

A GUIDE TO THE WINDS ON CRITICAL STREAMLINE SURFACES (WOCSS) CODE, SALT LAKE CITY AREA DATA AND OTHER RELATED FILES

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I. INTRODUCTION

I thought it might be helpful to the VTMX community to have objective analyses of historical winds in the Salt Lake City basin for October, 1999. Such winds might be helpful in planning the October, 2000 field studies. However, since each user may have different needs, as well as different hardware, I have chosen to provide the basic observations from which the objective analyses can be derived and the Winds on Critical Streamline Surfaces (WOCSS) Fortran source code for performing the analyses. The observations were archived last year by the University of Utah, and provided by Michael Splitt in the Meteorology Department.

The remaining text is intended to serve as an abbreviated "Users' Guide." A separate PDF file (*JAM39.pg335*) from the March, 2000 issue of the Journal of Applied Meteorology is included as a substitute for a discussion here of the theory and performance of the WOCSS objective analysis scheme. As noted later, there have been some modifications in the model since the above article was written.

Finally, if the user encounters any difficulties in using the code, do not hesitate to contact me via e-mail at fludwig@ce.stanford.edu. Even more importantly, I would like to be contacted if any user discovers errors or program bugs.

II WINDS ON CRITICAL STREAMLINE SURFACES (WOCSS) CODE

A. Basics

1. *Description (JAM39.pg335)*

A description of the WOCSS methodology is given in the enclosed Journal of Applied Meteorology (Volume 39, pp 335-348) by F. L. Ludwig and Douglas Sinton. That article focusses on the results of performance tests using San Francisco Bay area data. Very briefly, the model uses critical streamline concepts to define flow surfaces, from observed winds and temperature profile(s), that may intercept higher terrain features when the atmosphere has a stable stratification. Then when the flow on these surfaces is iteratively adjusted toward two-dimensional non divergence of the fluxes between surfaces, the flow is forced around orographic obstructions.

Several minor changes were made in the code described in the article. These changes involve adapting the input controls to give the user more flexibility in selecting output formats and input files. Options were also added for choosing the degree to which the analysis is held fixed near observation points.

There was also one major change, related to the way in which points surrounded by higher terrain, and points near observations were adjusted. Originally, when most of a flow surface was below ground over the domain, the lowest levels were determined by downward extrapolations from analyzed layers aloft. It was noted that this led to unrealistically smooth analyses near the surface. Now, points that have three or four surrounding points where the surface is penetrated are identified, and the iterative adjustments of the original interpolated values are constrained. The same constraints are also applied to the grid points closest to the observations. In all cases, the selected limit on adjustments is linearly reduced from its specified value near the surface to no constraint at the uppermost level, unless the point is nearest to a sounding.

2. Fortran Source Code (*SLCwox*)

The Fortran source code, *SLCwox1.f*, and its common blocks are given in the directory *SLCwox*. The code has been compiled and run on a Power Macintosh 6500/300, using an Absoft compiler with the VAX compatibility option invoked. For the most part, the code is ANSI standard and should require little change for use with other machines or compilers. The most likely exceptions to the preceding assertion are the "include" statements.

The source code is heavily annotated in the hope that the user will be able to follow what is being done, and if desired make changes. I have tried to use variable names with meaning, but will admit that the mnemonics may be unique to my thinking processes. A few explanations are in order. Some of the wind observation variables include "dop" in their designations, because very early versions envisioned using Doppler acoustic sounder data. Originally, this model used a sigma coordinate system, hence the "sig" in some of the flow surface variable designations. Finally, the "rhs" variable stands for relative (to the surface) height surface.

3. Array Dimensions (*file ngrids.par*)

I have tried to set up the code and its inputs so that it is not necessary to recompile when changing grids or other parameters. However, it would generally be wise to keep the array dimensions specified in the *ngrids.par* file consistent with the outputs being specified, especially if binary outputs are desired. This file contains the following parameter definitions:

PARAMETER (NXGRD=112,NYGRD=112,NZGRD=16)

PARAMETER (NSITES=151,NWSITE=5,NTSITE=5)

PARAMETER (NSNDHT=30,NHORIZ=10)

NXGRD and NYGRD are the maximum number of grid points in the x and y directions. They do not have to match the number of points for which terrain heights are input and for which calculations are made, but if binary outputs are specified, the arrays will correspond to NXGRD, NYGRD, not to the number of points specified in the input file discussed later. NZGRD is the maximum number of surfaces that will be used for the calculations.

The parameters NSITES, NWSITE and NTSITE are the maximum number of surface observations, upper wind sounding sites and upper temperature sounding sites that will be used. The number of observations must be less than the specified parameter values. NSNDHT specifies the maximum number of levels in the wind or temperature sounding that will be used. If more than NSNDHT levels are input, the analysis will ignore those between level NSNDHT-1 and the top.

Finally, NHORIZ is the maximum number of levels for which there will be outputs. The first level will be at anemometer height, usually 10 m above the local terrain surface, but a different height can be specified in the control file. The remaining NHORIZ - 1 levels can be defined in terms of desired horizontal surface heights above sea level. Again the specific heights are designated in the control file.

B. Input files (directory slcwoxins)

1. Prompted inputs

In order to minimize compilation requirements, the program requests the pathname to the input files. A 16-character string is expected. The string length can be changed before compilation by a change in the of the specification for the variable *chpath* in the *ngrids.par* file. The request for input ('input 16 character path for input files') at the beginning of the main program should also be changed accordingly. After the path name is input, the program requests, 'input grid size -- 1, 2 or 5.' This was specifically done for use with the Salt Lake area terrain files. Three different versions of sample control files have been included on this CD, one for each of three different sets of topographical inputs. They are discussed in the next section.

2. Control Files (files runstf .dat)

The control file has a name of the form, *runstf Δ .dat*, where the Δ is the grid spacing (1, 2 or 5) for which the file is appropriate. The variables input via the control file are discussed in the following paragraphs. The following examples are from a run made with *runstf2.dat*. Each line of the input file is shown and discussed. The actual file also includes brief descriptions of the inputs; these descriptions are ignored by the program. This file is read in subroutine *runrd*. Parameter values are in bold type at the left margin. Parameter names are in italics at the right margin.

```
*****Salt Lake City stuff*****
```

The first line is a header that is ignored by the WOCSS program.

```
JAZ04:slcout2km: chpout
```

The second line defines the 16-character path name, *chpout*. This is the path to the folder that will receive the program outputs. If the string length is changed, the character declarations for *chpout* and *chpvex* in the file, *ngrids.par*, must be changed. The *format 6002* definition in subroutine *runrd* should also be changed.

```
.false., .false. debug1 and debug2  
.true., .false. doMQ and dobin
```

The next two lines contain logical variable values. In the first of these, values of *.true.* will activate some additional outputs that were used during program debugging. The next two variables select the type of interpolation to be used for first guess fields, *.true.* will cause the program to use multiquadric interpolation and *.false.*, inverse distance-squared weighting. The last of the four logical variable values selects the form of the output files. A *.true.* value causes the output to be in binary files, one for each output level specified for *NFLAT* below. The sizes of these two-dimensional arrays are *NXGRD* by *NYGRD* (specified in *ngrids.par*), not *MCRS* by *NCRS* specified below.

If the ascii output option has been selected (*dobin=.false.*), then *NSKIP* defines the points to be written in the file. For example, all values are written when *NSKIP*=1, every fifth value (beginning at the southwest corner (1,1) of the grid, when *NSKIP*=5.

16

NLVL

NLVL is the number of flow surfaces used for calculations. It must be *NZGRD*.

.0,.02,.04,5,.6,.7,.8,.9,1.

SIGMA (NLVL values)

NLVL values of flow levels, expressed as fractions of the maximum height above the lowest point (*AVTHK*), as defined below. This is a remnant from the earliest versions, when sigma coordinates were used. Generally, the topmost value will be one, but it is not mandatory. It is mandatory that there be *NLVL* values, and that they be in increasing order, with zero first. The values of *NLVL* and *SIGMA* should be chosen so that there are enough surfaces aloft to resolve changes with height, and so that the lower surfaces will be low enough to intersect the major terrain features that will influence the flow during stable conditions.

10

NFLAT

NFLAT is the number of levels for which outputs will be given. The outputs will be on horizontal surfaces at the altitudes given by the next set of inputs. *NFLAT* must be *NHORIZ*.

10.,1300.,1400., . . . ,2800.,3200.

zchooz (NFLAT values)

NFLAT values of *zchooz*, the levels for which outputs are desired. Except for the first, these are expressed in meters above sea level. It is mandatory that there be *NFLAT* values, and that they in increasing order. The first value is interpreted differently from the others. It is taken as the anemometer height. Other levels are horizontal at the designated elevations (MSL), but the first level is at the designated height (AGL) above the local terrain.

152,1,1

NUMNWS, NUMTMP, NUMDOP

NUMNWS, *NUMTMP*, and *NUMDOP* are the upper limits on the the number of surface stations, upper wind stations and upper temperature stations that will be used, respectively. They must be *NSITES*, *NWSITE*, and *NTSITE*, as specified in *ngrids.par*.

1.0

SPDCNV

SPDCNV is a factor to convert input winds to m/s. For example, it will be 0.515 if the input speeds are given in knots, or 1 if they are already in m/s.

111,111

MCRS, NCRS

MCRS and *NCRS* are the number rows (points in N-S direction) and columns (points in E-W direction) to be used in the calculations. They must match the dimensions of the topography array, and they must not exceed *NYGRD* and *NXGRD* (specified in *ngrids.par*), respectively.

2.0

DSCRS

DSCRS is the horizontal grid spacing (km) to be used for the calculations. It must match the grid spacing of the input topography.

281.55, 4390.5

UTMAPX, UTMOPY

UTMAPX and *UTMOPY* are the coordinates of the point whose indices are given on the next line. The values given above correspond to point 1,1 for both the 2-km (*slc2km.dat*) and 5-km (*slc5km.dat*) grid topography files included on this CD. The coordinates for the origin of the 1-km grid are 351.55, 4450.5. All the UTM values are in zone 12. It is important that all coordinates be in the same zone system.

1,1

kgridx, kgridy

These two values are the indices of the point whose UTM coordinates were input on the preceding line. Usually, this will be the origin, or some point near the center, but it is not essential.

3000.

AVTHK

AVTHK is the height (m) of top surface used in the calculations, relative to the lowest point in the domain. It should be chosen to ensure that any stable layers which might affect the flow will be within the domain. The top level will always be this height over the lowest point, but it will generally be closer to the higher terrain, but higher relative to sea level.

1.0

SLFAC

SLFAC is the "slope factor," which governs the shape of the surfaces used for the "first guess" interpolated winds. Normally, a value of 1 is used to get terrain following surfaces; a zero value produces horizontal (flat) surfaces. The surfaces will be redefined according to the critical streamline formula in any event. *SLFAC* should be between zero and one.

0.1

CMPRES

CMPRES defines the maximum compression allowed for the space between flow surfaces. In essence it defines the degree to which stable layers aloft influence the flow at lower levels. The smaller the value, between zero and one, the more the influence of elevated stable layers. A value of zero will cause all lower layers to have the same shape as the most stable flow surface. A value of one will allow a lower layer to approach very close to the layer above. It is probably unrealistic to use values higher than about 0.7 or 0.8. The functioning of this parameter is discussed in greater detail in the JAM article by Ludwig and Sinton (file *JAM39.pg335*).

0.001

DPOTMIN

In order to avoid very large rises of the flow surfaces, a minimum value, *DPOTMIN*, is prescribed for the potential temperature lapse rate ($^{\circ}\text{K}/\text{m}$). The WOCSS analysis methodology does not reproduce convection from extremely unstable lapse conditions.

0.05, 10.0

ZZERO, Z10

ZZERO and *Z10* are the surface roughness length (m) and anemometer height (m) used to estimate winds at the first level. The anemometer height, *Z10*, should agree with the value used for *ZCHOOZ*(1), although this input will override the other one. The roughness length is used in log law interpolation between the surface and the lowest flow surface, when estimating winds at anemometer height.

0.1

D2MIN

D2MIN is the minimum distance used when the inverse distance weighting interpolation methodology is used to obtain "first guess" wind fields.

2.0

DTWT

DTWT is the power used for the inverse distance function. A value of two gives an inverse distance-squared interpolation scheme.

20

NIT

As noted before, the method by which the winds on the flow surfaces are balanced toward nondivergence is iterative. *NIT* is the maximum number of iterations used. Generally, improvement in the results slows markedly after 20 iterations.

0.0

ADJMAX

ADJMAX defines the maximum adjustments allowed at grid points nearest observations, and at grid points where 3 or 4 of the surrounding flow surface grid points are below the terrain. A value of zero holds the first guess values fixed at the lowest above-ground level for the affected points. This gradually changes to a full adjustment at the uppermost flow surface. A value of one, treats all points the same.

8, 93

1st pair of lowix & lowiy

12, 38

2nd pair of lowix & lowiy

57, 96

3rd pair of lowix & lowiy

30, 78

4th pair of lowix & lowiy

56, 52

5th pair of lowix & lowiy

Five pairs of grid point coordinates are required for each sounding used. The points are subjectively chosen to represent conditions over the low terrain that might be represented by the particular sounding. The values given above for *lowix* and *lowiy* were chosen to represent most of the regions with elevations less than 1300 m. When estimating the rise of the surfaces, it is necessary to have wind speed estimates

over the lower terrain. The wind speeds over the selected points are used for this purpose. Note, the indices of these points depend on which terrain grid is being used.

20

NEND

NEND is the number of hours that will be read and analyzed before stopping. It should be set large enough so that all the desired cases are processed.

3. Meteorological File Names (*slcfiles*)

The *slcfiles* file is simply a list of the meteorological data files that are to be analyzed. Each file name is on a single line and is of the form:

slcsfc.9910ddhhmm

where **dd** is the day of the month (October for these data), **hh** is the hour, **mm** is the minute. Times are Universal Time (UT, or GMT).

4. Meteorological Files (*slcsfc.9910hhmm*)

Each file identified in the *slcfiles* list is read and analyzed in order. The files contain lists of surface meteorological observations, upper level wind profiles and upper level temperature profiles, along with station location and other information. An explanation of the inputs follows.

```
03201001 1999                                time (0320), date (Oct 1) & year
                                             blank line
  58  0  0  0  0                            upper wind sta. ids (in list below, 0= no station)
                                             blank line
  58  0  0  0  0                            upper temp. sta. ids (in list below, 0= no station)
                                             blank line
  110                                         number of surface observations listed
WBB   428.26  4513.36  1465.00   849.76   16.50   310.50   .82
S01   336.53  4449.29  1324.00   864.71    4.17   125.00   2.11
S02   311.48  4435.44  1295.00   865.50   10.06   258.00   2.01
WMP   457.62  4480.94  1698.00   826.52    5.00   311.00   .00
```

4-character station id

utm coordinates (km easting & northing)

sfc pressure (mb.)

temperature (°C)

wind direction (deg.)

wind speed (m/s)

data format -- (1x,a4,1x,8f9.2)

.

.

complete station list for hour (110 in this case)

.

```
MUS   357.92  4498.83  1341.00 -9999.00    7.78   20.00   1.34
BUE   422.80  4555.60  1554.00 -9999.00   12.78   80.00   1.34
MUD   391.27  4406.12  1756.00 -9999.00    8.89  250.00   .87
PGR   436.38  4475.54  1585.00 -9999.00   14.44   60.00   2.21
```

blank line

418.15 4514.58

utm coordinates (km easting & northing)

```

25 SLCU
height-m direct. spd-m/s
1286. 130.0 3.1
1300. 309.2 1.7
1400. 308.3 1.7

```

number of input levels to follow & sta. id.
header line, not used
ht. (m MSL), wind dir. (deg) & spd. (m/s)

-
-
-

wind values at all levels (25 in this case)
sounding inputs are free (*) format

```

3500. 267.7 8.9
3750. 274.4 9.8
4000. 278.4 10.5

```

```

418.15 4514.58
25 2 SLCU
height-m temp.-C press.-mb
1286. 8.9 869.0
1300. 18.8 867.5
1400. 17.9 857.4
1500. 17.1 847.4

```

blank line
utm coordinates (km easting & northing)
no. input levels to follow, form of data, & sta. id.
header line, not used
ht. (m, MSL), temp. (°C), press. (mb)

-
-
-

temperature values at all levels (25 in this case)
sounding inputs are free (*) format

```

3350. 6.3 678.8
3500. 5.2 666.5
3750. 3.5 646.3
4000. 1.9 626.6

```

The data form identifier at the start of the temperature sounding allows the user to input any one of three different kinds of data. The value two used here means that the following data will be height (m, MSL), temperature (°C), and pressure (mb). A value of one indicates the data are given as height (m, MSL), temperature (°C), and potential temperature lapse rate (°K/m). Finally, a value of 3, indicates that heights are given in feet (MSL), , temperature (°C), and pressure (mb).

All meteorological data files on this CD are of type 2.

5. Topographical Data Files (*slc km.dat*)

Files of terrain data are available on this CD for use with the WOCSS analysis code in the Salt Lake region. All are derived from a 223 by 223 grid of surface elevation (*slc1km.all*) at 1-km intervals, with the origin (southwest corner, or point 1, 1) located at 281.55E, 4390.5N Zone 12 UTM coordinates. A 2-km grid (111 by 111) with the same origin (*slc2km.dat*) was obtained by taking alternate points from the original grid. Similarly, the 45 by 45 topography on a 5-km grid (*slc5km.dat*) was obtained by taking every fifth point. The 111 by 111 grid at 1-km intervals (*slc1km.dat*) has its origin at 351.55E, 4450.5N. The terrain data are read with the northernmost row first, i.e. from NROW to 1. The 5-km files have the format, (*1x, 45f5.0*). The 1-km and 2-km terrain data are in the format (*1x, 56f5.0, / 3x, 55f5.0*). The file

containing the complete 223 by 223 array of 1-km terrain elevations has the format (*1x, 45f5.0, 3(/ 3x, 44f5.0) / 3x, 44f5.0*). The terrain data are read in *subroutine topo*.

Other, 5-km and 10-km terrain files (*sl10km.dat* and *sl05km.dat*) are included for use with the MATLAB plotting programs discussed later. They have the southern row first.

All terrain data are given to the nearest meter above sea level.

C. Output Files

As noted earlier, the user can choose the form of the outputs. If ascii outputs are chosen, each component (u, v, or w) will be written to a separate output file. The naming of the files is of the form -- **czzf km.ddhh**, where c is the component, zz is the level, is grid spacing, and ddhh give the day of the month and the hour of the day. For example, **u01f2km.0100** contains the u components at the first level (anemometer height), calculated on a 2-km grid for October 1 at about 0000. The array dimensions will depend on the value chosen for *NSKIP*. The formatting provides for up to 111 values in a row, southernmost row first. The values are to the nearest cm/s.

If a binary output is chosen, the file names are of the form **c km.ddhh**. All points are represented on each level. Each record is a *ncol* by *nrow* integer array of components (cm/s) for a specific level, beginning with the first level (anemometer height values) and proceeding up to level *NFLAT*.

There are also files that contain intermediate and operational outputs that depend on whether or not the *debug* options have been invoked.

III INPUT DATA PREPARATION UTILITIES

A. Topography (directory *SLC_top*)

The source code for the programs used to read the complete terrain file (file *slcsfc.dat*) and write new files for input to WOCSS is in the directory *SLC_TOP*. The programs are *terr1km.f*, *terr2km.f* and *terr5km.f*. The complete 1-km data file (*slcsfc.dat*) is also here. Two other programs (*ter10km.f* and *sfc2kp.f*) that were used to write abbreviated terrain files for the MATLAB display programs are also included.

B. Meteorological (directory *SLC_met*)

Directory *SLC_met* contains the ascii files (translated from unix binary) received from the University of Utah (in the directories, *pressures*, *temperatures* and *winds*), and the lists of file names used with program *editwoxin.f*, which is also in this directory.

The program *editwoxin.f* was used to merge the three files for each hour into a single file for input to WOCSS. Some editing was done to remove surface observations from stations reporting negative wind speeds or speeds that were more than 4.5 standard deviations from the mean for that hour. Provisions are included for estimating pressures from temperature and height information, as required in WOCSS for getting potential temperatures. Finally, the latitude, longitude coordinates in the original files were transformed to UTM coordinates. The transformation uses fortran code developed by the United States Geological Survey and published on the world wide web at the address <http://mapping.usgs.gov/pub/amdahl/plane-sd.txt>

C. Miscellaneous Test Programs (directory *SLC_misc*)

The SLC_misc contains several small fortran codes that were used to test sections of other codes, and which might be useful to other researchers. Comments are included in the codes to help describe what they do.

D. Directories for WOCSS Outputs

The outputs from WOCSS are written to different directories, depending on the grid size and the type of interpolation chosen for the first guess fields. I have included the required directories for convenience. They are:

```
slcout1km  
slcout1mq  
slcout1r2  
slcout2km  
slcout2mq  
slcout2r2  
slcout5km  
slcout5mq  
slcout5r2
```

They are mostly empty, but there are a few files included. These files are used as inputs to the MATLAB display routines described in the next section.

IV SIMPLE DISPLAY UTILITIES (DIRECTORY SLC_MLab)

Two short, simple MATLAB programs are included in directory *SLC_MLab*. They are *dayhrvex.m* and *plot_4.m*. The first program plots a series of analyses from the 2-km grid calculations (using inverse-distance-squared weighted interpolation) at a specified level. Only every 5th point is in the input files used so the vectors are actually on a 10-km grid. Different levels can be plotted by changing the value of the variable *chlev*. Other times and hours can be selected by changing values of *jday1*, *jday2*, *jhr1* and *jhr2*. The file name designators can also be changed to plot results for other grid spacings or interpolation methods.

The other program, *plot_4.m*, presents four plots for each of 9 levels. The four plots allow comparison of the 1-km and 2-km grid calculations using both interpolation methods. Again the outputs used are for every 5th point so the 2-km grid results are plotted on a 10-km grid, and the 1-km results on a 5-km grid. Note that the area represented in the 1-km plots is a subsection of the larger domain used for 2-km results.

MATLAB, version 5 for the Macintosh was used for these programs. Some modifications might be required for use on other machines.