CariCOF 2019 Wet/Hurricane Season - Seasonal Forecast Training Workshop
Simpson Bay, Sint Maarten

21^{st} – 22^{nd} May, 2019

Workshop Report

WORKSHOP REPORT

The 2019 Wet/Hurricane Season pre-CariCOF forecasters' training was held on May 21^{st} and 22^{rd} in Simpson Bay, Sint Maarten, ahead of the Forum held on May 23-24. The CariCOF, including the training workshop, was hosted by the Meteorological Department of Sint Maarten. The training workshop was facilitated by Dr. Cédric Van Meerbeeck, Dr. Teddy Allen and Dr. Roché Mahon of the World Meteorological Organization (WMO) Caribbean Regional Climate Centre (Caribbean RCC) at the Caribbean Institute for Meteorology and Hydrology (CIMH), Dr. Simon Mason of the International Research Institute for Climate and Society (IRI) and Ms. Sarah Diouff the U.S. National Oceanic and Atmospheric Administration (NOAA), and included contributions from Mr. Kenneth Kerr of the Trinidad and Tobago Meteorological Services (TTMS), as well as, Dr. Federico Gómez Delgado of the WMO. It was made possible through CREWS Programme, with financial support from the World Meteorological Organization (WMO). The agenda is found in **Appendix 1**.

Day 1: Tuesday May 21st, 2019 – Quantifying the relationship between extreme wet spell and flash flood occurrence

After a word of welcome from the Director of the Meteorological Department of Sint Maarten, Mr. Joseph Isaac, and opening remarks by Sint Maarten's Secretary of Tourism. the training workshop's objectives were introduced by Dr. Cédric Van Meerbeeck.

Since 2012 and up until 2018, pre-CariCOF training workshops have focused on capacity building of Caribbean National Meteorological and Hydrological Services (NMHSs) in the art of seasonal forecasting at the time scales of 3-12 months and, since 2017 sub-seasonal forecasting. Starting from generic, tercile-based seasonal forecasts of rainfall totals, the diversity of outlook products has grown to include, amongst others, hazard-specific forecasts such as drought, heatwaves, extreme rainfall frequency. The so-called extreme wet spell frequency forecasts were the first product designed to address, by means of a crude, qualitative proxy, flash flood potential in Caribbean countries. Flash flood potential can be simply defined as the hydrometeorological component of flash flood risk, i.e. the hazard probability and impact intensity, and is very closely related to flash flood occurrence.

In taking the work further, the main aim of this workshop was to commence work on developing quantitative forecasts, both at sub-seasonal and seasonal timescale, of flash flood potential. The first day

Collaborators:

was entirely dedicated to some of the critical preparations to enable the research that will back this development. A second aim of the workshop was to introduce participants to updates in the tool utilised for seasonal and sub-seasonal forecasting in the Caribbean, namely the Climate Predictability Tool (CPT), developed and maintained by the IRI. A third aim was to setup a means of monitoring the progress of the Caribbean NMHSs in the delivery of climate services. Finally, as always, the last part of the training workshop was dedicated to a consensus building process to finalise climate outlooks to be presented before plenary at the CariCOF Forum the next day.

To quantitatively forecast flash flood potential, the relationship between extreme rainfall (e.g. extreme wet spells) and flash flood occurrence needs to be assessed. In that regard, a first set of presentations by Dr. Van Meerbeeck and Dr. Teddy Allen, explained participants:
- the Caribbean context of flash floods and their suspected strong relationship with spells of extreme rainfall;
- how CariCOF defines extreme wet spells and how those are calculated from daily rainfall records;
- the proposed approach to quantify the relationship between extreme rainfall and flash flood occurrence.

Quantifying the relationship between extreme wet spell and flash flood occurrence requires extensive and up to date historical records of daily rainfall totals on the one hand. Such records have previously been utilised to define extreme wet spells and, with this workshop in mind, have been updated to include data as recent as early 2019, as well as expanded to include more stations (now counting >65 records from across the region).

On the other hand, extensive and up to date historical records of flash flood occurrence per country were needed and prepared. The Caribbean Climate Impacts Database (CID), which was launched at the 2015 Wet/Hurricane Season CariCOF, has grown to include a dataset of over 9000 individual records of historical climate impacts. While thorough quality control of the dataset is currently in the pipeline, for the purpose of this workshop, only the records of reported floods (flash floods and flooding) were extracted, disaggregated by country, and filtered to remove duplicates, errors and aggregate occurrences on the same date in one country.

Because a large number of statistical calculations were required for the quantification of the relationship between extreme wet spell and flash flood occurrence, Dr. Van Meerbeeck and Dr. Allen had prepared a template EXCEL file in which both datasets were to be ingested and (nearly) all calculations made automatically from there. The choice for EXCEL reflects a consensus preference amongst participants in previous CariCOF training workshops.

In addition, to assist the NMHSs in performing the tasks, Dr. Van Meerbeeck and Dr. Allen prepared a detailed manual that outlined statistical concepts, all steps to be taken in working with the EXCEL templates to arrive at the calculations and an interpretation of the results based on seminal research done on two countries (Barbados and Trinidad). This manual was meant both for the purposes of this workshop, but also as a tool for "train-the-trainers" in which participants to this workshop could take the exercise to their home country and extend the training to more staff within their NMHS. It is therefore made available online on an ftp link. The manual is also provided as an **Appendix 2** to this report.

The second session involved hands-on work by all participants to set up both the extreme wet spells and the flash flood occurrence datasets for their country. This was done to start testing the proposed approach in quantifying the relationship between extreme wet spell and flash flood occurrence.

The first set of tests run before lunch time to quantify the relationship between extreme wet spell involved the calculation of:
- hits (i.e. there was an extreme wet spell at one or more weather stations and there was a coinciding flood event);
- misses (i.e. there was no extreme wet spell, but there was a flood)
- false alarms (i.e. there was an extreme wet spell, but no flood).

The reason why these statistics were calculated is their relation to successful early warning. One desires a forecasting system that has as high a hit-rate and as low miss- and false alarm-rates as possible. A low miss-rate ensures that flash flood potential is identified correctly most of the time. If the miss-rate is only 10%, that means the forecasts would nearly always give out an alert for flash flooding when it occurs. This means a successful early warning. However, a potential problem can be early warning fatigue, in which alerts are frequently given, but they materialise in an impact quite infrequently. In such cases, the audience risks losing interest in the alerts. By consequence, one would aim for the forecasting system to have as high a hit vs. false alarm ration. For example, if this ratio were 80%, that means that for 100 extreme wet spells, 80% resulted in floods (hits), while 20% did not (false alarms). Later in the day, participants would be introduced to an important potential use of the hit vs. false alarm ratio (which will be elaborated on briefly below). A summary of the results per country for all countries for which both daily rainfall data and reported flood occurrence data were available is given in **Appendix 3**.

Preliminary findings amongst participants were that the strength of the relationship as quantified by hits, misses and false alarms varied widely by country. The primary reason is that the size of the record for both rainfall, but especially reported flash floods varied widely from 1 weather station and less than 10 reported floods, to 6 stations or more and up to around 250 reported floods during an overlapping time interval. The second finding was that the false alarm rate was very heavily affected by the suspected underreporting of flood occurrence, as countries with longer records tended to show a higher hit vs. false alarm ratio. The third finding was that, within a country's record, the reporting method appeared to be inhomogeneous throughout the period, leading to artificial increases and decreases in false alarms throughout one country's time series. The fourth important finding was that not all reported floods related to flash floods and may, therefore, not present as strong a relationship with the occurrence of an extreme wet spell (or potentially no relationship at all, in case of coastal flooding associated with storm surges or exceptionally high tides). All in all, the problem often lay more in the incompleteness and temporal inhomogeneity of the flood occurrence record than in the rainfall record. The important implication is that the false alarm rate is expected to be artificially high in and inhomogeneous throughout a country's timeseries.

After lunch, a second and third set of tests were run, involving the calculation of a frequently utilised, but in this case inappropriate, correlation measure (i.e. the Pearson's correlation coefficient) and the associated R-squared score used to quantify the percentage of variance explained (in this case how many of the flash floods are explained by the occurrence of extreme wet spells). The inappropriateness was quickly suspected by the participants, as correlation values appeared to be much lower than anticipated. In essence, this exercise served as a caution in quantifying the strength of statistical association between two datasets using the most common statistic. However, the correlation calculations were not meant to be further utilised. That said, Dr. Federico Gómez Delgado (WMO) brought his hydrological and statistical expertise forth and suggested an alternative approach to calculating correlation in an appropriate manner. Such work would potentially be explored at a later date, not to delay the progress of this workshop.

The third set of tests consisted of finding out if a simple linear model of flash flood potential could be constructed using the occurrence of extreme wet spells as the explanatory variable. The model is as follows:

flash flood potential during a period = H/FA x the number of extreme wet spell during that period

where H/FA is the hit vs. false alarm ratio.

Earlier, it was mentioned that successful early warning would require a high hit vs false alarm ratio as well as a low miss-rate. The hit vs. false alarm ratio can be utilised as a coefficient allowing for extreme wet spell occurrence to be utilised as a quantitative proxy for flash flood potential. This ratio needs to be acceptably high for stakeholders requiring the forecast information. This is mainly to avoid early warning fatigue as well as unnecessary resource mobilisation to mitigate the impacts of flash floods which were alerted, for but did not materialise. For instance, if a stakeholder accepts a ratio of at least 20% that would mean that at least one out of five extreme wet spells leads to a flood event in their area. Once acceptable, the proposed linear model offers the opportunity to forecast flash flood potential that is based on a model requiring daily rainfall data only.

The simplicity combined with the efficacy (if the ratio is sufficiently high and the miss-rate sufficiently low) of such a linear model makes it a very attractive candidate for forecasting purposes within the context of CariCOF, since seasonal extreme wet spell frequency forecasts are already provided. However, false alarm rates may be artificially high for reasons mentioned above and primarily because the flood record contains only reported floods. This lowers the hit vs. alarm ratio too much to enable the use of the proposed simple linear model, unless techniques are employed to increase the ratio. The second, third and last sessions of the first day therefore focused on a number of such techniques. In conclusion, the participants saw the timeliness and need for, and therefore **recommended further research to optimise the definition of**

extreme wet spells and statistics calculations so as to reach hit vs false alarm ratios that are as high and as homogeneous as possible to enable the formulation of acceptable models for flash flood potential.

Day 2: Wednesday May 22nd, 2019 – CPT upgrades and preparation of the 2019 Wet/Hurricane season climate outlooks

During the first session on the second day of the training workshop, Dr. Simon Mason presented a number of important updates in the upcoming version 16 of CPT. Among those updates are an improved method for missing values estimation, which particularly benefits regions such as the Caribbean where the number of incomplete weather records is large. A second major update is that CPT 16 caters to users who wish to downscale ensembles of global model seasonal forecasts in single experiments, rather than just using one model per experiment. This follows a global trend in improved forecasting through the use of model ensembles. A third major update, which is necessary to enable sub-seasonal forecasting within CPT, is the ability to read in daily records of given variables and compute statistics based on those, rather than only monthly or seasonal records.

After the morning break, Dr. Roché Mahon and Mr. Kenneth Kerr presented on the regional, and Trinidad's progress in the roll out of their climate services agenda across the five pillars of the Global Framework for Climate Services. In addition, Dr. Mahon presented a proposal to enable NMHSs to efficiently monitor their progress over time. Dr. Mahon suggested monitoring activities to be tied to CariCOF or other platforms in future. Her presentation was followed by round-table discussions in which some of the challenges were addressed, e.g. 1. Who is responsible for such monitoring? 2. Shouldmonitoring reports bebe prepared for presentation at the Caribbean Meteorological Organisations (CMO) Annual Board Meetings? 3. What about the countries that are not CMO members? Dr. Mahon took note of all the mentioned concerns and suggestions and would work on furthering the proposal taking those into account.

This session continued with an unscheduled presentation by Mr. Kerr on the Trinidad floods of October 2018, which presented the participants with the early warning information provided ahead of and during the occurrence, as well as a pictorial overview of impacts, damage and losses incurred during the "Mother of All Floods" in Trinidad.

After lunch, Dr. Gómez Delgado made a presentation on "**Seasonal Hydrological Prediction** in WMO Regional Association IV", including inputs from, amongst others, Mr. Kerr (TTMS). The example of Trinidad's activities in hydrological prediction focused on seasonal to sub-seasonal rainfall and rainfall exceedance forecasts and Caroni Reservoir projections. Then, Dr. Gómez Delgado presented on Central American efforts in seasonal precipitation forecasting through the Central American Climate Outlook Forum (CACOF) and seasonal discharge forecasting through the Central American Hydrological Outlook Forum (CAHOF). He concluded his presentation with an introductory description of WMO's Global Hydrological Status and Outlook System (HydroSOS) system. This presentation was made to poll the interest of Caribbean NMHSs in the generation of seasonal to sub-seasonal hydrological predictions. A majority of NMHSs represented echoed Trinidad and Tobago's interests and an ensuing brief discussion tackled some common challenges and opportunities if moving forward with an agenda similar to the CAHOF or Trinidad and Tobago's hydrological prediction capacity building. This poll, in turn, was a first means to gauge the interest of the Caribbean in general, and it was **recommended that such potential agendas be presented to CariCOF plenary during the 2019 Dry Season CariCOF in November 2019, when the focus will be on agriculture and water, and a larger contingent of water management stakeholders could be polled.**

The last session of the training workshop, as has become customary for pre-CariCOF Forum forecasters' training workshops, concerned the preparation and review of all CariCOF outlook products for the 2019 wet/hurricane season, such that a consensus is reached between all climate forecasters within the Caribbean NMHSs and CIMH. The outlooks were summarised in a presentation that follows the template for RCOF/NCOF (National Climate Outlook Forum) type climate outlooks developed by CIMH. A first this time around, was the inclusion of sub-seasonal forecasts for weeks 1 and 2 and monthly forecasts for June, July, August, September and October provided by the US Regional Climate Centre (RCC-Washington) and presented by Ms. Diouf (NOAA).

APPENDIX 1 – Workshop Agenda

CariCOF 2019 Wet/Hurricane Season - Seasonal Forecast Training Workshop
Sint Maarten

21st – 22nd May, 2019

Day 1: Tuesday May 21st, 2019 – Quantifying the relationship between extreme wet spell and flash flood occurrence

09:00 – 09:20 Opening and welcome remarks (Met Service of St. Maarten, CIMH)

09:20 – 09:30 Workshop objectives (Cedric Van Meerbeeck, CIMH)

09:30 – 09:50 Extreme rainfall and flash floods – what is the Caribbean context? (Teddy Allen and Cedric Van Meerbeeck, CIMH)

09:50 – 10:05 Extreme wet spells calculations – a regional update up to 2018 (Teddy Allen, CIMH)

10:05 – 10:15 Flash floods and flooding in the Caribbean Climate Impacts Database (Cedric Van Meerbeeck, CIMH)

10:15 – 10:30 *Break*

10:30 – 11:00 Downloading and reviewing the extreme wet spells and flash floods/floods time series for each country – hands-on

11:00 – 11:45 Quantifying the relationship between extreme wet spell and flash flood occurrence: hits, misses and false alarms – demonstration (Cedric Van Meerbeeck and Teddy Allen, CIMH)

11:45 – 12:30 Quantifying the relationship between extreme wet spell and flash flood occurrence: hits, misses and false alarms – hands-on

12:30 – 13:30 *Lunch (provided)*

13:30 – 14:00 Quantifying the relationship between extreme wet spell and flash flood occurrence: correlation – demonstration (Cedric Van Meerbeeck and Teddy Allen, CIMH)

14:00 – 15:15 Quantifying the relationship between extreme wet spell and flash flood occurrence: correlation – hands-on

15:15 – 15:30 *Break*

15:30 – 16:00 Quantifying the relationship between extreme wet spell and flash flood occurrence: a simple linear model – demonstration (Teddy Allen and Cedric Van Meerbeeck, CIMH)

16:00 – 17:00 Quantifying the relationship between extreme wet spell and flash flood occurrence: a simple linear model – hands-on

Day 2: Wednesday May 22nd, 2019 – CPT upgrades and preparation of the 2019 Wet/Hurricane season climate outlooks

09:00 – 10:15 New functionalities of CPT16 – S2S, multi-model ensembles and missing values treatment (Simon Mason, IRI)

10:15 – 10:30 *Break*

10:30 – 12:15 Monitoring NMHS climate service delivery (Roché Mahon, CIMH)

12:15 – 13:30 *Lunch (provided)*

13:30 – 14:00 Development and production of seasonal hydrological predictions within the context of the Regional Hydrological Outlook Forum of Central America (Federico Gómez-Delgado, WMO)

14:00 – 15:15 Preparing the 2019 Wet/Hurricane Season climate outlooks – all

15:15 – 15:30 *Break*

15:30 – 16:45 Preparing the 2019 Wet/Hurricane Season climate outlooks – reaching a consensus

16:45 – 17:00 Closing Remarks (Adrian Trotman, CIMH)

END OF WORKSHOP

APPENDIX 2 – Quantifying the relationship between extreme wet spells and flash floods in the Caribbean

Collaborators:

Quantifying the relationship between extreme wet spells and flash floods in the Caribbean

A CariCOF exercise – May 2019

Prepared by Cedric Van Meerbeeck and Teddy Allen

Collaborators:

for the 2019 Wet/Hurricane Season pre-CariCOF training for NMHSs

Caribbean Institute for Meteorology and Hydrology

Quantifying the relationship between extreme wet spells and flash floods in the Caribbean

A CariCOF exercise – May 2019

FOCUS:
The focus of the first day of the CariCOF training in St. Maarten on 21 May 2019 is to start quantifying the relationship between the occurrence of extreme wet spells (as per the CariCOF definition of a 3-day period with rainfall totals above the 99^{th} percentile at a given station) and (flash) flood occurrence.

AIM:
For as many Caribbean territories as possible, establish the strength of extreme wet spells occurrence as a predictor for flash flood occurrence. In other words, to build a predictand set of flash flood potential (= the climate determinants of flash floods). I will elaborate on this in a subsequent e-mail later today.

METHODOLOGY:
To enable such investigation, daily rainfall records (to calculate extreme wet spells ahead of the workshop), and a dataset containing past occurrences of flooding/flash floods from your countries are distributed. The methodology and calculations have been tested prior to the workshop using data from Trinidad and from Barbados, two countries with at least a sizeable flood occurrence dataset.

Collaborators:

EXCEL EXERCISES

****Make sure to regularly save the files you are working in.****

1. Map the occurrences of extreme wet spells and flash floods/short-term flooding events

Extreme wet spells: from a daily rainfall record, a time series of the count of extreme wet spells will be calculated (in the file **3d-wetspell-floods-template.xlsx**)

Flash floods: from a table of country and location specific (but not geo-referenced) flash flood/short-term flooding events taken from the CID, a country time series of floods will be produced (ahead of the CariCOF, see sample file for Trinidad – **floods_Trinidad.xlsx**)

Both records will then be brought side by side to map the both sets of events.

INSTRUCTIONS:

Start by opening the following files in EXCEL:

- the template file in which all calculations will be made: **3d-wetspell-floods-template.xlsx**

- your country's daily rainfall record as available at CIMH: **daily_rainfall_[Country name].xlsx**

- your country's reported flood occurrence record as found in the Caribbean Climate Impacts Database as of May 2019: **floods_[Country name].xlsx**

Preparing the rainfall data:

The daily rainfall data in **daily_rainfall_[Country name].xlsx** should be in the CPT format for daily data:

xmlns:cpt=http://iri.columbia.edu/CPT/v10/				
cpt:field=dailyprecip, cpt:nrow=18352, cpt:ncol=2, cpt:row=T, cpt:col=station, cpt:units=proportion, cpt:missing=-99				
			CIMH	**GAIA**
cpt:X			-59.624	-59.485
cpt:Y			13.148	13.08
1969	1	1	0.3	-99
1969	1	2	0	-99

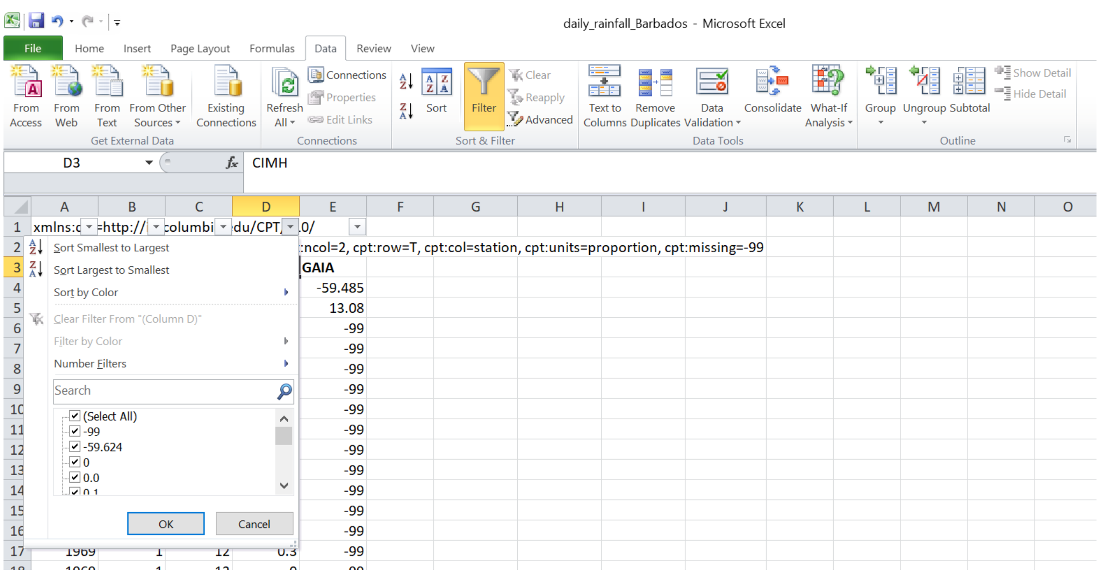
Rainfall is in mm. **Missing values** may either be assigned the value **-99**, or a similar **negative value**, or are simply **blank**. **Trace** values, if any, may be assigned either **Tr** or **0**.

Before copying the data into the template file for calculations, make sure that:

1) all **missing values** are set to **blank**;

2) any **Tr** value is set to **0**.

The quickest way to find out where such changes are necessary is by filtering the data. To do so, click on the cell containing the name of any station, then go in the menu to data -> Filter.



How to reassign values using the filter function?

i) When you click on the triangle in the cell on line one and the column in which your selected station is (in the screenshot: D1), you will see a list of all values found in that column.

ii) Scroll to find out if any **Tr**, **-99** or any suspicious values are correctly reassigned.

iii) If there are any such, first untick the mark next to select all, then tick the value you need to reassign and click OK.

iv) Make the necessary change (e.g. replace all **-99** values by blank, in other words, simply delete all -99s) for that value across all selected cells.

v) Click on the filter triangle (in the screenshot in cell D1), tick the mark for (Select All) and click OK.

vi) Repeat this for any other remaining values that need to be reassigned until the data is ready.

Inserting the rainfall data in the template file:

First, if you have more than 1 station in the daily rainfall file, you will need to rank them by completeness and quality of the record, as Station 1 (**Stn. 1**) and Station 2 (**Stn. 2**) will have to be the best and most representative stations for your country.

Second, if you use more than 2 stations, the template file accommodates for up to 6 stations. Important notes: 1) the calculations using at least 3 stations will be performed in the "calculations 6 stn." tab of the template file; and 2) the trainers can offer some assistance if you wish to use more than 6 stations.

Once you ranked your stations, order the station records accordingly from left to right in your daily rainfall file and save.

	A	B	C	E	F	G	H	I	J	L	M	N	O
2				[Name Stn. 1]	[Name Stn. 2]	[Name Stn. 3]	[Name Stn. 4]	[Name Stn. 5]	[Name Stn. 5]				
3				Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Floods	Flood location		
4	cpt:X			[lon stn. 1]	[lon stn. 2]	[lon stn. 3]	[lon stn. 4]	[lon stn. 5]	[lon stn. 6]	All	Localised	Widespread	Unspecified
5	cpt:Y			[lat stn. 1]	[lat stn. 2]	[lat stn. 3]	[lat stn. 4]	[lat stn. 5]	[lat stn. 6]	0	0	0	0
6	1969	1	1										
7	1969	1	2										
8	1969	1	3										
9	1969	1	4										
10	1969	1	5										
11	1969	1	6										
12	1969	1	7										
13	1969	1	8										
14	1969	1	9										
15	1969	1	10										
16	1969	1	11										
17	1969	1	12										
18	1969	1	13										
19	1969	1	14										
20	1969	1	15										
21	1969	1	16										
22	1969	1	17										
23	1969	1	18										
24	1969	1	19										
25	1969	1	20										
26	1969	1	21										
27	1969	1	22										
28	1969	1	23										

daily RR & flood data / Statistics & Scores / monthly records & correlations / Seasonality / Annual time series

Ready

Now the stations are ordered, you can insert them into the template file as follows:

1) Go to the **daily RR & flood data** tab and enter the names of the stations as per the order you gave them in your daily rainfall data files in cells E3 to J3 for as many stations as you have. If there are less than 6, there is no need to change anything in the additional columns.

2) Copy and paste the longitudes, latitudes and daily values.

	A	B	C	D	E	F
1	xmlns:cpt=http://iri.columbia.edu/CPT/v10/					
2	cpt:field=dailyprecip, cpt:nrow=18352, cpt:ncol=2, cpt:row=T,					
3				CIMH	GAIA	
4	cpt:X			-59.624	-59.485	
5	cpt:Y			13.148	13.08	
6	1969	1	1	0.3		
7	1969	1	2	0		
8	1969	1	3	0.5		
9	1969	1	4	0		
10	1969	1	5	0.5		
11	1969	1	6	0		
12	1969	1	7	3.6		
13	1969	1	8	0.3		
14	1969	1	9	0		

			CIMH	GAIA	[Name Stn. 3]	[Name Stn. 4]	[Name Stn. 5]	[Name Stn. 5]				
			Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Floods	Flood location		
cpt:X			-59.624	-59.485	[lon stn. 3]	[lon stn. 4]	[lon stn. 5]	[lon stn. 6]	All	Localised	Widespread	Unspecified
cpt:Y			13.148	13.08	[lat stn. 3]	[lat stn. 4]	[lat stn. 5]	[lat stn. 6]	0	0	0	0
1969	1	1	0.3									
1969	1	2	0									
1969	1	3	0.5									
1969	1	4	0									
1969	1	5	0.5									
1969	1	6	0									
1969	1	7	3.6									
1969	1	8	0.3									
1969	1	9	0									
1969	1	10	0									

3) save the template file as **3d-wetspell-floods-[Country name].xlsx**

Preparing the flood data:

As you will have seen, the **daily RR & flood data** tab in your **3d-wetspell-floods-[Country name].xlsx** file has four columns reserved for flood data that you will need to enter using the **floods_[Country name].xlsx** file.

Go to your flood record file, which should look like this:

	A	B	C	D	E	F	G
1	Event	Country	Island	Parish	Location	Date	Local/Widespread/Unknown
2	FLOOD	Barbados		St. Lucy		7/5/1901	L
3	FLOOD	Barbados		St. Michael, St. George, St. Philip, St. Thomas, St. Peter, St. James		8/20/1901	W
4	FLOOD	Barbados		St. George		6/30/1905	L
5	FLOOD	Barbados		St. Andrew, St. Thomas, St. Peter		12/25/1917	W
6	FLOOD	Barbados		St. Michael		8/25/1919	L

This flood record file is a post-processed subset of the dataset behind the Caribbean Climate Impacts Database (CID) which, to date, contains over 9000 reported climate impacts from across the region. Should you wish to find out more on the CID, do not hesitate to ask CIMH staff.

You will note that the flood reports are not georeferenced. Instead, the location (in some cases possibly down to the address level) is given. Recognising that some countries consist of multiple islands and may be subdivided in parishes/corporations/districts/etc., separate columns are included for Island, Parish and Location.

Most reported floods are given a specific date, while others (in some countries) may span several dates. These dates are reported dates and therefore may not always represent the exact timing or duration of the flood. Also, in the post-processing, some floods on successive dates have been aggregated if, at the parish level, different floods were reported on the successive dates. Likewise, different reported flood locations on the same date have been aggregated into 1 reported flood spanning all these locations. For the purposes of this exercise, aggregation of locations has primarily been done at the parish level, when available. This is under the assumption that a Met station with daily rainfall may be representative of rainfall in an area broader than just its location. This is a necessary assumption as no country has met stations in all individual locations in the country. For these reasons, CIMH does not and cannot guarantee that this aggregation is entirely accurate. Rather, countries are invited to verify the quality of the aggregation, should they choose to.

The last column (**column G**) contains a differentiation of the scale of the reported floods into widespread, local or unknown/unspecified:

- Unspecified or unknown (**U**) is for cases where no specifications are given at least at the parish level (i.e. no information regarding location is given or, in case of larger countries, only an indication such as northwestern Trinidad).

- Local (**L**) is when a flood was reported in 1 or a couple of adjacent locations, whether or not in the same parish/corporation/district (but not when in more than 2 parishes).

- Widespread (**W**) is when a flood was reported in 2 or more parishes or, if addresses are given, the flood was reported in a number of addresses in each of 2 parishes.

This may not be the most appropriate way of aggregating reported floods. If you feel it isn't, please raise the matter when discussing your results.

Here are the steps to enter the reported flood data into the template:

1) Find all records that lie within the period of record for daily rainfall. In this example, this means any flood from 1969 onwards.

2) Look at the first record within that period and capture the date and whether it is a **L**, **W** or **U**.

10	FLOOD	Barbados	St. Michael	9/30/1944	L
11	FLOOD	Barbados	St. Michael	8/21/1949	L
12	FLOOD	Barbados	St. Andrew, St. John, St. Joseph	10/2/1970	W
13	FLOOD	Barbados	St. Michael	10/30/1977	L
14	FLOOD	Barbados	Islandwide	8/3/1980	W

3) In your **3d-wetspell-floods-[Country name].xlsx** file, search for the relevant date and look for the appropriate column given whether the flood was **L**, **W** or **U**. For that date, enter a **1** in column L.

I646 St. Andrew, St. John, St. Joseph

	A	B	C	D	E	F	G	H	I	J	K	L
644	1970	9	30	8.9								
645	1970	10	1	175.3								
646	1970	10	2	211.1			1		St. Andrew, St. John, St. Joseph			
647	1970	10	3	36.1								
648	1970	10	4	72.9								
649	1970	10	5	25.7								
650	1970	10	6	26.4								

4) In the same row cell, simply enter the location(s) of the flood, preferably the parish(es) in the appropriate column **M**, **N** or **O** (i.e. **Local** / **Widespread** / **Unspecified**). If the flood is widespread, but no information on the parishes were given, use whichever is available, prioritising the larger scale (e.g. if only southwest Barbados was given in the Parish column and Broad Street, Bridgetown in the Location column, use southwest Barbados.

5) Move on to the next reported flood and repeat until all reported floods falling within the daily rainfall period of record are entered.

6) Save your **3d-wetspell-floods-[Country name].xlsx** file.

Now the top of the **daily RR & flood data** tab should look like this:

			CIMH	GAIA	[Name Stn. 3]	[Name Stn. 4]	[Name Stn. 5]	[Name Stn. 5]				
			Stn. 1	**Stn. 2**	**Stn. 3**	**Stn. 4**	**Stn. 5**	**Stn. 6**	**Floods**	**Flood location**		
cpt:X			-59.624	-59.485	[lon stn. 3]	[lon stn. 4]	[lon stn. 5]	[lon stn. 6]	**All**	**Localised**	**Widespread**	**Unspecified**
cpt:Y			13.148	13.08	[lat stn. 3]	[lat stn. 4]	[lat stn. 5]	[lat stn. 6]	**32**	**13**	**17**	**2**
1969	1	1	0.3									
1969	1	2	0									
1969	1	3	0.5									
1969	1	4	0									
1969	1	5	0.5									

Mapping the extreme wet spells and floods:

The **3d-wetspell-floods-template.xlsx** file has been created so that nearly all calculations will automatically be performed in the other tabs. This means that, now your **3d-wetspell-floods-[Country name].xlsx** file contains rainfall and flood data, the remainder of the exercise is mostly understanding the calculations and interpreting the results, statistics and scores.

Most of the calculations are done in the following tabs, which shall be referred to as the **four calculation tabs**:

- **calculations stn. 1**: the necessary calculations to obtain scores such as hits, misses and false alarms as we compare the flood occurrences with the extreme wet spell occurrences using daily rainfall for your station 1 only.

- **calculations stn. 2**: same as the above, but for station 2 only.

- **calculations 2 stn.**: same as the above, but scores are calculated using the occurrences of extreme wet spells at station 1 or station 2.

- **calculations 6 stn.**: same as **calculations 2 stn.** but for up to 6 stations.

In terms of mapping the extreme wet spells and floods together, there is a tab of relevance in **3d-wetspell-floods-template.xlsx** (plus two that will require just a few extra steps to produce):

1) **monthly records & correlations**: this provides a monthly record of the occurrence of extreme wet spells as based on one station, two stations (one or the other, or both combined), or up to 6 stations combined. It also provides a monthly record of all floods as well as the widespread floods only. It further provides the calculations on correlation (see exercise 3).

Monthly extreme wet spell (99th* perc.) and flood counts

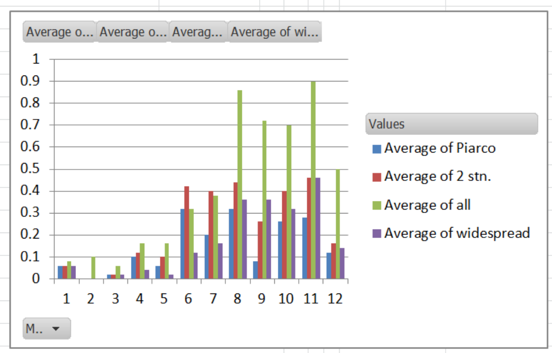
	Year	Month	CIMH	GAIA	2 stn.	6 stn.	all	widespread
			extr. wet spells				floods	
500	2010	4	0	0	0	0	0	0
501	2010	5	0	0	0	0	0	0
502	2010	6	0	1	1	1	0	0
503	2010	7	0	0	0	0	0	0
504	2010	8	0	0	0	0	0	0
505	2010	9	2	1	3	3	0	0
506	2010	10	2	2	2	3	1	0
507	2010	11	0	0	0	0	0	0
508	2010	12	0	0	0	0	0	0
509	2011	1	0	0	0	0	0	0
510	2011	2	0	0	0	0	0	0
511	2011	3	0	0	0	0	0	0
512	2011	4	1	1	1	1	1	0
513	2011	5	0	0	1	1	0	0
514	2011	6	0	0	0	0	0	0
515	2011	7	0	0	0	0	0	0
516	2011	8	0	0	0	0	0	0
517	2011	9	0	0	0	0	0	0
518	2011	10	1	0	1	1	0	0
519	2011	11	0	1	1	1	0	0
520	2011	12	0	0	0	0	0	0

Statistics & Scores | monthly records & correlations | Seasonality | Annual time series | calcu

2) **Seasonality** (to be recreated with your country's specific data): this tab contains a so-called pivot table, which is nothing but a summary of your monthly records in the **monthly records & correlations** tab by averaging the monthly counts over all years of the record. In essence, this is a tabulated, monthly climatology of the seasonality of extreme wet spells and flood occurrences. This climatology is also plotted in a graph.

The existing tab is based on Trinidad data and looks like this:

Row Labels	Average of Piarco	Average of 2 stn.	Average of all	Average of widespread
1	0.06	0.06	0.08	0.06
2	0	0	0.1	0
3	0.02	0.02	0.06	0.02
4	0.1	0.12	0.16	0.04
5	0.06	0.1	0.16	0.02
6	0.32	0.42	0.32	0.12
7	0.2	0.4	0.38	0.16
8	0.32	0.44	0.86	0.36
9	0.08	0.26	0.72	0.36
10	0.26	0.4	0.7	0.32
11	0.28	0.46	0.9	0.46
12	0.12	0.16	0.5	0.14
Grand Total	**0.151666667**	**0.236666667**	**0.411666667**	**0.171666667**

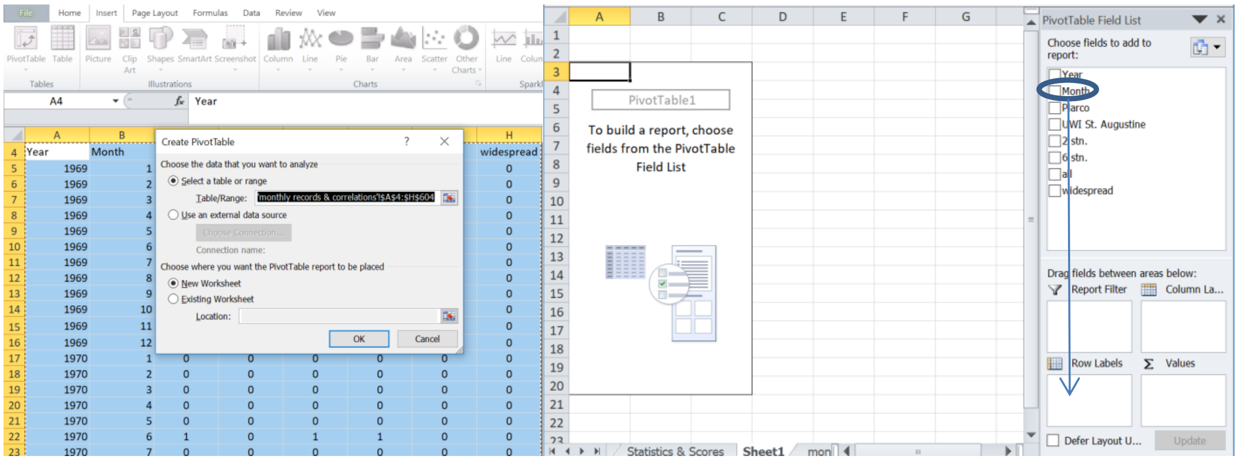


**This table contains precalculated results using Trinidad data. Scores will need to be recalculated for any other country.
Calculations involve manually changing the threshold for extreme wet spells in the tabs of interest

You can reproduce such results for your country this way:

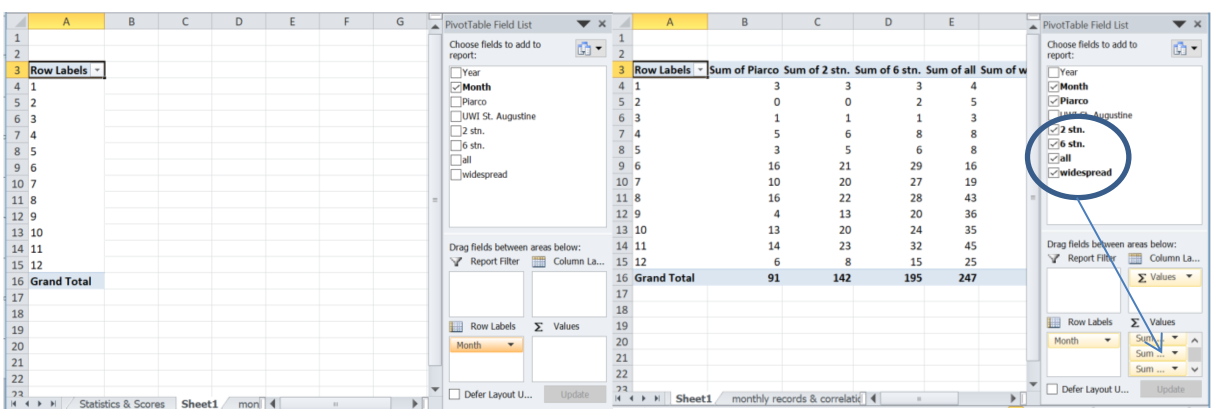
1) Go to your **monthly records & correlations** tab and select columns A to H starting from row 4 and down till the bottom of your record (*in this case down to December 2018, i.e. row 604*), including the names of the records (row 4) and the actual data (*rows 5 to 604*).

2) In the menu, go to Insert -> PivotTable and the below (left) window should pop up, in which you will simply click OK. Then the below (right) tab will be generated.



3) to create a Pivot Table of the monthly averages of extreme wet spell and flood occurrences, click and drag **Month** from **Choose fields to add to report** in the PivotTable Field List on the right and drop it into the box called **Row Labels**. The picture below (left) shows what pops up in your **Sheet 1** tab.

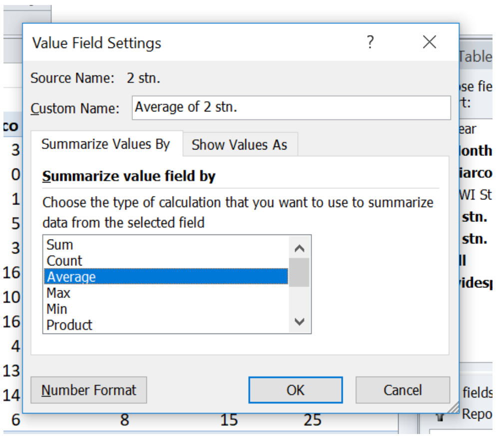
4) Then drag the following items into the Σ **Values** box: **[your Station 1** or **Station 2]**, **2 stn.**, **6 stn.**, **all** and **widespread**. By default, the sum of all values is calculated for each month as shown in the screenshot below (right).



5) to show the average per month instead of the sum, do the following for each of the elements now in the Σ **Values** box:

i) click on the inverted triangle and, subsequently on Value Field Settings.

ii) in the pop-up window, select in **Summarize value field by:** the option **Average** and click OK.

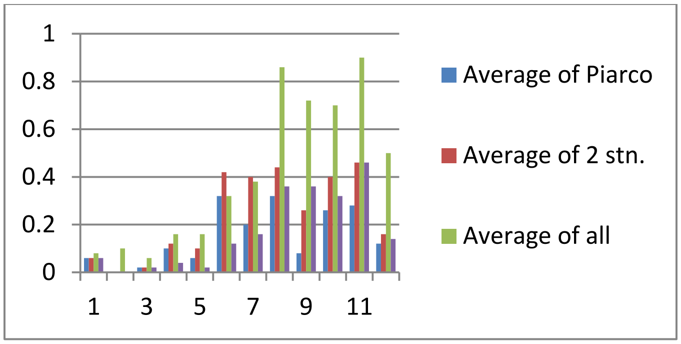


The result looks as follows:

Row Labels	Average of Piarco	Average of 2 stn.	Average of 6 stn.	Average of all	Average of widespread
1	0.06	0.06	0.06	0.08	0.06
2	0	0	0.04	0.1	0
3	0.02	0.02	0.02	0.06	0.02
4	0.1	0.12	0.16	0.16	0.04
5	0.06	0.1	0.12	0.16	0.02
6	0.32	0.42	0.58	0.32	0.12
7	0.2	0.4	0.54	0.38	0.16
8	0.32	0.44	0.56	0.86	0.36
9	0.08	0.26	0.4	0.72	0.36
10	0.26	0.4	0.48	0.7	0.32
11	0.28	0.46	0.64	0.9	0.46
12	0.12	0.16	0.3	0.5	0.14
Grand Total	**0.151666667**	**0.236666667**	**0.325**	**0.411666667**	**0.171666667**

Change the name of the tab from **Sheet 1** to **Seasonality**. Once you've done this, save your file.

The next step is to create the accompanying graph. To do so, select only the rows from month 1 to 12 in the PivotTable, then go to Insert -> Column. Click on the first option (clustered column under 2-D Column). The resulting graph then shows the average number of extreme wet spells and floods per category (Stn. 1, 2 Stn., 6 Stn., all [floods] and widespread [floods]).



Save your file.

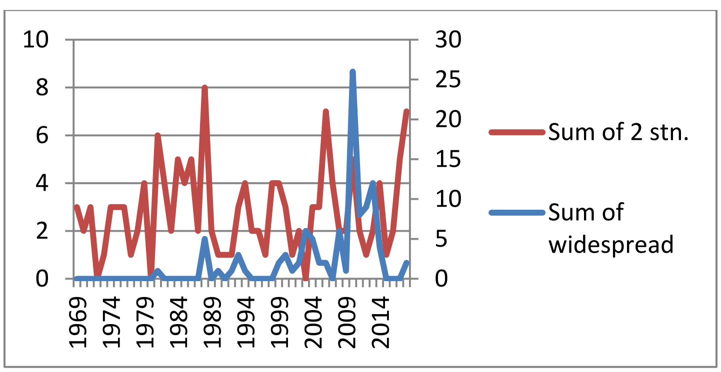
2) **Annual time series** (to be recreated with your country's specific data): this tab contains a pivot table containing annual sums of extreme wet spells (based on 2 stations) and annual sums of widespread floods, which are calculated from the **monthly records & correlations** tab by summing the monthly counts per year. The procedure is essentially the same as for the Seasonality, except for the following points:

i) after creating your Pivot Table, drag **Year** into the box called **Row Labels**.

ii) Then drag the following items into the Σ **Values** box: **2 stn.** and **widespread**.

iii) A more appropriate graph type for timeseries is line graphs. Select all years in the Pivot Table, go to Insert -> Line and click Line under 2-D Line.

The graph should look like this:



Note that, in this case, the two time series are plotted against different Y scales. If you wish to do so, you could ask for assistance where needed.

Collaborators:

Save your file.

QUESTIONS:

1) Looking at the Pivot Table and accompanying chart for Seasonality, would you say there is a close relationship between the seasonality of extreme wet spells and floods? Is that relationship stronger for widespread floods alone than for all floods?

2) Is there a close relationship between the seasonality of the wet/dry season and extreme wet spells? What are the similarities and differences in terms of the timing of the onset and end of seasons as well as their peak(s)?

3) When looking at the time series graph and before looking at the actual correlation, describe the relationship between extreme wet spells and flood occurrence. Does the number of floods increase in years with more extreme wet spells? If not, what would you think could be the explanation?

4) Identify sets of years during which there were very little or no flash floods. Do you know if there are more extensive flood records available for your country?

5) Save the graph of the seasonality as a picture and send it to cmeerbeeck@cimh.edu.bb and tallen@cimh.edu.bb .

2. Build contingency tables of hits, misses and false alarms w.r.t. extreme wet spells explaining flash floods

Contingency tables here summarise when extreme wet spells happened or not *versus* when there were floods or not.

Several scores are associated with contingency tables and will be looked at next.

SCORES:

hit = *there was **a** flash flood when **an** extreme wet spell was observed*

hit rate = *the number of hits divided by the number of flash floods*

miss = *there was **a** flash flood while **NO** extreme wet spell was observed*

false alarm = *there was **NO** flash flood when **an** extreme wet spell was observed*

false alarm rate = *the number of false alarms divided by the total number of days when there wasn't a flash flood*

The ratio of hits versus misses is a very simple metric of how close both variables are related. It estimated how well the record of extreme wet spells is apt at capturing all past flash floods. This ratio should be as high as possible.

The ratio of hits versus false alarms quantifies how many extreme wet spells it takes, on average, to produce a flash flood.

When multiplying the hits/false alarm ratio with the frequency of observed extreme events per month, a (proxy) predictand file for flash flood potential can be produced.

Finally, once available, such a predictand dataset can then obviously be utilised in CPT to make forecasts of flash flood potential.

Two main caveats:

i) the (flash) flood dataset is unlikely to be complete over the time period that we have daily rainfall data for.

In such case, the count of hits and misses is still valuable, but the count of false alarms is unreliable.

Proposed solution: wherever necessary and possible, we will look at time intervals where the flood dataset has most flood occurrences. That way, we will still be able to estimate the false alarm rate to a certain extent, at least for those intervals. If the flood record is still insufficient for such, we will only be able to count hits and misses to quantify the strength of the relationship between extreme wet spells and flash floods. In such cases, extreme wet spells can only be utilized to qualitatively estimate flash flood potential, as has been done thus far in CariCOF.

ii) flash floods occurred in an area geographically too different from the location of the rainfall station.

In such case, low ratios of hits/misses and hits/false alarms are anticipated for localized flood events. However, this may not pose a major problem for widespread flood events, as the rainfall was likely produced over much broader areas, including flood and station locations.

Proposed solution: wherever possible, a different rainfall station should be utilized. That alternative station should lie in an area as close as possible to and as geographically similar as where the flash floods were observed. This will be possible in territories with multiple stations (e.g. Trinidad and Tobago). In such case, subsequent research will identify whether the production of a predictand time series for flash flood potential should then be done at the national scale or if it can be done at the station scale within the territory. In territories with just one or two available stations which are not representative of the rainfall climatology of the flooded areas, extreme wet spells at those stations can only serve as a weak proxy for flash flood potential. The argument is then to ensure that, in the near future, time series from more relevant station locations will be added and the research done again.

INSTRUCTIONS:

All scores and statistics are pre-calculated using the default threshold (i.e. the current CariCOF definition for 3-day extreme wet spells threshold), which is the 99th percentile of 3-day rainfall totals.

Have a look at the **Summary_stats** tab. This tab consists of a number of parts.

1) **Scores for 99th* percentile threshold**:

this portion simply is a copy of part of rows 1 and 2 from **the four calculation tabs**. You will see a number of scores calculated.

3-day extreme wet spell start date : the total number of extreme wet spells.

Flash flood : the total number of reported floods in the record for the period of record of the daily rainfall dataset. (Similar for **Localised** and **Widespread**.)

hit all / **miss all** : the total number of hits / misses for all floods.

hit all (date+3-days) / **Miss all** (date+3-days) : the total number of hits / misses for all floods, but allowing for up to 3 days lag between the extreme wet spell and the flood.

Similarly, scores are calculated for **hit widespread** / **miss widespread** and **hit widespread** (date+3-days) / **miss widespread** (date+3-days).

false alarm (date+3-days) : the total number of false alarms assuming there may be a lag of up to 3 days between extreme wet spell and flood.

2) **Contingency tables** (99th percentile – precalculated ; 90th percentile – to be calculated): contingency tables are automatically generated for each of the two main stations, for those 2 stations combined and for up to 6 stations combined.

		Floods			
	CIMH	**Widespread**	**Others**	**None**	Total
extr. wet spells	**yes**	11	6	62	79
	no	6	9	17959	17974
	total	17	15	18021	18053

In the above example, the number of hits was 11 (out of 17) widespread floods, or 17 (out of 32 floods) for all floods (i.e. 11 widespread + 6 others). The number of misses was 6 for widespread floods and 15 for all floods. This suggests that, using only the CIMH station and with the current definition of extreme wet spells, just over half the floods could be identified.

Compare that to using GAIA data, where only 7 widespread floods could be identified, as well as, to using both stations, where 13 out of 17 widespread floods and 21 out of all 32 floods could be identified.

NOTE: If only 2 stations are employed, the results will be exactly the same for the **2 stn.** and the **6 stn.** tables.

3) **Hit rate / false alarm rate for the 99th* percentile threshold**:

This table compares some of the hit rates, false alarm rates and other score proportions.

Hit rate / false alarm rate for the 99th* percentile threshold

station name / threshold	hit rate all	hit rate all (date+3-day)	hit rate widespread	hit rate widespread (date+3-day)	false alarm rate all (date+3-days)	hit/miss all	hit/miss all (date+3-days)	hit/miss widespread	hit/miss widespread (date+3-days)
CIMH / 99th	0.38	0.53	0.59	0.65	**0.01**	0.60	1.13	1.43	1.83
GAIA / 99th	0.16	0.38	0.18	0.41	**0.01**	0.19	0.60	0.21	0.70
2 stn. / 99th	0.47	0.66	0.65	0.76	0.02	0.88	1.91	1.83	3.25
6 stn. / 99th	**0.47**	**0.66**	**0.65**	**0.76**	0.02	**0.88**	**1.91**	**1.83**	**3.25**

While the hit rate goes up with the number of stations employed (which one would expect because a larger part of the country can be covered with more stations), the false alarm rate increases too. In this case, the false alarm rate is still very low (0.02) when using 2 stations, but that is simply because the total number of extreme wet spells is very low using the current definition.

Improving the results – lowering the threshold?

For Barbados and Trinidad, only 21 out of 32 (2stn. combined) and 35 out of 247 (6 stn. combined) floods could be identified, respectively, when using the current definition for 3-day extreme wet spells. Hence, it may be worthwhile reproducing the same calculations for lower thresholds, to see if the definition is too strict. In other words, do floods occur even if the rainfall amounts during extreme wet spells are considerably less than the 99th percentile?

Following that train of thought, in the **four calculation tabs**, the only parameter we may choose to change at present is the **threshold percentile** for the calculation of 3-day extreme wet spells.

The other tables in the **Statistics & Scores** tab have been precalculated using Trinidad data and adopting progressively lower thresholds, down to the 90th percentile.

Let us first make a quick comparative analysis using both results from Trinidad and Barbados, to investigate whether it would make sense to lower the threshold.

Consider the following for Trinidad, here only using the Piarco airport station:

Contingency tables - 99th* percentile threshold

		Floods			
	Piarco	Widespread	Others	None	Total
extr. wet spells	yes	14	11	69	94
	no	86	136	18015	18237
	total	100	147	18084	18331

Contingency tables - 90th percentile threshold**

		Floods			
	Piarco	Widespread	Others	None	Total
extr. wet spells	yes	60	54	651	765
	no	40	93	18015	18148
	total	100	147	18666	18913

One can see that the number of hits is greatly increased by lowering the threshold to the 90th percentile. At Piarco, the 99th percentile of 3-day rainfall totals is around 100mm, whereas the 90th percentile is just about 43mm. At CIMH, the 99th percentile is around 92mm and the 90th only about 28mm. The latter may arguably be too low to cause extensive flash flooding.

In fact, when calculating the scores using 99th, 98th, 97th, 96th, 95th and 90th percentile successively for the two stations in Barbados, one finds that the hit rate barely goes up as one uses a threshold below the 96th percentile. In fact, while at the 99th percentile, only 21 of the 32 floods are identified, at the 96th percentile, it is already 29, and at the 90th percentile 30. In the meantime, the total number of false alarms increases from 99 at the 99th percentile, to 391 at the 96th and 914 at the 90th. See the below screenshot.

Hit rate / false alarm rate for various percentile thresholds**

station name / threshold	hit rate all	hit rate all (date+3-day)	hit rate widespread	hit rate widespread (date+3-day)	hit/miss all	hit/miss all (date+3-days)	hit/miss widespread	hit/miss widespread (date+3-days)	hit/false alarm all (date+3-days)
2 stn. / 98th	0.50	0.75	0.65	0.76	1.00	3.00	1.83	3.25	0.12
2 stn. / 97th	0.59	0.84	0.71	0.88	1.46	5.40	2.40	7.50	0.09
2 stn. / 96th	0.69	0.91	0.82	0.94	2.20	9.67	4.67	16.00	0.07
2 stn. / 95th	0.72	0.91	0.82	0.94	2.56	9.67	4.67	16.00	0.06
2 stn. / 90th	0.84	0.94	0.88	0.94	5.40	15.00	7.50	16.00	0.03

How does that compare with Trinidad for 6 stations?

The first finding is that most scores are quite a bit lower for Trinidad than for Barbados.

This could be indicative of a number of factors for a country with most of the floods recorded in low-lying, relatively flat terrain, including: (i) many of the reported floods were not actually flash floods, but long-term flooding. In such case, flooding mostly occurs through prior saturation of the soil, with a wet spell or series of longer lasting wet spells spilling the proverbial bucket and triggering the flood; (ii) flooding is triggered by more localised, intense showers than, meaning the 6 stations may not be sufficient to capture the spatial variability in intense showers. If the two reasons play any significant role, increasing the number of stations and increasing the duration of the wet spells in our definition may increase the hit rate further.

Hit rate / false alarm rate for various percentile thresholds**

station name / threshold	hit rate all	hit rate all (date+3-day)	hit rate widespread	hit rate widespread (date+3-day)	hit/miss all	hit/miss all (date+3-days)	hit/miss widespread	hit/miss widespread (date+3-days)	hit/false alarm all (date+3-days)
6 stn. / 99th	0.12	0.24	0.18	0.34	0.13	0.32	0.22	0.52	0.41
6 stn. / 98th	0.18	0.36	0.25	0.49	0.21	0.57	0.34	0.98	0.30
6 stn. / 97th	0.25	0.45	0.36	0.54	0.34	0.81	0.57	1.25	0.26
6 stn. / 96th	0.29	0.52	0.40	0.59	0.42	1.09	0.68	1.54	0.24
6 stn. / 95th	0.36	0.61	0.43	0.66	0.55	1.55	0.77	2.09	0.23
6 stn. / 90th	0.57	0.81	0.70	0.85	1.33	4.33	2.54	6.62	0.17

Looking at the scores in detail, one finds that the hit rate for all floods, as well as, for widespread floods only increases as one lowers the threshold to the 90th percentile. In fact, a substantial gain is achieved when going from the 95th percentile (hit rate below 0.7) to the 90th percentile (hit rate above 0.8). That said, doing so increases the number of extreme wet spells from 796 to 1392 for a total of 245 reported floods. This means the ratio hit / false alarm becomes rather large with odds of 1 to 4 against (or less than 20%) for a flood per extreme wet spell.

Ultimately, it would be up to the user of a flash flood potential forecast to identify which level of hits versus false alarms they would be willing to accept. To enquire about their preference, once must explain what needs to be balanced.

If one prefers to have a forecasting system that is set up to capture nearly all floods in a flash flood potential forecast, then one must favour a higher hit rate at the expense of a high false alarm rate, which would tend to induce early warning fatigue. That is, they may no longer be willing to pay attention to forecasts suggesting there is a likelihood for flash floods, since it seldomly pans out anyway. In our examples, a chance of around 20% for a flood occurrence per extreme wet spell may be acceptable. Therefore, adopting the 90th percentile would not be a bad choice.

On the other hand, if one want to avoid early warning fatigue, then that comes at the expense of a forecasting system which may not be able to capture a large majority of flood occurrences. If, for Barbados, the user will not allow for a chance of less than 10% for a flood occurrence per extreme wet spell, then the forecaster is limited to using the 98th percentile threshold. In this case, 75% percent of floods would still be captured. All in all, this may be acceptable to the user to.

In conclusion, the optimal threshold may be the 90th percentile for Trinidad, as based on the 6 stations and the available flood data. By comparison, it may well be the 98th percentile for Barbados, as based on the 2 stations and the available flood data. In any case, this simple analysis does demonstrate it may be worthwhile to lower the current threshold, but possibly down to a country- and user-specific set of thresholds.

INSTRUCTIONS:

To investigate the impacts of lowering the threshold for your country, you will need to follow the steps highlighted below. The thresholds are found in cell **E1** (in **calculations stn. 1** & **calculations stn. 2**), **E1** & **G1** (in **calculations 2 stn.**), **E1**, **G1**, **I1**, **K1**, **M1** & **O1** (in **calculations 6 stn.**).

1) Delete the values in the table **Scores for various thresholds** (90th, 95th, 96th, 97th, 98th & 99th percentile)** which pertain to Trinidad. Then copy the scores from the **Scores for 99th* percentile threshold** table up top and **paste (values only!!!)** in the relevant rows.

2) Change the threshold from 99th to 98th percentile by changing the function in the cells highlighted above from:

=ROUND(PERCENTILE(E3:E18264,**0.99**),1)

to

=ROUND(PERCENTILE(E3:E18264,**0.98**),1)

in all the relevant calculation tabs of your file.

3) Copy the scores from the **Scores for 99th* percentile threshold** table (which now, in reality, are scores using the 98th percentile threshold) up top and **paste (values only!!!)** in the relevant rows in the table **Scores for various thresholds** (90th, 95th, 96th, 97th, 98th & 99th percentile)**.

4) Repeat steps two and three with the 97th, 96th, 95th and 90th percentile.

5) Reset the threshold to the 99th percentile in the calculation tabs.

Save the file.

QUESTIONS:

1) One would expect the number of hits to be higher and misses to be lower when more daily rainfall records are utilised. Do you see a significant improvement? What are the hit rates for the calculations involving stn. 1, stn. 2, 2 stations and/or 6 stations?

2) If our aim ultimately is to forecast flash flood potential, what would you consider to be a sufficiently high hit rate (i.e. the proportion of floods that would have forecasted)? What about the false alarm rate, given that a higher false alarm rate means people will experience "early warning fatigue"?

3) Write down the total number of floods, the number of hits (allowing for 3 extra days) and the number of false alarms as you go down from the 99th to the 90th percentile threshold. Is there any threshold value below which the number of hits no longer substantially increases? Based on your answer, as well as the increasing number of false alarms, which threshold would you recommend for your country and why?

3. Perform a simple correlation analysis between extreme wet spells and flash flood occurrence time series

The Pearson's correlation (*r*) between extreme wet spell occurrence and flash flood occurrence is another standard metric that quantifies the relationship between the two variables. It enables the estimation of the proportion of variance of flash flood occurrence explained by extreme wet spell occurrence (R^2).

This correlation will be calculated on the monthly counts time series. Seasonal forecasts of flash flood potential can only identify the potential frequency of flash floods in the coming season, but not timing. Therefore, correlation at the monthly timescale and the corresponding R^2 can reveal the strength of the relationship between the two variables and, therefore, **quantify the strength of a flash flood potential time series based on extreme wet spells only as a predictand set for flash flood occurrence**.

INSTRUCTIONS:

All correlations and R^2 are calculated using the 99th percentile and are tabled in **monthly records & correlations** tab in the **99th percentile tables** as soon as your rainfall and flood data are entered into your file.

That is, if you have changed the percentile thresholds in cell **E1** (in **calculations stn. 1** & **calculations stn. 2**), **E1** & **G1** (in **calculations 2 stn.**), **E1**, **G1**, **I1**, **K1**, **M1** & **O1** (in **calculations 6 stn.**) to a different threshold, those values will be

For the 90th percentile tables, those initially contain values specific to the Trinidad data.

If you want to calculate the Pearson's correlation and R^2 for the 90th percentile threshold, simply change the thresholds in the relevant calculations tabs, then copy the values from the **99th percentile tables** and paste (**values only!!!**) into the **90th percentile tables**. Don't forget to reset the thresholds back to the 99th as explained at the bottom of page 17.

Furthermore, since it is quite likely that the reported flood record is incomplete, and that much of the flood data may be clustered in sections of the monthly timeseries, provision is made for the calculation of correlations and R^2 for portions of the timeseries in up to four extra tables. By default, the first table spans 50 years from 1969 to 2018.

To change the start and end month of the section of the record you want to make the calculations over, simply change the data range in the functions in columns L (Pearson correlation) to cover your section of interest. The function for the full record from 1969 to 2018 (i.e. 600 monthly time steps) reads:

=CORREL(C$**5**:C$**604**,G$**5**:G$60**4**)

The screenshots below show an example using Barbados (top) and Trinidad (bottom) data. Two findings stand out:

1) decreasing the threshold from the 99th to the 90th percentile may strongly improve the number of hits, but it will actually decrease the correlation and R^2. This is because there will be an increase of years where the extreme wet spell count is higher, but the flood count does not respond to it;

2) whereas for the Barbados case, increasing the number of stations does not change the correlation much at all, the correlation greatly improves from nearly naught to 0.25 for Trinidad when increasing the number of stations from 1 to 6. This is to be expected, since Barbados is a much smaller country than Trinidad, with a much closer distance and, hence, correlation in daily rainfall between the two different stations in Barbados.

In statistical terms, the two Barbados stations **co-vary** substantially, but there is less co-variation between different stations in Trinidad. Or, in other words, the stations in Trinidad vary more independently from one another. This immediately implies that adding stations adds independent information. That is why the **% of variance explained** increases with the number of stations in Trinidad from near to 0 to about 6%. This is a very low number and implies that the interannual variability in annual extreme wet spell counts may not be an appropriate predictor for flood occurrence.

However, before drawing such conclusions, looking at the **annual time series** reminds us that there is very tight clustering of flood occurrences into just 5 out of the 50 years of the record, i.e. 2010-2014. This would inevitably greatly reduce the Pearson's correlation, because the flood count appears to depend much more on the reporting methodology than on the interannual climate variability.

This is a well-known problem with the Pearson's correlation, which is highly sensitive to outliers (which here are 2010 to 2014). If there is no proportionate increase in extreme wet spells in those five years, then the correlation and, hence, the % of variance explained will be low.

Correlations

Record length ---stn. / flood type	99th* percentile		90th percentile**	
from 1969	Pearson's *r*	% variance (R^2)	Pearson's r	% variance (R^2)
CIMH / all floods	0.33	11.1	0.28	7.6
CIMH / widespread	0.31	9.6	0.20	4.1
GAIA / all floods	0.36	13.1	0.30	8.8
GAIA / widespread	0.35	12.2	0.23	5.3
2 stn. / all floods	0.40	15.8	0.29	8.3
2 stn. / widespread	0.39	15.0	0.22	4.7
6 stn. / all floods	0.40	15.8	0.29	8.3
6 stn. / widespread	0.39	15.0	0.22	4.7

Correlations

Record length ---stn. / flood type	99th* percentile		90th percentile**	
from 1969	Pearson's *r*	% variance (R^2)	Pearson's r	% variance (R^2)
Piarco / all floods	0.06	0.4	0.05	0.3
Piarco / widespread	0.10	0.9	0.07	0.5
UWI St. Augustine / all floods	0.08	0.6	0.07	0.5
UWI St. Augustine / widespread	0.08	0.6	0.07	0.4
2 stn. / all floods	0.09	0.9	0.08	0.7
2 stn. / widespread	0.11	1.2	0.09	0.9
6 stn. / all floods	0.24	5.8	0.37	13.6
6 stn. / widespread	0.25	6.1	0.33	10.9

QUESTIONS:

1) How do the Pearson's correlation coefficient (*r*) and % of variance (R^2) change according to the threshold value and, if relevant to your country, the number of stations? Try to explain your findings in the light of the (in)completeness of the reported flood record, the closeness of stations (if relevant).

2) For 30- to 50-year long records, a Pearson's correlation of more than 20% is significant. Is there a statistically significant correlation between annual extreme wet spell and flood counts in your country? If the correlation is very high and does not depend on just a couple of outliers, you may have a good basis to build a flash flood potential predictand file, provided the hit / false alarm ratio is sufficiently high. Argue whether you believe this is the case or not. If not, what do you believe is the main problem: amount of daily rainfall data – completeness of flood dataset – poor relationship between extreme wet spells and floods?

3) Bring your results to the trainer in front and fill out the table on the trainer's computer for your country's core results. (*These summary results from all countries will be shown to all and used for the Forum*.)

TRAINING vs RESEARCH:

There will likely only be time to work with 1 or 2 records per territory. Note that most territories have only 1 or 2 stations with a sufficiently long record of daily rainfall to build a flash flood potential anyway.

While this is a good start to show the potential of the research, further research will be needed to reach publishable results that include countries with more daily rainfall records. This becomes crucial especially for larger countries.

APPENDIX 3 – Summary results on quantifying the relationship between extreme wet spells and reported floods (to be used in conjunction with Appendix 2)

Island/Territory	Period of record (YYYY - YYYY)	# daily rainfall records used	# all floods	# wide-spread floods	Threshold 3-day rainfall sum at the 99th percentile
Antigua	1969-2017	1	7	3	84.1 mm
Aruba					
Bahamas	1980-2018	2	35	7	102.9mm
Barbados	1969 - 2018	2	32	7	82-92mm
Belize	1969-2018	6	9	7	107.1-200.6mm
Grand Cayman					
Cuba					
Curaçao					
Dominica	1982-2018	2	14	4	155.7mm
Dominican Rep.					
French Guiana					
Grenada	1985 - 2018	1	10	3	79.5mm
Guadeloupe					
Guyana	1969 - 2018	6	12	12	99.4-130.8mm
Haiti					
Jamaica	1973-2018	5	53	38	86.7-165.9 mm
Martinique					
Puerto Rico					
St. Kitts	1987-2018	1	10	1	99.2mm
Saint Lucia	1969-2018	2	29	13	104.9mm
St. Martin					
St. Vincent	1986-2017	2	35	12	122.8mm
Suriname	1969-2014	1	6	3	90.6mm
Trinidad	1969 - 2018	6	245	101	87-117mm

Collaborators:

Island/Territory	# Hits all (date + 3 days) at the 99th perc. threshold	# Hits widespread (date + 3 days) at the 99th perc. threshold	# False Alarms (date + 3 days) at the 99th perc. threshold	Hits / false alarms (date + 3 days) at the 99th perc. threshold
Antigua	7	3	64	0.109
Aruba				
Bahamas	10	3	110	0.091
Barbados	21	13	99	0.212
Belize	4	4	284	0.014
Grand Cayman				
Cuba				
Curaçao				
Dominica	9	3	109	0.083
Dominican Rep.				
French Guiana				
Grenada	2	2	52	0.038
Guadeloupe				
Guyana	7	7	253	0.028
Haiti				
Jamaica	24	20	146	0.164
Martinique				
Puerto Rico				
St. Kitts	1	0	32	0.031
Saint Lucia	8	7	41	0.195
St. Martin				
St. Vincent	11	6	46	0.239
Suriname	0	0	82	0.000
Trinidad	62	35	145	0.428

Island/Territory	Threshold percentile (and 3-day rainfall sum) below which hit rate no longer signif. increases	# Hits all (date + 3 days) at that threshold	# Hits widespread (date + 3 days) at that threshold	hit rate in %	# False Alarms (date + 3 days) at that threshold	Hits / false alarms (date + 3 days) at that threshold
Antigua	99 (84.1mm)	7	3	100	64	0.109
Aruba						
Bahamas	97(70.9mm)	11	4	31	211	0.052
Barbados	96 (48-50mm)	29	16	91	391	0.074
Belize	98(84.6-171.8mm)	7	7	78	507	0.014
Grand Cayman						
Cuba						
Curaçao						
Dominica	97 (97.5mm)	10	3	71	237	0.042
Dominican Rep.						
French Guiana						
Grenada	90 (26.5mm)	5	2	50	426	0.012
Guadeloupe						
Guyana	97 (70.6-94.5mm)	10	10	83	881	0.011
Haiti						
Jamaica	96(48.6-89.4 mm)	36	27	68	564	0.064
Martinique						
Puerto Rico						
St. Kitts	99(99.2mm)	1	0	10	32	0.031
Saint Lucia	95(58.1mm)	17	10	59	213	0.080
St. Martin						
St. Vincent	98(95.7mm)	16	10	46	94	0.170
Suriname	95(61.3 mm)	3	2	50	353	0.008
Trinidad	90 (38-46mm)	199	86	81	1201	0.166

Island/Territory	**Threshold percentile (and 3-day rainfall sum)** below which hits / false alarms falls below 0.1	**# Hits all** (date + 3 days) at that threshold	**# Hits widespread** (date + 3 days) at that threshold	**# False Alarms** (date + 3 days) at that threshold	**Hits / false alarms** (date + 3 days) at that threshold
Antigua	99 (84.1mm)	7	3	64	0.109
Aruba					
Bahamas	99(102.9mm)	8	3	211	0.038
Barbados	98 (63-71mm)	24	13	391	0.061
Belize	99(107.1-200.6mm)	4	4	284	0.014
Grand Cayman					
Cuba					
Curaçao					
Dominica	99 (155.7mm)	9	3	109	0.083
Dominican Rep.					
French Guiana					
Grenada	99 (79.5mm)	2	2	52	0.038
Guadeloupe					
Guyana	99 (99.4-130.8mm)	7	7	253	0.028
Haiti					
Jamaica	98(70.7-127.6 mm)	29	24	291	0.100
Martinique					
Puerto Rico					
St. Kitts	99(99.2mm)	1	0	32	0.031
Saint Lucia	96(65.2mm)	16	8	175	0.091
St. Martin					
St. Vincent	96(67.6mm)	19	10	188	0.101
Suriname	99(90.6mm)	0	0	82	0.000
Trinidad	90 (38-46mm)	199	86	1201	0.166