The International CLIVAR Climate of the 20th Century Plus (C20C+) Project: Report of the Sixth Workshop

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1. Introduction

The International CLIVAR Climate of the 20th Century Project (C20C; Folland et al., 2002) held its Sixth Workshop on 5-8 November 2013 at the University of Melbourne, Australia. The C20C project brings together climate modelling and data analysis groups to study climate variations and changes over periods up to the last 150 years using observational data and general circulation models (GCMs). There is an emphasis on atmospheric GCMs (AGCMs) typically forced with observed values of atmospheric composition (concentrations of greenhouse gases, aerosols, etc.) and surface conditions (SST, sea ice, land surface vegetation, etc.) as well as natural variations alone. As agreed at the fifth Workshop in Beijing in 2010 (Kinter and Folland, 2011), the new C20C core project involves research in collaboration with the International Detection and Attribution Group (IDAG) and the international Attribution of Climate-related Events (ACE) activity into the influence of anthropogenic forcing on climatic events, particularly extreme climate events, partly to support the new research topic of quasi-operational detection and attribution (e.g. Stott et al, 2013, Peterson et al, 2013). Updated monitoring of progress with seasonal operational attribution research can be viewed at http://www.csag.uct.ac.za/~daithi/forecast/.

The goal of the Sixth Workshop was to review early progress in the new core activity, some observational data sets that will support C20C activities, and the other key C20C projects. Many of these are only loosely coordinated, the main coordination being with model data. As in all previous C20C meetings, the forcing data sets being used in a new set of coordinated model experiments, including the new Hadley Centre's SST and sea-ice analysis (HadISST2) were discussed including the rapidly evolving arrangements for sharing the new experiments (see Section 10 below).

The 35 workshop participants from 18 institutions were welcomed by Prof. Janet Hergt, Dean of the Melbourne University Faculty of Science. A representative of the WCRP Working Group on Climate Modelling, Dr Claudia Tebaldi, also attended. The Workshop not only enjoyed excellent hospitality from the host institution but also a flutter on the prime local horse racing event of the year, the Melbourne Cup! The workshop included 26 presentations, six posters and two breakout groups covering the C20C projects. The workshop web site (http://www.iges.org/c20c/dome.html) includes downloadable copies of most of the presentations and posters, and a discussion of Workshop outcomes including this article and summaries of the breakout discussions. Some posters supported given talks, so only independent posters are mentioned here.

A key decision of the Workshop was to rename the project C20C+. Renaming of the project was done partly because of the new focus on research underpinning future operational detection and attribution but also because increasingly 21st century climate change is a crucial component of understanding variability and trend mechanisms. The projects and their progress are now described.

1. The C20C+ Detection and Attribution Project

The scientific aims are to characterise historical trends and variability in characteristics of damaging weather and short-term climate events, including the differences shown by climate models. A key component of the analyses is 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 will involve up to about 30 modelling groups around the world to run about 30 atmospheric models in a semi-coordinated study of weather risk attribution. Up to date details on the C20C+ Detection and Attribution Project are at http://portal.nersc.gov/c20c, including an updated technical document and a discussion of the input data for the simulations. These data will be used by other C20C+ projects as well.

A key component of the experimental design of future experiments will be the use of HadISST2 sea surface temperature and sea ice dataset as the surface boundary condition to force the AGCMs (see below). As agreed in previous meetings, other SST data sets can also be used, especially to determine the sensitivity of results to choice of SST data set. In the meantime HadISST1 and NOAA-OIv2 is being used. The experimental design can be summarised briefly as follows:

All-Hist: Simulations run under observed variations in radiative forcing and surface boundary conditions.
Nat-Hist: Simulations run under variations that might have occurred in radiative forcing and surface boundary conditions had anthropogenic emissions never interfered with the climate system.

For the simulations, the experiment consists of five components:
• A set of "All-Hist" baseline simulations of the past half century, to provide the baseline (for instance to estimate thresholds) and for analysing long-term trends.
• A set of "All-Hist" reference simulations of the past decade, to provide the "real-world" reference for estimating the recent and current nature of extreme events. These reference simulations may also include the baseline simulations.
• Three sets of "Nat-Hist" counterfactual simulations of the past decade, to provide estimates of the counterfactual "natural-world" that might have occurred in the absence of anthropogenic interference. The three sets of simulations differ in the prescribed sea surface temperatures (SSTs) and sea ice coverage used as estimates for the Nat-Hist scenario conditions, derived by appropriately removing the anthropogenic signal from HadISST2. One estimate of these modified ocean/ice conditions will be used across all models, while the other two can be unique and estimated using different techniques.

In addition, it is planned that some coupled global models, regional models and selected impacts models will be used. Observations and models will also supply key climate indices. Output from the main simulations is being published on the Earth System Grid Federation (ESGF, http://esg.nersc.gov) under the project name "c20c".

The Hadley Centre component of this project, Attribution of Climate-related Events (ACE, not to be confused with the international ACE activity), generates large ensembles through perturbing physics parameters. Otherwise the experimental design is broadly similar. It concentrates on the change in the likelihood of an event, given specific modes of internal variability. ACE contributes to the new European Union Framework 7-SPACE project EUCLEIA (EUropean CLimate and weather Events: Interpretation and Attribution). This started in January 2014 with 11 partners and is mainly concerned with developing an operational detection and attribution system for Europe. As with EUCLEIA, key extreme events include heat waves, cold spells, droughts, flooding periods and storm surges. A recent study involved 600 ensemble members with and without anthropogenic influences to study a flood event in Eastern Australia in March 2012 (Christidis et al, 2013).

More details of the experimental design for the core model integrations of the D&A subproject can be found on the C20C+ web site http://grads.iges.org/c20c/home.html, Detection and Attribution Working Group Report, 6th International C20C Workshop, and at the subproject web site http://portal.nersc.gov/c20c/.

2. HadISST

The Hadley Centre has developed an improved analysis of global SST and sea ice concentration so as to include more observations and attain greater accuracy and resolution. Titchner and Rayner (2014) publishes the sea ice component and forthcoming papers by Kennedy et al (2014) and Rayner et al (2014) will publish the SST component and the combined SST and sea ice data set respectively. Key improvements of HadISST2 over HadISST1 are multiple (100) realizations, better resolution in time, new bias corrections to SST right up to the present, inclusion of AATSR satellite data and a considerably improved sea ice extent data set. A subset of the 100 realisations of HadISST2 is now available for C20C+ via the Met Office Hadley Centre in the form of a pre-publication version (via *john.kennedy@metoffice.gov.uk*). Future versions will address the diurnal cycle through work planned under the European Space Agency (ESA) Climate Change Initiative SST project (see http://www.esa-sst-cci.org/).

It is highly desirable to have a high e.g. 0.5°-resolution daily version of HadISST, at least for the satellite era, because it has been shown that strong extratropical SST gradients have an important effect on deep convection and downstream atmospheric wave activity (e.g. Minobe et al, 2008). This of course requires climate models with comparable horizontal atmospheric resolution, now gradually becoming available. The short term new analyses, such as the single realization Met Office OSTIA analysis but without full bias correction, easily achieve this – see http://ghrsst-pp.metoffice.com/pages/latest_analysis/ostia.html. It is planned to integrate HadISST and OSTIA over the next few years. In the meantime, a small number of the approximately 100 realisations of HadISST2 will be used for the C20C+ project. All subprojects are likely to use integrations forced with HadISST1, HadISST2 or a NOAA SST data set, some only using original versions that do not adjust for anthropogenic forcing.

A full description of the complex process used to create HadISST was presented at the Workshop in two talks, one on the SST component and the other on the sea ice component. The HadISST2 SST analysis uses some innovative statistical methods only relatively recently introduced into the meteorological literature such as the variational Bayesian principal component analysis used to create optimum base patterns for the larger scales of SST analysis in HadISST2. HadISST2 should be openly available (beyond the C20C+ project) in 2015 at www.metoffice.gov.uk/hadobs.

3. Other Observational data sets

For the first time a C20C workshop highlighted some key types of observational data sets of particular use to sub-projects other than HadISST2. The data sets discussed and utilised included precipitation, reanalyses and a new extremes data set. The simulation of precipitation trends and events is a core C20C+ sub-project while the use of reanalyses to study changes in jet streams has already been important in the Summer NAO sub-project. As part of a study of precipitation trends over the last century, precipitation data sets were compared. On the global scale there is much disagreement since 1979. In another study of Indian Monsoon rainfall it was also noted that there was much disagreement though GPCP and MERRA reanalysis data looked most similar. Somewhat by contrast, six out of eight reanalysis data sets gave reasonably robust climatological characteristics of the main jet streams in the two hemispheres though, as might be expected, the 20th Century Reanalysis misses the existence of the near equatorial stratospheric jet associated with the QBO. HadISD is a new global sub daily data set underdevelopment that will be very useful for studying variations and trends studying daily and sub-daily extremes including storms, It is based on NCDC's Integrated Surface Dataset and uses hourly and 3-hourly station data from 6103 stations worldwide over 1973-2012. The variables are temperature, dewpoint, wind speed, sea level pressure and clouds (Dunn et al, 2012).

4. Weather Noise and performance of AGCMs Core Project

A key question for C2OC+ is the extent to which AGCMs forced with observed SST and sea ice extents give reliable results, at least when compared to their coupled model counterparts. As C20C+ uses AGCMs for many results, this has been an important sub-project especially in the light of some previous publications casting doubt on the ability of AGCMs to simulate correct teleconnections. This is also related to the problem of the relative contribution of SST forcing and weather noise to atmospheric variance. It is hypothesised that the information contained in detailed observational data sets like reanalyses can be best understood by indentifying and comparing the weather noise and forced responses. The work has also been motivated by previously published results showing that AGCMs and CGCMs have different teleconnections. The new results (e.g. Chen et al, 2013, Chen and Schneider, 2014) show that AGCMs can indeed be used to gain sights into teleconnections and SST forced responses as these are (almost) the same in the AGCMs and partner CGCMs. Some previous published results appear to be strongly affected by model biases. However an exception is quantitative estimates of precipitation where AGCMs clearly over-estimate responses to SST compared to CGCMs. The statistics of weather noise also appear to be similar in the AGCMs and their coupled partners. However where SST variations are dominated by weather noise, e.g. parts of the Tropical west Pacific, then atmospheric responses are unpredictable.

5. Precipitation variability and trends Core Project

This topic has a number of participants. CMIP3 and CMIP5 rainfall trends over the last century show low overall correlations. Non zero correlations are only due to external anthropogenic and natural forcing. However simulations agree over the oceans better than land while CMIP5 results are more sensitive to volcanic forcing than CMIP3. Another talk on long-term precipitation variations first confirmed in observations and CMIP5 simulations the well known tendency for high Northern latitudes to become wetter over the last century and many sub-tropical regions to become drier. The CMIP5 simulations add to the idea that much of the trend is related to greenhouse forcing. However the influences of the PDO, AMO as well as ENSO are substantial and make deductions from short records, such as the satellite precipitation record alone, ambiguous. A statistical study of the influence of 9 internal and external factors on Australian and global rainfall like the PDO concluded that despite some regionally considerable effects, over half of the worldwide precipitation variance remained unexplained.

Progress was demonstrated in understanding the mechanisms of monsoon rainfall using the very high resolution (16km) ATHENA model forced with observed SST. Flow anomalies are particularly realistic in the north east part of the region such that ATHENA can be more faithful to the best observational estimates of circulation and rainfall variations than some reanalyses. A related question concerns heavy rainfall changes under greenhouse warming around Japan. The MRI-AGCM3.2H shows that various mean and extremes precipitation indices will increase in the 21st century but the related conversion of precipitation from water vapour is more efficient for short-term extreme precipitation (e.g. 3 day maxima) than long-term (e.g. 10 day maxima).

For this workshop, relationships between ENSO and Australian rainfall were of particular interest, particularly after the recent (2011-12) exceptional wet period. One study concluded that ENSO remains dominant over anthropogenic effects for attributing such events. Specifying SST anomalies did not seem to provide a sufficient cause. This problem is compounded by another study that found that models forced with observed SST tend to show the opposite rainfall trends over Australia over 1950-99 to those observed. This clearly has implications for the veracity of projections. Results from an innovative analytical method (Frederiksen et al., 2013), partly developed under the C20C+ project, provided new insights into relationships between observed Australian rainfall and the atmospheric circulation by identifying modes of co-variability in the noise and signal components of these climate variables. When applied to ensembles of the CMIP5 models, an externally (radiatively) forced coupled trend mode was identified in both austral summer and winter, associated with an expansion of the tropics and positive trends in rain over northwest Western Australia (summer) and negative rainfall trends over southwest Western Australia (winter), consistent with observations. Of particular interest is the stationarity of relationships between precipitation and atmospheric factors. In both models and observations non stationarity was shown in relationships over the last century between patterns of Australian rainfall and the forcing factors ENSO and the Southern Annual Mode (SAM). Some of this non-stationarity though arises from longer term variations in the variance of ENSO and the SAM. Crowd sourcing experiments can provide very large numbers of integrations. Results were shown from over 750,000 model years of HasdAM3P obtained via the ***weather@home*** project. An interesting result is that HadAM3P can reproduce the asymmetric relationship between rainfall and ENSO over south east Australia in boreal summer.

Turning to another region, the causes of the long term drought in north East China (at least until a few years ago) have received much attention. In another talk, the decadal time scale influence of the PDO was highlighted using observations. Although not the only possible mechanism, the PDO appears to create an East Asian atmospheric teleconnection pattern with high PMSL and low level height anomalies over North East China and thus reduced rainfall and soil moisture.

6. Atmospheric and Oceanic Variability and Atmospheric Predictability

We first consider tropical cyclone trends. The MRI-AGCM3.2H has been used to investigate changes in the number and intensity of tropical cyclones in different ocean basins in the coming century. The model shows a clear decline in frequency in the 20th and 21st centuries globally and hemispherically. Despite some ocean basin variability, the chief cause is an increase of static stability that reduces upward mass flux faster than the increase of latent heat release due to increased precipitation in a warmer atmosphere. Another paper presented the new Okubo-Weiss-Zeta-Parameter cyclone new detection technique. This detects tropical cyclogenesis from larger scale structures in reanalyses and models and reproduces variability and mean tropical storm frequency in ERA-INTERIM. The observed frequency is reproduced using this method in many CMIP models run in historical mode but not all. The method creates a decrease in the frequency of simulated tropical cyclones in the coming century in many CMIP5 models, as for CMIP3, but this disagrees in some cases with results from other methodologies applied to some of the CMIP5 models (Tory et al, 2013). Another talk discussed observed reductions in South Australian rainfall in the last few decades due to observed reductions in baroclinic activity including the southwards movement of the storm track which is seen in many CMIP5 models under enhanced greenhouse gases.

The Grainger et al. (2011) statistical method has been used to study the veracity of atmospheric circulation modes in CMIP5 coupled model simulations to compare with CMIP3 for current climate. CMIP5 shows a general improvement in reproducing 500hPa slow modes with a particular improvement in December-February ENSO modes. Under strongly increasing greenhouse gases (RCP8.5) there is very little change in CMIP5 intra-seasonal modes but as expected, much larger changes in slow-internal modes. This suggests the natural modes of short term variability may not change much in character under greenhouse warming. Related to changes of atmospheric circulation is the now well-known recent expansion of the tropics. A study presented at the workshop using reanalyses and CMIP5 models concluded that the modelled rate of tropical expansion is towards the low end of the range of measurements, about 0.5 degrees/decade since 1979. The observed rate may however be overestimated due to natural variability at start of period. It was also concluded that regional and hemispheric differences in expansion are observed. Some reanalyses have inhomogeneities that make trends somewhat untrustworthy. Intriguingly there is some evidence of a faster than the recent average expansion of the tropics in the 1960s.Finally an important factor in the response of the atmospheric circulation to ENSO over the tropical Pacific is cloud forcing in the ENSO region. It was shown that improvements in precipitation, upward mass flux and cloud over the tropical Pacific in response to ENSO in the Chinese GAMIL2 AGCM compared to the GAMIL1 AGCM have been created through an improvement in the cloud water. The improvement in precipitation (and therefore diabatic heating) comes chiefly from stratiform cloud which gave little precipitation in GAMIL1 but also some from improved convective cloud.

Finally a talk was given on the response of surface temperature and the East Asian monsoon circulation to volcanic forcing. An ensemble of runs of the MPI-ESM model was run since 800AD with volcanic, solar, greenhouse and land surface forcing. Concentrating on China and recent eruptions, summer cooling after major eruptions is clear but precipitation responses are mixed. A Weakening of East Asian Summer Monsoon circulation giving northerly anomalies after the volcanic eruptions is dominated by the land-sea thermal contrast change.

7. Summer NAO – C20C+ Core sub-project

The Summer North Atlantic Oscillation (SNAO) exerts a strong influence on European climate, e.g. rainfall, temperature and cloudiness, but is also associated with climate variability in eastern North America, the Sahel region in Africa (Folland et al, 2009) and eastern Asia (Linderholm et al, 2011, 2013). Model and observational results indicate that interdecadal SNAO variations are related to those of the Atlantic Multidecadal Oscillation (AMO). There also appears to be a slow multi-century trend towards the positive phase since 1700 mirroring observed global warming over that period, supported by model experiments of enhanced greenhouse gas forcing.

Initial experiments with HadGEM3-N216 coupled model were presented showing that declining Arctic sea ice may affect the summer NAO differently from the winter NAO. In winter, the negative phase of the AO/NAO is favoured but in summer PMSL drops across much of the extra-tropics without a clear influence on the summer NAO. A hypothesis that the higher east Atlantic/European jet stream latitude associated with the positive phase of the SNAO may be associated with extra cyclonic activity off the East American coast with enhanced tropical-extratropical interactions was found using a storm track analysis to be possible though relatively weak factor. On the other hand, different reanalysis data sets confirm dynamical links of SNAO variability to that of the West African monsoon through the depth of the troposphere. Furthermore, there are links to variations in the Southern Hemisphere winter subtropical jet stream in Atlantic-Indian Ocean longitudes suggesting interhemispheric teleconnections in July and August. However, possible links between phases of the SNAO and QBO stratospheric winds, implicit in a paper on PMSL and the QBO published nearly 40 years ago, showed very weak influences in both reanalyses and a HadGEM3 experiment.

8. Other results

Extremes are also discussed under Section 3. A modified version of the Climate Extremes Index suitable for observations and global climate models was presented. The traditional Climate Extremes Index calculates the percentage area of a region experiencing much above or below normal conditions in Maximum temperature, Minimum temperature, Rainfall, Proportion of total rainfall from heavy rain days and the Annual number of wet and dry days. The new combined extremes index subtracts below normal extremes from above normal extremes for each component, giving information on the direction of change. The new index shows a rising trend over Australia since about 1970 in CMIP5 results and observations. Finally it was shown that SST variability tends to force land surface temperature variability with a higher amplitude. This occurs because SST variability in the tropical ocean regions leads to tropospheric temperatures at higher levels above the oceans with larger amplitudes due to latent heat release by moist convection. The well mixed free troposphere transports the amplified SST signal over land. The near surface land air temperature follows the upper temperature variability, but with smaller amplitudes. This amplification leads to a land/ocean temperature contrast greater than unity during interannual variability.

9. New CLIVAR Initiative

Because of the number of young scientists present, Dr Sarah Perkins on behalf of CLIVAR presented a new initiative, the CLIVAR Early Career Scientist's Network. This is an international network involving website, conferences and social media that can include any climate scientist who considers themselves in the primary stages of their career, student, post-doc, or permanent research scientist. A full discussion of this evolving proposal is at: www.clivar.org/sites/default/files/ECS/Documents/CLIVAR_ECS_Survey_report.pdf.

10. Key Workshop Plans for the development of C20C+

A relatively full discussion is at the summaries of the two Workshop Breakout Groups at http://grads.iges.org/c20c/home.html under Meetings and the current workshop: Working Group reports. Here we review the main conclusions and plans.

10a Detection and Attribution Research

The Detection and Attribution Working Group report discusses the main plans for future C20C+ integrations. These AGCM integrations will provide the main unifying model data source for all sub-projects, though additional coupled mode integrations are planned to be used for some sub-projects. A key decision of the Workshop was agreeing the main experimental design. This involves the comparison of simulations of atmospheric models following a scenario of observed "real world" boundary conditions against simulations following a scenario of "natural world" boundary conditions that might have existed had humans never emitted greenhouse gases. Because there are considerable uncertainties over the boundary conditions for the latter scenario, a number of estimates for those boundary conditions are available.

The experiment consists of three components:

- A set of simulations of the past ~half century, to provide the baseline (for instance for estimation of thresholds) and for analysis of long-term trends
- A set of simulations of the past ~decade, to provide the "real world" reference.
- A set of simulations of the past ~decade, to provide the counterfactual "natural world" that might have been.

Each model will be run under the following scenarios for the core experiment:

Scenario	**Radiative boundary conditions**	**Ocean surface boundary conditions**	**Simulations**
Real world (baseline)	Varying as observed: Greenhouse gas concentrations, anthropogenic aerosol burdens (or emissions), stratospheric ozone concentrations, land cover, stratospheric (volcanic) aerosol burden, solar luminosity	Sea surface temperatures and sea ice concentrations varying as observed (monthly or higher frequency)	10 or more covering the 1960 to ~1995 period
Real world (reference)	Same as for "Real world (baseline)"	Same as for "Real world (baseline)"	~50 covering the ~1995-2012 period
Natural world (CMIP5-est1 estimate)	Varying as observed: Stratospheric (volcanic) aerosol burden, solar luminosity, land cover Constant at pre-industrial (ca. 1850) values: Greenhouse gas concentrations, anthropogenic aerosol burdens (or emissions), stratospheric ozone concentrations	Observed sea surface temperature and sea concentration values minus an estimate of the change attributable to anthropogenic interference derived from a collection of CMIP5 simulations Identical attributable warming estimate used	~50 covering the ~1995-2012 period

		across all models	
Natural world (second estimate)	Same as for "Natural world (first estimate)"	Observed sea surface temperature and sea concentration values minus another estimate of the change attributable to anthropogenic interference Different attributable warming estimates to be used across the models, using different estimation techniques and data sources	~50 covering the ~1995-2012 period
Natural world (third estimate)	Same as for "Natural world (first estimate)"	Observed sea surface temperature and sea concentration values minus another estimate of the change attributable to anthropogenic interference Different attributable warming estimates to be used across the models, using different estimation techniques and data sources	~50 covering the ~1995-2012 period

Details of the generation of the sea surface temperatures for the "CMIP5-est1" estimate of the "natural world" scenario are described in a technical report available at http://portal.nersc.gov/c20c/input_data/C20C-DandA_dSSTs_All-Hist-est1_Nat-Hist-CMIP5-est1.20130530.pdf. Shortly after the Workshop, 15 modelling groups had expressed interest, listed in the Working Group Report.

A data portal has been set up for the project on the Earth System Grid Federation (ESGF) (the same facility used to disseminate CMIP5 output) under the project label "c20c". As of December 2013, output from a trial experiment conducted by two modelling groups had been published, along with boundary condition data sets for the core experiment. A project directory has only been set up on the NERSC node (http://esg.nersc.gov and accessible via the other ESGF portals) but directories on other nodes, e.g. in Australia, China, Japan, and the U.K., are likely. The idea of the ESGF is that data can be distributed across multiple nodes around the world but appear as one project data set to a user through a portal. Each node also has an http portal; all of them should appear identical to a user. The current NERSC directory is limited to 150 terabytes but is planned to be substantially expanded via access to tape archive. The Workshop report lists planned activities related to future activities with the data portals.

The core experiment will examine the total anthropogenic contribution to climate change. Possible future experiments discussed at the workshop include:

- examining just the effect of land use change
- examining just the effect of stratospheric ozone depletion
- examining just the effect of greenhouse gas emissions
- examining projections for some future period
- examining the effect anthropogenic radiative forcings but with ocean conditions at natural (non-anthropogenic) values (e.g. a geo-engineering experiment)

Once simulations for the core project are completed, they may be updated periodically (e.g. every 6 or 12 months) to provide data to support near-real-time analysis of extreme events. This is the key aim of operational detection and attribution. Such extensions will also support the now regular Bulletin of the American Meteorological Society's annual State of the Climate attribution supplement (Peterson et al, 2013). Finally between now and the next C20C+ Workshop (see below) it is hoped to organise a journal special issue providing an overview of the first results from the detection and attribution of extremes project.

10b Atmospheric circulation, rainfall and atmospheric noise

The Atmospheric Circulation and Rainfall Working Group discussed the plans for remaining C20C+ projects and their proposed participants. These projects can use any of the model data being made available through the Detection and Attribution project but also use other data.

Following several recent published papers, some listed below, the atmospheric noise project will look at long time-scales of climate variability. These may be forced (partly at least) by atmospheric noise due to coupled atmosphere-ocean processes or ocean internal variability. With the help of AMIP-type ensembles to estimate weather noise, the noise component of key drivers of decadal variability in CGCM control experiments and decadal prediction experiments will be studied using diagnostic models. Again, several papers are planned over the next few years.

There is increasing evidence that state of the art models represent processes affecting European climate considerably better than in the past (e.g. Scaife et al, 2011). The role of C20C+ here will be particularly in studying forcing mechanisms in the summer and for winter half year UK and European droughts. A paper on the latter concentrating on UK is well advanced and involves collaboration with UK hydrologists. The latter project is studying the mechanisms of European summer climate variability following a number of recent papers on the summer North Atlantic Oscillation. Particular emphases are tropical rainfall forcing, SST forcing including the AMO, and the effect of the decline in recent Arctic sea ice. Besides model output from the Detection and attribution project, a new high resolution coupled model in the HadGEM3 stable will be used. The project is also reconstructing the SNAO over the last millennium and using CMIP5 models to try to simulate SNAO variations over this long period. Reanalyses are important to this project; the SNAO essentially involves changes in the tropospheric jet stream and the reanalysis project is expected to provide further advice on suitable reanalyses and submit a paper for publication. There is considerable further potential to uncover the relative variance of potentially predictable modes like the SNAO, and internal variability, in both hemispheres using the method most recently described by Grainger et al (2011). Several papers are planned using reanalyses, CMIP5 models and decadal prediction experiments.

In the context of forcing factors for atmospheric circulation modes and for studies of rainfall data in their own right, there is a considerable need for a review of, and advice on, rainfall data sets to support C20C activities. This will be done, noting that many such global or quasi-global data sets now exist and are readily accessible through such sites as KNMI explorer. It is expected that using the core C20C+ model data, a much more extensive analysis will be done on trends and variations in global precipitation; this activity will also cast light the strengths and weaknesses of the many observed data sets. Further investigation of monsoon rainfall mechanisms will be done using the IFS 16km – T1279 1^{o} ocean resolution model. A 50-member ensemble is available for 1980-2010.

Finally as a background to these activities, it was agreed to add to the C20C+ project an ongoing study of the time-varying causes of the slowdown, pause or hiatus in global warming, and how this might end. This appears to have a distinct approach compared to papers that have so far appeared.

11. Next Workshop

Subject to circumstances and formal agreement, it was recommended that the 7th Workshop should be held at COLA, George Mason University, Maryland, USA in 2016 or 2017.

Acknowledgments

This report draws on the 32 talks and posters presented by participants and the two Working Group reports.

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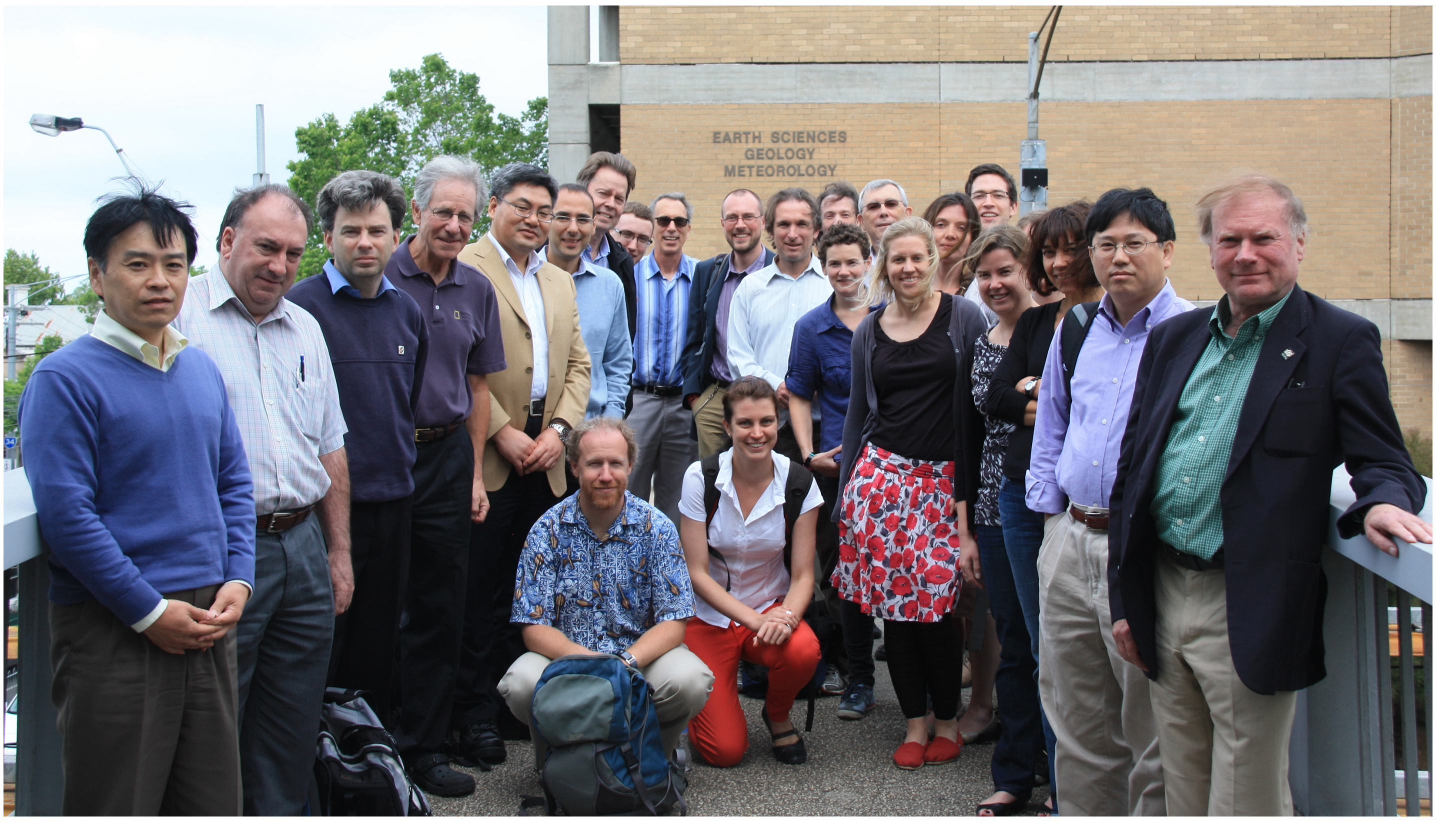
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