World Ocean Atlas 2009 (WOA09) DVD Documentation

For any questions about WOA09, please e-mail OCL.help@noaa.gov

This README document provides summary information for the WOA09 DVD. The DVD contains data files of objectively analyzed climatologies and related statistical fields of temperature, salinity, dissolved oxygen, Apparent Oxygen Utilization (AOU), percent oxygen saturation, phosphate, nitrate, and silicate for the world ocean. Section 1 (below) details the files and directories found on the DVD. Section 2 briefly describes the WOA09 statistical and objectively analyzed fields found in the data files, as well as mask files used in calculation of the objectively analyzed climatologies, and also lists standard depths for which data are available for each ocean variable. The data are available in two different ASCII formats (WOA grid format and comma separated value format) on the DVD. All files are compressed. Section 3 describes the comma-separated value (csv) format files. Section 4 describes the standard compact grid format files, the same file format used in previous editions of the World Ocean Atlas. Section 5 describes the usage of uncompression utility (gzip) provided on the DVD (gzip) for anyone who does not have this or a similar uncompression utility.

For a description of the data used, and the procedures for calculating WOA09 statistical fields, see documents in directory DOC.

When using these data for publication, please reference the appropriate citation from the following list:

Temperature: Locarnini, R. A., A. V. Mishonov, J. I. Antonov, T. P. Boyer, H. E. Garcia, O. K. Baranova, M. M. Zweng, and D. R. Johnson, 2010. World Ocean Atlas 2009, Volume 1: Temperature. S. Levitus, Ed. NOAA Atlas NESDIS 68, U.S. Gov. Printing Office, Washington, D.C., 184 pp.

Salinity: Antonov, J. I., D. Seidov, T. P. Boyer, R. A. Locarnini, A. V. Mishonov, H. E. Garcia, O. K. Baranova, M. M. Zweng, and D. R. Johnson, 2010. World Ocean Atlas 2009, Volume 2: Salinity. S. Levitus, Ed. NOAA Atlas NESDIS 69, U.S. Gov. Printing Office, Washington, D.C., 184 pp.

Oxygen (Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation): Garcia, H. E., R. A. Locarnini, T. P. Boyer, J. I. Antonov, O. K. Baranova, M. M. Zweng, and D. R. Johnson, 2010. World Ocean Atlas 2009, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation. S. Levitus, Ed. NOAA Atlas NESDIS 70, U.S. Gov. Printing Office, Washington, D.C., 344 pp.

Nutrients (phosphate, nitrate, silicate): Garcia, H. E., R. A. Locarnini, T. P. Boyer, J. I. Antonov, M. M. Zweng, O. K. Baranova, and D. R. Johnson, 2010. World Ocean Atlas 2009, Volume 4: Nutrients (phosphate, nitrate, silicate). S. Levitus, Ed. NOAA Atlas NESDIS 71, U.S. Gov. Printing Office, Washington, D.C., 398 pp.

Section 1: DVD structure

Directories and files on DVD:

readme.pdf – this file in portable document format
readme.txt – this file in ASCII text format

DOC – text and figures from 4 atlases

1. temperature
2. salinity
3. oxygen (includes dissolved oxygen, AOU, and percent oxygen saturation)
4. nutrients (includes phosphate, nitrate, silicate)

PROGRAMS – sample C and FORTRAN programs for reading WOA09 data files in compact grid format

MASKS - mask files which were used during calculation of WOA09 fields

UTILS – gzip utility for uncompressing data files

DATA – objectively analyzed climatological temperature and related statistical fields data files, in two different ASCII text formats (native gridded format and comma separated value format), compressed. Under this directory, there are 8 subdirectories, **temperature**, **salinity**, **oxygen**, **AOU**, **o2sat**, **phosphate**, **nitrate**, and **silicate**, corresponding to data for the named ocean variable. In each of these subdirectories are two subdirectories, **grid** and **csv**.
The **grid** directory contains data files for objectively analyzed and related statistical fields in separate files in the compact grid format. This is the same format used in previous versions of the World Ocean Atlas. The format and file naming conventions are described in section 4.
The **csv** directory contains data files in a comma-separated value (csv) format. The same objectively analyzed and related statistical field data are contained in the csv format as in the compact grid format files. The format and file naming conventions for the csv format are described in section 3.

Section 2: Available data fields

Table 1 lists the available statistical fields and whether they are available only as one-degree fields or as both one-degree fields and five-degree fields. One-degree fields represent the world as 360x180 one-degree longitude/latitude boxes. Five-degree fields divide the world into 72x36 five-degree longitude/latitude boxes. Five-degree statistical fields are the fields used for standard deviation window checks to filter the data used to calculate the one-degree climatologies.

Table 1. Available objectively analyzed and statistical fields

Field Name	One-degree field calculated	Five-degree field calculated	Field Type Code (for file names)
Objectively analyzed climatology	√		an
Statistical mean	√	√	mn
Number of observations	√	√	dd
Seasonal or monthly climatology minus annual climatology	√		ma
Standard deviation from statistical mean	√	√	sd
Standard error of the statistical mean	√	√	se
Statistical mean minus objectively analyzed climatology	√		oa
Number of mean values within radius of influence	√		gp

Descriptions of the statistical fields in WOA09

- **Objectively analyzed climatologies** are the objectively interpolated mean fields for an oceanographic variable at standard depth levels for the World Ocean.
- The **statistical mean** is the average of all unflagged interpolated values at each standard depth level for each variable in each one-degree and five-degree square which contain at least one measurement for the given oceanographic variable.
- The **number of observations** of each variable in each one-degree and five-degree square of the World Ocean at each standard depth level.
- The **seasonal or monthly climatology minus the annual climatology** at each one-degree square at each standard depth.
- The **standard deviation** about the statistical mean of each variable in each one-degree and five-degree square at each standard depth level.
- The **standard error of the mean** of each variable in each one-degree and five-degree square at each standard depth level.
- The **statistical mean minus the climatological mean** at each one-degree square at each standard depth. This value is used as an estimate of interpolation and smoothing error.
- The **number of one-degree squares within the smallest radius of influence around each one-degree square which contain a statistical mean**.

In addition to the statistical fields data files found in the **DATA** directory there are mask files (ending in suffix **.msk**) found in directory **MASK**. These files contain information used to calculate the statistical fields.

- The **landsea.msk** contains the standard depth level number at which the bottom of the ocean is first encountered at each one-degree square for the entire world. Land will have a value of 1, corresponding to the surface. Values of standard depth levels are listed in **Table 2**.
- The **basin.msk** contains the basin code number defined for each one-degree square at

each standard depth from the surface to 5500 m. Each basin is identified by a code number 1-58. The basin code number in a given one-degree square may change with increased depth level. **Appendix 1** lists the geographic basins names, the code number associated with each basin, and the standard depth level at which the given basin is first encountered.

- The **mixnumber.msk** contains the mixing number for each one-degree square at each standard depth from the surface to 5500 m. The mix number is a number between -2 and 2. If the basins (from **basin.msk**) of two one-degree grids within a radius of influence are not equal, the mean values in the one-degree squares can still be used to calculate the objectively analyzed values for these squares as long as the mix numbers add up to more than 0.

Table 2. Depths associated with each standard level number

Depth (m)	Level	Depth (m)	Level	Depth (m)	Level	Depth (m)	Level
0	1	250	11	1200	21	4500	31
10	2	300	12	1300	22	5000	32
20	3	400	13	1400	23	5500	33
30	4	500	14	1500	24	6000	34
50	5	600	15	1750	25	6500	35
75	6	700	16	2000	26	7000	36
100	7	800	17	2500	27	7500	37
125	8	900	18	3000	28	8000	38
150	9	1000	19	3500	29	8500	39
200	10	1100	20	4000	30	9000	40

2.1 Available oceanographic variables.

The statistical fields were calculated for eight oceanographic variables. Due to the differences in data distribution at various depths for distinct variables, not all variables were analyzed at all depths for all averaging periods (annual, individual seasons and months). **Table 3** shows the depth limits for each variable for each averaging period. **Table 2** shows the depth corresponding to each standard depth level.

Table 3. Depth ranges and number of standard levels for each variable for annual, seasonal, and monthly statistics for each available oceanographic variable. One-letter codes are first letter for file names for given variable.

Oceanographic Variable (one-letter code)	Depths for Annual Climatology	Depths for Seasonal Climatology	Depths for Monthly Climatology
Temperature (t)	0-5500 meters (33 levels)	0-5500 meters (33 levels)	0-1500 meters (24 levels)
Salinity (s)	0-5500 meters (33 levels)	0-5500 meters (33 levels)	0-1500 meters (24 levels)
Oxygen (o), AOU (A), $\%O_2$ (O)	0-5500 meters (33 levels)	0-5500 meters (33 levels)	0-1500 meters (24 levels)
Nitrate (n)	0-5500 meters (33 levels)	0-500 meters (14 levels)	0-500 meters (14 levels)
Phosphate (p)	0-5500 meters (33 levels)	0-500 meters (14 levels)	0-500 meters (14 levels)
Silicate (i)	0-5500 meters (33 levels)	0-500 meters (14 levels)	0-500 meters (14 levels)

Section 3: Comma-separated value format

WOA09 is also available in a comma delimited format files which contain all one-degree fields, or all five-degree fields (listed in **Table 1)** in one file for a given averaging period (annual, season or month). There is a separate file for each depth level. All depth levels for a given averaging period are included in a single tar file. Each depth level is stored in a separate file so the files may be viewed using Microsoft Excel or similar software. The header part of each file contains a title and a description of each field represented by each individual column. Each of these descriptive lines has a '#' in the first byte. The remaining lines contain latitude, longitude, and depth in the first 3 columns, with the statistical fields in the following 8 columns. Appendix 2 shows an example of the comma delimited format file.

3.1. File naming convention for comma-separated value format

Files are initially contained in one tar file and compressed using the **gzip** utility. The names of the tar files conform with the following convention: **[v]_[tp]_[g]d.tar.gz**.

When files are uncompressed (using both unzip and untar), the resultant files names are generated to conform with the following convention: **v_[tp]_[sl]_[g]d.csv**.

Where:

[v] represents the variable using one-letter code as listed in **Table 3**;
[tp] represents the averaging period, two digits code as follows:

00 – annual statistics, all data used;
13 to 16 – seasonal statistics:
season 13 - winter (first three months of the year - Jan-Mar);
season 14 – spring (Apr-Jun);
season 15 – summer (Jul-Sep);
season 16 – autumn (Oct-Dec);
01 to 12 – monthly statistics (starting with 01 – January, to 12 – December);

[g] represents the grid size, one digit code as follows:
1 – one-degree square file
5 – five-degree square file

[sl] represents standard depth level number, two digits code from 01 to 33 as in **Table 2.**

Example: AOU one-degre fields for summer are in file **A_15_1d.tar.gz**. When this file is uncompressed and untarred, there will be 33 files, **A_15_20_1d.csv** will be objectively analyzed summer AOU and related statistical fields at 1100 meters depth

Section 4: Compact grid data format

This is the standard WOA format, the same one used in WOA94, WOA98, WOA01, and WOA05.

Each individual datum is stored in one of two ways:

- For **gp** (grid point), **dd** (number of observations), and **msk** files, the value is stored as a seven digit numeral followed by a decimal point (FORTRAN format description as F8.0). The value "-100." indicates landmass or the seafloor in the **gp**, **dd**, and **basin.msk** files; the value "1." indicate land in the landsea.msk file.
- For all other files (**an**, **se**, **sd**, **mn**, **ma**, **oa**), the value is stored as a seven digit real with 4 places to the right of the decimal (FORTRAN format description as F8.4). The value

  "-99.9999" indicates landmass, the sea floor, or no data.

For both cases, there are 10 values per line, followed by a carriage return.

The first value in a one-degree square file corresponds to the grid box centered at latitude 89.5°S and longitude 0.5°E (grid box 1,1). The first 360 values are incremented eastward in longitude, constant in latitude. The 361st value in the file is for the grid square centered at latitude 88.5°S and longitude 0.5°E (grid box 2,1). **Figure 1** shows the one-degree coordinate system of the analyzed fields. The five-degree square files follow the same pattern, listing 72x36 values. **Figure 2** shows the five-degree coordinate system.

4.1. Programs for reading and reformatting compact grid format

All programs described here can be found in the PROGRAMS directory. Any changes or updates to these programs will become available online at http://www.nodc.noaa.gov/OC5/WOA09/programs09.html.

The program **analysis.f** and **analysis.c** are sample programs written in FORTRAN and C languages respectively and can be used for reading in data. The **analysis.exe** is an executable version of **analysis.f** for the Microsoft environment. The **analysis_64.exe** is an 64 bit executable version of **analysis.f** for the Microsoft environment. These programs read in a single WOA09 one-degree or five-degree data file, request a single latitude and longitude coordinate from the user, and return a 10x10 degree latitude-longitude grid of values centered on that coordinate: this output is only written to the screen. The user should modify these programs according to specific needs.

The program **anlyxyz.f** is a sample FORTRAN program which reads in a single WOA09 data file and writes out the entire 360x180 degree latitude-longitude grid values into an output file. The output file is in comma-separated value (csv) format, of the form "latitude, longitude, value", and uses the original file name, with an extension of ".###", where "###" is the standard depth level extracted (*e.g.* ".005" for standard level 5, or 50 meters - see **Table 2**). The program can extract a single depth level or all available levels (*e.g.* 1 to 33). The "**anlyxyz.exe**" is the DOS executable of this program. This program works with WOA05, WOA01, and WOA98 data files as well, and can read one-degree, five-degree, and quarter-degree formats. The "**anlyxyz_64.exe**" is the 64 bit executable of **anlyxyz.f** program.

4.2. File naming convention for compact grid format files

All files in the directories containing the data comply with the following naming convention:

[v][tp][ft][g].gz

where:

[v] – variable, one-letter code as listed in **Table 3**;
[tp] – time period:
00 – all data annual
13 to 16 – seasons (starting with 13 = Winter (Jan-Mar))
01 to 12 – months (starting with 01 = January)

[ft] – file type, two-letter code as listed in **Table 1**;
[g] – grid size:
1 – one-degree square file
5 – five-degree square file

Example:

t14se1.gz – temperature (**t**) spring (**14**) standard error (**se**) for one-degree square (**1**) compressed file (**.gz**).

Section 5: Utilities

Directory **utils** contains decompression freeware: gzip124.exe – self-extracting DOS executable, and **gzip124.tar** – a tar'd file containing source code for UNIX users.

A. Installing gzip for the first fime

DOS Users: The file **gzip124.exe** is a self-extracting DOS executable. Copy **gzip124.exe** to your hard drive, run **gzip124.exe** and use the file **gzip.exe** to uncompress data as described in section B.

UNIX Users: Copy gzip124.tar to your UNIX system.
Run the following command: **tar -xvf gzip124.tar**

This command will create a directory named **gzip-1.2.4** which include the **gzip** source code and documentation on copyrights, compression methods and how to compile and install the **gzip** code. Read through the README file and when ready to build the **gzip** executable, follow the instructions in the INSTALL file.

B. Decompressing data from WOA09

To decompress the WOA09 files, it is recommended to first copy the data files to a hard disk. Use **gzip** to decompress selected files or a directory and all subdirectories with one command. **gzip** has a limited help menu accessible with the **-h** option (e.g. **gzip -h**); additional information may be found at www.gzip.org.

To decompress a single file: **gzip -nd <filename>**

To decompress the contents of a directory and all of its subdirectories:
gzip -ndr <directoryname>

If an older version of gzip is used, the -n option is required in order to preserve the correct file names.

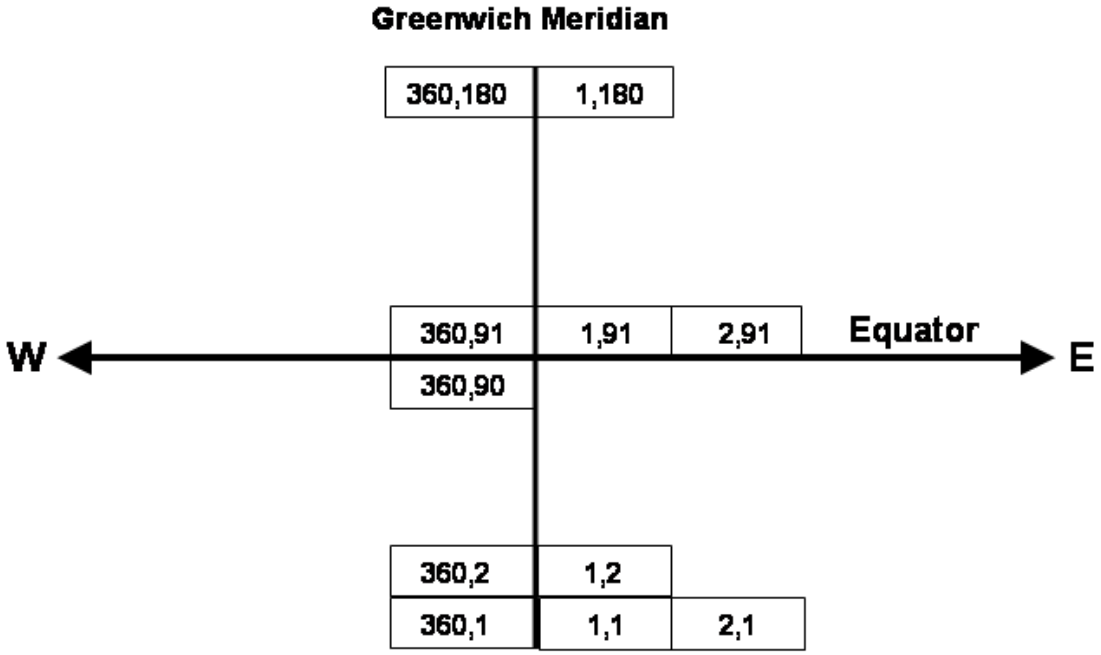

Figure 1. One-degree horizontal coordinate system for statistical field files

Each element F(i,j) of a statistical field F, where F is dimensioned F(360,180), is considered to represent the value at the center of a one-degree latitude/longitude square.

Longitude index, denoted by variable "i", varies from 1 at 0.5°E to 360 at 0.5°W
Latitude index, denoted by variable "j", varies from 1 at 89.5°S to 180 at 89.5°N

The point F(1,1) contains the statistical field value for 0.5°E, 89.5°S
The point F(218,20) contains the statistical field value for 142.5°W, 70.5°
The point F(360,91) contains the statistical field value for 0.5°, 0.5°N

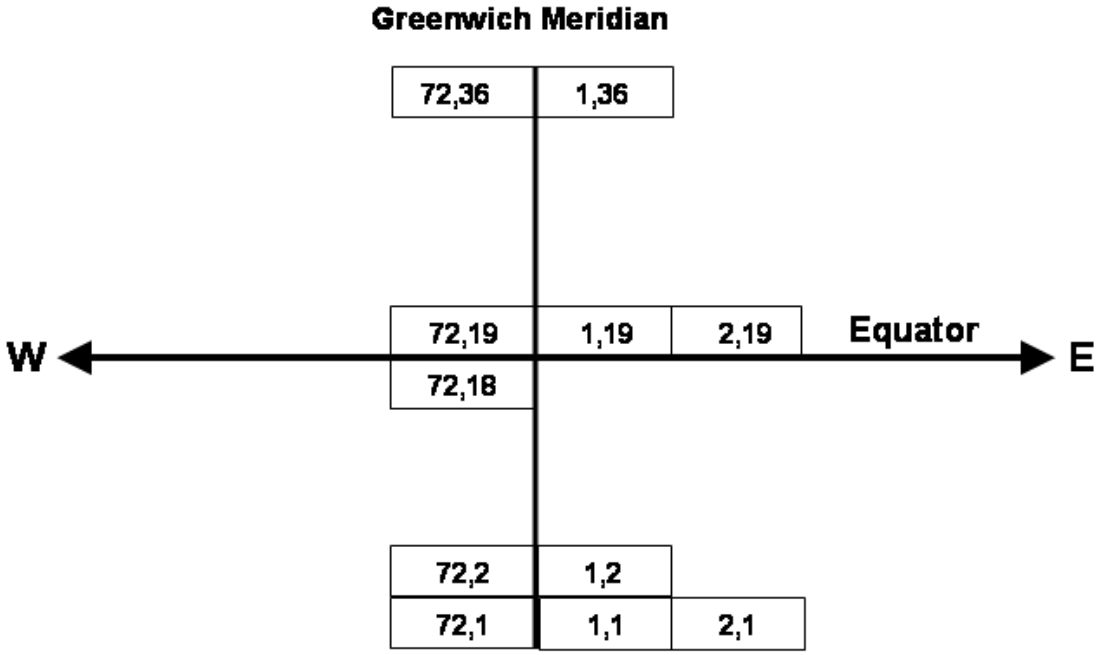

Figure 2. Five-degree horizontal coordinate system for statistical field files

Each element F(i,j) of a statistical field F, where F is dimensioned F(72,36), is considered to represent the value at the center of a five-degree latitude/longitude square.

Longitude index, denoted by variable "i", varies from 1 at 2.5°E to 72 at 2.5°W
Latitude index, denoted by variable "j", varies from 1 at 87.5°S to 36 at 87.5°N

Appendix 1. Basins defined for objective analysis and the shallowest standard depth level for which each basin is defined.

#	BASIN	STANDARD DEPTH LEVEL	#	BASIN	STANDARD DEPTH LEVEL
1	Atlantic Ocean	1	30	North American Basin	29
2	Pacific Ocean	1	31	West European Basin	29
3	Indian Ocean	1	32	Southeast Indian Basin	29
4	Mediterranean Sea	1	33	Coral Sea	29
5	Baltic Sea	1	34	East Indian Basin	29
6	Black Sea	1	35	Central Indian Basin	29
7	Red Sea	1	36	Southwest Atlantic Basin	29
8	Persian Gulf	1	37	Southeast Atlantic Basin	29
9	Hudson Bay	1	38	Southeast Pacific Basin	29
10	Southern Ocean	1	39	Guatemala Basin	29
11	Arctic Ocean	1	40	East Caroline Basin	30
12	Sea of Japan	1	41	Marianas Basin	30
13	Kara Sea	8	42	Philippine Sea	30
14	Sulu Sea	10	43	Arabian Sea	30
15	Baffin Bay	14	44	Chile Basin	30
16	East Mediterranean	16	45	Somali Basin	30
17	West Mediterranean	19	46	Mascarene Basin	30
18	Sea of Okhotsk	19	47	Crozet Basin	30
19	Banda Sea	23	48	Guinea Basin	30
20	Caribbean Sea	23	49	Brazil Basin	31
21	Andaman Basin	25	50	Argentine Basin	31
22	North Caribbean	26	51	Tasman Sea	30
23	Gulf of Mexico	26	52	Atlantic Indian Basin	31
24	Beaufort Sea	28	53	Caspian Sea	1
25	South China Sea	28	54	Sulu Sea II	14
26	Barents Sea	28	55	Venezuela Basin	14
27	Celebes Sea	25	56	Bay of Bengal	1
28	Aleutian Basin	28	57	Java Sea	6
29	Fiji Basin	29	58	East Indian Atlantic Basin	32

Appendix 2. Top and internal portions of a comma delimited file for March Salinity at the surface.

```
#MARCH SALINITY (unitless) at    0 meters depth
# 1 degree lat/lon grid
#Column definitions:
#1. Latitude (degrees,negative=south),
#2. Longitude (degrees,negative=west),
#3. Depth (meters),
#4. Objectively analyzed mean,
#5. statistical mean,
#6. standard deviation of statistical mean,
#7. standard error of statistical mean,
#8. objectively analyzed mean minus statistical mean,
#9. objectively analyzed mean minus objectively analyzed annual mean,
#10. number of grids with statistical means within radius of influence,
#11. number of data used to calculate statistical mean
-84.5,-161.5,0,34.292,,,,,0.109,0,0
-84.5,-160.5,0,34.289,,,,,0.113,0,0
-84.5,-159.5,0,34.275,,,,,0.104,0,0
-84.5,-158.5,0,34.267,,,,,0.112,0,0
-84.5,-157.5,0,34.255,,,,,0.126,0,0

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

35.5,35.5,0,38.820,38.907,0.073,0.051,0.087,-0.129,10,2
35.5,120.5,0,31.262,,,,,-0.216,21,0
35.5,121.5,0,31.759,30.549,0.451,0.319,-1.211,0.116,27,2
35.5,122.5,0,32.142,32.409,0.497,0.157,0.267,0.450,29,10
35.5,123.5,0,32.508,32.805,0.361,0.081,0.297,0.599,31,20
35.5,124.5,0,32.848,32.634,0.296,0.050,-0.214,0.616,33,35
35.5,125.5,0,33.157,32.537,0.401,0.055,-0.620,0.525,35,53
35.5,130.5,0,34.484,34.506,0.203,0.021,0.022,0.658,17,93
35.5,131.5,0,34.481,34.558,0.151,0.013,0.077,0.634,21,139
35.5,141.5,0,34.689,34.614,0.349,0.022,-0.075,0.205,42,248
35.5,142.5,0,34.594,34.733,0.297,0.043,0.139,0.162,48,47
35.5,143.5,0,34.579,34.746,0.307,0.085,0.168,0.139,53,13
```