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

  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*
  1.1; 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*
  1.1; od;
   t:=goldMin(t->ff(t*V0+(1-t)*V2),0..1,0.0001);
   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:
```

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

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

$$\pi := 3.141592654 \qquad (1$$

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

======================================

VERHULST FItAING

====================================== (2

```
> 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:
```

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

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

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

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

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

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

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

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

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

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

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

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

$$chi2e := (T, f\_) \rightarrow simplify\left(\sum_{k=1}^{nops(T)} \frac{evalf\left(ffe\_\left(T_k\right) - f\_(k)\right)^2}{dffe\_\left(T_k\right)^2 \sigma\left(T_k\right)^2}\right) \quad (3$$

```
> val:=proc() global data,i; local j; while not(data[i] in {"0","1","2","3","4","5","6","7","8",
"9","0","-","+"}) do i:=i+1: od:
 j:=i; while (data[i] in {"0","1","2","3","4","5","6","7","8","9","0","-","+"}) do i:=i+1: od:
parse(data[j..i-1]);
end:

T:=readdata(`Russia-i.txt`): nops(%); #
T1:=readdata(`Russia-r.txt`): nops(%); #
T2:=readdata(`Russia-h.txt`): nops(%); #
T3:=readdata(`Russia-m.txt`): nops(%); #
` `; `Russia`; status,data,headers:=HTTP:-Get("https://coronavirus-monitor.ru/coronavirus-v-
rossii/"): HTTP:-Code(status);
if %="OK"then
  i:=Search("",data): val(); val();  aa,bb:=1.*pr(%%-%),1.*pr(%%); i:='i':
  i:=Search("",data): val(); val();  aa1,bb1:=1.*pr(%%-%),1.*pr(%%); i:='i':
  i:=Search("",data); val(): val();  aa3,bb3:=1.*pr(%%-%),1.*pr(%%); i:='i':
                                      aa2:=aa-aa1-aa3; bb2:=bb-bb1-bb3;
  if bb=T[nops(T)] then else if aa>T[nops(T)] then T:=[op(T[1..nops(T)-1]),aa,bb];
     T1:=[op(T1[1..nops(T1)-1]),aa1,bb1]; T2:=[op(T2[1..nops(T2)-1]),aa2,bb2]; T3:=[op(T3[1..nops
(T3)-1]),aa3,bb3];
    else if aa=T[nops(T)-1] then T:=[op(T[1..nops(T)-1]),bb];
     T1:=[op(T1[1..nops(T1)-1]),bb1]; T2:=[op(T2[1..nops(T2)-1]),bb2];  T3:=[op(T3[1..nops(T3)-1]
),bb3];
    else if aa=T[nops(T)] then T:=[op(T),bb];
     T1:=[op(T1),bb1]; T2:=[op(T2),bb2]; T3:=[op(T3),bb3];
```

```
    fi; fi; fi; fi;
    writedata(`Russia-i.txt`,T);
    writedata(`Russia-r.txt`,T1); writedata(`Russia-h.txt`,T2);  writedata(`Russia-m.txt`,T3);
  fi:
  `Russia`; dd:=1: 'T'=T; 'T1'=T1; 'T2'=T2; 'T3'=T3;

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

79

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` `

Russia

"OK"

290945

299990

70289

76164

2754

2865

Russia

T = [7., 7., 7., 11., 11., 14., 14., 17., 20., 28., 34., 45., 59., 63., 93., 114., 147., 199., 251., 306., 367., 438., 503., 666., 845., 1040., 1256., 1534., 1840., 2337., 2780., 3548., 4150., 4734., 5410., 6351., 7517., 8678., 10145., 11929., 13612., 15806., 18352., 21160., 24567., 28005., 32084., 36932., 42983., 47302., 52937., 58119., 62886., 68766., 74788., 81079., 87336., 93678., 99623., 106631., 114573., 124244., 134906., 145452., 155594., 166127., 177288., 188063., 198862., 209966., 221573., 232378., 242430., 252560., 263013., 272244., 281918., 290945., 299990.]

T1 = [3., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 6., 9., 10., 18., 18., 20., 24., 36., 39., 47., 55., 67., 75., 142., 207., 254., 301., 355., 395., 429., 505., 598., 711., 804., 1054., 1293., 1473., 1709., 2006., 2317., 2609., 3081., 3303., 3457., 3906., 4431., 4907., 5589., 6311., 6781., 7369., 8518., 10300., 11629., 13285., 15056., 16676., 18157., 19923., 21370., 23830., 26693., 31993., 34363., 39863., 43540., 48119., 53648., 58321., 63258., 67432., 70275., 76164.]

$T2 = [4., 3., 3., 7., 7., 10., 10., 13., 16., 24., 30., 41., 55., 59., 89., 110., 141., 190., 241., 288., 349., 418., 479., 628., 804., 989., 1194., 1458., 1749., 2175., 2546., 3263., 3814., 4336., 4968., 5871., 6951., 8006., 9355., 11030., 12450., 14381., 16729., 19278., 22360., 25450., 29200., 33538., 39317., 43436., 48569., 53172., 57423., 62560., 67795., 73549., 79170., 84289., 88347., 93926., 100116., 107963., 116945., 125937., 134216., 143217., 151830., 159644., 165038., 173684., 179698., 186718., 192092., 196598., 202267., 206442., 211844., 217935., 220961.]$

$T3 = [0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 2., 2., 4., 7., 9., 16., 20., 27., 31., 35., 43., 47., 51., 61., 74., 79., 95., 108., 132., 150., 173., 201., 238., 275., 313., 363., 409., 462., 516., 556., 617., 682., 749., 797., 871., 976., 1076., 1172., 1225., 1285., 1358., 1455., 1540., 1628., 1726., 1831., 1919., 2012., 2120., 2219., 2314., 2425., 2544., 2642., 2735., 2865.]$

$$79$$

$[2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80]$ (4

```
> 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
  );
```

$$h := x \mapsto x$$

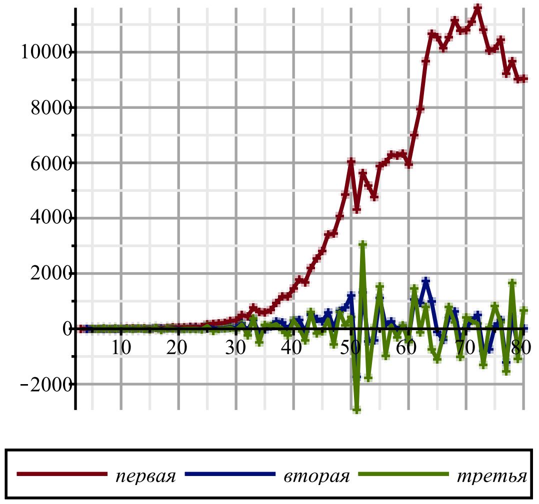
$[0., 0., 4., 0., 3., 0., 3., 3., 8., 6., 11., 14., 4., 30., 21., 33., 52., 52., 55., 61., 71., 65., 163., 179., 195., 216., 278., 306., 497., 443., 768., 602.,$

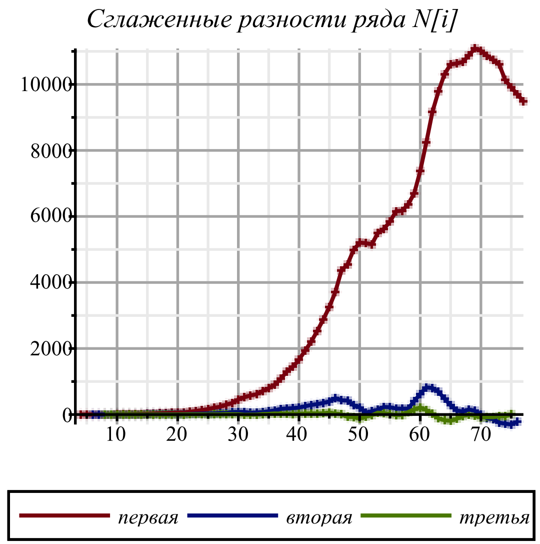
584., 676., 941., 1166., 1161., 1467., 1784., 1683., 2194., 2546., 2808., 3407., 3438., 4079., 4848., 6051., 4319., 5635., 5182., 4767., 5880., 6022., 6291., 6257., 6342., 5945., 7008., 7942., 9671., 10662., 10546., 10142., 10533., 11161., 10775., 10799., 11104., 11607., 10805., 10052., 10130., 10453., 9231., 9674., 9027., 9045.]

[0., 4., −4., 3., −3., 3., 0., 5., −2., 5., 3., −10., 26., −9., 12., 19., 0., 3., 6., 10., −6., 98., 16., 16., 21., 62., 28., 191., −54., 325., −166., −18., 92., 265., 225., −5., 306., 317., −101., 511., 352., 262., 599., 31., 641., 769., 1203., −1732., 1316., −453., −415., 1113., 142., 269., −34., 85., −397., 1063., 934., 1729., 991., −116., −404., 391., 628., −386., 24., 305., 503., −802., −753., 78., 323., −1222., 443., −647., 18.]

[4., −8., 7., −6., 6., −3., 5., −7., 7., −2., −13., 36., −35., 21., 7., −19., 3., 3., 4., −16., 104., −82., 0., 5., 41., −34., 163., −245., 379., −491., 148., 110., 173., −40., −230., 311., 11., −418., 612., −159., −90., 337., −568., 610., 128., 434., −2935., 3048., −1769., 38., 1528., −971., 127., −303., 119., −482., 1460., −129., 795., −738., −1107., −288., 795., 237., −1014., 410., 281., 198., −1305., 49., 831., 245., −1545., 1665., −1090., 665.]

Разности ряда N[i]





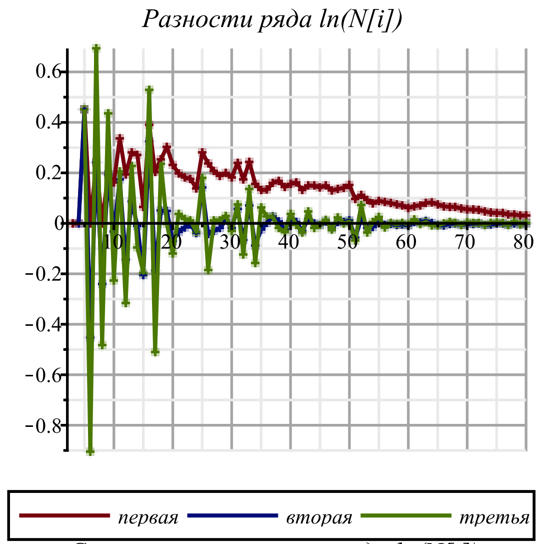

```
> h:=x->ln(x);

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

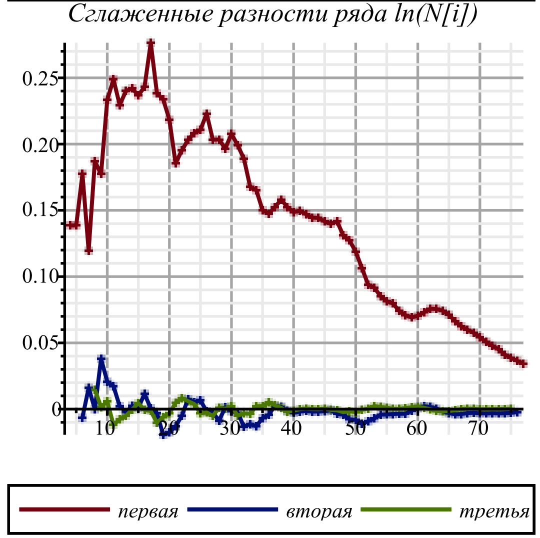
$$h := x \mapsto \ln(x)$$

[0., 0., 0.451985124, 0., 0.241162057, 0., 0.194156014, 0.162518930, 0.336472236, 0.194156015, 0.280301965, 0.270874954, 0.065597282, 0.389464767, 0.203598955, 0.254234139, 0.302872238, 0.232148114, 0.198132163, 0.181776746, 0.176857062, 0.138371260, 0.280699501, 0.238046956, 0.207639365, 0.188711355, 0.199946635, 0.181886869, 0.239102484, 0.173582872, 0.243933136, 0.156724270, 0.131662177, 0.133478582, 0.160363188, 0.168554841, 0.143623965, 0.156189886, 0.161991437, 0.131979347, 0.149437858, 0.149348945, 0.142374047, 0.149291474, 0.13097898, 0.13597440, 0.14072092, 0.15172631, 0.09574789, 0.11254995, 0.09339010, 0.07883093, 0.08938588, 0.08394800, 0.08076655, 0.07433876, 0.07010062, 0.06152969, 0.06798122, 0.07183789, 0.08103520, 0.08233087, 0.07526789, 0.06740392, 0.06550251, 0.06502297, 0.05900148, 0.05583411, 0.05433449, 0.05380650, 0.04761325, 0.04234765, 0.04093583, 0.04055462, 0.03449526, 0.03491753, 0.03151799, 0.03061490]

[0., 0.451985124, −0.451985124, 0.241162057, −0.241162057, 0.194156014, −0.031637084, 0.173953306, −0.142316221, 0.086145950, −0.009427011, −0.205277672, 0.323867485, −0.185865812, 0.050635184, 0.048638099, −0.070724124, −0.034015951, −0.016355417, −0.004919684, −0.038485802, 0.142328241, −0.042652545, −0.030407591, −0.018928010, 0.011235280, −0.018059766, 0.057215615, −0.065519612, 0.070350264, −0.087208866, −0.025062093, 0.001816405, 0.026884606, 0.008191653, −0.024930876, 0.012565921, 0.005801551, −0.030012090, 0.017458511, −0.000088913, −0.006974898, 0.006917427, −0.018312494, 0.00499542, 0.00474652, 0.01100539, −0.05597842, 0.01680206, −0.01915985, −0.01455917, 0.01055495, −0.00543788, −0.00318145, −0.00642779, −0.00423814, −0.00857093, 0.00645153, 0.00385667, 0.00919731, 0.00129567, −0.00706298, −0.00786397, −0.00190141, −0.00047954, −0.00602149, −0.00316737, −0.00149962, −0.00052799, −0.00619325, −0.00526560, −0.00141182, −0.00038121, −0.00605936, 0.00042227, −0.00339954, −0.00090309]

[0.451985124, −0.903970248, 0.693147181, −0.482324114, 0.435318071, −0.225793098, 0.205590390, −0.316269527, 0.228462171, −0.095572961, −0.195850661, 0.529145157, −0.509733297, 0.236500996, −0.001997085, −0.119362223, 0.036708173, 0.017660534, 0.011435733, −0.033566118, 0.180814043, −0.184980786, 0.012244954, 0.011479581, 0.030163290, −0.029295046, 0.075275381, −0.122735227, 0.135869876, −0.157559130, 0.062146773, 0.026878498, 0.025068201, −0.018692953, −0.033122529, 0.037496797, −0.006764370, −0.035813641, 0.047470601, −0.017547424, −0.006885985, 0.013892325, −0.025229921, 0.023307914, −0.00024890, 0.00625887, −0.06698381, 0.07278048, −0.03596191, 0.00460068, 0.02511412, −0.01599283, 0.00225643, −0.00324634, 0.00218965, −0.00433279, 0.01502246, −0.00259486, 0.00534064, −0.00790164, −0.00835865, −0.00080099, 0.00596256, 0.00142187, −0.00554195, 0.00285412, 0.00166775, 0.00097163, −0.00566526, 0.00092765, 0.00385378, 0.00103061, −0.00567815, 0.00648163, −0.00382181, 0.00249645]






```
> 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

` `

$$M := 299992.3415$$

$$N(t) = 299992.3415 - \frac{299992.3415}{e^{0.1344347982\,t - 8.554491946} + 1}$$

$$Chi2 := 21658.99100$$

Next day forecast: 270076

The level of 0.5 M is reached at 35 apr

The level of 0.85 M is reached at 48 apr

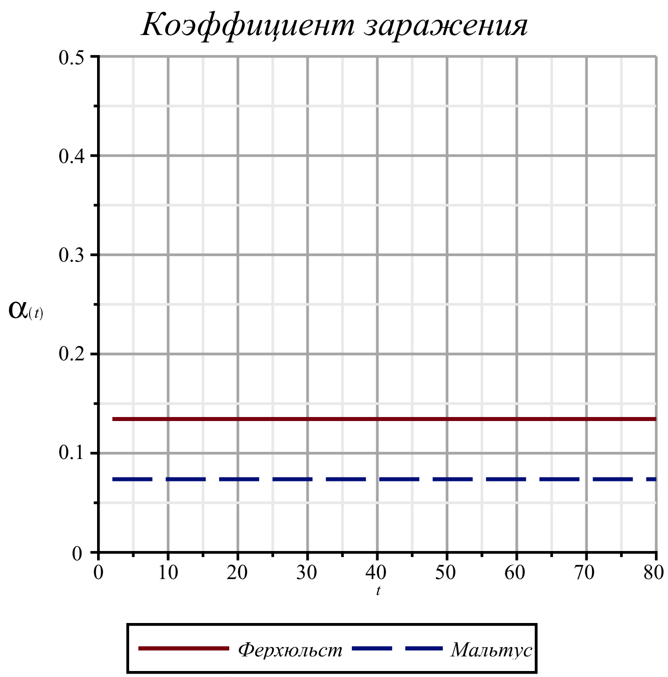
` `

Approximation of the infection schedule by solving the Malthus equation

` `

$$N(t) = e^{0.07374788544\,t + 7.014388425}$$

$$[0.1344347982]$$



$$d1 := 64.63301810$$

$$K\_ := 299992.3415$$

$$alpha\_ := 0.1344347982$$

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

` `

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

` `

$$M := 329132.6253$$

$$N(t) = 329132.6253 - \frac{329132.6253}{e^{1.055413649\,10^{-6}\,t^4 - 0.0001698945581\,t^3 + 0.008203654843\,t^2 + 0.04917706938\,t - 10.15515107} + 1}$$

$$Chi2 := 1436.251613$$

Next day forecast: 304762

The level of 0.5 M is reached at 37 apr

The level of 0.85 M is reached at 48 apr

` `

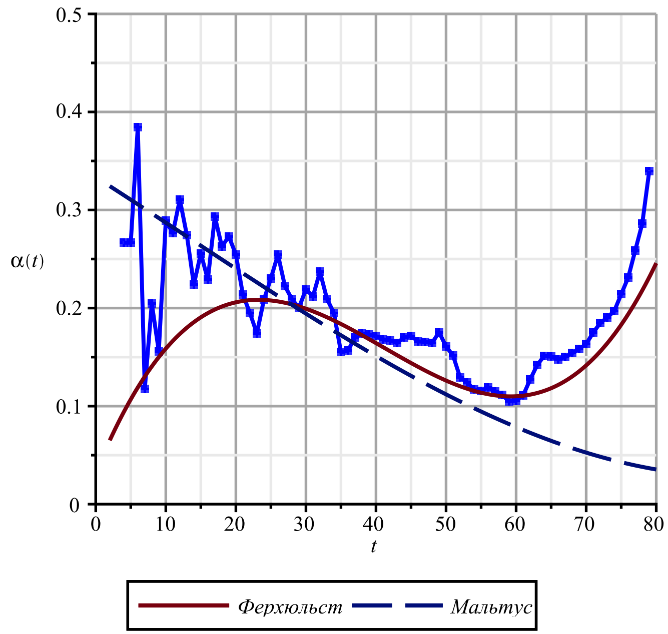
Approximation of the infection schedule by solving the Malthus equation

` `

$$N(t) = \mathrm{e}^{6.488066544\,10^{-8}\,t^4 - 3.157278530\,10^{-6}\,t^3 - 0.002293834581\,t^2 + 0.3289765232\,t - 0.01893619195}$$

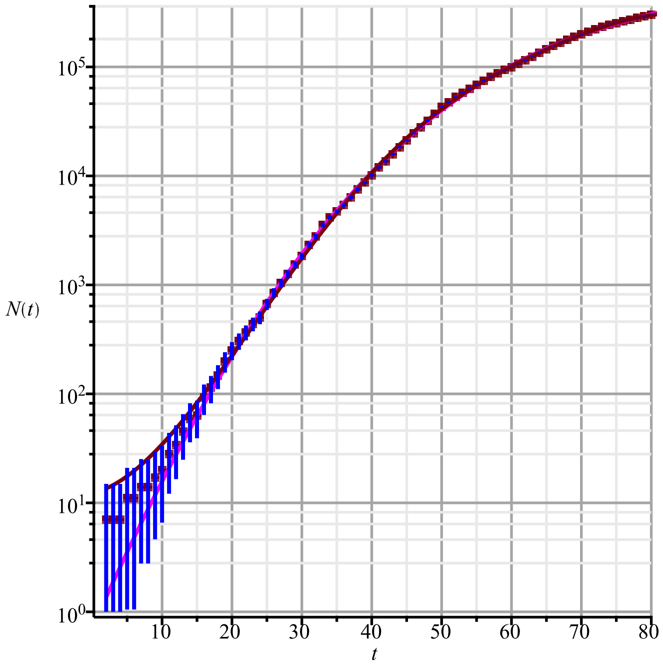
$$[0.0322558543600000,\ 0.0174393420000000,\ -0.000522348638100000,\ 4.221654596\,10^{-6}]$$

Коэффициент заражения

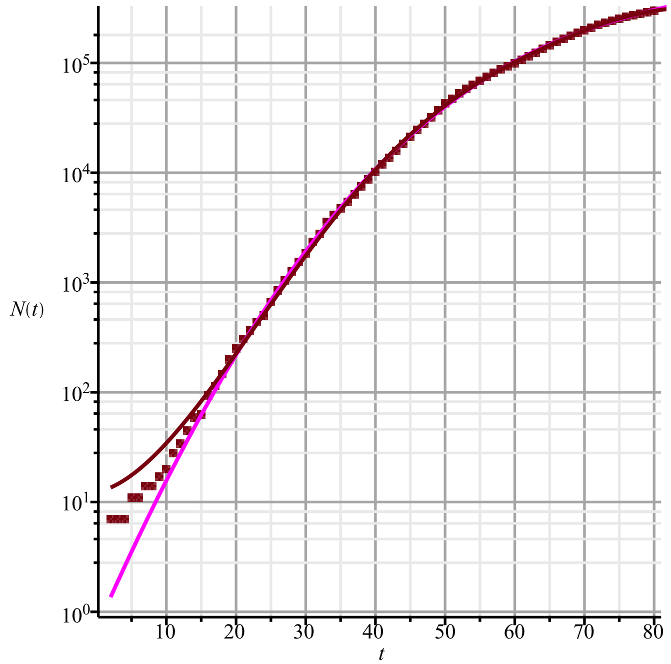



```
> df:=unapply(diff(f(i),i),i): ddf:=unapply(diff(f(i),i,i),i):

  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
```

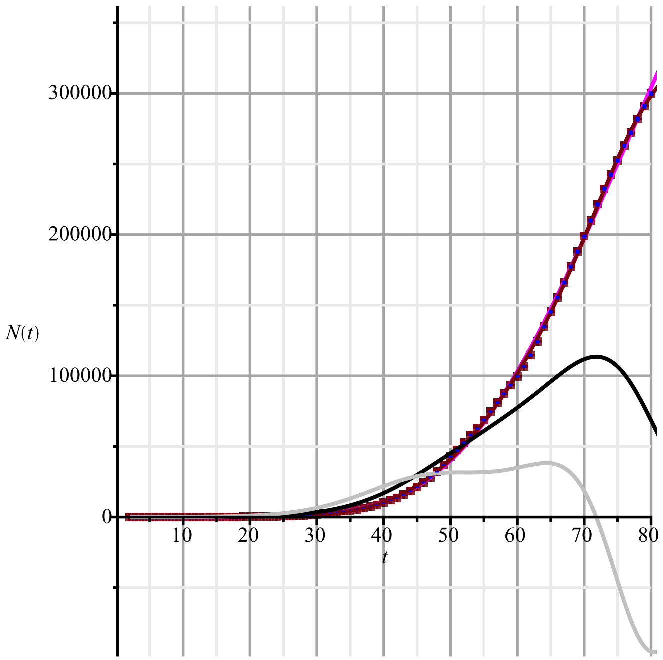
```
);

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
);
```



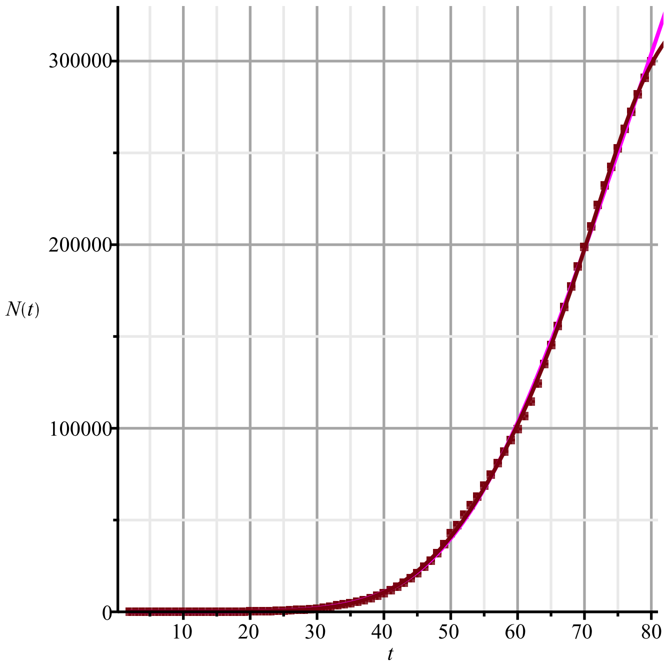
10^5
10^4
10^3
$N(t)$
10^2
10^1
10^0
10
20
30
40
50
60
70
80
t



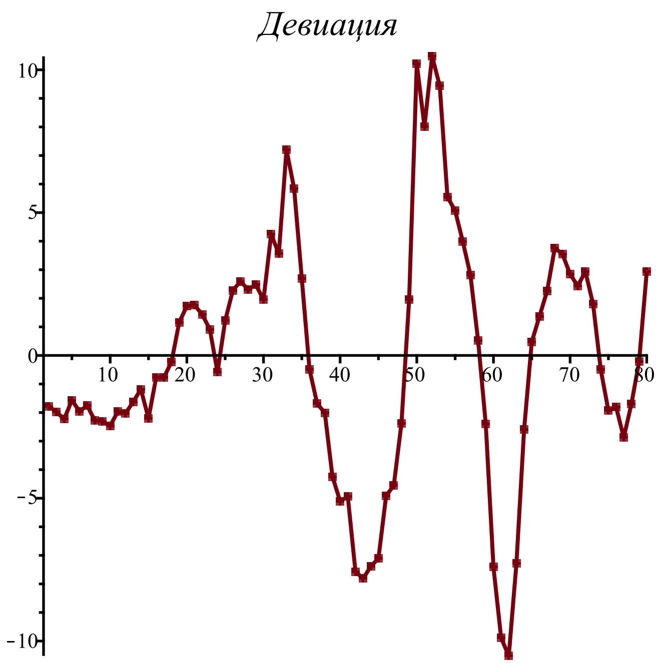
$N(t)$
10^5
10^4
10^3
10^2
10^1
10^0
10
20
30
40
50
60
70
80
t



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




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

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

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

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

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

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

$$\begin{bmatrix} \frac{\partial}{\partial t} A = P_{01} - \frac{B\,P_{12}\,A}{K} - P_{10}\,A \\ \frac{\partial}{\partial t} B = \frac{B\,P_{12}\,A}{K} - P_{23}\,B - P_{20}\,B \\ \frac{\partial}{\partial t} C = P_{23}\,B - P_{30}\,C \end{bmatrix} \qquad (6$$

```
> v:=M; alpha:='alpha': K:=k0; tA:=[1,15,35,50,58,62,74,nops(T)+dd]; kA:=['k1x||i' $ i=1..nops(tA)]
  ;

  par:=[d0,k0,op(kA),k2a,k2b,k3];

  param:=[
    P[`01`]=0,  P[`12`]=alpha(t,op(kA)), P[`23`]=beta(t,k2a,k2b),
    P[`10`]=0, P[`20`]=k3
  ];

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

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

$$K := k0$$

$$tA := [1, 15, 35, 50, 58, 62, 74, 80]$$

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

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

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

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

```
> res:=solve(map(rhs,eqs[1..2]),v[1..2]); res:=res[2]: subs(P[`30`]=P[`10`],param,res);

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

  subs(P[`30`]=P[`10`],pr(param),%); solve(%,{lambda});
```

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

$$\left[A = \frac{k0\,(\beta(t, k2a, k2b) + k3)}{\alpha(t, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8)}, B = 0\right]$$

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

$$\frac{(k0\,P_{20} + k0\,P_{23})\,\lambda^2}{(P_{23}+P_{20})\,k0} + \frac{P_{01}\,P_{12}\,\lambda}{(P_{23}+P_{20})\,k0} + \frac{-k0\,P_{10}\,P_{20}^2 - 2\,k0\,P_{10}\,P_{20}\,P_{23} - k0\,P_{10}\,P_{23}^2 + P_{01}\,P_{12}\,P_{20} + P_{01}\,P_{12}\,P_{23}}{(P_{23}+P_{20})\,k0}$$

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

$$\frac{(k0\,k3 + k0\,\beta(t, k2a, k2b))\,\lambda^2}{(\beta(t, k2a, k2b) + k3)\,k0}$$

$$\{\lambda = 0\}, \{\lambda = 0\} \qquad \textbf{(8}$$

```
> Eqs:=subs(map(q->q=q(t),v),Diff=diff,P[`30`]=P[`10`],param,eqs); #dsolve(%);
```

$$Eqs := \left[\frac{d}{dt}\,A(t) = -\frac{B(t)\,\alpha(t, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8)\,A(t)}{k0}, \frac{d}{dt}\,B(t) = \frac{B(t)\,\alpha(t, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8)\,A(t)}{k0} - \beta(t, k2a, k2b)\,B(t) - k3\,B(t), \frac{d}{dt}\,C(t) = \beta(t, k2a, k2b)\,B(t)\right] \qquad \textbf{(9}$$

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


  #val := [15.8899286782012, 329676.014723034, 0.127732236581742, 0.225361944044372,
  0.175420672694542, 0.152731388363946, #0.109559466974192, 0.122747130841807, 0.204501301139028,
  0.237187166988639, 0.0125745048847963, 0.0253127156294509, #0.000961959894040537];

  val:=readdata(`Russia3b.txt`);

  #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)-3),
t<tA[nops(tA)],Lag(t,tA[nops(tA)-3..nops(tA)],kA[nops(kA)-3..nops(kA)]),
kA[nops(kA)]))),t,op(kA));

beta:=(t,k2a,k2b)->piecewise(t<69,k2a,k2b);

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,x3),x0,xx,op(kA),x2a,x2b,x3):

chi2a:=proc(x0,xx,x1,x2a,x2b,x3) local i; global K_; K_:=xx;
  res(parameters=[corr(par,[x0,xx,op(x1),x2a,x2b,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((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(`Russia3b.txt`,val);

display(
 plot(map(q->q(t),v),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],labelfont=[roman,15],legendstyle=[font=[roman,15]]
): fdisplay(`Russia3b`,%);
```

$val := [15.8550116, 335976.7461, 0.1271708518, 0.2254822844, 0.1763595085, 0.1520522403, 0.1093828345, 0.1213080201, 0.1980967015, 0.2408345138, 0.01256950352, 0.02501057334, 0.00009592758406]$

$\alpha := (t, k1x1, k1x2, k1x3, k1x4, k1x5, k1x6, k1x7, k1x8) \mapsto \{$

$(-0.00004287429258 \cdot k1x1 + 0.0001020408163 \cdot k1x2 - 0.00009803921574 \cdot k1x3 + 0.0$

$(-0.00003322259134 \cdot k1x2 + 0.0001449275363 \cdot k1x3 - 0.0002380952381 \cdot k1x$

$(-0.0001073537306 \cdot k1x3 + 0.0006944444445 \cdot k1x4 - 0.001358695652 \cdot$

$(-0.0004340277780 \cdot k1x4 + 0.001953125000 \cdot k1x5 - 0.001736111111 \cdot k$

$(-0.0007102272727 \cdot k1x5 + 0.001157407407 \cdot k1x6 - 0.0008680555557 \cdot$

$$\beta := (t, k2a, k2b) \mapsto \begin{cases} k2a & t < 69 \\ k2b & otherwise \end{cases}$$

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

[15.8550116, 335976.7461, 0.1271708518, 0.2254822844, 0.1763595085, 0.1520522403, 0.1093828345, 0.1213080201, 0.1980967015, 0.2408345138, 0.01256950352, 0.02501057334, 0.00009592758406]

4269.72798513671

4269.72798513671

4268.56113469480

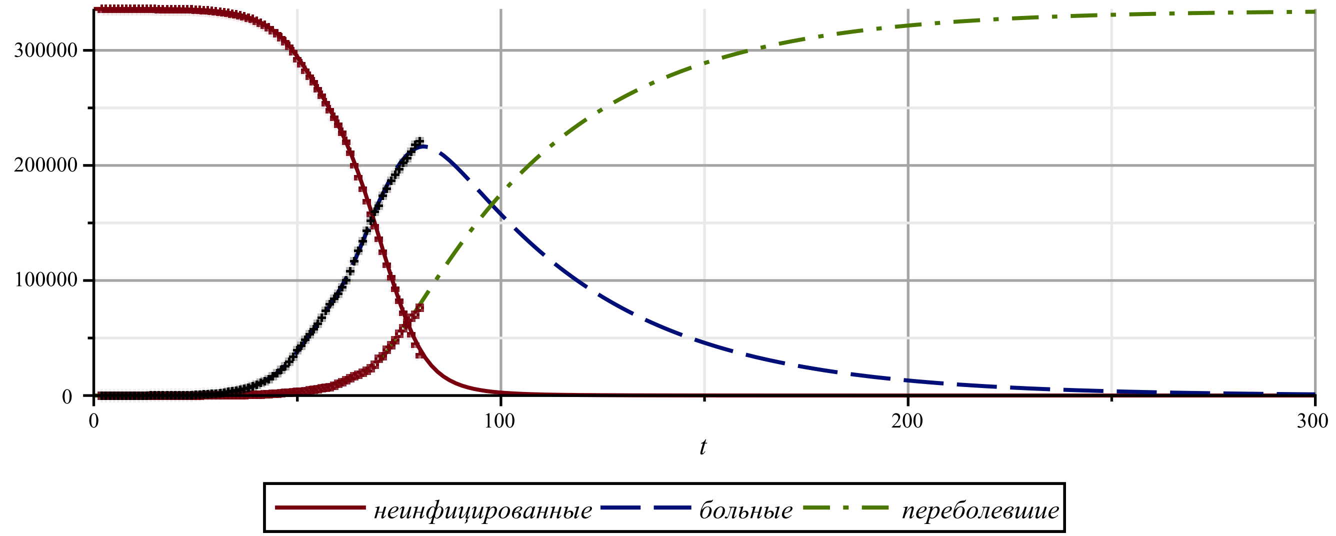
4267.92914105627

4267.86382621185

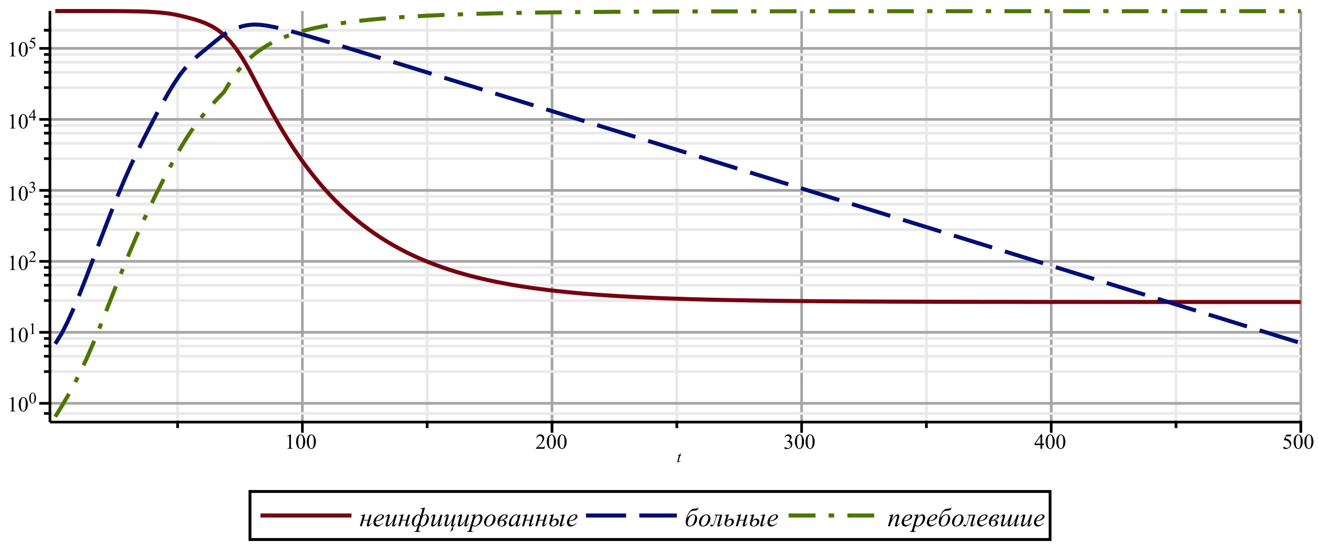
val := [15.8550387255577, 336016.762118403, 0.127168734811334, 0.225479858186473, 0.176359171630784, 0.152054949533006, 0.109390976656787, 0.121318021024613, 0.198062769096882, 0.240859612036758, 0.0125695690537504, 0.0250118599999145, 0.0000959278626075632]

4267.86382621185

Russia3b.jpg

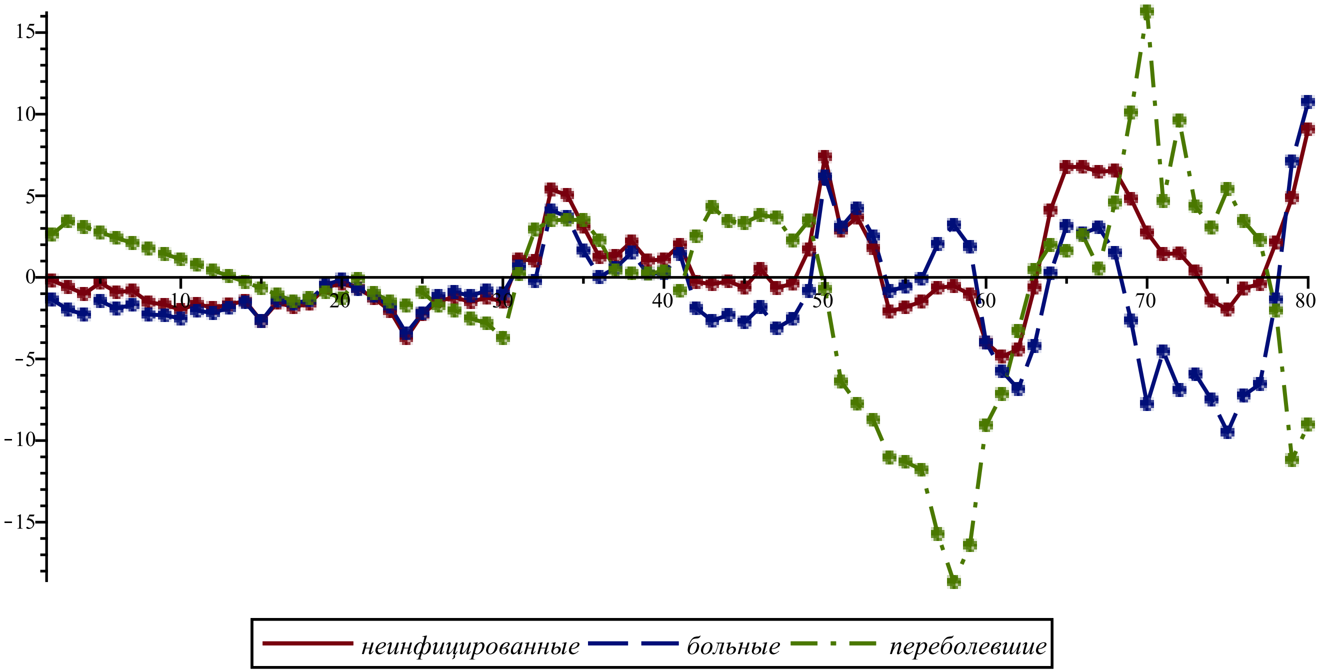



```
> logplot(map(q->q(t),v), t=1..500, legend=[``,``,``], linestyle=[solid,dash,dashdot],gridlines=true,size=[1000,400],legendstyle=[font=[roman,15]]);
```

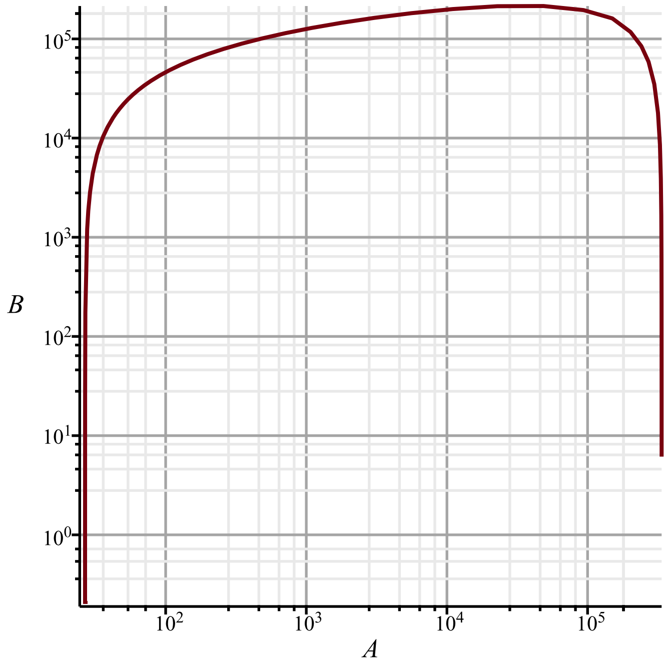



```
> display(
   plot([
    [[i,(T[i-dd]-(K_-A(i)))/sigma(K_-A(i))] $ i=1+dd..dd+nops(T)],
    [[i,(T2[i-dd]-(B(i)))/sigma(B(i))] $ i=1+dd..dd+nops(T)],
    [[i,(T1[i-dd]-(C(i)))/sigma(C(i))] $ i=1+dd..dd+nops(T)]
   ],linestyle=[solid,dash,dashdot],legend=[``,``,``]                    ),
   plot([
    [[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=[1000,500],legendstyle=[font=[roman,15]]
  ): fdisplay(`Russia3b-dev`,%);
```

Russia3b-dev.jpg



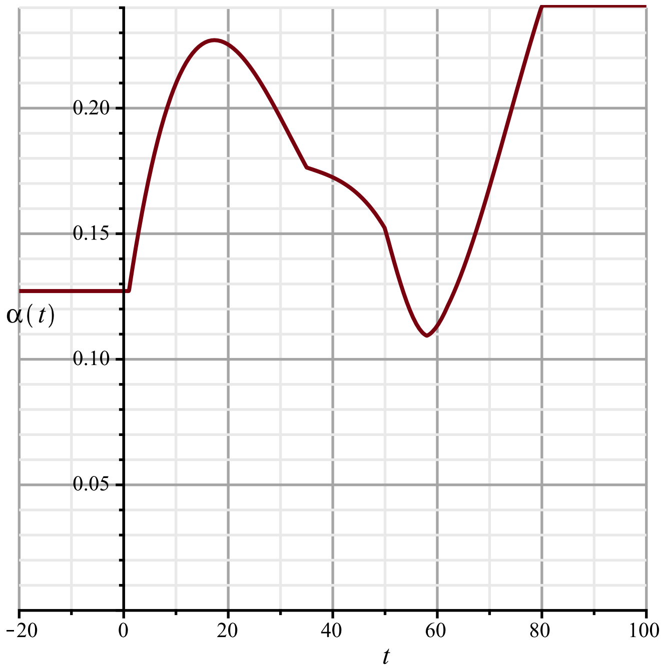

```
> plot([v[1](t),v[2](t),t=0..3.0e4],axis[1]=[mode=log],axis[2]=[mode=log],labels=[v[1],v[2]],
  labelfont=[roman,15],gridlines=true);
```

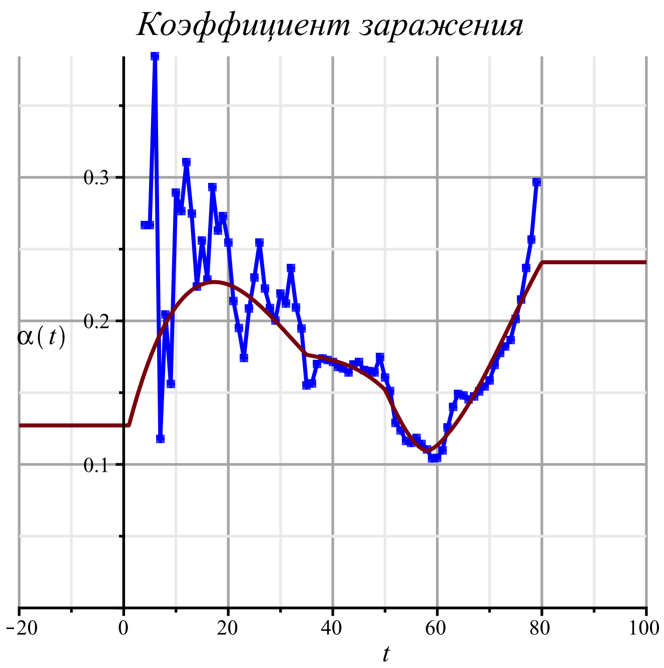



```
> [seq([i,(
   (T[i-dd]-T[i-dd-1]) /(T2[i-dd]+T2[i-dd-1]) /((1-T[i-dd]/K_)+(1-T[i-dd-1]/K_))
  )*4],i=1+dd+1..nops(T)+dd)]: [seq([%[i][1],(%[i-1][2]+%[i][2]+%[i+1][2])/3],i=2..nops(%)-1)]:
  Palpha:=display(plot([%],color=blue),plot([%],style=point,symbolsize=8,symbol=solidcircle,color=
  blue)):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

$$\begin{cases} 0.127168734811334 & t < 1. \\ 6.17654958113704\ 10^{-6}\ t^3 - 0.000593776307119014\ t^2 + 0.0150340955868188\ t + 0.112722238872147 & t < 35. \\ -4.30932673583075\ 10^{-6}\ t^3 + 0.000454811328295643\ t^2 - 0.0166856804037929\ t + 0.387976493427212 & t < 50. \\ 0.0000316414397254659\ t^3 - 0.00468614828972275\ t^2 + 0.223465440065686\ t - 3.26102630591943 & t < 58. \\ -0.0000199810130942701\ t^3 + 0.00408966869728457\ t^2 - 0.271903617003635\ t + 6.02069071952068 & t < 62. \\ -7.83567537056441\ 10^{-6}\ t^3 + 0.00173347316535203\ t^2 - 0.120378383634638\ t + 2.78876776751654 & t < 80. \\ 0.240859612036758 & 80. \le t \end{cases}$$

Region3c-zar.jpg




Коэффициент заражения
α(t)
0.1
0.2
0.3
-20
0
20
40
60
80
100
t