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OzClim for the MTSRF region

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Abstract: OzClim v3.1 is an advance on the OzClim v3.0 web service application suite introduced at MODSIM07. It is a useful and efficient way of assessing and reporting on climate change impacts and possible future climates. It is also a simple mechanism for delivering information about regional climate change and associated risk and uncertainty, based on the latest available global and regional climate model simulations.

Substantial progress has been made towards supporting exploration of climate change impacts at a regional level as well as at a national level. OzClim v3.1 now includes data for 23 global climate models from the CMIP3 data set submitted as part of the IPCC 4th Assessment Report, revised global warming curves, and a substantially expanded set of climate variables now including solar radiation, wind-speed, relative humidity, and ocean temperature and salinity. It supports regional grids at 5 km.

Additionally, OzClim v3.1 supports the probability density function approach to regional climate projections published in the "Climate Change in Australia" technical report 2007.

A CSIRO report (Thatcher and McGregor 2008) to the Marine and Tropical Sciences Research Facility (MTSRF) was based on dynamically downscaled climate data for the MTSRF region of interest using the CSIRO Mk3 model and the Cubic Conformal Atmospheric Model (CCAM), and that data has been incorporated into OzClim v3.1. The technique used to nest CCAM within CSIRO Mk3 can be used to dynamically downscale any GCM over a region to produce regional climate change projections.

Future developments of OzClim are likely to incorporate Web GIS tools to give interactive maps with pan and zoom functions, and so an example of what may be possible is provided.

Keywords: *OzClim, climate variable, global climate model, regional climate model, downscaling, GIS*

INTRODUCTION

OzClim v3.1 is a web service server and application family written for the Microsoft™ .NET framework which delivers information about regional climate change and associated risk and uncertainty. OzClim v3.0 was introduced at MODSIM07 (Ricketts and Page 2007). The main purposes of the tool at that time were to (a) provide possible future regional climate projections across Australia, using a pattern scaling method (Mitchell et al. 1999; Mitchell 2003; Whetton et al. 2005) applied to output from global climate models (GCMs) and (b) to apply those projections to various impact models as required.

In the intervening period substantial progress has been made towards the stated goals of incorporation of the latest models and tools for integrated assessments, dynamically downscaled regional models are becoming available for the MTSRF region, multi-model percentile maps are available as per the Climate Change In Australia Technical Report (CSIRO and Bureau of Meteorology 2007), and additional work has commenced on the possibility of provision of a full Web GIS interface.

The rest of this paper reviews the pattern scaling technique used and then tabulates the global climate models (GCMs) and patterns of change available within OzClim at present. It then introduces the MTSRF region as it is in OzClim and briefly explains the limitations of interpolation techniques for climate change projection at the smaller regional level and then introduces dynamical downscaling using CSIRO's CCAM hosted within CSIRO's Mk3.0 GCM. It demonstrates the refined pattern of change produced this way. Finally it surveys the plans for future development and integration with WebGIS tools and the architectural changes required.

1. PATTERN SCALING

The pattern scaling technique used is summarised in (Whetton et al. 2007) and also documented in (Ricketts and Page 2007). In summary monthly averages of climate variables of interest are obtained from GCM runs from present to 2100. For each year the model global warming is computed and for each month, at each grid point, a linear trend between the annual global warming and monthly value at the grid point of the climate variable is computed. For temperature variables the trend is in Degrees of change/Degree of global warming. For many variables the trend is expressed as a percentage of the model's own base climatology, as Percentage change/Degree global warming. The resulting twelve monthly grids are stored as monthly patterns of change for the variable within the run of the GCM. Future change is then computed from the pattern of change by first calculating the global warming for the year of interest and then simply multiplying the pattern of change at each grid point by that value.

2. ADDITIONAL CLIMATE MODELS AND VARIABLES

CSIRO has processed A1B runs from the CMIP3 data set for 23 GCMs. Not all climate models include all climate variables. At present we have patterns of change for the GCMs and climate variables listed in table 1 below. In addition, for the MTSRF region, OzClim is able to include finer scaled regional patterns of dynamically downscaled datasets derived from CSIRO Mk3.0 using CCAM. There is also 10^{th}, 50^{th} and 90^{th} percentile multi-model precipitation and temperature estimates as published in the Climate Change in Australia technical report (CSIRO and Bureau of Meteorology 2007).

In the IPCC Fourth Assessment Report (FAR), revised global warming curves were computed for the 6 SRES scenarios, and accordingly, OzClim now uses those curves.

3. MTSRF REGION

The Marine and Tropical Sciences Research Facility (MTSRF) was established to ensure the health of North Queensland's public environmental assets - particularly the Great Barrier Reef (GBR) and its catchments, tropical rainforests including the Wet Tropics World Heritage Area (WTWHA), and the Torres Strait (RRRC 2006). About 9,000 square kilometres of tropical rainforest stretch from Townsville to Cooktown and make up the Wet Tropics of Queensland World Heritage Site This runs parallel to the Great Barrier Reef (also a World Heritage Site) which covers an area of 344,400 square kilometres. Although the tropical rainforest covers much less than one percent of Australia's landmass, it is far more biodiverse than the rest of the country. Rainfall in this region shows a decreasing trend over the past century which is stronger after 1950 (Suppiah et al. 2007). Climate change projections produced by (CSIRO Atmospheric Research 2001) also show a tendency for drier conditions under enhanced greenhouse conditions. Atmospheric greenhouse gas concentrations have increased in the past century and are almost certain to continue to increase in the future (IPCC 2007). Any greenhouse warming induced climate change has significant implications for management and conservation of resources and biodiversity of the rainforest region of north Queensland. The MTSRF region of interest is a highly valued area by almost any measure.

The MTSRF region is defined in OzClim as the region between latitudes –10º and –20º, longitudes 140º and 150º, and is interpolated to 0.05 degree resolution.

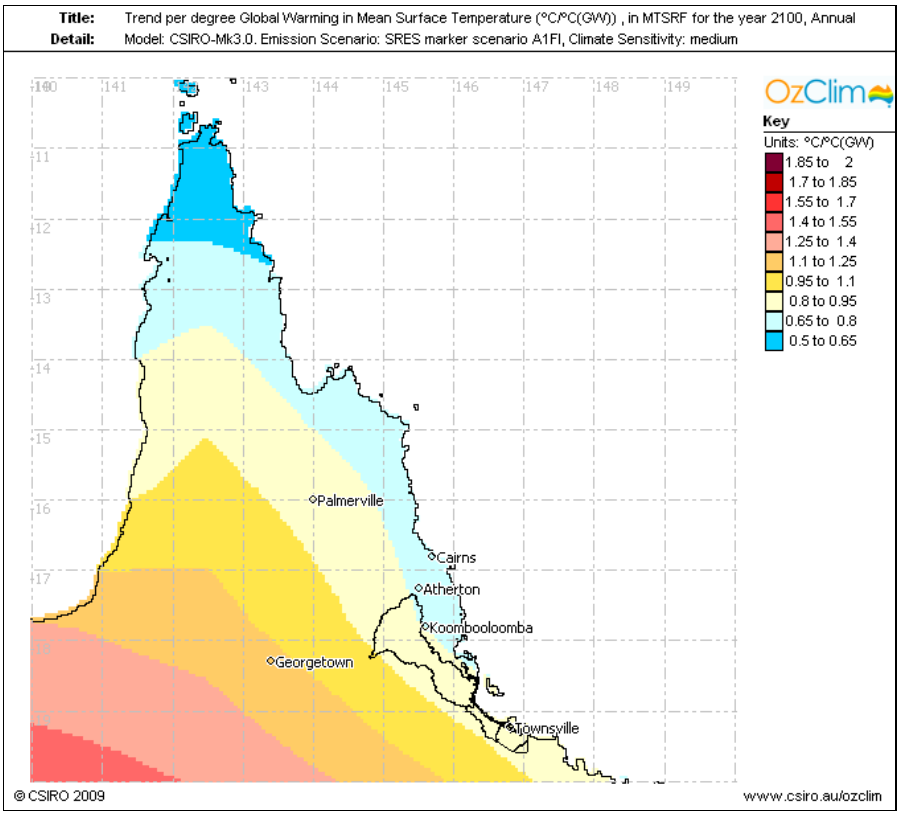
	Precipitation	Relative Humidity Average	Relative Humidity at 3pm	Relative Humidity at 9AM	Short Wave Downward Solar Radiation	Ocean Salinity	Sea Surface Temperature	Maximum Temperature	Minimum Temperature	Ocean Potential Temperature 250m	Mean Temperature	Wind Speed	Wet Area Evapo-transpiration
BCCR	Y	Y	Y	Y	Y			Y	Y		Y		
CCCMA-47	Y	Y	Y	Y	Y	25m	Y				Y	Y	Y
CCCMA-63	Y	Y	Y	Y		25m	Y				Y	Y	Y
CNRM	Y	Y	Y	Y	Y						Y	Y	
CSIRO-Mk30	Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y
CSIRO-Mk35	Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y
ECHAM5	Y				Y						Y	Y	
ECHO-G	Y				Y		Y				Y	Y	
GFDL-20	Y				Y	5m				Y	Y	Y	
GFDL-21	Y				Y					Y	Y	Y	
GISS_AOM	Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	
GISS-EH	Y	Y	Y	Y	Y		Y				Y	Y	Y
GISS-ER	Y	Y	Y	Y		0m	Y				Y	Y	
HADCM3	Y				Y		Y				Y	Y	
HADGEM1	Y				Y		Y				Y	Y	
IAP-FGOALS-g10	Y	Y	Y	Y			Y				Y	Y	
INGV_ECHAM4	Y										Y		
INMCM	Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y
ISPL-CM4	Y	Y	Y	Y	Y						Y	Y	Y
MIROC-H	Y	Y	Y	Y		0m	Y	Y	Y		Y	Y	Y
MIROC-M	Y	Y	Y	Y	Y	0m		Y	Y		Y	Y	Y
MRI-GCM232	Y	Y	Y	Y	Y		Y				Y	Y	Y
NCAR-CCSM	Y	Y	Y	Y							Y		Y
NCAR-PCM1	Y				Y		Y				Y		

Table 1: Currently, patterns of change are available for the listed global climate models (all from the CMIP3 set) for the indicated climate variables.

4. DYNAMICAL DOWNSCALING

The native resolution of GCMs is of the order of 2.5x2.5 degrees, so any interpolation technique adds little real fine-scale information. Bilinear interpolation is used in OzClim since it is fast to compute and produces no deceptive apparent detail. However, as CSIRO is being more often asked to provide regional climate change projections using OzClim we have commenced investigation of the practicalities of incorporating regional patterns of change using dynamical downscaling. The advantage of using this technique is that the finer scale detail is more reflective of regional considerations and thus should be more representative of a plausible future.

In the case of dynamical downscaling, Regional Climate Models (RCMs) simulate atmospheric dynamics and physics using modelling techniques that are similar to those used in GCM’s, but with enhancements for simulating meso-scale and local-scale meteorology. To account for surface forcings that influence the local climate, RCMs employ higher resolution surface datatsets (e.g., orography, land-use, albedo, etc). Most RCMs also assimilate some features of the large-scale synoptic weather patterns and global warming trends from the host GCM into their simulations.



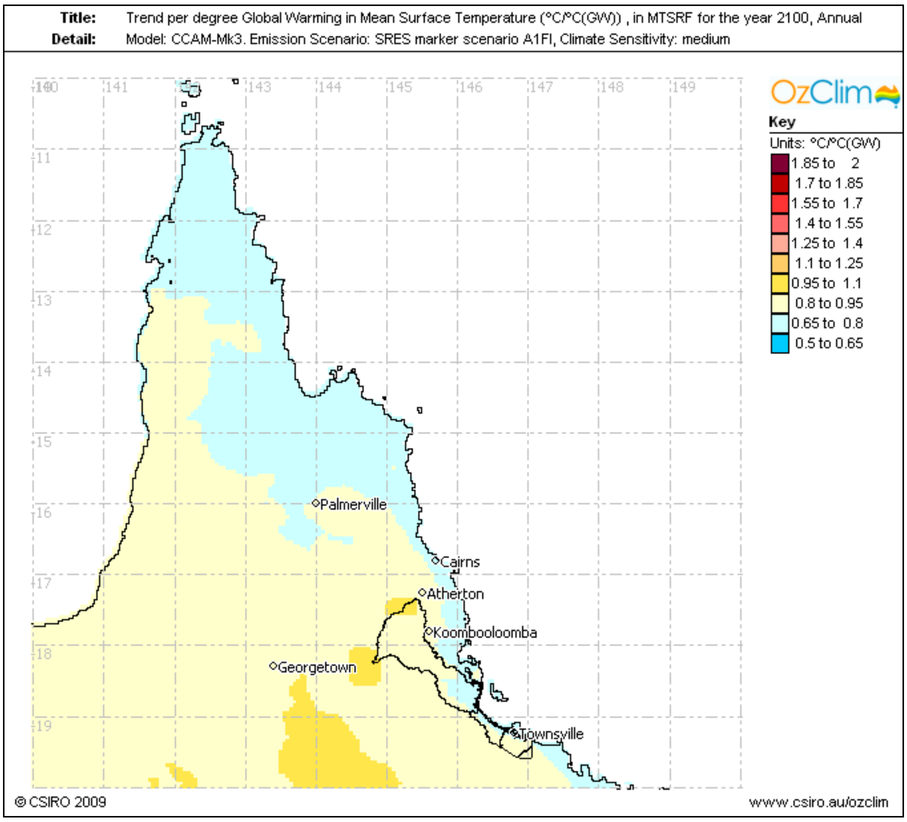


Figure 1: Patterns of change for temperature as available by interpolation from a GCM (CSIRO Mk3.0) contrasted with the dynamically downscaled output from CCM hosted within the same GCM. The top panel shows the change per degree of global warming for the MTSRF region as it has been available from OzClim up until now. The lower panel is the corresponding display as computed after dynamically downscaling.

In this way, RCMs are designed to dynamically respond to changes in climate like GCMs, while providing much higher spatial resolution for regional climate projections.

To make climate change projections for Australia, CSIRO developed the Mk3.0 coupled ocean-atmosphere GCM (Gordon et al. 2002) and the Conformal Cubic Atmospheric Model (CCAM) (McGregor 2005; McGregor and Dix 2008). Typically these two models are used together, with Mk3.0 simulating the global climate and CCAM dynamically downscaling the Mk3.0 output to regional scales. This is possible because CCAM is an Atmospheric Global Climate Model (AGCM) that employs a stretched global grid which can be focused for regional climate applications. CCAM is also computationally efficient due to its semi-implicit, semi-Lagrangian formulation, which allows the regional climate simulation to be completed within a practical amount of time (e.g., weeks instead of months or years) (Thatcher and McGregor 2008).

The downscaling of Mk3.0 output to 60 km resolution by CCAM was performed by (Nguyen and McGregor 2008). For the 60 km CCAM simulation they used the Sea Surface Temperatures (SSTs) from the Mk 3.0 output, after first subtracting present-day monthly-averaged biases. The broad-scale upper level winds (i.e., above 500 hPa) and the surface pressure were assimilated from Mk3.0 using a scale-selective filter (Thatcher and McGregor 2008) The scale-selective filter was used since it is far more effective at assimilating host model data into CCAM compared to boundary value nudging techniques (i.e., the scale-selective filter perturbs all grid points, not just at the boundaries). A filter diameter of approximately 30 degrees was used for the 60 km simulation and applied once every six hours.

The scale-selective filter is also used to assimilate the atmospheric data from the 60 km simulation into the CCAM 15 km simulation. In this case the winds, air temperature and mixing ratio above 900 hPa, as well as the surface pressure are assimilated. For the 15 km simulation a filter diameter of approximately 8 degrees is used, and the filter applied once every six hours.

Output from the runs was processed into monthly averaged patterns of change as percentage change per degree of global warming using the same methods as is used for the GCMs.

Work is continuing within CSIRO on performing dynamical downscaling using CCAM nested within other GCMs, e.g. GFDL 2.1, ECHAM 5, MIROC. To date we have output from CSIRO Mk3.0 over the MTSRF region, (see Figure 1) and have tested a number of others. There is no reason why more cannot be included as development of OzClim continues.

5. FUTURE PLANS

Increasingly CSIRO is being asked to provide climate change information to regional interests within Australia. Users are diverse, and many have expressed a requirement to be able to extract climate data over arbitrary regions as well as special areas of interest such as the MTSRF region of interest. Therefore, high on the agenda for future development is a requirement for interactive maps with panning and zoom. In order to provide the more interactive type of map drawing, the decision has been made to commence incorporation of WebGIS tools. There are several advantages to this. The WebGIS tools in current use are open source, familiar, and link to plentiful data sources, via a standard protocol overseen by the Open Geospatial Consortium, Inc.® (OGC). This involves use of geospatial libraries in the interface code, and an OGC compliant server. To this we are able to add a geospatially enabled database (for example PostGIS).

In the OGC framework, there are three types of service defined., Web Feature Services (WFS), Web Mapping Services (WMS), and Web Coverage Services (WCS). OzClim being extended to provide WCS. This means that climate maps will be returned as web coverages which can be overlaid on maps to indicate climate change. Properly constructed WCS allows gridded data to be extracted and coloured by rules on an OGC compliant server.

The implications for OzClim in this environment are significant. OzClim v4.0 is scheduled to carry the new mapping approach and is expected to be a substantial increment over OzClim v3.1. Figure 2 illustrates the power of this approach, where data has been pulled in from a number of sources on line, including a proptotype OzClim and combined in the browser application. Figure 3 shows the changes to the architecture of OzClim as first documented in (Ricketts and Page 2007) required.

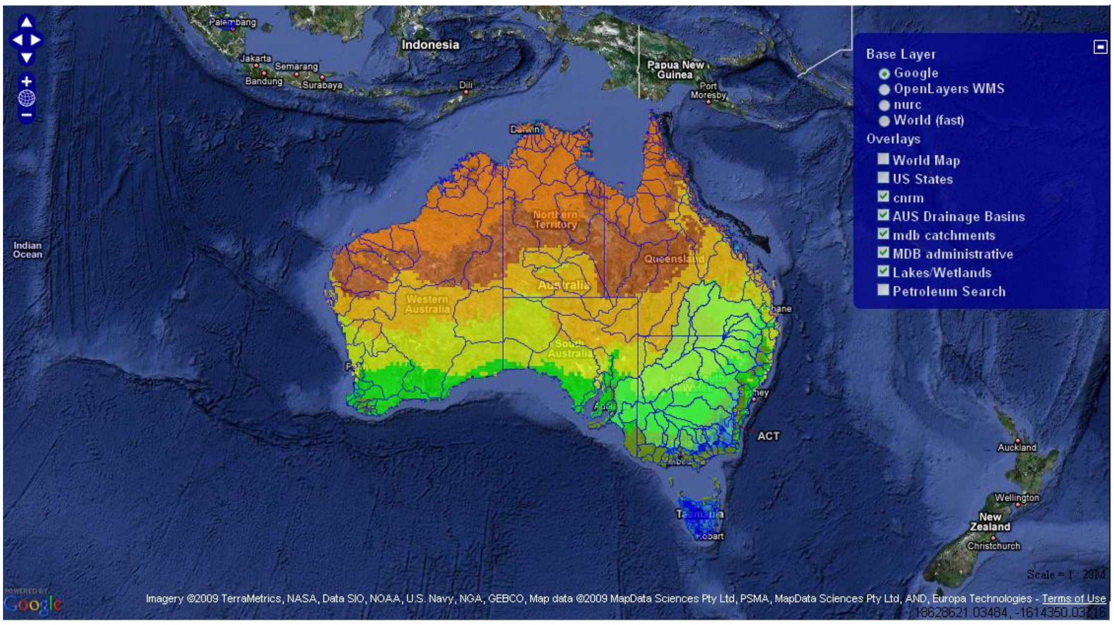


Figure 2: An example of a map drawn using Open Layers, incorporating information from a number of sources. The base layer is Google Maps, GeoServer was used to provide the Murray Darling Basin (shaded in green) and some catchment boundaries. The remaining shading is a web coverage representing future climate change under the CNRM GCM, extracted from OzClim and served also by GeoServer.

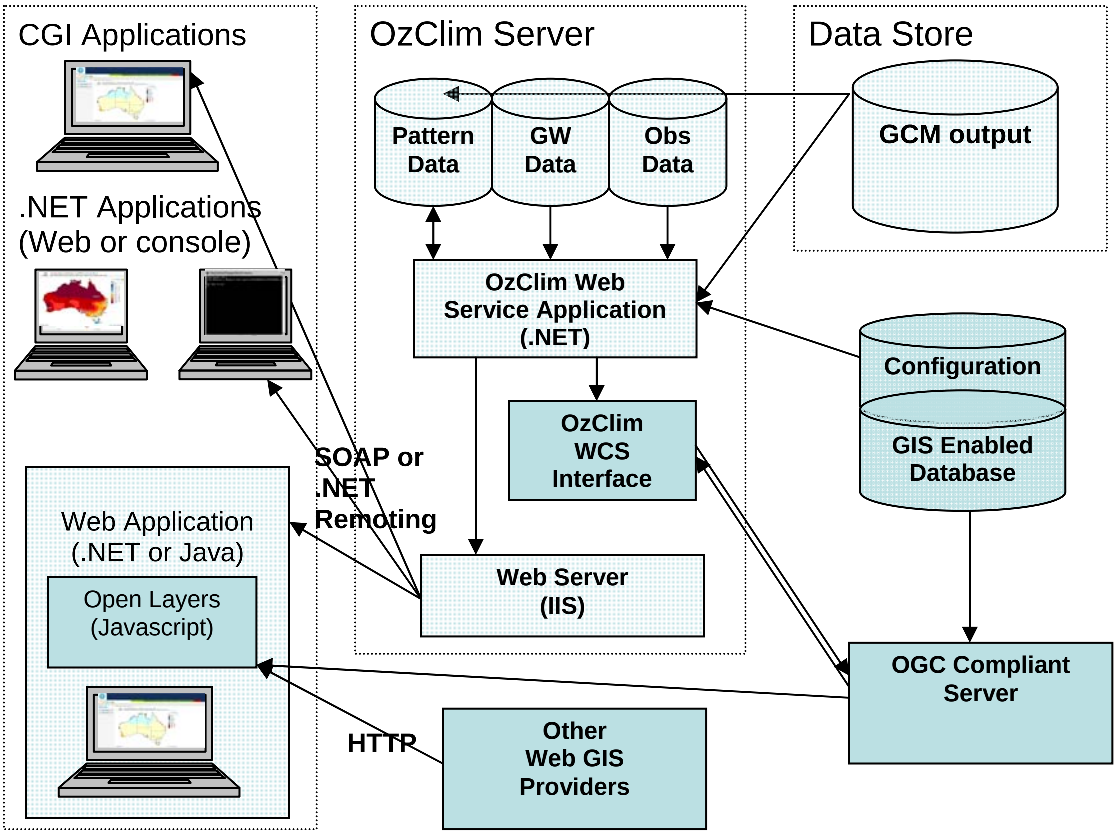


Figure 3: Revised OzClim architecture with WebGIS support. Components in darker colour are required to support WebGIS with the original OzClim v3.0 components shown in lighter colour. OzClim's Web Service Application will support output of climate change information maps via a WCS interface. Map production, currently carried out within the Web Service Application will be supported within the browser by Open Layers, calling out to OGC compliant WebGIS servers.

6. SUMMARY

The number of GCMs available has been expanded to 23 from the CMIP3 set. The number of climate variables available has been increased and will continue to increase as required, and also includes some ocean variables.

The MTSRF region is interpolated to higher resolution. Dynamical downscaling is a computationally intensive method of providing regional scale climate change projections which will require substantial resources. It is not yet fully evaluated within OzClim's functional framework, and that work continues. Other techniques of providing downscaled information (e.g. statistical downscaling, or ad. hoc. methods) have not been considered here.

The decision to go the OGC/WebGIS route opens up a range of possibilities for future development. Once users are provided with the facility to zoom in on maps then a decision must be made on how to present the relatively coarse grained patterns of change at high resolution. If dynamically downscaled data is available at particular locations then that may need to be incorporated with care.

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