Automation Script for WRF Model Data Assimilation System

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Abstract

Climatology and weather forecasting are important since they help to determine future climate expectation. They are important to most aspects of day to day life, including aviation, boating, other modes of transportation, farming, tourism, health care, sports, etc. Many software models exist for modeling and forecasting the weather. The weather prediction is very complex and needs in a lot of observational data. In the weather forecasting domain Armenia as a developing country gets much of the forecasting data from outside resources, and moreover, not all observation stations in Armenia provide daily observation data and they are not integrated into the global forecast systems. That's why the data assimilation techniques exist for making small corrections to a short-range forecast.

In this paper an automation script is introduced which in easy and user-friendly way generates a LITTLE_R format ASCII files from station observations SYNOP code, which is necessary for data assimilation WRFDA system in WRF model.

Keywords: data assimilation, automation, big data analysis, wrfda, synop, little_r

1. Introduction

In recent years the area of the weather forecast is growing very fast and in parallel with the computer technologies the different models are getting more accessible [1]. Numerical weather prediction (NWP) based on current weather predicts the weather using different mathematical models of the atmosphere and oceans. NWP focuses on taking current observations of weather and processing these data with computer models to forecast the ongoing state of weather. As the numerical computer models processing the initial data it is important to know the current state of the weather. Data assimilation is a process which produces outputs of precipitation, temperature and a lots of other meteorological elements from the oceans to the top of atmosphere as an input serving on the current weather observations. A number of global and regional forecast models are

run in different countries worldwide, using current weather observations relayed from radiosondes, weather satellites and other observing systems as inputs [2].

The mesoscale WRF model is specialized to the territory of Armenia and used for exploitative weather forecasting. One of the programs of the model is the WRFDA data assimilation system, used for making small corrections to a short-range forecast.

2. Tools and Definitions

2.1. Weather Research Forecast (WRF)

The weather research and forecasting (WRF) model is an NWP system and a set of software and tools, designed to bestead both atmospheric research and operational forecasting applications [3]. WRF features two dynamical (computational) cores, a data assimilation system, and a software architecture allowing for parallel computation and system expansibility. The model used in a wide range of meteorological applications across scales ranging from tens meters to thousands of kilometers. It includes the following features:

- Meteorological studies
- Real-time NWP
- Idealized
- Simulations
- Data assimilation
- Earth system model coupling
- Model training and educational support

In National Centers for Environmental Prediction (NCEP) and other national meteorological centers WRF is currently in operational use. In many laboratories, universities and private companies WRF model used in real-time forecasting configurations.

2.2. Data Assimilation – WRFDA System

Data assimilation is the technique by which observations are combined with an NWP product (the first guess or background forecast) and their respective error statistics to make small corrections to a short-range forecast (background), which is assumed to be good, to produce a model analysis. Variational (Var) data assimilation achieves this through the iterative minimization of a prescribed cost (or penalty) function. Differences between the analysis and observations/first guess are penalized (damped) according to their perceived error.

The WRFDA system is designed to be a flexible, state-of-the-art atmospheric data assimilation system that is portable and efficient on available parallel computing platforms (Fig. 1).
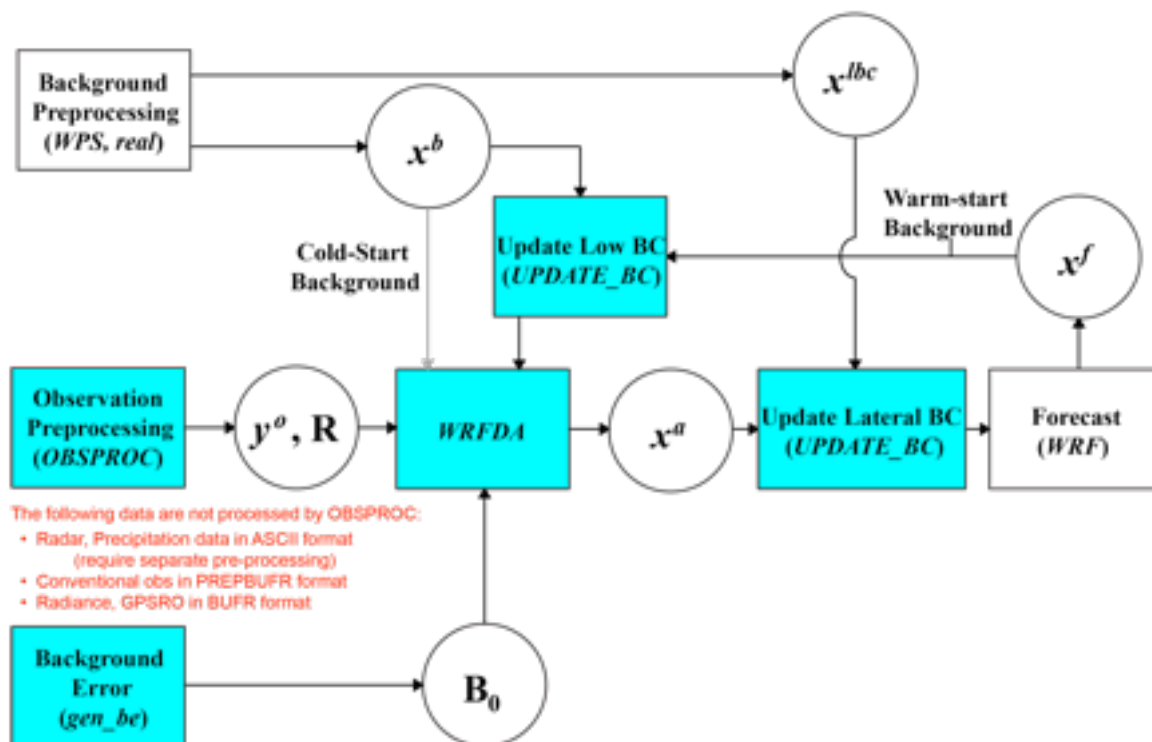
Fig 1. WRFDA system in WRF model.

WRFDA is suitable for use in a broad range of applications, across scales ranging from kilometers for regional and mesoscale modeling to thousands of kilometers for global scale modeling [4]. The OBSPROC program of the system reads observations in LITTLE_R format. It ingests multiple types of observations that are converted to LITTLE_R format and concatenated to one file, process the observation data and output the ASCII file(s) suitable for WRFDA needs − 3DVAR, FGAT (First Guess at Appropriate Time), 4DVAR.

The current script is mainly used for the 3DVAR system the basic goal of which is to seek an optimal estimate of the true atmospheric state at the time of analysis.

2.3. LITTLE_R

LITTLE_R is an ASCII-based observation file format. Because of many possible formats of raw observation data files such as ASCII, BUFR, PREBUFR, MADIS and HDF, LITTLE_R is designed to be an intermediate format so that WRFDA might be able to assimilate as many observation types as possible in a universal manner [5]. The report-based file format allows to all manner of observation types to easily combine together into an easy-to-read and edit text file.

It consists of reports. These reports are composed of sections: a header, the data itself, and three tail integers. Header is a single line located in the first line of each observation and contains information about their observation location, type and other fields. Data section comes after header section and it may contain multiple data records which usually correspond to the multiple vertical levels data for a single observation depending on the observation type. In case of FM-12 type of observation in Armenia the data section contains one row. For all observation types, after data

record(s), the single line ending record comes and for OBSPROC program the height and pressure fields must have a fixed flag value "-777777.00000". The tail integers are used by OBSPROC program to decide which observation to keep if two identical observation types are at identical places and times.

As the LITTLE_R is not used only for OBSPROC/WRFDA, but also for the other programs, there are many unused or missing fields which must be filled with missing flag value (for most of fields it's "-888888.00000") to indicate that that value does not exist.

2.4. SYNOP Code

SYNOP (surface synoptic observations) is a numerical code called FM-12 by WMO used for reporting weather observations made by manned and automated weather stations [6]. A report consists of groups of numbers describing general weather information, such as the temperature, barometric pressure and visibility at a weather station. SYNOP reports are typically sent every three hours.

3. Automation Script

The script is written in Python programming language. The structure is designed to be similar to the WRF model programs: properties are provided via configuration file called "namelist", which is used for main executable program. It contains 2 sections: input and output. The input section contains "stations_file" (path to the stations CSV file) and "synop_file" (path to the file containing the SYNOP code) parameters. Stations CSV file must contain the following required fields: [station WMO number], [name], [elevation], [latitude], [longitude] (see Fig 3).

```
37609;Ashotsk;2009;41,029444;43,876389
37618;Tashir;1502;41,123333;44,28
37626;Bagratashen;453;41,25;44,819722
37627;Odzun;1200;41,059167;44,613611
37682;Amasia;1876;40,96;43,78
-----------------------------------------------
```

Fig 3. Stations CSV file.

SYNOP code files must contain sections, each one has a date time in the first row and is followed by code information row for each station (see Fig 4).

```
00:00 June 01, 16


37875 326// 70301 10133 20092 38988 48482 51001 86930 555 10013=
37792 32998 00000 10047 20033 38224 48488 54000=
37682 32597 33402 10069 20064 38106 48487 53002 81940=
37686 32999 00000 10066 20038 38455 48484 52001=
37801 325// 53501 10154 20042 38010 48472 54000 85300=
37950 323// 80701 10072 20045 38153 48494 52003 885//=
37895 42996 62001 10123 20099 39173 48114 52004 86080=

------------------------------------------------------------------------
```

Fig 4. SYNOP code file.

Output section contains "prefix" parameter, which is used in the name of the generated LITTLE_R files.

For using the program at first configuration parameters in "namelist" file must be set with the corresponding values and after that running the main file run.py with python will generate LITTLE_R file(s).

In the case of Armenia the daily report of land station records contains 8 groups of information. Each group contains observation of fix time and the interval between those times is 3 hour. Each LITTLE_R file may contain information of many stations observations but for the same date time. So for each daily report the script generates 8 LITTLE_R format files.

4. Conclusion

The provided automation script makes simplify the work of the climatologists by using a user friendly approach obtain the observation data in LITTLE_R format, which are ready to be used as an input for WRF model WRFDA system. In the future it's planned to implement this script through a web-based platform of the weather forecast system.

References

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Ավտոմատացման սցենար WRF մոդելի տվյալների ասիմիլացիայի համակարգի համար

Հ. Գրիգորյան

Ամփոփում

Կլիմայագիտությունը և եղանակային կանխատեսումը կարևոր են, քանի որ օգնում են որոշել ապագա կլիմայի սպասումները: Նրանք կարևոր են առօրյա կյանքի բազմաթիվ ոլորտներում, այդ թվում `ավիացիայի, նավագնացության, տրանսպորտի, գյուղատնտեսության, զբոսաշրջության, առողջապահության, սպորտի և այլն: Առկա են շատ ծրագրային մոդելներ եղանակի մոդելավորման և կանխատեսման համար: Եղանակի կանխատեսումը շատ բարդ է և պահանջում է շատ դիտողական տվյալներ: Հայաստանը, որպես զարգացող երկիր եղանակային կանխատեսման ոլորտում, կանխատեսման տվյալների մեծ մասն օգտագործում է արտաքին ռեսուրսներից: Դիտորդական կայանների միայն շատ քիչ մասն է տրամադրում ամենօրյա դիտարկման տվյալները այդ համաշխարհային կանխատեսման համակարգերին: Նմանատիպ դեպքերի համար գոյություն ունեն տվյալների ասիմիլացիայի համակարգեր, որոնք նախատեսված են կարճաժամկետ հեռանկարում փոքր ուղղումներ կատարելու համար:

Այս հոդվածում ներկայացված է ավտոմատացման սցենար, որը հեշտ և հարմար օգտագործման ձևով ստեղծում է LITTLE_R ֆորմատով ASCII ֆայլեր` օգտագործելով կայանների դիտարկումների SYNOP կոդը, որն անհրաժեշտ է WRF մոդելի տվյալների ասիմիլացիայի համար WRFDA համակարգում:

Скрипт автоматизации для системы ассимиляции данных модели WRF

А. Григорян

Аннотация

Климатология и прогнозирование погоды важны, поскольку они помогают определить будущие климатические ожидания. Они важны для большинства аспектов повседневной жизни, включая авиацию, плавание, другие виды транспорта, сельское хозяйство, туризм, здравоохранение, спорт и т. д. Многие модели программного обеспечения существуют для моделирования и прогнозирования погоды. Прогноз погоды очень сложный и нуждается во множестве наблюдательных данных. В области прогнозирования погоды Армения, как развивающаяся страна, получает большую часть данных прогнозирования из внешних источников, и, кроме того, не все наблюдательные станции в Армении предоставляют ежедневные данные наблюдений, и они не интегрируют их в глобальные системы прогнозов. Вот почему существуют методы ассимиляции данных для внесения небольших поправок в краткосрочный прогноз.

В этой статье представлен скрипт автоматизации, который легко и удобно создает файлы ASCII формата LITTLE_R из кода наблюдений станции SYNOP, что необходимо для системы ассимиляции данных WRFDA в WRF-модели.