

# The International CLIVAR C20C+ Detection and Attribution Subproject

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**This document provides a brief description of the International CLIVAR Climate of the 20th Century Plus (C20C+) Detection and Attribution (D&A) Subproject. It is intended mainly to inform interested modelling groups about the experiments that form the basis of the project. It provides links to detailed project documentation and available resources on the project website (<http://portal.nersc.gov/c20c/>).**

**This is a working document which will be updated periodically as the project progresses.**

## 1 Rationale

Interest is growing in understanding recent trends in the frequency, intensity, and other characteristics of extreme weather events, as well as the contribution of such trends to trends in risk. The role of anthropogenic emissions in driving these trends is particularly receiving attention (e.g. Peterson et al. 2012; 2013). Thus far analyses of the role of anthropogenic emissions in trends in extremes have depended on the following data products:

### Observational data products:

**Examples:** Alexander et al. (2006); Cattiaux et al. (2009); Rahmstorf and Coumou (2011) (note some of these papers are very specific about not having investigated the cause of the underlying trend, yet they are given as examples because they are often interpreted in an anthropogenic context)

#### Strengths:

- Based directly on the real world

#### Weaknesses:

- Poor statistical sampling
- Subject to monitoring accuracy and coverage
- Existence of trend must be assumed to be evidence of attribution to anthropogenic emissions

### Attribution simulations of coupled atmosphere-ocean climate model products, particularly CMIP5:

**Examples:** Stott et al. (2004); Christidis et al. (2011); Min et al. (2011); Zwiers et al. (2011)

#### Strengths:

- Fullest modelling of climate system
- Direct evidence for understanding role of anthropogenic emissions

#### Weaknesses:

- Poor statistical sampling
- Poor spatial resolution
- Depends on quality of the climate model

### An ad hoc data optimally generated for a particular study with an atmospheric climate model:

**Examples:** Pall et al. (2011); Dole et al. (2011); Shiogama et al. (2013)

#### Strengths:

- Good statistical sampling possible
- Good spatial resolution possible

- Fullest modelling of the atmospheric system

**Weaknesses:**

- Missing representation of possibly important climatic processes (e.g. ocean variability)
- Designed only for a specific event, thus restricted in time period simulated and in other aspects of the experimental design
- Only uses one or two atmospheric models
- Depends on the quality of the atmospheric model

The above types of data products were not specifically designed to support investigations of the degree to which anthropogenic emissions have affected extreme events, a research topic which has unique data requirements. Thus, there appears to be a need for a new data product optimised for investigating the role of anthropogenic emissions in recent extreme weather events. The C20C+ D&A Project aims to fill this gap by producing a data product specifically designed to support:

- Investigations of trends in extreme weather and weather-related events over the past half-century;
- Investigations of the role of anthropogenic emissions in current properties of extreme weather and weather-related events.

It will broadly follow the experimental design of Pall et al. (2011) (also see Christidis et al. 2013; Imada et al. 2013; Shiogama et al. 2013; Wolski et al. 2014). It involves the generation of large initial-condition ensembles of simulations of atmospheric run under observed historical boundary conditions (radiative forcing, ocean surface conditions, land surface conditions) and under various scenarios of what those boundary conditions might have been in the absence of all historical anthropogenic emissions.

Further details are described in this document and in other linked documents. In summary, specific strengths and weaknesses of the anticipated product, with respect to investigating the detection and attribution of extreme events, are:

**Strengths:**

- Large samples for statistical sampling
- Use of a large number of global dynamical atmospheric models run under various configurations and resolutions, providing an indication of the uncertainty encapsulated in model formulation
- Use of a variety of dynamical and statistical downscaling methods and of models of “impact systems”, providing an indication of the uncertainty encapsulated in model formulation
- Simulation of half a century under observed historical conditions
- Simulation of at least a decade under conditions that might have been in the absence of anthropogenic emissions
- Usage of a large number of estimates of ocean surface conditions in the absence of anthropogenic emissions, derived using a number of methods

**Weaknesses:**

- Depends on the quality of the climate and other models in representing the processes behind specific types of extreme events, including those involving atmosphere-ocean coupling
- Does not consider the anthropogenic influence on ocean variability

## 2 Project background

The C20C+ D&A Project was adopted as a core subproject of the International CLIVAR Climate of the 20th Century Plus Project (C20C+, <http://www.iges.org/c20c/>) at its 5th Workshop, Beijing, October 2010 (Kinter and Folland 2011, [http://www.iges.org/c20c/C20C\\_5th\\_Workshop\\_2010.pdf](http://www.iges.org/c20c/C20C_5th_Workshop_2010.pdf)). Following trial experiments and development of required facilities, the role of the D&A subproject within C20C+ was reaffirmed at the 6th Workshop, Australia, November 2013.

The two primary purposes of the D&A subproject are:

- 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.

In addition, simulations produced under this subproject will support other C20C+ subprojects examining the nature of variability within the atmospheric system.

## 3 Experimental design of the core experiment

The experimental design comprises various large ensembles of atmospheric model simulations run under different historical scenarios of external radiative forcing and surface boundary conditions. The core experiment, comprises two scenarios:

**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.

In terms of 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 for estimation of thresholds) and for analysis of 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 include the baseline simulations, with any difference simply consisting of the time period covered.
- Three sets of "Nat-Hist" counterfactual simulations of the past decade, to provide estimates of the counterfactual "natural-world" that might have been in the absence of anthropogenic interference. The three sets of simulations differ in the prescribed sea surface temperatures and sea ice coverage used as estimates for the Nat-Hist scenario conditions. One estimate of the ocean/ice conditions will be used across all models, while the other two can be unique and estimated using different techniques.

Summary details of these five sets of simulations are given in Table 1 and specific details are described in the following subsections.

In general, there are no specified preferred or recommended boundary condition data sets for this project. There is one exception: the use of the Nat-Hist/CMIP5-est1 attributable ocean warming data set for simulations following that scenario, but this is a difference field which can be applied to whatever observational sea surface temperature data product is preferred by the modelling group. Links to possible boundary condition files are provided at [http://portal.nersc.gov/c20c/input\\_data/index.html](http://portal.nersc.gov/c20c/input_data/index.html).

Scenario	Radiative boundary conditions	Surface boundary conditions	Period	Simulations
All-Hist (baseline)	Varying as observed	Varying as observed	1960 to 1995 or earlier	10 or more
All-Hist (reference)	Same as for "All-Hist (baseline)"	Same as for "All-Hist (baseline)"	1996 or earlier through to the present	50 or more
Nat-Hist (CMIP5-est1 estimate)	Anthropogenic: at pre-industrial values; Natural: varying as observed	Ocean temperatures: varying as observed but with the "CMIP5-est1" estimate of attributable anthropogenic warming subtracted; sea ice coverage: adjusted for consistency with the ocean temperatures; land cover: as observed	Same as "All-Hist (reference)"	50 or more
Nat-Hist (second estimate)	Anthropogenic: at pre-industrial values; Natural: varying as observed	Ocean temperatures: varying as observed but with a second estimate of attributable anthropogenic warming subtracted (different estimates to be used for each model); sea ice coverage: adjusted for consistency with the ocean temperatures; land cover: as observed	Same as "All-Hist (reference)"	50 or more
Nat-Hist (third estimate)	Anthropogenic: at pre-industrial values; Natural: varying as observed	Ocean temperatures: varying as observed but with a second estimate of attributable anthropogenic warming subtracted (different estimates to be used for each model); sea ice coverage: adjusted for consistency with the ocean temperatures; land cover: as observed	Same as "All-Hist (reference)"	50 or more

Table 1: List of sets of simulations comprising the core experiment of the C20C+ D&amp;A Project.

### 3.1 All-Hist simulations

These simulations are intended to represent possible realisations under observed historical climate conditions. Ideally, the All-Hist simulations would all cover the full 1960-2013 period, with ~50 or more simulations in total. This may be too much for some modelling groups, so the All-Hist simulations are being divided into two sets, those covering the period before the past ~decade (“baseline”) and those covering the past ~decade (“reference”, as they provide the reference against which the “counterfactual” simulations can be compared). Note that these simulations are identical in all other aspects, it is just that there may be fewer covering the “baseline” period. In order to sample the 1997-1998 El Niño event, it is suggested that the “reference” simulations start on or before 1 January 1996.

#### 3.1.1 All-Hist “baseline” simulations

**Purpose:** These simulations are intended (with their continuations in the “reference” simulations) to inform estimates of trends in extreme events during the past half-century, as well as to provide estimates for the baseline climatology of extremes.

**Radiative boundary conditions:** The idea is to approximate the conditions that have actually prevailed since 1960, so all radiative forcings should be varied according to observational estimates. Variations in greenhouse gas concentrations, tropospheric sulphate aerosol burdens (or emissions), and stratospheric volcanic aerosol burdens should be considered a minimum, with a preference to also include variations in the burdens/emissions of other aerosols, stratospheric ozone concentrations, and solar luminosity. Further details are given in

[http://portal.nersc.gov/c20c/input\\_data/C20C-DandA\\_dSSTs\\_All-Hist-est1\\_Nat-Hist-CMIP5-est1.pdf](http://portal.nersc.gov/c20c/input_data/C20C-DandA_dSSTs_All-Hist-est1_Nat-Hist-CMIP5-est1.pdf), and some suggested input datasets are given at

[http://portal.nersc.gov/c20c/input\\_data/index.html](http://portal.nersc.gov/c20c/input_data/index.html).

**Surface boundary conditions:** Sea surface temperatures and sea ice concentrations should also be varied as observed, at monthly or higher frequency. There is a preference to include variations in land cover as well. Further details are given in

[http://portal.nersc.gov/c20c/input\\_data/C20C-DandA\\_dSSTs\\_All-Hist-est1\\_Nat-Hist-CMIP5-est1.pdf](http://portal.nersc.gov/c20c/input_data/C20C-DandA_dSSTs_All-Hist-est1_Nat-Hist-CMIP5-est1.pdf), and some suggested input datasets are given at

[http://portal.nersc.gov/c20c/input\\_data/index.html](http://portal.nersc.gov/c20c/input_data/index.html).

**Period:** The period should extend from the beginning of the experiment, 1960, through to the handover point to the “reference” simulations.

**Number of simulations:** In order to gain some sampling power for rare extremes, a minimum ensemble size of 10 is suggested.

#### 3.1.2 All-Hist “reference” simulations

**Purpose:** These simulations are intended to provide high sampling of the tails of the probability distributions of meteorological events during recent years to provide the real-world reference for attribution analysis.

**Radiative boundary conditions:** Exactly the same as for the All-Hist “baseline” simulations.

**Surface boundary conditions:** Exactly the same as for the All-Hist “baseline” simulations.

**Period:** The intention is to cover the a decent sample of recent years, and including the major 1997-1998 El Niño event would be interesting. So a start date of 1996 or earlier is suggested. These simulations should extend to the near-present (2013 at the time of writing). Some or all of these simulations may be continuations of the “baseline” simulations.

**Number of simulations:** In order to sample the probability of rare events, a minimum ensemble size of 50 is suggested.

## 3.2 Nat-Hist “counterfactual” simulations

These simulations are intended to represent possible realisations that might have occurred had anthropogenic emissions never interfered with the climate system. In particular, they are intended to provide high sampling of the probability distributions of meteorological events under this natural historical scenario. They thus provide the counterfactual for attribution analyses. Because ocean boundary conditions must be prescribed in (at least most of) the models participating in the C20C+ D&A Project, the importance of the uncertainty in the estimated ocean conditions must be sampled through a number of scenario estimates.

### 3.2.1 Nat-Hist/CMIP5-est1 simulations

**Purpose:** These simulations are intended both as a “first estimate” of Nat-Hist climate and as the primary Nat-Hist estimate for inter-model comparison. Thus, these simulations are to be carried out with all models using the same surface boundary conditions.

**Radiative boundary conditions:** All anthropogenic radiative forcings should be set to pre-industrial (ca. 1850) values. All natural radiative forcings should be exactly as for the All-Hist “reference” simulations. Further details are given in

[http://portal.neresc.gov/c20c/input\\_data/C20C-DandA\\_dSSTs\\_All-Hist-est1\\_Nat-Hist-CMIP5-est1.pdf](http://portal.neresc.gov/c20c/input_data/C20C-DandA_dSSTs_All-Hist-est1_Nat-Hist-CMIP5-est1.pdf), and some suggested input datasets are given at [http://portal.neresc.gov/c20c/input\\_data/index.html](http://portal.neresc.gov/c20c/input_data/index.html).

**Surface boundary conditions:** Sea surface temperatures should be as in the All-Hist “reference” simulations but with the “CMIP5-est1” attributable anthropogenic warming estimate subtracted. The “CMIP5-est1” estimate is a spatio-temporal estimate of the ocean warming attributable to anthropogenic emissions determined by subtracting the “HistoricalNat” simulations from the “historical” simulations performed by atmosphere-ocean models and available in the CMIP5 archive (Taylor et al. 2012). Sea ice coverage is modified for consistency following the method of Pall et al. (2011). Further details are given in

[http://portal.neresc.gov/c20c/input\\_data/C20C-DandA\\_dSSTs\\_All-Hist-est1\\_Nat-Hist-CMIP5-est1.pdf](http://portal.neresc.gov/c20c/input_data/C20C-DandA_dSSTs_All-Hist-est1_Nat-Hist-CMIP5-est1.pdf). The “CMIP5-est1” attributable sea surface temperature warming dataset and the application of that dataset to various observational products (including consistent sea ice adjustment) are provided at [http://portal.neresc.gov/c20c/input\\_data/index.html](http://portal.neresc.gov/c20c/input_data/index.html). Land cover should be the same as in the All-Hist “reference” simulations.

**Period:** These simulations should cover the same period as the All-Hist “reference” simulations.

**Number of simulations:** The ensemble size should be the same as for the All-Hist “reference” simulations, with 50 being suggested.

### 3.2.2 A second set of Nat-Hist simulations

**Purpose:** These simulations are intended to provide another estimate of Nat-Hist climate. They will differ from the Nat-Hist/CMIP5-est1 simulations in the estimate of attributable anthropogenic ocean warming used. The selection of attributable warming estimate is intended to be different for each model.

**Radiative boundary conditions:** The same as for the Nat-Hist/CMIP5-est1 simulations.

**Surface boundary conditions:** Sea surface temperatures should be as in the All-Hist “reference” simulations but with an estimate of the attributable anthropogenic warming estimate subtracted. Candidate datasets will be posted at [http://portal.neresc.gov/c20c/input\\_data/index.html](http://portal.neresc.gov/c20c/input_data/index.html), but modelling groups are also free to use their own estimates. Land cover should be the same as in the All-Hist “reference” simulations.

**Period:** These simulations should cover the same period as the All-Hist “reference” simulations.

**Number of simulations:** The ensemble size should be the same as for the All-Hist “reference” simulations, with 50 being suggested.

### 3.2.3 A third set of Nat-Hist simulations

**Purpose:** Like the second set of Nat-Hist simulations, these simulations are intended to provide another estimate of Nat-Hist climate. They will differ from the Nat-Hist/CMIP5-est1 simulations in the estimate of attributable anthropogenic ocean warming used. The selection of attributable warming estimate is intended to be different for each model.

**Radiative boundary conditions:** The same as for the Nat-Hist/CMIP5-est1 simulations.

**Surface boundary conditions:** Sea surface temperatures should be as in the All-Hist “reference” simulations but with an estimate of the attributable anthropogenic warming estimate subtracted. Candidate datasets will be posted at [http://portal.nersc.gov/c20c/input\\_data/index.html](http://portal.nersc.gov/c20c/input_data/index.html), but modelling groups are also free to use their own estimates. Land cover should be the same as in the All-Hist “reference” simulations.

**Period:** These simulations should cover the same period as the All-Hist “reference” simulations.

**Number of simulations:** The ensemble size should be the same as for the All-Hist “reference” simulations, with 50 being suggested.

## 4 Dissemination of output

### 4.1 Data portal

Output from these simulations is being published on the Earth System Grid Federation (ESGF, <http://esg.nersc.gov/esgf-web-fe/live>) under the project name “c20c”. Data can either be published on the NERSC ESGF node (<http://esg.nersc.gov>) or on other ESGF nodes, provided it is listed under the “c20c” project and the directory structure follows specifications of the C20C+ D&A Project.

- Published output should be in NetCDF format following the labeling and metadata structure described in [http://portal.nersc.gov/c20c/about/C20C\\_attribution\\_output\\_metadata.pdf](http://portal.nersc.gov/c20c/about/C20C_attribution_output_metadata.pdf) and the file name convention described in [http://portal.nersc.gov/c20c/about/C20C\\_attribution\\_portal.pdf](http://portal.nersc.gov/c20c/about/C20C_attribution_portal.pdf).
- For those publishing data on a new ESGF node, the required directory structure is described in [http://portal.nersc.gov/c20c/about/C20C\\_attribution\\_portal.pdf](http://portal.nersc.gov/c20c/about/C20C_attribution_portal.pdf). This document is also helpful for formulating metadata entries in the data files.
- To publish data on the NERSC ESGF node, contact [dstone@lbl.gov](mailto:dstone@lbl.gov).

### 4.2 Data usage

All output published on the ESGF data portal is to be freely available for all use. No registration or use of certificates is planned. Some groups are including the following “license” attribute in their NetCDF metadata:

*“Creative Commons License: <http://creativecommons.org/licenses/by-nc-sa/2.0/>”*

Some analyses will themselves produce data sets suitable for inclusion on the data portal. For instance, one analysis may take output from the global dynamic models may be downscaled over a region using a particular statistical method, or may estimate streamflow in a river basin using a basin-specific model. Researchers conducting such analyses are strongly encouraged to publish this output to the data portal. Thus, by publishing their data on the portal, modelling groups gain the benefit of calculations of derivative variables by disciplinary experts.

## 5 Project participation

### 5.1 Acceptable modelling contributions

This is an ad hoc project dependent on voluntary participation of modelling groups requiring usage of substantial computational resources. It is also the first major project exploring the importance of various contributors to uncertainty in event attribution estimates. Thus, specifications described in this document can generally be regarded as general guidelines and not necessarily as strict criteria. Probably the minimum requirement for participation is a 10-member ensemble of simulations following the All-Hist scenario (both the “baseline” and “reference” periods).

Examples of some cases where a contribution would definitely be useful even if it did not satisfy all suggested specifications of the core experiment are:

- Usage of a very high spatial resolution model or of a model with some representation of a dynamical ocean. The extra computational demands of these models may make 50-member ensembles prohibitive, but these models would add extra dimensions to analyses of the full C20C+ D&A Project data set.
- Simulations only completed for the All-Hist scenario. One of the main scientific goals of this project is to provide a modelling data source for better understanding trends in and interannual variability of extreme events. Meeting this goal does not require the Nat-Hist simulations.
- Simulations only completed for the All-Hist and Nat-Hist/CMIP5-est1 scenarios, with no simulations for any other Nat-Hist scenario estimate. Such a contribution would still be useful for understanding the importance of climate model selection for characterising uncertainty in event attribution estimates.

It should also be emphasised that the listed specifications of the core experiment are not an upper limit on contributions! Modelling groups are welcome to do larger ensembles, a larger number of Nat-Hist scenario estimates, and/or to do additional simulations using different estimates of observed boundary conditions. Please contact [dstone@lbl.gov](mailto:dstone@lbl.gov) for assigning experiment labels.

### 5.2 Concept of a model for this project

The emphasis of this project is on the use of global dynamical models of the atmospheric system. However, contributions are not intended to be limited to just these models, nor just to models of the climate system. Contributions are particularly invited from:

- Global dynamical models of the coupled atmosphere-ocean system.
- Regional downscaling methods (dynamical and statistical), downscaling output from the global models within a regional domain.
- Calculations of climate indices, for instance extreme value indices, based on the global model output or regionally downscaled output. Such contributions should also include calculations based on historical observational records, if possible.
- Output from “impacts” models whether global or regional in extent (for instance output from a model of a particular river basin), driven by output from the global model output or regionally downscaled output. Such contributions should also include output of simulations driven by historical observational records, if possible.

The structure of the data portal has been intentionally formulated to support dissemination of contributions for this wide variety of data types.

## 6 Timeline

**2013 (done):** Activation of project data portal, publication of output from trial experiment

**November 2014 (done):** Launch of core experiment at C20C 6th Workshop

**February 2014:** Expansion of NERSC ESGF data portal directory allocation

**Mid 2014:** Expansion of NERSC ESGF data portal to HPSS archive

**End 2014:** First collection of core simulations completed (more are welcome and anticipated at a later date, but these will form the basis for the first set of comparative analyses)

**Mid 2015:** Submission of papers for special journal issue on first set of comparative analyses. Interest in contributing to the special issue should be addressed to [dstone@lbl.gov](mailto:dstone@lbl.gov).

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