

Outline

- The open boundaries problem
- OBC (open boundary conditions) algorithm
- Toward open boundary control
- A toy model for developing with OBCs
- Current achievements
- Problems
- Conclusions

The open boundary problem in regional configurations

- Regional configurations are widely used
 - Open BCs are extracted from model runs with greater domain (global e.g.)
 - Interior solution extremely sensitive to OBCs
 - Exact compatibility between forcings and OBCs is not ensured
 - Even in the « most friendly » regional model, we will not feed the zoom with OBCs at each time step (usually 5d means)
 - Typically, we also add modifications in the forcing routines, or use a more recent forcing set than used in the global run, where we get our OBCs
 - Critical situation may occur in the vicinity of open boundaries. Reflection of incident patterns (not present in OBC data).
 - → OBC may need special handling : either specified (Fixed BC), or radiation algorithm (Orlanski)
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Toward open boundary control

- High sensitivity → optimization, control the OBC fields
- Use an augmented control vector : $J(x_0, b_0, b_1, \dots, b_n)$ where $b=(T,S,U,V)$ along the OBC, e.g. 5d means
- No theoretical difficulty with the FBC algorithm
- Indeed, OBC control (FBC) already investigated with T,S (Ph. D.)
- But radiation algorithm is really needed in the direct model

- Orlanski (1976)

$$\frac{\partial \phi}{\partial t} + c_\varphi \frac{\partial \phi}{\partial x} = \frac{\phi^c - \phi}{\tau}$$

$$\frac{\phi_b^{n+1} - \phi_b^{n-1}}{2 \delta t} + c_\varphi \frac{\phi_b^{n-1} + \phi_b^{n+1} - 2\phi_b^n}{2 \delta x} = \frac{1}{\tau} (\phi^c - \phi)_b^{n-1}$$

$$c_\varphi < 0 \Rightarrow c_\varphi := 0$$

$$c_\varphi > 1 \Rightarrow c_\varphi := 1$$

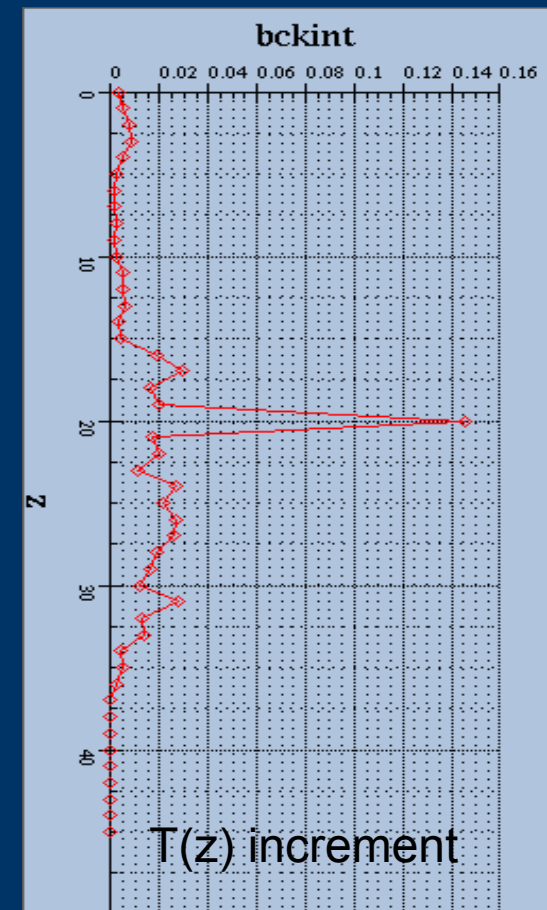
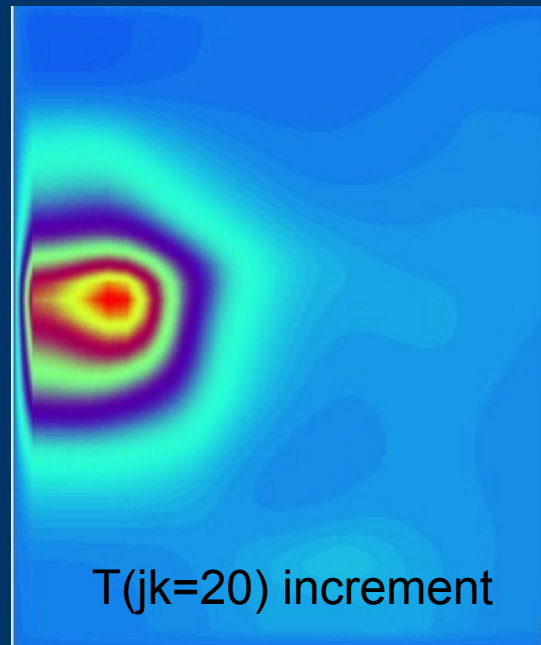
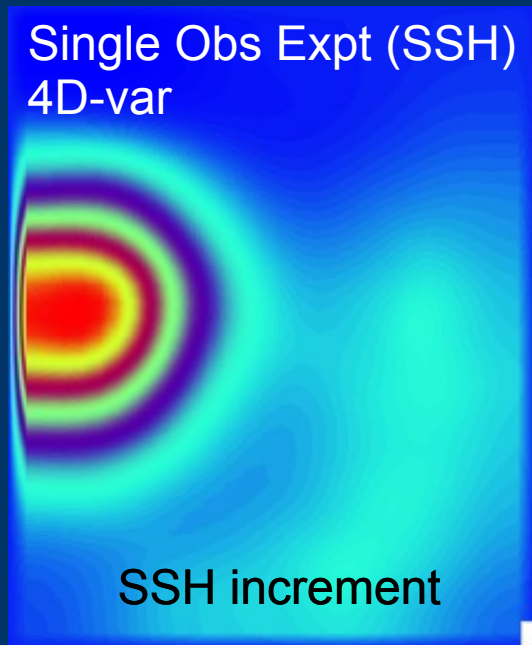
- Threshold process : not differentiable. Regularization needed ?
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A toy model for developing with OBCs

- POMME configuration
- Extracted from DRAKKAR $\frac{1}{4}^\circ$
- Small domain 30 x 40 x 46
- Easy to run on a laptop
- Created to easily and systematically test any new OBC developments in the direct model
- See SSH animation

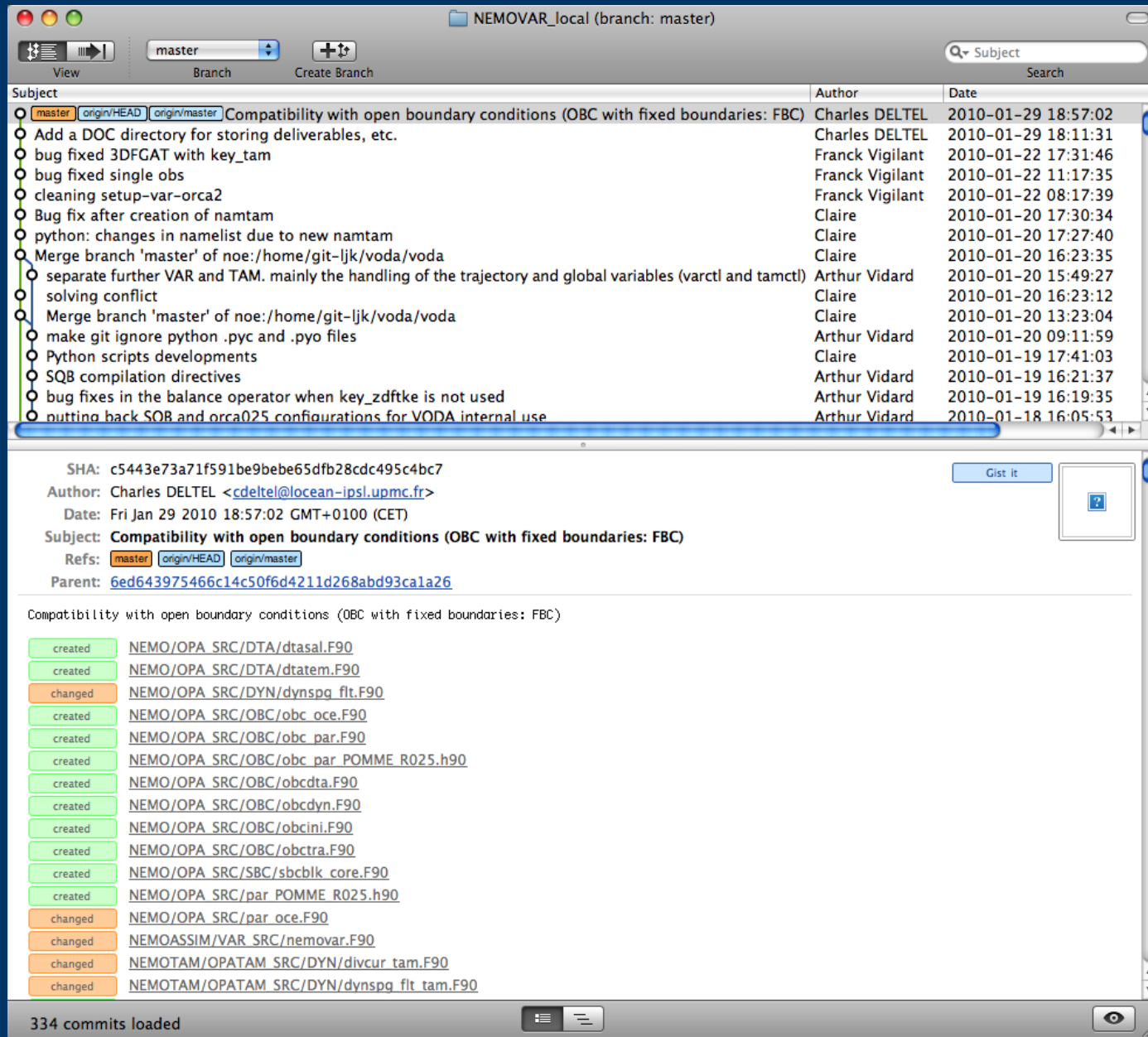
Current achievements and plans

- Steps to control OBCs
- 1) make the current VODA code compatible with FBC
- 2) add OBC input fields in the control vector
- 3) try to linearize the radiation algorithm?
- Step 1 is achieved.



Current achievements and plans

- The code modifications were pushed on the Git deposit



The screenshot displays a Git GUI window for the repository 'NEMOVAR_local (branch: master)'. The top bar shows the current branch 'master' and a search field for 'Subject'. Below this is a commit history table with columns for Subject, Author, and Date. The most recent commit is highlighted in blue.

Subject	Author	Date
Compatibility with open boundary conditions (OBC with fixed boundaries: FBC)	Charles DELTEL	2010-01-29 18:57:02
Add a DOC directory for storing deliverables, etc.	Charles DELTEL	2010-01-29 18:11:31
bug fixed 3DFGAT with key_tam	Franck Vigilant	2010-01-22 17:31:46
bug fixed single obs	Franck Vigilant	2010-01-22 11:17:35
cleaning setup-var-orca2	Franck Vigilant	2010-01-22 08:17:39
Bug fix after creation of namtam	Claire	2010-01-20 17:30:34
python: changes in namelist due to new namtam	Claire	2010-01-20 17:27:40
Merge branch 'master' of noe:/home/git-ljk/voda/voda	Claire	2010-01-20 16:23:35
separate further VAR and TAM. mainly the handling of the trajectory and global variables (varctl and tamctl)	Arthur Vidard	2010-01-20 15:49:27
solving conflict	Claire	2010-01-20 16:23:12
Merge branch 'master' of noe:/home/git-ljk/voda/voda	Claire	2010-01-20 13:23:04
make git ignore python .pyc and .pyo files	Arthur Vidard	2010-01-20 09:11:59
Python scripts developments	Claire	2010-01-19 17:41:03
SQB compilation directives	Arthur Vidard	2010-01-19 16:21:37
bug fixes in the balance operator when key_zdfcke is not used	Arthur Vidard	2010-01-19 16:19:35
putting back SOB and orca025 configurations for VODA internal use	Arthur Vidard	2010-01-18 16:05:53

Below the commit history, the details for the selected commit are shown:

SHA: c5443e73a71f591be9bbe65dfb28cdc495c4bc7
Author: Charles DELTEL <cdeltel@locean-ipsi.upmc.fr>
Date: Fri Jan 29 2010 18:57:02 GMT+0100 (CET)
Subject: Compatibility with open boundary conditions (OBC with fixed boundaries: FBC)
Refs: master origin/HEAD origin/master
Parent: 6ed643975466c14c50f6d4211d268abd93ca1a26

The commit message is 'Compatibility with open boundary conditions (OBC with fixed boundaries: FBC)'. Below this, a list of files is shown with their status (created or changed):

- created NEMO/OPA_SRC/DTA/dtasal.F90
- created NEMO/OPA_SRC/DTA/dtatem.F90
- changed NEMO/OPA_SRC/DYN/dynspg_ft.F90
- created NEMO/OPA_SRC/OBC/obc_oce.F90
- created NEMO/OPA_SRC/OBC/obc_par.F90
- created NEMO/OPA_SRC/OBC/obc_par_POMME_R025.h90
- created NEMO/OPA_SRC/OBC/obcdta.F90
- created NEMO/OPA_SRC/OBC/obcdyn.F90
- created NEMO/OPA_SRC/OBC/obcini.F90
- created NEMO/OPA_SRC/OBC/obctra.F90
- created NEMO/OPA_SRC/SBC/sbcblk_core.F90
- created NEMO/OPA_SRC/par_POMME_R025.h90
- changed NEMO/OPA_SRC/par_oce.F90
- changed NEMOASSIM/VAR_SRC/nemovar.F90
- changed NEMOTAM/OPATAM_SRC/DYN/divcur_tam.F90
- changed NEMOTAM/OPATAM_SRC/DYN/dynspg_ft_tam.F90

At the bottom of the window, it indicates '334 commits loaded'.

Current problems : need to test the tangent model

- Only short integrations so far (nitend=12)
- Code explosion with nitend>20, too large T increment
- Critical need to perform the tangent test

Current problems : test of the adjoint model

nitend=24

step_adj	U	.932335816868493E+17	.932335816868494E+17	.7E-15	.2E-15	warning
step_adj	V	.144055274542092E+18	.144055274542092E+18	.0E+00	.2E-15	ok
step_adj	T	.639133479472924E+15	.639133479472926E+15	.4E-14	.2E-15	warning
step_adj	S	.500271388844845E+14	.500271388844845E+14	.5E-15	.2E-15	warning
step_adj	SSH	.132634135356967E+09	.132634135356967E+09	.2E-14	.2E-15	warning
step_adj		.312025246631010E+18	.312025246631010E+18	.2E-15	.2E-15	ok

nitend=60

step_adj	U	.298046138117555E+25	.298046138117555E+25	.1E-14	.2E-15	warning
step_adj	V	.659171061128407E+25	.659171061128406E+25	.2E-14	.2E-15	warning
step_adj	T	.860170278845919E+22	.860170278845918E+22	.7E-15	.2E-15	warning
step_adj	S	.112156201225269E+22	.112156201225269E+22	.2E-14	.2E-15	warning
step_adj	SSH	.403591001548226E+13	.403591001548627E+13	.1E-11	.2E-15	RED ALERT <== but no red

alert in individual adj tests, so need further investigation

step_adj		.126166969812007E+26	.126166969812007E+26	.1E-14	.2E-15	warning
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Current problems : gradient test

- ln_tst_grad : explosion (temperatures > 2000K after 5 time steps)
- Who can explain me this test?

nemovar_inner_loop: Test the cost and gradient

Final cost_sim	=	.274921914355210E-01
Final cost_min	=	*****
Final gradient_sim norm	=	.669186599399976E-01
Final gradient_min norm	=	.192663968401696E-06
Ratio final cost_sim / initial cost_sim	=	.549843828710420E-01
Ratio final cost_min / initial cost_sim	=	*****
Ratio final grad_min norm / initial grad_sim norm	=	.147557167051508E-01
Ratio final grad_sim norm / initial grad_norm_sim	=	.424828431946279E-07
Error cost_min - cost_sim	=	.354063151373000E-01
Norm grad_min - grad_sim	=	.669186610911984E-01
Relative error cost_min - cost_sim / (1 + cost_sim)	=	.344589627370632E-01
Relative error grad_min - grad_sim / (1 + grad_sim)	=	.627214272313523E-01



Current problems : adjoint of the bkg error operator

- `ln_tst = .TRUE., ln_tst_obsadj = .TRUE., ln_tst_bkgadj = .TRUE.`

---> Test of the adjoint of the background error operator NOT OK

<code>bkg_corsqradj</code>		<code>.101818464585847E+17</code>	<code>.101818464585847E+17</code>	<code>.0E+00</code>	<code>.2E-15</code>	<code>ok</code>	<code><=== ?</code>
<code>balsaladj</code>		<code>.266669065028346E+15</code>	<code>.266669065028346E+15</code>	<code>.0E+00</code>	<code>.2E-15</code>	<code>ok</code>	
<code>balsshadj</code>	<code>T1</code>	<code>.770379297854979E+08</code>	<code>.770379297854979E+08</code>	<code>.0E+00</code>	<code>.2E-15</code>	<code>ok</code>	
<code>balsshadj</code>	<code>T2</code>	<code>.883531815854152E+08</code>	<code>.883531815854152E+08</code>	<code>.0E+00</code>	<code>.2E-15</code>	<code>ok</code>	
<code>balsshadj</code>	<code>T3</code>	<code>.238445501461891E+10</code>	<code>.238445501461891E+10</code>	<code>.0E+00</code>	<code>.2E-15</code>	<code>ok</code>	
<code>balsshadj</code>	<code>T4</code>	<code>.276044280253746E+10</code>	<code>.276044280253746E+10</code>	<code>.9E-15</code>	<code>.2E-15</code>	<code>warning</code>	
<code>balveladj</code>	<code>T1</code>	<code>.200179383193915E+08</code>	<code>.151290161853127E+09</code>	<code>.7E+01</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>
<code>balveladj</code>	<code>T2</code>	<code>.163188456024795E+13</code>	<code>.163188456024795E+13</code>	<code>.0E+00</code>	<code>.2E-15</code>	<code>ok</code>	
<code>balveladj</code>	<code>T3</code>	<code>.151217842864538E+13</code>	<code>.137812585334072E+13</code>	<code>.9E-01</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>
<code>baloptadj</code>	<code>T1</code>	<code>.898244845780251E+16</code>	<code>.898244851190986E+16</code>	<code>.6E-08</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>
<code>baloptadj</code>	<code>T2</code>	<code>.947427476040600E+16</code>	<code>.947427484930405E+16</code>	<code>.9E-08</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>
<code>baloptadj</code>	<code>T3</code>	<code>.947573630592248E+16</code>	<code>.947627424196151E+16</code>	<code>.6E-04</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>
<code>baloptadj</code>	<code>T4</code>	<code>.946982690244808E+16</code>	<code>.946931577532252E+16</code>	<code>.5E-04</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>
<code>baloptadj</code>	<code>T5</code>	<code>.951715937166968E+16</code>	<code>.951783144606189E+16</code>	<code>.7E-04</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>
<code>bkg_covsqradj</code>		<code>.816512705214658E+17</code>	<code>.816510315779494E+17</code>	<code>.3E-05</code>	<code>.2E-15</code>	<code>warning</code>	<code><=== ?</code>

- This is similar to GYRE results, so we have a problem somewhere...

- `nubvel` : it would be useful to deactivate the geotrophic balance operator

Current problems : adjoint of the observation error operator

```
dia_obs_adj T1          No T profile observations
dia_obs_adj T2          No S profile observations
dia_obs_adj T3 .241025997665554E-01 .241025997665554E-01 .0E+00 .2E-15 ok
dia_obs_adj T4          No SST observations
dia_obs_adj T5 .797118123287599E-01 .797118123287599E-01 .0E+00 .2E-15 ok
```



Current problems : convergence aspects

```
cat cost_diag_01_0000
 1  1  0  0.0000E+00  0.5000E+00  0.0000E+00  0.5000E+00
 1  2  1  0.2493E-01 -0.3131E-01  0.0000E+00 -0.6378E-02  <== NEGATIVE cost ??
 1  3  2  0.2663E-01 -0.3454E-01  0.0000E+00 -0.7914E-02
 1  4  3  0.2663E-01 -0.3454E-01  0.0000E+00 -0.7914E-02
 1  5  3  0.2663E-01  0.8616E-03  0.0000E+00  0.2749E-01  <== what is it?

cat grad_diag_01_0000
 1  1  0  0.6774E-04  0.2342E-03  0.5579E+01  0.1499E+02  0.3786E-03  0.2057E+02
 1  2  1  0.7495E-06  0.4090E-06  0.6696E-03  0.2387E-02  0.4929E-06  0.3058E-02
 1  3  2  0.5556E-09  0.1320E-09  0.6930E-07  0.1877E-06  0.2654E-09  0.2580E-06
 1  4  3  0.2681E-16  0.5081E-17  0.9096E-14  0.2797E-13  0.1874E-16  0.3712E-13  <==
convergence reached (zero gradient slope)
 1  5  3  0.8645E-06  0.5044E-06  0.9014E-03  0.3575E-02  0.5835E-06  0.4478E-02
```

Conclusions

- Interesting preliminary results
 - Still some bugs
 - Next steps
 - Finalize current version (debug...)
 - Parallelisation (MPI)
 - Apply to real data assimilation (not only single observation)
 - Add the OBC input fields time series in the control vector
 - And then : how should we handle the radiation algorithm?
 - Next generation OBC algorithm (method of characteristics, barotropic forcing [Flather], etc.)
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Discussion points

- Systematic validation of new developments against e.g. 3 reference versions: ORCA2, GYRE, POMME. This would ensure that new developments (performed on one given configuration) will not break previously working status.
 - Git deposit on `forge.ipsl.jussieu.fr` (same server as NEMO reference code) for private use inside the VODA project
 - ```
git clone
cdlod@forge.ipsl.jussieu.fr:/ipsl/forge/projets/voda/git/nemovar.git
NEMOVAR_new
```
  - We would like to make a 1st release of NEMOTAM on the reference NEMO subversion server
  - Need to isolate NEMOTAM, and its validation interface.
  - Need for a realistic demonstrator? (singular vectors, etc.)
  - NEMOTAM reference manual (on the NEMO wiki)
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