# The Decadal Climate Prediction Project (DCPP)

The term “decadal prediction” encompasses predictions on annual, multi-annual to decadal timescales. The possibility of making skilful forecasts on these timescales and the ability to do so is investigated by means of predictability studies and retrospective predictions (hindcasts) made using the current generation of climate models. Skilful decadal prediction of relevant climate parameters is a Key Deliverable of the WCRP’s Grand Challenge of providing Regional Climate Information (http://www.wcrp-climate.org/index.php/gc-regionalclimate).

The DCPP consists of three Components. Groups are invited to participate in any and/or all of the Components, each of which are separately “tiered”:

- *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
- *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
- *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

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 to improving decadal predictions and these are explored using observations, climate model studies and the results of decadal hindcasts. 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.

The Decadal Climate Prediction Panel in conjunction with the Working Group on Seasonal to Interannual Prediction (WGSIP), the Working Group on Coupled Modelling (WGCM), and the CLIVAR focus on decadal variability and predictability are involved in the coordination of the scientific and practical aspects of the DCPP.

# 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 prediction component of CMIP include:

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

**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
- investigation of broad questions (e.g. sources and limits of predictability, current abilities with respect to decadal prediction, potential applications, …)
- provision of benchmarks against which to compare improvements in models and prediction quality
- information on processes and mechanisms of interest (e.g., the hiatus, climate shifts, 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 to provide justification for 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
- an associated hierarchy of data sets of results generally and readily available to the scientific and applications communities

**Consultation and timing** for Component A:

- The proposed timing for Component A generally follows that outlined for CMIP6 (slide 11). In particular, the availability of historical forcing and future scenario information are key to DCPP timing.

Details of the proposed Component A decadal prediction component are listed below.

## DCPP Component A hindcast protocols

The approach parallels that of the "Near-term Decadal" component of CMIP5 (Taylor et al., 2009, dated 22 January, 2011, together with the Experiment Design Addendum at (http://cmippcmdi.llnl.gov/cmip5/experiment_design.html). Note the call for hindcasts to be produced every year, rather than every 5 years, over the hindcast period

**Table 1. Basic Component A: Hindcast/forecast experiments**

| # | Experiment | Notes | # of years |
|---|---|---|---|
| **TIER 1: Hindcast/forecast information** | | | |
| A1 | Ensembles of at least 5-year, but much preferably 10-year, *hindcasts* and *forecasts* | Coupled models with initialization based on observations<br><br>Start date *every year* from 1960 to the present if at all possible; otherwise every second year at minimum.<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 historical values of atmospheric composition and/or emissions (and other conditions including volcanic aerosols). Future forcing as the SolarMIP Tier 1 SSP2-4.5 scenario. | (30-60)x10x(5-10) = 1500-6000 years of integration |
| **TIER 2: To quantify the effects of initialization** | | | |
| A2 | 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 yrs of integration |

**Table 2. Other hindcast experiments (if resources permit)**

| # | Experiment | Notes | # of years |
|---|---|---|---|
| **TIER 3: Effects of increased ensemble size** | | | |
| A3 | Increase ensemble size for the Tier 1 Experiment | *m* additional ensemble members to improve skill and examine dependence of skill on ensemble size | 60x(5-10)x*m*=(300-600)*m* years of integration |
| **TIER 4: Improved estimates of hindcast skill** | | | |
| A4 | Ensembles of at least 5-year, but much preferably 10-year, hindcasts and forecasts | As Experiment 1 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** | | | |
| A5 | 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 the Tier 1 Experiment, i.e. with NO information from the future with respect to the start date. These are uninitialized versions of Experiment 4 hindcasts. | 1500-6000 yrs of integration |

## Explanatory comments

**Table 1** lists the main DCPP Component A experiments. The Tier 1 hindcast experiment parallels the corresponding CMIP5 decadal prediction experiment in using the same specified forcing during the forecasts as is used for the Tier 2 historical climate simulations (also a DECK component). 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 so affect the results very little. 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.

**Table 2** lists additional experiments which are of interest if resources permit. The Tier 3 experiment increases the ensemble size in order to quantify the expected benefits and as a guide to future forecast applications. It is not expected that many, if any, 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.

**Data retention.** See the file (DCPP_Data_Retention_Tables_30Mar15.doc) for an overview of proposed DCPP data retention. Data are to be served via the Earth System Grid (ESG) and to parallel CMIP5 although with changes to protocols as specified by the WGCM Infrastructure Panel (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.

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

The real-time decadal prediction component of CMIP will 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. It will build on the WMO structure already in place for seasonal forecasts. Forecasts and verification statistics will be made available via the web at WMO designated “Lead Centres” and mirrored via the ESGF. Lead Centres will collect forecast and verification data from designated “Contributing Centres”. Lead Centres will produce a multi-model forecast together with uncertainties, and maintain an archive of previous real-time forecasts from Contributing Centres along with an assessment of performance as verifying observations become available.

**Goals**

- the promotion of the science and practice of decadal prediction by generating *real-time* multi-model decadal predictions
- the production and retention of ongoing multi-year multi-model decadal forecast data in support of the Global Framework for Climate Services (GFCS)
- the provision of information potentially useful for the IPCC WG1 AR6 assessment report and other studies and reports on climate prediction and evolution

**Scientific aspects**

- assess decadal predictions of key variables including temperature, precipitation, mean sea level pressure, the AMO, PDO, Arctic sea ice, the NAO, and tropical storms
- assess uncertainties and generate a consensus forecast
- permit the assessment decadal predictions of associated climate impacts of societal relevance

**Practical aspects**

- the coordination of efforts based on agreed experimental structures and timelines as specified in the protocol below
- the contribution to the development of infrastructure, in particular a multi-purpose data archive of ongoing decadal forecasts 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**

- 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 DCPP Component B real-time decadal prediction component are listed below**.**

## DCPP/WMO/CMIP Real-time decadal forecast protocols

**Table 1. Basic Component B: 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* yrs of integration |
| B2.2 | Extend forecast duration to 10 years | To provide forecast information for the period 5 to10 years ahead | 10x5=50 yrs of integration |

## Table 2. 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 served via WMO Lead Centres and mirrored on the Earth System Grid (ESG) with protocols paralleling CMIP5 although with modifications as specified by the WGCM Infrastructure Panel (WIP). Data to be archived by March 31st 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, snow, 500hPa geopotential height, 850hPa temperature<br>- vertically integrated amounts of energy, salt in the ocean<br>- Atlantic MOC<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 other models and hindcast data sets. The intent is that the forecasts produced by these models will be augmented and/or replaced by Component A results as they become available**.**

## 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, numerics or forcings are perturbed. The mechanisms involved are of great interest as they underpin the inherent predictability of the system and as they govern forecast skill.

Predictability studies based on perturbations to models may be referred to as “perfect model” studies in the sense that one has perfect knowledge of the modelled climate system in terms of the computer code. They represent “attainable predictability” only to the extent that the model is sufficiently similar to the real system and it is important also to study their applicability. Predictability studies are intended to give an indication of the regions and timescales for which skilful forecasts may be possible and may also be used to study aspects of the physical mechanisms and processes involved.

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 in model integrations (variations of AMOC and the associated variation of N Atlantic 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 CLIVAR are proposing coordinated multi-model investigations of a restricted 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+: an investigation of the origin, mechanisms and predictability of long timescale variations in global mean temperature (and other variables) including periods of both enhanced warming and cooling with a focus on the current “hiatus”
- Volcanoes and prediction: an investigation of the influence and consequences of volcanic eruptions on decadal prediction and predictability

A description of the proposed experiments is found below. An AGCI Workshop in Aspen in June 2015 will provide the opportunity to review Component C and to suggest modifications and/or extensions guided by available results to that time.

The proposed experiments in Table 1 are intended to discover how models respond to a simple imposed forcing in the tropical Pacific and in the North Atlantic. The questions at issue is the consistency of model’s response to the forcing and the pathways through which the imposed forcing is expressed throughout the ocean and atmosphere, especially as this illuminates model behaviour and possible mechanistic links to retarded and accelerated global temperature variations and regional climate anomalies.

The proposed experiments in Table 2 are directed toward an understanding of the effects of volcanos on past and potentially on future decadal predictions. Radiative effects arising from the aerosol loading in the stratosphere, together with subsequent dynamical effects and/or coupled dynamical modes are of interest.

**Table 1.**

## Component C1: Haitus+: Accelerated and retarded rates of global temperature change

Objectives: To investigate the role of eastern Pacific and North Atlantic sea surface temperatures in the modulation of global surface temperature trends and in driving regional climate variations.

| # | TIER | Experiment | Notes | # of years |
|---|---|---|---|---|
| **Pacemaker experiments** | | | | |
| C1.1 | 1 | Coupled model restored to observed anomalies of sea surface temperature in the tropical Pacific | Follow the experimental design of Kosaka and Xie (2013).<br><br>Time period: 1950 to 2015<br>Ensemble size: 10 members<br>Restoring timescales: 10 days for 50m deep mixed layer suggested<br>Climatological period for computing anomalies: 1950-2015 | 66x10=660 years |
| C1.2 | 1 | As above but for the North Atlantic | As C1.1 but restored to observed sea surface temperature anomalies in the North Atlantic, $0^{o}$N to $60^{o}$N<br><br>Time period: 1950 to 2015<br>Ensemble size: 10 members<br>Restoring timescales: as for C1.1 | 66x10=660 years |
| C1.3 | 2 | As C1.1 | As C1.1 but for the period from 1920 making the full period of the experiment 1920-2015 (as a single integration to avoid a discontinuity at 1950) | 30x10=300 years |
| C1.4 | 2 | As C1.2 | As C1.2 but for the period from 1920 making the full period of the experiment 1920-2015 (as a single integration to avoid a discontinuity at 1950) | 30x10=300 years |

**Table 2.**

## 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.

| # | 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 N Atlantic "sub-polar ocean"[95$^o$ W to 30$^o$ E, 45$^o$ N-90$^o$ N with a linear transition between climatology and actual observations over the 10$^o$ buffer zone 35$^o$ N-45$^o$ 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 | ditto | as above with start dates 1992, 1997, 1998, 1999 | 200-400 years |

**Table 3.**

## 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

| # | TIER | Experiment | Notes | # of years |
|---|---|---|---|---|
| **Prediction experiments with and without volcano forcing** | | | | |
| C3.1 | 1 | Pinatubo | Repeat 1991 forecasts without Pinatubo forcing<br>- 5, preferably 10 years<br>- 10 ensemble members<br>- specify the "background" volcanic aerosol to be the same as that used in the 2015 forecast | (5,10)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 |