

# Statistically Downscaled Seasonal Rainfall Anomalies – Hawaiian Islands (SDSRA-HI)

Version 2.0, 2016-06-02

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**Title:** Statistically Downscaled Seasonal Rainfall Anomalies – Hawaiian Islands (SDSRA-HI)

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**Investigator:**

Oliver Elison Timm, Department of Atmospheric and Environmental Sciences, University at Albany, Albany, NY.

Thomas Giambelluca, Department of Geography, University of Hawai‘i at Mānoa, Honolulu, HI.

Henry F. Diaz, NOAA/ESRL Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, Colorado.

**Research and technical support:**

**Abby Frazier** (Dept. of Geography, University of Hawai‘i at Mānoa) and **Tamara Wong** (Dept. Botany, University of Hawai‘i at Mānoa) for creating GIS layers from the original NetCDF files. Mami LeMaster (Dept. of Geography, University of Hawai‘i at Mānoa) for data preparation and processing.

**Contact Information:**

Oliver Elison Timm,  
Department of Atmospheric and Environmental Sciences,  
University at Albany  
1400 Washington Avenue -ES 316A  
Albany, NY, 12222  
E-mail: oelisontimm@albany.edu

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**URL:** <http://apdrc.soest.hawaii.edu/projects/SD/>

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## History:

2016-06-02:

A coding error was detected in the originally used scripts, which caused an error in the downscaling of dry-season precipitation anomalies for all islands in all scenarios, except for Oahu. We recalculated the dry season rainfall changes and produced new maps and data sets for the dry season. Note that the wet season was not affected by the coding error. All wet season data and maps from the previous version are still valid.

Users of the corrected data set should refer to the new data product as a whole with this current version when working with both seasons. (If you only work with wet season data, the preferred version number to cite is the current version, preferably.)

Along with this new version, the delivered products had to be reduced, due to changes in the support of the research.

The products labeled 'PairedRainfall' in Version 1.0 are not updated, further.

The new product version does not include the derived products regarding the rainfall anomaly classification data CLFREQ–GIS. That is the frequency statistics for the precipitation classes is not provided in GIS format. The data are still available in netCDF and CSV format for the RCP 4.5 and RCP 8.5 scenarios (see CLFREQ-DATA).

2015-04-07:

Minor edits to the README file (V1.01)

Updated the CLFREQ NETCDF files: previous files had only partially updated NetCDF dimensions, variable names, and attributes (class 'very\_dry')

Processed all the files and checked the new variable names.

2015-03-25:

Finalized the data product and README file, release of Version 1.0

## Product development history and support:

The interpolated map products are based on the statistical downscaling methods that worked with station precipitation anomalies. The maps presented here are the result of a continued research that started initially in a project sponsored by the Pacific Islands Climate Change Cooperative (PICCC) [cooperative agreement #12200-A-J024, USGS Fish and Wildlife Service]. **In 2016, we discovered a mistake in the previous dry season downscaling results. In version 2.0, the dry season results have been updated to correct for an error in the computer code that generated the previous dry season results. The new corrected dry season rainfall scenarios represent a physically more consistent pattern of rainfall anomalies. In particular the region of Maui Nui shows now a typical gradient between the strong drying trend on leeward sides and neutral conditions (no significant change) on the wet- windward sides. Further details can be found in the correction to our JGR article (Elison Timm et al., 2015).**

Major improvements in the downscaling methods were made during 2012-2014, in particular efforts were made to provide spatially interpolated maps for the main Hawaiian Islands in various data formats. This activity was a main objective in the follow-up project that was sponsored by the USGS Pacific Islands Climate Science Center (PICSC) [cooperative agreement #G12AC20502, DOI, USGS]. The data products include now GIS, NetCDF and CSV formats, which will make the statistically downscaled seasonal mean precipitation anomaly maps accessible to a larger user community. The principal investigators gratefully acknowledge the support by the aforementioned agencies and institutions, USGS, PICSC, and PICCC. Furthermore, this research profited from related research projects on rainfall variability in and around the Hawaiian Islands. These projects were sponsored and supported by the Department of the Army, U.S. Army Corps of Engineers [cooperative agreement #W912HZ-11-2-0035], and the State of Hawai'i Commission on Water Resource Management, Honolulu District under Section 22 of the Water Resources Development Act of 1974.

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- Patrick Grady for helping us organizing the data products and integrating them into the USGS data base
- Jeff Burgett at PICCC and David Helweg at PICSC for their continued support

Mahalo!

# 1 Contents

The archive contains several products, which are grouped by their contents and data formats into different directories (in red are the directories that have been updated in version 2.0)

<del>PairedRainfall</del>	<del>CLFREQ-DATA</del>	SDVAL-DATA	SDSRA-DATA
	<del>CLFREQ-GIS</del>	SDVAL-GIS	SDSRA-GIS

Version 2 update: PairedRainfall and CLFREQ-GIS are no longer updated!

~~PairedRainfall contains the first produced interpolated future climate change rainfall scenarios as spatially interpolated maps. These files were derived from a first spatial interpolation product, which was based on ordinary Kriging applied to station data points. A second Kriging operation was applied to bring the data onto a finer 250m by 250m grid (and a coarser 3km by 3km grid). Further, the maps of the four independently mapped island regions were combined into a statewide map products. The data are provided in GIS conform format and NetCDF format. The maps in high resolution of 250m by 250m are matching the grid of the Rainfall Atlas of Hawaii (Giambelluca et al., 2013). This folder includes the seasonal baseline maps (the present-day seasonal mean climatology from the Rainfall Atlas of Hawaii) and one of the future climate change scenarios, the RCP 8.5 scenario averaged over the years 2041-2070. For more details please see the README file in the PairedRainfall folder.~~

Directories ending on 'DATA' contain NetCDF and text-based spreadsheet tables in CSV format with gridded geospatial data. The directories ending on 'GIS' contain various types of data formats suitable for the import into GIS applications (ArcGIS, QVIS). We note here that different software tools were used in the spatial interpolation methods, and different resolutions have been created, so a 100 matching between the NetCDF /CSV / GIS data formats. All gridded products, however have the same data source base, namely the station-based results from the statistical downscaling model, which is described in Elison Timm et al (2015).

The directories beginning with 'SDSRA' contain the statistically downscaled seasonal rainfall anomalies for the future climate change scenarios. Directories named 'SDVAL' contain data sets with the Monte-Carlo generated cross-validation results (spatially interpolated Pearson correlation coefficients) measuring the correlation between observed seasonal rainfall anomalies and downscaled anomalies.

The directories beginning with 'CLFREQ' contain derived products from the multi-model ensemble downscaling results. They measure relative frequency of future rainfall anomalies within five different rainfall anomaly categories (very-dry, dry, neutral, wet, very wet). See section 5 for more information.

Note: The present-day rainfall basemaps are provided in the folder SDSRA-GIS. They are based on the *Rainfall Atlas of Hawai'i* data from Giambelluca et al (2013).

## 2 SDSRA-GIS

Here we provide the future rainfall anomalies as gridded data sets in formats that can be integrated into Geographic Information System (GIS) software. Further, we provided the present-day seasonal rainfall normals (climatologies) for reference. The interpolation was done with ArcGIS using Ordinary Kriging. The future anomalies are expressed as percent changes relative to these seasonal mean rainfall climatology (years 1978-2007). The directory structure can be seen in the following tree-structure:

```
SDSRA-GIS
|
Staterasters
|
3KM
|
Future_Anom
|
250M
|
Future_Anom
|
Future_Inches
|
Future_mm
|
Baseline_Grids
|
info
|
st_sum_m_o_in
|
st_sum_m_o_mm
|
st_sum_n_a_in
|
st_sum_n_a_mm
```

Staterasters contains subfolders 3KM containing the coarser-resolution raster files with a 3km by 3km grid cell resolution; the folder 250M contains the 250m by 250m grid cell resolution. The high-resolution data is at the same resolution as the Rainfall Atlas of Hawai'i (Giambelluca et al., 2013; <http://rainfall.geography.hawaii.edu>). Baseline\_Grids contains the seasonal mean rainfall climatologies.

## 2.1 Baseline\_Grids

The baseline grids come in the metric units of millimeter (mm) and in conventional units of inches (in). The filename convention is

st\_sum\_m\_o\_\*: Rainfall totals of months May, June, July, August, September, October

st\_sum\_n\_a\_\*: Rainfall totals of months November, December, January, February, March, April

In the report and peer-reviewed publication, the months May to October are called 'dry season' and the months November-April are called 'wet season'. This naming convention is representative for the rainfall character in many locations on the Hawaiian Islands. It is recommended to confirm that the wet-dry season definition applies to the location of interest before adopting this 'state-wide' definition of wet and dry seasons.

The placeholder “\*” stands for either “mm” or “in” in the file name. The former indicates files that contain the rainfall amounts in metric units millimeter and the latter in the conventional units of inches.

## 2.2 250M

The folder 250M contains the following subfolders and files:

- Future\_Anom
- Future\_Inches
- Future\_mm

## 2.2.1 Future\_Anom

Future\_Anom contains the raster files of the projected future rainfall anomalies. The units are percent of the present-day seasonal mean rainfall normals. The rainfall normals are based on the Rainfall Atlas of Hawai'i product (We provide these data as 250m x 250m resolution raster files in the folder SDSRA-HI/StateRasters/Baseline\_Grids). The future rainfall anomalies are organized in subfolders by season, climate change scenario, and time period:

```
Future_Anom
|
| Drylate45_ano
|
| Drylate85_ano
|
| Drymid45_ano
|
| Drymid85_ano
|
| info
|
| Wetlate45_ano
|
| Wetlate85_ano
|
| Wetmid45_ano
|
| Wetmid85_ano
```

Note that each subfolder in Future\_Anom has an Auxiliary file connected with it in XML format. These files ending (\* .aux.xml) have the same name structure except for using a 'DryLate', 'DryMid', and 'WetLate' and 'WetMid'. Wet and Dry indicate the two seasons (see section BaselineGrids for definition). Each of the subfolders contains one specific time horizon. The label 'mid' refers to the mid 21<sup>st</sup> century projections and is a representative 30-yr average for the years 2041-2070. The label 'late' refers to the late 21<sup>st</sup> century and is a representative 30-yr average for the years 2071-2100. The two-digit label '45' and '85' distinguish the CMIP5 representative concentrations pathway (RCP). The number divided by 10 indicates the effective radiative forcing by the year 2100 in watts per square meter (for details see Intergovernmental Panel on Climate Change (IPCC) Working Group 1 the fifth Assessment Report (AR5) published in 2013, <http://ipcc.ch/report/ar5>). The '45' label indicates a moderate warming scenario, the '85' is the more severe warming scenario.

In each subfolder is a list of GIS files needed to project data in a GIS application:

```
dblbnd.adf  
hdr.adf  
metadata.xml  
prj.adf  
sta.adf  
w001001.adf  
w001001x.adf
```

### 2.3.2 Future Inches and Future mm

The 250M folder contains Future\_Inches and Future\_mm. These folders provide the future rainfall anomalies in units of inches and mm, respectively. They were obtained by multiplying the maps of the Baseline\_Grids (i.e. the Rainfall Atlas of Hawai'i present-day climatological seasonal rainfall sums) with future anomaly percentage maps. The folders and data are organized as described in section 2.3.1.

### 2.3 3KM

The folder 3KM contains the coarser-resolution data on a 3km by 3km grid. We provide the future rainfall maps only in units of percent anomalies in the subfolders. It is otherwise organized in the same way as described in Section 2.2.1.

## 3 SDSRA-DATA

The netCDF data files were created originally in *R* (Hornig, 2015) using the package *geoR* (Diggle, P.J. & Ribeiro Jr 2007; Paulo et al., 2001). We applied ordinary Kriging for the interpolation of the station-based precipitation anomalies onto a regular longitude-latitude grid with 0.5 minute resolution in longitude and latitude. This is an intermediate resolution between the 3km and 250m raster files described in section 2 (Note that the GIS files were created with ArcGIS software).

The directory contains the following subfolders and data:

CSV

NETCDF

SCRIPTS

The folders CSV and NETCDF contain the exact same gridded data in different formats. In the folder CSV are text-based CSV spreadsheet files using commas as column delimiters. The data tables store the gridded information as in a table with columns for longitude (degrees E), latitude (degrees N), and a column called 'pr' with the interpolated rainfall anomalies expressed in percent of the present-day climatological seasonal rainfall amount. The column 'err' includes the Kriging Error variance estimate for the grid point location. Note that these files contain open-ocean grid points with 'extrapolated' data values. Users should be prepared to create their own land-sea masks to blend out ocean regions. Further, the files have not been merged into a state-wide table. The data tables contain of the order of 30,000 rows (varies by island region).



### 3.1 Filename conventions

The filenames contain information to distinguish regions, scenarios, seasons, and time periods:

`cmip5_SCEN_ensemble_precip_ano_stat_SEA_REGION_YEARS_kc.csv`

The following strings are placeholders for the actual values:

SCEN: rcp45 or rcp85

(for the CMIP5 Representative Concentrations Pathway RCP 4.5 and RCP 8.5)

SEA: the wet and dry season (see Section 2.1).

REGION: KA, OA, MA, BI

(for the four island regions Kauai, Oahu, Maui Nui, Big Island)

YEARS: 2041-2070, 2071-2099

(30-yr average and 29 year averages for the years of the future scenario simulations).

Example: The anomalies for the CMIP5 RCP 8.5 scenario averaged over the years 2071-2099, wet season, Oahu is:

`cmip5_rcp85_ensemble_precip_ano_stat_wet_OA_2071-2099_kc.csv`

Folder `NETCDF` contains the corresponding NetCDF files. They have the same file name structure, but ending with `'.nc'`.

The `SCRIPTS` directory contains additional script files, which were used in generating or post-processing the data files. They are usually not of interest to the user of the data and can be ignored.

## 4 SDVAL

The folders contains the results from the Monte-Carlo cross-validation. Geospatial interpolation was applied in two stages to obtain from the station-based correlation values gridded data. The correlation coefficient at each station measures how strong the variability of observed seasonal rainfall anomalies correlates with the statistically downscaled values. We obtained correlation coefficients by randomly subdividing the observational data into two sets. One was used for model fitting (calibration) and the second set of years was reserved as independent data to calculate the correlation coefficient. This serves as one measure of the skill of the downscaling method.

The first interpolation was done with ordinary Kriging (half minute resolution in longitude and latitude). From these gridded data, we interpolated with the Generic Mapping Tools (GMT) to a 3km by 3km and 250m by 250m resolution (GMT's 'surface' function; see <http://gmt.soest.hawaii.edu/> for more information). The data process generates netCDF and CSV spreadsheet files. The netCDF files were imported into QGIS (see <http://qgis.org/en/site/> for more information) to convert the files into geoTIFF files and shape files with contour lines. Note: The conversion was actually done in a batch mode with the gdal tools that are part of the QGIS software package.

### 4.1 SDVAL-GIS

The folder contains geo-referenced TIFF (geoTIFF) files for both the 3km and the higher 250m resolution files. In addition, we created shape files with contoured information.

geoTIFF files:

The filename convention is:

`mc_val_SEA_REGION_RES.tif` (plus XML file)

SEA stands for string values 'wet' or 'dry' for the two seasons

REGION is one of the four island region labels (Kauai, KA; Oahu, OA; Maui Nui, MA; BI Big Island)

RES is either 3km or 250m for the two different resolutions.

The shape files with the contour information are stored in separate subfolders, they follow a similar naming convention (except we only used the 250m resolution data to derive the contour layers): Each file comes with three files.

```
mc_val_SEA_REGION_250m_contour
|
contour.dbf
contour.shp
contour.shx
```

## 4.2 SDVAL-DATA

The folder contains subdirectories NETCDF and CSV for the data files in format NetCDF and CSV, respectively. FIGURES contain PDF figures obtained from the netCDF files using Generic Mapping Tools (GMT). SCRIPTS contains some support scripts that were used to prepare the NetCDF and GIS files. Note the ocean grid points were masked out in the interpolated 3km and 250m maps; the \*.kc.csv files, which were the first interpolated maps have still included open-ocean points with extrapolated correlation values.

### CSV

- |
  - mc\_val\_SEA\_REGION\_kc.csv
  - mc\_val\_SEA\_REGION\_kc\_3km.csv
  - mc\_val\_SEA\_REGION\_kc\_250m.csv

### NETCDF

- |
  - 250m
    - |
      - mc\_val\_SEA\_REGION\_kc\_250m.cdf
  - 3km
    - |
      - mc\_val\_SEA\_REGION\_kc\_3km.cdf

### KRIGING

- |
  - mc\_val\_SEA\_REGION\_kc.nc

### SCRIPTS

### FIGURES

- |
  - mc\_val\_SEA\_REGION\_3km.pdf
  - mc\_val\_SEA\_REGION\_250m.pdf

## 5 CLFREQ

The data in this folder contain additional statistical information on the future rainfall scenarios. We took the statistical downscaling output from 32 different CMIP5 models for each scenario and analyzed the seasonally downscaled rainfall anomalies in 29-year to 31-year windows but looking at all years individually. Given the present-day distribution of the year-to-year rainfall anomalies (1975-2005) from the historical runs, we divided the rainfall anomalies into five categories (or classes):

- 'neutral': anomalies in the range of  $\pm 1$  standard deviation from the present-day mean.
- 'wet': anomalies in the range of  $> 1$  standard deviation above the present-day mean to the maximum anomaly at present-day conditions.
- 'very wet': anomalies greater than the present-day maximum anomaly
- 'dry': anomalies in the range of  $< 1$  standard deviation below the present-day mean to the minimum anomaly at present-day conditions.
- 'very dry': anomalies lower than the present-day minimum anomaly

Every downscaled seasonal anomaly gets classified in one of the five categories and the frequency of occurrences is counted. We present the data in percentages of the total samples in each 30-year period. We analyzed the future RCP 4.5 and RCP 8.5 scenarios and in addition we took a retrospective look at the historical simulation C.E. 1880-2005.

Note: The five classes form a complete sample space, and hence summing all events up must give 100%. This is true only for the station-based data. The interpolated gridded that were done separately for each class, and adding the five classes together result is values close to 100%, but not exactly 100%.

### 5.1 CLFREQ-GIS

(GIS format not supported under version 2.0)

The files were derived from the gridded NetCDF data using QGIS/gdal tools. We worked with the 3km resolution only.

#### 5.1.1 SHAPEFILES

Layers with contours are stored in SHAPEFILES subdirectories with naming convention:

cmip5\_SCEN\_ensemble\_precip\_class\_CLASS\_SEA\_REGION\_YEARS\_3km\_contour  
(each containing three files: contour.dbf, contour.shp, contour.shx)

The placeholders represent the following string values

SCEN	historical, rcp45, rcp85
CLASS	very_dry, dry, neutral, wet, very_wet
SEA	wet and dry season: here we use 'ndjfma' and 'mjjaso' to avoid confusion with the class name: 'ndjfma' is the November-April wet season, mjjaso is the May-October dry season.
REGION	the four island region labels (Kauai, KA; Oahu, OA; Maui Nui, MA; BI Big Island)
YEARS	have several values depending on the scenario. The most important for comparison with the seasonal mean anomalies are 2041-2071, 2071-2099.

Note: the historical scenarios for the years 1975-2005 provide the present-day reference statistics. These are not based on direct observations but on the statistically downscaled rainfall anomalies for that historical season, so future changes in the frequency of precipitation anomalies in the five classes can be studied as anomalies with respect to the historical 1975-2005 frequencies.

E.g.:

```
cmip5_historical_ensemble_precip_class_very_wet_mjjaso_KA_1975-2005_3km_contour
```

is the file with the reference values for the very\_wet rainfall anomalies during the dry season on Kauai (per definition the very\_wet category is zero % (so are the very\_dry category data) for this present-day reference period.

## 5.1.2 RASTERFILES

### (GIS format not supported under version 2.0)

The folder contains the geoTIFF raster files with 3km by 3km grid resolution.  
The file name structure is similar to the subfolders in SHAPEFILES

```
cmip5_SCEN_ensemble_precip_class_CLASS_SEA_REGION_YEARS_3km_georef
```

The file extension is `.tif`, and each file comes with an extra xml file. (`.aux.xml` extension).

For example, the file

```
cmip5_rcp45_ensemble_precip_class_dry_mjjaso_BI_2071-2099_3km_georef.tif
```

is the frequency of category 'dry' rainfall anomalies on Hawaii (Big Island) in the RCP4.5 future change scenario. The season is the dry season (mjjaso) and the time period is 2071-2099.  
Please read section 5.1.1 for a description of the placeholder's string values.

## 5.2 CLFREQ-DATA

The netCDF and CSV data files are located in the subdirectories NETCDF and CSV, respectively. The file name structure is as follows:

cmip5\_SCEN\_ensemble\_precip\_class\_CLASS\_SEA\_REGION\_YEARS\_3km  
plus a file name extension (.cdf, and .csv)

Example file names are:

cmip5\_rcp85\_ensemble\_precip\_class\_wet\_ndjfma\_OA\_2071-2099\_3km.cdf  
cmip5\_rcp85\_ensemble\_precip\_class\_wet\_ndjfma\_OA\_2071-2099\_3km.csv

Please see the file name conventions in the previous section for details.

We provide further figure files in PDF format in the subfolder FIGURES. These plots show the 3km by 3km gridded data in color shadings. The small circles in the figures show the station locations, from which the interpolated maps were obtained. The file name convention follows the same structure as seen here for the netCDF and CSV files, e.g.

cmip5\_rcp85\_ensemble\_precip\_class\_wet\_ndjfma\_OA\_2071-2099\_3km.pdf is the figure file corresponding to the above mentioned data files.

## 6 References

Elison Timm, O., T. W. Giambelluca, and H. F. Diaz (2015), Statistical downscaling of rainfall changes in Hawai‘i based on the CMIP5 global model projections, *J. Geophys. Res. Atmos.*, 120, 92–112, doi:[10.1002/2014JD022059](https://doi.org/10.1002/2014JD022059).

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## 7 Disclaimer

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