Climb Rate – Altitude Correlation from Analysis of IGC Files

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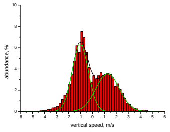

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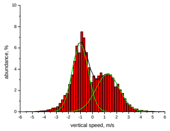
Source data: Competition flights

Advantages: Open access
Well-defined pilot strategy
Well-defined terrain and weather conditions

```
B1400235136607N01245193EA0169801810002081730 08
B1400475136514N01246159EA0167901780002071690 10
```

Convert data string to 5-dimensional flight vector V(t, y, x, h, w=dh/dt)

14.0064, 51.6101, 12.7532, 1698, -2.67
14.0131, 51.6086, 12.7693, 1679, -0.79



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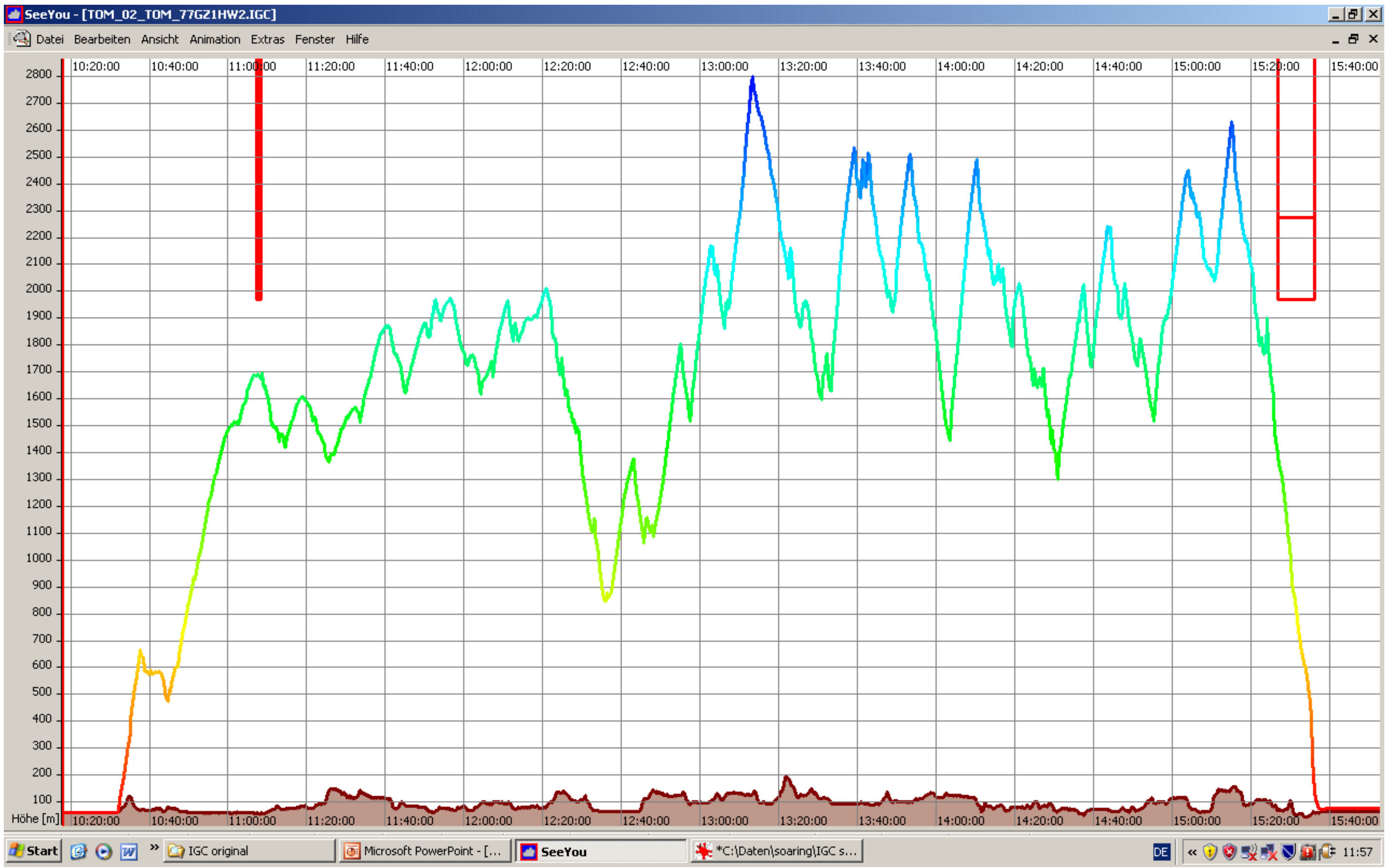
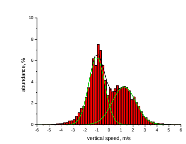
Competition data pre-treatment

removal of pre-start and post-finish data





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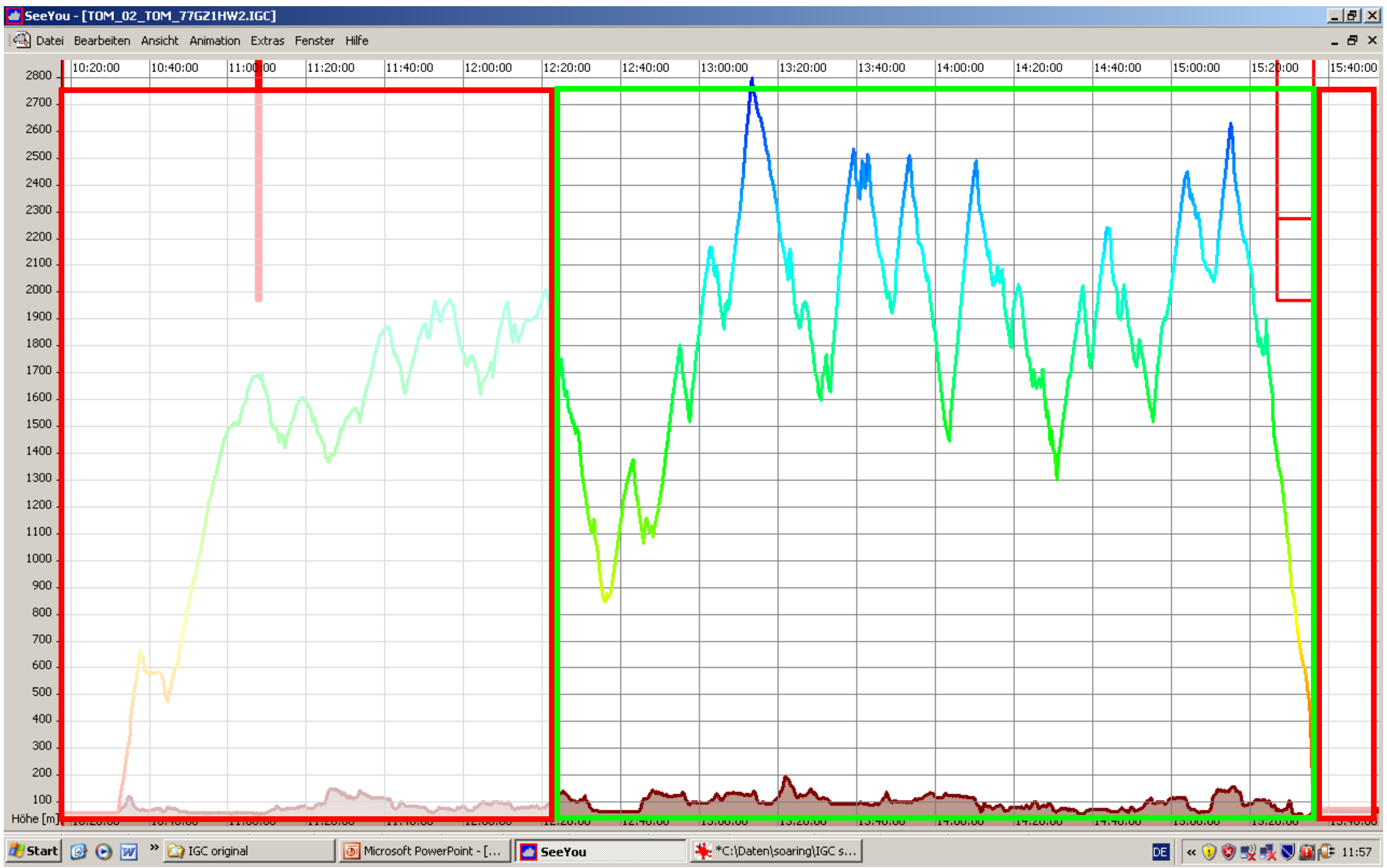

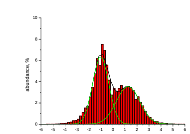

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Analyzed competitions (2007):

1) Lilienthal Glide, Lüsse, Germany, July 14 to 27

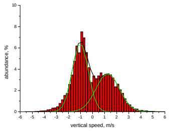
97 competitors
July 16, 23, 26
254 flights
127,000 data points

2) European Gliding Championships, Issoudun, France, Aug 6 to 19

91 competitors
August 9, 12, 13, 16, 18
386 flights
177,000 data points

3) Junior World Gliding Championships, Rieti, Italy, July 28 to Aug 11

53 competitors
July 29, 30, August 4, 6, 7
221 flights
95,000 data points



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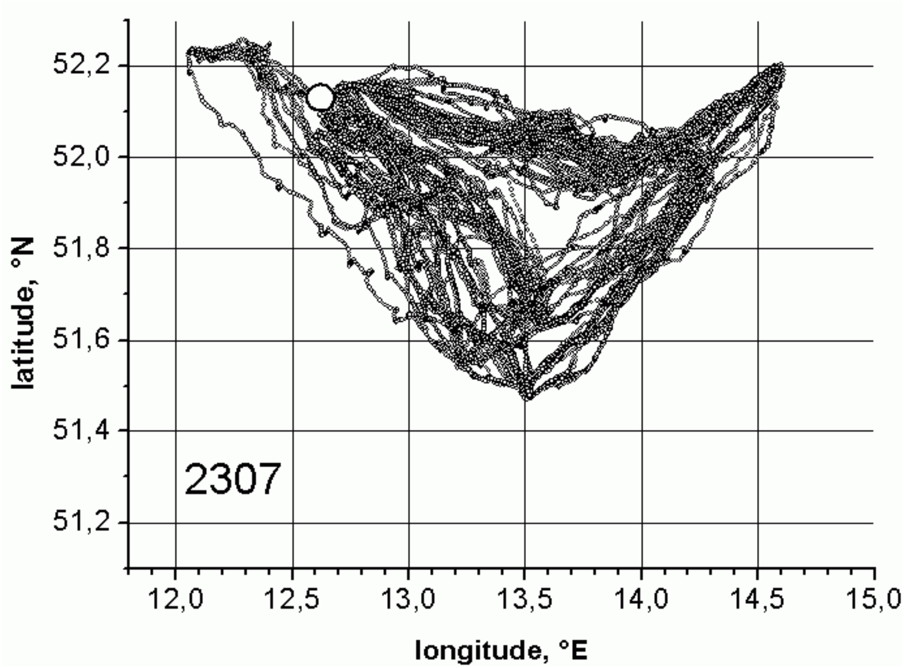
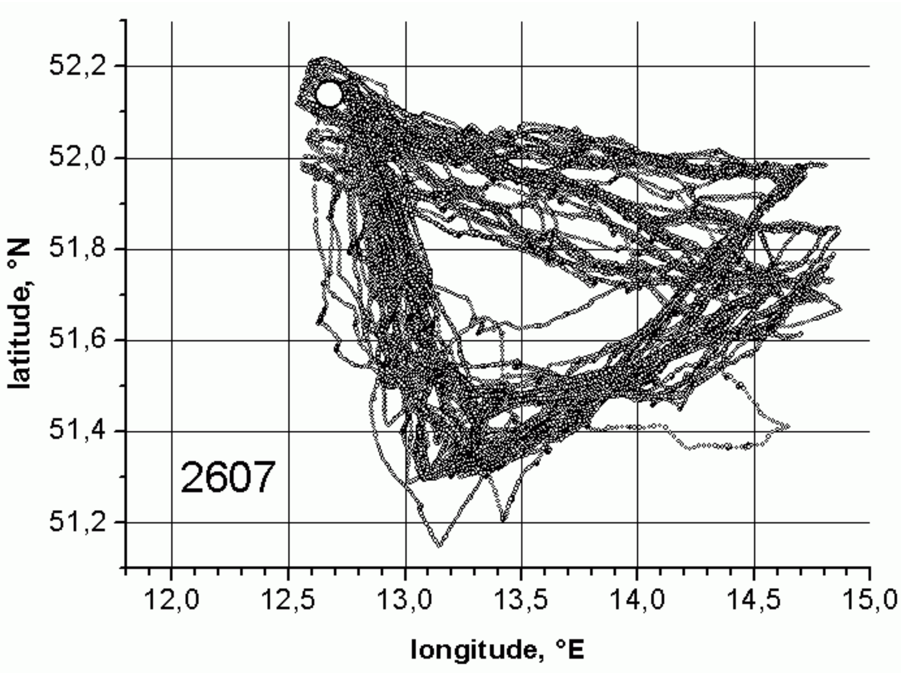
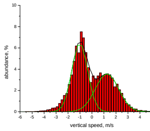
Basic results – tracks – y(x):

well defined geographical area with homogenous sampling

Lilienthal Glide







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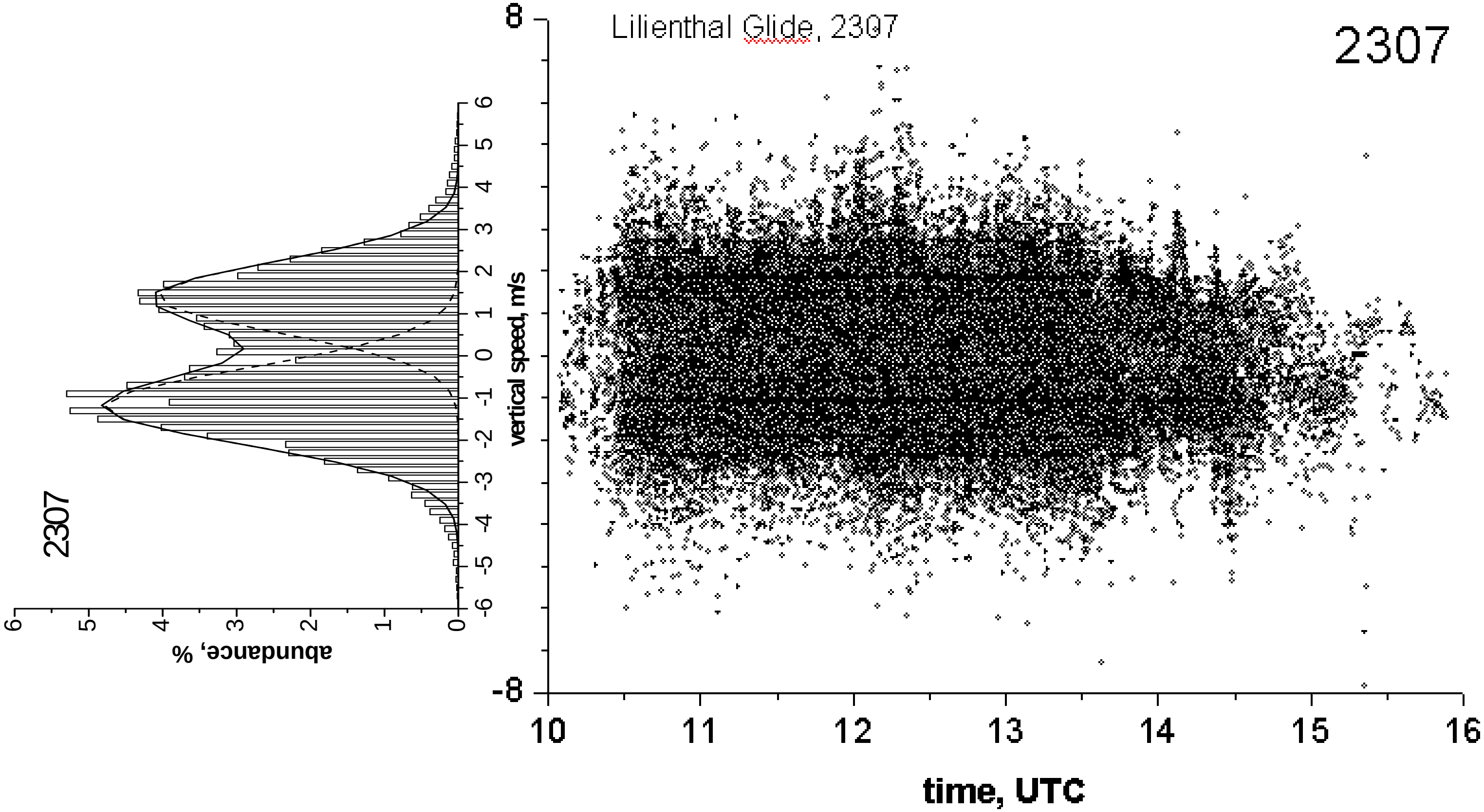
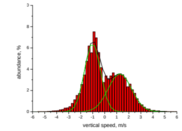
From variograms w(t) to vertical speed distributions f(w):

projection of variogram onto w axis





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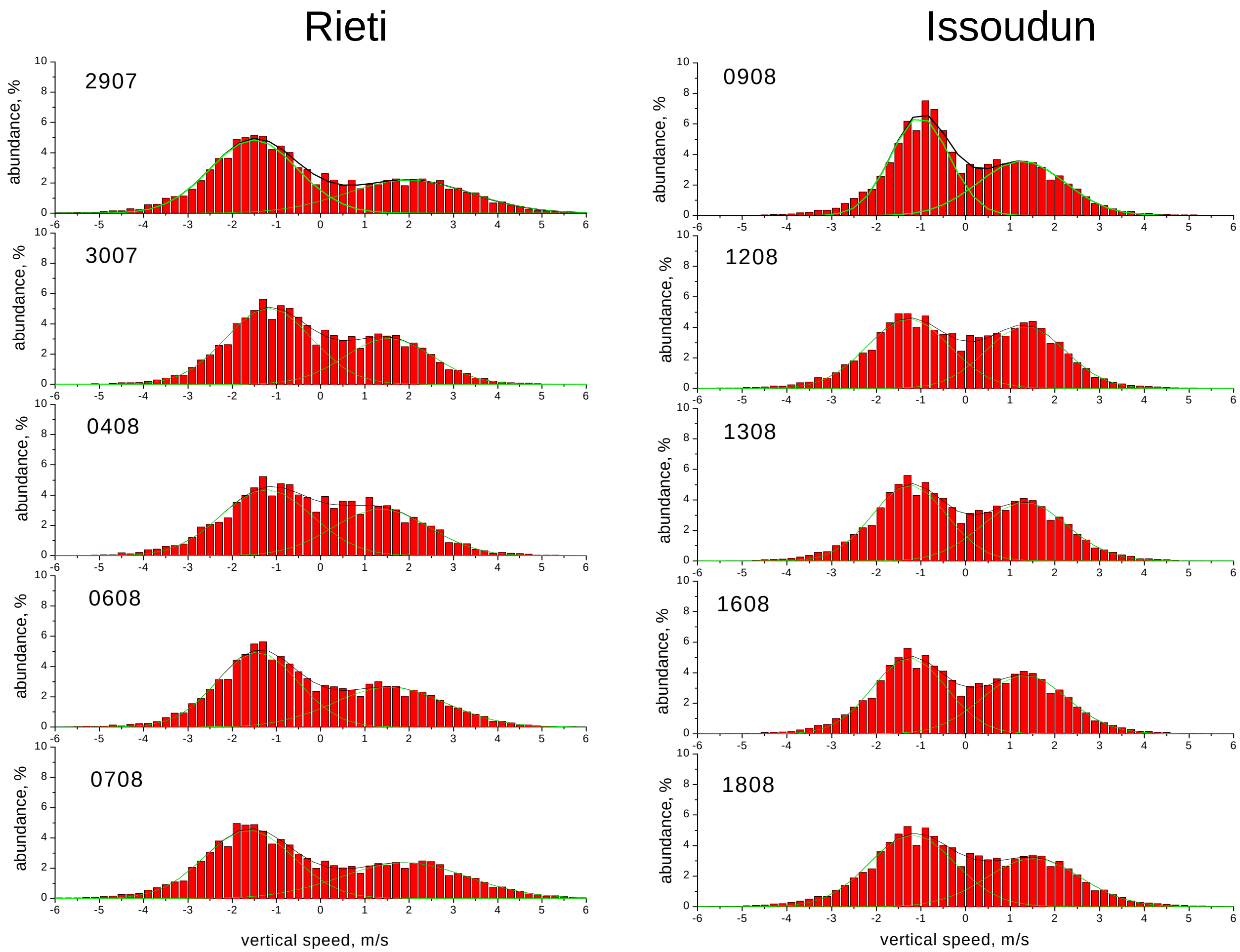
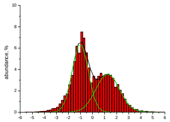
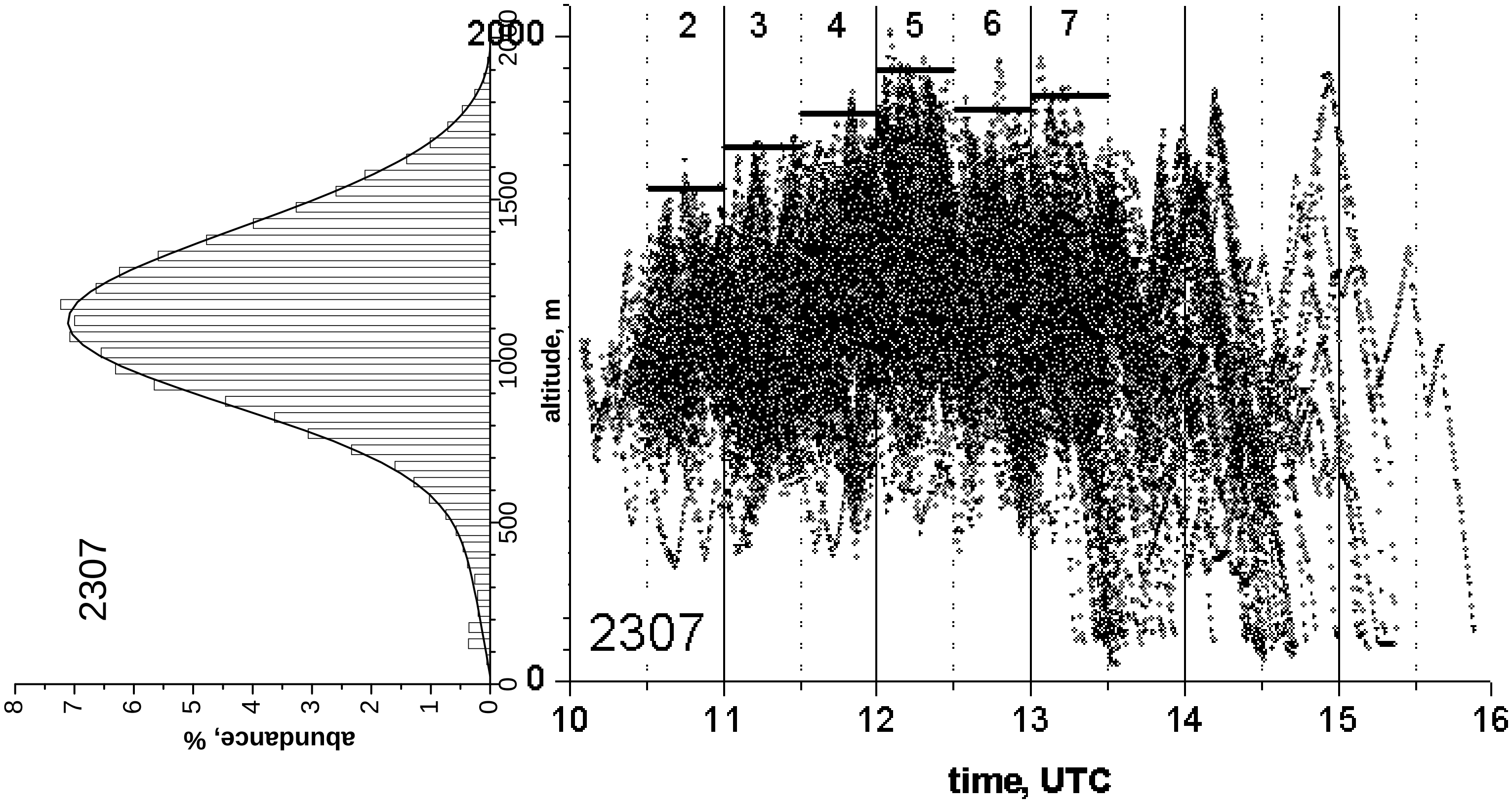
Climb and sink vertical speed distributions are general features

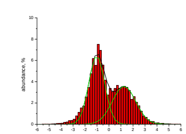




From barograms h(t) to altitude distributions f(h):

projection of barogram onto h axis





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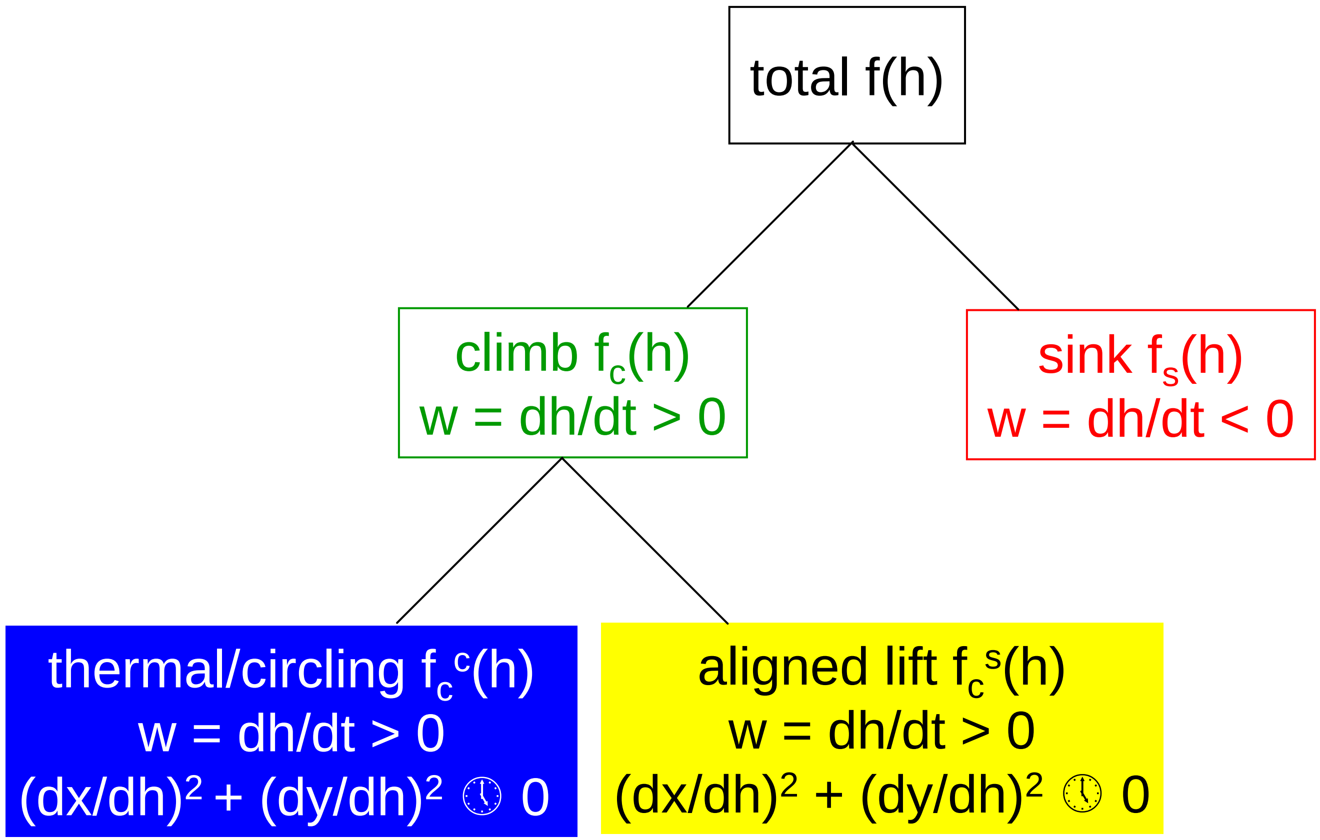
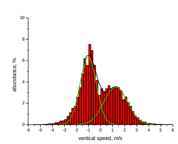
Circling vs. straight climb





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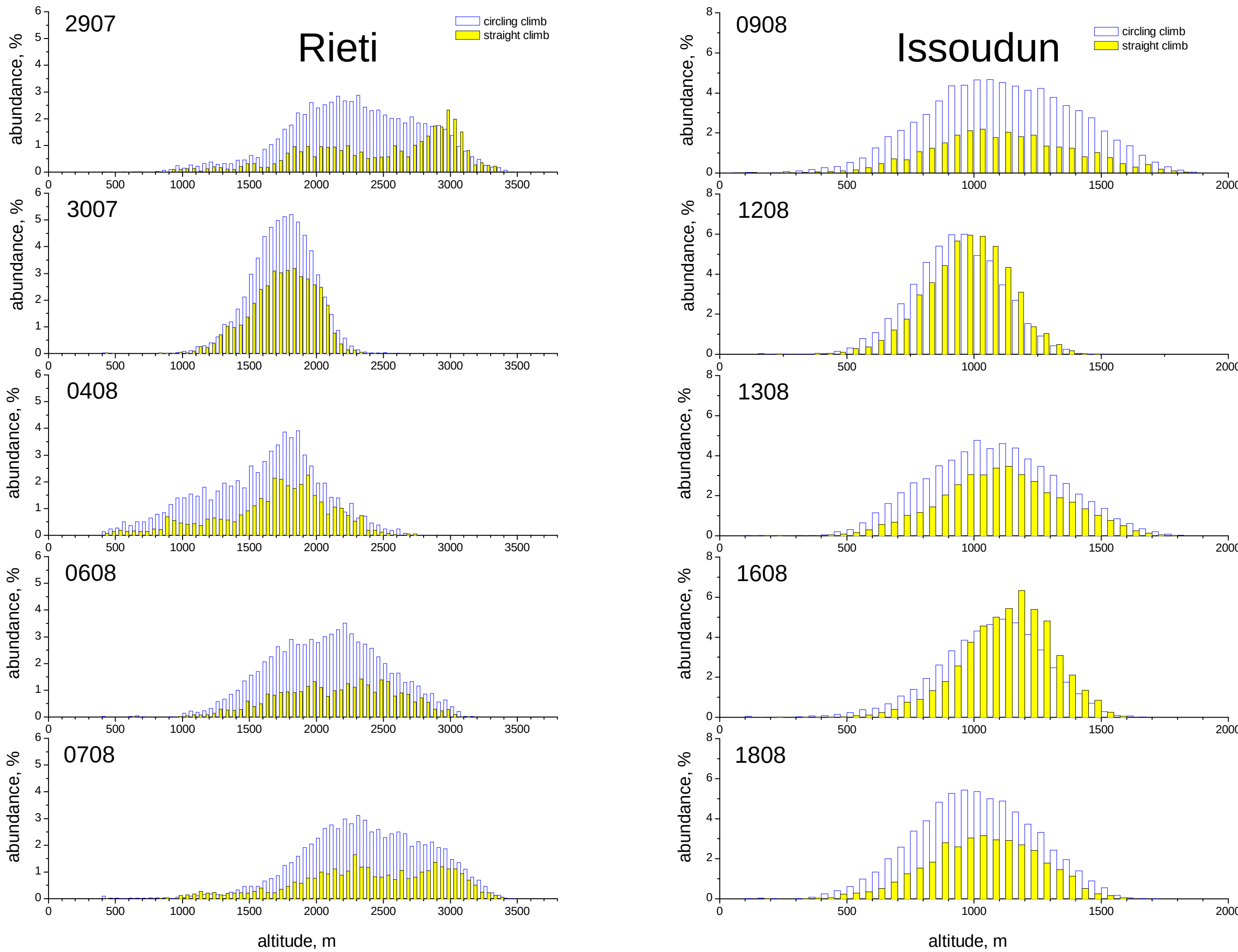
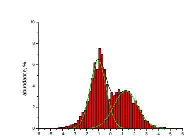
Altitude distributions of thermal $f_c^c(h)$ (☒) vs. aligned $f_c^s(h)$ (☒) lift. Significant variations, aligned lift accounts for as much as 50% of total lift!





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Description of circling climb altitude distributions $f_c^c(h,w>0)$.

If w-h correlatins are absent, $f_c^c(h,w>0)$ can be obtained by integrating over thermal entering and thermal exiting altitude distributions $f_{in}(h)$ and $f_{out}(h)$:

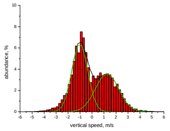
$$f_c^c(h) = \int_0^h \left(f_{in}(h') - f_{out}(h')\right) dh' \qquad (1)$$

Consequently, $f_{in}(h)$ and $f_{out}(h)$ can be obtained by differentiating f(h):

$$\frac{df_c^c(h)}{dh} = f_{in}(h) - f_{out}(h) \qquad (2)$$

Alternatively, $f_{in}(h)$ and $f_{out}(h)$ can be directly obtained from identifying thermals from flight recorder data.

Both methods should give identical results!



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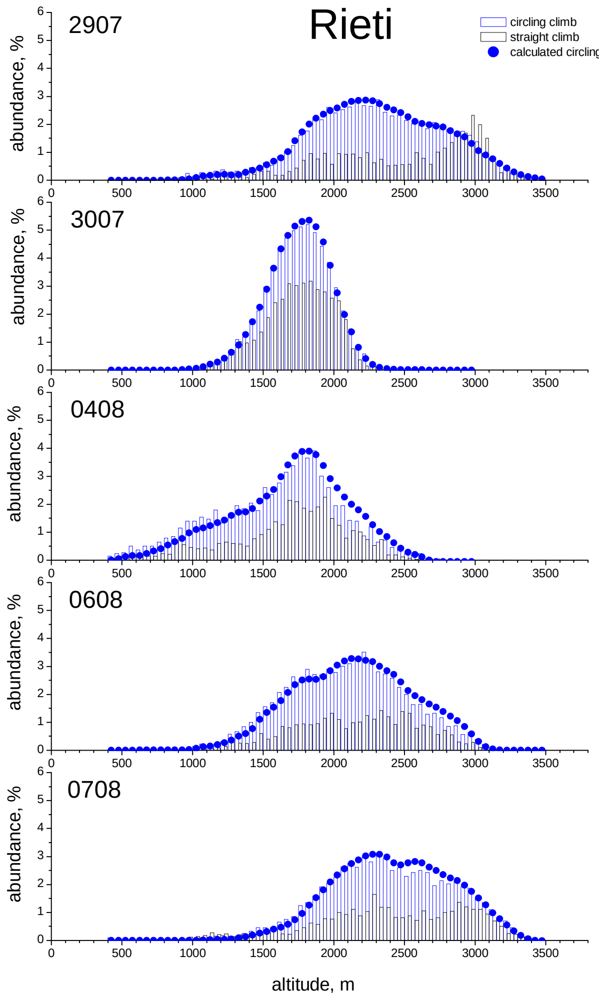
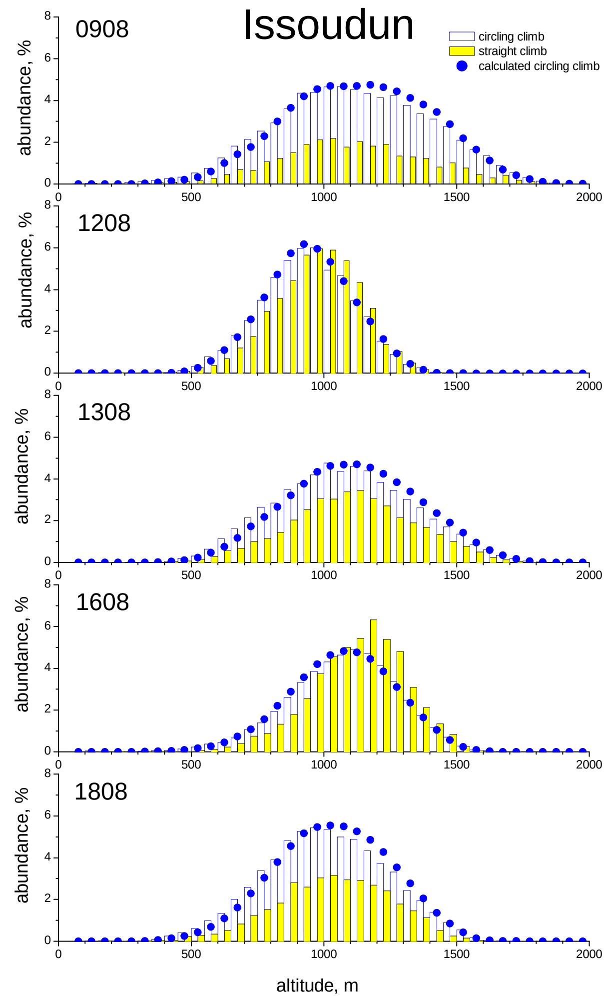
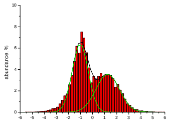
Excellent agreement between altitude distributions $f_c^c(h)$ obtained from flight recorder data (⊠) and from integration of eq.1 (↘).







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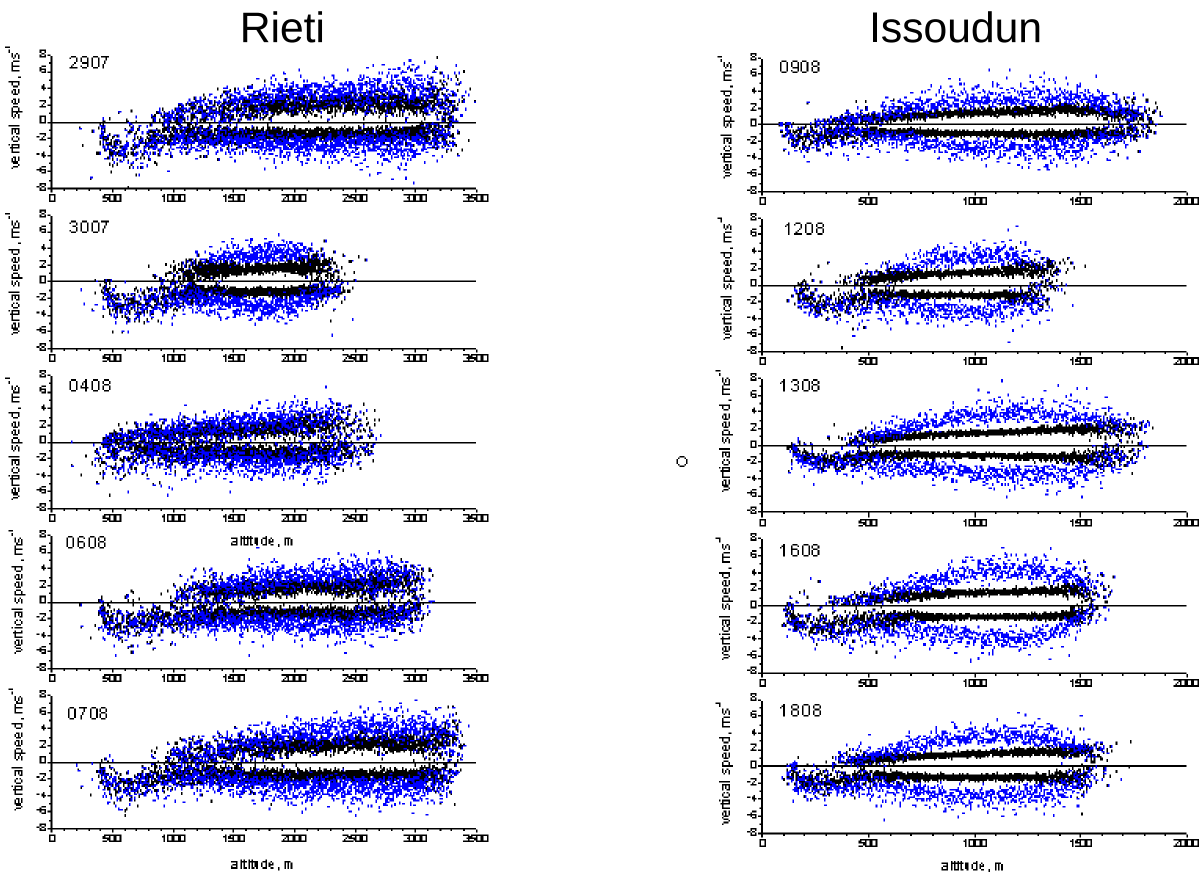
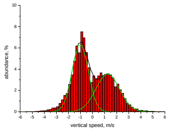
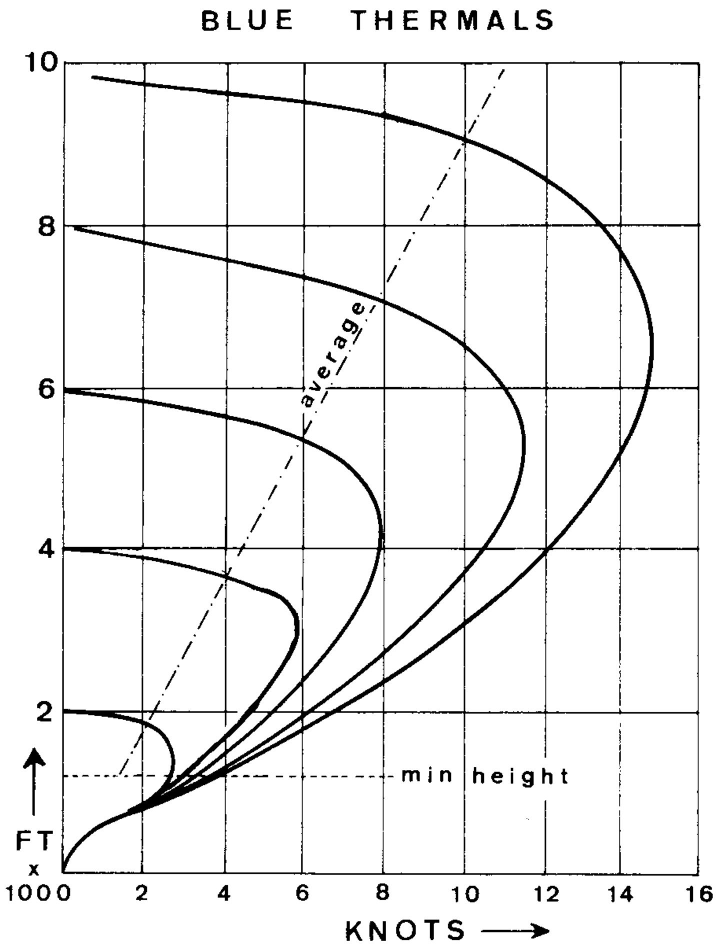
Result corroborated by absence of w-h correlation.



Mean vertical speeds (**black**) are essentially independent of altitude. In contrast, maximum and minimum vertical speed values (**blue**) occur at medium altitudes.



Result is in contradiction to accepted theory, see e.g. "Meteorology and Flight" by T. Bradbury:



65. Lift in cloudless thermals

"Average rates of climb may be only half these values."

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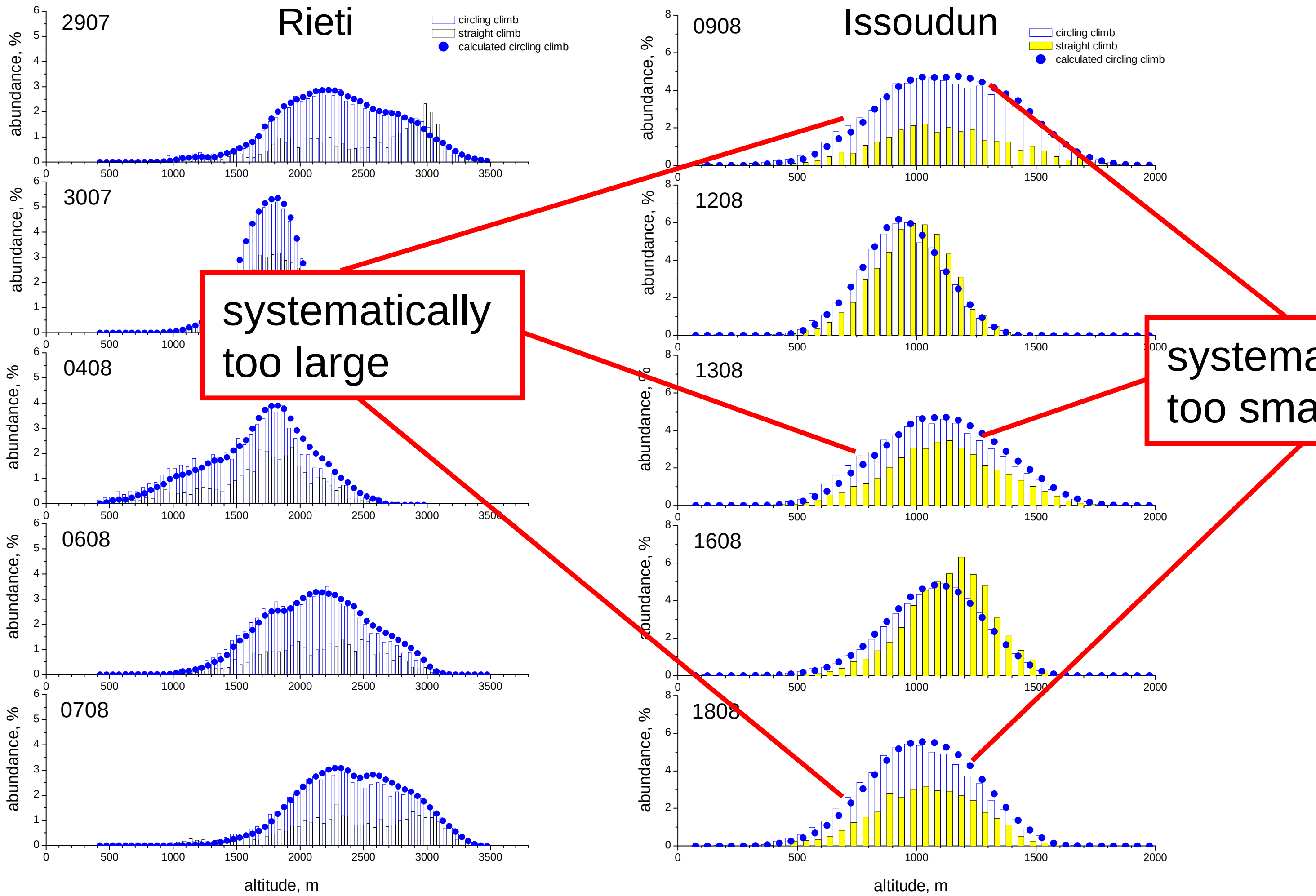
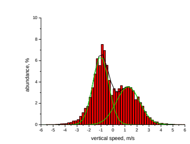
A second look to altitude distributions

Excellent agreement between altitude distributions $f_c^c(h)$ obtained from flight recorder data (⌧) and from integration of eq.1 (↘).





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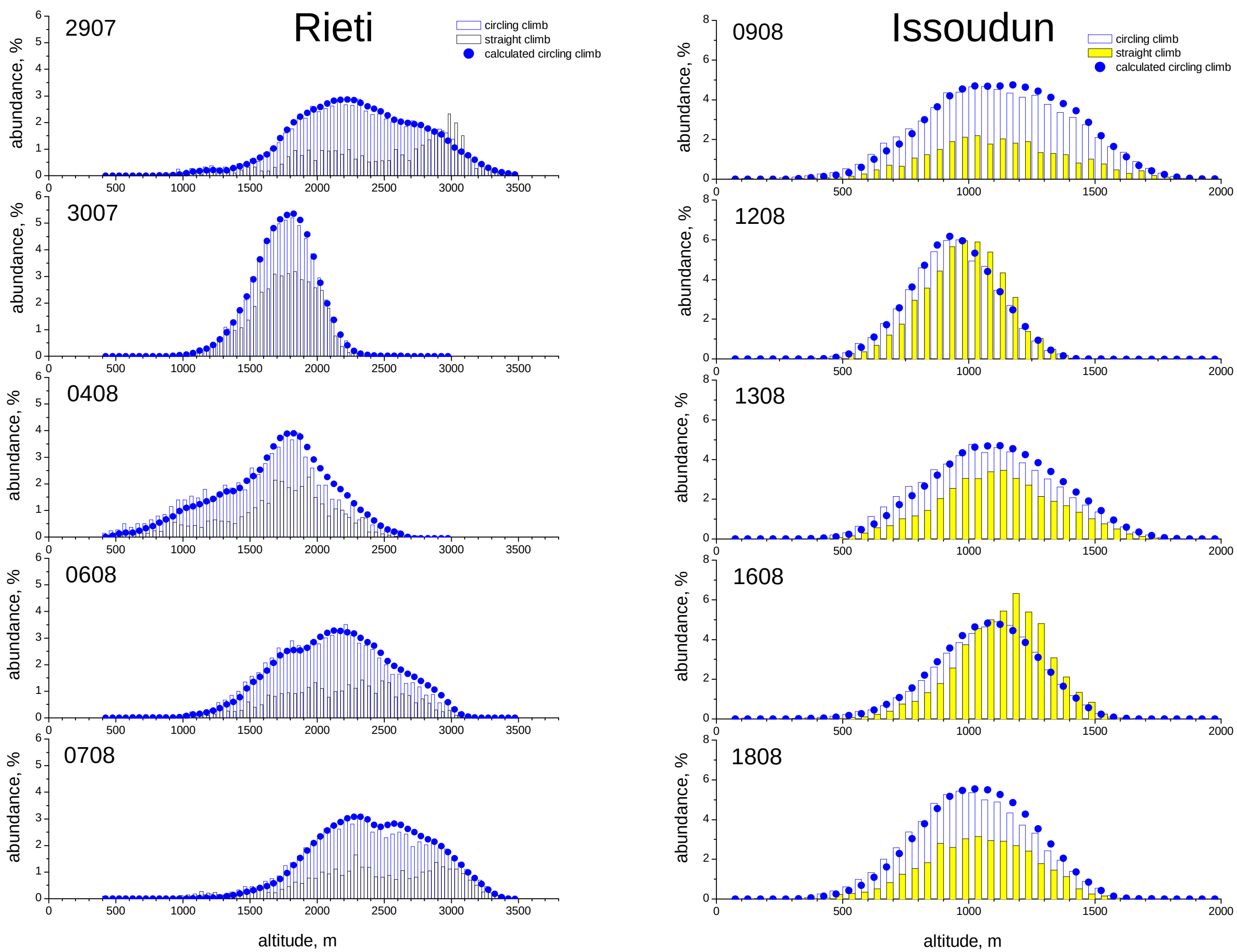
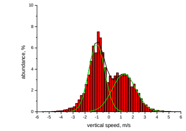
A second look to altitude distributions

~~Excellent~~ Good agreement between altitude distributions $f_c^c(h)$ obtained from flight recorder data (⊠) and from integration of eq.1 (↘).





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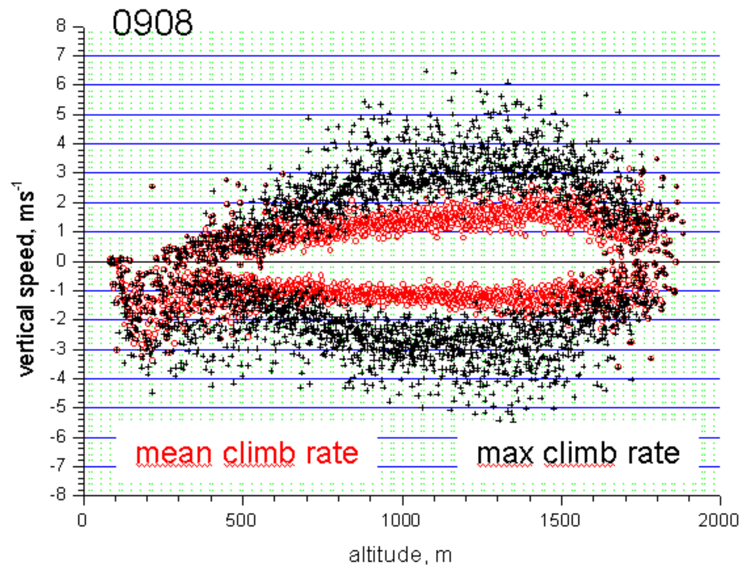
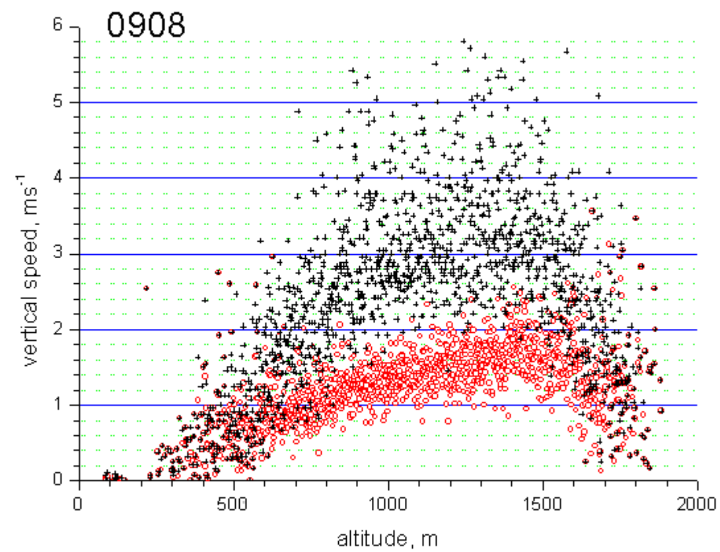
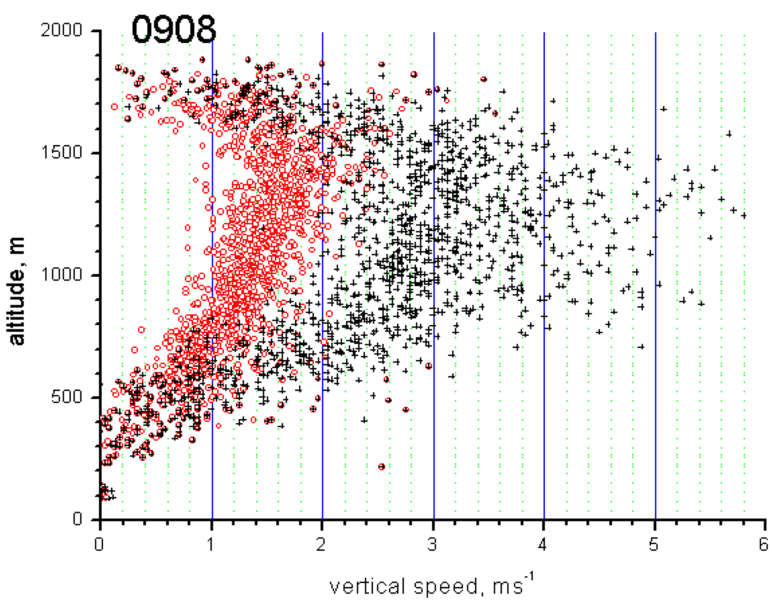
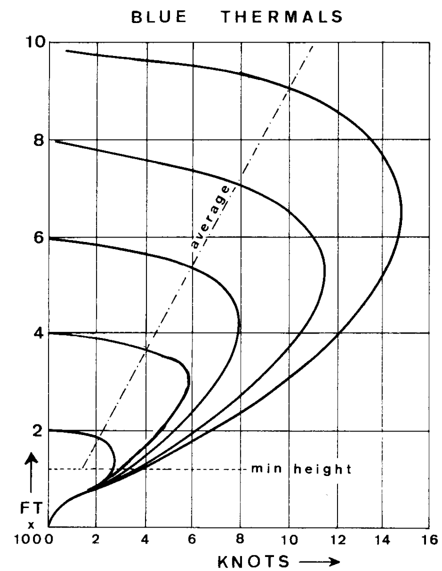
A second look to w-h correlations









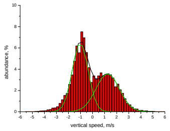
65. Lift in cloudless thermals

Strategy

fit 3rd order polynomial to maximum climb rate data (black)

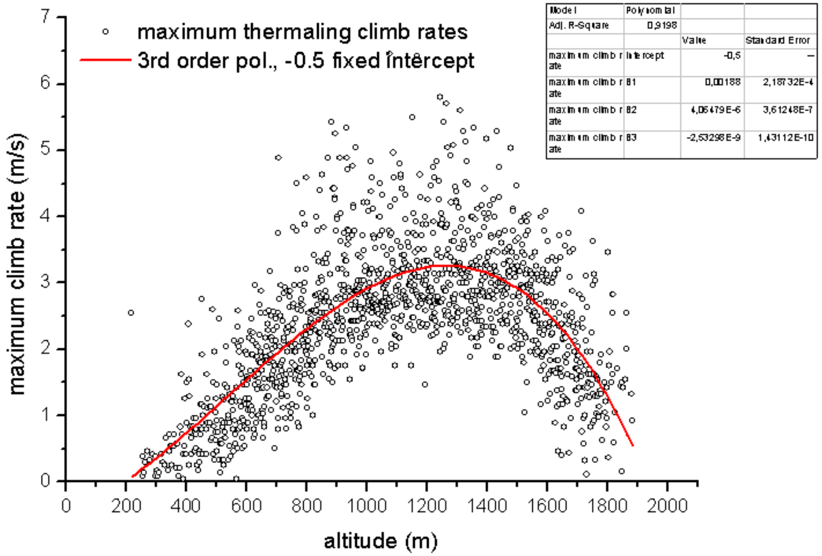
fix intercept at -0.5 m/s and compare to Bradbury

divide result by 2 (*average rates of climb may be only half these values)* and compare to mean climb rate data (red)



3rd order polynomial fir to maximum climb rate data intercept -0.5 m/s

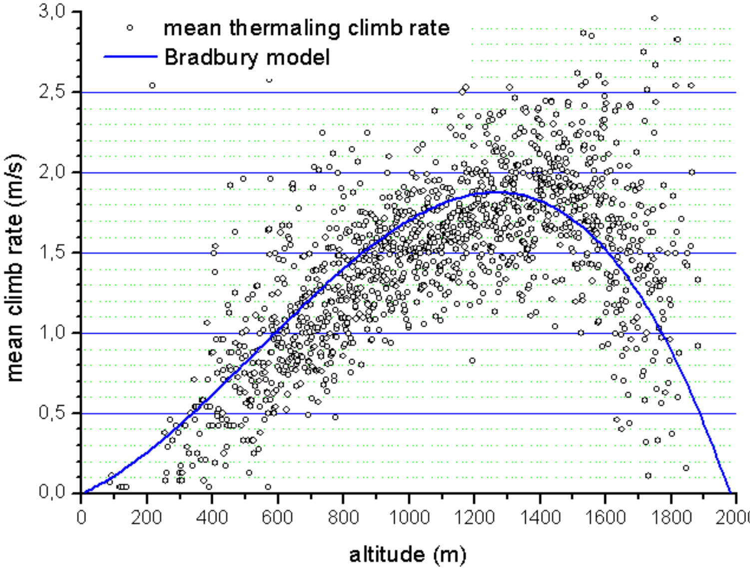
Issoudun 20070809

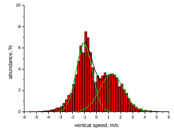


Model	Polynomial		
Adj. R-Square	0,9198		
		Value	Standard Error
maximum climb rate	Intercept	-0,5	--
maximum climb rate	B1	0,00188	2,18732E-4
maximum climb rate	B2	4,06479E-6	3,61248E-7
maximum climb rate	B3	-2,53298E-9	1,43112E-10

No fit! Result from above divided by 2, compared to mean climb rate data

Issoudun 20070809





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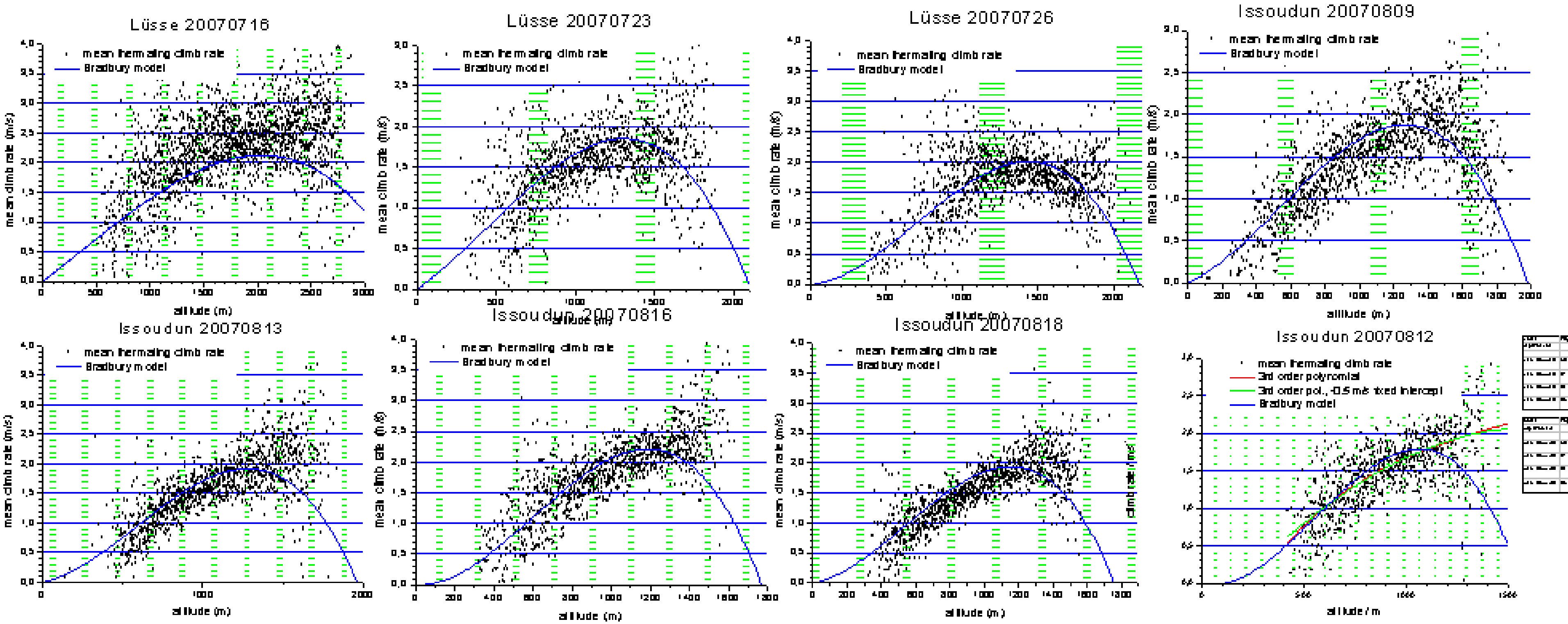
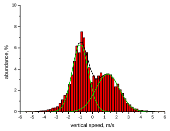
"Bradbury correlation" applied to mean thermaling climb rates of Luesse and Issoudun competitions





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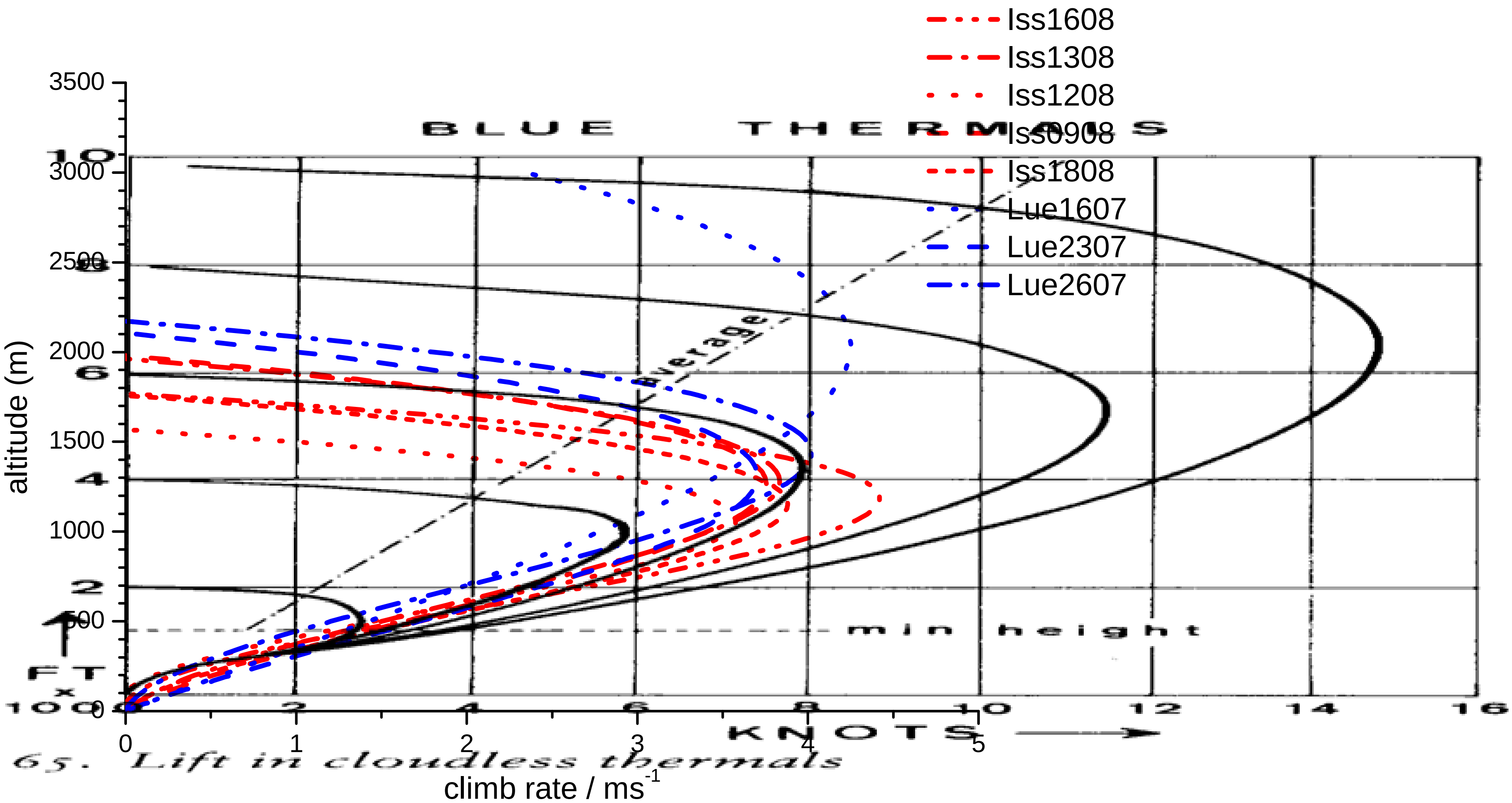
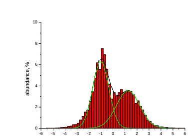
final comparison of statistical analysis to Bradbury's model



another excellent agreement!



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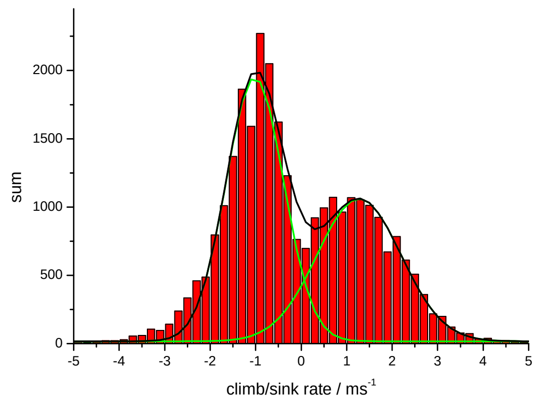
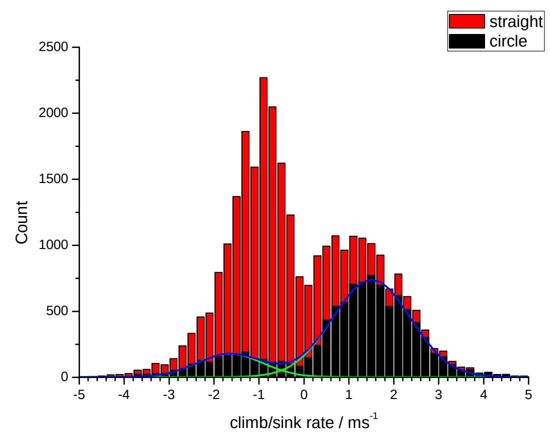
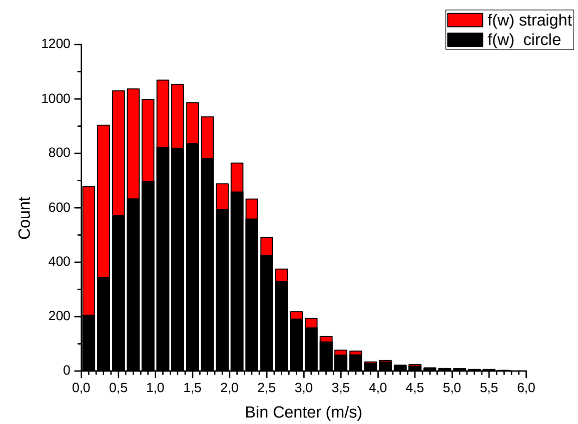
Another add-on to previous work concerning vertical speed distributions

Gaussian or non-Gaussian?

Issoudun, 9.8.07



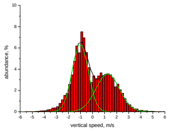




straight and circling
Gaussian

straight flight only
Gaussian

same data
but *look* non-Gaussian



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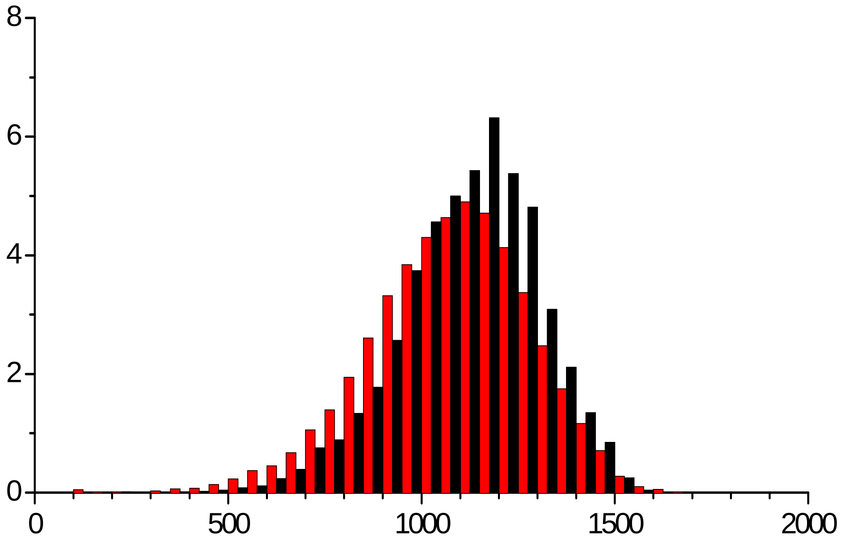
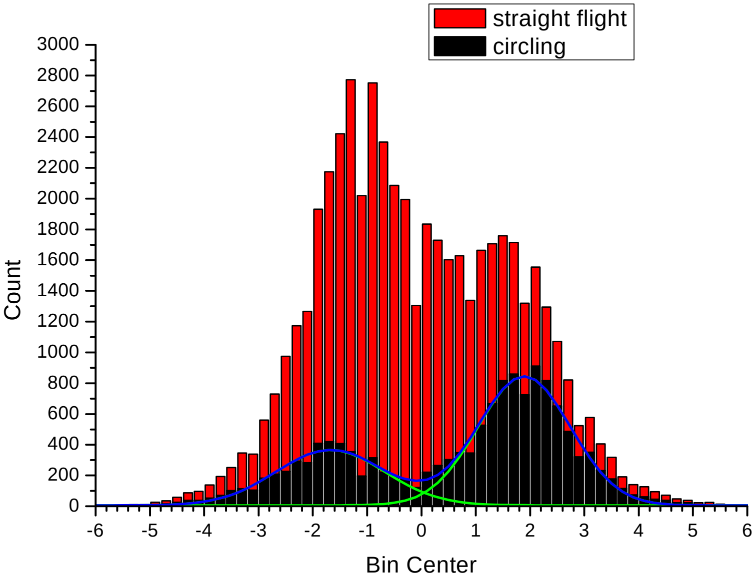
Issoudun, 16.8.07

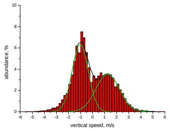




altitude distribution
straight and circling

vertical speed distribution
straight and circling

more than 50% straight climb
circling climb rate distribution is Gaussian



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Summary of new results

1) vertical speed – altitude correlation

A close look reveals very good agreement of evaluated data with correlation reported by Bradbury.

2) vertical speed distribution

No deviation from Gaussian normal distributions is observed. Holds also for circling only climb data.