

Vertical structure

1. Sounding-based upper-air maps, snmap, and gdplot2

We continue our examination of 19-20 December 2012 snow storm and now turn our attention to upper air maps. Today we will use GEMPAK to plot the 300-mb and 850-mb maps from radiosonde data on 12 Z on 20 Dec 2012. We will then analyze the maps as a means to visualize the vertical structure at this time in the life of the frontal cyclone. *You will need the surface analysis from Lab 1 to help answer questions at the end of this exercise.*

The first task is to log onto bat and then 'cd' into the directory you are using for this case study (**cd atsc5007**). It is recommended that you make a new directory for the upper air data, naming the new directory something like 'upperair'. Then 'cd' into this directory to start. The file that we are working with is found in the directory: /netdata/R1/data/ldm/upperair.

This path is long, so you may want to set

```
setenv UA /netdata/R1/data/ldm/upperair
```

The file of interest to plot the upper air data is 201212_upa.gem. This file contains the 19 and 20 Dec 2012 radiosonde data for stations in North America. You can find out what data are in a particular GEMPAK upper air sounding file by using the program **snlist**. We are going to use the program **snmap** to create upper air maps, and then **gdplot2** to contour some variables. The tools you learned from creating surface maps will help out here so refer to the *.nts files that you have saved when you have questions as to the appropriate set of parameters, eg you can use the same domain as before.

Step1: Working with snmap

When you type **snmap**, you will see something that looks like the following:

AREA	Data area	WV
GAREA	Graphics area	WV
SATFIL	Satellite image filename(s)	
RADFIL	Radar image filename(s)	
IMCBAR	Color/ornt/anch/x;y/ln;wd/freq	
SNPARM	Sounding parameter list	;TMPC;;HGHT;DWPC;BRBM
DATTIM	Date/time	LAST
LEVELS	Vertical levels	500
VCOORD	Vertical coordinate type	PRES
SNFILE	Sounding data file	\$GEMDATA/HRCBOB.SND
COLORS	Color list	1
MAP	Map color/dash/width/filter flag	1
MSCALE	fgc;bgc;mask/units/lat;hide/valu	0
LATLON	Line color/dash/width/freq/inc/	1
TITLE	Title color/line/title	1
CLEAR	Clear screen flag	YES
PANEL	Panel loc/color/dash/width/regn	0
DEVICE	Device name x size;y size color	XW
PROJ	Map projection/angles/margins dr	MER
FILTER	Filter data factor	YES
TEXT	Size/fnt/wdth/brdr/N-rot/just/hw	1
LUTFIL	Enhancement lookup table filename	
STNPLT	Txtc/txt attr marker attr stnfil	

Your actual settings may look somewhat different depending if you have run GEMPAK routines from your current working directory previously. Again you will note that not all parameters will need to be set. Many of the parameters will look familiar from previous exercises so jump right in. You probably do not have to play with the FILTER setting, because there are fewer sounding sites than surface stations. For our case here, we will be working with about 90 sounding stations. To start, you will need to set AREA again. It is best to use what worked best for you previously so go back and check your *.nts files saved from the surface map exercise. The *.nts files are simply text files that can be read with any text editor in unix, such as **gedit**. It is thus possible to open the *.nts file without running GEMPAK. Type **gedit** and a window will open, from which you can access the particular file. So if you need to see what worked before, just open the text editor and copy parameters within **gedit** and paste them into your GEMPAK command.

Key parameters for our upper air maps are those listed in SNPARM. Note that for the default setting here, parameters will be plotted in a position such as you would find on a station model for upper air. Needless to say, key parameters should include temperature in °C, height of the isobaric surface, wind barb (use speed in knots, one full barb is 10 kts) and dew point or some other moisture indicator. For the 300 mb map, you can omit dewpoint, because it is so dry up at 300 mb (snparm=;TMPC;;HGHT;;BRBK). For the 850 mb map, however, an arguably more relevant moisture parameter is the dew point depression. This is nothing more than the difference between the temperature and the dew point temperature. Look for low dew point depression values (less than 5°C) to identify areas of high moisture content. On your 850 mb map, plot the dew point depression (in °C) instead of the dewpoint. Use 'help snparm' to find the relevant GEMPAK name of dew point depression. It is your task to create both the 300 mb and 850 mb map for **1200 UTC 20 December 2012**. Here are some requirements:

For each map, plot the radiosonde observations in RED. Also, plot latitudes and longitudes at 10° increments as before, in dashed lines with color 4, thickness 2, labeling each line. Your map should be in Lambert Conformal projection (proj= lcc/25;-95;55) as before. Since you are adding model output on top (see step 2 below), make sure to set CLEAR=NO.

Remember to save your settings, by typing something like "save my_uamap_v1.nts" within this gempak program.

Step 2: Working with GDPLLOT2

We are going to use the program **gdplot2** to create some contours on top of the radiosonde observations. Note that we use gridded model output for this. We will use your own WRF model output. The model output is far richer than the radiosonde dataset, as models are initialized with additional upper-level data sources (esp satellite) and with model output from the previous model run.

See **Appendix A** to convert your WRF model output to a .gem file, which we 'll call dec19_12z.gem (you can choose the filename).

You can find out what grids are in a particular GEMPAK grid file by using the program **gdinfo**. Again, the tools you learned from creating surface and upper level maps will help out here so refer to the *.nts files that you have saved when you have questions regarding the appropriate set of parameters. You can **gedit file.nts** and then cut and paste.

When you type **gdplot2**, you will see something that looks like the following:

GDFILE	Grid file	\$GEMDATA/HRCBOB.GRD
GDATTIM	Grid date/time	LAST
GLEVEL	Grid level	500
GVCORD	Grid vertical coordinate	PRES
PANEL	Panel loc/color/dash/width/regn	0
SKIP	Skip_cntr/skip_plt_x;skip_plt_y	0
SCALE	Scalar scale / vector scale	999
GDPFUN	Scalar grid or vector grid funct	TMPC
TYPE	GDPLLOT2 function processing type	C
CONTUR	Subbox/smooth	0

CINT	Contour interval/min/max	0
LINE	Color/type/width/label/smith/fltr	3
FINT	Fill interval/min/max	0
FLINE	Fill colors/fill types	10-20
HILO	Color/symbol/rng/rad/cnt/intp	
HLSYM	HILO txt size/posn/font/wdth/hw	
CLRBAR	Color/ornt/anch/x;y/ln/wd/freq t	
WIND	Wind symbol/siz/wdth/typ/hdsz	BM1
REFVEC	Mag;x;y;txtsiz/font/wdth/HW;labl	
TITLE	Title color/line/title	1
TEXT	Size/fnt/wdth/brdr/N-rot/just/hw	1
CLEAR	Clear screen flag	YES
GAREA	Graphics area	WV
IJSKIP	Iskp;Istrt;Istp/Jskp;Jstrt;Jstp	
PROJ	Map projection/angles/margins dr	MER
MAP	Map color/dash/width/filter flag	1
MSCALE	fgc;bgc;mask/units/lat;hide/valu	0
LATLON	Line color/dash/width/freq/inc/l	
DEVICE	Device name x size;y size color	XW
STNPLT	Txtc txt attr marker attr stnfil	
SATFIL	Satellite image filename(s)	
RADFIL	Radar image filename(s)	
IMCBAR	Color/ornt/anch/x;y/ln/wd/freq	
LUTFIL	Enhancement lookup table filename	
STREAM	lines/arrows/stop/slow/scale	
POSN	Position / Text format	0
COLORS	Color list	1
MARKER	Marker color/type/size/width/hw	0
GRDLBL	Grid point label color	0
FILTER	Filter data factor	YES

Your actual settings may look somewhat different depending if you have run GEMPAK routines from your current working directory previously. Again you will note that not all parameters will need to be set. Most of you are familiar with **gdplot2** from your ATSC 5004 Dynamics class, so jump right in.

To start, you will need to set GDFILE to the input file. You can use a **softlink**, and simply refer to the file in your directory that has a soft link to your .gem grid file. For details, see **Appendix B**. GDATTIM is the time of interest and we will set that to 121220/1200. (This assumes your 24 hour forecast; it is equivalent to GDATTIM=121219/1200F2400) Remember that GEMPAK help is only a few keystrokes away by typing, for example, 'help GDAT' to get help with the expected format. We will start with the 300 mb map so set 'GLEVEL=300'. GVCORD should be set for PRES as shown above.

The key parameter to set is GDPFUN (or abbreviated as GDPF). That sets all parameters that you want to contour. In our case we will start out by contouring the height field plus some isotherms. To contour multiple fields, simply separate variable names with an exclamation mark. Thus, set 'GDPF = hght !tmpc'. Again, 'help GDPF' will let you know what parameter names exist in GEMPAK. You will find that even if particular grids do not contain a desired variable, GEMPAK sometimes (but not always) can calculate and contour it.

The next category is TYPE. This just specifies the type of plot. In our case, we have contour plots for height and temperature so we can set 'type = c ! c. For other maps, you will need to use type= f for fill (see below). You can type 'help type' for more information. Again, the exclamation point separates the variables listed in TYPE. Remember that GEMPAK is not case sensitive so 'TYPE' and 'type' are understood to be the same.

The next parameter is CONTUR and for now leave that blank. This parameter gives us some smoothing options that we should not need to explore.

The next two parameters in the list are important. To start, CINT specifies the contour intervals. For the 300 mb map, we want to plot height contours at 60-m increments with a minimum height to 8400 m (to make certain that 9000 m is contoured). For temperature, use 4°C increments. Set CINT to get the contours as indicated (use 'help cint' for information). The next parameter 'LINE' is also critical. 'LINE' specifies the type of contour line, color of line, line thickness, etc. In our case, contour the heights in thick solid lines. For each variable, label the contours for every other line.

Once you are happy with your map, set DEVICE to ps|mymap.ps to create Postscript files for all maps. Remember to save your final files as an *.nts scripts. Remember that when you end a GEMPAK session, always type 'gpend' to end. Again, you can see if you inadvertently ended a GEMPAK session without using 'gpend' by typing 'ipcs' in a terminal window. If you are not currently using GEMPAK, you shouldn't see your username listed in the message queues section. If you do see yourself listed, use 'cleanup' to clear out your orphaned queues.

Once you are happy with your map, set DEVICE to ps|my_ua_map.ps to create a Postscript file. If you want to save your maps, remember to give them different file names.

Remember that when you end a GEMPAK session, always type 'gpend' to end. Again, you can see if you inadvertently ended a GEMPAK session without using 'gpend' by typing 'ipcs' (for inter-process communication status) in a terminal window. If you are not currently using GEMPAK, you shouldn't see your username listed in the message queues section. If you do see yourself listed, use 'cleanup' to clear out your orphaned queues.

TASKS

We want to plot a combination of upper-air observations and contour analysis. The latter comes from gridded data, since radiosondes are limited to land only. Larry Oolman has some examples of gempak-based upper-air analyses at: <http://weather.uwyo.edu/upperair/uamap.html>

A. Two maps (10 points)

Create two upper-air maps for 12 UTC 20 Dec 2012, i.e. the same time as the surface map (Lab 1). One is at 300 mb, the other at 850 mb. Both should have radiosonde data (snmap). Then, using gdplot2, contour the **height** fields (thick solid lines) for both maps. 850-mb contours 1500 m \pm 30 m, 300-mb contours 9000 m \pm 60 m. Also contour **isotherms** (dashed lines) at 4°C increments for both maps. You can find the GEMPAK variable name by typing 'help gparm' to get a variable list. For both maps, add model wind barbs (not vectors). Use the actual wind (WND). Choose barb size and the skipping factor (JSKIP) wisely such that the barbs are large enough to see, and not too dense that they criss-cross. Make sure that the scale is such that a full barb equals 10 kts (that is the default).

For the 300-mb map, contour **isotachs** (thin solid lines) at 20 knot intervals for winds over 70 knots. Please add color shading and a color bar (CLRBAR), as Larry Oolman does for his 300 mb analysis (<http://weather.uwyo.edu/upperair/uamap.html>)

For the 850-mb map, contour (thin solid line) the area where the dew point depression is equal or less than 3°C. Again, color-shade this area and add a color bar. Choose your color table wisely: I suggest you use light, transparent colors so that the background is still visible.

It is worth pursuing this extra credit, because you will use the color fill and color bar in future lab assignments.

B. Answer the questions below. (14 points in total)

Note: You need the 12 UTC 20 Dec 2012 surface chart as well.

1. (4 pts) **Model validation**. You overlaid radiosonde observations with gridded model data (24 hour simulation). How good is your model? Examine the correspondence between the model and the radiosonde

data. At 850 mb, examine dewpoint depression, and at 300 mb, examine wind speed. At both levels, compare the wind barbs and temperature. Look for a few discrepancies, in any field. Are these discrepancies large?

2. (2 pts) Describe the *observed* phase relationship between the troughs of low pressure at the surface with the axis of the troughs at 850 mb and 300 mb. Explain physically why this is the case. (examine the observations first, then relate this to theory, as an explanation)
3. (2 pts) How is the 850-mb region of dew point depression related to the fronts on the surface map?
4. (2 pts) Describe the jet stream pattern at 300 mb. Is there a well-developed jet core? Where is the jet axis in relation to the surface low?
5. (2 pts) Can you discern an ageostrophic component in the *observed* or the model wind at 300 mb? Note that the ageostrophic wind can be both *along* to height contours (as in troughs and ridges) and *across* the height contours (as in a jet streak). In the next lab assignment you will plot the model's ageostrophic winds, and you will see the effect of curvature and speed changes more clearly.
6. (4 pts) Determine the position on both maps where the strongest geostrophic cold air advection is occurring. Use the solenoid method: the smaller the trapezoid defined by two isotherms and two height lines, the stronger the advection. At that location, calculate the local advective change of temperature in °C per hour at each level, by estimating the height gradient (and geostrophic wind) and the temperature gradient along this wind. Which level has the larger horizontal temperature advection?

2. Vertical profile

We now look at stability and wind profiles for select radiosonde stations at 12 UTC on 20 Dec 2012. We will then interpret the vertical structure in the context of the frontal cyclone. You are expected to be familiar with aerological diagrams (such as a skew T log p diagram) and to be able to interpret them in terms of static stability. If not please read the “handout on static stability” available at <http://www.atmos.uwyo.edu/~geerts/atc5160/> (I wrote this for a senior undergraduate student audience.). Or, do something more entertaining/interactive and take the Skew T mastery primer at <http://www.meted.ucar.edu/mesoprim/skewt/> (this is for free, but you have to register/login).

The program to use is **snprof**. You will get something like this.

SNFILE	Sounding data file	\$UA/121220_upa.gem
DATTIM	Date/time	121220/1200
AREA	Data area	24;-125;55;-60
SNPARM	Sounding parameter list	;TMPC;;HGHT;DWPC;BRBM
LINE	Color/type/width/label/smith/fltr	5/1/1!3/2/2
PTYPE	Plot type/h:w ratio/margins	LOG
VCOORD	Vertical coordinate type	PRES
STINDEX	Stability indices	SHOW
STNCOL	Stability index color	1
WIND	Wind symbol/siz/wdth/typ/hdsz	bk5/1/2
WINPOS	Wind position	1
MARKER	Marker color/type/size/width/hw	0
BORDER	Background color/type/width	1
TITLE	Title color/line/title	1
DEVICE	Device name x size;y size color	xw
YAXIS	Ystrt/ystop/yinc/lbl;gln;tck	dset
XAXIS	Xstrt/xstop/xinc/lbl;gln;tck	-30/40/10/1;1;1
FILTER	Filter data factor	
CLEAR	Clear screen flag	yes

PANEL	Panel loc/color/dash/width/regn	0
TEXT	Size/fnt/wdth/brdr/N-rot/just/hw	1.3/23/hw
THTALN	THTA color/dash/width/mn/mx/inc	24/1/2
THTELN	THTE color/dash/width/mn/mx/inc	1/2/2
MIXRLN	MIXR color/dash/width/mn/mx/inc	3/33/2

You may not have the same settings for the theta, theta_e, and mixing ratio lines. Just copy the ones listed above, they work well for dev=xw and dev=ps. Also just copy the xaxis and yaxis settings, this gives a nicely-shaped skew T. Some other parameters to change:

- for stability index, use LFTV, the lifted index computed by using virtual temperature.
- for ptype, select skewt (Skew T log p)
- for snparm, enter tmpc;dwpc (this plots the observed temperature and dewpoint)
- for area, enter @STI , where STI is the station ID, to be defined below

TASKS

A. Three skew T diagrams (10 points)

Generate a Skew T for Nashville TN (station ID: BNA), Davenport IA (DVN), and Bismarck ND (BIS), at 12 UTC on 20 Dec 2012. By hand, draw a temperature (red line) and dewpoint (blue line) profile of an air parcel lifted from the surface to 300 mb, in each of the three soundings.

B. Answer the questions below (2 points each, 8 in total)

1. Verify the value of the lifted index (LFTV) listed on top of your plot, by comparing the 500 mb parcel T to the 500 mb environmental T. The higher the lifted index, the more stable the lower troposphere (surface to 500 mb) is. More about the lifted index can be found in the handout on static stability online. Which sounding is the most stable, and which is the least stable?
2. Examine the wind profiles, and determine the main pattern(s) of geostrophic temperature advection (show CAA and WAA layers next to the wind profile on each skew T from the surface to the tropopause). Explain the observed WAA (veering wind, i.e. clockwise turning with height) and CAA (wind backing with height) in terms of the frontal system analyzed on your surface chart.
3. Indicate what airmass exists near the surface at BNA and BIS. (the choice is simple: continental polar or moist tropical). Explain why.
4. Examine the stability profile for each sounding. Identify any stable layers, and determine whether they can be attributed to a frontal surface aloft, the tropopause, or to a type of airmass. (Note: continental polar airmasses tend to be more stable).

Appendix A: Converting WRF output to gempak files

Here are the directions for conversion of WRF netcdf (.nc) files to .gem files. **Students that took ATSC5004 last semester are familiar with this, they can simply copy the 'convert.nl' file from their atsc5004 directory and then edit it.**

You should have compiled both WRFV3 and WPS. From WPS we should have run *geogrid.exe*, *ungrib.exe*, and *metgrid.exe*. Once we have the met_em* files, we can link them within the test/em_real subdirectory in the WRFV3 directory, run *real.exe* and then *wrf.exe*. After WRF has completed running, you should be informed by the last few lines of your WRF log file that the run was successful. For our class we have used a single domain and thus the output from WRF will be in one output file in the test/em_real subdirectory called 'wrfout_d01_2012-12-19_12:00:00'. This naming convention is straightforward with the domain, and initial time specified in the file name. WRF output files are in netCDF format. Remember that we can see what variables are contained in the netCDF file by the *ncdump* utility. For example, to see variables in the outer domain just use

```
ncdump -h wrfout_d1* > output_file
```

which will redirect the output to an output file that you can examine with any text editor. There are a host of applications that can be used to examine and manipulate WRF output. Among them are the NCAR Command Language or NCL, Unidata IDV, and GEMPAK. NCL and IDV are nice in that they can analyze the netCDF WRF files directly without additional processing. For our class, we will build on our previous experience in ATSC5004 and work with GEMPAK. To work in this environment, however, an additional step is required to convert from the WRF netCDF format to GEMPAK format. The program we will work with is *wrf2gem*, a program written by graduate student Steve Decker at the University of Wisconsin. A paper describing the *wrf2gem* program can be found at <http://www.mmm.ucar.edu/wrf/users/workshops/WS2005/abstracts/Session3/44-Decker.pdf>

For your WRF simulation, first create a directory called output within your main WRF directory and copy the file 'convert.nl' and the file README. The README file discusses the variables output from the program. In general, we can output variables on the native sigma coordinate system or interpolated to isobaric surfaces. Sigma levels are normalized heights, ranging in value between 1.0 at the surface to 0.0 at the top of the model domain, which a default value of 50 mb in your namelist (you may have changed this). Sigma coordinates are a common means to represent the effects of irregular terrain. The bulk of what we will do in this class will focus on the isobaric interpolation so that the model output can be analyzed in gempak.

First, we need to add two fields to the WRF output file, the zonal and meridional components of the non-divergent wind. To do this, run a script developed by Xia Chu, called **add_variable_to_wrf_output.ncl**. Follow these steps:

1. Copy `add_variable_to_wrf_output.ncl` from <http://www.atmos.uwyo.edu/~geerts/atsc5160/> to your work directory on bat.
2. Open `add_variable_to_wrf_output.ncl` with `gedit` or `vi` or any other editors. Change the directory and file name (dir and filename) to match yours. Save and close the program.
Note: I suggest that you back up your original wrf output files before you run `add_variable_to_wrf_output.ncl`.
3. To run the program, simply type in **`ncl add_variable_to_wrf_output.ncl`**.
4. If your screen shows you text as shown below, the new variables should be in your wrf output file now. You can double check it with `ncdump` or `ncl_filedump`:

```
ncdump -h wrfout_dXX_YYYY-MM-DD_HH:MM:00|grep UND
ncl_filedump wrfout_ dXX_YYYY-MM-DD_HH:MM:00.nc|grep VND
```

```
Variable: und
Type: float
Total Size: 21168000 bytes
```

```

5292000 values
Number of Dimensions: 4
Dimensions and sizes: [Time | **] x [bottom_top | **] x [south_north | **] x [west_east | **]
Coordinates:
Number Of Attributes: 4
units : m/s
short_name : u wind
long_name : Non-divergent zonal wind
_FillValue : 9.96921e+36

Variable: vnd
Type: float
Total Size: 21168000 bytes
5292000 values
Number of Dimensions: 4
Dimensions and sizes: [Time | **] x [bottom_top | **] x [south_north | **] x [west_east | **]
Coordinates:
Number Of Attributes: 4
units : m/s
short_name : v wind
long_name : Non-divergent meridional wind
_FillValue : 9.96921e+36

```

Next, you need to edit the file 'convert.nl'. It can be opened in any text editor. You will see the following variables in 'convert.nl'. Edit these as follows:

```

&OUTFILES
numFiles = 1 /
&WRFFILE
fName = "../WRFV3/test/em_real/wrfout_d01_2012-12-19_12:00:00" /
&GEMFILE
gFName = "./dec19_12z.gem",
maxGrd = 30000,
pack = .true.,
overwrite = .true. /
&NUMOUTS
num = 25 /
&VARS
outFields = 1, 11,12,13,30,101,103,109,110,111,112,114,121,123,124,125,138,501,502, 503,504,505,506, 507, 508
pb = 1000,
pt = 100,
dp = 25 /

```

where

- **fName**: the path and filename for your WRF output file. In the edited example above, the output from domain 1 is being used with a path that follows from the directory contained in the output website. Another option is to create a soft link to the WRF output file within the output directory. Then you can set fName = "wrfout_d01_2012-12-19_12:00:00" /.
- **gFName**: the name you will give for the GEMPAK file that is to be created (your choice).
- **maxGrd**: the maximum number of GEMPAK grids (leave as is)
- **pack**: packing information (leave as is)
- **overwrite**: whether to overwrite a file if it already exists (leave as is). In some instances, you may want to add additional grids later on to the same GEMPAK file. This will allow for that to happen. If you set

overwrite=.false/ you will get an error message if you want to add additional grids to a preexisting GEMPAK file.

- **num**: the number of variables you wish to output (25 in this case). Make certain that 'num' is set to the same number of grids specified under 'outFields'. The 'outFields' command specifies which grids are to be created within the GEMPAK file. See list below. Details can be found in the README file.
- **pb**: lowest pressure level (mb)
- **pt**: highest pressure level (mb)
- **dp**: vertical resolution of isobaric levels in .gem file (25 mb is a good choice)

note: if you have a lot of grid points, convert.nl may give an error message about too large a file. It then aborts without converting all desired fields. You can reduce the .gem file by excluding several 3D variables in sigma coordinates, since we do not use them in the future lab assignments. You can make the list shorter as follows:
outFields = 1, 11,12,13,21,30,101,103,109,121,138,501,502, 503,504,505,506, 507, 508

outField identifiers:

- 1 - HGT: Terrain height (m)
- 2 - T2: 2-m temperature (K)
- 3 - Q2: 2-m water vapor mixing ratio (kg/kg)
- 4 - ZNU: Eta coordinate on mass (half) levels
- 5 - PB: Base state pressure (Pa)
- 6 - P: Perturbation pressure (Pa)
- 7 - T: Perturbation potential temperature (K)
- 8 - U: U component of wind (m/s)
- 9 - V: V component of wind (m/s)
- 10 - W: W component of wind (m/s)
- 11 - U10: U at 10 m (m/s)
- 12 - V10: V at 10 m (m/s)
- 13 - QVAPOR: Water vapor mixing ratio (kg/kg)
- 14 - QCLOUD: Cloud water mixing ratio (kg/kg)
- 15 - QICE: Ice mixing ratio (kg/kg)
- 16 - RAINC: Accumulated cumulus precip (mm)
- 17 - RAINNC: Accumulated grid-scale precip (mm)
- 18 - PH: Perturbation geopotential (m^2/s^2)
- 19 - PHB: Base-state geopotential (m^2/s^2)
- 20 - ZNW: Eta coordinate on w (full) levels
- 21 - LU_INDEX: Land use category
- 22 - MU: Perturbation dry air mass in column (Pa)
- 23 - MUB: Base-state dry air mass in column (Pa)
- 24 - TH2: 2-m potential temperature (K)
- 25 - QRAIN: Rain water mixing ratio (kg/kg)
- 26 - QSNOW: Snow mixing ratio (kg/kg)
- 27 - QGRAUP: Graupel mixing ratio (kg/kg)
- 28 - PBLH: PBL height (m)
- 29 - SST: Sea surface temperature (K)
- 30 - TSK: Surface skin temperature (K)
- 31 - SWDOWN: Downward short wave flux at ground surface (W/m^2)
- 32 - GLW: Downward long wave flux at ground surface (W/m^2)
- 33 - GRDFLX: Ground heat flux (W/m^2)
- 34 - HFX: Upward heat flux at the surface (W/m^2)
- 35 - QFX: Upward moisture flux at the surface (W/m^2)
- 36 - LH: Latent heat flux at the surface (W/m^2)
- 40 - UND: zonal component of the nondivergent wind (m/s)
- 41 - VND: zonal component of the nondivergent wind (m/s)

Diagnostics

- 101 - Surface pressure (hPa)
- 102 - Pressure at 2 m (hPa)
- 103 - Sea level pressure (hPa)
- 104 - Convective precipitation accumulated over one hour (mm)
- 105 - Total precipitation accumulated over one hour (mm)
- 106 - Total precipitation accumulated over three hours (mm)
- 107 - Total precipitation accumulated over six hours (mm)
- 108 - Total accumulated precipitation (mm)
- 109 - Pressure (hPa)
- 110 - Potential temperature (K)
- 111 - Unstaggered U component of wind (m/s)
- 112 - Unstaggered V component of wind (m/s)
- 113 - Cloud water + Ice mixing ratio (kg/kg)
- 114 - Unstaggered W component of wind (m/s)
- 115 - 2-m temperature including at initial time (K)
- 116 - 2-m water vapor mixing ratio including at initial time (kg/kg)
- 117 - U at 10 m including at initial time (m/s)
- 118 - V at 10 m including at initial time (m/s)
- 119 - Lifted Index using lowest 4 levels (K)
- 120 - Mean relative humidity (%) in 850-500-hPa layer
- 121 - Geopotential height (m) on w (full) levels
- 122 - 2-m specific humidity (kg/kg)
- 123 - Specific humidity (kg/kg)
- 124 - Temperature (K)
- 125 - Geopotential height (m) on half levels
- 126 - Dry air mass in column (Pa)
- 127 - Most unstable CAPE w/ virt. temp. correction (J/kg)
- 128 - Lifted parcel level of the most unstable parcel (m)
- 129 - Surface-based CAPE w/ virt. temp. correction (J/kg)
- 130 - Surface-based CIN w/ virt. temp. correction (J/kg)
- 131 - Mixed-layer CAPE w/ virt. temp. correction (J/kg)
- 132 - Mixed-layer CIN w/ virt. temp. correction (J/kg)
- 133 - Mixed-layer LCL (m)
- 134 - Mixed-layer LFC (m)
- 135 - U component of Bunkers storm motion (m/s)
- 136 - V component of Bunkers storm motion (m/s)
- 137 - 0-1-km storm relative helicity (m²/s²)
- 138 - Column integrated precipitable water (cm)
- 139 - Reflectivity (dBZ)
- 140 - Composite reflectivity (dBZ)

Diagnostics interpolated to isobaric levels

- 501 - Temperature (K)
- 502 - U component of wind (m/s)
- 503 - V component of wind (m/s)
- 504 - W component of wind (m/s)
- 505 - Geopotential height (m)
- 506 - Specific humidity (kg/kg)
- 507 - UND: zonal component of the nondivergent wind (m/s)
- 508 - VND: meridional component of the nondivergent wind (m/s)

- pb* -- Bottom pressure level for isobaric diagnostics
- pt* -- Top pressure level for isobaric diagnostics
- dp* -- Pressure interval for isobaric diagnostics

We can interpret the list such that numbers 1 through 140 are output on the native sigma surfaces. Variables from the 500 group are the interpolated isobaric variables. For the example line from above, we will output 23 variables. From the sigma levels, we output terrain height (1), 10-m winds U (11) and V (12), water vapor (13), land use category (21) and surface skin temperature (30). These are directly output from WRF. We also output on sigma surfaces some “diagnostic” variables, computed from the WRF output. You can match the output from the list above. We also output the entire 500 group to isobaric surfaces. You will note that for our case we will need fields 501 (temperature), 502 (u), 503 (v), 504 (w), 505 (Z), 506 (specific humidity q), 507 & 508 (U and V components of the non-divergent wind), all at increments of 25 mb, and 2D fields 1 (terrain height), 106 (3 hour precip P3), and 107 (6 hour precip P6). You can output whatever variables you see appropriate. It is also possible to output additional variables. The README file discusses this briefly. Feel free to experiment.

Once you have edited the *convert.nl* program, save and close it. To run simply type *wrf2gem* and the program will start.

wrf2gem (not *./wrf2gem*)

You will note that it informs you of the progress as the GEMPAK file is being created. Once completed, move this *.gem* file to your ATSC5007 folder for further analysis using *gdplot2*. The first thing to do is to check the contents of the GEMPAK field created using the ‘*gdinfo*’ command.

If something does not work, please let me know.

Appendix B: Creating soft links to the grid files

We could simply type the usual command

```
ln -s /yourpath/dec19_12z.gem
```

as we have done before. Here 'yourpath' can be /netdata/ R1/data/yourbatusername/class/at5c5007, for instance. Instead, you can work with a unix script to provide experience playing with a nice tool that saves on repetitive typing. A script is just a series of executable commands. For multiple files, you can use this script:

```
#!/bin/sh
path=/yourpath/
for fname in dec19_12z dec20_12z; do
  ln -s ${path}${fname}.gem
done
```

You can cut and paste this text into a text editor like **gedit**. You may have to edit it. Be careful with blank spaces and carriage returns.

Once you have finished editing 'softlink', you are not quite ready to run the script. You need to make it executable. To make 'softlink' executable, we need to run the 'chmod' command. This 'chmod' command (abbreviated from change mode) is a shell command in unix that allows the file owner to change file system modes such as permissions. If you type

```
ls -l softlink
```

you will see something at the beginning of the descriptor that looks like:

```
-rw-r--r-- 1 yourbatusername general 189      date time      softlink
```

This tells us something about the file 'softlink'. In particular, the first 11 characters tell us something about the type of file and permissions for this file. There are three categories regarding ownership: 'user', 'group' and 'others'. For the 11 characters, the first character pertains to the file (i.e., 'd' for directory, 'l' for link, '-' for regular file), the next 3 characters pertain to the 'owner', next 3 to the 'group' and last 3 to 'others'. The 'user' generally owns the file and can change permissions for the 'group' and 'others' classes. Briefly, there are permissions regarding 'reading' indicated by 'r', 'writing' indicated by 'w', 'executing' indicated by 'x' that are of interest to us. For the example above, the 11 character notation '-rw-r--r--' indicates that 'softlink' is a regular file and the 'owner' can read and write to the file and the 'group' and 'others' can only read the file. We want to make the file 'softlink' executable. To do this, simply type

```
chmod +x softlink
```

This will make the file 'softlink' executable. If we now type

```
ls -l softlink
```

we will see that it now looks like

```
-rwxr-xr-x 1 yourbatusername general 189      date time      softlink
```

If you don't want anyone else to be able to access your file, type 'chmod go = softlink' where the 'g' and 'o' refers to 'group' and 'others' and the blank character following 'go' clears all permissions in the 'group' and 'others' categories. For now, just type 'chmod +x softlink'. Check to see that it is executable and then just type 'softlink' (or ./softlink) and enter and you should see that soft links have been created to all the .gem files.