Future climate change in the Antilles: Regional climate, tropical cyclones and sea states

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3rd Caribaea Initiative Research & Conservation Workshop, Guadeloupe, May 30th 2018
Regional Climate in the Antilles
4 regions

Jury et al. 2007 J Geophys Res

4 groups (rainfall)

Annual precip: (1)
Semi-annual: (2)-(4)

Dry season ~Jan-Apr
Wet season ~May-Nov

Precipitation clusters from factor analysis over 35 stations in 1951-1981

How might these and other patterns change with global warming?
• **Background**: observed trends in the Caribbean and future projections.

• **Previous work @Météo-France**: climate change in the Lesser Antilles.

• **The C3AF project**: revisiting climate projections for the French West Indies. Changes in tropical cyclone activity and sea states.

• **Concluding remarks**.
Background
Observed trends in the Caribbean
Temperature changes

Day-time temp.

Night-time temp.

Day-night diff.

Increase in min & max temp.

Day-time temp: +1.0°C in 50 years

Night-time temp: +1.4°C in 50 years

Reduced day-night temp. difference

Trends in max/min temp. & diurnal thermal amplitude (°C) in 1961-2010
Observed trends in the Caribbean
Precipitation changes

Trends in total & extreme precipitation (%) in 1961-2010

- No significant trend in total precip
- No significant trend in extreme precip (except W. Cuba)
- Records too short? Decadal variations?
Projected trends in the Caribbean
Precipitation changes

Cuba/Jamaica/Barbados/Belize collaboration: PRECIS RCM 50 km resolution (UK Met Office)

Change in monthly mean rainfall (%) in 2071-2100 (A2) relative to 1961-1990

Strong drying of wet season (25-50%)
Consistent with IPCC-AR5 projections
Related to increased trade winds in the western Caribbean Sea (CLLJ)
May also lead to reduced tropical cyclone activity?


Change in Caribbean rainfall (%) in 2071-2100 (A2) relative to 1961–1990
Projected trends in the Caribbean
Regional climate change

US/Central America/Jamaica collaboration:
WRF RCM 12 km resolution (USA)

Year-round regional warming
+0.1-0.3°C/decade over the Antilles
Insensitive to resolution: ocean control?

Drying trend over the Antilles
Greater Antilles: max in wet season
Lesser Antilles: max in dry season

But very short 5-yr simulations!

Change in monthly mean temperature (°C) & rainfall (%) in 2056-2060 (RCP8.5) relative to 2006-2010
Projected trends in the Caribbean Tropical cyclone activity

Cyclone activity in 2078-2099 (RCP8.5) & 1982-2003

Atlantic cyclone activity shifts northward
- Shorter hurricane season with less events
- + frequent intense & long-lasting hurricanes

But 50 km resolution (CORDEX, RegCM4)

3rd CI RCW
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Projected trends in the Caribbean Sea states (waves)?

Atlantic: wave heights reduce 5-10% all-year

Caribbean: increase 5-10% wet season (CLLJ?)

Large model ensemble but not high resolution (0.5°-1.25° waves / 0.2°-0.6° winds)

Atlantic hurricane wave heights:
rise ~40% in two climate model scenarios
fall ~40% in a third scenario
=> Uncertainties in cyclone projections

Model ensemble, not high res (0.5° waves/winds)

Change in JAS wave heights (%) for 2070-2100 (A2/A1B/B2) relative to 1979-2009

Hemer et al. 2013 Nature Climate Change

Fan et al. 2013 J. Climate

Change in JAS extreme wave heights (%) for 2081-2100 (A1B) relative to 2001-2020

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Previous work @Météo-France
Regional Climate Change
Modelling Approach

Dynamical downscaling

ALADIN-Climate
- Limited domain: Lesser Antilles
- Horizontal resolution: 10 km
- Driving GCM: ARPEGE 50 km
- Only one member
- RCP4.5/8.5 2071-2100

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Regional Climate Change
Projections of temperature over the Lesser Antilles

Stronger warming on land than sea (1.6/3.0°C – 1.2/2.3°C) and during the wet season

Night temperatures rise more

Max warming in Dominica, min in Marie-Galante. Relief effect?

Homogeneous warming at sea

Change in seasonal mean temperature (°C) in 2071-2100 relative to 1971-2000

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Regional Climate Change
Projections of rainfall over the Lesser Antilles

Change in seasonal mean rainfall (%) in 2071-2100 relative to 1971-2000

General drying at sea (-15%), max in MJJ

Drying on land in FMA (-10%)

Max drying in Dominica, wetter e.g. in Martinique & St-Lucia.

=> Strong local response
Extreme precipitation
Statistical downscaling over Guadeloupe

Cantet et al. 2014 Tellus

22 stations & 16 model points (long series daily obs. needed)

Change in extreme rainfall indices (%) for regional/global climate models:
- cdd: consecutive dry days
- cwd: consecutive wet days
- sdii: simple daily intensity
- cumul: total wet day precip.

Rain gauge data to correct model outputs @closest grid point (q-q plot)

Clear increase in extreme rainfall: longer dry periods (+2d), larger annual precip (+170mm), + very heavy precip days (+3/yr), stronger 1d max precip (+20mm). Consistent with IPCC-AR5

No trends in low-resolution model (Puerto Rico)
The C3AF Project
C3AF Project
Revisiting climate projections

Change in the modelling approach @Météo-France

Cantet: Dynamical downscaling

ALADIN-Climate
- Limited domain: Lesser Antilles
- Horizontal resolution: 10 km
- Only one member
- RCP4.5/8.5 2071-2100

C3AF: global model, stretched grid

Resolution locale (en kms)

ARPEGE-Climate
- Centered on Atlantic basin 20°N - 50°W
- Horizontal resolution: 10-15 km+
- Ensemble simulations (5 members)
- RCP8.5, 2020-2080
- IPCC Physics (CNRM-CM5)

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C3AF Project
Projections of tropical cyclone activity (Antilles)

example of cat-4 hurricane simulated by ARPEGE

Wind-pressure relationships (Antilles)

Chauvin et al. in prep.
C3AF Project
Projections of tropical cyclone activity (North Atlantic)

**Distribution max wind**

![Graph showing cyclone seasonality]

- Reduced hurricane season (2-3 weeks)

**Change in cyclone track density**

- Displacement of cyclonic hazard towards the north (extra-tropics) and east ("cape-verde" cyclones) in relation with the projected expansion of the tropics.

=> Reduction for the Caribbean? Use caution.
Consistent with Diro et al. 2014.

**Chauvin et al. in prep.**

- Reductions: cat-1
  + Increases: cat-4/5

**Nb TC days /20 yrs (200 km radius)**

**3rd CI RCW**

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C3AF Project
Multi-scale sea state modelling

Example of Matthew (2016)

Belmadani et al. in prep.

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High-resolution wave model for the Lesser Antilles

French Antilles: 200 m resolution
Other islands: 500 m resolution

St-Martin, St-Barthélémy (Anguilla)
Martinique
Guadeloupe

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C3AF Project
Modelling changes in cyclonic wave climate

Modelling strategy
3 scenarios x 5 members x 30 yrs = 450
MFWAM05: 450 hurricane seasons
MFWAM01: 450 hurricane seasons
WW3: 450 peaks hurricane season

C3AF configuration: example of tropical storm in the Lesser Antilles and wave response

Belmadani et al. in prep.

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C3AF Project
Projections of cyclonic wave climate (North Atlantic)

MFWAM 2051-2080 vs. 1984-2013

Change in JASO wave heights (m)

- 5-10%

Change in JASO wave height variability (m)

+ 10-15%

Change in JASO wave period variability (s)

+10%

Tropical N.Atl. (cyclonic season): reduced wave heights by ~10 cm on average yet increased variability in wave heights/periods: + hurricane swells?
Overall consistent with previous studies

Belmadani et al. in prep.

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Reduced wave heights by up to 10 cm on average
More frequent waves 3 m+ at hurricane season peak
Less frequent waves 3 m+ at end of hurricane season
Work in progress & WW3 simulations now being analyzed.
C3AF Project
Impact studies: storm surge, coastal erosion, hydrology, risks

Organigramme C3AF

Gouvernance opérationnelle
UA/MF/BRGM/GRED

Comité de pilotage
Coordinateur (N. Zahibo, D. Bernard)
Coordination technique : L. Prévost
Responsable des Work Packages
(P. Palany, N. Zahibo, Y. Legendre, F. Leone)

Assistance au pilotage et à la gouvernance

WP1 Climat

WP2 Submersion
WP3 Trait de côte

WP4 Changement géologique et hydrogéologique

WP5
Synthèse et vulgarisation : géo-indicateurs du CC et des risques, Communication et valorisation des résultats
Information et sensibilisation sur les enjeux scientifiques, techniques et socio-économiques posés par le CC
valorisation des résultats d’expertise construite autour de jeux d’indicateurs spatialisés (géo-indicateurs)
Mini-atlas du changement climatique et des risques associés

Collaborateur directs

3rd CI RCW
Le Gosier, Guadeloupe, May 30th 2018
Observations: regional warming trend (0.2-0.3°C/decade). No significant trends in rainfall (yet?).

Projections of regional climate: general agreement in year-round warming and wet-season drying trends over the Caribbean (stronger trades). High resolution (e.g. 10-15 km) is essential to represent local effects at the island scale, especially for the Lesser Antilles.

Projections of local climate: dry-season drying on land in the Lesser Antilles, unlike the ocean. Large inter-island variability, possible role of topography. More frequent extreme precipitation events. Being revisited with new modelling approach (ARPEGE-Climate), C3AF project.

Conclusion
Projections of cyclonic activity: increased frequency of extreme Atlantic hurricanes but shortening of the hurricane season and displacement of the hazard towards the extra-tropics and Cape-Verde => possible reduction in hurricane hazard over the Caribbean? A cautionary note.

Projections of sea states (2051-2080): during the hurricane season, wave heights are reduced by up to 10 cm on average off Antilles Atlantic coasts but increased frequency of high surf events for the Lesser Antilles => possible increase in cyclonic swell and sea? Work in progress and high-resolution coastal projections for the Lesser Antilles now being analyzed.

Future research: projections will need to be confirmed by using other GCMs to drive ARPEGE to increase confidence and better assess uncertainties. Opportunities of collaboration for high-resolution impact studies (atmosphere, waves) over other islands.
Thanks for your attention!

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Sea level ~2-5 mm/year

Sea level rise from satellite altimetry (1993-2009)

Willis et al. 2010

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• **RCP 8.5**: in 2100, an 8.5 W/m² radiative forcing is reached, corresponding to CO₂ concentration ~1370 ppm. Radiative forcing is still increasing in 2100.