CLIMATE CHANGE CONSIDERATIONS: A CHALLENGE FOR ENGINEERS

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ABSTRACT
This paper looks at some climate science basics and discusses the implications of a warming climate. A high-level overview of impacts is provided, particularly in the context of global sea level rise, and the question of "what's in store?" is posed. Finally, a local case example is presented, where rainfall effects are combined with sea level rise, and the departure from our accepted norms is discussed.

SOME CLIMATE SCIENCE BASICS

The Intergovernmental Panel on Climate Change (IPCC) has collected and assessed the work of thousands of scientists, who are all working on the science of climate change. They have expressed our climate future in terms of Representative Concentration Pathways (RCP's). An RCP represents a greenhouse gas (e.g., CO2, Methane, NO) trajectory that has been modelled by climate scientists. Four pathways were used for climate modelling and research for the IPCC's 5th Assessment Report (AR5) in 2014. These pathways describe different climate futures, all considered to be possible in the years to come.

The RCP's, originally RCP2.6, RCP4.5, RCP6 and RCP8.5, are labelled after a possible range of radiative forcing (this is the change in energy flux in the atmosphere caused by natural, or anthropogenic factors of climate change as measured in Watts/m^2) values in the year 2100. Since the completion of AR5, the original pathways are considered together with Shared Socioeconomic Pathways (SSP's), as alternate ways of examining climate futures.

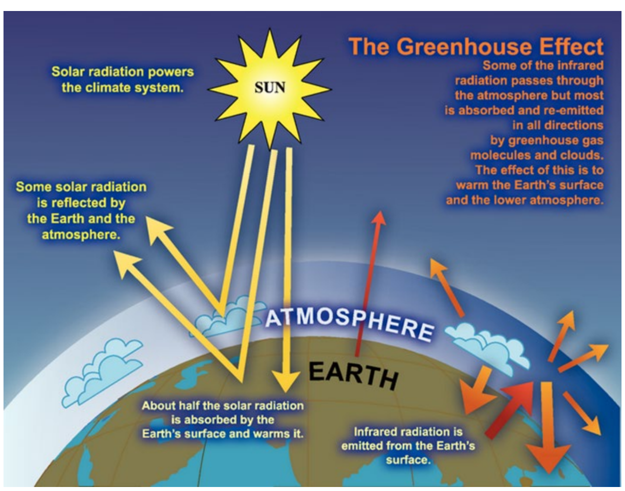

Figure 1 – The Greenhouse Effect

A WARMING ATMOSPHERE

Comparing global atmospheric temperatures in June, July, and August to a 1951-1980 average, it can be seen that global summer temperatures have continued to rise above the average baseline.

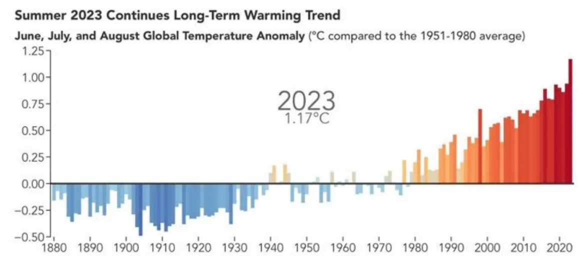

Figure 2 – Average Global Summer Temperature Anomaly

OVERVIEW OF IMPACTS – HIGH LEVEL

The following impacts have been noted as being very likely to occur:

- **Sea levels** will continue to rise for millennia.
- The total **number of Tropical Cyclones (hurricanes) per season** is likely to decrease or remain unchanged.
- The **number of higher category Tropical Cyclones** (Cat 3, 4 and 5) are likely to **increase** in the future.
- **Rainfall rates associated with hurricanes** are likely to **increase** in the future. Warmer temperatures bring greater convection and more atmospheric moisture.
- **Maximum wind speeds** associated with hurricanes are likely to **increase.** Work done in Bermuda indicates that for each 1^{o}C increase in temp, could lead to +1.0-1.5 m/s changes.
- Longer periods of **drought** are predicted.
- More episodes of **torrential rainfall**.
- Hotter **air temperatures** (more hot days, fewer cool ones).
- Hotter **sea surface temperatures**.

GLOBAL SEA LEVEL RISE

Global mean sea level (GMSL) rise is due to Thermal Expansion of ocean water, as a result of warming; and from ocean mass gain from melting of land-locked ice. GMSL is modified *regionally* by climate processes and *locally* by a variety of factors, some driven or influenced by human activity.

Extreme sea level (ESL) events, can be considered, and these include sea level rise, storm surges and tides. These events that occurred in the recent past with a frequency of once per century, are now projected to occur at least once/year at many locations by 2050 for all climate scenarios. Up to 2050, the uncertainty in climate driven future sea level predictions is relatively small. Beyond that, the error bands are wider. The impacts on our oceans are in existence on a much larger scale and are happening way faster than predicted.

WHAT'S IN STORE?

The 100-year flood event is predicted to occur more frequently in the future, such that it will eventually be considered a 30-year event, and eventually a 10-year event, and possibly an annual occurrence.

This figure from IPCC (2019) Special Report on the Ocean and Cryosphere shows how Historical Centennial Events (HCE's, 100-year return period events) are predicted to eventually transition to annual events (1-year events).

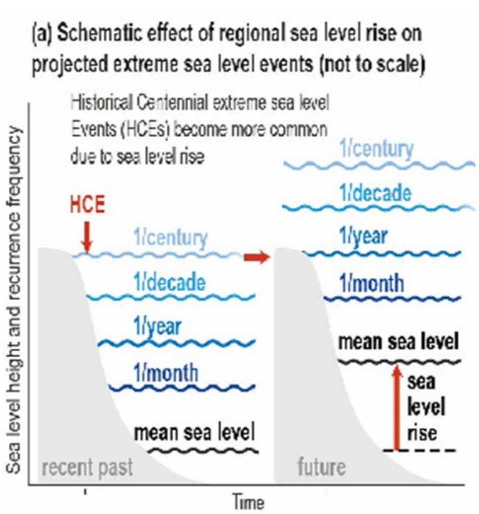

Figure 3 – The Transition from HCE to Annual

COASTLINE RISKS FROM SEA LEVEL RISE

Presently, engineers use the Bruun Rule to predict coastal retreat. This method indicates that retreat could be 10 – 50 times higher than sea level rise, depending on the slope of the coast. For example, a 10cm rise in water level could lead to a 1m – 5m shoreline retreat.

Coastal risks can be quantified, and it is the responsibility of the engineer to prescribe adaptation approaches. These could include:

- Set-back distances from the HWL
- Higher floor elevation levels
- Hard structures such as seawalls
- Nature based solutions such as mangroves

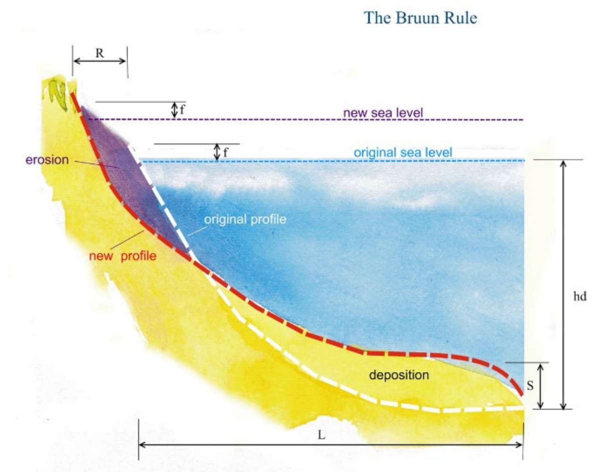

Figure 4 – The Bruun Rule for Coastal Retreat

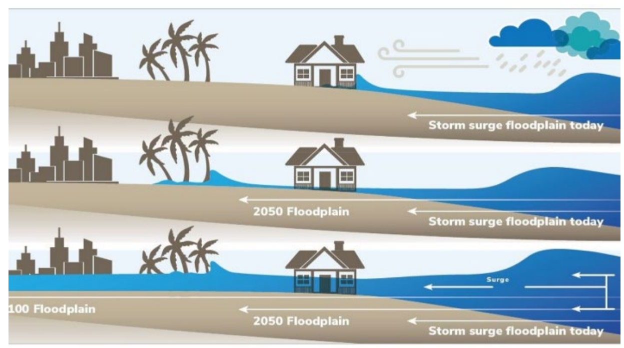

Figure 5 – Predicted Floodplains – Today, 2050, 2100

LOCAL EXAMPLE

A local example of the effects of torrential rainfall coinciding with tidal effects and sea level rise, can be obtained from observations made at the NMIA on 23rd August 2023 at approximately 8:00PM. At that time, major flooding was observed in the parking lot at NMIA following very intense rainfall. This rain coincided with the occurrence of high tides. The effects observed begs the question of what can be expected to occur when rainfall intensity increases, and sea levels rise.

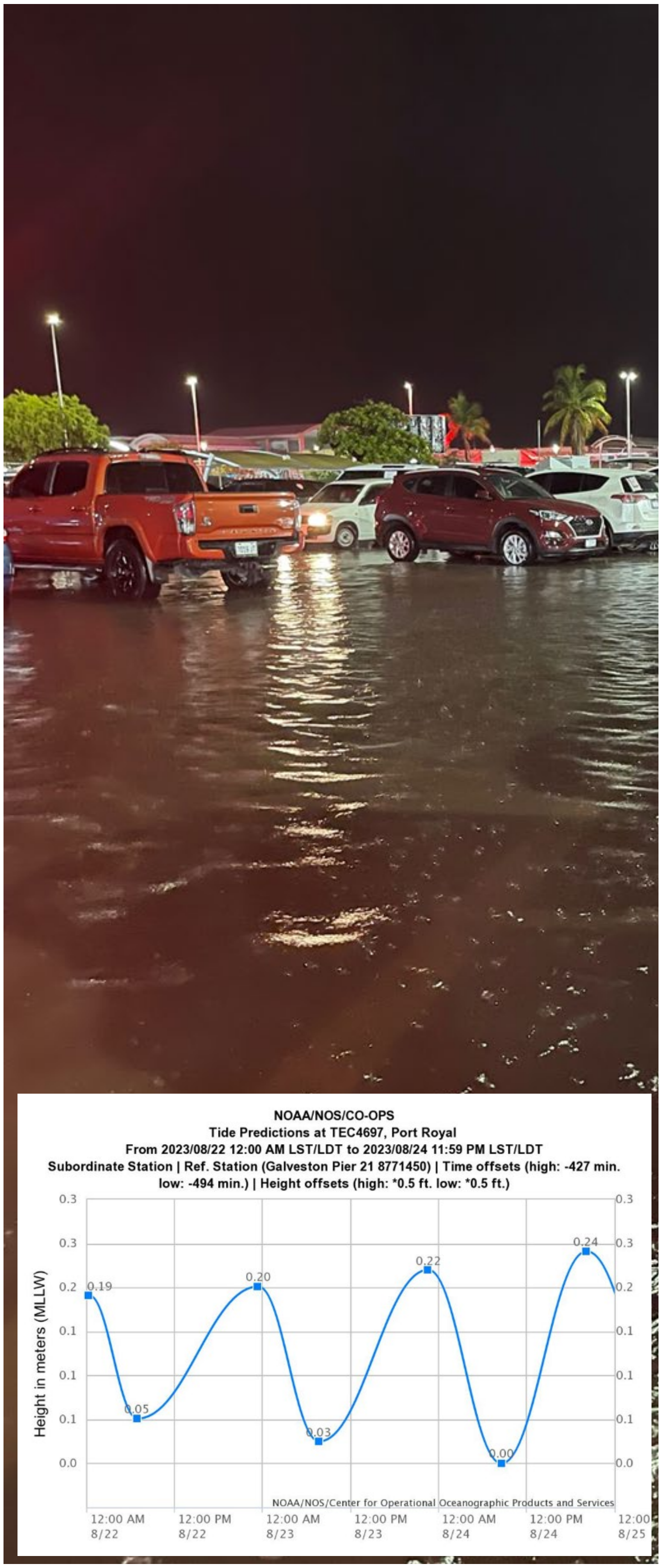

Figure 6 – Flooding in NMIA Parking Lot

CONCLUSIONS

Following are some conclusions and "take-aways" for our profession:

- Our engineering analyses usually assume the concept of ergodicity (uniformity in space), and stationarity (not changing with time).
- As such, we use past events to predict future outcomes, for instance in assessing return periods for use in design.
- Climate change, and in particular, sea level rise, is upending that approach.
- It is now important to use past events analysis **+** future predictions, to set design return periods with some confidence.
- To aid this revised process, we will need to:
  - Promote local data collection.
  - Analyse and identify trends.
  - Review and revise design standards for our region.
- Revise risk levels and Design Criteria used in the design of drainage structures and river training works, to allow for extreme events.
- Account for joint occurrences of high sea levels and extreme runoff.

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Figure 7 – Jacks Hill, Jamaica (2014)

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