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TECHNICAL REPORT

Use of NCMRWF Global Model Forecasts in HYSPLIT Model – A Preprocessing System

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A-50, Sector 62, NOIDA – 201 309, INDIA

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10.	Abstract	A description of the pre-processing system that prepares the atmospheric forcing for the HYbrid Single Particle Lagrangian Integrated Trajectory model (HYSPLIT) using the NGFS (NCMRWF Global Forecast System) and NCUM (NCMRWF Unified Model) global model analyses/forecasts is presented in this report. A brief description of the HYSPLIT model installed at NCMRWF, pre-processing package that prepares NGFS and NCUM analyses/forecasts in the HYSPLIT specific format for the computation of forward and backward trajectories and a sample trajectory forecast are given in the report.
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Abstract

A description of the pre-processing system that prepares the atmospheric forcing for the HYbrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model using the NGFS (NCMRWF Global Forecast System) and NCUM (NCMRWF Unified Model) global model analyses/forecasts is presented in this report. A brief description of the HYSPLIT model installed at NCMRWF, pre-processing package that prepares NGFS and NCUM analyses/forecasts in the HYSPLIT specific format for the computation of forward and backward trajectories and a sample trajectory forecast are given in the report.

Contents

1. Introduction

The HYSPLIT_4 (HYbrid Single Particle Lagrangian Integrated Trajectory) model (version 4) is developed by ARL (Air Resources Laboratory), NOAA (http://ready.arl.noaa.gov/HYSPLIT.php). The HYSPLIT model can compute simple trajectories to complex dispersion and deposition simulations using either puff or particle approach. The model uses gridded atmospheric variables on a latitude-longitude grid. The atmospheric variables are required at regular time intervals. The main features of the HYSPLIT model are:

- Predictor-corrector advection scheme- (capable of forward or backward computations)
- Linear spatial and temporal interpolation of atmospheric variables
- Vertical mixing based upon surface layer (SL) similarity, boundary layer Richardson number (BL Ri), or Turbulent Kinetic Energy (TKE)
- Horizontal mixing based upon velocity deformation, SL similarity, or TKE
- Mixing coefficients converted to velocity variances for dispersion
- Dispersion computed using 3D particles, puffs, or both simultaneously
- Modelled particle distributions (puffs) can be either Top-Hat or Gaussian
- Air concentration from particles-in-cell or at a point from puffs
- Multiple simultaneous meteorology and concentration grids
- Latitude-longitude or conformal projections supported for meteorology
- Nested meteorology grids use most recent and finest spatial resolution
- Non-linear chemistry modules using a hybrid Lagrangian-Eulerian exchange

The basis of any Lagrangian model is that dispersion is computed following the particle, puff or a combination of both. In a puff model, the source is simulated by releasing pollutant puffs at regular intervals over the duration of release. Each puff contains the appropriate fraction of the pollutant mass. The puff is advected according to the trajectory of its center position while the size of the puff (both horizontally and vertically) expands in time to account for the dispersive nature of a turbulent atmosphere. In the particle model, the dispersion process is represented by adding a turbulent component to the mean velocity obtained from the atmospheric data. The particle model can be applied in the vertical, horizontal, or both directions. The advection of a particle is computed independently of the dispersion calculation. The time integrated advection of each particle can be viewed as a

simple trajectory that requires the three dimensional velocity fields (zonal, meridional and vertical components).

The atmospheric variables for trajectories are obtained as output fields from Numerical Weather Prediction (NWP) models. These fields cannot be directly used by HYSPLIT without some pre-processing. The atmospheric variables may be provided on one of the four different vertical coordinate systems: pressure-sigma, pressure-absolute, terrain-sigma or hybrid absolute-pressure-sigma. The model requires the horizontal wind components and temperature at height or pressure levels and the surface pressure. The vertical velocity field that contains the vertical motion relative to the NWP model's terrain following coordinate system also has to be provided. The NGFS and NCUM model outputs give the atmospheric variables on pressure surfaces and heights of pressure surfaces are assumed to be relative to msl (mean sea level).

HYSPLIT Graphical User Interface (GUI) is set up in IBM P6 machine at NCMRWF, which can be accessed by any user. The HYSPLIT graphical display programs can convert the trajectory output files to postscript format, which can be viewed in ghostscript and ghostview. More details on the HYSPLIT model is given in Draxler and Hess (2004) and HYSPLIT4 User's guide (2014).

2. Pre-processing of NGFS and NCUM analyses/forecasts

The HYSPLIT model (version 4) of NOAA ARL implemented at NCMRWF can be used to compute air mass trajectories (both forward and backward) from/to any location. A pre-processing system is developed for the generation of the required atmospheric fields from NGFS and NCUM model analyses/forecasts to run the HYSPLIT model.

2.1. NGFS atmospheric variables file creation

Atmospheric data fields to run the model is created from analysis and forecast outputs. The NGFS GRIB (GRIdded Binary) analysis/forecast files are converted to the ARL HYSPLIT compatible format. The process is described below in detail. The NGFS atmospheric variables used for the HYSPLIT simulations are:

- Upper level variables: zonal (u) and meridional (v) wind, temperature (T), relative humidity (RH), geopotential height (z) and vertical velocity (ω in Pa/s) on 1000, 975, 950, 925, 900, 850, 800, 750, 700, 600, 500, 400, 300, 200 and 100 hPa pressure levels
- Surface level variables: surface pressure (ps), zonal (u10m) and meridional wind (v10m), temperature (T2m), surface geopotential height (z) and planetary boundary layer height (HPBL)

Preparation of HYSPLIT input from NGFS for backward trajectory

To generate backward trajectories, six hourly analysis fields are required. The "zero hour forecast" fields (instead of analysis output) from all four cycles are used for the number of days (n) for which the backward trajectory has to be calculated. The NGFS "zero hour forecast" file valid for 00Z cycle is available at /gpfs1/home/exp/gfs/nwdata/gdas/prod/gdas.yyyymmdd/gdas1.t00z.pgrbf00. Similarly, 06Z (gdas1.t06z.pgrbf00), 12Z (gdas1.t12z.pgrbf00) and 18Z (gdas1.t18z.pgrbf00) cycle files are also used for the computation of backward trajectories. All the files (from four cycles) are interpolated into 1°×1° latitude-longitude resolution. From these files, the required atmospheric variables are selected (using wgrib utility) and written into the file "gfs_t${HR}z.grb" for HR=00Z, 06Z, 12Z and 18Z cycles of a day, respectively. The four files are appended to generate a single file (gfs_yyyymmdd.grb) for a day. The above process is repeated for "n" days depending on *n*-day back trajectory to be calculated. The file "gfs_yyyymmdd_nday.grb" is generated by combining all "gfs_yyyymmdd.grb" files for "n" days.

Preparation of HYSPLIT input from NGFS for forward trajectory

To get the forward trajectory, the six hourly interval forecast files are used (/gpfs1/home/exp/gfs/nwdata/post/gdas.yyyymmdd/gdas1.t00z.grbf06). It may be noted that the forecast is available at 6 hour interval starting at 06h. The files are available up to 240h forecast in 6 hourly interval (gdas1.t00z.grbf240), hence, up to 10-day forward trajectory can be computed. The forecast fields are interpolated into a 1°×1° latitude-longitude grid. The required variables are extracted from every 6 hour forecast, which create the files gfs_00_06h.grb, gfs_00_12h.grb,…, gfs_00_240h.grb. The files are then appended into a single GRIB file (gfs_yyyymmdd.grb).

2.2. NCUM atmospheric variables file creation

Similar to NGFS, the data from NCUM is used to compute forward and backward trajectories. The NCUM files in the Met Office "fields file format" have to be converted into GRIB format first, which is done by using the utility umfld2grib.sh. More details on the utility umfld2grib.sh are given in Mohandas (2014). The variables are taken from different files from the directory /gpfs1/home/umprod/PS28IN_UMPROD/UM/yyyymmdd/00 (or /gpfs1/home/umfcst/NCUM/fcst/yyyymmdd/00) as given below:

- Upper air fields: zonal (u) and meridional (v) wind, geopotential height (z), temperature (T), relative humidity (RH) and vertical velocity (w in m/s) on 1000, 950, 925, 850, 700,

600, 500, 400, 300, 200 and100 hPa pressure levels. These fields are taken from the files *.pp0 (for analyses) and ${EXPID}_pd0${fcst} (for forecasts). The utility umfld2grib.sh is used for the extraction of each of the variables listed as given below:

For analysis,

umfld2grib.sh *.pp0 ${var1} -1 0 0 24 1 -1 1 360 181 0.0 359.0 1.0 -90.0 90.0 1.0

where ${var1} is ugrd, vgrd, hgt, tmp, rh, vvel

For forecast,

umfld2grib.sh ${EXPID}_pd0${fcst} ${var2} -1 0 3 6 1 -1 1 360 181 0.0 359.0 1.0 -90.0 90.0 1.0

where ${var2} is ugrd, vgrd, hgt, tmp, rh, vvel and ${fcst} is 00, 24, …, 240.

- Surface level variables: 10m zonal wind (u10m), 10m meridional wind (v10m) and 2m temperature (T2m) from file ${EXPID}_pe000. The surface pressure (pres) is taken from the file *.pp0. The extraction of each of the variables listed is given below:

  umfld2grib.sh ${EXPID}_pe0${fcst} ${var2} -1 0 1 2 3 10 1 360 181 0.0 359.0 1.0 -90.0 90.0 1.0

  where ${var2} is u10m, v10m

  umfld2grib.sh ${EXPID}_pe0${fcst} t2m -1 0 1 2 3 1 1 360 181 0.0 359.0 1.0 -90.0 90.0 1.0

  umfld2grib.sh ${EXPID}_pe0${fcst} pres -1 0 1 2 0 -1 1 360 181 0.0 359.0 1.0 -90.0 90.0 1.0

  Surface geopotential height (z)/orography from file *.pp0

  umfld2grib.sh *.pp0 hgtsfc -1 0 0 24 0 1 1 360 181 0.0 359.0 1.0 -90.0 90.0 1.0

  Planetary boundary layer height (hpbl) from file ${EXPID}_pb0${fcst}

  umfld2grib.sh ${EXPID}_pb0${fcst} hpbl -1 0 1 2 0 -1 1 360 181 0.0 359.0 1.0 -90.0 90.0 1.0

  For analysis: ${EXPID} is xakuna and ${fcst} is 00.

  For forecast: ${EXPID} is xaviaa and ${fcst} is 00,.., 240

The GRIB files created for each of the above mentioned variables are combined together to form a single file um_model_${fcst}_yyyymmdd.grb.

Preparation of HYSPLIT input from NCUM for backward trajectory

To generate backward trajectories based on the NCUM output, ${EXPID}_pb000, ${EXPID}_pe000 and *.pp0 files are used. HYSPLIT requires vertical velocity in Pa/s (ω), which is computed from w (in m/s) (available in the NCUM output file *.pp0).

The vertical velocity, w (m/s) is converted into ω (Pa/s) using the following equation:

$$w = -\frac{\omega}{\rho g} \tag{1}$$

$$\rho = \frac{P}{R_g T(K)} \tag{2}$$

where $R_g = 287.058$ J/kgK, $g = 9.80665$ m/s^2.

All the required fields are written into a GRIB ncum_${HR}z.grb file, which is generated for each cycle making use of the utility gfs2grib.sh. More details on this utility are given in Mohandas (2014). The files for all the four cycles are combined to produce ncum_yyyymmdd_day.grb. The above process is repeated for "n" days depending on how many days (*n*-day) back trajectory has to be computed. The GRIB file ncum_yyyymmdd_day.grb is combined for "n" days into a file ncum_yyyymmdd_nday.grb.

Preparation of HYSPLIT input from NCUM for forward trajectory

To generate forward trajectories the NCUM output files ${EXPID}_pb0${fcst}, ${EXPID}_pd0${fcst}, ${EXPID}_pe0${fcst} and *.pp0 are used where ${fcst} depends on the number of days for which the trajectory forecast has to be computed. A GRIB file created contains the forecast field (um_model_${fcst}.grb). From this GRIB file the required fields at every 3 hourly forecast is extracted and saved in the file ncum_${fcst}_03h.grb, ncum_${fcst}_06h.grb, …, ncum_${fcst}_21h.grb and ncum_${fcst}_24h.grb respectively for each 3h forecast. The files ncum_00z_03.grb, ncum_00z_06.grb, …, ncum_00z_246.grb are combined to give a file for a day as ncum_yyyymmdd_nday.grb.

The script 'bkwd_frwd_traj.sh' is set up to compute the backward/forward trajectories. It has the option to enter the date (in yyyymmdd), type of trajectory required (forward or backward) and the number of days for which the trajectory has to be determined. The model to be used to calculate trajectories can also be selected. Details of the script is given in Appendix-I.

2.3. Preparation of NGFS and NCUM files in the ARL format

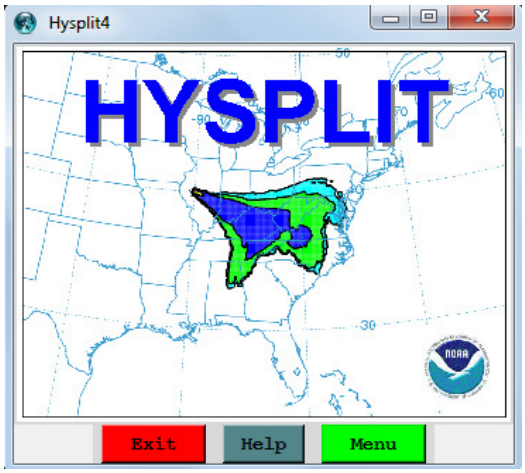
To convert the above created NGFS and NCUM files in the GRIB format into HYSPLIT compatible format (ARL format), ARL utilities are used. To facilitate this, "metprog" of ARL is installed in the IBM machine. All source code and scripts related to the pre-processing system is available at /gpfs1/home/umprod/util/HYSPLIT/. For conversion of both NGFS and NCUM pre-processed files into ARL format, grib2arl programme is used. The usage of grib2arl is given below:

grib2arl –i(input GRIB file) –g3

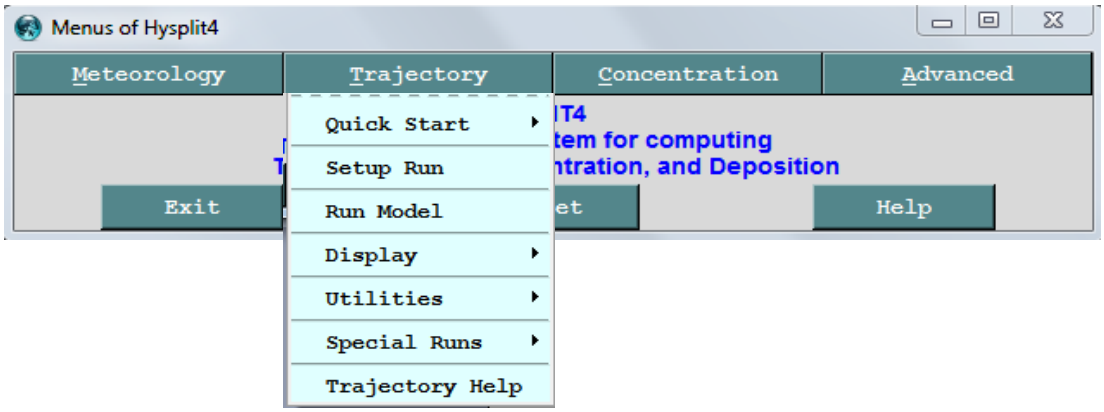
The GRIB file created for each day is given as the input file that creates DATA.ARL, which is HYSPLIT compatible and can be directly used in the HYSPLIT model. The pre-processed input GRIB files of NGFS are gfs_yyyymmdd_nday.grb (backward trajectory) and gfs_yyyymmdd.grb (forward trajectory). The input GRIB file for NCUM is ncum_yyyymmdd_nday.grb (both backward and forward trajectory).

3. Preparation of HYSPLIT trajectories using GUI

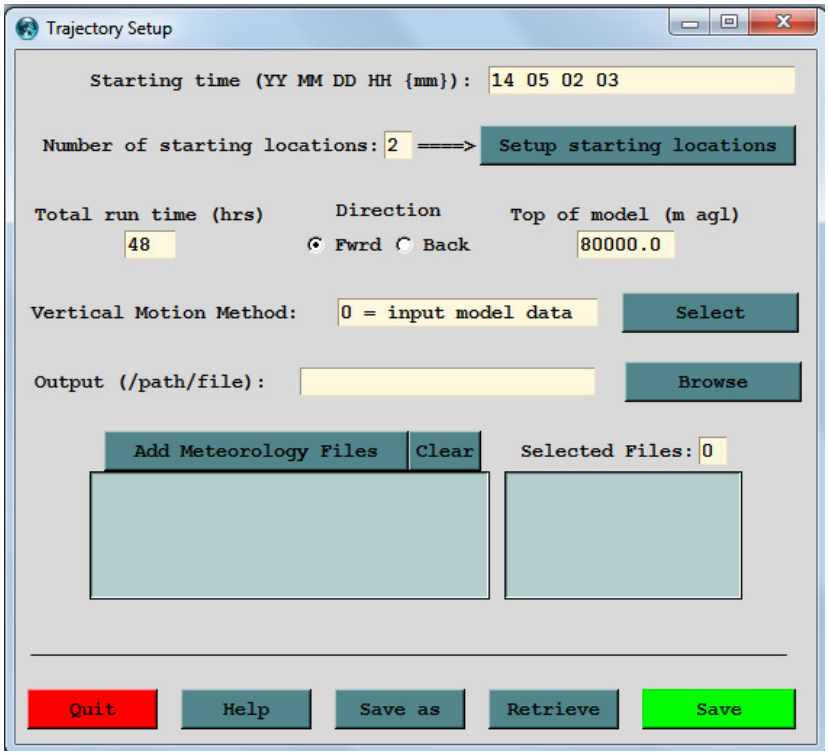
The HYSPLIT is installed at the location /gpfs1/software/hysplit. The Tk graphical user interface (version 8.5) has to be added before running the HYSPLIT. From the location /gpfs1/software/hysplit/trunk/working the script hysplit4.tcl is run, the following window popes up.



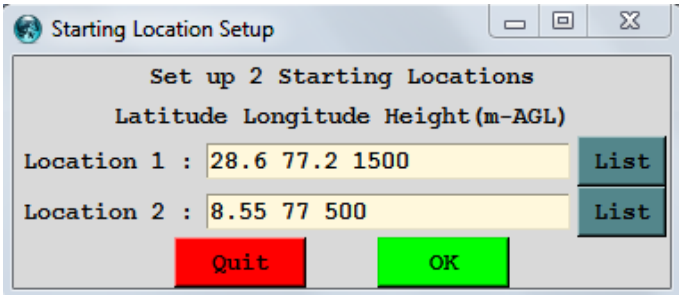
From the above window select *Menu* that lead to the next window as shown below:



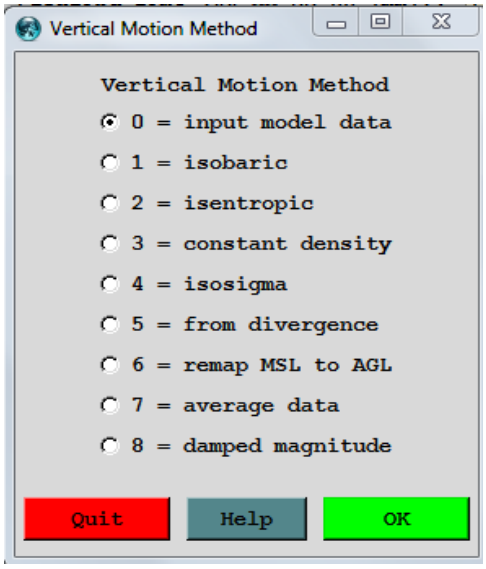
From the above window go to *Trajectory* → *Setup Run*, which brings the menu shown below.



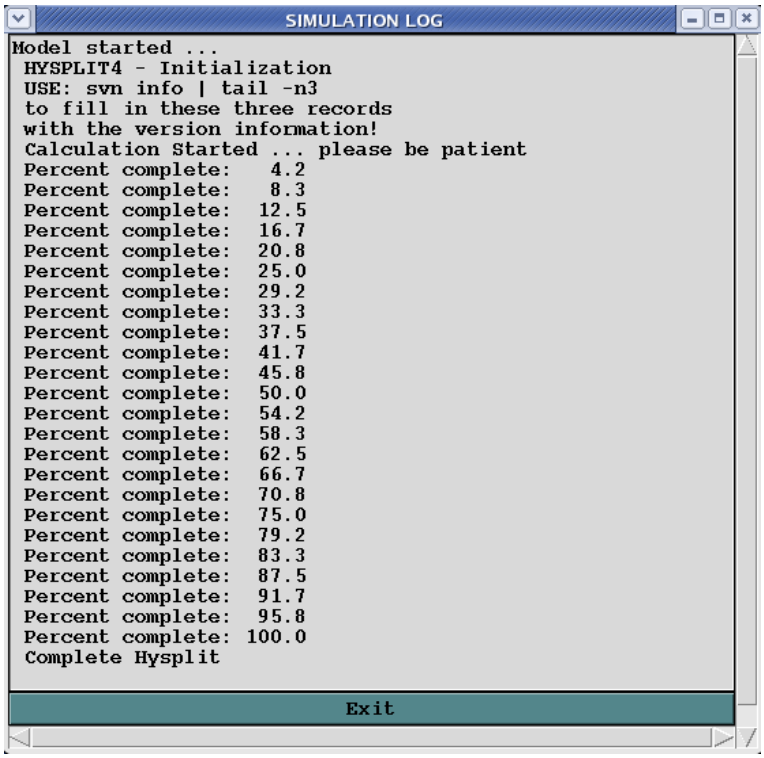
In the above menu, *Starting time* is the time when the trajectories to/from a location are computed. For backward trajectory HH can be 00, 06, 12 and 18 and for forward trajectory 06, 12, 18,…, 240 (NGFS) and 03, 06, 09,…, 246 (NCUM). The *Starting location* can be single or multiple, which is mentioned in *number of starting locations*. The location position is in degrees and decimal (west and south are negative). The height is entered as meters above ground level as shown in the window below:



Total run time hours corresponds to the duration of the calculation in hours. Backward (Forward) calculations are configured by setting the run time to a negative (positive) value. For example, if it is for 5-days then the total run time hours is -120 (backward trajectory) or 120 (forward trajectory). *Top of model* sets the vertical limit of the internal meteorological grid. If calculations are not required above a certain level, fewer meteorological data are processed. It is taken as 60 km (NGFS) and 80 km (NCUM). The *vertical motion method* by default will use the NWP model's vertical velocity fields. The other options available are shown below:

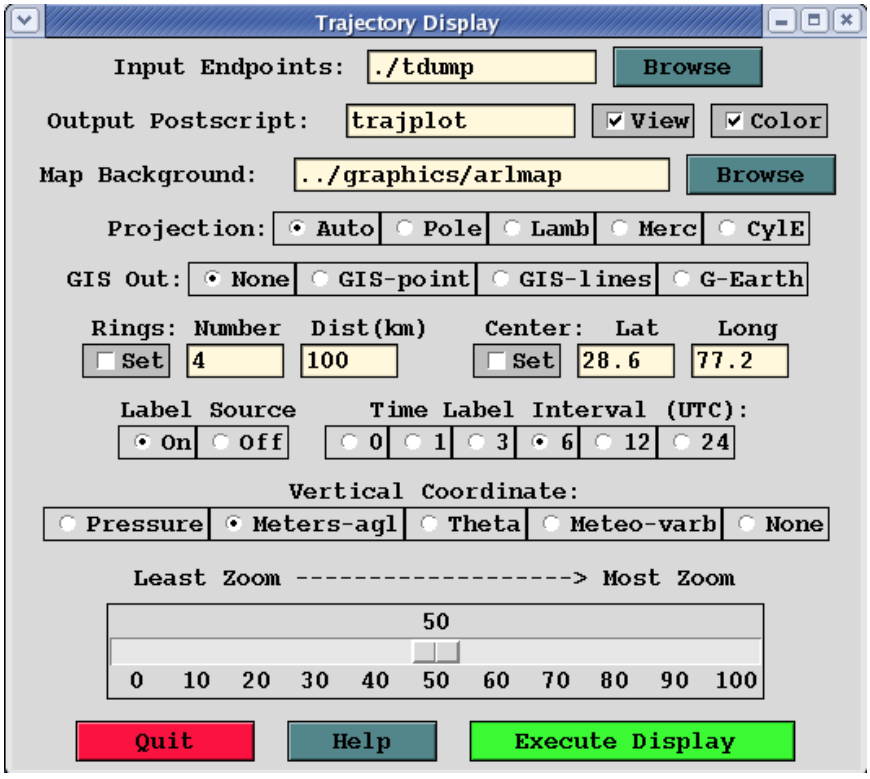


There is an option for the *output*, which has to be in the user area. Another important feature of the main menu is how to select or add atmospheric variables data files. The *clear* button will erase all file selections, then pressing the *Add meteorology files* go to the location where the ARL formatted file is saved. Select the required file and click open and the file will be added to the main menu. For each additional file, it is necessary to click again on the *Add meteorology files* tab. With each new file the selected files number is incremented by one. Once the simulation is configured as required, click the *Save* menu tab. This causes the GUI menu to overwrite the values and closes the menu. Then execute the *Run Model*, the trajectory model runs and the output messages are written to a window, an example of which is shown below:



Successful completion of a simulation will show a similar message. Additional run-time diagnostic messages and other error messages are always written to a file called *MESSAGE*. Depending upon the nature of the error message, a failure in the model initialization process, error messages may also appear in the above window. Once the model has completed, press Exit to close the window.

The trajectory model generates a text output file of end-point positions. The end-point position file is processed by *trajplot* to produce the postscript file. *Trajplot* can be accessed through the GUI. The display program has a variety of command line options, most of which are available through the GUI. There is a one-to-one relationship between the GUI options, an example of which is shown below. There are several features particular to the GUI. The *Trajectory Display* menu will not open unless the *Trajectory Setup* menu is first opened and saved. This procedure sets all the GUI variables, which are shown in the *Display* menu. The map projection computes automatically based upon the location and length of the trajectory. Any graphical package can be used to plot the *trajplot*, which is an ASCII file.



A sample backward (NGFS) and forward (NCUM) trajectory is shown in Figure 1. The path traced by the air mass 3-days before reaching the location (marked by black star) is evident from Figure 1a. Figure 1b shows the movement of the air mass from the marked location in the next 3-days.

4. Conclusions

A pre-processing system is developed for the use of NGFS and NCUM analysis and forecast fields in the HYSPLIT model. A description of the pre-processing package is given in this report. The report also describes the HYSPLIT_4 GUI through which the HYSPLIT model can run. Few examples of the situations where the trajectory model studies are important are given below:

- During the break monsoon condition, the backward trajectories will help in identifying the location from where the air mass is coming.
- During winter season northern parts of India is affected by fog; the trajectories can be used to determine if stagnant air mass is prevailing over the region and hence, a forecast can be made.
- Forward trajectories give information on the airflow reaching a location, which is a useful tool during certain events like biomass burning, etc.
- These trajectories can be effectively used to identify the possible source regions and transport features.

Acknowledgment

We are thankful to the NOAA Air Resources Laboratory for providing the HYSPLIT transport and dispersion model.

Figures

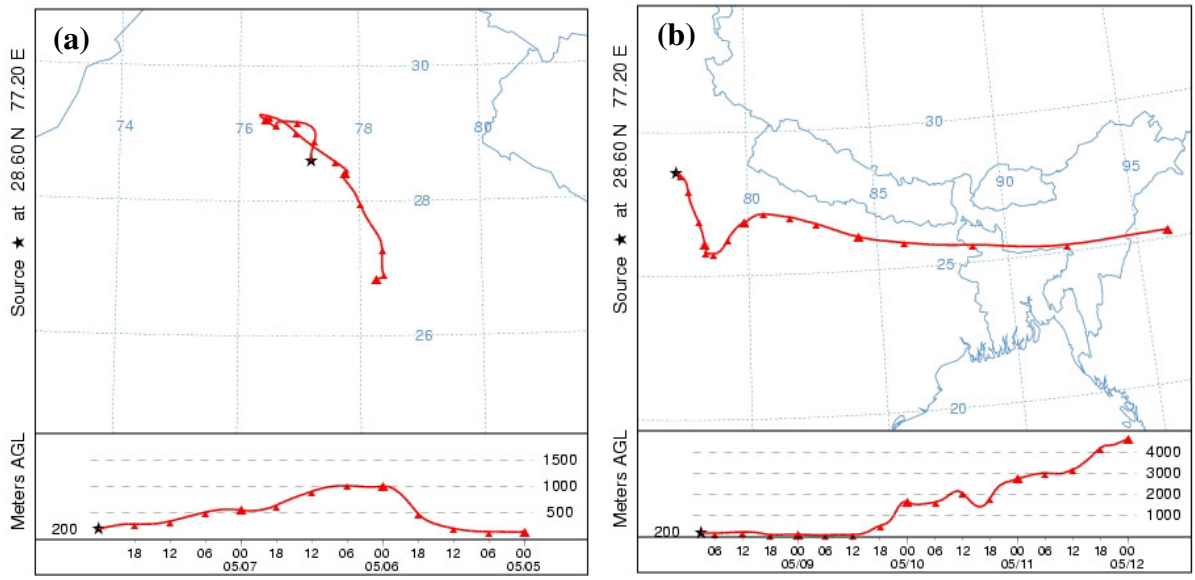


Figure 1. The 3-day (a) backward trajectory ending at 00 UTC of 8th May 2014 using NGFS and (b) forward trajectory starting at 03 UTC of 8th May 2014 using NCUM.

Appendix-I

Model data pre-processing script developed at NCMRWF

Main Script: bkwd_frwd_traj.sh

```
#!/bin/sh
set +x
#-------------------------------------------------------------------
echo 'Enter the date (in yyyymmdd):'
read PDY
yr=`echo $PDY | cut -c1-4`
mnth=`echo $PDY | cut -c5-6`
day=`echo $PDY | cut -c7-8`
#-------------------------------------------------------------------
echo 'Enter the model to calculate the trajectories'
echo '1 for GFS and 2 for NCUM'
read MODEL
#-------------------------------------------------------------------
echo 'Enter the required trajectory'
echo '1 for Backward and 2 for Forward'
read TRAJ
#-------------------------------------------------------------------
echo 'Enter the number of days for the trajectory analysis'
read NN
#-------------------------------------------------------------------
if [ -d output ]
then
 echo ' The directory output exist'
else
 mkdir output
fi
#-------------------------------------------------------------------
if [ ${MODEL} -eq 1 -a ${TRAJ} -eq 1 ]
then
 sed -e "1,\$s/yr/$yr/g" -e "1,\$s/mnth/${mnth}/g" -e
"1,\$s/DD/${day}/g" -e "1,\$s/ND/${NN}/g" gfs_bkwd_traj.sh > run.sh
 chmod +x run.sh
 ./run.sh
elif [ ${MODEL} -eq 1 -a ${TRAJ} -eq 2 ]
then
 sed -e "1,\$s/yr/$yr/g" -e "1,\$s/mnth/${mnth}/g" -e
"1,\$s/DD/${day}/g" -e "1,\$s/ND/${NN}/g" gfs_frwd_traj.sh > run.sh
 chmod +x run.sh
 ./run.sh
elif [ ${MODEL} -eq 2 -a ${TRAJ} -eq 1 ]
then
 sed -e "1,\$s/yr/$yr/g" -e "1,\$s/mnth/${mnth}/g" -e
"1,\$s/DD/${day}/g" -e "1,\$s/NN/${NN}/g" ncum_bkwd_traj.sh > run.sh
 chmod +x run.sh
 ./run.sh
elif [ ${MODEL} -eq 2 -a ${TRAJ} -eq 2 ]
then
 sed -e "1,\$s/yr/$yr/g" -e "1,\$s/mnth/${mnth}/g" -e
"1,\$s/DD/${day}/g" -e "1,\$s/NN/${NN}/g" ncum_frwd_traj.sh > run.sh
 chmod +x run.sh
```

```
 ./run.sh
fi
#-----------------------------------------------------------------
rm run.sh
#-----------------------------------------------------------------
echo 'Data in the directory output is given as an input to the
HYSPLIT model'
```

NGFS backward trajectory: gfs_bkwd_traj.sh

```
#!/bin/sh
set -x

UTILDIR=/gpfs1/home/exp/gfs/nwprod/util/exec
ln -s /gpfs1/home/raghu/bin/advday
#-----------------------------------------------------------------
pp=0
while [ ${pp} -le ND ]
 do
  advday /DDmnthyr -${pp} yyyymmdd >day
  day_1=`cat day`
#-----------------------------------------------------------------
  for HR in 00 06 12 18;do
#echo '---------Getting 00 06 12 18 UT data from GFS area----------'
   ln -s
/gpfs1/home/exp/gfs/nwdata/gdas/prod/gdas.${day_1}/gdas1.t${HR}z.pgr
bf00 .
#---------------Conversion of model data to NCEP format-----------
#-----------------------------For ${HR} UT-------------------------
   $UTILDIR/copygb -x -g3 gdas1.t${HR}z.pgrbf00 gfs_${HR}.grb
#--------------------Extracting geopotential height----------------
   wgrib gfs_${HR}.grb | egrep
"(^1:|^2:|^3:|^4:|^5:|^6:|^7:|^8:|^9:|^10:|^11:|^12:|^13:|^14:|^15:|
^16:|^17:|^18:|^19:|^20:|^21:|^340:)" | wgrib -i gfs_${HR}.grb -grib
-o gfs_t${HR}z.grb
#------------------------Extracting temperature-------------------
   wgrib gfs_${HR}.grb | egrep
"(^27:|^28:|^29:|^30:|^31:|^32:|^33:|^34:|^35:|^36:|^37:|^38:|^39:|^
40:|^41:|^42:|^43:|^44:|^45:|^46:|^47:|^381:)" | wgrib -i
gfs_${HR}.grb -grib -append -o gfs_t${HR}z.grb
#-----------------Extracting pressure vertical velocity-----------
   wgrib gfs_${HR}.grb | egrep
"(^53:|^54:|^55:|^56:|^57:|^58:|^59:|^60:|^61:|^62:|^63:|^64:|^65:|^
66:|^67:|^68:|^69:|^70:|^71:|^72:|^73:)" | wgrib -i gfs_${HR}.grb -
grib -append -o gfs_t${HR}z.grb
#--------------------Extracting relative humidity-----------------
   wgrib gfs_${HR}.grb | egrep
"(^74:|^75:|^76:|^77:|^78:|^79:|^80:|^81:|^82:|^83:|^84:|^85:|^86:|^
87:|^88:|^89:|^90:|^91:|^92:|^93:|^94:)" | wgrib -i gfs_${HR}.grb -
grib -append -o gfs_t${HR}z.grb
#------------------------Extracting u wind----------------------
   wgrib gfs_${HR}.grb | egrep
"(^170:|^172:|^174:|^176:|^178:|^180:|^182:|^184:|^186:|^188:|^190:|
```

```
^192:|^194:|^196:|^198:|^2${HR}:|^202:|^204:|^206:|^208:|^210:|^386:
)" | wgrib -i gfs_${HR}.grb -grib -append -o gfs_t${HR}z.grb
#--------------------------Extracting v wind----------------------
   wgrib gfs_${HR}.grb | egrep
"(^171:|^173:|^175:|^177:|^179:|^181:|^183:|^185:|^187:|^189:|^191:|
^193:|^195:|^197:|^199:|^201:|^203:|^205:|^207:|^209:|^211:|^387:)"
| wgrib -i gfs_${HR}.grb -grib -append -o gfs_t${HR}z.grb
#------------------Extracting PBLH and Press at surface -----------
   wgrib gfs_${HR}.grb | egrep "(^383:|^324:)" | wgrib -i
gfs_${HR}.grb -grib -append -o gfs_t${HR}z.grb
  done
#---------------------------------------------------------------------
 rm gdas1*
 cat  gfs_t00z.grb gfs_t06z.grb gfs_t12z.grb gfs_t18z.grb >
gfs_${day_1}.grb
 rm gfs_t*z.grb
 rm gfs_??.grb day
#---------------------------------------------------------------------
pp=$(($pp+1))
done
rm advday
#---------------------------------------------------------------------
cat gfs_yr????.grb > gfs_yrmnthDD_NDday.grb
rm gfs_yr????.grb
#---------------------------------------------------------------------
grib2arl -igfs_yrmnthDD_NDday.grb -g3
mv DATA.ARL ./output/DATA.ARL_gfs_yrmnthDD_NDday_bkwd
rm gfs_yrmnthDD_NDday.grb
#---------------------------------------------------------------------
rm CFG_GRIB CFG_ARL MESSAGE ARLTIME
#---------------------------------------------------------------------
echo 'Output file is in ./output'
echo 'File name is DATA.ARL_gfs_yrmnthDD_NDday_bkwd'
```

NGFS forward trajectory: gfs_frwd_traj.sh

```
#!/bin/sh
set -x

export HR=00
export PDY=yrmnthDD$HR
export INDIR='.'
#export NN=ND
#---------------------------------------------------------------------
UTILDIR=/gpfs1/home/exp/gfs/nwprod/util/exec
UTIL=/gpfs1/home/liji/util
#---------------------------------------------------------------------
fcst=06
tt=$((ND+1))
pp=$(($tt \* 24))

while [ ${fcst} -le ${pp} ]
 do
#echo '---------------Getting data from GFS area------------------'
```

```
  ln -s
/gpfs1/home/exp/gfs/nwdata/post/gdas.yrmnthDD/gdas1.t${HR}z.grbf${fc
st} .
#---------------Conversion of model data to NCEP format-----------
  $UTILDIR/copygb -x -g3 gdas1.t${HR}z.grbf${fcst}
gfs_model_${fcst}.grb
#  mv gdas1.t${HR}z.grbf${fcst} gfs_model_${fcst}.grb
#-------------------Extracting geopotential height----------------
  wgrib gfs_model_${fcst}.grb | egrep
"(^1:|^2:|^3:|^4:|^5:|^6:|^7:|^8:|^9:|^11:|^13:|^15:|^17:|^19:|^21:|
^340:)" | wgrib -i gfs_model_${fcst}.grb -grib -o
gfs_${HR}_${fcst}h.grb
#-----------------------Extracting temperature--------------------
  if [ ${fcst} -eq 00 ]
  then
   wgrib gfs_model_${fcst}.grb | egrep
"(^27:|^28:|^29:|^30:|^31:|^32:|^33:|^34:|^35:|^37:|^39:|^41:|^43:|^
45:|^47:|^381:)" | wgrib -i gfs_model_${fcst}.grb -grib -append -o
gfs_${HR}_${fcst}h.grb
  else
   wgrib gfs_model_${fcst}.grb | egrep
"(^27:|^28:|^29:|^30:|^31:|^32:|^33:|^34:|^35:|^37:|^39:|^41:|^43:|^
45:|^47:|^406:)" | wgrib -i gfs_model_${fcst}.grb -grib -append -o
gfs_${HR}_${fcst}h.grb
  fi
#---------------Extracting pressure vertical velocity-------------
  wgrib gfs_model_${fcst}.grb | egrep
"(^53:|^54:|^55:|^56:|^57:|^58:|^59:|^60:|^61:|^63:|^65:|^67:|^69:|^
71:|^73:)" | wgrib -i gfs_model_${fcst}.grb -grib -append -o
gfs_${HR}_${fcst}h.grb
#----------------------Extracting relative humidity----------------
  wgrib gfs_model_${fcst}.grb | egrep
"(^74:|^75:|^76:|^77:|^78:|^79:|^80:|^81:|^82:|^84:|^86:|^88:|^90:|^
92:|^94:)" | wgrib -i gfs_model_${fcst}.grb -grib -append -o
gfs_${HR}_${fcst}h.grb
#--------------------------Extracting u wind----------------------
  if [ ${fcst} -eq 00 ]
  then
   wgrib gfs_model_${fcst}.grb | egrep
"(^170:|^172:|^174:|^176:|^178:|^180:|^182:|^184:|^186:|^190:|^194:|
^198:|^202:|^206:|^210:|^386:)" | wgrib -i gfs_model_${fcst}.grb -
grib -append -o gfs_${HR}_${fcst}h.grb
  else
   wgrib gfs_model_${fcst}.grb | egrep
"(^170:|^172:|^174:|^176:|^178:|^180:|^182:|^184:|^186:|^190:|^194:|
^198:|^202:|^206:|^210:|^428:)" | wgrib -i gfs_model_${fcst}.grb -
grib -append -o gfs_${HR}_${fcst}h.grb
  fi
#--------------------------Extracting v wind----------------------
  if [ ${fcst} -eq 00 ]
  then
  wgrib gfs_model_${fcst}.grb | egrep
"(^171:|^173:|^175:|^177:|^179:|^181:|^183:|^185:|^187:|^191:|^195:|
^199:|^203:|^207:|^211:|^387:)" | wgrib -i gfs_model_${fcst}.grb -
grib -append -o gfs_${HR}_${fcst}h.grb
  else
```

```
  wgrib gfs_model_${fcst}.grb | egrep
"(^171:|^173:|^175:|^177:|^179:|^181:|^183:|^185:|^187:|^191:|^195:|
^199:|^203:|^207:|^211:|^429:)" | wgrib -i gfs_model_${fcst}.grb -
grib -append -o gfs_${HR}_${fcst}h.grb
  fi
#---------------Extracting PBLH and Press at surface---------------
  if [ ${fcst} -eq 00 ]
  then
   wgrib gfs_model_${fcst}.grb | egrep "(^383:|^324:)" | wgrib -i
gfs_model_${fcst}.grb -grib -append -o gfs_${HR}_${fcst}h.grb
  else
   wgrib gfs_model_${fcst}.grb | egrep "(^413:|^324:)" | wgrib -i
gfs_model_${fcst}.grb -grib -append -o gfs_${HR}_${fcst}h.grb
  fi
#------------------------------------------------------------------
  ff=$(($fcst+6))
  if [ $ff -lt 10 ]
  then
   fcst=0$ff
  else
   fcst=$ff
  fi
done
#------------------------------------------------------------------
rm gdas1*
cat gfs_00_*.grb > gfs_yrmnthDD.grb
rm gfs_model_??.grb gfs_00_*.grb
#--------------------Conversion to ARL format---------------------
grib2arl -igfs_yrmnthDD.grb -g3
mv DATA.ARL ./output/DATA.ARL_gfs_yrmnthDD_NDday_frwd
rm gfs_yrmnthDD.grb
#------------------------------------------------------------------
rm CFG_GRIB CFG_ARL MESSAGE ARLTIME
#------------------------------------------------------------------
echo 'Output file is in ./output'
echo 'File name is DATA.ARL_gfs_yrmnthDD_NDday_frwd'
```

NCUM backward trajectory: ncum_bkwd_traj.sh

```
#!/bin/sh
set -x

UTIL=/gpfs1/home/liji/util
ln -s /gpfs1/home/raghu/bin/advday
#------------------------------------------------------------------
fcst=00
pp=0
HR=0

while [ ${pp} -le NN ]
 do
  advday /DDmnthyr -${pp} yyyymmdd >day1
  day_1=`cat day1`
  export PDY=${day_1}$HR
```

```
  export INDIR='.'
#-----------------------------------------------------------------
#echo '-------------Getting data from UMprod area-----------------
if [ ${day_1} -lt 20140501 ]
  then
   ln -s
/gpfs1/home/umprod/PS28IN_UMPROD/UM/${day_1}/00/*_pb0${fcst} .
   ln -s
/gpfs1/home/umprod/PS28IN_UMPROD/UM/${day_1}/00/*_pe0${fcst} .
   ln -s /gpfs1/home/umprod/PS28IN_UMPROD/UM/${day_1}/00/*.pp0 .
  else
   ln -s /gpfs1/home/umfcst/NCUM/fcst/${day_1}/00/xakuna_pb0${fcst}
.
   ln -s /gpfs1/home/umfcst/NCUM/fcst/${day_1}/00/xakuna_pe0${fcst}
.
   ln -s /gpfs1/home/umfcst/NCUM/fcst/${day_1}/00/*.pp0 .
  fi
#----------Conversion of model data to NCEP format-----------------
#--------For ugrd vgrd hgt tmp rh vvel on press lev----------------
for var in ugrd vgrd hgt tmp rh vvel; do
   umfld2grib.sh *.pp0 ${var} -1 0 0 24 1 -1 1 360 181 0.0 359.0 1.0
-90.0 90.0 1.0
  done
#----------------------For u10m v10m-------------------------------
for var1 in u10m v10m ; do
   umfld2grib.sh *_pe0${fcst} ${var1} -1 0 1 2 3 10 1 360 181 0.0
359.0 1.0 -90.0 90.0 1.0
  done
#-----------------------For t2m-------------------------------------
umfld2grib.sh *_pe0${fcst} t2m -1 0 1 2 3 1 1 360 181 0.0 359.0 1.0
-90.0 90.0 1.0
#----------------For pres hpbl hgt surface-------------------------
umfld2grib.sh *_pe0${fcst} pres -1 0 1 2 0 -1 1 360 181 0.0 359.0
1.0 -90.0 90.0 1.0
  umfld2grib.sh *_pb0${fcst} hpbl -1 0 1 2 0 -1 1 360 181 0.0 359.0
1.0 -90.0 90.0 1.0
  umfld2grib.sh *.pp0 hgtsfc -1 0 0 24 0 1 1 360 181 0.0 359.0 1.0 -
90.0 90.0 1.0
#-----------------------------------------------------------------
cat ugrd.grb vgrd.grb hgt.grb tmp.grb rh.grb vvel.grb u10m.grb
v10m.grb t2m.grb hpbl.grb pres.grb hgtsfc.grb >
um_model_${fcst}_${day_1}.grb
  rm ugrd.grb vgrd.grb hgt.grb tmp.grb rh.grb vvel.grb u10m.grb
v10m.grb t2m.grb hpbl.grb pres.grb hgtsfc.grb output.grb
#-----------------------------------------------------------------
#-------------------Extracting u wind-----------------------------
wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^1:|^2:|^3:|^4:|^5:|^6:|^7:|^8:|^9:|^10:|^11:|^12:|^13:)" | wgrib
-i um_model_${fcst}_${day_1}.grb -grib -o var_${day_1}.grb
#-------------------Extracting v wind-----------------------------
wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^199:|^200:|^201:|^202:|^203:|^204:|^205:|^206:|^207:|^208:|^209:|
^210:|^211:)" | wgrib -i um_model_${fcst}_${day_1}.grb -grib -append
-o var_${day_1}.grb
#----------------------Extracting HGT-----------------------------
if [ ${day_1} -lt 20140501 ]
```

```
  then
    wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^397:|^398:|^399:|^400:|^401:|^402:|^403:|^404:|^405:|^406:|^407:|
^408:|^409:|^1293:)" | wgrib -i um_model_${fcst}_${day_1}.grb -grib
-append -o var_${day_1}.grb
  else
    wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^397:|^398:|^399:|^400:|^401:|^402:|^403:|^404:|^405:|^406:|^407:|
^408:|^409:|^1204:)" | wgrib -i um_model_${fcst}_${day_1}.grb -grib
-append -o var_${day_1}.grb
  fi
#----------------------Extracting TMP-----------------------------
wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^595:|^596:|^597:|^598:|^599:|^600:|^601:|^602:|^603:|^604:|^605:|
^606:|^607:)" | wgrib -i um_model_${fcst}_${day_1}.grb -grib -o
var_${day_1}_prof.grb
#----------------------Extracting RH------------------------------
wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^793:|^794:|^795:|^796:|^797:|^798:|^799:|^800:|^801:|^802:|^803:|
^804:|^805:)" | wgrib -i um_model_${fcst}_${day_1}.grb -grib -append
-o var_${day_1}.grb
#----------------------Extracting VVEL----------------------------
wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^991:|^992:|^993:|^994:|^995:|^996:|^997:|^998:|^999:|^1000:|^1001
:|^1002:|^1003:)" | wgrib -i um_model_${fcst}_${day_1}.grb -grib -
append -o var_${day_1}_prof.grb
#------------Extracting u10 v10 TMP2m HPBL Pres sfc---------------
if [ ${day_1} -lt 20140501 ]
  then
    wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^1189:|^1213:|^1237:|^1261:|^1269:)" | wgrib -i
um_model_${fcst}_${day_1}.grb -grib -o var_${day_1}_sfc.grb
  else
    wgrib um_model_${fcst}_${day_1}.grb | egrep
"(^1191:|^1194:|^1197:|^1199:|^1203:)" | wgrib -i
um_model_${fcst}_${day_1}.grb -grib -o var_${day_1}_sfc.grb
  fi
#--------------------------------------------------------------------
echo "${day_1}00" > newdate
  for var1 in ugrd vgrd ; do
    gfs2grib.sh var_${day_1}_sfc.grb ${var1} -1 0 0 0 3 10 -101
  done
  gfs2grib.sh var_${day_1}_sfc.grb tmp -1 0 0 0 3 1 -101
  for var2 in pres hpbl ; do
    gfs2grib.sh var_${day_1}_sfc.grb ${var2} -1 0 0 0 0 -1 -101
  done

  cat ugrd.grb vgrd.grb tmp.grb pres.grb hpbl.grb >
var_mod_${day_1}_sfc.grb
  rm ugrd.grb vgrd.grb tmp.grb pres.grb hpbl.grb
var_${day_1}_sfc.grb
  rm *.grib1 newdate
#--------------------------------------------------------------------
rm *_pb0${fcst} *_pe0${fcst} *.pp0 um_model_${fcst}_${day_1}.grb
#--------------------------------------------------------------------
sed -e "1,\$s/day/${day_1}/g" ncum_run_bkwd.sh > run1.sh
```

```
  chmod +x run1.sh
  ./run1.sh

  cat ncum_*z.grb  > ncum_${day_1}_day.grb
  rm ncum_*z.grb

  pp=$(($pp+1))
done
#-----------------------------------------------------------------
cat ncum_yr????_day.grb > ncum_yrmnthDD_NNday.grb
rm ncum_yr????_day.grb
#------------------Conversion to ARL format-----------------------
grib2arl -incum_yrmnthDD_NNday.grb -g3
mv DATA.ARL ./output/DATA.ARL_ncum_yrmnthDD_NNday_bkwd
rm ncum_yrmnthDD_NNday.grb advday day1
#-----------------------------------------------------------------
rm CFG_GRIB CFG_ARL MESSAGE ARLTIME
#-----------------------------------------------------------------
echo 'Output file is in ./output'
echo 'File name is DATA.ARL_ncum_yrmnthDD_NNday_bkwd'
```

ncum_run_bkwd.sh

```
#!/bin/sh
set -x

for HR in 00 06 12 18 ; do
 export PDY=day${HR}
 export INDIR='.'
 echo "day${HR}" > newdate
#--------------------At different pressure levels-------------------
if [ ${HR} -gt 00 ]
 then
   for var in ugrd vgrd hgt rh ; do
     for LEV in 1000 950 925 850 700 600 500 400 300 200 100 ; do
       gfs2grib.sh var_day.grb ${var} -1 0 0 0 1 ${LEV} -100
       mv ${var}.grb ${var}_${LEV}hPa_${HR}.grb
     done
     cat ${var}_*hPa_${HR}.grb > ${var}_${HR}.grb
     rm ${var}_*hPa_${HR}.grb
   done
   cat ugrd_${HR}.grb vgrd_${HR}.grb hgt_${HR}.grb rh_${HR}.grb >
var_day_press_${HR}.grb
   rm  ugrd_${HR}.grb vgrd_${HR}.grb hgt_${HR}.grb rh_${HR}.grb
   for var1 in ugrd vgrd ; do
     gfs2grib.sh var_mod_day_sfc.grb ${var1} -1 0 0 0 3 10 -100
   done
   gfs2grib.sh var_day.grb hgtsfc -1 0 0 0 0 1 -100
   gfs2grib.sh var_mod_day_sfc.grb tmp -1 0 0 0 3 1 -100
   for var2 in pres hpbl ; do
     gfs2grib.sh var_mod_day_sfc.grb ${var2} -1 0 0 0 0 -1 -100
   done
   cat ugrd.grb vgrd.grb hgtsfc.grb tmp.grb pres.grb hpbl.grb >
var_day_sfc_${HR}.grb
```

```
   rm ugrd.grb vgrd.grb hgtsfc.grb tmp.grb pres.grb hpbl.grb
 else
   cp var_day.grb var_day_press_${HR}.grb
   cp var_mod_day_sfc.grb var_day_sfc_${HR}.grb
 fi

 for LEV in 1000 950 925 850 700 600 500 400 300 200 100 ; do
   gfs2grib.sh var_day_prof.grb tmp -1 0 0 0 1 ${LEV} -100
   gfs2grib.sh var_day_prof.grb vvel -1 0 0 0 1 ${LEV} -100
#-----------------Conversion from w to omega-----------------------
cc=`echo $LEV | awk '{print $1 * (-3.4162608)}'`
   cdo div vvel.grb tmp.grb temp.grb
   cdo mulc,$cc temp.grb vvel_temp.grb
#------------------------------------------------------------------
mv tmp.grb tmp_${LEV}hPa_${HR}.grb
   mv vvel_temp.grb vvel_${LEV}hPa_${HR}.grb
   rm vvel.grb temp.grb
 done
 cat tmp_*hPa_${HR}.grb > tmp_${HR}.grb
 cat vvel_*hPa_${HR}.grb > vvel_${HR}.grb
 rm tmp_*hPa_${HR}.grb vvel_*hPa_${HR}.grb

 cat tmp_${HR}.grb vvel_${HR}.grb > var_press_${HR}.grb
 rm tmp_${HR}.grb vvel_${HR}.grb
#------------------------------------------------------------------
cat var_day_press_${HR}.grb var_day_sfc_${HR}.grb
var_press_${HR}.grb > ncum_${HR}z.grb
 rm var_day_press_${HR}.grb var_day_sfc_${HR}.grb
var_press_${HR}.grb
done
#------------------------------------------------------------------
rm var_day.grb var_mod_day_sfc.grb var_day_prof.grb
rm *.grib1 newdate
```

NCUM forward trajectory: ncum_frwd_traj.sh

```
#!/bin/sh
set -x

export HR=00
export PDY=yrmnthDD$HR
export INDIR='.'
#------------------------------------------------------------------
UTILDIR=/gpfs1/home/exp/gfs/nwprod/util/exec
UTIL=/gpfs1/home/liji/util
#------------------------------------------------------------------
pp=0
fcst=00

while [ ${pp} -le NN ]
 do
#echo '-------------Getting data from UMprod area-------------------
if [ yrmnthDD -lt 20140501 ]
  then
```

```
   ln -s
/gpfs1/home/umprod/PS28IN_UMPROD/UM/yrmnthDD/00/*_pb0${fcst} .
   ln -s
/gpfs1/home/umprod/PS28IN_UMPROD/UM/yrmnthDD/00/*_pd0${fcst} .
   ln -s
/gpfs1/home/umprod/PS28IN_UMPROD/UM/yrmnthDD/00/*_pe0${fcst} .
   ln -s /gpfs1/home/umprod/PS28IN_UMPROD/UM/yrmnthDD/00/*.pp0 .
  else
   ln -s /gpfs1/home/umfcst/NCUM/fcst/yrmnthDD/00/xaviaa_pb0${fcst}
.
   ln -s /gpfs1/home/umfcst/NCUM/fcst/yrmnthDD/00/xaviaa_pd0${fcst}
.
   ln -s /gpfs1/home/umfcst/NCUM/fcst/yrmnthDD/00/xaviaa_pe0${fcst}
.
   ln -s /gpfs1/home/umfcst/NCUM/fcst/yrmnthDD/00/*.pp0 .
  fi
#------------Conversion of model data to NCEP format---------------
#------------For ugrd vgrd hgt tmp rh vvel on press lev-------------
for var in ugrd vgrd hgt tmp rh vvel; do
   umfld2grib.sh *_pd0${fcst} ${var} -1 0 3 6 1 -1 1 360 181 0.0
359.0 1.0 -90.0 90.0 1.0
  done
#-----------------------For u10m v10m-----------------------------
for var1 in u10m v10m ; do
   umfld2grib.sh *_pe0${fcst} ${var1} -1 0 1 2 3 10 1 360 181 0.0
359.0 1.0 -90.0 90.0 1.0
  done
#--------------------------For t2m----------------------------------
umfld2grib.sh *_pe0${fcst} t2m -1 0 1 2 3 1 1 360 181 0.0 359.0 1.0
-90.0 90.0 1.0
#-------------------For pres hpbl hgt surface----------------------
umfld2grib.sh *_pe0${fcst} pres -1 0 1 2 0 -1 1 360 181 0.0 359.0
1.0 -90.0 90.0 1.0
  umfld2grib.sh *_pb0${fcst} hpbl -1 0 3 6 0 -1 1 360 181 0.0 359.0
1.0 -90.0 90.0 1.0
  umfld2grib.sh *.pp0 hgtsfc -1 0 0 24 0 1 1 360 181 0.0 359.0 1.0 -
90.0 90.0 1.0
#-----------------------------------------------------------------
cat ugrd.grb vgrd.grb hgt.grb tmp.grb rh.grb vvel.grb u10m.grb
v10m.grb t2m.grb hpbl.grb pres.grb hgtsfc.grb > um_model_${fcst}.grb
  rm ugrd.grb vgrd.grb hgt.grb tmp.grb rh.grb vvel.grb u10m.grb
v10m.grb t2m.grb hpbl.grb pres.grb hgtsfc.grb output.grb
#-----------------------------------------------------------------
#-----------------------Extracting u wind-------------------------
wgrib um_model_${fcst}.grb | egrep
"(^1:|^2:|^3:|^4:|^5:|^6:|^7:|^8:|^9:|^10:|^11:|^12:|^13:|^867:)" |
wgrib -i um_model_${fcst}.grb -grib -o ncum_${fcst}_03h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^19:|^20:|^21:|^22:|^23:|^24:|^25:|^26:|^27:|^28:|^29:|^30:|^31:|^
870:)" | wgrib -i um_model_${fcst}.grb -grib -o ncum_${fcst}_06h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^37:|^38:|^39:|^40:|^41:|^42:|^43:|^44:|^45:|^46:|^47:|^48:|^49:|^
873:)" | wgrib -i um_model_${fcst}.grb -grib -o ncum_${fcst}_09h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^55:|^56:|^57:|^58:|^59:|^60:|^61:|^62:|^63:|^64:|^65:|^66:|^67:|^
876:)" | wgrib -i um_model_${fcst}.grb -grib -o ncum_${fcst}_12h.grb
```

```
  wgrib um_model_${fcst}.grb | egrep
"(^73:|^74:|^75:|^76:|^77:|^78:|^79:|^80:|^81:|^82:|^83:|^84:|^85:|^
879:)" | wgrib -i um_model_${fcst}.grb -grib -o ncum_${fcst}_15h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^91:|^92:|^93:|^94:|^95:|^96:|^97:|^98:|^99:|^100:|^101:|^102:|^10
3:|^882:)" | wgrib -i um_model_${fcst}.grb -grib -o
ncum_${fcst}_18h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^109:|^110:|^111:|^112:|^113:|^114:|^115:|^116:|^117:|^118:|^119:|
^120:|^121:|^885:)" | wgrib -i um_model_${fcst}.grb -grib -o
ncum_${fcst}_21h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^127:|^128:|^129:|^130:|^131:|^132:|^133:|^134:|^135:|^136:|^137:|
^138:|^139:|^888:)" | wgrib -i um_model_${fcst}.grb -grib -o
ncum_${fcst}_24h.grb
#----------------------Extracting v wind--------------------------
wgrib um_model_${fcst}.grb | egrep
"(^145:|^146:|^147:|^148:|^149:|^150:|^151:|^152:|^153:|^154:|^155:|
^156:|^157:|^891:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_03h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^163:|^164:|^165:|^166:|^167:|^168:|^169:|^170:|^171:|^172:|^173:|
^174:|^175:|^894:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_06h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^181:|^182:|^183:|^184:|^185:|^186:|^187:|^188:|^189:|^190:|^191:|
^192:|^193:|^897:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_09h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^199:|^200:|^201:|^202:|^203:|^204:|^205:|^206:|^207:|^208:|^209:|
^210:|^211:|^900:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_12h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^217:|^218:|^219:|^220:|^221:|^222:|^223:|^224:|^225:|^226:|^227:|
^228:|^229:|^903:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_15h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^235:|^236:|^237:|^238:|^239:|^240:|^241:|^242:|^243:|^244:|^245:|
^246:|^247:|^906:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_18h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^253:|^254:|^255:|^256:|^257:|^258:|^259:|^260:|^261:|^262:|^263:|
^264:|^265:|^909:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_21h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^271:|^272:|^273:|^274:|^275:|^276:|^277:|^278:|^279:|^280:|^281:|
^282:|^283:|^912:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_24h.grb
#----------------------Extracting HGT-----------------------------
wgrib um_model_${fcst}.grb | egrep
"(^289:|^290:|^291:|^292:|^293:|^294:|^295:|^296:|^297:|^298:|^299:|
^300:|^301:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_03h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^307:|^308:|^309:|^310:|^311:|^312:|^313:|^314:|^315:|^316:|^317:|
```

```
^318:|^319:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_06h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^325:|^326:|^327:|^328:|^329:|^330:|^331:|^332:|^333:|^334:|^335:|
^336:|^337:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_09h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^343:|^344:|^345:|^346:|^347:|^348:|^349:|^350:|^351:|^352:|^353:|
^354:|^355:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_12h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^361:|^362:|^363:|^364:|^365:|^366:|^367:|^368:|^369:|^370:|^371:|
^372:|^373:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_15h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^379:|^380:|^381:|^382:|^383:|^384:|^385:|^386:|^387:|^388:|^389:|
^390:|^391:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_18h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^397:|^398:|^399:|^400:|^401:|^402:|^403:|^404:|^405:|^406:|^407:|
^408:|^409:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_21h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^415:|^416:|^417:|^418:|^419:|^420:|^421:|^422:|^423:|^424:|^425:|
^426:|^427:|^969:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_24h.grb
#-----------------------Extracting TMP----------------------------
wgrib um_model_${fcst}.grb | egrep
"(^433:|^434:|^435:|^436:|^437:|^438:|^439:|^440:|^441:|^442:|^443:|
^444:|^445:|^915:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_03h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^451:|^452:|^453:|^454:|^455:|^456:|^457:|^458:|^459:|^460:|^461:|
^462:|^463:|^918:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_06h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^469:|^470:|^471:|^472:|^473:|^474:|^475:|^476:|^477:|^478:|^479:|
^480:|^481:|^921:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_09h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^487:|^488:|^489:|^490:|^491:|^492:|^493:|^494:|^495:|^496:|^497:|
^498:|^499:|^924:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_12h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^505:|^506:|^507:|^508:|^509:|^510:|^511:|^512:|^513:|^514:|^515:|
^516:|^517:|^927:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_15h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^523:|^524:|^525:|^526:|^527:|^528:|^529:|^530:|^531:|^532:|^533:|
^534:|^535:|^930:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_18h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^541:|^542:|^543:|^544:|^545:|^546:|^547:|^548:|^549:|^550:|^551:|
^552:|^553:|^933:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_21h.grb
```

```
  wgrib um_model_${fcst}.grb | egrep
"(^559:|^560:|^561:|^562:|^563:|^564:|^565:|^566:|^567:|^568:|^569:|
^570:|^571:|^936:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_24h.grb
#--------------------Extracting RH & HPBL---------------------------
wgrib um_model_${fcst}.grb | egrep
"(^577:|^578:|^579:|^580:|^581:|^582:|^583:|^584:|^585:|^586:|^587:|
^588:|^589:|^937:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_03h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^595:|^596:|^597:|^598:|^599:|^600:|^601:|^602:|^603:|^604:|^605:|
^606:|^607:|^938:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_06h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^613:|^614:|^615:|^616:|^617:|^618:|^619:|^620:|^621:|^622:|^623:|
^624:|^625:|^939:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_09h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^631:|^632:|^633:|^634:|^635:|^636:|^637:|^638:|^639:|^640:|^641:|
^642:|^643:|^940:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_12h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^649:|^650:|^651:|^652:|^653:|^654:|^655:|^656:|^657:|^658:|^659:|
^660:|^661:|^941:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_15h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^667:|^668:|^669:|^670:|^671:|^672:|^673:|^674:|^675:|^676:|^677:|
^678:|^679:|^942:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_18h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^685:|^686:|^687:|^688:|^689:|^690:|^691:|^692:|^693:|^694:|^695:|
^696:|^697:|^943:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_21h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^703:|^704:|^705:|^706:|^707:|^708:|^709:|^710:|^711:|^712:|^713:|
^714:|^715:|^944:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_24h.grb
#--------------------Extracting VVEL & Press surf-------------------
wgrib um_model_${fcst}.grb | egrep
"(^721:|^722:|^723:|^724:|^725:|^726:|^727:|^728:|^729:|^730:|^731:|
^732:|^733:|^947:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_03h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^739:|^740:|^741:|^742:|^743:|^744:|^745:|^746:|^747:|^748:|^749:|
^750:|^751:|^950:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_06h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^757:|^758:|^759:|^760:|^761:|^762:|^763:|^764:|^765:|^766:|^767:|
^768:|^769:|^953:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_09h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^775:|^776:|^777:|^778:|^779:|^780:|^781:|^782:|^783:|^784:|^785:|
^786:|^787:|^956:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_12h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^793:|^794:|^795:|^796:|^797:|^798:|^799:|^800:|^801:|^802:|^803:|
```

```
^804:|^805:|^959:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_15h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^811:|^812:|^813:|^814:|^815:|^816:|^817:|^818:|^819:|^820:|^821:|
^822:|^823:|^962:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_18h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^829:|^830:|^831:|^832:|^833:|^834:|^835:|^836:|^837:|^838:|^839:|
^840:|^841:|^965:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_21h.grb
  wgrib um_model_${fcst}.grb | egrep
"(^847:|^848:|^849:|^850:|^851:|^852:|^853:|^854:|^855:|^856:|^857:|
^858:|^859:|^968:)" | wgrib -i um_model_${fcst}.grb -grib -append -o
ncum_${fcst}_24h.grb
#-------------------------------------------------------------------
rm *_pb0${fcst} *_pd0${fcst} *_pe0${fcst} *.pp0 um_model_${fcst}.grb
#-------------------------------------------------------------------
sed -e "1,\$s/yy/yr/g" -e "1,\$s/mm/mnth/g" -e "1,\$s/dd/DD/g" -e
"1,\$s/forcast/${fcst}/g" ncum_run_frwd.sh > run1.sh
  chmod +x run1.sh
  ./run1.sh
  pp=$(($pp+1))
  fcst=$(($fcst+24))
done
#-------------------------------------------------------------------
cat ncum_${HR}z_*.grb  > ncum_yrmnthDD_NNday.grb
rm ncum_${HR}z_*.grb
#-----------------Conversion to ARL format-----------------------
grib2arl -incum_yrmnthDD_NNday.grb -g3
mv DATA.ARL ./output/DATA.ARL_ncum_yrmnthDD_NNday_frwd
rm ncum_yrmnthDD_NNday.grb
#-------------------------------------------------------------------
rm CFG_GRIB CFG_ARL MESSAGE ARLTIME
#-------------------------------------------------------------------
echo 'Output file is in ./output'
echo 'File name is DATA.ARL_ncum_yrmnthDD_NNday_frwd'
```

ncum_run_frwd.sh

```
#!/bin/sh
set -x

HR=00

export PDY=yymmdd${HR}
export INDIR='.'
F_hr=forcast
#-------------------------------------------------------------------
for FHR in 03 06 09 12 15 18 21 24 ; do
 if [ ${F_hr} -eq 00 ]
 then
  TT=$(($FHR+0))
 elif [ ${F_hr} -eq 24 ]
 then
```

```
  TT=$(($FHR+24))
 elif [ ${F_hr} -eq 48 ]
 then
  TT=$(($FHR+48))
 elif [ ${F_hr} -eq 72 ]
 then
  TT=$(($FHR+72))
 elif [ ${F_hr} -eq 96 ]
 then
  TT=$(($FHR+96))
 elif [ ${F_hr} -eq 120 ]
 then
  TT=$(($FHR+120))
 fi

 if [ ${TT} -lt 10 ]
 then
  T2=0${TT}
 else
  T2=${TT}
 fi
r}.grb
 echo "yymmdd${HR}" > newdate
#------------------At different pressure levels--------------------
for var in ugrd vgrd hgt rh ; do
  for LEV in 1000 950 925 850 700 600 500 400 300 200 100 ; do
   gfs2grib.sh ncum_forcast_${FHR}h.grb ${var} -1 0 ${T2} 0 1 ${LEV}
-101
   mv ${var}.grb ${var}_${LEV}hPa_${T2}.grb
  done

  cat ${var}_*hPa_${T2}.grb > ${var}_${T2}.grb
  rm ${var}_*hPa_${T2}.grb
 done

 for LEV in 1000 950 925 850 700 600 500 400 300 200 100 ; do
  gfs2grib.sh ncum_forcast_${FHR}h.grb tmp -1 0 ${T2} 0 1 ${LEV} -
101
  gfs2grib.sh ncum_forcast_${FHR}h.grb vvel -1 0 ${T2} 0 1 ${LEV} -
101
#--------------------Conversion from w to omega--------------------
cc=`echo $LEV | awk '{print $1 * (-3.4162608)}'`
  cdo div vvel.grb tmp.grb temp.grb
  cdo mulc,$cc temp.grb vvel_temp.grb
#------------------------------------------------------------------
mv tmp.grb tmp_${LEV}hPa_${T2}.grb
  mv vvel_temp.grb vvel_${LEV}hPa_${T2}.grb
  rm temp.grb vvel.grb
 done
 cat tmp_*hPa_${T2}.grb > tmp_${T2}.grb
 cat vvel_*hPa_${T2}.grb > vvel_${T2}.grb
 rm tmp_*hPa_${T2}.grb vvel_*hPa_${T2}.grb

 cat ugrd_${T2}.grb vgrd_${T2}.grb hgt_${T2}.grb tmp_${T2}.grb
rh_${T2}.grb vvel_${T2}.grb > var_press_${T2}.grb
```

```
 rm ugrd_${T2}.grb vgrd_${T2}.grb hgt_${T2}.grb tmp_${T2}.grb
rh_${T2}.grb vvel_${T2}.grb
#--------------------------Near surface----------------------------
for var1 in ugrd vgrd ; do
  gfs2grib.sh ncum_forcast_${FHR}h.grb ${var1} -1 0 ${T2} 0 3 10 -
101
 done

 gfs2grib.sh ncum_forcast_${FHR}h.grb tmp -1 0 ${T2} 0 3 1 -101

 for var2 in pres hpbl ; do
  gfs2grib.sh ncum_forcast_${FHR}h.grb ${var2} -1 0 ${T2} 0 0 -1 -
101
 done

 gfs2grib.sh ncum_forcast_${FHR}h.grb hgt -1 0 ${T2} 0 0 1 -101

 cat ugrd.grb vgrd.grb tmp.grb hpbl.grb pres.grb hgt.grb >
var_surf_${T2}.grb
 rm ugrd.grb vgrd.grb tmp.grb hpbl.grb pres.grb hgt.grb

 cat var_press_${T2}.grb var_surf_${T2}.grb > ncum_${HR}z_${T2}.grb
 rm var_press_${T2}.grb var_surf_${T2}.grb
 rm ncum_forcast_${FHR}h.grb
done
#-----------------------------------------------------------------
-------------------------------------------------------
rm *.grib1 input.grb gfsfile.grb
rm dec.? output.txt newgribheader.txt
rm newdate
```

References

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Mohandas, S. (2014), Utility to convert UM fields file output to NCEP GRIB1 format: A user guide, Technical Report, NMRF/TR/01/2014, 46p, http://www.ncmrwf.gov.in/reports.php.