Multivariate background errors in WRFDA: Impact of additional correlations and its performance in Tropics and Arctic

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Abstract

For Numerical Weather Prediction (NWP), initial balance of wind and moisture is very important. Regression technique is used to derive empirical relationships between different analysis control variables using forecast error statistics. Thus a multivariate background error (MBE) statistics along with a new set of analysis control variables are implemented within the framework of WRF data assimilation (WRFDA). To assess the impact of implementing additional correlations and to examine the performance of multivariate background errors in lower and higher latitudes, a set of MBEs are generated by activating different regression coefficients for a domain representing tropical region and an Arctic domain.

A series of single of observation tests are undertaken to understand and demonstrate the response of different MBEs in the two domains under study. With the implementation of additional correlations between mass (surface pressure, temperature and moisture) and wind field via MBE statistics, it is expected that it may help in reducing the problems associated with moisture initialization by improving the balance between wind and moisture field. Various aspects of utilizing MBE within WRFDA system are studied in a domain representative of tropics. This paper is aimed to discuss the results about this study.

1 Introduction

The spatial and multivariate structure of the analysis increments in 3D-variational analysis is driven by the formulation of the background error covariance matrix (**B**) [J. Derber, 1999]. Thus B plays a crucial role in three dimensional variational data assimilation (3DVar). Mostly, the NMC method [Parrish and Derber, 1992] is employed for estimating background error statistics assuming it to be well approximated by averaged forecast difference.

The NMC method provides a climatological estimate of **B** including the regression coefficients, which is used in defining "balance" part of different control variables. The control variable is the "unbalanced" part of the field, which is obtained by removing "balanced" part form the respective "full" field. The current formulation defining the "unbalanced" part in WRFDA follows 3DVar analysis originally developed for MM5 model [Barker et al, 2003]. Following the ideas of pioneering work of Berre [Berre, 2000], a multivariate background error (MBE) statistics along with a new set of analysis control variables are implemented [Rizvi, 2010] within the framework of WRF data assimilation (WRFDA).

To assess the impact of implementing additional correlations and to examine the performance of multivariate background errors in tropics and arctic, a set of MBEs are generated by activating different regression coefficients for a domain representing tropical region and an Arctic domain. A series of single of observation tests are undertaken to understand and demonstrate the response of different MBEs in the two domains under study.

2. Formulation of multivariate B and case studies:

The respective "unbalanced" parts of the new multivariate **B** can be find in [Rizvi, 2010]. Seven Cases have been designed to illustrate the impact of the modified definition of **B**. First Case, Case-1 (control run), is performed with the original formulation of **B**. In Case-2 and Case-3, correlation of stream function (ψ) and unbalanced velocity potential (χ_u) are included in the balanced part of temperature and surface pressure respectively. Case-4 to Case-7 gradually includes additional correlations of relative humidity (rh) correlations with other control variables leading to different definition for unbalanced humidity variable. These cases are shown on Table 1.

Table 1: Correlation coefficients activated for seven Cases

Case name	**Active regression coefficients**
Case-1	$\alpha_{\chi\psi}$, $\alpha_{T\psi}$,and $\alpha_{Ps\psi}$
Case-2	In addition to which are active in Case-1, and $\alpha_{\chi_u T}$
Case-3	In addition to which are active in Case-2, and $\alpha_{\chi_u Ps}$
Case-4	In addition to which are active in Case-3, and $\alpha_{\psi r_h}$
Case-5	In addition to which are active in Case-4,and $\alpha_{\chi_u r_h}$
Case-6	In addition to which are active in Case-5 and $\alpha_{T_u r_h}$
Case-7	In addition to which are active in Case-6 and α_{Psr_h} (all)

3. Characteristics of background error covariance matrix

In this part, individual contributions of different additional correlations will be discussed. In Fig.1 (left represents tropical domain and the right Arctic domain), individual contributions (correlation) of additional correlations in formulating the balanced part are shown. It can be seen that the contribution of unbalanced velocity potential has more contribution than stream function for temperature, surface pressure and relative humidity fields in tropics. Whereas for Arctic domain, contribution of unbalanced velocity potential has less contribution than stream function. It is found that corresponding contributions are of same order in mid-latitude [Rizvi 2010].

In addition, it is seen that total contribution of balanced part of surface pressure, both from stream function and unbalanced velocity potential, is about 34% in tropical domain, which is about 90% in Arctic domain. The total contribution of balanced part of surface pressure only from stream function, is about 11% in tropical domain and the same is about 75% for Arctic domain.

It also can been seen that, both in tropics and arctic domain, balanced part of relative humidity is mainly contributed by the unbalanced part of temperature and the unbalanced part of surface pressure field has very little contribute to balanced part of relative humidity. Similar behavior is found in mid-latitude [Rizvi 2010].

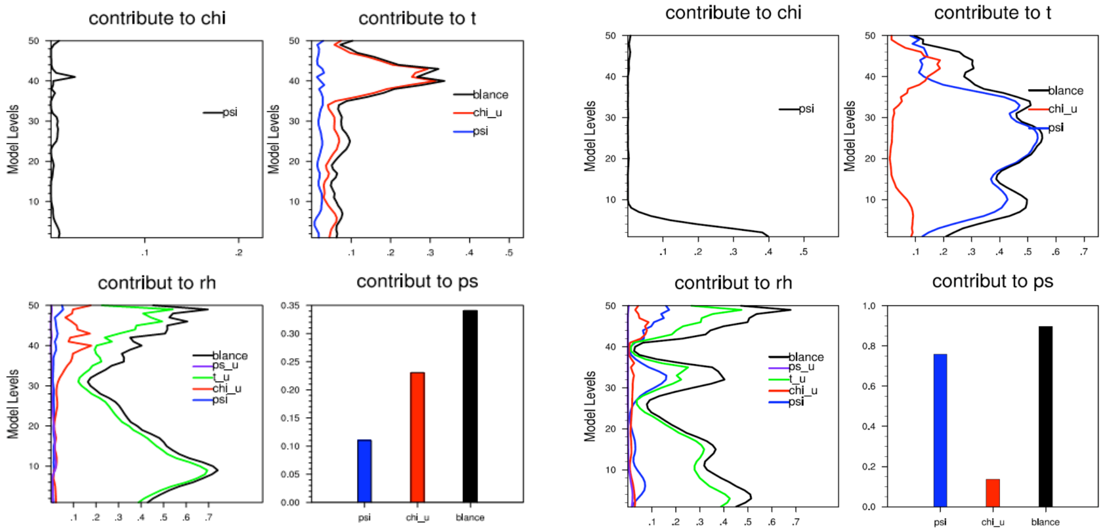

Fig.1 Individual contributions for case-7. Left(tropical domain),right(arctic domain)

4 Single observation tests

For understanding the response of new background errors, a variety of single observations tests are made.

4.1 The effect of $\alpha_{\chi_u T}$

In tropics with additional $\alpha_{\chi_u T}$ term (case-2), the increment of temperature and wind field have a rotation as a result of assimilating single wind and single temperature observation. Further, the temperature and wind increments are large because in tropics the contribution of $\alpha_{\chi_u T}$ is very large. On the other hand for Arctic, since the contribution of $\alpha_{\chi_u T}$ is small, temperature and wind increments are less and both temperature and wind field have less rotation as a result of assimilating single wind and single temperature observation.

4.2 The effect of $\alpha_{\chi_u Ps}$

In tropics with additional $\alpha_{\chi_u Ps}$ term (case-3), increments of surface pressure have a rotation and its magnitude is also more as a result of assimilating single wind observation. Assimilation of single temperature observation produced larger surface pressure increment. In addition, with active $\alpha_{\chi_u Ps}$,by assimilating single surface pressure, It will get a little impact on temperature field, similar impact is not possible without $\alpha_{\chi_u Ps}$ .In arctic domain, Because the contribution of correlation coefficient ($\alpha_{\chi_u Ps}$) of surface pressure field is less than it in tropic domain, the increment of surface pressure field have less rotation and less increment (not show).

4.3 The effect of $\alpha_{\psi r_h}$, $\alpha_{\chi_u rh}$, $\alpha_{T_u r_h}$ and $\alpha_{Ps r_h}$

As expected, both in tropics and Arctic domain, with active $\alpha_{\psi r_h}$, $\alpha_{\chi_u rh}$, $\alpha_{T_u r_h}$ and $\alpha_{Ps r_h}$, assimilation of single observations corresponding to wind, temperature and surface pressure, lead to moisture increments (not shown). Similarly the assimilation of single moisture observation also lead to increments in other variables like wind, temperature etc. (Fig.2, right). Similar impact is not possible without these additional regression coefficients (Fig.2, left).

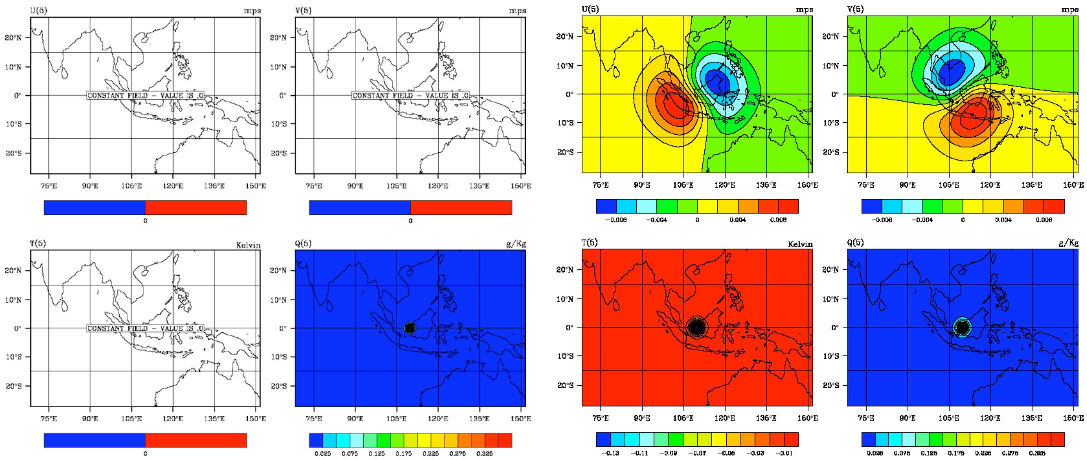

Fig.2 Horizontal cross-section of analysis increments at 5th sigma level for wind, temperature and moisture, as a result of assimilating single moisture observation with innovations=1g/kg corresponding to case-3 (left) and case-7 (right).

5. Summary and conclusions

Multivariate background error covariance have been computed and its impact have been studied within the framework of WRFDA for tropics and Arctic domain. Contributions of different of regression coefficients have been studied with a variety of single observation tests. With additional correlations between mass (surface pressure, temperature and moisture) and wind field via MBE statistics, balances between mass and wind field is improved. Study reveals the contrasting role of stream function and velocity potential for lower and higher latitudes. It is found that the contribution of unbalanced velocity potential has more contribution than stream function in tropics. However in case of Arctic domain, which represents the higher latitudes, this situation is exactly opposite. Total contribution of balanced part of surface pressure is higher (which is about 90%) in Arctic domain than in tropics (which is about 34%). For each domain, the balanced part of relative humidity is mainly contributed by the unbalanced part of temperature. The role of unbalance surface pressure is very small for the contribution of balanced part of relative humidity.

Acknowledgments

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