CAST

CONVECTION, AEROSOL, AND SYNOPTIC-EFFECTS IN THE TROPICS
2015 CORP SCIENCE SYMPOSIUM

SEPTEMBER 17TH, 2015

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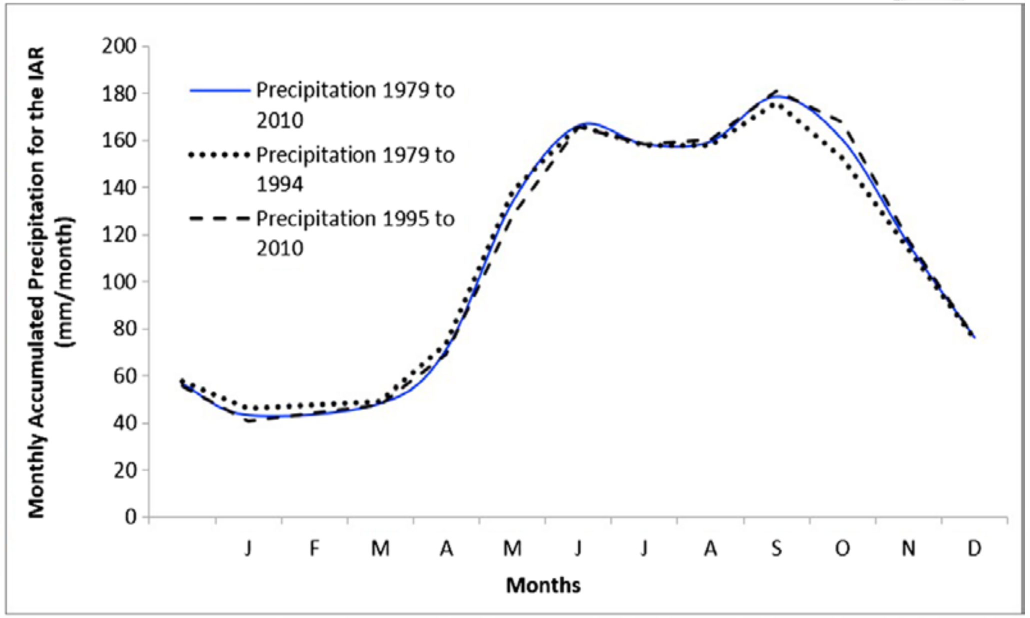
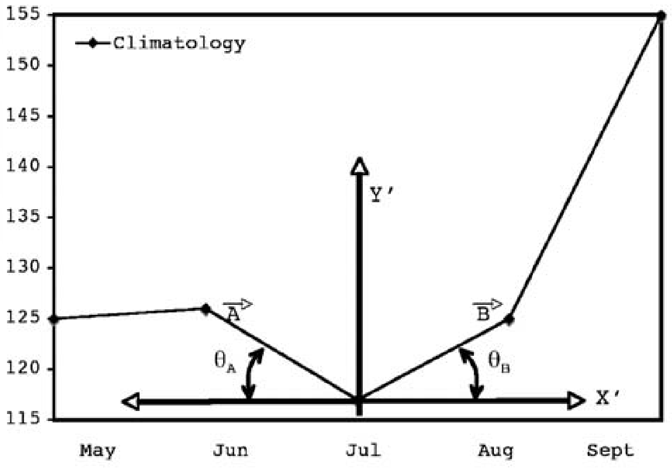
THE CARIBBEAN MID-SUMMER DROUGHT (MSD)

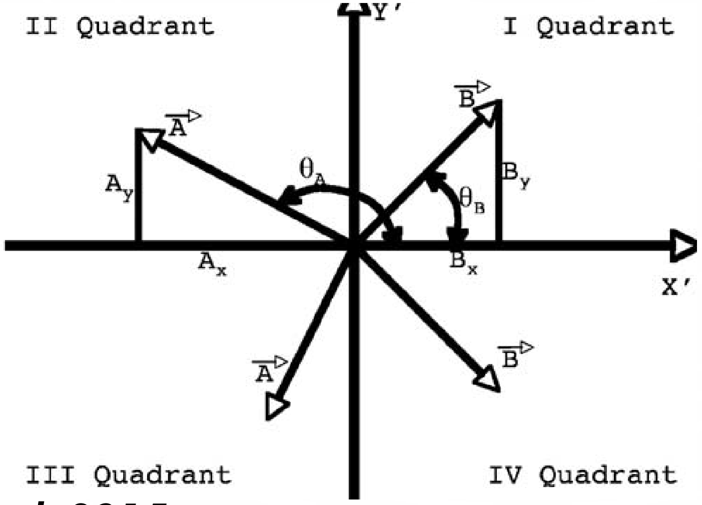
DURING JUNE-JULY, A REDUCTION IN PRECIPITATION OCCURS ACROSS THE CARIBBEAN (ANNUAL), THE FIGURE ILLUSTRATES THE 32 YEAR MONTHLY ACCUMULATED PRECIPITATION (1979–2010), THE MONTHLY ACCUMULATED PRECIPITATION FROM 1979–1994, AND THE MONTHLY ACCUMULATED PRECIPITATION FROM 1995–2010 GENERATED FROM GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (GPCP) MONTHLY PRECIPITATION DATA.



Glenn et al. 2015

THE INTENSITY OF THE MSD CAN BE DETERMINED VIA THE BIMODAL INDEX (BI):





Angeles et al. 2015

$$BI = BF\left|\frac{y}{y_{clim}}\right|$$

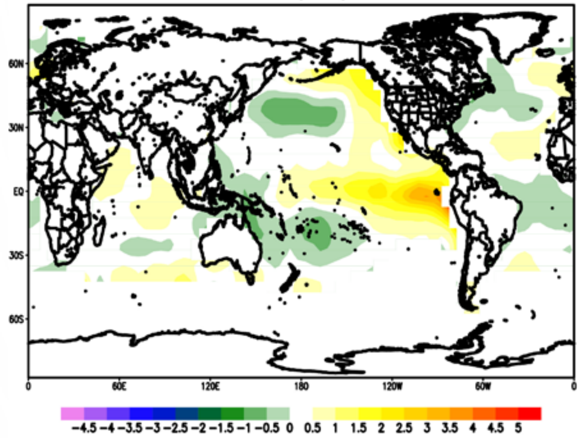
WHERE $BF = \begin{cases} 1\ if\ A\ is\ in\ II\ and\ B\ is\ in\ I, \\ -1\ if\ A\ is\ in\ III\ and\ B\ is\ in\ IV, \\ 0\ if\ \theta_A\ or\ \theta_B = 0 \end{cases}$

$y = A_y + B_y$, and $y_{clim} = A_{y_{clim}} + B_{y_{clim}}$

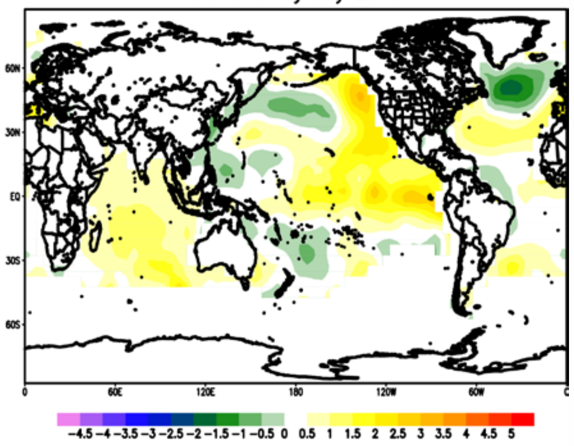
MSD (ENSO AND PRECIPITATION)

THE STRENGTH OF THE MSD IS STRONGLY CONNECTED TO THE EL NIÑO SOUTHERN OSCILLATION. DURING EL NIÑO PHASES, SEA SURFACE TEMPERATURE (SST) IN THE PACIFIC OCEAN IS WARMER THAN THE CLIMATOLOGICAL AVERAGE, INCREASING PRECIPITATION IN THE PACIFIC. IN THE ATLANTIC, SST IS COOLER THAN THE CLIMATOLOGICAL AVERAGE, TRADE WIND INTENSITY INCREASES ALONG WITH VERTICAL WIND SHEAR (VWS), AND RAINFALL AMOUNTS DIP. IN THE LA NIÑA PHASE, THE ATLANTIC IS WARMER AND THE PACIFIC IS COLDER.

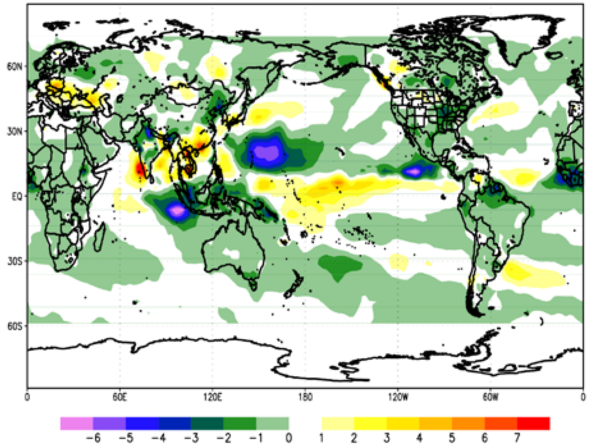
SST Anomaly July 1997



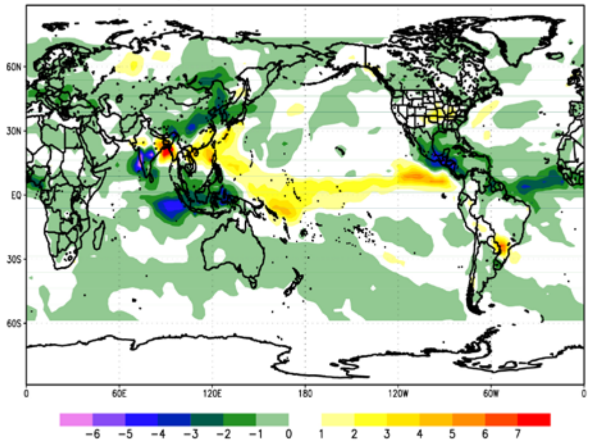
SST Anomaly July 2015



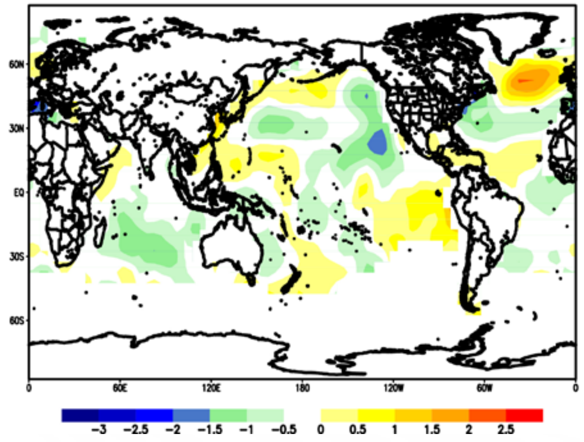
July 1997 Precipitation Anomalies



July 2015 Precipitation Anomalies

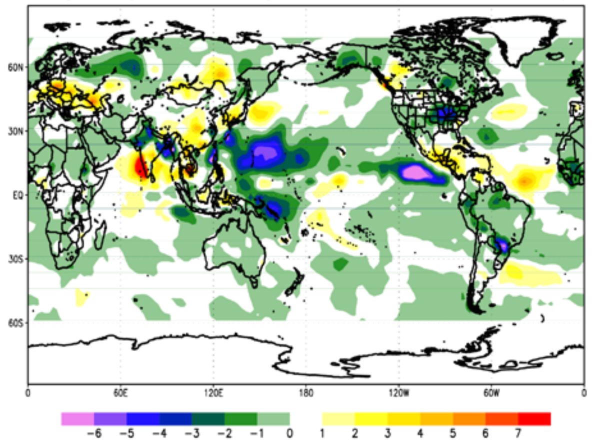


July SST Anomaly Difference (1997 minus 2015)



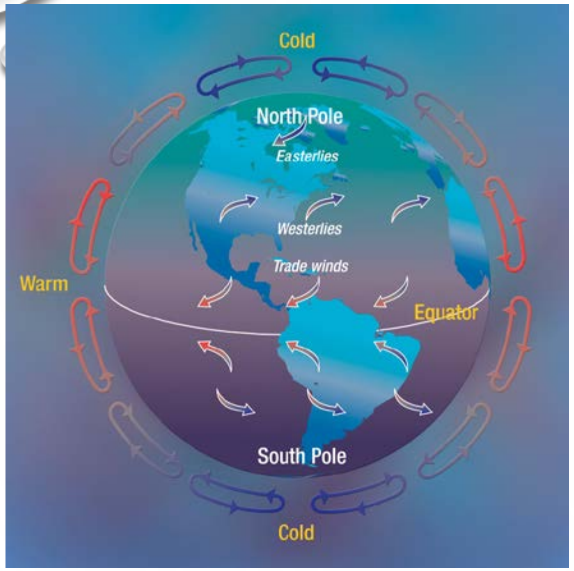
All plots are in °C.

July Precipitation Anomaly Differences (1997 minus 2015)



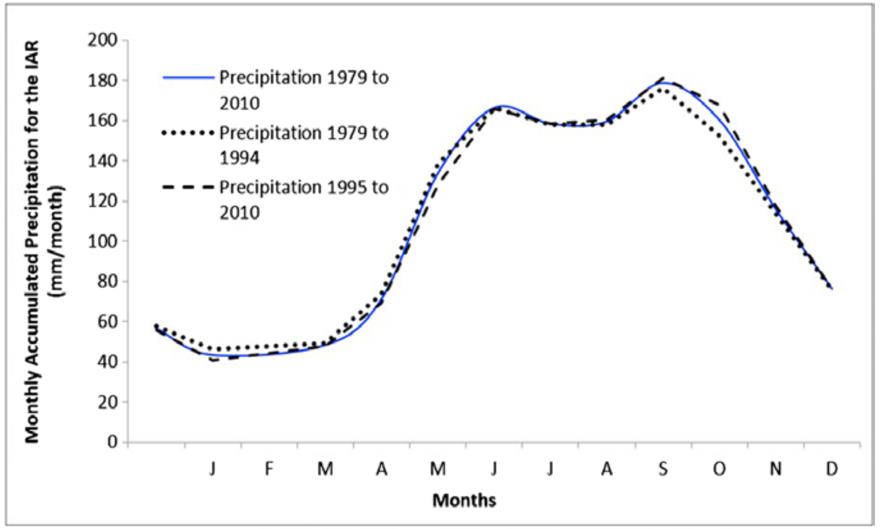
All plots are in mm day^{-1}.

MSD (SAHARAN DUST)

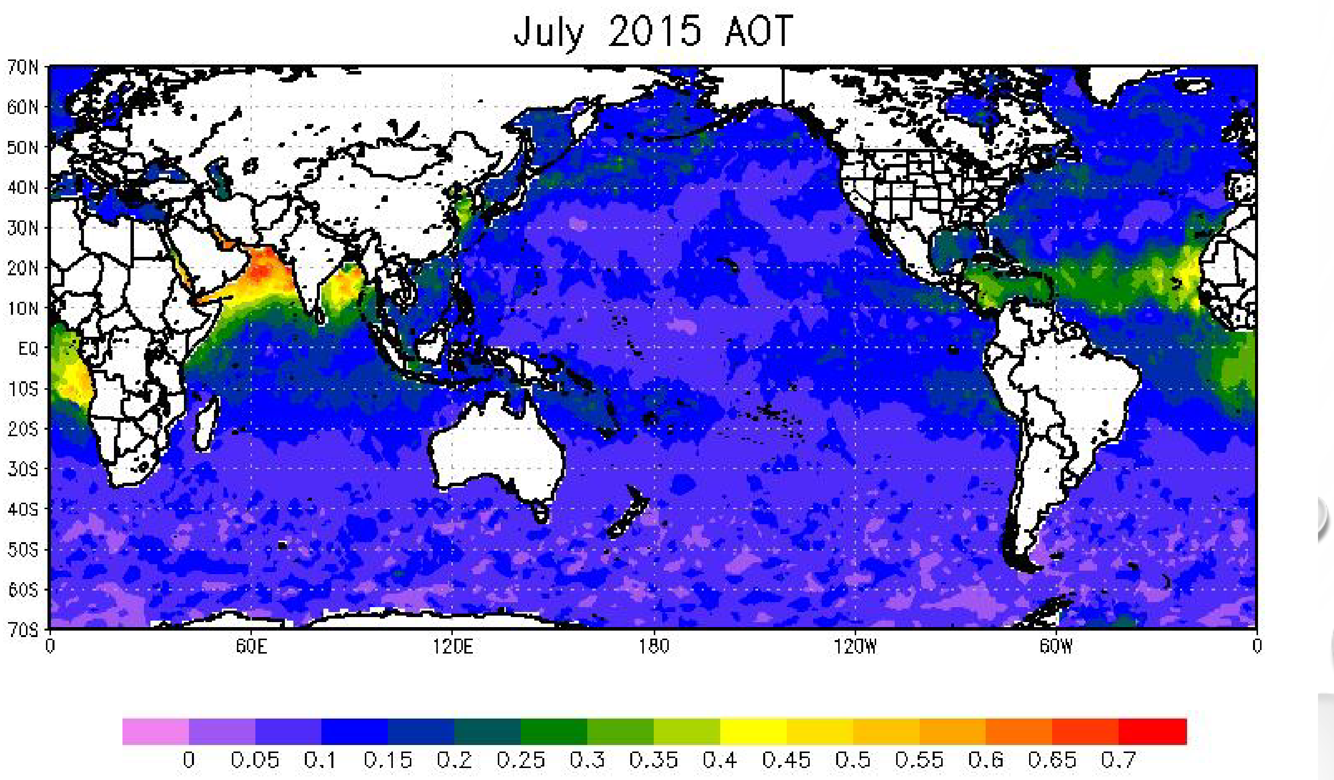


http://scied.ucar.edu/

THE TRADE WINDS FORCE SAHARAN DUST (SD) SOURCED FROM THE AFRICAN SAHEL WESTWARD. WITH STRONGER TRADE WINDS OVER THE ATLANTIC DURING EL NIÑO THAN IN OTHER PHASES, MORE SD IS LIKELY TO BE TRANSPORTED TO THE CARIBBEAN DURING THE MSD. AEROSOL OPTICAL THICKNESS (AOT), A PROXY FOR THE INTENSITY OF AEROSOL IS HIGH IN THE TROPICAL BAND DURING JULY, WHICH CAN BE SEEN BY POES SATELLITE DATA.



Glenn et al. 2015

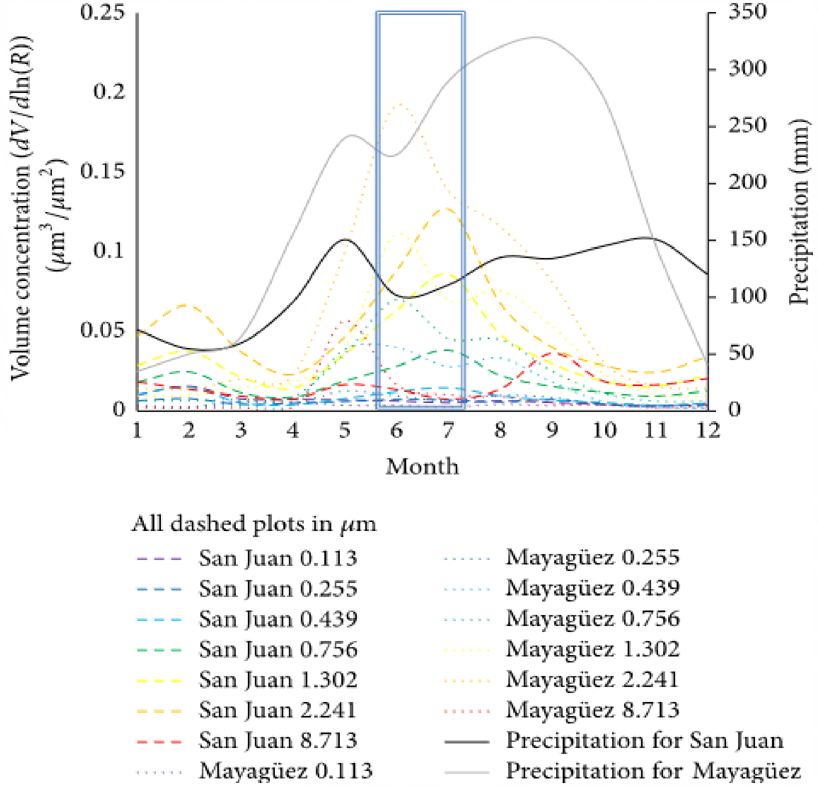


MSD (PUERTO RICO)

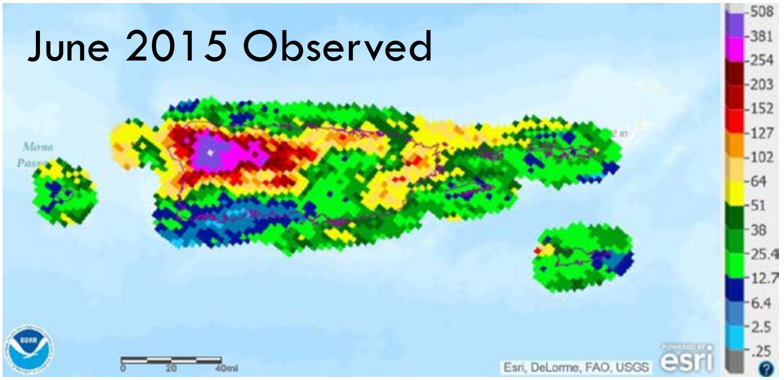
WHEN WE LOOK AT THE MSD FOR PUERTO RICO, WE NOTE A CLIMATOLOGICAL PRECIPITATION MINIMUM IN JUNE FOR BOTH SAN JUAN AND MAYAGUEZ. THIS REDUCTION CORRELATES TO A PEAK IN AEROSOL VOLUME CONCENTRATION (AERONET) ATTRIBUTED TO SD.

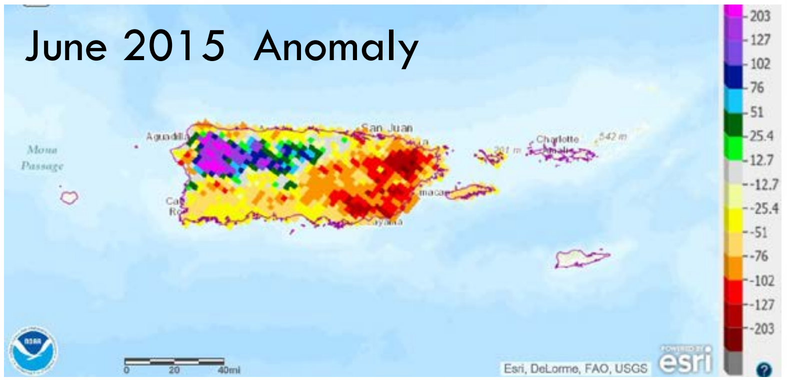
BY THE DEFINITION OF THE BI, PUERTO RICO HAS A NEGATIVE ONE SINCE JULY PRODUCES HIGHER PRECIPITATION THAN JUNE. HOWEVER, THE 2015 MSD HAS BEEN DRIER THAN NORMAL, AND RAINFALL IN JULY HAS DECREASED IN DRAMATIC FASHION. THIS HAS FORCED THE BI POSITIVE.

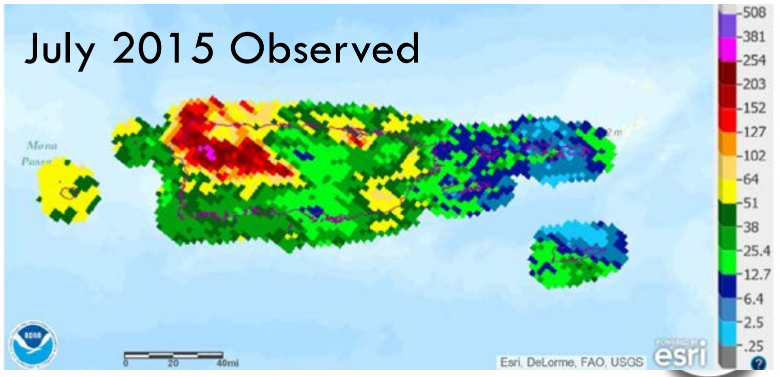
DROUGHT INGREDIENTS: HIGH PRESSURE OVER PUERTO RICO, LOWER AVAILABLE PRECIPITABLE WATER, LOWER SST, HIGHER CONCENTRATIONS OF SAHARAN DUST (SD).

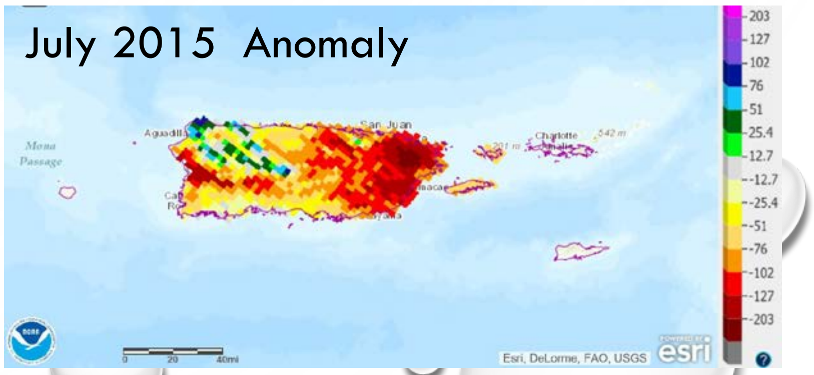


Hosannah et al. 2015

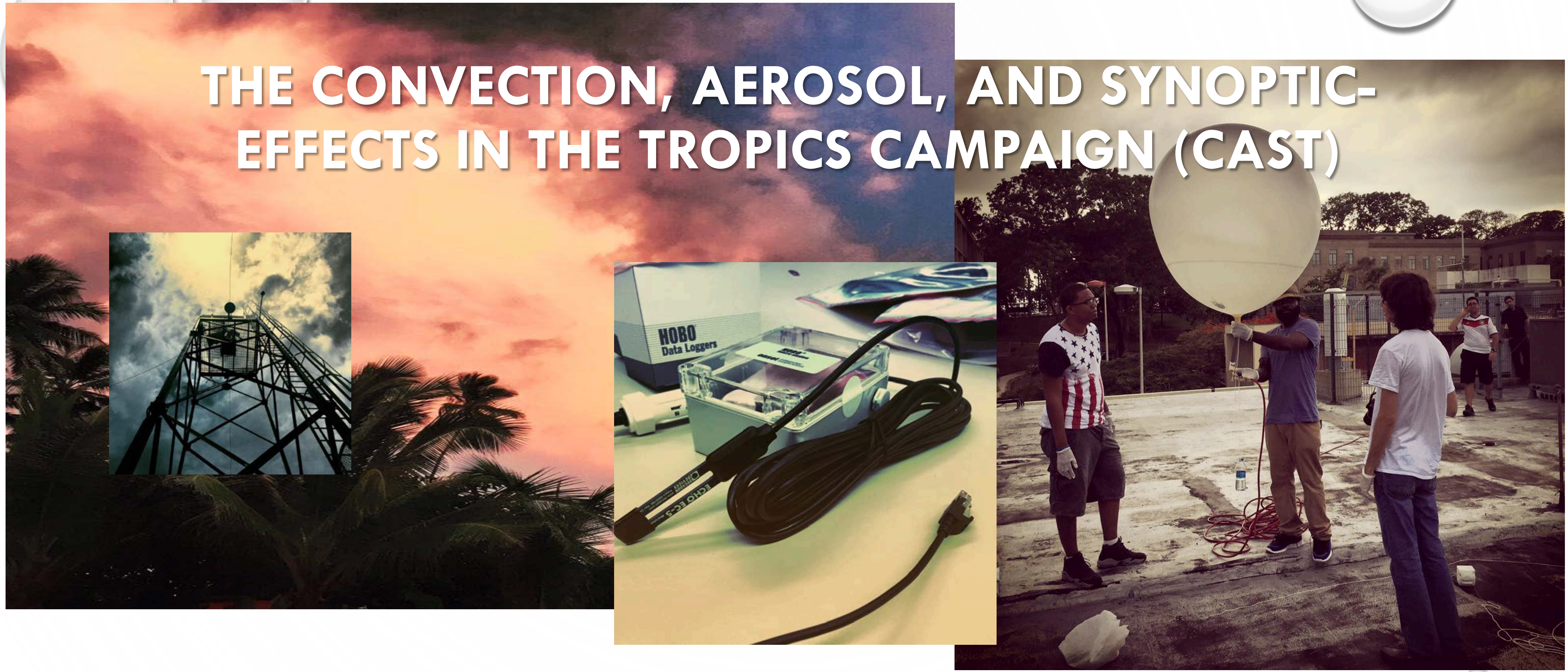








THE CONVECTION, AEROSOL, AND SYNOPTIC-EFFECTS IN THE TROPICS CAMPAIGN (CAST)



CAST IS AN ATMOSPHERIC DATA CAMPAIGN BASED AT THE UNIVERSITY OF PUERTO RICO (UPRM) FROM 22 JUNE - 10 JULY 2015 WHICH INCLUDED MEASUREMENTS FROM A VARIETY OF SENSORS, INCLUDING A THREE-CHANNEL LIDAR SYSTEM, A CEILOMETER, MULTIPLE SUNPHOTOMETERS IN THE AERONET, SOIL MOISTURE UNITS, RADIOSONDES, A DISDROMETER, WEATHER STATIONS, SATELLITES, NEXRAD, AND RADAR.

CAST SCIENCE QUESTIONS

HOW DOES/DO SURFACE HEAT BALANCE/PROCESSES INFLUENCE CONVECTION LEVELS?

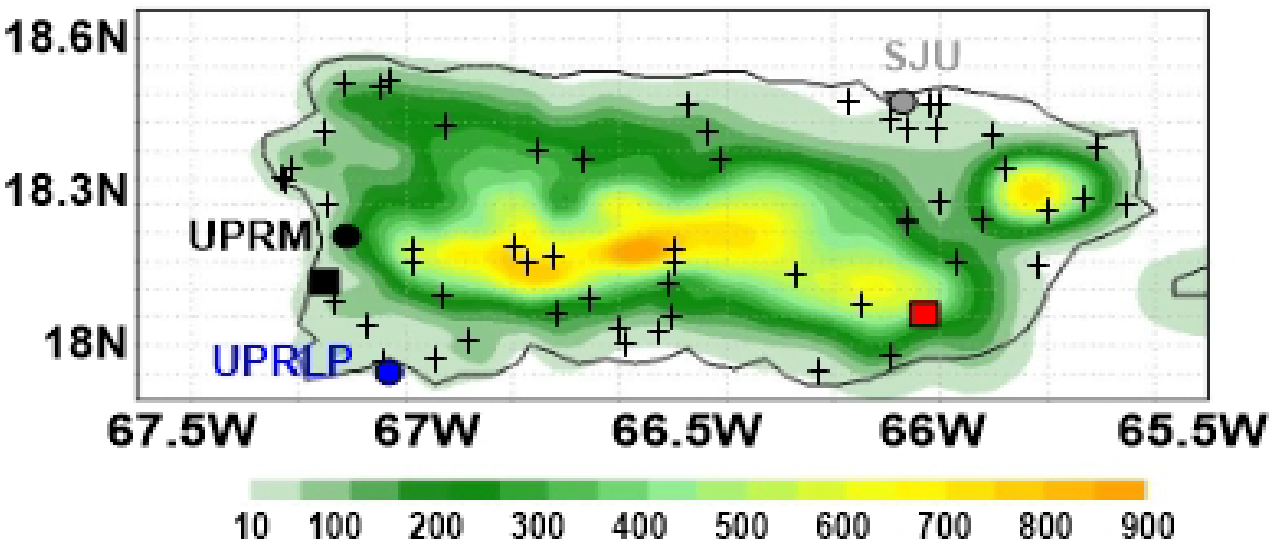
HOW DO GENERAL CIRCULATION AND SYNOPTIC PROCESSES (I.E. TRADE WINDS, SD, VWS, ENSO, EL NIÑO) INTERACT WITH LOCAL COASTAL PROCESSES TO ENHANCE / SUPPRESS CONVECTION / PRECIPITATION?

HOW DO AEROSOLS INFLUENCE WARM SURFACE CONVECTIVE PROCESSES IN COASTAL/WARM ENVIRONMENTS (ENERGY PROCESSES/PRECIPITATION)?

WHAT IS THE IMPACT OF AEROSOL CHEMISTRY ON PRECIPITATION?

CAST SENSORS AND DATA AVAILABILITY

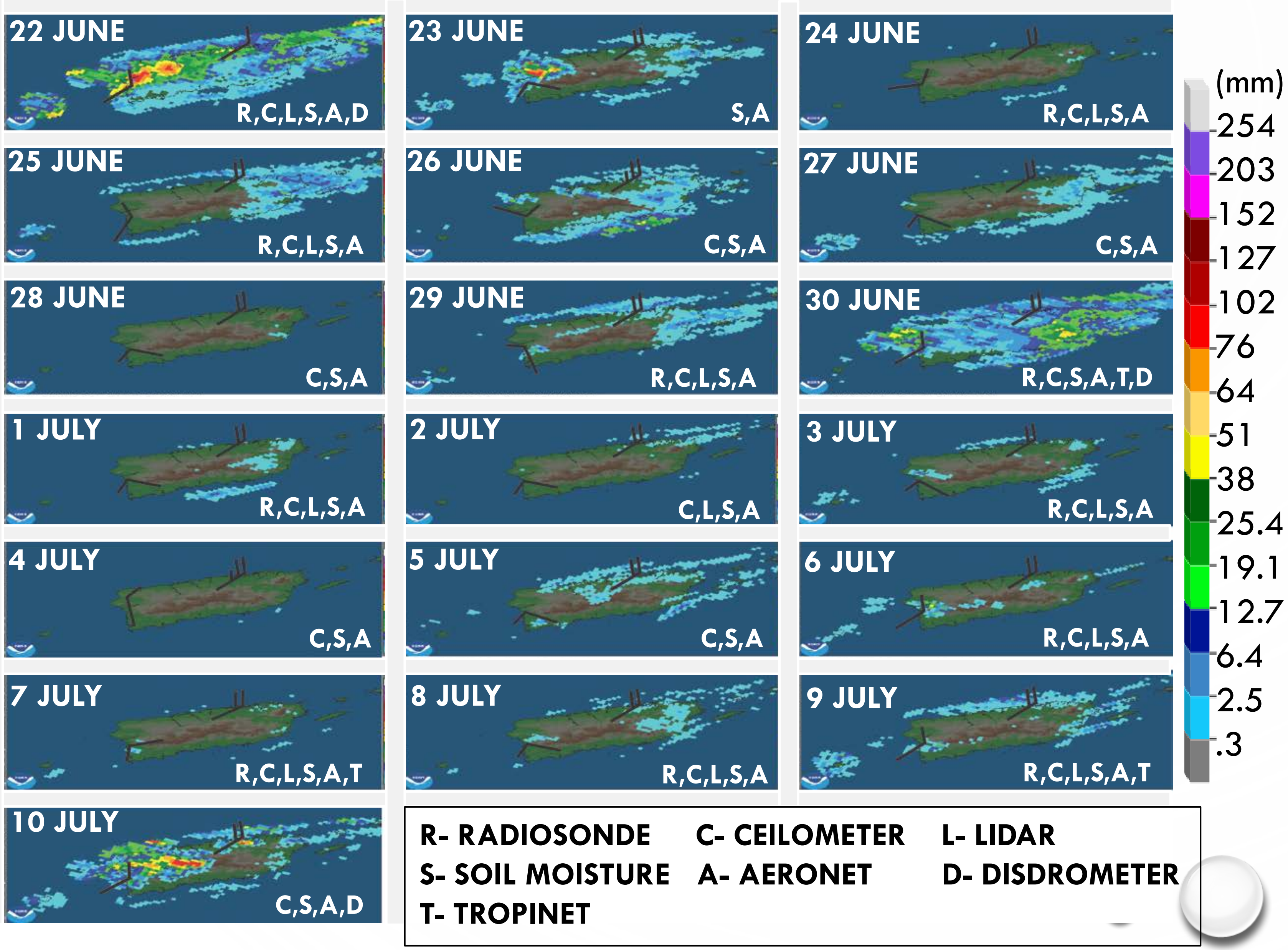
Puerto Rico Sensor Sites over Topography (m)



WORKING INSTRUMENT SITES IN PUERTO RICO. "+" DENOTES GLOBAL HISTORICAL CLIMATE NETWORK (GHCN) WEATHER STATIONS, SQUARES DEPICT RADAR SITES- RED FOR NWS NEXRAD, AND BLACK FOR THE CABO ROJO TROPINET SITE.

INSTRUMENT/SENSOR
LIDAR (UPRM)
CEILOMETER (UPRM)
RADIOSONDE (UPRM)
AERONET (UPRM, UPRLP, SAN JUAN, GUADELOUPE)
TROPINET (CABO ROJO, LAJAS, AGUADILLA)
PARTICLE SAMPLER (UPRLP)
SOIL MOISTURE SENSORS (UPRM AND NEARBY)
DISDROMETER (UPRM)

CAST AT A GLANCE



DURING THE CAMPAIGN, FOUR SUBSTANTIAL RAIN EVENTS OCCURRED (22 JUNE 2015, 23 JUNE 2015, 30 JUNE 2015, AND 10 JULY 2015.

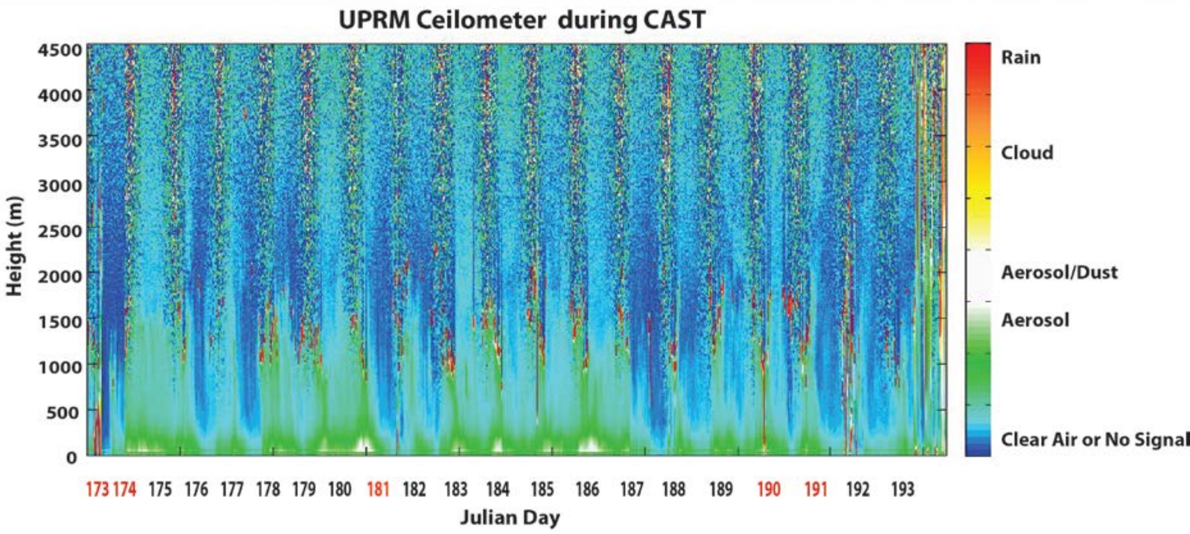
ALL EXCEPT 23 JUNE WERE DUE TO THE PASSAGE OF EASTERLY WAVES.

OTHER RAIN EVENTS INVOLVED LIGHT DRIZZLE, RESULTING IN LITTLE RAINFALL.

SOME EVIDENCE OF RAIN DUE TO CONVERGENCE BETWEEN THE TRADES AND THE WESTERLY SEABREEZE, IN ADDITION TO OROGRAPHIC LIFTING.

CAST SENSORS (LIDAR, CEILOMETER, AND AERONET)

AT 910 NM, THE CEILOMETER IS ABLE TO CAPTURE SD EVENTS, WHILE LIDAR CAN SEPARATE THE SIGNAL. 532 NM IS MOST RESPONSIVE, WITH AN INTENSE SIGNAL TO THE 4 KM LEVEL. HIGHEST INTENSITIES ARE SHOWN BELOW 2 KM, IN PART BECAUSE THE CLOUD BLOCKS THE SIGNAL. CLOUD LEVELS RANGED FROM 1 - 3 KM DURING CAST. AERONET AOT SUPPORTS LIDAR DATA THAT SHOWS 6/30, 07/01, 7/06, and 7/10 HAD THE LOWEST SD CONCENTRATIONS. THEIR DAY AVERAGED AOTS WERE 0.10, 0.09, 0.16, AND 0.14 RESPECTIVELY. AOT OVER 0.5 IS CONSIDERED A HEAVY SD DAY.



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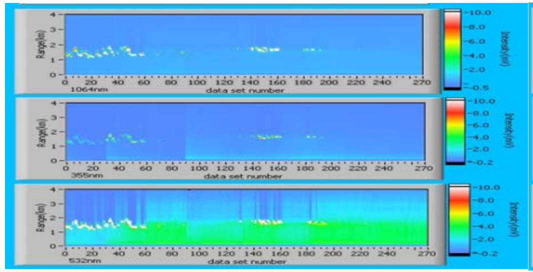

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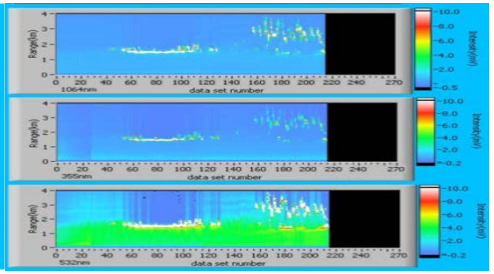

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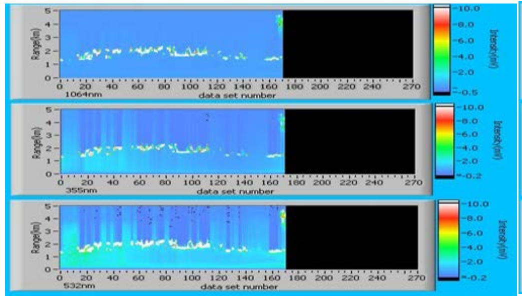

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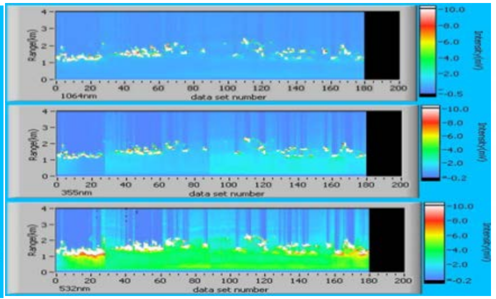
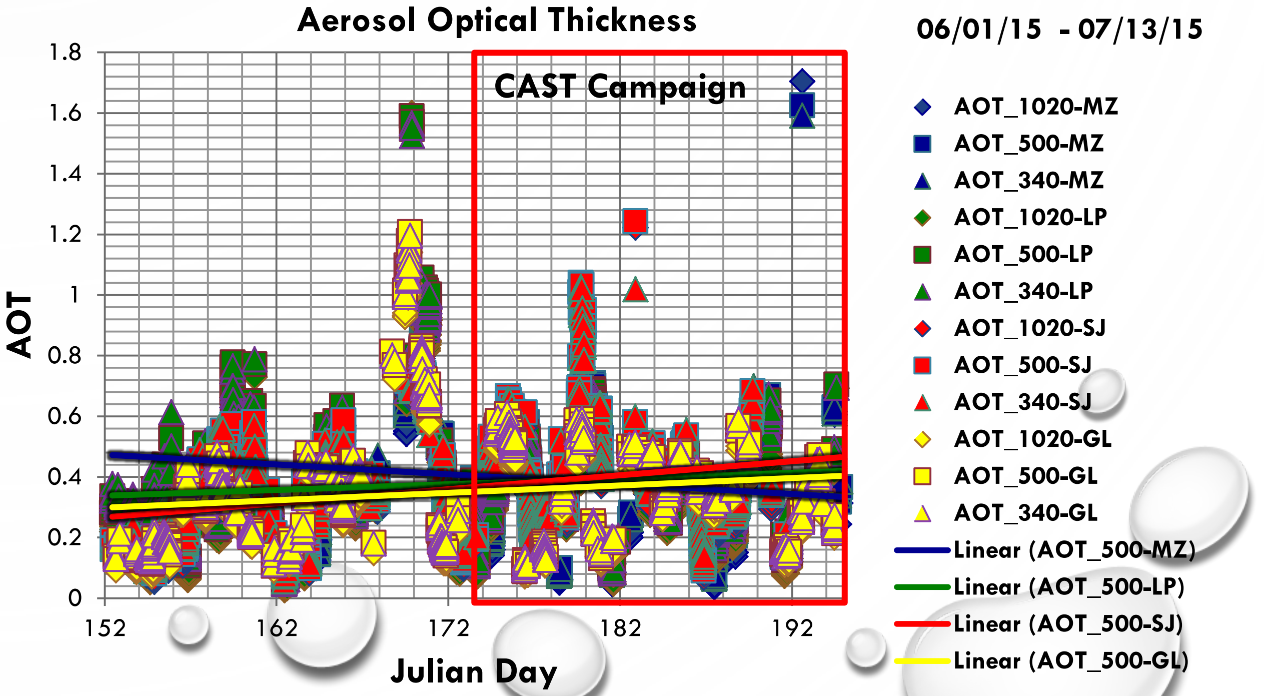
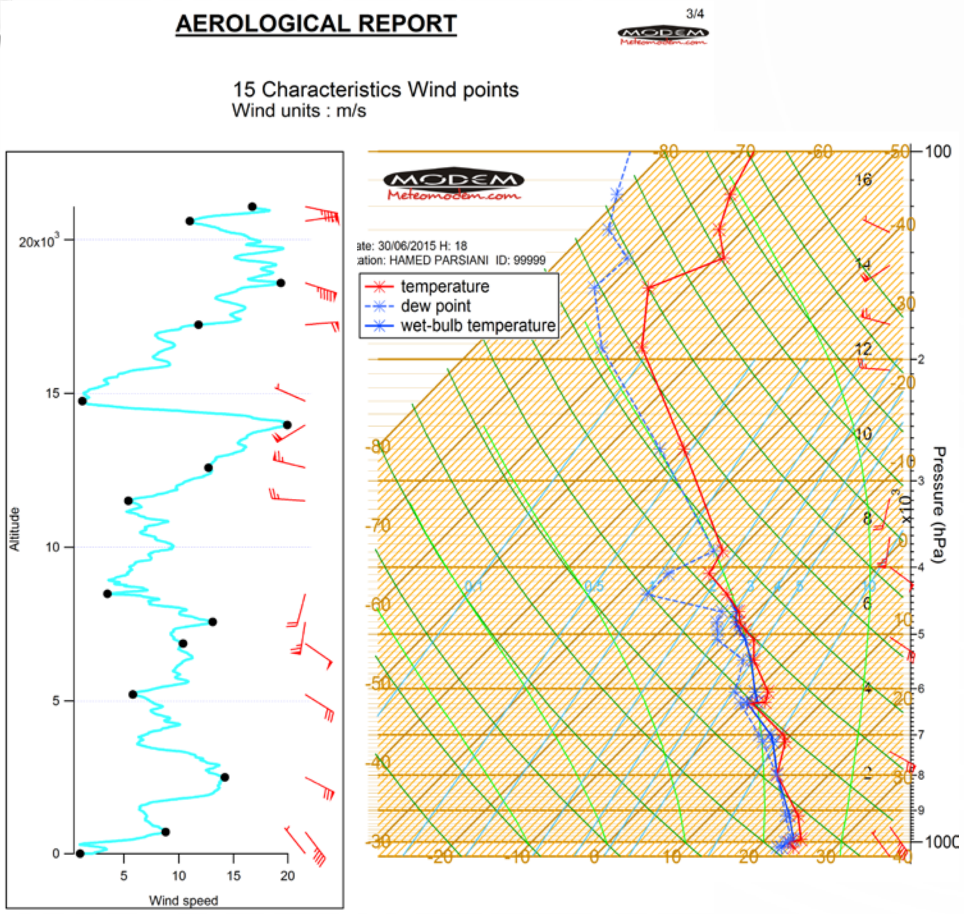




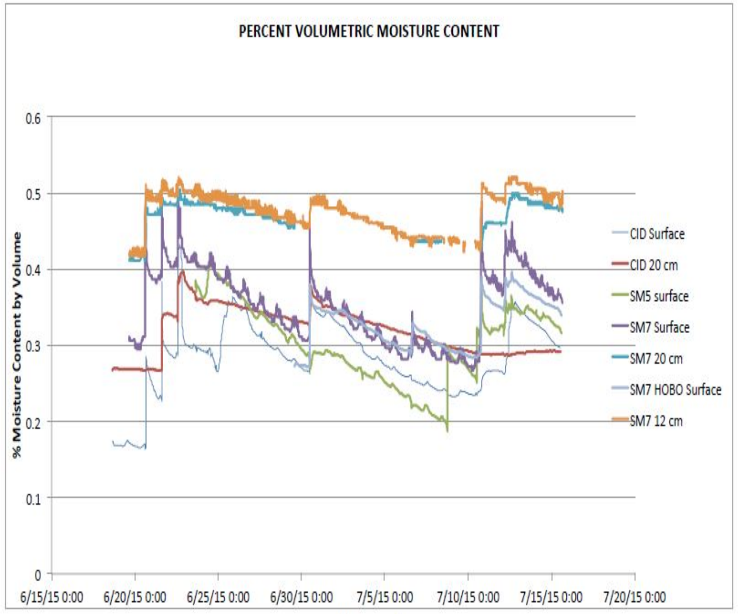
CAST SENSORS (RADIOSONDES)

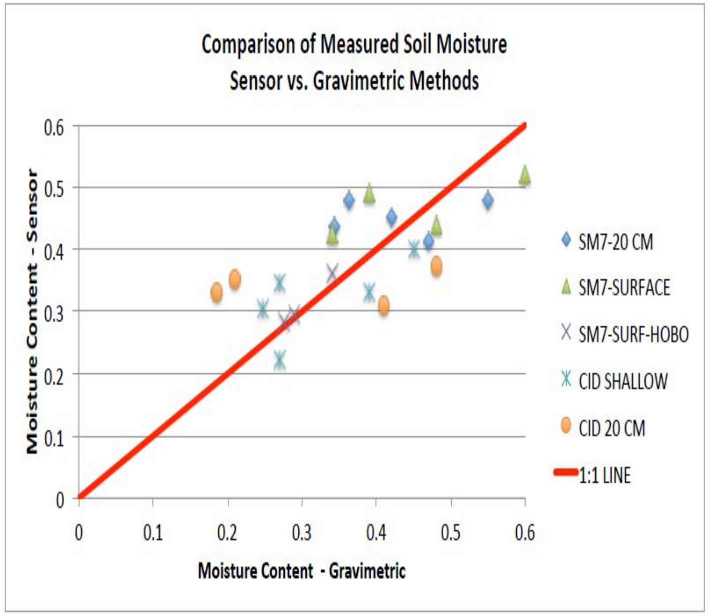


UPRM SKEW-T PLOTS WERE GENERATED FROM RADIOSONDE DATA FOR ALL LAUNCH DATES EXCEPT 6/22. SURFACE WINDS DURING AFTERNOON LAUNCHES WERE NOT ALWAYS WESTERLY. THE PATH OF TROPICAL WAVES LED TO A WIDE RANGE OF WEST COAST WIND DIRECTIONS, INCLUDING NORTHERLY AND SOUTHEASTERLY FLOWS.

Date	Launch Time (AST)	Temperature Inversion Points (km)	Temperature Inversion Characteristic	Wind Inversion Point (km)	VWS (s^{-1})	CAPE ($kJ\ kg^{-1}$)
6/22/15	1247	----	----	6	----	----
6/24/15	1319	1.9, 4.3	Constant	7	0.60	1.76
6/25/15	1253	2, 4.5	Increase	8	-0.87	1.48
6/29/15	1522	2.1, 3.9	Increase	8	-0.20	1.58
6/30/15	1238	2, 3.8	Slight Increase	7	-0.31	2.28
7/1/15	1213	2.2	Constant	6	-0.24	1.91
7/3/15	0931	1, 4	Constant	5	3.40	1.50
7/6/15	1223	1, 4.2	Constant	8	-0.03	1.85
7/7/15	1348	2, 4.7	Slight Increase	6	2.08	1.36
7/8/15	1204	2.8	Increase	7	2.34	1.85
7/9/15 (1)	1208	2, 4.5	Increase	6	0.51	2.10
7/9/15 (2)	1502	2.1	Slight Increase	5	0.77	2.68

CAST (SOIL MOISTURE)





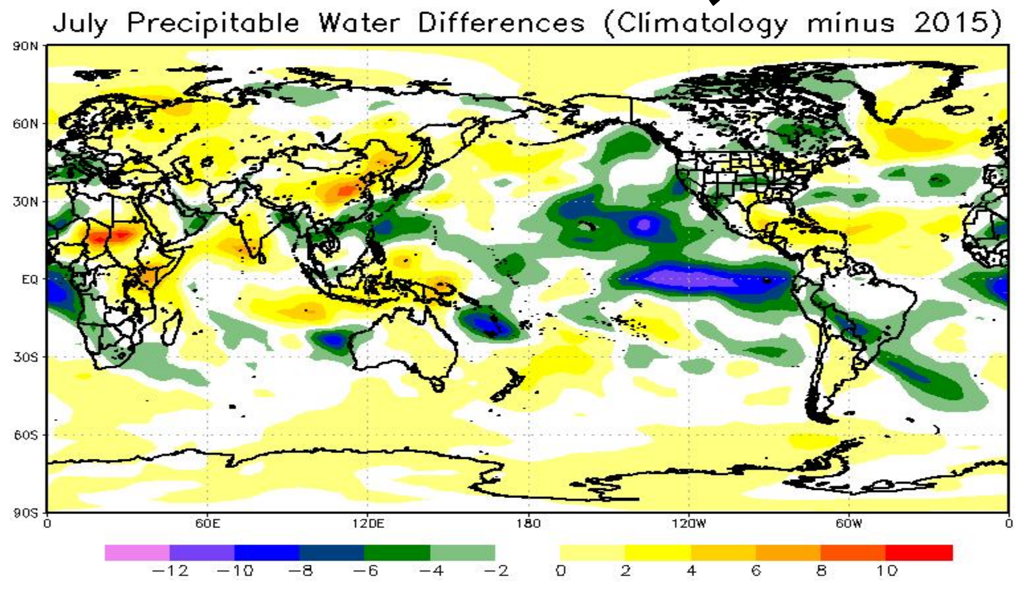
WE PLACED MULTIPLE SOIL MOISTURE SENSORS AT THE SURFACE AND 20 CM DEEP AT THREE DIFFERENT LOCATIONS ALONG THE 18.21 LATITUDE.

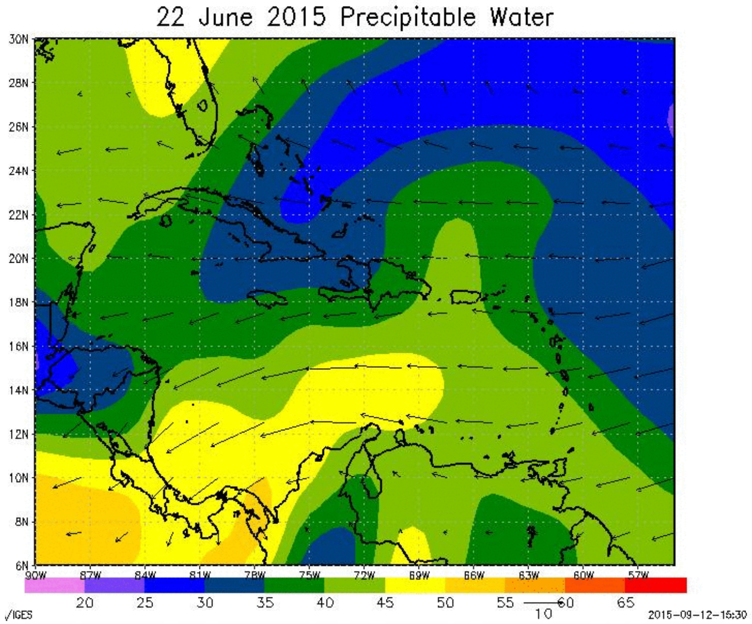
MEASUREMENTS TAKEN DURING CAST SHOW THAT MOISTURE CONTENT INCREASES WITH INCREASING DISTANCE INLAND FROM THE WEST COAST. ALL SENSORS CAPTURE THE RAIN EVENTS, GRADUALLY DECREASING IN WATER CONTENT OVER THE DRY PERIOD.

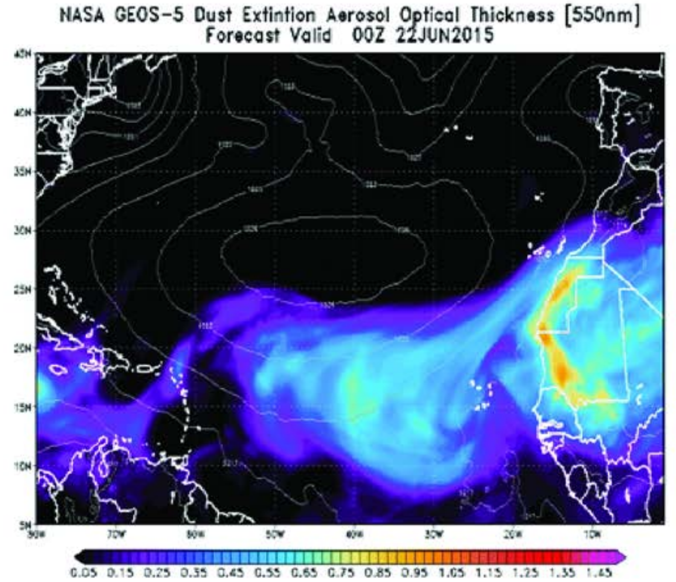
A COMPARISON BETWEEN MEASURED SOIL MOISTURE FROM THE SENSORS AND GRAMETRIC METHODS SHOW GOOD AGREEMENT BETWEEN THEM.

SATURATED SOIL ENHANCES MOIST CONVECTION.

THE BIG (AND LOCAL) PICTURE







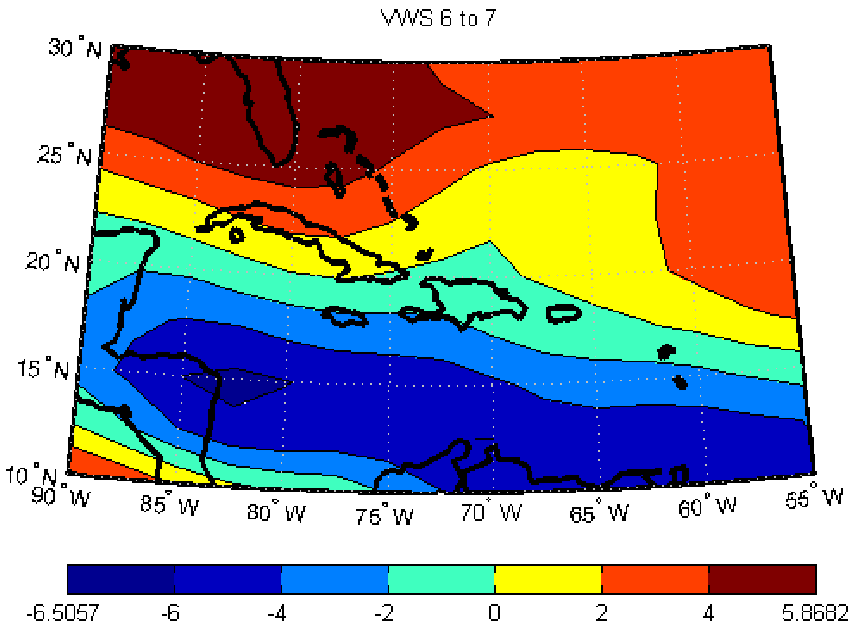
PRECIPITABLE WATER IN THE TROPICAL ATLANTIC WAS 4-6 KG M^{-2} LOWER THAN THE CLIMATOLOGICAL AVERAGE FOR BOTH JUNE (NOT SHOWN) AND JULY OF 2015.

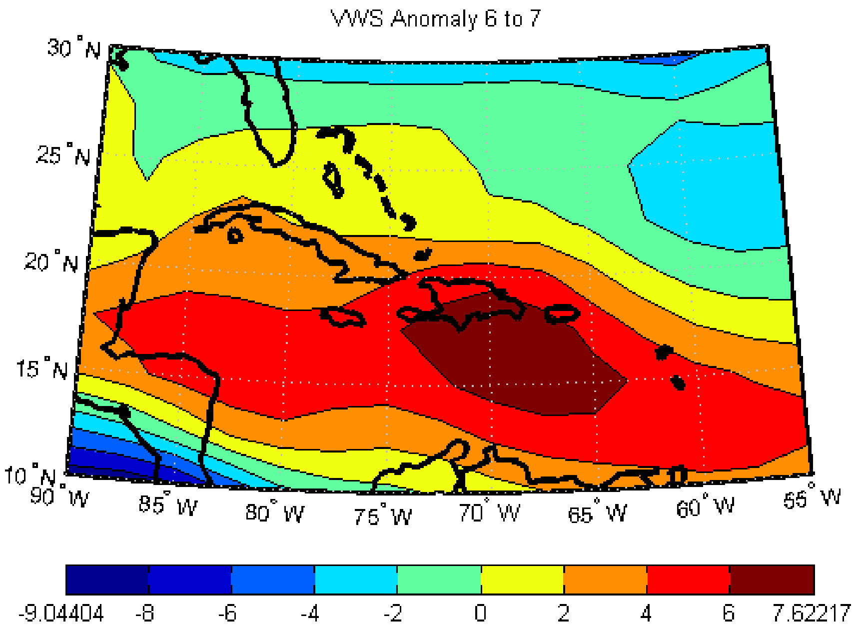
IN THE PRESENCE OF HIGH SD (AOT > 0.5), RAIN IS SUPPRESED. MEAN PRECIPITABLE WATER IN THE COLUMN REACHED UPWARDS OF 40 KG M^{-2} FOR 26-27 JUNE AND 3 JULY, AND PRODUCED TRACE RAINFALL AMOUNTS.

IN THE CASE OF AOT < 0.2, (22, 23, AND 30 JUNE AND 10 JULY) THE MEAN PRECIPITABLE WATER WAS 35-45 KG M^{-2}, WITH HEAVY PRECIPITATION. THIS RAIN WAS DUE THE PASSING OF EASTERLY WAVES.

WITH STRONG CONVECTION (CAPE > 1.85 KJ KG^{-2}), DUE TO TRADE/SEABREEZE CONVERGENCE, MODERATE SD (AOT~0.3), AND MEAN PRECIPITABLE WATER OF > 30 KG M^{-2} LOCAL ISOLATED STORMS ARE ABLE TO DEVELOP NEAR THE WEST COAST OF PUERTO RICO (6 JULY).

THE BIG (AND LOCAL) PICTURE (CONT.)





VWS SHOWS ANOMALIES OVER THE CARIBBEAN SEA FROM JUNE TO JULY 2015. THE CLIMATOLOGY WAS CALCULATED FROM 1979 TO 2014.

THESE ANOMALIES CAN REDUCE THE RAINFALL GENERATION BUT IT IS NOT ENOUGH TO DECLINE THE RAINFALL BECAUSE IT'S LESS THAN 8 M S^{-1} ACROSS THE REGION. WITH SD COMBINED, A DRIER SEASON IS LIKELY.

CAN CAST DATA ANSWER OUR SCIENCE QUESTIONS?

HOW DOES/DO SURFACE HEAT BALANCE/PROCESSES INFLUENCE CONVECTION LEVELS?

SOIL MOISTURE DATA OVER THE COURSE OF THE CAMPAIGN MAY BE USED AS INPUT FOR MODELING STUDIES TO CALCULATE SURFACE FLUXES, AND INVESTIGATE HOW FLUXES IMPACT CONVECTION. SATURATED SOIL SHOULD FUELI CONVECTION OF MOIST AIR ADJACENT TO THE SURFACE.

HOW DO GENERAL CIRCULATION AND SYNOPTIC PROCESSES (I.E. TRADE WINDS, SD, VWS, ENSO, EL NIÑO) INTERACT WITH LOCAL COASTAL PROCESSES TO ENHANCE/SUPPRESS CONVECTION/PRECIPITATION?

RADIOSONDE SOUNDINGS, AERONET AOT, AND MODELING OF THE MSD WITH VARIED BIMODAL INDICES AND LOW/HIGH ENSO SEASONS MAY ASSIST IN ANSWERING THIS QUESTION. WE NOTE THAT THERE HAS BEEN LITTLE PRECIPITATION IN HIGH SD SCENARIOS, AND IN LOW SD SCENARIOS WITH WEAK SEABREEZE. AS VWS SUPRESSES CONVECTION AND IS HIGHEST OVER THE CARIBBEAN DURING MSD, WE ARE NOT SURPRISED BY REDUCED PRECIPITATION OVER PUERTO RICO. DURING THE MSD, HIGH PRECIPITATION AMOUNTS ARE STILL RECORDED ON THE WEST COAST (CLIMATOLOGICALY), WHICH IS SUBJECTED TO ENHANCED CONVECTION DUE TO SEABREEZE TRADE WIND CONVERGENCE. THIS SUMMER, THERE WERE LOWER THAN EXPECTED TOTALS AND REDUCED RAINFALL FREQUENCY ON THE WEST COAST. THIS IS LIKELY ATRIBUTED TO THE HIGHER INTENSITY OF SD EPISODES, AND A PREVAILING HIGH PRESSURE SYSTEM OVER PUERTO RICO.

CAN CAST DATA ANSWER OUR SCIENCE QUESTIONS?

HOW DO AEROSOLS INFLUENCE WARM SURFACE CONVECTIVE PROCESSES IN COASTAL/WARM ENVIRONMENTS (ENERGY PROCESSES/PRECIPITATION)?

RADIOSONDE SOUNDINGS, AERONET AOT, MODELING ETC. CAN ASSIST IN ANSWERING THIS QUESTION. BY CAPPING THE PBL, SD HAS THE EFFECT OF LIMITING CONVECTION. THE CLEAREST EFFECTS OF THE AEROSOLS (SD) ON WARM SURFACE PROCESSES ARE TEMPERATURE INCREASES THAT COME WITH HIGH SD CONCENTRATIONS, AND HUMIDITY REDUCTION. THERE MAY ALSO BE AN EFFECT OF SD ON WIND INTENSITY AND DIRECTION. IN ORDER TO DETERMINE THIS, AOT/WIND DATA MUST BE ATTAINED FOR MULTIPLE ISLANDS IN THE CARIBBEAN.

WHAT IS THE IMPACT OF AEROSOL CHEMISTRY ON PRECIPITATION?

AS THE PARTICLE SAMPLER WAS NOT WORKING, WE HAVE NO SPECIATION DATA. IF WE CAN GET DATA FROM PM2.5 AND PM10 FILTERS AT SOME OF THE LOCATIONS ON THE ISLAND, PERHAPS WE CAN DO AN OBSERVATIONAL ANALYSIS THAT WILL SUPPORT MODELLING EXPERIMENTS.

THANK YOU! ANY QUESTIONS?

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