Kralendijk Declaration, recommendations from Coastal Dynamics and Ecosystem Change: Caribbean, Quo Vadis?

Bonaire, October 18-21, 2016

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Conference on Coastal Dynamics and Ecosystem Change: Caribbean, Quo Vadis?

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Kralendijk Declaration

The Caribbean comprises a mosaic of communities and environments that add up to a globally unique and highly (bio) diverse region. Endemism, inherent to the region's physiography, makes the Caribbean a hotspot of biodiversity. Simultaneously it is one of the most vulnerable regions as to coastal zone ecosystem degradation and coastal erosion.

Natural drainage systems, mangrove forests, seagrass meadows and coral reefs all play an important role in coastal protection. High population pressure, limited protection of natural resources in combination with global climate change has resulted in region-wide degradation of coastal ecosystems above and below water. The degradation of natural systems has caused a decline in the buffering capacity of the system, which coincides with a loss of associated ecosystem services and threatening beaches, fisheries, tourism, coastal communities and associated cultural heritage. This includes threats to the archaeological record of 8000 years of human presence and development.

Over the past decades, the Caribbean region has experienced development pressures. Tourism development but also for other economic functions have impacted ecosystems to the extend that as a consequence communities are now at risk. The reduced natural buffering capacity of well-functioning coastal ecosystems has rendered beaches, coastal towns, and cultural heritage resources more vulnerable than ever before. Especially given the challenges the region faces due to a changing climate. The Caribbean is among the world's most vulnerable regions to the effects of global warming and the associated ecosystem changes result in numerous interlinked challenges:

- Caribbean coasts will be impacted by more frequent extreme events as a result of stronger storms and sea level rise.
- Caribbean landscapes and cultural heritage resources will be compromised if not destroyed as a result of poor resource management and increased coastal erosion.
- Coastal ecosystems are among the most important (economic) resources of the communities living in the Caribbean. Pressure resulting from the human footprint on the islands and mainland Caribbean coasts combined with climate change demand rethinking of the way they live in coastal areas.
- Finally, environmental degradation resulting from increased coastal development, climate change and sea level rise will adversely affect tourism, the most important source of revenue for many Caribbean nations.

The root causes of global warming are beyond the control of Caribbean nations, especially since CO_2 contributions from the Caribbean as a whole are negligible. However, Caribbean people will experience serious impacts as a result of global climate change. The damaging effects of sea level rise are exacerbated by poor planning and weak regulatory oversight for coastal development projects and insufficient enforcement.

What can be done?

- **Understanding the problems and drafting recommendations with local involvement**. Earth and climate scientists, social scientists, and archaeologists/heritage managers are investigating the implications of global warming from their areas of expertise. Some of these researchers are examining climate change diachronically, ranging in scale from tens to hundreds to thousands of years. This allows us to document trends and project future implications across a wide range of societal fields and scales. However, if scientific understanding is not meaningfully translated to the general public and local island decision-makers then scientists run the risk of being viewed as mere alarmists, not as the providers of information that can guide adaptive measures for coastal communities. Local capacity building is essential to promote changes in attitudes towards land-use practices and implementation of effective regulatory frameworks managing and protecting coastal zones. This requires a serious engagement at the local and regional levels, especially with community members and local decision makers.

- **Working together as a region and among disciplines**. The Caribbean region consists of a mosaic of communities which as a result of the region's physical, political and cultural heritage is fragmented. It is unrealistic to expect individual nations, especially the smaller and less wealthy islands, to have the capacity to cope with the immediate problems associated with global climate change.

  Generating reliable information and developing and implementing best practices in environmental stewardship and mitigation efforts will benefit from broad regional data and methodology sharing. Effective coastal zone management requires regional cooperation and an inter- and transdisciplinary approach. It requires various disciplines including archaeology, economics, cultural and social sciences, geology, water management, oceanography, environmental policy, meteorology and climate science, marine biology, political science and information technology (for data management). Such an approach would recognize not only local physical characteristics but also respect the cultural and social circumstances within which the management measures have to be implemented in partnership with the local population.

  Regional collaboration in these knowledge areas is desirable because many small (island) nations individually lack the capacity to effectively address these broad and emergent challenges. More cooperation and linking among existing initiatives is important so that data and information can be easily shared. This calls for a coordinated regional approach in research, the development of Caribbean Region focused (data)management strategies and technical support to assist in implementation at a local level.

  We saw a preview of this cooperation at the recent conference on Coastal Dynamics and Ecosystem Change: Caribbean Quo Vadis? (Bonaire, Oct 18-21 2016). Approximately 60 scientists with strong scholarly records relevant to Caribbean coastal ecosystems were invited to Bonaire to present their research and views on changing Caribbean coastal environments. The meeting was unique in its breadth and focus; not often do archaeologists, biologists, climatologists, ecologists, engineers, geologists, geographers, oceanographers, and paleontologists meet in a single conference for a single purpose. The complementarity of the various approaches became evident as the program unfolded, and it was decided that the momentum of the group should be preserved.

Therefore, the undersigned conference contributing participants,

Recognize that the communities of the Caribbean region are threatened by the combined effects of local human induced ecological degradation and global warming,

Convinced that our collective understanding of changing Caribbean environments needs to be advanced in order to provide, and develop with Caribbean stakeholders effective management strategies,

Convinced that this advancement requires a holistic approach, which can only be achieved if various scientific disciplines and groups that study Caribbean environments integrate perspectives and datasets locally and regionally,

Convinced that research does not only deliver scientific results for the benefit of coping with global warming, but also serves to train the next generation of local experts,

Recognize that science needs to engage with (local) stakeholders in order to achieve local acceptance of the scientific results and insights of research programs and have them applied.

Recognize that scientific research programs should have inclusive policies for carrying out their work in the region, including consultation, education, and direct employment opportunities for specifically local residents,

Recognize that the Caribbean community is not only a recipient of research results but also an active partners in the design and execution of research,

Commit themselves in accordance with their specific scientific, institutional, and personal frameworks, to:

1. pursue cooperative transdisciplinary research projects supporting the Caribbean region in dealing with the effects of ecological change and global warming as outlined in the conference research agenda (Appendix 1);
2. ensure that such research meets short-term achievable goals, which are to be shared across scientific disciplines with Caribbean stakeholders;
3. support the development of an open platform and accompanying standards for sharing regionally relevant data sets for coastal zone research and management in the Caribbean region;
4. undertake action that communicates to an audience ranging from local community members to high-level policy makers the nature and urgency of the challenges at hand and to offer realistic coastal zone management solutions.

Conference contributing participants:

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Appendix 1: Kralendijk Research Agenda

For each of the Coastal Dynamics and Ecosystem Change: Caribbean Quo Vadis? (Bonaire, Oct 2016) conference sessions the chair and speakers were asked to identify key research questions relevant for their topic. The research agenda below is based on this input.

Session 1: Sea level rise and climate change

Session 1 addressed the topics of Future sea level change and the effects on coasts, Relative sea level changes in the Caribbean, and modelling of Caribbean regional relative sea level rise. The lectures by Anny Cazenave and Michael Tsimplis provided a comprehensive overview of present-day and future regional and sub-regional processes of relative sea level change. This includes results both from modelling studies and from the analysis of data sets of decades of sea level change monitoring in the Caribbean.

The afternoon session focused on climate change, through presentations on the modelling of the Caribbean regional climate (Michael Taylor, Ulric Trotz), Caribbean islands in a changing climate, and Governance and climate change in the Caribbean (Donovan Campbell). These lectures aimed to contribute to the understanding of the driving forces and magnitudes of climate change at the global, regional and sub-regional scales, while simultaneously providing insight into the socio-economic impacts of climate processes.

The following needs and research questions have been identified based on the presentations and ensuing discussion:

- Sea level monitoring network at local / regional level needs to be improved. In particular data collection from tide gauges co-located with GPS-type precise positioning systems to account for vertical land movement is important. The COCOnet GPS network had agreed in 2010/2011 to develop in a multi-use format thus providing vertical land movement estimates for sea level studies. A renewed effort to achieve this would be useful. Note that the GPS sensors of this network are not co-located so further sensors will be needed.

- Better understanding of the localized impacts of sea level rise needed. At a local level there needs to be more insight concerning the question what is the role of recent-past sea level rise in the Caribbean region compared to other natural processes and direct human intervention on shoreline erosion? In addition there is a strong need for local (coastal) ‘relative’ sea level projections (under different scenarios of future GHG emissions) accounting for all processes acting at the coast.

- Improved understanding of potential impacts in order to prioritize climate research work.

- Regional need for coastal database and modelling. This requires working with national services to assist them in overcoming the difficulties in data collection and modelling either by providing knowhow and resources or by encouraging to cooperate regionally for the development of a regional climatic database with appropriate data protocols and access in order to facilitate the needs of the Caribbean countries. In addition, there may be a need for ‘operational‘ services delivering ‘interpreted’ data (or products) to be easily accessible and useable for a variety of ‘end-users’ (e.g., coastal managers; and also the scientific community)?

- There is a need for training local scientists in some research disciplines particularly sea level measurements and modelling.

- There is a need of training policy makers in integrated assessment as well as understanding climate research updates. Workshops and summer schools can be very beneficial.

- There is a need of developing specific tools:

    - A surge and tidal model with ability to include waves is essential

    - A high resolution 3d oceanic model is also needed in order to understand the contribution of the oceanic circulation. This should be capable of including biological and geochemical components.

    - A GIS database of the islands and the coastal areas should be developed if not available yet, and used to identify the areas most at risk and the functions/services that are at risk (ports, touristic regions, reefs, mangroves etc.).

Session 2: Ecosystem response to sea level rise and climate change

Session 2 focused on the ecosystem response to sea level rise, climate change and human footprint. The first part of the morning session dealt with Coral Reefs, Seagrasses and Mangroves; their interrelation and their crucial role in coastal protection. The first two lectures (Chris Perry, Mark Vermeij) focused on coral reef decline and provided an overview of various threats to reef health (diseases, phase shifts, acidification and global warming) as well as provided insight in coral reef resilience, decline and recovery attempts. The second part assessed seagrass (Brigitte van Tussenbroek,) and mangrove ecosystems as transition areas between the reefs and shore (Ken Kraus). This was followed by a lecture on the threats of a future increase of Harmful Algal Blooms, in response to environmental change and anthropogenic pollution (Francesca Sangiorgi).

Suggested themes for inter-disciplinary/integrated research relating to session 2 include:

- There is clearly an urgent need for datasets that account for local (site specific) variations in reef accretion potential, set against more reliable local scale Sea Level rise projections.

- There would be considerable value in integrated studies that explore the interactive effects of Sea Level rise on reefs and proximal nearshore lagoonal (seagrass and mangrove) ecosystems where they occur – in terms of wave energy, sediment transport/accumulation, shoreline retreat rates etc. There are likely to be markedly varying responses between different settings based in part on coastal/nearshore configurations.

- There would also be much interest in integrating modelling of wave energy, sediment transport impacts under different Sea Level rise rate scenarios in these diverse settings, including the role of 3D complexity of benthic communities on wave energy attenuation. The key goal here would be to provide a suite of exemplar scenarios for different types of reef-seagrass-mangrove systems.

- Of additional widespread concern and interest is that we currently have no capabilities/methods to quantify how much sediment coral reefs and reef-associated habitats produce, nor the types (sizes) of sediment that are produced. This is a major knowledge gap that has relevance to anyone interested in the persistence and maintenance of beaches and shallow lagoon ecosystems. Again there would be very great potential to link such empirical studies to nearshore transport modelling efforts, and especially to integrate such datasets with future projections of sediment generation that factor for pH and SST change scenarios.

- There is clearly an urgent need for an improved understanding of the occurrence and wider role of microorganisms in reef and coastal ecosystems – including those that can drive benthic ecological changes and harmful/toxic blooms. In addition recent macro algae blooms of Sargassum spp. in the region (2011-2015): have caused damage to tourist industry and coastal ecosystems We suggest this may form an interesting area for a future inter-disciplinary research agenda – it is a theme with ecological, social and economic implications.

Session 3: Human footprint, sea level, climate, environments

The first part of the afternoon session started with a review on 6000 years of human migration and colonization in the Caribbean island domains. Emphasis was laid on the time-progressive increase of the effects of human footprint on coastal environments, caused by the impact of deforestation, eutrophication, mining activities and (over)fishing. During this session the relevance of studying and preserving the tremendously rich cultural heritage of the Caribbean was highlighted in three presentations by Corinne Hofman, Peter Siegel and Andrzej Antczak.

The second part of the session included two presentations on terrestrial paleo-ecology (Ligia Urrego and Gerald Islebe) and one on modelling efforts to reconstruct Caribbean sea-level changes during the Holocene in high detail (Matthew Peros).

The intensive archaeological research ongoing in the Caribbean as well as the paleo-ecological studies revealed a large number of common key questions that both disciplines address, but still from different methodological angles.

The potential and limitations outlined in this series of talks positively highlights the added value of a closer collaboration between these two research lines and approaches. Areas of interest include:

- Paleo-ecological studies can provide a sound context of climatological background dynamics of the regions in which the early Caribbean settlements were established.

- Identifying phases of persistent drought or excessive precipitation can help to better explain potential stress on human populations.

- Human-induced versus natural causes of past vegetation changes are more readily identifiable when archaeological insights are included in the interpretation.

- Improved shoreline modelling is essential to study migration routes of ancient humans, but is also highly relevant for past ecological changes, e.g., mangrove community dynamics through time.

Session 4: Coastal configurations and morphodynamics

Session 4 covered various aspects of coastal development, by analyzing Caribbean coastal configurations and coastal zone morphodynamics. The first lecture by Terrence McCloskey covered an overview of the impact, frequency and regional aspects of extreme events in the Caribbean. The second lecture by Gregg Brooks focused on human development impacts on erosion and sediment delivery to coastal environments of the Virgin Islands. The first part of this session concluded with an overview of the tectonic movements in the Caribbean. The second part of this session focused on coastal erosion patterns and management practices with the presentation of a case study from Mexico by Rodolfo Silva Casarin and Colombia by Nelson Rangel-Buitrago.

- Historic occurrence of extreme events (Hurricanes and Tsunamis) can be determined by looking at the sediment record. However both have the same sedimentary signature and therefore there is some controversy concerning data interpretation. It was suggested that the paleo record might be useful to better distinguish between events because of the different impacts they had on human live in areas impacted.

- Modelling does not support necessarily that the frequency of storms will increase. Modeling further suggests that as the Bermuda High (BH) and TCZ Systems are expected to move north storm tracks are likely to move north as a result. At this point there is a need for improvement in quantifiable calculations of the return intervals. It was further pointed out that physical markers of extreme events (for example large boulders or rubble deposits) should be protected as part of the geological record and form useful indicators of how far inland extreme events can have an impact.

- Concerning beach erosion (major concern in Colombia and Mexico) there is a lack of monitoring taking place to adequately document erosion rates. Further there is a need for better information on sand transport in the region.

- The balance between ecological and economic interests determines the response to coastal erosion. Loss of beaches in these regions will have a major impact, as they are principal economic drivers. This makes the question how to respond to coastal erosion a difficult one and retreat unpopular. Within the context of this discussion it is important to provide the decision makers with options what to prepare for.

Session 5: The Caribbean challenge, perspectives and constraints

Session 5 explored the opportunities and limitations of nature based flood defence (Tjeerd Bouma) and a case study on the effects of climate change on coastal communities of the Greater Everglades (Marguerite Koch). This session was followed by a discussion and a concluding session concerning follow-up and continuation of the network. The presentation of Tjeerd Bouma demonstrated how nature based solutions can help to reduce the impacts of extreme events. Various ecosystems are well suited for eco-engineered solutions that can help with wave attenuation (seagrass beds, mangrove etc.). Hard and soft-engineered solutions can be combined (for example a bio-friendly hard solution that allows vegetation to grow on it). Vegetation establishment can be tough because certain thresholds need to be met. This requires an accurate system understanding.

The Everglades case study presented the following recommendations that may be regionally relevant:

- An integrative and resilience-focused management strategy is needed as marine-terrestrial boundaries become dynamic with marine transgression, particularly in landscapes such as South Florida with micro-elevation gradients.
- Develop large-scale watershed-coastal models that integrate water, land, infrastructure and management to optimize natural and built system sustainability. Downscaled sea level rise models. Modeling climate impacts and upstream water management effects on critical coastal habitats. Model data requirements (water quality, hydrographic, geomorphological, and ecological)
- Active approach to management to sustain marine ecosystems succumbing to climate impacts.
- Develop a comprehensive regional/local governance and planning framework to coordinate research and planning efforts to sustain South Florida under climate change.

Development of a regional Caribbean coastal zone management research and decision support infrastructure:

Development and maintenance of a state of the art Caribbean (Distributed) Open Database (based on data-protocols to ensure interoperability) of relevant coastal zone management data for the Caribbean region. Including the development of Caribbean region specific (monitoring) data sets and modelling tools for informed local decision making.