

Modelling Hurricane Intensity in the Caribbean Region (for Caribbean SIDS)

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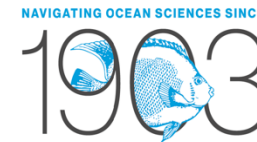
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ICARUS
Irish Climate Analysis and Research Units



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TOPIM - Agenda

- What is TOPIM
- Hurricane trends in the Caribbean since 1965
- TOPIM model and real-time intensity predictions
- Using TOPIM for future scenario planning

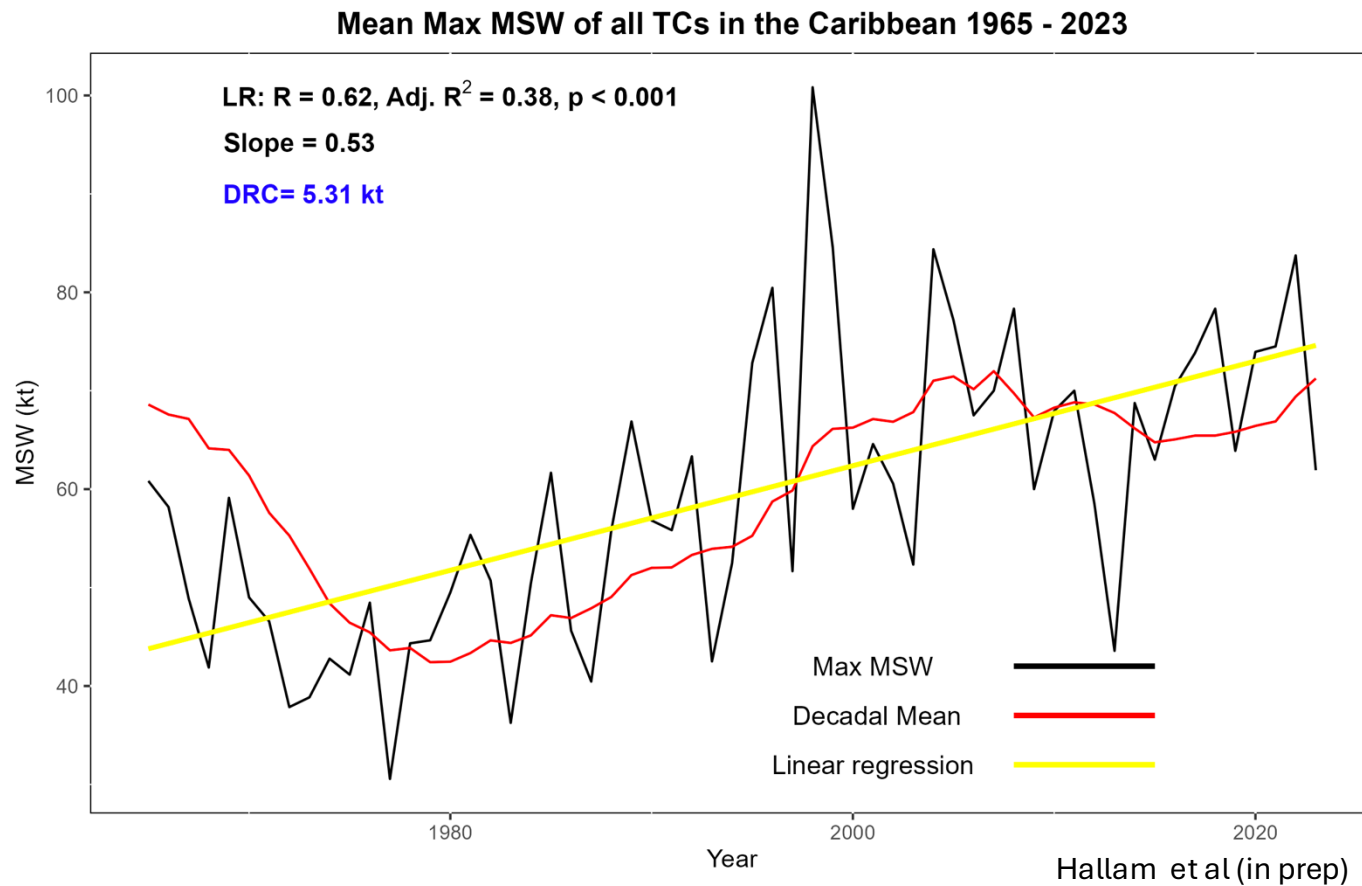


TOPIM Background



- **TOPIM** stands for **Tropical Cyclone Ocean-coupled Potential Intensity Model**.
- Model which predicts hurricane intensity (minimum pressure and maximum sustained windspeed) in near real-time and can be used for future scenario analysis too
- **Although predicting individual TC intensity remains difficult**, it is accepted that thermodynamic limits to intensity exist and are based on SST and vertical structure of the atmosphere (Emanuel 1995,1999)
- While Potential Intensity is a good predictor of TC maximum intensity, it is a poor predictor of actual TC intensity as most TCs fail to obtain intensities near their PI.
- Bender et al. 2007, Lui et al 2013 and Hallam et al. 2021 found **upper ocean coupling (and using ocean temperatures in the upper ocean layer) resulted in predictions closer to actual intensities**
- This led to Bermuda PI model (Hallam-Guishard) which was prototyped in 2020 and used by Bermuda Weather Service since to assist with hurricane predictions for Bermuda.
- Led to TOPIM – PI model for Caribbean SIDS, a freely available web app to ensure accessible

Tropical cyclone intensity in the Caribbean 1965-2023



Caribbean region (10-30N, 55-90W) using HURDAT data from 1965-2023

Average Max MSW across all hurricane tracks in each year

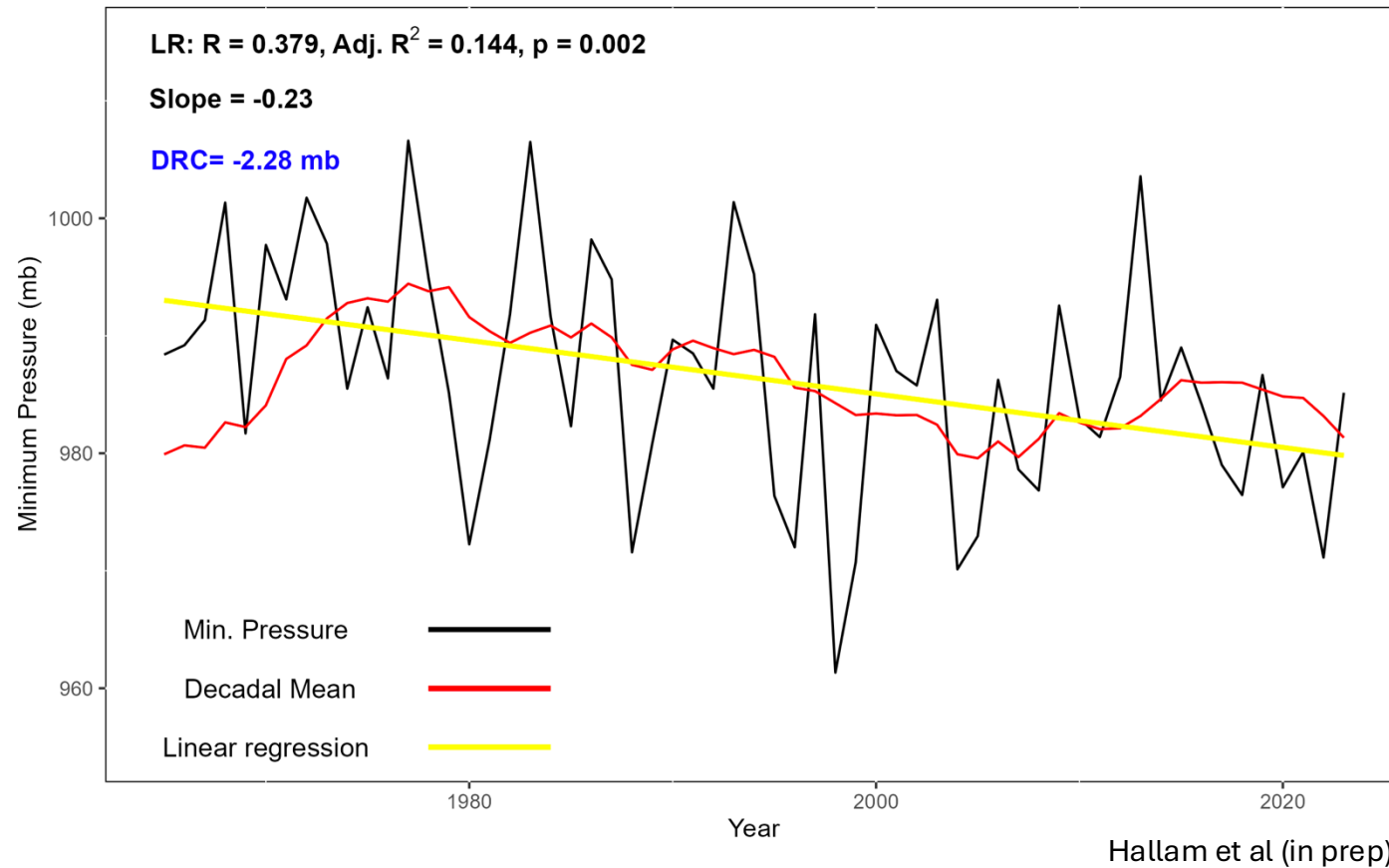
Increasing maximum sustained winds of 5.3 kts per decade from around 42kts to 72kts over last 58 years

Trend has implications for the Caribbean

Tropical cyclone minimum pressure in the Caribbean 1965-2023



Annual Mean Lowest Min. Pressure of all TCs in the Caribbean 1965 - 2023

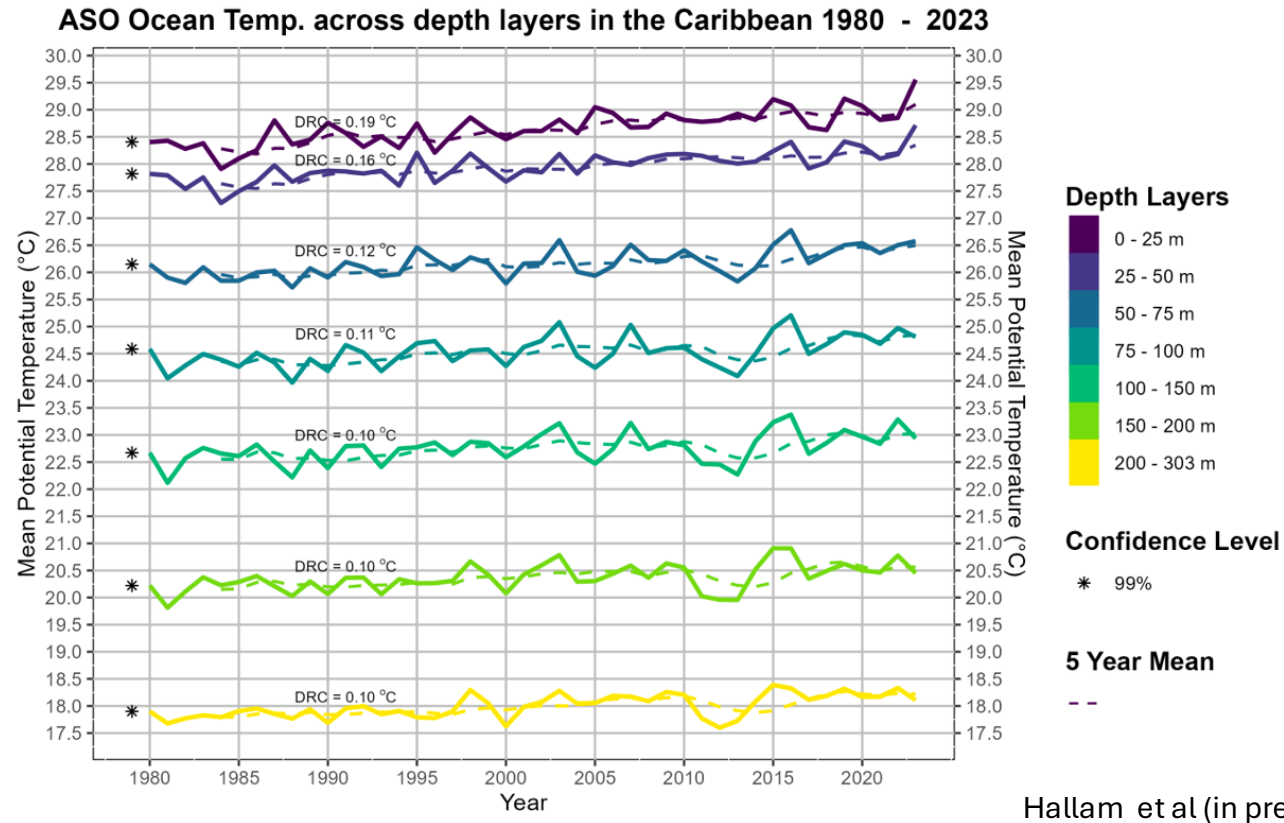


Caribbean region (10-30N, 55-90W)
using HURDAT data from 1965-2023

Decreasing Minimum Pressure of 2.3
mb per decade

A decrease of 13mb from 995mb to
982mb across the period 1965-2023

Caribbean ocean temperatures 1980 -2023



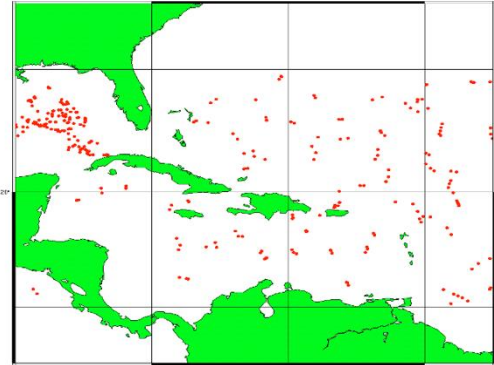
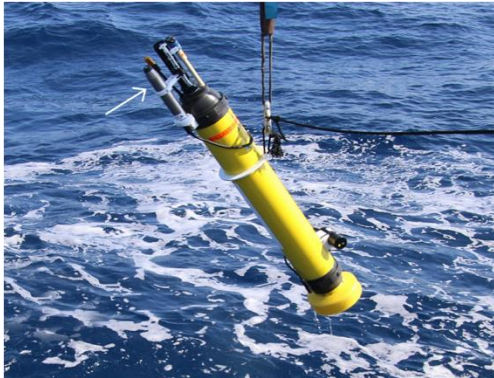
Hallam et al (in prep)

Ocean temperatures using GODAS dataset

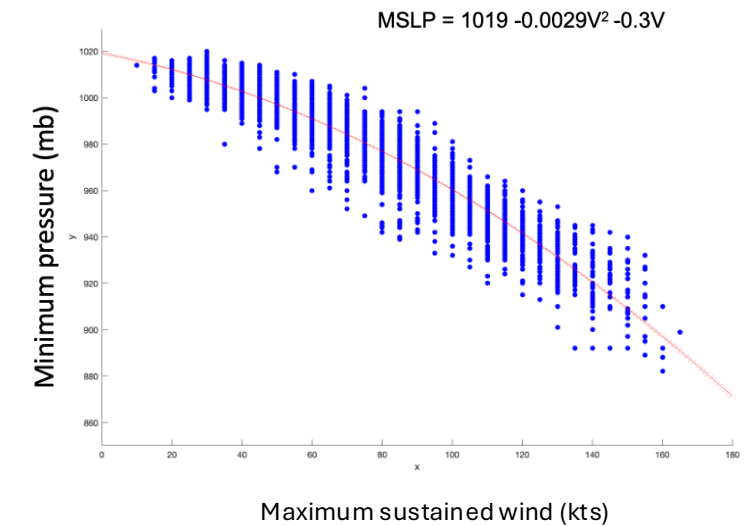
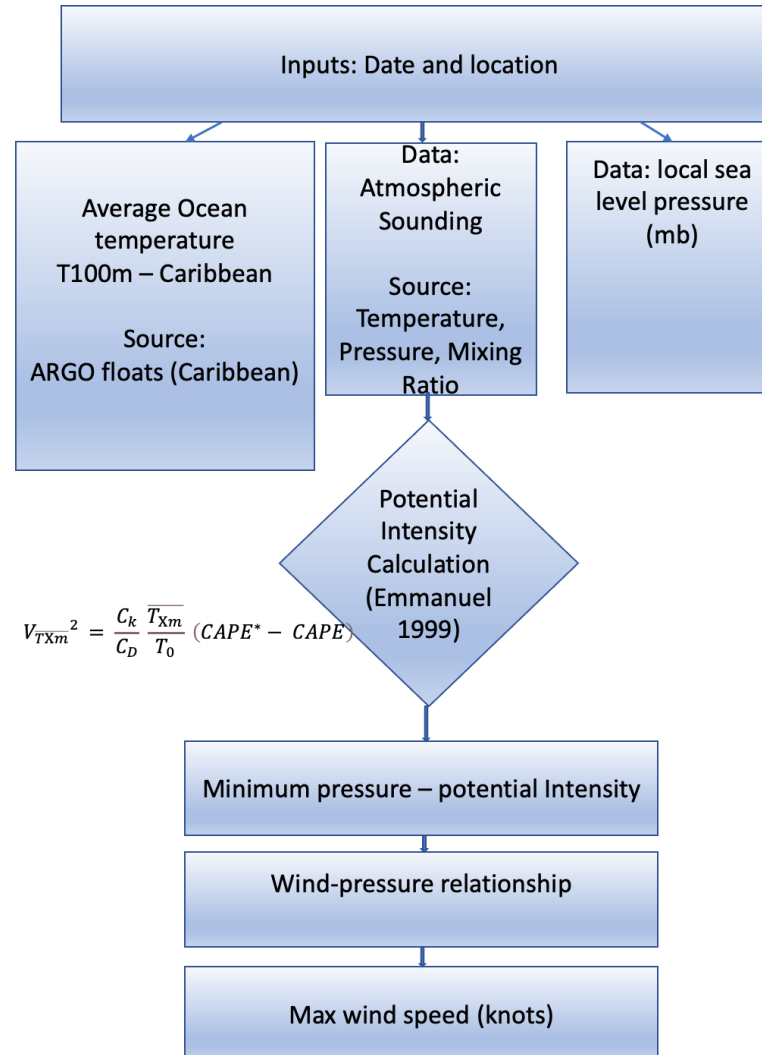
August September October (ASO)
Increasing SST 0.2°C per decade
(1°C every 50 years)

The rising ocean temperatures are significantly correlated with the increasing tropical cyclone intensity

TOPIM Model



Upper: Argo Float Lower: Red circles indicate Argo float locations as at March 2024



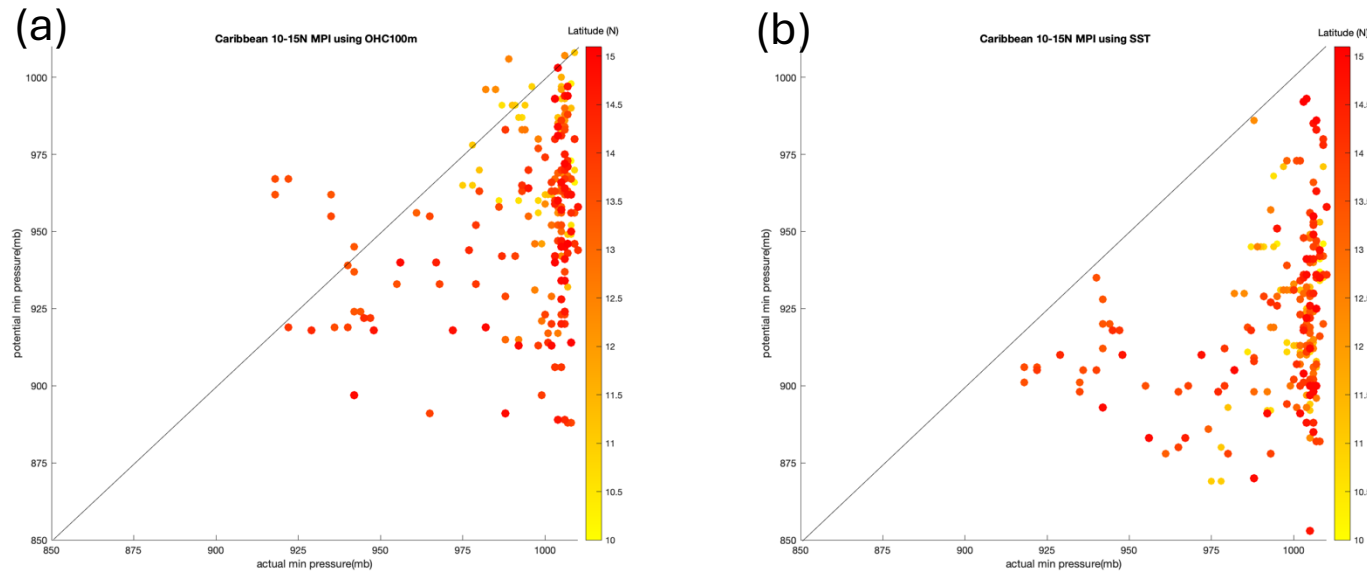
Hallam et al (in prep)

Atmospheric sounding locations across the Caribbean



'Environmental conditions near XX location would support a XX knot storm, based on observations, theory and historical data'.

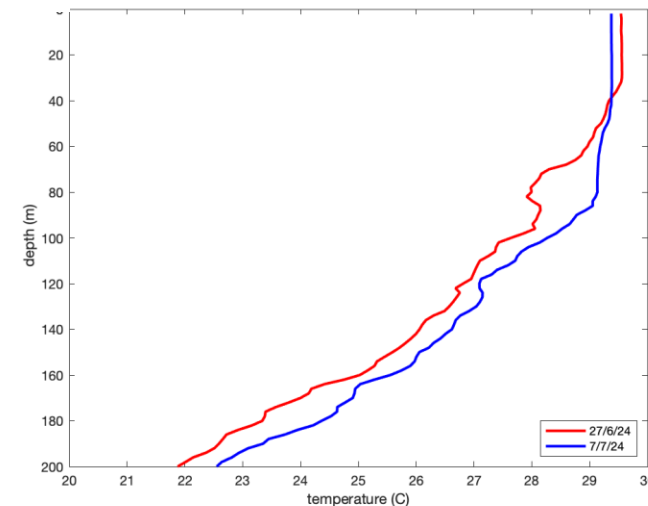
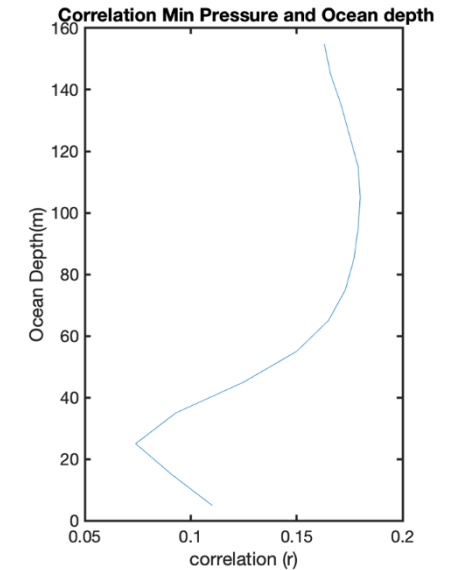
Ocean Coupled Hurricane Prediction



Hallam et al (in prep)

Tropical Cyclone Potential Intensity using (a) average temperature over the top 100m ocean layer (b) Sea Surface Temperature

MPI correlation between MSLP and ocean depth



Ocean Temperature before and after hurricane Beryl on 2/7/24 (17N 77W)

Near Real Time Prediction (Milton, 9th October 2024)



TOPIM model parameters

Date

Time UTC

☒ Use UTC Time

☒ Use Latitude and Longitude

Latitude °

Longitude °

Sea Level Pressure mBar

Ocean Layer Depth m

☒ Use custom ocean temperature

Custom Ocean Temperature °C

Run model

Summary

Environmental conditions in the region **23N** and **86W** would support a **145kts** storm, based on observations, theory and historical data.

Outputs

Results

Maximum windspeed **145 kts**

Minimum central pressure **911 mBar**

Atmospheric data

Sounding station Aerop.Internacional Yuc

Sounding location 20.98°N , -89.65°E

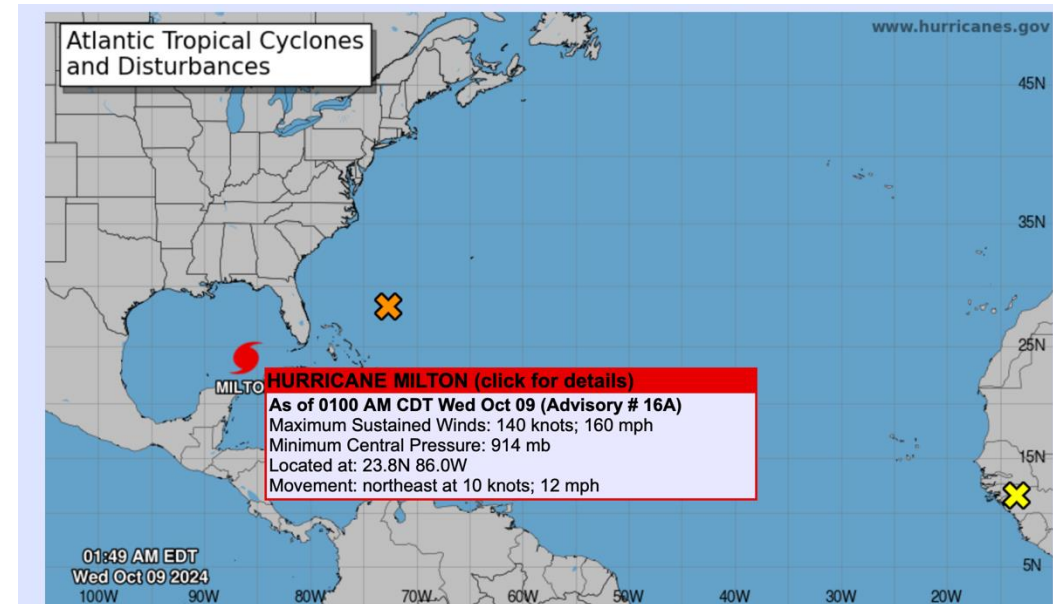
Sounding date 2024-10-08T00:00:00.000Z

ARGO ocean data

Average ocean temperature (100m) **29.70°C**

ARGO location 23.07°N , -86.37°E

ARGO date 2024-09-21T05:15:43.000Z



Near Real Time Prediction (Beryl 2/7/24, 15N 66W)



TOPIM model parameters

Date

01/07/2024

Time

14:49 IST

☐ Use UTC Time

☒ Use Latitude and Longitude

Latitude

15° N

Longitude

066° W

Sea Level Pressure

1016 mBar

Ocean Layer Depth

100 m

☐ Use custom ocean temperature

Custom Ocean Temperature

25 °C

Run model

Summary

Environmental conditions in the region 15N and 66W would support a 135kts storm, based on observations, theory and historical data.

Outputs

Results

Maximum windspeed

135 kts

Minimum central pressure

932 mBar

Atmospheric data

Sounding station

San Juan

Sounding location

18.43°N , -65.99°E

Sounding date

2024-07-01T12:00:00.000Z

ARGO ocean data

Average ocean temperature (100m)

28.54°C

ARGO location

14.17°N , -66.65°E

ARGO date

2024-06-30T03:07:18.000Z

Sea Surface Temperature Anomaly (°C)

June 2024 - 1980-2000

ECMWF ERA5 (0.5x0.5 deg)

TOPIM model parameters

Date

01/07/2024

Time

14:49 IST

☐ Use UTC Time

☒ Use Latitude and Longitude

Latitude

15° N

Longitude

066° W

Sea Level Pressure

1016 mBar

Ocean Layer Depth

100 m

☒ Use custom ocean temperature

Custom Ocean Temperature

27 °C

Run model

Summary

Environmental conditions in the region 15N and 66W would support a 100kts storm, based on observations, theory and historical data.

Outputs

Results

Maximum windspeed

100 kts

Minimum central pressure

967 mBar

Atmospheric data

Sounding station

San Juan

Sounding location

18.43°N , -65.99°E

Sounding date

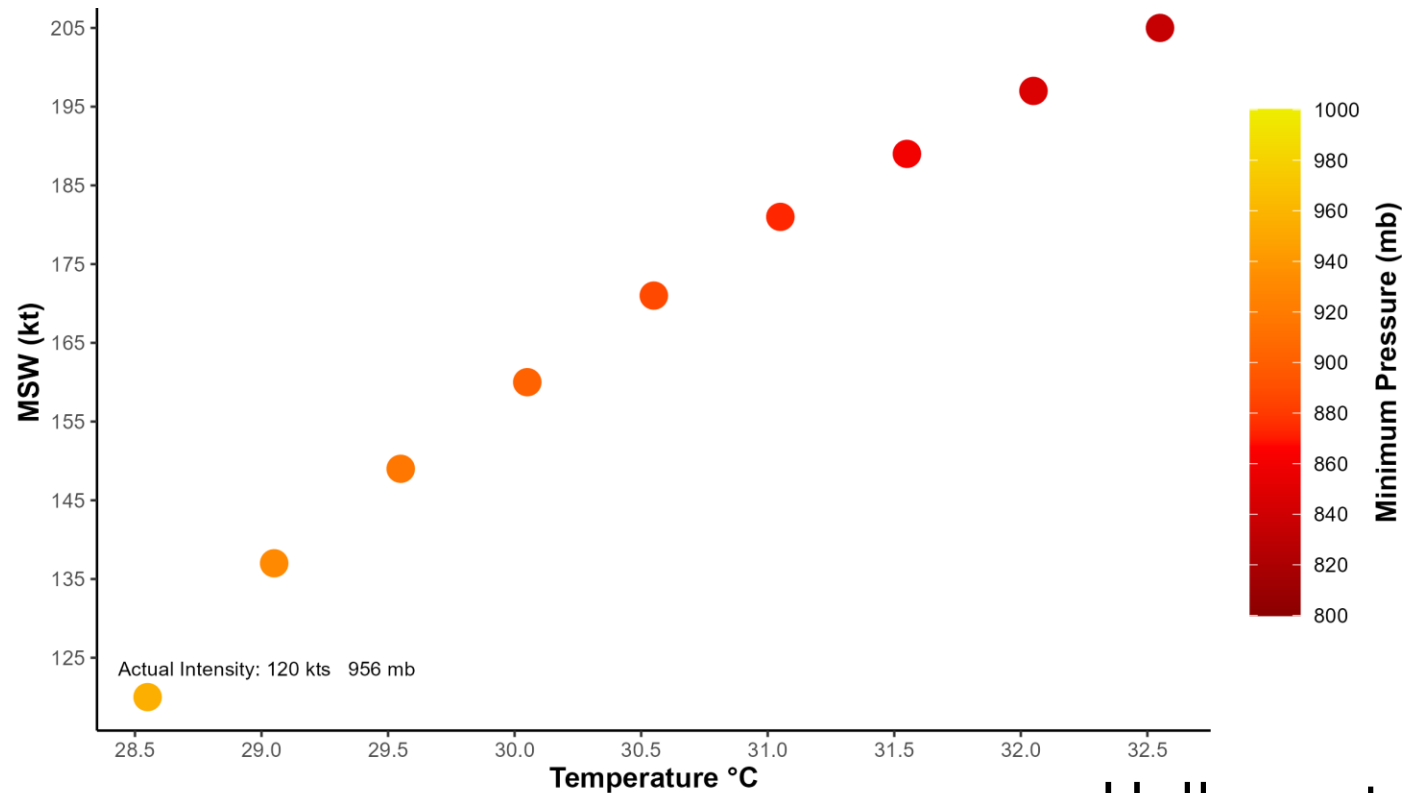
2024-07-01T12:00:00.000Z

In June 2024 eastern Caribbean ocean temperatures were over 1.5°C warmer than climatology 28.5C vs 27C and suggests Beryl was Cat 5 (135kt) instead of Cat 3 (100kts)

Future Scenario Analysis (Beryl 28/6/24)



Future Scenarios of Tropical Cyclone Beryl at 12.9843 °N -61.2872 °W
Impacted St. Vincent and the Grenadines on 28/06/2024



Take an historical storm, and undertake an **ocean sensitivity** analysis to rising ocean temperatures (atmospheric conditions remain the same)

Hurricane Beryl 1°C rise in ocean temperatures results in 27kt increase in wind speed

Think back to the historical slide seen 1°C rise since 1965 and 30kt increase in wind

Hallam et al (in prep)

Key messages

- **TOPIM** - Tropical **C**yclone **O**cean-coupled **P**otential Intensity **M**odel.
- TOPIM predicts hurricane potential intensity (minimum pressure and maximum sustained windspeed), for the Caribbean Region in near real-time and can be used for future scenario analysis too. The model uses near real-time Argo float (ocean) and atmospheric sounding data.
- TOPIM is a freely available web app, which can be used alongside other tools to provide potential intensity analysis, for example “Environmental conditions near XX location would support a XX knot storm, based on observations, theory and historical data”.
- TOPIM launched to Caribbean Meteorological offices and Disaster Recovery agencies in 2024. Talk at Hurricane Committee Ocean Panel in April 2025
- In the Caribbean Region using ocean temperature over the top 100 m layer results in a potential intensity prediction closer to actual intensity (Hallam et al. in prep)
- TOPIM can be used for future scenario planning by taking an historical storm, and undertaking an **ocean sensitivity** analysis to rising ocean temperatures (atmospheric conditions remain the same)
- Since 1965 tropical cyclone intensity has been increasing at 5.3kts per decade linked to rising ocean temperatures in the region of 0.2°C per decade.
- Future developments; incorporate salinity, glider data.... But need more funding



Scan here for TOPIM
model

<https://www.topim.org>

[Thank you](#)

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Funding Statements

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