

# Squall-lines as an aid for long distance glider flights in Argentine

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## Abstract

Some statistical aspects of squall-lines over Argentine are analysed. Parameters shown are extent, orientation, total distance of displacement, associated synoptic situation, regional and temporal (diurnal and annual) characteristics.

From a synoptic viewpoint it is concluded that squall-line activity greatly determines weather conditions over Argentine, north of 40 degrees latitude and during summer.

It is also found that scale and behavior of squall-lines differ widely from case to case.

Long distance flights are possible but need a certain period for preparation depending on the time interval of suitable squall-line passages.

## 1. Introduction

As has been stressed by some addicts to soaring, squall-lines (s.l.) or instability lines may well be used for long distance flights. Synoptic experience shows a relatively high frequency of this kind of weather phenomena over Argentine. The purpose of this paper is to show some statistical aspects of the s.l. in this region. At the end of this paper a pronounced case is analysed.

## 2. Selection of cases

Some difficulty concerning the definition of the phenomenon to be analysed is found. For brevity the definition for squall-line given by C. W. Newton (1) may be repeated here: The squall-line is a line of thunderstorm activity connected with high winds, heavy downpours, lightning, hail and tornadoes.

Later investigations (2, 3, 4) reveal a variety of weather phenomena which conform more or less to what initially was called s.l. The selection of cases in this paper is based on the above definition and on conventional synoptic weather maps. No other information was considered.

Considering the scale of the phenomenon, only those s.l. were selected whose longitudinal dimension equalled or exceeded 100 km and whose duration exceeded 2 hours. It has to be mentioned here that in some cases the information used was insufficient to distinguish between a s.l. and a cold front. Cases with strong generalised downdraft wind were included. Those s.l. which could be determined to be cold fronts were excluded from the present study even though they could have been used for long distance flights.

## 3. General aspects

The synoptic maps studied correspond to 03, 06, 09, 12, 15, 18 and 20 official Argentine time (HOA) from 1st January 1952 to 31st December 1961. 365 s.l. were counted during these 10 years.

The following data were taken into account: Date, hour and region of formation; date, hour and region of dissipation; total distance of displacement; mean length; general orientation; intensity; synoptic situation.

### 3.1. Mean length of squall-lines

Table 1

Extents km	Number of cases
200	2
300	8
400	47
500	71
600	57
700	46
800	31
900	7
1000	60
1100	7
1200	20
1300	3
1400	2
1500	3
1600	0
1700	0
1800	0
1900	0
2000	1

Several facts make it difficult to define the mean length: Instability lines are more or less curved, their lateral edges are ill-defined and undergo strong and rapid variations. Some subjectivity could not be avoided (maximum at 1000 km). The mean length has always been taken in hundreds of kilometers.

On the average, the mean length is 711 km, the maximum mean length is 2000 km and the minimum 200 km. Most lines belong to the 500 km class, and the distribution is asymmetric toward longer lines.

### 3.2. Total distance of displacement

Table 2

Distance	Number of cases
100	8
200	21
300	38
400	41
500	49
600	33
700	44
800	22

Distance	Number of cases
900	11
1000	36
1100	18
1200	23
1300	2
1400	6
1500	8
1600	3
1700	1
1800	0
1900	0
2000	0
2100	0
2200	0
2300	1
Total	365

The mean travel distance is 687 km, the maximum 2300 km and the minimum 100 km. Most lines are again in the 500 km class, and the distribution is asymmetric towards the greater distances.

On the other hand, only the first and last maps on which the s.l. were active and existed as such were taken into account. So the distances may be somewhat too low (about 10%).

Another difficulty consists in the fact that a great number of s.l. disappeared from the denser synoptic network into other regions and their final place of dissipation could not be found. In those cases the distance was taken from the place of birth to the limit of the denser network. So table 2 indicates a lower limit for the distances that can be expected. See par. 5.2.

The correlation coefficient between mean length and total distance of displacement is

$$r = + 0.86$$

This is a higher value than expected. As the order of magnitude of both parameters is the same, the area covered by a s.l. should have similar length and width.

### 3.3. Mean speed of movement

This was obtained by dividing the total distance of displacement by the time needed for it. Table 3 gives the results. The average mean velocity is 48 km/h, the maximum 125 km/h and the minimum 12 km/h. Note that 71% of the cases range from 30 to 59.9 km/h.

Speed km/h	Number of cases
0- 9,9	0
10- 19,9	5
20- 29,9	34
30- 39,9	86
40- 49,9	87
50- 59,9	86
60- 69,9	40
70- 79,9	12
80- 89,9	10
90- 99,9	0
100-109,9	3
110-119,9	1
120-129,9	1

### 3.4. Synoptic situation

At the moment of formation of the s.l. they could be divided into six groups:

- I) Non frontal. (Distance to front more than 500 km.)
- II) Pre-cold-frontal. (Distance to front less than 500 km.)
- III) Frontal. (Thunderstorm activity on cold front which later separated advancing in form of a s.l.)
- IV) Stationary or warm front, waves, air mass limits and other kind of baroclinic situations at a distance less than 500 km. (S.l. formed in warm air mass.)
- V) Same as IV, but s.l. formed in a region occupied by colder air mass below.
- VI) Upper cold air advection or upper cold front.

Table 4 gives the result.

51% correspond to the classical pre-cold-frontal squall-line. 84% are related to baroclinity and only 16% formed on account of air mass instability alone.

Table 4

Synoptic situation	Number of cases
I	55
II	161
III	27
IV	110
V	6
VI	6
Total	365

It is beyond the scope of this study to go farther into detail. Nevertheless synoptic and aerological characteristics will be studied later.

### 3.5. General orientation of squall-lines

Generally one finds that squall lines form curves like part of an ellipse, the strongest convection being situated in the left center looking in the direction of movement. Therefore it is difficult to define orientation and only three classes have been taken:

76% correspond to NW-SE; 19% to W-E and 5% to N-S orientation with displacements towards the north-east, north and east respectively.

### 3.6. Mean time of life cycle

Taking the first and last maps of existence one obtains 17,3 hours on the average. Because of the reasons pointed out in 3.1 this represents a minimum. The distribution shown in table 5 has the same characteristics regarding mean length and total distance of displacement. The minimum life time was 2 hours and the maximum 72 hours.

Table 5

Duration hours	Number of cases	Duration hours	Number of cases
2	8	10	3
3	9	11	15
4	0	12	29
5	24	13	16
6	26	14	11
7	5	15	19
8	18	16	6
9	20	17	39

Duration hours	Number of cases	Duration hours	Number of cases
18	10	34	1
19	10	35	3
20	2	36	5
21	13	37	7
22	3	38	0
23	0	39	4
24	30	40	0
25	0	41	3
26	2	42	1
27	7	43	1
28	0	44	0
29	7	45	0
30	5	46	0
31	2	47	0
32	1	48	1
33	6	and one case of 72 hours.	

#### 4. Diurnal and seasonal variations

##### 4.1. Hour of formation

Table 6. Hour of formation. Official Argentine time (45° W.)

Time H.O.A. from	Time H.O.A. to	Number of cases	Rate of formation per hour an 10 years
20	03	129	18,4
03	06	23	7,7
06	09	19	6,3
09	12	38	12,7
12	15	60	20,0
15	18	42	14,0
18	20	54	27,0

Table 6 gives the results. In the last column the data indicate the number of lines which formed per 10 years and per hour. One finds a general preference for the afternoon. The maximum occurs between 18 and 20 H.O.A. and the rate decreases slowly to a minimum between 06 and 09 H.O.A.

It should be mentioned here that some irregularities appear probably because the maps of 09, 15 and 20 H.O.A. contain more information than those of 03, 06, 12 and 18 H.O.A., especially during the first years of the statistics.

It is believed that the relative minimum occurring between 15 and 18 H.O.A. is due to this fact.

##### 4.2. Hour of dissipation (or exit beyond the limits of the dense synoptic network)

Table 7

Hour of dissipation (or exit beyond the dense synoptic network)

Time H.O.A. from	Time H.O.A. to	Number of cases	Rate of dissipation per hour and per 10 years
20	03	139	20,0
03	06	25	8,3
06	09	32	10,7
09	12	63	21,0
12	15	32	10,7
15	18	46	15,3
18	20	28	14,0

Table 7 contains this aspect. Two maxima appear which may be real, one during the night and one between 09 and 12 H.O.A.

When a comparison between table 6 and 7 is made it appears that the maximum number of lines exist at 20 H.O.A. and the minimum at 12 H.O.A., and that s.l. are more frequent during the night.

An earlier research of one of the authors (5) noted hours of passages of s.l. through Olivos (Buenos Aires) from 1939 to 1954 (only intense cases). Table 8 gives the result.

Table 8

Time of passage through Olivos (Buenos Aires) of s.l. of force 8 or more Beaufort (1939-54)

Time H.O.A. from	Time H.O.A. to	Number of cases
0	1	3
1	2	4
2	3	4
3	4	5
4	5	6
5	6	6
6	7	4
7	8	4
8	9	4
9	10	7
10	11	2
11	12	2
12	13	1
13	14	0
14	15	3
15	16	4
16	17	5
17	18	9
18	19	7
19	20	10
20	21	9
21	22	7
22	23	6
23	24	4
Total		116

(Local storms are not excluded.)

The maximum corresponds to the interval from 19 to 20 H.O.A. with 10 cases and the minimum to 13 to 14 H.O.A. with 0 cases.

##### 4.3. Monthly distribution of squall-lines

Table 9. Monthly distribution of squall-lines.

Month	Number of cases	Percentage	Season
January	71	19%	Summer 51%
February	39	11%	
March	44	12%	
April	20	5%	Autumn 19%
May	6	2%	
June	2	0,5%	Winter 3%
July	2	0,5%	
August	8	2%	
September	17	5%	Spring 27%
October	38	10%	
November	43	12%	
December	75	21%	

Table 9 gives the result. December and January are by far the months of maximum activity. Summer has 51% of the cases, autumn 19%, winter 3% and spring 27%. March has much more cases than September and even more than October. March is also the rainiest month over all of eastern Argentine. One may infer that while in October and November instability through strong surface heating is created, in March there must be a humid, convectively unstable, tropical air mass present.

## 5. Regional Characteristics

### 5.1. Formation of squall-lines



Fig. 1

The results may be seen in Fig. 1, where the area has been divided into 28 regions. Inserted are two numbers for each region:

The left one refers to the total number of formations and the right one gives the frequency per unit area. (Number of line formations per 100,000 km<sup>2</sup> and 10 years.)

The maximum corresponds to north-eastern Buenos Aires Province, followed by central, south-eastern and north-western Buenos Aires and north-eastern La Pampa.

There is some uncertainty concerning the Mendoza region. It is probable that several s.l. whose origin was taken to be San Luis or Córdoba might have moved on from Mendoza, the synoptic network of the travesía (desert) being inadequate for this study. In spite of this, it is believed that the mountainous region of San Luis and Córdoba represents a secondary maximum of s.l. formation.

### 5.2. Dissipation of squall-lines

In Fig. 2 the total number of cases is shown. It is seen that 127 s.l. (approximately one third of the total) move out of the denser synoptic network.



Fig. 2

### 5.3. Details of squall-lines which formed in different areas

Fig. 3 denotes four big regions. We may call region I the south-west, II mountains, III N.-E. littoral and IV Río de la Plata.

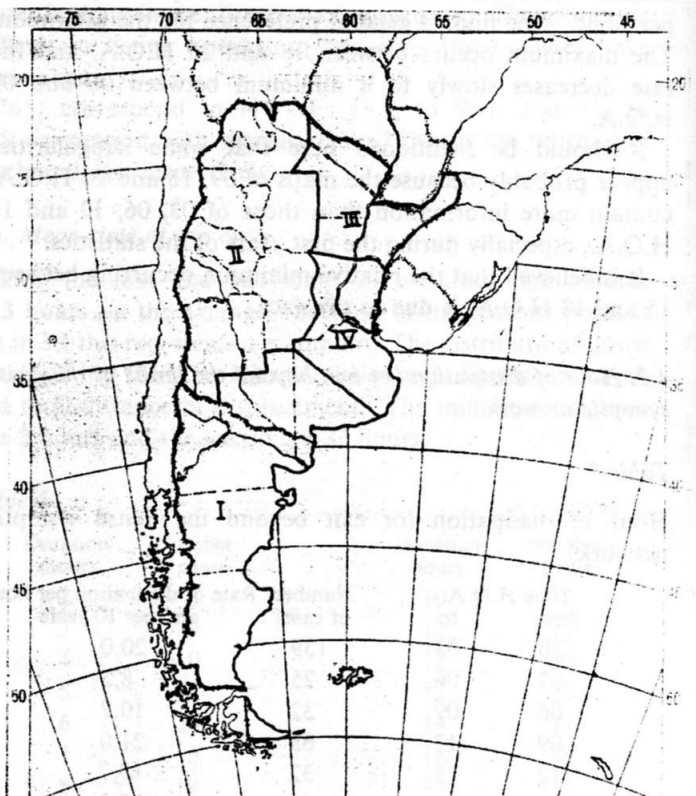


Fig. 3

Table 10

Time of formation. Regional distribution (only 1954-61).

Time H.O.A.	Region				Total
	I	II	III	IV	
20-03	26	27	19	29	101
03-06	5	6	1	6	18
06-09	3	5	2	4	14
09-12	8	6	7	7	28
12-15	13	8	6	19	46
15-18	16	3	3	6	28
18-20	11	15	3	9	38
Total	82	70	41	80	273

Table 11

Monthly distribution. Regional differences.

Month	Region				Total
	I	II	III	IV	
January	30	13	5	23	71
February	13	12	4	10	39
March	17	10	4	13	44
April	6	1	4	9	20
May	3	0	0	3	6
June	0	0	0	2	2
July	0	0	2	0	2
August	2	0	2	4	8
September	3	2	6	6	17
October	7	11	7	13	38
November	15	13	7	8	43
December	22	27	12	14	75
Total	118	89	53	105	365

Table 12

Regional differences for seasonal distribution.

Season	Region				Total
	I	II	III	IV	
Summer	65	52	21	47	185
Autumn	26	11	8	25	70
Winter	2	0	4	6	12
Spring	25	26	20	27	98
Total	118	89	53	105	365

Tables 10, 11 and 12 give the results for hour of formation, monthly distribution and seasonal distribution respectively.

From table 11 it can be seen that nocturnal formations prefer the north-eastern littoral region. A striking fact is that late afternoon formations are at maximum in mountain regions while over flat land early afternoon formations occur more frequently.

Tables 11 and 12 show that mountain region has the most pronounced summer maximum, and no s.l. is seen from May to August. The most even seasonal variation occurs over the north-east littoral region.

#### 5.4. Difference of intensity from region to region

An arbitrary parameter was defined to study if lines of some region were particularly suitable. This parameter was the sum of time of duration (full hours), the mean length (kilo-

meters divided by 20) and the total distance of displacement (kilometers divided by 20).

No difference was found for three of the regions. Only north-eastern littoral has no large values. This is due to the fact that those lines that formed there could not be traced until they finished their life cycle.

#### 5.5. Passages of squall-lines through selected points



Fig. 4

Taking into account only the information listed in par. 3, we find for Corrientes 166, Paraná 159, Junín 150, Ceres 146, Concordia 145, Buenos Aires 143, Córdoba 133, Posadas 132, Laboulaye 131, Azul 108, Santiago del Estero 85, Santa Rosa 68, San Luis 27, Bahía Blanca 20, Puelches 14, Patagones 2 and Cipolletti 1 passages.

Fig. 4 gives the distribution of the total s.l. passages. Attention is drawn to the fact that there is a decay towards the extreme eastern part of Argentina, as given by the pairs of values Corrientes-Posadas, Paraná-Concordia, Junín-Buenos Aires. It is believed to be real.

#### 6. Number of squall-lines which are considered specially suitable for soaring

A note was added to every case which was considered to present excellent soaring conditions. The following factors were taken into account: The cloudiness immediately in advance of the s.l., the wind shift, the temperature discontinuity and the distance from the first gust line to the precipitation.

Out of 365, 139 s.l. were selected, that is 39%. One of these s.l. is shown in the next par.

A new statistical investigation was carried out with this selection of s.l. The behavior of this sample was the same as that of the total discussed earlier.

## 7. The squall-line of 22nd January 1960

On January 21st a cold front moved through northern Patagonia. General baroclinity was present in the warmer air mass as an east-west orientated frontolysis along 35 degrees south.

Strong northerly winds up to 50 kts were blowing in advance of the cold front during the morning and a field of stratocumulus and altocumulus was present from the first hours of the day.

At 15 H.O.A. some 150 km ahead of the cold front the first thunderstorm was observed at San Antonio Oeste.

20 H.O.A.: a weak pre-cold frontal s.l. had organised and was advancing towards north-east.

03 of the 22nd: a severe squall line was advancing rapidly through Buenos Aires and La Pampa provinces.

09: A characteristic thunderstorm high had developed and was followed by a wake through. A general pressure rise is seen behind the wake through and the cold front, now ill-defined, was losing speed.

Between the s.l. and the cold front a weak anticyclone with fine weather became evident by 20 H.O.A. This indicates that the squall-line was accompanied by a change of the circulation. Possibly a through or shear line was present up to great heights.

From 21nd to 23rd January winds over Ezeiza (Buenos Aires) changed throughout the troposphere but the thermal characteristics of air mass varied little.

Fig. 5 gives the isochrones of the s.l. On the right side, looking into the direction of movement, the edge was ill-defined. Note the western extension of the s.l. north of the San Luis-Córdoba mountain system. From precipitation maps it is concluded that the s.l. was quite continuous

forming a solid barrier of cumulonimbus. The line traversed more than 2000 km during 29 hours. It is readily seen that it represents a rather strong case.

## 8. Conclusions

From the synoptic point of view it is evident that weather conditions are deeply influenced by squall-line activity north of 40 degrees over central and eastern Argentine during summer.

The squall-lines have a wide range of size and behaviour. It is desirable to investigate all phenomena which, in the past, have been called squall-lines or instability lines and which in reality compose a variety of systems, the physical and synoptic interpretation and classification of which must be studied with the aid of more aerological data.

December and January are the months of highest squall-line activity. Taking the whole summer (incl. February) the mean interval between the occurrences of two squall-lines over Argentine is about 3 days.

But if we take an instance at random in order to wait for the occurrence of a squall-line the variability of this phenomenon indicates that the most probable waiting time will be 5,75 days. The interval ranges from three different lines occurring at the same day to 44 days between one and the next s.l.

If the glider pilot goes to a certain point, let us say, Junin, also at random, he will have to wait, most probably, 13,8 days for the passage of a squall-line through this point. This interval may be less, if only December and January were taken into account, but it can be much longer if one considers that a great number of s.l. pass in the evening or during the night.

It must be concluded then, that squall-lines over Argentine are excellent means for long distance flights, but to make use of them a considerable period of preparation and organisation for these flights is required and the success will depend to a certain degree on luck.

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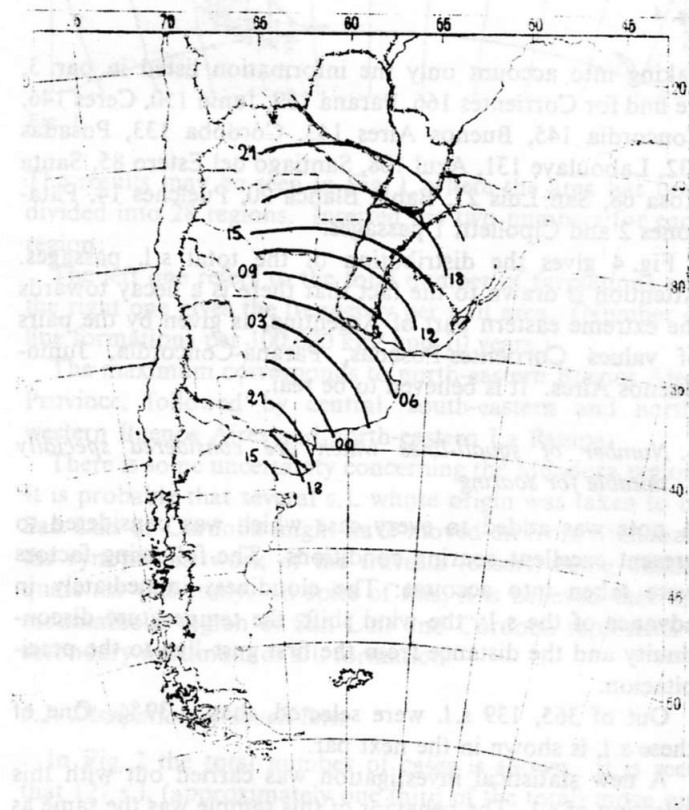


Fig. 5