A Brief Guide for WRFDA Developers

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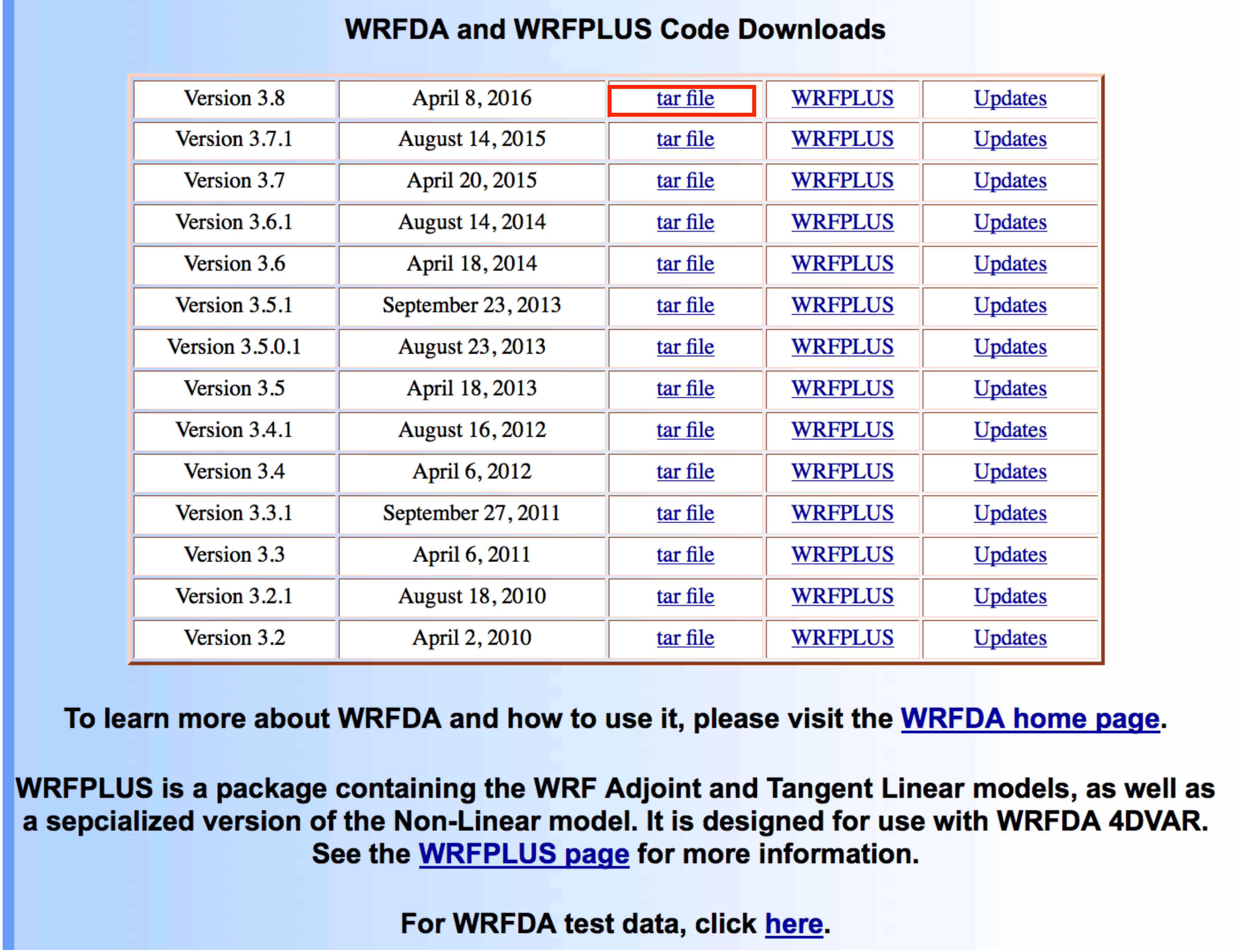


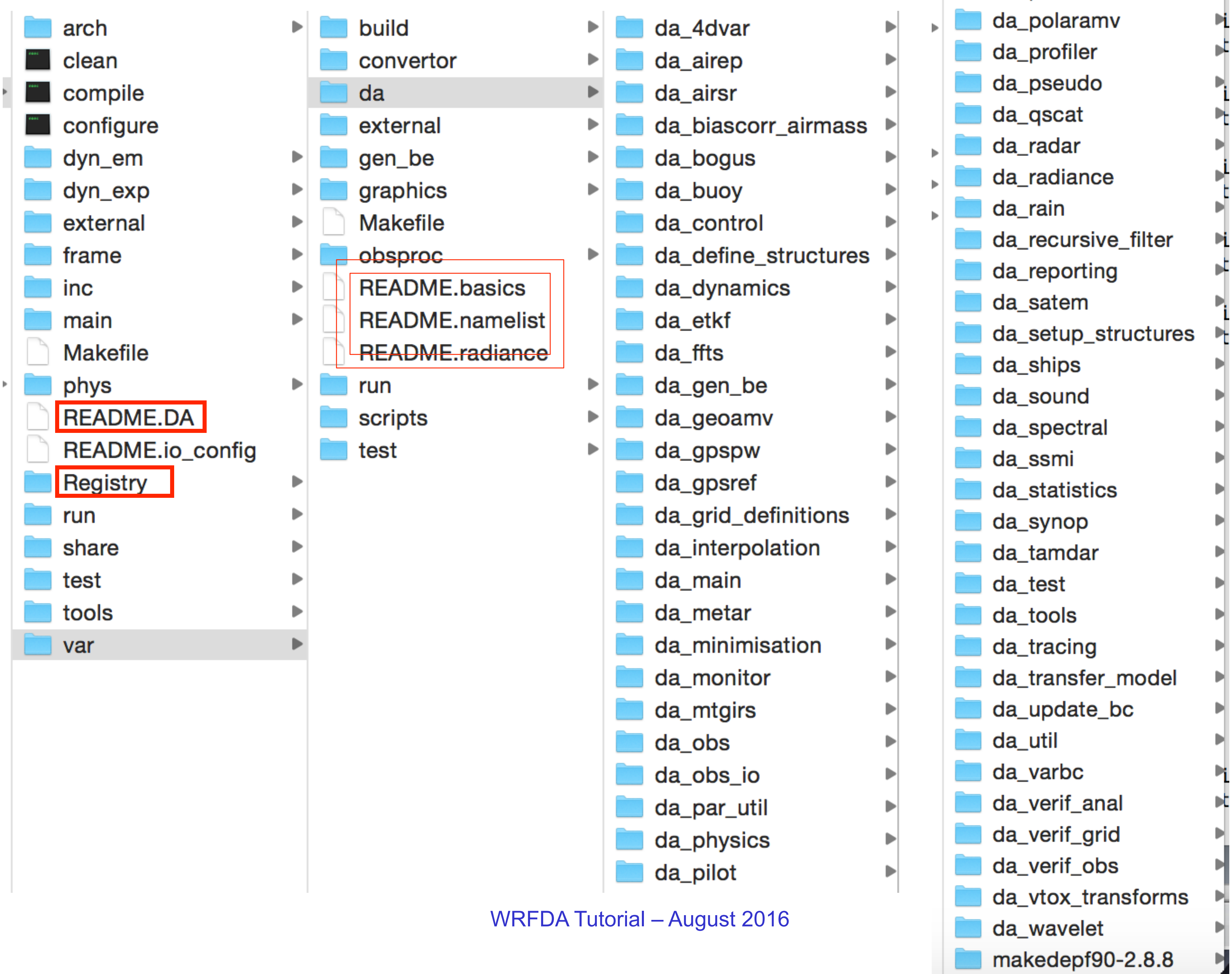
WRFDA and WRFPLUS Code Downloads

Version 3.8	April 8, 2016	tar file	WRFPLUS	Updates
Version 3.7.1	August 14, 2015	tar file	WRFPLUS	Updates
Version 3.7	April 20, 2015	tar file	WRFPLUS	Updates
Version 3.6.1	August 14, 2014	tar file	WRFPLUS	Updates
Version 3.6	April 18, 2014	tar file	WRFPLUS	Updates
Version 3.5.1	September 23, 2013	tar file	WRFPLUS	Updates
Version 3.5.0.1	August 23, 2013	tar file	WRFPLUS	Updates
Version 3.5	April 18, 2013	tar file	WRFPLUS	Updates
Version 3.4.1	August 16, 2012	tar file	WRFPLUS	Updates
Version 3.4	April 6, 2012	tar file	WRFPLUS	Updates
Version 3.3.1	September 27, 2011	tar file	WRFPLUS	Updates
Version 3.3	April 6, 2011	tar file	WRFPLUS	Updates
Version 3.2.1	August 18, 2010	tar file	WRFPLUS	Updates
Version 3.2	April 2, 2010	tar file	WRFPLUS	Updates

To learn more about WRFDA and how to use it, please visit the WRFDA home page.

WRFPLUS is a package containing the WRF Adjoint and Tangent Linear models, as well as a sepcialized version of the Non-Linear model. It is designed for use with WRFDA 4DVAR. See the WRFPLUS page for more information.

For WRFDA test data, click here.



arch
clean
compile
configure
dyn_em
dyn_exp
external
frame
inc
main
Makefile
phys
README.DA
README.io_config
Registry
run
share
test
tools
var

build
convertor
da
external
gen_be
graphics
Makefile
obsproc
README.basics
README.namelist
README.radiance
run
scripts
test

da_4dvar
da_airep
da_airsr
da_biascorr_airmass
da_bogus
da_buoy
da_control
da_define_structures
da_dynamics
da_etkf
da_ffts
da_gen_be
da_geoamv
da_gpspw
da_gpsref
da_grid_definitions
da_interpolation
da_main
da_metar
da_minimisation
da_monitor
da_mtgirs
da_obs
da_obs_io
da_par_util
da_physics
da_pilot

da_polaramv
da_profiler
da_pseudo
da_qscat
da_radar
da_radiance
da_rain
da_recursive_filter
da_reporting
da_satem
da_setup_structures
da_ships
da_sound
da_spectral
da_ssmi
da_statistics
da_synop
da_tamdar
da_test
da_tools
da_tracing
da_transfer_model
da_update_bc
da_util
da_varbc
da_verif_anal
da_verif_grid
da_verif_obs
da_vtox_transforms
da_wavelet
makedepf90-2.8.8

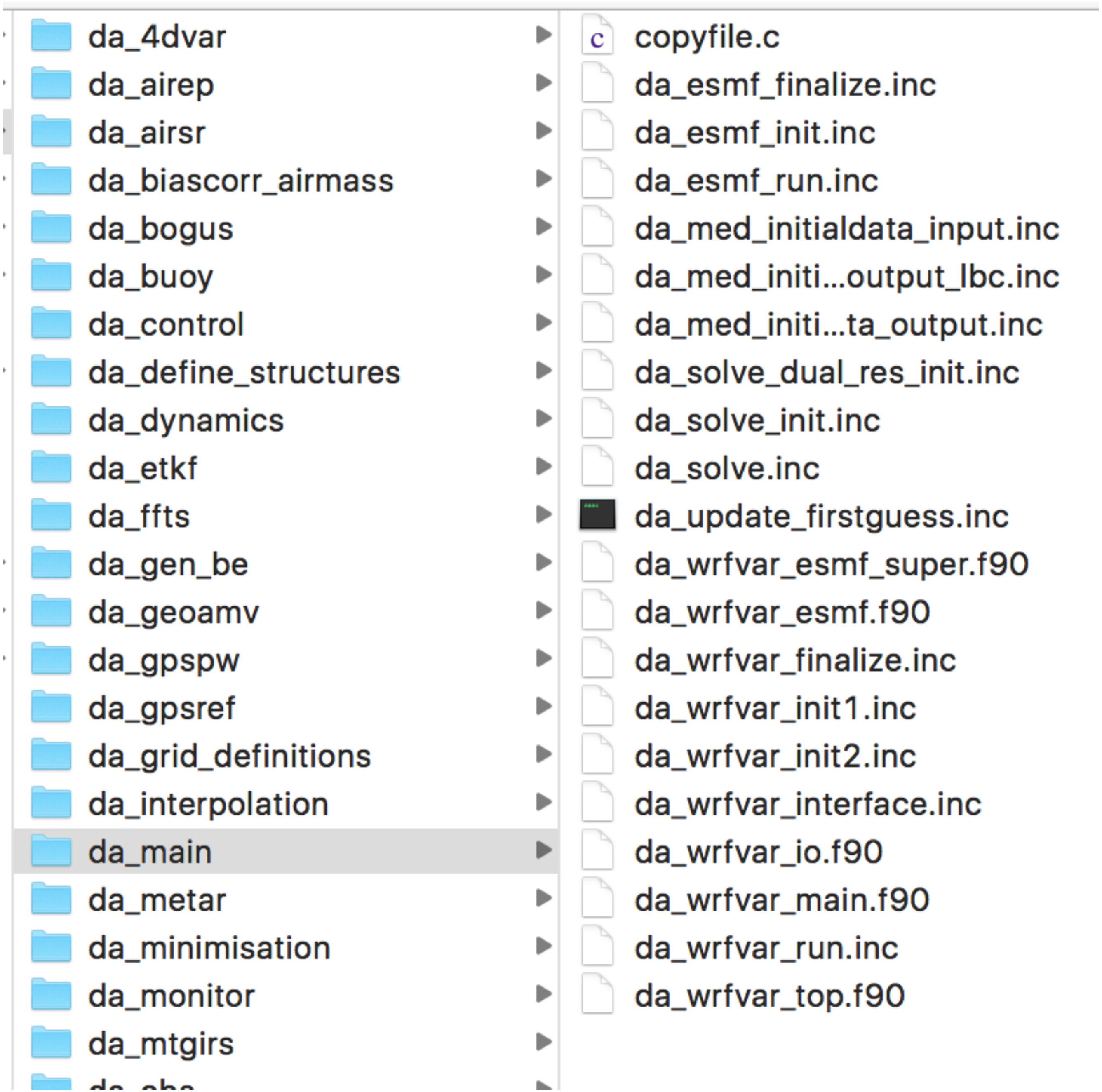
WRFDA/var/da

da_main
da_4dvar
da_control
da_etkf
da_define_structures
da_dynamics
da_grid_definitions
da_interpolation
da_minimisation
da_physics
da_setup_structures
da_varbc
da_vtox_transforms

Observation-related code

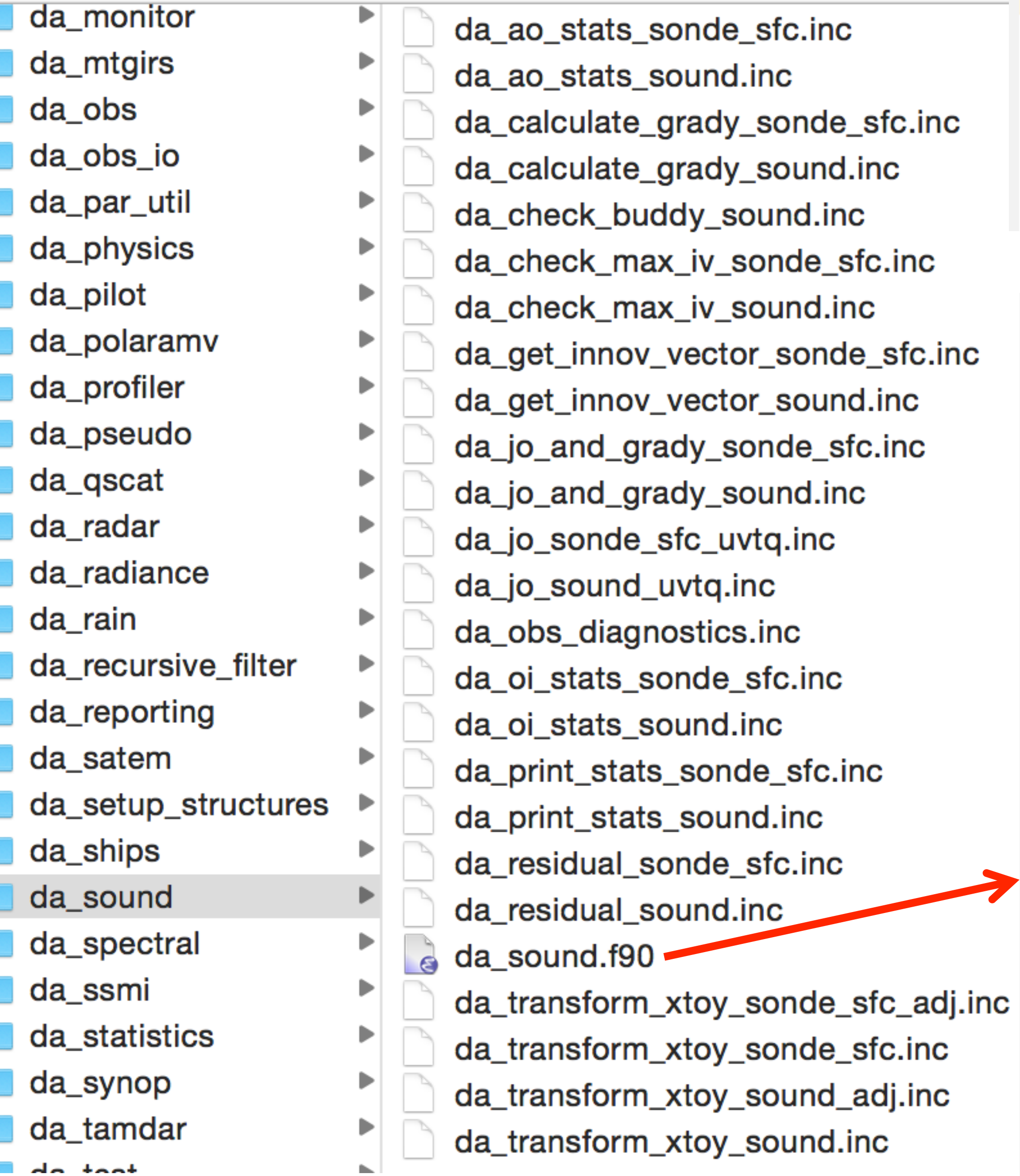
da_airep
da_airsr
da_bogus
da_buoy
da_geoamv
da_gpspw
da_gpsref
da_metar
da_mtgirs
da_pilot
da_polaramv
da_profiler

da_pseudo
da_qscat
da_radar
da_radiance
da_rain
da_satem
da_ships
da_sound
da_ssmi
da_synop
da_tamdar
da_obs
da_obs_io



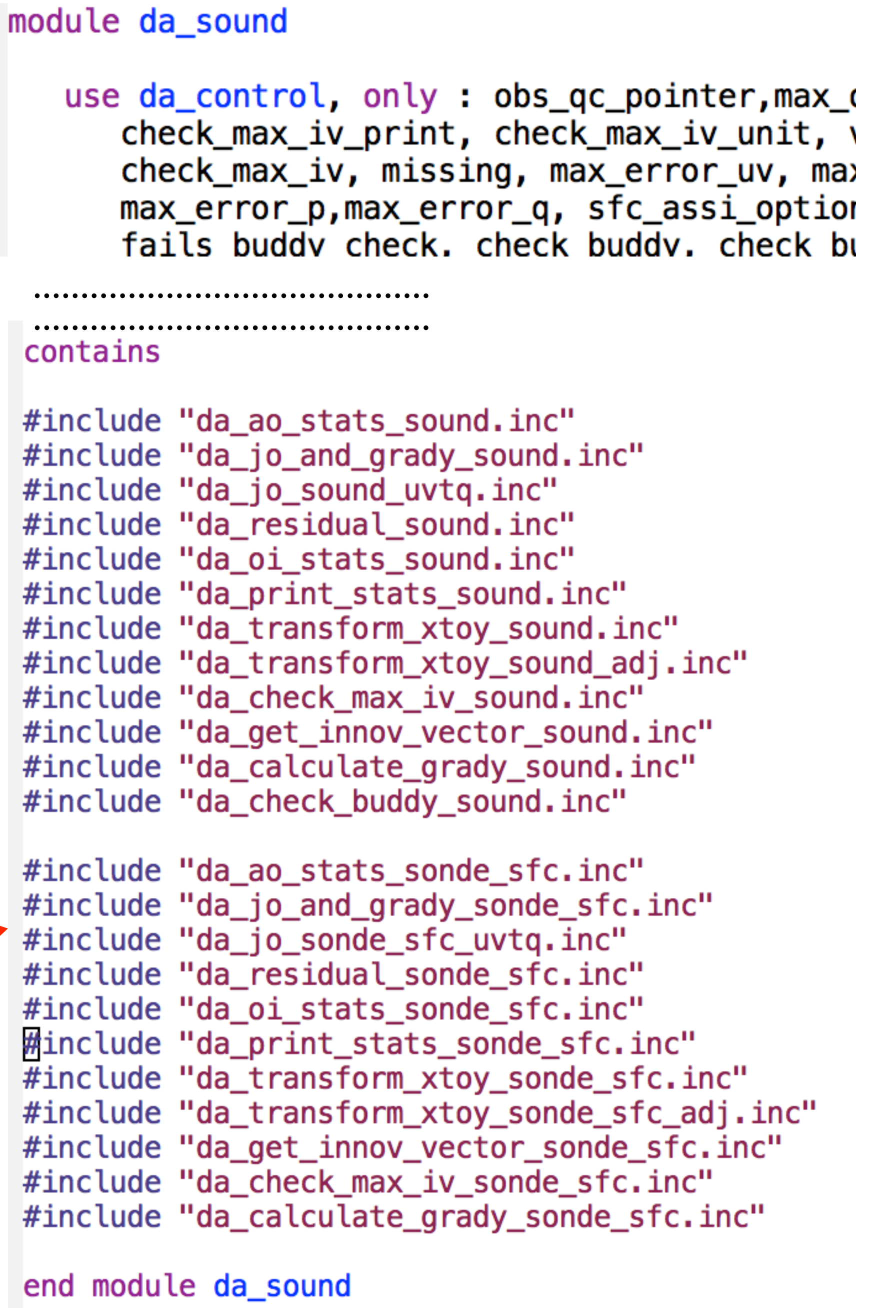
da_4dvar
da_airep
da_airsr
da_biascorr_airmass
da_bogus
da_buoy
da_control
da_define_structures
da_dynamics
da_etkf
da_ffts
da_gen_be
da_geoamv
da_gpspw
da_gpsref
da_grid_definitions
da_interpolation
da_main
da_metar
da_minimisation
da_monitor
da_mtgirs
da_obs

copyfile.c
da_esmf_finalize.inc
da_esmf_init.inc
da_esmf_run.inc
da_med_initialdata_input.inc
da_med_initi...output_lbc.inc
da_med_initi...ta_output.inc
da_solve_dual_res_init.inc
da_solve_init.inc
da_solve.inc
da_update_firstguess.inc
da_wrfvar_esmf_super.f90
da_wrfvar_esmf.f90
da_wrfvar_finalize.inc
da_wrfvar_init1.inc
da_wrfvar_init2.inc
da_wrfvar_interface.inc
da_wrfvar_io.f90
da_wrfvar_main.f90
da_wrfvar_run.inc
da_wrfvar_top.f90



- da_monitor ▶
- da_mtgirs ▶
- da_obs ▶
- da_obs_io ▶
- da_par_util ▶
- da_physics ▶
- da_pilot ▶
- da_polaramv ▶
- da_profiler ▶
- da_pseudo ▶
- da_qscat ▶
- da_radar ▶
- da_radiance ▶
- da_rain ▶
- da_recursive_filter ▶
- da_reporting ▶
- da_satem ▶
- da_setup_structures ▶
- da_ships ▶
- da_sound ▶
- da_spectral ▶
- da_ssmi ▶
- da_statistics ▶
- da_synop ▶
- da_tamdar ▶

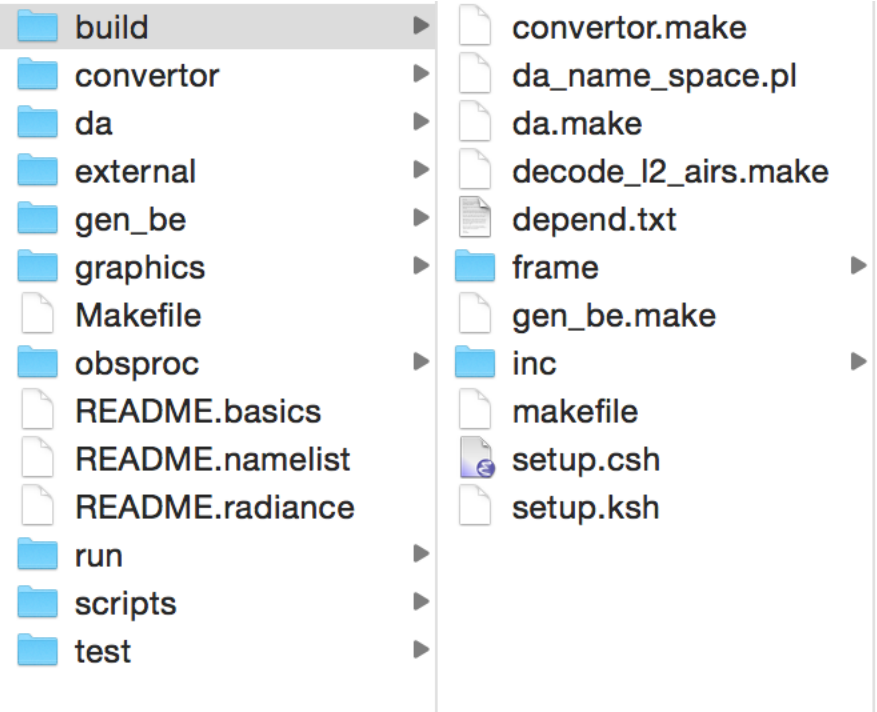
- da_ao_stats_sonde_sfc.inc
- da_ao_stats_sound.inc
- da_calculate_grady_sonde_sfc.inc
- da_calculate_grady_sound.inc
- da_check_buddy_sound.inc
- da_check_max_iv_sonde_sfc.inc
- da_check_max_iv_sound.inc
- da_get_innov_vector_sonde_sfc.inc
- da_get_innov_vector_sound.inc
- da_jo_and_grady_sonde_sfc.inc
- da_jo_and_grady_sound.inc
- da_jo_sonde_sfc_uvtq.inc
- da_jo_sound_uvtq.inc
- da_obs_diagnostics.inc
- da_oi_stats_sonde_sfc.inc
- da_oi_stats_sound.inc
- da_print_stats_sonde_sfc.inc
- da_print_stats_sound.inc
- da_residual_sonde_sfc.inc
- da_residual_sound.inc
- da_sound.f90
- da_transform_xtoy_sonde_sfc_adj.inc
- da_transform_xtoy_sonde_sfc.inc
- da_transform_xtoy_sound_adj.inc
- da_transform_xtoy_sound.inc



```
module da_sound

   use da_control, only : obs_qc_pointer,max_(
      check_max_iv_print, check_max_iv_unit, \
      check_max_iv, missing, max_error_uv, max
      max_error_p,max_error_q, sfc_assi_optior
      fails buddv check. check buddv. check bu

 .....................................
 .....................................
contains

#include "da_ao_stats_sound.inc"
#include "da_jo_and_grady_sound.inc"
#include "da_jo_sound_uvtq.inc"
#include "da_residual_sound.inc"
#include "da_oi_stats_sound.inc"
#include "da_print_stats_sound.inc"
#include "da_transform_xtoy_sound.inc"
#include "da_transform_xtoy_sound_adj.inc"
#include "da_check_max_iv_sound.inc"
#include "da_get_innov_vector_sound.inc"
#include "da_calculate_grady_sound.inc"
#include "da_check_buddy_sound.inc"

#include "da_ao_stats_sonde_sfc.inc"
#include "da_jo_and_grady_sonde_sfc.inc"
#include "da_jo_sonde_sfc_uvtq.inc"
#include "da_residual_sonde_sfc.inc"
#include "da_oi_stats_sonde_sfc.inc"
#include "da_print_stats_sonde_sfc.inc"
#include "da_transform_xtoy_sonde_sfc.inc"
#include "da_transform_xtoy_sonde_sfc_adj.inc"
#include "da_get_innov_vector_sonde_sfc.inc"
#include "da_check_max_iv_sonde_sfc.inc"
#include "da_calculate_grady_sonde_sfc.inc"

end module da_sound
```

***.inc are subroutines**

Compilation of code: under var/build



build
convertor
da
external
gen_be
graphics
Makefile
obsproc
README.basics
README.namelist
README.radiance
run
scripts
test

convertor.make
da_name_space.pl
da.make
decode_l2_airs.make
depend.txt
frame
gen_be.make
inc
makefile
setup.csh
setup.ksh

- Link *.inc to ~build
- cpp *.inc and *.f90 into *.f (WRFDA code to be really compiled)
- Also use some WRF code
  - Raw WRF code: *.F
  - Cpp: .F to *.f90
- Also use auto-generated code var/build/inc/*.inc (with registry mechanism)

Capability control via conditional compilation

```
#if defined(RTTOV) || defined(CRTM)
  if (use_rad .and. (use_varbc.or.freeze_varbc)) call da_varbc_init(iv, be)
#endif
```

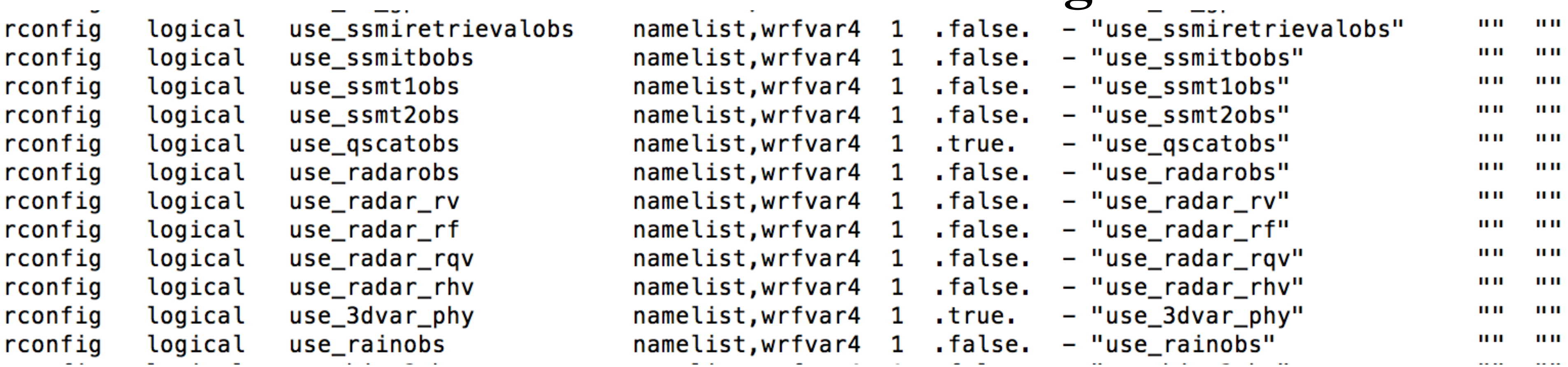
```
#ifdef CLOUD_CV
     be % v6  % mz = 0
     be % v7  % mz = 0
     be % v8  % mz = 0
     be % v9  % mz = 0
     be % v10 % mz = 0
     be % v11 % mz = 0
#endif
```

Need to set corresponding environment variables (e.g., setenv CLOUD_CV 1) to have segments of code appear in cpp-preprocessed *.f file.

Control in compilation step can save memory usage by removing code for unused capability.

```
#ifdef VAR4D                (this is activated through "./configure 4dvar")
       if (it &gt; 1) then
          call kj_swap (grid%u_2, model_grid%u_2, &amp;
                    grid%xp%ims, grid%xp%ime, grid%xp%jms, grid%xp%jme, grid%xp%kms, grid%xp%kme)
  …….
#else
      write(unit=message(1),fmt='(A)')'Please re-compile the code with 4dvar option'
      call da_error(__FILE__,__LINE__,message(1:1))
#endif
```

Run-time control via namelist parameter convenient to switch on/off with single executable



```
rconfig   logical   use_ssmiretrievalobs    namelist,wrfvar4  1  .false.  - "use_ssmiretrievalobs"     ""  ""
rconfig   logical   use_ssmitbobs           namelist,wrfvar4  1  .false.  - "use_ssmitbobs"            ""  ""
rconfig   logical   use_ssmt1obs            namelist,wrfvar4  1  .false.  - "use_ssmt1obs"             ""  ""
rconfig   logical   use_ssmt2obs            namelist,wrfvar4  1  .false.  - "use_ssmt2obs"             ""  ""
rconfig   logical   use_qscatobs            namelist,wrfvar4  1  .true.   - "use_qscatobs"             ""  ""
rconfig   logical   use_radarobs            namelist,wrfvar4  1  .false.  - "use_radarobs"             ""  ""
rconfig   logical   use_radar_rv            namelist,wrfvar4  1  .false.  - "use_radar_rv"             ""  ""
rconfig   logical   use_radar_rf            namelist,wrfvar4  1  .false.  - "use_radar_rf"             ""  ""
rconfig   logical   use_radar_rqv           namelist,wrfvar4  1  .false.  - "use_radar_rqv"            ""  ""
rconfig   logical   use_radar_rhv           namelist,wrfvar4  1  .false.  - "use_radar_rhv"            ""  ""
rconfig   logical   use_3dvar_phy           namelist,wrfvar4  1  .true.   - "use_3dvar_phy"            ""  ""
rconfig   logical   use_rainobs             namelist,wrfvar4  1  .false.  - "use_rainobs"              ""  ""
```

Portion of WRFDA/Registry/registry.var file that defines all WRFDA-related namelist parameters. Developer can add new parameters for new capabilities. e.g., new amsr2 radiance DA in V3.8.

```
rconfig   logical   use_amsr2obs        namelist,wrfvar4  1  .false.  - "use_amsr2obs"        ""  ""
```

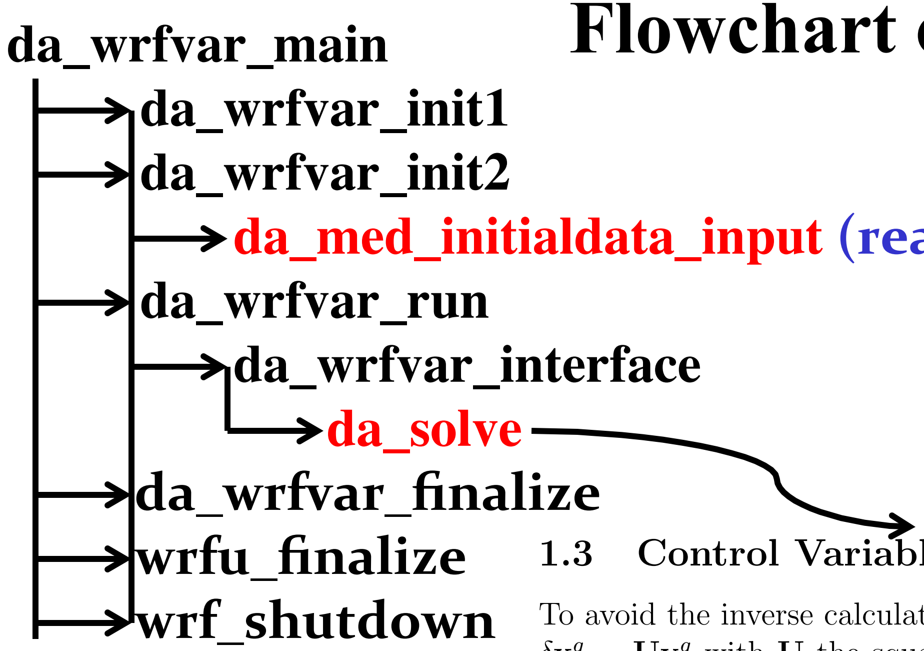
```
   if (use_amsr2obs) then
#if defined(HDF5)
        write(unit=stdout,fmt='(a)') 'Reading AMSR2 data in HDF5 format'
        call da_read_obs_hdf5amsr2 (iv, 'L1SGRTBR', 'L2SGCLWLD')
#else
        message(1)='To read AMSR2 data, WRFDA must be compiled with HDF5'
        call da_error(__FILE__,__LINE__,message(1:1))
#endif
   end if
```

da_setup_radiance_structures.inc

```
module da_radiance
    ........

    use da_control, only : .... &
       ..., use_amsr2obs, ... &
      ............
end module da_radiance
```

da_radiance.f90

Flowchart of WRFDA main program



da_wrfvar_main
da_wrfvar_init1
da_wrfvar_init2
da_med_initialdata_input (read ‘fg’ into grid%*)
da_wrfvar_run
da_wrfvar_interface
da_solve
da_wrfvar_finalize
wrfu_finalize
wrf_shutdown

1.3 Control Variable Transform (CVT)

To avoid the inverse calculation of large $\mathbf{B}$ matrix, do a change of variable $\delta\mathbf{x} = \mathbf{U}\mathbf{v}$ and $\delta\mathbf{x}^g = \mathbf{U}\mathbf{v}^g$ with $\mathbf{U}$ the square root of $\mathbf{B}$, namely $\mathbf{B} = \mathbf{B}^{1/2}\mathbf{B}^{\mathrm{T}/2} = \mathbf{U}\mathbf{U}^{\mathrm{T}}$ or $\mathbf{U} = \mathbf{B}^{1/2}$. Also $\mathbf{B}^{-1} = \mathbf{U}^{-\mathrm{T}}\mathbf{U}^{-1}$. Then the cost function with respect to the control variable $\mathbf{v}$ becomes

$$J(\mathbf{v}) = \frac{1}{2}(\mathbf{v} - \mathbf{v}^g)^{\mathrm{T}}(\mathbf{v} - \mathbf{v}^g) + \frac{1}{2}(\mathbf{HUv} - \mathbf{d})^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{HUv} - \mathbf{d}) \qquad (4)$$

1.4 Solution of Incremental 3DVAR

The minimization of the cost function requires its gradient with respect to $\mathbf{v}$ to be zero, namely

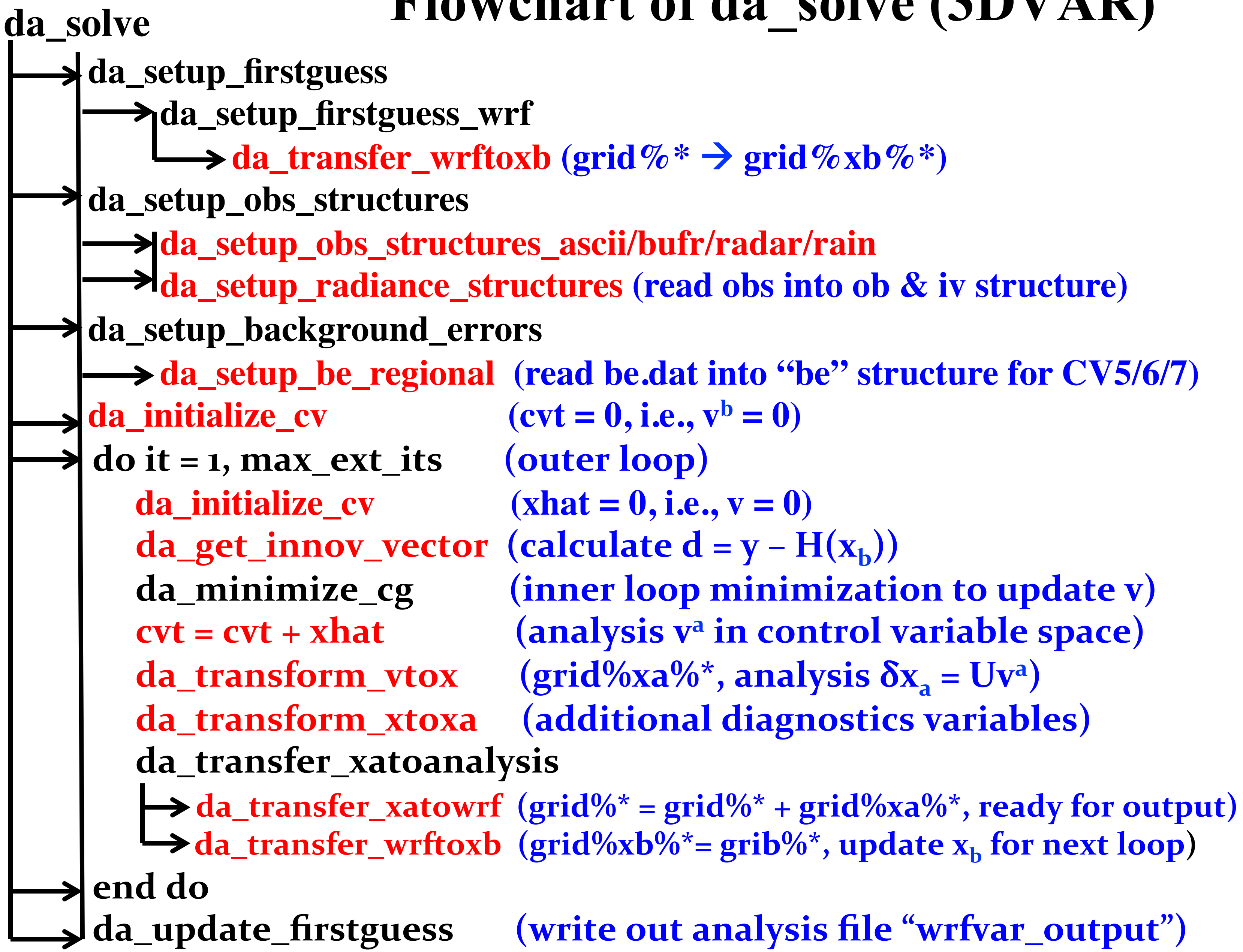
$$\nabla_{\mathbf{v}} J(\mathbf{v}) = (\mathbf{v} - \mathbf{v}^g) + \mathbf{U}^{\mathrm{T}}\mathbf{H}^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{HUv} - \mathbf{d}) = 0 \qquad (5)$$

$$\mathbf{v}^a = (\mathrm{I} + \mathbf{U}^{\mathrm{T}}\mathbf{H}^{\mathrm{T}}\mathbf{R}^{-1}\mathbf{HU})^{-1}(\mathbf{v}^g + \mathbf{U}^{\mathrm{T}}\mathbf{H}^{\mathrm{T}}\mathbf{R}^{-1}\mathbf{d})$$

The analysis increment and the analysis in model space are

$$\mathbf{x}^a = \mathbf{x}^g + \delta\mathbf{x}^a = \mathbf{x}^g + \mathbf{U}\mathbf{v}^a$$

Flowchart of da_solve (3DVAR)



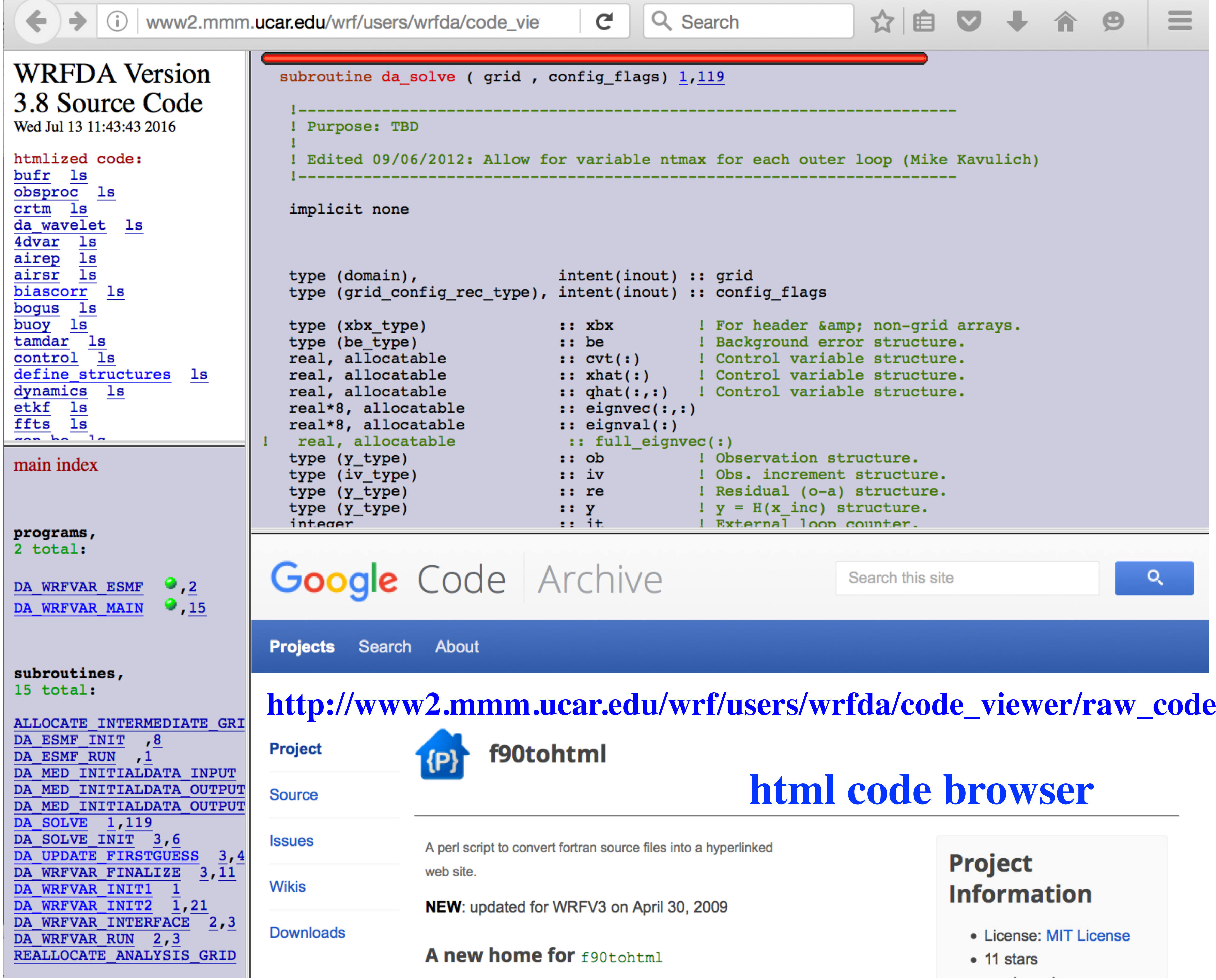
```
da_solve
    da_setup_firstguess
        da_setup_firstguess_wrf
            da_transfer_wrftoxb (grid%* → grid%xb%*)
    da_setup_obs_structures
        da_setup_obs_structures_ascii/bufr/radar/rain
        da_setup_radiance_structures (read obs into ob & iv structure)
    da_setup_background_errors
        da_setup_be_regional  (read be.dat into "be" structure for CV5/6/7)
    da_initialize_cv              (cvt = 0, i.e., $v^b = 0$)
    do it = 1, max_ext_its        (outer loop)
        da_initialize_cv          (xhat = 0, i.e., v = 0)
        da_get_innov_vector       (calculate $d = y - H(x_b)$)
        da_minimize_cg            (inner loop minimization to update v)
        cvt = cvt + xhat          (analysis $v^a$ in control variable space)
        da_transform_vtox         (grid%xa%*, analysis $\delta x_a = Uv^a$)
        da_transform_xtoxa        (additional diagnostics variables)
        da_transfer_xatoanalysis
            da_transfer_xatowrf   (grid%* = grid%* + grid%xa%*, ready for output)
            da_transfer_wrftoxb   (grid%xb%*= grib%*, update $x_b$ for next loop)
    end do
    da_update_firstguess          (write out analysis file "wrfvar_output")
```

da_minimize_cg (…, be, iv, j_grad_norm_target, xhat, cvt, re, y, j)

- **da_calculate_j** $J(\mathbf{v}) = \frac{1}{2}(\mathbf{v}-\mathbf{v}^g)^{\mathrm{T}}(\mathbf{v}-\mathbf{v}^g) + \frac{1}{2}(\mathbf{HUv}-\mathbf{d})^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{HUv}-\mathbf{d})$
  - **da_transform_vtoy** (calculate y = HUv)
    - da_transform_vtox + da_transform_xtoxa → da_transform_xtoy
  - **da_calculate_residual** (calculate re = HUv – d)
  - **da_jo_and_grady** (calculate R^{-1} * re and J % jo = 0.5* re * R^{-1} * re)
  - J % jb = 0.5 * da_dot_cv (cvt + xhat, cvt + xhat)
  - J % total = J % jb + J % jo + …
  - **da_calculate_gradj**
- Do iter = 1, ntmax(it) !! Inner loop
  - **da_calculate_gradj** $\nabla_{\mathbf{v}} J(\mathbf{v}) = (\mathbf{v}-\mathbf{v}^g) + \mathbf{U}^{\mathrm{T}}\mathbf{H}^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{HUv}-\mathbf{d})$
    - **da_transform_vtoy (apply Tangent Linear operator H U)**
    - **da_calculate_grady**
    - **da_transform_vtoy_adj (apply Adjoint operator U^T H^T)**
- End Do
- **da_calculate_j** !! Calculate J after iteration

WRFDA Data Structures

- grid% : WRF variables in staggered C-grid
- grid%xb% : x_g in A-grid
- grid%xa% : analysis increment in model space
- grid%vv% : vv = U_h v (U_h is recursive filter)
- grid%vp% : vp = U_v vv = E $L^{1/2}$ vv (vertical EOF)
- be% : background error
- ob% : observations
- iv% = d : innovation
- y% = HUv
- re% = HUv – d



WRFDA Version 3.8 Source Code

Wed Jul 13 11:43:43 2016

htmlized code:
- bufr ls
- obsproc ls
- crtm ls
- da_wavelet ls
- 4dvar ls
- airep ls
- airsr ls
- biascorr ls
- bogus ls
- buoy ls
- tamdar ls
- control ls
- define_structures ls
- dynamics ls
- etkf ls
- ffts ls

main index

programs,
2 total:

DA_WRFVAR_ESMF ●,2
DA_WRFVAR_MAIN ●,15

subroutines,
15 total:

ALLOCATE_INTERMEDIATE_GRI
DA_ESMF_INIT ,8
DA_ESMF_RUN ,1
DA_MED_INITIALDATA_INPUT
DA_MED_INITIALDATA_OUTPUT
DA_MED_INITIALDATA_OUTPUT
DA_SOLVE 1,119
DA_SOLVE_INIT 3,6
DA_UPDATE_FIRSTGUESS 3,4
DA_WRFVAR_FINALIZE 3,11
DA_WRFVAR_INIT1 1
DA_WRFVAR_INIT2 1,21
DA_WRFVAR_INTERFACE 2,3
DA_WRFVAR_RUN 2,3
REALLOCATE_ANALYSIS_GRID

```
 subroutine da_solve ( grid , config_flags) 1,119

   !---------------------------------------------------------------------------
   ! Purpose: TBD
   !
   ! Edited 09/06/2012: Allow for variable ntmax for each outer loop (Mike Kavulich)
   !---------------------------------------------------------------------------

   implicit none


   type (domain),                intent(inout) :: grid
   type (grid_config_rec_type), intent(inout) :: config_flags

   type (xbx_type)                :: xbx          ! For header &amp; non-grid arrays.
   type (be_type)                 :: be           ! Background error structure.
   real, allocatable              :: cvt(:)       ! Control variable structure.
   real, allocatable              :: xhat(:)      ! Control variable structure.
   real, allocatable              :: qhat(:,:)    ! Control variable structure.
   real*8, allocatable            :: eignvec(:,:)
   real*8, allocatable            :: eignval(:)
!   real, allocatable              :: full_eignvec(:)
   type (y_type)                  :: ob           ! Observation structure.
   type (iv_type)                 :: iv           ! Obs. increment structure.
   type (y_type)                  :: re           ! Residual (o-a) structure.
   type (y_type)                  :: y            ! y = H(x_inc) structure.
   integer                        :: it           ! External loop counter.
```

Google Code Archive

http://www2.mmm.ucar.edu/wrf/users/wrfda/code_viewer/raw_code/

f90tohtml

html code browser

A perl script to convert fortran source files into a hyperlinked web site.

NEW: updated for WRFV3 on April 30, 2009

A new home for `f90tohtml`

Project Information

- License: MIT License
- 11 stars

Scenarios for new development

- Add a new observation type
  - Conventional data
  - Clear-sky radiance data
- Add new analysis variables
  - e.g., cloud/precip, aerosol/chemistry
- Add both new obs and analysis variables
  - e.g., cloud/precip-affected radiance DA, radar DA
- Add new cost function term
  - Variational bias correction of radiance data
  - Variational bias correction of aircraft data
  - Hybrid-3DEnVar/4DEnVar, dynamic constraint

Add new obs type: follow templates

- Near surface level observations:
  - da_synop, da_metar, da_buoy, da_ships, da_qscat
- Profile observations
  - da_sound, da_pilot, da_profiler, da_airsr,
  - da_satem, da_geoamv, da_polaramv, da_gpsref
- Moving aircraft platforms
  - da_airep, da_tamdar
- Integrated quantity
  - da_gpspw : TPW or Zenith Total Delay
- Other types
  - da_ssmi : retrieved TPW and wind speed, and radiance (obsolete)
  - da_radiance, da_radar, da_rain

Example: add TAMDAR data in little_r format

1. obsproc
   - obsproc/src/3dvar_obs.F90
   - obsproc/src/fm_decoder.F90
   - obsproc/src/sort_platform.F90
   - obsproc/src/module_decoded.F90
   - obsproc/src/module_write.F90
   - obsproc/src/module_complete.F90
   - obsproc/src/module_duplicate.F90
   - obsproc/src/platform_interface.inc
   - obsproc/src/module_namelist.F90
   - obsproc/src/module_err_afwa.F90
   - obsproc/src/module_per_type.F90
   - obsproc/src/module_qc.F90

Decode little_r TAMDAR data into WRFDA-recognized ASCII format and perform quality control.

Example: add TAMDAR data in little_r format

2. define_structures

- da/da_define_structures/da_deallocate_y.inc
- da/da_define_structures/da_zero_y.inc
- da/da_define_structures/da_deallocate_observations.inc
- da/da_define_structures/da_allocate_y.inc
- da/da_define_structures/da_allocate_observations.inc
- da/da_define_structures/da_define_structures.f90
- da/da_setup_structures/da_setup_obs_structures.inc
- da/da_setup_structures/da_setup_structures.f90

Define data structure

3. da_obs_io

- da/da_obs_io/da_search_obs.inc
- da/da_obs_io/da_write_filtered_obs.inc
- da/da_obs_io/da_read_obs_ascii.inc
- da/da_obs_io/da_scan_obs_ascii.inc
- da/da_obs_io/da_obs_io.f90

Read ASCII format TAMDAR data

Example: add TAMDAR data in little_r format

4. da_tamdar
   - da/da_tamdar/da_ao_stats_tamdar.inc
   - da/da_tamdar/da_calculate_grady_tamdar.inc
   - da/da_tamdar/da_check_max_iv_tamdar.inc
   - da/da_tamdar/da_get_innov_vector_tamdar.inc
   - da/da_tamdar/da_jo_and_grady_tamdar.inc
   - da/da_tamdar/da_jo_tamdar_uvtq.inc
   - da/da_tamdar/da_oi_stats_tamdar.inc
   - da/da_tamdar/da_print_stats_tamdar.inc
   - da/da_tamdar/da_residual_tamdar.inc
   - da/da_tamdar/da_tamdar.f90
   - da/da_tamdar/da_transform_xtoy_tamdar.inc
   - da/da_tamdar/da_transform_xtoy_tamdar_adj.inc

Calculate OmB, Jo and gradJo term.

Example: add TAMDAR data in little_r format

5. da_obs
   - da/da_obs/da_random_omb_all.inc
   - da/da_obs/da_add_noise_to_ob.inc
   - da/da_obs/da_obs.f90
   - da/da_obs/da_count_filtered_obs.inc
   - da/da_obs/da_fill_obs_structures.inc
   - da/da_obs/da_transform_xtoy.inc
   - da/da_obs/da_transform_xtoy_adj.inc
   - da/da_obs/da_use_obs_errfac.inc
   - da/da_obs/da_fm_decoder.inc

Upper-level routines to call TAMDAR-related routines.

Example: add TAMDAR data in little_r format

6. da_minimization
   - da/da_minimisation/da_calculate_grady.inc
   - da/da_minimisation/da_calculate_residual.inc
   - da/da_minimisation/da_minimisation.f90
   - da/da_minimisation/da_get_innov_vector.inc
   - da/da_minimisation/da_get_var_diagnostics.inc
   - da/da_minimisation/da_jo_and_grady.inc
   - da/da_minimisation/da_write_diagnostics.inc

Upper-level routines to call TAMDAR-related routines.

7. control/registry/compile
   - da/da_control/da_control.f90
   - Registry/registry.var
   - var/build/da.make
   - var/build/depend.txt

namelist and compilation.

Example: add TAMDAR data in little_r format

8. da_test
   - da/da_test/da_check_xtoy_adjoint_tamdar.inc
   - da/da_test/da_test.f90
   - da/da_test/da_check_xtoy_adjoint.inc
   - da/da_test/da_get_y_lhs_value.inc

Check correctness of TL/AD

Example: add new radiance data

- The way of radiance DA implementation is different from conventional observations
  - Key is to use indexing of different platforms/satellites/sensors
  - This makes adding a new radiance data much easier

```
&wrfvar14
  RTMINIT_NSENSOR  = 14
  RTMINIT_PLATFORM = 12, 1, 1, 1, 9,10, 1, 1,17, 1, 1, 10, 9, 2
  RTMINIT_SATID    =  3,16,18,19, 2, 2,15,16, 0,18, 19, 2, 2,16
  RTMINIT_SENSOR   = 21, 3, 3, 3, 3, 3, 4, 4,19,15, 15,15,11,10
```

CRTM	**RTTOV**
seviri_m10.SpcCoeff.bin	**rtcoef_msg_3_seviri.dat**
amsua_n19.SpcCoeff.bin	**rtcoef_noaa_19_amsua.dat**

To assimilate radiance data, corresponding coefficient files must be available in CRTM or RTTOV and WRFDA reads coefficient files according to these “triplets”.

RTTOV Users Guide

http://nwpsaf.eu/deliverables/rtm/docs_rttov11/users_guide_11_v1.4.pdf

Table 2 and Table 3

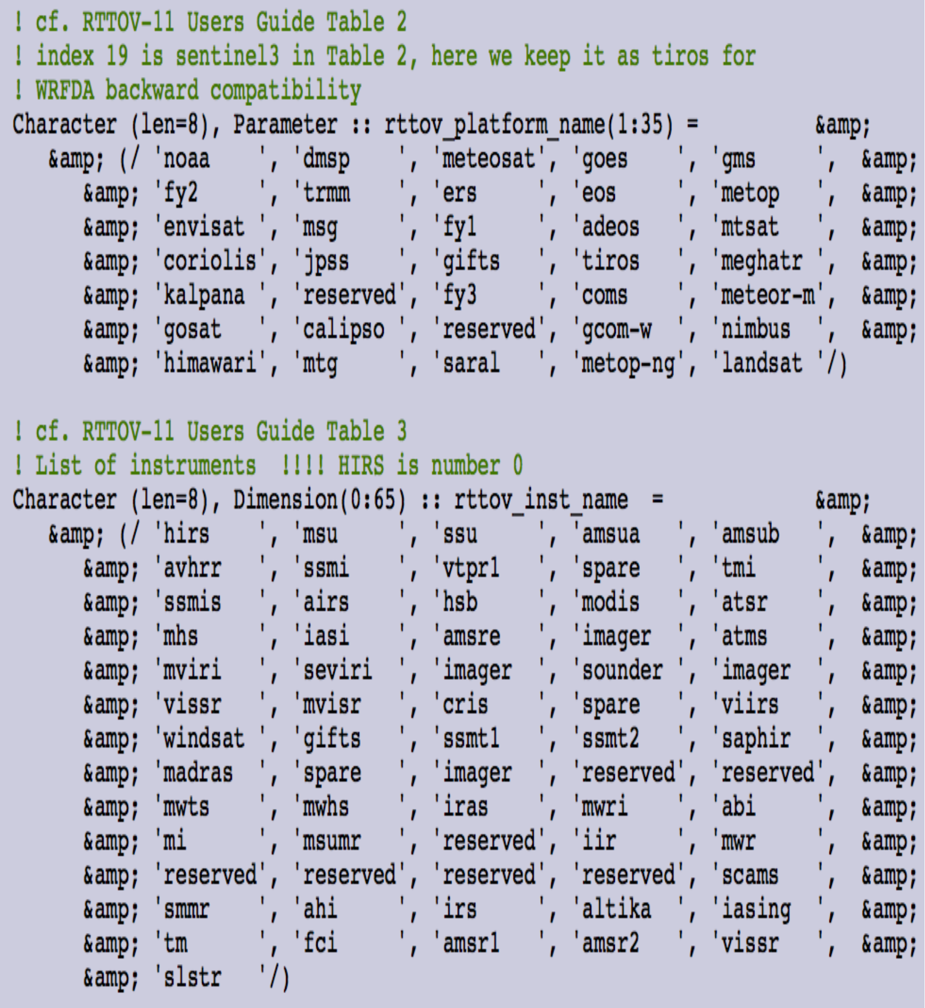
Instrument triplets **platform_id**
satellite_id
sensor_id

platform	platform_id	satellite_id
NOAA	1	15, 16, 17, 18 ,19
METOP	10	1, 2
EOS	9	2
JPSS	17	0
MSG	12	1, 2, 3
DMSP	2	16, 17, 18, 19
FY3	23	1, 2
GCOM-W	29	1

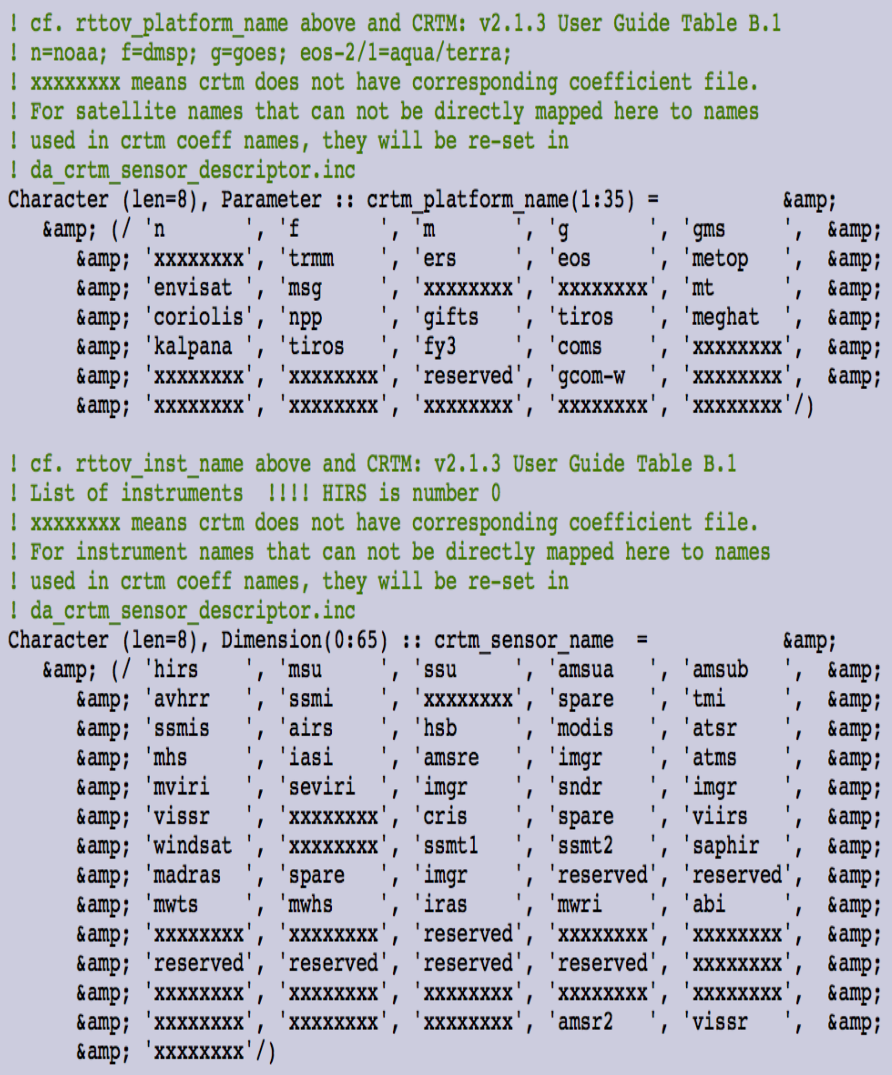
```
metop-2 = metop-a
metop-1 = metop-b
jpss-0  = npp
msg-1   = meteosat-8
msg-2   = meteosat-9
msg-3   = meteosat-10
```

sensor	sensor_id
HIRS	0
AMSU-A	3
AMSU-B	4
SSMIS	10
AIRS	11
MHS	15
IASI	16
ATMS	19
SEVIRI	21
FY3 MWTS	40
FY3 MWHS	41
AMSR2	63

da_radiance/module_radiance.f90

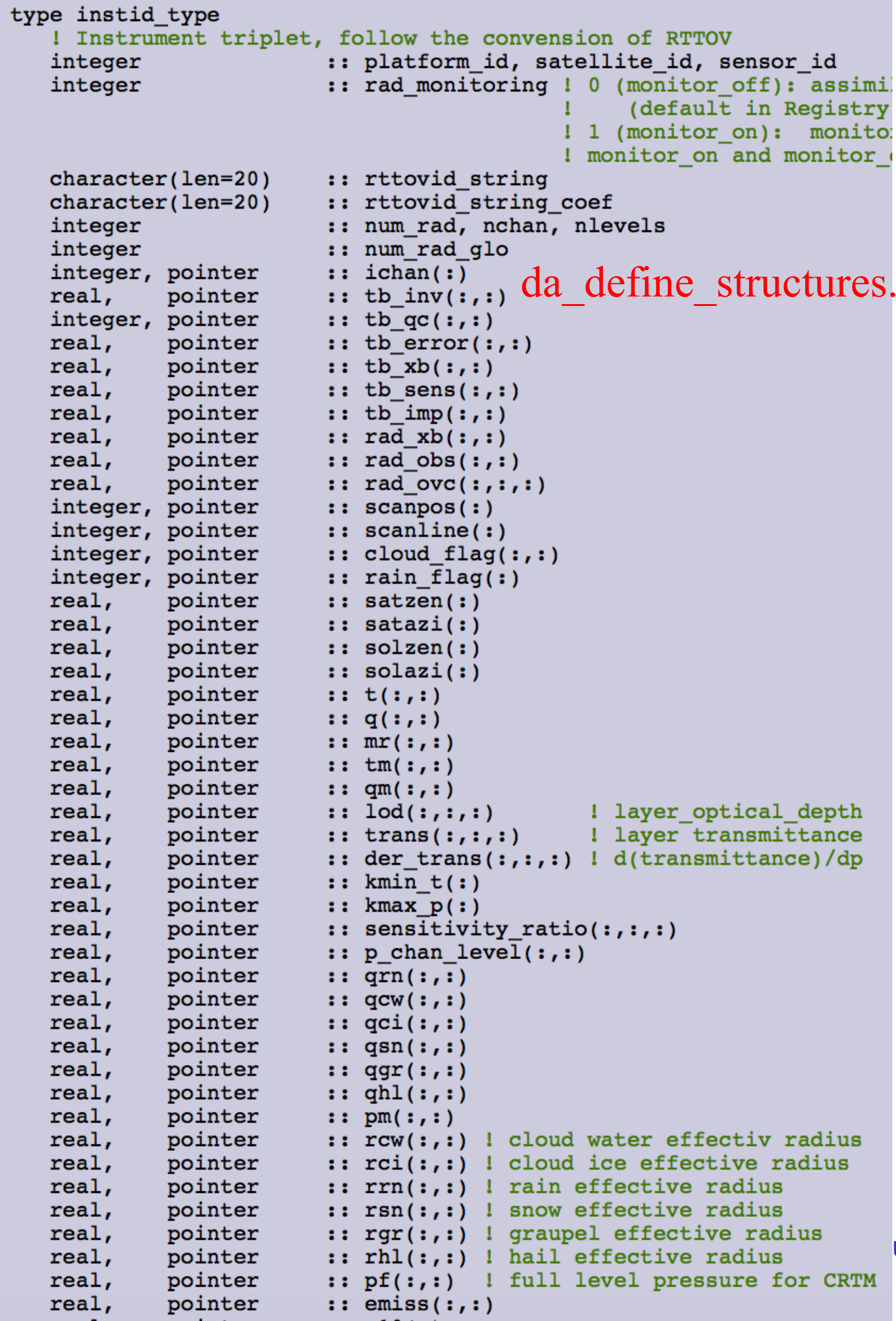


```
! cf. RTTOV-11 Users Guide Table 2
! index 19 is sentinel3 in Table 2, here we keep it as tiros for
! WRFDA backward compatibility
Character (len=8), Parameter :: rttov_platform_name(1:35) =          &amp;
   &amp; (/ 'noaa    ', 'dmsp    ', 'meteosat', 'goes    ', 'gms     ', &amp;
      &amp; 'fy2     ', 'trmm    ', 'ers     ', 'eos     ', 'metop   ', &amp;
      &amp; 'envisat ', 'msg     ', 'fy1     ', 'adeos   ', 'mtsat   ', &amp;
      &amp; 'coriolis', 'jpss    ', 'gifts   ', 'tiros   ', 'meghatr ', &amp;
      &amp; 'kalpana ', 'reserved', 'fy3     ', 'coms    ', 'meteor-m', &amp;
      &amp; 'gosat   ', 'calipso ', 'reserved', 'gcom-w  ', 'nimbus  ', &amp;
      &amp; 'himawari', 'mtg     ', 'saral   ', 'metop-ng', 'landsat '/)

! cf. RTTOV-11 Users Guide Table 3
! List of instruments  !!!! HIRS is number 0
Character (len=8), Dimension(0:65) :: rttov_inst_name  =             &amp;
   &amp; (/ 'hirs    ', 'msu     ', 'ssu     ', 'amsua   ', 'amsub   ', &amp;
      &amp; 'avhrr   ', 'ssmi    ', 'vtpr1   ', 'spare   ', 'tmi     ', &amp;
      &amp; 'ssmis   ', 'airs    ', 'hsb     ', 'modis   ', 'atsr    ', &amp;
      &amp; 'mhs     ', 'iasi    ', 'amsre   ', 'imager  ', 'atms    ', &amp;
      &amp; 'mviri   ', 'seviri  ', 'imager  ', 'sounder ', 'imager  ', &amp;
      &amp; 'vissr   ', 'mvisr   ', 'cris    ', 'spare   ', 'viirs   ', &amp;
      &amp; 'windsat ', 'gifts   ', 'ssmt1   ', 'ssmt2   ', 'saphir  ', &amp;
      &amp; 'madras  ', 'spare   ', 'imager  ', 'reserved', 'reserved', &amp;
      &amp; 'mwts    ', 'mwhs    ', 'iras    ', 'mwri    ', 'abi     ', &amp;
      &amp; 'mi      ', 'msumr   ', 'reserved', 'iir     ', 'mwr     ', &amp;
      &amp; 'reserved', 'reserved', 'reserved', 'reserved', 'scams   ', &amp;
      &amp; 'smmr    ', 'ahi     ', 'irs     ', 'altika  ', 'iasing  ', &amp;
      &amp; 'tm      ', 'fci     ', 'amsr1   ', 'amsr2   ', 'vissr   ', &amp;
      &amp; 'slstr   '/)
```



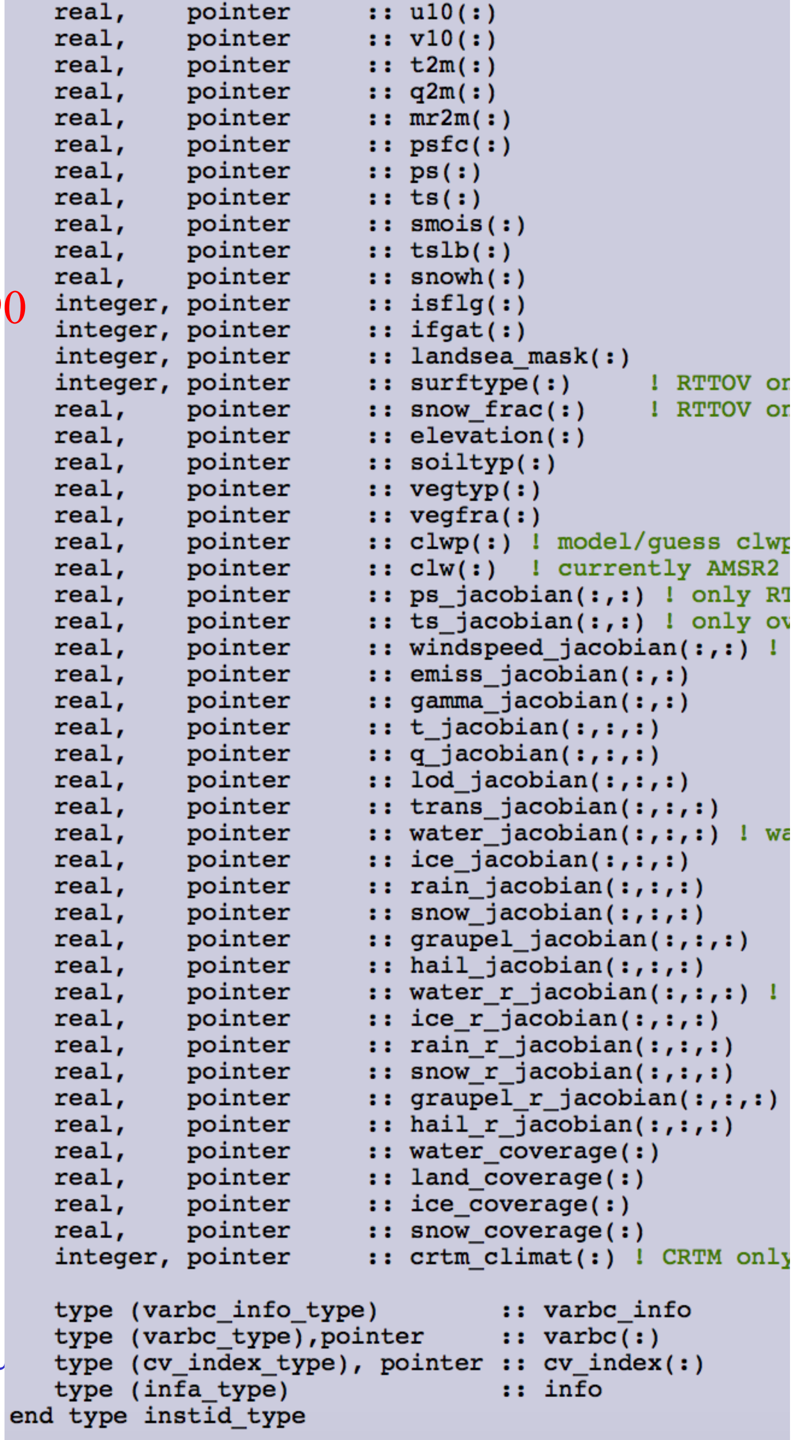
```
! cf. rttov_platform_name above and CRTM: v2.1.3 User Guide Table B.1
! n=noaa; f=dmsp; g=goes; eos-2/1=aqua/terra;
! xxxxxxxx means crtm does not have corresponding coefficient file.
! For satellite names that can not be directly mapped here to names
! used in crtm coeff names, they will be re-set in
! da_crtm_sensor_descriptor.inc
Character (len=8), Parameter :: crtm_platform_name(1:35) =           &amp;
   &amp; (/ 'n       ', 'f       ', 'm       ', 'g       ', 'gms     ', &amp;
      &amp; 'xxxxxxxx', 'trmm    ', 'ers     ', 'eos     ', 'metop   ', &amp;
      &amp; 'envisat ', 'msg     ', 'xxxxxxxx', 'xxxxxxxx', 'mt      ', &amp;
      &amp; 'coriolis', 'npp     ', 'gifts   ', 'tiros   ', 'meghat  ', &amp;
      &amp; 'kalpana ', 'tiros   ', 'fy3     ', 'coms    ', 'xxxxxxxx', &amp;
      &amp; 'xxxxxxxx', 'xxxxxxxx', 'reserved', 'gcom-w  ', 'xxxxxxxx', &amp;
      &amp; 'xxxxxxxx', 'xxxxxxxx', 'xxxxxxxx', 'xxxxxxxx', 'xxxxxxxx'/)

! cf. rttov_inst_name above and CRTM: v2.1.3 User Guide Table B.1
! List of instruments  !!!! HIRS is number 0
! xxxxxxxx means crtm does not have corresponding coefficient file.
! For instrument names that can not be directly mapped here to names
! used in crtm coeff names, they will be re-set in
! da_crtm_sensor_descriptor.inc
Character (len=8), Dimension(0:65) :: crtm_sensor_name  =            &amp;
   &amp; (/ 'hirs    ', 'msu     ', 'ssu     ', 'amsua   ', 'amsub   ', &amp;
      &amp; 'avhrr   ', 'ssmi    ', 'xxxxxxxx', 'spare   ', 'tmi     ', &amp;
      &amp; 'ssmis   ', 'airs    ', 'hsb     ', 'modis   ', 'atsr    ', &amp;
      &amp; 'mhs     ', 'iasi    ', 'amsre   ', 'imgr    ', 'atms    ', &amp;
      &amp; 'mviri   ', 'seviri  ', 'imgr    ', 'sndr    ', 'imgr    ', &amp;
      &amp; 'vissr   ', 'xxxxxxxx', 'cris    ', 'spare   ', 'viirs   ', &amp;
      &amp; 'windsat ', 'xxxxxxxx', 'ssmt1   ', 'ssmt2   ', 'saphir  ', &amp;
      &amp; 'madras  ', 'spare   ', 'imgr    ', 'reserved', 'reserved', &amp;
      &amp; 'mwts    ', 'mwhs    ', 'iras    ', 'mwri    ', 'abi     ', &amp;
      &amp; 'xxxxxxxx', 'xxxxxxxx', 'reserved', 'xxxxxxxx', 'xxxxxxxx', &amp;
      &amp; 'reserved', 'reserved', 'reserved', 'reserved', 'xxxxxxxx', &amp;
      &amp; 'xxxxxxxx', 'xxxxxxxx', 'xxxxxxxx', 'xxxxxxxx', 'xxxxxxxx', &amp;
      &amp; 'xxxxxxxx', 'xxxxxxxx', 'xxxxxxxx', 'amsr2   ', 'vissr   ', &amp;
      &amp; 'xxxxxxxx'/)
```

da_define_structures.f90



```
type instid_type
   ! Instrument triplet, follow the convension of RTTOV
   integer                :: platform_id, satellite_id, sensor_id
   integer                :: rad_monitoring ! 0 (monitor_off): assimi
                                            !    (default in Registry
                                            ! 1 (monitor_on):  monito
                                            ! monitor_on and monitor_

   character(len=20)      :: rttovid_string
   character(len=20)      :: rttovid_string_coef
   integer                :: num_rad, nchan, nlevels
   integer                :: num_rad_glo
   integer, pointer       :: ichan(:)
   real,    pointer       :: tb_inv(:,:)
   integer, pointer       :: tb_qc(:,:)
   real,    pointer       :: tb_error(:,:)
   real,    pointer       :: tb_xb(:,:)
   real,    pointer       :: tb_sens(:,:)
   real,    pointer       :: tb_imp(:,:)
   real,    pointer       :: rad_xb(:,:)
   real,    pointer       :: rad_obs(:,:)
   real,    pointer       :: rad_ovc(:,:,:)
   integer, pointer       :: scanpos(:)
   integer, pointer       :: scanline(:)
   integer, pointer       :: cloud_flag(:,:)
   integer, pointer       :: rain_flag(:)
   real,    pointer       :: satzen(:)
   real,    pointer       :: satazi(:)
   real,    pointer       :: solzen(:)
   real,    pointer       :: solazi(:)
   real,    pointer       :: t(:,:)
   real,    pointer       :: q(:,:)
   real,    pointer       :: mr(:,:)
   real,    pointer       :: tm(:,:)
   real,    pointer       :: qm(:,:)
   real,    pointer       :: lod(:,:,:)       ! layer_optical_depth
   real,    pointer       :: trans(:,:,:)     ! layer transmittance
   real,    pointer       :: der_trans(:,:,:) ! d(transmittance)/dp
   real,    pointer       :: kmin_t(:)
   real,    pointer       :: kmax_p(:)
   real,    pointer       :: sensitivity_ratio(:,:,:)
   real,    pointer       :: p_chan_level(:,:)
   real,    pointer       :: qrn(:,:)
   real,    pointer       :: qcw(:,:)
   real,    pointer       :: qci(:,:)
   real,    pointer       :: qsn(:,:)
   real,    pointer       :: qgr(:,:)
   real,    pointer       :: qhl(:,:)
   real,    pointer       :: pm(:,:)
   real,    pointer       :: rcw(:,:) ! cloud water effectiv radius
   real,    pointer       :: rci(:,:) ! cloud ice effective radius
   real,    pointer       :: rrn(:,:) ! rain effective radius
   real,    pointer       :: rsn(:,:) ! snow effective radius
   real,    pointer       :: rgr(:,:) ! graupel effective radius
   real,    pointer       :: rhl(:,:) ! hail effective radius
   real,    pointer       :: pf(:,:)  ! full level pressure for CRTM
   real,    pointer       :: emiss(:,:)
```

ugu

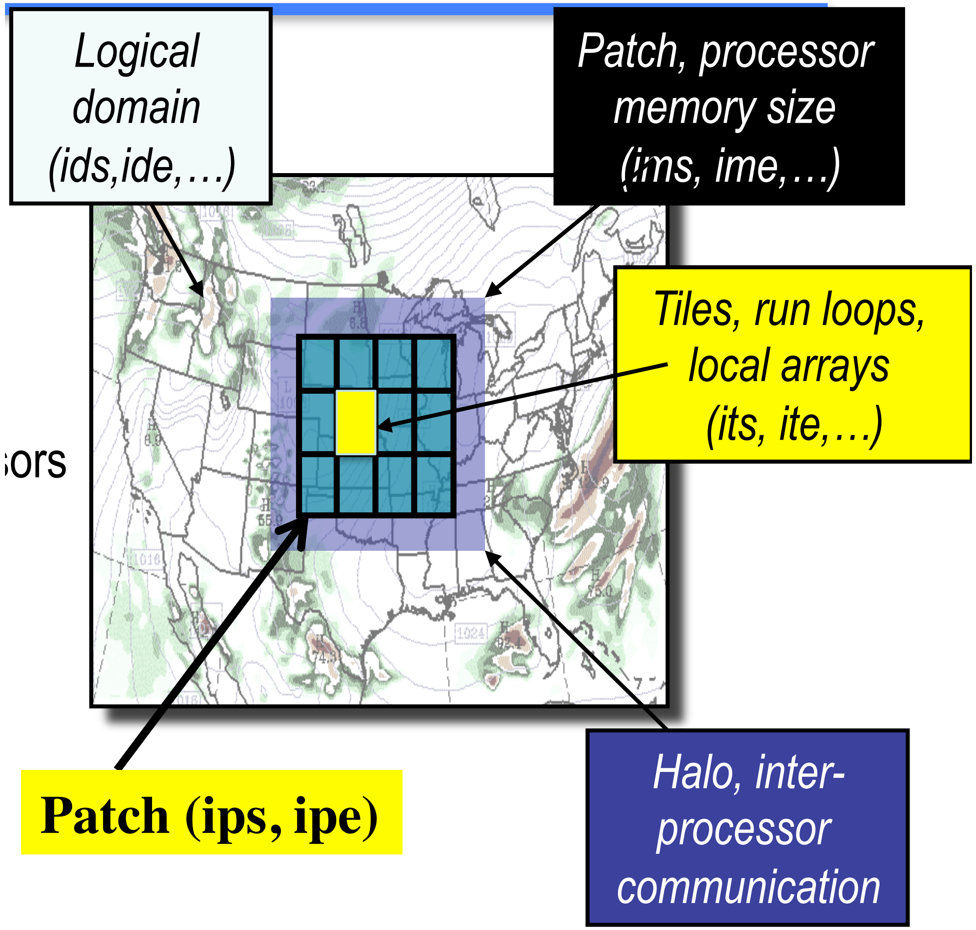


```
   real,    pointer     :: u10(:)
   real,    pointer     :: v10(:)
   real,    pointer     :: t2m(:)
   real,    pointer     :: q2m(:)
   real,    pointer     :: mr2m(:)
   real,    pointer     :: psfc(:)
   real,    pointer     :: ps(:)
   real,    pointer     :: ts(:)
   real,    pointer     :: smois(:)
   real,    pointer     :: tslb(:)
   real,    pointer     :: snowh(:)
   integer, pointer     :: isflg(:)
   integer, pointer     :: ifgat(:)
   integer, pointer     :: landsea_mask(:)
   integer, pointer     :: surftype(:)     ! RTTOV or
   real,    pointer     :: snow_frac(:)    ! RTTOV or
   real,    pointer     :: elevation(:)
   real,    pointer     :: soiltyp(:)
   real,    pointer     :: vegtyp(:)
   real,    pointer     :: vegfra(:)
   real,    pointer     :: clwp(:) ! model/guess clwp
   real,    pointer     :: clw(:)  ! currently AMSR2
   real,    pointer     :: ps_jacobian(:,:) ! only RT
   real,    pointer     :: ts_jacobian(:,:) ! only ov
   real,    pointer     :: windspeed_jacobian(:,:) !
   real,    pointer     :: emiss_jacobian(:,:)
   real,    pointer     :: gamma_jacobian(:,:)
   real,    pointer     :: t_jacobian(:,:,:)
   real,    pointer     :: q_jacobian(:,:,:)
   real,    pointer     :: lod_jacobian(:,:,:)
   real,    pointer     :: trans_jacobian(:,:,:)
   real,    pointer     :: water_jacobian(:,:,:) ! wa
   real,    pointer     :: ice_jacobian(:,:,:)
   real,    pointer     :: rain_jacobian(:,:,:)
   real,    pointer     :: snow_jacobian(:,:,:)
   real,    pointer     :: graupel_jacobian(:,:,:)
   real,    pointer     :: hail_jacobian(:,:,:)
   real,    pointer     :: water_r_jacobian(:,:,:) !
   real,    pointer     :: ice_r_jacobian(:,:,:)
   real,    pointer     :: rain_r_jacobian(:,:,:)
   real,    pointer     :: snow_r_jacobian(:,:,:)
   real,    pointer     :: graupel_r_jacobian(:,:,:)
   real,    pointer     :: hail_r_jacobian(:,:,:)
   real,    pointer     :: water_coverage(:)
   real,    pointer     :: land_coverage(:)
   real,    pointer     :: ice_coverage(:)
   real,    pointer     :: snow_coverage(:)
   integer, pointer     :: crtm_climat(:) ! CRTM only

   type (varbc_info_type)         :: varbc_info
   type (varbc_type),pointer      :: varbc(:)
   type (cv_index_type), pointer  :: cv_index(:)
   type (infa_type)               :: info
end type instid_type
```

New AMSR2 radiance DA in V3.8

- da_radiance/da_read_obs_hdf5amsr2.inc
- da_radiance/da_qc_amsr2.inc
- Add obs error file for new sensor under ~var/run/radiance_info
- Other related modifications are mostly minor

About WRFDA parallelism



Logical domain (ids,ide,…)

Patch, processor memory size (ims, ime,…)

Tiles, run loops, local arrays (its, ite,…)

Patch (ips, ipe)

Halo, inter-processor communication

ims/ime = ips/ipe + halo

- Only MPI
- ntiles = 1 for each patch
- So ips/ipe = its/ite

To contribute back your code

- Start your development from WRF Github code repository

- Entire WRF code repository will move from internal subversion to external github in the middle of this August

WRFDA Fortran Coding Standard

- All USE statements should have ONLY and specify exactly what module items they use
- Lower case filenames, function, module, subroutine, variable names
- "Implicit none" in every subroutine.
- Keep within 100 columns
- Do not use DIMENSION keyword in variable declarations
- One subroutine per file.
- Indent if/do blocks by 3 spaces.
- Only label do loops if exit/cycle would be ambiguous
- Only CONTINUE statements can have numeric labels
- Use descriptive names for variables/subroutines when usage is unique (e.g. psichi_to_uv).
- Use generic names for variables/subroutines when usage is varied, i.e. maintain flexibility - e.g. field(:,:) for general interpolation routines.

WRFDA Fortran Coding Standard

- Include compact, informative comments for each group of operations.
- Any commented out declaration or code must have an associated comment saying why.
- Do not mix changes - commit separately to help reviewers understand what they are reviewing (tidying changes should be performed separately from other changes for which there is non-zero impact).
- All IO using units defined by da_get_unit, da_free_unit system
- *Use* statements only occur in modules, not individual routines
- No unused variables. Assigning and then not using variables is only allowed for reading pad data in IO routines.
- No unused types coming through *use* statements.
- Do not pass different levels of a derived data into a routine, so *call x(grid,grid%xb)* is bad.
- all types should end with "_type"
- Refer to real constants as 0.0, not 0.

Follow good code in WRFDA, not bad ones