Projecting agro-hydrological outcomes using the "APEXgraze (Agricultural Policy/Environmental eXtender Graze) Model" and various climate scenarios from Global Circulation Models

UTA USDA-ARS Program

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Project Objectives

- Create projections of agricultural watersheds utilizing a calibrated APEXgraze model and various climate scenarios suggested by the Intergovernmental Panel on Climate Change (IPCC)

- Investigate the impacts of grazing activities on grasslands and croplands under different climate scenarios

- Develop and refine post processing the results from APEXgraze

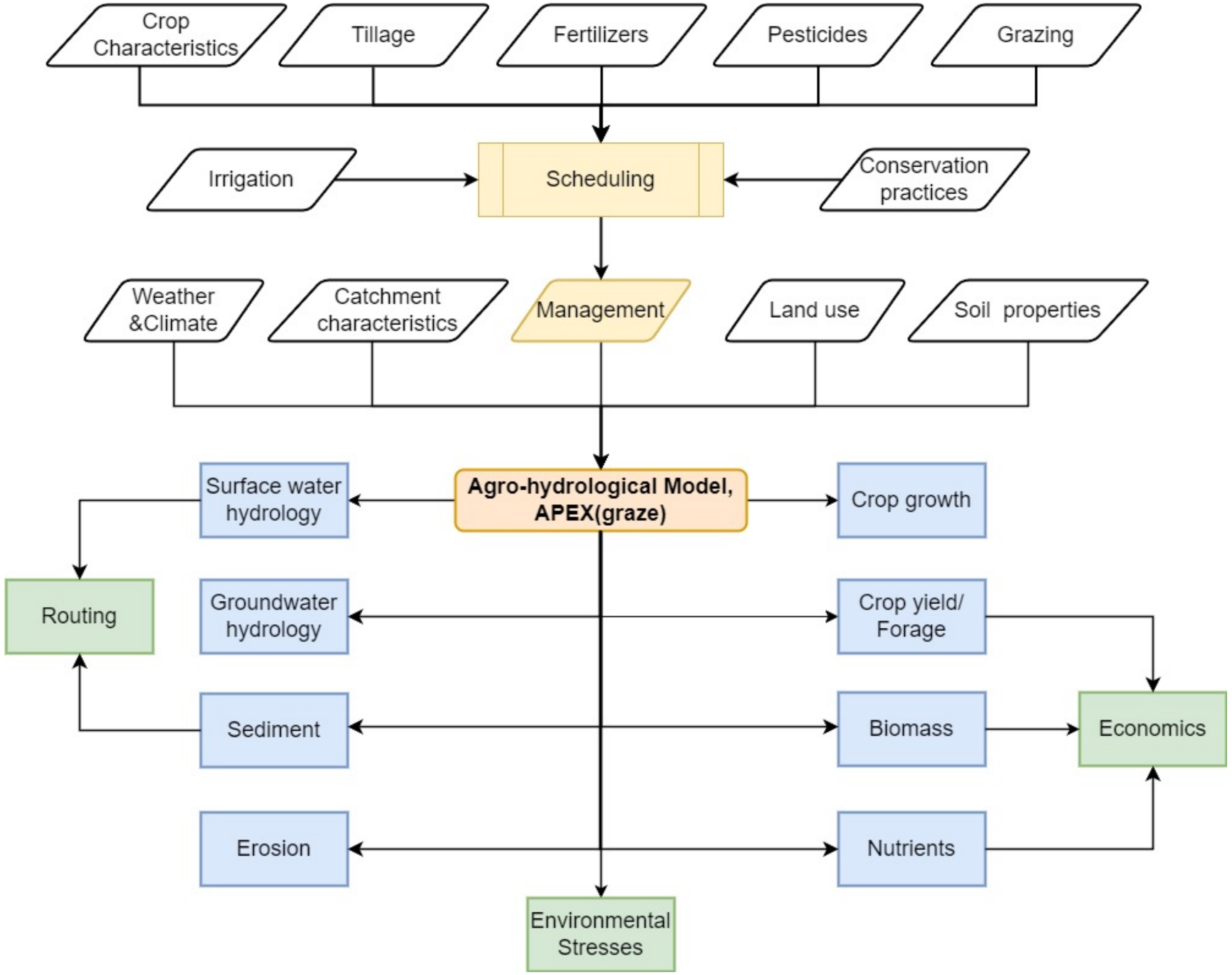
APEX

- Agricultural Policy/Environmental Extender (APEX): an agro-hydrological model
  - Process-Based Model
    - Can perform long-term, continuous simulations
  - Originally written in Fortran with pyAPEX companion scripts more recently developed
    - pyAPEX is used to feed input parameters and post-processing of the model

APEXgraze

- APEXgraze is a modified APEX model with grazing modules and grazing databases

- Aids in land management systems:
  - Better understanding of grazing impacts
  - Suggests sustainable agricultural practices under different climate scenarios
  - Platform for future research



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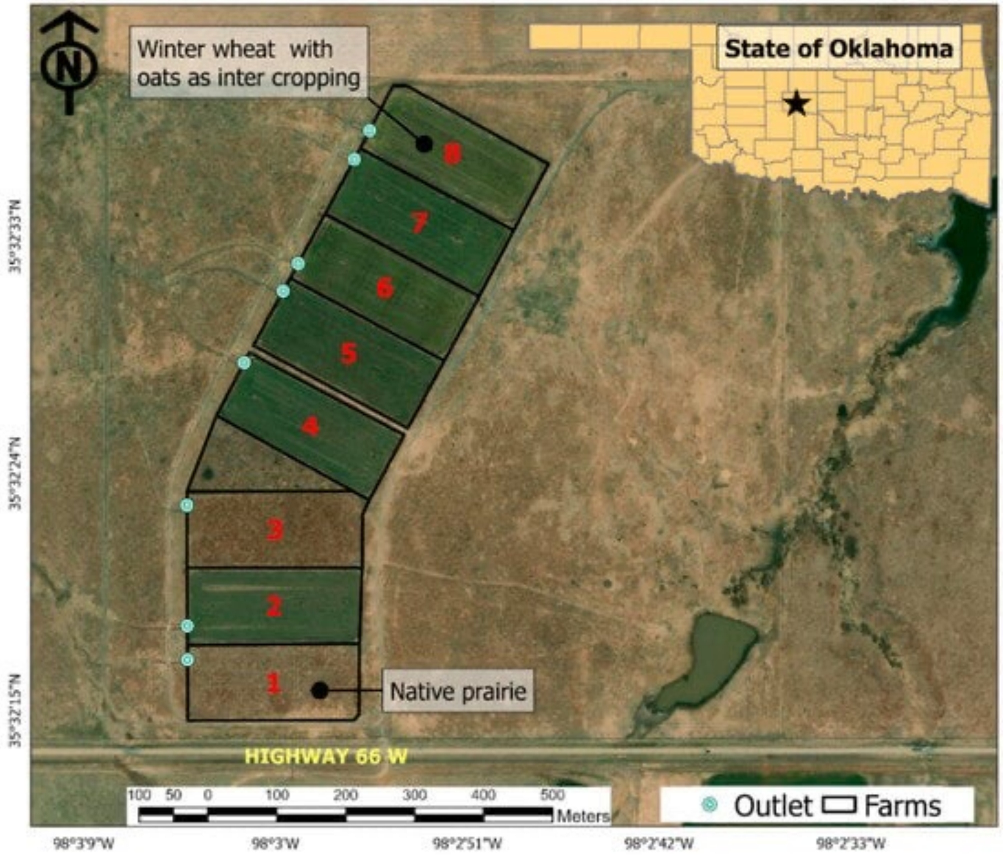
Background

- Sampling Site: USDA-ARS Oklahoma and Central Plains Agricultural Research Center
  - Eight Water Resource and Erosion (WRE) watersheds established to measure precipitation and surface runoff quality and quantity
    - Focused on two watersheds: a) grass land with native prairie and b) cropland with winter wheat and one season of oats.
    - Both these watersheds were grazed
  - Located near El Reno, OK
  - Data collected from 1977-1999

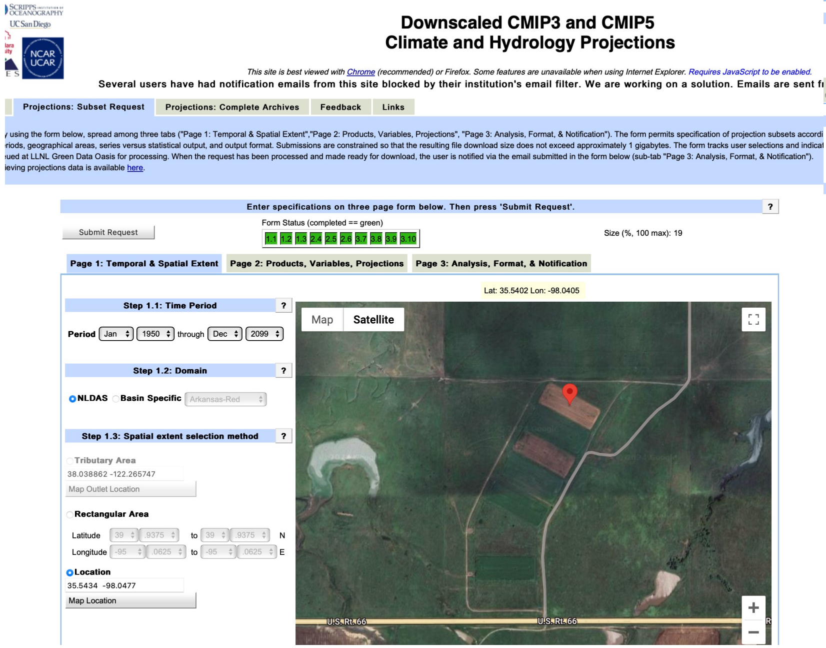


How to Run the APEXgraze Model:

- Collect Global Circulation Model Data from IPCC reports (climate projection data)
- Convert .CSV files to .DLY (APEX readable format)
- Concatenate climate, historical, and projection data into one .DLY file
- Adjust the model's reading parameters
- Run the model using concatenated .DLY file

Running the APEXgraze Model:

- Collect GCM Data from IPCC reports (climate projection data)



Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

This site is best viewed with Chrome (recommended) or Firefox. Some features are unavailable when using Internet Explorer. Requires JavaScript to be enabled.

Several users have had notification emails from this site blocked by their institution's email filter. We are working on a solution. Emails are sent fr

y using the form below, spread among three tabs ("Page 1: Temporal & Spatial Extent","Page 2: Products, Variables, Projections", "Page 3: Analysis, Format, & Notification"). The form permits specification of projection subsets accordi
riods, geographical areas, series versus statistical output, and output format. Submissions are constrained so that the resulting file download size does not exceed approximately 1 gigabytes. The form tracks user selections and indicat
ued at LLNL Green Data Oasis for processing. When the request has been processed and made ready for download, the user is notified via the email submitted in the form below (sub-tab "Page 3: Analysis, Format, & Notification").
ieving projections data is available here.

Enter specifications on three page form below. Then press 'Submit Request'.

Form Status (completed == green): 1.1 1.2 1.3 2.4 2.5 2.6 3.7 3.8 3.9 3.10

Size (%, 100 max): 19

Submit Request
Page 1: Temporal & Spatial Extent
Page 2: Products, Variables, Projections
Page 3: Analysis, Format, & Notification

Step 1.1: Time Period

Period Jan 1950 through Dec 2099

Step 1.2: Domain

● NLDAS ○ Basin Specific Arkansas-Red

Step 1.3: Spatial extent selection method

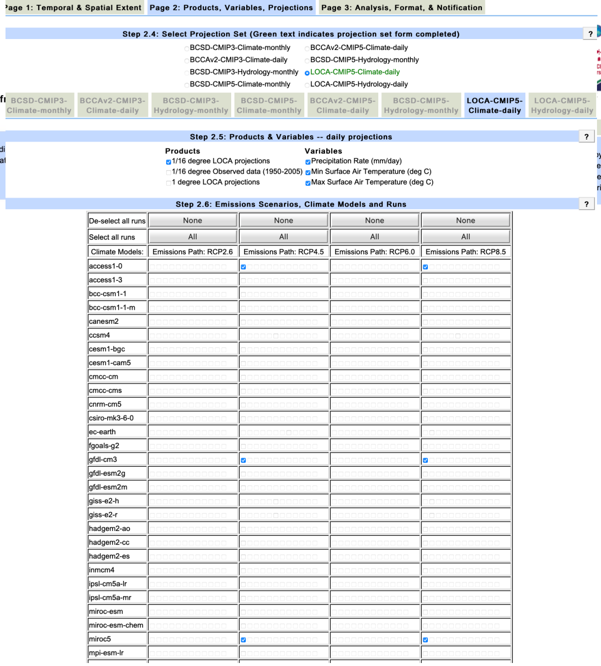
○ Tributary Area
38.038862 -122.265747
Map Outlet Location

○ Rectangular Area
Latitude 39 .9375 to 39 .9375 N
Longitude -95 .0625 to -95 .0625 E

● Location
35.5434 -98.0477
Map Location

Lat: 35.5402 Lon: -98.0405

Map
Satellite
U.S. Rt. 66
U.S. Rt. 66



Page 1: Temporal & Spatial Extent
Page 2: Products, Variables, Projections
Page 3: Analysis, Format, & Notification

Step 2.4: Select Projection Set (Green text indicates projection set form completed)

○ BCSD-CMIP3-Climate-monthly
○ BCCAv2-CMIP3-Climate-daily
○ BCSD-CMIP3-Hydrology-monthly
○ BCSD-CMIP5-Climate-monthly
○ BCCAv2-CMIP5-Climate-daily
○ BCSD-CMIP5-Hydrology-monthly
● LOCA-CMIP5-Climate-daily
○ LOCA-CMIP5-Hydrology-daily

BCSD-CMIP3-Climate-monthly
BCCAv2-CMIP3-Climate-daily
BCSD-CMIP3-Hydrology-monthly
BCSD-CMIP5-Climate-monthly
BCCAv2-CMIP5-Climate-daily
BCSD-CMIP5-Hydrology-monthly
LOCA-CMIP5-Climate-daily
LOCA-CMIP5-Hydrology-daily

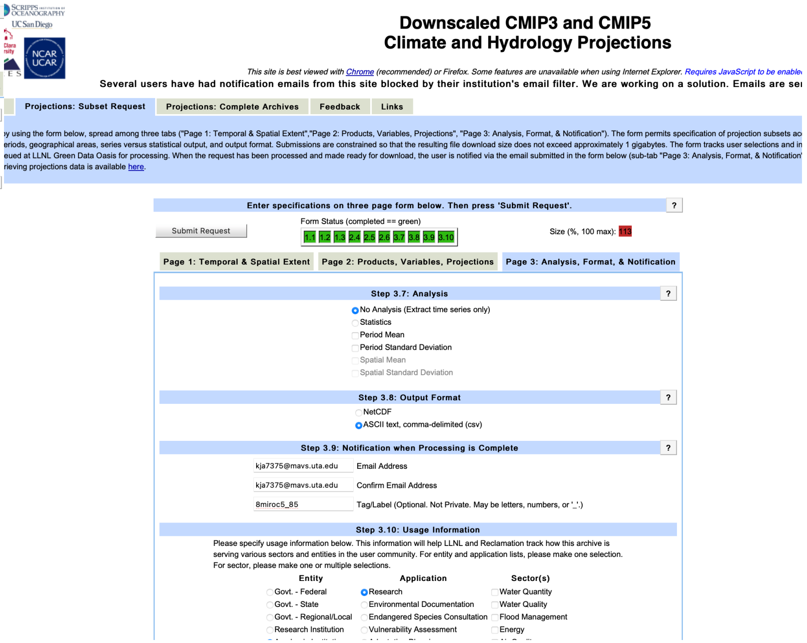
Step 2.5: Products & Variables -- daily projections

Products
☑ 1/16 degree LOCA projections
☐ 1/16 degree Observed data (1950-2005)
☐ 1 degree LOCA projections

Variables
☑ Precipitation Rate (mm/day)
☑ Min Surface Air Temperature (deg C)
☑ Max Surface Air Temperature (deg C)

Step 2.6: Emissions Scenarios, Climate Models and Runs

De-select all runs	None	None	None	None
Select all runs	All	All	All	All
Climate Models:	Emissions Path: RCP2.6	Emissions Path: RCP4.5	Emissions Path: RCP6.0	Emissions Path: RCP8.5
access1-0		☑		☑
access1-3				
bcc-csm1-1				
bcc-csm1-1-m				
canesm2				
ccsm4				
cesm1-bgc				
cesm1-cam5				
cmcc-cm				
cmcc-cms				
cnrm-cm5				
csiro-mk3-6-0				
ec-earth				
fgoals-g2				
gfdl-cm3		☑		☑
gfdl-esm2g				
gfdl-esm2m				
giss-e2-h				
giss-e2-r				
hadgem2-ao				
hadgem2-cc				
hadgem2-es				
inmcm4				
ipsl-cm5a-lr				
ipsl-cm5a-mr				
miroc-esm				
miroc-esm-chem				
miroc5		☑		☑
mpi-esm-lr				



Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

This site is best viewed with Chrome (recommended) or Firefox. Some features are unavailable when using Internet Explorer. Requires JavaScript to be enable

Several users have had notification emails from this site blocked by their institution's email filter. We are working on a solution. Emails are se

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eriods, geographical areas, series versus statistical output, and output format. Submissions are constrained so that the resulting file download size does not exceed approximately 1 gigabytes. The form tracks user selections and in
eued at LLNL Green Data Oasis for processing. When the request has been processed and made ready for download, the user is notified via the email submitted in the form below (sub-tab "Page 3: Analysis, Format, & Notification"
rieving projections data is available here.

Enter specifications on three page form below. Then press 'Submit Request'.

Form Status (completed == green): 1.1 1.2 1.3 2.4 2.5 2.6 3.7 3.8 3.9 3.10

Size (%, 100 max): 113

Step 3.7: Analysis

● No Analysis (Extract time series only)
○ Statistics
☐ Period Mean
☐ Period Standard Deviation
☐ Spatial Mean
☐ Spatial Standard Deviation

Step 3.8: Output Format

○ NetCDF
● ASCII text, comma-delimited (csv)

Step 3.9: Notification when Processing is Complete

kja7375@mavs.uta.edu Email Address
kja7375@mavs.uta.edu Confirm Email Address
8miroc5_85 Tag/Label (Optional. Not Private. May be letters, numbers, or '_'.)

Step 3.10: Usage Information

Please specify usage information below. This information will help LLNL and Reclamation track how this archive is serving various sectors and entities in the user community. For entity and application lists, please make one selection. For sector, please make one or multiple selections.

Entity	Application	Sector(s)
○ Govt. - Federal	● Research	☐ Water Quantity
○ Govt. - State	○ Environmental Documentation	☐ Water Quality
○ Govt. - Regional/Local	○ Endangered Species Consultation	☐ Flood Management
○ Research Institution	○ Vulnerability Assessment	☐ Energy

- Time Period: Jan. 1st 1950 to Dec. 31st 2099

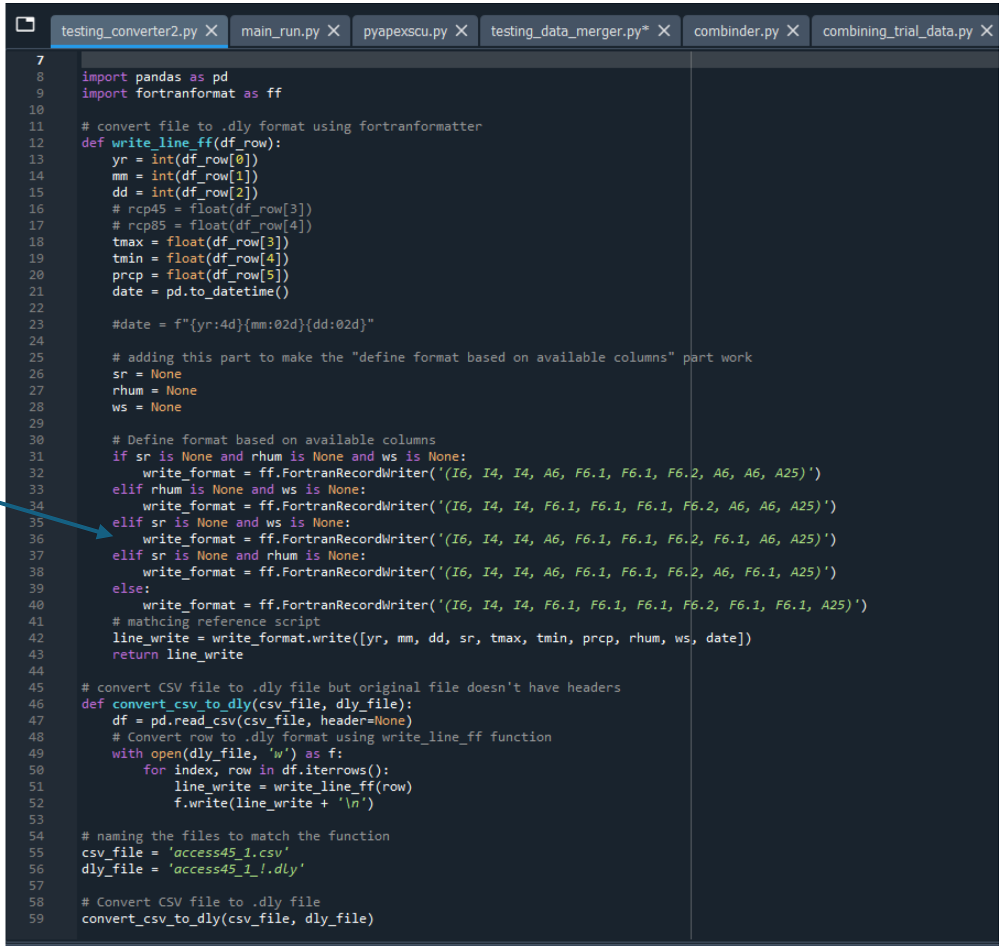
- Access1 4.5 & 8.5
- GFDL-cm3 4.5 & 8.5
- Miroc5 4.5 & 8.5

- Temperature Max, Temperature Min, and Precipitation

Running the APEXgraze Model:

- Convert .CSV files to .DLY

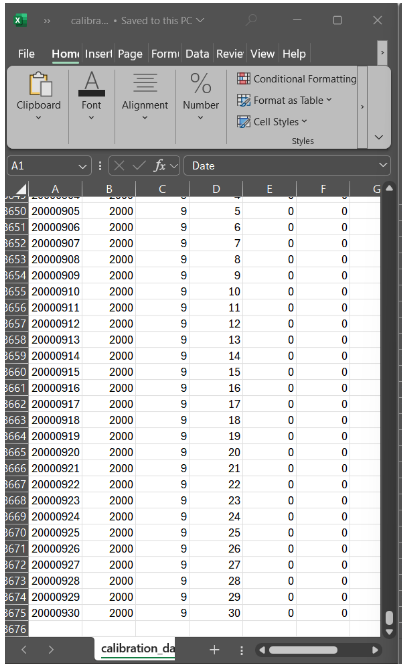
Spacing data using FortranFormatter



```python

import pandas as pd
import fortranformat as ff

# convert file to .dly format using fortranformatter
def write_line_ff(df_row):
    yr = int(df_row[0])
    mm = int(df_row[1])
    dd = int(df_row[2])
    # rcp45 = float(df_row[3])
    # rcp85 = float(df_row[4])
    tmax = float(df_row[3])
    tmin = float(df_row[4])
    prcp = float(df_row[5])
    date = pd.to_datetime()

    #date = f"{yr:4d}{mm:02d}{dd:02d}"

    # adding this part to make the "define format based on available columns" part work
    sr = None
    rhum = None
    ws = None

    # Define format based on available columns
    if sr is None and rhum is None and ws is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, A6, F6.1, F6.1, F6.2, A6, A6, A25)')
    elif rhum is None and ws is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, F6.1, F6.1, F6.1, F6.2, A6, A6, A25)')
    elif sr is None and ws is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, A6, F6.1, F6.1, F6.2, F6.1, A6, A25)')
    elif sr is None and rhum is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, A6, F6.1, F6.1, F6.2, A6, F6.1, A25)')
    else:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, F6.1, F6.1, F6.1, F6.2, F6.1, F6.1, A25)')
    # mathcing reference script
    line_write = write_format.write([yr, mm, dd, sr, tmax, tmin, prcp, rhum, ws, date])
    return line_write

# convert CSV file to .dly file but original file doesn't have headers
def convert_csv_to_dly(csv_file, dly_file):
    df = pd.read_csv(csv_file, header=None)
    # Convert row to .dly format using write_line_ff function
    with open(dly_file, 'w') as f:
        for index, row in df.iterrows():
            line_write = write_line_ff(row)
            f.write(line_write + '\n')

# naming the files to match the function
csv_file = 'access45_1.csv'
dly_file = 'access45_1_!.dly'

# Convert CSV file to .dly file
convert_csv_to_dly(csv_file, dly_file)
```

Running the APEXgraze Model:

- Concatenate historical and projection data using dates provided from calibration data into one .DLY file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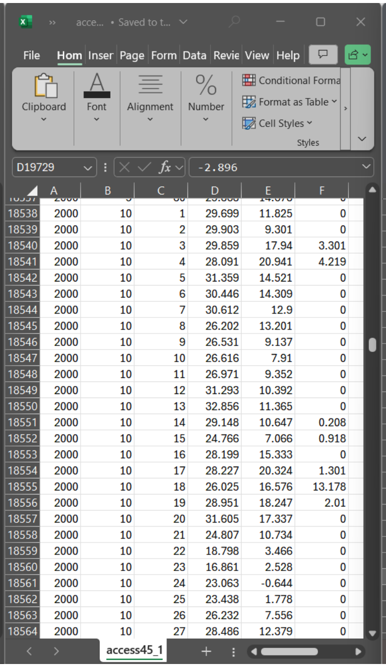
calibration_da

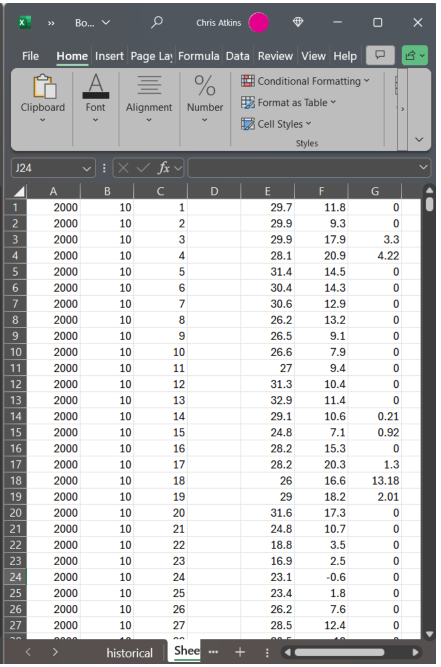
A1 | Date

	A	B	C	D	E	F	G
3650	20000905	2000	9	5	0	0	
3651	20000906	2000	9	6	0	0	
3652	20000907	2000	9	7	0	0	
3653	20000908	2000	9	8	0	0	
3654	20000909	2000	9	9	0	0	
3655	20000910	2000	9	10	0	0	
3656	20000911	2000	9	11	0	0	
3657	20000912	2000	9	12	0	0	
3658	20000913	2000	9	13	0	0	
3659	20000914	2000	9	14	0	0	
3660	20000915	2000	9	15	0	0	
3661	20000916	2000	9	16	0	0	
3662	20000917	2000	9	17	0	0	
3663	20000918	2000	9	18	0	0	
3664	20000919	2000	9	19	0	0	
3665	20000920	2000	9	20	0	0	
3666	20000921	2000	9	21	0	0	
3667	20000922	2000	9	22	0	0	
3668	20000923	2000	9	23	0	0	
3669	20000924	2000	9	24	0	0	
3670	20000925	2000	9	25	0	0	
3671	20000926	2000	9	26	0	0	
3672	20000927	2000	9	27	0	0	
3673	20000928	2000	9	28	0	0	
3674	20000929	2000	9	29	0	0	
3675	20000930	2000	9	30	0	0	
3676							



D19729 | -2.896

	A	B	C	D	E	F
18538	2000	10	1	29.699	11.825	0
18539	2000	10	2	29.903	9.301	0
18540	2000	10	3	29.859	17.94	3.301
18541	2000	10	4	28.091	20.941	4.219
18542	2000	10	5	31.359	14.521	0
18543	2000	10	6	30.446	14.309	0
18544	2000	10	7	30.612	12.9	0
18545	2000	10	8	26.202	13.201	0
18546	2000	10	9	26.531	9.137	0
18547	2000	10	10	26.616	7.91	0
18548	2000	10	11	26.971	9.352	0
18549	2000	10	12	31.293	10.392	0
18550	2000	10	13	32.856	11.365	0
18551	2000	10	14	29.148	10.647	0.208
18552	2000	10	15	24.766	7.066	0.918
18553	2000	10	16	28.199	15.333	0
18554	2000	10	17	28.227	20.324	1.301
18555	2000	10	18	26.025	16.576	13.178
18556	2000	10	19	28.951	18.247	2.01
18557	2000	10	20	31.605	17.337	0
18558	2000	10	21	24.807	10.734	0
18559	2000	10	22	18.798	3.466	0
18560	2000	10	23	16.861	2.528	0
18561	2000	10	24	23.063	-0.644	0
18562	2000	10	25	23.438	1.778	0
18563	2000	10	26	26.232	7.556	0
18564	2000	10	27	28.486	12.379	0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historical
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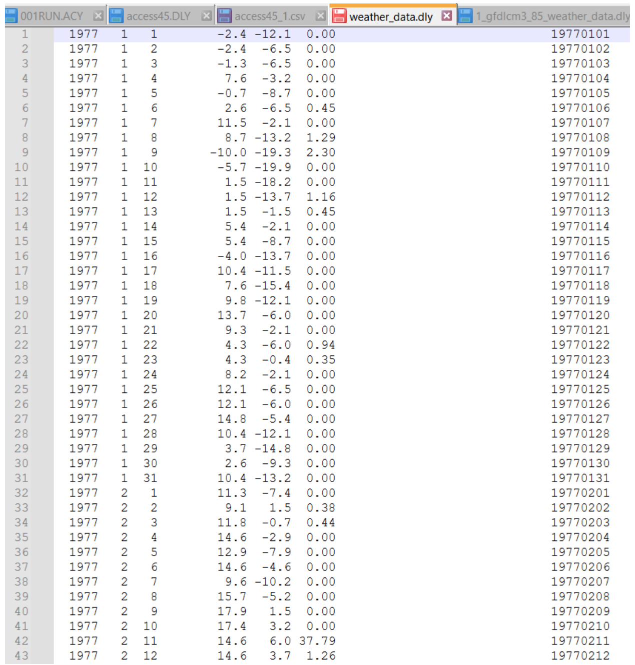
J24

	A	B	C	D	E	F	G
1	2000	10	1		29.7	11.8	0
2	2000	10	2		29.9	9.3	0
3	2000	10	3		29.9	17.9	3.3
4	2000	10	4		28.1	20.9	4.22
5	2000	10	5		31.4	14.5	0
6	2000	10	6		30.4	14.3	0
7	2000	10	7		30.6	12.9	0
8	2000	10	8		26.2	13.2	0
9	2000	10	9		26.5	9.1	0
10	2000	10	10		26.6	7.9	0
11	2000	10	11		27	9.4	0
12	2000	10	12		31.3	10.4	0
13	2000	10	13		32.9	11.4	0
14	2000	10	14		29.1	10.6	0.21
15	2000	10	15		24.8	7.1	0.92
16	2000	10	16		28.2	15.3	0
17	2000	10	17		28.2	20.3	1.3
18	2000	10	18		26	16.6	13.18
19	2000	10	19		29	18.2	2.01
20	2000	10	20		31.6	17.3	0
21	2000	10	21		24.8	10.7	0
22	2000	10	22		18.8	3.5	0
23	2000	10	23		16.9	2.5	0
24	2000	10	24		23.1	-0.6	0
25	2000	10	25		23.4	1.8	0
26	2000	10	26		26.2	7.6	0
27	2000	10	27		28.5	12.4	0



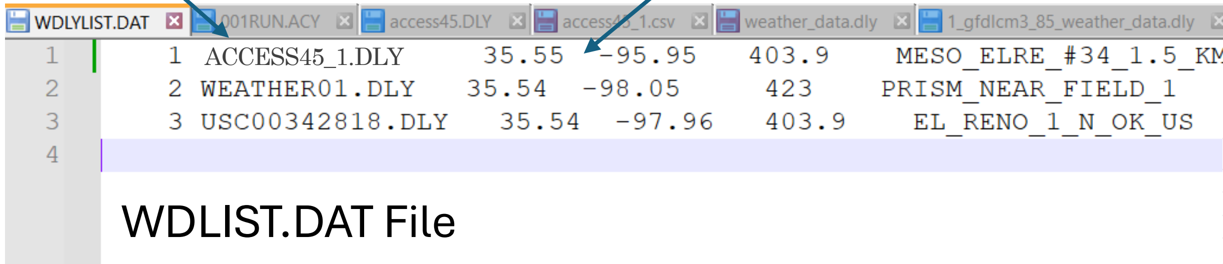
```
 1977   1   1       -2.4 -12.1  0.00                            19770101
 1977   1   2       -2.4  -6.5  0.00                            19770102
 1977   1   3       -1.3  -6.5  0.00                            19770103
 1977   1   4        7.6  -3.2  0.00                            19770104
 1977   1   5       -0.7  -8.7  0.00                            19770105
 1977   1   6        2.6  -6.5  0.45                            19770106
 1977   1   7       11.5  -2.1  0.00                            19770107
 1977   1   8        8.7 -13.2  1.29                            19770108
 1977   1   9      -10.0 -19.3  2.30                            19770109
 1977   1  10       -5.7 -19.9  0.00                            19770110
 1977   1  11        1.5 -18.2  0.00                            19770111
 1977   1  12        1.5 -13.7  1.16                            19770112
 1977   1  13        1.5  -1.5  0.45                            19770113
 1977   1  14        5.4  -2.1  0.00                            19770114
 1977   1  15        5.4  -8.7  0.00                            19770115
 1977   1  16       -4.0 -13.7  0.00                            19770116
 1977   1  17       10.4 -11.5  0.00                            19770117
 1977   1  18        7.6 -15.4  0.00                            19770118
 1977   1  19        9.8 -12.1  0.00                            19770119
 1977   1  20       13.7  -6.0  0.00                            19770120
 1977   1  21        9.3  -2.1  0.00                            19770121
 1977   1  22        4.3  -6.0  0.94                            19770122
 1977   1  23        4.3  -0.4  0.35                            19770123
 1977   1  24        8.2  -2.1  0.00                            19770124
 1977   1  25       12.1  -6.5  0.00                            19770125
 1977   1  26       12.1  -6.0  0.00                            19770126
 1977   1  27       14.8  -5.4  0.00                            19770127
 1977   1  28       10.4 -12.1  0.00                            19770128
 1977   1  29        3.7 -14.8  0.00                            19770129
 1977   1  30        2.6  -9.3  0.00                            19770130
 1977   1  31       10.4 -13.2  0.00                            19770131
 1977   2   1       11.3  -7.4  0.00                            19770201
 1977   2   2        9.1   1.5  0.38                            19770202
 1977   2   3       11.8  -0.7  0.44                            19770203
 1977   2   4       14.6  -2.9  0.00                            19770204
 1977   2   5       12.9  -7.9  0.00                            19770205
 1977   2   6       14.6  -4.6  0.00                            19770206
 1977   2   7        9.6 -10.2  0.00                            19770207
 1977   2   8       15.7  -5.2  0.00                            19770208
 1977   2   9       17.9   1.5  0.00                            19770209
 1977   2  10       17.4   3.2  0.00                            19770210
 1977   2  11       14.6   6.0 37.79                            19770211
 1977   2  12       14.6   3.7  1.26                            19770212
```

Running the APEXgraze Model:

- Adjust the model’s reading parameters

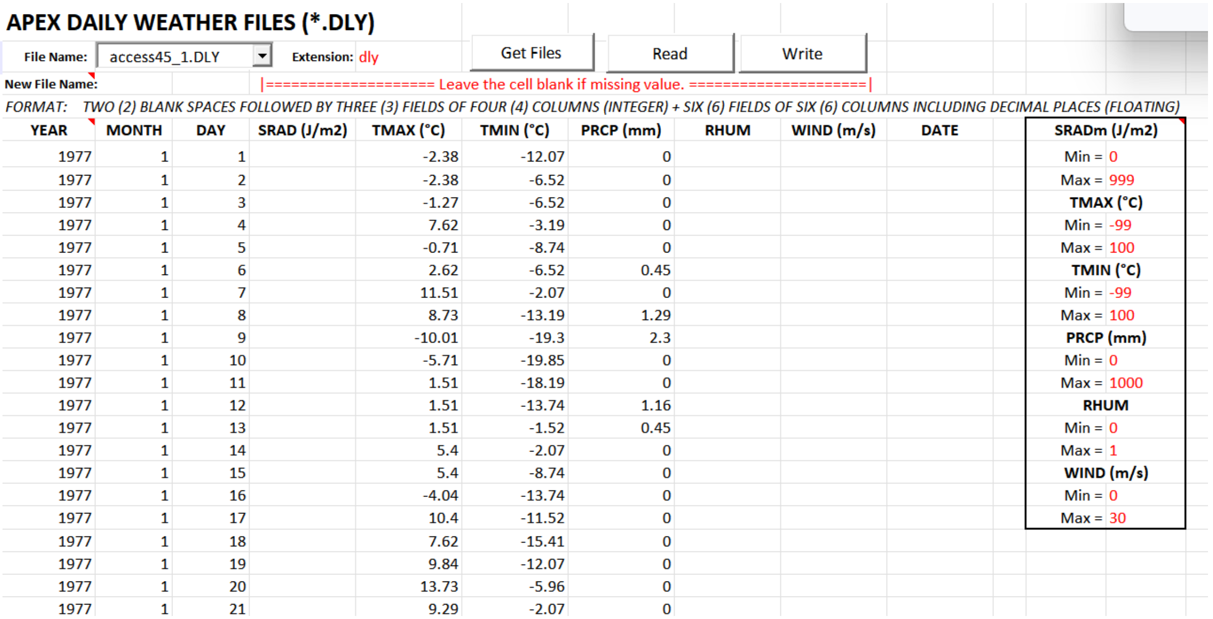
Concatenated File

Watershed Coordinates


WDLYLIST.DAT
001RUN.ACY
access45.DLY
access45_1.csv
weather_data.dly
1_gfdlcm3_85_weather_data.dly
1_access1_45_weather_data_automated.dly

```
   1  ACCESS45_1.DLY      35.55   -95.95     403.9     MESO_ELRE_#34_1.5_KM_NOTH-EAST_OF_WRE
   2 WEATHER01.DLY    35.54   -98.05      423    PRISM_NEAR_FIELD_1
   3 USC00342818.DLY    35.54   -97.96     403.9     EL_RENO_1_N_OK_US
```

WDLIST.DAT File



APEX DAILY WEATHER FILES (*.DLY)

File Name: access45_1.DLY   Extension: dly

New File Name:

|==================== Leave the cell blank if missing value. =====================|

FORMAT: TWO (2) BLANK SPACES FOLLOWED BY THREE (3) FIELDS OF FOUR (4) COLUMNS (INTEGER) + SIX (6) FIELDS OF SIX (6) COLUMNS INCLUDING DECIMAL PLACES (FLOATING)

YEAR	MONTH	DAY	SRAD (J/m2)	TMAX (°C)	TMIN (°C)	PRCP (mm)	RHUM	WIND (m/s)	DATE
1977	1	1		-2.38	-12.07	0			
1977	1	2		-2.38	-6.52	0			
1977	1	3		-1.27	-6.52	0			
1977	1	4		7.62	-3.19	0			
1977	1	5		-0.71	-8.74	0			
1977	1	6		2.62	-6.52	0.45			
1977	1	7		11.51	-2.07	0			
1977	1	8		8.73	-13.19	1.29			
1977	1	9		-10.01	-19.3	2.3			
1977	1	10		-5.71	-19.85	0			
1977	1	11		1.51	-18.19	0			
1977	1	12		1.51	-13.74	1.16			
1977	1	13		1.51	-1.52	0.45			
1977	1	14		5.4	-2.07	0			
1977	1	15		5.4	-8.74	0			
1977	1	16		-4.04	-13.74	0			
1977	1	17		10.4	-11.52	0			
1977	1	18		7.62	-15.41	0			
1977	1	19		9.84	-12.07	0			
1977	1	20		13.73	-5.96	0			
1977	1	21		9.29	-2.07	0			

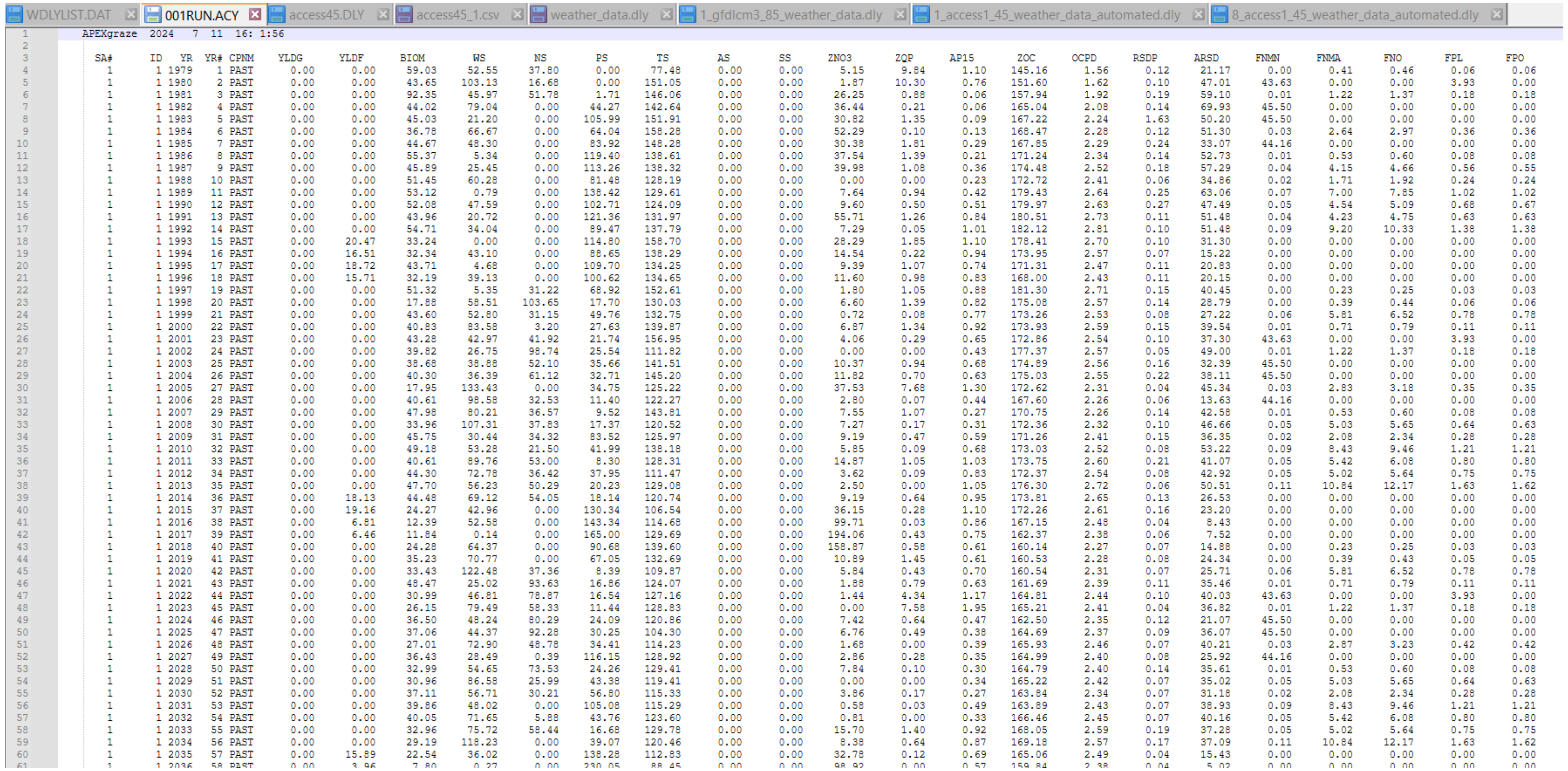
SRADm (J/m2)	
Min =	0
Max =	999
TMAX (°C)	
Min =	-99
Max =	100
TMIN (°C)	
Min =	-99
Max =	100
PRCP (mm)	
Min =	0
Max =	1000
RHUM	
Min =	0
Max =	1
WIND (m/s)	
Min =	0
Max =	30

APEXgraze Editor

Running the APEXgraze Model:

- Run the model using concatenated .DLY file

Final file is from Jan. 1st 1979 to Dec. 31st 2099



WDLYLIST.DAT
001RUN.ACY
access45.DLY
access45_1.csv
weather_data.dly
1_gfdlcm3_85_weather_data.dly
1_access1_45_weather_data_automated.dly
8_access1_45_weather_data_automated.dly

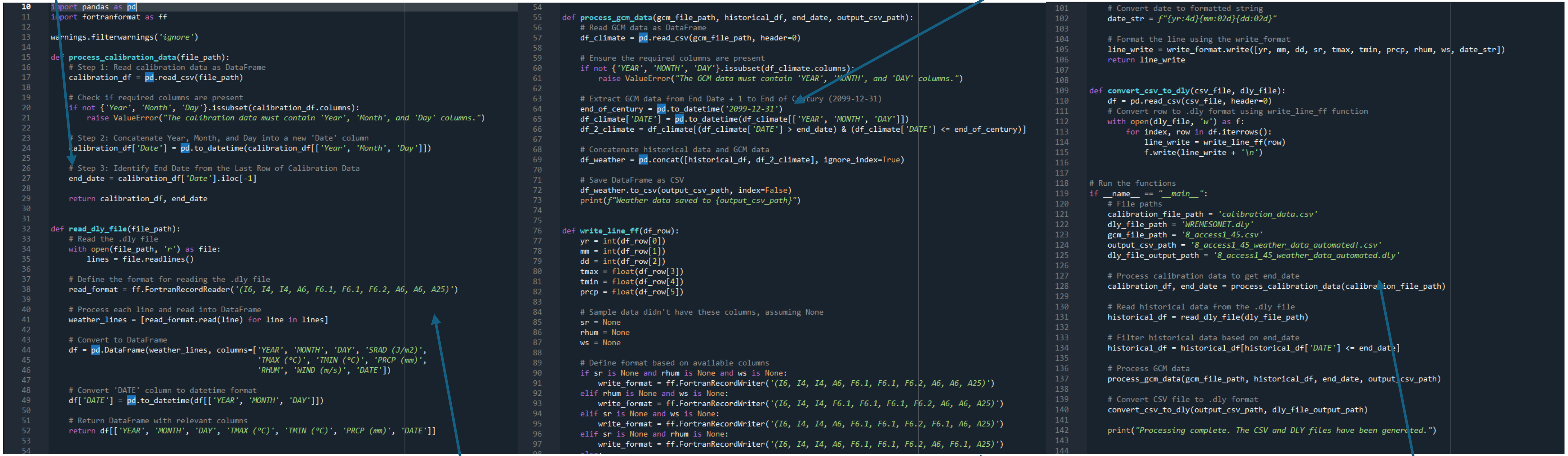
```
   APEXgraze  2024   7  11  16: 1:56

  SA#      ID   YR  YR# CPNM      YLDG      YLDF      BIOM        WS        NS        PS        TS        AS        SS      ZNO3       ZQP      AP15       ZOC      OCPD      RSDP      ARSD      FNMN      FNMA       FNO       FPL       FPO
    1       1 1979    1 PAST      0.00      0.00     59.03     52.55     37.80      0.00     77.48      0.00      0.00      5.15      9.84      1.10    145.16      1.56      0.12     21.17      0.00      0.41      0.46      0.06      0.06
    1       1 1980    2 PAST      0.00      0.00     43.65    103.13     16.68      0.00    151.05      0.00      0.00      1.87     10.30      0.76    151.60      1.62      0.10     47.01     43.63      0.00      0.00      3.93      0.00
    1       1 1981    3 PAST      0.00      0.00     92.35     45.97     51.78      1.71    146.06      0.00      0.00     26.25      0.88      0.06    157.94      1.92      0.19     59.10      0.01      1.22      1.37      0.18      0.18
    1       1 1982    4 PAST      0.00      0.00     44.02     79.04      0.00     44.27    142.64      0.00      0.00     36.44      0.21      0.06    165.04      2.08      0.14     69.93     45.50      0.00      0.00      0.00      0.00
    1       1 1983    5 PAST      0.00      0.00     45.03     21.20      0.00    105.99    151.91      0.00      0.00     30.82      1.35      0.09    167.22      2.24      1.63     50.20     45.50      0.00      0.00      0.00      0.00
    1       1 1984    6 PAST      0.00      0.00     36.78     66.67      0.00     64.04    158.28      0.00      0.00     52.29      0.10      0.13    168.47      2.28      0.12     51.30      0.03      2.64      2.97      0.36      0.36
    1       1 1985    7 PAST      0.00      0.00     44.67     48.30      0.00     83.92    148.28      0.00      0.00     30.38      1.81      0.29    167.85      2.29      0.24     33.07     44.16      0.00      0.00      0.00      0.00
    1       1 1986    8 PAST      0.00      0.00     55.37      5.34      0.00    119.40    138.61      0.00      0.00     37.54      1.39      0.21    171.24      2.34      0.14     52.73      0.01      0.53      0.60      0.08      0.08
    1       1 1987    9 PAST      0.00      0.00     45.89     25.45      0.00    113.26    138.32      0.00      0.00     39.98      1.08      0.36    174.48      2.52      0.18     57.29      0.04      4.15      4.66      0.56      0.55
    1       1 1988   10 PAST      0.00      0.00     51.45     60.28      0.00     81.48    128.19      0.00      0.00      0.00      0.00      0.23    172.72      2.41      0.06     34.86      0.02      1.71      1.92      0.24      0.24
    1       1 1989   11 PAST      0.00      0.00     53.12      0.79      0.00    138.42    129.61      0.00      0.00      7.64      0.94      0.42    179.43      2.64      0.25     63.06      0.07      7.00      7.85      1.02      1.02
    1       1 1990   12 PAST      0.00      0.00     52.08     47.59      0.00    102.71    124.09      0.00      0.00      9.60      0.50      0.51    179.97      2.63      0.27     47.49      0.05      4.54      5.09      0.68      0.67
    1       1 1991   13 PAST      0.00      0.00     43.96     20.72      0.00    121.36    131.97      0.00      0.00     55.71      1.26      0.84    180.51      2.73      0.11     51.48      0.04      4.23      4.75      0.63      0.63
    1       1 1992   14 PAST      0.00      0.00     54.71     34.04      0.00     89.47    137.79      0.00      0.00      7.29      0.05      1.01    182.12      2.81      0.10     51.48      0.09      9.20     10.33      1.38      1.38
    1       1 1993   15 PAST      0.00     20.47     33.24      0.00      0.00    114.80    158.70      0.00      0.00     28.29      1.85      1.10    178.41      2.70      0.10     31.30      0.00      0.00      0.00      0.00      0.00
    1       1 1994   16 PAST      0.00     16.51     32.34     43.10      0.00     88.65    138.29      0.00      0.00     14.54      0.22      0.94    173.95      2.57      0.07     15.22      0.00      0.00      0.00      0.00      0.00
    1       1 1995   17 PAST      0.00     18.72     43.71      4.68      0.00    109.70    134.25      0.00      0.00      9.39      1.07      0.74    171.31      2.47      0.11     20.83      0.00      0.00      0.00      0.00      0.00
    1       1 1996   18 PAST      0.00     15.71     32.19     39.13      0.00    100.62    134.65      0.00      0.00     11.60      0.98      0.83    168.00      2.43      0.11     20.15      0.00      0.00      0.00      0.00      0.00
    1       1 1997   19 PAST      0.00      0.00     51.32      5.35     31.22     68.92    152.61      0.00      0.00      1.80      1.05      0.88    181.30      2.71      0.15     40.45      0.00      0.23      0.25      0.03      0.03
    1       1 1998   20 PAST      0.00      0.00     17.88     58.51    103.65     17.70    130.03      0.00      0.00      6.60      1.39      0.82    175.08      2.57      0.14     28.79      0.00      0.39      0.44      0.06      0.06
    1       1 1999   21 PAST      0.00      0.00     43.60     52.80     31.15     49.76    132.75      0.00      0.00      0.72      0.08      0.77    173.26      2.53      0.08     27.22      0.06      5.81      6.52      0.78      0.78
    1       1 2000   22 PAST      0.00      0.00     40.83     83.58      3.20     27.63    139.87      0.00      0.00      6.87      1.34      0.92    173.93      2.59      0.15     39.54      0.01      0.71      0.79      0.11      0.11
    1       1 2001   23 PAST      0.00      0.00     43.28     42.97     41.92     21.74    156.95      0.00      0.00      4.06      0.29      0.65    172.86      2.54      0.10     37.30     43.63      0.00      0.00      3.93      0.00
    1       1 2002   24 PAST      0.00      0.00     39.82     26.75     98.74     25.54    111.82      0.00      0.00      0.00      0.00      0.43    177.37      2.57      0.05     49.00      0.01      1.22      1.37      0.18      0.18
    1       1 2003   25 PAST      0.00      0.00     38.68     38.88     52.10     35.66    141.51      0.00      0.00     10.37      0.94      0.68    174.89      2.56      0.16     32.39     45.50      0.00      0.00      0.00      0.00
    1       1 2004   26 PAST      0.00      0.00     40.30     36.39     61.12     32.71    145.20      0.00      0.00     11.82      0.70      0.63    175.03      2.55      0.22     38.11     45.50      0.00      0.00      0.00      0.00
    1       1 2005   27 PAST      0.00      0.00     17.95    133.43      0.00     34.75    125.22      0.00      0.00     37.53      7.68      1.30    172.62      2.31      0.04     45.34      0.03      2.83      3.18      0.35      0.35
    1       1 2006   28 PAST      0.00      0.00     40.61     98.58     32.53     11.40    122.27      0.00      0.00      2.80      0.07      0.44    167.60      2.26      0.06     13.63     44.16      0.00      0.00      0.00      0.00
    1       1 2007   29 PAST      0.00      0.00     47.98     80.21     36.57      9.52    143.81      0.00      0.00      7.55      1.07      0.27    170.75      2.26      0.14     42.58      0.01      0.53      0.60      0.08      0.08
    1       1 2008   30 PAST      0.00      0.00     33.96    107.31     37.83     17.37    120.52      0.00      0.00      7.27      0.17      0.31    172.36      2.32      0.10     46.66      0.05      5.03      5.65      0.64      0.63
    1       1 2009   31 PAST      0.00      0.00     45.75     30.44     34.32     83.52    125.97      0.00      0.00      9.19      0.47      0.59    171.26      2.41      0.15     36.35      0.02      2.08      2.34      0.28      0.28
    1       1 2010   32 PAST      0.00      0.00     49.18     53.28     21.50     41.99    138.18      0.00      0.00      5.85      0.09      0.68    173.03      2.52      0.08     53.22      0.09      8.43      9.46      1.21      1.21
    1       1 2011   33 PAST      0.00      0.00     40.61     89.76     53.00      8.30    128.31      0.00      0.00     14.87      1.05      1.03    173.75      2.60      0.21     41.07      0.05      5.42      6.08      0.80      0.80
    1       1 2012   34 PAST      0.00      0.00     44.30     72.78     36.42     37.95    111.47      0.00      0.00      3.62      0.09      0.83    172.37      2.54      0.08     42.92      0.05      5.02      5.64      0.75      0.75
    1       1 2013   35 PAST      0.00      0.00     47.70     56.23     50.29     20.23    129.08      0.00      0.00      2.50      0.00      1.05    176.30      2.72      0.06     50.51      0.11     10.84     12.17      1.63      1.62
    1       1 2014   36 PAST      0.00     18.13     44.48     69.12     54.05     18.14    120.74      0.00      0.00      9.19      0.64      0.95    173.81      2.65      0.13     26.53      0.00      0.00      0.00      0.00      0.00
    1       1 2015   37 PAST      0.00     19.16     24.27     42.96      0.00    130.34    106.54      0.00      0.00     36.15      0.28      1.10    172.26      2.61      0.16     23.20      0.00      0.00      0.00      0.00      0.00
    1       1 2016   38 PAST      0.00      6.81     12.39     52.58      0.00    143.34    114.68      0.00      0.00     99.71      0.03      0.86    167.15      2.48      0.04      8.43      0.00      0.00      0.00      0.00      0.00
    1       1 2017   39 PAST      0.00      6.46     11.84      0.14      0.00    165.00    129.69      0.00      0.00    194.06      0.43      0.75    162.37      2.38      0.06      7.52      0.00      0.00      0.00      0.00      0.00
    1       1 2018   40 PAST      0.00      0.00     24.28     64.37      0.00     90.68    139.60      0.00      0.00    158.87      0.58      0.61    160.14      2.27      0.07     14.88      0.00      0.23      0.25      0.03      0.03
    1       1 2019   41 PAST      0.00      0.00     35.23     70.77      0.00     67.05    132.69      0.00      0.00     10.89      1.45      0.61    160.53      2.28      0.08     24.34      0.00      0.39      0.43      0.05      0.05
    1       1 2020   42 PAST      0.00      0.00     33.43    122.48     37.36      8.39    109.87      0.00      0.00      5.84      0.43      0.70    160.54      2.31      0.07     25.71      0.06      5.81      6.52      0.78      0.78
    1       1 2021   43 PAST      0.00      0.00     48.47     25.02     93.63     16.86    124.07      0.00      0.00      1.88      0.79      0.63    161.69      2.39      0.11     35.46      0.01      0.71      0.79      0.11      0.11
    1       1 2022   44 PAST      0.00      0.00     30.99     46.81     78.87     16.54    127.16      0.00      0.00      1.44      4.34      1.17    164.81      2.44      0.10     40.03     43.63      0.00      0.00      3.93      0.00
    1       1 2023   45 PAST      0.00      0.00     26.15     79.49     58.33     11.44    128.83      0.00      0.00      0.00      7.58      1.95    165.21      2.41      0.04     36.82      0.01      1.22      1.37      0.18      0.18
    1       1 2024   46 PAST      0.00      0.00     36.50     48.24     80.29     24.09    120.86      0.00      0.00      7.42      0.64      0.47    162.50      2.35      0.12     21.07     45.50      0.00      0.00      0.00      0.00
    1       1 2025   47 PAST      0.00      0.00     37.06     44.37     92.28     30.25    104.30      0.00      0.00      6.76      0.49      0.38    164.69      2.37      0.09     36.07     45.50      0.00      0.00      0.00      0.00
    1       1 2026   48 PAST      0.00      0.00     27.01     72.90     48.78     34.41    114.23      0.00      0.00      1.68      0.00      0.39    165.93      2.46      0.07     40.21      0.03      2.87      3.23      0.42      0.42
    1       1 2027   49 PAST      0.00      0.00     36.43     28.49      0.39    116.15    128.92      0.00      0.00      2.86      0.28      0.35    164.99      2.40      0.08     25.92     44.16      0.00      0.00      0.00      0.00
    1       1 2028   50 PAST      0.00      0.00     32.99     54.65     73.53     24.26    129.41      0.00      0.00      7.84      0.10      0.30    164.79      2.40      0.14     35.61      0.01      0.53      0.60      0.08      0.08
    1       1 2029   51 PAST      0.00      0.00     30.96     86.58     25.99     43.38    119.41      0.00      0.00      0.00      0.00      0.34    165.22      2.42      0.07     35.02      0.05      5.03      5.65      0.64      0.63
    1       1 2030   52 PAST      0.00      0.00     37.11     56.71     30.21     56.80    115.33      0.00      0.00      3.86      0.17      0.27    163.84      2.34      0.07     31.18      0.02      2.08      2.34      0.28      0.28
    1       1 2031   53 PAST      0.00      0.00     39.86     48.02      0.00    105.08    115.29      0.00      0.00      0.58      0.03      0.49    163.89      2.43      0.07     38.93      0.09      8.43      9.46      1.21      1.21
    1       1 2032   54 PAST      0.00      0.00     40.05     71.65      5.88     43.76    123.60      0.00      0.00      0.81      0.00      0.33    166.46      2.45      0.07     40.16      0.05      5.42      6.08      0.80      0.80
    1       1 2033   55 PAST      0.00      0.00     32.96     75.72     58.44     16.68    129.78      0.00      0.00     15.70      1.40      0.92    168.05      2.59      0.19     37.28      0.05      5.02      5.64      0.75      0.75
    1       1 2034   56 PAST      0.00      0.00     29.19    118.23      0.00     39.07    120.46      0.00      0.00      8.38      0.64      0.87    169.18      2.57      0.17     37.09      0.11     10.84     12.17      1.63      1.62
    1       1 2035   57 PAST      0.00     15.89     22.54     36.02      0.00    138.28    112.83      0.00      0.00     32.78      0.12      0.69    165.06      2.49      0.04     15.43      0.00      0.00      0.00      0.00      0.00
    1       1 2036   58 PAST      0.00      3.96      7.80      0.27      0.00    230.05     88.45      0.00      0.00     98.92      0.00      0.57    159.84      2.38      0.04      5.02      0.00      0.00      0.00      0.00      0.00
```

How can we make this better?

An Automated System:

Finding end_date of calibration data

Processing the GCM data and finding the last data entry of the century



```python
import pandas as pd
import fortranformat as ff

warnings.filterwarnings('ignore')

def process_calibration_data(file_path):
    # Step 1: Read calibration data as DataFrame
    calibration_df = pd.read_csv(file_path)

    # Check if required columns are present
    if not {'Year', 'Month', 'Day'}.issubset(calibration_df.columns):
        raise ValueError("The calibration data must contain 'Year', 'Month', and 'Day' columns.")

    # Step 2: Concatenate Year, Month, and Day into a new 'Date' column
    calibration_df['Date'] = pd.to_datetime(calibration_df[['Year', 'Month', 'Day']])

    # Step 3: Identify End Date from the Last Row of Calibration Data
    end_date = calibration_df['Date'].iloc[-1]

    return calibration_df, end_date


def read_dly_file(file_path):
    # Read the .dly file
    with open(file_path, 'r') as file:
        lines = file.readlines()

    # Define the format for reading the .dly file
    read_format = ff.FortranRecordReader('(I6, I4, I4, A6, F6.1, F6.1, F6.2, A6, A6, A25)')

    # Process each line and read into DataFrame
    weather_lines = [read_format.read(line) for line in lines]

    # Convert to DataFrame
    df = pd.DataFrame(weather_lines, columns=['YEAR', 'MONTH', 'DAY', 'SRAD (J/m2)',
                                              'TMAX (°C)', 'TMIN (°C)', 'PRCP (mm)',
                                              'RHUM', 'WIND (m/s)', 'DATE'])

    # Convert 'DATE' column to datetime format
    df['DATE'] = pd.to_datetime(df[['YEAR', 'MONTH', 'DAY']])

    # Return DataFrame with relevant columns
    return df[['YEAR', 'MONTH', 'DAY', 'TMAX (°C)', 'TMIN (°C)', 'PRCP (mm)', 'DATE']]

```

```python

def process_gcm_data(gcm_file_path, historical_df, end_date, output_csv_path):
    # Read GCM data as DataFrame
    df_climate = pd.read_csv(gcm_file_path, header=0)

    # Ensure the required columns are present
    if not {'YEAR', 'MONTH', 'DAY'}.issubset(df_climate.columns):
        raise ValueError("The GCM data must contain 'YEAR', 'MONTH', and 'DAY' columns.")

    # Extract GCM data from End Date + 1 to End of Century (2099-12-31)
    end_of_century = pd.to_datetime('2099-12-31')
    df_climate['DATE'] = pd.to_datetime(df_climate[['YEAR', 'MONTH', 'DAY']])
    df_2_climate = df_climate[(df_climate['DATE'] > end_date) & (df_climate['DATE'] <= end_of_century)]

    # Concatenate historical data and GCM data
    df_weather = pd.concat([historical_df, df_2_climate], ignore_index=True)

    # Save DataFrame as CSV
    df_weather.to_csv(output_csv_path, index=False)
    print(f"Weather data saved to {output_csv_path}")


def write_line_ff(df_row):
    yr = int(df_row[0])
    mm = int(df_row[1])
    dd = int(df_row[2])
    tmax = float(df_row[3])
    tmin = float(df_row[4])
    prcp = float(df_row[5])

    # Sample data didn't have these columns, assuming None
    sr = None
    rhum = None
    ws = None

    # Define format based on available columns
    if sr is None and rhum is None and ws is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, A6, F6.1, F6.1, F6.2, A6, A6, A25)')
    elif rhum is None and ws is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, F6.1, F6.1, F6.1, F6.2, A6, A6, A25)')
    elif sr is None and ws is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, A6, F6.1, F6.1, F6.2, F6.1, A6, A25)')
    elif sr is None and rhum is None:
        write_format = ff.FortranRecordWriter('(I6, I4, I4, A6, F6.1, F6.1, F6.2, A6, F6.1, A25)')
    else:
```

```python
    # Convert date to formatted string
    date_str = f"{yr:4d}{mm:02d}{dd:02d}"

    # Format the line using the write_format
    line_write = write_format.write([yr, mm, dd, sr, tmax, tmin, prcp, rhum, ws, date_str])
    return line_write


def convert_csv_to_dly(csv_file, dly_file):
    df = pd.read_csv(csv_file, header=0)
    # Convert row to .dly format using write_line_ff function
    with open(dly_file, 'w') as f:
        for index, row in df.iterrows():
            line_write = write_line_ff(row)
            f.write(line_write + '\n')


# Run the functions
if __name__ == "__main__":
    # File paths
    calibration_file_path = 'calibration_data.csv'
    dly_file_path = 'WREMESONET.dly'
    gcm_file_path = '8_access1_45.csv'
    output_csv_path = '8_access1_45_weather_data_automated!.csv'
    dly_file_output_path = '8_access1_45_weather_data_automated.dly'

    # Process calibration data to get end_date
    calibration_df, end_date = process_calibration_data(calibration_file_path)

    # Read historical data from the .dly file
    historical_df = read_dly_file(dly_file_path)

    # Filter historical data based on end_date
    historical_df = historical_df[historical_df['DATE'] <= end_date]

    # Process GCM data
    process_gcm_data(gcm_file_path, historical_df, end_date, output_csv_path)

    # Convert CSV file to .dly format
    convert_csv_to_dly(output_csv_path, dly_file_output_path)

    print("Processing complete. The CSV and DLY files have been generated.")

```

Converting historical data into readable file and making a Date-Time column

Using FortranFormatter to convert from .CSV to .DLY

Inputting file names

UTA

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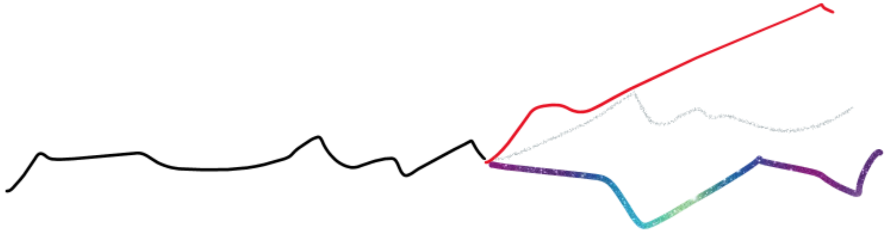
Moving Forward

- Continue working with this amazing team
- Refine post-processing
- Visualize results
- Assist in outlining a manuscript
- Speak at conferences and research symposiums
  - Tri-Society Meeting 2024 – San Antonio
    - American Society of Agronomy, Crop Science Society of America, Soil Science Society of America



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Moving Forward

- Make APEXgraze accessible
  - Potential web-based tools
  - Potential python packages

- Make automated scripts available
  - Useful for similar models
  - Platform for future research
  - Peer Review

Thank you