Appendix A.4 (report was formatted by HDSC)

Final Report
Production of Rainfall Frequency Grids for Puerto Rico and the U.S. Virgin Islands Using a Specifically Optimized PRISM System

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Project Goal

The Hydrometeorological Design Studies Center (HDSC) within the Office of Hydrologic development of NOAA's National Weather Service is updating precipitation frequency estimates for Puerto Rico and the U.S. Virgin Islands (PRVI). In order to complete the spatial interpolation of point estimates, HDSC requires spatially interpolated grids of mean annual maximum precipitation. To that end, the PRISM Group (formerly known as the Spatial Climate Analysis Service) at Oregon State University, produced a series of grids for rainfall frequency estimation using an optimized system based on the Parameter-elevation Regressions on Independent Slopes Model (PRISM) and HDSC-calculated point estimates for the Puerto Rico and Virgin Islands study domains.

Background

HDSC used the "Index Flood" approach as described by Hosking and Wallis in "Regional Frequency Analysis; An Approach Based on L-Moments", 1997, to estimate rainfall frequencies. In this approach, the mean of the underlying rainfall frequency distribution is estimated at point locations with a sufficient history of observations. This mean is referred to as the "Index Flood" because early applications of the method were used to analyze flood data in hydrology. The form of the distribution its parameters are estimated regionally. Once the form of the distribution has been selected and its parameters have been estimated, rainfall frequency estimates can be computed from grids of the Index Flood. The grids that are the subject of this report are spatially interpolated grids of the point estimates of the Index Flood for various precipitation durations. The point estimates of the Index Flood were provided by HDSC. HDSC selected an appropriate rainfall frequency distribution along with regionally estimated parameters and used this information with the grids of the Index Flood to derive grids of rainfall frequency estimates.

The PRISM Group has previously performed similar work to produce spatially interpolated Index Flood grids for updates of precipitation frequency estimates in the Semiarid Southwest United States and the Ohio River Basin and Surrounding States study areas.

This Report

This report describes tasks performed to produce final index flood grids for 14 precipitation durations, ranging from 60 minutes to 60 days, for PRVI. These tasks were not necessarily performed in this order, nor were they performed just once. The process was dynamic and had numerous feedbacks.

Adapting the PRISM system

The PRISM modeling system was adapted for use in this project after a small investigation was performed for the Semiarid Southwest United States, and subsequently used in the Ohio River Basin and Surrounding States study area. This investigation and adaptation procedure is summarized below.

PRISM is a knowledge-based system that uses point data, a digital elevation model (DEM), and many other geographic data sets to generate gridded estimates of climatic parameters (Daly et al. 1994, 2002, 2003, 2006) at monthly to daily time scales. Originally developed for precipitation estimation, PRISM has been generalized and applied successfully to temperature, among other parameters. PRISM has been used extensively to map precipitation, dew point, and minimum and maximum temperature over the United States, Canada, China, and other countries. Details on PRISM formulation can be found in Daly et al. (2002, 2003).

Adapting the PRISM system for mapping precipitation frequencies required an approach slightly different than the standard modeling procedure. The amount of station data available to HDSC for precipitation frequency was much less than that available for high-quality precipitation maps, such as the peer-reviewed PRISM 1961-1990 mean precipitation maps (USDA-NRCS 1998). Data sources suitable for long-term mean precipitation but not for precipitation frequency included snow courses, short-term COOP stations, remote storage gauges, and others. In addition, data for precipitation durations of less than 24 hours were available from hourly rainfall stations only. This meant that mapping precipitation frequency using HDSC stations would sacrifice a significant amount of the spatial detail present in the 1961-1990 mean precipitation maps.

A pilot project to identify ways of capturing more spatial detail in the precipitation frequency maps was undertaken. Early tests showed that mean annual precipitation (MAP) was an excellent predictor of precipitation frequency in a local area, much better than elevation, which is typically used as the underlying, gridded predictor variable in PRISM applications. In these tests, the DEM, the predictor grid in PRISM, was replaced by the official USDA digital map of MAP for the lower 48 states (USDA-NRCS 1998, Daly et al. 2000). Detailed information on the creation of the USDA PRISM precipitation grids is available from Daly and Johnson (1999). MAP was found to have superior predictive capability over the DEM for locations in the southwestern US. The relationships between MAP and precipitation frequency were strong because much of the incorporation of the effects of various physiographic features on mean precipitation patterns had already been accomplished with the creation of the MAP grid from PRISM. Preliminary PRISM maps of 2-year and 100-year, 24-hour precipitation were made for the Semiarid Southwest and compared to hand-drawn HDSC maps of the same statistics. Differences were minimal, and mostly related to differences in station data used.

Further investigation found that the square-root transformation of MAP produced somewhat more linear, tighter and cleaner regression functions, and hence, more stable predictions, than the untransformed values; this transformation was incorporated into subsequent model applications. Square-root MAP was a good local predictor of not only longer-duration precipitation frequency

statistics, but for short-duration statistics, as well. Therefore, it was determined that a modified PRISM system that used square-root MAP as the predictive grid was suitable for producing high-quality precipitation frequency maps for this project.

For this study, previously-developed grids of MAP for Puerto Rico (1963-1995 averaging period) and the Virgin Islands (1971-2000) were used. Both of these grids were developed under funding from the International Institute of Tropical Forestry, US Forest Service (Daly et al., 2003). MAP grids for Puerto Rico and the Virgin Islands (US and British) are shown in Figures 1 and 2.

PRISM Configuration and Operation for PRVI

In general, PRISM interpolation consists of a local moving-window regression function between a predictor grid and station values of the element to be interpolated. The regression function is guided by an encoded knowledge base and inference engine (Daly et al., 2002). This knowledge base/inference engine is a series of rules, decisions and calculations that set weights for the station data points entering the regression function. In general, a weighting function contains knowledge about an important relationship between the climate field and a geographic or meteorological factor. The inference engine sets values for input parameters by using default values, or it may use the regression function to infer grid cell-specific parameter settings for the situation at hand. PRISM acquires knowledge through assimilation of station data, spatial data sets such as MAP and others, and a control file containing parameter settings.

The other center of knowledge and inference is that of the user. The user accesses literature, previously published maps, spatial data sets, and a graphical user interface to guide the model application. One of the most important roles of the user is to form expectations for the modeled climatic patterns, i.e., what is deemed "reasonable." Based on knowledgeable expectations, the user selects the station weighting algorithms to be used and determines whether any parameters should be changed from their default values. Through the graphical user interface, the user can click on any grid cell, run the model with a given set of algorithms and parameter settings, view the results graphically, and access a traceback of the decisions and calculations leading to the model prediction.

For each grid cell, the moving-window regression function for index flood vs. MAP took the form

$$\text{Index flood value} = \beta_1 * \text{sqrt(MAP)} + \beta_0 \qquad (1)$$

where β_1 is the slope and β_0 is the intercept of the regression equation, and MAP is the grid cell value of mean annual precipitation.

Upon entering the regression function, each station was assigned a weight that is based on several factors. In the general PRISM formulation for precipitation, the combined weight of a station can be a function of distance, elevation, cluster, vertical layer, topographic facet, coastal proximity, and effective terrain weights, respectively. A full discussion of the station weighting functions is available in Daly (2002) and Daly et al. (2002).

A subset of these functions was used for this study. For PR, the combined weight of a station was a function of distance, MAP, cluster, topographic facet, and coastal proximity, respectively. For VI, only distance and cluster weighting were used, due to lack of station data, and the small size of the islands. Distance, MAP, and cluster weighting are relatively straightforward in concept. A station is down-weighted when it is relatively distant or has a much different MAP value than the target grid

cell, or when it is clustered with other stations (which can lead to over-representation). Facet weighting effectively groups stations into individual hillslopes (or facets), at a variety of scales, to account for sharp changes in climate regime that can occur across facet boundaries. Coastal proximity weighting is used to define gradients in precipitation that may occur due to proximity to large water bodies (Daly et al., 2003).

The moving-window regression function was populated by station data provided by the HDSC. Locations of these stations are shown in Figure 3. A PRISM GUI snapshot of the moving-window relationship between MAP and 24-hour index flood in the Cordillera Central (Central Mountains) is shown in Figure 4a.

As exemplified by the 60-minute duration station map in Figure 3a, there were little station data available for durations of 12 hours or less from which to perform the interpolation. In addition, it became clear that, at least in Puerto Rico, the spatial patterns of durations of 12 hours or less were very different than those of durations of 24 hours or more. In an effort to bring the ≤ 12-hour station density up to that for ≥ 24 hours, the following procedure was developed:

(1) Convert available ≤ 12-hour station values to an index flood/24-hr index flood ratio (termed R24) by dividing by the 24-hour values;

(2) using the station R24 data in (1), interpolate R24 values for each ≤ 12-hour duration (60 minutes, and 2, 3, 6, and 12 hours) using PRISM in inverse-distance weighting mode;

(3) using bi-linear interpolation from the cells in the R24 grids from (2), estimate R24 at the location of each station having data for ≥ 24-hour durations only;

(4) multiply the estimated R24 values from (3) by the 24-hour value at each ≥ 24-hour station to obtain estimated ≤ 12-hour values;

(5) append the estimated stations from (4) to the ≤ 12-hour station list to generate a station list that matches the density of that for ≥ 24 hours; and

(6) interpolate index flood values for ≤ 12-hour durations with PRISM, using MAP as the predictor grid.

Investigation of the little available data failed to provide convincing evidence that the spatial patterns of R24 values were strongly affected by MAP, coastal proximity, topographic facets, or other factors. Therefore, the slope of the moving-window regression function for R24 vs. MAP of the form

$$R24 = \beta_1 * \text{sqrt}(MAP) + \beta_0 \qquad (2)$$

was forced to zero everywhere. This meant that, for both PR and VI, the interpolated value of R24 was a function of distance and cluster weighting only (essentially inverse-distance weighting). A PRISM GUI snapshot, shown in Figure 4b, of the relationship between MAP and 60-minute R24 in the Cordillera Central (Central Mountains) shows a rather weak scatter plot, with no obvious relationship between 60-minute R24 and MAP.

Relevant PRISM parameters for applications to 60-minute R24 and 24-hour index flood statistics are listed in Tables 1 and 2, respectively. Further explanations of these parameters and associated

equations are available in Daly (2002) and Daly et al. (2002). The difference to note between the parameter set in Tables 1 and 2 and that in Daly et al. (2002) is that the elevation weighting parameters in Daly et al. (2002) are now referred to here as MAP weighting parameters. This is because MAP, rather than elevation, was used as the predictor variable. Input parameters used for the 60-minute R24 application were generally applied to all durations for which it was applied (less than or equal to 12 hours). The 24-hour index flood input parameters were generally applied to all durations.

The values of radius of influence (*R)*, the minimum number of on-facet (s_f) and total (s_t) stations required in the regression were based on information from user assessment via the PRISM graphical user interface, and on a jackknife cross-validation exercise, in which each station was deleted from the data set one at a time, a prediction made in its absence, and mean absolute error statistics compiled (see Results section).

Input parameters that changed readily among the various durations were the maximum allowable slope (β_{1x}) and default slope (β_{1d}) of the regression function. Slopes are expressed in units that are normalized by the average observed value of the precipitation in the regression data set for the target cell. Evidence gathered during PRISM model development indicates that this method of expression is relatively stable in both space and time (Daly et al. 1994).

Bounds are put on the slopes to minimize unreasonable slopes that might occasionally be generated due to local station data patterns; if the slope is out of bounds and cannot be brought within bounds by the PRISM outlier deletion algorithm, the default slope is invoked (Daly et al., 2002). Slope bounds and default values were based on PRISM diagnostics that provided information on the distribution of slopes across the modeling region. The default value was set to approximate the average regression slope calculated by PRISM. The upper and lower bounds were set to approximately the 95th and 5th percentiles of the distribution of slopes, respectively, because many of the slopes outside this range are typically found to be questionable. For these applications, slope bounds typically increased with increasing duration (Table 3). In general, the longer the duration, the larger the maximum allowable slope. This is primarily a result of higher precipitation amounts at the longer durations, and the tendency for longer-duration index flood statistics to bear a stronger and steeper relationship with MAP than shorter-duration statistics.

Review of Draft Grids

Initial draft grids of 1- and 24-hour index flood statistics for the PR and VI regions were produced by running PRISM directly on the index flood station data for all durations (the ratio method for durations of 12 hours or less was not developed until after the external review). HDSC derived 100-year return period maps from the initial drafts, and also made these available for review. Comments received and our responses are presented in Appendix A.

The external review resulted in two major changes to the mapping methodology:

(1) Development and implementation of the ratio (R24) method for durations of 12 hours and less (discussed earlier): and
(2) A revision of the MAP grid for PR that lowers the precipitation on the hill discussed in Question 5, Appendix A. MAP grid revision required that the PRISM model be re-applied to PR after adding an estimated station on the questionable hill with a MAP of 1564 mm.

Results

PRISM grids of 60-minute/24-hour index flood intensity ratio (R24), 60-minute index flood intensity, and 24-hour index flood intensity are shown in Figures 5, 6, and 7, respectively. In inverse-distance-weighting mode, PRISM produces a R24 map that has no appreciable physiographic features (Figure 5). Current data are insufficient to provide further insight into the causes and controls of these spatial patterns. However, major patterns across the island are clearly evident. The western side of the island has substantially higher R24 values than the eastern side. The northwestern corner of PR had 60-minute index flood values that were over 60 percent of the 24-hour values. On the eastern side, values were as low 30 percent. This spatial discrepancy in R24 is the source of the differences in spatial patterns between the 60-minute index flood (Figure 6) and the 24-hour index flood maps (Figure 7). Sixty-minute values are highest in the northwest and in the western portion of the Cordillera Central (Central Mountains), with smaller maxima in the eastern mountains, especially the Luquillos. In contrast, the 24-hour map bears a much greater resemblance to the MAP map (Figure 1), with the highest values in the central and eastern Cordillera Central, and the Luquillo Mountains.

PRISM cross-validation statistics for applications 1- and 24-hour applications to the PRVI region were compiled and summarized in Tables 4 and 5. Overall bias was less than 2 percent and the mean absolute error was less than 10 percent for the 60-minute/24-hour index flood ratio, and the 60-minute and 24-hour index flood intensities. Errors for 2- to 12-hour durations were similar to those for the 60-minute duration, and errors for 2 to 60-day durations were similar to those for the 24-hour duration. Given the lack of data, one would have expected the 1 to 12-hour index flood errors to be somewhat higher than those for the 24-hour to 60-day index floods. A likely reason for this is that the addition of many synthesized stations, derived from a PRISM interpolation of R24 values, resulted in a station data set that was spatially consistent, and thus, somewhat easier to interpolate with each station deleted from the data set. Therefore, there is little doubt that the true interpolation errors for the 1–hour index flood are higher than those shown in Table 4.

Deliverables

A full set of maps for all index flood durations were produced for the PRVI region, including 60 minutes, 2, 3, 6, 12, and 24 hours; and 2, 4, 7, 10, 20, 30, 45, and 60 days. The maps were subjected to pixel-by-pixel tests to ensure that shorter duration values did not exceed those of longer duration values. PRISM modeling was performed at 15-second (~450-m) resolution in PR and at 3-second (~90-m) resolution in VI. The PR grids were subsequently filtered to a 3-second resolution to match that of VI using a modified Gaussian filter (Barnes, 1964), and the PR and VI grids merged into single PRVI grids. These grids were delivered electronically to HDSC via ftp.

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USDA-NRCS, 1998. *PRISM Climate Mapping Project--Precipitation. Mean monthly and annual precipitation digital files for the continental U.S.* USDA-NRCS National Cartography and Geospatial Center, Ft. Worth TX. December, CD-ROM.

Table 1. Values of relevant PRISM parameters for interpolation of 60-minute/24-hour index flood ratio (60-minute R24) for PR (Puerto Rico) and VI (US Virgin Islands). See Daly et al. (2002) for details on PRISM parameters.

Name	Description	PR/VI Values
Regression Function		
R	Radius of influence	1.7/0.4 km*
s_f	Minimum number of on-facet stations desired in regression	4/4 stations
s_t	Minimum number of total stations desired in regression	12/12 stations
β_{1m}	Minimum valid regression slope	0.0/0.0[+]
β_{1x}	Maximum valid regression slope	0.0/0.0[+]
β_{1d}	Default valid regression slope	0.0/0.0[+]
Distance Weighting		
A	Distance weighting exponent	2.0/2.0
F_d	Importance factor for distance weighting	1.0/1.0
D_m	Minimum allowable distance	0.0/0.0 km
MAP Weighting**		
B	MAP weighting exponent	NA/NA
F_z	Importance factor for MAP weighting	NA/NA
Δz_m	Minimum station-grid cell MAP difference below which MAP weighting is maximum	NA/NA
Δz_x	Maximum station-grid cell MAP difference above which MAP weight is zero	NA/NA
Facet Weighting		
C	Facet weighting exponent	NA/NA
g_m	Minimum inter-cell elevation gradient, below which a cell is flat	NA/NA
λ_x	Maximum DEM filtering wavelength for topographic facet determination	NA/NA
Coastal Proximity Weighting		
v	Coastal proximity weighting exponent	NA/NA

* Expands to encompass minimum number of total stations desired in regression (s_t).

[+] Slopes are expressed in units that are normalized by the average observed value of the precipitation in the regression data set for the target cell. Units here are 1/[sqrt(MAP(mm))*1000].

** Normally referred to as elevation weighting.

Table 2. Values of relevant PRISM parameters for modeling of 24-hour index flood statistics for PR (Puerto Rico) and VI (US Virgin Islands). See Daly et al. (2002) for details on PRISM parameters.

Name	Description	PR/VI Values
Regression Function		
R	Radius of influence	1.0/0.4 km*
s_f	Minimum number of on-facet stations desired in regression	10/6 stations
s_t	Minimum number of total stations desired in regression	10/15 stations
β_{1m}	Minimum valid regression slope	0.0/0.0+
β_{1x}	Maximum valid regression slope	6.1/10.0+
β_{1d}	Default valid regression slope	1.7/5.0+
Distance Weighting		
A	Distance weighting exponent	2.0/2.0
F_d	Importance factor for distance weighting	0.5/0.5
D_m	Minimum allowable distance	0.0/2.7 km
MAP Weighting**		
B	MAP weighting exponent	1.0/0.0
F_z	Importance factor for MAP weighting	0.5/0.5
Δz_m	Minimum station-grid cell MAP difference below which MAP weighting is maximum	50/50%
Δz_x	Maximum station-grid cell MAP difference above which MAP weight is zero	500/500%
Facet Weighting		
C	Facet weighting exponent	1.5/NA
g_m	Minimum inter-cell elevation gradient, below which a cell is flat	1 m/NA
λ_x	Maximum DEM filtering wavelength for topographic facet determination	17 km/NA
Coastal Proximity Weighting		
v	Coastal proximity weighting exponent	1.0/NA

* Expands to encompass minimum number of total stations desired in regression (s_t).

+ Slopes are expressed in units that are normalized by the average observed value of the precipitation in the regression data set for the target cell. Units here are 1/[sqrt(MAP(mm))*1000].

** Normally referred to as elevation weighting

Table 3. Values of PRISM slope parameters for modeling of index flood statistics for PR (Puerto Rico) and VI (US Virgin Islands) for all durations. For durations of 12 hours and below, station data were expressed as the ratio of the given duration's index flood value to the 24-hour index flood value, and interpolated; this was followed by an interpolation of the actual index flood values. See text for details. See Table 1 for definitions of parameters.

	Puerto Rico			**Virgin Islands**		
Duration	β_{1m}	β_{1x}	β_{1d}	β_{1m}	β_{1x}	β_{1d}
60m/24h ratio	0.0	0.0	0.0	0.0	0.0	0.0
2h/24h ratio	0.0	0.0	0.0	0.0	0.0	0.0
3h/24h ratio	0.0	0.0	0.0	0.0	0.0	0.0
6h/24h ratio	0.0	0.0	0.0	0.0	0.0	0.0
12h/24h ratio	0.0	0.0	0.0	0.0	0.0	0.0
60 minute index flood	0.0	5.0	1.4	0.0	5.0	10.0
2 hour index flood	0.0	5.0	1.4	0.0	5.0	10.0
3 hour index flood	0.0	5.0	1.4	0.0	5.0	10.0
6 hour index flood	0.0	5.0	1.4	0.0	5.0	10.0
12 hour index flood	0.0	5.0	1.4	0.0	5.0	10.0
24 hour index flood	0.0	6.1	1.7	0.0	5.0	10.0
48 hour index flood	0.0	6.3	1.7	0.0	5.0	10.0
4 day index flood	0.0	6.3	1.9	0.0	5.0	10.0
7 day index flood	0.0	6.5	2.4	0.0	5.0	10.0
10 day index flood	0.0	6.7	2.7	0.0	5.0	10.0
20 day index flood	0.0	6.9	3.3	0.0	5.0	10.0
30 day index flood	0.0	7.0	3.7	0.0	5.0	10.0
45 day index flood	0.0	8.0	3.8	0.0	5.0	10.0
60 day index flood	0.0	10.0	4.0	0.0	5.0	10.0

Table 4. PRISM cross-validation errors for 60-minute/24-hour index flood ratio and 24-hour index flood applications to PR (Puerto Rico). Since the 60-minute/24-hour index flood ratio was expressed as a percent, the percent bias and mean absolute error are the given as the bias and MAE in the original percent units (not as a percentage of the percent).

Statistic	N	% Bias	% MAE
60-min/24-hr index flood ratio	23	0.64	5.78
60-minute index flood	113	1.77	8.38
24-hour index flood	113	1.83	8.82

Table 5. PRISM cross-validation errors for 60-minute/24-hour index flood ratio and 24-hour index flood applications to VI (US Virgin Islands). Since the 60-minute/24-hour index flood ratio was expressed as a percent, the percent bias and mean absolute error are the given as the bias and MAE in the original percent units (not as a percentage of the percent).

Statistic	N	% Bias	% MAE
60-min/24-hr index flood ratio	2	0.0	2.00
60-minute index flood	19	2.32	8.88
24-hour index flood	19	2.32	8.88

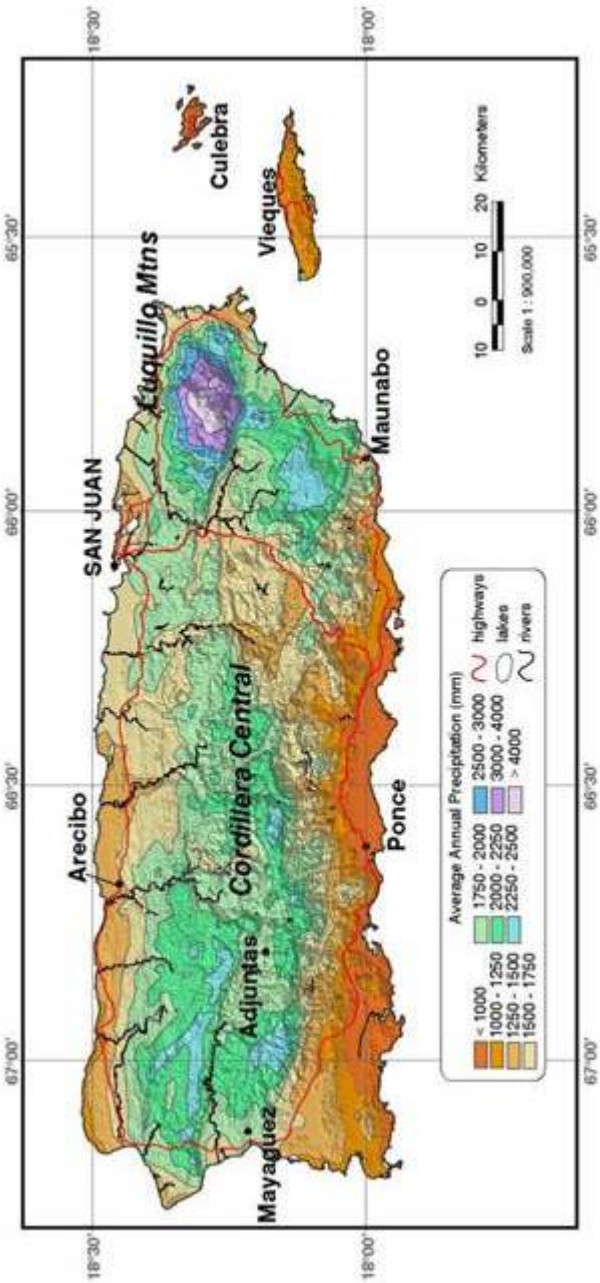


Figure 1. 1963-1995 mean annual precipitation (MAP) grid for Puerto Rico (Source: Daly et al., 2003).

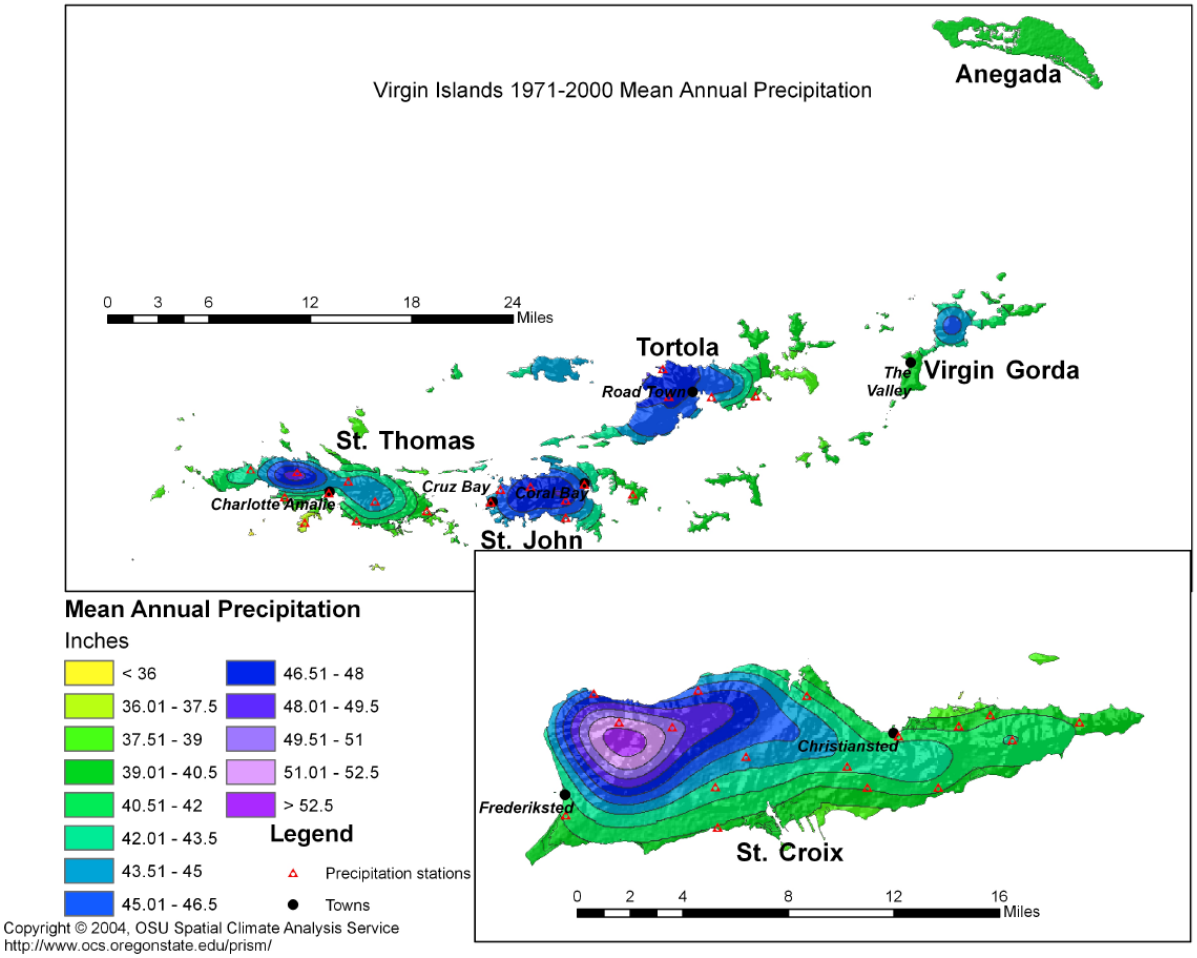
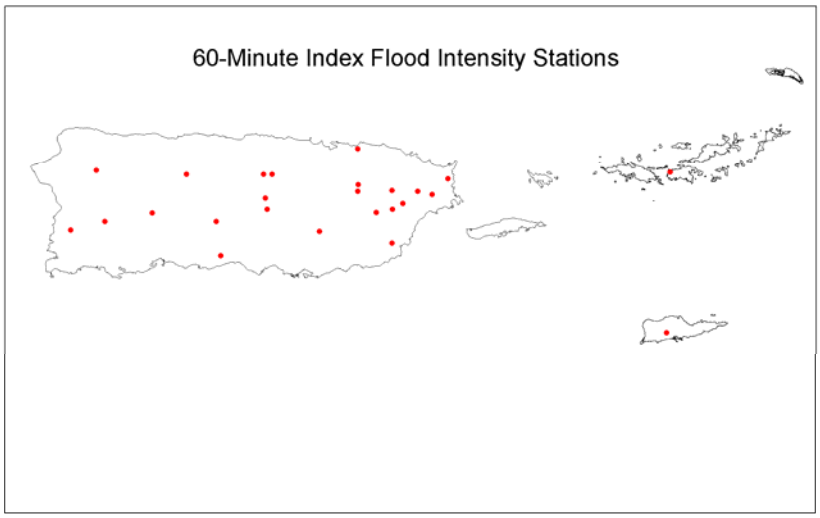


Figure 2. 1971-2000 mean annual precipitation (MAP) grid for the Virgin Islands.

(a)\



(b)

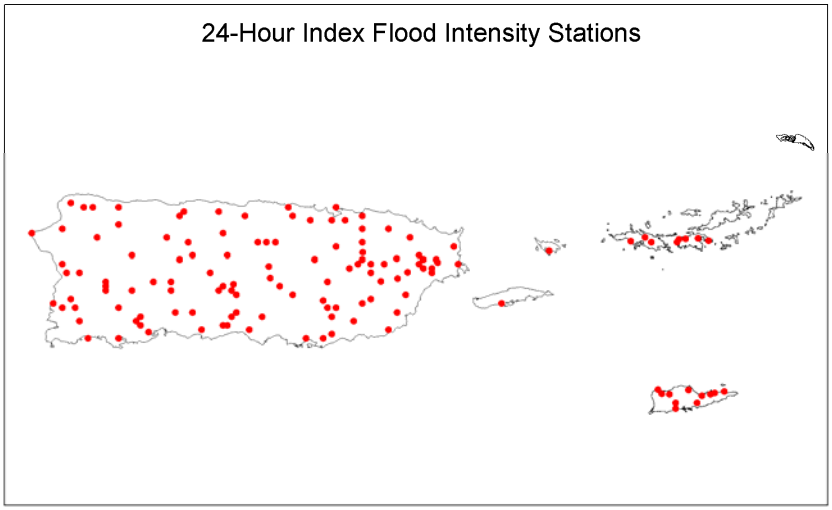
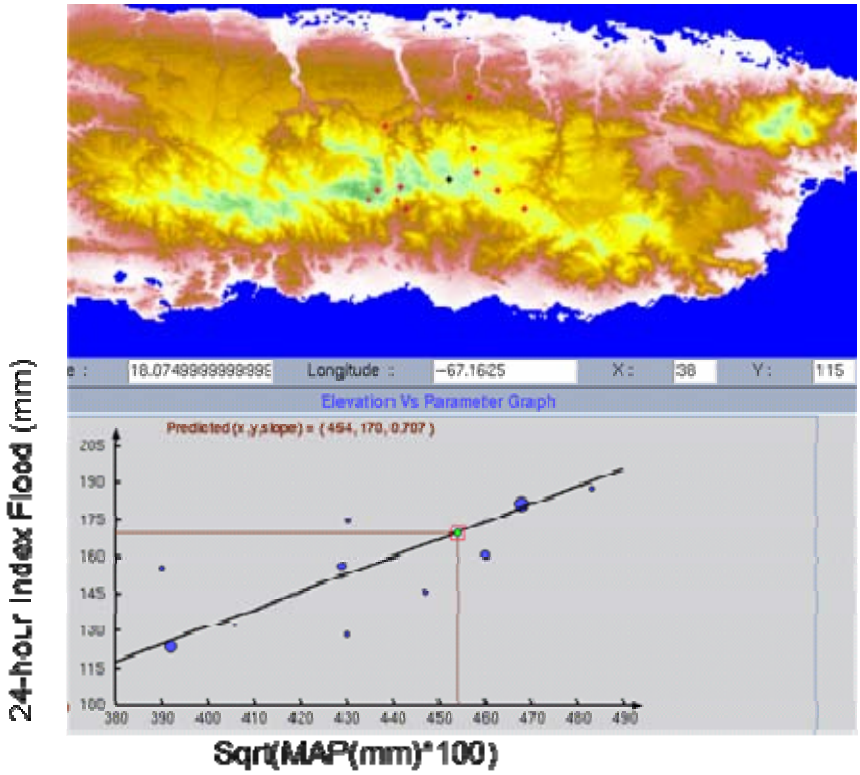


Figure 3. Distribution of station data in the PRVI region: (a) 60-minute; and (b) 24-hour index flood intensities.

(a)



(b)

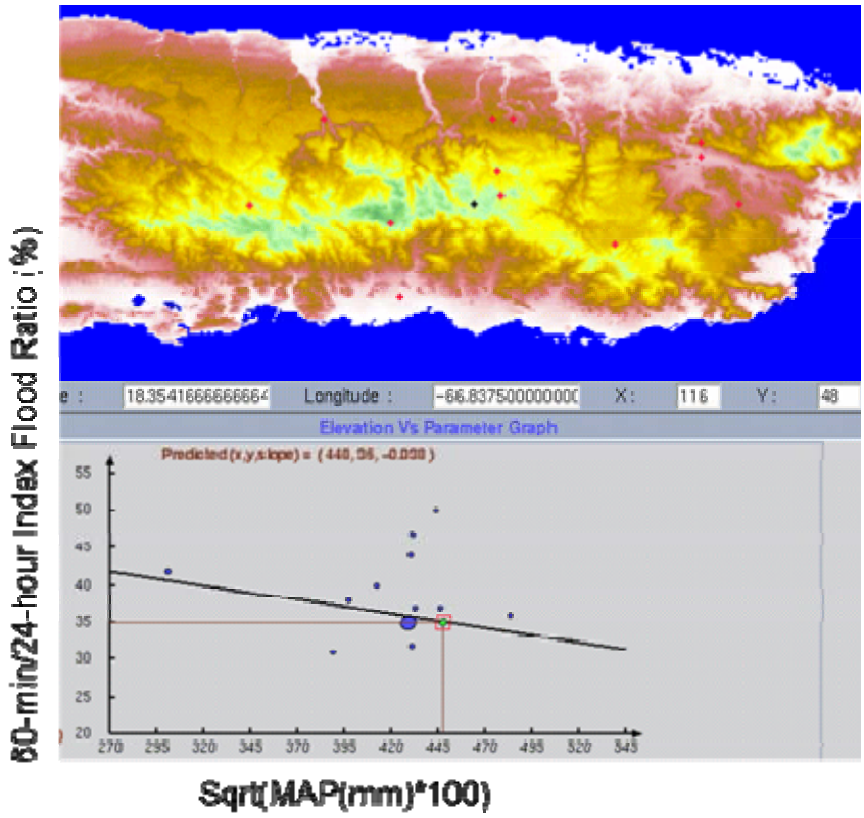


Figure 4. PRISM GUI snapshot of the moving-window relationship between: (a) MAP and 24-hour index flood; and (b) MAP and the 60-minute/24-hour ratio (R24), in the Cordillera Central (Central Mountains) of Puerto Rico.

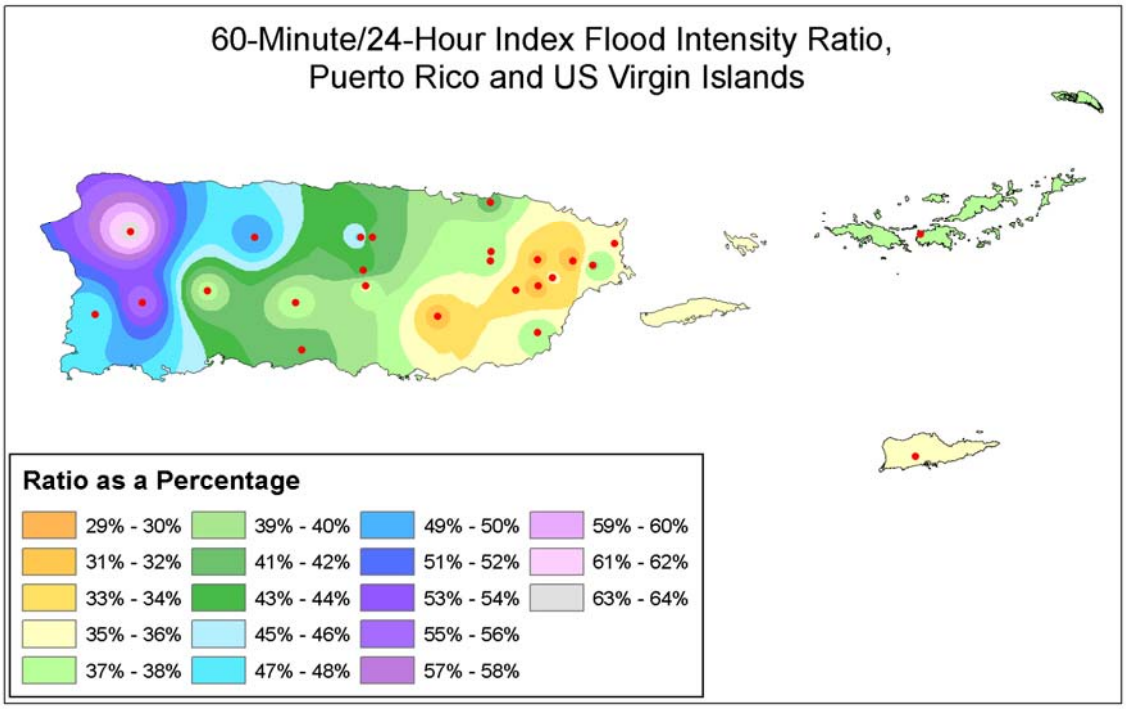


Figure 5. PRISM grid of 60-minute/24-hour index flood intensity ratio (R24) for the PRVI region.

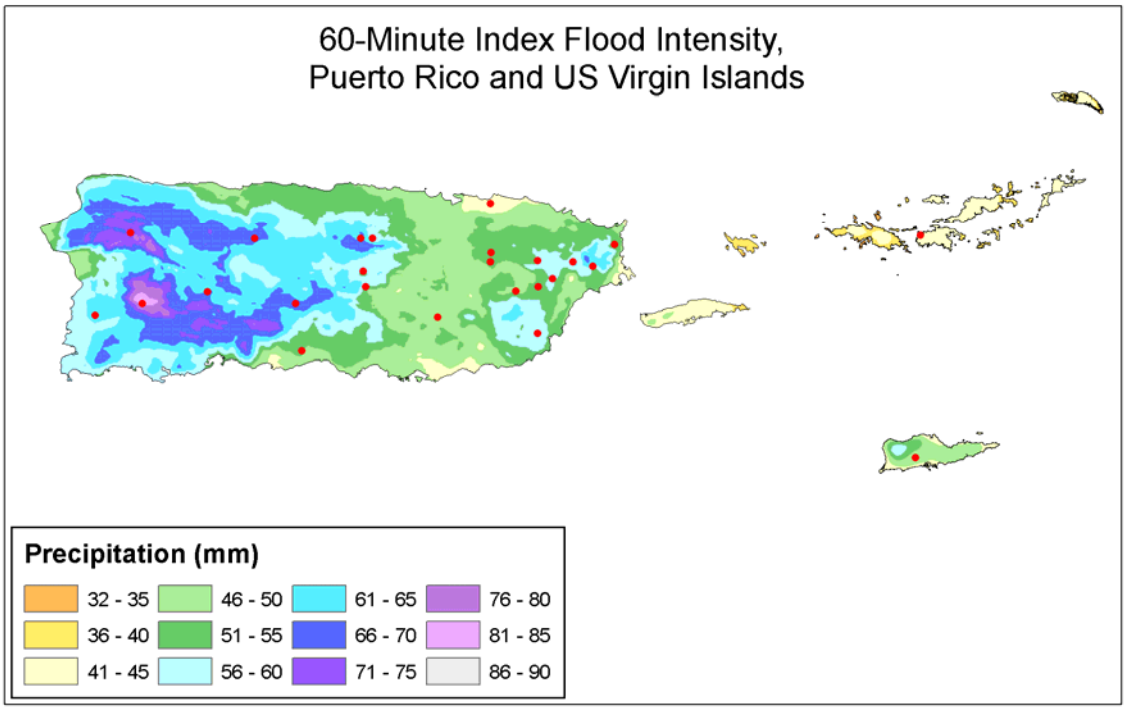


Figure 6. PRISM grid of 60-minute index flood intensity for the PRVI region.

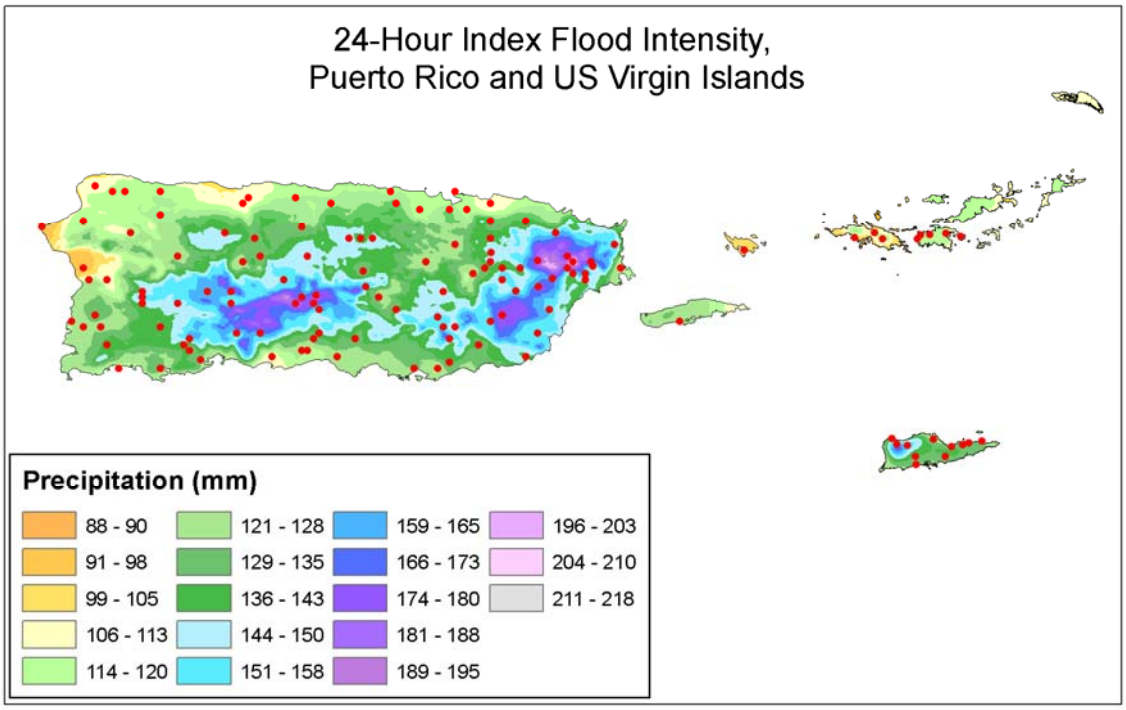
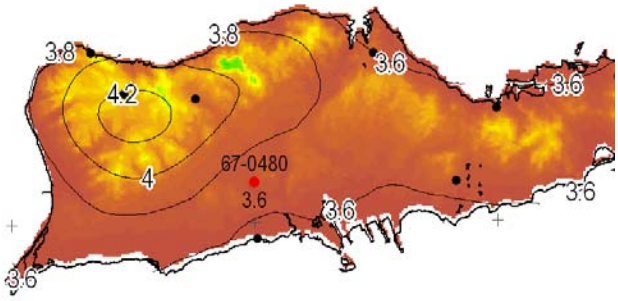


Figure 7. PRISM grid of 24-hour index flood intensity for the PRVI region.

APPENDIX A
External Review Comments and Responses

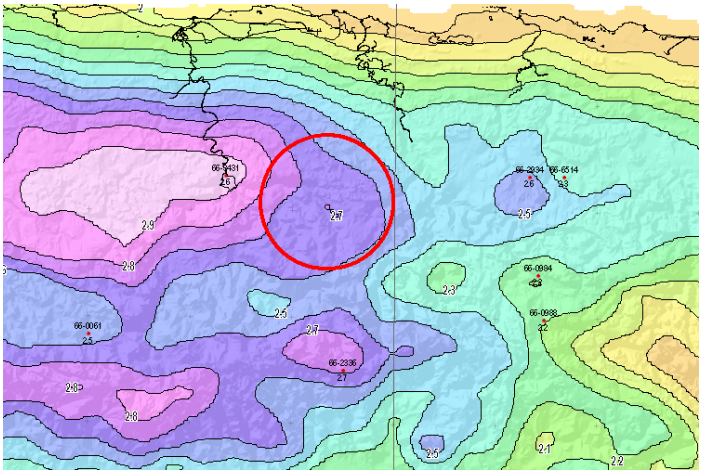
1. Question: Are we correctly capturing all of the high precip (at 60m & 24h) areas on St Croix? It appears as though the maximum should maybe extend slightly more eastward to pick up additional high terrain.

   DEM overlaid by 100-yr 60-min:



   Response by Chris Daly: That is difficult to say, due to lack of data. The PRISM MAP map shows a relatively sharp extension of maximum values over the terrain question, and the 24-hour index flood map shows a similar extension. There is only one 60-minute precipitation station on St, Croix, giving us little to go on at that duration. Recall that the MAP map was generated by PRISM using a DEM that was filtered to a 5-minute effective wavelength, which does produce relatively smooth patterns. Typically, for topical islands, I have been using a DEM filtered to a wavelength of 2.5 to 5 minutes. The precipitation patterns to not appear to respond to small-scale terrain variations, but we frankly do not have the high-quality, high-resolution precipitation station data to be able to reproduce the actual patterns with a high degree of confidence.

2. Question: What is driving up the 60-min means in this area? We expect lower values since it's on a down slope side and at a lower elevation. 66-3431 station value is 2.60 and PRISM interpolated 2.95. To be exact, PRISM interpolates it to be 2.93, but still that is a 12.8% difference; this is the biggest deviation in the dataset. The average difference is 1.01%. Perhaps Chris can force this to match a little better and not gloss over these valleys.



Response by Chris Daly: This question is not easily answered, and may lead to a change in our interpolation methodology for durations of 12 hours and less.

3. Question: How are the Islands with no hourlies interpolated? It does not seem consistent or relies too much on mean annual? For instance, the Vieques value for the entire Island seems to be 2.1 while Culebra is 1.4 for the entire Island. How can we justify it with no stations?

   Response by Tye Parzybok: PRISM interpolated the mean annual precipitation on these islands, and for our work, PRISM is simply using the relationships from nearby islands (with hourly data) and PR to interpolate the means on these islands. Are we OK with this, well, good question. I checked the PRISM values against TP-42 and they are comparable. PRISM has Culebra at about 2.7" and TP-42 (2-yr) has Culebra at 2.3-2.8. PRISM has Vieques at about 1.5-1.6", TP-42 (2-yr) has Vieques at about 1.9". So Vieques might be too dry, but Culebra is about right. Regardless, I will add this to my list of things to consider in the final run.

   Response by Chris Daly: Tye is correct, the values here are dependent on the relationships between 60-minute precipitation and MAP from stations on Puerto Rico. Lacking corroborating data, it is unknown whether this is a good idea. However, there are 24-hour observations on Culebra and Vieques. Comparing the relationships between the 24-hour index flood and MAP on each island, we see that the ratio is exactly the same: 0.12. If I use the PRISM GUI and pick off the 60-minute values at these station locations, we again get identical ratios, this time 0.05. This gives us some confidence that at least the relationships are consistent.

	MAP	*24 hour (obs)/MAP ratio*	*60-minute (estimated)/MAP ratio*
Vieques	*1051mm*	*124/1051=0.12*	*52/1051=0.05*
Culebra	*842mm*	*100/842=0.12*	*41/842=0.05*

4. Question: On Vieques 9793 is 4.9" but the east end of the Island drops way off to 4.3" based on no stations. Is PRISM handling this OK? Seems like too much of a drop off to me.

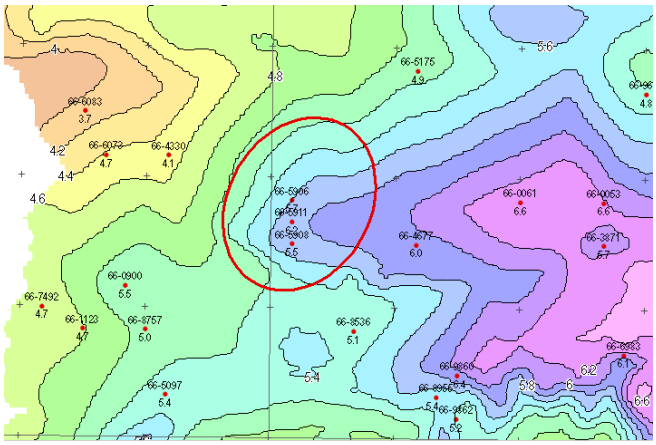
   Response by Tye Parzybok: The TP-42 maps hint at a gradient like this (wetter west, drier east), but yes, perhaps not as steep as PRISM has it. We, nor did TP-42 have any data for the eastern part of Vieques, so we're all guessing to some extent. I wonder if Culebra's dryness is influencing this gradient. Again, I will add this to my list of things to look at again.

   Response by Chris Daly: This appears to be driven largely by a drop in mapped MAP from about 1050 mm on the west side of Vieques to about 950 mm on the east side. The lower values appear to be influenced slightly by lower values on Culebra. The10% drop in MAP results in a 12% drop in 24-hour precipitation, which, again, is probably well within the error margin of the observations.

5. Question: Local experts (peer reviewers) believe this area on the 24-hour mean map is too high. Can you reduce this interpolated/extrapolated maximum a little?

Response by Chris Daly: Yes, I am aware of this hill, and agree it does seem a little high. This hill is on the southern edge of a steep rain shadow transition from the relatively wet Cordillera Central to the relatively dry southern coast. Part of the reason for the relatively high value is station 66-4126, just to the southwest of the hill in question. If we compare this station to 66-1634, (a station used in the MAP mapping only, a little southeast of 66-9774), further to the north and also just to the southwest of a hill of lower elevation, it has a very similar MAP value (66-4126=1268 mm, 66-4126=1224 mm. PRISM sees the hill in question as being in a similar precipitation regime as the hill to the north. However, the hill in question is physically removed from the main mountain chain, and should, therefore, have a little less increase in precipitation per unit elevation than further to the north, due to less influence of blow-over precipitation. There is no easy way to force the model to do this, so MAP will have to be remapped. I will attempt to do that.

6. Question: Local experts (peer reviewers) believe this area on the 24-hour mean map isn't high enough:



Response by Chris Daly: This is an area where there are three stations in close proximity, with different 24-hour index flood values: 5.7", 6.2", and 5.5". The modeled values are approximately 5.6", 5.7", and 5.6", respectively. This translates into differences of approximately 2%, 8%, and 2%, respectively. These are not large differences.