Implementation of multivariate background error (MBE) statistics in WRFDA

Syed RH Rizvi

NCAR/NESL/MMM/DAS, Boulder, CO, USA

A new control variable option to implement multivariate background error (MBE) statistics in WRFDA have been introduced. It may be activated by setting the "namelist" variable "cv_options=6". This option introduces six additional correlation coefficients in the definition of balanced part of analysis control variables. Thus with this implementation, moisture analysis is multivariate in the sense that temperature and wind may lead to moisture increments and vise-versa. The "gen_be" utility has also been updated to compute the desired MBE statistics required for this option. The updates include basic "source code", "scripts" and "graphics" to display some important diagnostics about MBE statistics.

Rest of this document briefly describes the important updates in WRFDA for the implementation of MBE statistics procedure. How to generate and use MBE statistics with the updated WRDA procedure has been discussed. It also describes the set of additional "namelist" parameters, which are included for tuning MBE statistics. Important diagnostics of MBE statistics coming out of new WRFDA procedure has been displayed for "Katrina 12 Km" domain. Geographical location of "Katrina 12 Km) domain has also been shown in Figure 1. The most important aspect of the updated procedure, namely the multivariate nature of analysis increments has been demonstrated for this domain with the use of single moisture observation test.

Source code update:

Following is the list of important source code, which has been updated in WRFDA to implement MBE statistics in the new procedure. Brief description about this code is also documented.

a) "*var/da/da_vtoxtransforms/da_transform_vptox.inc*": Forward operator with new definition of "balanced" part of analysis control variables.
b) "*var/da/da_vtoxtransforms/da_transform_vptox_adj.inc*": Adjoint code of the forward operator with new definition of "balanced" part of analysis control variables.
c) "*var/da/da_define_structures/ da_define_structures.f90*": Includes additional set of variables for implementing new "background errors" corresponding "cv_options=6".
d) "*Registry/Registry.wrfvar*": Nine additional "namelist" variables have been included in "*wrfvar13*" for assigning weights to the corresponding nine additional regression coefficients. Their default values are set to 1.0.
e) "*var/da/da_setup_structures/da_setup_be_regional.inc*": It builds necessary arrays for implementing new regional "background errors" corresponding to "cv_options=6".

f) "*var/gen_be/gen_mbe_stage2.f90*": This new code merges the existing WRFDA procedure for computing "regression" coefficients (stage2) and the "control variables" (stage2a). This way, a considerable amount of I/O is saved in the new procedure.

g) "*var/gen_be/gen_be_cov2d3d_contrib.f90*": It is new code which computes the contribution of "surface pressure" for other 3D control variables, like stream function, velocity potential, temperature etc.

h) "*var/gen_be/gen_be_cov3d3d_bin3d_contrib.f90*": It is new code which computes the contribution of "stream function" in determining the balanced part of "velocity potential" field.

i) "*var/gen_be/gen_be_cov3d3d_contrib.f90*": It is new code which computes the contribution of any general 3D field on the "balanced" part of other 3D fields. Here it may be noted that the contribution of "stream function" on the balanced part of "velocity potential" is not computed by this code. It is done separately by "*gen_be_cov3d3d_bin3d_contrib.f90*"

j) "*var/gen_be/gen_be_hist.f90*": It is new code which computes the frequency distribution of new background errors for different variables in the desired number of "*bins*" for the desired "*bin width*"

Scripts update:

Following is the list of important scripts update in WRFDA to implement the generation of MBE statistics.

a) "*var/scripts/gen_be/gen_mbe.ksh*" : This is top level script parallel to old "*gen_be.ksh*". This executes different "stages" for the computation of background errors for "cv_optiopns=6. It calls "gen_be_cov2d3d_contrib.ksh", "*gen_be_cov3d3d_bin3d_contrib.ksh*", "*gen_be_cov3d3d_contrib.ksh*" and "*gen_be_cov3d2d_contrib.ksh*" to implement the procedure corresponding to "*gen_be_cov2d3d_contrib.f90*", "*gen_be_cov3d3d_bin3d_contrib.f90*", "*gen_be_cov3d3d_contrib.f90*" and "*gen_be_cov3d2d_contrib.f90*" respectively.

b) "*var/scripts/gen_be/gen_be_hist.ksh*": This script implements the procedure corresponding to "*gen_be_hist.f90*"

Graphics update:

Following NCL scripts is added to display some useful background error diagnostics related with MBS statistics.

a) "*var/graphics/ncl/gen_be/gen_mbe_contrib.ncl*": This displays diagnostic for the contributions of different fields (either 2d or 3d) for the balanced part.

How to generate multivariate background error statistics for WRFDA?

Multivariate background error statistics for WRFDA is generated by executing a top level script *"gen_be/gen_mbe.ksh*" residing under "*SCRIPTS_DIR*" via a suitable wrapper script. Rest of the procedure remains same as with normal running of "*gen_be*" utility. Successful run will create a "*be.dat*" file in "*RUN_DIR*" directory.

How to run WRFDA with multivariate background error statistics?

After successfully generating multivariate background error statistics file "*be.dat*" the procedure for running WRFDA is straight. If WRFDA is run through "wrapper" script, declare suitably the namelist variable "NL_CV_OPTIONS=6" in the "wrapper" script. If WRFDA is run directly (by executing "*da_wrfvar.exe"*) then, include "cv_options=6" in "*namelist.input*" file under "*wrfvar7*" list of namelist options.

How to tune multivariate background error statistics in running WRFDA?

Following is the list of nine tuning parameters available in WRFDA. Default values for these variables are set as "1.0". By setting corresponding values > 1.0 (< 1.0) will increase (decrease) the corresponding contributions as described in the following Table.

Variable name	Description
psi_chi_factor	Parameter to control contribution of stream function in defining balanced part of velocity potential
psi_t_factor	Parameter to control contribution of stream function in defining balanced part of temperature
psi_ps_factor	Parameter to control contribution of stream function in defining balanced part of surface pressure
psi_rh_factor	Parameter to control contribution of stream function in defining balanced part of moisture
chi_u_t_factor	Parameter to control contribution of unbalanced part of velocity potential in defining balanced part of temperature
chi_u_ps_factor	Parameter to control contribution of unbalanced part of velocity potential in defining balanced part of surface pressure
chi_u_rh_factor	Parameter to control contribution of unbalanced part of velocity potential in defining balanced part of moisture
t_u_rh_factor	Parameter to control contribution of unbalanced part of temperature in defining balanced part of moisture
ps_u_rh_factor	Parameter to control contribution of unbalanced part of surface pressure in defining balanced part of moisture

Important MBE diagnostics for Katrina 12 Km domain

For "Katrina12 Km domain", Figure 2 displays the contribution of stream function (psi) in defining the balanced part of velocity potential (chi), contribution of stream function (psi) and unbalanced part of velocity potential (chi_u) in defining the balanced part of temperature (t), contribution of stream function (psi), unbalanced part of velocity potential (chi_u), unbalanced part of temperature (t_u) and unbalanced part of surface pressure (ps_u) in defining the balanced part of moisture field and the contribution of stream function (psi) and unbalanced part of velocity potential (chi_u) in defining the balanced part of surface pressure field respectively in cyclic order, starting top left corner.

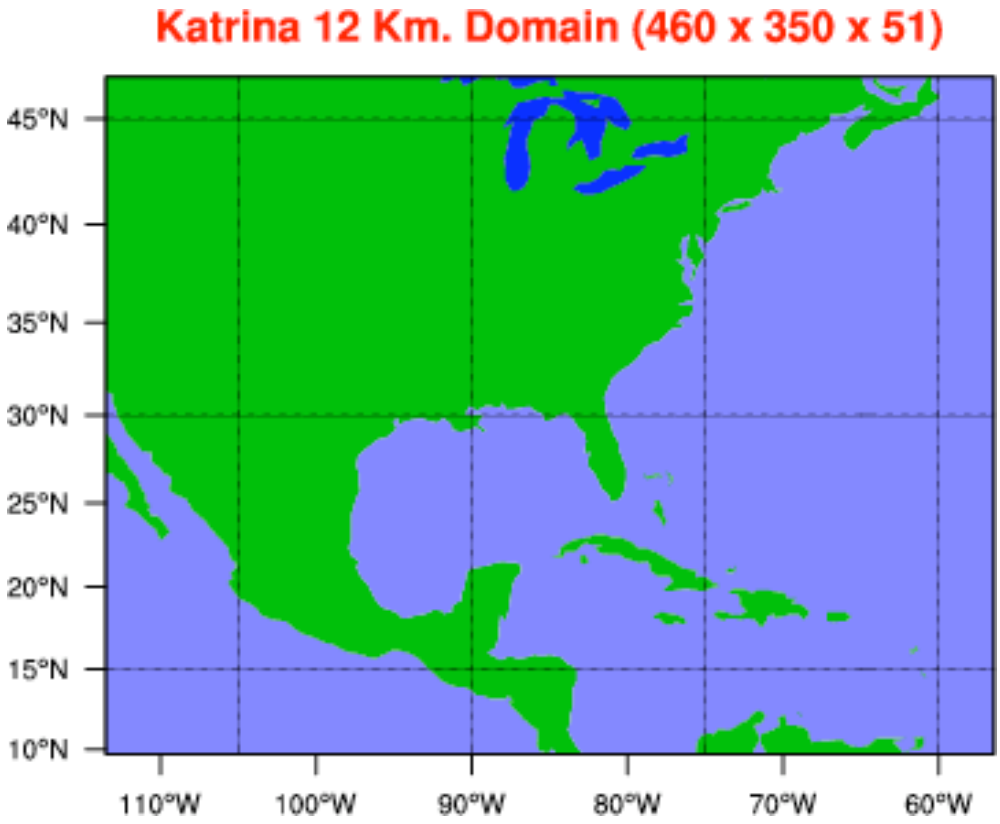

Figure 1: Geographical location of "Katrina 12 Km" domain

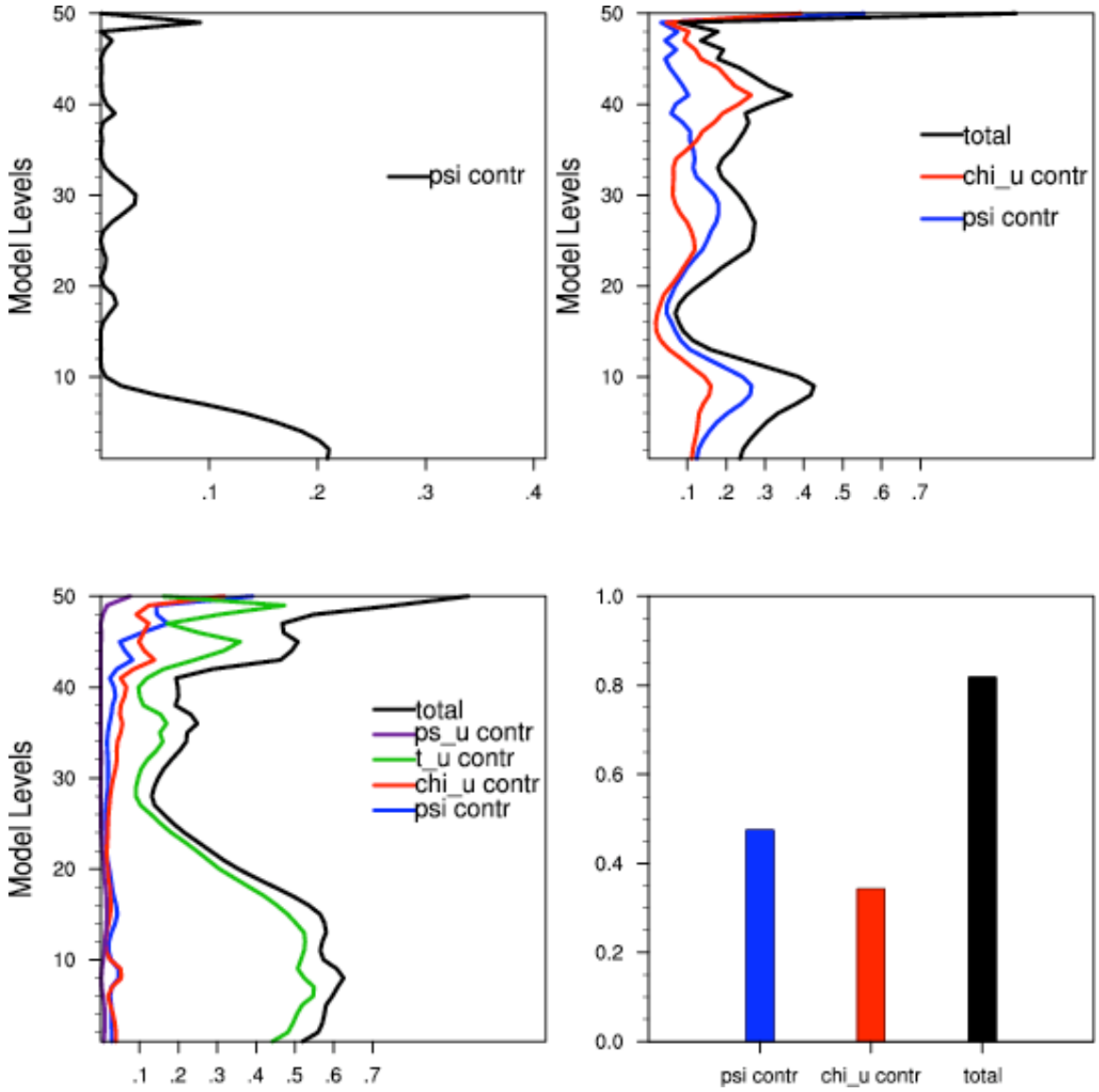

Figure 2: Diagnostics for multivariate background error statistics, namely the contribution to balanced part for velocity potential, temperature, moisture (rh) and surface pressure for "Katrina 12 Km" domain from different analysis control variables.

Results with single moisture observation test

Multivariate nature of analysis increments with the updated WRFDA procedure has been demonstrated for "Katrina 12 Km" domain by activating WRFDA "pseudo_obs" utility, for single moisture observation. Figure 3 displays horizontal cross-section of analysis increments at sigma level 25 for westerly component of wind (u), southerly component of wind (v), temperature (t) and specific humidity increments with single moisture observation with unit (=1 gm/Kg) innovation at sigma level 25 located exactly in the middle of the domain. As desired, it may be seen that moisture increments lead to wind and temperature increments.

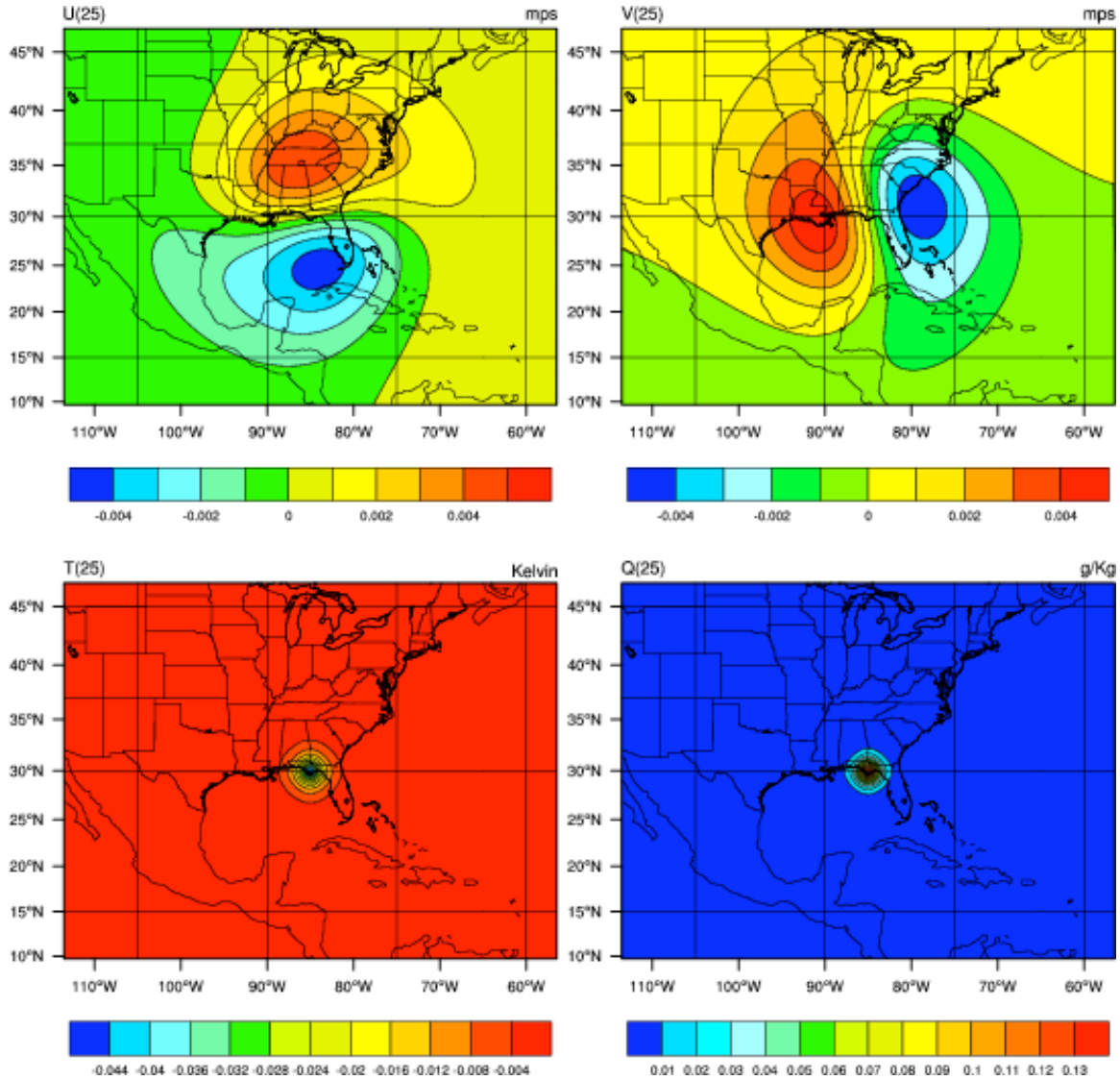

Figure 3: Horizontal cross-section of analysis increments at sigma level=25 for u, v, t and q produced by one single moisture observation with unit (=1.0 g/Kg) innovation at the sigma level=25 located exactly in the middle of the domain.