08- BASING FLOOD DEFENCE PLANNING ON REALISTIC DATA FOR SEA LEVEL RISE

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Abstract

Many sources used in the context of sea defence planning, including those used by local authorities, have presented deficient information on sea level rise. An example is Dublin City Council's Climate Change Action Plan 2019-2024. We have posted an analysis of the information given there at https://oneillp.wordpress.com/. Here, a summary of our analysis is given. The DCC Plan states that the current rate of sea level rise in Dublin is 6-7 mm/year while the global mean rate of rise is 3-4 mm/year. This information has been given without appropriate context. The DCC Plan does not mention that sea level rise, both globally and in Dublin, shows strong multi-decadal variability, present rates of rise having been equalled by, exceeded by or being of opposite sign to rates in the recent past. Nor does the DCC Plan mention that the current period of global mean sea level rise began around 1850, long before atmospheric greenhouse gas increase became significant. A recent NASA-led study has led to a downward revision of the estimated linear trend of global mean sea level rise over the 20th century from 1.9 mm/year to 1.4 mm/year. The linear trend since 1993 as given by both satellite altimetry and reconstructed tide gauge measurements considerably exceeds this, being about 3.3 mm/year, but this recent value is not unprecedented, having been equalled in the period 1934-1953. The DCC Plan refers to a projected sea level rise of 6m. Such a figure is not realistic in the context of contemporary circumstances. In connection with this, the DCC Plan also refers to a projected increase in the frequency of strong winds and storm surges. This projection is found not to be in agreement with the evidence to date.

1. INTRODUCTION

We examine the topic of flood defence planning, with particular emphasis on Dublin and on information relevant to flooding given in Dublin City Council's Climate Change Action Plan 2019-2024 (Dublin City Council, 2019), hereafter referred to as the DCC Plan. Our considerations are based on current understanding of this topic in the relevant scientific literature and on examination of the tide gauge data for Dublin. We present our analysis under the headings of global mean sea level rise, sea level rise in Dublin, and sea level rise and extreme weather events. We point out a number of deficiencies in the information on these subjects given in the DCC Plan. Further details on the matters discussed here can be found in Bates and O'Neill (2021) and Bates, O'Neill and Ryan (2021).

2. GLOBAL MEAN SEA LEVEL RISE

Global mean sea level (GMSL) has been rising since the end of the last ice age, having risen by about 130 metres between 20,000 and 7,000 years ago. Subsequently, the rate of rise became slower, with intermissions during cold periods such as the Little Ice Age (approx. 1350-1850 AD). The current period of GMSL rise began around 1850, as the Little Ice Age came to an end and the effect of melting glaciers became evident; see Figure 1.

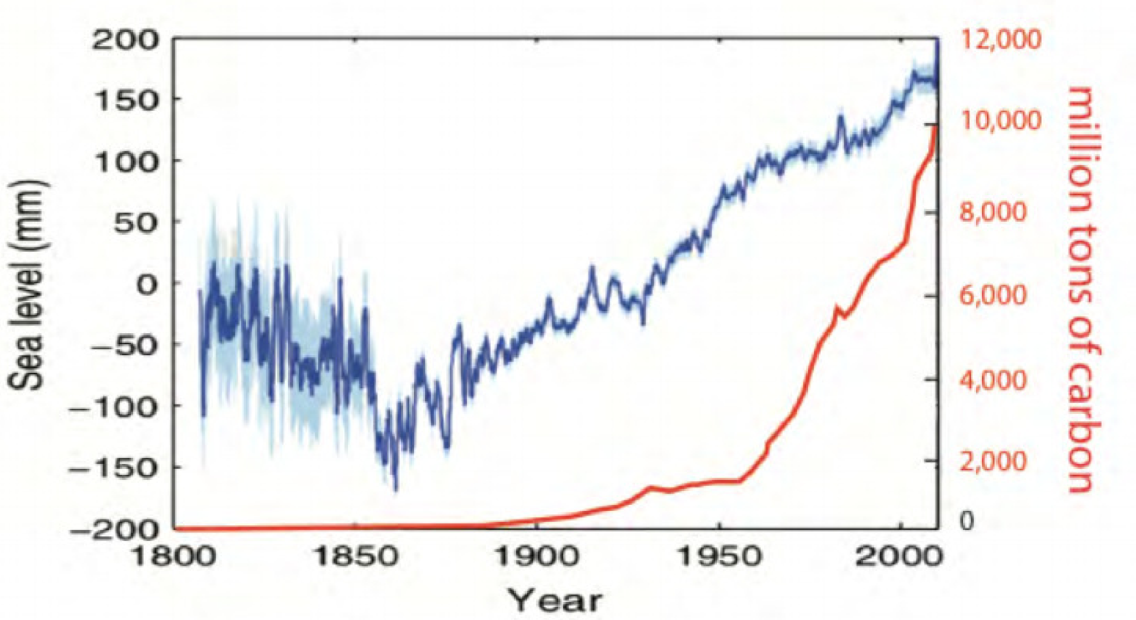

Figure 1: Global mean sea level anomalies (mm; blue) and carbon emitted (millions of tonnes; red) since the early 19th century. Reproduced from Fig. 4.1 of Curry (2018). [Sea level from Jevrejeva et al. (2014), carbon from Carbon Dioxide Information Analysis Centre (CDIAC, 2014)].

It is clear from Figure 1 that the GMSL was rising long before 1950, when fossil fuel emissions began to be appreciable. The rate of rise since 1850 is not constant, but shows substantial multi-decadal variability. Douglas (1992) has argued that acceleration in observed GMSL rise needs at least 50 years of observations to be significant; otherwise, it is merely short-term variation. The sea level reconstruction of Jevrejeva et al. (2014) shown in Figure 1 indicates a linear trend of 1.9 ± 0.3 mm/year during the 20th century.

Recently, a NASA-led study has resulted in a state-of-the-art framework that brings together advances in sea level models and satellite observations to improve our understanding of sea level rise for the past 120 years (Frederikse et al. 2020). The GMSL rise over the period 1900-2018 obtained in this study are shown in Figure 2.

This figure again shows multi-decadal variability. The results show that, relative to the Jevrejeva et al. value given above, the average rate of GMSL rise during the 20th century has had to be revised downward to 1.4 mm/yr. The rate of GMSL rise shown by the study's reconstructed tide gauge data in the period 1993-2018 is seen to be in good agreement with the satellite altimetry data available during the same period, both rates of rise being about 3.3 mm/yr.

The Frederikse et al. data also show that the rate of GMSL rise in the 20-year period 1934-1953 was 3.3 mm/year, about the same as in the period 1993-2018. According to their paper, the above-average rate of GMSL rise in the 1934-1953 period is attributable to above-average contributions from glaciers and the Greenland Ice Sheet, with the Greenland contribution around 1935 being slightly greater than in 2018 (see their Figure 1d).

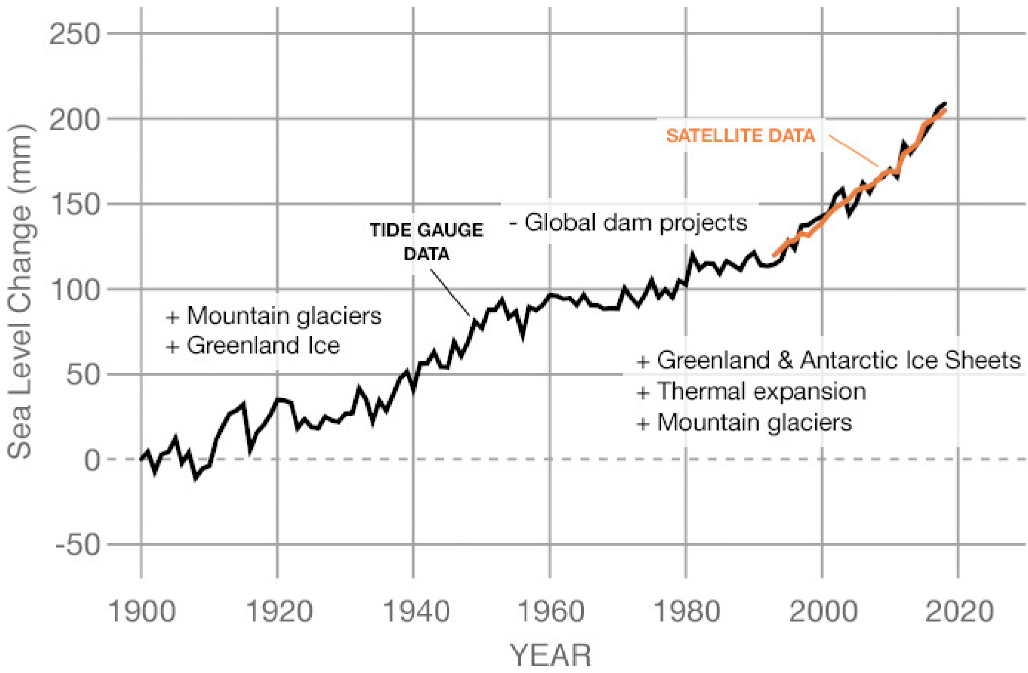

Figure 2: Global sea level rise, 1900-2018, as measured by tide gauge after correcting for the imprint of Glacial Isostatic Adjustment, the effects of Gravity, Rotation and Deformation, and the effects of Vertical Land Movement. Source: Frederikse et al. (2020). Reproduced from https://climate.nasa.gov/vital-signs/sea-level/. Data at: https://opendap.jpl.nasa.gov/opendap/allData/homage/L4/gmsl/global_timeseries_measures.nc.html

The Summary for Policymakers (SPM) of the recent Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2021) depicts observed sea level rise as accelerating, stating (page SPM-6) that: "The average rate of sea level rise was 1.3 [0.6 to 2.1] mm/year between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm/year between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm/year between 2006 and 2018 (*high confidence*)." The SPM does not mention the fact, clearly pointed out by Frederikse et al. (2020) and acknowledged in an interior chapter of a previous IPCC Report (IPCC, 2013, page 290) that: "The trend in Global Mean Sea Level observed since 1993 is not significantly larger than the estimates of 18-year trends in previous decades (e.g., 1920-1950)."

The rate of GMSL rise quoted in the DCC Plan, 3-4 mm/yr, is close to the current rate as given above. However, like the SPM, the DCC Plan does not mention that similar rates of rise occurred before 1950. Nor does it mention that significant sea level rise started around 1850, well before greenhouse gas emissions were of any significance.

The SPM of IPCC (2021) also presents projections of sea level rise to 2100 in the following terms (page SPM-28): "Relative to 1995-2014, the *likely* global mean sea level rise by 2100 is 0.28-0.55 m under the very low GHG emissions scenario (SSP1-1.9), 0.32-0.62 m under the low GHG emissions scenario (SSP1-2.6), 0.44-0.76 m under the intermediate GHG emissions scenario (SSP2-4.5), and 0.63-1.01 m under the very high GHG emissions scenario (SSP5-8.5)." The sea level projections using the very high emissions scenario SSP5-8.5 are qualified by the statement (page SPM-30) that they involve "low-likelihood, high-impact ice sheet processes that cannot be ruled out". This qualification is considerably weaker than that of Hausfather and Peters (2020), who state that the use of the RCP8.5 emissions scenario (which corresponds to the SSP5-8.5 scenario used in the current IPCC Report) is in itself misleading: "RCP8.5 was intended to explore an unlikely high-risk future. But it has been widely used by some experts, policymakers and the media as something else entirely: as a likely 'business as usual' outcome. A word we climatologists rarely get to use – the world imagined in RCP 8.5 is one that, in our view, becomes increasingly implausible with every passing year. Emission pathways to get to RCP 8.5 generally require an unprecedented fivefold increase in coal use by the end of the century, an amount larger than some estimates of recoverable coal reserves."

3. SEA LEVEL RISE IN DUBLIN

In the DCC Plan, the value 6-7 mm/year is given as the rate of sea level rise in Dublin between the years 2000 and 2016. This is about twice as large as the current GMSL values given by the IPCC and NASA, as quoted above. A graph of sea level rise in Dublin port for the period 1938 to 2018 is given in Figure 3. Just as in the case of the GMSL, it exhibits significant inter-decadal variations.

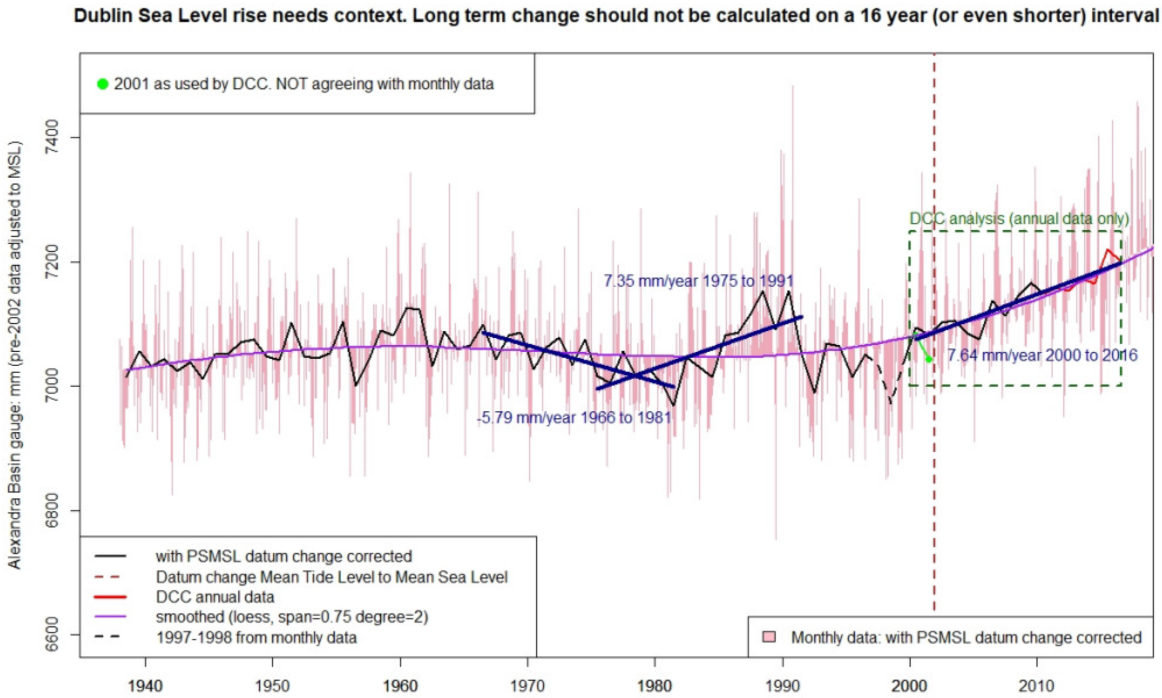

Figure 3: Sea level at Dublin Port (Alexandra Basin tide gauge), 1938 to present. MSL refers to the Mean Sea Level datum, based on an arithmetic mean of regularly sampled measurements between high and low water; the Mean Tide Level datum is based on an average of mean low water and mean high water. Note the DCC analysis within the box to the upper right. The 16-year linear trends centred at earlier times (approx. 1985 and 1975) have been inserted independently. Data sources: Permanent Service for Mean Sea Level (1938-2009), Marine Institute (2009 and after).

The linear trend over the period 2000-2016 in this graph is 7.64 mm/year. However, by going back a few decades a negative rate of sea level rise of comparable magnitude over a similar period can be found. For example, in the period 1966-1981 there was a falling trend of -5.79 mm/year. This kind of variability in the Dublin record was not referred to in the DCC Plan.

Another study of sea level rise in Dublin from Maynooth University (Nejad et al., 2021) finds a rate of sea level rise of 10 mm/year over 2003-2015 (a period still shorter by four years than that used by Dublin City Council). Our estimate over this shorter period would also increase to almost the same value — illustrating the variability of estimated sea level rise over short periods.

Nejad et al. find that the rate of rise in Dublin over the longer period of 1938-2015 was 1.67 mm/year which is in good agreement with the global average. They also point out that the current elevated rate of rise in Dublin is greater than the rates of rise at nearby and further distant tide gauges, suggesting a malfunction of the Dublin tide gauge. They state in relation to their analysis: “This suggests that the malfunction probably started during or after the year 2002. We would consider the Howth Harbour sea level record, alongside the modelled MSL data created in our study, as more reliable dataset for future analysis of sea level in Dublin Bay compared to Dublin Port’s dataset.”

Additional sea level results from four tide gauges widely spread around the coast of Ireland are given in EPA (2021, Figure 3.7). These records are of shorter duration than the Dublin record and it is stated that the time series they provide are not yet long enough to determine any trend. EPA (2021, Figure SB3.1) also shows the recent short window (2000-2016) within which the rate of sea level rise in Dublin seems to have increased substantially. The longer 1938-2018 time series is also shown (Figure 3.8). Like Nejad et al., the EPA report questions the reliability of the recent apparent increase in the rate of rise in Dublin, suggesting possible issues with the data themselves as a factor (page 75).

On page 38 of the DCC Plan, under the heading “Future Risks”, the following sentences occur:
“In terms of relative land vulnerabilities, Dublin, Louth and Wexford are at highest risk. Under a projected sea level rise of 6m, it is estimated that close to 1,200 km^2 of land area would be at risk.”
To reach the 6m rise in sea level cited here would take about 800 years if the 2000-2016 rate of Dublin sea level rise of 7.64 mm/year were to continue, and 4,200 years if Frederikse’s average 20th century GMSL rate of 1.4 mm/year were used. In referring to future sea level rises of 6m, Dublin City Council appears to be looking into the very distant future.

A broader perspective on sea level trends in Dublin can be gained by examining European data. Figure 4 shows the time series (as processed by NOAA) from Cuxhaven, Germany, which has a long record. From this it can be seen that there is a long-term trend of rising sea level at a rate of 2.11±0.14 mm/year, with large residual variability superimposed.

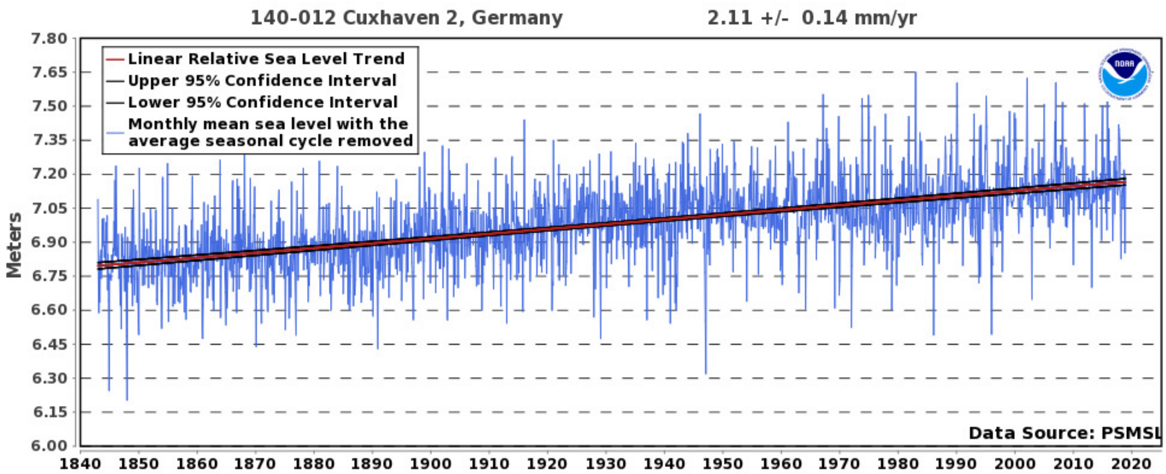

Figure 4: Relative Sea Level Trend for Cuxhaven, Germany.
https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=140-012

Figure 5 shows moving 50-year trends from this station over the full record. Clearly, there is much variability even on this timescale, with a quasi-periodicity of 60–70 years.

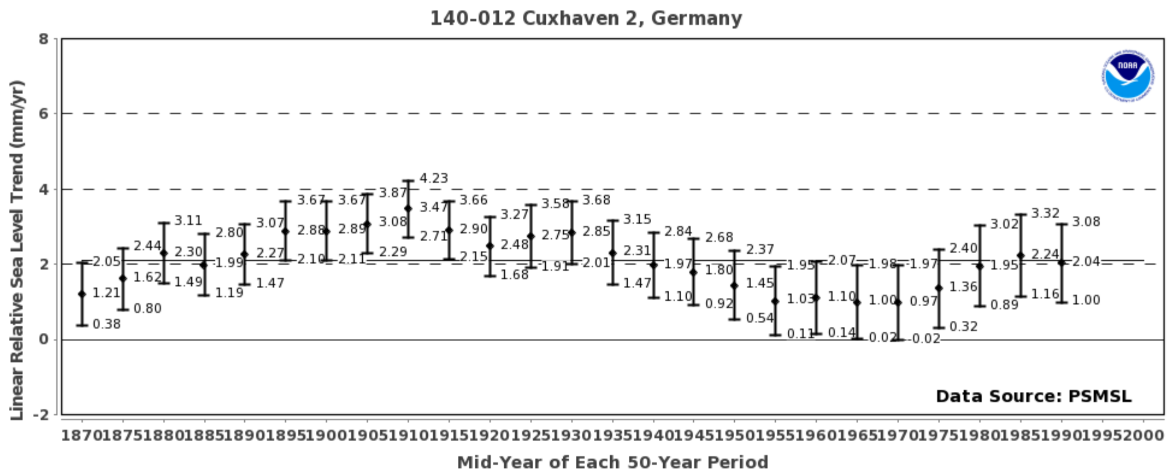

Figure 5: Variation of 50-year Relative Sea Level Trends for Cuxhaven.
https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=140-012

The Dublin Port tide gauge has too short a record to have been included by NOAA among the European tide gauges with variation of 50-year sea level trends such as shown in Figures 4 and 5, but the pattern of longer-term trends in Dublin should not be expected to differ greatly from that of other tide gauges located at the eastern side of the North Atlantic. The inter-annual variability of mean sea level along the European coastline is known to be coherent (having a constant phase relationship).

The European results given above reinforce our conclusion that short-term sea level trends in Dublin, which show extreme variations, should not be regarded as a suitable basis for longer-term planning. Even a 50-year trend for Dublin is unreliable for projection into the future, because stations with longer records show that 50-year trends are quasi-periodic with 60-70 year periodicities. These limitations hold true even if the measurements themselves are accurate.

4. SEA LEVEL RISE AND EXTREME WEATHER EVENTS

The DCC Plan places much emphasis on a claimed increase in the occurrence of extreme weather events. This is linked with sea level rise and an increased risk of flooding, as in the sentence "The slow, gradual increase in temperatures and sea level rise will contribute to the increased frequency and intensity of extreme weather events and flooding." (p. 29).

Neither meteorological theory nor empirical evidence support a link between anthropogenic global warming and an increase in extreme weather events such as suggested in the DCC Plan. Dynamic meteorology informs us that the main energy source for storms in middle latitudes is the horizontal temperature gradient between equator and pole. As global warming increases, the temperature gradient in northern middle latitudes decreases, because the Arctic warms faster than latitudes to the south. Therefore, there is less available potential energy to cause mid-latitude storminess.

The winter of 2013-2014 was held to be the stormiest on record for Ireland and the UK (Matthews et al., 2014). However, a more recent review of storminess over the North Atlantic (Feser et al., 2015) suggests that decadal variability dominates for the last 100-150 years and that there is no evidence of a sustained long-term trend. Kelly (2016) states: "A survey of official weather sites and the scientific literature provides strong evidence that the first half of the 20th century had more extreme weather than the second half."

We present here some information, taken from our more detailed studies of the DCC Plan referred to earlier, on trends in wind speed and rainfall affecting Dublin.

(a) Wind Speed

An analysis of Met Éireann data reveals that storms in Ireland and Dublin are getting less frequent and less severe since records began. In the case of Dublin, Figure 6 illustrates that the maximum speeds in gusts at Dublin Airport have been decreasing at a rate of about 0.5 knots each decade since 1945.

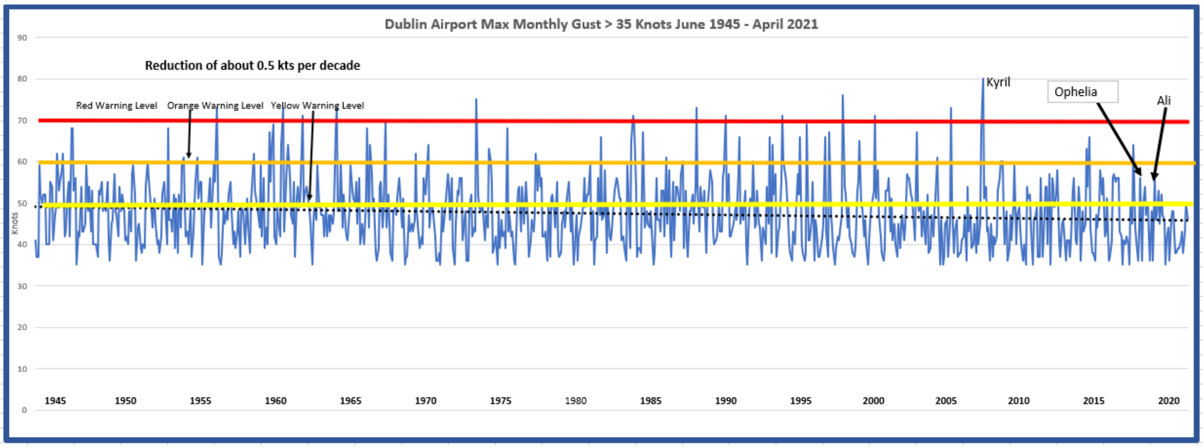

Figure 6: Dublin Airport maximum monthly gust > 35 in knots from June 1945 to April 2021. The warning levels (Red: 70 knots. Orange: 60 knots. Yellow: 50 knots) are shown. There is a downward trend at the rate of about 0.5 knots per decade.

(b) Rainfall

In the case of rainfall events, it is reasonable to assume that the maximum flow of the Liffey would be a good indicator of rainfall trends in the catchment. Figure 7 shows the maximum annual flow rate at Leixlip over the past 20 years. This is seen to have been decreasing, at a rate of about 10 m^3/s per decade (OPW data, waterlevel.ie).

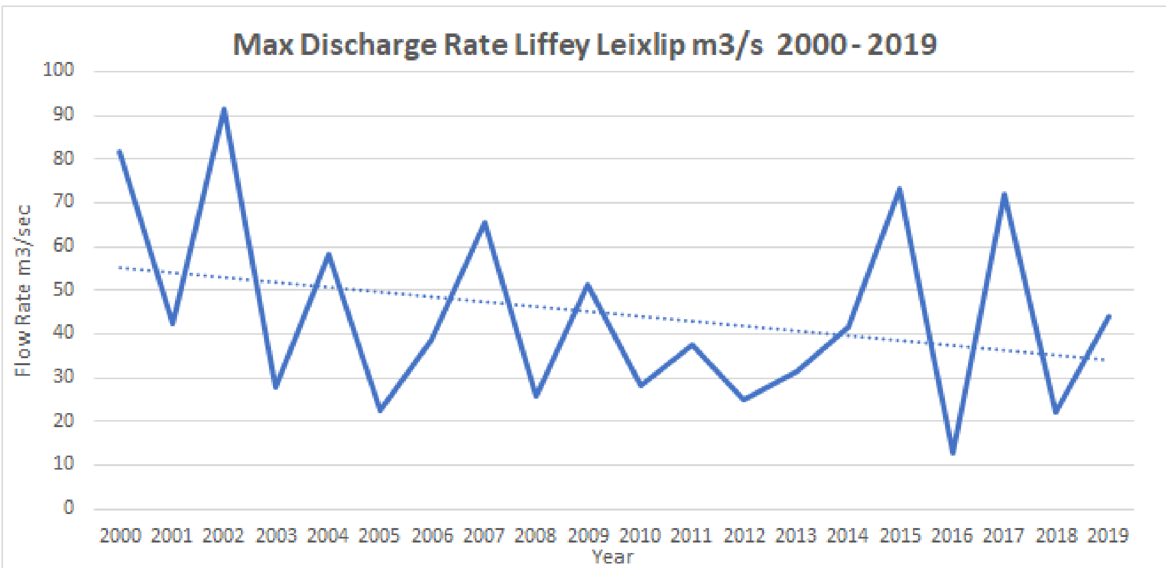

Figure 7: Annual maximum discharge rate of the Liffey at Leixlip, 2000-2019.

5. CONCLUSIONS

Dublin City Council's Climate Change Action Plan 2019-2024 states that the current rate of sea level rise in Dublin is 6-7 mm/year while the global mean rate of rise is 3-4 mm/year. This information is provided without appropriate context. The DCC Plan does not mention that sea level rise, both globally and in Dublin, shows strong multi-decadal variability, present rates of rise having been equalled by, exceeded by or being of opposite sign to rates in the recent past. Nor does the DCC Plan mention that the current period of global mean sea level rise began around 1850, long before atmospheric greenhouse gas increase became significant.

Consideration of the following details is important to gain a realistic perspective.

- Globally, a recent NASA-led study has led to a downward revision of the linear trend of global mean sea level rise over the 20th century to 1.4 mm/year. The linear trend since 1993 as given by both satellite altimetry and reconstructed tide gauge measurements considerably exceeds this, being 3.3 mm/year, but this recent value is not unprecedented, having been equalled in the period 1934-1953.

- In Dublin, sea level rise over the full measurement period 1938-2015 had a linear trend of 1.67 mm/yr. The current 16-year trend greatly exceeds this value, but multi-decadal variability in Dublin is so marked that in the 16-year period 1966-1981 there was a falling trend of -5.79 mm/year. Forward projection using trends over short periods does not provide a reliable guide to the future. The DCC Plan refers to a projected sea level rise of 6m. Such a figure is not realistic in the context of contemporary circumstances.
- In relation to the consequences of sea level rise, the DCC Plan places a marked emphasis on a claimed increase in the occurrence of extreme weather events. This claimed increase is not in accord with the evidence presented here. For example, in the last 76 years at Dublin Airport, the strengths of gusts over 35 knots have been decreasing.
- To broaden the context of Dublin sea level trends, we have provided an example of a European station with a much longer record, i.e., Cuxhaven, Germany. The data for this station confirm that trends over short periods are very volatile. Even 50-year trends are not reliable for making projections because they have quasi-periodic variations with periods of 60-70 years. The long-term sea level trend for Cuxhaven over the period 1843-2018 is 2.11 mm/year.

Overall it is clear that flood defence planning should not be based on short term trends such as those reported for Dublin over the past couple of decades.

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