climate_indices Documentation

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James Adams

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This project contains Python implementations of various climate index algorithms which provide a geographical and temporal picture of the severity of precipitation and temperature anomalies useful for climate monitoring and research.

The following indices are provided:

- SPI, Standardized Precipitation Index, utilizing both gamma and Pearson Type III distributions
- SPEI, Standardized Precipitation Evapotranspiration Index, utilizing both gamma and Pearson Type III distributions
- PET, Potential Evapotranspiration, utilizing either Thornthwaite or Hargreaves equations
- PNP, Percentage of Normal Precipitation

The following are provided as experimental/development versions only, not fully vetted nor suitable for research purposes:

- PDSI, Palmer Drought Severity Index
- scPDSI, Self-calibrated Palmer Drought Severity Index
- PHDI, Palmer Hydrological Drought Index
- Z-Index, Palmer moisture anomaly index (Z-index)
- PMDI, Palmer Modified Drought Index

This Python implementation of the above climate index algorithms is being developed with the following goals in mind:

- to provide an open source software package to compute a suite of climate indices commonly used for climate monitoring, with well documented code that is faithful to the relevant literature and which produces scientifically verifiable results
- to provide a central, open location for participation and collaboration for researchers, developers, and users of climate indices
- to facilitate standardization and consensus on best-of-breed climate index algorithms and corresponding compliant implementations in Python
- to provide transparency into the operational code used for climate monitoring activities at NCEI/NOAA, and consequent reproducibility of published datasets computed from this package
- to incorporate modern software engineering principles and scientific programming best practices

Getting started

The installation and configuration described below is performed using a bash shell, either on Linux, Windows, or MacOS.

Windows users will need to install and configure a bash shell in order to follow the usage shown below. We recommended either babun or Cygwin for this purpose.

1.1 Configure the Python environment

This project's code is written in Python 3. It is recommended to use either the Miniconda3 (minimal Anaconda) or Anaconda3 distribution. The below instructions will be Anaconda specific (although relevant to any Python virtual environment), and assume the use of a bash shell.

A new Anaconda environment can be created using the conda environment management system that comes packaged with Anaconda. In the following examples, we'll use an environment named *indices_env* (any environment name can be used instead of *indices_env*) which will be created and populated with all required dependencies through the use of the provided setup.py file.

First, create the Python environment:

\$ conda create -n indices_env

The environment can now be 'activated':

\$ source activate indices_env

Once the environment has been activated then subsequent Python commands will run in this environment where the package dependencies for this project are present.

Now the package can be added to the environment along with all required modules (dependencies) via pip:

\$ python -m pip install climate-indices

For development of the package itself it pays to install the dependencies via the requirements.txt file:

\$ python -m pip install -r requirements.txt

When adding dependencies to the package they should be added to the *pyproject.toml* file in the dependencies section, then we can rebuild the requirements.txt file using pip-tools:

\$ python -m piptools compile -o requirements.txt pyproject.toml

1.2 NCO

NetCDF Operators is a requirement and must be installed for utilization of this package. Instructions for installation on various platforms is available here. If using an Anaconda environment as advised above then it's as simple as running the following command within the activated conda environment:

\$ conda install -c conda-forge nco

Indices Processing

The installation will provide an "entry point" script which interacts with the core computational package to compute one or more climate indices. This script is process_climate_indices and is used to compute indices corresponding to gridded NetCDF datasets as well as US climate division NetCDF datasets.

This Python entry point script is written to be run via bash shell command, i.e.

\$ process_climate_indices <options>

The options for the entry point script are described below:

tion which of the climate indices to compute. Valid values are 'spi', 'spei', 'prp', 'scaled', 'pet', and 'palmers'. 'scaled' indicates all three scaled indices (SPI, SPEI, and PNP) and 'palmers' indicates all Palmer indices (PDS, PHD), PMD1, SCPDS1, and Z-Index). pe- The periodicity of the input dataset files. Valid values are 'monthly' and 'daily'. rid. NOTE: Only SPI and PNP support daily inputs. odd isity netGOL [speiiNeICDF file containing a precipitation so as to identify the NetCDF's precipitation variable. var_name_precipit no conjunction so as to identify the NetCDF's precipitation variable. var_nameAgneoifthe precipitation variable within the input precipitation NetCDF. netGOL [stepit NetCDF file containing a temperature dataset, required for PET. If specified in conjunction with an index specification of SPEI or Palmers the PET will be computing SPEI and/or Palmers. Requires the use of var_name_temp in conjunction so as to identify the NetCDF's temperature variable. var_nambaueroff the temperature variable within the input temperature NetCDF. netGoL jetu VetCDF file containing a PET dataset, required for PEI and Palmers. This option is mutually exclusive with netGT file containing a Net To dataset, required for PAlmers. netGoL jetu NetCDF file containing a PET adtaset, required for Palmers. Requires the use of var_name_temp. as either temperature of PET is required as an input (but not both) when computing SPEI addors Palmers. netGoL jetu NetCDF file contatining available water capacity	Op-	Description
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2.1 Example Input and Output Datasets

Example NetCDF datasets that are valid input to the indices processing scripts described above are available from the associated project example_climate_indices. The input NetCDF files used in the examples below (*nclimdiv.nc*, *nclimgrid_lowres_prcp.nc*, etc.) can be fetched from this repository, as well as associated output NetCDF datasets that can be used to validate result of the below examples.

2.2 Example Command Line Invocations

2.2.1 US Climate Divisions (all indices)

\$ process_climate_indices --index all --periodicity monthly --scales 3 6 --netcdf_precip /data/nclimdiv.nc --netcdf_temp /data/nclimdiv.nc --netcdf_awc /data/nclimdiv.nc --output_file_base /data/nclimdiv --var_name_precip prcp --var_name_temp tavg --var_name_awc awc --calibration_start_year 1951 --calibration_end_year 2010

The above command will compute all indices from an input NetCDF dataset containing precipitation, temperature, and available water capacity variables (in this case, the US Climate Divisions NetCDF dataset provided in the example inputs directory). The input dataset is monthly data and the calibration period 2010. used will be Jan. 1951 through Dec. The indices will be computed at 3-month and 6-month Upon completion the individual NetCDF files will contain variables for all computed indices: scales. /data/nclimdiv_pet.nc, /data/nclimdiv_pnp_03.nc, /data/nclimdiv_pnp_06.nc, /data/nclimdiv_spi_gamma_03.nc, /data/nclimdiv_spi_gamma_06.nc, /data/nclimdiv_spi_pearson_03.nc, /data/nclimdiv_spi_pearson_06.nc, /data/nclimdiv_spei_gamma_03.nc, /data/nclimdiv_spei_gamma_06.nc, /data/nclimdiv_spei_pearson_03.nc, /data/nclimdiv_spei_pearson_06.nc, /data/nclimdiv_pdsi.nc, /data/nclimdiv_phdi.nc, /data/nclimdiv_pmdi.nc, /data/nclimdiv_scpdsi.nc, and /data/nclimdiv_zindex.nc. Parallelization will occur utilizing all but one of the available CPUs (default since the *-multiprocessing* option is omitted).

2.2.2 PET monthly

\$ process_climate_indices --index pet --periodicity monthly --netcdf_temp /data/nclimgrid_lowres_tavg.nc --var_name_temp tavg --output_file_base <out_dir>/nclimgrid_lowres --multiprocessing all_but_one

The above command will compute PET (potential evapotranspiration) using the Thornthwaite method from an input temperature dataset (in this case, the reduced resolution nClimGrid temperature dataset provided in the example inputs directory). The input dataset is monthly data and the calibration period used will be Jan. 1951 through Dec. 2010. The output file will be *<out_dir>/nclimgrid_lowres_pet.nc*. Parallelization will occur utilizing all but one of the available CPUs.

2.2.3 SPI daily

```
$ process_climate_indices --index spi --periodicity daily --netcdf_precip
/data/cmorph_lowres_daily_conus_prcp.nc --var_name_precip prcp
--output_file_base <out_dir>/cmorph_lowres_daily_conus --scales 30 90
--calibration_start_year 1998 --calibration_end_year 2016 --multiprocessing
all
```

The above command will compute SPI (standardized precipitation index, both gamma and Pearson Type III distributions) from an input precipitation dataset (in this case, the reduced resolution CMORPH precipitation dataset provided in the example inputs directory). The input dataset is daily data and the calibration period used will be Jan. 1st, 1998 through Dec. 31st, 2016. The index will be computed at 30-day and 90-day timescales. The output files will be *<out_dir>/cmorph_lowres_daily_conus_spi_gamma_90.nc*, *<out_dir>/cmorph_lowres_daily_conus_spi_pearson_90.nc*. Parallelization will occur utilizing all CPUs.

2.2.4 SPI monthly

```
$ process_climate_indices --index spi --periodicity monthly --netcdf_precip
/data/nclimgrid_lowres_prcp.nc --var_name_precip prcp --output_file_base
<out_dir>/nclimgrid_lowres --scales 6 12 --calibration_start_year 1951
--calibration_end_year 2010 --multiprocessing all
```

The above command will compute SPI (standardized precipitation index, both gamma and Pearson Type III distributions) from an input precipitation dataset (in this case, the reduced resolution nClimGrid precipitation dataset provided in the example inputs directory). The input dataset is monthly data and the calibration period used will be Jan. 1951 through Dec. 2010. The index will be computed at 6-month and 12-month timescales. The output files will be <out_dir>/nclimgrid_lowres_spi_gamma_06.nc, <out_dir>/nclimgrid_lowres_spi_gamma_12.nc, <out_dir>/nclimgrid_lowres_spi_pearson_06.nc, and <out_dir>/nclimgrid_lowres_spi_pearson_12.nc. Parallelization will occur utilizing all CPUs.

2.2.5 SPEI monthly

```
$ process_climate_indices --index spei --periodicity monthly --netcdf_precip
/data/nclimgrid_lowres_prcp.nc --var_name_precip prcp --netcdf_pet /
data/nclimgrid_lowres_pet.nc --var_name_pet pet --output_file_base
<out_dir>/nclimgrid_lowres --scales 9 18 --calibration_start_year 1951
--calibration_end_year 2010 --multiprocessing all
```

The above command will compute SPEI (standardized precipitation evapotranspiration index, both gamma and Pearson Type III distributions) from input precipitation and potential evapotranspiration datasets (in this case, the reduced resolution nClimGrid precipitation and PET datasets provided in the example inputs directory). The input datasets are monthly data and the calibration period used will be Jan. 1951 through Dec. 2010. The index datasets will be computed at 9-month and 18-month timescales. The output files will be *<out_dir>/nclimgrid_lowres_spei_gamma_09.nc*, *<out_dir>/nclimgrid_lowres_spei_gamma_18.nc*, *<out_dir>/nclimgrid_lowres_spei_pearson_09.nc*, and *<out_dir>/nclimgrid_lowres_spei_pearson_18.nc*. Parallelization will occur utilizing all CPUs.

2.2.6 Palmers monthly

```
$ process_climate_indices --index palmers --periodicity monthly
--netcdf_precip /data/nclimgrid_lowres_prcp.nc --var_name_precip prcp
--netcdf_pet /data/nclimgrid_lowres_pet.nc --var_name_pet pet --netcdf_awc /
data/nclimgrid_lowres_soil.nc --var_name_awc awc --output_file_base <out_dir>/
nclimgrid_lowres --calibration_start_year 1951 --calibration_end_year 2010
--multiprocessing all
```

The above command will compute the Palmer drought indices: PDSI (original Palmer Drought Severity Index), PHDI (Palmer Hydrological Drought Index), PMDI (Palmer Modified Drought Index), Z-Index (Palmer Z-Index), and SCPDSI (Self-calibrated Palmer Drought Severity Index) from input precipitation, potential evapotranspiration, and available water capacity datasets (in this case, the reduced resolution nClimGrid precipitation, PET, and AWC datasets provided in the example inputs directory). The input datasets are monthly data and the calibration period used will be Jan. 1951 through Dec. 2010. The output files will be <*out_dir>/nclimgrid_lowres_pdsi.nc*, <*out_dir>/nclimgrid_lowres_pdsi.nc*, <*out_dir>/nclimgrid_lowres_pdsi.nc*, <*out_dir>/nclimgrid_lowres_pdsi.nc*, <*out_dir>/nclimgrid_lowres_scpdsi.nc*, and <*out_dir>/nclimgrid_lowres_zindex.nc*. Parallelization will occur utilizing all CPUs.

2.2.7 Pre-compute SPI distribution fitting variables

In order to pre-compute fitting parameters for later use as inputs to subsequent SPI calculations we can save both gamma and Pearson distributinon fitting parameters to NetCDF, and later use this file as input for SPI calculations over the same calibration period.

```
$ spi --periodicity monthly --scales 1 2 3 6 9 12 24 36 48 60 72
--calibration_start_year 1998 --calibration_end_year 2016 --netcdf_precip /
data/nclimgrid/nclimgrid_prcp.nc --var_name_precip prcp --output_file_base
/data/nclimgrid/nclimgrid --multiprocessing all --save_params /data/nclimgrid/
nclimgrid_fitting.nc --overwrite
```

```
$ spi --periodicity monthly --scales 1 2 3 6 9 12 24 36 48 60 72
--calibration_start_year 1998 --calibration_end_year 2016 --netcdf_precip /
data/nclimgrid/nclimgrid_prcp.nc --var_name_precip prcp --output_file_base
/data/nclimgrid/nclimgrid --multiprocessing all --load_params /data/nclimgrid/
nclimgrid_fitting.nc
```

In the above example we demonstrate how distribution fitting parameters can be saved as NetCDF. This fittings NetCDF can then be used as pre-computed variables in subsequent SPI computations. Initial command computes both distribution fitting values and SPI for various month scales. The distribution fitting variables are written to the file specified by the *-save_params* option. The second command also computes SPI but instead of computing the distribution fitting values it loads the pre-computed fitting values from the NetCDF file specified by the *-load_params* option.

For Developers

3.1 Download the code

Clone this repository:

\$ git clone https://github.com/monocongo/climate_indices.git

Move into the source directory:

\$ cd climate_indices

Within this directory, there are four subdirectories:

- climate_indices: main computational package
- tests: unit tests for the main package
- notebooks: Jupyter Notebooks describing the internals of the computational modules
- docs: documentation files

3.2 Testing

Initially, all tests should be run for validation:

\$ tox

If you run the above from the main branch and get an error then please send a report and/or add an issue, as all tests should pass.

Get involved

Please use, make suggestions, and contribute to this code. Without diverse participation and community adoption this project will not reach its potential.

Are you aware of other indices that would be a good addition here? Can you identify bottlenecks and help optimize performance? Can you suggest new ways of comparing these implementations against others (or other criteria) in order to determine best-of-breed? Please fork the code and have at it, and/or contact us to see if we can help.

- Read our contributing guidelines
- File an issue, or submit a pull request
- Send us an email

Copyright and licensing

This is a developmental version of code that is originally developed at NCEI/NOAA, official release version available on drought.gov. This software is under BSD 3-Clause license, copyright James Adams, 2017. Please read more on our license page.

Citation

You can cite *climate_indices* in your projects and research papers via the BibTeX entry below.

```
@misc {climate_indices,
    author = "James Adams",
    title = "climate_indices, an open source Python library providing reference_
    implementations of commonly used climate indices",
        url = "https://github.com/monocongo/climate_indices",
        month = "may",
        year = "2017--"
}
```