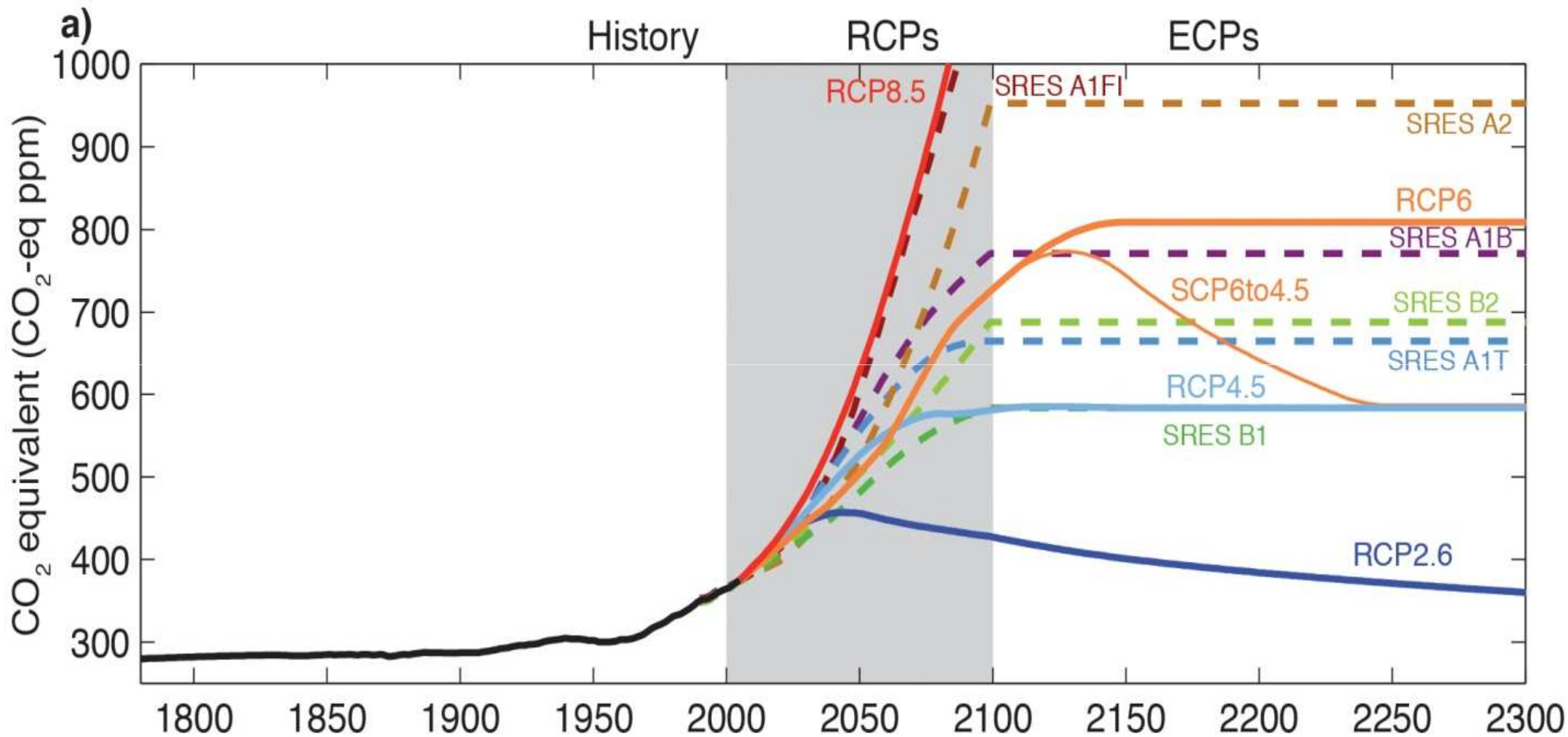
Enhancing access to information on climate change, natural disasters and coastal vulnerability in the Caribbean region workshop: leaving no one behind
Dominican Republic - 10 August 2016

"Effects of climate change on the coasts of Latin America and the Caribbean"

Carlos de Miguel

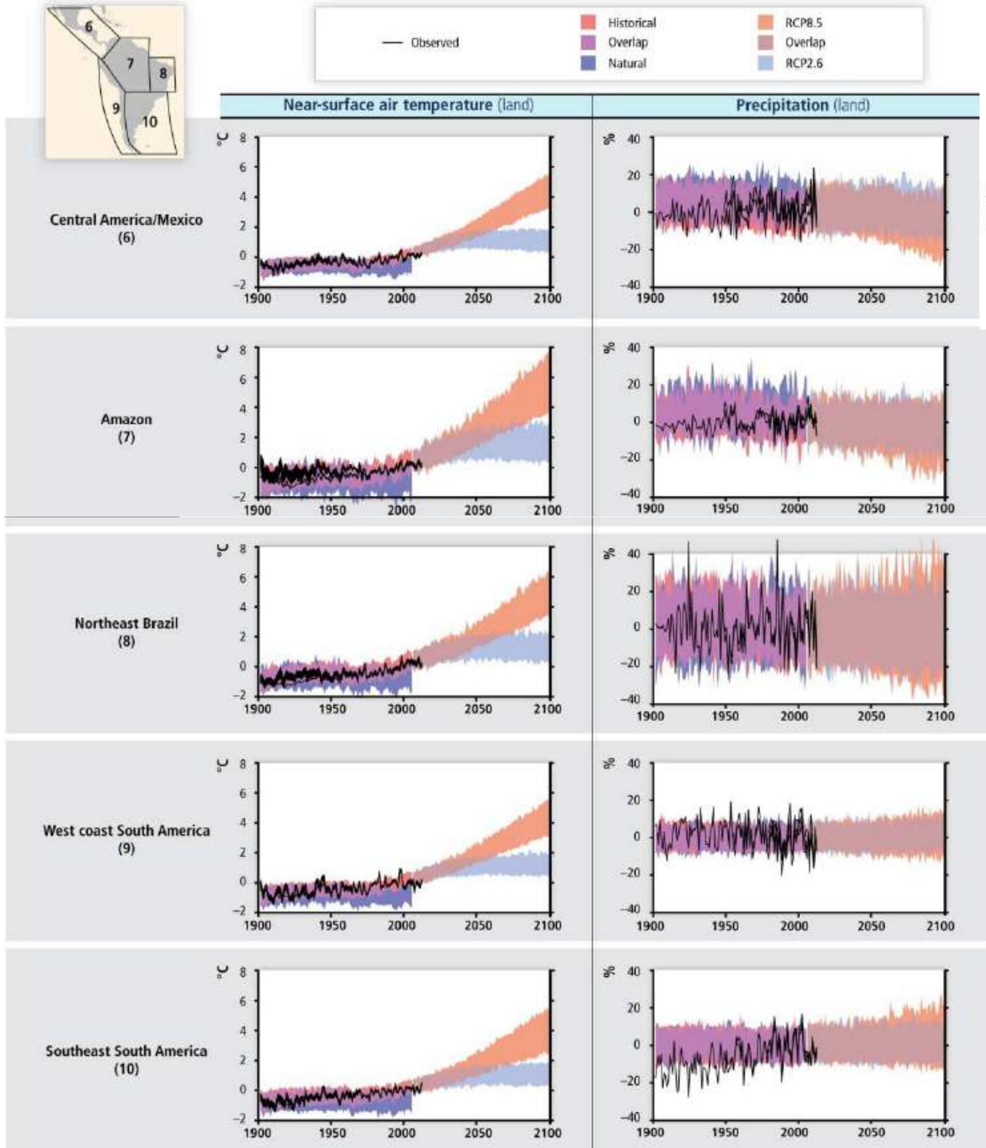
Chief, Unit of Sustainable Development Policies, SDHSD, ECLAC

IPCC's Scenarios: Past and present reports



Source: IPCC (2014), *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

Latin America and the Caribbean: observations and projections of temperature and precipitation, IPCC (2014)



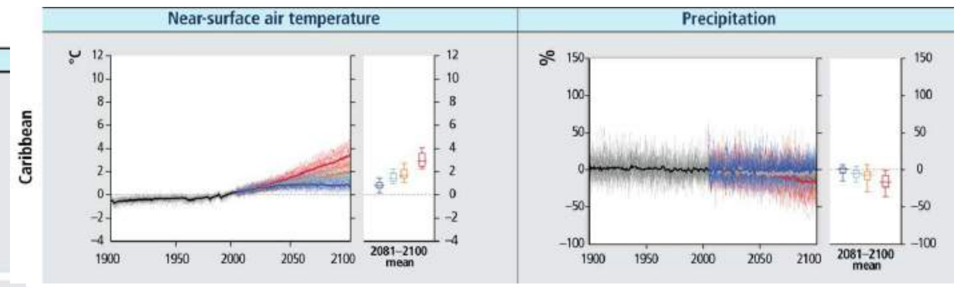
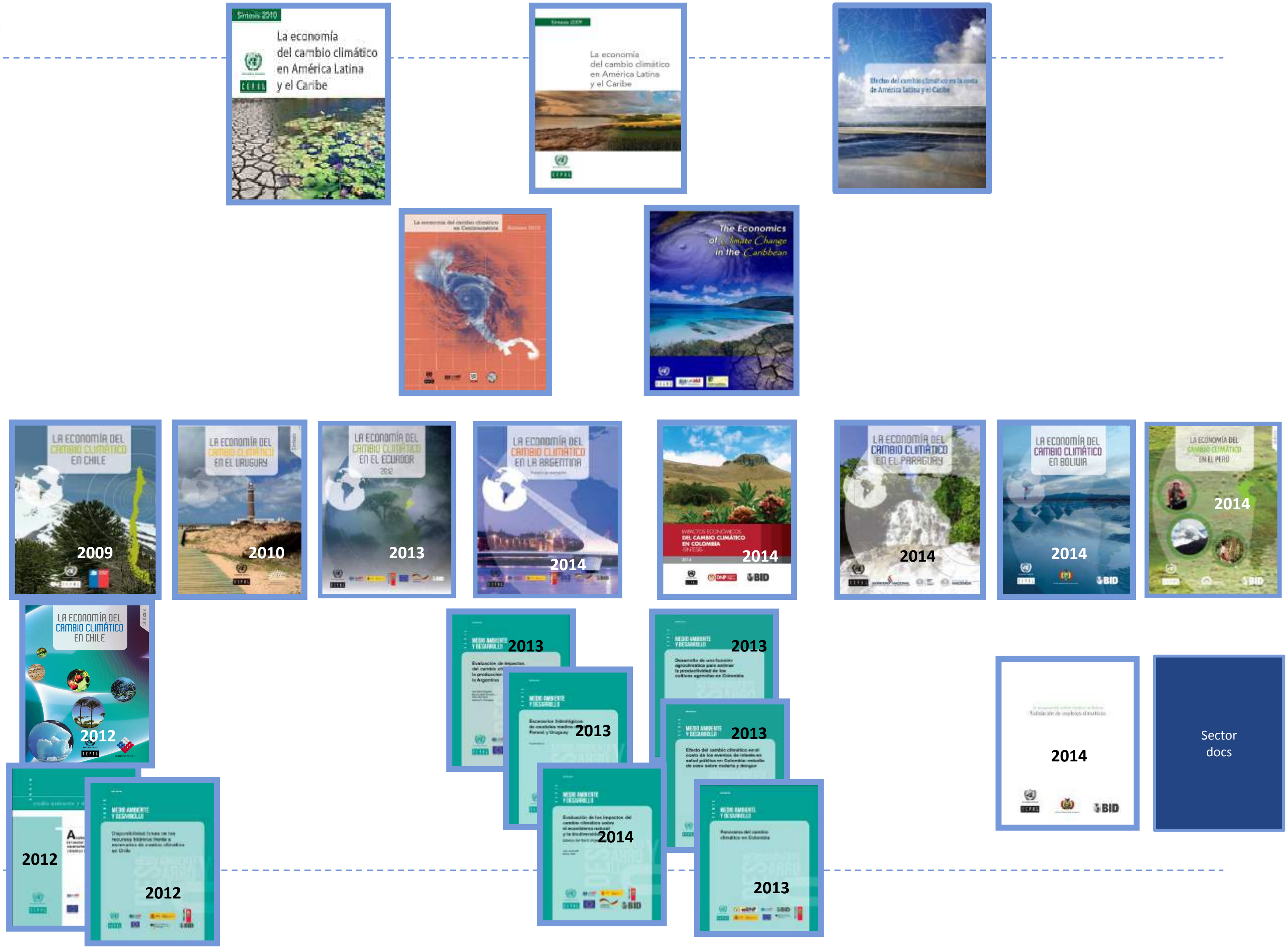


Table 29-1 | Climate change projections for the intermediate low (500–700 ppm CO_2e) Representative Concentration Pathway 4.5 (RCP4.5) scenario for the main small island regions. The table shows the 25th, 50th (median), and 75th percentiles for surface temperature and precipitation based on averages from 42 Coupled Model Intercomparison Project Phase 5 (CMIP5) global models (adapted from WGI AR5 Table 14.1). Mean net regional sea level change is evaluated from 21 CMIP5 models and includes regional non-scenario components (adapted from WGI AR5 Figure 13-20).

Small island region	RCP4.5 annual projected change for 2081–2100 compared to 1986–2005						
	Temperature (°C)			Precipitation (%)			Sea level (m)
	25%	50%	75%	25%	50%	75%	Range
Caribbean	1.2	1.4	1.9	−10	−5	−1	0.5–0.6
Mediterranean	2.0	2.3	2.7	−10	−6	−3	0.4–0.5
Northern tropical Pacific	1.2	1.4	1.7	0	1	4	0.5–0.6
Southern Pacific	1.1	1.2	1.5	0	2	4	0.5–0.6
North Indian Ocean	1.3	1.5	2.0	5	9	20	0.4–0.5
West Indian Ocean	1.2	1.4	1.8	0	2	5	0.5–0.6

ECONOMICS OF CLIMATE CHANGE IN LATIN AMERICA AND THE CARIBBEAN



Main objective

Compile the information required to analyze the modifications and impacts of climate change in the coastal areas of Latin America and the Caribbean

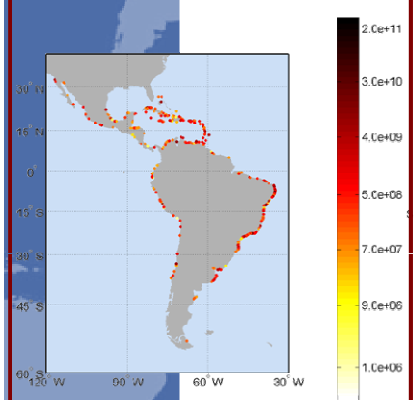
PROJECT STRUCTURE AND DOCUMENTS

Climate change in Latin American and Caribbean coastal areas			
Document 1: **Coastal agents (available in English)** • Dynamics • Trends • Climate variability in coastal areas	Document 2: **Vulnerability**	Document 3: **Impacts** **(Available in English)**	Document 4: **Risks**

Supplementary documents		
Theoretically derived effects of climate change in coastal areas	Methodological handbook	Project findings web viewer

Framework of the project

Risk



Scenarios

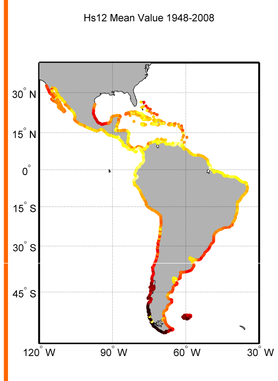
Extrapolation of trends

Scenarios

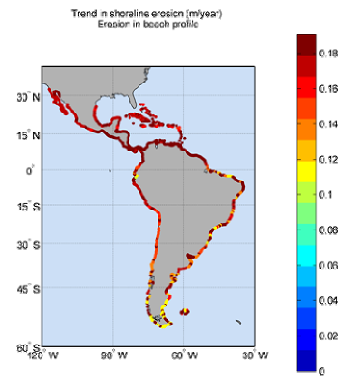
=

Probable danger

Dynamics

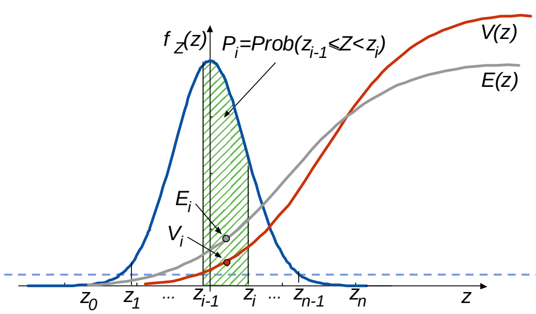


Impacts



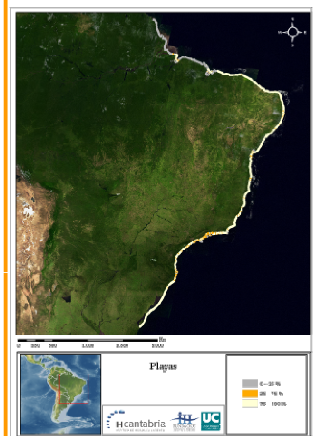
Uncertainty

Climate change trends



x

Exposure



Coast types

Beaches, ports, coral reefs, urban areas, etc.

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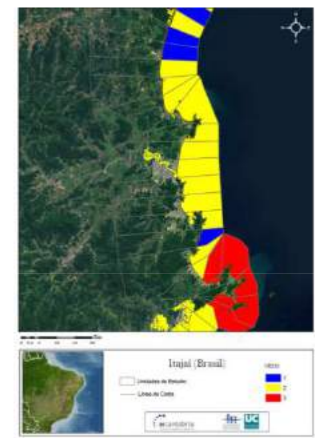
Vulnerability



Functions of the coast

Physical Vuln.

Ecological

Socioeconomic

Framework of the project

Spatial scales: Presentation of results: ~50 kms

Evaluation of results: ~5 kms (unit of study)

Integration

Vulnerability: (Spatial resolution digital model of territory)

Existing databases and generated by IHC

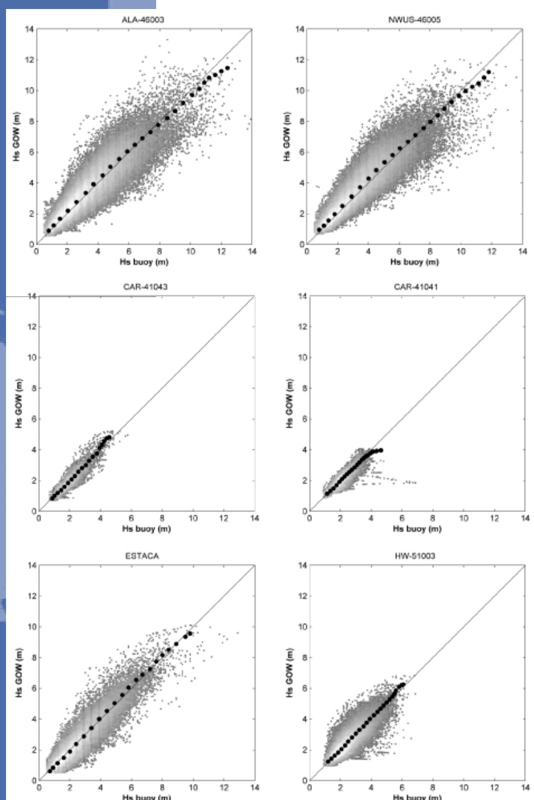
Type of information	Time period covered	Spatial resolution	Source
Mean sea level (MSL)	1950-2009 / monthly	Global, 1º	CSIRO—Commonwealth Scientific and Industrial Research Organisation.
	Variable	Global, dispersed	Tide gauges UHSLC—University of Hawaii Sea Level Center.
Subsidence	-	Variable	DIVA—Dynamic Interactive Vulnerability Assessment. (Peltier et al. 2000)
Tides	Harmonic constants	Global, 0.25º	TPXO—Global model of ocean tides based on altimetric data from the TOPEX/POSEIDON mission.
Salinity (SAL)	1980-2009 / monthly	Global, 1ºx0.333º	NCEP - GODAS—National Centers for Environmental Prediction (USA), Global Ocean Data Assimilation System.
	1948-2011 / monthly	Global, 2.5º (Gaussian grid)	NCEP - NCAR—National Centers for Environmental Prediction (USA), National Center for Atmospheric Research.
Sea surface temperature (SST)	1950-2009 / monthly	Global, 2º	ERSSTv3 - NOAA—Extended Reconstructed Sea Surface Temperature, National Oceanic and Atmospheric Administration (USA).
Air temperature anomaly	1950-2005 / monthly	Global, 2º	GISS - NASA—Goddard Institute for Space Studies, National Aeronautics and Space Administration (USA).
Air temperature	1948-2009 / monthly	Global, 2.5º (Gaussiana grid)	NCEP - NCAR
Atmospheric pressure	1948-2009 / 6h	Global, 2.5º (Gaussian grid)	NCEP - NCAR
Wind	1948-2009 / 6h	Global, 2.5º (Gaussian grid)	NCEP - NCAR
Hurricanes	1950-2010	Global, dispersed	National Hurricane Center, NOAA
Swells	Variable	Global, dispersed	CSIRO satellite data
	Variable	Global, dispersed	NOAA buoys
	Variable	Global, dispersed	State port buoys
Bathymetry	-	Global, 2´	ETOPO—Earth Topography Digital Dataset. A global relief model of the Earth's surface that integrates land topography and ocean bathymetry.
	-	Global, 0.5´	GEBCO—General Bathymetric Chart of the Oceans.

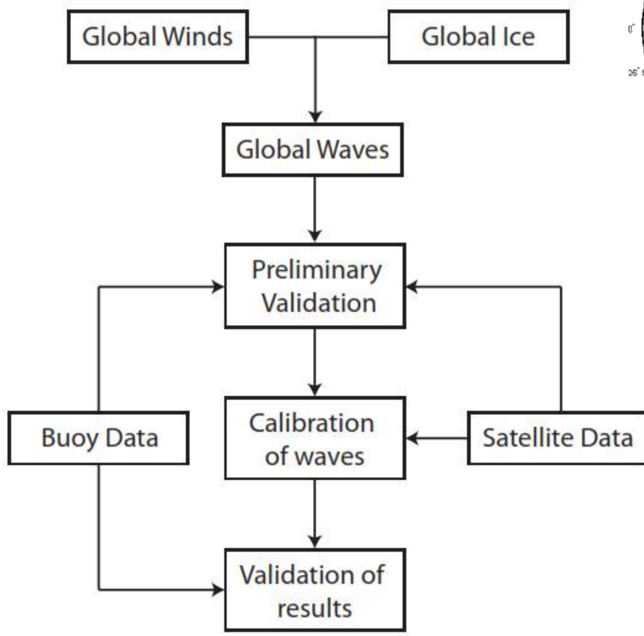
Type of information generated by IHC	Period of time covered	Spatial resolution	Source
Swells	1948-2010	Global, Latin America and the Caribbean 0.25º (Caribbean) and 0.5º	GOW-IHC
Storm surges	1948-2010	Global, Latin America and the Caribbean 0.25º	GOS-IHC
Tides	1948-2010	Global, Latin America and the Caribbean 0.25º	GOT-IHC

Databases generated: swells, storm surges and tides

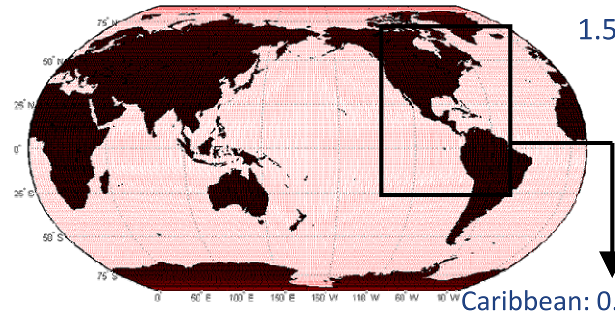
Reanalysis of GOW
(*Global Ocean Waves)*

Preliminary validation in buoys





Global Ocean Surge (GOS)
Satellite numeric database since 1948

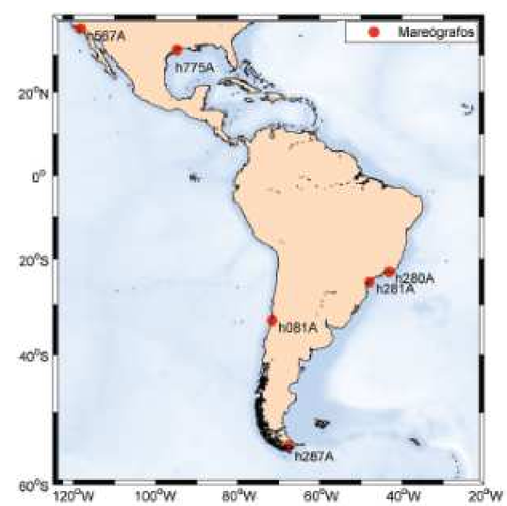


1.5ºx1º

Caribbean: 0.25x0.25

Atlantic and Pacific: 0.5x0.5

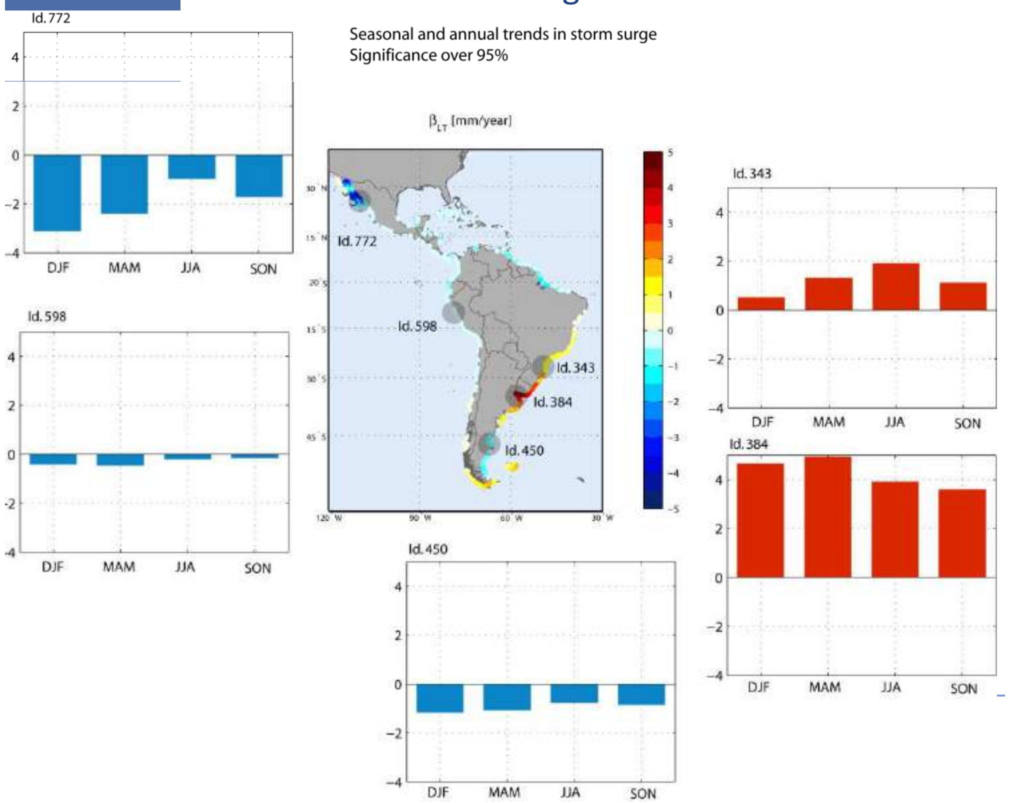
Locations and names of tide gauges



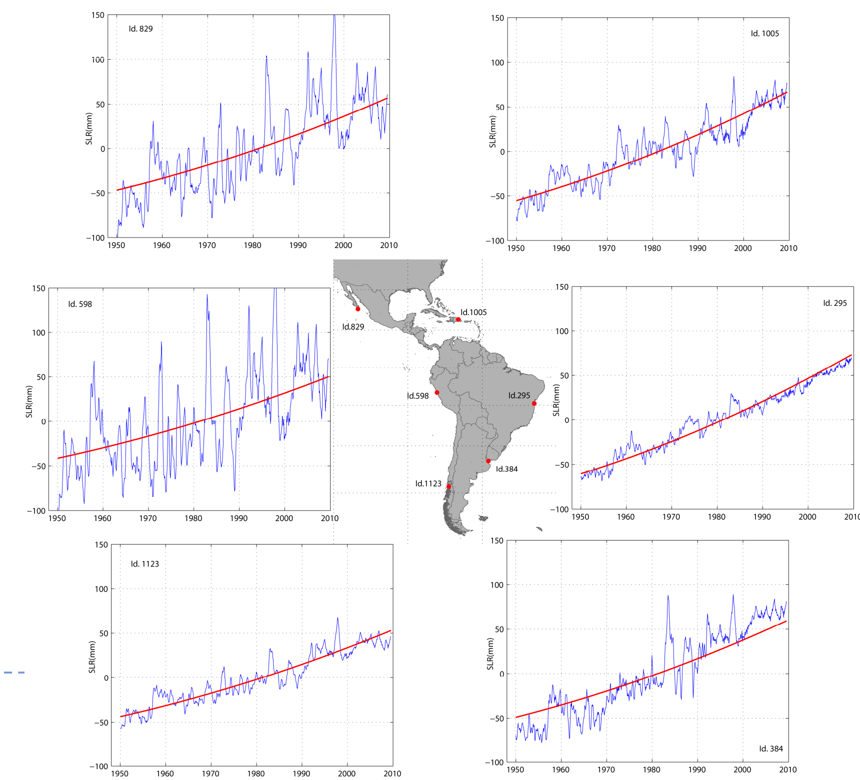
Overview of coastal variables in this study

Meteo-oceanographic variables	Coastal dynamics (IHC)	Extreme events	Hurricane events
• Mean sea level (MSL) • Sea surface temperature (SST) • Salinity (SAL) • Air surface temperature (AST) • Wind (W)	• Waves (monthly mean, monthly peak, height exceeded 12 hours per year and mean wave direction) • Storm surge • Tide	• Waves • Storm surges	• Winds • Waves • Storm surges

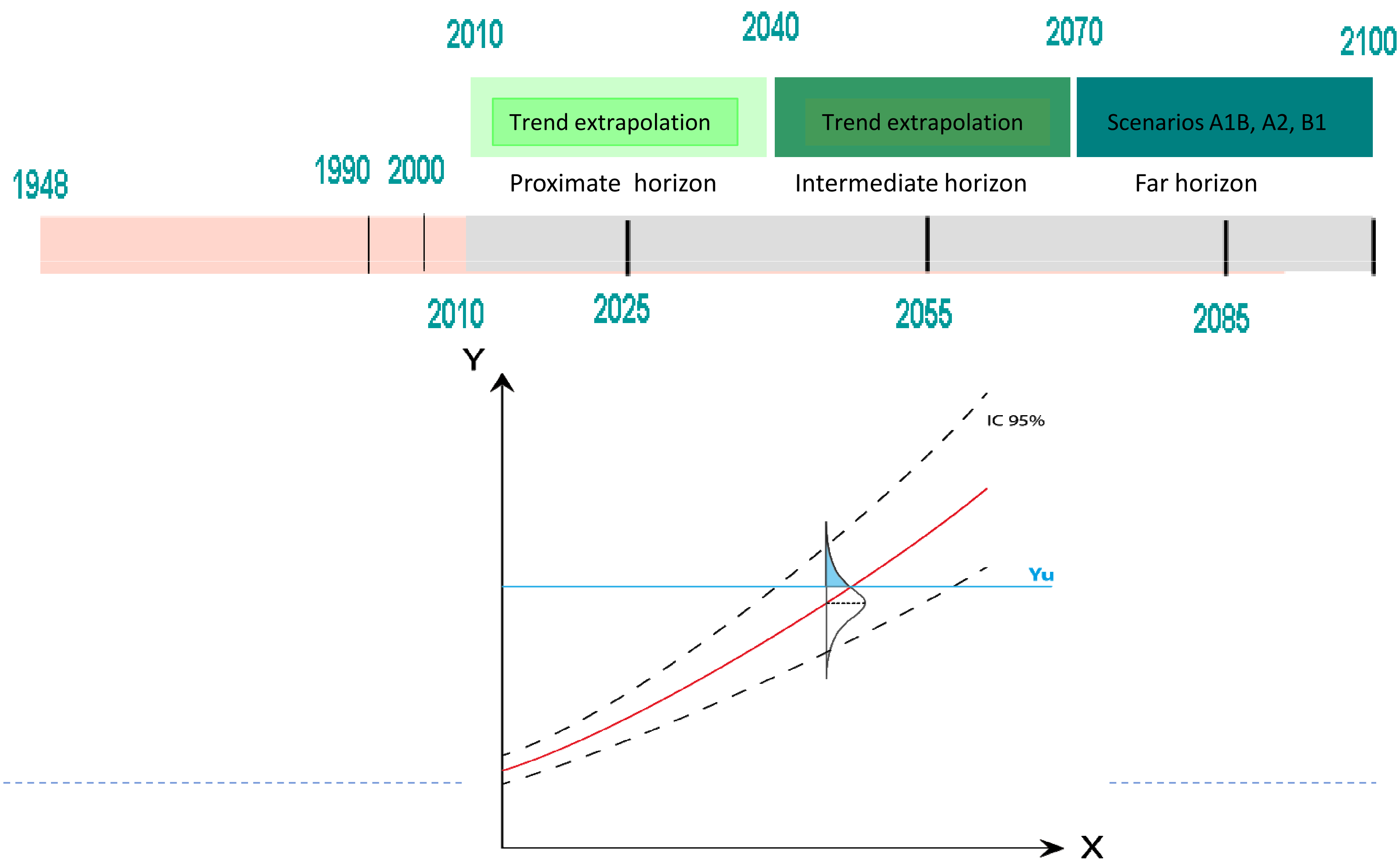
Trends of Storm Surge



Trends of sea level rise



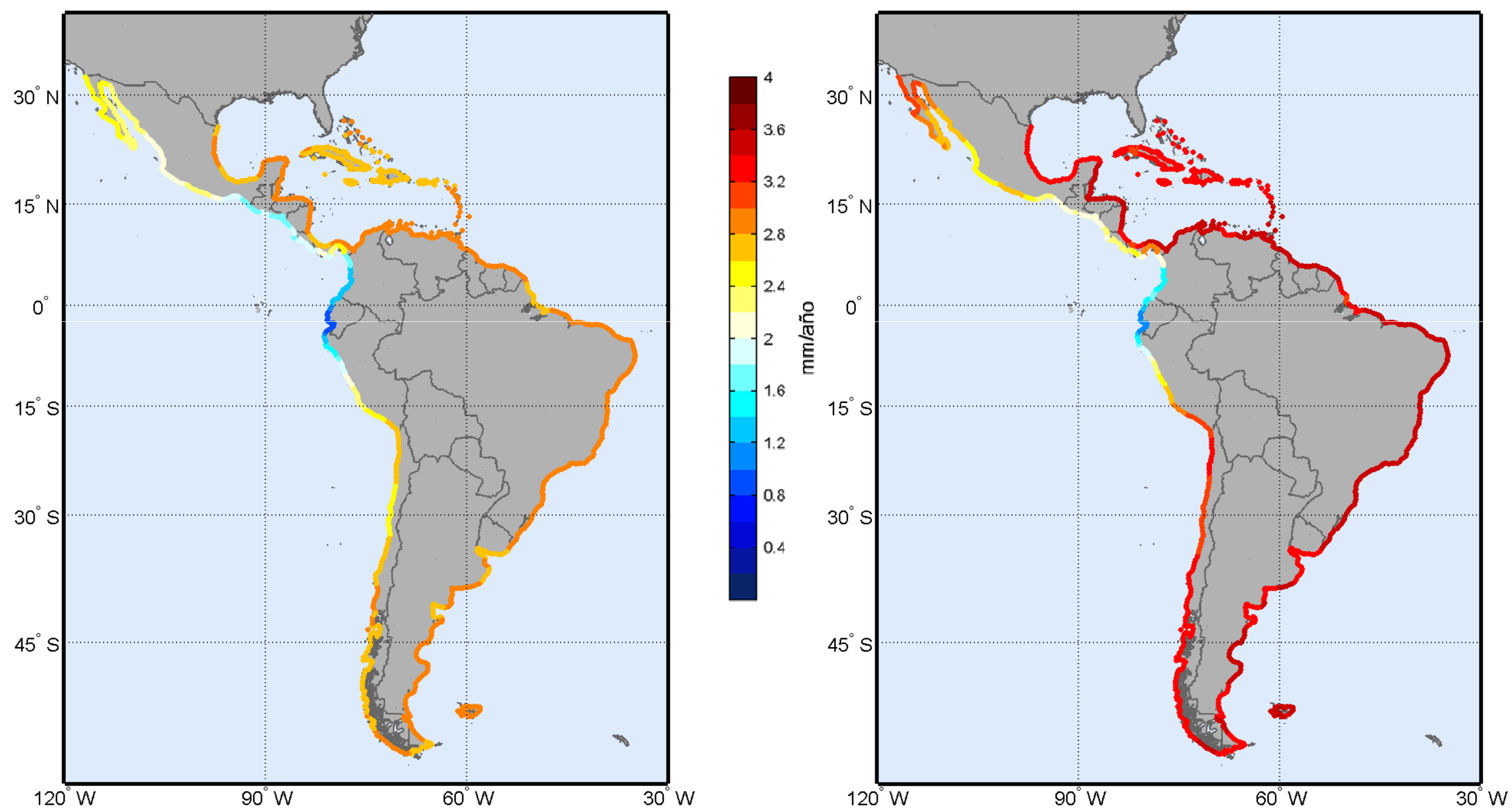
Temporal dimension and methodologies for each time horizon



Long-term trends of the coastal dynamics

Mean trend in sea level for 2010-2040 and 2040-2070

Tendencia Media SLR entre 2010 y 2040 (mm/año) | Tendencia Media SLR entre 2040 y 2070 (mm/año)



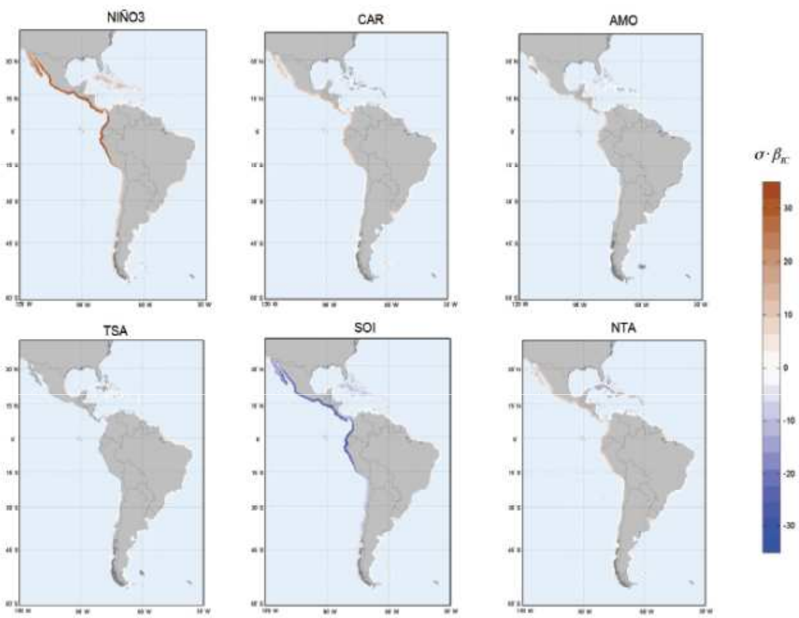
Some examples

Study Units	Trends in 50-Years return periods for significant wave heights		
	2040	2050	2070
Montevideo	50	41,85	34,73
Ensenada	50	30,03	18,21
Puerto Plata	50	38,37	29,60
I. Taggart	50	52,49	55,02

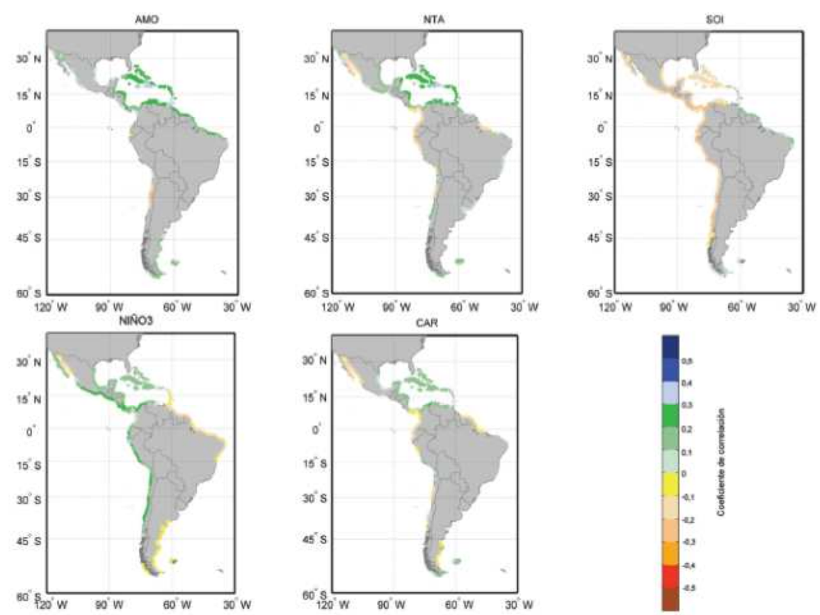
Stady Units	Variation in the likelihood of change in H_{s12} exceeding 50 cm relative to 2010		
	2040	2050	2070
Montevideo	0,31	0,45	0,73
Ensenada	0,27	0,36	0,60
Puerto Plata	0,06	0,08	0,12
I. Taggart	-0,01	-0,01	-0,02

Inter-annual variability in the coastal dynamics

Correlation of standard deviation in sea levels

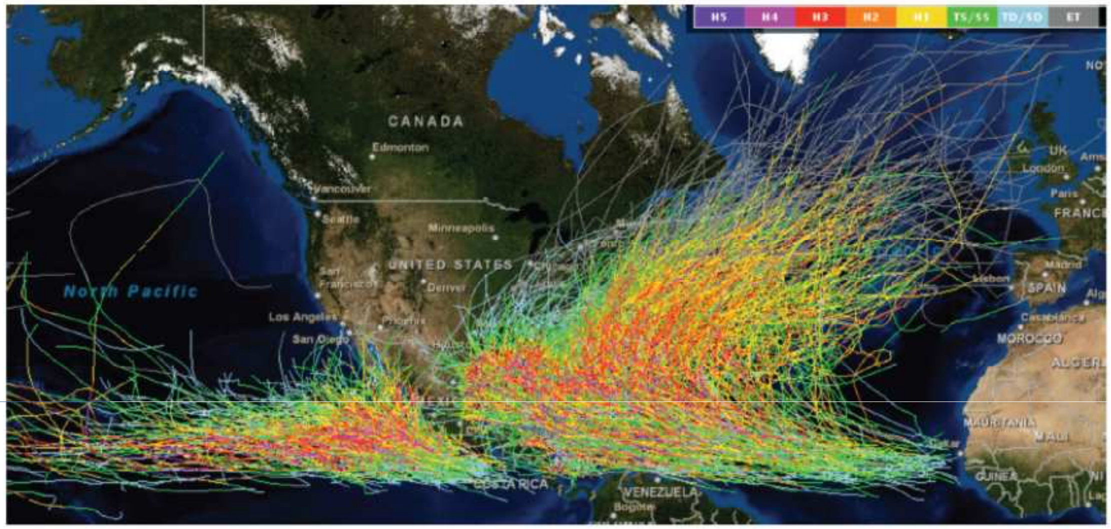


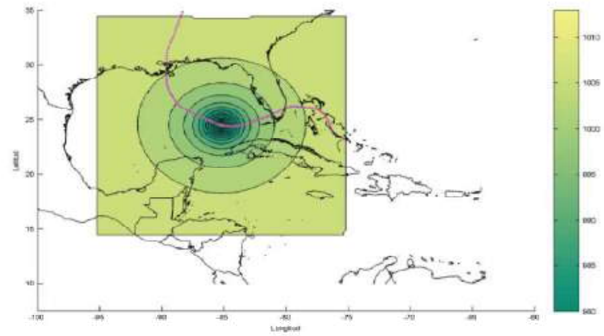
Correlation 95th quantile for storm surges for several indexes



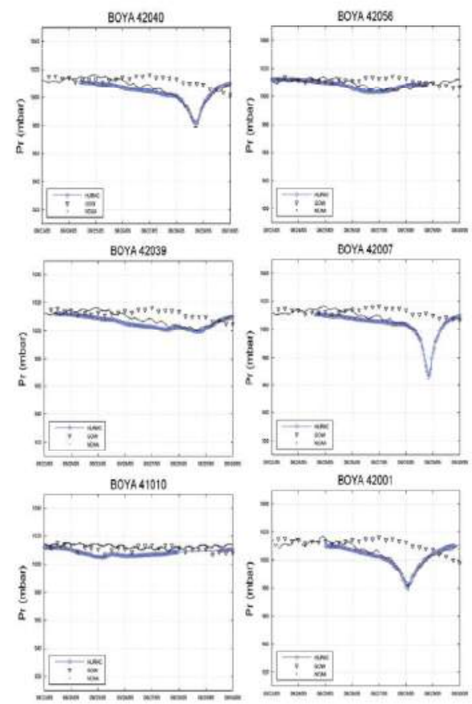
Map the historical data on pressure, waves, winds and sea levels during hurricanes using analytical and parametric models

Positions and intensities of hurricanes over a 54-year period



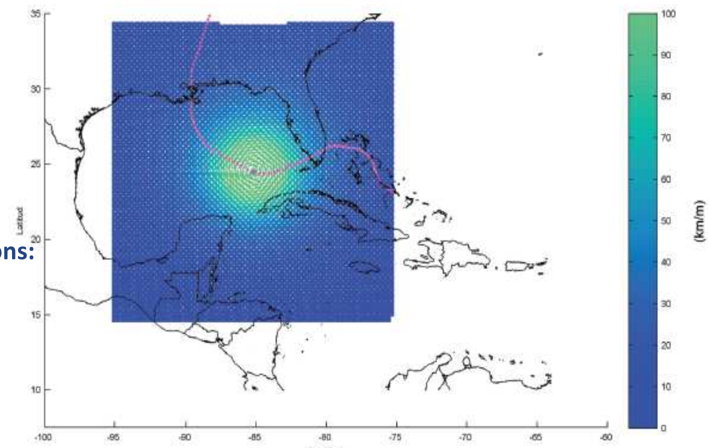


Atmospheric pressure map for hurricane Katrina (*Mbar)*

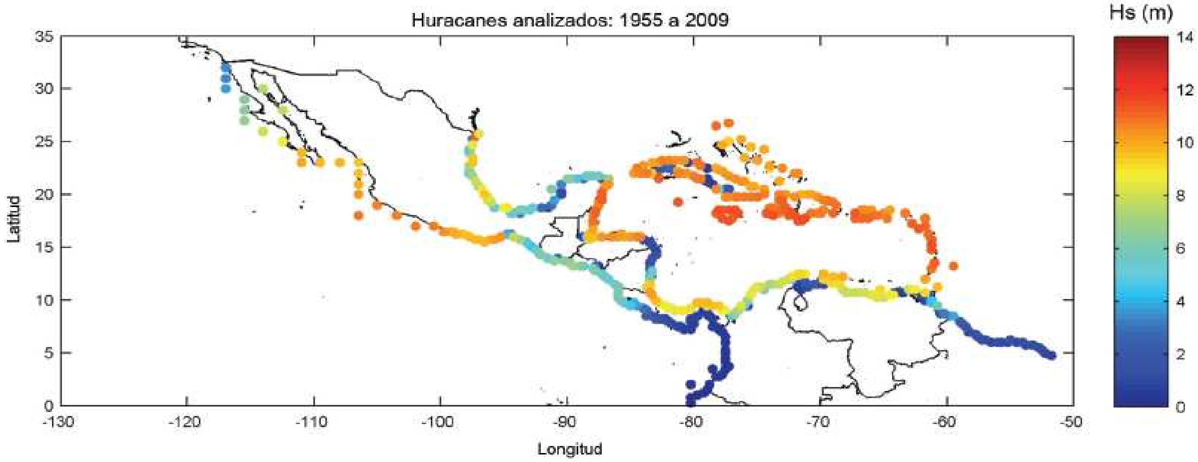


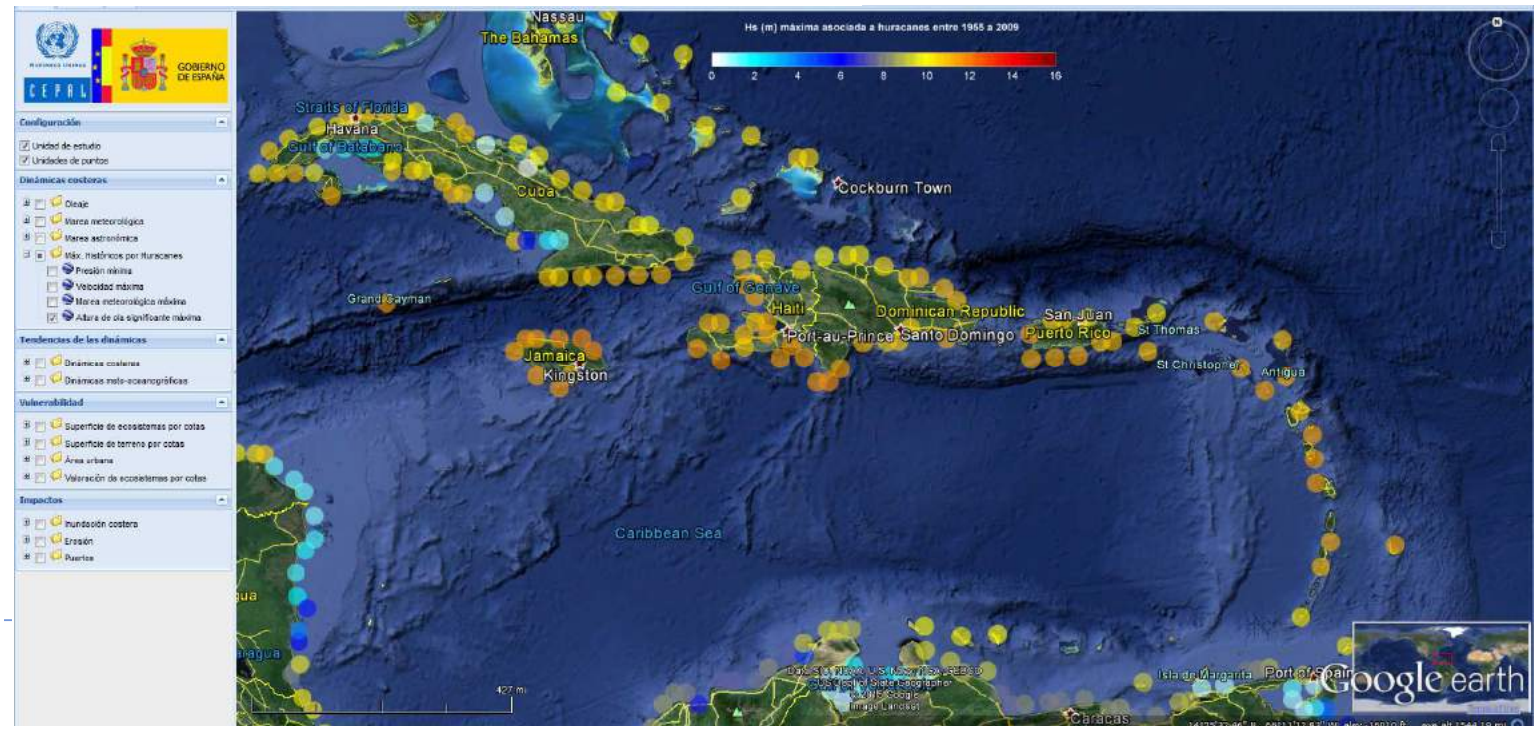
Comparison of pressure series for the hurac-hydromet-rankin vortex model (1980), buoy data and NCEP/NCAR reanalysis for hurricane Katrina (2005)

Map of wind variations: hurricane Katrina (*km/metres)*

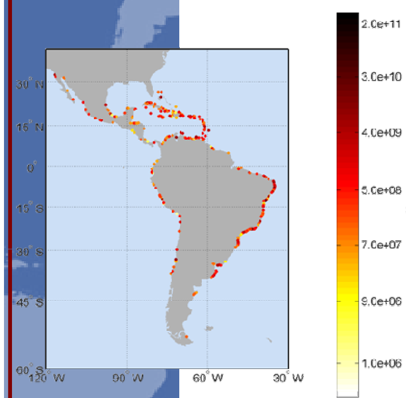
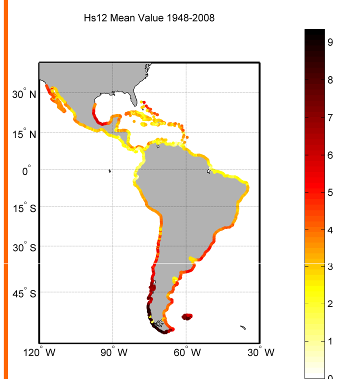
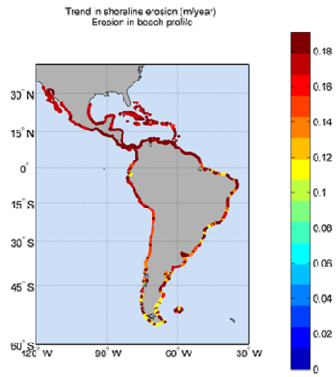
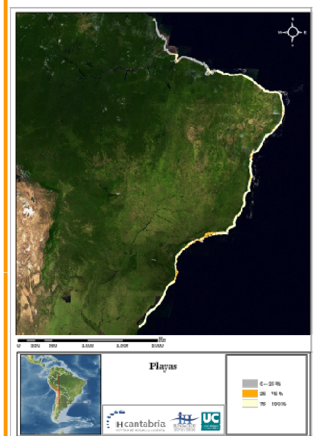
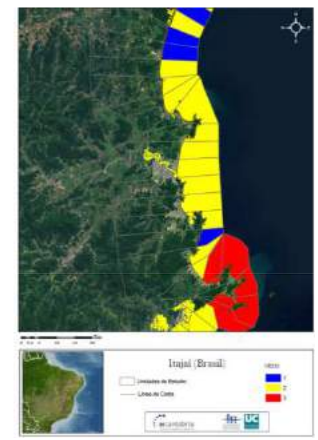


Map of historical maximums (54 years) for significant wave heights at specified control points



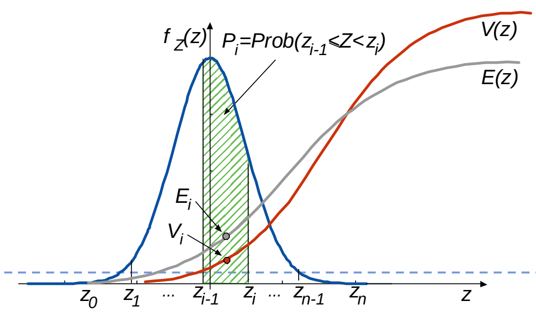


Framework of the project

Risk	=	Probable danger		x	Exposure	x	Vulnerability
		Dynamics	**Impacts**				
							
Scenarios		**Uncertainty** **Climate change trends**			**Coast** **types**		**Functions of the coast**

Extrapolation of trends

Scenarios



Beaches, ports, coral reefs, urban areas, etc.

Physical Vuln.

Ecological

Socioeconomic

Scenarios used for impact assessments

Scenario		Time horizon	Method	Dynamics assessed	Variants-observations
A		2040	Statistical trends	Statistical trends. All	-
B		2050	Statistical trends	Statistical trends. All	-
C		2070	Statistical trends	Statistical trends. All	-
D		2100	Justification - IPCC SLR scenario	Sea level rise of 0.5 m	Statistical trends – other dynamics as of 2070
E		2100	Justification - IPCC SLR scenario	Sea level rise of 1 m	Statistical trends – other dynamics as of 2070
F	F1	2010	El Niño 98	Sea level	El Niño of 1998 at present
	F2	2100	El Niño 98 + IPCC SLR scenario	Sea level rise of 1 m	El Niño of 1998 with CC scenario
G	G1	2010	La Niña 89	Sea level	La Niña of 1989 at present
	G2	2100	La Niña 89 + IPCC SLR scenario	Sea level rise of 1 m	La Niña of 1989 with CC scenario
H	H1	2010	Hurricanes	Sea level and flood level	Hurricanes at present
	H2	2100	Hurricanes + IPCC SLR scenario	Sea level rise of 1 m	Hurricanes with CC scenario

Impacts covered in the study, dynamics and the techniques used to compute the scale of long-term changes

Impact	Variables	Analytical techniques used
Permanent flooding	Sea level rise (SLR)	Long-term statistical trends
Temporary flooding	Storm surge, sea level rise, tides, wave setup and seasonality of sea levels	Long-term statistical trends
Beach erosion	H_{S12}, sea level rise, wave direction	Long-term statistical trends
Port activity	Overtopping and wave-related navigation conditions	Long-term statistical trends
Reliability of maritime structures	Extreme wave heights (modification of heights used in calculations)	Models of non-stationary extremes
Coral bleaching	Sea surface temperature	Long-term statistical trends
Potential sediment transport	Waves and winds	Disturbance-based trends and long-term statistical trends

Examples of impacts on the coast: flooding

Coastal flooding by sea level rise

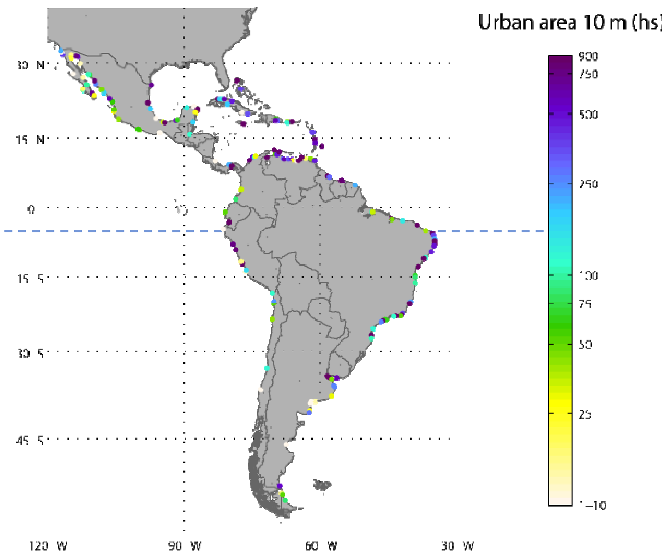
The distribution of the population and the territory is the main factor of impact caused by floods in the coastal strip

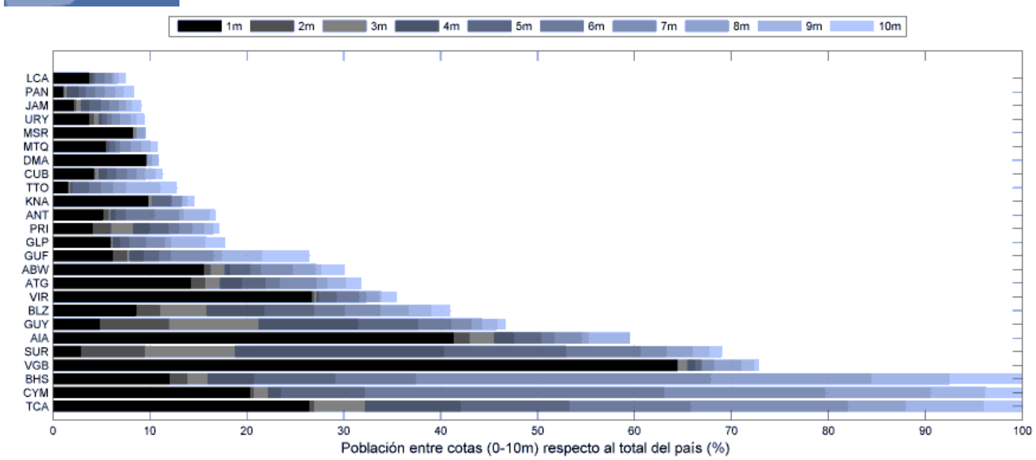
Particular concern is on the **Caribbean islands and the Atlantic** coast regarding to the mean sea level

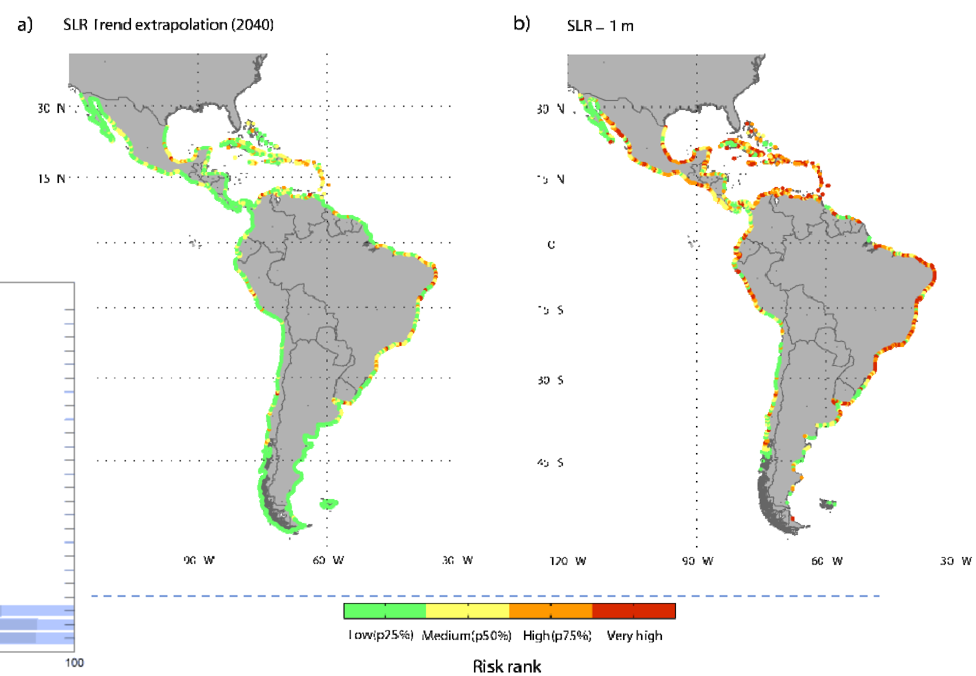
In the tropical **Pacific coast**, the influence of ENSO on sea level change is greater than the magnitude of the long-term trend of sea level rise.

The impact of hurricanes due to a rise of 1 m would change significantly (p.e. **Venezuela, Honduras, Panama or Costa Rica**)

In other countries the variation in the impact is not as significant compared to the current level impact (p.e. Dominican Republic).



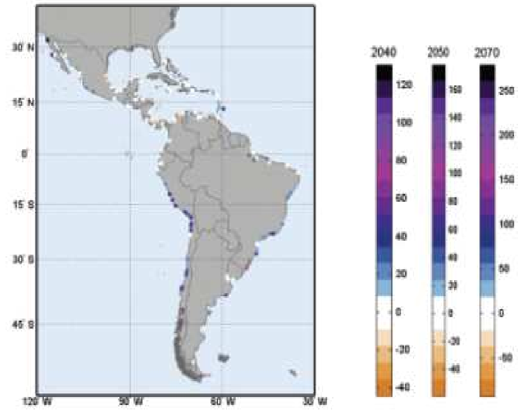




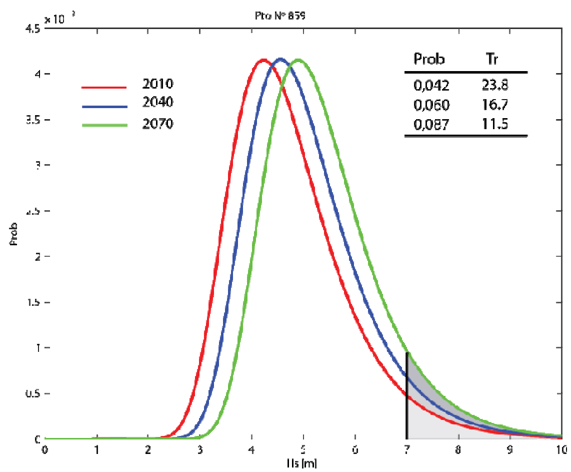
Examples of impacts on the coast: ports

Port activity and infrastructure protection

Under mean conditions, the probability of the occurrence of a significant wave height of over 3 m will increase, navigation conditions for ships wishing to enter ports in the region will worsen.



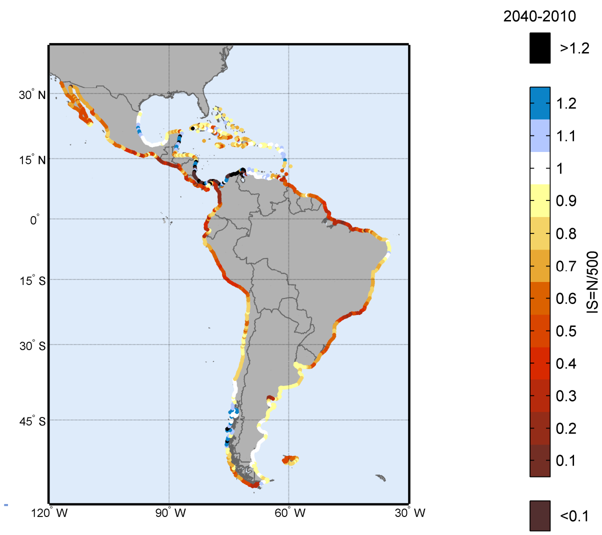
The **reliability of existing maritime structures** and of those designed in the near future without factoring in the effects of long-term changes **will be reduced by around 60%** (in mean terms as of 2070) in a large part of the region (other than the inner portion of the Caribbean Sea, where tropical storms are the main design actions taken into account).



Baja California

For the most part, except in some areas of the Caribbean, any maritime structure is going to need to be shielded with heavier components in the future.

Generally speaking, the ability of maritime structures to withstand the effects of climate change is expected to decline. However, in the southern Caribbean, there will be gains in the reliability of maritime structures due to the foreseen reduction in the design wave height.

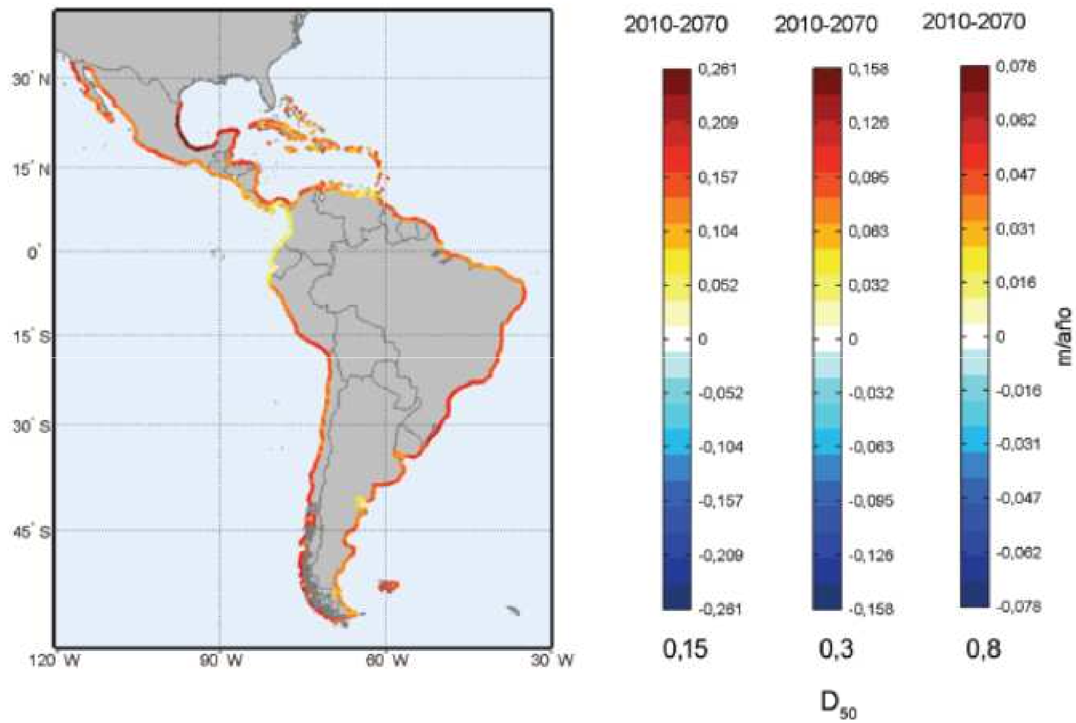


MARITIME STRUCTURAL SAFETY INDEX FOR A MEAN RECURRENCE INTERVAL OF 500 YEARS: 2040 TIME HORIZON (SCENARIO A)

Impacts on the coast: beach erosion

MEAN TREND IN BEACH EROSION FROM CHANGES IN EQUILIBRIUM PROFILE BETWEEN 2010 AND 2070

(Metres/year)

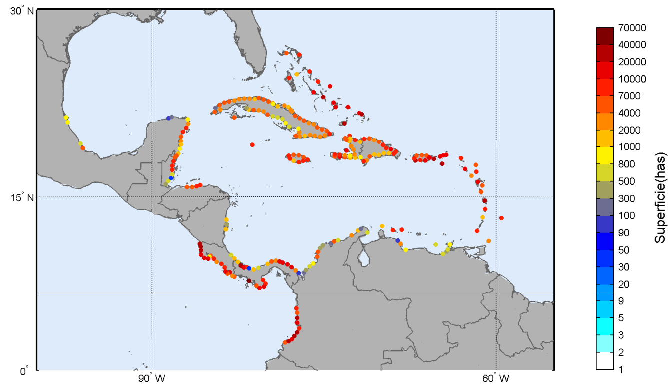


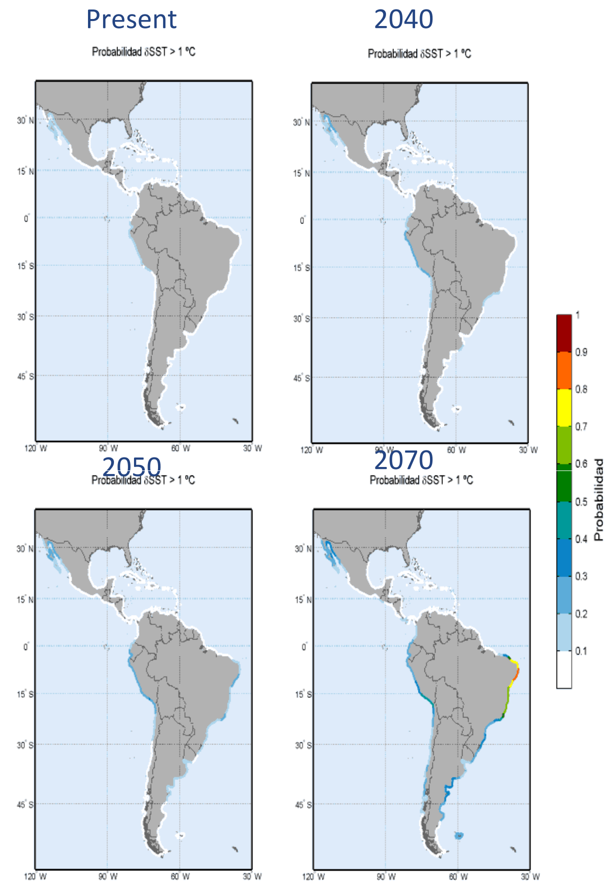
The worst affected areas will be the **northern Caribbean** and the coastlines to the south of Brazil down to the Río de la Plata. Erosion is, in any case, generalized throughout the region, **especially in the event of sea level rise**.

The **largest changes from beach** rotation are likely to occur on the southern coasts of Brazil (more than 1 m/year), **the Caribbean coasts** (especially eastern Cuba and the easterly islands), part of the coast of Chile and the north-east coast of Mexico; in the last case again at rates of over 1 m of erosion per year on average.

Impacts on the coast: coral reefs

Surface area of coral reefs in the Caribbean sea and the Central Pacific
(hectares)

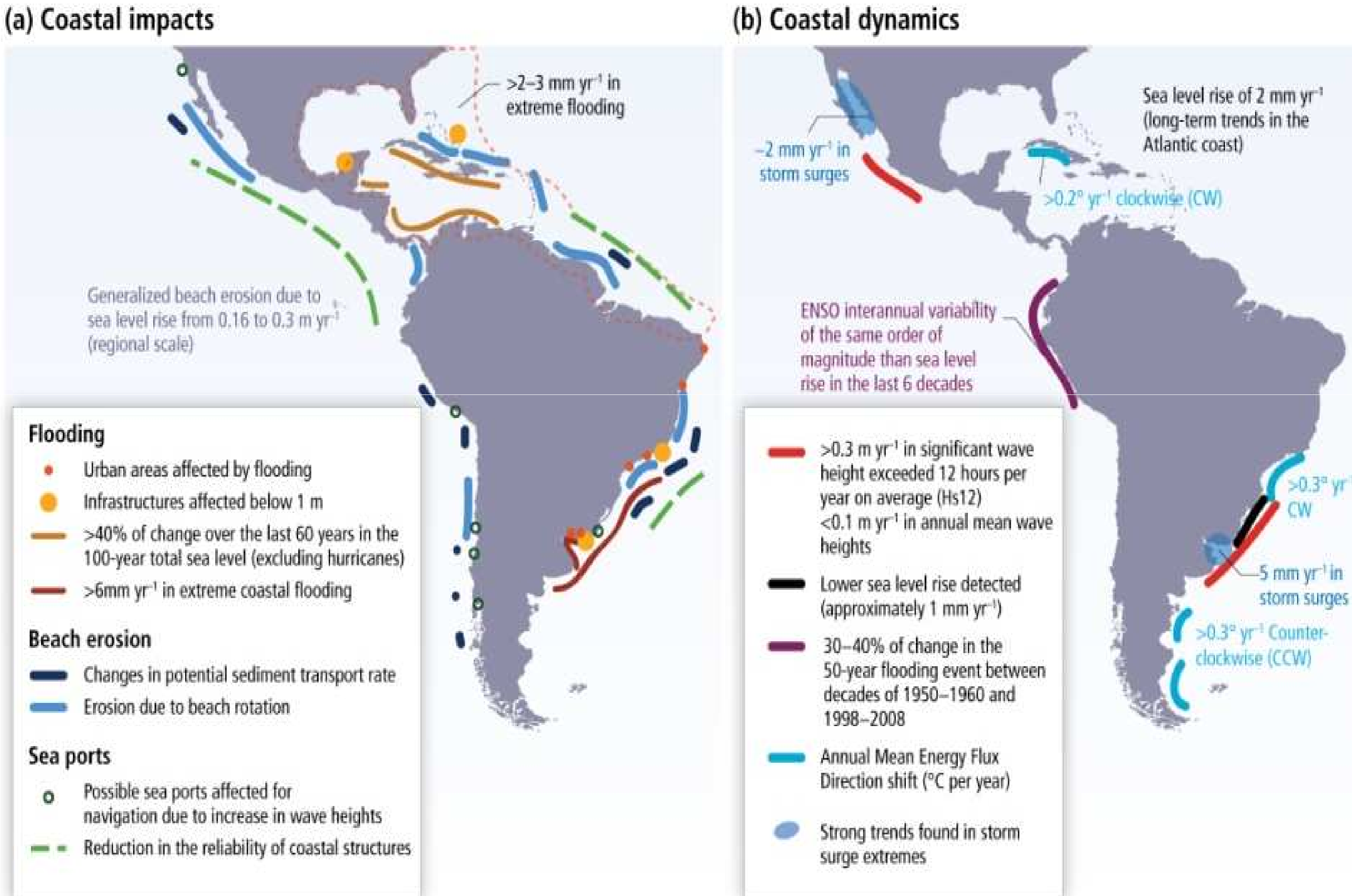




Mean probability of an increase in sea surface temperature in excess of 1°C

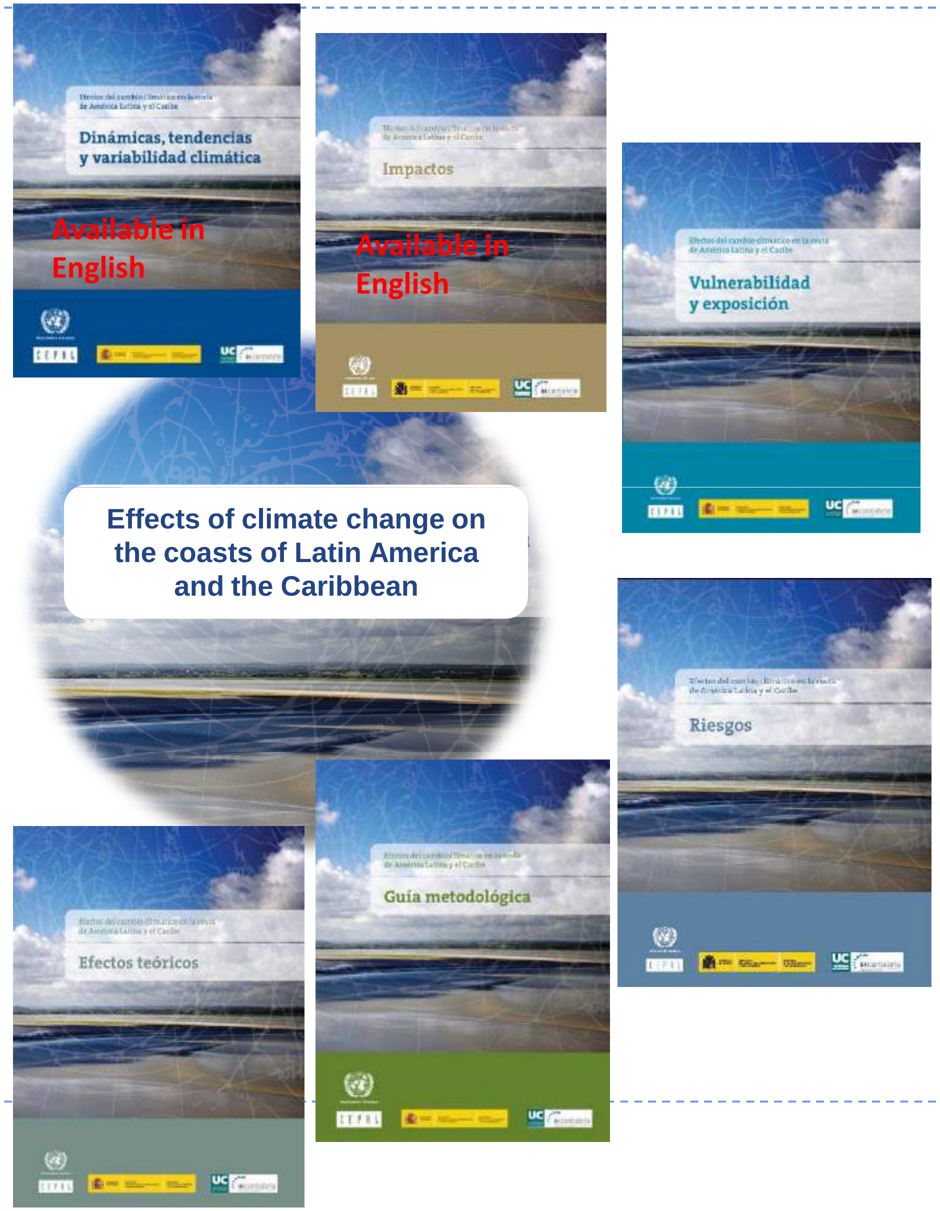
It is probable that the **current impacts being seen in the Caribbean will spread** to islands where there are virtually no such impacts at present. Finally, for the Caribbean islands where the probability of exceeding the threshold value is currently below 0.1, **the probability will rise to 0.2 by 2070.**

Current and predicted coastal impacts and coastal dynamics in response to climate change



Source: Taken form ECLAC 2011, 2012 in Magrin, G.O., et al, 2014: Central and South America. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

Publications of the project and web



Available at:
http://www.cepal.org/es/efectos-cambio-climatico-la-costa-america-latina-caribe

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Oleaje
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Marea astronómica
Máx. Históricos por Huracanes
Tendencias de las dinámicas
Dinámicas costeras
Dinámicas meto-oceanográficas
Vulnerabilidad
Superficie de ecosistemas por cotas
Superficie de terreno por cotas
Área urbana
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Impactos
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28°43'19.60" S 90°11'19.87" W elev -11563 ft
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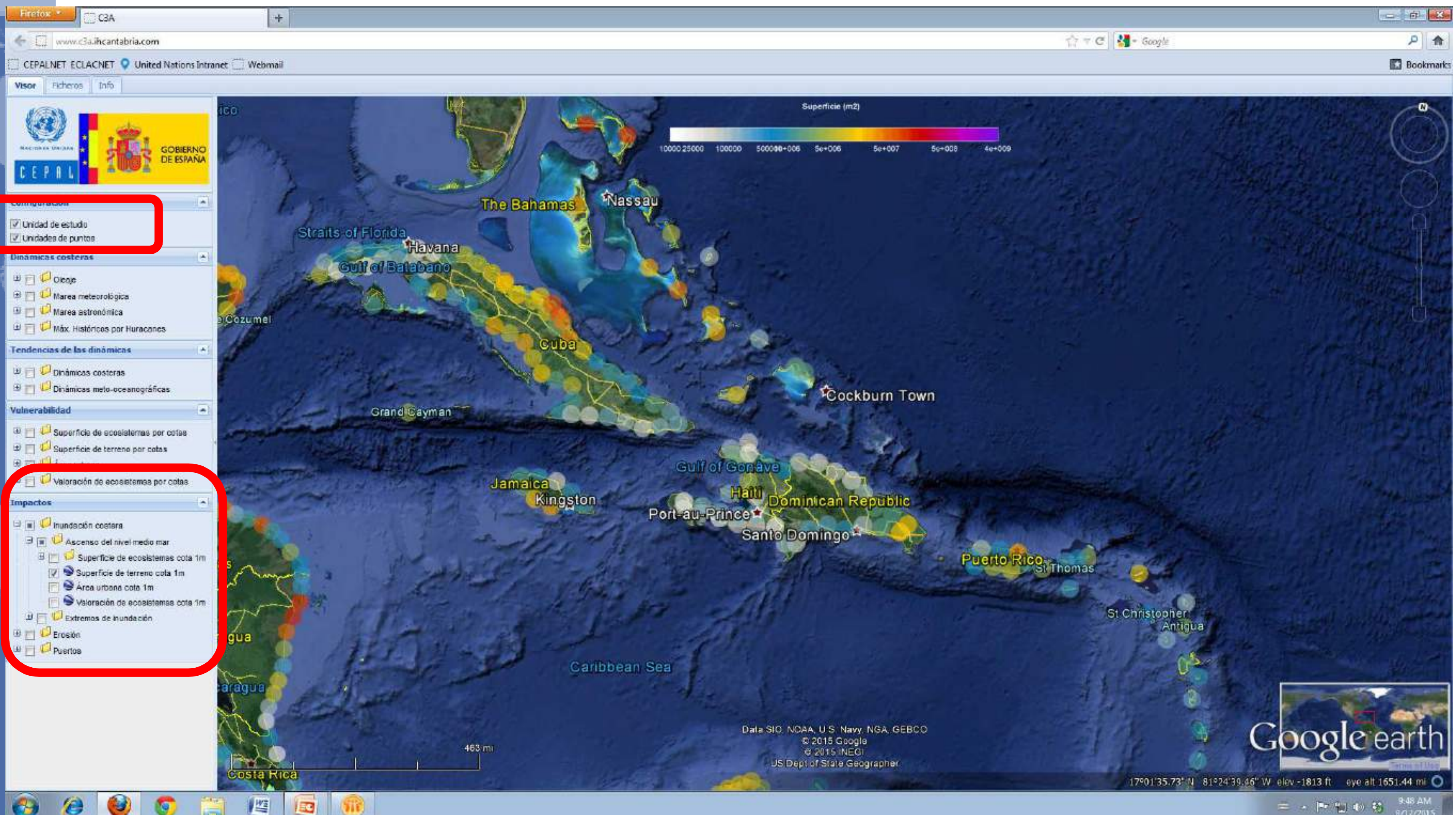
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Dinámicas meteo-oceanográficas
Vulnerabilidad
Superficie de ecosistemas por cotas
Superficie de terreno por cotas
Valoración de ecosistemas por cotas
Impactos
Inundación costera
Ascenso del nivel medio mar
Superficie de ecosistemas cota 1m
Superficie de terreno cota 1m
Área urbana cota 1m
Valoración de ecosistemas cota 1m
Extremos de inundación
Erosión
Puertos
Superficie (m2)
The Bahamas
Nassau
Straits of Florida
Havana
Gulf of Batabano
Cuba
Cockburn Town
Grand Cayman
Gulf of Gonave
Jamaica
Kingston
Haiti
Dominican Republic
Port-au-Prince
Santo Domingo
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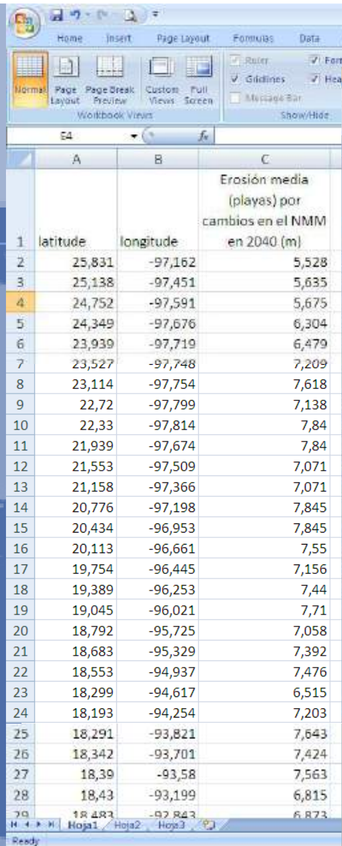


	A	B	C
1	latitude	longitude	Erosión media (playas) por cambios en el NMM en 2040 (m)
2	25,831	-97,162	5,528
3	25,138	-97,451	5,635
4	24,752	-97,591	5,675
5	24,349	-97,676	6,304
6	23,939	-97,719	6,479
7	23,527	-97,748	7,209
8	23,114	-97,754	7,618
9	22,72	-97,799	7,138
10	22,33	-97,814	7,84
11	21,939	-97,674	7,84
12	21,553	-97,509	7,071
13	21,158	-97,366	7,071
14	20,776	-97,198	7,845
15	20,434	-96,953	7,845
16	20,113	-96,661	7,55
17	19,754	-96,445	7,156
18	19,389	-96,253	7,44
19	19,045	-96,021	7,71
20	18,792	-95,725	7,058
21	18,683	-95,329	7,392
22	18,553	-94,937	7,476
23	18,299	-94,617	6,515
24	18,193	-94,254	7,203
25	18,291	-93,821	7,643
26	18,342	-93,701	7,424
27	18,39	-93,58	7,563
28	18,43	-93,199	6,815
29	18,483	-92,843	6,873

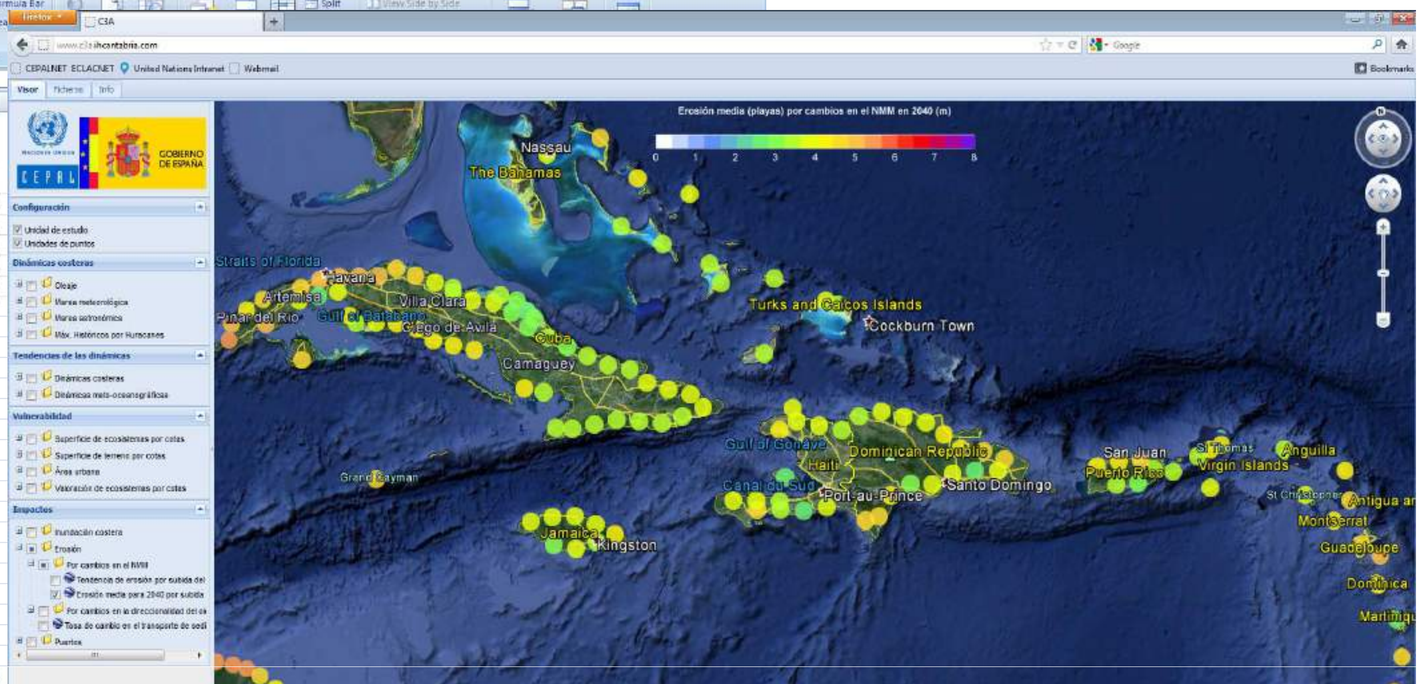
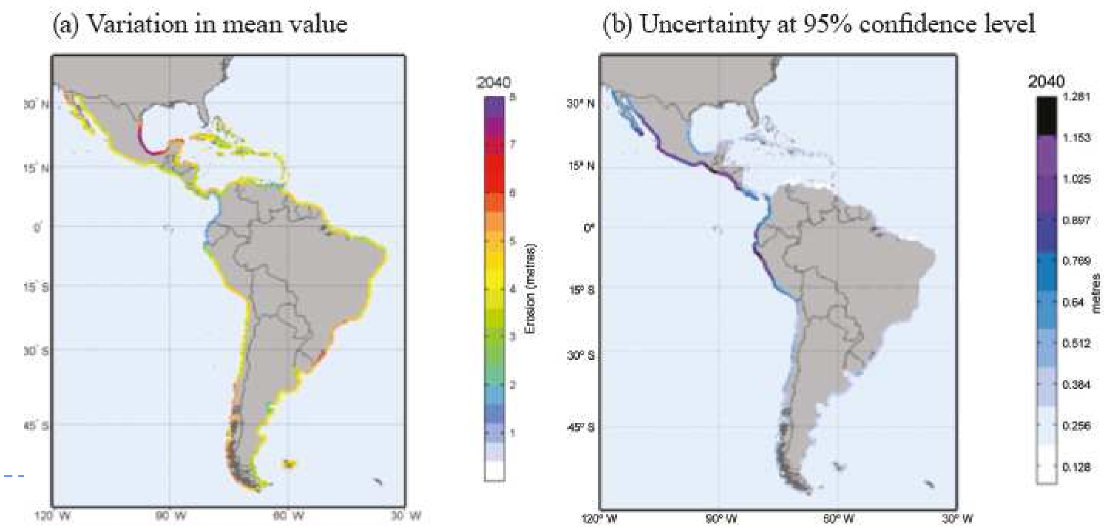
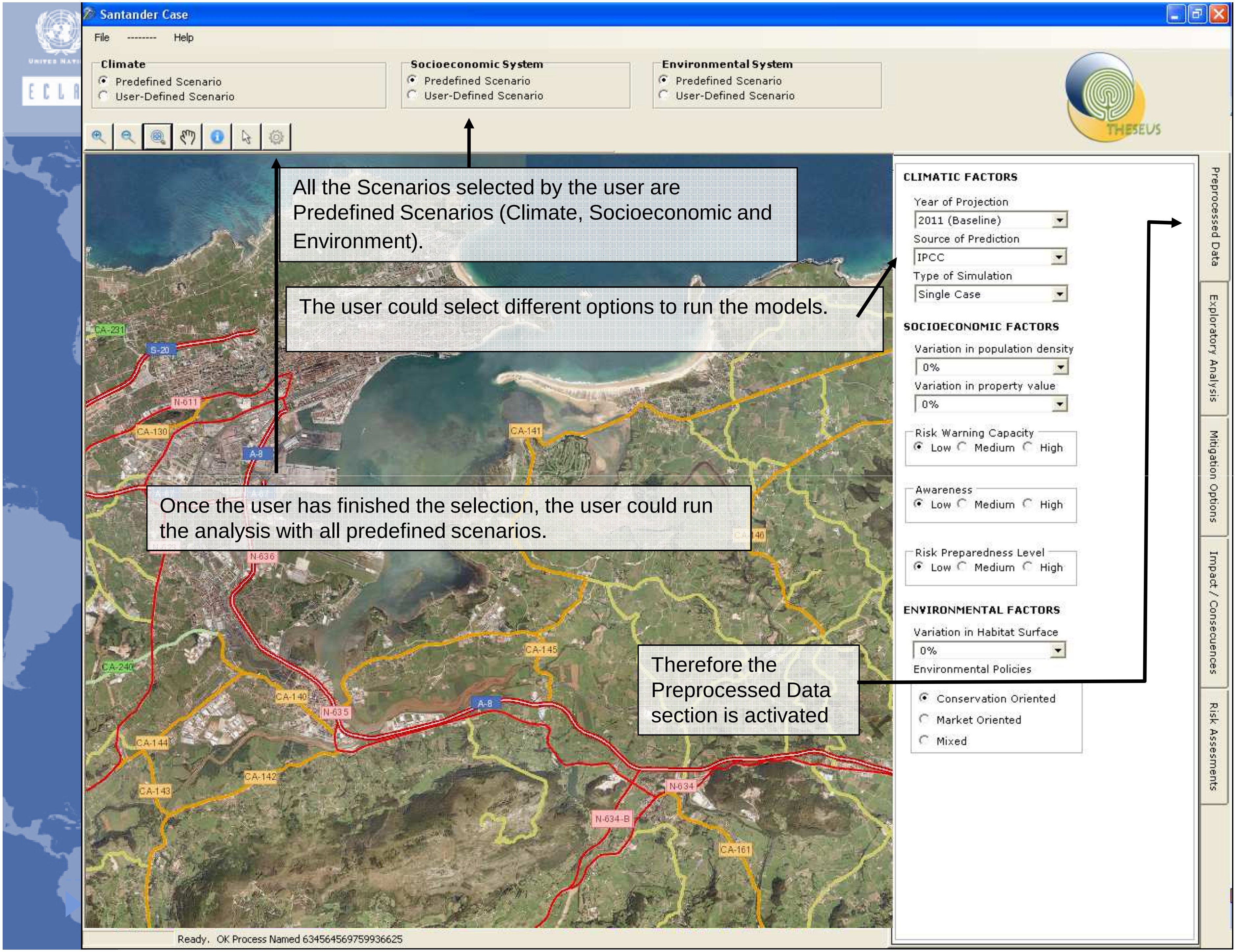


FIGURE 3.41
BEACH EROSION FROM CHANGES IN EQUILIBRIUM PROFILE, IN 2040
(Metres)



Source: Prepared by the authors.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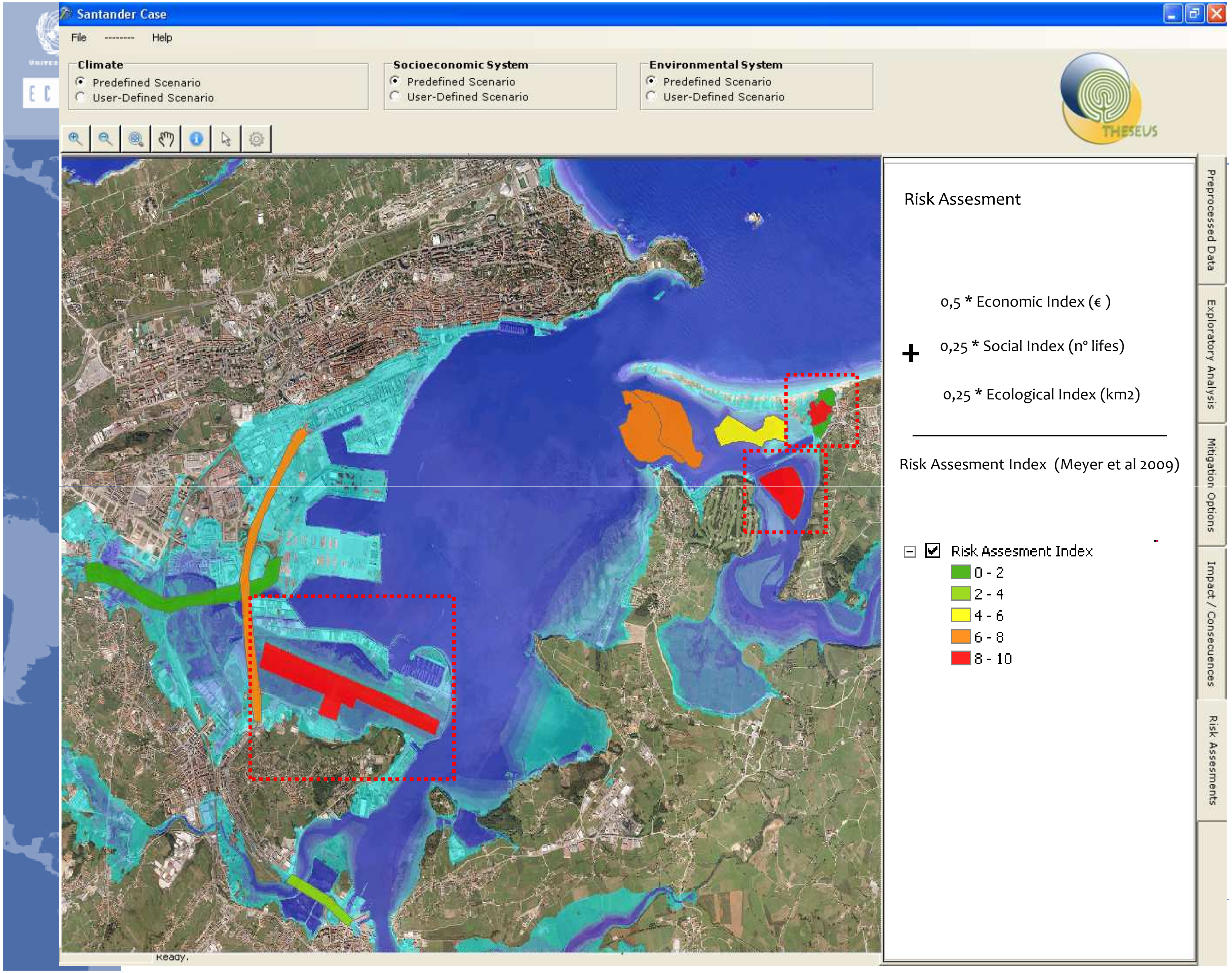
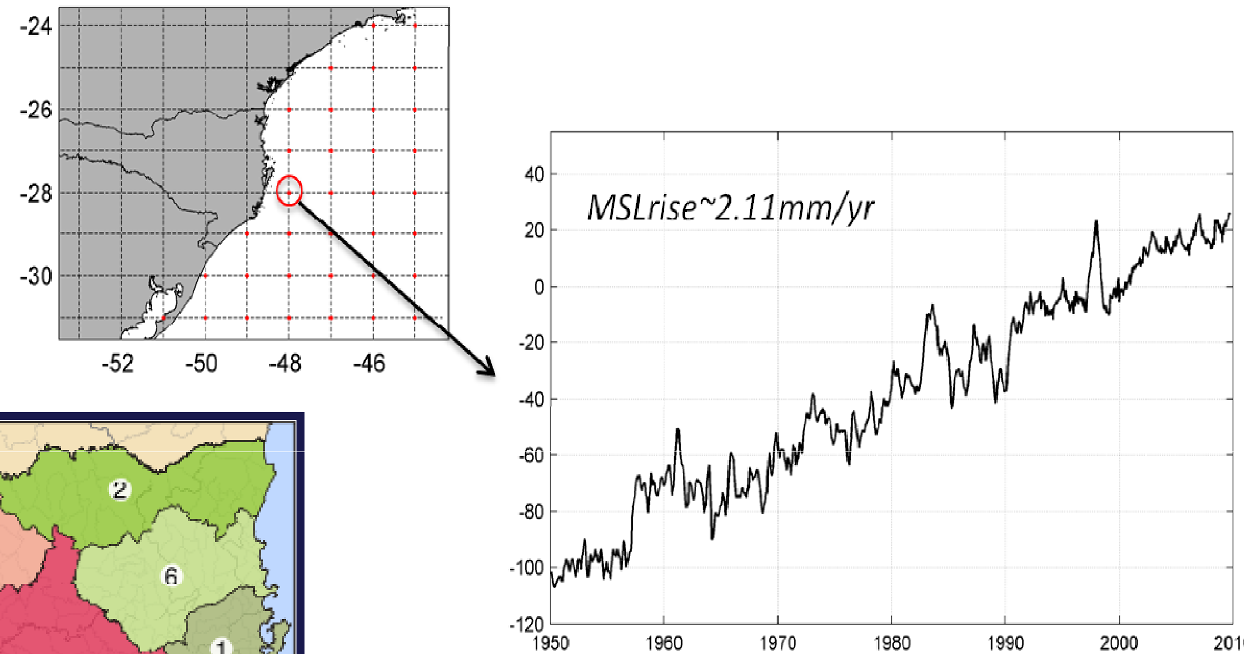
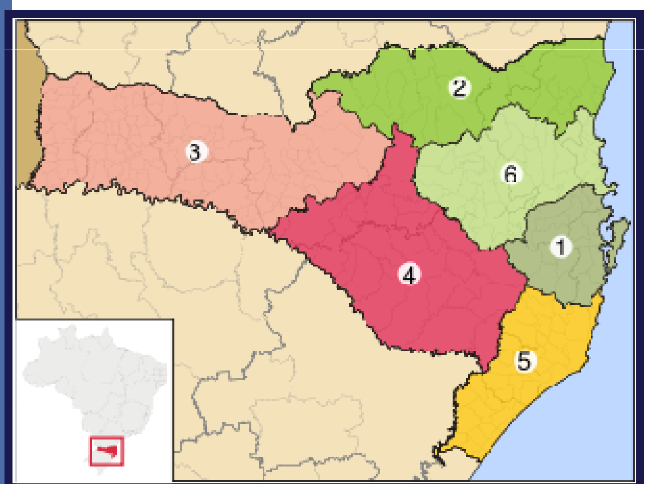
File -------- Help
Climate
Predefined Scenario
User-Defined Scenario
Socioeconomic System
Predefined Scenario
User-Defined Scenario
Environmental System
Predefined Scenario
User-Defined Scenario
THESEUS
All the Scenarios selected by the user are Predefined Scenarios (Climate, Socioeconomic and Environment).
The user could select different options to run the models.
Once the user has finished the selection, the user could run the analysis with all predefined scenarios.
Therefore the Preprocessed Data section is activated
CLIMATIC FACTORS
Year of Projection
2011 (Baseline)
Source of Prediction
IPCC
Type of Simulation
Single Case
SOCIOECONOMIC FACTORS
Variation in population density
0%
Variation in property value
0%
Risk Warning Capacity
Low Medium High
Awareness
Low Medium High
Risk Preparedness Level
Low Medium High
ENVIRONMENTAL FACTORS
Variation in Habitat Surface
0%
Environmental Policies
Conservation Oriented
Market Oriented
Mixed
Preprocessed Data
Exploratory Analysis
Mitigation Options
Impact / Consecuences
Risk Assesments
Ready. OK Process Named 634564569759936625


Santander Case
File

Help
Climate
Predefined Scenario
User-Defined Scenario
Socioeconomic System
Predefined Scenario
User-Defined Scenario
Environmental System
Predefined Scenario
User-Defined Scenario
THESEUS
Risk Assesment
0,5 * Economic Index (€)
+
0,25 * Social Index (nº lifes)
0,25 * Ecological Index (km2)
Risk Assesment Index (Meyer et al 2009)
Risk Assesment Index
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
Preprocessed Data
Exploratory Analysis
Mitigation Options
Impact / Consecuences
Risk Assesments
Ready.

Santa Catarina (Brasil)- Increase on mean sea level rise

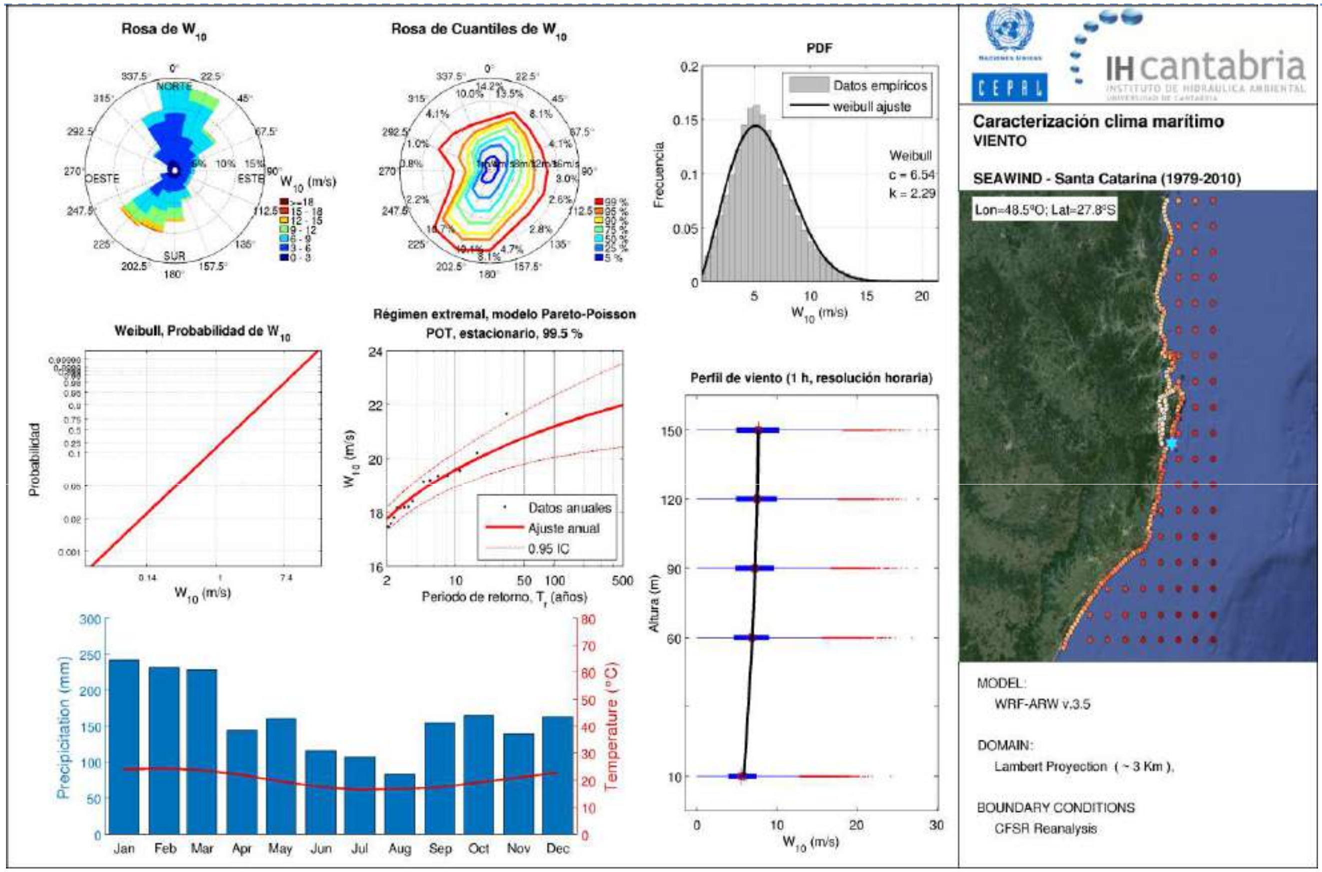




Source: ECLAC/IHC. Document in progress.

The estimated historical trend on mean seal level rise in Santa Catarina is 2,11 mm/year, indicating an increase of 4.6 cm over the past 22 years and more than 10 cm over the past 50 years.

Santa Catarina (Brasil)- Climate Atlas characterization of wind

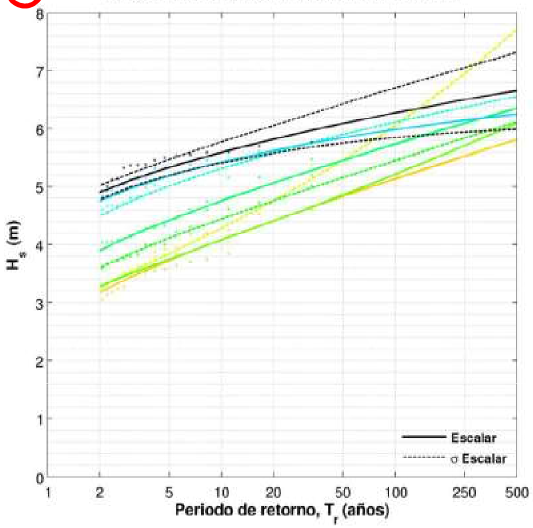


Source: ECLAC/IHC. Document in progress.

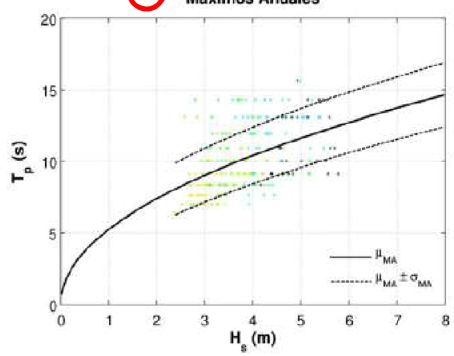
Climate Atlas with statistical characterization for historical data (wind, waves, sea level). Fact sheets were made for the coastline of Santa Catarina with a resolution of 1 km for a series of separate points around 10 km. In total, 232 coastal and marine sites were characterized.

Santa Catarina (Brasil)- Climate Atlas characterization of waves

1 Régimen extremal ajustado con la técnica POT a un modelo Pareto-Poisson en términos de la función GEV



2 Máximos Anuales



3

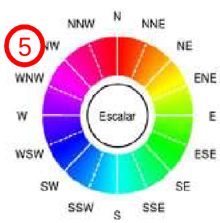
Sector	u	λ	σ	μ	ψ	ξ	c_o	c_1	c_2	c_3
N										
NNE										
NE	2.256	4.156	0.530	2.992	0.504	-0.035	1.121	-0.583	0.078	0.003
ENE	2.583	3.812	0.351	3.108	0.435	0.159	1.499	-0.963	0.189	-0.006
E	2.583	4.375	0.358	3.135	0.391	0.061	1.384	-0.858	0.158	-0.004
ESE	2.791	4.062	0.467	3.437	0.456	-0.017	1.862	-0.948	0.128	0.000
SE	3.064	3.844	0.504	3.726	0.478	-0.040	1.622	-0.669	0.055	0.005
SSE	3.490	4.500	0.598	4.315	0.503	-0.115	1.057	-0.096	-0.090	0.015
S	3.792	4.594	0.603	4.591	0.453	-0.188	-3.011	2.431	-0.601	0.048
SSW										
SW										
WSW										
W										
WNW										
NW										
NNW										
Escalar	4.099	4.125	0.494	4.747	0.423	-0.110	1.930	-0.228	-0.125	0.020

4

$$\mu_{MA}(T_p|H_s) = aH_s^b$$
$$\sigma_{MA}(T_p|H_s) = aH_s^b$$

T_p	a	b
$\mu_{MA}(T_p\|H_s)$	5.266	0.493
$\sigma_{MA}(T_p\|H_s)$	1.560	0.172

5



Función de distribución Pareto-Poisson

$$F(H_s;u,\lambda,\sigma,\xi) = \exp\left(-\lambda\left(1+\xi\left(\frac{H_s-u}{\sigma}\right)\right)^{-1/\xi}\right)$$
$$H_s(T_r;u,\lambda,\sigma,\xi) = u-\frac{\sigma}{\xi}\left(1-(\lambda T_r)^{\xi}\right)$$

Función de distribución GEV

$$F(H_s;\mu,\psi,\xi) = \exp\left(-\left(1+\xi\left(\frac{H_s-\mu}{\psi}\right)\right)^{-1/\xi}\right)$$
$$H_s(T_r;\mu,\psi,\xi) = \mu-\frac{\psi}{\xi}\left(1-\left(\frac{1}{T_r}\right)^{-\xi}\right)$$
$$\sigma(H_s;c_o,c_1,c_2,c_3) = c_o+c_1H_s+c_2H_s^2+c_3H_s^3$$

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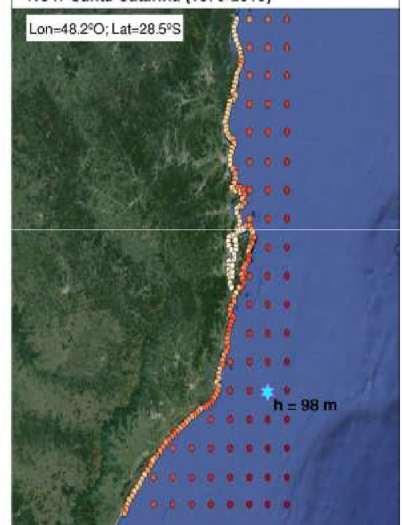
Caracterización clima marítimo
OLEAJE
Régimen extremal direccional
ROW Santa Catarina (1979-2010)



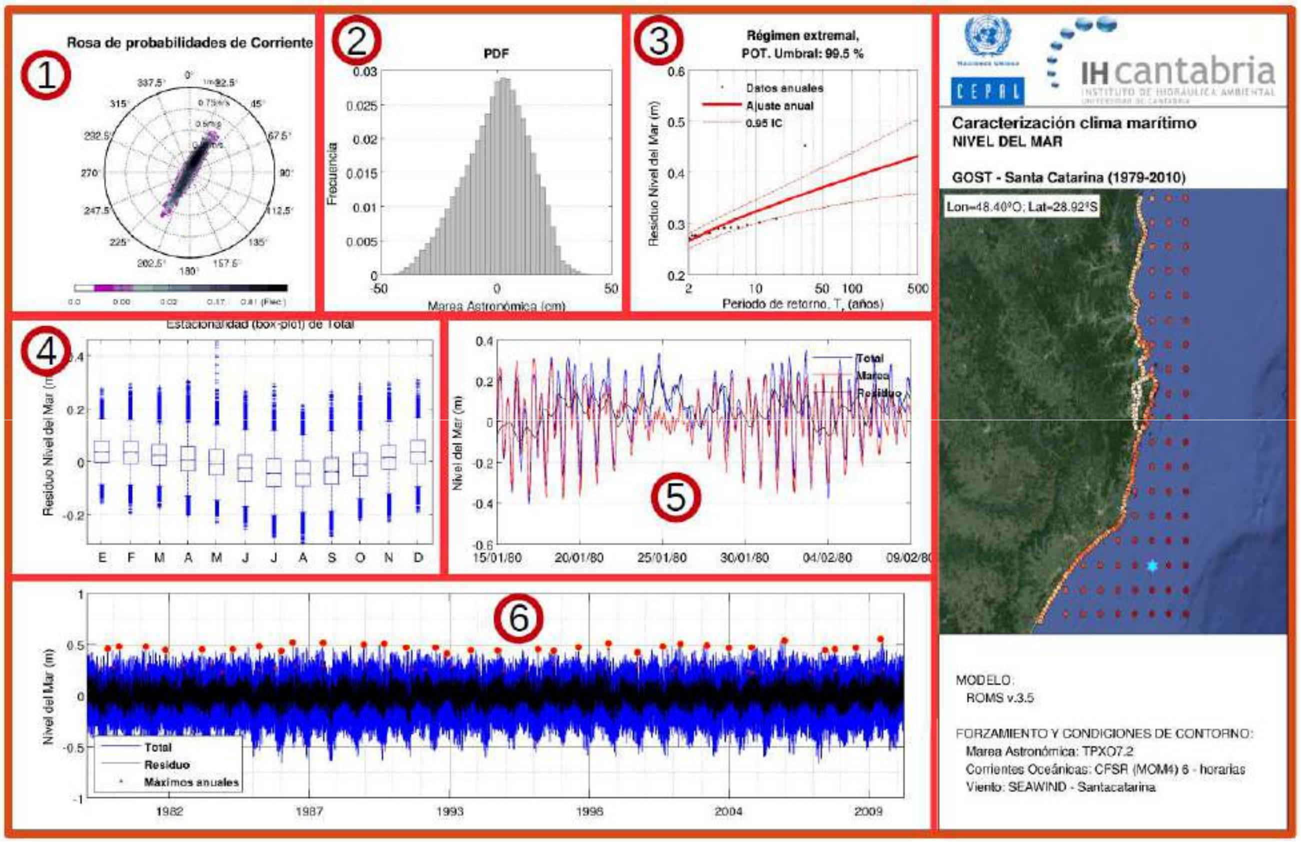
MODEL:
SWAN 41.01 (0.01ºx0.01º)

FORCING:
GOW 2.0 (WAVEWATCH III 4.18, 0.25ºx0.25º, + Satélite Calibrated)

SEAWIND (WRT 3.5, 0.003ºx0.003º)

Source: ECLAC/IHC. Document in progress.

Santa Catarina (Brasil)- Climate Atlas characterization of sea level rise



Source: ECLAC/IHC. Document in progress.

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Effects of climate change on the coasts of Latin America and the Caribbean

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