WRF Data Assimilation System

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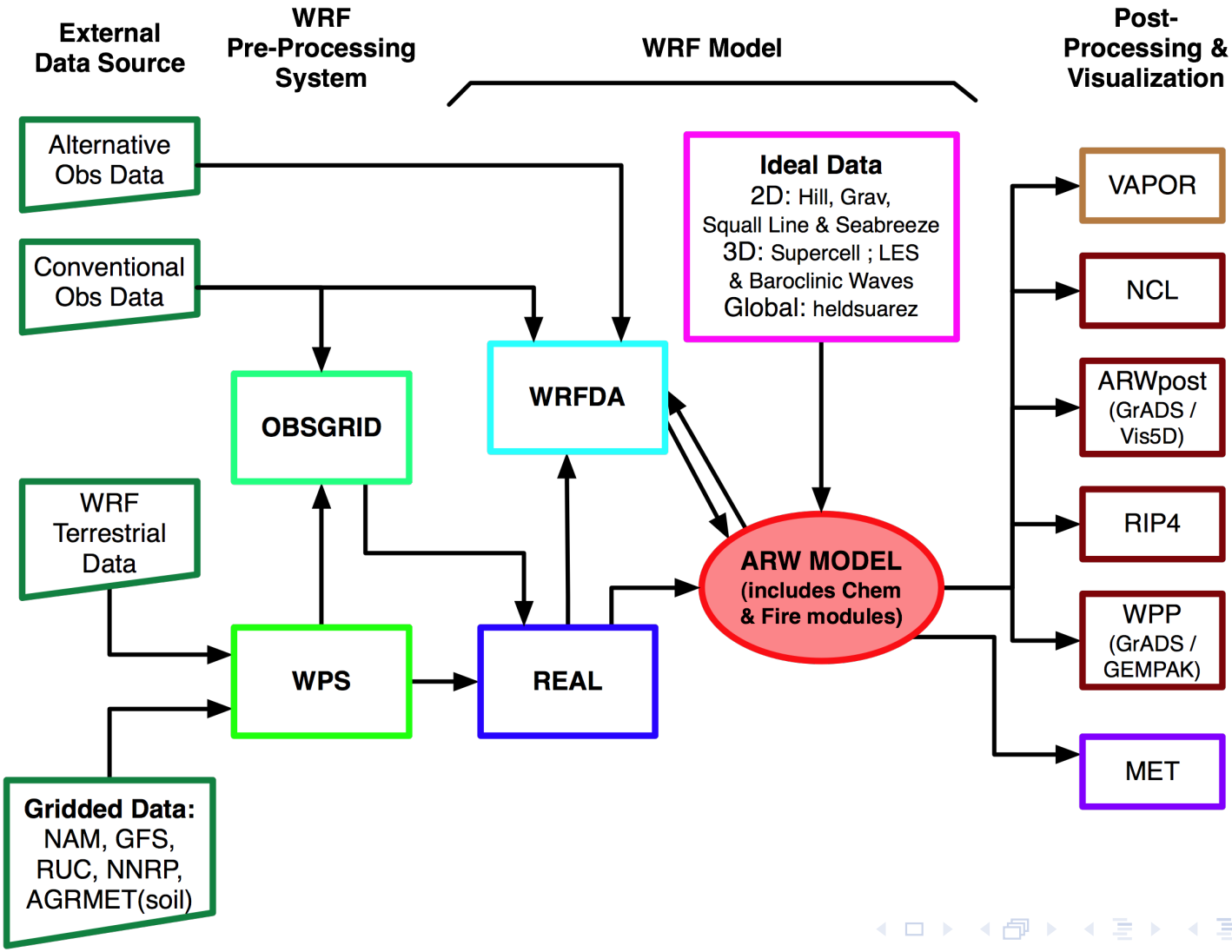
Presented on August 3, 2010
WRFDA Tutorial

NCAR is sponsored by the National Science Foundation

What is WRFDA ?

- WRFDA : A Data Assimilation system for WRF (ARW) model
  - Variational and Ensemble methods
  - Used for both research and operational data analysis
- It is a supported community model, i.e. a free and shared resource with distributed development and centralized support

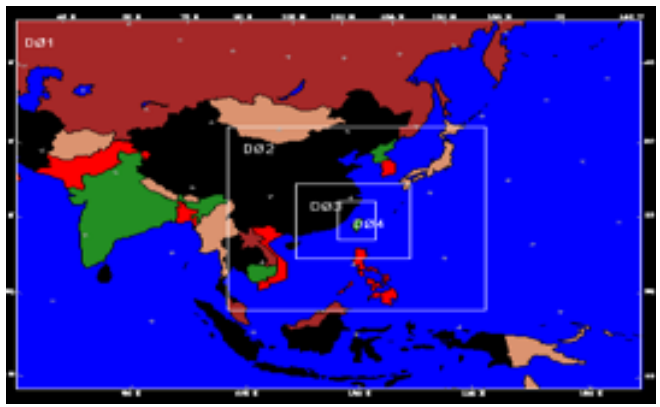
WRF Modeling System Flow Chart



WRFDA Applications

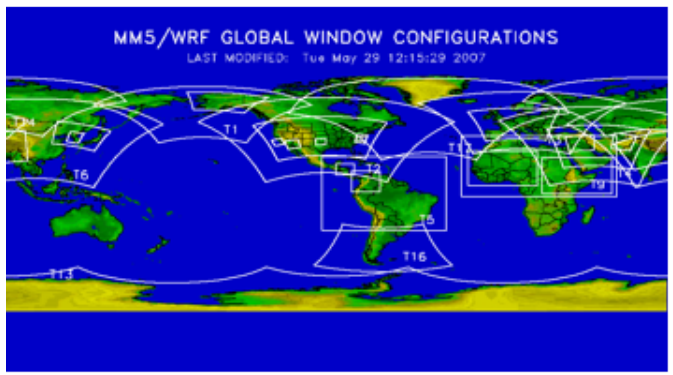
Goal: Community WRF DA system for

- regional/global
- research/operations, and
- deterministic/probabilistic applications



Techniques:

- 3D-Var
- 4D-Var (regional)
- Ensemble DA
- Hybrid Variational/Ensemble DA



Model: WRF (ARW, NMM, Global)

Support:

- NCAR/ESL/MMM/DAS
- NCAR/RAL/JNT/DATC

Observations: Conv. + Sat. + Radar

Prepare the BE

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x} - \mathbf{x^b})^{\mathbf{T}}\mathbf{B^{-1}}(\mathbf{x} - \mathbf{x^b}) + \frac{1}{2}(\mathbf{y} - H(\mathbf{x}))^{\mathbf{T}}\mathbf{R^{-1}}(\mathbf{y} - H(\mathbf{x}))$$

- Nominally, **B** is the background error covariance

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  - be.dat.cv3 (CV option 3) from source code tar file can be used for general test domains

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  - be.dat.cv3 (CV option 3) from source code tar file can be used for general test domains
- Ultimately, **B** should be specific to the particular model domain (and season)

Prepare the Background

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- In cycling mode: the output of the WRF model
  - WRF can output wrfinput-formatted files used for cycling

Prepare the Observations

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- Separate input file for satellite radiances, BUFR format

Run WRFDA

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x} - \mathbf{x^b})^{\mathbf{T}}\mathbf{B^{-1}}(\mathbf{x} - \mathbf{x^b}) + \frac{1}{2}(\mathbf{y} - H(\mathbf{x}))^{\mathbf{T}}\mathbf{R^{-1}}(\mathbf{y} - H(\mathbf{x}))$$

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- H is the observational operator, which calculate the counterpart of observations in model space
- Conjuagate gradient method
- Try to find a $\mathbf{x}^a$, which make the J minimal

Update Boundary Condition

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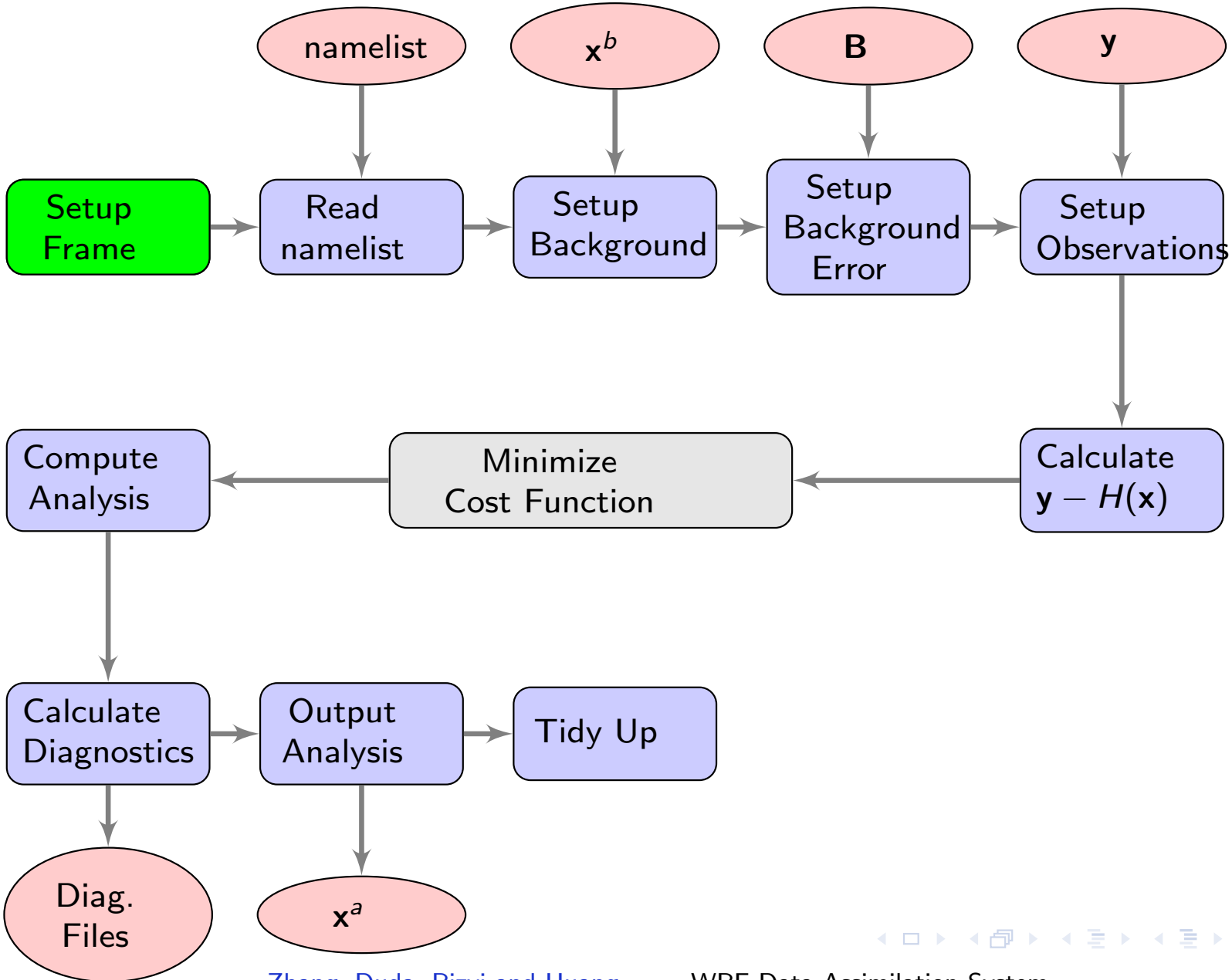
Update Boundary Condition

- After creating an analysis, $\mathbf{x}^a$, we have changed the initial conditions for the model
- However, tendencies in wrfbdy_d01 file are valid for background, $\mathbf{x}^b$
- The update_bc program adjusts these tendencies based on the difference $\mathbf{x}^a - \mathbf{x}^b$
- Of course, if $\mathbf{x}^a$ was produced for reasons other than running WRF, there is probably not a need to update boundary conditions


namelist
$\mathbf{x}^b$
B
y
Setup Frame
Read namelist
Setup Background
Setup Background Error
Setup Observations
Compute Analysis
Minimize Cost Function
Calculate $\mathbf{y} - H(\mathbf{x})$
Calculate Diagnostics
Output Analysis
Tidy Up
Diag. Files
$\mathbf{x}^a$

Setup Frame

- Reads grid dimensions from *namelist.input* file

Setup Frame

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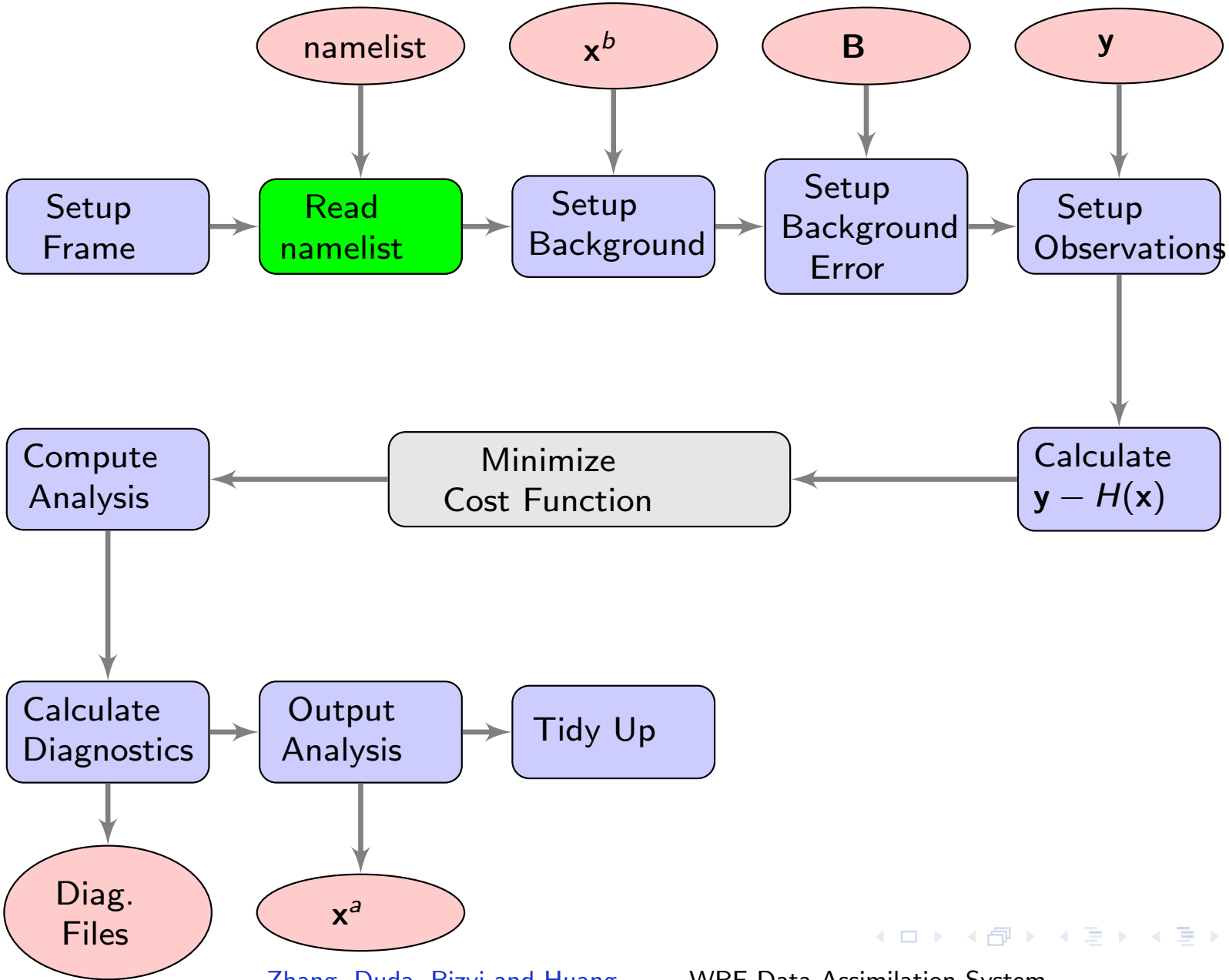
- Use WRF framework distributed memory capability to initialize tile, memory, patch dimensions, etc.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Read namelist

- Reads WRFDA data assimilation options from namelist.input file

Read namelist

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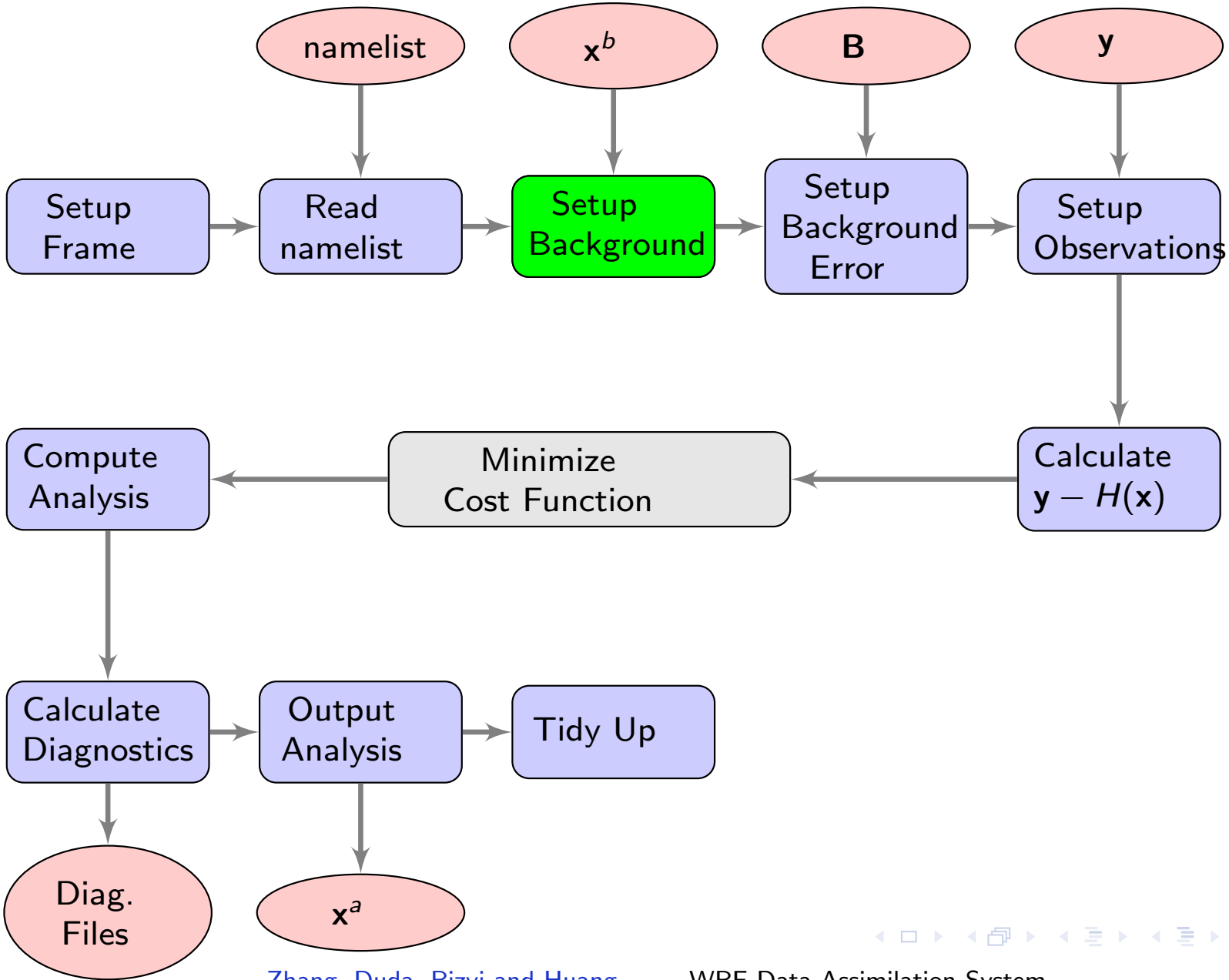
- Performs consistency checks between namelist options.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Setup Background

- Reads the first-guess file

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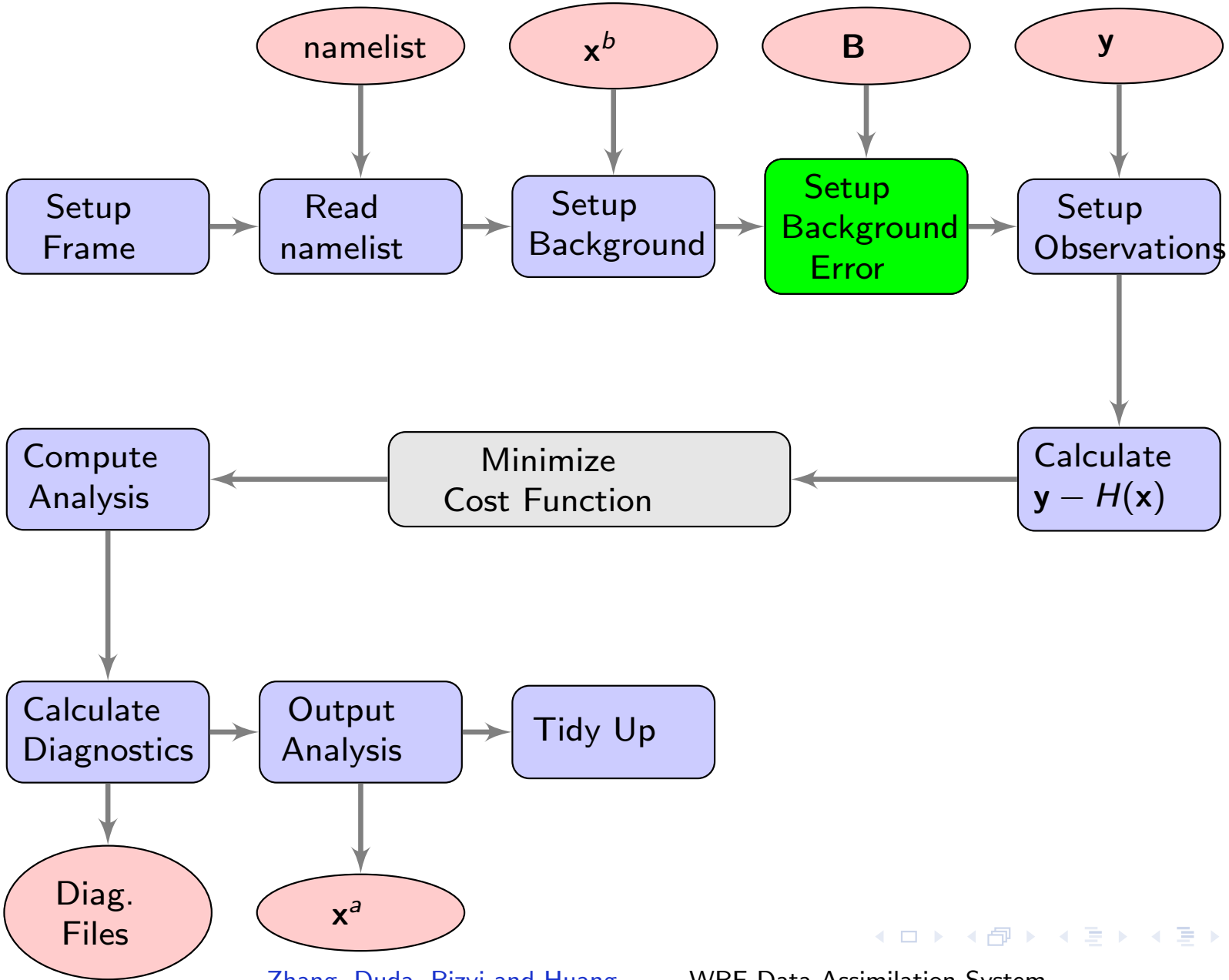
- Extracts fields used by WRFDA

Setup Background

- Reads the first-guess file
- Extracts fields used by WRFDA
- Creates background FORTRAN 90 derived data type *xb* etc.
- Reference :**Online BE Documents**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Setup Background Error

- Reads in background error statistics

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- Extracts necessary quantities: eigenvectors, eigenvalues, lengthscales, regression coefficients, etc.

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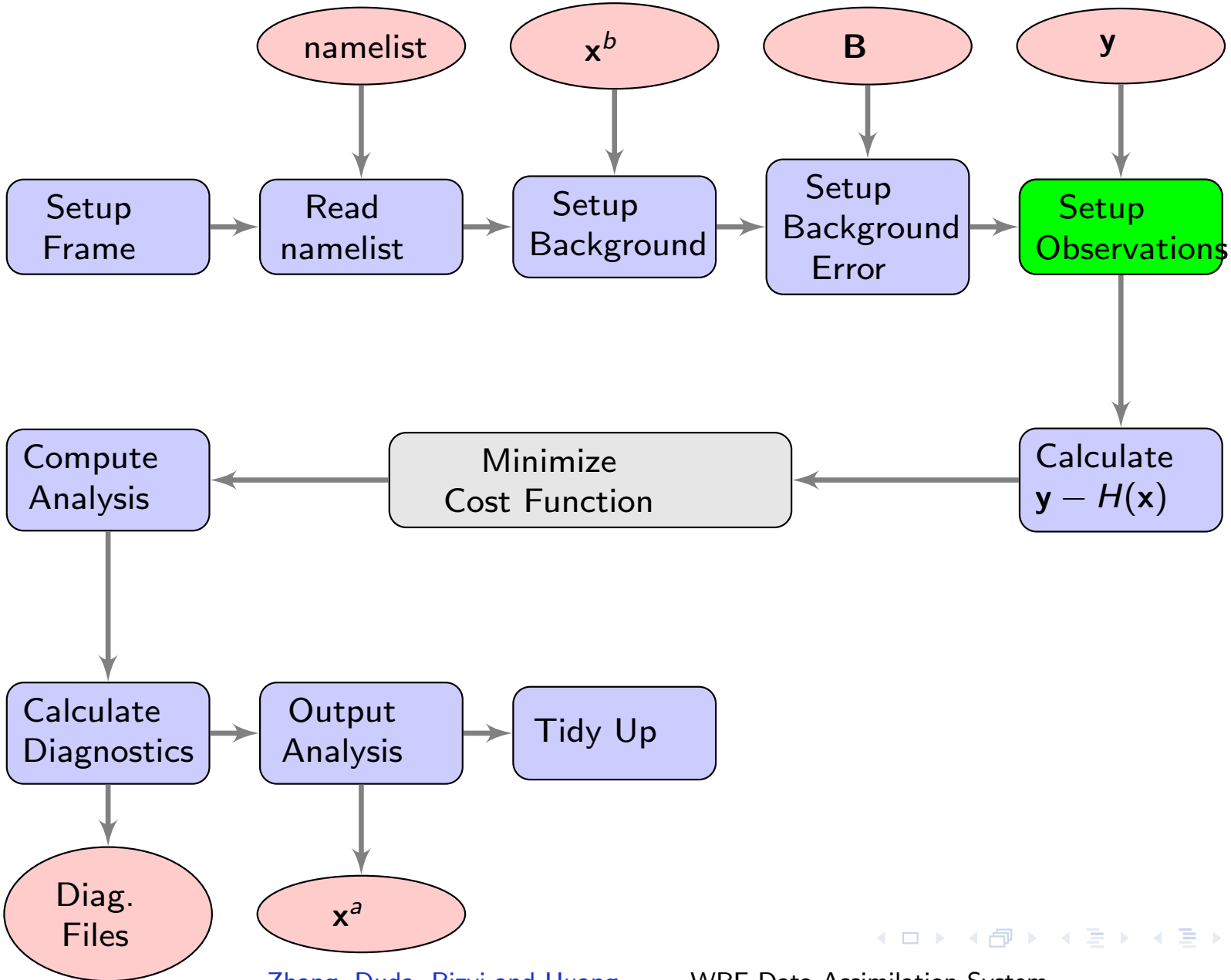
- Creates background error FORTRAN 90 derived data type *be*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Setup Observations

- Reads in observations

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- Creates observation FORTRAN 90 derived data type *ob*

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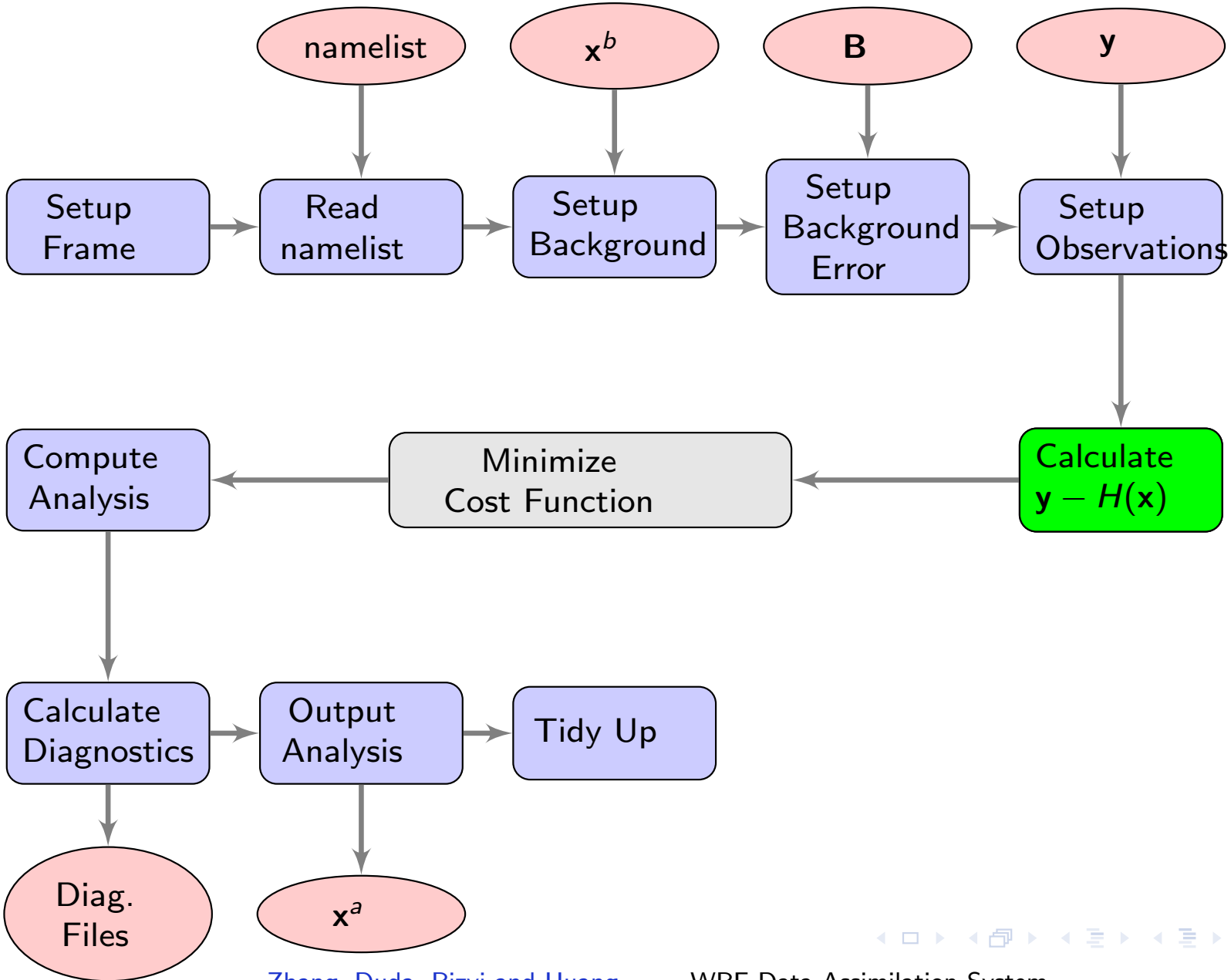
- Domain and time check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Calculate Innovation

- Calculates model equivalent of observations through interpolation and change of variable

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- Computes observation minus first guess ($\mathbf{y} - H(\mathbf{x})$) value

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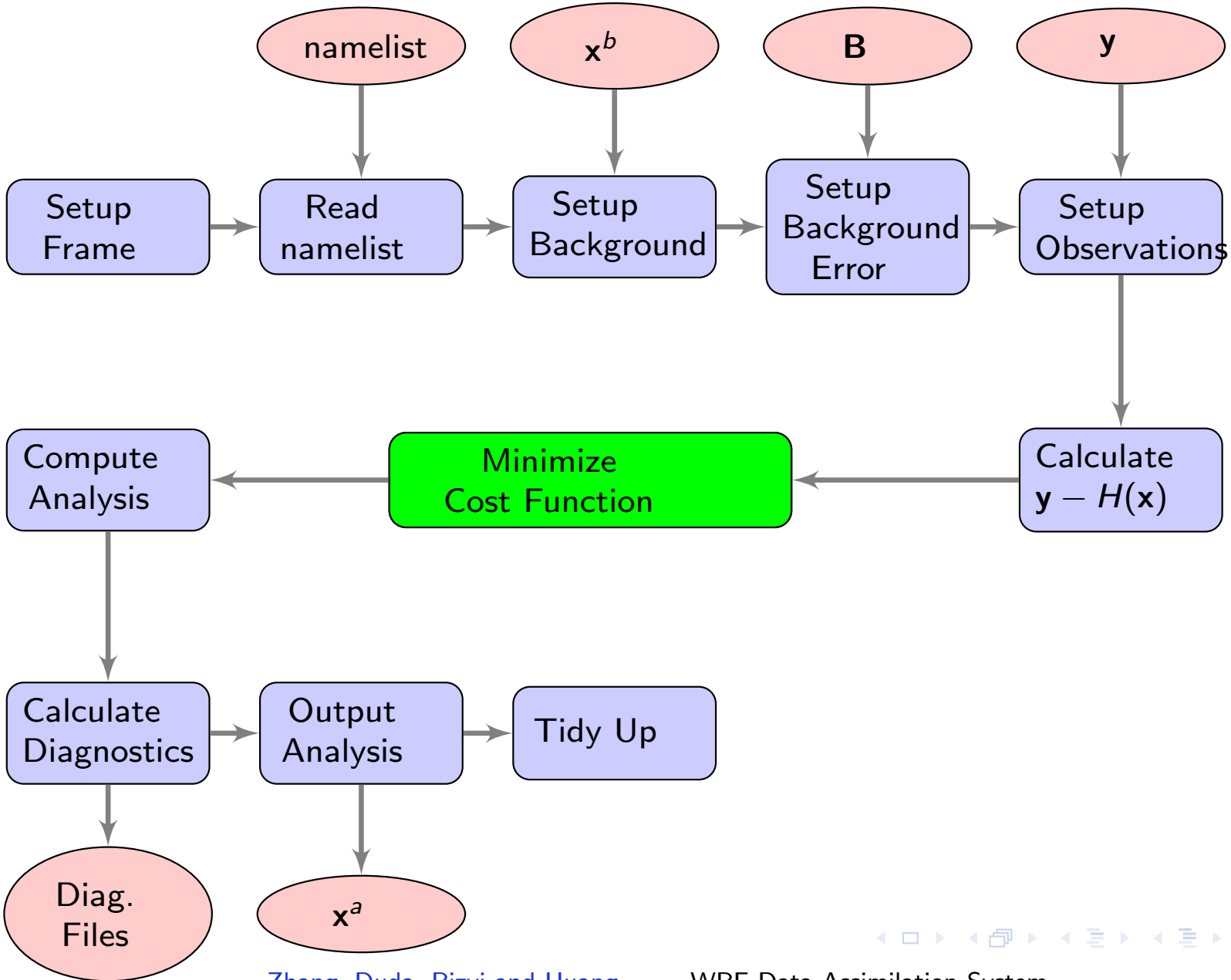
- Creates innovation vector FORTRAN 90 derived data type *iv*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Minimization

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- Computes cost function (if desired)

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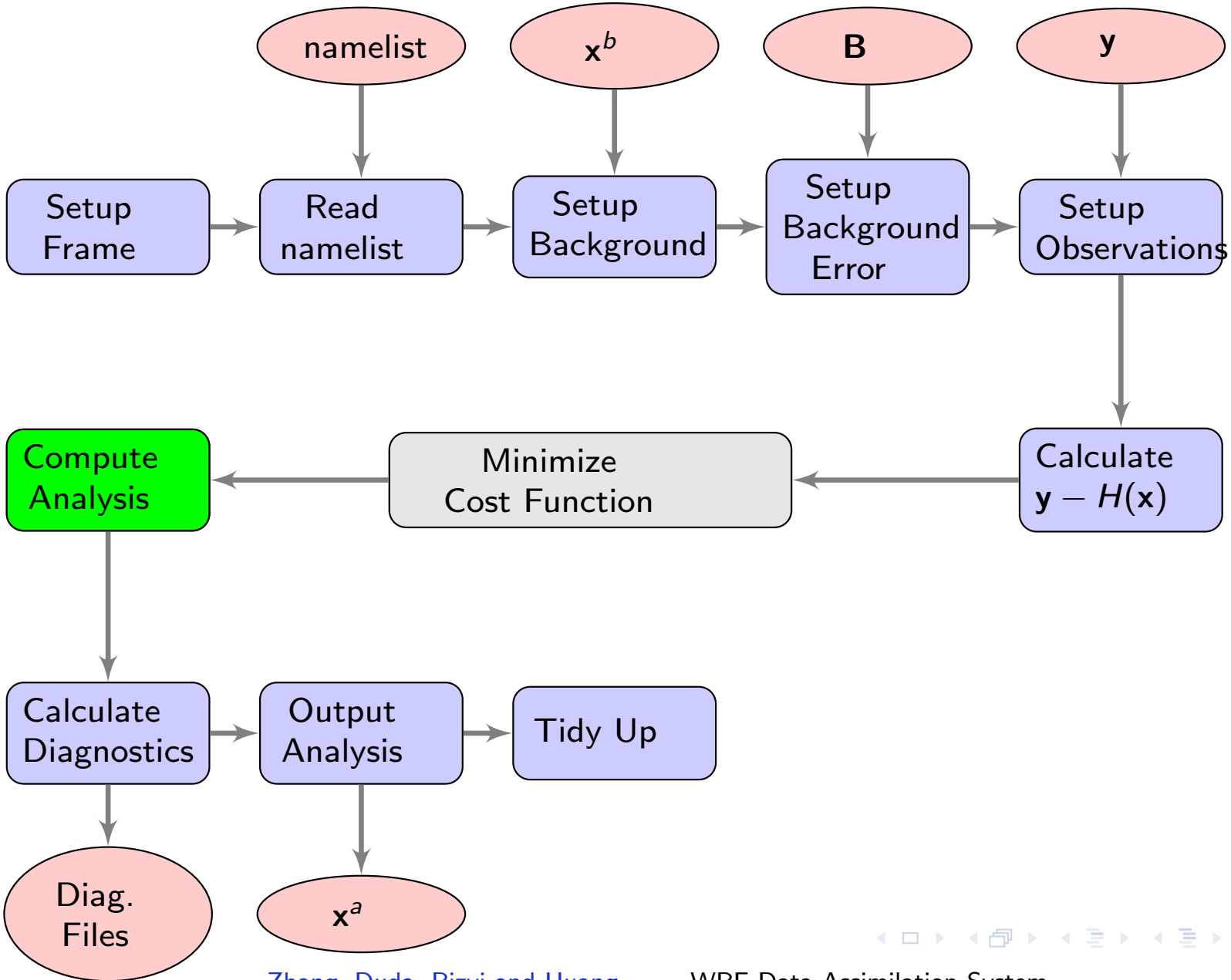
Minimization

Use conjugate gradient method

- Initializes analysis increments to zero
- Computes cost function (if desired)
- Computes gradient of cost function
- Uses cost function and gradient to calculate new value of analysis control variable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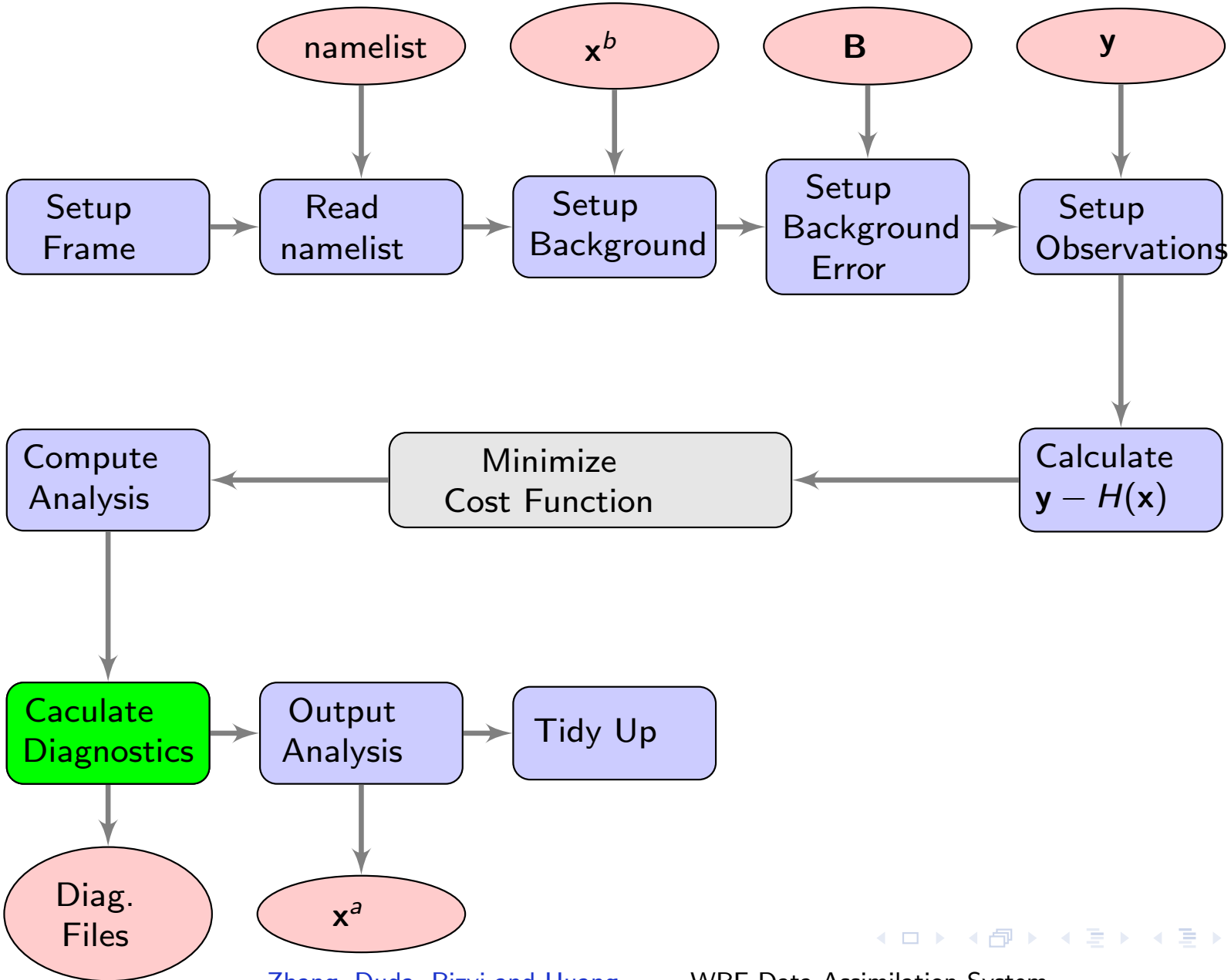
- Optionally, do outer loop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Calculate Diagnostics

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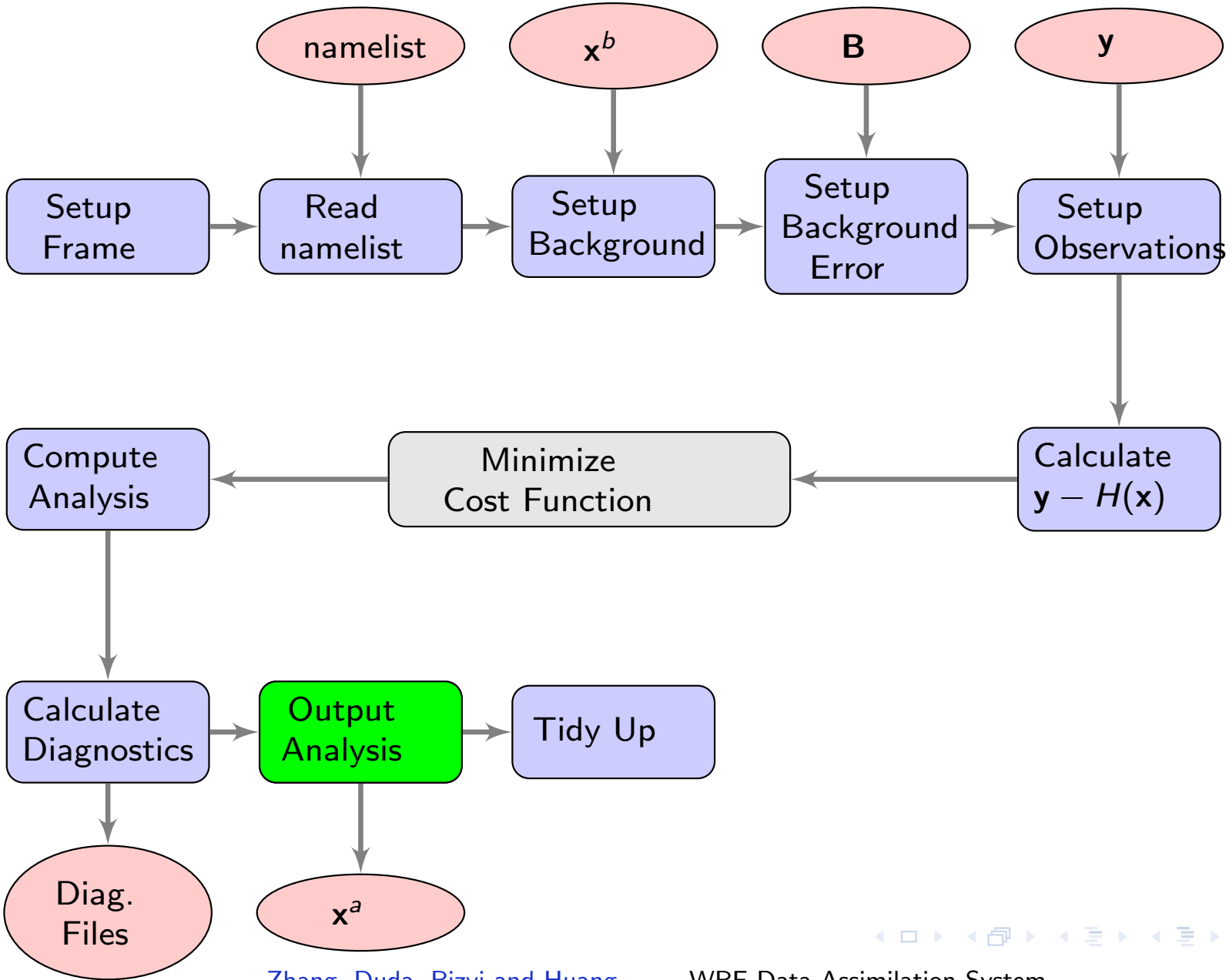
- Statistics include minimum, maximum (and their locations), mean and standard deviation.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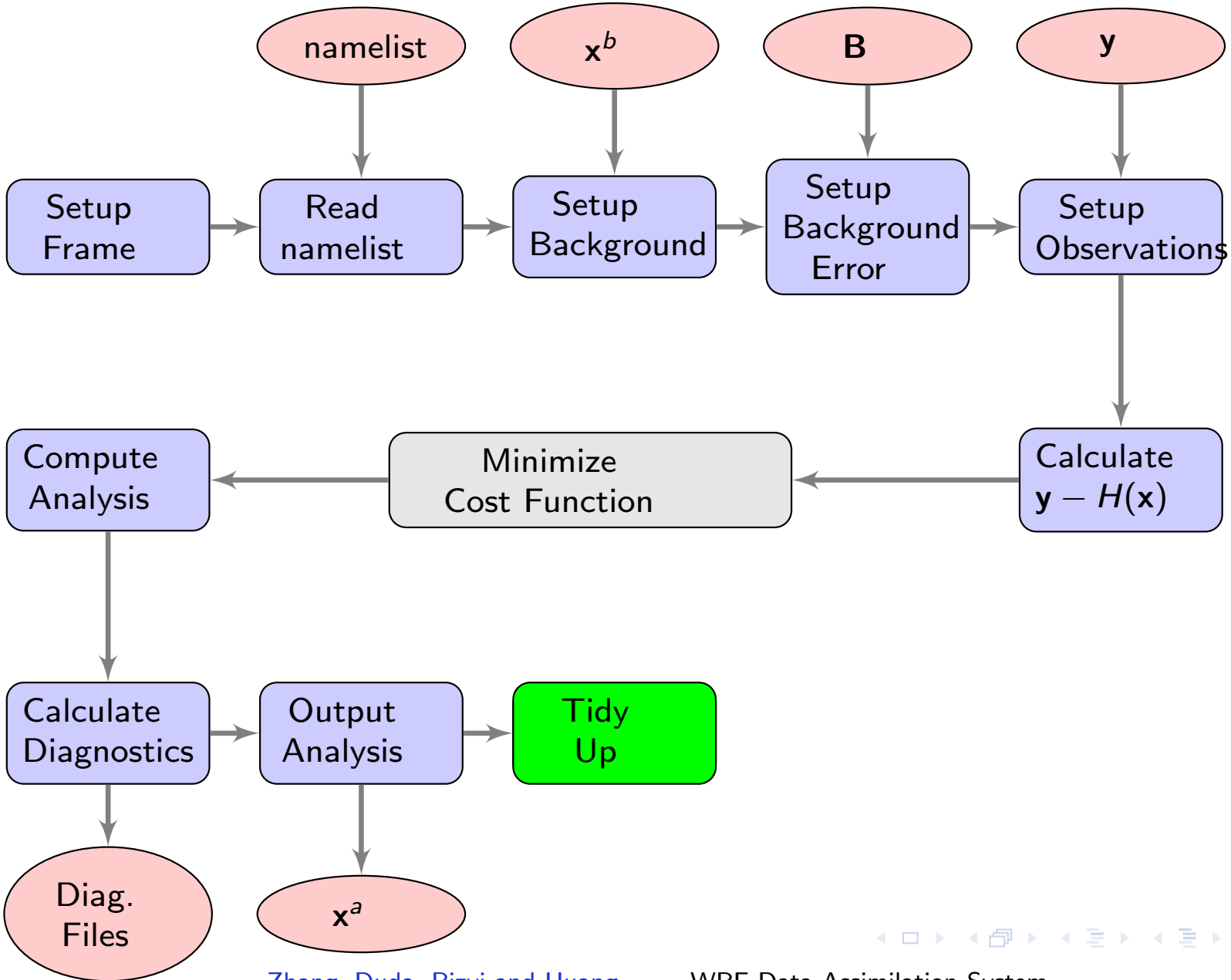
Output Analysis

- Outputs analysis in native model format.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- Clean end to WRFDA

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  - Distributed-memory(dm)
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- Supported platforms
  - IBM: XLF
  - Linux: PGI, IFORT, GFORTRAN (higher version needed)
  - Macintosh intel: PGI, G95
- Included libraries
  - CRTM 2.0.2 (well tested)
  - RTTOV 8.7 (upgrading to V9)
  - BUFR, BLAS and LAPACK

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- ./clean -a
- ./configure (-d) wrfda (-d : compile with debug mode)

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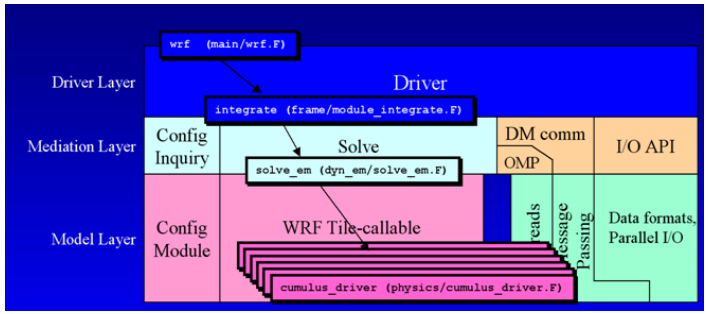
- ./clean -a
- ./configure (-d) wrfda (-d : compile with debug mode)
- ./compile all_wrfvar

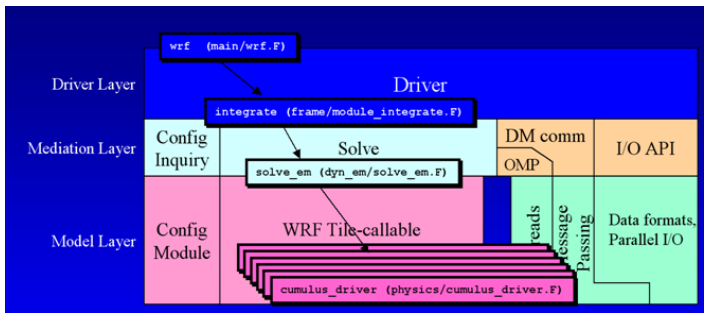
- Install NETCDF (V3.6 above) with THE SAME COMPILER you will choose to compile WRFDA codes.
- Setup the environmental variable
  - csh, tcsh : setenv NETCDF *your_netcdf_path*
  - bash, ksh : export NETCDF=*your_netcdf_path*
- cd WRFDA
- ./clean -a
- ./configure (-d) wrfda (-d : compile with debug mode)
- ./compile all_wrfvar
- 40 executables should be generated under var/build directory

WRFDA Software Framework



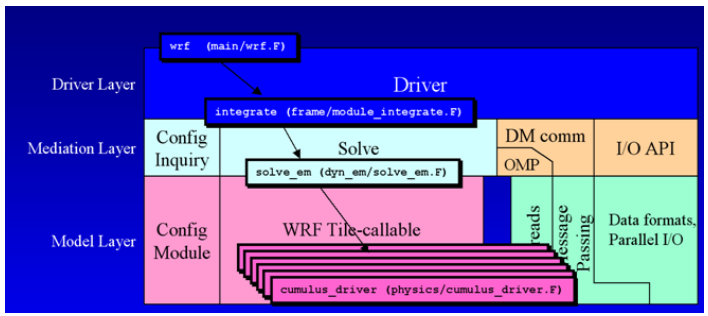
- WRFDA relies on the WRF Software framework for

WRFDA Software Framework



- WRFDA relies on the WRF Software framework for
  - Distributed memory parallelism (halo exchanges, etc.)
  - Input/Output of first guess and analysis files
  - Parallel transposes

WRFDA Software Framework



- WRFDA relies on the WRF Software framework for
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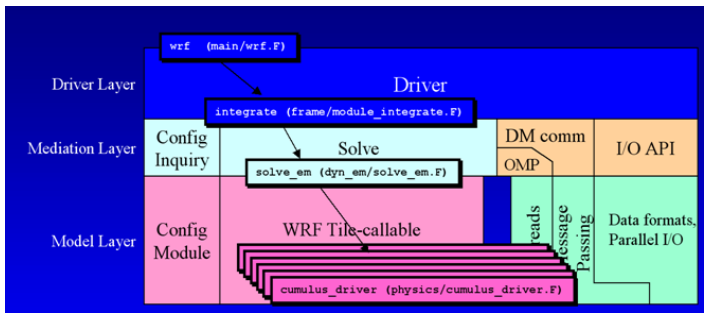
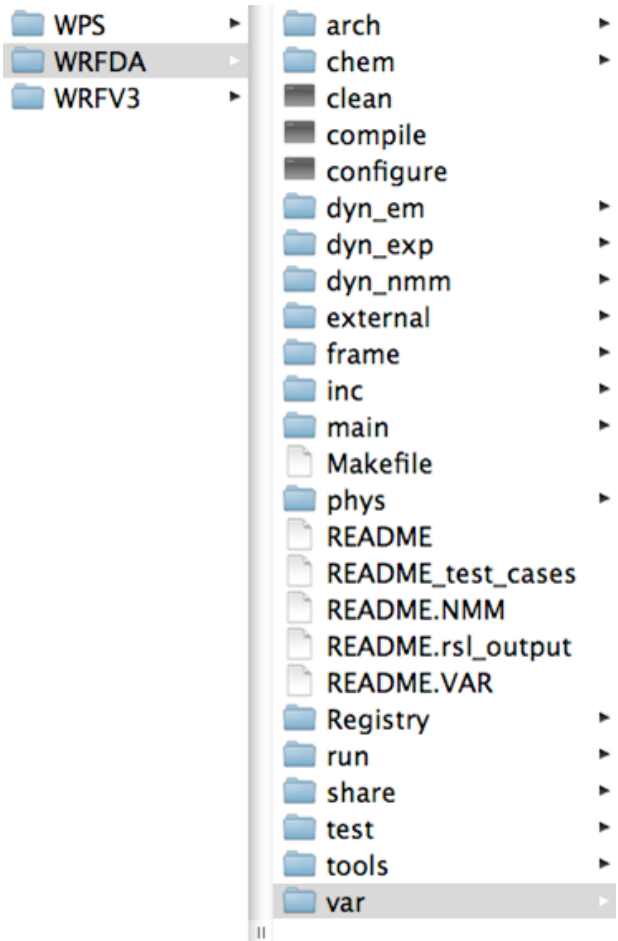
  - Parallel transposes
- WRFDA also uses

WRFDA Software Framework



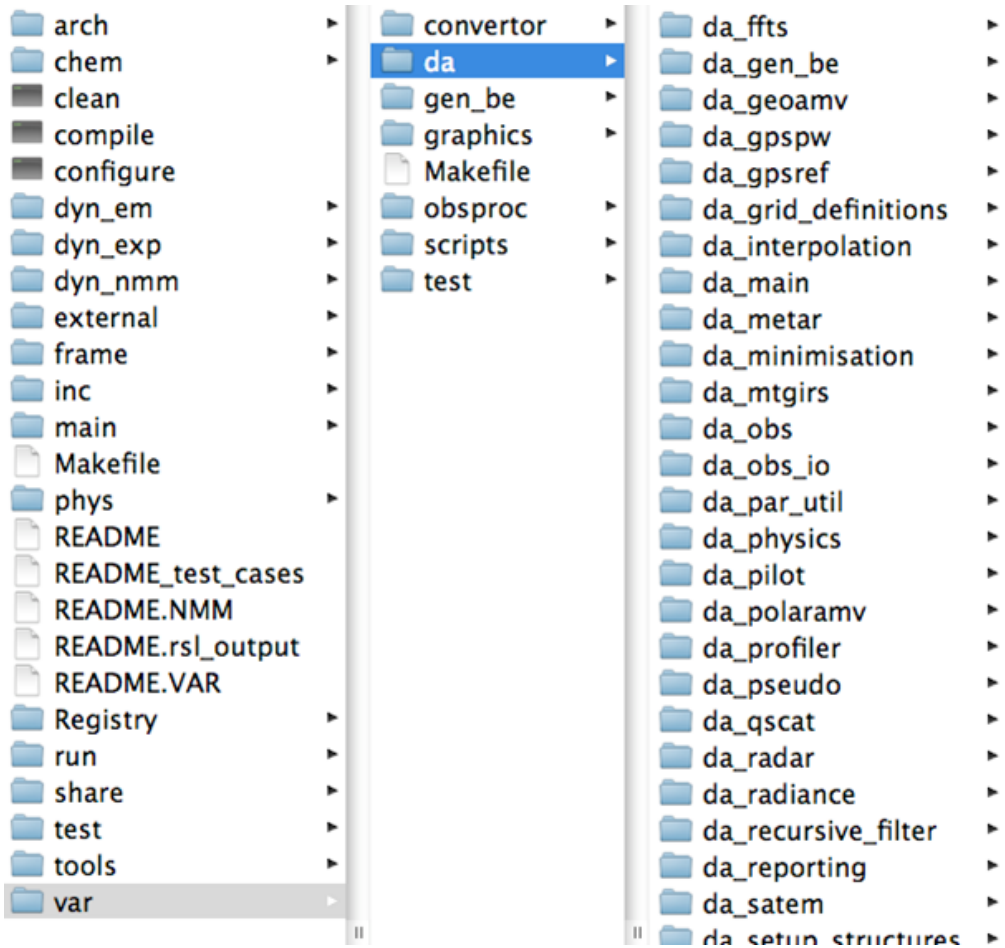
- WRFDA relies on the WRF Software framework for
  - Distributed memory parallelism (halo exchanges, etc.)
  - Input/Output of first guess and analysis files
  - Parallel transposes
- WRFDA also uses
  - The WRF Registry mechanism to handle definitions of fields, halos, type, package and transposes (Registry.wrfvar)
  - The WRF build system (clean, configure, compile)

WRFDA Code Organization



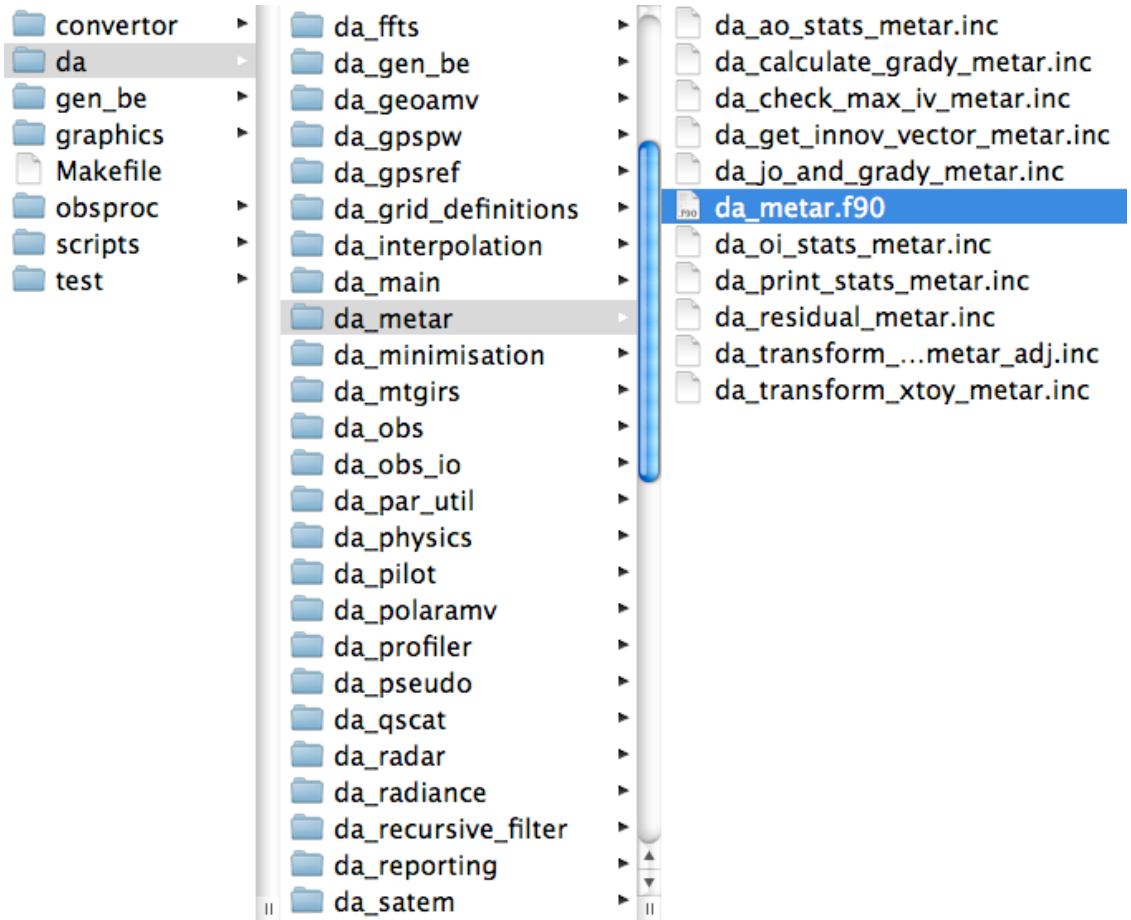
Besides the directories for WRF, the WRFDA tar file contains a *var* directory, which holds all of the WRFDA code

WRFDA Code Organization



Generally, each subdirectory of *da* contains a Fortran module with the same name

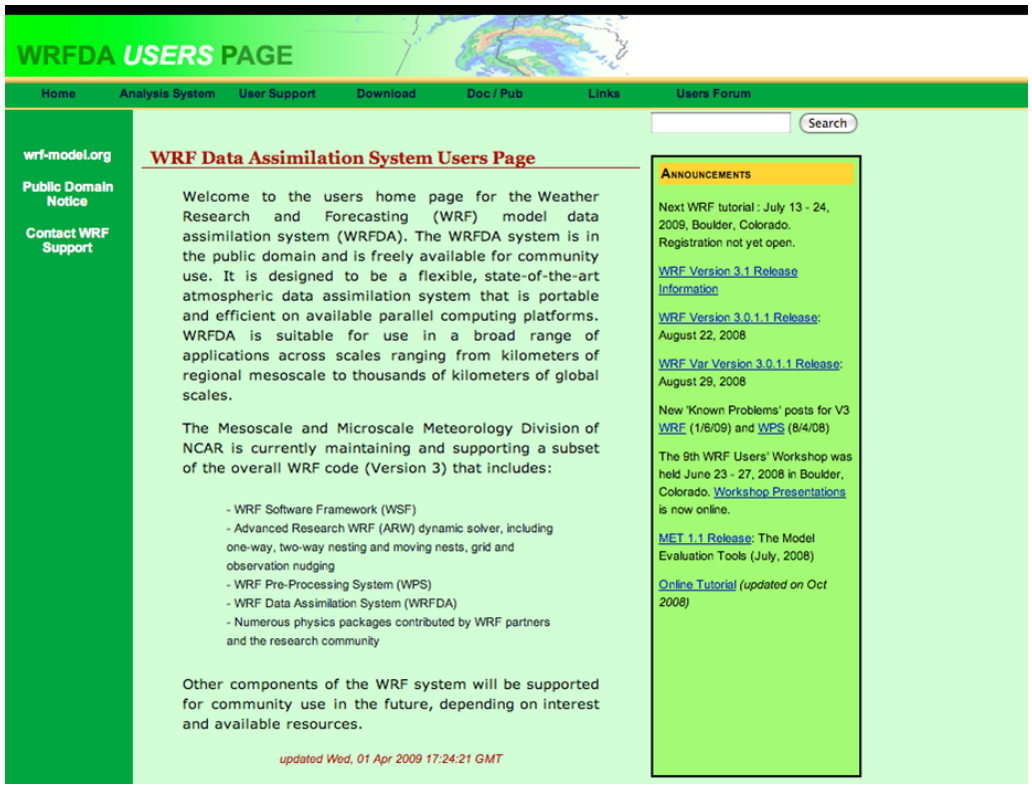
WRFDA Code Organization



- da_metar.f90 contains a Fortran module
- Each .inc file corresponds to a subroutine within the module

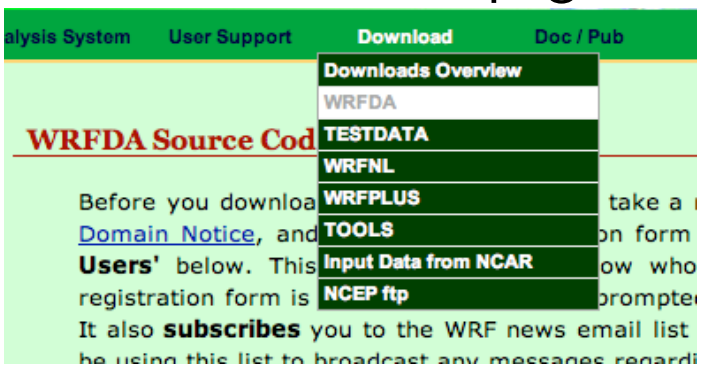
Online WRFDA Resources

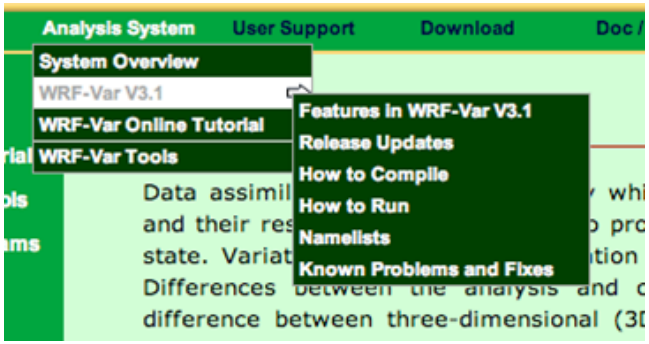
WRFDA has a dedicated page, similar to the ARW Users page:
WRFDA User Page



Online Resources

From the WRFDA page, one can access:





Thank You

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To advance understanding of weather, climate, atmospheric composition and processes;
To provide facility support to the wider community; and,
To apply the results to benefit society.

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