hydrology-code

June 17, 2024

1 Engineering Hydrology Interpolation and Calculation Code

Caclulation of Potential Evapotranspiration

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Date: 08th June, 2024.

This document comprises the calculation of the average monthly PET from closed grassland of Tribhuvan Airport (Latitude=27°48' and longitude = 85°22', elevation = 1350m with the given weather data)

[84]:
```
#reading datas from excel file
data_ew = pd.read_excel("hydrology.xlsx",sheet_name=0)
data_ha = pd.read_excel("hydrology.xlsx", sheet_name=1)
data_n = pd.read_excel("hydrology.xlsx", sheet_name=2)
data_airport = pd.read_excel("hydrology.xlsx", sheet_name=3)
```

[65]:
```
data_ew
```

[65]:

	Temp	ew	A
0	0.0	4.58	0.30
1	5.0	6.54	0.45
2	7.5	7.78	0.54
3	10.0	9.21	0.60
4	12.5	10.87	0.71
5	15.0	12.79	0.80
6	17.5	15.00	0.95
7	20.0	17.54	1.05
8	22.5	20.44	1.24
9	25.0	23.76	1.40
10	27.5	27.54	1.61
11	30.0	31.82	1.85
12	32.5	36.68	2.07
13	35.0	42.81	2.35
14	37.5	48.36	2.62
15	40.0	55.32	2.95
16	45.0	71.20	3.66

[66]:
```
data_ha
```

[66]:
```
   lat   Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov  \
0    0  14.5  15.0  15.2  14.7  13.9  13.4  13.5  14.2  14.9  15.0  14.6
1   10  12.8  13.9  14.8  15.2  15.0  14.8  14.8  15.0  14.9  14.1  13.1
2   20  10.8  12.3  13.9  15.2  15.7  15.8  15.7  15.3  14.4  12.9  11.2
3   30   8.5  10.5  12.7  14.8  16.0  16.5  16.2  15.3  13.5  11.3   9.1
4   40   6.0   8.3  11.0  13.9  15.9  16.7  16.3  14.8  12.2   9.3   6.7
5   50   3.6   5.9   9.1  12.7  15.4  16.7  16.1  13.9  10.5   7.1   4.3

    Dec        Avg
0  14.3  14.433333
1  12.4  14.233333
2  10.3  13.625000
3   7.9  12.691667
4   5.4  11.375000
5   3.0   9.858333
```

[67]:
```
data_n
```

[67]:
```
   lat   Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov  \
0    0  12.1  12.1  12.1  12.1  12.1  12.1  12.1  12.1  12.1  12.1  12.1
1   10  11.6  11.8  12.1  12.4  12.6  12.7  12.6  12.4  12.9  11.9  11.7
2   20  11.1  11.5  12.0  12.6  13.1  13.3  13.2  12.8  12.3  11.7  11.2
3   30  10.4  11.1  12.0  12.9  13.7  14.1  13.9  13.2  12.4  11.5  10.6
4   40   9.6  10.7  11.9  13.2  14.4  15.0  14.7  13.8  12.5  11.2  10.0
5   50   8.6  10.1  11.8  13.8  15.4  16.4  16.0  14.5  12.7  10.8   9.1

    Dec        Avg
0  12.1  12.100000
1  11.5  12.183333
2  10.9  12.141667
3  10.2  12.166667
4   9.4  12.200000
5   8.1  12.275000
```

[68]:
```
data_airport
```

[68]:
```
   Unnamed: 0                 Unnamed: 1 Unnamed: 2 Unnamed: 3 Unnamed: 4  \
0         NaN                        NaN        NaN        NaN        NaN
1         NaN                    MH_data        Jan        Feb        Mar
2         NaN             Temp in degree       9.45       11.2       15.5
3         NaN                     RH (%)         76         57         45
4         NaN                 wind speed        1.3        2.2        2.2
5         NaN  actual sunshine in hrs(n)          8        8.5        9.5

  Unnamed: 5 Unnamed: 6 Unnamed: 7 Unnamed: 8 Unnamed: 9 Unnamed: 10  \
```

```
0        NaN        NaN        NaN        NaN        NaN        NaN
1        Apr        May        Jun        Jul        Aug        Sep
2       19.2       21.6       23.2       23.4       23.3         22
3         35         43         77         80         84         77
4        2.8        2.8        3.3        2.3        2.4        1.5
5        9.4       10.5       11.5         12         11       11.2

  Unnamed: 11 Unnamed: 12 Unnamed: 13 Unnamed: 14
0         NaN         NaN         NaN         NaN
1         Oct         Nov         Dec         Avg
2          19        14.1        10.2   17.679167
3          74          71          65   65.333333
4         1.3         1.8         1.4    2.108333
5          10         9.5           9   10.008333
```

[69]:
```
data_airport = data_airport.drop(data_airport.columns[[0]], axis=1)
```

[70]:
```
data_airport
```

[70]:
```
                  Unnamed: 1 Unnamed: 2 Unnamed: 3 Unnamed: 4 Unnamed: 5  \
0                        NaN        NaN        NaN        NaN        NaN
1                   MH_data         Jan        Feb        Mar        Apr
2            Temp in degree        9.45       11.2       15.5       19.2
3                    RH (%)          76         57         45         35
4                wind speed         1.3        2.2        2.2        2.8
5  actual sunshine in hrs(n)           8        8.5        9.5        9.4

  Unnamed: 6 Unnamed: 7 Unnamed: 8 Unnamed: 9 Unnamed: 10 Unnamed: 11  \
0        NaN        NaN        NaN        NaN         NaN         NaN
1        May        Jun        Jul        Aug         Sep         Oct
2       21.6       23.2       23.4       23.3          22          19
3         43         77         80         84          77          74
4        2.8        3.3        2.3        2.4         1.5         1.3
5       10.5       11.5         12         11        11.2          10

  Unnamed: 12 Unnamed: 13 Unnamed: 14
0         NaN         NaN         NaN
1         Nov         Dec         Avg
2        14.1        10.2   17.679167
3          71          65   65.333333
4         1.8         1.4    2.108333
5         9.5           9   10.008333
```

[71]:
```
new_header = data_airport.iloc[1]  # Store the first row as the new header
data_airport = data_airport[2:]  # Take the data less the header row
data_airport.columns = new_header  # Set the header row as the DataFrame header
```

[72]:
```
data_airport
```

[72]:
```
1                    MH_data   Jan   Feb   Mar   Apr   May   Jun   Jul   Aug  \
2             Temp in degree  9.45  11.2  15.5  19.2  21.6  23.2  23.4  23.3
3                    RH (%)    76    57    45    35    43    77    80    84
4                 wind speed   1.3   2.2   2.2   2.8   2.8   3.3   2.3   2.4
5  actual sunshine in hrs(n)     8   8.5   9.5   9.4  10.5  11.5    12    11

1   Sep  Oct   Nov   Dec        Avg
2    22   19  14.1  10.2  17.679167
3    77   74    71    65  65.333333
4   1.5  1.3   1.8   1.4   2.108333
5  11.2   10   9.5     9  10.008333
```

[73]:
```
#initializing constant and known values
L = 27.8 #latitude in decimal degrees
Rl = 1350 #known elevation
r = .22 #albedo constant
a = .29 * np.cos(np.radians(L)) #constant
b = .52 #constant
sigma = 2.01E-9 #stefan's constant
gamma = .485 #psychrometric constant .485 mm of mercury
```

[74]:
```
# Assuming data_airport is  DataFrame
data = {
    'MH_data': ['Temp in degree', 'RH (%)', 'wind speed', 'actual sunshine in␣
 ↪hrs(n)'],
    'Jan': [9.45, 76, 1.3, 8],
    'Feb': [11.2, 57, 2.2, 8.5],
    'Mar': [15.5, 45, 2.2, 9.5],
    'Apr': [19.2, 35, 2.8, 9.4],
    'May': [21.6, 43, 2.8, 10.5],
    'Jun': [23.2, 77, 3.3, 11.5],
    'Jul': [23.4, 80, 2.3, 12],
    'Aug': [23.3, 84, 2.4, 11],
    'Sep': [22, 77, 1.5, 11.2],
    'Oct': [19, 74, 1.3, 10],
    'Nov': [14.1, 71, 1.8, 9.5],
    'Dec': [10.2, 65, 1.4, 9],
    'Avg': [17.679167, 65.333333, 2.108333, 10.008333]
}

data_airport = pd.DataFrame(data)

# Extract monthly data
Ta_months = np.array(data_airport.iloc[0, 1:])  # Temperature in degrees
RH_months = np.array(data_airport.iloc[1, 1:])  # Relative humidity in %
```

```
WS_months = np.array(data_airport.iloc[2, 1:])  # Wind speed
SS_months = np.array(data_airport.iloc[3, 1:])  # Sunshine hours in n

# Print the extracted data
print("Monthly Data:")
print("Temperature:", Ta_months)
print("Relative Humidity:", RH_months)
print("Wind Speed:", WS_months)
print("Sunshine Hours:", SS_months)
```

```
Monthly Data:
Temperature: [9.45 11.2 15.5 19.2 21.6 23.2 23.4 23.3 22.0 19.0 14.1 10.2
17.679167]
Relative Humidity: [76.0 57.0 45.0 35.0 43.0 77.0 80.0 84.0 77.0 74.0 71.0 65.0
65.333333]
Wind Speed: [1.3 2.2 2.2 2.8 2.8 3.3 2.3 2.4 1.5 1.3 1.8 1.4 2.108333]
Sunshine Hours: [8.0 8.5 9.5 9.4 10.5 11.5 12.0 11.0 11.2 10.0 9.5 9.0
10.008333]
```

[75]:
```
months =␣
  ↪["Jan","Feb","Mar","Apr","May","Jun","Jul","Aug","Sep","Oct","Nov","Dec","Avg"]
```

[76]:
```
ew_months = []
A_months = []
Ha_months = []
N_months = []

for month in months:
    t = data_airport[month][0]
    t_low = data_ew[["Temp"][0]][(data_ew["Temp"]<=t)].to_list()[-1]
    t_high = data_ew[["Temp"][0]][(data_ew["Temp"]>=t)].to_list()[0]

    ew_low = data_ew[["ew"][0]][(data_ew["Temp"]<=t)].to_list()[-1]
    ew_high = data_ew[["ew"][0]][(data_ew["Temp"]>=t)].to_list()[0]
    ew = ew_low + (ew_high-ew_low)*(t-t_low)/(t_high-t_low)
    ew_months.append(ew)

    a_low = data_ew[["A"][0]][(data_ew["Temp"]<=t)].to_list()[-1]
    a_high = data_ew[["A"][0]][(data_ew["Temp"]>=t)].to_list()[0]
    a_req = a_low + (a_high-a_low)*(t-t_low)/(t_high-t_low)
    A_months.append(a_req)

    lat_low = data_ha["lat"][data_ha["lat"]<=L].to_list()[-1]
    lat_high = data_ha["lat"][data_ha["lat"]>=L].to_list()[0]

    ha_low = data_ha[month][data_ha["lat"]<=L].to_list()[-1]
    ha_high = data_ha[month][data_ha["lat"]>=L].to_list()[0]
```

```
    ha = ha_low + (ha_high-ha_low)*(L-lat_low)/(lat_high-lat_low)
    Ha_months.append(ha)

    N_low = data_n[month][data_n["lat"]<=L].to_list()[-1]
    N_high = data_n[month][data_n["lat"]>=L].to_list()[0]
    N = N_low + (N_high-N_low)*(L-lat_low)/(lat_high-lat_low)
    N_months.append(N)

print("The interpolated datas are as follows:")
print("ew =", ew_months)
print("A =", A_months)
print("Ha =",Ha_months)
print("N =", N_months)

ew_months = np.array(ew_months)
A_months = np.array(A_months)
Ha_months =np.array(Ha_months)
N_months = np.array(N_months)
```

```
The interpolated datas are as follows:
ew = [8.8954, 10.0068, 13.232, 16.7272, 19.396, 21.369600000000002, 21.6352,
21.5024, 19.86, 16.524, 12.098799999999999, 9.3428, 15.182033672]
A = [0.5868, 0.6527999999999999, 0.8300000000000001, 1.018, 1.1716000000000002,
1.2848, 1.2975999999999999, 1.2912, 1.202, 1.01, 0.7676000000000001,
0.6087999999999999, 0.9571666799999999]
Ha = [9.006, 10.896, 12.963999999999999, 14.888, 15.934, 16.346, 16.09, 15.3,
13.698, 11.652000000000001, 9.562, 8.428, 12.897000000000002]
N = [10.554, 11.187999999999999, 12.0, 12.834, 13.568, 13.924, 13.746, 13.112,
12.378, 11.544, 10.732, 10.354, 12.161166666666666]
```

[77]:
```
ea_months = ew_months*RH_months/100 #calculating value of ea from ew
n_by_N = SS_months/N_months  #calculating n/N
sT4 = sigma*(Ta_months+273)**4   #calculating sigma * T^4 for each months
u2 = WS_months/1.944*86400/1000

Hn = Ha_months*(1-r)*(a+b*n_by_N)-sT4*(0.56-0.092*(ea_months)**(0.5))*(0.1+0.
 ↪9*n_by_N)
Ea = .35*(1+u2/160)*(ew_months-ea_months)
PET = (A_months * Hn + Ea * gamma)/(A_months + gamma)
```

[78]:
```
PET
```

[78]:
```
array([1.2052986840685505, 2.205081486547634, 3.3824425004125556,
       4.654278649532656, 5.296025953409124, 5.483665970712675,
       5.3931366835045695, 4.930573695304668, 4.200186175137865,
       2.93562923870675, 1.8107051166377035, 1.1811798749385671,
       3.388440815731834], dtype=object)
```

[79]:
```
interpolated_data = {months[n]:[ew_months[n], A_months[n], Ha_months[n],␣
↪N_months[n]] for n in range(len(months))}
df_intp = pd.DataFrame(interpolated_data)
df_intp.to_excel("interpolated.xlsx")
```

[80]:
```
final_data = {months[n]:[ew_months[n], A_months[n], Ha_months[n], N_months[n],␣
↪ea_months[n],
                sT4[n], Hn[n], Ea[n], PET[n]] for n in range(len(months))}

final_df = pd.DataFrame(final_data)
col_1 = ["ew", "A", "Ha", "N", "ea", " T^4", "Hn", "Ea", "PET"]
final_df.insert(0, "MH_Data\Month", col_1, True)
```

[81]:
```
final_df
```

[81]:

	MH_Data\Month	Jan	Feb	Mar	Apr	May
0	ew	8.895400	10.006800	13.232000	16.727200	19.396000
1	A	0.586800	0.652800	0.830000	1.018000	1.171600
2	Ha	9.006000	10.896000	12.964000	14.888000	15.934000
3	N	10.554000	11.188000	12.000000	12.834000	13.568000
4	ea	6.760504	5.703876	5.954400	5.854520	8.340280
5	T^4	12.792705	13.112707	13.924491	14.652675	15.140040
6	Hn	1.360897	2.040674	2.960951	3.648573	4.640685
7	Ea	1.017041	2.426371	4.103758	6.765223	6.879115
8	PET	1.205299	2.205081	3.382443	4.654279	5.296026

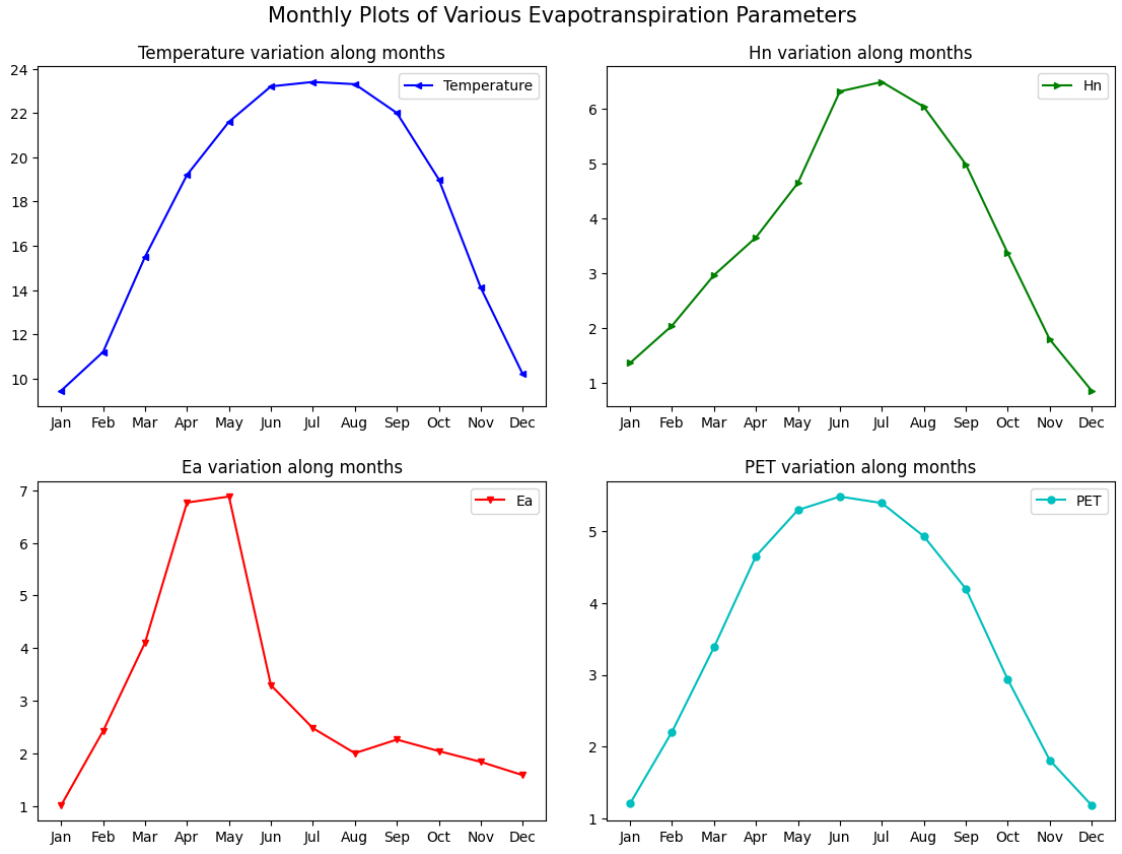
	Jun	Jul	Aug	Sep	Oct	Nov
0	21.369600	21.635200	21.502400	19.860000	16.524000	12.098800
1	1.284800	1.297600	1.291200	1.202000	1.010000	0.767600
2	16.346000	16.090000	15.300000	13.698000	11.652000	9.562000
3	13.924000	13.746000	13.112000	12.378000	11.544000	10.732000
4	16.454592	17.308160	18.062016	15.292200	12.227760	8.590148
5	15.471637	15.513467	15.492541	15.222435	14.612599	13.656167
6	6.309055	6.481209	6.028766	4.981076	3.362500	1.790905
7	3.297151	2.482038	2.006891	2.264867	2.046681	1.842042
8	5.483666	5.393137	4.930574	4.200186	2.935629	1.810705

	Dec	Avg
0	9.342800	15.182034
1	0.608800	0.957167
2	8.428000	12.897000
3	10.354000	12.161167
4	6.072820	9.918929
5	12.929123	14.349993
6	0.855833	3.625345
7	1.589574	2.920901
8	1.181180	3.388441

[82]:
```
fig = plt.figure("Monthly Plots of various Parameters", figsize=(12,9))␣
 ↪#figsize allots total size of area where plots can be made
axes = list(range(4)) #to store each axes object
to_plot = {"Temperature":Ta_months[:-1], "Hn":Hn[:-1], "Ea":Ea[:-1], "PET":PET[:
 ↪-1]}

for (n,(k,v)) in enumerate(to_plot.items()):
    axes[n]=fig.add_subplot(int(f"22{n+1}"))
    lines = axes[n].plot(months[:-1], v, label=k, c='bgrcmykbg'[n],␣
 ↪marker="<>vo"[n], ms=5)
    axes[n].set_title(f"{k} variation along months")
    axes[n].legend(loc="upper right")

fig.tight_layout(pad=4, w_pad=3, h_pad=2) #to ensure good spacing of all figures
fig.suptitle(r"Monthly Plots of Various Evapotranspiration Parameters",␣
 ↪fontsize = 15)
plt.show()
```



[83]:
```
data = {
```

```
    'Month': ['Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul', 'Aug', 'Sep',␣
 ↪'Oct', 'Nov', 'Dec', 'Avg'],
    'ew': [8.895400, 10.006800, 13.232000, 16.727200, 19.396000, 21.369600, 21.
 ↪635200, 21.502400, 19.860000, 16.524000, 12.098800, 9.342800, 15.182034],
    'A': [0.586800, 0.652800, 0.830000, 1.018000, 1.171600, 1.284800, 1.297600,␣
 ↪1.291200, 1.202000, 1.010000, 0.767600, 0.608800, 0.957167],
    'Ha': [9.006000, 10.896000, 12.964000, 14.888000, 15.934000, 16.346000, 16.
 ↪090000, 15.300000, 13.698000, 11.652000, 9.562000, 8.428000, 12.897000],
    'N': [10.554000, 11.188000, 12.000000, 12.834000, 13.568000, 13.924000, 13.
 ↪746000, 13.112000, 12.378000, 11.544000, 10.732000, 10.354000, 12.161167],
    'ea': [6.760504, 5.703876, 5.954400, 5.854520, 8.340280, 16.454592, 17.
 ↪308160, 18.062016, 15.292200, 12.227760, 8.590148, 6.072820, 9.918929],
    ' T^4': [12.792705, 13.112707, 13.924491, 14.652675, 15.140040, 15.471637,␣
 ↪15.513467, 15.492541, 15.222435, 14.612599, 13.656167, 12.929123, 14.349993],
    'Hn': [1.360897, 2.040674, 2.960951, 3.648573, 4.640685, 6.309055, 6.
 ↪481209, 6.028766, 4.981076, 3.362500, 1.790905, 0.855833, 3.625345],
    'Ea': [1.017041, 2.426371, 4.103758, 6.765223, 6.879115, 3.297151, 2.
 ↪482038, 2.006891, 2.264867, 2.046681, 1.842042, 1.589574, 2.920901],
    'PET': [1.205299, 2.205081, 3.382443, 4.654279, 5.296026, 5.483666, 5.
 ↪393137, 4.930574, 4.200186, 2.935629, 1.810705, 1.181180, 3.388441]
}

# Create a DataFrame
df = pd.DataFrame(data)

# Save to Excel
excel_file = "output.xlsx"
df.to_excel(excel_file, index=False)
```

PET due to of average of PET of each month = 3.388441

PET due to average of Annual PET = 3.556517

Error(%) = 4.725862 (was calculated in excel)