4.6. MULTIPLE REGRESSION ANALYSIS OF WEATHER AND MIGRATION DATA IN SWITZERLAND.

DR. B. BRUDERER, SWITZERLAND

Multiple regression analysis of weather and migration data in Switzerland

B. Bruderer, Schweizerische Vogelwarte, CH-6204 Sempach

Methods

The present study follows the method of Nisbet and Drury (1968) and of Noer et al. (1970), using a standard computer program of the BMD series for stepwise multiple regression analysis.

The migration data used for this pilot study were collected with a tracking radar during 44 nights of spring migration in 1968 and 1969. Figure 1 shows the arrangement of the radar for bird counts. By counting the night migrants (usually single birds) crossing the plane of registration during a certain interval of time, we get the migration traffic rate (MTR). MTR depends on the ground speed of the birds and is so directly influenced by the wind. Dividing MTR by the mean ground speed of the birds in a particular night, we get the volume of migration (VM), that is the number of birds being in flight at a given time above a certain area. VM is a measure of migration activity, while MTR is a measure of the success of migration. MTR and VM are the basic dependent variables in our regression analysis. In order to get information on unlinearities within the regressions, two transformations of MTR and VM were used as additional dependent variables: namely the square root and log (1+ the basic variable). Because the logarithmic transformation led to nearly the same results as the square root, we omitted it in our present paper.

For the weather data we selected 18 variables in close accordance with the above mentionned papers. Unstandardised variables were used. The data set of Zurich (21, 00, and 03 h) stands for the weather in the actual migration area, the data of Payerne und Geneva (18 and 21 h) for the weather in the recruiting area, and the data of Friedrichshafen and Munich (03 and 06 h) for the weather in the area of destination (compare Figure 2).
The correlation between the weather in the recruiting area at the time of departure and the intensity of migration in the following night is the data set which is of most interest for the bird strike problem because it may lead to migration forcasts. So we will confine our discussion to this aspect of the analysis.

F 1

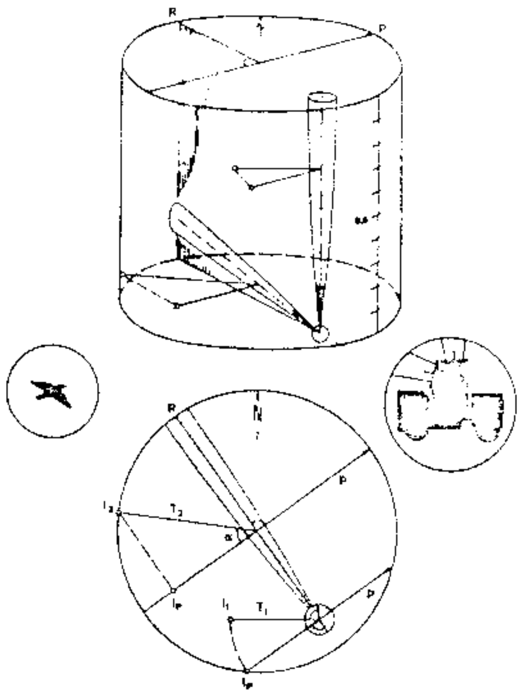
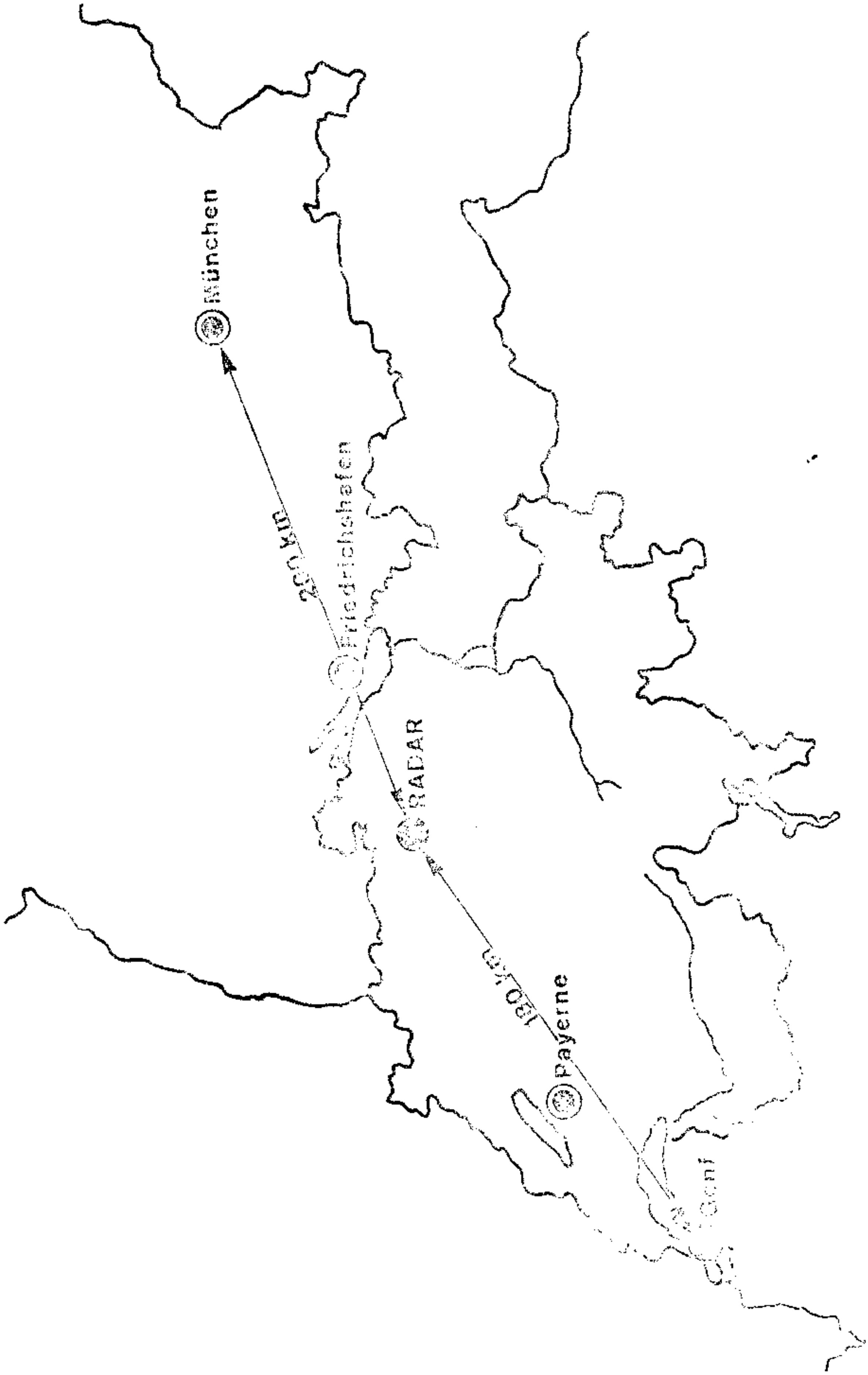


FIGURE 1. Principle of improved vertical-beam method: Beam is pointed vertically upward in the first phase, so ranges up to 4000 m above ground could be surveyed. Levels next to the ground are surveyed in second phase with low antenna elevation. Graph above shows volume of a cylinder with a height of 1 km and the radar site to the SE. Diagram beneath is the ground plan for the figure above. In both drawings *P* gives the supposed principal direction of migration and *R* is the plane of registration for low-elevation counts. Small circles mark position of single birds: I_p marking an individual with principal direction; I_1 and I_2 are individuals with the track directions T_1 and T_2. α is angle between actual and supposed migration direction.


München
200 km
Friedrichshafen
RADAR
180 km
Payerne
Genf

Results

In Table 1 the single variables are arranged according to the order, in which they were included in the step-up analysis. Variables which were included with a significance level higher than 0.05 are shaded. The left column is an attempt to summarise the other four columns.
We recognise that only TEMPERATURE and VISIBILITY reach always the desired F-level for inclusion. These are two variables, which in other studies (Able, 1973, Nisbet and Drury, 1968, Noer et al., 1970) have never reached significant levels (cf. also Table 2). CHANGE IN TEMPERATURE is included in all the four columns of Table 2, but in one of our analyses it misses to reach a significant level. TIME SINCE RAIN is in our analysis always included with high priority, it can perhaps be compared to the variable DAYS SINCE COLD FRONT of other authors, being negatively correlated with migration in autumn and positively in spring.
With respect to the other variables we realize an uncoordinated appearance or lack of the different variables within our analysis and in comparison with other studies. SURFACE TAILWIND with its high simple correlation and its high priority in Able's analysis is almost absent, and at the only point where it is present, correlation is negative. UPPER TAILWINDS and its CHANGES are included, but in negative correlation with VM and in positive correlation with MTR.
Furthermore we will see in our analysis of simple correlation, that the inclusion of PRESSURE, RELATIVE HUMIDITY and CHANGE IN CLOUDCOVER is very problematic because of autocorrelation with rain. These large differences between various analyses could tempt to conclude that it is a matter of chance for a variable to be included in a multiple regression or not.
The different analyses do not even give the possibility of excluding certain variables from further studies, because every variable once appears with high priority and a pertaining interpretation of the interrelationships between the variables of multiple regressions seems, at the moment, imppossible to me.

MTR	VM
- birds crossing plane of registration during a certain interval of time	- birds being in flight at a given time above a certain area
- influenced by wind	- influence of wind excluded
- success of migration	- migration activity
MTR $\sqrt{MTR}$ log(1+MTR)	VM $\sqrt{VM}$ log(1+VM)

T 1

AREA OF DEPARTURE

MULTIPLE REGRESSION

all nights included

	MTR	$\sqrt{MTR}$		VM	$\sqrt{VM}$
1 temperature +	visibility +	visibility +		temperature +	temperature +
2 visibility +	temperature +	temperature +		visibility +	visibility +
3 change in temp. +	change temp. +	change temp. +		change temp. +	time s.rain +
4 time since rain +	change cloudc. -	time s.rain +		up. tailw. -	change temp. +
5 change up. crossw. +	ch.up.tailw. +	ch.up.crossw. +		ch.up.crossw. +	change press -
6 change cloudcover -	ch.up.crossw. +	change press. -		change cloudc. -	ch.up.crossw +
7 change up. tailw. +-	rel. hum. +	rel. hum. +		ch.up.tailw. -	ch.up.tailw. -
8 change pressure -	time s.rain +	cloudheight +		pressure -	change cloud -
9 rel. humidity +	change press. -	change cloudc. -		time s.rain +	change hum. +
10 pressure -	surf.tailw. -	change hum. +		rel. hum. +	pressure -
11 upper crosswind +	up. tailw. +	pressure -		up. crossw. +	cloudheight +
12 upper tailwind +-	up. crossw. +	ch.up.tailw. -		atm. instab. +	up. crossw. +

Simple correlations are closer to our understanding than multiple correlations. They are accessible to interpretations and to some manipulations, which can lead to a fairly good understanding of dependences of migration on weather.

In Table 3 we see the simple correlation coefficients between our 18 weather variables and the four dependent variables, once with the data of all nights and once with rainy nights excluded. The differences between the rough values of migration intensity and their non-linear transformation is usually in the order of .05 to .1. They may indicate that linear regressions are in certain cases only a very rough approximation of the reality. With large correlation coefficients this is (in the present analysis of simple correlations) not very important, but with small coefficients it may go as far as a charge in + and - (cf. variables 13 and 16). Differences between MTR and VM are mainly confined to winds, and most pronounced in tailwinds. With respect to the other weather variables, MTR and VM lead to similar results.

In the right part of table 3 (without rainy nights), we have marked all the variables which show a pronounced difference to the left part (all nights):

5) TIME SINCE RAIN shows a less pronounced correlation because all the nights with zero time since last rain and very weak migration are excluded.

6, 10, 13 and 14) TAILWINDS and CROSSWINDS show a better correlation because of rainy/weak-migration nights, usually associated with strong westernly or southwesternly winds, are eliminated.

9 and 11) RELATIVE HUMIDITY and its CHANGES are no longer correlated with migration, the correlation on the left side appearing as a matter of correlation with rain. The same is valid for the CHANGE IN CLOUDCOVER (15), and even the CLOUDCOVER (8) itself shows only a weak correlation.

PRESSURE is medium but slightly sinking. An inflow of warm air in the upper atmosphere leads to a certain ATMOSPHERIC INSTABILITY.

References

Able, K.P. (1973): The role of weather variables and flight direction in determining the magnitude of nocturnal bird migration. Ecology 54, 1031-1041.

Nisbet, I.C.T. and Drury, W.H. (1968): Short-term effects of weather on bird migration: A field study using multivariate statistics. Anim. Behav. 16, 496-530.

Noer, H., Rabøl, J. and Joensen, A.H. (1970): A forecast model for bird migration in Denmark. Distributed to members of BSCE.

[redacted] [redacted]

AREA OF DEPARTURE

SIMPLE CORRELATION

		all nights included				without rainy nights			
	mean	MTR	√MTR	VM	√VM	MTR	√MTR	VM	√VM
emperature	+.46	+.41	+.42	+.43	+.44	+.43	+.54	+.46	+.55
ays of delay	-.44	-.34	-.40	-.33	-.40	-.44	-.60	-.43	-.58
isibility	+.38	+.44	+.43	+.34	+.35	+.44	+.38	+.33	+.29
hange in temperature	+.33	+.32	+.25	+.32	+.25	+.39	+.39	+.34	+.34
ime since rain	+.26	+.23	+.33	+.35	+.42	+.06	+.17	+.21	+.28
urface tailwind	+.24	+.11	+.13	+.04	+.05	+.38	+.49	+.30	+.40
loudheight	+.21	+.26	+.29	+.20	+.25	+.19	+.21	+.10	+.15
loudcover	-.20	-.25	-.33	-.32	-.39	-.02	-.02	-.15	-.13
el. humidity	-.17	-.22	-.29	-.30	-.35	+.01	-.00	-.12	-.12
pper tailwind	+.17	+.22	+.20	+.03	+.06	+.36	+.37	+.04	+.11
hange in humidity	-.14	-.27	-.20	-.24	-.19	-.14	-.01	-.11	+.01
m. instability	+.14	+.13	+.11	+.24	+.19	+.04	+.04	+.18	+.16
per crosswind	+.13	+.07	+.01	+.04	-.02	+.23	+.25	+.23	+.24
ange in up. crosswind	+.13	+.12	+.10	+.01	+.09	+.14	+.22	+.16	+.22
ange in cloudcover	-.09	-.19	-.17	-.18	-.17	-.07	+.08	-.06	+.07
ange in up. tailwind	-.07	+.01	+.05	-.03	+.03	-.15	-.09	-.22	-.15
ange in pressure	-.07	-.10	-.12	-.10	-.11	-.04	-.13	-.04	-.14
essure	+.05	+.15	+.19	+.14	+.19	-.05	-.08	-.07	-.09

T 4 simple correlation AREA OF DEPARTURE simple correlation

Denmark (autumn)

●●●	1 change in temp.	-.59
ooo	2 change in tailw.	+.53
●	3 days since coldfront	-.41
ooo	4 tailwind	+.39
●●	5 visibility	+.34
	(6 cloudcover	-.16)
oo	7 atm. instability	+.15
	8 days of delay	-.13
●	9 time since rain	-.12
●●●	10 temperature	-.11
o	11 cloudheight	+.11
	(12 pressure	-.07)
	13 change in crosswind	+.06
	(14 change in humidity	-.05)
	15 rain last 24 h	-.04
	?16 change in pressure ?	-.03
	17 crosswind	-.02
	(18 rel. humidity	-.02)
	(19 change in cloud	-.01)

Switzerland (spring)

●●●	1 temperature	+.46
	2 days of delay	-.44
●●	3 visibility	+.38
●●●	4 change in temp.	+.33
●	5 time since rain	+.26
ooo	6 surface tailwind	+.24
o	7 cloudheight	+.21
	(8 cloudcover	-.20)
	(9 rel. humidity	-.17)
	10 upper tailwind	+.17
	(11 change in humidity	-.14)
oo	12 atm. instability	+.14
	13 upper crosswind	+.13
	14 change in up. crossw.	+.13
	(15 change in cloudcover	-.09)
	16 change in up. tailw.	-.07
	?17 change in pressure	-.07
	(18 pressure	+.05)