Speech at the Dinner of the annual conference of the Institution of Civil Engineers (ICE)

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It is an honour and a pleasure to address the dinner of the annual conference at Cambridge; particularly since I am grateful to I.C.E. for the scholarship they awarded me in 1960 when I was an undergraduate reading Engineering at Trinity College Cambridge. During my professional career in research and consulting, I worked with Civil Engineers over many years on problems of wind loads on structures, and all aspects of wind engineering. There have been great advances since the 1960's in the collaboration between wind engineers and structural engineers. The lack of mutual understanding was indicated by structural designers asking aerodynamicists for the 'equivalent steady load'. I recall on one exasperating occasion explaining that even a mouse (in the days before computers) could in principle destroy a resonant structure if it pushed at the right frequency! Some of you may have heard the story of the collapse in 80 mph winds of the Ferrybridge Cooling Towers. Their thickness relative to the diameter was less than that of an eggshell to an egg. As the resonant oscillation steadily amplified - during the notorious tea-break in November 1965 - when three of them actually collapsed, an observant Yorkshireman described them as 'going like a belly dancer!'

Although I have spent part of my career in energy research, mostly I have focussed on environmental issues starting on the scale of buildings, cities and mountains. Thanks to my period at the Met Office I eventually reached the global scale problems of climate change, a major theme of this conference and of my remarks this evening.

One wonders whether the great engineers who built the reputation of the ICE, such as Stephenson, Telford and Brunel, who wanted to harness and control the 'great forces of nature', ever imagined that by human action these enormous forces would one day be significantly affected by technology and other human activities. In fact even by the mid 1800's, Tyndall and Arrehius argued that human emissions of CO_2 could affect the atmosphere even though it makes up $1/4$ of $1/10$ % of the gases of the atmosphere. They and others predicted that, partly by looking at other planets, the increase of CO_2 could lead to significant temperature rises. My great grandfather attended Tyndall's lectures at the Royal School of Mines. Those ideas were further quantified and by scientists including the great Russian geophysicist Budyko - which is ironic given the scepticism of the Russian academic, official and governmental circles we see today.

Predicting climate changes caused by small anthropogenic emissions is immensely complex, involving delicate feedback processes affecting the whole ocean-atmosphere system. There is persuasive quantitative evidence that predictions of weather and climate on all time scales, including waves and currents in the ocean, are improving with the aid of numerical models; large Teraflop computers and huge volumes of measurement data, especially from satellites ($>10^7$/day). The first person to work out a practical scheme for numerical weather forecasts was Lewis Fry Richardson (who studied Natural Sciences here at King's College but developed numerical methods at University College London under the statistician Karl Pearson). Olec Zienkiewicz, our most distinguished colleague, always refers to LFR's 1910 paper in the Royal Society Transactions on the Aswan Dam as the basis for his great development of finite element method for structural engineering. Last Saturday (July 17) we celebrated 100 years since the establishment of the observatory at Eskdalemuir in the Scottish lowlands where LFR was superintendent from 1913 to 1916. It was there in the 'bleak and humid solitude' that he developed his method - published in 1922. In terms of accuracy the method then was a great failure as were many of the early numerical codes in solid mechanics. But perseverance and the arrival of electronic computers via the USA revolutionised our business.

On the short term 3 day forecasts are now as good as 1 day forecasts 20 years ago. I am well aware that civil engineers, especially those dealing with coastal and offshore structures, keenly appreciate that the average error for predicting a tropical cyclone or hurricane or typhoon has greatly improved. It is now 130 km over 24 hrs. It was 220 km in 1991. The accuracy of seasonal forecasts for the climate over the next 3 to 6 months is quite dependent on the part of the world for which they are made. But a combination of computer and statistical methods does provide real skill, e.g. last summer's extreme heat on the continent was forecast two months in advance.

As for climate change, over the last ten years our models are beginning to consistently simulate some of the variability of past and present climates, (e.g. both extremes and decadal changes) and also to show the sensitivity of the climate to natural perturbations. Some of these may be relatively weak like CO_2 and aerosols, but they have a significant impact, such as volcanoes, solar variability. Understanding these natural experiments, such as the cooling following the Mt. Pinatubo eruption gives confidence about predictions for human influenced effects. For good summaries of the present state of knowledge for engineers and decision makers I strongly recommend two very recent reviews issued this year by the Association of British Insurers and Benfield Hazard Research Centre at UCL. What do we find? Rising temperatures on land, 5^o-8^o in some areas, with more peak temperatures, especially high in

Russia, mid US, Brazil, China. These episodes will lead to human distress, especially in urban areas where the heat island affect reduces the normal cooling in the evening. This led in 2003 to thousands of deaths, especially of elderly people in France, Spain and to a lesser extend the UK. In some situations great heat may coincide with inversion conditions and high air pollution - as in Athens a few years ago. Engineers together with architects, scientists and politicians need to be involved in designing every aspect of our future cities. Concern is also increasing about the reduction in agricultural productivity in a warmer world providing ever more water may not be the solution. There are real concerns that the Asian monsoon is beginning to change. I heard from an engineer in Sri Lanka how the increasing temperature necessitates new tarmac for roads. In Arctic areas melting of the permafrost is likely to lead to the large release of methane which has an effect on global warming 20 times more than that of CO_2. Some estimates have been made that this could raise temperatures by a further 2^oC.

With higher temperatures the oceans are expanding and sea level around our coasts are rising. At the same time there is increasing evidence that the strength of westerly winds and the amplitude of ocean waves are both increasing. These have serious consequences for coastal flooding and perhaps the permanent aquatification of parts of the East of England. Furthermore the extremes of rainfall are becoming greater and more tropical in their nature. This will lead to inland flooding and in coastal areas a combined effect, which is always the greatest concern to the operators and designers of present and future Thames Barriers, emphasised by the reports of I.C.E. by Professor Flemming and by the Office of Science & Technology Foresight Initiative in 2004.

Perhaps in East Anglia and even Cambridge a more aquatic mode of life will reassert itself as it did before the Dutch engineers drained the fens in the 17th century. We could see a resurgence of water born tourism, more people living in water side housing developments, and habitation and expanded fresh/salt water fisheries. By contrast to the UK's pragmatic approach to sea level rise that will vary from place to place the Netherlands Parliament passed a law requiring their government to maintain their country's land area even if the sea level rises. This is probably not practical in the UK.

Some of the effects of climate change can be explained by the increased instability of the lower atmosphere and increased level of the tropopause. As John Mitchell, Chief Scientist at the Met Office, has pointed out, this explains intense rainfall and is one of the dynamical reasons why the 'shutting off' of the Gulf Stream is exceedingly unlikely. The Gulf Stream is partly drawn by the westerly winds and these are strengthening. This may also be connected to the observed changes in the Asian seasonal weather conditions with high rains over the Himalayas and droughts over the plains. Over Indonesia and Malaysia, as our I.C.E. Honorary Fellow in Malaysia reminded us this month when he commented on how the interaction of air pollution and climate change is particularly severe in this region, exacerbated by reduced monsoon winds and reduced rains that they normally bring with them.

Engineers have three special responsibilities at this time. Firstly developing really effective methods for mitigating climate change by reducing CO_2 emissions through extending and disseminating the remarkable energy efficiency and conservation programmes that began with the 1970's oil crisis and can still go much further; through renewable energy systems from the largest to the domestic scale using the latest technological developments; through nuclear power, while ensuring risk free waste disposal systems (the hybrid fusion-fission option should also be considered). Engineering institutions should press government to maintain focus on these technologies and development projects as much as on climate change research. This is the point made by the municipal governments which have been the most innovative in introducing mitigation technologies, namely Woking in the UK, Heidelberg in Germany and Toronto, Canada. I am Chairman of CERC Ltd based here in Cambridge, whose software systems for prediction/monitoring greenhouse gasses is now used by local authorities in the UK and abroad.

Secondly there are many opportunities for engineers to develop practical solutions for adaptation, by finding new models and systems for societies and individuals in the changed physical, human economic conditions of a changing climate, for example through appropriately designed buildings, transportation and cities, flood protection and aquatic infrastructure; through helping agriculture and dealing with weather extremes in a changing climate.

Thirdly engineers, because of their great practical experience and their measured approach to any changing situation are ideally placed to educate and explain to society about what needs to be done in practical terms about climate change. Engineering departments are now increasingly including lectures and exercises on sustainable development in their courses. They also need to keep talking to politicians, civil servants and the general public. Next year in 2005, when the UK holds the presidency of G8 and the European Union, the Prime Minister has placed climate change and African at the top of the agenda. I am sure that I.C.E. will seize this great opportunity for engineers to demonstrate their practical achievements and plans for the future. They could put over the message that dealing with climate change is not only both essential and feasible, but that everyone needs to be involved.