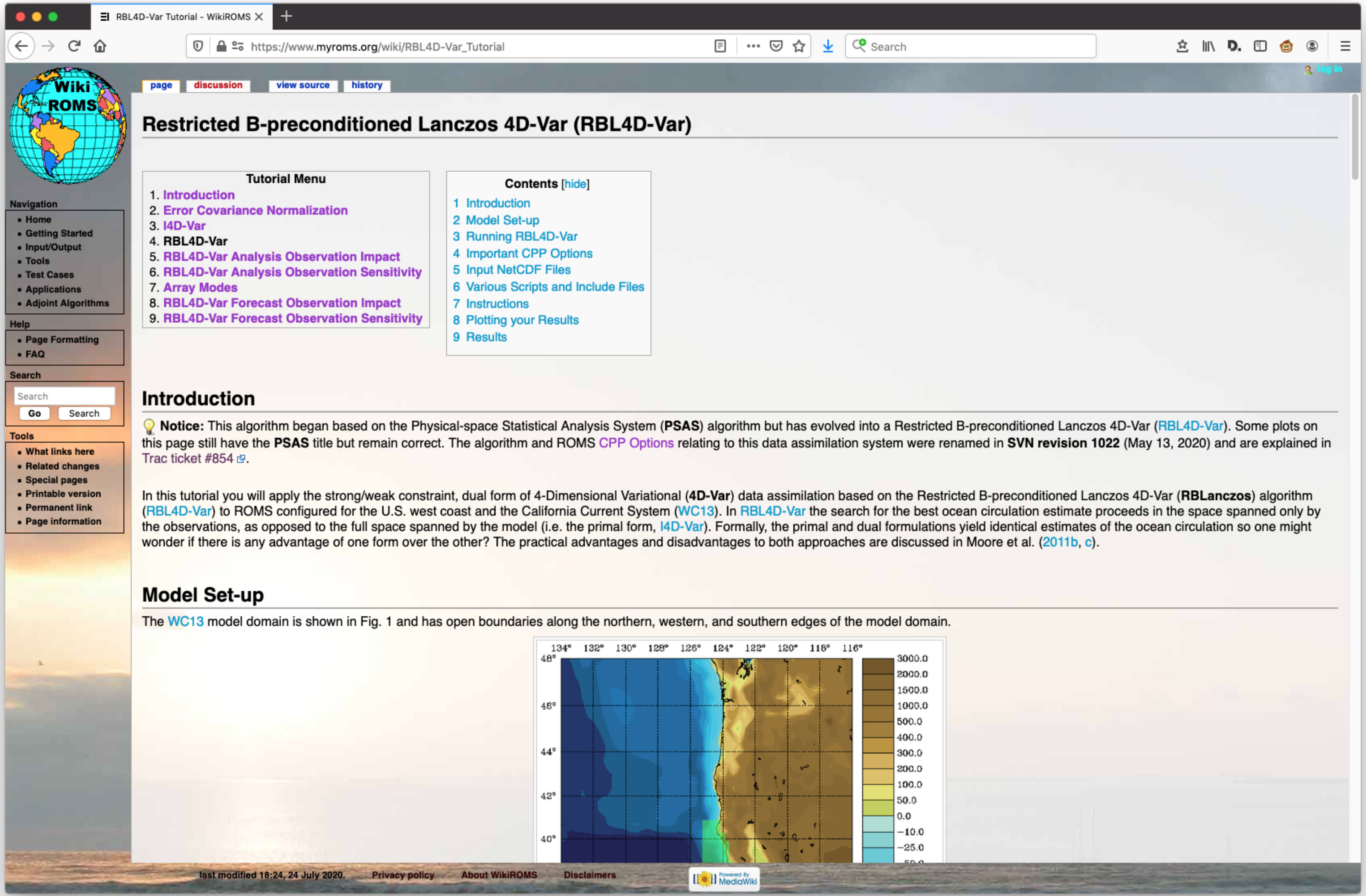
Tutorial 5:
Explanation of CPP Options, roms.in, and rbl4dvar.in

RBL4D-Var Tutorial Wiki Page



Restricted B-preconditioned Lanczos 4D-Var (RBL4D-Var)

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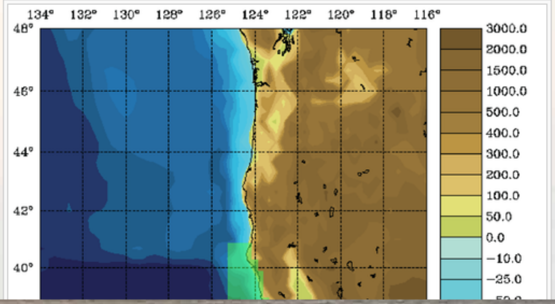
Introduction

Notice: This algorithm began based on the Physical-space Statistical Analysis System (**PSAS**) algorithm but has evolved into a Restricted B-preconditioned Lanczos 4D-Var (RBL4D-Var). Some plots on this page still have the **PSAS** title but remain correct. The algorithm and ROMS CPP Options relating to this data assimilation system were renamed in **SVN revision 1022** (May 13, 2020) and are explained in Trac ticket #854.

In this tutorial you will apply the strong/weak constraint, dual form of 4-Dimensional Variational (**4D-Var**) data assimilation based on the Restricted B-preconditioned Lanczos 4D-Var (**RBLanczos**) algorithm (RBL4D-Var) to ROMS configured for the U.S. west coast and the California Current System (WC13). In RBL4D-Var the search for the best ocean circulation estimate proceeds in the space spanned only by the observations, as opposed to the full space spanned by the model (i.e. the primal form, I4D-Var). Formally, the primal and dual formulations yield identical estimates of the ocean circulation so one might wonder if there is any advantage of one form over the other? The practical advantages and disadvantages to both approaches are discussed in Moore et al. (2011b, c).

Model Set-up

The WC13 model domain is shown in Fig. 1 and has open boundaries along the northern, western, and southern edges of the model domain.



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WC13 C-preprocessing Options
(Basic Configuration)

Momentum Equations Options:

```
#define UV_ADV              including advection terms
#define UV_COR              including Coriolis term
#define UV_U3HADVECTION     3rd-order Upstream Horizontal advection
#define UV_C4VADVECTION     4th-order Centered Vertical advection
#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
#define SPLINES_VVISC       parabolic Splines for Vertical Viscosity
```

Tracers Equations Options:

```
#define TS_U3HADVECTION     3rd-order Upstream horizontal advection
#define TS_C4VADVECTION     4th-order Centered  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 SPLINES_VDIFF       parabolic splines for vertical Diffusion

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

Surface Forcing Options:

```
#define BULK_FLUXES         surface bulk fluxes parameterization

#define DIURNAL_SRFLUX      modulate shortwave by the local diurnal cycle
#define EMINUSP             compute Salt Flux using E-P
#define LONGWAVE_OUT        compute outgoing longwave radiation
#define SOLAR_SOURCE        solar radiation source term
```

Vertical Turbulent Mixing Parameterization Options:

```
#define GLS_MIXING          Generic Length Scale Mixing (K-omega)
#ifdef GLS_MIXING
# define N2S2_HORAVG        smoothing of buoyancy/shear
# define KANTHA_CLAYSON     stability function
# RI_SPLINES                parabolic splines for Ri Number
#endif
```

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 ANA_SPONGE          analytical viscosity/diffusion sponge
```

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

Algorithm:

```
#define RBL4DVAR             dual form strong/weak constraint RBL4D-Var
#undef  MINRES               Minimal Residual Method for minimization
#undef  RPCG                 Restricted B-preconditioned Lanczos minimization
#undef  TIME_CONV            Weak-constraint 4D-Var time convolution
#undef  BGQC                 background quality control of observations
#undef  POSTERIOR_EOFS       estimate posterior error analysis error cross-covariance EOFs
#indef  POSTERIOR_ERROR_I    estimate initial conditions posterior analysis error covariance
```

Control Vector:

```
#define ADJUST_BOUNDARY      open boundary conditions increments
#define ADJUST_STFLUX        surface tracer flux increments
#define ADJUST_WSTRESS       surface wind stress increments
#define NL_BULK_FLUXES       using bulk fluxes computed by nonlinear model
#define TS_U3HADVECTION_TL   TL/AD 3rd-order upstream horizontal tracer advection
#define TS_C4VADVECTION_TL   TL/AD 4th-order centered vertical tracer advection
```

Error Covariance Modeling:

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

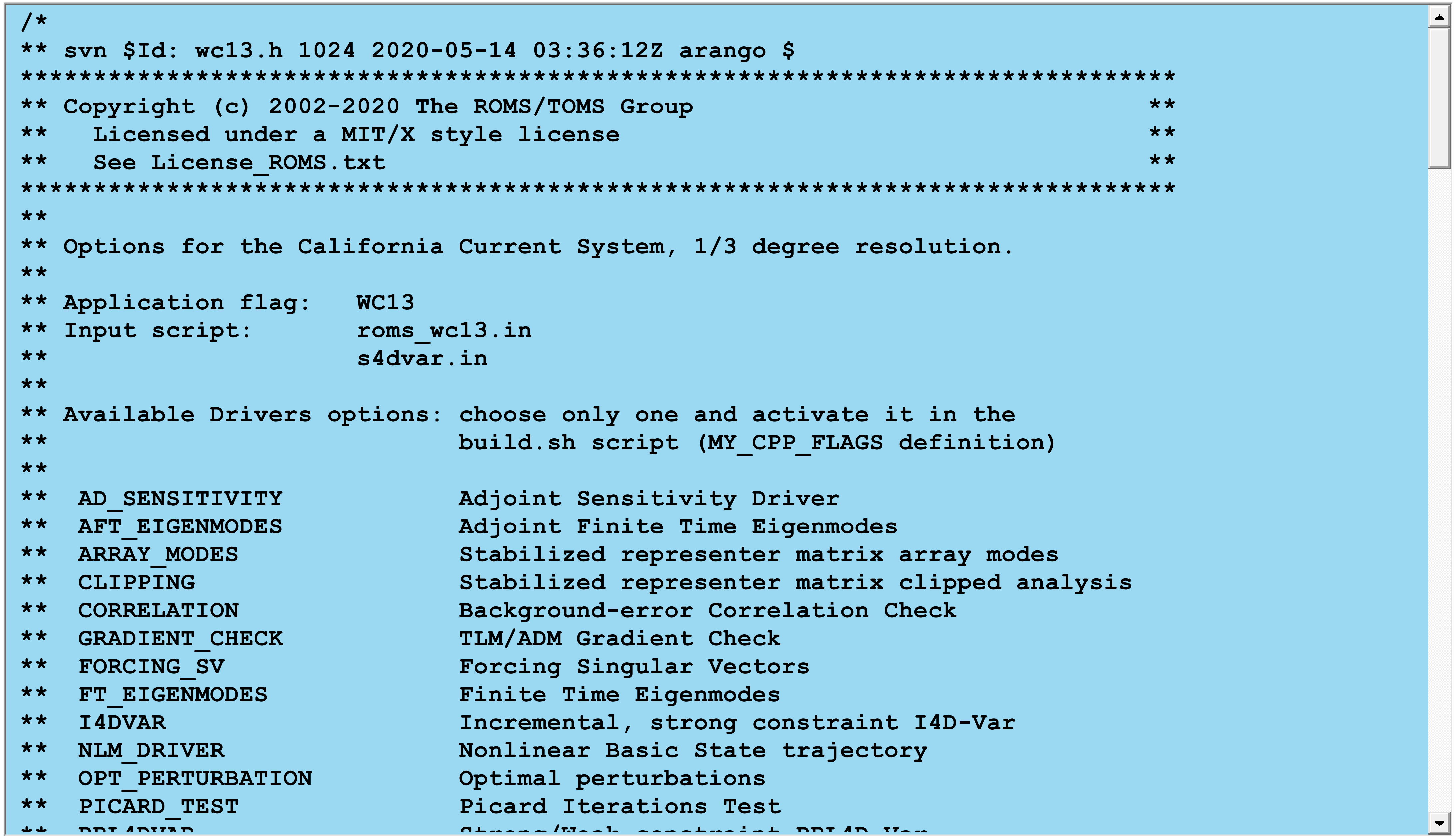
Prior:

```
#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
```

I/O :

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

Include File: wc13.h

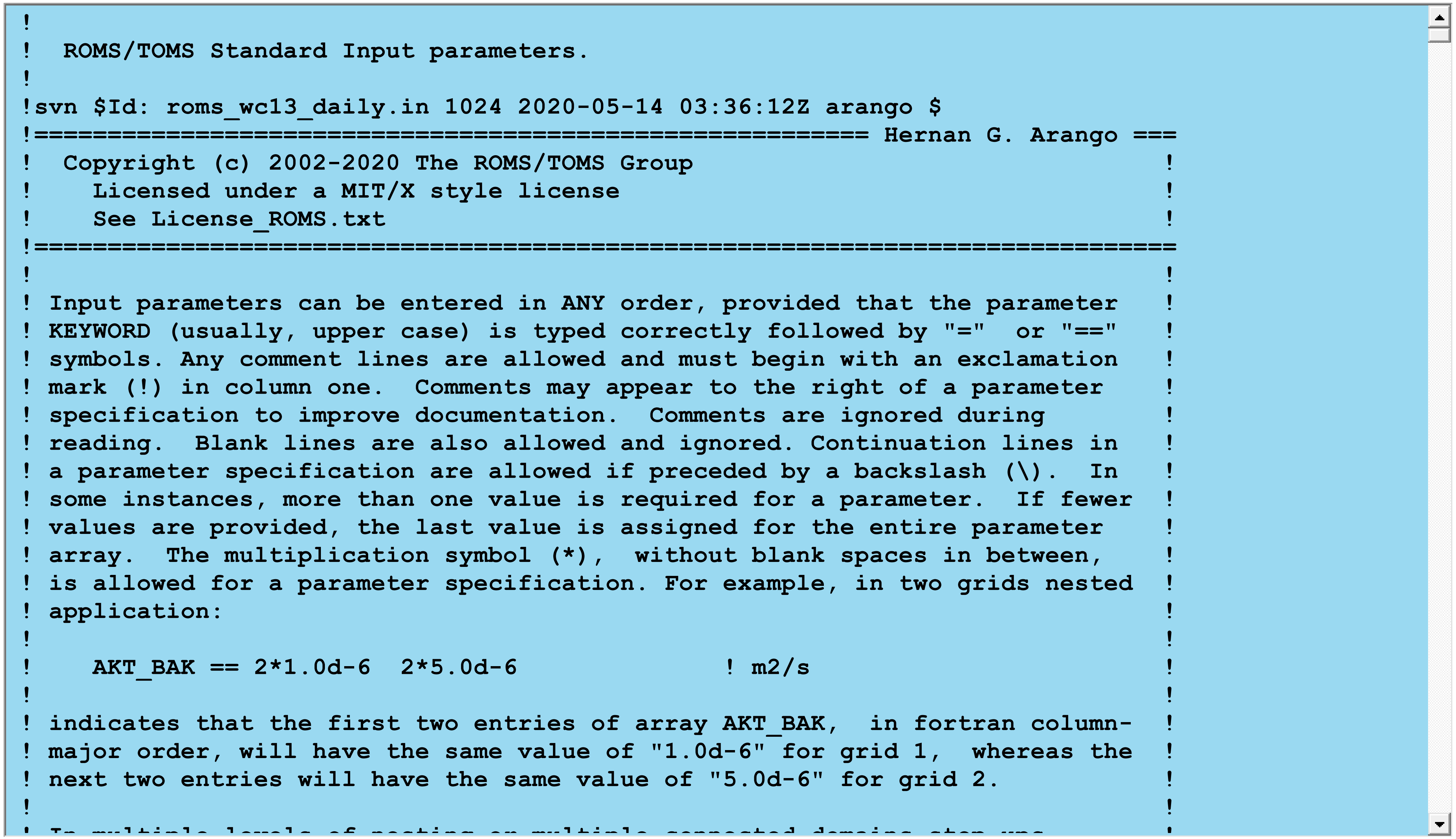


```
/*
** svn $Id: wc13.h 1024 2020-05-14 03:36:12Z arango $
*******************************************************************************
** Copyright (c) 2002-2020 The ROMS/TOMS Group                              **
**   Licensed under a MIT/X style license                                   **
**   See License_ROMS.txt                                                   **
*******************************************************************************
**
** Options for the California Current System, 1/3 degree resolution.
**
** Application flag:   WC13
** Input script:       roms_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
**  I4DVAR                    Incremental, strong constraint I4D-Var
**  NLM_DRIVER                Nonlinear Basic State trajectory
**  OPT_PERTURBATION          Optimal perturbations
**  PICARD_TEST               Picard Iterations Test
```

ROMS Standard Input Parameters: roms_wc13.in

```
       NtileI == 2              ! I-direction partition
       NtileJ == 4              ! 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 =  26             ! 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)
  !      NADJ == 48             ! Steps between writing of ADM data (weak   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     ! I4D-Var standard input parameters
```

Standard Input File: roms_wc13.in



```
!
!  ROMS/TOMS Standard Input parameters.
!
!svn $Id: roms_wc13_daily.in 1024 2020-05-14 03:36:12Z arango $
!========================================================= Hernan G. Arango ===
!  Copyright (c) 2002-2020 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 are ignored during        !
! reading.  Blank lines are also allowed and ignored. Continuation lines in   !
! a parameter specification are allowed if 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 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 or multiple connected domains step-ups        !
```

4D-Var Parameters: Normalization

```
Nmethod   == 0                  ! normalization method:  0=Exact (expensive) or 1=Approximated (randomization)
Nrandom   == 5000               ! randomization iterations
 . . .
LdefNRM   == F F F F            ! Create a new normalization files (model, IC, OBC, surface forcing)
LwrtNRM   == F F F F            ! Compute and write normalization  (model, IC, OBC, surface forcing)
 . . .
CnormM(isFsur) =  T             ! model error covariance, 2D variable at RHO-points
CnormM(isUbar) =  T             ! model error covariance, 2D variable at U-points
CnormM(isVbar) =  T             ! model error covariance, 2D variable at V-points
CnormM(isUvel) =  T             ! model error covariance, 3D variable at U-points
CnormM(isVvel) =  T             ! model error covariance, 3D variable at V-points
CnormM(isTvar) =  T T           ! model error covariance, NT tracers
 . . .
CnormI(isFsur) =  T             ! IC error covariance, 2D variable at RHO-points
CnormI(isUbar) =  T             ! IC error covariance, 2D variable at U-points
CnormI(isVbar) =  T             ! IC error covariance, 2D variable at V-points
CnormI(isUvel) =  T             ! IC error covariance, 3D variable at U-points
CnormI(isVvel) =  T             ! IC error covariance, 3D variable at V-points
CnormI(isTvar) =  T T           ! IC error covariance, NT tracers
 . . .
CnormB(isFsur) =  T             ! OBC error covariance, 2D variable at RHO-points
CnormB(isUbar) =  T             ! OBC error covariance, 2D variable at U-points
CnormB(isVbar) =  T             ! OBC error covariance, 2D variable at V-points
CnormB(isUvel) =  T             ! OBC error covariance, 3D variable at U-points
CnormB(isVvel) =  T             ! OBC error covariance, 3D variable at V-points
CnormB(isTvar) =  T T           ! OBC error covariance, NT tracers
 . . .
CnormF(isUstr) =  T             ! surface forcing error covariance, U-momentum stress
CnormF(isVstr) =  T             ! surface forcing error covariance, V-momentum stress
CnormF(isTsur) =  T T           ! Surface forcing error covariance, NT tracers fluxes
 . . .
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

Model error correlations (m):

HdecayM(isFsur) ==  50.0d+3                                 ! free-surface   (16 convolutions)
HdecayM(isUbar) ==  50.0d+3                                 ! 2D U-momentum  (16 convolutions)
HdecayM(isVbar) ==  50.0d+3                                 ! 2D V-momentum  (16 convolutions)
HdecayM(isUvel) ==  50.0d+3                                 ! 3D U-momentum  (16 convolutions)
HdecayM(isVvel) ==  50.0d+3                                 ! 3D V-momentum  (16 convolutions)
HdecayM(isTvar) ==  50.0d+3   50.0d+3                       ! 1:NT tracers   (16 convolutions)

VdecayM(isUvel) ==  30.0d0                                  ! 3D U-momentum  (8  convolutions)
VdecayM(isVvel) ==  30.0d0                                  ! 3D V-momentum  (8  convolutions)
VdecayM(isTvar) ==  30.0d0    30.0d0                        ! 1:NT tracers   (8  convolutions)

Initial conditions error correlations (m):

HdecayI(isFsur) ==  50.0d+3                                 ! free-surface   (16 convolutions)
HdecayI(isUbar) ==  50.0d+3                                 ! 2D U-momentum  (16 convolutions)
HdecayI(isVbar) ==  50.0d+3                                 ! 2D V-momentum  (16 convolutions)
HdecayI(isUvel) ==  50.0d+3                                 ! 3D U-momentum  (16 convolutions)
HdecayI(isVvel) ==  50.0d+3                                 ! 3D V-momentum  (16 convolutions)
HdecayI(isTvar) ==  50.0d+3   50.0d+3                       ! 1:NT tracers   (16 convolutions)

VdecayI(isUvel) ==  30.0d0                                  ! 3D U-momentum  (8  convolutions)
VdecayI(isVvel) ==  30.0d0                                  ! 3D V-momentum  (8  convolutions)
VdecayI(isTvar) ==  30.0d0    30.0d0                        ! 1:NT tracers   (8  convolutions)

Surface forcing error correlations (m):

HdecayF(isUstr) == 100.0d+3                     ! surface U-momentum stress   (66 convolutions)
HdecayF(isVstr) == 100.0d+3                     ! surface V-momentum stress   (66 convolutions)
HdecayF(isTsur) == 100.0d+3  100.0d+3           ! 1:NT surface tracer flux    (66 convolutions)
```

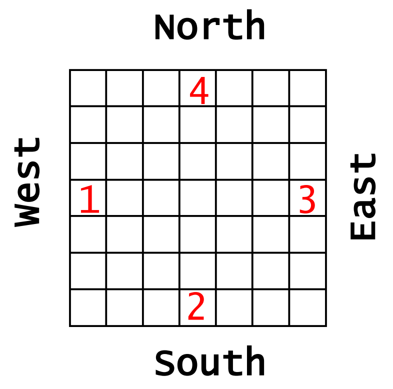
4D-Var Parameters: Decorrelation Scales

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)
```

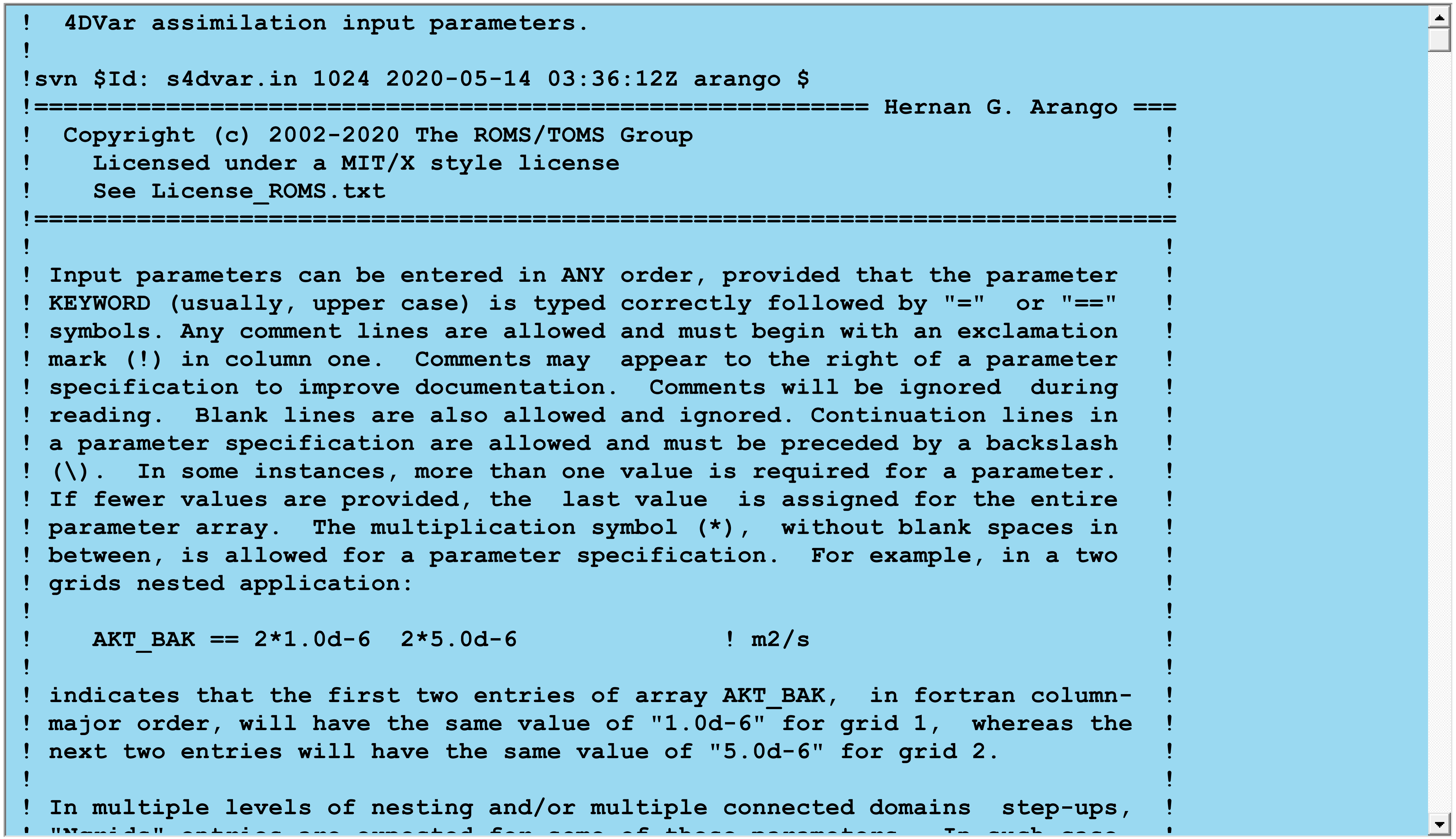
State Variables switches:

```
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 = 25                  ! Posterior error analysis Lanczos iterations

             Nvct = 10                  ! Stabilized representer matrix eigenvector
                                            to process
```

RBL4D-Var Parameters File: rbl4dvar.in



```
!  4DVar assimilation input parameters.
!
!svn $Id: s4dvar.in 1024 2020-05-14 03:36:12Z arango $
!========================================================= Hernan G. Arango ===
!  Copyright (c) 2002-2020 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   !
```

RBL4D-Var Job Script: job_rbl4dvar.csh

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. 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
```

5. Set model, 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
```

6. 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.

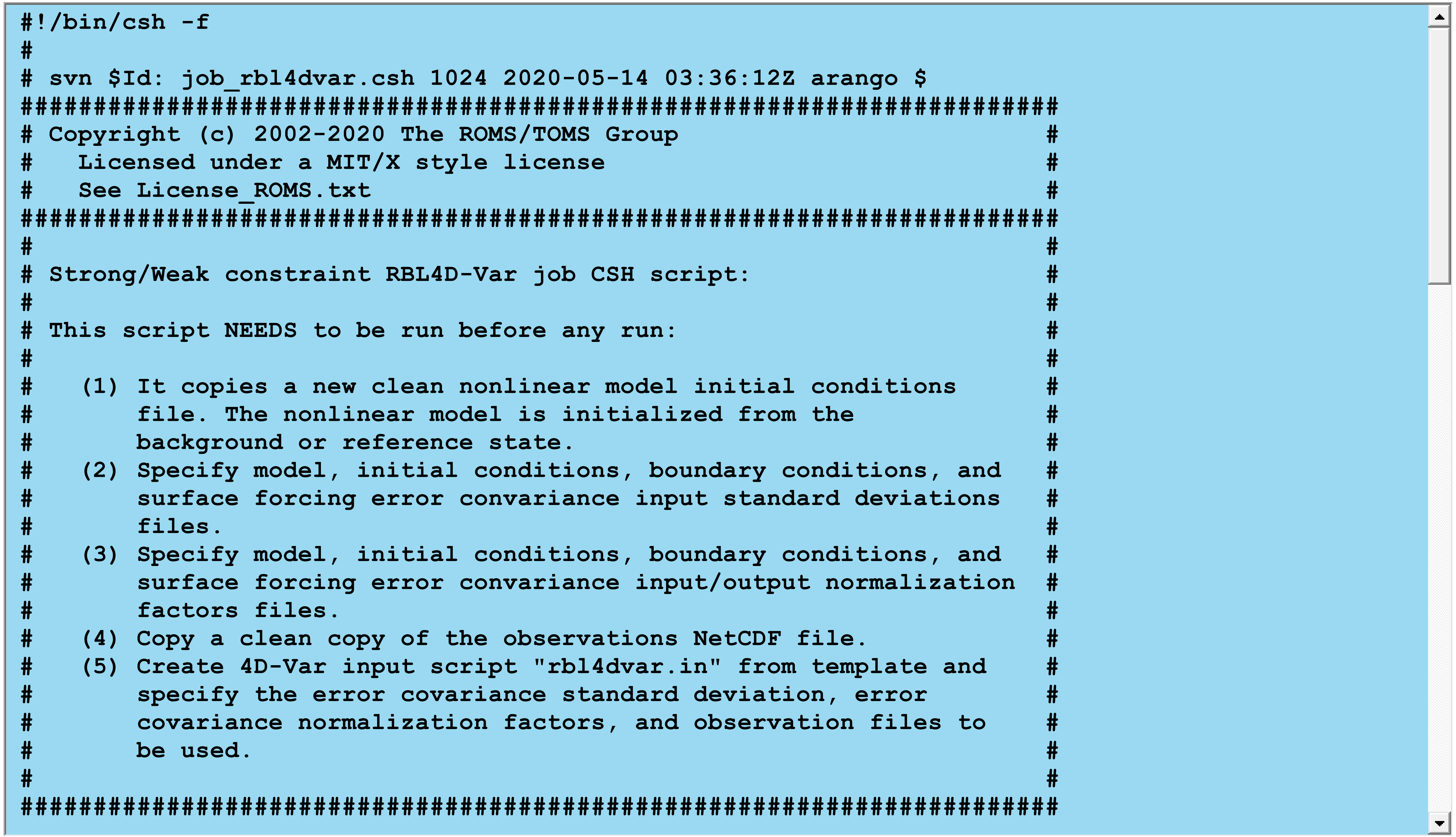
```
cp -p ${Dir}/Data/${OBSname} .
```

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

```
set RBL4DVAR = rbl4dvar.in
if (-e $RBL4DVAR) then
  /bin/rm $RBL4DVAR
endif
cp s4dvar.in $RBL4DVAR
```

```
$SUBSTITUTE $RBL4DVAR roms_std_m.nc $STDnameM
$SUBSTITUTE $RBL4DVAR roms_std_i.nc $STDnameI
$SUBSTITUTE $RBL4DVAR roms_std_b.nc $STDnameB
$SUBSTITUTE $RBL4DVAR roms_std_f.nc $STDnameF
$SUBSTITUTE $RBL4DVAR roms_nrm_m.nc $NRMnameM
$SUBSTITUTE $RBL4DVAR roms_nrm_i.nc $NRMnameI
$SUBSTITUTE $RBL4DVAR roms_nrm_b.nc $NRMnameB
$SUBSTITUTE $RBL4DVAR roms_nrm_f.nc $NRMnameF
$SUBSTITUTE $RBL4DVAR roms_obs.nc   $OBSname
$SUBSTITUTE $RBL4DVAR roms_hss.nc   wc13_hss.nc
$SUBSTITUTE $RBL4DVAR roms_lcz.nc   wc13_lcz.nc
$SUBSTITUTE $RBL4DVAR roms_mod.nc   wc13_mod.nc
$SUBSTITUTE $RBL4DVAR roms_err.nc   wc13_err.nc
```

RBL4D-Var Job Script File: job_rbl4dvar.sh



```
#!/bin/csh -f
#
# svn $Id: job_rbl4dvar.csh 1024 2020-05-14 03:36:12Z arango $
#######################################################################
# Copyright (c) 2002-2020 The ROMS/TOMS Group                         #
#   Licensed under a MIT/X style license                              #
#   See License_ROMS.txt                                              #
#######################################################################
#                                                                     #
# Strong/Weak constraint RBL4D-Var job CSH 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) Specify model, initial conditions, boundary conditions, and   #
#       surface forcing error convariance input standard deviations   #
#       files.                                                        #
#   (3) Specify model, initial conditions, boundary conditions, and   #
#       surface forcing error convariance input/output normalization  #
#       factors files.                                                #
#   (4) Copy a clean copy of the observations NetCDF file.            #
#   (5) Create 4D-Var input script "rbl4dvar.in" from template and    #
#       specify the error covariance standard deviation, error        #
#       covariance normalization factors, and observation files to    #
#       be used.                                                      #
#                                                                     #
#######################################################################
```

Compile: build_roms.sh

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

```
 export          MY_ROOT_DIR=${HOME}/ocean/toms/repository
 export       MY_PROJECT_DIR=${PWD}
```

2. Location of your ROMS source code.

```
 export          MY_ROMS_SRC=${MY_ROOT_DIR}/trunk
```

3. Path of Makefile configuration (*mk) files

```
 export            COMPILERS=${MY_ROMS_SRC}/Compilers
 export            COMPILERS=${HOME}/Compilers/ROMS
```

4. Build script invoked CPP options.

```
 export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DRBL4DVAR“
 export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DANA_SPONGE“
#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DMINRES“
#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DTIME_CONV“

#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DBGQC“

#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DPOSTERIOR_EOFS“       # Nouter=1
#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DPOSTERIOR_ERROR_I“    # Nouter=1

#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DCOLLECT_ALLREDUCE“
#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DREDUCE_ALLGATHER“

#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DDEBUGGING”
#export         MY_CPP_FLAGS="${MY_CPP_FLAGS} -DPOSITIVE_ZERO"
```

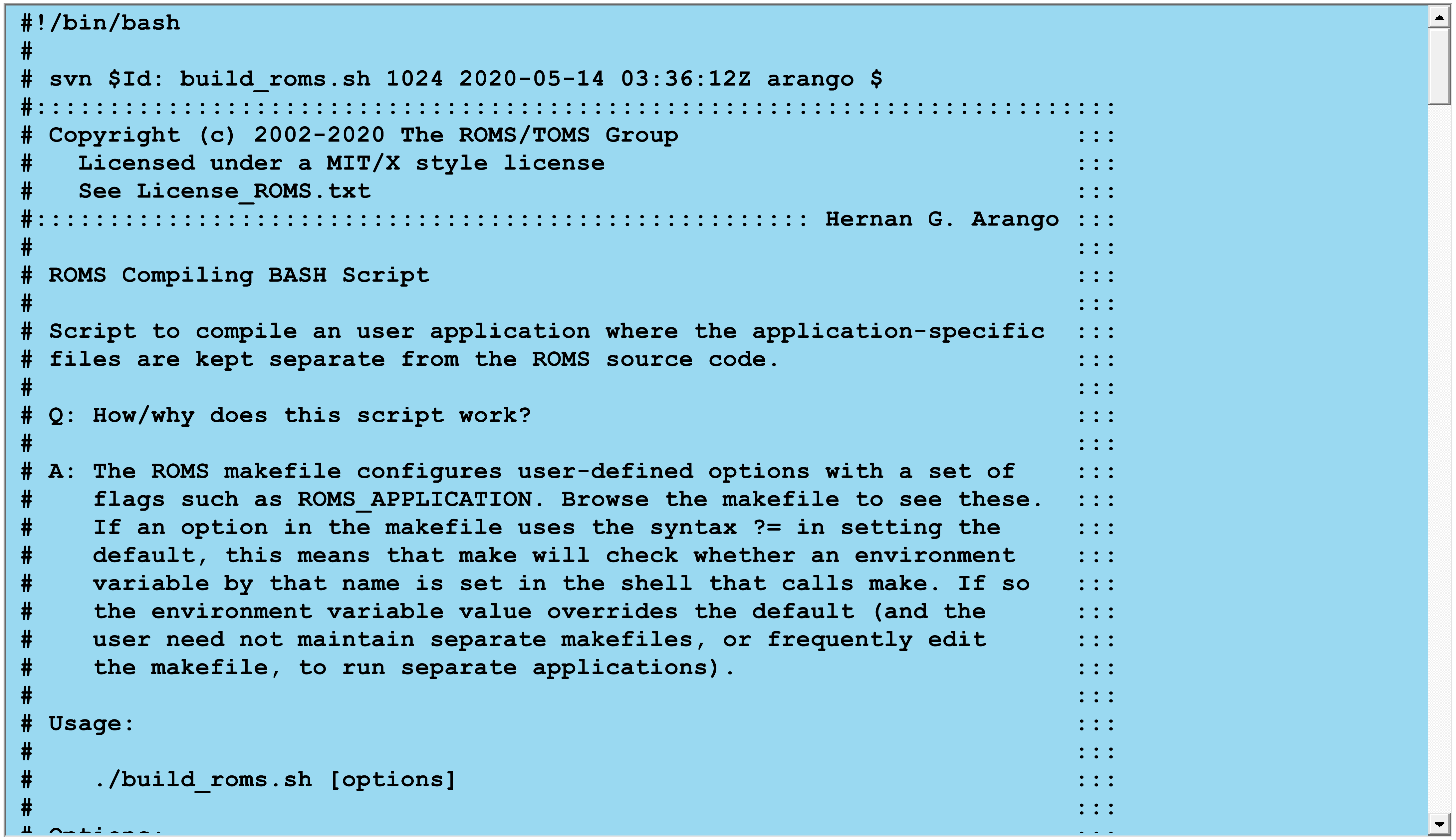
5. Compiler selection environment variables.

```
 export             USE_MPI=on
 export          USE_MPIF90=on
 export           which_MPI=openmp

 export                FORT=ifort
```

6. Use custom library paths

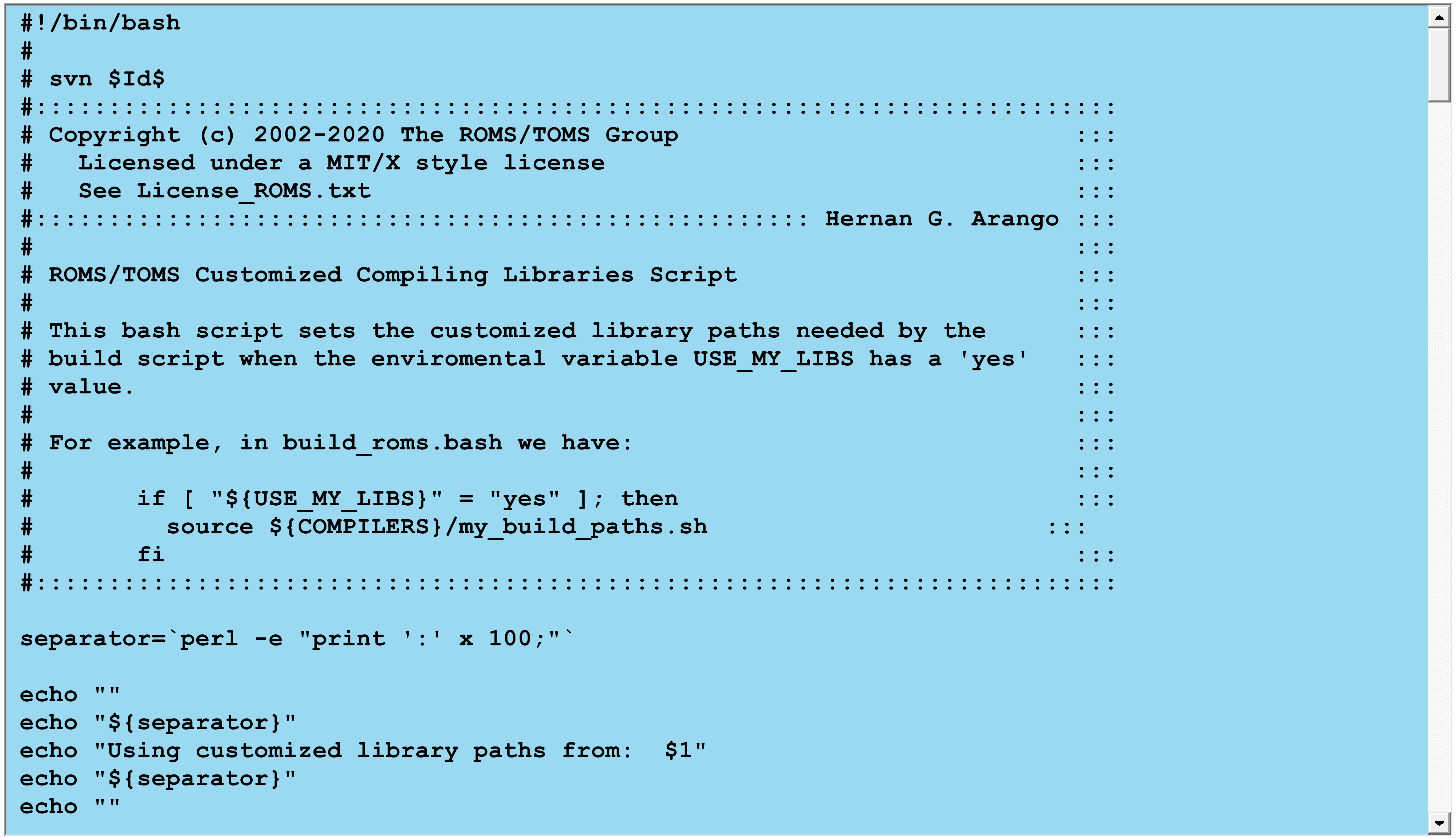
```
 export USE_MY_LIBS=no           # use system default library paths
#export USE_MY_LIBS=yes          # use my customized library paths

 MY_PATHS=${COMPILERS}/my_build_paths.bash
 if [ “$USE_MY_LIBS” == “yes”]; then
   source ${MY_PATHS} ${MY_PATHS}
 fi
```

Build Script: build_roms.sh



```
#!/bin/bash
#
# svn $Id: build_roms.sh 1024 2020-05-14 03:36:12Z arango $
#::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
# Copyright (c) 2002-2020 The ROMS/TOMS Group                        :::
#   Licensed under a MIT/X style license                             :::
#   See License_ROMS.txt                                             :::
#:::::::::::::::::::::::::::::::::::::::::::::::::::: Hernan G. Arango :::
#                                                                    :::
# ROMS Compiling BASH 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_roms.sh [options]                                       :::
#                                                                    :::
```

Build Script: my_build_paths.sh



```
#!/bin/bash
#
# svn $Id$
#::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
# Copyright (c) 2002-2020 The ROMS/TOMS Group                           :::
#   Licensed under a MIT/X style license                                :::
#   See License_ROMS.txt                                                :::
#::::::::::::::::::::::::::::::::::::::::::::::::::::: Hernan G. Arango :::
#                                                                       :::
# ROMS/TOMS Customized Compiling Libraries Script                       :::
#                                                                       :::
# This bash script sets the customized library paths needed by the      :::
# build script when the enviromental variable USE_MY_LIBS has a 'yes'   :::
# value.                                                                :::
#                                                                       :::
# For example, in build_roms.bash we have:                              :::
#                                                                       :::
#       if [ "${USE_MY_LIBS}" = "yes" ]; then                           :::
#         source ${COMPILERS}/my_build_paths.sh                       :::
#       fi                                                              :::
#::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::

separator=`perl -e "print ':' x 100;"`

echo ""
echo "${separator}"
echo "Using customized library paths from:  $1"
echo "${separator}"
echo ""
```