THE SEA LEVEL RISE OF THE NEXT HUNDRED YEARS. THE CASE STUDY OF MIAMI AS A PARADIGMATIC EXAMPLE FOR MEDITERRANEAN COASTS

Chiara Simoncini

Abstract: The climate crisis demands urgent strategies to stabilize our settlements and improve city sustainability. This challenge, especially in rapidly changing areas, has driven research to develop precise monitoring and analysis tools. In Miami-Dade County, sea levels have risen by 30 cm since the early 1900s, surpassing the global average. *King tides* are now four times more frequent than 15 years ago. Predictions for sea level rise by the end of the century suggest an increase of 1.5 meters for the U.S. eastern coast. If this happens Southern Florida will become uninhabitable. The county's protection plan involves increasing residential density in low-value neighborhoods, primarily inhabited by low-income families and minorities, risking "climate gentrification." This could displace current residents due to rising costs, altering urban identity and demographics. These issues, though less familiar to the Mediterranean, are increasingly relevant as *medicanes* cause growing damage. The Miami case study's analysis, based on IPCC and NOAA forecasts, provides crucial data for designing coastal protection systems and preventing similar social issues in other country.

Keywords: Medicanes, Flooding, Sea level rise, Climate Change

Chiara Simoncini, University of Florence, Italy, chiara.simoncini@unifi.it, 0000-0001-7232-7916

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Introduction

The contemporary interpretation of the Mediterranean as an economic, social, and political unit/multiplicity involves a long-term examination of human interactions with the spaces that have always defined it. The coastal zone, historically a site of significant transformations, has now become a stage for current major changes, driven not by large-scale mercantile exchanges but by catastrophic climatic events. These events have made it increasingly urgent to formulate hypotheses that might allow us to continue living in the world we know, by halting ongoing events or, optimistically, improving the condition of our cities and, consequently, our lives, thus enabling us to become actors in a potentially sustainable system.

This challenge, in certain areas experiencing more rapid and sudden climatic changes, has spurred research to identify emerging practical applications, allowing for more precise monitoring and analysis of marine dynamics. For example, in South Florida, particularly Miami-Dade County, sea levels have risen by 30 cm since the early 1900s and over 10 cm since 1993, at a much faster rate than the rest of the planet. Experts project a significant rise of approximately 1.5 to 2 meters by the end of the century. If this scenario becomes reality, nearly one-third of present-day South Florida will become uninhabitable due to sea-level rise.

Methods

Miami is currently experiencing a projected future of a catastrophic reality that the entire Mediterranean basin will have to confront in the near future. Although it is a location subjected to different climatic pressures, and although it involves oceanic dynamics rather than Mediterranean ones, characterized by a much more rapid temporal scale and a higher level of catastrophic assessment, it is becoming a Mediterranean issue as well.

The evaluation of this case study is based on a review of the existing scientific literature and on empirical data collected through in-situ survey instruments in Miami and several Mediterranean coastal locations. Through a multidisciplinary approach, it was possible to examine sea level rise in Miami and the potential implications for Mediterranean coasts. The methodology was structured into four main phases: collection and analysis of historical data and future projections, assessment of socio-economic impact through qualitative and quantitative methods, examination of adaptation strategies, and study of comparative cases.

Historical Data and Future Projections: Using data provided by the National Oceanic and Atmospheric Administration (NOAA) and the Intergovernmental Panel on Climate Change (IPCC) [fig.1], we charted historical sea level trends for Miami-Dade County and several Mediterranean coastal areas characterized by different coastal types: sandy or rocky seabeds, sandy or rocky shorelines. Utilizing advanced climate models, we extrapolated sea level rise projections up to 2100, considering different greenhouse gas emission scenarios (RCP2.6, RCP4.5, RCP8.5).

- *Economic Impact*: Identifying critical infrastructures essential for community life allowed us to determine the potential economic loss if sea level rise rendered these infrastructures unusable, thereby causing significant disruptions to community life.
- *Social Impact*: The evolution of this environmental dynamic is effectively transforming the determination of safe areas, leading to large-scale population migration. Surveys and interviews with residents and local authorities were conducted to assess the perception of risk regarding these issues.
- *Adaptation Strategies*: We examined the measures adopted by Miami-Dade County authorities to counteract sea level rise and evaluated their applicability to Mediterranean coasts, considering environmental, economic, and cultural differences.

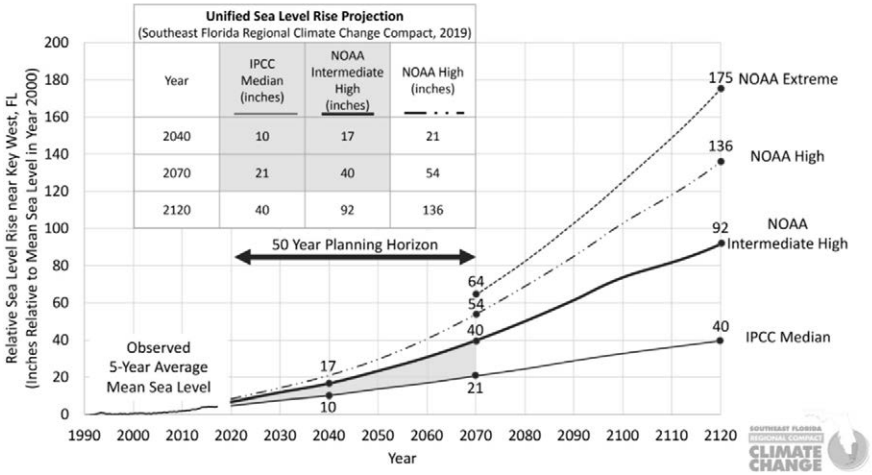


Figure 1 – Unified Sea Level Rise Projection, Southeast Florida Regional Climate Change Compact, 2019.

The latest updated (2019) "Unified Sea Level-Rise Projection" presented by the Southeast Florida Climate Change Compact partnership incorporates sea-level rise estimations from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2014) and projections from the National Oceanic and Atmospheric Administration (NOAA) (Sweet et al., 2017). These projections (Figure 1) served as the foundation for the development of this study.

Projected sea-level rise, especially beyond 2070, exhibits a significant range of variation due to uncertainties in future greenhouse gas emission reduction efforts and the decisions and investments communities will make to enhance their climate resilience. It is important to note that these models are rapidly evolving and depend on numerous key factors. The NOAA Extreme model is included in this study to

illustrate potential outcomes if carbon emissions continue to rise unchecked and account for the rapid degradation of ice sheets in polar regions. Including extreme scenarios is a common practice, as seen in California's H++ scenario, referenced in the Unified Sea Level Rise Projection Report. The reported data do not account for the process of subsidence but exclusively consider the eustatic process, focusing solely on absolute sea level rise rather than relative variation.

Observing the average sea-level rise alone does not fully capture the potential damages, as tidal variations also significantly contribute to inundation. To provide a more comprehensive prediction of the financial and social impacts on Miami, this study has also considered the effects of tidal cycles, which cause short-term sea-level fluctuations and can lead to temporary inundation of areas that would otherwise remain dry if only the average sea level was considered.

To better understand the potential magnitude of these events, the mean higher high water (MHHW) level at the Miami Biscayne Station [fig.2], which represents the average height of the highest tide recorded each day during the recording period, has been analyzed and incorporated into each sea-level rise prediction discussed.

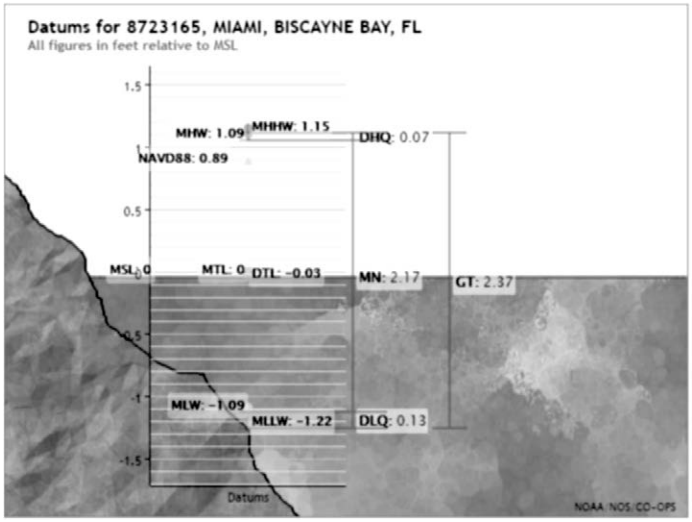


Figure 2 – Datums for Miami Biscayne Bay Station (relative to MSL), Florida.

Results

The data for this project was primarily sourced from three repositories: the Miami-Dade County Open Data Hub, ArcGIS Business Analyst, and the NOAA Tides and Currents Database [fig.3].

A geographic information system (GIS) connects data to maps, enabling the creation, management, and analysis of various types of information. GIS is a

powerful tool that enhances communication, efficiency, management, and decision-making.

The analysis began with a 2018 Digital Elevation Model (DEM) created using Light Detection and Ranging (LIDAR) data for Miami-Dade County. This DEM has a horizontal resolution of 5 feet, meaning that all LIDAR data points within each 5-foot by 5-foot area were averaged to a single representative point for that area.

Additional layers were imported from the MDC Open Data Hub, including line layers representing streets, polygon layers representing parcels, and point layers containing property valuations. These layers are essential for conducting financial evaluations [fig.4, fig. 5].

Understanding community vulnerabilities and capacities is crucial to estimating the social impact of sea-level rise and flooding on the city. To assess these impacts, eight key infrastructures were selected based on their importance and the magnitude of disruption their inaccessibility would cause:

- Educational Buildings
- Electricity Generation
- Fire Departments
- Food Supply
- Government Offices
- Healthcare Services
- Police Departments
- Water/Wastewater Systems

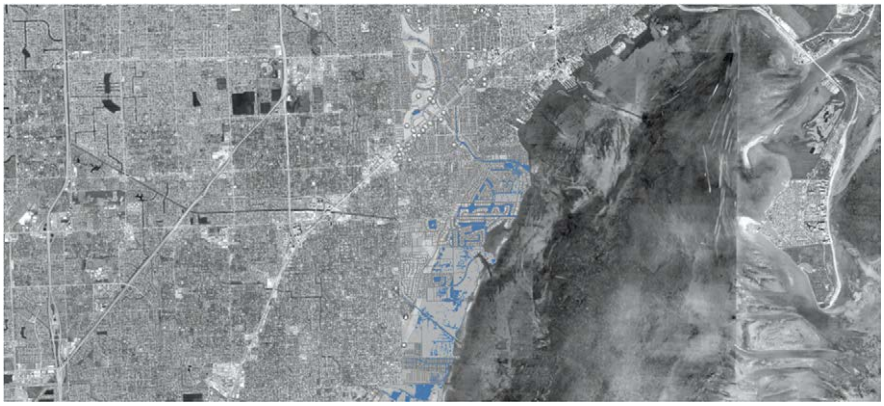


Figure 3 – Miami 2022.

NOAA Intermediate-High with MHHW **(2040)**

Estimated overall impact: **977,5 Million dollars**

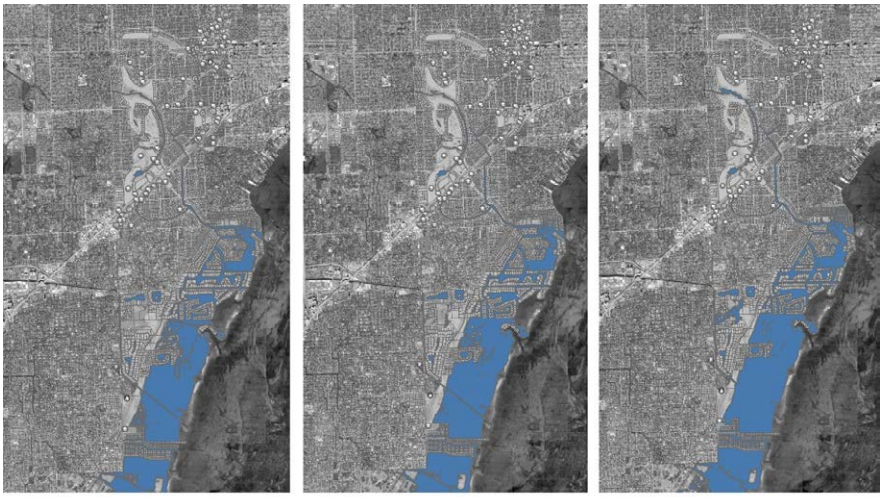
NOAA Intermediate-High with MHHW **(2070)**

Estimated overall impact: **5,1 Billion dollars**

NOAA Intermediate-High with MHHW **(2120)**

Estimated overall impact: **11,5Billion dollars**

Figure 4 - NOAA Intermediate-High with MHHW in 2040, 2070, 2120.



IPCC Median with MHHW **(2040)**

Estimated overall impact: **414,3 Million dollars**

IPCC Median with MHHW **(2070)**

Estimated overall impact: **1,2 Billion dollars**

IPCC Median with MHHW **(2120)**

Estimated overall impact: **4,5Billion dollars**

Figure 5 – IPCC Median with MHHW in 2040, 2070, 2120.

This investigation allows us to establish a general overview of what the situation might be for the eastern Florida coast, particularly in Miami-Dade County, in the absence of any protective strategies.

In response to this emergency, we explored the strategies adopted by Florida authorities to adapt to such changes and evaluated their applicability to Mediterranean coasts.

- *Literature Review*: We examined scientific literature and government reports on the adaptation measures implemented in Miami, including engineering projects, urban policies, and water management techniques.
- Comparative Analysis: We compared Miami's strategies with those adopted in similar Mediterranean locations, assessing the feasibility and effectiveness of various adaptation measures.
- *Adaptability Assessment*: We analyzed the geographical, climatic, and economic differences between Miami and Mediterranean coasts to determine how Miami's strategies could be modified and adapted to the Mediterranean context.

Government authorities have currently proposed implementing a series of land protection plans that hypothesize increasing residential density in areas further from the coast. These areas are traditionally characterized by low property values and a predominance of low-income families, many of whom belong to ethnic, religious, or linguistic minorities.

This strategy, by not addressing the resolution of the catastrophic scenarios predicted by climate trends, has inadvertently caused a series of unexpected social effects: the territorial neo-colonization by the wealthier class is effectively leading to the ghettoization of the less affluent classes, who are forced to relocate, resulting in permanent alterations to the urban, social, and territorial identity.

These environmental, urban, social, territorial, and especially maritime issues are increasingly highlighting the need to develop project hypotheses capable of addressing the crisis affecting the entire territory of Florida. This serves as a paradigmatic case of an oceanic dynamic that, although characterized by a much faster temporal scale and a higher level of catastrophic assessment, is also becoming a Mediterranean issue.

Conclusion

The new catastrophic climatic dynamics, including torrential rains and increasingly frequent Mediterranean hurricanes, have established a line of similarity with the American reality, which is currently experiencing a projection of the future scenario for our seas. This provides us with more time for reflection, a period in which action is still possible, and where architecture, as a tool for territorial requalification, remains a plausible means of resolution. Architecture is capable of safeguarding the territory, the landscape, and, therefore, the entire system of the most vulnerable areas that dot the Mediterranean.

The Mediterranean coasts, hosting numerous urban centers and crucial economic activities such as tourism, are equally vulnerable. Beach erosion,

groundwater salinization, and the increase in storm surges present concrete threats to the economy and quality of life.

Miami can thus become a paradigmatic case for the development of adaptation measures, including:

- Elevation of roads and infrastructure: Some roads have been elevated to prevent flooding.
- Water pumping systems: Pump systems have been installed to manage rainwater and floods.
- Storm surge barriers: Construction projects for barriers and levees are underway to protect the most vulnerable areas.

These strategies can be adapted to the Mediterranean coasts, with modifications to better align them with the local landscape and territorial systems.

- Local-scale engineering projects: Considering the different coastal morphology and available resources, solutions must be customized for each location.
- Strengthening existing infrastructure: Enhancing urban infrastructure to withstand flooding and erosion.
- Sustainable urban planning: Integrating adaptation measures into the master plan, encouraging the construction of resilient buildings and the use of sustainable materials.

To safeguard is to preserve the material and immaterial heritage that would be lost if the reality in which we live were to vanish. To safeguard is simultaneously to defend and to act in the redetermination of those fragile places.

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