Schwarz iterations for ocean-atmosphere interface coherency in CNRM-CM6-1D

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1. Introduction

In this document, the experiments performed with CNRM-CM6-1D implementing Schwarz iterations for a better consistency of the ocean-atmosphere interface are reported. One-day (Nov 13th 2011) and two-day (Nov 13th-14th 2011) simulations for one point in the Indian ocean covered by the Cindy Dynamo campaign (Ciesielski et al. 2014) are realized with different coupling periods and the impact of Schwarz iterations is analyzed.

The Schwarz method (Marti et al 2021, Lemarié et al. 2015) allows for correcting the time inconsistency of asynchronous coupling, leading to a coherent ocean-atmosphere interface. Lemarié et al. (2014) show that using the Schwarz coupling method in a regional coupled model for a multi-member ensemble simulation of a tropical cyclone leads to a significant reduction in the ensemble spread in terms of cyclone trajectory and intensity, thus suggesting that a source of error linked to the asynchronous coupling has been removed.

The principle of the Schwarz method is to repeat each integration period, possibly encompassing many coupling periods, many times with the same initial condition for each iteration, but with evolving boundary conditions at the ocean-atmosphere interface. Instead of using the surface variables calculated by the ocean during the previous coupling period (as in the asynchronous scheme), the atmosphere uses the surface variables calculated by the ocean for that same coupling period but during the previous iteration. And vice-versa for the ocean that uses during each iteration the fluxes calculated by the atmosphere for the same period during the previous iteration. This is repeated until convergence of the surface variables and fluxes.

2. CNRM-CM6-1D

The single-column atmosphere has 91 vertical levels from the surface to about 80 km and is coupled through OASIS3-MCT to the single column version of the NEMO ocean model with 75 vertical levels. Coupling fields exchanged at the interface include from the ocean to the atmosphere: SST, surface eastward and northward sea water velocity; from the atmosphere to the ocean: surface downward eastward and northward wind stresses, magnitude of the surface downward stress and wind velocity, snowfall, rainfall, surface liquid evaporation flux, and the total solar and non-solar heat fluxes.

The atmospheric part of CNRM-CM6-1D is forced by horizontal advections of temperature and moisture and the large-scale vertical velocity; some variables such as the horizontal velocities, temperature and humidity are nudged toward observations or reanalysis (Abdel-Lathif, 2018). More precisely:

- The horizontal velocities u and v are:
    - from the surface to 50 hPa, nudged toward NSA profiles with a 3-hour timescale
    - from 50 to 1 hPa, nudged toward ERA-Interim profiles
    - above 1 hPa, nudged toward 0
- The temperature temp and the specific humidity qv are:
    - from the surface to 50 hPa, subject to an advection term estimated from ECMWF analyses corrected using Cindy Dynamo campaign observations
    - from 50 to 1 hPa, nudged toward ERA-Interim profile

- above 1 hPa, nudged toward Coesa (1976) standard atmosphere profile for temp and toward 0 for qv
- The vertical velocity w is
  - prescribed by the NSA profile NSA from the surface to 50 hPa
  - prescribed to 0 above 50 hPa

In the oceanic part of CNRM-CM6-1D, no lateral forcing or nudging is applied.

The atmosphere and ocean timestep is 300s for both.

3. Schwarz implementation

Schwarz iterations have been implemented using CNRM-CM6-1D for one point in the Indian ocean in one-day (November 13th 2011) and two-day (November 13th-14th 2011) simulations, which covers a relatively dry period. For the one-day and two-day simulations, the iteration period was respectively one day and two days and different experiments were realized with different coupling periods i.e. 300s, 600s, 900s,1200s, 3600s, 3hrs, 6hrs, 12hrs, 24hrs.

The practical implementation of Schwarz iterations takes advantage of the OASIS3-MCT coupler flexibility to respect some constraints resulting from the way the coupling is implemented in CNRM-CM6-1D (for example, different coupling periods are not allowed for the different atmospheric fields).

For all experiments described below, a one-day simulation is first performed with standard asynchronous coupling at the given coupling period starting from the following initial conditions:

- For the atmosphere, all variables are initialized with the observations realized for Nov 13th 2011 for the Revelle case during the Cindy Dynamo campaign
- For the ocean, T and S are initialized with CTD observations and u and v with ORAS5 observation
- For the coupling restart fields, the coupling fields obtained from a one-day simulation starting with null fluxes (from the atmosphere to the ocean) and SST from GLORYS and null velocities (from the ocean to the atmosphere) are used.

All experiments described below start from the coupled model state at the end of that day and are run for Nov 13th or Nov 13th -14th. Schwarz iterations are chained as illustrated on Fig. 1, which shows the specific case of one-day simulations with a coupling period of 1200s. For each coupling period, one or two days of simulation with standard asynchronous coupling is first performed; this corresponds to the first Schwarz iteration. The coupling fields averaged over each coupling period are saved. These averaged coupling fields are duplicated for the number of model timesteps in the coupling period; for the 1200s coupling period, the fields are duplicated 4 times. Then a 2nd iteration is performed starting from the same initial conditions as the 1st one but using, as coupling fields, the (duplicated) fields calculated during the 1st iteration for the same coupling period. At the same time, the fields produced during each coupling period are saved, averaged over the coupling period and duplicated so to have as many instances as timesteps during the coupling period. Then a 3rd iteration is performed starting from the same initial conditions as the 1st and 2nd ones but using as coupling fields the (averaged and duplicated) fields calculated during the 2nd iteration for the same coupling period. And so on for 20 iterations in total for each value of the coupling period for the one-day and two-day experiments.

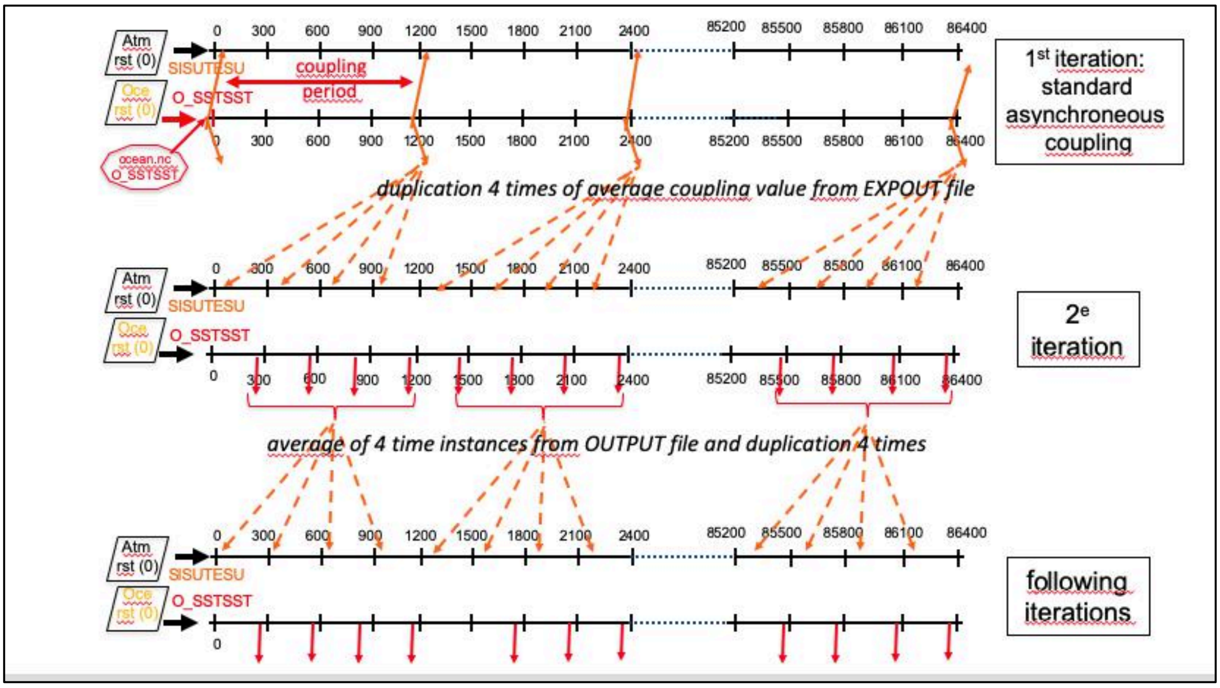


Figure 1 – Implementation of Schwarz iterations in CNRM-CM-1D for the specific case of one-day simulation with a coupling period of 1200s

All the environment to reproduce the Schwarz iterations described here has been saved under git at https://nitrox.cerfacs.fr/globc/COCOA .

4. Convergence criteria

To determine if the Schwarz iterations converge or not, we have defined somewhat arbitrary "weak" and "strong" convergence criteria applicable individually to each variable studied. For the weak or strong convergence, the difference between two iterations (and all the following ones) must be smaller than 1/10 or 1/100 times the amplitude of the diurnal cycle for all 288 (one day) or 576 (two days) timesteps.

Those criteria have been evaluated for different simulated variables and the number of iterations needed to reach either weak or strong convergence is given in Appendix 1 for one-day simulations and in Appendix 2 for two-day simulations.

It has to be stressed that if those criteria give objective measures of the evolution of the variables during the Schwarz iterations, they do not always give a proper idea of the ability of Schwarz iterations to readjust the diurnal cycle(s) toward the "reality" corresponding to a fully coherent ocean-atmosphere interface. For example, a variable that evolves very little in all cases (such as some of the variables at the deeper ocean level analyzed) will appear as converging rapidly; also variables having a marked amplitude of the diurnal cycle will appear as converging more easily.

The evaluation of the weak or strong convergence for the different variables was done with python scripts in a Jupyter notebook environment and are also available under git at https://nitrox.cerfacs.fr/globc/COCOA .

5. Variables studied

The simulated variables for which we studied are the following ones:

For the ocean :

- The temperature (votemper, in deg C)
- The salinity (vosaline, in PSU)
- The zonal current (vozocrtx, in m/s) for

all three for levels 1, 2, 3, 8, 19 (i.e. 0.5, 1.6, 2.7, 9.8, 53.9 m)

- The Net Upward Water Flux (sowaflup, in Kg/m2/s) which is an input coupling field
- The Net Downward Heat Flux (sohefldo in W/m2) which is an input coupling field

For the atmosphere :

- The Air Temperature (temp in deg K)
- The Specific Humidity (qv kg/kg)

both for level = 91 (~1008.7 HPa), 90 (~1005.8 HPa), 89 (~996.5 HPa), 85 (~973.5 HPa), 80 (~905.5 HPa)

6. Results

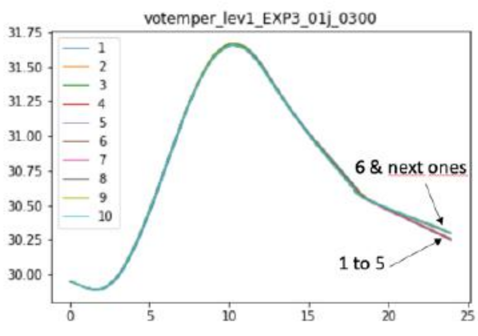
Schwarz iterations have been implemented as described in Sect. 3 using CNRM-CM6-1D for one point in the Indian ocean in one-day (November 13th 2011) and two-day (November 13th-14th 2011) simulations, which correspond to relatively dry periods of the Cindy Dynamo campaign (Ciesielski et al. 2014) from which the atmospheric lateral forcings are obtained. For all simulations, 20 iterations were realized. Runs with coupling periods of 300 s (which is the timestep of the models), 600 s, 900 s, 1200 s, 3600 s, 3 hrs, 6 hrs,12 hrs and 24 hrs were realized and are presented here after. For each figure shown, we give the length of the simulation and the coupling period between parentheses just after the figure number, e.g. “Fig.6 (1-day - 6hrs) “:

6.1. One-day November 13th 2011 simulations (EXP3_01j)

Results are analyzed here for the one-day November 13th 2011 simulations (EXP3_01j) for the different coupling periods. For each variable and each coupling period, the number of iterations needed to reach either weak or strong convergence is given in Appendix 1; a number of 20 indicates that no convergence is attained within the 20 iterations.

- Coupling period of 300s

Schwarz iterations readjust the diurnal cycle for all variables, but for temp lev80 and qv all levels that show no real diurnal cycle. All variables reach weak and strong convergence in maximum 8 iterations. Fig.2 shows iterations 1 to 10 for votemper lev1 and temp lev91 which show strong convergence after 7 and 8 iterations respectively.



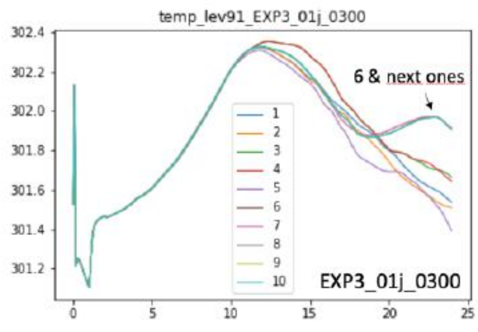


Figure 2 (1-day – 300s): diurnal cycle of votemper lev1 (left) and temp lev91 (right) for iterations 1 to 10.

- Coupling period of 600s

Schwarz iterations readjust the diurnal cycle for all variables, but for temp lev80 and qv all levels that show no real diurnal cycle. All variables reach weak and strong convergence in maximum 6 iterations.

- Coupling period of 900s

Schwarz iterations readjust the diurnal cycle for all variables, but for temp lev80 and qv all levels that show no real diurnal cycle. All variables reach weak and strong convergence in maximum 9 and 11 iterations respectively.

- Coupling period of 1200 s

Schwarz iterations readjust the diurnal cycle for all variables, but for temp lev80 and qv all levels that shows no real diurnal cycle. All variables reach weak and strong convergence in maximum 9 iterations.

- Coupling period of 3600s

Schwarz iterations readjust the diurnal cycle for all variables, but for temp lev80 and qv all levels that shows no real diurnal cycle. All variables reach weak and strong convergence in maximum 8 and 10 iterations respectively. Fig.3 shows iterations 1 to 10 for temp lev91 and vosaline lev1 and which show strong convergence after 9 and 8 iterations respectively.

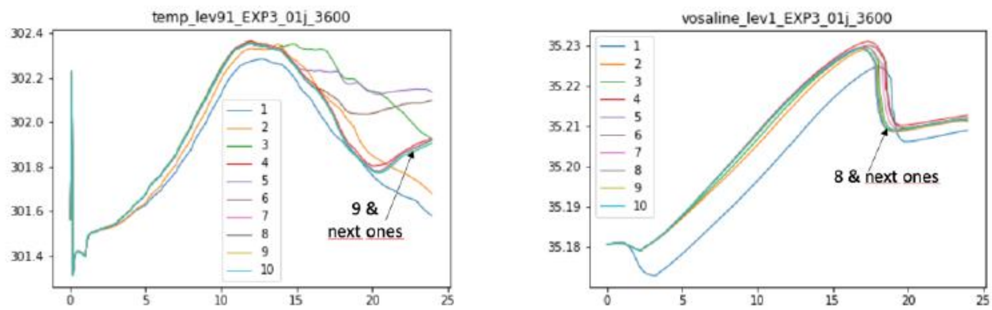


Figure 3 (1-day – 3600s): diurnal cycle of temp lev91 (left) and vosaline lev1 (right) for iterations 1 to 10.

- Coupling period of 3hrs

With 3hr coupling period, Schwarz iterations succeed in readjusting the diurnal cycle for all variables, but for temp lev80 and qv all levels that shows no real diurnal cycle. Furthermore, this coupling period generates very particular behaviors for the different variables, which never converge completely but oscillate between two states (the only exceptions are for vosaline and vozocrtx at lev8 & lev19, which converge strongly without any oscillation at 1st iteration). For atmospheric variables, iterations 11-12-15-16-… and iterations 9-10-13-14-17-18-… overlap themselves, and for oceanic variables, iterations 6-7-10-11-14-15-… and iterations 8-9-12-13-16-17-…

overlap themselves (i.e. there is a lag of 1 between atmospheric and oceanic variable overlap).

For some variables, the oscillations stay within the strong and/or weak convergence criteria. In particular:

- vozocrtx lev1-2-3 oscillate between two states but these states are so close that the strong convergence criterion is fulfilled in maximum 3 iterations
- votemper lev1-2-3-8-19, vosaline lev3 and sohefldo, also oscillate between two states but these states are close enough so that the weak convergence criterion is fulfilled in 4 or less iterations, as shown on Fig. 4 for votemper lev1.

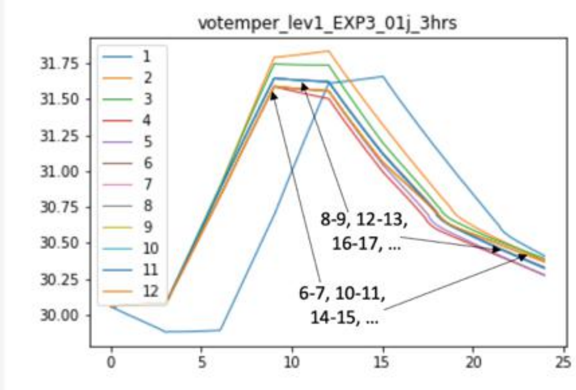


Figure 4 (1-day – 3hrs): diurnal cycle of votemper lev1 for different iterations; votemper oscillate between two states but these two states stay within the weak convergence criterion.

- temp lev91-90-89-85-80, qv lev91-90-89-85-80, vosaline lev1-2 and sowaflup show no weak or strong convergence but they oscillate between two states This is illustrated at Fig.5 for temp lev91 and for vosaline lev1.

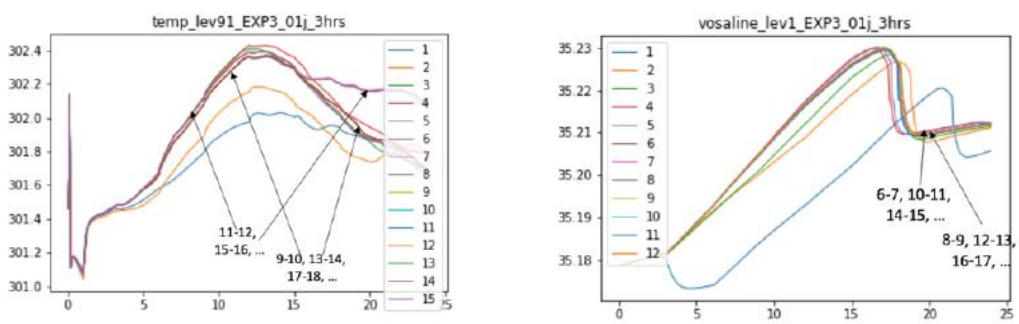


Figure 5 (1-day – 3hrs): diurnal cycle of temp lev91 (left) and vosaline lev1 (right) for different iterations; the variables oscillate between two states.

- Coupling period of 6hrs

Again here, Schwarz iterations succeed in readjusting the diurnal cycle for all variables, but for temp lev80 and qv all levels that show no real diurnal cycle. This coupling period also generates very particular behaviors for the different variables, which oscillate without never converging completely, and the oscillations seem quite arbitrary, not between two distinct states as for the 3hrs coupling period. For some variables, the oscillations stay within the strong and/or weak convergence criteria. As for the 3hrs coupling period, the only exceptions are for vosaline and vozocrtx at the deepest levels analyzed (lev8 & lev19) which converge strongly without any oscillation at first iteration. In particular:

- vozocrtx lev1-2-3 oscillate but the oscillations are so close that the strong convergence criterion is fulfilled in maximum 4 iterations as shown on Fig.6

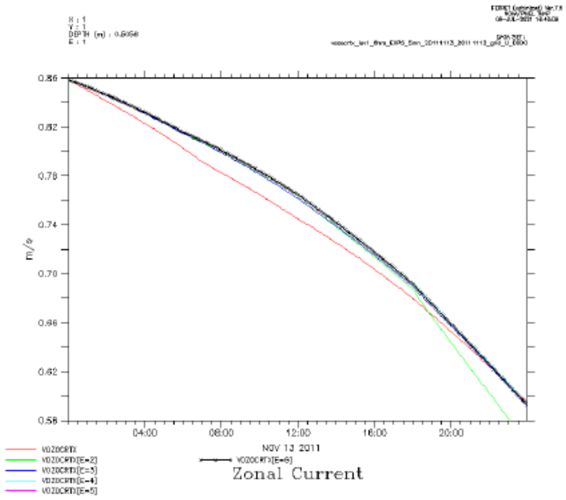


Figure 6 (1-day – 6hrs): diurnal cycle of vozocrtx for different iterations 1 to 5; vozocrtx keeps on oscillating but within the strong convergence criterion.

- votemper lev1-2-3-8-19, vosaline lev3, sohefldo, temp lev91 oscillate with no specific behavior, but within the weak convergence in maximum 17 iterations, as is illustrated on Fig.7 for temp lev91 (left) and for votemper lev1 (right)

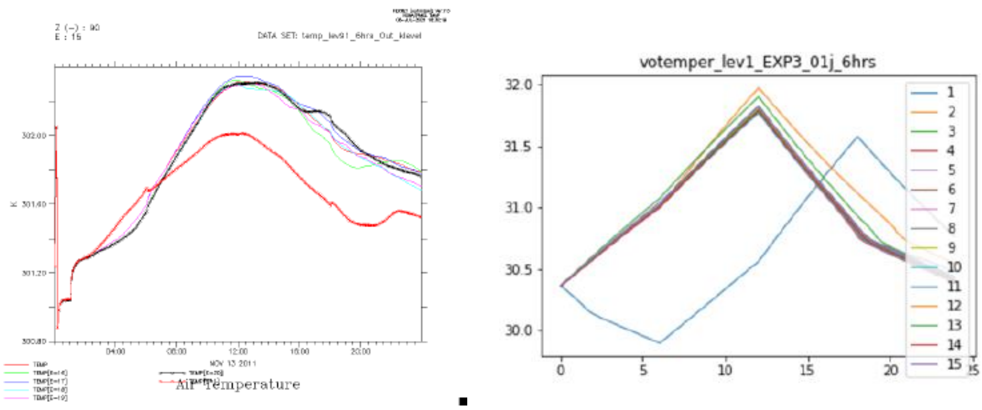


Figure 7 (1-day – 6hrs): diurnal cycle of temp lev91 for iterations 1-15-16-17-18-19-20 (left) and votemper lev1 for iterations 1 to 15 (right).

- vosaline lev1-2, sowaflup, temp lev90-89-85-80, qv lev 91-90-89-85-80 keep on oscillating without showing any weak or strong convergence, as shown on Fig.8 for qv lev80 and qv lev91.

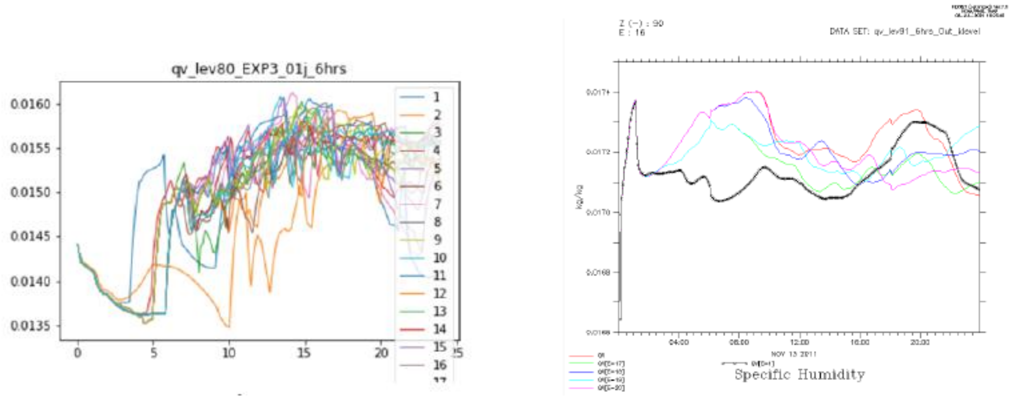


Figure 8 (1-day - 6hrs) : diurnal cycle of qv lev80 for iterations 1 to 17 (left) and qv lev91 for iterations 1-16-17-18-19-20 (right), which show no convergence and no readjustment of the diurnal cycle.

- Coupling period of 12hrs

Surprisingly, the behavior of the variables for a coupling period of 12hrs is similar to the one for coupling period of 3600s or less, i.e. Schwarz iterations readjust the diurnal cycle of all variables, but for temp lev80 and qv all levels that show no real diurnal cycle. For ocean variables, Schwarz even completely inverse the diurnal cycle, as shown for vosaline lev1 and votemper lev1 on Fig. 9. All variables reach strong convergence in maximum 11 iterations, even if the behavior of some variables may appear quite chaotic, e.g. temp lev80 that is shown on Fig.9.

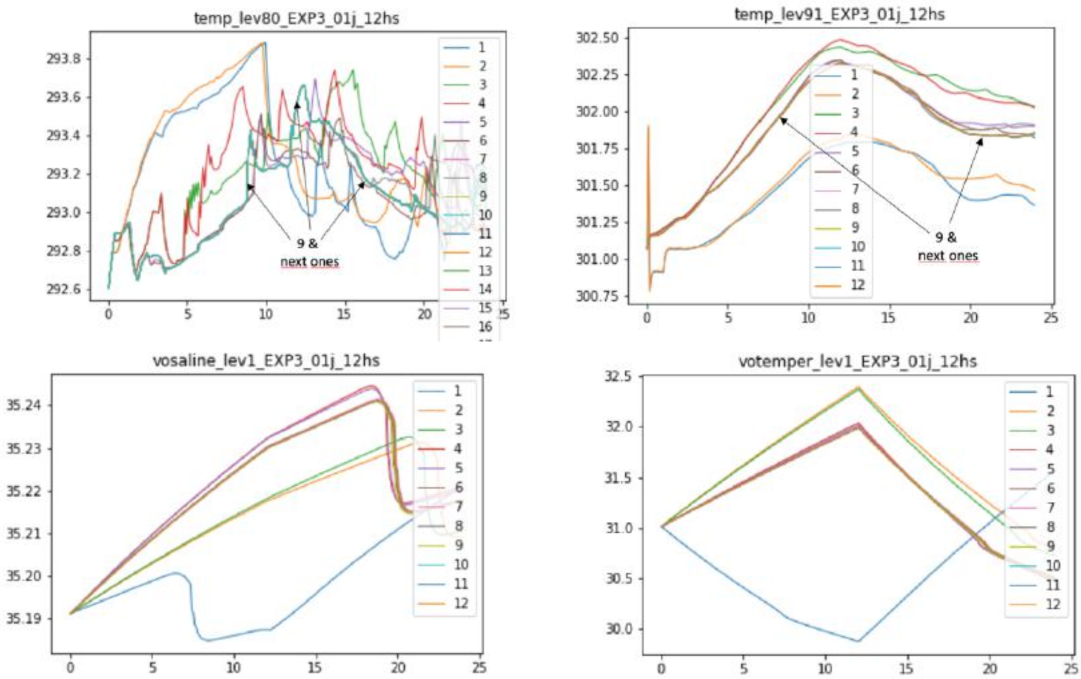


Figure 9 (1-day - 12hrs): diurnal evolution of temp lev80 (top left), temp lev91 (top right), vosaline lev1 (bottom left), votemper lev1 (bottom right) for iterations 1 to 12 (and to 17 for temp lev80).

- Coupling period of 24hrs

With this coupling period, which is equal to the Schwarz iteration period, variables never converge completely but oscillate between **four** different states. For oceanic variables, iterations 7-12-15-20-… , 9-14-17-… , 10-13-18-… ,11-16-19 respectively overlap themselves, while for atmospheric variables, iterations 8-13-16-… , 10-15-18-…, 11-14-19-…, 12-17-20-… (i.e. with a lag of 1 iteration compared to the oceanic variables) respectively overlap themselves. For some variables, these 4 states are close enough so that the strong and/or weak convergence criteria are fulfilled. The only exceptions are for vosaline and vozocrtx at the deepest level analyzed (lev19) which converge strongly without any oscillation at first iteration. In particular:

- Strong convergence with oscillations between the four states is reached in maximum 3 iterations for votemper lev8-19, , vozocrtx lev 1-2-3-8, as shown for vozocrtx on Fig.10.

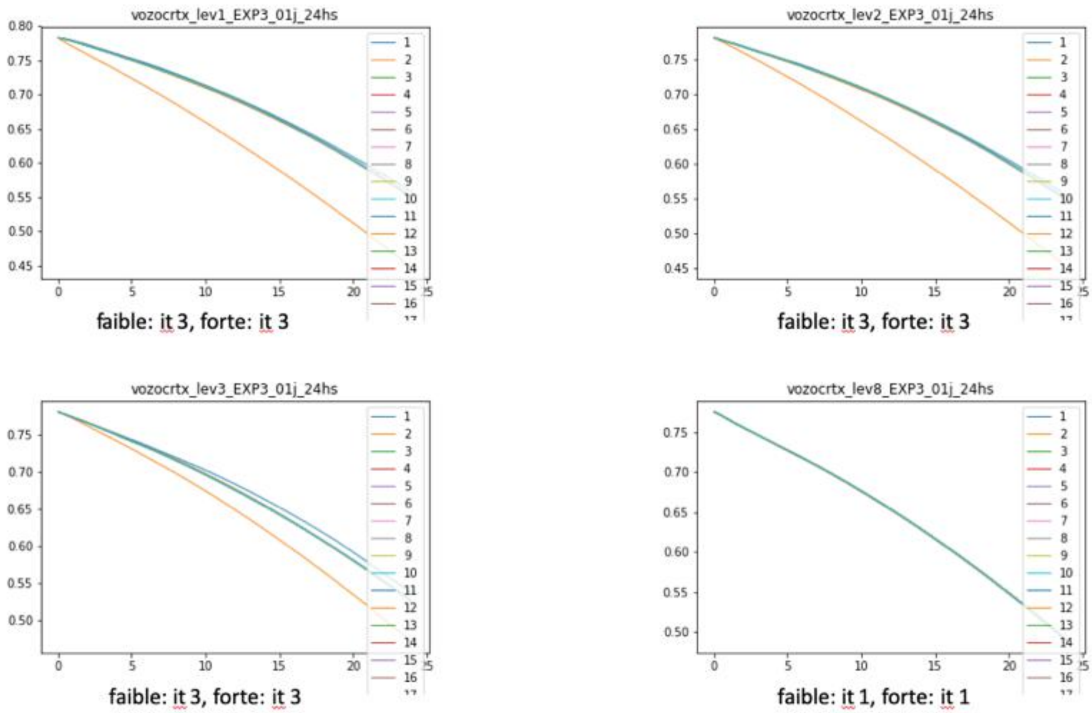


Figure 10 (1-day - 24hrs): diurnal cycle of vozocrtx lev1-2-3-8 for iterations 1 to 17 for a coupling period of 24hrs; vozocrtx oscillate between four different states (not visible on the figure) but these four states stay within the strong convergence criterion after maximum 3 iterations

- Weak convergence with oscillation between the four states is reached in maximum 4 iterations for votemper lev2 and lev3 and vosaline lev3 and lev8 as shown on Fig.11 bottom for vosaline lev3 and lev8

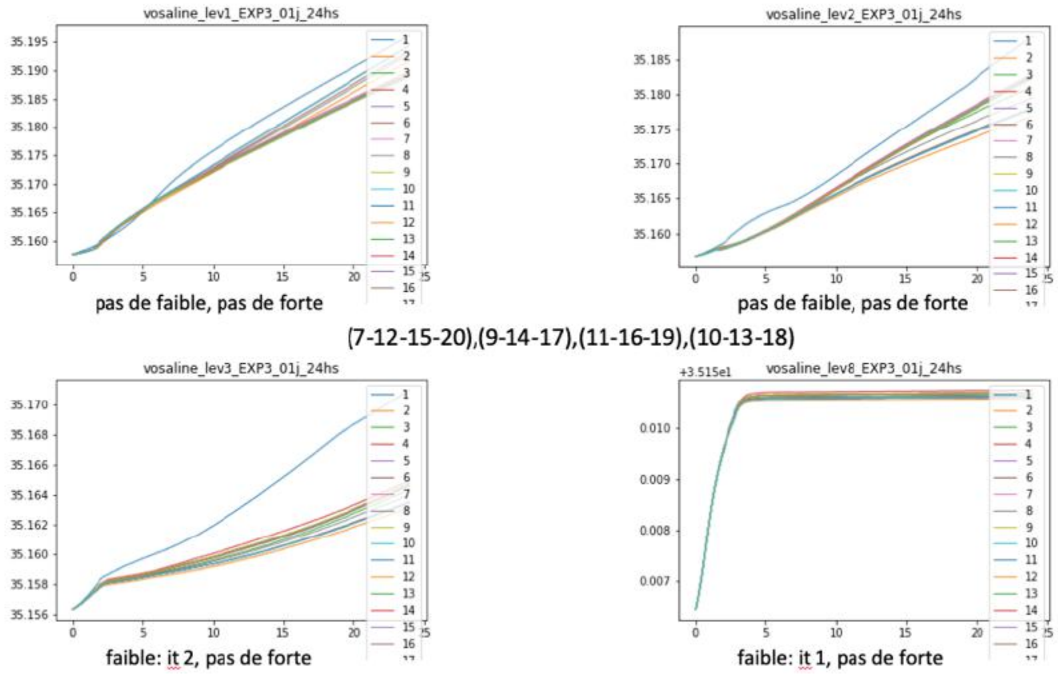


Figure 11 (1-day - 24hrs): diurnal cycle of vosaline lev1-2-3-8 for iterations 1 to 17 for a coupling period of 24hrs; vosaline oscillate between four different states (not visible on the figure); for vosaline lev3-8 these four states stay within the weak convergence criterion after maximum 2 iterations

- No strong or weak convergence is reached for the other variables that keep on oscillating between four states outside the weak and strong convergence criteria (votemper lev1, vosaline lev1-2, sowaflup, sohefldo, temp lev91-90-89-85-80, qv lev91-90-89-85-80).

In summary for the one-day November 13th 2011 simulations (EXP3_01j):

- For all coupling periods but for 24hrs, Schwarz iterations readjust the diurnal cycle for all variables except for temp lev80 and qv all levels, that show no real diurnal cycle. This is certainly linked to the fact that variable temp lev80, which is at ~905 HPa, is probably outside the boundary layer; for qv all levels, this behavior is somewhat harder to explain.
- For coupling periods of 300s, 600s, 900s, 1200s, 3600s, and12hrs: strong convergence is reached for all variables in a maximum of 11 iterations.
- For 3hrs, variables (but vosaline lev8-19 and vozocrtx lev8-19 which converge completely at first iteration) end up oscillating between two states, either within the strong convergence criterion (vozocrtx lev1-2-3) or the weak convergence criterion (votemper lev1-2-3-8-19, vosaline lev3 and sohefldo) or outside the convergence criteria (temp lev91-90-89-85-80, qv lev91-90-89-85-80, vosaline lev1-2 and sowaflup).
- For 6hrs, variables (but vosaline lev8-19 and vozocrtx lev8-19 which converge completely at first iteration) end up oscillating quite arbitrarily, either within the strong convergence criterion (vozocrtx lev1-2-3), or within the weak convergence criterion (votemper lev1-2-3-8-19, vosaline lev3, sohefldo, temp lev91), or

outside the convergence criteria (vosaline lev1&2, sowaflup, temp lev90-89-85-80, qv lev 91-90-89-85-80) at all.

- For 24hrs, all variables (but vosaline lev19 and vozocrtx lev19 which converge completely at first iteration) oscillate between 4 states. For some variables, these oscillations remain within the strong convergence criterion (votemper lev8-19, vozocrtx 1-2-3-8) or only the weak convergence criterion (votemper lev2-3, vosaline 3-8) or outside the convergence criteria for some variable even inside the strong criterion (votemper lev1, vosaline lev1-2, sowaflup, sohefldo, temp lev91-90-89-85-80, qv lev91-90-89-85-80)

6.2. Two-day November 13th – 14th 2011 simulations (EXP3_02j)

Two-day simulations covering Nov 13th and Nov 14th with a Schwarz iteration period of 2 days (EXP3_02j) were then realized for the different coupling periods and results are discussed here. For each variable and each coupling period, the number of iterations needed to reach either weak or strong convergence is given in Appendix 2; a number of 20 indicates that no convergence is reached within the 20 iterations.

- Coupling period of 300s

Schwarz iterations readjust the diurnal cycle for all variables but for temp lev80 and qv all levels that show no real diurnal cycle. All variables show strong convergence in 19 iterations maximum (which is higher than the 8 iterations maximum for the one-day simulation) but sowaflup, temp lev85-80, qv lev85-80 which show only weak convergence because of unstable behavior after 18h on the 2nd day. This is illustrated for votemper lev1 (strong convergence in 17 iteration) and for sowaflup (weak convergence only in 17 iterations) on Fig.12

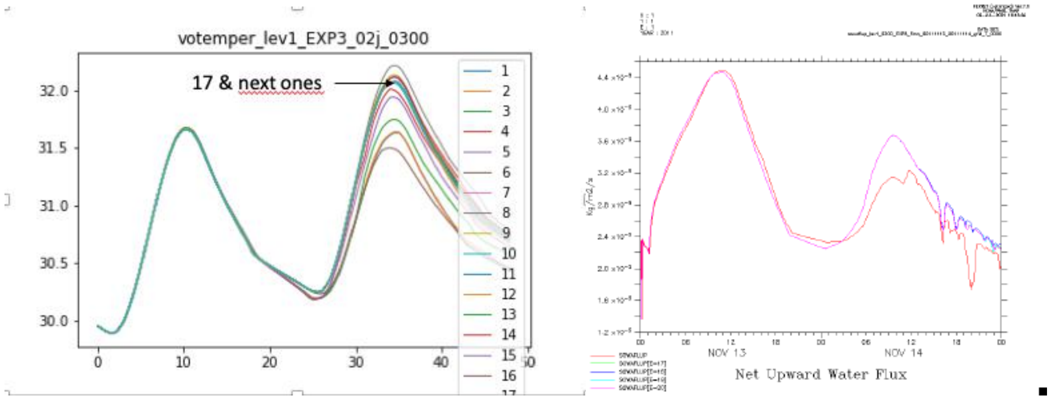


Figure 12 (2-day - 300s): diurnal cycles of votemper lev 1 for iterations 1 to 17 (left, strong convergence in 17 iterations) and for sowaflup for iterations 1(in red) and 17-20 (other superimposed curves) (right, weak convergence only in 17 iterations).

- Coupling period of 600s

Schwarz iterations readjust the diurnal cycle for all variables but for temp lev80 and qv all levels that show no real diurnal cycle. All variables show weak and strong convergence in 16 iterations maximum (no exception).

- Coupling period of 900s

Schwarz iterations readjust the diurnal cycle for all variables but for temp lev80 and qv all levels that show no real diurnal cycle. All variables show strong convergence in 18 iterations maximum except qv lev89-85-80, sohefldo, and temp lev80 which show only weak convergence in maximum 19 iterations and temp lev91-90-89-85 which show no convergence because of more unstable behavior after 18h 2nd day, as shown on Fig. 13 for temp lev91.

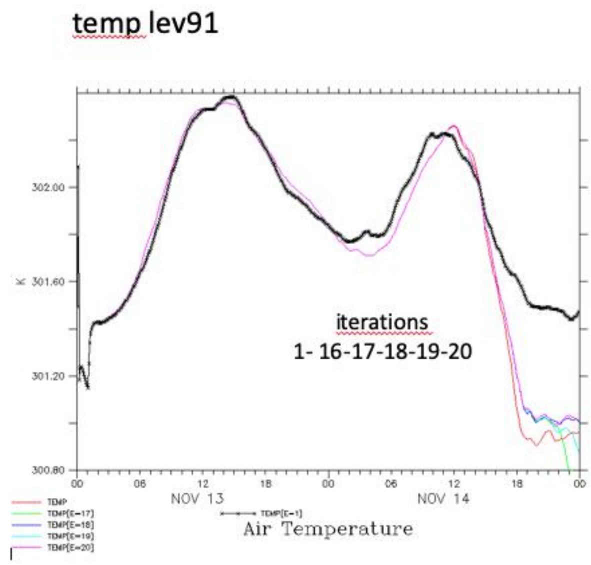


Figure 13 (2-day - 900s): diurnal cycles of temp lev91 for iterations 1 (thick dark) and 16 to 20 (other colored curves); no weak or strong convergence is reached because of unstable behavior after 18h 2nd day.

- Coupling period of 1200s

Schwarz iterations readjust the diurnal cycle for all variables, but for temp lev80 and qv all levels that show no real diurnal cycle. All variables reach strong convergence in 19 iterations maximum but sowaflup which shows only weak convergence in 18 iterations because of more unstable behavior after 18h 2nd day

- Coupling period of 3600s

Schwarz iterations readjust the diurnal cycle for all variables, which all show weak and strong convergence in 17 or less iteration (no exception)

- Coupling period of 3hrs

As for the one-day simulation, Schwarz iterations readjust the diurnal cycles all variables, but for temp lev80 and qv all levels that show no real diurnal cycle. All variables (except vosaline lev8-19 and vozocrtx lev8-19 which converge completely at first iteration) end up oscillating between two states, and for some within the strong (vozocrtx lev1-2-3 in 2 iterations) or weak convergence criteria (votemper lev3-8-19, sohefldo in maximum 7 iterations) or outside the weak and strong convergence criteria. This is shown on Fig.14 for votemper lev1, which does not finally reach either strong or weak convergence because of these two-state oscillations.

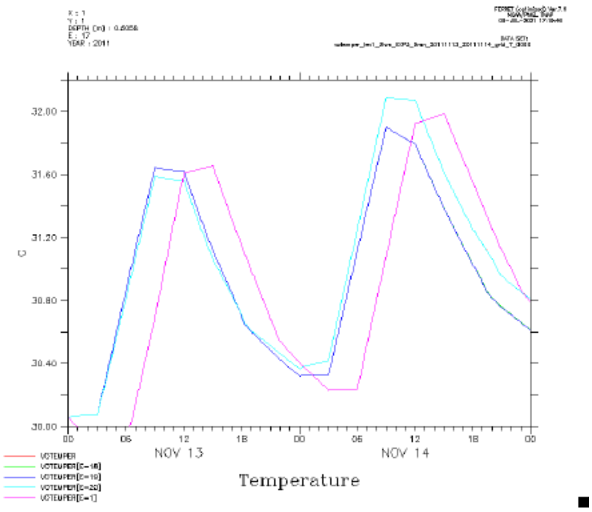


Figure 14 (2-day – 3hrs): diurnal cycles of votemper lev1 for iterations 1 (pink), 17 and 20 (superimposed appearing in light blue) and 18 and 19 (superimposed appearing in dark blue); no weak or strong convergence is reached because of these two-state oscillations.

- Coupling period of 6hrs

The behavior is very similar to the one-day simulation. Schwarz iterations readjust the diurnal cycles for all variables, but for temp lev80 and qv all levels that show no real diurnal cycles. This is shown on Fig.15 for temp lev91 and votemper lev1. All variables (but vosaline lev8-19 and vozocrtx lev8-19 which converge completely at first iteration) end up oscillating quite arbitrarily, either within the strong convergence criterion (vozocrtx lev1-2-3,votemper lev8-19), or within the weak convergence criterion(votemper lev1-2-3, vosaline lev3, sohefldo), or outside both convergence criteria (vosaline lev1&2, sowaflup, temp lev91-90-89-85-80, qv lev 91-90-89-85-80).

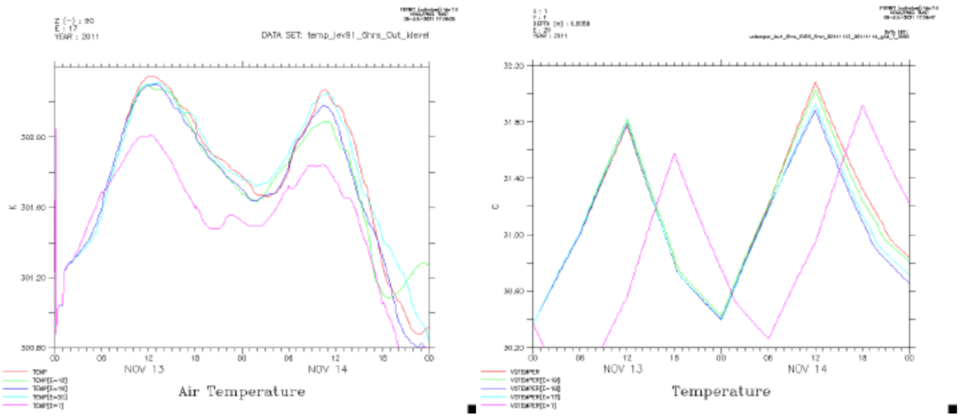


Figure 15 (2-day – 6hrs): diurnal cycles of temp lev91 (left) and votemper lev1 (right) for iterations 1 (pink)and 17-20 (other colored curves); Schwarz iterations readjust the diurnal cycles even if only weak (for votemper lev1) or no convergence (for temp lev91) is reached because of oscillations.

- Coupling period of 12hrs

The behavior is very similar to the one-day simulation. Schwarz iterations readjust the diurnal cycles for all variables but for temp lev80 and qv all levels that show no real diurnal cycle. All variables show strong convergence in maximum 17 iterations (vs 11 for one-day simulation) except for sowaflup, and temp (all levels) and qv (all levels) that reach only weak convergence in 17 iterations maximum.

- Coupling period of 24hrs :

The behavior of the different variables is very hard to characterize: some variables reach the weak or strong convergence criteria but all variables (except vosaline lev19 and vozocrtx lev19 which converge completely at first iteration) keep on oscillating quite arbitrarily (and not between 4 different states as for the one day). This is shown on Fig.16 for votemper lev1, which officially reach the weak convergence criterion in 14 iterations.

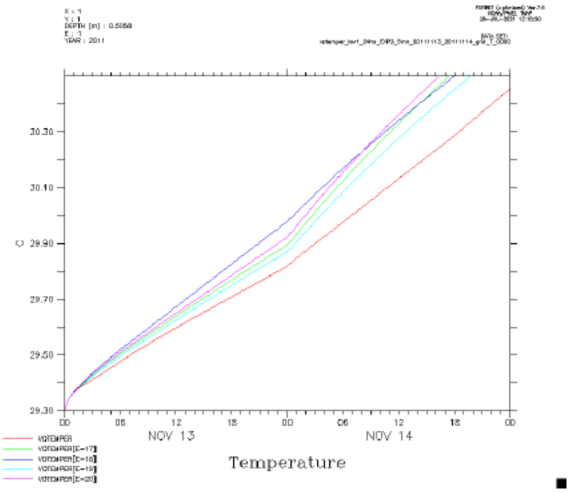


Figure 16 (2-day – 12hrs): diurnal cycles of votemper lev1 for iterations 1 (red) and 17-20 (other colored curves); votemper keeps on oscillating quite arbitrarily even if it officially reach the weak convergence criterion in 14 iterations.

In summary for the two-day November 13th-14th 2011 simulations (EXP3_02j), the behavior is analogous to the one-day simulations except that convergence is always harder to reach and sometimes is never reached. This is most probably because of non-linearities in the model which make convergence harder for a longer Schwarz iteration period.

- For all coupling periods except 24hrs, as for the one-day simulations, Schwarz iterations readjust the diurnal cycle for all variables but for temp lev80 and qv all levels (that show no real diurnal cycle).
- For 300s:
  - sowaflup, temp lev85-80, qv lev85-80 reach weak convergence in maximum 17 iterations
  - all other variables reach strong convergence in maximum 19 iterations
- For 600s: All variables show weak and strong convergence in 16 iterations maximum (no exception).
- For 900s:

- temp lev91-90-89-85 for 900s: no convergence because more unstable behavior after 18h 2nd day
- qv lev89-85-80, sohefldo, and temp lev80 which show only weak convergence in maximum 19 iterations
- All other variables show strong convergence in 18 iterations maximum.

- For 1200s:
  - sowaflup shows only weak convergence in 18 iterations because of more unstable behavior after 18h 2nd day
  - All other variables reach strong convergence in 19 iterations maximum
- For 3600s
  - All variables show strong convergence in 17 or less iteration (no exception)
- For 12hrs:
  - sowaflup, and temp (all levels) and qv (all levels) reach only weak convergence in 17 iterations maximum
  - All other variables show strong convergence in maximum 17 iterations (vs 11 for one-day simulation)
- For 3hrs:
  - vosaline lev8-19 and vozocrtx lev8-19 converge completely at first iteration but all other variables oscillate between two states (as for one-day simulations)
  - vozocrtx lev1-2-3 show strong convergence in 2 iterations
  - votemper lev3-8-19, sohefldo show weak convergence in maximum 7 iterations
  - other variables do not show either weak or strong convergence
- For 6hrs:
  - vosaline lev8-19 and vozocrtx lev8-19 converge completely at first iteration but all other variables end up oscillating quite arbitrarily (as for one-day simulations)
  - vozocrtx lev1-2-3,votemper lev8-19 show strong convergence in respectively 2 and 19 iterations
  - votemper lev1-2-3, vosaline lev3, sohefldo show weak convergence criterion in maximum 19 iterations
  - vosaline lev1&2, sowaflup, temp lev91-90-89-85-80, qv lev 91-90-89-85-80 do not show either weak or strong convergence.
- For 24hrs, the behavior of the different variables is very hard to characterize. Beside vosaline lev19 and vozocrtx lev19 that converge completely at first iteration, variables keep on oscillating quite arbitrarily (and not between 4 different states as for the one day) and for some variables within the weak or strong convergence criteria.

7. Summary and perspectives

The Schwarz experiments performed over one day (Nov 13th 2011) or two days (Nov 13th - 14th) lead us to the following conclusions:

- For coupling periods of 300s, 600s, 900s, 1200s, 3600s, and 12hrs Schwarz iterations succeed in readjusting the diurnal cycle(s) of all variables but for temp lev80 and qv all levels (that show no real diurnal cycles). For one-day simulations, strong convergence is reached for all variables in a maximum of 11 iterations. For two-day simulations, strong or weak convergence is sometimes reached for some variables but is much harder to realize than for one-day simulations because of unstable behavior mostly after 18h on the 2nd day.

- For 3hrs coupling period, Schwarz iterations readjust the diurnal cycles of all variables but for temp lev80 and qv all levels (that show no real diurnal cycles). All variables (except vosaline lev8-19 and vozocrtx lev8-19 that converge completely at first iteration) oscillate between two states and for some within the strong or weak convergence criteria.
- For 6hrs, Schwarz iterations readjust the diurnal cycles of all variables but for temp lev80 and qv all levels (that show no real diurnal cycles). All variables (except vosaline lev8-19 and vozocrtx lev8-19 that converge completely at first iteration) keep on up oscillating quite arbitrarily, and for some within the weak or strong convergence criteria.
- For 24hrs, the behavior of the different variables is very hard to characterize. For one-day simulations, all variables (but vosaline lev19 and vozocrtx lev19 that reach full convergence within one iteration) oscillate between 4 states, and for some within the weak or strong convergence criteria. For two-day simulations, some variables reach the weak or strong convergence criteria but all keep on oscillating quite arbitrarily (and not between 4 states as for the one-day simulations).

Oscillation between 4 states

The figures hereafter show the readjustements of the diurnal cycles obtained with the Schwarz iterations. They show the diurnal cycles for different coupling periods for traditional asynchronous coupling (on the left) and after convergence of Schwarz iterations (on the right) for votemper lev1 (Fig.17) above for the one-day experiment above and below for the two-day experiment), for votemper lev8 (Fig.18) and for temp lev91 (Fig.19)

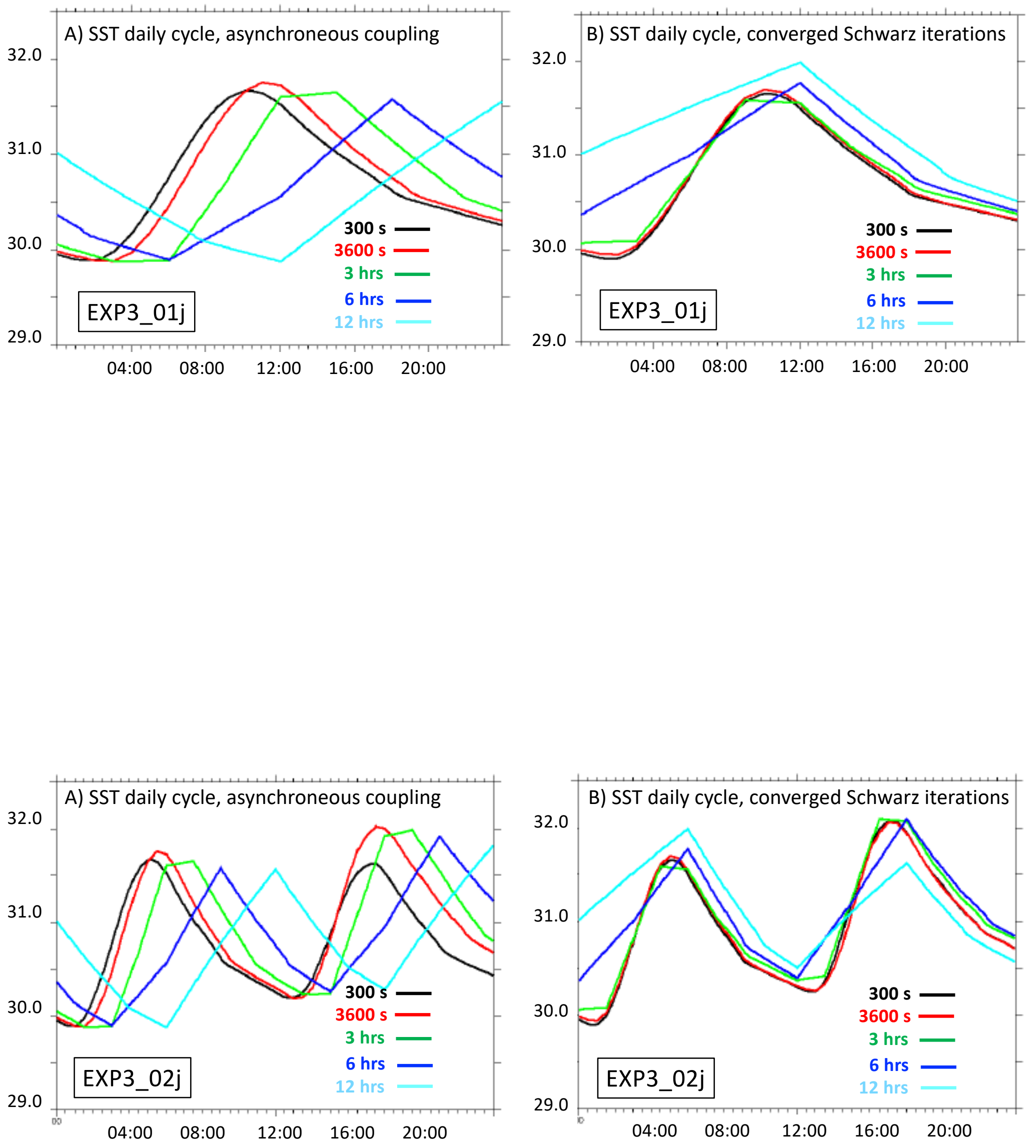


Figure 17: Diurnal cycle for the votemper lev1 (SST) for the one-day simulation (above) and for the two-day simulation (below) for different coupling periods of 300s, 3600s, 3hrs, 6hrs and 12hrs: left-A) traditional asynchronous coupling, right-B) after convergence of Schwarz iterations. For the 3hrs, only one of the two oscillating states is shown.

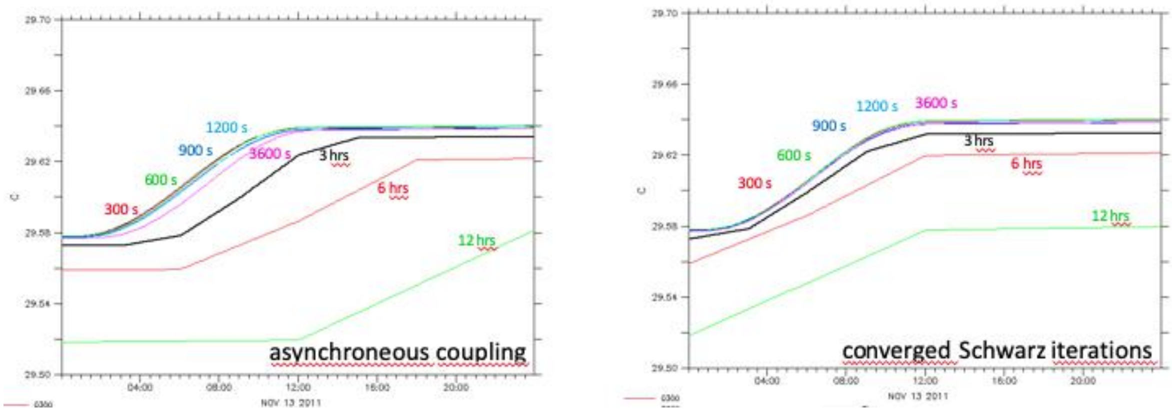


Figure 18: Diurnal cycle for the votemper lev8 for the one-day simulation for different coupling periods of 300s, 3600s, 3hrs, 6hrs and 12hrs: left- traditional asynchronous coupling, right- after convergence of Schwarz iterations. For the 3hrs, only one of the two oscillating states is shown.

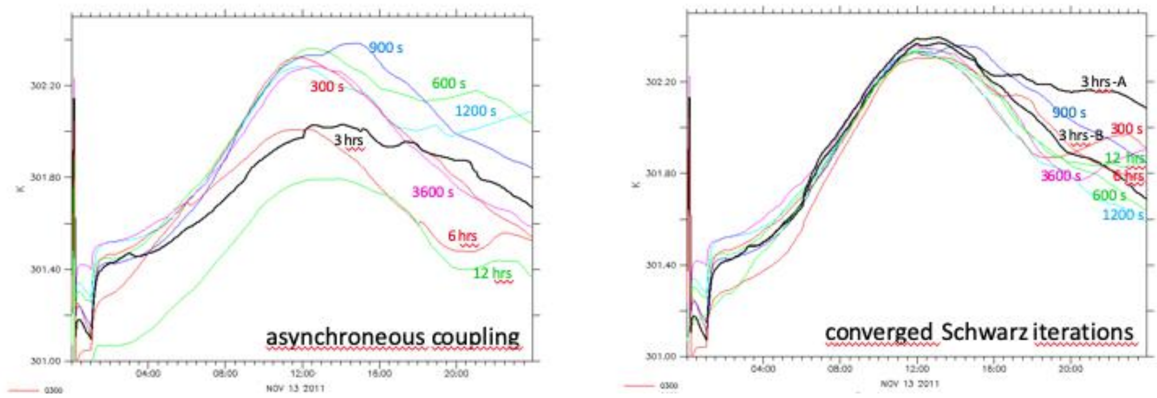


Figure 19: Diurnal cycle for the temp lev91 for the one-day simulation for different coupling periods of 300s, 3600s, 3hrs, 6hrs and 12hrs: left- traditional asynchronous coupling, right- after convergence of Schwarz iterations. For the 3hrs, both oscillating states are shown.

Fig. 17-18-19 show that the coupling period can have a strong impact on asynchronous simulations. This is linked to the fact that the coupling fields used for one coupling period are averaged over the previous coupling period. The longer the coupling period is, the more lagged the diurnal cycle is. For a coupling period of 12 hours, the cycle is even completely inversed. In practice, a coupling period of 12 hours is never used as this would mean that each model uses during the day coupling fields calculated by the other model during the night and vice-versa. As shown on these figures, the Schwarz method is very efficient to reposition the diurnal cycle. It even succeeds in reversing the diurnal cycle obtained for the run with the coupling period of 12 hours.

In our asynchronous coupling, we could use another operator than the average one to define the coupling fields passed from one coupling period to another one. What is mandatory is to conserve the fluxes. We could for example store the value of the coupling fields for each timestep and use the resulting time series for the next coupling period; in that case, the length of the coupling period should have less impact.

The Schwarz iterative method represents an efficient way of correcting the inconsistencies introduced by the asynchronous coupling and obtaining a coherent ocean-atmosphere interface. Schwarz iterations can be considered as a method to provide a clean reference coupled solution that can be used to evaluate the biases of other coupling methods. However, the cost involved is clearly very high for 3D models as applying even only two iterations would double the cost of the simulation. Work is underway to identify subsystem in the models, e.g. only the atmospheric physics and not the whole dynamics, onto which the iterations could be applied, thereby reducing the cost of the method. Another way to accelerate the convergence would be to start iterations with a first-guess closer to the expected converged state; in this respect, we are planning to test the impact of using polynomial extrapolations.

Another perspective is to repeat the experiments but for a relatively wet period of the Cindy Dynamo campaign (e.g. October 15-16 2011) to check the influence of the meteorological state on the convergence of the Schwarz iterations. Finally, we are also planning to set up an experiment involving sea ice at the surface to see how the Schwarz iterations succeed or not in readjusting the diurnal cycle in that more complex case.

Appendix 1 - EXP3_01j convergence table

Cpl	**variable**	**level**	**0.1**	**0.01**		**Cpl**	**variable**	**level**	**0.1**	**0.01**	
300	votemper	lev1	1	7		600	votemper	lev1	1	5	
300	votemper	lev2	1	7		600	votemper	lev2	1	6	
300	votemper	lev3	1	6		600	votemper	lev3	1	4	
300	votemper	lev8	1	2		600	votemper	lev8	1	4	
300	votemper	lev19	1	2		600	votemper	lev19	1	4	
300	vosaline	lev1	7	7		600	vosaline	lev1	6	6	
300	vosaline	lev2	7	7		600	vosaline	lev2	6	6	
300	vosaline	lev3	6	7		600	vosaline	lev3	4	6	
300	vosaline	lev8	1	2		600	vosaline	lev8	1	2	
300	vosaline	lev19	1	1		600	vosaline	lev19	1	1	
300	vozocrtx	lev1	1	1		600	vozocrtx	lev1	1	1	
300	vozocrtx	lev2	1	1		600	vozocrtx	lev2	1	1	
300	vozocrtx	lev3	1	6		600	vozocrtx	lev3	1	1	
300	vozocrtx	lev8	1	1		600	vozocrtx	lev8	1	1	
300	vozocrtx	lev19	1	1		600	vozocrtx	lev19	1	1	
300	sowaflup	lev1	2	8		600	sowaflup	lev1	4	6	
300	sohefldo	lev1	2	7		600	sohefldo	lev1	2	4	
300	temp	lev91	6	8		600	temp	lev91	3	6	
300	temp	lev90	6	8		600	temp	lev90	3	6	
300	temp	lev89	6	8		600	temp	lev89	3	6	
300	temp	lev85	6	8		600	temp	lev85	5	6	
300	temp	lev80	6	8		600	temp	lev80	6	6	
300	qv	lev91	6	8		600	qv	lev91	3	6	
300	qv	lev90	6	8		600	qv	lev90	5	6	
300	qv	lev89	6	8		600	qv	lev89	5	6	
300	qv	lev85	6	8		600	qv	lev85	5	6	
300	qv	lev80	8	8		600	qv	lev80	6	6	

Cpl	variable	level	0.1	0.01		Cpl	variable	level	0.1	0.01	
900	votemper	lev1	1	8		1200	votemper	lev1	1	5	
900	votemper	lev2	6	8		1200	votemper	lev2	3	6	
900	votemper	lev3	1	6		1200	votemper	lev3	1	5	
900	votemper	lev8	1	4		1200	votemper	lev8	1	2	
900	votemper	lev19	1	4		1200	votemper	lev19	1	2	
900	vosaline	lev1	8	8		1200	vosaline	lev1	5	5	
900	vosaline	lev2	8	10		1200	vosaline	lev2	5	6	
900	vosaline	lev3	6	10		1200	vosaline	lev3	5	9	
900	vosaline	lev8	1	1		1200	vosaline	lev8	1	2	
900	vosaline	lev19	1	1		1200	vosaline	lev19	1	1	
900	vozocrtx	lev1	1	1		1200	vozocrtx	lev1	1	1	
900	vozocrtx	lev2	1	1		1200	vozocrtx	lev2	1	1	
900	vozocrtx	lev3	1	1		1200	vozocrtx	lev3	1	1	
900	vozocrtx	lev8	1	1		1200	vozocrtx	lev8	1	1	
900	vozocrtx	lev19	1	1		1200	vozocrtx	lev19	1	1	
900	sowaflup	lev1	2	8		1200	sowaflup	lev1	1	6	
900	sohefldo	lev1	2	8		1200	sohefldo	lev1	2	6	
900	temp	lev91	7	9		1200	temp	lev91	5	9	
900	temp	lev90	7	9		1200	temp	lev90	5	9	
900	temp	lev89	7	9		1200	temp	lev89	5	9	
900	temp	lev85	7	11		1200	temp	lev85	5	9	
900	temp	lev80	9	11		1200	temp	lev80	9	9	
900	qv	lev91	7	9		1200	qv	lev91	5	9	
900	qv	lev90	7	9		1200	qv	lev90	5	9	
900	qv	lev89	7	9		1200	qv	lev89	5	9	
900	qv	lev85	7	11		1200	qv	lev85	5	9	
900	qv	lev80	9	11		1200	qv	lev80	9	9	

Cpl	variable	level	0.1	0.01		Cpl	variable	level	0.1	0.01	
3600	votemper	lev1	2	8		3hrs	votemper	lev1	4	20	
3600	votemper	lev2	2	8		3hrs	votemper	lev2	4	20	
3600	votemper	lev3	2	8		3hrs	votemper	lev3	2	20	
3600	votemper	lev8	2	2		3hrs	votemper	lev8	2	20	
3600	votemper	lev19	2	2		3hrs	votemper	lev19	2	20	
3600	vosaline	lev1	8	8		3hrs	vosaline	lev1	20	20	
3600	vosaline	lev2	8	8		3hrs	vosaline	lev2	20	20	
3600	vosaline	lev3	2	8		3hrs	vosaline	lev3	6	20	
3600	vosaline	lev8	1	2		3hrs	vosaline	lev8	1	1	
3600	vosaline	lev19	1	1		3hrs	vosaline	lev19	1	1	
3600	vozocrtx	lev1	1	3		3hrs	vozocrtx	lev1	1	3	
3600	vozocrtx	lev2	1	2		3hrs	vozocrtx	lev2	1	3	
3600	vozocrtx	lev3	1	1		3hrs	vozocrtx	lev3	1	2	
3600	vozocrtx	lev8	1	1		3hrs	vozocrtx	lev8	1	1	
3600	vozocrtx	lev19	1	1		3hrs	vozocrtx	lev19	1	1	
3600	sowaflup	lev1	4	10		3hrs	sowaflup	lev1	20	20	
3600	sohefldo	lev1	2	8		3hrs	sohefldo	lev1	2	20	
3600	temp	lev91	7	9		3hrs	temp	lev91	19	19	
3600	temp	lev90	7	9		3hrs	temp	lev90	19	19	
3600	temp	lev89	7	9		3hrs	temp	lev89	19	19	
3600	temp	lev85	7	9		3hrs	temp	lev85	19	19	
3600	temp	lev80	7	9		3hrs	temp	lev80	19	19	
3600	qv	lev91	7	7		3hrs	qv	lev91	19	19	
3600	qv	lev90	7	7		3hrs	qv	lev90	19	19	
3600	qv	lev89	7	7		3hrs	qv	lev89	19	19	
3600	qv	lev85	7	7		3hrs	qv	lev85	19	19	
3600	qv	lev80	7	9		3hrs	qv	lev80	19	19	

Cpl	variable	level	0.1	0.01		Cpl	variable	level	0.1	0.01	
6hrs	votemper	lev1	3	20		12hs	votemper	lev1	4	10	
6hrs	votemper	lev2	17	20		12hs	votemper	lev2	4	10	
6hrs	votemper	lev3	2	20		12hs	votemper	lev3	4	6	
6hrs	votemper	lev8	2	20		12hs	votemper	lev8	2	6	
6hrs	votemper	lev19	2	20		12hs	votemper	lev19	2	6	
6hrs	vosaline	lev1	20	20		12hs	vosaline	lev1	10	10	
6hrs	vosaline	lev2	20	20		12hs	vosaline	lev2	10	10	
6hrs	vosaline	lev3	4	20		12hs	vosaline	lev3	4	6	
6hrs	vosaline	lev8	1	1		12hs	vosaline	lev8	1	1	
6hrs	vosaline	lev19	1	1		12hs	vosaline	lev19	1	1	
6hrs	vozocrtx	lev1	3	4		12hs	vozocrtx	lev1	3	4	
6hrs	vozocrtx	lev2	3	4		12hs	vozocrtx	lev2	3	4	
6hrs	vozocrtx	lev3	1	3		12hs	vozocrtx	lev3	3	3	
6hrs	vozocrtx	lev8	1	1		12hs	vozocrtx	lev8	1	1	
6hrs	vozocrtx	lev19	1	1		12hs	vozocrtx	lev19	1	1	
6hrs	sowaflup	lev1	19	20		12hs	sowaflup	lev1	6	12	
6hrs	sohefldo	lev1	2	20		12hs	sohefldo	lev1	2	6	
6hrs	temp	lev91	17	20		12hs	temp	lev91	5	9	
6hrs	temp	lev90	20	20		12hs	temp	lev90	9	11	
6hrs	temp	lev89	20	20		12hs	temp	lev89	9	11	
6hrs	temp	lev85	20	20		12hs	temp	lev85	9	11	
6hrs	temp	lev80	20	20		12hs	temp	lev80	9	11	
6hrs	qv	lev91	20	20		12hs	qv	lev91	7	11	
6hrs	qv	lev90	20	20		12hs	qv	lev90	9	11	
6hrs	qv	lev89	20	20		12hs	qv	lev89	9	11	
6hrs	qv	lev85	20	20		12hs	qv	lev85	9	11	
6hrs	qv	lev80	20	20		12hs	qv	lev80	11	11	

Cpl	variable	level	0.1	0.01
24hs	votemper	lev1	20	20
24hs	votemper	lev2	4	20
24hs	votemper	lev3	2	20
24hs	votemper	lev8	2	2
24hs	votemper	lev19	2	2
24hs	vosaline	lev1	20	20
24hs	vosaline	lev2	20	20
24hs	vosaline	lev3	2	20
24hs	vosaline	lev8	1	20
24hs	vosaline	lev19	1	1
24hs	vozocrtx	lev1	3	3
24hs	vozocrtx	lev2	3	3
24hs	vozocrtx	lev3	3	3
24hs	vozocrtx	lev8	1	1
24hs	vozocrtx	lev19	1	1
24hs	sowaflup	lev1	20	20
24hs	sohefldo	lev1	20	20
24hs	temp	lev91	20	20
24hs	temp	lev90	20	20
24hs	temp	lev89	20	20
24hs	temp	lev85	20	20
24hs	temp	lev80	20	20
24hs	qv	lev91	20	20
24hs	qv	lev90	20	20
24hs	qv	lev89	20	20
24hs	qv	lev85	20	20
24hs	qv	lev80	20	20

Appendix 2 - EXP3_02j convergence table

Cpl	**variable**	**level**	**0.1**	**0.01**		**Cpl**	**variable**	**level**	**0.1**	**0.01**	
300	votemper	lev1	9	17		600	votemper	lev1	4	14	
300	votemper	lev2	9	19		600	votemper	lev2	4	14	
300	votemper	lev3	7	15		600	votemper	lev3	1	10	
300	votemper	lev8	7	15		600	votemper	lev8	1	10	
300	votemper	lev19	7	15		600	votemper	lev19	1	10	
300	vosaline	lev1	17	17		600	vosaline	lev1	14	16	
300	vosaline	lev2	17	17		600	vosaline	lev2	14	16	
300	vosaline	lev3	7	15		600	vosaline	lev3	4	14	
300	vosaline	lev8	1	1		600	vosaline	lev8	1	1	
300	vosaline	lev19	1	1		600	vosaline	lev19	1	1	
300	vozocrtx	lev1	1	1		600	vozocrtx	lev1	1	1	
300	vozocrtx	lev2	1	1		600	vozocrtx	lev2	1	1	
300	vozocrtx	lev3	1	1		600	vozocrtx	lev3	1	4	
300	vozocrtx	lev8	1	1		600	vozocrtx	lev8	1	1	
300	vozocrtx	lev19	1	1		600	vozocrtx	lev19	1	1	
300	sowaflup	lev1	17	20		600	sowaflup	lev1	16	16	
300	sohefldo	lev1	12	19		600	sohefldo	lev1	10	14	
300	temp	lev91	14	18		600	temp	lev91	13	15	
300	temp	lev90	14	18		600	temp	lev90	13	15	
300	temp	lev89	14	18		600	temp	lev89	13	15	
300	temp	lev85	14	20		600	temp	lev85	13	15	
300	temp	lev80	16	20		600	temp	lev80	13	15	
300	qv	lev91	14	16		600	qv	lev91	13	15	
300	qv	lev90	14	18		600	qv	lev90	13	15	
300	qv	lev89	14	18		600	qv	lev89	13	15	
300	qv	lev85	14	20		600	qv	lev85	13	15	
300	qv	lev80	16	20		600	qv	lev80	14	15	

Cpl	variable	level	0.1	0.01		Cpl	variable	level	0.1	0.01	
900	votemper	lev1	6	18		1200	votemper	lev1	10	14	
900	votemper	lev2	6	18		1200	votemper	lev2	10	14	
900	votemper	lev3	6	14		1200	votemper	lev3	6	10	
900	votemper	lev8	1	14		1200	votemper	lev8	6	10	
900	votemper	lev19	1	14		1200	votemper	lev19	6	10	
900	vosaline	lev1	14	18		1200	vosaline	lev1	10	18	
900	vosaline	lev2	18	18		1200	vosaline	lev2	10	18	
900	vosaline	lev3	7	10		1200	vosaline	lev3	6	10	
900	vosaline	lev8	1	1		1200	vosaline	lev8	1	1	
900	vosaline	lev19	1	1		1200	vosaline	lev19	1	1	
900	vozocrtx	lev1	1	1		1200	vozocrtx	lev1	1	1	
900	vozocrtx	lev2	1	1		1200	vozocrtx	lev2	1	1	
900	vozocrtx	lev3	1	6		1200	vozocrtx	lev3	1	3	
900	vozocrtx	lev8	1	1		1200	vozocrtx	lev8	1	1	
900	vozocrtx	lev19	1	1		1200	vozocrtx	lev19	1	1	
900	sowaflup	lev1	20	20		1200	sowaflup	lev1	18	20	
900	sohefldo	lev1	10	20		1200	sohefldo	lev1	10	16	
900	temp	lev91	20	20		1200	temp	lev91	16	17	
900	temp	lev90	20	20		1200	temp	lev90	16	17	
900	temp	lev89	20	20		1200	temp	lev89	16	17	
900	temp	lev85	20	20		1200	temp	lev85	13	17	
900	temp	lev80	17	20		1200	temp	lev80	17	19	
900	qv	lev91	17	19		1200	qv	lev91	11	17	
900	qv	lev90	17	19		1200	qv	lev90	11	17	
900	qv	lev89	17	20		1200	qv	lev89	11	17	
900	qv	lev85	17	20		1200	qv	lev85	11	17	
900	qv	lev80	19	20		1200	qv	lev80	17	17	

Cpl	variable	level	0.1	0.01		Cpl	variable	level	0.1	0.01
3600	votemper	lev1	8	15		3hrs	votemper	lev1	20	20
3600	votemper	lev2	8	15		3hrs	votemper	lev2	20	20
3600	votemper	lev3	1	14		3hrs	votemper	lev3	5	20
3600	votemper	lev8	1	8		3hrs	votemper	lev8	2	20
3600	votemper	lev19	1	8		3hrs	votemper	lev19	2	20
3600	vosaline	lev1	15	16		3hrs	vosaline	lev1	20	20
3600	vosaline	lev2	16	16		3hrs	vosaline	lev2	20	20
3600	vosaline	lev3	8	10		3hrs	vosaline	lev3	20	20
3600	vosaline	lev8	1	2		3hrs	vosaline	lev8	1	1
3600	vosaline	lev19	1	1		3hrs	vosaline	lev19	1	1
3600	vozocrtx	lev1	1	1		3hrs	vozocrtx	lev1	1	2
3600	vozocrtx	lev2	1	1		3hrs	vozocrtx	lev2	1	2
3600	vozocrtx	lev3	1	8		3hrs	vozocrtx	lev3	1	2
3600	vozocrtx	lev8	1	1		3hrs	vozocrtx	lev8	1	1
3600	vozocrtx	lev19	1	1		3hrs	vozocrtx	lev19	1	1
3600	sowaflup	lev1	15	19		3hrs	sowaflup	lev1	20	20
3600	sohefldo	lev1	8	16		3hrs	sohefldo	lev1	7	20
3600	temp	lev91	13	17		3hrs	temp	lev91	19	20
3600	temp	lev90	13	17		3hrs	temp	lev90	19	20
3600	temp	lev89	13	17		3hrs	temp	lev89	19	20
3600	temp	lev85	13	17		3hrs	temp	lev85	19	20
3600	temp	lev80	15	17		3hrs	temp	lev80	19	20
3600	qv	lev91	13	15		3hrs	qv	lev91	19	19
3600	qv	lev90	13	17		3hrs	qv	lev90	19	19
3600	qv	lev89	13	17		3hrs	qv	lev89	19	19
3600	qv	lev85	13	17		3hrs	qv	lev85	19	19
3600	qv	lev80	15	17		3hrs	qv	lev80	19	20

Cpl	variable	level	0.1	0.01		Cpl	variable	level	0.1	0.01	
6hrs	votemper	lev1	7	20		12hs	votemper	lev1	10	17	
6hrs	votemper	lev2	19	20		12hs	votemper	lev2	10	17	
6hrs	votemper	lev3	3	20		12hs	votemper	lev3	10	10	
6hrs	votemper	lev8	2	19		12hs	votemper	lev8	10	12	
6hrs	votemper	lev19	2	19		12hs	votemper	lev19	9	12	
6hrs	vosaline	lev1	20	20		12hs	vosaline	lev1	17	17	
6hrs	vosaline	lev2	20	20		12hs	vosaline	lev2	17	17	
6hrs	vosaline	lev3	4	20		12hs	vosaline	lev3	4	12	
6hrs	vosaline	lev8	1	1		12hs	vosaline	lev8	1	1	
6hrs	vosaline	lev19	1	1		12hs	vosaline	lev19	1	1	
6hrs	vozocrtx	lev1	1	2		12hs	vozocrtx	lev1	1	3	
6hrs	vozocrtx	lev2	1	2		12hs	vozocrtx	lev2	1	3	
6hrs	vozocrtx	lev3	1	2		12hs	vozocrtx	lev3	1	2	
6hrs	vozocrtx	lev8	1	1		12hs	vozocrtx	lev8	1	1	
6hrs	vozocrtx	lev19	1	1		12hs	vozocrtx	lev19	1	1	
6hrs	sowaflup	lev1	20	20		12hs	sowaflup	lev1	17	20	
6hrs	sohefldo	lev1	5	20		12hs	sohefldo	lev1	10	12	
6hrs	temp	lev91	20	20		12hs	temp	lev91	16	20	
6hrs	temp	lev90	20	20		12hs	temp	lev90	16	20	
6hrs	temp	lev89	20	20		12hs	temp	lev89	16	20	
6hrs	temp	lev85	20	20		12hs	temp	lev85	16	20	
6hrs	temp	lev80	20	20		12hs	temp	lev80	16	20	
6hrs	qv	lev91	20	20		12hs	qv	lev91	15	20	
6hrs	qv	lev90	20	20		12hs	qv	lev90	16	20	
6hrs	qv	lev89	20	20		12hs	qv	lev89	16	20	
6hrs	qv	lev85	20	20		12hs	qv	lev85	16	20	
6hrs	qv	lev80	20	20		12hs	qv	lev80	16	20	

Cpl	**variable**	**level**	**0.1**	**0.01**
24hs	votemper	lev1	14	20
24hs	votemper	lev2	2	20
24hs	votemper	lev3	1	20
24hs	votemper	lev8	1	18
24hs	votemper	lev19	1	18
24hs	vosaline	lev1	20	20
24hs	vosaline	lev2	14	20
24hs	vosaline	lev3	2	20
24hs	vosaline	lev8	1	19
24hs	vosaline	lev19	1	1
24hs	vozocrtx	lev1	1	3
24hs	vozocrtx	lev2	1	3
24hs	vozocrtx	lev3	1	3
24hs	vozocrtx	lev8	1	1
24hs	vozocrtx	lev19	1	1
24hs	sowaflup	lev1	20	20
24hs	sohefldo	lev1	20	20
24hs	temp	lev91	20	20
24hs	temp	lev90	20	20
24hs	temp	lev89	20	20
24hs	temp	lev85	20	20
24hs	temp	lev80	20	20
24hs	qv	lev91	20	20
24hs	qv	lev90	20	20
24hs	qv	lev89	20	20
24hs	qv	lev85	20	20
24hs	qv	lev80	20	20

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