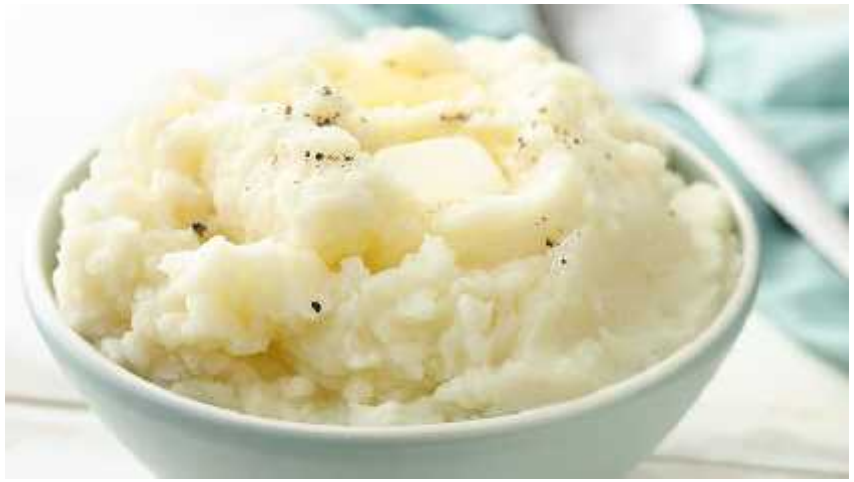
THE POTENTIAL OF SPECTROMETRY FOR QUANTIFYING IN-SITU ANTI-ICING AND DEICING CHEMICALS

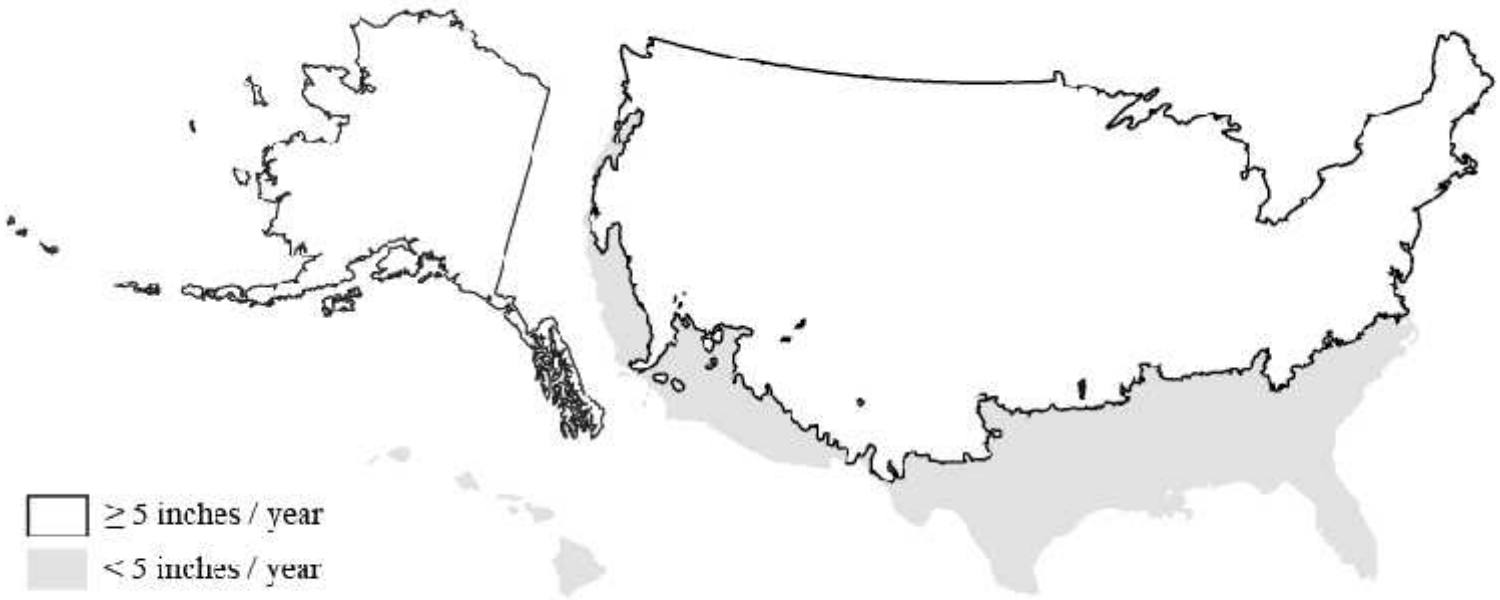
Dr. Nathan Belz, Associate Professor, University of Alaska Fairbanks
Gabriel Fulton, M.S., Assistant Engineer, Oregon Department of Transportation

BACKGROUND

WHAT'S THE DIFFERENCE?



70% of roads,
over 2.8 million miles



Data Source: Snow Data Assimilation System (SNODAS) from 2005 through 2015

20% of all DOT maintenance
budgets (2.3$ billion)

SNOW/ICE FIGHTING AND REMOVAL

Mechanical Removal

- Plowing
- Blowing
- Shoveling

Chemical Treatments

- Chlorides: NaCl, $MgCl_2$, $CaCl_2$
- Acetates: CMA, KAc
- Carbohydrates: Beet Juice, Molasses, Corn Syrup

SNOW/ICE FIGHTING AND REMOVAL

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Utilized by AKDOT&PF Northern Region

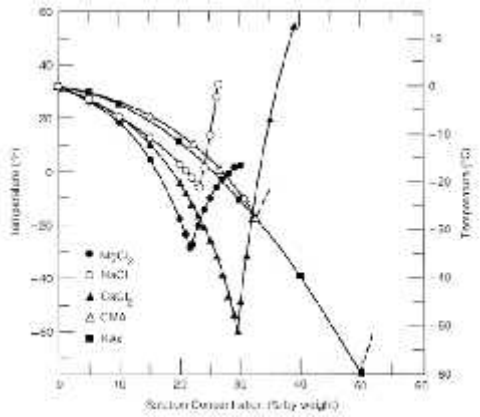
SNOW/ICE FIGHTING AND REMOVAL

"The Secret Sauce"

Pre-wetting sand or salt:	8 to 14 gallons of brine or brine with additive per ton of material
Aggregate:	400-750 pounds per lane mile
Salt:	75-300 pounds per lane mile (condition dependent)
Brine or Brine with additive:	20-30 gallons per lane mile when anti-icing; 30-50 gallons per lane mile when de-icing

SNOW/ICE FIGHTING AND REMOVAL

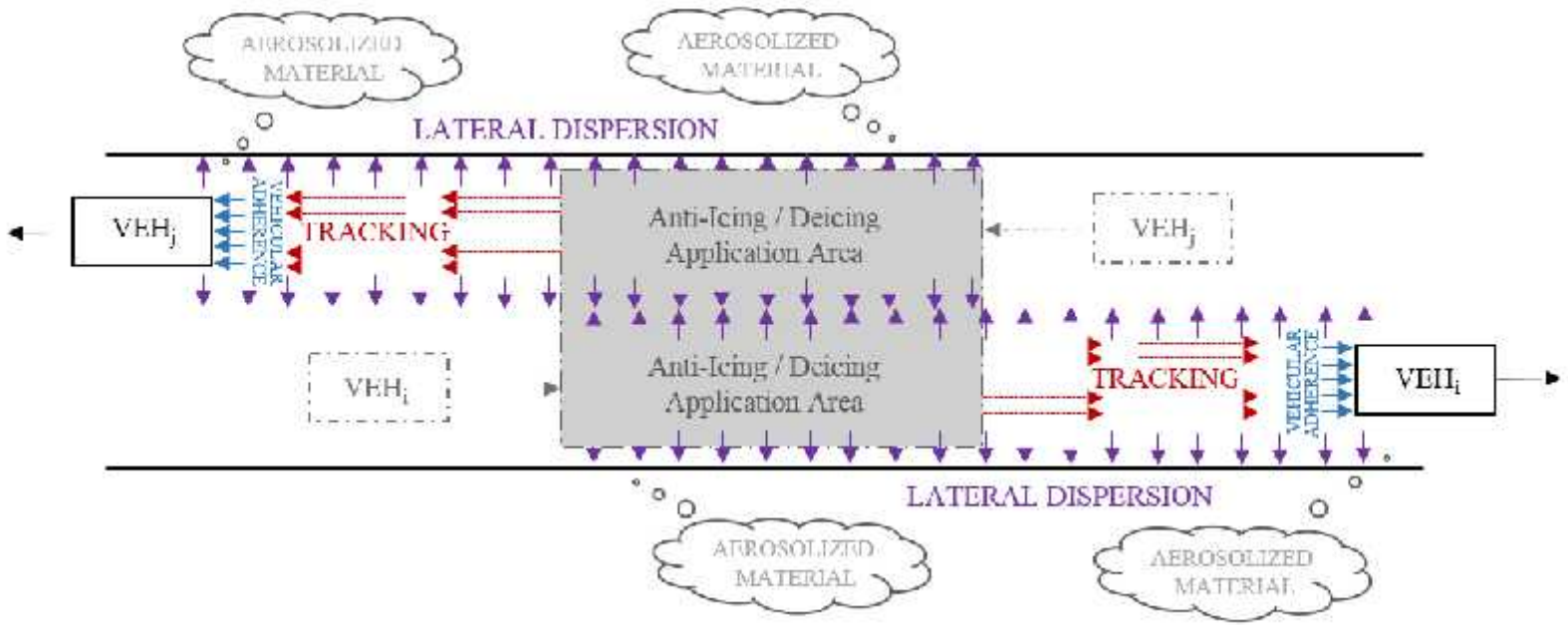
LIMITATIONS: high enough concentration, enough coverage, acceptable temp.



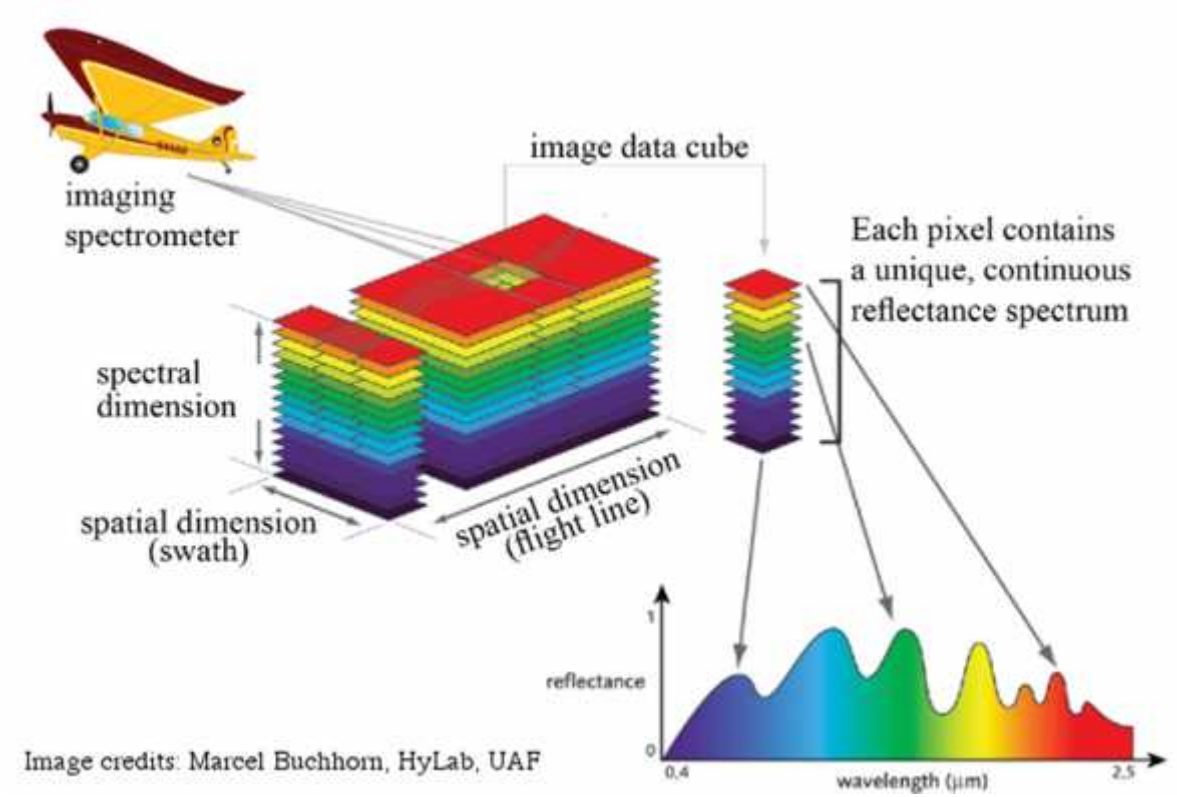
AKDOT&PF – judgement based;
estimated reapplication

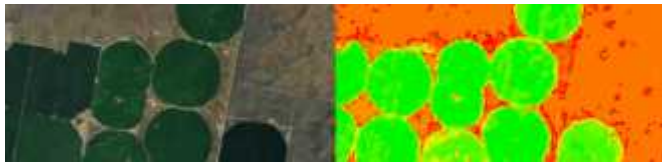
SNOW/ICE FIGHTING AND REMOVAL

LIMITATIONS: imposed loss of chemical



SPECTROMETRY AND REMOTE SENSING





$$NDVI = \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + \rho_{Red}}$$

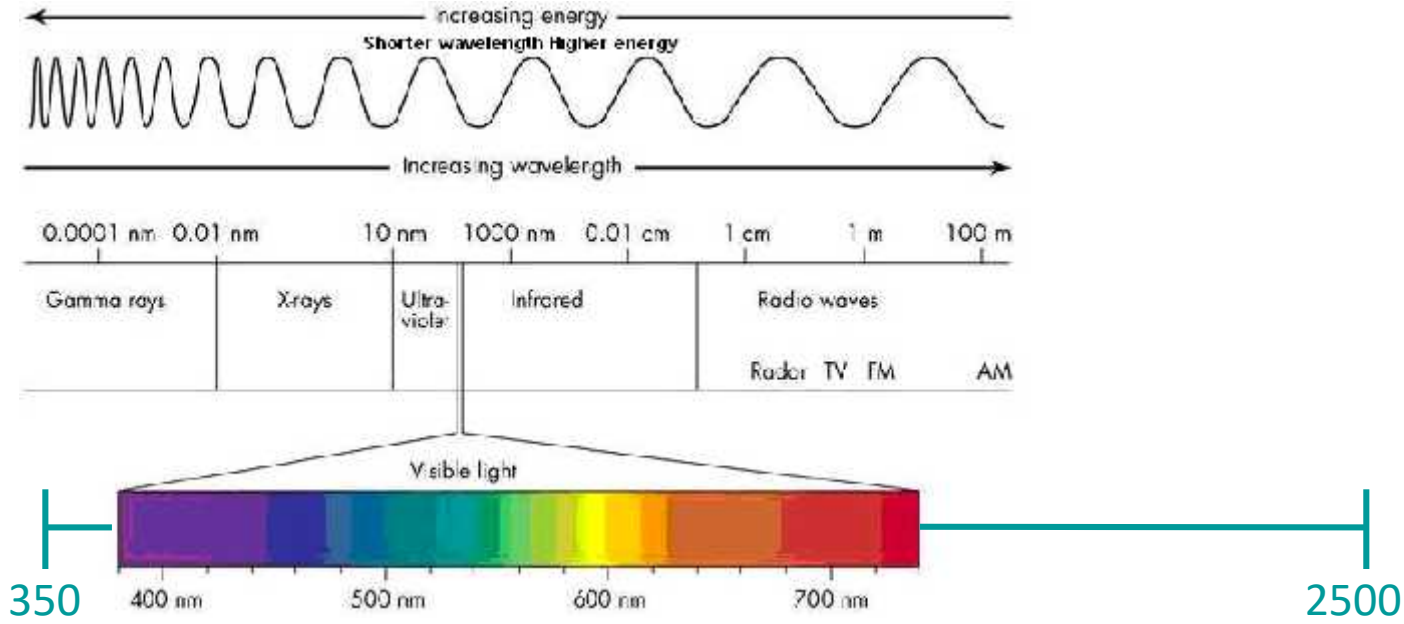
SPECTROMETRY AND REMOTE SENSING

Similar Research

- Salt in soil (660 + 830 nm)
  - Success
- Lab brine concentrations
  - Severely limited bands
  - Unsuccessful
- Pork loin brine
  - Success

Lack of Data

- Spectra of winter roadway materials not comprehensive
- Brine concentration analysis with reflectance not done successfully
- Beet-Brine concentration analysis nonexistent



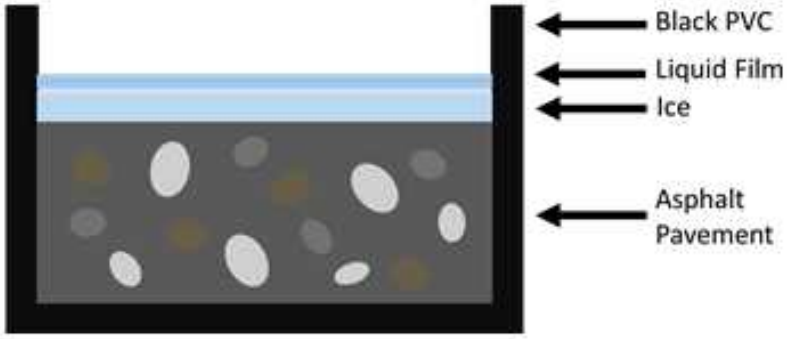
PROJECT GOAL

Determine to what extent anti-icing and deicing chemicals can be detected using spectrometry

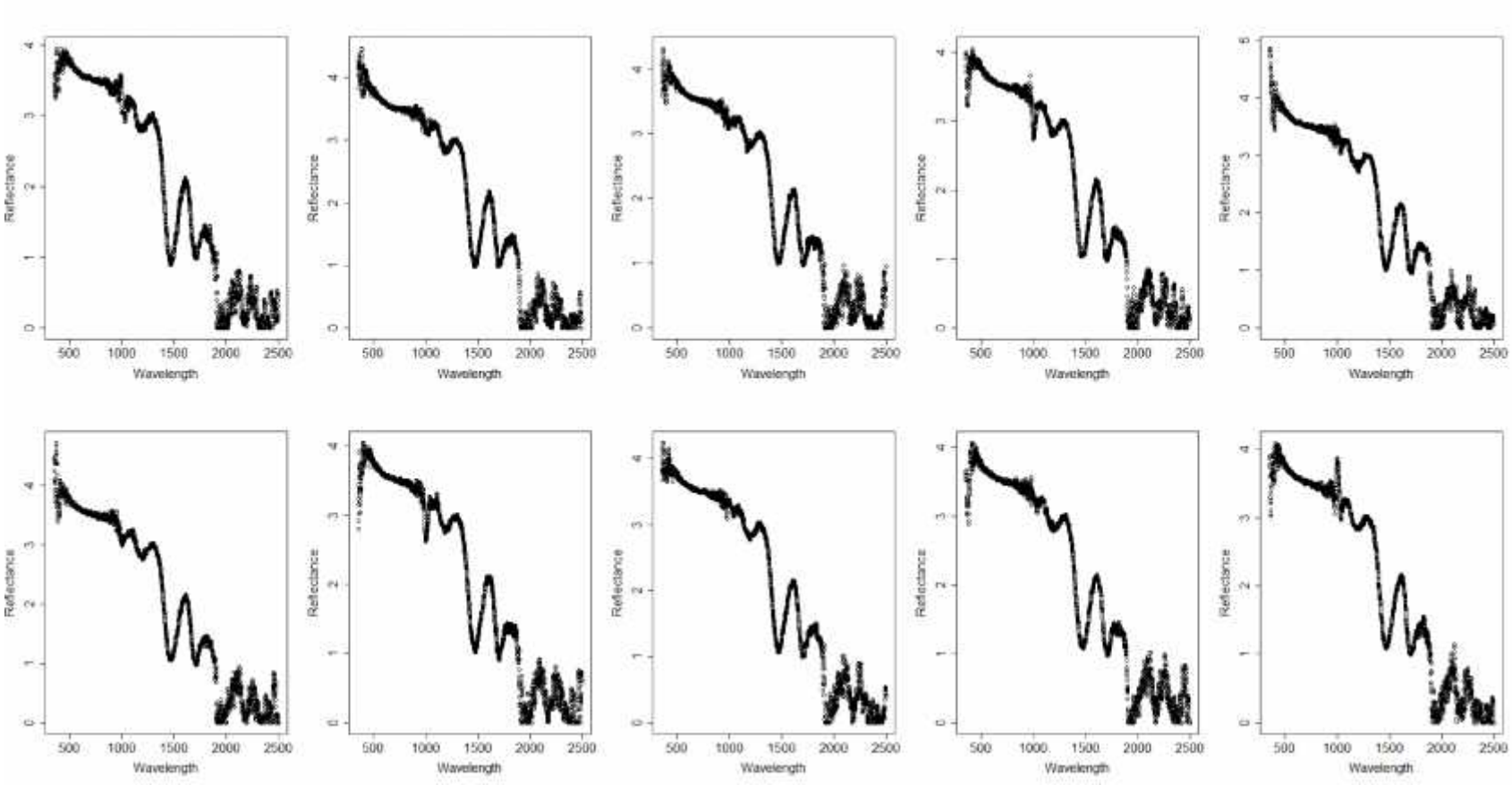
(A) Presence / no presence
(B) Percent coverage of a specified area
(C) Direct quantification of concentration

DATA AND METHODS

EQUIPMENT (LAB)

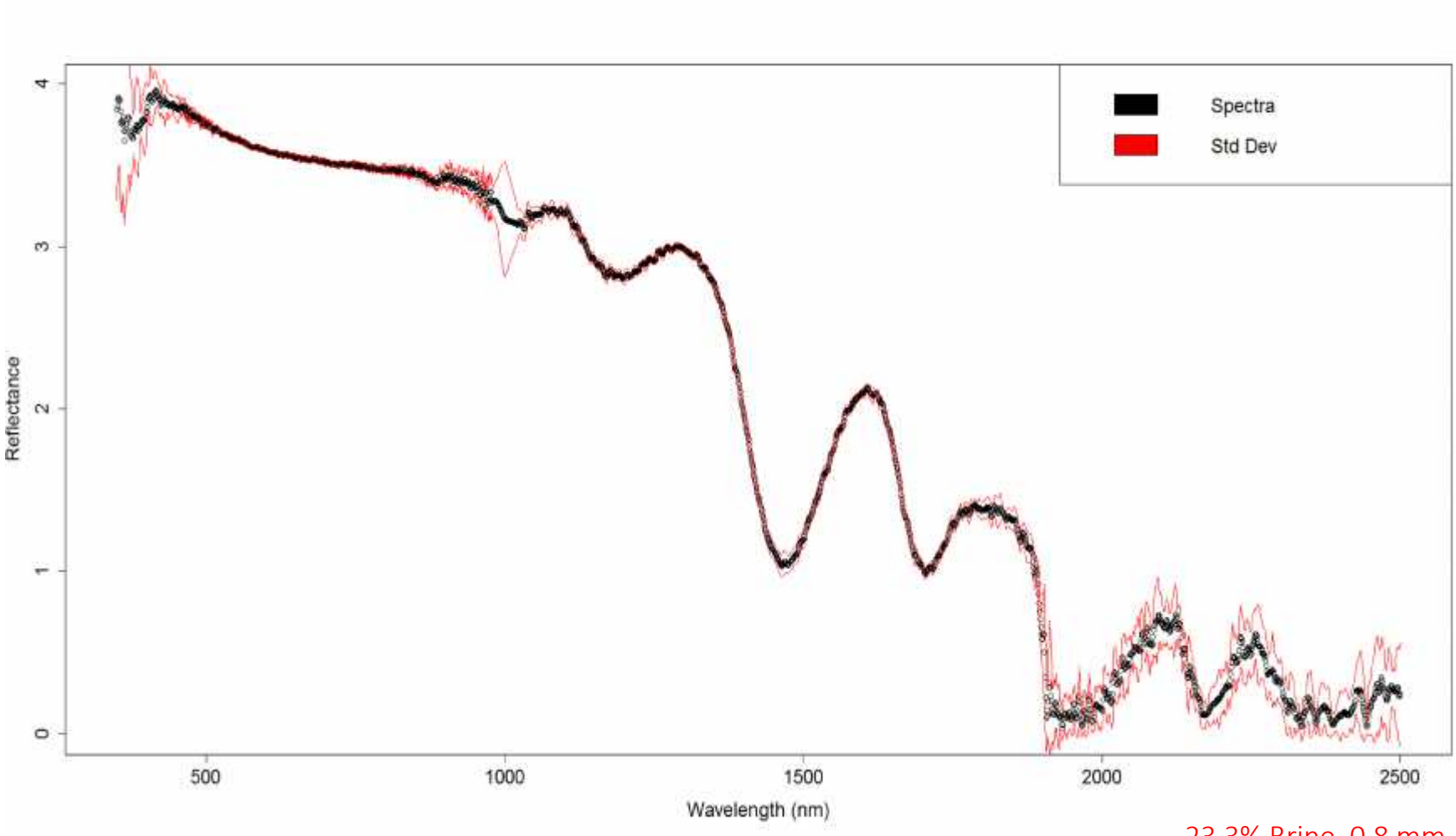


EXAMPLE OUTPUT (10 READINGS PER SAMPLE)



23.3% Brine, 0.8 mm

EXAMPLE OUTPUT (AVERAGED)



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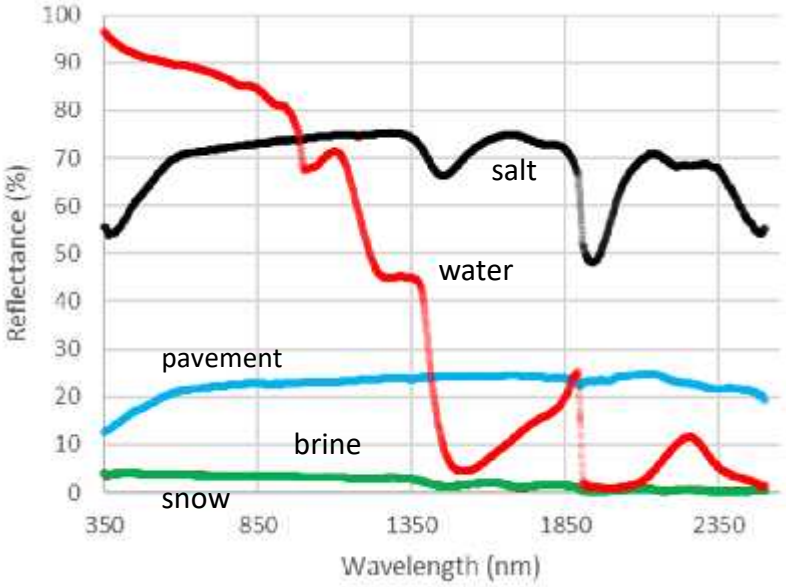
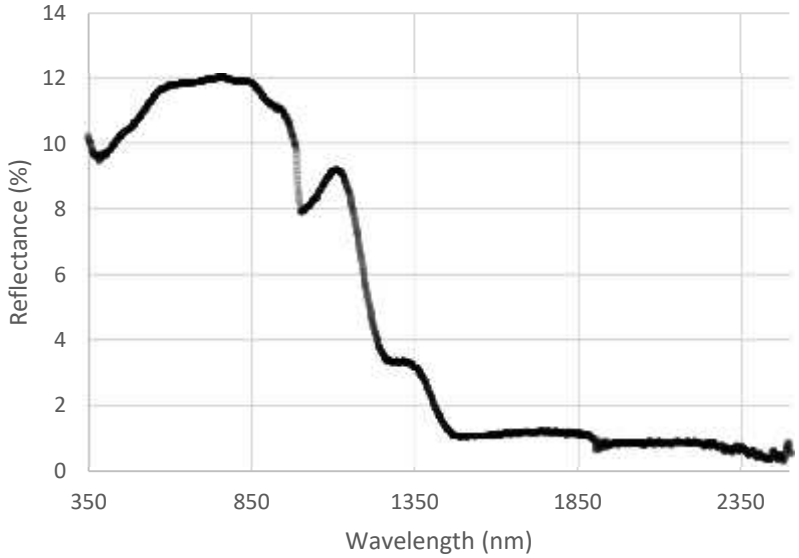
EQUIPMENT (FIELD)

DATA

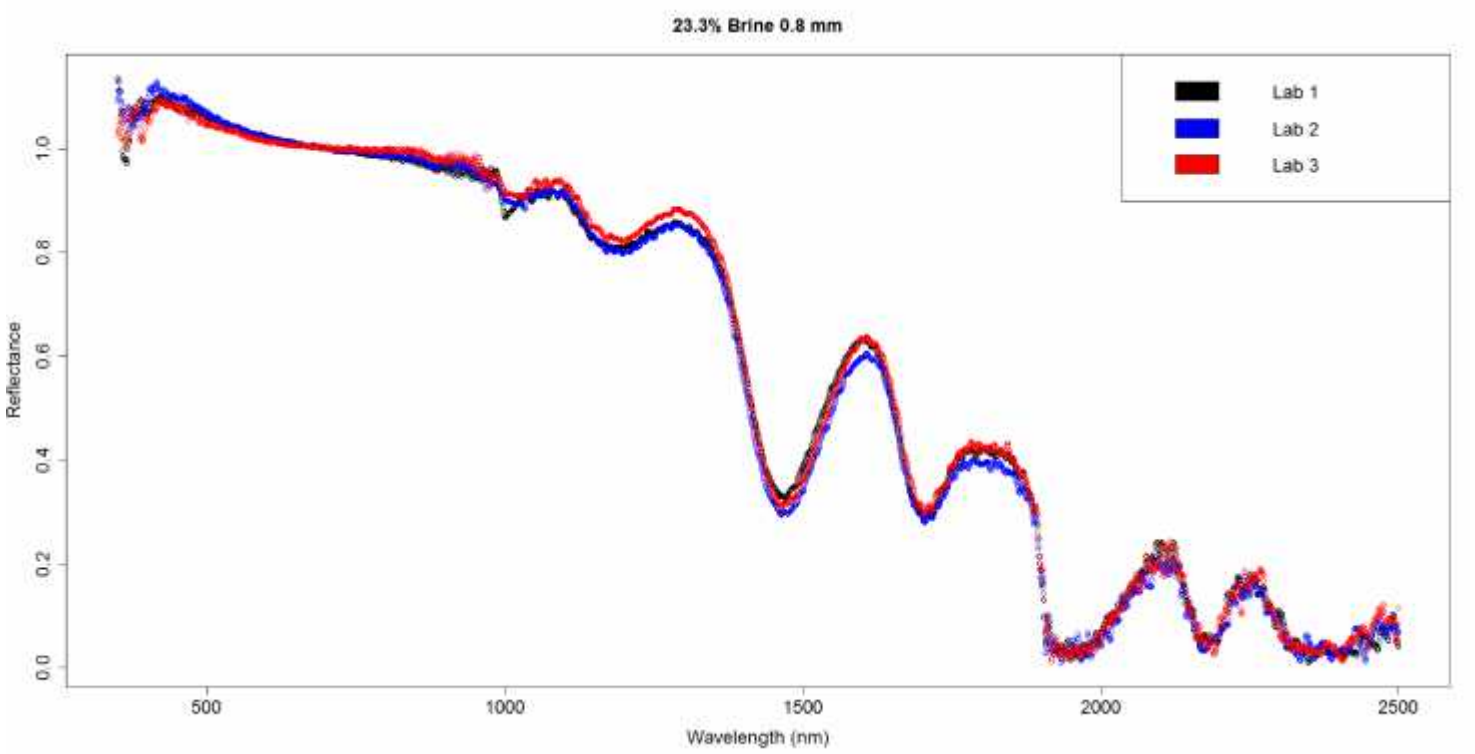
Individual Members



Combined



Lab Date	Height	Brine Concentration (%)						Analysis
24-Jan	3.6 mm	0	5	10	15	23.3	~40	Excel, POI, Cor, R
15-Jun	3.6 mm	-	5	10	15	23.3	~40	Excel, POI, Cor, R
27-Jun	1.6 mm	0	5	10	15	23.3	~40	Excel, POI, Cor, R
9-Jul	1.6 mm	0	5	10	15	23.3	~40	R
6-Sep	0.8 mm	0	5	10	15	23.3	~40	R
17-Sep	0.8 mm	0	5	10	15	23.3	~40	R
28-Jan	0.8 mm	0	5	10	15	23.3	~40	R



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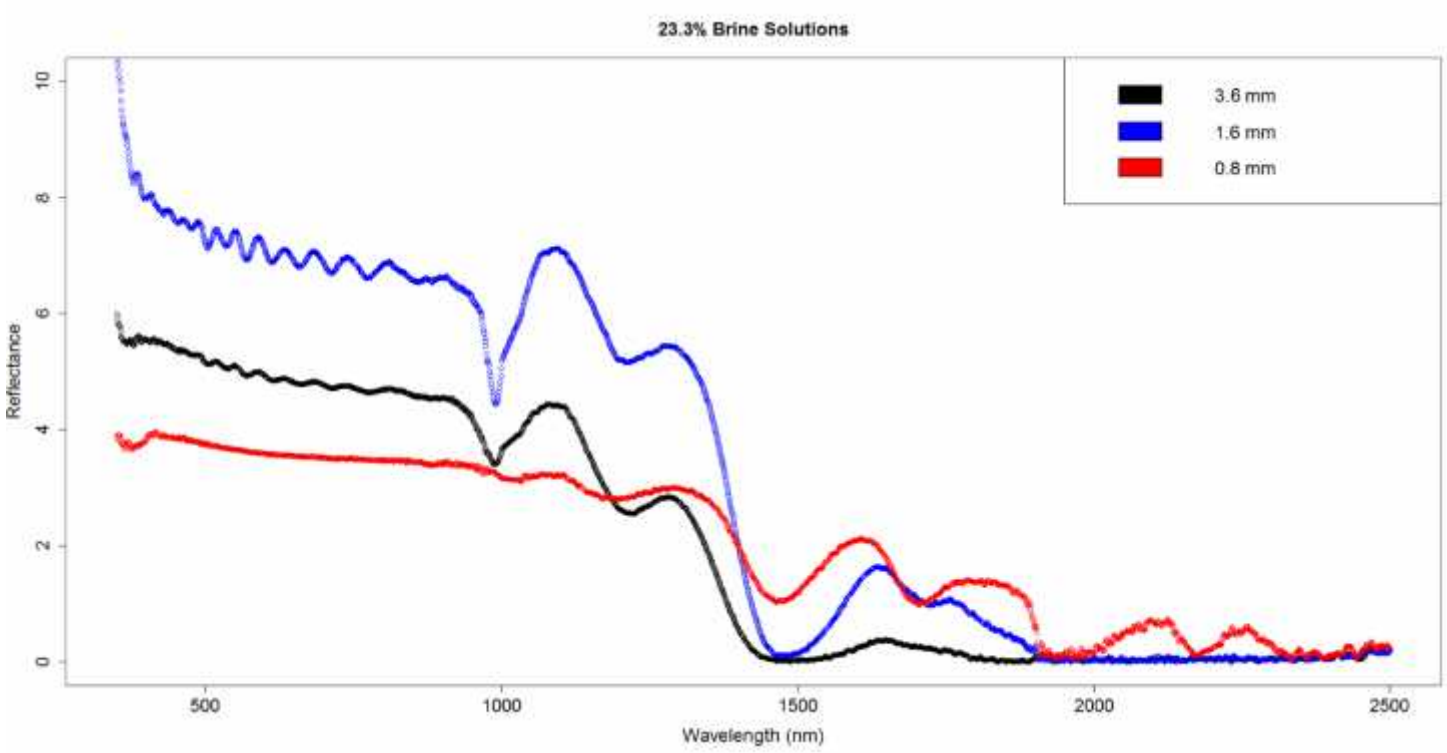

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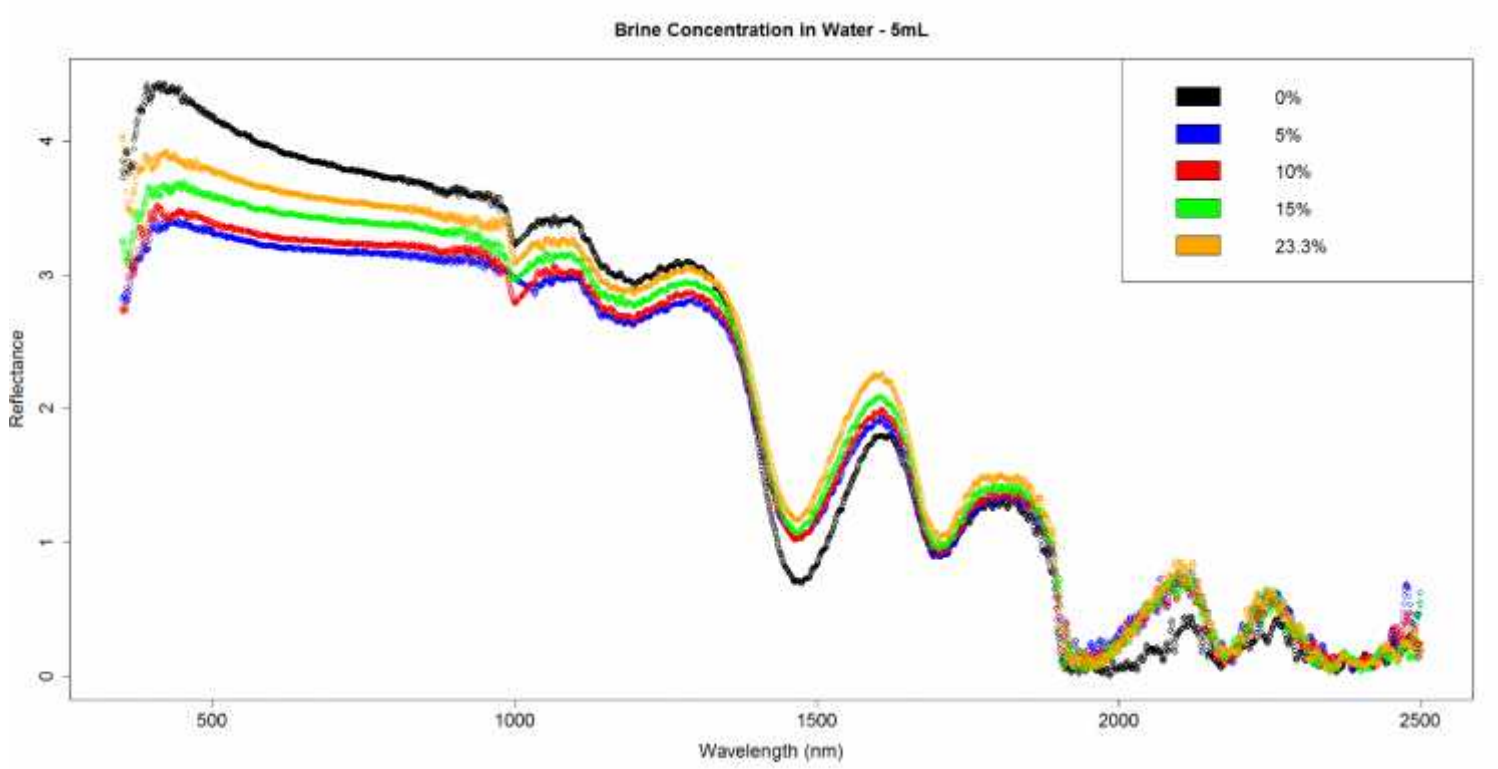


ANALYSIS/RESULTS

PEAK/VALLEY (MANUAL APPROACH)

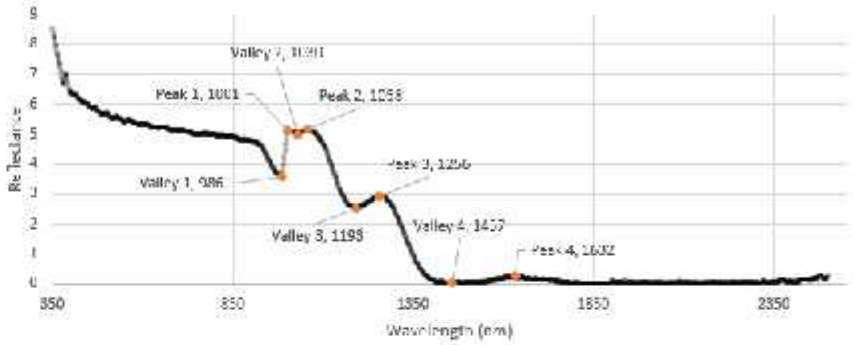
Relationship Adjustments

Salt water in petri dish analysis:

23.3% POI

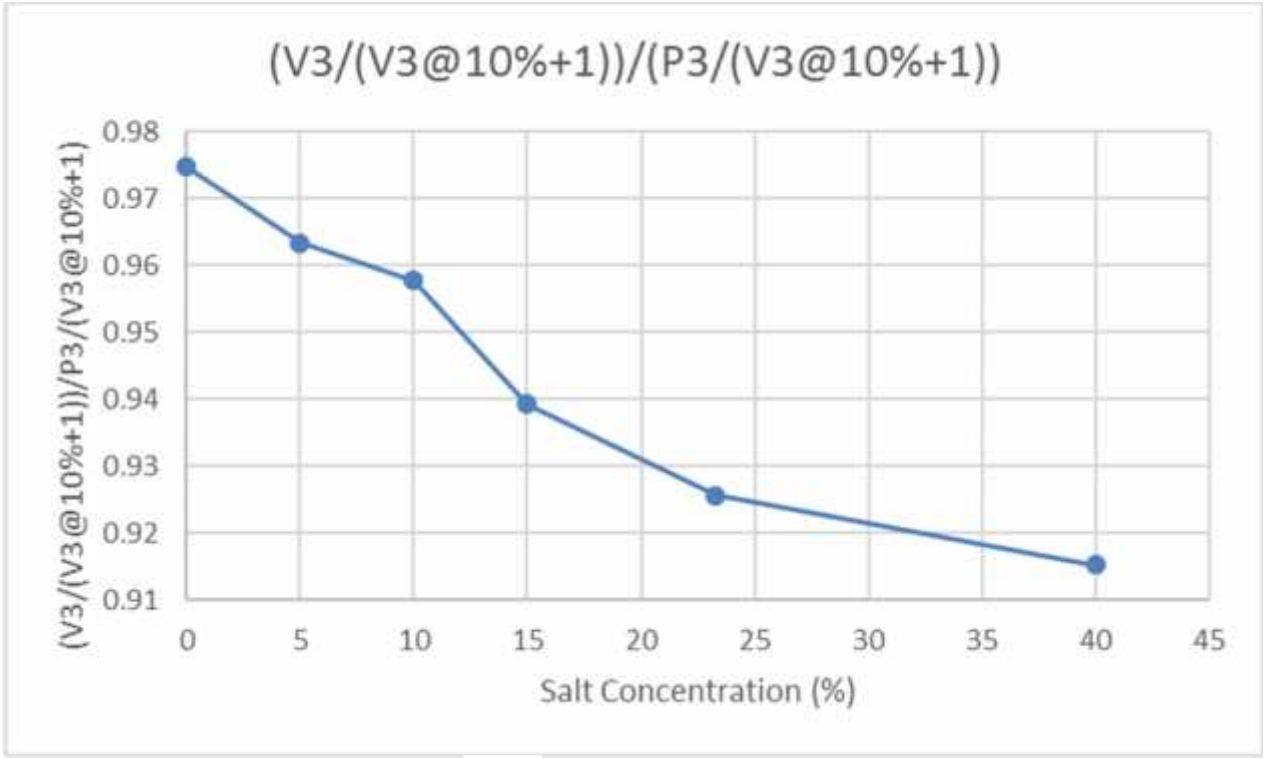
feature	x	y
Valley 1	986	3.56587
Peak 1	1001	5.11018
Valley 2	1030	4.98735
Peak 2	1058	5.13705
Valley 3	1193	2.50581
Peak 3	1256	2.91556
Valley 4	1457	0.03038
Peak 4	1582	0.23096

* - logged



REGULAR	Result						Linear Relationship?			Logged Result*						Logged Linear Relationship?		
Relationship	0	5	10	15	23.3	40	0 to 40	5 to 40	10 to 40	0	5	10	15	23.3	40	0 to 40	5 to 40	10 to 40
V1/P1	0.79328	0.849057	0.78432	0.592232	0.607797	0.763311	0	0	0	0.839543	0.871592	0.838517	0.755795	0.779415	0.885544	0	0	0
V1/P2	0.774037	0.782598	0.759008	0.590008	0.604147	0.762542	0	0	0	0.82586	0.81918	0.820975	0.754174	0.779917	0.880347	0	0	0
V1/P3	1.33556	1.551588	1.350457	1.140071	1.220048	1.115467	0	0	0	1.314605	1.654265	1.322765	1.069868	1.188161	1.064564	0	0	0
V1/P4	31.76435	108.8698	28.38387	21.69719	15.43934	3.348762	0	1	1	0.53932	0.31029	0.60522	1.1158	0.86755	2.368504	0	0	0
V1/V2	0.789445	0.808609	0.772493	0.59823	0.7157	0.763263	0	0	0	0.836733	0.830569	0.830133	0.753402	0.79171	0.86562	0	0	0
V1/V3	1.40914	1.696311	1.486179	1.265099	1.423041	1.284082	0	0	0	1.394825	1.907677	1.457896	1.169689	1.384053	1.135744	0	0	0
V1/V1	240.0001	101.8236	165.3357	98.90227	89.41459	5.078972	0	0	1	-0.32417	-0.3162	-0.32093	-0.51089	-0.35102	-1.182066	0	0	0
V2/P1	1.004858	1.049905	1.01531	0.989874	0.974985	1.000063	0	0	0	1.008358	1.038217	1.0101	0.995256	0.98447	1.000027	0	0	0
V2/P2	0.981115	0.968182	0.983191	0.986048	0.969885	0.989991	0	0	0	0.984005	0.976142	0.988908	0.995509	0.981315	0.991046	0	0	0
V2/P3	1.693154	1.918623	1.751109	1.910564	1.709869	1.467649	0	0	0	1.571453	1.97054	1.593462	1.415192	1.503756	1.202167	0	0	0
V2/P4	40.23631	134.6235	36.74823	36.16493	21.57235	4.38742	0	1	1	0.64455	0.3696	0.72307	1.46931	1.0958	2.674402	0	0	0
V2/V3	1.784076	2.007582	1.923674	2.114525	1.969319	1.662294	0	0	0	1.656989	2.272367	1.755219	1.54021	1.748181	1.282429	0	0	0
V2/V4	178.1076	125.9105	219.2082	165.8082	124.9835	6.654292	0	0	1	0.38778	0.37665	0.39263	0.71818	0.49844	5.061602	0	0	0
V3/P1	0.562558	0.500831	0.527718	0.418181	0.419367	0.591104	0	0	0	0.601898	0.446888	0.570156	0.646182	0.563139	0.775791	0	0	0

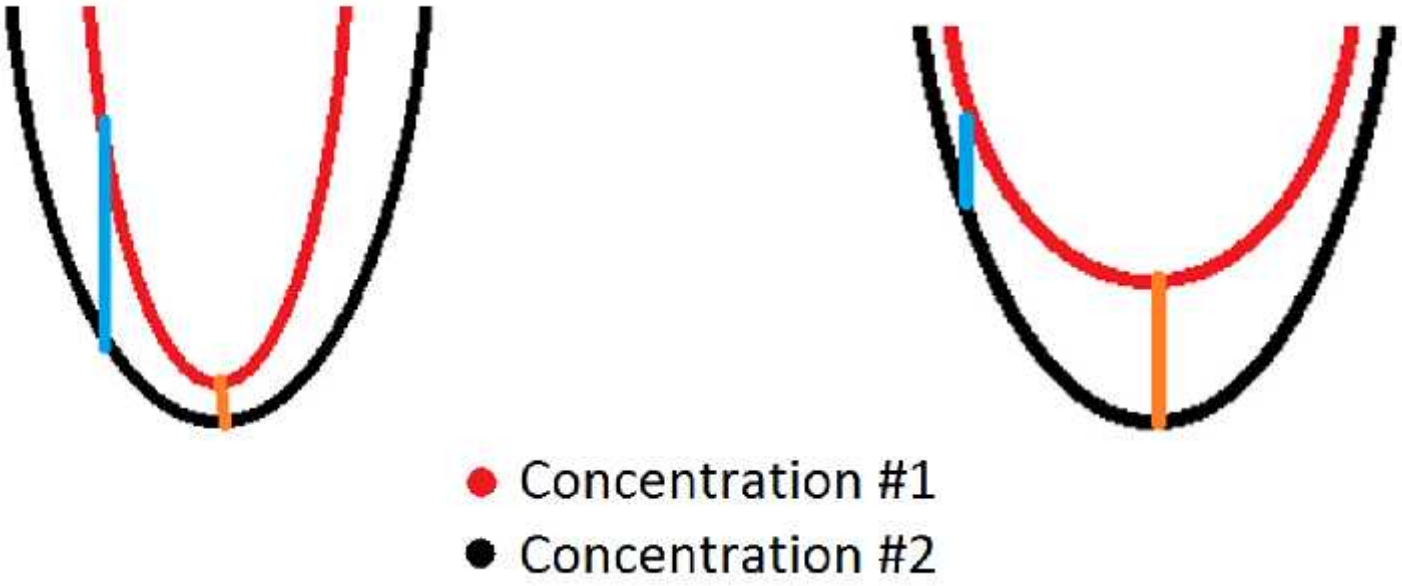
PEAK/VALLEY (MANUAL APPROACH)



Points of change likely not limited to peaks and valleys

Transformations:

- Normalize to emphasize changes due to brine concentration
- Offset by 1 due to proximity to 0% reflectance



Effects of Depression in Two Spectra for Different Concentrations

KEY POINTS (AUTOMATED APPROACH)

Example: Rstudio – 1.6 mm 23.3% brine

27-Jun	10 mL
Wvl (nm)	Freq
2083	1677
2084	1656
2041	1593
2363	1571
2145	1521
1995	1514
2364	1459
2035	1374
2287	1374
2163	1230
1484	1160
1534	1133
1533	1124
1668	1116
1892	1116
2342	1109
1667	1105
1891	1102
2445	1100
1450	1099

+

9-Jul	10 mL
Wvl (nm)	Freq
1535	1426
1534	1422
1533	1404
1536	1393
1588	1389
1559	1383
1393	1381
1589	1380
1558	1379
1560	1379
1587	1379
1392	1374
1394	1374
1391	1371
1402	1371
1538	1371
1561	1371
1390	1370
1423	1369
1430	1369

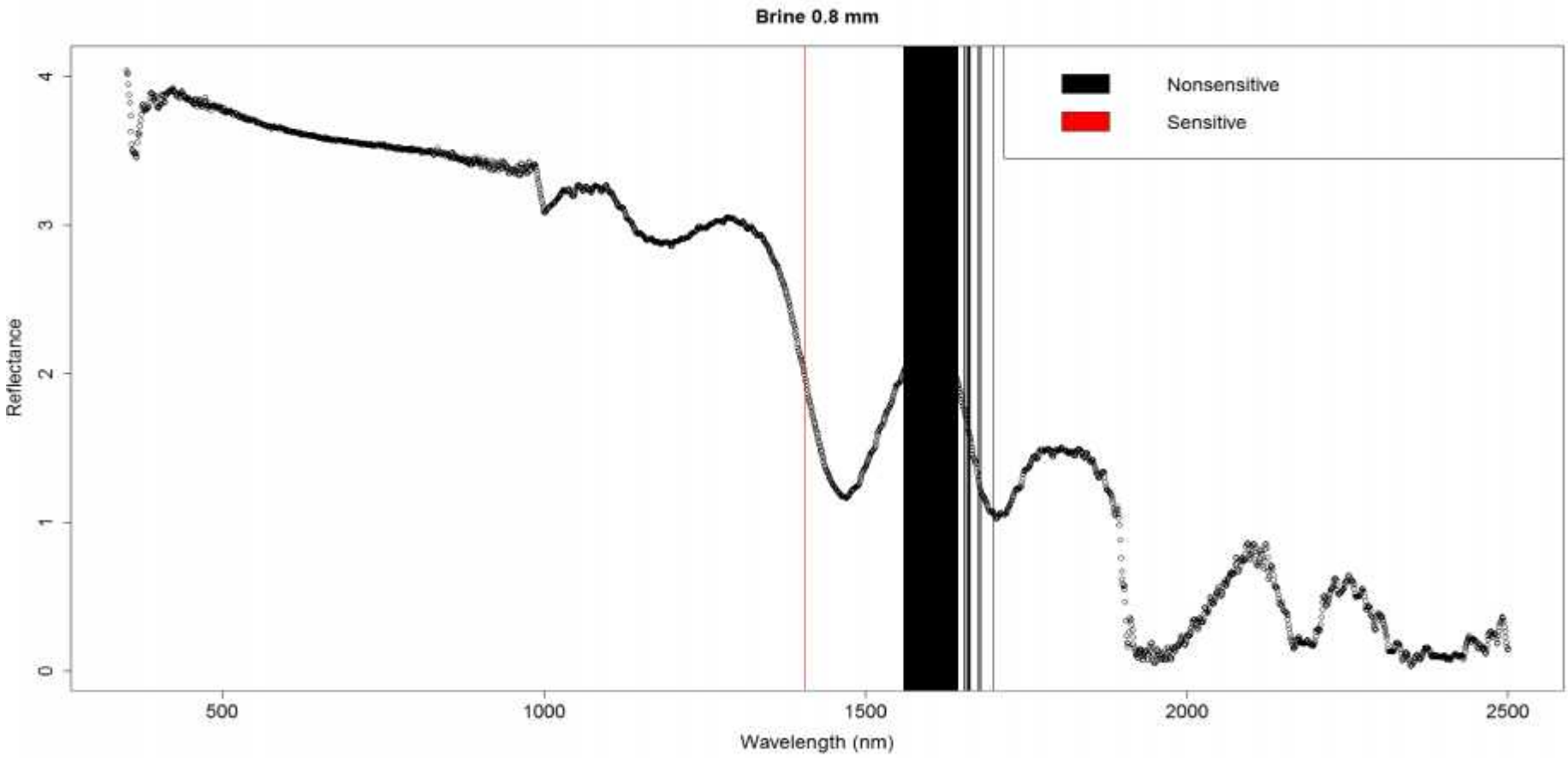
=

Repeated	10 mL
Wvl (nm)	Freq
1484	1073
1534	1070
1668	1064
1533	1063
1667	1051
1680	1045
1679	1038
1678	1036
1669	1030
1483	1029
1677	1007
1507	1001
1508	997
1482	993
1666	975
1532	973
1500	953
1535	944
1681	936
1691	888

1. Use Rstudio to find wavelength pairs that create linear trend w.r.t. concentration
2. Replicate samples and spectral acquisition
3. Extract pairs from each to create new set that only includes pairs that are repeated
4. Display top 20 with replicated pairs (denoted with red)

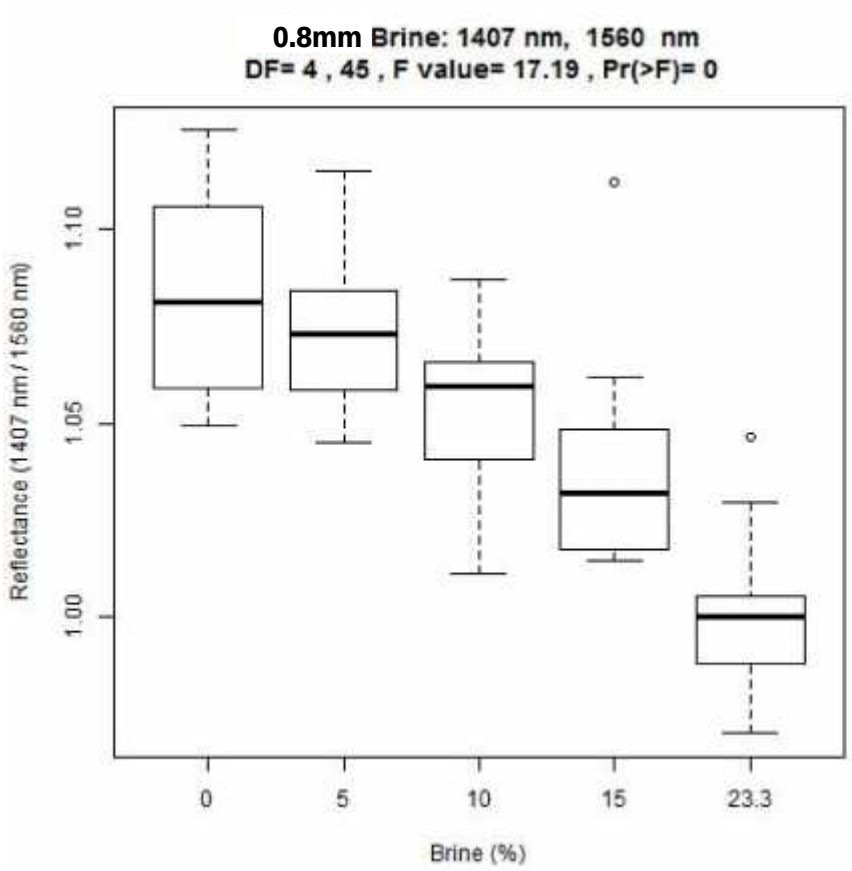
KEY POINTS (AUTOMATED APPROACH)

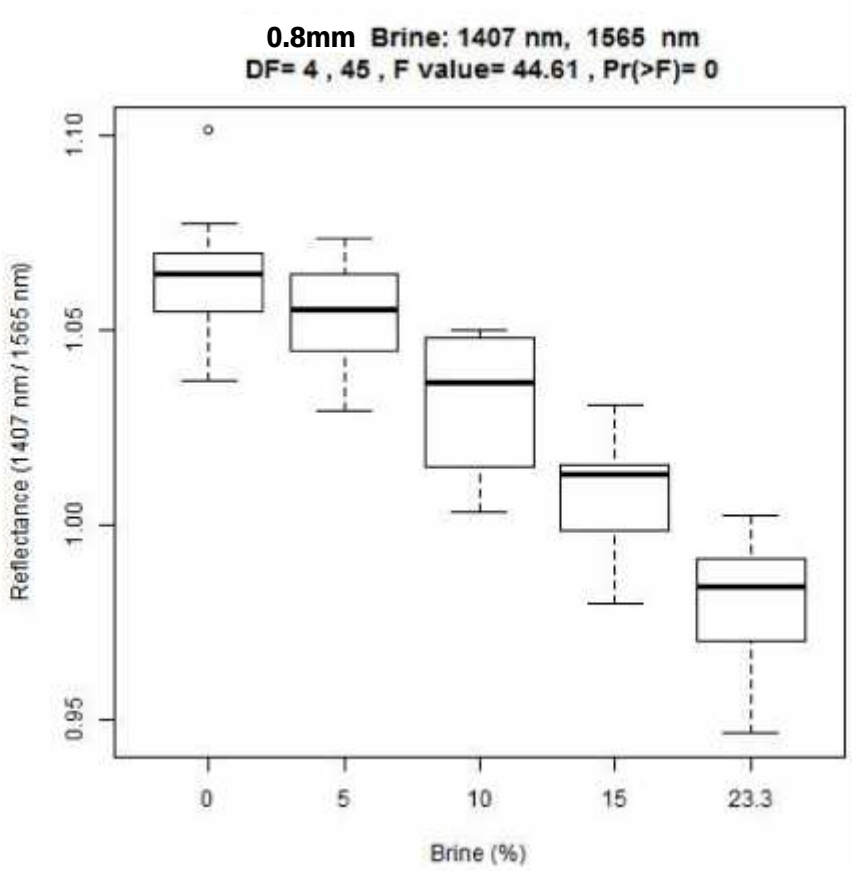
Example: Rstudio – 0.8 mm 23.3% brine



KEY POINTS (AUTOMATED APPROACH)

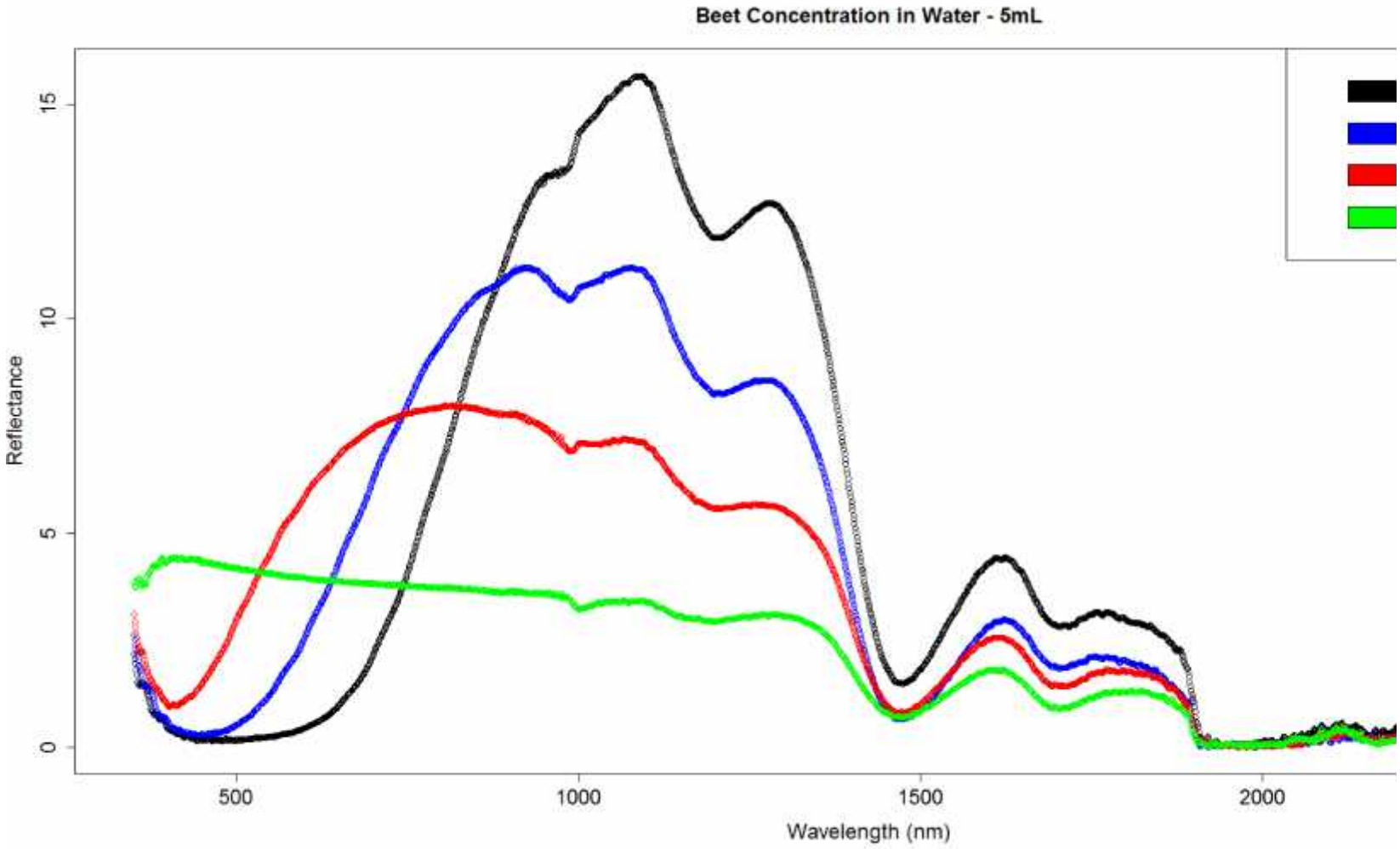
Example: Rstudio – 0.8 mm w/ concentration (brine)





KEY POINTS (AUTOMATED APPROACH)

Example: Rstudio – Beet



KEY POINTS (AUTOMATED APPROACH)

Example: Rstudio – beet

21-Sep	5 mL
Wvl (nm)	Freq
413	1887
412	1886
424	1883
425	1882
426	1880
414	1875
427	1875
411	1874
423	1874
415	1868
428	1867
431	1866
432	1866
404	1865
420	1863
433	1863
410	1862
417	1862
421	1862
403	1861

+

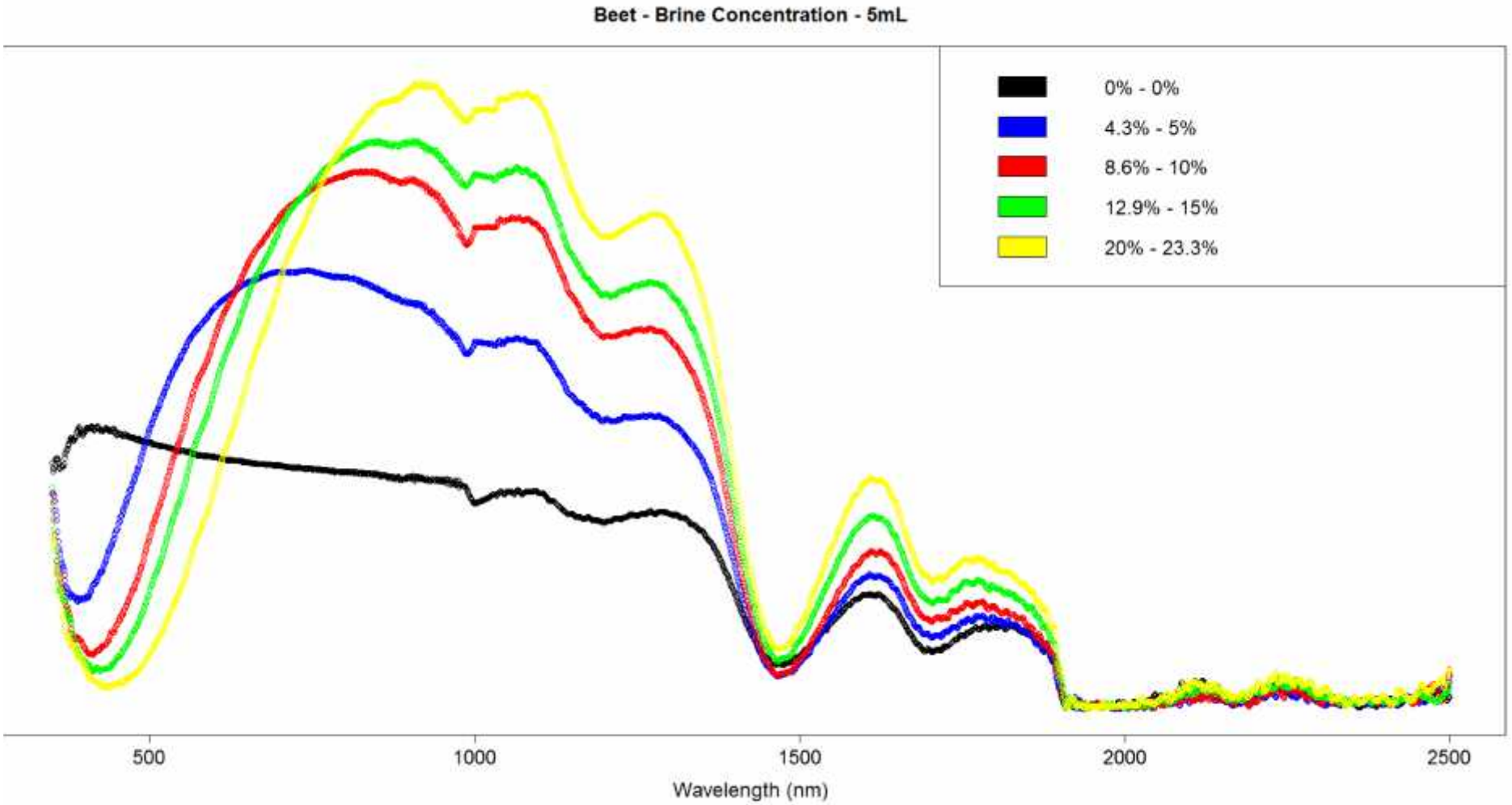
28-Jan	5 mL
Wvl (nm)	Freq
432	1714
431	1713
433	1710
430	1709
441	1708
440	1706
442	1705
434	1703
439	1700
435	1699
438	1698
429	1697
437	1696
443	1696
436	1693
414	1687
458	1686
444	1685
454	1681
457	1680

=

Repeated	5 mL
Wvl (nm)	Freq
403	1553
404	1550
402	1548
414	1541
405	1539
432	1538
431	1536
413	1535
401	1534
433	1532
430	1531
406	1530
415	1530
412	1525
399	1524
429	1524
400	1520
417	1517
425	1516
426	1516

KEY POINTS (AUTOMATED APPROACH)

Example: Rstudio – Beet



KEY POINTS (AUTOMATED APPROACH)

Example: Rstudio – beet-brine

21-Sep	5 mL
Wvl (nm)	Freq
429	1784
419	1781
430	1780
426	1774
427	1774
418	1773
428	1772
420	1769
425	1766
431	1765
421	1763
432	1763
437	1761
433	1759
438	1759
422	1757
424	1755
436	1754
417	1753
423	1749

+

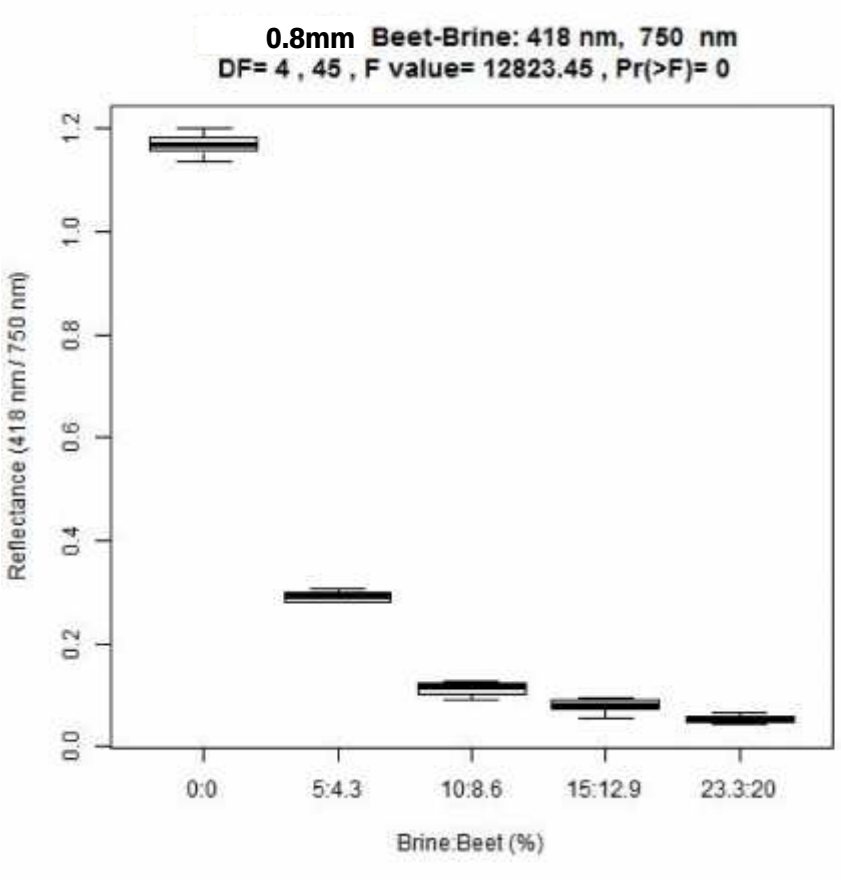
28-Jan	5 mL
Wvl (nm)	Freq
418	1518
419	1518
417	1510
416	1493
420	1493
415	1483
2043	1480
427	1473
421	1472
426	1469
429	1466
435	1462
436	1462
428	1461
430	1456
423	1455
424	1455
414	1447
425	1446
422	1445

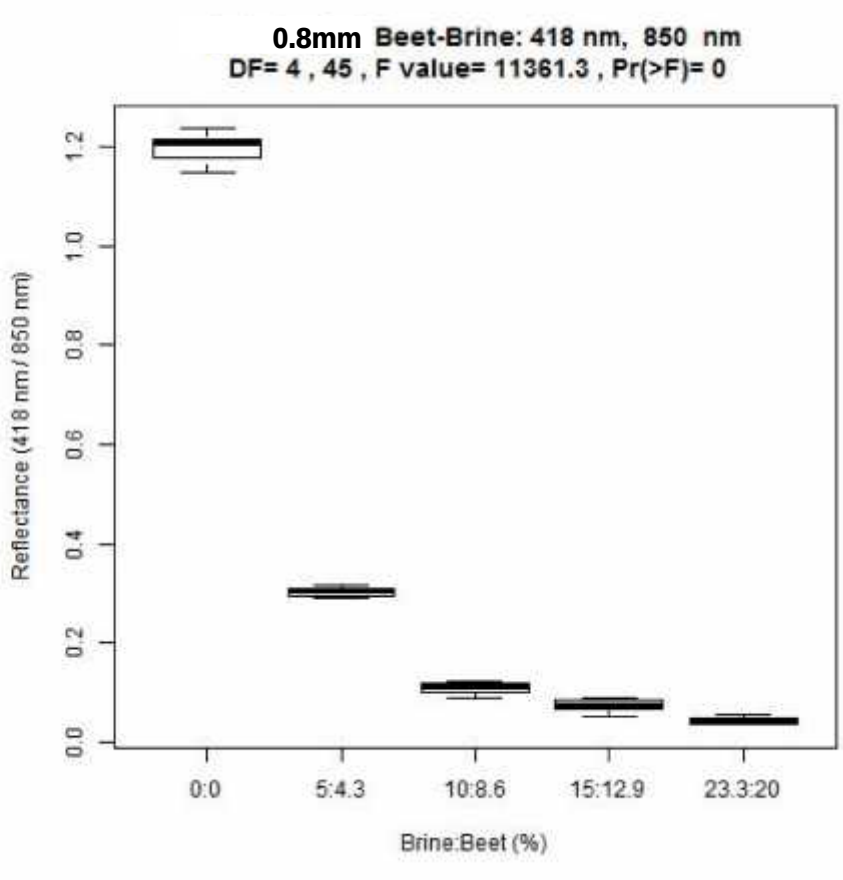
=

Repeated	5 mL
Wvl (nm)	Freq
419	1471
418	1470
417	1462
420	1451
416	1449
415	1440
421	1431
427	1430
426	1427
429	1421
428	1417
435	1416
423	1414
424	1414
430	1414
436	1414
414	1407
425	1406
422	1404
434	1398

KEY POINTS (AUTOMATED APPROACH)

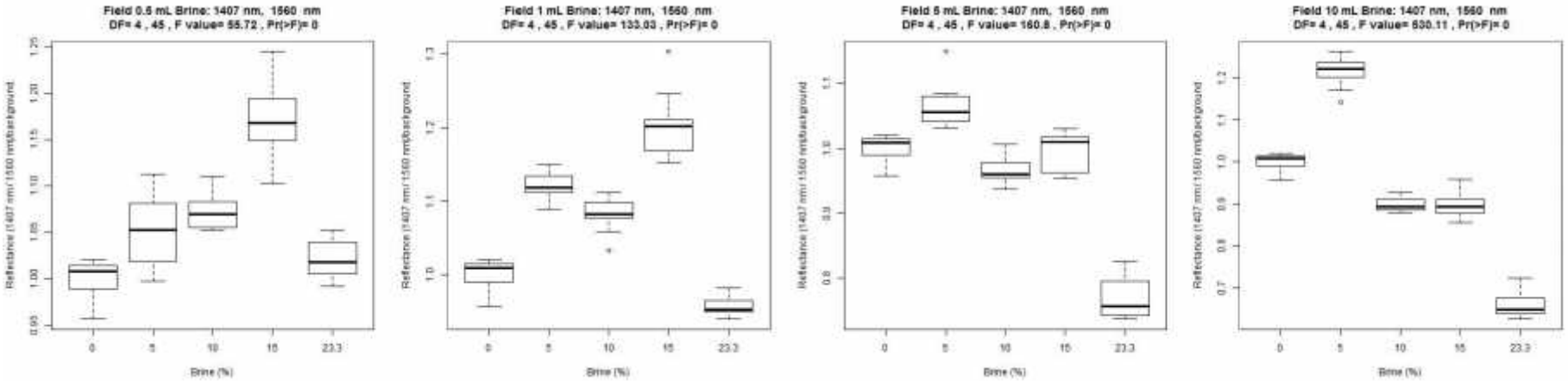
Example: Rstudio – 0.8 mm w/ concentration (beet-brine)



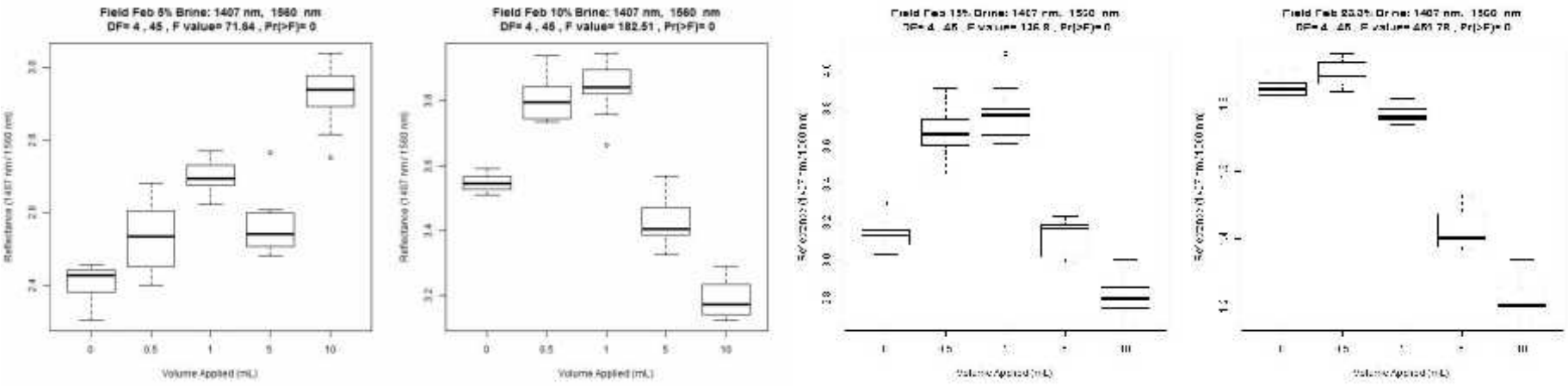


FIELD

Example: Brine



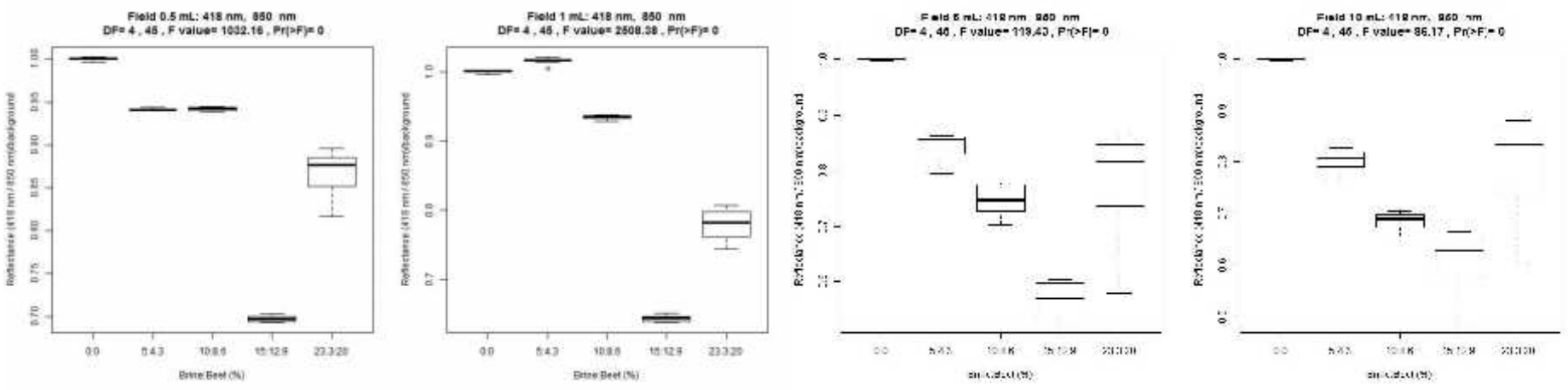
Increasing Brine Volume →



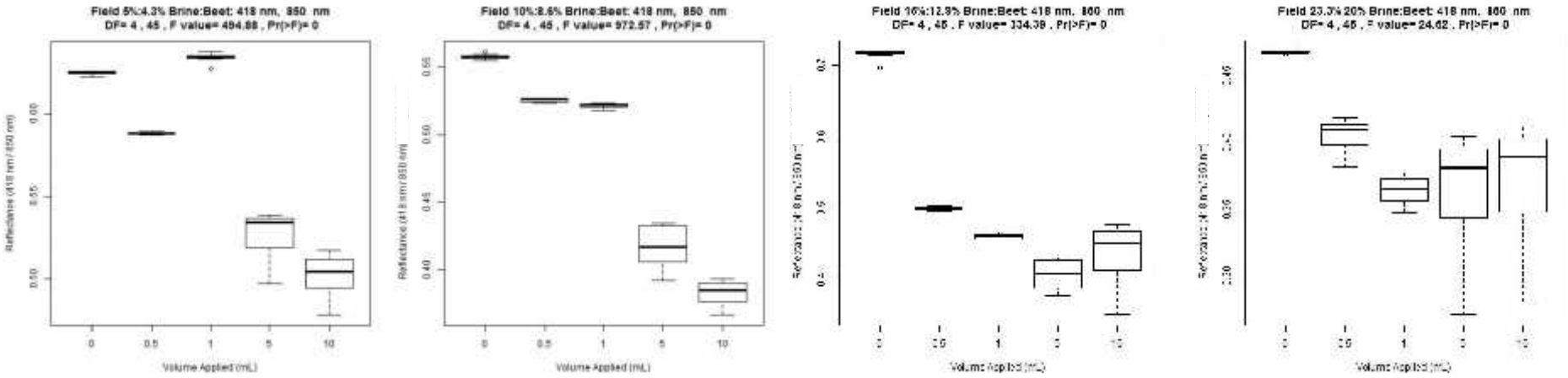
Increasing Brine Concentration →

FIELD

Example: Beet+Brine



Increasing Brine:Beet Volume



Increasing Beet:Brine Concentration

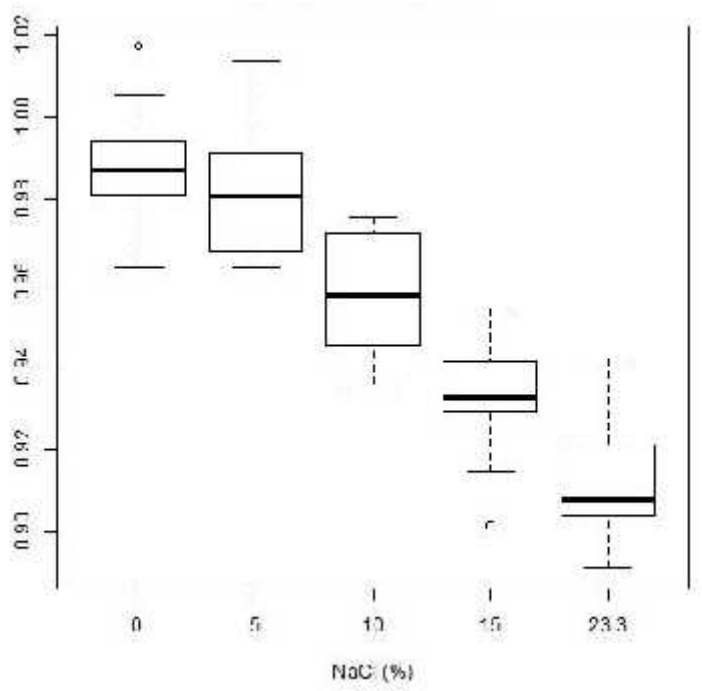
CONCLUSIONS

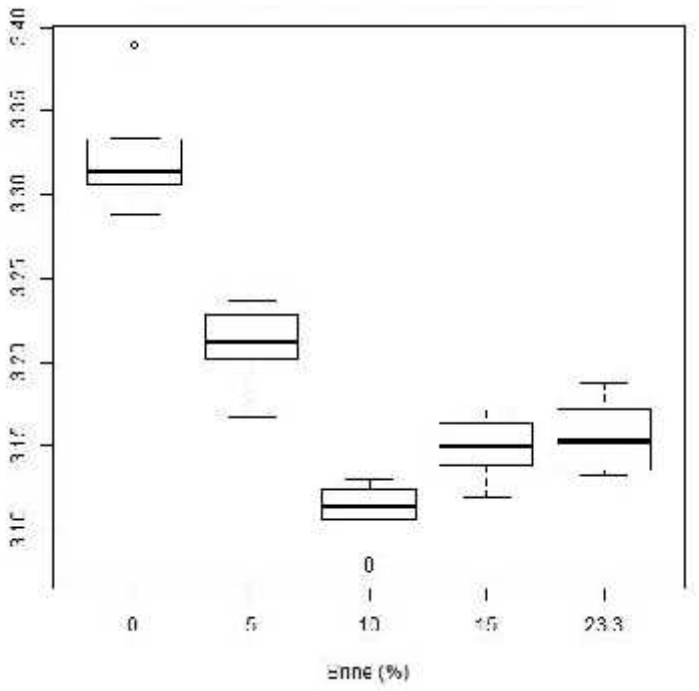
GENERAL RESULTS

Some successes and some failures

- Successfully detected changes in chemical and derivatives in lab setting
- Moving to field setting showed serious degradation of lab generated relationships but
- Alternative relationships calibrated specifically for field setting may be more effective
- Improvement over existing paired-reflectance comparisons (leveraging key points in the near-infrared spectrum)

Thesis generated vs. ground based salt index
(1407 nm, 1585 nm) vs. (665 nm, 835 nm)





VALUE ADDED

- Illustrates promise in using spectrometry to aid in decision making for organizations that utilize brine and derivatives
- Generates new data that can be stored in online databases and repositories that that provide open-access to spectra
- Advances reflectance research particularly with applications to transportation and maintenance

FUTURE RESEARCH

- Explore more complex equations/relationships (include more critical points)
- Refine field data collection procedure to control for environmental and climatic variables

Thanks for listening.

Dr. Nathan Belz
npbelz@alaska.edu
drtraffic.community.uaf.edu
@dr_traffic

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