3rd ClimEd Online Training on Digital Tools and Datasets for Climate Change Education

A3 Group HWA

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Homework Assignment – Group A3

Main Theme: Water management

Project: Efficiency of green roofs in urban areas for stormwater retention under climate change

Areas: Kyiv, Kharkiv, Odessa cities

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Green roofs advantages:

- retain storm water
- reduce peak flow and increase time-to-peak flow
- reduce total runoff volume
- decrease of load to stormwater drainage system
- prevent streets flooding

- air purification
- carbon sequestration
- decrease of building heating
- mitigation of urban heat island effects
- additional habitat for wildlife
- aesthetic appeal

Norway

Poland

Kyiv

Kyiv region

Homework Assignment – Group A3

Historical and forecasted climate indices

Annual precipitation, monthly precipitation, monthly min/max precipitation, heavy precipitation, number of rainless days, duration of consecutive rainless days, duration of vegetation period, min/max temperature

Additional data

Urban built-up areas, roofs areas

Data sources

Copernicus Climate Change Service (CDS)

Expected outcomes

Feasibility assessment of green roof implementation in three Ukrainian cities (Kyiv, Kharkiv, Odessa) under different scenarios of climate change

UN SDGs

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The work is based on ten-year experience of observations on the author's "green roof" in steppe climate in Donetsk by Tetiana Tkachenko.

Main influencing factors (averaged by year):

- temperature *t*, °C
- relative humidity *rh*, %
- cloud coverage *c*, %
- wind speed *w*, m /s

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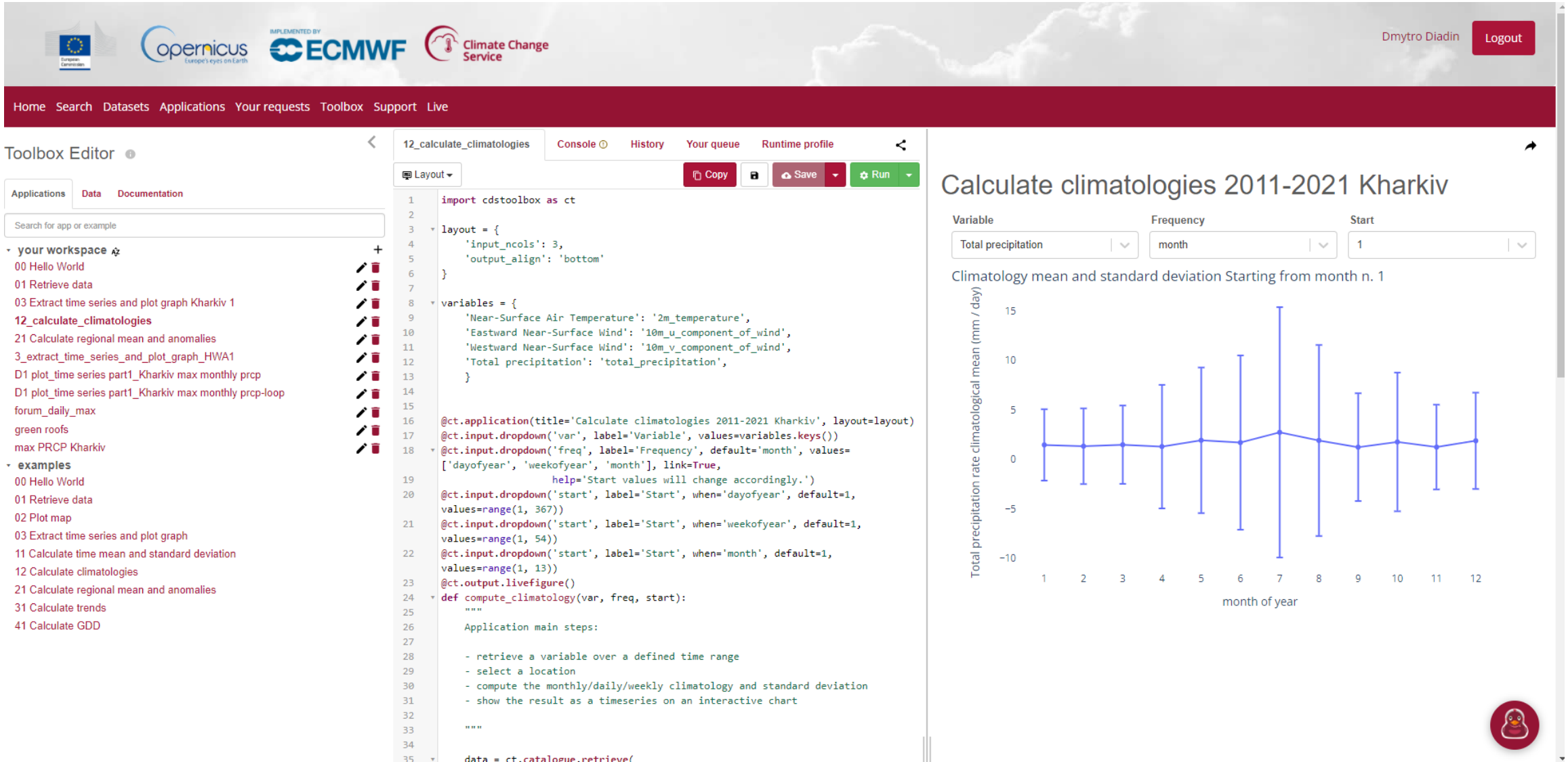
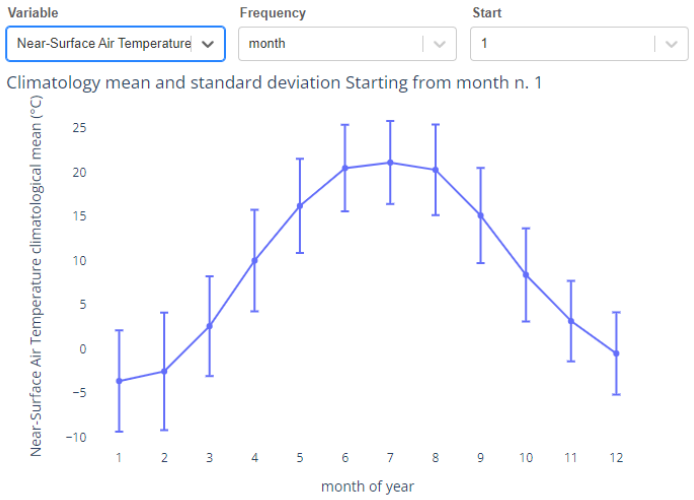
Calculating climatologies 2011-2021 for Kyiv, Kharkiv, Odessa



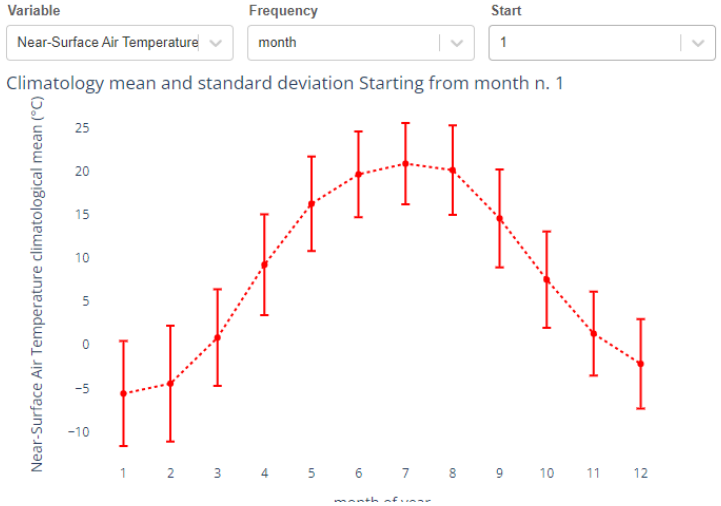
Homework Assignment – Group A3

Calculating climatologies 2011-2021

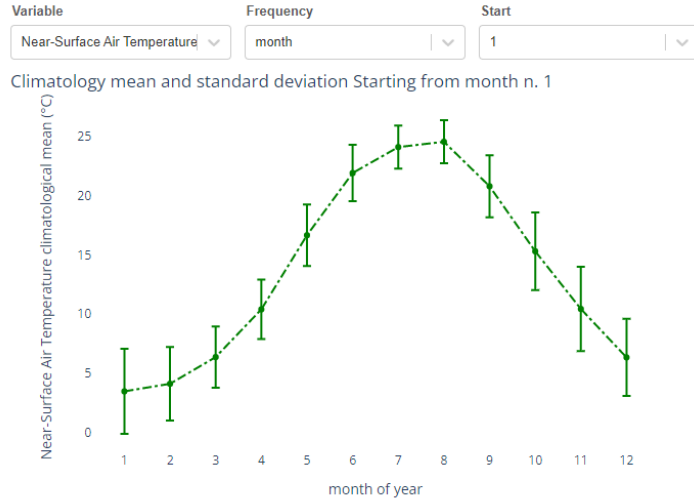
Kyiv



Kharkiv

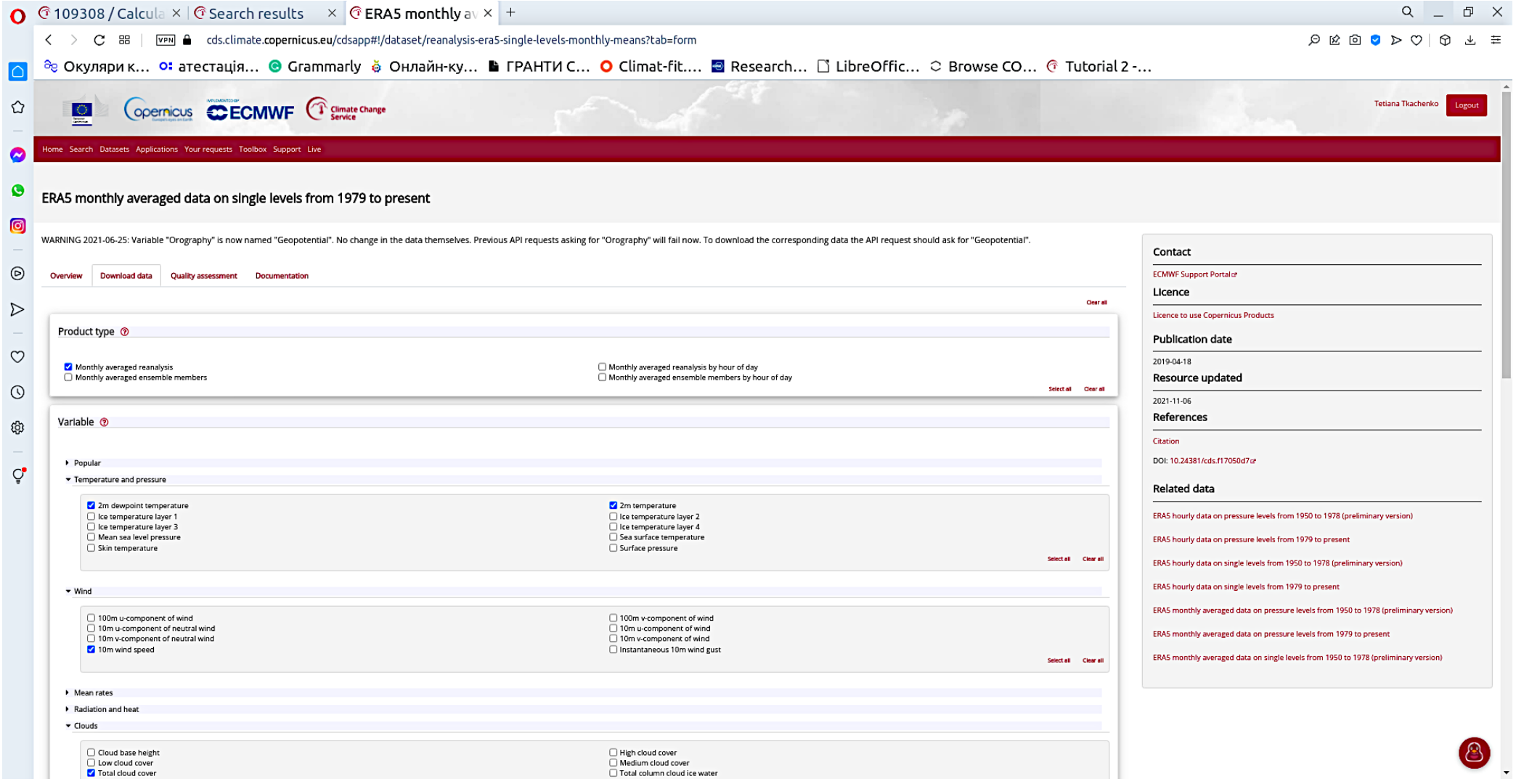


Odessa



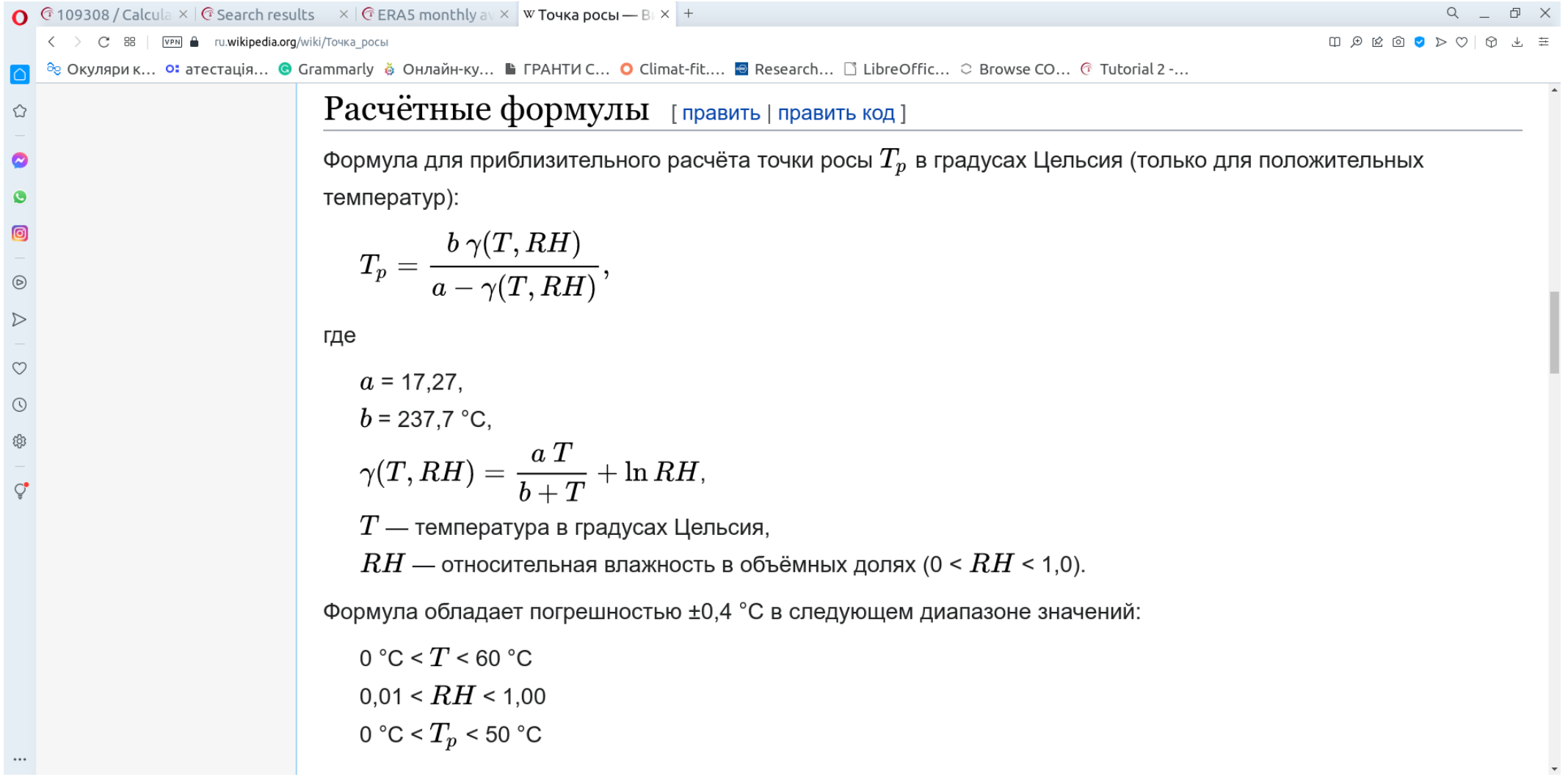
Homework Assignment – Group A3

Estimation of plant development conditions based on wind speed, relative humidity, temperature, cloud cover



Homework Assignment – Group A3

Calculation of relative humidity by air temperature and dew point



Homework Assignment – Group A3

The formula should be transformed to find relative humidity

wxMaxima 21.05.2 (Linux 5.14.0-17.1-liquorix-amd64 x86_64) [Dew point to relative humidity.wxmx]

Файл Редагування Перегляд Комірка Maxima Рівняння Матриця Аналіз Спрощення Список Креслення Обчислення Довідка

Calculation of relative humidity by air temperature and dew point

1 Equation of dew point

t - temperature, °C;
td - dew point temperature, °C;
RH - relative humidity.
Deviation by dew point temperature ±0,4 °C.
a = 17.27;
b = 237.7.
Source: https://ru.wikipedia.org/wiki/Точка_росы

(%i1) hama:a·t/(b+t)+log(RH);

(%o1) $\frac{a\,t}{t+b}+\log(RH)$

(%i2) Formulatd:td=b·hama/(a−hama);

(%o2) $td=\frac{b\left(\frac{a\,t}{t+b}+\log(RH)\right)}{-\frac{a\,t}{t+b}+a-\log(RH)}$

Maxima готова до введення команд. Готова до введення команди

2 Calculation of relative humidity

(%i3) FormulaRH0:radcan(solve(Formulatd,RH));

(%o3) $\left[RH=\%e^{\frac{a\,b\,td-a\,b\,t}{(t+b)\,td+b\,t+b^2}}\right]$

Simplification of the exponent

(%i4) factor((a·b·td−a·b·t)/((t+b)·td+b·t+b^2));

(%o4) $\frac{a\,b\,(td-t)}{(t+b)\,(td+b)}$

And finally

(%i6) FormulaRH:RH=exp((a·b·(td−t))/((t+b)·(td+b)));

(%o6) $RH=\%e^{\frac{a\,b\,(td-t)}{(t+b)\,(td+b)}}$

Testing the results

(%i7) radcan(FormulaRH−FormulaRH0[1]);

(%o7) 0 = 0

Factor a·b

(%i8) 17.27·237.7;

(%o8) 4105.079

Maxima готова до введення команд. Готова до введення команди

$$RH = e^{\frac{4105.079(td-t)}{(t+237.7)(td+237.7)}}$$

Homework Assignment – Group A3

The next step is to write the software for calculations using CDS Toolbox and Python language:

- retreiving data;
- resampling the data for year-averaged one;
- calculating the regression equation,

  which describes the observations results;
- plotting.

Regression equations for estimation of plant development (phenotype) for the following plant groups:

GROUP I - *armeria*, *aster alpinus*, *dianthus deltoides*, *iris*, *centaurea*:

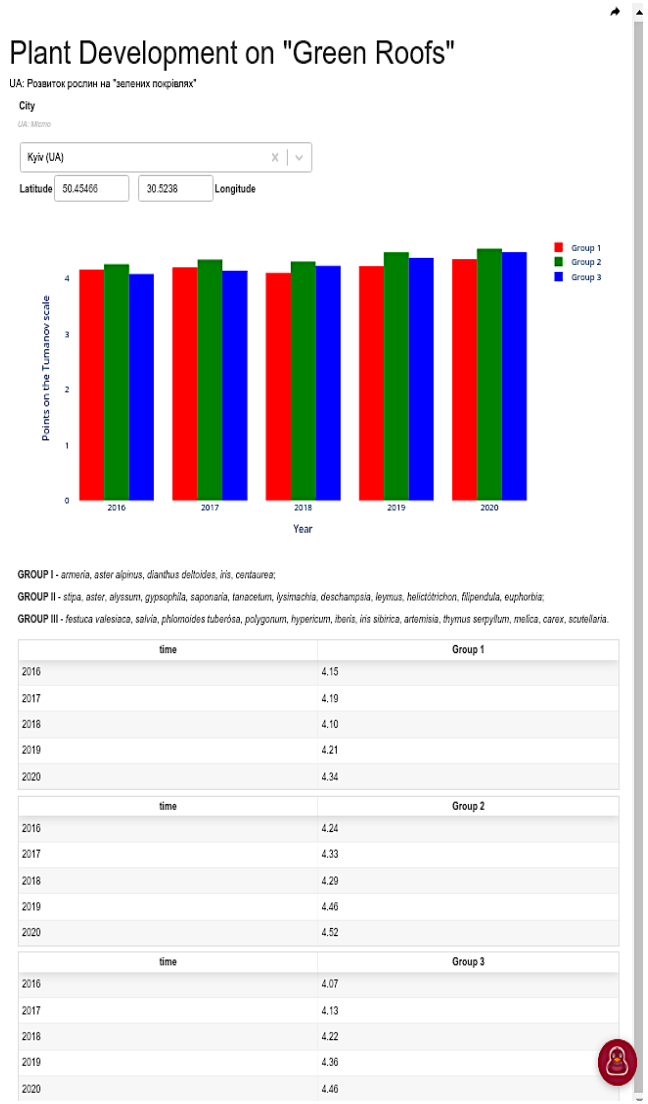
$$FT1 = 5.31 + 0.144\,t - 5.926\,rh + 0.0477\,c - 0.38\,w$$

GROUP II - *stipa, aster, alyssum, gypsophila, saponaria, tanacetum, lysimachia, deschampsia*, *leymus*, *helictotrichon*, *filipendula*, *euphorbia*:

$$FT2 = 4.49 + 0.157\,t - 1.836\,rh - 0.00064\,c - 0.0795\,w$$

GROUP III - festuca valesiaca, salvia, phlomoides tuberosa, polygonum, hypericum, iberis, iris sibirica, artemisia, thymus serpyllum, melica, carex, scutellaria:

$$FT3 = 7.526 + 0.188\,t - 5.6\,rh + 0.0159\,c - 0.603\,w$$



time	Group 1
2016	4.15
2017	4.19
2018	4.10
2019	4.21
2020	4.34

time	Group 2
2016	4.24
2017	4.33
2018	4.29
2019	4.46
2020	4.52

time	Group 3
2016	4.07
2017	4.13
2018	4.22
2019	4.36
2020	4.46

Homework Assignment – Group A3

The software code

```
# EN ##########################################
# APPLICATION FOR CALCULATION OF               #
# PLANT DEVELOPMENT ON "GREEN ROOFS"           #
#                                              #
# It is based on a mathematical regression     #
# model of plant development after             #
# more than ten years of observations          #
# by Tetiana TKACHENKO for "green roofs"       #
# in Ukraine.                                  #
#                                              #
# DEVELOPED BY:                                #
#     Tetiana TKACHENKO, Dr hab, prof.,        #
#     Viktor MILEIKOVSKYI, Dr hab, prof.       #
#     Kyiv National University                 #
#     of Construction and Architecture         #
##############################################
# UA ##########################################
# ЗАСТОСУНОК ДЛЯ РОЗРАХУНКУ РОЗВИТКУ           #
# РОСЛИН НА "ЗЕЛЕНИХ ПОКРІВЛЯХ"                #
#                                              #
# Базується на математичній регресійній        #
# моделі розвитку рослин на підставі           #
# понад десяти років спостережень              #
# Тетяни ТКАЧЕНКО за "зеленими                 #
# покрівлями" в Україні.                       #
#                                              #
# РОЗРОБНИКИ:                                  #
#     Тетяна ТКАЧЕНКО, д.т.н., проф.,          #
#     Віктор МІЛЕЙКОВСЬКИЙ, д.т.н., проф.      #
#     Київський національний університет       #
#     будівництва і архітектури                #
##############################################

import cdstoolbox as ct

layout = {
    'input_ncols': 2,
    'output_align': 'bottom'
}

#Defining the application
#Визначення застосунку
@ct.application(title='Plant Development on "Green Roofs"',
                description='UA: Розвиток рослин на "зелених покрівлях"',
                layout=layout)
#Input of the calculation city
#Увід розрахункового міста
@ct.input.city('CityToCalc',
                label='City',
                description='UA: Місто')
#Output of the plot
#Вивід графіка
@ct.output.livefigure()
#Output of the plant groups
#Вивід груп рослин
@ct.output.markdown()
#Output of the tables
#Вивід таблиць
@ct.output.table()
@ct.output.table()
```

```
@ct.output.table()
#Main function
#Головна функція
def plot_time_series(CityToCalc):
    """
    Application main steps:
    Основні дії додатку:

    - retreiving data;
      отримуємо дані;

    - resampling the data for year-averaged one
      масштабуємо дані до середньорічних

    - calculating the regression equation
      розраховуємо рівняння регресії

    - plotting
      креслимо

    """
    #Input data
    #Вхідні дані
    years=['2016','2017','2018','2019','2020']
    lat=CityToCalc.get('lat')
    lon=CityToCalc.get('lon')
    # Retrieving the weather data around the city
    # Отримуємо погодні дані навколо міста
    wind,dew,temp,cloud = ct.catalogue.retrieve(
        'reanalysis-era5-single-levels-monthly-means',
        {
            'product_type': 'monthly_averaged_reanalysis'
            'variable': [
                '10m_wind_speed',
                '2m_dewpoint_temperature',
                '2m_temperature',
                'total_cloud_cover',
            ],
            'time': '00:00',
            'year': years,
            'month': [
                '01', '02', '03',
                '04', '05', '06',
                '07', '08', '09',
                '10', '11', '12',
            ],
            'area': [
                lat+1, lon-1, lat-1,
                lon+1
            ],
        }
    )
    #Extracting the data for the city.
    # It cannot be resampled until
    # relative humidity calculation
    #Видобуваємо дані для міста.
    # Вони не можуть бути масштабовані
    # до розрахунку відносної вологості
    wind = ct.cube.interpolate(wind,lon=lon,lat=lat)
    dew = ct.cube.interpolate(dew,lon=lon,lat=lat)-273.15
```

```
    dew = ct.cdm.update_attributes(dew, attrs={'units': '°C'})
    temp = ct.cube.interpolate(temp,lon=lon,lat=lat)-273.15
    temp = ct.cdm.update_attributes(temp, attrs={'units': '°C'})
    cloud = ct.cube.interpolate(cloud,lon=lon,lat=lat)
    #Calculating relative humidity using dew point
    #Розраховуємо відносну вологість
    # з використанням точки роси
    rh = ct.math.exp((4105.079*(dew-temp))/((temp+237.7)*(dew+237.7)));
    rh = ct.cdm.update_attributes(rh, attrs={'units': ''})
    #Averaging the data by each year
    #Усереднюємо дані за кожним роком
    wind=ct.cube.resample(wind,freq='year',skipna=True)
    dew=ct.cube.resample(dew,freq='year',skipna=True) #not necessary
    temp=ct.cube.resample(temp,freq='year',skipna=True)
    cloud=ct.cube.resample(cloud,freq='year',skipna=True)
    rh=ct.cube.resample(rh,freq='year',skipna=True)
    #Simulating the plant development
    #Моделюємо розвиток рослин
    FT1=5.31+0.144*temp-5.926*rh+0.0477*cloud-0.38*wind              #
#
    FT2=4.49+0.157*temp-1.836*rh-0.00064*cloud-0.0795*wind
    FT3=7.526+0.188*temp-5.6*rh+0.0159*cloud-0.603*wind
    FT1 = ct.cdm.update_attributes(FT1, attrs={'units': '', 'long_name': 'Group 1'})
    FT2 = ct.cdm.update_attributes(FT2, attrs={'units': '', 'long_name': 'Group 2'})
    FT3 = ct.cdm.update_attributes(FT3, attrs={'units': '', 'long_name': 'Group 3'})
    #Plotting
    #Креслимо
    fig = ct.chart.bar(FT1,bar_kwargs={
                                        'name': 'Group 1',
                                        'showlegend': True,
                                        'marker': {'color': 'red'},
                                        'texttemplate': '%y'},
                            layout_kwargs = {'xaxis': {'title':'Year'},
                                             'yaxis': {'title':"Points on the Tumanov
scale"}})
    fig = ct.chart.bar(FT2,fig=fig,bar_kwargs={
                                                'name': 'Group 2',
                                                'showlegend': True,
                                                'marker': {'color': 'green'},
                                                'texttemplate': '%y'
                                               })
    fig = ct.chart.bar(FT3,fig=fig,bar_kwargs={
                                                'name': 'Group 3',
                                                'showlegend': True,
                                                'marker': {'color': 'blue'},
                                                'texttemplate': '%y'
                                               })
    grp = '''
**GROUP I** - *armeria*, *aster alpinus*, *dianthus deltoides*, *iris*, *centaurea*;

**GROUP II** - *stipa*, *aster*, *alyssum*, *gypsophila*, *saponaria*, *tanacetum*,
*lysimachia*, *deschampsia*, *leymus*, *helictótrichon*, *filipendula*, *euphorbia*;

**GROUP III** - *festuca valesiaca*, *salvia*, *phlomoides tuberósa*, *polygonum*,
*hypericum*, *iberis*, *iris sibirica*, *artemisia*, *thymus serpyllum*, *melica*,
*carex*, *scutellaria*.
'''
    return fig, grp, ct.chart.table(FT1, dim_format='%Y'), ct.chart.table(FT2,
dim_format='%Y'), ct.chart.table(FT3, dim_format='%Y')
```

Homework Assignment – Group A3

Plant Development on "Green Roofs"

UA: Розвиток рослин на "зелених покрівлях"

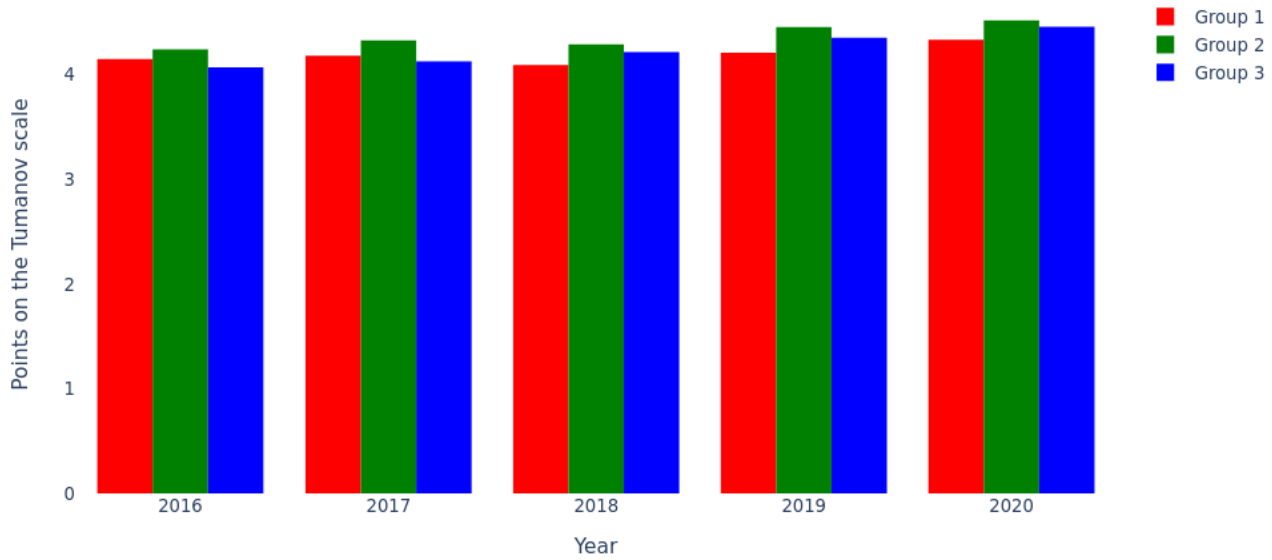
City

UA: Місто

Kyiv (UA)

Latitude 50.45466 30.5238 **Longitude**

Kyiv



time	Group 1
2016	4.15
2017	4.19
2018	4.10
2019	4.21
2020	4.34

time	Group 2
2016	4.24
2017	4.33
2018	4.29
2019	4.46
2020	4.52

time	Group 3
2016	4.07
2017	4.13
2018	4.22
2019	4.36
2020	4.46

GROUP I - *armeria, aster alpinus, dianthus deltoides, iris, centaurea*;

GROUP II - *stipa, aster, alyssum, gypsophila, saponaria, tanacetum, lysimachia, deschampsia, leymus, helictótrichon, filipendula, euphorbia*;

GROUP III - *festuca valesiaca, salvia, phlomoides tuberósa, polygonum, hypericum, iberis, iris sibirica, artemisia, thymus serpyllum, melica, carex, scutellaria.*

Homework Assignment – Group A3

Plant Development on "Green Roofs"

UA: Розвиток рослин на "зелених покрівлях"

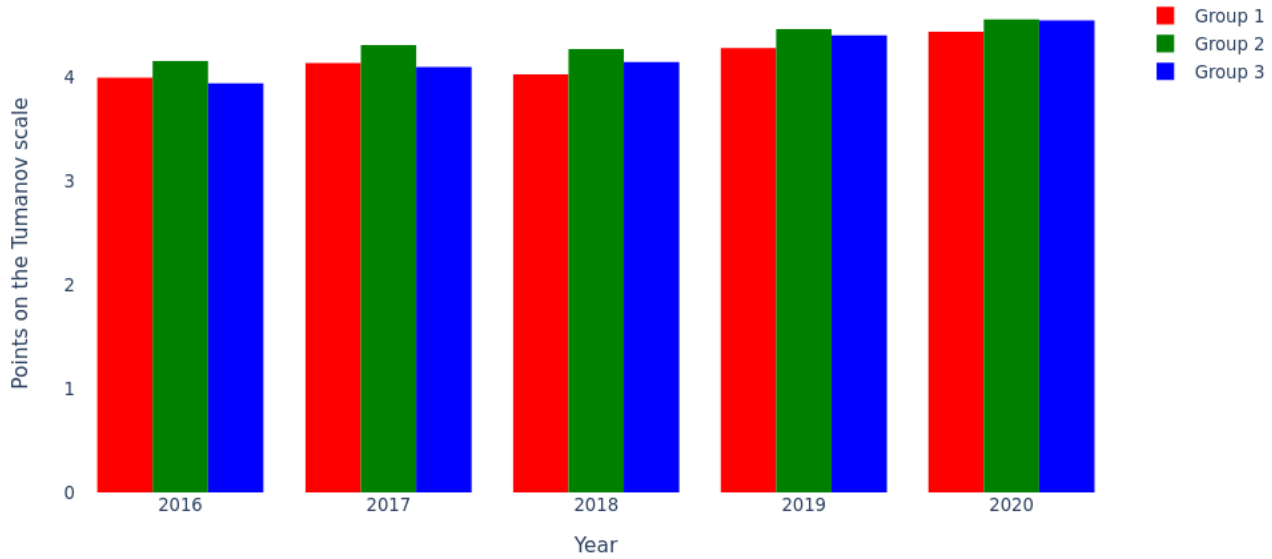
Kharkiv

City

UA: Місто

Kharkiv (UA)

Latitude 49.98081 36.25272 **Longitude**



time	Group 1
2016	3.99
2017	4.13
2018	4.03
2019	4.28
2020	4.44

time	Group 2
2016	4.15
2017	4.31
2018	4.27
2019	4.46
2020	4.56

time	Group 3
2016	3.94
2017	4.10
2018	4.14
2019	4.40
2020	4.55

GROUP I - *armeria, aster alpinus, dianthus deltoides, iris, centaurea;*

GROUP II - *stipa, aster, alyssum, gypsophila, saponaria, tanacetum, lysimachia, deschampsia, leymus, helictótrichon, filipendula, euphorbia;*

GROUP III - *festuca valesiaca, salvia, phlomoides tuberósa, polygonum, hypericum, iberis, iris sibirica, artemisia, thymus serpyllum, melica, carex, scutellaria.*

Homework Assignment – Group A3

Plant Development on "Green Roofs"

UA: Розвиток рослин на "зелених покрівлях"

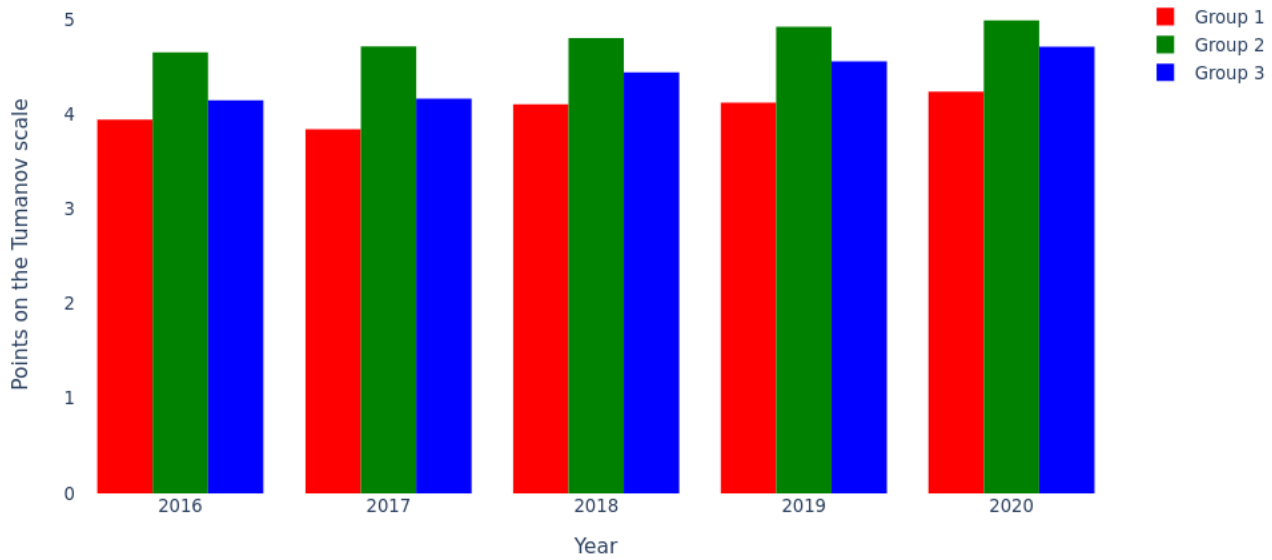
City

UA: Місто

Odessa (UA)

Latitude 46.47747 30.73262 **Longitude**

Odessa



time	Group 1
2016	3.94
2017	3.84
2018	4.10
2019	4.12
2020	4.24

time	Group 2
2016	4.65
2017	4.71
2018	4.80
2019	4.92
2020	4.99

time	Group 3
2016	4.14
2017	4.16
2018	4.44
2019	4.56
2020	4.71

GROUP I - *armeria, aster alpinus, dianthus deltoides, iris, centaurea;*

GROUP II - *stipa, aster, alyssum, gypsophila, saponaria, tanacetum, lysimachia, deschampsia, leymus, helictótrichon, filipendula, euphorbia;*

GROUP III - *festuca valesiaca, salvia, phlomoides tuberósa, polygonum, hypericum, iberis, iris sibirica, artemisia, thymus serpyllum, melica, carex, scutellaria.*

Homework Assignment – Group A3

Results

Year	Plant development (phenotype) estimation [points on the Tumanov scale] at city								
	Kyiv			Kharkiv			Odessa		
	Group I	Group II	Group III	Group I	Group II	Group III	Group I	Group II	Group III
2020	4,34	4,52	4,46	4,44	4,56	4,55	4,24	4,99	4,71
2019	4,21	4,46	4,36	4,28	4,46	4,40	4,12	4,92	4,56
2018	4,10	4,29	4,22	4,03	4,27	4,14	4,1	4,80	4,44
2017	4,19	4,33	4,13	4,13	4,31	4,10	3,84	4,71	4,16
2016	4,15	4,24	4,07	3,99	4,15	3,94	3,94	4,65	4,14
Ave-rage	4,198	4,368	4,248	4,174	4,35	4,226	4,048	4,814	4,402

Green – the best; Brown – medium; Red – the worse

During the last five full years, the plants of group II are the leaders of phenotype. In other groups, the situation was changed in 2018. This year, group III won the second place. In Kharkiv, the group take approximately the same mark as the leader.