```
> restart;
  with(plots):
  with(StringTools):
  with(LinearAlgebra):
  with(DEtools):

  ##########################################################################################

  Region:=`Moscow`; url:="https://gogov.ru/covid-19/msk#data";

  #valp := [14.3017011620847, 174294.606596865, 0.112136011920555, 0.227305036587638,
  0.168356213163325, 0.132723499424831, #0.0924368623344482, 0.130118851494360, 0.163817974575960,
  0.162539645677865, 0.00976372140309013, 0.0198876861922680, #0.00009699484445241616];

  valp:=readdata(cat(Region,`3c.txt`));

  ##########################################################################################

  fdisplay:=proc(f,p)
   print(cat(f,`.jpg`)); #print(cat(f,`.eps`));
   plotsetup(jpeg,plotoutput=cat(f,`.jpg`),plotoptions=`noborder`); print(display(p));
   plotsetup(ps,plotoutput=cat(f,`.eps`),plotoptions=`noborder`); print(display(p));
   plotsetup(default,plotoptions=`noborder`): print(display(p));
  end:

  pr:=proc(x) print(x); x; end:

  grad:=(F,V)->map(q->diff(F,q),V):

  linsplit:=(F,V)->subs(map(q->q=0,V),[op(grad(F,V)),F]):

  corr:=proc(x,y) local i; seq(x[i]=y[i],i=1..nops(x)): end:

  ssum:=(F,V)->convert([seq(F,V)],`+`):

  pprod:=(F,V)->convert([seq(F,V)],`*`):

  Lag:=proc(t,tx,kx) local i,j;
   ssum(kx[i]*pprod(piecewise(j=i,1,(t-tx[j])/(tx[i]-tx[j])),j=1..nops(tx)),i=1..nops(tx)):
  end:
```

```
Lag(t,[ta,tb],[a,b]); Lag(t,[ta,tb,tc],[a,b,c]);

pi:=evalf(Pi);


gM:=evalf(solve((1-x)^2=x,x)[2]):
goldMin:=proc(f,T,epsilon) local a,b,c,d,fa,fb,fc,fd,k;
 a:=op(1,T); b:=op(2,T); fa:=f(a); fb:=f(b); k:=0;
 c:=a+(b-a)*gM; fc:=f(c); d:=b-(b-a)*gM; fd:=f(d);
 while abs(a-b)>epsilon do: k:=k+1;
  if fc>fd then a:=c; fa:=fc; c:=d; fc:=fd; d:=b-(b-a)*gM; fd:=f(d);
  else b:=d; fb:=fd; d:=c; fd:=fc;+ c:=a+(b-a)*gM; fc:=f(c);
  fi;
 od: #print(k);
 (a+b)/2;
end:

findMin1:=proc(F,V) local f,df,f0,f1,f2,V0,V1,V2,ff,t,dt,i,j;
 ff:=V->F(op(evalf(map(exp,V)))); V1:=evalf(map(ln,V)); f1:=F(op(V));
 f:=[seq(F(seq(evalf(exp(V1[j]+piecewise(j=i,0.0001,0))),j=1..nops(V))),i=1..nops(V))];
 df:=[seq((f[j]-f1)/0.1,j=1..nops(V))];
 V0:=V1-0.001*df; f0:=ff(V0);  V2:=V1+0.001*df; f2:=ff(V2);
 dt:=0.0001; while f0<f1 do: V2:=V1; f2:=f1; V1:=V0; f1:=f0; V0:=V0-dt*df; f0:=ff(V0); dt:=dt*
1.5; od;
 dt:=0.0001; while f2<f1 do: V0:=V1; f0:=f1; V1:=V2; f1:=f2; V2:=V2+dt*df; f2:=ff(V2); dt:=dt*
1.5; od;
 t:=goldMin(t->ff(t*V0+(1-t)*V2),0..1,0.001);
 map(exp,t*V0+(1-t)*V2);
end:

findMin:=proc(F,V) local V1,Z1,Z2;
 Z2:=pr(F(op(V))); V1:=findMin1(F,V); Z1:=pr(chi2(op(V1)));
 while abs(1-Z1/Z2)>0.0001 do; Z2:=Z1; V1:=findMin1(F,V1); Z1:=pr(chi2(op(V1))); end;
 V1;
end:
```

$$Region := Moscow$$

$$url := \text{"https://gogov.ru/covid-19/msk\#data"}$$

$$valp := [13.71214965, 220689.9212, 0.1046895272, 0.2134720246, 0.1782006759, 0.1216279446, 0.08916969542, 0.1172713974,$$

0.09673479683, 0.1811377111, 0.01119895789, 0.006644970495, 0.0345222548, 0.0007474477074]

$$\frac{a\,(t-tb)}{ta-tb}+\frac{b\,(t-ta)}{tb-ta}$$

$$\frac{a\,(t-tb)\,(t-tc)}{(ta-tb)\,(ta-tc)}+\frac{b\,(t-ta)\,(t-tc)}{(tb-ta)\,(tb-tc)}+\frac{c\,(t-ta)\,(t-tb)}{(tc-ta)\,(tc-tb)}$$

$$\pi := 3.141592654$$

(1

```
> dig:={"0","1","2","3","4","5","6","7","8","9","0"}: val:=proc() global data,i; local j,f; f:=0;
   while not(data[i] in dig) or f=1 and data[i] in {"+"} union dig do:
   if f=1 and not(data[i] in dig) then f:=0; else if data[i]="+" then f:=1; fi fi; i:=i+1: od:
   j:=i; while (data[i] in dig or data[i] in {"-","+"}) do i:=i+1: od: parse(data[j..i-1]);
  end:
  ` `; Region; status,data,headers:=HTTP:-Get(url): HTTP:-Code(status); i:=Search("<th>",data):

  iter:=proc() global i; local r;
   r:=val(); if data[i]<>"." then NULL else [r,val(),val(),val(),val(),val()],iter() fi;
  end:

  [iter()]: tA:=[seq(%[nops(%)+1-i],i=1..nops(%))];
  dd:=tA[1][1]+piecewise(tA[1][2]=2,-29,tA[1][2]=4,31,0)-1;
  T:=map(q->q[4],tA): #writedata(Region || `-i.txt`,%): #
  T3:=map(q->q[5],tA): #writedata(Region || `-m.txt`,%): #
  T1:=map(q->q[6],tA): #writedata(Region || `-r.txt`,%): #
  T2:=[seq(T[i]-(T1[i]+T3[i]),i=1..nops(T))]: #writedata(Region || `-h.txt`,%): #
  i:='i':
  Region; 'T'=T; 'T1'=T1; 'T2'=T2; 'T3'=T3;

  nops(T); [i+dd $ i=1..%];
```

``

Moscow

"OK"

$tA :=$ [[2, 3, 20, 1, 0, 0], [3, 3, 20, 1, 0, 0], [4, 3, 20, 1, 0, 0], [5, 3, 20, 1, 0, 0], [6, 3, 20, 6, 0, 0], [7, 3, 20, 6, 0, 1], [8, 3, 20, 6, 0, 1], [9, 3, 20, 9, 0, 1], [10, 3, 20, 9, 0, 1], [11, 3, 20, 15, 0, 1], [12, 3, 20, 19, 0, 1], [13, 3, 20, 24, 0, 1], [14, 3, 20, 33, 0, 1], [15, 3, 20, 33, 0, 1], [16, 3, 20, 53, 0, 1], [17, 3, 20, 56, 0, 1], [18, 3, 20, 86, 0, 1], [19, 3, 20, 98, 0, 5], [20, 3, 20, 131, 0, 5], [21, 3, 20, 137, 0, 8], [22, 3, 20, 191, 0, 8], [23, 3, 20, 262, 0, 9], [24, 3, 20, 290, 0, 9], [25, 3, 20, 410, 2, 15], [26, 3, 20, 546, 2, 15], [27, 3, 20, 703, 3, 18], [28, 3, 20,

817, 4, 18], [29, 3, 20, 1014, 6, 28], [30, 3, 20, 1226, 6, 28], [31, 3, 20, 1613, 11, 70], [1, 4, 20, 1880, 16, 115], [2, 4, 20, 2475, 19, 140], [3, 4, 20, 2923, 20, 168], [4, 4, 20, 3357, 27, 194], [5, 4, 20, 3893, 29, 198], [6, 4, 20, 4484, 29, 206], [7, 4, 20, 5181, 31, 222], [8, 4, 20, 5841, 31, 270], [9, 4, 20, 6698, 38, 313], [10, 4, 20, 7822, 50, 350], [11, 4, 20, 8852, 58, 499], [12, 4, 20, 10158, 72, 687], [13, 4, 20, 11513, 82, 837], [14, 4, 20, 13002, 95, 1016], [15, 4, 20, 14776, 106, 1205], [16, 4, 20, 16146, 113, 1394], [17, 4, 20, 18105, 127, 1517], [18, 4, 20, 20754, 148, 1679], [19, 4, 20, 24324, 176, 1763], [20, 4, 20, 26350, 204, 1838], [21, 4, 20, 29433, 233, 2057], [22, 4, 20, 31981, 261, 2267], [23, 4, 20, 33940, 288, 2448], [24, 4, 20, 36897, 325, 2735], [25, 4, 20, 39509, 366, 3047], [26, 4, 20, 42480, 404, 3175], [27, 4, 20, 45351, 435, 3524], [28, 4, 20, 48426, 479, 4130], [29, 4, 20, 50646, 546, 4610], [30, 4, 20, 53739, 611, 5135], [1, 5, 20, 57300, 658, 5766], [2, 5, 20, 62658, 695, 6374], [3, 5, 20, 68606, 729, 7029], [4, 5, 20, 74401, 764, 7573], [5, 5, 20, 80115, 816, 7870], [6, 5, 20, 85973, 866, 8458], [7, 5, 20, 92676, 905, 9227], [8, 5, 20, 98522, 956, 10259], [9, 5, 20, 104189, 1010, 12779], [10, 5, 20, 109740, 1068, 13790], [11, 5, 20, 115909, 1124, 17822], [12, 5, 20, 121301, 1179, 19642], [13, 5, 20, 126004, 1232, 21506], [14, 5, 20, 130716, 1290, 23327], [15, 5, 20, 135464, 1358, 24562], [16, 5, 20, 138969, 1432, 26032], [17, 5, 20, 142824, 1503, 27490], [18, 5, 20, 146062, 1580, 28913], [19, 5, 20, 149607, 1651, 31496], [20, 5, 20, 152306, 1726, 36936], [21, 5, 20, 155219, 1794, 40682], [22, 5, 20, 158207, 1867, 43582], [23, 5, 20, 161397, 1934, 47413], [24, 5, 20, 163913, 1993, 49840], [25, 5, 20, 166473, 2034, 53586], [26, 5, 20, 169303, 2110, 61619], [27, 5, 20, 171443, 2183, 67458], [28, 5, 20, 173497, 2254, 71251], [29, 5, 20, 175829, 2330, 74725], [30, 5, 20, 178196, 2408, 78324], [31, 5, 20, 180791, 2477, 80179], [1, 6, 20, 183088, 2553, 82239], [2, 6, 20, 185374, 2624, 88269], [3, 6, 20, 187216, 2685, 91654], [4, 6, 20, 189214, 2749, 94715], [5, 6, 20, 191069, 2806, 97358], [6, 6, 20, 193061, 2864, 100431], [7, 6, 20, 195017, 2919, 102714], [8, 6, 20, 197018, 2970, 104347], [9, 6, 20, 198590, 3029, 109737], [10, 6, 20, 199785, 3085, 113533], [11, 6, 20, 201221, 3138, 115769], [12, 6, 20, 202935, 3187, 118024], [13, 6, 20, 204428, 3231, 119558], [14, 6, 20, 205905, 3281, 121691], [15, 6, 20, 207264, 3334, 123240], [16, 6, 20, 208680, 3386, 126114], [17, 6, 20, 209745, 3434, 128385], [18, 6, 20, 210785, 3483, 130431], [19, 6, 20, 211921, 3531, 132434], [20, 6, 20, 212978, 3565, 134549], [21, 6, 20, 213946, 3597, 135556], [22, 6, 20, 215014, 3617, 136670]]

$$dd := 1$$

Moscow

T = [1, 1, 1, 1, 6, 6, 6, 9, 9, 15, 19, 24, 33, 33, 53, 56, 86, 98, 131, 137, 191, 262, 290, 410, 546, 703, 817, 1014, 1226, 1613, 1880, 2475, 2923, 3357, 3893, 4484, 5181, 5841, 6698, 7822, 8852, 10158, 11513, 13002, 14776, 16146, 18105, 20754, 24324, 26350, 29433, 31981, 33940, 36897, 39509, 42480, 45351, 48426, 50646, 53739, 57300, 62658, 68606, 74401, 80115, 85973, 92676, 98522, 104189, 109740, 115909, 121301, 126004, 130716, 135464, 138969, 142824, 146062, 149607, 152306, 155219, 158207, 161397, 163913, 166473, 169303, 171443, 173497, 175829, 178196, 180791, 183088, 185374, 187216, 189214, 191069, 193061, 195017, 197018, 198590, 199785, 201221, 202935, 204428, 205905, 207264, 208680, 209745, 210785, 211921, 212978, 213946, 215014]

TI = [0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 5, 5, 8, 8, 9, 9, 15, 15, 18, 18, 28, 28, 70, 115, 140, 168, 194, 198, 206, 222, 270, 313, 350,

499, 687, 837, 1016, 1205, 1394, 1517, 1679, 1763, 1838, 2057, 2267, 2448, 2735, 3047, 3175, 3524, 4130, 4610, 5135, 5766, 6374, 7029, 7573, 7870, 8458, 9227, 10259, 12779, 13790, 17822, 19642, 21506, 23327, 24562, 26032, 27490, 28913, 31496, 36936, 40682, 43582, 47413, 49840, 53586, 61619, 67458, 71251, 74725, 78324, 80179, 82239, 88269, 91654, 94715, 97358, 100431, 102714, 104347, 109737, 113533, 115769, 118024, 119558, 121691, 123240, 126114, 128385, 130431, 132434, 134549, 135556, 136670]

$T2$ = [1, 1, 1, 1, 6, 5, 5, 8, 8, 14, 18, 23, 32, 32, 52, 55, 85, 93, 126, 129, 183, 253, 281, 393, 529, 682, 795, 980, 1192, 1532, 1749, 2316, 2735, 3136, 3666, 4249, 4928, 5540, 6347, 7422, 8295, 9399, 10594, 11891, 13465, 14639, 16461, 18927, 22385, 24308, 27143, 29453, 31204, 33837, 36096, 38901, 41392, 43817, 45490, 47993, 50876, 55589, 60848, 66064, 71429, 76649, 82544, 87307, 90400, 94882, 96963, 100480, 103266, 106099, 109544, 111505, 113831, 115569, 116460, 113644, 112743, 112758, 112050, 112080, 110853, 105574, 101802, 99992, 98774, 97464, 98135, 98296, 94481, 92877, 91750, 90905, 89766, 89384, 89701, 85824, 83167, 82314, 81724, 81639, 80933, 80690, 79180, 77926, 76871, 75956, 74864, 74793, 74727]

$T3$ = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 3, 4, 6, 6, 11, 16, 19, 20, 27, 29, 29, 31, 31, 38, 50, 58, 72, 82, 95, 106, 113, 127, 148, 176, 204, 233, 261, 288, 325, 366, 404, 435, 479, 546, 611, 658, 695, 729, 764, 816, 866, 905, 956, 1010, 1068, 1124, 1179, 1232, 1290, 1358, 1432, 1503, 1580, 1651, 1726, 1794, 1867, 1934, 1993, 2034, 2110, 2183, 2254, 2330, 2408, 2477, 2553, 2624, 2685, 2749, 2806, 2864, 2919, 2970, 3029, 3085, 3138, 3187, 3231, 3281, 3334, 3386, 3434, 3483, 3531, 3565, 3597, 3617]

113

[2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114] **(2**

```
> `====================================`;
  `VERHULST FItAING`;
  `====================================`;
```

==========

VERHULST FItAING

========== **(3**

```
> h:=x->x;

  [seq(h(T[i])-h(T[i-1]),i=2..nops(T))]; [seq(%[i]-%[i-1],i=2..nops(%))]; [seq(%[i]-%[i-1],i=2..
  nops(%))];
  [seq([i+dd+1,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+2,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+3,%%%[i]
  ],i=1..nops(%%%))]:
  display(
```

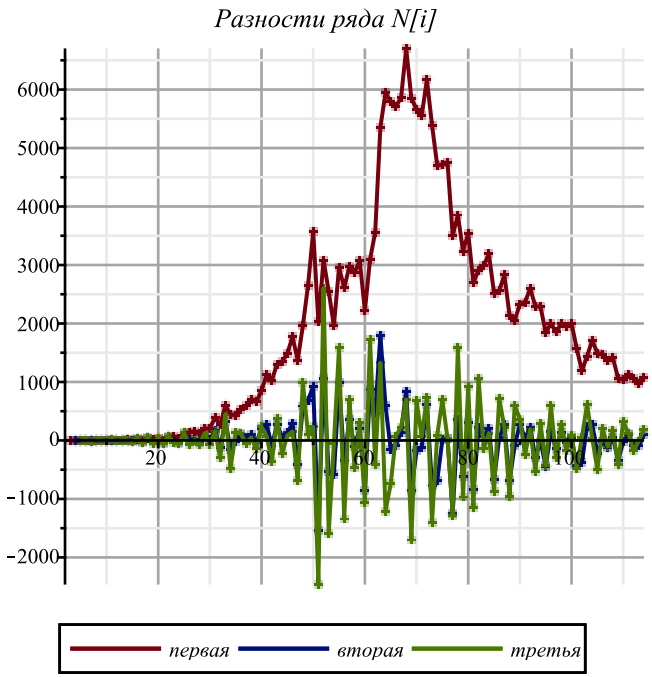
```
 plot([%%%,%%,%],style=point),
  plot([%%%,%%,%],legend=[``,``,``]),
  title=`  N[i]`,titlefont=[roman,15]  ,gridlines=true
);

[seq((h(T[i])-h(T[i-5]))/5.,i=6..nops(T))]: [seq((%[i]-%[i-3])/3.,i=4..nops(%))]: [seq((%[i]-%
[i-3])/3.,i=4..nops(%))]:
[seq([i+dd+2,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+4,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+6,%%%[i]
],i=1..nops(%%%))]:
display(
 plot([%%%,%%,%],style=point),
  plot([%%%,%%,%],legend=[``,``,``]),
   title=`     N[i]              `,titlefont=[roman,15],gridlines=true
);
```

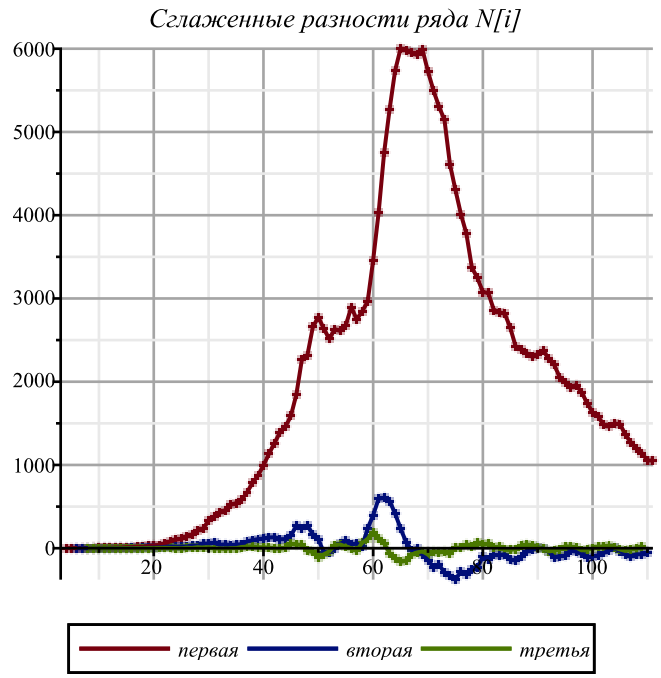
$$h := x \mapsto x$$

[0, 0, 0, 5, 0, 0, 3, 0, 6, 4, 5, 9, 0, 20, 3, 30, 12, 33, 6, 54, 71, 28, 120, 136, 157, 114, 197, 212, 387, 267, 595, 448, 434, 536, 591, 697, 660, 857, 1124, 1030, 1306, 1355, 1489, 1774, 1370, 1959, 2649, 3570, 2026, 3083, 2548, 1959, 2957, 2612, 2971, 2871, 3075, 2220, 3093, 3561, 5358, 5948, 5795, 5714, 5858, 6703, 5846, 5667, 5551, 6169, 5392, 4703, 4712, 4748, 3505, 3855, 3238, 3545, 2699, 2913, 2988, 3190, 2516, 2560, 2830, 2140, 2054, 2332, 2367, 2595, 2297, 2286, 1842, 1998, 1855, 1992, 1956, 2001, 1572, 1195, 1436, 1714, 1493, 1477, 1359, 1416, 1065, 1040, 1136, 1057, 968, 1068]

[0, 0, 5, −5, 0, 3, −3, 6, −2, 1, 4, −9, 20, −17, 27, −18, 21, −27, 48, 17, −43, 92, 16, 21, −43, 83, 15, 175, −120, 328, −147, −14, 102, 55, 106, −37, 197, 267, −94, 276, 49, 134, 285, −404, 589, 690, 921, −1544, 1057, −535, −589, 998, −345, 359, −100, 204, −855, 873, 468, 1797, 590, −153, −81, 144, 845, −857, −179, −116, 618, −777, −689, 9, 36, −1243, 350, −617, 307, −846, 214, 75, 202, −674, 44, 270, −690, −86, 278, 35, 228, −298, −11, −444, 156, −143, 137, −36, 45, −429, −377, 241, 278, −221, −16, −118, 57, −351, −25, 96, −79, −89, 100]

[0, 5, −10, 5, 3, −6, 9, −8, 3, 3, −13, 29, −37, 44, −45, 39, −48, 75, −31, −60, 135, −76, 5, −64, 126, −68, 160, −295, 448, −475, 133, 116, −47, 51, −143, 234, 70, −361, 370, −227, 85, 151, −689, 993, 101, 231, −2465, 2601, −1592, −54, 1587, −1343, 704, −459, 304, −1059, 1728, −405, 1329, −1207, −743, 72, 225, 701, −1702, 678, 63, 734, −1395, 88, 698, 27, −1279, 1593, −967, 924, −1153, 1060, −139, 127, −876, 718, 226, −960, 604, 364, −243, 193, −526, 287, −433, 600, −299, 280, −173, 81, −474, 52, 618, 37, −499, 205, −102, 175, −408, 326, 121, −175, −10, 189]


Разности ряда N[i]
6000
5000
4000
3000
2000
1000
0
-1000
-2000
20
40
60
80
100
первая
вторая
третья




```
> h:=x->evalf(ln(x));

  [seq(h(T[i])-h(T[i-1]),i=2..nops(T))]; [seq(%[i]-%[i-1],i=2..nops(%))]; [seq(%[i]-%[i-1],i=2..
  nops(%))];
  [seq([i+dd+1,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+2,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+3,%%%[i]
  ],i=1..nops(%%%))]:
  display(
   plot([%%%,%%,%],style=point),
    plot([%%%,%%,%],legend=[``,``,``]),
    title=`  ln(N[i])`,titlefont=[roman,15]   ,gridlines=true
  );

  [seq((h(T[i])-h(T[i-5]))/5.,i=6..nops(T))]: [seq((%[i]-%[i-3])/3.,i=4..nops(%))]: [seq((%[i]-%
  [i-3])/3.,i=4..nops(%))]:
  [seq([i+dd+2,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+4,%%%[i]],i=1..nops(%%%))]: [seq([i+dd+6,%%%[i]
  ],i=1..nops(%%%))]:
  display(
   plot([%%%,%%,%],style=point),
    plot([%%%,%%,%],legend=[``,``,``]),
```

```
    t i t l e = `                    ln(N[i])`,titlefont=[roman,15],gridlines=true
  );
```

$$h := x \mapsto evalf(\ln(x))$$

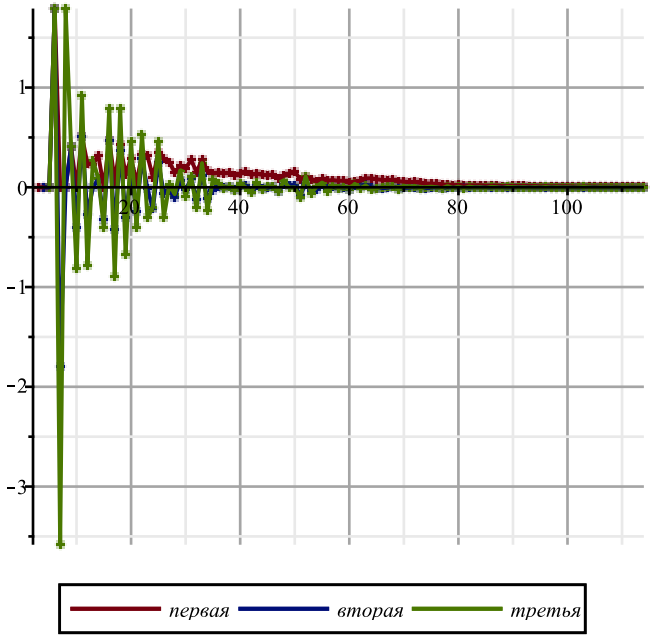
[0., 0., 0., 1.791759469, 0., 0., 0.405465109, 0., 0.510825623, 0.236388778, 0.233614851, 0.318453731, 0., 0.473784353, 0.055059777, 0.428995605, 0.130620183, 0.290229844, 0.044783603, 0.332292502, 0.316071076, 0.101536419, 0.346276237, 0.286461816, 0.252737916, 0.150282203, 0.216019089, 0.189853932, 0.274338962, 0.153175978, 0.274968619, 0.166370090, 0.138437232, 0.148132351, 0.141335436, 0.144482583, 0.119903927, 0.136906959, 0.155131302, 0.123703146, 0.137618150, 0.125215260, 0.121626360, 0.127901051, 0.088668098, 0.114515802, 0.136550856, 0.158724522, 0.08000475, 0.11064822, 0.08302549, 0.05945228, 0.08353599, 0.06839824, 0.07250489, 0.06539885, 0.06560463, 0.04482339, 0.05927874, 0.06416163, 0.08939075, 0.09068862, 0.08108939, 0.07399372, 0.07057019, 0.07507625, 0.06117033, 0.05592669, 0.05190737, 0.05469147, 0.04546966, 0.03803859, 0.03671338, 0.03567889, 0.02554497, 0.02736221, 0.02241809, 0.02398066, 0.01787980, 0.01894537, 0.01906728, 0.01996287, 0.01546863, 0.01549733, 0.01685688, 0.01256084, 0.01190946, 0.01335162, 0.01337214, 0.01445760, 0.01262524, 0.01240849, 0.00988763, 0.01061562, 0.00975597, 0.01037158, 0.01008053, 0.01020836, 0.00794731, 0.00599939, 0.00716202, 0.00848192, 0.00733010, 0.00719907, 0.00657844, 0.00680864, 0.00509053, 0.00494615, 0.00537490, 0.00497531, 0.00453478, 0.00497949]

[0., 0., 1.791759469, −1.791759469, 0., 0.405465109, −0.405465109, 0.510825623, −0.274436845, −0.002773927, 0.084838880, −0.318453731, 0.473784353, −0.418724576, 0.373935828, −0.298375422, 0.159609661, −0.245446241, 0.287508899, −0.016221426, −0.214534657, 0.244739818, −0.059814421, −0.033723900, −0.102455713, 0.065736886, −0.026165157, 0.084485030, −0.121162984, 0.121792641, −0.108598529, −0.027932858, 0.009695119, −0.006796915, 0.003147147, −0.024578656, 0.017003032, 0.018224343, −0.031428156, 0.013915004, −0.012402890, −0.003588900, 0.006274691, −0.039232953, 0.025847704, 0.022035054, 0.022173666, −0.078719772, 0.03064347, −0.02762273, −0.02357321, 0.02408371, −0.01513775, 0.00410665, −0.00710604, 0.00020578, −0.02078124, 0.01445535, 0.00488289, 0.02522912, 0.00129787, −0.00959923, −0.00709567, −0.00342353, 0.00450606, −0.01390592, −0.00524364, −0.00401932, 0.00278410, −0.00922181, −0.00743107, −0.00132521, −0.00103449, −0.01013392, 0.00181724, −0.00494412, 0.00156257, −0.00610086, 0.00106557, 0.00012191, 0.00089559, −0.00449424, 0.00002870, 0.00135955, −0.00429604, −0.00065138, 0.00144216, 0.00002052, 0.00108546, −0.00183236, −0.00021675, −0.00252086, 0.00072799, −0.00085965, 0.00061561, −0.00029105, 0.00012783, −0.00226105, −0.00194792, 0.00116263, 0.00131990, −0.00115182, −0.00013103, −0.00062063, 0.00023020, −0.00171811, −0.00014438, 0.00042875, −0.00039959, −0.00044053, 0.00044471]

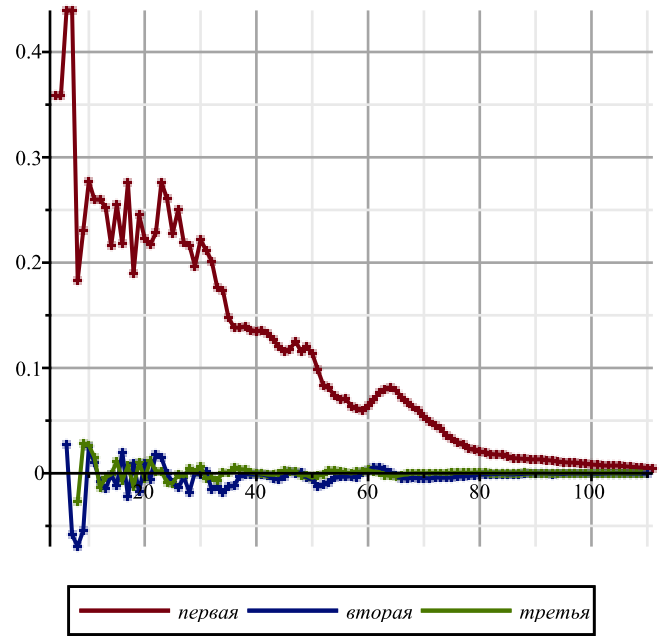
[0., 1.791759469, −3.583518938, 1.791759469, 0.405465109, −0.810930218, 0.916290732, −0.785262468, 0.271662918, 0.087612807, −0.403292611, 0.792238084, −0.892508929, 0.792660404, −0.672311250, 0.457985083, −0.405055902, 0.532955140, −0.303730325, −0.198313231, 0.459274475, −0.304554239, 0.026090521, −0.068731813, 0.168192599, −0.091902043,

0.110650187, −0.205648014, 0.242955625, −0.230391170, 0.080665671, 0.037627977, −0.016492034, 0.009944062, −0.027725803, 0.041581688, 0.001221311, −0.049652499, 0.045343160, −0.026317894, 0.008813990, 0.009863591, −0.045507644, 0.065080657, −0.003812650, 0.000138612, −0.100893438, 0.109363242, −0.05826620, 0.00404952, 0.04765692, −0.03922146, 0.01924440, −0.01121269, 0.00731182, −0.02098702, 0.03523659, −0.00957246, 0.02034623, −0.02393125, −0.01089710, 0.00250356, 0.00367214, 0.00792959, −0.01841198, 0.00866228, 0.00122432, 0.00680342, −0.01200591, 0.00179074, 0.00610586, 0.00029072, −0.00909943, 0.01195116, −0.00676136, 0.00650669, −0.00766343, 0.00716643, −0.00094366, 0.00077368, −0.00538983, 0.00452294, 0.00133085, −0.00565559, 0.00364466, 0.00209354, −0.00142164, 0.00106494, −0.00291782, 0.00161561, −0.00230411, 0.00324885, −0.00158764, 0.00147526, −0.00090666, 0.00041888, −0.00238888, 0.00031313, 0.00311055, 0.00015727, −0.00247172, 0.00102079, −0.00048960, 0.00085083, −0.00194831, 0.00157373, 0.00057313, −0.00082834, −0.00004094, 0.00088524]

Разности ряда ln(N[i])



Сглаженные разности ряда ln(N[i])




```
> f_:=d->sum(a[j]*d^j,j=0..n); fe_:=d->sum(a[j]*d^j,j=0..ne);

  M:='M':
  ff:=x->M*(1-1/(exp(x)+1)); ff_:=unapply(solve(y=ff(x),x),y); diff(ff_(x),x); dff_:=unapply
  (simplify(%,x),x);
  ffe:=x->exp(x); ffe_:=unapply(solve(y=ffe(x),x),y); diff(ffe_(x),x); dffe_:=unapply(simplify(%,
  x),x);

  sigma:=x->simplify(sqrt(x));

  chi2:=(T,f_)->simplify(sum(evalf(ff_(T[k])-f_(k))^2/dff_(T[k])^2/sigma(T[k])^2,k=1..nops(T)));
  chi2e:=(T,f_)->simplify(sum(evalf(ffe_(T[k])-f_(k))^2/dffe_(T[k])^2/sigma(T[k])^2,k=1..nops(T)));

  F:=proc(T,chi2,f_) chi2(T,f_);
   indets(%); grad(%%,%); subs(solve(%,%%),f_(i)); unapply(%,i);
  end:
```

$$f\_ := d \mapsto \sum_{j=0}^{n} a_j \cdot d^j$$

$$fe\_ := d \mapsto \sum_{j=0}^{ne} a_j \cdot d^j$$

$$ff := x \mapsto M \cdot \left(1 - \frac{1}{e^x + 1}\right)$$

$$ff\_ := y \mapsto \ln\left(\frac{y}{M - y}\right)$$

$$\frac{\left(\frac{1}{M-x} + \frac{x}{(M-x)^2}\right)(M-x)}{x}$$

$$dff\_ := x \mapsto \frac{M}{(M-x)\cdot x}$$

$$ffe := x \mapsto e^x$$

$$ffe\_ := y \mapsto \ln(y)$$

$$\frac{1}{x}$$

$$dffe\_ := x \mapsto \frac{1}{x}$$

$$\sigma := x \mapsto simplify\left(\sqrt{x}\right)$$

$$\chi 2 := (T, f\_) \rightarrow simplify\left(\sum_{k=1}^{nops(T)} \frac{evalf\left(ff\_\left(T_k\right) - f\_(k)\right)^2}{dff\_\left(T_k\right)^2 \sigma\left(T_k\right)^2}\right)$$

$$chi2e := (T, f\_) \rightarrow simplify\left(\sum_{k=1}^{nops(T)} \frac{evalf\left(ffe\_\left(T_k\right) - f\_(k)\right)^2}{dffe\_\left(T_k\right)^2 \sigma\left(T_k\right)^2}\right)$$

(4

```
> n:=1: ne:=n: 'f(t)'=Sum(a[j]*t^j,j=0..n);
```

```
fM:=proc(x) global M,chi2,F,T,f_; M:=x; chi2(T,F(T,chi2,f_)); end:

` `; `Approximation of the infection schedule by the solution of the Verhulst equation`; ` `;
M:=goldMin(fM,max(T)+2..max(T)*2,1);
nu:=F(T,chi2,f_): f:=unapply(ff(%(t)),t): N(t)=%(t); Chi2:=chi2(T,%%%);
cat(`Next day forecast:   `,round(f(nops(T)+1)));
cat(`The level of  0.5 M  is reached at   `,round(1+fsolve(f(d)=0.5*M,d=30)+dd-31),`  apr`);
cat(`The level of  0.85 M  is reached at   `,round(1+fsolve(f(d)=0.85*M,d=30)+dd-31),`  apr`);
` `; `Approximation of the infection schedule by solving the Malthus equation`; ` `;
nue:=F(T,chi2e,f_): fe:=unapply(ffe(%(t)),t): N(t)=%(t);

simplify([diff(nu(d-dd),d),diff(nue(d-dd),d)]): [coeff(%[1],d,i) $ i=0..n-1];
plot(%%,d=1+dd..nops(T)+dd,view=[0..nops(T)+dd,0..0.5],legend=[``,``],
linestyle=[solid,dash],title=`  `        ,titlefont=[roman,20],labels=[t,alpha(t)],
gridlines=true);

d1:=fsolve(f(d)=0.5*M,d=30)+dd; K_:=M; alpha_:=coeff(nu(t),t,1);

n:=4: ne:=n: 'f(t)'=Sum(a[j]*t^j,j=0..n);

fM:=proc(x) global M,chi2,F,T,f_; M:=x; chi2(T,F(T,chi2,f_)); end:

` `; `Approximation of the infection schedule by the solution of the Verhulst equation`; ` `;
M:=goldMin(fM,max(T)+2..max(T)*2,1);
nu:=F(T,chi2,f_): f:=unapply(ff(%(t)),t): N(t)=%(t); Chi2:=chi2(T,%%%);
cat(`Next day forecast:   `,round(f(nops(T)+1)));
cat(`The level of  0.5 M  is reached at   `,round(1+fsolve(f(d)=0.5*M,d=30)+dd-31),`  apr`);
cat(`The level of  0.85 M  is reached at   `,round(1+fsolve(f(d)=0.85*M,d=30)+dd-31),`  apr`);
` `; `Approximation of the infection schedule by solving the Malthus equation`; ` `;
nue:=F(T,chi2e,f_): fe:=unapply(ffe(%(t)),t): N(t)=%(t);

[seq([i,(
 (T[i-dd]-T[i-dd-1]) /(T2[i-dd]+T2[i-dd-1]) /((1-T[i-dd]/M)+(1-T[i-dd-1]/M))
)*4],i=1+dd+1..nops(T)+dd)]: [seq([%[i][1],(%[i-1][2]+%[i][2]+%[i+1][2])/3],i=2..nops(%)-1)]:
Palpha:=display(plot([%],color=blue),plot([%],style=point,symbolsize=8,symbol=solidcircle,color=
blue)):

simplify([diff(nu(d-dd),d),diff(nue(d-dd),d)]): [coeff(%[1],d,i) $ i=0..n-1];
plot(%%,d=1+dd..nops(T)+dd,view=[0..nops(T)+dd,0..0.5],legend=[``,``],
linestyle=[solid,dash],title=`  `        ,titlefont=[roman,20],labels=[t,alpha(t)],
```

```
gridlines=true):

display(Palpha,%);
```

$$f(t) = \sum_{j=0}^{1} a_j t^j$$

Approximation of the infection schedule by the solution of the Verhulst equation

$$M := 215016.3960$$

$$N(t) = 215016.3960 - \frac{215016.3960}{e^{0.1008744659\,t - 7.134769012} + 1}$$

$$Chi2 := 36677.17887$$

Next day forecast: 212317

The level of 0.5 M is reached at 42 apr

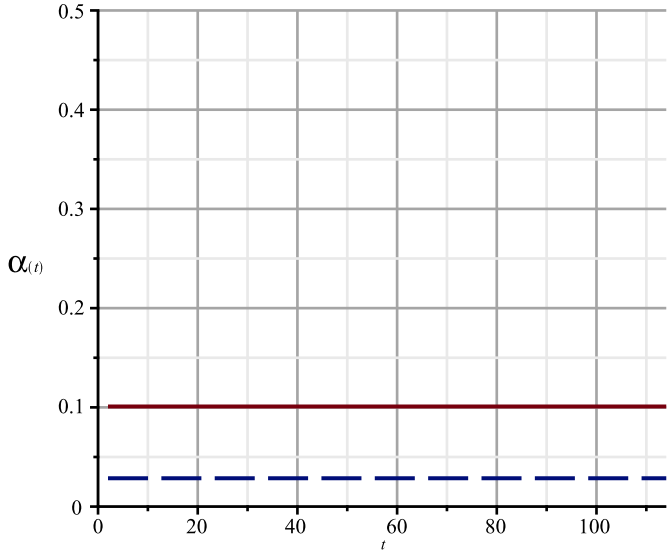
The level of 0.85 M is reached at 59 apr

Approximation of the infection schedule by solving the Malthus equation

$$N(t) = e^{0.02856630861\,t + 9.373962424}$$

$$[0.1008744659]$$

Коэффициент заражения



$d1 := 71.72918749$

$K\_ := 215016.3960$

$alpha\_ := 0.1008744659$

$$f(t) = \sum_{j=0}^{4} a_j t^j$$

Approximation of the infection schedule by the solution of the Verhulst equation

$M := 430025.8328$

$$N(t) = 430025.8328 - \frac{430025.8328}{e^{5.756275756\,10^{-8}\,t^4 - 9.992102969\,10^{-6}\,t^3 - 0.0007482365281\,t^2 + 0.2321004397\,t - 11.64175524} + 1}$$

$Chi2 := 6906.770864$

Next day forecast: 216302

The level of 0.5 M is reached at 84 apr

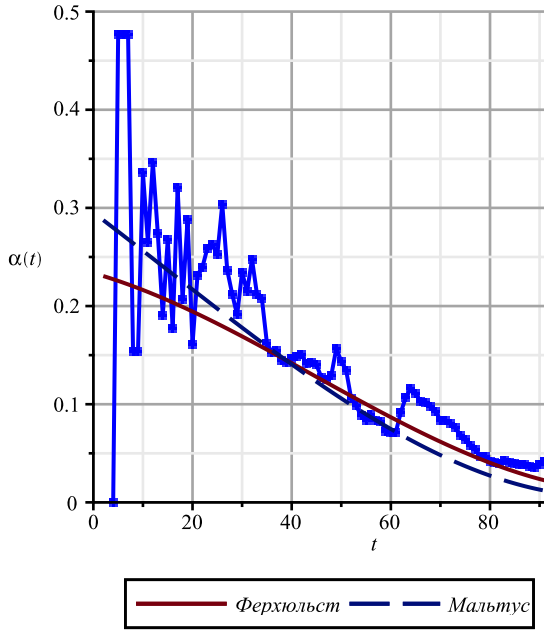
The level of 0.85 M is reached at 121 apr

Approximation of the infection schedule by solving the Malthus equation

$$N(t) = e^{4.251842898\,10^{-8}\,t^4 - 2.345336756\,10^{-6}\,t^3 - 0.001924494022\,t^2 + 0.2913901788\,t + 0.3926849942}$$

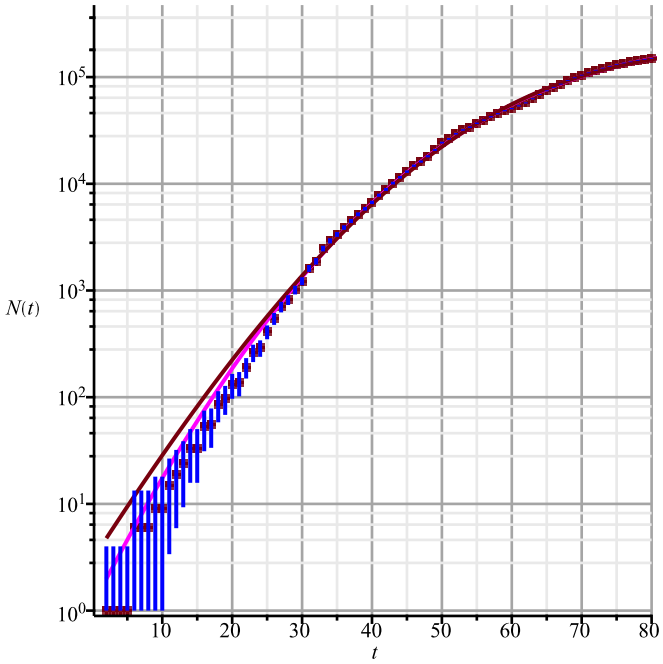
$$[0.233566706200000,\ -0.00143582968500000,\ -0.0000306670620000000,\ 2.302510302\,10^{-7}]$$

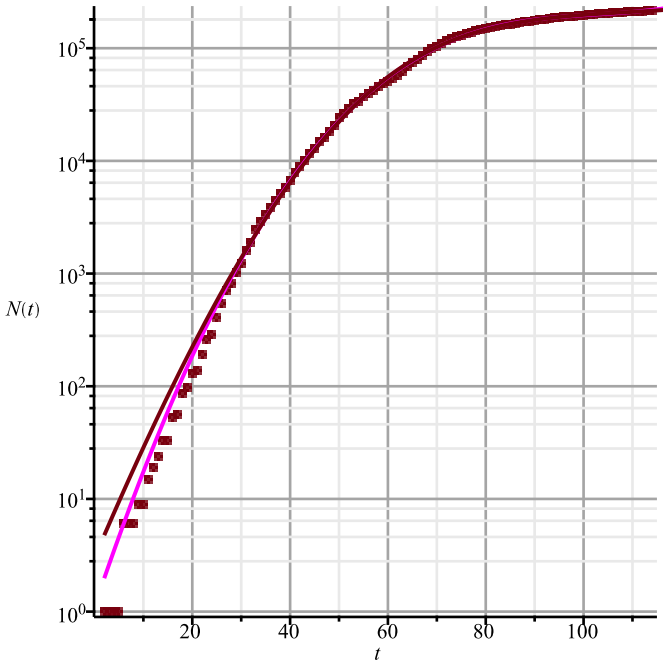
Коэффициент заражения

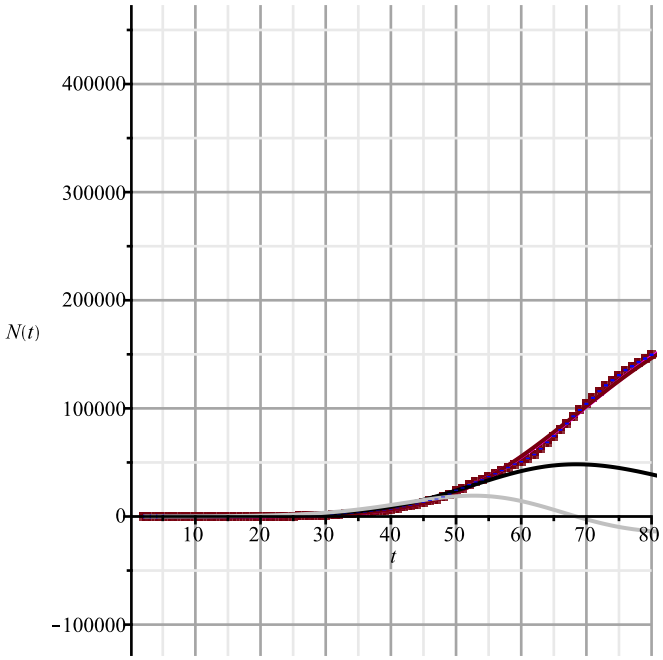


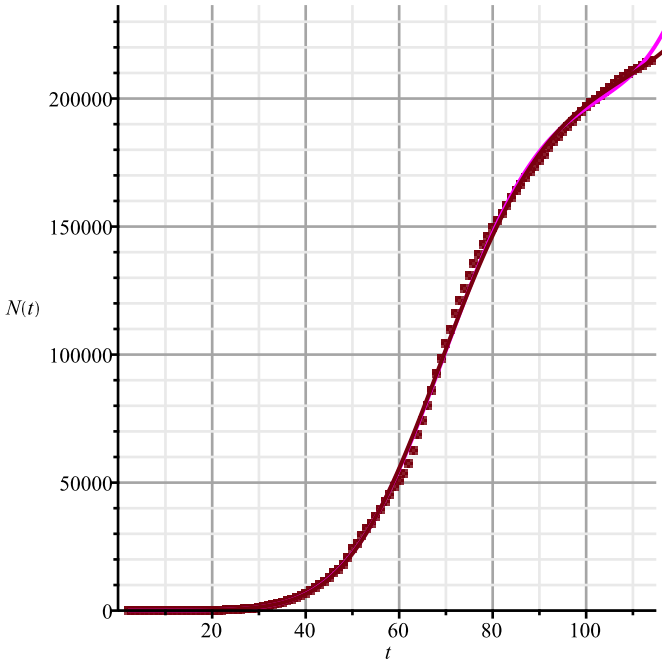

```
> df:=unapply(diff(f(i),i),i): ddf:=unapply(diff(f(i),i,i),i):

  display(
   plot([[i+dd,T[i]] $ i=1..nops(T)],style=point,symbolsize=10,symbol=solidcircle),
   plot(fe(i-dd),i=1+dd..max(90,dd+nops(T)),color=magenta),
   plot(f(i-dd),i=1+dd..max(90,dd+nops(T))),
   seq(plot([[i+dd,T[i]+3*sqrt(T[i])],[i+dd,T[i]-3*sqrt(T[i])]],color=blue),i=1..nops(T)),
   axis[2]=[mode=log],
   view=[1..80,1..M*1.1],labels=[t,N(t)],gridlines=true
```

```
);

display(
 plot([[i+dd,T[i]] $ i=1..nops(T)],style=point,symbolsize=8,symbol=solidcircle),
 plot(fe(i-dd),i=1+dd..max(120,dd+nops(T)),color=magenta),
 plot(f(i-dd),i=1+dd..max(120,dd+nops(T))),
# seq(plot([[i+dd,T[i]+3*sqrt(T[i])],[i+dd,T[i]-3*sqrt(T[i])]],color=blue),i=1..nops(T)),
 axis[2]=[mode=log],
 view=[1..nops(T)+dd+1,1..T[nops(T)]*1.1],labels=[t,N(t)],gridlines=true
);


display(
 plot([[i+dd,T[i]] $ i=1..nops(T)],style=point,symbolsize=10,symbol=solidcircle),
 plot(fe(i-dd),i=1+dd..max(120,dd+nops(T)),color=magenta),
 plot(f(i-dd),i=1+dd..max(dd+nops(T),90)),
 plot(10*df(i-dd),i=1+dd..max(dd+nops(T),120),color=black),
 plot(100*ddf(i-dd),i=1+dd..max(dd+nops(T),120),color=gray),
 seq(plot([[i+dd,T[i]+3*sqrt(T[i])],[i+dd,T[i]-3*sqrt(T[i])]],color=blue),i=1..nops(T)),
 view=[1..80,-M*0.3..M*1.1],labels=[t,N(t)],gridlines=true
);

display(
 plot([[i+dd,T[i]] $ i=1..nops(T)],style=point,symbolsize=8,symbol=solidcircle),
 plot(fe(i-dd),i=1+dd..max(120,dd+nops(T)),color=magenta),
 plot(f(i-dd),i=1+dd..max(dd+nops(T),120)),
# seq(plot([[i+dd,T[i]+3*sqrt(T[i])],[i+dd,T[i]-3*sqrt(T[i])]],color=blue),i=1..nops(T)),
 view=[1..nops(T)+dd+1,1..T[nops(T)]*1.1],labels=[t,N(t)],gridlines=true
);
```

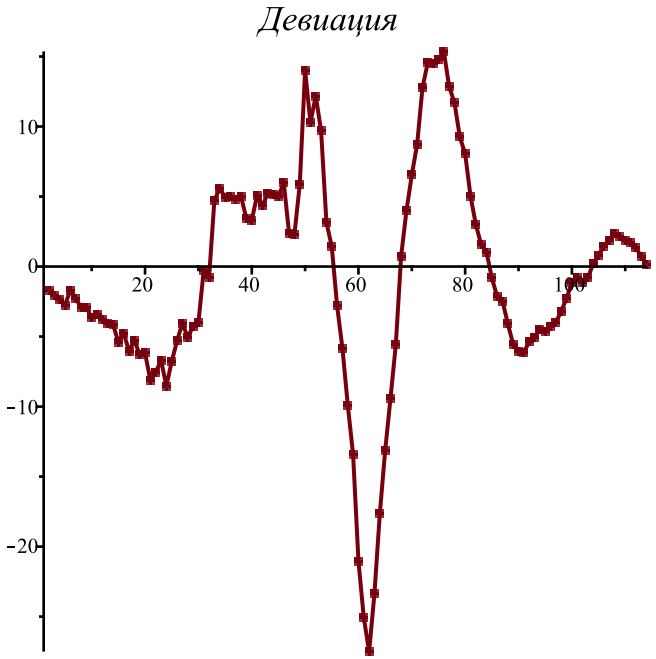

10^5
10^4
10^3
10^2
10^1
10^0
$N(t)$
10
20
30
40
50
60
70
80
t


10^5
10^4
10^3
$N(t)$
10^2
10^1
10^0
20
40
60
80
100
t


400000
300000
200000
N(t)
100000
0
10
20
30
40
50
60
70
80
t
-100000




```
> dT:=[[i,(T[i-dd]-f(i-dd))/sigma(f(i-dd))] $ i=1+dd..dd+nops(T)]:
  display( plot(%), plot(%,style=point,symbolsize=8,symbol=solidcircle),t i t l e = ` `     ,titlefont=
  [roman,20] );
```




```
> `====================================`;
  `FORECAST`;
  `====================================`;
```

```
====================================
```

FORECAST

```
====================================
```

(5

```
> proc3:=proc(E)
   E[1]*convert(map(X->X^coeff(E[2],X,1),M),`*`);
  end:

  proc2:=proc(X,E)
   proc3(E)*(coeff(E[3],X,1)-coeff(E[2],X,1));
  end:

  proc1:=proc(X)
   convert(map(E->proc2(X,E),L),`+`);
  end:
```

```
> A:='A': B:='B': C:='C': Q:='Q': M:=[A,B,C,Q];

  L:=[
   [(A+C)*P[`01`],0,A],
   [(B/K)*P[`12`],A,B],
   [P[`23`],B,C],
   [P[`10`],A,0], [P[`20`],B,Q], [P[`30`],C,0]
  ]: Matrix(%);

  eqs:=map(X->Diff(X,t)=proc1(X),M); Vector(%);
```

$$M := [A, B, C, Q]$$

$$\begin{bmatrix} (A+C)\,P_{01} & 0 & A \\ \frac{B\,P_{12}}{K} & A & B \\ P_{23} & B & C \\ P_{10} & A & 0 \\ P_{20} & B & Q \\ P_{30} & C & 0 \end{bmatrix}$$

$$eqs := \left[\frac{\partial}{\partial t} A = (A+C)\,P_{01} - \frac{B\,P_{12}\,A}{K} - P_{10}\,A,\ \frac{\partial}{\partial t} B = \frac{B\,P_{12}\,A}{K} - P_{23}\,B - P_{20}\,B,\ \frac{\partial}{\partial t} C = P_{23}\,B - P_{30}\,C,\ \frac{\partial}{\partial t} Q = P_{20}\,B \right]$$

(6

$$\left[\begin{array}{c} \frac{\partial}{\partial t} A = (A + C)\, P_{01} - \frac{B\, P_{12}\, A}{K} - P_{10}\, A \\ \frac{\partial}{\partial t} B = \frac{B\, P_{12}\, A}{K} - P_{23}\, B - P_{20}\, B \\ \frac{\partial}{\partial t} C = P_{23}\, B - P_{30}\, C \\ \frac{\partial}{\partial t} Q = P_{20}\, B \end{array}\right] \quad (6$$

```
> v:=M; alpha:='alpha': K:=k0; tA:=[-7,15,35,50,58,62,78,nops(T)+dd]; kA:=['k1x||i' $ i=1..nops(tA)
  ];

  par:=[d0,k0,op(kA),k2a,k2b,k2c,k3]; kappa:=0; 0.011/365;

  param:=[
    P[`01`]=kappa,  P[`12`]=alpha(t,op(kA)), P[`23`]=beta(t,k2a,k2b,k2c),
    P[`10`]=kappa, P[`20`]=k3,  P[`30`]=kappa
  ];

  init:=[   A(-d0)=K,   B(-d0)=1,   C(-d0)=0,   Q(-d0)=0   ];
```

$$v := [A, B, C, Q]$$

$$K := k0$$

$$tA := [-7, 15, 35, 50, 58, 62, 78, 114]$$

$$kA := [k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8]$$

$$par := [d0, k0, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8, k2a, k2b, k2c, k3]$$

$$\kappa := 0$$

$$0.00003013698630$$

$$param := \left[P_{01} = 0, P_{12} = \alpha(t, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8), P_{23} = \beta(t, k2a, k2b, k2c), P_{10} = 0, P_{20} = k3, P_{30} = 0\right]$$

$$init := [A(-d0) = k0, B(-d0) = 1, C(-d0) = 0, Q(-d0) = 0] \quad (7$$

```
> Eqs:=subs(map(q->q=q(t),v),Diff=diff,param,eqs); #dsolve(%);
```

$$Eqs := \left[\frac{\mathrm{d}}{\mathrm{d}t} A(t) = -\frac{B(t)\,\alpha(t, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8)\,A(t)}{k0}, \frac{\mathrm{d}}{\mathrm{d}t} B(t) \right. \tag{8}$$

$$= \frac{B(t)\,\alpha(t, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8)\,A(t)}{k0} - \beta(t, k2a, k2b, k2c)\,B(t) - k3\,B(t), \frac{\mathrm{d}}{\mathrm{d}t} C(t) = \beta(t, k2a, k2b,$$

$$k2c)\,B(t), \frac{\mathrm{d}}{\mathrm{d}t} Q(t) = k3\,B(t) \left.\right]$$

```
> N:='N': A:='A': B:='B': C:='C': Q:='Q': val:=valp:

  #alpha:=unapply(simplify(evalf(piecewise(t<tA[1],kA[1],t<tA[2],Lag(t,tA[1..3],kA[1..3]),
  # seq(op([t<tA[i+1],(Lag(t,tA[i-1..i+1],kA[i-1..i+1])+Lag(t,tA[i..i+2],kA[i..i+2]))/2]),i=2..nops
  (kA)-2),
  #t<tA[nops(tA)],Lag(t,tA[nops(tA)-2..nops(tA)],kA[nops(kA)-2..nops(kA)]),
  #kA[nops(kA)]))),t,op(kA)):

  alpha:=unapply(simplify(evalf(piecewise(t<tA[1],kA[1],t<tA[3],Lag(t,tA[1..4],kA[1..4]),
   seq(op([t<tA[i+1],Lag(t,tA[i-1..i+2],kA[i-1..i+2])]),i=3..nops(kA)-2),
  t<tA[nops(tA)],Lag(t,tA[nops(tA)-2..nops(tA)],kA[nops(kA)-2..nops(kA)]),
  kA[nops(kA)]))),t,op(kA)):

  beta:=(t,k2a,k2b,k2c)->piecewise(t<55,Lag(t,[20,55],[k2a,k2b]),t<90,Lag(t,[55,90],[k2b,k2c]),k2c)
  :
  beta:=unapply(simplify(evalf(beta(t,k2a,k2b,k2c))),t,k2a,k2b,k2c);

  EQS:=[op(Eqs),op(init)]:

  res:=dsolve(EQS,numeric,map(q->q(t),v),output=listprocedure,parameters=par); assign('v[i]=subs
  (res,v[i](t))' $ i=1..nops(v)):

  chi2a:='chi2a': chi2:=unapply(chi2a(x0,xx,kA,x2a,x2b,x2c,x3),x0,xx,op(kA),x2a,x2b,x2c,x3):

  chi2a:=proc(x0,xx,x1,x2a,x2b,x2c,x3) local i; global K_; K_:=xx;
    res(parameters=[corr(par,[x0,xx,op(x1),x2a,x2b,x2c,x3])]):
    sum((T[i]-(K_-A(i+dd)))^2/(K_-A(i+dd)),i=1..nops(T))+
    sum((T2[i]-B(i+dd))^2/B(i+dd),i=1..nops(T2))+
    sum((T3[i]-Q(i+dd))^2/Q(i+dd),i=1..nops(T2))+
    sum((T1[i]-C(i+dd))^2/C(i+dd),i=1..nops(T1));
```

```
  end:

  chi2(op(pr(val))); val:=findMin(chi2,val); chi2(op(%));

  #plot(map(q->q(t),v),t=0..3.0e4,legend=[``,``,``],
  #linestyle=[solid,dash,dashdot],gridlines=true);

  writedata(cat(Region,`3c.txt`),val);

  display(
   plot(map(q->q(t),v[1..3]),t=0..300,legend=[``,``,``],
    linestyle=[solid,dash,dashdot],gridlines=true),
   plot([[seq([i+dd,K_-T[i]],i=1..nops(T))]],style=point,symbolsize=7,symbol=asterisk),
   plot([[seq([i+dd,T1[i]],i=1..nops(T1))]],style=point,symbolsize=7,symbol=circle),
   plot([[seq([i+dd,T2[i]],i=1..nops(T2))]],style=point,symbolsize=7,symbol=diamond,color=black),
   size=[1000,400],legendstyle=[font=[roman,15]]
  ): fdisplay(cat(Region,`3c`),%);
```

$$\beta := (t, k2a, k2b, k2c) \mapsto \begin{cases} (-0.02857142857 \cdot k2a + 0.02857142857 \cdot k2b) \cdot t + 1.571428571 \cdot k2a - 0.5714285714 \cdot k2b & t < 55. \\ (-0.02857142857 \cdot k2b + 0.02857142857 \cdot k2c) \cdot t + 2.571428571 \cdot k2b - 1.571428571 \cdot k2c & t < 90. \\ k2c & 90. \le t \end{cases}$$

$res := [t = \mathbf{proc}(t) \ \ldots \ \mathbf{end\ proc}, A(t) = \mathbf{proc}(t) \ \ldots \ \mathbf{end\ proc}, B(t) = \mathbf{proc}(t) \ \ldots \ \mathbf{end\ proc}, C(t) = \mathbf{proc}(t) \ \ldots \ \mathbf{end\ proc}, Q(t) = \mathbf{proc}(t)$
$\ldots$
end proc]

[13.71214965, 220689.9212, 0.1046895272, 0.2134720246, 0.1782006759, 0.1216279446, 0.08916969542, 0.1172713974, 0.09673479683, 0.1811377111, 0.01119895789, 0.006644970495, 0.0345222548, 0.0007474477074]

26017.0000923763
26017.0000923763
24837.3930950240
24232.7308277804
23667.6102386326
23428.4398494484
23232.9645105395

23065.9338559835
22773.6137739018
22565.8865476780
22536.7364273996
22502.9776625321
22485.5910312501
22461.9232490194
22444.9238278099
22422.3420091323
22404.8954906419
22348.6415049279
22300.1622087870
22249.7123403351
22205.4136562738
22165.5769973986
22128.9962578916
22059.9239673558
22000.1984715544
21963.0768341602
21931.0380714446
21811.2916862762
21706.2322228959
21686.4702221250
21668.3377111982
21610.5315750495
21566.5343715997
21550.4358033787
21535.3582966810
21326.7443303599
21150.7297344744

21143.3230689353
21131.0832349421
21121.8192994497
21106.6031219764
21096.5882540322
21073.6244028349
21054.7163090214
21018.8746812036
20977.0029115847
20963.8945811262
20946.5083497459
20939.1193862167
20926.0056835041
20916.0600862981
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20863.8476165396
20840.1257070909
20822.8866544634
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20732.4693085103
20724.9105470009
20713.2298355049
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20696.5294642473
20690.0332581380
20669.6682625393
20655.2846187868
20460.1266271263
20280.1028272242
20274.8937484662

20264.9104334369
20258.2160303925
20242.6956765713
20232.1545819959
20199.7977516221
20164.9637928598
20159.1943968161
20149.6383647321
20145.1683294219
20136.9770882682
20131.1183095175
19998.9342598685
19902.3609898571
19887.7421973191
19874.0420581093
19866.1600828402
19857.1444980825
19851.5094640414
19843.9946259923
19839.1057080194
19820.9509500168
19807.6719265125
19777.0166694983
19744.3018453573
19738.4685189727
19728.0817189235
19723.6192389609
19714.0125316758
19708.4795147279
19683.7960696955

19665.3459545771
19577.6191332801
19502.7408385399
19496.7833163521
19487.5846794063
19482.8924081804
19455.3001238256
19438.9259286277
19409.4536643938
19381.9398061244
19375.8952989693
19367.5455174840
19364.5296535630
19357.6000311481
19354.2401624713
19346.8199578600
19341.1083458713
19326.3355240095
19316.2294513991
19305.9818974122
19297.7248016184
19283.6516200074
19271.4503987727
19201.4928089092
19131.5285638298
19129.5365582811
19109.2606131025
19096.7020106003
19077.5607170079
19056.5856664630

19053.1043630586

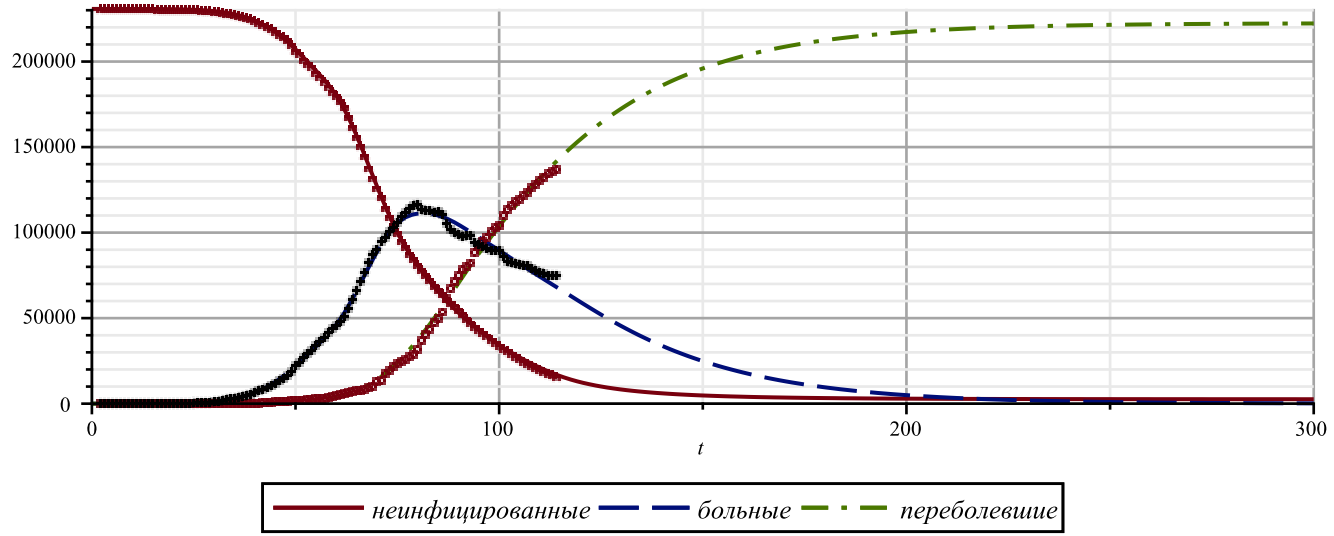
19047.4068941248

19045.7514783638

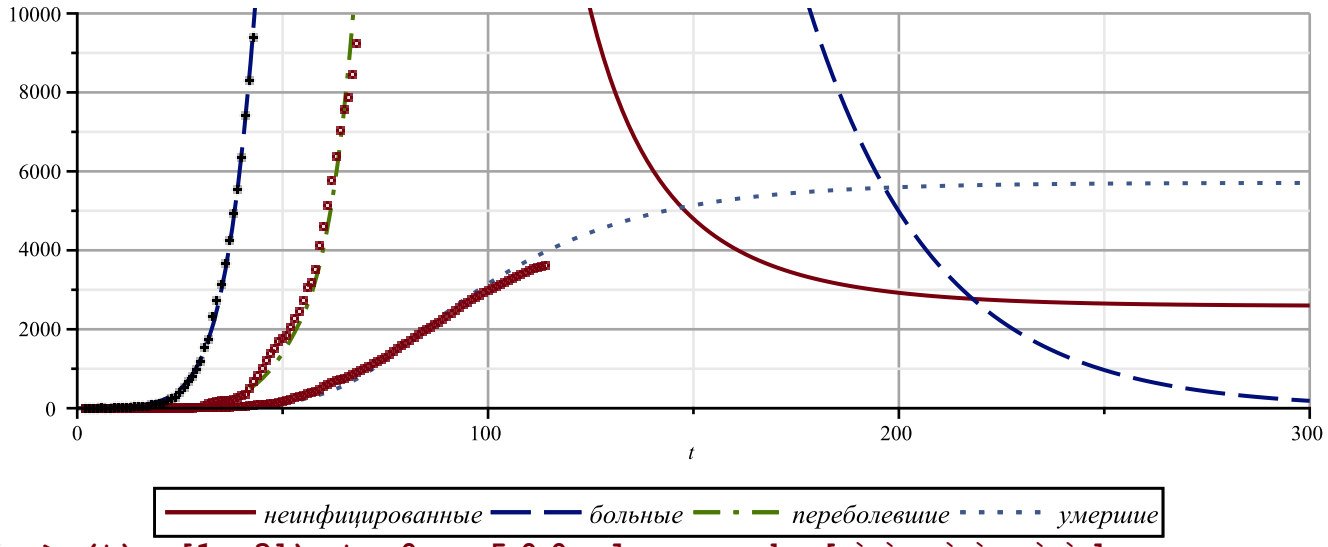
val := [13.7708545080647, 230778.263166214, 0.105060380724454, 0.213435907310072, 0.178259228493389, 0.120690586312894, 0.0885983426160155, 0.115810796583579, 0.0860551719132781, 0.183688912563891, 0.0113318682911344, 0.00662680851333080, 0.0342433770252834, 0.000737878386869957]

19045.7514783638

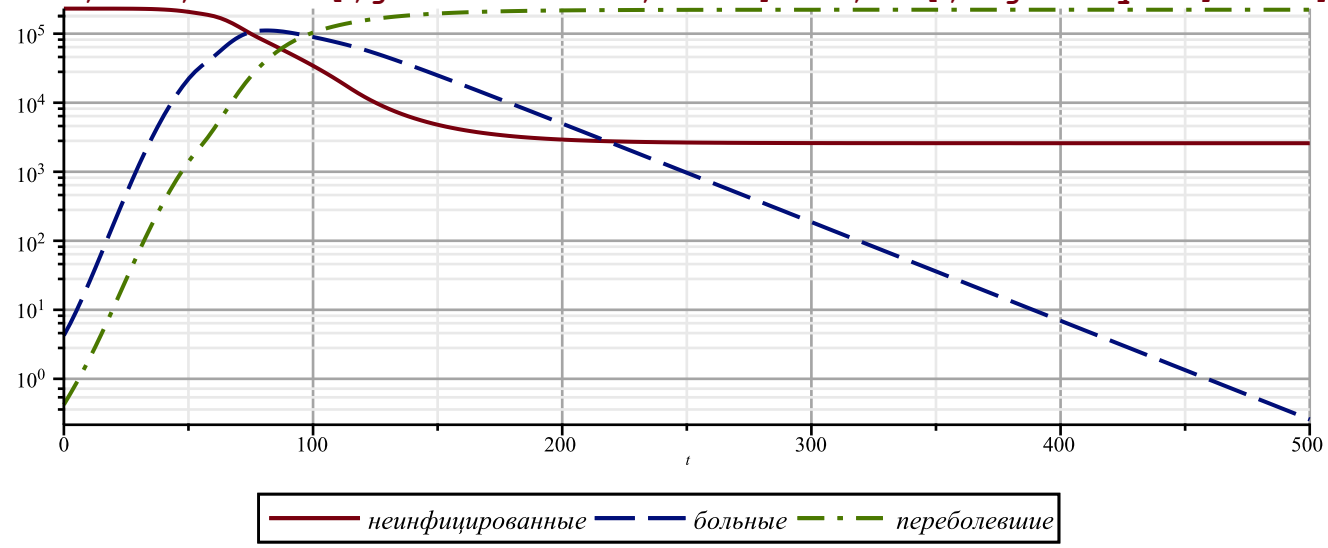
Moscow3c.jpg




```
> display(
   plot(map(q->q(t),v), t = 0 . . 3 0 0 , l e g e n d = [ ` ` , ` ` , ` ` , ` `                                    ],
    linestyle=[solid,dash,dashdot,dot],gridlines=true),
   plot([[seq([i+dd,K_-T[i]],i=1..nops(T))]],style=point,symbolsize=7,symbol=asterisk),
   plot([[seq([i+dd,T1[i]],i=1..nops(T1))]],style=point,symbolsize=7,symbol=circle),
   plot([[seq([i+dd,T3[i]],i=1..nops(T1))]],style=point,symbolsize=7,symbol=circle),
   plot([[seq([i+dd,T2[i]],i=1..nops(T2))]],style=point,symbolsize=7,symbol=diamond,color=black),
   size=[1000,400],legendstyle=[font=[roman,15]],view=[0..300,0..10000]
  );
```



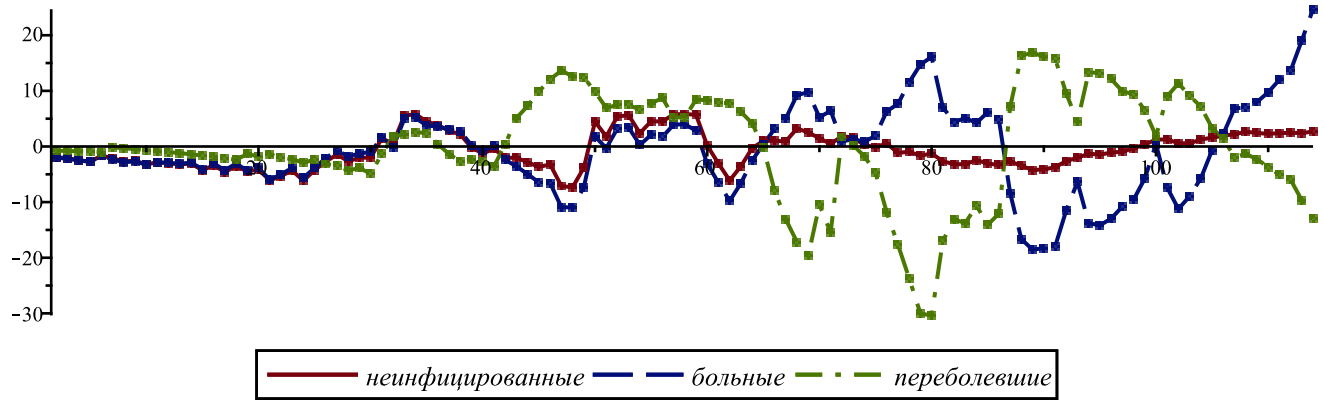

```
> logplot(map(q->q(t),v[1..3]), t=0..500, legend=[``,``,``],
  linestyle=[solid,dash,dashdot],gridlines=true,size=[1000,400],legendstyle=[font=[roman,15]]);
```




```
> display(
   plot([
    [[i,(T[i-dd]-(K_-A(i)))/sigma(K_-A(i))] $ i=1+dd..dd+nops(T)],
    [[i,(T2[i-dd]-(B(i)))/sigma(B(i))] $ i=1+dd..dd+nops(T)],
```

```
  [[i,(T1[i-dd]-(C(i)))/sigma(C(i))] $ i=1+dd..dd+nops(T)]
 ],linestyle=[solid,dash,dashdot],l e g e n d = [ ` ` , ` ` , ` ` ]                    ),
 plot([
  [[i,(T[i-dd]-(K_-A(i)))/sigma(K_-A(i))] $ i=1+dd..dd+nops(T)],
  [[i,(T2[i-dd]-(B(i)))/sigma(B(i))] $ i=1+dd..dd+nops(T)],
  [[i,(T1[i-dd]-(C(i)))/sigma(C(i))] $ i=1+dd..dd+nops(T)]
 ],style=point,symbolsize=8,symbol=solidcircle),
 size=[1000,300],legendstyle=[font=[roman,15]]
): fdisplay(cat(Region,`3c-dev`),%);
```

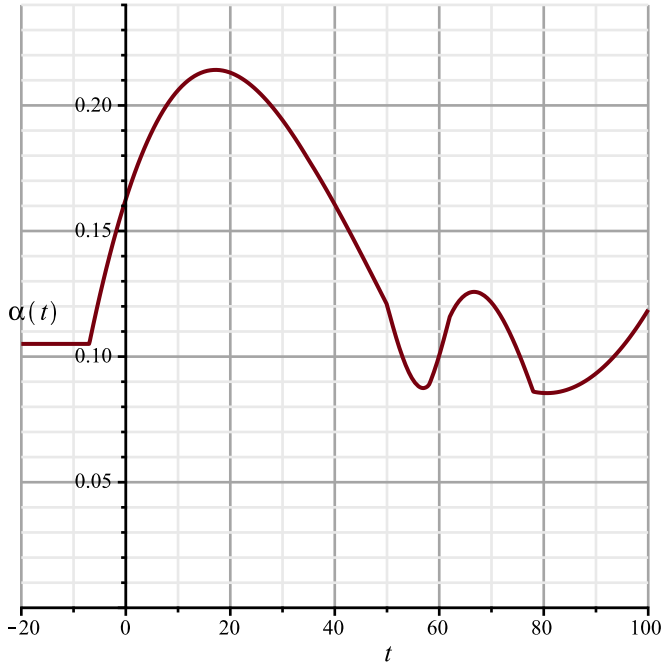
Moscow3c-dev.jpg



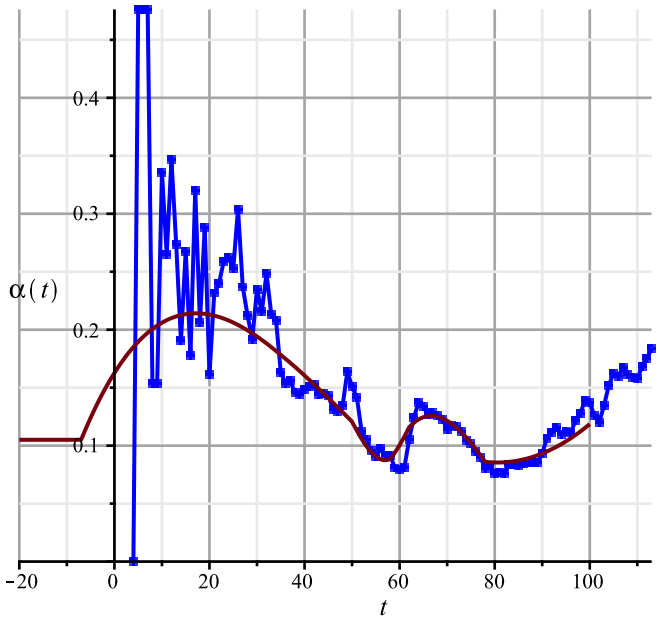

```
> [seq([i,(
  (T[i-dd]-T[i-dd-1]) /(T2[i-dd]+T2[i-dd-1]) /((1-T[i-dd]/K_)+(1-T[i-dd-1]/K_))
 )*4],i=1+dd+1..nops(T)+dd)]: [seq([%[i][1],(%[i-1][2]+%[i][2]+%[i+1][2])/3],i=2..nops(%)-1)]:
 Palpha:=display(plot([%],color=blue),plot([%],style=point,symbolsize=8,symbol=solidcircle,color=
 blue)):
 #display(%,gridlines=true,labels=['t','alpha(t)'],labelfont=[roman,15],view=[0..nops(T)+dd,0.
 .0.9]);

 subs(corr(par,val),alpha(t, op(kA)));
 plot(%,t=-20..100,gridlines=true,labels=['t',''alpha(t)''],labelfont=[roman,15],view=[-20..100,0.
 .0.24]):
 fdisplay(cat(Region,`3c-zar`),%); display([Palpha,%],t i t l e = `   `                ,titlefont=
 [roman,20]);
```

$$\begin{cases} 0.105060380724454 & t < -7. \\ 1.75025212721533\ 10^{-6}\ t^3 - 0.000234427371406942\ t^2 + 0.00650578666295597\ t + 0.162688165043012 & t < 35. \\ 1.20589349811613\ 10^{-6}\ t^3 - 0.000179991506142797\ t^2 + 0.00485910174486936\ t + 0.176977579732872 & t < 50. \\ 0.0000336581136297726\ t^3 - 0.00482065899800068\ t^2 + 0.221639932702216\ t - 3.11692276743315 & t < 58. \\ -0.0000476557975093785\ t^3 + 0.00900270591307610\ t^2 - 0.558648359737147\ t + 11.5033184644608 & t < 62. \\ 9.30465623215374\ 10^{-6}\ t^3 - 0.00227546393630502\ t^2 + 0.179331279934780\ t - 4.47340529576942 & t < 78. \\ 0.0000879187479687395\ t^2 - 0.0141683512532007\ t + 0.656288907483489 & t < 114. \\ 0.183688912563891 & 114. \le t \end{cases}$$

Moscow3c-zar.jpg

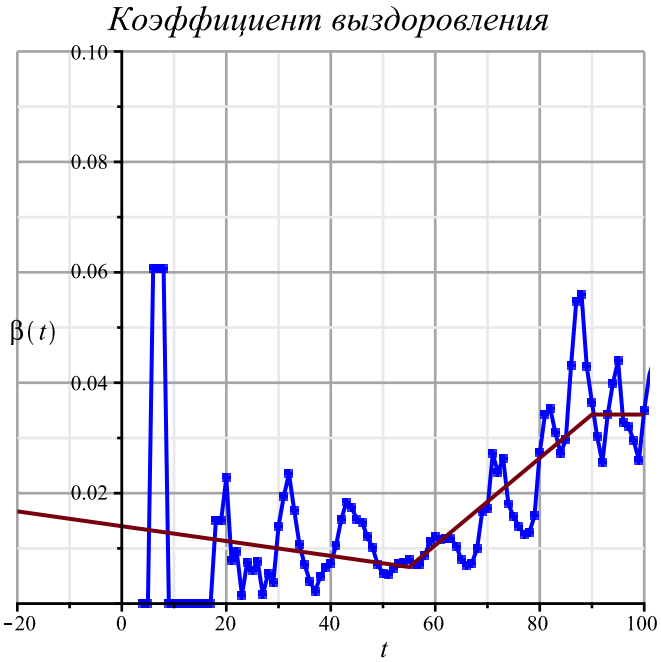


Коэффициент заражения

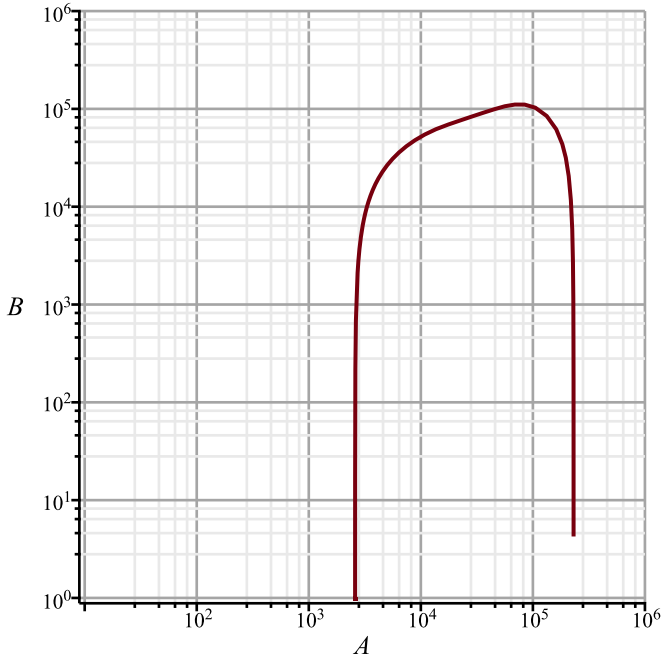



```
> [seq([i,(
   (T1[i-dd]-T1[i-dd-1]) /(T2[i-dd]+T2[i-dd-1])
  )*2],i=1+dd+1..nops(T1)+dd)]: [seq([%[i][1],(%[i-1][2]+%[i][2]+%[i+1][2])/3],i=2..nops(%)-1)]:
  Pbeta:=display(plot([%],color=blue),plot([%],style=point,symbolsize=8,symbol=solidcircle,color=
  blue)):

  subs(corr(par,val),beta(t,k2a,k2b,k2c));
  plot(%,t=-20..100,gridlines=true,labels=['t',''beta(t)''],labelfont=[roman,15]):
  display([Pbeta,%],t i t l e = `   `                    ,titlefont=[roman,20],view=[-20..100,0..0.1]);
```

$$\begin{cases} -0.000134430279359096\,t + 0.0140204738737836 & t < 55. \\ 0.000789044814587764\,t - 0.0367706562793304 & t < 90. \\ 0.0342433770252834 & 90. \le t \end{cases}$$




```
> plot([v[1](t),v[2](t),t=0..3.0e4],axis[1]=[mode=log],axis[2]=[mode=log],labels=[v[1],v[2]],
  labelfont=[roman,15],gridlines=true,view=[10^1..10^6,10^0..10^6]);
```




```
> res:=solve(map(rhs,eqs[1..2]),v[1..2]); res:=res[2]; evalf(subs(param,t=100,res));

  J:=Matrix(subs(res,map(q->grad(rhs(q),v[1..2]),eqs[1..2]))); J:=evalf(subs(param,corr(par,val),t=
  100,J));
  evalm(%-lambda): collect(Determinant(%),lambda);

  #evalf(subs(param,corr(par,val),t=100,%));
  solve(%,{lambda});
```

$$res := \left[\left[A = \frac{C\,P_{01}}{P_{10} - P_{01}}, B = 0\right], \left[A = \frac{k0\left(P_{23} + P_{20}\right)}{P_{12}}, B = \frac{C\,P_{01}\,P_{12} + k0\,P_{01}\,P_{20} + k0\,P_{01}\,P_{23} - k0\,P_{10}\,P_{20} - k0\,P_{10}\,P_{23}}{P_{12}\left(P_{23} + P_{20}\right)}\right]\right]$$

$$res := \left[A = \frac{k0\left(P_{23} + P_{20}\right)}{P_{12}}, B = \frac{C\,P_{01}\,P_{12} + k0\,P_{01}\,P_{20} + k0\,P_{01}\,P_{23} - k0\,P_{10}\,P_{20} - k0\,P_{10}\,P_{23}}{P_{12}\left(P_{23} + P_{20}\right)}\right]$$

$$\left[A = \frac{k0\,(k2c + k3)}{-0.37019231\,k1x6 + 0.92361112\,k1x7 + 0.446581197\,k1x8}, B = 0.\right]$$

$$J := \begin{bmatrix} P_{01} - \dfrac{C\,P_{01}\,P_{12} + k0\,P_{01}\,P_{20} + k0\,P_{01}\,P_{23} - k0\,P_{10}\,P_{20} - k0\,P_{10}\,P_{23}}{(P_{23} + P_{20})\,k0} - P_{10} & -P_{23} - P_{20} \\ \dfrac{C\,P_{01}\,P_{12} + k0\,P_{01}\,P_{20} + k0\,P_{01}\,P_{23} - k0\,P_{10}\,P_{20} - k0\,P_{10}\,P_{23}}{(P_{23} + P_{20})\,k0} & 0 \end{bmatrix}$$

$$J := \begin{bmatrix} 0. & -0.0349812554121533 \\ 0. & 0. \end{bmatrix}$$

$$\lambda^2$$

$$\{\lambda = 0\},\ \{\lambda = 0\}$$

(9

```
> N:='N': A:='A': B:='B': C:='C': Q:='Q':

  param:=[
    P[`01`]=kappa,  P[`12`]=k1, P[`23`]=k2,
    P[`10`]=kappa, P[`20`]=k3, P[`30`]=k4
  ];
  corr(par,val);
  subs(param,eqs); R:=solve(%,[k1,k2,k3,k4])[1];

  X:='X': X1:='X1': subs(R,Diff(A,t)=-X1[1][i][2],Diff(B,t)=X1[2][i][2],Diff(C,t)=X1[3][i][2],Diff
  (Q,t)=X1[4][i][2],A=k0-X[1][i][2],B=X[2][i][2],C=X[3][i][2],Q=X[4][i][2],[k1,k2,k3,k4]): XX:=
  unapply(subs(k0=K_,%),i):
```

$$param := [P_{01} = 0, P_{12} = k1, P_{23} = k2, P_{10} = 0, P_{20} = k3, P_{30} = k4]$$

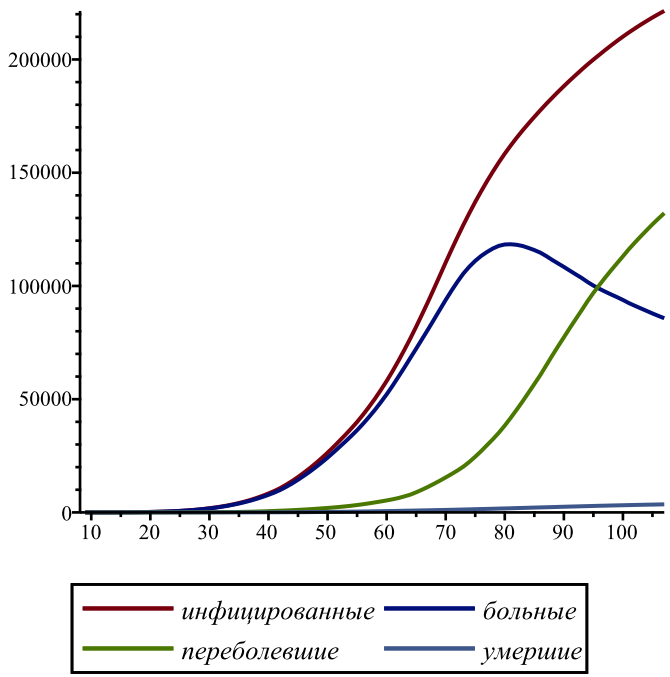
$d0 = 13.7708545080647,\ k0 = 230778.263166214,\ k1x1 = 0.105060380724454,\ k1x2 = 0.213435907310072,\ k1x3 = 0.178259228493389,\ k1x4 = 0.120690586312894,\ k1x5 = 0.0885983426160155,\ k1x6 = 0.115810796583579,\ k1x7 = 0.0860551719132781,\ k1x8 = 0.183688912563891,\ k2a = 0.0113318682911344,\ k2b = 0.00662680851333080,\ k2c = 0.0342433770252834,\ k3 = 0.000737878386869957$

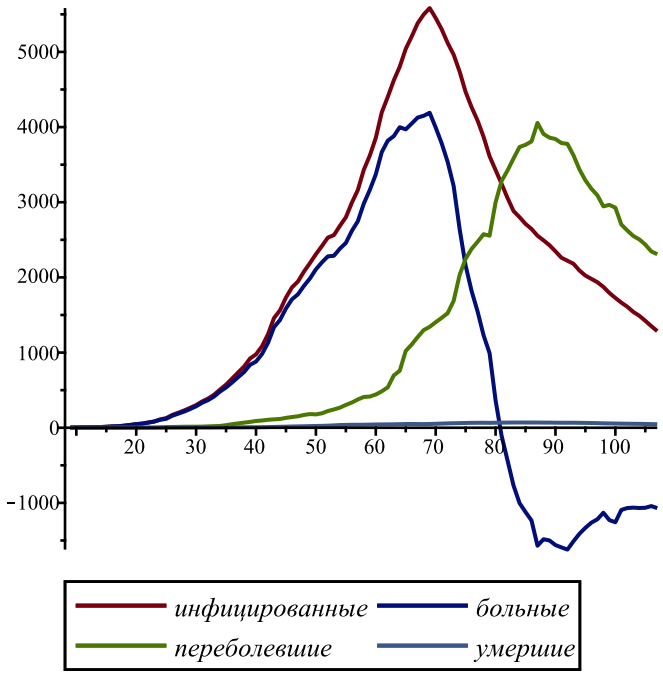
$$\left[\frac{\partial}{\partial t}\ A = -\frac{B\,k1\,A}{k0},\ \frac{\partial}{\partial t}\ B = \frac{B\,k1\,A}{k0} - k2\,B - k3\,B,\ \frac{\partial}{\partial t}\ C = k2\,B - C\,k4,\ \frac{\partial}{\partial t}\ Q = k3\,B\right]$$

$$R := \left[k1 = -\frac{\frac{\partial}{\partial t} A\,k0}{A\,B},\ k2 = -\frac{\frac{\partial}{\partial t} A + \frac{\partial}{\partial t} B + \frac{\partial}{\partial t} Q}{B},\ k3 = \frac{\frac{\partial}{\partial t} Q}{B},\ k4 = -\frac{\frac{\partial}{\partial t} A + \frac{\partial}{\partial t} B + \frac{\partial}{\partial t} Q + \frac{\partial}{\partial t} C}{C} \right] \quad \text{(10}$$

```
> k:=7;
  X:=map(q->[seq([i+dd,(ssum(q[i+j],j=-k..k))/(2*k)],i=1+k..nops(q)-k)],[T,T2,T1,T3]):
  plot(%,legend=[` `, ` `, ` `, ` `]                                    ,legendstyle=[font=[roman,15]]
  );
  X1:=map(q->[seq([i+dd,(q[i+k]-q[i-k])/(2*k)],i=1+k..nops(q)-k)],[T,T2,T1,T3]):
  plot(%,legend=[` `, ` `, ` `, ` `]                                    ,legendstyle=[font=[roman,15]]
  );
```

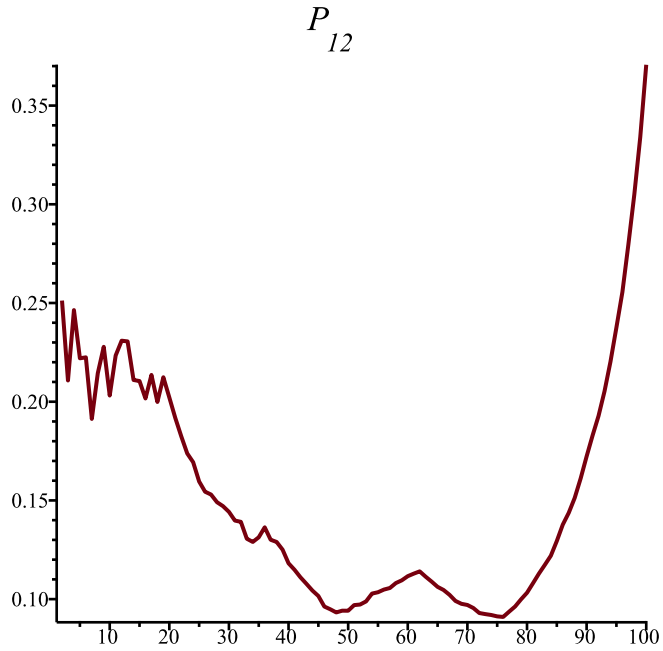
$k := 7$

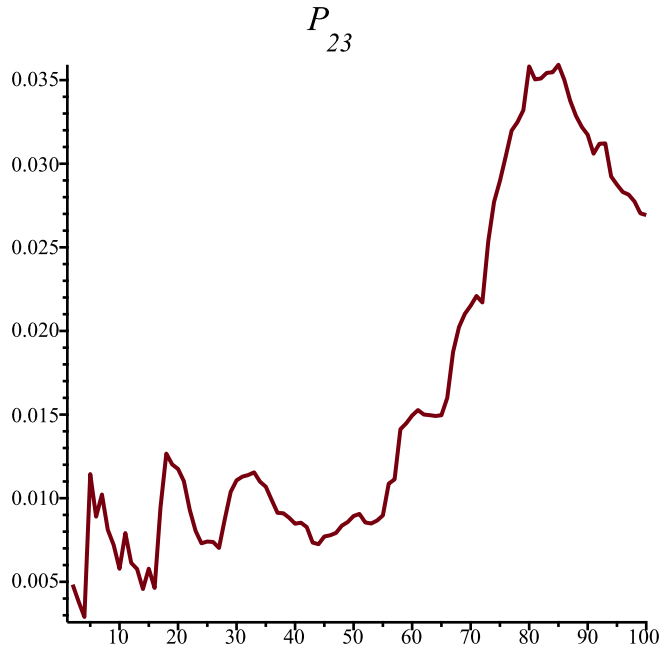


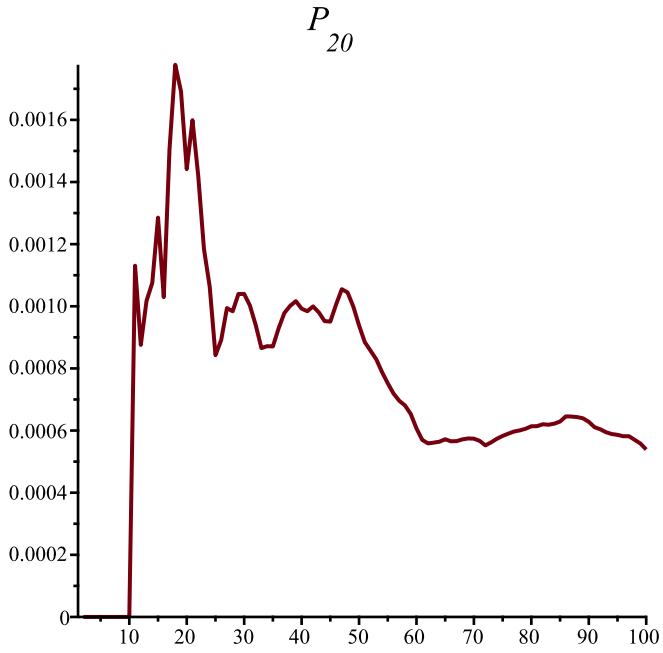



```
> k:=0;

  [seq([i+dd+k,XX(i)[1]],i=1..nops(X[1]))]: [seq([%[i][1],(ssum(%[i+j][2],j=-k..k))/(2*k+1)],i=1+k.
  .nops(%)-k)]:
  plot([%],title=P[`12`],titlefont=[roman,20]);

  [seq([i+dd+k,XX(i)[2]],i=1..nops(X[1]))]: [seq([%[i][1],(ssum(%[i+j][2],j=-k..k))/(2*k+1)],i=1+k.
  .nops(%)-k)]:
  plot([%],title=P[`23`],titlefont=[roman,20]);

  [seq([i+dd+k,XX(i)[3]],i=1..nops(X[1]))]: [seq([%[i][1],(ssum(%[i+j][2],j=-k..k))/(2*k+1)],i=1+k.
  .nops(%)-k)]:
  plot([%],title=P[`20`],titlefont=[roman,20]);
```

$$k := 0$$


P_{12}
0.35
0.30
0.25
0.20
0.15
0.10
10
20
30
40
50
60
70
80
90
100


P_{23}
0.035
0.030
0.025
0.020
0.015
0.010
0.005
10
20
30
40
50
60
70
80
90
100


P_{20}
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0
10
20
30
40
50
60
70
80
90
100