Global Climate Visualization for the Hadley Centre

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The Manchester Visualization Centre has for the past four years been working with the Hadley Centre for Climate Modelling to undertake all their requirements for visualization and computer animation. The Hadley Centre, a division of the UK Meteorological Office, undertakes studies of the global climate using similar, though more extensive, models of the global biosphere as are used by the rest of the Meteorological Office for the prediction of weather conditions. The Hadley Centre's interest is in the long-term prediction of the results of natural effects and human activity on the future evolution of the global climate.

The models used by the Hadley Centre are based on data gathered from the large number of weather stations which have been in place, world-wide, for close to a hundred years and they produce enormous amounts of predicted data which can only be interpreted through the use of visualization techniques. Their predictive simulations are based on HadCM3 (Hadley Climate Model version 3). They have turned to the Manchester Visualization Centre to provide state of the art visualization techniques both for general research work and for use in publicity materials.

The initial phase of the work was to develop a series of data visualizations, supplied as MPEG2 and on video, to be used at the CoP4 (Conference of the Parties to the UN Framework Convention on Climate Change) conference on global warming held in Buenos Aires and attended by representatives of the majority of the world's major governments. These visualizations were demonstrated to the visitors at the conference and were also used at a presentation to Mr. Michael Meacher MP, Minister for the Environment, before the conference. The videos produced were also supplied to news gathering agencies at that presentation and used by both BBC news and Channel 4 news on their evening news broadcasts. Since that conference our work has continued with further productions for the CoP5, CoP6 and CoP7 conferences. In addition MVC also contributed modified visualizations for an episode of the BBC series, "Correspondents".

Throughout the production of material for the Hadley Centre, MVC has strived to enhance the quantity, quality and diversity of the visualization techniques and the video production procedures. MVC has worked closely with the Hadley Centre to develop new visualization techniques and new representations of the data in order to help to make the disturbing conclusions which scientists are drawing from their models clear to the world's leaders. Each year the Hadley Centre has focused on a number of themes, including:

- The global average temperature rise
- Effects on sea-level rise due to gradual warming of the deep ocean
- Severity of El Nino and subsequent climate changes
- Breakdown of the Gulf Stream, due to deep ocean warming and desalination due to the melting of the ice caps and its effect on the UK
- Reduction in size of the polar ice-caps
- Impact on regional climate e.g., cyclones in the Mozambique Channel and the Bay of Bengal and subsequent flooding
- Decimation of South American rainforests and vegetation

As the complexity of the visualizations has increased along with the production quality, the demands on resources have significantly increased. From the initial set of animations which required 400MB of disk storage for the MPEG-2 animations, the most recent set of animations required a storage capacity of 58GB for all the individual frames, movie clips, titles and final digital movies in both uncompressed AVI and MPEG-4. This is mostly the result of increased animation quality, where the visual clarity has been improved through the use of anti-aliasing steps and multi-image composition for titles, labels and visualizations.

Background

The Intergovernmental Panel on Climate Change (IPCC) has published projections of future emissions in their Special Report on Emissions Scenarios (SRES). The basis for these scenarios is a number of 'storylines' describing the way in which the world will develop over the coming century. Assumptions are made about the future including greater prosperity and increased technology. The levels of greenhouse gas emissions are generally less than previous IPCC scenarios, especially towards the end of the 21st century. The emissions of sulphur dioxide, which produce sulphate aerosols that have a cooling effect on climate, are substantially less.

The SRES scenarios are based on recent projections of global population and span a range of potential economic futures. There are four families of scenarios:

Quoted from UK Met Office Web Site:

"The A1 family describes a world with rapid economic growth during the 21st century and a substantial reduction in the regional variations of income per head. Global population rises during the first half of the century, peaks mid-century, then declines. New and efficient technology is rapidly introduced. The A1FI scenario sees the continuation of fossil fuels as the main energy source.

The B1 family describes a world with the same population growth as the A1 family. There are rapid changes in economic activity away from production towards a service economy. Clean and efficient technologies are introduced. Like A1, this storyline describes a convergent world.

The A2 family describes a world that remains heterogeneous with regional identity being preserved and lower income growth per head. Global population rises continuously throughout the century. The introduction of new and efficient technology is less rapid than the other scenarios.

The B2 family describes a world with population increasing throughout the 21st century, but at a lower rate than A2. Levels of economic growth and technological development are less than those of A1 and B1."

Predictions of climate change were made for the A2, B2 and A1FI scenarios using the HadCM3 model to simulate the response of atmospheric concentrations of greenhouse gases and sulphur. The greenhouse-gas concentrations were calculated from the SRES emissions using separate computer models. The sulphur emissions were converted to concentrations of sulphate aerosol particles concentrations within the climate model itself.

Between the present day and the end of the 21st century, the Hadley Centre predict a warming of over 4C for the A1FI scenario; 3.5C for the A2 scenario; 2C for the B2 scenario. From additional calculations warming of just under 2C is predicted for the B1 scenario.

Results

Figure 1 shows changes in global temperature for four SRES (Special Report on Emissions Scenarios) emissions scenarios, known as A1Fi, A2, B1 and B2. The A1Fi scenario in Figure 1(a) shows the simulation starting state with recorded data. Figures 1(b), 1(c) and 1(d) show the unmitigated emissions of pollutants of A1Fi against the other scenarios, the result of which can be seen clearly in 2100 when some areas have risen by more than 12'deg'C. The B1 scenario shows a lesser effect, where emissions have been reduced significantly.

The results for the scenarios show that surface warming is expected over most of the globe, with the largest increase at high northern latitudes. The melting sea ice causes less sunlight to be reflected and more to be absorbed at the surface leading to large warming of the region. The patterns of temperature rise also show a sharp contrast between land and sea, where the land is warming approximately 80% faster.

Figure 2 shows the effect of pollutant emissions on the Arctic Ice Cap. The size of the ice cap is normally at its greatest in March and at its lowest in September. Figure 2 shows results for two scenarios, A1Fi and B1 for the years 1960 and 2100. As can be seen by 2100 the September ice-cap has all but disappeared and the March ice-cap is considerably smaller. Consequences of this are rising sea-levels and desalinization of the oceans, which in turn effects currents e.g., Gulf Stream.

The HadCM3 simulations predict that the extent and thickness of northern hemisphere sea ice will decrease as temperature increases. By the end of the 21st century the area of sea ice coverage is predicted to fall to around 55% for A1Fi scenario.

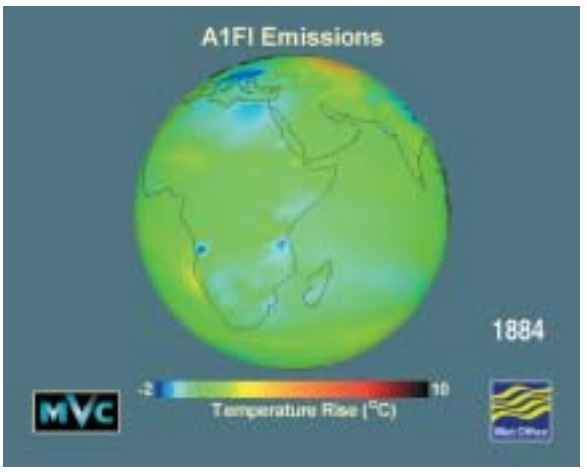

Figure 1(a)
The simulation starting state

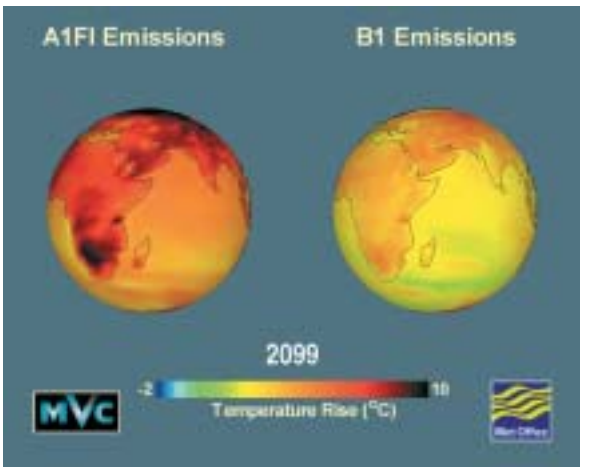

Figure 1(b)
Unmitigated emissions of pollutants of A1Fi against the B1 scenario

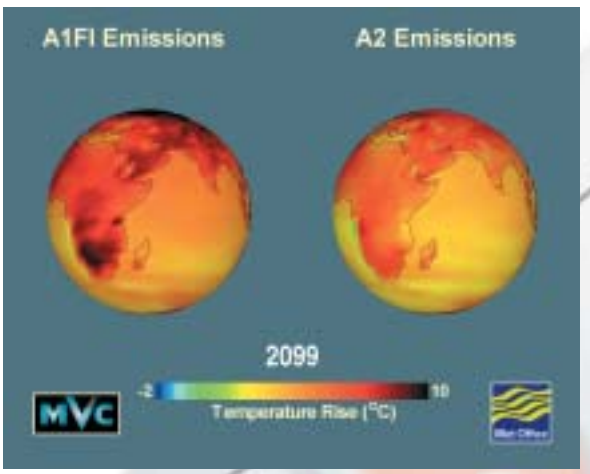

Figure 1(c)
Unmitigated emissions of pollutants of A1Fi against the A2 scenario

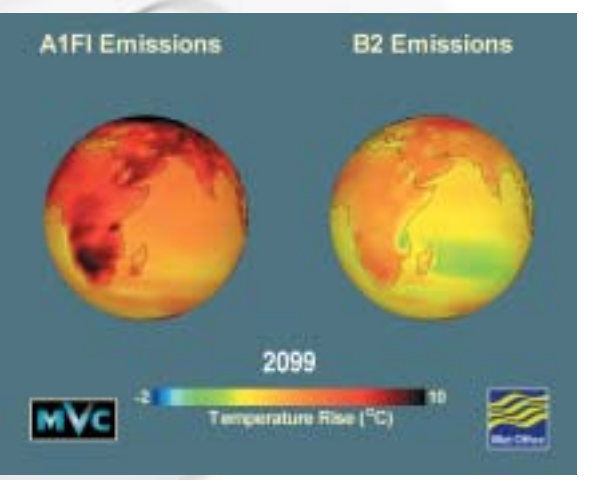

Figure 1(d)
Unmitigated emissions of pollutants of A1Fi against the B2 scenario

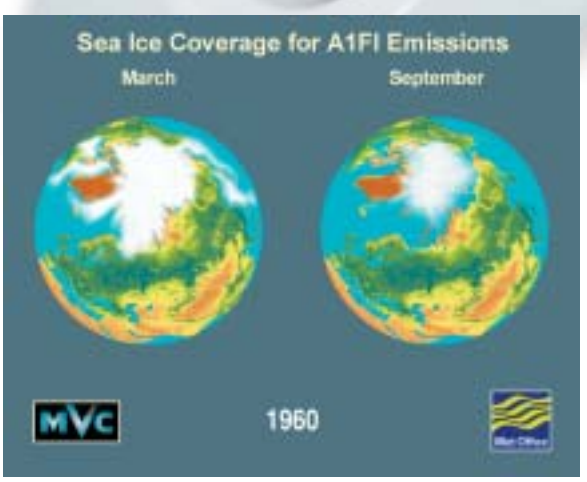

Figure 2(a)
A1Fi scenario - 1960

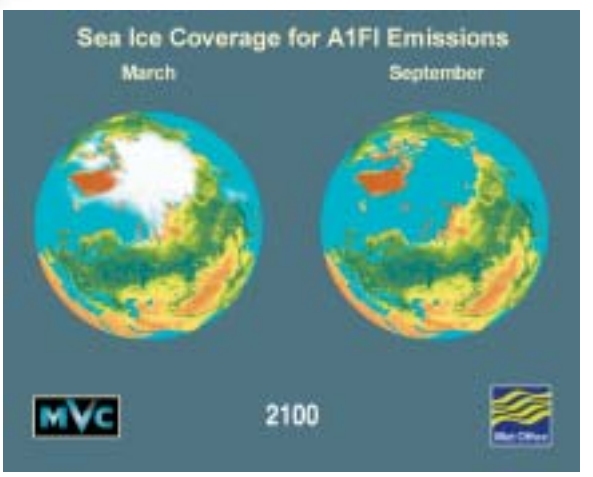

Figure 2(b)
A1Fi scenario - 2100

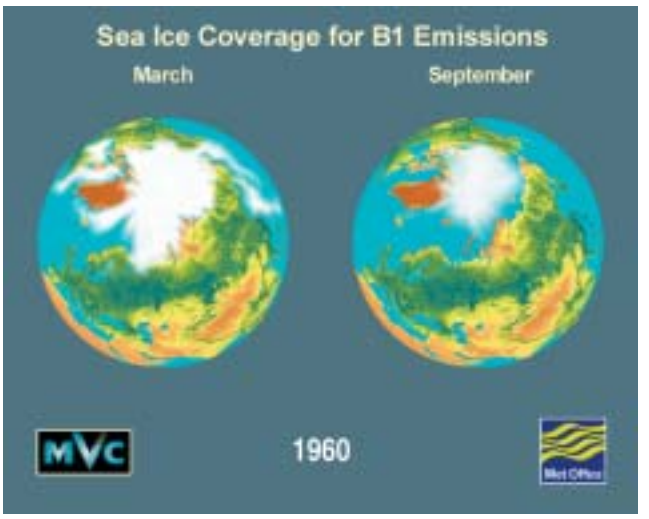

Figure 2(c)
B1 scenario - 1960

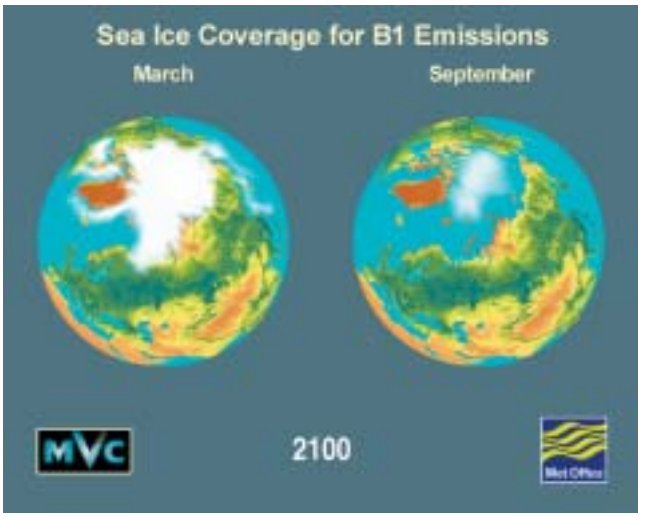

Figure2(d)
B1 scenario - 2100

Figure 3 shows the effect of global warming and human deforestation programmes on the rainforests on South America. The glyph based visualization shows the change in levels of various vegetation that is predicted to occur from the initial starting data of 1860. As shown the rainforest density is radically different by the year 2100.

Figure 3(a)
Levels of vegetation - 1860

Figure 3(b)
Levels of vegetation - 2100

Figures 4 and 5 show a comparison of two models, GCM and RCM. The Global Climate Model (GCM) is of much smaller resolution than the Regional Climate Model (RCM). In this visualization of a cyclone in the Mozambique Channel, it is clearly seen that the GCM does not effectively simulate the cyclone.

Figure 4 shows the wind magnitude and direction for both models from two examples of the various time-steps produced.

Figure 4 (a)
Wind magnitude/direction - day 1

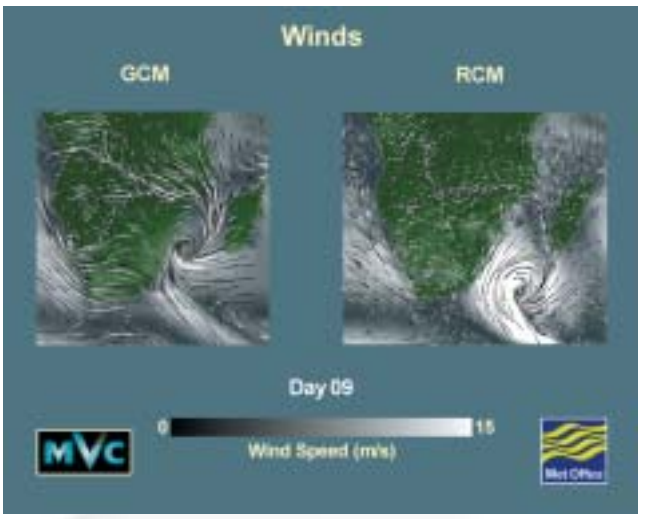

Figure 4 (b)
Wind magnitude/direction - day 9

Figure 5 shows the sea-level-pressure and precipitation for the same simulation, again only two examples have been included.

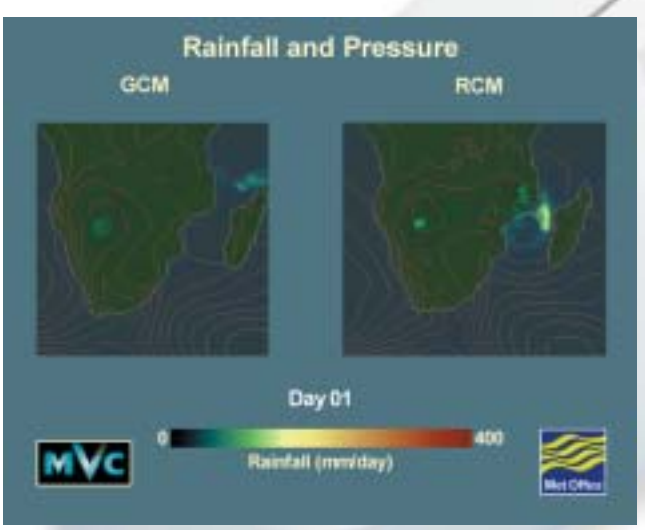

Figure 5 (a)
Sea-level pressure and precipitation - day 1

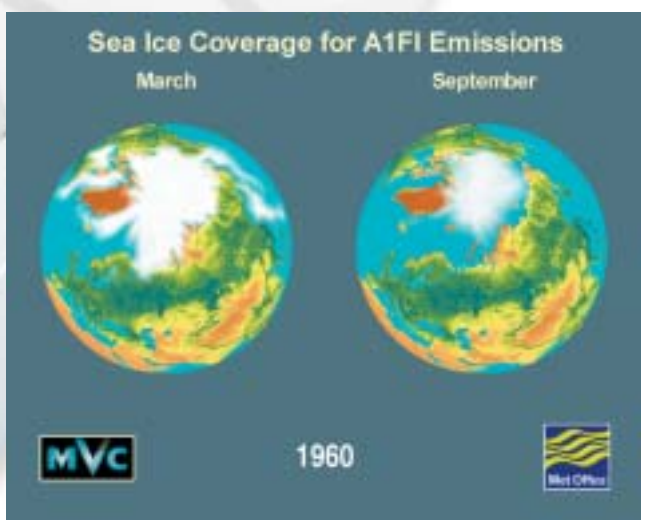

Figure 5 (b)
Sea-level pressure and precipitation - day 9

As can be clearly seen, the higher resolution model (RCM) produces more effective results and will enable the Met Office to conduct more precise predictions in the future, when higher resolution simulations can be used for global rather than regional climate prediction.

In conclusion, the animations produced have proved effective tools for the Hadley Centre to dramatically demonstrate what the future may hold should the governments of this world not take heed of the warnings already evident. The animations have been well received at conferences and have led to the U.K. adopting the proposal to reduce emissions levels to the lowest recommended.

If you would like to know how visualization can help you in your work, please contact the CSAR Helpdesk.