Climate, Climate Change Nuclear Power and the Alternatives

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PHYC 40050

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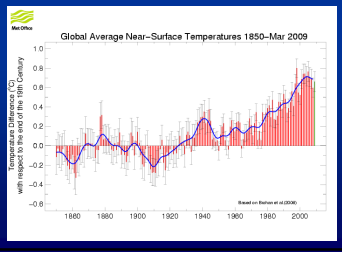
Lecture 8

Climate Change and Wind Energy

[Based in part on PhD work of Paul Nolan]
Supervisor: Peter Lynch

Overview

- Greenhouse gas emissions are having a significant effect on the Earth's climate.
- Globally, the 11 of the 12 warmest years on record were in the 1990s and 2000s.

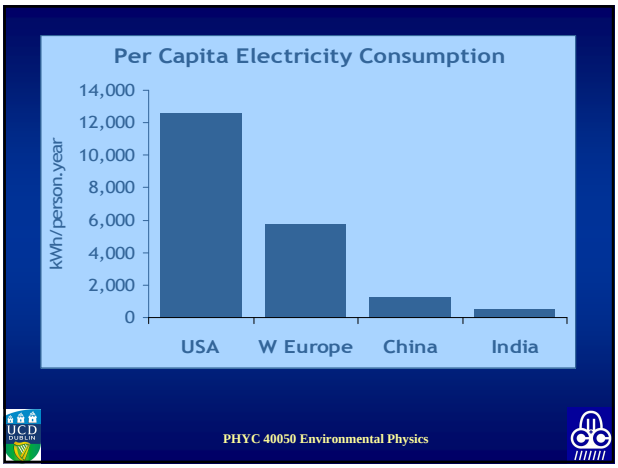


Overview

- Temperatures in Ireland have mirrored this global trend
- Changes in the wind climatology are expected
- New increased target of 40% of electricity from renewable resources by 2020
- It is vital to model the impact of climate change on future wind patterns over Ireland.

Wind Energy – the next 50 years

- 50 year world outlook: context population stablized or declining, oil and gas running out, coal restricted, nuclear?
- Nearer term oil limited to transport sector
- Global energy demand and resources of renewables available.



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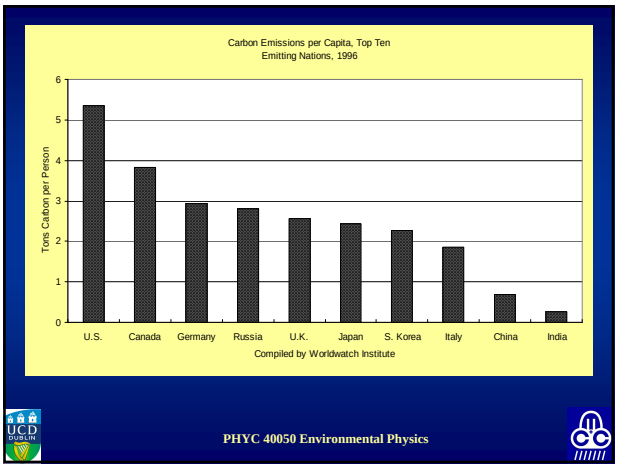

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ESTIMATED LAND WIND RESOURCES

The world's wind resources are about 53,000 TWh/year.

- Australia *3,000*
- North America *14,000*
- Latin America *5,400*
- Western Europe *4,800*
- Eastern Europe and former Soviet Union *10,600*
- Rest of Asia *4,600*
- Africa *10,600*

Ref: Windforce 12 Greenpeace
Source: Wind resources from Michael Grubb and Niels Meyer, 1994

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Onshore Wind Farm

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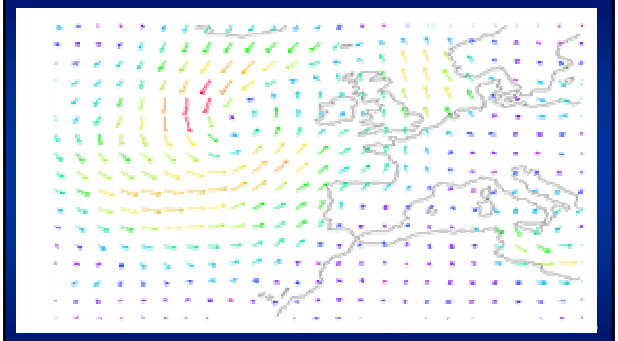
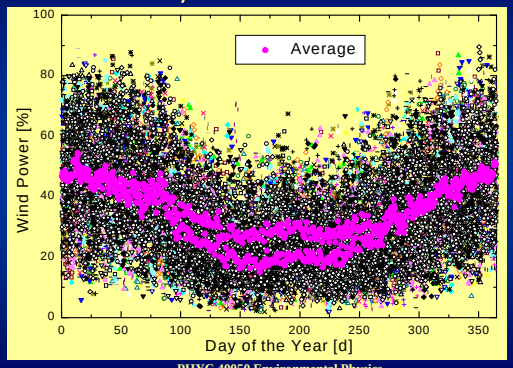
Typical wind field over Europe

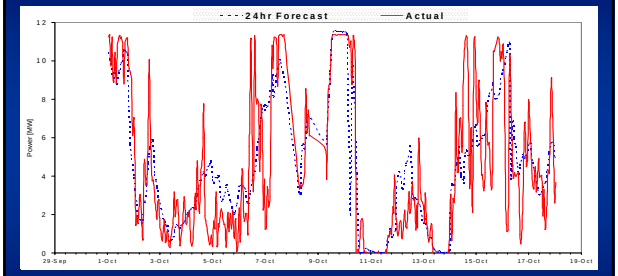


European average wind power generation between 1965 and 1998, over 60 well-distributed sites



Ref: G.Giebel

Typical 24 hour Forecast



The Wind Supergrid

Wind versus Nuclear Costs

Wind On land:
Range 30 euro[1] to 80 euro[2] per MWh

Wind Offshore:
Range 90 euro[3] to 110 euro per MWh

Nuclear
43 euro[4] and 54.3 euro[5] per MWh

Stern Review: 58 to 52 euro
Sustainable Development Commission, UK: 33.9 to 51.6 euro

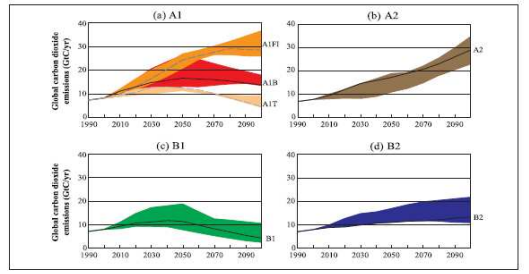
References
1. Airtricity US
2. Germany July 2006
3. Current North Sea
4. UK Energy Review July 2006 Nuclear Cost Benefit
5. UK Energy Review Synthesis of Cost Benefit Analysis

Modelling the Winds

- The impact of greenhouse gases on climate change can be simulated using Global Climate Models
- The typical resolution of Global models is 50km or greater

- We are using a Regional Climate Model (RCM) to dynamically downscale the coarse information from the global models.

The IPCC Green house Gas Emission Scenarios

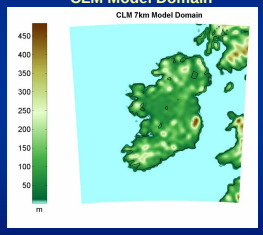


Total global annual CO2 emissions from all sources from 1990 to 2100 (in gigatonnes of carbon (GtC/yr))

CLM Experiment Setup

- 90*94 grid boxes → resolution of 7 km
- Global → CLM 18km → CLM 7km
- Wind fields output every hr
- 32 vertical levels
- Validation run:
  ERA-40; 1981-2000
- Future Projections:
  ECHAM 2021-2060 A1B

CLM Model Domain

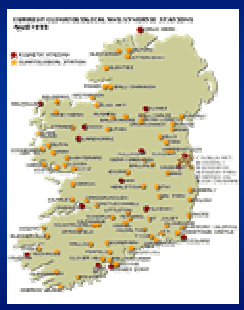


CLM Setup

- The CLM 7km simulations were run on the 'Stokes' Linux cluster at the Irish Centre for High-End Computing (ICHEC)
- Each compute node has two Intel Xeon E5462 quad-core processors and 16GB of RAM.
- See http://www.ichec.ie

Validation of the CLM Regional Climate Model

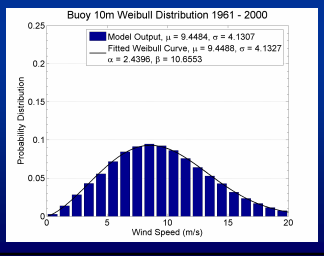
- The CLM was validated by performing a 20-year climate simulation (1981-2000)
- ERA-40 and ECHAM5 boundary data were used
- We compared the results with observations and ERA-40 data



Weibull Distribution

- At each grid point *(i,j)* we fit a Weibull distribution

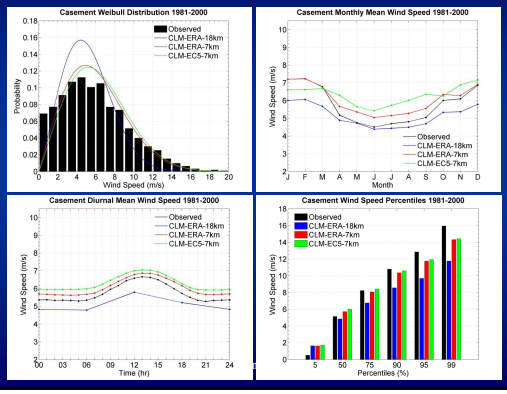
$$W(x) = \alpha\beta^{-\alpha}x^{\alpha-1}e^{-\left(\frac{x}{\beta}\right)^{\alpha}} \quad for\ x \in [0,\infty), \alpha, \beta > 0$$



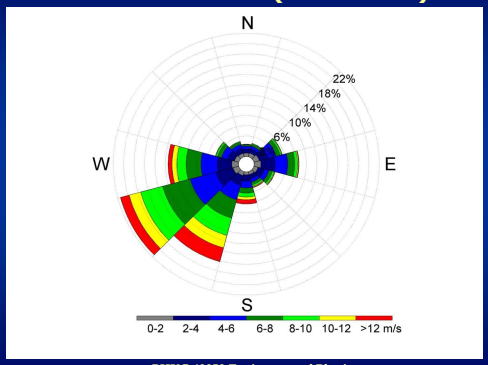
Birr Observatory:

Buoy 60km West of Galway

CLM Validation at Casement Station (1981-2000)



Observed Wind Rose at Casement Station (1981-2000)



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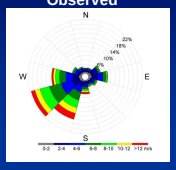
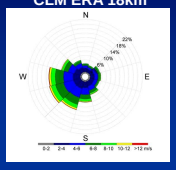
Location of Casement Station

CLM Validation at Casement Station (1981-2000)

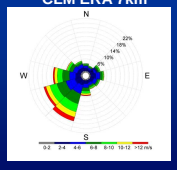
Observed



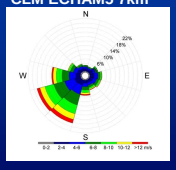
CLM ERA 18km



CLM ERA 7km



CLM ECHAM5 7km



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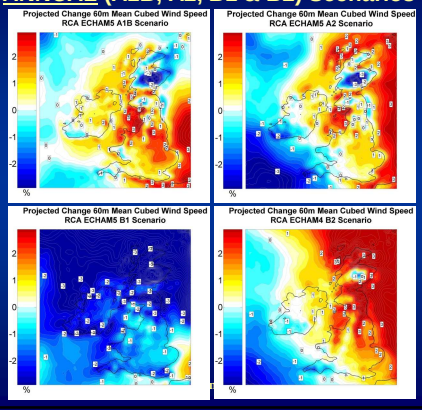
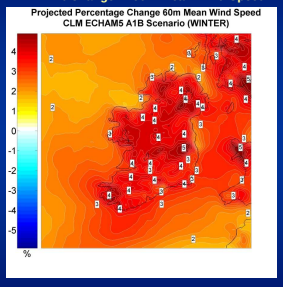
RCA Future Climate Projections 2021-2060 *ANNUAL* (A1B, A2, B1 & B2) Scenarios

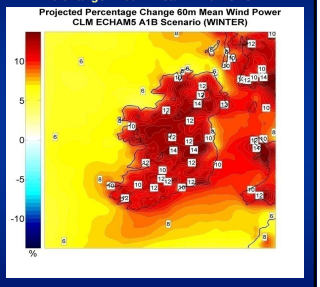


CLM Future Climate Projections *Winter* A1B Scenario (2021 – 2060)

% Change in 60m Mean Wind Speed



% Change in 60m Mean Wind Power



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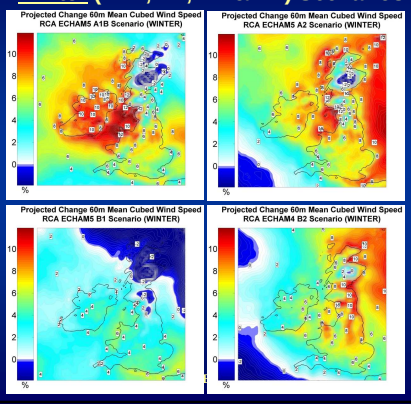
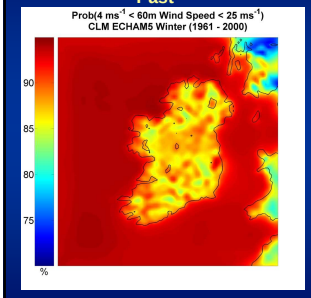
RCA Future Climate Projections 2021-2060 *Winter* (A1B, A2, B1 & B2) Scenarios

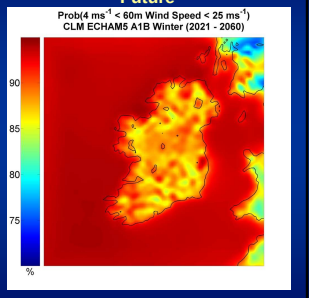


CLM A1B Scenario Winter Projections: Probability of wind speeds between 4m/s and 25m/s

Past

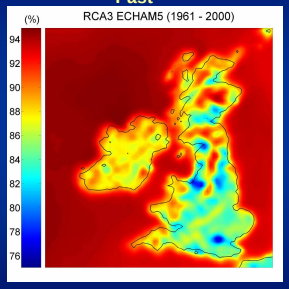


Future

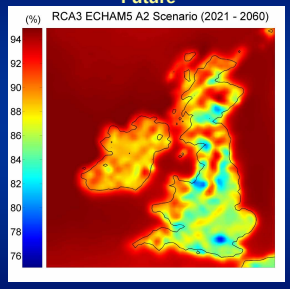


RCA A2 Scenario Winter Projections: Probability of wind speeds between 4m/s and 25m/s

Past



Future



Summary & Conclusions

- The method of Regional Climate Modelling was used to simulate the wind climatology of Ireland at high spatial resolution.
- The models were validated by performing past simulations of the Irish climate and comparing the results to observations.
- Projections for the future Irish climate were generated by downscaling for a reference period 1961-2000 and future period 2021-2060
- Results show an overall increase in mean wind speeds for the future winter months and a decrease during the summer months.
- The projected changes for summer and winter were found to be statistically significant over most of Ireland.

End of Lecture 8