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# An Evaluation of the NASA/GSFC Barnes Field Spectral Reflectometer Model 14-758, Using Signal/Noise as a Measure of Utility

Robin Bell and Mark L. Labovitz

JULY 1982



National Aeronautics and
Space Administration

**Goddard Space Flight Center**
Greenbelt, Maryland 20771

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Geophysics Branch, 922

## ABSTRACT

A Barnes field spectral reflectometer which collected information in 373 channels covering the region from 0.4 to 2.5 micrometers ($\mu$m) was assessed for signal utility. A band was judged unsatisfactory if the probability was 0.1 or greater that its signal to noise ratio was less than eight to one. For each of the bands the probability of a noisy observation was estimated under a binomial assumption from a set of field crop spectra covering an entire growing season. A 95% confidence interval was calculated about each estimate and bands whose lower confidence limits were greater than 0.1 were judged unacceptable. As a result, 283 channels were deemed statistically satisfactory. Excluded channels correspond to portions of the electromagnetic spectrum (EMS) where high atmospheric absorption and filter wheel overlap occur. In addition, the analyses uncovered intervals of unsatisfactory detection capability within the blue, red and far infrared regions of vegetation spectra. From the results of the analysis it was recommended that 90 channels monitored by the instrument under consideration be eliminated from future studies. These channels are tabulated and discussed. An appendix of the signal to noise ratio averages and standard deviations for each channel is included.

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# AN EVALUATION OF THE NASA/GSFC BARNES FIELD SPECTRAL REFLECTOMETER MODEL 14-758, USING SIGNAL/NOISE AS A MEASURE OF UTILITY

## INTRODUCTION

The continual appearance of new radiometers and reflectometers occurring with rapid changes in microprocessors and related electronics produces a pressure on the researcher to get the instrument "into the field" and collecting data. However great this pressure, it is important that performance of any instrument be verified prior to substantive data collection. Unknown performance idiosyncrasies could potentially invalidate conclusions drawn from analyses of data collected with such unexamined equipment and thereby waste valuable resources.

We examine in this study the GSFC Barnes Model 14-758 field spectral reflectometer. Specifically, a value of the noise level synchronously recorded with reflectance for each channel monitored is assessed. In this study the instrument's utility is defined as the strength of the signal at each channel for each spectral interval. We propose a method to assess utility, and then apply the method in an analysis wherein utility is defined within the overall field measurement setting, and where the field setting is the measurement of agricultural crops.

## FIELD MEASUREMENT ENVIRONMENT

The target-instrument system may be compartmentalized into components potentially causing variation during the evaluation of a particular field instrument. These sources of potential variation can be conveniently grouped as sources (1) internal to the instrumentation, (2) external to the instrumentation, and (3) arising from the interactions of internal and external sources. We will briefly describe each of these groups, starting with the latter.

The interaction of internal and external sources is mentioned largely for completeness, and represents the fact that changes in components of subsystems often do not have strictly independent and additive effects upon the output of the system. For example, an interaction source of variation would be present if the output from the sensing system (be it digital counts or radiance) was among other things, not only a function of the solar flux and type of detector, but also a function of a specific combination of these two factors.

Measurements in the field are subject to meteorological variation such as cloud cover and precipitation. Where the latter can result in great variation in observations made on successive days, cloud cover can contribute to data variation on the time scale of seconds. Other sources of variation external to the instrument result from changes in the target (field plot). These can also be a result of meteorological changes, such as changes in the target structure related to winds (short term) or can result from a progressive change in a target over a growing season (long term). The solar illumination flux, with energy varying over wavelength, must also be taken in consideration.

Internal sources of variation include scan time, spectral resolution, calibration of the instrument, detector type and specific wavelength interval (Holmes, 1970).

The internal sources of variation combine to determine the sensitivity of an instrument. The sensitivity is largely defined by spectral resolution and detector type of the instrument in question. The spectral resolution is linked to the filter system used. Various methods exist for isolating desired portions of the electromagnetic spectrum (EMS). Whether a prism or interference filters are used to selectively eliminate certain portions of the EMS, it is important to understand the specifications and thereby determine how discrete the spectral elements of the instrument truly are. Once isolated, the desired spectral range is passed on to the detector. The detector is the pivot point of any radiometer, as other design specifications, such as cooling and effective spectral coverage must accommodate the detector used (Holter, 1970).

## EXPERIMENT

In this experiment we evaluate a new field radiometer specifically for sensitivity. Using the output of a sensing system, sensitivity in this study is viewed as the utility of the signal from a spectral channel, and is operationally defined below as a function of the signal to noise ratio (S/N). The instrument, a Barnes Model 14–758 field spectral reflectometer, is described in the following section. The experiment analyzed observations from the field environment in which the instrument was used, so the targets were field crops – corn, wheat and soybean plots – located on the USDA's Beltsville Agricultural Research Center, Beltsville, MD. Since the experiment was not designed, i.e., we were working with previously collected data, the sources of unwanted variation were treated by holding them constant. This was accomplished by only using data collected under similar conditions; sunny, relatively still days between 10 a.m. and 2 p.m. solar time, with the instrument mounted on a cherry picker, nadir pointing and seven meters above the target. A white reflectance standard was used to calibrate the readings. (The instrument offers a sky-tube as optional reference.) In short, the study was designed to examine the instrument's reliability with respect to obtaining what the authors considered a useable signal over the various wavelengths monitored.

## INSTRUMENTATION

The Barnes Radiometer is a self-calibrating spectral scanner with spectral resolution on the order of three percent of the wavelength (Barnes Engineering Company, 1976). It is designed to operate over a range of 0.4 to 2.5 $\mu$m. Incoming energy for shorter and longer wavelengths is extremely attenuated by atmospheric effects in addition to the initially lessened incoming energy outside of this interval (Figure 1). Specifically in the Barnes instrument, differing wavelength intervals over a 0.3905–2.5355 $\mu$m segment of the EMS are effected by a rotating, continuously variable filter. This filter which consists of three segments, has 373 filter positions of varying band width. Incoming energy is separated by a rotating chopper blade that revolves once every 200 milliseconds so that the reference and the sample are each viewed five times within one second. The resulting 5 Hz pulses are recorded at a 400 Hz rate to maintain at approximately less than one percent any confusion between sample and reference views. The filter position stepper motor is driven at the rate of one step every 200 milliseconds so that a new filter position is reached synchronously with the 5 Hz chopper. This filtered energy is focused upon a lead sulfide detector, cooled to 0° C (Barnes

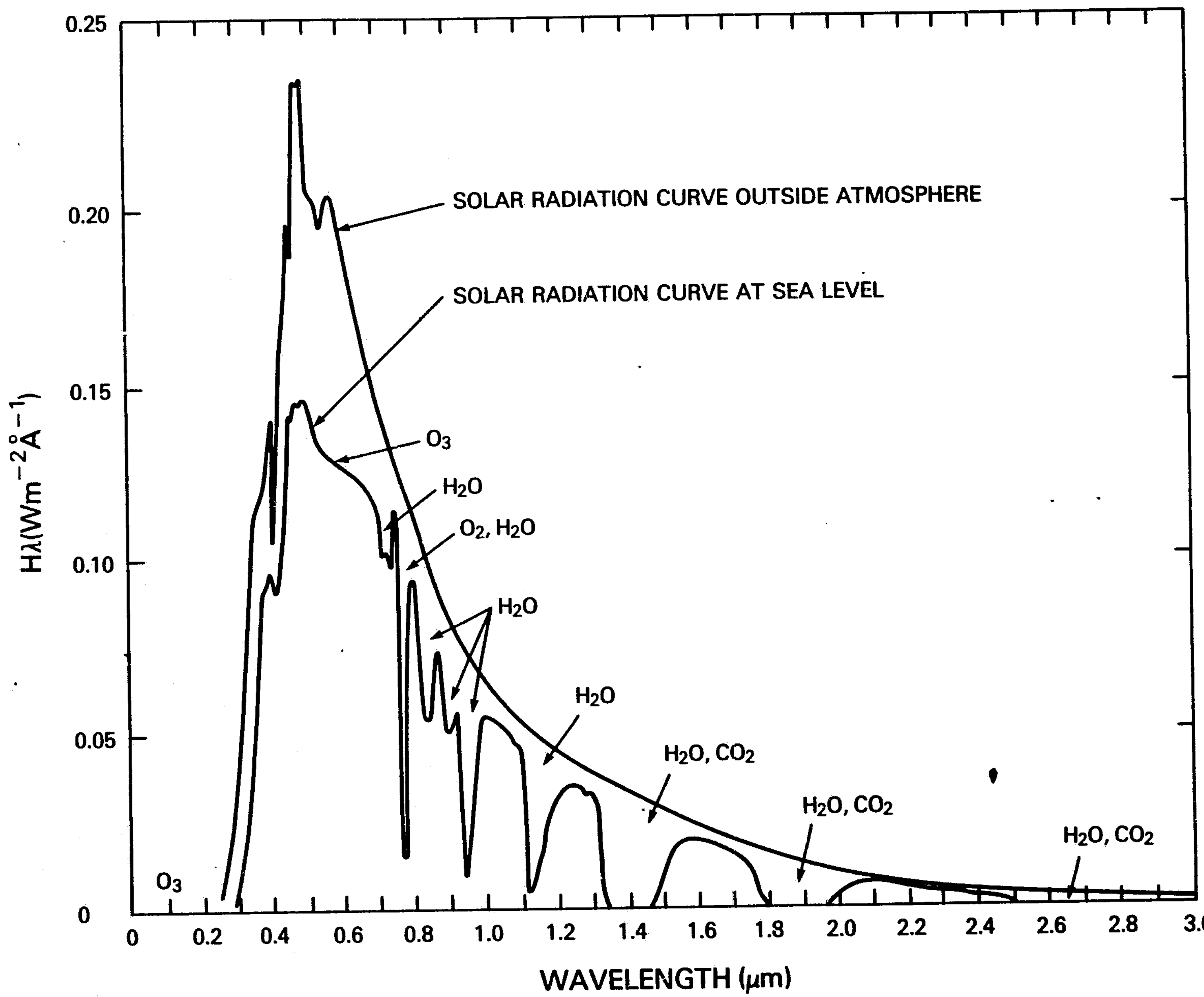



Figure 1. Atmospheric Absorption of Solar Flux (after Valley, 1965)

Engineering Company, 1976). The wavelengths monitored are separated into approximately four nanometer intervals for the first two segments, and 13 nanometer intervals for the third filter wheel segment (Table 1). Specified wavelengths are the midpoints of the filter positions and there is considerable overlap. At the two points in the spectrum monitored where there is a filter wheel segment change, there is overlap in spectral coverage. These regions are from 0.6523 $\mu$m to 0.7177 $\mu$m, and from 1.3744 $\mu$m to 1.4145 $\mu$m.

## FORMAL ANALYSIS SETTING

### Definition of Sensitivity

As stated previously, the purpose of this work is to determine the utility of the 373 channels of the Barnes instrument by assessing channel sensitivity. Sensitivity is defined here as a function of the S/N monitor of useable signal, which was recorded by the reflectometer at the same time as the reflectance values. As the recorded S/N value was the variable of choice for this analysis, and the authors were unable to determine how the instrument recorded variable was derived, various regression models were employed in an attempt to estimate the strength and form of any relationship between instrument recorded S/N data and a more generally accepted method of computation. From the original data (defined below, refer to Data section), a S/N data set was calculated using

$$\overline{Y}_{\text{reflectance } \lambda}/\sigma^2_{\text{reflectance } \lambda} = S/N_\lambda$$

where $\overline{Y}_{\text{reflectance } \lambda}$ = mean of the reflectance values for wavelength $\lambda$

and $\sigma^{2*}_{\text{reflectance } \lambda}$ = variance of the reflectance values for wavelength $\lambda$.

The $S/N_\lambda$ value was used as the dependent variable in the regressions, with the Barnes recorded S/N for the respective wavelengths as the predictor variable. One hundred and twenty average reflectance values and their respective average variances were used in the models. Channels corresponded to the lowest through the highest machine recorded S/N values. From plots of the calculated S/N against the Barnes recorded S/N and from residual plots from linear models, it was determined that a non-linear asymptotic curve best described the relationship between the two S/N variables (Figure 2).

Table 1

Barnes Filter Positions and Their Respective Mid Point Target Wavelengths
(in Nanometers)

Channels Performing Unsatisfactorily (S/N <8) Asterisked
Filter Segment Spectral Overlap α

| Filter Position | Mid Point λ | Filter Position | Mid Point λ | Filter Position | Mid Point λ | |
|---|---|---|---|---|---|---|
| 5* | 390.5 | 45 | 535.9 | 85α | 681.4 | |
| 6* | 394.1 | 46 | 539.6 | 86*α | 685.0 | |
| 7* | 397.8 | 47 | 543.2 | 87*α | 688.6 | |
| 8* | 401.4 | 48 | 546.8 | 88α | 692.9 | |
| 9* | 405.0 | 49 | 550.5 | 89α | 695.9 | |
| 10* | 408.7 | 50 | 554.1 | 90α | 699.5 | |
| 11* | 412.3 | 51 | 557.7 | 91α | 703.2 | |
| 12* | 415.9 | 52 | 561.4 | 92α | 706.8 | |
| 13* | 419.6 | 53 | 565.0 | 93α | 710.4 | Filter |
| 14* | 423.2 | 54 | 568.6 | 94α | 714.1 | Segment |
| 15* | 426.8 | 55 | 572.3 | 95α | 717.7 | 1 |
| 16* | 430.5 | 56 | 575.9 | 105*α | 653.5 | Filter |
| 17* | 434.1 | 57 | 579.6 | 106*α | 657.5 | Segment |
| 18* | 437.7 | 58 | 583.2 | 107*α | 661.5 | 2 |
| 19* | 441.4 | 59 | 586.8 | 108α | 665.5 | |
| 20* | 445.0 | 60 | 590.5 | 109α | 669.5 | |
| 21* | 448.7 | 61 | 594.1 | 110α | 673.6 | |
| 22* | 452.3 | 62 | 597.7 | 111α | 677.6 | |
| 23* | 455.9 | 63 | 601.9 | 112α | 681.6 | |
| 24* | 459.6 | 64 | 605.0 | 113α | 685.6 | |
| 25* | 463.2 | 65 | 608.6 | 114α | 689.6 | |
| 26* | 466.8 | 66 | 612.3 | 115α | 693.6 | |
| 27* | 470.5 | 67 | 615.9 | 116α | 697.6 | |
| 28* | 474.1 | 68 | 619.5 | 117α | 701.6 | |
| 29* | 477.7 | 69 | 623.2 | 118α | 705.6 | |
| 30* | 481.4 | 70 | 626.8 | 119α | 709.6 | |
| 31* | 485.0 | 71 | 630.5 | 120α | 713.6 | |
| 32* | 488.7 | 72 | 634.1 | 121α | 717.6 | |
| 33* | 492.3 | 73 | 637.7 | 122 | 721.6 | |
| 34* | 495.9 | 74 | 641.4 | 123 | 725.6 | |
| 35* | 499.6 | 75 | 645.0 | 124 | 729.6 | |
| 36* | 503.2 | 76 | 648.6 | 125 | 733.6 | |
| 37 | 506.8 | 77*α | 652.3 | 126 | 737.6 | |
| 38* | 510.5 | 78*α | 655.9 | 127 | 741.6 | |
| 39 | 514.1 | 79*α | 659.5 | 128 | 745.6 | |
| 40 | 517.7 | 80*α | 663.2 | 129 | 749.6 | |
| 41 | 521.4 | 81*α | 666.8 | 130 | 753.7 | |
| 42 | 528.6 | 82*α | 670.5 | 131 | 757.7 | |
| 43 | 528.6 | 83*α | 674.1 | 132 | 761.7 | |
| 44 | 532.3 | 84α | 677.7 | 133 | 765.7 | |

Table 1 (continued)

Channels Performing Unsatisfactorily (S/N <8) Asterisked
Filter Segment Spectral Overlap $\alpha$

| Filter Position | Mid Point $\lambda$ | Filter Position | Mid Point $\lambda$ | Filter Position | Mid Point $\lambda$ |
|---|---|---|---|---|---|
| 134 | 769.7 | 177 | 941.9 | 220 | 1114.1 |
| 135 | 773.7 | 178 | 945.9 | 221 | 1118.1 |
| 136 | 777.7 | 179 | 949.9 | 222 | 1122.1 |
| 137 | 781.7 | 180 | 953.9 | 223 | 1126.1 |
| 138 | 785.7 | 181 | 957.9 | 224 | 1130.1 |
| 139 | 789.7 | 182 | 961.9 | 225 | 1134.1 |
| 140 | 793.7 | 183 | 965.9 | 226 | 1138.1 |
| 141 | 797.7 | 184 | 969.9 | 227 | 1142.1 |
| 142 | 801.7 | 185 | 973.9 | 228 | 1146.1 |
| 143 | 805.7 | 186 | 977.9 | 229 | 1150.1 |
| 144 | 809.7 | 187 | 981.9 | 230 | 1154.2 |
| 145 | 813.7 | 188 | 985.9 | 231 | 1158.2 |
| 146 | 817.7 | 189 | 989.9 | 232 | 1162.2 |
| 147 | 821.7 | 190 | 994.0 | 233 | 1166.2 |
| 148 | 825.7 | 191 | 998.0 | 234 | 1170.2 |
| 149 | 829.7 | 192 | 1002.0 | 235 | 1174.2 |
| 150 | 833.8 | 193 | 1006.0 | 236 | 1178.2 |
| 151 | 837.8 | 194 | 1010.0 | 237 | 1182.2 |
| 152 | 841.8 | 195 | 1014.0 | 238 | 1186.2 |
| 153 | 845.8 | 196 | 1018.1 | 239 | 1190.2 |
| 154 | 849.8 | 197 | 1022.0 | 240 | 1194.2 |
| 155 | 853.8 | 198 | 1026.0 | 241 | 1198.2 |
| 156 | 857.8 | 199 | 1030.0 | 242 | 1202.2 |
| 157 | 861.8 | 200 | 1034.0 | 243 | 1206.2 |
| 158 | 865.8 | 201 | 1038.0 | 244 | 1210.2 |
| 159 | 869.8 | 202 | 1042.0 | 245 | 1214.2 |
| 160 | 873.8 | 203 | 1046.0 | 246 | 1218.2 |
| 161 | 877.8 | 204 | 1050.0 | 247 | 1222.2 |
| 162 | 881.8 | 205 | 1054.0 | 248 | 1226.2 |
| 163 | 885.8 | 206 | 1058.0 | 249 | 1230.2 |
| 164 | 889.8 | 207 | 1062.0 | 250 | 1234.3 |
| 165 | 893.8 | 208 | 1066.0 | 251 | 1238.3 |
| 166 | 897.8 | 209 | 1070.0 | 252 | 1242.3 |
| 167 | 901.8 | 210 | 1074.1 | 253 | 1246.3 |
| 168 | 905.8 | 211 | 1078.1 | 254 | 1250.3 |
| 169 | 909.8 | 212 | 1082.1 | 255 | 1254.3 |
| 170 | 913.9 | 213 | 1086.1 | 256 | 1258.3 |
| 171 | 917.9 | 214 | 1090.1 | 257 | 1262.3 |
| 172 | 921.9 | 215 | 1094.1 | 258 | 1266.3 |
| 173 | 925.9 | 216 | 1098.1 | 259 | 1270.3 |
| 174 | 929.9 | 217 | 1102.1 | 260 | 1274.3 |
| 175 | 933.9 | 218 | 1106.1 | 261 | 1278.3 |
| 176 | 937.9 | 219 | 1110.1 | 262 | 1282.3 |

Table 1 (continued)

Channels Performing Unsatisfactorily (S/N <8) Asterisked
Filter Segment Spectral Overlap α

| Filter Position | Mid Point λ | |
|---|---|---|
| 263 | 1286.3 | |
| 264 | 1290.3 | |
| 265 | 1294.3 | |
| 266 | 1298.3 | |
| 267 | 1302.3 | |
| 268 | 1306.3 | |
| 269 | 1310.3 | |
| 270 | 1314.3 | |
| 271 | 1318.4 | |
| 272 | 1322.4 | |
| 273 | 1326.4 | |
| 274 | 1330.4 | |
| 275 | 1334.4 | |
| 276 | 1338.4 | |
| 277 | 1342.4 | |
| 278 | 1346.4 | |
| 279 | 1350.4 | |
| 280 | 1354.4 | |
| 281 | 1358.4 | |
| 282 | 1362.4 | |
| 283 | 1366.4 | |
| 284* | 1370.4 | |
| 285*α | 1374.4 | |
| 286*α | 1378.4 | |
| 287*α | 1382.4 | |
| 288*α | 1386.4 | |
| 289*α | 1390.4 | |
| 290*α | 1394.5 | |
| 291*α | 1398.5 | |
| 292*α | 1402.5 | |
| 293*α | 1406.5 | |
| 294*α | 1410.5 | Filter Segment 2 |
| 295*α | 1414.5 | |
| 305*α | 1373.2 | |
| 306*α | 1386.1 | Filter Segment 3 |
| 307*α | 1399.0 | |
| 308*α | 1411.9 | |
| 309α | 1424.8 | |
| 310α | 1437.8 | |
| 311 | 1450.7 | |
| 312 | 1463.6 | |
| 313 | 1476.5 | |
| 314 | 1489.4 | |

| Filter Position | Mid Point λ |
|---|---|
| 315 | 1502.3 |
| 316 | 1515.2 |
| 317 | 1528.2 |
| 318 | 1541.1 |
| 319 | 1554.0 |
| 320 | 1566.9 |
| 321 | 1579.8 |
| 322 | 1592.7 |
| 323 | 1605.6 |
| 324 | 1618.6 |
| 325 | 1631.5 |
| 326 | 1644.4 |
| 327 | 1657.3 |
| 328 | 1670.2 |
| 329 | 1683.1 |
| 330 | 1696.1 |
| 331 | 1709.0 |
| 332 | 1721.9 |
| 333 | 1734.8 |
| 334 | 1747.7 |
| 335 | 1760.6 |
| 336 | 1773.5 |
| 337 | 1786.5 |
| 338 | 1799.4 |
| 339* | 1812.3 |
| 340* | 1825.2 |
| 341* | 1838.1 |
| 342* | 1851.0 |
| 343* | 1863.9 |
| 344* | 1876.9 |
| 345* | 1889.8 |
| 346* | 1902.7 |
| 347* | 1915.6 |
| 348* | 1928.5 |
| 349* | 1941.4 |
| 350* | 1956.6 |
| 351 | 1967.3 |
| 352 | 1980.2 |
| 353 | 1993.1 |
| 354 | 2006.0 |
| 355 | 2018.9 |
| 356 | 2031.8 |
| 357 | 2044.8 |

| Filter Position | Mid Point λ |
|---|---|
| 358 | 2057.7 |
| 359 | 2070.6 |
| 360 | 2083.5 |
| 361 | 2096.4 |
| 362 | 2109.3 |
| 363 | 2122.2 |
| 364 | 2135.2 |
| 365 | 2148.1 |
| 366 | 2161.0 |
| 367 | 2173.9 |
| 368 | 2186.8 |
| 369 | 2199.7 |
| 370 | 2212.7 |
| 371 | 2225.6 |
| 372 | 2238.5 |
| 373 | 2251.4 |
| 374 | 2269.3 |
| 375 | 2277.2 |
| 376 | 2290.1 |
| 377 | 2303.1 |
| 378 | 2316.0 |
| 379* | 2328.9 |
| 380* | 2341.8 |
| 381* | 2354.7 |
| 382* | 2367.6 |
| 383* | 2380.5 |
| 384* | 2393.5 |
| 385* | 2406.4 |
| 386* | 2419.3 |
| 387* | 2432.2 |
| 388* | 2445.2 |
| 389* | 2450.0 |
| 390* | 2471.0 |
| 391* | 2483.9 |
| 392* | 2496.8 |
| 393* | 2509.7 |
| 394* | 2522.6 |
| 395* | 2535.5 |

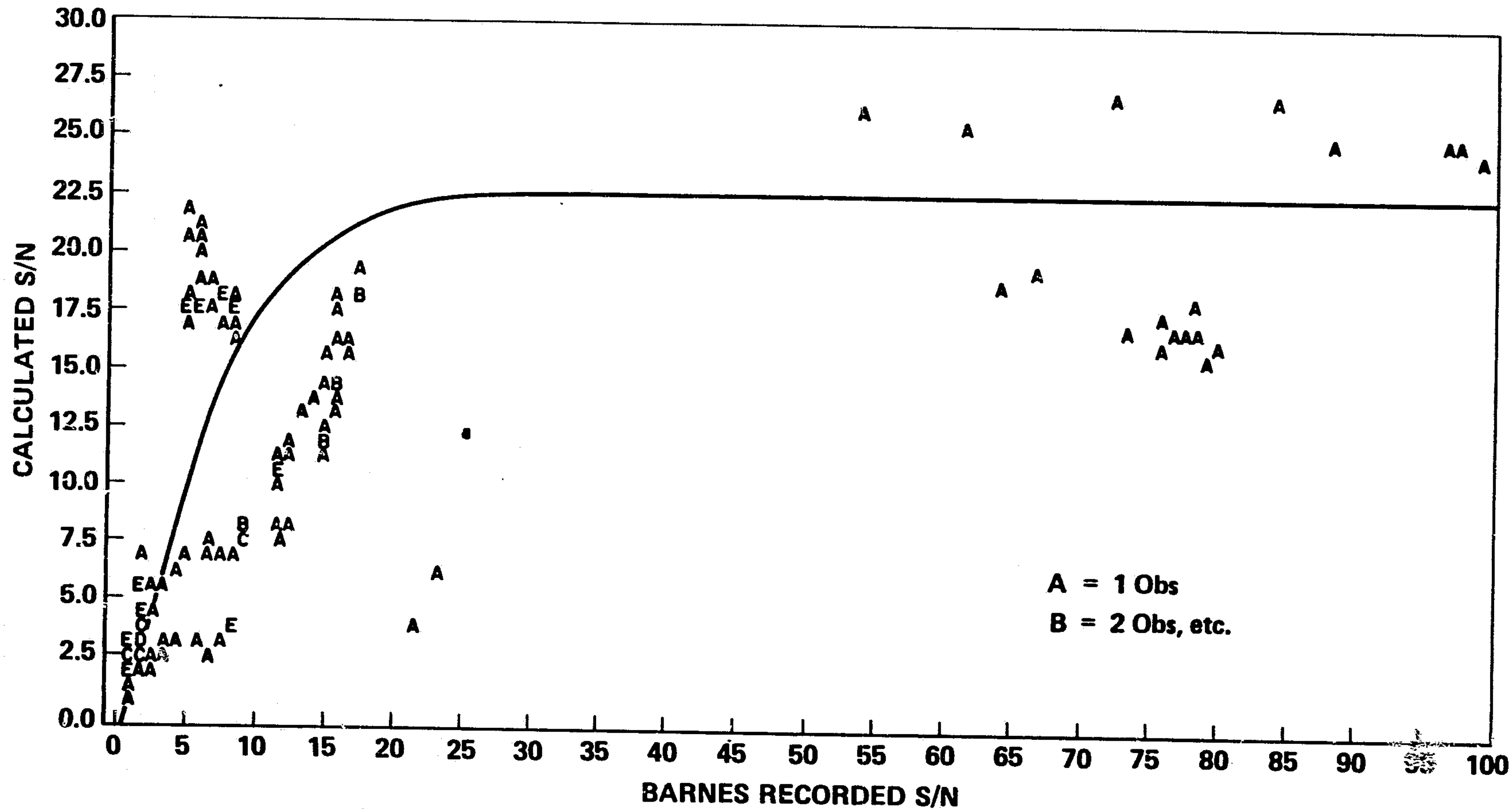



Figure 2. Non-linear Asymptotic Curve

The model

$$S/N_{calc} = A-B\left(e^{-C \cdot S/N_{bar}}\right)$$

where $S/N_{calc}$ = calculated S/N

$S/N_{bar}$ = Barnes recorded S/N

is highly significant with an F ratio of >244. The correlation coefficient between the recorded S/N and the calculated S/N is .74659, significant for $\alpha < .01$.

From Figure 2 it can be seen that while for larger $S/N_{bar}$ values the $S/N_{calc}$ is highly overestimated, the lower S/N values correspond almost one to one. We therefore feel justified in using the recorded S/N as representative of the signal strength; any error due to estimation would tend to favor conservatism in channel assessment of sensitivity.

A S/N value of eight to one was the minimum the authors considered an acceptable level, as the poorest performance anticipated is near 10 for a one percent reflective target (Barnes Engineering Company, 1976).

For any individual channel we have the following operational definition.

$$S/N < 8{:}1 = \text{bad data} \equiv B$$

$$S/N \geq 8{:}1 = \text{good data} \equiv G.$$

If we assign the value 1 to a bad observation and the value 0 to a good observation, then the random variable X has a state space S which is a set that consists of two values $\{0,1\}$. The probability space defined on X and S is likewise a two element set, $\{p,q\}$ for any $\lambda$, where $p = Pr\{B\} = P(X=1)$, the probability of getting an unacceptable observation $(0 \leq p \leq 1)$ and $q = Pr\{G\} = P(X=0) = 1-p$, the probability of getting an acceptable observation. Under the assumption that p remains constant for each measure of the S/N from a given band and that each determination of the acceptability of the S/N is independently measured, X is known as a Bernoulli trial and the probability structure can be summarized as

$$P(X=x) = p^x q^{(1-x)} \quad (x=0,1) \quad \text{for any } \lambda.$$

A reliable channel was operationally defined, by the authors, as one which would give an acceptable S/N for 90 percent or greater of the observations. This yields the following null and alternative hypotheses:

$$H_0: \ p_\lambda \leq .1 \implies \text{channel is satisfactory}$$

$$H_1: \ p_\lambda > .1 \implies \text{channel is unsatisfactory.}$$

Since $\hat{p}_\lambda$ is a parameter, we must estimate it. The maximum likelihood estimate of $p_\lambda$ is formed as follows, if there are n observations of X, then

$$\hat{p}_\lambda = \frac{n_{zero}}{n} 0 + \frac{n_{one}}{n} .1,$$

where

$n_{zero}$ = number of times X=0 for channel $_\lambda$,

$n_{one}$ = number of times X=1 for channel $_\lambda$, and

$n$ = $n_{zero} + n_{one}$

Then using normal approximation theory for the distribution of $\hat{p}_\lambda$, we construct a 95 percent confidence interval about the point estimate of $\hat{p}_\lambda$. We define a channel as unreliable if its 95 percent confidence interval does not include 0.1.

Data

A total of 480 scans of 373 channels each were used. From original data sets of soybean with 160 scans, wheat with 195, and corn with 182 spectral scans (each scan covering 373 channels), data sets of 160 scans were selected for each crop to balance the design. Scans were eliminated by use of a random number generator.

All three crop data sets span the growing season, with spectral readings from youngest plants through progressively maturing plants. Observations spanning this varying canopy closure were used so that conclusions concerning reliability of a specific band were as general as possible over the entire growing season.

Because our model requires that $p_\lambda$ remain constant over the growing season and across crops, a two way analysis of variance was performed. The levels for the crop factor were wheat, corn and soybean. The levels for the time factor consisted of 20 time intervals, each composed of eight consecutive scans. This design yielded eight observations of S/N per crop-time interval combination which were used to estimate $p_\lambda$ for this examination of constancy. There was no significant difference in the estimate of $p_\lambda$ over the eight time intervals. From the results of the analysis, we therefore concluded that $p_\lambda$ was constant over the growing season, but varied over the crop factor. Upon further examination, it was concluded that $p_\lambda$ remained constant across wheat and soybean but differed for corn. Therefore, the analysis of reliability proceeded as two separate analyses, one for wheat and soybean with 320 observations per channel and the second for corn with 160 observations per channel.

RESULTS AND DISCUSSION

Table 1 shows the channels for which we rejected the null hypothesis and accepted the alternate, $p_\lambda > .1$. These channels as per our definition are considered unsatisfactory. In order to be considered unreliable a channel had to be unreliable for the estimate of p using the combined soy-wheat data and the corn data. Appendix A gives the 95 percent confidence interval for p for each channel for the soybean-wheat combination and corn separately, and Appendix B lists the average S/N and standard deviation for each channel.

Looking at the unreliable bands as groups or regions, the analysis showed many channels at the shorter wavelengths, (0.39 - 0.69 $\mu$m), those centered around 1.4 $\mu$m and 1.8 - 1.95 $\mu$m, and all wavelengths longer than 2.3289 $\mu$m to be unsatisfactory. Regions of unreliable bands are displayed graphically in Figure 3 and summarized in Table 2, which also lists the utility (for vegetation) and source(s) of unreliability for each region. To explain poor instrument performance at the shortest, pigment absorbing wavelengths, it is necessary to return briefly to a continuation of instrument discussion. Certain detectors are more or less effective over different portions of the electromagnetic spectrum (Figure 4), and detectors used in the visible region are quite different from those used in

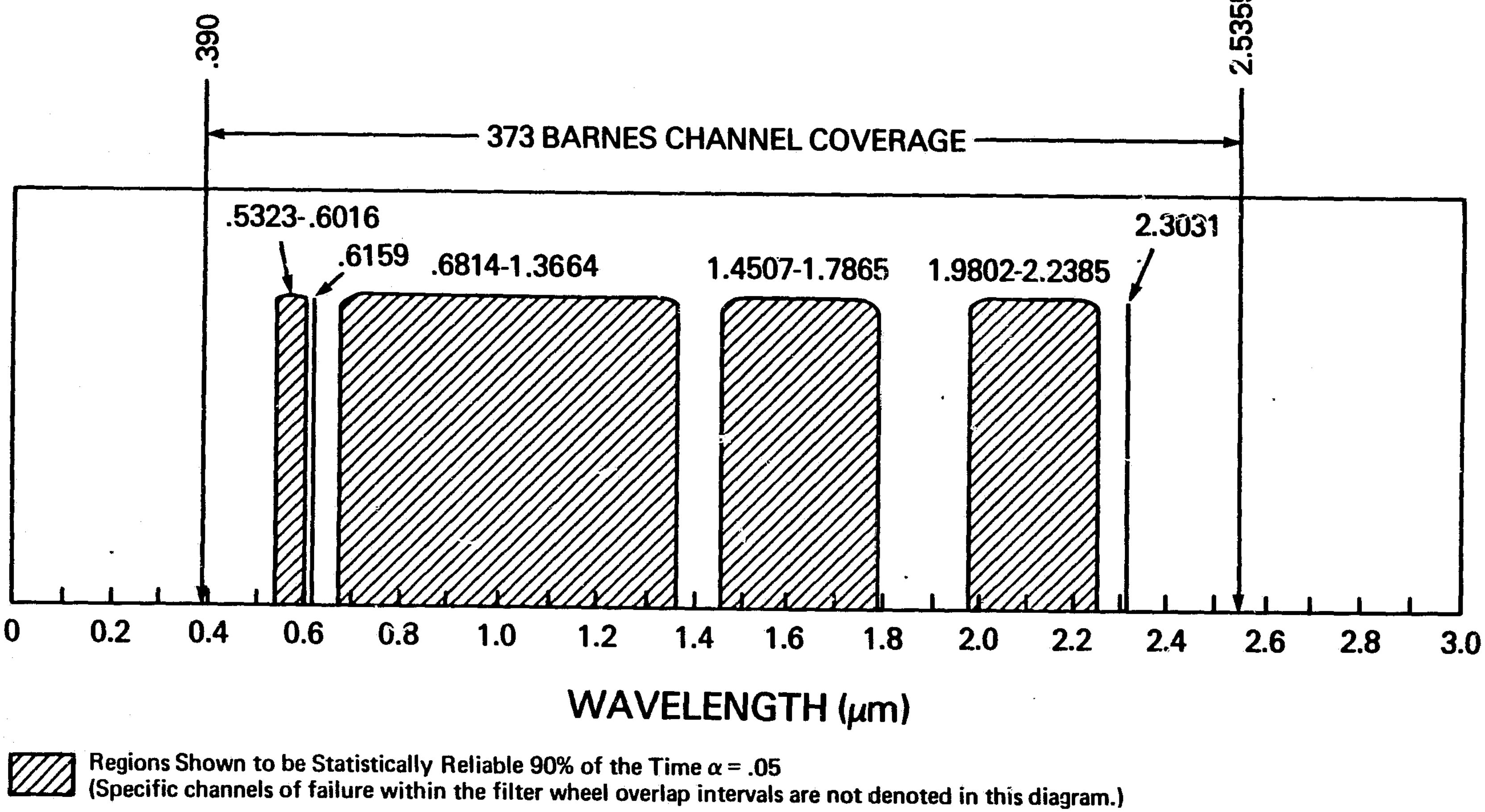
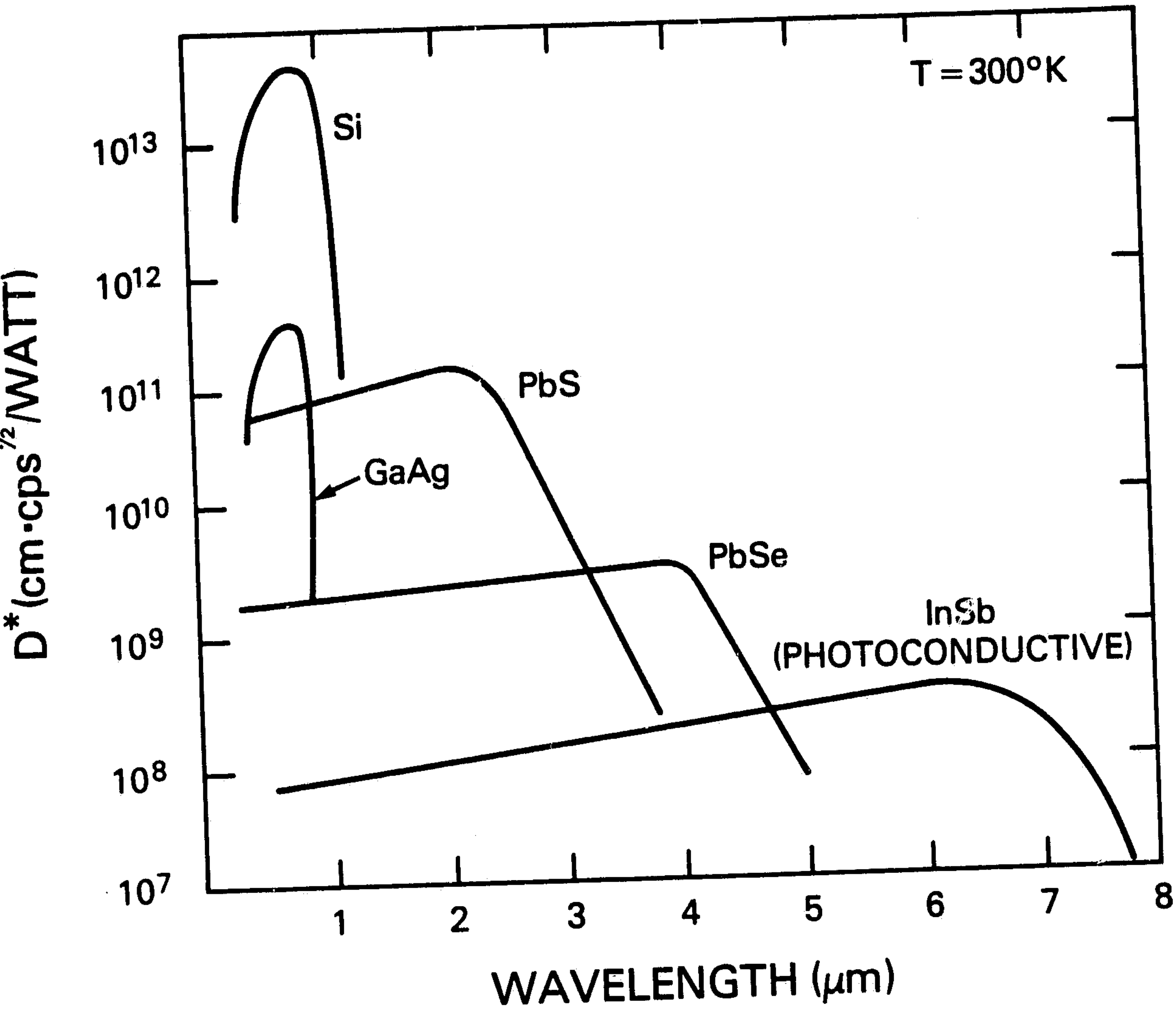



Figure 3. Spectral Coverage of the Barnes Reflectometer




$D^* = A^{1/2}/P_N$ (cm-cps$^{1/2}$/watts)

where

A = Area of the Detector in cm$^2$

$P_N$ = Noise Equivalent Power in watts/cps$^{1/2}$

Figure 4. Detectivity Normalized to Unit Area and Bandwidth (after Potter and Eisenman, 1962)

Table 2

Summary Table of Unsatisfactory Regions

| Filter Position | Wavelength ($\mu$m) | Potential Information (after Tucker, 1978) | Problem |
|---|---|---|---|
| 5–36, 38 | .3905–.5032, 5105 | direct in vivo carotenoid and chlorophyll sensitivity | detector |
| 77–83 | .6523–.6741 | direct in vivo chlorophyll sensitivity | detector/filter wheel overlap/ low vegetative reflectance |
| 86–87 | .6850–.6886 | " | " |
| 105–107 | .6535–.6615 | " | " |
| 284–308 | 1.3704–1.4119 | direct in vivo foliar water sensitivity | atmospheric absorption/ filter wheel overlap |
| 330–350 | 1.8123–1.9566 | " | atmospheric absorption |
| 379–395 | 2.3289–2.5355 | " | instrument design (detector?) |

the IR although there is overlap of detector capability. There are two major groups of detectors employed in monitoring the agricultural region of the EMS, photoemissive for the visible, and photon counters for longer wavelengths, both of which work through the energy of incoming photons. In photodetectors, or photon counters, the electrons which react with incoming photons are bound into the sensitive element. Free charge carriers are produced and electrical properties that depend on the concentration of these free carriers are then monitored (Holter, 1970). As stated, this type of detector functions best in the IR. Within the photoconductor detector group, wavelength sensitivity varies, with some capability overlapping into the visible (Figure 4). For the shortest wavelengths monitored by photoconductors the Si detector is preferable, but in the near IR a PbS detector is more sensitive (Potter and Eisenman, 1962). The decreasing performance of a PbS detector in the shorter wavelengths becomes obvious when viewing Figure 4. Additionally, as the detector in the Barnes is cooled to approximately 0°C, its effectiveness peaks at about 2.5 $\mu$m (Potter and Eisenman, 1962).

Thus, the unreliability of channels monitoring wavelengths shorter than 0.5 μm (the first 30 channels) is inherent to the Barnes instrument. Problems appear to be uncorrelated with atmospheric interference, as there are wide windows in the atmosphere from 0.39 to 0.70 μm, and the solar curve indicates similar incoming energy levels at both 0.39 μm and 0.83 μm (Figure 1). By incorporating a continuously variable filter into the design, the Barnes reflectometer integrates a differing portion of the incoming solar energy curve at each wavelength; spectral intervals are proportional to wavelength. However from the solar irradiance curve, there appears to be adequate incoming energy between 0.35 μm and 0.7 μm to compensate for the shorter spectral intervals. The presence of pigment absorption in the shorter (visible) wavelengths is a factor that also weakens performance. Where low target reflectance is combined with lowered detector sensitivity the overall S/N often falls to a low, non-utilitarian value (Figure 5).

Though inappropriate detector and low target reflectance do explain the unsatisfactory visible performance, in the 0.65 μm - 0.69 μm region there is also an area of filter wheel overlap (Table 1). The latter point is quite likely coincidental, but should none the less be noted.

The filter has two regions of overlapping bands (Figure 5, Table 1). The first region of overlap, the pigment absorption region, has already been mentioned. The second region, from 1.37 μm to 1.44 μm, coincides with the second major area of poor performance, and also falls across a water vapor and carbon dioxide absorption curtain centered at 1.4 μm (Figure 1). These bands potentially carry information on vegetative water content, but are normally considered unsatisfactory for field work due to extreme atmospheric attenuation. In any case, for data from channels in the 1.37 - 1.44 μm region, caution should be practiced if utilized in any analyses.

The next region of unsatisfactory performance falls from 1.81 μm to 1.95 μm, and also coincides with atmospheric absorption related to $CO_2$ and $H_2O$ (Figure 1). This atmospherically attenuated region, as well as the former region are poor portions of the EMS for monitoring of vegetation in the field. As it is unlikely that any instrument could offer satisfactory field performance over these

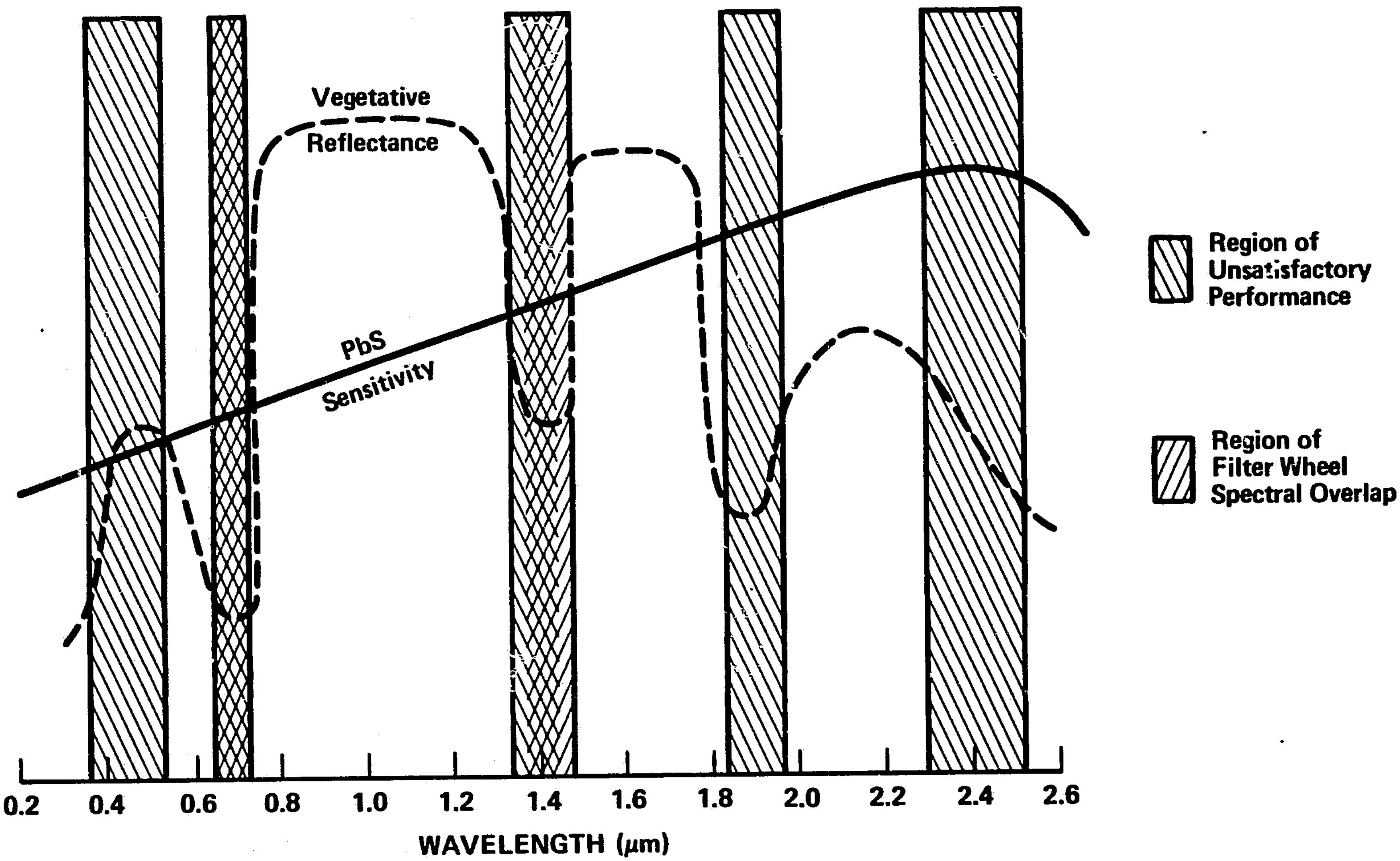



Figure 5. Comparison of Vegetative Reflectance and PbS Detector Sensitivity with Regions of Spectral Overlap and Unsatisfactory Performance

spectral intervals since high variance in the data would generally mask any useful information, the channels monitoring these intervals should be used with discretion.

The unsatisfactory performance in the region from 2.3289 μm to 2.5355 μm is related to the amount of incoming energy over a variable solar irradiation flux. As was previously indicated, a continuously variable filter alters the spectral bandwidth in proportion to wavelength in another attempt to compensate for variable solar irradiance at the ground level, specifically compensating for the lower energy in the longer wavelengths. According to Barnes documentation, the product of irradiance and responsivity is lowest at the ends of the region being used. The worst S/N for the target signal anticipated for a 100 percent reflective target is 1000 in full sunlight for 2.4 μm, or about 50 for a five percent reflective target (Barnes Engineering Company, 1976). This figure is valid when excluding atmospheric attenuation. However, from Figure 1 it can be seen that atmospheric absorption is not the problem at 2.4 μm, but rather the lowered amount of incoming energy. This supposedly worst case representation has been found to be off by an order of magnitude from the S/N recorded by the instrument.* Consistently the wavelengths at the shorter and longer ends of the spectral range used show S/N values of less than eight.

In addition to adjusted bandwidth intervals, the Barnes reflectometer attempts to compensate for lessened irradiance in the longer wavelengths monitored by using the responsivity inherent in a PbS detector (Figure 4). From our analyses, the endeavor is unsuccessful. Therefore, data from the longest wavelength block of unsatisfactory channels (2.3289 μm to 2.5355 μm), where the low S/N values are related to the amount of energy initially entering the atmosphere should be used only with the realization that the data are mainly noise. This caveat is particularly directed towards future analyses where the goal would be to discern relatively small reflectance changes.

*Average S/N recorded for soy and wheat at 2.4064 μm = 5.31 ±2.32.

Another potential for poor channel performance is identified by Potter and Eisenman (1962) who state that a PbS detector at ambient room temperature can be chopped, or modulated up to a frequency of 100 Hz without reducing the detectivity optimum. The Barnes reflectometer modulates at 400 Hz. Effects on the detectivity could be noticeable, and perhaps there are synergistic effects where the incoming signal is low. To our knowledge no work has been done with the instrument in this area.

## CONCLUSIONS AND RECOMMENDATIONS

This study analyzed the utility of the Barnes Field Spectral Reflectometer Model 14–758 using S/N as a measure of performance. The results indicate that 283 bands have a more than 95 percent chance of yielding a $S/N \geq 8$ at least 90 percent of the time, leaving 90 bands with a $S/N < 8$. These 90 bands fall within the blue, red and far infrared regions of the spectrum. The performance in these poorer areas is principally related to the fact that the Barnes has only a PbS detector. This detector type is poor for observation in the visible region of the spectrum (for less than 1.0 $\mu$m, photon counting silicon is over two orders of magnitude more sensitive than PbS) and accounts for the unsatisfactory performance in the blue and red regions. Also, the PbS detector does not compensate for the lessened solar flux in the mid IR. Another potential reason for poor performance is related to the design of the rotating filter wheel, specifically its two regions of overlap (red and far infrared). Atmospheric absorption peaks also contribute to the unreliability in various regions, particularly in the far infrared.

Since this experiment utilizes previously collected data, an experiment specifically designed to verify these results should be performed. Short of performing such an experiment, any program or investigation based upon Barnes reflectometer data in field crop observation should be adjusted so that when monitoring these 90 bands (or for investigations utilizing previously collected data) these unsatisfactory channels should be regarded circumspectly. Appendix B can be utilized to assess individual analytical usefulness. However, it is strongly felt that any results obtained or conclusions made using the tabulated, noisy, and highly variable bands as raw data would be questionable, particularly when the data are used to discern regions of small reflectance changes. We conclude by noting again that 283 channels are more than adequate to monitor vegetation, and that even omittance of the 90 noted bands should not adversely affect future studies as there remains an over abundance of available information.

## ACKNOWLEDGMENTS

The authors wish to thank E. Chappelle of the Earth Resources Branch, NASA/GSFC for supplying the data used in this study. The assistance of Juan F. Dudley, University of D.C. is acknowledged. Also thanks are due B. Holben, C. C. Schnetzler, B. Markham, and W. Webster of NASA/GSFC for their time and suggestions concerning both style and science, to Ms. P. Sine, also of NASA/GSFC, for her continuously reliable professionalism, and to Ms. B. Davis for carrying on where others left off.

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# APPENDIX A

## TWO SIGMA CONFIDENCE LIMITS AROUND P FOR 373 CHANNELS
## (S/N <8:1 = UNSATISFACTORY)

### SOY-WHEAT

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 1 | 0.96 | 0.936 | 0.983 |
| 2 | 0.94 | 0.913 | 0.969 |
| 3 | 0.90 | 0.861 | 0.932 |
| 4 | 0.86 | 0.819 | 0.900 |
| 5 | 0.85 | 0.805 | 0.889 |
| 6 | 0.80 | 0.750 | 0.843 |
| 7 | 0.75 | 0.703 | 0.803 |
| 8 | 0.70 | 0.650 | 0.756 |
| 9 | 0.67 | 0.618 | 0.726 |
| 10 | 0.64 | 0.585 | 0.696 |
| 11 | 0.64 | 0.582 | 0.693 |
| 12 | 0.61 | 0.550 | 0.663 |
| 13 | 0.58 | 0.518 | 0.632 |
| 14 | 0.54 | 0.486 | 0.601 |
| 15 | 0.50 | 0.446 | 0.561 |
| 16 | 0.46 | 0.399 | 0.514 |
| 17 | 0.37 | 0.313 | 0.424 |
| 18 | 0.29 | 0.238 | 0.343 |
| 19 | 0.25 | 0.197 | 0.297 |
| 20 | 0.23 | 0.182 | 0.280 |
| 21 | 0.23 | 0.185 | 0.283 |
| 22 | 0.24 | 0.191 | 0.290 |
| 23 | 0.21 | 0.165 | 0.260 |
| 24 | 0.20 | 0.157 | 0.250 |
| 25 | 0.19 | 0.148 | 0.240 |
| 26 | 0.20 | 0.154 | 0.246 |
| 27 | 0.19 | 0.145 | 0.236 |
| 28 | 0.19 | 0.142 | 0.233 |
| 29 | 0.18 | 0.139 | 0.229 |
| 30 | 0.19 | 0.148 | 0.240 |
| 31 | 0.20 | 0.151 | 0.243 |
| 32 | 0.19 | 0.142 | 0.233 |
| 33 | 0.20 | 0.151 | 0.243 |
| 34 | 0.17 | 0.125 | 0.212 |
| 35 | 0.17 | 0.125 | 0.212 |
| 36 | 0.14 | 0.097 | 0.178 |
| 37 | 0.14 | 0.097 | 0.178 |
| 38 | 0.12 | 0.081 | 0.157 |
| 39 | 0.10 | 0.062 | 0.132 |
| 40 | 0.07 | 0.041 | 0.102 |
| 41 | 0.07 | 0.041 | 0.102 |
| 42 | 0.05 | 0.026 | 0.080 |
| 43 | 0.05 | 0.022 | 0.072 |
| 44 | 0.05 | 0.022 | 0.072 |
| 45 | 0.04 | 0.017 | 0.064 |
| 46 | 0.03 | 0.012 | 0.056 |
| 47 | 0.03 | 0.008 | 0.048 |
| 48 | 0.03 | 0.012 | 0.056 |
| 49 | 0.03 | 0.012 | 0.056 |
| 50 | 0.04 | 0.015 | 0.060 |
| 51 | 0.05 | 0.024 | 0.076 |
| 52 | 0.05 | 0.022 | 0.072 |
| 53 | 0.05 | 0.024 | 0.076 |
| 54 | 0.06 | 0.031 | 0.087 |
| 55 | 0.08 | 0.047 | 0.110 |
| 56 | 0.08 | 0.047 | 0.110 |
| 57 | 0.08 | 0.049 | 0.113 |
| 58 | 0.08 | 0.052 | 0.117 |
| 59 | 0.09 | 0.054 | 0.121 |
| 60 | 0.10 | 0.068 | 0.139 |
| 61 | 0.10 | 0.065 | 0.135 |
| 62 | 0.11 | 0.076 | 0.149 |
| 63 | 0.12 | 0.078 | 0.153 |
| 64 | 0.13 | 0.086 | 0.164 |
| 65 | 0.14 | 0.103 | 0.185 |
| 66 | 0.15 | 0.106 | 0.188 |
| 67 | 0.15 | 0.108 | 0.192 |
| 68 | 0.18 | 0.134 | 0.223 |
| 69 | 0.18 | 0.134 | 0.223 |
| 70 | 0.18 | 0.137 | 0.226 |
| 71 | 0.18 | 0.139 | 0.229 |
| 72 | 0.21 | 0.162 | 0.256 |
| 73 | 0.23 | 0.182 | 0.280 |
| 74 | 0.26 | 0.209 | 0.310 |
| 75 | 0.28 | 0.229 | 0.333 |
| 76 | 0.31 | 0.259 | 0.366 |
| 77 | 0.32 | 0.262 | 0.369 |
| 78 | 0.31 | 0.256 | 0.363 |
| 79 | 0.33 | 0.277 | 0.386 |
| 80 | 0.31 | 0.259 | 0.366 |
| 81 | 0.30 | 0.250 | 0.356 |
| 82 | 0.27 | 0.218 | 0.320 |
| 83 | 0.23 | 0.182 | 0.280 |
| 84 | 0.16 | 0.120 | 0.205 |
| 85 | 0.12 | 0.078 | 0.153 |
| 86 | 0.08 | 0.047 | 0.110 |
| 87 | 0.05 | 0.026 | 0.080 |
| 88 | 0.03 | 0.008 | 0.048 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 89 | 0.03 | 0.006 | 0.044 |
| 90 | 0.02 | 0.002 | 0.036 |
| 91 | 0.02 | 0.000 | 0.031 |
| 92 | 0.53 | 0.474 | 0.589 |
| 93 | 0.44 | 0.383 | 0.498 |
| 94 | 0.37 | 0.316 | 0.428 |
| 95 | 0.29 | 0.235 | 0.340 |
| 96 | 0.16 | 0.117 | 0.202 |
| 97 | 0.14 | 0.103 | 0.185 |
| 98 | 0.12 | 0.084 | 0.160 |
| 99 | 0.10 | 0.062 | 0.132 |
| 100 | 0.08 | 0.044 | 0.106 |
| 101 | 0.06 | 0.034 | 0.091 |
| 102 | 0.04 | 0.019 | 0.068 |
| 103 | 0.02 | 0.004 | 0.040 |
| 104 | 0.02 | 0.004 | 0.040 |
| 105 | 0.01 | -.002 | 0.027 |
| 106 | 0.01 | -.002 | 0.027 |
| 107 | 0.01 | -.004 | 0.017 |
| 108 | 0.01 | -.003 | 0.022 |
| 109 | 0.01 | -.002 | 0.027 |
| 110 | 0.01 | -.002 | 0.027 |
| 111 | 0.01 | -.003 | 0.022 |
| 112 | 0.01 | -.003 | 0.022 |
| 113 | 0.01 | -.002 | 0.027 |
| 114 | 0.01 | -.004 | 0.017 |
| 115 | 0.01 | -.004 | 0.017 |
| 116 | 0.01 | -.00[illegible] | 0.017 |
| 117 | 0.01 | -.004 | 0.017 |
| 118 | 0.01 | -.002 | 0.027 |
| 119 | 0.01 | -.002 | 0.027 |
| 120 | 0.01 | -.002 | 0.027 |
| 121 | 0.01 | -.002 | 0.027 |
| 122 | 0.01 | -.002 | 0.027 |
| 123 | 0.01 | -.002 | 0.027 |
| 124 | 0.01 | -.003 | 0.022 |
| 125 | 0.01 | -.002 | 0.027 |
| 126 | 0.01 | -.003 | 0.022 |
| 127 | 0.01 | -.003 | 0.022 |
| 128 | 0.01 | -.003 | 0.022 |
| 129 | 0.01 | -.002 | 0.027 |
| 130 | 0.01 | -.002 | 0.027 |
| 131 | 0.01 | -.003 | 0.022 |
| 132 | 0.01 | -.002 | 0.027 |
| 133 | 0.01 | -.002 | 0.027 |
| 134 | 0.01 | -.002 | 0.027 |
| 135 | 0.01 | -.002 | 0.027 |
| 136 | 0.01 | -.002 | 0.027 |
| 137 | 0.01 | -.002 | 0.027 |
| 138 | 0.01 | -.002 | 0.027 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 139 | 0.01 | -.002 | 0.027 |
| 140 | 0.01 | -.002 | 0.027 |
| 141 | 0.01 | -.002 | 0.027 |
| 142 | 0.01 | -.003 | 0.022 |
| 143 | 0.01 | -.003 | 0.022 |
| 144 | 0.01 | -.004 | 0.017 |
| 145 | 0.01 | -.004 | 0.017 |
| 146 | 0.01 | -.003 | 0.022 |
| 147 | 0.01 | -.003 | 0.022 |
| 148 | 0.01 | -.004 | 0.017 |
| 149 | 0.01 | -.004 | 0.017 |
| 150 | 0.01 | -.004 | 0.017 |
| 151 | 0.01 | -.004 | 0.017 |
| 152 | 0.01 | -.004 | 0.017 |
| 153 | 0.01 | -.004 | 0.017 |
| 154 | 0.01 | -.004 | 0.017 |
| 155 | 0.01 | -.003 | 0.022 |
| 156 | 0.01 | -.003 | 0.022 |
| 157 | 0.01 | -.003 | 0.022 |
| 158 | 0.01 | -.003 | 0.022 |
| 159 | 0.01 | -.003 | 0.022 |
| 160 | 0.01 | -.004 | 0.017 |
| 161 | 0.01 | -.003 | 0.022 |
| 162 | 0.01 | -.002 | 0.027 |
| 163 | 0.02 | 0.000 | 0.031 |
| 164 | 0.02 | 0.000 | 0.031 |
| 165 | 0.02 | 0.002 | 0.036 |
| 166 | 0.02 | 0.004 | 0.040 |
| 167 | 0.04 | 0.015 | 0.060 |
| 168 | 0.02 | 0.004 | 0.040 |
| 169 | 0.02 | 0.000 | 0.031 |
| 170 | 0.02 | 0.000 | 0.031 |
| 171 | 0.01 | -.002 | 0.027 |
| 172 | 0.01 | -.002 | 0.027 |
| 173 | 0.01 | -.003 | 0.022 |
| 174 | 0.01 | -.004 | 0.017 |
| 175 | 0.01 | -.004 | 0.017 |
| 176 | 0.01 | -.004 | 0.017 |
| 177 | 0.01 | -.004 | 0.017 |
| 178 | 0.01 | -.004 | 0.017 |
| 179 | 0.01 | -.004 | 0.017 |
| 180 | 0.01 | -.004 | 0.017 |
| 181 | 0.01 | -.004 | 0.017 |
| 182 | 0.01 | -.004 | 0.017 |
| 183 | 0.01 | -.004 | 0.017 |
| 184 | 0.01 | -.004 | 0.017 |
| 185 | 0.01 | -.004 | 0.017 |
| 186 | 0.01 | -.004 | 0.017 |
| 187 | 0.01 | -.004 | 0.017 |
| 188 | 0.01 | -.004 | 0.017 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 189 | 0.01 | -.004 | 0.017 |
| 190 | 0.01 | -.004 | 0.017 |
| 191 | 0.01 | -.004 | 0.017 |
| 192 | 0.01 | -.004 | 0.017 |
| 193 | 0.01 | -.004 | 0.017 |
| 194 | 0.01 | -.004 | 0.017 |
| 195 | 0.01 | -.004 | 0.017 |
| 196 | 0.00 | -.005 | 0.011 |
| 197 | 0.00 | -.005 | 0.011 |
| 198 | 0.00 | -.005 | 0.011 |
| 199 | 0.00 | -.005 | 0.011 |
| 200 | 0.00 | -.005 | 0.011 |
| 201 | 0.00 | -.005 | 0.011 |
| 202 | 0.00 | -.005 | 0.011 |
| 203 | 0.00 | -.005 | 0.011 |
| 204 | 0.00 | -.005 | 0.011 |
| 205 | 0.00 | -.005 | 0.011 |
| 206 | 0.00 | -.005 | 0.011 |
| 207 | 0.00 | -.005 | 0.011 |
| 208 | 0.00 | -.005 | 0.011 |
| 209 | 0.00 | -.005 | 0.011 |
| 210 | 0.00 | -.005 | 0.011 |
| 211 | 0.01 | -.004 | 0.017 |
| 212 | 0.01 | -.003 | 0.022 |
| 213 | 0.02 | 0.002 | 0.036 |
| 214 | 0.04 | 0.017 | 0.064 |
| 215 | 0.05 | 0.026 | 0.080 |
| 216 | 0.05 | 0.026 | 0.080 |
| 217 | 0.04 | 0.017 | 0.064 |
| 218 | 0.02 | 0.004 | 0.040 |
| 219 | 0.02 | 0.002 | 0.036 |
| 220 | 0.01 | -.002 | 0.027 |
| 221 | 0.01 | -.003 | 0.022 |
| 222 | 0.01 | -.003 | 0.022 |
| 223 | 0.01 | -.004 | 0.017 |
| 224 | 0.01 | -.004 | 0.017 |
| 225 | 0.01 | -.004 | 0.017 |
| 226 | 0.01 | -.003 | 0.022 |
| 227 | 0.01 | -.003 | 0.022 |
| 228 | 0.01 | -.003 | 0.022 |
| 229 | 0.01 | -.003 | 0.022 |
| 230 | 0.01 | -.003 | 0.022 |
| 231 | 0.01 | -.003 | 0.022 |
| 232 | 0.01 | -.003 | 0.022 |
| 233 | 0.01 | -.003 | 0.022 |
| 234 | 0.01 | -.003 | 0.022 |
| 235 | 0.01 | -.003 | 0.022 |
| 236 | 0.01 | -.003 | 0.022 |
| 237 | 0.01 | -.003 | 0.022 |
| 238 | 0.01 | -.003 | 0.022 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 239 | 0.01 | -.003 | 0.022 |
| 240 | 0.01 | -.003 | 0.022 |
| 241 | 0.01 | -.003 | 0.022 |
| 242 | 0.01 | -.003 | 0.022 |
| 243 | 0.01 | -.003 | 0.022 |
| 244 | 0.01 | -.003 | 0.022 |
| 245 | 0.01 | -.003 | 0.022 |
| 246 | 0.01 | -.003 | 0.022 |
| 247 | 0.01 | -.003 | 0.022 |
| 248 | 0.01 | -.003 | 0.022 |
| 249 | 0.01 | -.003 | 0.022 |
| 250 | 0.01 | -.003 | 0.022 |
| 251 | 0.01 | -.003 | 0.022 |
| 252 | 0.01 | -.003 | 0.022 |
| 253 | 0.01 | -.003 | 0.022 |
| 254 | 0.01 | -.003 | 0.022 |
| 255 | 0.01 | -.003 | 0.022 |
| 256 | 0.01 | -.003 | 0.022 |
| 257 | 0.01 | -.003 | 0.022 |
| 258 | 0.01 | -.003 | 0.022 |
| 259 | 0.01 | -.003 | 0.022 |
| 260 | 0.01 | -.003 | 0.022 |
| 261 | 0.01 | -.003 | 0.022 |
| 262 | 0.01 | -.003 | 0.022 |
| 263 | 0.01 | -.003 | 0.022 |
| 264 | 0.01 | -.002 | 0.027 |
| 265 | 0.01 | -.002 | 0.027 |
| 266 | 0.02 | 0.002 | 0.036 |
| 267 | 0.02 | 0.004 | 0.040 |
| 268 | 0.04 | 0.017 | 0.064 |
| 269 | 0.10 | 0.062 | 0.132 |
| 270 | 0.14 | 0.097 | 0.178 |
| 271 | 0.20 | 0.157 | 0.250 |
| 272 | 0.45 | 0.396 | 0.510 |
| 273 | 0.70 | 0.644 | 0.750 |
| 274 | 0.88 | 0.847 | 0.922 |
| 275 | 0.98 | 0.969 | 1.000 |
| 276 | 1.00 | 0.989 | 1.005 |
| 277 | 1.00 | 0.989 | 1.005 |
| 278 | 1.00 | 0.989 | 1.005 |
| 279 | 1.00 | 0.989 | 1.005 |
| 280 | 1.00 | 0.989 | 1.005 |
| 281 | 0.99 | 0.973 | 1.002 |
| 282 | 0.97 | 0.952 | 0.992 |
| 283 | 0.93 | 0.901 | 0.961 |
| 284 | 0.73 | 0.680 | 0.782 |
| 285 | 0.53 | 0.471 | 0.586 |
| 286 | 0.33 | 0.274 | 0.382 |
| 287 | 0.13 | 0.092 | 0.171 |
| 288 | 0.09 | 0.060 | 0.128 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 289 | 0.03 | 0.010 | 0.052 |
| 290 | 0.02 | 0.000 | 0.031 |
| 291 | 0.02 | 0.000 | 0.031 |
| 292 | 0.01 | -.002 | 0.027 |
| 293 | 0.03 | 0.012 | 0.056 |
| 294 | 0.01 | -.003 | 0.022 |
| 295 | 0.01 | -.004 | 0.017 |
| 296 | 0.01 | -.004 | 0.017 |
| 297 | 0.01 | -.004 | 0.017 |
| 298 | 0.01 | -.004 | 0.017 |
| 299 | 0.01 | -.004 | 0.017 |
| 300 | 0.01 | -.004 | 0.017 |
| 301 | 0.01 | -.004 | 0.017 |
| 302 | 0.01 | -.004 | 0.017 |
| 303 | 0.01 | -.004 | 0.017 |
| 304 | 0.01 | -.004 | 0.017 |
| 305 | 0.01 | -.004 | 0.017 |
| 306 | 0.01 | -.004 | 0.017 |
| 307 | 0.02 | 0.002 | 0.036 |
| 308 | 0.02 | 0.002 | 0.036 |
| 309 | 0.02 | 0.002 | 0.036 |
| 310 | 0.02 | 0.002 | 0.036 |
| 311 | 0.02 | 0.002 | 0.036 |
| 312 | 0.02 | 0.002 | 0.036 |
| 313 | 0.02 | 0.002 | 0.036 |
| 314 | 0.02 | 0.002 | 0.036 |
| 315 | 0.03 | 0.010 | 0.052 |
| 316 | 0.08 | 0.052 | 0.117 |
| 317 | 0.22 | 0.168 | 0.263 |
| 318 | 0.69 | 0.637 | 0.744 |
| 319 | 0.98 | 0.960 | 0.996 |
| 320 | 1.00 | 0.989 | 1.005 |
| 321 | 1.00 | 0.989 | 1.005 |
| 322 | 1.00 | 0.939 | 1.005 |
| 323 | 1.00 | 0.989 | 1.005 |
| 324 | 0.90 | 0.861 | 0.932 |
| 325 | 0.80 | 0.750 | 0.843 |
| 326 | 0.59 | 0.537 | 0.650 |
| 327 | 0.37 | 0.313 | 0.424 |
| 328 | 0.16 | 0.117 | 0.202 |
| 329 | 0.10 | 0.065 | 0.135 |
| 330 | 0.08 | 0.047 | 0.110 |
| 331 | 0.07 | 0.041 | 0.102 |
| 332 | 0.04 | 0.019 | 0.068 |
| 333 | 0.04 | 0.015 | 0.060 |
| 334 | 0.04 | 0.017 | 0.064 |
| 335 | 0.04 | 0.017 | 0.064 |
| 336 | 0.04 | 0.015 | 0.060 |
| 337 | 0.03 | 0.012 | 0.056 |
| 338 | 0.03 | 0.010 | 0.052 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 339 | 0.03 | 0.010 | 0.052 |
| 340 | 0.03 | 0.010 | 0.052 |
| 341 | 0.03 | 0.010 | 0.052 |
| 342 | 0.03 | 0.010 | 0.052 |
| 343 | 0.03 | 0.010 | 0.052 |
| 344 | 0.04 | 0.015 | 0.060 |
| 345 | 0.04 | 0.015 | 0.060 |
| 346 | 0.04 | 0.019 | 0.068 |
| 347 | 0.07 | 0.036 | 0.095 |
| 348 | 0.08 | 0.049 | 0.113 |
| 349 | 0.09 | 0.054 | 0.121 |
| 350 | 0.09 | 0.057 | 0.124 |
| 351 | 0.09 | 0.057 | 0.124 |
| 352 | 0.11 | 0.070 | 0.142 |
| 353 | 0.09 | 0.060 | 0.128 |
| 354 | 0.10 | 0.065 | 0.135 |
| 355 | 0.10 | 0.068 | 0.139 |
| 356 | 0.12 | 0.081 | 0.157 |
| 357 | 0.14 | 0.100 | 0.181 |
| 358 | 0.15 | 0.108 | 0.192 |
| 359 | 0.17 | 0.125 | 0.212 |
| 360 | 0.20 | 0.154 | 0.246 |
| 361 | 0.23 | 0.182 | 0.280 |
| 362 | 0.32 | 0.268 | 0.376 |
| 363 | 0.43 | 0.371 | 0.485 |
| 364 | 0.60 | 0.547 | 0.659 |
| 365 | 0.74 | 0.690 | 0.791 |
| 366 | 0.89 | 0.851 | 0.924 |
| 367 | 0.99 | 0.983 | 1.004 |
| 368 | 1.00 | 0.989 | 1.005 |
| 369 | 1.00 | 0.989 | 1.005 |
| 370 | 1.00 | 0.989 | 1.005 |
| 371 | 1.00 | 0.989 | 1.005 |
| 372 | 1.00 | 0.989 | 1.005 |
| 373 | 1.00 | 0.989 | 1.005 |

CORN

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 1 | 0.93 | 0.888 | 0.975 |
| 2 | 0.90 | 0.849 | 0.951 |
| 3 | 0.89 | 0.834 | 0.941 |
| 4 | 0.86 | 0.797 | 0.915 |
| 5 | 0.83 | 0.769 | 0.894 |
| 6 | 0.82 | 0.755 | 0.883 |
| 7 | 0.80 | 0.733 | 0.867 |
| 8 | 0.79 | 0.726 | 0.861 |
| 9 | 0.77 | 0.699 | 0.839 |
| 10 | 0.76 | 0.685 | 0.827 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 11 | 0.74 | 0.671 | 0.816 |
| 12 | 0.73 | 0.658 | 0.805 |
| 13 | 0.68 | 0.598 | 0.752 |
| 14 | 0.58 | 0.500 | 0.663 |
| 15 | 0.53 | 0.443 | 0.607 |
| 16 | 0.43 | 0.350 | 0.513 |
| 17 | 0.34 | 0.259 | 0.416 |
| 18 | 0.30 | 0.224 | 0.376 |
| 19 | 0.28 | 0.207 | 0.356 |
| 20 | 0.23 | 0.161 | 0.301 |
| 21 | 0.26 | 0.190 | 0.335 |
| 22 | 0.26 | 0.190 | 0.335 |
| 23 | 0.23 | 0.156 | 0.294 |
| 24 | 0.24 | 0.167 | 0.308 |
| 25 | 0.22 | 0.150 | 0.287 |
| 26 | 0.22 | 0.150 | 0.287 |
| 27 | 0.24 | 0.167 | 0.308 |
| 28 | 0.16 | 0.101 | 0.224 |
| 29 | 0.22 | 0.150 | 0.287 |
| 30 | 0.21 | 0.144 | 0.281 |
| 31 | 0.20 | 0.133 | 0.267 |
| 32 | 0.16 | 0.101 | 0.224 |
| 33 | 0.16 | 0.096 | 0.217 |
| 34 | 0.16 | 0.101 | 0.224 |
| 35 | 0.16 | 0.096 | 0.217 |
| 36 | 0.16 | 0.096 | 0.217 |
| 37 | 0.13 | 0.075 | 0.188 |
| 38 | 0.13 | 0.069 | 0.181 |
| 39 | 0.11 | 0.059 | 0.166 |
| 40 | 0.11 | 0.054 | 0.158 |
| 41 | 0.09 | 0.040 | 0.135 |
| 42 | 0.08 | 0.030 | 0.120 |
| 43 | 0.07 | 0.025 | 0.112 |
| 44 | 0.06 | 0.021 | 0.104 |
| 45 | 0.07 | 0.025 | 0.112 |
| 46 | 0.06 | 0.017 | 0.096 |
| 47 | 0.07 | 0.025 | 0.112 |
| 48 | 0.06 | 0.021 | 0.104 |
| 49 | 0.07 | 0.025 | 0.112 |
| 50 | 0.06 | 0.017 | 0.096 |
| 51 | 0.05 | 0.012 | 0.088 |
| 52 | 0.05 | 0.012 | 0.088 |
| 53 | 0.07 | 0.025 | 0.112 |
| 54 | 0.07 | 0.025 | 0.112 |
| 55 | 0.08 | 0.030 | 0.120 |
| 56 | 0.08 | 0.035 | 0.128 |
| 57 | 0.10 | 0.049 | 0.151 |
| 58 | 0.11 | 0.054 | 0.158 |
| 59 | 0.12 | 0.064 | 0.173 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 60 | 0.10 | 0.049 | 0.151 |
| 61 | 0.11 | 0.054 | 0.158 |
| 62 | 0.11 | 0.054 | 0.158 |
| 63 | 0.11 | 0.059 | 0.166 |
| 64 | 0.12 | 0.064 | 0.173 |
| 65 | 0.12 | 0.064 | 0.173 |
| 66 | 0.13 | 0.069 | 0.181 |
| 67 | 0.12 | 0.064 | 0.173 |
| 68 | 0.14 | 0.085 | 0.203 |
| 69 | 0.13 | 0.069 | 0.181 |
| 70 | 0.14 | 0.080 | 0.195 |
| 71 | 0.14 | 0.085 | 0.203 |
| 72 | 0.16 | 0.096 | 0.217 |
| 73 | 0.18 | 0.112 | 0.238 |
| 74 | 0.19 | 0.128 | 0.260 |
| 75 | 0.20 | 0.133 | 0.267 |
| 76 | 0.20 | 0.133 | 0.267 |
| 77 | 0.18 | 0.117 | 0.245 |
| 78 | 0.18 | 0.117 | 0.245 |
| 79 | 0.17 | 0.106 | 0.231 |
| 80 | 0.16 | 0.096 | 0.217 |
| 81 | 0.16 | 0.096 | 0.217 |
| 82 | 0.19 | 0.128 | 0.260 |
| 83 | 0.21 | 0.144 | 0.281 |
| 84 | 0.14 | 0.080 | 0.195 |
| 85 | 0.13 | 0.075 | 0.188 |
| 86 | 0.10 | 0.049 | 0.151 |
| 87 | 0.09 | 0.040 | 0.135 |
| 88 | 0.08 | 0.035 | 0.128 |
| 89 | 0.06 | 0.021 | 0.104 |
| 90 | 0.07 | 0.025 | 0.112 |
| 91 | 0.06 | 0.017 | 0.096 |
| 92 | 0.53 | 0.449 | 0.614 |
| 93 | 0.31 | 0.236 | 0.389 |
| 94 | 0.24 | 0.167 | 0.308 |
| 95 | 0.16 | 0.096 | 0.217 |
| 96 | 0.14 | 0.080 | 0.195 |
| 97 | 0.13 | 0.069 | 0.181 |
| 98 | 0.11 | 0.054 | 0.158 |
| 99 | 0.10 | 0.049 | 0.151 |
| 100 | 0.11 | 0.054 | 0.158 |
| 101 | 0.09 | 0.044 | 0.143 |
| 102 | 0.08 | 0.030 | 0.120 |
| 103 | 0.07 | 0.025 | 0.112 |
| 104 | 0.07 | 0.025 | 0.112 |
| 105 | 0.06 | 0.021 | 0.104 |
| 106 | 0.06 | 0.017 | 0.096 |
| 107 | 0.05 | 0.012 | 0.088 |
| 108 | 0.05 | 0.012 | 0.088 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 109 | 0.05 | 0.012 | 0.088 |
| 110 | 0.04 | 0.008 | 0.079 |
| 111 | 0.04 | 0.008 | 0.079 |
| 112 | 0.04 | 0.008 | 0.079 |
| 113 | 0.05 | 0.012 | 0.088 |
| 114 | 0.07 | 0.025 | 0.112 |
| 115 | 0.11 | 0.054 | 0.158 |
| 116 | 0.13 | 0.069 | 0.181 |
| 117 | 0.13 | 0.069 | 0.181 |
| 118 | 0.13 | 0.069 | 0.181 |
| 119 | 0.13 | 0.069 | 0.181 |
| 120 | 0.13 | 0.069 | 0.181 |
| 121 | 0.13 | 0.069 | 0.181 |
| 122 | 0.13 | 0.069 | 0.181 |
| 123 | 0.13 | 0.069 | 0.181 |
| 124 | 0.13 | 0.069 | 0.181 |
| 125 | 0.13 | 0.069 | 0.181 |
| 126 | 0.13 | 0.069 | 0.181 |
| 127 | 0.13 | 0.069 | 0.181 |
| 128 | 0.13 | 0.069 | 0.181 |
| 129 | 0.13 | 0.069 | 0.181 |
| 130 | 0.13 | 0.069 | 0.181 |
| 131 | 0.13 | 0.069 | 0.181 |
| 132 | 0.13 | 0.069 | 0.181 |
| 133 | 0.13 | 0.069 | 0.181 |
| 134 | 0.13 | 0.069 | 0.181 |
| 135 | 0.13 | 0.069 | 0.181 |
| 136 | 0.13 | 0.069 | 0.181 |
| 137 | 0.13 | 0.069 | 0.181 |
| 138 | 0.13 | 0.069 | 0.181 |
| 139 | 0.13 | 0.069 | 0.181 |
| 140 | 0.13 | 0.069 | 0.181 |
| 141 | 0.13 | 0.069 | 0.181 |
| 142 | 0.13 | 0.069 | 0.181 |
| 143 | 0.13 | 0.069 | 0.181 |
| 144 | 0.13 | 0.069 | 0.181 |
| 145 | 0.13 | 0.069 | 0.181 |
| 146 | 0.13 | 0.069 | 0.181 |
| 147 | 0.13 | 0.069 | 0.181 |
| 148 | 0.13 | 0.069 | 0.181 |
| 149 | 0.13 | 0.075 | 0.188 |
| 150 | 0.13 | 0.069 | 0.181 |
| 151 | 0.13 | 0.069 | 0.181 |
| 152 | 0.13 | 0.069 | 0.181 |
| 153 | 0.13 | 0.069 | 0.181 |
| 154 | 0.13 | 0.069 | 0.181 |
| 155 | 0.13 | 0.069 | 0.181 |
| 156 | 0.13 | 0.069 | 0.181 |
| 157 | 0.13 | 0.069 | 0.181 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|
| 158 | 0.13 | 0.069 | 0.181 |
| 159 | 0.13 | 0.069 | 0.181 |
| 160 | 0.13 | 0.069 | 0.181 |
| 161 | 0.13 | 0.069 | 0.181 |
| 162 | 0.13 | 0.069 | 0.181 |
| 163 | 0.12 | 0.064 | 0.173 |
| 164 | 0.13 | 0.075 | 0.188 |
| 165 | 0.13 | 0.075 | 0.188 |
| 166 | 0.13 | 0.075 | 0.188 |
| 167 | 0.13 | 0.075 | 0.188 |
| 168 | 0.13 | 0.075 | 0.188 |
| 169 | 0.13 | 0.075 | 0.188 |
| 170 | 0.13 | 0.075 | 0.188 |
| 171 | 0.13 | 0.069 | 0.181 |
| 172 | 0.13 | 0.069 | 0.181 |
| 173 | 0.13 | 0.069 | 0.181 |
| 174 | 0.13 | 0.069 | 0.181 |
| 175 | 0.13 | 0.069 | 0.181 |
| 176 | 0.12 | 0.064 | 0.173 |
| 177 | 0.11 | 0.059 | 0.166 |
| 178 | 0.09 | 0.044 | 0.143 |
| 179 | 0.09 | 0.044 | 0.143 |
| 180 | 0.09 | 0.044 | 0.143 |
| 181 | 0.09 | 0.040 | 0.135 |
| 182 | 0.09 | 0.040 | 0.135 |
| 183 | 0.09 | 0.040 | 0.135 |
| 184 | 0.09 | 0.040 | 0.135 |
| 185 | 0.08 | 0.035 | 0.128 |
| 186 | 0.10 | 0.049 | 0.151 |
| 187 | 0.09 | 0.044 | 0.143 |
| 188 | 0.09 | 0.040 | 0.135 |
| 189 | 0.09 | 0.040 | 0.135 |
| 190 | 0.09 | 0.040 | 0.135 |
| 191 | 0.09 | 0.040 | 0.135 |
| 192 | 0.09 | 0.044 | 0.143 |
| 193 | 0.09 | 0.044 | 0.143 |
| 194 | 0.09 | 0.044 | 0.143 |
| 195 | 0.09 | 0.044 | 0.143 |
| 196 | 0.09 | 0.044 | 0.143 |
| 197 | 0.09 | 0.044 | 0.143 |
| 198 | 0.09 | 0.044 | 0.143 |
| 199 | 0.09 | 0.044 | 0.143 |
| 200 | 0.09 | 0.044 | 0.143 |
| 201 | 0.09 | 0.040 | 0.135 |
| 202 | 0.09 | 0.044 | 0.143 |
| 203 | 0.09 | 0.040 | 0.135 |
| 204 | 0.09 | 0.040 | 0.135 |
| 205 | 0.09 | 0.044 | 0.143 |
| 206 | 0.09 | 0.040 | 0.135 |

| BAND | PROB | LOWER C.I. | UPPER C.I. | BAND | PROB | LOWER C.I. | UPPER C.I. |
|---|---|---|---|---|---|---|---|
| 207 | 0.11 | 0.059 | 0.166 | 256 | 0.04 | 0.008 | 0.079 |
| 208 | 0.12 | 0.064 | 0.173 | 257 | 0.06 | 0.017 | 0.096 |
| 209 | 0.12 | 0.064 | 0.173 | 258 | 0.04 | 0.004 | 0.071 |
| 210 | 0.13 | 0.075 | 0.188 | 259 | 0.04 | 0.008 | 0.079 |
| 211 | 0.14 | 0.080 | 0.195 | 260 | 0.03 | 0.001 | 0.062 |
| 212 | 0.14 | 0.085 | 0.203 | 261 | 0.03 | 0.001 | 0.062 |
| 213 | 0.15 | 0.090 | 0.210 | 262 | 0.03 | 0.001 | 0.062 |
| 214 | 0.16 | 0.096 | 0.217 | 263 | 0.04 | 0.004 | 0.071 |
| 215 | 0.18 | 0.117 | 0.245 | 264 | 0.09 | 0.040 | 0.135 |
| 216 | 0.18 | 0.112 | 0.238 | 265 | 0.13 | 0.075 | 0.188 |
| 217 | 0.15 | 0.090 | 0.210 | 266 | 0.14 | 0.085 | 0.203 |
| 218 | 0.12 | 0.064 | 0.173 | 267 | 0.16 | 0.101 | 0.224 |
| 219 | 0.09 | 0.040 | 0.135 | 268 | 0.14 | 0.085 | 0.203 |
| 220 | 0.09 | 0.044 | 0.143 | 269 | 0.20 | 0.133 | 0.267 |
| 221 | 0.09 | 0.040 | 0.135 | 270 | 0.26 | 0.190 | 0.335 |
| 222 | 0.08 | 0.035 | 0.128 | 271 | 0.33 | 0.248 | 0.402 |
| 223 | 0.08 | 0.030 | 0.120 | 272 | 0.49 | 0.405 | 0.570 |
| 224 | 0.06 | 0.021 | 0.104 | 273 | 0.86 | 0.805 | 0.920 |
| 225 | 0.06 | 0.017 | 0.096 | 274 | 0.89 | 0.842 | 0.946 |
| 226 | 0.06 | 0.017 | 0.096 | 275 | 0.92 | 0.872 | 0.965 |
| 227 | 0.06 | 0.017 | 0.096 | 276 | 0.91 | 0.857 | 0.956 |
| 228 | 0.05 | 0.012 | 0.088 | 277 | 0.88 | 0.827 | 0.936 |
| 229 | 0.04 | 0.004 | 0.071 | 278 | 0.87 | 0.812 | 0.925 |
| 230 | 0.04 | 0.004 | 0.071 | 279 | 0.86 | 0.805 | 0.920 |
| 231 | 0.04 | 0.004 | 0.071 | 280 | 0.87 | 0.812 | 0.925 |
| 232 | 0.04 | 0.004 | 0.071 | 281 | 0.86 | 0.805 | 0.920 |
| 233 | 0.03 | -.003 | 0.053 | 282 | 0.85 | 0.790 | 0.910 |
| 234 | 0.04 | 0.004 | 0.071 | 283 | 0.84 | 0.783 | 0.904 |
| 235 | 0.04 | 0.008 | 0.079 | 284 | 0.78 | 0.713 | 0.850 |
| 236 | 0.04 | 0.008 | 0.079 | 285 | 0.61 | 0.526 | 0.687 |
| 237 | 0.03 | 0.001 | 0.062 | 286 | 0.43 | 0.350 | 0.513 |
| 238 | 0.03 | -.003 | 0.053 | 287 | 0.29 | 0.213 | 0.362 |
| 239 | 0.04 | 0.004 | 0.071 | 288 | 0.23 | 0.161 | 0.301 |
| 240 | 0.04 | 0.008 | 0.079 | 289 | 0.18 | 0.117 | 0.245 |
| 241 | 0.04 | 0.004 | 0.071 | 290 | 0.09 | 0.040 | 0.135 |
| 242 | 0.04 | 0.008 | 0.079 | 291 | 0.06 | 0.021 | 0.104 |
| 243 | 0.04 | 0.008 | 0.079 | 292 | 0.05 | 0.012 | 0.088 |
| 244 | 0.05 | 0.012 | 0.088 | 293 | 0.03 | 0.001 | 0.062 |
| 245 | 0.06 | 0.017 | 0.096 | 294 | 0.03 | 0.001 | 0.062 |
| 246 | 0.05 | 0.012 | 0.088 | 295 | 0.04 | 0.008 | 0.079 |
| 247 | 0.04 | 0.004 | 0.071 | 296 | 0.04 | 0.004 | 0.071 |
| 248 | 0.04 | 0.008 | 0.079 | 297 | 0.04 | 0.004 | 0.071 |
| 249 | 0.04 | 0.008 | 0.079 | 298 | 0.03 | 0.001 | 0.062 |
| 250 | 0.03 | -.003 | 0.053 | 299 | 0.03 | 0.001 | 0.062 |
| 251 | 0.03 | -.003 | 0.053 | 300 | 0.05 | 0.012 | 0.088 |
| 252 | 0.04 | 0.004 | 0.071 | 301 | 0.05 | 0.012 | 0.088 |
| 253 | 0.02 | -.006 | 0.043 | 302 | 0.06 | 0.017 | 0.096 |
| 254 | 0.03 | 0.001 | 0.062 | 303 | 0.06 | 0.021 | 0.104 |
| 255 | 0.04 | 0.008 | 0.079 | 304 | 0.06 | 0.021 | 0.104 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
| --- | --- | --- | --- |
| 305 | 0.06 | 0.021 | 0.104 |
| 306 | 0.06 | 0.021 | 0.104 |
| 307 | 0.07 | 0.025 | 0.112 |
| 308 | 0.06 | 0.021 | 0.104 |
| 309 | 0.09 | 0.044 | 0.143 |
| 310 | 0.12 | 0.064 | 0.173 |
| 311 | 0.12 | 0.064 | 0.173 |
| 312 | 0.13 | 0.069 | 0.181 |
| 313 | 0.13 | 0.069 | 0.181 |
| 314 | 0.14 | 0.080 | 0.195 |
| 315 | 0.16 | 0.101 | 0.224 |
| 316 | 0.28 | 0.201 | 0.349 |
| 317 | 0.50 | 0.418 | 0.582 |
| 318 | 0.81 | 0.747 | 0.878 |
| 319 | 0.89 | 0.834 | 0.941 |
| 320 | 0.89 | 0.834 | 0.941 |
| 321 | 0.89 | 0.834 | 0.941 |
| 322 | 0.88 | 0.827 | 0.936 |
| 323 | 0.86 | 0.797 | 0.915 |
| 324 | 0.83 | 0.769 | 0.894 |
| 325 | 0.70 | 0.624 | 0.776 |
| 326 | 0.62 | 0.539 | 0.699 |
| 327 | 0.39 | 0.313 | 0.474 |
| 328 | 0.24 | 0.173 | 0.315 |
| 329 | 0.23 | 0.161 | 0.301 |
| 330 | 0.21 | 0.144 | 0.281 |
| 331 | 0.19 | 0.122 | 0.253 |
| 332 | 0.17 | 0.106 | 0.231 |
| 333 | 0.13 | 0.075 | 0.188 |
| 334 | 0.13 | 0.069 | 0.181 |
| 335 | 0.11 | 0.054 | 0.158 |
| 336 | 0.10 | 0.049 | 0.151 |
| 337 | 0.09 | 0.040 | 0.135 |
| 338 | 0.09 | 0.040 | 0.135 |
| 339 | 0.09 | 0.040 | 0.135 |
| 340 | 0.09 | 0.040 | 0.135 |
| 341 | 0.08 | 0.035 | 0.128 |
| 342 | 0.09 | 0.040 | 0.135 |
| 343 | 0.09 | 0.040 | 0.135 |
| 344 | 0.09 | 0.040 | 0.135 |
| 345 | 0.11 | 0.059 | 0.166 |
| 346 | 0.19 | 0.122 | 0.253 |
| 347 | 0.23 | 0.161 | 0.301 |
| 348 | 0.21 | 0.144 | 0.281 |
| 349 | 0.22 | 0.150 | 0.287 |
| 350 | 0.23 | 0.161 | 0.301 |
| 351 | 0.26 | 0.184 | 0.329 |
| 352 | 0.26 | 0.184 | 0.329 |
| 353 | 0.26 | 0.184 | 0.329 |

| BAND | PROB | LOWER C.I. | UPPER C.I. |
| --- | --- | --- | --- |
| 354 | 0.22 | 0.150 | 0.287 |
| 355 | 0.21 | 0.144 | 0.281 |
| 356 | 0.25 | 0.178 | 0.322 |
| 357 | 0.26 | 0.190 | 0.335 |
| 358 | 0.29 | 0.213 | 0.362 |
| 359 | 0.31 | 0.236 | 0.389 |
| 360 | 0.34 | 0.259 | 0.416 |
| 361 | 0.34 | 0.265 | 0.422 |
| 362 | 0.38 | 0.295 | 0.455 |
| 363 | 0.50 | 0.418 | 0.582 |
| 364 | 0.64 | 0.565 | 0.723 |
| 365 | 0.88 | 0.819 | 0.931 |
| 366 | 0.95 | 0.912 | 0.988 |
| 367 | 0.97 | 0.938 | 0.999 |
| 368 | 0.99 | 0.967 | 1.008 |
| 369 | 0.99 | 0.967 | 1.008 |
| 370 | 0.99 | 0.967 | 1.008 |
| 371 | 0.99 | 0.978 | 1.009 |
| 372 | 0.99 | 0.978 | 1.009 |
| 373 | 1.00 | 0.997 | 1.003 |

## APPENDIX B

## MEAN AND STANDARD DEVIATION OF S/N FOR EACH CHANNEL RECORDED AS A POWER OF 2.0

### SOY-WHEAT

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 1 | 0.76 | 0.96 |
| 2 | 0.99 | 1.00 |
| 3 | 1.16 | 1.08 |
| 4 | 1.45 | 1.07 |
| 5 | 1.58 | 1.06 |
| 6 | 1.82 | 1.05 |
| 7 | 1.95 | 1.06 |
| 8 | 2.16 | 1.08 |
| 9 | 2.22 | 1.10 |
| 10 | 2.35 | 1.05 |
| 11 | 2.37 | 1.08 |
| 12 | 2.44 | 1.04 |
| 13 | 2.47 | 1.07 |
| 14 | 2.55 | 1.03 |
| 15 | 2.63 | 1.07 |
| 16 | 2.72 | 1.10 |
| 17 | 2.87 | 1.10 |
| 18 | 3.00 | 1.07 |
| 19 | 3.08 | 1.08 |
| 20 | 3.12 | 1.10 |
| 21 | 3.16 | 1.13 |
| 22 | 3.14 | 1.14 |
| 23 | 3.17 | 1.14 |
| 24 | 3.21 | 1.12 |
| 25 | 3.23 | 1.12 |
| 26 | 3.22 | 1.14 |
| 27 | 3.26 | 1.14 |
| 28 | 3.25 | 1.12 |
| 29 | 3.26 | 1.14 |
| 30 | 3.26 | 1.14 |
| 31 | 3.23 | 1.14 |
| 32 | 3.26 | 1.14 |
| 33 | 3.27 | 1.15 |
| 34 | 3.32 | 1.14 |
| 35 | 3.33 | 1.15 |
| 36 | 3.38 | 1.12 |
| 37 | 3.41 | 1.15 |
| 38 | 3.47 | 1.11 |
| 39 | 3.51 | 1.10 |
| 40 | 3.62 | 1.07 |
| 41 | 3.71 | 1.07 |
| 42 | 3.85 | 1.06 |
| 43 | 3.88 | 1.05 |
| 44 | 3.92 | 1.06 |
| 45 | 3.97 | 1.05 |
| 46 | 4.03 | 1.02 |
| 47 | 4.06 | 1.01 |
| 48 | 4.07 | 1.02 |
| 49 | 4.06 | 1.03 |
| 50 | 4.05 | 1.03 |
| 51 | 4.03 | 1.05 |
| 52 | 3.99 | 1.08 |
| 53 | 3.97 | 1.10 |
| 54 | 3.95 | 1.12 |
| 55 | 3.90 | 1.13 |
| 56 | 3.84 | 1.14 |
| 57 | 3.82 | 1.16 |
| 58 | 3.78 | 1.18 |
| 59 | 3.76 | 1.17 |
| 60 | 3.73 | 1.20 |
| 61 | 3.75 | 1.19 |
| 62 | 3.74 | 1.22 |
| 63 | 3.72 | 1.24 |
| 64 | 3.69 | 1.23 |
| 65 | 3.64 | 1.27 |
| 66 | 3.61 | 1.26 |
| 67 | 3.59 | 1.27 |
| 68 | 3.55 | 1.27 |
| 69 | 3.54 | 1.30 |
| 70 | 3.53 | 1.28 |
| 71 | 3.52 | 1.31 |
| 72 | 3.47 | 1.34 |
| 73 | 3.45 | 1.35 |
| 74 | 3.42 | 1.38 |
| 75 | 3.38 | 1.36 |
| 76 | 3.35 | 1.41 |
| 77 | 3.36 | 1.40 |
| 78 | 3.35 | 1.44 |
| 79 | 3.36 | 1.47 |
| 80 | 3.42 | 1.47 |
| 81 | 3.42 | 1.46 |
| 82 | 3.48 | 1.44 |
| 83 | 3.51 | 1.41 |
| 84 | 3.63 | 1.32 |
| 85 | 3.74 | 1.28 |
| 86 | 3.93 | 1.21 |
| 87 | 4.07 | 1.12 |
| 88 | 4.33 | 1.02 |

ORIGINAL PAGE IS
OF POOR QUALITY

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 89 | 4.51 | 1.02 |
| 90 | 4.63 | 0.98 |
| 91 | 4.75 | 0.91 |
| 92 | 2.55 | 1.44 |
| 93 | 2.95 | 1.39 |
| 94 | 3.25 | 1.42 |
| 95 | 3.49 | 1.45 |
| 96 | 3.68 | 1.36 |
| 97 | 3.76 | 1.36 |
| 98 | 3.84 | 1.35 |
| 99 | 3.90 | 1.34 |
| 100 | 3.97 | 1.31 |
| 101 | 4.13 | 1.21 |
| 102 | 4.27 | 1.14 |
| 103 | 4.53 | 1.01 |
| 104 | 4.69 | 0.99 |
| 105 | 4.88 | 0.93 |
| 106 | 5.02 | 0.88 |
| 107 | 5.17 | 0.93 |
| 108 | 5.24 | 0.96 |
| 109 | 5.32 | 0.96 |
| 110 | 5.35 | 0.97 |
| 111 | 5.43 | 0.94 |
| 112 | 5.44 | 0.93 |
| 113 | 5.48 | 0.92 |
| 114 | 5.52 | 0.89 |
| 115 | 5.52 | 0.90 |
| 116 | 5.50 | 0.89 |
| 117 | 5.47 | 0.92 |
| 118 | 5.38 | 0.98 |
| 119 | 5.33 | 1.00 |
| 120 | 5.32 | 1.00 |
| 121 | 5.37 | 0.98 |
| 122 | 5.44 | 0.97 |
| 123 | 5.50 | 0.92 |
| 124 | 5.50 | 0.93 |
| 125 | 5.50 | 0.93 |
| 126 | 5.50 | 0.93 |
| 127 | 5.50 | 0.93 |
| 128 | 5.50 | 0.92 |
| 129 | 5.47 | 0.96 |
| 130 | 5.45 | 0.96 |
| 131 | 5.45 | 0.96 |
| 132 | 5.38 | 1.00 |
| 133 | 5.34 | 1.00 |
| 134 | 5.32 | 0.99 |
| 135 | 5.35 | 1.00 |
| 136 | 5.36 | 1.00 |
| 137 | 5.33 | 1.01 |
| 138 | 5.38 | 1.03 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 139 | 5.43 | 0.97 |
| 140 | 5.49 | 0.95 |
| 141 | 5.51 | 0.94 |
| 142 | 5.53 | 0.90 |
| 143 | 5.56 | 0.89 |
| 144 | 5.57 | 0.88 |
| 145 | 5.60 | 0.87 |
| 146 | 5.61 | 0.89 |
| 147 | 5.62 | 0.88 |
| 148 | 5.65 | 0.87 |
| 149 | 5.67 | 0.90 |
| 150 | 5.73 | 0.93 |
| 151 | 5.72 | 0.93 |
| 152 | 5.72 | 0.95 |
| 153 | 5.70 | 0.95 |
| 154 | 5.68 | 0.94 |
| 155 | 5.63 | 0.93 |
| 156 | 5.57 | 0.95 |
| 157 | 5.54 | 0.97 |
| 158 | 5.53 | 1.01 |
| 159 | 5.54 | 1.04 |
| 160 | 5.51 | 1.02 |
| 161 | 5.43 | 0.97 |
| 162 | 5.41 | 1.02 |
| 163 | 5.21 | 1.07 |
| 164 | 5.01 | 1.10 |
| 165 | 4.89 | 1.14 |
| 166 | 4.77 | 1.14 |
| 167 | 4.77 | 1.18 |
| 168 | 4.83 | 1.16 |
| 169 | 4.98 | 1.15 |
| 170 | 5.04 | 1.11 |
| 171 | 5.26 | 1.07 |
| 172 | 5.49 | 1.14 |
| 173 | 5.68 | 1.08 |
| 174 | 5.81 | 1.07 |
| 175 | 5.93 | 1.07 |
| 176 | 6.08 | 1.04 |
| 177 | 6.16 | 1.07 |
| 178 | 6.23 | 1.03 |
| 179 | 6.30 | 1.01 |
| 180 | 6.36 | 1.01 |
| 181 | 6.38 | 1.00 |
| 182 | 6.38 | 1.02 |
| 183 | 6.41 | 1.02 |
| 184 | 6.42 | 1.00 |
| 185 | 6.42 | 1.02 |
| 186 | 6.43 | 1.01 |
| 187 | 6.42 | 1.02 |
| 188 | 6.44 | 1.00 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 189 | 6.44 | 1.00 |
| 190 | 6.44 | 0.99 |
| 191 | 6.47 | 0.99 |
| 192 | 6.47 | 0.99 |
| 193 | 6.47 | 1.00 |
| 194 | 6.47 | 0.97 |
| 195 | 6.48 | 0.97 |
| 196 | 6.51 | 0.92 |
| 197 | 6.49 | 0.93 |
| 198 | 6.47 | 0.93 |
| 199 | 6.48 | 0.91 |
| 200 | 6.49 | 0.94 |
| 201 | 6.48 | 0.94 |
| 202 | 6.48 | 0.93 |
| 203 | 6.45 | 0.97 |
| 204 | 6.43 | 0.99 |
| 205 | 6.46 | 0.95 |
| 206 | 6.38 | 0.97 |
| 207 | 6.32 | 0.98 |
| 208 | 6.20 | 1.03 |
| 209 | 6.00 | 1.06 |
| 210 | 5.88 | 1.05 |
| 211 | 5.63 | 1.11 |
| 212 | 5.37 | 1.15 |
| 213 | 5.00 | 1.15 |
| 214 | 4.86 | 1.23 |
| 215 | 4.69 | 1.26 |
| 216 | 4.71 | 1.27 |
| 217 | 4.92 | 1.29 |
| 218 | 5.10 | 1.26 |
| 219 | 5.33 | 1.25 |
| 220 | 5.62 | 1.19 |
| 221 | 5.86 | 1.17 |
| 222 | 5.99 | 1.14 |
| 223 | 6.13 | 1.07 |
| 224 | 6.22 | 1.08 |
| 225 | 6.29 | 1.07 |
| 226 | 6.31 | 1.10 |
| 227 | 6.34 | 1.10 |
| 228 | 6.36 | 1.08 |
| 229 | 6.39 | 1.11 |
| 230 | 6.42 | 1.12 |
| 231 | 6.43 | 1.10 |
| 232 | 6.47 | 1.08 |
| 233 | 6.50 | 1.06 |
| 234 | 6.48 | 1.07 |
| 235 | 6.50 | 1.08 |
| 236 | 6.55 | 1.07 |
| 237 | 6.59 | 1.06 |
| 238 | 6.59 | 1.11 |
| 239 | 6.61 | 1.12 |
| 240 | 6.64 | 1.10 |
| 241 | 6.68 | 1.09 |
| 242 | 6.70 | 1.11 |
| 243 | 6.69 | 1.09 |
| 244 | 6.67 | 1.09 |
| 245 | 6.63 | 1.08 |
| 246 | 6.58 | 1.07 |
| 247 | 6.57 | 1.06 |
| 248 | 6.55 | 1.09 |
| 249 | 6.57 | 1.08 |
| 250 | 6.58 | 1.09 |
| 251 | 6.59 | 1.09 |
| 252 | 6.63 | 1.11 |
| 253 | 6.68 | 1.13 |
| 254 | 6.69 | 1.13 |
| 255 | 6.63 | 1.13 |
| 256 | 6.62 | 1.12 |
| 257 | 6.58 | 1.10 |
| 258 | 6.53 | 1.12 |
| 259 | 6.45 | 1.14 |
| 260 | 6.41 | 1.15 |
| 261 | 6.31 | 1.15 |
| 262 | 6.19 | 1.15 |
| 263 | 6.02 | 1.21 |
| 264 | 5.89 | 1.24 |
| 265 | 5.71 | 1.25 |
| 266 | 5.48 | 1.23 |
| 267 | 5.08 | 1.19 |
| 268 | 4.86 | 1.25 |
| 269 | 4.33 | 1.26 |
| 270 | 3.86 | 1.24 |
| 271 | 3.13 | 1.28 |
| 272 | 2.52 | 1.22 |
| 273 | 1.88 | 1.16 |
| 274 | 1.37 | 1.06 |
| 275 | 0.88 | 0.98 |
| 276 | 0.59 | 0.90 |
| 277 | 0.42 | 0.83 |
| 278 | 0.39 | 0.83 |
| 279 | 0.38 | 0.82 |
| 280 | 0.45 | 0.87 |
| 281 | 0.52 | 0.93 |
| 282 | 0.68 | 1.02 |
| 283 | 0.81 | 1.12 |
| 284 | 1.53 | 1.39 |
| 285 | 2.26 | 1.51 |
| 286 | 3.15 | 1.52 |
| 287 | 3.89 | 1.46 |
| 288 | 4.43 | 1.40 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 289 | 5.01 | 1.35 |
| 290 | 5.58 | 1.28 |
| 291 | 6.14 | 1.26 |
| 292 | 6.64 | 1.19 |
| 293 | 6.82 | 1.69 |
| 294 | 7.31 | 1.23 |
| 295 | 7.43 | 1.18 |
| 296 | 7.51 | 1.15 |
| 297 | 7.53 | 1.15 |
| 298 | 7.58 | 1.17 |
| 299 | 7.63 | 1.20 |
| 300 | 7.73 | 1.21 |
| 301 | 7.80 | 1.20 |
| 302 | 7.84 | 1.18 |
| 303 | 7.84 | 1.19 |
| 304 | 7.84 | 1.17 |
| 305 | 7.83 | 1.21 |
| 306 | 7.78 | 1.21 |
| 307 | 7.66 | 1.46 |
| 308 | 7.58 | 1.47 |
| 309 | 7.46 | 1.46 |
| 310 | 7.29 | 1.42 |
| 311 | 7.17 | 1.45 |
| 312 | 7.02 | 1.46 |
| 313 | 6.77 | 1.45 |
| 314 | 6.25 | 1.36 |
| 315 | 5.63 | 1.39 |
| 316 | 4.53 | 1.37 |
| 317 | 3.21 | 1.36 |
| 318 | 1.84 | 1.25 |
| 319 | 0.86 | 1.03 |
| 320 | 0.38 | 0.79 |
| 321 | 0.24 | 0.78 |
| 322 | 0.30 | 0.83 |
| 323 | 0.41 | 0.91 |
| 324 | 0.80 | 1.20 |
| 325 | 1.38 | 1.46 |
| 326 | 2.28 | 1.56 |
| 327 | 3.09 | 1.61 |
| 328 | 3.88 | 1.64 |
| 329 | 4.27 | 1.59 |
| 330 | 4.49 | 1.59 |
| 331 | 4.59 | 1.57 |
| 332 | 4.86 | 1.52 |
| 333 | 5.10 | 1.53 |
| 334 | 5.34 | 1.55 |
| 335 | 5.42 | 1.52 |
| 336 | 5.49 | 1.49 |
| 337 | 5.58 | 1.48 |
| 338 | 5.69 | 1.44 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 339 | 5.77 | 1.47 |
| 340 | 5.77 | 1.45 |
| 341 | 5.81 | 1.44 |
| 342 | 5.75 | 1.45 |
| 343 | 5.58 | 1.43 |
| 344 | 5.32 | 1.33 |
| 345 | 5.15 | 1.36 |
| 346 | 4.91 | 1.35 |
| 347 | 4.43 | 1.23 |
| 348 | 4.17 | 1.22 |
| 349 | 4.13 | 1.26 |
| 350 | 4.10 | 1.27 |
| 351 | 4.11 | 1.25 |
| 352 | 4.11 | 1.31 |
| 353 | 4.10 | 1.28 |
| 354 | 4.07 | 1.28 |
| 355 | 4.05 | 1.28 |
| 356 | 3.99 | 1.31 |
| 357 | 3.79 | 1.30 |
| 358 | 3.59 | 1.25 |
| 359 | 3.38 | 1.19 |
| 360 | 3.13 | 1.21 |
| 361 | 2.97 | 1.24 |
| 362 | 2.70 | 1.26 |
| 363 | 2.41 | 1.22 |
| 364 | 2.05 | 1.15 |
| 365 | 1.78 | 1.15 |
| 366 | 1.37 | 1.10 |
| 367 | 1.00 | 0.96 |
| 368 | 0.53 | 0.82 |
| 369 | 0.23 | 0.66 |
| 370 | 0.05 | 0.52 |
| 371 | 0.03 | 0.50 |
| 372 | 0.03 | 0.50 |
| 373 | 0.03 | 0.50 |

## CORN

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 1 | 0.71 | 0.96 |
| 2 | 0.90 | 1.04 |
| 3 | 1.04 | 1.06 |
| 4 | 1.23 | 1.15 |
| 5 | 1.43 | 1.17 |
| 6 | 1.57 | 1.19 |
| 7 | 1.70 | 1.27 |
| 8 | 1.79 | 1.30 |
| 9 | 1.90 | 1.31 |
| 10 | 2.19 | 1.19 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 11 | 2.27 | 1.23 |
| 12 | 2.26 | 1.21 |
| 13 | 2.40 | 1.24 |
| 14 | 2.47 | 1.27 |
| 15 | 2.56 | 1.24 |
| 16 | 2.65 | 1.25 |
| 17 | 2.82 | 1.25 |
| 18 | 2.91 | 1.25 |
| 19 | 3.03 | 1.25 |
| 20 | 3.09 | 1.24 |
| 21 | 3.11 | 1.24 |
| 22 | 3.14 | 1.28 |
| 23 | 3.15 | 1.25 |
| 24 | 3.14 | 1.27 |
| 25 | 3.15 | 1.27 |
| 26 | 3.20 | 1.27 |
| 27 | 3.16 | 1.28 |
| 28 | 3.24 | 1.20 |
| 29 | 3.19 | 1.25 |
| 30 | 3.20 | 1.27 |
| 31 | 3.24 | 1.23 |
| 32 | 3.29 | 1.26 |
| 33 | 3.32 | 1.28 |
| 34 | 3.31 | 1.27 |
| 35 | 3.33 | 1.29 |
| 36 | 3.37 | 1.28 |
| 37 | 3.46 | 1.29 |
| 38 | 3.49 | 1.30 |
| 39 | 3.52 | 1.29 |
| 40 | 3.57 | 1.28 |
| 41 | 3.72 | 1.25 |
| 42 | 3.82 | 1.22 |
| 43 | 3.89 | 1.24 |
| 44 | 3.95 | 1.22 |
| 45 | 3.98 | 1.23 |
| 46 | 4.02 | 1.21 |
| 47 | 3.99 | 1.25 |
| 48 | 4.05 | 1.23 |
| 49 | 4.04 | 1.25 |
| 50 | 4.04 | 1.25 |
| 51 | 4.05 | 1.22 |
| 52 | 4.00 | 1.23 |
| 53 | 3.94 | 1.26 |
| 54 | 3.91 | 1.26 |
| 55 | 3.88 | 1.30 |
| 56 | 3.83 | 1.30 |
| 57 | 3.77 | 1.34 |
| 58 | 3.71 | 1.33 |
| 59 | 3.69 | 1.33 |
| 60 | 3.72 | 1.32 |
| 61 | 3.71 | 1.31 |
| 62 | 3.67 | 1.32 |
| 63 | 3.67 | 1.36 |
| 64 | 3.63 | 1.36 |
| 65 | 3.63 | 1.35 |
| 66 | 3.60 | 1.35 |
| 67 | 3.63 | 1.36 |
| 68 | 3.59 | 1.36 |
| 69 | 3.59 | 1.36 |
| 70 | 3.59 | 1.38 |
| 71 | 3.59 | 1.40 |
| 72 | 3.54 | 1.41 |
| 73 | 3.57 | 1.43 |
| 74 | 3.46 | 1.37 |
| 75 | 3.45 | 1.38 |
| 76 | 3.52 | 1.40 |
| 77 | 3.52 | 1.42 |
| 78 | 3.52 | 1.38 |
| 79 | 3.55 | 1.41 |
| 80 | 3.56 | 1.36 |
| 81 | 3.57 | 1.37 |
| 82 | 3.54 | 1.42 |
| 83 | 3.49 | 1.45 |
| 84 | 3.61 | 1.38 |
| 85 | 3.67 | 1.35 |
| 86 | 3.84 | 1.35 |
| 87 | 3.97 | 1.36 |
| 88 | 4.13 | 1.32 |
| 89 | 4.20 | 1.29 |
| 90 | 4.33 | 1.27 |
| 91 | 4.45 | 1.28 |
| 92 | 2.77 | 1.49 |
| 93 | 3.16 | 1.45 |
| 94 | 3.42 | 1.45 |
| 95 | 3.60 | 1.43 |
| 96 | 3.71 | 1.48 |
| 97 | 3.83 | 1.51 |
| 98 | 3.87 | 1.47 |
| 99 | 3.94 | 1.47 |
| 100 | 3.97 | 1.45 |
| 101 | 4.12 | 1.43 |
| 102 | 4.26 | 1.40 |
| 103 | 4.32 | 1.37 |
| 104 | 4.44 | 1.35 |
| 105 | 4.63 | 1.25 |
| 106 | 4.73 | 1.31 |
| 107 | 4.88 | 1.20 |
| 108 | 4.93 | 1.17 |
| 109 | 5.02 | 1.14 |
| 110 | 5.14 | 1.11 |

| BAND | AVERAGE | STANDARD DEVIATION | BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|---|---|---|
| 111 | 5.45 | 1.07 | 161 | 5.41 | 1.07 |
| 112 | 5.47 | 1.10 | 162 | 5.31 | 1.06 |
| 113 | 5.52 | 1.02 | 163 | 5.08 | 1.15 |
| 114 | 5.52 | 0.98 | 164 | 4.94 | 1.22 |
| 115 | 5.56 | 1.03 | 165 | 4.61 | 1.21 |
| 116 | 5.55 | 1.04 | 166 | 4.57 | 1.23 |
| 117 | 5.53 | 1.03 | 167 | 4.61 | 1.22 |
| 118 | 5.44 | 1.03 | 168 | 4.74 | 1.27 |
| 119 | 5.35 | 1.06 | 169 | 4.97 | 1.25 |
| 120 | 5.42 | 1.01 | 170 | 5.11 | 1.20 |
| 121 | 5.48 | 1.01 | 171 | 5.29 | 1.14 |
| 122 | 5.52 | 1.01 | 172 | 5.52 | 1.13 |
| 123 | 5.59 | 0.96 | 173 | 5.71 | 1.04 |
| 124 | 5.57 | 0.96 | 174 | 5.82 | 1.07 |
| 125 | 5.59 | 0.94 | 175 | 6.04 | 1.09 |
| 126 | 5.56 | 0.99 | 176 | 6.06 | 1.07 |
| 127 | 5.59 | 0.95 | 177 | 6.17 | 1.00 |
| 128 | 5.55 | 0.98 | 178 | 6.31 | 0.99 |
| 129 | 5.55 | 0.95 | 179 | 6.39 | 1.01 |
| 130 | 5.53 | 0.99 | 180 | 6.47 | 0.98 |
| 131 | 5.51 | 1.04 | 181 | 6.46 | 1.08 |
| 132 | 5.47 | 0.97 | 182 | 6.53 | 0.97 |
| 133 | 5.34 | 1.02 | 183 | 6.56 | 0.96 |
| 134 | 5.28 | 1.00 | 184 | 6.56 | 0.96 |
| 135 | 5.24 | 1.08 | 185 | 6.55 | 0.94 |
| 136 | 5.32 | 1.02 | 186 | 6.54 | 1.00 |
| 137 | 5.47 | 1.01 | 187 | 6.58 | 0.98 |
| 138 | 5.52 | 1.00 | 188 | 6.56 | 0.95 |
| 139 | 5.58 | 0.96 | 189 | 6.54 | 0.97 |
| 140 | 5.61 | 0.95 | 190 | 6.56 | 0.95 |
| 141 | 5.61 | 1.00 | 191 | 6.52 | 0.96 |
| 142 | 5.61 | 0.91 | 192 | 6.51 | 1.00 |
| 143 | 5.63 | 0.92 | 193 | 6.54 | 1.00 |
| 144 | 5.62 | 0.93 | 194 | 6.54 | 0.99 |
| 145 | 5.66 | 0.93 | 195 | 6.52 | 0.97 |
| 146 | 5.66 | 0.95 | 196 | 6.51 | 1.01 |
| 147 | 5.67 | 0.97 | 197 | 6.52 | 1.05 |
| 148 | 5.71 | 0.98 | 198 | 6.47 | 1.07 |
| 149 | 5.71 | 1.09 | 199 | 6.52 | 1.06 |
| 150 | 5.77 | 1.02 | 200 | 6.51 | 1.04 |
| 151 | 5.77 | 0.98 | 201 | 6.49 | 1.01 |
| 152 | 5.73 | 1.02 | 202 | 6.42 | 1.05 |
| 153 | 5.74 | 1.01 | 203 | 6.45 | 1.04 |
| 154 | 5.64 | 0.98 | 204 | 6.40 | 1.06 |
| 155 | 5.64 | 0.98 | 205 | 6.36 | 1.06 |
| 156 | 5.59 | 1.00 | 206 | 6.31 | 1.06 |
| 157 | 5.59 | 1.03 | 207 | 6.09 | 1.15 |
| 158 | 5.60 | 0.98 | 208 | 5.96 | 1.18 |
| 159 | 5.61 | 1.02 | 209 | 5.84 | 1.14 |
| 160 | 5.58 | 1.03 | 210 | 5.66 | 1.18 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 211 | 5.36 | 1.28 |
| 212 | 5.10 | 1.32 |
| 213 | 4.85 | 1.44 |
| 214 | 4.54 | 1.45 |
| 215 | 4.50 | 1.53 |
| 216 | 4.51 | 1.50 |
| 217 | 4.79 | 1.50 |
| 218 | 5.08 | 1.38 |
| 219 | 5.29 | 1.32 |
| 220 | 5.59 | 1.26 |
| 221 | 5.84 | 1.23 |
| 222 | 5.94 | 1.21 |
| 223 | 6.07 | 1.17 |
| 224 | 6.07 | 1.15 |
| 225 | 6.20 | 1.17 |
| 226 | 6.30 | 1.21 |
| 227 | 6.34 | 1.19 |
| 228 | 6.36 | 1.16 |
| 229 | 6.42 | 1.16 |
| 230 | 6.46 | 1.08 |
| 231 | 6.49 | 1.07 |
| 232 | 6.55 | 1.06 |
| 233 | 6.54 | 1.02 |
| 234 | 6.60 | 1.06 |
| 235 | 6.51 | 1.14 |
| 236 | 6.58 | 1.[illegible] |
| 237 | 6.63 | 1.10 |
| 238 | 6.69 | 1.11 |
| 239 | 6.74 | 1.11 |
| 240 | 6.76 | 1.06 |
| 241 | 6.81 | 0.98 |
| 242 | 6.81 | 1.03 |
| 243 | 6.82 | 1.05 |
| 244 | 6.77 | 1.18 |
| 245 | 6.77 | 1.13 |
| 246 | 6.72 | 1.05 |
| 247 | 6.71 | 1.07 |
| 248 | 6.72 | 1.05 |
| 249 | 6.73 | 1.05 |
| 250 | 6.72 | 1.04 |
| 251 | 6.73 | 1.10 |
| 252 | 6.69 | 1.12 |
| 253 | 6.61 | 1.17 |
| 254 | 6.57 | 1.24 |
| 255 | 6.49 | 1.31 |
| 256 | 6.39 | 1.46 |
| 257 | 6.27 | 1.48 |
| 258 | 6.18 | 1.60 |
| 259 | 6.14 | 1.63 |
| 260 | 6.09 | 1.64 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 261 | 5.89 | 1.62 |
| 262 | 5.69 | 1.54 |
| 263 | 5.53 | 1.59 |
| 264 | 5.35 | 1.70 |
| 265 | 5.05 | 1.73 |
| 266 | 4.84 | 1.77 |
| 267 | 4.52 | 1.69 |
| 268 | 4.19 | 1.71 |
| 269 | 3.84 | 1.68 |
| 270 | 3.29 | 1.57 |
| 271 | 2.75 | 1.55 |
| 272 | 2.34 | 1.51 |
| 273 | 1.71 | 1.53 |
| 274 | 1.44 | 1.63 |
| 275 | 1.09 | 1.67 |
| 276 | 0.94 | 1.77 |
| 277 | 0.87 | 1.92 |
| 278 | 0.91 | 2.06 |
| 279 | 0.91 | 2.08 |
| 280 | 0.97 | 2.13 |
| 281 | 1.10 | 2.15 |
| 282 | 1.26 | 2.25 |
| 283 | 1.37 | 2.32 |
| 284 | 1.85 | 2.37 |
| 285 | 2.36 | 2.38 |
| 286 | 3.09 | 2.38 |
| 287 | 3.73 | 2.36 |
| 288 | 4.22 | 2.22 |
| 289 | 4.81 | 2.14 |
| 290 | 5.41 | 1.95 |
| 291 | 5.93 | 1.82 |
| 292 | 6.36 | 1.80 |
| 293 | 6.74 | 1.76 |
| 294 | 6.76 | 1.76 |
| 295 | 6.98 | 1.81 |
| 296 | 7.12 | 1.79 |
| 297 | 7.19 | 1.85 |
| 298 | 7.17 | 1.97 |
| 299 | 7.23 | 2.06 |
| 300 | 7.21 | 2.16 |
| 301 | 7.16 | 2.20 |
| 302 | 7.13 | 2.26 |
| 303 | 7.10 | 2.28 |
| 304 | 7.06 | 2.30 |
| 305 | 6.98 | 2.30 |
| 306 | 6.99 | 2.29 |
| 307 | 6.86 | 2.35 |
| 308 | 6.80 | 2.41 |
| 309 | 6.66 | 2.49 |
| 310 | 6.32 | 2.62 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 311 | 6.13 | 2.57 |
| 312 | 5.90 | 2.49 |
| 313 | 5.67 | 2.42 |
| 314 | 5.13 | 2.22 |
| 315 | 4.48 | 1.96 |
| 316 | 3.36 | 1.75 |
| 317 | 2.32 | 1.60 |
| 318 | 1.48 | 1.57 |
| 319 | 0.90 | 1.53 |
| 320 | 0.75 | 1.70 |
| 321 | 0.72 | 1.75 |
| 322 | 0.74 | 1.79 |
| 323 | 0.93 | 1.86 |
| 324 | 1.23 | 1.87 |
| 325 | 1.69 | 2.03 |
| 326 | 2.45 | 2.09 |
| 327 | 3.14 | 2.12 |
| 328 | 3.73 | 2.12 |
| 329 | 4.05 | 2.10 |
| 330 | 4.21 | 2.10 |
| 331 | 4.31 | 2.03 |
| 332 | 4.61 | 1.97 |
| 333 | 4.79 | 1.94 |
| 334 | 4.95 | 1.96 |
| 335 | 4.97 | 1.92 |
| 336 | 5.13 | 1.94 |
| 337 | 5.19 | 1.84 |
| 338 | 5.29 | 1.84 |
| 339 | 5.31 | 1.84 |
| 340 | 5.34 | 1.84 |
| 341 | 5.25 | 1.80 |
| 342 | 5.21 | 1.81 |
| 343 | 5.14 | 1.79 |
| 344 | 4.98 | 1.68 |
| 345 | 4.86 | 1.71 |
| 346 | 4.39 | 1.64 |
| 347 | 4.10 | 1.57 |
| 348 | 3.92 | 1.60 |
| 349 | 3.77 | 1.63 |
| 350 | 3.70 | 1.65 |
| 351 | 3.69 | 1.64 |
| 352 | 3.72 | 1.67 |
| 353 | 3.71 | 1.65 |
| 354 | 3.66 | 1.66 |
| 355 | 3.66 | 1.63 |
| 356 | 3.49 | 1.65 |
| 357 | 3.29 | 1.58 |
| 358 | 3.14 | 1.58 |
| 359 | 2.98 | 1.63 |
| 360 | 2.70 | 1.61 |

| BAND | AVERAGE | STANDARD DEVIATION |
|---|---|---|
| 361 | 2.47 | 1.55 |
| 362 | 2.14 | 1.49 |
| 363 | 1.91 | 1.34 |
| 364 | 1.69 | 1.29 |
| 365 | 1.37 | 1.12 |
| 366 | 1.02 | 0.94 |
| 367 | 0.69 | 0.80 |
| 368 | 0.36 | 0.55 |
| 369 | 0.11 | 0.37 |
| 370 | 0.03 | 0.17 |
| 371 | 0.01 | 0.08 |
| 372 | 0.0 | 0.0 |
| 373 | 0.0 | 0.0 |