An Inventory of Approaches to Climate Modeling and Downscaling

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Introduction

With the advent of ever more sophisticated climate models, it has become increasingly important for the water utility management community to stay current on climate model developments. A variety of models and downscaling approaches exist today. They can have widely differing spatial and temporal scales, as well as output parameters. This paper will provide an inventory of the most important climate models and downscaling techniques in use. The information contained herein can be used as the "raw material" for making informed water management decisions.

Is/Is Not

This paper is a detailed inventory of the status and availability of data for current climate modeling and downscaling efforts (with an emphasis on those that apply to the continental USA). The different efforts and approaches will be compared and contrasted. In addition, certain items or concepts that were mentioned in the Options for Improving Climate Modeling to Assist Water Utility Planning for Climate Change whitepaper (Chapter 3) but not fully explained (e.g. the North American Regional Climate Change Assessment Project, NARCCAP) will be covered.

This paper is not a Climate Science or Climate Modeling/Downscaling primer. It is assumed the audience has a level of understanding of these topics at least on par with what was presented in Chapter 3 of the above mentioned whitepaper. Also, while this paper attempts to provide a thorough explanation of the topics it addresses, it will not, for example, try to pick a "best" approach.

Outline

This paper has three primary sections.

The first section, Recent and Current Modeling Projects, will cover the recent history and current status of the Coupled Model Intercomparison Project (CMIP). A short discussion of efforts to improve the resolution of climate models is also included here. Also in this section, NARCCAP, and the Regional Climate Prediction Dot Net (RegCPDN) project will be examined.

The next section, Recent and Current Downscaling Projects, will cover a number of representative downscaling projects. Both statistical and dynamical downscaling projects will be treated here. This section is not meant to be a comprehensive list of all existing downscaling projects. Rather, the projects profiled were selected because they are well known, use a particularly innovative approach, or have some other unique attribute(s).

Finally, in the Conclusion, summary tables are included for the Models and Downscaling projects discussed.

A short section on Geospatial Equivalences, a Glossary of Acronyms, Citations, and Links are also provided at the end of the paper.

Recent and Current Modeling Projects

Coupled Model Intercomparison Project, Phase 3 (CMIP3)

The data archive for CMIP3 (officially known as the "WCRP CMIP3 multi-model dataset") is maintained by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at Lawrence Livermore National Lab. The archive consists of the output for 23 global climate models from around the world run in response to various forcing scenarios. Data is currently available to registered users.

CMIP3 results, and analysis based on those results, was used as the basis for many of the climate modeling discussions in the IPCC AR4.

A summary of a representative subset of the CMIP3 experiments is below.

Experiment	Years	Notes
Pre-Industrial Control	>100 yrs	No anthropogenic or natural forcing
Present Day Control	>100 yrs	No natural forcing and anthropogenic influences will be set at the present-day level
Climate of the 20th Century	~1850-present	Initialize from a point early in the pre-industrial control; run through 2000
Committed	present-2100	Initial condition = end of Climate of the 20th Century run
SRES A2	present-2100	Initial condition = end of Climate of the 20th Century run
SRES A1B	present-2300	Initial condition = end of Climate of the 20th Century run
SRES B1	present-2300	Initial condition = end of Climate of the 20th Century run
1%/yr CO2 to doubling	220 yrs	Hold CO2 fixed after reaching doubling
1%/yr CO2 to quadrupling	290 yrs	Hold CO2 fixed after reaching quadrupling

There was no single consistent resolution at which all of the models included in CMIP3 was run. Each model was run at its native resolution. The table below specifies the models, and resolutions for each, included in CMIP3.

CMIP Model Name, Vintage	Sponsor(s), Country	Atmos Res (degrees)	Ocean Res (degrees)
BCC-CMI, 2005	Beijing Climate Center., China	1.9x1.9	1.9x1.9
BCCR-BCM2.0, 2005	Bjerknes Centre for Climate Research, Norway	1.9x1.9	0.5-1.5x1.5
CCSM3, 2005	National Center for Atmospheric Research, USA	1.4x1.4	0.3-1.0x1.0
CGCM3.1(T47), 2005	Canadian Centre for Climate Modeling and Analysis, Canada	2.8x2.8	1.9x1.9
CGCM3.1(T63), 2005	Canadian Centre for Climate Modeling and Analysis, Canada	1.9x1.9	0.9x1.4
CNRM-CM3, 2004	Météo-France/Centre National de Recherches Météorologiques, France	1.9x1.9	0.5-2.0x2.0
CSIRO-MK3.0, 2001	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	1.9x1.9	0.8x1.9
ECHAM5/MPI-OM, 2005	Max Planck Inst. for Meteorology, Germany	1.9x1.9	1.5x1.5
ECHO-G, 1999	Meteorological Institute of the University of Bonn, Meteorological Research Institute of the Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea	3.9x3.9	0.5-2.8x2.8
FGOALS-g1.0, 2004	National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)/Institute of Atmospheric Physics, China	2.8x2.8	1.0x1.0
GFDL-CM2.0, 2005	U.S. Department of Commerce/National Oceanic and Atmospheric Administration (NOAA)/ Geophysical Fluid Dynamics Laboratory (GFDL), USA	2.0x2.5	0.3-1.0x1.0
GFDL-CM2.1, 2005	U.S. Department of Commerce/National Oceanic and Atmospheric Administration (NOAA)/ Geophysical Fluid Dynamics Laboratory (GFDL), USA	2.0x2.5	0.3-1.0x1.0
GISS-AOM, 2004	National Aeronautics and Space Administration (NASA)/Goddard Institute for Space Studies (GISS), USA	3.0x4.0	3.0x4.0
GISS-EH, 2004	National Aeronautics and Space Administration (NASA)/Goddard Institute for Space Studies (GISS), USA	4.0x5.0	2.0x2.0

CMIP Model Name, Vintage	Sponsor(s), Country	Atmos Res (degrees)	Ocean Res (degrees)
GISS-ER, 2004	National Aeronautics and Space Administration (NASA)/Goddard Institute for Space Studies (GISS), USA	4.0x5.0	4.0x5.0
INM-CM3.0, 2004	Inst. for Numerical Mathematics, Russia	4.0x5.0	2.0x2.5
IPSL-CM4, 2005	Institut Pierre Simon Laplace, France	2.5x3.75	2.0x2.0
MIROC3.2(hires), 2004	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	1.1x1.1	0.2x0.3
MIROC3.2(medres), 2004	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	2.8x2.8	0.5-1.4x1.4
MRI-CGCM2.3.2, 2003	Meteorological Research Inst., Japan	2.8x2.8	0.5-2.0x2.5
PCM, 1998	National Center for Atmospheric Research, USA	2.8x2.8	0.5-0.7x1.1
UKMO-HadCM3	Hadley Centre for Climate Prediction and Research/Met Office, UK	2.5x3.75	1.25x1.25
UKMO-HadGEM1	Hadley Centre for Climate Prediction and Research/Met Office, UK	1.3x1.9	0.3-1.0x1.0

The CMIP3 data archive contains a wealth of output parameter data. Depending on the parameter, output frequency may be 3 hourly, daily, monthly, or “extreme” (i.e. “derived data in the form of annual indicator time series” (Frich et al, 2002)). See the “Links” section below for the url which links to the output parameter specifics. Data is available in NetCDF format.

Coupled Model Intercomparison Project, Phase 5 (CMIP5)

In September 2008, the world climate modeling community agreed on a new set of coordinated climate modeling experiments. This new set of experiments is known as CMIP5 (there was no CMIP4). The purpose of CMIP5 is to extend the research performed as part of CMIP3, and answer questions that arose as part of the IPCC AR4. CMIP5 experiments will be used as the basis for the IPCC’s AR5, due to be published in 2013.

Preliminary CMIP5 model runs have begun, although availability of results is still (as of November 2010) very limited. Participating modeling groups self-select the model(s) they will be using. As such, no information has yet been published as to models that will be included in CMIP5.

However, the CMIP5 experimental design (Taylor et al. 2009) has been published. It is summarized below.

There are two distinct foci of the CMIP5 modeling effort: 1) near-term simulations of 10-30 years, and 2) long-term simulations on century time scales. In some cases the long-term simulations may be coupled to a carbon cycle model (aka an Earth System Model - ESM).

Experiments for both timescales are grouped into a “core” experimental set, and one (near-term) or two (long-term) additional “tiers” of experiments. Tiers 1 and 2 are more detailed groups of experiments exploring additional aspects of climate system response and projections. It is desired that the core experiments be performed by all modeling groups. Modeling groups are encouraged to move on to Tiers 1 and 2 as time and resources allow.

A listing of the core experiments for both timescales follows.

Near Term Core Experiments	Long Term Core Experiments
Ensembles of 10-year hindcasts and predictions	Coupled model, pre-industrial control
Ensembles of 30-year hindcasts and predictions	Historical (1850-2005) ensemble
	Atmospheric Model Intercomparison Project (AMIP) ensemble (1979-2008)
	Projected responses to Representative Concentration Pathways (RCP’s) 4.5, 8.5
	Idealized 1%/year CO2 increase
	Prescribed sea surface temps to diagnose “fast” responses to 4X CO2
	Diagnosis of climate system “slow” responses to abrupt 4X CO2

Tier 1 and tier 2 experiments are much more numerous than the core experiments. Space does not allow for a complete listing of them here. However, a few representative Tier 1 and 2 experiments are listed below. See Taylor et al. 2009 for a detailed complete listing of all experiments.

Representative Near Term T1 Exps.	Representative Long Term T1/T2 Exps.
1%/yr CO2 increase	Extension of RCP4.5 through 2300 (T1)
Hindcasts without volcanoes	Extension of RCPs 2.6, 8.5 through 2300 (T2)
Predictions with 2010 Pinatubo-like eruption	Impose last glacial maximum conditions (ice sheets, GHG’s) (T1)
Increased ensemble sizes	Historical runs with only natural (e.g. solar variability), and only GHG forcings (T1)
Alternative initialization strategies	Historical last millennium (850-1850) (T2)

As in CMIP3, there are numerous output parameters available on a 3 or 6 hourly basis, or as daily/monthly/annual means. See the Links section for the url which specifies in detail all output parameters requested for CMIP5.

CMIP3/5 Comparison

CMIP5 represents the evolution of the CMIP3 project. CMIP5 plans call for significantly more experiments and perturbations than CMIP3. Also, an expanded set of output parameters should be available from CMIP5. And, it is expected that the newest generation of available climate models will be included in CMIP5.

High Resolution Global Models

Output from GCM's is often of limited use to those interested in local climate change impacts. This is primarily due to the coarseness of the output (typically on the order of a couple of degrees of latitude/longitude). Efforts to improve resolution are primarily focused on three areas:

1. High resolution everywhere

Examples of this approach are the Japan Agency for Marine-Earth Science and Technology Earth Simulator (ES) and the GFDL High Resolution GCM efforts.

The ES was one of the largest and fastest supercomputers ever built. The Earth Simulator 2 (ES2) was turned on in 2009, significantly improving on the performance of its predecessor. The ES has enabled global GCM runs at a nominal resolution of 20KM. (JAMEST 2009)

Efforts are under way at the GFDL to improve the resolution of their "workhorse" climate model, CM2.1 (with an ocean resolution of ~100KM/1 degree and atmospheric resolution of ~200KM/2 degrees). CM2.1 was used in the IPCC AR4. CM models under development include v2.4 (0.25 degree ocean/1.0 degree atmosphere); v2.5 (0.25 degree ocean/0.5 degrees atmosphere); and v 2.6 (0.1 degree ocean/0.5 degrees atmosphere). In addition to increased resolution, the ocean flow of these models is more energetic and realistic. Due to the computational demands of these higher resolution models, some simulations have had to be moved off the GFDL site to facilities with even more extensive computing resources. (GFDL 2010)

2. Variable grid spacing, which entails running a global model at its "normal" resolution, but with a higher resolution grid over the area of interest

Varying the grid spacing of the GCM (as in #1 above), allows for more realistic meso-scale predictions/projections for a limited domain, without having to resort to a fine-scale grid for the entire domain (Jablonowski et al. 2004).

3. Nested regional modeling; this is the approach detailed in the NARCCAP and Regional Climate Prediction Dot Net sections elsewhere in this paper

North American Regional Climate Change Assessment Program (NARCCAP)

NARCCAP produces high resolution (50KMx50KM) climate change simulations in order to investigate uncertainties in regional scale projections of future climate and generate climate change scenarios for use in impacts research. The project consists of regional climate models (RCMs) driven by a set of atmosphere-ocean general circulation models (AOGCMs) over a domain covering the conterminous United States and most of Canada. Depending on the RCM, anywhere from about 25% to 75% of the state of AK is in the domain.

NARCCAP is being implemented in three phases. Phase I consists of 25 year simulations (1979-2004) using NCEP (National Centers for Environmental Prediction) boundary conditions as the driver to the RCMs. Phase IIa nests the RCMs in AOGCMs for the current period (1971-2000) and 2041-2070 (SRES A2 emissions). Phase IIb consists of "Timeslice Experiments" where the atmospheric component of an AOGCM is run without the full-coupled ocean component of the model, both for the historical and future ("scenario") time periods. For the IIb runs, the boundary conditions for sea surface and ice for the historical run are based on observational data, and boundary conditions for the scenario run are derived by perturbing the same observed seasurface temperature and ice data by an amount based on the results of a lower resolution run of the full AOGCM.

Model information on the RCM's and AOGCM's included in NARCCAP is below.

Regional Models		
Model ID (alias)	**Full Name**	**Modeling Group**
CRCM (MRCC)	Canadian Regional Climate Model	OURANOS/UQAM
ECPC (RSM)	Experimental Climate Prediction Center	UC San Diego/Scripps
HRM3 (PRECIS,HadRM3)	Hadley Regional Model 3	Hadley Centre
MM5I (MM5,MM5P)	PSU/NCAR mesoscale	Iowa St. University
RCM3 (RegCM3)	Regional Climate Model v3	UC Santa Cruz
WRFP (WRF)	Weather Research and Forecasting	PNNL

Global Models		
Model ID	**Full Name**	**Modeling Group**
CCSM	Community Climate System Model	NCAR
CGCM3	Third Generation Coupled Global Climate Model	Canadian Centre for Climate Modeling and Analysis
GFDL	Geophysical Fluid Dynamics Lab GCM	U.S. Department of Commerce/National Oceanic and Atmospheric Administration (NOAA)/Geophysical Fluid Dynamics Laboratory (GFDL), USA
HADCM3	Hadley Centre Coupled Model v3	Hadley Centre
NCEP	NCEP/DOE AMIP II Reanalysis	National Centers for Environmental Protection

The table below specifies the global/regional modeling pairs that will be executed as part of NARCCAP. Pairs indicated with “X” currently have at least some data available to registered users. Those pairs with an “O” are planned, but no data is yet (as of November 2010) available. Pairs with no character will not be executed.

	Global Models				
Regional Models	GFDL	CGCM3	HADCM3	CCSM	NCEP
CRCM		X		O	X
ECPC	O		O		X
HRM3	O		X		X
MM5I			O	X	X
RCM3	X	X			X
WRFP		O		X	X
Time Slices	X			O	

The NARCCAP data archive also contains a wealth of output parameter data. Depending on the parameter, output frequency may be 3 hourly or daily. See the “Links” section below for the url which links to the output parameter specifics. Data is available in NetCDF format to registered users.

Regional Climate Prediction Dot Net (RegCPDN)

The RegCPDN project is similar in concept to NARCCAP, except it uses only one global/regional model pairing, but runs at roughly twice the resolution (25x25KM). It is essentially a framework for generating a large ensemble of regional climate futures. An interesting aspect of this project is that instead of the models being run on the large computer(s) at a research facility, small pieces of the project are “farmed out” to volunteer computers (desktop PC’s and Mac’s, mostly). Historically, projects of this kind have been able to draw on the resources of 1000’s of volunteer computers.

This experiment will run both the global and regional models together. The global model is HadAM3P, a high resolution (150KM resolution) atmosphere-only model very similar to that used already in another climateprediction.net experiment. Sea surface temperatures and sea ice will be prescribed (using either observed or projected values) for this model. As with the main climateprediction.net experiment, values of uncertain parameters in the model will differ across simulations. The regional model is HadRM3P, used by the UK Met Office's Providing REgional Climates for Impacts Studies (PRECIS) program. Values of uncertain parameters in the regional model will also be altered across simulations.

This experiment will focus on three regions: one set of simulations will have the regional model placed over western North America (218-258W; 28-54N), one will have it placed over Southern Africa, whilst the third will place the regional model over Europe. The computing power available via the project volunteers allows for a number of parameter perturbations/experiments to be run. A full list of experiments is not yet available online. For more information on parameter perturbations, contact one of the project’s PI’s, listed at http://climateprediction.net/content/regional-model.

Two emissions scenarios are part of the Regional CPDN project, A1B and B1. Currently, the historical time period from 1959-2010 is being simulated. Plans include extending this window to 2010-2100.

For the western North America region, approximately 50 output parameters are available, including mean temperature and precipitation, frost days, metrics on heat waves and dry days, extreme daily precipitation, wind speed, extreme wind events, snowpack, and coastal upwelling. Depending on the parameter, frequencies include daily, monthly means, and "counts" (e.g. Number of days with Tmax > 30 degC). Data is available in NetCDF format. Given that RegCPDN has just recently gone live, detailed output specifications are not yet available online. For more information, contact one of the project's PI's, listed at http://climateprediction.net/content/regional-model.

Recent and Current Downscaling Projects

Downscaling of global climate data to spatial and temporal scales more useful to water utilities is an area of active research. Downscaling efforts fall into two broad categories; statistical downscaling and dynamical downscaling. Statistical downscaling uses empirical relationships between large scaled model output and local conditions to produce data on a local scale. Dynamical downscaling uses mechanistic models run at high resolution to produce local data. As mentioned above, dynamic regional models are often "nested" within lower resolution GCM's.

Two dynamical downscaling projects, NARCCAP and RegCPDN were discussed earlier. Following is a discussion of several statistical downscaling projects (and one additional dynamic downscaling effort).

US Bureau of Reclamation/Santa Clara University (USBR/SCU) (Maurer et al. 2007)

About: A joint project between the US Bureau of Reclamation, Santa Clara University, Lawrence Livermore National Lab, and Climate Central, this project provides downscaled climate datasets for the lower 48 US states. Global downscaled datasets at a coarser resolution have also been generated.

Resolution: 1/8 degree (~12KMx12KM) or 0.5x0.5 degrees

Timestep(s): monthly for both datasets

Periods: 1950-2099 for both datasets

Methodology: bias corrected and spatially downscaled using a two step procedure; Step 1 = bias correct the GCM using quantile mapping, Step 2 = spatial downscaling (Wood et al. 2002, Wood et al. 2004, Maurer 2007)

Domain: 1/8 degree = lower 48 states + southern Canada and northern Mexico (25.125 to 52.875N, -124.624 to -67.000 E); 0.5 degree = global

# of Scenarios: lower 48 = three SRES scenarios, A2, A1B, B1; 1-5 runs with unique initial conditions for each scenario; 16 CMIP3 models; total of 112 unique experiments; Global = A2, A1B, B1; 16 CMIP3 models; total of 48 unique experiments

Parameters Available: precipitation, mean daily rate during each month, mm/day; surface air temp, monthly mean, degrees C

Data Format(s): ASCII comma-delimited, NetCDF

Data Source(s): CMIP3

ClimateWizard

About: ClimateWizard is a web-based program allows the user to choose a state or country and both assess how climate has changed over time and to project what future changes are predicted to occur in a given area. An easy to use GUI allows the user to select multiple combinations of domain, emissions, time period, and parameters in order to explore historical and projected climate. ClimateWizard ties together other downscaled data sets mentioned in this paper, namely the USBR/SCU 12KM US dataset and the CRU 50KM global dataset. Map images and data in a GIS friendly format can be downloaded from the site.

Resolution: 4KM (historical US),12KM (future US), 50KM (global)

Output Frequency: monthly, seasonal, yearly

Period(s): past 50 years, 2050's, 2080's

Methodology: 4KM US historical = PRISM (www.prism.oregonstate.edu); 12KM US future = USBR/SCU (see above); 50KM global historical = CRU (see below); 50KM global future =USBR/SCU (see above).

Domain: US (lower 48) and global

# of Scenarios: (3) - A2, A1B, B1

Parameters Available: average temperature, precipitation

Data Format(s): Arc ASCII, PNG

Data Source(s): USBR/SCU, CRU

Northeast Climate Impacts Assessment (NECIA) (Hayhoe et al. 2008))

About: NECIA is a collaboration between the Union of Concerned Scientists (UCS) and a team of independent experts to develop and communicate a new assessment of climate change, impacts on climate-sensitive sectors, and solutions in the northeastern United States.

Resolution: 1/8" for entire NE; plus downscaled data also available for Boston, Buffalo, Concord, NYC, Philadelphia, and Pittsburgh (i.e. GCM data is downscaled to give time series data for each of the above cities)

Output Frequency: daily/monthly/yearly

Period(s): historical = 1960-1999; future = 2000-2099

Methodology: bias correct and empirically downscale (spatial disaggregation) to 1/8" as in USBR/SCU above (Wood et al. 2002); city level downscaling rescaled AOGCM grid-cell temperature values based on monthly regression relations and probability distributions (Dettinger et al. 2004)

Domain: Northeast US

# of Scenarios: 2 - A1FI and B1

Parameters Available: min/max/avg temperature; precipitation; derived variables coldest day of year, hardiness zone, days over 90 or 100F, growing season length, June-July-August heat index

Data Format(s): timeseries and geographic; ASCII, Arc ASCII, PNG, NetCDF, Postscript

Data Source(s): CMIP3 GCM's - NOAA/GFDL CM2.1, UKMO HadCM3, and NCAR PCM

University of Wisconsin - Madison, Center for Climatic Research (Tabor and Williams 2010)

About: Future climate projections from the World Climate Research Programme's (WCRP's) CMIP3 multi-model dataset are statistically downscaled using the CRU CL 2.0 20th century climate dataset. A joint project between the University of Wisconsin Department of Geography, Nelson Institute's Land Tenure Center, and Conservation International.

Resolution: 10 minutes (1/6 degree)

Output Frequency: monthly

Period(s): 1961-1990; 2041-2060; 2081-2100

Methodology: de-bias against CRU historical observations, then apply change-factor downscaling procedure

Domain: global

# of Scenarios: (3) - A2, A1B, B1

Parameters Available: avg monthly temperature; avg monthly precipitation

Data Format(s): Arc ASCII

Data Source(s): CMIP3, CRU CL2.0 historical

USGS CASCaDE (Computational Assessments of Scenarios of Change for the Delta Ecosystem)

About: The CASCaDE project is an approach for determining how multiple drivers of environmental change would interact to change ecosystems targeted for restoration. The area of focus is California's Sacramento-San Joaquin Delta ecosystem.

Resolution: 12KM

Output Frequency: Daily

Period(s): 1950-2099

Methodology: constructed analogs (Hidalgo et al. 2008)

Domain: lower 48, plus parts of the Columbia River basin in Canada

# of Scenarios: (2) - A2, B1

Parameters Available: precipitation, maximum and minimum temperature

Data Format(s): Direct access binary written from FORTRAN

Data Source(s): CMIP3; the two model subset used was NCAR's PCM and the GFDL CM2.1

Climatic Research Unit (CRU), East Anglia University

About: The Climatic Research Unit at the University of East Anglia makes available a number of high resolution data sets. These include historical climatology and time-series data, as well as future scenarios projections. Aggregate "countries" data is also available for allowing international comparisons. Climatological data sets detail the climate of the recent past, allowing spatial comparisons of environmental features. Time-series data sets give the month-by-month variations over the last century and allow comparison of variations in climate with variations in other phenomena. Scenarios (future) data sets are useful as inputs to environmental impact models.

Resolution: 10 minutes (climatology) and 0.5 degrees (time-series and scenarios) global, land surface only, excl. Antarctica

Output Frequency: monthly

Period(s): 1961-1990 (climatology); 1901-2002 (time-series); 1901-2100 (countries)

Methodology: 10 minute climatology = interpolated from station means; 0.5 global time-series = development of a reference series, interpolation; 0.5 global scenarios = combined the time-series of global warming and patterns of change from GCMs with the baseline climate and sub-centennial variability from the observed record

Domain: global

# of Scenarios: (4) - A1FI, A2, B1, B2

Parameters Available: climatology = precipitation, wet day frequency, daily mean temperature, diurnal temperature range, relative humidity, sunshine duration, frost day frequency, wind speed; time series = precipitation, daily mean temp, monthly average daily min/max temperature, diurnal temperature range, vapor pressure, cloud cover, wet and frost day frequency; scenarios = precipitation, daily mean temperature, daily temperature range, vapor pressure, cloud cover; countries = precipitation, daily mean temperature, daily temperature range, vapor pressure, cloud cover, wet and frost days frequency, monthly average daily min/max temperature

Data Format(s): ASCII, NetCDF

Data Source(s): IPCC TAR (models = CGCM2, CSIRO mk2, NCAR/DOE PCM, HadCM3, ECHam4)

University of Washington, Climate Impacts Group (CIG) (Hamlet et al.)

About: The University of Washington's Climate Impact Group's downscaling projects consist primarily of statistical downscaling via a suite of methods, and dynamic downscaling using the Weather Research and Forecasting (WRF) model.

Resolution: statistical = 1/16 degree; WRF = 12KM PNW, 36KM western US

Output Frequency: statistical = daily, monthly; WRF = 3/6 hourly

Period(s): statistical = 1915-2006, 1950-2100; WRF = 3 x 100 year simulations

Methodology: statistical = Transient Bias Correction and Statistical Downscaling (BCSD), Hybrid Delta method, Delta Method; WRF = the Weather Research and Forecasting regional climate model

Domain: Western US, focused on the PNW

# of Scenarios: (2) A1B, B1

Parameters Available: Statistical = min/max temperature, precipitation; WRF = temperature, precipitation, winds, snow cover, soil moisture, and upper atmospheric fields

Data Format(s): ASCII, Grid ASCII

Data Source(s): CMIP3; 5/10 “best” CGM’s used for select analysis

Conclusion

Modeling Projects

The tables below summarize what has been presented above.

	Modeling Project			
	CMIP3	CMIP5	NARCCAP	RegCPDN
Approximate Resolution (degrees unless noted)	Atmos: 1.1x1.1 - 4.0x5.0 Ocean: 0.2x0.3 - 4.0x5.0	native model resolution; details TBD	50 KM	25x25KM (Atmos only)
Output Timestep(s) Frequency	3 hrly; mon/daily mean; extreme	3/6 hrly; mon/ daily/annual mean	3 hrly; daily	daily; monthly means; count[d]
Domain	global	global	North America	Western US
# Models	23	TBD	Regional = 6; Global = 4 (not incl. NCEP); 20 combo's planned	(1) Regional/ Global pairing - HadRM3P/ HadAM3P
# Output Params	118[a]	404[b]	49	50
SRES/RCP Emissions Scenarios	(3) A2, A1B, B1	(4) RCP's 2.6, 4.5, 6, 8.5	(1) A2	(2) A1B, B1
Time Periods Covered	1850-2000; 2000-2100; 2000-2300	850-2300[c]	1980-2004; 1971-2000; 2041-2070	1959-2010; 2010-2100 planned`
Notes	basis for IPCC AR4 (2007)	basis for IPCC AR5 (due late 2013)		

[a]"High Priority Output" only; only ocean and atmosphere available
[b]"Priority 1" output only; ocean, land, and atmosphere available
[c]Range dependent on exactly which Tier 1 and Tier 2 experiments are selected
[d]For example, Number of days with Tmax > 30 degC

Representative Downscaling Projects

	Project						
	USBR/ SCU	Climate Wizard	NECIA	UWisc	USGS Cascade	CRU	UW CIG
Resolution (degrees unless noted)	1/8, 0.5	1/8, 4KM, 50KM	city to regional (1/8)	10 mins	12KM	10 mins, 0.5	1/16; 12KM, 36KM
Output Timestep	monthly	monthly, seasonal, yearly	daily, monthly, yearly	monthly	daily	monthly	3/6 hrly, daily, monthly
Period(s)	1950-2099	1951-2006; 2050s; 2080s	1961-2099	1961-1990; 2041-2060; 2081-2100	1950-2099	1901-2002; 1961-1990; 1901-2100	1915-2006; 1950-2100; 3x100
Method/ Algorithm	bias correct/ interp. (spatial)	various (USBR/ SCU, CRU)	bias correct/ interp.; regress., prob. dist.	bias correct/ change factor	construct-ed analogs	interp. change patterns, etc.	BCSD, (Hybrid) Delta; WRF model
Domain	US (1/8); Global (0.5)	US (1/8,4KM); Global (50KM)	NE USA	Global	USA + Columbia R. (Canada)	Global	Western US; PNW
Emissions Scenarios	(3) A2, A1B, B1	(3) A2, A1B, B1	(2) A1FI, B1	(3) A1B, B1, A2	(2) A2, B1	(4) A2,B2, B1, A1FI	(2) A1B, B1
Params	precip, surface air temp	avg air temp, precip	min/max/ avg temp; precip; extremes	avg air temp and precip	precip, min/max temp	precip,wet days, temp, wind, etc	temp, precip, winds, soil moist, etc
Data Source(s)	CMIP3	USBR/ SCU, PRISM, CRU, CMIP3	CMIP3 - GFDL, HadCM3, PCM	CMIP3	CMIP3 - PCM, GFDL	5 IPCC TAR models	CMIP3 (5/10 best)
Notes	48 or 112 scenarios; 16 models					includes 20 change scenarios at 0.5	

Geospatial Equivalences

There are 360 degrees of longitude around the globe, and 180 degrees of latitude from pole to pole. One degree of latitude/longitude is equal to 60 minutes (60') of arc. Thus, 10' of arc is equal to 1/6 of a degree of latitude/longitude. One degree of latitude is equal to ~111KM on the surface (regardless of the longitude). One degree of longitude ranges from ~111KM at the equator to 0KM right at the poles. At 45 degrees N latitude (the approximate latitude of Portland, OR), 1 degree of longitude is ~79KM on the surface.

Glossary of Acronyms

AOGCM: Atmosphere-Ocean General Circulation Model
AMIP: Atmospheric Model Intercomparison Program
CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem
CIG: Climate Impacts Group (at the University of Washington)
CMIP: Coupled Model Intercomparison Program
CRU: Climatic Research Unit (at East Anglia University, UK)
ESM: Earth System Model
GCM: General Circulation Model
GHG: Greenhouse gas
IPCC: Intergovernmental Panel on Climate Change
IPCC AR4/AR5: IPCC Assessment Report 4 (2007) or 5 (2013)
NARCCAP: North American Regional Climate Change Assessment Program
NCEP: National Centers for Environmental Prediction
NECIA: Northeast Climate Impacts Assessment
NetCDF: Network Common Data Form
OCCRI: Oregon Climate Change Research Institute (at Oregon State)
PCMDI: Program for Climate Model Diagnosis and Intercomparison
PRECIS: Providing REgional Climates for Impacts Studies
PRISM: Parameter-elevation Regressions on Independent Slopes Model
RCM: Regional Climate Model
RCP: Representative Concentration Pathway
(Reg)CPDN: (Regional) Climate Prediction Dot Net
SCU: Santa Clara University
SRES: Special Report on Emissions Scenarios
UCS: Union of Concerned Scientists
USBR: United States Bureau of Reclamation
USGS: United States Geological Survey
WCRP: World Climate Research Program

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Links

CMIP/CMIP3/CMIP5

CMIP Home Page: http://cmip-pcmdi.llnl.gov/index.html
CMIP3 Home Page: http://cmip-pcmdi.llnl.gov/cmip3_overview.html?submenuheader=1
CMIP3 Data Archive Home Page: http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php
CMIP3 Output Parameter Specifications: http://www-pcmdi.llnl.gov/ipcc/standard_output.html
CMIP5 Home Page: http://cmip-pcmdi.llnl.gov/cmip5/index.html
CMIP5 Output Parameter Specifications: http://pcmdi-cmip.llnl.gov/cmip5/docs/standard_output.pdf

NARCCAP

Home Page: http://www.narccap.ucar.edu/
Output Parameter Specifications: http://www.narccap.ucar.edu/data/data-tables.html

Regional CPDN

Home Page: http://climateprediction.net/content/regional-model

USBR/SCU Downscaling

Home Pages: http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html,
http://www.engr.scu.edu/~emaurer/global_data/

Climate Wizard

Home Page: http://www.climatewizard.org/

NE Climate Impacts Assessment/Climate Data

Home Page: http://www.northeastclimatedata.org/ (registration required)

University of WI - Madison 10' Downscaling

Home Page: http://ccr.aos.wisc.edu/model/ipcc10min/futclimateinfo.html

USGS CASCaDE

Home Page: http://cascade.wr.usgs.gov/data/Task1-climate/index.shtm

CRU

Home Page: http://www.cru.uea.ac.uk/
High Resolution Datasets: http://www.cru.uea.ac.uk/cru/data/hrg/

University of Washington Climate Impacts Group

Home Page: http://www.hydro.washington.edu/2860/