

Definition of the global $1/2^\circ$ experiment with CORE interannual forcing, ORCA05-G50

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1 Introduction

Running ocean/ice models forced by a prescribed atmosphere is a difficult problem, because the ocean-atmosphere system is inherently coupled. This has been a topic for discussion within the Working Group for Ocean Model development, co-chaired by C. Böning and S. Griffies. This group is sponsored by CLIVAR and WCRP: annual reports are found on the CLIVAR web site. Over the years, the discussions have led to the endorsement of a forcing dataset and a modelling strategy called CORE (Coordinated Ocean Reference Experiments). This strategy is described on documents available on the GFDL CORE website, as well as in an article in the FLUXNEWS WCRP newsletter (Griffies et al, 2007). The CORE forcing dataset itself has been put together by Large and Yeager and is fully documented in a report (Large and Yeager, 2004).

The ORCA05-G50 experiment described here uses the global $1/2^\circ$ ORCA05 ice-ocean model based on the NEMO code. The experiment follows the CORE forcing strategy. It covers years 1958 to 2004 after 9 years of spin-up using a repeated 1958 year forcing. Our parameterizations differs from other ORCA05 experiments performed at Kiel (Biastoch et al) because we implement the global $1/2^\circ$ model in an eddy permitting mode. This may seem surprising at such a low resolution: it is less so when we look back 15 years. The first so-called "eddy resolving" semi-global model of Semtner and Chervin (1992) had a grid size of 0.4° at the equator, barely less than ORCA05. The Fine Resolution Antarctic Model FRAM (see for example Stevens and Killworth, 1992) had the same resolution as ORCA05 (722 grid points in the zonal direction). The present document describes the experiment set-up. It is a technical report: users that are not familiar with the NEMO modelling system (www.lodyc.jussieu.fr/NEMO) should refer to the model documentation. The code is based on version NEMO 1.09.

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Key	Description
key_orca_r05_l46	Configuration name (l46 refers to the 46 layer version)
key_dynspg_ft	Filtered free surface
key_zdftke	TKE vertical mixing scheme
key_dtem	Use temperature data for initial conditions
key_dtasal	Use salinity data for initial conditions
key_flx_core	Use CORE forcing routines and NCAR bulk formulae
key_traldf_c2d	2D lateral diffusion for tracers (depends on dx)
key_dynldf_c2d	2D lateral diffusion for dynamics (depends on dx ³)
key_ldfslp	Need to calculate isopycnal slope
key_passivetr	Passive tracers
key_cfc	One cfc (code James Orr)
key_c14bomb	C14 bomb (code James Orr)
key_partial_steps	Partial steps topography
key_trabbl_dif	diffusive bottom boundary layer parameterization
key_dimgout	dimg format for outputs
key_mpp_mpi	multiprocessor MPI run
key_ice_lim	Ice model
key_lim_fdd	Ice model interaction with the ocean.
key_vectopt_loop	optimization of loop for vector computers
key_vectopt_memory	recalculates less arrays each step, more memory usage

Table 1: CPP keys for ORCA05-G50 run

2 Basic settings

The list of CPP keys used for this run is found in table 1.

2.1 Horizontal grid

The horizontal grid was defined as a generic 'ORCA' type mesh with 3 poles, using a f-point pivot for the north pole condition. The horizontal grid resolution is 1/2 deg at the equator, leading to horizontal dimensions of 722×511 . The minima of the scale factors (ocean points) are 12.6 km (zonal direction) and 9.4 km (meridional direction). The maximum is 55.6 km at the equator.

2.2 Vertical grid

There are 46 levels on the vertical, with grid spacing ranging from 6 m near the surface to 250 m at 5750 m. The maximum depth allowed in the model is 6000 m. To reach that depth with partial cells, the deepest cell can have a thickness as large as 500 m in the deep basins. The details of the vertical levels as well as the vertical metrics are given in annex A.

2.3 Bathymetry

The bathymetry is calculated from ETOPO2. Note that for the DRAKKAR 1/4° model we have used the GEBCO bathymetry on the ocean continental shelves, mainly because we had found problems off the African coast and in the Indonesian throughflow region. We are not sure those problems are significant at lower model resolutions, so no effort has been made to improve the ORCA05 bathymetry using GEBCO. The basic file ETOPO2 is the 2-minute bathymetry file of NGDC, combination of Smith and Sandwell satellite-based bathymetry (8.2 version), IBCAO (in the Arctic region) and other data in the Antarctic region. The MERCATOR project team has applied additional corrections near the Antarctic (Remy et al, 2003). The interpolation onto the model grid has been conducted by taking all the original grid points falling into an ORCA05 grid box, and taking the median of those points. This procedure produces a smoothing of the sub-grid scale topography. Contrary to higher resolution configurations, no smoothing is applied here because we feared that this would tend to close narrow passages. To get rid of unwanted "one-grid-point" ponds or seamounts, we fill the ponds defined as one grid point lower than all surrounding communicating grid points (four directions). 14842 points are affected. Then we lower the "spikes" (one grid point higher than all eight surrounding points). This treatment modifies 7212 points.

The experiment is run using the partial cell representation of the topography (`key_partial_steps`). The following values are used to calculate the partial cell layer thicknesses (in namelist `namdom`: `e3zps_min = 25.` and `e3zps_rat = 0.2`).

Hand editions have been made, but some of them did not end up as intended. For details of those corrections, please contact the DRAKKAR team.

2.4 Initial conditions

The initial conditions for temperature and salinity were derived from the Levitus 98 data set for the mean and low latitudes. For high latitudes PHC climatology was used instead. For the Mediterranean Sea, **medatlas** climatology was used. The initial condition for sea ice is a constant thickness of 3 meters in the Arctic and 1 m in the Antarctic.

3 Forcings

3.1 Runoffs

A new runoff file has been calculated using the Dai and Trenberth dataset (Dai and Trenberth, 2002) by Romain Bourdalle-Badie at Mercator: `runoff_coast1pt_ant1pt_obtaz_1m_ORCA05.nc`. It is a monthly climatology and includes 99 major rivers and coastal runoffs. The method is the same as for the global 1/4° model, documented in a report on the DRAKKAR web site (Bourdalle-Badie and Treguier, 2006). We use the namelist variable `nrunoff=2`. In that case, a special treatment is applied in runoff regions, where the array `upsrnfh` is non zero. This array is read in the runoff file (netcdf variable `socoefr`). It has a value of zero where there is no runoff and 0.5 at runoff points. Since we do not use the centered scheme, there is no need to revert

to upstream near runoffs (the TVD advection scheme is used everywhere). In our case the special treatment consists in an enhanced vertical diffusion at the interface of layers 1 and 2 applied in step.F90 (Drakkar configuration manager version):

```
avt (:,:,2) = avt (:,:,2) + 1.e-3 * upsrnfh(:,:)
```

The vertical mixing is then set to 500 below the top level at runoff points.

3.2 Atmospheric forcing files

Forcing files are from the CORE dataset (Large and Yeager, 2004) available on the GFDL CORE website. at 2m and atmospheric pressure.

The input files are the following:

- **Air temperature and specific humidity :** 6-hourly values at 10 m height from CORE (based on NCEP).
- **Solar and infra-red downwelling radiation :** Daily values from satellites (ISCCP, Zhang et al. 2004). The corrected version of this product available into the CORE dataset is used. (`qsw_CORE.nc` and `qlw_CORE.nc` for short-wave=solar and long-wave=infra-red).
- **Precipitation (total precipitation and snow) :** Monthly fields from CORE based on satellite measurements (is there a correction???)

The turbulent fluxes, outgoing radiation and albedo are calculated using the formulae proposed with the CORE dataset (Large and Yeager, 2004).

3.3 Interpolation

The forcing fields are preprocessed and interpolated using the int2df interpolation package (Brodeau 2004), available at :

<http://laurent.brodeau.free.fr/f90/interp/int2df-v0.3.tar.gz>

The algorithm used follows Akima, 1974 : “A method of bivariate interpolation and smooth surface fitting based on local procedures”. Prior to the interpolation, the GAP procedure implemented into int2df is used to extrapolate sea values onto an extended land mask, this prevents some coastal land values from influencing the interpolation process. Another important feature of the interpolation process is the rotation of the wind vector onto distorted regions of the target grid (northward 40°N for ORCA grids).

3.4 Forcing parameters

The forcing routine and the ice model are called only once every three hours, e.g. every 5 time steps (`nfice=5` and `nfbulk=5`) in the namelist namdom. There is relaxation to sea surface salinity (monthly climatology of Levitus/PHC). The coefficient (m/day) is set in the new namelist:

```
&namsbc
cdmp = 0.1666666667
```

This value is chosen by consistency with the "strong relaxation" cases in the CORE papers by Griffies *et al.*, 2006. It amounts to a decay time of 60 days for 10 m of water depth. There is no SSS restoring under the ice cover. We also add extra restoring for the Red Sea. (`oce_sbc_dmp` routine).

3.5 Miscellaneous

We use the standard NEMO scheme for penetrative solar radiation, based on clear water only. It does not take into account data of water colour.

Note that there is no representation of the diurnal cycle in this experiment: this would require a vertical resolution of 1 m in the upper layers (Bernie and Madec, personal communication).

3.6 Sea surface height adjustment

We do not use any SSH adjustment. We set `ln_fwb = .false.` in the namelist. No attempt is made to ensure that the correction term (erp) by relaxation to observed SSS had a zero integral over the global ocean (suppression of the adjustments using "aplus" and "aminus" in routine `ocesbc.F90`). As other experiments with CORE forcings we find an increase of the global SSH (1.9 m).

4 Ice model

The ice parameters are the following. Note that the turning angle for the oceanic stress, the rheology parameter pstar and the eddy diffusivity for sea ice ah10 differ from the ORCA025 1/4° model. The ice thickness for lateral accretion hicrit is larger than in ORCA025.

```
&namicerun
ln_limdyn = .true.
acrit = 1.0e-06 , 1.0e-06
hsndif = 0.0
hicdif = 0.0
/
&namicewini
ln_lim_ini = .false.
ttest = 2.0
hninn = 0.5
hginn = 3.0
alinn = 0.05
hnins = 0.1
hgins = 1.0
alins = 0.1
/
&namicedyne
```

```

epsd    = 1.0e-20
alpha   = 0.5
dm      = 0.6e+03
nbiter  = 1
nbitdr  = 100
om      = 0.5
resl    = 5.0e-05
cw      = 5.0e-03
angvg   = -5.0
pstar   = 1.5e+04
c_rhg   = 20.0
etamn   = 0.0e+07
creapl  = 2.0e-08
ecc     = 2.0
ahi0    = 350.e0
/
&namicetrp
  bound  = 0.
/
&namicethd
  hmelt   = -0.15
  hiccrit = 0.9 , 0.6
  hicmin  = 0.2
  hiclim   = 0.05
  amax    = 0.999
  swiqst  = 1.
  sbeta   = 1.
  parlat  = 0.0
  hakspl  = 0.5
  hibspl  = 0.5
  exld    = 2.0
  hakdif  = 1.0
  thth    = 0.2
  hnzst   = 0.1
  parsut  = 1.0
  alphs   = 1.0
/

```

5 Parametrizations

All runs are performed with the free surface, constant volume formulation (`key_dynspg_flt` defined).

5.1 Advection schemes:

We use TVD for tracers (`ln_traadv_tvd = .true.`). We use the new momentum advection scheme suitable for partial step topography (`ln_dynvor_een = .true.`).

5.2 Lateral mixing:

- tracer : a laplacian isopycnal diffusion is used with $aht0= 2000\text{m}^2/\text{s}$ at the equator.
The coefficient decreases polewards proportionally to the grid size. Associated keys are key_traldf_c2d and key_ldfslp.
- dynamics : A biharmonic horizontal viscosity is used with $ahm0= -8.5 \cdot 10^{11} \text{ m}^4/\text{s}^2$.
The viscosity depends on the grid size with δx^3 .

5.3 Bottom boundary layer:

A diffusive bottom boundary layer is activated using `key_trabbl_dif` with `atrbbl =6000 $\text{m}^2.\text{s}^{-1}$` . We do not activate the advective BBL scheme (`key_trabbl_adv`) because we do not think it would make much difference at that resolution.

5.4 Vertical mixing:

There is no double-diffusive mixing.

- tke: TKE is used to compute the vertical mixing. We use the new version of the TKE routine recently proposed by Gurvan MADEC with the following namelist parameters

```
!-----  
!      namtke    turbulent eddy kinetic dependent vertical diffusion  
!      ( #ifdef "key_zdftke" )  
!  
!      ln_rstke flag to restart with tke from a run without tke (default F)  
!      ediff     coef. to compute vertical eddy coef. (avt=ediff*mxl*sqrt(e) )  
!      ediss     coef. of the Kolmogoroff dissipation  
!      ebb       coef. of the surface input of tke  
!      efave     coef. to applied to the tke diffusion ( avtke=efave*avm )  
!      emin      minimum value of tke ( $\text{m}^2/\text{s}^2$ )  
!      emin0     surface minimum value of tke ( $\text{m}^2/\text{s}^2$ )  
!      nitke     number of restart iterative loops  
!      ri_c      critic richardson number  
!      nmxl      flag on mixing length used  
!                  = 0 bounded by the distance to surface and bottom  
!                  = 1 bounded by the local vertical scale factor  
!                  = 2 first vertical derivative of mixing length bounded by 1  
!      npdl      flag on prandtl number  
!                  = 0 no vertical prandtl number (avt=avm)  
!                  = 1 prandtl number function of richarson number (avt=pdl*avm)  
!                  = 2 same as = 1 but a shapiro filter is applied on pdl  
!      nave      = horizontal averaged (=1/2) or not (=0) of avt (default =1)  
!      navb      = 0 cst background avt0, avm0 / =1 profile used on avtb  
!      ln_lsfc   computation surface value of buoyancy lenght scale as function of wind stress  
!      lmin      buoyancy lenght scale minimum value if ln_lsfc = F  
!      n_etau    test param. to add tke induced by wind  
!                  = 0 no add tke induced by wind  
!                  = 1 add tke induced by wind
```

```

!           = 2 add tke induced by wind only at the base of the mixed layer
! fr_emin fraction of TKE surface value which penetrates inside the thermocline
! ln_lc   flag to take into account Langmuir circulation
! c_lc    coef to compute verticla velocity of LC
&namtke
  ln_rstke = .false.
  ediff =      0.1
  ediss =      0.7
  ebb   =      60.
  efave =      1.
  emin  =     1.e-6
  emin0 =    1.e-4
  nitke =      50
  nmxl  =       3
  npdl  =       1
  navb  =       0
  nave   =       1
  ln_lsfc = .true.
  lmin   =     0.4
  n_etau =       1
  nhtau =       3
  fr_emin =     0.05
  ln_lc  = .true.
  c_lc   =     0.15

```

The key modification made to tke is `fr_emin`, the proportion of energy allowed to enter into the stratified ocean below the mixed layer. This is meant to represent mixing by unresolved turbulence due to surface waves and swell. It is supposed to improve the depth of summer mixed layers that were too shallow in experiment G42. The parameter `nhtau` is changed from ORCA025-G50 (it used to be 1). It sets the scheme for the penetration of this energy. The depth is hardwired in the routine. It used to be 40m with a decrease to 5m at the equator. With `nhtau=3`, the depth is allowed to be different in different hemispheres, but finally after testing we set it to 30m in both hemispheres. We want to avoid unrealistic mixing under the ice. For this reason, the Langmuir cells contribution is removed under the ice, and the background coefficient is reduced (see next paragraph).

-background and convection: The enhanced vertical diffusion is used when convection is diagnosed. The corresponding namelist block is :

```

!-----
!      namzdf  vertical physics
!-----
!  ln_zdfevd enhanced vertical diffusion      (default T)
!  ln_zdfnpn Non-Penetrative Convection      (default T)
!  avm0    vertical eddy viscosity for the dynamic (m2/s)
!  avt0    vertical eddy diffusivity for tracers (m2/s)
!  avevd   vertical coefficient for enhanced diffusion scheme (m2/s)
!  nevdm   = 0  apply enhanced mixing on tracer only
!          = 1  apply enhanced mixing on both tracer and momentum
!  ln_zdfexp  vertical physics: (=T) time splitting (T)      (Default=F)

```

```

!
!           (=F) euler backward (F)
! n_zdfexp   number of sub-timestep for time splitting scheme
&namzdf
  ln_zdfevd = .true.
  ln_zdfnp = .false.
  avm0      = 1.e-4
  avt0      = 1.e-5
  avevd     = 10.
  nevdm     = 1
  ln_zdfexp = .false.
  n_zdfexp = 3
/

```

In the previous version of TKE there was an enhancement of the background by a factor of 10 in the top layer (and 5 and 2.5 in the second and third) in order to avoid too shallow mixed layers in summer. This is suppressed in the new version of TKE. The background coefficient is divided by a factor of 10 under the ice.

5.5 Bottom friction and lateral boundary condition

The namelist is the following. We use a spatially variable coefficient: the bottom friction coefficient is multiplied by bfrien=50 in Torres Strait: this is to reduce the flow through this strait, that is observed to be small.

```

!-----
!      nambfr  bottom friction
!-----
!
! nbotfr  type of bottom friction
!          nbotfr = 0 , no slip
!          nbotfr = 1 , linear friction
!          nbotfr = 2 , nonlinear friction
!          nbotfr = 3 , free slip
!
! bfri1   bottom drag coefficient (linear case)
! bfri2   bottom drag coefficient (non linear case)
! bfeb2   bottom turbulent kinetic energy  (m^2/s^2)
! ln_bfr2d: flag for 2d coef enhancement read in file
! bfrien: enhancement coefficient (integer > 1)
&nambfr
  nbotfr =      2
  bfri1  =  4.e-4
  bfri2  =  1.e-3
  bfrien = 50
  ln_bfr2d = .TRUE.
  bfeb2  =  2.5e-3
/

```

The lateral boundary condition is free slip (shlat=0 in namelist). Contrary to other global configurations like ORCA2 and ORCA025, there is no local modification of the lateral friction in some straits.

6 miscellaneous:

- timestep** : The time steps is set to 2160 s (40 steps/day).
- hpg implicit** : The semi-implicit scheme is applied to allow a larger time step (a factor of two on the cfl criterion linked with internal wave propagation).
- asselin** : the asselin coefficient is taken to 0.1

7 Simulation strategy

The present run starts in 1949 with a nine year spin-up using year 1958, periodized and repeated 9 times(fictitious years numbered 1949 to 1957). The experiment proceeds with interannual CORE forcing for years 1958 to 2004.

8 Transient tracers

The bomb C14 and CFCs forcings are provided by Zouhair Lachktar and James Orr. The tracers use the same parameterizations as the physics (isopycnal mixing) and the TVD advection scheme.

The transients tracers begin after one year of dynamical spin-up in order to avoid the initial geostrophic adjustment of the dynamics (calendar year and model year 1950).

9 Model outputs

9.1 Archived fields

Files are stored every 5 days (nwrite = 300 steps). 3D variables are U , V , T , S , W , K_z . K_z is a time-average of the total vertical mixing including convection events (suitable for off-line tracer calculations). Two dimensional fields are taux and tauy (in U and V files) and in the "grid T" files:

sossheig Sea surface height (in meters)
somxl010 Mixed layer depth (in m) based on a σ_0 difference of 0.01 with the surface
sohefldo Net Downward Heat Flux (in $\text{W} \cdot \text{m}^{-2}$)
soshfldo Short wave downward radiative flux (in $\text{W} \cdot \text{m}^{-2}$)
sowaflup Net upward water flux in $\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-1}$ (forcing of the sea surface height)
sowafldp Surface water flux damping in $\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-1}$
iowaflup Ice-ocean water flux in $\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-1}$

sowaflcd Concentration-dilution water flux (the product of this flux with surface salinity
is the forcing term in the salinity equation)

solhflup Latent heat flux (in $\text{W} \cdot \text{m}^{-2}$)

solwfldo Long wave downward radiative flux (in $\text{W} \cdot \text{m}^{-2}$)

sosbfhfup Sensible heat flux (in $\text{W} \cdot \text{m}^{-2}$)

9.2 Storage strategy

Although we have thought about storage in 16 bits, for now the netcdf variables are floats with 32 bits. For best performances, the output are written by each processor in direct acces files. Those files are recombined immediately after the experiment (see Molines (2004) [9] for more details). The output files stored on gaya at IDRIS are 5 days averages. They are netcdf files very similar to classical OPA netcdf output, excepted for a few differences:

- one file for each 5-day average
- definition of time_counter: The time_counter gives the number of seconds since the begining of the run.
- naming convention for the files: There are 5 types of files; 4 corresponds to the different grid points: gridT, gridU, gridV and gridW; a fifth type of file corresponds to the ice model output. File names are almost self explanatory: (*e.g.* ORCA05-G50_y0010m10d03_gridT.nc or ORCA05-G50_y0010m10d03_icemod.nc). The time indicated in the name of the file corresponds to the date at the **end** of the period used to time-average the data.
- archiving the results: The results are archived on rcli002@gaya:ORCA05/. Data are organized in many directories. Raw results from the run are stored under ORCA05-CASE-S (one sub-directory per year then). Mean values computed from the raw results are stored in ORCA05-CASE-MEAN. There are monthly means, quarterly means and annual means (one sub-directory per year). Interannual means are also computed. The implementation of this directory tree for archiving the results, is part of the strategy used in DRAKKAR to share different configurations between groups of users (see Molines *et al.*(2004) [10]).

Note that the special value on land is zero. This is properly referenced in the header of each file (and causes problems with older versions of the "ncra" software).

10 Numerics

10.1 Domain decomposition

ORCA05 runs on a massively parallel computer, using a domain decomposition technique. The message passing between processors is explicitly done using the MPI library (option

”isend”).

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A Annex A

vertical levels

```

zgr_z : Reference vertical z-coordinates
~~~~~
zsur, za0, za1 computed from
    zdzmin = 6.00000000000000000000
    zhmax = 5720.0000000000000000
Namelist namzgr : value of coefficients for vertical mesh:
    zsur = -2143.95922194325158
    za0 = 127.451110365423233
    za1 = 123.075814004137086
    zkth = 23.56299999999999988
    zacr = 9.00000000000000000000

Reference z-coordinate depth and scale factors:
level   gdept     gdepw     e3t      e3w
  1       3.05      0.00     6.19      6.00
  2       9.45      6.19     6.64      6.40
  3      16.36     12.83     7.19      6.90
  4      23.88     20.03     7.88      7.52
  5      32.18     27.92     8.74      8.29
  6      41.44     36.68     9.80      9.25
  7      51.87     46.49    11.12     10.43
  8      63.78     57.62    12.74     11.89
  9      77.48     70.38    14.73     13.69
 10     93.39     85.13    17.18     15.89
 11    112.01    102.33    20.16     18.60
 12    133.92    122.52    23.78     21.88
 13    159.82    146.33    28.14     25.86
 14    190.49    174.50    33.36     30.63
 15    226.85    207.90    39.54     36.32
 16    269.92    247.48    46.78     43.02
 17    320.80    294.31    55.16     50.83
 18    380.63    349.52    64.70     59.78
 19    450.57    414.27    75.38     69.90
 20    531.74    489.69    87.11     81.12
 21    625.09    576.84    99.72     93.32
 22    731.40    676.59   112.98    106.29
 23    851.17    789.58   126.59    119.76
 24    984.59    916.17   140.22    133.42
 25   1131.50   1056.38   153.54    146.94
 26   1291.46   1209.89   166.25    159.99
 27   1463.71   1376.10   178.10    172.29

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28	1647.31	1554.16	188.92	183.65
29	1841.17	1743.03	198.61	193.91
30	2044.14	1941.59	207.13	203.01
31	2255.05	2148.67	214.51	210.96
32	2472.80	2363.14	220.82	217.79
33	2696.36	2583.92	226.15	223.60
34	2924.82	2810.03	230.62	228.49
35	3157.35	3040.62	234.32	232.56
36	3393.25	3274.92	237.38	235.93
37	3631.93	3512.27	239.89	238.70
38	3872.87	3752.14	241.93	240.96
39	4115.66	3994.06	243.60	242.81
40	4359.96	4237.64	244.95	244.31
41	4605.47	4482.58	246.04	245.52
42	4851.97	4728.61	246.92	246.50
43	5099.25	4975.52	247.63	247.29
44	5347.18	5223.15	248.20	247.93
45	5595.62	5471.34	248.66	248.44
46	5844.47	5720.00	249.03	248.86