# New tools to fine-tune quality harvests : spectroscopy applications in viticulture

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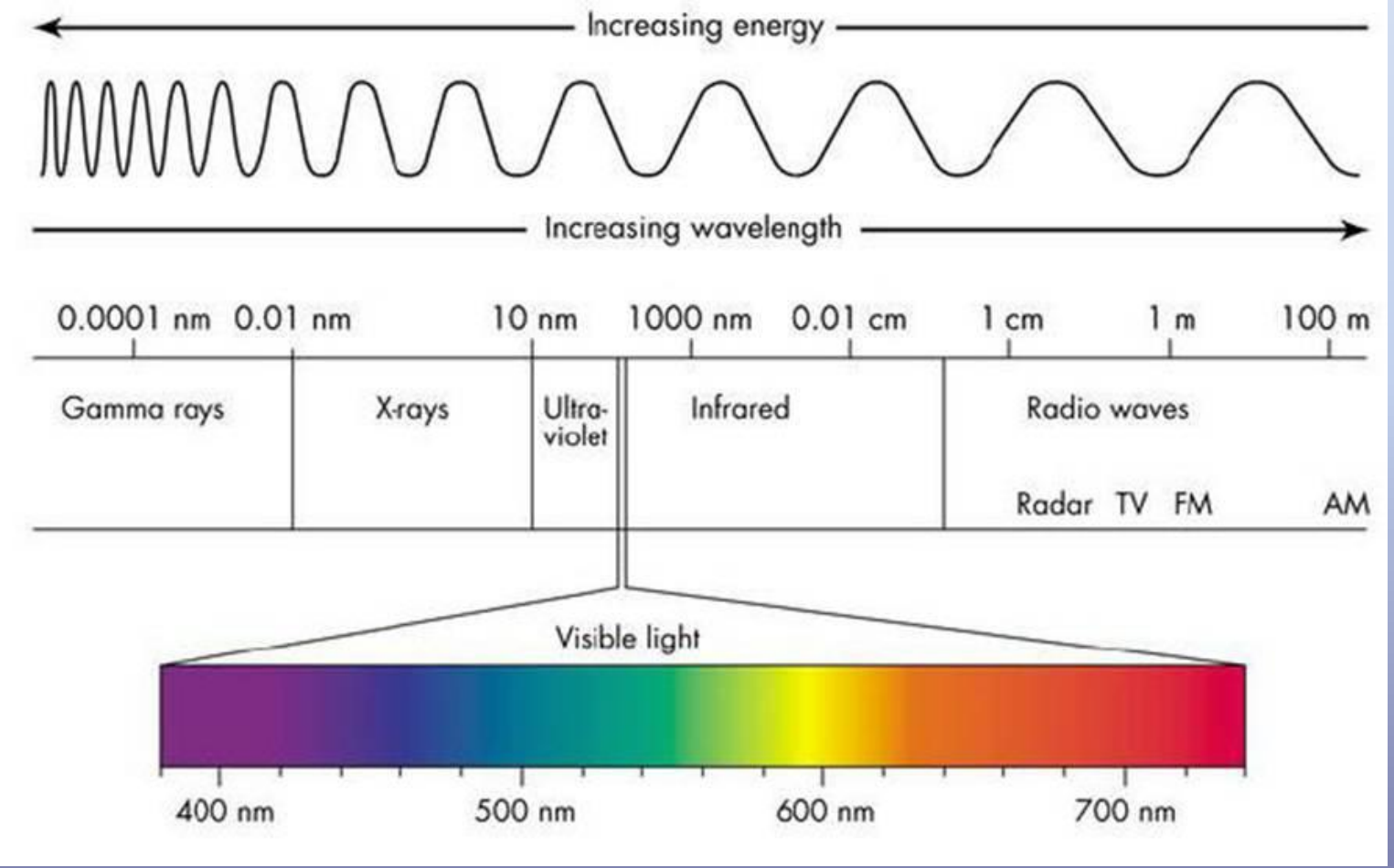
# 1. Visible/NIR Spectroscopy of Grapes

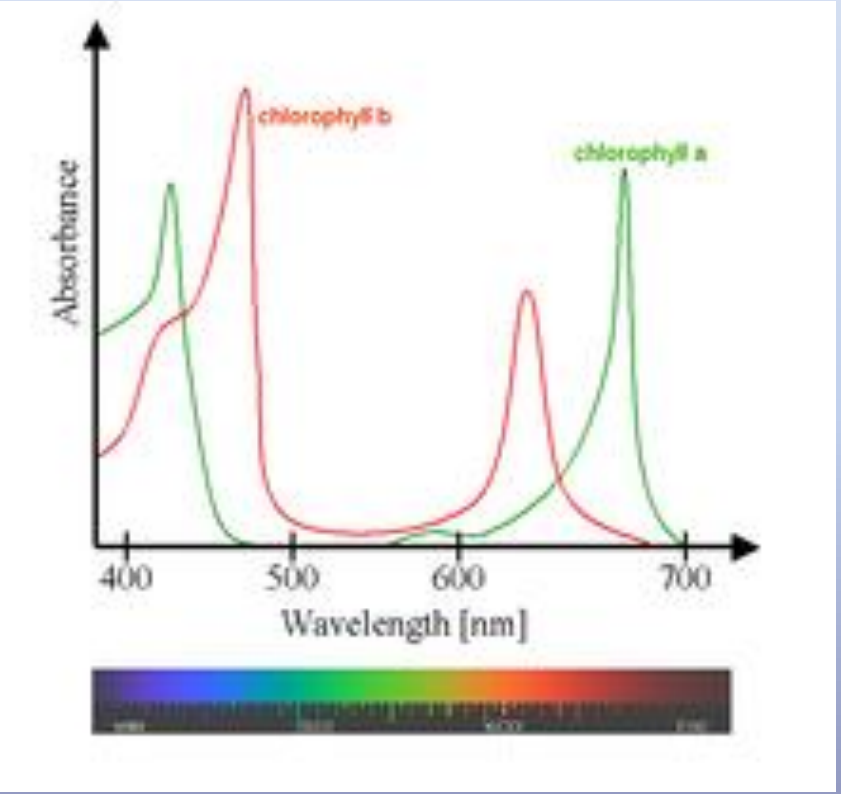
- Interaction of matter with light (absorbance, reflectance) depends upon chemical composition
- Atomic and molecular energy levels (vibration, rotation, spin energy, etc.) are specific to quantum energy of a particular wavelength
- Spectral response pattern reveals aspects of chemical composition – “chemometrics”
- Estimate fruit quality, e.g., total solids (°Brix), titratable acidity, pH, phenolics, anthocyanins from spectral characteristic

# The Electromagnetic Spectrum



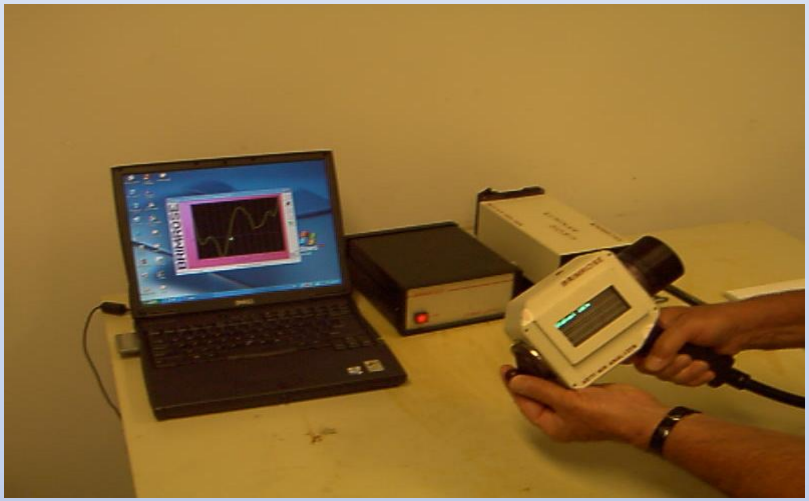
# Spectral absorption of some grape components…

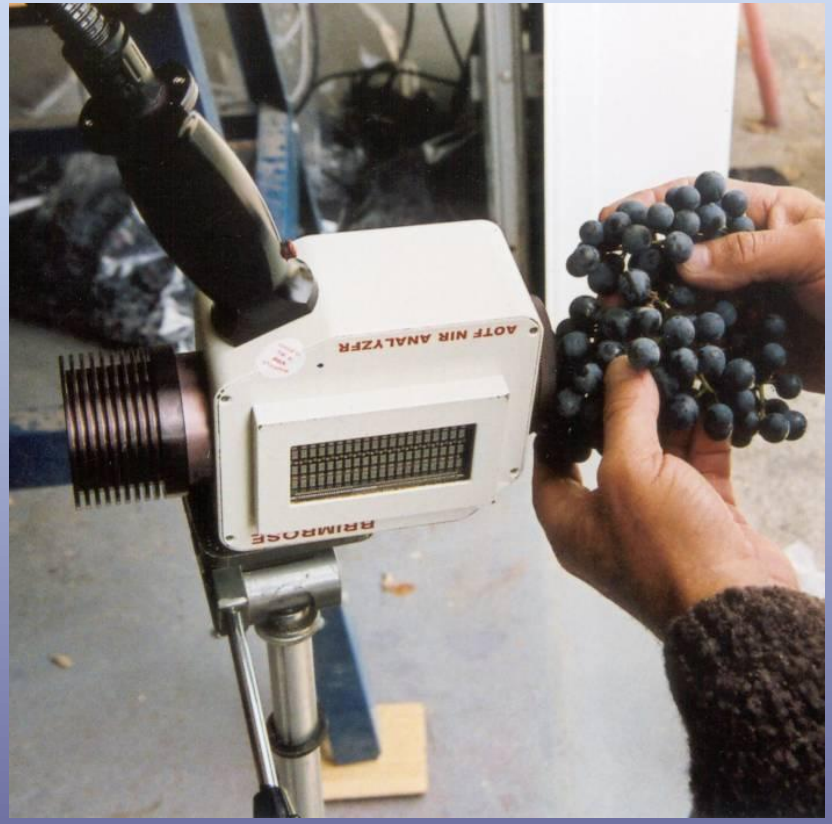
- *Chlorophyll* absorbs blue and red, reflects green
- *Anthocyanins* – absorb green, reflect blue and red
- *Water* O-H bond peaks at 760, 970, 1450, 1940 nm




http://en.wikipedia.org/wiki/Chlorophyll#cite_note-18

# Brimrose Luminar 5030 NIR – “le Vigneron”



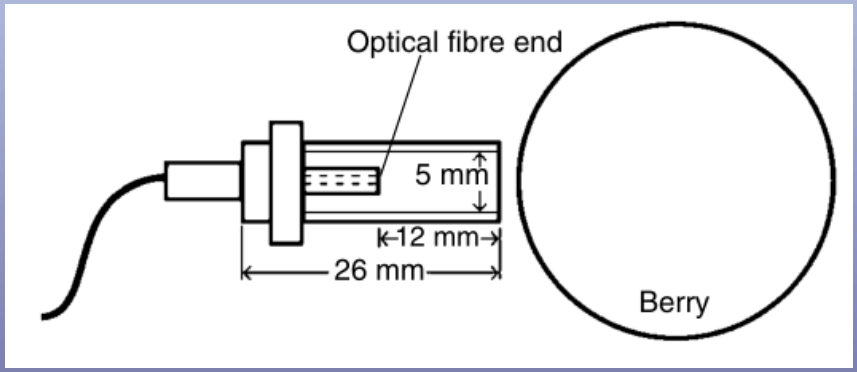


# The Brimrose “le Vigneron” NIR System

- Portable handheld instrument scans one grape berry at a time in NIR spectrum
- Can be used in vineyard, or with fruit samples
- Season-to-season prediction has not been robust, needs re-calibration
- *Requires contact with single berry, many berries must be sampled for representative values*
- *Expensive, time consuming but has shown good performance*

# Portable VIS/NIR Transflectance Probe

- Developed and tested in Chile
- Uses inexpensive Visible/NIR spectrometer with fibreoptic probe
- Good estimation of  Brix, pH and anthocyanins ($R^2$ values were >0.85 with most above 0.90)
- *Probe measures one berry at a time, requires contact with fruit – time consuming, need many measurements*

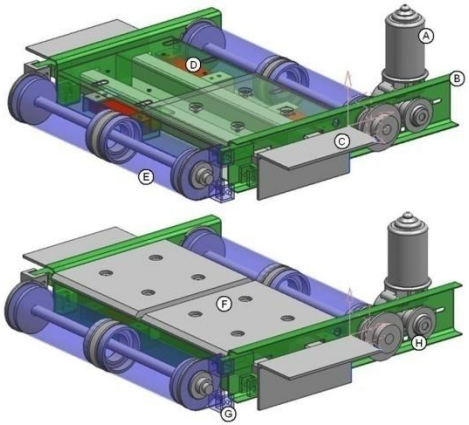



From Herrera et al., 2003

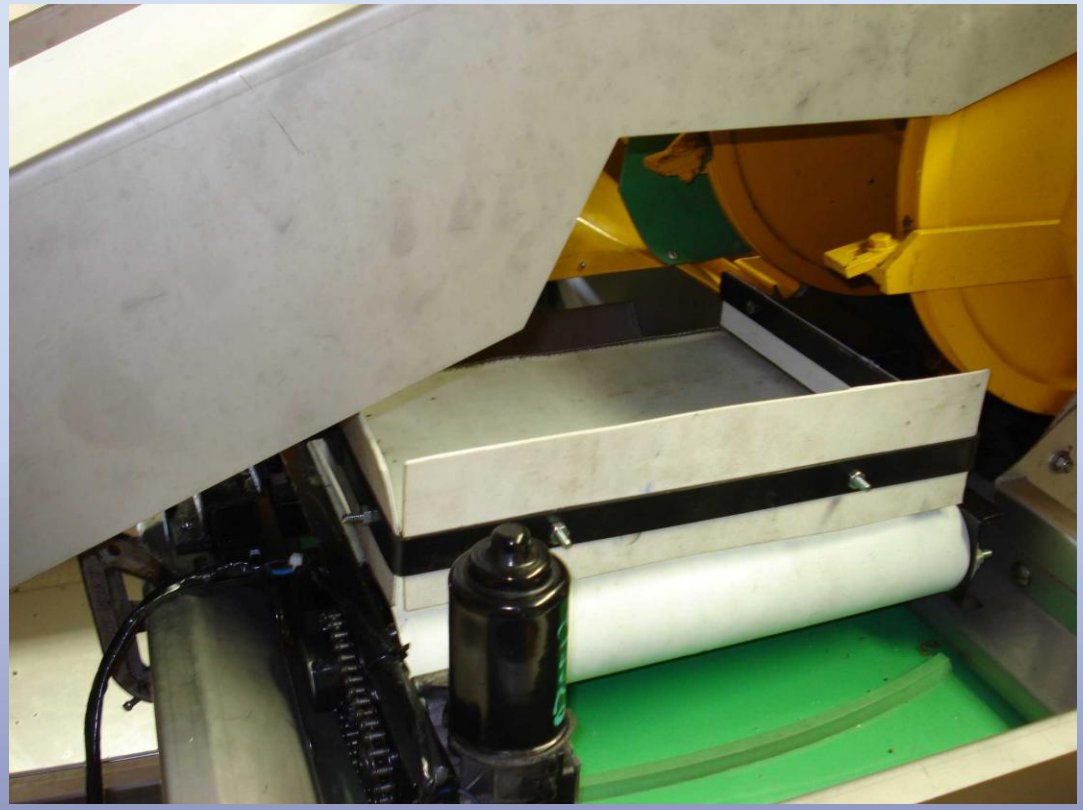
# 1. Free-air VIS/NIR Spectroscopy Trials

- Why free-air?
  - Don’t have to be in contact with fruit
  - Larger field of view, more representative
  - Compatible with mounting on harvester
- Why VIS/NIR?
  - Inexpensive spectrometer, standard optics
  - Information from visible spectrum (colour)

# Integrate VIS/NIR instrument with yield monitor?




(A) Gear Head Drive Motor
(B) Outer Conveyor Frame
(C) Inner Conveyor Frame
(D) Load Cell
(E) Conveyor Belt Roller
(F) Top Loading Plates
(G) Belt Tension Mechanism
(H) Roller Chain Drive Sprockets



OCE – Etech /U of Guelph project with Lakeview Vineyard Equipment Inc.

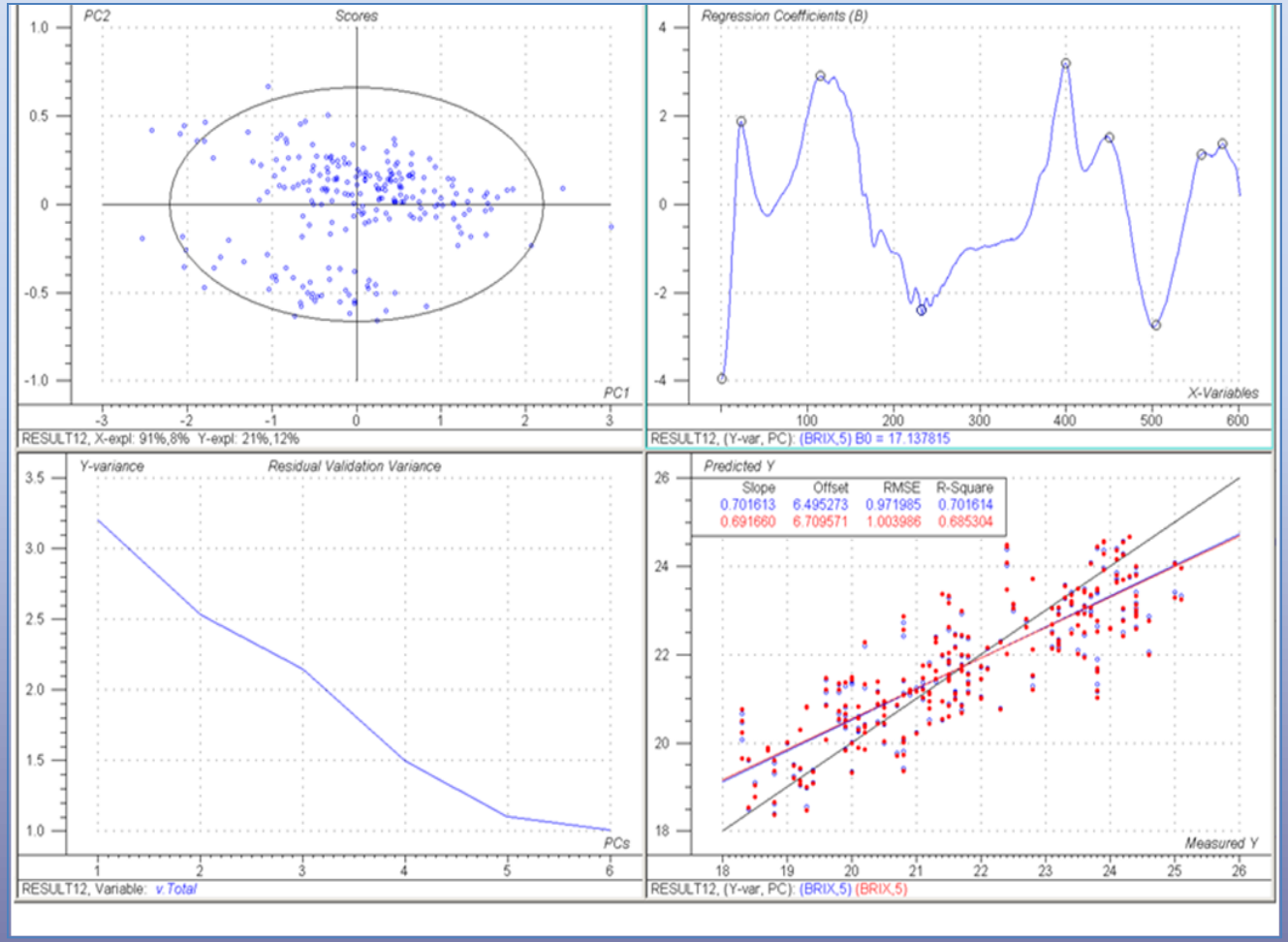
# Free-air VIS/NIR setup used in 2008 (Wade Milton)


Laptop and USB fibreoptic spectrometer with halogen lamps used for composite sample reflectance

# Collaborator: J-L Groux, Stratus Vineyard
(with K. Bailey, R. Blackadder, 2008-2010)

- Cab Sauvignon, Cab Franc, Syrah blocks sampled from early post-veraison to harvest
- Sample procedure (200-berry composite sample)
  - Sample front, back, top, bottom and shoulders of bunches, alternate on upper and lower wires, both sides of row
- Use inexpensive USB spectrometer for visible and NIR reflectance characteristics
- Scan entire composite sample (rapid, portable, more representative of vineyard block)
- Chemical analysis in Andy Reynolds lab at Brock

# Partial least-squares regression for Brix using VIS/NIR and Unscrambler® 2008



# Predictions from Spectral Reflectance

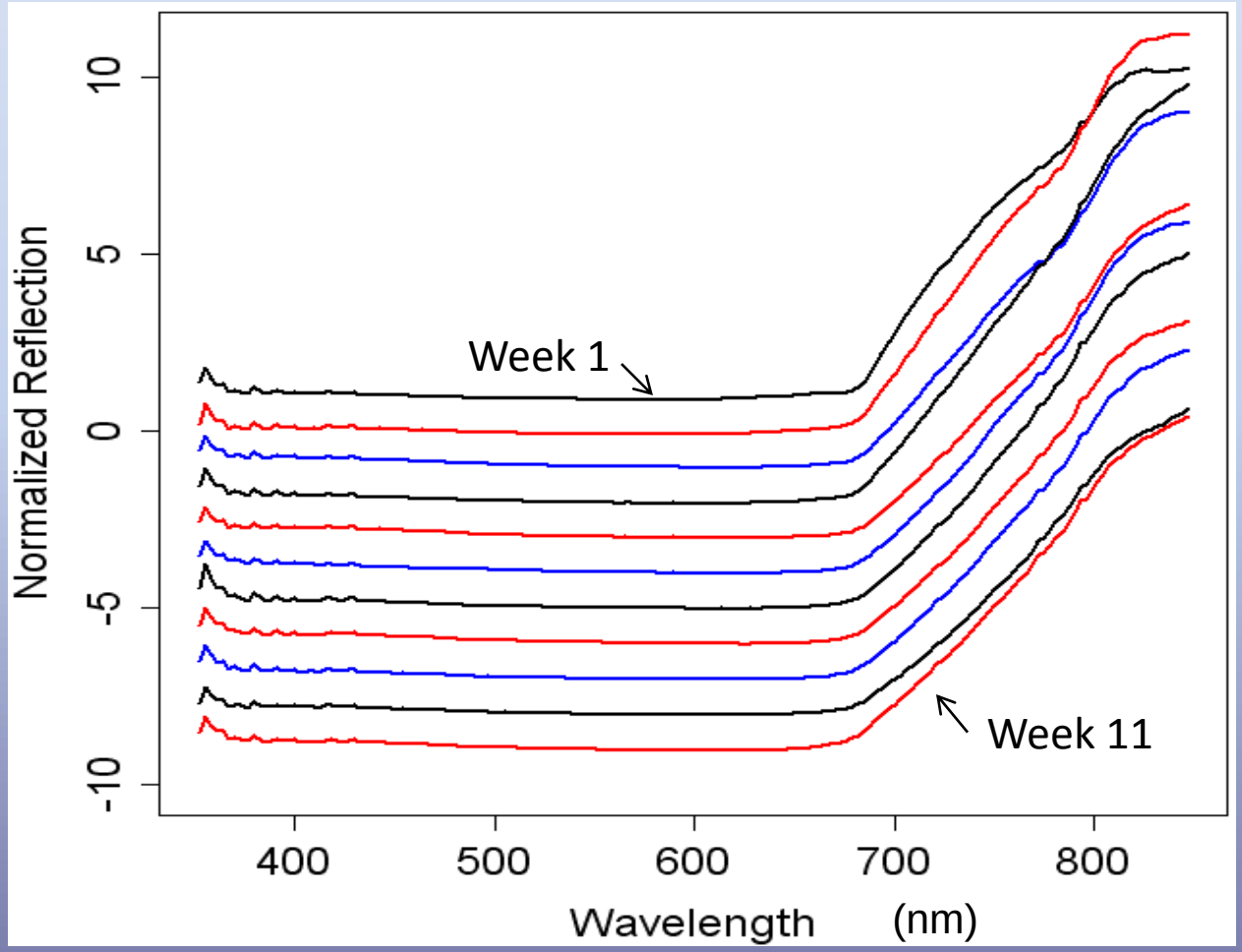
| | | 2008 Brimrose | 2008 PLS VIS/NIR | 2008 PLS/GA VIS/NIR |
|---|---|---|---|---|
| Sugar | $R^2$ | 0.702 | 0.785 | 0.868 |
| (° Brix) | RMSEP | 0.97 | 0.98 | 0.66 |
| pH | $R^2$ | 0.595 | .855 | 0.842 |
| | RMSEP | 0.06 | 0.06 | 0.05 |
| TA | $R^2$ | 0.595 | 0.696 | 0.848 |
| (g/L) Tartaric acid | RMSEP | 0.73 | 0.64 | 0.84 |
| Phenolics | $R^2$ | 0.434 | 0.484 | 0.488 |
| (mg/L) Gallic acid | RMSEP | 35.15 | 34.88 | 34.74 |

# Setup for 2009-2010 reflectance measurements (Mike Fadock)

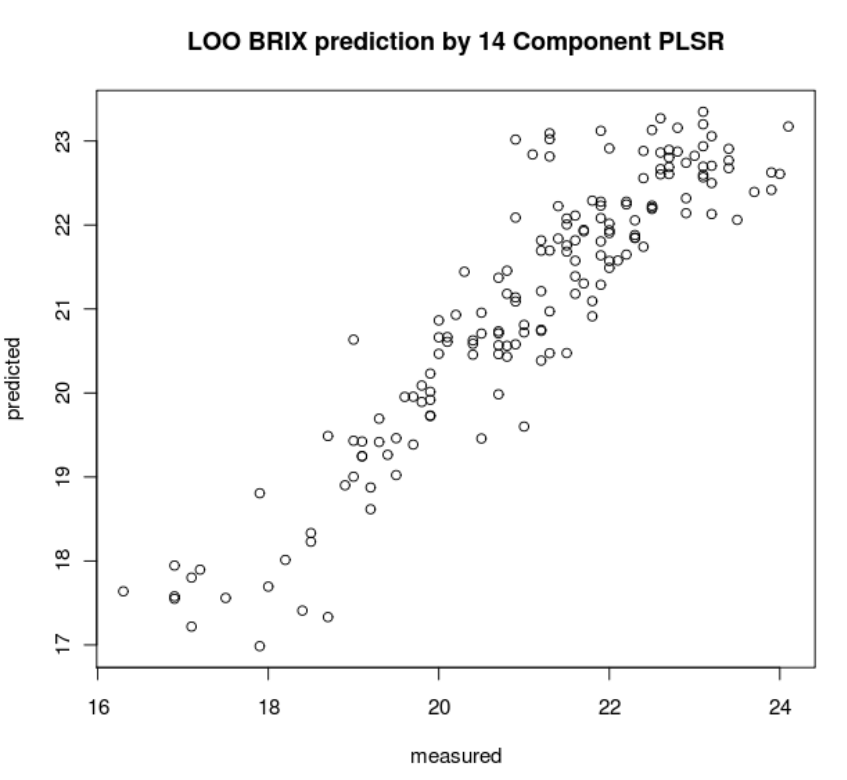
- Enclosure designed to exclude ambient light effects
- Non-reflective container allowed re-orientation of berries between measurements
- Repeat measurements after gentle shaking

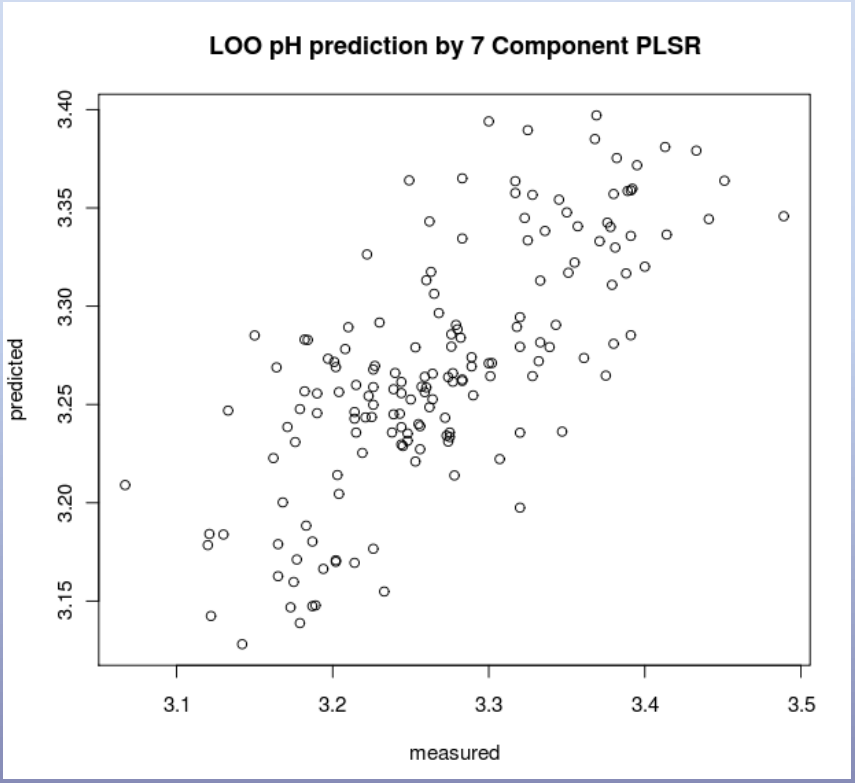
# Weekly Averaged Grape Reflectance – 2010

(weeks 2-11 shifted down to separate curves)



# 2009 PLS Predictions – Brix and pH



# Prediction of Berry Values from VIS/NIR Reflectance

| 2009 | | | |
|---|---|---|---|
| | Range | $R^2$ | RMSEP |
| ° Brix | 16.3-24.0 | .84 | 0.65 |
| pH | 3.1-3.5 | .58 | 0.05 |
| TA (g/L tartaric acid) | 6.9-12.3 | .56 | 0.59 |
| Phenols (mg/L gallic acid) | 185-385 | .27 | 31.7 |
| Anthocyanins (mg/L malvidin) | 725-1370 | .65 | 74.7 |

| 2010 | | | |
|---|---|---|---|
| | Range | $R^2$ | RMSEP |
| ° Brix | 17.1-26.6 | .89 | 0.65 |
| pH | 3.1-3.8 | .81 | 0.05 |
| TA (g/L tartaric acid) | 5-13.8 | .58 | 0.86 |
| Phenols (mg/L gallic acid) | 110-275 | .25 | 27.9 |
| Anthocyanins (mg/L malvidin) | 470-1130 | .17 | 111 |

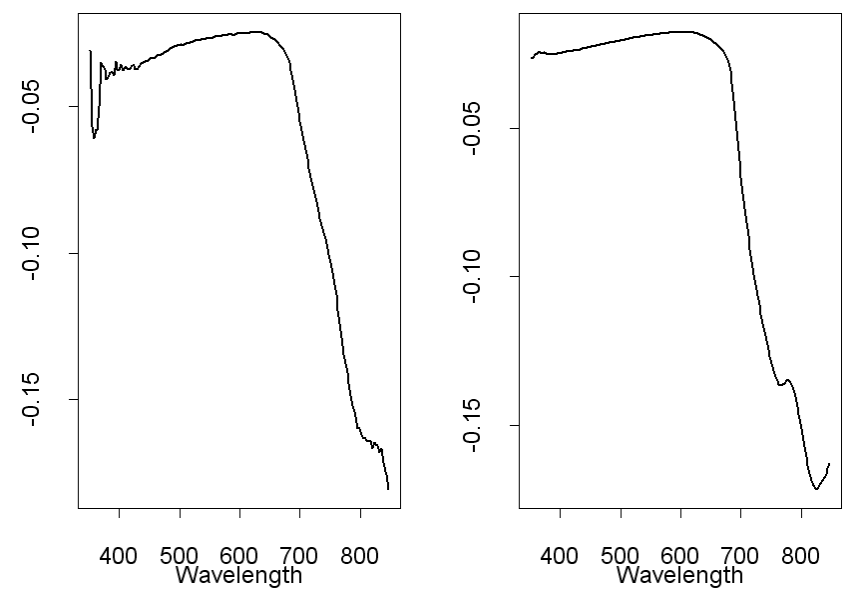
# How robust is PLS model for prediction?

- Is spectral response consistent from year to year, and between similar varieties?

- Does system have to be re-calibrated each year?
  - Can we build on each previous dataset?

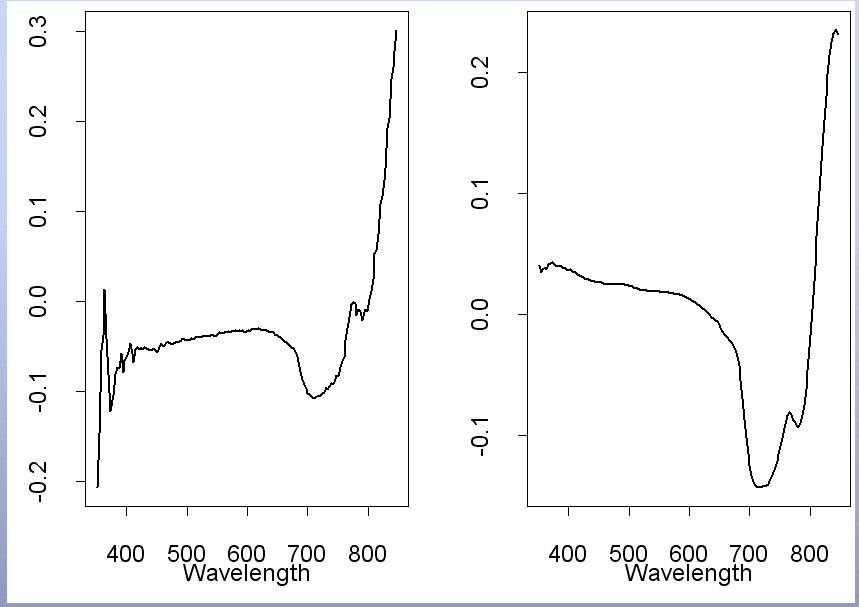
# PCA Loadings – 2009 and 2010
## (consistent year-to-year spectral contribution)

1st Component



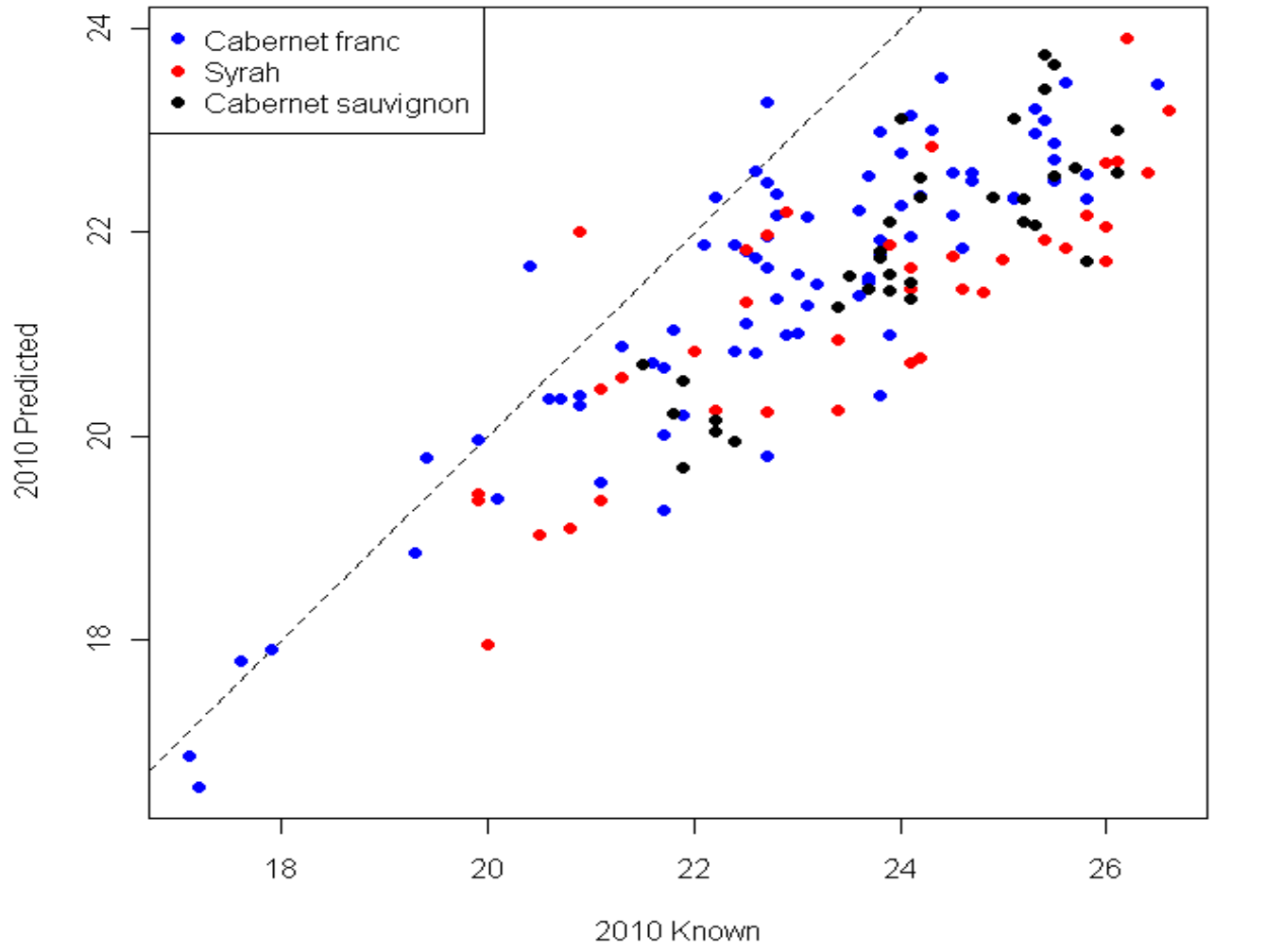

2009 2010

3rd Component

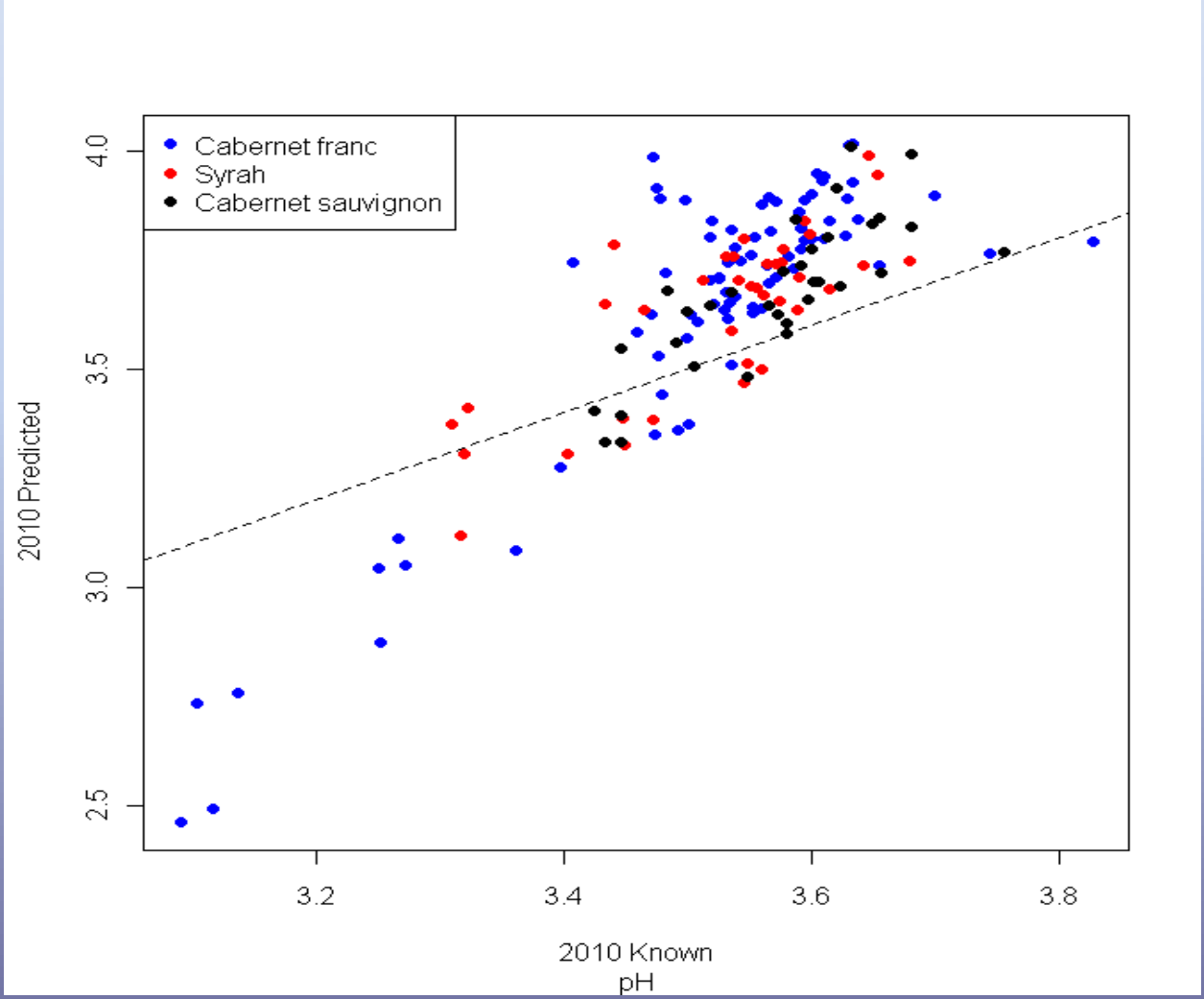



2009 2010

# 2010 ˚Brix Prediction from 2009 Model



# 2010 pH Prediction from 2009 Model



# Future of spectral methods for rapid fruit quality

- Currently *good results* for Brix, pH, TA
- Potential for rapid estimation of phenolics and anthocyanins
- Drawbacks to commercial equipment – expensive, need to calibrate, time consuming
- New technology for spectral sensing and information processing promises less expensive, more useful instruments soon…

# Recent developments in fruit reflectance applications….

New Pellenc Spectron™ portable handheld vis/NIR spectrometer

- Based on research by Gilles Rabatel with "le tromblon" at Cemagref, Montpellier, France

From www.pellenc.com/en/description.asp

# 2. Spectroscopy of leaves and canopy

- Visual assessment of vines (scouting) is important - disease, nutrition, water stress, etc.
- Other information may be there but we are limited to the visible spectrum
- Instrumental spectroscopy of canopy and leaves in ultraviolet (UV), visible, near-infrared (NIR) can be useful…

# Leaf spectral reflectance and vine health…

Leafroll virus image courtesy CFIA

- Good fruit quality starts with a healthy, well-balanced vine
- Plant stress shows up in the foliage – photosynthesis apparatus and other plant pigments affected
- These absorb and reflect in different parts of the spectrum, cause changes in leaf reflectance

# Leaf responses to physiological stress

- Environmental stress (e.g., ozone, powdery mildew) **increased reflectance in 535-640 nm range, 670 nm unresponsive** (Gregory Carter, 1993)
- Phylloxera-infested vines in California showed **increased green reflectance** (~550 nm) in remote sensing images (Lee Johnson, 1999)
- Anthocyanin biosynthesis in leaves from drought, extreme temperatures and light caused **reduced green reflectance** (Steele *et al.*, 2009)
- NIR reflectance is relatively constant except under extreme water stress

# Vegetation Reflectance Indices

- *Normalized Difference Vegetation Index* (NDVI) used in remote sensing is related to photosynthetically active biomass

$$NDVI = (\rho_{NIR} - \rho_{RED} / \rho_{NIR} + \rho_{RED})$$

- *Normalized Green-Red Reflectance* (NGRR) uses *difference* between green (550 nm) and red (670 nm) for detecting plant stress

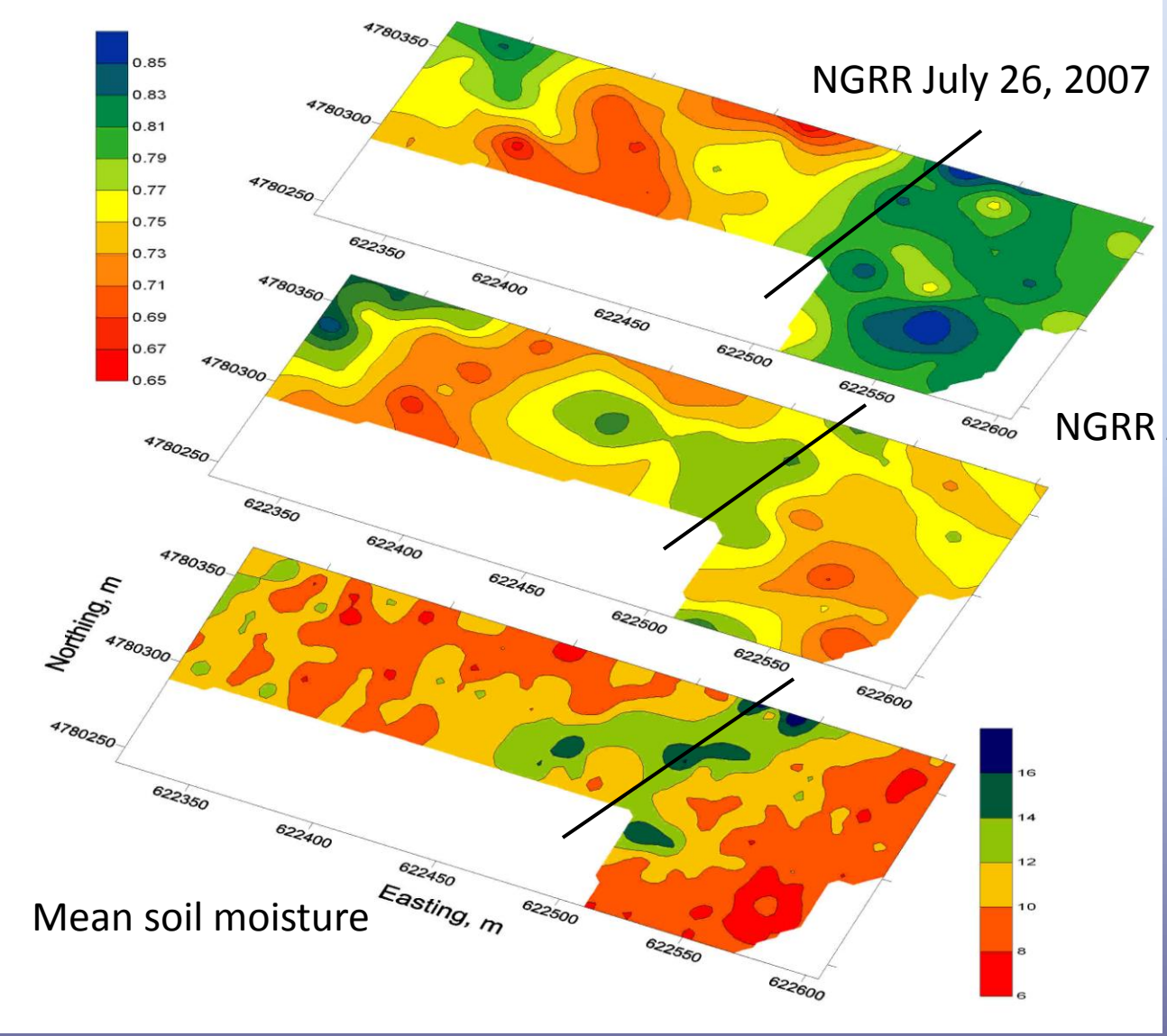
$$NGRR = \rho_{NIR} - (\rho_{GREEN} - \rho_{RED}) / \rho_{NIR} + (\rho_{GREEN} - \rho_{RED})$$

# Can we use leaf reflectance to monitor vine status?

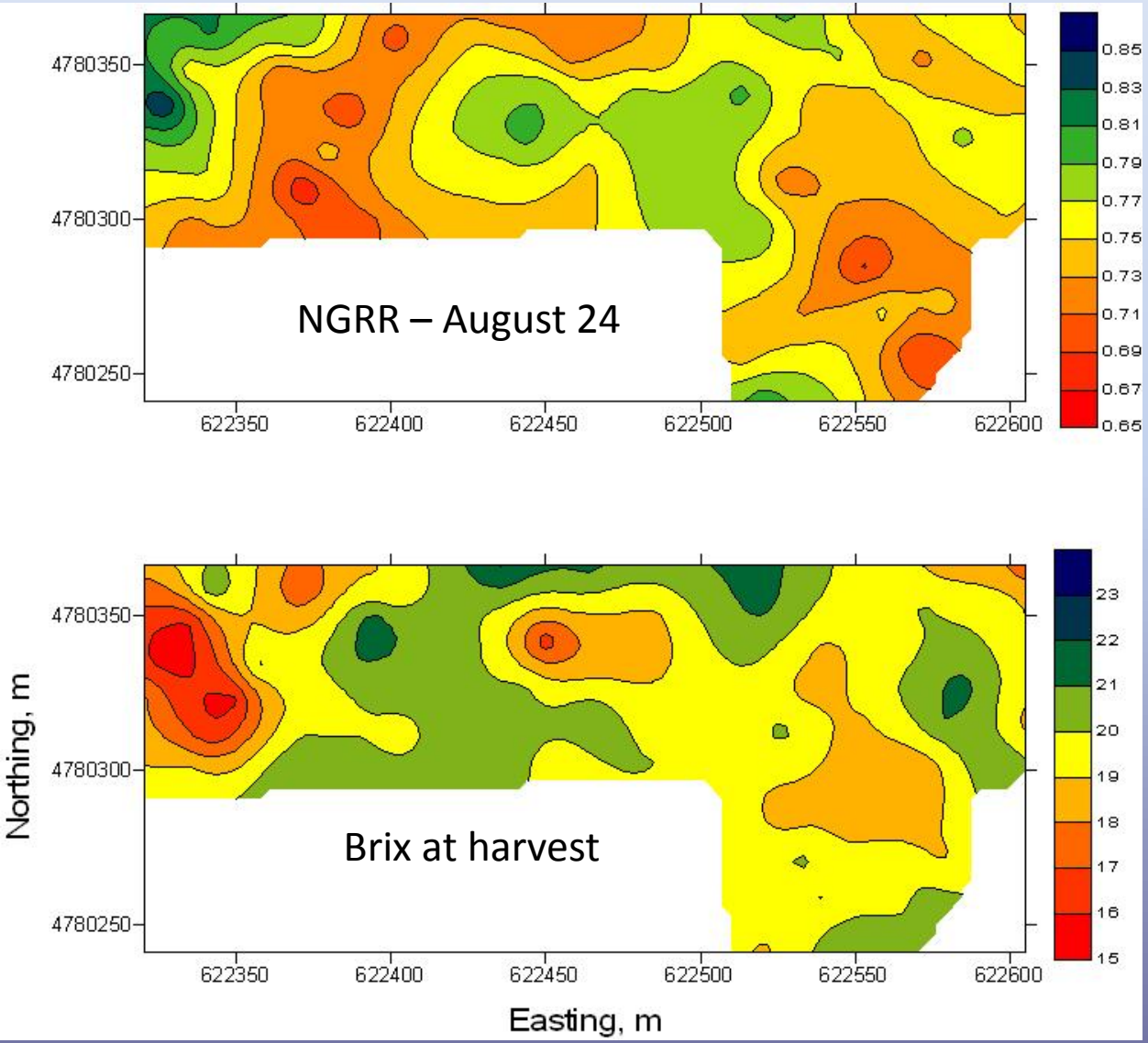
- 30-Bench Winemakers Riesling vineyard (Precision Viticulture project)
- Investigate single-leaf reflectance *in situ* and monitor vine and fruit performance
- Measure reflectance of fully-expanded leaves (5 per vine) monthly for ~ 500 sentinel vines
- Also determine soil moisture, vine water stress, harvest yield and quality

# Taking leaf reflectance measurements at 30-Bench Winemakers vineyard

# Normalized Green-Red Reflectance (NGRR) with Soil Moisture at 30-Bench Vineyard



# NGRR and °Brix at harvest - 2007



# Leaf reflectance and fruit quality

- There is a relationship between plant stress (moisture, disease, etc.), leaf reflectance (NGRR) and subsequent fruit quality
- But relationship is complex, correlations are not reliable enough for easy direct prediction
- Other factors (crop load, weather, pruning) have large effects
- *Leaf reflectance has potential to map precision viticulture management zones – e.g., differential harvest*

# Handheld instruments for leaf reflectance

Fieldscout CM1000 NDVI meter
Spectrum Technologies Inc.
www.specmeters.com/store/cm1000ndvi



CCM-200 chlorophyll meter
Opti-Sciences Inc.
www.optisci.com/ccm200.htm

# Automated sensor for canopy reflectance

Greenseeker ™

Images courtesy Ntech Industries, Inc.

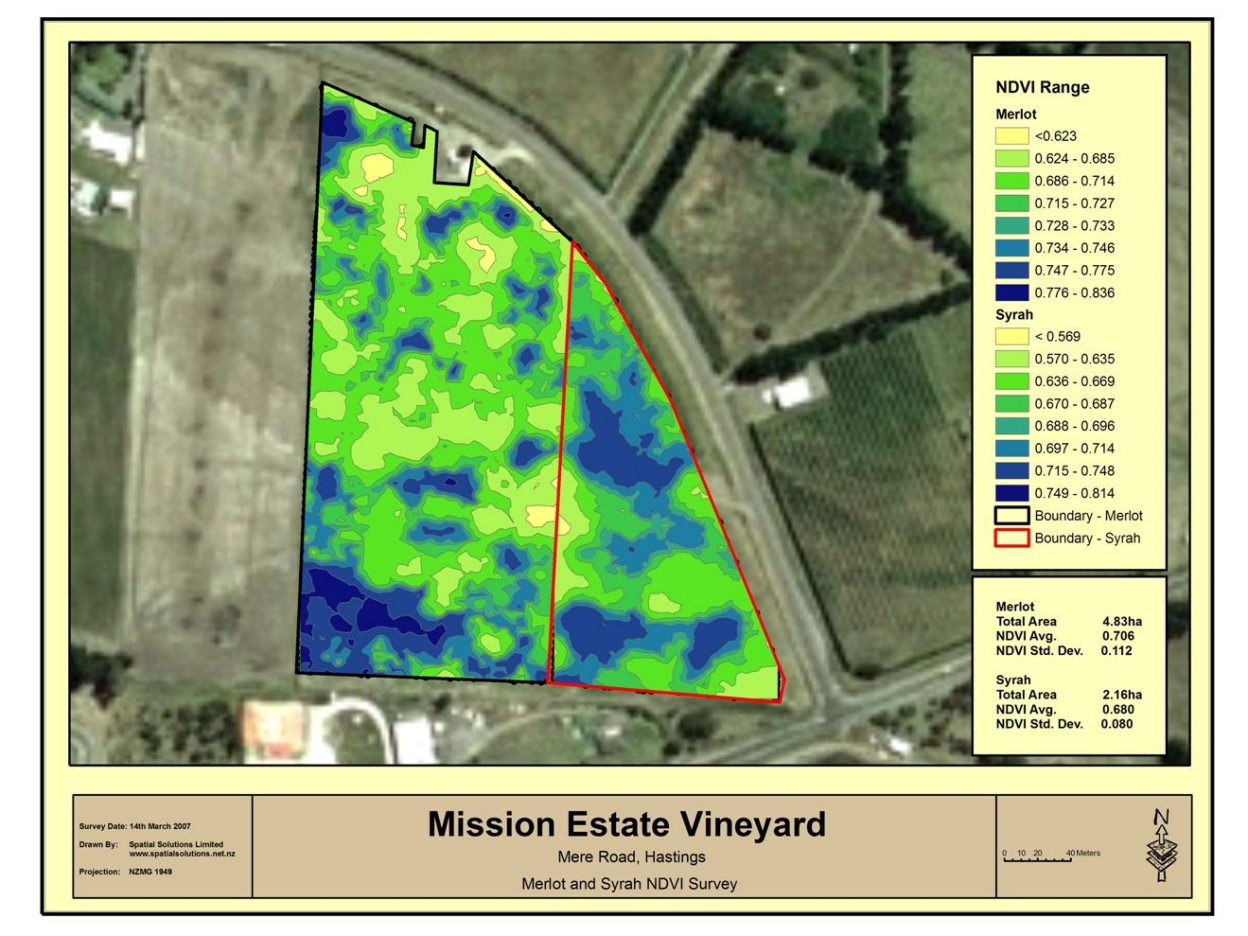
# Automated Sensors used for NDVI Mapping

GreenSeeker® NDVI
Sensor on a quad bike

Images courtesy Ntech Industries, Inc.

NDVI map from GreenSeeker® sensor

# Map of canopy reflectance (NDVI) used to make harvest decisions…




Courtesy Caine Thompson, Spatial Solutions NZ

# Is there potential for using vineyard canopy reflectance in Precision Viticulture?

- Greenseeker® and CropCircle® systems are commercially available
- Evidence that NDVI variation (biomass) is related to harvest quantity and quality
- May be more convenient than remote sensing to define management and harvest zones
- Need more research on linkages between vine balance, health and fruit quality

# New tools to fine-tune quality harvests : spectroscopy applications in viticulture

Thank you!