TP 14065E

Comparison of the IRV and the ERD on Winter Contaminated Surfaces

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by
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16. Abstract

The American Society for Testing and Materials standard for the International Runway Friction Index (IRFI) specifies a reference tester for calibration of runway friction devices in order to harmonize measurements to the IRFI. This report compares measurements made by Electronic Recording Decelerometers (ERDs) with the measurements made by the International Reference Vehicle (IRV).

Starting in 1998 the Joint Winter Runway Friction Measurement Program conducted tests in a manner that all devices made measurements on the same surfaces within a very short time of each other. These paired data are used in this report to compare the ERD with the IRV. The data from 1998 and 1999 obtained by the Instrument de Mesure Automatique de Glissance (IMAG) are converted to the predicted IRV values using the relationship (IRV = 0.95 IMAG) developed in a previous study (TP 13791E).

Most of the ERD data (10 data sets) used in the comparison were for a Chevrolet Blazer, but two data sets were for the ERD mounted on a Ford pickup truck and one data set was on a Nissan SUV. A total of 2069 data points were used in the comparison on ice, compacted snow and bare pavement. The IRV was operated at slip ratios of 30, 60 and 90 percent for 158 additional data points. Linear regressions of the data showed poor correlation between the IRV/IMAG data and the ERD for many of the data sets analyzed. This is due to several factors, which differentiate the ERD and the IRV/IMAG measurements.

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International Reference Vehicle, IRV, Electronic Recording Decelerometer, ERD, runway friction index, winter contaminated runway

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16. Résumé

La norme de l'American Society for Testing and Materials (ASTM) concernant l'Indice international de la glissance des pistes (IRFI) prescrit un appareil de référence pour l'étalonnage des appareils de mesure du frottement, dans le but d'harmoniser avec l'IRFI les différentes mesures recueillies. Le présent rapport compare des mesures prises par des décéléromètres électroniques (ERD) et par le Véhicule de référence international (IRV).

Commencé en 1998, le Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH) a mené des essais durant lesquels tous les appareils de mesure utilisés ont ausculté les mêmes surfaces, dans un intervalle très rapproché. Les couples de valeurs obtenues durant ces essais servent de base de comparaison entre les deux véhicules de mesure examinés, l'ERD et l'IRV. Les données de 1998 et de 1999 obtenues avec l'Instrument de mesure automatique de glissance (IMAG) sont converties en valeurs IRV prévues au moyen du facteur (IRV = 0,95 IMAG) mis au point dans une étude antérieure (TP 13791E).

La plupart des données recueillies avec l'ERD (10 ensembles de données) et utilisées pour la comparaison concernaient un Chevrolet Blazer; pour le reste, deux ensembles de données ont été recueillies avec l'ERD installé dans un pick-up Ford et un autre ensemble avec un sport utilitaire Nissan. Au total, on disposait de 2 069 points de données pour les mesures sur glace, sur neige tassée et sur chaussée dégagée sèche. Un autre 158 points de données ont été recueillis avec le Véhicule de référence international opéré à des taux de glissement de 30, 60 et 90 p. cent. Après exécution de régressions linéaires, on avait une corrélation insatisfaisante entre les données IRV/IMAG et l'ERD pour un bon nombre d'ensembles analysés. Cette situation est due à plusieurs caractéristiques distinctives des mesures prises par l'ERD et par l'IRV/IMAG.

17. Mots clés Véhicule de référence international, IRV, décéléromètre électronique, ERD, coefficient de frottement des pistes, piste contaminée l'hiver	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

The American Society for Testing and Materials standard for the International Runway Friction Index (IRFI) specifies a reference tester for calibration of runway friction devices in order to harmonize measurements to the IRFI. The International Reference Vehicle (IRV) was dedicated to the Joint Winter Runway Friction Measurement Program (JWRFMP) in January 2000. In earlier years testing was performed with an Instrument de Mesure Automatique de Glissance (IMAG), which is of the same design as the IRV. In an earlier report (TP 13791E) the relationship between the IMAG used prior to 2000 and the IRV was established.

The objective of this report is to compare measurements made by Electronic Recording Decelerometers (ERDs) with the measurements made by the IRV. Starting in 1998 the JWRFMP conducted tests in a manner that all devices made measurements on the same surfaces within a very short time of each other. These paired data are used in this report to compare the ERD with the IRV. The data from 1998 and 1999 obtained by the IMAG are converted to the predicted IRV values using the relationship (IRV = 0.95 IMAG) developed in the previous study (TP 13791E). The normal slip ratio for the IRV and the IMAG is 15% slip, although it can be operated at slip ratios up to 90%.

Most of the ERD data (10 data sets) used in the comparison were for a Chevrolet Blazer, but two data sets were for the ERD mounted on a Ford pickup truck and one data set was on a Nissan SUV. A total of 2069 data points were used in the comparison on ice, compacted snow and bare pavement. The IRV was operated at slip ratios of 30, 60 and 90% for 158 additional data points.

Linear regressions of the data showed poor correlation between the IRV/IMAG data and the ERD for many of the data sets analyzed. This is due to several factors that differentiate the ERD and the IRV/IMAG measurements:

1. The ERD measures several spots in the test section while the IRV and IMAG average the entire length of the segment.
2. The ERD operates at a much higher slip ratio (100%) than the normal slip ratio of the IRV and IMAG (15%).
3. The contact pressure between the tire and the surface is much higher for the ERD than for the IRV and IMAG.

When the best four correlations are combined and outliers removed, the agreement is fair for the resulting data set of 712 points:

$$\text{IRV} = 0.115 + 0.765 \text{ ERD Blazer} \qquad R^2 = 0.849$$

SOMMAIRE

La norme de l’American Society for Testing and Materials (ASTM) concernant l’Indice international de la glissance des pistes (IRFI) prescrit un appareil de référence pour l’étalonnage des appareils de mesure du frottement, dans le but d’harmoniser avec l’IRFI les différentes mesures recueillies. Le Véhicule de référence international (IRV) a été affecté au Programme conjoint de recherche sur la glissance des chaussées aéronautiques l’hiver (PCRGCAH) en janvier 2000. Dans les années précédentes, les essais étaient réalisés avec l’Instrument de mesure automatique de glissance (IMAG), dont la conception est identique à celle de l’IRV. Une étude antérieure (TP 13791E) avait établi une relation entre l’IRV et le véhicule IMAG, utilisé avant 2000.

Le présent rapport compare des mesures prises par des décéléromètres électroniques (ERD) et par le Véhicule de référence international (IRV). Commencé en 1998, le Programme conjoint de recherche sur la glissance des chaussées aéronautiques l’hiver a mené des essais durant lesquels tous les appareils de mesure utilisés ont ausculté les mêmes surfaces, dans un intervalle très rapproché. Les couples de valeurs obtenues durant ces essais servent de base de comparaison entre les deux véhicules de mesure examinés, l’ERD et l’IRV. Les données de 1998 et de 1999 obtenues avec l’Instrument de mesure automatique de glissance (IMAG) sont converties en valeurs IRV prévues au moyen du facteur (IRV = 0,95 IMAG) mis au point dans une étude antérieure (TP 13791E). l’IRV et l’IMAG sont normalement opérés à un taux de glissement de 15 p. cent, bien que des taux jusqu’à 90 p. cent soient possibles.

La plupart des données recueillies avec l’ERD (10 ensembles de données) et utilisées pour la comparaison concernaient un Chevrolet Blazer; pour le reste, deux ensembles de données ont été recueillies avec l’ERD installé dans un pick-up Ford et un autre ensemble avec un sport utilitaire Nissan. Au total, on disposait de 2 069 points de données pour les mesures sur glace, sur neige tassée et sur chaussée dégagée sèche. Un autre 158 points de données ont été recueillis avec le Véhicule de référence international opéré à des taux de glissement de 30, 60 et 90 p. cent.

Après exécution de régressions linéaires, on avait une corrélation insatisfaisante entre les données IRV/IMAG et l’ERD pour un bon nombre d’ensembles analysés. Cette situation est due à plusieurs caractéristiques distinctives des mesures prises par l’ERD et par l’IRV/IMAG :

1. L’ERD effectue plusieurs mesures ponctuelles sur la surface d’essai, alors que l’IRV et l’IMAG produisent une valeur moyenne pour la longueur complète de la surface évaluée.
2. L’ERD présente un taux de glissement (100 p. cent) de beaucoup supérieur à celui de l’IRV et de l’IMAG (15 p. cent).

3. Dans le cas du véhicule ERD, la pression de contact réalisée entre le pneu et la surface de la chaussée est beaucoup plus élevée qu'avec l'IRV et l'IMAG.

En combinant les quatre meilleures corrélations et en éliminant les aberrations, on obtient une juste concordance avec l'ensemble de 712 points de données qui en résulte.

$$\text{IRV} = 0{,}115 + 0{,}765 \text{ ERD Blazer} \qquad R^2 = 0{,}849$$

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1. OBJECTIVE

The objective of this study was to establish the relationship between the data obtained from the International Reference Vehicle (IRV) and Electronic Recording Decelerometers (ERDs), which participated in the Joint Winter Runway Friction Measurement Program (JWRFMP) between 1998 and 2001. Since the IRV was not introduced until January 2001, data obtained by the Instrument de Mesure Automatique de Glissance (IMAG) were used to predict the IRV values using a relationship (IRV = 0.95 IMAG) established in a previous study (1).

2. INTRODUCTION

The *Service Techniques des Base Aériennes* (STBA) has participated in the JWRFMP since its inception in 1995, bringing an IMAG to the JWRFMP winter tests. The purpose of these winter tests is to develop a harmonized International Runway Friction Index (IRFI) that can be reported by any of various types of runway friction testers. To accomplish this harmonization, a stable reference device is needed to establish the "true value" of the IRFI to which other systems can be calibrated. In January 2000 the STBA made a device similar to the IMAG available to the project to be adopted as the IRV. The ASTM Standard E-2100 for the IRFI (2) specifies the IRV as the reference.

In Canada, friction measurements on winter contaminated runways are made with vehicles (cars, SUVs, or pickup trucks) equipped with ERDs. The procedure described in ASTM Standard E-2101 (3) is followed for these measurements. The results are reported to aircraft operators as the Canadian Runway Friction Index (CRFI).

This report uses the results of paired measurements where the ERD and the IRV, or the ERD and the IMAG prior to January 2000, were operated over the same surfaces and within a very short time (typically 15 seconds) of each other to relate the ERD to the IRV and the IMAG measurements.

The principles of the measurement by the IRV and IMAG differ considerably from the ERD type devices. Most of the IRV and IMAG data were obtained at 65 km/h at 15% slip. This results in a slip speed of 9.75 km/h. The ERD devices are operated at 50 km/h and the wheels are locked (100% slip). This corresponds to a slip speed of 50 km/h, approximately five times the slip speed of the IRV and the IMAG. This difference may not be important on winter contaminated surfaces as it has been determined that on ice and compacted snow, the friction is independent of speed. The IMAG and IRV can be operated at high slip ratios up to 90%. Some limited data were obtained at higher slip ratios in January 2000.

Another difference is the actual contact pressure between the tire surface and the pavement. The contact pressure is defined as the load on the tire divided by the area of the rubber in contact with the surface as determined by measurement of the footprint of the tire. The Chevrolet Blazer used with the ERD in the JWRFMP has a contact pressure of 814 kPa, while the IRV has a contact pressures of 149 kPa. This difference may be of significance on winter contaminated surfaces since it affects the manner in which the tire breaks through the sometimes fragile contaminant layer.

Perhaps the most significant difference occurs on non-uniform surfaces. The IRV and IMAG measure the friction continuously along the surface and report an average over a test section. The ERD devices measure discrete spots where the operator decides to apply the brakes. Thus the ERD reports the average of three to five spots along a section, which may not be representative of the average of the test section. Driver technique in braking, suspension characteristics and brake condition may also affect the measurement in an unpredictable manner.

Considering the above, it is not surprising that the correlation between the ERD and the IRV/IMAG is poor. When considering the relationship to aircraft braking performance, the ERD has a contact pressure closer to an aircraft than the IRV. On the other hand, the IRV provides average friction values over a patchy, variable surface which the aircraft also does.

3. DATA

The IMAG and the IRV provide friction based on both force and torque measurements, and these were reported for each test. Tests were conducted for a wide variety of winter surface conditions, including ice, compacted snow, slush, and bare pavement. Conditions also included loose snow cover up to about 5 mm in depth over ice, compacted snow, and bare pavement.

Test locations were:

- Jack Garland Airport in North Bay, Ontario (1998 – 2001)
- K.I. Sawyer Airport in Gwinn, Michigan (1999)
- Oslo Airport in Oslo, Norway (1998)
- Franz Strauss Airport in Munich, Germany (2000)
- Erding Airforce Base in Erding, Germany (2001)

Three different vehicles have been equipped with ERDs in the JWRFMP during the years 1998-2001. Most of the data were collected with the Chevrolet Blazer SUV (ERD BLAZER). A Nissan SUV (ERD NISSAN) was used in Norway in 1998, and when the Blazer was not available at North Bay a Ford pickup truck (ERD NB) was used.

Eighteen data sets were used in the analysis. These are summarized in Table 1.

Data Set	ERD VEHICLE	IMAG/IRV	Year	Location	N
1	ERD NB	.95 IMAG	1998	North Bay	82
2	ERD NISSAN	.95 IMAG	1998	Oslo	169
3	ERD BLAZER	.95 IMAG	1999	North Bay	244
4	ERD BLAZER	.95 IMAG	1999	Gwinn	169
5	ERD BLAZER	.95 IMAG	1999	Oslo	339
6	ERD BLAZER	.95 IMAG	1999	All Locations	752
7	ERD BLAZER	.95 IMAG	2000	North Bay	109
8	ERD BLAZER	IRV	2000	North Bay	178
9	ERD BLAZER	IRV	2000	Munich	205
10	ERD BLAZER	IRV	2000	Both Locations	383
11	ERD BLAZER	IRV	2001	North Bay	311
12	ERD BLAZER	.95 IMAG	2001	Erding	215
13	ERD NB	IRV	2001	North Bay (2)	48
		SLIP STUDY			
14	ERD BLAZER	IRV (15%)	2001	North Bay	311
15	ERD BLAZER	IRV (30%)	2001	North Bay	62
16	ERD BLAZER	IRV (60%)	2001	North Bay	45
17	ERD BLAZER	IRV (90%)	2001	North Bay	51
		COMBINATION OF DATA SETS			
18	ERD BLAZER	IRV/IMAG	Combined #7, 8, 11 & 12		813
19	ERD BLAZER	IRV/IMAG	#18 - Outliers Removed		692
20	ERD NB	IRV/IMAG	Combined #1 and #13		140

Table 1. The Data Sets

Note that Data Set #6 is a combination of #3, 4 and 5; Data Set #10 is a combination of #8 and 9; #14 and #11 are the same; #18 is a combination of #7, 8, 11, and 12; and #19 is the Data Set #18 with the outliers removed.

When the IMAG data was used, it was multiplied by 0.95 to predict the value that would have been obtained if the IRV had been used.

4. ANALYSIS

A linear correlation in the form:

$$IMAG/IRV = a + b \text{ ERD VEHICLE} \quad (1)$$

where IMAG/IRV is either the value reported by the IRV or its prediction when the IMAG is used by multiplying the IMAG value by 0.95. The results are given in Table 2 and plots of the data are given in Figures 1 through 20.

Data Set	a	b	R^2	n
1	0.080	0.852	0.433	82
2	0.059	0.631	0.673	169
3	0.131	0.481	0.435	244
4	0.158	0.564	0.454	169
5	0.113	0.592	0.272	339
6	0.116	0.622	0.426	752
7	0.132	0.847	0.708	109
8	0.126	0.847	0.685	178
9	0.230	0.177	0.058	205
10	0.191	0.363	0.242	383
11	0.085	0.873	0.710	311
12	0.098	0.747	0.772	215
13	0.055	0.953	0.928	48
SLIP STUDY				
14	0.085	0.873	0.710	311
15	0.055	0.997	0.434	62
16	0.094	0.462	0.296	45
17	0.091	0.436	0.614	51
COMBINATION OF DATA SETS				
18	0.115	0.773	0.719	813
19	0.115	0.765	0.849	692
20	0.068	0.923	0.918	130

Table 2. Regression Analysis Results

Correlation coefficients (R^2) of less than 0.5 are considered very poor. In some of the data sets the reason is the variability of the test surface and the locations where the ERD operator chose to perform the measurement. This is particularly true in Munich 2000 (Data Set #9) and also, to a lesser extent, in Oslo 1999 (Data Set #5).

The highest correlation coefficient (R^2 = 0.928) was obtained in Data Set #13, where the Ford pickup truck (ERD NB) was used. Reference to Figure 13 can explain this result as there are three clusters of data: one for ice, one for wet snow, and one for bare pavement. These measurements were made in North Bay in late March 2001 when the temperatures were moderate during the day. The opposite is true for the ERD NB in Data Set #1 as can be seen in Figure 1, where there were no bare pavement data and the data are for ice and compacted snow. However, when the data from 1998 and 2001 were combined (Data Set #20), the resulting correlation with 130 data points was also very good:

$$IRV = 0.068 + 0.923 \text{ ERD NB} \qquad (2)$$

with a correlation coefficient (R^2) of 0.918.

In the Slip Study it can be seen that the higher slip ratios did not improve the correlation. However, it must be noted that the 15% slip data (the normal slip ratio for the IRV) is a much larger data set than the higher slip data sets. At 30% and 60% slip the correlation is poor, but at 90% the correlation is improved. These results confirm the earlier findings that, for ice and compacted snow surfaces, the slip speed is not a significant parameter.

The most consistent regressions for the ERD BLAZER and the IMAG or IRV are Data Sets #7, 8, 11 and 12. This suggested combining these sets into one very large data set of 813 points. The standard deviation of the error of prediction by the regression was 0.082 for this data set. Errors greater than 0.10 (1.22 standard deviations) were considered to be outliers and these were removed for Data Set #19, resulting in a data set of 692 points. This represents the best relationship between the ERD BLAZER and the IRV that can be obtained from the available data:

$$IRV = 0.115 + 0.765 \text{ ERD BLAZER} \qquad (3)$$

with a correlation coefficient (R^2) of 0.849.

The ERD NISSAN in Norway had a poor correlation with 169 data points (Data Set #2):

$$IRV = 0.059+0.631 \text{ ERD NISSAN} \qquad (4)$$

with a correlation coefficient (R^2) of only 0.673.

5. CONCLUSIONS AND RECOMMENDATIONS

It must be recognized that the differences in the principle of operation of the ERD and the IMAG and IRV will result in weak correlation of their data, particularly when the surfaces are variable. The IMAG and IRV average the conditions along the surfaces, while the ERD measures spots chosen by the operator. Also, since the contact pressure of the ERD is much higher than the ERD, some types of conditions found on winter surfaces that are fragile will be more easily penetrated by the ERD.

An additional reason for the poor correlation between the IRV and the ERD could be the fact that ERD tests were conducted in conditions that would not normally be allowed for the ERD (for example, ERD tests are not made on slush, loose snow exceeding 25 mm, or on water exceeding 1 mm on a bare pavement surface). If tests with these surface conditions were excluded, perhaps the correlations would improve. For example, for the Munich 2000 tests, most of the test surfaces were slushy snow, resulting in very poor correlation between the IRV and the ERD.

The data sets where the surface was relatively uniform and where the range of friction was large, ranging from ice through compacted snow to bare and wet, the results are fairly good.

Additional data are needed to determine the variability of the ERD with operator techniques and vehicle characteristics. Investigations of the effect of increased contact pressure on the IRV should be carried out and compared with aircraft performance.

The relationship between the three different configurations of the ERD and IMAG/IRV were found to be different.

Figure 1. ERD NB vs. IRV(IMAG): North Bay 1998

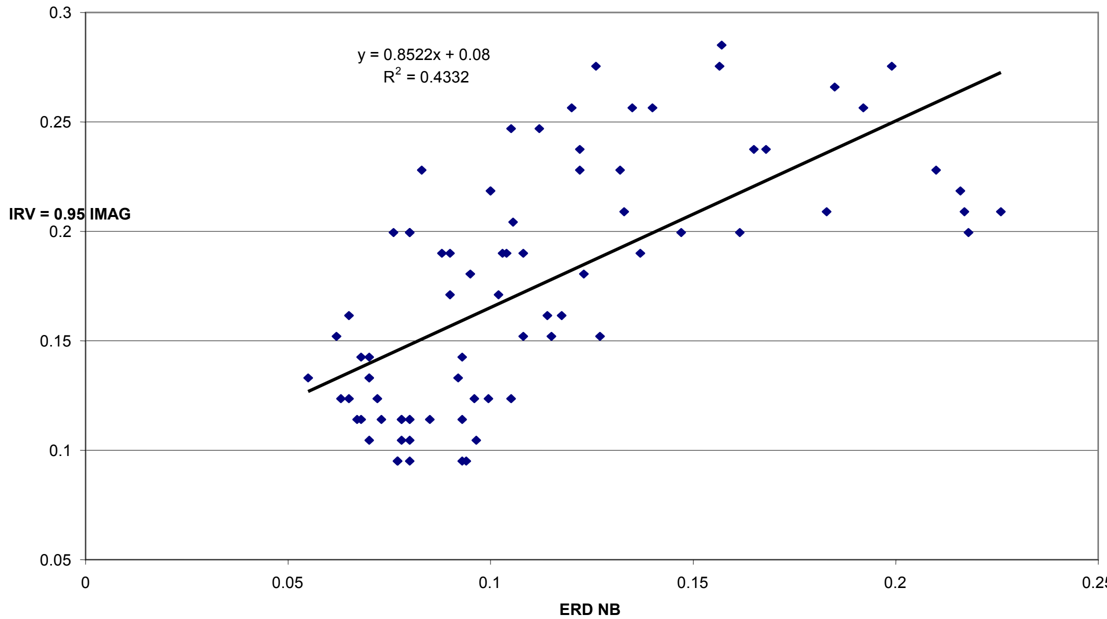

Figure 2. ERD Nissan vs. IRV(IMAG): Oslo 1998

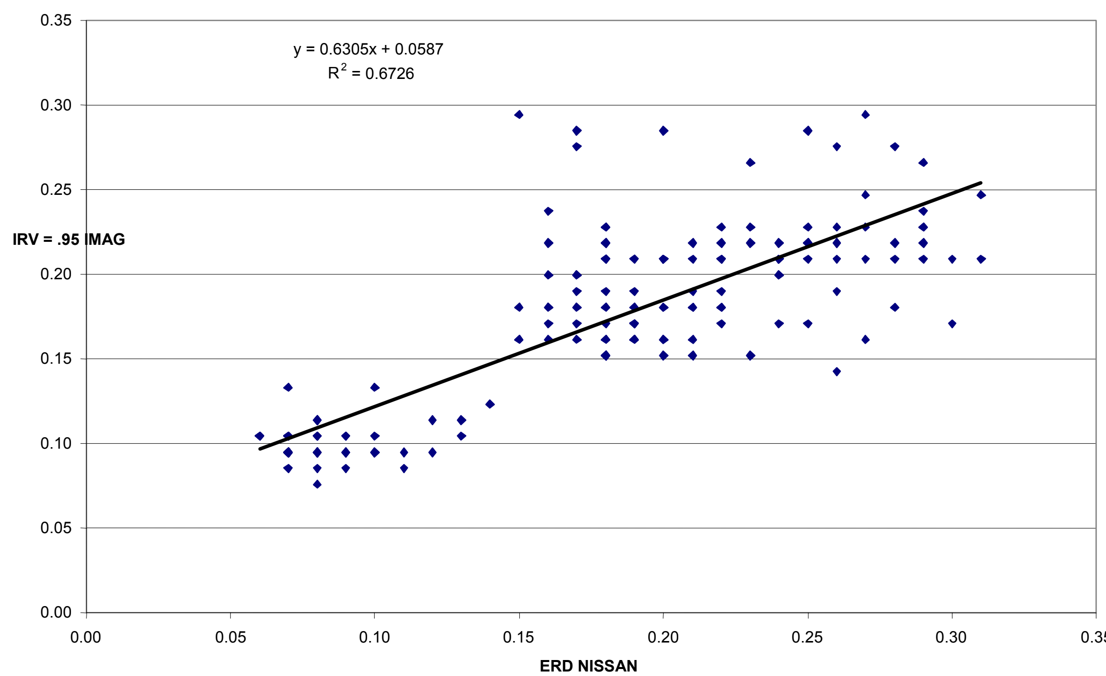

Figure 3. ERD vs. IRV(IMAG): North Bay 1999

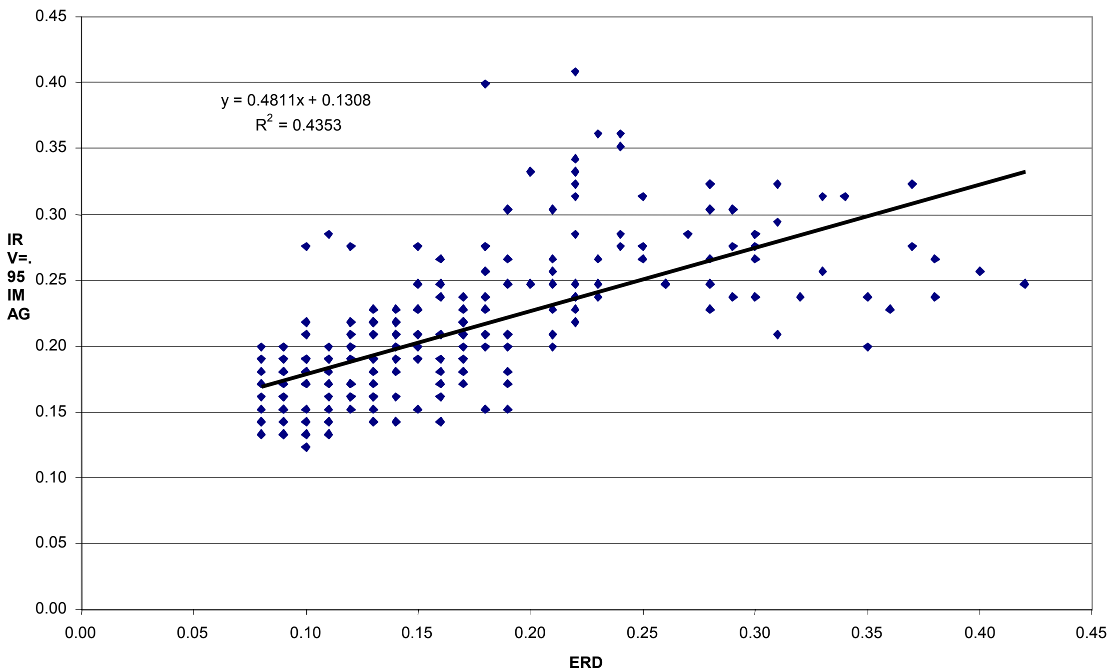

Figure 4. ERD vs. IRV(IMAG): Gwinn 1999

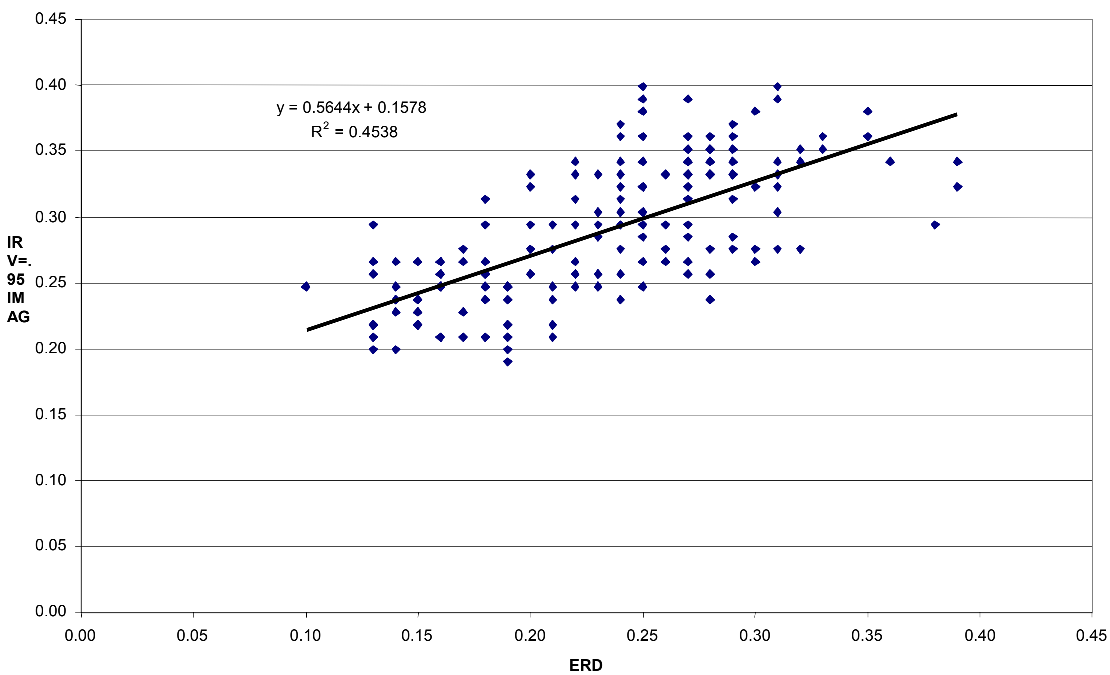

Figure 5. ERD vs. IRV(IMAG): Oslo 1999

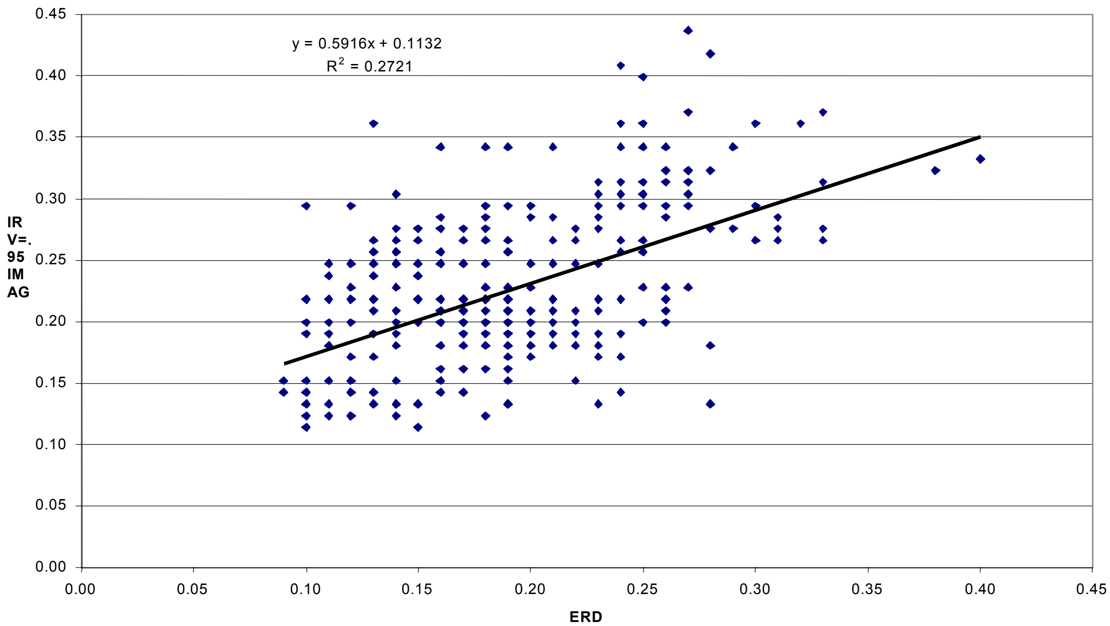

Figure 6. ERD vs. IRV(IMAG): All Locations 1999

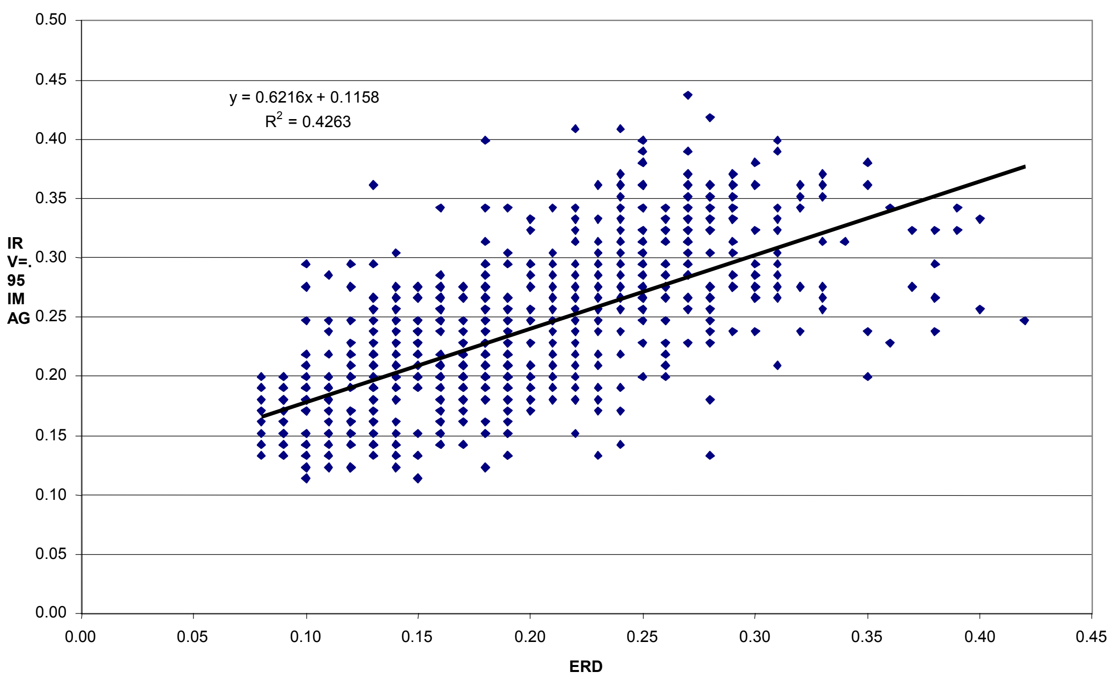

Figure 7. ERD vs. IRV(IMAG): North Bay 2000

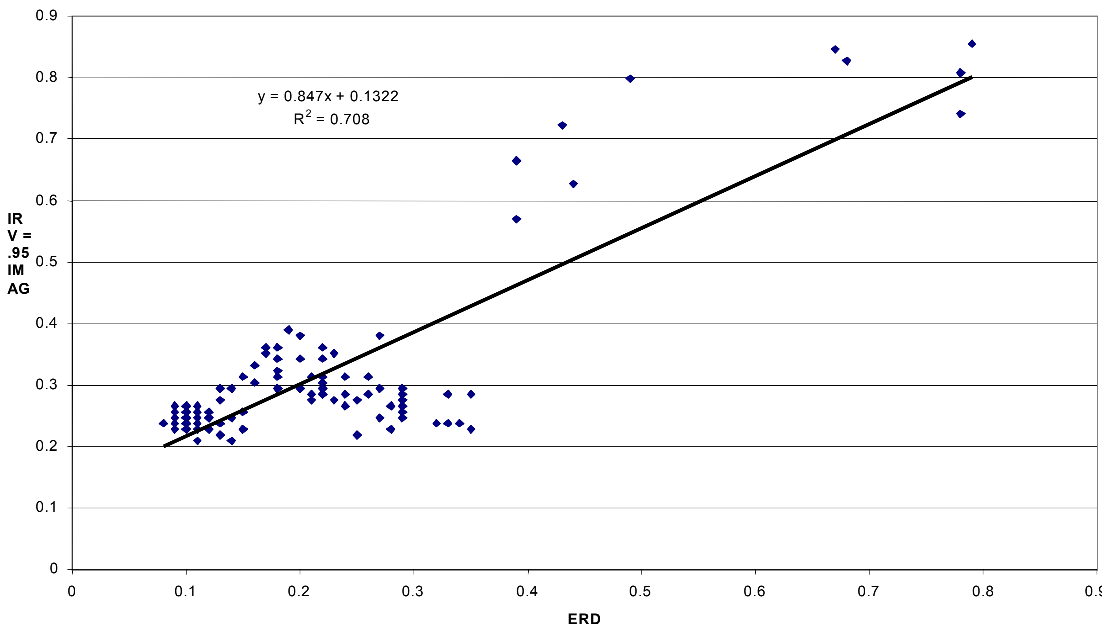

Figure 8. ERD vs. IRV: North Bay 2000

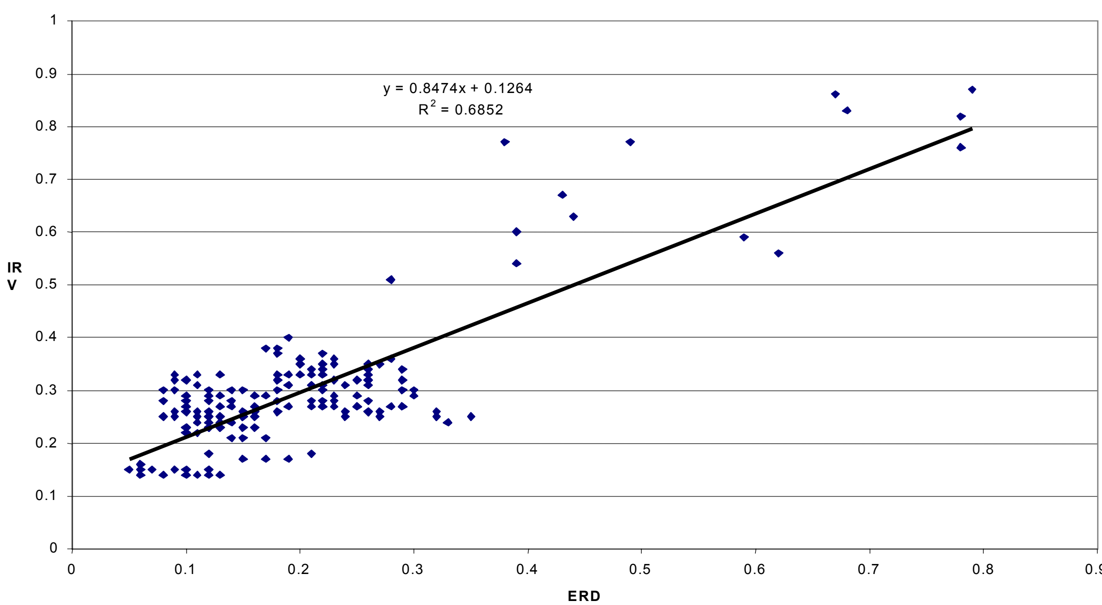

Figure 9. ERD vs. IRV: Munich 2000

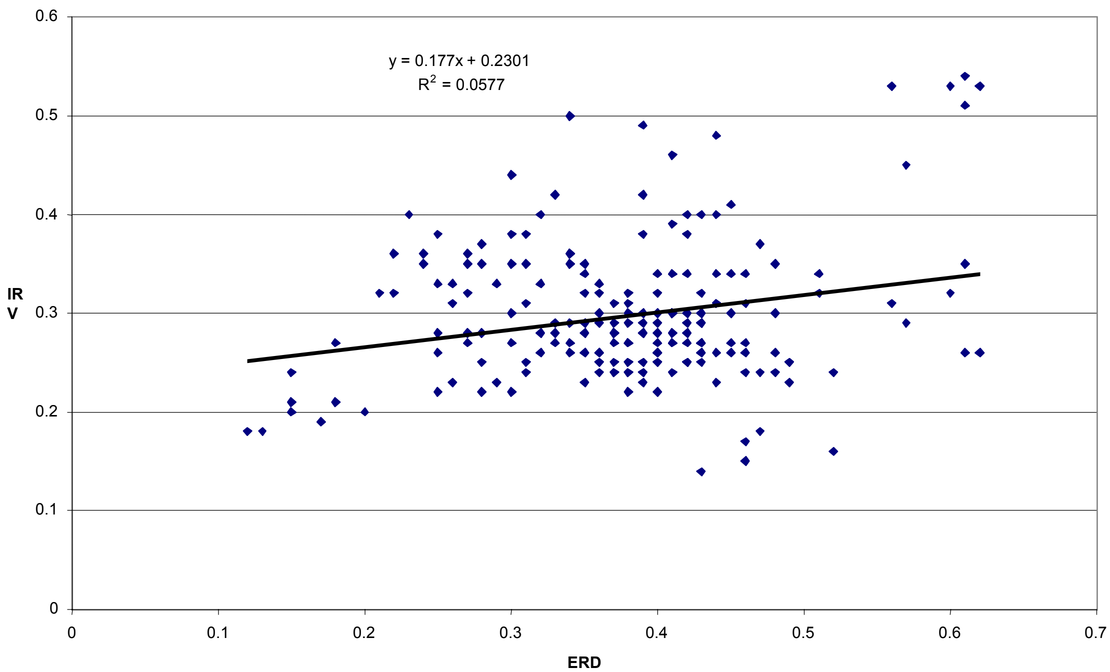

Figure 10. ERD vs. IRV Both Locations 2000

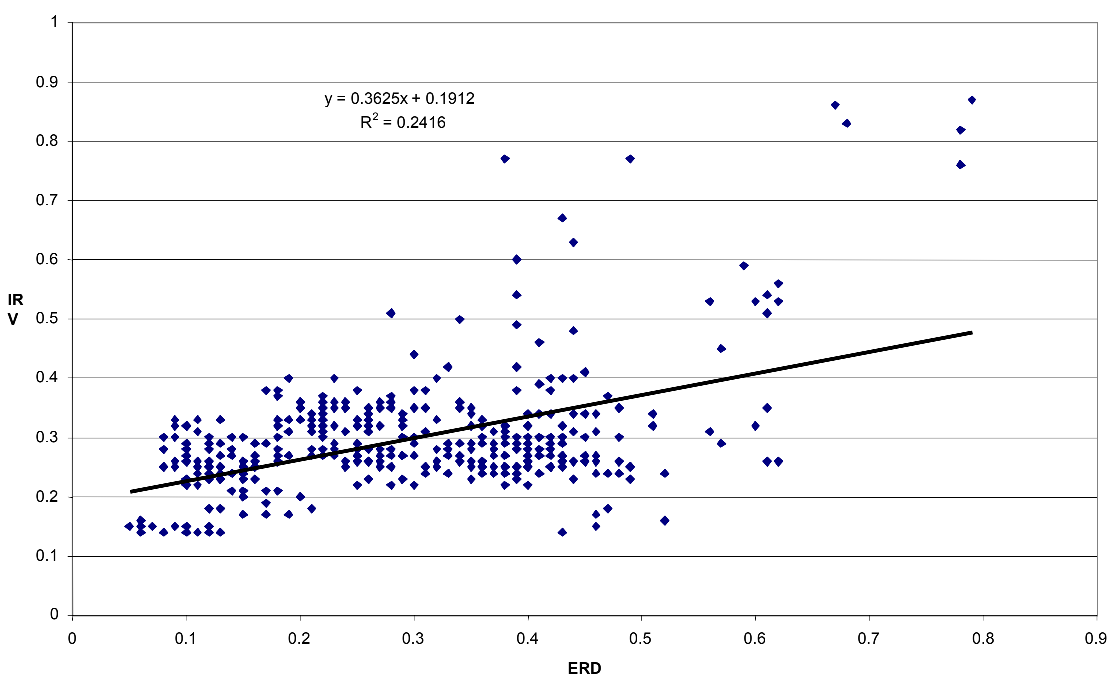

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Figure 11. ERD vs. IRV: North Bay 2001

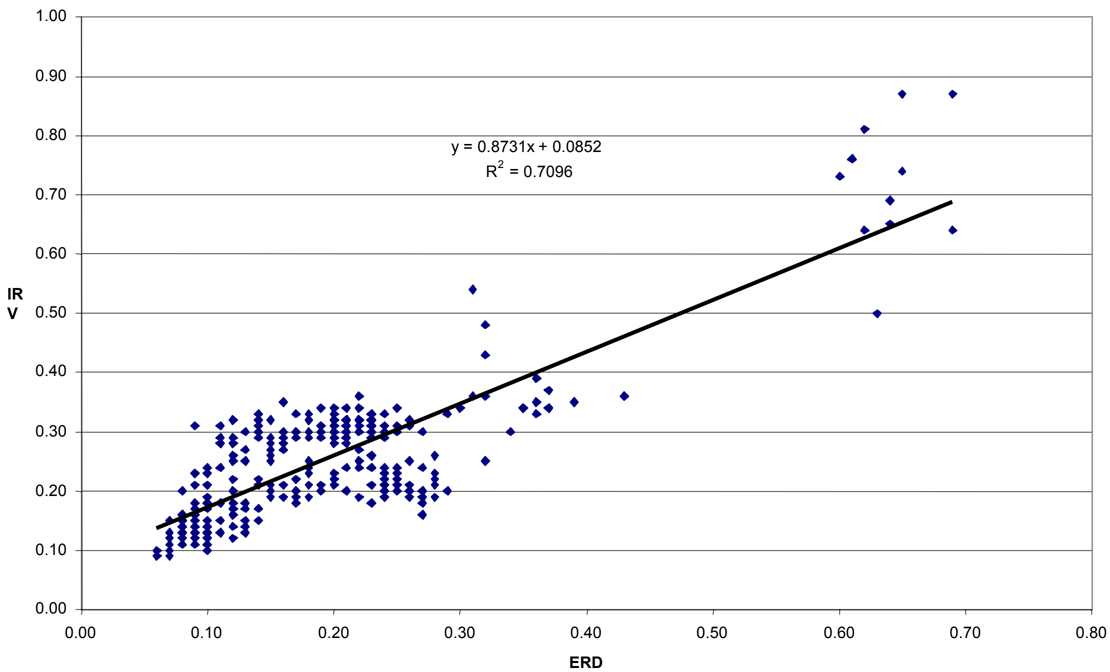


Figure 12. ERD vs. IRV(IMAG): Erding 2001

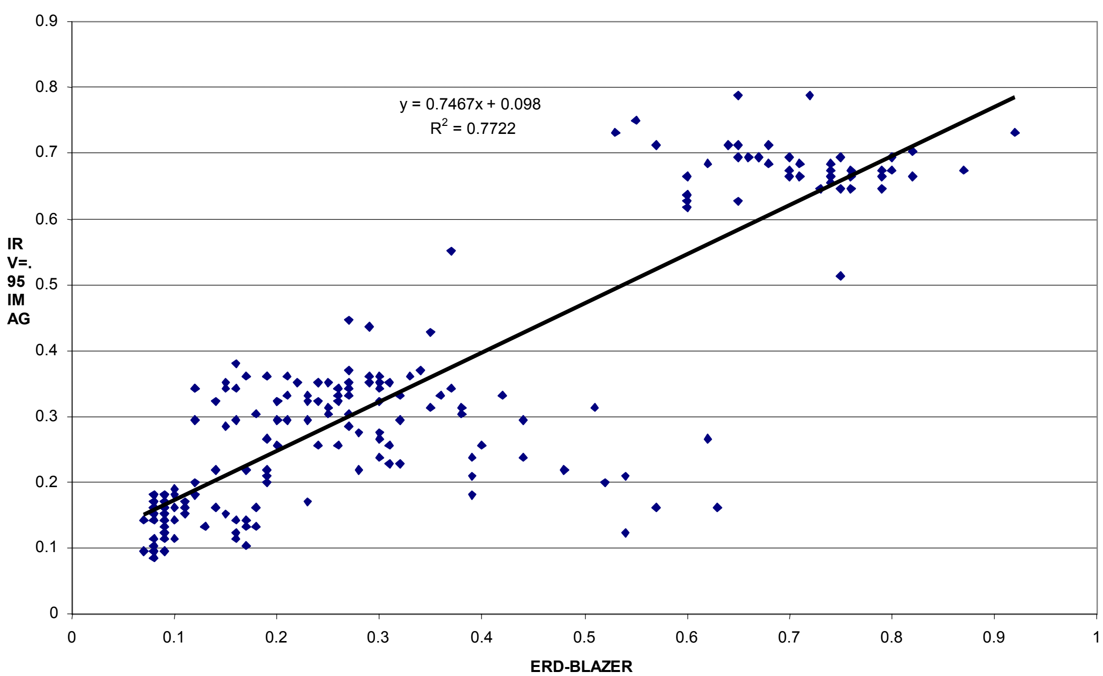


Figure 13. ERD NB vs. IRV: North Bay 2001

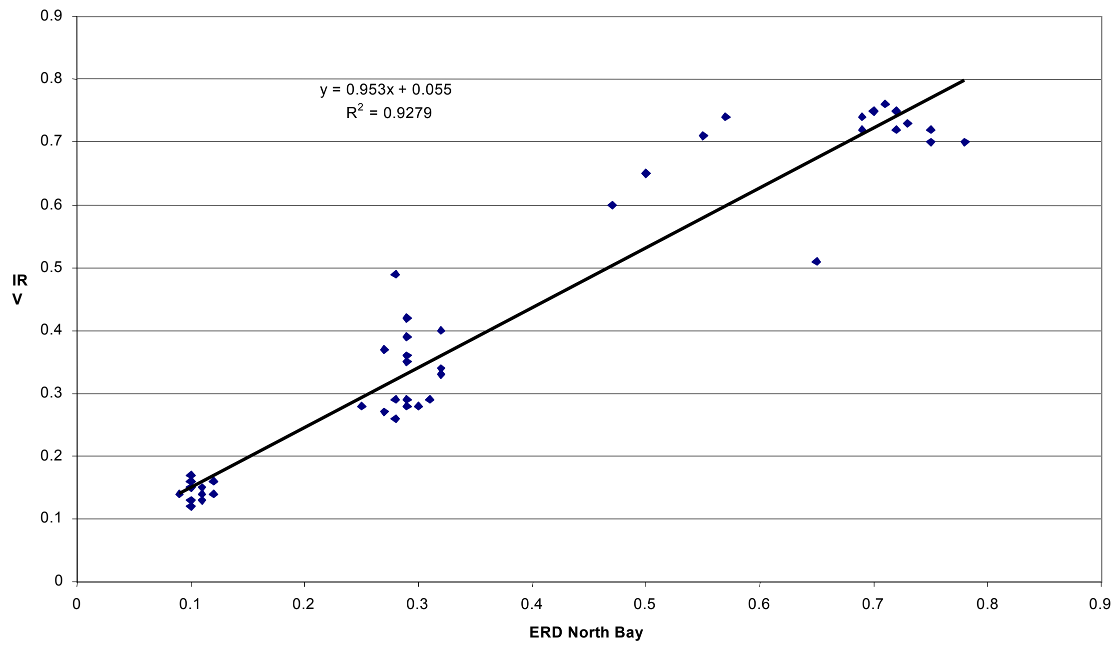


Figure 14. ERD vs. IRV (15%): North Bay 2001

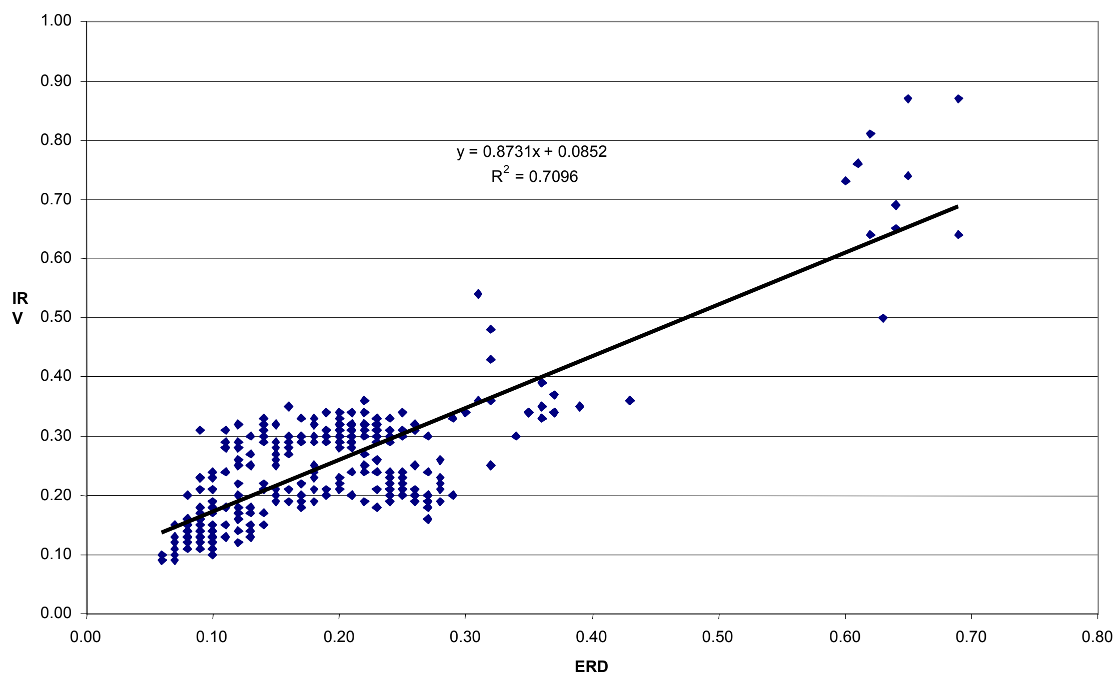


Figure 15. ERD vs. IRV (30%): North Bay 2001

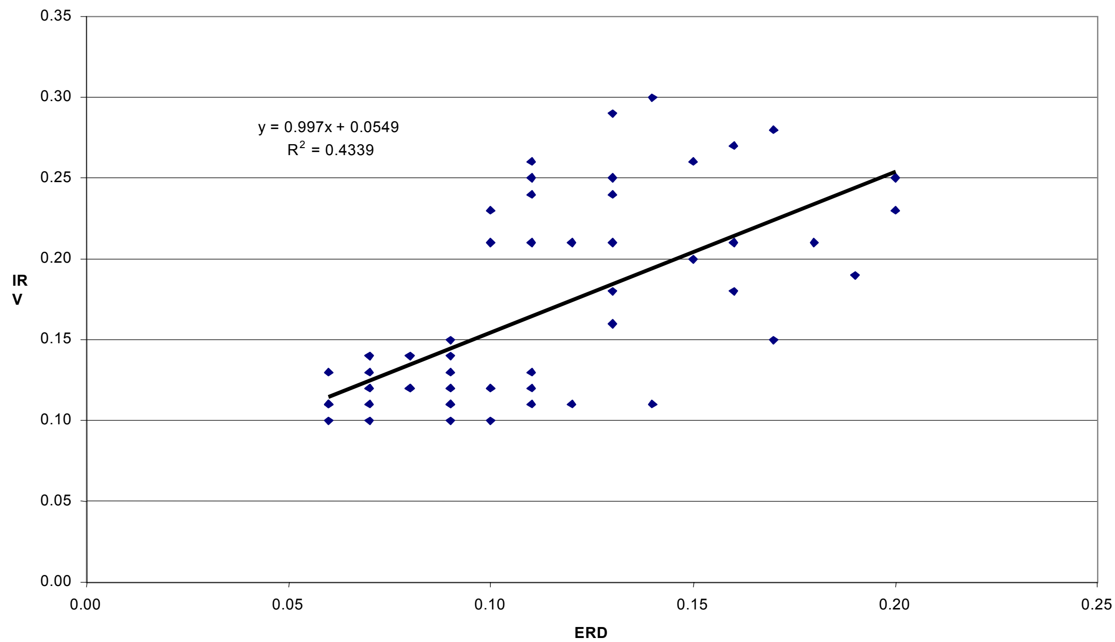


Figure 16. ERD vs. IRV (60%): North Bay 2001

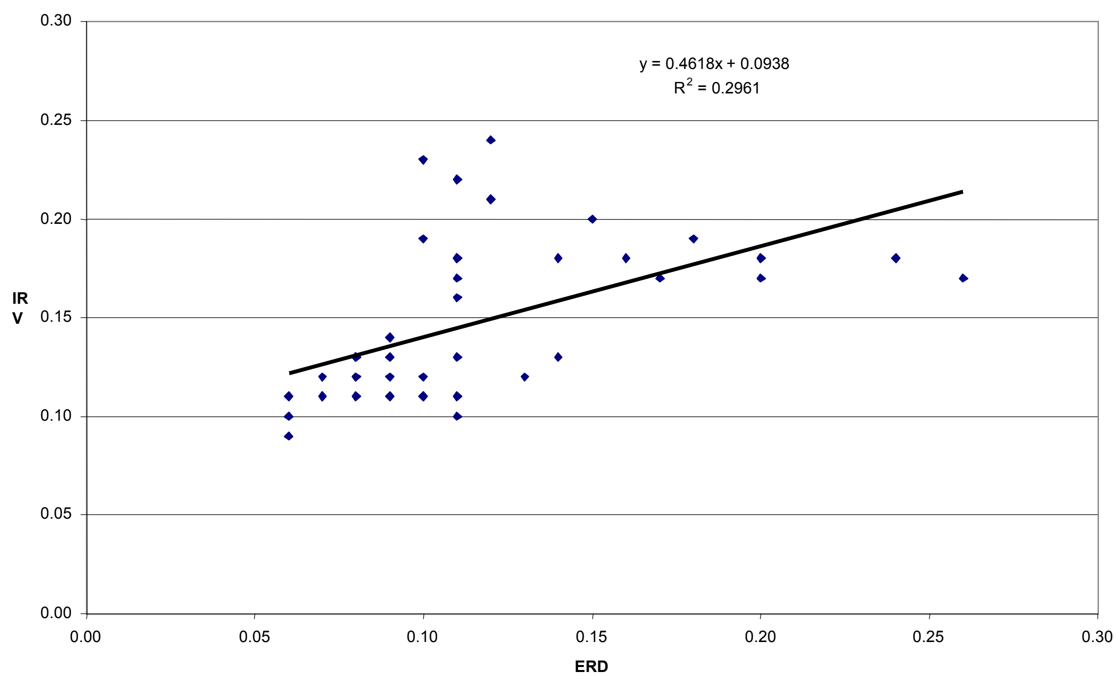


Figure 17. ERD vs. IRV (90%): North Bay 2001

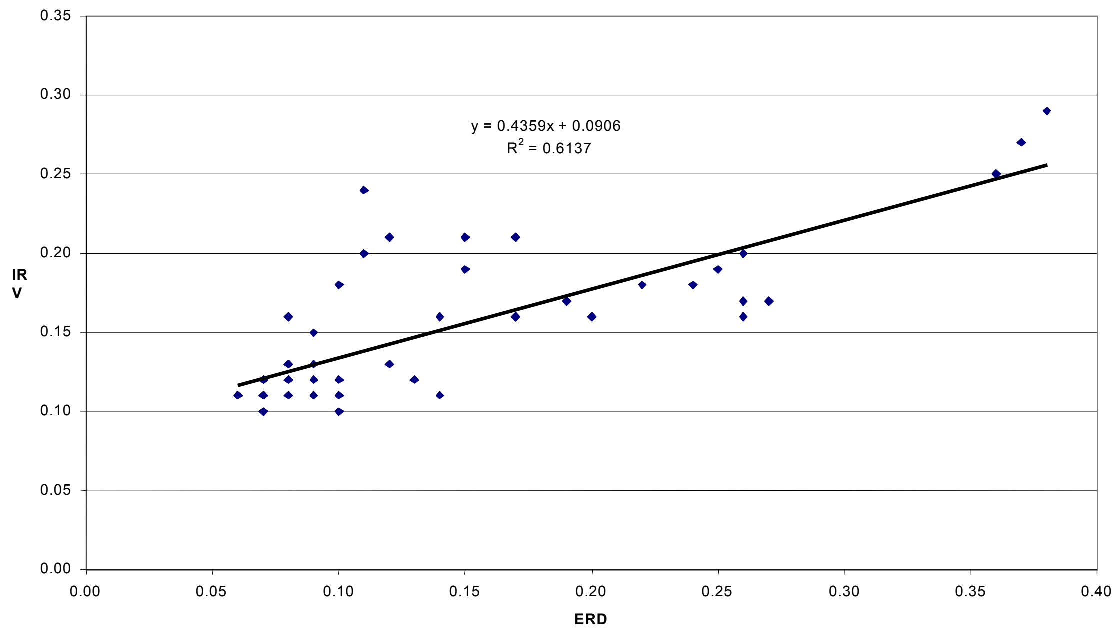


Figure 18. ERD vs. IRV/IMAG for Combined Data Sets

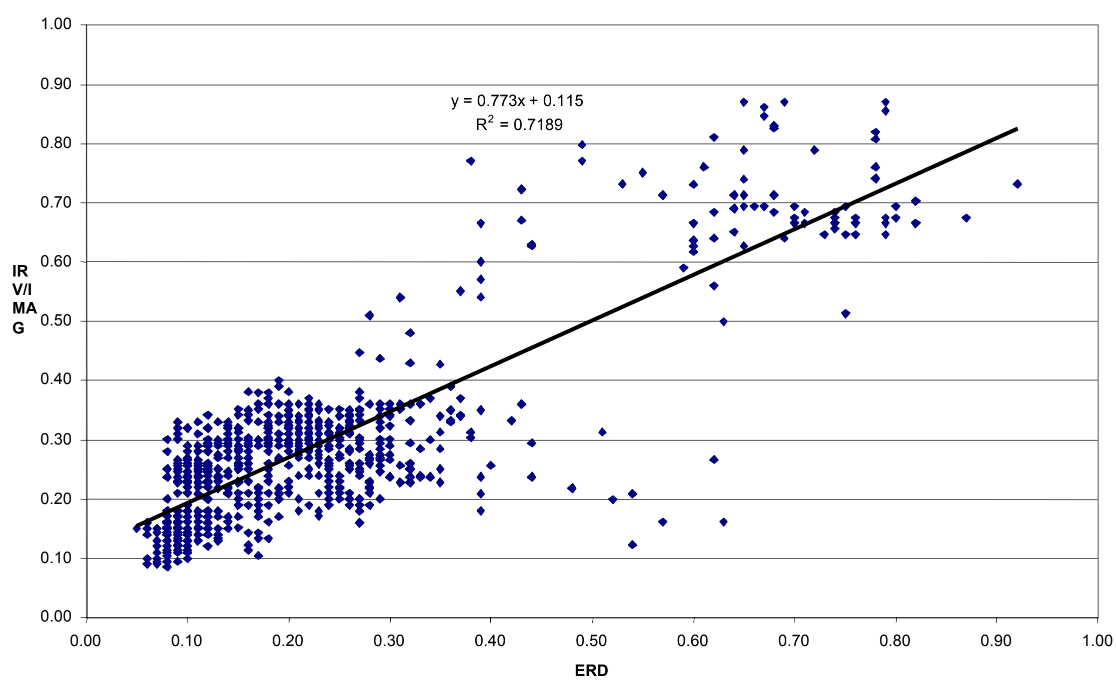


Figure 19. ERD vs. IRV/IMAG for Combined Sets with Outliers Removed

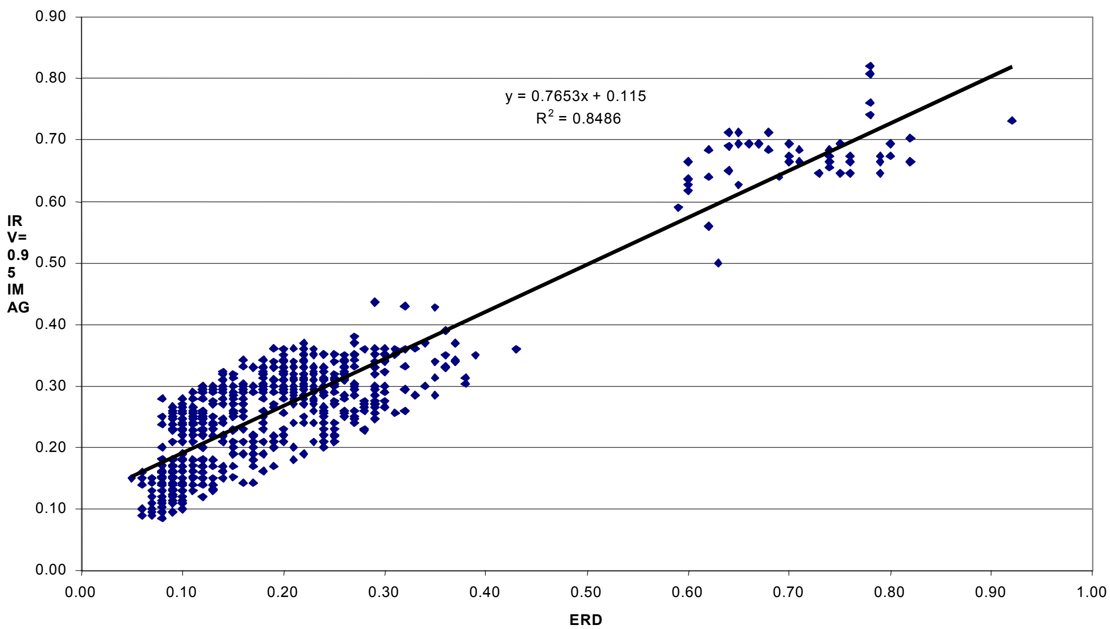
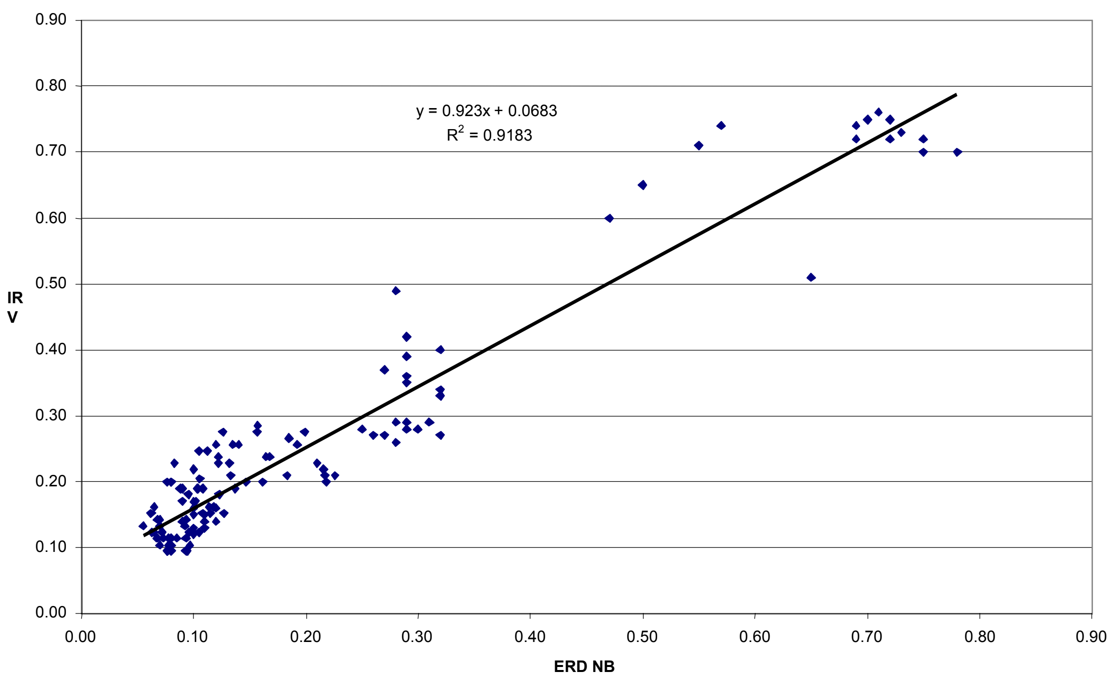


Figure 20. ERD NB vs. IRV: North Bay 1998 & 2001



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2. Standard Practice for Calculating the International Runway Friction Index, ASTM Standard E-2100, Annual Book of ASTM Standards Volume 04.03, Philadelphia, PA, 2001
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