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USING PCGRIDDS TO FORECAST PRECIPITATION TYPE

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1. Theory

PCGRIDDS(Personal Computer Gridded Information Display and Diagnostic System) is a very useful software package that allows meteorologists to examine countless data fields in greater detail than through AFOS. Additionally, PCGRIDDS allows meteorologists to develop several macro-programs for a variety of meteorological calculations. Coding PCGRIDDS macros to derive various diagnostic and prognostic model output fields are easy compared to conventional programming languages, as explained by Meier (1993) and Zubrick (1993).

A particular macro developed at WSFO Louisville is called "TKKY.cmd". This command file evaluates the thicknesses of four different layers in the atmosphere. The purpose is to forecast precipitation type and the location of the rain/snow line during winter weather situations. "TKKY.cmd" was used operationally at WSFO Louisville during Winter 1994-95, and proved to be very helpful to forecasters besides other thermal and dynamic parameters.

Temperatures at certain constant pressure levels have long been known to give a first guess at where the rain/snow line may be located at the surface. For example, on the 850mb chart, the 0°C line is widely used to imply the rain/snow line. However, an alternate way to determine precipitation type is to use thicknesses of various layers. A thickness between two pressure levels is just the geopotential height difference between the two levels. From the hydrostatic equation, the thickness is directly proportional to the mean virtual temperature of the layer between the two levels.

The determination of precipitation type during a multiple-phase precipitation event can be a difficult procedure. The important deciding factors are the mean temperatures and depths of the warm layer aloft (more than 0°C) and the low-level cold layer (less than 0°C). For the cold layer, the mean temperature is more important and often the deciding factor in whether freezing rain or sleet is more probable. For sleet to occur, there must be sufficient freezing nuclei and a mean air temperature of below -10°C in the cold layer to freeze liquid droplets before reaching the ground. With temperatures greater than -10°C, freezing rain is more probable as the droplets may remain super cooled and only freezes when reaching the below freezing surface. The exception, however, is if only partial melting of ice crystals occurs in the warm layer aloft. Mixed ice crystal/liquid water particles will refreeze in the low-level cold layer resulting in sleet instead of freezing rain despite a mean temperature greater than -10°C due to the presence of the ice crystals.

For the warm layer aloft, a mean temperature of less than 1°C generally will allow only partial melting of snowflakes. Assuming a cold low-level layer, these particles will refreeze and snow would likely be occurring at the surface. But, Stewart and King (1987) found that in a warm layer aloft with a mean temperature of 3 to 4°C, complete melting of ice crystals will take place, and freezing rain or rain will occur depending on the surface temperature. Sleet forms when a warm layer mean temperature of approximately 1 to 3°C and a significant cold layer below would have to exist. Finally, the depth of the warm layer must be considered. The deeper (shallower) the warm layer the more (less) time there is for ice crystals to melt.

Based on this information, statistical relationships were developed relating the depth of various thickness layers to the occurrence of different precipitation types. For freezing rain to occur, the depth of the 1000-850 mb cold layer generally should be from 1290 to 1300 meters, the 850-700 mb warm layer generally should be greater than 1550 meters in depth, and the surface temperature must be less than 0°C. Hanks (1967) used the 1000 to 700 mb layer and found that the 2840 meter thickness line separated snow from liquid precipitation 85 percent of the time. The 2840 meter thickness corresponds to a mean layer temperature of -1.3°C. Other relationships between thicknesses and rain/snow lines were developed over the years. For example, the "Winter Weather-Precipitation Type" booklet from the National Weather Service Training Center (1994) shows some correlations between thicknesses and rain/snow lines (Table 1).

RAIN/SNOW THICKNESS RELATIONSHIPS

LAYER	MAINLY SNOW	50%	MAINLY RAIN
1000-700	2800	2840	2870
1000-850	1275	1300	1325
1000-500	5360	5400	5460
850-700	1520	1540	1555

Table 1. Thicknesses (in meters) of various atmospheric layers (in mb) used for determination of rain/snow lines. The 50% values mark an equal chance for liquid or frozen precipitation. Values need to be modified in mountainous terrain.

The WSFO Louisville PCGRIDDS command file "TKKY.cmd" (Figure 1) combines the AFOS graphics NMCGPHK0K, NMCGPHK0L, and NMCGPHK0S.

The macro computes model-forecasted thickness values and mean winds for each layer stated in Table 1 at any 6-h forecast interval, and highlights the critical 50 percent values for the rain/snow line (Table 1). Finally, only the critical 50 percent thickness values for each layer are superimposed on a plan view for comparison. This allows forecasters to easily spot cold and warm layers, and areas of concern for freezing rain, sleet, and snow.

```
LOOP
AREA 39 89 12
ERAS
TXT3    *** WELCOME TO THE WSFO LOUISVILLE COMMMAND FILE ***
TXT4    *** TO CALCULATE THICKNESS VALUES IN VARIOUS LAYERS ***
TXT6 This file will calculate model forecast thickness values for TXT7 the following layers: 1000-
850 mb, 1000-700 mb, 1000-500 mb, TXT8 850-700 mb. In addition, critical thickness values for rain
TXT9 versus snow are highlighted. Average layer winds also are
TXTA displayed. Finally, the critical line for all four layers
TXTB will be displayed on one plan view. Please use this file
TXTC to help determine precipitation type.
TXTF *** CHOOSE YOUR FORECAST HOUR OF INTEREST
TXTG (00,06,12,18,24,30,36,42,48) ***
FHOR
ENDL
LOOP
ERAS
STOF
SLYR 1000 850
NLBL HGHT LDIF CI05 CLR2
NLBL HGHT LDIF GRTN 1295 LSTN 1305 CI05 CLR6/
NLBL VAVR[BKNT 1000,BKNT 850] CLR5/
TXT2 THICKNESSES AND AVERAGE LAYER WINDS FOR THE **1000 TO 850 MB TXT3
LAYER**. TXT3 CRITICAL VALUES FOR RAIN VERSUS SNOW ARE
TXT4 HIGHLIGHTED!!!!!!!
ENDL
LOOP
STOF
ERAS
SLYR 1000 700
NLBL HGHT LDIF CI10 CLR2
NLBL HGHT LDIF GRTN 2830 LSTN 2850 CI10 CLR6/
NLBL VAVR[BKNT 1000,BKNT 700] CLR5/
TXT2 THICKNESSES AND AVERAGE LAYER WINDS FOR THE **1000 TO 700 MB TXT3
LAYER**. CRITICAL VALUES FOR RAIN VERSUS SNOW ARE
TXT4 HIGHLIGHTED!!!!!!!
ENDL
LOOP
STOF
ERAS
SLYR 1000 500
NLBL HGHT LDIF CI20 CLR2
NLBL HGHT LDIF GRTN 5380 LSTN 5420 CI20 CLR6/
NLBL VAVR[BKNT 1000,BKNT 500] CLR5/
```

```
TXT2 THICKNESSES AND AVERAGE LAYER WINDS FOR THE **1000 TO 500 MB TXT3
LAYER**. CRITICAL VALUES FOR RAIN VERSUS SNOW ARE
TXT4 HIGHLIGHTED!!!!!!!
ENDL
LOOP
STOF
ERAS
SLYR 850 700
NLBL HGHT LDIF CI05 CLR2
NLBL HGHT LDIF GRTN 1535 LSTN 1545 CI05 CLR6/
NLBL VAVR[BKNT 850,BKNT 700] CLR5/
TXT2 THICKNESSES AND AVERAGE LAYER WINDS FOR THE **850 TO 700 MB TXT3
LAYER**. TXT3 CRITICAL VALUES FOR RAIN VERSUS SNOW ARE
TXT4 HIGHLIGHTED!!!!!!!
ENDL
LOOP
SLYR 1000 850
NLBL HGHT LDIF GRTN 1300 LSTN 1305 CI05 CLR3
SLYR 1000 700
NLBL HGHT LDIF GRTN 2840 LSTN 2850 CI10 CLR2/
SLYR 1000 500
NLBL HGHT LDIF GRTN 5395 LSTN 5405 CI05 CLR5/
SLYR 850 700
NLBL HGHT LDIF GRTN 1540 LSTN 1545 CI05 CLR6/
TXT1 ** CRITICAL THICKNESS VALUE (50 percent) FOR 1000-850 MB TXT2 (WHITE), 1000-
700 MB (RED), 1000-500 MB (BLUE), AND 850-700 TXT3 MB (GREEN) ** Example: If 1000-850
thickness is below
TXT4 threshold (cold) but 850-700 thickness is above threshold TXT5 (warm), then freezing rain
and/or sleet psbl.
ENDL
LOOP
ERAS
TXT3 *** THANK YOU FOR USING THE WSFO LOUISVILLE THICKNESS MACROS TXT4 ***
TXT6 To use this command file again for a different time, simply TXT7 enter
TXT8 "TKKY." at the command line above, then enter your new time TXT9 period when prompted
to do so.
TXTM MIKE KOCH, CHANCE HAYES, TED FUNK
ENDL
```

Figure 1. PC-GRIDDS command file code for WSFO Louisville's "TKKY.cmd" macro.

2. Case Study

On 9 March 1994, a mixed precipitation event occurred across the Ohio Valley in which all forms were reported either separately or in different combinations. At 1200 UTC, a weak surface low pressure center was located across southwestern Louisiana with a stationary front extending northeastward from the low through central Alabama into central North Carolina (not shown). In addition, an inverted trough axis extended from Alabama northeastward to central West Virginia. North of the stationary front, prevailing surface winds were from the northeast and a large area of precipitation was occurring across Kentucky. The freezing precipitation line in Kentucky extended from roughly Ft. Knox to Louisville to Lexington to Jackson. At 500 mb, a positively tilted trough was located across the Plains into Mexico, with southwest flow across the Ohio Valley.

Using "TKKY.cmd", the 1200 UTC 9 March NGM initial analysis showed that the 1000-850 mb 1300 meter thickness line was located from Bowling Green in southwest Kentucky through Lexington in east-central Kentucky and into West Virginia (Figure 2). Within the 850-700 mb layer (Figure 3), the critical 1540 meter thickness line extended from extreme northern Kentucky westward across southern Indiana. Meanwhile, the 1000-500 mb 5400 meter thickness line was well north of Kentucky (Figure 4). Thus, in areas where freezing rain or freezing drizzle was occurring at 1200 UTC (e.g., Lexington, Louisville, Ft. Knox, and Jackson), low-level cold air was in place from 1000 to 850 mb, while a relatively warm upper-level layer was located between 850 and 500 mb. It should be noted that Jackson was located in the area of greater than 1300 meter 1000-850 mb thicknesses, but due to its high station elevation, the critical thickness value is higher. On the other hand, Cincinnati reported all snow, and was located north of both the 1000-850 and 850-700 mb critical thickness values. Figure 5 shows NGM thickness values for the 1000-700 mb layer, while Figure 6 shows the superimposed critical thickness isopleths for the four layers. Thus, the NGM gridded initialized thickness values corresponded well with precipitation type in this case.

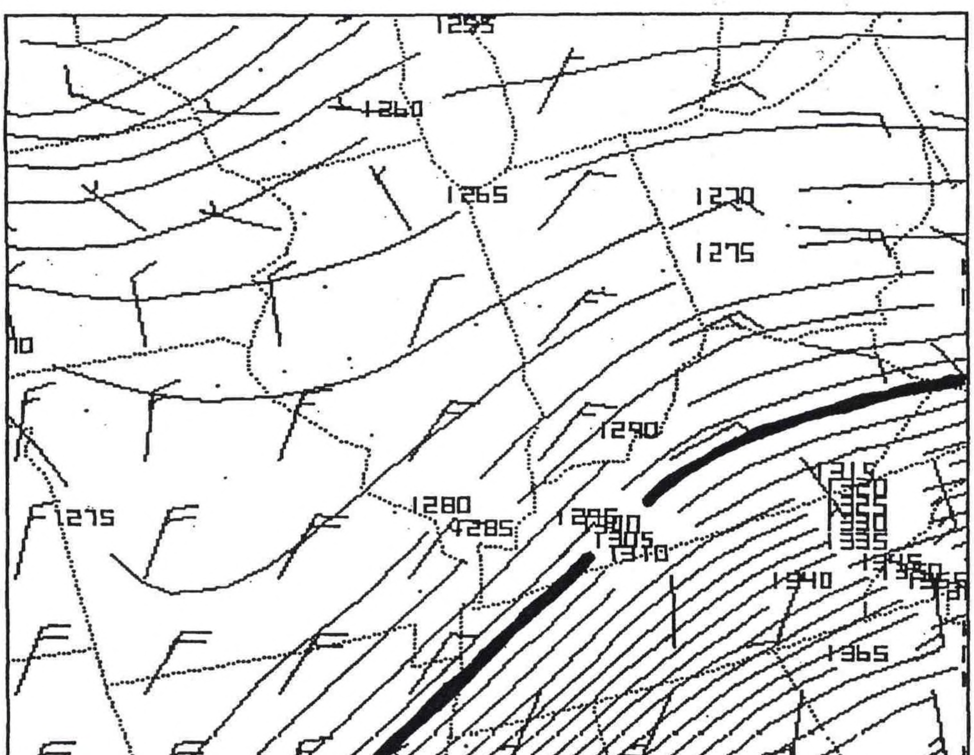

Figure 2. NGM 1200 UTC 9 March 1994 initial analysis of 1000-850 mb thicknesses (solid lines, in m) and mean layer winds (in kts). Critical 1300 m thickness lines in highlighted in bold.

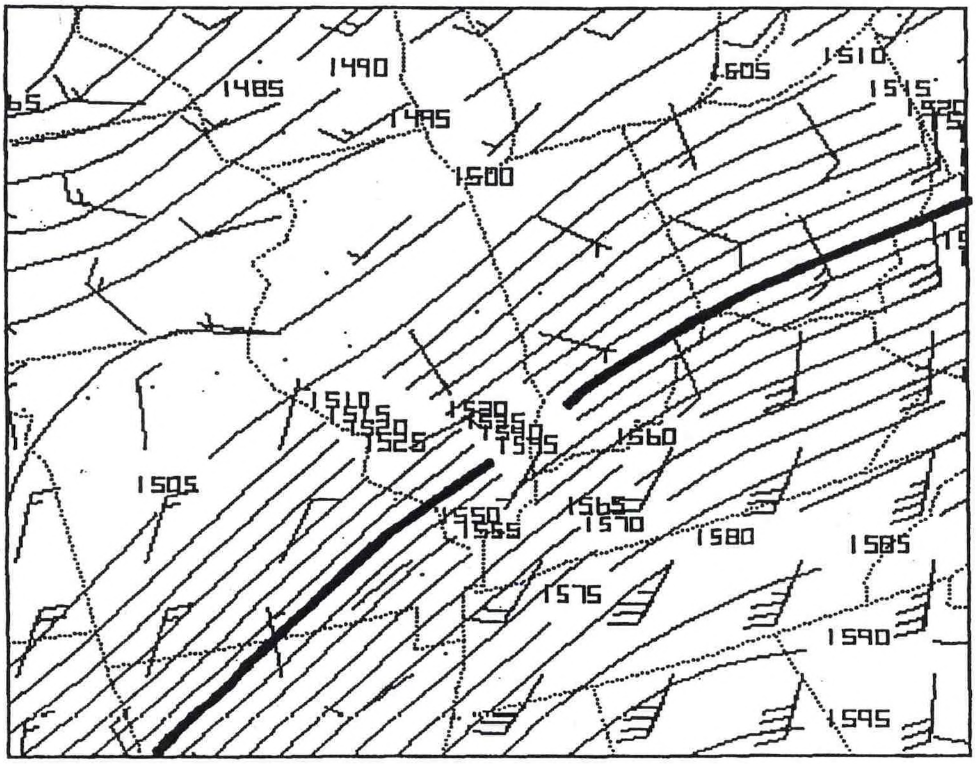

Figure 3. Same as Figure 2 except for the 850-700 mb layer. Critical 1540 m thickness line is highlighted in bold.

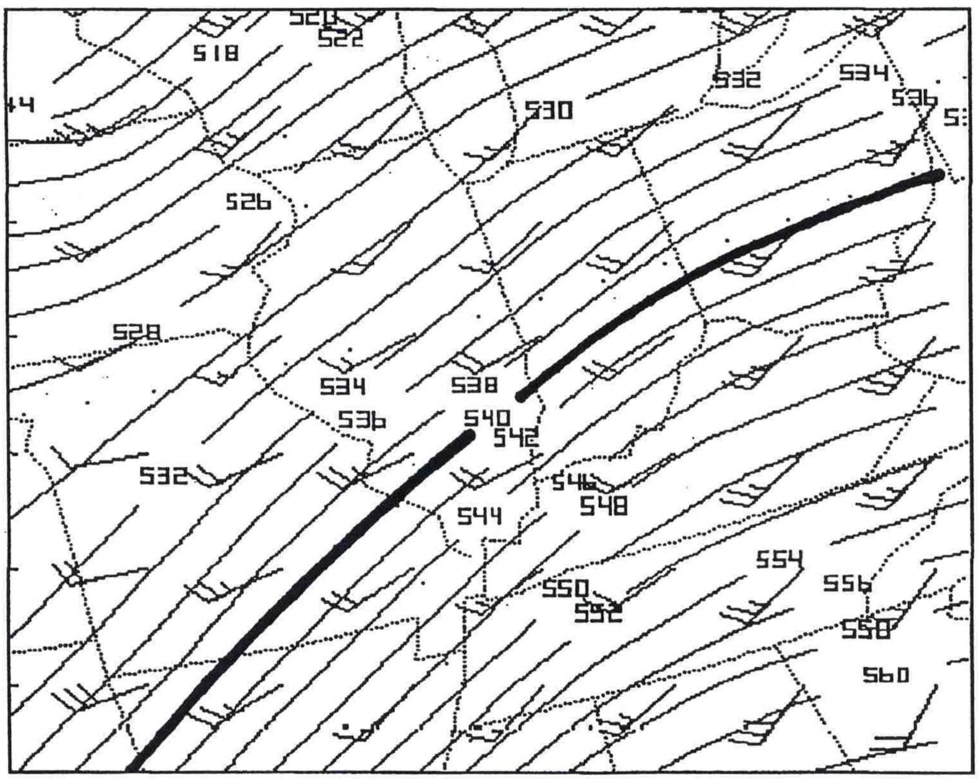

Figure 4. Same as Figure 2 except for the 1000-500 mb layer with units of dm. Critical 5400 m thickness line is highlighted in bold.

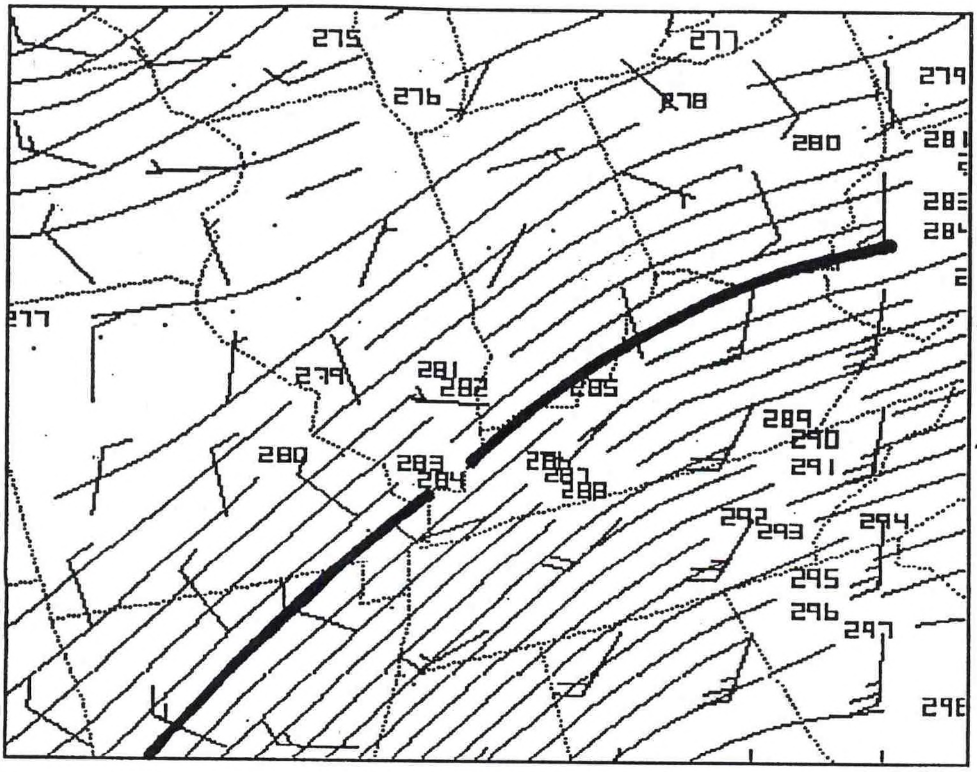

Figure 5. Same as Figure 2 except for the 1000-700 mb layer with units of dm. Critical 2840 m thickness line is highlighted in bold.

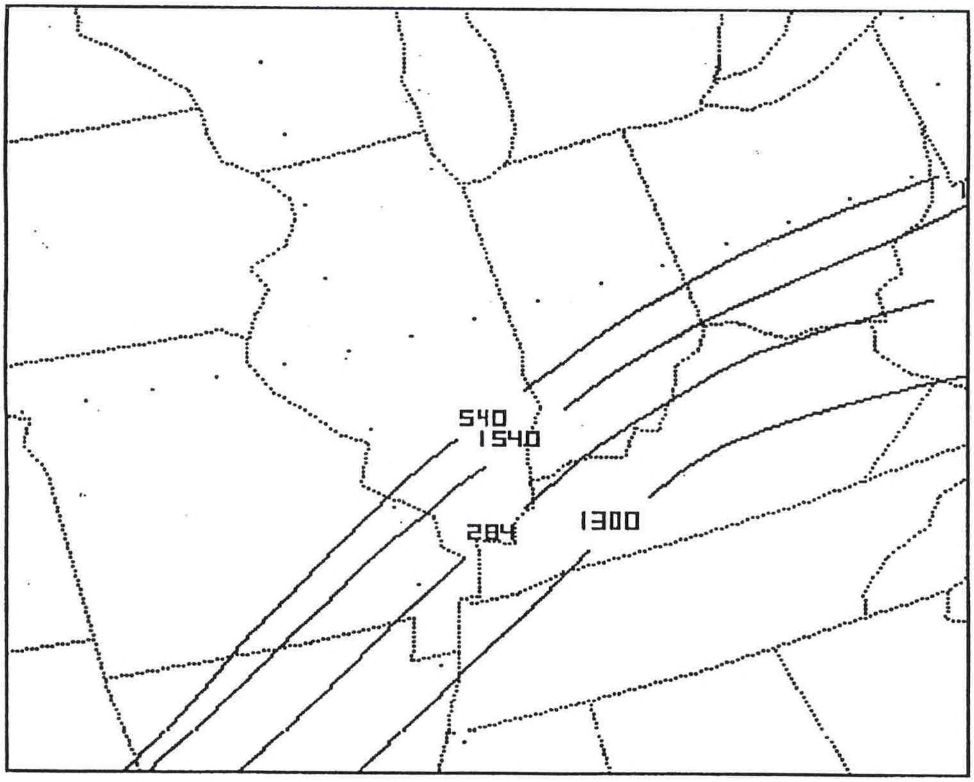

Figure 6. Fifty percent critical thickness lines from the 1200 UTC 9 March 1994 NGM initial analysis for the four layers in Figures 2-5.

3. Conclusions

When using thicknesses to forecast precipitation type, there are few points to consider. First, the use of critical thicknesses as a forecast tool (e.g., those in "TKKY.cmd") often work best in overrunning events when the atmosphere usually is stable stratified. Second, for very shallow arctic air masses, even the 1000-850 mb layer may be too thick to properly diagnose the low-level cold layer. In these situations, freezing rain may still occur despite apparently "warm" 1000-850 mb thickness values. In addition, one must consider that the thickness values are based on numerical models that contain various biases. Many of these biases are summarized by Junker et al. (1989), Kousky and Grumm (1993), and Junker and Hoke (1990), among others. Therefore, forecasters must incorporate knowledge of model data when evaluating critical model thickness values.

Finally, thicknesses are only one way to determine expected precipitation type. Other concepts such as utilizing modified soundings, surface and 850 mb temperature, vertical motion, and adiabatic and diabatic (including evaporation and melting) considerations are still irreplaceable and need to be accounted for. Nevertheless, using thicknesses of different atmospheric layers is an important forecasting technique that should be utilized during the winter season.

4. Acknowledgments

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5. References

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