Parameterizing Diffuse Proportion & Transmittivity Values Using TMY3 Data Creating Radiation Grids

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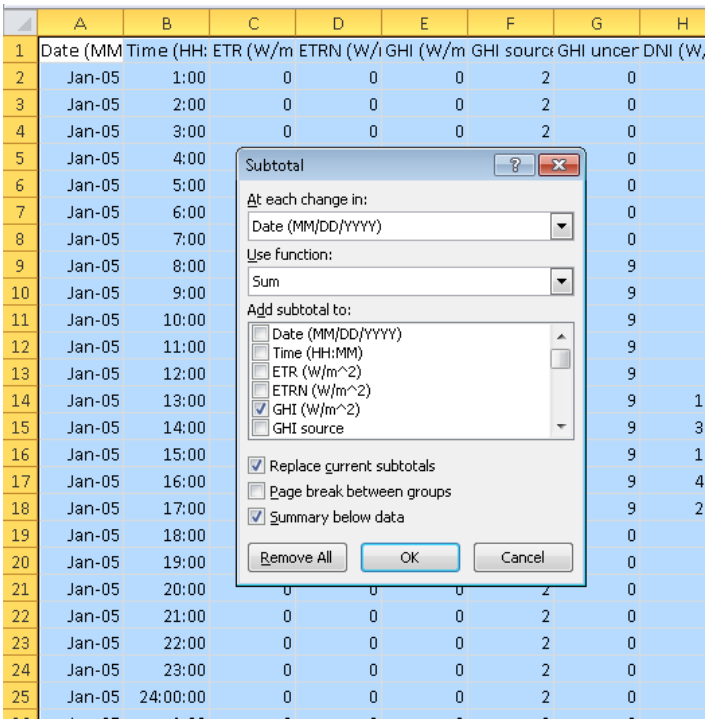
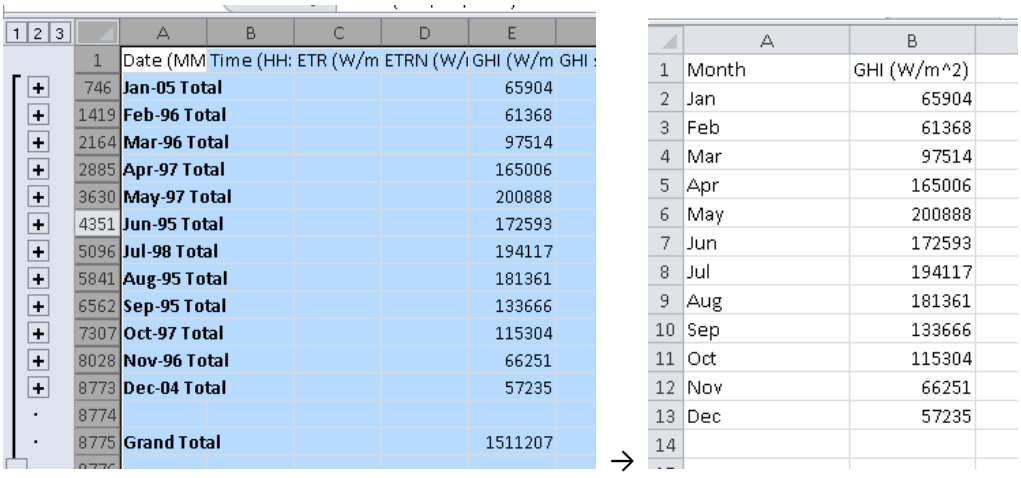
Part I: Obtaining radiation estimates

- Download solar radiation data from the National Solar Radiation Database (http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/)
- Open the downloaded .csv file for the desired site. Save it as an Excel file, including the station name (e.g. Winchester-VA_724053TY.xlsx).
- You will need to copy the latitude and longitude values at a later step. But to keep an "unadulterated copy" of these data, copy everything to a new worksheet.
- In the new worksheet, delete Row 1 (site info), so data column headings become Row 1.
- Format Column A (Date) as Month-Year (i.e., Mar-01)
- Use Data-Subtotals to sum GHI (W/m^2) for each month:



- Collapse the Subtotals, then copy the sums and paste-special (values) to a new worksheet; reformat as necessary:



	A	B	C	D	E
1	Date (MM	Time (HH:	ETR (W/m	ETRN (W/	GHI (W/m	GHI
746	**Jan-05 Total**				65904	
1419	**Feb-96 Total**				61368	
2164	**Mar-96 Total**				97514	
2885	**Apr-97 Total**				165006	
3630	**May-97 Total**				200888	
4351	**Jun-95 Total**				172593	
5096	**Jul-98 Total**				194117	
5841	**Aug-95 Total**				181361	
6562	**Sep-95 Total**				133666	
7307	**Oct-97 Total**				115304	
8028	**Nov-96 Total**				66251	
8773	**Dec-04 Total**				57235	
8774						
8775	**Grand Total**				1511207	

→

	A	B
1	Month	GHI (W/m^2)
2	Jan	65904
3	Feb	61368
4	Mar	97514
5	Apr	165006
6	May	200888
7	Jun	172593
8	Jul	194117
9	Aug	181361
10	Sep	133666
11	Oct	115304
12	Nov	66251
13	Dec	57235
14		

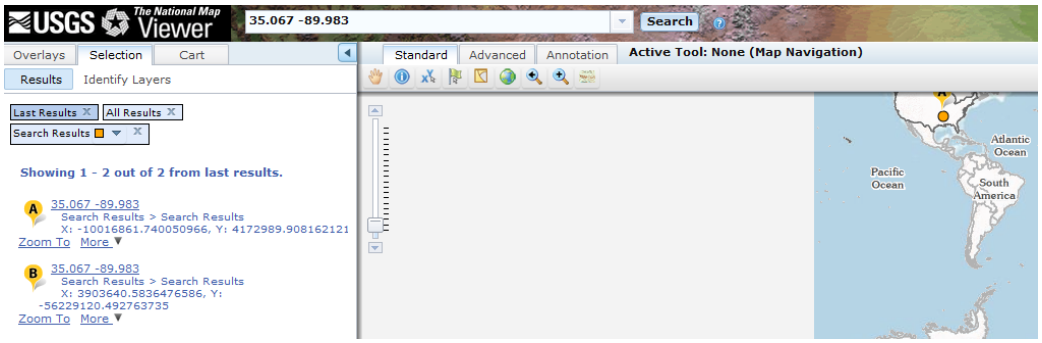
- Open “Best_D-T_Computations.xlsx”
    - Copy-and paste-special (transpose) the GHI monthly sums into this new spreadsheet (cells C2-N2). Also copy latitude & longitude values from the site info in the original worksheet you downloaded:

	A	B	C	D	E	F	G	H	I	J	K	L	M
1			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
2	(Wh/m2)	Enter GHI (TMY3) -->	65904	61368	97514	165006	200888	172593	194117	181361	133666	115304	66251
3	Latitude	Longitude											
4	39.15	-78.15											
5	Below:	ArcGIS Solar values											
6	D	T	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
7	0.2	0.3											
8	0.2	0.4											
9	0.2	0.5											
10	0.2	0.6											

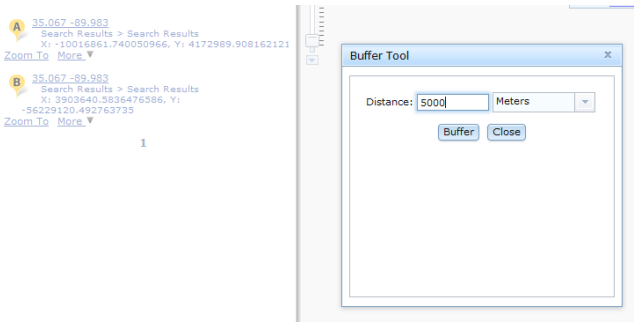
Part II: Getting ready to run ArcGIS Solar Radiation tool on each TMY3 site.

Step 1: Download the DEM for each TMY3 point from The National Map: http://viewer.nationalmap.gov/viewer/

- Enter the Latitude & Longitude coordinates for the TMY3 site, then Search.



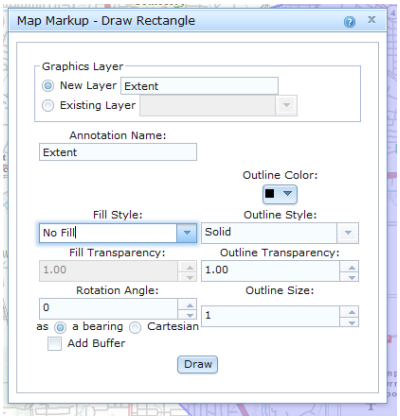
- Click on the “More” link for the correct location, then select Buffer. Enter 5000 meters, then click “Buffer.”



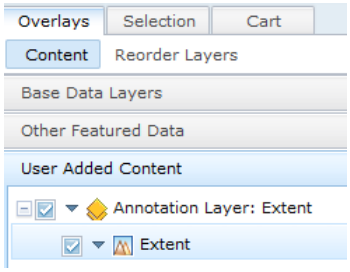
- Click on the “Zoom To” button for the correct location. You will see the Circular Buffer.
- At the top of the map, click on the Annotation tab, then the Draw Rectangle icon:

- Draw a rectangle circumscribing the Buffer Circle by holding down, then releasing the left mouse key. (It doesn’t need to be perfect.)

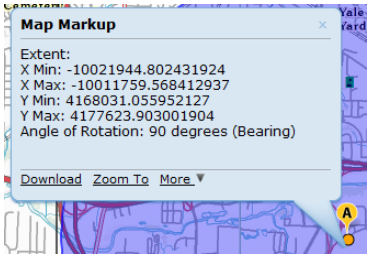
- Enter “Extent” for “New Layer” and “Annotation Name.” [Optional: set Fill Style to “No Fill.”] Click “Draw.”



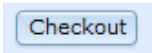
- Under “User Added Content” in the left pane (Overlays – Content), click on the + sign. Then click on the graphic (mountains) next to “Extent” annotation name.



- Click on the Download link:



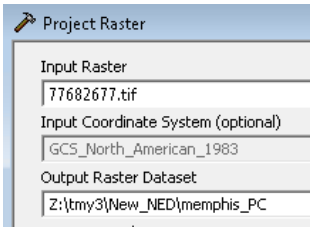
- Select Elevation, then hit Next: 

- If available, select NED 1/3 (or 1/9) arc second, “Dynamic” (not Staged) Type, and hit Next.
- Click on Checkout 

, enter your e-mail, and Place Order. You will be e-mailed a download link.
- Download the Zipped file, ideally changing its name to the city name (e.g., Memphis.zip)

Step 2: Project the downloaded DEM from “Geographic Coordinate System” (GCS) to a meter-based grid (“World Plate Carree” in this example)

- After unzipping the DEM, add it to ArcGIS
- ArcToolbox: Data Management Tools – Projections and Transformations – Raster – Project Raster. Save the new raster, with a descriptive name that ends with “PC.” (Grid names have to be <13 characters, no spaces.)



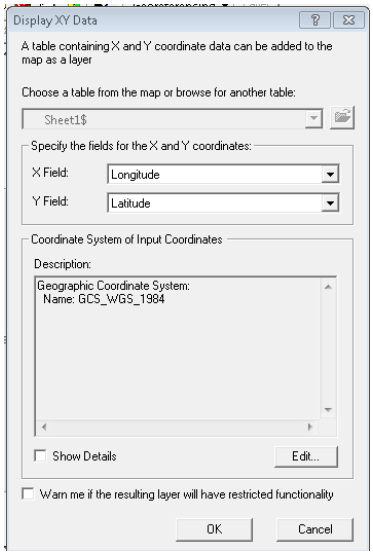
- For Output Coordinate System:
    - "Select" – Projected Coordinate Systems – World – Plate Carree (world)
- Geographic Transformation:
    - NAD_1983_To_WGS_1984_5 (appropriate for the US)
- Resampling Technique:
    - BILINEAR (**Important!**)
- Then hit "OK"

Step 3: Create a point shapefile for your TMY3 site:

- Create a spreadsheet with column headings for site name, latitude, and longitude (available in your downloaded TMY3 file). Save the file in Excel 97-2003 (*.xls) format, then close.

	A	B	C	D	E	F
1	USAF	Site	State	Latitude	Longitude	
2	724053	WINCHESTER RGNL	VA	39.15	-78.15	
3						

- Add this newly-created Excel worksheet to ArcGIS, right-click on it, and "Display XY Data" (specifying WGS 1984 as coordinate system):



- This will create a new "Events" layer in your Table of Contents, that will need to be saved as a shapefile: Right-click on its name, then Data – Export Data. Add the new shapefile to your project.
- Change its coordinate system to match the DEM (Plate Carree): *Data Management Tools – Projections and Transformations – Features – Project*. Add the newly-projected point shapefile to your project.

Step 4: Running ArcGIS Solar Radiation tool. This part of the analysis determines the values of monthly D & T that best match actual "GHI" radiation values downloaded earlier. (Nearly) "all possible combinations" of D & T are run, and the best match selected.

Note: In the example below, I run permutations of D (0.2 – 0.7) and T (0.3 – 0.7), i.e., 30 possible combinations. These combinations make sense for the humid eastern United States. In actuality, I have only seen these 21 combinations selected as "best" for eastern U.S. sites:

- D2T5, D2T6, D2T7
- D3T4, D3T5, D3T6, D3T7
- D4T4, D4T5, D4T6, D4T7
- D5T4, D5T5, D5T6
- D6T3, D6T4, D6T5, D6T6
- D7T3, D7T4, D7T5

In other environments (e.g., arid, or high elevation), other values may be more appropriate.

- In ArcGIS Toolbox, go to *Spatial Analyst Tools – Solar Radiation*, then RIGHT-CLICK on "Points Solar Radiation" and select "Batch."

Use default values except for the following:

- Input Raster = study area's DEM (e.g., Memphis_PC)
- Input Points Feature = point shapefile of solar radiation collection site (e.g., Memphis_PC*.shp*)
- Output global radiation feature = "*name*_D#T#" (where D#T# are the particular values of diffuse proportion and transmittivity under investigation, e.g., Memphis_D2T3.shp).
- Latitude = value in attribute table of point shapefile.
- Sky size = 512
- **Time configuration: Whole year with monthly interval**
  - Year: *1985* (really any year that is not a leap year)
- Create outputs for each interval: **Change to true**. (type over the default "false.")
- Slope and Aspect input type = FLAT_SURFACE (since solar collectors are horizontal)
- Azimuth divisions = 16
- Diffuse Proportion – *Value being tested as part of "all possible combinations" (e.g. 0.2 → 0.7)*
- Transmittivity – *Value being tested as part of "all possible combinations" (e.g. 0.3 → 0.7)*

Setting up the "batch" processing:

- Using example above, there are 30 combinations of D&T to run, so hit the "Add Row" (+) button 29 times.
- Right-click on the first row's entry (the ones you changed) for each column, and select "fill." This copies the first row's value for all 30 rows.
- For the "Output global radiation features" you will need to change the rows:
  - …D2T3
  - …D2T4
  - …D2T5
  - …D2T6
  - …D2T7
  - …D3T3 When you change the D value, right-click on the entry and "fill" again
  - …D3T4 etc.

- You will also need to change the "D values" and "T values" to match the "Output features" name
    - Fill the "0.3" value for the Transmittivity column
    - Then change rows so that they alternate:
        - 0.3
        - 0.4
        - 0.5
        - 0.6
        - 0.7
        - 0.3 etc.
    - When the "T" row goes back to 0.3, increase the "D" value (e.g. 0.2 → 0.3), then "fill."
- Hi "OK"

Part III: Detemining "Best" Diffuse Proportion and Transmittivity Values

- If necessary, open "Best_D-T_Computations.xlsx"
- Click the "open" file icon, and navigate to the folder containing the "D#T#" shapefiles created in the previous step. Select "dBase Files (*.dbf)" as the type of file to open (not "All Excel Files").
- Highlight each"D#T#" dbf file and open.
- Copy the "T0-T11" values, close the spreadsheet, and paste the values into the appropriate row of the "Best_D-T_Computations.xlsx" spreadsheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	(Wh/m2)	Enter GHI (TMY3) -->	65904	61368	97514	165006	200888	172593	194117	181361	133666	115304	66251	5723
3	Latitude	Longitude												
4	39.15	-78.15												
5	Below:	ArcGIS Solar values												
6	D	T	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
22	0.5	0.3												
23	0.5	0.4												
24	0.5	0.5												
25	0.5	0.6												
26	0.5	0.7												
27	0.6	0.3												
28	0.6	0.4												
29	0.6	0.5												
30	0.6	0.6												
31	0.6	0.7												
32	0.7	0.3												
33	0.7	0.4												
34	0.7	0.5												
35	0.7	0.6												
36	0.7	0.7	221550	264859	405120	495459	588643	579636	583650	545096	445665	321558	233136	19805

- At the bottom of the spreadsheet, the "best" D & T values are automatically computed, as well as the percentage difference compared to the TMY3 value for each month. These are the monthly values to run for your entire study area.

Part IV

Once monthly D & T parameters are obtained for the study area, Solar Radiation can be run on the entire grid:

You will be using the same DEM grids used when running Solar Radiation for Points.

<u>General reminders about using grids in ArcGIS</u>:

- Grid names should be ≤13 characters, begin with a letter, and there should be no spaces in grid names or folder names (such as …\Documents and Settings\)
- You won't be able to delete or rename grids if they have been open in the current session of ArcMap.
- Estimates of radiation computed with the Solar Radiation Toolset are in Wh/m^2

The Solar Radiation Toolset allows the user to compute solar radiation grids for each month in the year, or for a single month. Both options are described below. In terms of time to run the program, initial investigations suggests that Option 1 is faster if two or more months have the same D & T values, whereas Option 2 is faster if only one month has a particular D & T combination.

Option 1 – "Whole year with monthly interval"

This method will create one grid for each month for the particular D/T combination (e.g., DEM01_3_5_c0, DEM01 _3_5_c1, …, DEM01_3_5_c11 – Note that month "0" is January, and month "11" is December). For D/T combinations that are needed for multiple months, this might be the best approach – to create twelve monthly grids, even though all twelve won't be retained for further analysis.

In ArcToolbox: Spatial Analyst Tools – Solar Radiation – **Area** Solar Radiation.

Use default values except for the following:

- Input Raster = study area's DEM (e.g., DEM01)
- Output global radiation raster = "*DEM01*_D_T" (where D_T are the values of diffuse proportion and transmittivity determined from Part I, e.g. "DEM01_3_5")
- Latitude = latitude of the site (to two decimal places if possible)
- **Time configuration: Whole year with monthly interval**
  - Year: *1985*
  - Be sure to check "Output for each interval"

Topographic Parameters

No changes; use default "slope and aspect from DEM"

Radiation Parameters

- Azimuth division = 16
- Diffuse Proportion – *As determined for each month from Part I*
- Transmittivity – *As determined for each month from Part I*

You'll need to run Solar Radiation for each combination of D/T (from Part I) for the study area.

Option 2 – "Multiple days in a year"

For D/T combinations that are only needed for one month, it might be faster to create only that one grid.

In ArcToolbox: Spatial Analyst Tools – Solar Radiation – **Area** Solar Radiation.

Use default values except for the following:

- Input Raster = study area's DEM (e.g., DEM01)
- Output global radiation raster = "*name*_D_T" (where D_T are the values of diffuse proportion and transmittivity determined from Part I, e.g. "DEM01_3_5")
- Latitude = latitude of the site (to two decimal places if possible)

- **Time configuration: Multiple Days in a Year**
  - Year: *1985*
  - Use two calendars to select first & last days of the month for start/end dates. NOTE: Midnight represents the start/stop time for each specified day. Therefore, the "end date" for a particular month should be the first day of the next month.

Jan	1-32
Feb	32-60
Mar	60-91
Apr	91-121
May	121-152
Jun	152-182
Jul	182-213
Aug	213-244
Sep	244-274
Oct	274-305
Nov	305-335
Dec	335-365

  - Do not check "Output for each interval"

Topographic Parameters (same as Option 1)
No changes; use default "slope and aspect from DEM"

Radiation Parameters (same as Option 1)

- Azimuth division = 16
- Diffuse Proportion – *As determined for each month from Part I*
- Transmittivity – *As determined for each month from Part I*

You'll need to run Solar Radiation for each combination of D/T for that particular site.

File Maintenance

After Solar Radiation is finished running, use ArcCatalog to rename those grids that you wish to keep. Instead of the D/T combination in the name, it will be more helpful to have the particular month indicated: "DEM01_3_5_c8" (for September) can be renamed "DEM01_09." Note that the Solar Radiation tool will have named the grids it created starting with "c0" for January (e.g., DEM01_3_5_c0). So in renaming them, grid c0 = month 01, c1 = 02 … c11 = 12. After renaming the "keeper" grids, you can delete the D/T grids for months that you do not need. (Just be sure before you delete!)

If you used "Option 2" (only creating a grid for a single month), there will not be a "c##" extension on the grid name. Since there is no month designation at all with the name (e.g. DEM01_5_6), it is imperative that you use ArcCatalog to change its name before you "forget" what the grid represents (e.g., DEM01_02 for February's grid).