Adjusting Solar Panel Voc for Low Temperature Conditions

Why worry about Voc and Temperature?

Panels specs are all given for Standard Test conditions at 25°C. However, if the panel is colder than 25°C, it will produce a higher Voc. This table from the US National Electric Code shows the level of voltage increase for various temperature ranges:

Table 690.7(A) Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules

Correction Factors for Ambient Temperatures Below 25°C (77°F). (Multiply the rated open-circuit voltage by the appropriate correction factor shown below.)

Ambient Temperature (°C)	Factor	Ambient Temperature (°F)
24 to 20	1.02	76 to 68
19 to 15	1.04	67 to 59
14 to 10	1.06	58 to 50
9 to 5	1.08	49 to 41
4 to 0	1.10	40 to 32
−1 to −5	1.12	31 to 23
−6 to −10	1.14	22 to 14
−11 to −15	1.16	13 to 5
−16 to −20	1.18	4 to −4
−21 to −25	1.20	−5 to −13
−26 to −30	1.21	−14 to −22
−31 to −35	1.23	−23 to −31
−36 to −40	1.25	−32 to −40

As you can see, even at freezing temperature (0°C), there is a 10% increase in voltage and at more extreme temperatures it can be as much as a 25% increase. Many areas in North America and Europe regularly get well below 0°C and the voltage increase can become substantial.

Meanwhile, the most important not-to-exceed spec on an MPPT Solar Charge Controller (SCC) is the input voltage. If you just use the Voc and do not adjust for temperature extremes for your area, you might burn out the SCC.

Example: *The Victron SmartSolar 75/15 has a 75 Volt limit on its PV input. The QCell 250 Watt Poly Solar Panel has a 37.49V Voc. At first look, it seems that you could put two in series for 74.98V and not exceed the 75V SmartSolar limit. However, when temperature is considered, almost anything below 25°C will create a voltage above the 75V limit.*

NEC Table 690.7(A) is conservative, and you would probably be safe just using it for calculating the Temp Adjusted Max Voc . However, if the panel spec provides a Voc Temperature Coefficient (Sometimes called β or Beta), the NEC requires you to calculate the Max Voc using β. Furthermore, since the table is conservative, calculating the Voc from the Temperature Coefficient may allow panel configurations that the NEC table wouldn't.

The remainder of this paper will describe how to use β to calculate the Temperature Adjusted Max Voc for a panel

Shortcut: Appendix A

You are encouraged to review the following pages to understand how to use the temperature coefficient to calculate voltage rise. However, there is a shortcut. Appendix A at the end of this document has a table that can be used to look up the correction factors for almost any temperature and Voc Temperature coefficient (Beta) you would need. This makes the process a simple table lookup and a multiplication.

Values needed to adjust Voc of a panel for low temperatures.

To adjust the Voc for cold temperatures you need the following numbers:

1) **Panel Voc** from the Panel Specification. (Voc is in units of Volts)

2) **Panel Voc Temperature Coefficient (β)** from the Panel Specification. (β is in units of %/^{o}C)
   β will be a negative number. However, for these calculations, it is easiest to ignore the negative of the Temperature Coefficient and use it as a positive number. (I will be using it as a positive number for this paper)

   The number is usually between -0.25 and -0.40. (I have noticed that many of the newer high wattage panels tend to be closer to the -.25 than the -.40. That is a good thing)

   Note: NEC Table 690.7(A) is calculated with a β of -0.40

3) **The lowest daytime temperature the panels will experience(T_L).** (T_L is in units of ^{o}C)
   I use the minimum all time temperature for the location the panels are installed. This can be found with simple on-line searches. It is typically going to be a night-time temp, but minimum daytime temp is usually not available.

   Note: All calculations are done with degrees in centigrade

   Note: Some people argue that as soon as the sun hits the panel, the panel starts to warm up, so the minimum all-time temperature is overly conservative. However, it takes very little light for a panel to produce it's Voc so this is not a safe assumption.

Four Steps to adjust Voc of a panel for low temperatures.

1) Calculate Temperature Difference between Standard Test Conditions and the lowest temp condition(T_D). Standard test conditions specify 25°C so to determine the difference, subtract the minimum temperature (T_L) from 25°C:
   T_D=25°*C*- T_L

2) Calculate the percent increase in voltage by multiplying the Temperature Difference (T_D) by the Temperature Coefficient (β).
   % Increase = T_D x β

3) Calculate the Voltage Increase by multiplying the % increase by Voc of the panel.
   (Note: Since it is a percent increase, you must divide it by 100 before multiplying it by Voc.)
   Voltage Increase = (% Increase/100) * Voc (This is the voltage increase, not the total.)

4) Calculate the max Voc by adding the original Voc.
   Max Voc = Voltage Increase + Voc

The 4 steps can be represented as a single formula:

Max Voc = Voc + (((25°*C*- T_L) x β /100) * Voc)

(I find it easier to remember the four separate steps than remembering the complex formula)

Trust me, it gets easy after you have done it a few times. See the following example.

EXAMPLE

The QCell 250 Watt Poly Solar Panel from the previous example has a **Voc of *37.49V*** *and a* **β of -0.30%/^{o}C**.
If the lowest temperature will be -20^{o}C, what will the Temp Adjusted Max Voc be?

1) The temperature difference will be:
   $25^oC - T_L = T_D$
   $25^oC - (-20^oC) = 45^oC$

2) The percent Increase will be
   $T_D \times \beta = \%$ Increase
   $45^oC * .30\%/^oC = 13.5\%$ (Notice that I ignored the negative of the β)

3) The voltage Increase will be:
   (% change/100) * Voc = Voltage Increase
   13.5%/100 * 37.49V = 5.06 V

4) The Max Voc will be:
   Voltage Increase + Voc = Max Voc
   5.06V + 37.49V = $\boxed{42.55V}$

QUIZ:

What is the Max Voc at -12ºC for the Renogy RNG-320D 320W Monocrystalline Solar Panel?
The Panel Specs are shown below.

Renogy RNG-320D

Electrical Data

Maximum Power at STC*	320 W
Optimum Operating Voltage (V_{mp})	33.7 V
Optimum Operating Current (I_{mp})	9.50 A
Open Circuit Voltage (V_{oc})	40.1V
Short Circuit Current (I_{sc})	10.08 A
Module Efficiency	19.18%
Maximum System Voltage	1000VDC UL
Maximum Series Fuse Rating	15 A

Mechanical Data

Solar Cell Type	Monocrystalline (6.25 x 6.25 in)
Number of Cells	60 (6 x 10)
Dimensions	65.6 x 39.4 x 1.4 in (1666 x 1002 x 35 mm)
Weight	40.8 lbs (18.5 kg)
Front Glass	Tempered Glass 0.13 in (3.2 mm)
Frame	Black Anodized Aluminium Alloy
Connectors	Solar Connectors
Fire Rating	Type 2

Thermal Characteristics

Operating Module Temperature	-40ºC to +90ºC
Nominal Operating Cell Temerature (NOCT)	47±2ºC
Temperature Coefficient of Pmax	-0.47%/ºC
Temperature Coefficient of Voc	-0.33%/ºC
Temperature Coefficient of Isc	0.03%/ºC

Solar Connectors

Rated Current	30A
Maximum Voltage	1000VDC
Maximum AWG Size Range	10 AWG
Temperature Range	-40ºF to 194ºF
IP Rating	IP 67

(Answer on next page)

Quiz Answer

Q) What is the Max Voc at -12^{o}C for the Renogy RNG-320D 320W Monocrystalline Solar Panel?

The spec says the **Voc is 40.1V** and the **Temperature Coefficient (β) is -0.33%/^{o}C**.

1) The temperature difference will be:
   $25^oC - T_L = T_D$
   $\mathbf{25^oC - (-12^oC) = 37^oC}$

2) The percent change will be
   $T_D \times \beta = \%$ Change
   $\mathbf{37^oC * 0.33\%/^oC = 12.21\%}$

3) The voltage Increase will be:
   (% change/100) * Voc = Voltage Increase
   12.21%/100 * 40.10V = 4.896 V

4) The Max Voc will be:
   Voltage Increase + Voc = Max Voc
   4.896V + 40.10V = $\boxed{\mathbf{44.996V}}$

Calculating temperature from Voc@25^{o}C, MPPT Max V and Beta

Sometimes you have the Voc and the voltage limit of the MPPT controller and want to know what the lowest possible temperature is.

Example: If the MPPT max input voltage is 140V and you have 4 panels with Voc of 29 V. If the beta is -.38%/^{o}C, what is the coldest temp the setup can handle.

1) First calculate the string Voc@25 ^{o}C.
   4x29V= 116V

2) Now calculate the difference between the string Voc and Max Voc
   140V-116=24V

3) Calculate the difference as a percentage gain.
   (24/116V) x 100 = 20.7%

4) Calculate what temp <u>difference</u> from the Standard 25 ^{o}C would give 20.7% by dividing by beta.
   20.7% / (.38%/ ^{o}C) = 54.5^{o}C.

5) Calculate the actual temperature by subtracting the difference from 25^{o}C
   25^{o}C – 54.5^{o}C = -29.5^{o}C (-21^{o}F)

Measured vs actual Voc

A forum member recently pointed out that he was measuring a Voc considerably lower than the specified number and wondered if he could use that instead of the higher spec number.

It is true that the spec Voc is a max number for the panel and in real life the actual number will be something lower.   However, if you measure a Voc and try to use that as the starting point, you must also know the exact temperature of the panel at the time of the measurement.   Then in the calculations, you must use that temperature instead of the 25^{o}C standard conditions value.   I do not recommend trying to do this.

Appendix A

Voc Temperature Correction Factor Tables

The tables on the following two pages allow the user to look up a VOC Temperature Correction Factor based on the panel Voc Temperature Coefficient and the lowest expected temperature.

This makes calculating the Temperature Adjusted Voc a simple mater of looking up the correction factor and multiplying by the panel Voc.

Voc Correction Factors : 25^{o}C to -15^{o}C

Note:
Lower temperatures are shown on next page

How to use this table:

1) Select column for Panel Voc Temperature coefficient (Beta)

2) Select Row for lowest temperature

3) Multiply Voc by the correction factor shown for the selected Beta and Temperature.

Note:
The US National Electric Code table 690.7A is calculated based on a temperature coefficient of 0.4%/^{o}C. However, the code requires calculating from the panels specs when they are available.

Lowest Temperature panel will experience		Beta(Voc temperature coefficient)																
		0.24	**0.25**	**0.26**	**0.27**	**0.28**	**0.29**	**0.30**	**0.31**	**0.32**	**0.33**	**0.34**	**0.35**	**0.36**	**0.37**	**0.38**	**0.39**	**0.40**
Centigrade	**Fahrenheit**	**Temperature Adjusted Voc Correction Factor**																
25°	**77°**	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
24°	**75.2°**	1.002	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.004	1.004	1.004	1.004	1.004	1.004
23°	**73.4°**	1.005	1.005	1.005	1.005	1.006	1.006	1.006	1.006	1.006	1.007	1.007	1.007	1.007	1.007	1.008	1.008	1.008
22°	**71.6°**	1.007	1.008	1.008	1.008	1.008	1.009	1.009	1.009	1.010	1.010	1.010	1.011	1.011	1.011	1.011	1.012	1.012
21°	**69.8°**	1.010	1.010	1.010	1.011	1.011	1.012	1.012	1.012	1.013	1.013	1.014	1.014	1.014	1.015	1.015	1.016	1.016
20°	**68°**	1.012	1.013	1.013	1.014	1.014	1.015	1.015	1.016	1.016	1.017	1.017	1.018	1.018	1.019	1.019	1.020	1.020
19°	**66.2°**	1.014	1.015	1.016	1.016	1.017	1.017	1.018	1.019	1.019	1.020	1.020	1.021	1.022	1.022	1.023	1.023	1.024
18°	**64.4°**	1.017	1.018	1.018	1.019	1.020	1.020	1.021	1.022	1.022	1.023	1.024	1.025	1.025	1.026	1.027	1.027	1.028
17°	**62.6°**	1.019	1.020	1.021	1.022	1.022	1.023	1.024	1.025	1.026	1.026	1.027	1.028	1.029	1.030	1.030	1.031	1.032
16°	**60.8°**	1.022	1.023	1.023	1.024	1.025	1.026	1.027	1.028	1.029	1.030	1.031	1.032	1.032	1.033	1.034	1.035	1.036
15°	**59°**	1.024	1.025	1.026	1.027	1.028	1.029	1.030	1.031	1.032	1.033	1.034	1.035	1.036	1.037	1.038	1.039	1.040
14°	**57.2°**	1.026	1.028	1.029	1.030	1.031	1.032	1.033	1.034	1.035	1.036	1.037	1.039	1.040	1.041	1.042	1.043	1.044
13°	**55.4°**	1.029	1.030	1.031	1.032	1.034	1.035	1.036	1.037	1.038	1.040	1.041	1.042	1.043	1.044	1.046	1.047	1.048
12°	**53.6°**	1.031	1.033	1.034	1.035	1.036	1.038	1.039	1.040	1.042	1.043	1.044	1.046	1.047	1.048	1.049	1.051	1.052
11°	**51.8°**	1.034	1.035	1.036	1.038	1.039	1.041	1.042	1.043	1.045	1.046	1.048	1.049	1.050	1.052	1.053	1.055	1.056
10°	**50°**	1.036	1.038	1.039	1.041	1.042	1.044	1.045	1.047	1.048	1.050	1.051	1.053	1.054	1.056	1.057	1.059	1.060
9°	**48.2°**	1.038	1.040	1.042	1.043	1.045	1.046	1.048	1.050	1.051	1.053	1.054	1.056	1.058	1.059	1.061	1.062	1.064
8°	**46.4°**	1.041	1.043	1.044	1.046	1.048	1.049	1.051	1.053	1.054	1.056	1.058	1.060	1.061	1.063	1.065	1.066	1.068
7°	**44.6°**	1.043	1.045	1.047	1.049	1.050	1.052	1.054	1.056	1.058	1.059	1.061	1.063	1.065	1.067	1.068	1.070	1.072
6°	**42.8°**	1.046	1.048	1.049	1.051	1.053	1.055	1.057	1.059	1.061	1.063	1.065	1.067	1.068	1.070	1.072	1.074	1.076
5°	**41°**	1.048	1.050	1.052	1.054	1.056	1.058	1.060	1.062	1.064	1.066	1.068	1.070	1.072	1.074	1.076	1.078	1.080
4°	**39.2°**	1.050	1.053	1.055	1.057	1.059	1.061	1.063	1.065	1.067	1.069	1.071	1.074	1.076	1.078	1.080	1.082	1.084
3°	**37.4°**	1.053	1.055	1.057	1.059	1.062	1.064	1.066	1.068	1.070	1.073	1.075	1.077	1.079	1.081	1.084	1.086	1.088
2°	**35.6°**	1.055	1.058	1.060	1.062	1.064	1.067	1.069	1.071	1.074	1.076	1.078	1.081	1.083	1.085	1.087	1.090	1.092
1°	**33.8°**	1.058	1.060	1.062	1.065	1.067	1.070	1.072	1.074	1.077	1.079	1.082	1.084	1.086	1.089	1.091	1.094	1.096
0°	**32°**	1.060	1.063	1.065	1.068	1.070	1.073	1.075	1.078	1.080	1.083	1.085	1.088	1.090	1.093	1.095	1.098	1.100
-1°	**30.2°**	1.062	1.065	1.068	1.070	1.073	1.075	1.078	1.081	1.083	1.086	1.088	1.091	1.094	1.096	1.099	1.101	1.104
-2°	**28.4°**	1.065	1.068	1.070	1.073	1.076	1.078	1.081	1.084	1.086	1.089	1.092	1.095	1.097	1.100	1.103	1.105	1.108
-3°	**26.6°**	1.067	1.070	1.073	1.076	1.078	1.081	1.084	1.087	1.090	1.092	1.095	1.098	1.101	1.104	1.106	1.109	1.112
-4°	**24.8°**	1.070	1.073	1.075	1.078	1.081	1.084	1.087	1.090	1.093	1.096	1.099	1.102	1.104	1.107	1.110	1.113	1.116
-5°	**23°**	1.072	1.075	1.078	1.081	1.084	1.087	1.090	1.093	1.096	1.099	1.102	1.105	1.108	1.111	1.114	1.117	1.120
-6°	**21.2°**	1.074	1.078	1.081	1.084	1.087	1.090	1.093	1.096	1.099	1.102	1.105	1.109	1.112	1.115	1.118	1.121	1.124
-7°	**19.4°**	1.077	1.080	1.083	1.086	1.090	1.093	1.096	1.099	1.102	1.106	1.109	1.112	1.115	1.118	1.122	1.125	1.128
-8°	**17.6°**	1.079	1.083	1.086	1.089	1.092	1.096	1.099	1.102	1.106	1.109	1.112	1.116	1.119	1.122	1.125	1.129	1.132
-9°	**15.8°**	1.082	1.085	1.088	1.092	1.095	1.099	1.102	1.105	1.109	1.112	1.116	1.119	1.122	1.126	1.129	1.133	1.136
-10°	**14°**	1.084	1.088	1.091	1.095	1.098	1.102	1.105	1.109	1.112	1.116	1.119	1.123	1.126	1.130	1.133	1.137	1.140
-11°	**12.2°**	1.086	1.090	1.094	1.097	1.101	1.104	1.108	1.112	1.115	1.119	1.122	1.126	1.130	1.133	1.137	1.140	1.144
-12°	**10.4°**	1.089	1.093	1.096	1.100	1.104	1.107	1.111	1.115	1.118	1.122	1.126	1.130	1.133	1.137	1.141	1.144	1.148
-13°	**8.6°**	1.091	1.095	1.099	1.103	1.106	1.110	1.114	1.118	1.122	1.125	1.129	1.133	1.137	1.141	1.144	1.148	1.152
-14°	**6.8°**	1.094	1.098	1.101	1.105	1.109	1.113	1.117	1.121	1.125	1.129	1.133	1.137	1.140	1.144	1.148	1.152	1.156
-15°	**5°**	1.096	1.100	1.104	1.108	1.112	1.116	1.120	1.124	1.128	1.132	1.136	1.140	1.144	1.148	1.152	1.156	1.160

Voc Correction Factors 0°C to -41°C

Note: Higher temperatures are shown on previous page

How to use this table:

1) Select column for Panel Voc Temperature coefficient (Beta)

2) Select Row for lowest temperature

3) Multiply Voc by the correction factor shown for the selected Beta and temperature

Note:
The US National Electric Code table 690.7A is calculated based on a temperature coefficient of 0.4%/°C. However, the code requires calculating from the panels specs when they are available.

Lowest Temperature panel will experience		Beta(Voc temperature coefficient)																
		0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40
Centigrade	Fahrenheit	Temperature Adjusted Voc Correction Factor																
0°	32°	1.060	1.063	1.065	1.068	1.070	1.073	1.075	1.078	1.080	1.083	1.085	1.088	1.090	1.093	1.095	1.098	1.100
-1°	30.2°	1.062	1.065	1.068	1.070	1.073	1.075	1.078	1.081	1.083	1.086	1.088	1.091	1.094	1.096	1.099	1.101	1.104
-2°	28.4°	1.065	1.068	1.070	1.073	1.076	1.078	1.081	1.084	1.086	1.089	1.092	1.095	1.097	1.100	1.103	1.105	1.108
-3°	26.6°	1.067	1.070	1.073	1.076	1.078	1.081	1.084	1.087	1.090	1.092	1.095	1.098	1.101	1.104	1.106	1.109	1.112
-4°	24.8°	1.070	1.073	1.075	1.078	1.081	1.084	1.087	1.090	1.093	1.096	1.099	1.102	1.104	1.107	1.110	1.113	1.116
-5°	23°	1.072	1.075	1.078	1.081	1.084	1.087	1.090	1.093	1.096	1.099	1.102	1.105	1.108	1.111	1.114	1.117	1.120
-6°	21.2°	1.074	1.078	1.081	1.084	1.087	1.090	1.093	1.096	1.099	1.102	1.105	1.109	1.112	1.115	1.118	1.121	1.124
-7°	19.4°	1.077	1.080	1.083	1.086	1.090	1.093	1.096	1.099	1.102	1.106	1.109	1.112	1.115	1.118	1.122	1.125	1.128
-8°	17.6°	1.079	1.083	1.086	1.089	1.092	1.096	1.099	1.102	1.106	1.109	1.112	1.116	1.119	1.122	1.125	1.129	1.132
-9°	15.8°	1.082	1.085	1.088	1.092	1.095	1.099	1.102	1.105	1.109	1.112	1.116	1.119	1.122	1.126	1.129	1.133	1.136
-10°	14°	1.084	1.088	1.091	1.095	1.098	1.102	1.105	1.109	1.112	1.116	1.119	1.123	1.126	1.130	1.133	1.137	1.140
-11°	12.2°	1.086	1.090	1.094	1.097	1.101	1.104	1.108	1.112	1.115	1.119	1.122	1.126	1.130	1.133	1.137	1.140	1.144
-12°	10.4°	1.089	1.093	1.096	1.100	1.104	1.107	1.111	1.115	1.118	1.122	1.126	1.130	1.133	1.137	1.141	1.144	1.148
-13°	8.6°	1.091	1.095	1.099	1.103	1.106	1.110	1.114	1.118	1.122	1.125	1.129	1.133	1.137	1.141	1.144	1.148	1.152
-14°	6.8°	1.094	1.098	1.101	1.105	1.109	1.113	1.117	1.121	1.125	1.129	1.133	1.137	1.140	1.144	1.148	1.152	1.156
-15°	5°	1.096	1.100	1.104	1.108	1.112	1.116	1.120	1.124	1.128	1.132	1.136	1.140	1.144	1.148	1.152	1.156	1.160
-16°	3.2°	1.098	1.103	1.107	1.111	1.115	1.119	1.123	1.127	1.131	1.135	1.139	1.144	1.148	1.152	1.156	1.160	1.164
-17°	1.4°	1.101	1.105	1.109	1.113	1.118	1.122	1.126	1.130	1.134	1.139	1.143	1.147	1.151	1.155	1.160	1.164	1.168
-18°	-0.4°	1.103	1.108	1.112	1.116	1.120	1.125	1.129	1.133	1.138	1.142	1.146	1.151	1.155	1.159	1.163	1.168	1.172
-19°	-2.2°	1.106	1.110	1.114	1.119	1.123	1.128	1.132	1.136	1.141	1.145	1.150	1.154	1.158	1.163	1.167	1.172	1.176
-20°	-4°	1.108	1.113	1.117	1.122	1.126	1.131	1.135	1.140	1.144	1.149	1.153	1.158	1.162	1.167	1.171	1.176	1.180
-21°	-5.8°	1.110	1.115	1.120	1.124	1.129	1.133	1.138	1.143	1.147	1.152	1.156	1.161	1.166	1.170	1.175	1.179	1.184
-22°	-7.6°	1.113	1.118	1.122	1.127	1.132	1.136	1.141	1.146	1.150	1.155	1.160	1.165	1.169	1.174	1.179	1.183	1.188
-23°	-9.4°	1.115	1.120	1.125	1.130	1.134	1.139	1.144	1.149	1.154	1.158	1.163	1.168	1.173	1.178	1.182	1.187	1.192
-24°	-11.2°	1.118	1.123	1.127	1.132	1.137	1.142	1.147	1.152	1.157	1.162	1.167	1.172	1.176	1.181	1.186	1.191	1.196
-25°	-13°	1.120	1.125	1.130	1.135	1.140	1.145	1.150	1.155	1.160	1.165	1.170	1.175	1.180	1.185	1.190	1.195	1.200
-26°	-14.8°	1.122	1.128	1.133	1.138	1.143	1.148	1.153	1.158	1.163	1.168	1.173	1.179	1.184	1.189	1.194	1.199	1.204
-27°	-16.6°	1.125	1.130	1.135	1.140	1.146	1.151	1.156	1.161	1.166	1.172	1.177	1.182	1.187	1.192	1.198	1.203	1.208
-28°	-18.4°	1.127	1.133	1.138	1.143	1.148	1.154	1.159	1.164	1.170	1.175	1.180	1.186	1.191	1.196	1.201	1.207	1.212
-29°	-20.2°	1.130	1.135	1.140	1.146	1.151	1.157	1.162	1.167	1.173	1.178	1.184	1.189	1.194	1.200	1.205	1.211	1.216
-30°	-22°	1.132	1.138	1.143	1.149	1.154	1.160	1.165	1.171	1.176	1.182	1.187	1.193	1.198	1.204	1.209	1.215	1.220
-31°	-23.8°	1.134	1.140	1.146	1.151	1.157	1.162	1.168	1.174	1.179	1.185	1.190	1.196	1.202	1.207	1.213	1.218	1.224
-32°	-25.6°	1.137	1.143	1.148	1.154	1.160	1.165	1.171	1.177	1.182	1.188	1.194	1.200	1.205	1.211	1.217	1.222	1.228
-33°	-27.4°	1.139	1.145	1.151	1.157	1.162	1.168	1.174	1.180	1.186	1.191	1.197	1.203	1.209	1.215	1.220	1.226	1.232
-34°	-29.2°	1.142	1.148	1.153	1.159	1.165	1.171	1.177	1.183	1.189	1.195	1.201	1.207	1.212	1.218	1.224	1.230	1.236
-35°	-31°	1.144	1.150	1.156	1.162	1.168	1.174	1.180	1.186	1.192	1.198	1.204	1.210	1.216	1.222	1.228	1.234	1.240
-36°	-32.8°	1.146	1.153	1.159	1.165	1.171	1.177	1.183	1.189	1.195	1.201	1.207	1.214	1.220	1.226	1.232	1.238	1.244
-37°	-34.6°	1.149	1.155	1.161	1.167	1.174	1.180	1.186	1.192	1.198	1.205	1.211	1.217	1.223	1.229	1.236	1.242	1.248
-38°	-36.4°	1.151	1.158	1.164	1.170	1.176	1.183	1.189	1.195	1.202	1.208	1.214	1.221	1.227	1.233	1.239	1.246	1.252
-39°	-38.2°	1.154	1.160	1.166	1.173	1.179	1.186	1.192	1.198	1.205	1.211	1.218	1.224	1.230	1.237	1.243	1.250	1.256
-40°	-40°	1.156	1.163	1.169	1.176	1.182	1.189	1.195	1.202	1.208	1.215	1.221	1.228	1.234	1.241	1.247	1.254	1.260
-41°	-41.8°	1.158	1.165	1.172	1.178	1.185	1.191	1.198	1.205	1.211	1.218	1.224	1.231	1.238	1.244	1.251	1.257	1.264