HydroMetriks, Ltd.

HydroMetriks – Frequency/Intensity Tool (Hydro-FIT)

Application Guide

Version 1.0

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Introduction

The HydroMetriks Frequency/Intensity Tool (Hydro-FIT) is a statistical tool developed by HydroMetriks, Ltd., that facilitates the frequency analysis of various types of hydrological and meteorological data. Hydro-FIT uses the method of L-moments to calculate descriptive statistics (L-moments) for a dataset. These L-moments are used to determine parameters for any of 13 different standard distributions, which are then used to estimate the exceedance and non-exceedance growth curves of the data. Hydro-FIT also can estimate the impacts of climate variability on event intensities for a wide range of storm frequencies. The objective has been to design such a tool in a way that is useful to academic institutions, government agencies, and private consulting firms. Another objective has been to design the tool to be user-friendly; Hydro-FIT only contains two main windows from which data are uploaded and the specific conditions for an analysis are chosen, and from which to observe the results in several ways. Hydro-FIT can produce such deliverables as PDF curves, exceedance and non-exceedance growth curves and tables, contour plots, regressions that demonstrate global climate index correlations, etc.

Hydro-FIT Documentation

The Hydro-Fit package includes two documents that are meant to help the user learn to use the Hydro-FIT software and to take advantage of all the features that Hydro-FIT offers. The following documents are included:

1. <u>User's Manual</u>: This document is a guide that gives detailed explanations concerning the functionality of Hydro-FIT and the many features that are offered. The manual provides installation instructions, instructions on how to create an input file that can be read by Hydro-FIT in one of two formats, detailed descriptions of each feature of Hydro-FIT, and how to view data and results both in graphical and tabular form.
2. <u>Application Guide</u>: This document contains an example that demonstrates the various features available in Hydro-FIT and steps the user through the entire process. This example utilizes Palmer Drought Index (PDI) data from central and northern Argentina to determine if there is a global climate index that correlates well with this data at a particular lag time. If a correlation is found, the example demonstrates the method by which the user can examine the impact of different phases of the climate index on the magnitude of the PDI at various exceedance frequencies.

Example: Palmer Drought Index Data in Argentina

Purpose

The purpose of this example is to demonstrate the overall capabilities of Hydro-FIT as applied to a specific problem in central and northern Argentina. The problem entails determining in advance whether a season of the year will experience lower or greater than normal precipitation using Palmer Drought Index (PDI) data that are provided for various sites throughout central and northern Argentina. An attempt will be made to correlate the PDI data during the season of interest to one of several global climate indices included in Hydro-FIT using various lag times. Once an index is found, its potential impact on rainfall will be estimated for the upcoming season and for the various storm frequencies that are analyzed in Hydro-FIT.

Global Climate Index Correlation

Select 'New Analysis' from the 'File' menu on the 'Title Screen' of Hydro-FIT; the 'Screen Data' window will appear. Click the 'Browse' button and select the location of the input file of PDI data that was provided with Hydro-FIT. After selecting the file and clicking 'OK', several options will become available in the 'Screen Data' window. As the current analysis will involve analyzing monthly rainfall data during a particular season of the year, the first three options listed below the 'Browse' button need to be selected accordingly. Select 'Monthly' from the 'Data Resolution' pull-down menu; select 'All Data' from the 'Analysis Type' pull-down menu; and select 'Index' from the 'Data Type' pull-down menu. The 'No Data Value' should not be changed from its current value of -999. In the 'Data Screening' portion of the window the options titled 'Beginning Year' and 'Duration (years)' have been disabled as these are only used during an extreme value analysis or when 'Peak Annual' is selected from the 'Analysis Type' pull-down menu. Select 'October' as the 'Beginning Month' and enter a monthly duration of four months. This will cause the monthly rainfall data for the months of October – January to be cumulated for each year; these annual cumulated values will become the data values that are analyzed during the following frequency analysis. The months of October – January are chosen because they correspond to the rainy season in central and northern Argentina. The 'Minimum Data' required in terms of number of years for each station can be left at '5', and the 'Data Units' should be specified as 'PDI' for 'Palmer Drought Index'. Click the checkbox next to the words 'Index Analysis' to enable all of the 'Index Analysis' options. Prior to determining which, if any, of the global climate indices that are included in Hydro-FIT correlate well with the rainfall data, a lag time must be entered in units of months; this represents the time between the average value of the global climate index and the rainfall period being analyzed. For example, if a lag time of two months is entered for this analysis, Hydro-FIT will attempt to correlate rainfall totals during the period October – January to average index values for the period August – November. The beginning and end months are lagged by two months while keeping the duration unchanged. Therefore, for this analysis, enter '2' in the 'Lag (months)'

text box. Click the 'Graph' button to perform the correlation analysis. (The results of the correlation analysis do not depend on the climate index that is selected in the 'Index Name' drop-box; all indices are considered when performing the correlation analysis.)

Within the 'Index Regression' window, choose the site 'Parana' from the drop-box of sites in the upper-left corner. The window should appear as shown in Fig. 1. A list of indices exhibiting the top five highest correlations with the rainfall data using a two-month lag are listed on the left-hand side. Continue the analysis with the radio button next to 'MJO9' selected. A plot of the regression between the PDI and MJO9 is shown on the right. Note that the middle value for the MJO9 on the x-axis is approximately -0.10; this value will be used later. Select other site names and indices to explore how similar or different the correlations are between sites. To fit a regression equation to the data, the data in the plot should be saved as a table by clicking the 'Save as Table' button at the bottom of the window. The data can be saved in a text file, which can then be opened in a spreadsheet program such as Microsoft Excel for further analysis. When finished with the 'Index Regression' window, click the 'Close' button.

To find out more about the various indices that correlate well with the data at the site 'Parana', click the 'Index Name' drop-down box and scroll down until the 'Madden-Julian Oscillation @ 20E or MJO9' index is visible. Select the 'MJO9' index and click the 'Info' button on the right. The window shown in Fig. 2 will appear. Repeat this procedure for other indices of interest. After you are finished, make sure that the 'MJO9' index is selected in the 'Index Name' drop-down box and enter an 'Upper Limit' of -0.10 in the 'Upper Limit' text box. Using the selected climate index (MJO9) and the upper limit that was entered (-0.10), Hydro-FIT will screen the input data and only include data from years when the average August – November MJO9 index value was less than -0.10. The 'Screen Data' window should appear exactly as is shown in Fig. 3; if not, please make the required changes to replicate what is shown in Fig. 3. When ready, click the 'Site Analysis' button to perform the frequency analysis.
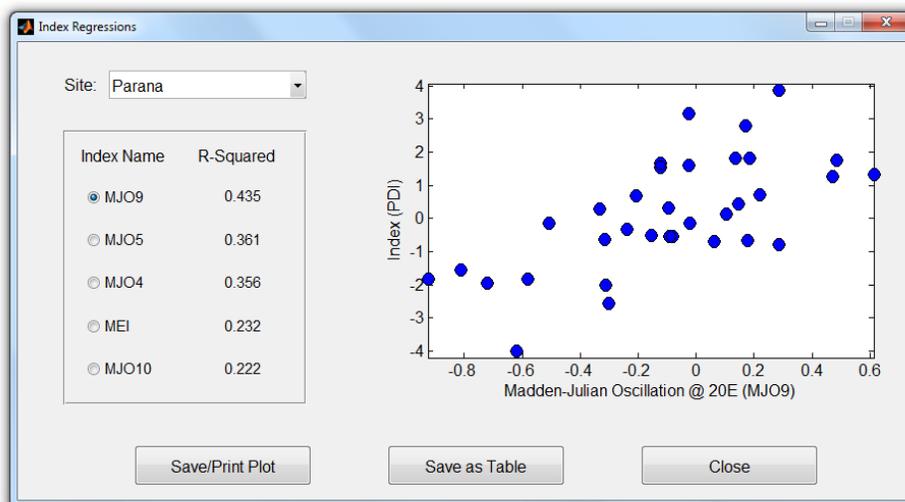

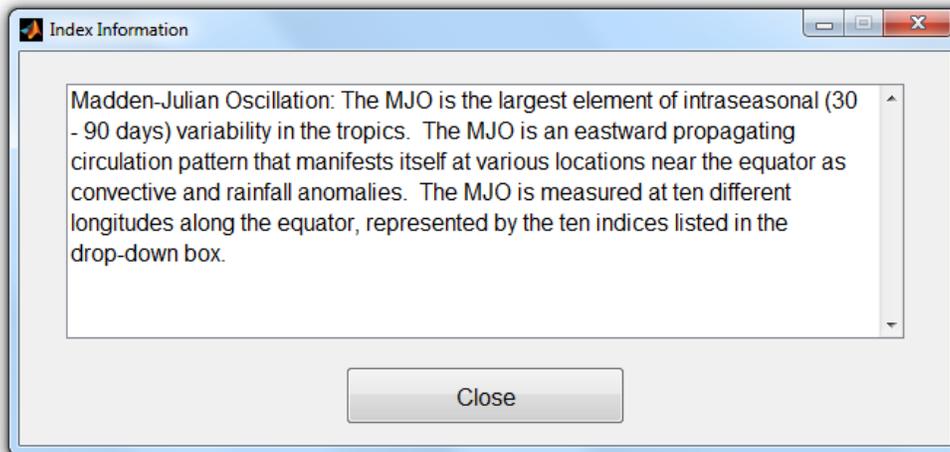Figure 1: Example of the 'Index Regression' window.

Figure 2: 'Index Information' window showing a brief description of the Madden-Julian Oscillation.
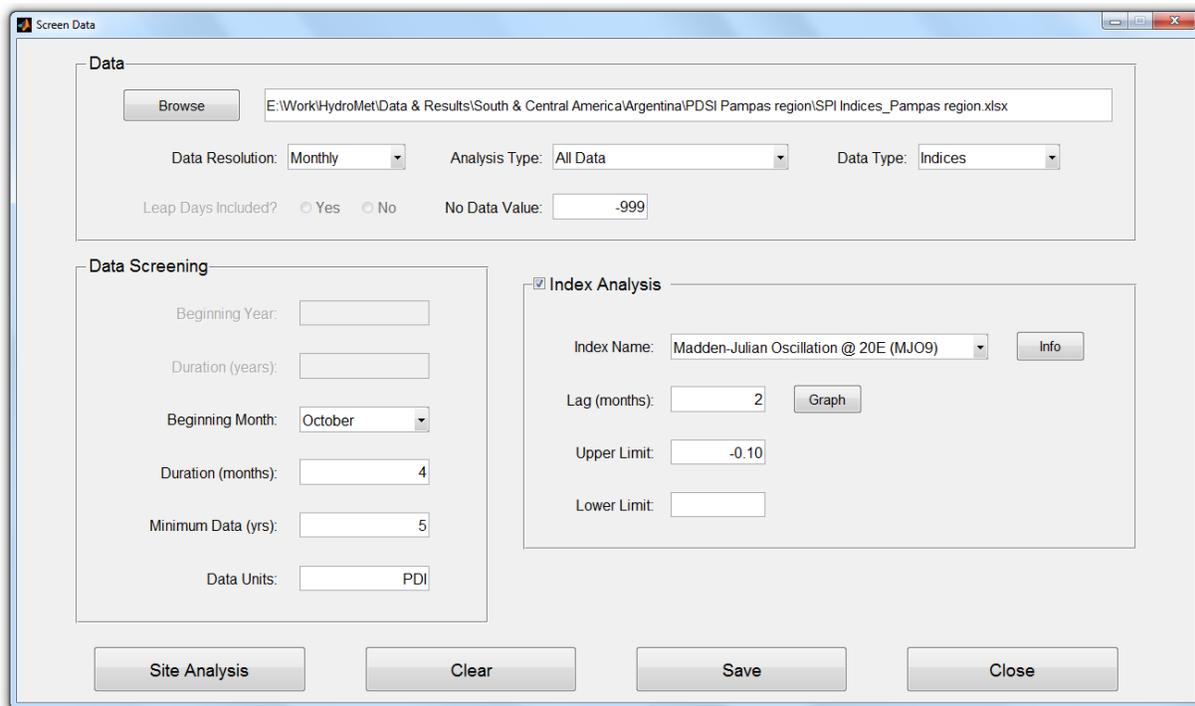

Figure 3: 'Screen Data' window.

Site Frequency Analysis

After the frequency analysis has been completed, the 'Site Analysis' window will appear. As there are several types of results and methods used to display those results within this window, you should become familiar with all the options available. Select the site named 'Parana' from the list of 'Good Sites' in the upper-left corner; the 'Site Analysis' window should now look like the window shown in Fig. 4. The plot in the middle of the window represents a time series of all data for years during which there were no invalid or missing data.   This set of valid data for the selected site is split into those data that meet the 'Index Analysis' criterion set in the 'Screen Data' window (MJO9 < -0.10) and are represented as blue dots, and those data that did not meet the criterion (MJO9 > -0.10) and are represented as gray dots. This plot provides the user with a qualitative assessment as to whether a phase of a climate index can be associated with below-normal or above-normal precipitation during the period chosen in the 'Screen Data' window.
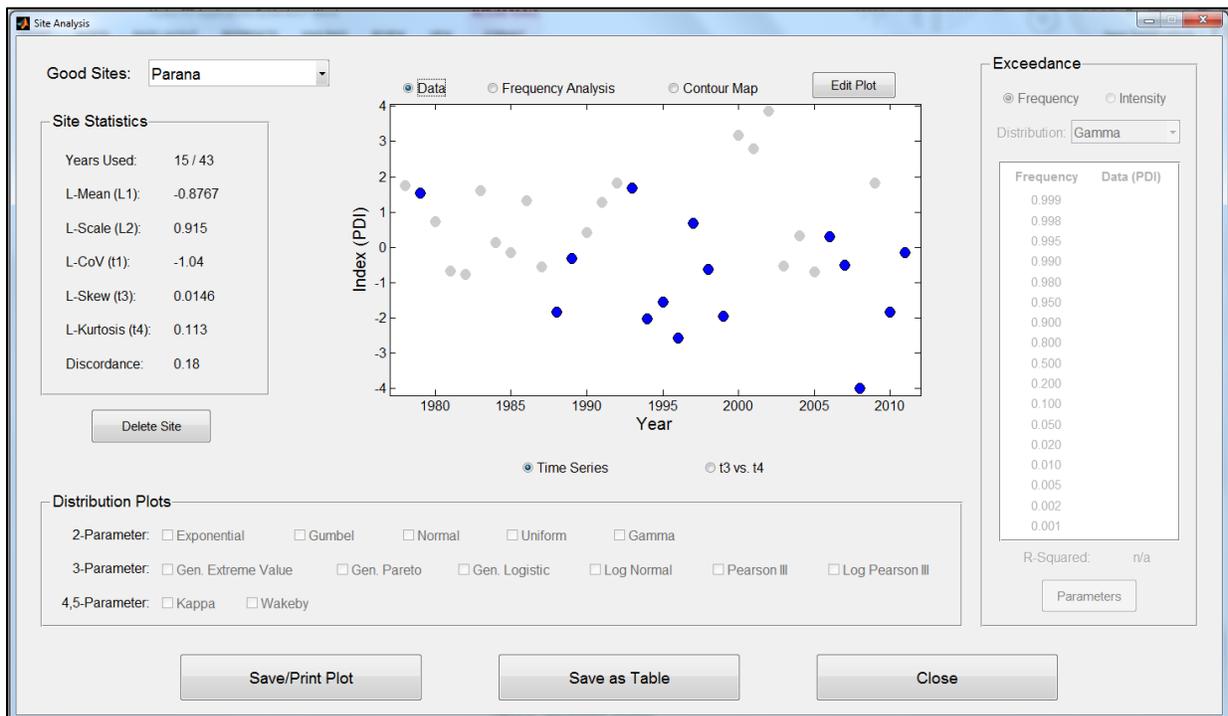

Figure 4: 'Site Analysis' window.

Now click the radio button labeled '*t3* vs. *t4*'. The variables *t3* and *t4* represent the L-Skewness and L-Kurtosis of the rainfall distribution for a site, respectively. An initial indication of the standard distribution that best fits the data for a site can be made using the plot of '*t3* vs. *t4*' (not shown). Each two-parameter distribution is plotted as a point, while each three-parameter distribution is plotted as a curve. The Kappa and Wakeby distributions are not shown because they contain more than three parameters. Notice that all sites are plotted as gray dots, while the selected site (Parana) is plotted as a black dot. Also notice how some sites are plotted closer to the red line (Generalized Pareto or GPA), while others are plotted closer to the black line (Generalized Logistic or GLO), and still others are somewhere in the middle with the possibility of their distribution being described by any of several standard distributions. The site 'Parana' is in the middle close to three different distributions: Normal (NOR), Pearson Type III (PE3), and Generalized Extreme Value (GEV). This gives an initial guess as to which distribution will be chosen to describe the distribution of rainfall at Parana.

Select the radio button labeled 'Frequency Analysis' near the top of the window, and then make sure that the radio button labeled 'PDF' below the graph is selected. Notice that due to the limited period of record of the current dataset, the distribution does not have the typical shape to which we are accustomed. There is also less data because we filtered the original data based on one phase of the MJO9 index. This example merely illustrates the overall process, but when there is limited data as in this case, the conclusions that can be made from an analysis like the current analysis will be limited. Select various distributions to get an idea of how Hydro-FIT attempts to fit the distributions to the data. As there are not sufficient data, the distribution fits of the PDF will not be good; an alternative would be to do a regional frequency analysis, which will be included in Version 2 of Hydro-FIT. Prior to moving on, make sure that the only distributions that are selected are the Normal, Generalized Extreme Value, and Pearson Type III distributions. Select the radio buttons labeled 'Non-Exceedance' and 'Exceedance' to visualize the fits of these three distributions to the two types of group curves. Notice that even though there are few data, the fits are close to the data up to a recurrence interval of 10 years in the case of the non-exceedance curve and 20 years in the case of the exceedance curve. In addition to the three distributions already selected, select the checkbox next to the Gumbel distribution. Notice how the Gumbel exhibits a closer fit on the non-exceedance curve, while the other distributions fit the exceedance curve better.

If it is not already selected, select the radio button labeled 'Frequency' near the top right corner of the window above the 'Frequency' table. Also, select the 'GEV' distribution from the drop-down box. The resulting values shown in the table quantify what is shown in the exceedance and non-exceedance plots. The top half of the table represents exceedance frequencies and their associated rainfall magnitudes. For example, the frequency '0.990' refers to an event that is exceeded in terms of magnitude once every 100 years. In the current analysis, the average PDI (for the period of October – January during years when the average MJO9 for the period of August - November is less than -0.10) will exceed a value of 2.83 on average once in every 100 years. In contrast, the frequency '0.010' refers to an event that is not exceeded in terms of

magnitude once every 100 year. In the current analysis, the average PDI (for the period of October – January during years when the average MJO9 for the period of August - November is less than -0.10) will not exceed a value of -4.45 on average once in every 100 years. Using the current dataset, we should not look beyond the 20-year exceedance and non-exceedance events (frequencies of 0.950 and 0.050, respectively) due to the limited data that is available. Clicking the 'Intensity' radio button above the table reveals the frequencies associated with various magnitudes of rainfall given in terms of multiples of the mean rainfall. This feature is especially useful in agricultural applications. For now, select the 'Frequency' radio button once again and make sure that the 'GEV' distribution is still selected in the distribution drop-box. Click the 'Save as Table' button at the bottom of the screen. Select 'table' from the drop-box as the frequency table is the object we would like to save from the 'Site Analysis' window. (Selecting 'chart' would convert the current plot on the 'Site Analysis' window into a table prior to saving.) Choose a location to save the text file and click 'OK'.

Click the radio button labeled 'Contour Map' above the plot window; a contour plot of the region of interest should appear within seconds. Below the plot window there should be two drop-boxes that allow the user to change the distribution and frequency that are used to create the contour plot. Verify that the selected distribution is the Gumbel distribution and that the selected frequency is 0.95 (20-year exceedance). Click the 'Edit Plot' button at the top of the window; this will open a window from which you can customize the contour plot. Click the checkbox next to 'Markers'. Select the color 'magenta' from the drop-box next to 'Face'. Click 'Apply' at the bottom of the window. Return to the 'Site Analysis' window without closing the 'Edit Plots' window to make sure that all site locations have been plotted on the contour plot. We would like to focus the contour plot on the region in the lower-right portion of the plot. To accomplish this, return to the 'Edit Plots' window and enter -63 and -56 in the x-axis 'Minimum' and 'Maximum' textboxes, respectively, within 'Axis Properties'. Also, enter -39 and -34 in the y-axis 'Minimum' and 'Maximum' textboxes, respectively. Press 'OK' to apply the changes and close the 'Edit Plots' window. The 'Site Analysis' window should appear exactly as is shown in Fig. 5. Select the 'Save/Print Plot' button to save the contour plot. A separate window will appear that contains the contour plot. To save, click the 'Save' icon in the upper-left corner of the window and choose a location and image type. Press 'OK' when you are ready to save.

We would like to compare the results from the different phases of the MJO9. Therefore, close the 'Site Analysis' window by clicking the 'Close' button at the bottom of the screen. The 'Screen Data' window should now be the active window. Delete the value of -0.10 from the 'Upper Limit' textbox and enter the same number in the 'Lower Limit' textbox. While leaving all other options unchanged, click the 'Site Analysis' button. Once the 'Site Analysis' window opens, the change in the location of the sites that meet the specified criterion can be observed. Select the site 'Parana' and choose options like those that were chosen for the prior analysis following the same procedure as described above in order to compare results. When looking at the graph of *t3* vs. *t4*, notice how several sites cluster on the red curve, which represents the Generalized Pareto distribution. Also notice that when looking at the 'PDF' graph, the
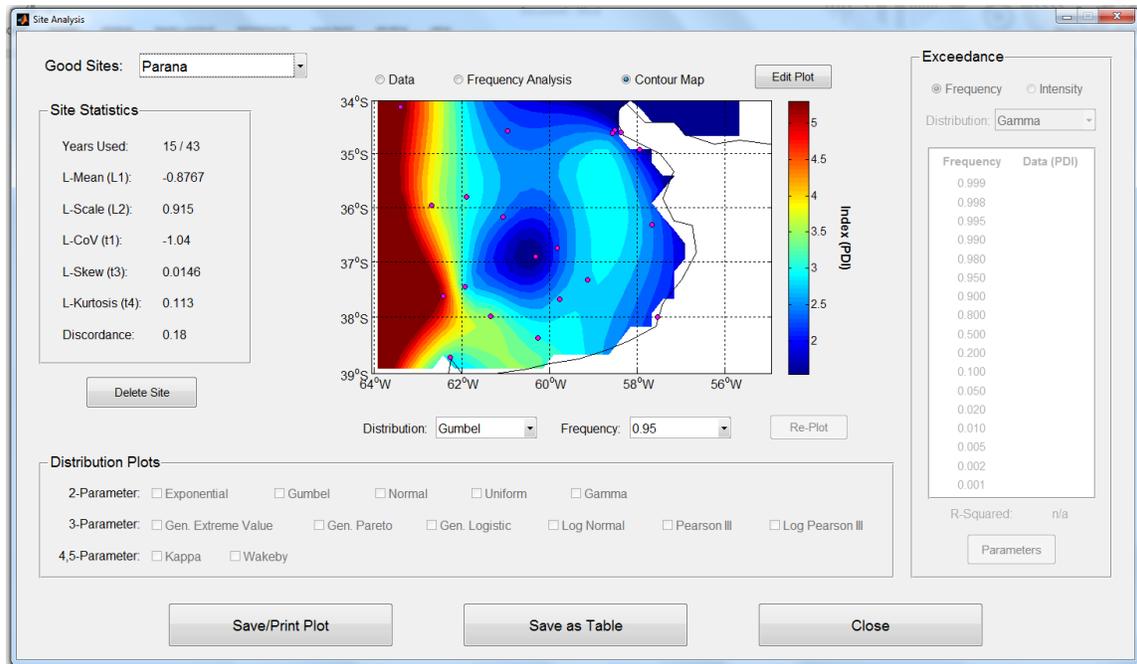
Figure 5: 'Site Analysis' window showing a contour plot with site locations.

Exponential distribution produces the best fit. With the 'Frequency Analysis' radio button above the plot selected, select the Exponential distribution from the 'Distribution' drop-box on the right-side of the window. Save the resulting frequency table and compare to the previously saved table that corresponded to the opposite phase of the MJO9. The tables should appear as shown in Fig. 6.

Summary

As a review of the previous example, Palmer Drought Index (PDI) data were analyzed over central Argentina during the rainy season (October – January) to determine if the data correlated with any of several global climate indices. PDI data from the Parana site were analyzed in more detail and it was found that the PDI at this location during the October – January period correlated to the average August – November intensity of the Madden Julian Oscillation over Africa (MJO9). Time series of the data, PDF graphs, plots of the exceedance and non-exceedance growth curves, and a contour plot of the 20-year event over the region of interest, were created and compared between the two phases of the MJO9. A tabular comparison between the magnitudes of the PDI for various frequencies during the two phases was also performed.

Frequency	Data (mm)
0.999	3.67
0.998	3.47
0.995	3.14
0.990	2.83
0.980	2.45
0.950	1.84
0.900	1.25
0.800	0.52
0.500	-0.91
0.200	-2.27
0.100	-2.95
0.050	-3.48
0.020	-4.07
0.010	-4.45
0.005	-4.78
0.002	-5.18
0.001	-5.45

(a)

Frequency	Data (PDI)
0.999	10.47
0.998	9.35
0.995	7.87
0.990	6.75
0.980	5.63
0.950	4.15
0.900	3.03
0.800	1.91
0.500	0.43
0.200	-0.32
0.100	-0.51
0.050	-0.6
0.020	-0.65
0.010	-0.67
0.005	-0.68
0.002	-0.68
0.001	-0.68

(b)

Figure 6: Tables show exceedance values of the October – January average PDI index for various frequencies when the average August – November MJO9 value is (a) < -0.10 and (b) > -0.10, using the GEV and Exponential distributions, respectively.

Contact Information

Hydro-FIT is being continuously designed and updated by HydroMetriks, Ltd., while keeping in mind the needs of our customers and collaborators. Any comments or suggestions regarding how Hydro-FIT can better fit your needs are welcome. Please feel free to contact HydroMetriks staff at giovanja@live.com or 612-554-6159.