

Course Deviation to Find Stronger Lift (No Wind)

Instructions on how to use the spreadsheets

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Theory

In his *Course Deviations* article in the December 2011 issue of *Soaring*, John Cochrane writes that it's a mistake to measure course deviations using distance, and that "the only thing that matters is how many degrees you go of course." This is always true when the course deviation is made in order to avoid sink or to cruise through lift. If, however, we are deviating off course in order to find stronger lift, this will only be true in a special case when we are starting the glide at the top of a thermal *and* the next turn point is very far away. Otherwise, a number of additional factors come into play: the initial altitude, the maximum and minimum altitudes (the working band), the aforementioned distance to the next turn point and whether or not the stronger thermal can be reached in a single glide at or above the minimum altitude.

The net gain or loss of time when making a course deviation in order to find stronger lift can be calculated from a simple equation with the following three factors:

- T_a = Total additional time spent in cruise (compared to staying on course).
- T_b = Additional time spent in the next climb in order to recover the altitude lost during T_a .
- T_c = Time saved by climbing in the stronger thermal, excluding T_b .

The total time difference dT can then be calculated as $dT = T_a + T_b + T_c$. A negative dT indicates time saved while a positive dT indicates time lost.

When the starting altitude is below the maximum altitude, the maximum angle of course deviation is usually 180° , meaning that back-tracking in order to climb in a stronger thermal can save time overall. How far we can back-track before the time-saved melts away and becomes time-lost, depends on the thermal strengths, glider performance all the above mentioned additional factors.

Course Deviation - Simple Example

The calculations for the example below are contained in Excel file:

Course Deviation in Order to Find Stronger Lift (No Wind, Simple Example).xls

Suppose you are gliding straight on course, thinking that the next thermal ahead will be 3 knots (3 knot MacCready setting). Also suppose that the cruise speed for $MC=3kts$ is 80 knots with L/D of 40 (2 knots sink rate). Now suppose that your team member radios that he's climbing in a 5 knot thermal and that his position is 4 NM far from yours, exactly 90° off course. Should you deviate?

Before we can answer that question, we need a couple of additional pieces of information:

- a) Your altitude compared to the how high you expect to be able to climb
- b) The distance to the next turn point.

Let's assume that you are flying at an altitude of 3,038 ft (which is equal to 0.5 nm) and that you expect to be able to climb to the altitude of 9,114 ft (or 1.5 nm). Also, in order to simplify the calculation, let's assume that the distance to the next turn point is very large, so the additional cruise distance will be

exactly 4 nm and that you keep the cruise speed at 80 knots. From these assumptions, we can calculate $T_a = 3 \text{ min}$ ($4 \text{ nm} / 80 \text{ kts} = 0.05 \text{ h} = 4 \text{ min}$); $T_b = 1.2 \text{ min}$ (additional altitude lost in cruise = $0.1 \text{ nm} / 5 \text{ kts} = 0.02 \text{ h} = 1.2 \text{ min}$); $T_c = -8 \text{ min}$ [$(3 \text{ kt} - 5 \text{ kt}) / 1 \text{ nm climb} = -0.1333 \text{ h} = -8 \text{ min}$]. Finally, $dT = 3 + 1.2 - 8 = -3.8 \text{ min}$, meaning that by deviating 90° from the course for 4 nm, we shaved 3.8 minutes off our time on task. Not bad, eh!

It may be interesting to note how changing some input parameters would affect the calculation:

- a) If the initial distance to the next turn point was reduced from infinite to 9.6 nm, the additional cruise distance would increase from 4 to 4.8 nm and the total time saved would drop from 3.8 min to 2.8 min.
- b) If the distance to the thermal off course was 6 nm instead of 4 nm, the time saved would decrease to 1.7 min.
- c) If the course deviation angle was reduced from 90° to 60° , the time saved would increase to 6.3 min.
- d) If the course deviation angle was increased from 90° to 120° (which would mean going not just sideways but also back away from the next TP), the time saved would decrease to 1.3 min, but it would still be to our advantage to make the course deviation!
- e) If the course deviation angle was increased to 180° (for a total course reversal) and at the same time the distance was reduced to 1.83 nm, the time saved would remain the same at 3.8 min.
- f) If the strength of the thermal off course was 4 instead of 5 knots, the time saved would decrease to 0.5 min.
- g) If the expected altitude after the climb is 6,076 ft (1 nm) instead of 9,114 ft (or 1.5 nm), then dT would become +0.2 min, meaning that the course deviation would end up costing you 12 seconds.
- h) If the expected altitude after the climb is further reduced to 4,557 ft (0.75 nm), then the time lost would increase to 2.2 min.

Course Deviation Graphs

This section contains the instructions on how to use the interactive graphing Excel spreadsheets:

- *Course Deviation in Order to Find Stronger Lift (No Wind, Graphs).xls* (Excel 2003)
- *Course Deviation in Order to Find Stronger Lift (No Wind, Graphs).xlsm* (Excel 2007 & 2010)

General Notes

- The spreadsheets are “macro enabled”, so you will have to enable macros in order to use it. I guarantee that they contain no malware.
- The worksheets are password protected to prevent accidentally overtyping the cells containing formulas. You can unprotect them by clicking on any of the **Unprotect** buttons and protect them by clicking on any of the **Protect** buttons.
- Some of the rows on the sheets are hidden in order to reduce clutter. You can unhide and hide these rows by clicking on any of the **Show Rows** and **Hide Rows** buttons.
- The VBA code that does the automation and calculations is password protected.
- Check the **Synchronize** checkbox above the table to synchronize the changes in input data across sheets dTo , dTa and dTb .

Common Input Data

The common input data is shown in the tables above the graphs in sheets dTo, dTa and dBt:

Description	Q'ty	Unit
Initial Altitude	3,000	ft
Maximum Altitude	8,000	ft
Minimum Altitude	2,000	ft
Initial Distance to Next TP	8	mi
Use Glider Polar for	Std. Cirrus	
Wing Loading	6.2	lb/sf
Climb Rate in Thermal 1 (MC setting)	2	kts
Climb Rate in Thermal 2	3	kts
Extend Glide [TRUE/FALSE]	FALSE	

- **Initial Altitude** – The initial altitude at the start of the glide (at point 0,0).
- **Maximum Altitude** – The altitude at the end of the climb in thermal #2; also the top of the “working altitude band”.
- **Minimum Altitude** – The minimum altitude below which we do not want to glide in search of thermals, i.e., the bottom of the “working altitude band”.
- **Initial Distance to Next TP** – The initial distance to the next Turn Point.
- **Use Glider Polar for** – Enables you to select one of the 5 glider polars.
- **Wing Loading** – The wing loading for the selected glider.
- **Climb Rate in Thermal 1 (MC setting)** – Climb rate in thermal #1 (the one on the course line). This climb rate is also used as the MacCready setting when calculating the cruise speed.
- **Climb Rate in Thermal 2** – Climb rate in thermal #2 (the stronger one, off the course line)
- **Extend Glide [TRUE/FALSE]** – Set to TRUE to extend the glide to thermal #2 if it is unreachable from initial altitude. If thermal #2 (the stronger one off the course) cannot be reached at an altitude equal or above the minimum altitude (when starting the glide from our initial altitude), then we have two options: a) consider this thermal unreachable and b) extend the glide by climbing in weaker lift along the way to thermal #2. The rate of climb in the weaker lift equals the MacCready ring setting = thermal 1.

dTo Sheet

dTo sheet shows break-even ($dT=0$) curves or curves for a given dT (remember that negative dT indicates time saved). To set the desired dT , enter the value at the bottom of the input data table:

Calculate curves for $dT <> 0$ (set dT)	0	min
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The curves are drawn for five different rates of climb, as a function of climb rates in thermal #1 and thermal #2. Note that the curve #4 shows the thermal #2 climb rate. The graph on the right shows a blown up area of ± 10 nm (mi or km, depending on the selected units) from the starting point. The five lines drawn on an angle over the graphs show the 15° , 30° , 45° , 60° and 75° course deviation angles.

dTa Sheet

dTa sheet shows five time difference curves, starting with dT=0, and incremented by dT increment (negative for time saved). To set the desired dT increment, enter the value at the bottom of the input data table:

dT increment (negative for time saved)	-2	min
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dTa Sheet

dTb sheet shows a time difference surface graph, with basically the same information as dTa sheet. Note that the graph on this sheet is rotated 90° (the course line is horizontal). Also, only the area to the left of the course line is shown. This sheet allows you to change the size of the area shown by entering the Y max (maximum distance from the current location):

Grid - Y max	10	mi
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Units Sheet

The Units sheet allows you to select different units for the following variables:

Variable	Available Units			
Length	nm	mi	km	
Altitude	nm	ft	m	
Horizontal Speed	kts	mph	km/h	
Vertical Speed	kts	m/s	ft/min	
Wing Loading	kg/m ²	lb/sf		
Temperature	°C	°F		
Altitude (Atmosphere Model)	m	ft		
Pressure (Atmosphere Model)	Pa	kPa	mb	inHg

Polars Sheet

The Polars sheet shows the list of available glider polars that can be used for generating the graphs. The polars are defined using SeeYou® polar coefficients. The speed-sink and glide ratio curves are shown below the table.

You can easily modify one or more polars to suit your needs (e.g., replace one of the polars with that of your glider) by changing the glider name and the SeeYou® polar coefficients. If you don't know the coefficients, you can calculate them by entering the wing loading and the speed-sink coordinates of 3 points on the polar, and then the calculated values of the coefficients into the SeeYou Polar Coefficients table.

Atm Sheet

The Atm sheet lets you select between the **Standard Atmosphere** and a **Custom Atmosphere** model using the Custom Atmosphere Definition. In the custom model you can have up to 5 layers, each with a constant lapse rate and defined Temperature (T) and Dew Point (Tdp) at the boundary between the layers. The height (H) is given in geo potential feet or meters. The bottom height of the first layer defines the ground level. The QNH is the seal level barometric pressure.

The example Custom Atmosphere is defined with the ground level at 200 ft AMSL (Above Mean Sea Level), a superadiabatic layer up to 600 ft AMSL, dry adiabatic layer to 12,000 ft AMSL (also the Cumulus Condensation Level - CCL), and the top of Cu's at 13,000 ft AMSL.

About the Model

The curves are calculated based on the selected input data in the following way:

- The wind speed is assumed to be zero.
- The mean altitude used in calculations is taken as the average of the initial and the maximum altitudes.
- The speed and sink rate in cruise are calculated from the selected polar, taking into account the effects of the selected wing loading and air density.
- The air density is calculated from the selected atmosphere model for the mean altitude.
- The calculations of the time saved or lost by course deviation are the same as the one used in the Simple Example spreadsheet. In order to facilitate generation of the graphs, these calculations are encapsulated in VBA code through three worksheet functions described below.

- **Calc_dT_AD** – Calculates total time difference dT due to course deviation in order to find a stronger lift. The location of thermal #2 is given in polar (angle/distance) coordinates. Returns Time difference (negative = time saved) [min]. Parameters:

H_0	[nm]	Initial Altitude
H_max	[nm]	Maximum Altitude
H_min	[nm]	Minimum Altitude
Extend_Glide	[TRUE/FALSE]	True to extend the glide to thermal #2 if unreachable
D_TP	[nm]	Initial Distance to Next Turn Point
V_cr	[kts]	True Air Speed in Cruise
W_cr	[kts]	True Glider Sink Rate in Cruise
W_th1	[kts]	Climb Rate in Thermal #1 (on the course line)
W_th2	[kts]	Climb Rate in Thermal #2 (off the course line)
A_dev	[°]	Angle of course deviation (0 to 360°)
D_Dev_Th2	[nm]	Distance to thermal #2
dT_given	[min]	Given value for time difference (negative = time saved)
dTmax	[min]	Optional cutoff for maximum time lost (used in some graphs)

- **Calc_D_dev** – Calculates the distance to Thermal #2 for a given time difference and deviation angle. Uses Newton numerical method. Returns Distance to Thermal #2 [nm]. Parameters:

H_0	[nm]	Initial Altitude
H_max	[nm]	Maximum Altitude
H_min	[nm]	Minimum Altitude
Extend_Glide	[TRUE/FALSE]	True to extend the glide to thermal #2 if unreachable
D_TP	[nm]	Initial Distance to Next Turn Point
V_cr	[kts]	True Air Speed in Cruise
W_cr	[kts]	True Glider Sink Rate in Cruise
W_th1	[kts]	Climb Rate in Thermal #1 (on the course line)
W_th2	[kts]	Climb Rate in Thermal #2 (off the course line)
A_dev	[°]	Angle of course deviation (0 to 360°)
dT_given	[min]	Given value for time difference (negative = time saved)

dTmax [min] Optional cutoff for maximum time lost (used in some graphs)
 Start_From_0 [TRUE/FALSE] True (default) to start searching for distance from zero, otherwise start from TP

- Calc_dT_XY** – Calculates total time difference dT due to course deviation in order to find a stronger lift. The location of thermal #2 is given in X/Y coordinates. Returns Time difference (negative = time saved) [min]. Parameters:
 - H_0 [nm] Initial Altitude
 - H_max [nm] Maximum Altitude
 - H_min [nm] Minimum Altitude
 - Extend_Glide [TRUE/FALSE] True to extend the glide to thermal #2 if unreachable
 - D_TP [nm] Initial Distance to Next Turn Point
 - V_cr [kts] True Air Speed in Cruise
 - W_cr [kts] True Glider Sink Rate in Cruise
 - W_th1 [kts] Climb Rate in Thermal #1 (on the course line)
 - W_th2 [kts] Climb Rate in Thermal #2 (off the course line)
 - X [nm or custom unit] Distance to thermal #2 perpendicular to the course line (can be single row array if used in array formula)
 - Y [nm or custom unit] Distance to thermal #2 along the course line (can be single column array if used in array formula)
 - L_mul [-] Distance unit multiplier to convert custom unit to nm
 - D_Dev_Th2 [nm] Distance to thermal #2
 - dT_given [min] Given value for time difference (negative = time saved)
 - dTmax [min] Optional cutoff for maximum time lost (used in some graphs)