Proposed plan for C20C project on detection and attribution
Fifth C20C Workshop, IAP, Beijing, 25-28 October
Dáithí Stone (stoned@csag.uct.ac.za) and Peter Stott (peter.stott@metoffice.gov.uk)

This document reports on the discussions of a breakout group at the Fifth C20C Workshop which discussed the adoption of a detection and attribution project as a core C20C project over the next several years. The primary purposes of this project would be:

- to characterise historical trends and variability in the probabilities of damaging weather events, including the differences across climate models;
- to estimate the fraction of the historical, present, and future probabilities of damaging weather events that is attributable to anthropogenic emissions, and to characterise underlying uncertainties in these estimates.

This project will comprise various ensembles of simulations run under different scenarios of external radiative forcing, land use, and sea surface temperatures. Along with the base scenario of past observed changes in the boundary conditions, other scenarios will examine the effect of leaving out changes in selected boundary conditions.

Main project

The main project will involve the generation of a standard C20C ensemble of historical simulations with perturbed initial conditions covering the 1950-2020 period, using HadISST2 and DePreSys for sea surface temperature conditions, and forced with historical changes in greenhouse gases, tropospheric aerosols, land surface, volcanic aerosols, and solar luminosity. This ensemble will provide a basis for estimating changes in the probabilities of damaging events. Some evaluation of model relevance will be possible where observations permit for relatively frequent events.

A parallel ensemble will then be generated in which the anthropogenic contributions to the forcings are altered to pre-industrial conditions and the sea surface temperatures are altered accordingly. Comparison of these two ensembles will indicate the degree to which anthropogenic emissions have contributed to the probability of weather events and how that contribution is changing. The altered sea surface temperatures will be estimated using an optimal fingerprinting regression analysis, a standard tool in detection and attribution studies. It works on the principle that the spatio-temporal patterns of the responses of the climate system to different external forcings are strongly constrained by well understood properties, for instance by the location of ice feedbacks and the timing of volcanic eruptions, but that the amplitudes of the responses are governed by less well understood feedback processes. The spatio-temporal response patterns are therefore estimated from climate model simulations, while the amplitudes of those patterns are objectively constrained by the observed historical spatio-temporal variations.

For this project the regression will use the following scenarios:

- a scenario including variations in "all" known external forcings;
- a scenario including variations in natural external forcings only;
- a scenario including variations in greenhouse gas forcing only.

Simulations from these scenarios are already available from a handful of "CMIP3-class" models and more are due to be generated as part of the CMIP5 campaign. The regression will thus be of the form:

$$T_{obs}(x)=\beta_{all}(\check{T}_{all}(x)+v_{all}(x)+\mu_{all}(x))+\beta_{ghg}(\check{T}_{ghg}(x)+v_{ghg}(x)+\mu_{ghg}(x))+\beta_{nat}(\check{T}_{nat}(x)+v_{nat}(x)+\mu_{nat}(x))+v_{obs}(x)$$

where $T_{obs}(x)$ are the observed spatial-temporal SST variations over the past century, and $\check{T}_{all}(x)$, $\check{T}_{ghg}(x)$, and $\check{T}_{nat}(x)$ are the multi-mean responses of simulations of atmosphere-ocean climate models to historical changes in all considered forcings, greenhouse gas forcings only, and natural forcings only respectively. Following the optimal fingerprinting approach, these T(x)s are actually the projection onto the principal components of the unforced internally generated variability of the climate system, as estimated from unforced control simulations from the coupled model, allowing the regression to be performed in the space of maximum signal-to-noise ratio. The v(x)'s represent sampling uncertainty due to the natural internally generated variability of the climate system, while the μ(x)'s represent uncertainty due to the approximations of climate models. The βs are regression coefficients which represent observationally constrained scaling factors by which to scale the climate model-estimated responses in order to be consistent with observations. Uncertainty in the β scaling factors is estimated using control simulations of the coupled climate models with constant external forcings. More details can be found in Allen and Tett (1999), Allen and Stott (2003), Stott et alii (2003), and Huntingford et alii (2006).

Using the adjustment factors and linear combinations of the climate model response patterns, a spatio-temporal anthropogenic signal in sea surface temperatures will be estimated that will then be subtracted from HadISST2. Various methods for treating sea ice are being examined, with an option for no-change being the backup.

Table 1: Summary of the simulations in the main experiment.

Scenario name	Scenario description	Sea surface temperatures and sea ice coverage	Number of simulations per model	Date range
ALL	Including changes in "all" known external forcings (including at least greenhouse gases, tropospheric aerosols, land use, stratospheric aerosols, and solar luminosity)	HadISST2	50	1950-2020
NAT	Including changes in the natural external forcings only (including stratospheric aerosols and solar luminosity)	HadISST2 minus estimate of anthropogenic signal	50	1950-2020

With a number of different models contributing to the analyses there will be an opportunity to assess the robustness of estimates of the anthropogenic contributions:

- to atmospheric model formulation;
- to underlying sea surface temperature anomaly pattern;
- to event definition.

The main project is envisaged to start in or after mid-2011, when the HadISST2 dataset has become available, modelling groups have had time to configure their models, and modelling groups are no longer constrained by CMIP5 obligations.

Additional projects

Options for later phases were also discussed, including various sensitivity studies. In particular, the LUCID experiment, examining the contribution of land cover change, could take advantage of this experimental setup, so measures should be taken to ensure compatibility of the main experiment with LUCID. In addition, the WAMME experiment, which is interested in investigating the role of sulphate aerosols on the West African monsoon, could take advantage of this experimental setup and additionally add experiments which look at the effects of non greenhouse gas anthropogenic forcings.

Table 2: Summary of possible additional experiments to include in the project, with the ALL scenario as reference.

Scenario name	Scenario description	Sea surface temperatures and sea ice coverage	Number of simulations per model	Date range
LAN	Including changes in land use change only (from LUCID)	HadISST2 minus estimate of anthropogenic land use signal	50	1950-2020
AER	Including anthropogenic changes in tropospheric aerosols	HadISST2 minus estimate of anthropogenic aerosol signal	50	1950-2020

The regression procedure for estimating the sea surface temperature response signal for estimating the adjusted sea surface temperatures actually produces an estimate of the probability distribution of the response. Generating other NAT scenarios which sample the uncertainty in this SST response pattern should be a priority issue. A thorough sampling with 50-member ensembles is probably beyond all the modelling groups, so a sampling matrix will have to be devised in which only one or two further NAT scenario possibilities are sampled with each model but collectively all models provide a thorough sampling of the NAT scenario uncertainty.

Preliminary project

A plan was discussed for a preliminary experiment similar to the main project taking advantage of existing C20C simulations, performed by a subset of the C20C modelling groups based on interest and ability to participate. The idea is that such simulations could be completed by September 2011, allowing some analysis to be completed before the July 2012 IPCC AR5 deadline. Participants in this preliminary experiment currently include the Met Office Hadley Centre, NOAA's Earth System Research Laboratory, and the University of Cape Town, with a hope for involvement from further C20C members.