18th SESSION IOCARIBE

unesco
Intergovernmental Oceanographic Commission

Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

A NEW APPROACH: EARLY WARNING SYSTEM FOR CURAÇAO

JONATHAN ZOETRUM, MSc.
CLIMATOLOGY, SEISMOLOGY AND RESEARCH
METEOROLOGICAL DEPARTMENT CURAÇAO

Brasilia, Brazil
April 23–25, 2025

unesco
Intergovernmental Oceanographic Commission

Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

Early Warning for All – Implementation Strategies for Curaçao

Jonathan Zoetrum, MSc.
Meteorological Department Curaçao

Overview

Sub-Commission for the Caribbean and Adjacent Regions

unesco
Intergovernmental Oceanographic Commission

Subcomisión para el Caribe y Regiones Adyacentes

Ocean Warming Trends in Curaçao

- How are we impacted
- Our Current Early Warning System
- Understanding the limitations
- New Strategies

A new approach…

IOCARIBE: Curaçao

IOCARIBE: Curaçao

unesco
Intergovernmental Oceanographic Commission

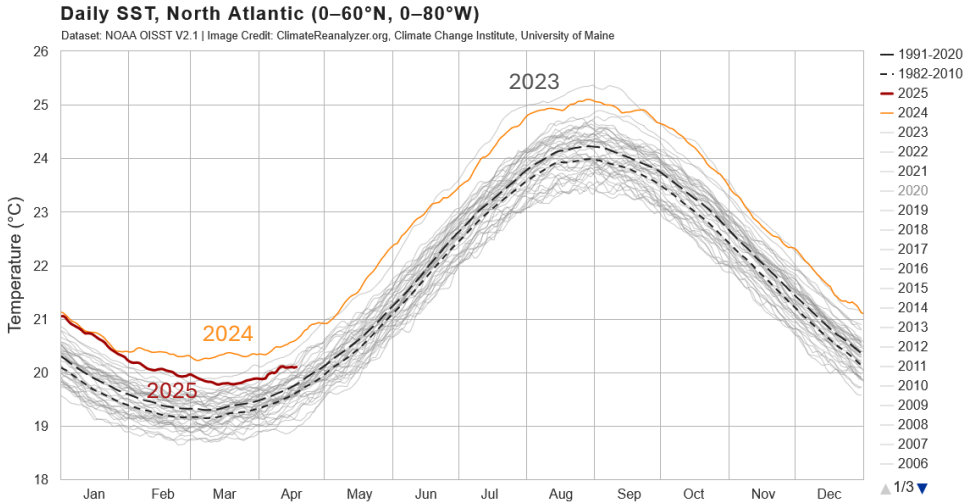
Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

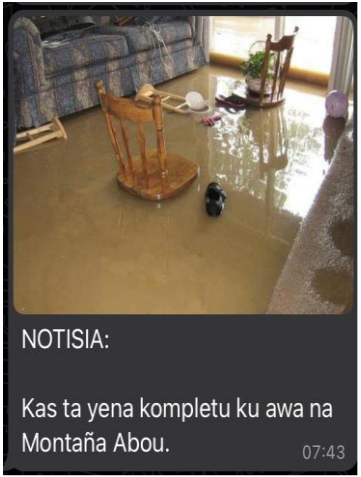
How are we impacted?

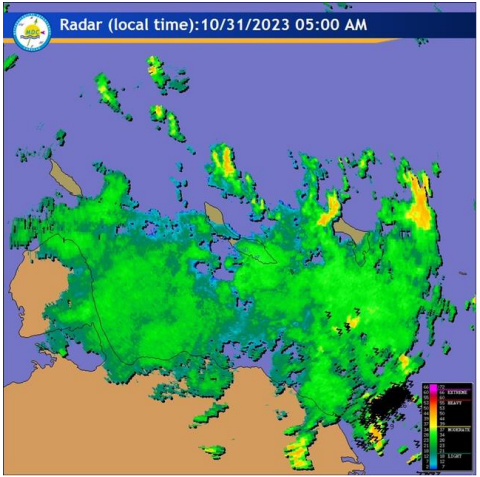
Ocean Warming Impact

Ocean Warming



Active Thunderstorm (Oct 2023)



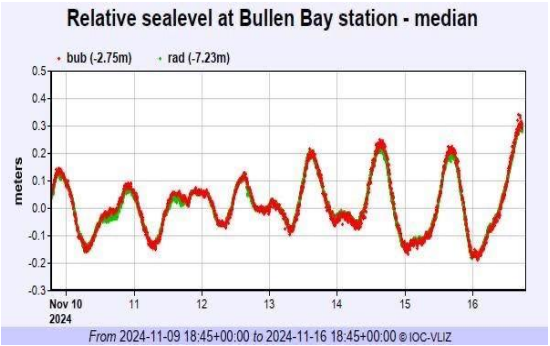


Flash Flooding in Banda Abou (May 2024)

310 mm in 4 hours, about $1 million

Sea Rise – Waaigat (normal)

Sea Rise + High Tide (Nov 2024)



unesco
Intergovernmental Oceanographic Commission

Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

Model limitations

Observational data limitations and oceanic models

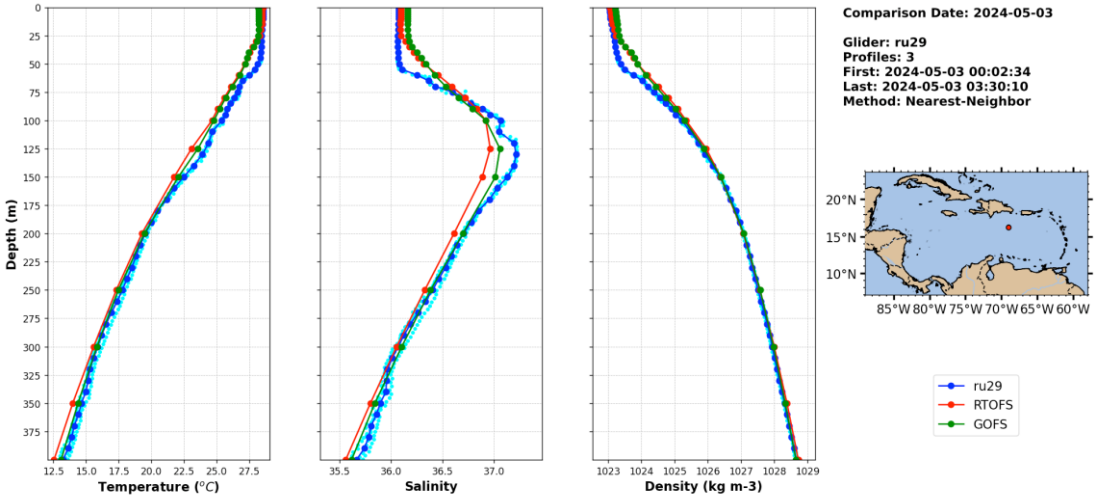
Observation: RU 29 Glider

- Deployed through a partnership between Rutgers University Center for Ocean Observing Leadership (RUCOOL) and regional institutions.
- Mission covered 383 miles between the Dominican Republic and Curaçao in July 2023.

Data Collected

- Temperature, salinity, oxygen, and current profiles.
- Delivered real-time ocean data during Hurricane Beryl, approaching within 20 miles of the eyewall.

RU29 Glider: Model vs Observation



unesco
Intergovernmental Oceanographic Commission

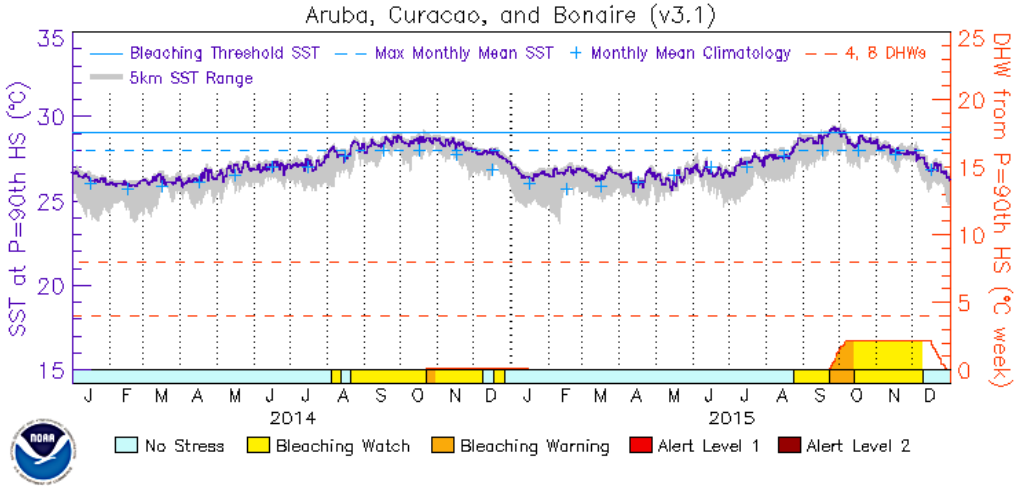
Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

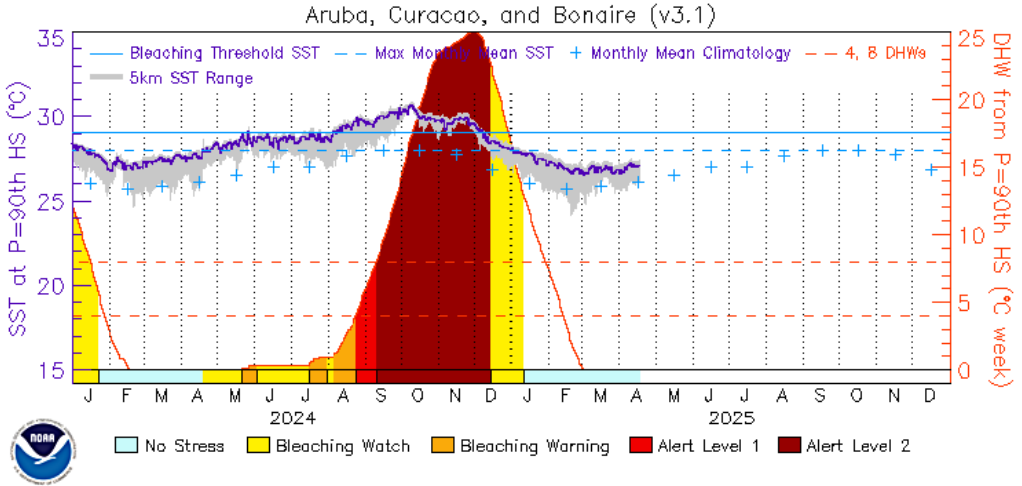
Coral Bleaching

NOAA Stress Map for 2014 and 2024

Curaçao Coral Bleaching (2014)



Ocean Warming Impacts Today



unesco
Intergovernmental Oceanographic Commission

Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

Early Warning System

Our current Early Warning System for Curaçao

What are the limitations?

Our Current Early Warning System

Sub-Commission for the Caribbean and Adjacent Regions

unesco Intergovernmental Oceanographic Commission

Subcomisión para el Caribe y Regiones Adyacentes

Pillars Early Warnings for all:

1. Disaster risk knowledge
2. Detection, observation, monitoring, analysis and forecasting
3. Warning dissemination and communication
4. Preparedness and response capabilities

Disaster Risk Knowledge

unesco
Intergovernmental Oceanographic Commission

Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

Early warning system

	SEVERE THUNDERSTORM		ROUGH SEAS
	SEVERE WIND		TSUNAMI
	FUNNEL CLOUD		EARTHQUAKE
	EXCESSIVE HEAT		VOLCANIC ASH
	SUNBURN		SAHARAN DUST

Phases for extreme situations

unesco Intergovernmental Oceanographic Commission
Sub-Commission for the Caribbean and Adjacent Regions
Subcomisión para el Caribe y Regiones Adyacentes

Phase	Definition:
	No hazard.
Precaution --- Be Alert ---	Possible occurrence (lower than 30%) of a natural hazard with minor impact.
Watch ---Prepare Yourself---	Conditions of a natural hazard are possible (30 to 50%) within medium impact.
Warning --- Protect Yourself---	Conditions of a natural hazard are imminent (higher than 50%), with higher impact.

Phases for Tropical Cyclones

Tropical Cyclone Bulletin (TCB) Types

Fase	Definishon:
	No hazard
Information --- Be Alert ---	Tropical cyclone poses possible threat within next 120 hours
Watch ---Prepare Yourself---	Tropical cyclone conditions are possible within next 48 hours
Warning --- Protect Yourself---	Tropical cyclone conditions are expected within next 36 hours
Strike --- Seek shelter!---	Tropical cyclone conditions are imminent within next 6 hours

Stakeholders

unesco
Intergovernmental Oceanographic Commission
Sub-Commission for the Caribbean and Adjacent Regions
Subcomisión para el Caribe y Regiones Adyacentes

METEOROLOGICAL DEPARTMENT
MDC
N
NW
SE
S
CURAÇAO

Rampenbeheersingsorganisatie
Curaçao
Preventie,Preparatie,Protectie

CITIZENS RESCUE ORGANIZATION
CITRO

CUR
CURAÇAO INTERNATIONAL AIRPORT

Kustwacht
Caribisch Gebied

DC ANSP
Dutch Caribbean Air Navigation Service Provider

Understanding the Limitations

- Extreme Weather Events Are Increasing:
  Due to rising ocean temperatures, Curaçao is experiencing more intense and unpredictable rainfall and storms
- Forecasting Challenges:
  Traditional numerical weather prediction models are becoming less reliable due to the non-linear and complex nature of climate-induced weather patterns.
- Early Warning System Current Challenges:
  - Delayed or uncertain warnings during fast-developing events
  - Inadequate model resolution or outdated climatological assumptions
  - Limited integration of real-time observational and ocean data
  - Meteorologist is overloaded -> big data.

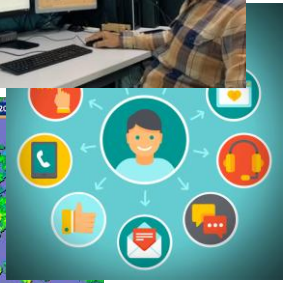
New Forecasting Strategies

- Integration of AI and Machine Learning:
  There's a growing emphasis on incorporating AI and machine learning to enhance data assessment (ocean and atmospheric data), validation, and timely analysis and forecasting.

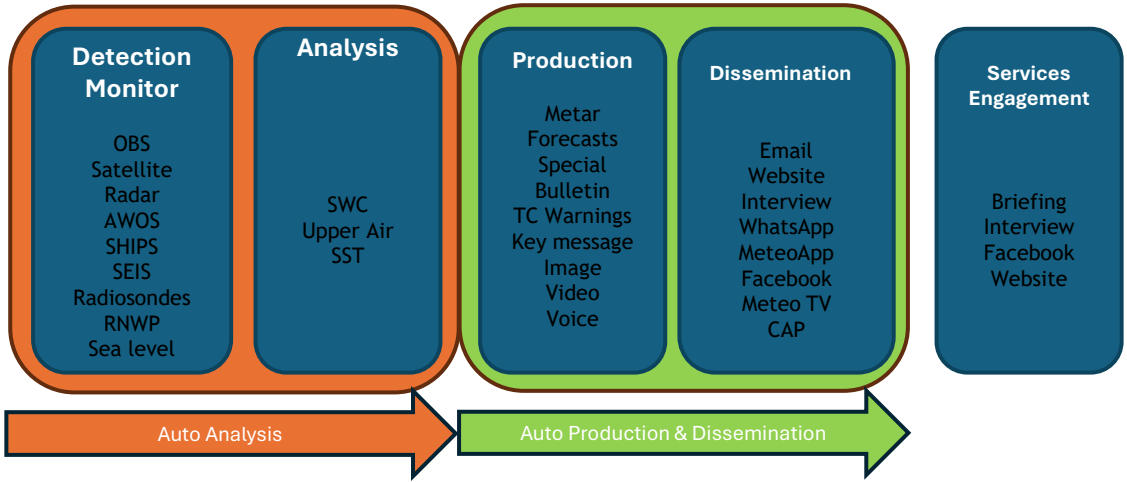
- Forecaster-Centric Interfaces:
  Developing user-friendly interfaces that provide meteorologists with actionable insights is crucial for timely and effective responses to extreme weather events.

Development for AI Early Warning System analysis and auto production and dissemination.

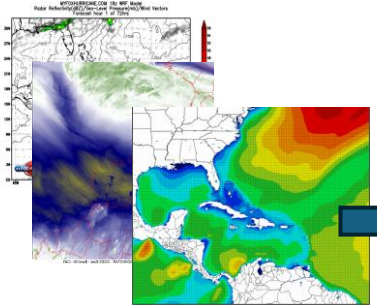
AI-Augmented Forecasting



Production and Service Process



Future MDC Auto Analysis



Using Mechanisms (GDI and CAPE Levels)

1. Weather Models (levels)
2. Satellite channels
3. Wave model

Machine Learning

AWOS
Upper Air
Buoy data
Sea Level Buoy
High and low Tide

Severe Event Criteria

Weather Analysis

Improved Forecast model

1. Weather
2. Sea state
3. Meteograms (15)

Potential Severe Event

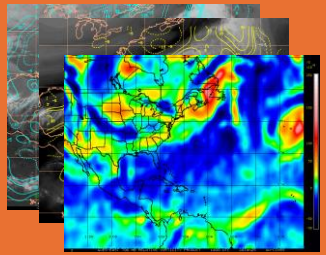
Interactive Forecaster (t=0,6,12,...)

unesco
Intergovernmental Oceanographic Commission

Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

AI Models Display



High level Divergence
Midlevel Humidity
Low level Convergence
Low level Wind
Sea state and sea level

Potential Severe Event (t=xx)

Validation Potential Severe Event

unesco Intergovernmental Oceanographic Commission
Sub-Commission for the Caribbean and Adjacent Regions
Subcomisión para el Caribe y Regiones Adyacentes

Severe Event

Phase	Definition:
	No hazard.
Precaution -- Be Alert --	Possible occurrence (lower than 30%) of a natural hazard with minor impact.
Watch --Prepare Yourself--	Conditions of a natural hazard are possible (30 to 50%) within medium impact.
Warning --- Protect Yourself---	Conditions of a natural hazard are imminent (higher than 50%), with higher impact.

Tropical Cyclone Bulletin (TCB) Type	
Face	Definition:
	No hazard
Information -- Be Alert --	Tropical cyclone poses possible threat within next 120 hours
Watch --Prepare Yourself--	Tropical cyclone conditions are possible within next 48 hours
Warning --- Protect Yourself---	Tropical cyclone conditions are expected within next 36 hours
Strike --- Seek shelter!---	Tropical cyclone conditions are imminent within next 6 hours

SPECIAL BULLETIN

SPECIAL BULLETIN No. 1, SEVERE THUNDERSTORM WATCH

A SEVERE THUNDERSTORM WATCH HAS BEEN ISSUED.

DATE ISSUED: THURSDAY, NOVEMBER 16, 2017, 00:29 L.T.
VALID UNTIL: THURSDAY, NOVEMBER 16, 2017, 05:29 L.T.

THIS IS A SEVERE THUNDERSTORM WATCH FOR CURACAO

*****RADAR AND SATELLITE IMAGES INDICATE SEVERE THUNDERSTORMS THAT MAY BE A THREAT TO SECTIONS OF CURACAO*****

ESTIMATED INITIATION TIME:04:00 (UTC), 00:00 (L.T.)
Bear in mind that the estimated initiation time above is not an exact measure and only gives an approximation.

EXPECTED IMPACT:

- Heavy rainfall may lead to local flooding and/or landslides over sections of the island;
- Strong winds which can turn loose objects into projectiles;
- Area of rapidly descending air beneath a thunderstorm (downburst), with winds reaching very high velocities that can cause significant damage along their path;
- Lightning.

PRECAUTIONARY/PREPAREDNESS ACTIONS:

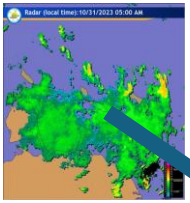
- During thunderstorms avoid using electrical appliances and unplug those, not in use. Use telephones only in an emergency;
- Secure loose objects outside and move pets and yourself indoors;

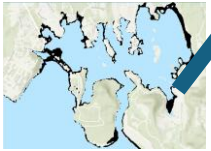
VALIDATION

Satellite ✓
Radar ✓
AWOS ✓

Publish

Automated Advisory





Direct messages for the Authorities that include location

Automated Notification to All Stakeholders

AI-Augmented Forecasting

Interactive AI Forecast Tools give meteorologists advanced layers of analysis:

- Real-time model comparisons (GFS, ICON, regional data)
- Highlighted anomaly zones (e.g., CAPE spikes, convergence lines)
- Live dashboard validation using radar, satellite, AWOS

Automated Early Warning Agents:

- Detect patterns and thresholds (e.g., localized flash flood risk)
- Automatically create **custom warnings**: right **message**, right **audience**, right **time**
- Deliver via WhatsApp, SMS, app notifications—beyond general population bulletins

Conclusion

- Curaçao faces growing challenges from ocean warming: intensified storms, flash floods and rising seas.
- While our current early warning systems have served us well, they now face limitations in speed, resolution and precision.
- We are developing a next-generation Early Warning System powered by AI Agent.
- AI Agents help shift us from generalized, delayed alerts to **precise, real-time responses**, tailored for individual users and communities.

Thank you for your attention, and I look forward to collaboration across the region as we prepare for the climate challenges ahead.

18th SESSION IOCARIBE

unesco
Intergovernmental Oceanographic Commission

Sub-Commission for the Caribbean and Adjacent Regions

Subcomisión para el Caribe y Regiones Adyacentes

THANK YOU
MUCHAS GRACIAS
MERCI BEAUCOUP

JONATHAN.ZOETRUM@METEO.CW