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# The Decadal Climate Prediction Project

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**Abstract.**

The Decadal Climate Prediction Project (DCPP) is a coordinated multi-model investigation into decadal climate prediction, predictability, and variability. The DCPP makes use of past experience in simulating and predicting decadal variability and forced climate change gained from CMIP5 and elsewhere. It builds on recent improvements in models, in the reanalysis of climate data, in methods of initialization and ensemble generation, and in data treatment and analysis to propose an extended comprehensive decadal prediction investigation as part of CMIP6. The DCPP consists of three Components. Component A comprises the production and analysis of an extensive archive of retrospective forecasts to be used to assess and understand historical decadal prediction skill, as a basis for improvements in all aspects of end-to-end decadal prediction, and as a basis for forecasting on annual to decadal timescales. Component B undertakes ongoing production, dissemination and analysis of experimental quasi-real-time multi-model forecasts as a basis for potential operational forecast production. Component C involves the organization and coordination of case studies of particular climate shifts and variations, both natural and naturally forced (e.g. the "hiatus", volcanoes), including the study of the mechanisms that determine these behaviours. Groups are invited to participate in as many or as few of the Components of the DCPP, each of which are separately prioritized, as are of interest to them.

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The Decadal Climate Prediction Project addresses a range of scientific issues involving the ability of the climate system to be predicted on annual to decadal timescales, the skill that is currently and potentially available, the mechanisms involved in long timescale variability, and the production of forecasts of benefit to both science and society.

## 1 Introduction

The term "decadal prediction" encompasses predictions on annual, multi-annual to decadal timescales. The possibility of making skillful forecasts on these timescales, and the ability to do so, is investigated by means of predictability studies and retrospective predictions (hindcasts) made using the latest generation of climate models. Skillful decadal prediction of relevant climate parameters is a Key Deliverable of the Grand Challenge of Near Term Climate Prediction under consideration by the World Climate Research Programme (WCRP).

The Decadal Climate Prediction Panel, in conjunction with the Working Group on Seasonal to Interannual Prediction (WGSIP) and the Working Group on Coupled Modelling (WGCM ) is coordinating the scientific and practical aspects of the Decadal Climate Prediction Project (DCPP) which will contribute to the 6th Coupled Model Intercomparison Project (Eyring et al., 2015). The DCPP website (http://www.wcrp-climate.org/dcp-overview) contains up-to-date information on the DCPP and related issues. The CMIP6 website (http://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6) contains information on CMIP6, including links to forcing information and data treatment.

Predictability is a feature of a physical and/or mathematical system which characterizes "its ability to be predicted" as indicated, for instance, by the rate at which the trajectories of initially close states separate. Predictability may be estimated from models although with the proviso that such indications depend on the model on which they are based and do not necessarily fully represent the behaviour of the physical climate system. Predictability studies, used with care, can give an indication as to where, under what circumstances, and the level of confidence with which it may be possible to predict various climate parameters on timescales from seasons to decades.

Forecast skill, on the other hand, is measured by comparing initialized forecasts with observations and indicates the "ability to predict" the actual evolution of the climate system. A forecast is essentially useless unless there is some indication of its expected skill. A sequence of retrospective forecasts (known as "hindcasts") made with a single model, or preferably multiple models, can provide historical skill measures as well as estimates of predictability. The forecasts also provide information, together with targeted simulations, for understanding the physical mechanisms that govern climate variations and this is important for the science as well as for engendering confidence in the forecasts.

The evolutions of the forecast and observed variables of the physical climate system are a combination of externally forced and internally generated components, both of which are important on annual to decadal timescales. The externally forced

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components are the result of changes in greenhouse gases, anthropogenic and volcanic aerosols, variations in solar irradiance and the like. Examples of internally generated variability include the El Niño Southern Oscillation (ENSO), important on annual timescales, and the multi-year to multi-decadal variations in both the Pacific and Atlantic Oceans. Decadal predictions encompass aspects of both an initial value and a forced boundary value problem as indicated in Figure 1. It is important for successful decadal prediction that both the externally forced and internally generated components of the system are initialized and it is also useful to diagnose their contributions to the skill of the hindcasts and forecasts.

The DCPP's extensive archive of annual, multi-annual to decadal climate hindcasts and results of targeted experiments will support improved understanding of the mechanisms underlying forced and naturally occurring climate variability. The information generated by the DCPP can provide a basis for socially relevant operational predictions of climatic parameters on annual to decadal timescales. These results will be of interest generally as well as to international organizations such as the Global Framework for Climate Services (GFCS) and the WMO Commission for Basic Systems (CBS).

## 2 Decadal prediction and CMIP5

While long-term climate simulations have been investigated for some time, the fifth Coupled Model Intercomparison Project (CMIP5; Taylor et al., 2012) represented one of the first attempts at a coordinated multi-model initialized decadal forecasting experiment as illustrated in Figure 2. Results based on the hindcasts from the CMIP5 experiments have been reported in the literature and have contributed to Chapter 11 of the Intergovernmental Panel on Climate Change fifth assessment report (AR5) entitled Near-term Climate Change: Projections and Predictability (Kirtman et al, 2013). These comparatively early results indicate that there is skill in predicting the annual mean temperature evolution for a number of years into the future (e.g., Doblas-Reyes et al. 2013). The upper panels of Figure 3 plot the correlation skill of the year 1 and year 2 forecasts and the year 2-5 average forecast for surface air temperature. The impact of initialization is plotted in the lower panels. The results are based on the output of 6 forecast models participating in CMIP5. Similar results for precipitation are available but show considerably less skill at this stage but the expectation is that the improvements in the forecast systems participating in CMIP6 will lead to improved skill for this important parameter. The results in Figure 1 are based on earlier models and approaches but it is clear that predictions of surface air temperature have considerable skill for a number of years. The enhancement of skill due to the initialization of the forecasts is greatest in the first few years and becomes less so at longer forecast ranges where skill is provided mainly by the externally forced component.

This behaviour is seen also in Figure 4 where the global average of the correlation skill for surface air temperature from a single model is plotted. The orange curve indicates the overall correlation skill associated with the prediction of both forced and internally generated components of variability. While the separation is approximate, the blue curve estimates the skill associated with the initialization of the internally generated component and the difference between the curves indicates the skill associated with the forced component. The skill of the initialized internally generated component displays classical forecast behaviour and declines toward zero as the forecast progresses. The externally forced component, on the other hand, maintains skill at longer forecast times. The result is that the overall skill of decadal forecasts does not decline to zero but plateaus or even increases as forecast range increases. Finally, Figure 4 also plots an estimate of "potential skill" which is the skill that the model obtains when predicting its own evolution. To the extent that the model suitably reflects the behaviour of the actual system this at least suggests that there may be additional skill that could be accessed by the improved forecasting systems that will be used in the DCPP.

## 3 The DCPP and CMIP6

The approach taken in CMIP6 differs in some respects from CMIP5 although both climate simulations and decadal hindcasts are again important components. The DCPP is a CMIP6-endorsed model intercomparison project which consists of three Components, each of which comprises a central "core" and additional desirable, but less central, experiments and integrations. Terminology has changed slightly compared to CMIP5 and Figure 1 with core experiments now denoted as "Tier 1" and so on for the other tiers. The experience gained in CMIP5 and the subsequent improvements made in forecast systems make it timely to revisit an improved and extended decadal prediction component for CMIP6.

The lessons learned from the CMIP5 decadal prediction experiments have been incorporated into the design of the DCPP. Differences in the CMIP6 experimental protocol compared to that of CMIP5 include more frequent hindcast start dates and larger ensembles of hindcasts for each start date intended to provide robust estimates of skill (e.g. Sienz et al. 2016), the addition of ongoing quasi-operational experimental decadal forecasts (Smith et al. 2013), and the addition of targeted experiments to provide insight into the physical processes affecting decadal variability forecast skill (e.g. Ruprich-Robert et al. 2016).

The three Components of the DCPP are:

- *Component A, Hindcasts:* the design and organization of a coordinated decadal prediction (hindcast) component of CMIP6 in conjunction with the seasonal prediction and climate modelling communities and the production of a comprehensive archive of results for research and applications
- *Component B, Forecasts:* the ongoing production of experimental quasi-operational decadal climate predictions in support of multi-model annual to decadal forecasting and the application of the forecasts to societal needs
- *Component C, Predictability, mechanisms, and case studies:* the organization and coordination of decadal climate predictability studies and of case studies of particular climate shifts and variations including the study of the mechanisms that determine these behaviours

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Components A and B are directed toward the production, analysis and application of annual, multi-annual to decadal forecasts. A major output of these Components is a multi-model archive of retrospective and real-time forecasts, which will serve as a resource for the analysis, understanding, and improvement of near-term climate forecasts and forecasting techniques and of their potential application (e.g. Caron, et al., 2015).

Component C proposes targeted investigations which seek to understand some of the mechanisms that produce long timescale variability in the climate system and that support successful predictions of both internally generated and externally forced climate variability. Mechanisms investigated via targeted simulations include aspects and effects of Pacific Decadal Variability (PDV) and Atlantic Multidecadal Variability (AMV) as well as volcanic effects on prediction and predictability. Many scientific and practical questions are involved. The understanding of the physical processes that govern the long timescale predictability of the climate system is vital for improving decadal predictions and gaining further confidence in forecasts.

The analysis of available observations for initializing forecasts, the improvement of the models used in the production of the forecasts, post processing of forecasts including bias adjustment, calibration and multi-model combination, together with the production and application of probabilistic decadal forecasts, are all involved in the research and development efforts contributing to the DCPP. As has been the case for weather forecasting, continued improvement in each of the components of a decadal forecasting system is expected to yield improvement in decadal prediction skill.

Groups are invited to participate in as many or as few of the Components, each of which are separately "tiered", as are of interest to them. The number of years of integration associated with Tiers 1 to 3 of each of the Components and sub-Components is listed in Table 1 where the Tier 1 experiments are shaded in yellow. Groups are invited to consider also the Tier 4 experiments, described in detail on the DCPP website, but these are expected to be of interest to fewer groups. It is hoped that most groups will participate in the Tier 1 experiments associated with at least one of the Components but it is not expected that all groups will participate in all experiments or tiers.

## 4 DCPP Component A: A multi-year multi-model decadal hindcast experiment

The decadal hindcast component of CMIP follows the example of other coordinated experiments as a protocol-driven multi-model multi-national project with data production and data sharing as integral components.

**The Goals** of the decadal hindcast component of CMIP include:

- the promotion of the science and practice of decadal prediction (forecasts on timescales up to and including 10 years)

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- the provision of information potentially useful for the IPCC WG1 AR6 assessment report and other studies and reports on climate prediction and evolution
- the production and retention of a multi-year multi-model collection of decadal hindcast data in support of climate science and of use to the Global Framework for Climate Services (GFCS) and other organizations

**Scientific aspects** of the DCPP to which Component A can contribute include:

- a system view (data; analyses; initial conditions; ensemble generation; models and forecast production; post processing and assessment) of decadal prediction
- the investigation of broad questions (e.g. sources and limits of predictability, current abilities with respect to decadal prediction, potential applications, …)
- the provision of benchmarks against which to compare improvements in forecast system components and their contribution to prediction quality
- information on processes and mechanisms of interest (e.g., the hiatus, climate shifts, Atlantic meridional overturning circulation (AMOC), etc.) in a collection of hindcasts

**Practical aspects** of Component A include:

- the coordination of efforts based on agreed experimental structures and timelines in order to promote research, intercomparison, multimodel approaches, applications, and new research directions
- a contribution to the development of infrastructure, in particular a multi-purpose data archive of decadal hindcasts useful for a broad range of scientific and application questions and of benefit to national and international climate prediction and climate services organizations.

**The basic elements** of Component A are:

- a coordinated set of multi-model multi-member ensembles of retrospective forecasts initialized each year from 1960 to the present
- the resulting archive of forecast results generally and readily available to the scientific and applications communities via the Earth System Grid Federation (ESGF)

**Consultation and timing** for Component A:

- The proposed timing for Component A generally follows that outlined for CMIP6 (Eyring et al. 2015). In particular, the availability of historical forcing and future scenario information are key to DCPP timing.

Details of the proposed Component A decadal prediction hindcasts are listed in **Appendix A** and are also available on the DCPP website.

## 5. DCPP Component B: Experimental real-time multi-model decadal predictions

The real-time decadal prediction component of the DCPP will also follow the example of other coordinated experiments as a protocol-driven multi-model multi-national project with data production and data sharing as integral components. The WMO structure already in place for seasonal forecasts is an example. Forecasts and verification statistics will be made available on the ESGF as part of CMIP6. Current efforts in quasi-real time annual and multi-annual predictions are being undertaken by individual groups, are collected at the UK Met Office (http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel), and provide the basis of a multi-model prediction effort (Smith et al. 2013). An example of such a multi-model quasi-real-time prediction is shown in Figure 5. Results from the newer forecasting systems employed in Component A will be incorporated as they become available and are expected to improve these quasi-operational forecasts. At some later time the WMO may designate "Lead Centres" to collect forecast and verification data in order to produce an operational multi-model real-time forecast together with an assessment of performance. A demonstrated ability to produce skillful real-time multi-annual forecasts will be a contribution to the GFCS.

**Goals:**

- as for Component A but with the added dimension that the goals apply to quasi-operational real-time multi-model decadal predictions

**Scientific aspects**

- the assessment of decadal predictions of key variables including surface temperature, precipitation, mean sea level pressure, AMV, PDV, Arctic sea ice, the North Atlantic Oscillation (NAO), and tropical storms
- the assessment of uncertainties and the generation of a consensus forecast
- the assessment of decadal predictions and associated climate impacts of societal relevance

**Basic elements**

- an ongoing coordinated set of multi-model multi-member ensembles of real-time forecasts, updated each year
- an associated hierarchy of data sets of results generally and readily available to the scientific and applications communities

Details of the proposed Component B real-time decadal decadal prediction component are listed in the **Appendix B** and are also available on the DCPP website.

## 6 DCPP Component C: Predictability, Mechanisms and Case Studies

The climate system varies on multiple timescales, which may be studied using physically based and statistical models. Diagnostic studies investigate climate system behaviour inferred indirectly from a long series of observations and/or model simulations. Prognostic studies investigate the behaviour of models when initial conditions or model features such as physical parameterizations, numerical treatments or forcings are perturbed. The mechanisms involved in the long timescale behaviour of the climate system are of great interest as they underpin the inherent predictability of the system that governs forecast skill.

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Case studies are hindcasts which focus on a particular climatic event and the mechanisms and impacts involved. These are typically hindcast studies of an observed event although they can include particular kinds of events seen in model integrations (variations of AMOC and the associated variation of the North Atlantic sea surface temperatures (SSTs) in models are an example). Studies of the skill with which a particular event (e.g. the hiatus, climate shift, an extreme year, etc.) can be forecast and the mechanisms which support (or perhaps make difficult) a skilful prediction are all of interest.

The DCPP and the CLIVAR DCVP are proposing coordinated multi-model investigations of a limited number of mechanism/predictability/case studies believed to be of broad interest to the community. Two research areas are the current foci of Component C. They are:

- Hiatus+: this is used as shorthand to indicate investigations into the origins, mechanisms and predictability of long timescale variations in both global mean surface temperature (and other variables) and regional imprints including periods of both enhanced global warming and cooling with a focus on the most recent slowdown that began in the late 1990s.
- Volcanoes in a prediction context: an investigation of the influence and consequences of volcanic eruptions on decadal prediction and predictability

Full details of the proposed experiments are given in **Appendix C.**

The proposed experiments in Table C1 of Appendix C are intended to discover how models respond to imposed slowly evolving SST anomalies in the Atlantic and the Pacific, which are perceived as originating in ocean heat content or heat transport convergence anomalies. The questions at issue are the consistency of models' responses to these SSTs and the pathways through which the responses are expressed throughout the ocean and atmosphere. The experiments are expected to illuminate model behaviour on decadal time scales and possible mechanistic links to retarded and accelerated global surface temperature variations and regional climate anomalies. In other words, to what extent to can modulations of global mean surface temperatures be attributed to ocean heat content variations, what are the respective roles of Atlantic and Pacific SST anomalies in these changes, and to what extent can we attribute decadal climate anomalies at regional scale (particularly over land) to the patterns of Atlantic Multidecadal Variability (AMV) and Pacific Decadal Variability (PDV) sea surface temperature that are illustrated in Figures 6 and 7? These experiments also address the interrelationships between the AMV and PDV shifts and the mechanisms at play.

A second set of Component C experiments in Table C2 of Appendix C investigates the predictability of the mid-1990s warming of the Atlantic subpolar gyre, and its impacts on climate variability. Some CMIP5 decadal hindcasts successfully predicted this event (Robson et al. 2012, Yeager et al. 2012, Msadek et al. 2014) together with some aspects of associated climate impacts (Robson et al. 2013, Smith et al. 2010). The proposed experiments will investigate in more detail the role of initialization of the Atlantic subpolar gyre. Analysis of these experiments will include assessment of the role of the Atlantic

Meridional Overturning Circulation (AMOC) in the subpolar gyre warming, and the impact of the subpolar gyre on the AMV pattern and associated climate impacts, including rainfall over the Sahel, Amazon, US and Europe, and Atlantic tropical storms.

The final set of Component C experiments in Table C3 of Appendix C are jointly proposed with VolMIP (Zanchettin et al. 2016) and are directed toward an understanding of the effects of volcanoes on past and potentially on future decadal predictions. Removing the forcing due to major volcanic eruptions from hindcasts during which they occurred and introducing volcanic forcing into forecasts during which no volcano occurred will allow estimates of the impact on skill to be made (e.g. Maher et al., 2015, Meehl et al., 2015, Timmreck et al., 2016). Comparing the effects of the same eruption in hindcasts and forecasts also allows the impact of the background climate state to be assessed. In addition to assessing the radiative effects arising from the aerosol loading in the stratosphere, an important aspect of the analysis of these experiments will be to investigate subsequent dynamical responses including, for example, those involving the NAO and ENSO.

Participants are invited to undertake as many or as few of the Component C experiments as are of interest to them. Please see the Notes at the end of Appendix C for additional details on the Component C experimental protocol.

## 7 Concluding comments

The DCPP is unique in bringing together researchers from communities with expertise in seasonal to interannual prediction (as represented by WGSIP), climate simulation (as represented by WGCM), and decadal variability and predictability in general (as represented by CLIVAR). The models used and approaches taken represent to varying degrees the interests and abilities of these communities.

For climate models, control and sensitivity experiments are a necessary backdrop to climate change simulations. Most models used in the DCPP will also participate in other aspects of CMIP6 and will have performed climate integrations as well as other simulations and MIP experiments. The data retained for these studies provides information on forced responses and the statistics of internal variability which are important for DCPP-related studies of many different aspects of decadal variability and prediction. The forecasting aspect of DCPP encourages emphasis on methods of initializing models, generating ensembles of forecasts and, especially, on assessing results against observations. The two approaches represent complementary views for the understanding and prediction of forced and internally generated climate variations. The tiered set of retained data for the DCPP is intended to assist in the evaluation and analysis of DCPP results, but groups are encouraged to retain additional data relevant to other MIPs if possible.

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We believe that the Decadal Climate Prediction Project represents an important evolutionary advance from the CMIP5 decadal prediction component and addresses an integrated range of scientific issues broadly characterized as the ability of the system to be predicted on decadal timescales, the currently available skill, the mechanisms that control long timescale variability, and the ongoing production of forecasts of potential benefit for both science and societal applications. This will be a major resource to support the WCRP's new Grand Challenge of Near Term Climate Prediction and an important asset for the development of climate services on time scales relevant to a wide range of users.

## 8 Data Availability

The model output from DCPP hindcasts, forecasts, and targeted experiments described in this paper will be distributed through the Earth System Grid Federation (ESGF) with digital object identifiers (DOIs) assigned. The list of requested variables, including frequencies and priorities, is given in Appendix D and has been submitted as part of the "CMIP6 Data Request Compilation". As in CMIP5, the model output will be freely accessible through data portals after a simple registration process that is unique to all CMIP6 components. In order to document CMIP6's scientific impact and enable ongoing support of CMIP, users are requested to acknowledge CMIP6, the participating modelling groups, and the ESGF centres (see details on the CMIP website). Further information about the infrastructure supporting CMIP6, the metadata describing the model output, and the terms governing its use are provided by the WGCM Infrastructure Panel (WIP). Links to this information may be found on the CMIP6 website and is discussed in the WIP contribution to this Special Issue. Along with the data itself, the provenance of the data will be recorded, and DOI's will be assigned to collections of output so that they can be appropriately cited. This information will be made readily available so that research results can be compared and the modelling groups providing the data can be credited.

The WIP is coordinating and encouraging the development of the infrastructure needed to archive and deliver the large amount of information generated by CMIP6. Datasets of natural and anthropogenic forcing information are required for the DCPP hindcasts, forecasts, and simulations. These datasets are described in separate contributions to this Special Issue and will be made available through the ESGF with version control and DOIs assigned.

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**Table 1. DCPP Experiments –Tiers 1-3**

| | Experiment | Tier | Years | Description |
|---|---|---|---|---|
| Component A: | A1 | 1 | 3000 | Five year hindcasts each year from 1960 to present |
| Decadal Hindcasts | A2.1 | 2 | 3000 | Extend A1 hindcast duration to 10 years |
| | A2.2 | 2 | 1700 | Ensemble of historical simulations |
| | A3.1 | 3 | 300m | Increase ensemble size by *m* for A1 |
| | A3.2 | 3 | 300m | Increase ensemble size by *m* for A2.1 |
| Component B: | B1 | 1 | 50 | Ongoing near real-time forecasts |
| Decadal Forecasts | B2.1 | 2 | 5m | Increase ensemble size by *m* for B1 |
| | B2.2 | 2 | 50 | Extend forecast duration to 10 years for B1 |
| Component C: | C1.1 | 1 | 250 | Idealized Atlantic control |
| Hiatus+ | C1.2 | 1 | 250 | Idealized impact of AMV+ |
| | C1.3 | 1 | 250 | Idealized impact of AMV- |
| | C1.4 | 1 | 100 | Idealized Pacific control |
| | C1.5 | 1 | 100 | Idealized impact of PDV+ |
| | C1.6 | 1 | 100 | Idealized impact of PDV- |
| | C1.7 | 2 | 500 | Idealized impact of extratropical AMV+ and AMV- |
| | C1.8 | 2 | 500 | Idealized impact of tropical AMV+ and AMV- |
| | C1.9 | 3 | 650 | Pacemaker Pacific experiment |
| | C1.10 | 3 | 650 | Pacemaker Atlantic experiment |
| Component C: | C2.1 | 3 | 200-400 | Predictability of 1990s warming of Atlantic gyre |
| Atlantic gyre | C2.2 | 3 | 200-400 | Additional start dates |
| Component C: | C3.1 | 1 | 50-100 | Repeat 1991 hindcast but without Pinatubo forcing |
| Volcano | C3.2 | 2 | 50-100 | Repeat 1982 hindcast but without El Chichon forcing |
| | C3.3 | 2 | 50-100 | Repeat 1963 hindcast but without Agung forcing |
| | C3.4 | 1 | 50-100 | Repeat 2015 forecast with added Pinatubo forcing |
| | C3.5 | 3 | 50-100 | Repeat 2015 forecast with added El Chichon forcing |
| | C3.6 | 3 | 50-100 | Repeat 2015 forecast with added Agung forcing |

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**Figures**

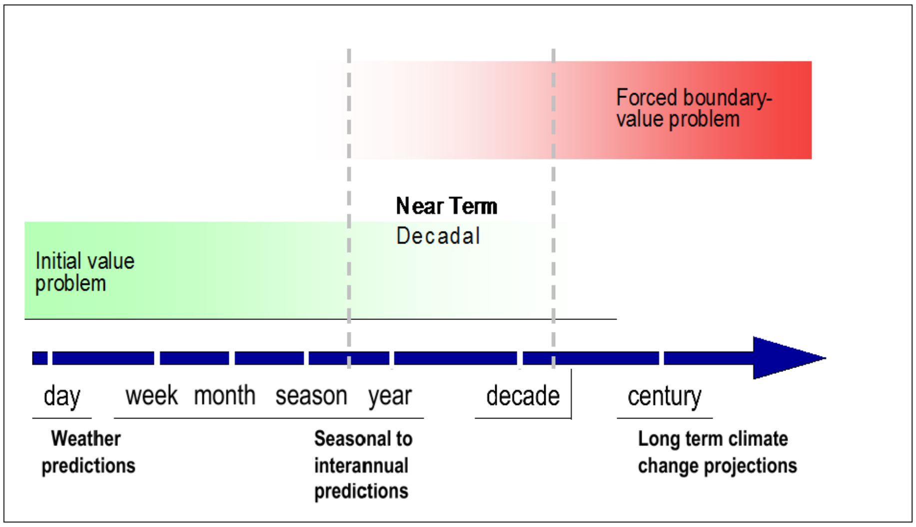


**Figure 1.** Predictions of interest to the Decadal Climate Prediction Project proceed from an initial condition problem at shorter timescales to a forced boundary-value problem at longer timescales (modified from Kirtman et al, 2013, Figure 11.2)

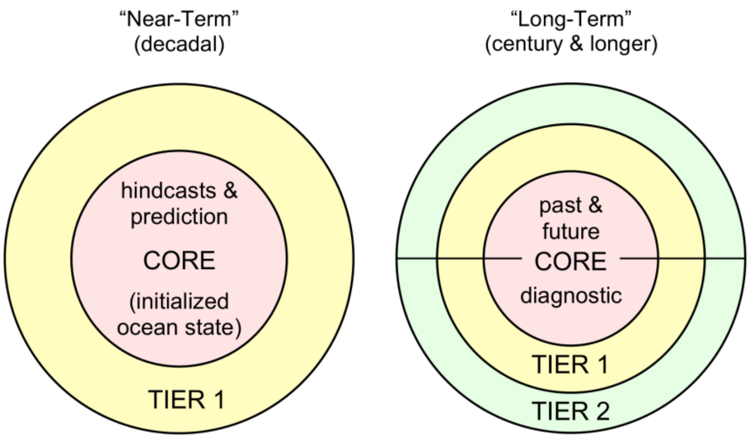


**Figure 2.** Schematic of focus areas of CMIP5 divided into prioritized tiers of experiments (from Taylor et al., 2009). The DCPP structure is similar, but consists of three focus areas (Hindcasts, Forecasts, Mechanisms) each of which are tiered as summarized Table 1 and in the Appendices as well as on the DCPP website.

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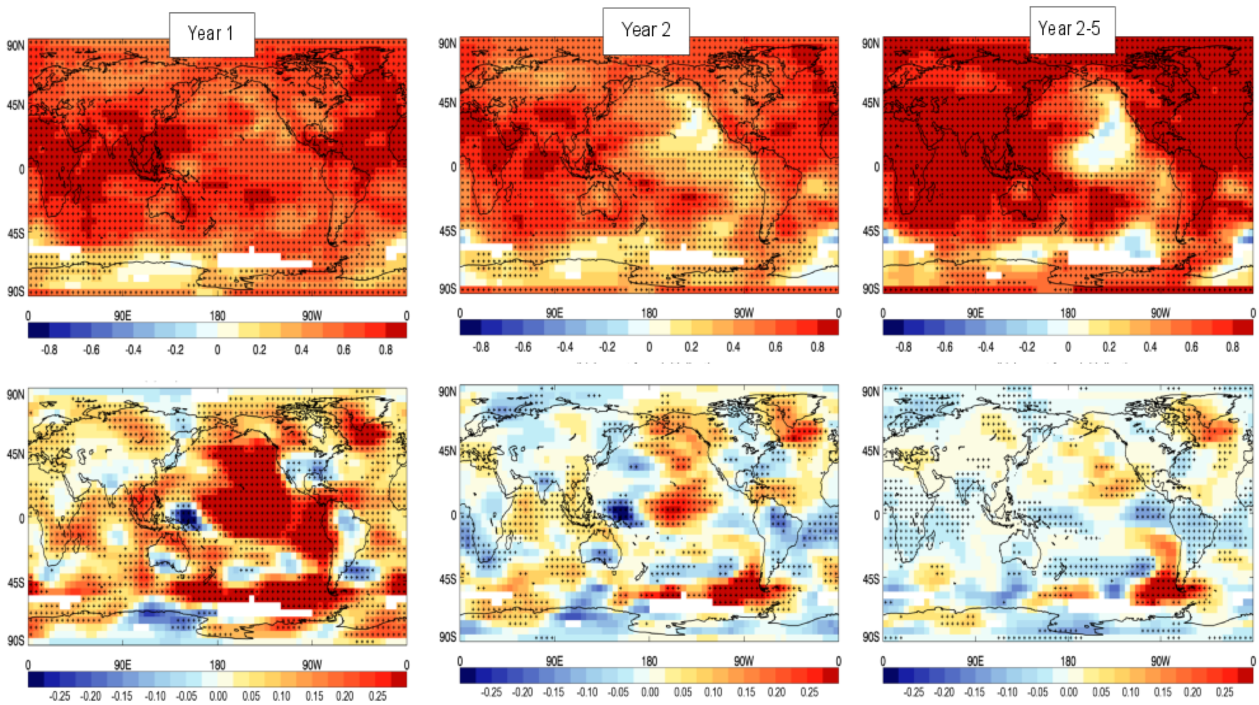


**Figure 3**. Correlation skill for Year 1, Year 2 and Year 2-5 forecasts of surface air temperature (upper panels). Impact of initialization (lower panels) based on the results from 6 models participating in CMIP5. Stippling denotes that the results are significant at the 90% level (using a 2 tailed test). Plots kindly provided by R. Eade (private communication).

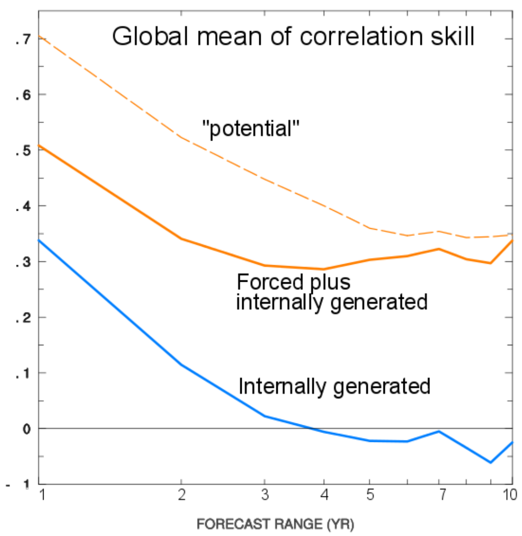


Figure 4. Global average correlation skill for surface air temperature from a single model (based on results from Boer et al., 2013). The orange curve plots the overall skill and the blue curve the skill associated with the initialized internally generated component. The difference between the two curves is associated with the forced component. The dashed line is an estimate of the "potential" skill that could be available if the actual system operated in the same fashion as the model.

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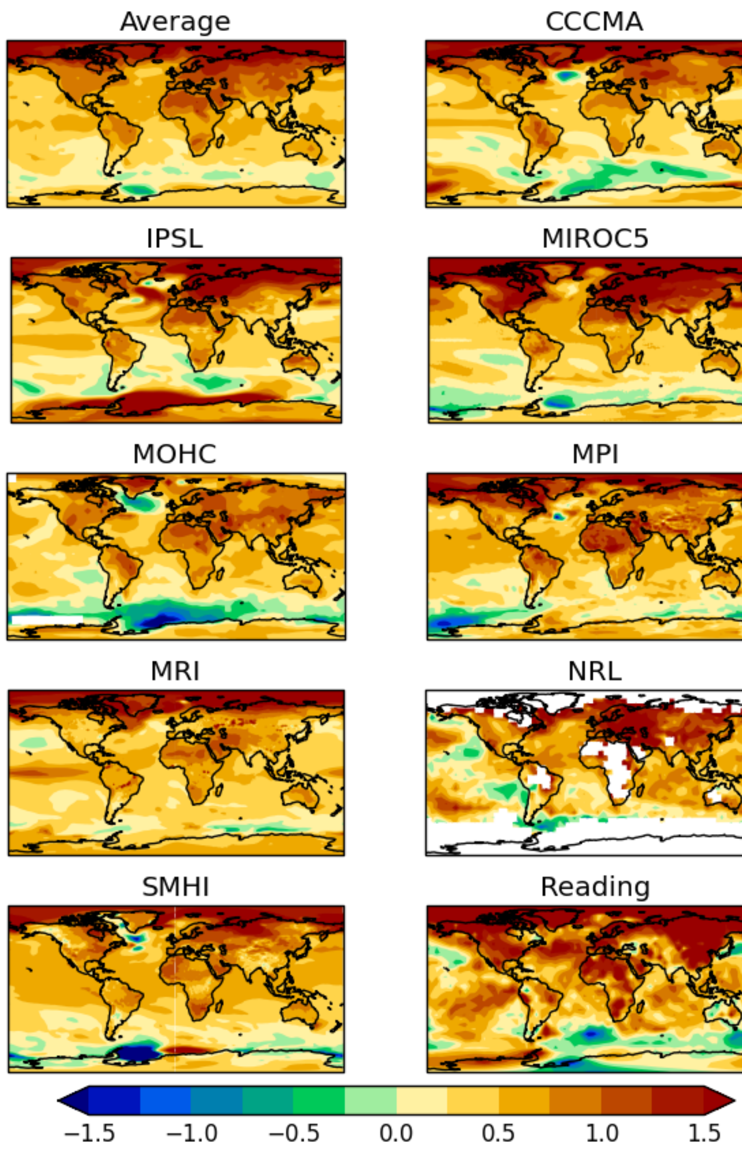


Figure 5. Example real-time multimodel decadal predictions (Smith et al. 2013, available from http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel). Maps show predicted near surface temperature anomalies (°C) relative to the average over 1971 to 2000 for the 5 year period 2015-2019 from forecasts starting at the end of 2014.

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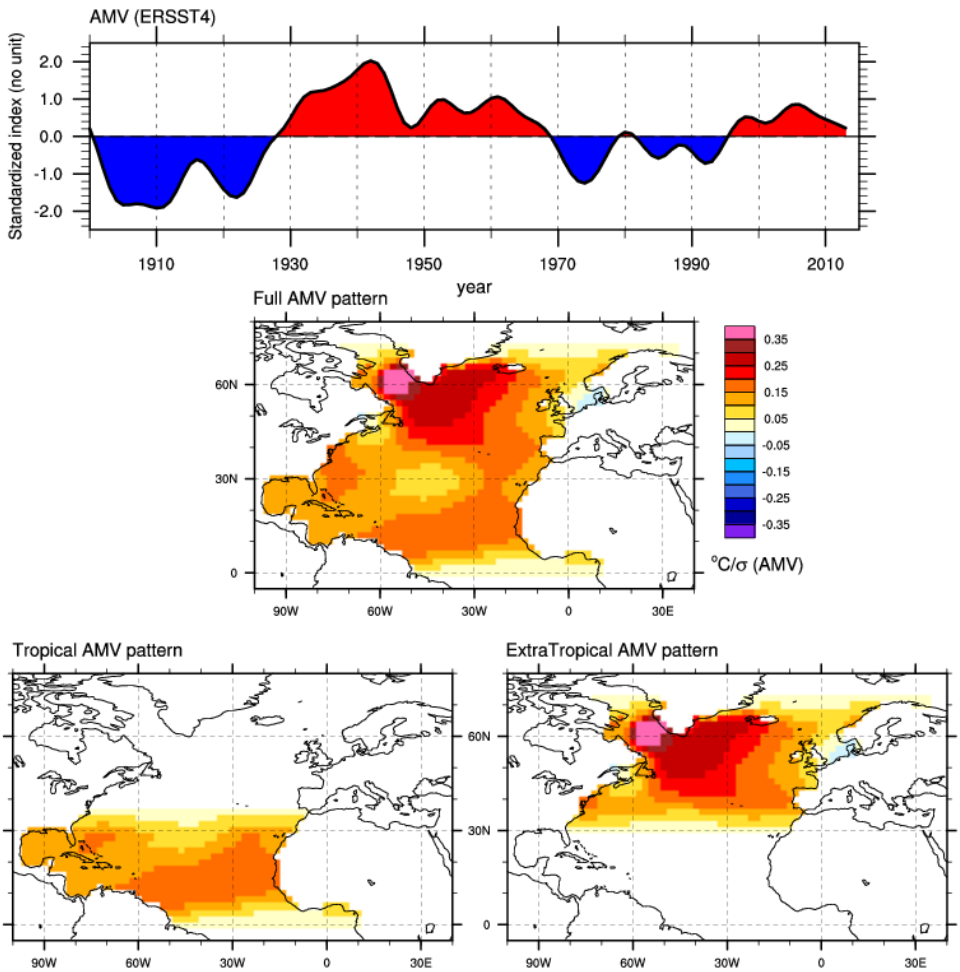


Figure 6. Idealized Atlantic SST pattern. The time series (upper panel) and pattern (middle panel) are derived following the procedure documented in Ting et al (2009) using ERSSTv4 (Huang et al. 2014). Experiments C1.1 to C1.3 use the total AMV pattern (middle panel), whereas experiments C1.7 and C1.8 apply anomalies in the extra-tropics and tropics separately (lower panels).

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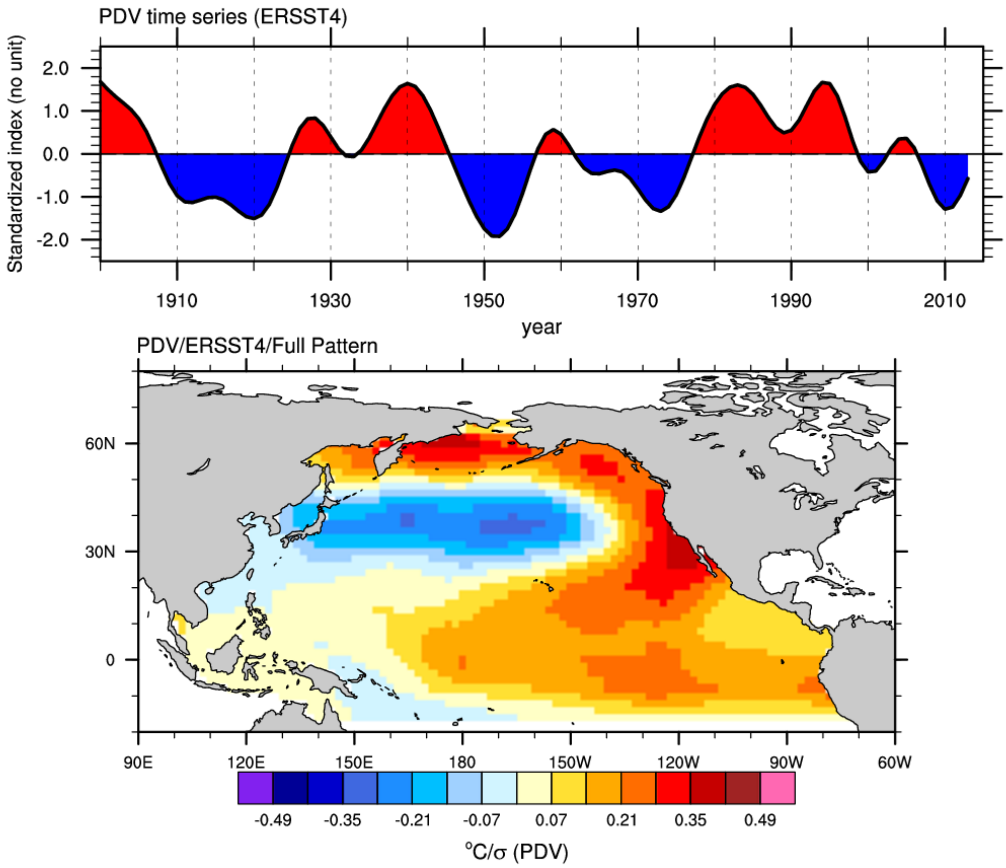


Figure 7. Idealized Pacific SST pattern. The time series (upper panel) and pattern (lower panel) are derived following the procedure documented in Ting et al (2009) using ERSSTv4 (Huang et al. 2014). This pattern is used for experiments C1.5 and C1.6.

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**Apppendix A. Component A hindcasts**

The approach parallels that of the "Near-term Decadal" component of CMIP5 (Taylor et al. 2009) with important differences, notably that the hindcasts are to be produced every year, rather than every 5 years. The Tier 1 experiment consists of hindcasts for years 1-5 for which the impact of initialization is expected to be greatest. Nevertheless, there is reason to believe that some regions may exhibit skill at longer timescales and the A2.1 experiment extends the hindcasts to years 6-10 to allow for the identification of these regions. The A2.2 uninitialized historical simulations are compared with the initialized forecast to assess the impact of initialization.

**Table A1. Basic Component A: Hindcast/forecast experiments**

| # | Experiment | Notes | # of years |
|---|---|---|---|
| **TIER 1: Hindcast/forecast information** | | | |
| A1 | Ensembles of 5 year *hindcasts* and *forecasts* | Coupled models with initialization based on observations<br><br>Start date *every year* from 1960 to the present (i.e. the first full hindcast year is 1961)<br><br>Start date on or before 31 Dec of the year preceding the forecast period (start dates on or before Nov 15 allow for DJF seasonal forecast results and are recommended)<br><br>10 ensemble members (more if possible)<br><br>Prescribed CMIP6 historical values of atmospheric composition and/or emissions (and other conditions including volcanic aerosols). Future forcing as the SSP2-4.5 scenario. | 60x10x5=3000 years of integration |
| **TIER 2: Increase the forecast range to 10 years** | | | |
| A2.1 | Extend the A1 hindcasts and forecasts | Extend the hindcasts and forecast in A1 for another 5 years up to and including year 10 | 60x10x5=3000 years of integration |
| **TIER 2: To quantify the effects of initialization (encompasses CMIP6/historical simulations)** | | | |
| A2.2 | Ensembles of historical and near-future climate *simulations* | Made with the same model as used for hindcasts<br><br>1850 to 2030, with initial conditions from a preindustrial control simulation<br><br>10 ensemble members (more if possible)<br><br>Prescribed historical and future forcing as for the A1 Experiment | 170x10=1700 years of integration |

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**Table A2. Other hindcast experiments (if resources permit)**

| ▪ | Experiment | Notes | # of years |
|---|---|---|---|
| **TIER 3: Effects of increased ensemble size** | | | |
| A3.1 | Increased ensemble size for the A1 Experiment | *m* additional ensemble members to improve skill and examine dependence of skill on ensemble size | 60x5x*m*=300*m* years of integration |
| A3.2 | Increased ensemble size for the A2 Experiment | As A4 but for the A2 Experiment | 60x5x*m*=300*m* years of integration |
| **TIER 4: Improved estimates of hindcast skill** | | | |
| A4.1 | Ensembles of at least 5-year, but much preferably 10-year, hindcasts and forecasts | As A1 but with no information from the future with respect to the forecast<br><br>Radiative and other forcing information (e.g., greenhouse gas concentrations, aerosols, etc.) maintained at initial state value or projected in a simple way. No inclusion of volcano or other short term forcing unless available at initial time. | 1500-6000 years of integration |
| **TIER 4: Improved estimates of the effects of initialization** | | | |
| A4.2 | Ensembles of at least 5-year, but much preferably 10-year, hindcasts and forecasts | Historical climate simulations up to the start dates of corresponding forecast with prescribed forcing<br><br>Simulations continued from forecast start date but with the same forcing as in A4.1, i.e. with NO forcing information from the future with respect to the start date. These are uninitialized versions of A4.1 hindcasts. | 1500-6000 years of integration |

**Table A1** lists the main DCPP Component A experiments. The A1 hindcast experiment parallels the corresponding CMIP5 decadal prediction experiment in using the same specified forcing during the forecasts as is used for the historical climate simulations of experiment A2.2. The specification of historical and scenario forcing introduces some information from the future with respect to the forecast and may lead to slightly overestimated historical forecast skill measures. The main effect is expected to be due to the specification of short term radiative forcings such as volcanoes which occur during a forecast. Other forcings, such as those associated with greenhouse gas and aerosol emissions and/or concentrations, vary comparatively slowly over the five or ten year period of a forecast and are expected to have little effect on the results. The benefits of using specified forcings include the use of common values across models, the ease of treatment within models, the possibility of documenting improvements with respect to CMIP5 hindcasts, the ability to estimate the effects of initialization by comparing forecasts and simulations which use the same forcings, and the estimation of drift corrections from hindcasts which include the forcings and so are more suitable for the purpose of future decadal forecasts.

Component A benefits from and builds on the experience gained from the decadal component of CMIP5. It calls for hindcasts every year, rather than every 5 years, which will improve the statistical stability of results, allow more sophisticated drift treatments, more clearly delineate skill levels, and foster improved assessment, combination, and calibration of the forecasts. Broad participation in Component A will potentially allow classification of results according to i) the initialization of climate components in the models, ii) model resolutions including atmospheric model top, and iii) methods of initialization and ensemble generation. DCPP component A also provides an opportunity to study solar effects on climate. In order to take advantage of this, however, groups should use the correct ozone forcing time series which is important for the impact of solar variations.

**Table A2** lists additional experiments which are of interest if resources permit. The Tier 3 experiments, A3.1 and A3.2, increase the ensemble size in order to quantify the benefits thereof and as a guide to future forecast applications. It is not expected that many groups will undertake the Tier 4 experiments which require an additional large commitment of resources. These experiments are of interest in order to quantify the effects of specifying forcing during the forecast period and are included for completeness and in case the needed resources become available.

**DECK and CMIP6 historical simulations.** The DCPP is unique in bringing together researchers from communities with expertise in seasonal to interannual prediction as well as climate simulation. For climate models, control and sensitivity experiments are a backdrop to climate change simulations and most models used in the DCPP will also participate in other aspects of CMIP6 and will have performed DECK and 20th century climate change integrations. The DCPP strongly encourages participants to perform the DECK simulations but recognizes that this may not be feasible for all groups (those proposing to use high resolution models for prediction for instance). It is not intended that the DECK requirements should bar DCPP participation in these special cases.

**Data retention.** See the CMIP6 website for links to the CMIP6 Data Request Compilation and CMIP6 Forcing Data Sets. The DCPP input to the CMIP6 Data Request appears in Appendix D and applies to all experiment tiers. Data are to be served via the ESGF and to parallel CMIP5 although with changes to protocols as specified by the WIP. At this time, 6-hourly decadal prediction data for dynamical downscaling are not considered a priority. The hope is that, in conjunction with the WIP, a coordinated set of “basic” or “common” tiered data tables can be developed across MIPs together with “MIP specific” tables associated with individual MIPs.

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**Appendix B.**

**Component B: Forecasts**

Objective:

- Production, collection and combination of real-time quasi-operational decadal forecasts

**Table B1. Real-time decadal forecasts**

| # | Experiment | Notes | # of years |
|---|---|---|---|
| **TIER 1: Real-time forecasts** | | | |
| B1 | Ensembles of ongoing real-time 5-year forecasts | Coupled models with initialization based on observations<br><br>Start date *every year* ongoing<br><br>Start date on or before 31 Dec (start dates on or before Nov 15 allow for DJF seasonal forecast results and are recommended)<br><br>10 ensemble members (more if possible)<br><br>Atmospheric composition and/or emissions (and other conditions including volcanic aerosols) to follow a prescribed forcing scenario as in A1. | 10x5=50 years of integration for 5-year forecasts |
| **TIER 2: Increased ensemble size and duration** | | | |
| B2.1 | Increase ensemble size | *m* additional ensemble members to reduce noise and improve skill | 5*m* years of integration |
| B2.2 | Extend forecast duration to 10 years | To provide forecast information for the period 5 to 10 years ahead | 10x5=50 years of integration |

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**Table B2. Component B: Data**

Because of its "quasi-real time" aspect, the data aspects of Component B differ somewhat from those of Components A and C. Data to be retained on the ESGF are the same as listed in the DCPP Data Retention Table in Appendix D but the subset of these data in Table B2 will also be served via WMO Lead Centres. Data to be archived at WMO Lead Centre by March 31st of each year.

| Priority | Description | Notes |
|---|---|---|
| **Priority 1**<br>- monthly means<br>- basic variables<br>- single level files | - surface air temperature, precipitation, mean sea level pressure, sea-ice fraction, snow depth, 500hPa geopotential height, 850hPa temperature<br>- vertically integrated amounts of energy and salt in the upper 300m of the ocean<br>- AMOC<br>- fluxes of energy and moisture at the TOA and surface | Basic data sets for many investigations. Applies to quasi-real time decadal predictions currently being made. |
| **Priority 2**<br>**-** hindcast data for skill assessment and forecast calibration | - Same variables as for Priority 1 | Hindcast data for models which have contributed to the multi-model prediction exercise since CMIP5 |
| **Priority** as in the DCPP Data Retention Table | - Variables as in the DCPP Data Retention Table | More extensive data for forecast production, research and applications. Ongoing upon the completion of Component A hindcasts. |

**Explanatory comment**

Component B real-time decadal forecasts are currently being produced based on CMIP5 and using other models and hindcast data sets. The intent is that the forecasts produced by these models will be augmented by Component A results as they become available**.**

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**Appendix C.**

**Component C: Predictability, mechanisms, and case studies**

Component C consists of targeted simulations and prediction intend to: i) investigate the origins, mechanisms and predictability of long timescale variations in climate as well as their regional imprints and ii) to investigate the influence and consequences of volcanic eruptions on decadal prediction and predictability

**Component C1: Accelerated and retarded rates of global temperature change and associated regional climate variations**

Objective:

- To investigate the role of Eastern and North Pacific and North Atlantic SSTs in the modulation of global surface temperature trends and in driving regional climate variations.

**Table C1.**

| # | TIER | Experiment | Notes | # of years |
|---|---|---|---|---|
| **SST forcing experiments** | | | | |
| C1.1 | 1 | Idealised Atlantic control experiment | Restore North Atlantic SST to model control run climatology<br>-Time period: 10 years<br>- Region 10°N to 65°N (with 8° buffer, see notes below)<br>-Ensemble size: 25 members, sampling different ocean states if possible<br>- Restoring of SSTs using a restoring coefficient of 40 $Wm^{-2}K^{-1}$, which is equivalent to about 2 months for a 5050 m deep mixed layer<br>-No interannual changes in external forcings (set to pre-industrial control values)<br>- Minimization of drift if necessary (see notes below) | 25x10=250 years |
| C1.2 | 1 | Idealised climate impacts of AMV+ | As C1.1 but restore North Atlantic SSTs to positive AMV anomaly (provided - see notes) superimposed on model climatology | 25x10=250 years |
| C1.3 | 1 | Idealised climate impacts of AMV- | As C1.2 but for negative AMV anomaly pattern | 25x10=250 years |
| C1.4 | 1 | Idealised Pacific control experiment | As C1.1 but for the Pacific<br>- Region specified by PDV anomaly (provided – see notes)<br>- Ensemble size: 10 members | 10x10=100 years |

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| | | | | |
|---|---|---|---|---|
| C1.5 | 1 | Idealised climate impacts of PDV+ | As C1.4 but restore to positive PDV anomaly (provided – see notes) superimposed on model climatology | 10x10=100 years |
| C1.6 | 1 | Idealised climate impacts of PDV- | As C1.5 but restore to negative PDV anomaly | 10x10=100 years |
| C1.7 | 2 | Idealised Atlantic extratropics | As C1.2 and C1.3 AMV+ and AMV- patterns but with restoring only in the extratropics 30-65$^{o}$N<br>Ensemble size: 25 members | 2x25x10=500 years |
| C1.8 | 2 | Idealised Atlantic tropics | As C1.7 but with restoring in the tropical band 10-30$^{o}$N | 2x25x10=500 years |
| C1.9 | 3 | Pacemaker Pacific: coupled model restored to observed anomalies of sea surface temperature in the tropical eastern Pacific | -Follow the experimental design of Kosaka and Xie (2013).<br>-Time period: 1950 to 2014 (from 1920 if possible)<br>-Ensemble size: 10 members or more.<br>- Restoring timescales and ensemble generation as in C1.1 -Monthly SST anomalies (base period 1950-2014) will be provided | 65x10=650 years |
| C1.10 | 3 | Pacemaker Atlantic: as above but for the North Atlantic | As C1.9 but restored to 12-month running mean SST anomalies (to be provided) in the North Atlantic, 10$^{o}$N to 65$^{o}$N<br>-Time period: 1950 to 2014<br>-Ensemble size: 10 members (25 preferable)<br>-Restoring timescales and ensemble generation: as for C1.1<br>-Minimization of drift if necessary (see notes below) | 65x10=650 years |

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**Component C2: Case study of mid-1990s Atlantic subpolar gyre warming**

Objectives:

- To investigate the predictability of the mid-1990s warming of the subpolar gyre and its impact on climate variability.

**Table C2.**

| # | TIER | Experiment | Notes | # of years |
|---|---|---|---|---|
| | | **Prediction experiments** | | |
| C2.1 | 3 | Repeat hindcasts with altered initial conditions | Initialize with climatology (the average over 1960 to 2009) in the North Atlantic "sub-polar ocean"[95° W to 30° E, 45° N-90° N]<br>-Linear transition between climatology and actual observations over the 10° buffer zone 35° N-45° N<br>- 10 member ensembles<br>- 5, but much preferably 10 years<br>- Start dates end of 1993, 1994, 1995, 1996 | 4x(5,10)x10=200-400 years |
| C2.2 | 3 | Same as in C2.1 | As above with start dates 1992, 1997, 1998, 1999 | 200-400 years |

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**Component C3: Volcano effects on decadal prediction**

Objectives:

- Assess the impact of volcanoes on decadal prediction skill
- Investigate the potential effects of a volcanic eruption on forecasts of the coming decade
- Investigate the sensitivity of volcanic response to the state of the climate system

**Table C3.**

| # | TIER | Experiment | Notes | # of years |
|---|---|---|---|---|
| **Prediction experiments with and without volcano forcing** | | | | |
| C3.1 | 1 | Pinatubo | Repeat 1991 hindcasts without Pinatubo forcing<br>- 5 year, but preferably 10, year hindcasts<br>-10 ensemble members<br>-Specify the "background" volcanic aerosol to be the same as that used in the 2015 forecast | (5 or10)x10=50-100 years |
| C3.2 | 2 | El Chichon | 1982 hindcasts as above but without El Chichon forcing | 50-100 years |
| C3.3 | 2 | Agung | 1963 hindcasts as above but without Agung forcing | 50-100 years |
| **#** | **TIER** | **Experiment** | **Notes** | **# of years** |
| **Prediction experiments for 2015 with added forcing** | | | | |
| C3.4 | 1 | Added forcing | Repeat 2015-2019/24 forecast with Pinatubo forcing | 50-100 years |
| C3.5 | 3 | Added forcing | Repeat 2015-2019/24 forecast with El Chichon forcing | 50-100 years |
| C3.6 | 3 | Added forcing | Repeat 2015-2019/24 forecast with Agung forcing | 50-100 years |

**Notes**

**Experiments C1.1-1.8** are idealized coupled model experiments (Ruprich-Robert et al. 2016) similar to the "pacemaker" protocol for experiments C1.9-1.10 but using idealised fixed SST patterns (Figures 6 and 7, and available from http://rda.ucar.edu/). These patterns are derived from the difference between observations and the ensemble mean of coupled model historical simulations (Ting et al. 2009) and are an estimate of unforced internal variability. Although this estimate is not perfect because the modelled response to external factors such as anthropogenic aerosols may not be entirely correct, the experiments nevertheless provide information on the climate response to North Atlantic and Pacific SST variations. The

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experiments are based on model control integrations rather than historical simulations and therefore may be performed before the updated CMIP6 forcings become available.

**Experiments C1.7 and C1.8** follow experiments C1.2 and C1.3 but apply the SST anomalies in the extratropical and tropical regions separately (Figure 6, data available from http://rda.ucar.edu/) in order to assess their relative importance.

**Experiment C1.9** follows the design of Kosaka and Xie (2013) in which observed SST anomalies are imposed in the tropical Pacific region in coupled model simulations. The results will be compared to the standard historical simulations to infer the impact of the tropical Pacific SSTs.

**Experiment C1.10** follows C1.9 but imposing observed time series of the SST anomalies in the North Atlantic.

**The "pacemaker" experiments** (C1.9 and C1.10) are of considerable interest in a multi-model context in which the response of the models to SSTs, imposed in the manner Kosaka and Xie (2013), is considered. Questions include the robustness of the results across models, the geographic and global effects on climate and the pathways in the ocean and atmosphere through which the forcing is expressed. The experiments are Tier 3, however, because there may be coupled adjustment and drift issues that affect the results and this should be considered before undertaking the experiments. These include drift minimization (see below) and differences in variance and seasonality between models and observations. For these experiments:

- Observed monthly SST anomalies (base period 1950-2014, available from http://rda.ucar.edu/) are superimposed on the model climatology over the same period computed from historical simulations in order to minimize model drift.
- Experiments should cover the period from 1950 to 2014, but starting from 1920 is desirable if possible.
- External forcings as for historical simulations.

**For all experiments:**

- The SST signal is imposed either by altering surface fluxes or by restoring the SST directly. A restoring coefficient based on a restoring coefficient of 40 $Wm^{-2}K^{-1}$ is recommended. To minimise shocks, the restoring coefficient should decrease to zero over an 8° buffer zone bounding the restored region. No restoring if sea ice present. Outside of the restoring region, the model evolves freely allowing full climate system response.
- In order to sample uncertainties in the ocean initial state it is recommended that, if possible, ensemble members are generated by taking initial conditions from different members of the historical simulations. Otherwise, ensembles may be generated by perturbing atmospheric conditions.
- There is evidence that the signal to noise of the atmospheric response to North Atlantic SST is comparatively weak in models (Ruprich-Robert et al 2016) and 25 ensemble members are requested, if possible.

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**Drift minimization.** Experiments have shown that SST restoring, especially in the Atlantic, may lead to undesirable effects on ocean currents and associated heat transport such as AMOC which may affect SSTs in other regions (including the South Atlantic) and which can obscure the results. It is recommended that groups monitor this potential response and take steps to minimise it, if necessary. For instance, one way to minimise the AMOC response is to apply additional salinity restoring such that the upper ocean density over the restored domain remains unchanged. Another approach is to perform 3D restoring of temperature and salinity below the mixed layer or to use a restoring coefficient that depends on the depth of the mixed layer. Groups will be invited to provide a set of common diagnostics to evaluate the drifts and energy imbalance of the coupled system for all the pacemakers experiments.

## Appendix D. DCPP Data Retention Tables

The DCPP is concerned with prediction and a main interest is in variables that can be verified against observations. Variables that provide insight into the ability to predict observed behaviour and the mechanisms involved are, of course, also of interest. There is a somewhat different emphasis on retained variables for the DCPP compared to the more usual approach which aims to study budgets, balances, processes etc. in the context of climate simulation rather than prediction. The large number of forecast years involved in the DCPP is also a consideration.

We stress that the DCPP data retention tables are *not intended to exclude* other variables. If modelling groups are willing and able to retain the variables requested for other MIPs also for the DCPP this would be ideal.

The following is intended as a prioritized set of variables for verification and investigation but is *not intended to restrict* the amount of data that groups retain for their DCPP integrations. With this understanding, the DCPP list is ordered into priorities as follows:

- Priority 1. These are basic forecast variables aimed at permitting bias adjusted forecast assessment, especially of well observed surface parameters and some atmospheric and oceanic structures, together with data that provides some information on the budgets and balances involved

- Priority 2. These are important variables that allow more detailed forecast assessment including, to some extent, predictions for the body of the atmosphere and ocean.

- Priority 3. These variables are intended for special interest investigations.

Participants should strive to retain at least Priority 1 variables and also Priority 2 variables to the extent that this is possible.

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These tables are intended to provide an overview. Detailed specifications, including units etc., will be part of the "CMIP6 Data Request Compilation". The table headings indicate the nature of the data (e.g. TOA, BOA indicate top or bottom of the atmosphere) and the averaging period monthly, daily or 6hour sampling.

We have attempted to use standard CMIP5 variable names throughout although it is possible that there could be some differences with the CMIP6 Data Request Compilation. Three new variables, which lack CMIP5 standard names are indicated by an asterisk and names will be assigned by CMIP6.

**Table D. DCPP Data Retention Tables.**

| **CMIP5 name** | **Short description** | **Averaging or sampling period and Priority** | | |
|---|---|---|---|---|
| | | **Month** | **Day** | **6h** |
| **TOA fluxes** | | | | |
| rsdt | solar incident | 1 | 3 | |
| rsut | solar out | 1 | 3 | |
| rlut | lw out | 1 | 3 | |
| rsutcs | clear sky solar out | 2 | | |
| rlutcs | clear sky lw out | 2 | | |
| **2D atmosphere and surface variables** | | | | |
| tas | sfc air T | 1 | 1 | 2 |
| tasmax | day T max | 1 | 1 | |
| tasmin | day T min | 1 | 1 | |
| uas | EW wind | 1 | 2 | 2 |
| vas | NS wind | 1 | 2 | 2 |
| sfcWind | day mean wind | 1 | 1 | |
| sfcWindmax | day max wind | 1 | 1 | |
| q | specific humidity | 1 | | |
| qsat | saturated humidity | 2 | | |
| rhs | relative humidity | 1 | | |
| tdps | dewpoint temp | 2 | 2 | |
| clt | cld frac | 1 | 2 | |
| ps | sfc pres | 2 | | |
| psl | mean sea level pressure | 1 | 1 | 2 |
| | | | | |
| Other high frequency data | | | | |
| zg1000 | 1000hPa geopotential | | | 2 |
| rv850* | 850hPa relative vorticity | | | 3 |
| | | | | |
| **BOA fluxes** | | | | |
| rsds | solar down | 1 | 1 | |
| rlds | LW down | 3 | 3 | |
| rss | net solar | 1 | 3 | |
| rls | net LW | 1 | 2 | |
| tauu | EW stress down | 2 | 3 | |

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| | | | | |
|---|---|---|---|---|
| tauv | NS stress down | 2 | 3 | |
| hfss | sensible up | 1 | 3 | |
| hfls | latent up | 1 | 3 | |
| evspsbl | net evap | 1 | | |
| pr | net pcp | 1 | 1 | 2 |
| prsn | pcp as sno | 3 | 3 | |
| prhmax | day pcp max | 1 | 1 | 3 |
| | | | | |
| **Land** | | | | |
| ts | skin temp | 1 | | |
| alb | sfc albedo | 1 | | |
| mrso | soil moist | 1 | 3 | |
| mrfso | frozen soil moist | 1 | | |
| snld | sno depth | 1 | 3 | |
| mrro | runoff | 1 | | |
| | | | | |
| **Sea Ice** | | | | |
| tsice | sfc temp | 3 | 3 | |
| sic | icefraction | 1 | 3 | |
| sit | ice thickness | 1 | | |
| snld | sno thickness | 2 | 3 | |
| hflsi | heat flux down | 3 | | |
| usi | EW ice speed | 3 | | |
| vsi | NS ice speed | 3 | | |
| strairx | EW stress down | 3 | | |
| strairy | NS stress down | 3 | | |
| | | | | |
| **2D Ocean** (preferably on regular grid) | | | | |
| *Physical variables* | | | | |
| tas | SST | 1 | | |
| t20d | depth 20C | 1 | 2 | |
| mlotst | thickness mix layer | 1 | 2 | |
| thetaot | depth avg pot temp | 1 | | |
| theta300* | depth avg pot temp to 300m | 1 | | |
| theta700* | 700m | 1 | | |
| theta2000* | 2000m | 1 | | |
| msftmyz | MOC | 1 | | |
| msftmyza | MOC atlantic | 1 | | |
| msftmyzba | bolus MOC | 2 | | |
| hfnorth | northward ocean heat transport | 2 | | |
| hfnortha | Atlantic northward heat transport | 2 | | |
| sltnorth | northward ocean salt transport | 2 | | |
| sltnortha | Atlantic northward salt trasport | 2 | | |
| zos | sea sfc height | 1 | | |
| zossq | square sea sfc height | 2 | | |
| zostoga | thermosteric sea level change | 2 | | |
| volo | volume sea water | 2 | | |
| hfds | net heat into ocean | 1 | | |

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| | | | | |
|---|---|---|---|---|
| vsf | virtual salt into ocean (or equivalent fresh water flux) | 1 | | |
| *Biophysical variables(for ESMs)* | | | | |
| intpp | primary production | 2 | | |
| epc100 | export production | 2 | | |
| epcalc100 | CaCO3 export @100m | 2 | | |
| epsi100 | opal export @100m | 2 | | |
| phyc | sfc phytoplankton C conc | 2 | | |
| chl | sfc chlorophyll conc | 2 | | |
| spco2 | sfc pCO2 | 2 | | |
| fgco2 | air-sea CO2 flux | 2 | | |
| co2 | atmospheric CO2 | 2 | | |
| | | | | |
| **3D Atmos (850, 500, 200, 100, 50) Priority 1**<br>**(925, 700, 300, 30,20, 10) Priority 2** | | | | |
| ta | temp | 1 | | |
| ta850 | temp 850 | | 1 | |
| ua | EW wind | 1 | | |
| va | NS wind | 1 | | |
| hus | spec hum | 2 | | |
| zg | geopotential | 1 | | |
| zg500 | geopotential 500 | | 1 | |
| wap | vertical press velocity | 2 | | 2 |
| | | | | |
| **3D Ocean** (preferably on a regular grid at standard levels) | | | | |
| *Physical variables* | | | | |
| thetao | pot temp | 2 | | |
| so | salt | 2 | | |
| uo | EW speed | 2 | | |
| vo | NS speed | 2 | | |
| wo | upward speed | 3 | | |
| *Biophysical variables(for ESMs)* | | | | |
| dissic | DIC | 2 | | |
| talk | TA | 2 | | |
| no3 | nitrate | 2 | | |
| o2 | o2 conc | 2 | | |

These tables include some variables intend to aid the prediction/assessment/study of

- storm tracking
- energy production applications
- drought/flood studies
- sea level
- prediction of biophysical quantities

**Special Data Sets for consideration in support of other MIPs**

A subset of DynVar variables has been suggested for retention by DCPP participants, namely zonally and daily averaged geopotential (zg) on 17 or 23 standard pressure levels.

Variables listed under SolarMIP should also be considered for retention by participants interested in investigating the effect of solar variability on prediction.

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