1. ADMINISTRATIVE:

**Principal Investigator:** Eric P Salathé Jr, University of Washington Bothell, salathe@uw.edu, 206-616-5351

**Project title:** Uncertainty and Extreme Events in Future Climate and Hydrologic Projections for the Pacific Northwest: Providing a Basis for Vulnerability and Core/Corridor Assessments

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**Time period:** July 15, 2011 to June 30, 2013  
**Actual total cost:** $150,000.00

2. PUBLIC SUMMARY

Resource management under climate change benefits from understanding the effects of climate change and variability on ecosystem services. However, some ecological processes may be influenced more by climate extremes than interannual climate variability or change in mean climate. Understanding the role of climate extremes in climate impacts on managed resources has been limited by a lack of comprehensive climate products that allow analysis of the role of extremes. In short, the vulnerability of ecosystems or ecological processes to climate change may manifest through sensitivities to extremes rather than changes in average conditions. A rigorous and physically-based treatment of uncertainty (ranges of projections and sources of model disagreement) in future climate scenarios in the Pacific Northwest and Northern Rockies does not exist. This is particularly true of the extreme climate and weather events that affect aquatic and terrestrial ecosystems. In this project, existing University of Washington Climate Impacts Group (UW CIG) products and partnerships were extended to develop a comprehensive library of products that account for climate model uncertainty in future climate and hydrologic scenarios. These products can be used to determine likely impacts on vegetation and aquatic habitat in the Pacific Northwest region, including WA, OR, ID, northwest MT to the continental divide, Northern CA and NV, UT, and the Columbia Basin portion of western WY. Climate data products were based on multiple global model projections (an ensemble of 10 climate models and including four models bracketing a range of conditions), statistical downscaling, and dynamical downscaling.

The significant products of the project are extreme statistics for surface hydrology (*e.g.* soil moisture deficit, snow pack) and streamflow (*e.g.* the 100-year flood, extreme 7-day low flows with a 10-year recurrence interval). To enable uncertainty analysis, these are provided for multiple climate scenarios. Specific analyses include: 1) The ratio of future projected extremes to the historical magnitude for both the flood and low flow statistics, computed for each future time period and scenario. 2) Analysis of soil moisture to indicate the change in the frequency of soil moisture extremes, with a primary emphasis on changes in summer water deficit. 3) Analysis of snowpack vulnerability as indicated by the ratio of April 1 snow water to cool-season precipitation.
3. TECHNICAL SUMMARY

The goals of this project were to build upon the hydro-climatic projections described by Littell et al. (2011) by expanding the domain, adding new climate projections including bracketing models, and providing additional information on changes to hydrologic extremes. Specific technical achievements include:

a. The Littell et al. dataset was expanded to include projections for California and parts of southern Oregon, thereby covering all of the Western U.S. from about 104W longitude to the Pacific coast,

b. Climate projections were corrected for slight errors in the original dataset due to the piecemeal approach originally employed, and supplemented with projections from two additional global models,

c. Additional climate projections obtained using a regional climate model as opposed to statistical downscaling, and

d. New assessments of changes to extreme low flows, flooding, and variations in soil moisture were included in the suite of data products available to users.

Technical details of each of these achievements is described below:

a. New California Gridded Meteorological Data Set and Downscaling

Through CSC project funding, previous existing gridded historical and projected future data sets were extended to include basins in the California region. A spatially and temporally continuous historical dataset of meteorological variables including daily precipitation, maximum and minimum temperature, and surface wind was produced for the years 1915 through 2010 on a 0.0625-degree (i.e. 1/16-degree) grid. To construct the dataset, National Climatic Data Center (NCDC) Cooperative Observer (COOP) network stations were queried to incorporate stations having at least 5 years of data and at least 365 days of continuous observations. Selected stations were then regridded to the 0.0625-degree grid using the Smap algorithm, an inverse-distance weighting of the 4 nearest neighbors reporting on a given day (Sheppard, 1984; Maurer et al., 2002; Hamlet and Lettenmaier, 2005). The station network configuration evolves throughout the available record and therefore monthly time-step U.S. Historical Climatology Network version 2 (HCN) stations are used to correct temporal biases and shifts arising from network changes. The Precipitation Regression on Independent Slopes (PRISM; Daly et al., 1994; 2002) monthly normals are then aggregated from a regular 30 arc-second grid to the 0.0625-degree grid and subsequently used to scale precipitation and mean temperature, to the PRISM calendar month climatology—improving representation of orographic influences and minimizing observing network biases. The final gridded dataset was then used as input to the Variable Infiltration Capacity hydrologic model (Liang et al., 1994; Gao et al., 2010) to produce hind-cast hydrologic simulations.

The same procedures and datasets previously developed for the rest of the western U.S. were also used to develop downscaled climate scenarios for a domain including southern Oregon, western Nevada, and all of California. The downscaling consisted of 5 scenarios as
described below: A CMIP3 ensemble mean delta and four bracketing GCMs. All 5 scenarios were used as input into the VIC hydrologic model.

b. Updated Climate Projections
Littell et al. (2011) used only two GCMs as bracketing scenarios. In this work, additional global model projections were chosen as “bracketing” models, and were intended to complement the composite (average) projection by providing an estimate of the range among models. The two models included in the Littell et al. dataset were the PCM1 (Meehl et al., 2006) and MIROC 3.2 (Hasumi and Emori, 2004) models. Averaged over the Western U.S., these models bracket the range in annual temperature and winter precipitation – spanning from both “cooler” (less warming) and drier (PCM1) to warmer and wetter (MIROC 3.2) than the composite of the 10 best-performing models (note that all models show warming, but that some show less warming, others more). Since these bracket one axis of hydrologic change (namely, from lower to higher flood risk, respectively), another pair of models was chosen to bracket the other axis: spanning from “cooler” and wetter (ECHAM5; Roeckner et al., 1999, 2003) to warmer and drier (HadGEM1; Johns et al., 2006). These correspond to lower and higher water stress, respectively.

c. Regional Climate Model Projections
In addition to the statistically downscaled results, we included one dynamically downscaled scenario in the analysis for this project. Dynamical downscaling is performed by running a regional climate model with boundary conditions taken from the global model being downscaled. In this case, the Weather Research and Forecasting (WRF) regional model was run using boundary conditions from the ECHAM5 global model and SRES A1B emissions scenario.

The WRF model has been implemented as a regional climate model over the northwest United States at 12 km grid spacing (see Salathé et al., 2010 and Salathé et al., 2013 for details). The simulations for this project used nested grids at 36-km and 12-km spacing. Climate simulations are performed using 6-hourly forcing fields from ECHAM5. The outer 36-km nest receives boundary conditions and interior nudging from the global fields; the inner 12-km nest is forced at its boundary by the outer nest. This study uses a 100-year (1970-2070) simulation with the WRF model using boundary conditions from the ECHAM5 global climate model (see Section 2.2). The model performance over the Northwest region has been extensively evaluated using simulations forced by reanalysis fields and is capable of resolving the fine scale structure of storms and their effects on precipitation in complex terrain (Zhang et al. 2009; Duliere et al. 2011). In particular, the model successfully simulates important large-scale features of Pacific Northwest winter storms, such as atmospheric rivers, which have been shown to be the major cause of the largest floods in rivers that drain the windward (western) slopes of the Cascades (Neiman et al. 2011; Warner et al. 2012).

For this study, we use simulated WRF daily output of total precipitation, maximum and minimum temperature, and mean wind speed. Although regional scale climate models represent the important topographic features of the PNW and the mesoscale structure of storms that control flooding in PNW rivers better than global models, RCM simulations are
still subject to substantial biases resulting from deficiencies in both the global forcing fields and the regional model (Wood et al. 2004; Christensen et al, 2008). To obtain acceptable hydrologic simulations, these biases must be removed when using RCM results in impacts studies. In addition, to link the WRF results to the VIC hydrologic model, the simulations require additional downscaling from the 12 km WRF grid to the 0.0625-degree VIC grid.

d. Assessment of Extreme flow Statistics
Extreme flow statistics such as the 100-year flood (Q100) and extreme 7-day low flows with a 10-year recurrence interval (7Q10) were estimated using Generalized Extreme Value (GEV) distribution using L-moments (Wang 1997; Hosking and Wallis 1993; Hosking 1990) at the spatial resolution of 12-digit hydrologic unit codes (HUCs), or the 6th level watershed classification as delineated by the USGS. For this analysis, the area weighted fraction of each VIC grid cell implemented at 1/16-degree within each HUC watershed was calculated using ArcGIS. Daily streamflow at each HUC was then estimated by summing up VIC outputs of daily runoff and baseflow within each HUC watershed based on the area weighted fraction of each grid cell. Summing, rather than routing, of flows is justified because of the small size of 6th-Level HUC basins.

For flood statistics, annual peak daily flow was extracted from each water year and ranked by flow magnitude. A quantile was assigned to each ranked value using an unbiased quantile estimator (Stedinger et al., 1993) and then Generalized Extreme Value (GEV) distribution using L-moments was fitted to the annual maxima to estimate flood magnitude with a given return interval such as the flood magnitude with 100-year return frequency (Q100) (Wang, 1997; Hosking and Wallis, 1993; Hosking, 1990). Low-flow statistics were computed following a similar approach but the 7-day consecutive lowest flow was extracted per each water year instead of daily peak flow. From both the flood and low flow statistics, the ratio of the projected future magnitudes of the extremes to the historical magnitude was computed for each future time period and scenario.

Additional analysis of extremes was performed to evaluate variations in monthly soil moisture. Soil moisture variations were classified in two ways: (1) by corresponding future projections of soil moisture with the percentile of past variations, and (2) by evaluating changes in the return period of 20-year soil moisture extremes (high extremes in winter, low extremes in summer). Both are intended to give a perspective on the change in the frequency of soil moisture extremes, with a primary emphasis on changes in summer water deficit.

New research: Funding from the NW CSC made the following accomplishments possible:
1. Updating and extending downscaled climate scenarios for the full western US to include California and two additional statistically downscaled GCMs,
2. Incorporating WRF regional climate simulations into extremes analysis.
3. Performing comprehensive analysis of projected hydrologic extremes and addressing uncertainty by assessing multiple downscaled scenarios.

4. PURPOSE AND OBJECTIVES
The purpose of this project was to (a) provide an internally-consistent set of downscaled projections across the full Western U.S., (b) include information about projection uncertainty, and (c) assess projected changes and the uncertainty in projections of hydrologic extremes. These objectives were designed to address decision support needs for climate adaptation and resource management actions. Specifically, uncertainty in climate projections – in particular for extreme events – is currently a key scientific barrier to adaptation planning and vulnerability assessment.

The new dataset fills in the domain to cover a key gap in the previous dataset, adds additional projections, both from other global models and a comparison with dynamical downscaling, and includes an assessment of changes to flow and soil moisture extremes. This new information can be used to assess variations in impacts across the landscape, uncertainty in projections, and how these vary as a function of region, variable, and time period.

5. ORGANIZATION AND APPROACH

• **Task 1:** Develop gridded, downscaled historical and future scenarios and hydrologic model runs for all of California to the level of previously existing work in Columbia, Missouri, Colorado, and Great basins.

  Methods follow Littell et al. 2011. Briefly, the 1915-2006 historical climate as manifest in HCN and COOP network archives was used to develop a 1/16-degree gridded historical climatology (max and min daily temperature, precipitation) for California. Future deltas estimated under the SRES A1B scenario for grid cells over the California domain were developed for the 10 CMIP3 GCMs with the highest fidelity to regional climate variations. The 10 selected GCMs were used to compute an ensemble mean delta. In addition, four GCMs (ECHAM5, HadGEM1, PCM1, MIROC 3.2) were selected as bracketing models. All 5 scenarios were used as input into the VIC hydrologic model.

• **Task 2:** Spatially explicit uncertainty analysis of parameter agreement across models and full domain

  Gridded western-U.S. products have been cross-checked for agreement. Minor discontinuities that are generated by approaching the 5 basins in piecemeal fashion were discovered and corrected.

• **Task 3:** Uncertainty analysis of extreme flow statistics. Sub-tasks include:
  1. Grid-cell summaries of soil moisture and water deficit scenarios
  2. Flow extremes by HUC
  3. Downscaling the WRF run
  4. VIC run using the downscaled WRF

6. PROJECT RESULTS
The primary focus of this project was to update and augment an existing set of hydroclimatic projections for the Western U.S. Changes include: wider geographic coverage, new bracketing projections for a more complete assessment of uncertainty, dynamically downscaled results, projected changes in flow and soil moisture extremes, and fixes to a few technical errors identified in the previous dataset. For the periods 1916-2006 (historical), 2040s (2030-2059), and 2080s (2070-2099), we developed gridded, downscaled (1/16-degree, or ~6 km / 3.75 mi) except in the Great Basin, which is 1/8-degree, or ~12 km / 7.5 mi) climatologies of temperature, precipitation, and 21 hydrologic variables including snow water equivalent, runoff, water balance deficit, etc.

Of primary interest for use in vulnerability assessments, connectivity analyses, and to develop derived products to be used by resource managers, this new dataset can be used to assess changes in hydrologic extremes and their associated uncertainties across all of the Western U.S. This includes the flow and soil moisture extremes already calculated, and could include any other extremes metrics, which could be calculated from the daily-resolved downscaled projections available on the project website. The entire project dataset, from raw primary data to summarized data tables and figures, are all archived on the project website (described in detail below).

![Figure 1](image-url)

**Figure 1.** Change in the return period for low August soil moisture. Maps show the future (2040s A1b) recurrence interval for historical 20-year dry episodes: values less than 20 indicate that dry episodes become more frequent in the future, while the opposite applies for values greater than 20. The composite average projection (middle) is shown along with two bracketing projections for the Pacific Northwest: ECHAM5 (cooler, wetter) and HadGEM1 (warmer, drier). Note that all models project warming, but that some project less warming than others, and that the choice of bracketing models is regionally dependent.

As an example of our results, Figure 1 shows the projected changes in soil moisture extremes for the entire domain. Maps show the change in the return period of dry episodes that historically have had a 20-year recurrence interval. Note that by including bracketing projections, it is possible to quantify which regions show robust changes (i.e., consistently drier or wetter in the future), and which regions do not. For instance, Figure 1 highlights the fact that many of the mountainous regions of the west (Cascades, Sierra Nevada, Rocky Mountains and foothills) show consistent drying. In contrast, many of the driest locations (Great basin, Columbia basin, San Joaquin valley, Snake River plain) show inconsistent changes. This is likely a consequence of the capacity for additional water loss – such areas may not have much water to lose – but also a result of the fact that soil moisture changes
appear to be quite sensitive to changes in precipitation. For example, the increase in the Southwest is possibly driven by increases in monsoonal moisture, and a small change in precipitation amount in drier areas represents a proportionally larger effect in water availability. Results for flood potential and low flows show similarly interesting patterns, highlighting the utility of combining region-wide projections with estimates of projection uncertainty.

![Image](image_url)

**Figure 2.** Downscaled summer change in water balance deficit (potential evapotranspiration – actual evapotranspiration). Water balance deficit is well correlated with many climate impacts to vegetation. In this representation, positive responses reflect and increase in deficit (less water availability and brown shaded), while negative responses reflect decrease (blue shaded). Ten-model composite (upper left) and WRF-derived (upper right) followed by four bracketing scenarios.

A second example appears in Fig 2. Changes in mean summer water deficit show important subregional trends. In all three scenarios, much of the southwest decreases its deficit.
(closer to water surplus), likely due to summer monsoon intensification. However, much of the central Rockies, Sierra Nevada, and Cascades have increased deficit.

Figure 3 depicts snowpack vulnerability, or the proportion of cool season (October to March) precipitation contained in the snowpack on April 1. Rain dominant watersheds have less than 10% of cool season precipitation stored in April 1 snowpack; “transitional” watersheds have between 10% and 40% of cool season precipitation stored in April 1 snowpack; snow dominant watersheds have >40% of cool season precipitation stored in April 1 snowpack. Purple lines represent basin boundaries. Note the shift from historically snow dominant (blue) to future transitional in the 2040s, particularly in the northern Rockies and southern Cascades.

Figure 3. the proportion of cool season (October to March) precipitation entrained in April 1 snowpack. Rain dominant watersheds have less than 10% of cool season precipitation stored in April 1 snowpack; transitional watersheds have between 10% and 40% of cool season precipitation stored in April 1 snowpack; snow dominant watersheds have >40% of cool season precipitation stored in April 1 snowpack. Purple lines represent basin boundaries.

Much of the anticipated utility in these datasets centers on the derivation of hydrologic extremes from the downscaled climate drivers and VIC-modeled hydrologic responses. Figure 4 and Figure 5 illustrate west-wide changes in low (7Q10) and high (Q100) flows expected under climate change scenarios.
Figure 4. Changes from historical 7Q10 (the lowest weekly average flow that occurs on average once every 10 years), is a measure of extreme low flow periods in streams. The climate-change driven change in low flows depends on characteristics unique to each watershed as well as the future climate. Low flow extremes would likely be more frequently exceeded in all scenarios in the Cascades, but other areas of the West depend considerably on the bracketing model. The Columbia Basin, upper Snake River, and southeastern CA / southwestern OR would possibly less frequently exceed low flows.
Figure 5. Changes from historical Q100 (the 100 year flood flow), is a measure of extreme high flow periods in streams. The climate-change driven change in Q100 depends on characteristics unique to each watershed as well as the future climate. Q100 extremes would likely be more frequently exceeded in all scenarios in the Cascades, and in much of the Southwest, but other areas of the West depend considerably on the bracketing model. Note the differences in the WRF (dynamically downscaled) results.
7. ANALYSIS AND FINDINGS

Currently, a primary barrier to adaptation planning and vulnerability assessment is a lack of information on the uncertainties in hydrologic projections, in particular as they pertain to extremes. Resource managers need to know which variables show robust changes, and how such uncertainties vary with context (geographic location, hydrologic regime, etc.). The goal of this project was to provide the basis for such assessments. Specifically:

a. Consistent set of projections over a wide domain
b. Complement average projection with projections from “bracketing” models, that span the range of changes in temperature in precipitation
c. Include a dynamically downscaled projection, for comparison with statistically downscaled results

Derived products from this project focus on variables proximate to actual impacts such as such as snowpack vulnerability and water deficit – sometimes referred to as “plant relevant variables”. These data represent a step forward in the ability of the climate impacts community to analyze ecological problems using specifically tailored information and without relying on more distantly correlated mechanisms with temperature and precipitation.

These provide the basis for ongoing assessments of the magnitude and uncertainty in projected changes in hydrologic extremes. As an important first step, the dataset includes an assessment of changes in flow and soil moisture extremes. Other extremes metrics can be easily added to these in the future – CIG is currently using the dataset as a basis for several projects examining the role of uncertainty in hydrologic projections.

8. CONCLUSIONS AND RECOMMENDATIONS

The primary products of this project are the gridded data, projections and associated graphical analyses described elsewhere in this report. The results are based on climate model downscaling and hydrologic modeling methods applied in a consistent fashion across the UW west. In particular, the results address uncertainties in climate parameters based on multiple scenarios and downscaling methods. These data products have been specifically tailored to address climate impacts applications by simulating plant-relevant variables and extreme statistics relevant to ecological applications. The products are therefore ready to use as the basis of future analyses. For example, the gridded data can be used to develop maps of thresholds associated with vegetation or disturbance processes in forest ecosystems, or baseflow input into river systems of concern for resident and anadromous fish species. The average response and range of likely impacts (at least as estimated by physical climate and hydrology alone) can be estimated with the bracketing scenarios, and the role of extremes assessed appropriately.

Next Steps We plan to continue work based on this project at UW CIG. Specific tasks include:

1. Comparisons between results from statistical downscaling and regional climate model simulations.
2. Develop an online data visualization and access tool for resource managers
3. Use these data for a study of hydrologic model uncertainty
4. Include project results in publications on data products for use in impacts assessment

9. MANAGEMENT APPLICATIONS AND PRODUCTS

This dataset was designed to address decision support needs for climate adaptation and resource management actions. Specifically, uncertainty in climate projections – in particular for extreme events – is currently a key scientific barrier to adaptation planning and vulnerability assessment. In other cases, the variables required for impacts and vulnerability assessment or adaptation were not available – resource responses are frequently tied to more specific mechanisms than just temperature and precipitation. In previous iterations of similar products, CIG identified a set of products with input from scientists and agency employees that could meet more (though clearly not all) of the downscaled climate and hydrologic data needs in the climate impacts and adaptation community. More specifically, our collaborators needed:

- Summaries for units used in planning (e.g., HUCs, ecoregions)
- Variables from hydrologic modeling that were more relevant to impacts being studied (potential and actual evapotranspiration, snowpack, soil moisture, etc.)
- More explicit characterization of uncertainty, including:
  - Approaches to incorporating natural climate variability (such as PDO and ENSO) into future projections, which we do by superimposing future projected trends on the historical time series (1916-2006)
  - Multi-model ensembles and bracketing models to illustrate physically consistent single-model projections that can be used as examples in risk-tolerant or risk-averse situations (i.e., a more quantitative approach to scenario planning)
- More explicit consideration of extremes tied to observed responses in ecosystems, particularly in temperature, drought, and low and high streamflows.

This product responded to all these needs. It is beyond the scope of our role to suggest what decisions should be made. However, the process of developing these products over three years suggests to us how agencies can make use of the products and what decisions might consider this information. These include:

- **Land management (USFS, USFWS, BLM, USGS, BIA, state and local agencies, etc.)**
  This product filled a key void, in particular the need for quantitative, downscaled climate and hydrologic projections that could be used in agency-mandated (e.g., USFS) adaptation planning, vulnerability assessments, and prioritization of conservation efforts. The projections were for variables thought to be important drivers of vegetation response, and tailored to useful management units and incorporated variables linked to recent resource effects purported to be from climate change (e.g., fire, low flows, tree mortality, etc.) but for which little formal attribution has been done.
• Water resources management (US Army Corps, USBR, state and local water utilities, etc.)
This product was a direct result of listening to regional agencies charged with managing everything from fish passage to hydropower. Flood risk reduction, aquatic and terrestrial habitat management, and water resources planning all depend on knowing about how future flows compare to historical, but also what plausible extremes might look like – flooding and low flows. These datasets are ready to be used in impacts and vulnerability assessment.

Specific managers and researchers that have made use of this dataset:

• Morrison, J. (Forest Service, Region 1)

• McKelvey, K.S. et al. (Forest Service, Region 1)
  Used projected changes in snowpack to quantify future declines in wolverine habitat across the Western U.S. (McKelvey et al., 2011).

• Wenger, S. et al. (Univ. of Georgia, Athens)
  Used projected changes in streamflow along with a stream temperature model to estimate changes in habitat suitability for four different species of trout (Wenger et al., 2011).

• Littell, J.S. et al. (CIG, now at DOI Climate Science Center, AK)
  Used observed and simulated variations in temperature and water availability to evaluate the relationship between wildfire risk and climate change (Littell and Gwozdz, 2011; McKenzie and Littell, 2011).

• Mauger, G.S. et al (Univ. of Washington, Seattle)
  Evaluated the utility of downscaled climate projections for habitat connectivity planning (WHCWG, 2013). Climate change may alter decisions regarding habitat restoration, land acquisition, and other activities that could promote connectivity.

• Chuck Dalby (Water Resources Division, Montana DNRC)
  Evaluating climate change impacts on water resources for the Montana State Water Plan. Results from this study will inform decisions regarding water supply infrastructure, conservation practices, and other measures for ensuring an adequate and safe supply of water.

10. OUTREACH
The project website (http://cses.washington.edu/data/wus_csc.shtml) includes a description of the project goals and methods, along with links for viewing/downloading data. Links to the data repository are organized by category and complexity, and include explanatory text to guide user navigation. Data products included in the dataset are as follows:

- **Summary products**: These products are intended for non-technical users interested in high-level summaries of the results.
- **Primary data**: These are the raw projections that form the basis of the dataset, including daily and monthly results for the full suite of hydro-climatic variables included in the results.
- **Model setup**: These are the source code and configuration files used to run the hydrologic model.

The primary data include raw data for each of the major subregions included in the analysis: Pacific Northwest, Upper Missouri basin, California, Great basin, and Colorado River basin. Two other domains are included: summary data for the full Western U.S. domain, as well as dynamically downscaled data from the Weather Research and Forecasting (WRF; http://www.wrf-model.org; Salathé et al., 2013) regional climate model, the domain of which is smaller than the full Western U.S. domain. Within each subregion directory a separate directory is included for each scenario: historical, plus 10 statistically downscaled scenarios (2 future time periods x 5 model projections). Data in each of these directories are stored as follows (for more on the format of these files, see Hamlet et al., 2010):

- Daily time-step raw model output: stored as a zipped “fluxes” directory
- Summaries of raw model output:
  - In time-series format: “fluxes_monthly_summary” directory.
  - Gridded files: “monthly_summaries” directory.
- Annual statistics of snow accumulation: “swe_stats” directory.

In the Western U.S. and WRF directories, additional directories store information on:

- changes in flow extremes, summarized by 12-digit HUC: “flow_stats_12digit” directory, and
- changes in soil moisture extremes: “percentile_change” directory

All files are stored in either ascii space-delimited format or ArcInfo compatible ascii-grid format. Future efforts at CIG will involve producing additional summary products and providing an improved online interface for obtaining and viewing data.

**Conference presentations:**


Communications:

Morrison (now retired) was interested in incorporating the derived extremes into forest planning and risk assessment for Region 1 of the USFS. Morrison spearheaded the original funding of the products on which the PNWCSC funds leveraged. Littell worked with Morrison to understand what bracketing approaches might make sense for USFS planning and how the USFS might serve the ensuing data products.

J. Littell to M. Mahaffy (USFWS), NPLCC science coordinator. 6 Dec 2012.

Mahaffy and others (including USFS Region 6 acting climate change coordinator Karen Bennett) had suggested that the CIG’s downscaled products would be even more useful if they were available for south-central Oregon and northern California. Littell indicated to Mahaffy at the Dec 2012 NPLCC meeting that these products were now available and CIG was ready to coordinate access to any interested users.
REFERENCES


distributions, connectivity, and dispersal corridors. *Ecological Applications*, 21(8):2882–2897


