



## **Tongass Climate Change Projections: Technical Methods and Interpretation**

Todd J. Brinkman<sup>1\*</sup>, Tom Kurkowski<sup>1</sup>, Scott Rupp<sup>1</sup>, and Greg Hayward<sup>2</sup>

<sup>1</sup>Scenarios Network for Alaska & Arctic Planning, University of Alaska Fairbanks

<sup>2</sup>US Forest Service

The purpose of this technical report is to provide scientific information on methods used to create climate change projections for the Tongass National Forest. This report is part of a package of products delivered to the USFS by the Scenarios Network for Alaska & Arctic Planning (SNAP) during phase 1 of a project entitled Tongass Climate Change Vulnerability Assessment. The goals of phase I were to (1) develop robust and relevant climate projections for the region, and (2) identify and prioritize key resources in the Tongass (salmon, hydropower, etc.) affected by climate change. This technical report focuses on the methods used to obtain goal 1.

### **Methods**

SNAP provided historic (1971-2000 or 1970-1999) annual mean and projected decadal annual mean (2010-2019, 2050-2059, 2090-2099) data and maps for the Tongass National Forest for 4 climate variables: temperature, precipitation, date of freeze, and date of thaw. Estimated ordinal date (1-365 starting January 1) of freeze and thaw were calculated by assuming a linear change in temperature between consecutive months. Mean monthly temperatures are used to represent daily temperature on the 15<sup>th</sup> day of each month. The day of transition (freeze or thaw) is the day when temperature crosses zero degrees Celsius.

SNAP obtained historic climate data from the Climate Research Unit (CRU; <http://www.cru.uea.ac.uk/>) at the University of East Anglia in England. These data were based on readings from 3000 weather stations located on land and sea. For projected data, SNAP obtains Global Climate Models (GCM) outputs from the Lawrence Livermore National Laboratory Program for Climate Model Diagnosis and Intercomparison (PCMDI) data portal (<http://www-pcmdi.llnl.gov/>). These climate models also are referred to as atmosphere-ocean General Circulation Models and are the most complex and widely used tools for projecting climate over a century time scale (Randall et al. 2007). These models are simplified versions of reality that use mathematic equations based on physical properties to represent how the climate functions because of several atmospheric, land, cryosphere, and oceanic factors. Input variables include atmospheric and ocean surface pressure, horizontal components of velocity in layers, temperature and water vapor in layers, solar radiation, terrestrial long-wave radiation, convection, albedo, cloud cover, and hydrology. Interactions are calculated based on the principles of physics, fluid motion, and chemistry. GCMs are developed by various research organizations around the world and submitted to the United Nations Intergovernmental Panel on Climate Change (IPCC) where they are periodically reviewed and assessed (1990, 1995, 2001, 2007).

SNAP projected climate change for the Tongass using the average of the 5 Global Climate Models (GCMs) that perform best for Alaska (Walsh et al. 2008) (Table 1). Models are validated by generating runs for past time periods and then analyzing the statistical relationship between real weather patterns and model outputs. SNAP compared GCM output to historical weather station data based on four different metrics: monthly mean values, seasonal variability, annual variability, and long-term climate trends ([http://www.snap.uaf.edu/resource\\_page.php?resourceid=6](http://www.snap.uaf.edu/resource_page.php?resourceid=6)). The Tongass climate projections were

\*Contact: [tjbrinkman@alaska.edu](mailto:tjbrinkman@alaska.edu), (907)-474-7139

derived from model outputs from the IPCC's Fourth Assessment Report (Solomon et al. 2007). The fifth assessment report (AR5) will be completed in 2014 and findings will be incorporated into SNAP products produced after that date.

**Table 1. Global climate models used to project climate change for the Tongass National Forest, Alaska.**

Center	Model Name and Version	Acronym
Candian Centre for Climate Modelling and Analysis	General Circulation Model version 3.1 – t47	cccma_gcm31
Max Planck Institute for Meteorology	European Centre Hamburg Model 5	mpi_echam5
Geophysical Fluid Dynamics Laboratory	Coupled Climate Model 2.1	Gfdl_cm21
UK Met Office – Hadley Centre	Coupled Model 3.0	Ukmo_hadcm3
Center for Climate System Research	Model for Interdisciplinary Research on Climate (medium resolution)	Miroc3_2_medres

SNAP obtained GCMs in coarse spatial resolutions (ranging 0.5° to 5 degrees latitude and longitude). To examine finer resolution patterns, SNAP researchers downscaled climate projections using PRISM (Parameter-elevation Regressions on Independent Slopes Model; <http://prism.oregonstate.edu/>) and produced projections useful at regional or watershed spatial scales (Daly et al. 2008). PRISM is an analytical tool that uses variables such as elevation, slope, coastlines, and other spatial data sets to interpolate between point data from weather stations. The resolution and quality of interpolation depends strongly on the array of weather stations providing the baseline climate data and how long each weather station has been reporting. In Alaska, long-term weather stations are uncommon and represent a poor sample of elevation and geographic variation. Therefore, compared to other regions of North America, downscale modeling in Alaska presents a particularly challenging modeling task. Consequently, resource managers familiar with downscaled models from other regions should keep in mind the paucity of local data available for modeling on the Tongass. SNAP created climate projections for the Tongass National Forest at resolutions of 771x771m.

The climate models used to project climate change for the Tongass National Forest behave differently under different greenhouse gas emission scenarios (i.e., different assumptions about possible futures) (Nakicenovic et al. 2000). SNAP uses three scenarios commonly employed by climate modelers based on assumptions that greenhouse gas emissions (mainly carbon dioxide) are the primary driver of recent climate change (Meehl et al. 2007, Core Writing Team 2007). These scenarios are referred to as B1, A1B, and A2. Each scenario assumes different pathways of human development, considering demographics, economics, and technology associated with greenhouse gas emissions. As the scenarios are defined, projected future climate changes most under the A2 emissions scenario, and least under B1. B1 assumes reduced emissions in the future because of cleaner and more efficient technologies. A1B assumes moderate emissions into the future with a balance between fossil fuel and alternative cleaner technologies. A2, essentially a scenario of maintaining the status quo, assumes increased emissions with a rapidly growing human population mainly dependent on fossil fuels. For the Tongass Climate Change Projections, we used the midrange scenario, A1B. Choice of models by SNAP is not intended to suggest that one or another scenario is more likely. Rather, by examining a range of scenarios, resource managers can consider a range of potential future conditions.

SNAP provided climate variable maps for the Tongass National Forest to USFS in portable network graphic (PNG) format to support image transfer on the internet. SNAP also provided the USFS with

georeferenced tagged image file format (GEOTIFF) files to foster use with GIS software. These files used Tongass National Forest boundaries to define the area of interest for climate projection spatial data. SNAP produces climate projection across Alaska and large regions of Western Canada that are available for download at the SNAP website (<http://www.snap.uaf.edu/data.php>). These, state-wide projections can be examined to provide context for the Tongass-specific maps. Furthermore, a broad array of other derived climate variables beyond the four examined in this report can be explored by examining the output on the SNAP website.

While climate data values are based on the best available climate models, they are model estimates only. There is variation among climate models, and annual variation within each model. There are three main sources of uncertainty in the use of GCMs for climate projections: natural variability, the range of possible emission scenarios (e.g., B1, A1B, A2), and differences among models' formulations (Walsh et al. 2011). Furthermore, climate projections are not intended to predict specific weather events – rather they provide insights into potential future conditions at the temporal scale of multiple decades. Interpretation of impacts was not part of Phase I of this project. Interpretation adds additional uncertainty. Previous SNAP projects have qualitatively explored regional impacts ([http://www.snap.uaf.edu/attachments/Alaska\\_Regional\\_Climate\\_Projections\\_Southeast.pdf](http://www.snap.uaf.edu/attachments/Alaska_Regional_Climate_Projections_Southeast.pdf)) and provide a sound starting place for consideration of the consequences of changing climate.

### Literature Cited

Core Writing Team, R. K. Pachauri, and A. Reisinger (Eds.). 2007. Climate Change 2007: Synthesis Report. Contribution of working groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.

Daly, C., M. Halbleib, J. I. Smith, W. P. Gipson, M. K. Doggett, G. H. Taylor, J. Curtis, and P. P. Pasteris. 2008. Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. *International Journal of Climatology* 15:2031-2064.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Nakicenovic, N., O. Davidson, F. Davis, A. Grubler, T. Kram, E. Lebre La Rovere, B. Metz, T. Morita, W. Pepper, H. Pitcher, A. Sankovski, P. Shukla, T. Swart, R. Watson, and Z. Dadi. 2000. Emission Scenarios: Summary for Policymakers. A special report of Working Group III of the Intergovernmental Panel on Climate Change. ISBN: 92-9169-113-5. (<http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf>)

Randall, D.A., R.A. Wood, S. Bony, R. Colman, T. Fichet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R.J. Stouffer, A. Sumi and K.E. Taylor, 2007: Climate Models and Their Evaluation. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.). 2007. The Physical Science Basis. Contribution of working group I to the fourth assessment

report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, NY, USA.

Walsh, J. 2008. Global Climate Model performance over Alaska and Greenland. *Journal of Climate* 21:6156-6174

Walsh, J. E., M. Mueller-Stoffels, and P. H. Larsen. 2011. Scenarios as a tool to understand and respond to change. Chapter 3 *in* A. L. Lovecraft and H. Eicken (Eds.) *North by 2020: Perspectives on Alaska's Changing Social-Ecological Systems*. University of Chicago Press, USA.