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SYMPOSIUM OP'24 | In partnership with unesco Intergovernmental Oceanographic Commission | 2021 2030 United Nations Decade of Ocean Science for Sustainable Development

The Salinity Effect on Ocean-Atmosphere Interaction in Global Tropical Cyclogenesis

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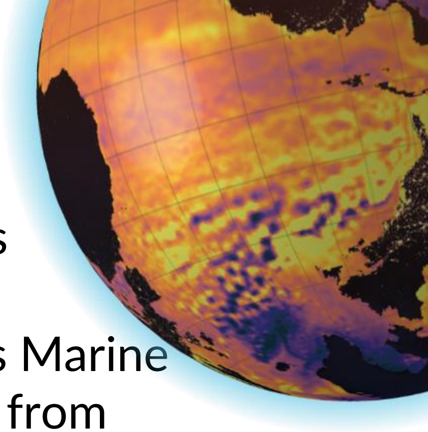
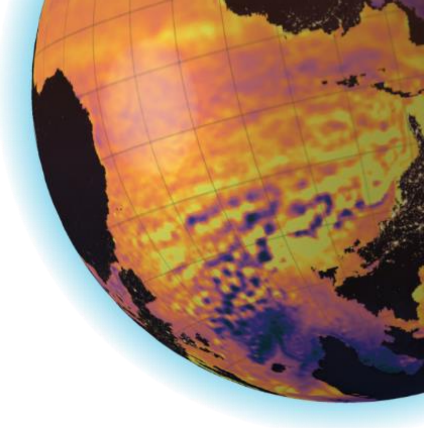


Abstract

The formation of tropical cyclones (TCs) is not fully understood. Six factors of tropical cyclogenesis are presented in modern scientific literature. However, TCs may occasionally form without all these factors being present. The authors therefore undertook further research using data from Copernicus Marine Service (Global Ocean 1/4° Physics Analysis and Forecast updated Daily). Specifically, salinity values from varying geographic locations were accurately obtained. Over the last years the authors of this paper have presented materials on the role of salinity in tropical cyclogenesis, likening its action to a valve. This can be demonstrated using the example of the Atlantic Ocean. The Atlantic Ocean (AO) has a unique feature - in the Northern and Southern Hemispheres there are completely different results of tropical cyclogenesis. For example, in the Northern Hemisphere, we see hurricanes of varying strength, often causing significant destruction, but in the Southern Hemisphere, these hurricanes are practically absent. As a first approximation, we concluded that under the conditions of possible tropical cyclogenesis, sea water salinity (really SSS – sea surface salinity) over 37 (37.2) ppt on a sufficiently large surface will block the formation and development of a TC. Another interesting case is that of of the North Indian Ocean. There are serious differences in salinity in the Western and Eastern areas which are reflected in the tropical cyclogenesis. Given this starting point, we therefore examined the SSS values at the start of the tropical cyclone season. The aim of this paper is to demonstrate the role of salinity in TC formation at the start of each TC season for the last 50 years. For each year we found the geographical location of TCs in the different oceans or parts thereof. In all cases SSS was less then 37 ppt. If an ocean has medium or lightly salted water (< 37 ppt), TC can appear anywhere. If salinity varies across the ocean then tropical cyclogenesis is restricted to those areas where SSS is around or less than 37 ppt.

Factors of tropical cyclogenesis



Tropical cyclogenesis requires six main factors:

A. Warm sea surface temperatures (>26.5 °C);

B. Enough Coriolis force to develop (> 555 km from equator)

C. High humidity in the lower to middle levels of the troposphere;

D. A low-pressure centre (<1000 mbar);

E. Low vertical wind shear (less than 10 m/s).

F. Atmospheric instability. A pre-existing low-level focus or disturbance;

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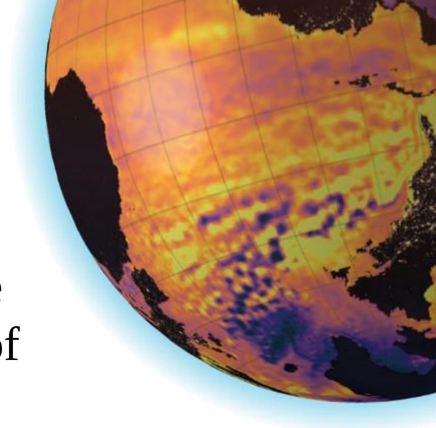
Equation of state for seawater (EOS)



Seawater is a complex, dynamic mixture of dissolved minerals, salts, and organic materials that despite scientists best efforts, presents difficulties in measuring its potential to contain and disperse energy.

The Practical Salinity Scale, or PSS-78, and the previous International Equation of State of Seawater, which expresses the density of seawater as a function of Practical Salinity, temperature and pressure, have served the oceanographic community well for three decades

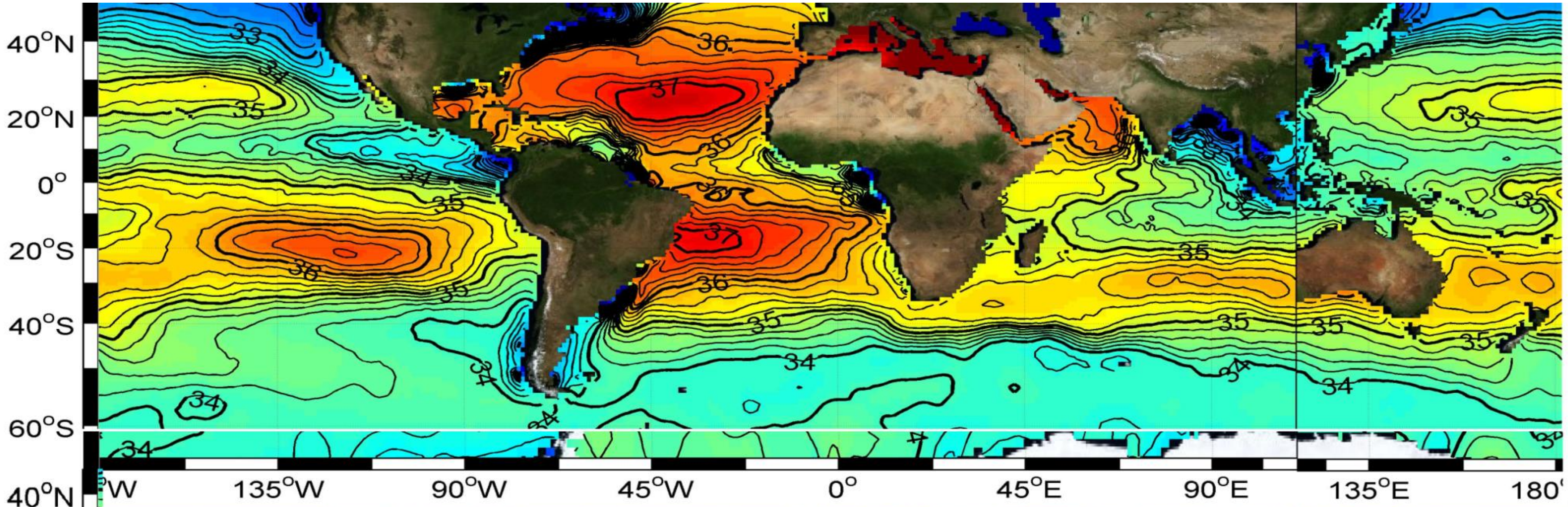
The new equation of state is a free energy function that can yield all the thermodynamic values of seawater of known temperature, salinity and pressure.

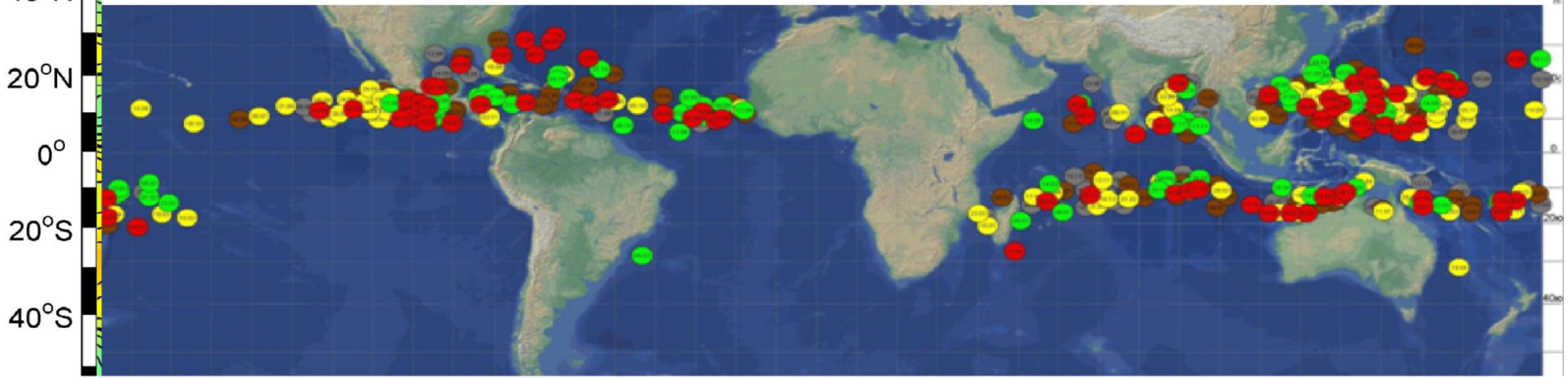
$$F(\rho, S, T, p) = 0$$

"Since 86% of global evaporation and 78% of global precipitation occur over the ocean, ocean surface salinity is the key variable for understanding how fresh water input and output affects ocean dynamics. By tracking ocean surface salinity we can directly monitor variations in the water cycle: land runoff, sea ice freezing and melting, and evaporation and precipitation over the oceans."

"The ocean stores more heat in the uppermost three (3) meters than the entire atmosphere. Thus density-controlled circulation is key to transporting heat in the ocean and maintaining Earth's climate. Excess heat associated with the increase in global temperature during the last century is being absorbed and moved by the ocean." (https://science.nasa.gov/earth-science/oceanography/physical-ocean/salinity#:~:text=Evaporation%20of%20ocean%20water%20and,snow%2C%20and%20melting%20of%20ice.)

"Increasing water salinity reduces evaporation since the dissolved salt ions lower the free energy of the water molecules, i.e., reduce the water activity, and hence reduce the saturation vapor pressure above the saline water at a given water temperature (Harbeck, 1955; Lee, 1927; Salhotra et al., 1985; Stumm & Morgan, 1981).





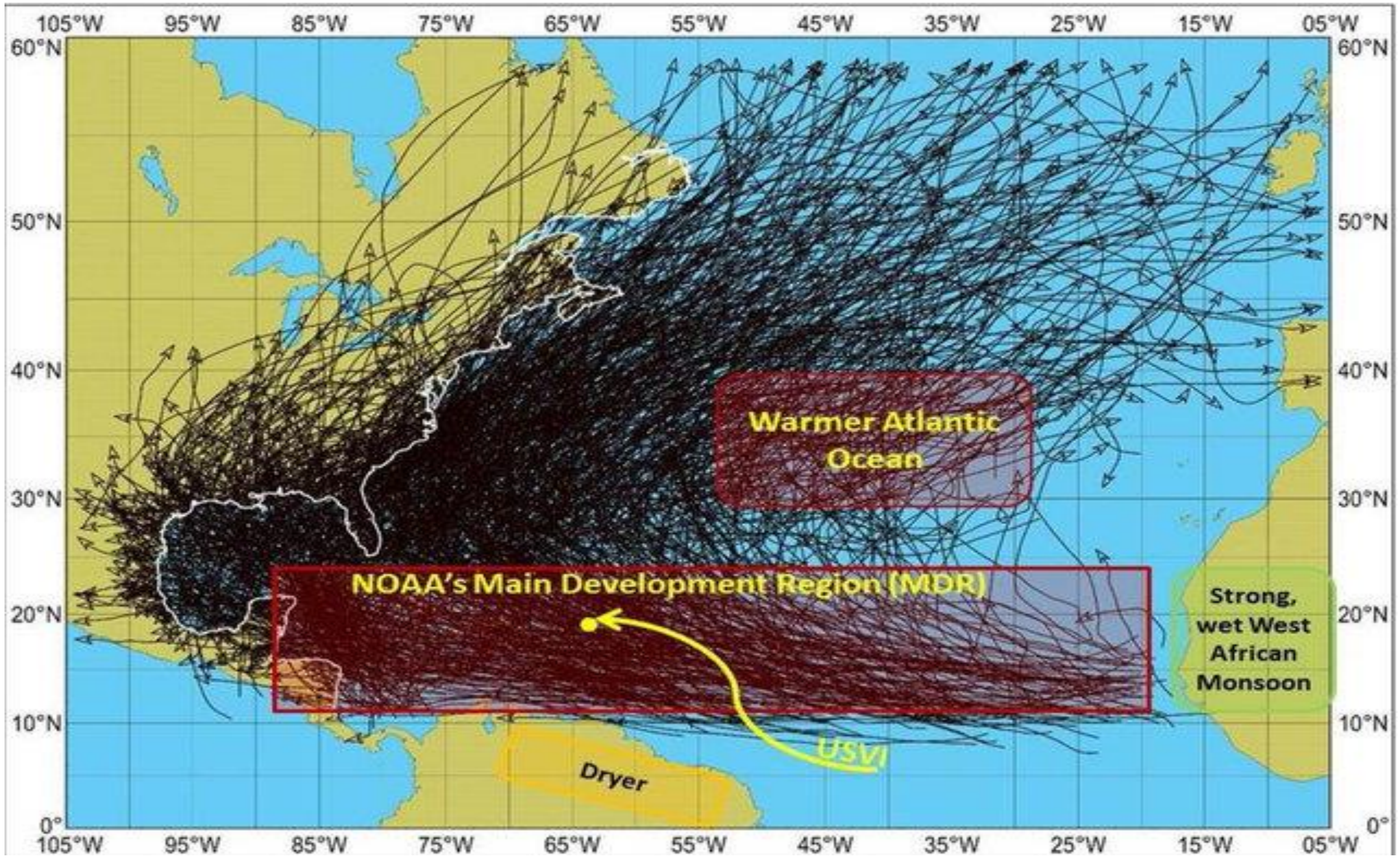
The reduced latent heat flux of evaporation from saline water increases the surface water temperature, which promotes evaporation, yet, the effect of salinity overcomes the effect of temperature rise and the evaporation is eventually reduced. These concepts were demonstrated in a systematic set of experiments with pans filled with water of various salinities and different ion compositions (Salhotra et al., 1985, 1987)."

//Z. Mor, S. Assouline et al., Effect of Water Surface Salinity on Evaporation: The Case of a Diluted Buoyant Plume Over the Dead Sea.

R. A. WatlingtonE. LewisD. Drost,

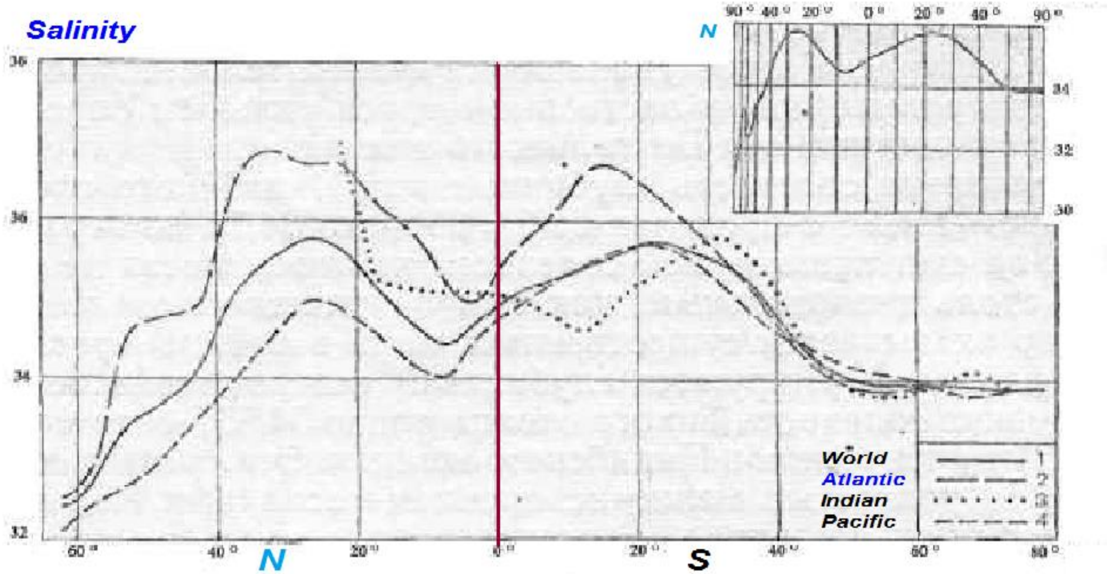
Coordinated management of coastal hazard awareness and preparedness in the USVI.

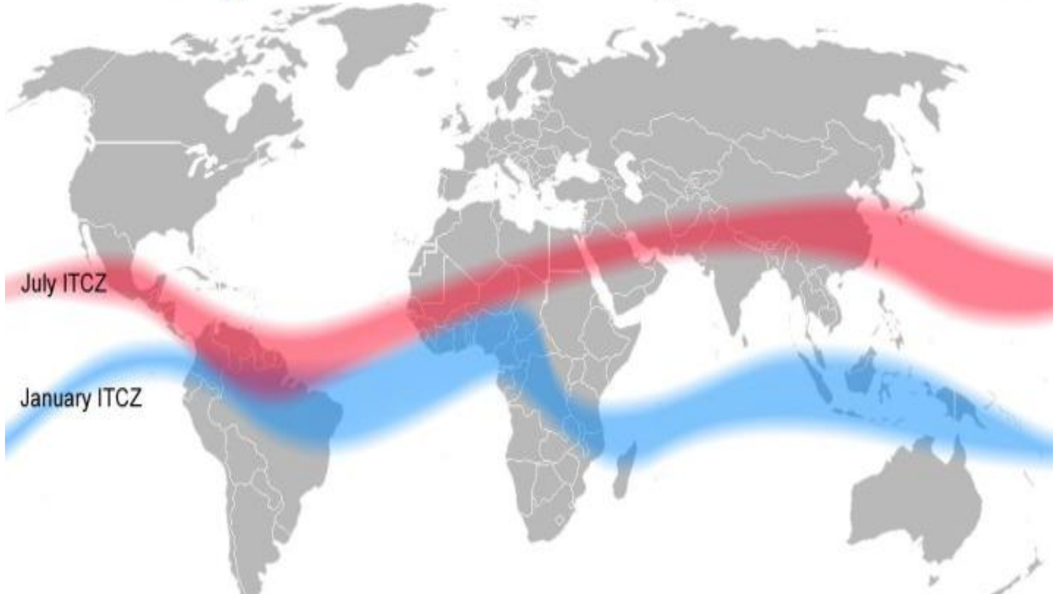
DOI: 10.5194/adgeo-38-31-2014



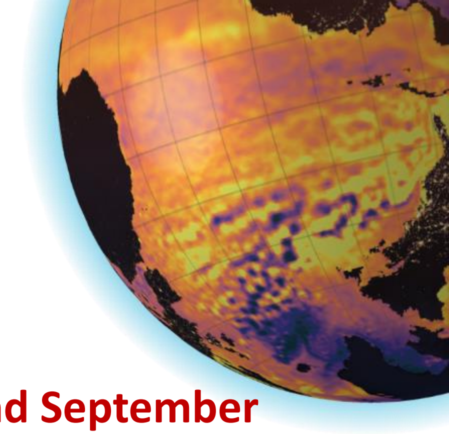
MDR and hurricane tracks 1851–2004.

The arrow indicates the location of the USVI within the sector designated as the Main Development Region (MDR) for tropical storm activity since 1995 in the months August through October (synthesis of NOAA graphics , after Climate Prediction Center, 2013).

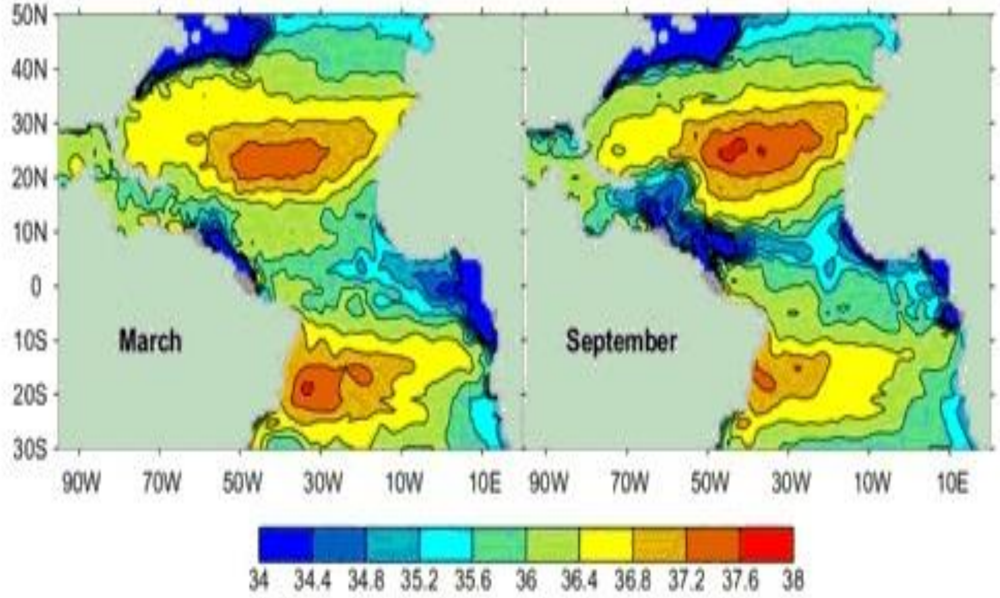




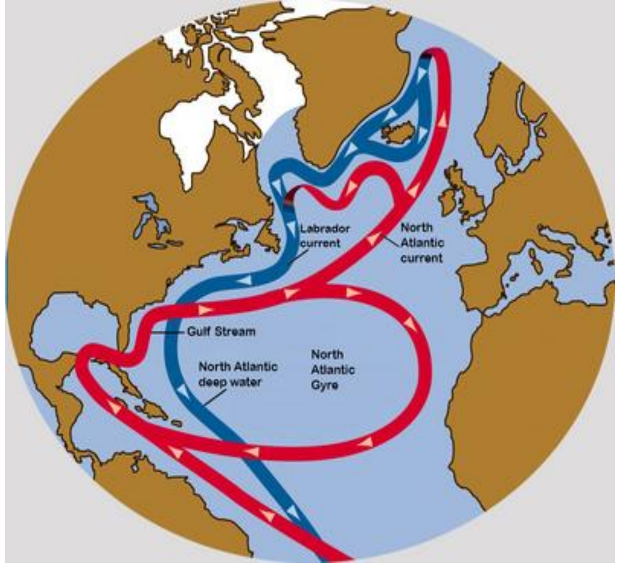
the Inter-Tropical Convergence Zone



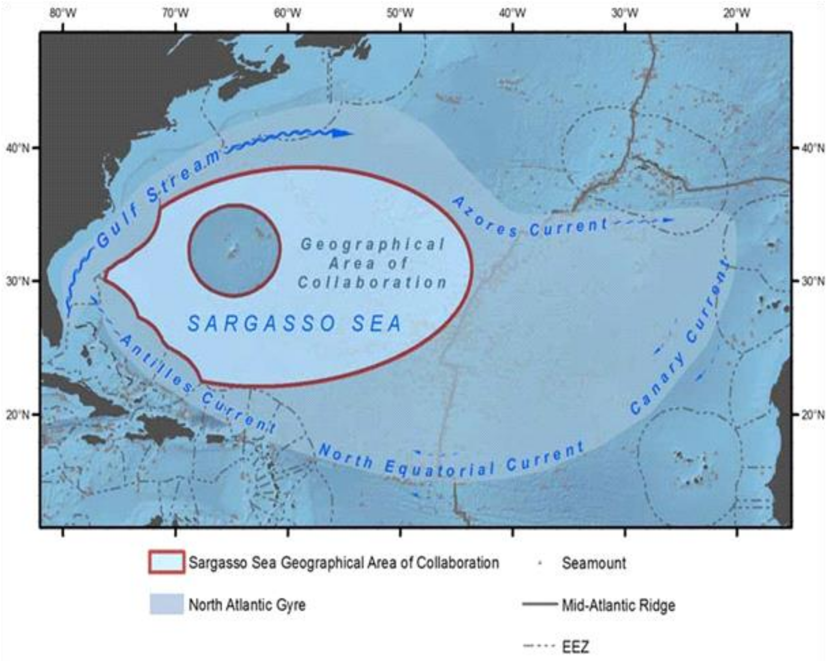
Average SSS for March and September

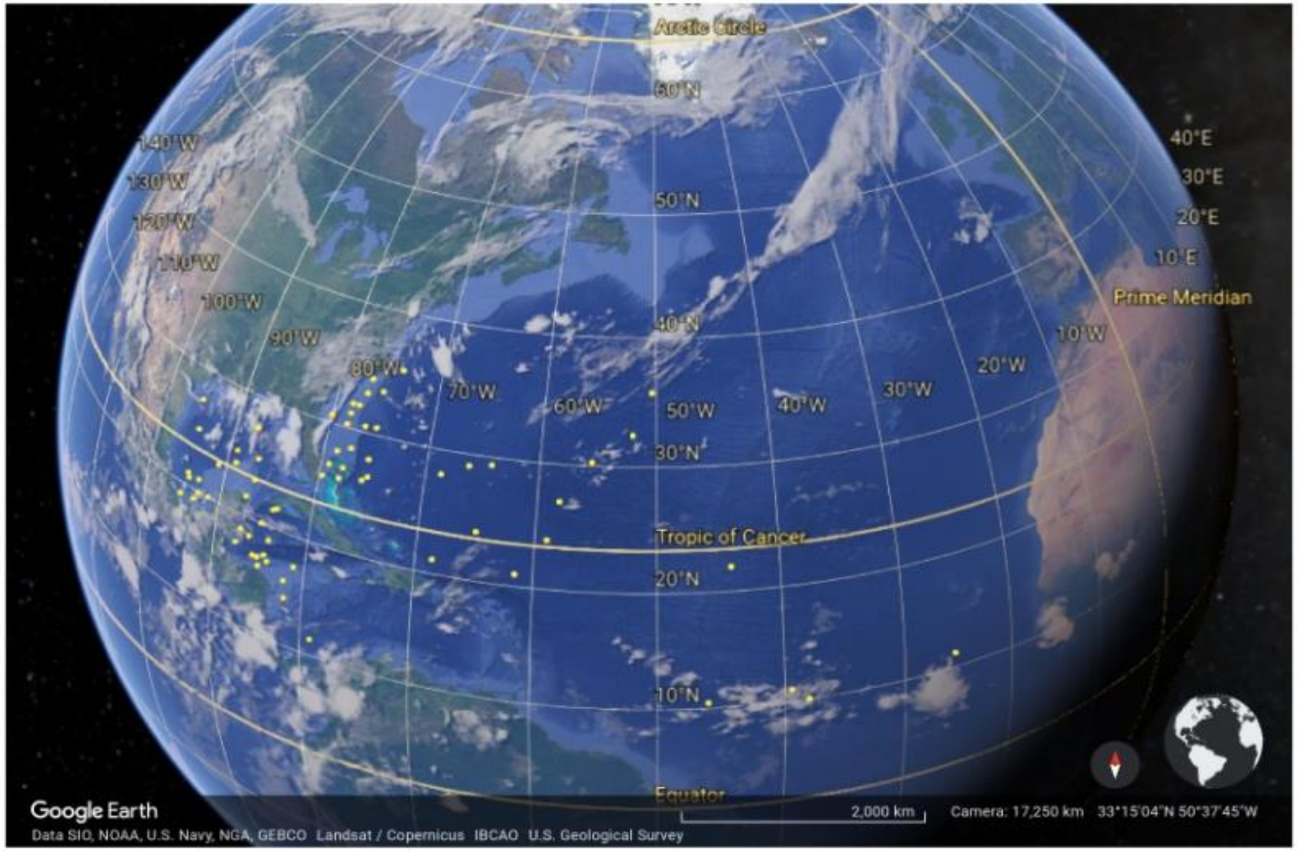


G. Reverdin et al. / Progress in Oceanography 73 (2007) 311–340

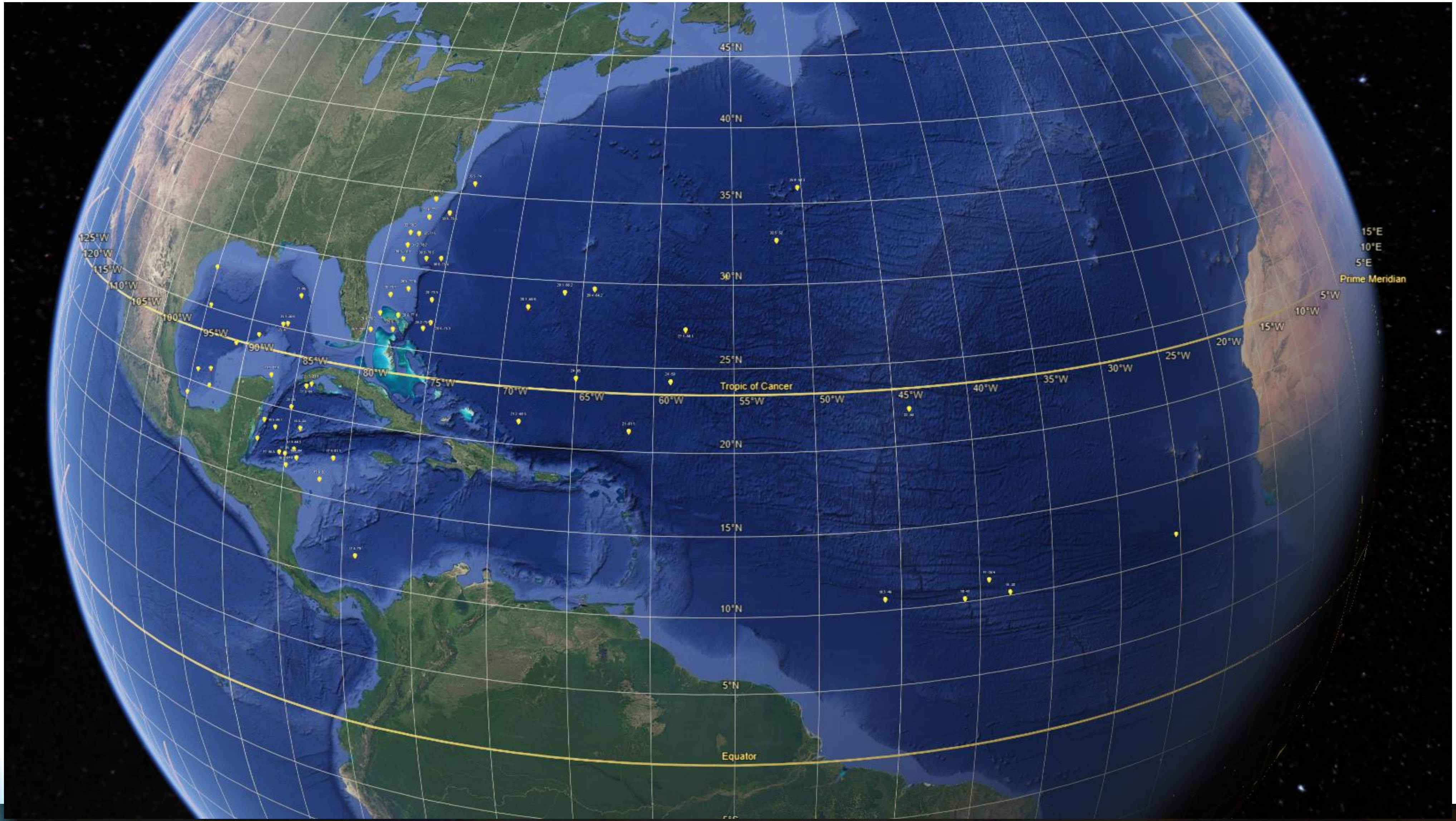


In this illustration we can see the warm flow of the North Atlantic Gyre and North Atlantic current, as well as the cold deep backflow heading South, eventually crossing under the Gulf Stream.





The North Atlantic Cyclogenesis (at the start of the each hurricane season from 1951 to 2023)



"The effect of salinity on evaporation is illustrated very clearly when the Mediterranean Sea Breeze front reaches the station at the diluted plume and later on, the station in the open lake. In the open lake, the evaporation rate increases monotonically with increasing wind speed, as expected under uniform salinity profiles. In the diluted plume, at low wind speed, the plume is stable, salinity is low, and evaporation is high and positively correlated with wind speed as expected. However, beyond a certain wind speed threshold, the salinity stratification in the plume breaks down due to wind mixing, surface salinity increases, and consequently evaporation rate decreases due to the reduced water activity although wind speed continue to increase. This introduces an interesting dual role of wind speed in evaporation from stratified diluted plumes in hypersaline environments."

Michael T. Montgomery

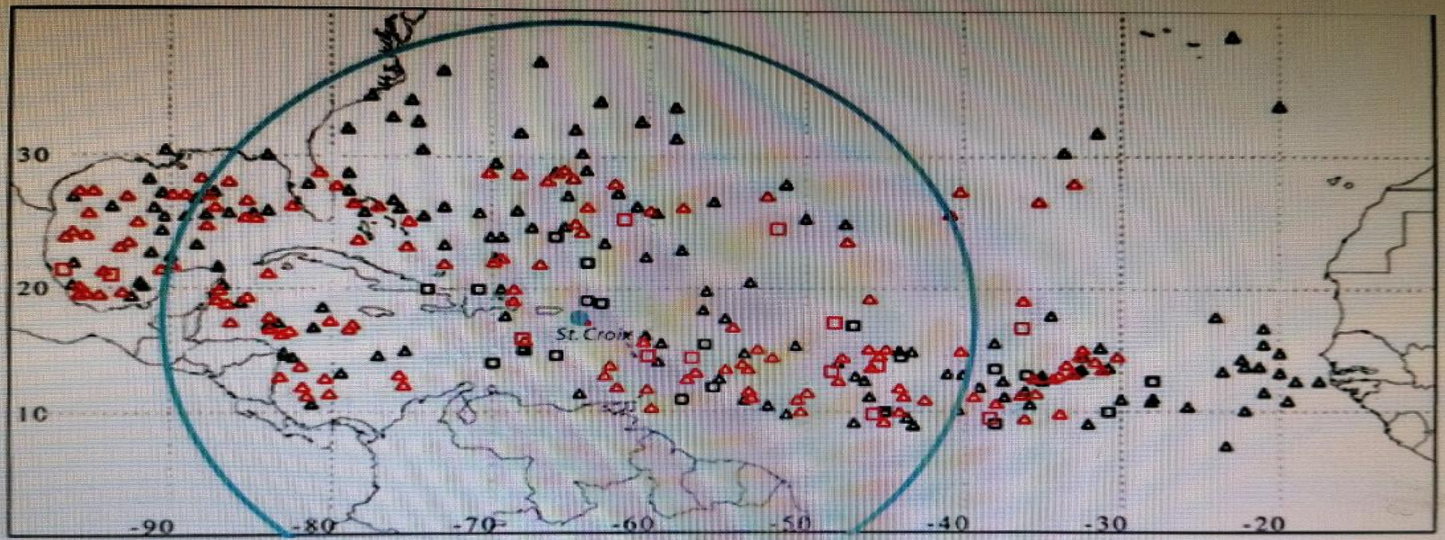
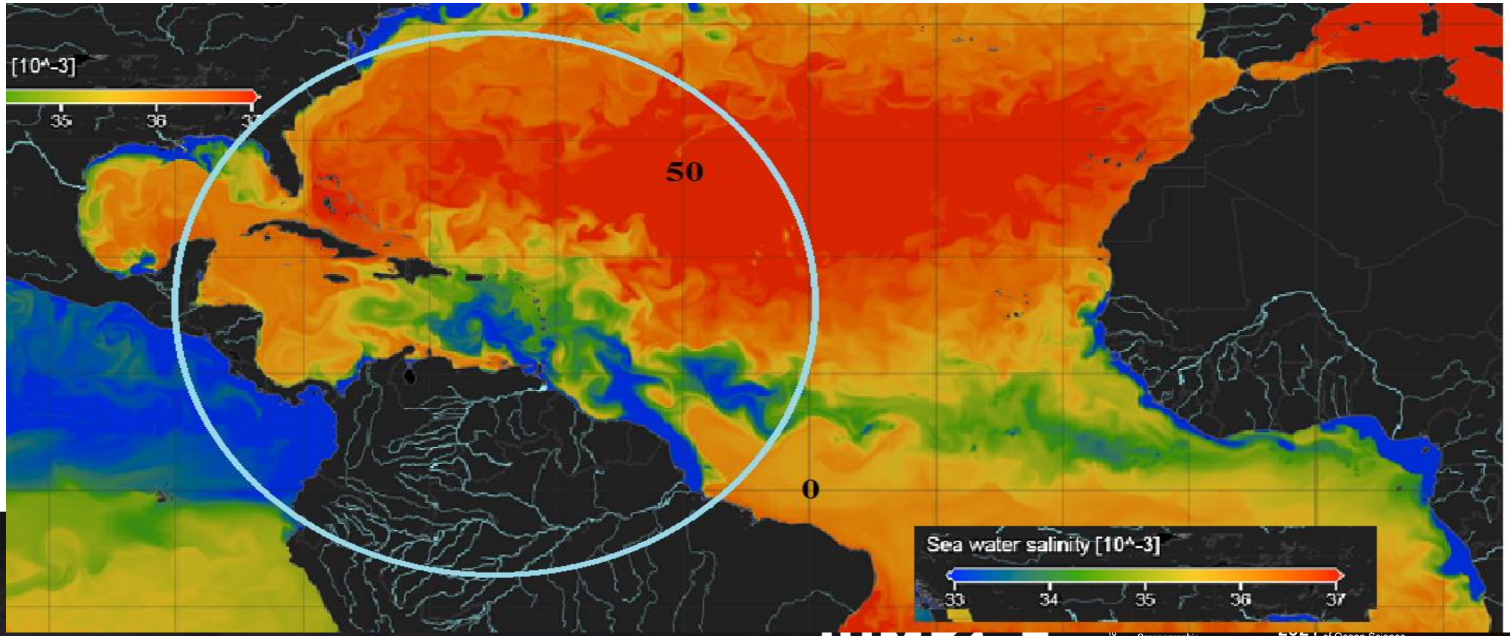
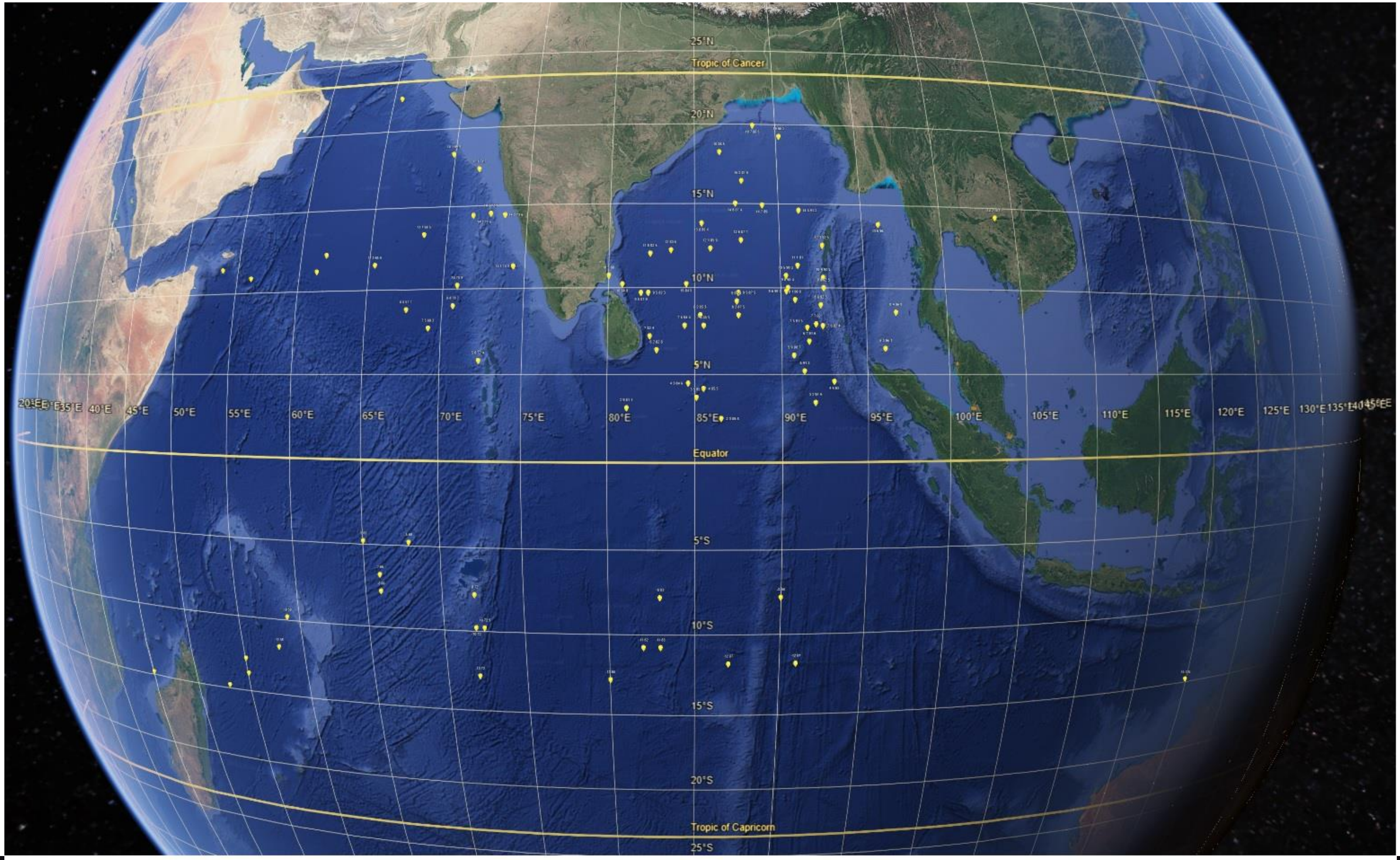


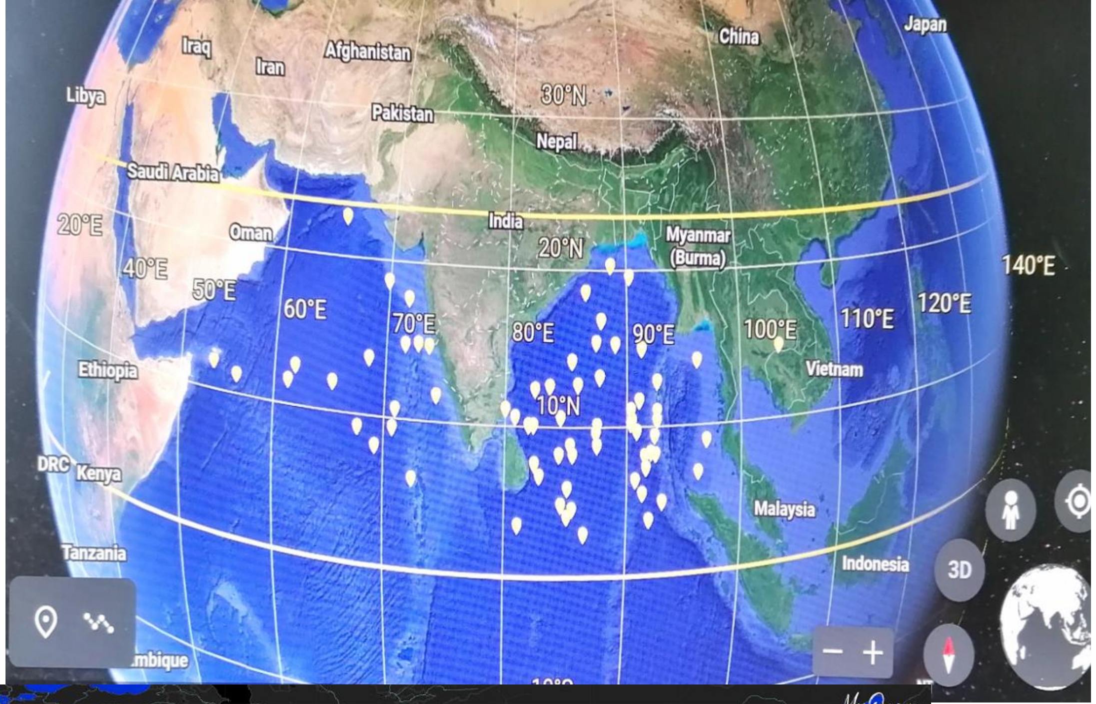
Fig. First-detection locations of developing (triangles) and non-developing (squares) tropical depressions from 1975 to 2005 (1995-2005 in red), adapted from Bracken and Bosart (2000). The blue circle denotes the approximate PREDICT domain.



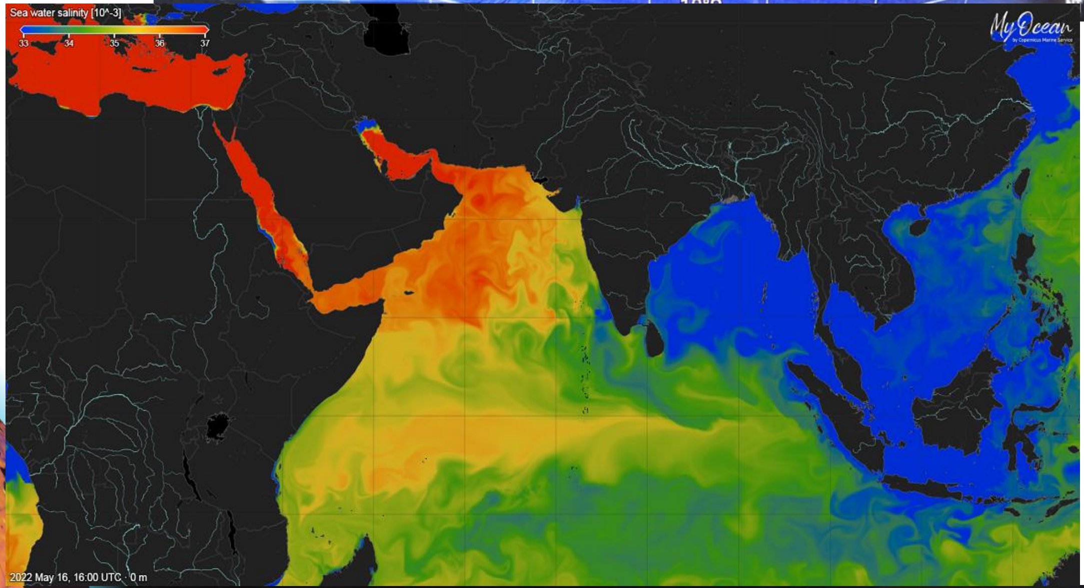
The Indian Ocean Cyclogenesis (at the start of the each tropical season from 1950 to 2022)

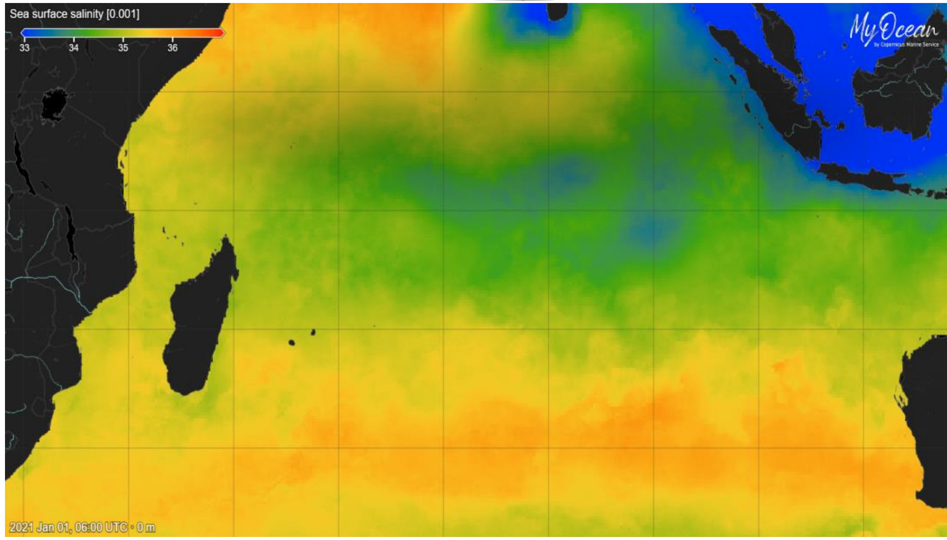


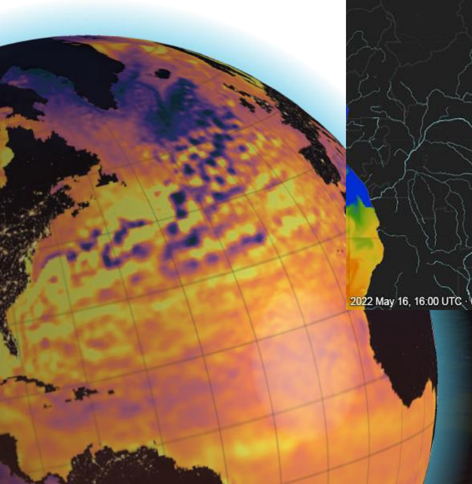
North Indian Ocean



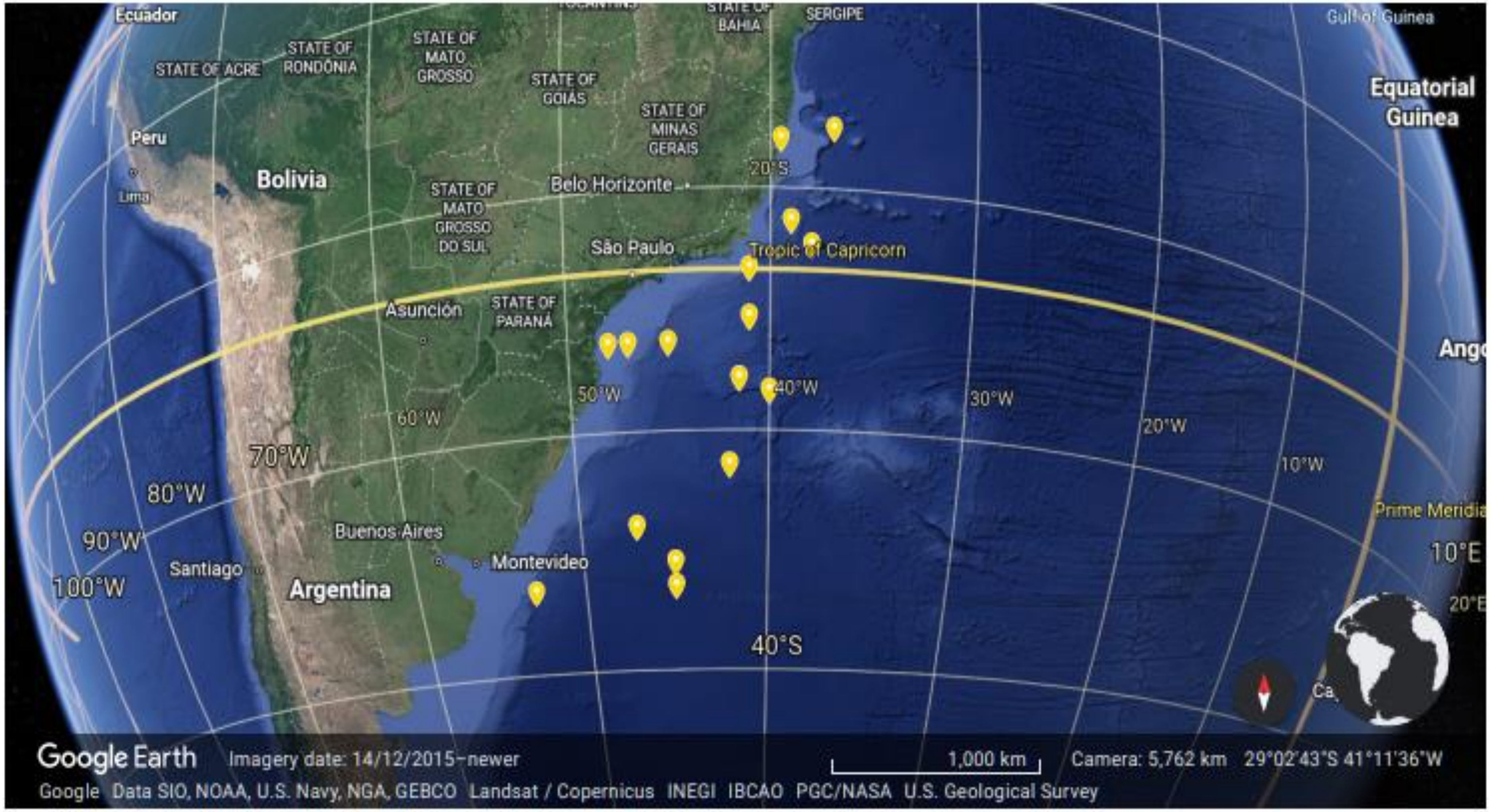
South Indian Ocean



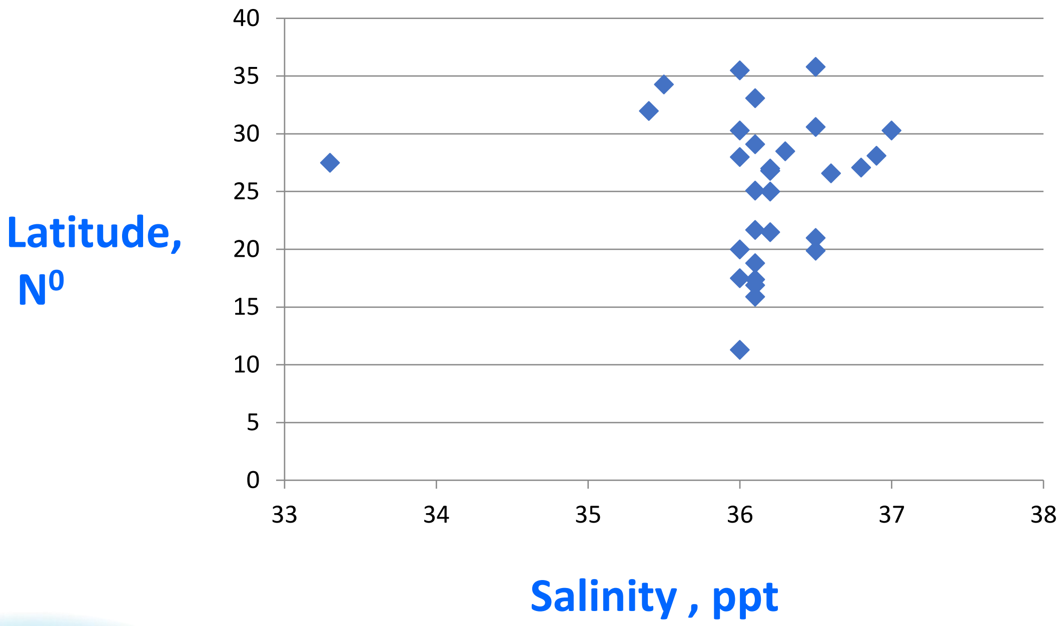


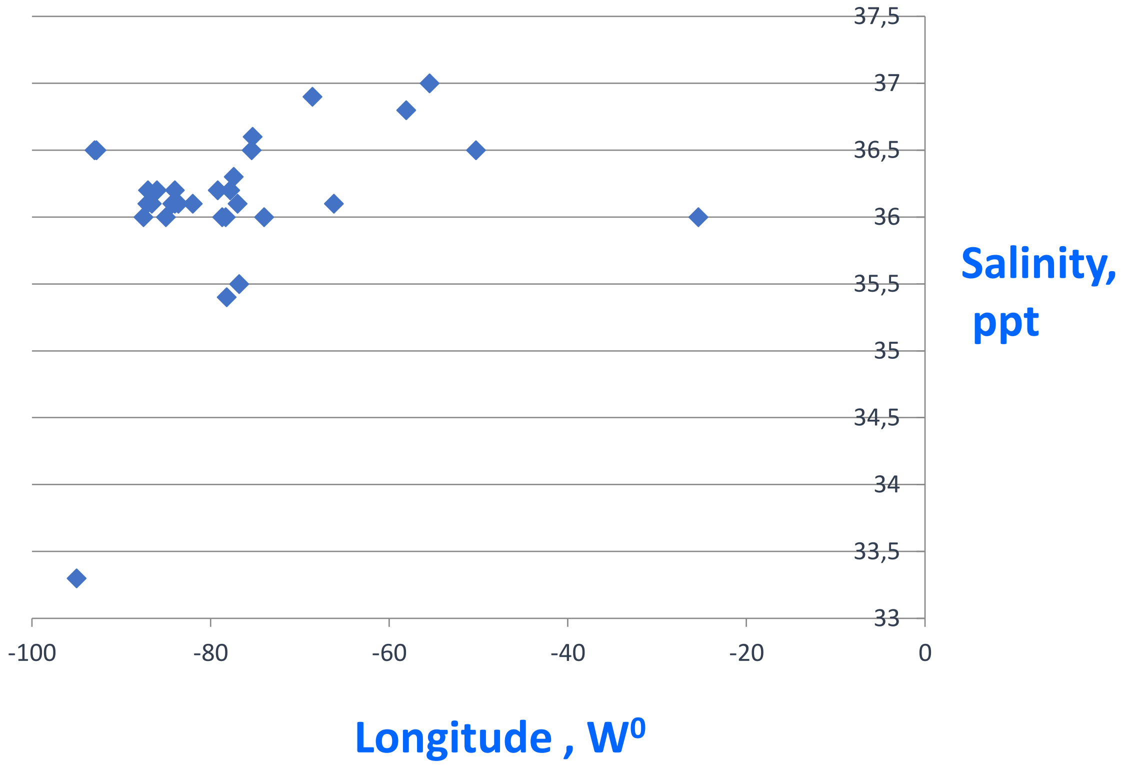


Tropical Cyclogenesis in the South Atlantic

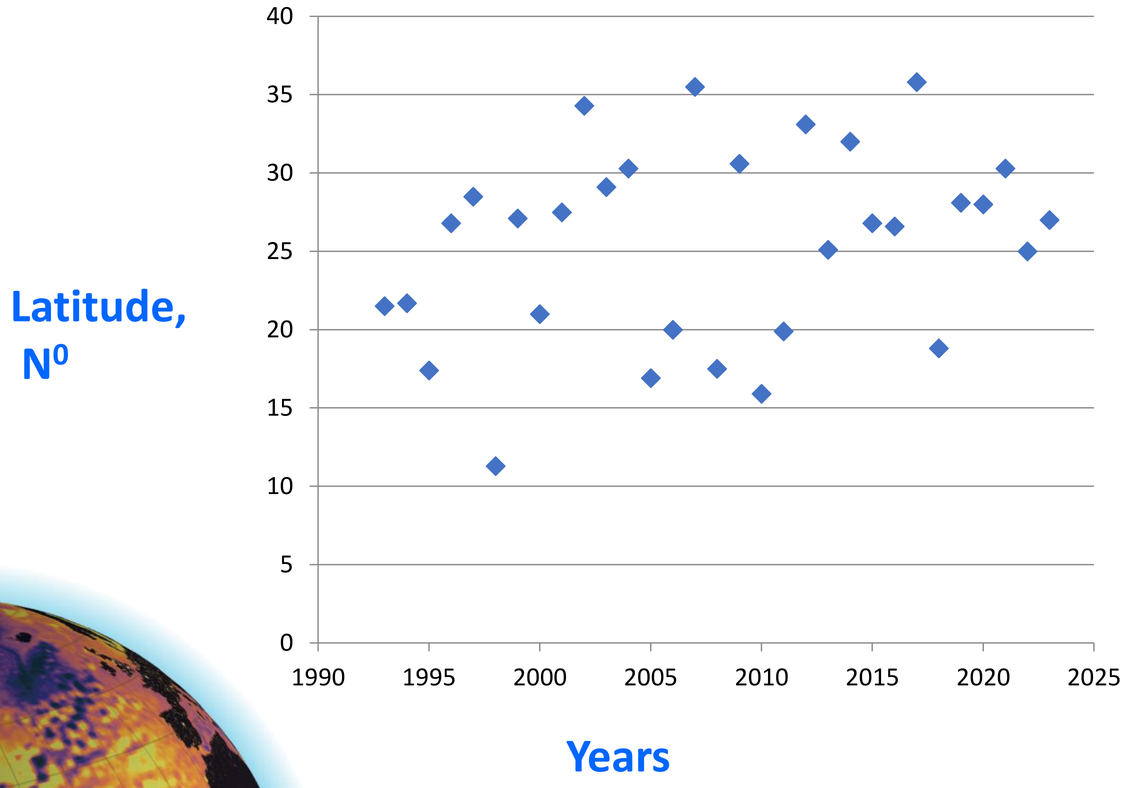


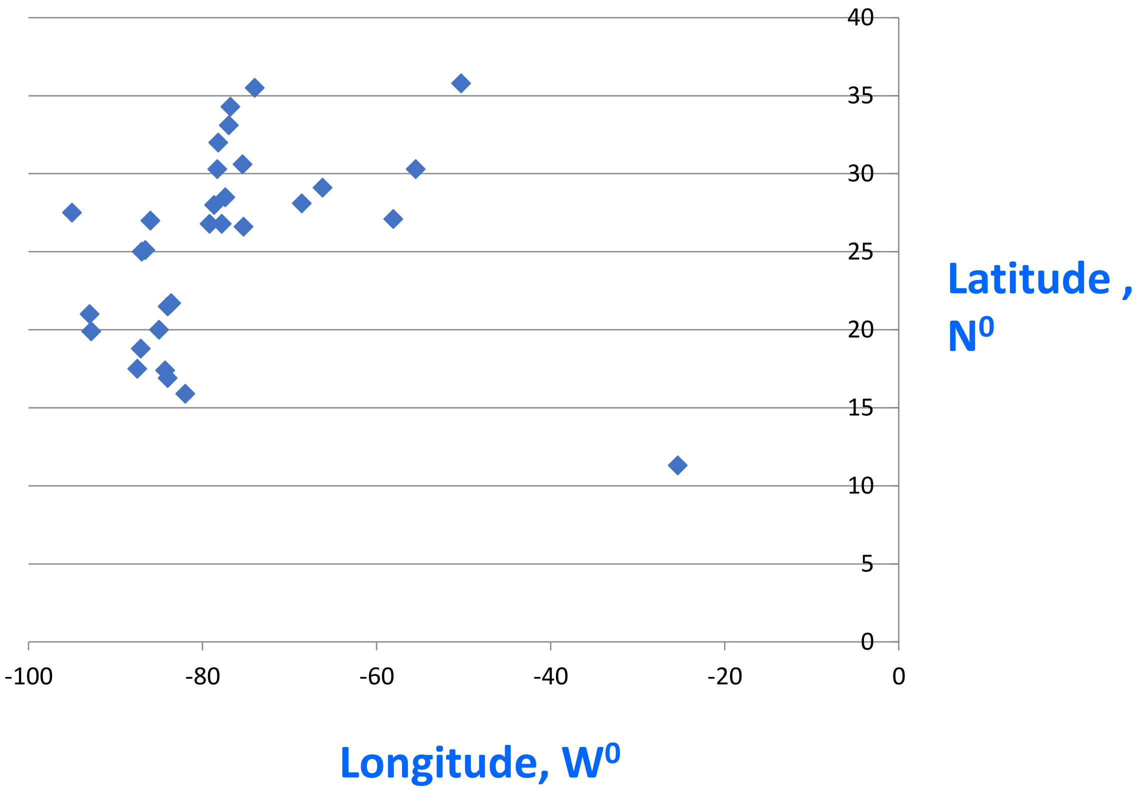
The North Atlantic Cyclogenesis (at the start of the tropical cyclone season (1993-2023))





The North Atlantic Cyclogenesis (at the start of the tropical cyclone season (1993-2023))





CONCLUSIONS

In this presentation we looked at examples of tropical cyclogenesis over the past 50 years. The salinity values SSS did not exceed 37 ppt mostly. The dependence of the formation of tropical cyclones in the North Indian Ocean is especially clear. Also, to clarify the effect of salinity, we took the values of this parameter at the beginning of each season in the Southern Atlantic region.

Over the past 30 years, salinity values have varied on average from 36 to 36.5 with a maximum of 37ppt (in 2021). The main conclusion of this presentation is an indication that a 7th factor should appear as part of the main factors of tropical cyclogenesis, namely, a limitation of the salinity value of about 37ppt.

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