Executive Summary

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Ireland's climate is changing. This is consistent with regional and global trends which display rapid changes in many aspects of climate over the last century and the first decade of this century. The availability of high-quality climate observations is a critical starting point from which an understanding of past and emerging trends in the current climate can be developed. Such observations are vital for detecting change and providing the information needed to help manage and plan for the future in a wide range of socio-economic sectors.

Observations are also essential to help build robust projections of future climate, which can in turn inform policy formulation for appropriate mitigation and adaptation measures. Such measures should help us limit the negative socio-economic impacts and position us to take advantages of opportunities offered by a changing climate.

This report brings together observational information and data for over 40 climate variables and highlights changes and trends in aspects of Irish climate across the atmospheric, oceanic and terrestrial domains. The observations presented in this report contribute to the formulation of the Essential Climate Variables (ECVs) as defined by the Global Climate Observing System (GCOS). The key findings in relation to Ireland's climate are:

Atmosphere

- Mean annual surface air temperature has increased by approximately 0.8°C over the last 110 years. The number of annual frost days has decreased whilst the number of warm days has increased.
- Average annual national rainfall has increased by approximately 60 mm or 5% in the period 1981 to 2010, compared to the 30-year period 1961 to 1990. However, clear changes in rainfall spatial patterns across the country cannot be determined with a high level of confidence.
- Current carbon dioxide (CO_2) concentrations of more than 390 ppm as measured at Mace Head, Co. Galway are in line with observations from around the globe and are higher than at any time over the last 400 thousand years.
- Concentrations of other greenhouse gases including methane (CH_4) and nitrous oxide (N_2O) are approximately 140% and 20% respectively above pre-industrial values and concentrations continue to increase.
- No long-term trend in wind speed can be determined with confidence.

Oceans

- Mean annual sea surface temperature, as measured at Malin Head, Co. Donegal, is now more than 1.0°C higher than the long-term average calculated for the period 1961–1990.
- Global surface ocean acidity has increased by over 30% since the Industrial Revolution. Observations in sub-surface and deep offshore waters around Ireland between 1991 and 2010 show significant increases in acidity.
- Historically, sea level has not been measured with the necessary accuracy to determine sea-level changes around Ireland. This represents a key gap in the Irish observation system. However, measurements from Newlyn, in southwest England, show a sea-level rise of 1.7 cm per decade since 1916. These measurements are considered to be representative of the situation to the south of Ireland.

- Since 2000, the occurrence of some potentially harmful ocean phytoplankton species during the winter months has increased.

Terrestrial

- One of the major land-use changes across Ireland since 1990 has been the conversion of grassland and peatland to forest. This expansion of forest area has seen the amount of carbon stored or sequestered in forest increase by 40%.
- It is estimated that Ireland's soil carbon stock has decreased by 27 million tonnes between 1990 and 2000. This is mainly due to changes in the management of peatland, including drainage and peat extraction and to a lesser extent to changes in patterns of agricultural land use and urban development.
- Observations of the timing of bud-burst for a number of tree species at the phenological gardens indicate that the beginning of the growing season (BGS) is now occurring more than a week earlier than in the 1970s, leading to an extension of the growing season. Such changes have been linked to a rise in average spring air temperature.
- Analysis of long-term river flows from over 40 measurement sites around the country shows a tendency for increasing annual mean flows. Moreover, seasonal analysis indicates that summer mean flows are dominated by increasing trends while there is a tendency also for increases in winter mean flows.

Observational Infrastructure

Many elements of Ireland's climate observation infrastructure are robust – however, there are a number of gaps and areas where improvements are necessary. The network of synoptic, climatological and rainfall stations operated by Met Éireann needs to be maintained and further developed to ensure the future of long-term, representative measurements. The Mace Head Research station, operated by the National University of Ireland Galway, has become a global reference site for the observation of a number of atmospheric composition variables. Nonetheless, many of its observation programmes are funded on an ad hoc basis via projects, and the long-term availability of funding to maintain them is not assured.

There has been a significant growth and consolidation of ocean-observing systems since 2000, which is proving invaluable in improving understanding of ocean climate. It is vital that these systems are maintained and where possible enhanced to increase the number and quality of the measurements made. Only with long time-series will it be possible to detect trends in the ocean-climate variables and assist in making appropriate adaptation decisions. Ocean acidification is of growing international concern. There is a need for a long-term national commitment to monitoring the ocean carbonate system and ocean acidity in order to improve understanding of its potential impact on the Irish marine environment and economy.

A number of the land surface and hydrological variables have been monitored by various organisations for many years in support of policy and management objectives (e.g. water supply, land use). There is a need to ensure that these observations also contribute to long-term monitoring for climate purposes.

At least a dozen organisations have a role to play in monitoring aspects of Ireland's climate. It is vital that long-term monitoring is coordinated between these different bodies to avoid duplication and to maximise possibilities for synergy.

Systematic collection and management of climate data are essential. However, regular analyses and the reporting of status, trends and projections are also required. Long time-series, many in excess of 50 years, exist for a number of the meteorological and hydrological variables, yet only partial analyses have been carried out. Furthermore, observations of many of the land-surface variables have been made by satellite for a number of decades, but limited analyses of these have been completed for Ireland.

Opportunities and Recommendations

As an island on the western margins of Europe facing the Atlantic Ocean, Ireland is in a unique location for climate monitoring. It is recognised internationally as an ideal site for baseline atmospheric and oceanic observations. Ireland can capitalise on this and

contribute to developing improved environmental sensors, data transmission, storage, management and analysis solutions. These can be prototyped, tested and refined in the living laboratory offered by the Irish environment. Such developments would also contribute to the enhancement of the GCOS to which Ireland contributes as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC).

This report demonstrates that many elements of a climate observation, analysis and reporting system are in place, nonetheless there are a number of issues that need to be addressed in order to make it more robust and capable of addressing the country's long-term needs with regard to climate monitoring and understanding. The following recommendations are made as a result of this study:

1. A structure or body is required to enhance coordination between organisations carrying out atmospheric, oceanic and terrestrial climate observations to ensure an integrated national approach and efficient utilisation of resources.
2. Observation programmes for some of the ECVs are well established (e.g. meteorological). Other ECV observations are carried out on a project or ad hoc basis (e.g. atmospheric composition, oceanic). It is vital that adequate resources are provided to: (i) maintain existing, established climate-observation programmes and (ii) guarantee the long-term continuity of project-based monitoring to international standards.
3. No long-term national observation programmes exist for a number of the ECVs (ocean acidification, pCO_2, ocean currents, phytoplankton, soil carbon, fire disturbance, water use). A prioritisation and costing exercise should be carried out with a view to implementing appropriate programmes over time.
4. Some variables are monitored under various operational and management programmes (e.g. river flows and lake levels as part of the Water Framework Directive; sea state for ocean weather forecasting) but not for climate purposes. Appropriate long-term climate observation sites should be identified and designated from among current observation sites.
5. Ensure data from the Irish National Tide Gauge Network established over the last decade by the Marine Institute and a number of public and private sector organisations can be used for the calculation of sea-level change. Provide analyses of these data with historical records from established, reliable tide gauges and link these to regional satellite-derived information on sea-level change.
6. Safeguard all existing and historical ECV data, complete digitisation of paper records (e.g. air temperature, precipitation and wind) and carry out quality checks and homogenisation of these data to ensure their adequacy for climate monitoring.
7. Comprehensive analysis has been carried out for the atmospheric composition and some of the meteorological and oceanic ECVs. However, only partial analyses have been completed for the majority of the other ECVs. Complete and regular detailed analysis should be carried out and reported on all ECV observations, including satellite data records where appropriate.

Conclusions

This analysis of Ireland's ECVs demonstrates that Ireland's climate is changing. These changes are consistent with regional and global trends, but local patterns of change are evident. It is essential that Ireland's climate observation system is maintained and enhanced in order to have the information required to understand these changes to enable planning for appropriate adaptation. This report makes a number of recommendations as to how Ireland's climate observation system can be improved in order to meet these needs.