Regional Climate Modelling for Ireland using a Representative Carbon Pathways Approach

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A key limitation of Global Climate Models (GCM's) is the fairly coarse horizontal resolution, typically 3.75^{o} by 2.5^{o} (500 km x 300 km). For practical planning, countries require information on a much smaller scale than GCM's are able to provide. One of the solutions is to dynamically downscale the output from the GCM using a Regional Climate Model (RCM).

Climate and forecasting applications share a common ancestry and also build on the same physical principles. Nevertheless, climate research and forecasting are commonly seen as different applications. The concept of "seamless prediction" (cf. WCRP) is emerging to forge forecasting and climate change into a joint topic.

The need for an Earth System model is recognized by various ECMWF Member States (MS). A consortium with representatives from 11 MS is formed in which the seasonal forecast system of ECMWF (system 3) is developed into an earth system model. The project, which is named EC-EARTH, has a general objective to develop a global Earth System model consisting of the: European Centre for Medium Range Weather Forecasts (ECMWF) atmospheric general circulation model, the Nucleus for European Modelling of the Ocean (NEMO) developed by the institute Pierre Simon Laplace (IPSL) as the ocean component, a sea-ice model, a land model, and an atmospheric chemistry model (see http://ecearth.knmi.nl).

The aim of this work is to provide dynamically downscaled RCM output data for use in other disciplines such as: biodiversity mapping, forestry pest and disease control, water resource management etc. and to use the output of the most up to date (2012) CMIP5 European Global Climate Model, 'EC-EARTH'.

Met-Eireann the Irish Meteorological Service, which is a member of the EC_EARTH consortium and ICHEC, the Irish Centre for High End Computing have provided us with the Representative Carbon Pathway (RCP) EC_EARTH output data. This has been dynamically downscaled to a scale more useful to the local environment (10km x 10km) through the use of a Regional Climate Model (RCM). The model is the Weather Research Forecasting Model (WRFV3.1.1).

In the past GCM's have relied upon hypothetical scenarios, Special Report on Emission Scenarios (SRES) based on four future predictions of world development: A1, A2, B1, B2. The SRES scenarios, however, do not encompass the full range of possible futures: emissions may change less than the scenarios imply, or they could change more? Current thinking within the Intergovernmental Panel on Climate Change (IPCC) has resulted in a new approach to scenarios: choosing a handful of emission trajectories, known as Representative Carbon Pathways (RCP's). The RCP's then became the basis for a series of new climate runs in the latest climate models, such as the EC-EARTH GCM. The new choice of scenarios has five emission trajectories to focus on and have labeled them based on how much heating they produce at the end of the 21st century – Four future runs (2005 -2100): 8.5, 6, 4.5 and 2.6 watts per meter squared (Wm^2) and an Historical run (1870-2005). At the high end, by the end of the 21st century in the case of the 8.5 Wm^2 RCP, carbon dioxide levels rise to 1,300 parts per million.

The present research has sought to dynamically downscale the Historical (RCP) output from the EC-EARTH GCM for the period 1961 – 1990 for Ireland and the UK. As all models (regional and global) suffer from systematic error, climate change is evaluated by comparing the future simulations against the same models run in the current climate (i.e. over a reference period). The period 1961-1990 is usually taken as the reference and is used here as the climatological baseline for the 8.5 (Wm^2) RCP 2041-2100 future predictions. This was carried out using The National Center for Atmospheric Research (NCAR's) Weather Research and Forecasting Model (WRFV3.1.1) as a regional climate model (RCM).

Model Description and Details

The version of WRFV3.1.1 used in this research encompassed the modification by CLWRF *SantanderMetGroup* (Fernandez et al.,(2011). The 1961-1990 and 2041-2100 simulations utilized in the research used one domain with a 10km x 10km grid space with 28 vertical and 4 soil levels. The initial fields were obtained from the EC-EARTH ECMWF model and used for the lateral boundary conditions.

Precipitation processes on the grid scale are represented by the explicit moisture scheme WRF Single-Moment Class 3 (WSM3) following Hong et al.,(2004). A major difference from other approaches is the diagnostic relationship for ice number concentrations that is based on ice mass content rather than temperature. Deep moisture convection is represented in the model by the Kain-Frisch parameterization (Kain and Fritsch

1993). The scheme removes Convective Available Potential Energy (CAPE) which is calculated using the traditional, parcel-ascent method through vertical reorganization of mass.

Cumulus parameterizations are theoretically valid for coarser grid scales (e.g. greater than 10km), where they are necessary to properly release latent heat on realistic time scales in the convective columns. In this research release times between cumulus physics calls are set to 5 minutes.

The Land-Surface model Noah LSM was developed by jointly by NCAR and NCEP, and is used in the operational North American Mesoscale Model (NAM). This is a 4-layer soil temperature and moisture model with canopy moisture and snow cover prediction. The scheme provides sensible and latent heat fluxes to the boundary-layer scheme Yonsei University (YSU) PBL (Hong et al., 2006).

The YSU scheme has an explicit treatment of the entrainment layer at the top of the Planetary Boundary Layer and is responsible for vertical sub-grid-scale fluxes due to eddy transport in the whole atmospheric column, not just the boundary layer. YSU PBL produces a well-mixed boundary-layer profile. Sea surface temperature are based on the initial analysis fields provided in the EC-EARTH GCM and are updated within the analysis fields provided by NEMO to the EC-EARTH model. Both short and longwave-radiative effects are accounted for where clouds are explicitly represented in the model. Surface radiative fluxes are provided by the RRTM and Dudhia schemes, (Dudhia 1989).

Results.

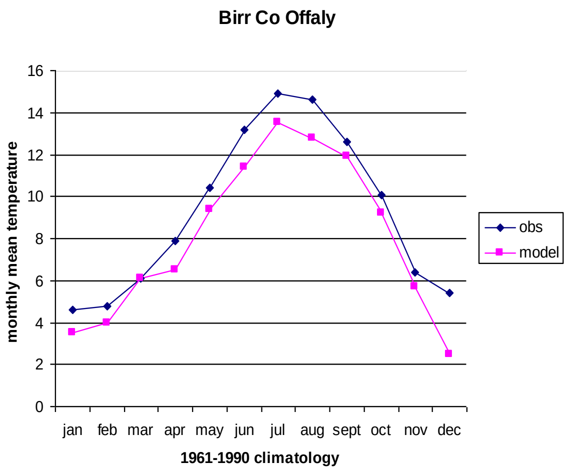

Figure 1. This is a comparison between observed mean temperature at Birr Co Offaly Ireland (1961-1990) and EC_EARTH – CLWRF modelled 1961-1990 mean temperature for the same location.

The model shows greater bias from observed temperatures in summer (JJA) than either spring (AMJ) or autumn (SON). Similar biases have been observed in WRFV3.1.1 results by members of the modelling community in Ireland (Mooney et al. Poster Presentation NCAR Tutorial 2011). They observed that WSM5 together with LSM parameterization produced less bias in the summer period than WSM3 micro-physics scheme. Whilst Birr is close to the centre of Ireland, other observing stations close to the west coast Valentia and Belmullet show similar biases in the summer period. The conclusion being that the present parameterization schemes within the model results in the model having a 2^0 degree cool bias in the summer months, over the 1961-1990 period and a 1^0 to 1.5^0 cool bias in spring and autumn. Spatially there appears to be a good degree of correlation between the observed and model output.

Future 2041-2070 Mean Temperature Divergence from 1961-1990 Monthly T2mean

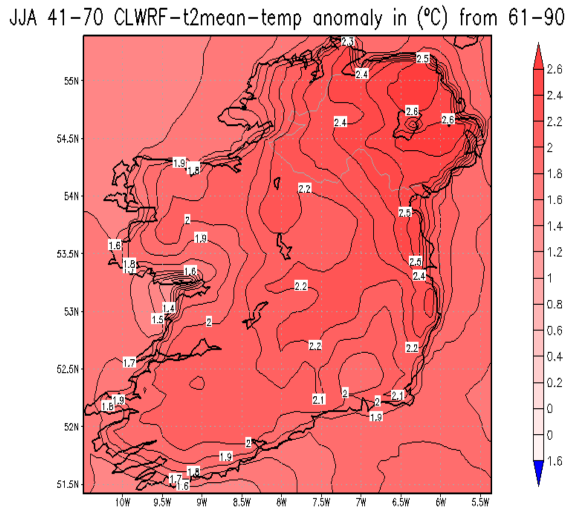

Figure 2. This is the 30 year CLWRF t2mean temperature anomaly 2041–2070 minus the CLWRF 1961-1990 temperature climatology for Ireland.

Figure 2 shows a marked positive temperature differential between the north-east and south-west of Ireland between 2.6° and 1.8°C for the 30 years 2041-2070, relative to the 1961-1990 temperature climatology. An increase of this magnitude would result in summer temperatures at Birr Co Offaly experiencing mean temperatures during the mid-century of 17°C, an increase of 2.1°C.

Previous Modelling using ECHAM-5 C4i Data.

Previous modelling was undertaken by the Met-Eireann modelling group C4i using ECHAM-5 GCM data and RCA3 regional climate model. This focused on simulations of 1961-2000 and 2021-2100 using ECHAM5 A2 emission scenarios.

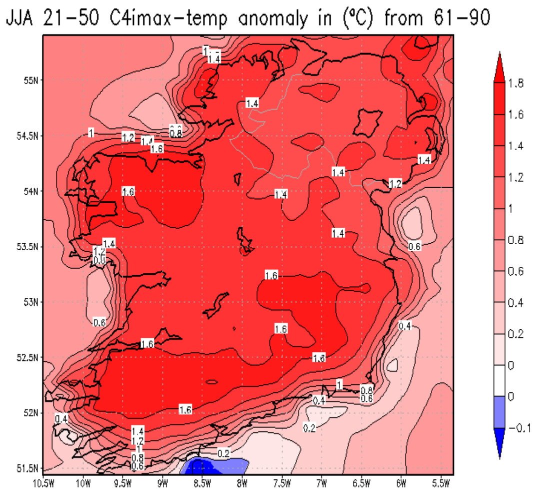

Figure 3. 30 years 2021-2050 ECHAM5 and C4i RCA3 output minus the current 40 year RCA3 1961-2000 temperature anomalies. See http://www.c4i.ie .

As can be seen, the mid-century climate is warming, particularly in the summer and also in the autumn (1.2°-1.6°C) with further increases up to 3.4° C towards the end of the century (not shown). The warming is greatest in the south and east of the country. As compared with figure 2, the spatial distribution is south and east whereas figure 2 mid-century warming is from north-east to south west and of a greater magnitude (reflecting the difference between the A2 SRES scenario and 8.5 Wm^2 RCPs).

Changing Climate: Consequences for Irish Forestry.

Forestry is an important commodity for Ireland's economy. Considerable investment has been made not only by the Irish state body Coillte but also by many small private investors. Forestry also plays a large part in Ireland meeting its commitments under the Koyoto agreement. Therefore, it is vital that forests are protected and well managed. It is important that pests and disease which threaten to destroy forestry are understood and measures taken to combat them. Understanding how temperatures and precipitation will change in the future is a key element to pest and disease control. One such pest is the Pine Weevil (*Hylobius Abietis).*

Figure 4. Hylobius Abietis (Pine Weevil).

This is the most damaging pest for young Irish conifer plantations. They feed on the bark of young trees and typically can kill 30%-100% of unprotected new plantings. Activity starts in the early spring when temperatures reach 8-9°C and become very active at 13-16°C. The development process can accelerate if temperatures become warmer in the early spring and carry forward into autumn. Weevils can consume five times as much tree bark at 20°C than at 10°C, therefore climate variability is an important aspect of their life-cycle and ultimately the forests.

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