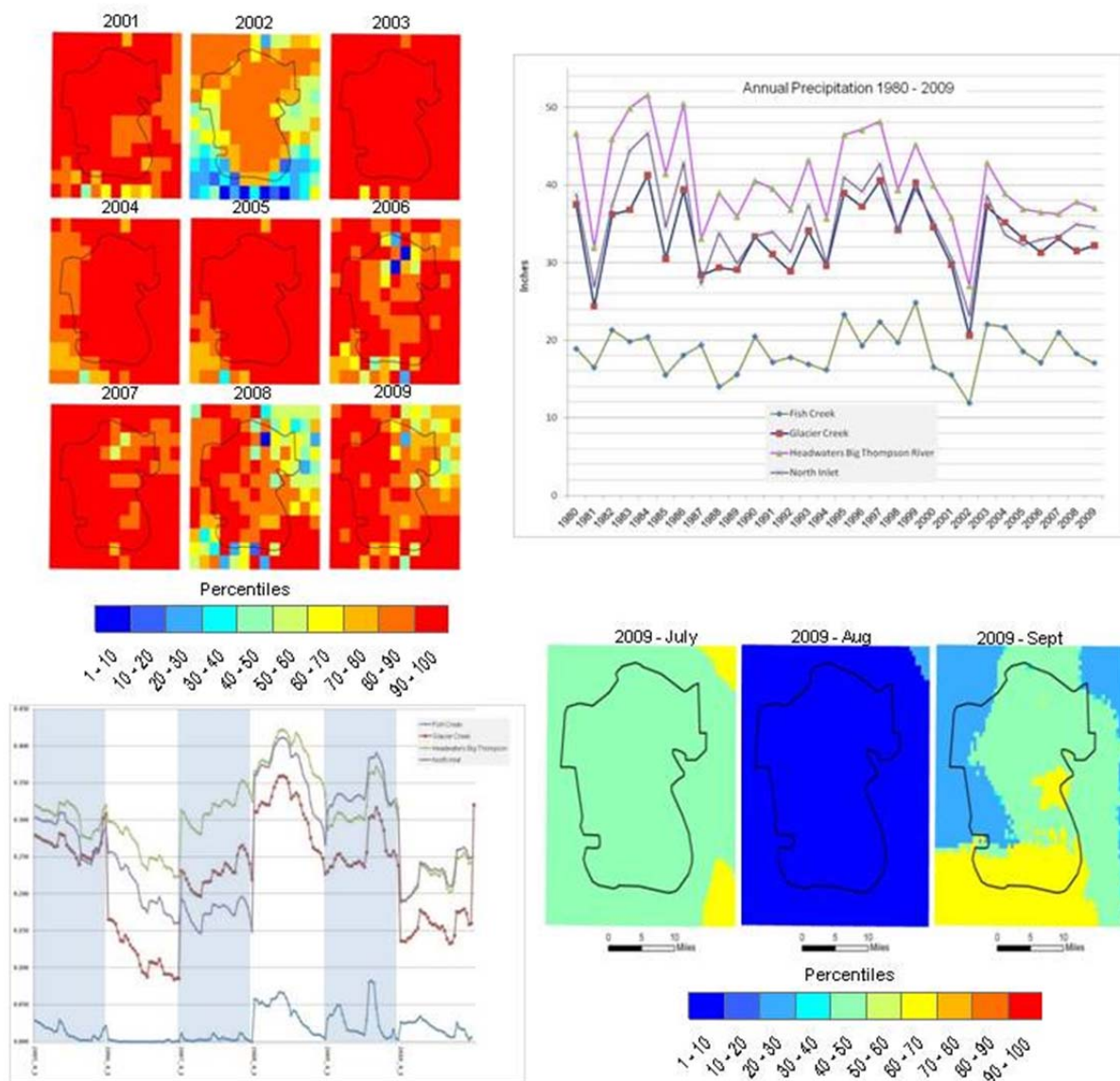




Climate Grid Analysis Toolset (CGAT) - Tools for Assessing Regional Climatological Trends

Standard Operating Procedure (Version 1.2)

Natural Resource Report NPS/NRSS/IMD/NRR—2011/411



ON THE COVER

Example CGAT analysis outputs:

Upper Left – Parameter-elevation Regressions on Independent Slopes Model (PRISM)-derived annual mean minimum temperature (tmin) percentile calculations for each year between 2001-2009 versus the thirty year period between 1971-2000 for Rocky Mountain National Park (ROMO) (outline in black); see Figure 4.

Upper Right – PRISM derived annual precipitation between 1980 – 2009 for four 12th level National Hydrologic Dataset (NHD) hydrological units; see Figure 5.

Lower Left – Snow Data Assimilation System (SNODAS)-derived mean daily Snow Water Equivalent (SWE) values for four NHD 12th level Hydrologic Unit Codes (HUCs) (NHD 2010) in and near ROMO, for the month of April between the years of 2005-2010; see Figure 6.

Lower Right – SNODAS derived 2009 July, August and September total monthly liquid precipitation percentile values across the five year period of 2005-2009 for ROMO (outline in black); see Figure 7.

The Climate Grid Analysis Toolset (CGAT) - Tools for Assessing Regional Climatological Trends

Standard Operating Procedure (Version 1.2)

Natural Resource Report NPS/NRSS/IMD/NRR—2011/411

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June 2011

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Abstract

Increasingly, land managers recognize the need for using historical climatic data to inform management decisions. Additionally, given anticipated climatic change, having baseline knowledge of historical climatic conditions is essential for understating potential implications of future climatic change. While most managers rely on point-based observations, stations are often few in number and not representative of the entire park. Gridded datasets, including PRISM and SNODAS, are derived from weather observations, are spatially continuous (4km and 1km resolutions), and spatially and temporally extensive across the contiguous United States. The Climate Grid Analysis Toolset (CGAT) is a suite of GIS Python scripts developed to facilitate efficient analysis of PRISM and SNODAS geospatial climatic datasets. CGAT performs three analyses for user-defined spatial and temporal ranges: (1) cell-based average or totals, (2) percentile calculation, and (3) user-defined zonal statistics.

Overall, CGAT is intended to be a tool which facilitates the use of the highly relevant and information rich PRISM and SNODAS datasets. The CGAT suite is packaged as two sets of python scripts requiring only basic understanding of python/computer programming, and a moderate level of proficiency in GIS.

Acknowledgments

We would like to thank Laura O’Gan and Jennie Skancke for their help in providing feedback on the SOP and beta versions of the CGAT scripts. Additionally we thank Simon Kingston for review and edit of the SOP manuscript.

1. Introduction

This standard operating procedure (SOP) provides a step-by-step guide for the Climatic Grid Analysis Toolset (CGAT), which is designed to facilitate the efficient analysis of PRISM and SNODAS geospatial climatic datasets. CGAT performs three analysis functions over user defined areas of interest and at user defined time steps (months or years). These functions are: cell based average or total, percentile calculation, and user defined zonal statistics on PRISM and SNODAS data. Each of these analyses will be further explained.

CGAT is organized into two sets of scripts: one each for PRISM and SNODAS data. Each set consists of a master script which is used to define the desired analysis parameters and acts as the interface for the analysis functions which are located on the respective functions script. Figure 1 provides a schematic of the CGAT model.

This SOP is divided into three main sections. Section One provides general information and background on the PRISM and SNODAS datasets. Section Two introduces and discusses the three main analysis functions. Finally, section Three provides user directions for setting up and running CGAT.

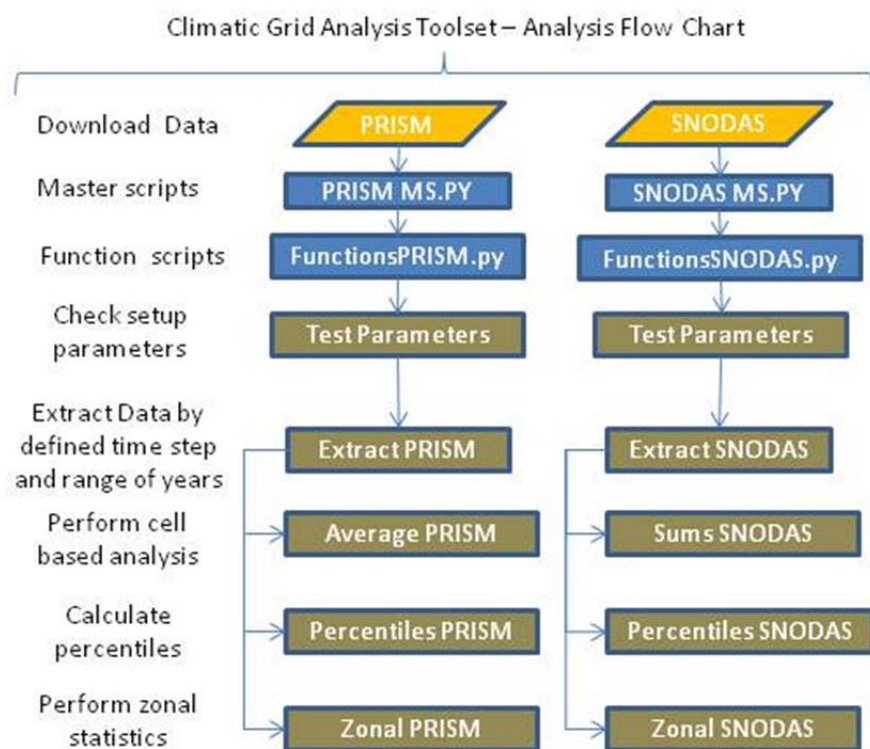


Figure 1. Climate Grid Analysis Toolset – Analysis Flow Chart.

This SOP and model are written with the following assumptions:

- You have either ArcGIS 9.3 or ArcGIS 10 – service pack 1 installed and the Spatial Analyst extension installed and working
- You have experience using ArcGIS and are familiar with gridded datasets
- You have some familiarity with PRISM/SNODAS data and know how you intend to use it to meet the objectives of your analysis

2. Climatic Data

2.1 PRISM Data

PRISM (Parameter-elevation Regressions on Independent Slopes Model) climatic data comes from the PRISM Climate Group at Oregon State University. Using point-based observational data, PRISM data is modeled using the PRISM climate mapping system. PRISM data is spatially continuous for the continental US, and has been modeled from the year 1895 to the present. The spatial resolution of PRISM data is 2.5-arcminutes (4km), and it is modeled at a monthly time step (i.e. temporal resolution).

PRISM data consists of four climatic variables: Average maximum temperature (tmax), average minimum temperature (tmin), average dewpoint temperature (tdmean), and total precipitation (ppt). For further information on PRISM data and appropriate usage please visit the PRISM group website at <http://www.prism.oregonstate.edu/>. The PRISM archive is downloadable via FTP at <ftp://prism.oregonstate.edu/pub/prism/us/grids/>. Use of a FTP download program such as FileZilla <http://filezilla-project.org> is recommended for efficient download of data.

2.2 SNODAS Data

SNODAS (SNOW Data Assimilation System) climatic data is modeled by the NOAA National Weather Service's National Operational Hydrologic Remote Sensing Center. SNODAS data is available for the continental US at a 1-km spatial resolution at a 24-hour (daily) temporal resolution.

SNODAS climatic variables are Snow Water Equivalent, Snow Depth, Snow Melt Runoff at the Base of the Snow Pack, Snowpack Sublimation, Blowing Snow Sublimation, Solid Precipitation, Liquid Precipitation, and Snow Pack Average Temperature. For further information on SNODAS data and appropriate usage please visit the SNODAS site at http://nsidc.org/data/docs/noaa/g02158_snodas_snow_cover_model/index.html. The SNODAS archive is available from October 2003 through the present and is downloadable via ftp from <ftp://sidacs.colorado.edu/DATASETS/NOAA/G02158/>. Use of a FTP download program such as FileZilla <http://filezilla-project.org> is recommended for efficient download of data.

Table 1. PRISM and SNODAS Variables, Abbreviations, Output variable unit, Cell Based Analysis default, and Spatial and Temporal resolutions.

DataSet	Variable	Abrev	Variable Unit	Analysis Default	Spatial	Temporal
PRISM	Precipitation	ppt	mm	Total	4km	Monthly
PRISM	Average Maximum Temp	tmax	Celsius	Average	4km	Monthly
PRISM	Average Minimum Temp	tmin	Celsius	Average	4km	Monthly
PRISM	Average Dewpoint Temp	tdmean	Celsius	Average	4km	Monthly
SNODAS	Snow Water Equivalent	1034	meters	Total	1km	Daily
SNODAS	Snow Depth	1036	meters	Total	1km	Daily
SNODAS	Snow Melt Runoff	1044	meters	Total	1km	Daily
SNODAS	Snowpack Sublimation	1050	meters	Total	1km	Daily
SNODAS	Blowing Snow Sublimation	1039	meters	Total	1km	Daily
SNODAS	Solid Precipitation	1025 L01	kg/sq m	Total	1km	Daily
SNODAS	Liquid Precipitation	1025 L00	kg/sq m	Total	1km	Daily
SNODAS	Snow Pack Average Temp	1038	kelvin	Total	1km	Daily

3. CGAT Analyses

3.1 Cell-Based Average/Total

Cell-based averages or totals can be used to develop a baseline value over a temporal range of interest. The cell-based functions calculate the average or total value for each grid cell over the user-defined temporal range of interest.

Depending on the defined time step, either monthly or yearly cell-based calculations will be performed. For monthly time steps, the month of interest must be defined. For each defined time step (month or year) cell-based calculations will be derived across the defined range of years.

It is important to understand specifically what your climatic variable is measuring and what would be an appropriate usage. Keeping this in mind, CGAT performs default cell-based averages or totals as defined by the analysis default field in Table 1. The default cell-based analysis (i.e., average or total) may not be appropriate for your intended usage. If a cell-based analysis other than the default is desired please contact the authors for further direction.

3.2 Percentile Calculation

Cell-based percentile calculations are derived using the average and total data layers from section 3.1. Percentile calculations are referenced against a year (e.g., 2009) or month within a year (e.g., April/2009) as defined by the percentileDate variable. This reference data is then compared against the defined temporal range of interest (e.g., 2000-2009), leading to the calculation of the percentile value.

Output from percentile calculation is a percentile grid for the defined reference year. Percentiles are calculated using the formula below:

$$P_n = \frac{100}{N} \left(n - \frac{1}{2} \right)$$

N = the number values by cell (i.e. the temporal range of interest).

n = rank of N percentile date across all N values ordered from least to greatest. (Least = 1 and greatest = N).

Percentiles are calculated at the monthly or annual time step. Below is an example percentile calculation for an annual time step with a reference year of 2008 between the years 2005-2009: Example data: (73₂₀₀₅, 62₂₀₀₆, 68₂₀₀₇, 72₂₀₀₈, 61₂₀₀₉), in this case the 2008 value of 72 is the 70th percentile between the years of 2005 – 2009.

$$\left(\frac{100}{5}\right)\left(4 - \frac{1}{2}\right) = 70.$$

Next is an example percentile calculation for a monthly time step with a reference month year combo of 200804 (April of 2008) between the years 2005-2009: Example data: (80₂₀₀₅₀₄, 92₂₀₀₆₀₄, 30₂₀₀₇₀₄, 18₂₀₀₈₀₄, 11₂₀₀₉₀₄), in this case the 200804 value of 18 is the 30th percentile between the years of 2005 – 2009.

$$\left(\frac{100}{5}\right)\left(2 - \frac{1}{2}\right) = 30.$$

Note only the month of April is compared across the temporal range of interest, because the percentileDate variable (200804) defined both 2008 and 04 (April) as the year and month of interest.

3.3 Zonal Statistics

The third CGAT analysis performs zonal statistics, which calculates summary statistics for specific areas of interest. Example areas could include fire boundaries, watersheds, park boundaries, etc. Output from zonal statistics is a dbf table with the zonal statistics by zone per monthly or annual data layer for PRISM data, or daily data layer for SNODAS data. Statistical zones are defined by the specified field in either a feature class or grid layer zone dataset. ESRI provides thorough documentation on the zonal statistics method for ArcGIS 9.3 (ESRI, 2010).

4. CGAT Preplanning

Before using CGAT three questions need to be addressed. First it is necessary to determine which climatic variable(s) are best suited to address your climatic question(s) of interest. Secondly, it is critical to determine the desired temporal range of analysis. The temporal range of analysis consists of two factors: the range of years over which the analysis will be performed, and the year of comparison (if performing percentile calculations). Lastly the desired time step (yearly or monthly) for analysis must be defined.

Determining the appropriate temporal range of analysis and time step is subjective and highly dependent upon the user specific question(s) of interest. As an example, Ashton et. al. (2010) used CGAT to perform a percentile analysis on PRISM average maximum temperature, using a yearly time step with a temporal range of analysis defined between 1971 and 2000 in comparison to the year 2009.

4.1 CGAT Software Requirements

CGAT has been designed to run in the Python scripting language <http://www.python.org/>, on a computer with ArcGIS 9.3 or ArcGIS 10 – service pack 1 functionality. CGAT uses a combination of both Python functions and ArcGIS geospatial toolbox functions to process PRISM and SNODAS data. In each of the python scripts (PRISM_MS.py, FunctionsPRISM.py, SNODAS_MS, and FunctionsSNODAS.py) it is necessary to have the correct path to the Spatial Analyst, Conversion and Data Management ArcGIS Toolboxes. By default the CGAT scripts are pointing to “C:/arcgis/ArToolbox/Toolboxes/”. If these toolboxes are located elsewhere, **change and save as appropriate for your computer.**

If processing SNODAS data, it will be necessary to download the command line version of the 7-Zip archive utility. 7-Zip can be downloaded at <http://www.7-zip.org/download.html>.

As an alternative to using the default IDLE python editor, we recommend using PythonWin to edit and run the CGAT scripts. PythonWin is an extension in the pywin32 project package and is downloadable at <http://sourceforge.net/projects/pywin32/>.

5. PRISM Processing

For the PRISM precipitation variable (ppt), a water year total (Oct-Sept) can be calculated in addition to the standard yearly (Jan-Dec) total. For the tmax, tmin and tdmean variables an average value (rather than total) is the default output. For PRISM data zonal statistics are calculated on the average/total grids (section 3.1) as defined by the time step and temporal range of analysis.

5.1 Setting Analysis Parameters

This section discusses the basic workflow for processing PRISM data (Figure 1). The PRISM_MS.py master script and FunctionsPRISM.py scripts are utilized to process PRISM data. After the raw data has been downloaded into a local workspace directory, CGAT analysis parameters will need to be defined in the PRISM_MS.py script.

General Model Parameters:

- workspace - Working directory location, where zipped PRISM data sets are located.
- BeginYear - Beginning year for which the three analysis functions will be performed.
- EndYear - End year for which the three analysis functions will be performed.
- parkExtent - Park Extent or area of analysis in decimal degrees.
- variable - PRISM climatic variable to be processed, (“ppt”|“tmax”|“tmin”|“tdmean”).
- averageType - Defines if ppt variables will be averaged using a water year (Oct-Sept) or standard calendar year (Jan – Dec), (“WaterYear”|“CalendarYear”).
- logFileName - logfile name and path. Note a return code of 1 = success, while a return code of 0 indicates it did not run or an error.
- scratchWorkSpace – Scratch workplace directory, this is used for temporary layer generation.
- timeStep - Defines the temporal time step of interest, this can be set as year or month (“Year”|“Month”). CGAT will calculate monthly or yearly percentile values as defined by timeStep.
- Memory - Switch defining if memory preservation processing is desired (“Yes” | “No”). Default value should be “No”- see appendix for further detail.
- indexFileName – Index file used if memory – windows scheduler processing is selected

Percentile Parameters:

- percentiles - Defines if percentile calculations are desired, (“Yes”|“No”).
- percentileDate – The percentile date of reference, either year (e.g. 2009) or year month (e.g. 200904 for April 2009). This is the time period for which the percentile calculation will be referenced over the defined range of years. For a monthly time step the month of interest is defined by the month given in the percentileDate parameter.

Zonal Statistic Parameters:

- zonal - Defines if zonal statistics are desired, (“Yes”|“No”).
- polygonFile - Path to zonal data set (Polygon or Raster).
- zoneField – Name of field in zonal data set (Polygon file) defining the zones for zonal statistic calculations.

Miscellaneous:

- A processing code of 1 will be returned to the logfile and interactive window in PythonWin after successfully completing each individual function. A return code of 0 signifies failure to successfully complete a function.

An example PRISM_MS.py master script is shown in Figure 2. In this example the precipitation variable is being analyzed for a bounding box of Rocky Mountain National Park between the years of 2000 – 2009. The timeStep is set to *Year* and the percentile date is 2009. A calendar year is being used for the yearly average calculations, and zonal statistics are being calculated.

```

PRISM_MS.py

#####
workspace = "D:\\PRISM\\ppt\\" ## Working Directory Location with PRISM data zip files to be p
BeginYear = [2000] ## Beginning Year for which the range of percentiles calcul
EndYear = [2009] ## End Year for which the range of percentiles calculation
parkExtent = [-105.95, 40.1, -105.41, 40.58] ## Park Extent or area of analysis in Decimal Deg
variable = "ppt" ## PRISM climatic variable to be processed, ("ppt"|"tmax"|"tm
averageType = "calendaryear" ## ("WaterYear"|"CalendarYear") Switch defining if PPT var
logFileName = workspace + "AA_PRISM_logfile.txt" ## Log File for PRISM_MS.py.
scratchWorkSpace = "E:\\workspace\\" ## Scratch Workplace Directory, used for temporary layer
timeStep = "Year" ## ("Year"|"Month") Switch defining the temporal time step o
memory = "yes" ## ("Yes"|"No") Switch defining if memory - windows shedule
indexFileName = workspace + "CGATIndex.txt" ## Index File used for memory - windows scheduler

#####
# Percentile Parameters
#####
percentiles = "Yes" ## Switch defining if percentile calculations are desired, ("Ye
percentileDate = 2009 ## period for which the percentile calculation will be referenced

#####
# Zonal Statistic parameters
#####
zonal = "Yes" ## Switch defining if zonal statistics should be calcul
polygonFile = "E:\\CGAT\\NHD\\NHD192415.mdb\\Basins_4_huc12_wgs72" ## Path to zonal data set (P
zoneField = "HU_12_Name" ## Name of field in zonal data set (Polygon fil

#####
# End of Parameters requiring set up.
#####

```

Figure 2. Example PRISM_MS.py master script and parameters requiring set up.

6. SNODAS Processing

SNODAS data have gaps across space and time, thus a sum calculation is the default. All no data values in SNODAS data (-9999) are reclassified to a value of zero, allowing for correct sum calculation. Because SNODAS data are downloaded at a daily resolution, monthly and yearly values must be calculated.

The SNODAS zonal statistics are derived for all extracted daily files as defined by the temporal range of analysis. SNODAS zonal statistics are derived at the daily level, allowing utilization of the high temporal resolution. SNODAS daily resolution could be very beneficial. For example, a hydrologist may be interested in the daily snow melt (SNODAS code 1044) in a watershed during the spring runoff between March and May. Using the CGAT zonal statistics function in conjunction with SNODAS data, such information can easily be synthesized.

6.1 Setting Analysis Parameters

This section discusses the basic workflow for processing SNODAS data (Figure 1). The SNODAS_MS.py master script and FunctionsSNODAS.py scripts are utilized to process SNODAS data. After the raw data have been downloaded into a workspace directory, CGAT analysis parameters will need to be defined in the SNODAS_MS.py script.

General Model Parameters:

- workspace - Working directory location, where tarred SNODAS data sets are located.
- BeginYear - Beginning year for which the three analysis functions will be performed.
- EndYear - End year for which the three analysis functions will be performed.
- months - List of months to be evaluated [1,2,3,4,5,6,7,8,9,10,11,12].
- days - Range of days to be evaluated [1,31] or [1,15].
- parkExtent - Park Extent or area of analysis in decimal degrees.
- parametercodes - SNODAS climatic variable to be processed ([1025][1034][1036][1038][1039][1044][1050], see Table 1).
- precipType - If parametercode 1025 "Precipitation" it is necessary to define if Solid or Liquid Precipitation ("Solid"|"Liquid"|"Na").
- headerFile - Generic Corrected SNODAS Header File for Continental US, this is required.
- ziptool - Path to the 7zip command line executable (7z.exe).
- logFileName - Logfile name and path. Note a return code of 1 = success, while a return code of 0 indicates it did not run or an error occurred.
- scratchWorkSpace – Scratch workplace directory. This is used for temporary layer generation.
- timeStep – Defines the temporal time step of interest. This can be set as year or month ("Year"|"Month"). If set to year, CGAT calculates yearly average and percentiles. If set to month, CGAT calculates monthly averages and percentiles.
- Switch defining if memory preservation processing is desired ("Yes" | "No"). Default value should be "No"- see appendix for further detail.
- indexFileName – Index file used if memory – windows scheduler processing is selected

Percentile Parameters:

- percentiles - Defines if percentile calculations are desired, (“Yes”|“No”).
- percentileDate – The percentile date of reference, either year (e.g. 2009) or year month (e.g. 200904 for April 2009). This is the time period for which the percentile calculation will be referenced over the defined range of years. For a monthly time step the month of interests is defined by the month give in the percentileDate parameter.

Zonal Statistic Parameters:

- zonal - Defines if zonal statistics are desired, (“Yes”|“No”).
- polygonFile - Path to zonal data set (Raster or Polygon (i.e. shapefile or geodatabase feature class)).
- zoneField – Name of field in zonal data set (Polygon file) defining the zones for zonal statistic calculations.

Miscellaneous:

- A processing code of 1 will be returned to the logfile and interactive window in PythonWin after successfully completing each individual function. A return code of 0 signifies failure to successfully complete a function.

An example SNODAS_MS.py master script is shown in Figure 3. In this example the snow water equivalent (SWE) variable (1034) is analyzed for a bounding box of Rocky Mountain National Park between the years of 2005 – 2010. The timeStep is set to *month*, the percentile date is *201004*, and zonal statistics are being calculated. In this example total SWE for April (04) is calculated for each year between 2005-2010. Additionally, the April 2010 SWE percentile is calculated with reference to all April SWE values between 2005-2010.

```

SNODAS_MS.py

#####
# Start of Parameters requiring set up.
#####
workspace = ("D:\\SNODAS2\\")          ## Working Directory Location with SNODAS data tar
BeginYear = [2005]                    ## Beginning Year for which the range of perc
EndYear = [2010]                      ## End Year for which the range of percentile
months = [4]                          ## List of months to be evaluated [1,2,3,4,5,
days = [1,31]                        ## Range of days to be evaluated [1,31] or [1
parkExtent = [-105.95, 40.1, -105.41, 40.58] ## Park Extent or area of analysis in Decima
parametercodes = [1034]               ## SNODAS climatic variable to be processed (
precipType = "Na"                     ## If parametercode 1025 "Precipitation" define
headerFile = "D:\\SNODAS2\\SNODAS_Header.hdr" ## Generic Corrected SNODAS Header File for
ziptool = "D:\\7zip\\7-Zip\\7z.exe"    ## Path to the 7zip executable
logFileName = workspace + "AA SNODAS_logfile.txt" ## Log File for SNODAS.py
scratchWorkSpace = "E:\\workspace"    ## Scratch Workplace Directory, used for temporary la
timeStep = "Month"                    ## Switch defining the temporal time step of int

#####
# Percentile Parameters
#####
percentiles = "Yes"                   ## Switch defining if percentile calculations are des
percentileDate = 201004                ## The percentile date of reference, either year (e.
                                       ## period for which the percentile calculation will k

#####
# Zonal Statistic parameters
#####
zonal = "Yes"                         ## Switch defining if zonal statistics should
polygonFile = "F:\\NHD192415.mdb\\zones" ## Path to zonal data set (Polygon or Raster).
zoneField = "HU_12_Name"              ## Name of field in zonal data set (F

#####
# End of Parameters requiring set up.
#####

```

Figure 3. Example SNODAS_MS.py master script and parameters requiring set up.

The generic header file which is zipped as part of the CGAT package is a correction header file which is necessary to replace the corrupt header file associated with the SNODAS data downloaded from FTP.

7. Example Output

7.1 PRISM

Ashton et. al. (2010) used CGAT and PRISM data to derive 30 year percentile values for the maximum temperature, minimum temperature and precipitation PRISM variables in a regional study of climatic patterns in and around Glacier National Park. This is an excellent example of how CGAT can be used to inform park managers about regional climatological trends.

We provide two examples of PRISM output for two PRISM analyses for an area encompassing the general region of Rocky Mountain National Park (ROMO). In the first example the annual average minimum temperature (tmin) percentiles for the years 2001-2009 are compared to the tmin values from the previous thirty year period between 1971-2000 (Figure 4).

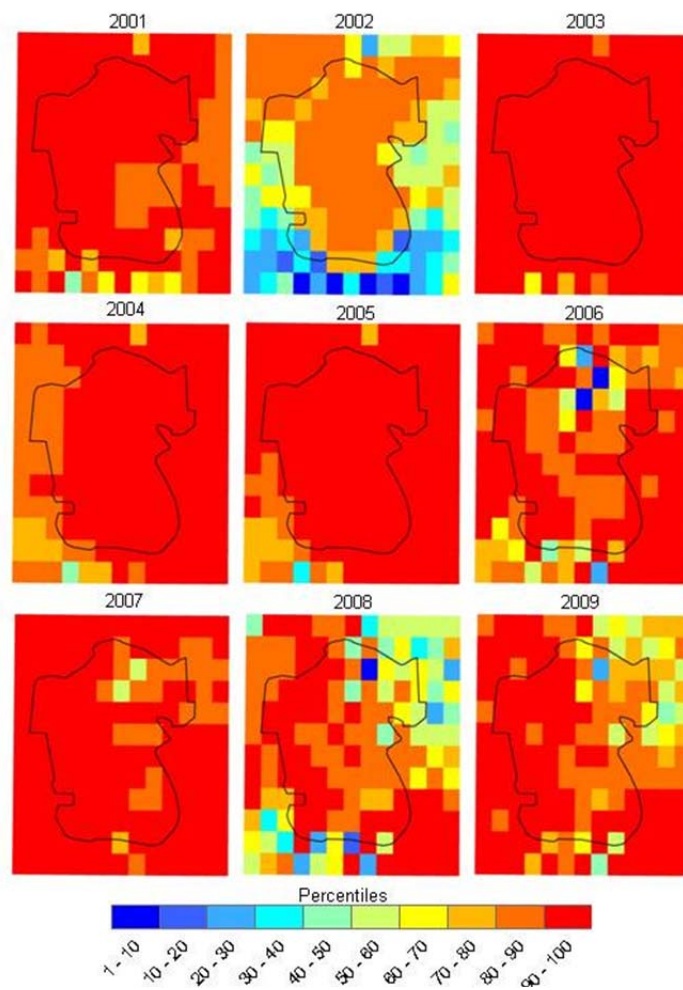


Figure 4. The annual mean minimum temperature (tmin) percentile calculations for each year between 2001-2009 versus the thirty year period between 1971-2000 for ROMO (outline in black).

For this nine year period, a majority of the cells have high percentiles in the 80-100 value range. Following the formula in section 3.2, these high percentile values imply the average yearly minimum temperature was substantially higher for the 2001-2009 years relative to the previous thirty years (1971-2000). In this example evidence of higher annual mean minimum temperatures in recent years relative to longer term climatic averages might help park managers better understand complicated processes and drivers (e.g. increased bark beetle outbreaks due to warmer annual minimum temperatures). Upon seeing a strong relationship of increased annual minimum temperatures, a logical next step might be to evaluate the PRISM data at a finer monthly scale. Analysis at a monthly scale could further provide better understanding of when during the year are the average minimum temperatures higher. In the case of bark beetle outbreaks a park entomologist might specifically be interested in using CGAT to find the average minimum temperature percentiles during the winter months.

Using the CGAT setup parameters given in Figure 2, the map in Figure 5, shows the 2009 annual water year (Oct-Sept) total precipitation percentile values in comparison to the thirty year period between 1980-2009. Additionally using the zonal statistics output, the annual precipitation values for four national hydrology data 12th level hydrological units (HUCs) (NHD 2010) are graphed for the years 1980-2009. In this example the percentile map suggests that annual precipitation totals for 2009 relative to the 1980-2009 period was about average, with some areas having moderately higher total precipitation (50-70 percentiles) and others moderately lower total precipitation (10-30). The annual precipitation graph in figure 5, highlights the inter-annual variability in total precipitation, and the variability by hydrological unit (i.e. elevation, topographic position, windward or leeward position, etc.).

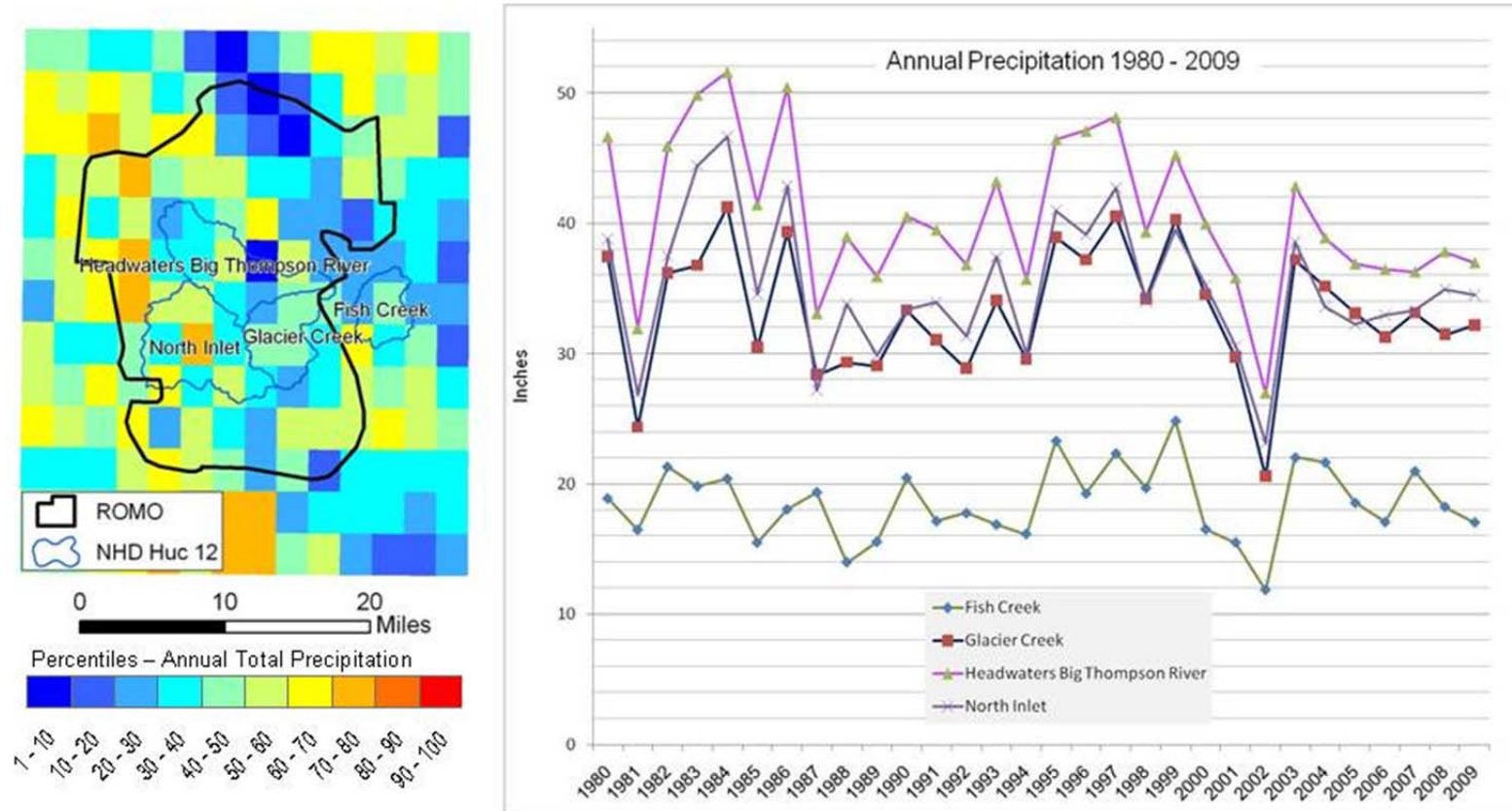


Figure 5. The 2009 annual water year total precipitation percentile values versus the thirty year period between 1980-2009 for ROMO (outline in black). Graph of annual precipitation between 1980 – 2009 for four 12th level NHD hydrological units.

7.2 SNODAS

Below is an example of SNODAS output for the mean daily Snow Water Equivalent values (1034) for four NHD 12th level HUCs (NHD 2010) in and near ROMO, for the month of April between the years of 2005-2010. The daily time step SWE data graphed in Figure 6, allows for the observation of individual weather events. For example, in 2009 across all four HUCs, a mid- April snow storm resulted in large increases in the SWE values.

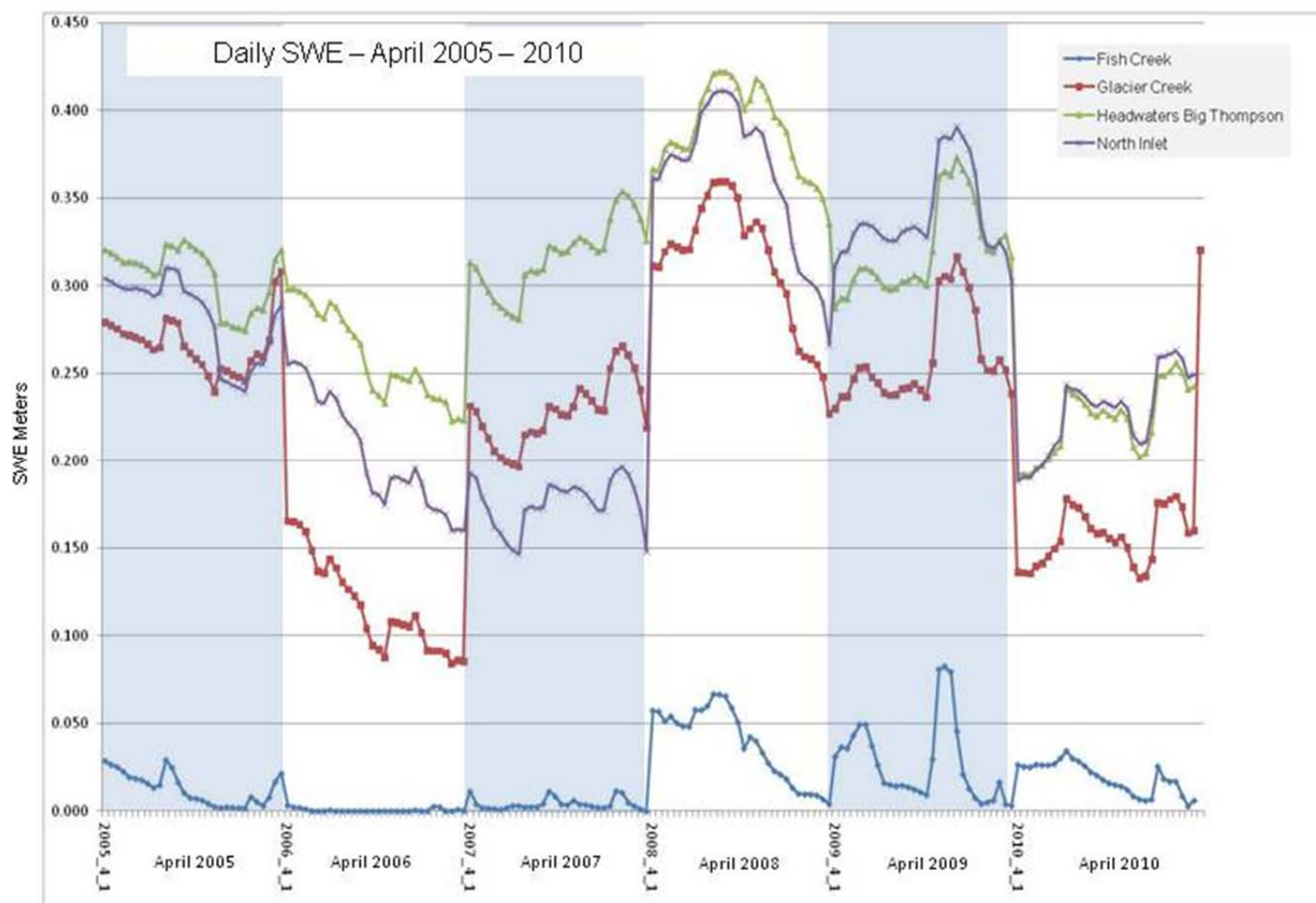


Figure 6. Mean daily snow water equivalent values (1034) for four NHD 12th level HUCs for the month of April between 2005-2010.

Lastly we provide a spatial example for SNODAS output. In Figure 7, the 2009 July, August and September total monthly liquid precipitation percentile values (1025-L01) across the five year period of 2005-2009 are shown. With percentile values predominately in the 50-60 range, the July and August precipitation values can be considered around average. Conversely the total precipitation for August 2009 was low for the same period with nearly all being in the 1-10 percentile value range.

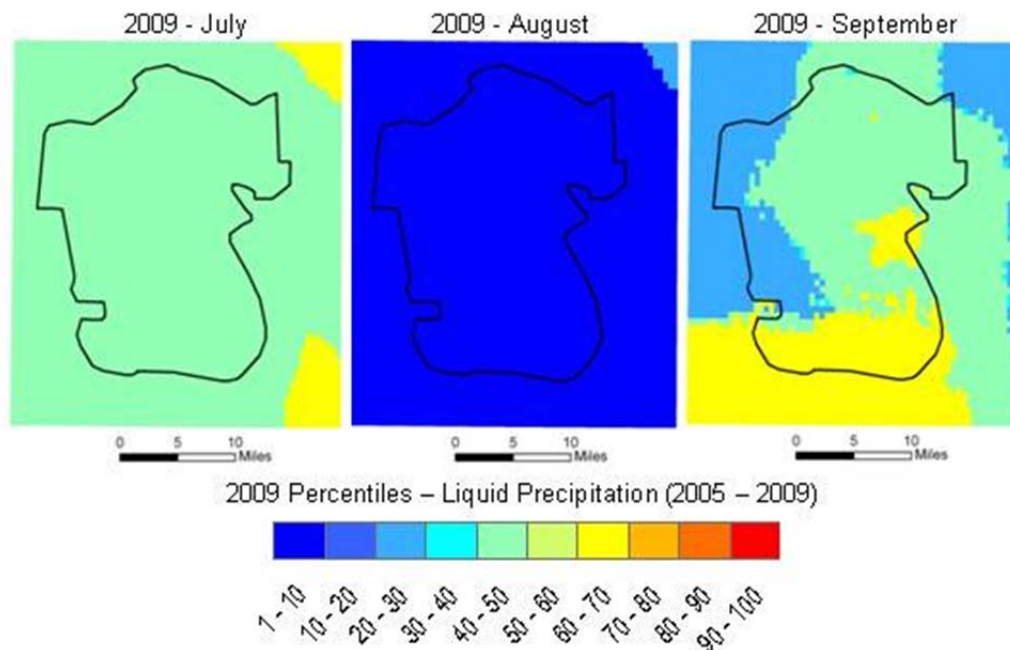


Figure 7. The 2009 July, August and September total monthly liquid precipitation percentile values across the five year period of 2005-2009 for ROMO (outline in black).

8. Literature Cited

Ashton, I. W., L. O'Gan, and K. Sherrill. 2010. Climate Monitoring in Glacier National Park: Annual Report for 2009. Natural Resource Technical Report NPS/ROMN/NRTR—2010/388. National Park Service, Fort Collins, Colorado.

ESRI 2010 (http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=zonal_statistics).

National Operational Hydrologic Remote Sensing Center. *Snow Data Assimilation System (SNODAS) Data Products at NSIDC*. Boulder, Colorado USA: National Snow and Ice Data Center.

NHD 2010. National Hydrography Dataset, USGS, <http://nhd.usgs.gov/data.html>, October, 2010.

PRISM Climate Group, Oregon State University, <http://www.prism.oregonstate.edu/> .

9. Appendix

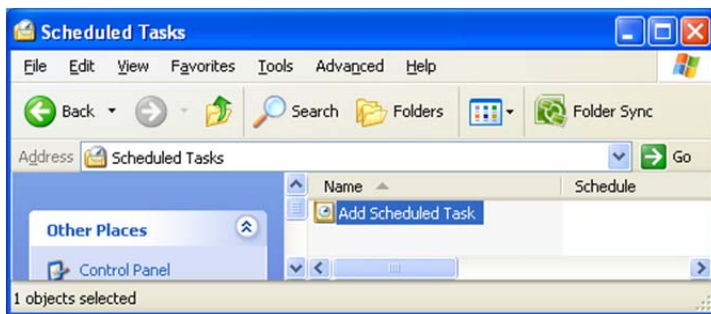
When processing large amounts of climatic data it is possible to encounter memory-related issues resulting from the interaction of the Python interface and the ArcGIS geoprocessing functions. A workaround to this issue has been incorporated in the CGAT scripts. If the “memory” switch is set to “yes”, the CGAT scripts will utilize the windows Scheduled Tasks utility to achieve a work flow which reduces memory usage.

Using an index file and working in conjunction with the windows Scheduled Tasks utility, when the variable “memory” is set to “yes”, the CGAT scripts will perform one function (i.e Extract, Average, Percentiles, and Zonal) at a time and then exit the script. Upon exiting the PRISM or SNODAS script at the next scheduled task interval (e.g.. every 5 minutes) the script will continue on to the next function within the script and then subsequently exit upon completion of this function. In this iterative manner processing of the PRISM or SNODAS data will be performed until all desired functions have been performed.

Outlined below are the steps required to perform CGAT processing in memory preservation mode. In the following example(s) the SNODAS script is being processed in the memory preservation mode, with the windows Scheduled Tasks utility set to run every 5 minutes.

Step 1 – Set up Scheduled Tasks utility in windows. In the windows control panel select, scheduled tasks, then select add scheduled tasks.

Control Panel – Scheduled Tasks – Add Scheduled Task



Appendix Figure 1. Scheduled Tasks

Step 2- work through the Scheduled Task Wizard interface, which has six interface windows shown in Appendix Figure 2.

Window one (App. Fig. 2-I) select- **Next**

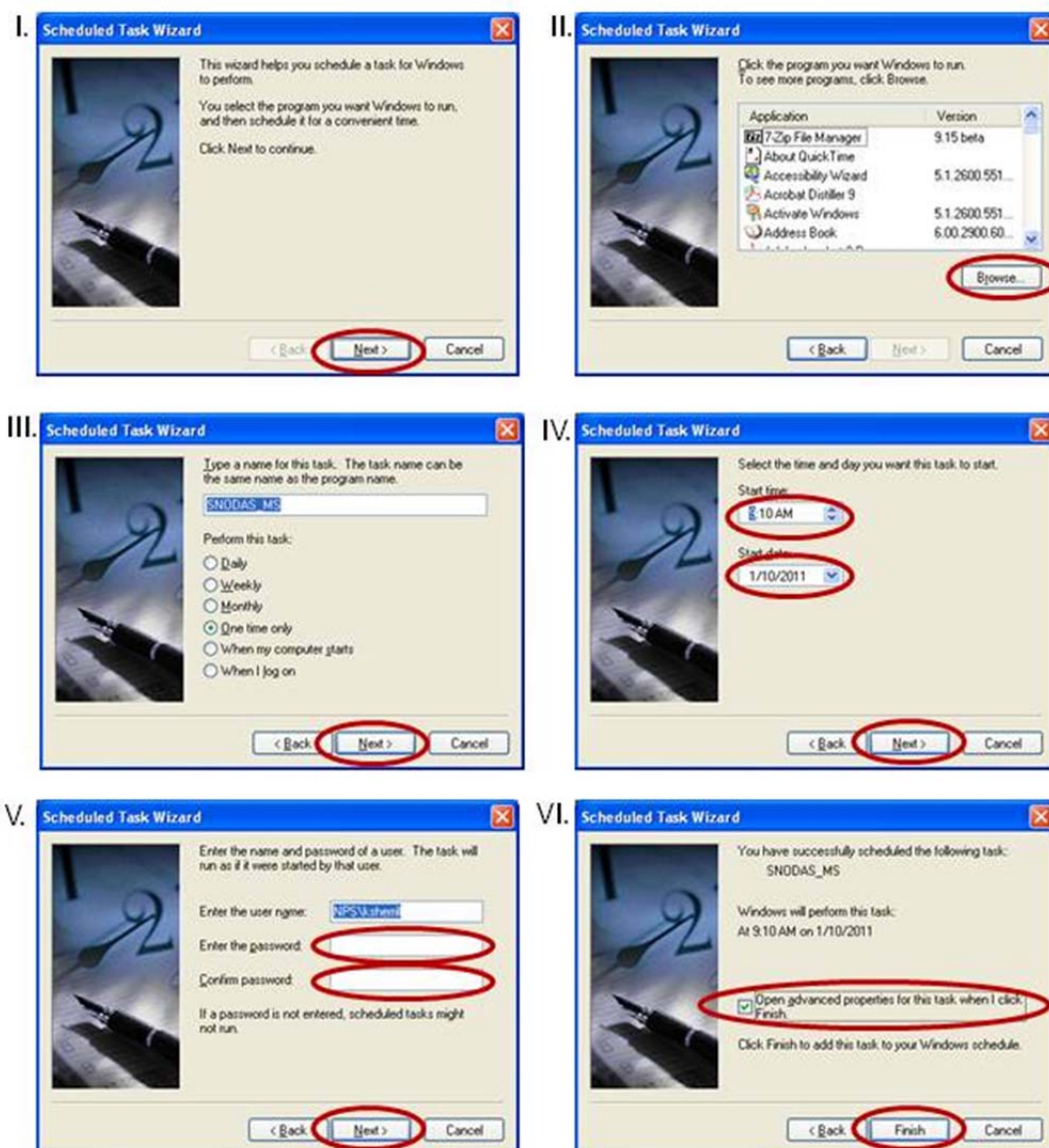
Window two (App. Fig. 2-II) - Select the Browse button and navigate to either the PRISM_MS.py or SNODAS_MS.py script and click open

Window three (App. Fig. 2-III) - Select the desired frequency (One time only is recommended) for the scheduled task to be performed and click **Next**.

Window four (App. Fig. 2-IV) - Set the desired time and date for the scheduler to start – Click **Next**.

Window five (App. Fig. 2-V) - Enter your operating system password then click **Next**

Window six (App. Fig. 2-IV) – **Check** open advanced properties for this task - and then click **Finish**.



Appendix Figure 2. Scheduled Task Wizard Interfaces

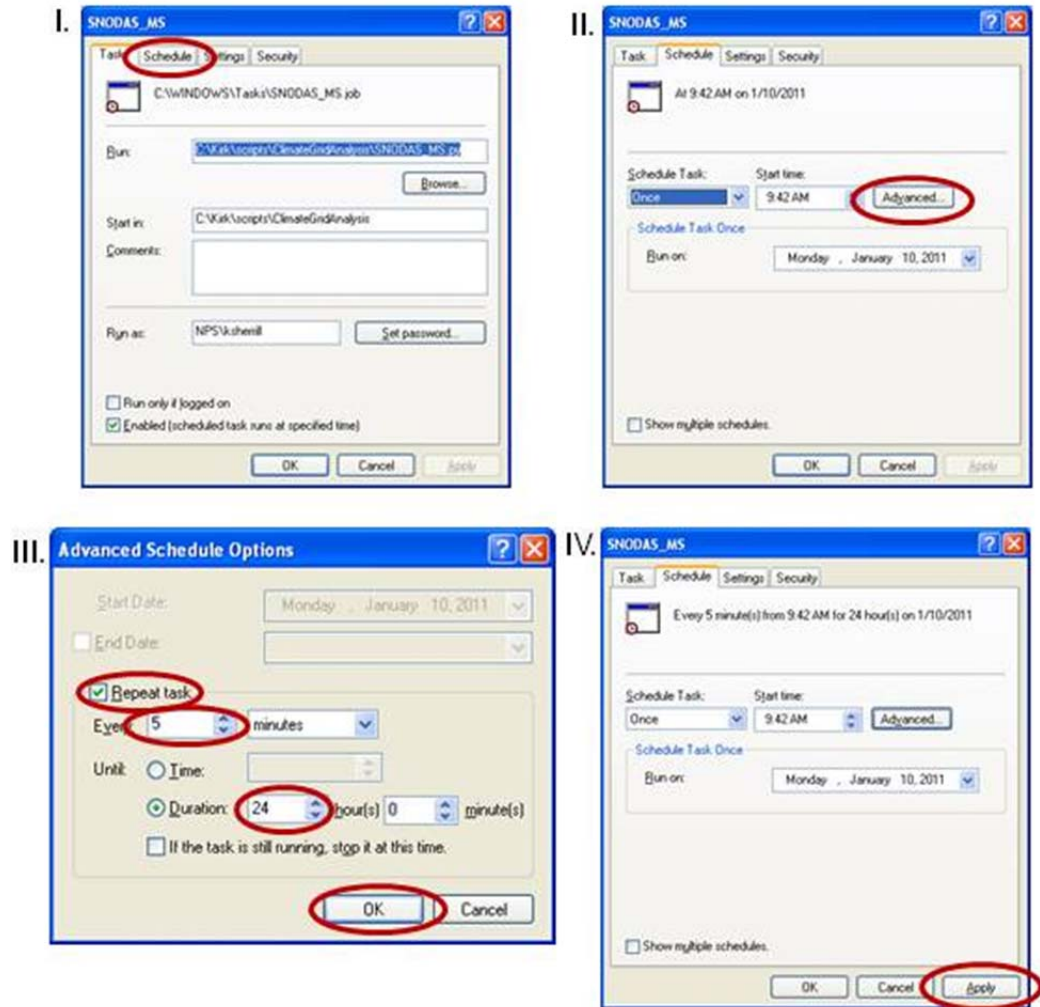
Step 3 requires defining the advanced scheduler properties (Appendix Figure 3), which will open after selecting finish on the Scheduled Task Wizard Interface.

Window one (App. Fig. 3-I) - click on the **Schedule** tab.

Window two (App. Fig. 3-II) - click on the **Advanced** button.

Window three (App. Fig. 3-III) - **Check** Repeat task – define the desired repeat interval (5 minutes in this example) – and set the duration for which the scheduler is allowed to run (24 hours in this example- then click **Ok**.

Window four (App. Fig. 3-IV) – Click **Apply**



Appendix Figure 3. Advanced Schedule Options interface windows.

The advance scheduler properties settings given in this SOP are only examples. The interval between repeating tasks and the duration of the scheduled task should be set as appropriate on a case by case basis. After hitting the apply function the scheduled task will show up in the scheduled tasks window. The SNODAS or PRISM scripts will run at the start time specified in the schedule task wizard.

Note it is necessary for .py file types to be set to open with python when processing in memory preservation mode.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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