WRFDA Tools and Verification

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Special thanks to Syed RH Rizvi

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Overview

- WRFDA verification package
  - Verification against what?
  - Verification scores
- Forecast Sensitivity to Observations (FSO)
- WRFDA graphics and plotting tools
- Observation error tuning
  - Desroziers method
  - Hollingsworth method

WRFDA verification

- What can we verify against?
  - Observations
  - Analyses
- What scores can we use?
  - Root mean square error (RMSE)
  - Mean bias
  - Absolute mean bias

WRFDA verification

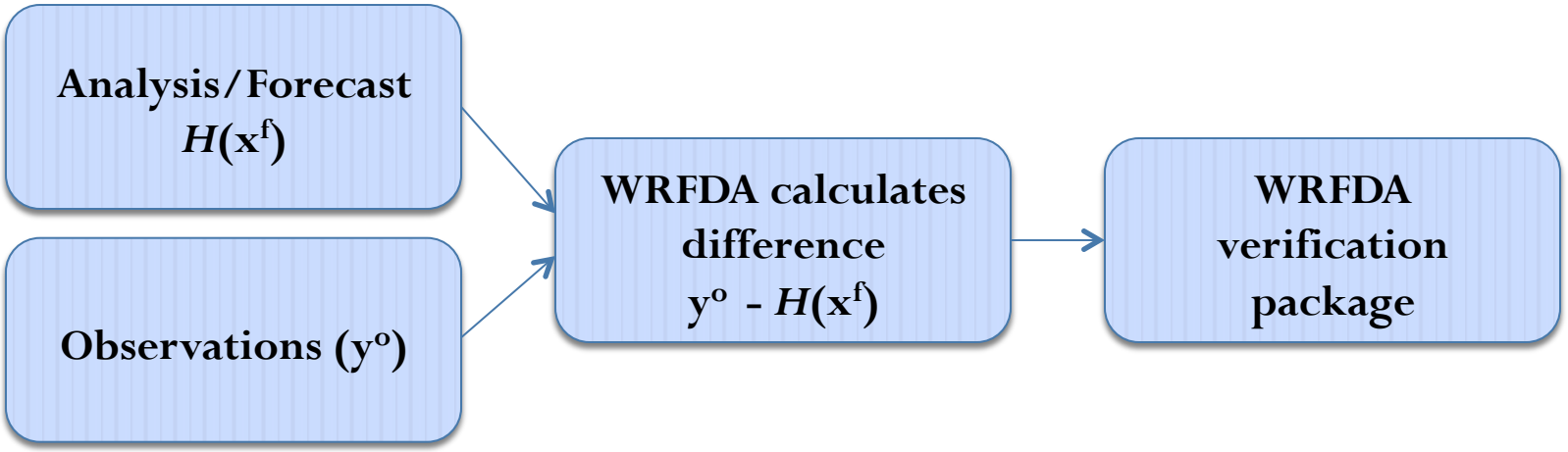
Advantages

- Consistent with WRFDA QC
- Consistent with WRF model topography
- Consistent with WRFDA observation operators
- Verification is possible against any
  - Observation type(s)
  - WRF input or output file
- Has its own NCL package

Disadvantages

- Can only verify against observations that WRFDA can assimilate

Observation-based verification



- Executables used for this process are da_verif_obs.exe and da_wrfvar.exe
- Source code for da_verif_obs.exe can be found in WRFDA/var/da/da_verif_obs
- Observation verification can be run for most types of conventional observations:
  - SYNOP, METAR, SHIPS, BUOY, SOUND, SCAT, AIREP, PILOT, PROFILER, AMV, TAMDAR, GPSPW, GPSRO

Observation-based verification

- This verification is run in three steps
  1. A set of "filtered_obs" files are produced by running WRFDA with the option:

     &wrfvar17

     analysis_type = "QC-OBS"

     - A "filtered_obs" file is an observation file in WRFDA-input ASCII format containing observations that have undergone basic QC checks, ensuring that there is a consistent set of observations used for verification among different experiments
  2. For each experiment, WRFDA is run in "verify" mode:

     &wrfvar17

     analysis_type = "VERIFY"

     - Verify mode forces the variables check_max_iv=.false. and ntmax=0; this means that no assimilation will be performed, but WRFDA will output OMB statistics for this experiment in the file gts_omb_oma_01
     - This step can be controlled by the script "da_run_suite_verif_obs.ksh"

Observation-based verification

- This verification is run in three steps
  3. Diagnostic statistics are computed with da_verif_obs.exe, and plots are made from the results
     - da_verif_obs.exe reads the statistics found in gts_omb_oma_01 created in the previous step and outputs detailed diagnostic files
     - These diagnostic files can then be read by a series of ncl scripts, which produce plots of the verification details
       - verif_obs_time_series.ncl
       - verif_obs_vert_profile.ncl
       - verif_obs_time_average.ncl
       - verif_obs_vert_profile_gpsref.ncl
     - This step can be controlled by the script "da_verif_obs_plot.ksh"

Observation verification

Variables declared in first script (da_run_suite_verif_obs.ksh):

INITIAL_DATE:	Verification starting date (yyyymmddhh)
FINAL_DATE:	Verification ending date (yyyymmddhh)
CYCLE_PERIOD:	The period in hours between forecasts
EXP_DIR:	Full path of experiment directory name
FILTERED_OBS_DIR:	Directory where the ("filtered_obs" files) against which verification will be done are located
VERIFY_HOUR:	00 for analysis; 12, 24, etc. corresponding to the desired forecast hour verification
BE_DIR:	Location of background error file be.dat
NL_E_WE, NL_E_SN, NL_E_VERT, NL_DX, NL_DY:	Used to set the necessary domain namelist values e_we, e_sn, e_vert, dx, and dy, respectively
NL_ANALYSIS_TYPE:	=verify; this tells the script to run WRFDA in verify mode for this step

Observation verification

Variables declared in second script (da_verif_obs_plot.ksh):

WRFVAR_DIR: WRFDA main directory (full path)
REG_DIR: Directory holding sub-directories for each experiment generated in Step 1

For example: "gts_omb_oma" file corresponding to experiment "verify_12" (directory for 12 hr forecast verification) for "2005081700" should be in $REG_DIR/verify_12/2005081700/wrfvar

RUN_DIR: Full path of the directory where plots will be generated
NUM_EXPT: Total number of experiments (Maximum 10)
EXP_NAMES: Experiment directory names as they exist in REG_DIR (blank separated)
EXP_LEGENDS: Legend strings for each experiments respectively (comma separated)
START_DATE: Starting date ("YYYYMMDDHH") for verification
END_DATE: Ending date ("YYYYMMDDHH") for verification
INTERVAL: Time interval (in hours) for incrementing date/time.

Observation verification

Variables declared in second script cont'd (da_verif_obs_plot.ksh):

NUM_OBS_TYPE:	Number of observation types for verification
OBS_TYPES:	Verification observation types like, "synop", "buoy", "sound" etc.
PLOT_WKS:	"x11" to display plots on screen, "pdf" to save as pdf files
DESIRED_LEVELS:	Pressure levels (in hPa) for plotting diagnostics
DESIRED_SCORES:	Diagnostics like "RMSE", "BIAS" or "ABIAS"
EXP_LINES_COLORS:	Color sequence for various experiments.
VERIFY_DATE_RANGE:	Title of x-axis in the output plots

Note about wrapper scripts

- These verification scripts are designed to work best when called by a wrapper script to declare the necessary variables.

```
#!/bin/ksh -aeux
# Wrapper script for running WRFDA obs verification package
# Settings for ./da_run_suite_verif_obs.ksh
export INITIAL_DATE=2013122312
export FINAL_DATE=2013122512
export WRFVAR_DIR=/kumquat/users/${USER}/DA/WRFDA
...  etc ...
# Run the first script
./da_run_suite_verif_obs.ksh

# Settings for da_verif_obs_plot.ksh

export START_DATE=2013122312
export END_DATE=2013122512
export RUN_DIR=$EXP_DIR/plots
...  etc ...
# Run the first script
./da_verif_obs_plot.ksh
```

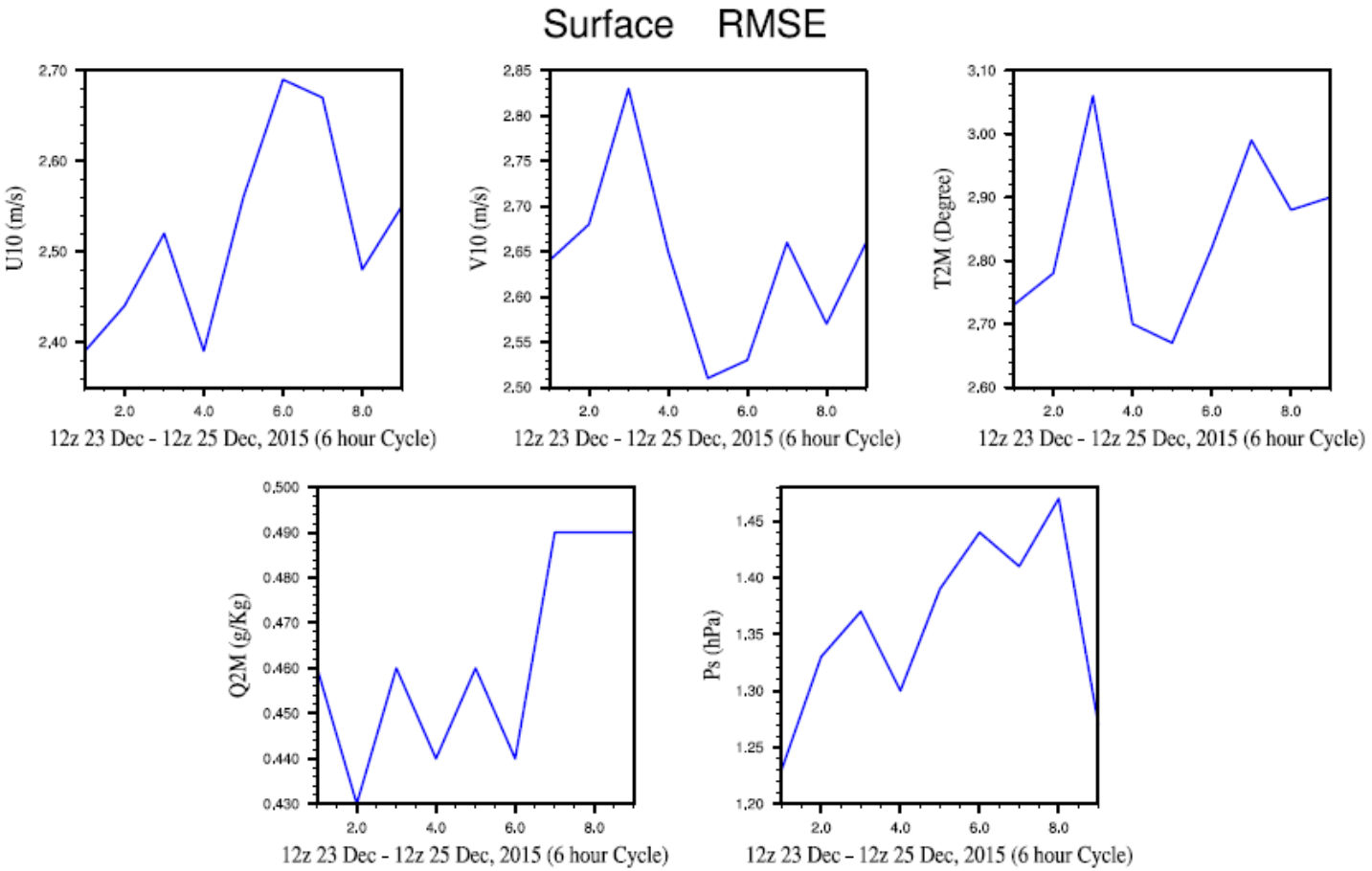
Observation verification: Output

A successful run will produce a number of different plots in RUN_DIR, dependent on the options you choose

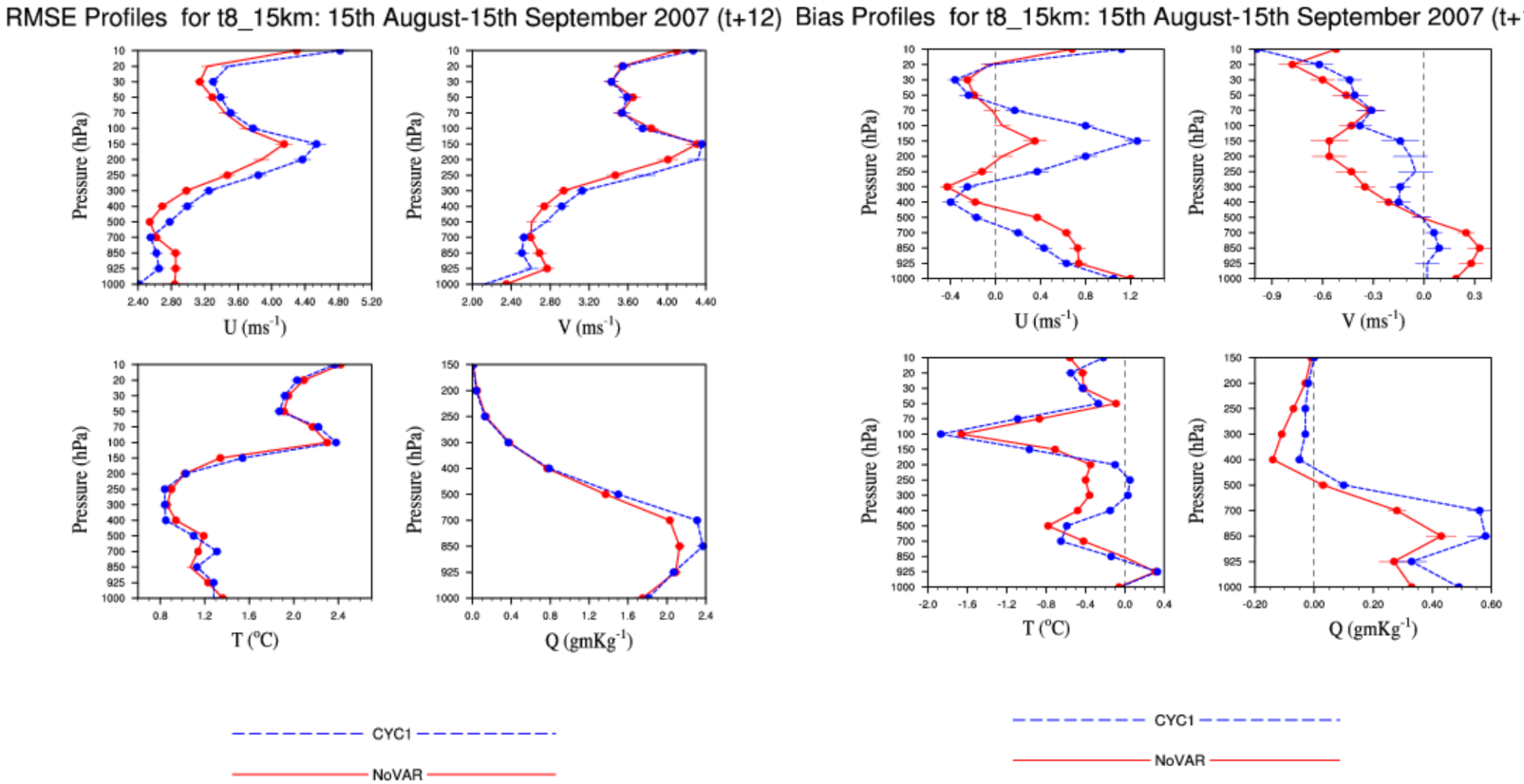
- Time series for surface and all the desired upper air levels
- Vertical profiles
- Time Average for surface and all the upper air levels (Histograms)

```
-rw-r--r-- 1 rizvi ncar 597691 Oct 13 12:49 Time_Series_SFC_RMSE.pdf
-rw-r--r-- 1 rizvi ncar 291856 Oct 13 12:49 Time_Series_SFC_BIAS.pdf
-rw-r--r-- 1 rizvi ncar 319570 Oct 13 12:49 Time_Series_SFC_ABIAS.pdf
-rw-r--r-- 1 rizvi ncar 1571714 Oct 13 12:49 Time_Series_UPA_RMSE.pdf
-rw-r--r-- 1 rizvi ncar 753440 Oct 13 12:49 Time_Series_UPA_BIAS.pdf
-rw-r--r-- 1 rizvi ncar 769452 Oct 13 12:49 Time_Series_UPA_ABIAS.pdf
-rw-r--r-- 1 rizvi ncar 463151 Oct 13 12:49 Profile_RMSE.pdf
-rw-r--r-- 1 rizvi ncar 467553 Oct 13 12:49 Profile_BIAS.pdf
-rw-r--r-- 1 rizvi ncar 12769280 Oct 13 14:54 Profile_ABIAS.pdf
-rw-r--r-- 1 rizvi ncar 129469 Oct 13 12:49 Time_Average_SFC_RMSE.pdf
-rw-r--r-- 1 rizvi ncar 136679 Oct 13 12:49 Time_Average_SFC_BIAS.pdf
-rw-r--r-- 1 rizvi ncar 142219 Oct 13 12:49 Time_Average_SFC_ABIAS.pdf
-rw-r--r-- 1 rizvi ncar 352928 Oct 13 12:49 Time_Average_UPA_RMSE.pdf
-rw-r--r-- 1 rizvi ncar 402740 Oct 13 12:49 Time_Average_UPA_BIAS.pdf
-rw-r--r-- 1 rizvi ncar 365264 Oct 13 12:49 Time_Average_UPA_ABIAS.p
```

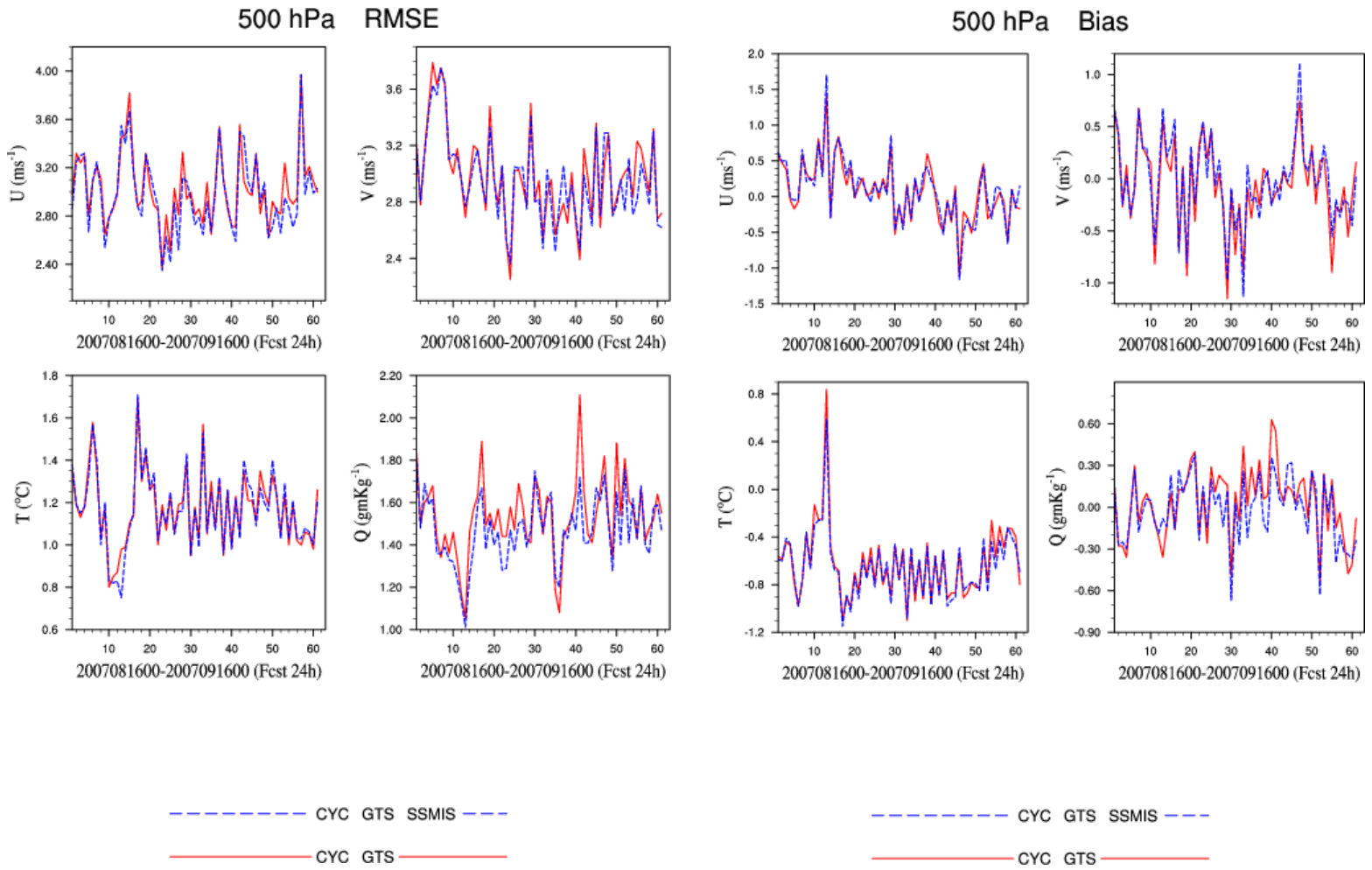
Observation verification: Output



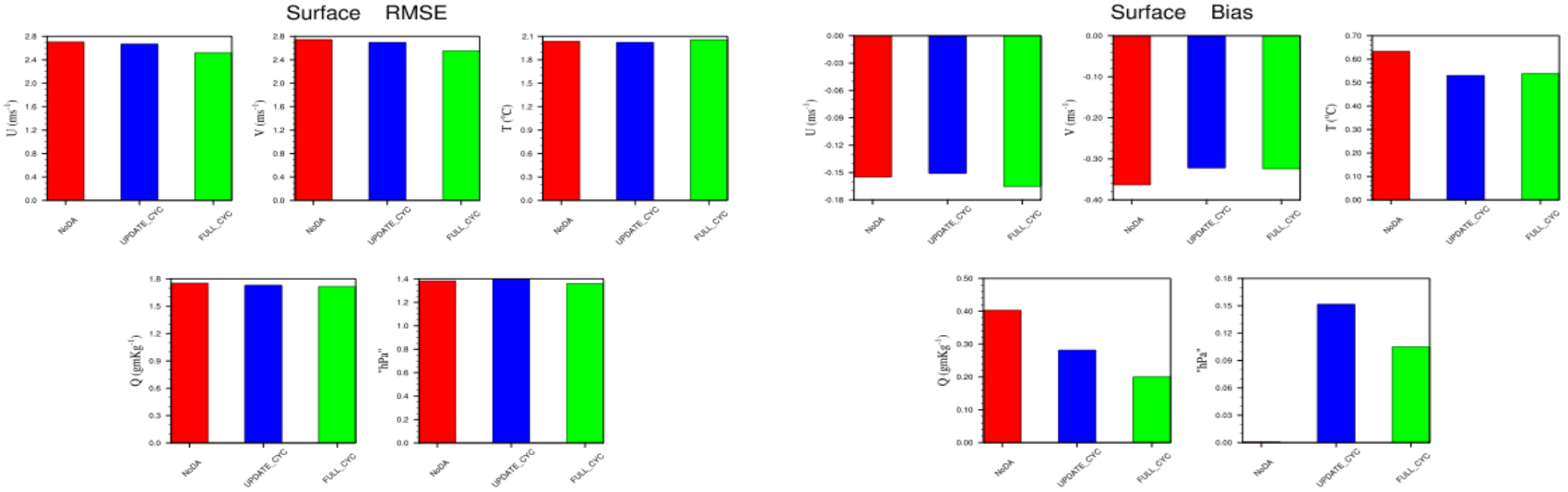
Observation verification: Output



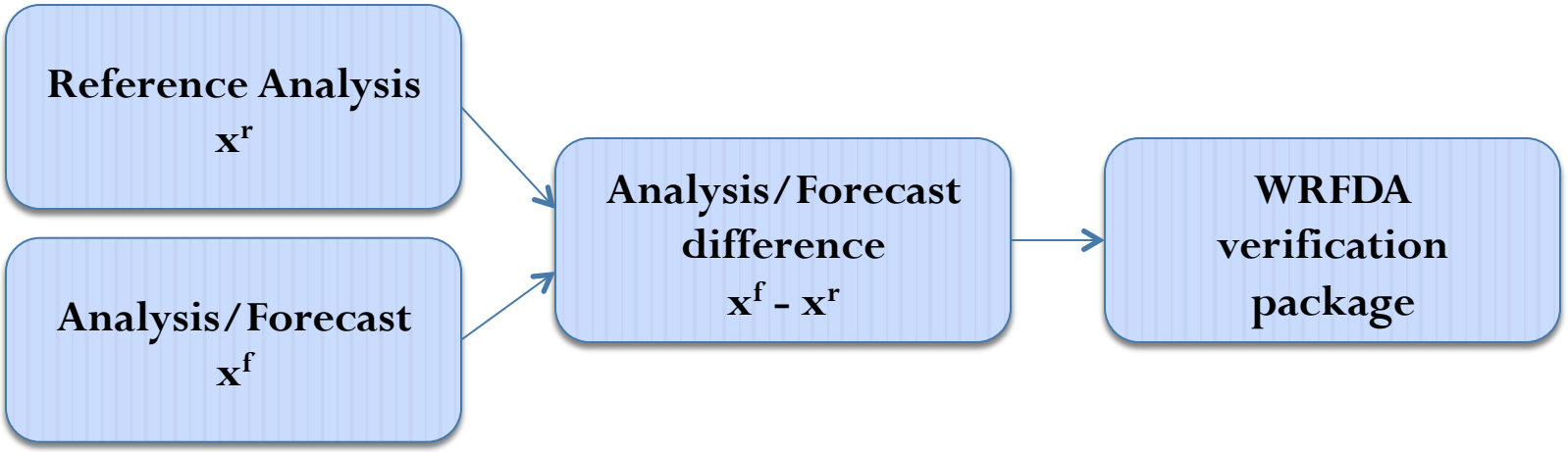
Observation verification: Output



Observation verification: Output



Analysis-based verification



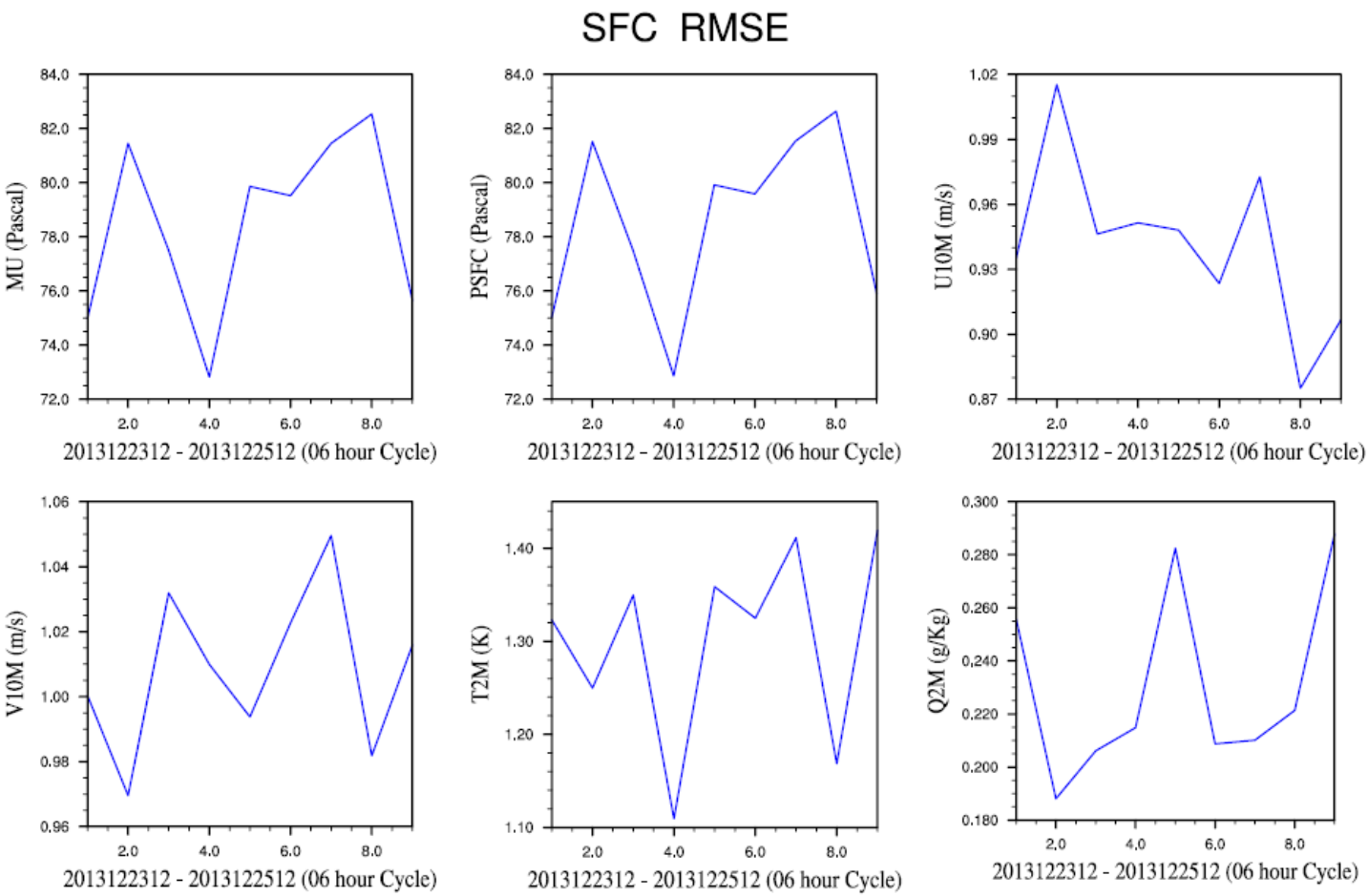
- The verification suite for observations is run with a script
  - WRFDA/var/script/da_verif_grid.ksh
- Executable called by this script is da_verif_grid.exe
- Source code for this executable can be found in WRFDA/var/da/da_verif_grid
- Analysis-based verification is run using wrfout files
- The analysis domain must be exactly the same as the domain being verified: same horizontal and vertical resolution

Analysis-based verification

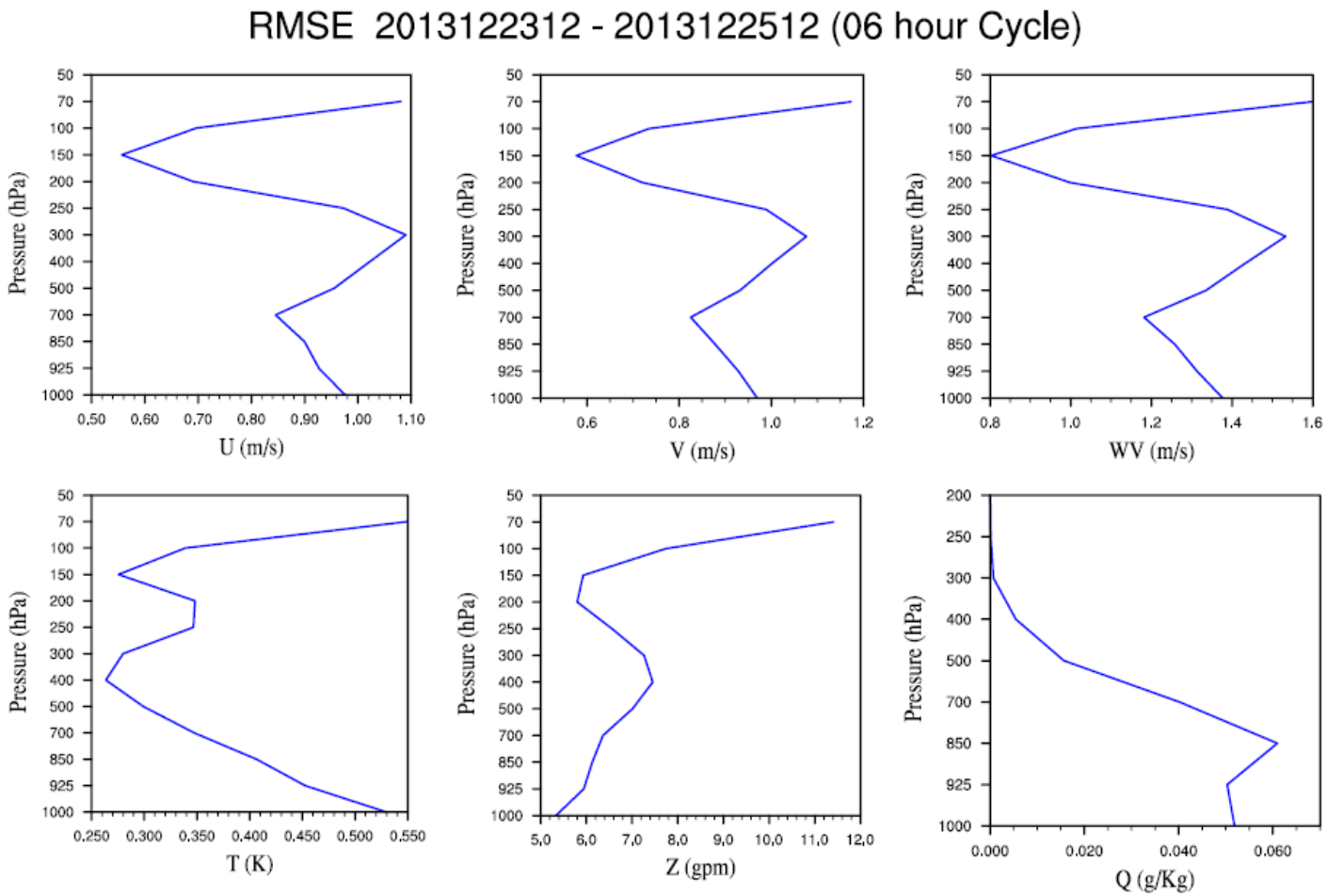
Variables declared in script (da_verif_grid.ksh):

WRFVAR_DIR:	WRFDA main directory (full path)
START_DATE:	Verification starting date (yyyymmddhh)
END_DATE:	Verification ending date (yyyymmddhh)
INTERVAL:	Cycling interval in hours
REG_DIR:	Directory holding forecast sub-directories for each experiment
NUM_EXPT:	Number of experiments
EXP_DIR:	Experiment directory name(s) in REG_DIR
EXP_NAMES:	Experiment name(s)
RUN_DIR:	Where output will be produced
DESIRED_LEVELS:	The pressure levels desired for diagnostics (in hPa)
DESIRED_SCORES:	Which diagnostics are desired (RMSE, BIAS, ABIAS)
VERIFY_HOUR:	00 for analysis; 12, 24, etc. corresponding to the desired forecast hour verification
CONTROL_EXP_DIR:	Directory name of the reference analysis to be used for verification
VERIFY_ITS_OWN_ANALYSIS:	Set to "true" if there is no control analysis; the experiment's own analysis will be used for verification
VERIFY_DATE_RANGE:	Title of x-axis in the output plots
PLOT_WKS:	"x11" to display plots on screen, "pdf" to save as pdf files

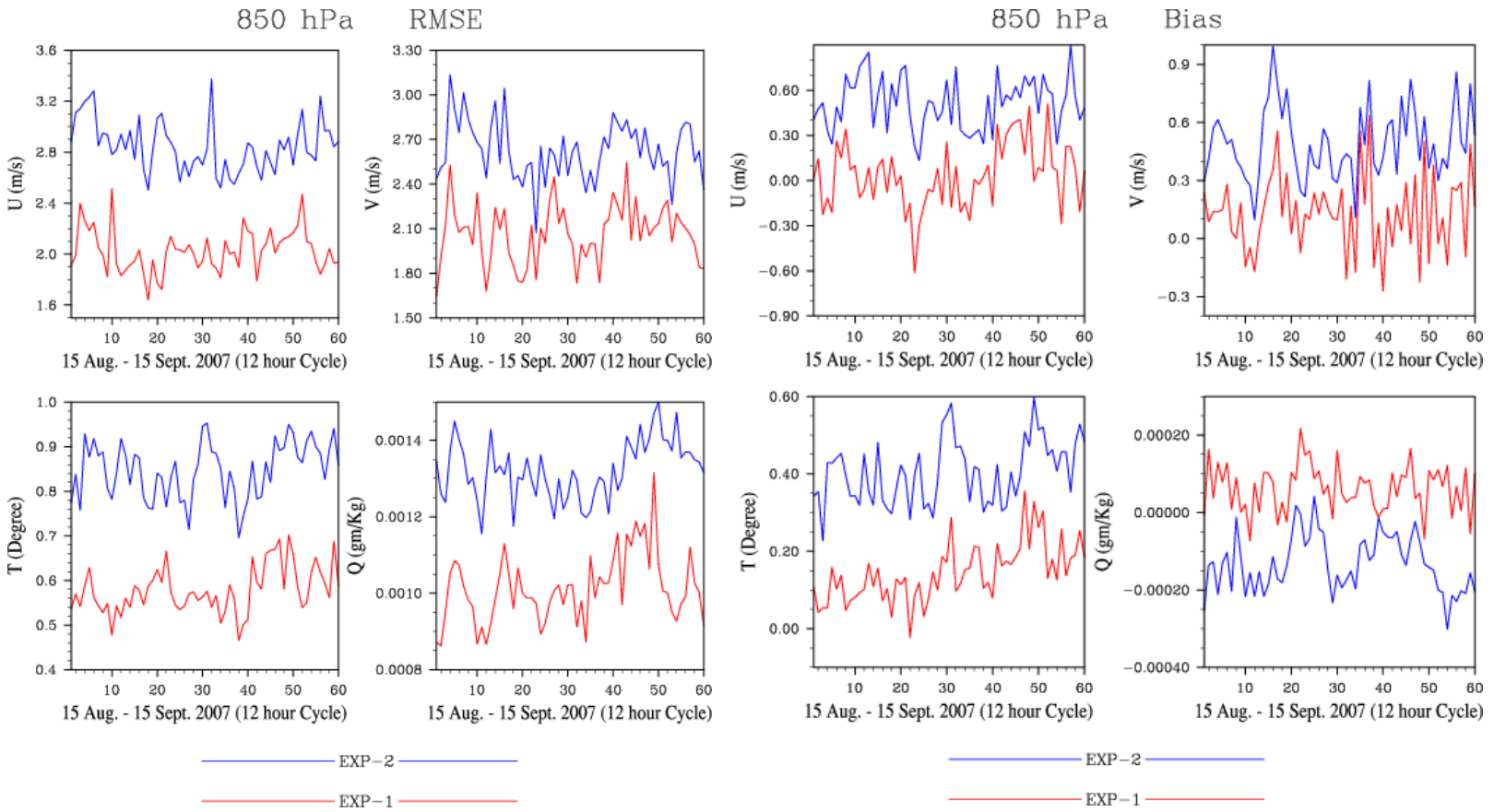
Analysis verification: Output



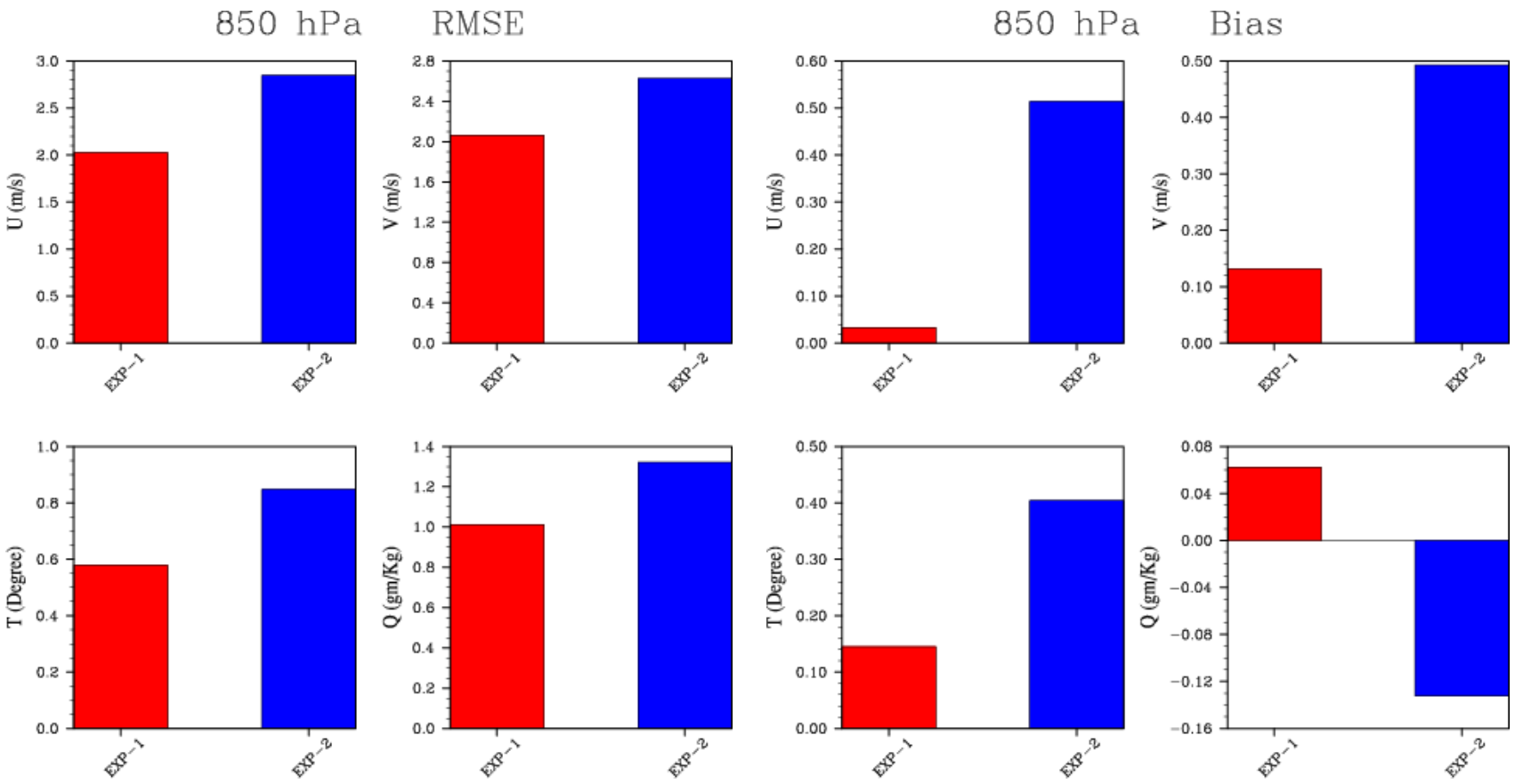
Analysis verification: Output



Analysis verification: Output



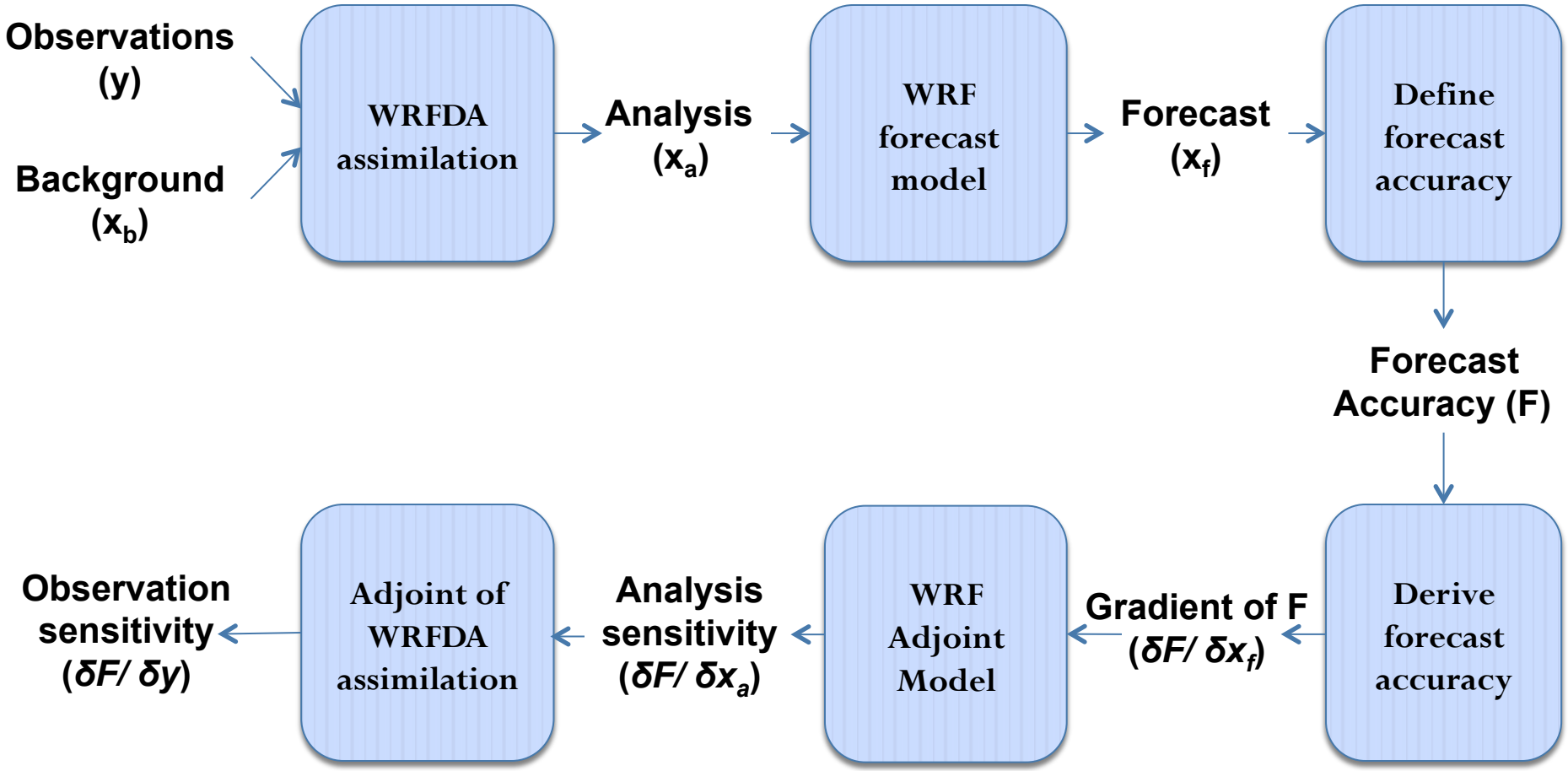
Analysis verification: Output



Forecast Sensitivity to Observations

- FSO is a diagnostic tool that can determine quantitatively which observations improved or degraded the forecast skill
- It requires the use of an adjoint atmospheric model, in addition to the non-linear forward model
  - These are a part of the WRFPLUS package
- A wrapper script "wrapper_run_fso.ksh" is provided to call the necessary scripts in order for FSO.

Forecast Sensitivity to Observations



Forecast Sensitivity to Observations

- wrapper_run_fso.ksh must be run in two stages
- The first stage will run WRFDA and update the boundary conditions for the WRF run
- Run the first stage with the following settings

  export RUN_WRFVAR=**true**
  export RUN_UPDATE_BC=**true**

- And ensure the following lines are commented (with a "#" at the beginning of the line):

  #export RUN_ADJ_SENS=false
  #export RUN_OBS_IMPACT=false
  #export NL_USE_LANCZOS=true
  #export NL_WRITE_LANCZOS=true
  #export NL_EPS=1E-5

- You should also set NUM_PROC and the variables controlling directories such as WRFVAR_DIR
- If you are using your own data, you will need to change the variables listed under "Namelist parameters" as well, and possibly others. For your own case, examine the available options in the wrapper script carefully

Forecast Sensitivity to Observations

- The second stage will run the remaining steps, calling the WRF model, adjoint, and calculating the observation impact
- Uncomment the lines that were commented for Step 1, and use the following settings

  export RUN_WRFVAR=**false**
  export RUN_UPDATE_BC=**false**
  export RUN_ADJ_SENS=true
  export RUN_OBS_IMPACT=true

  export NL_USE_LANCZOS=true
  export NL_WRITE_LANCZOS=true
  export NL_EPS=1E-5

- No other changes should be necessary

WRFDA Scripts and Graphics Tools

- The WRFDA Tools package has a number of shell and NCL (NCAR Command Language) scripts
- http://www2.mmm.ucar.edu/wrf/users/wrfda/download/tools.html
- Shell scripts can be found in TOOLS/var/scripts
- ncl scripts can be found in TOOLS/var/graphics/ncl
  - A description of some of the available tools can be found in the file TOOLS/var/graphics/ncl/README

- **Due to lack of funding, these scripts are provided as-is, and can not be supported at this time**

WRFDA Scripts and Graphics Tools

Some useful shell scripts

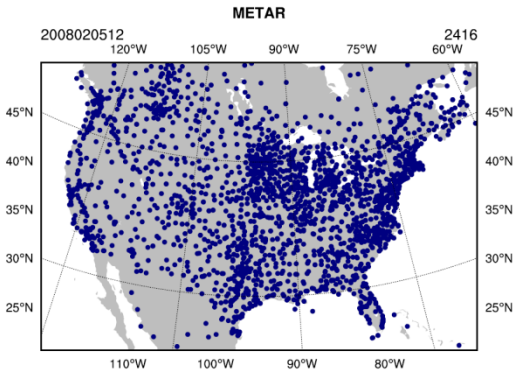
da_run_wrfvar.ksh
da_run_wrfvar_psot.ksh
da_run_suite_verif_obs.ksh
da_run_suite_wrapper_qc_obs.ksh
da_run_psot.ksh
da_plot_psot.ksh
da_tune_obs_hollingsworth.ksh
da_tune_obs_desroziers.ksh
da_run_suite_wrapper_verif_obs.ksh
da_verif_obs_plot.ksh
da_verif_anal_plot.ksh
da_run_wps.ksh da_run_wrf.ksh
da_run_obsproc.ksh
da_run_real.ksh

Some useful NCL scripts

WRF-Var_plot.ncl
plot_cost_grad_fn.ncl
plot_obascii_loc.ncl
plot_gts_omb_oma.ncl
plot_rad_diags.ncl
plot_rad_varbc_param.ncl
verif_obs_time_series.ncl
verif_obs_time_average.ncl
verif_anal_vert_profile.ncl
verif_anal_time_series.ncl
verif_anal_time_average.ncl
verif_anal_vert_profile

WRFDA Scripts and Graphics Tools

- da_run_wrfvar.ksh
  - Wrapper script for running WRFDA in a variety of configurations
  - Can be used on its own, but it is often called by other scripts
- WRF-Var_plot.ncl
  - Can be used to make a plot of the difference between two WRF files (for example, fg and wrfvar_output)
- plot_ob_ascii_loc.ncl
  - Plots locations of observations for an ASCII observation file, separated by type



Observation error tuning

- Two methods of observation error tuning are available in WRFDA
- The Hollingsworth method
  - Assumes that errors in the first guess are spatially correlated, but observation errors are not
  - Ref: Hollingsworth and Lönnberg, 1986, *Tellus* doi:10.1111/j.1600-0870.1986.tb00460.x
- The Desroziers method
  - Requires running WRFDA twice for the observations in question: once with default options, and the other with added gaussian noise
  - Ref: Desroziers and Ivanov, 2001, *Quarterly Journal of the Royal Meteorological Society* doi:10.1002/qj.49712757417

Error tuning: Hollingsworth method

- Uses the executables da_tune_obs_hollingsworth1.exe and da_tune_obs_hollingsworth2.exe in WRFDA/var/build, called from the script da_tune_obs_hollingsworth.ksh
- The following variables need to be set in da_tune_obs_hollingsworth.ksh:
  - WRFVAR_DIR: Location of main WRFDA directory
  - SCRIPTS_DIR: Location of "scripts" directory in TOOLS package
  - EXP_DIR: Directory path holding "gts_omb_oma" files which were created by WRF-WRFDA cycling run. You may have to edit the path in the script depending on the settings you used for cycling.
  - START_DATE: Start date for the tuning period
  - END_DATE: End date for the tuning period
  - RUN_DIR: The directory where output will be generated

Error tuning: Hollingsworth method

- After a successful run, you will see a number of log files in your selected RUN_DIR, and the output will be stored in RUN_DIR/working
- You should see a file corresponding to each observation type and each state variable
  - sound_u_omb.sigma_o_b, buoy_v_omb.sigma_o_b, etc.
- These files contain the computed observation error tuning parameters

Error tuning: Desroziers method

- Prior to running the tuning script, you should produce two cycling runs for your observation tuning period: one "unperturbed" with normal settings, and the other with random perturbations added
  - The random perturbations are added with the following namelist variables:
  - &wrfvar5
    put_rand_seed=.true.
    omb_add_noise=.true.
    &wrfvar11
    SEED_ARRAY1 =${SEED1},
    SEED_ARRAY2 =${SEED2},
- These runs can be set up easily using the "da_run_suite_verif_obs.ksh" script described in the observation verification section
- The necessary output from these two runs are
  - The "unpert_obs", "jo" and "rsl.out.0000.html" files from the unperturbed run
  - The "rand_obs_error" and "pert_obs" files from the perturbed run

Error tuning: Desroziers method

- Uses the executable da_tune_obs_desroziers.exe in WRFDA/var/build, called from the script da_tune_obs_desroziers.ksh
- The following variables need to be set in da_tune_obs_desroziers.ksh:
  - WRFVAR_DIR: Location of main WRFDA directory
  - SCRIPTS_DIR: Location of "scripts" directory in TOOLS package
  - Y_DIR: Directory path holding the unperturbed WRFDA runs. You may have to edit the path in the script depending on the settings you used for cycling.
  - YP_DIR: Directory path holding the perturbed WRFDA runs. You may have to edit the path in the script depending on the settings you used for cycling.
  - START_DATE: Start date for the tuning period
  - END_DATE: End date for the tuning period
  - RUN_DIR: The directory where output will be generated
- After execution, you should see the output file "errfac.dat"