GOES-PRWEB-Estimated Soil Moisture and Crop Stress-Related Parameters During the 2015 Puerto Rico Drought

Eric Harmsen
Professor, Dept. of Agricultural and Biosystems Eng.,
Univ. of Puerto Rico-Mayaguez
Email: eric.harmsen@upr.edu

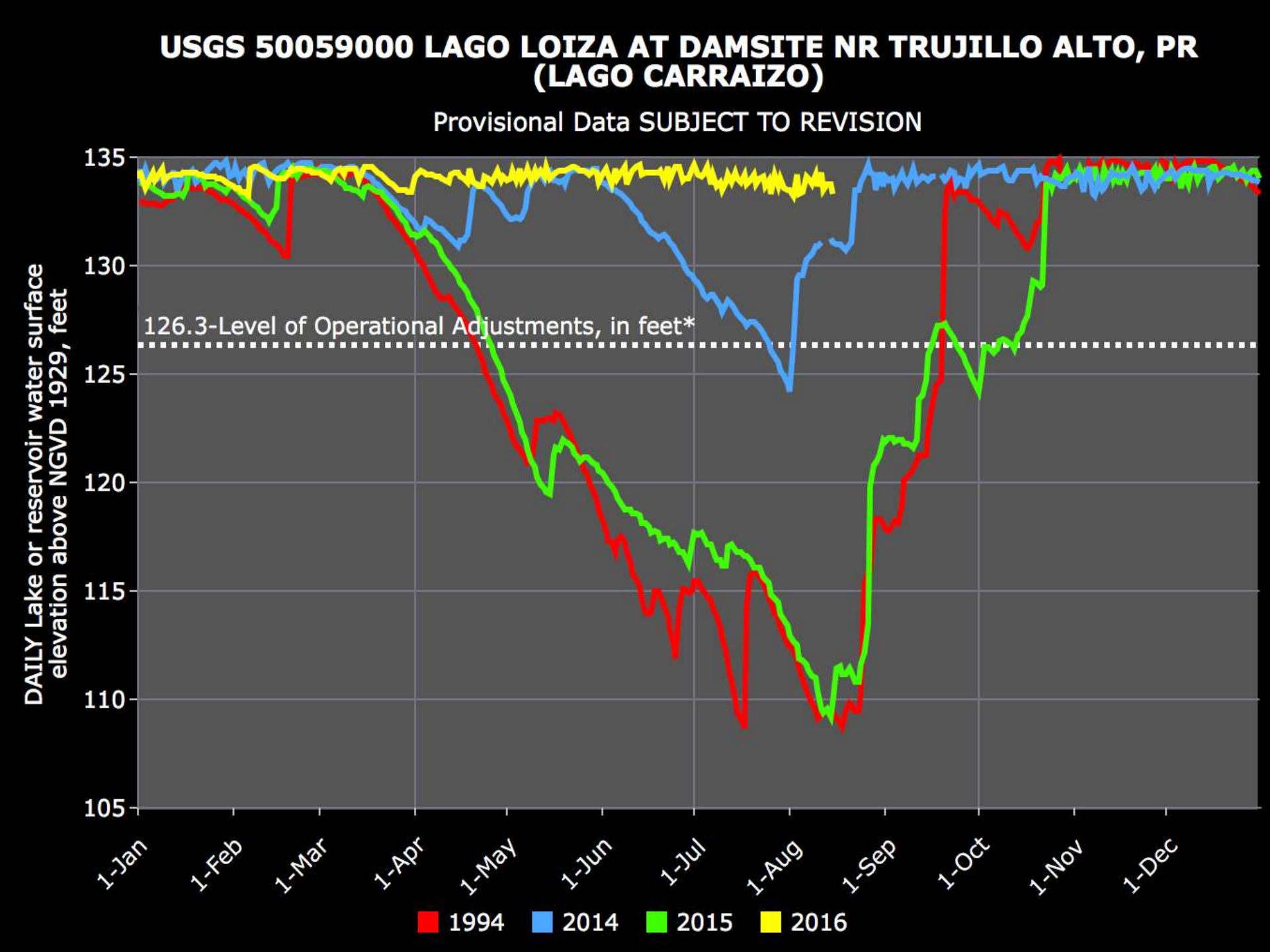
PRYSIG2016, UPRM

7 October, 2016

Background

- During 2015, Puerto Rico experienced a severe drought, thought to be associated with a strong El Niño event. The greatest impacts from the drought occurred in the eastern half of the island. Many of the island's water supply reservoirs dropped to levels not seen since the devastating drought of 1994.

June 19, 2015, aerial photo shows the drought-affected lakeshore of La Plata reservoir in Toa Alta, Puerto Rico.


USGS 50059000 LAGO LOIZA AT DAMSITE NR TRUJILLO ALTO, PR
(LAGO CARRAIZO)
Provisional Data SUBJECT TO REVISION
DAILY Lake or reservoir water surface elevation above NGVD 1929, feet
135
130
125
120
115
110
105
126.3-Level of Operational Adjustments, in feet*
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
1994
2014
2015
2016

Response

- In response to the 2014 drought, the Government established the Puerto Rico Scientific Drought Committee (Comité Científico de Sequía de Puerto Rico), whose task is to provide short and long-term recommendations to the Governor of Puerto Rico and his Secretaries, with the goal of improving the island's response the extreme drought events.

Participants

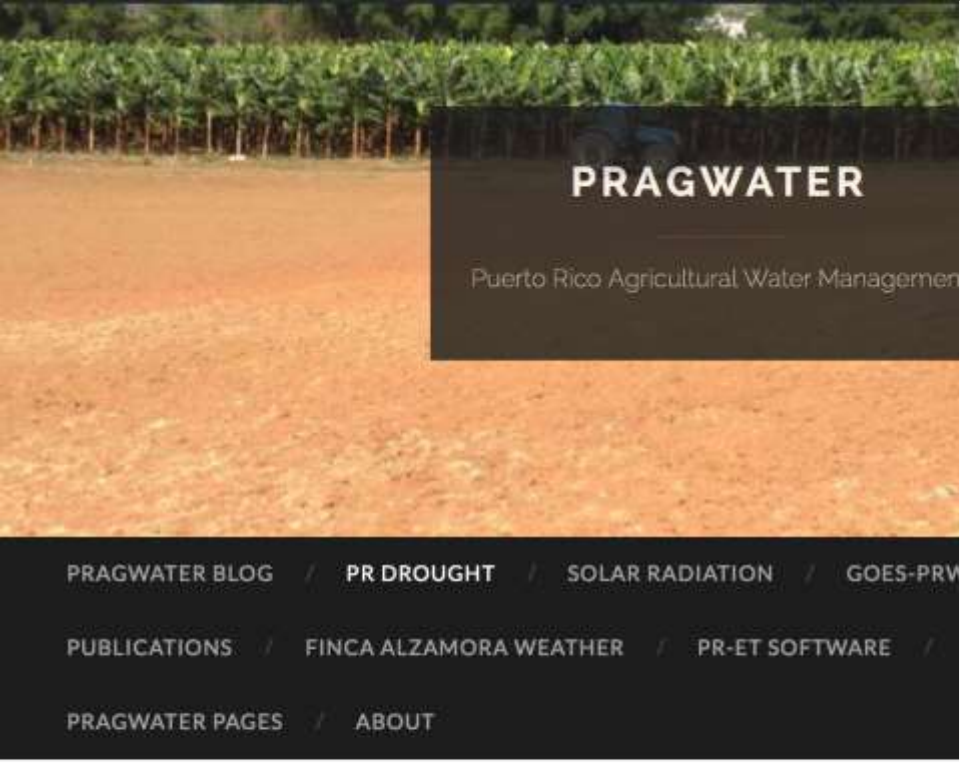
- Participants on the Committee included the National Weather Service, U.S. Geological Survey, U.S. Forest Service, USDA Natural Resource Conservation Service, the University of Puerto Rico, the Puerto Rico (PR) Department of Natural Resources and the Environment, PR Department of Agriculture, PR Department of Emergency Management, Puerto Rico Electric Authority and Puerto Rico Aqueducts and Sewer Authority.

Evaluation and Recommendations

- From May through December 2015, the Committee met weekly to discuss the progress of the drought, the various ways it was impacting the island, and to develop recommendations for managing the island's water resources.
- Data evaluated included rainfall amounts, regional weather forecasts, drought classifications by the U.S. Drought Monitor, water supply lake levels, groundwater levels, stream flows, stream and lake biological health, forest fires, agricultural damage, etc.

Soil moisture and crop-stress-related parameters

- To assistant in the evaluation of the hydrologic and agricultural impacts of the drought, soil moisture and crop-stress-related parameters, derived from the daily operational water and energy balance model GOES-PRWEB, were evaluated by the Committee.
- Specific output considered included volumetric soil moisture, soil moisture saturation, crop stress factor, ratio of the actual to potential evapotranspiration, Bowen ratio and the agricultural rainfall deficit.



Progress of 2015 Puerto Rico Drought – Selected Soil and Water Parameters

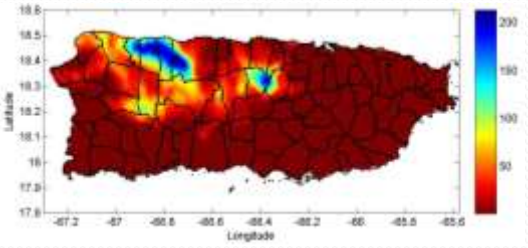
Weekly maps can be viewed by clicking on the following links:

Rainfall
Agricultural rainfall deficit
Agricultural rainfall deficit (negative values only)
Soil Moisture Saturation
Volumetric Soil Moisture Content
Crop Stress Coefficient
Reference (Potential)
Evapotranspiration Actual
Evapotranspiration Natural Log of the Bowen Ratio

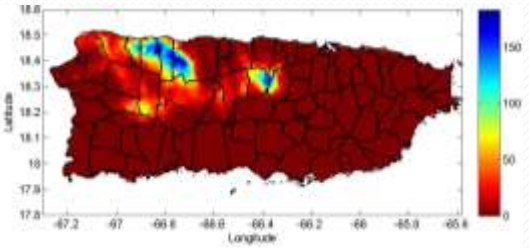
Monthly maps can be viewed by clicking on the following links:

Rainfall
Agricultural Rainfall Deficit
Soil Moisture Saturation
Volumetric Soil Moisture Content
Crop Stress Coefficient
Reference (Potential) Evapotranspiration
Actual Evapotranspiration
Natural Log of the Bowen Ratio

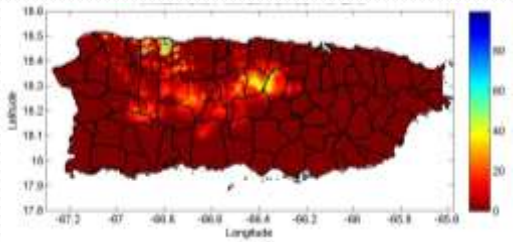
Water and Energy Balance
November 24, 2015



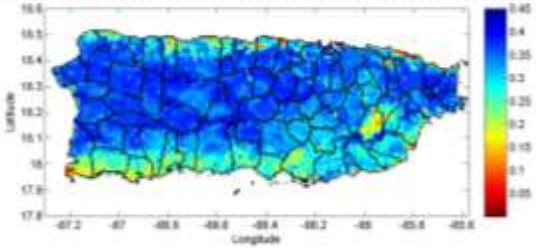
Rainfall



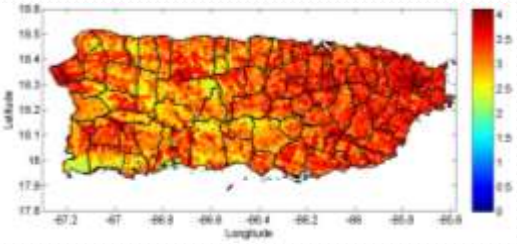
Runoff



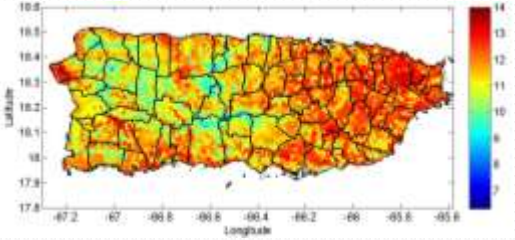
Aquifer Recharge



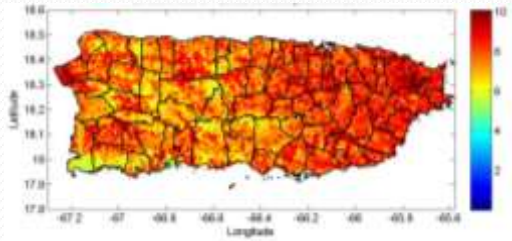
Soil Moisture



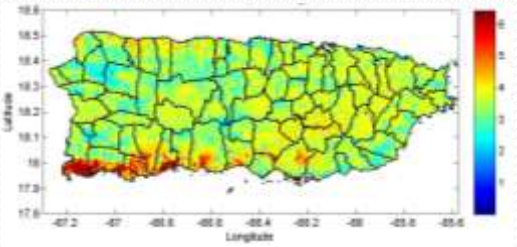
Actual ET



Net Radiation



Latent Heat Flux

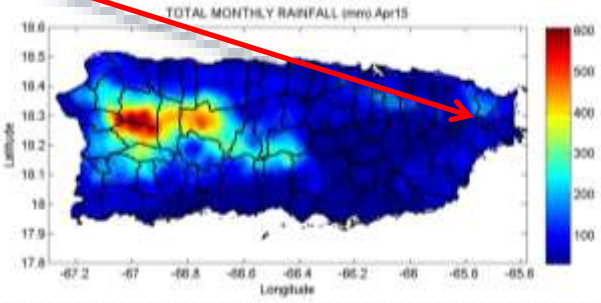


Sensible Heat Flux

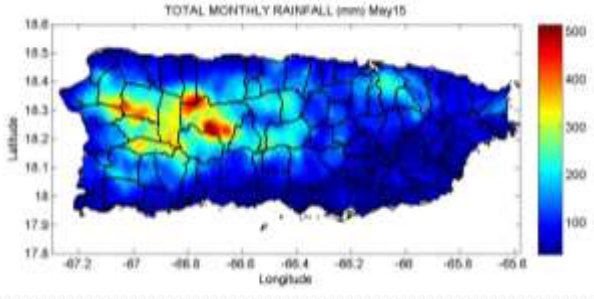
RAINFALL (mm)

NOAA's Advanced Hydrologic Prediction Service

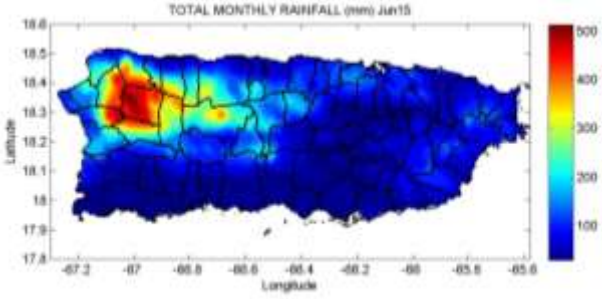
El Yunque Tropical Rain Forest



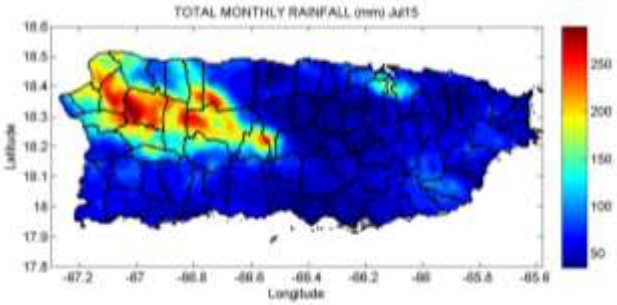
Apr



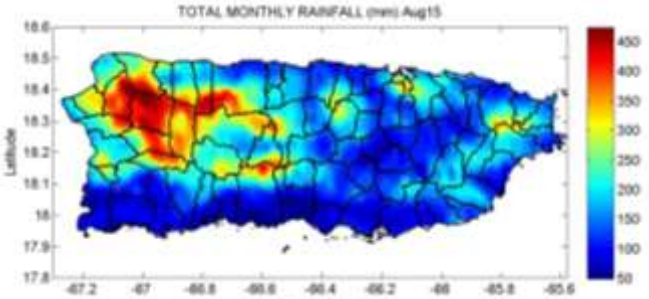
May



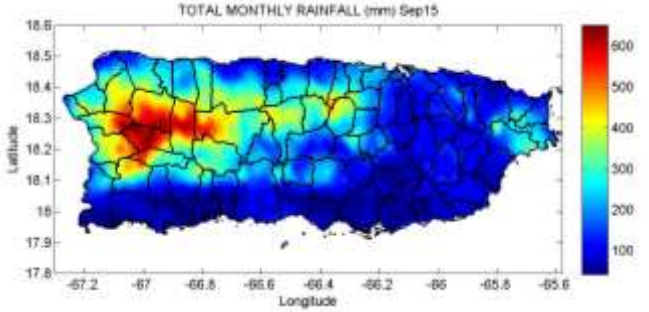
Jun



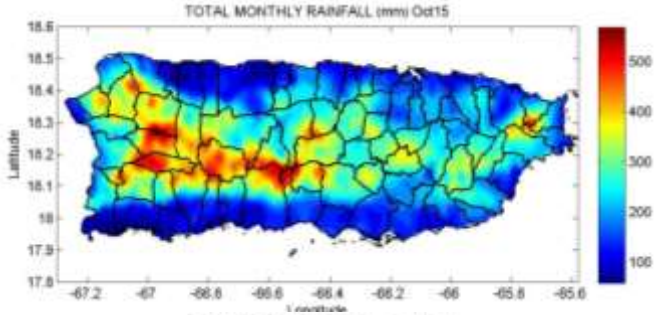
Jul



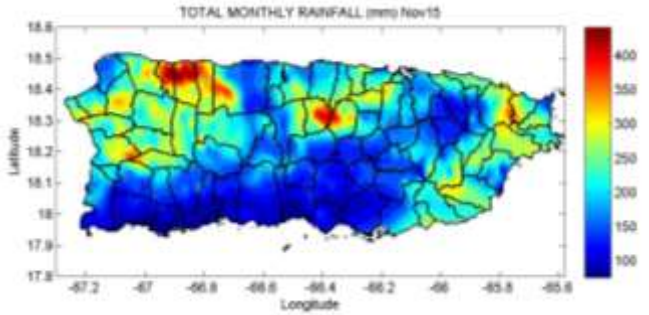
Aug



Sep

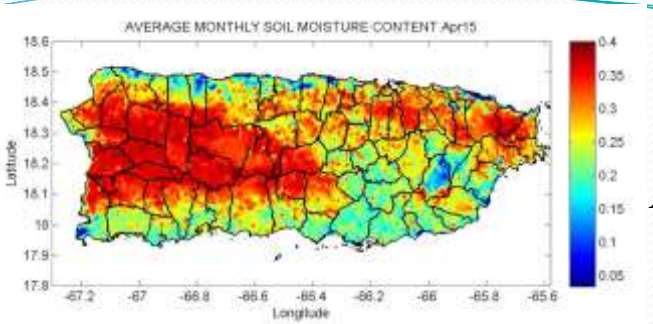


Oct

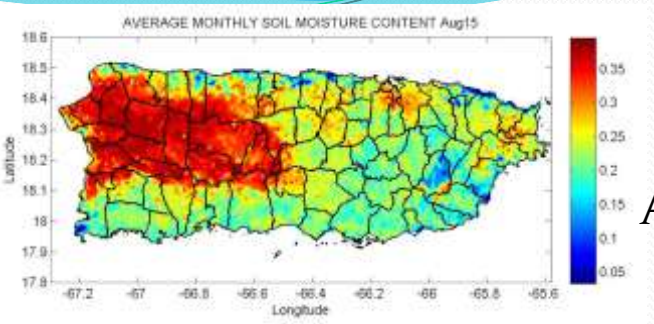


Nov

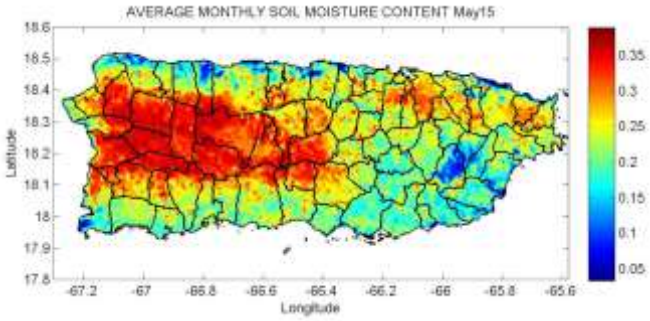
Volumetric Soil Moisture Content (cm^3/cm^3)



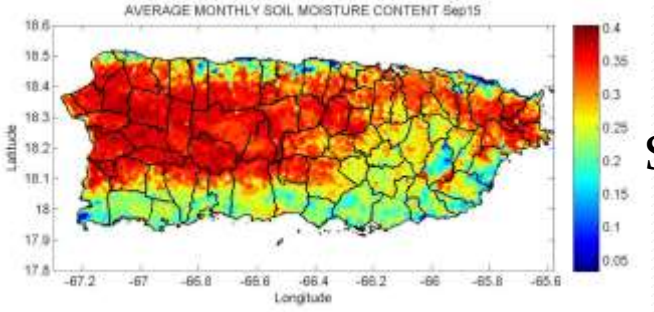
Apr



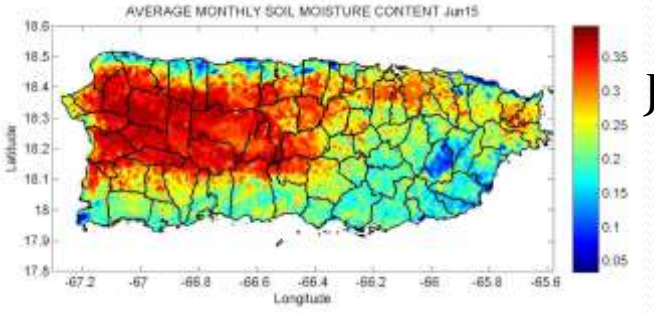
Aug



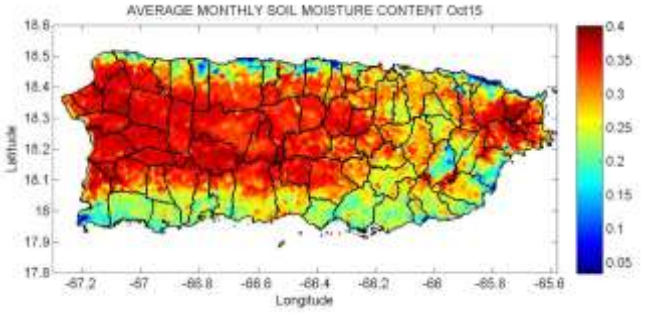
May



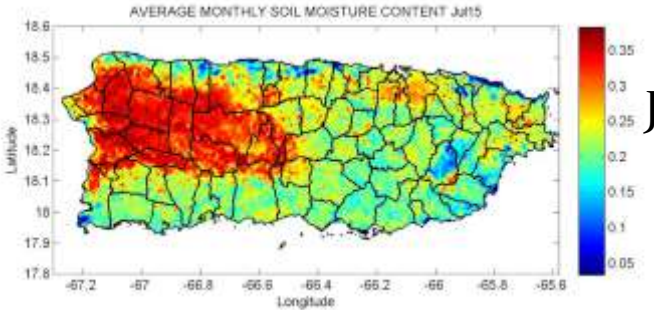
Sep



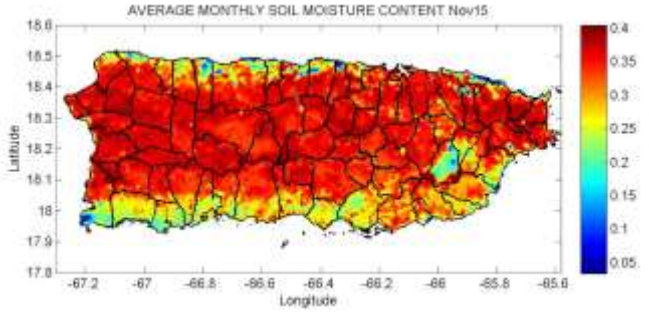
Jun



Oct

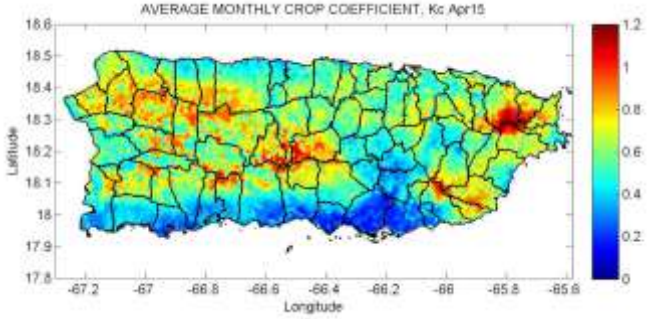


Jul

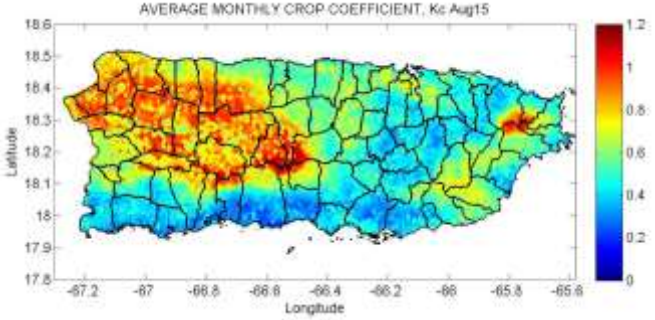


Nov

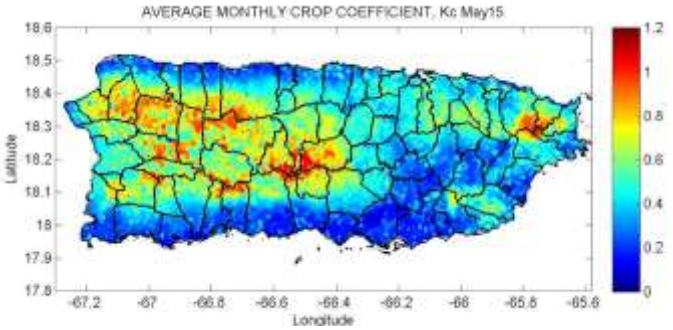
Effective Crop Coefficient



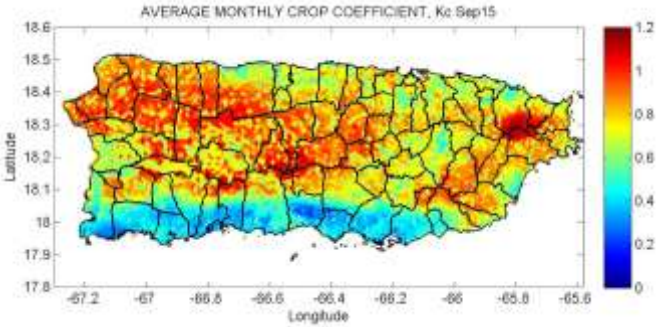
Apr



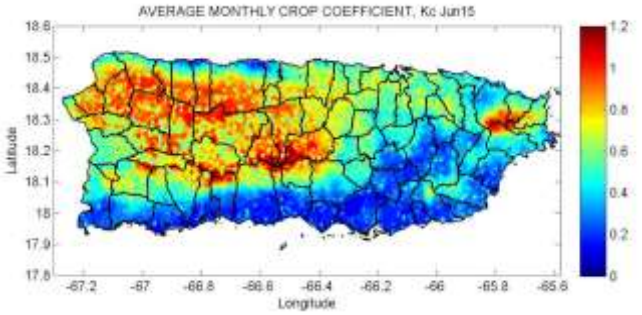
Aug



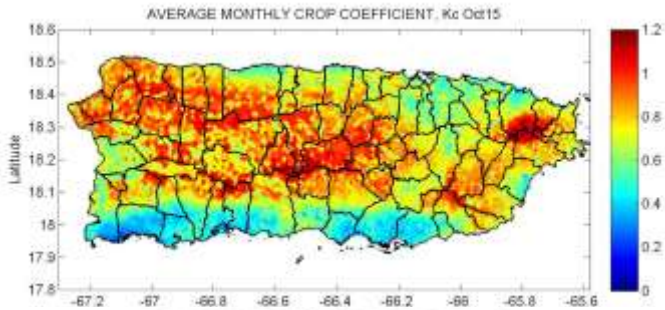
May



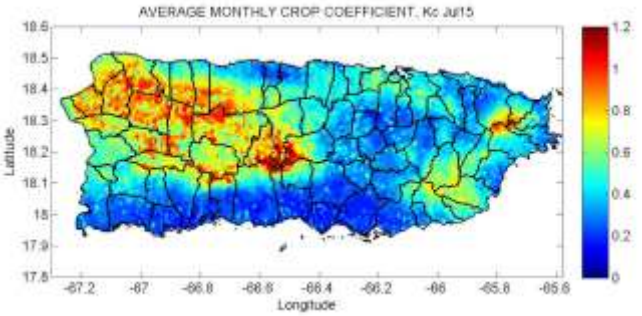
Sep



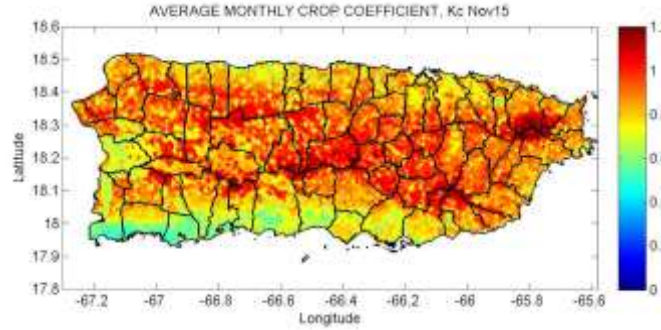
Jun



Oct



Jul



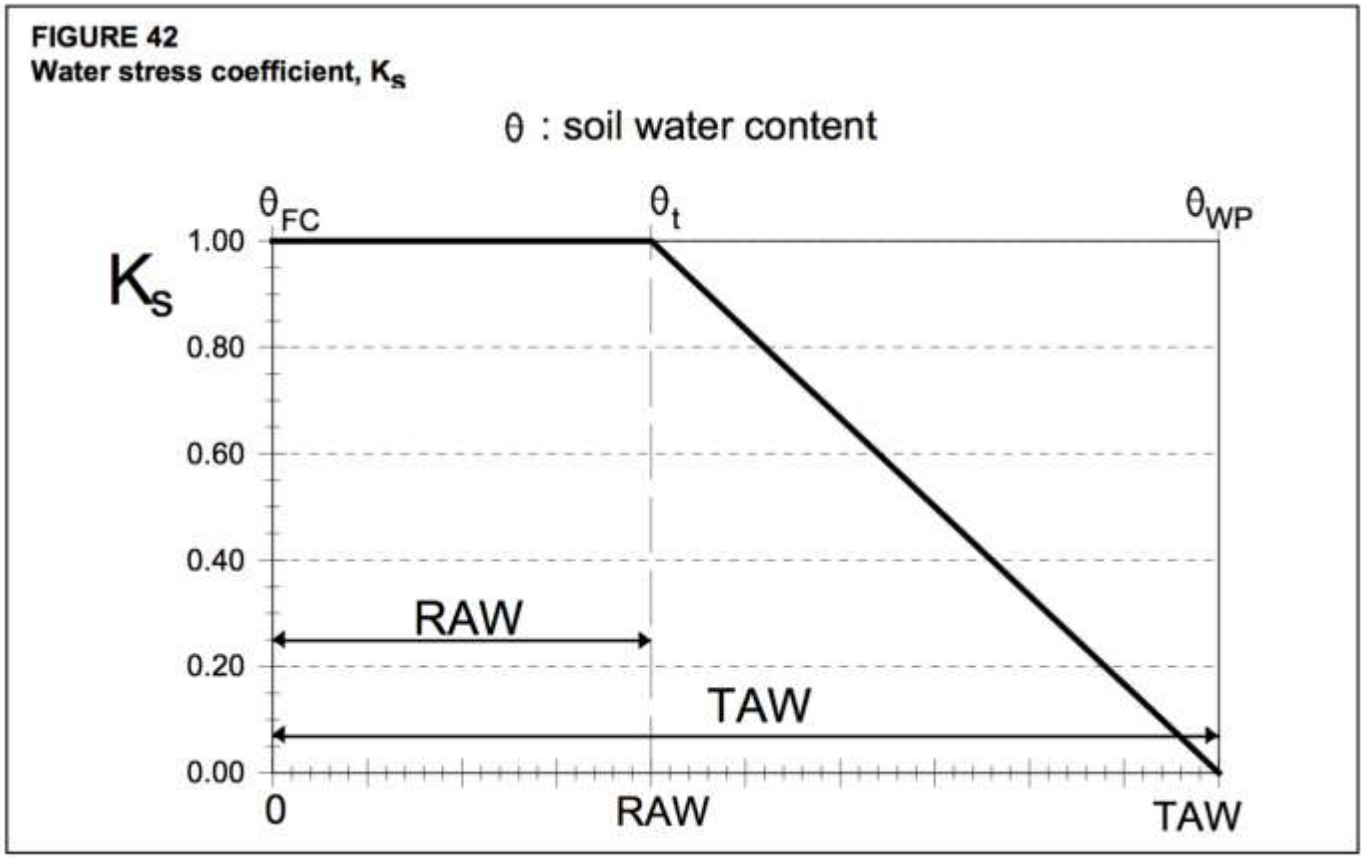
Nov

Water Stress Coefficients (K_s)

$$K_s = \frac{TAW - D_r}{TAW - RAW} = \frac{TAW - D_r}{(1 - p)\ TAW}$$

$$ET_{c\ adj} = K_s\ K_c\ ET_o$$

FIGURE 42
Water stress coefficient, K_s



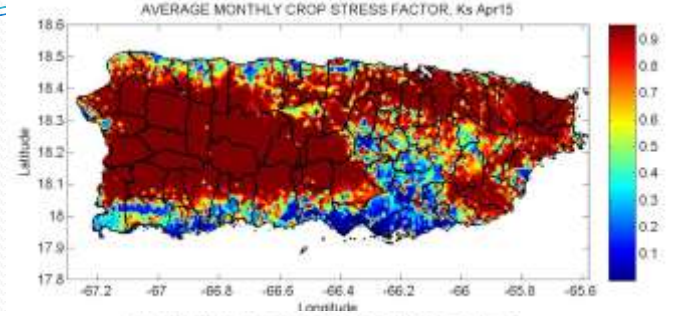
Relative Crop Yield (Y_a/Y_m)

$$\left(1 - \frac{Ya}{Y_m}\right) = K_y \left(1 - \frac{ET_{c\,adj}}{ET_c}\right)$$

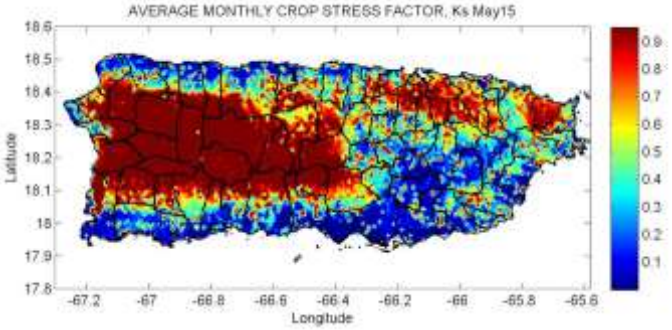
where:

K_y	a yield response factor [-]
$ET_{c\,adj}$	adjusted (actual) crop evapotranspiration [mm d^{-1}]
ET_c	crop evapotranspiration for standard conditions (no water stress) [mm d^{-1}]

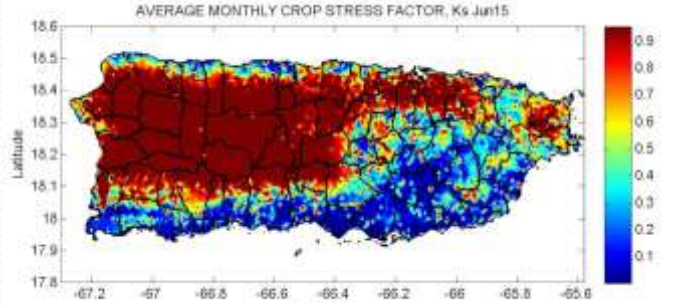
Water Stress Coefficient



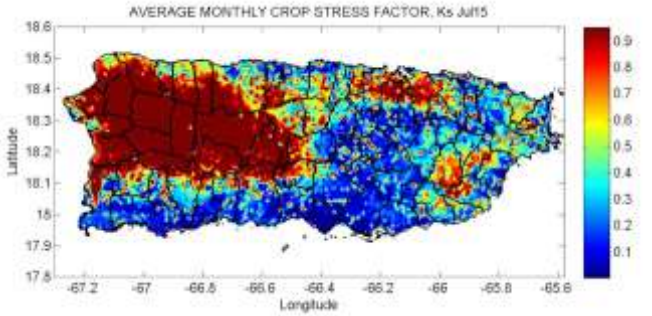
Apr



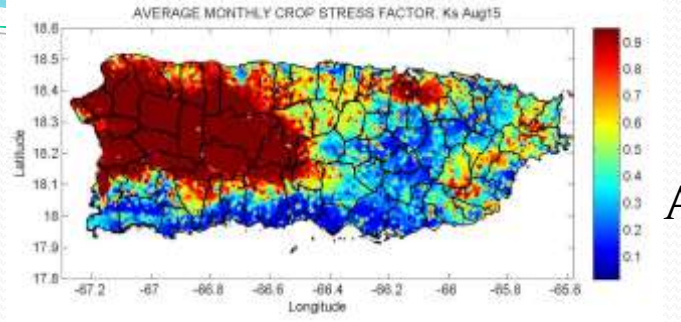
May



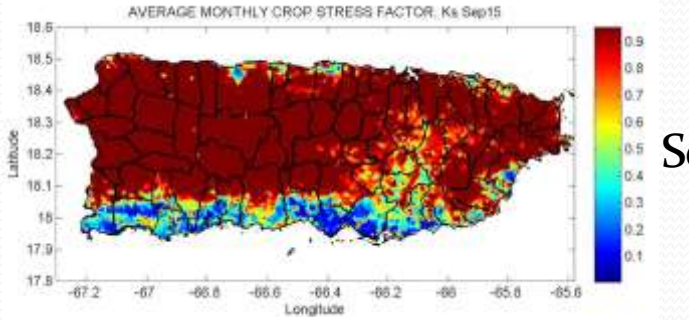
Jun



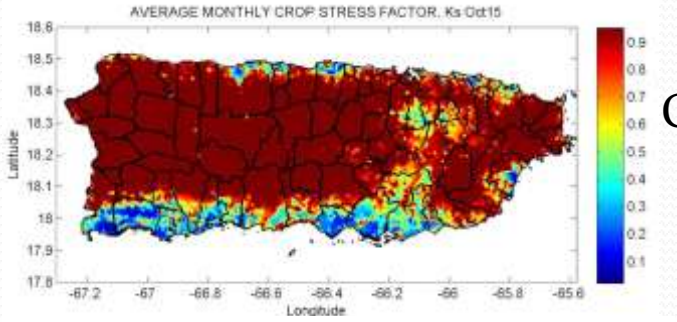
Jul



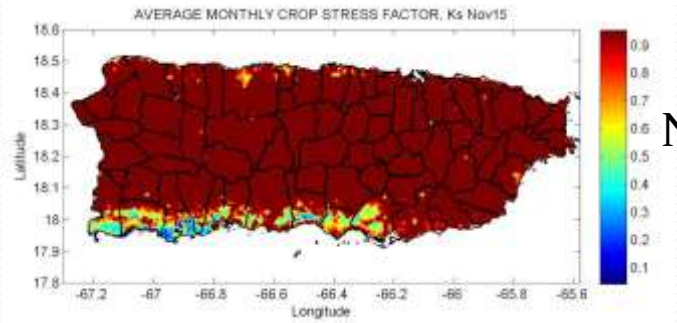
Aug



Sep



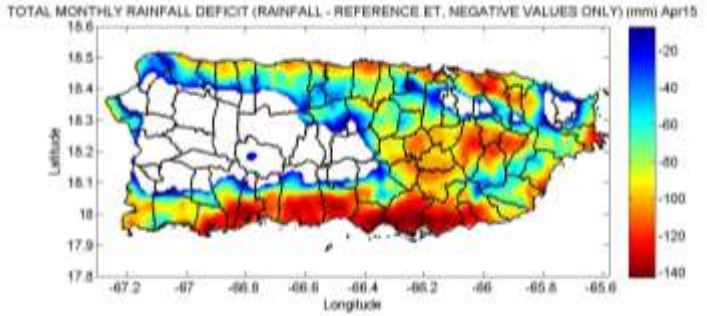
Oct



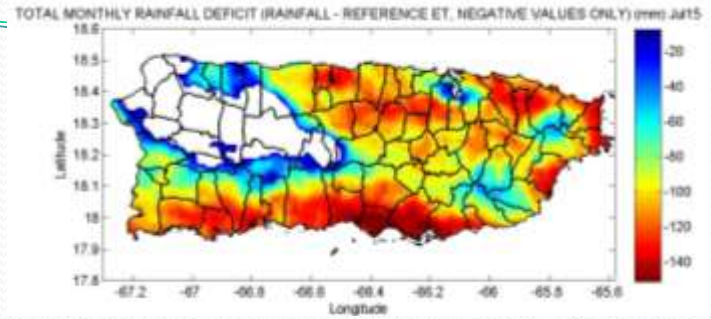
Nov

Rainfall Deficit (negative values only) (mm)

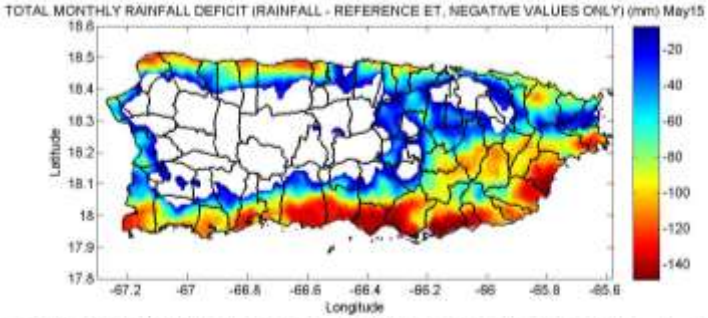
Rainfall – Reference Evapotranspiration



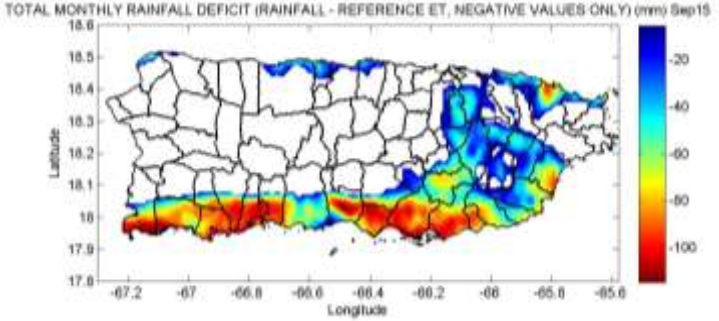
Apr



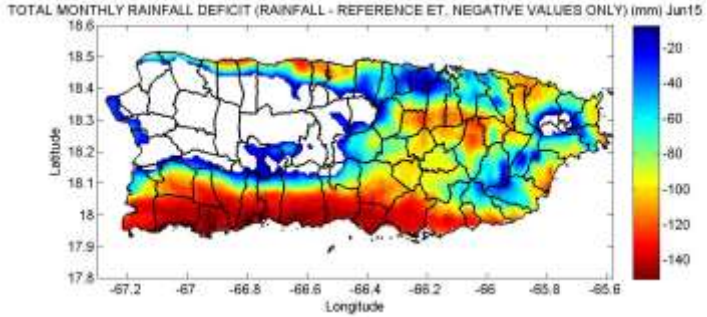
Aug



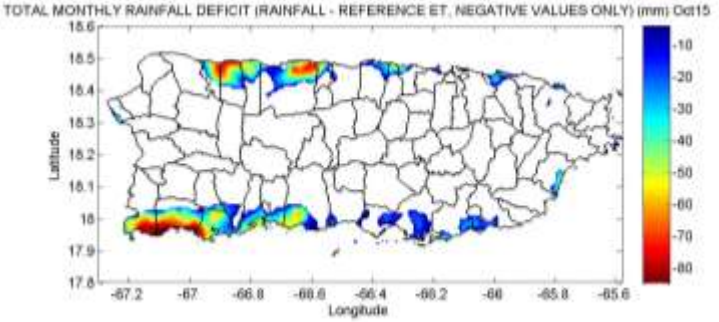
May



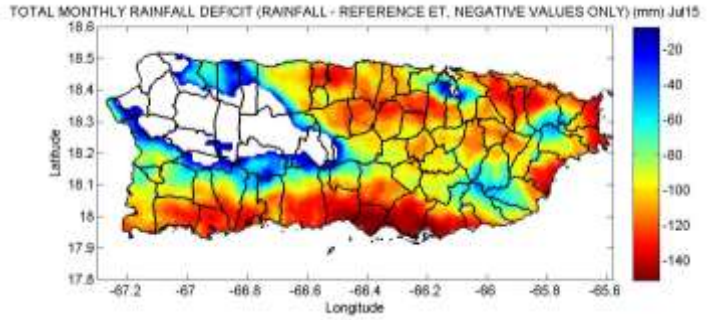
Sep



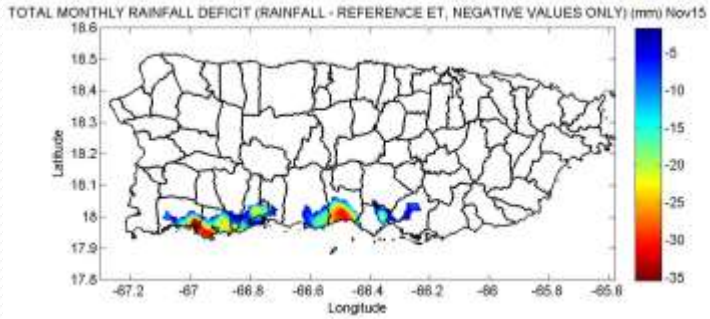
Jun



Oct

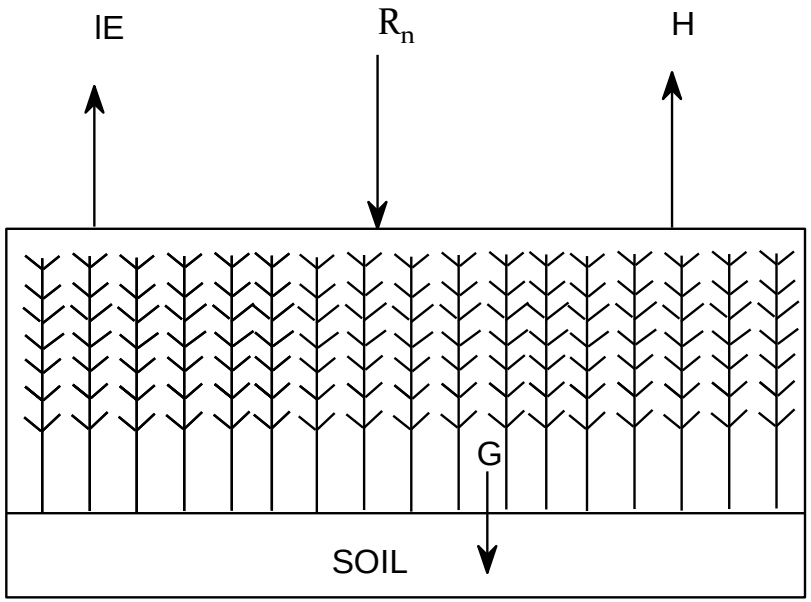


Jul



Nov

Canopy Energy Balance



$$R_n + lE + H + G + aA = o$$

R_n = Net radiation

lE = Latent heat flux

H = Sensible heat flux.

G = Soil heat flux

aA = energy utilized in photosynthetic activity.

Bowen Ratio

$$\beta = \frac{H}{LE}$$

$$= \gamma \left(\frac{T_s - T_a}{e_s - e_a} \right)$$

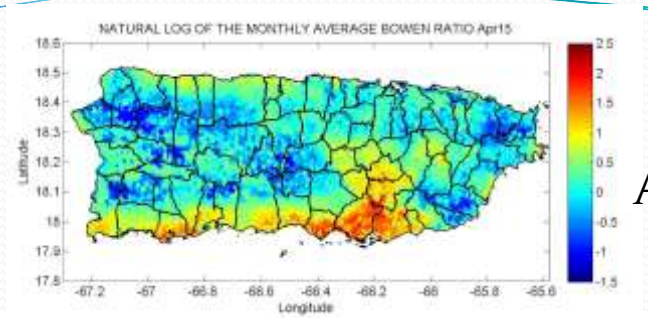
Where *H* and *LE* are the sensible and latent heat flux, respectively,

T_s and T are the water surface and air temperatures respectively, in degrees Celsius,

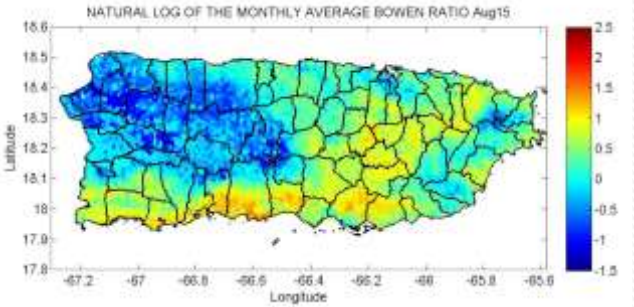
e_s and e_a are vapor pressures at the water surface and air, respectively, in kilopascals, and

γ is the psychometric constant, in kilopascals per degree Celsius.

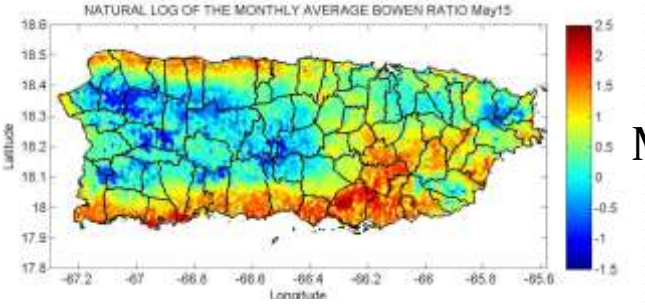
Log of the Bowen Ratio



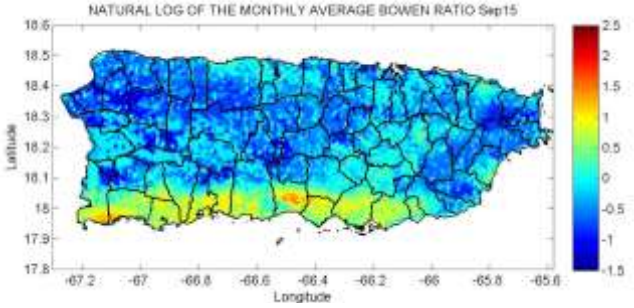
Apr



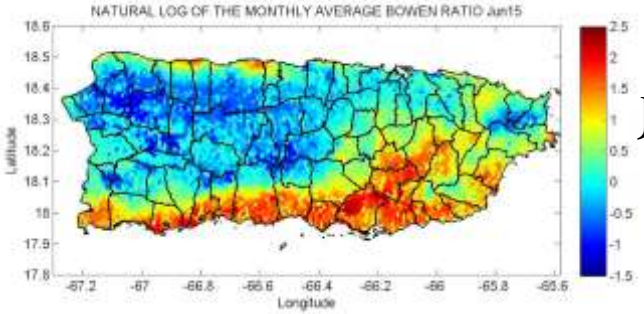
Aug



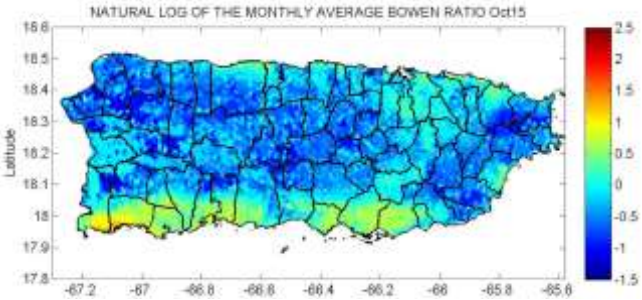
May



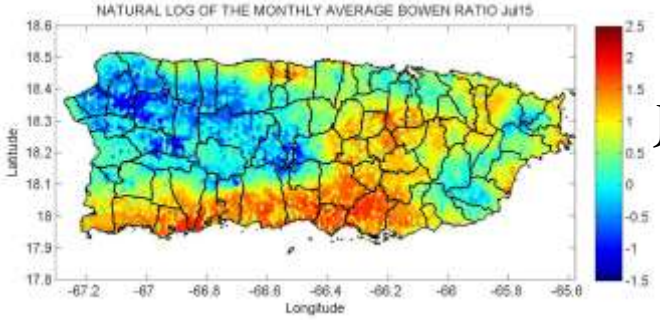
Sep



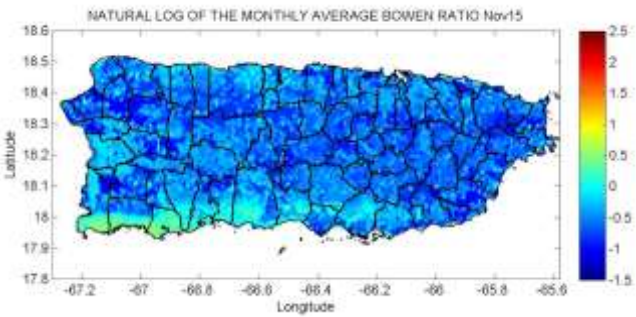
Jun



Oct

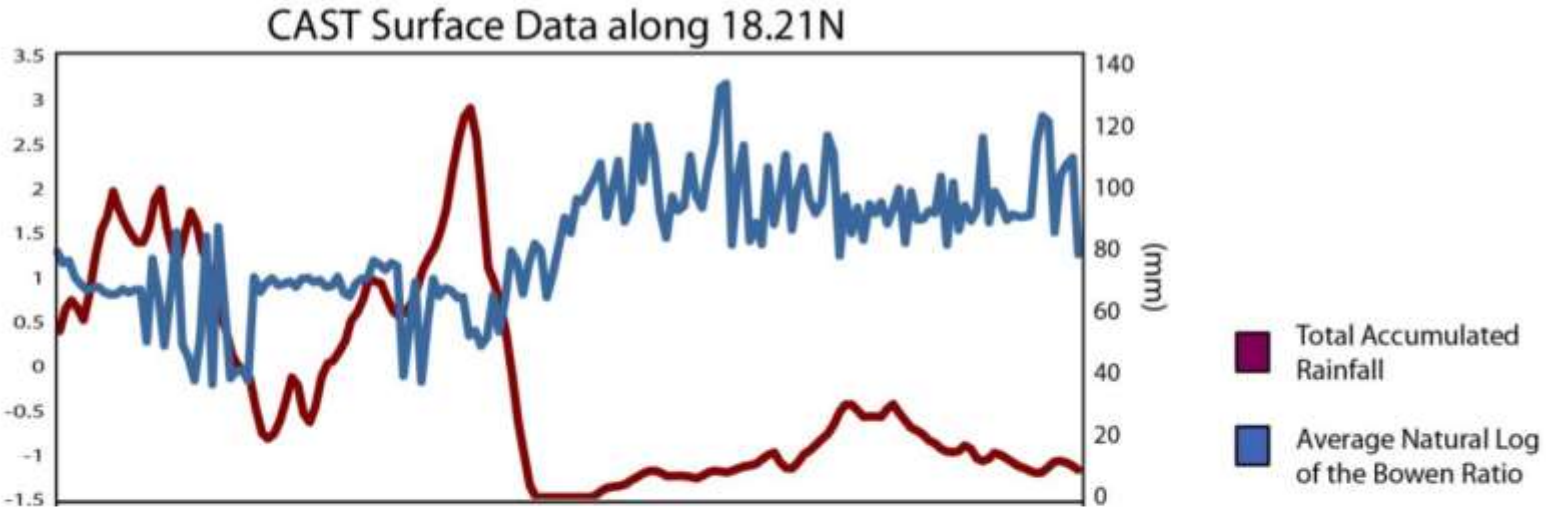


Jul



Nov

Natural Log of Bowen Ratio along Transect 18.21 N Latitude from Jun 20 to Jul 10, 2015



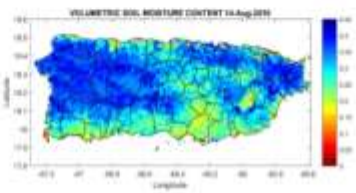
Local forecast by "City, St" or Zip
Code City, St
Go
XML RSS Feeds
Current Hazards
Local
Nationwide
Outlooks
Graphical HWO
Forecasts
Local Forecast Discussion
Activity Planner
Graphical
Tropical Weather
Fire Weather
Aviation Weather
Hydrology
Marine Weather
Beach Forecast PR
Beach Forecast USVI
En Español
Current Weather
Observations
Satellite Images
Rivers/Lakes
Regional Weather
Radar Imagery
Nationwide
Local

Climate & Drought Information

DISCLAIMER: Graphical display of observed rainfall is derived from a combination of USGS raingauge sensors and radar data retrieved by the Advanced Hydrologic Prediction Service (AHPS). Graphical display of Normal rainfall is derived from Puerto Rico 1981-2010 PRISM data. Please note, quality control is not performed on a daily basis.

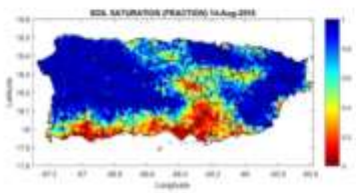
Click here to access the PR & USVI Daily Precipitation & Deficits from AHPS

Click to enlarge



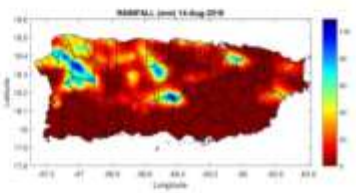
**PRAGWATER Soil Moisture

Click to enlarge



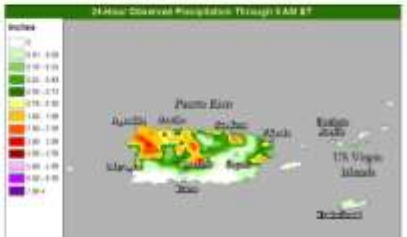
**PRAGWATER Soil Saturation

Click to enlarge

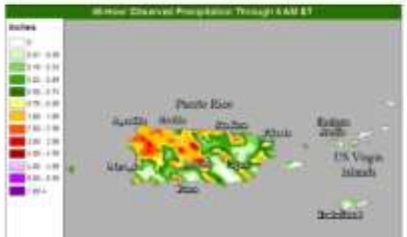


**PRAGWATER Yesterday Rainfall

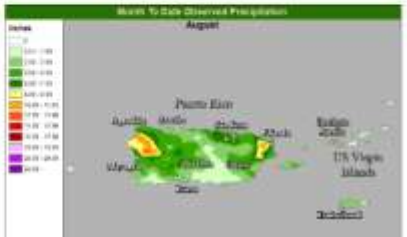
Click to enlarge



Click to enlarge



Click to enlarge



Rainfall in NW Puerto Rico

- Of practical interest is the fact that the northwest part of the island received more or less normal rainfall amounts in 2015.

- A preliminary evaluation of rainfall in this area, considering 17 drought years, revealed that the average rainfall during those years was only slightly less than non-drought years, suggesting that the northwest part of the island may be a potential source of water for the east when severe drought is experienced in the eastern side of the island.

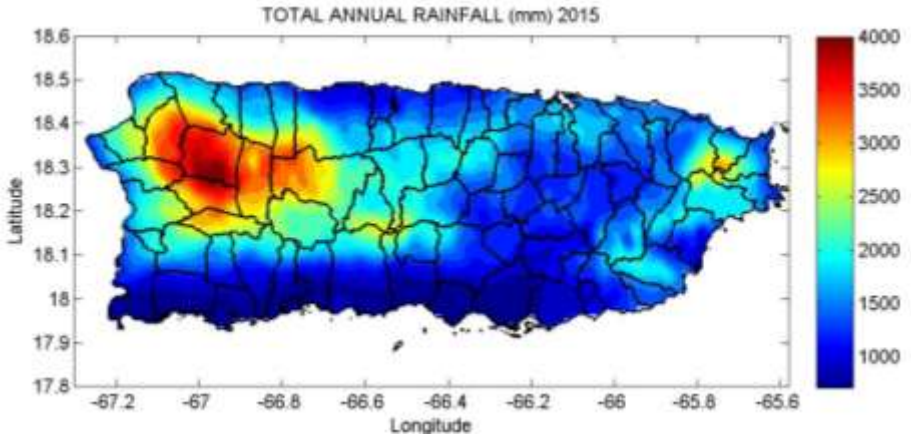
Comparisons of Rainfall in NW PR for drought and non-drought years

Weather Station	Avg. rain drought yrs.	Avg. rain non-drought yrs.
Coloso	72.88	77.48
Hacienda constanza	68.7	69.51
Maricao fish hatchery	81.92	98.62
Mayaguez city	62.31	67.44
Mayaguez airport	62.44	78.24
San sebastian 2 wnw	86.26	91.24

Compared average of:

17 Drought Years

94 Non-Drought Years



Conclusions

- The 2015 drought has shown us how vulnerable our water supply system is in Puerto Rico.
- Reservoirs were overdrawn and the irrigation districts were operating at a fraction of their production potential.
- In this presentation, selected soil and water-related parameters from GOES-PRWEB, used by the Scientific Drought Committee, were presented
- Historical Rainfall data for northwest PR indicated that additional water supplies could potentially be obtained from that area drought years.

ACKNOWLEDGEMENT

- Colegio de Ciencias Agrícolas, Universidad de Puerto Rico
- USDA Hatch Project (H-402)
- NOAA-CREST Project
- Thanks to Dr. Roberto Rivera and Ada Vilches for the rainfall analysis