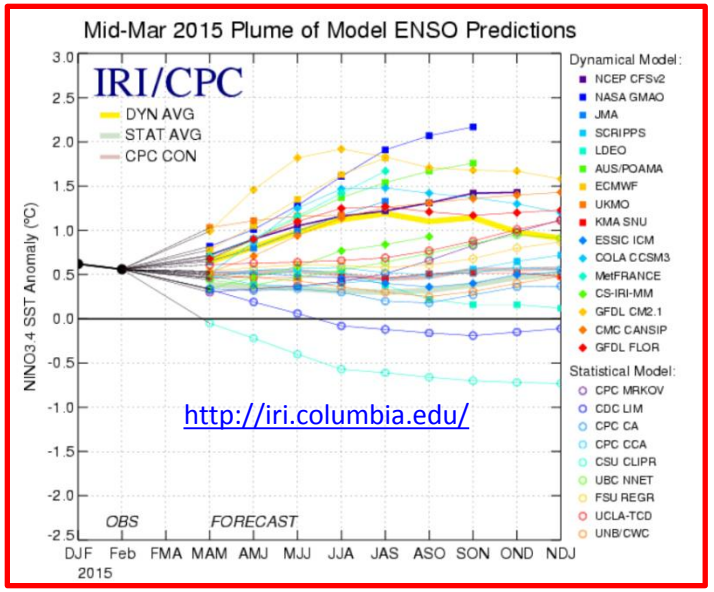

Summary

- Droughts are natural events that occur in nearly all climate zones but with widely variable characteristics.
- Differences in hydrometeorological variables and socioeconomic factors become an obstacle to having a precise definition of drought.
  - Conceptual definitions, formulated in general terms, help people understand the concept of drought.
  - The droughts are generally classified (operational definitions) into four categories.
- A number of different indices have been developed to quantify a drought, each with its own strengths and weaknesses.
- Based on 12-month , Drought with the highest intensity 93-96 followed by 66-69. Drought with the highest duration 71-76.