Chapter 16

Open boundary conditions

This chapter deals with the setup of the open boundary conditions for the 2-D and 3-D mode. The following routines, located in *Usrdef_Model.90*, are discussed in the next four sections:

- usrdef_2dobc_spec: specifies the type of conditions for the 2-D mode
- usrdef_2dobc_data: defines the input of open boundary data for the 2-D mode
- usrdef_profobc_spec: specifies the type of conditions for the 3-D mode
- usrdef_profobc_data: defines the input of open boundary data for the 3-D currents and scalars
- usrdef_rlxobc_spec: setup for applying the relaxation open boundary scheme

16.1 2-D mode

16.1.1 Open boundary specifiers for the 2-D mode

The routine usrdef_2dobc_spec is called if iopt_obc_2D=1 and modfiles(io_2uvobc,1,1)%status='N'. Important to note is that the file index for open boundary specifiers is 1. The open boundary data itself are defined in files whose attributes are stored in modfiles(io_2uvobc,ifil,1) where ifil takes values of 2 upto nofiles. The number of associated data files is therefore given by nofiles-1.

External (specified) values for U, V or ζ are written in the general form (4.354). The first part ψ_0^e must be defined in usrdef_2dobc_data, usually as time series input from a data file. The amplitudes A_n and phases φ_n are time-independent and must be defined in usrdef_2dobc_spec together with the arrays discussed below.

16.1.1.1 general specifiers

ityp2dobu(nobu) Type of open boundary condition at U-nodes. See Section 4.10.1 for details (0).

- 0 : clamped
- 1 : zero slope
- 2 : zero volume flux
- 3 : specified elevation
- 4 : specified transport
- 5 : radiation condition using shallow water speed
- 6 : Orlanski (1976) condition
- 7 : Camerlengo & O'Brien (1980)
- 8 : Flather (1976) with specified elevation and transport
- 9 : Flather with specified elevation
- 10: Røed & Smedstad (1984)
- 11: characteristic method with specified elevation and transport
- 12: characteristic method with specified elevation
- 13: characteristic method using a zero normal gradient condition

ityp2dobv(nobv) Type of open boundary condition at V-nodes. Meaning is the same as above with U replaced by V and West/East by South/North (0).

iloczobu(nobu) If the elevation has to be specified at the open boundary, the array selects the position of the specified elevation with respect to the open boundary.

- 0: not required
- 1: at the open boundary U-node
- 2: at the "nearest" C-node outside the domain

iloczobv(nobv) As previous now for V-node open boundary points.

itypintobu(nobu) Disables/enables advection of momentum next to U-open boundaries if iopt_obc_int=1 (0/1).

itypintobv(nobv) Disables/enables advection of momentum next to V-open boundaries if iopt_obc_int=1 (0/1).

16.1.1.2 specifiers for the data files

no2dobc(2:nofiles) number of data locations within each data file

iobc2dtype(2:nofiles) identifies the variables within the data file

1: depth-integrated currents and elevations

2: elevations only

3: depth-integrated currents only

index2dobc(nobu+nobv,2:nofiles) Each data file contains a sub-set of open boundary data points. The element index2dobc(idat,ifil) maps, for file ifil, the local data point idat into a corresponding global open boundary index (between 1:nobu for U- and nobu+1:nobu+nobv for V-open boundaries). The physical size of the first dimension for file ifil equals no2dobc(ifil).

The procedure is illustrated in Figure 16.1. The filled circles represent open boundary points. The data are spread over 4 data files. The number in parentheses denotes the number of the data file (between 2 and 5), the second number to the right the open boundary index ranging from 1 to nobu at U-nodes and nobu+1 to nobu+nobv at V-nodes. In the example, nobu=11 and nobv=8. Each file contains data for the following points:

- ifil=2: data at (U-)o.b. points 1 to 8
- ifil=3: data at (U-)o.b. points 9 to 11
- ifil=4: data at (V-)o.b. points 12 to 14
- ifil=5: data at (V-)o.b. points 15 to 18
- ifil=6: data at (V-)o.b. point 19

The definitions in FORTRAN code are:

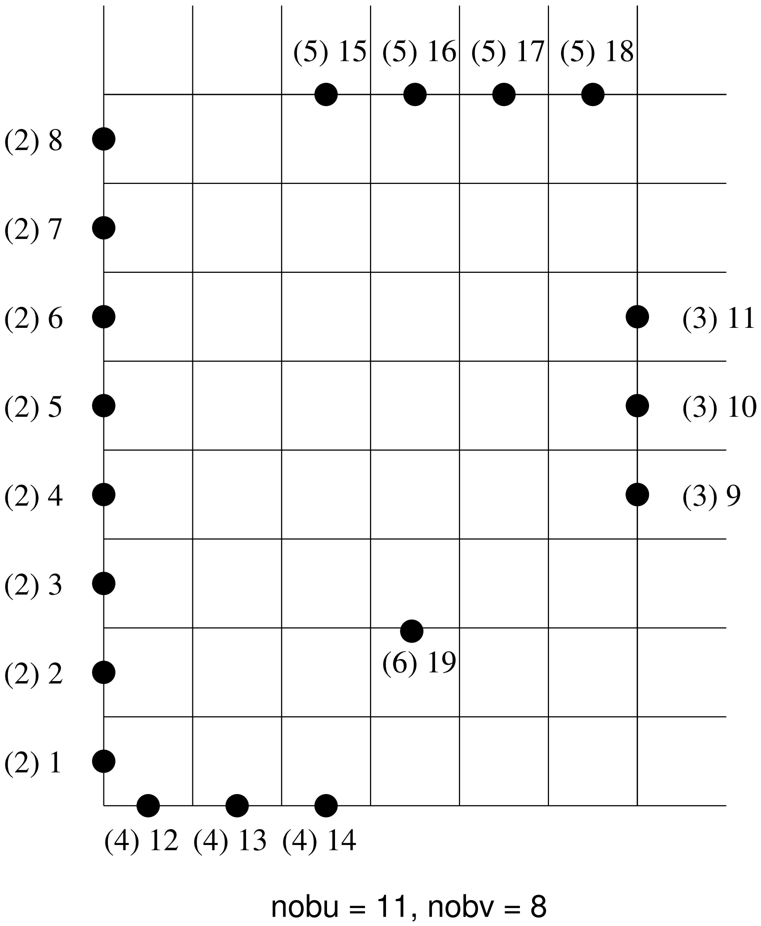

Figure 16.1: Example showing how to define the arrays no2dobc and index2dobc.

```
nofiles = 6
no2dobc = (/8,3,3,4,1/)
index2dobc(1:8,2) = (/1,2,3,4,5,6,7,8/)
index2dobc(1:3,3) = (/9,10,11/)
index2dobc(1:3,4) = (/12,13,14/)
index2dobc(1:4,5) = (/15,16,17,18/)
index2dobc(1,6) = 19
```

If iobc2dtype(ifil)=1, each data location in file ifil contains two data values (one for the depth-integrated current and one for the surface elevation). Otherwise, only one data is defined (either depth-integrated current of elevation).

16.1.1.3 amplitudes and phases

ud2obu_amp(nobu,nconobc)	amplitudes of the depth-integrated current U at U-open boundaries [m^2/s]
vd2obv_amp(nobv,nconobc)	amplitudes of the depth-integrated current V at V-open boundaries [m^2/s]
zetobu_amp(nobu,nconobc)	amplitudes of the surface elevation ζ at U-open boundaries [m]
zetobv_amp(nobv,nconobc)	amplitudes of the surface elevation ζ at V-open boundaries [m]
ud2obu_pha(nobu,nconobc)	phases of the depth-integrated current U at U-open boundaries [rad]
vd2obv_pha(nobv,nconobc)	phases of the depth-integrated current V at V-open boundaries [rad]
zetobu_pha(nobu,nconobc)	phases of the surface elevation ζ at U-open boundaries [rad]
zetobv_pha(nobv,nconobc)	phases of the surface elevation ζ at V-open boundaries [rad]

By default, the program uses zero values for amplitudes and phases. In that case, the program will (obviously) not make an harmonic expansion of harmonic constituents, even when the tidal frequencies index_obc are defined in usrdef_mod_params.

16.1.2 Open boundary data for the 2-D mode

The data for 2-D mode open boundary conditions are defined in usrdef_2dobc_data which is called if iopt_obc_2D=1 and modfiles(io_2uvobc,ifil,1)%status='N' where ifil is the file index of the data file. The routine is declared in the program as follows:

```
SUBROUTINE usrdef_2dobc_data(ifil,ciodatetime,data2d,nodat,novars)
CHARACTER (LEN=lentime), INTENT(INOUT) :: ciodatetime
INTEGER, INTENT(IN) :: ifil, nodat, novars
REAL, INTENT(INOUT), DIMENSION(nodat,novars) :: data2d
```

where

ifil	file number index of the data file (>1)
nodat	the number of data points given by no2dobc(ifil)

novars the number of data variables depending on the value of iobc2dtype(ifil)

1: novars equals 2 since both depth integrated current and surface elevation data are required.

2: novars equals 1 since only surface elevation data are required.

3: novars equals 1 since only depth integrated current data are required.

The arguments of INTENT(INOUT) and INTENT(OUT) need to be defined here. They have the following meaning:

ciodatetime date/time of the input data in string format[1]

data2d values of the open boundary data

16.2 3-D mode

16.2.1 Open boundary specifiers for the 3-D mode

The specifier arrays for open boundary conditions in the 3-D case are defined in usrdef_profobc_spec. The routine is called by the program for 3-D baroclinic currents and all 3-D scalar quantities for which a transport equations needs to be solved (currently T and S). No conditions are to be defined for turbulence variables, which are solved with the default zero gradient condition at the open boundaries. The routine is declared with several arguments:

```
SUBROUTINE usrdef_profobc_spec(iddesc,itypobu,itypobv,iprofobu,&
                            & iprofobv,iprofrlx,noprofsd,&
                            & indexprof,indexvar,novars,nofiles)
INTEGER, INTENT(IN) :: iddesc, nofiles, novars
INTEGER, INTENT(INOUT), DIMENSION(2:nofiles) :: noprofsd
INTEGER, INTENT(OUT), DIMENSION(nobu) :: itypobu
INTEGER, INTENT(OUT), DIMENSION(nobv) :: itypobv
INTEGER, INTENT(INOUT), DIMENSION(nobu,novars) :: iprofobu
INTEGER, INTENT(INOUT), DIMENSION(nobv,novars) :: iprofobv
INTEGER, INTENT(INOUT), DIMENSION(novars*(nobu+nobv),2:nofiles) :: indexprof
INTEGER, INTENT(INOUT), DIMENSION(novars*(nobu+nobv),2:nofiles) :: indexvar
INTEGER, INTENT(INOUT), DIMENSION(norlxzones) :: iprofrlx
```

[1] If the parameter time_zone is defined with a non-zero value, the time of the input data must be given in local time.

The INTENT(IN) arguments have the following meaning:

iddesc The file descriptor key id of the 3-D quantity which may take the following values

- io_3uvobc baroclinic currents
- io_salobc salinity
- io_tmpobc temperature
- io_sedobc sediment fractions

nofiles the number of data files plus 1 (the file index for data files ranges from 2 to nofiles)

novars the number of variables for which open boundary conditions are defined. For currents, temperature and salinity its value is 1, for sediments novars equals the number of sediment fractions

The routine is called if the appropriate switch (iopt_obc_3D, iopt_obc_sal, iopt_obc_temp) is set to 1 and modfiles(iddesc,1,1)%status='N'.

16.2.1.1 general specifiers

itypobu type of open boundary condition at U-nodes. In case of baroclinic currents

- 0: External data profile or first order zero gradient (default) condition
- 1: Second order zero gradient condition
- 2: Local solution
- 3: Radiation condition using internal wave speed
- 4: Orlanski type of radiation condition

In case of C-node scalar(s)

- 0: default, i.e. zero gradient condition or specified external profile
- 1: radiation condition using the internal wave speed
- 2: Orlanski condition

itypobv type of open boundary condition at V-nodes. Definitions are the same as above for itypobu.

iprofobu profile number used at U-open boundaries (0 is none) and for each data variable, e.g. sediment fraction if novars>1 iprofobv profile number used at V-open boundaries (0 is none) and for each data variable, e.g. sediment fraction if novars>1

iprofrlx Disables/enables the application of the open boundary relaxation scheme within the zones defined in usrdef_rlxobc_spec (0/1). See Section 16.3 below. Default is 0.

Remarks

- If, at an U-open boundary point with index ii, itypobu(ii)=0 then a zero gradient condition applies for variable ivar if iprofobu(ii,ivar)=0, whereas a positive value of iprofobu(ii,ivar) designates the external profile number used at this point. Negative values are not allowed. The procedure is obviously the same for the arrays itypobv and iprofobv at V-open boundaries

- The same profile number can be used at different open boundary locations or for different variables, i.e.

  iprofobu(ii1,ivar1) = iprofobu(ii2,ivar2) or
  iprofobv(jj1,ivar1) = iprofobu(jj2,ivar2) or
  iprofobu(ii1,ivar1) = iprofobv(jj2,ivar2)

  for any ii1, ii2, jj1, jj2,ivar1, ivar2.

- The data profiles itself are defined as time series in usrdef_profobc_data.

- By default, itypobu, itypobv, iprofobu, iprofobv are set to zero.

16.2.1.2 specifiers for the data files

noprofsd number of profiles per data file

indexprof Each data file contains a sub-set of open boundary profiles. The element indexprof(iprof,ifil) maps, for file ifil, the local profile number iprof into a corresponding "global" index as defined by iprofobu and iprofobv. The physical size of the first dimension for file ifil equals noprofsd(ifil). If not defined and nofiles=2, the program sets indexprof(1:noprofsd(2),2) = (/(1,2,...,noprofsd(2))/). The procedure is illustrated with an example below.

indexvar The argument does not need to be defined for currents, temperature and salinity. For multi-variable data arays (e.g. sediment fractions), indexvar(iprof,ifil) denotes the variable number (e.g. number of sediment fraction) corresponding to profile iprof in ifil

Remarks Let noprofsivar = MAX(MAXVAL(iprofobu(:,ivar)),MAXVAL(iprofobv(:,ivar))) where ivar is an array index between 1 and novars. The following constraints apply

- For each iprof between 1 and noprofsivar, there is at least one array element of iprofobu or iprofobv equal to iprof.
- The array indexvar must have values between 1 and novars.
- If indexvar(iprof,ifil)=ivar, then indexprof(iprof,ifil) must be between and 1 and noprofsivar.
- For each ivar between 1 and novars and iprof between 1 and noprofsivar, there must correspond one and only one data profile for which indexvar(iprof,ifil)=ivar and indexprof(iprof,ifil)=iprof.

The procedure is illustrated in Figure 16.2. The filled circles represent open boundary points. The data are spread over 4 data files. The number in parentheses denotes the number of the data file (between 2 and 5), the second number to the right the number of the profile applied at the open boundary location. In the example a zero gradient condition is applied at the eastern boundary. The data files contain the following profiles

- ifil=2: profiles 1 and 2
- ifil=3: profile 3
- ifil=4: profile 4
- ifil=5: profile 5

In FORTRAN code, the definitions become

```
nobu = 11; nobv = 8
itypobu = 0; itypobv = 0
iprofobu = (/1,1,1,1,2,2,2,2,0,0,0/)
iprofobv = (/3,3,3,4,4,4,4,5/)
nofiles = 5; noprofsd(2:5) = (/2,1,1,1/)
indexprof(1:2,2) = (/1,2/)
indexprof(1,3) = 3
indexprof(1,4) = 4
indexprof(1,5) = 5
```

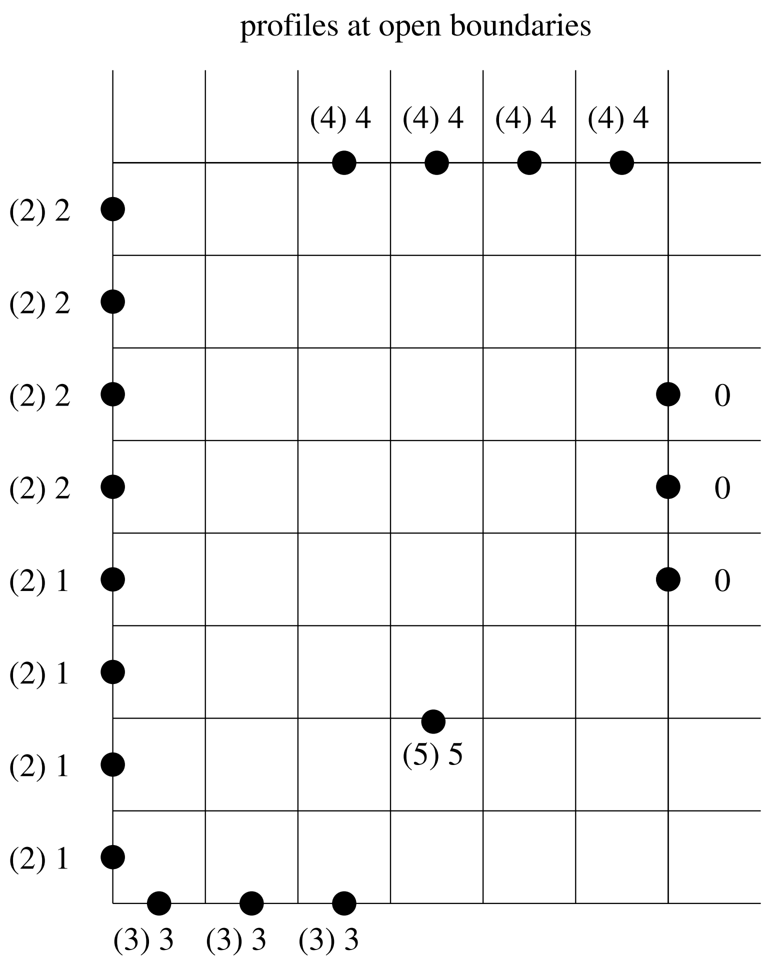

Figure 16.2: Example how to define the open boundary specifier arrays.

16.2.2 Open boundary data for the 3-D mode

The data for 3-D mode open boundary conditions are defined in usrdef_profobc_data which is called if the appropriate switch (iopt_obc_3D, iopt_obc_sal, iopt_obc_temp) equals 1 and modfiles(iddesc,ifil,1)%status='N' where iddesc if the file descriptor id and ifil the file index of the data file. The routine is declared in the program as follows:

```
SUBROUTINE usrdef_profobc_data(iddesc,ifil,ciodatetime,psiprofdat,numprofs)
CHARACTER (LEN=lentime), INTENT(INOUT) :: ciodatetime
INTEGER, INTENT(IN) :: iddesc, ifil, numprofs
REAL, INTENT(INOUT), DIMENSION(numprofs,nz) :: psiprofdat
```

The INTENT(IN) arguments have the following meaning:

iddesc The file descriptor key id of the 3-D quantity which may take the following values:

- io_3uvobc baroclinic currents
- io_salobc salinity
- io_tmpobc temperature
- io_sedobc sediment fractions

ifil file number index of the data file (>1)

numprofs The number of profiles which must be equal to noprofsd(ifil).

The following INTENT(OUT) variables must be defined here

ciodatetime date/time of the profile data in string format[1]

psiprofdat values of the profile data

Values in the data array which are lower than or equal to the flag value real_min are considered as flagged. In that case the open boundary condition at that specific vertical location (only) is changed from an external data profile to a zero gradient condition. This may be used e.g. to prevent unrealistic data input below a pycnocline depth. Note that the vertical profile data of baroclinic currents must be either all flagged or all non-flagged.

In the user defined routines, it is necessary to define separate cases when boundary conditions for different variables (salinity, sediment, 3D velocity profile) are defined. This can be done by a select case statement. An example is given below. In this example, a constant sediment profile (in space and time) is defined for each sediment fraction separately.

```
SUBROUTINE usrdef_profobc_data(iddesc,ifil,ciodatetime,psiprofdat,numprofs)

CALL log_timer_in()

!---open data file on first call
IF (modfiles(iddesc,ifil,1)%iostat.EQ.0) THEN
!  ---open data file
   CALL open_filepars(modfiles(iddesc,ifil,1))
!  ---in the absence of a data file set the iostat attribute
   modfiles(iddesc,ifil,1)%iostat = 1
   GOTO 1000
ENDIF

ciodatetime = ?

SELECT CASE (iddesc)

CASE (io_3uvobc)
!  ---boundary condition for velocity profile
   psiprofdat(1,:) = ?
CASE (io_salobc)
!   ---boundary profile for salinity
    psiprofdat(1,:) = ?
CASE (io_sedobc)
!  ---sediment profile at the boundary for the first profile
   psiprofdat(1,) = ?
!  ---sediment profile at the boundary for the second profile
   psiprofdat(2,:) = ?
END SELECT

1000 CALL log_timer_out()
```

16.3 Specifiers for relaxation open boundary conditions

Open boundary relaxation is discussed in Section 4.10.3. The following arrays need to be defined in routine usrdef_rlxobc_spec if iopt_obc_relax=1 and modfiles(io_rlxobc,1,1)%status='N':

inodesrlx(2) Disables/enables relaxation at different nodes (0/1)

	1: C-nodes
	2: U- and V-nodes
idirrlx(norlxzones)	Determines position of each zone
	1: West
	2: East
	3: South
	4: North
ityprlx(norlxzones)	Type of interpolation scheme
	1: linear
	2: quadratic
	3: hyperbolic
iposrlx(norlxzones)	(global) X-index of the lower left corner of each zone
jposrlx(norlxzones)	(global) Y-index of the lower left corner of each zone
ncrlx(norlxzones)	size of the zones (number of grid points) in the X-direction
nrrlx(norlxzones)	size of the zones (number of grid points) in th Y-direction.

An illustrative case is shown in Figure 16.3 showing a case with four boundary zones.The FORTRAN definitions become

```
norlxzones = 4
idirrlx = (/1,3,2,4/)
iposrlx = (/1,1,nc-2,5/)
jposrlx = (/9,1,1,nr-1/)
ncrlx = (/2,15,2,10/)
nrrlx = (/9,3,nr-1,1/)
```

The following general remarks have to be given

- A relaxation zone can have only one relaxation direction. For example, zone 2 in the example has two adjacent open boundaries but the scheme is only applied in the Y-direction along the southern boundary (idirrlx(2)=3) since the area is defined as “southern”. In the same way no relaxation is applied towards the southern and northern boundaries within zone 3 since idirrlx(3)=2.
- The zones are defined as rectangles. This means that the scheme can only be used at straight and not at ragged (“stair-case”) open boundaries.

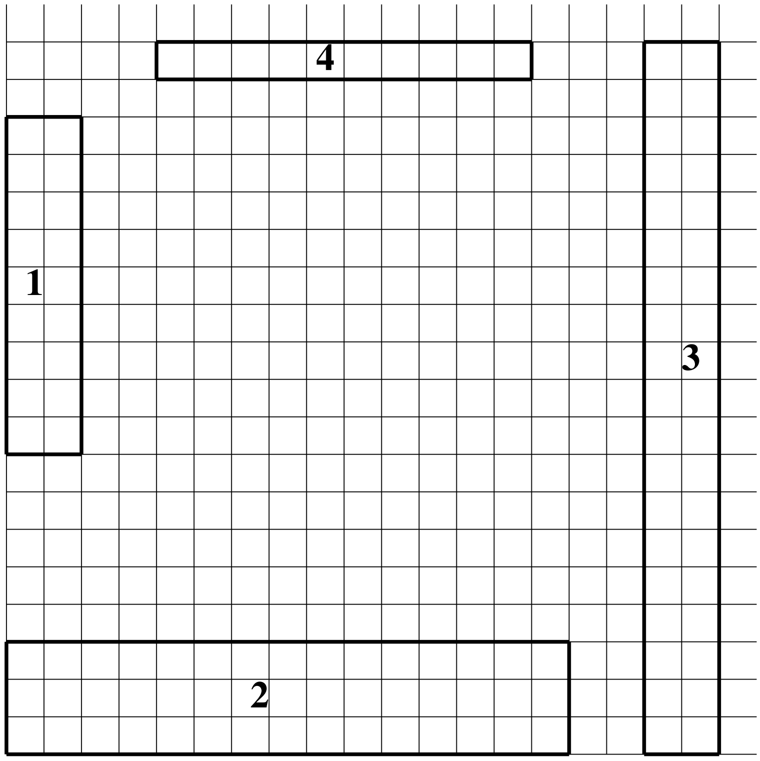

Figure 16.3: Example definitions of open boundary zones for application of the relaxation scheme.

- No relaxation is applied at a center or velocity node grid point, if the line segment, normal to the open boundary, which joins this point and the corresponding open boundary location crosses a dry cell or a solid velocity interface.

- The scheme can be activated for 3-D baroclinic currents, temperature and salinity by setting iopt_obc_relax to 1 and the appropiate elements of the vector iprofrlx to 1 for each specific variable. Note that relaxation of 2-D transports is not available in the current implementation.