Implementation of the Statistical/Dynamical Ensemble Forecast System for Probabilistic Quantitative Precipitation Forecasts

Gregory E. Gahrs and Richard Pfeffer
Geophysical Fluid Dynamics Institute and Meteorology Department, The Florida State University, Tallahassee Florida

Xu-Feng Niu
Department of Statistics, The Florida State University, Tallahassee Florida

Report in fulfillment of UCAR COMET Partners Subaward S04-44699

Table of Contents

Information for Implementing the Statistical/Dynamical Ensemble Forecast System for Probabilistic Quantitative Precipitation Forecasts

NOTE: All programs and files can be obtained at http://www.gfdi.fsu.edu/~gahrs/hpcproj

Section 1 – Download Grib files from NCEP website.

A script called “noaaget.sh” has been created to download the Grib files from the NCEP website.

Section 2 – Extract the necessary data from the Grib files and place them into text files.

A script called “extractdata.sh” has been created which runs the grib program and extracts the necessary fields from the Grib files from Section 1 and places each field into its own text file. Please note that the variable “prog” within this script will have to point to where the grib executable is located on your local machine, and my grib executable is called “wgribg”. This script creates directories “f00”, “f06”, “f12”, “f18”, “f24”, “f30”, “f36”, “f42”, and “f48” for each of the valid forecast times and places the fields into files in the appropriate directory. Please note the first line in each data file will have the dimension of the grid. For NGM and Eta the dimension is 147X110 and for AVN it is 360X181. For more about the grids please see the next section. For these data files the first line following the header giving the dimension array will be the data value for point (1,1), then point (2,1) and so on. Here is a directory listing of all the files for the fields valid at f06, the basic format for the file name is the model, parameter, level (when applicable) and forecast time. I have included a basic description for the parameter after the file name in bold.

gahrs@diana:/hd4/gahrs/f06$ ls -l
total 17936

-rw-r--r--	1	gahrs	gahrs	354567	Jul	5	13:45	avnhgt1000f06.dat	**geop. height**
-rw-r--r--	1	gahrs	gahrs	441812	Jul	5	13:45	avnhgt300f06.dat	
-rw-r--r--	1	gahrs	gahrs	442680	Jul	5	13:45	avnhgt500f06.dat	
-rw-r--r--	1	gahrs	gahrs	443100	Jul	5	13:45	avnhgt700f06.dat	
-rw-r--r--	1	gahrs	gahrs	442924	Jul	5	13:45	avnhgt850f06.dat	
-rw-r--r--	1	gahrs	gahrs	180893	Jul	5	13:45	avnprecf06.dat	**6 hr. precipitation**
-rw-r--r--	1	gahrs	gahrs	446957	Jul	5	13:45	avnprmslf06.dat	**sea level pressure**
-rw-r--r--	1	gahrs	gahrs	187576	Jul	5	13:45	avnrh500f06.dat	**relative humidity**
-rw-r--r--	1	gahrs	gahrs	194301	Jul	5	13:45	avnrh700f06.dat	
-rw-r--r--	1	gahrs	gahrs	197205	Jul	5	13:45	avnrh850f06.dat	
-rw-r--r--	1	gahrs	gahrs	378406	Jul	5	13:45	avntmp1000f06.dat	**temperature**
-rw-r--r--	1	gahrs	gahrs	378052	Jul	5	13:45	avntmp500f06.dat	
-rw-r--r--	1	gahrs	gahrs	378254	Jul	5	13:45	avntmp700f06.dat	
-rw-r--r--	1	gahrs	gahrs	378140	Jul	5	13:45	avntmp850f06.dat	

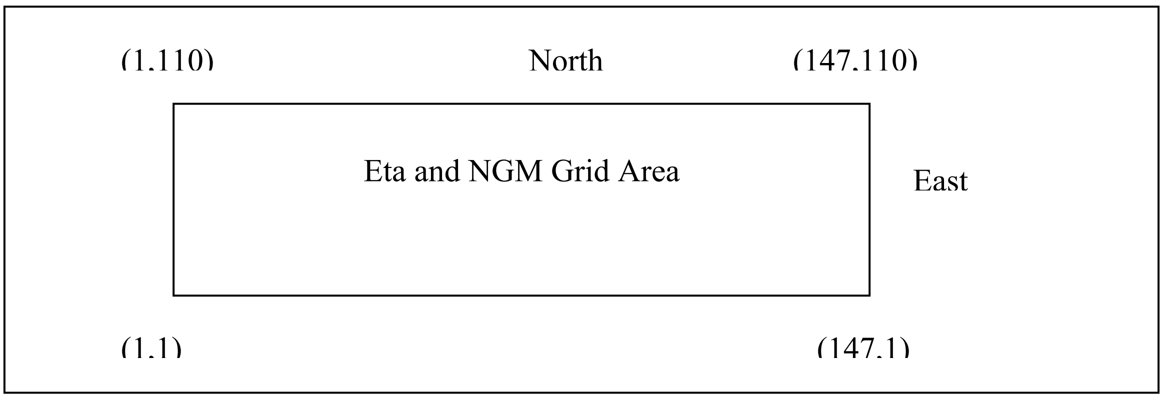
-rw-r--r--	1	gahrs	gahrs	284255	Jul	5	13:45	avnugrd1000f06.dat	**u-wind**
-rw-r--r--	1	gahrs	gahrs	300507	Jul	5	13:45	avnugrd300f06.dat	
-rw-r--r--	1	gahrs	gahrs	292722	Jul	5	13:45	avnugrd500f06.dat	
-rw-r--r--	1	gahrs	gahrs	285874	Jul	5	13:45	avnugrd700f06.dat	
-rw-r--r--	1	gahrs	gahrs	285441	Jul	5	13:45	avnugrd850f06.dat	
-rw-r--r--	1	gahrs	gahrs	281660	Jul	5	13:45	avnvgrd1000f06.dat	**v-wind**
-rw-r--r--	1	gahrs	gahrs	302938	Jul	5	13:45	avnvgrd300f06.dat	
-rw-r--r--	1	gahrs	gahrs	295813	Jul	5	13:45	avnvgrd500f06.dat	
-rw-r--r--	1	gahrs	gahrs	289260	Jul	5	13:45	avnvgrd700f06.dat	
-rw-r--r--	1	gahrs	gahrs	283673	Jul	5	13:45	avnvgrd850f06.dat	
-rw-r--r--	1	gahrs	gahrs	409727	Jul	5	13:45	avnvvel300f06.dat	**vertical velocity**
-rw-r--r--	1	gahrs	gahrs	410266	Jul	5	13:45	avnvvel500f06.dat	
-rw-r--r--	1	gahrs	gahrs	409195	Jul	5	13:45	avnvvel700f06.dat	
-rw-r--r--	1	gahrs	gahrs	409808	Jul	5	13:45	avnvvel850f06.dat	
-rw-r--r--	1	gahrs	gahrs	116156	Jul	5	13:45	etadpt500f06.dat	**dewpoint**
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etadpt700f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etadpt850f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etaelonf06.dat	**longitude**
-rw-r--r--	1	gahrs	gahrs	131434	Jul	5	13:45	etahgt1000f06.dat	**geop. height**
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etahgt300f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etahgt500f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etahgt700f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etahgt850f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etahgt950f06.dat	
-rw-r--r--	1	gahrs	gahrs	131345	Jul	5	13:45	etanlatf06.dat	**latitude**
-rw-r--r--	1	gahrs	gahrs	63096	Jul	5	13:45	etaprecf06.dat	**6 hr. precipitation**
-rw-r--r--	1	gahrs	gahrs	116241	Jul	5	13:45	etaprmslf06.dat	**sea level pressure**
-rw-r--r--	1	gahrs	gahrs	54257	Jul	5	13:45	etarh500f06.dat	**relative humidity**
-rw-r--r--	1	gahrs	gahrs	131341	Jul	5	13:45	etarh700f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etarh850f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etarh950f06.dat	
-rw-r--r--	1	gahrs	gahrs	182901	Jul	5	13:45	etaspfh500f06.dat	**specific humidity**
-rw-r--r--	1	gahrs	gahrs	162738	Jul	5	13:45	etaspfh700f06.dat	
-rw-r--r--	1	gahrs	gahrs	172597	Jul	5	13:45	etaspfh850f06.dat	
-rw-r--r--	1	gahrs	gahrs	160406	Jul	5	13:45	etaspfh950f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etatmp1000f06.dat	**temperature**
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etatmp500f06.dat	
-rw-r--r--	1	gahrs	gahrs	116156	Jul	5	13:45	etatmp700f06.dat	
-rw-r--r--	1	gahrs	gahrs	116156	Jul	5	13:45	etatmp850f06.dat	
-rw-r--r--	1	gahrs	gahrs	131340	Jul	5	13:45	etatmp950f06.dat	
-rw-r--r--	1	gahrs	gahrs	142965	Jul	5	13:45	etaugrd1000f06.dat	**u-wind**
-rw-r--r--	1	gahrs	gahrs	138860	Jul	5	13:45	etaugrd300f06.dat	
-rw-r--r--	1	gahrs	gahrs	136663	Jul	5	13:45	etaugrd500f06.dat	
-rw-r--r--	1	gahrs	gahrs	140117	Jul	5	13:45	etaugrd700f06.dat	
-rw-r--r--	1	gahrs	gahrs	127037	Jul	5	13:45	etaugrd850f06.dat	
-rw-r--r--	1	gahrs	gahrs	142758	Jul	5	13:45	etaugrd950f06.dat	

-rw-r--r--	1	gahrs	gahrs	141608	Jul	5	13:45	etavgrd1000f06.dat **v-wind**
-rw-r--r--	1	gahrs	gahrs	140412	Jul	5	13:45	etavgrd300f06.dat
-rw-r--r--	1	gahrs	gahrs	141558	Jul	5	13:45	etavgrd500f06.dat
-rw-r--r--	1	gahrs	gahrs	141640	Jul	5	13:45	etavgrd700f06.dat
-rw-r--r--	1	gahrs	gahrs	129462	Jul	5	13:45	etavgrd850f06.dat
-rw-r--r--	1	gahrs	gahrs	140959	Jul	5	13:45	etavgrd950f06.dat
-rw-r--r--	1	gahrs	gahrs	155244	Jul	5	13:45	etavvel300f06.dat **vertical velocity**
-rw-r--r--	1	gahrs	gahrs	160940	Jul	5	13:45	etavvel500f06.dat
-rw-r--r--	1	gahrs	gahrs	153504	Jul	5	13:45	etavvel700f06.dat
-rw-r--r--	1	gahrs	gahrs	164452	Jul	5	13:45	etavvel850f06.dat
-rw-r--r--	1	gahrs	gahrs	59559	Jul	5	13:45	ngmhgt1000f06.dat **geop. height**
-rw-r--r--	1	gahrs	gahrs	80858	Jul	5	13:45	ngmhgt300f06.dat
-rw-r--r--	1	gahrs	gahrs	80858	Jul	5	13:45	ngmhgt500f06.dat
-rw-r--r--	1	gahrs	gahrs	80858	Jul	5	13:45	ngmhgt700f06.dat
-rw-r--r--	1	gahrs	gahrs	80858	Jul	5	13:45	ngmhgt850f06.dat
-rw-r--r--	1	gahrs	gahrs	64688	Jul	5	13:45	ngmhgt950f06.dat
-rw-r--r--	1	gahrs	gahrs	48519	Jul	5	13:45	ngmmodrhf06.dat **model avg. RH**
-rw-r--r--	1	gahrs	gahrs	76611	Jul	5	13:45	ngmprecf06.dat **6 hr. precipitation**
-rw-r--r--	1	gahrs	gahrs	113138	Jul	5	13:45	ngmprmslf06.dat **sea level pressure**
-rw-r--r--	1	gahrs	gahrs	48024	Jul	5	13:45	ngmpwatf06.dat **precipitable water**
-rw-r--r--	1	gahrs	gahrs	47576	Jul	5	13:45	ngmrh500f06.dat **relative humidity**
-rw-r--r--	1	gahrs	gahrs	48436	Jul	5	13:45	ngmrh700f06.dat
-rw-r--r--	1	gahrs	gahrs	48543	Jul	5	13:45	ngmrh850f06.dat
-rw-r--r--	1	gahrs	gahrs	48574	Jul	5	13:45	ngmrh950f06.dat
-rw-r--r--	1	gahrs	gahrs	93912	Jul	5	13:45	ngmtmp1000f06.dat **temperature**
-rw-r--r--	1	gahrs	gahrs	93796	Jul	5	13:45	ngmtmp500f06.dat
-rw-r--r--	1	gahrs	gahrs	93730	Jul	5	13:45	ngmtmp700f06.dat
-rw-r--r--	1	gahrs	gahrs	93928	Jul	5	13:45	ngmtmp850f06.dat
-rw-r--r--	1	gahrs	gahrs	93842	Jul	5	13:45	ngmtmp950f06.dat
-rw-r--r--	1	gahrs	gahrs	71679	Jul	5	13:45	ngmugrd1000f06.dat **u-wind**
-rw-r--r--	1	gahrs	gahrs	73431	Jul	5	13:45	ngmugrd300f06.dat
-rw-r--r--	1	gahrs	gahrs	73025	Jul	5	13:45	ngmugrd500f06.dat
-rw-r--r--	1	gahrs	gahrs	71847	Jul	5	13:45	ngmugrd700f06.dat
-rw-r--r--	1	gahrs	gahrs	71898	Jul	5	13:45	ngmugrd850f06.dat
-rw-r--r--	1	gahrs	gahrs	72085	Jul	5	13:45	ngmugrd950f06.dat
-rw-r--r--	1	gahrs	gahrs	69994	Jul	5	13:45	ngmvgrd1000f06.dat **v-wind**
-rw-r--r--	1	gahrs	gahrs	74116	Jul	5	13:45	ngmvgrd300f06.dat
-rw-r--r--	1	gahrs	gahrs	71244	Jul	5	13:45	ngmvgrd500f06.dat
-rw-r--r--	1	gahrs	gahrs	70186	Jul	5	13:45	ngmvgrd700f06.dat
-rw-r--r--	1	gahrs	gahrs	69959	Jul	5	13:45	ngmvgrd850f06.dat
-rw-r--r--	1	gahrs	gahrs	69994	Jul	5	13:45	ngmvgrd950f06.dat
-rw-r--r--	1	gahrs	gahrs	103110	Jul	5	13:45	ngmvvel300f06.dat **vertical velocity**
-rw-r--r--	1	gahrs	gahrs	102933	Jul	5	13:45	ngmvvel500f06.dat
-rw-r--r--	1	gahrs	gahrs	102851	Jul	5	13:45	ngmvvel700f06.dat
-rw-r--r--	1	gahrs	gahrs	102739	Jul	5	13:45	ngmvvel850f06.dat

Section 3 - Grids

Part A Eta and NGM Grids – NCEP Grid 104

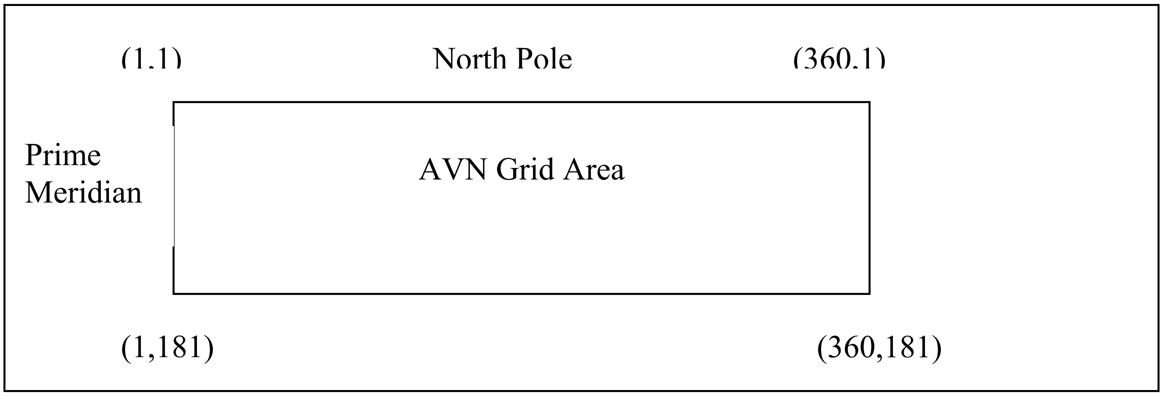
The Eta and NGM data are stored on NCEP grid 104. As mentioned in section 2, the data is stored in one long column for each field. The dimension of this grid is 147X110. The first value corresponds to point (1,1), the second to point (2,1), and so on. A schematic of this grid follows:



The 148th value will correspond to point (1,2) which lies above point (1,1). The data is read going from west to east while progressing from south to north. Therefore, the last 147 values in each data file correspond to all of the points along the top boundary. The latitude and longitude and grid spacing for these data points can be found in the file "latlongsp104.dat" and is produced by the program "grdlocs104.f". The columns of this data file refer to grid point i, grid point j, latitude in degrees N, longitude in degrees W, and the grid spacing in km, respectively. For the eastern region of the United States which ranges from about 25 deg N to 50 deg N and 110 deg W to 60 deg W all of the data should be inclusive from (69:134, 27:76) for the data matrix.

Part B AVN grid – NCEP Grid 3 – Global Grid

The AVN grid is a 1 deg X 1 deg global grid with the first data value corresponding to the North Pole and Prime Meridian. This data is listed in one long column with the second data value corresponding to the point 90 deg N 1 deg E. The array for this grid is 360X181. Therefore, the first 360 data values all correspond to the North Pole. The 361^{st} data value corresponds to 89 deg N and 0 deg E. Therefore, like Grid 104 the data progresses from west to east, however, unlike Grid 104 the rows progress from north to south which will be important when doing finite difference calculations. The pertinent region of this grid which applies to the eastern part of the U.S. is contained in the (251:301, 41:66) portion of the data matrix. A schematic of this grid follows:



Section 4 - Data Units

Since the training of the model was done with data from Gempak files having different standard data units than those in the Grib files available on the NCEP server, some of the units in the Grib files must be converted to those used by Gempak. Here is a list of the parameters that had conflicts in units between Gempak and Grib.

Pressure – Gempak uses mb; Grib uses pascal; must convert to mb; 100 Pa = 1 mb

Vertical Velocity – Gempak used mb/s; Grib uses Pa/s; must convert to mb; 100 Pa=1mb

Specific Humidity/Mixing ratio – Gempak uses g/kg; Grib uses g/g;

Otherwise both sets of parameters have the same units.

Section 5 – Predictors

Please note that the predictors for the f0-6 period differ from those in the other forecast periods. Most notably the f0-6 period has 205 predictors while the others have 210. The predictors that are not available for the f0-6 period are:

AVN precipitation @ +0 hours
ETA precipitation @ +0 hours
NGM precipitation @ +0 hours
NGM average vertical velocity [850, 700, 500] @ +0 hours
NGM vertical velocity 300mb @ +0 hours

Tables 1a,b,c contain the predictors for the 0-6 hour forecast period for the AVN, Eta, and NGM models, respectively. In these tables, the second column gives the predictor identifier at the beginning of the time period and the 3rd column gives it at the end of the period. The predictor is described in column 4 and the units are given in the fifth column. The last column entitled scale factor is what the predictor must be multiplied by (i.e. $10^{\text{scale factor}}$) for its coefficients to be applied properly.

Tables 2a,b,c contain the same information as Table 1 except that it is for the 6-12 through the 42-48 periods. An example of how to read this is that predictor x2.36 for the 0-6 hour period would be the u-wind @ 300 mb at the +6 hour time in the forecast period in Table 1a and that predictor x2.36 for all the other prediction times would be the AVN model u-wind average of the 850, 700, 500 mb values. These values are used in conjunction with the predictors selected which will be talked about in the next section.

Table 1a Predictors for the 0-6 hour forecast period for the AVN model. An "m" in the 2nd and 3rd columns indicates the predictor is missing.

AVN Preds.			Description	units	scale factor
for f0-6 only	"+ 0hours"	"+6hours"			
	x2.1	x2.34	u wind 1000mb	m/s	0
	x2.2	x2.35	u wind (average 850,700,500)	m/s	0
	x2.3	x2.36	u wind 300mb	m/s	0
	x2.4	x2.37	v wind 1000mb	m/s	0
	x2.5	x2.38	v wind (average 850,700,500)	m/s	0
	x2.6	x2.39	v wind 300mb	m/s	0
	x2.7	x2.40	geopotential ht. 1000mb	m	0
	m	m	geopotential ht 950mb	m	0
	x2.8	x2.41	geopotential ht. 850mb	m	0
	x2.9	x2.42	geopotential ht. 700mb	m	0
	x2.10	x2.43	geopotential ht. 500mb	m	0
	x2.11	x2.44	geopotential ht. 300mb	m	0
	x2.12	x2.45	temp (average 1000,850,700,500)	K	0
	m	x2.46	6 hr precip	mm	0
	m	m	Precipitable water	mm	0
	x2.13	x2.47	mixing ratio (average 850,700,500)	g/kg	0
	x2.14	x2.48	relative hum. Average(850,700,500)	%	0
	m	m	model average Rel Hum (sfc~500mb)	%	0
	x2.15	x2.49	thickness (300mb minus 850mb)	m	0
	x2.16	x2.50	K-index	C	0
	x2.17	x2.51	lapse rate (700 minus 500)	K	0
	x2.18	x2.52	Total Totals Index	C	0
	x2.19	x2.53	Cross Totals Index	C	0
	x2.20	x2.54	Vertical Totals index	C	0
	x2.21	x2.55	mean sea level press.	mb	0
	x2.22	x2.56	equiv. Pot. Temp (average 850, 700)	K	0
	x2.23	x2.57	vertical velocity (average 850,700,500)	mb/s	3
	x2.24	x2.58	vertical velocity 300mb	mb/s	3
	x2.25	x2.59	equiv. Pot. Temp advection average (850,700)	K/s	4
	x2.26	x2.60	temp. advection average (850, 700, 500)	K/s	4
	x2.27	x2.61	relative vorticity average (850, 700, 500)	1/s	5
	x2.28	x2.62	divergence 300mb	1/s	5
	x2.29	x2.63	differential divergence (850 minus 300)	1/s	5
	x2.30	x2.64	spec hum advection average (850, 700, 500)	g/kgs	8
	x2.31	x2.65	vorticity advection by geostrophic wind average (700, 500)	$1/s^2$	9
	x2.32	x2.66	moisture divergence average (850, 700, 500)	g/kgs	9
	x2.33	x2.67	q-vector divergence average (850, 700, 500)	K/sm^2	15

Table 1b Predictors for the 0-6 hour foecast period for the Eta model. An "m" in the 2nd and 3rd columns indicates the predictor is missing.

Eta Pred				units	scale factor
for f0-6 only	x2.68	x2.101	u wind 1000mb	m/s	0
	x2.69	x2.102	u wind (average 950, 850, 700, 500)	m/s	0
	x2.70	x2.103	u wind 300mb	m/s	0
	x2.71	x2.104	v wind 1000mb	m/s	0
	x2.72	x2.105	v wind (average 950,850,700,500)	m/s	0
	x2.73	x2.106	v wind 300mb	m/s	0
	x2.74	x2.107	geopotential ht. 1000mb	m	0
	x2.75	x2.108	geopotential ht 950mb	m	0
	x2.76	x2.109	geopotential ht. 850mb	m	0
	x2.77	x2.110	geopotential ht. 700mb	m	0
	x2.78	x2.111	geopotential ht. 500mb	m	0
	x2.79	x2.112	geopotential ht. 300mb	m	0
	x2.80	x2.113	temp (average 1000,950,850,700,500)	K	0
	m	x2.114	6 hr precip	mm	0
	m	m	precipitable water	mm	0
	x2.81	x2.115	mixing ratio (average 950,850, 700,500)	g/kg	0
	x2.82	x2.116	relative hum. (average 950,850,700,500)	%	0
	m	m	model average Rel Hum (sfc~500mb)	%	0
	x2.83	x2.117	thickness (300 minus 850)	m	0
	x2.84	x2.118	K-index	C	0
	x2.85	x2.119	lapse rate (700 minus 500)	K	0
	x2.86	x2.120	T-Totals index	C	0
	x2.87	x2.121	C-Totals index	C	0
	x2.88	x2.122	V-Totals index	C	0
	m	m	mean sea level press.	mb	0
	x2.89	x2.123	equiv. Pot. Temp (average 850, 700)	K	0
	x2.90	x2.124	vertical velocity (average 950,850,700,500)	mb/s	3
	x2.91	x2.125	vertical velocity 300mb	mb/s	3
	x2.92	x2.126	equiv. Pot. Temp advection (average 850,700)	K/s	4
	x2.93	x2.127	temp. advection (average 850,700,500)	K/s	4
	x2.94	x2.128	relative vorticity (average 950,850,700,500)	1/s	5
	x2.95	x2.129	divergence 300mb	1/s	5
	x2.96	x2.130	differential divergence (850 minus 300)	1/s	5
	x2.97	x2.131	spec hum advection (average 850,700,500)	g/kgs	8
	x2.98	x2.132	vorticity advection by geostrophic wind (average 700,500)	$1/s^2$	9
	x2.99	x2.133	moisture divergence (average 950,850,700,500)	g/kgs	9
	x2.100	x2.134	q-vector divergence (average 850, 700,500)	K/sm^2	15

Table 1c Predictors for the 0-6 hour forecast period for the NGM model. An "m" in the 2^{nd} and 3^{rd} columns indicates the predictor is missing.

NGM preds				units	scale factor
for f0-6 only	x2.135	x2.169	u wind 1000mb	m/s	0
	x2.136	x2.170	u wind (average 950,850,700,500)	m/s	0
	x2.137	x2.171	u wind 300mb	m/s	0
	x2.138	x2.172	v wind 1000mb	m/s	0
	x2.139	x2.173	v wind (average 950,850,700,500)	m/s	0
	x2.140	x2.174	v wind 300mb	m/s	0
	x2.141	x2.175	geopotential ht. 1000mb	m	0
	x2.142	x2.176	geopotential ht 950mb	m	0
	x2.143	x2.177	geopotential ht. 850mb	m	0
	x2.144	x2.178	geopotential ht. 700mb	m	0
	x2.145	x2.179	geopotential ht. 500mb	m	0
	x2.146	x2.180	geopotential ht. 300mb	m	0
	x2.147	x2.181	temp (average 1000,950,850,700,500)	K	0
	m	x2.182	6 hr precip	mm	0
	x2.148	x2.183	precipitable water	mm	0
	x2.149	x2.184	mixing ratio (average 950,850,700,500)	g/kg	0
	x2.150	x2.185	relative hum. (average 950,850,700,500)	%	0
	x2.151	x2.186	model average Rel Hum (sfc~500mb)	%	0
	x2.152	x2.187	thickness (300 minus 850)	m	0
	x2.153	x2.188	K-index	C	0
	x2.154	x2.189	lapse rate (700 minus 500)	K	0
	x2.155	x2.190	T-Totals index	C	0
	x2.156	x2.191	C-Totals index	C	0
	x2.157	x2.192	V-Totals index	C	0
	x2.158	x2.193	mean sea level press.	mb	0
	x2.159	x2.194	equiv. Pot. Temp (average 850,700)	K	0
	m	x2.195	vertical velocity (average 850,700,500)	mb/s	3
	m	x2.196	vertical velocity 300mb	mb/s	3
	x2.160	x2.197	equiv. Pot. Temp advection (average 850,700)	K/s	4
	x2.161	x2.198	temp. advection (average 850,700,500)	K/s	4
	x2.162	x2.199	relative vorticity average (950,850,700,500)	1/s	5
	x2.163	x2.200	divergence 300mb	1/s	5
	x2.164	x2.201	differential divergence (850 minus 300)	1/s	5
	x2.165	x2.202	spec hum advection (average 850,700,500)	g/kgs	8
	x2.166	x2.203	vorticity advection by geostrophic wind (average 700,500)	$1/s^2$	9
	x2.167	x2.204	moisture divergence (average 950,850,700,500)	g/kgs	9
	x2.168	x2.205	q-vector divergence (average 850,700,500)	K/sm^2	15

Table 2a Predictors for the 6-12 through 42-48 hour forecast period for the AVN model. An “m” in the 2nd and 3rd columns indicates the predictor is missing.

AVN Preds.			Description	units	scale factor
for f6-12 to	"+ 0hours"	"+6hours"			
f42-48	x2.1	x2.35	u wind 1000mb	m/s	0
	x2.2	x2.36	u wind (average 850,700,500)	m/s	0
	x2.3	x2.37	u wind 300mb	m/s	0
	x2.4	x2.38	v wind 1000mb	m/s	0
	x2.5	x2.39	v wind (average 850,700,500)	m/s	0
	x2.6	x2.40	v wind 300mb	m/s	0
	x2.7	x2.41	geopotential ht. 1000mb	m	0
	m	m	geopotential ht 950mb	m	0
	x2.8	x2.42	geopotential ht. 850mb	m	0
	x2.9	x2.43	geopotential ht. 700mb	m	0
	x2.10	x2.44	geopotential ht. 500mb	m	0
	x2.11	x2.45	geopotential ht. 300mb	m	0
	x2.12	x2.46	temp (average 1000,850,700,500)	K	0
	x2.13	x2.47	6 hr precip	mm	0
	m	m	precipitable water	mm	0
	x2.14	x2.48	mixing ratio (average 850,700,500)	g/kg	0
	x2.15	x2.49	relative hum. Average(850,700,500)	%	0
	m	m	model average Rel Hum (sfc~500mb)	%	0
	x2.16	x2.50	thickness (300mb minus 850mb)	m	0
	x2.17	x2.51	K-index	C	0
	x2.18	x2.52	lapse rate (700 minus 500)	K	0
	x2.19	x2.53	Total Totals Index	C	0
	x2.20	x2.54	Cross Totals Index	C	0
	x2.21	x2.55	Vertical Totals index	C	0
	x2.22	x2.56	mean sea level press.	mb	0
	x2.23	x2.57	equiv. Pot. Temp (average 850, 700)	K	0
	x2.24	x2.58	vertical velocity (average 850,700,500)	mb/s	3
	x2.25	x2.59	vertical velocity 300mb	mb/s	3
	x2.26	x2.60	equiv. Pot. Temp advection average (850,700)	K/s	4
	x2.27	x2.61	temp. advection average (850, 700, 500)	K/s	4
	x2.28	x2.62	relative vorticity average (850, 700, 500)	1/s	5
	x2.29	x2.63	divergence 300mb	1/s	5
	x2.30	x2.64	differential divergence (850 minus 300)	1/s	5
	x2.31	x2.65	spec hum advection average (850, 700, 500)	g/kgs	8
	x2.32	x2.66	vorticity advection by geostrophic wind average (700, 500)	$1/s^2$	9
	x2.33	x2.67	moisture divergence average (850, 700, 500)	g/kgs	9
	x2.34	x2.68	q-vector divergence average (850, 700, 500)	K/sm^2	15

Table 2b Predictors for the 6-12 through 42-48 hour forecast period for the Eta model. An "m" in the 2nd and 3rd columns indicates the predictor is missing.

Eta Pred				units	scale factor
for f6-12 to	x2.69	x2.104	u wind 1000mb	m/s	0
f42-48	x2.70	x2.105	u wind (average 950, 850, 700, 500)	m/s	0
	x2.71	x2.106	u wind 300mb	m/s	0
	x2.72	x2.107	v wind 1000mb	m/s	0
	x2.73	x2.108	v wind (average 950,850,700,500)	m/s	0
	x2.74	x2.109	v wind 300mb	m/s	0
	x2.75	x2.110	geopotential ht. 1000mb	m	0
	x2.76	x2.111	geopotential ht 950mb	m	0
	x2.77	x2.112	geopotential ht. 850mb	m	0
	x2.78	x2.113	geopotential ht. 700mb	m	0
	x2.79	x2.114	geopotential ht. 500mb	m	0
	x2.80	x2.115	geopotential ht. 300mb	m	0
	x2.81	x2.116	temp (average 1000,950,850,700,500)	K	0
	x2.82	x2.117	6 hr precip	mm	0
	m	m	precipitable water	mm	0
	x2.83	x2.117	mixing ratio (average 950,850, 700,500)	g/kg	0
	x2.84	x2.118	relative hum. (average 950,850,700,500)	%	0
	m	m	model average Rel Hum (sfc~500mb)	%	0
	x2.85	x2.119	thickness (300 minus 850)	m	0
	x2.86	x2.120	K-index	C	0
	x2.87	x2.121	lapse rate (700 minus 500)	K	0
	x2.88	x2.122	T-Totals index	C	0
	x2.89	x2.123	C-Totals index	C	0
	x2.90	x2.124	V-Totals index	C	0
	m	m	mean sea level press.	mb	0
	x2.92	x2.125	equiv. Pot. Temp (average 850, 700)	K	0
	x2.93	x2.126	vertical velocity (average 950,850,700,500)	mb/s	3
	x2.94	x2.127	vertical velocity 300mb	mb/s	3
	x2.95	x2.128	equiv. Pot. Temp advection (average 850,700)	K/s	4
	x2.96	x2.129	temp. advection (average 850,700,500)	K/s	4
	x2.97	x2.130	relative vorticity (average 950,850,700,500)	1/s	5
	x2.98	x2.131	divergence 300mb	1/s	5
	x2.99	x2.132	differential divergence (850 minus 300)	1/s	5
	x2.100	x2.133	spec hum advection (average 850,700,500)	g/kgs	8
	x2.101	x2.134	vorticity advection by geostrophic wind (average 700,500)	$1/s^2$	9
	x2.102	x2.135	moisture divergence (average 950,850,700,500)	g/kgs	9
	x2.103	x2.136	q-vector divergence (average 850, 700,500)	K/sm^2	15

Table 2c Predictors for the 6-12 through 42-48 hour forecast period for the NGM model. An "m" in the 2nd and 3rd columns indicates the predictor is missing.

NGM preds				units	scale factor
for f6-12 to	x2.137	x2.174	u wind 1000mb	m/s	0
f42-48	x2.138	x2.175	u wind (average 950,850,700,500)	m/s	0
	x2.139	x2.176	u wind 300mb	m/s	0
	x2.140	x2.177	v wind 1000mb	m/s	0
	x2.141	x2.178	v wind (average 950,850,700,500)	m/s	0
	x2.142	x2.179	v wind 300mb	m/s	0
	x2.143	x2.180	geopotential ht. 1000mb	m	0
	x2.144	x2.181	geopotential ht 950mb	m	0
	x2.145	x2.182	geopotential ht. 850mb	m	0
	x2.146	x2.183	geopotential ht. 700mb	m	0
	x2.147	x2.184	geopotential ht. 500mb	m	0
	x2.148	x2.185	geopotential ht. 300mb	m	0
	x2.149	x2.186	temp (average 1000,950,850,700,500)	K	0
	x2.150	x2.187	6 hr precip	mm	0
	x2.151	x2.188	precipitable water	mm	0
	x2.152	x2.189	mixing ratio (average 950,850,700,500)	g/kg	0
	x2.153	x2.190	relative hum. (average 950,850,700,500)	%	0
	x2.154	x2.191	model average Rel Hum (sfc~500mb)	%	0
	x2.155	x2.192	thickness (300 minus 850)	m	0
	x2.156	x2.193	K-index	C	0
	x2.157	x2.194	lapse rate (700 minus 500)	K	0
	x2.158	x2.195	T-Totals index	C	0
	x2.159	x2.196	C-Totals index	C	0
	x2.160	x2.197	V-Totals index	C	0
	x2.161	x2.198	mean sea level press.	mb	0
	x2.162	x2.199	equiv. Pot. Temp (average 850,700)	K	0
	x2.163	x2.200	vertical velocity (average 850,700,500)	mb/s	3
	x2.164	x2.201	vertical velocity 300mb	mb/s	3
	x2.165	x2.202	equiv. Pot. Temp advection (average 850,700)	K/s	4
	x2.166	x2.203	temp. advection (average 850,700,500)	K/s	4
	x2.167	x2.204	relative vorticity average (950,850,700,500)	1/s	5
	x2.168	x2.205	divergence 300mb	1/s	5
	x2.169	x2.206	differential divergence (850 minus 300)	1/s	5
	x2.170	x2.207	spec hum advection (average 850,700,500)	g/kgs	8
	x2.171	x2.208	vorticity advection by geostrophic wind (average 700,500)	$1/s^2$	9
	x2.172	x2.209	moisture divergence (average 950,850,700,500)	g/kgs	9
	x2.173	x2.210	q-vector divergence (average 850,700,500)	K/sm^2	15

Section 6 - Coefficients for the models

The coefficients for the predictors can be found in hard copy form included at the end of this report or in excel files with the naming convention **xx-yy**hour**seas**preds.xls. These excel files can be downloaded at:

http://www.gfdi.fsu.edu/~gahrs/hpcproj

Where,
xx = beginning hour of the forecast period
yy= ending hour of the forecast period
seas= season; cool runs from Oct-March; warm runs from April-Sept.

Each excel file contains a worksheet that is named for a specified region and precipitation threshold. Each worksheet contains the following information:

Columns A through C contain the information pertaining to the Classification and Regression Tree forecasts. First, the precipitation in units of mm must be interpolated from the AVN grid to the Eta and NGM grid and averaged for all three dynamical models. This calculated value is the predictor. Column B separates the average precipitation amounts into bins, and Column C has the forecast in decimal form. Therefore, a forecast of .89 would be 89%.

The next series of columns on each worksheet contain the predictors and the coefficients to be used for the following PQPF forecasts:

Columns D-F AVN Linear regression
Columns G-I ETA Linear regression
Columns J-L NGM linear regression
Columns M-O AVN Logistic regression
Columns P-R Eta logistic regression
Columns S-U Ngm logistic regression
Columns V-X Ensemble linear regression

The first column contains the model; the second contains the predictor identifier and the third contains the coefficients.

The equation for the linear regression forecast probability (P) is given by:

$$P = a_0 + \sum (a_1 x_1 + a_2 x_2 + \ldots + a_n x_n)$$

where a_0 is the intercept, a_i are the coefficients and x_i are the predictors.

The form of the logistic regression equation probability forecast (P) is given by:

$$P = \frac{e^V}{1+e^V}$$

where V is given by:

$$V = a_0 + \sum (a_1 x_1 + a_2 x_2 + \ldots + a_n x_n)$$

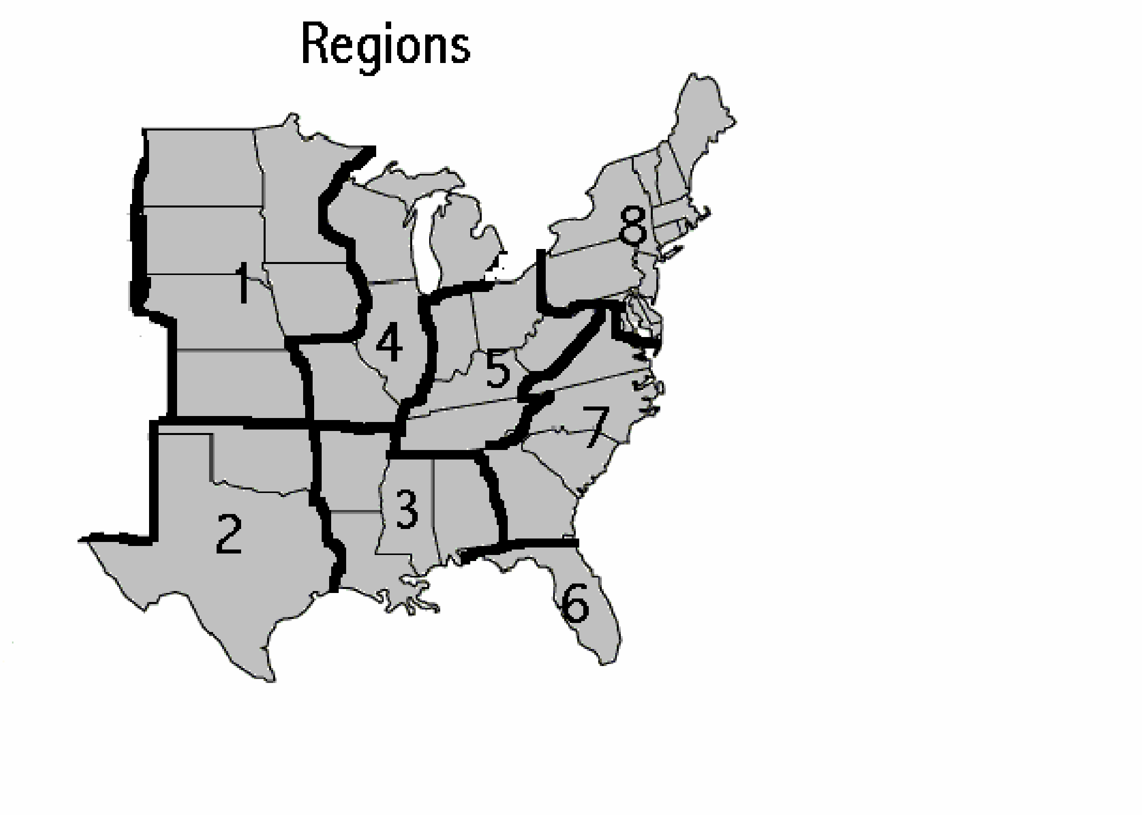
Now, once all 7 probability forecasts are made, they are combined using the ensemble linear regression equation and coefficients by:

Final probability forecast = *Intercept* + a_1*Avnlin* + a_2*Etalin* + a_3*NGMlin* +a_4*Avnlog* +a_5*Etalog* + a_6*NGMlog* + a_7*Tree,*

where the a_i are the coefficients for each of the respective probability forecasts.

Also included in this section in Fig. 1 is a map of the eight regions for which each set of coefficients is valid.

Fig. 1 Map of the 8 regions.



Section 7 – Calculating the predictors

Most of the predictors can be used directly from the Grib data, but some have to be calculated. Here is a rundown of all of the predictors for each of the three models and whether they can be used directly, used directly but just averaged, or whether there must be some computation. Unless otherwise noted they can be used directly.

AVN Model

Here are some general formulae to calculate the different terms for a dummy quantity B centered on grid location (i,j) where *dx* and *dy* is the grid spacing in the x and y directions, respectively.

ADVECTION

$$AdvectionB = -u(i,j)\left[\frac{B(i+1,j)-B(i-1,j)}{2dx}\right] - v(i,j)\left[\frac{B(i,j-1)-B(i,j+1)}{2dy}\right]$$

VORTICITY

$$Vorticity = \left[\frac{v(i+1,j)-v(i-1,j)}{2dx}\right] - \left[\frac{u(i,j-1)-u(i,j+1)}{2dy}\right]$$

DIVERGENCE

$$divergence = \left[\frac{u(i+1,j)-u(i-1,j)}{2dx}\right] + \left[\frac{v(i,j-1)-v(i,j+1)}{2dy}\right]$$

Please note that the j term is reversed due to the fact that this grid is read from North to South.

PREDICTORS
1) u wind 1000mb
2) u wind (average 850,700,500mb) – average 3 levels
3) u wind 300mb
4) v wind 1000mb
5) v wind (average 850,700,500mb) – average 3 levels
6) v wind 300mb
7) geopotential ht. 1000mb
8) geopotential ht. 850mb
9) geopotential ht. 700mb
10) geopotential ht. 500mb
11) geopotential ht. 300mb
12) temperature (average 1000,850,700,500) – average 4 levels
13) 6 hr precipitation

14) mixing ratio (average 850,700,500) –average 3 levels

Since this quantity is not supplied by the Grib files it must be calculated accordingly:

a.) Calculate Saturation Vapor Pressure $e_s = \exp(C_{15} - C_1 T - C_2/T)$

where

T = Temperature in Kelvin

$C_1 = .0091379024$

$C_2 = 6106.396$

$C_{15} = 26.66082$

b.) Calculate Vapor pressure e = Relative Humidity x e_s

c.) Calculate mixing ratio (q):

$$q = \frac{\varepsilon e}{(p - (1-\varepsilon)e)}$$

where,

$\varepsilon = .622$

p = pressure in units of mb

15) Relative Humidity (average 850,700,500) – Average the 3 levels

16) thickness (300mb minus 850mb) – 300 geop. ht minus 850 geop ht.

17) K-index = T850 – T500 +TD850 - (T700 –TD700)

where T is temperature and TD is dewpoint and the number following these parameters is the pressure level.

Since dewpoint is not supplied it must be calculated using the following formula:

$$J = \log_{10}\left(\frac{e}{6.112}\right)$$

$$TD = \left(\frac{(237.7J)}{(7.5-J)}\right) + 273.15$$

where

e= vapor pressure (from previous calculation in 14b)

TD= dewpoint in Kelvin

18) lapse rate (700 minus 500) = T700-T500

19) Total Totals Index = (T850-T500) +(TD850-T500)

Calculate dewpoint as in 17.

20) Cross Totals Index = TD850-T500

Calculate dewpoint as in 17.

21) Vertical Totals index= T850-T500
22) mean sea level pressure – convert from Pascals to mb
23) Equivalent Potential Temperature (average 850, 700) – average 2 levels
Calculated using the following equation:

$$\theta_e = \left(T + q\frac{L}{C_p}\right)\left(\frac{P_{00}}{P}\right)^{\frac{R}{C_p}}$$

R= 287 $JK^{-1}kg^{-1}$
C_p= 1004 $JK^{-1}kg^{-1}$
L = 2.5 X $10^6 Jkg^{-1}$
T= Temperature in Kelvin
q= specific humidity in g/g

24) Vertical velocity (average 850,700,500) – average the 3 levels
Must be converted from Pa to mb.

25) Vertical velocity 300mb – convert from Pa to mb

26) Equivalent Potential Temperature advection (average 850,700) –average 2 levels
Use the advection formula in the top of this section and calculate equivalent potential temperature as in 23.

27) Temperature advection (average 850, 700, 500) – average the 3 levels
Use the advection formula to calculate at each level.

28) Relative vorticity (average 850, 700, 500) –average the 3 levels
Use the vorticity formula to calculate at each level.

29) Divergence 300mb
Use the divergence formula.

30) Differential divergence (850 minus 300)
Calculate the divergence and take the divergence at 850mb minus the divergence at 300mb

31) Specific humidity advection (average 850, 700, 500) – average the 3 levels
Use the advection formula at each level.

32) Vorticity advection by geostrophic wind (average 700, 500) – average the 2 levels
Use the vorticity calculation from 28. Then calculate the geostrophic wind using.

$$u_g = -\frac{1}{f}\left[\frac{\phi(i,j-1)-\phi(i,j+1)}{2dy}\right]$$
$$v_g = \frac{1}{f}\left[\frac{\phi(i+1,j)-\phi(i-1,j)}{2dx}\right]$$

where,
$f = 2\Omega \sin\varphi$
Ω=7.29X10^{-5} rad/s
Φ = latitude

Now use the advection equation and substitute in the geostrophic wind for the actual wind.

Then average the 2 levels.

33) Moisture divergence (average 850, 700, 500) – average 3 levels
Calculate the moisture divergence for the 3 levels using:

$$moisturedivergence = \left[\frac{u(i+1,j)q(i+1,j)-u(i-1,j)q(i-1,j)}{2dx}\right]+\left[\frac{v(i,j-1)q(i,j-1)-v(i,j+1)q(i,j+1)}{2dy}\right]$$

34) Q-vector divergence (average 850, 700, 500) – average the 3 levels

Calculate the potential temperature using:

$$\theta = T\left(\frac{P_{00}}{P}\right)^{\frac{R}{C_p}}$$

Then use the following finite difference formulae to calculate the i and j components of the Q-vector.

i - component:
$$Qvect(i) = -\left[\frac{u_g(i+1,j)-u_g(i-1,j)}{2dx}\right]\left[\frac{\theta(i+1,j)-\theta(i-1,j)}{2dx}\right]-\left[\frac{v_g(i+1,j)-v_g(i-1,j)}{2dx}\right]\left[\frac{\theta(i,j-1)-\theta(i,j+1)}{2dy}\right]$$

j - component:
$$Qvect(j) = -\left[\frac{u_g(i,j-1)-u_g(i,j+1)}{2dy}\right]\left[\frac{\theta(i+1,j)-\theta(i-1,j)}{2dx}\right]-\left[\frac{v_g(i,j-1)-v_g(i,j+1)}{2dy}\right]\left[\frac{\theta(i,j-1)-\theta(i,j+1)}{2dy}\right]$$

Now that we have the i and j components of the Q-vector the divergence formula can be used by substituting in the i-component for u and the j-component for v.

Eta Model

Here are some general formulae to calculate the different terms for a dummy quantity B centered on grid location (i,j) where *dx* and *dy* is the grid spacing in the x and y directions, respectively.

ADVECTION

$$AdvectionB = -u(i,j)\left[\frac{B(i+1,j)-B(i-1,j)}{2dx}\right] - v(i,j)\left[\frac{B(i,j+1)-B(i,j-1)}{2dy}\right]$$

VORTICITY

$$Vorticity = \left[\frac{v(i+1,j)-v(i-1,j)}{2dx}\right] - \left[\frac{u(i,j+1)-u(i,j-1)}{2dy}\right]$$

DIVERGENCE

$$divergence = \left[\frac{u(i+1,j)-u(i-1,j)}{2dx}\right] + \left[\frac{v(i,j+1)-v(i,j-1)}{2dy}\right]$$

PREDICTORS

1) u wind 1000mb
2) u wind (average 950, 850,700,500mb) – average 4 levels
3) u wind 300mb
4) v wind 1000mb
5) v wind (average 950 850,700,500mb) – average 4 levels
6) v wind 300mb
7) geopotential ht. 1000mb
8) geopotential ht. 950mb
9) geopotential ht. 850mb
10) geopotential ht. 700mb
11) geopotential ht. 500mb
12) geopotential ht. 300mb
13) temperature (average 1000,950,850,700,500) – average 5 levels
14) 6 hr precipitation
15) mixing ratio (average 950 850,700,500) –average 4 levels
16) Relative Humidity (average 950, 850,700,500) – Average the 4 levels
17) thickness (300mb minus 850mb) – 300 geop. ht minus 850 geop ht.
18) K-index = T850 – T500 +TD850 - (T700 –TD700)
    - unlike the Avn and NGM we have the dewpoints directly

19) lapse rate (700 minus 500) = T700-T500
20) Total Totals Index = (T850-T500) +(TD850-T500)
21) Cross Totals Index = TD850-T500
22) Vertical Totals index= T850-T500

23) Equivalent Potential Temperature (average 850, 700) – average 2 levels

Calculated using the following equation:

$$\theta_e = \left(T + q\frac{L}{C_p}\right)\left(\frac{P_{00}}{P}\right)^{\frac{R}{C_p}}$$

R= 287 $JK^{-1}kg^{-1}$
C_p= 1004 $JK^{-1}kg^{-1}$
L = 2.5 X $10^6 Jkg^{-1}$
T= Temperature in Kelvin
q= specific humidity in g/g

24) Vertical velocity (average 950,850,700,500) – average the 4 levels

Must be converted from Pa to mb.
Since Eta 950 is not available from the Grib files for the Eta then average the 3 other levels.

25) Vertical velocity 300mb – convert from Pa to mb

26) Equivalent Potential Temperature advection (average 850,700) –average 2 levels

Use the advection formula in the top of this section and calculate equivalent potential temperature as in 23.

27) Temperature advection (average 850, 700, 500) – average the 3 levels

Use the advection formula to calculate at each level.

28) Relative vorticity (average 950, 850, 700, 500) –average the 4 levels

Use the vorticity formula to calculate at each level.

29) Divergence 300mb

Use the divergence formula.

30) Differential divergence (850 minus 300)

Calculate the divergence and take the divergence at 850mb minus the divergence at 300mb

31) Specific humidity advection (average 850, 700, 500) – average the 3 levels

Use the advection formula at each level.

32) Vorticity advection by geostrophic wind (average 700, 500) – average the 2 levels

Use the vorticity calculation from 28. Then calculate the geostrophic wind using.

$$u_g = -\frac{1}{f}\left[\frac{\phi(i,j+1)-\phi(i,j-1)}{2dy}\right]$$

$$v_g = \frac{1}{f}\left[\frac{\phi(i+1,j)-\phi(i-1,j)}{2dx}\right]$$

where,
$f = 2\Omega \sin\varphi$
Ω=7.29X10^{-5} rad/s
Φ = latitude

Now use the advection equation and substitute in the geostrophic wind for the actual wind.

Then average the 2 levels.

33) Moisture divergence (average 950, 850, 700, 500) – average 4 levels
Calculate the moisture divergence for the 3 levels using:

$$moisturedivergence = \left[\frac{u(i+1,j)q(i+1,j)-u(i-1,j)q(i-1,j)}{2dx}\right]+\left[\frac{v(i,j-1)q(i,j+1)-v(i,j+1)q(i,j-1)}{2dy}\right]$$

34) Q-vector divergence (average 850, 700, 500) – average the 3 levels

Calculate the potential temperature using:

$$\theta = T\left(\frac{P_{00}}{P}\right)^{\frac{R}{C_p}}$$

Then use the following finite difference formulae to calculate the i and j components of the Q-vector.

i - component:

$$Qvect(i) = -\left[\frac{u_g(i+1,j)-u_g(i-1,j)}{2dx}\right]\left[\frac{\theta(i+1,j)-\theta(i-1,j)}{2dx}\right]-\left[\frac{v_g(i+1,j)-v_g(i-1,j)}{2dx}\right]\left[\frac{\theta(i,j+1)-\theta(i,j-1)}{2dy}\right]$$

j - component:

$$Qvect(j) = -\left[\frac{u_g(i,j+1)-u_g(i,j-1)}{2dy}\right]\left[\frac{\theta(i+1,j)-\theta(i-1,j)}{2dx}\right]-\left[\frac{v_g(i,j+1)-v_g(i,j-1)}{2dy}\right]\left[\frac{\theta(i,j+1)-\theta(i,j-1)}{2dy}\right]$$

Now that we have the i and j components of the Q-vector the divergence formula can be used by substituting in the i-component for u and the j-component for v.

NGM Model

Here are some general formulae to calculate the different terms for a dummy quantity B centered on grid location (i,j) where *dx* and *dy* is the grid spacing in the x and y directions, respectively.

ADVECTION

$$AdvectionB = -u(i,j)\left[\frac{B(i+1,j)-B(i-1,j)}{2dx}\right]-v(i,j)\left[\frac{B(i,j+1)-B(i,j-1)}{2dy}\right]$$

VORTICITY

$$Vorticity = \left[\frac{v(i+1,j)-v(i-1,j)}{2dx}\right]-\left[\frac{u(i,j+1)-u(i,j-1)}{2dy}\right]$$

DIVERGENCE

$$divergence = \left[\frac{u(i+1,j)-u(i-1,j)}{2dx}\right]+\left[\frac{v(i,j+1)-v(i,j-1)}{2dy}\right]$$

PREDICTORS

1) u wind 1000mb
2) u wind (average 950, 850,700,500mb) – average 4 levels
3) u wind 300mb
4) v wind 1000mb
5) v wind (average 950 850,700,500mb) – average 4 levels
6) v wind 300mb
7) geopotential ht. 1000mb
8) geopotential ht. 950mb
9) geopotential ht. 850mb
10) geopotential ht. 700mb
11) geopotential ht. 500mb
12) geopotential ht. 300mb
13) temperature (average 1000,950,850,700,500) – average 5 levels
14) 6 hr precipitation
15) precipitable water – directly from ngmpwatfXX.dat file where XX is the forecast time

16) mixing ratio (average 950 850,700,500) –average 4 levels
Calculated the same way as in the AVN section.

17) Relative Humidity (average 950, 850,700,500) – Average the 4 levels
18) Average Releative humidity from the model – found in ngmmodrhfxx.dat file where XX is the forecast time.

19) thickness (300mb minus 850mb) – 300 geop. ht minus 850 geop ht.
20) K-index = T850 – T500 +TD850 - (T700 –TD700)
See AVN sheet to see how to calculate dew point.

21) lapse rate (700 minus 500) = T700-T500

22) Total Totals Index = (T850-T500) +(TD850-T500)
23) Cross Totals Index = TD850-T500
See AVN sheet to see how to calculate dew point.

24) Vertical Totals index= T850-T500
25) Mean Sea Level Pressure – Convert from Pa to mb.
26) Equivalent Potential Temperature (average 850, 700) – average 2 levels
Need to use the specific humidity from (16)

Calculated using the following equation:

$$\theta_e = \left(T + q\frac{L}{C_p}\right)\left(\frac{P_{00}}{P}\right)^{\frac{R}{C_p}}$$

R= 287 $JK^{-1}kg^{-1}$
C_p= 1004 $JK^{-1}kg^{-1}$
L = 2.5 X $10^6 Jkg^{-1}$
T= Temperature in Kelvin
q= specific humidity in g/g

27) Vertical velocity (average 850,700,500) – average the 3 levels
Must be converted from Pa to mb.

28) Vertical velocity 300mb – convert from Pa to mb

29) Equivalent Potential Temperature advection (average 850,700) –average 2 levels
Use the advection formula in the top of this section and calculate equivalent potential temperature as in 26.

30) Temperature advection (average 850, 700, 500) – average the 3 levels
Use the advection formula to calculate at each level.

31) Relative vorticity (average 950, 850, 700, 500) –average the 4 levels
Use the vorticity formula to calculate at each level.

32) Divergence 300mb
Use the divergence formula.

33) Differential divergence (850 minus 300)

Calculate the divergence and take the divergence at 850mb minus the divergence at 300mb

34) Specific humidity advection (average 950, 850, 700, 500) – average the 4 levels
Use the advection formula at each level. Need to use specific humidity from 16.

35) Vorticity advection by geostrophic wind (average 700, 500) – average the 2 levels
Use the vorticity calculation from 28. Then calculate the geostrophic wind using.

$$u_g = -\frac{1}{f}\left[\frac{\phi(i,j+1)-\phi(i,j-1)}{2dy}\right]$$
$$v_g = \frac{1}{f}\left[\frac{\phi(i+1,j)-\phi(i-1,j)}{2dx}\right]$$

where,
$f = 2\Omega \sin\varphi$
Ω=7.29X10^{-5} rad/s
Φ = latitude

Now use the advection equation and substitute in the geostrophic wind for the actual wind.

Then average the 2 levels.

36) Moisture divergence (average 950, 850, 700, 500) – average 4 levels
Calculate the moisture divergence for the 4 levels using:

$$moisturedivergence = \left[\frac{u(i+1,j)q(i+1,j)-u(i-1,j)q(i-1,j)}{2dx}\right]+\left[\frac{v(i,j-1)q(i,j+1)-v(i,j+1)q(i,j-1)}{2dy}\right]$$

37) Q-vector divergence (average 850, 700, 500) – average the 3 levels

Calculate the potential temperature using:

$$\theta = T\left(\frac{P_{00}}{P}\right)^{\frac{R}{C_p}}$$

Then use the following finite difference formulae to calculate the i and j components of the Q-vector.

i - component:

$$Qvect(i) = -\left[\frac{u_g(i+1,j)-u_g(i-1,j)}{2dx}\right]\left[\frac{\theta(i+1,j)-\theta(i-1,j)}{2dx}\right]-\left[\frac{v_g(i+1,j)-v_g(i-1,j)}{2dx}\right]\left[\frac{\theta(i,j+1)-\theta(i,j-1)}{2dy}\right]$$

j- component:

$$Qvect(j) = -\left[\frac{u_g(i,j+1)-u_g(i,j-1)}{2dy}\right]\left[\frac{\theta(i+1,j)-\theta(i-1,j)}{2dx}\right]-\left[\frac{v_g(i,j+1)-v_g(i,j-1)}{2dy}\right]\left[\frac{\theta(i,j+1)-\theta(i,j-1)}{2dy}\right]$$

Now that we have the i and j components of the Q-vector the divergence formula can be used by substituting in the i-component for u and the j-component for v.

Section 8 – Some other important information

1.) If any of the probability forecasts using linear regression are below 0% or above 100%, then clip the forecasts so that they are equal to 0% or 100%, respectively.

2.) Make sure to define the gridpoints for each of the 2 grids (AVN and Eta, NGM) to the appropriate region based on the region map. This is important for applying the proper predictors and coefficients.

3.) Each region, threshold, forecast period, season, and model have a unique set of predictors. In all there are (8x4x8x2x8) 4096 sets of predictors.

Section 9 -Summary for implementing the model

1.) Run the script to download the grib files from the NCEP website: noaaget.sh
2.) Run the script to extract the data from the grib files and place them into text files: extractdata.sh
3.) Create a program which will follow through on the steps from reading the data from the text files to producing a final ensemble forecast. I prefer Fortran and have included code for the first step in reading the data.

A.) Read the data from the text file and place them into an array. This code is contained in the file: readdata.f

B.) Compute the basic quantities needed in order to compute the predictors which are not directly given by the numerical model.

C.) Calculate the predictors at the beginning and the end of the forecast period for which you are making the forecast. These predictors and a description are given in Section 7. For some predictors they can be taken directly from the text files, some must be vertically averaged, and some must be calculated. Note that for the tree method, which uses the average precipitation amount of the three models the AVN values must be interpolated to the Eta and NGM grid.

D) Apply the coefficients (Section 6) for each region, threshold, model and particular season for which you are making the forecast in order to produce the 7 probability forecasts (3 Linear regression, 3 Logistic regression and 1 Classification and Regression Tree). It is important to classify the grid points into the region to which they belong. Also, the linear regression forecasts must be clipped if they are above 100% or below 0%.

E) Create the statistical/dynamical probability forecast by applying linear regression to using the 7 probability forecasts using the ensemble coefficients referred to in Section 6. Before applying the proper coefficients, the forecasts from the AVN grid must be interpolated to the Eta and NGM grid. Make sure to clip these forecasts if they are above 100% or below 0%.