Appendix A: Description of the FREEZCH 9 program.

FREEZCH9 to be use when evolving ice covered lakes loose liquid water by freezing and have it replaced by new inflow water of fixed chemistry and isotopic composition.

The program is called FREEZCH9.FOR which is virtually identical to FREEZCH8.FOR.

This program takes the water isotope enhanced FREZCHEM(v15) and makes it into a subroutine that accepts a time varying input file called INPUT5B.TXT that changes each loop. The main chemistry part of FREZCHEM(15) has not been changed at all. All that is needed for the additional calculations is taken from the PPRINT subroutine in FREZCHEM(V15) by saving the needed results in new array names. The basic chemistry has been isolated from changes made by us. Checks have verified this.

Table 1: File names and numbers in the FREEZCH9

File number	File name (all "TXT" file types)	Function
9	**INPUT5 (if kount=1) INPUT5B (if kount≠1)**	**INPUT5 is input for initial state of lake & INPUT5B is mixed water input file for each subsequent loop**
11	**FRUDLOOP**	**Main summary file for post loop results for chem. and isotopes**
2	**FRout**	**Main output file for chemistry produced for each loop but only last loops' is saved**
8	**TEST8**	**Generated temperature scan results for chem. and isotopes each loop. Only last loops' is saved.**

NB A few small files are needed to run FREZCHEM ("NUANCES"," SOLIDMASS" and "SOLIDPHASE"). These are described in the Appendix A. These are set and left usually; see Appendix.

Table 2: Keyboard Inputs in the FREEZCH9 program

Name of variable	Function
GRFACT	For each loop some amount of new glacier water is added to the lake. GRFACT is the fraction of that additions chemistry to assume.
XXIM	The lake water slug followed, starts each loop as 1000 gms of liquid water and ends up nominally with (1000-XXIM) gms. So XXIM is the replacement rate in parts per thousand; ie 1 % = 10 ppt.
ITKOUNT	The total number of loops or additions to the lake. (Loop counter is KOUNT).
SITKOUNT	The fraction of loop output to store in FRUDLOOP , a "10" means $1/10^{th}$ is saved.
UTEKWDTH	The temperature scan width in number of temperature steps (DELTEM) to run FREZCHEM over each loop. It starts just above the last melting Temperature (TL) and goes below the temperature at which XXIM gms has been frozen out each loop. For strong chemistry this input can be ~ 10 and for weak chemistry ~ 40. Experiment sometimes required and the file TEST8.TXT shows if the scan width is large enough.

Added subroutines

The subroutines associated with the water isotopes are written up in the Appendix A and are the same as used here. The main one is ISOFREEZ which gets and stores the water and ice isotopes.

The main two new subroutines specific to this lake mixing looping program is :

1) **FREEZCHLP**: this is the "subroutinized" version of FREZCHEM(v15). FREZCHEM(v15) gets solved for each loop using the newly mixed waters that are defined in the INPUT5B file which is defined in the "Mixing" subroutine called "**LOOPIN**".

Argument for FREEZCHLP is (ITKOUNT,KOUNT,SITKOUNT,XCXIM,UTEKWDTH,GRFACT,DELTEM).

2) **LOOPIN:** This routine takes the state of the lake's chemistry and isotopes after an amount of freezing DICE ≥ XXIM has occurred and then mixes the same amount (DICE) of new glacier water into the lake to produce the input chemistry and isotopes for the next loop. This is all stored in the dynamic input file INPUT5B. The hydrated precipitates are accumulated from loop to loop and it is assumed that the ice formed is pure and that all the soluble chemistry is left behind in the lake (liquid) water.

The main summary output file FRUDLOOP.TXT is also populated by LOOPIN. The quantities in FRUDLOOP for the various loops are all post mixing for that loop.

Argument for LOOPIN is
(PATH,NEQFR,XIM,AMOLAR,SL,FINTEM,UTEKWDTH,ITKOUNT,DELTEM,FINWAT,DELWAT,FINPRE,
DELPRE,TEMPI,ALK,JDAF,XXIM,KOUNT,SITKOUNT,TEUCT).

NB. It is realized that some of the water chemistry might find its way into the ice formed each loop so the chemistry produced by this program is probably somewhat high.

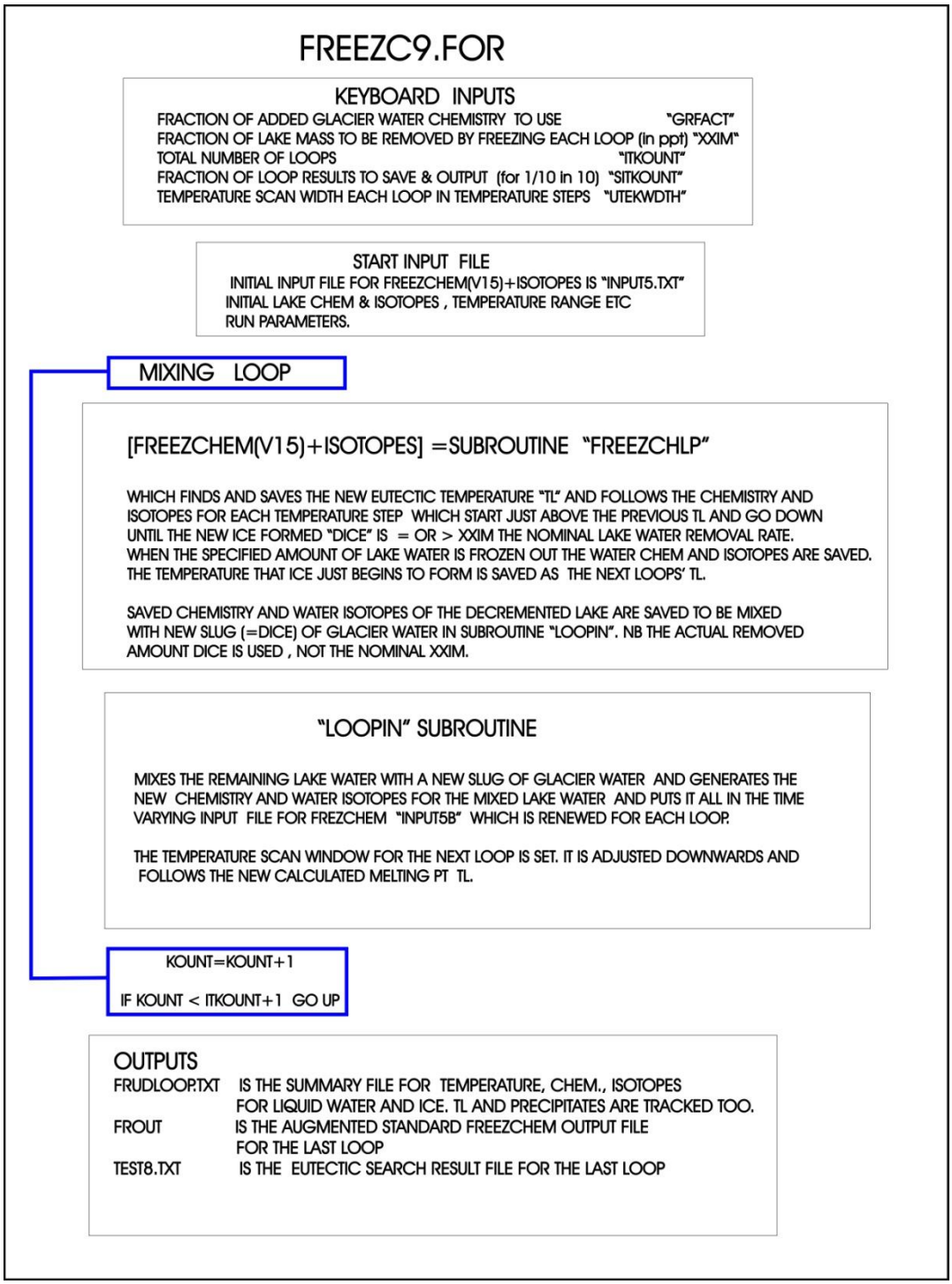

Figure 1 : Flow chart for the **FREEZCH9** program.

Appendix B: Stable water isotope data for the surface (upper 50 cm) of the Anuchin Glacier.

Sample ID	Latitude (°S)	Longitude (°E)	δD (‰)	$\delta^{18}O$ (‰)
D-AT-2-0	-71.333	13.488	-278.5	-36.1
D-AT-2-1	-71.332	13.491	-276.2	-35.9
D-AT-2-2	-71.327	13.492	-280.6	-36.4
D-AT-2-3	-71.323	13.494	-272.4	-35.4
D-AT-2-4	-71.314	13.501	-261.2	-33.9
D-AT-2-5	-71.305	13.510	-268.8	-34.9
D-AT-3-0	-71.334	13.496	-278.8	-36.2
D-AT-3-2	-71.328	13.502	-249.8	-32.6
D-AT-3-3	-71.323	13.504	-247.9	-32.6
D-AT-3-4	-71.314	13.510	-241.8	-30.9
D-AT-3-5	-71.305	13.518	-234.1	-30.9

Appendix C: Stable water isotope data for Lake Untersee's water column (sampling location = 71.337°S, 13.475°E).

Sample ID	Depth	δD (‰)	$\delta^{18}O$ (‰)
Untersee OH - 10 m	10 m	-287.5	-37.8
Untersee OH - 20 m	20 m	-287.5	-37.7
Untersee OH - 30 m	30 m	-288	-37.8
Untersee OH - 40 m	40 m	-287.8	-37.8
Untersee OH - 50 m	50 m	-287.9	-37.8
Untersee OH - 60 m	60 m	-287.9	-37.8
Untersee OH - 70 m	70 m	-288	-37.8
Untersee OH - 80 m	80 m	-288.4	-37.8
Untersee OH - 90 m	90 m	-287.3	-37.7
Untersee OH - 100 m	100 m	-288.3	-37.9
Untersee OH - 110 m	110 m	-288.4	-37.9
Untersee OH - 120 m	120 m	-287.5	-37.6
Untersee OH - 130 m	130 m	-287.9	-37.6
Untersee OH - 140 m	140 m	-288.2	-37.7
Untersee OH - 150 m	150 m	-288	-37.6

Appendix D: Stable water isotope data for Lake Untersee's ice cover (Core #1 taken at 71.349°S, 13.429°E; Core #2 taken at 71.356°S, 13.429°E).

Sample ID	Depth	δD (‰)	$\delta^{18}O$ (‰)
Core #1 - 2 cm	2 cm	-276.2	-34.8
Core #1 - 4 cm	4 cm	-276.7	-34.8
Core #1 - 6 cm	6 cm	-277.2	-35
Core #1 - 8 cm	8 cm	-277.7	-35.1
Core #1 - 10 cm	10 cm	-277.8	-35.1
Core #1 - 12 cm	12 cm	-276.3	-34.7
Core #1 - 14 cm	14 cm	-277.3	-34.9
Core #1 - 16 cm	16 cm	-277.6	-34.8
Core #1 - 18 cm	18 cm	-277.5	-34.7
Core #1 - 20 cm	20 cm	-278.1	-34.7
Core #1 - 22 cm	22 cm	-277	-34.5
Core #1 - 24 cm	24 cm	-276.9	-34.3
Core #1 - 26 cm	26 cm	-276.5	-33.8
Core #1 - 28 cm	28 cm	-277	-33.7
Core #1 - 30 cm	30 cm	-277.2	-33.5
Core #1 - 32 cm	32 cm	-277.5	-34.9
Core #1 - 34 cm	34 cm	-277.4	-34.8
Core #1 - 36 cm	36 cm	-277.9	-34.7
Core #1 - 38 cm	38 cm	-278.8	-34.9
Core #1 - 40 cm	40 cm	-278	-34.7
Core #1 - 42 cm	42 cm	-277	-34.9
Core #1 - 44 cm	44 cm	-278.2	-35.3
Core #1 - 46 cm	46 cm	-278	-35.6
Core #1 - 48 cm	48 cm	-278.4	-35.8
Core #1 - 50 cm	50 cm	-278.5	-36.2
Core #1 - 52 cm	52 cm	-277	-34.7
Core #1 - 54 cm	54 cm	-277.7	-34.9
Core #1 - 56 cm	56 cm	-278.2	-35.3
Core #1 - 58 cm	58 cm	-277.8	-35.1
Core #1 - 60 cm	60 cm	-277.5	-35.2
Core #1 - 62 cm	62 cm	-277.6	-34.9
Core #1 - 64 cm	64 cm	-278.7	-35.1
Core #1 - 66 cm	66 cm	-278.6	-35
Core #1 - 68 cm	68 cm	-277.5	-34.9
Core #1 - 70 cm	70 cm	-278	-35
Core #1 - 72 cm	72 cm	-274.3	-34.6
Core #1 - 74 cm	74 cm	-275.7	-34.9
Core #1 - 76 cm	76 cm	-274.9	-34.8
Core #1 - 78 cm	78 cm	-275.6	-34.9
Core #1 - 80 cm	80 cm	-278.1	-34.9

Core #1 - 82 cm	82 cm	-278.4	-35
Core #1 - 84 cm	84 cm	-279.5	-35.2
Core #1 - 86 cm	86 cm	-278.8	-35.1
Core #1 - 88 cm	88 cm	-279.2	-35.4
Core #1 - 90 cm	90 cm	-277.4	-35
Core #1 - 92 cm	92 cm	-277.5	-35
Core #1 - 94 cm	94 cm	-278.7	-35.3
Core #1 - 96 cm	96 cm	-278.2	-35.2
Core #1 - 98 cm	98 cm	-278.5	-35.3
Core #1 - 100 cm	100 cm	-277.2	-34.8
Core #1 - 102 cm	102 cm	-277.6	-34.8
Core #1 - 104 cm	104 cm	-278	-34.9
Core #1 - 106 cm	106 cm	-278.3	-34.9
Core #1 - 108 cm	108 cm	-278.8	-35.1
Core #1 - 110 cm	110 cm	-277	-34.8
Core #1 - 112 cm	112 cm	-277.9	-34.7
Core #1 - 114 cm	114 cm	-277.9	-34.9
Core #1 - 116 cm	116 cm	-278.6	-35
Core #1 - 118 cm	118 cm	-278.1	-34.8
Core #1 - 120 cm	120 cm	-277.2	-35
Core #1 - 122 cm	122 cm	-277.2	-34.7
Core #1 - 124 cm	124 cm	-277.7	-34.9
Core #1 - 126 cm	126 cm	-277.9	-34.8
Core #1 - 128 cm	128 cm	-278.1	-34.9
Core #1 - 130 cm	130 cm	-277.4	-34.9
Core #1 - 132 cm	132 cm	-278.1	-34.9
Core #1 - 134 cm	134 cm	-278.7	-35
Core #1 - 136 cm	136 cm	-277.9	-34.9
Core #1 - 138 cm	138 cm	-277.7	-34.9
Core #1 - 140 cm	140 cm	-277	-34.9
Core #1 - 142 cm	142 cm	-277.2	-34.7
Core #1 - 144 cm	144 cm	-278	-34.6
Core #1 - 146 cm	146 cm	-277.9	-34.6
Core #1 - 148 cm	148 cm	-276.4	-34.3
Core #1 - 150 cm	150 cm	-275.2	-34.6
Core #1 - 152 cm	152 cm	-275.4	-34.5
Core #1 - 154 cm	154 cm	-277.4	-34.9
Core #1 - 156 cm	156 cm	-278.7	-35.2
Core #1 - 158 cm	158 cm	-277.9	-35.2
Core #1 - 160 cm	160 cm	-277.7	-34.9
Core #1 - 162 cm	162 cm	-277.4	-34.7
Core #1 - 164 cm	164 cm	-277.1	-34.8
Core #1 - 166 cm	166 cm	-277.9	-34.8
Core #1 - 168 cm	168 cm	-277.3	-34.8
Core #1 - 170 cm	170 cm	-277.1	-34.9

Core #1 - 172 cm	172 cm	-276.8	-34.7
Core #1 - 174 cm	174 cm	-277.7	-34.9
Core #1 - 176 cm	176 cm	-277.9	-34.9
Core #1 - 178 cm	178 cm	-268.5	-34.7
Core #1 - 180 cm	180 cm	-268.7	-34.6
Core #1 - 182 cm	182 cm	-269.1	-34.5
Core #1 - 184 cm	184 cm	-269.3	-34.6
Core #1 - 186 cm	186 cm	-269.1	-34.6
Core #1 - 188 cm	188 cm	-277.7	-35
Core #1 - 190 cm	190 cm	-278.8	-35
Core #1 - 192 cm	192 cm	-278.7	-35.1
Core #1 - 194 cm	194 cm	-279	-35
Core #1 - 196 cm	196 cm	-278.4	-34.9
Core #1 - 198 cm	198 cm	-277.5	-35
Core #1 - 200 cm	200 cm	-278.2	-35.3
Core #1 - 202 cm	202 cm	-278.9	-35.4
Core #1 - 204 cm	204 cm	-276.9	-35.1
Core #1 - 206 cm	206 cm	-277.9	-35.2
Core #1 - 208 cm	208 cm	-277.7	-35.2
Core #1 - 210 cm	210 cm	-278.1	-35.4
Core #1 - 212 cm	212 cm	-278.2	-35.4
Core #1 - 214 cm	214 cm	-278.3	-35
Core #1 - 216 cm	216 cm	-278.6	-35
Core #1 - 218 cm	218 cm	-279.3	-35
Core #1 - 220 cm	220 cm	-279.2	-34.9
Core #1 - 222 cm	222 cm	-278.7	-34.5
Core #1 - 224 cm	224 cm	-277.1	-34.9
Core #1 - 226 cm	226 cm	-278	-34.9
Core #1 - 228 cm	228 cm	-277.8	-34.8
Core #1 - 230 cm	230 cm	-278	-34.8
Core #1 - 232 cm	232 cm	-277.5	-34.6
Core #1 - 234 cm	234 cm	-276.7	-34.7
Core #1 - 236 cm	236 cm	-278	-34.9
Core #2 - 2 cm	2 cm	-273	-34.2
Core #2 - 4 cm	4 cm	-275.5	-34.4
Core #2 - 6 cm	6 cm	-276.7	-34.6
Core #2 - 8 cm	8 cm	-277.1	-34.5
Core #2 - 10 cm	10 cm	-276.9	-34.6
Core #2 - 12 cm	12 cm	-276.9	-34.7
Core #2 - 14 cm	14 cm	-277.5	-34.8
Core #2 - 16 cm	16 cm	-277.8	-34.8
Core #2 - 18 cm	18 cm	-277.4	-34.8
Core #2 - 20 cm	20 cm	-277.4	-34.8
Core #2 - 22 cm	22 cm	-277.2	-35
Core #2 - 24 cm	24 cm	-277.9	-35.1

Core #2 - 26 cm	26 cm	-277.8	-35.1
Core #2 - 28 cm	28 cm	-277.9	-35.2
Core #2 - 30 cm	30 cm	-277.8	-35.4
Core #2 - 32 cm	32 cm	-276.3	-34.7
Core #2 - 34 cm	34 cm	-277.5	-34.9
Core #2 - 36 cm	36 cm	-277.7	-34.9
Core #2 - 38 cm	38 cm	-277.6	-34.7
Core #2 - 40 cm	40 cm	-277.3	-34.7
Core #2 - 42 cm	42 cm	-276.5	-34.8
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Core #2 - 46 cm	46 cm	-277.6	-34.7
Core #2 - 48 cm	48 cm	-277.7	-34.8
Core #2 - 50 cm	50 cm	-278.3	-34.9
Core #2 - 52 cm	52 cm	-276.7	-35.1
Core #2 - 54 cm	54 cm	-276.8	-35.2
Core #2 - 56 cm	56 cm	-276.8	-35.1
Core #2 - 58 cm	58 cm	-276.9	-35.3
Core #2 - 60 cm	60 cm	-277.8	-35.3
Core #2 - 62 cm	62 cm	-275.9	-34.8
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Core #2 - 66 cm	66 cm	-278.4	-35.2
Core #2 - 68 cm	68 cm	-278.2	-35.2
Core #2 - 70 cm	70 cm	-278.3	-35.3
Core #2 - 72 cm	72 cm	-276.5	-34.8
Core #2 - 74 cm	74 cm	-277.8	-35
Core #2 - 76 cm	76 cm	-278	-35
Core #2 - 78 cm	78 cm	-277.9	-35.2
Core #2 - 80 cm	80 cm	-278.3	-35.3
Core #2 - 82 cm	82 cm	-276.3	-34.9
Core #2 - 84 cm	84 cm	-277.2	-35
Core #2 - 86 cm	86 cm	-277.1	-35.1
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Core #2 - 90 cm	90 cm	-277.2	-35.5
Core #2 - 92 cm	92 cm	-276.8	-34.8
Core #2 - 94 cm	94 cm	-278	-35
Core #2 - 96 cm	96 cm	-278.1	-34.9
Core #2 - 98 cm	98 cm	-278.3	-35
Core #2 - 100 cm	100 cm	-278.3	-35
Core #2 - 102 cm	102 cm	-276.9	-34.7
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Core #2 - 108 cm	108 cm	-277.5	-34.7
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Core #2 - 112 cm	112 cm	-277.7	-35
Core #2 - 114 cm	114 cm	-278	-34.8

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Core #2 - 124 cm	124 cm	-277	-34.9
Core #2 - 126 cm	126 cm	-277	-35
Core #2 - 128 cm	128 cm	-277.7	-35
Core #2 - 130 cm	130 cm	-277.8	-35
Core #2 - 132 cm	132 cm	-277.1	-35
Core #2 - 134 cm	134 cm	-277.2	-34.9
Core #2 - 136 cm	136 cm	-277.6	-35.1
Core #2 - 138 cm	138 cm	-277.6	-34.9
Core #2 - 140 cm	140 cm	-276.9	-34.8
Core #2 - 142 cm	142 cm	-277.9	-34.8
Core #2 - 144 cm	144 cm	-276.7	-34.6
Core #2 - 146 cm	146 cm	-277.5	-34.9
Core #2 - 148 cm	148 cm	-277.8	-34.9
Core #2 - 150 cm	150 cm	-278.3	-34.9
Core #2 - 152 cm	152 cm	-277.5	-35
Core #2 - 154 cm	154 cm	-277.2	-34.9
Core #2 - 156 cm	156 cm	-277.2	-35
Core #2 - 158 cm	158 cm	-277.8	-34.9
Core #2 - 160 cm	160 cm	-277.9	-34.9
Core #2 - 162 cm	162 cm	-277	-34.9
Core #2 - 164 cm	164 cm	-277.3	-35.1
Core #2 - 166 cm	166 cm	-277.5	-34.8
Core #2 - 168 cm	168 cm	-276.4	-34.7
Core #2 - 170 cm	170 cm	-277.4	-34.9
Core #2 - 172 cm	172 cm	-277.5	-35
Core #2 - 174 cm	174 cm	-278.1	-35
Core #2 - 176 cm	176 cm	-278.3	-35.1
Core #2 - 178 cm	178 cm	-277.7	-35
Core #2 - 180 cm	180 cm	-278.3	-35.2
Core #2 - 182 cm	182 cm	-277	-35
Core #2 - 184 cm	184 cm	-277.8	-35.2
Core #2 - 186 cm	186 cm	-277.5	-35.1
Core #2 - 188 cm	188 cm	-277.2	-35
Core #2 - 190 cm	190 cm	-277.7	-35.1