A Meteorological System for Planning and Analyzing Soaring Flights in Colorado USA

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Presented at the XXVIII OSTIV Congress, Eskilstuna, Sweden, 8-15 June 2006

Abstract

The Regional Atmospheric Modeling System (RAMS) at the Colorado State University was adapted to produce meteorological predictions for the Analysen and Konzepte TopTask Competition (TTC) soaring flight planning and analysis algorithm. The predictions were for regions surrounding the major gliderports in Colorado USA. The TTC algorithm required predictions, at 30 minute intervals through the daily convective-cycle, of the height of the convective boundary layer (CBL), the climb rates and the horizontal winds at 1000 m AGL. The RAMS-TTC system was tested using flight records from the On-line Contest. The system was found to be particularly sensitive to the climb rate predictions. Using the longest flights from May 2006 (average flight 553 km), the predictions of the flight speeds, CBL heights and climb rates were verified: the average predicted and actual speeds were 107+/-3 kph and 112+/-6 kph, the average CBL height and climb rates were predicted to be, respectively, 5.3+/-0.2 km MSL and 2.0+/-0.1 m/s while the average actual height and rates were 5.1+/-0.2 km MSL and 2.0+/-0.1 m/s. The average 1000 m AGL horizontal wind predictions were not as accurate. These results demonstrate that the RAMS predictions can be used with the TTC algorithm for planning and analyzing soaring flights in Colorado and, no doubt, elsewhere in the USA.

Introduction

Currently, USA glider pilots have on-line meteorological predictions for planning soaring flights[1]. Their European counterparts also have an on-line but interactive system where the pilot "flies" through the predicted weather to plan a flight. This interaction is accomplished through the TopTask algorithm[2] nested in the on-line pilot briefing system called "pc_met" of the German Weather Service (DWD)[3].

As a first step to bring TopTask in "pc_met" to the USA, the Regional Atmospheric Modeling System (RAMS)[4] at the Colorado State University (CSU) was adapted to produce the meteorological predictions (*.ram files) required by the Analysen and Konzepte TopTask Competition (TTC) algorithm. To plan a flight using TTC, a pilot downloaded a *.ram file from a CSU web-site, built a task using the flight-analysis program SeeYou[5] (*.cup file) then inserted both files into TTC to predict the task speed. After the flight, the flight recorder data (*.igc file) were inserted to TTC to compare the predicted and actual speeds.

TTC has been validated[6] using the meteorological predictions from the DWD local model and the *.igc files from the first and second place finishers from various European glider competitions. The predicted speeds were most frequently within +/- 10% of the winners' actual speed indicating the meteorological predictions were accurate. Further, if the predicted speed was significantly slower than the actual speed, the pilot was found to have used aligned lift. Conversely, if the predicted speed was significantly faster than the actual speed, the meteorological prediction was found to have been inaccurate. Thus, if an actual flight speed is close to the predicted speed, a pilot can conclude they were flying like a champion!

Motivated by these encouraging results, we experimented with the RAMS-TTC system in Colorado USA. The purpose of this paper is to describe the RAMS, the TTC and the performance of the RAMS-TTC system. The system was evaluated using flights originating from the Owl Canyon Gliderport (OCGP) operated by the Colorado Soaring Association (www.soarcsa.org) on the plains of northeastern Colorado about 18 km east of the foothills of the Rocky Mountains. Also, the system was evaluated for Boulder (BDU) at the foot of the Front Range of the Rockies, for Kelly Airpark (CO15) on the Palmer Lake Divide just northeast of Pikes Peak and for Buena Vista (AEJ) in the heart of the central Rockies. It will be shown that the RAMS-TTC system achieved results similar to those of the DWD-TTC system.

The RAMS at CSU

Description

The RAMS has been used by the first author[7] to successfully simulate an unusually high summertime wave flight over the Catskill Mountains of southern New York State USA. This success plus the Cotton Soaring Index produced routinely by the RAMS[8] made the RAMS a logical choice to produce the meteorological predictions required by TTC.

The RAMS is a state-of-the-art, primitive-equation model with sophisticated parameterizations for radiation, cloud and precipitation microphysics, land/atmospheric interactions and sub-grid scale convection and mixing[4]. Atmospheric structure is simulated in three dimensions. The simulations were made using Version 4.3 of the RAMS running at CSU.

The simulations were configured like the real-time RAMS forecast simulations that have been run once or twice daily at CSU for many years[9]. Two-way interactive grid nesting was utilized, with a parent grid (Grid 1) covering the U.S. at 32 km horizontal grid-point spacing, Grid 2 with 12 km spacing covering Colorado and portions of the adjacent states and a third grid (Grid 3) with 3 km spacing covering the northern and central Colorado Rockies and Front Range. Predictions from Grid 2 were used. A terrain-following vertical coordinate system had vertical spacing beginning at 75 m at the surface and gradually stretched to 1000 m spacing above 9000 m MSL. There were 17 model levels in the lowest 3000 m. The model top extended to 17 km MSL, well into the stratosphere.

The RAMS simulations were made for the next-day convective cycle (0600 to 1800 LST). The simulations were initialized at 0000 UTC (LST+7h). The 26-hour simulations required, on average, 6 hours of computer time on a Linux-based, dual-processor PC with 3.0 Gb of random-access-memory (RAM) at 266 mHz speed and 5 Gb of hard-drive memory. The minimum computer resources to run the RAMS-for-TTC are 512 Mb of RAM at 1 GHz with 1 Gb of hard-disc memory.

The initial conditions were based on the National Center for Environmental Prediction's (NCEP's) operational ETA model forecast cycle initialized at 0000 UTC. The ETA initialization data, available at 80 km horizontal grid spacing and at 50 mb vertical spacing, were interpolated onto the RAMS grids. Time dependent lateral and top boundary conditions utilized the 6-hour and 12-hour forecasts from that operational ETA run. The RAMS predictions were saved at 30 minute intervals for Grid 2. The files contained standard meteorological variables at each grid point in the 3D space.

RAMS adaptation for TTC

The TTC algorithm required, at 30 minute intervals from 06 to 18 LST, predictions of the surface temperature and dew-point, the height of the cloud-free or cloud-topped convective boundary layer (CBL), the average climb rate and the 1000 m AGL wind speed and direction. These predictions were required for forecast regions surrounding OCGP. A forecast region is a region with uniform convective cloud bases, uniform terrain and surface characteristics[6].

Forecast regions surrounding OCGP were constructed and RAMS grid-points within the regions were identified. To determine where OCGP pilots most frequently flew, *.igc files were obtained from the On-Line Contest (OLC, www.ssa.org/members/contestreports/OLC.htm) for 2004, 2005 and 2006. Then, SeeYou was used to construct the regions. The steps to construct the regions and identify the grid-points are detailed in Appendix A. Figure 1 illustrates the resulting 22 forecast regions surrounding OCGP and Fig. 2 illustrates the 670 grid-points within the regions.

The meteorological predictions at the RAMS grid-points within a forecast region were averaged to produce an atmospheric sounding for each region. Then, using the soundings, the values for the *.ram file were determined. The steps to produce a *.ram file were based on Olofsson and Olson[10] and are detailed in Appendix B where Figs. 3, 4 and 5 are developed. The meteorological variables and their values for a typical forecast region in a *.ram file are listed in Table 1. Figure 6 is the TTC presentation of the values listed in Table 1.

TopTask Competition

Details of the TTC flight planning and analysis algorithm are provided elsewhere[2,6]. Briefly, to simulate a flight, the algorithm utilizes the weather prediction (Table 1), the sailplane polar, speed-to-fly-theory which depends primarily on climb rate expected in the next isolated thermal and a flight-track. Flights can be simulated for a proposed task contained in a SeeYou file and for an actual flight contained in a *.igc file. First, an example of a proposed task is illustrated.

In Fig. 7 a task has been constructed in forecast regions A (plains), B (foothills) and C (mountains). The tow was to above the CBL, so after release, the glider descended into the CBL as denoted by the descending black line. In this layer, a series of climbs and glides illustrates the “soaring phase” of the flight denoted by the horizontal red line. When the glider transitioned from the plains into the foothills, a “climbing phase” is denoted by the vertical yellow line. In Region B the glider soared and climbed to transition into Region C. After soaring in Region C, the glider returned and was above the CBL of Region B. Thus, it descended into Region B and soared until final glide was assured and, then, descended back into Region A to finish the task. If a task speed was calculated by TTC, then the task was feasible. If a task speed was not calculated, then the task was not feasible.

Figure 8 illustrates the TTC analysis of a proposed 302 km task from OCGP on 21 May 2006 for a Duo Discus. TTC predicted a 118 kph task speed for departure at 2700 m MSL at 1115 LST. Hence, the task was predicted to be feasible.

Figure 9 illustrates the 65l10yj1.igc file resulting from the flight illustrated in Fig. 8. It can be seen that the actual speed was 107 kph over a distance of 342 km. The TTC analysis was superimposed on the flight trace by clicking on the TopTask box. The result is shown in Figure 10. It can be seen that the TTC "flew" the 342 km flight at 117 kph. Notice, TTC "stayed" higher and, hence, initiated an earlier final glide which caused the faster predicted speed. Thus, the task was flown 10 kph slower than the expected speed of a champion pilot.

Performance of the RAMS-TTC system

Flights originating from OCGP

To evaluate predictions from the RAMS-TTC system, the OLC was searched for flights originating from OCGP for the 2004, 2005 and 2006 (thru 22 April) gliding seasons. A total of 52 flight records were located, downloaded and analyzed. The average flight was 254 km with average predicted and actual speeds of 111+/-3 kph and 98+/-2 kph, a significant difference (the +/- values are the uncertainty of the means or standard error). The average predicted CBL depth was 2.7+/-0.08 km AGL while the average maximum achieved altitude was 2.8+/-0.1 km AGL, not a significant difference. The average predicted climb rate for the forecast regions through which the tasks were flown was 2.4+/-0.08 m/s while the average climb rate for the entire flight (from the "circling total" analysis using SeeYou) was 1.4+/-0.07 m/s, a significant difference. The significantly different speeds and climb rates but similar CBL depths suggested that either the climb rates were over-predicted or the pilots were not flying as fast as possible or both. For these analyses Equation B-2 was employed with a leading coefficient of 1.

The 27 flights of two top pilots were isolated from the 52 flights and analyzed because these pilots most likely flew as fast a possible. The results were similar to those obtained from the 52 flights: an average flight of 269 km, predicted and actual speeds of 110+/-3 and 100+/-3 kph, predicted CBL depth and maximum achieved altitude of 2.8+/-0.1 and 2.9+/-0.1 km AGL and predicted and actual climb rates of 2.4+/-0.1 and 1.5+/-0.1 m/s. Thus, the climb rates were over predicted.

Consequently, to "tune" Equation B-2, values of the maximum achieved altitude and the corresponding average climb rate for an entire flight were extracted from the 27 flight records of the two top pilots. The results are illustrated in Fig. 4. It can be seen in the figure that there is an extremely good correlation in the data (R = 0.88). The average climb rates were for the entire flight; the weak pre-start thermals were included. Thus, to give a more representative value for the climb rates on course, the upper boundary of the data was chosen producing the fit 0.75 x (h/100). This expression was adopted in Equation B-2.

The 27 flights were then re-analyzed producing average predicted and actual speeds much closer (99 and 101 kph). Thus, the magnitude of the climb rate has a significant effect on predicted speeds as expected from the speed-to-fly theory. The distribution of the actual and predicted speeds is illustrated in Fig 5. It can be seen the speeds correlated poorly (R = 0.30) as will be discussed. It remains to be determined if the 0.75 value in Equation B-2 will be valid for other regions in the USA. .

Flights originating from other Colorado gliderports

Following the procedures outlined in Appendix A, 30 additional forecast regions were constructed to cover the areas over flown by pilots launching from Boulder, Kelly Airpark, Buena Vista and Salida. The 52 Colorado forecast regions are illustrated in Fig. 11. Flights originating from these fields during May 2006 (through 21 May) that were posted on the OLC were downloaded. The longest flights (those traversing the most forecast regions) were analyzed to determine the performance of the RAMS-TTC system. The flights were analyzed for distance, actual and predicted speeds, maximum achieved altitude and corresponding predicted CBL height, actual and predicted average climb rates and 1000 m AGL actual winds at the gliderport and predicted winds in the forecast region of the gliderport at 14LST (21Z). The winds at the gliderport were obtained from archived NAM soundings downloaded from www.arl.noaa.gov/ready.html/. The results of the analyses are illustrated in Fig 12.

The results in Fig. 12 are similar to and in some cases better than those obtained from the re-analysis of the 27 flights from the two top OCGP pilots: an average flight of 553 km, average predicted and actual speeds of 107+/-3 and 112+/-6 kph, average predicted CBL height and maximum achieved altitude of 5.3+/-0.2 and 5.1+/-0.2 km MSL and identical average predicted climb rates and actual rates of 2.0+/-0.1 m/s. It should be noted, that the USA VFR ceiling is 5.5 km MSL and a number of predicted CBL heights exceeded this value and, hence could not be validated. This fact probably led to the slightly higher predicted CBL heights.

The average predicted and actual 1000 m AGL wind speeds and directions in Fig 12 were significantly different: 15+/-1.1 vs 10+/-1.7 kts. Also, the predicted and actual directions deviated, on average, by 104 degrees.

Discussion

The OLC flight records from OCGP for 2004, 2005 and 2006 were used to calibrate the RAMS-TTC system using records from two top pilots. Then, the system was tested using OLC flight records from Boulder, Kelly Airpark and Buena Vista for the month of May 2006 using only the longest flights. The average flight was 553 km. The longest flights went though the most forecast regions and, hence, provided the sternest test of the RAMS-TTC system.

On average, the system predicted flight speeds, CBL heights and climb rates that were not significantly different than the achieved values. However, the regression analyses of the flight speeds in Figs. 5 and 12 reveal a bias: actual speeds slower-than average tended to be over-predicted while actual speeds faster-than average tended to be under-predicted. Further, there was no bias in the predicted and actual CBL heights in Fig. 12, but, weak climb rates were over predicted and strong climb rates were under-predicted. Additionally, the predicted speeds were highly correlated (R = 0.82) with the predicted climb rates. So, the over-predicted speeds were due to the over-predicted climb rates and vice versa. Finally, it can be seen in Fig. 12 little skill was achieved in predicting wind speeds and some skill was achieved in predicting wind directions.

The analyses in Fig. 12 suggest that the climb rates affected the speeds much greater that the horizontal winds. Hence, it appears further study is required to refine the climb rates made from the RAMS predictions which are used in TTC. A similar conclusion was reached by Liechti, et al.[6] for the DWD-TTC system. Another approach for estimating climb rates has been proposed by Young[12] and may be worth investigating.

The following is a historical note about the validation of atmospheric predictions using flight logger data. In the late 1930's, Kuettner[13] used smoked barogram traces from gliding competitions in Germany to characterize the mountain lee-wave phenomena. He, then, used first principles to demonstrate the mechanism causing the lee-wave. Here, some 70-years later, we use electronic barogram traces from gliding competitions to characterize the CBL and compare the characterizations to CBL predictions based on first-principles. There is nothing new under the Sun!

Conclusions

The Colorado Sate University Regional Atmospheric Modeling System (RAMS) was adapted to produce the meteorological predictions for the Analysen and Konzepte TopTask Competition (TTC) flight planning and analysis algorithm. The RAMS, on average, produced accurate predictions for sixteen (16) flights in Colorado USA made during May 2006 which averaged 553 km: the average CBL height and climb rates were predicted to be, respectively, 5.3+/-0.2 km MSL and 2.0+/-0.1 m/s while average actual height and climb rates were 5.1+/-0.2 km MSL and 2.0+/-0.1 m/s (the +/- values are standard errors of the means). The RAMS 1000 m AGL horizontal wind predictions were, on average, too fast by 5 kts and deviated 104 degrees in direction. The 1000 m AGL altitude for the winds, perhaps, should be higher for Colorado due to the often 3-4km CBL depths; the winds should be a function of the CBL depth, say 2/3 the depth.

The RAMS-TTC system was evaluated using the sixteen flights. The average predicted and actual flight speeds were quite similar (107+/-3 and 112+/-6 kph). This result is similar to that achieved using the DWD-TTC system with Viking Glide 2005 flights[6] (the average flight was 341 km and the average predicted and actual speeds were 108+/-1 and 104+/-2 kph). The similar results suggest the climb rates, which were calculated using different approaches, are comparable. However, for the RAMS-TTC system, actual speeds slower-than average tended to be over-predicted while actual speeds faster-than average were under-predicted and weak climb rates were over predicted and vice versa for strong climb rates. Hence, it appears further study is required to refine the climb rates made from the RAMS predictions.

As computer power increases, it may be possible to "fly" TTC through RAMS 3-D grid space as is currently done with sophisticated, massive, multi-player, on-line role playing games like World of Warcraft (www.worldofwarcraft.com) or Everquest (www.everquest.com). This capability is expected to allow the planning and analyses of glider flights that utilize ridge lift and wave lift.

Acknowledgements

EEH received support from a City University of New York Fellowship (sabbatical leave for the academic year 2005-06) and from NOAA-CREST at CCNY. Ray McAnelly obtained the 2004 and 2005 NCEP initialization data for the RAMS-for-TTC runs.

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Appendix A

Determine forecast regions

The forecast regions are defined in SeeYou by polygons whose sides are defined by turn-points. The idea is to define flight tasks (polygons) that encompass the forecast regions. First, the turn-points needed to construct the tasks are created. The turn-points were named C001, C002, C003,... and the same name could not be used twice. The position of the turn-points can be modified after a task is constructed and the task will adjust automatically.

Second, a task was constructed that went clockwise around each region. This was done in the task window. Click on the turn-points in a clockwise sequence to define the task. To end the task, hit "esc". A name was assigned to the task (right click on the task in the list, click "Task properties" and "Options" and type the name in the "Description" box). The names were chosen as gNNN with NNN = 700,701,702, ...

The task file containing the forecast regions was saved as "Gebiete_Colorado.cup".

Assemble the regions

A program called Konverter.exe (all programs and files in this section may be obtained from A & K) allows one to select *.cup files and to convert the tasks to individual *.dat files. All *.dat files were saved into the same directory. The suggested name for each *.dat file is the name assigned to the task in SeeYou.

Into this same directory the following files were copied: mergeCO.BAT that merges g700.dat, g701.dat .. gNNN.dat to "co.dat", mergeRT_CO.BAT that merges the European regions "regtherm_E.dat" with the Colorado regions "co.dat" plus some basic geography in "regthermGEO.dat. The result of mergeRT_CO.BAT is the file "regtherm.dat" (about 180k). This file was copied to the same directory as TopTask.exe.

When one updates "regtherm.dat" with these tools, TTC will use the updated file if one selects File/New from the menu bar. With these tools and TTC, one will easily recognize overlaps and gaps when defining forecast regions.

Assign RAMS grid-points to the regions

The procedure to identify the RAMS grid points within the forecast regions was as follows. The menu "Domain" in a special version of TTC allowed one:

- to read the RAMS grid-point file RAMS_GP.txt into TTC,
- to save the grid points assigned to the forecast regions as SoarRegions.txt (an interface file between RAMS and TTC),
- and to clear the grid points.

The file RAMS_GP.txt was kept in the same directory as regtherm.dat and TTC. When the file RAMS_GP.txt was read successfully into TTC, the grid points were displayed on the map of the forecast regions.

Assign elevations to the regions

The file co.dat needed to be run through a digital elevation model to assign average elevations to the regions for the flight planning in TTC. These elevations must be coded into TTC so that the flight planning knows them. These elevations can be seen in TTC as an olive line below the barogram trace (eg., Fig. 6).

Appendix B

The meteorological variables required by TTC were predicted every 30 minutes by the RAMS for the period 17MST (00Z) to 18MST (01Z) the next day, a 26-hour simulation. These calculations produced about 360 megabytes of output. The daunting task of extracting the proper variables at the proper gridpoints and times was accomplished utilizing the REVU diagnostic package associated with the RAMS. Once the variables were extracted, the required height of the CBL, climb rates and 1000 m AGL winds could be determined as follows.

Determine height of the CBL

Following Olofsson and Olsson[10], the predicted surface temperature and dew point values and the predicted environmental sounding were used to determine the height of the cloud-free and cloud-topped CBL as depicted in Fig. 3. The dT term in the figure denotes the buoyancy of the rising air parcel where

$$dT\ (C) = 0.4\ (1 + W/200)\ 20/ff \qquad \text{(B-1)}$$

and W is the net sensible heat flux near ground in W/m^2 (if W > 200, W = 200) and ff is the wind speed near ground (10 m) in kph (if ff < 20 (10 kts), ff = 20). It was found by Liechti[6] that when W was calculated to be greater than 200 W/m^2 in reality the value would not exceed 200 as the sensible heat flux is dispersed by thermals. The ff term in Equation (B-1) accounts for the effect of strong winds "shredding" thermals near the ground.

Determine average climb rates

Again, following Olofsson and Olsson[10], the mean rate of climb **w** (m/s) is given by

$$w = 0.75(h/1000)W/200(1 - TADV/2)20/FF \qquad \text{(B-2)}$$

where h is the depth of the CBL in m AGL, W is as in Equation (B-1), TADV is the temperature advection at 1000 m in C/h (cold air advection enhances lift and vice versa) and FF is the wind speed at 1000 m AGL in knots; if FF < 20, FF = 20 (large wind speeds reduce climb rates and vice versa). The leading constant in Equation (B-2) used by Olofsson and

Olsson was 1 after guidance from WMO TN158[11]. But, this value produced TTC task speeds significantly larger than actual speeds (111 vs 98 kph) for the 52 OCGP flight records from the OLC for 2004, 2005 and 2006. The constant 0.75 was determined using 27 flight records from two top pilots at OCGP as depicted in Fig. 4. Using this value in Equation (B-2) produced average TTC speeds and actual speeds much closer (99 vs 101 kph). The data are illustrated in Fig. 5.

Determine winds at 1000 m AGL

The predicted winds at 1000 m AGL were extracted directly from the environmental soundings.

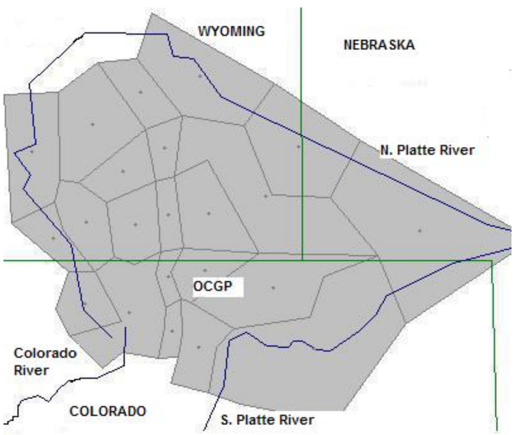

Figure 1 The TTC forecast regions surrounding Owl Canyon Gliderport (OCGP). The Colorado, Wyoming and Nebraska borders are indicated. The major rivers are indicated.

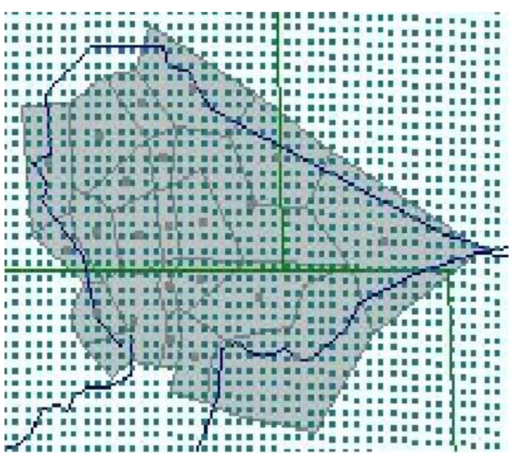

Figure 2 The RAMS grid-points at 12 km spacing within the forecast regions. The grid-points are not orthogonal in this image due to distortion but are orthogonal in the model.

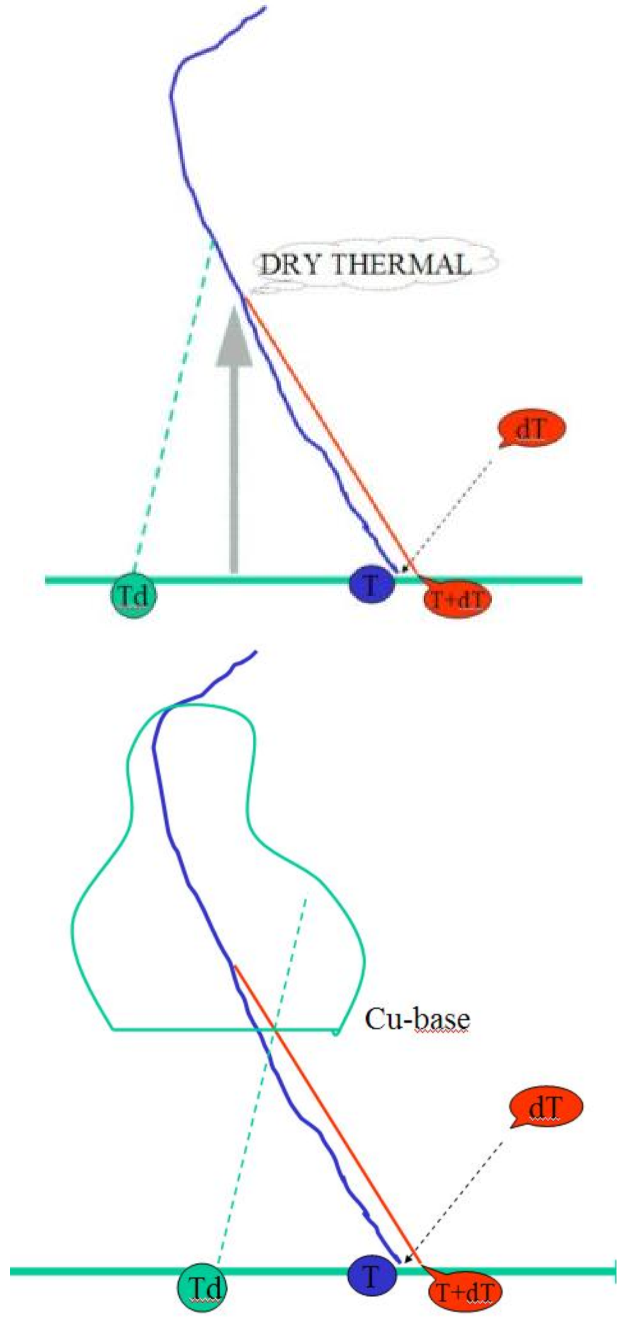

Figure 3 Schematic of the Olofsson-Olsson[7] procedure to determine the height of the cloud-free convective boundary layer (CBL) **(top)** and cloud-topped CBL **(bottom)**. The surface temperature (T) and dew point (Td) values are indicated. The blue line is the predicted environmental sounding, the red line is a dry adiabat and the green dashed line is a constant mixing ratio. The dT term is defined in Appendix B.

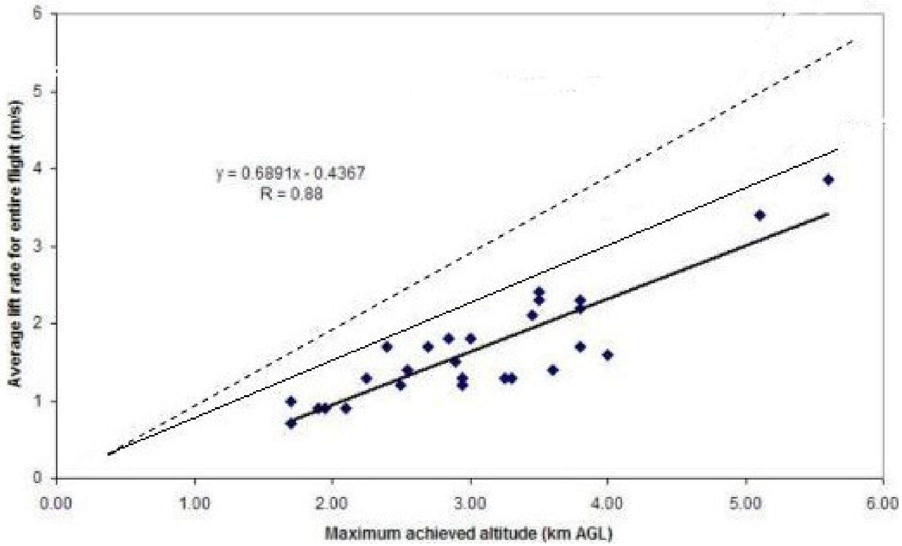

Figure 4 Data from Faris and Odehnal On-Line Contest flights analyzed using SeeYou for 2004, 2005 and 2006 (thru 22 April) and the resulting regression (thick solid line). The thin solid line is the upper limit of the flight data and represents the 0.75 x (h/1000) expression in Eq. B-2. The "gospel" from WMO TN158[11] (dashed line) of a 1:1 average climb rate as a function of height above ground was employed by Olofsson and Olsson[10].

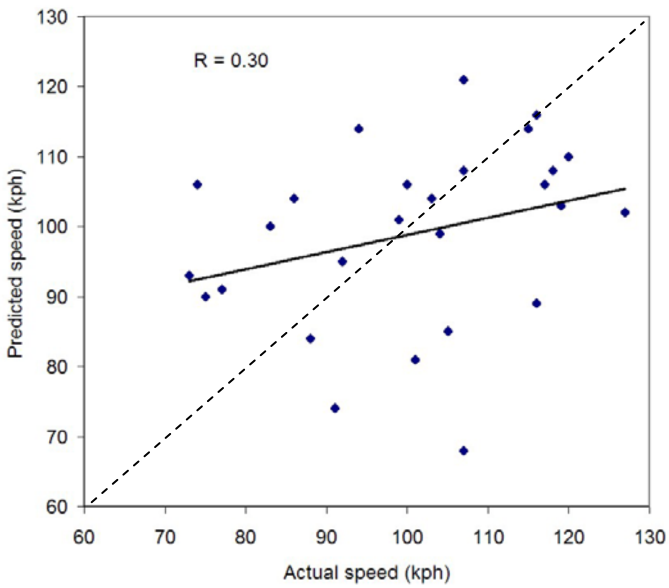

Figure 5 The twenty-seven Faris and Odehnal On-Line Contest flights for 2004, 2005, 2006 (thru 22 April) produced an average speed of 101 +/- 3 kph and a TTC predicted speed of 99 +/- 3 kph (the +/- values are standard errors of the means).

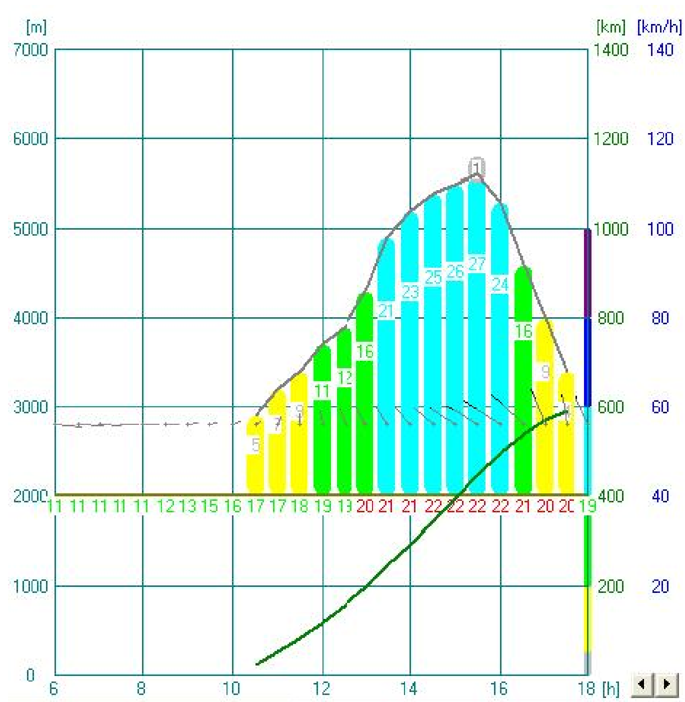

Figure 6 TTC presentation of the data in Table 1. The surface temperatures (C) are the horizontal line of numbers just below the horizontal olive line which is the mean elevation of the region. The wind speed and directions are given by the horizontal line of flags (grey 0-10kts, **black** 11-20kts). The climb rates are the columns (m/s x 10). The CBL height is the grey line and a cloud is predicted to form at 1530LST. The diagonal green line is the distance a Standard Class glider could fly (Potential Flight Distance, PFD).

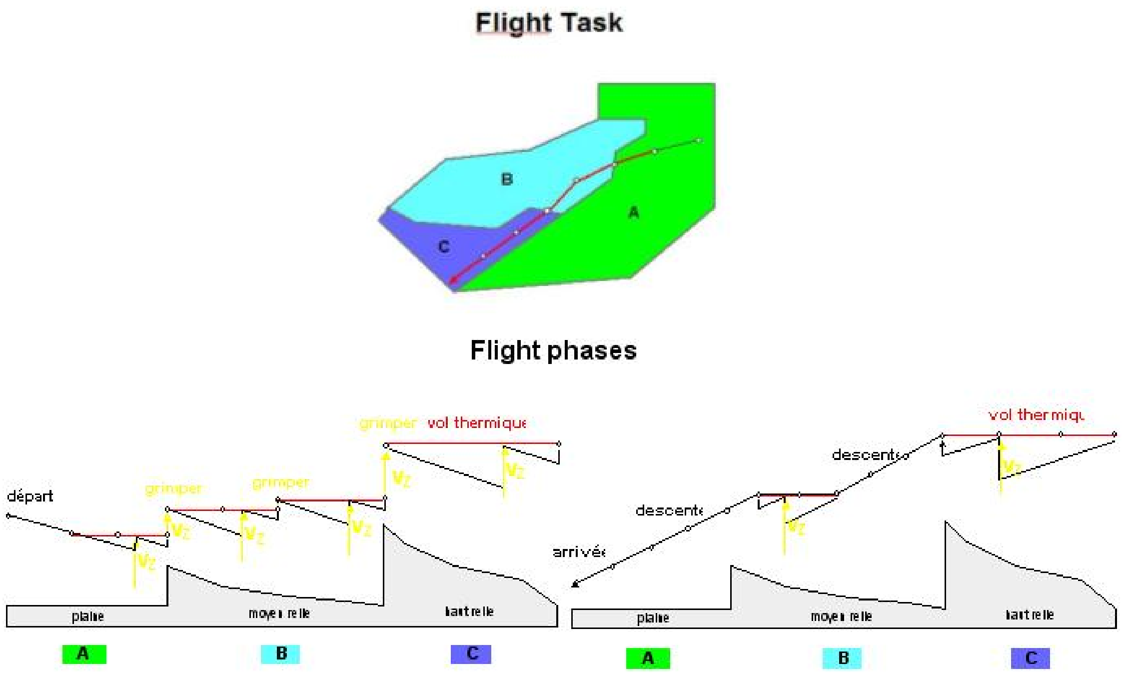

Figure 7 The TTC algorithm calculates a flight task in three forecast regions (A, B, C) using the gliding (black), soaring (red) and climbing (yellow) phases of a flight. Details are in the text.

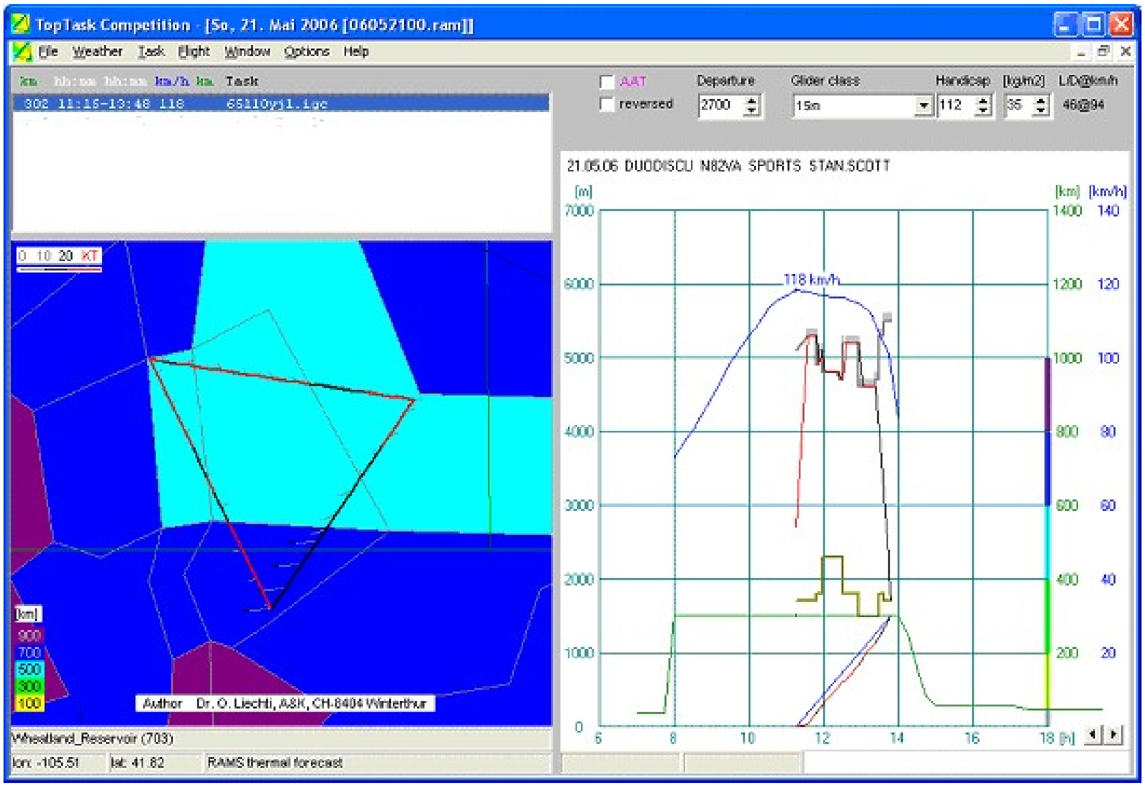

Figure 8 TTC analysis of a proposed 302 km task from OCGP on 21 May 2006 for a Duo Discus. The departure to produce the fastest task speed (118 kph) is at 1115LST at 2700 m MSL. The sloped diagonal lines represent the time it takes to cover the indicated distance (km).

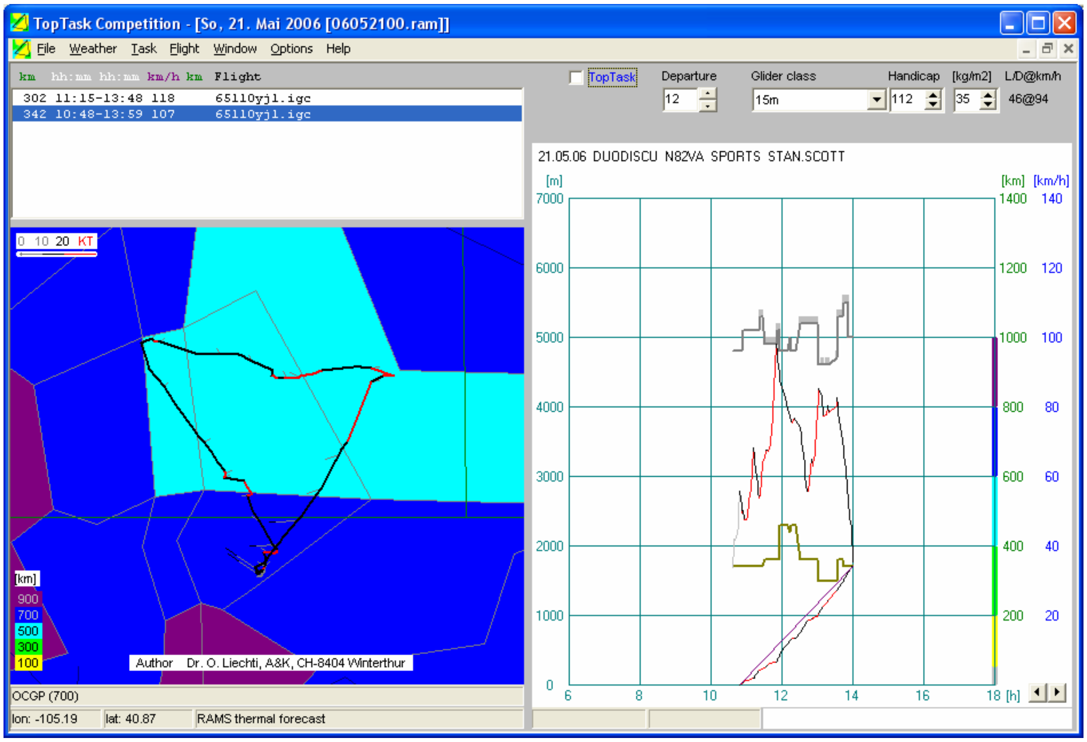

Figure 9 TTC presentation of the actual flight for the task illustrated in Figure 8. The actual speed was 107 kph over a distance of 342 km.

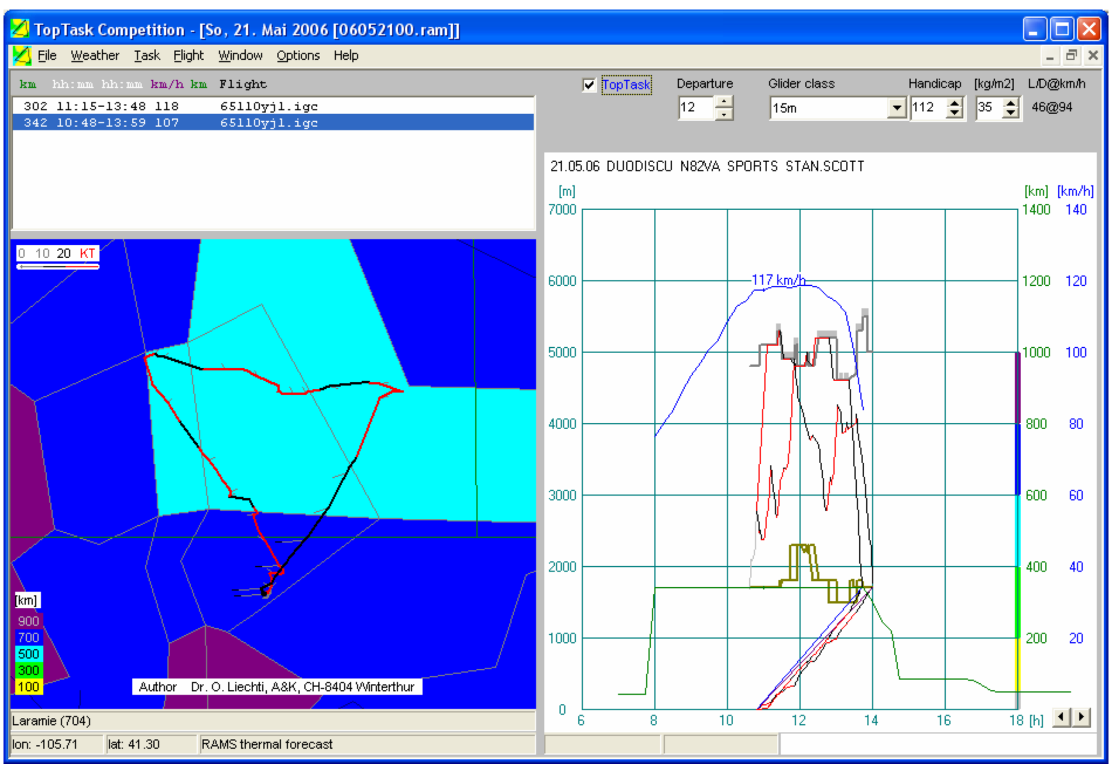

Figure 10 The TTC analysis superimposed on the flight trace illustrated in Figure 9. The TTC "flew" the flight trace at 117 kph. Notice, TTC stayed higher and, hence, initiated an earlier final glide.

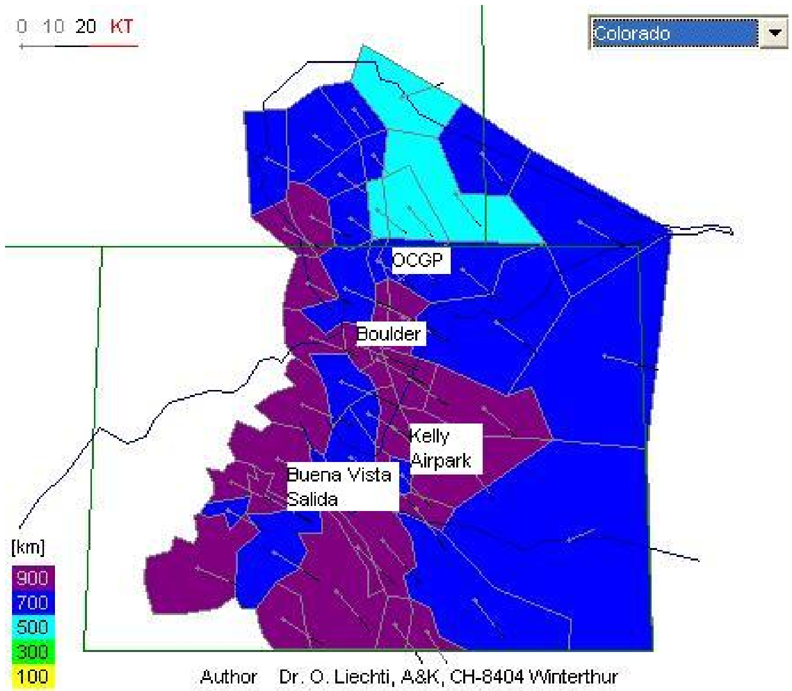

Figure 11 Colorado forecast regions covering flights originating from the indicated gliderports. The colors denote the Potential Flight Distance (km) - the distance that could be flown by a Standard Class glider starting with the first thermal of the day and ending with final glide from the last thermal. The wind flags in the center of each region denote the direction and speed of the 06 LST 1000 m AGL winds. These predictions are for 21 May 2006.

Table 1

Predicted values of the meteorological variables for the Wheatland Reservoir forecast region in Wyoming extracted from 06042200.ram (22 April 2006): Surface temperature and dew-point (T, Td), average climb rate (m/s), convective boundary depth (m AGL, a cloud with no base means a cloud-free boundary layer) and 1000 m AGL wind direction (blowing from) and speed. Note, UTC time is really LST.

ZCZC
gggg703
GG703Wheatland_Reservoir, Mi 22.04.2006

UTC hh:mm	T [C]	Td [C]	Steig [m/s]	Basis-Top [m] - [m]	Wind [deg/kt]
06:00	11	-6			275 10
06:30	11	-6			275 09
07:00	11	-6			274 08
07:30	11	-6			272 07
08:00	11	-6			271 06
08:30	12	-6			269 05
09:00	13	-6			266 04
09:30	15	-6			261 03
10:00	16	-7			249 03
10:30	17	-8	0.5	2900	228 02
11:00	17	-8	0.7	3200	201 03
11:30	18	-8	0.9	3400	178 04
12:00	19	-8	1.1	3700	168 05
12:30	19	-8	1.2	3900	160 06
13:00	20	-8	1.6	4300	154 07
13:30	21	-8	2.1	4900	148 07
14:00	21	-7	2.3	5200	140 08
14:30	22	-7	2.5	5400	131 09
15:00	22	-7	2.6	5500	123 11
15:30	22	-6	2.7	5600-5600	121 13
16:00	22	-6	2.4	5300	123 16
16:30	21	-6	1.6	4600	133 16
17:00	20	-5	0.9	4000	158 14
17:30	20	-4	0.4	3400	170 11
18:00	19	-4			156 11

NNNN

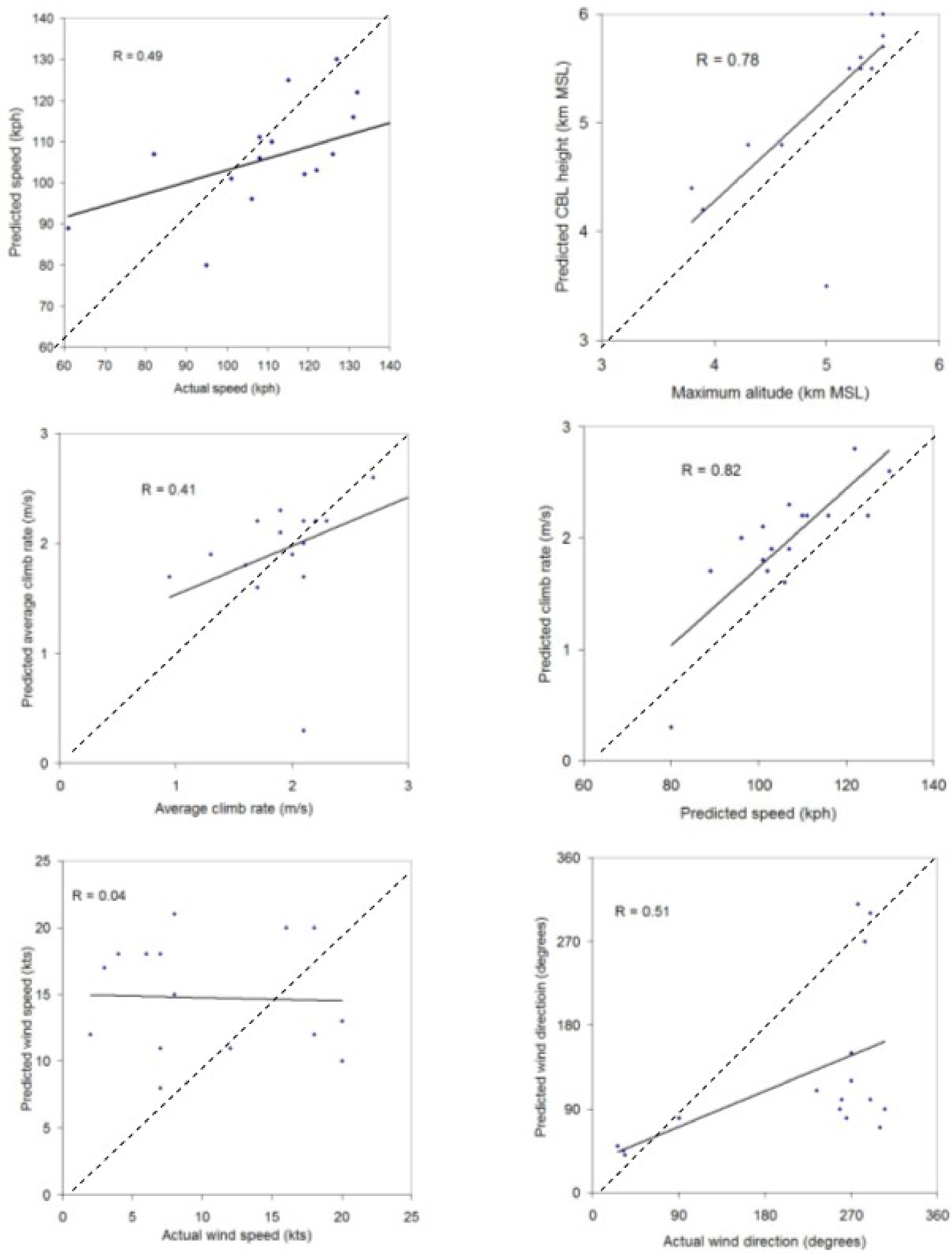

Figure 12 Results from the longest flights during May 2006 (through 21 May) originating from the Boulder, Kelly Airpark and Buena Vista gliderports in Colorado USA. The dashed line in each plate is the 1:1 correspondence and R is the linear correlation coefficient. See text for details.