Annex L: Biophysical Aspects Break-Out Group (Part III, Chapters 4-7)

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Overall Points Related to Completing the Table and the Biophysical Aspects Part of the WCR Assessment

The participants noted this part of the WOA needs to:

1) consider several unique characteristics of the Caribbean Sea: river outflows from Amazon and Mississippi rivers; the Caribbean Sea is semi-enclosed; the Caribbean Sea is connected to other regions of North Atlantic Ocean;
2) consider atmosphere, such as trade winds, rainfall and hurricane activity;
3) address ocean acidification, which will have a large impact on coral reefs and thus on fisheries and food issues in society;
4) incorporate the IPCC-AR5 report into the sea level rise analysis because the report will provide much enhanced information because it will have a much better handle on sea-ice melting effects;
5) consider that sea-level rise is not uniform and, consequently, we need to study the historical and future projection of the sea-level rise for the Caribbean Sea; and
6) consider approaching insurance companies, which may have some related data.

Atmospheric influences over the CS are insufficiently studied such as the importance of rainfall, which input of freshwater onto the surface layers is estimated to be greater than direct rivers inputs. Rainfall patterns are partially controlled by the fluctuation of the trade winds, and hurricane activity.

Until now the impact of ocean acidification is not known, the monitoring of acidification is incipient in the WCR, although it would have a large impact on coral reef stability, thus on associated fisheries and livelihoods. The eventual loss of reefs would increase the vulnerability of coastlines.

The WCR is particularly vulnerable to the effects of climate change. Inundation of lowlands and islands, could lead to the loss of special habitats and ecosystems like mangroves, sea-grasses and coral reefs. It is also expected a significant change of the rainfall patterns over the region. These effects together with less frequent but more intense hurricanes will have an overall negative impact on the economy of the region, especially in the island states.

Sea-level rise is not uniform around the world. Sea level in the Caribbean Sea is raising at a lesser rate than elsewhere, although there are areas in the WCR with significant subduction. The group considered that it would be important to study the historical record as well as the future projection of the sea-level rise for the Caribbean Sea. For sea-level rise the IPCC-AR5 report will provide much enhanced information because it will address the dynamic aspects of glaciers and continental ice melting effects.

Topics (e.g. Oceans' roles in hydrological cycle) and Sub-Topics (e.g. Freshwater fluxes…) to Include in the WCR Assessment	Relevant Studies, Documents, Reports and Other Sources of Information (refer to the Inventory list)	Priority Individuals & Institutions to Engage (email; who suggested)	Information Gaps	Comments
Oceans' roles in hydrological cycle (Chapter 4) • Freshwater fluxes into the ocean, sea ice, sea level • Socioeconomic implications of ocean warming, sea level change, and freshwater fluxes • Changes in chemical composition of seawater – salinity and nutrients – and their socioeconomic implications • Sediment Inputs (new sub-topics) - account for Inputs	*Fresh Water Fluxes* Siung Chang A.M. & Lum Kong A. 2001. Possible link between reef-fish mortality and South American River Discharge. Bull Mar Sci 68:343-340. Joyce et al 1999, DSR II 46: 245-278. long term hydrographic changes… LOICZ 2011 Coastal discharge to the coastal ocean, Cambridge Press 2008 USF Bob Weisburg JPO – Altimetry based Coral core data based studies Global International Water Assessment: UNEP, 2004. Bernal, M.C., Londono, L.M. Troncoso, W. Sierra-Correa, P.C. and F.A Arias-Isaza Caribbean Sea/Small Islands. GIWA Regional assessment 3a. University of Kalmar, Kalmar, Sweden. UNEP, 2006. Isaza, C. F.A., Sierra-Correa, P.C. Bernal-Velasquez, M., Londono, L.M., and W.	*Fresh Water Fluxes* Bob Weisberg (USF) Dr. Javier Alcocer, UNAM (Mexico) Dr. Jorge Herrera Silveira, CINVESTAV-IPN (Mexico) Enrique Mejia Maravilla, CONAGUA (Mexico) Salvador Arimendi Guadarrama, CONAGUA (Mexico) Dra. Margarita Caso, Instituto Nacional de Ecología y Cambio Climático (Mexico) José Luis Ochoa de la Torre – CICESE (Mexico) Dr. Jorge Zavala, UNAM (Mexico)	*Fresh Water Fluxes* In situ measurement test of rainfall contribution to WCR (vs riverine input) Need for Reference stations *Socioeconomics* SLR and relative rates of change in WCR (in situ gauges needed) *Changes in Chemistry* Regional data	*Fresh Water Fluxes* Coral core data may provide freshwater flux variability in the region in historical perspectives *Socioeconomics* Increased humidity in the atmosphere makes the high latitude regions more vulnerable to diseases. *Changes in Chemistry* (no comments) *Heat Transport* Data available but not easily accessible (no centralized body) -working paper

from Magdalena, Mississippi, Orinoco, Amazon, etc • Ocean heat transport, ocean circulation, and patterns – El Nino – and their socioeconomic implications	Troncoso. Caribbean Sea/Colombia & Venezuela, Caribbean Sea/Central America & Mexico, GIWA Regional assessment 3b, 3c. University of Kalmar, Kalmar, Sweden. Jose Benito and Vives De Andreis, 2003: Netherlands Climate Change Studies Assistant Program, Colombia: Defining vulnerability of Bio-geophysical and Socio-economic systems due to sea level change in the Columbia coastal zone (Caribbean and Pacific) and adaptation measures. Executive Summary. Institute de Investigaciones Marinas y Costeras, Santa Marta ESA CCI 2012 SLR 1993-2010. Puerto Rico – stations (~30) –Tsunami GLOS – IOC Surface drifter Data (AOML) Carioco project: US-Venezuela joint project Caribbean Atlantic time series: www.caricoos.org Moore WS and TM Church. 1996 Nature 382:122 – submarine groundwater discharge Florida cable data at AOML: Western Boundary time series Rainfall time series from TRIM satellite project	*Socioeconomics* CDMA – Caribbean disaster management (Barbados) WRI. Natural Capital Project UN ECLAC National Disaster Prevention Center (Mexico; e.g. frequency of events) CDMA Patrick McConney CERMES National Weather Service (USVI/PR) *Changes in Chemistry* NOAA/AOML/OCD - US *Sediment* Restrepo – Medellin, Flux of Magdalena River Alvarado-Barranquilla Caribbean Environment Program-UNEP	are scattered. -it is desirable that all those data be added to the WOA There is a database of nutrients - NOAA World Ocean Atlas: WOA *Sediment* Other rivers impacting region (lack of data)e.g. Rio San Juan, Central America *Heat Transport* -Data accessibility -El Nino is not the only factor that controls climate. -We need to know more about local processes,	

	Underground hydrolgy (cenotes) Alcocer, J., Lugo,A., Marín, L. y Escobar, E. (1998).“Hydrochemistry of waters from five cenotes and evaluation of their suitability for drinking- watersupplies, northeastern Yucatán, Mexico”. Hydrgeology Journal, 6, 293-301. Coastal Atlas of Puerto Morelos Merino, M. y L. Otero. 1991. Atlas Ambiental Costero. Puerto Morelos-Quintana Roo. CONACYT, UNAM y CIQRO. 80 pp. + 1 Carta. *Socioeconomics* Regional Tsunami Program NCAP project WRI – Cooper et al 2009 – valuation barrier reef Nat Cap 2012 - Project – Belize, Mesoamerican Reef communities at risk WRI – Lauretta’s work (see Day 1 presentation) UN ECLAC – Climate Change Impact Reports - multisector -*inundation level data exist in many countries in the Caribbean*. Tendencias del nivel del mar en las costas mexicanas. Jorge Zavala-Hidalgo, Rebeca de Buen Kalman, Rosario Romero-Centeno, Felipe Hernández Maguey. En: A.V. Botello, S. Villanueva-Fragoso, J. Gutiérrez y J. L. Rojas	*Heat Transport* CATHALAC Carlos Andrade candrade@exocol.com.co Chris Mooers (works with C. Andrade) Ed Barton (Colombian basin) (works with C. Andrade)	such as those associated with the Atlantic multi-decadal oscillation (AMO).	

	Galaviz (eds.), Vulnerabilidad de las zonas costeras mexicanas ante el cambio climático. SyG Editores. Gobierno del Estado de Tabasco. Semarnat-INE, UNAM-ICMyL, Universidad Autónoma de Campeche, pp. 249-267, 514 p. ISBN 978-607-7887-11-9 (v. impresa). ISBN 978-607-7887-12-6 (v. electrónica), 2010.m *Changes in Chemistry* LBSP (Point/Non-Point Loading) Reports POPS(Persistent Organics) REPCAR Report Next year Nutrient Meeting Gulf of Mexico database –National Institute of Ecology and Climate Change Herrera-Silveira, J.A. 1994. Nutrients from uderground discharges in a coastal lagoon (Celestún, Yucatán, México). Verh. Internat. Verein. Limnol. 25: 1398-1403. Herrera-Silveira, J.A. 1994. Spatial and temporal patterns in a tropical coastal lagoon with groundwater discharges. Journal of Coastal Research 10 (3): 738-746. Herrera-Silveira, J .A. 1994. Phytoplankton productivity and submerged macrophytes biomass variation in a tropical coastal lagoon with groundwater discharge. Vie Milieu. 44 (3-4):257-			

	266. Herrera-Silveira, J.A. and F.A. Comín. 1995. Nutrient fluxes in a tropical coastal lagoon. Ophelia. (42):127-146. Caso, M., E. Peters, V. Gutiérrez-Avedoy 2013. The establishment of the baseline for the Mexican portion of the Gulf of Mexico in response to the British Petroleum oil spill. This information is confidential and will be released probably in 2013. *Sediments* LBS Report- Orinoco Plume Influx references: http://www.cep.unep.org/publications-and-resources/marine-and-coastal-issues-links/sedimentation-and-erosion#ref *Heat Transport* Factors influencing: FL Straits, Warm Pool, Upwelling (in south of region), Riverine Inputs Satellite observations Jouanno et al., 2012. Seasonal and interannual modulation of the eddy kinetic energy in the Caribbean Sea. J. Phys. Ocean. 2012. doi: 10.1175/JPO-D-12-048.1 Coastal circulation in the Mexican Caribbean Sea Aspectos de la Circulacion Costera Superficial del Caribe Mexicano con base en Observaciones			

	Utilizando Tarjetas de Deriva - José Luis Ochoa (CICESE) Apoyo a los Análisis de datos de corrientes, hidrológicos y meteorológicos y su consistencia con teorías y modelos numéricos. Lograr un entendimiento integral de la circulación oceánica a lo largo del Caribe Mexicano. Obtener los patrones de circulación oceánica a lo largo del Caribe mexicano; entendiendo la interacción entre la circulación de gran escala y la cercana a la costa de tal forma que se puedan diseñar forzamientos realistas para la modelación de corrientes y transporte de partículas y difusión de substancias.			
Sea/air interaction (Chapter 5) • Atmospheric fluxes, oxygen production, carbon dioxide sequestration • Hurricanes, monsoon, trade winds (no typhoons in the region; new: El Nino impacts) • Trends in meteorological	*Atmospheric fluxes, etc* -IPCC Assessment Report 5 -National Communications to UNFCCC *Hurricanes* -UN ECLAC – Reports on Socioeconomic Impacts -Future Water Availability/Shortages IDRC CATHALAC Funded Impacts of El Niño - Magaña Rueda Víctor (Editor) (2004). Los impactos del niño en México. Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México, Secretaría de Gobernación. México, 229 p. *Ocean acidification* -Coral Reef impacts of OA. IUCN Reports	*Atmospheric fluxes, etc* - Roy Armstrong (Aeolian Flux –Sahara/Hurricanes) -Rik Wanninkhof –AOML -Jorge Zavala –UNAM -Julio Scheinbaum –CICESE -Julio Candela-CICESE - Dr. Roberto Iglesias Prieto, Unidad Académica: Puerto Morelos (UNAM) *Hurricanes* -NOAA/AOML/HRD -NOAA/NWS/NHC *Meteorological phenomena*	*Atmospheric fluxes, etc* -cruise ships emit CO2 to the atmosphere, but we do not know how much it contributes to the overall emission in the region. *Hurricanes* -lower frequency/hig	*Atmospheric fluxes, etc* -Saharan dust (Aeolian Flux) is an important source of nutrients and also affects source of CO2 compared to background sources *Hurricanes* ENSO related regional impacts -displacement of individuals due to

phenomena and their socioeconomic implications • Ocean acidification and the socioeconomic implications	- PMEL Stations - Hoegh-Guldberg, O., Mumby, P.J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, D. C., Sale, P., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A., and Hatziolos, M. (2007). The carbon crisis: coral reefs under rapid Climate and ocean acidification. Science, 318: 1737–1742. - Hoegh-Guldberg, O., Mumby, P.J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, D. C., Sale, P., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A., and Hatziolos, M. (2007). Coral adaptation in the face of climate change-Response. Science, 320:315-316. - Magaña V. y C. Gay. Vulnerabilidad y Adaptación Regional Ante El Cambio Climático y sus Impactos Ambiental, Social y Económicos http://www2.ine.gob.mx/descargas/cclimatico/vulnerabilidad	-Colombian Institute of Meteorology -Vasu Misra – FSU -Dave Enfield – rainfall? -Art Douglas -Roger Pulwarty – CIMH(Barbados) -Climate Services CCCCC – climate change - Ulric Trotz Homero Silva-UTech/PAHO Felipe Vasquez – National Meteorological Service - Mexico) - CATHALAC *Ocean acidification* Ian Enochs, Derek Manzello (sp?) NOAA/AOML Corals & OA -Rik Wanninkhof - AOML	her intensity hurricanes? *Meteorological phenomena* Data describing regional-scale meteorological phenomena -impact of ENSO, NAO, AMO indices (teleconnections) *Ocean acidification* -Open and active area of research -Where to measure (long-term) Monitoring system -longitudinal shifts in OA impact (storage of CO2) from WCR to Atlantic (offshore,	changes in rainfall patterns (i.e. damage from storms) -possible changes in regional rainfall (forecasting), changes in precipitation (i.e. less rainfall) - decreases/ changes in thermohaline circulation and influence on WCR -Human Health impacts-disease transmission (related to vector-transmitted) *Ocean acidification* -Extend one of WOCE monitoring lines into WCR -Impact to livelihoods (via impact to e.g. conch fishery), tourism, -Risk to coastal ocean development (i.e. fringe reefs), wave energy

			central Caribbean, inshore)	dissipation Impact to fisheries (finfish & shellfish) by way of impact to lower trophic levels (e.g. pteropods)
Primary production, cycling of nutrients, surface layer and plankton (Chapter 6) • Primary production distribution • Surface layer and plankton, factors influencing the surface layer and species variation • Socioeconomic implications of primary production trends and other factors affecting food webs	*Primary production distribution* -Riverine Influx of nutrients, Dead Zones Biogeosciences. Special Issue on Hypoxia (2011) -Carbon sequestration by Mangroves (GEF) – Blue Carbon initiatives -CarSea Report 2007 - loss of mangroves paper by John Agard -Low carbon Development Strategy –LCDS, REDD+ D E Canfield et al. Science 2010;330:192-196 -R. A. Duce *et al. Science* 320, 893 (2008); Impacts of Atmospheric Anthropogenic Nitrogen on the Open Ocean -J N Galloway et al. Science 2008;320:889-892; Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions - El sistema ecológico de la Bahía de Chetumal, costa occidental del Mar Caribe. Julio Espinoza Ávalos (editor principal) Gerald Alexander Islebe y Héctor Abuid Hernández Arana http://w2.ecosur-qroo.mx/cna/julio/libbahia.pdf *Surface layer and plankton* -CATS time series(?) -Ships of Opportunity Program -1980s Indian Ship (publications available) -CARICOMP -IOC data availability?	*Primary production distribution* -John Agard (Mangroves) -Frank Muller-Karger -USF -HABSOS Monitoring Network - Frank Muller-Karger -Dr. Martin Merino Ibarra, UNAM *Surface layer and plankton* -Center for Marine Sciences – Dale Webber UWI -Francisco Arias-INVEMAR *Socioeconomics /Food webs* -Rabalais N. – Hypoxia Gulf of Mexico -CERMES -Robin Mahon -Mark Jury –UPR -Sharon Herzka-CICESE	*Primary production distribution* -What and where to measure and consistency of data (long-term data production) *Surface layer and plankton* -Need to reestablish in situ chlorophyll (and other) measurements in WCR -need regularly monitored stations (Eularian time series data) -Long term satellite data	*Primary production distribution* Lots of Mangroves being lost (but doing well in Belize). Intra-regional differences. Red Tides increasing *Socioeconomics* Changes in Food Web- micro-pico plankton (i.e. nutrient flux impacts lower trophic levels), change in phytoplankton/zooplankton ratios Campeche Sound - possible 2nd Hypoxic Zone

	-Fixed Buoys – weather, Tsumani, etc (WHOI) -ICON Stations -Meso-Scale Eddies & Transport, influence on currents -TOPEX/Poseidon Data -Corredor J.E. and Morell J. M. 2001. Seasonal variation of physical and biogeochemical features in eastern Caribbean surface Water. J. of Geophysical Research. 106, 4517-4525. *Socioeconomics/ Food webs* -Possible linkages among shelf spp and OA; e.g. altering food webs, loss of apex predators, shift; e.g. JBC Jackson et al 2001 Science (Historical Overfishing) -Jury MR. 2011. Environmental Influences on Caribbean Fish Catch. International Journal of Oceanography.		already exist and need to be better utilized. -Many diffuse data sources, but lacking a central organizing body as access point (data inventory needed)	
Ocean-sourced carbonate production (Chapter 7) • Role of ocean-sourced carbonate production in the formation of atolls and beaches and potential impacts of ocean acidification • Loss of habitat associated with ocean-sourced carbonate (new sub-topic)		Shakira Khan-Butterfield – Marine Geology unit, UWI Blanca Posada – geologist INVEMAR Roberto Iglesias - UNAM	Lack of regional-scale data describing the relationship between ocean-sourced carbonate chemistry and impact on atolls/beaches -Importance of silicate vs carbonate in WCR (unique)	Ocean-sourced carbonate Could make this a subsection of other chapters, or make focus broader Main cause of loss of beaches

Overall Assessment Capacity Needs Related to Biophysical Aspects and How to Address Them

The participants identified the following needs:

- development of a regional framework – participating in the WOA process is viewed as capacity development for nations involved;
- support for reestablishing in situ measurements;
- access to research vessels for region – vessel from Norway, US NOAA vessels, identification of vessels, ships of opportunity;
- improved capacity and capability of people who can collect new and analyze existing data at regional level; systematic standardized training program for people in the region; inter-institutional training network;
- clear articulation of scientific questions for the region– common goals for region; and
- plan for new forecasting tools to move WCR biophysical oceanography programs into a strategic position for the coming decades. Students could go to this location to receive training for protracted period of time, then return to internally build capacity.

There was a consensus that the region has access to an important volume of data and information; However, these data are not always readily available or synthesized in a usable form. There is also an important amount of information that is not published (grey-literature) or exists only as internal reports of the public or private sector. Although this is a weakness due to often fragile institutional arrangements, in the context of the World Ocean Assessment it represents an opportunity, if an effort to produce these synthesis is organized, for example to draft Working Papers on the different subjects. This discussion highlights the needs for capacity development in the region, a topic that was addressed several times during the discussions. It was suggested that some sort of collective regional institution or institutional arrangements could facilitate significantly the work that is required to provide a solid science foundation to the decision making processes at the regional and national level. This requires an institution capable of providing regularly information on the biophysical conditions in WCR. Existing initiatives like IOCARIBE GOOS, designed to provide regular information services, can serve as interesting examples.

In summary the group considers that the WOA might be a first step in a renewed effort to mobilize institutions and experts of the region to enhance cooperative work and to find synergies in order to produce the needed information to address the common problems due to the increased use of the ocean and its resources and to prepare and adapt the WCR to the impact of global change.

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