WRFDA
Background Error Estimation

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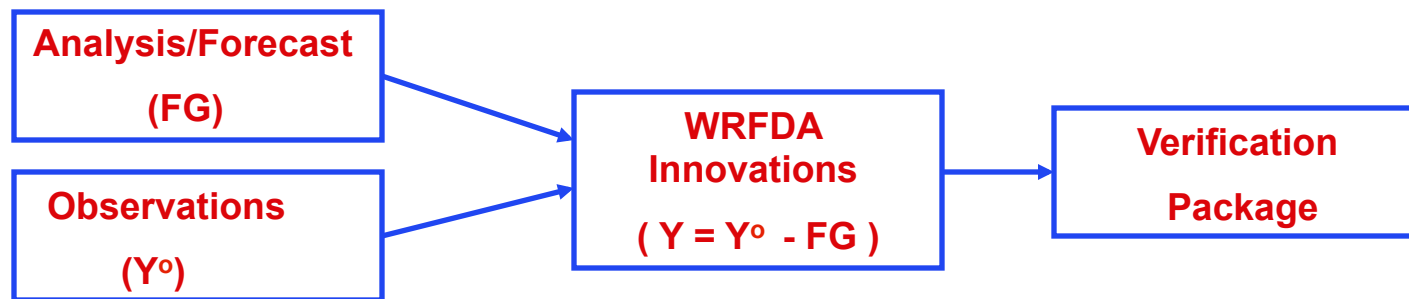
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Talk overview

- **WRFDA verification package**
    - **What are its advantages/disadvantages?**
    - **How to run WRFDA verification package**
    - **Expected graphics**
    - **Upcoming new feature - AFWA Go-Index**
- **WRFDA scripts and graphic tools**
- **Obs error tuning (Desroziers method)**
  (QJRMS (2001), Vol. *127*, pp. 1433-1452)
- **Obs error tuning Hollingsworth method)**
  (Tellus (1986), Vol. *38*, pp. 111-161, Part I & II)

How to Verify Analysis/Forecast?

- **Two ways:**

    - **Against Observations**

    - **Against any analysis available in grid space (Control Analysis)**

- **Verification scores:**

    - **Root Mean Square Error (RMSE)**

    - **Mean bias (BIAS)**

    - **Absolute Mean bias (ABIAS)**
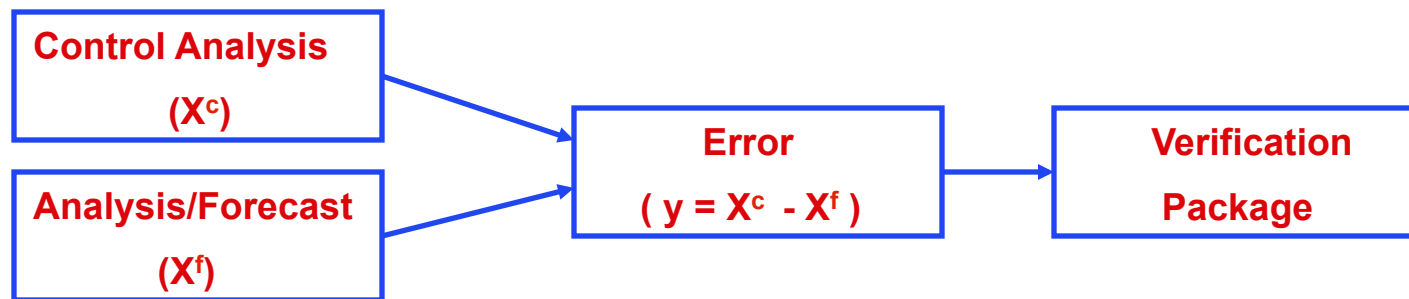
Observation based Verification

```
┌──────────────────────┐
│ Analysis/Forecast    │
│                      │─────┐
│      (FG)            │     │
└──────────────────────┘     │      ┌──────────────────┐      ┌──────────────────┐
                             ├─────▶│     WRFDA        │─────▶│  Verification    │
┌──────────────────────┐     │      │   Innovations    │      │                  │
│  Observations        │─────┘      │ ( Y = Yᵒ  - FG ) │      │    Package       │
│                      │            └──────────────────┘      └──────────────────┘
│      (Yᵒ)            │
└──────────────────────┘
```

Verification code is under

var/da/da_verif_obs

compile all_wrfvar creates the desired executable

da_verif_obs.exe

Analysis based Verification

```
┌─────────────────────┐
│  Control Analysis   │─────┐
│       (Xᶜ)          │      \
└─────────────────────┘       \      ┌──────────────────┐      ┌──────────────────┐
                               ──────▶│      Error       │─────▶│   Verification   │
┌─────────────────────┐       /       │ ( y = Xᶜ - Xᶠ ) │      │     Package      │
│  Analysis/Forecast  │─────┘         └──────────────────┘      └──────────────────┘
│       (Xᶠ)          │
└─────────────────────┘
```

Code resides under "var/da/da_verif_anal" directory

"compile all_wrfvar" creates the desired executable

(da_verif_anal.exe)

Advantages/disadvantages

- **Consistent with WRFDA QC**

- **Consistent with WRF model topography**

- **It makes use of built-in WRFDA observation operators**

- **In principle, verification is possible against any**

  - **Observation type individually or collectively**

  - **Verification analysis may be from any independent source or produced by any experiment**

- **It has its own built-in graphics (NCL) package**

- **In principle one can verify against only those observations which WRFDA can assimilate. Thus quantities like "rainfall" etc. cannot be verified.**

How to run verification against observation?

It works in two steps

- **Step 1:** Execute "var/script/da_run_suite_verif_obs.ksh"

  It will create all the desired input files (gts_omb_oma") for verification

- **Step 2:** Execute "var/script/da_verif_obs_plot.ksh"

  It will generate the desired graphics

- These scripts are executed (in the same order) via a suitable wrapper script

Wrapper for da_run_suite_verif_obs

Important variables to be declared via wrapper script:

INITIAL_DATE : Verification starting date (yyyymmddhh)

FINAL_DATE : Verification ending date (yyyymmddhh)

CYCLE_PERIOD : Date advance increment in hour

EXP_DIR : Experiment directory name (full path)

FILTERED_OBS_DIR : Directory where the observations "filtered_obs" against which verification will be done

VERIFICATION_FILE_STRING : It is either "wrfout" or "wrf_3dvar_input", depending on which files are saved while running WRF-forecasts in FC_DIR

VERIFY_HOUR : 00 for analysis & 12, 24, etc. corresponding to the desired forecast hour verification

Wrapper for da_verif_obs_plot

Important variables:

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 (Currently 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.
NUM_OBS_TYPE	: Number of observation types for verification
OBS_TYPES	: Verification observation types like, "synop", "buoy", "sound" etc.
PLOT_WKS	: Name of workstation for plots like "X11", "pdf" etc.
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	: String to specify title for X-axis

Verif_obs_plot output

In RUN_DIR, following graphics will be generated for each of the desired scores (RMSE, BIAS, ABIAS)

- **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.pdf
```
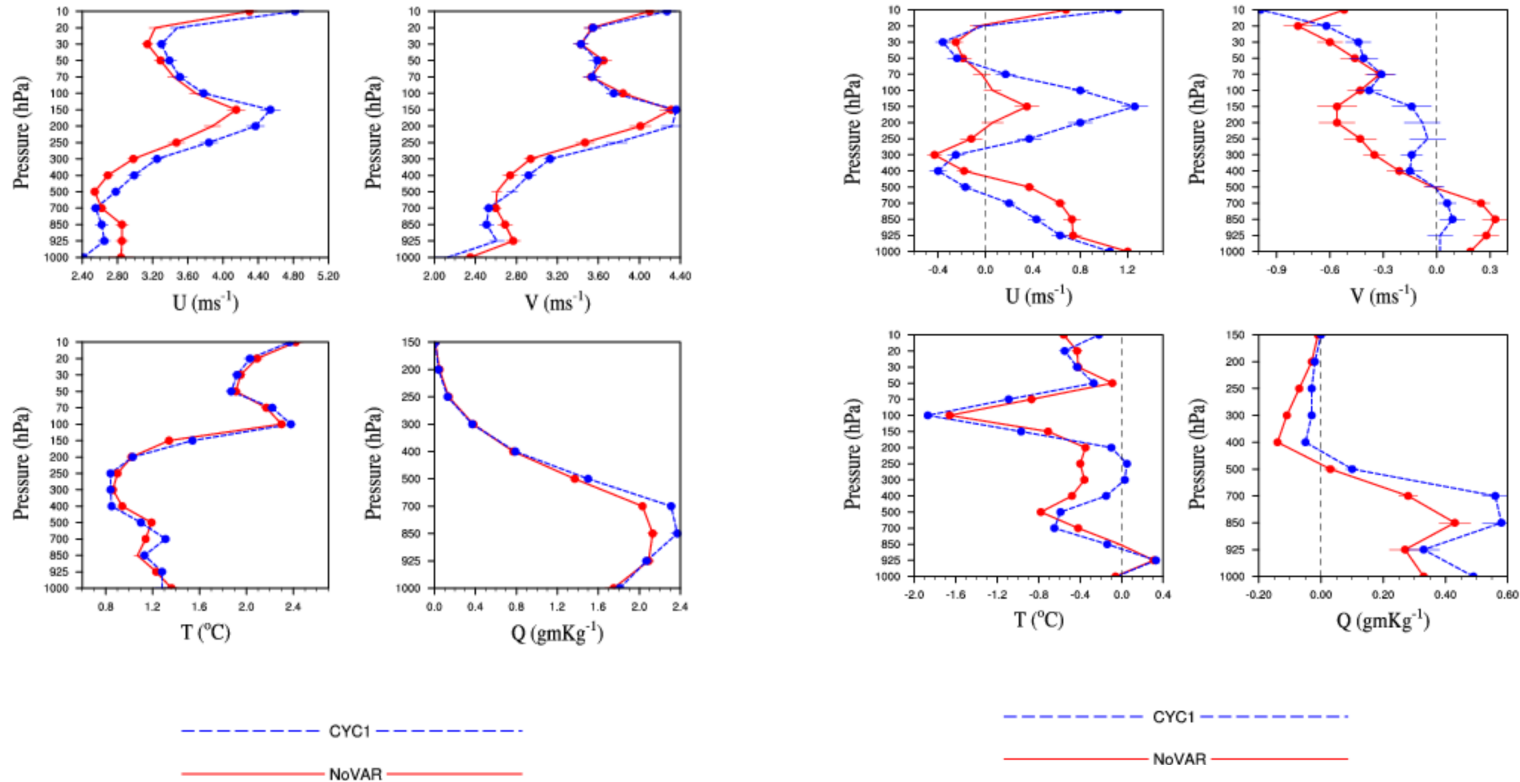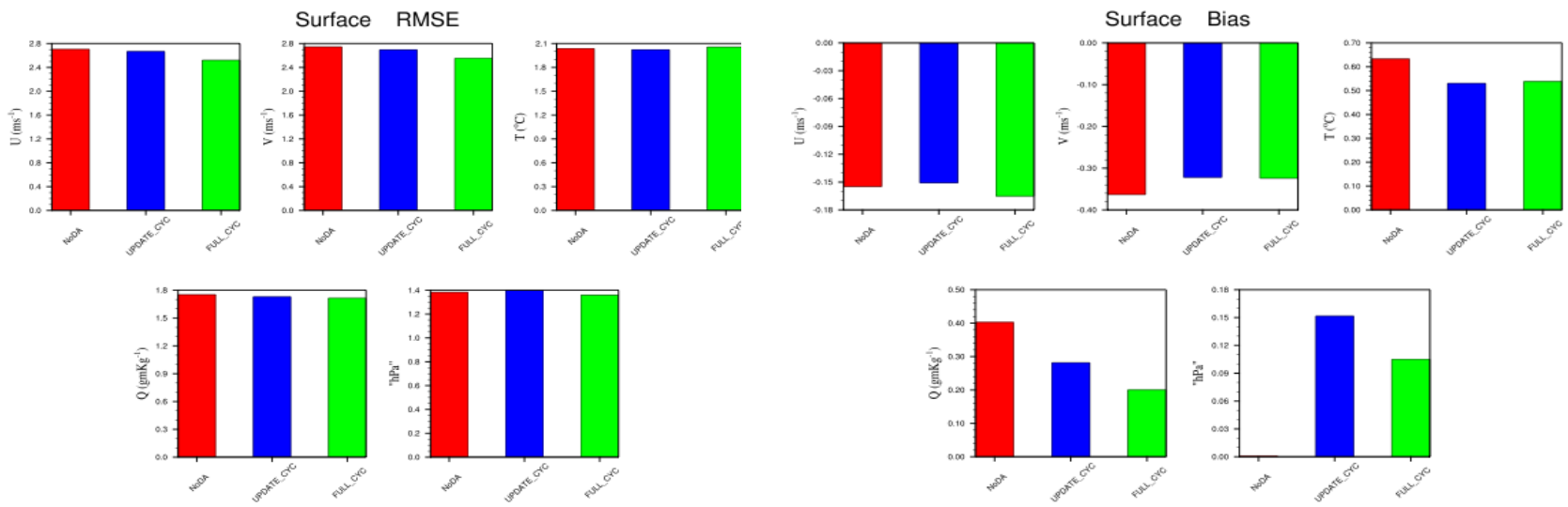
Verif_obs_plot   -- Surface Time Series
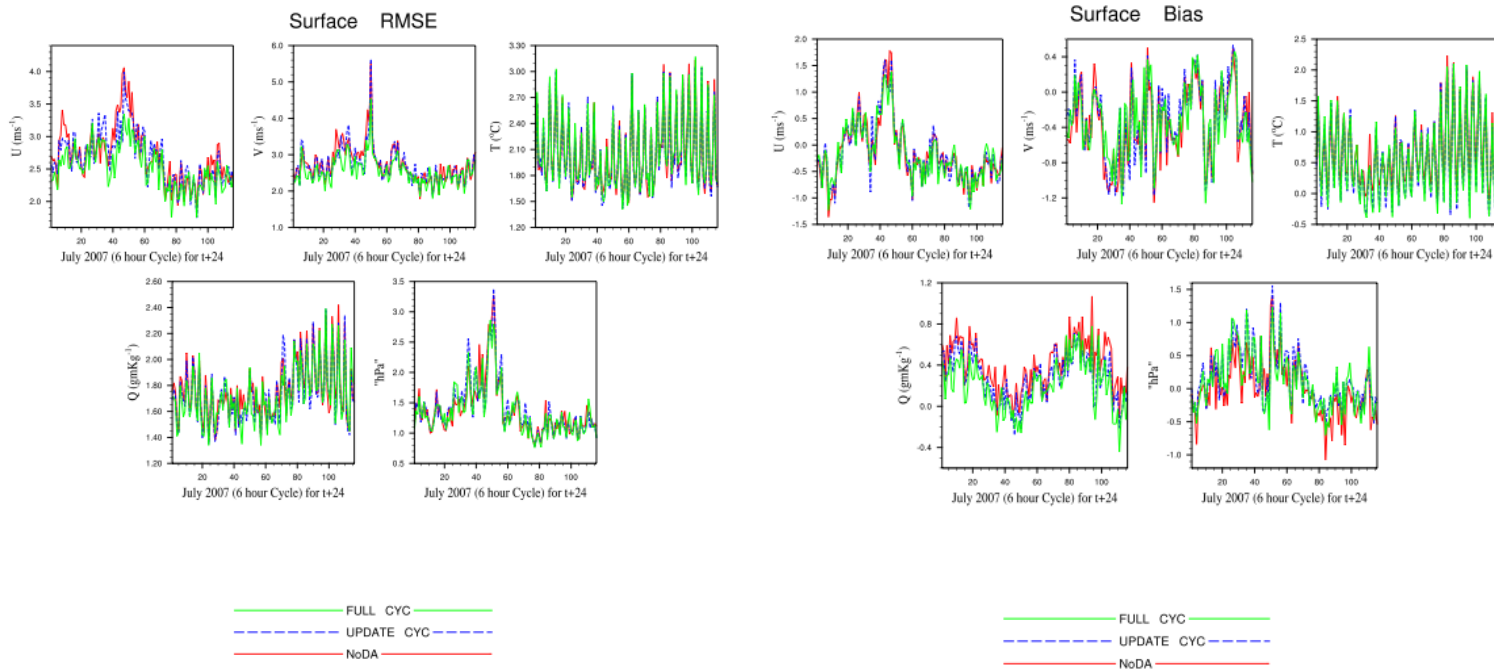
Verif_obs_plot -- Upper air Time Series
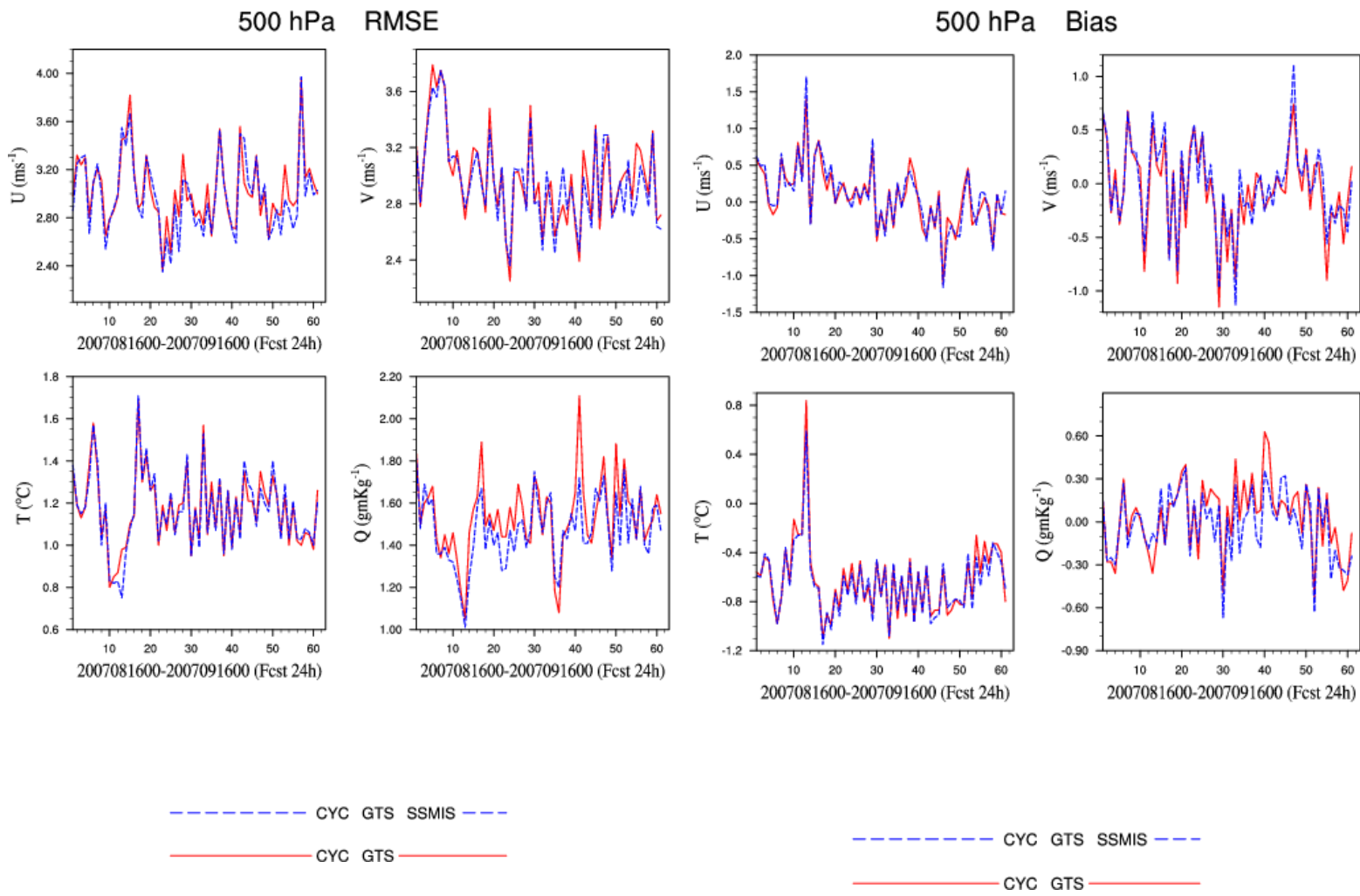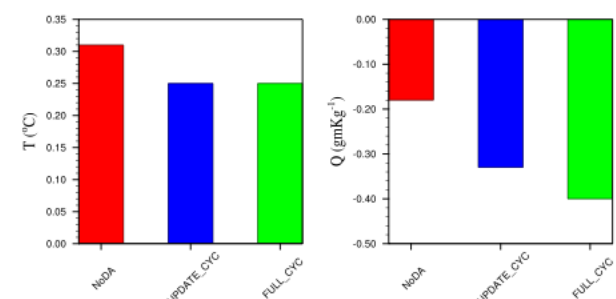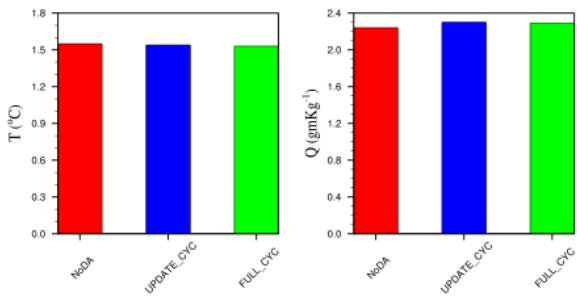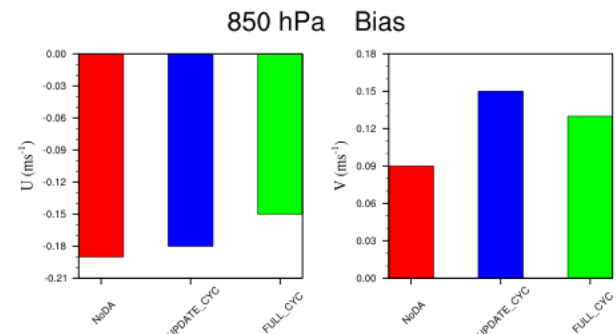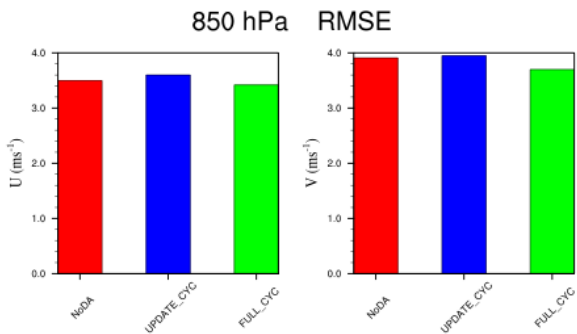
Verif_obs_plot -- Profile

RMSE Profiles for t8_15km: 15th August-15th September 2007 (t+12)   Bias Profiles for t8_15km: 15th August-15th September 2007 (t+12)

Verif_obs_plot   -- Surface Time Average

Verif_obs_plot   -- Upper air Time Average

How to run verification grid verification?

Basic requirement for each experiment output:

- **It should be in standard "wrf-netcdf" format with standard "wrfout" like file names**

- **It should be at the same horizontal and vertical resolution**

- **Forecasts corresponding to each experiment needs to be arranged in separate directories with date-wise (YYYYMMDDHH) sub-directories**

How to run?

- **Desired graphics will be generated in "RUN_DIR" by executing "var/script/da_verif_grid.ksh" via a suitable wrapper script**

Wrapper for da_verif_grid.ksh

Important variables:

WRFVAR_DIR	: Main WRFDA directory (full path)
REG_DIR	: Directory holding forecast sub-directories for each experiment
RUN_DIR	: Directory where plots will be generated
NUM_EXPT	: Total number of experiments (Currently maximum 10)
EXP_DIR	: Experiment directory names as they exist in REG_DIR (blank separated)
EXP_NAMES	: Experiment names as they exist in REG_DIR (blank separated)
EXP_LEGENDS	: Legend string for each experiments (comma separated)
DESIRED_LEVELS	: Legend string for each experiments (comma separated)
DESIRED_SCORES	: Diagnostics like "RMSE", "BIAS" or "ABIAS"
START_DATE	: Starting date ("YYYYMMDDHH") for verification
END_DATE	: Ending date ("YYYYMMDDHH") for verification
INTERVAL	: Time interval (in hours) for incrementing date/time
VERIFY_HOUR	: Verification hour
CONTROL_EXP_DIR	: Directory name for verifying analysis
VERIFY_ITS_OWN_ANALYSIS	: Set "true" or "false" if each experiment is going to be verified against its own analysis or against a fixed analysis in "CONTROL_EXP_DIR"
VERIFICATION_FILE_STRING	: It should be "wrfout" or "wrfinput" depending on what is available
VERIFY_DATE_RANGE	: String to specify X-axis title
PLOT_WKS	: Name of workstation for plots like "X11", "pdf" etc.

da_Verif_grid.ksh output

**In RUN_DIR, following graphics will be generated for each of the the desired scores (RMSE, BIAS or ABIAS)**

- Time series for surface fields (U10, V10, T2, Q2 & Psfc)

- Time series for upper air fields (U, V, T & Q) for the desired levels

- Upper air profiles for U, V, T & Q

- Time average for surface and upper air fields for the desired levels (Histogram)

```
-rw-r--r--  1 rizvi   ncar       235624 Dec 31 15:14 Time_Series_UPA_RMSE-850-hr24.pdf
-rw-r--r--  1 rizvi   ncar       237504 Dec 31 15:14 Time_Series_UPA_BIAS-850-hr24.pdf
-rw-r--r--  1 rizvi   ncar       183367 Dec 31 15:14 Time_Series_UPA_RMSE-200-hr24.pdf
-rw-r--r--  1 rizvi   ncar       173293 Dec 31 15:14 Time_Series_UPA_BIAS-200-hr24.pdf
-rw-r--r--  1 rizvi   ncar       322432 Dec 31 15:14 Time_Series_SFC_RMSE-hr24.pdf
-rw-r--r--  1 rizvi   ncar       325796 Dec 31 15:14 Time_Series_SFC_BIAS-hr24.pdf
-rw-r--r--  1 rizvi   ncar       100323 Dec 31 15:14 Time_Average_UPA_RMSE-850-hr24.pdf
-rw-r--r--  1 rizvi   ncar       112711 Dec 31 15:14 Time_Average_UPA_BIAS-850-hr24.pdf
-rw-r--r--  1 rizvi   ncar        71525 Dec 31 15:14 Time_Average_UPA_RMSE-200-hr24.pdf
-rw-r--r--  1 rizvi   ncar        81035 Dec 31 15:14 Time_Average_UPA_BIAS-200-hr24.pdf
-rw-r--r--  1 rizvi   ncar       163671 Dec 31 15:14 Time_Average_SFC_RMSE-hr24.pdf
-rw-r--r--  1 rizvi   ncar       182593 Dec 31 15:14 Time_Average_SFC_BIAS-hr24.pdf
-rw-r--r--  1 rizvi   ncar       237409 Dec 31 15:14 Profile_RMSE-hr24.pdf
-rw-r--r--  1 rizvi   ncar       238775 Dec 31 15:14 Profile_BIAS-hr24.pdf
```
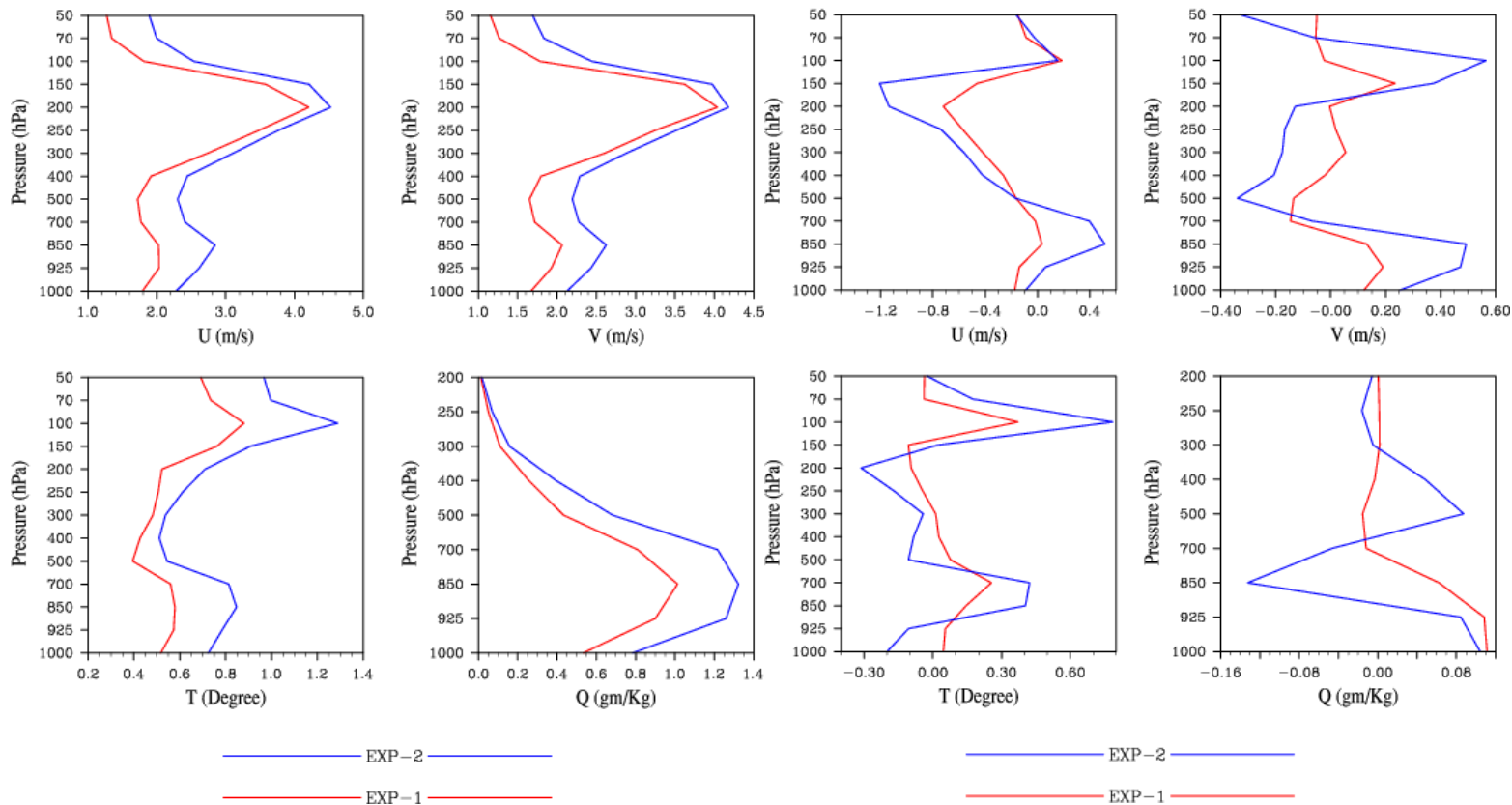
Verif_grid -- Surface Time Series
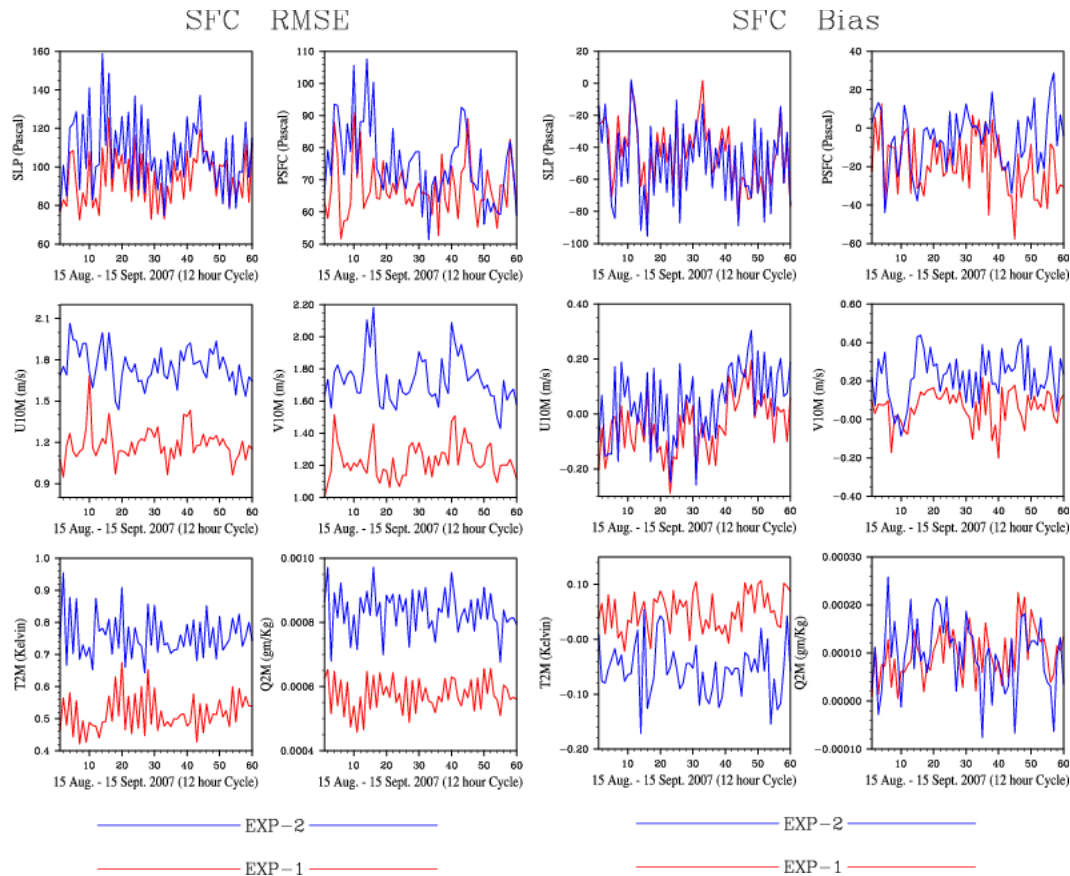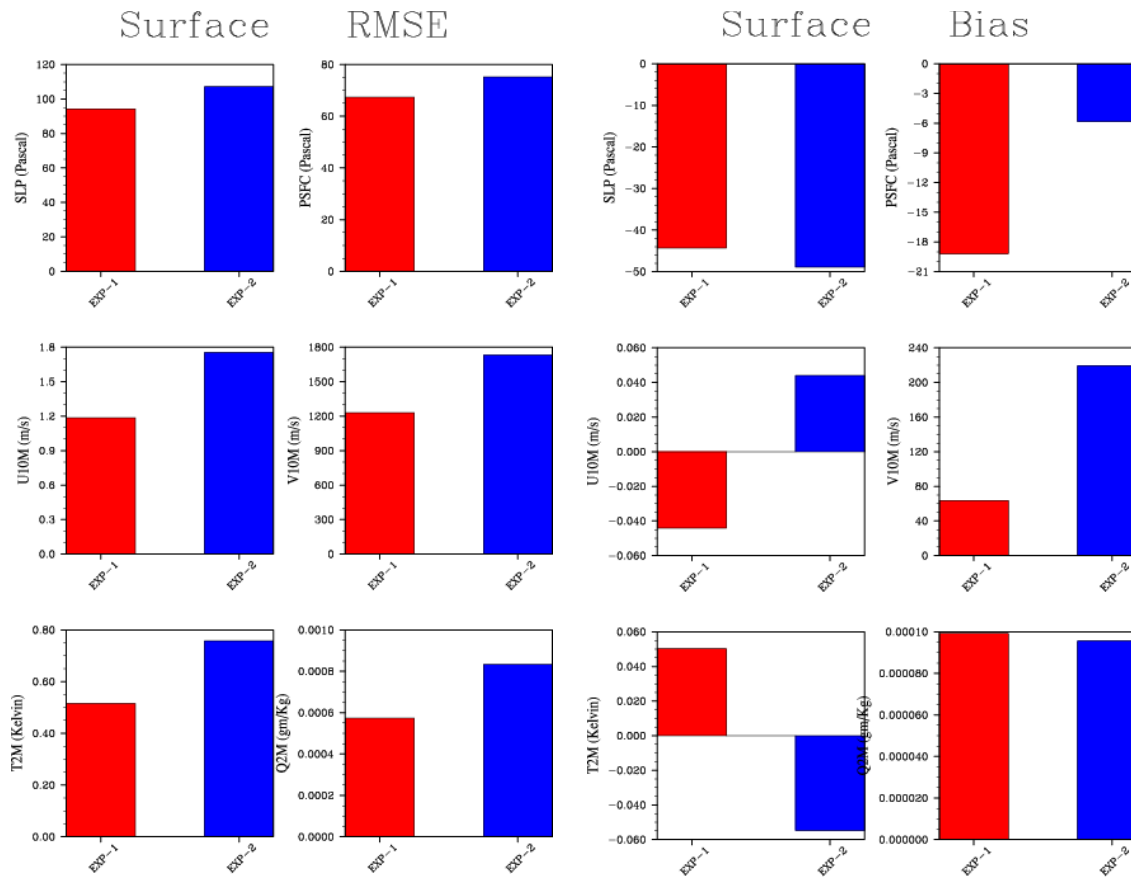
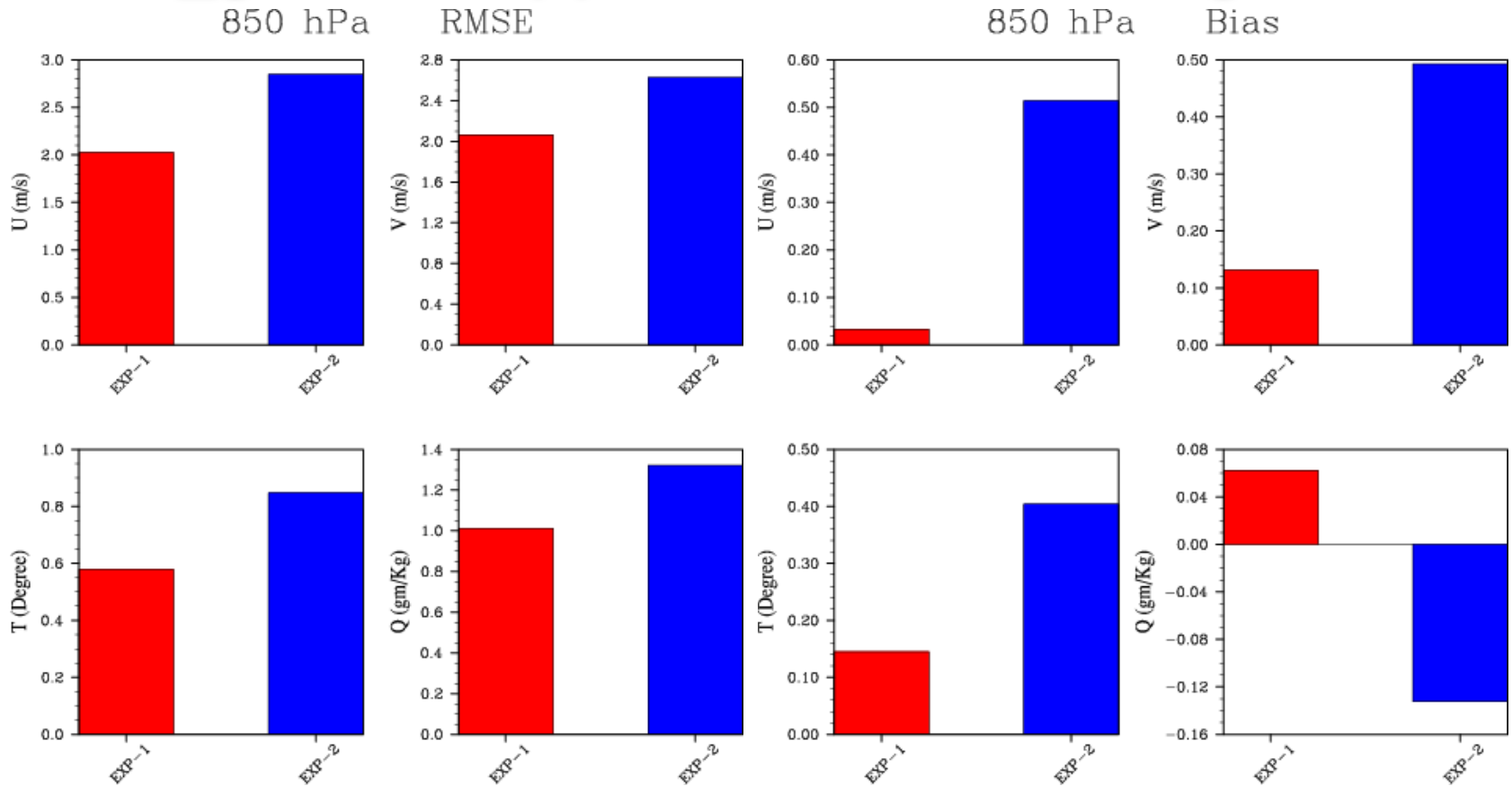# Verif_grid -- Upper air Time Series
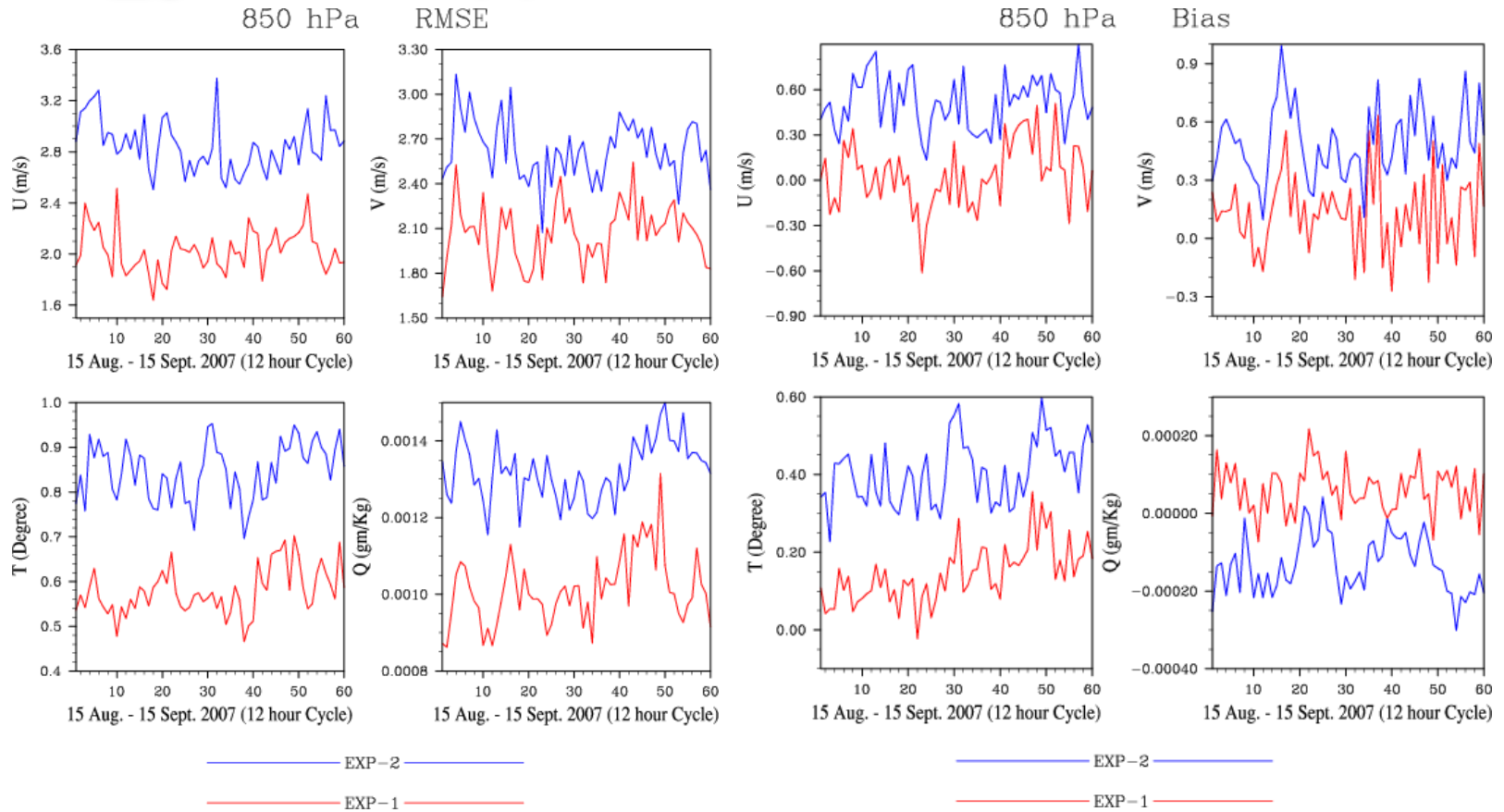
Verif_grid -- Profile

Verif_grid -- Surface Time Average

Verif_grid -- Upper air Time Average

Upcoming new feature -AFWA Go-Index

- **Go-Index (N) is defined in terms of weighted average of RMSE of some selected variables at different levels for 12, 24, 36 and 48 hours forecast lead time (i)**

$$S_i = 1 - \left\{\frac{RMSE_{expt}}{RMSE_{ctrl}}\right\}^2 \qquad S_w = \frac{1}{\sum_i w_i}\left(\sum_i w_i S_i\right) \qquad Go\,Index\,(N) = \sqrt{\frac{1}{1-S_w}}$$

- **Pre-defined weights (W_i) are as follows**

Variable	Level	Weights by lead time			
		12 h	24 h	36 h	48 h
Wind Speed	250 hPa	4	3	2	1
	400 hPa	4	3	2	1
	850 hPa	4	3	2	1
	Surface	8	6	4	2
Dew Point Temperature	400 hPa	8	6	4	2
	700 hPa	8	6	4	2
	850 hPa	8	6	4	2
	Surface	8	6	4	2
Temperature	400 hPa	4	3	2	1
	Surface	8	6	4	2
Height	400 hPa	4	3	2	1
Pressure	Mean sea level	8	6	4	2

- **Go-Index > 1 means, experiment (*expt*) performed better than control (*ctrl*)**

WRFDA Scripts and GroaphicTools

Shell scripts and NCL based graphics are available

http://www.mmm.ucar.edu/wrf/users/wrfda/download/tools.html

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_run_gsi.ksh	da_run_gsi_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

Note: For details read　"WRFDA/var/graphics/ncl/README"

Obs error tuning (Desroziers method)

- **Step 1: Make sure that "va/build/da_tune_obs_desroziers.exe" exists**
- **Step 2: Run two set of parallel WRFDA cycling experiments:**
  a) "unperturbed" : Normal WRFDA cycling run with default option
  b) "perturbed"   : WRFDA cycling run with "omb_add_noise" and "put_rand_seed" as "TRUE"

- **Step 3: Execute "var/scripts/da_tune_obs_desroziers.ksh" via a "wrapper" script.**
- **Important environment variables to be declared in "wrapper" script**

  WRFVAR_DIR : Path for main WRFDA
  Y_DIR   : Path for WRF-Var normal run "unperturbed run"
  YP_DIR   : Path for WRF-Var run with "put_rand_seed" & "oma_add_noise" as true "perturbed run"
- **Finally, a file named "errfac.dat" will be generated which needs to be copied in "wrfda/run" directory**
- **More details are available at https://wiki.ucar.edu/display/mmm/Syed+Rizvi**

Obs error tuning (Hollingsworth method)

- **Step 1: Make sure that "va/build/da_tune_obs_hollingsworth1.exe" & "var/build/ da_tune_hollingsworth2.exe" exists**

- **Step 2: Run WRFDA cycling run for at least one month**

- **Step 3: Execute "var/scripts/da_tune_obs_hollingsworth.ksh" via a "wrapper" script.**

  Important environment variables to be declared in "wrapper" script
  WRFVAR_DIR   : Path for main WRFDA
  EXP_DIR   : RUN_DIR for WRFDA cycling run
  START_DATE   : Start date for the tuning period
  END_DATE   : End date for the tuning period

- **Finally, for each desired observation type like "sound" , "sound_u_omb.sigma_o_b", "sound_v_omb.sigma_o_b" etc. will be created**

- **More details are available at:**
          https://wiki.ucar.edu/display/mmm/Syed+Rizvi