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NOAA Technical Memorandum NWS WR-215

WEATHERTOOLS

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WEATHERTOOLS

I. INTRODUCTION

On a typical day at a busy weather office the forecaster is called upon to answer many questions. When the problems are algebraic, a spreadsheet is a perfect vehicle for solutions. Version 5.01 of WeatherTools has eleven spreadsheets combined into one toolkit to find quick answers to some complex and time-consuming problems common to many weather offices, especially those in mountainous areas.

Unlike computer programs that require enormous amounts of time to develop, debug, and refine, a spreadsheet is fast and flexible. Any of the WeatherTools sheets can be removed or changed easily.

Though WeatherTools may seem to be geared for mountain weather forecasting, more than half of the spreadsheets are generic and can be used by other offices as well. Many of the algorithms used should be familiar to most forecasters. Caution should be used in interpreting results. In some cases the answers provided are just a start of the solution. In every case, the answer is an estimate.

The author invites any user to adapt the spreadsheets for their own needs and encourages further development of WeatherTools. There is plenty of room for expansion. If you find WeatherTools useful, you may also find its companion, HydroTools (Egger 1991), equally helpful.

II. ENVIRONMENT, SETUP, AND RUNNING WEATHERTOOLS

ENVIRONMENT:

WeatherTools is driven by QUATTRO or 1-2-3 on an IBM compatible machine running DOS 2.1 or higher. The hardware required is 512K of RAM, one floppy drive, a hard drive, and a monochrome or color monitor.

The distribution floppy should contain the following files:

WXTOOLSC.WK1	- QUATTRO or 1-2-3 spreadsheet color version
WXTOOLSM.WK1	- QUATTRO or 1-2-3 spreadsheet monochrome version
WXTOOLS	- WeatherTools User's Guide

SETUP:

Copy the appropriate spreadsheet to the QUATTRO or 1-2-3 directory. For a QUATTRO user, assuming \QUAT is the QUATTRO directory and a color monitor used, put the distribution floppy in the A: drive and from the A: prompt, type,

COPY WXTOOLSC.WK1 C:\QUAT

If a monochrome monitor is used, then do the following:

COPY WXTOOLSM.WK1 C:\QUAT

Notice the M instead of C in the spelling.

RUNNING WXTOOLS:

In the Quattro directory, type Q WXTOOLSC for color systems or Q WXTOOLSM for monochrome systems. Sorry, no instructions for the 1-2-3 users. See your 1-2-3 user manual for loading and running spreadsheets.

The WeatherTools title screen should appear as below.

```
                                                           ver 4.02

                         WeatherTools:
            Spreadsheet Solutions to several meteorological problems.
               Tom Egger / WSFO-Boise, Idaho / (208) 334-9860

            Sheet 1........Mountain Temperatures
            Sheet 2........Forecast max temps from 850/700 temps
            Sheet 3........Snow Avalanche Temps
            Sheet 4........Freezing Levels from 850 temps
            Sheet 5........Conversions
            Sheet 6-2......Pressure/Density Altitude, Altimetry
            Sheet 7........Windchill
            Sheet 8........Distance/Speed on a Sphere
            Sheet 9........Degree Days
            Sheet 10-3.....Stability, Lapse Rates, Cloud Height, Haines
            Sheet 11.......Forecast min temps
    ....................................................................
       Use Pg Up/Pg Dn keys to desired sheet.  Then use arrow cursor
       keys to position over input cell.  NEVER use the delete key.
```

If the above menu page is not displayed, then hit the Home key on the number pad (make sure the Num Lock is not engaged). Notice there are eleven spreadsheet topics. A few topics have related spreadsheets: 1.1, 1.2, 10.1, 10.2, etc. Related spreadsheets are on side pages (more on that later). Dislocation (getting lost) in the spreadsheet can be corrected by depressing the Home key.

MOVING AROUND:

The cursor keys, Page Up/Down, Ctrl, and number keys on the top row are the only keys needed for entry and moving around.

1. Select a spreadsheet (topic) with the Page Up/Down keys.
2. Enter data by moving to the highlighted cursor box with the cursor keys, then use number keys for changing a value.
3. Observe the answers change in output boxes.
4. **Never use the Delete (Del) key.**

Example:

Determine the maximum temperature today using the 700 mb temperature and height from this morning's sounding. Using the coded mandatory level message CCCMANXXX, enter the following keystrokes:

1. Home
2. Page Down
3. Page Down
4. Move cursor to the 700 tmp input box.
5. Enter the 700 mb temperature in deg C from the CCCMANXXX.
6. Enter the coded 700 mb height (as is) from the MAN message.

On a color monitor the input area is blocked and highlighted. In monochrome the input area is just highlighted. If it is not, adjust the contrast and brightness until you can distinguish between the input and other areas. Keep the cursor in the input area at all times. The estimated answer is at the bottom of the screen. Change the temperature several times and notice the answers. Depress the Home key and then select a different spreadsheet.

A few macros will make some procedures easier:

ALT-E - UNPROTECT AND SET EDIT MODE
ALT-M - PROTECT AND SET MONOCHROME
ALT-C - PROTECT AND SET COLOR MODE
ALT-Q - QUIT

SPREADSHEET 1 MOUNTAIN TEMPERATURES

```
Sheet 1...Mountain Temps. (Given Temp. and lapse rate at one level)
INPUT:
      Lapse Rt.  >     4.2 < deg F/1000 ft  (5.5 dry, 3.6 std, 3.0 wet)
     Base Elev.  >    2800 < msl
     Base Temp.  >      60 < deg F        Top Elev.  >    9700 < msl
                                         Bot'm Elev.  >    6435 < msl
....................................................................
OUTPUT:  12000 ft>      21       -6 < deg F  deg C
         11000 ft>      26       -4 <
         10000 ft>      30       -1 <       NOTE: No allowance for
          9000 ft>      34        1 <       latitude, pressure,
          8000 ft>      38        3 <       moisture, slope, snow
          7000 ft>      42        6 <       cover, wind, clouds,
          6000 ft>      47        8 <       inversions etc..
          5000 ft>      51       10 <
          4000 ft>      55       13 <       OTHER LEVELS:
          3000 ft>      59       15 <          ELEV.    deg F    deg C
          2000 ft>      63       17 <           9700       31       -1
          1000 ft>      68       20 <           6435       45        7
          MSL    >      72       22 <
```

PURPOSE:

One of the biggest challenges to a weather forecaster is predicting temperatures for complex terrain. Several techniques could be employed. One common practice associates temperatures and height data obtained from nearby soundings with the elevation in question. Since height labels on Skew-T and Pseudo-adiabatic diagrams are with respect to the standard atmosphere, the temperatures used for an elevation may be off by quite a bit. Unless the atmosphere is "unusually standard" the temperatures indicated are not really for the given elevation. When was the last time you analyzed a perfectly standard sounding? Another popular technique would be to mentally make adjustments for elevation using a standard lapse rate. Spreadsheet 1 is similar to this method.

Instead of using the standard lapse rate of 3.6 deg F for each 1000 feet, Spreadsheet 1 allows for different lapse rates. See Spreadsheet 10.1 for averaging lapse rates.

FORMULA:

$$T1 = (((H0-H1)/1000)*LR)+T0$$

where

- T1 = temperature deg F at higher level
- T0 = temperature deg F at surface
- H1 = higher elevation
- H0 = surface elevation
- LR = lapse rate deg F/1000 ft

APPLICATION:

The Forest Service calls and needs a maximum temperature forecast for 6435 feet and 9700 feet at a fire site. The nearby weather station is at 2800 feet where the expected maximum temperature is 60 degrees. You already ran Spreadsheet 10.1 and determined your average lapse rate to be 4.2 deg F/1000 feet. He is in a hurry and needs an answer quickly. No other information about slope or exposure was provided. Your response?

1. Page down to Spreadsheet 1.
2. Move the cursor to the Base elevation block and enter 2800.
3. Enter 60 degrees in the base temp block.
4. Enter 4.2 in the lapse rate block.
5. Move the cursor over to the Top Elev: block and enter 9700.
6. Enter 6435 in the block just below labeled Bot'm Elev..

Response:

9700 ft max = 31
6435 ft max = 45

CAUTIONS AND RESTRICTIONS:

No allowance is made for slope, aspect, snow cover, inversions, etc. The output is limited by the input of only three parameters: elevation, temperature, and lapse rate.

Spreadsheet 1 works best on estimating maximum temperatures when no inversion is present (i.e., the morning inversion is mixed out).

SPREADSHEET 2 FORECAST MAXIMUM TEMPERATURE

```
SHEET 2...FORECAST MAX TEMP (based on 850 or 700 or 500 temp):
Get temps and heights from AFOS product CCCMANXXX:
INPUT:
          elev.  :>    2840                  |
                       deg C     hgt.        |     feet     deg F
          850 tmp:>      7.0      439        |     4721      44.6
          700 tmp:>     -1.1        6        |     9863      30.0
          500 tmp:>    -18.5      550        |    18046      -1.3
...........................................................................
OUTPUT:
                                    FULL SUN                CLOUDY

            bring 850 down >        55  deg F            50  deg F
            bring 700 down >        69  deg F            51  deg F
            bring 500 down >        82  deg F            44  deg F

...........................................................................
>>>> FULL SUN uses 5.5 deg F/1000 feet        | NOTE: At Boise use 850
>>>> CLOUDY uses 3.0 deg F/1000 lapse rate    | in Winter...700 Summer.
```

PURPOSE:

Maximum temperatures are commonly estimated by "bringing down" to the surface dry-adiabatically the 850 mb temperature on a Pseudo or Skew-T diagram . During the summer in the West, the 700 mb level is used at many sites. Accomplishing this on a small diagram with finely plotted lines is difficult. You will probably find Spreadsheet 2 to be an improvement.

FORMULA:

$$Tx = (((h7 - h0) / 1000) * 5.5) + t7$$

where

Tx = maximum temperature at surface h0
h7 = 700 mb height in feet
h0 = surface elevation in feet
t7 = temperature deg F at 700 mb

APPLICATION:

1. Page down to Spreadsheet 2.
2. Move the cursor to the "elev. :>" block and enter station elevation in feet.
3. Enter 850/700/500 mb temperature and height data directly from the mandatory level message CCCMANXXX. The spreadsheet will decode the height data. (Ex: 70006 01156 would be entered as -1.1 for the temperature and 6 for the height).

4. Check the output section for results. Make allowances for warm and cold air advection (WAA and CAA) by changing the input temperature accordingly. Example: the morning 700 mb temperature is -1.1 but WAA would make the afternoon temperature closer to +2.0. Enter the 2.0 instead.

Note: It is not necessary to enter the 500 mb and 850 mb data if 700 mb is the desired level.

SPREADSHEET 3 SNOW AVALANCHE TEMPERATURES (GIVEN 850t, LAPSE RATE, 850h)

SHEET 3...Snow Avalanche Temps. (Given 850t, lapse rate, 850 ht):
Enter 850 temp, lapse rate, and 850 ht.

	850 t deg C	lapse rate	850mb hgt.	ht meters	ft
00Z aftn	12.0	4.0	120	1200	3937
12Z morn	13.0	4.0	140	1400	4593
00Z tmrw	15.0	5.0	150	1500	4922

	FAHRENHEIT tdy	FAHRENHEIT tnt	FAHRENHEIT tmrw	CELSIUS tdy	CELSIUS tnt	CELSIUS tmrw
10000FT TEMP: >	29	34	34	-1	1	1
9000 FT TEMP: ** >	33	38	39	1	3	4
8000 FT TEMP: >	37	42	44	3	5	6
7000 FT TEMP: ** >	41	46	49	5	8	9
6000 FT TEMP: >	45	50	54	7	10	12
5000 FT TEMP: >	54	55	59	12	13	15

PURPOSE:

Mountain snow rangers monitor snowpack conditions for signs of instabilities that lead to avalanches. Accurate temperature forecasts for several elevations are needed for planning purposes. When model output temperatures, as in the FD(1-3) messages, do not provide acceptable guidance; alternate approaches are desirable. Estimating temperatures by extrapolating 850 mb data from the NGM is sometimes used. Spreadsheet 3 using 850 mb temperature and height data can provide useful results in winter when the surface inversion does not extend above 850 mb. All conversion of units is handled automatically. This spreadsheet was originally designed to assist the Boise forecaster during the winter months in the development of snow avalanche guidance product BOISAGBOI.

FORMULA:

$$Ts = ((H8 - Hs) / 1000) * LR + T8$$

where

Ts = Temperature at other surface
T8 = 850 mb temperature in deg F
LR = lapse rate deg F / 1000 feet
H8 = 850 mb height in thousands of feet
Hs = other surface elevation

APPLICATION:

Using the NGM graphic charts 8(2,4,6,8)T and 8(2,4,6,8)H, extract temperature and height values for the area under concern by reading the contours. Enter the temperature in deg C and coded height values in the input area of Spreadsheet 3 along with an appropriate lapse rate (in deg F/1000 ft). Obtain lapse rates from Spreadsheet 10.1.

Example:

1. Page down to Spreadsheet 3.
2. Move the cursor to the 00Z aftn (afternoon) block below the 850 t deg C column.
3. On AFOS, call up NGM graphics 8(4,6,8)H,T.
4. Read the 850 mb temperature contours for Sun Valley in South Central Idaho: -2.0 for 84T , -1.0 for 86T , and 3.0 for 88T.
5. Enter these values in the spreadsheet for 00Z aftn, 12z morn, and 00z tmrw (afternoon, morning, tomorrow). Include appropriate lapse rates too.
6. Read the contours for Sun Valley on the 850 mb height charts 84H, 86H, and 88H.
7. Enter these values in the appropriate cells.

Results:

Notice the output in degrees F for today, tonight, and tomorrow at the bottom of the sheet. Forecast temperatures at 7000 feet are 19, 21, and 30 degrees F for today, tonight, and tomorrow.

CAUTIONS AND RESTRICTIONS:

This technique is intended for use in the winter when a surface inversion does not rise above the 850 mb level. No allowances have been made for slope, aspect, inversions, etc.

SPREADSHEET 4.1 FREEZING LEVEL ESTIMATES (GIVEN 850 MB HEIGHT AND TEMPERATURE, LAPSE RATE) (method 1)

```
SHEET 4...FREEZING LEVEL ESTIMATES (GIVEN 850t, lapse rate, 850h):
ENTER 850mb TEMPS/HTS FROM NGM GRAPHICS 8(0,2,4,6,8)H,T:
                850 t    lapse    850ht   |        meters      ft
12Z TDY >        5.0      3.5      141    |         1410      4626
00Z DAY1>        5.0      3.5      141    |         1410      4626
12Z DAY1>        2.0      3.5      141    |         1410      4626
00Z DAY2>        6.0      3.5      141    |         1410      4626
12Z DAY2>        6.0      4.0      145    |         1450      4757
12Z DAY3>        7.0      4.0      147    |         1470      4823
****************************************
OUTPUT - FREEZING LEVELS:
                        START    ----------- DAY 1 ------------
                         12Z       18Z       00Z       06Z       12Z
          MSL           7198      7198      7198      6426      5655

                      ----------- DAY 2 ------------         DAY 3
                         18Z       00Z       06Z       12Z       12Z
          MSL           6683      7712      7572      7457      7973
```

PURPOSE:

Several users need accurate freezing level forecasts including River Forecast Centers. If it is winter or early spring and the surface inversion does not extend above 850 mb, then Spreadsheet 4 can provide estimates of freezing levels in lieu of other guidance. This spreadsheet was originally designed to assist the Boise forecaster during the winter months in the development of AFOS product BOIQPSBOI, a guidance product required by the Northwest River Forecast Center.

FORMULA:

FZ = ((T85 - 32) / LP) * 1000 + H8
where
FZ = Freezing Level
T85 = 850 mb temperature in deg F
LP = lapse rate deg F / 1000 feet
H8 = 850 mb height in thousands of feet

APPLICATION:

Obtain the 850 mb temperatures by reading the isotherms on NGM graphics 8(0,2,4,6,8)T over the site of interest. Enter these values (deg C) in the input column labelled deg C. Determine a lapse rate from Spreadsheet 10.1 and enter this value in the lapse rate block (deg F/1000 ft). Results in deg F are indicated in the lower half of the spreadsheet. Since 850 mb is a pressure surface, it is not always 5000 feet above sea level. Spreadsheet 4 makes allowances for the height vs. elevation differences. As with the AFOS 8xT charts, read the 850 mb height labels on AFOS graphics 8(0,2,4,6,8)H and place the labels "as is" in the column labelled 850ht; the sheet will compute the elevation from the height. For instance, if the 850 mb contour was 143 (1430 meters), enter 143 on the spreadsheet. For informational purposes a conversion of meters to feet is output to the right of the input area. Lapse rates are required for each time period but no guidance is available. Until a "feel" for lapse rates is developed, you may want to enter the same value for each time period.

The output form of Spreadsheet 4 suits the needs of AFOS product CCCQPSXXX; the QPF and freezing level message.

Example:

1. Page down to Spreadsheet 4.
2. Move the cursor to the first column of input blocks below 850t. Moving down the column, enter the 850 mb temperatures. Do the same for the next two columns, the lapse rates and 850 mb heights.

Assuming the lapse rates, 850 mb temperatures and heights are as indicated in the sample screen above, estimates of the freezing level for the next 10 periods are provided in the lower half of the screen. The output in the upper right are the corresponding elevations for the 850 mb surfaces.

CAUTIONS AND RESTRICTIONS:

Depending on what time of the day this procedure is run, the last one or two periods may not have any NGM guidance. Do not use this technique when a surface inversion extends above the 850 mb surface. Remember, a single lapse rate is being employed to generate the freezing level, a typical sounding will not be so "smooth".

SPREADSHEET 4.2 FREEZING LEVEL ESTIMATES (method 2)

```
SHEET 4-2...Freezing Levels (Given 850mb ht & temp and lapse rate):
                                           |
INPUT:                                     |
               850 t    lapse    850mb     |      ht        ht
               deg C    rate     hgt.      |    meters      ft      deg F
period 1        5.0      3.5      141      |     1410      4626       41
period 2        2.0      3.5      141      |     1410      4626       36
.....................................
OUTPUT:
          freezing lvl pd1:>    7198 < feet msl
          freezing lvl pd2:>    5655 < feet msl
.......................................................................
Alternate Method (using sfc data):
          INPUT:            sfc elev>     2800 < feet msl
                            lapse rt>      5.0 < deg F/K ft
                            sfc temp>       52 < deg F
.......................................................................
          OUTPUT:
                      freezing level:>    6800 < feet msl
```

PURPOSE:

If the format in Spreedsheet 4.1 does not suit your needs, perhaps this alternate method will be more practical. Two approaches are offered: the first utilizes only 850 mb data while the second assumes only surface data are available.

FORMULA:

$$FZ = ((T85 - 32) / LP) * 1000 + H8$$

or

$$FZ = ((Ts - 32) / LP) * 1000 + Hs$$

where

FZ = Freezing Level
T85 = 850 mb temperature in deg F
LP = lapse rate deg F / 1000 feet
H8 = 850 mb height in thousands of feet
Ts = surface temperature in deg F.
Hs = elevation above sea level in feet.

APPLICATION:

Obtain the 850 mb temperatures and heights by reading the isogons on NGM graphics 8(0,2,4,6,8)T,H over the site of interest. Enter these values "as is" (the heights will be decoded and computed) in the input columns. Determine a lapse rate from Spreadsheet 10.1 and enter this value in the lapse rate block. Results in deg F are indicated in the lower half of the spreadsheet.

Example 1 (using 850 mb data):

1. Page down to Spreadsheet 4.1.
2. Page over to Spreadsheet 4.2 with CTRL RIGHT ARROW.
3. Move the cursor to the first column of input blocks below 850t. Moving down the column, enter the 850 mb forecast temperatures. Do the same for the next two columns, the lapse rates and 850 mb heights.

Assuming the lapse rates, 850 mb temperatures and heights are entered as in the sample screen above, estimates of the freezing level for the next 2 periods are provided in the lower half of the screen. In the upper right of the screen, the corresponding elevations for the 850 mb surfaces are output.

Example 2 (only surface data available):

1. Move the cursor to the bottom of screen - to the Alternate Method area.
2. Enter the surface elevation, an appropriate lapse rate, then your afternoon maximum in deg F.

The computed freezing level is indicated just below the dotted line.

CAUTIONS AND RESTRICTIONS:

Do not use this technique when a surface inversion is present. Remember, a single lapse rate is being employed to generate the freezing level, a typical sounding will not be so "smooth".

SPREADSHEET 5 CONVERSIONS

SHEET 5...CONVERSIONS (input in highlighted cross blocks ONLY)
Beware of slight round-off errors.

temps:

deg F	deg C	deg K
-40.0	-40.0	233.6
-40.0	-40.0	233.6
-40.0	-40.0	233.6

length: (large units)

sm	nm	km
100.0	86.8	160.9
100.0	86.8	160.8
100.0	86.8	160.8

std. atmosphere: (< 36,000 ft)

elev.	deg C	p-mb
5,000	5	843
2,523	10	924
9,875	-5	700

length: (small units)

in	cm	mm
6.00	15.24	152.40
6.00	15.24	152.40
6.00	15.24	152.40

pressure: (stnd.)

in Hg	mm Hg	mb	atmos.
4.35	110.5	147.3	0.145
29.92	759.9	1013.1	1.000
2.95	75.0	100.0	0.099
29.92	760.0	1013.2	1.000

velocity:

mph	kts	mps	km/h
58.0	50.3	25.9	93.3
57.9	50.3	25.9	93.2
57.9	50.3	25.9	93.2
57.9	49.8	25.9	93.2

PURPOSE:

Display quick conversions of popular meteorological quantities.

FORMULA:

Temperature:

C = 5/9 (F - 32) = K - 273.16
F = 9/5C + 32 = 9/5 (K - 273.16) + 32
K = C + 273.6 = 5/9 (F - 32) + 273.16

Standard Atmosphere Estimates (T=temp, Z=elev, P=pres):

T = 15 - .0065 * Z / 32.38
Z = (T - 15) * 3.28 / -.0065
P = 1013.25 * ((288 - .0065 * Z) / 288)^5.256

Standard Pressure using Mercury (Hg):

1 mb = .750 mm Hg = .0295 in Hg
1 mm = 1.33 mb = .0394 in Hg
1 in = 33.864 mb = 25.4 mm Hg
1 atmos = 1013.25 mb = 760 mm Hg = 29.921 in Hg

Length (large units):

1 sm = .868 nm = 1.609 km
1 nm = 1.152 sm = 1.853 km
1 km = .621 sm = .54 nm
sm = statute mile   nm = nautical mile

Length (small units):
1 in = 2.54 cm = 25.4 mm
1 cm = .394 in = 10.0 mm
1 mm = .039 in = .10 cm

Velocity:
1 mps = 3.6 km/hr = 1.94 kts = 2.24 mph
1 kts = 1.15 mph = .53 mps = 1.85 km/h
1 mph = .87 kts = .45 mps = 1.61 km/h
1 km/h = .28 mps = .53 kts = .62 mph
mps = meters per second

APPLICATION:

Input procedures are a little different for this spreadsheet. Instead of entering data in vertically stacked columns, entry is made in diagonal rows. If you are using a color monitor, the input cells are blocked. For monochrome users, input cells are high intensity, output is low intensity; adjust contrast if this is not apparent.

Example 1:

Convert -12 deg C to deg F.

1. Move cursor to the second row of deg C column, enter -12.
2. Read deg F in the 2nd row first column...deg K are located in the same row column 3.

deg F	deg C	deg K
10.4	-12.0	261.6

Example 2:

Convert 58 mph to kts, mps (meters per second), km/h

1. Move cursor to first row first column of velocity section, enter 58.
2. Answers: 58.0 mph 50.3 kts 25.9 mps 93.3 km/h

SPREADSHEET 6.1 PRESSURE ALTITUDE AND DENSITY ALTITUDE

```
  SHEET 6-1...PRESSURE ALTITUDE & DENSITY ALTITUDE

INPUT:

           FIELD ELEVATION: >    5280 < FEET
           ALT. SETTING    :>   30.00 < INCHES
           Sfc. Temp:       >      90 < deg F              32.2 deg C

.......................................................................

OUTPUT:

              PRESSURE ALT: >    5207 < FEET

               DENSITY ALT: >    8512 < FEET   approx.
```

PURPOSE:

Pilot briefers are accustomed to using a series of tables or a "fuzzy" chart to determine pressure and density altitude. Spreadsheet 6 displays results instantly and permits "what-ifing" to better understand the relationship of one parameter to another.

FORMULA:

Pressure Altitude:

$PA = [((Pz / 29.921)^{.190259} * 288) - 288) / (-.0065 * 3.28)] + Ha$

where

PA = pressure altitude

Ha = field elevation

Pz = altimeter setting

Density Altitude:

$DA = PA + (66.67 * Vt)$

where

DA = density altitude

PA = pressure altitude

66.67 = constant (66.67 feet per 1 deg F)

Vt = actual temperature minus standard temperature at the pressure altitude (deg F) (see spreadsheet 5 for standard temps).

APPLICATION:

Enter field elevation in the block labelled FIELD ELEVATION, the current altimeter setting in the next block down, and the surface temperature in deg F next block. A conversion for deg C is provided on the right while pressure altitude and density altitude are output in the lower half of the spreadsheet.

Example:

1. Enter Field elevation of 3600 feet.
2. Altimeter setting of 30.15 inches.
3. Air Temperature 94 degrees.

    PA = 3309 feet
    DA = 6528 feet

What happens when the pressure falls at the same temperature? Enter a few different values in the pressure block for the answer.

SPREADSHEET 6.2 ALTIMETRY (CONVERT STATION PRESSURE TO ALTIMETER SETTING OR ALTIMETER SETTING TO STATION PRESSURE)

```
SHEET 6-2...ALTIMETRY (CONVERT STN PRES TO ALSTG OR ALSTG TO STN PRES)

Station Pres.   :>   26.00   | Altimeter Setn'g:>   30.09
Elevation ft    :>    4964   | Elevation ft    :>    4964
.............................................................
                             |
                             |
Altimeter Set'ng:>   31.15   | Station Press.  :>   25.08
```

PURPOSE:

When the pressure wheel is not handy and you must answer questions about uncorrected pressure (station pressure) Spreadsheet 6.2 should prove useful.

FORMULA:

$$A = (P - .01) * [1 + ((Po^{n})*a/To)*(Hb/P1^{n})]^{1/n}$$

where

A = altimeter in inches
P = pressure in inches
Po = standard sea level pressure 29.921 inches
P1 = pressure in inches - .01 when Po = 29.921
a = lapse rate (.0065 deg C/m)
To = standard sea level temperature 288 deg K
Hb = station elevation in meters
n = .190284

therefore

$$P = [((A^{n}-(29.921^{.190284})*.0065/288)*Hb)^{1/.190284} -.01]$$

APPLICATION:

A local laboratory is doing a chemical experiment. They need the uncorrected barometric pressure. Given the laboratory's elevation of 4964 feet and the current altimeter setting 30.09 inches: What is the station pressure?

Solution:

1. Enter 30.09 in the altimeter setting block on the right side of the spreadsheet.
2. Enter 4964 in the elevation block just below.
3. The answer is 25.08 and appears in the Station Pressure block in the lower right quarter of the spreadsheet.

SPREADSHEET 7 WINDCHILL

```
SHEET 7...WINDCHILL

INPUT:
UNITS (1=mph-deg F, 2=kts-deg F, 3=km/h-deg C, 4=mps-deg C):

 UNITS (1,2,3,4):>        1 < English
         WIND SP:>       20 < MPH
         TEMP:   >       60 < deg F

......................................................................

         OUTPUT:

      WIND CHILL:>       47 < deg F
```

PURPOSE:

How many times have you had a request for a windchill that was beyond the range of the charts? Or, found the chart was in the wrong units. This spreadsheet handles both problems: allows for values off-the-chart and different units of measure.

FORMULA:

$$Twc = .0817 * ((3.17 * (V^{.5}) + 5.81 - .25 * V)) * (T - 91.4) + 91.4$$

where

Twc = wind chill in deg F
V = velocity in mph
T = temperature deg F

APPLICATION:

A nearby ski resort was chosen as the sight for Olympic Ski Trials. The European contestants request metric units for windchill.

1. Enter 4 in the unit selection cell.
2. Enter 25 in the wind speed cell.
3. Enter -5 in the in temperature cell.

Results:

wind chill = -27 deg C

SPREADSHEET 8 SPHERICAL DISTANCE COMPUTATION

```
Sheet 8...DISTANCE COMPUTATION (using Spherical coordinates):
Obtain coordinates from SWIS or AFOS Graphic, then determine distance.

                                   decimal
                                    units            DEG      MIN      SEC
ENTER LATITUDE  POINT A: >  46.0000 <                 50       30        0
ENTER LONGITUDE POINT A: > 125.0000 <                123       15        0

ENTER LATITUDE  POINT B: >  46.0000 <                 50       45        0
ENTER LONGITUDE POINT B: > 116.0000 <                116       50        0

COMPUTE? 1=TIME 2=SPEED  >        1 <
SPEED FROM A TO B:       >     20.0 < mph          >      10.0 < mph

.......................................................................

DISTANCE BETWEEN PTS.    <    433.9 > MILES        >     283.1 > MILES
                 TIME    <     21.7 < hours        >      28.3 < hours
```

PURPOSE:

Determine speed or travel time of weather systems given latitude and longitude (Egger and Fortune 1984). Computation limits are latitude 0-90 deg N and longitude 0-180 W.

FORMULA:

COS(AA) = COS(B)*COS(C) + SIN(B)*SIN(C)*COS(A)
PROP = AA/360
DIST = PROP*25000
where
A = latitude b - latitude a
B = 90 - latitude a
C = 90 - latitude b
AA = angle between a and b
PROP = proportion of Great Circle
DIST = distance between two points on Planet Earth

APPLICATION:

Satellite pictures show a fast moving cloud mass at 45N and 130W at 06Z. It was at 47N and 135N at 12Z (6 hours between positions). How fast was it moving?

Example 1 (computing speed and distance):

In the decimal units column enter:

1. Latitude for point A should read 45.
2. Longitude cell point A should read 130.
3. Latitude Point B: should read 47.
4. Longitude Point B: should read 135.
5. Enter 2 to compute the speed of the cloud mass.
6. Enter Time 6 for the elapsed time between positions.

Results:

distance = 278 miles
speed = 46 mph

Example 2 (computing travel time):

Hurricane Roseann is moving northeast at 20 mph. Current location 24N and 75W. How long will it take Hurricane Roseann to reach Jacksonville 30 deg 19 min 44 sec N and 81 deg 39 min 32 sec W?

Using DEG MIN SEC columns enter:

1. Latitude Point A: 24 00 00
   Longitude Point A: 75 00 00
   Latitude Point B: 30 19 44
   Longitude Point B: 81 39 32

2. Move cursor to Compute? block, enter 1 to compute travel time.

3. Speed A to B: enter 20 for the current speed.

Results:

Distance:> 602 miles
Travel Time:>60 hours
2.51 days

SPREADSHEET 9 DEGREE DAYS

```
Sheet 9...DEGREE DAYS: heating, cooling, growing, freezing, ETC.
                                  |
 INPUT:                           | Other base (Lower Limit):
                                  |
MX TEMP:>        95 < deg F       |    * UPPER LIMIT:>      86 < deg F
MN TEMP:>        77 < deg F       | BASE LOWER LIMIT:>      50 < deg F
                                  |
                                  | * Enter a number above the max
..................................   temperature, if no limit.
                                  |
        >        86 < AVG         | ...................................
                                  | OUTPUT WITH BASE:>      50
 HEATING:>        0 <             |
 COOLING:>       21 <             | no limit>      0 < below base
                                  | no limit>     36 < above base
 GROWING:>       32 < BASE 50     |
 GROWING:>       37 < BASE 40     |          >    32 < with limits
                                  |
 FREEZ'G:>        0 <             |
```

PURPOSE:

Generate a variety of degree days given maximum and minimum daily temperature.

FORMULA:

$$\begin{aligned}
\text{HDD.CDD} &= ((\text{max}+\text{min})/2) - 65 \\
\text{GD50} &= ((\text{mx5}+\text{mn5})/2) - 50 \\
\text{GD40} &= ((\text{mx4}+\text{mn4})/2) - 40 \\
\text{FRZD} &= ((\text{max}+\text{min})/2) - 32
\end{aligned}$$

where

HDD.CDD = heating/cooling degrees when negative/positive
GD50 = growing degree day base 50
GD40 = growing degree day base 40
FRZD = freezing degree day
max = daily maximum
min = daily minimum
mx5 = max temp | max $\leq$ 86 and $\geq$ 50
mn5 = min temp | min $\leq$ 86 and $\geq$ 50
mx4 = max temp | max $\leq$ 77 and $\geq$ 40
mn4 = min temp | min $\leq$ 77 and $\geq$ 40

Note: | means such that

If a maximum or minimum temperature falls outside the range, 50-86 for base 50 or 40-77 for base 40, the max/min is truncated to the nearest limit. Example: for GD50 a maximum of 89 and minimum of 43 would be changed to 86 and 50, respectively.

APPLICATION:

Enter the daily maximum temperature in the MX TEMP block, then the daily minimum in the MN TEMP block. The equivalent heating, cooling, growing and freezing days are output in the lower half of the spreadsheet. If the degree day base is not listed on the lower left of the screen, use the optional degree base portion of the spreadsheet on the right side of the screen.

Example 1 (established degree base):

A corn grower and a lettuce grower would like to know the amount of degree days for their respective crops that today's maximum and minimum temperatures generated. Today's maximum was 93 and the minimum was 48.

1. Enter 93 in the maximum temp block.
2. Enter 48 in the minimum temp block.

Results:

Average temperature was 71.
Growing degrees BASE 50 (corn grower) was 18.
Growing degrees BASE 40 (lettuce grower) was 23.

Example 2 (optional degree base with upper limit):

A hybrid corn grower uses 47 degrees as a growing degree day base. The corn becomes stressed with temperatures above 85 deg F, so he does not use temperatures above that level (upper limit) in measuring degree days. Using the same maximum and minimum as before, compute base 47 degree days that have an upper limit of 85 degrees.

1. Enter 93 in the maximum temp block.
2. Enter 48 in the minimum temp block.
3. On the right side of the screen enter 85 as the upper limit.
4. Enter 47 as the base.

Results:

The "with limits" block in the lower right of the screen contains the answer 20. Put another way, 20 degree days (base 47) were accumulated.

Example 3 (optional degree base without upper limit):

A citizen sets his thermostat at 70 degrees all year-round. Instead of a 65 degree day base, he uses a 70 degree base. Compute heating degree days for base 70.

Winter temperatures (max 25...min -5):

1. Enter 25 in the maximum temp block.
2. Enter -5 in the minimum temp block.
3. On the right side of the screen enter 100 in the upper limit block (any number above 25 would do).
4. Enter 70 in the base lower limit block.

Results:

The "no limit" blocks contain the answers. The average temperature of 10 degrees yielded 60 degrees of heating (below base). Put another way, 60 degrees of heating base 70 were accumulated. Notice on the left side of the screen, that using a base of 65, 55 heating degrees were accumulated.

SPREADSHEET 10.1 STABILITY INDICES (Western U.S.)

```
SHEET 10-1...STABILITY INDICES (Western US):
INPUT:              deg C      HGT        |      Km      feet     deg F
        850 TMP:>    23.2      543        |    1.543     5063      73.8
        700 TMP:>    11.6      202        |    3.202    10506      52.9
        500 TMP:>   -10.9      590        |    5.900    19358      12.4
  850 DEPRESSION:>   20.0                 |
  700 DEPRESSION:>   17.0                 |
...........................................
OUTPUT:
        K-INDEX:>      20 <====== isolated tstms
        Vert T: >      34 <====== scattered tstms
        Cross T:>      14 <====== need at least 18
        TOT TOT:>      48 <====== isolated tstms

................................
FORMULA:                        | LAPSE RATES:  F/K ft     C/Km
>> K= (850T-500T)+850Td-700dep  |    850-700:>    3.8      7.0
>> VT= (850T-500T)              |    700-500:>    4.6      8.3 <M burst?
>> CT= (850Td-500T)             |    850-500:>    4.3      7.8
>> TT= VT+CT                    |        AVG:>    4.2      7.7
```

PURPOSE:

Unlike traditional stability computer programs for AFOS that number crunch RAOB data and output several indices and leave the user to recall their meaning, Spreadsheet 10.1 displays their meaning along with several other useful bits of information. Since the atmosphere is dynamic, this interactive spreadsheet allows for advection at any level by encouraging the what-if approach to interpreting sounding data. What if the 500 mb temperature decreased another 3 degrees; what if the 850 temperature warmed another 2; or what if there was less moisture in the lower levels...? It also displays average lapse rates in deg F/1000 ft and deg C/km.

FORMULA:

See above screen clip (lower left of screen) for the stability formula. As for the lapse rate:

LR = (T1-T2)/(H2-H1)

where

LR = lapse rate
T1 = temperature at lower level
T2 = temperature at upper level
H1 = height of lower level
H2 = height of upper level

APPLICATION:

Suppose the coded groups indicated below were extracted from your latest raob message CCCMANXXX. What do they mean in terms of thunderstorms, fire danger, and lapse rates.

85474 18070 30511 70092 04062 24520 50572 16967 23018

1. Enter 18 in the 850 TMP block.
2. Enter 474 in the 850 HGT block.
3. Enter 4 in the 700 TMP block.
4. Enter 92 in the 700 HGT block.
5. Enter -16.9 in the 500 TMP block.
6. Enter 572 in the 500 HGT block.
7. Enter 20 in the 850 depression block.
8. Enter 12 in the 700 depression block.

RESULTS:

Thunderstorm Potential:

K-INDEX:	21	isolated tstms
Vert T:	35	scattered tstms
Cross T:	15	need at least 18
TOT TOT:	50	isolated tstms

Lapse Rates:

850-700 mb	4.7 F/1000 feet	8.7 C/Km	
700-500 mb	4.4 F/1000 feet	8.0 C/Km	<M burst?
850-500 mb	4.5 F/1000 feet	8.3 C/Km	

Notice the microburst remark, <M burst?, along 8.0 C/Km. Whenever the 700-500 mb lapse rate exceeds 8 deg C per kilometer, high probabilities of microbursts exist (Caplan and Bedard 1990). A flag will appear next to the lapse rate at 8.0 C/km and above. The thunderstorm potential categories are based on Western Region Technical Attachment No. 84-14.

SPREADSHEET 10.2 HAINES FIRE INDEX

```
SHEET 10-3...HAINES FIRE INDEX

 OUTPUT HAINES INDICES ARE BASED ON TEMPERATURE INPUT IN SHEET 10.1

 OUTPUT:

    HIGH TERRAIN:>          5 <====== moderate ptnl lg fire
     MED TERRAIN:>          6 <====== high ptnl lg fire
     LOW TERRAIN:>          5 <====== moderate ptnl lg fire
```

PURPOSE:

The Haines Fire Index (Ochoa and Werth 1990) is a helpful predictor of large fire potential. This spreadsheet uses input from Spreadsheet 10.1 (SS 10.1) to work up the low, mid, and high elevation large fire potential indices. Remember, **this is an output only spreadsheet.** The input is supplied by SS 10.1.

FORMULA:

$$
\begin{aligned}
\text{HAINES INDEX} &= \text{STABILITY} + \text{MOISTURE} \\
&= (Tp1-Tp2) + (Tp1-Tdp1) \\
&= A + B
\end{aligned}
$$

where T is the temperature at two pressure surfaces (P1,P2); and Tp1 and Tdp1 are the dry bulb temperature and dew-point temperature at a lower level. All temperatures values are in deg C.

ELEVATION	STABILITY TERM	MOISTURE TERM
LOW	950 - 850 MB TEMP	850 T - dew point
	A=1 when 3 or less	B=1 when 5 or less
	A=2 when 4-7	B=2 when 6-9
	A=3 when 8 or more	B=3 when 10 or more
MID	850 - 700 MB TEMP	850 T - dew point
	A=1 when 5 or less	B=1 when 5 or less
	A=2 when 6-10	B=2 when 6-12
	A=3 when 11 or more	B=3 when 13 or more
HIGH	700 - 500 MB TEMP	700 T - dew point
	A=1 when 17 or less	B=1 when 14 or less
	A=2 when 18-21	B=2 when 15-20
	A=3 when 22 or more	B=3 when 21 or more

Add the factor values (A + b):

(A + B)	Potential for large fire
2-3	very low
4	low
5	moderate
6	high

APPLICATION:

To get to SS 10.2 from SS 10.1 hold down Ctrl and Right Arrow keys. The SS will move sideways to SS 10.2. Using the same coded data as in SS 10.1:

85474 18070 30511 70092 04062 24520 50572 16967 23018

The fire dangers are:

Elevation	Index	Meaning
HIGH	3	very low ptnl lg fire
MID	6	high ptnl lg fire
LOW	4	low ptnl lg fire

NOTE: The 950 mb temperature is computed using an algorithm similar to those employed in several of the earlier SS's.

SPREADSHEET 10.3 CONVECTIVE CLOUD HEIGHT

```
SHEET 10-2...CONVECTIVE CLOUD HEIGHT LEVEL:

IF CUMULUS CLOUDS ARE JUST BEGINNING TO FORM,
USE THIS FOR CLOUD BASE   H=227*(T-Td):

        INPUT:

                ELEV.:  >   2800  feet
                TEMP:   >     74  deg F
                DEW PT: >     45  deg F

.....................................................................

        OUTPUT:

                Cloud Ht.:

                            6438  agl

                            9238  msl
```

PURPOSE:

Most of the previous spreadsheets involved fairly complex algorithms. The intent of WeatherTools was not only to provide a convenient toolkit but to encourage further development or new development utilizing spreadsheets. This spreadsheet's main purpose was intended to give entry level programmers a place to start; it's the simplest spreadsheet. Using the ALT-E macro to enter edit mode, move the cursor around the cells to view or change the formula. When you are done, depress ALT-C for color monitors or ALT-M for monochrome to protect your changes, then ALT-S to save the changes or ALT-Q to just quit without saving. Sorry 1-2-3 users, the ALT's will not work.

The convective cloud height formula is commonly known and widely used for determining the base of a newly forming cumulus cloud. The formula is simple and is often found or applied in the form of a diagram or table. Spreadsheet 10.3 offers another and more versatile method for determining cumulus cloud bases.

FORMULA:

$$H = 227 * (T - Td)$$

where

H = height of newly forming cumulus
T = temperature deg F
Td= dew point deg F

APPLICATION:

Skies have been clear all morning. You are far from the mountains. It is 11 am and you notice cumulus beginning to form. The temperature is 74 degrees F, the dew point 45, and your elevation is 2800 feet. How high are the bases of the cumulus?

From Spreadsheet 10.1 (SS 10.1), depress the Ctrl and right arrow keys twice to get to SS 10.3. Then,

1. Enter 2800 in the Elev block.
2. Enter 74 in the temp block.
3. Enter 45 in the dew point block.

Answer:

Cloud Ht:

6438 feet agl
9238 feet msl

SPREADSHEET 11 FORECAST MINIMUM TEMPERATURE (Olsen method)

```
SHEET 11...FORECAST MIN TEMP (UNDER CLEAR SKY- OLSEN METHOD):

ENTER:                                          GROUND CONDITIONS:
                                                INCHES:
   MAX. PREV DAY:>      76 < deg F                 FRESH SNOW  :>        0
 AFTN. DEW-POINT:>      41 < deg F                 DRY SNOW    :>        0
AV WD SPD 06-12Z:>       3 < kts                   CRUSTY SNOW :>        0
                                                   WET SNOW    :>        0
NOTE:  Enter dates with Ctrl-D
MAR 21 CUR. YEAR:>03/21/91 < MM/DD/YY           WET GROUND (Y/N):>N
DATE TO COMPUTE: >06/16/91 < MM/DD/YY
.....................................................................
OUTPUT:
   T min (deg F):>      45 < unadjusted
                >       48 < + wind adjustment
                >       48 < + ground cond adjustment
.....................................................................
FORMULA:
   Tmin = 3.92*Tmax^.5 * Tdp^.25 (1+.015*SIN(Pi/180 * (Date-MAR 21))
```

PURPOSE:

Many forecast offices have objective techniques for forecasting minimum temperatures. Several years ago Dave Olsen (Area Manager, Great Falls, MT), then a forecaster at Boise, adapted an empirical formula that he developed for Helena, Montana (Olsen 1968). This technique is still used today with a few modifications made by local forecasters. The formula was utilized in a variety of ways; from nomograms and tables to careful labeling on the blank side of an anachronistic slide rule. After years of use, the slide ruler's indelible ink has faded. The technique survives time in the form of this spreadsheet. This procedure works well at many different sites in the West, perhaps with little or no modification it will work for your office.

FORMULA:

$$\text{Tmin} = 3.92 * (\text{Tmax}^{.5}) * (\text{Tdp}^{.25}) * [\,1 + .015 * \sin(\text{Pi}/180(\text{date} - \text{Mar } 21))]$$

where

Tmin = forecast minimum temperature
Tmax = observed afternoon maximum temperature
Tdp = observed dew-point at maximum temperature
date = today's date

APPLICATION:

Tuesday afternoon's maximum was 72 deg F, the dew point at that time was 41 deg F while the expected average wind speed Wednesday morning between 06-12Z is 3 knots. No snow was on the ground and the ground was not wet. What is your forecast for the Wednesday morning minimum?

Enter the temperatures and wind speed in the appropriate input cells. Then move the cursor down to the "Date to Compute cell". The program automatically computes the current date. If you wish to compute a different date, procedures are a little different than entering numbers. Hold down Ctrl and D at the same time. In the lower right corner of the screen you will notice a "Date Ready" statement. Enter today's month/day. Example: enter 6/16/91 as 6/16.

Answer: 48 degrees

CONCLUSION

Version 5.01 of WeatherTools is a framework for solving problems typical to many forecast offices in the western United States. Further development at other offices is encouraged. If you are new to spreadsheeting, begin by studying your spreadsheet User Manual, then "open up" these spreadsheets to see the techniques employed. Use the Alt-E feature to view the cell formulas. Spreadsheet 10.3 is a good place to begin experimenting. Before manipulating any of the formulas, be sure to make a backup copy of WeatherTools.

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