



INSTITUT DES
ACTUAIRES

SECTIONS VIRTUAL
COLLOQUIUM | 2020



The scourge of the Indies : Global Warming impacts on North Atlantic Hurricanes



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Groupama

May 11th – May 15th 2020

FLIBUSTIERS & CORSAIRES

D'APRÈS LES TEXTES ET LES ESTAMPES DE L'ÉPOQUE.
LEURS ORIGINES – LA COUTUME DE LA CÔTE – QUELQUES
FIGURES DE FLIBUSTIERS – MONBARS L'EXTERMINATEUR –
LE BORDELAIS MONTAUBAN – LE CHEVALIER DE GRAMMONT
– NAU L'OLONNAIS – JEAN-BAPTISTE DUCASSE.
SUIVI DU : VOYAGE A LA MER DU SUD PAR RAVENAU DE
LUSSAN DE 1685 à 1688 ET D'UN MÉMOIRE SUR UN CHIRURGIEN
CORSAIRE LE CAPITAINE FRANÇOIS THUROT (1726 - 1760).



ÉDITIONS DUCHARTRE
& VAN BUGGENHOUDT
PARIS MCMXXXVIII

About the speakers



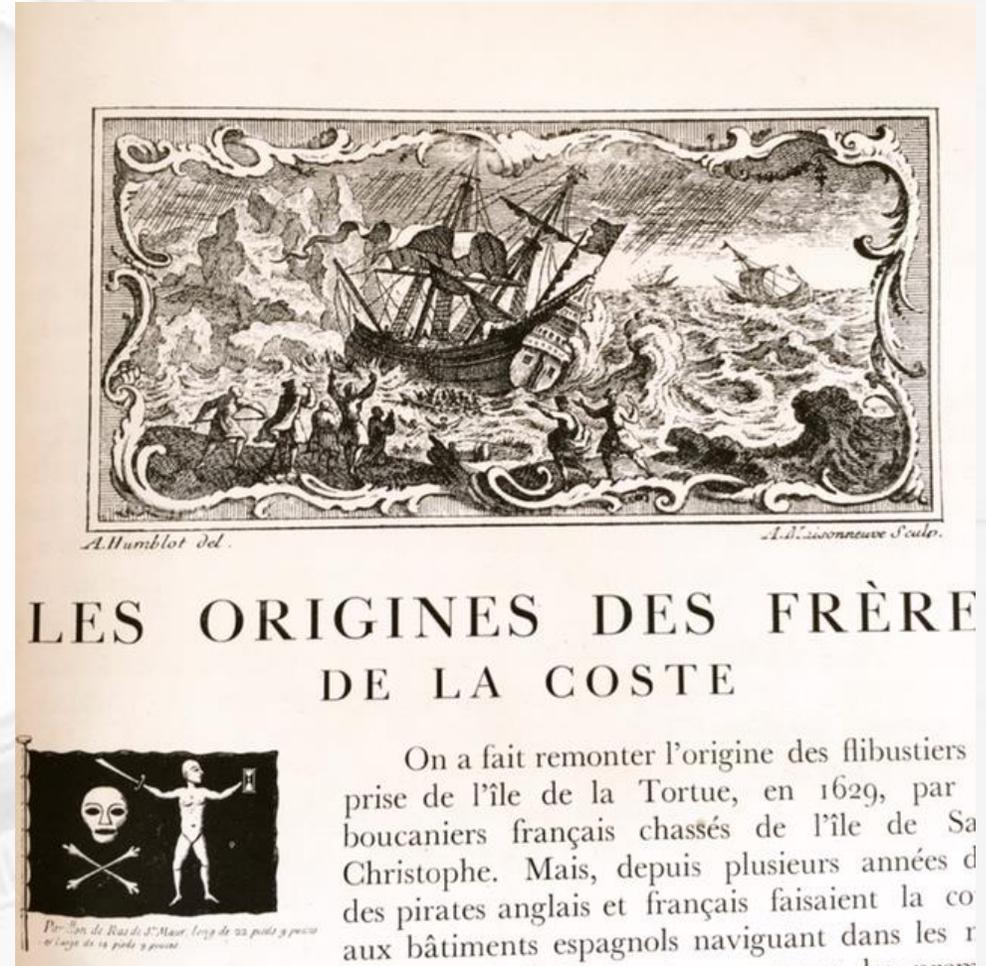
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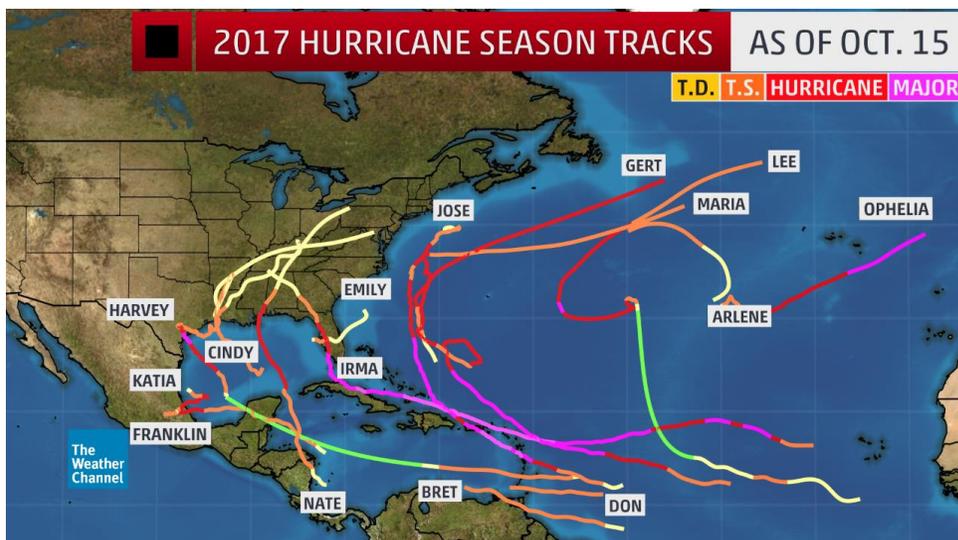


Groupama in the Caribbean



- Generalist network offering the full range of property and casualty insurance, life and health insurance, savings and life insurance products :
 - 77 M€ in non-life insurance premium income
 - 250 employees
 - 160 elected representatives
 - 61,900 client-members
 - 27 agencies spread over 3 departments : Guadeloupe, French Guiana and Martinique.

Flashback on 2017



- According to SwissRe sigma, HIM caused economic damages of USD 217 billion. Hurricane Irma inflicted the heaviest economic losses ever experienced in the Caribbean, and Maria essentially crippled the entire infrastructure system in Puerto Rico.

Call for action



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#OuraganIRMA #OuraganMARIA Les équipes de Groupama Antilles-Guyane poursuivent leur mobilisation.

DES MESURES D'URGENCE SONT MISES EN PLACE

- > UN NUMÉRO UNIQUE DISPONIBLE 24H/24 ET 7JRS/7 : 0800 303 330
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- > LE VERSEMENT D'ACOMPTES POUR FAIRE FACE AUX PREMIÈRES DÉPENSES.
- > LA MOBILISATION DES EXPERTS, CONSEILLERS ET GESTIONNAIRES AU PLUS PRÈS DU TERRAIN.

#OuraganIRMA

#OuraganMARIA



- Until Irma and Maria the French West Indies were impacted by hurricanes of category 3 or 4 on the Safir Simpson scale.
- Irma was classified as a category 5 hurricane for the longest continuous period of time. 500 km in diameter, Highest winds 1-minute sustained: 180 mph (285 km/h).
- Followed by Category 5 Maria two weeks later. Irma and Maria were respectively the Third and Fourth costliest tropical cyclone on record.

1:00 PM · 21 sept. 2017 · Twitter Media Studio

Sign of times



- Martinique could have been impacted by either one or the other.
- They're what you'd expect over a 1,000-year return period.
- The real question is whether, as a result of global warming
- The return periods of this type of cyclone would only become much smaller

Climate change



MONTBARS L'EXTERMINATEUR (Gravure de Rosalco.)

- Coastal zones and islands of the intertropical zone even more exposed to soil and flood risks due to heavy rains and sea-level rise
- Increased coastal erosion and saltwater intrusion into coastal areas
- According to the IPCC¹, by 2050, the number of tropical cyclones will either decrease or remain essentially unchanged (from -6% to -34%). However, increasing number of major hurricanes, from 0% to 30% (cat. 4-5 on Saffir-Simpson scale)

Current assessment!

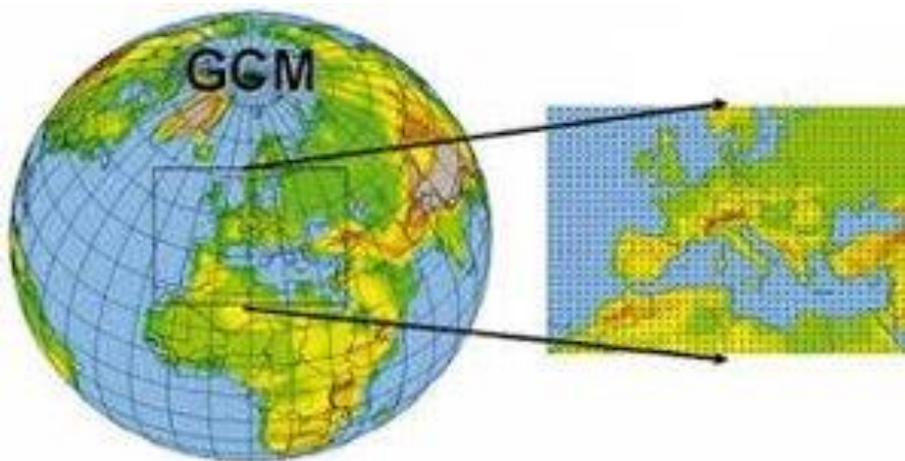
- Information report of the French Senate on major natural hazards in overseas France dated 14 November 2019.
- After an initial study devoted to the evolution of natural risks by 2050 in France, the Caisse centrale de Réassurance (CCR) will publish with Météo France in autumn 2019 a second study on overseas territories. This study takes into account a broad spectrum of possible years, of the order of 400.
- According to the CCR, the EuroCordex simulations make it possible to refine IPCC trends and produce estimates for the French overseas territories with :
 - a strong expected increase in the frequency of cyclones in Guadeloupe, of the order of 42%
 - a moderate increase in Martinique, of the order of 7%
 - a moderate increase in Reunion Island, of the order of 4 per cent
- Guadeloupe is the only territory where the change in hurricane frequency is significantly marked.

Why do we need models ?



- NHC : National Hurricane Center, public institution (Miami, Florida)
- Responsible for tracking and predicting tropical weather systems in the North Atlantic and eastern Pacific
- Provides a reference database : HurDat2
 - All the storms from 1851 to 2018
 - Footprint for each storm (6 hours timesteps with wind-speed, pressure, etc)
 - Data from multiple stations, flights, ships and satellites
 - Re-analysis performed
- Historical database of this study
- **Limit** : reflect past climate

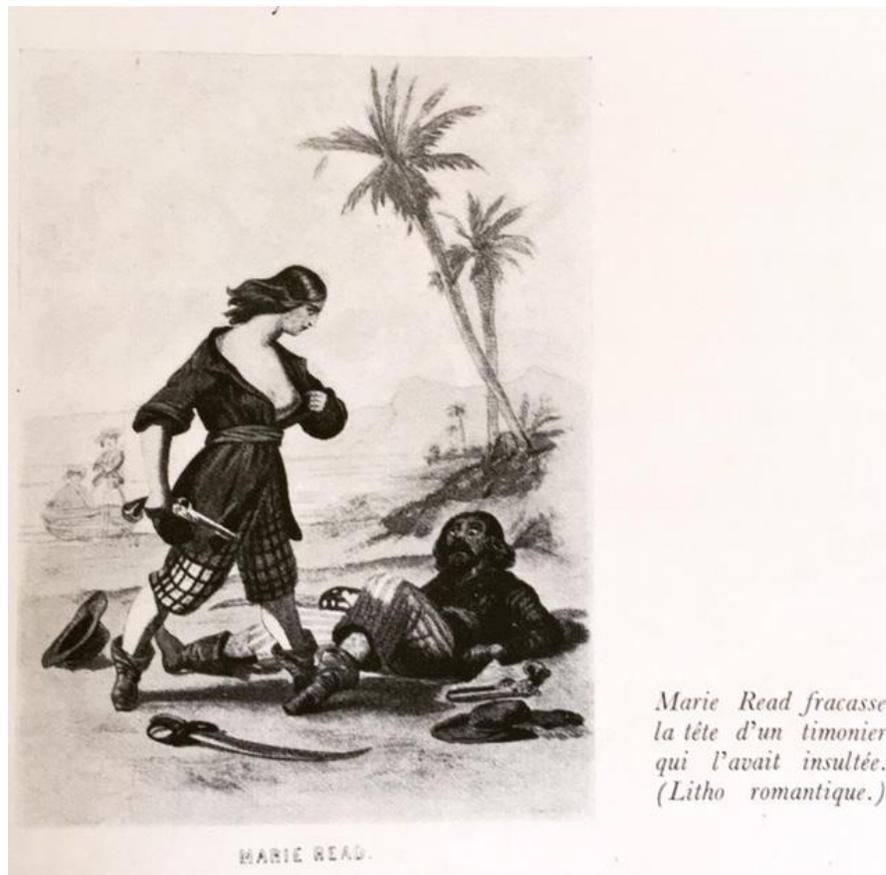
Why do we need models ?



- GCM (Global Circulation Model)
 - Widely-used to model climate (weather and climate change forecasting, ...)
 - Produces results for each point of a grid (coarse mesh, 200x200 km for example)
- CORDEX (**CO**ordinated **R**egional **D**ownscaling **EX**periment)
 - An international program, sponsored by WCRP (World Climate Research Programme)
 - Goal : to improve regional climate models and coordinate their results
 - Results obtained by downscaling the outputs of GCMs
 - **Finer mesh** (thanks to downscaling)
 - Results used for the Assessment Reports of the IPCC

Some definitions

- Saffir-Simpson scale :



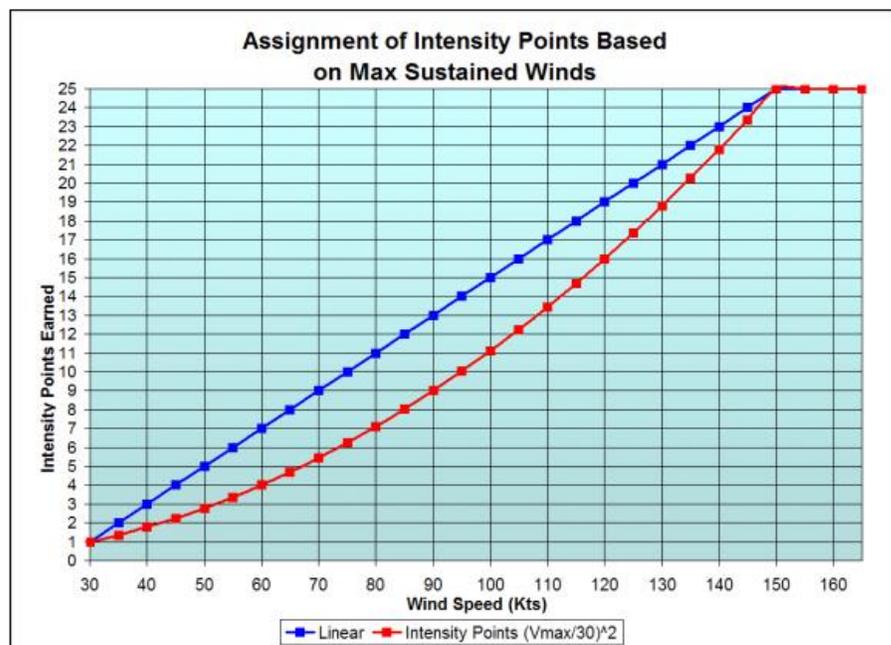
Category	Wind speeds (for 1-minute maximum sustained winds)			
	m/s	knots (kn)	mph	km/h
Five	≥ 70 m/s	≥ 137 kn	≥ 157 mph	≥ 252 km/h
Four	58–70 m/s	113–136 kn	130–156 mph	209–251 km/h
Three	50–58 m/s	96–112 kn	111–129 mph	178–208 km/h
Two	43–49 m/s	83–95 kn	96–110 mph	154–177 km/h
One	33–42 m/s	64–82 kn	74–95 mph	119–153 km/h

(maximum wind speed of the hurricane)

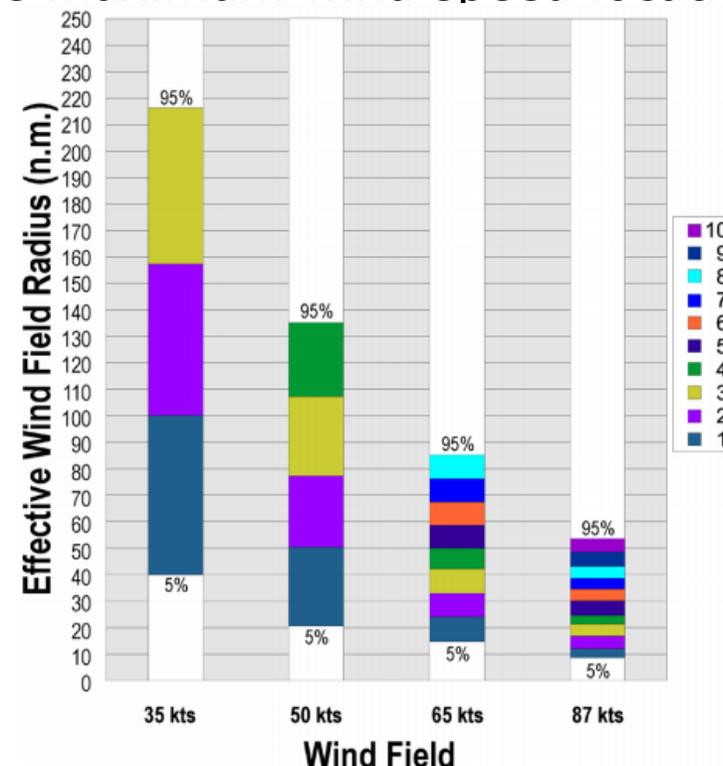
Some definitions

- **Hurricane severity index (HSI)²**

- Goal : to categorize hurricanes by taking into account speed and shape
- 50 points scale :
 - 25 points for the maximum wind speed



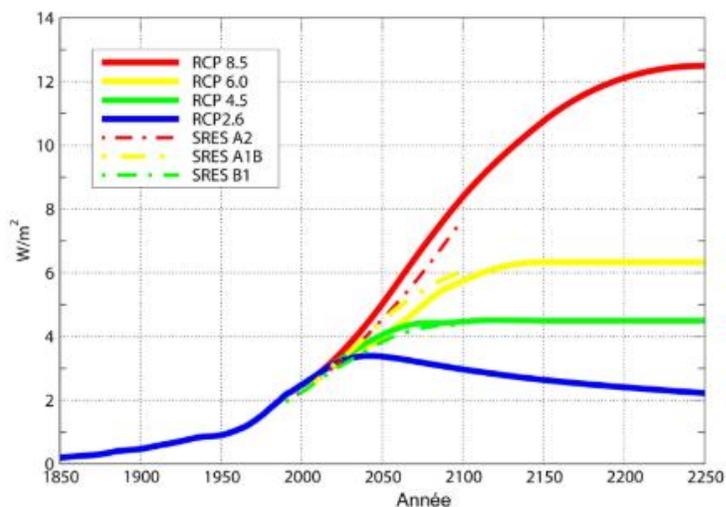
25 points for the shape of the hurricane at the maximum wind speed location



Some definitions

• RCP scenarios

- A RCP (Representative Concentration Pathway) is a greenhouse gas concentration trajectory
- Scenarios used by the IPCC
- The pathways describe different climate futures depending on the volume of greenhouse gases emitted
- Each pathway is labelled with a radiative forcing value that corresponds to the possible radiative forcing value in 2100 : RCP 4.5 for example (4.5 stands for 4.5 W/m² of radiative forcing in 2100)



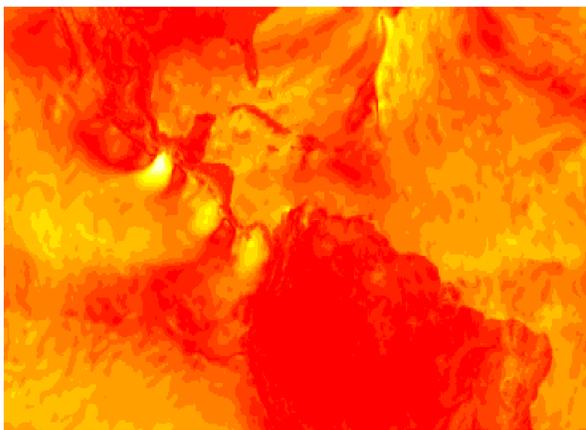
- Radiative forcing in a nutshell :

"the rate of energy change per unit area of the globe as measured at the top of the atmosphere"³

3. Rockström, Steffen, Noone, Persson, Chapin, Lambin, Lenton, Scheffer (2009), "A safe operating space for humanity" (*Nature*)

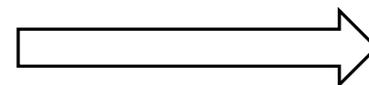
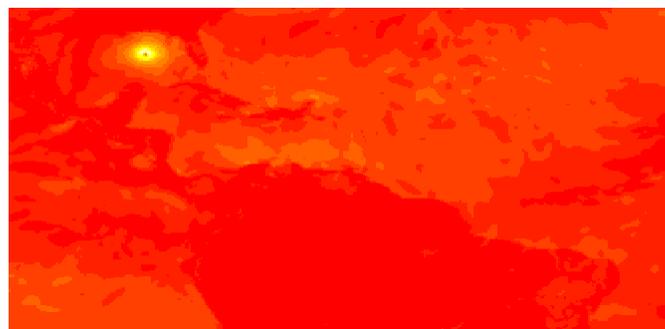
CORDEX for the Caribbean

- Climate projections until 2100 under 2 scenarios : RCP 2.6 & RCP 8.5
- RCP 8.5 is the worst-case scenario : greenhouse gas emissions continue to increase
- RCP 2.6 is the best-case scenario : greenhouse gas emissions decrease before 2050
- Data :
 - Wind speed projections every 3 hours for each point
 - Resolution : 25x25 km
 - An example :

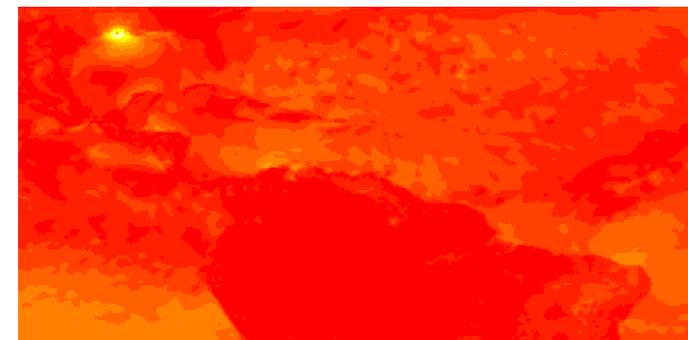


CORDEX for the Caribbean

- **Goal** : to identify hurricanes and their main characteristics
- **Identification in 3 steps**
 1. Detection of near-surface wind speeds of 33 m.s^{-1} or higher (at least cat. 1 on the Saffir-Simpson scale)
 2. To track hurricanes over several images (tracking step)



Same hurricane ?

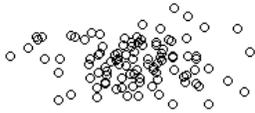


3. Duration controle : the footprint must last at least 5 days

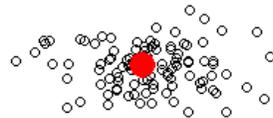
CORDEX for the Caribbean

- Focus on the tracking step :

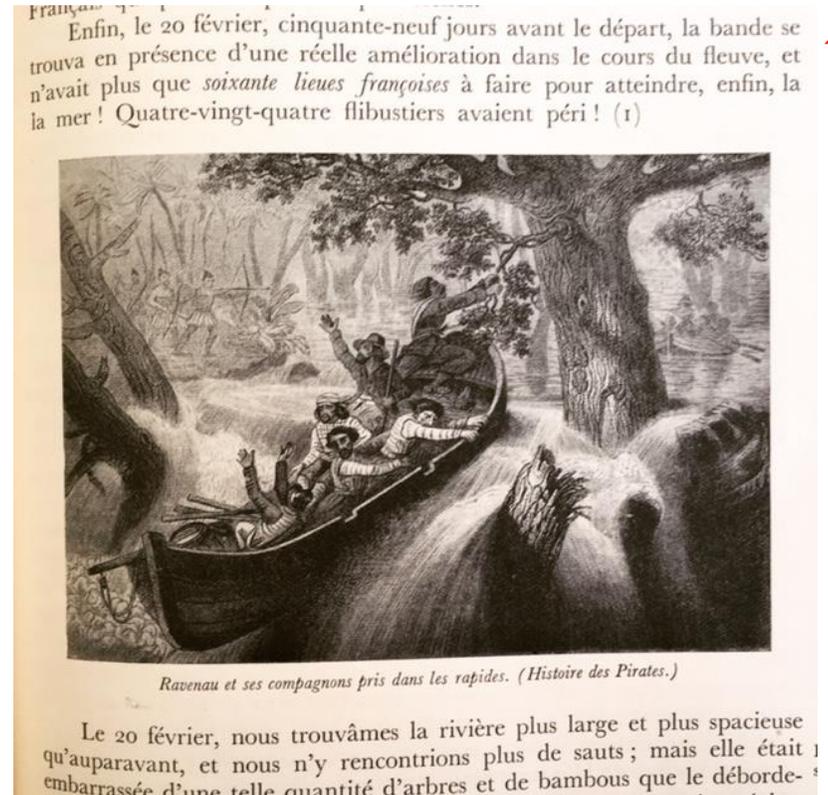
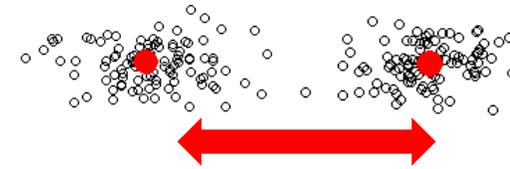
Get the locations of high wind speed points (≥ 33 m/s)



Get the center of the hurricane (Mean Shift clustering)



Make sure that the distance between t and $t+1$ centers is lower than 300 km



CORDEX for the Caribbean

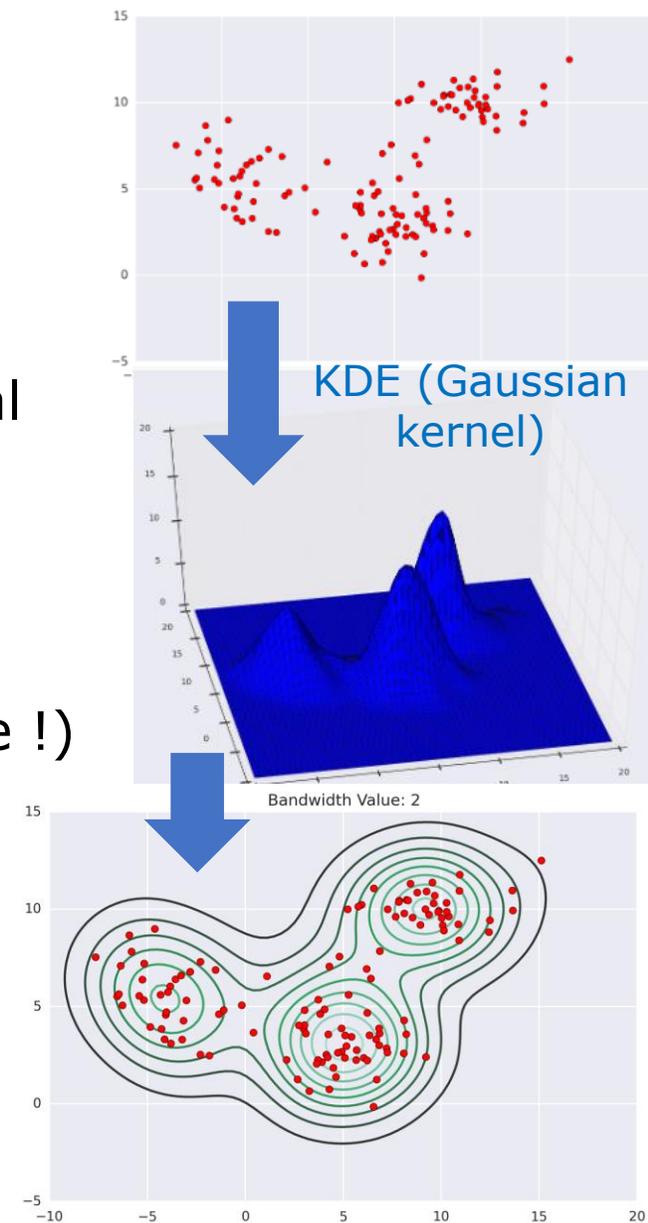
- Focus on the tracking step :

Why clustering ?

- The tracking algorithm has to be able to deal with one or more hurricanes. Clustering is useful in case there are several hurricanes.

Why Mean Shift clustering ?

- The Mean Shift algorithm is centroid-based : the goal is to locate the center of each group (-> center of the hurricane !)
- No need to choose the number of groups
- KDE step : Gaussian kernel particularly well-suited to data



CORDEX for the Caribbean

- **Focus on the duration controle step :**

Why ?

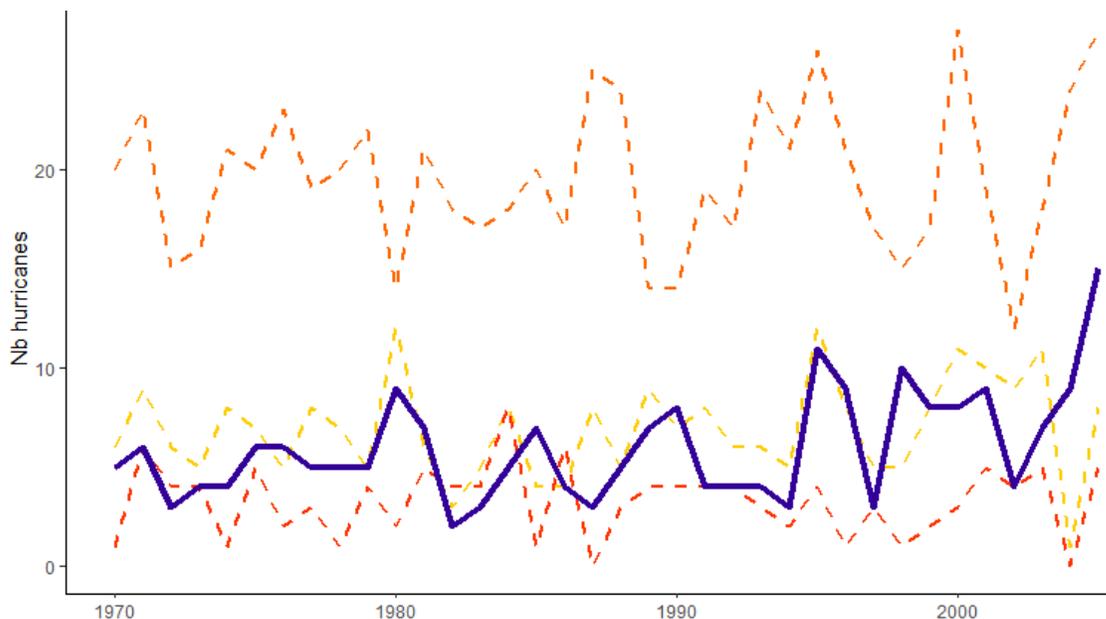
- Wind speed is the main criterion to detect hurricanes
- However, research papers on the CORDEX project⁴ take into account additional criteria (pressure, temperature, ...) to determine if a storm is powerful enough to become a hurricane.
 - Too complicated to check these criteria easily
- If these criteria are not taken into account : too many hurricanes detected
 - We have to find a new and simple criterion

How ?

- Let's take a look at the durations (begining – end of footprints) of the historical hurricanes (NHC database, 1970-2005) : the 5%-quantile is approximatively 5 days.
 - 95% of the historical hurricanes last longer than 5 days.
- Therefore, our new criteria is : duration \geq 5 days

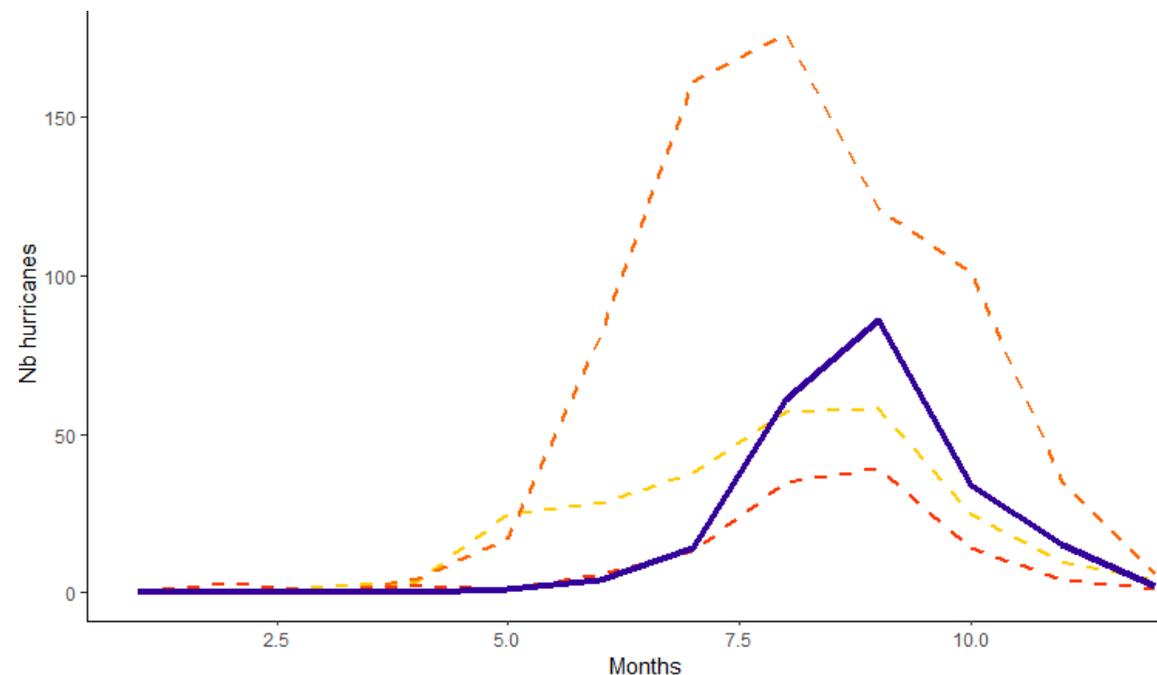
Historical backtesting (1970-2005)

- Climate projections produced by downscaling the output of a GCM
- 3 different GCMs for the Indies : we have to choose the best
- CORDEX provides outputs from these GCMs under historical conditions
 - comparison of frequencies under historical conditions : **MOHC-HadGEM2 is the chosen GCM**



MOHC-HadGEM2 MPI-M-MPI-ESM-LR NCC_NorESM1-M_2 Historical

Number of hurricanes per year over the period



MOHC-HadGEM2 MPI-M-MPI-ESM-LR NCC_NorESM1-M_2 Historical

Number of hurricanes per month over the period

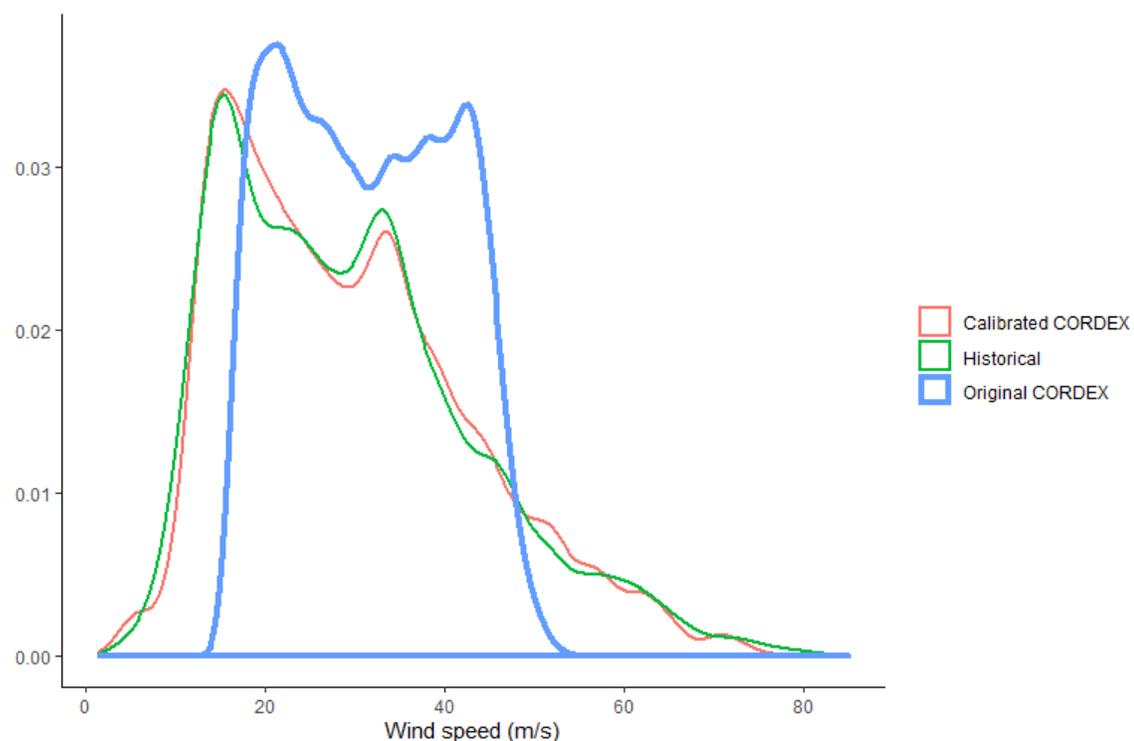
Elected model!



- Focus on the MOHC-HadGEM2 selected GCM for our study :
 - Developed by the Met Office Hadley Centre (MOHC, one of the UK's foremost climate change research centres)
 - HadGEM2 stands for Hadley Centre Global Environment Model version 2 : common physical framework with different model configurations
 - Coupled atmosphere-ocean configuration

Historical backtesting (1970-2005)

- Truncated tail of the CORDEX historical wind speeds distribution
- The tail represents wind speeds of major hurricanes : the most important part of the distribution (-> we have to correct data)

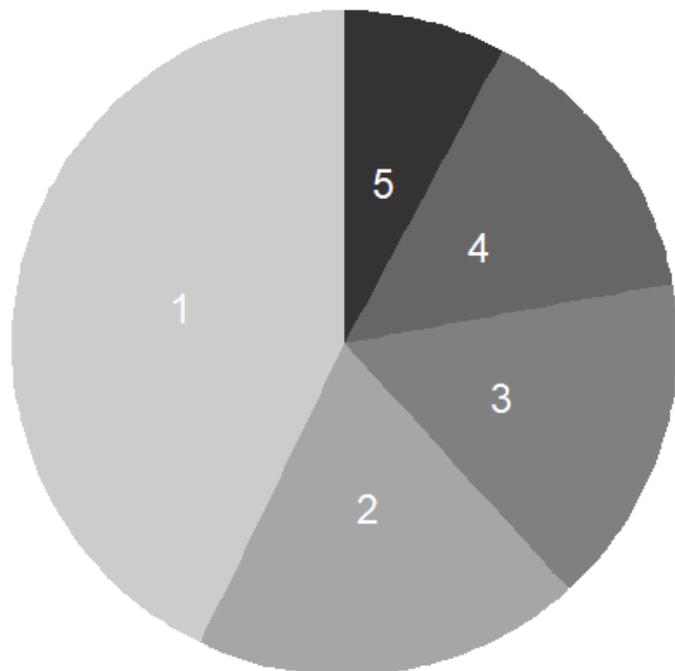


To enhance the reliability of RCM data at local scale, a quantile–quantile adjustment has been applied to the simulated regional scenarios. This method focuses not only on the bulk spectrum of the cumulative distribution functions but also on its tails.

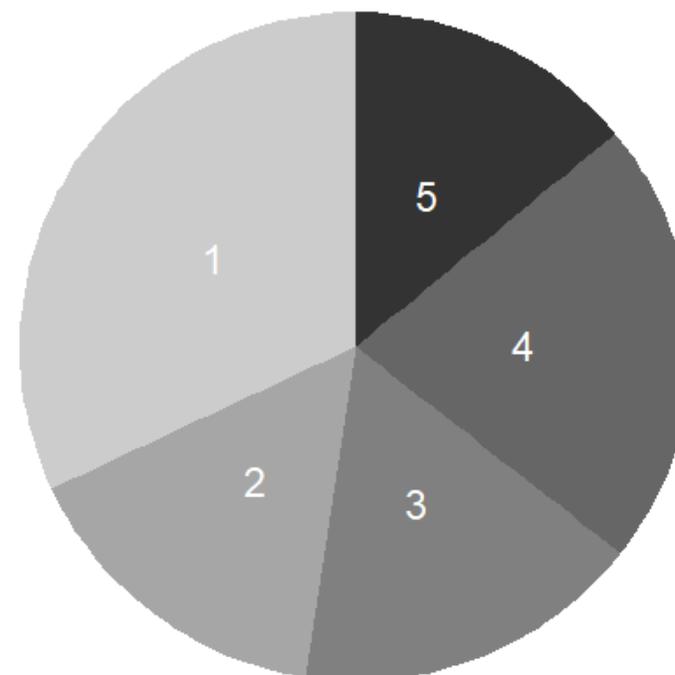
Historical backtesting (1970-2005)

- Slightly more cat. 5 hurricanes (and less cat. 1) : the selected GCM is more conservative

Historical



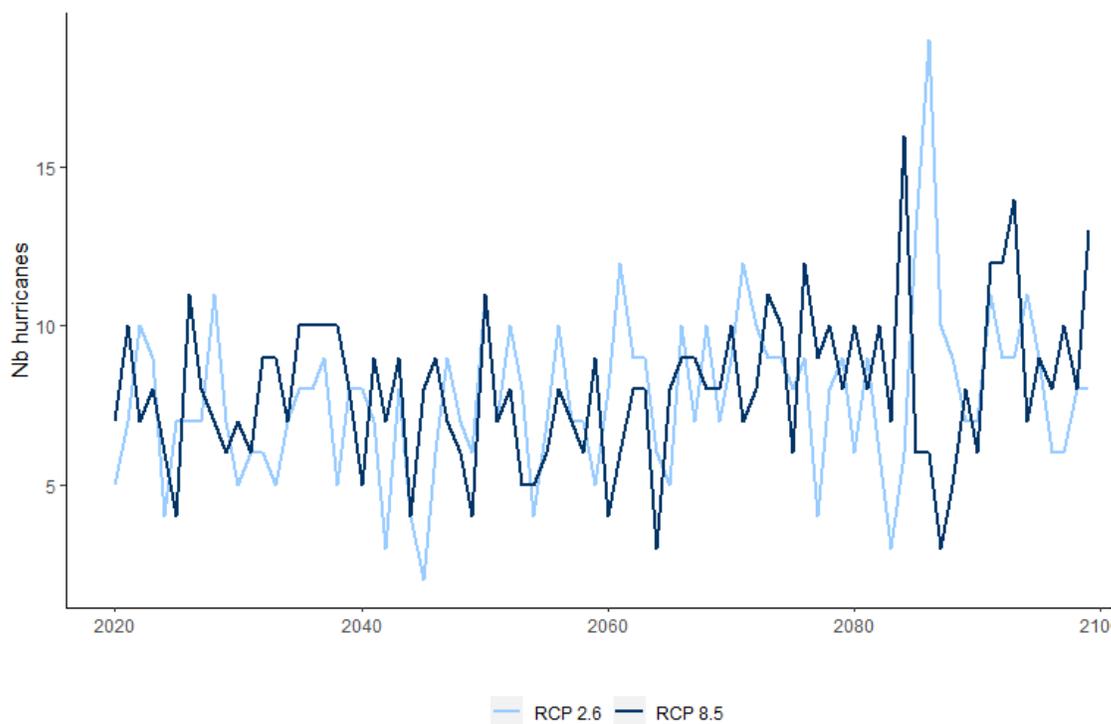
MOHC-HadGEM2 GCM under historical conditions



Piecharts giving the proportion of hurricanes in the Caribbean Sea per category (Saffir-Simpson scale)

RCP 2.6 and RCP 8.5 scenarios

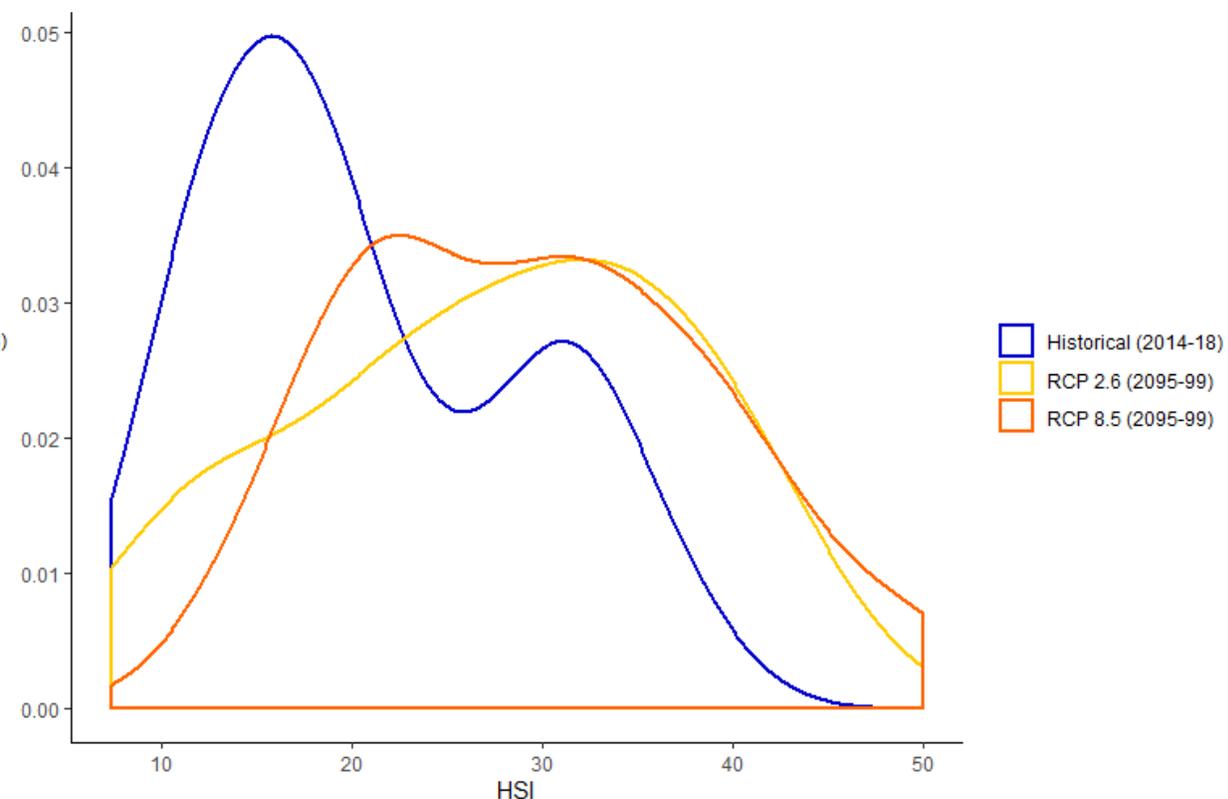
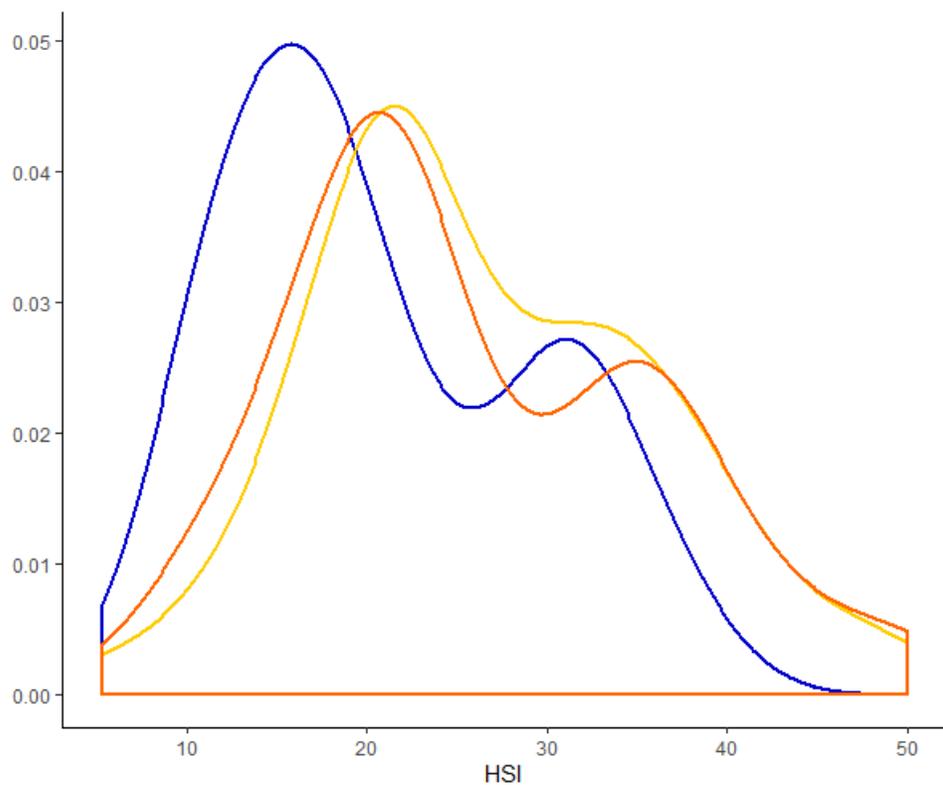
- The number of hurricanes per year in the Caribbean Sea remains essentially unchanged
 - Confirms the IPCC statement
 - Globally from Category 1 to 5
 - But can vary by intensity...



Number of hurricanes in the Caribbean Sea per year

RCP 2.6 and RCP 8.5 scenarios

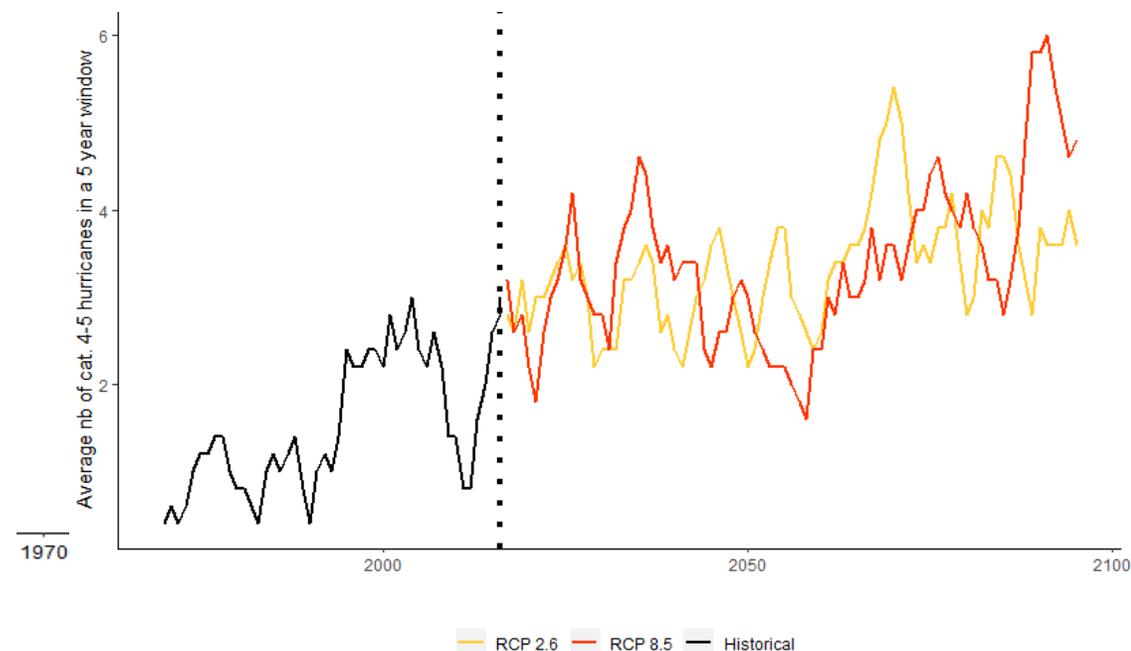
- Increasing proportion of powerful hurricanes (in terms of wind speed and size)



HSI distribution for hurricanes between 2046 and 2050 (left), between 2095 and 2099 (right)

RCP 2.6 and RCP 8.5 scenarios

- Slight decreasing trend in the number of cat. 1-2-3 hurricanes
- Increase in the number of major hurricanes (cat. 4-5) by 2050
 - RCP 2.6 & RCP 8.5 consistent with the IPCC statement (0%-30% increase in the number of major hurricanes)
- By 2100 : Continuing the trend towards an increase in the number of intense hurriances and a reduction in the number of smaller cyclones, the gap is widening!



Moving average (5-year window) of the number of **cat. 1-2-3** hurricanes (left) and **cat. 4-5** hurricanes (right) in the Caribbean Sea

RCP 2.6 and RCP 8.5 scenarios

2046-2050 period

- We can already observe the decreasing trend in the number of cat. 1-2-3 hurricanes in the RCP 2.6 scenario
- High volatility in the RCP 2.6 scenario for cat. 1-2-3 (CoV 75%) and the RCP 8.5 scenario for cat. 4-5 (CoV 67%)

	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5
Historical (2014-2018)	13	6	6	4	6
RCP 2.6	7	7	6	8	11
RCP 8.5	12	8	4	4	9

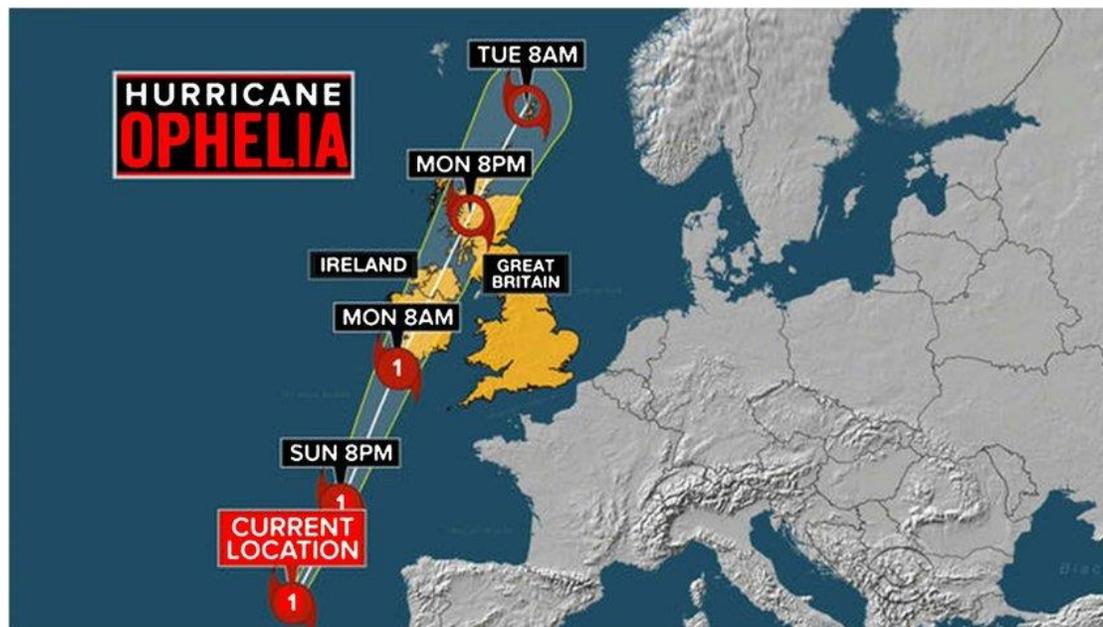
2095-2099 period

- Decreasing trend in the number of cat. 1-2-3 hurricanes observed in the 2 scenarios
- Net increase in the number of cat. 4-5 hurricanes
- Increased volatility in comparison to 2046-2050

	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5
Historical (2014-2018)	13	6	6	4	6
RCP 2.6	8	4	7	6	12
RCP 8.5	10	6	8	11	13

Total number of hurricanes per category over the 2046-2050 period (left) and 2095-2099 period (right)

Conclusion



Hurricane Ophelia 2017 worst storm to affect Ireland in 50 years, and easternmost Atlantic major hurricane on record!

- Main results
 - 2050 : In total stable but volatile number of cyclones, though slight decrease of low intensity cyclones and increase of larger ones
 - 2100 : The trend is even more contrasted with an increasing average number of hurricanes!
 - Limit: quantile quantile adjustment
- Next steps
 - Design *gates* to count hurricanes in specific areas
 - Characterize tracks and highlight atypical ones (Ophelia in 2017 for example)
 - Use these *gates* to get hurricane-related losses for each area

Thank you for your attention



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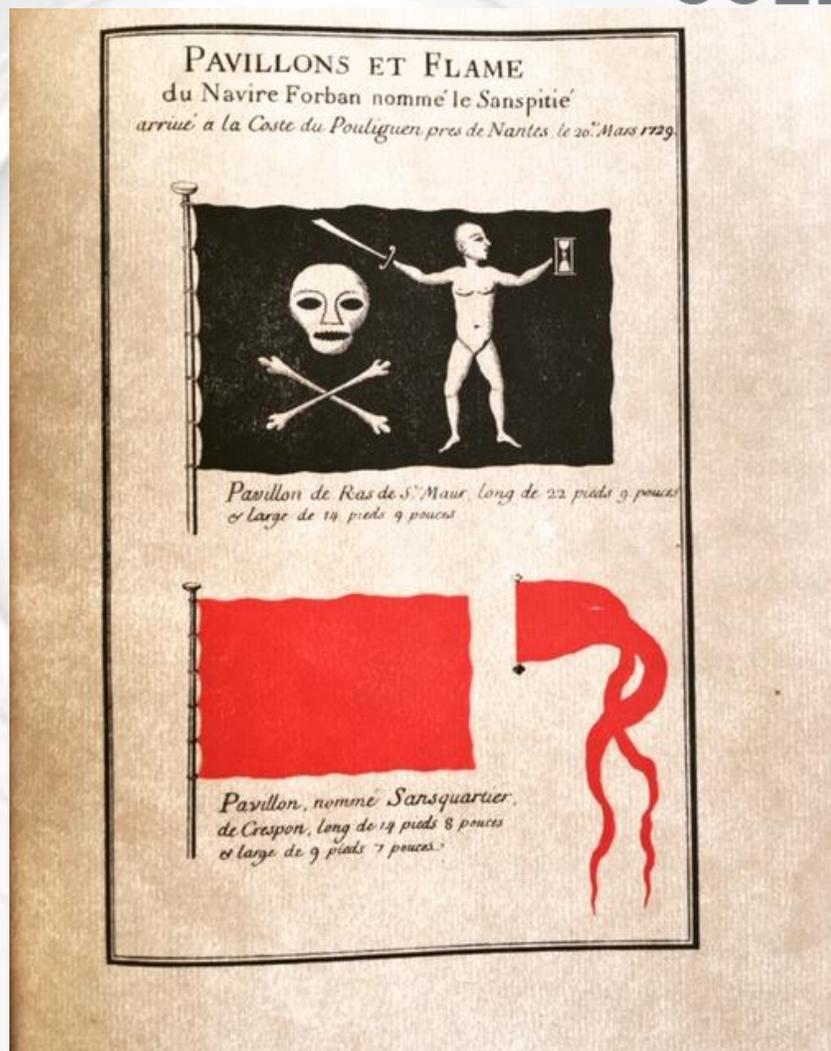
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Illustrations from :
**The Scourge of the Indies -
Maurice Besson - Published
by George Routledge and
Sons, London (1929)**

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