Задание лабораторной работы

- Выбрать набор данных (датасет) для решения задачи прогнозирования временного ряда.
- Визуализировать временной ряд и его основные характеристики.
- Разделить временной ряд на обучающую и тестовую выборку.
- Произвести прогнозирование временного ряда с использованием как минимум двух методов.
- Визуализировать тестовую выборку и каждый из прогнозов.
- Оценить качество прогноза в каждом случае с помощью метрик.

Ячейки Jupyter-ноутбука

Выбор и загрузка данных

Текстовое описание

В качестве датасета для решения задачи прогнозирования временного ряда будем использовать набор данных, содержащий ежедневные климатические данные в городе Дели с 2013 по 2017 год. Данный набор доступен по адресу: https://www.kaggle.com/datasets/sumanthvrao/daily-climate-time-series-data

Набор данных имеет следующие атрибуты:

- date Дата метка времени
- meantemp Средняя температура средняя температура, расчитанная по нескольким 3-часовым интервалам в день
- humidity Влажность показатель влажности в граммах воды на кубический метр воздуха
- wind speed Скорость ветра скорость ветра в километрах в час
- meanpressure Среднее давление среднее давление в атмосферах

Импорт библиотек

Импортируем библиотеки с помощью команды import:

In [8]:import numpy as np import pandas as pd from matplotlib import pyplot

import matplotlib.pyplot as plt

Уберем предупреждения:

In [9]:**import** warnings warnings.filterwarnings('ignore')

Загрузка данных

Выборка уже разделена. Для первичного анализа объединим тестовую и обучающую выборку:

In [12]:data_test = pd.read_csv('DailyDelhiClimateTest.csv', header=0, parse_dates=['date'], index_col='date') data_train = pd.read_csv('DailyDelhiClimateTrain.csv', header=0, parse_dates=['date'], index_col='date') data = pd.concat([data_train, data_test], axis=0)

Первичная обработка данных и визуализация

Первичный анализ

Выведем первые 5 строк датасета:

In [13]:data.head()

Out[13]:		meantemp	humidity	wind_speed	meanpressure
	date				
	2013-01-01	10.000000	84.500000	0.000000	1015.666667
	2013-01-02	7.400000	92.000000	2.980000	1017.800000
	2013-01-03	7.166667	87.000000	4.633333	1018.666667
	2013-01-04	8.666667	71.333333	1.233333	1017.166667
	2013-01-05	6.000000	86.833333	3.700000	1016.500000

Определим размер датасета:

In [14]:data.shape

Out[14]:(1576, 4)

Определим типы данных:

In [15]:data.dtypes

Out[15]:meantemp float64 humidity float64 wind_speed float64 meanpressure float64 dtype: object

Обработка данных

Оставим только столбец влажности для временного ряда:

2:-#471-

Out[17]: humidity

date

2013-01-01 84.5000002013-01-02 92.0000002013-01-03 87.000000

2013-01-04 71.333333

2013-01-05 86.833333

Основные статистические характеристки

Определим основные статистические характеристки временного ряда:

In [18]:data.describe()

Out[18]: humidity

count 1576.000000

mean 60.445229

std 16.979994

min 13.428571

25% 49.750000

50% 62.440476

75% 72.125000

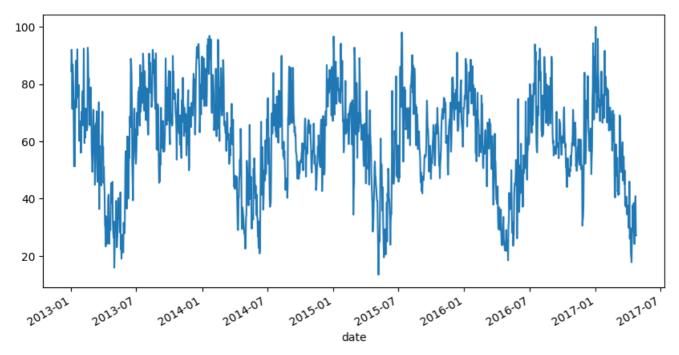
max 100.000000

Визуализация исходного временного ряда

В виде графика:

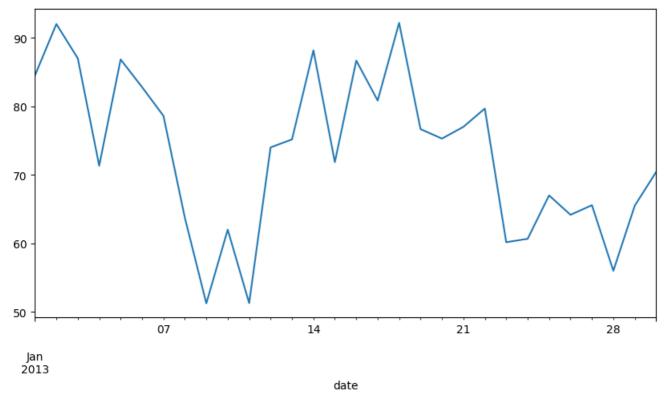
In [19]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(10,5)) fig.suptitle('Временной ряд в виде графика') data.plot(ax=ax, legend=**False**) pyplot.show()

Временной ряд в виде графика



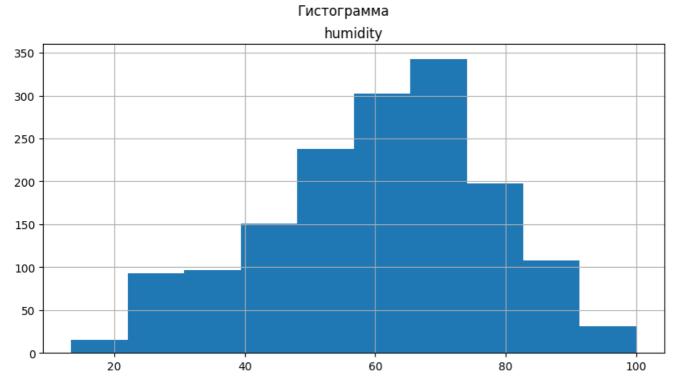
In [20]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(10,5)) fig.suptitle('Первые 30 точек ряда') data[:30].plot(ax=ax, legend=**False**) pyplot.show()

Первые 30 точек ряда



В виде гистограммы:

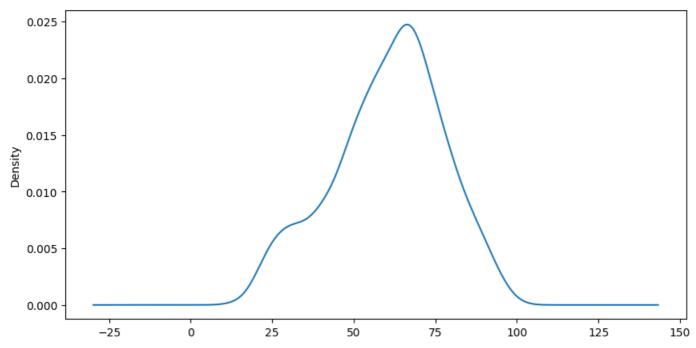
```
In [21]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(10,5)) fig.suptitle('Гистограмма') data.hist(ax=ax, legend=False) pyplot.show()
```



Вероятностная плотность распределения данных:

In [22]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(10,5)) fig.suptitle('Плотность вероятности распределения данных') data.plot(ax=ax, kind='kde', legend=**False**) pyplot.show()

Плотность вероятности распределения данных

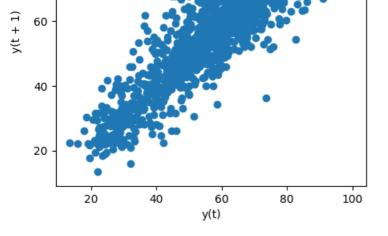


С помощью Lag Plot:

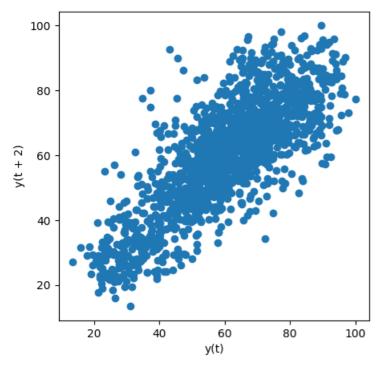
In [23]:for i in range(1, 5): fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(5,5)) fig.suptitle(f'Лаг порядка $\{i\}'$) pd.plotting.lag_plot(data, lag=i, ax=ax) pyplot.show()

Лаг порядка 1

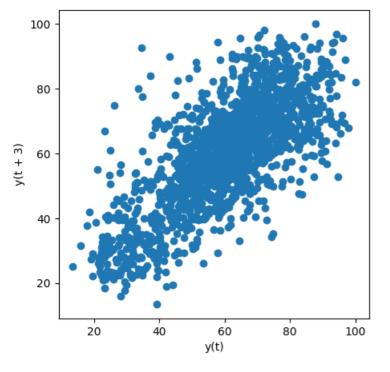




Лаг порядка 2

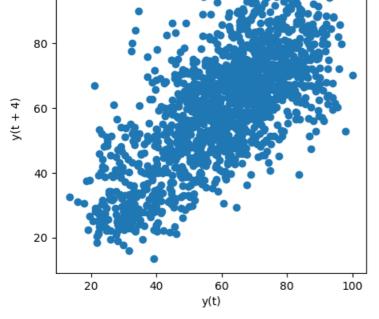


Лаг порядка 3



Лаг порядка 4



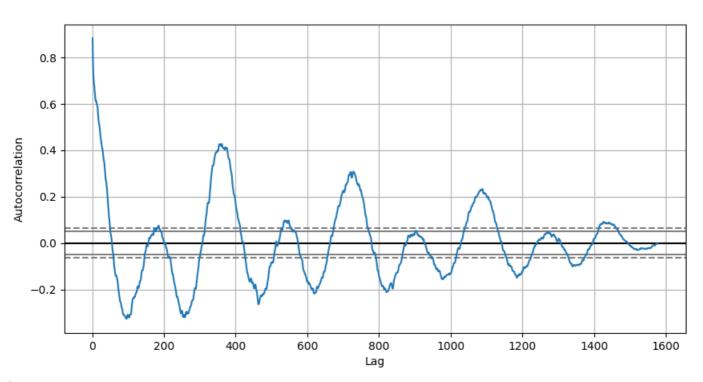


Наблюдается достаточно сильная положительная корреляция.

Автокорреляционная диаграмма:

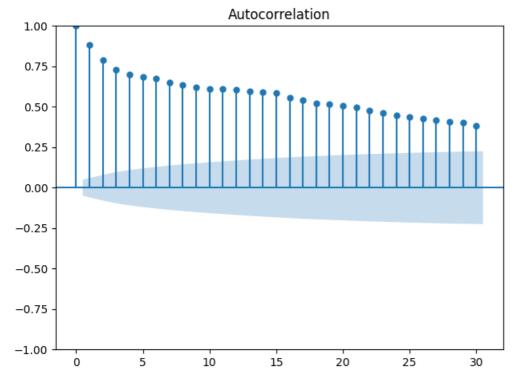
In [24]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(10,5)) fig.suptitle('Автокорреляционная диаграмма') pd.plotting.autocorrelation_plot(data, ax=ax) pyplot.show()

Автокорреляционная диаграмма



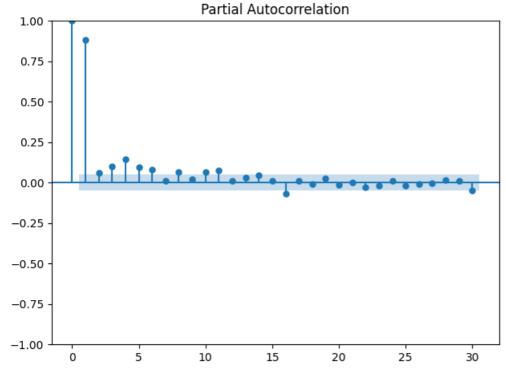
Автокорреляционная функция:

In [25]:**from** statsmodels.graphics.tsaplots **import** plot_acf plot_acf(data, lags=30) plt.tight_layout()



Частичная автокорреляционная функция:

In [26]:**from** statsmodels.graphics.tsaplots **import** plot_pacf plot_pacf(data, lags=30) plt.tight_layout()



Временной ряд со скользящими средними:

```
In [27]:data2 = data.copy()
```

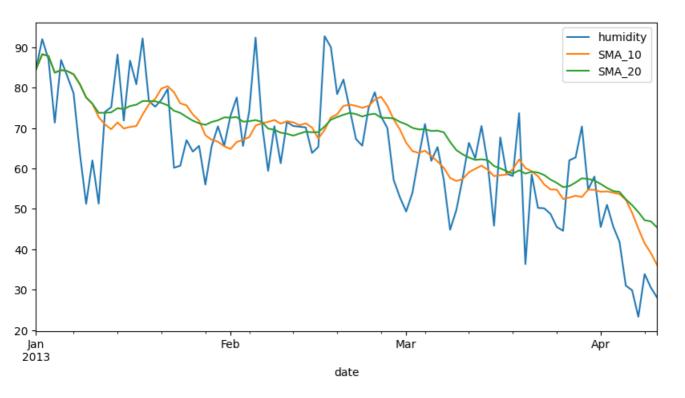
In [28]:data2['SMA_10'] = data2['humidity'].rolling(10, min_periods=1).mean() data2['SMA_20'] = data2['humidity'].rolling(20, min_periods=1).mean()

In [29]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(10,5)) fig.suptitle('Временной ряд со скользящими средними')

data2[:100].plot(ax=ax, legend=**True**)

data2[:100].plot(ax=ax, legend=1rue pyplot.show()

Временной ряд со скользящими средними



Прогнозирование временного ряда с использованием авторегрессионного метода

Будем использовать авторегриссионный метод ARIMA:

In [30]:from statsmodels.tsa.arima.model import ARIMA

Разделение выборки на обучающую и тестовую

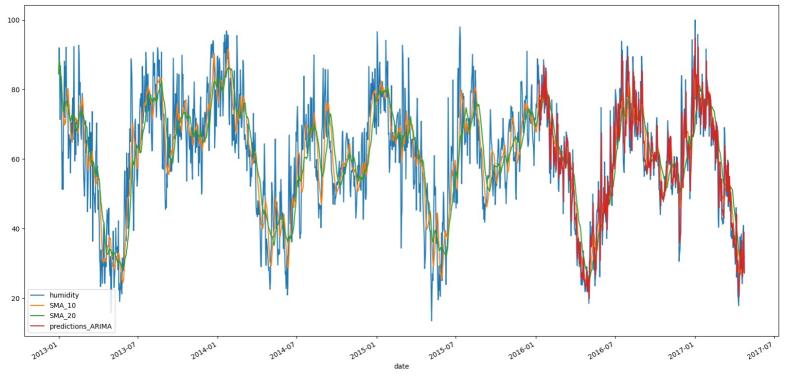
```
In [31]:xnum = list(range(data2.shape[0]))
    Y = data2['humidity'].values
    train_size = int(len(Y) * 0.7)
    xnum_train, xnum_test = xnum[0:train_size], xnum[train_size:]
    train, test = Y[0:train_size], Y[train_size:]
    history_arima = [x for x in train]
```

Прогноз ARIMA

```
In [35]:arima_order = (6, 1, 0)
    predictions_arima = list()
    for t in range(len(test)):
        model_arima = ARIMA(history_arima, order=arima_order)
        model_arima_fit = model_arima.fit()
        yhat_arima = model_arima_fit.forecast()[0]
        predictions_arima.append(yhat_arima)
        history_arima.append(test[t])
In [33]:data2['predictions_ARIMA'] = (train_size * [np.NAN]) + list(predictions_arima)
```

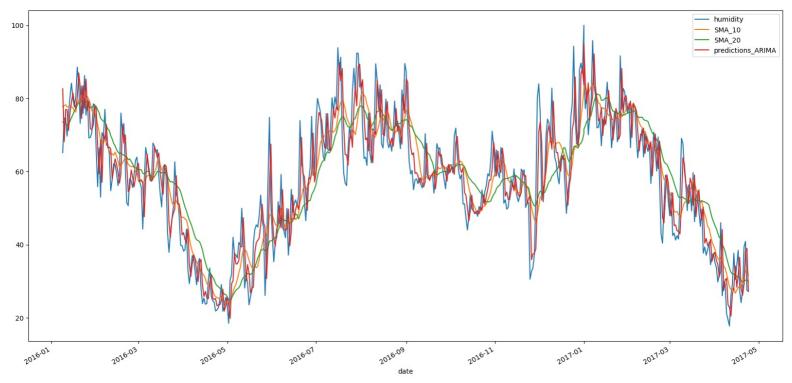
Визуализация

```
In [34]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(20,10)) fig.suptitle('Предсказания временного ряда') data2.plot(ax=ax, legend=True) pyplot.show()
```



In [36]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(20,10)) fig.suptitle('Предсказания временного ряда (тестовая выборка)') data2[train_size:].plot(ax=ax, legend=**True**) pyplot.show()

Предсказания временного ряда (тестовая выборка)



Предсказания ARIMA точны, близки к исходному, далеки от среднего скользящего.

Метрики

MAE и MSE:

In [37]: from sklearn.metrics import mean_absolute_error, mean_squared_error

 $In~[38]: mean_squared_error(test,~predictions_arima,~squared \textbf{=False})$

Out[38]:7.491497821228328

In [39]:mean_absolute_error(test, predictions_arima)

Out[39]:5.595463345661848

Прогнозирование временного ряда с использованием метода символьной регрессии

est_gp = SymbolicRegressor(population_size=500, metric='mse',

In [41]:function set = ['add', 'sub', 'mul', 'div', 'sin']

Прогноз

```
generations=200, stopping_criteria=0.01,
                        init_depth=(4, 10), verbose=1, function_set=function_set,
                        const_range=(-10, 10), random_state=0)
In [42]:est_gp.fit(np.array(xnum_train).reshape(-1, 1), train.reshape(-1, 1))
  | Population Average |
                                 Best Individual
Gen Length
                  Fitness Length
                                       Fitness
                                                 OOB Fitness Time Left
    263.65
              1.91324e+67
                              26
                                       3366.8
                                                     N/A
                                                            5.85m
  1
    161.42
              1.73488e+15
                               3
                                      771.22
                                                     N/A
                                                            2.54m
 2
     62.67
             3.99717e+14
                              3
                                      771.22
                                                    N/A
                                                           1.53m
 3
     39.15
             3.51722e+10
                                      285.6
                                                    N/A
                                                           1.56m
                              3
     24.00
                                      285.6
                                                    N/A
                                                          56.82s
 4
             3.38638e+11
                              3
 5
     26.05
             6.84991e+09
                              34
                                      280.86
                                                     N/A
                                                           59.61s
 6
     11.13
              1.4874e+10
                             35
                                     280.438
                                                     N/A
                                                           47.45s
 7
     19.15
              4.04141e+06
                                      280.136
                                                     N/A
                                                            1.04m
 8
     33.94
             2.44637e+10
                              62
                                      279.776
                                                     N/A
                                                            1.22m
 9
     36.48
              2.2103e+06
                             42
                                                    N/A
                                                           1.38m
                                      279.19
 10
                                                      N/A
                                                             1.31m
     45.82
              1.61747e+09
                              39
                                      279.026
 11
     50.83
                                                      N/A
                                                             1.34m
              1.24868e+06
                              60
                                      278,728
 12
     51.02
              1.20327e+06
                              72
                                      278.686
                                                      N/A
                                                             1.26m
 13
     46.53
              5.97296e+08
                              64
                                      278.507
                                                      N/A
                                                             1.27m
 14
     59.07
                 988142
                            67
                                    278.056
                                                    N/A
                                                           1.44m
 15
     80.40
               1.4714e+06
                              70
                                      277.651
                                                      N/A
                                                            1.91m
 16
     91.46
              4.15928e+06
                                      274.954
                                                      N/A
                                                             1.70m
                              58
 17
     94.69
                                      274.954
                                                      N/A
                                                             1.75m
              1.16678e+06
                              58
 18
     131.75
               3.04158e+06
                               113
                                        274.223
                                                       N/A
                                                              2.32m
     154.79
                             70
                                     267.841
                                                           2.65m
 19
                  599428
 20
    129.60
               5.39217e+06
                              128
                                       267.662
                                                       N/A
                                                              2.63m
 21
     100.25
               4.61995e+06
                               67
                                       263.942
                                                       N/A
                                                              2.85m
 22
     92.04
                 274173
                           103
                                     263.402
                                                    N/A
                                                           3.33m
 23
     107.35
                  193345
                                                    N/A
                            183
                                      258.85
                                                           2.55m
 24
     108.87
                  140414
                            183
                                     258.017
                                                     N/A
                                                            2.20m
 25
     123.21
                  185654
                            212
                                     240.913
                                                     N/A
                                                            2.36m
 26
     180.34
                  297662
                            210
                                      240.84
                                                    N/A
                                                           3.03m
 27
     208.77
                  143690
                            211
                                     239.988
                                                     N/A
                                                            3.51m
 28
     213.35
                  338481
                            299
                                     238.607
                                                     N/A
                                                            3.29m
     222.05
                  231000
                            476
                                                     N/A
 29
                                     238.538
                                                            3.46m
     267.90
                  200555
                                                    N/A
 30
                            303
                                      238.41
                                                           4.08m
 31
     298.85
                  110925
                            556
                                     238.103
                                                     N/A
                                                            4.18m
     309.06
 32
                  185395
                            556
                                      238.07
                                                    N/A
                                                           4.85m
 33
     340.90
                  132016
                            354
                                     238.051
                                                     N/A
                                                            5.55m
 34
     326.51
                  129423
                            332
                                     237.828
                                                     N/A
                                                            4.59m
                                     237.792
 35
    314.32
                  939493
                            344
                                                     N/A
                                                            4.49m
                                                            4.54m
 36
     327.52
                  129602
                            303
                                     230.187
                                                     N/A
 37
     318.18
               7.70537e+07
                              340
                                        220.34
                                                       N/A
                                                              4.36m
 38
     329.86
                  157729
                            366
                                     220.279
                                                     N/A
                                                            4.51m
 39
     330.05
                                                     N/A
                                                            5.05m
                  310550
                            329
                                     219.403
 40
     342.88
                  184113
                            348
                                      218.34
                                                    N/A
                                                           5.12m
               1.90276e+09
 41
     349.80
                              329
                                        217.718
                                                       N/A
                                                              4.90m
 42
     360.93
                  303619
                            327
                                     217.701
                                                     N/A
                                                            6.29m
 43
     344 29
                  226896
                            320
                                     210.026
                                                     N/A
                                                            4.87m
 44
     337.52
                  231055
                                     206.541
                                                     N/A
                                                            4.57m
                            398
 45
     340.60
                  294015
                            398
                                     206.541
                                                     N/A
                                                            5.00m
 46
     359.81
                  256564
                            407
                                      195.67
                                                    N/A
                                                           5.32m
 47
    407.65
                  152362
                            493
                                     193.514
                                                     N/A
                                                            5.29m
 48 424.48
                              450
                                        190.798
               5.85872e+06
                                                       N/A
                                                              5.26m
    464.99
 49
                  356433
                            450
                                     190.793
                                                     N/A
                                                            5.66m
 50
    479.00
               2.61636e+06
                              469
                                        189.585
                                                       N/A
                                                              5.69m
 51
     463.20
                 97706.7
                            574
                                     181.247
                                                     N/A
                                                            6.84m
     486.36
                  314938
                                     180.519
                                                            5.64m
 52
                            641
                                                     N/A
 53
     533.12
                  319413
                            582
                                     180.251
                                                     N/A
                                                            6.14m
 54
     599.20
                  154258
                            580
                                     179.739
                                                     N/A
                                                            6.82m
     605.87
                            780
                                                     N/A
 55
                  115203
                                     179.665
                                                            7.16m
     607.26
 56
               1.10202e+06
                              580
                                        161.751
                                                       N/A
                                                              7.07m
 57
     590.25
                  325810
                            607
                                                     N/A
                                                            6.39m
                                     157,107
 58
    599.51
                  175627
                            498
                                     154.816
                                                     N/A
                                                            6.50m
 59
    615.73
               2.05937e+07
                              585
                                        147.345
                                                       N/A
                                                              6.93m
 60
    572.38
                  381544
                            597
                                     146.883
                                                     N/A
                                                            7.29m
 61 576.44
                  289927
                            509
                                     145.037
                                                     N/A
                                                            6.44m
                  243327
                                     144.194
                                                     N/A
                                                            5.95m
 62 557.31
                            651
               2.80685e+06
                                                       N/A
 63
     574.89
                              579
                                        142.065
                                                              6.23m
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139 1678.08 26897.3 1753 108.847 N/A 7.11m 140 1722.07 122838 1936 107.952 N/A 6.89m				
140 1722.07 122838 1936 107.952 N/A 6.89m				

142 1842.02	48335.6 1971	107.611	N/A 7.22m
143 1947.55	82681.7 1964	107.512	N/A 7.34m
144 1933.71	6.0061e+08 1970	107.395	N/A 7.41m
145 1972.54	74686.6 1970	106.999	N/A 7.25m
146 1954.03	64469.6 2011	106.981	N/A 7.01m
147 1951.31	8795.11 1942	106.773	N/A 7.13m
148 1955.85	975.374 1941	106.647	N/A 6.79m
149 1965.40	3.42713e+06 2020	106.646	N/A 6.81m
150 1947.16	78761.9 2019	106.512	N/A 6.78m
151 1933.35	58093.1 2018	106.506	N/A 6.43m
152 1964.62	57360.7 2004	106.35	N/A 7.60m
153 1970.03	69364.7 1881	106.234	N/A 6.80m
154 1950.37	5.95297e+08 1882	106.112	N/A 6.76m
155 1939.50	123477 1878	106.099	N/A 7.77m
156 1909.67	217390 1824	105.998	N/A 6.49m
157 1879.78	48951.3 1841	105.954	N/A 6.38m
158 1852.92	2.00151e+07 1828	105.831	N/A 6.02m
159 1834.71	41082 1828	105.831	N/A 5.37m
160 1817.06	74661.6 1832	105.797	N/A 5.38m
161 1814.77	3860.34 1832	105.783	N/A 5.64m
162 1808.57	62680.3 1842	105.664	N/A 5.77m
163 1758.15	203506 1712	105.417	N/A 4.38m
164 1690.86	92262 1712	105.394	N/A 3.88m
165 1692.49	116450 1741	105.261	N/A 3.78m
166 1727.47	66436.9 1739	105.171	N/A 4.42m
167 1716.24	3.89336e+11 1741	105.171	N/A 4.42111 N/A 6.18m
168 1730.61	1.00493e+07 1750	105.092	N/A 3.93m
169 1741.79	571328 1742	104.97	N/A 3.29m
170 1733.52	1.78267e+07 1741	104.953	N/A 3.29111 N/A 3.07m
170 1733.32	502739 1954	104.847	N/A 2.91m
171 1730.00	196115 1954	104.847	N/A 2.9111 N/A 3.33m
172 1755.25	5.67425e+08 2047	104.254	N/A 3.3311
173 1755.07	82979 2047	104.254	N/A 3.60m
175 1806.70	93743.3 2049	103.817	N/A 3.02m
176 1954.89	35559.4 2022	103.736	N/A 2.94m
177 2026.45	73924 2036	103.736	N/A 2.90m
177 2020.43	87278.4 2048	103.544	N/A 2.79m
179 2045.47	124714 2047	103.372	N/A 2.64m
180 2031.76	130210 2134	103.226	N/A 2.50m
181 2055.03	35068.6 2631	102.926	N/A 2.51m
182 2066.12	72599.6 2633	102.919	N/A 2.41m
183 2030.26	161098 2032	103.01	N/A 2.22m
184 2020.91	136310 2076	102.829	N/A 2.22m
185 2018.65	30982.9 2009	102.519	N/A 2.12m
186 2003.83	6.01768e+08 2012	102.519	N/A 1.78m
187 2022.74	79395.3 2527	102.476	N/A 1.59m
188 2005.91	56386.1 2100	102.348	N/A 1.41m
189 2016.43	115070 2184	102.345	N/A 1.41111 N/A 1.19m
190 2016.36	94111.4 2147	102.343	N/A 1.1911 N/A 1.05m
191 2018.53	173633 2083	102.054	N/A 57.01s
192 2020.19	116259 2085	102.034	N/A 51.89s
193 2036.41	134852 2081	102.036	N/A 51.698 N/A 43.04s
193 2036.41	63033.3 2077	101.931	N/A 45.048 N/A 36.30s
194 2064.99			
195 2083.19	33114.6 2082	101.271	
196 2076.44	242556 2082 192377 2082	101.259 101.247	N/A 21.29s N/A 16.55s
197 2075.79	192377 2082 5.95726e+08 2101	101.247	N/A 16.558 N/A 7.75s
198 2089.56	5.957260+08 2101	101.067	N/A 7.758 N/A 0.00s
0+[42]	00920.0 2001	101.040	1N/A 0.005

SymbolicRegressor

Out[42]: 🔻

 $Out[43]: array([73.80469798, 74.62276246, 74.81765215, 74.88961676, 74.91224874, \\74.90617581, 74.87934757, 74.83554142, 74.77687615, 74.70473071])$

In [44]:data2['predictions_GPLEARN'] = (train_size * [np.NAN]) + list(y_gp)

```
Визуализация
Построим дерево по символьной регрессии:
In [47]:import graphviz
      import pydotplus
      from sklearn.tree import export_graphviz
In [50]:dot_data = est_gp._program.export_graphviz()
      pydot_graph = pydotplus.graph_from_dot_data(dot_data)
      pydot_graph.set_size(10)
      gvz_graph = graphviz.Source(pydot_graph.to_string())
      gvz_graph
FileNotFoundError
                                  Traceback (most recent call last)
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\backend\execute.py:79, in run_check(cmd, input_lines, encoding, qui
et, **kwargs)
  78
          kwargs['stdout'] = kwargs['stderr'] = subprocess.PIPE
         proc = _run_input_lines(cmd, input_lines, kwargs=kwargs)
---> 79
  80 else:
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\backend\execute.py:99, in run_input_lines(cmd, input_lines, kwargs)
   98 def _run_input_lines(cmd, input_lines, *, kwargs):
         popen = subprocess.Popen(cmd, stdin=subprocess.PIPE, **kwargs)
  101
         stdin_write = popen.stdin.write
File ~\AppData\Local\Programs\Python\Python310\lib\subprocess.py:971, in Popen.__init__(self, args, bufsize, executable, stdin, stdout, stderr, pre
exec fn, close fds, shell, cwd, env, universal newlines, startupinfo, creationflags, restore signals, start new session, pass fds, user, group, extr
a_groups, encoding, errors, text, umask, pipesize)
  968
             self.stderr = io.TextIOWrapper(self.stderr,
  969
                  encoding=encoding, errors=errors)
--> 971
          self._execute_child(args, executable, preexec_fn, close_fds,
  972
                     pass_fds, cwd, env,
  973
                     startupinfo, creationflags, shell,
  974
                     p2cread, p2cwrite,
  975
                     c2pread, c2pwrite,
  976
                     errread, errwrite,
  977
                     restore_signals,
  978
                     gid, gids, uid, umask,
  979
                     start_new_session)
  980 except:
        # Cleanup if the child failed starting.
File ~\AppData\Local\Programs\Python\Python310\lib\subprocess.py:1440, in Popen. execute_child(self, args, executable, preexec_fn, close_fds, p
ass_fds, cwd, env, startupinfo, creationflags, shell, p2cread, p2cwrite, c2pread, c2pwrite, errread, errwrite, unused_restore_signals, unused_gid, u
nused_gids, unused_uid, unused_umask, unused_start_new_session)
 1439 try:
-> 1440
          hp, ht, pid, tid = winapi.CreateProcess(executable, args,
 1441
                         # no special security
  1442
                        None, None,
  1443
                        int(not close_fds),
  1444
                        creationflags.
  1445
                        env.
  1446
                        cwd.
  1447
                        startupinfo)
  1448 finally:
  1449
         # Child is launched. Close the parent's copy of those pipe
  1450
         # handles that only the child should have open. You need
 (...)
 1453
         # pipe will not close when the child process exits and the
  1454
         # ReadFile will hang.
FileNotFoundError: [WinError 2] Не удается найти указанный файл
The above exception was the direct cause of the following exception:
ExecutableNotFound
                                    Traceback (most recent call last)
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\IPython\core\formatters.py:974, in MimeBundleFormatter. call (self, obj, inclu
de, exclude)
  971
         method = get_real_method(obj, self.print_method)
  973
        if method is not None:
--> 974
            return method(include=include, exclude=exclude)
  975
        return None
  976 else:
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\jupyter_integration.py:98, in JupyterIntegration. repr_mimebundle (self
, include, exclude, ** )
   96 include = set(include) if include is not None else {self._jupyter_mimetype}
```

97 include -= set(exclude or [])

```
---> 98 return {mimetype: getattr(self, method_name)()
   99
          for mimetype, method_name in MIME_TYPES.items()
  100
           if mimetype in include}
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\jupyter_integration.py:98, in <dictcomp>(.0)
   96 include = set(include) if include is not None else {self._jupyter_mimetype}
   97 include -= set(exclude or [])
---> 98 return {mimetype: getattr(self, method name)()
          for mimetype, method_name in MIME_TYPES.items()
  100
           if mimetype in include}
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\jupyter_integration.py:112, in JupyterIntegration._repr_image_svg_xml(
self)
  110 def _repr_image_svg_xml(self) -> str:
  111
         """Return the rendered graph as SVG string."""
         return self.pipe(format='svg', encoding=SVG_ENCODING)
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\piping.py:104, in Pipe.pipe(self, format, renderer, formatter, neato_no
_op, quiet, engine, encoding)
  55 def pipe(self,
   56
           format: typing.Optional[str] = None,
   57
           renderer: typing.Optional[str] = None,
  (...)
   61
           engine: typing.Optional[str] = None,
   62
           encoding: typing.Optional[str] = None) -> typing.Union[bytes, str]:
        """Return the source piped through the Graphviz layout command.
   63
   64
   65
        Args:
  (...)
           '<?xml version=
  102
  103
--> 104
         return self._pipe_legacy(format,
  105
                        renderer=renderer
  106
                        formatter=formatter.
  107
                        neato no op=neato no op,
  108
                        quiet=quiet,
  109
                        engine=engine,
  110
                        encoding=encoding)
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\ tools.py:171, in deprecate positional args.<locals>.decorator.<locals>.
wrapper(*args, **kwargs)
  162
         wanted = ', '.join(f'{name}={value!r}'
  163
                    for name, value in deprecated.items())
  164
         warnings.warn(f'The signature of {func.__name__}) will be reduced'
                 f' to {supported_number} positional args'
  165
  166
                 f' {list(supported)}: pass {wanted}'
  167
                 ' as keyword arg(s)',
  168
                 stacklevel=stacklevel,
  169
                 category=category)
--> 171 return func(*args, **kwargs)
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\piping.py:121, in Pipe_pipe_legacy(self, format, renderer, formatter, n
eato no op, quiet, engine, encoding)
  112 @ tools.deprecate positional args(supported number=2)
  113 def pipe legacy(self,
  114
                format: typing.Optional[str] = None,
  (...)
  119
                 engine: typing.Optional[str] = None,
  120
                encoding: typing.Optional[str] = None) -> typing.Union[bytes, str]:
         return self. pipe future(format,
--> 121
  122
                        renderer=renderer
  123
                        formatter=formatter,
  124
                        neato no op=neato no op,
  125
                        quiet=quiet,
  126
                        engine=engine,
  127
                        encoding=encoding)
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\piping.py:149, in Pipe._pipe_future(self, format, renderer, formatter, ne
ato_no_op, quiet, engine, encoding)
  146 if encoding is not None:
        if codecs.lookup(encoding) is codecs.lookup(self.encoding):
  147
  148
           # common case: both stdin and stdout need the same encoding
--> 149
            return self._pipe_lines_string(*args, encoding=encoding, **kwargs)
  150
        trv:
  151
           raw = self. pipe lines(*args, input encoding=self.encoding, **kwargs)
File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\backend\piping.py:212, in pipe lines string(engine, format, input line
```

s, encoding, renderer, formatter, neato no op, quiet)

```
206 cmd = dot_command.command(engine, format,
207 renderer=renderer,
208 formatter=formatter,
209 neato_no_op=neato_no_op)
210 kwargs = {'input_lines': input_lines, 'encoding': encoding}
--> 212 proc = execute.run_check(cmd, capture_output=True, quiet=quiet, **kwargs)
213 return proc.stdout
```

File ~\AppData\Local\Programs\Python\Python310\lib\site-packages\graphviz\backend\execute.py:84, in run_check(cmd, input_lines, encoding, qui et. **kwargs)

```
82 except OSError as e:
```

if e.errno == errno.ENOENT:

--> 84 raise ExecutableNotFound(cmd) from e

85 raise

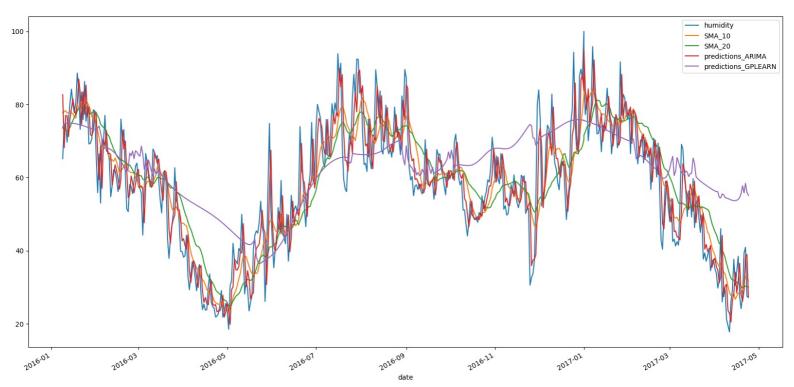
87 if not quiet and proc.stderr:

ExecutableNotFound: failed to execute WindowsPath('dot'), make sure the Graphviz executables are on your systems' PATH Out[50]:<graphviz.sources.Source at 0x205a716a3b0>

Построим график по тестовой выборке:

```
In [51]:fig, ax = pyplot.subplots(1, 1, sharex='col', sharey='row', figsize=(20,10)) fig.suptitle('Предсказания временного ряда (тестовая выборка)') data2[train_size:].plot(ax=ax, legend=True) pyplot.show()
```

Предсказания временного ряда (тестовая выборка)



Визуально предсказания по методу сивольной регрессии менее точны, чем предсказания по ARIMA. Для повышения точности требуется настройка параметров метода, в частности увеличенное количество итераций цикла. Однако при этом сильно возрастут затраты времени.

Метрики

MAE и MSE:

In [52]:mean_squared_error(test, y_gp, squared=False)

Out[52]:13.52324614284193

In [53]:mean_absolute_error(test, y_gp)

Out[53]:10.607119049073066

Сранение качества моделей

Чем ближе значение MAE и MSE к нулю, тем лучше качество модели.

МАЕ для авторегрессионного метода ARIMA = 5.5, а для метода символьной регрессии = 10.6.

MSE для авторегрессионного метода ARIMA = 7.3, а для метода символьной регрессии = 13.5.

Качество модели для авторегрессионного метода ARIMA выше. Для выполенения ARIMA также требуется меньше времени.