Petit retour sur le TD1

Some aspect concerning the LMDZ dynamical core and its use

1. **Grid**
    - **Staggered grid and dynamics/physics interface**
    - **Zooming capability**
    - **Vertical discretization**
    - **Nudging**

2. **Temporal scheme and filtering**
    - **Temporal schemes illustrated on a 0D model**
    - **The Matsuno/Leapfrog scheme**
    - **CFL criterion and longitudinal filtering**

3. **Dissipation**
    - **Principle of dissipation in 1D**
    - **Operator splitting**
    - **Constraints on the time step**

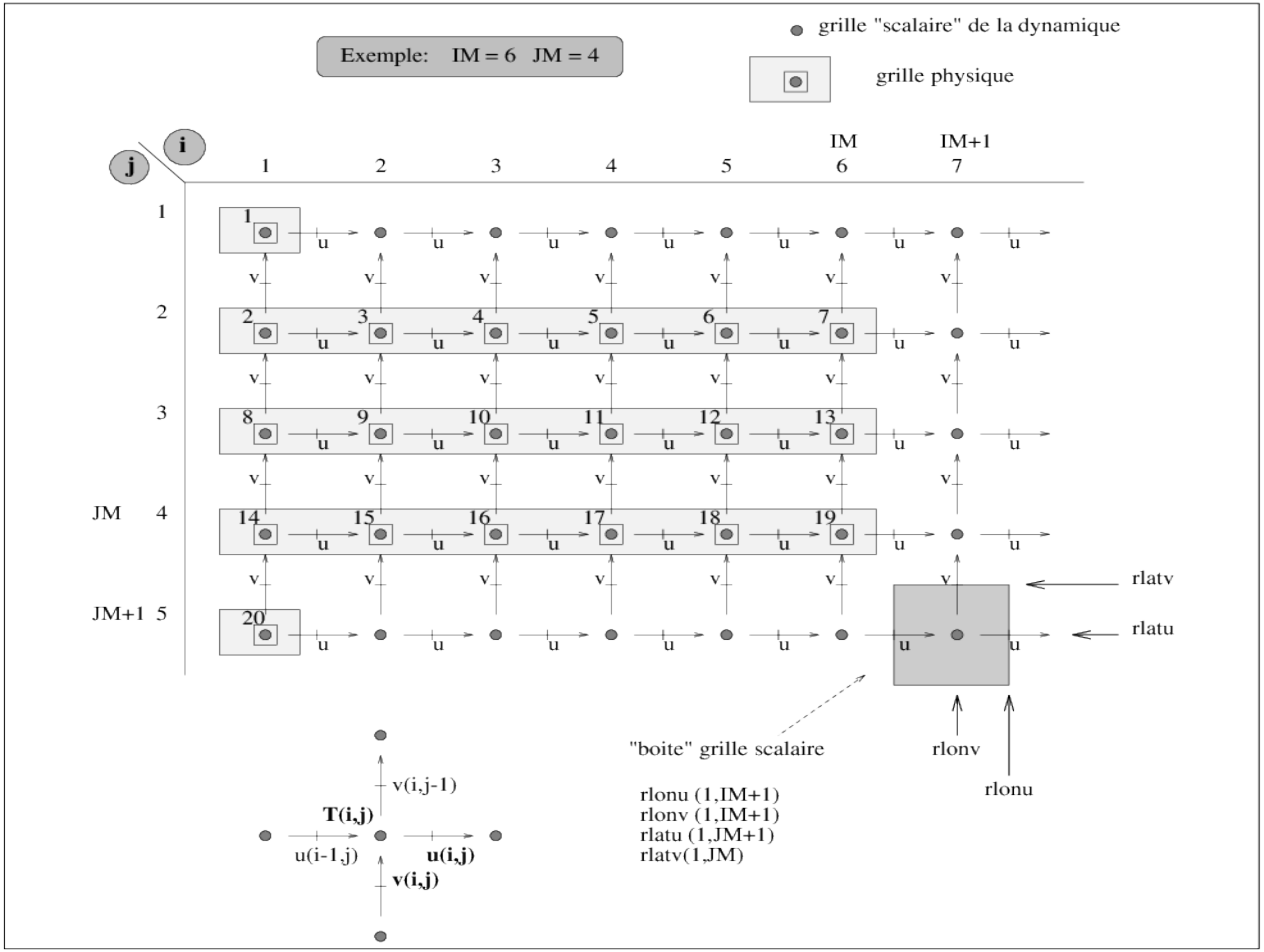
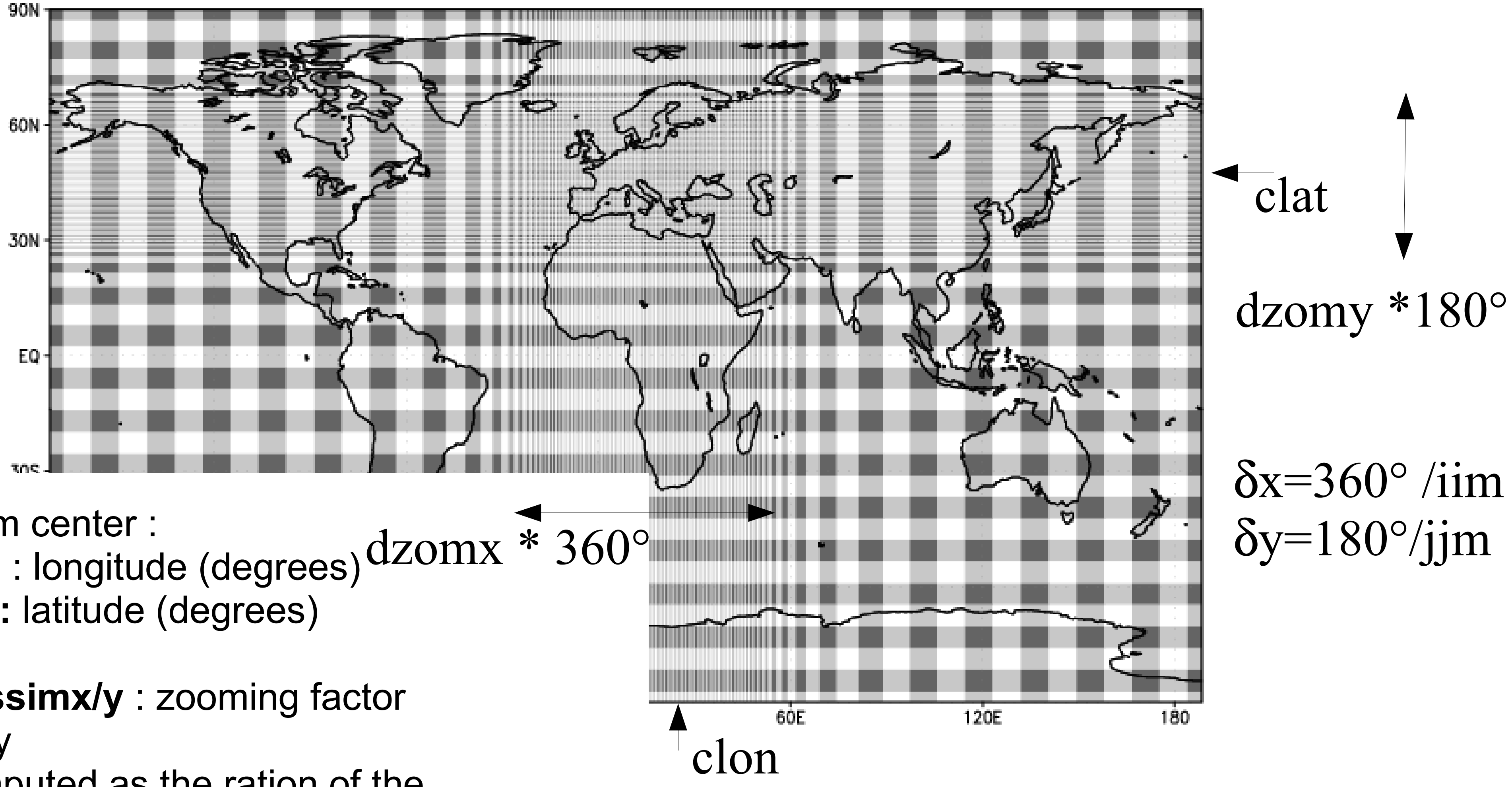


FIG. 2.2 – Grilles dynamique et physique pour une resolution horizontale 6 × 7. Dans la dynamique (mais pas dans la physique) Les vents u et v sont sur une grille dynamique décalée. Les autres variables sont sur la grille "scalaire" dynamique. La physique utilise cette même grille scalaire pour toutes les variables, sauf que les points sont indexés en 1 seul vecteur contenant NGRID=2+(JM-1)×IM points en comptant à partir du pôle nord. NB. Dans le programme fortran, on utilise les variables suivantes : `iim=IM` , `iip1=IM+1`, `jjm=JM` , `jjp1=JM+1`.

iim, jjm, llm

Defined at
The compilation

option
-d 64x48x29
In makegcm
Or makelmdz*



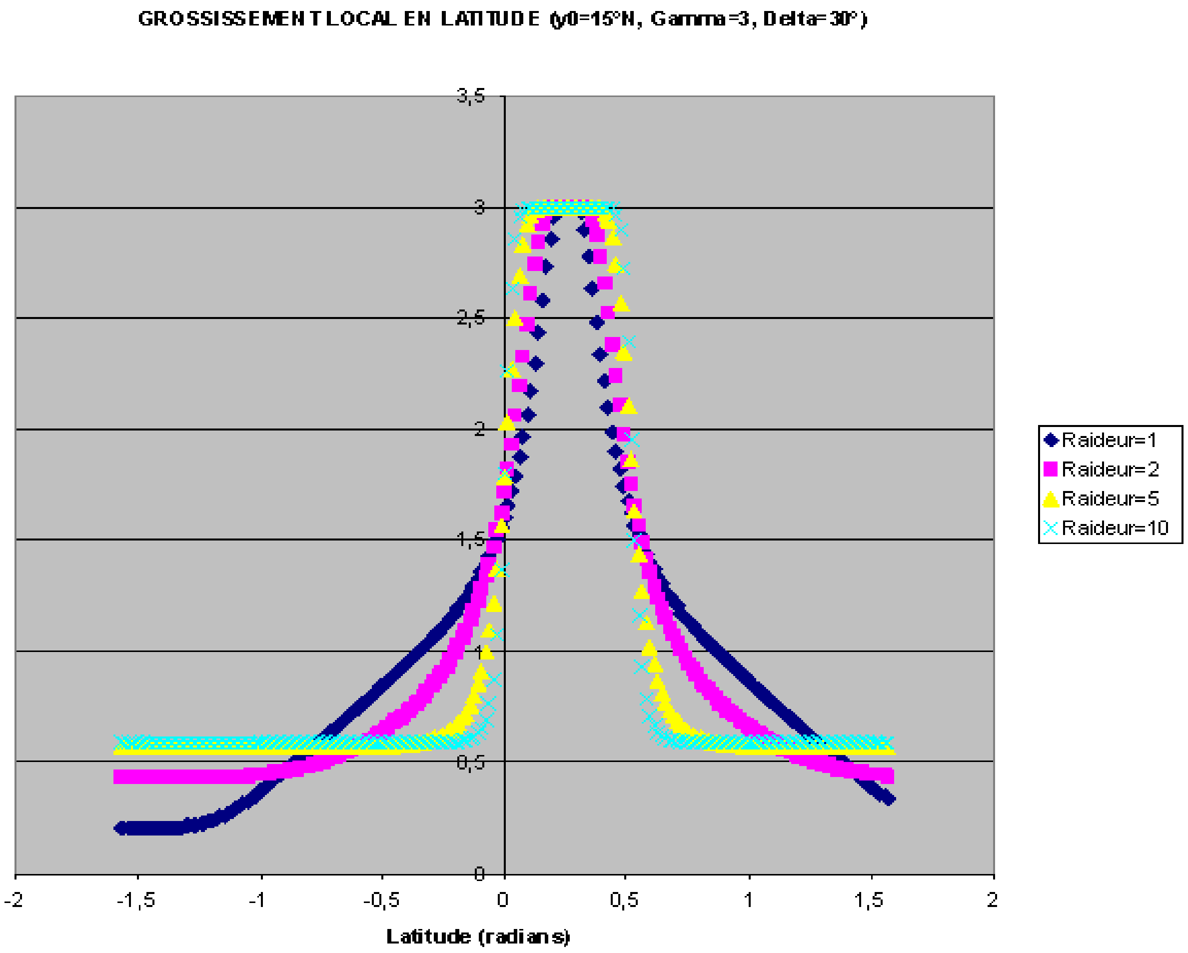
$\delta x = 360° / iim$
$\delta y = 180° / jjm$

Zoom center :
clon : longitude (degrees)
clat : latitude (degrees)

grossimx/y : zooming factor in x/y
Computed as the ration of the Finest model grid mesh length and of the equivalent length for the regular grid with same number of points.

dzoomx/y : fraction of the grid in which the resolution is increased.

http://lmdz.lmd.jussieu.fr/developpeurs/notes-techniques



Zoom center :
clon : longitude (degrees)
clat : latitude (degrees)

grossimx/y : zooming factor in x/y
Computed as the ration of the Finest model grid mesh length and of the equivalent length for the regular grid with same number of points.

dzoomx/y : fraction of the grid in which the resolution is increased.

taux/y : « stiffness »

http://lmdz.lmd.jussieu.fr/developpeurs/notes-techniques

Nudging :
Relaxation toward analyzed fields

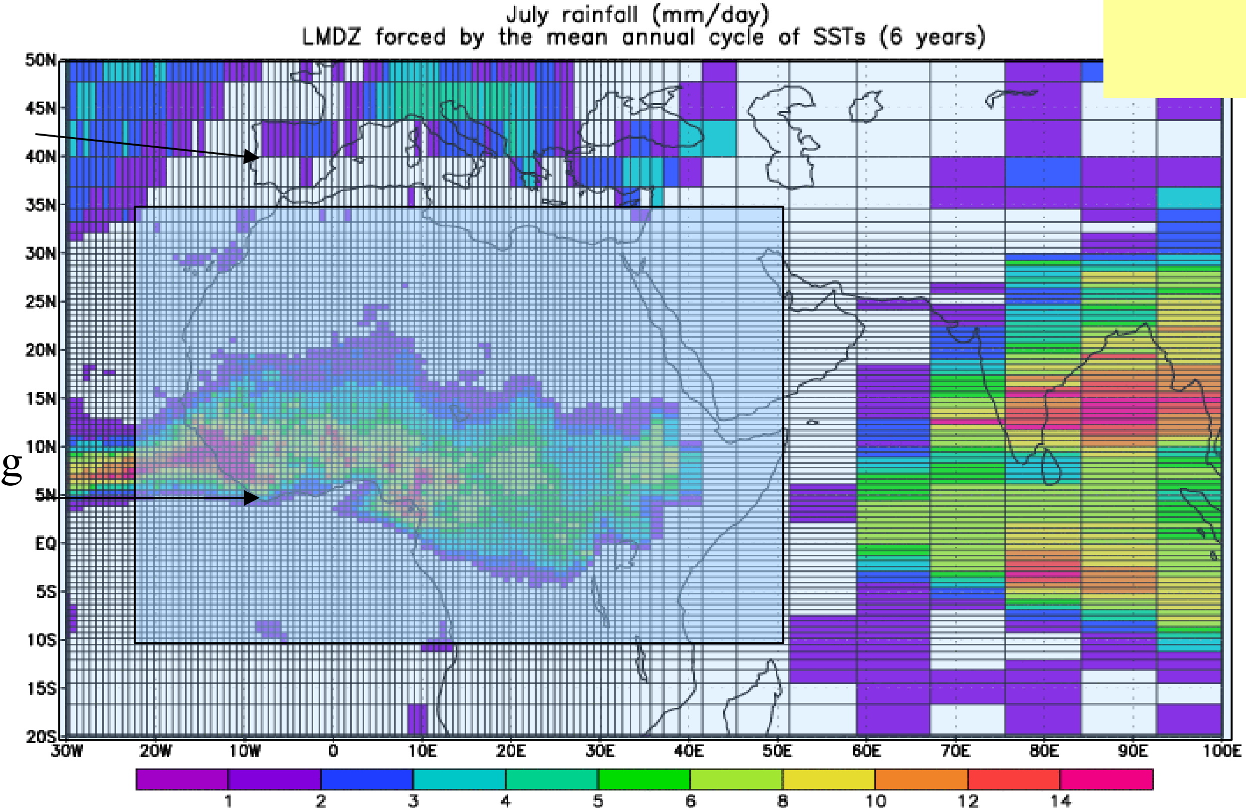
Nudging

$$\frac{\partial u}{\partial t} = \frac{\partial u}{\partial t}_{GCM} + \frac{u_{analysis} - u}{\tau}$$

$$\frac{\partial v}{\partial t} = \frac{\partial v}{\partial t}_{GCM} + \frac{v_{analysis} - v}{\tau}$$

τ Time constant for the relaxation of the model wind toward analyses

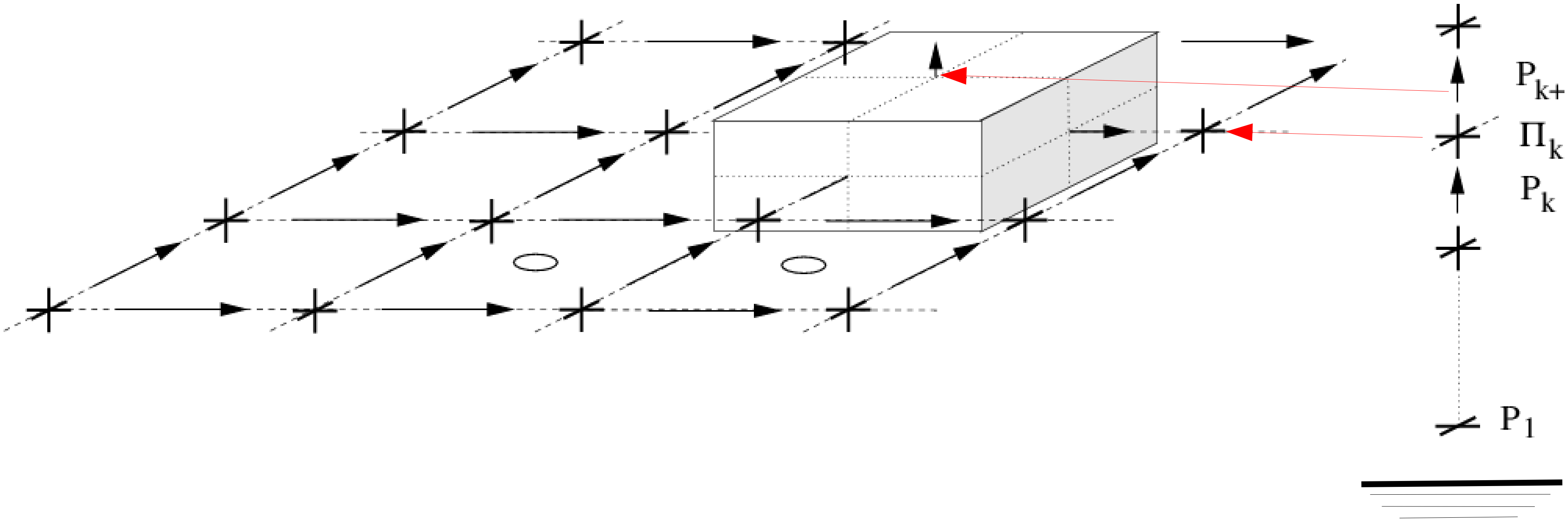
$u_{analysis}$ $v_{analysis}$



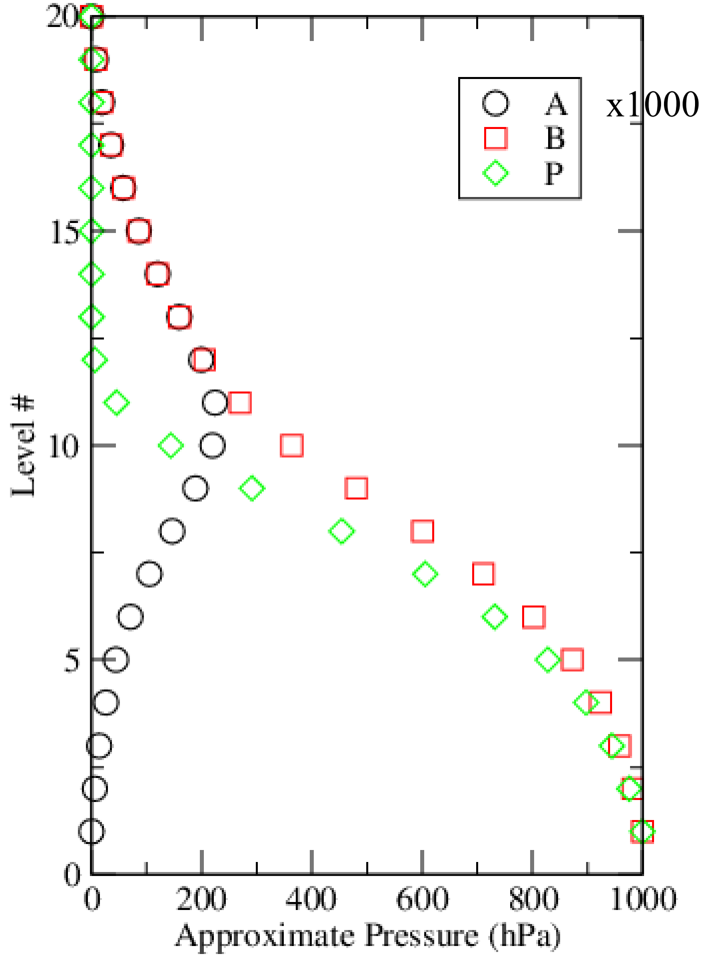
Strong nudging
(τ=30min)

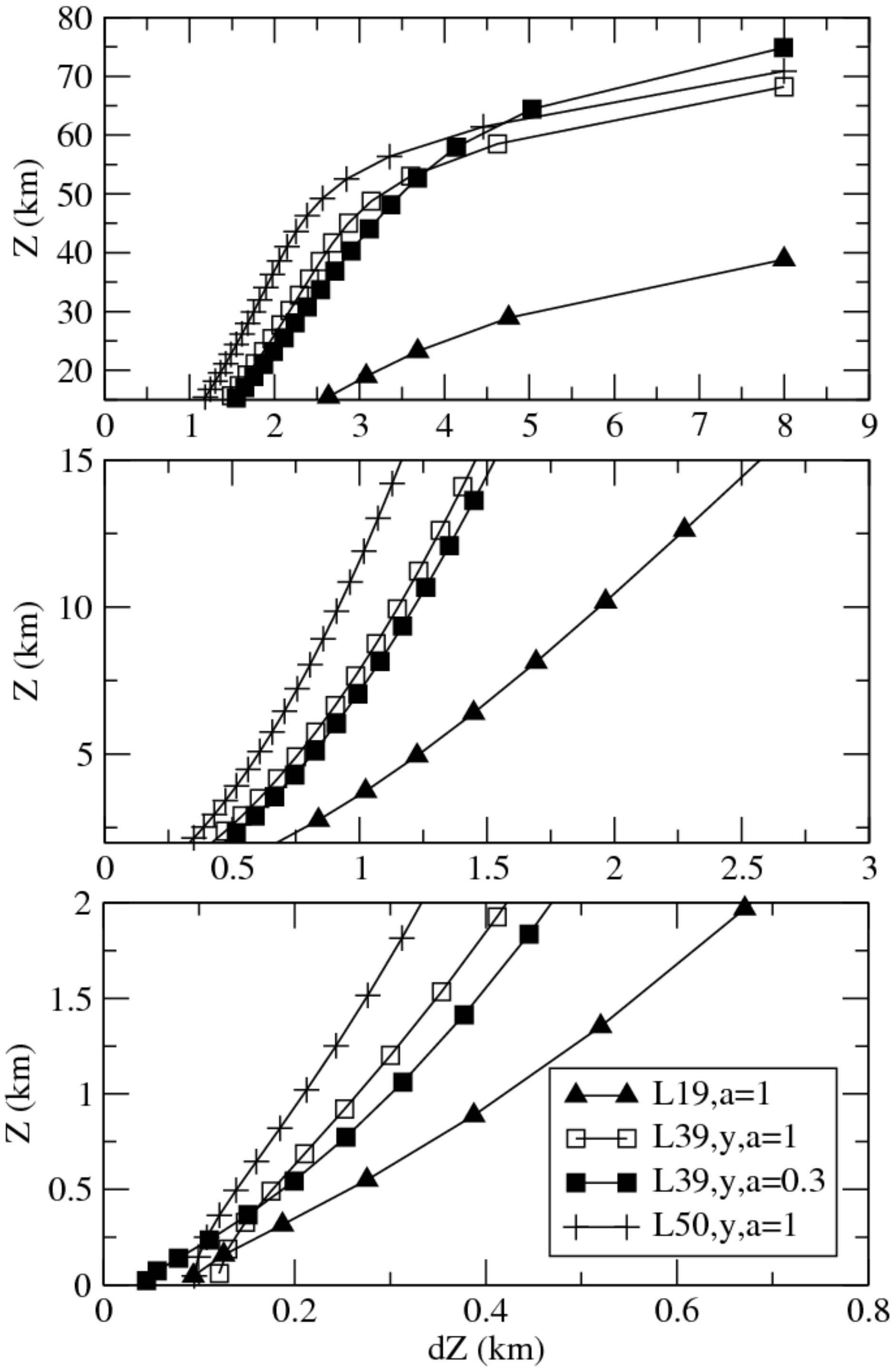
Weaker nudging
(τ=10 days)

```
ok_guide=y
guide_u= y
guide_v= y
guide_T= n
guide_P= n
guide_Q= n
tau_min_u=0.0208333
tau_max_u=10
tau_min_v=0.0208333
tau_max_v=10
```

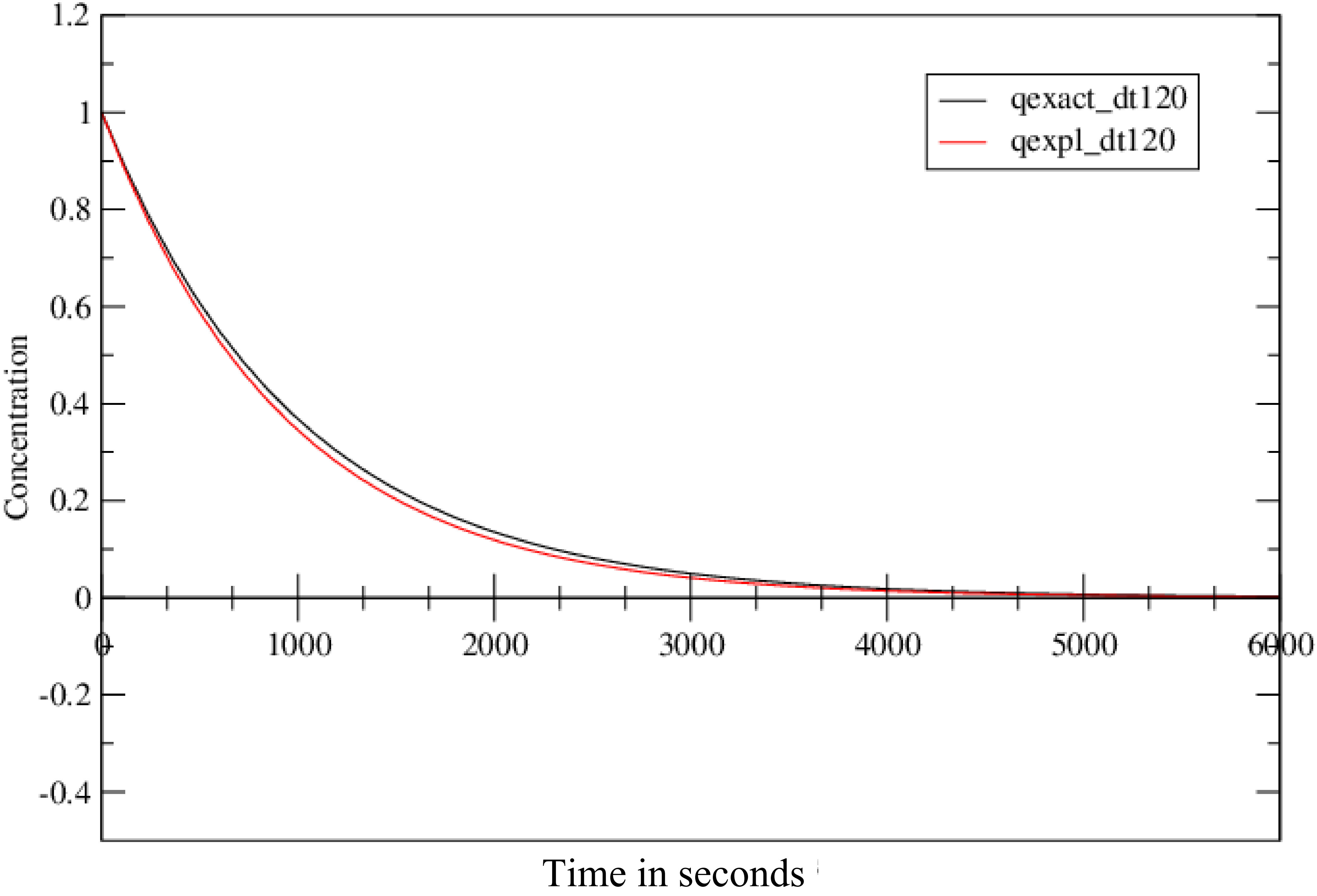

P_{k+1} W_{k+1}
Π_k m_k
P_k W_k
P_1

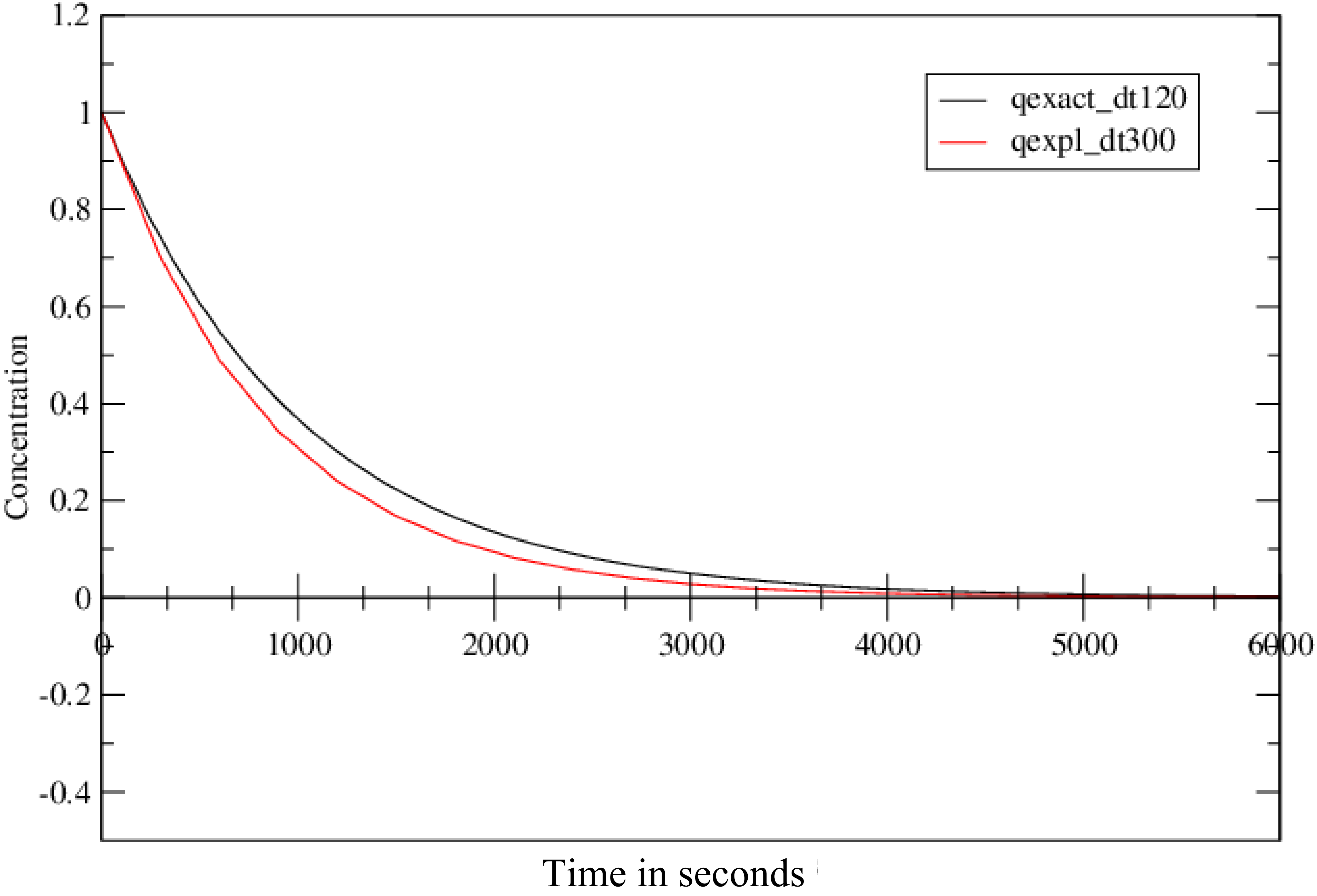
$$P_{i,j,l} = A_l + Ps_{i,j}\, B_l$$



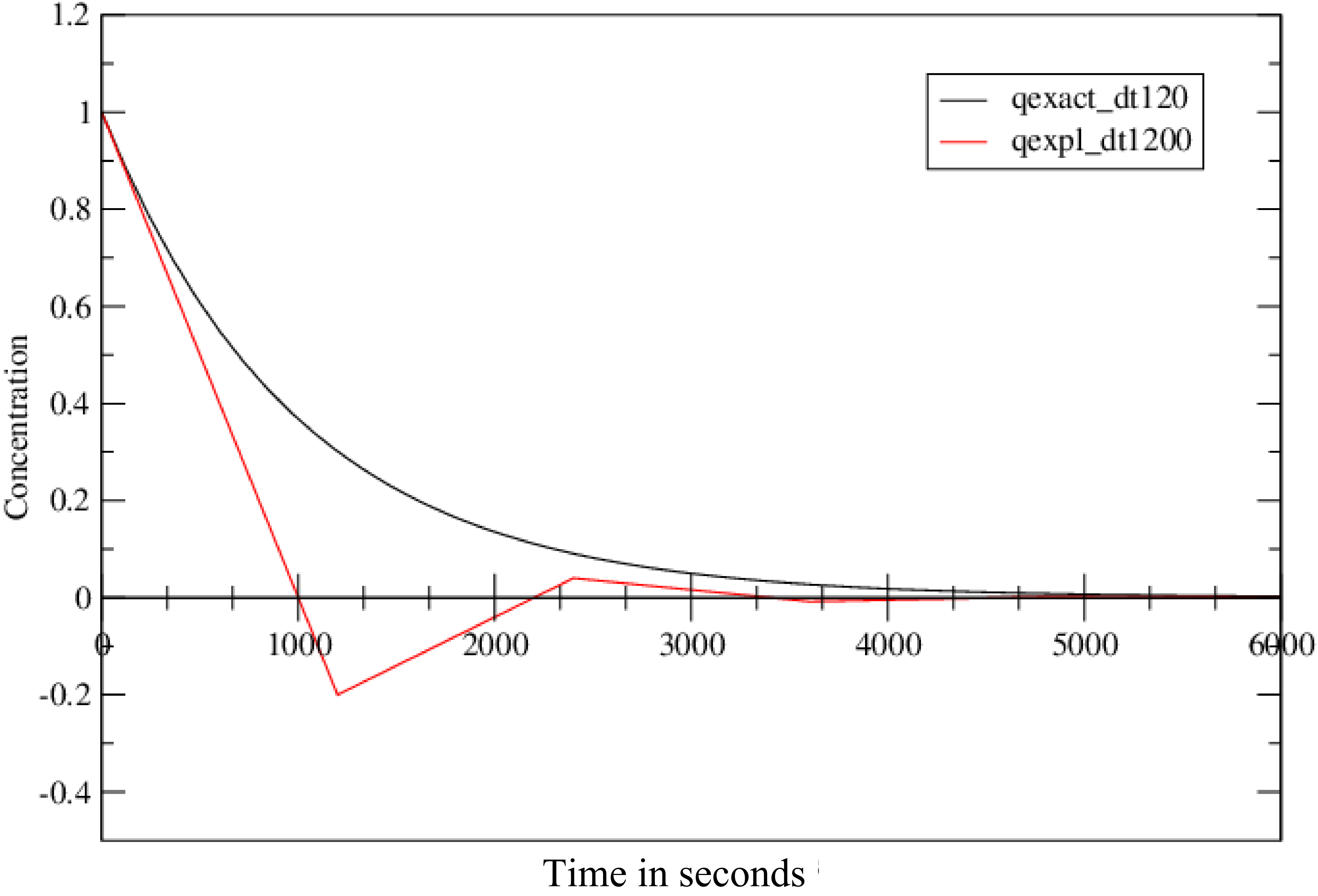


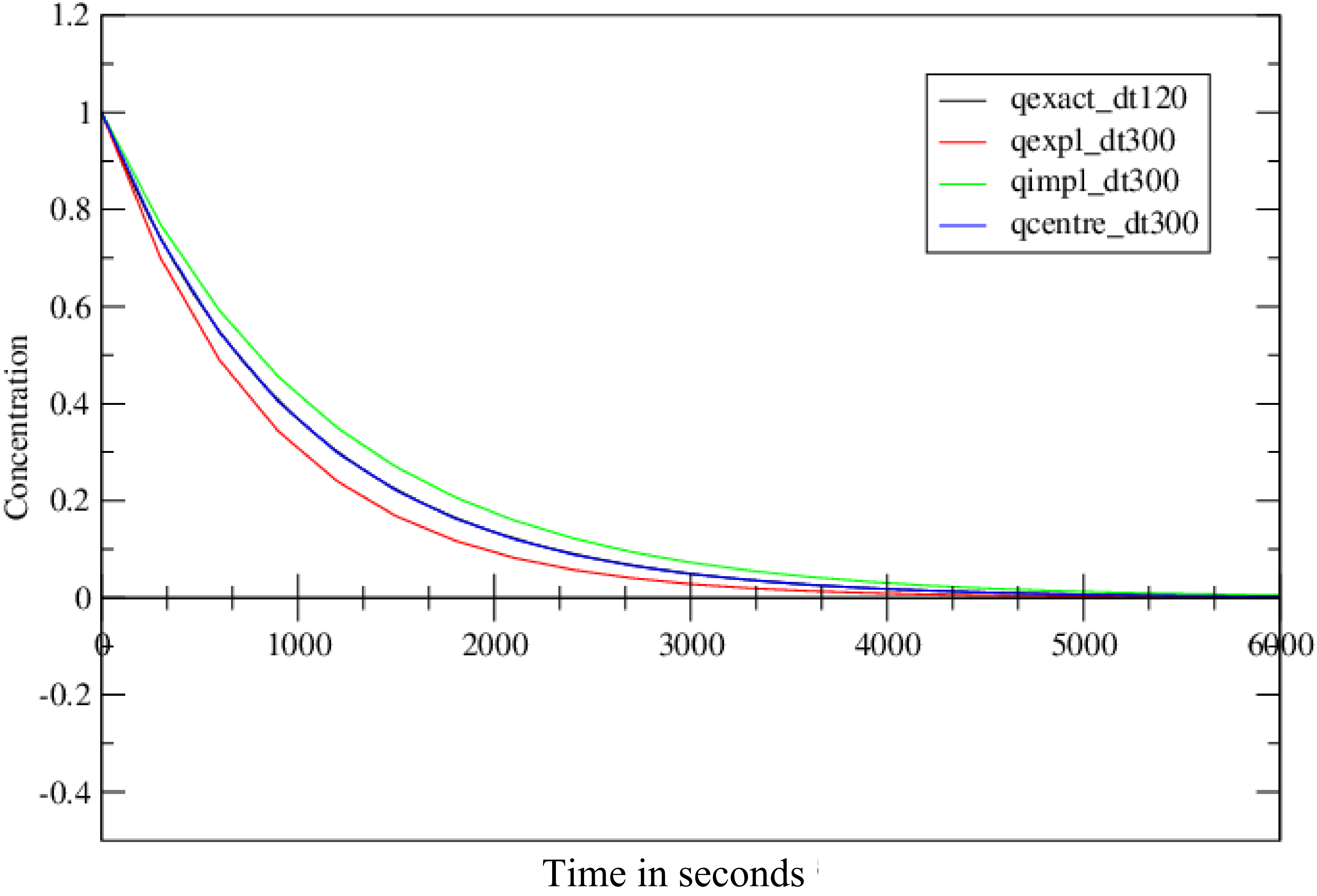
~/LMDZ/PEDAGO/VERT/vert.sh
~/LMDZ/NOTES/RESOLV/vertz.png


qexact_dt120
qexpl_dt120
Concentration
Time in seconds
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
1000
2000
3000
4000
5000
6000

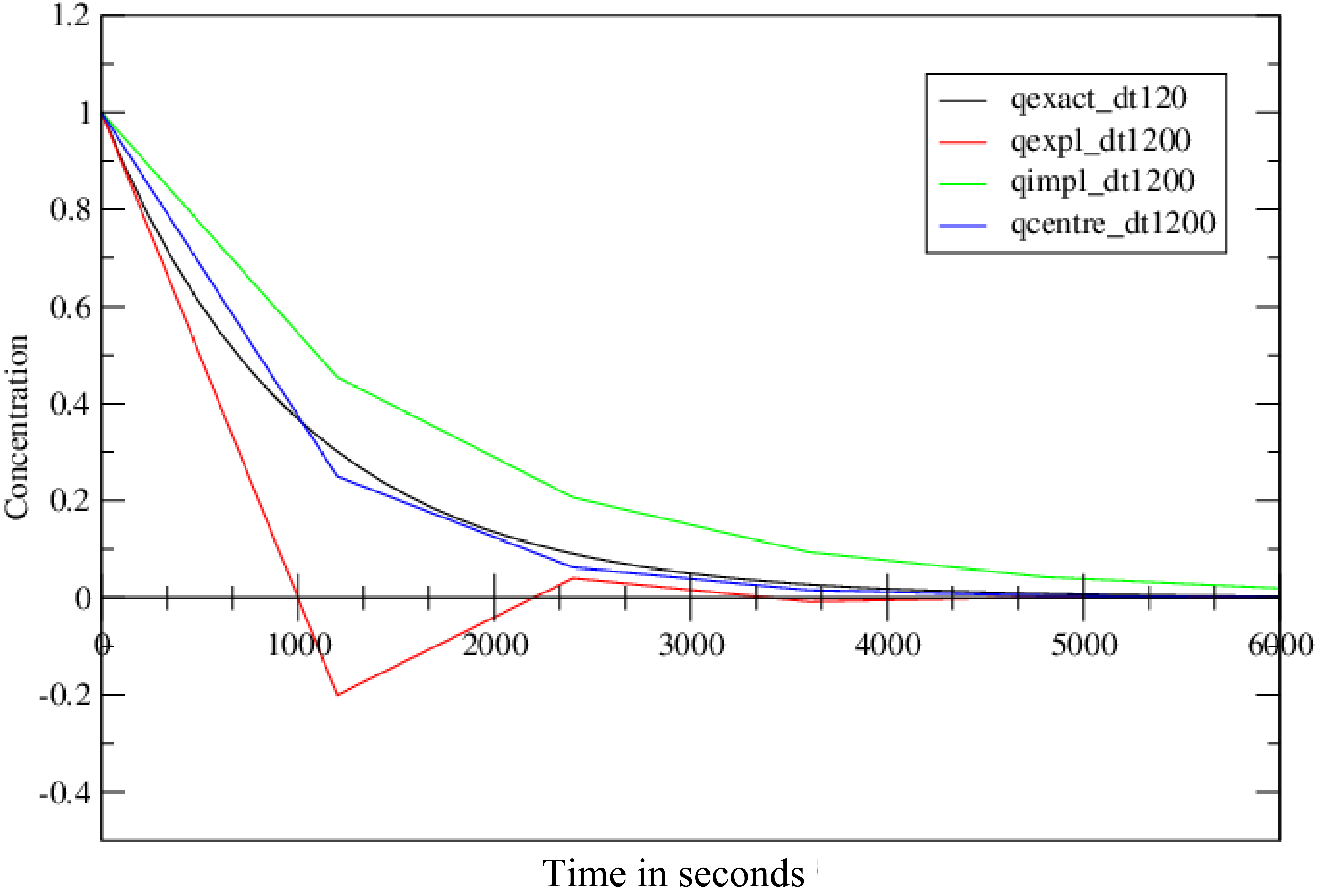


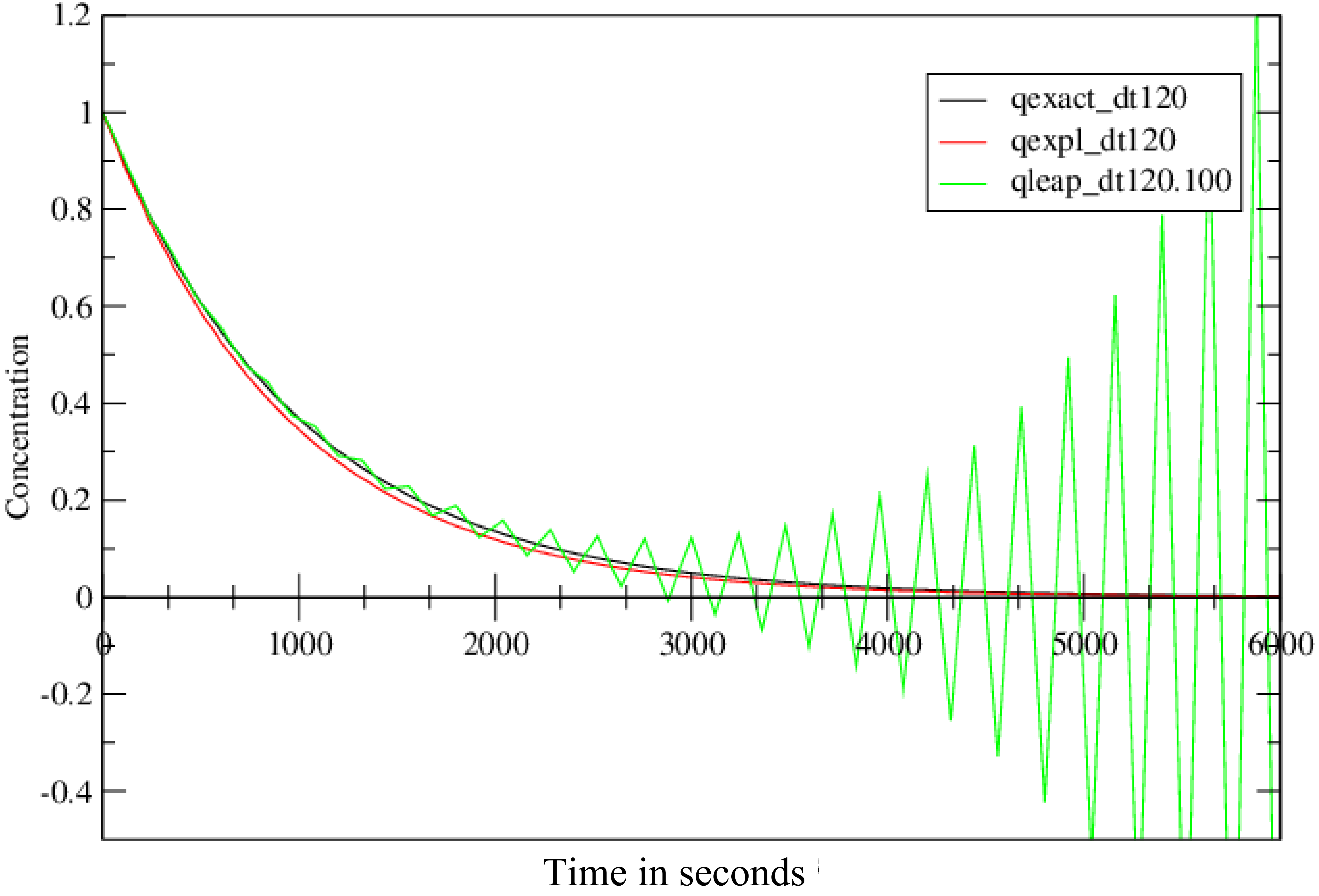
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Concentration
0
1000
2000
3000
4000
5000
6000
Time in seconds
qexact_dt120
qexpl_dt300

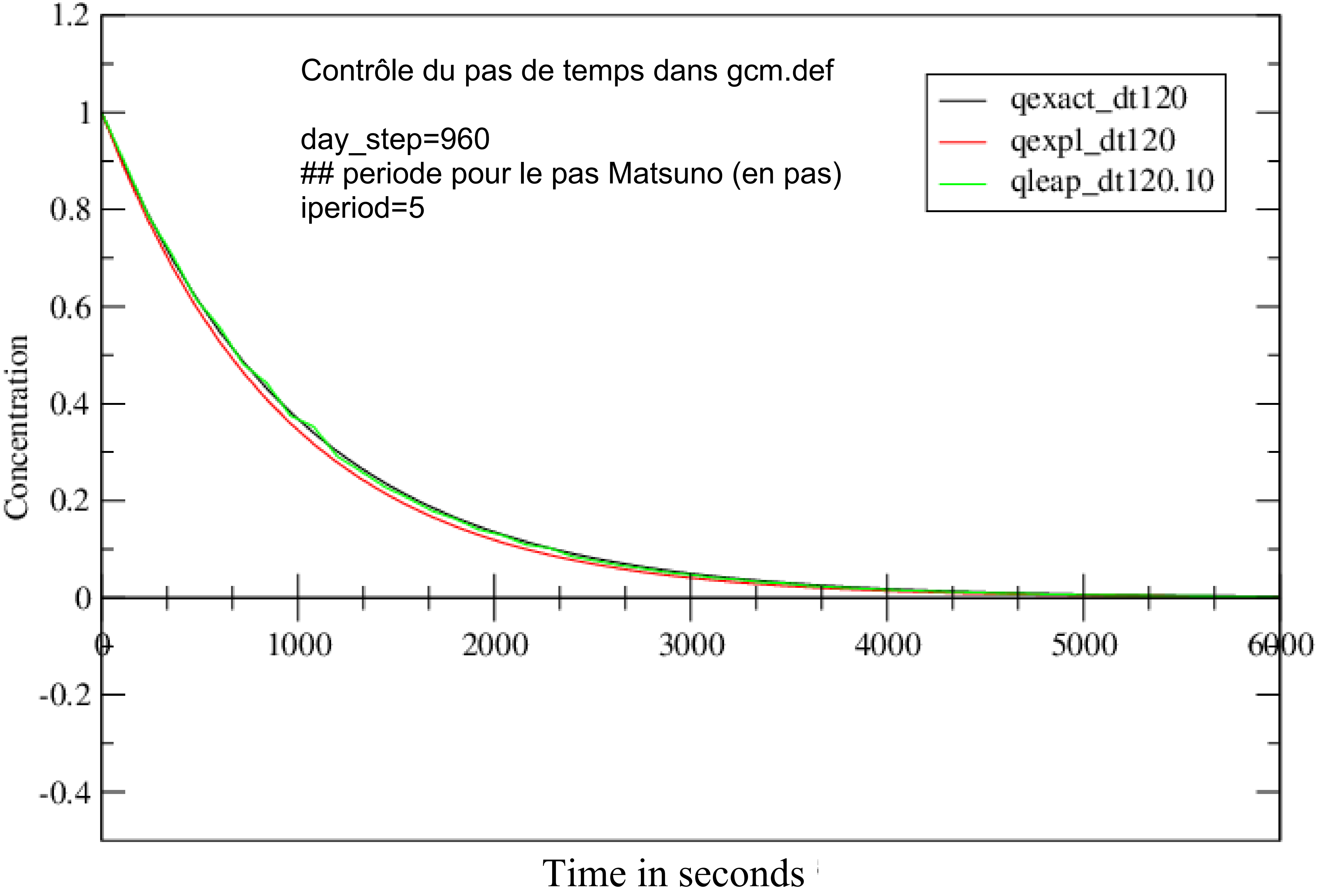

qexact_dt120
qexpl_dt1200
Concentration
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
1000
2000
3000
4000
5000
6000
Time in seconds



1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Concentration
0
1000
2000
3000
4000
5000
6000
Time in seconds
qexact_dt120
qexpl_dt300
qimpl_dt300
qcentre_dt300

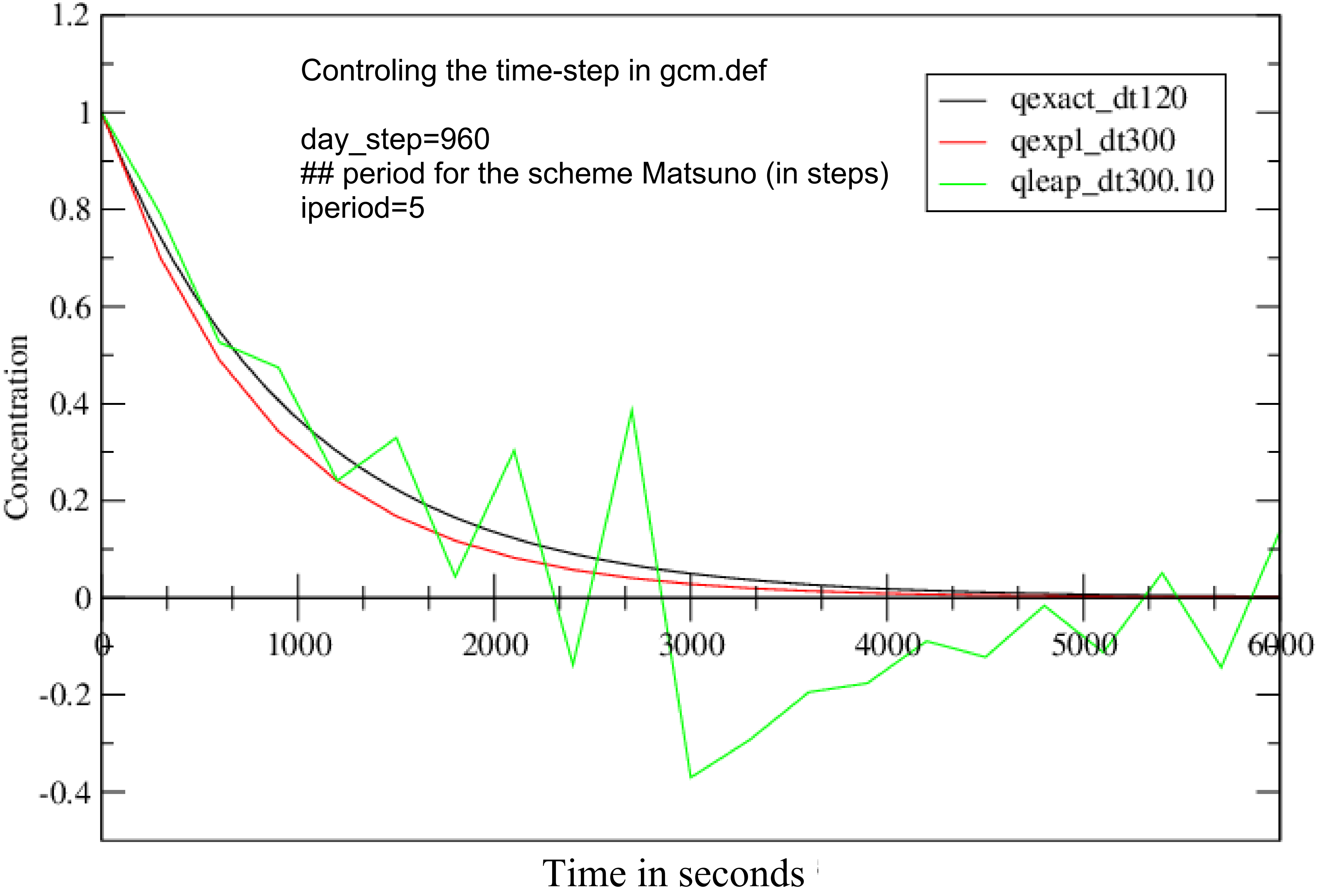

1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Concentration
0
1000
2000
3000
4000
5000
6000
Time in seconds
qexact_dt120
qexpl_dt1200
qimpl_dt1200
qcentre_dt1200


qexact_dt120
qexpl_dt120
qleap_dt120.100
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Concentration
0
1000
2000
3000
4000
5000
6000
Time in seconds



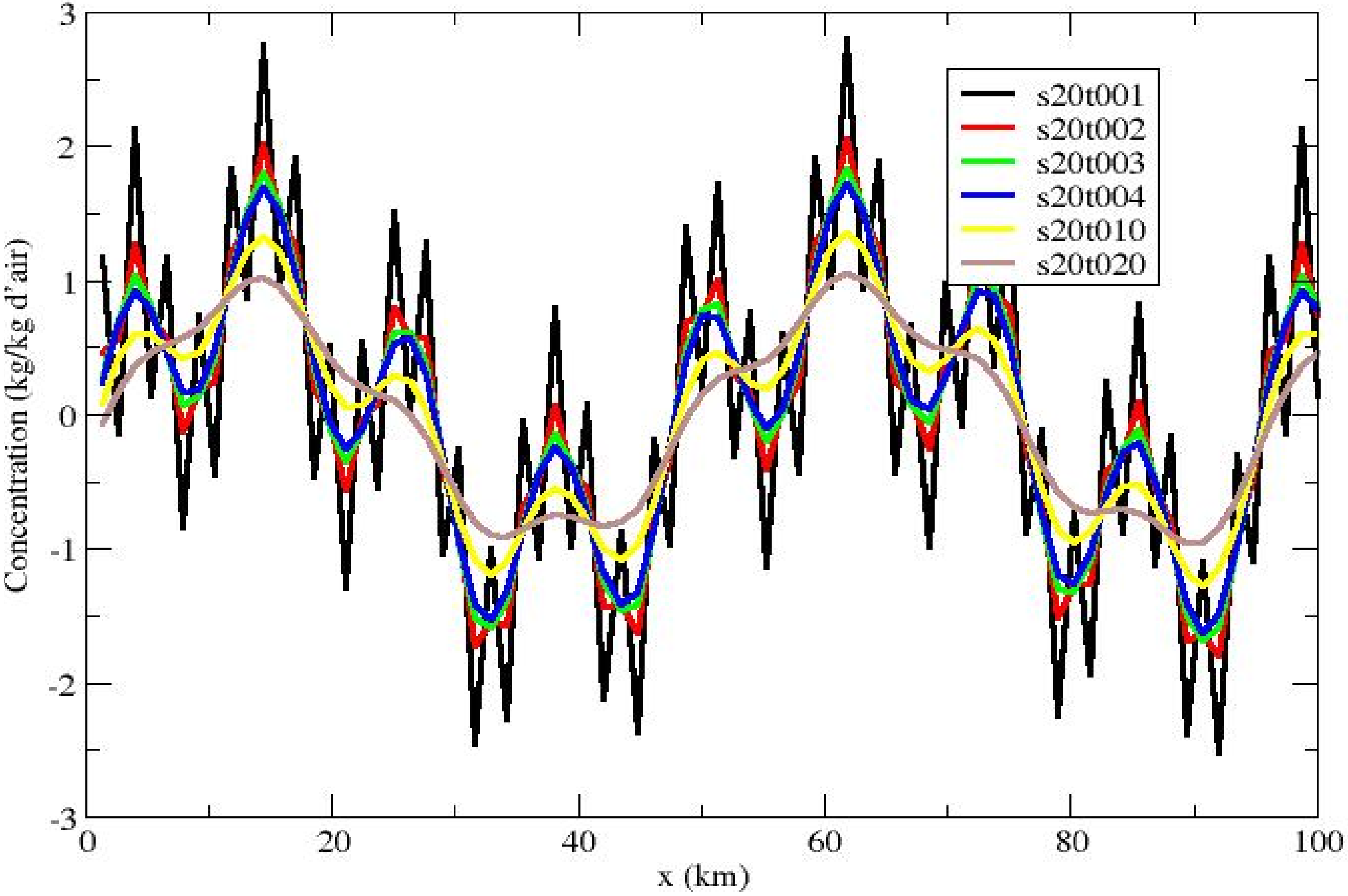
Contrôle du pas de temps dans gcm.def

day_step=960
periode pour le pas Matsuno (en pas)
iperiod=5



Controling the time-step in gcm.def

```
day_step=960
## period for the scheme Matsuno (in steps)
iperiod=5
```



Example of dissipation computation in 1D on an initial field consisting of the sum of two sign functions + a numerical mode

Controling dissipation in gcm.def

```
## dissipation periodicity (in time-step)
idissip=5
## Disssipation operator choice (star or  non star )
lstardis=y
## number of iterations for the dissipation   gradiv
nitergdiv=1
## number of iterations for the dissipation  nxgradrot
nitergrot=2
## number of iterations for the dissipation  divgrad
niterh=2
## dissipation time for the smallest wave length for u,v (gradiv)
tetagdiv=5400.
## dissipation time for the smallest wave length for u,v (nxgradrot)
tetagrot=5400.
##  dissipation time for the smallest wave length for  h ( divgrad)
tetatemp=5400.
```

Example of parameter tuning in gcm.def

Sensibility tests to horizontal resolution (Foujols et al.)

http://forge.ipsl.jussieu.fr/igcmg/wiki/ResolutionIPSLCM4_v2

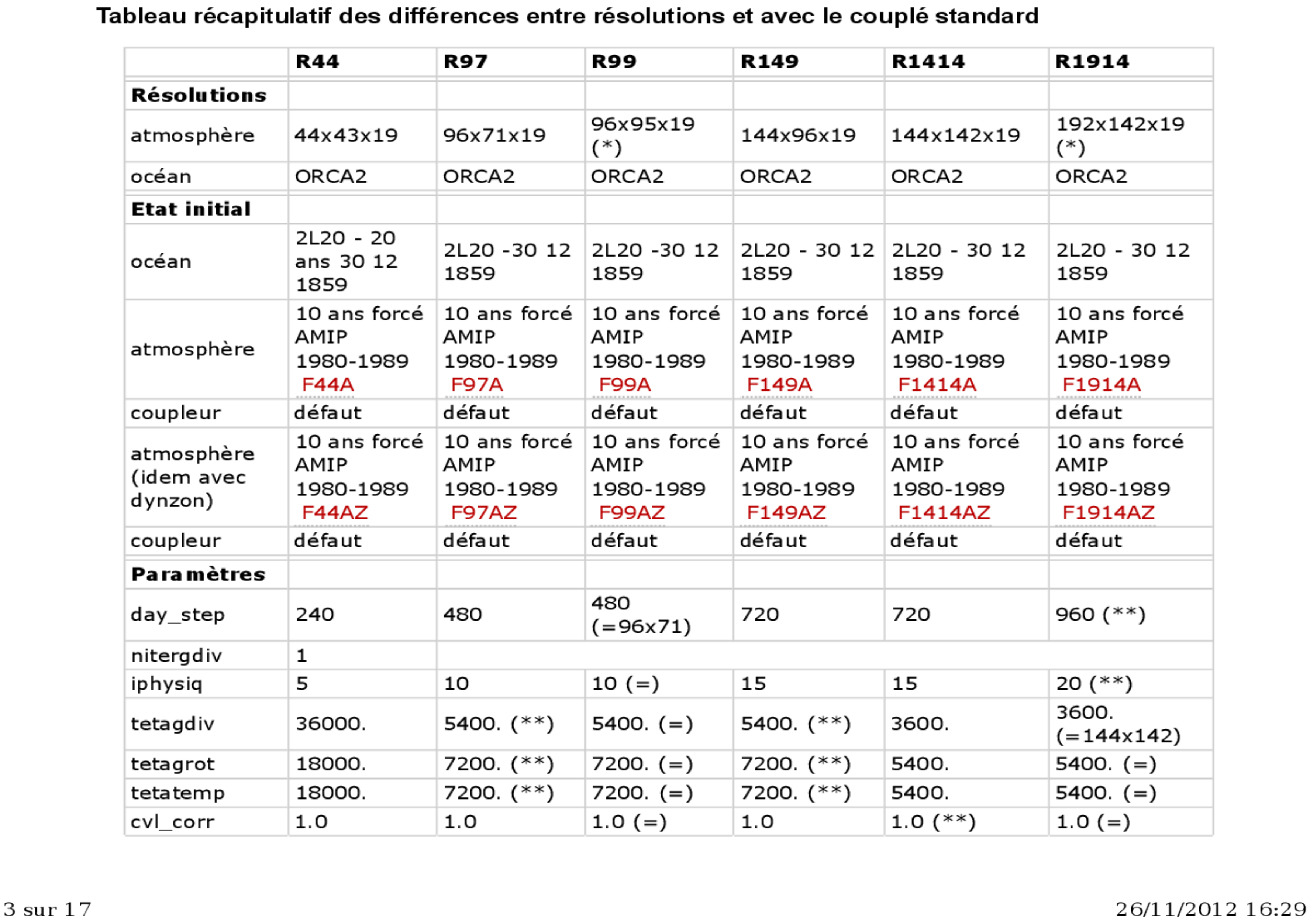


Tableau récapitulatif des différences entre résolutions et avec le couplé standard

	R44	R97	R99	R149	R1414	R1914
Résolutions						
atmosphère	44x43x19	96x71x19	96x95x19 (*)	144x96x19	144x142x19	192x142x19 (*)
océan	ORCA2	ORCA2	ORCA2	ORCA2	ORCA2	ORCA2
Etat initial						
océan	2L20 - 20 ans 30 12 1859	2L20 -30 12 1859	2L20 -30 12 1859	2L20 - 30 12 1859	2L20 - 30 12 1859	2L20 - 30 12 1859
atmosphère	10 ans forcé AMIP 1980-1989 F44A	10 ans forcé AMIP 1980-1989 F97A	10 ans forcé AMIP 1980-1989 F99A	10 ans forcé AMIP 1980-1989 F149A	10 ans forcé AMIP 1980-1989 F1414A	10 ans forcé AMIP 1980-1989 F1914A
coupleur	défaut	défaut	défaut	défaut	défaut	défaut
atmosphère (idem avec dynzon)	10 ans forcé AMIP 1980-1989 F44AZ	10 ans forcé AMIP 1980-1989 F97AZ	10 ans forcé AMIP 1980-1989 F99AZ	10 ans forcé AMIP 1980-1989 F149AZ	10 ans forcé AMIP 1980-1989 F1414AZ	10 ans forcé AMIP 1980-1989 F1914AZ
coupleur	défaut	défaut	défaut	défaut	défaut	défaut
Paramètres						
day_step	240	480	480 (=96x71)	720	720	960 (**)
nitergdiv	1					
iphysiq	5	10	10 (=)	15	15	20 (**)
tetagdiv	36000.	5400. (**)	5400. (=)	5400. (**)	3600.	3600. (=144x142)
tetagrot	18000.	7200. (**)	7200. (=)	7200. (**)	5400.	5400. (=)
tetatemp	18000.	7200. (**)	7200. (=)	7200. (**)	5400.	5400. (=)
cvl_corr	1.0	1.0	1.0 (=)	1.0	1.0 (**)	1.0 (=)

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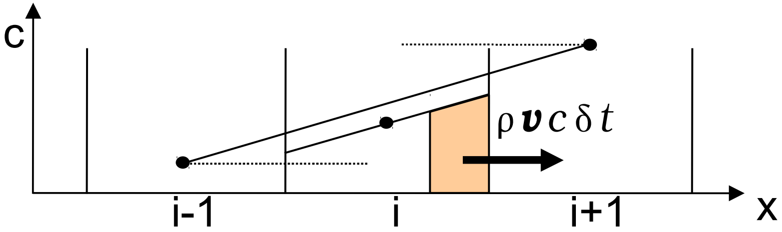
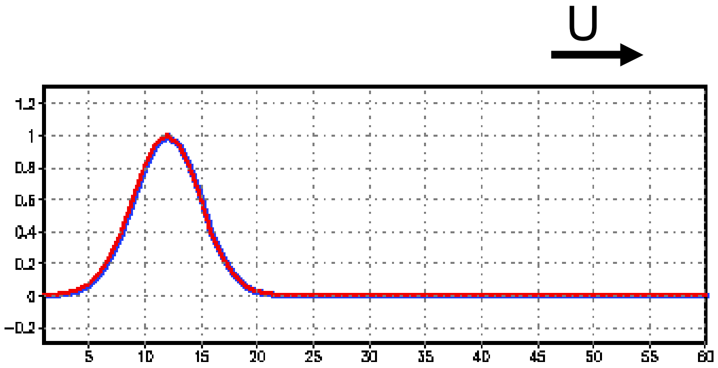
Large scale advection

Introduction of the Van Leer I scheme (1977), a second order finite volume scheme with slope limiters (MUSCL, MINMOD) (Hourdin et Armengaud, 1999).
Guaranty of fundamental physical properties of transport : conservation of the total quantity, postitivity, monotony, non increase of extrema, weak numerical diffusion

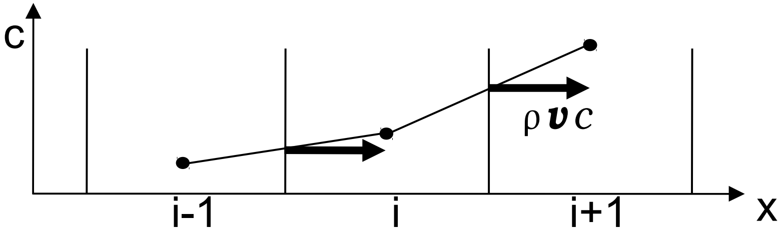
1D advection test with a Gaussian bell
— Initial distribution
▬ Exact solution (translation)
▬ Computation with advection scheme
U constant, CFL number U dt/dx = 0.2

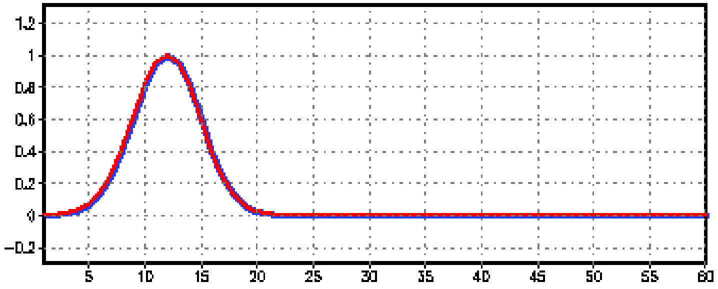
Scheme I by Van Leer (1977)



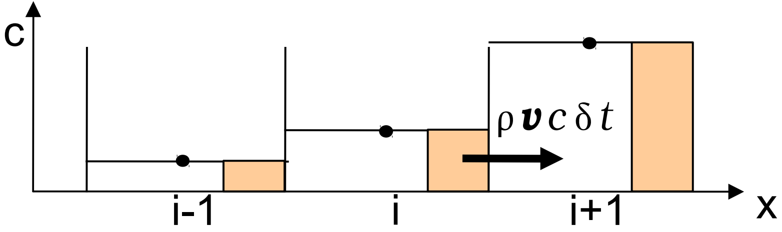


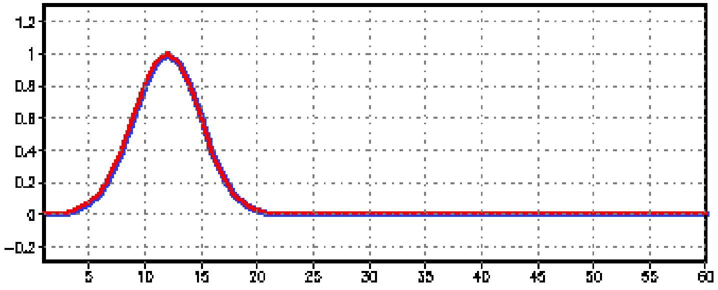
Centered finite differences (second order)





Upwind first order scheme (Godunov, 1952)





dtvr = daysec / day_step
dtphys=iphysiq*dtvr
dtdiss=dissip_period*dtvr
dtvrtrac=iapp_trac*dtvr

Contraintes
dtvr limité par le CFL sur les ondes   Cmax dt < min(dxmin,dymin)
dtrtrac limité par un CFL d'advection   Umax dt < min(dxmin,dymin)
iphysiq, dissip_period,dtvrtrac = multiples de **iperiod**
iperiod (=5 par défaut) : fréquence d'appel à Matsuno
dtdiss << teta_temp, teta_rot, teta_temp

Grille régulière :
day_step(max(iim,jjm)=N) ~ day_step(max(iim,jjm)=M) * M/N
Grille régulière :
day_step (zoom) ~ day_step (reg) * max(grossismx,grossimy)

Main « calls » in dyn3d /leapfrog.F

```
CALL pression ( ip1jmp1, ap, bp, ps, p       )
     CALL exner_hyb( ip1jmp1, ps, p,alpha,beta, pks, pk, pkf )

       call guide_main(itau,ucov,vcov,teta,q,masse,ps)

     CALL SCOPY( ijmllm ,vcov , 1, vcovm1 , 1 )
     CALL SCOPY( ijp1llm,ucov , 1, ucovm1 , 1 )
     CALL SCOPY( ijp1llm,teta , 1, tetam1 , 1 )
     CALL SCOPY( ijp1llm,masse, 1, massem1, 1 )
     CALL SCOPY( ip1jmp1, ps  , 1,   psm1 , 1 )
     CALL SCOPY   ( ijp1llm,   masse, 1, finvmaold,     1 )

     CALL filtreg ( finvmaold ,jjp1, llm, -2,2, .TRUE., 1 )

     CALL geopot  ( ip1jmp1, teta  , pk , pks,  phis  , phi   )

     CALL caldyn

     CALL caladvtrac(q,pbaru,pbarv,

     CALL integrd ( 2,vcovm1,ucovm1,tetam1,psm1,massem1 ,

     CALL calfis( lafin , jD_cur, jH_cur,

     CALL top_bound( vcov,ucov,teta,masse,dufi,dvfi,dtetafi)

     CALL addfi( dtvr, leapf, forward   ,

     CALL dissip(vcov,ucov,teta,p,dvdis,dudis,dtetadis)

     CALL dynredem1("restart.nc",0.0)

     CALL bilan_dyn(2,dtvr*iperiod,dtvr*day_step*periodav,
```

Physical tendencies $\underline{U}, \theta, q \rightarrow \underline{F}, Q, Sq$

Time integration for physical tendencies

$(\underline{U}, \theta, q)_{t+\delta t} = (\underline{U}, \theta, q)_t + \delta t * (\underline{F}, Q, Sq)$

Main « calls » in dyn3d /leapfrog.F

`CALL pression ( ip1jmp1, ap, bp, ps, p      )`	Computation of pressure from Al, Bl coefs
`CALL exner_hyb( ip1jmp1, ps, p,alpha,beta, pks, pk, pkf )`	
`call guide_main(itau,ucov,vcov,teta,q,masse,ps)`	Nudging

`CALL SCOPY( ijmllm ,vcov , 1, vcovm1 , 1 )`
`CALL SCOPY( ijp1llm,ucov , 1, ucovm1 , 1 )`
`CALL SCOPY( ijp1llm,teta , 1, tetam1 , 1 )`
`CALL SCOPY( ijp1llm,masse, 1, massem1, 1 )`
`CALL SCOPY( ip1jmp1, ps  , 1,   psm1 , 1 )`
`CALL SCOPY   ( ijp1llm,   masse, 1, finvmaold,     1 )`	

`CALL filtreg ( finvmaold ,jjp1, llm, -2,2, .TRUE., 1 )`	Longitudinal filtering near poles
`CALL geopot  ( ip1jmp1, teta  , pk , pks,  phis  , phi   )`	Hydrostatic equation vertical integration
`CALL caldyn`	Computation of dynamical tendencies
`CALL caladvtrac(q,pbaru,pbarv,`	Tracer advection
`CALL integrd ( 2,vcovm1,ucovm1,tetam1,psm1,massem1 ,`	Time integration for dynamics
`CALL calfis( lafin , jD_cur, jH_cur,` ◄	Physical tendencies $\underline{U}, \theta, q \rightarrow \underline{F}, Q, Sq$
`CALL top_bound( vcov,ucov,teta,masse,dufi,dvfi,dtetafi)`	
`CALL addfi( dtvr, leapf, forward   ,` ◄	Time integration for physical tendencies
`CALL dissip(vcov,ucov,teta,p,dvdis,dudis,dtetadis)`	$(\underline{U}, \theta, q)_{t+\delta t} = (\underline{U}, \theta, q)_t + \delta t * (\underline{F}, Q, Sq)$
`CALL dynredem1("restart.nc",0.0)`	Horizontal dissipation
`CALL bilan_dyn(2,dtvr*iperiod,dtvr*day_step*periodav,`	