AUSTRALIAN CAPITAL TERRITORY

MEMORANDUM OF UNDERSTANDING

Dated	20 June 2011
Parties	**AUSTRALIAN CAPITAL TERRITORY**
	NSW OFFICE OF ENVIRONMENT AND HERITAGE
	NSW AND ACT REGIONAL CLIMATE MODEL (NARCliM)
MOU Number	**2011.16225.210**
Prepared by	Environment and Sustainable Development Directorate Macarthur House 12 Wattle Street Lyneham ACT 2602 Ph: 02 6207 5870 Fax: 02 6207 2316 Ref: 2011/4010
Version	Final June 2011

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PARTIES: **AUSTRALIAN CAPITAL TERRITORY,** the body politic established by section 7 of the *Australian Capital Territory (Self-Government) Act 1988* (Cwlth) **(Territory)** represented by the Environment and Sustainable Development Directorate (ESDD).

NEW SOUTH WALES GOVERNMENT represented by the Office of Environment and Heritage (OEH).

BACKGROUND

A. This MOU sets out the understanding between ESDD and OEH in relation to provision of regional climate modelling projections for NSW and the ACT.

B. Several of the key challenges identified in the ACT Climate Change Strategy 2007-2025 *Weathering the Change* are:

- the need to understand the causes and impacts of climate change likely to occur in the ACT region and;
- to take actions to prepare ourselves for the changes in climate that we now face, and will face in the future.

In dealing with these challenges the ACT Government recognises it has an ongoing role in supporting research into the projected short-term and long-term changes in climate that could occur and are likely to occur in the ACT and surrounding region. It also recognises that this research should yield the best available data in terms of its currency, prediction reliability, and resolution at spatial and time scales. This will provide critical information needed by government agencies, business and the broader community in and around the ACT for assessing and adapting to the likely impacts on key areas of concern including health, infrastructure, biodiversity conservation, natural resource management, agriculture, bushfire, weather extremes, flooding, and services such as water and energy supplies.

Current climate projections for the ACT and region such as OEH's *NSW Climate Impact Profile* and the CSIRO's *Climate Change in Australia – Technical Report 2007* are based on Global Climate Models (GCMs). The usefulness of GCM projections for critical public and private planning purposes in the ACT and region is primarily limited by coarseness of spatial resolution (typically 100 – 400 km grids), and omission of sub-continental topography (e.g. the Great Dividing Range) and key oceanic processes (e.g. Eastern Australian Current). The proposed dynamical regional climate modelling (RCM) approach offered by NSW Office of Environment and Heritage provides an opportunity to overcome many of the limitations of GCMs and provide significantly higher (10km grid) resolution projections of temperature, rainfall and many other meteorological variables for the ACT and surrounding region that have not been previously available.

IT IS AGREED by the parties as follows.

1. Interpretation

1.1 Definitions

The following definitions apply in this MOU, unless the context otherwise requires.

MOU means this memorandum of understanding.

Representatives means, in relation to each party, the representatives whose names and contact details are specified in **Item 1 Schedule 1**, or as notified in writing from time to time by one party to the other.

Term means the term specified in **Item 2 Schedule 1**, or if extended under **clause 3.2**, the initial term and the extended term.

Territory means:

(1) when used in a geographical sense, the Australian Capital Territory; and

(2) when used in any other sense, the body politic established by section 7 of the *Australian Capital Territory (Self-Government) Act 1988* (Cwlth).

1.2 General

In this MOU, unless the context otherwise requires:

(1) references to "OEH" includes any employees, agents or subcontractors of OEH;

(2) references to legislation or to provisions in legislation include references to amendments or re-enactments of them and to all regulations and instruments issued under the legislation;

(3) words importing a gender include the others; words in the singular number include the plural and vice versa; and where a word or phrase is given a particular meaning, other parts of speech and grammatical forms of that word or phrase have corresponding meanings;

(4) "include" is not to be construed as a word of limitation; and

(5) headings have no effect on the interpretation of the provisions.

2. MOU

2.1 Intention of MOU

This MOU is a statement of intent and does not create legal obligations between the parties.

2.2 Variations of MOU

This MOU may be varied only by the written agreement of the parties prior to the expiration of this MOU.

3. Term

3.1 Term

This MOU is for the Term unless terminated under the provisions of this MOU.

3.2 Extension

This MOU may be extended by the written agreement of the parties prior to the expiration of this MOU.

4. Scope of Work

The parties agree that the scope of work covered by this MOU is outlined in Schedule 2.

5. Dispute Resolution

If a difference or dispute **(Dispute)** arises in relation to this MOU, the parties agree to resolve the Dispute by negotiations, including by referring the Dispute to persons who have authority to intervene and direct some form of resolution.

6. Notices

Any notice, including any other communication, required to be given or sent to either party under this MOU must be in writing and given to the relevant Representative. A notice will be deemed to have been given:

(1) if delivered by hand, on delivery;

(2) if sent by prepaid mail, on the expiration of two business days after the date on which it was sent;

(3) if sent by facsimile, on the sender's facsimile machine recording that the facsimile has been successfully and properly transmitted to the recipient's address; or

(4) if sent by electronic mail, on the other party's acknowledgment of receipt by any means.

SCHEDULE 1

Item 1.	**Representatives**	<u>For the Territory:</u> Simon French Climate Change Environment and Sustainable Development Directorate Macarthur House 12 Wattle Street Lyneham ACT 2602 Facsimile No: (02) 6207 2316 <u>For the NSW Government:</u> Dr Peter Smith Manager, Climate Change Science NSW Office of Environment and Heritage 10 Valentine Avenue Parramatta NSW 2124 Facsimile No: (02) 9895 7876
Item 2.	**Term**	This MOU is deemed to have started from 11 May and will expire on 30 June 2014 unless extended by the parties.
Item 3	**Cost**	(1) Contribution: $275,000 (including GST) (2) The Contribution will be paid to OEH in one instalment before 30 June 2011 and is the Territory's current agreed contribution over the life of the project. (3) If, for any reason, OEH terminates this project or fails to complete the Project by the end of the Term, or any other date agreed by the parties, ESDD shall be entitled to a refund of its contribution on a pro-rata basis, determined according to the percentage of the project remaining incomplete.

SCHEDULE 2

Scope of Work

1. This MOU sets out the intentions of the Parties in a funding agreement for OEH to provide ESDD with regional climate modelling projections for NSW and the ACT.
2. The Term of this MOU and Contribution are specified in Schedule 1.
3. Payment of the Contribution to OEH will be made following signing of this MOU by both Parties.
4. Details of the project goals, background information, and scope of work are contained in the OEH Project Plan for the NSW & ACT Regional Climate Model dated May 2011 in Attachment 1. The scope of work covers:
   - Modelling methodology;
   - Peer review processes;
   - Deliverables including data products, analysis reports, data use limitations guide, and final outcomes presentation to the ACT Government;
   - Data storage and access arrangements;
   - Timeframes;
   - Governance arrangements including ACT Government membership of the project steering committee;
   - Budgetary costings; and
   - Partners and stakeholders.

DATE OF THIS MOU ....20 June.......... 2011

SIGNED for and on behalf of the **AUSTRALIAN CAPITAL TERRITORY** in the presence of:)	Heath Tomlinson Signature of Territory delegate
Signature of witness	HEATHER TOMLINSON Print name 20/6/2011
Simon French Print name	
SIGNED by or for and on behalf of **NSW OFFICE OF ENVIRONMENT AND HERITAGE** in the presence of:)	Ross P. Williams Signature of authorised officer 15/06/2011
Signature of witness	**Ross Williams** **Director, Catchment & Environment Protection Science** **Scientific Services Division** Print name and position
Graeme Brokman. Print name	

ATTACHMENT 1

Office of Environment & Heritage

NSW and ACT Regional Climate Model
(NARCliM)

Project Plan

June 2011

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1. Purpose of the project

The Office of Environment and Heritage (OEH) is developing a regional climate model ensemble that will generate detailed climate projections for the State and the Australian Capital Territory. Projections at such a fine scale have not been available in NSW before and will provide the detailed information fire and emergency management, water and energy management, agriculture, urban planning and biodiversity management need to adapt to a future climate. The express purpose of the project is to deliver robust climate change projections at a scale relevant for use in local-scale decision-making.

2. Background

Projections about our future climate form a critical part of adaptation planning. They take us a step beyond assuming that our climate will remain the same in the future, or that it will unpredictably fluctuate within the bounds of natural variability. They help us ask the question: given our understanding of climate drivers, and plausible future scenarios of greenhouse gas emissions, how will our climate system respond – 20 or 50 years down the track?

The NSW Government has developed a 'first cut' of climate projections for NSW through the NSW Climate Impact Profile. These projections are based on a small number of dynamical global climate models (GCMs) that were selected because of their skill in modelling major climate variables for this region of the globe[1]. GCMs are based on physical processes (e.g. how

[1] Perkins et al. (2007), Evaluation of the AR4 Climate Models' Simulated Daily Maximum Temperature, Minimum Temperature and Precipitation over Australia Using Probability Density Functions, *J. Climate*, 20, 4356

solar radiation, the atmosphere, land and oceans interact to generate weather and climate) and evolve over time (hence 'dynamical').

GCM projections do have a number of limitations which reduces their usefulness in predicting future climate at the fine scale regional level:

- Typically they have a resolution of between 100 and 400 kilometres. For instance, a single temperature or rainfall figure may be produced for an area 250 km x 250 km in size.
- As a result of their coarse scale GCMs are not able to factor in sufficient detail sub-continental scale topography such as the Great Dividing Range, which we know plays a very important role in determining regional climate.
- GCMs do not capture important offshore processes such as the East Australian Current (EAC).
- While GCMs are reasonably good at simulating temperature, there is less confidence in their projections of rainfall.

One way of improving the resolution of global climate model projections is known as statistical downscaling. This method takes the existing climate – for instance actual observed time series of temperature and rainfall in a particular location – as its foundation, rather than the physical principles of climate drivers. It then uses statistical techniques to apply changes to the observed time series based on outputs from GCMs. Unlike dynamical models, statistical models adjust an existing time series rather than creating a new one. One problem with this method is that it does not allow for any changes in the existing relationship between weather variables or climate drivers. This is an assumption that, given our understanding of climate drivers and the likely affect of climate change on them, is unlikely to hold true.

Using a dynamical regional climate model (RCM) overcomes many of the limitations of GCMs and statistical downscaling. The Weather Research and Forecasting (WRF) model is an RCM capable of providing high resolution projections of temperature, rainfall and a large number of other meteorological variables. WRF was jointly developed by a number of major United States weather and research centres and is widely used among the international research community. It has a demonstrated ability to simulate temperature and rainfall in NSW. As its name suggests, WRF is also used for day to day weather forecasting which, among other things, requires it to provide a good representation of local topography and offshore processes such as the East Australian Current.

3. Project outcomes

Businesses, industries and the wider communities of New South Wales and the Australian Capital Territory have access to high quality climate change projections for use in local decision-making.

Achieving this outcome will require:

- local scale projections to be developed from existing global climate projection datasets using scientifically robust methods
- data storage capacity to manage the very large resulting dataset and its ongoing management
- the means for the wider community to access both raw data and processed information, and
- A report synthesising and interpreting the projected changes in climate across NSW.

4. Stakeholder consultation

The Office of Environment and Heritage has consulted broadly with NSW State Government agencies and the Australian Capital Territory in developing the Regional Climate Model proposal. This consultation included a presentation on 14 December 2010 to a range of agencies and was followed up by individual meetings. These individual meetings have assisted in defining the project and the specific climate information needs of stakeholders.

Stakeholders consulted to date:

- Australian Capital Territory Government agencies
- Sydney Catchment Authority
- Hunter Water Corporation
- Sydney Water Corporation
- NSW Office of Water
- Emergency Management NSW
- Rural Fire Service
- State Emergency Service
- NSW Health
- Department of Primary Industries
- Department of Planning
- NSW Transport, and
- Australian Rainfall and Runoff Review Technical Committee (Engineers Australia).

The views of the stakeholders have been positive and reinforced the need to understand how climate change will affect local climates and, in particular, how climate change will affect natural hazards (flood, fire, heatwave, drought etc). Several stakeholders are providing funding for the project.

5. Linkage to OEH corporate plan and other projects

5.1 Linkage to OEH corporate priorities

This project will:

- meet the State Plan target of tackling climate change using science and local knowledge, to help NSW minimise the impacts of climate change on our natural environment, economy and communities;
- help the Office of Environment and Heritage meet its goal of minimising the impacts of climate change to protect the environment, the economy and community wellbeing;
- support OEH in achieving the following objectives:
  - Government, businesses and the wider community are aware of potential climate change impacts, and use this information to inform their decisions; and
  - Improved understanding of the impacts of climate change on biodiversity, water resources, coastal environments and bushfire regimes;
- help the OEH deliver key outcomes, so that:
  - Communities are supported and active in adapting to climate change
  - The increased risks to life, livelihoods, property and the environment from coastal erosion, flooding, bushfires and droughts are minimised and managed.
- Develop and improve regionalised climate projections, identified as a program priority in the NSW Climate Change Impacts and Adaptation Research Framework,

5.2 Linkage to other projects

NSW Climate Impact Profile

As a first step, in July 2010 the former Department of Environment, Climate Change and Water published the *NSW Climate Impact Profile*. The Profile has functioned as a "building block" on which additional OEH (and NSW Government agencies) adaptation programs are based. These projections, based on information from global climate models, provide a very broad indication of future changes to the NSW climate but do not adequately account for local and regional influences on climate, such as topography (eg. the Great Dividing Range). Projections at this scale provide limited information for decision-making and planning for land use, infrastructure and emergency and health services.

The *Climate Impact Profile* projections have low reliability in some locations of State and national significance (i.e. coastal areas with high population density). In addition these projections are unable to show future potential changes in extreme temperature and rainfall that can have devastating social, environmental and economic impacts (eg. the 2009 Melbourne heatwaves). This project will seek to overcome some of these short comings.

Projections for Sydney Adaptation Strategy

A separate project, but related to NARCliM, UNSW is undertaking a set of high resolution climate projections for OEH for the Sydney metropolitan region using a single GCM (CSIRO Mk 3.5) at a grid size of 2km. These projections will be form the basis of climate change impact analysis for the development of an Adaptation Strategy for Sydney – an action in the Metropolitan Plan for Sydney 2036. These projections will also be made available to stakeholders when available - expected in 2012

Projects reliant on the NSW & ACT Regional Climate Model
Three additional projects will commence in the 2011/12 financial year that are reliant on outputs delivered by this project.

1) Evaluation of Bush Fire Weather Simulations funded under the Emergency Management NSW State Projects Program.
2) Estimating climate change induced changes to rainfall and runoff in NSW funded under the Emergency Management NSW State Projects Program.
3) Statistical downscaling of regional climate projections over Sydney's Water Catchment, which will inform the next Sydney metropolitan water plan.

6. Project scope of work

6.1 Scope

OEH is developing a regional climate model for NSW and ACT (NARCliM) using the Weather Research and Forecasting model. It will produce climate projections over the entire state including the Australian Capital Territory, at a resolution of 10km grid squares. The model will be developed by the Climate Change Research Centre based at the University of NSW.

Producing projections at this fine scale will enable modelling of the probability of changes in temperature, wind and rainfall extremes with greater confidence than can be done for NSW at present. This in turn will provide critical information for managing impacts on health and settlements, agriculture, fire weather extremes, flooding and services such as water and energy supplies.

The NARCliM ensemble has been designed to develop 12 regional climate model outputs or runs. Twelve RCM runs were selected as a minimum number of runs to improve the probability of capturing the range of possible future climates. The process of developing the 12 RCMs first includes the selection of the GCMs that will be downscaled. The project will be run using four independent GCMs to provide the boundary conditions for three RCM simulations for four separate global climate models (GCMs) for a total of 12 runs. The GCM selection process will be based on a combined evaluation of GCM performance in simulating actual climate for this region, provide independent estimates of the future climate and that provide an ability to span the range of future climate change projections. Three 20 year simulations will be performed with each of the 12 GCM/RCM combinations, for the present day (1990-2010) and two future periods, 2020-2040 and 2060-2080. The methodology for the model selection and modelling steps to be performed is outlined at Appendix 1.

A single, representative emissions scenario (the IPCC high emissions scenario A2) will be used in each case. Projections for a number of key variables will be produced. Standard core variable outputs, available at monthly, daily and 3-hourly time steps (unless other time steps are indicated), will include:

1. 2-metre temperature (& hourly)
2. Daily maximum 2-metre temperature
3. Daily minimum 2-metre temperature
4. Precipitation (peak 5, 10, 20, 30, 60min; total 1 hour)
5. Surface pressure
6. 2-metre specific humidity (& hourly)
7. 10-metre wind speed (peak 10min wind gust) (& hourly)
8. Surface evaporation
9. Soil moisture
10. Snow amount
11. Sea surface temperature.

WRF can produce projections for many other variables which project partners will be able to specify (eg. Vertical/altitudinal profiles), along with the time scales that are most relevant in their planning for climate change.

A full list of climate variables produced by the WRF model is attached. Data for all of these variables will be stored for each of the 12 RCM/GCM model runs.

Data Storage and Access

Data will be stored, including back-up allocation, at Intersect Australia and will first be made available to funding partners (see section 6.2 for further details). Stakeholders and the general public will have access to the data after the final models have been selected and the project has been completed. Establishment of data interrogation interfaces is a critical component of the program, with pilot prototypes developed in the early stages of data availability. Development of data inquiry, summary and visualisation tools will be driven by inputs from the user reference group and may include, for example, links to Fire Hazard Forecast Algorithms.

6.2 Milestones and Deliverables

Project milestones	Due
1. Project Commencement	May 2011
2. Stakeholder workshop to develop project specifications	11 May 2011
3. Peer review of project plan and methodology	May 2011
4. Finalise project specifications	June 2011
5. 1st Meeting of Project Partners Steering Group	July 2011
6. Procurement of data storage and management	July 2011
7. Review and selection of GCMs	Sept 2011
8. Selection of RCMs	Sept 2011
9. Re-Analysis 40year historical period (1970-2010)	Dec 2011
10. Data delivery of 1st RCM suite (from GCM1) to partners (raw data for 3 epochs)	May 2012
11. Data delivery of 2nd RCM suite (from GCM2) to partners (raw data for 3 epochs)	Sept 2012
12. Data delivery of 3rd RCM suite (from GCM3) to partners (raw data for 3 epochs)	Feb 2013
13. Data delivery of final RCM suite (from GCM4) to partners (raw data for 3 epochs)	June 2013
14. Deliver full ensemble simulations to partners	Dec 2013
15. Peer review ensemble simulations and uncertainty	Dec 2013
16. Public release data and reports via portal	June 2014

6.2.1. Project Timeframes

Stages	Step	No	Pre-requisite step	Month - month 1 commences May 2011																																			
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
Model	Scenario, time period and output selection	1	None																																					Workshop with end users
	Review GCM skill	2	None																																					In house development of criteria and review
	GCM selection	3	Step 1 and 2																																					skill and data output needs
	WRF programming (amend for local conditions and outputs)	4	Step 1																																					
	Obtain GCM data	7	Step 5																																					
	Secure data processing time	8	None																																					
	Initialize and run WRF	9	Step 5 and 7						GCM1				GCM 2				GCM 3				GCM 4																			
	Evaluate and validate model outputs	10	Step 8										GCM 1				GCM 2				GCM 3				GCM 4															
	Output data	11	Step 9												GCM 1				GCM 2				GCM 3				GCM 4													
	3 RCM Bundle delivered	12	Step 11 (part)																																					
	Develop ensemble 'best estimate' and uncertainty ranges	17	Step 11- GCM 4																																					
Storage	Establish data storage needs	5	Step 3																																					
	Purchase data storage capacity	6	Step 5																																					
Outputs	Identify and develop useful outputs	13	Step 9 - GCM 1																																					Workshop with end users
	Data access interface - Trial web Prototype on first GCM run	14a	Step 12																																					
	Data access interface - develop to full production web model	14b	Step 11																																					
	NSW Climate Change Projections Report	15	Step 9 - GCM 4																																					
	Add on tools	16	Step 10 - GCM 1																																					Add on tools developed will be dependent on partners

6.3 Project Governance & Funding

NARCliM project management and delivery will be the responsibility of the OEH. Project management and governance arrangements are set out in Figure 1 below.

Executive Sponsor

The Executive Director of Scientific Services of OEH will be the Executive Sponsor. The Executive Sponsor will oversee the project and final decision-making will reside with the Executive Sponsor. The NARCliM Project Management team will report to the Executive Sponsor on project milestones and delivery of outputs. The Executive Sponsor will also receive advice directly from the Project Steering Group.

Project Management Team

The Project Management Team will be responsible for the day to day management of the project and will meet regularly to ensure project milestones are being met and project updates are disseminated as required. The Project Management Team will develop a program for developing data dissemination tools and working directly with end-users to design tools that will provide useful information to the end-users.

OEH will draw on its science and policy capabilities to project manage NARCliM. The University of NSW will also be included in the project management team, which will comprise:

Project leader – Peter Smith, Manager Climate Change Science, OEH
Project manager – Graham Turner, Principal Scientist, OEH
Climate modelling (lead) – Jason Evans, Senior Lecturer, Climate Change Research Centre, UNSW
Policy support – State Co-ordinator Impacts & Adaptation, OEH

The NARCliM and project management team will also be supported by:

- Data management (lead) – Malcolm Stephens, Manager Spatial Information & Analysis, OEH
- Climate modelling team – 3 modellers for three years at UNSW and OEH
- Data storage – data storage and management costs through Intersect Australia Ltd based at Redfern NSW.
- Data delivery – delivery of data produced by NARCliM will be a key component of this project. Resources will be dedicated to developing data delivery support tools and ongoing communication with end-users about their information needs.

Project Steering Group

The contribution and involvement of the ACT Government and other NSW Government agencies in the development and funding of NARCliM is critical to the success of the project. Funding partners will sit on the NARCliM Project Steering Group that will meet twice a year or as needed. Funding partners will have access to the model projections data, through a web interface tool, at the completion of each of the four GCM runs (see milestones above).

Through the Project Steering Group, funding Partners will be provided with project updates, be able to track progress on milestones, and provide input to the project's development directly to the Project Management team and the Executive Sponsor. The Project Steering Group will also be required to approve the methodology and reports of the three peer review stages covered in Section 7. The Steering Group would be required to endorse interim and final reports, the NARCliM outputs, recommendations from the End-User Group, and any amendments to the Project Plan, prior to submission to the Executive sponsor for approval.

End User Group
The End-User reference group will provide input into how the projections generated by NARCliM are provided in a useable format. This will include data delivery mechanisms and tools that will be scoped and developed once the modelling work is underway. It is proposed that the End-User Reference Group will meet once per year. End-users will have access to the model outputs once they are publicly released in June 2014.

Funding

Expenditure
The total NARCliM project costs have been calculated at $2.2 million. This includes funds for the climate modelling, data storage and delivery of the NARCliM outputs in an accessible web interface. A break-down of project costs is included in Table 1 below. The Office of Environment and Heritage is contributing $1.05 million directly to the project, in addition to its in-kind contribution of dedicated staff time.

Table 1: Funding Required

Component		2010/11	2011/12	2012/13	2013/14	Total
Modelling	*Sub-Total*	*$260,416*	*$374,797*	*$384,789*	*$130,014*	***$1,150,017***
Data Storage	Salaries - Data Manager	$32,128	$66,825	$69,499	$72,279	$240,731
	Asset & maintenance costs	$310,000	$10,000	$10,000	$10,000	$340,000
	Sub-Total	*$342,128*	*$76,825*	*$79,499*	*$82,279*	***$580,731***
Decision support tools and Communication	*Sub-Total*	*$10,000*	*$134,867*	*$139,861*	*$165,054*	***$449,782***
Project Expenditure	**Total**	**$612,544**	**$586,490**	**$604,149**	**$377,347**	**$2,180,530**

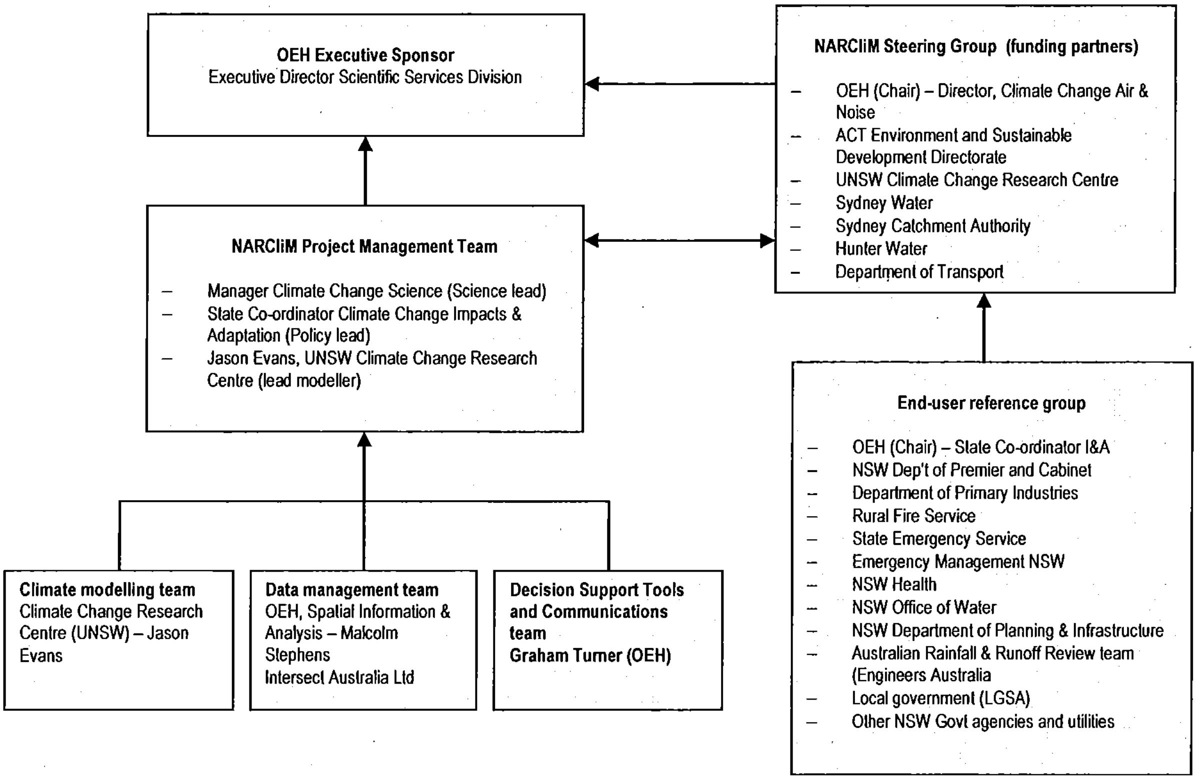
Sources
Project partners have committed funding to the project as follows:

- NSW Office of Environment and Heritage $1,050,000
- Sydney Catchment Authority $370,000
- Australian Capital Territory Government $250,000
- Sydney Water Corporation $100,000
- Emergency Management NSW $75,000
- Department of Transport $50,000
- Hunter Water Corporation $30,000

OEH will continue discussions with other NSW Government agencies who may be interested in becoming project partners.

Figure 1: REGIONAL CLIMATE MODEL FOR NSW & ACT (NARCliM)

Governance and Project Management Structure



7. Risks and Risk Management

The NARCliM project is a significant investment of both staff and financial resources for the NSW and ACT Governments. There are a number of risk factors that could affect the success of the project meeting its objectives. These can be summarised into four main areas, namely access to appropriately qualified personnel, continued access to the super computing facility, data storage acquisition and maintenance and interface and tool development failure. The following table lists the major risks for the project, assesses the consequence and likelihood of failure and provides the NARCliM project's contingency plans to address these risks.

Factor	Consequences	Likelihood	Strategy/Contingency
Availability/Retention of trained modelling staff	High	Medium	OEH has established one of the modelling positions in house from Feb 2011. Other modelling staff recruitment has commenced as a priority If modelling staff are not recruited as needed, the project timeframes will not be met, and additional time will be required.
Access to super computing resource facility	High	Low	Few contingency options are available although it is likely that over time resource availabilities will widen and increase in capacities to alleviate/spread risk
Data storage access	Low	Low	Storage Disks acquisition is already in place; Two replicate data repositories will be maintained (one off-site failsafe catastrophic event at the Intersect facility.
Interface development fail	Medium	Low	Pilot Prototype or sample trialled early to ensure development
Project takes longer to deliver than planned, impacting budget and deliverables	High	Medium	This Project involves three separate components and delivery of large amounts of data over 2-3 years. A dedicated Project Manager with the appropriate skills has been allocated to the Project and will work closely with the Project Management Team to ensure milestones are met. The Project has been designed around realistic timeframes for delivery of model runs and budget has been allocated accordingly.
Limited uptake of outputs and knowledge transfer	Low	Medium	Extensive consultation has been carried out with end-users in the project planning phase, important project partnerships have been established and project briefings have taken place. A Decision Support Tools & Communications sub-team as been included in the Project specifically for this purpose, and Project Steering Committee will play a key role in ensuring that mechanisms for delivery of project outputs are established in an end-user accessible way, and outputs are communicated to a wide range of end users.
Single climate change scenario underestimate climate change impacts	High	Low	Selection of multiple scenarios is constrained by project budget and computing capacity. The A2 scenario has been chosen as currently the most likely climate change scenario based on current global emissions trajectory.
Political sensitivity	Medium	Medium	The Project involves a broad range of government stakeholders. Broad stakeholder involvement is important for highlighting any political sensitivities related to the project outcomes, and reduces risks by allowing these sensitivities to dealt with as the Project progresses.

8. Peer review

A peer review process of NARCliM will be undertaken. The first peer review is intended to verify the proposed project methodology and will be undertaken prior to any model selection. The second peer review period will occur after the release of the first three RCMs. The final peer review will be undertaken near the end of the project, after the ensemble (i.e. after the final models have been selected) has been completed and prior to public and stakeholder release. There will also be a number of research papers generated by the project which will be submitted for publication in scientific journals.

Professor Andy Pittman of the Climate Change Research Centre, University of New South Wales and Dr Penny Whetton, Centre for Australian Weather and Climate Research (CSIRO), two leading climate researchers will review the project. Prof Pitman and Dr Whetton may nominate delegates within their respective agencies if they are unable to accommodate project review timelines.

9. Communication to the Community

Providing key information to the community and the private sector about the projected impacts of climate change on NSW is an important aspect of NARCliM. Information about the project and NARCliM outputs will be disseminated broadly to the community through information sessions and reports. An information web portal will be developed to allow for easy access to data as well various support tools that will be derived from input of user needs. A final report on the NARCliM projections for NSW is expected to be published in 2014.

Appendix 1: NARCliM Downscaling Methodology

*This summarizes the steps to be taken in performing the downscaling for this project. The aim of the methodology is to produce a high resolution regional climate ensemble that samples the uncertainty of future climate found in the CMIP3 GCM ensemble [*Meehl et al., *2007] and in the dynamical downscaling technique, as well as spanning as much of the range of future climate projections found in the CMIP3 ensemble as possible. While acknowledging that ideally all GCMs would be downscaled using multiple RCMs, limitations of computing time and data storage space require pragmatic choices to be made.*

*The project is limited to a twelve member GCM/RCM ensemble. This will be created by choosing four GCMs and downscaling each of these with three different RCMs. In each case three 20-year time-slices will be simulated. For future projections the SRES A2 emission scenario [*IPCC, *2000] will be used. All RCM simulations will be performed at 10km resolution over NSW/ACT. This high resolution domain will be embedded within a 50km resolution domain that covers the CORDEX-AustralAsia region. Choosing this larger domain ensures that a future stage of the project focused on CMIP5 results can take advantage of simulations performed for the CORDEX initiative [*Giorgi et al., *2009].*

The project methodology proceeds in six main steps.

1. *A series of stakeholder meetings have been held to determine the climate related variables of most interest to both the project partners and the larger stakeholder community focused on climate change impacts.*
2. *The three RCMs that will be used to perform the downscaling must be identified.*
3. *These RCMs will then be used to perform long historical simulations driven by reanalysis that will facilitate an extensive evaluation of the RCM performance including their ability to downscale the effect of inter-decadal variability.*
4. *The four GCMs from which to downscale must be chosen.*
5. *These will then be used to drive the three RCMs to simulate three time-slices that represent the present-day, the near-future and the far-future.*
6. *Once the ensemble has been created it will be evaluated for its "present-day" performance and analysed to produce ensemble best-estimates of the future change and uncertainty range around that change.*

Each of these steps is examined in more detail below.

1. Incorporating stakeholder desired model outputs

A series of stakeholder meetings have been held to both inform them of the planned project and to illicit feedback concerning various aspects of the project in order to ensure the outcomes will be useful for them. This feedback has been incorporated into the project plan described here. In particular, a number of output variables not currently built into the RCM output procedures have been requested. Incorporating these variables requires RCM code development which must be completed before the climate simulations can be performed. In some cases, this will be the first time these

variables have ever been produced in climate model output creating a truly unique dataset that will enable world leading research.
The extra variables identified through the stakeholder process include:

1. *Maximum 5, 10, 20, 30 and 60 minute precipitation accumulations each day*
2. *Peak 10 minute wind gust each day*

All variables will be output at a 3-hourly time step except for the following which will be output hourly:

1. *Precipitation*
2. *2-metre temperature*
3. *2-metre humidity*
4. *10-metre winds*

2. Choosing the RCMs to perform the downscaling

*The RCMs to be used will be based on the Weather Research and Forecasting (WRF) modelling system [*Skamarock et al., *2008]. This system facilitates the use of many RCMs by allowing all model components to be changed and hence many structurally different RCMs can be built. The aim of this methodology is to choose three RCMs from a large ensemble of adequately performing RCMs, such that they retain as much independent information as possible while spanning the uncertainty range found in the full ensemble. Due to computational limitations, the RCM performance and independence will be evaluated based on a series of event simulations rather than using multi-year simulations.*

2.1. Evaluate RCM performance for a series of important precipitation events

*By limiting the evaluation period to a series of representative events for NSW, a much larger set of RCMs can be tested. In this case an ensemble of 36 RCMs will be created by using various parametrizations for the Cumulus convection scheme, the cloud microphysics scheme, the radiation schemes and the Planetary Boundary Layer (PBL) scheme. Each of these RCMs will be used to simulate a set of 7 representative storms that cover the various NSW storm types discussed in the literature [*Shand et al., *2010;* Speer et al., *2009]. An eighth event focused on a period of extreme fire weather will also be analysed. In each case a two week period is simulated centred around the peak of the event. Subsequent analysis then includes pre and post-event climate as well as the event itself.*
*Evaluation will be performed against daily precipitation, minimum and maximum temperature from the Bureau of Meteorology's (BoMs) Australian Water Availability Project [*Jones et al., *2009]. Evaluation will also be performed against the mean sea level pressure and the 10m winds obtained from BoMs MesoLAPS analysis [*Puri et al., *1998]. Any RCMs that perform consistently poorly will be removed from further analysis. The overall spread in these results provides a measure of the uncertainty in the RCM.*

2.2. Determine RCM independence

Using the method of Abramowitz and Bishop *[2010] the level of independence between the RCMs will be quantified. This method uses the correlation of model errors as an indicator of model independence. In combination, more independent* *models provide more robust estimates of the climate. Quantification of the model independence provides an indicator of which models contribute the most independent information and hence should be retained in the three chosen RCMs.*

2.3. Choose the RCMs

The ensemble subset of adequately performing models, which is anticipated to be most of the 36 member ensemble, is identified in section 2.1 This ensemble subset is then evaluated for model independence (section 2.2) The most independent RCMs that span the subset ensemble variance will be chosen.

3. Perform and analyse historical RCM simulations

*The aim of this section is to provide a comprehensive analysis of the performance of the RCMs over the recent past. Forty year historical simulations (1970 – 2010) of the chosen RCMs driven by the NCEP/NCAR reanalysis [*Kalnay et al., *1996] will be performed. This will allow evaluation of the RCM performance on time scales ranging from hourly through to decadal. While previous work suggests that good performance is likely [*Evans and McCabe, *2010], this evaluation will identify strengths and weaknesses of the RCMs that will be considered when analysing the future simulations. At least one of these simulations will begin in 1950 and extend for 60 years. This will capture the very wet decade of the 50s and allow for an entire Inter-decadal Pacific Oscillation (IPO) cycle to be investigated.*

4. Choosing the Global Climate Models (GCMs) to downscale from

Four GCMs will be chosen to downscale from the CMIP3 GCMs. The criteria used to make this choice are: 1. the GCMs produce adequate simulations of present-day climate for the region; 2. the GCMs provide independent estimates of the climate; and 3. the GCMs span the range of future climate change projections.

4.1. Evaluate GCM performance

Many evaluation studies of CMIP3 GCMs focused on south-east Australia have been performed. A comprehensive literature review will be performed to extend the meta-analysis of these studies that was done by Smith and Chandler *[2010] and will provide a comprehensive evaluation that uses a suite of evaluation techniques and metrics. This and similar studies have shown that identifying the overall best performing GCMs is a difficult, if not impossible, task. The evaluation performed here will not aim to do this but rather it will aim to identify GCMs that produce consistently poor results. These GCMs will be removed from the subsequent analysis.*

4.2. Determine the GCM independence

Similar to section 2.2, the method of Abramowitz and Bishop *[2010] will be used to determine the level of independence of the adequately performing GCMs. In contrast to section 2.2, this will be determined by examining the model results over several recent decades rather than a series of events. The relative level of model independence will be an important factor with GCMs that demonstrate greater independence being chosen preferentially.*

4.3. Examine the future changes projected by the GCMs

*In order to span the range of future climate projections within the GCM ensemble a future climate change matrix will be used [*Whetton and Hennessy, *2010]. In this* *technique the GCMs can be placed in categories based on their projected future changes in temperature and precipitation. The number of GCMs in each cell of the future change matrix provides an indication of the likelihood of that change occurring.*

4.4. Choose the GCMs

Focusing only on the GCMs that perform adequately for south-east Australia and using the information from sections 4.2 and 4.3, the most independent GCMs that span the projected future change matrix will be chosen. Practical considerations such as the availability of 6 hourly data to drive the Regional Climate Models (RCMs) will also need to be considered.

5. Perform GCM/RCM simulations

Three 20 year simulations will be performed with each GCM/RCM combination, for the present-day (1990-2010) and two future periods (2020-2040 and 2060-2080). The process will be staggered with each GCM being downscaled by the three RCMs before the next GCM is downscaled. When the downscaling for each GCM is completed the data will be made available to project partners through the NARCliM data server.
While the second GCM is being downscaled, results from the first GCM will be analysed, and so forth. The analysis will start with an evaluation of the performance for the present-day using statistics of the observations. A comparison with the reanalysis driven RCMs will also be performed. This provides an opportunity to understand which errors are derived from the GCM and which from the RCM (e.g. Evans, *2010). Following this the projected future changes will be examined.*

6. Ensemble best estimate and uncertainty

Given the collection of 12 GCM/RCM simulations, ensemble best estimates and the related uncertainty will be calculated to facilitate ease of use for impacts assessments. A number of factors will be considered when producing the ensemble best estimate. First the evaluation against observations will be examined to ensure no GCM/RCM simulation performs unacceptably poorly. The model independence will again be examined and a combination of the level of model independence and the likelihood of the GCM future climate change matrix category will be used to produce an ensemble best estimate.
The uncertainty in these future climate projections will be quantified in a number of ways. These techniques will range in complexity from simply investigating the spread in the future climate projections through to employing a Bayesian analysis of the changes given the prior knowledge of the simulation performance for present-day and the position in the GCM future change matrix.

6.1. Evaluate GCM/RCM performance

Using the same suite of evaluation techniques and metrics as used for the GCMs, the regional simulations will be evaluated thus providing a measure of the level of confidence in each GCM/RCM combination. If any particular ensemble member performs unacceptably poorly it will be removed from further analysis. This *evaluation step will also establish a basis for bias correction of variables commonly used in impacts assessments.*

6.2. Determine GCM/RCM independence

Again the method of Abramowitz and Bishop *[2010] will be used to determine the level of independence between the GCM/RCMs. In this case the independence quantification can be used as a set of weights to produce an optimum independence weighted ensemble mean.*

6.3. Produce regional climate change best estimates

These model independence derived weights will be combined with the likelihood of the GCM projected climate derived from the GCM future climate change matrix, to produce an ensemble best estimate that accounts for both the model independence of the GCM/RCM simulations and the range of the projected future climates from the whole CMIP3 GCM ensemble.

6.4. Produce regional uncertainty estimates

Uncertainty estimates of the future regional climate changes will be produced by examining the spread in GCM/RCM simulations, the change in probability distribution functions for various climate variables in a manner similar to Deque and Somot *[2010], and a Bayesian analysis of the changes simulated given the simulation of present climate and the position in the GCM future change matrix (e.g.* Buser et al., *2010;* Tebaldi and Sanso, *2009).*

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Appendix 2: Full List of parameters available from RCM runs (WRF model).

LAND USE CATEGORY
eta values on half (mass) levels
eta values on full (w) levels
DEPTHS OF CENTERS OF SOIL LAYERS
THICKNESSES OF SOIL LAYERS
x-wind component
y-wind component
z-wind component
perturbation geopotential
base-state geopotential
perturbation potential temperature (theta-t0)
perturbation dry air mass in column
base state dry air mass in column
perturbation pressure
BASE STATE PRESSURE
fraction of frozen precipitation
accumulated potential evaporation
snow phase change heat flux
bottom soil temperature
upper weight for vertical stretching
lower weight for vertical stretching
inverse d(eta) values between full (w) levels
inverse d(eta) values between half (mass) levels
d(eta) values between full (w) levels
d(eta) values between half (mass) levels
extrapolation constant
extrapolation constant
QV at 2 M
TEMP at 2 M
POT TEMP at 2 M
SFC PRESSURE
U at 10 M
V at 10 M
INVERSE X GRID LENGTH
INVERSE Y GRID LENGTH
TIME WEIGHT CONSTANT FOR SMALL STEPS
ZETA AT MODEL TOP
2nd order extrapolation constant
2nd order extrapolation constant
2nd order extrapolation constant
minutes since simulation start
Water vapor mixing ratio
Cloud water mixing ratio
Rain water mixing ratio
LAND MASK (1 FOR LAND, 0 FOR WATER)
SOIL TEMPERATURE
SOIL MOISTURE
SOIL LIQUID WATER
SEA ICE FLAG

SEA ICE FLAG (PREVIOUS STEP)
SURFACE RUNOFF
UNDERGROUND RUNOFF
DOMINANT VEGETATION CATEGORY
DOMINANT SOIL CATEGORY
VEGETATION FRACTION
GROUND HEAT FLUX
SNOW WATER EQUIVALENT
PHYSICAL SNOW DEPTH
SNOW DENSITY
CANOPY WATER
SEA SURFACE TEMPERATURE
Droplet number source
Map scale factor on mass grid
Map scale factor on u-grid
Map scale factor on v-grid
Map scale factor on mass grid, x direction
Map scale factor on mass grid, y direction
Map scale factor on u-grid, x direction
Map scale factor on u-grid, y direction
Map scale factor on v-grid, x direction
Inverse map scale factor on v-grid, x direction
Map scale factor on v-grid, y direction
Coriolis sine latitude term
Coriolis cosine latitude term
Local sine of map rotation
Local cosine of map rotation
Terrain Height
Height of orographic shadow
SURFACE SKIN TEMPERATURE
PRESSURE TOP OF THE MODEL
Max map factor in domain
Max map factor in domain
ACCUMULATED TOTAL CUMULUS PRECIPITATION
ACCUMULATED TOTAL GRID SCALE PRECIPITATION
PRECIP RATE FROM CUMULUS SCHEME
TIME-STEP CUMULUS PRECIPITATION
ACCUMULATED TOTAL GRID SCALE SNOW AND ICE
EDT FROM GD SCHEME
DOWNWARD SHORT WAVE FLUX AT GROUND SURFACE
DOWNWARD LONG WAVE FLUX AT GROUND SURFACE
TOA OUTGOING LONG WAVE
LATITUDE, SOUTH IS NEGATIVE
LONGITUDE, WEST IS NEGATIVE
LATITUDE, SOUTH IS NEGATIVE
LONGITUDE, WEST IS NEGATIVE
LATITUDE, SOUTH IS NEGATIVE
LONGITUDE, WEST IS NEGATIVE
ALBEDO
BACKGROUND ALBEDO
SURFACE EMISSIVITY
SOIL TEMPERATURE AT LOWER BOUNDARY
LAND MASK (1 FOR LAND, 2 FOR WATER)
U* IN SIMILARITY THEORY

PBL HEIGHT
UPWARD HEAT FLUX AT THE SURFACE
UPWARD MOISTURE FLUX AT THE SURFACE
LATENT HEAT FLUX AT THE SURFACE
FLAG INDICATING SNOW COVERAGE (1 FOR SNOW COVER)