WRF-Var System

WRF Tutorial

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WRF-Var in the WRF Modeling System

WRF-Var in the WRF Modeling System

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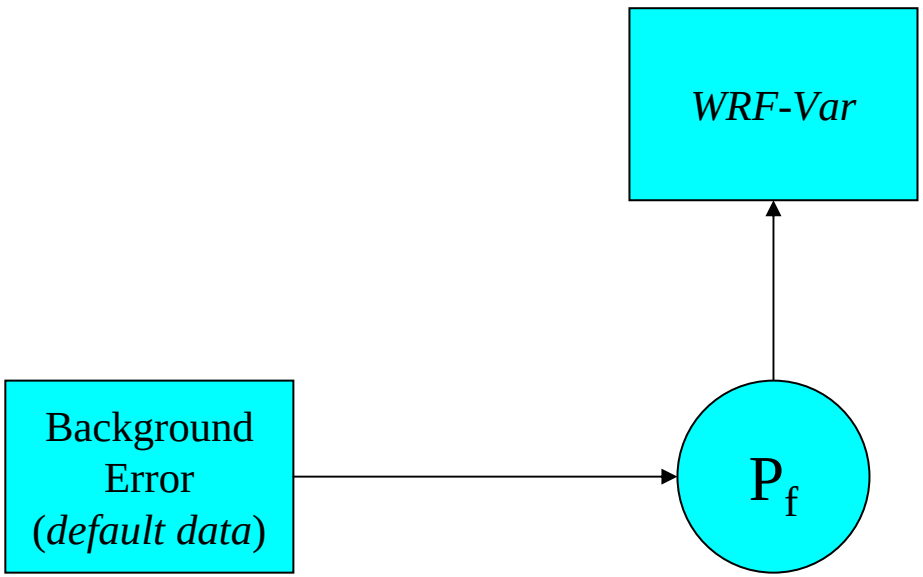
WRF-Var in the WRF Modeling System

1. Prepare BE data (initially use default statistics)



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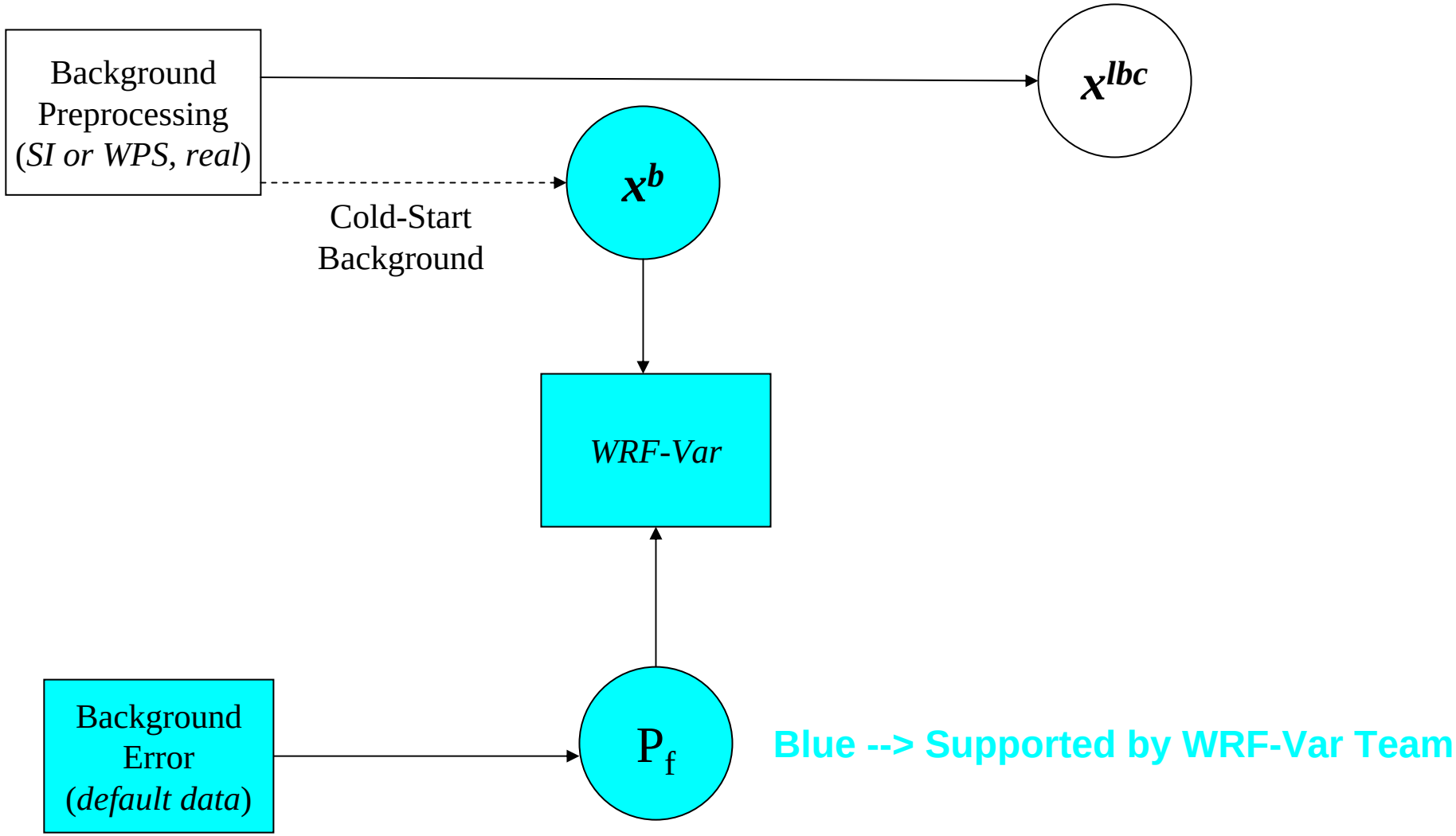
WRF-Var in the WRF Modeling System

2. Prepare background (SI or WPS & real)



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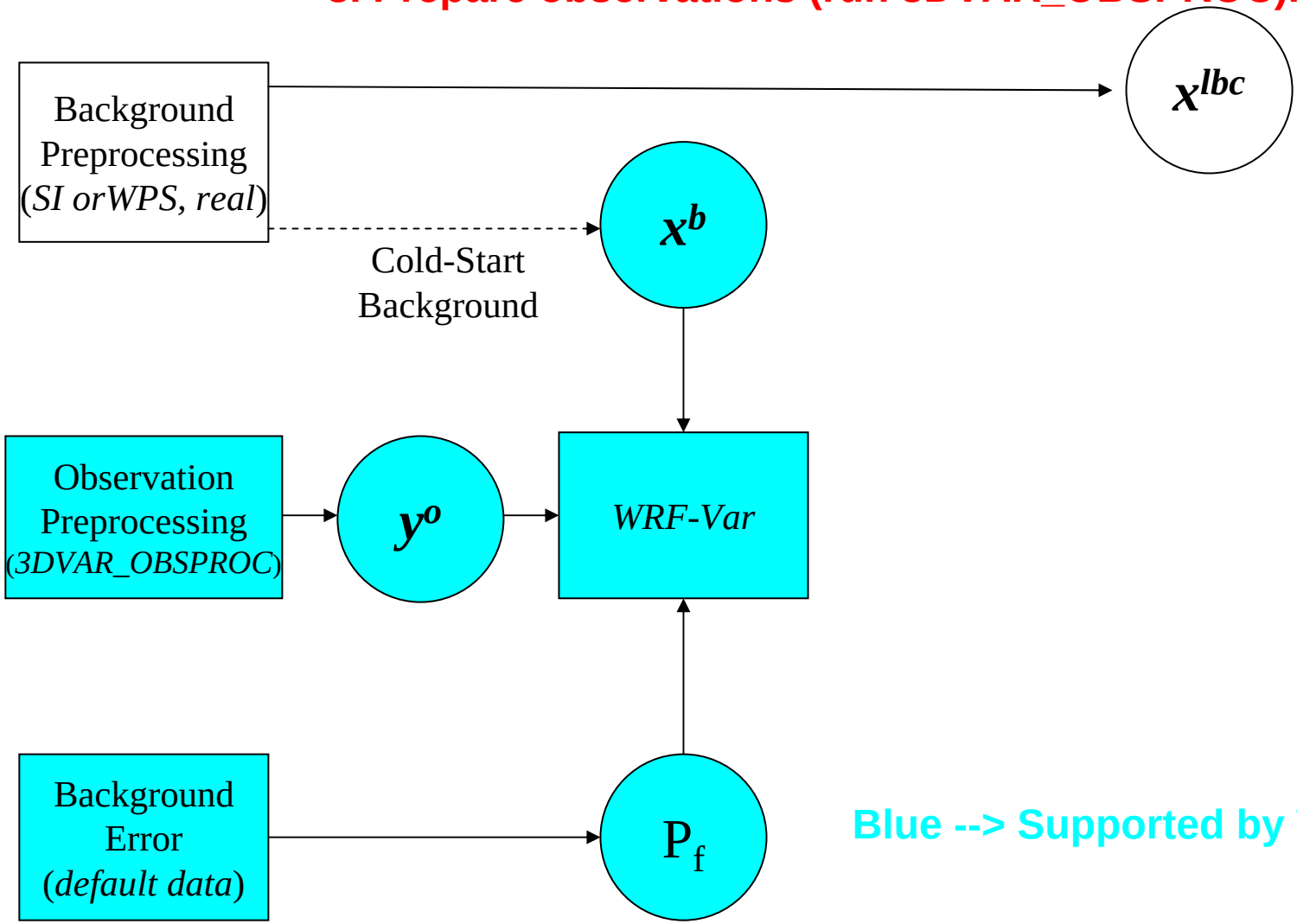
WRF-Var in the WRF Modeling System

3. Prepare observations (run 3DVAR_OBSPROC).



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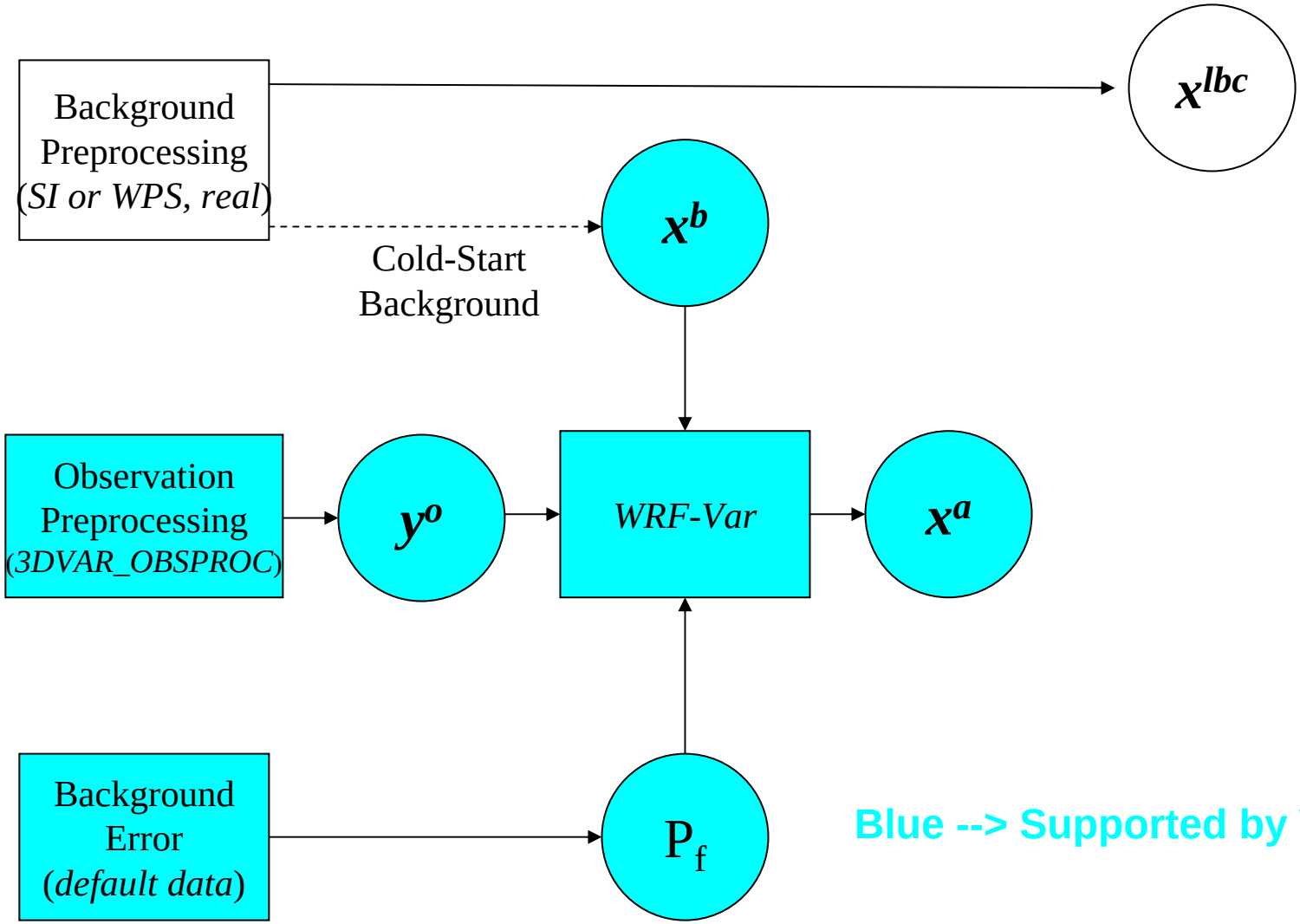
Observation Input (y^o)

- **Observation input for WRF-Var is supplied through observation preprocessor (3DVAR_OBSPROC)**
- **WRF-Var accepts input both in ASCII & BUFR format**
- **Separate input file (ASCII) for Radar, both reflectivity and radial velocity.**

WRF-Var in the WRF Modeling System

4. Run WRF-Var.



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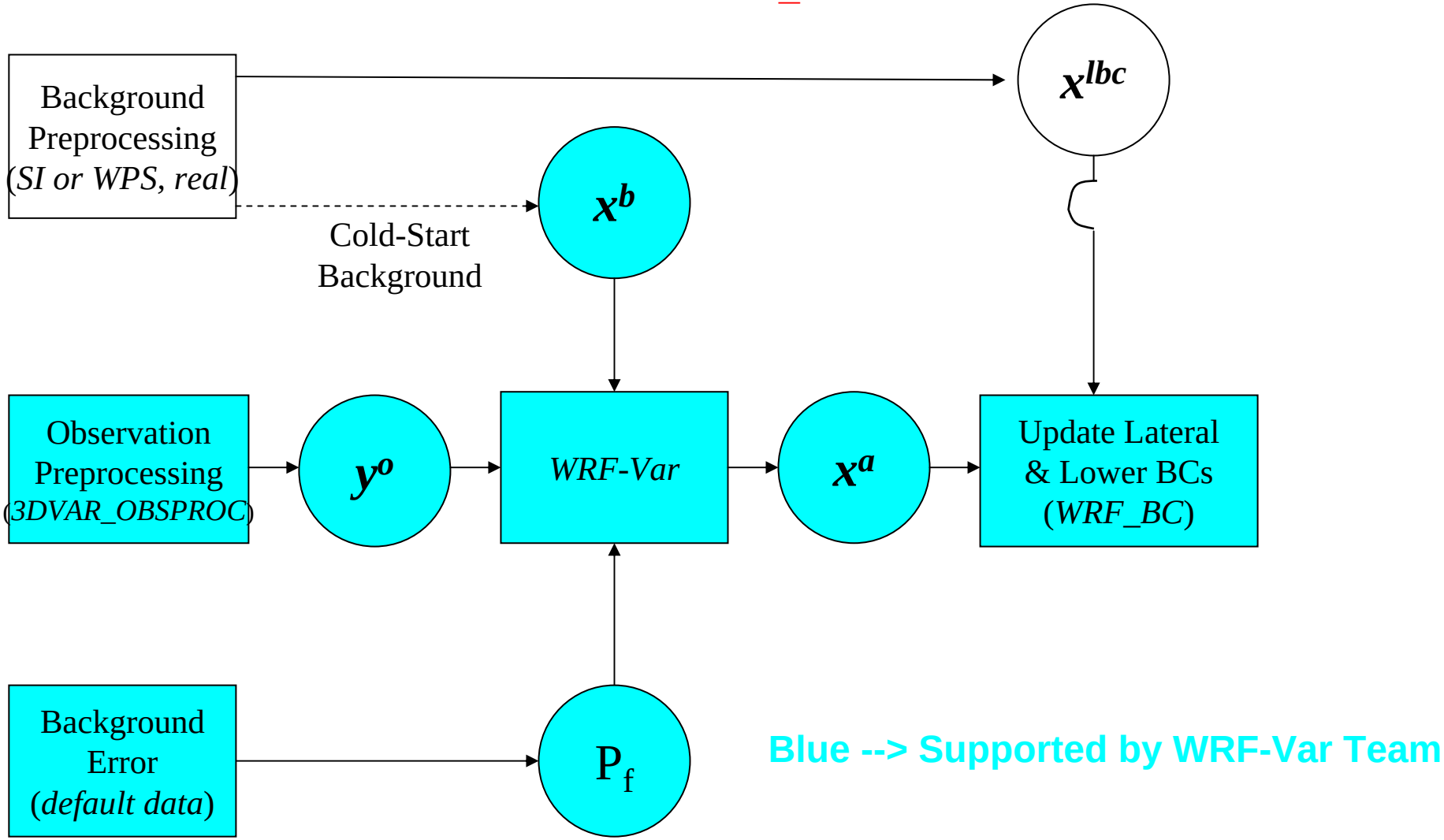
WRF-Var in the WRF Modeling System

5. Run WRF_BC.



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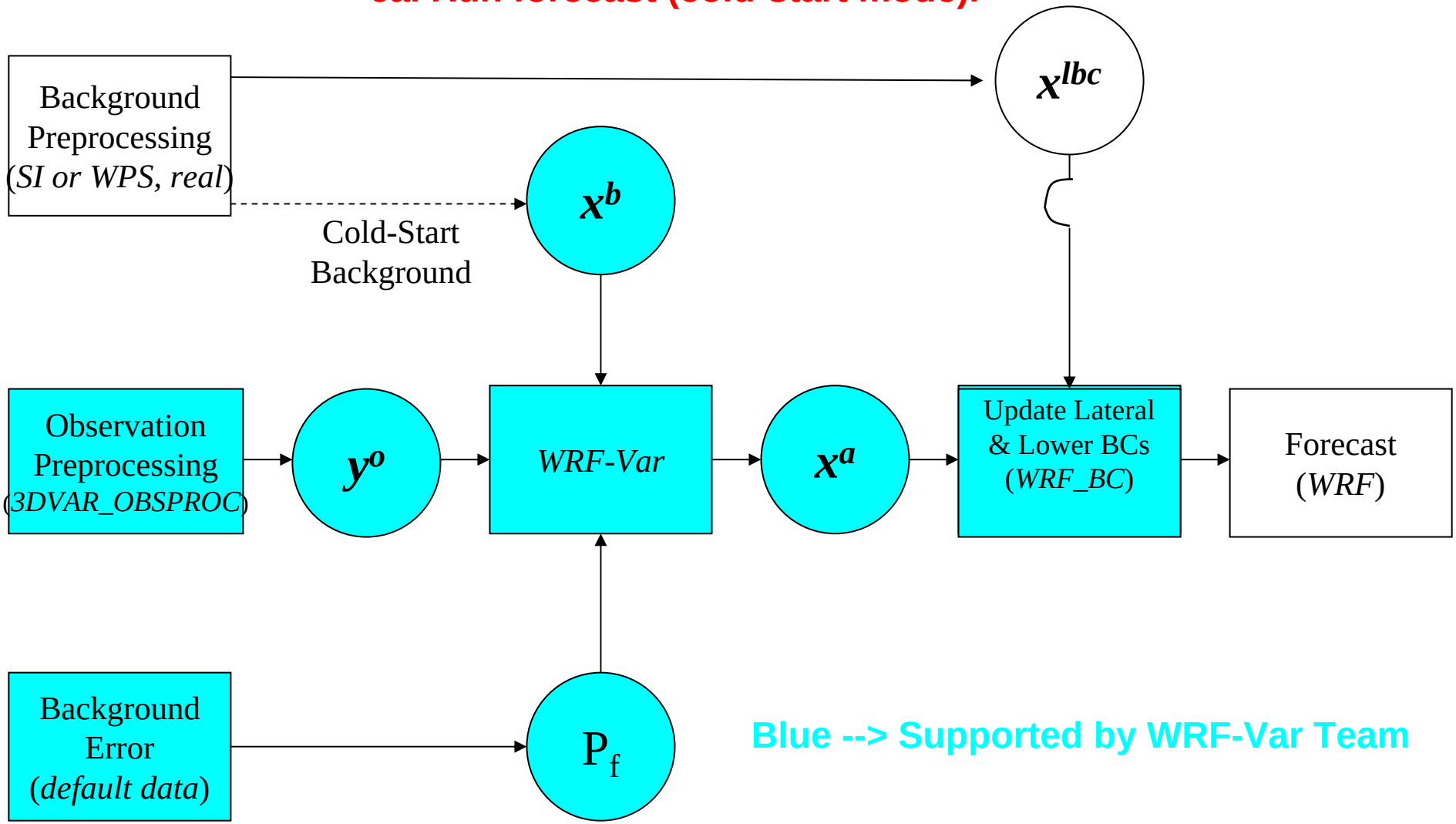
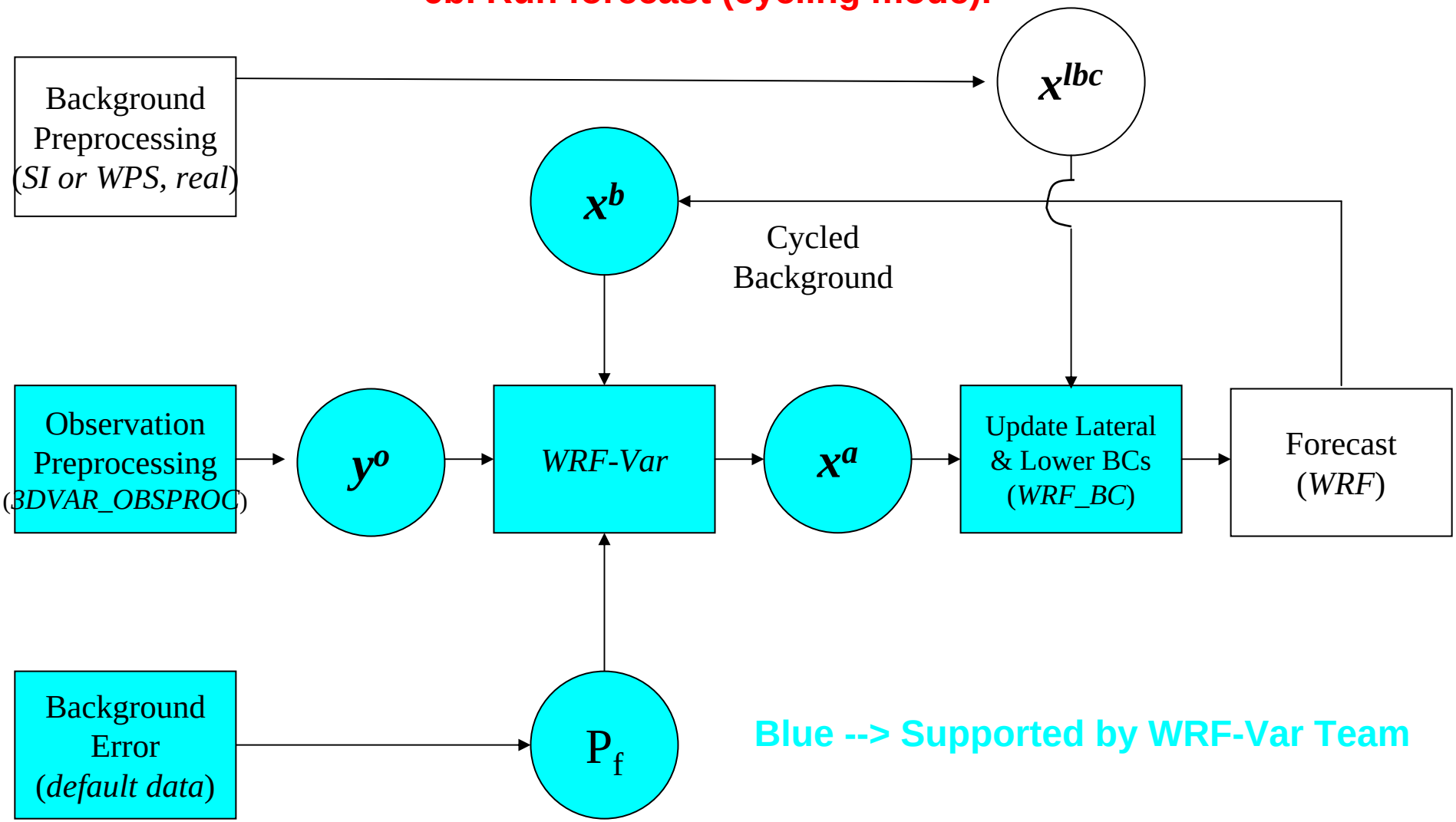
WRF-Var in the WRF Modeling System

6a. Run forecast (cold-start mode).



WRF-Var in the WRF Modeling System

6b. Run forecast (cycling mode).



Background Error (BE) for WRF-Var

- **The number 1 question from WRF-Var users is**

“What background error are best for my application?”.

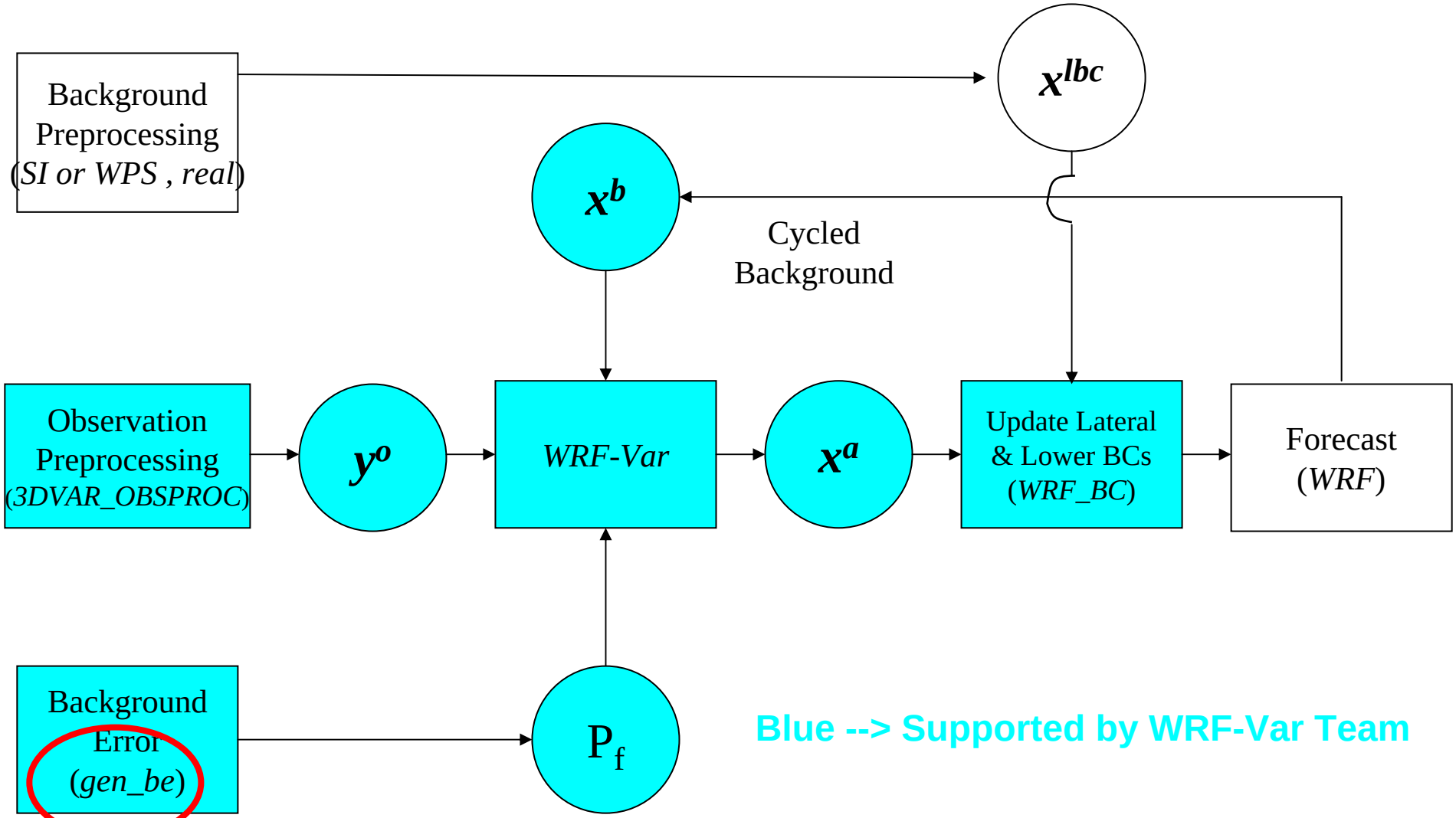
Answer:

- **Create your own once you have run your**
- **system for ~a few weeks.**
- **Implement, tune, and iterate.**

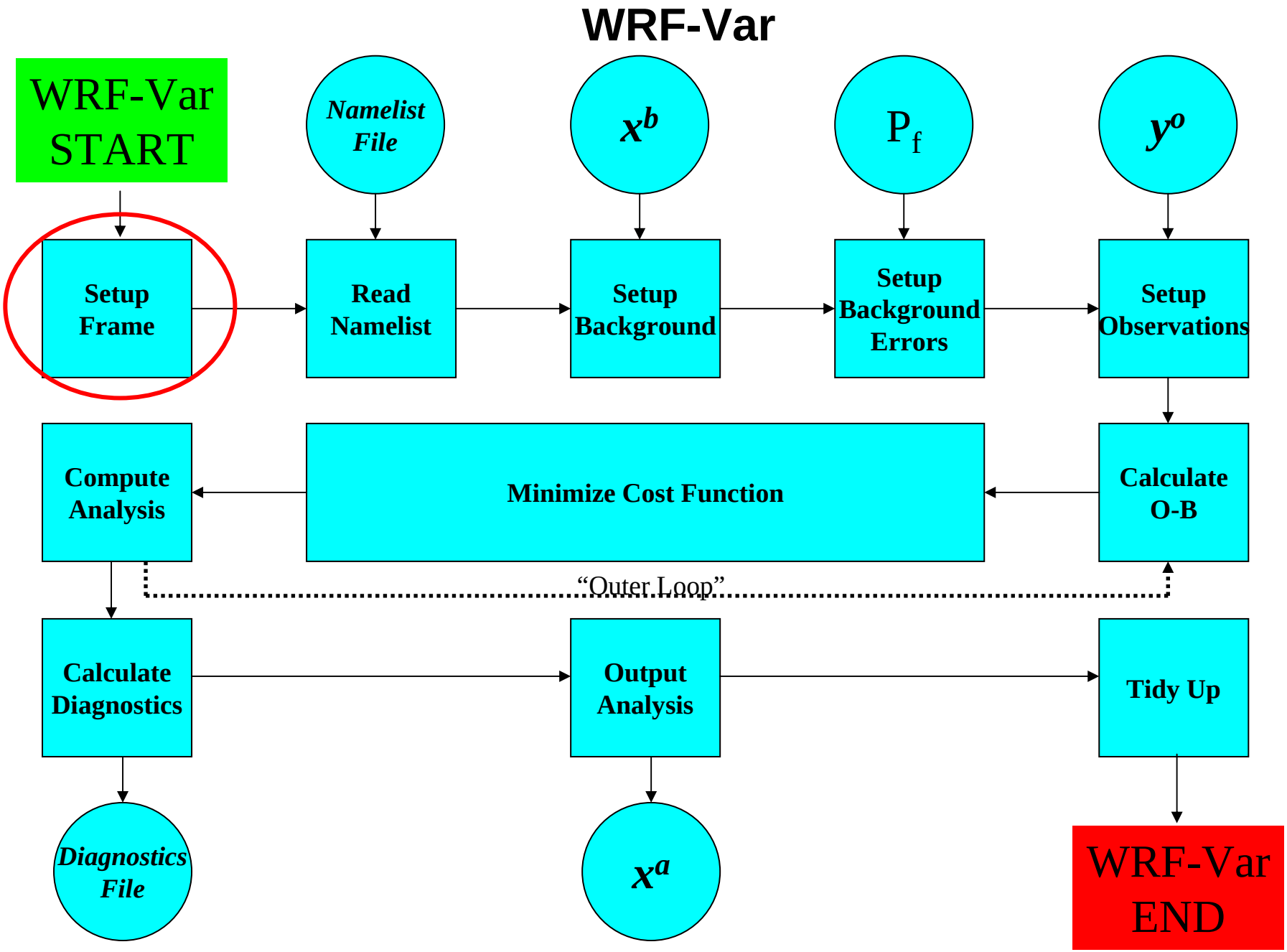
A new utility “*gen_be*” has been developed at NCAR to calculate BEs.

WRF-Var in the WRF Modeling System

7. WRF-Var/WRF Ultimate Configuration!



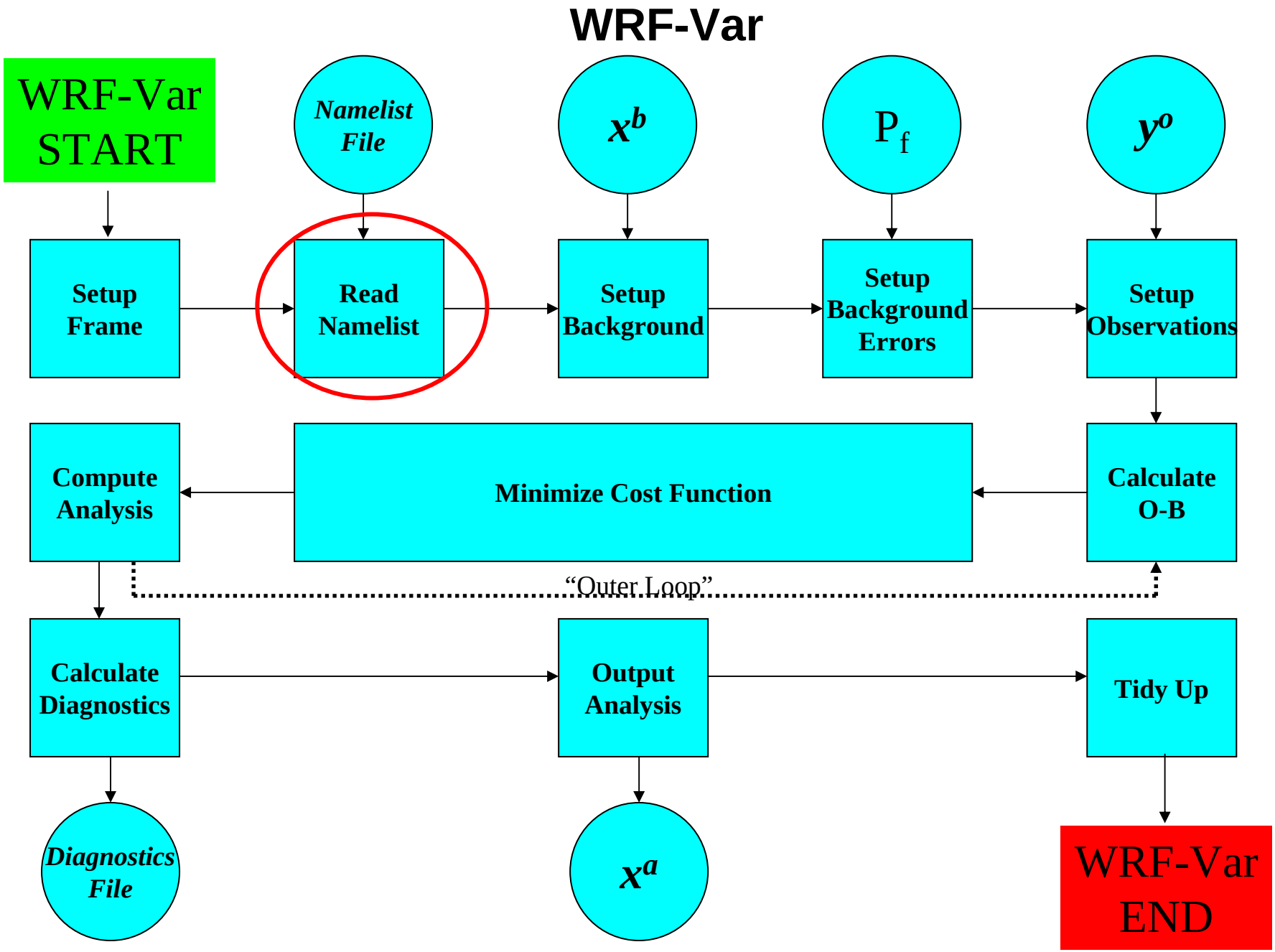
WRF-Var Code Overview


WRF-Var
WRF-Var START
Namelist File
x^b
P_f
y^o
Setup Frame
Read Namelist
Setup Background
Setup Background Errors
Setup Observations
Compute Analysis
Minimize Cost Function
Calculate O-B
"Outer Loop"
Calculate Diagnostics
Output Analysis
Tidy Up
Diagnostics File
x^a
WRF-Var END

Setup Frame

- **Reads grid dimensions from “namelist.3dvar” file.**

- **Use WRF framework’s distributed memory capability to initialize tile, memory, patch dimensions, etc.**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WRF-Var END

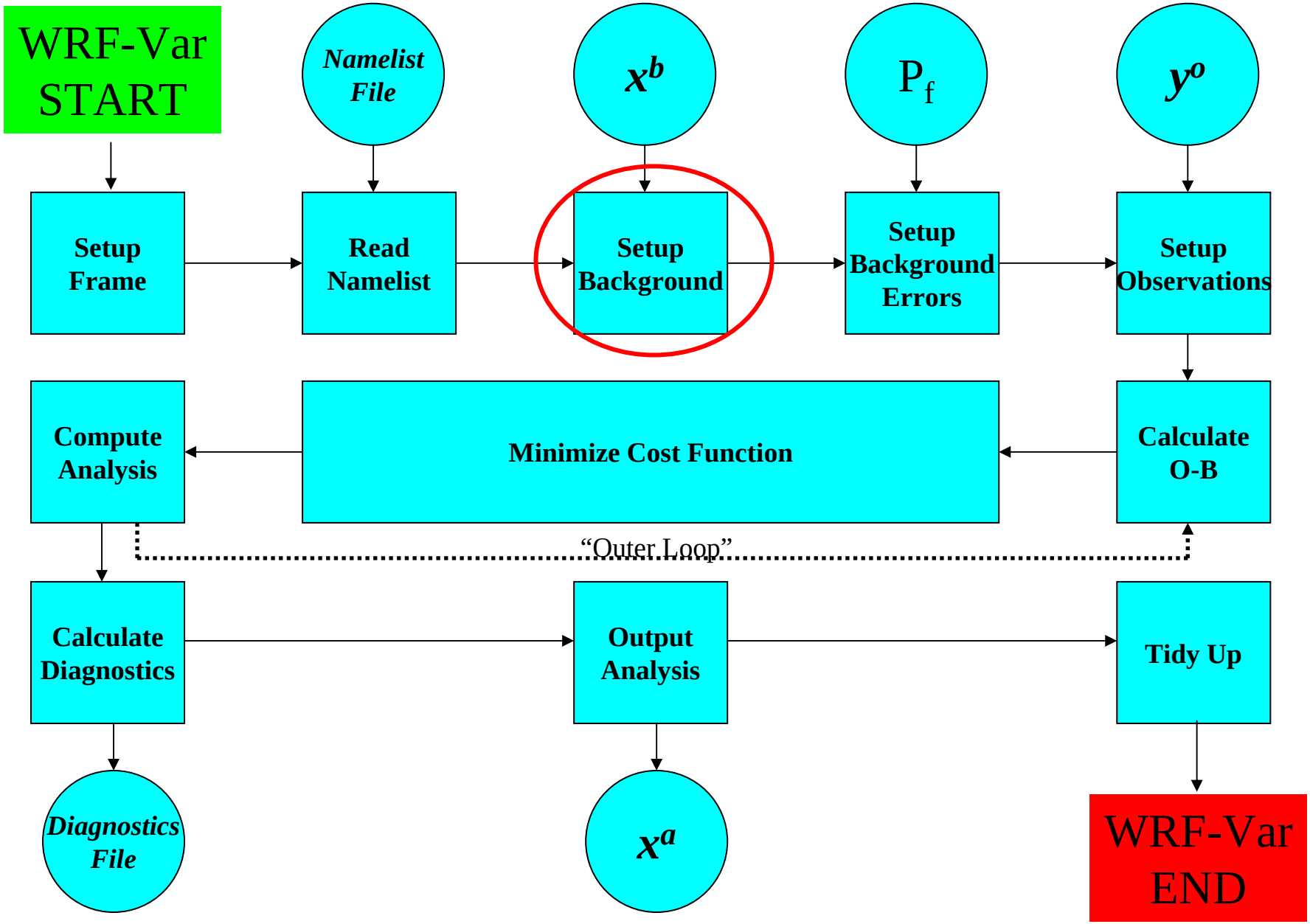
Read Namelist

- **Reads WRF-Var data assimilation options from "namelist.3dvar" file.**
- **"namelist.3dvar" file is created automatically at run-time by the DA_Run_WRF_Var.csh script in wrfvar/run.**
- **Performs consistency checks between namelist options.**

namelist.3dvar

```
&record1
 MODEL_TYPE = 'WRF',
 WRITE_INCREMENTS = .FALSE. ,
 GLOBAL          = .FALSE.,
 PRINT_DETAIL   = 0 /

&record2
 ANALYSIS_TYPE = '3D-VAR',
 ANALYSIS_DATE = '2004-05-01_00:00:00.0000',
 ANALYSIS_ACCU =  900 /

&record3
 fg_format = 1,
 ob_format = 2,
 num_fgat_time = 1 /

&record4
 PROCESS_OBS    = 'YES',
 obs_qc_pointer = 0,
 Use_SynopObs   = .TRUE.,
 Use_ShipsObs   = .TRUE.,
 Use_MetarObs   = .TRUE.,
 Use_PilotObs   = .TRUE.,
 Use_SoundObs   = .TRUE.,
 Use_SatemObs   = .TRUE.,
 Use_GeoAMVObs  = .TRUE.,
 Use_PolarAMVObs = .TRUE.,
 Use_AirepObs   = .TRUE.,
 Use_GpspwObs   = .TRUE.,
 Use_GpsrefObs  = .TRUE.,
 Use_ProfilerObs = .TRUE.,
 Use_BuoyObs     = .TRUE.,
 Use_SsmiRetrievalObs = .FALSE.,
 Use_SsmiTbObs  = .FALSE.,
 use_ssmt1obs   = .FALSE.,
 use_ssmt2obs   = .FALSE.,
 use_qscatobs   = .TRUE.,
 use_radarobs   = .FALSE.,
 Use_Radar_rv   = .FALSE.,
 Use_Radar_rf   = .FALSE.,
 check_max_iv   = .FALSE.,
 use_obs_errfac = .FALSE.,
 put_rand_seed  = .FALSE.,
 omb_set_rand   = .FALSE.,
 omb_add_noise  = .FALSE. /

&record5
 TIME_WINDOW    = 3.,
 /

&record6
 max_ext_its    = 1,
 EPS          = 1.E-02, 1.E-02, 1.E-02, 1.E-02, 1.E-02, 1.E-02, 1.E-02,,
 NTMAX         = 100,
 NSAVE         = 4,
 WRITE_SWITCH   = .FALSE.,
 WRITE_INTERVAL = 5 /

&record7
 RF_PASSES      = 6,
 VAR_SCALING1   = 1.0,
 VAR_SCALING2   = 1.0,
 VAR_SCALING3   = 1.0,
 VAR_SCALING4   = 1.0,
 VAR_SCALING5   = 1.0,
 LEN_SCALING1   = 1.0,
 LEN_SCALING2   = 1.0,
 LEN_SCALING3   = 1.0,
 LEN_SCALING4   = 1.0,
 LEN_SCALING5   = 1.0 /

&record8
 def_sub_domain = .FALSE.,
 x_start_sub_domain = 55.0,
 y_start_sub_domain = 35.0,
 x_end_sub_domain   = 80.0,
 y_end_sub_domain   = 60.0 /

&record10
 Testing_3DVAR  = .FALSE.,
 Test_Transforms = .FALSE.,
 Test_Statistics = .FALSE.,
 Interpolate_Stats = .TRUE. /

&record11
 minimisation_option = 2,
 write_outer_loop    = .FALSE.,
 lat_stats_option    = .FALSE.,
 calculate_cg_cost_function = .FALSE.,
 cv_options     = 3,
 cv_options_hum = 3,
 check_rh       = 2,
 as1          = 0.25, 0.75, 1.5,
 as2          = 0.25, 0.75, 1.5,
 as3          = 0.25, 0.75, 1.5,
 as4          = 0.25, 0.75, 1.5,
 as5          = 0.25, 0.75, 1.5,
sfc_assi_options = 1,
 set_omb_rand_fac = 1.0,
 seed_array1    = 0,
 seed_array2    = 0 /

&record12
 balance_type   = 1 /

&record13
 vert_corr      = 2,
 vertical_ip    = 0,
 vert_evalue    = 1,
 max_vert_var1  = 99.0,
 max_vert_var2  = 99.0,
 max_vert_var3  = 99.0,
 max_vert_var4  = 99.0,
 max_vert_var5  = 99.0 /

&pseudo_ob_nl
 num_pseudo     = 0,
 pseudo_x       = 165.0,
 pseudo_y       = 65.0,
 pseudo_z       = 15.0,
 pseudo_val     = 1.0,
 pseudo_err     = 1.0,
 pseudo_var     = 'u' /
```

WRF-Var


WRF-Var START
Namelist File
x^b
P_f
y^o
Setup Frame
Read Namelist
Setup Background
Setup Background Errors
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Compute Analysis
Minimize Cost Function
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"Outer Loop"
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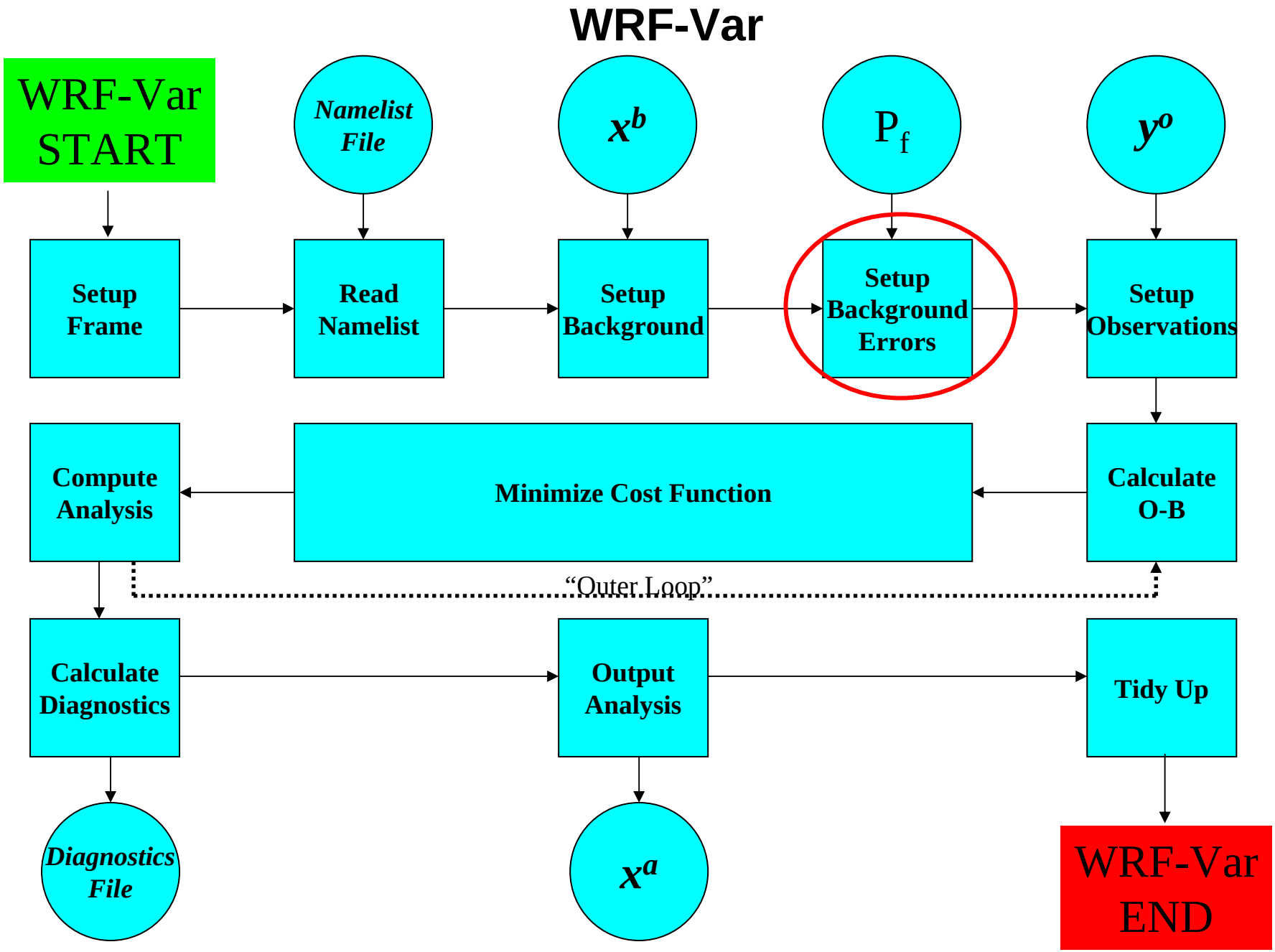
Output Analysis
Tidy Up
Diagnostics File
x^a
WRF-Var END

Setup Background (First-Guess)

- **Reads in the first-guess field.**
- **Format depends on namelist option**
- **“fg_format” ; 1= WRF, 2= MM5, 3= global**
- **Extracts necessary fields.**
- **Creates background FORTRAN 90 derived data type “xb” e.g. xb % mix, xb % u(:,:,:), ….**


WRF-Var
WRF-Var START
Namelist File
x^b
P_f
y^o
Setup Frame
Read Namelist
Setup Background
Setup Background Errors
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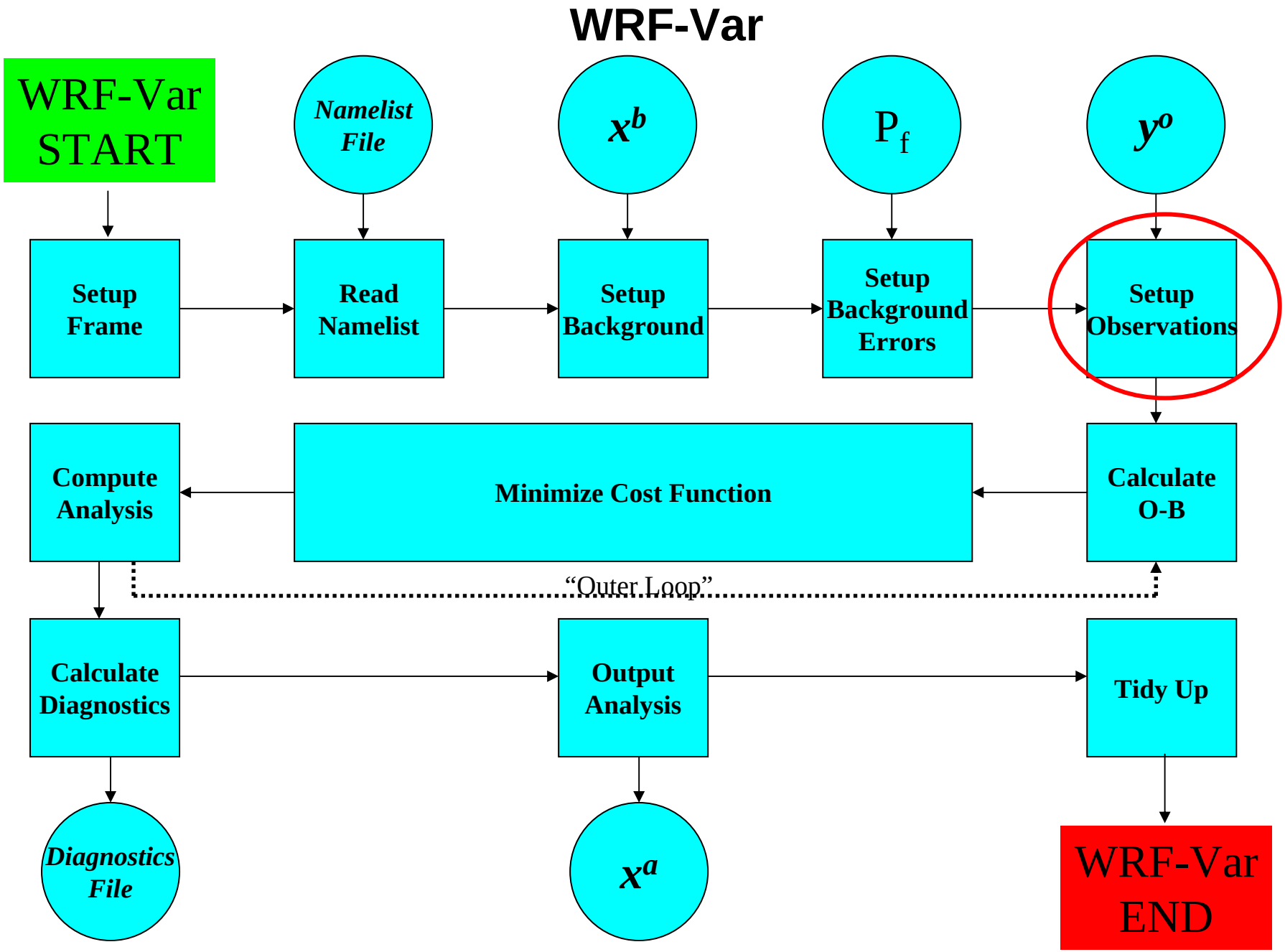
x^a
WRF-Var END

Setup Background Errors (BE)

- **Reads in background error statistics.**
- **Format depends on namelist option “cv_options” 2=MM5, 3 = GFS-based, 4=Global, 5=WRF regional.**
- **Extracts necessary quantities – eigenvectors, eigenvalues, lengthscales, regression coefficients, etc (see gen_be talk).**
- **Creates background error FORTRAN 90 derived data type “be” e.g. be % v1 % evec(:,:), be % v2 % eval(:), etc, ….**


WRF-Var
WRF-Var START
Namelist File
x^b
P_f
y^o
Setup Frame
Read Namelist
Setup Background
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Setup Observations
Compute Analysis
Minimize Cost Function
Calculate O-B
"Outer Loop"
Calculate Diagnostics
Output Analysis
Tidy Up
Diagnostics File
x^a
WRF-Var END

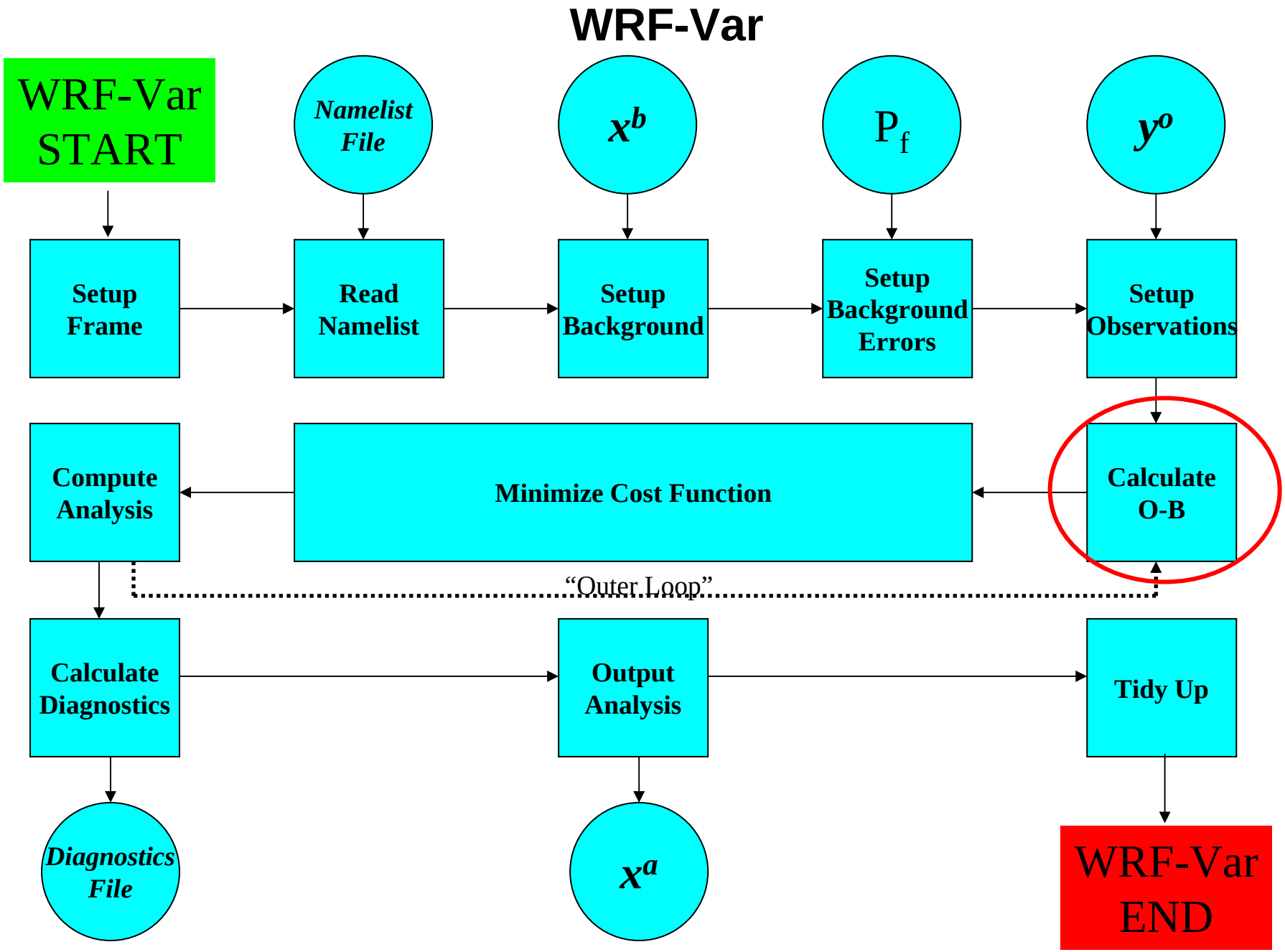
Setup Observations

- **Reads in observations.**

- **Format depends on namelist variable “ob_format”**
  1 = BUFR, 2 = ASCII “WRF-Var” format.

- **Creates observation FORTRAN 90 derived data type “ob” e.g. ob % num_gpspw, ob % metar(:),**
  ob % sound(:) % u(:), etc, ….

- **Identifies Obs outside/inside the domain**


WRF-Var
WRF-Var START
Namelist File
x^b
P_f
y^o
Setup Frame
Read Namelist
Setup Background
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Tidy Up
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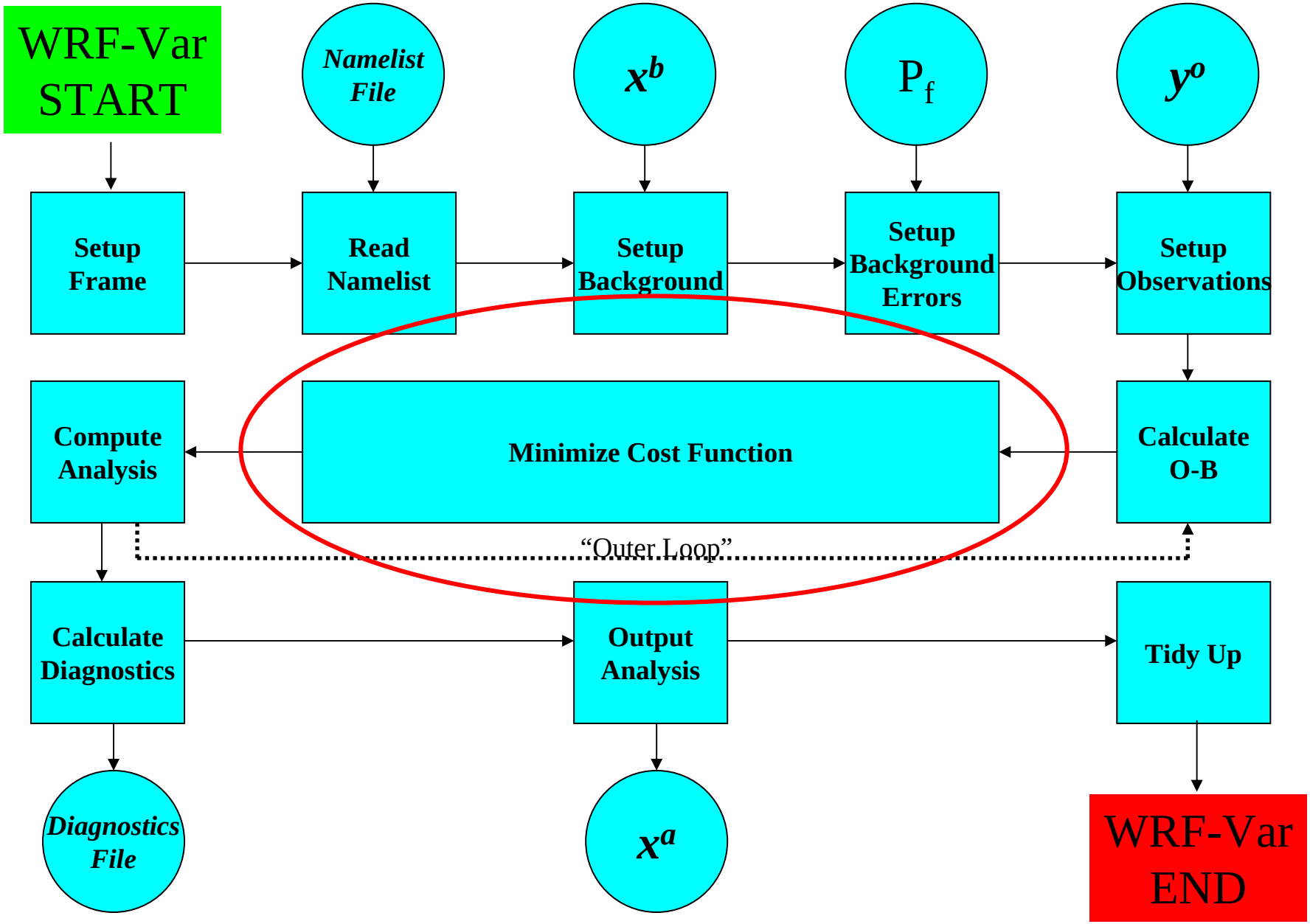
x^a
WRF-Var END

Calculate Innovation Vector (O-B)

- **Calculates "model equivalent" B of observation O through interpolation and change of variable.**
- **Computes observation minus first guess (O-B) value.**
- **Creates innovation vector FORTRAN 90 derived data type "iv" e.g. iv % metar(:), iv % qscat(:) % u,**
- **iv % sound(:) % u(:), etc ….**

WRF-Var


WRF-Var START
Namelist File
x^b
P_f
y^o
Setup Frame
Read Namelist
Setup Background
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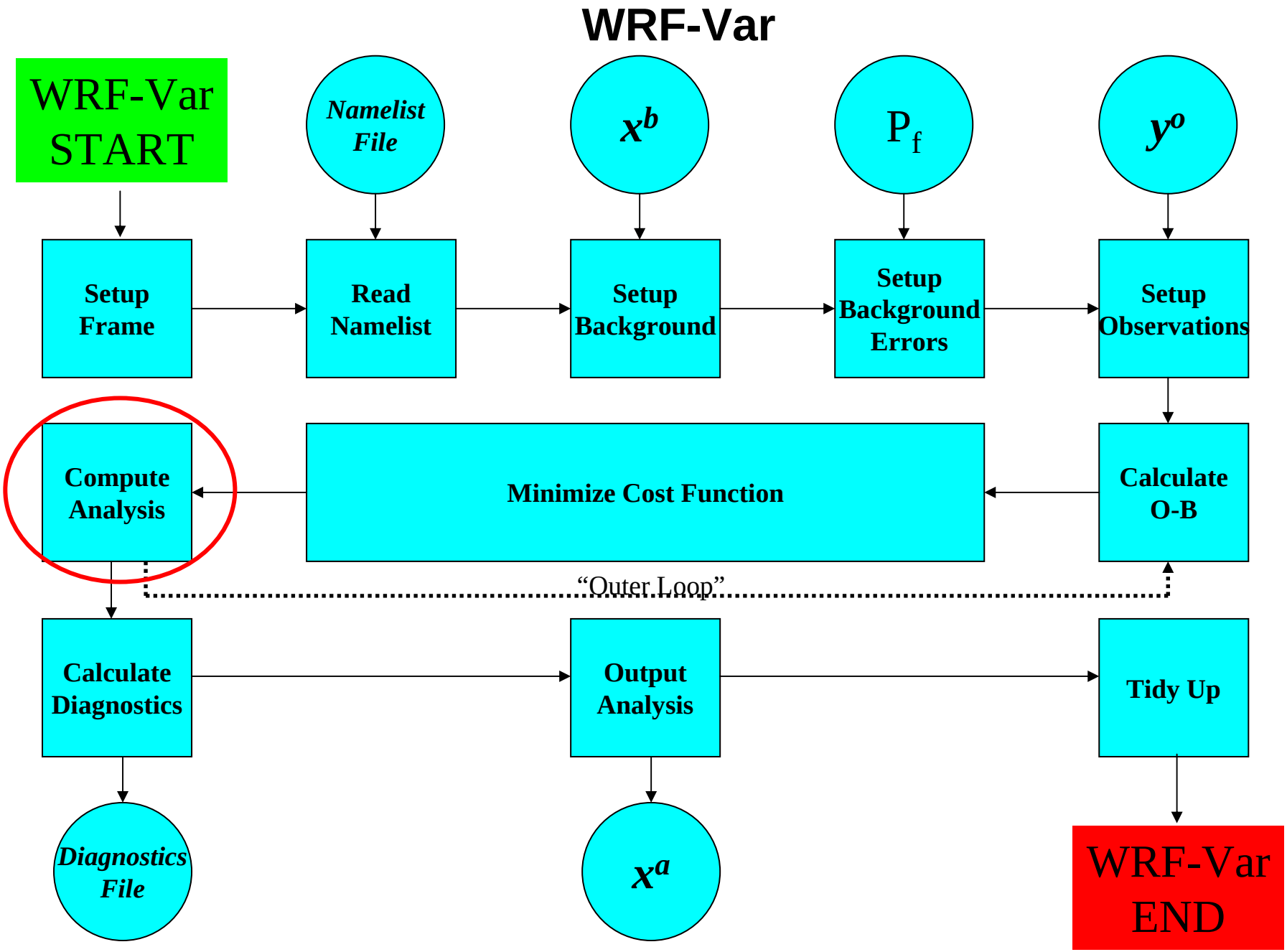
x^a
WRF-Var END

Minimize Cost Function

- **(a) Initializes analysis increments to zero.**
- **(b) Computes cost function (if desired).**
- **(c) Computes gradient of cost function.**
- **(d) Uses cost function and gradient to calculate new value of analysis control variable (v)**
- **Iterate (b) to (d)**


WRF-Var
WRF-Var START
Namelist File
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P_f
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x^a
WRF-Var END

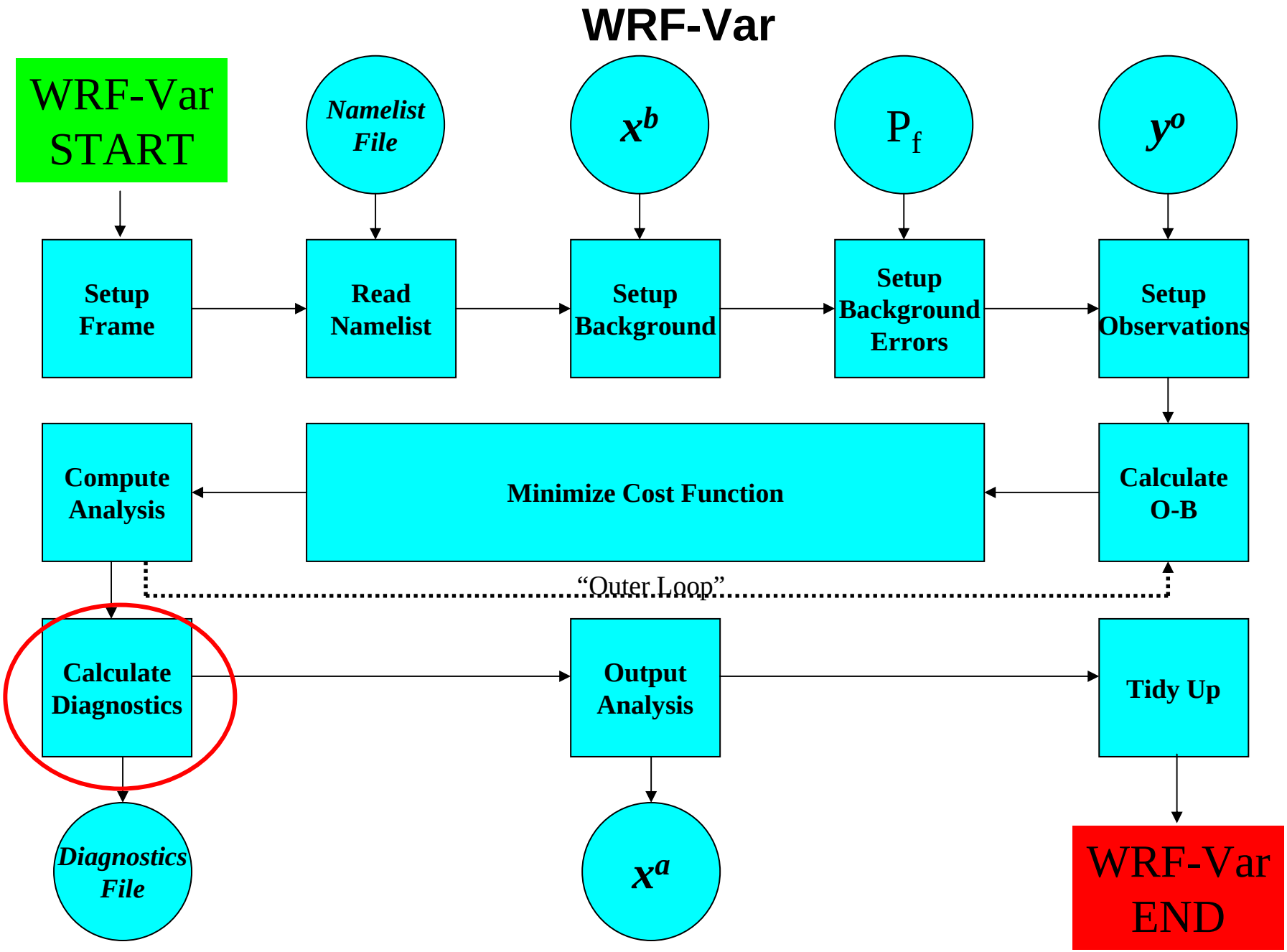
Compute Analysis

- **Once WRF-Var has found a converged control variable, convert convert control variable to model space analysis increments**

- **Calculate:**

  analysis = first-guess + analysis increment

- **Performs consistency checks e.g. remove negative humidity etc.**


WRF-Var
WRF-Var START
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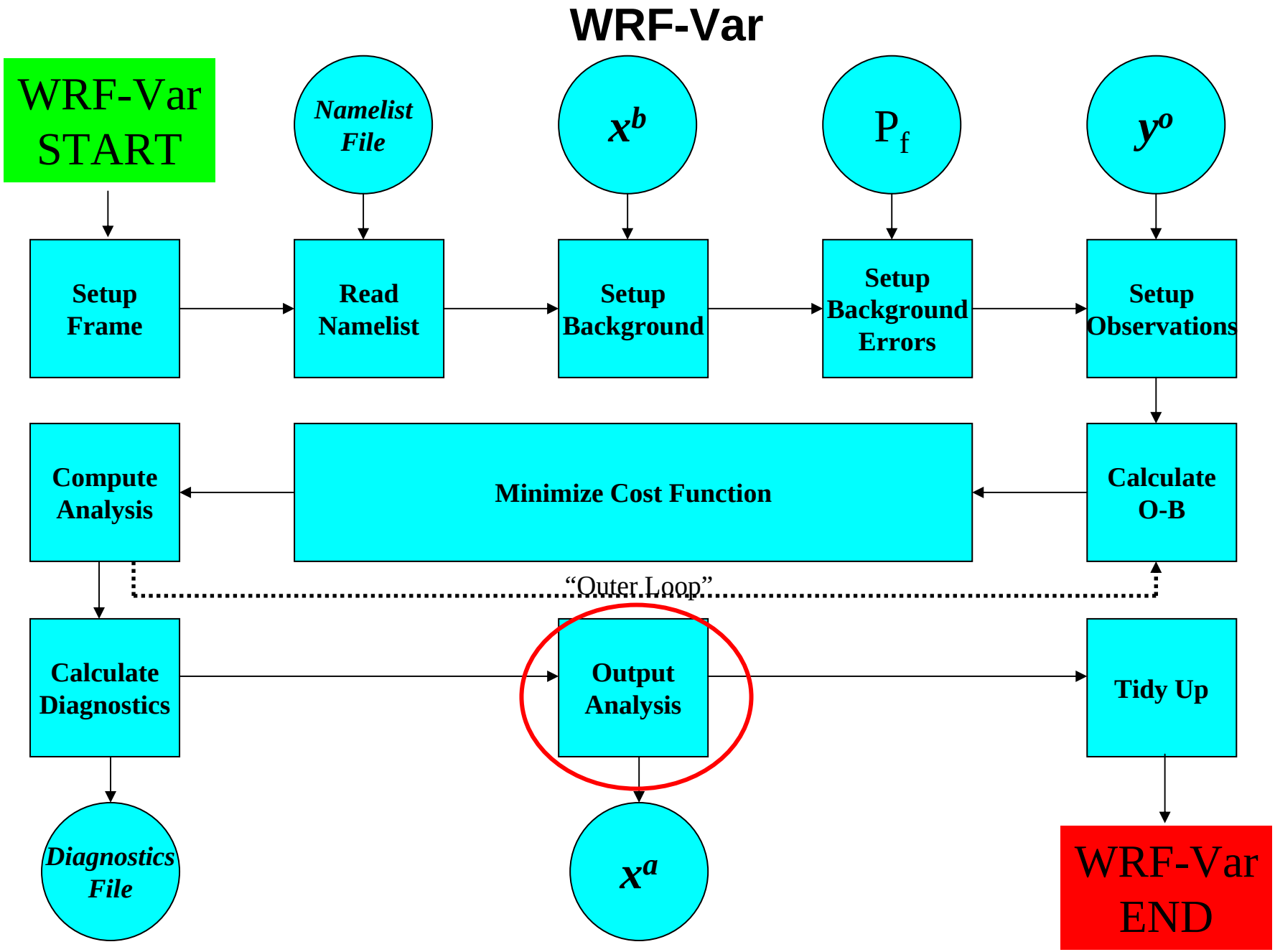
x^a
WRF-Var END

Compute Diagnostics

- **Compute O-B, O-A statistics for all observation types and variables.**
- **Compute A-B (analysis increment) statistics for all model variables and levels.**
- **Statistics include minimum, maximum (and their locations), mean and standard deviation.**
- **Compute “specialist diagnostics” for error tuning (fort.45, fort.46, fort.47, fort.50 etc.).**


WRF-Var
WRF-Var START
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x^b
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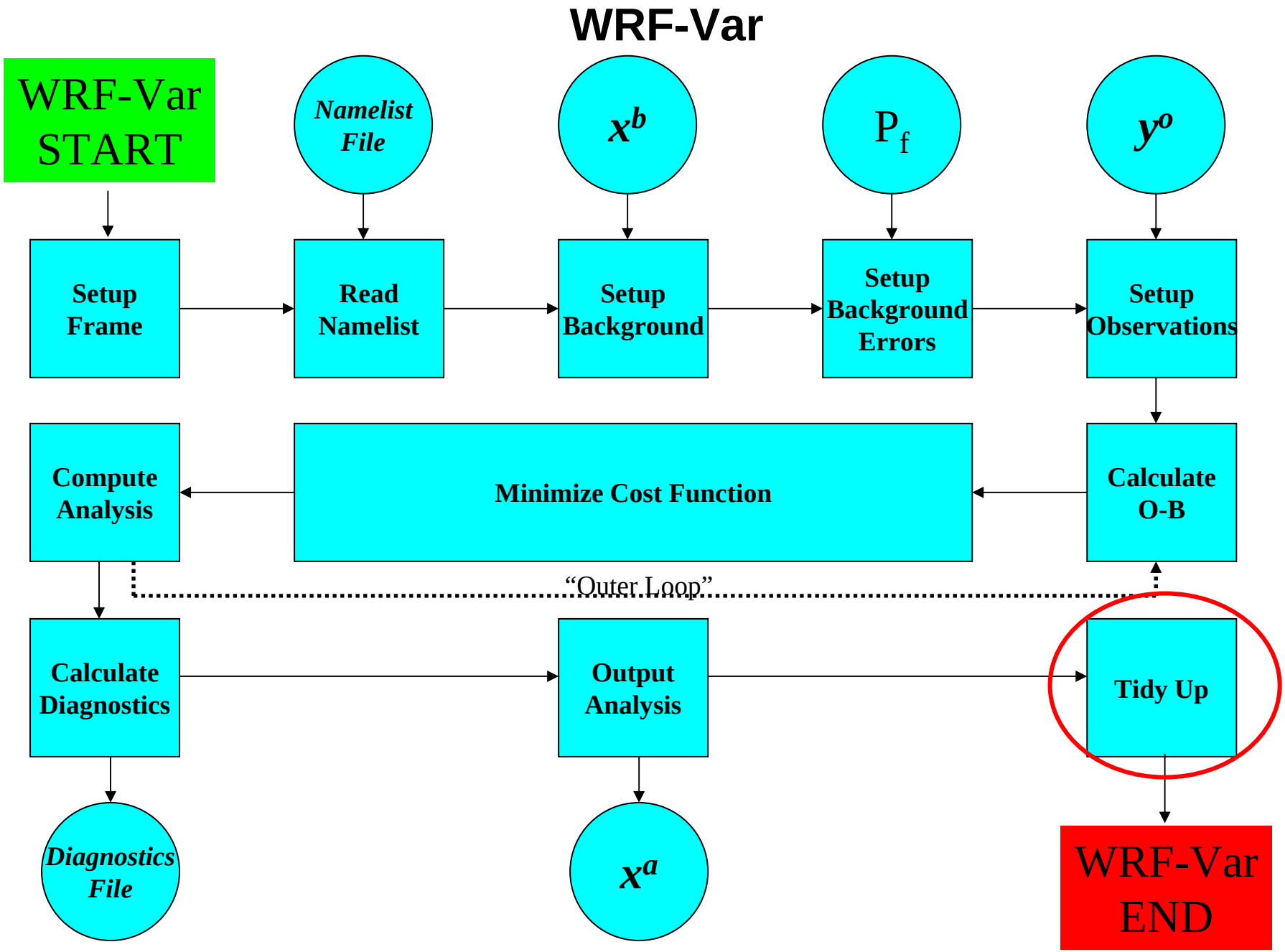
x^a
WRF-Var END

Output Analysis

- **Outputs analysis in native model format. Choice is made through namelist option “fg_format”**
  - **1 = WRF, 2 = MM5, etc.**

- **Also output analysis increments (for diagnostic purposes) in native model format. Switch off by setting DA_WRITE_INCREMENTS = .FALSE. in namelist.3dvar.**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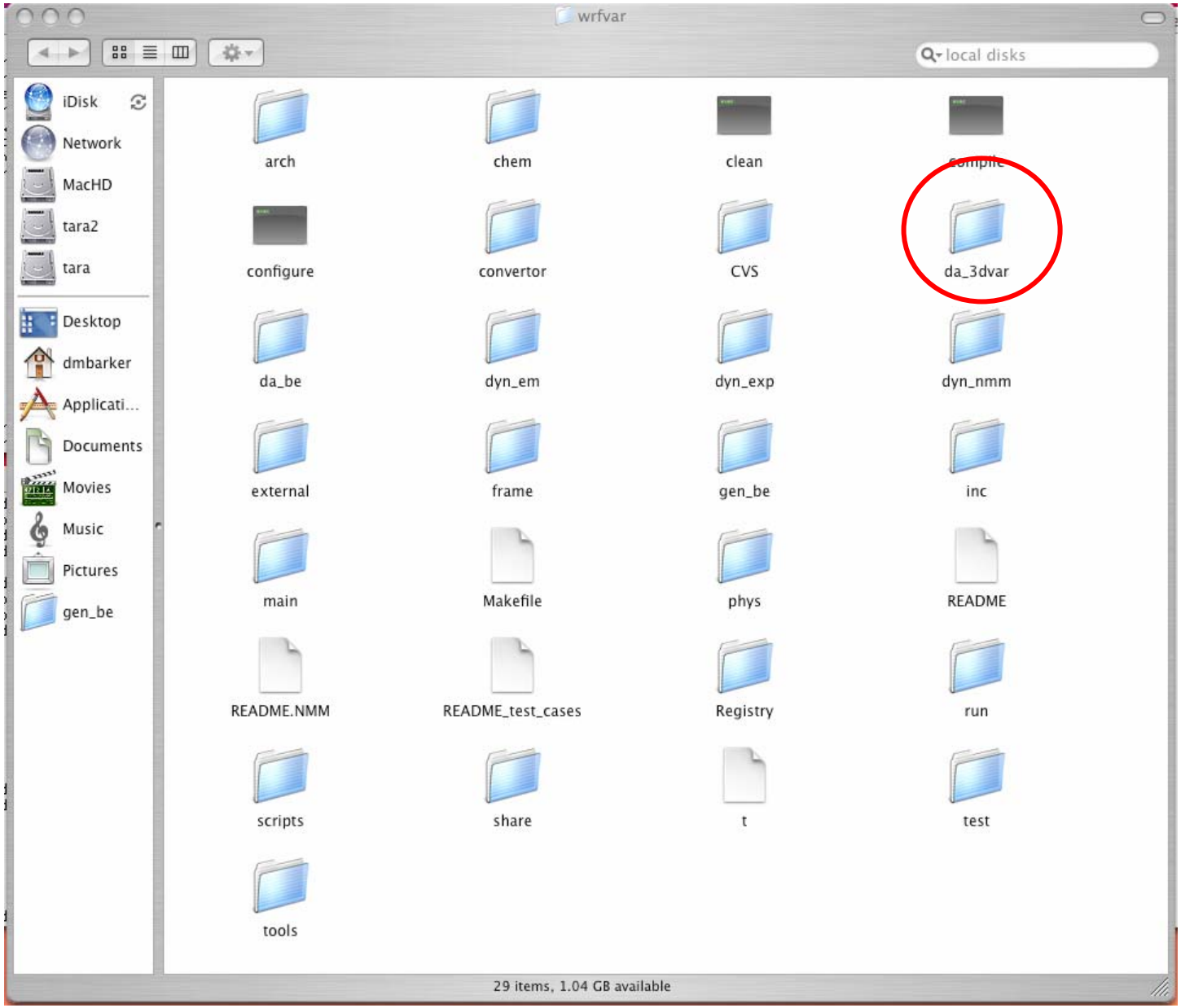
WRF-Var END

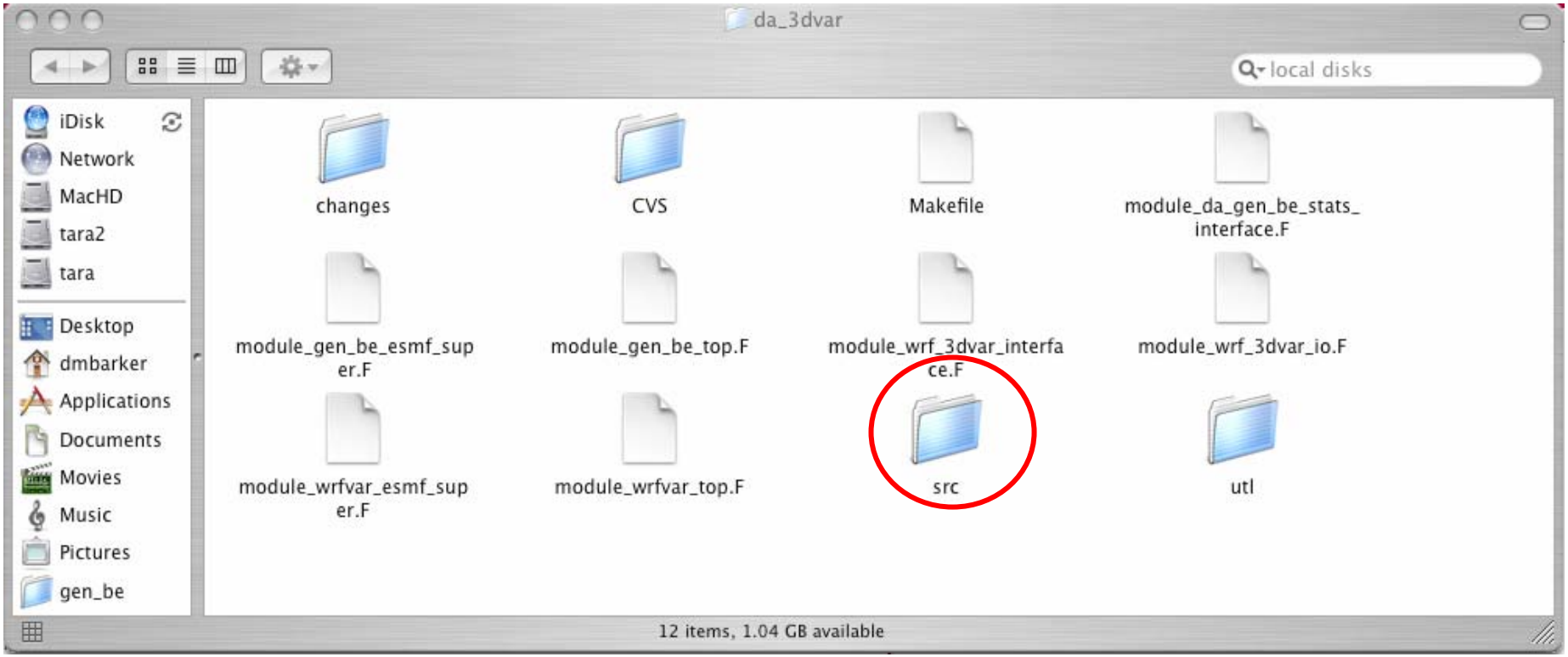
Tidy Up

- **Deallocate dynamically-allocated arrays, structures, etc.**
- **Timing information.**
- **Clean end to WRF-Var.**

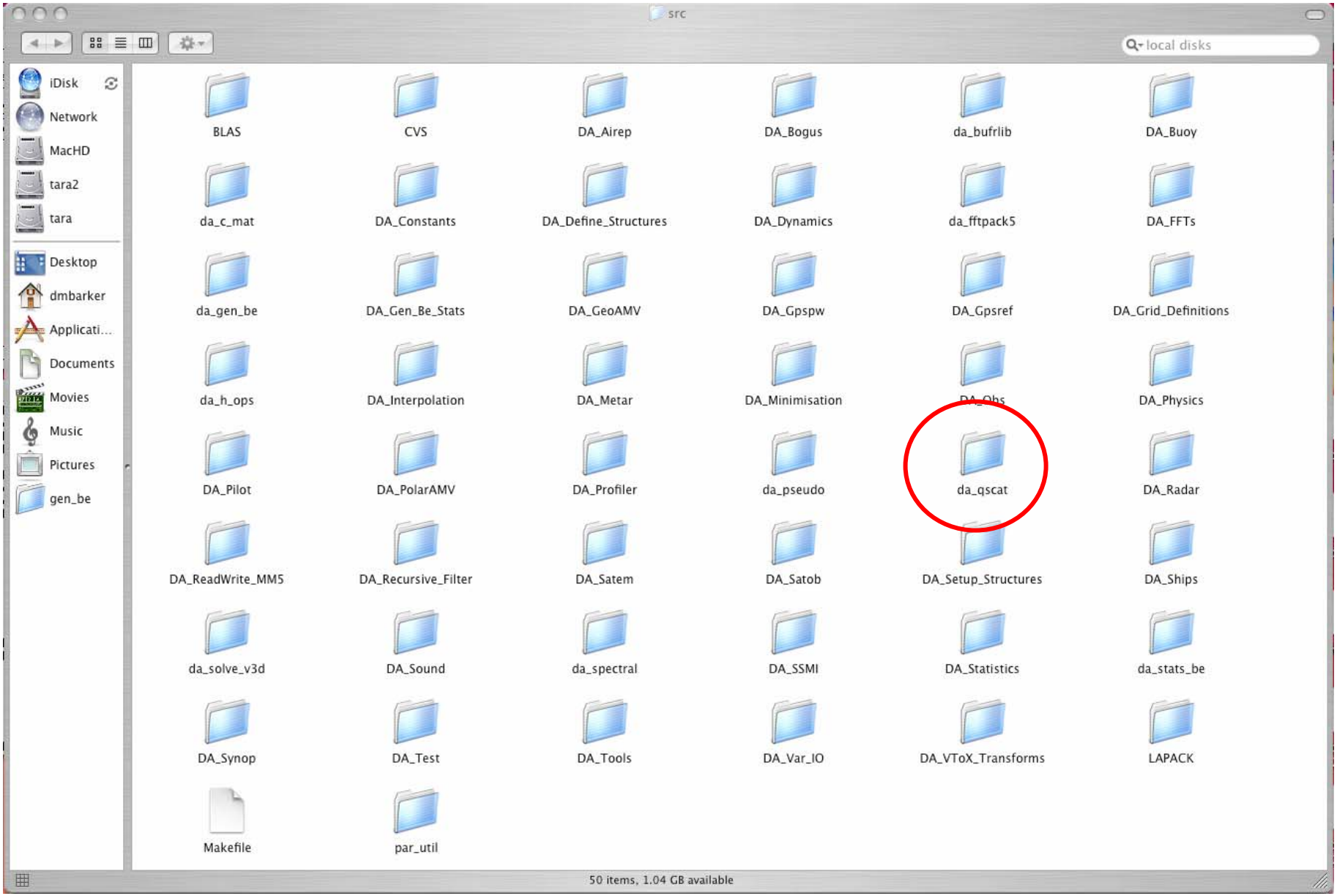
Source Code 1: *WRF-Var*



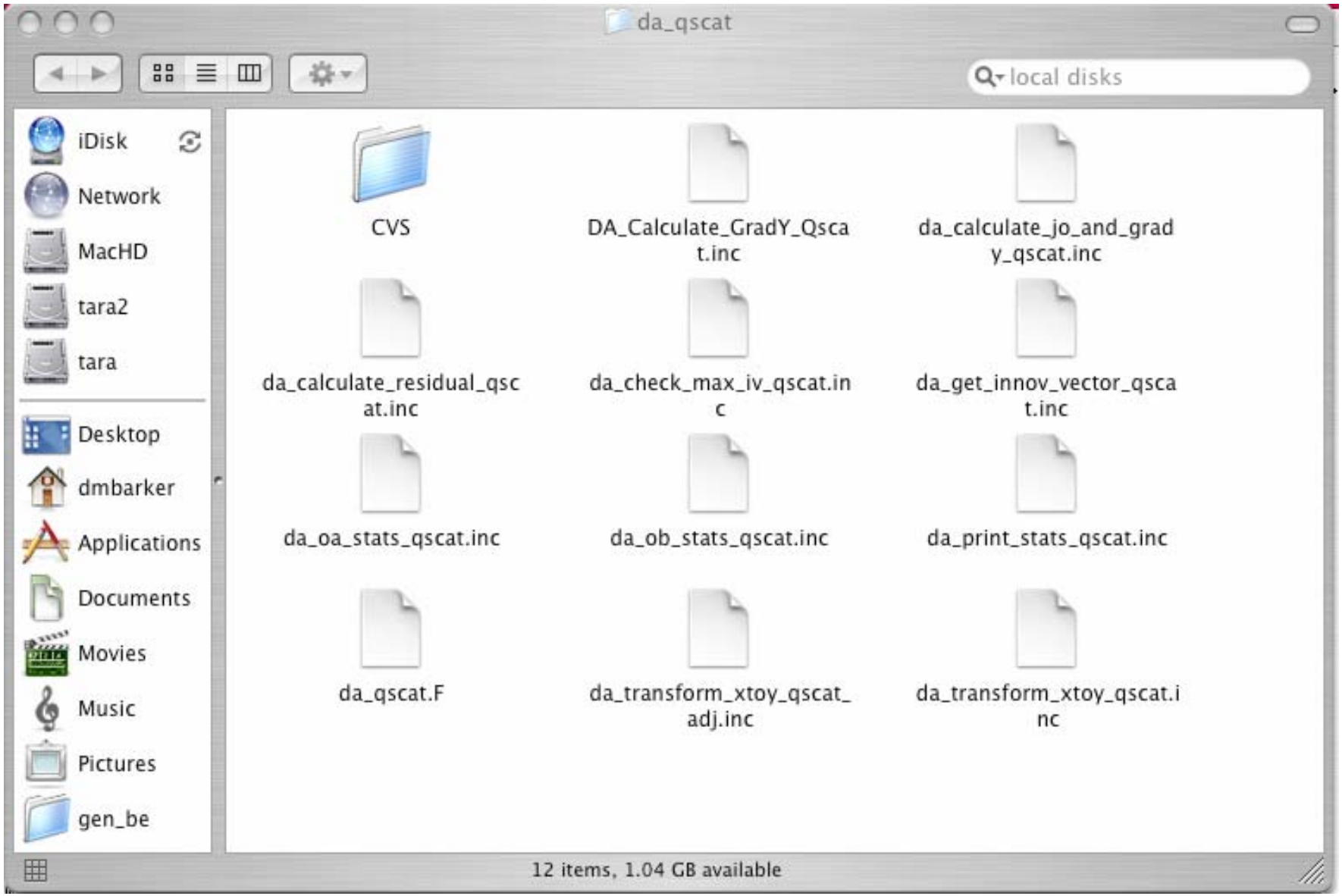
Source Code 2: *wrfvar/da_3dvar*



Source Code 3: *wrfvar/da_3dvar/src*



Source Code 4: *wrfvar/da_3dvar/src/da_qscat*



Source Code 5: *wrfvar/da_3dvar/src/da_qscat/da_qscat.F*

da_qscat.F

```
module da_qscat

   USE DA_Constants
   USE DA_Define_Structures
   USE DA_Interpolation
   USE DA_Statistics
   USE DA_Tools
   USE PAR_UTIL

! The "stats_qscat_type" is ONLY used locally in DA_Qscat:

   TYPE residual_qscat1_type
      REAL          :: u                        ! u-wind.
      REAL          :: v                        ! v-wind.
   END TYPE residual_qscat1_type

   TYPE maxmin_qscat_stats_type
        TYPE (maxmin_type)         :: u, v
   END TYPE maxmin_qscat_stats_type

   TYPE stats_qscat_type
        TYPE (maxmin_qscat_stats_type)  :: maximum, minimum
        TYPE (residual_qscat1_type)     :: average, rms_err
   END TYPE stats_qscat_type

CONTAINS

#include "da_calculate_jo_and_grady_qscat.inc"
#include "da_calculate_residual_qscat.inc"
#include "da_check_max_iv_qscat.inc"
#include "da_get_innov_vector_qscat.inc"
#include "da_oa_stats_qscat.inc"
#include "da_ob_stats_qscat.inc"
#include "da_print_stats_qscat.inc"
#include "da_transform_xtoy_qscat.inc"
#include "da_transform_xtoy_qscat_adj.inc"
#include "DA_Calculate_GradY_Qscat.inc"


end module da_qscat
```

Procedure for adding new Observations

- **Edit DA_Define_Structure.F to add new data type.**
- **Make new observation sub-directory under “src”.**
- **Develop desired programs like getting innovation vector, forward observation operator, tangent linear & its adjoint, gradient & cost function etc. in this new sub-directory.**
- **Input observation (update DA_Obs).**
- **Sometimes it might be needed to add certain grid arrays in Registry.**
- **Link into minimization package (DA_Minimisation)**

DA_Run_WRF-Var.csh (summary)

 # USER: Define non-default job via environment variables:

e.g.: setenv START_DATE 2004050200 overrides the default.

##
#USER: DO NOT MAKE CHANGES BELOW (if you do, you're on your own!)
##

 # [1.0] Specify default environment variables:

e.g. if (! $?START_DATE) setenv START_DATE 2004050100 # Analysis date.

 # [2.0] Perform sanity checks:

e.g. check input observation file exists

 # [3.0] Prepare for assimilation:

Create WRF-Var V2.1 namelist file (namelist.3dvar).

Create WRF V2.1 namelist file (namelist.input).

#[4.0] Run WRF-Var:

e.g. mpirun -v -np 16 -nolocal -machinefile hosts ./wrfvar.exe >&! /dev/null

Learning To Use WRF-Var

- **Consult WRF-Var documentation at:**

  http://www.mmm.ucar.edu/wrf/WG4

- **Run through the Online WRF-Var Tutorial available at:**

  http://www.mmm.ucar.edu/wrf/WG4/wrfvar.htm

- **If still confused, ask questions via:**

  wrfhelp@ucar.edu