
Environmental Systems Modelling Platform

# EnSym Climate Change Impact Modelling Functionality

**There is now overwhelming scientific consensus that increasing anthropogenic greenhouse gas emissions are very likely contributing to increases in global average temperatures observed since the mid 20$^{th}$ century (IPCC 2007).**

**Research to date suggests that anthropogenic climate change will alter global and local climates. Victoria is likely to see a generally warmer and drier future, with an increased likelihood of more extreme events such as heatwaves, bushfires, floods and storm surges (CSIRO, 2007). In regards to catchment hydrology, changes to the timing and magnitude of hydrological events such as groundwater recharge and surface water runoff are expected. The EnSym climate change impact modelling functionality aims to provide information on the impact of various climate scenarios on catchment dynamics.**

## *Functionality Aim*

The aim of the Climate Change Impact Modelling Functionality is to allow EnSym end-users the ability to run EnSym's biophysical model (BioSim) on a range of climate change projections. This will allow a user to assess and visualise, both spatially and temporally, the likely impact of climate change on catchment dynamics, with the ultimate aim of providing a better understanding of how the Victorian landscape will respond to differing climatic futures.

Future climate sequences are provided initially using 6 Global Circulation Models (GCM's) and 2 Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emissions scenarios provided by CSIRO Marine and Atmospheric Research (CMAR). This gives users 12 different future potential climate sequences that can be run through EnSym. To help account for model uncertainty multiple model results will be able to be compared at the one time giving a range and distribution of results. The climate change impact modelling functionality within EnSym will be constructed in a manner that allows for the easy incorporation of future climate model outputs and emissions scenarios as they become available.

Example uses of the EnSym Climate Change Impact Modelling Functionality will be to provide information to assist answering questions such as:

- What is the relationship between changing temporal rainfall distribution and groundwater recharge?
- Which areas of a particular region will be most susceptible to crop failure under a high emissions scenario?

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- Can land use or land management change be used as part of a strategy to minimise the impact of climate change on catchment yield?
- What is the expected range of temperature change at a particular location in 2070?
- Which areas of Victoria will have the largest change in projected autumn rainfall compared to the long term average?

## *Climate Data*

Projected daily climate data is provided by CSIRO Marine and Atmospheric Research using 6 coupled Ocean-Atmosphere General Climate Models (GCM's) and 2 IPCC greenhouse gas emissions scenarios. The data was created specifically for the 'Tasmanian Climate Futures' project, however model output for this project also covered Victoria.

Corney et al (2010) details the methodology and approach in creating the daily climate projections that are used within the EnSym Climate Change Impact Modelling Functionality. A summary is offered below however users are referred to the Corney et al (2010) report for further detail.

## *GCM Selection*

The IPCC considered 23 GCM's when compiling its Fourth Assessment Report. By using a multitude of GCM's the IPCC reported on a range of indicative model results thus providing an estimate of uncertainty.

Within the Tasmanian Climate Futures Project, 6 GCM's were chosen primarily because of how well they replicated Australian rainfall according to Smith and Chandler (2009). Bennett et al (2010) highlighted that of the 6 GCM's selected there is no obvious reason to rank or weight them based on performance thus the output from each of the six GCM's are treated evenly within EnSym. The six GCM's selected by Corney et al (2010) and thus utilised within EnSym's Climate Change functionality are listed below.

| GCM | Country of Origin |
|---|---|
| CSIRO-Mk3.5 | Australia |
| ECHAM5/MPI-OM | Germany |
| GFDL-CM2.0 | USA |
| GFDL-CM2.1 | USA |
| MIROC3.2(medres) | Japan |
| UKMO-HadCM3 | United Kingdom |

Another consideration on GCM selection was the availability of simulation results for the chosen SRES[1] emission scenarios, not all GCM results are available across all SRES emissions scenarios.

[1] The Special Report on Emission Scenarios (SRES), published in 2000 by the IPCC, contains four 'families' of predicted greenhouse gas emission scenarios – A1, A2, B1 and B2.

## *SRES Emissions Scenario Selection*

Within the Tasmanian Climate Futures project the A2 and B1 emissions scenarios were chosen to downscale the GCM modelling from. A2 and B1, respectively a high and a low emissions scenario, provide a range of possible climate change impacts.

Recently, observed global greenhouse gas emissions have been tracking above original estimates thus creating discussion around the appropriateness of using SRES scenarios to designate high, medium and low emissions projections. Former high emissions projections are now more likely to be medium projections. As suggested by Corney et al (2010) the A1F1 scenario may seem like the most realistic choice for the high emission scenario however A1F1 starts with the most fossil fuel use but is overtaken by the A2 scenario around the middle of the 21$^{st}$ century. Corney et al (2010) also adds that the IPCC's Fourth Assessment Report did not feature any simulations for the A1F1 emissions scenario, therefore likely changes to temperature and sea level rises were scaled results from the A1B emissions scenario thus rendering the A1F1 emissions scenario from being usable in the CSIRO adopted downscaling methodology.

Work by Grose et al. (2010) suggested that intra-scenario variability, produced by multiple models, each with slightly different internal mechanisms, is at least as great as the inter-scenario variability. This lead Corney et al. (2010) to the conclusion that "diversity of GCM's is of more importance than the spread of emissions scenarios, and so we have chosen to concentrate on more models and only two emissions scenarios".

## *Dynamic Downscaling*

Bennett et al (2010) when summarising the 'Tasmanian Climate Futures' dynamic downscaling methodology states:

"*Corney et al (2010) dynamically downscaled sixIPCC AR4-class GCMs for the Tasmanian region.The six GCMs downscaled are listed in Table 1.2. Corney et al (2010) used the CSIRO Conformal Cubic Atmospheric Model (CCAM) to dynamically downscale these six GCM's to a fine resolution of 0.1 degrees, or approximately 10 km by 10 km grid cells, over Tasmania. CCAM is a global atmospheric model that uses a stretched grid to increase the grid resolution (and thus shrink the size of grid cells) over the region of interest. Because it is a global model, CCAM does not have lateral boundaries like nested limited-area dynamical models. CCAM has only one boundary: the ocean. CCAM was forced only by GCM sea surface temperatures (SSTs) and sea ice concentration. Biases inherent in GCM SSTs were removed using a simple additive bias-adjustmentmethod that ensured that all GCMs were able to describe the observed climate during the reference period (Corney et al 2010). Removing GCM SST biases meant that the fine-resolution modelling could more accurately simulate mean sea-level pressure and the interaction of regional weather systems with local topography and land surfaces.*

*The dynamical downscaling method used by Corney et al (2010) offers three major benefits for our hydrological study:*

*1. Bias-adjusting the GCM SSTs before downscaling improves the representation of the current climate in the downscaled-GCMs while retaining the climate variability and climate change signal from the GCMs.*

*2. The downscaled-GCM outputs simulate spatial distributions of interpolated rainfall observations and other climate variables far better than GCM projections (Corney et al 2010).*

*3. CCAM simulates regional weather systems and their interaction with Tasmanian topography. In a warmer and more moist future, climate drivers of Tasmanian rainfall are free to vary in CCAM according to current understanding of meteorology and atmospheric physics (Grose et al 2010).”*

## *Climate Projections v Weather Predictions*

It is critical to note the important differences between ‘projections’, as used in the EnSym Climate Change Interface, and ‘predictions’ as used in weather forecasting. The IPCC defines climate projections as:

*A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, is often based on simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasise that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised and are therefore subject to substantial uncertainty.* (IPCC, 2007 )

As Barron et al (2010) points out “climate projections are not simulations that attempt to estimate the actual evolution of the climate in the future in terms of seasonal, interannual or interdecadal time scales.“ As such the climate projections used within the EnSym Climate Change Impact Modelling Functionality represent possible future climates that are based on the assumptions within the climate models and emissions scenarios adopted.

## *Model Uncertainty*

It is important to note that each of the 12 climate projection outcomes should not be assessed independently of each other; rather all 12 climate projections should be run providing a range of results which allows a probability distribution thus accounting for some model uncertainty. Users of the EnSym Climate Change Impact Modelling Functionality are directed to CSIRO (2007) Chapter 6 for further reading on representing and qualifying uncertainty in climate impact modelling.

## *EnSym Functionality*

As of March 2012 the EnSym Climate Change Impact Modelling Functionality is available only for internal use by ecoMarkets. External users requiring data can request ecoMarkets run future climate scenarios on their behalf.

The typical workflow for developing and adding new capabilities into EnSym are as follows:

**1. ecoMarkets Functionality**

Functionality is added to EnSym for internal use by ecoMarkets team members. EcoMarkets can generate desired outputs for EnSym end-users on entering a service level agreement with ecoMarkets.

## 2. Project Specific End-User Testing

On a project-by-project basis, EnSym is modified so that EnSym end-users can use the new Climate Change Impact Modelling Functionality. When using the new functionality, end-users are requested to provide feedback, allowing ecoMarkets to improve the product.

## 3. General EnSym Integration

After testing is complete, the new functionality is incorporated into the main EnSym software, and can be used by all EnSym end-users. Generally additional training will be required for the end-users to be able to use the new functionality.

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Published by the Victorian Government Department of Sustainability and Environment
Melbourne, December 2012 
Authorised by the Victorian Government, 8 Nicholson Street, East Melbourne.
ISBN 978-1-74287-474-6 (online)
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