Tutorial 5: Explanation of CPP Options, ocean.in, and r4dvar.in

Tutorial 5: Explanation of CPP Options, ocean.in, and psas.in

R4D-Var Tutorial Wiki Page

WC13 C-preprocessing Options
(Basic Configuration)

Momentum Equations Options:

```
#define UV_ADV              including advection terms
#define UV_COR              including Coriolis term
#define DJ_GRADPS           splines density Jacobian PGF
#define UV_QDRAG            quadratic bottom friction
#define UV_VIS2             harmonic horizontal mixing
#define MIX_S_UV            mixing along s-levels
```

Tracers Equations Options:

```
#define TS_U3HADVECTION     3rd-order Upstream H. advection
#define TS_C4VADVECTION     4th-order Centered V. advection
#define TS_DIF2             harmonic horizontal mixing
#define MIX_GEO_TS          mixing along geo-potentials
#define SALINITY            including salinity
#define NONLIN_EOS          nonlinear equation of state

#define ANA_BTFLUX          analytical bottom Temp flux
#define ANA_BSFLUX          analytical bottom Salt flux
```

Vertical Turbulent Mixing Parameterization:

```
#define GLS_MIXING          Generic Length Scale Mixing
#ifdef GLS_MIXING                 (K-omega)
# define KZSZ_HORAVG        smoothing of buoyancy/shear
# define KANTHA_CLAYSON     stability function
#endif
```

Atmospheric Boundary Layer Parameterization:

```
#define BULK_FLUXES         Air/sea COARE bulk fluxes

#define DIURNAL_SRFLUX      imposing local diurnal cycle
#define SOLAR_SOURCE        solar radiation source term
#define LONGWAVE_OUT        compute outgoing long wave rad
#define EMINUSP             compute E-P
```

Model Configuration Options:

```
#define SOLVE3D             solve 3D primitive equations
#define CURVGRID            curvilinear grid
#define MASKING             land/sea masking
#define SPHERICAL           spherical grid
#define PROFILE             time profiling

#define SPLINES             parabolic splines
                              reconstruction
```

Lateral Boundary Conditions:

```
#define EASTERN_WALL        closed eastern wall condition

#define WEST_FSCHAPMAN      free-surface, Chapman
#define WEST_M2FLATHER      2D momentum, Flather
#define WEST_M3CLAMPED      3D momentum, clamped
#define WEST_TCLAMPED       tracers, clamped condition

#define NORTH_FSCHAPMAN     free-surface, Chapman
#define NORTH_M2FLATHER     2D momentum, Flather
#define NORTH_M3CLAMPED     3D momentum, clamped
#define NORTH_TCLAMPED      tracers, clamped

#define SOUTH_FSCHAPMAN     free-surface, Chapman
#define SOUTH_M2FLATHER     2D momentum, Flather
#define SOUTH_M3CLAMPED     3D momentum, clamped
#define SOUTH_TCLAMPED      tracer, clamped

#define SPONGE              enhanced viscosity/diffusion
                              areas
```

WC13 C-preprocessing Options
(R4D-Var Configuration)

Algorithm:

```
#define W4DVAR              dual form strong/weak constraint indirect representer algorithm
#define POSTERIOR_EOFS      estimate posterior error analysis error
#define POSTERIOR_ERROR_I   estimate initial conditions posterior analysis error
```

Control Vector:

```
#define ADJUST_BOUNDARY     open boundary conditions increments
#define ADJUST_STFLUX       surface tracer flux increments
#define ADJUST_WSTRESS      surface wind stress increments
```

Error Covariance Modeling:

```
#define VCONVOLUTION        Vertical correlation modeling
#define IMPLICIT_VCON       Implicit vertical diffusion operator
#define BALANCE_OPERATOR    Multivariate balance constraint
#ifdef BALANCE_OPERATOR
# define ZETA_ELLIPTIC      SSH elliptic equation method
#endif
```

Prior:

```
#define FORWARD_READ        read basic state linearization in TLM and ADM files
#define FORWARD_WRITE       writing basic state by the NLM
#define FORWARD_MIXING      processing basic state vertical mixing coefficients
#define NL_BULK_FLUXES      surface kinematic fluxes from nonlinear model
#define RPM_RELAXATION      include relaxation term using previous Picard iteration solution
```

I/O :

```
#define OUT_DOUBLE          double precision data in output NLM, TLM, RPM, and ADM
```

WC13 C-preprocessing Options
(4D-PSAS Configuration)

Algorithm:

```
#define W4DPSAS             dual form strong/weak constraint 4D-PSAS
#define POSTERIOR_EOFS      estimate posterior error analysis error
#define POSTERIOR_ERROR_I   estimate initial conditions posterior analysis error
```

Control Vector:

```
#define ADJUST_BOUNDARY     open boundary conditions increments
#define ADJUST_STFLUX       surface tracer flux increments
#define ADJUST_WSTRESS      surface wind stress increments
```

Error Covariance Modeling:

```
#define VCONVOLUTION        Vertical correlation modeling
#define IMPLICIT_VCON       Implicit vertical diffusion operator
#define BALANCE_OPERATOR    Multivariate balance constraint
#ifdef BALANCE_OPERATOR
# define ZETA_ELLIPTIC      SSH elliptic equation method
#endif
```

Prior:

```
#define FORWARD_READ        read basic state linearization in TLM and ADM files
#define FORWARD_WRITE       writing basic state by the NLM
#define FORWARD_MIXING      processing basic state vertical mixing coefficients
#define NL_BULK_FLUXES      surface kinematic fluxes from nonlinear model
#define RPM_RELAXATION      include relaxation term using previous Picard iteration solution
```

I/O :

```
#define OUT_DOUBLE          double precision data in output NLM, TLM, RPM, and ADM
```

Include File: wc13.h

```
/*
** svn $Id: wc13.h 476 2010-06-26 20:25:30Z arango $
*******************************************************************************
** Copyright (c) 2002-2010 The ROMS/TOMS Group                               **
**   Licensed under a MIT/X style license                                    **
**   See License_ROMS.txt                                                    **
*******************************************************************************
**
** Options for the California Current System, 1/3 degree resolution.
**
** Application flag:   WC13
** Input script:       ocean_wc13.in
**                     s4dvar.in
**
** Available Drivers options: choose only one and activate it in the
**                            build.sh script (MY_CPP_FLAGS definition)
**
**  AD_SENSITIVITY            Adjoint Sensitivity Driver
**  AFT_EIGENMODES            Adjoint Finite Time Eigenmodes
**  ARRAY_MODES               Stabilized representer matrix array modes
**  CLIPPING                  Stabilized representer matrix clipped analysis
**  CORRELATION               Background-error Correlation Check
**  GRADIENT_CHECK            TLM/ADM Gradient Check
**  FORCING_SV                Forcing Singular Vectors
**  FT_EIGENMODES             Finite Time Eigenmodes
**  IS4DVAR                   Incremental, strong constraint 4DVAR
**  NLM_DRIVER                Nonlinear Basic State trajectory
**  OPT_PERTURBATION          Optimal perturbations
**  PICARD_TEST               Picard Iterations Test
**  R_SYMMETRY                Representer Matrix Symmetry Test
**  SANITY_CHECK              Sanity Check
**  SO_SEMI                   Stochastic Optimals: Semi-norm
```

ROMS Standard Input Parameters

```
    NtileI == 2           ! I-direction partition
    NtileJ == 2           ! J-direction partition
. . .
    NTIMES == 192         ! Number of time-steps (4 days)
        DT == 1800.0d0    ! Number of time-steps (48 steps per day)
. . .
    Nouter =  1           ! Number of 4D-Var outer loops
    Ninner =  50          ! Number of 4D-Var inner loops
. . .
   LDEFOUT == T           ! Switch to create new history files
      NHIS == 48          ! Steps between writing of NLM data (daily)
   NDEFHIS == 0           ! Steps between creation of new NLM files
. . .
 LcycleTLM == F           ! Switch to recycle records in TLM file
      NTLM == 48          ! Steps between writing of TLM data (daily)
   NDEFTLM == 0           ! Steps between creation of new TLM files
 LcycleADJ == T           ! Switch to recycle records in ADM file
      NADJ == 192         ! Steps between writing of ADM data (strong constraint)
   NDEFADJ == 0           ! Steps between creation of new ADM files
      NSFF == 48          ! Steps between adjustment of surface fluxes (daily)
      NOBC == 48          ! Steps between adjustment of open boundary (daily)
. . .
   APARNAM =  r4dvar.in   ! R4D-Var standard input parameters
```

ROMS Standard Input Parameters

```
    NtileI == 2           ! I-direction partition
    NtileJ == 2           ! J-direction partition
. . .
    NTIMES == 192         ! Number of time-steps (4 days)
        DT == 1800.0d0    ! Number of time-steps (48 steps per day)
. . .
    Nouter =  1           ! Number of 4D-Var outer loops
    Ninner =  50          ! Number of 4D-Var inner loops
. . .
   LDEFOUT == T           ! Switch to create new history files
      NHIS == 48          ! Steps between writing of NLM data (daily)
   NDEFHIS == 0           ! Steps between creation of new NLM files
. . .
 LcycleTLM == F           ! Switch to recycle records in TLM file
      NTLM == 48          ! Steps between writing of TLM data (daily)
   NDEFTLM == 0           ! Steps between creation of new TLM files
 LcycleADJ == T           ! Switch to recycle records in ADM file
      NADJ == 192         ! Steps between writing of ADM data (strong constraint)
   NDEFADJ == 0           ! Steps between creation of new ADM files
      NSFF == 48          ! Steps between adjustment of surface fluxes (daily)
      NOBC == 48          ! Steps between adjustment of open boundary (daily)
. . .
   APARNAM =  psas.in     ! 4D-PSAS standard input parameters
```

Standard Input File: ocean_wc13.in

```
!
!  ROMS/TOMS Standard Input parameters.
!
!svn $Id: ocean_wc13.in 476 2010-06-26 20:25:30Z arango $
!========================================================== Hernan G. Arango ===
!  Copyright (c) 2002-2010 The ROMS/TOMS Group                                 !
!    Licensed under a MIT/X style license                                      !
!    See License_ROMS.txt                                                      !
!==============================================================================
!                                                                              !
! Input parameters can be entered in ANY order, provided that the parameter    !
! KEYWORD (usually, upper case) is typed correctly followed by "="  or "=="    !
! symbols. Any comment lines are allowed and must begin with an exclamation    !
! mark (!) in column one.  Comments may  appear to the right of a parameter    !
! specification to improve documentation.  Comments will be ignored  during    !
! reading.  Blank lines are also allowed and ignored. Continuation lines in    !
! a parameter specification are allowed and must be preceded by a backslash    !
! (\).  In some instances, more than one value is required for a parameter.    !
! If fewer values are provided, the  last value  is assigned for the entire    !
! parameter array.  The multiplication symbol (*),  without blank spaces in    !
! between, is allowed for a parameter specification.  For example, in a two    !
! grids nested application:                                                    !
!                                                                              !
!    AKT_BAK == 2*1.0d-6  2*5.0d-6              ! m2/s                         !
!                                                                              !
! indicates that the first two entries of array AKT_BAK,  in fortran column-   !
! major order, will have the same value of "1.0d-6" for grid 1,  whereas the   !
! next two entries will have the same value of "5.0d-6" for grid 2.            !
!                                                                              !
! In multiple levels of nesting and/or multiple connected domains  step-ups,   !
! "Ngrids" entries are expected for some of these parameters.  In such case,    !
! the order of the entries for a parameter is extremely important.  It  must   !
```

4D-Var Parameters: Normalization

```
Nmethod  == 0                ! normalization method
Nrandom  == 5000             ! randomization iterations
. . .
LdefNRM  == F F F F          ! Create a new normalization files
LwrtNRM  == F F F F          ! Compute and write normalization
. . .
CnormI(isFsur) =  T          ! 2D variable at RHO-points
CnormI(isUbar) =  T          ! 2D variable at U-points
CnormI(isVbar) =  T          ! 2D variable at V-points
CnormI(isUvel) =  T          ! 3D variable at U-points
CnormI(isVvel) =  T          ! 3D variable at V-points
CnormI(isTvar) =  T T        ! NT tracers
. . .
CnormB(isFsur) =  T          ! 2D variable at RHO-points
CnormB(isUbar) =  T          ! 2D variable at U-points
CnormB(isVbar) =  T          ! 2D variable at V-points
CnormB(isUvel) =  T          ! 3D variable at U-points
CnormB(isVvel) =  T          ! 3D variable at V-points
CnormB(isTvar) =  T T        ! NT tracers
. . .
CnormF(isUstr) =  T          ! surface U-momentum stress
CnormF(isVstr) =  T          ! surface V-momentum stress
CnormF(isTsur) =  T T        ! NT surface tracers flux
. . .
NRMnameM == wc13_nrm_m.nc    ! model error (weak constraint)
NRMnameI == wc13_nrm_i.nc    ! initial conditions
NRMnameB == wc13_nrm_b.nc    ! open boundary conditions
NRMnameF == wc13_nrm_f.nc    ! surface forcing (wind stress and net heat flux)
```

4D-Var Parameters: Decorrelation Scales

Horizontal and vertical stability and accuracy factors (< 1):

```
!                IC       Model    OBC      Sur For

        Hgamma =  0.5      0.5      0.5      0.5       ! horizontal operator
        Vgamma =  0.0005   0.0005   0.0005   0.0005    ! vertical operator
```

Initial conditions correlations (m):

```
HdecayI(isFsur) ==  50.0d+3                            ! free-surface
HdecayI(isUbar) ==  50.0d+3                            ! 2D U-momentum
HdecayI(isVbar) ==  50.0d+3                            ! 2D V-momentum
HdecayI(isUvel) ==  50.0d+3                            ! 3D U-momentum
HdecayI(isVvel) ==  50.0d+3                            ! 3D V-momentum
HdecayI(isTvar) ==  50.0d+3   50.0d+3                  ! 1:NT tracers

VdecayI(isUvel) ==  30.0d0                             ! 3D U-momentum
VdecayI(isVvel) ==  30.0d0                             ! 3D V-momentum
VdecayI(isTvar) ==  30.0d0    30.0d0                   ! 1:NT tracers
```

Surface forcing correlations (m):

```
HdecayF(isUstr) == 100.0d+3                      ! surface U-momentum stress
HdecayF(isVstr) == 100.0d+3                      ! surface V-momentum stress
HdecayF(isTsur) == 100.0d+3  100.0d+3            ! 1:NT surface tracer flux
```

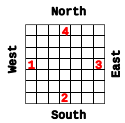
4D-Var Parameters: Decorrelation Scales

Open boundary conditions correlations (m):

```
!                 1: west  2: south  3: east  4: north

HdecayB(isFsur) == 100.0d+3 100.0d+3 100.0d+3 100.0d+3    | free-surface
HdecayB(isUbar) == 100.0d+3 100.0d+3 100.0d+3 100.0d+3    | 2D U-momentum
HdecayB(isVbar) == 100.0d+3 100.0d+3 100.0d+3 100.0d+3    | 2D V-momentum
HdecayB(isUvel) == 100.0d+3 100.0d+3 100.0d+3 100.0d+3    | 3D U-momentum
HdecayB(isVvel) == 100.0d+3 100.0d+3 100.0d+3 100.0d+3    | 3D V-momentum
HdecayB(isTvar) == 4*100.0d+3  4*100.0d+3                 | 1:NT tracers

VdecayB(isUvel) ==  30.0d0   30.0d0   30.0d0   30.0d0     | 3D U-momentum
VdecayB(isVvel) ==  30.0d0   30.0d0   30.0d0   30.0d0     | 3D V-momentum
VdecayB(isTvar) == 4*30.d0  4*30.d0                       | 1:NT tracers
```

Boundary edges to adjust (logical switches):

```
!                 1   2   3   4

   Lobc(isFsur) == T   T   F   T          | free-surface
   Lobc(isUbar) == T   T   F   T          | 2D U-momentum
   Lobc(isVbar) == T   T   F   T          | 2D V-momentum
   Lobc(isUvel) == T   T   F   T          | 3D U-momentum
   Lobc(isVvel) == T   T   F   T          | 3D V-momentum

   Lobc(isTvar) == T   T   F   T  \
                   T   T   F   T
```



4D-Var Parameters: Balance Operator

SSH, elliptic solver:

```
         Nbico == 200                    | biconjugate gradient iterarion
```

SSH, integration of hydrostatic equation:

```
      LNM_depth == 1000.0d0              | level of no motion (m, positive)
      LNM_flag  =  1                     | Integration flag

                                           [0] integrate from bottom to surface
                                           [1] integrate from LNM to surface or
                                               from local depth, if shallower
```

Balanced salinity empirical T-S relationship:

```
       dTdz_min == 0.001d0               | minimun dT/dz (Celsius/m)
       ml_depth == 100.0d0               | mixed-layer depth (m; positive)
```

State Variables switches:

```
balance(isSalt) =  T                     | salinity
balance(isFsur) =  T                     | free-sruface
balance(isVbar) =  F                     | 2D momentum (ubar, vbar)
balance(isVvel) =  T                     | 3D momentum (u, v)
```

Other 4D-Var Parameters

Lanczos algorithm parameters:

```
        GradErr = 1.0d-4                 | Upper bound on the relative error of the
                                             gradient
       HevecErr = 1.0d-1                 | Maximum error bound on Hessian eigenvectors
     LhessianEV = T                      | Compute approximated hessian eigen pairs
```

Preconditioning:

```
       Lprecond = F                      | Limitted-Memory Preconditioner: Spectral
          Lritz = T                      | Limitted-Memory Preconditioner: Ritz
        NritzEV = 0                      | If preconditioning, number of eigenvectors
                                             if NritzEV = 0, use HevecErr
```

Weak constraint:

```
      LhotStart = T                      | Hot start in subsequent outer loops
         NpostI = 50                     | Posterior error analysis Lanczos iterations
           Nvct = 50                     | Stabilized representer matrix eigenvector
                                             to process
      tl_M2diff == 0.0d0                 | RPM relaxation (m2/s), 2D momentum
      tl_M3diff == 0.0d0                 | RPM relaxation (m2/s), 3D momentum

       tl_Tdiff == 0.0d0  0.0d0          | RPM relaxation (m2/s), tracers
```

Other 4D-Var Parameters

```
Lanczos algorithm parameters:
       GradErr = 1.0d-4              ! Upper bound on the relative error of the
                                       gradient
      HevecErr = 1.0d-1              ! Maximum error bound on Hessian eigenvectors
    LhessianEV = T                   ! Compute approximated hessian eigen pairs

Preconditioning:
      Lprecond = F                   ! Limitted-Memory Preconditioner: Spectral
         Lritz = T                   ! Limitted-Memory Preconditioner: Ritz
       NritzEV = 0                   ! If preconditioning, number of eigenvectors
                                       if NritzEV = 0, use HevecErr
Weak constraint:
     LhotStart = T                   ! Hot start in subsequent outer loops

       NpostI = 50                   ! Posterior error analysis Lanczos iterations

         Nvct = 50                   ! Stabilized representer matrix eigenvector
                                       to process

   tl_M2diff == 0.0d0                ! RPM relaxation (m2/s), 2D momentum
   tl_M3diff == 0.0d0                ! RPM relaxation (m2/s), 3D momentum

   tl_Tdiff == 0.0d0  0.0d0          ! RPM relaxation (m2/s), tracers
```

R4D-Var Parameters File: r4dvar.in

```
!  4DVar assimilation input parameters.
!
!svn $Id: s4dvar.in 474 2010-06-25 20:19:44Z arango $
!========================================================== Hernan G. Arango ===
!  Copyright (c) 2002-2010 The ROMS/TOMS Group                         !
!    Licensed under a MIT/X style license                              !
!    See License_ROMS.txt                                              !
!=======================================================================
!                                                                      !
! Input parameters can be entered in ANY order, provided that the parameter   !
! KEYWORD (usually, upper case) is typed correctly followed by "="  or "=="   !
! symbols. Any comment lines are allowed and must begin with an exclamation   !
! mark (!) in column one.  Comments may  appear to the right of a parameter   !
! specification to improve documentation.  Comments will be ignored  during   !
! reading.  Blank lines are also allowed and ignored. Continuation lines in   !
! a parameter specification are allowed and must be preceded by a backslash   !
! (\).  In some instances, more than one value is required for a parameter.   !
! If fewer values are provided, the  last value  is assigned for the entire   !
! parameter array.  The multiplication symbol (*),  without blank spaces in   !
! between, is allowed for a parameter specification.  For example, in a two   !
! grids nested application:                                            !
!                                                                      !
!    AKT_BAK == 2*1.0d-6  2*5.0d-6             ! m2/s                  !
!                                                                      !
! indicates that the first two entries of array AKT_BAK,  in fortran column-  !
! major order, will have the same value of "1.0d-6" for grid 1,  whereas the  !
! next two entries will have the same value of "5.0d-6" for grid 2.    !
!                                                                      !
! In multiple levels of nesting and/or multiple connected domains  step-ups,  !
! "Ngrids" entries are expected for some of these parameters.  In such case,  !
! the order of the entries for a parameter is extremely important.  It  must  !
! follow the same order (1:Ngrids) as in the state variable declaration. The  !
```

R4D-Var Job Script: job_r4dvar.sh

1. Set path definition to one directory up in the tree.

```
set Dir = `dirname ${PWD}`
```

2. Set string manipulations perl script.

```
set SUBSTITUTE = ${ROMS_ROOT}/ROMS/Bin/substitute
```

3. Copy nonlinear model initial conditions file.

```
cp -p ${Dir}/Data/wc13_ini.nc wc13_ini.nc
```

4. Copy representer model intial conditions file, same as nonlinear model

```
cp -p ${Dir}/Data/wc13_ini.nc wc13_irp.nc
```

5. Copy representer model initial conditions file.

```
cp -p ${Dir}/Data/wc13_ini.nc wc13_irp.nc
```

6. Set model, initial conditions, boundary conditions and surface forcing error covariance standard deviations files.

```
set STDnameM = ../Data/wc13_std_m.nc
set STDnameI = ../Data/wc13_std_i.nc
set STDnameB = ../Data/wc13_std_b.nc
set STDnameF = ../Data/wc13_std_f.nc
```

7. Set initial conditions, boundary conditions and surface forcing error covariance normalization factors files.

```
set NRMnameM = ../Data/wc13_nrm_m.nc
set NRMnameI = ../Data/wc13_nrm_i.nc
set NRMnameB = ../Data/wc13_nrm_b.nc
set NRMnameF = ../Data/wc13_nrm_f.nc
```

8. Set observations file.

```
set OBSname = wc13_obs.nc
```

7. Get a clean copy of the observation file. This is really important since this file is modified.

```
cp -p ${Dir}/Data/${OBSname} .
```

8. Modify 4D-Var template input script and specify above files.

```
set R4DVAR = r4dvar.in
if (-e $R4DVAR) then
  /bin/rm $R4DVAR
endif
cp s4dvar.in $R4DVAR

$SUBSTITUTE $R4DVAR ocean_std_m.nc $STDnameM
$SUBSTITUTE $R4DVAR ocean_std_i.nc $STDnameI
$SUBSTITUTE $R4DVAR ocean_std_b.nc $STDnameB
$SUBSTITUTE $R4DVAR ocean_std_f.nc $STDnameF
$SUBSTITUTE $R4DVAR ocean_nrm_m.nc $NRMnameM
$SUBSTITUTE $R4DVAR ocean_nrm_i.nc $NRMnameI
$SUBSTITUTE $R4DVAR ocean_nrm_b.nc $NRMnameB
$SUBSTITUTE $R4DVAR ocean_nrm_f.nc $NRMnameF
$SUBSTITUTE $R4DVAR ocean_obs.nc   $OBSname
$SUBSTITUTE $R4DVAR ocean_hss.nc   wc13_hss.nc
$SUBSTITUTE $R4DVAR ocean_lcz.nc   wc13_lcz.nc
$SUBSTITUTE $R4DVAR ocean_mod.nc   wc13_mod.nc
$SUBSTITUTE $R4DVAR ocean_err.nc   wc13_err.nc
```

4D-PSAS Job Script: job_psas.sh

1. Set path definition to one directory up in the tree.

```
set Dir = `dirname ${PWD}`
```

2. Set string manipulations perl script.

```
set SUBSTITUTE = ${ROMS_ROOT}/ROMS/Bin/substitute
```

3. Copy nonlinear model initial conditions file.

```
cp -p ${Dir}/Data/wc13_ini.nc wc13_ini.nc
```

4. ~~Copy representer model initial conditions file, same as nonlinear model~~

```
~~cp -p ${Dir}/Data/wc13_ini.nc wc13_irp.nc~~
```

5. Copy representer model initial conditions file.

```
cp -p ${Dir}/Data/wc13_ini.nc wc13_irp.nc
```

6. Set model, initial conditions, boundary conditions and surface forcing error covariance standard deviations files.

```
set STDnameM = ../Data/wc13_std_m.nc
set STDnameI = ../Data/wc13_std_i.nc
set STDnameB = ../Data/wc13_std_b.nc
set STDnameF = ../Data/wc13_std_f.nc
```

7. Set initial conditions, boundary conditions and surface forcing error covariance normalization factors files.

```
set NRMnameM = ../Data/wc13_nrm_m.nc
set NRMnameI = ../Data/wc13_nrm_i.nc
set NRMnameB = ../Data/wc13_nrm_b.nc
set NRMnameF = ../Data/wc13_nrm_f.nc
```

8. Set observations file.

```
set OBSname = wc13_obs.nc
```

7. Get a clean copy of the observation file. This is really important since this file is modified.

```
cp -p ${Dir}/Data/${OBSname} .
```

8. Modify 4D-Var template input script and specify above files.

```
set PSAS = psas.in
if (-e $PSAS) then
  /bin/rm $PSAS
endif
cp s4dvar.in $PSAS

$SUBSTITUTE   $PSAS   ocean_std_m.nc  $STDnameM
$SUBSTITUTE   $PSAS   ocean_std_i.nc  $STDnameI
$SUBSTITUTE   $PSAS   ocean_std_b.nc  $STDnameB
$SUBSTITUTE   $PSAS   ocean_std_f.nc  $STDnameF
$SUBSTITUTE   $PSAS   ocean_nrm_m.nc  $NRMnameM
$SUBSTITUTE   $PSAS   ocean_nrm_i.nc  $NRMnameI
$SUBSTITUTE   $PSAS   ocean_nrm_b.nc  $NRMnameB
$SUBSTITUTE   $PSAS   ocean_nrm_f.nc  $NRMnameF
$SUBSTITUTE   $PSAS   ocean_obs.nc    $OBSname
$SUBSTITUTE   $PSAS   ocean_hss.nc    wc13_hss.nc
$SUBSTITUTE   $PSAS   ocean_lcz.nc    wc13_lcz.nc
$SUBSTITUTE   $PSAS   ocean_mod.nc    wc13_mod.nc
$SUBSTITUTE   $PSAS   ocean_err.nc    wc13_err.nc
```

R4D-Var Job Script File: job_r4dvar.sh

```
#!/bin/csh -f
#
# svn $Id: job_r4dvar.sh 474 2010-06-25 20:19:44Z arango $
#########################################################################
# Copyright (c) 2002-2010 The ROMS/TOMS Group                           #
#   Licensed under a MIT/X style license                                #
#   See License_ROMS.txt                                                #
#########################################################################
#                                                                       #
# Strong/Weak constraint R4D-Var job script:                            #
#                                                                       #
# This script NEEDS to be run before any run:                           #
#                                                                       #
#   (1) It copies a new clean nonlinear model initial conditions        #
#       file. The nonlinear model is initialized from the               #
#       background or reference state.                                  #
#   (2) It copies representer model initial condition, same as          #
#       nonlinear model.                                                #
#   (3) Specify model, initial conditions, boundary conditions, and     #
#       surface forcing error convariance input standard deviations     #
#       files.                                                          #
#   (4) Specify model, initial conditions, boundary conditions, and     #
#       surface forcing error convariance input/output normalization    #
#       factors files.                                                  #
#   (5) Copy a clean copy of the observations NetCDF file.              #
#   (6) Create 4D-Var input script "r4dvar.in" from template and        #
#       specify the error covariance standard deviation, error          #
#       covariance normalization factors, and observation files to      #
#       be used.                                                        #
#                                                                       #
#########################################################################
```

Compile: build.sh

1. Set a local environmental variable to define the path to the directories where all this project's files are kept.

```
setenv MY_ROOT_DIR          /home/arango/ocean/toms/repository
setenv MY_PROJECT_DIR       ${PWD}
```

2. Location of your ROMS source code.

```
setenv MY_ROMS_SRC          ${MY_ROOT_DIR}/branches/arango
```

3. Build script invoked CPP options.

```
setenv MY_CPP_FLAGS "-DW4DVAR"
setenv MY_CPP_FLAGS "${MY_CPP_FLAGS} -DPOSTERIOR_EOFS"
setenv MY_CPP_FLAGS "${MY_CPP_FLAGS} -DPOSTERIOR_ERROR_I"
```

4. Compiler selection environment variables.

```
setenv USE_MPI              on
setenv USE_MPIF90           on
setenv FORT                 pgi
```

5. Use custom library paths.

```
#setenv USE_MY_LIBS         on
```

Libraries for PGI

```
if (${?USE_MY_LIBS}) then
  switch ($FORT)
    case "pgi*"
      setenv ARPACK_LIBDIR      /opt/pgisoft/serial/ARPACK
      if (${?USE_MPI}) then
        setenv PARPACK_LIBDIR   /opt/pgisoft/mpich/PARPACK
      endif

      if (${?USE_NETCDF4}) then
        if (${?USE_MPI}) then
          setenv NETCDF_INCDIR  /opt/pgisoft/mpich/netcdf4/include
          setenv NETCDF_LIBDIR  /opt/pgisoft/mpich/netcdf4/lib
          setenv HDF5_LIBDIR    /opt/pgisoft/mpich/hdf5/lib
        else
          setenv NETCDF_INCDIR  /opt/pgisoft/serial/netcdf4/include
          setenv NETCDF_LIBDIR  /opt/pgisoft/serial/netcdf4/lib
          setenv HDF5_LIBDIR    /opt/pgisoft/serial/hdf5/lib
        endif
      else
        setenv NETCDF_INCDIR    /opt/pgisoft/serial/netcdf3/include
        setenv NETCDF_LIBDIR    /opt/pgisoft/serial/netcdf3/lib
      endif
    breaksw
```

Compile: build.sh

1. Set a local environmental variable to define the path to the directories where all this project's files are kept.

```
setenv MY_ROOT_DIR          /home/arango/ocean/toms/repository
setenv MY_PROJECT_DIR       ${PWD}
```

2. Location of your ROMS source code.

```
setenv MY_ROMS_SRC          ${MY_ROOT_DIR}/branches/arango
```

3. Buld script invoked CPP options.

```
setenv MY_CPP_FLAGS "-DW4DPSAS"
setenv MY_CPP_FLAGS "${MY_CPP_FLAGS} -DPOSTERIOR_EOFS"
setenv MY_CPP_FLAGS "${MY_CPP_FLAGS} -DPOSTERIOR_ERROR_I"
```

4. Compiler selection environment variables.

```
setenv USE_MPI              on
setenv USE_MPIF90           on
setenv FORT                 pgi
```

5. Use custom library paths.

```
#setenv USE_MY_LIBS         on
```

Libraries for PGI

```
if (${?USE_MY_LIBS}) then
  switch ($FORT)
    case "pgi"
      setenv ARPACK_LIBDIR      /opt/pgisoft/serial/ARPACK
      if (${?USE_MPI}) then
        setenv PARPACK_LIBDIR   /opt/pgisoft/mpich/PARPACK
      endif

      if (${?USE_NETCDF4}) then
        if (${?USE_MPI}) then
          setenv NETCDF_INCDIR  /opt/pgisoft/mpich/netcdf4/include
          setenv NETCDF_LIBDIR  /opt/pgisoft/mpich/netcdf4/lib
          setenv HDF5_LIBDIR    /opt/pgisoft/mpich/hdf5/lib
        else
          setenv NETCDF_INCDIR  /opt/pgisoft/serial/netcdf4/include
          setenv NETCDF_LIBDIR  /opt/pgisoft/serial/netcdf4/lib
          setenv HDF5_LIBDIR    /opt/pgisoft/serial/hdf5/lib
        endif
      else
        setenv NETCDF_INCDIR    /opt/pgisoft/serial/netcdf3/include
        setenv NETCDF_LIBDIR    /opt/pgisoft/serial/netcdf3/lib
      endif
    breaksw
```

Build Script: build.sh

```
#!/bin/csh -f
#
# svn $Id: build.sh 474 2010-06-25 20:19:44Z arango $
#:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::: John Wilkin :::
# Copyright (c) 2002-2010 The ROMS/TOMS Group                               :::
#   Licensed under a MIT/X style license                                    :::
#   See License_ROMS.txt                                                    :::
#::::::::::::::::::::::::::::::::::::::::::::::::::::: Hernan G. Arango :::
#                                                                           :::
# ROMS/TOMS Compiling Script                                                :::
#                                                                           :::
# Script to compile an user application where the application-specific      :::
# files are kept separate from the ROMS source code.                        :::
#                                                                           :::
# Q: How/why does this script work?                                         :::
#                                                                           :::
# A: The ROMS makefile configures user-defined options with a set of        :::
#    flags such as ROMS_APPLICATION. Browse the makefile to see these.      :::
#    If an option in the makefile uses the syntax ?= in setting the         :::
#    default, this means that make will check whether an environment        :::
#    variable by that name is set in the shell that calls make. If so       :::
#    the environment variable value overrides the default (and the          :::
#    user need not maintain separate makefiles, or frequently edit          :::
#    the makefile, to run separate applications).                           :::
#                                                                           :::
# Usage:                                                                    :::
#                                                                           :::
#    ./build.sh [options]                                                   :::
#                                                                           :::
# Options:                                                                  :::
#                                                                           :::
#    -j [N]      Compile in parallel using N CPUs                           :::
```