DOCTORAL THESIS

Numerical methods for data assimilation in weather forecasting

Yan, Hanjun

Date of Award:
2018

Abstract

Data assimilation plays an important role in weather forecasting. The purpose of data assimilation is try to provide a more accurate atmospheric state for future forecast. Several existed methods currently used in this field fall into two categories: statistical data assimilation and variational data assimilation. This thesis focuses mainly on variational data assimilation.

The original objective function of three dimensional data assimilation (3D-VAR) consists of two terms: the difference between the pervious forecast and analysis and the difference between the observations and analysis in observation space. Considering the inaccuracy of previous forecasting results, we replace the first term by the difference between the previous forecast gradients and analysis gradients. The associated data fitting term can be interpreted using the second-order finite difference matrix as the inverse of the background error covariance matrix in the 3D-VAR setting. In our approach, it is not necessary to estimate the background error covariance matrix and to deal with its inverse in the 3D-VAR algorithm. Indeed, the existence and uniqueness of the analysis solution of the proposed objective function are already established. Instead, the solution can be calculated using the conjugate gradient method iteratively. We present the experimental results based on WRF simulations. We show that the performance of this forecast gradient based DA model is better than that of 3D-VAR.

Next, we propose another optimization method of variational data assimilation. Using the tensor completion in the cost function for the analysis, we replace the second term in the 3D-VAR cost function. This model is motivated by a small number of observations compared with the large portion of the grids. Applying the alternating direction method of multipliers to solve this optimization problem, we conduct numerical experiments on real data. The results show that this tensor completion based DA model is competitive in terms of prediction accuracy with 3D-VAR and the forecast gradient based DA model.

Then, 3D-VAR and the two model proposed above lack temporal information, we construct a third model in four-dimensional space. To include temporal information, this model is based on the second proposed model, in which introduce the total variation to describe the change of atmospheric state. To this end, we use the alternating direction method of multipliers. One set of experimental results generates a positive performance. In fact, the prediction accuracy of our third model is better than that of 3D-VAR, the forecast gradient based DA model, and the tensor completion based DA model. Nevertheless, although the other sets of experimental results show that this model has a better performance than 3D-VAR and the forecast gradient based DA model, its prediction accuracy is slightly lower than the tensor completion based model.

Keywords: data assimilation, 3DVAR, conjugate gradient, ADMM, WRF, tensor completion.

Table of Contents