RCOF Review 2017

[Caribbean Climate Outlook Forum]

Status Report (Survey)

Annotated Outline

1. Specific Climate features of concerned region

Apart from the northern portion of the Guianas that has two wet and dry seasons per year, the wet season in the Caribbean runs from May-June to November-December and coincides with the hurricane season. The dry season covers the other half year. Around 70-80% of annual rainfall falls within the wet season[1]. In much of the Greater Antilles, wet season rainfall exhibits a bimodal peak interposed by a distinct drier episode, colloquially referred to as the "Mid-Summer Drought"[2]. Despite this sub-regional bimodality, absent from most other Caribbean islands[3], much of the region shows a primary maximum in the latter half of the wet season - September to October/November.

The wet and hurricane season drivers include the migration of the Hadley Cell and the fluctuation of the Inter-Tropical Convergence Zone (ITCZ) that result in changes in strength and in the northward migration of the sub-tropical high pressure (Bermuda-Azores), changes in Atlantic Sea Surface Temperature (SST), and migration of tropical waves and other disturbances which can strengthen to form cyclones including hurricanes.

Important drivers of sub-seasonal to interannual rainfall variability include:

- the El Niño Southern Oscillation (ENSO) and the gradient in sea surface temperature (SST) between the Pacific and the Atlantic[1,4,5,6,7,8]. During an El Niño year, the Southern and Eastern Caribbean tend to be drier while the extreme north (in the vicinity of The Bahamas) is wetter than usual. During a La Niña year, the opposite takes place. ENSO constitutes the most predictable strong driver of interannual rainfall variability.
- the North Atlantic Oscillation (NAO)[9] and North Atlantic High Pressure cell[2]. The NAO positive phase intensifies the dry season in the South and East due to stronger and more southward Azores high pressure and associated stronger trade winds (which lower SST), but also indirectly contributes to wetter conditions in the Northwest. The NAO negative phase is characterised by opposite anomalous climate conditions over the region.
- the Madden Julian Oscillation (MJO)[10] promotes deep convection for a couple of weeks and decreases it afterwards, in a cycle taking approximately 30-60 days. Hence, the MJO tends to enhance rainfall at sub-seasonal timescales.

Additional drivers that have been receiving some attention in recent years are the Caribbean Low-Level Jet[11,12] and the Saharan Air layer[13,14].

Consisting mainly of Small Island Developing States (SIDS) that are highly vulnerable to hydro-meteorological hazards, the Caribbean is particularly risk prone to rainfall extremes. Rainfall, the most variable and limiting climate factor in the Caribbean, affects many sectors. At times, the effects of temperature can exacerbate rainfall impacts, particularly during drought. For example, the primary impacts to agriculture include limited water availability for rainfed and irrigated agriculture, for drinking and sanitizing livestock due to seasonal drought; and flooding, water logging and

increase in diseases such as root rot as a result of excessive rainfall – all of which limit production. The dry season often poses problems for this sector, particularly in the more water stressed countries and areas. These concerns are exacerbated during prolonged dry seasons.

On the other end of the spectrum, hyper-humid areas are often exposed to unavailability of clean water for human consumption or hygiene. Other climate-related health concerns include heat stress, increase in water-borne diseases due to flooding (gastro-intestinal diseases) and vector-borne diseases (dengue, chikungunya) of which outbreaks are more likely during warm and wet periods.

Besides that, an economically crucial, but very climate sensitive sector, tourism depends heavily on sunny, warm weather tempered by gentle breezes, as well as on beaches and water-intensive recreation. With a peak tourism season during the Caribbean dry season, a wetter dry season is seen as unattractive, whereas intense or extended dry seasons further restrict freshwater access. It should be further noted that there is a strong perceived link between tourism arrivals and inclement weather and climate conditions in source markets, making the sector dependent on climate variability in North America and Western Europe.

Finally, living in a region of SIDS, the Caribbean people are exposed to disasters which cause substantial loss of life, infrastructure and environmental damage, aggravate food insecurity and slow down or even reverse socio-economic development gains.

2.The RCOF background

In response to the strongest El Niño on record (the 1997 to 1998 event), the first Caribbean Climate Outlook Forum (CariCOF) was convened on May 21-22, 1998 in Jamaica. The Caribbean event formulated a consensus precipitation forecast for the Caribbean for the period of June-July-August 1998 (http://iri.columbia.edu/climate/forecast/sup/May98_CAm/). The second CariCOF was held in Barbados in April 1999. The aim of this Forum was to discuss the regional climate events since the first Forum, to consider the recommendations of that Forum, to develop a consensus climate outlook for the months of May, June, July, 1999 and to evaluate the three-month precipitation outlooks which the Caribbean Institute for Meteorology and Hydrology (CIMH) had produced. A third CariCOF was convened in the Dominican Republic in May 2000.

Though originally intended for CIMH to produce the forecasts with the assistance of regional meteorologists and research groups, the exercise was soon left to CIMH to produce alone. From 1999 up until 2011, the CIMH produced zero-month lead three month tercile precipitation outlooks every 2 months starting in January – a total of six information products per year. The data used in producing these forecasts were obtained from climate forecast maps published by the IRI and the European Centre for Medium-Range Weather Forecasts (ECMWF) from climatological means and expected sea surface temperature conditions. Verification information using a simple method was also provided to give credibility to the forecast process.

After a decade of dormancy, it took yet another El Niño event for Caribbean and international partners to rejuvenate CariCOF in June 2010. The 2009 to 2010 event took a toll on regional water resources to the extent that Caribbean Community (CARICOM) Heads of Government requested CIMH and the then Caribbean Environmental Health Institute (now a branch of the Caribbean Public Health Agency – CARPHA) to prepare a status report on drought that was discussed at two subsequent high level meetings (Farrell et al, 2010[15]). The re-establishment CariCOF was led by the CIMH, the US National Oceanic and Atmospheric Administration (NOAA) and the United States Geological Survey (USGS), with support from the Caribbean Community Climate Change Centre

(CCCCC), IRI and others. The follow up to the re-establishment of CariCOF led to a training exercise for meteorologists and climatologists in the art of forecasting using the International Research Institute for Climate and Society (IRI's) Climate Predictability Tool (CPT) in February 2012. The training preceded a forum that brought together key regional and international partners and users of climate information who discussed the rainfall forecast and its implications, as well as other climate information needs and gaps. This RCOF execution format has generally been followed since 2012.

Importantly, since the 2012 CARICOF, the CIMH has been coordinating climate forecasting activities leading to a consistently growing body of Caribbean climate forecasters contributing to the monthly production of consensus-based seasonal climate outlooks. The forecasters also engage the user community, allowing awareness-building within sector communities that are sensitive to climate. During these sessions, users also get the opportunity to identify their climate information needs and how existing products can be interpreted to support decision-making. Equally important is the opportunity presented to meteorologists and climatologists and the user community to interface, and to build mutual understanding and trust. It was also from 2012 that monthly updates, rather than bimonthly updates of the precipitation outlooks began to be prepared.

Another significant decision tabled and accepted at the 2012 CariCOF was the recommendation to pursue hosting CariCOF biannually, just prior to the beginning of the wet and dry seasons, and to have the forum rove across the region so that more national agencies can be exposed to the forum.

Today in 2017, CariCOF covers the Caribbean region from the Guianas to the south up the eastern island chain, across the Greater Antilles, and The Bahamas, and including the Central American country of Belize. It includes the NMHSs of the English, French, Spanish and Dutch islands of the Caribbean, along with mainland territories of the three Guianas and Belize. The CariCOF process is led by the Caribbean Regional Climate Centre (RCC) at CIMH, with support from international agencies such as the IRI, NOAA, the University of Arizona and more recently, has garnered the support of regional sectoral agencies represented in the newly formed Consortium of Sectoral Early Warning Information Systems Across Climate Timescales (EWISACTs) Coordination Partners. This group of leading sectoral allies, namely the Caribbean Agriculture Research and Development Institute (CARDI), the Caribbean Water and Wastewater Association (CWWA), the Caribbean Disaster Emergency Management Agency (CDEMA), the Caribbean Public Health Agency (CARPHA), the Caribbean Tourism Organization (CTO), and the Caribbean Hotel and Tourism Association (CHTA) have committed through a multi-lateral Letter of Agreement to work along with the CIMH in co-designing, co-developing and co-delivering sector-specific climate early warning information. Although this co-production usually happens in the months leading up to the CariCOF, mature outputs are routinely showcased at the biannual event. Moreover, sectoral partners now play a key process-oriented role in stewarding their sectoral representatives at the CariCOF, as well as, representing sector issues and positions at the forum.

3. The RCOF process

3.1 Preparing seasonal predictions and CariCOF consensus outlooks

Consensus CariCOF climate outlooks are produced each month by combining global, regional and national forecasts and expert interpretation. National and region-wide forecasts are produced using the Caribbean Outlook Generator (CAROGEN), an automation platform that utilises its own daily and monthly precipitation and temperatures, as well as, GPC-LRF and IRI input data to drive a regionally agreed set of ensemble experiments run with CPT which is integrated in CAROGEN. 0-month and 3-month lead, regional, objective consensus forecast maps are considered together with

global dynamical climate models. Global forecasts that are examined include those from the IRI, the U.K. Met Office, ECMWF, Météo-France, NOAA Climate Prediction Center (CPC), the World Meteorological Organization (WMO) Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME), the APCC, Japan Meteorological Agency (JMA), Environment and Climate Change Canada Canadian Meteorological Centre (CMC) and the North American Multi-Model Ensemble (NMME).

Probabilities for three-month rainfall totals and temperature averages are estimated for sub-regions based on the model outputs, the level of agreement between the different models and expert knowledge of the regional setting. In the majority of cases, and unless known deficiencies of the objective models are identified, the ensemble mean probabilities of each type of objective ensemble forecast is followed in the preparation of the draft, subjective consensus outlook maps. The tercile-based consensus Precipitation Outlooks, and Minimum, Mean and Maximum Temperature Outlooks are then issued in the form of GIS map layers within CAROGEN at national level and, after post-processing using GIS scripts, at the CariCOF level.

Besides the generic RCOF outlook products, CariCOF produces a series of thematic or hazard-specific outlook products. Drought Outlooks are issued in the form of a presentation that combines alert maps, with four categories of increasing alert level, with a narrative on recent and near-future drought conditions. Another product, Wet Days and Wet Spells Outlooks, forecasts number ranges and frequency shifts in wet days and wet spells. It is issued in the form of a presentation that links the 0-month lead regional Precipitation Outlook, with the climatology and forecasts of wet days and wet spells, as well as expected climate impacts in the coming three months. Finally, most recently in 2017, experimental Heatwave Outlooks have been developed and are now produced and updated monthly during the warmest part of the year.

In some instances, the information is repackaged. For example, relevant historical climate, monitored climate conditions and climate impacts information is packaged into a Caribbean Climate Outlook Newsletter, which primarily targets the region's NMHSs, but adopts a less technical language to satisfy the needs of some sectoral and general users. Moreover, each month, the drought outlooks are packaged with drought monitoring maps and information into a Drought Bulletin issued by the Caribbean Drought and Precipitation Monitoring Network.

Before all these outlooks are disseminated to the CariCOF's user base, all NMHSs are sent all above draft products along with an extensive technical outlook presentation, that includes information such as experimental set up, skill of individual forecasts, all objective and subjective draft maps and outlooks, as well as an overview of some recent climate diagnostics and indices, GPC, IRI and APCC precipitation and temperature outlooks and downscaled guidance from those global outlooks. The NMHSs then briefly review the material electronically, with comments then integrated by the Caribbean RCC.

3.2 Dissemination of the CariCOF outlooks at regional and national levels

Once the review process is complete, the CariCOF climate outlooks, the Caribbean Climate Outlook Newsletter and the Caribbean Drought Bulletin are ready for dissemination primarily via e-mail lists and through the RCC web page. The RCC further advertises the CariCOF products through its social media channels by focusing on captivating stories that link to the outlooks.

In addition, sector-specific bulletins that translate, package and communicate the sectoral implications of forecast and other information from the RCC's suite of CariCOF outlooks and other climate products have also been operationalised. The Caribbean Society for Agro-Meteorology integrated the CariCOF outlooks into its monthly Caribbean Agro-Climatic Bulletin (a further

development of the former Caribbean Agro-Meteorological Initiative (CAMI) Bulletin), which primarily caters for agronomists, agriculturists, and agriculture and food security policymakers and practitioners. Moreover, new quarterly bulletins targeting the health and tourism sectors, namely the Caribbean Health-Climatic Bulletin and the Caribbean Tourism-Climatic Bulletin - are jointly developed and issued by the Caribbean Public Health Agency, and the Pan-American Health Organization, as well as, the Caribbean Tourism Organisation, the Caribbean Hotel and Tourism Association in collaboration with the Caribbean RCC, respectively. A key feature of the sector-specific Bulletins, inspired by the EWISACTs philosophy, is their co-delivery with sectoral partners. This collaboration has opened up scope for the wider dissemination of the Caribbean Agro-Climatic Bulletin, the Caribbean Health-Climatic Bulletin and the Caribbean Tourism Climatic Bulletin not only via the CIMH RCC website but also via partner websites and social media platforms.

Furthermore, through engagement with the region's media houses, further dissemination and translation of the CariCOF outlooks into general public information has become more and more of a routine, rather than an occasional occurrence. This dissemination mode is currently most effective during and after the CariCOF forums.

Our research (Mahon et. al., *forthcoming*) shows that, many of the NMHSs participating in the CariCOF either produce and disseminate down-scaled, national climate outlooks that adopt the common methodological standard through CAROGEN, or contextualise the CariCOF outlooks for their country, or go beyond that and produce a range of user-oriented climate outlook products and services and present them at NCOFs. Dissemination of the CariCOF or downscaled national level outlooks is done through NMHS web sites, social media channels, email lists, and also via in-person and over-the-phone contact. Another structured method for interfacing with users is the National Climate Outlook Forum (NCOF), which would be modelled after the CariCOF but adapted to the national level. NCOFs are now routinely organised in 4 Caribbean countries (Belize, Guyana, Suriname, Trinidad and Tobago), mostly ahead of the important seasons.

Each month, once the monthly rainfall sums and average mean temperatures are updated in CAROGEN by the NMHSs participating in CariCOF, the most recent 0-month lead precipitation and mean temperature outlooks spanning months that are completed, are evaluated by the Caribbean RCC. Performance verification is done by comparing those outlook maps with maps of the observed category of station-based precipitation and mean temperatures. In addition, for rainfall, a map showing the percentage of 1981-2010 standard normal precipitation for each station is generated. Those maps are then posted on the Caribbean RCC web page.

3.3 Seasonal Climate Forecast verification

In addition, for research purposes, several verification studies have been done, namely:

- a study by Bedward and Van Meerbeeck[16], compared the performance of the 0-month lead IRI and the consensus CariCOF precipitation outlooks using the SPSS and the Heidke Skill Scores calculated over 13 forecasts. The conclusion was that skill was slightly positive, but with more hits for the CariCOF outlooks, due to the downscaling.
- a follow-up study by Bedward and Van Meerbeeck (*in review for* CERMES Technical Report) then verified the performance of the 0-month lead CariCOF precipitation outlooks issued before an objective, standard ensemble forecasting methodology adopted in 2013 (as described above). The study revealed that, over a period covering nearly 13 years of subjective forecasts, the ROC for above-normal rainfall was insufficient (0.614) to effectively discriminate wet years from other years and thereby successfully drive a simplistic flood risk model. This highlighted the need for an objective, statistical model based approach to seasonal forecasting.

- an unpublished study in 2015 by Lumsden and Van Meerbeeck systematically sought to identify whether the operational ensemble forecasting system adopted in 2013 could statistically significantly be outperformed by ensembles driven by different predictor sets than those operationally used. The Kendall's tau rank correlation revealed no significant improvements among a broad range of predictor sets, signaling that the operational model is setup quite optimally. This inspires confidence that the ensemble forecasting system is credible, although it is recommended that a broader parameter space for predictor sets be investigated in future.

Finally, a study currently being conducted by the Caribbean RCC aims at demonstrating the strengths of the CariCOF drought outlooks. To demonstrate the improvements in forecast quality over canonical precipitation outlooks, it is looking at several scores assessing forecast discrimination, amongst other attributes, and has come to the preliminary conclusion that a 12-SPI based probabilistic drought outlook for the water year – starting at the beginning of a wet season and ending at the end of the ensuing dry season – can correctly identify 88 out of 100 impactful droughts with 6-month lead time.

4. Capacity needs of the Caribbean region

4.1 The Caribbean RCC

With regard to the development of technical information, some investment needs of the Caribbean RCC are clear:

1. There have been many recommendations from various sector practitioners for information outside the seasonal (scale) outlooks, with sub-seasonal and inter-annual scales being linked with potential decision-making processes in various sectors that would not be facilitated by seasonal information. The sub-seasonal scale, in particular, is of particular interest to CariCOF.
2. Dynamical downscaling techniques to supplement/complement the statistical downscaling techniques of the CPT at the seasonal scale are being considered. Building capacity at the RCC in Dynamic downscaling techniques would also be beneficial in the RCC pursuits to support other regional institutions in providing climate change projections in the future.
3. Going forward, greater emphasis should be placed on sector-specific seasonal impact forecasting. Due to the lack of sector-specific impact forecasting models appropriate to the local context of Caribbean SIDS, this will require a major technical research thrust. With the sector-specific products, which would also consider decision-making processes within the sectors of interest, would reduce the level of interpretation needed for the more generic climate products.

4.2 Caribbean NMHSs

Ongoing studies at CIMH have shown that Caribbean NMHSs outperform other major potential providers of climate information in the Caribbean on user interaction. National users also receive more information on seasonal climate forecasts from NMHSs than from other sources such as CIMH. So it is paramount that capacity needs in the NMHSs are met so that engagement and climate information provision for the user community can be sustained and/or enhanced.

To support NMHSs, and for them to have sustained versions at the national level (i.e. NCOFs) there is need for the following:

1. In some cases, NMHSs do not have the legal mandate to even serve the country through weather updates and forecasts. There is a need in some cases for legal status to be established. One that would include climate information provision (including climate forecasting).
2. There is concern over the lack of political interest and support to move responsibilities of NMHSs beyond aviation meteorology and public weather forecasting to include climate services, including services related to seasonal climate forecasts.
3. Changes to the hierarchical and management structure of the NMHSs, such that non-aviation meteorology (including climate, applied meteorology and database management) can become critical aspects of their day-to-day operational activities.
4. Though trained at pre-CariCOF training events, some NMHSs can only support the development of regional climate outlooks, and support their countrymen in the interpretation and potential application of the outlooks, but with their other duties are unable to spend the time to develop their own national products. To support production of seasonal climate forecasts, there is the need to employ climatologists in more Caribbean NMHSs. Adequate financing is needed to support this modified structure and the necessary positions. In the interim, continued resources/access to financing that can support the training of NMHS staff in the art of seasonal (and sub-seasonal) forecasting.
5. Enhancing GIS skills would also support product development.
6. Almost 50% of Caribbean NMHS do not manage a Climate Data Management System. Support for this, however would come from CIMH through its customised database system. Though there was some training for database managers on the customised database system at CIMH, this is not yet enough and CIMH should in the near future provide further training for the Caribbean NMHSs on this database.
7. Most NMHSs in the Caribbean have no support from communications specialists.
8. There is some concern over whether NMHSs have the capacity to interact with certain sectors regarding the seasonal climate forecasts, and therefore some capacity needs to be built. NMHSs have to look into training in areas of applied meteorology.

4.3 User Community in the Caribbean

Research on user needs collected at CariCOFs convened from 2015-2016 indicates that:

1. Insufficient baselines exist in the Caribbean to inform product tailoring and development of forecasts for climate-sensitive sectors.
2. There is the need for focal persons in the sectors where a dedicated part of their work is on climate information and its application to their sector – a climate focal point.
3. These sector agency focal/resource persons would need more capacity in interpreting seasonal climate forecasts in their current form, and applying the information to their sectors.
4. Users also need to understand the limitations of their NMHSs. Exposure at more meetings and workshops such as CariCOF, where meteorologists interact and discuss issues is a good platform to build this understanding, and develop mutual trust.

4.4 Addressing Capacity Needs in the Caribbean

Through the pre-CariCOF training workshops, NMHSs capacity is built in the art of climate forecasting using the statistical downscaling model CPT.

Those training workshops also supports NMHSs in how to themselves interpret the information and present the information to stakeholders, as well as how to communicate and disseminate the information.

After the release of the forecast, users (particularly from the GFCS priority sectors) and NMHSs participants discuss the implications of the forecasts to these sectors, and recommend options for risk reduction in those sectors in their country contexts.

Through such discussions with the user community at the forum, recommended information products (not only seasonal forecast products) are pursued by CIMH, so that NMHSs and region can provide the products demanded by the region, as best and as much as possible. So the CariCOF acts as an important feedback mechanism.

The forum discussions also facilitate understanding of how users operate within their sectors and what are important to them relative to seasonal forecasting information. NMHSs staff learn quite a bit about the sectors themselves, including how to begin to apply the forecast information.

Through interactive sessions, drama and competitive settings such as the International Drought Tournament[17] (and more recently an experimental Multi-Hazard Tournament), providers and users of climate information get the opportunity to think through various management and decision-making options when faced with various climate scenarios.

5. User involvement

CariCOF has engaged all five priority sectors of the GFCS, as well as tourism – which is of great economic importance to the Caribbean region. Six regional agencies representing five of these sectors (the energy sector has not yet formally joined the partnership) joined forces with CIMH in 2016-17 to establish the EWISACTs Coordination Partners, committed to co-managing, co-producing and co-delivering sector tailored climate information. These agencies that partner to provide such support, are invited to each CariCOF, as they seek to work with CIMH to satisfy the climate information needs (including seasonal forecasting information) of their communities of practice. Though it is agreed that both the Wet/Hurricane Season and the Dry season can both threaten the viability of any of the priority sectors, more emphasis is paid to DRR during the Wet/Hurricane Season CariCOF because of the threat from severe systems such as tropical cyclones and tropical waves. The dry season places much pressure on the water and agriculture and food security sectors. These sectors are invited to participate in the relevant CariCOF with a larger national scale sectoral attendance from across the Caribbean. Because of the decision to rove CariCOF across the Caribbean, all priority sectors, along with *inter alia*, environment, physical development, finance, planning, and financial institutions from the host country are invited to participate. Depending on recent impacts, or forecasted impacts, other GFCS priority sectors would be invited accordingly to the two seasonal sessions.

CariCOF is a major mechanism for feedback through its many discussions and interactive sessions, which are captured in reporting and further discussed as opportunities arise at meetings of the Consortium or at national climate meetings. These meeting discussions, including those at CariCOF, are essential to the enhancing of existing products and the development of new ones.

One thing clear from the many discussions in the region, as like in other regions, is that tercile forecasts do not by themselves satisfy the needs of the users, but that more tailored products should be pursued that can be more applicable to the sectors. Such discussions led to more tailored

products such as drought outlooks (which are supported by recommended alert messaging), wet days and wet spells outlooks, and heat wave outlook (currently experimental) products.

The focus of the Caribbean is to determine how outlook products can be more sector-specific. Sector specific products for health, agriculture and tourism are currently being sought after. Until sector-specific forecast products (or sector specific impact forecast products) are delivered, the current (relevant) outlook products are packaged along with appropriate messaging to support interpretation and application for the specific sectors. So far three packaged products exists for agriculture, health and tourism.

6. SWOT analysis

A report by Guido et al.[18] on the two CariCOFs held in 2014 (Wet/Hurricane Season CariCOF in Jamaica and the Dry Season CariCOF in Antigua and Barbuda) identified the following barriers to the use of seasonal climate forecasts (SCFs) coming out of CariCOF:

1. lack of capacity or resources
2. difficulty in demonstrating the value of the forecast to potential forecast users,
3. difficulty with interpreting and explaining the forecast to others (which includes challenges with understanding technical scientific language, and explaining tercile output),
4. a lack of trust in the SCF,
5. challenges associated with the scientific language

CIMH and its partners have sought to remove these barriers to CariCOF effectiveness, and to some extent, two years later some progress have been made in some areas, and more attention needs to be paid to others.

6.1 Strengths

Since 2014, much work has been done in making SCFs more useful and usable for sectoral users, as well as, more manageable to produce for national level meteorologists who often have to perform many tasks in addition to the preparation of the outlooks. So one of the strengths of the RCC is building capacity of and training of NMHSs, particularly on a tool that automates and standardizes the forecast process, while at the same time significantly reducing the subjectivity of the forecasts. (This tool is the aforementioned CAROGEN, developed by the RCC.)

Not only are the capacity needs of the NMHSs addressed, but those user capacity needs earlier identified, are also being addressed – supporting the understanding, interpretation and application of not only CariCOF outlook information, but a range of climate-related information that supports sector decision-making.

Another positive that showed a strength to remove barriers identified in the Guido et al. analysis[18] was providing more tailored information as indicated in an earlier section. So instead of tercile rainfall and temperature, the Caribbean RCC has added drought alerting information, shifts in frequency of wet days and wet spell to alert to the possibility of flooding, and most recently heat (experimental) products that are potentially applicable to, *inter alia*, human, poultry and livestock health and construction.

Further, as an emerging strength, the move toward tailored sector bulletins, co-developed by practitioners in the sectors' lead regional organisations, can stimulate far more interest by users, and present more opportunities for the growth and relevance of CariCOF.

Another strength is the engagement of the media. Opportunities are sought and grabbed by the Caribbean RCC to build capacity and awareness in sectors and the media (particularly through interactive sessions) and outside CariCOF. There have been media campaigns and training sessions for media houses that have placed much focus on CariCOF sessions, with many CariCOF articles in the public media.

Most NMHSs and many sectors (and even some media houses) have been sending a stable pool of representatives to CariCOF sessions and this has built a number of "focal points" with a wealth of knowledge and exposure to CariCOF and its information. Feedback suggests that constant exposure of sector participants at CariCOF and other capacity building and awareness building sessions have made interpretation of information easier. The interactive type sessions (including the tournaments) have also been useful in thinking through decision-making options.

Only 4 NMHSs (Belize, Guyana, Suriname, and Trinidad and Tobago) have been able to convene an NCOF. In the absence of such a key user interface mechanism, the CariCOF (whose location cycles through various Caribbean countries) acts as a proxy for convening an interactive, multi-sectoral user-interface platform.

Research conducted at CariCOFs has been crucial in identifying sector-specific climate information needs. This in turn has led to the CIMH working with international and regional institutions on product research and development initiatives that have impact and value for climate-sensitive sectors currently being served by the RCC (e.g. the Participatory Integrated Climate Services for Agriculture (PICSA) approach by the University of Reading, and climate-driven vector-proliferation model).

6.2 Weaknesses

1. There is the need for more engagement of the private sector, including from the financial and energy sectors. This would open many more opportunities.

2. Though there was much effort to have decision-makers at the highest level of government, and there is great interest and participation from senior sector technocrats, there has been a disappointing level of participation by political figures.

3. There is still much work to be done on the sector-specific products, but CariCOF is now in a much better position to move on with this.

4. One of the weaknesses of the region is the inability to illustrate the economic value of the CariCOF products and services. There are many reports of their usefulness and how they are used, but illustration of economic value would capture the attention and interest of the private sector and Ministries of Finance and planning.

6.3 Opportunities

With the donor community viewing climate adaptation, including through climate services provision, as a major need of both developed and developing communities, the Caribbean RCC has

an opportunity to continue the CariCOF, while at the same time promoting and building in-country capacity toward the national version – the NCOFs.

With a newly provided video-conferencing facility at the Caribbean RCC, capacity building, particularly amongst NMHSs, need not only be a twice per year activity, but can be more frequent through remote means such as this. Small sector capacity building sessions can be made more frequently, and with the recent strides made in providing or developing sector tailored packages and products, the interest developed amongst the sectors for the seasonal forecast and other information can provide great opportunities for expansion.

With growing interests and research on other time-scales, particularly sub-seasonal and inter-annual outlooks, the opportunity exists for the Caribbean to expand its forecasting/outlook portfolio. Such expansion is likely to mean interest from other public and private sector players.

With growing interest in valuing weather and climate services at the global scale, the Caribbean RCC is in a position to emphasise the need for valuation of RCOF (including CariCOF) products. Involving regional economists in the valuation process also exposes them as a new set of players (and potential users of products) at the same time.

With the growing interest and publicity of CariCOF across Caribbean nations, not only because of the interest of sectors in the wealth of information and engagement, but also because of the involvement of the media, there is the opportunity to engage high level decision-makers and the private sector more. In the more recent two years, in particular, CariCOF did have remarks given by Ministers, and even one Head of State, which attracted a wealth of media attention, and of course by extension public attention, and awareness of CariCOF. So there is opportunity here to engage high level Government officials, including Ministries of Finance, along with the private sector. With private sector interest being built, there is also opportunity for revenue generation.

6.4 Threats

Probably the greatest threat to CariCOF is the lack of funding. In today's economic climate in the Caribbean, there is not enough indication that national Governments will be prepared to fund participants to CariCOF.

Financial limitations have knock on effects of limiting research and the capacity building process across NMHSs and sectors. Necessary human and infrastructural resources also become major limitations under such scenarios.

Though it is not likely to affect most NMHSs in attending CariCOF, there is some concern that legal mandates of some NMHSs to provide public forecasts, and that current structures in some NMHSs do not support providing climate forecasts; there might be lack of interest by some future decision-makers in releasing their staff for CariCOF-related activities, whether it is to attend CariCOF or to deliver products and services.

7. Sustainability of RCOF

The WMO Caribbean Regional Climate Centre (RCC) hosted by the CIMH provides overall technical coordination for CariCOF sessions, including pre-CariCOF training for NMHSs. The RCC also brokers the financial resources to conduct CariCOF. Though there is much interest and enthusiasm expressed by national sector in what they learn and gain during CariCOF sessions,

CariCOF has relied on, and continues to rely on external financial support, initially coming from the National Oceanic and Atmospheric Administration (NOAA) and the World Meteorological Organization. Examples of two projects that recently provided significant support for CariCOF are 1) the Programme for Building Regional Climate Capacity in the Caribbean (BRCCC Programme) funded by the USAID, and 2) the Programme for Implementing the Global Framework for Climate Services (GFCS) at Regional and National Scales funded by Environment and Climate Change Canada (ECCC).

The Caribbean RCC has been discussing a number of avenues to reduce the dependence on external funding. These include:

1. Greater engagement of the private sector, such that they not only participate and benefit from information provided, but also that some of these entities can provide support for the forums. There is also the opportunity for revenue generation that can be plugged back into the CariCOF and climate services processes.
2. National support for the staff of NMHSs and sector agencies; this would suggest that CariCOF participation would be a part of their annual budgets.
3. Through the Programme for Building Regional Climate Capacity in the Caribbean (BRCCC Programme), a teleconferencing facility has been made available to support capacity building exercises led by CIMH. CariCOF can benefit from the use of this facility by accommodating remote, on-line participation.

CariCOF continues to benefit from external technical support that upgrades its climate science capabilities. Mention should be made of the commitment from the IRI of the Columbia University and NOAA for their roles in establishing the current line of CariCOF products. They were both particularly supportive of pre-CariCOF training for NMHSs. The IRI in particular, earlier through 1. the Building Capacity to Manage Water Resources and Climate Risk in the Caribbean Project and 2. the International Research and Applications Project's (IRAP), Integrating Climate Information and Decision Processes for Regional Climate Resilience and more recently through the BRCCC Programme, provides crucial assistance in the pursuit of new and tailored products.

The Caribbean RCC has placed much emphasis on enhancing climate services through social science methods and research. This activity has been significantly supported by the University of Arizona, through both the IRAP and BRCCC programmes. There has been technical support from other international agencies as the need arises.

8. The Way forward

Research to enhance the relevance of the seasonal forecasts is also necessary. These would include areas such as:

1. Influence of drivers (ENSO, SSTs, NAO) on the wet and dry season, including their start and end, which are so important to sectors such as agriculture and water. How these interplay to cause differences in rainfall, in particular across the Caribbean.

2. Impacts forecasting associated with climate-sensitive activities within sectors. This also needs to be supported by research.

3. With the support of the EWISACTs Consortium at the regional level, and similar national level structures recommended through national Capacity mapping exercises conducted in select countries, information needs would continue to guide future product development.

4. Items defined through the process in 3. above also needs continued support from social sciences research to make sure of relevance of new products and enhanced products, the fit to the various sector decision-making processes, and how the information or messages are disseminated across each sector.

5. Interest in heat wave products have illustrated the greater focus that should be paid to use of data other than rainfall and temperature. Interest in wildfire occurrence also supports the embracing of parameters other than rainfall in the Caribbean setting. Other parameters such as relative humidity and wind become increasingly important to the CariCOF. With intentions to engage private sector more, including the energy sector, solar and wind data could become increasingly important in developing future products.

Engagement of the private sector will be a major focus of the CariCOF in the near future. With more intense discussions recently with energy interests, and the operationalising of the regional energy entity, potential for working more with and catering for the private sector exists. This will expand the reach of CariCOF and climate services in the Caribbean.

There will also be major emphasis in the near future on engaging the highest level of decision making in government. In this engagement, important would be discussions on structure and resources of NMHSs not only to deliver, disseminate and support interpretation and application of outlook products, but also to sustain such activity through resourcing, and developing the necessary enabling environment for use of such climate information through relevant policy-making and planning.

There have been calls in the region to expand the timescales for outlooks. Sub-seasonal information is now in greater demand in the region, along with inter-annual information. The near-future thrust of the RCC will be in providing sub-seasonal information.

Finally, one of the way forward for CariCOF is not to see it as a separate activity, but see it as a part of the entire building out of the climate services portfolio in the Caribbean. It is part of one major programme on climate services, and the success of climate services as a whole will be partly because of CariCOF and vice versa.

8.1 Future Efforts in the Science

Several lines of climatological research would offer key support in building climate forecast products and services that benefit Caribbean sectoral stakeholders from climate sensitive sectors. Among the key research questions that CariCOF and NCOFs in the region have raised are:

1. is there predictability in wild fire occurrence at the seasonal scale? Answering this question will reveal whether a robust impact prediction model can be developed and whether capacity building within the NMHSs of countries concerned with wild fire risk can become part of the

CariCOF/NCOF agenda. Jamaica has made the first footsteps in answering this question with support of Columbia University's IRI, which can serve as a model to be upscaled to the entire region as several other nations have identified the need for seasonal wild fire prediction, including e.g. Trinidad and Tobago (from a community-level DRR perspective) and Belize (from a DRR and an agriculture and forestry perspective).

2. is there predictability in flash flood, long-term flooding and landslide occurrence at the seasonal scale? From a DRR standpoint, most, if not all, Caribbean nations could benefit from robust impact prediction models for those hazards. Research has already enabled the operational roll-out of wet spells outlooks, which could serve as one of the building blocks to statistical forecasting of flash floods, flooding and landslides. Other pieces of the puzzle have also been extensively worked on in recent years, including flood and landslide hazard and risk mapping, GIS integration of existing climate and non-climate drivers of flood and landslide risk. In fact, CDEMA – who as one of the foremost regional DRR parties have raised the need for such prediction information – and the Caribbean RCC have been collaborating in such efforts and aim to continue the R&D effort.

3. in a region where the onset and end of the wet season is often unclear and remains undefined – with the exception of Trinidad and Tobago who has a clear cut definition for the onset –, can earlier or later dates be predicted? While the onset of the wet season is essential to crop planting, water resources management and drought relief, amongst others, detailed information has remained largely elusive. However, past and ongoing research into the statistical and physical links between ENSO, variability in the sea surface temperatures of the Tropical North Atlantic and onset dates suggests that, in principle, skillful prediction models could be developed. Similar, detailed research has not yet been conducted with respect to the end of the wet season, which matters in hydropower dam operation, rainfed and irrigated crop farming or to tourism sector practitioners.

4. Is there sufficient predictability of excessive heat exposure at the sub-seasonal to seasonal (S2S) timescales in the Caribbean? In most regions of the world, heatwaves are amongst the most deadly and costly, but relatively unnoticed meteorological hazards – with the exception of some notorious heatwaves, such as the 2003 European Heatwave, responsible for around 70,000 premature deaths. With Caribbean temperatures and the frequency and intensity of heatwaves already steadily rising[19], it would be very unlikely that its population would not be significantly affected by excess heat. Even though there presently is not enough centralized data serving as solid evidence for excess mortality (mostly premature deaths) or excess morbidity (non-communicable diseases) due to heat stress, which is primarily a factor of excessive heat exposure, there is a growing concern amongst Caribbean health professionals on the impacts of heat. Besides impacting human health, heat stress is known to affect livestock and poultry as well as to increase cooling demand, thus impacting the agriculture and food security and energy sectors. There is an additional concern that labour productivity may also be affected by excessive heat exposure. In response to the need for heat stress information, ongoing research suggests that the number of heatwaves differs greatly between years at individual locations and that, within sub-regions in the Caribbean, the annual number of heatwave days tends to be quite well correlated, spurring hope that seasonal prediction models may show some skill. However, such preliminary findings need confirmation by in-depth statistical analyses.

5. Which climate information from outside the region could help inform decision-making in the tourism sector? The notion that many vacationers from mid- and high latitudes seek sun, sea and

sand, implies that tourists are anxious to escape inclement weather in their place of residence. Hence, knowing months in advance, i.e. when vacationers typically book their escape vacation, that inclement weather may dominate an upcoming season, may benefit tourism professionals by predicting a rise in tourism arrivals in the Caribbean.

8.2 Setting Global Standards for the use of objective regional seasonal forecasts

As revealed in the section above on SCF verification, there appears to be merit in the use of objective regional SCFs. In addition, having the CariCOF adopt a standard, objective methodology – which, scientifically speaking, is perhaps the most robust form of consensus – benefits the quality of SCFs. Not to mention the benefits in terms of capacity development at the national scale for the provision of SCFs due to a larger community of practice and, therefore, a larger operational support base. Furthermore, the standard methodology adopted by CariCOF has contributed to greater confidence in the forecasts, including by the more technically inclined user community. This is not only because the method allows better reproducibility, but it is also easier to study skill, reliability and discrimination. Furthermore, the objective, standard methodology allows a more effective communication of model and forecast uncertainty. Moreover, the adoption of a regional standard enabled the automation process, with all its benefits w.r.t. capacity issues. And finally, a standard is emerging in terms of the CariCOF presentations of climate outlooks at the regional level – which has also started gaining traction at the national level – since 2016. That standard allows a more confident and understandable, yet less error prone, delivery of the outlooks to user stakeholders.

8.3 Expanding the RCOF product portfolio

As mentioned above, the current product range of the CariCOF already is quite expansive. Indeed, the portfolio counts no less than 15 map based, regional SCF products that are updated monthly and contextual information products to accompany them as well as packaging products to enhance effective and efficient communication and dissemination. Experience since the re-establishment of CariCOF has shown that the provision of contextual information – in terms of historical climatologies, impact information, monitoring information and expected impacts – is primordial to climate service delivery, including outlook information. As such, a range of RCC products developed in recent years has, in many cases, been inspired by CariCOF.

That said, capacity development and roll out of products and services related to seasonal wild fire, flash flood, flooding, landslide, excessive heat exposure prediction as well as climate prediction outside the Caribbean would all benefit the CariCOF. Besides such prediction information, early warning information for vector borne diseases, water borne diseases, crop pests, as well as hydrological outlooks, all at the S2S timescales are in demand within the GFCS priority sectors, and merit prioritization in terms of capacity development.

https://rcc.cimh.edu.bb/long-range-forecasts/caricof-climate-outlooks/

https://rcc.cimh.edu.bb/caricof/

References

[1]Enfield, D.B. & Alfaro, E.J. 1999. The dependence of Caribbean rainfall on the interaction of the tropical Atlantic and Pacific oceans. Journal of Climate, 12: 2093-2103

[2]Gamble, D. W., D. B. Parnell, and S. Curtis. 2008. Spatial variability of the Caribbean mid-summer drought and relation to north Atlantic high circulation. Int. J. Climatol., 28, 3. John Wiley & Sons, Ltd. DOI - 10.1002/joc.1600

[3]Angeles, M. E. et al. 2010. Origins of the Caribbean Rainfall Bimodal Behavior. J. Geophys. Res., 115, D11106, doi:10.1029/2009JD012990

[4]Giannini, A., Kushnir, Y. & Cane, M.A. 2000. Interannual variability of Caribbean rainfall, ENSO and the Atlantic Ocean. Journal of Climate 13, 297-310

[5]Giannini, A. et al. 2001. The ENSO teleconnection to the tropical Atlantic ocean: contributions of the remote and local SSTs to rainfall variability in the tropical Americas. Journal of Climate 14: 4530–4544

[6]Taylor, M. A., Enfield, D.B. & Chen, A.A. 2002. Influence of tropical Atlantic versus the tropical Pacific on Caribbean rainfall. J. of Geophysical Research 107 (C9), doi:10.1029/2001/JC001097

[7]Stephenson, T. C., Chen, A. A. & Taylor, M. A. 2007. Toward the development of prediction models for the primary Caribbean dry season. Theor. Appl. Climatol. (2007), doi:10.1007/s00704-007-0308-2

[8]Taylor, M. A. et al. 2011. Tropical gradient influences on Caribbean rainfall. J. Geophys. Res., 116, D00Q08, doi:10.1029/2010JD015580

[9]Charlery, J., Nurse, L. & Whitehall, K. 2006. Exploring the relationship between the North Atlantic oscillation and rainfall patterns in Barbados. Int. J. of Climatology, 26, pp. 819-827

[10]Martin, E. R., & Schumacher, C. 2011: Modulation of Caribbean precipitation by the Madden–Julian oscillation. J. Climate, 24, pp. 813–824.
http://journals.ametsoc.org/doi/10.1175/2010JCLI3773.1

[11]Cook, K. H. & Vizy, E.K. 2010. Hydrodynamics of the Caribbean low-level jet and its relationship to precipitation. Special U.S. CLIVAR Drought Collection. American Meteorological Society, pp. 1477-1494

[12]Taylor, M. A. et al. 2012. Why Dry. Int'l J. Climatology, 33 (3), doi:10.1002/joc.3461

[13]Prospero, J. M. & Lamb, P. J. 2003. African droughts and dust transport to the Caribbean: Climate change implications. Science 302 (5647), pp. 1024-1027

[14]Rodriguez, A. 2013. African dust clouds worry Caribbean scientists. Phys. Org. http://phys.org/news/2013-08-african-clouds-caribbean-scientists.html

[15]Farrell, D., Trotman, A. & Cox, C. 2010. Drought early warning system and risk reduction: a case study of the Caribbean drought of 2009-2010. *Global assessment report on disaster risk reduction.* United Nations International Strategy for Disaster Reduction (ISDR), Geneva.

[16]Bedward, S. & Van Meerbeeck, C. J. 2013. Assessing the skill of seasonal rainfall outlooks for the Caribbean. Geophys. Res. Abstracts 15, EGU2013-5968.

[17]Hill, H., et al. 2014. The Invitational Drought Tournament: What is it and why is it a useful tool for drought preparedness and adaptation? Weather Clim. Extremes, 3, pp. 107–116.

[18]Guido, Z. et al. 2016. Connecting Climate Information Producers and Users: Boundary Organization, Knowledge Networks, and Information Brokers at Caribbean Climate Outlook Forums. *Weather, Climate, and Society* 8 (3), pp. 285-298.

[19]Stephenson, T.S. et al. 2014. Changes in extreme temperature and precipitation in the Caribbean region.1961-2010. Int. J. of Climatology, 34 (9): pp. 2957–2971, DOI: 10.1002/joc.3889.