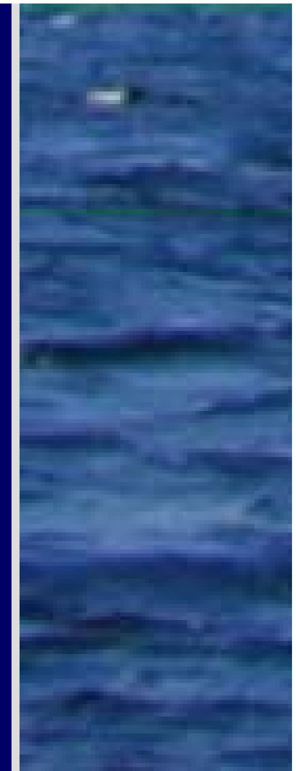
The use of remote sensing to measure water quality in New England (USA) lakes

Shane Bradt
University of New Hampshire

- **Remote sensing of water**
- Methods
- Spectral results
- Remote sensing algorithms
- Next steps…



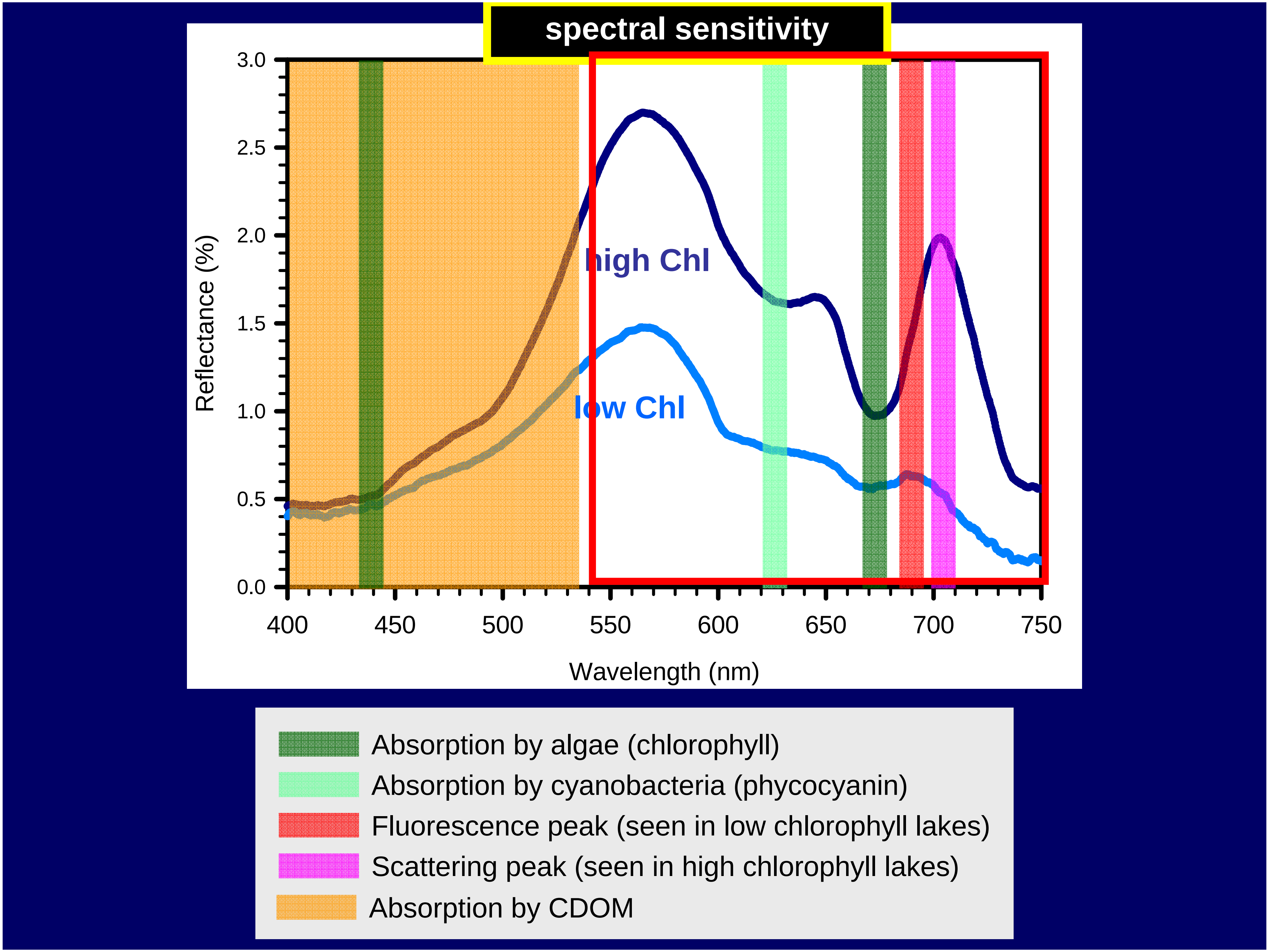
Steps in water RS

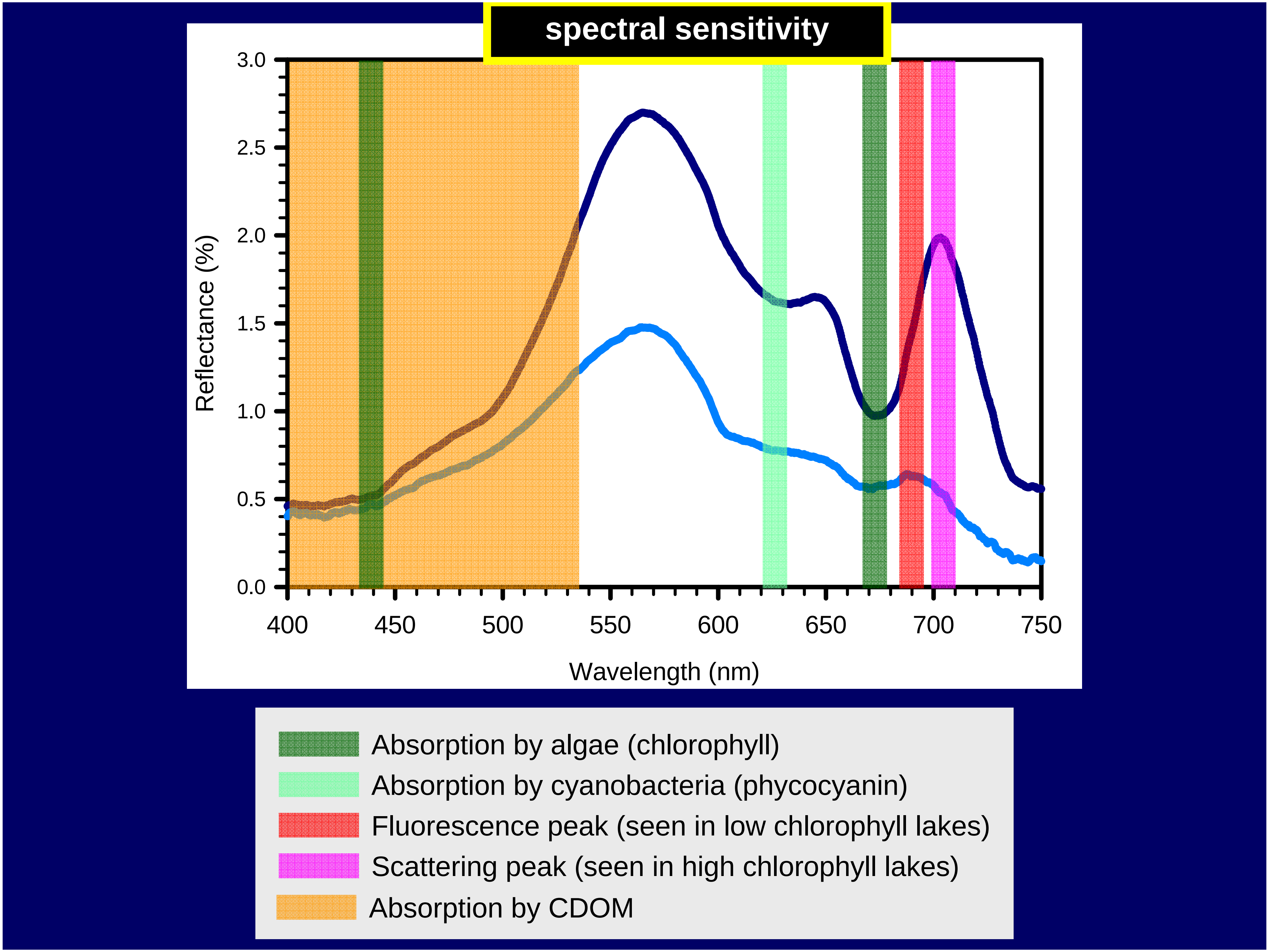
1. Collect lake spectral measurements from lakes paired with relevant limnological data
   - Chlorophyll, microcystins, CDOM, ect.
2. Characterize the spectral patterns found in New England lakes
3. Develop algorithms to measure water quality in New England lakes
4. Apply algorithms to satellite imagery to validate the techniques

Things to think about for water RS

1. How is water different than land?
   a) Low reflectance
   b) Rapid changes
   c) Narrow bands of interest

==> return time of sensor
==> turn around time of data
==> atmospheric correction
==> spectral sensitivity
==> radiometric sensitivity


spectral sensitivity
Reflectance (%)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
400
450
500
550
600
650
700
750
Wavelength (nm)
high Chl
low Chl
Absorption by algae (chlorophyll)
Absorption by cyanobacteria (phycocyanin)
Fluorescence peak (seen in low chlorophyll lakes)
Scattering peak (seen in high chlorophyll lakes)
Absorption by CDOM


spectral sensitivity
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Reflectance (%)
400
450
500
550
600
650
700
750
Wavelength (nm)
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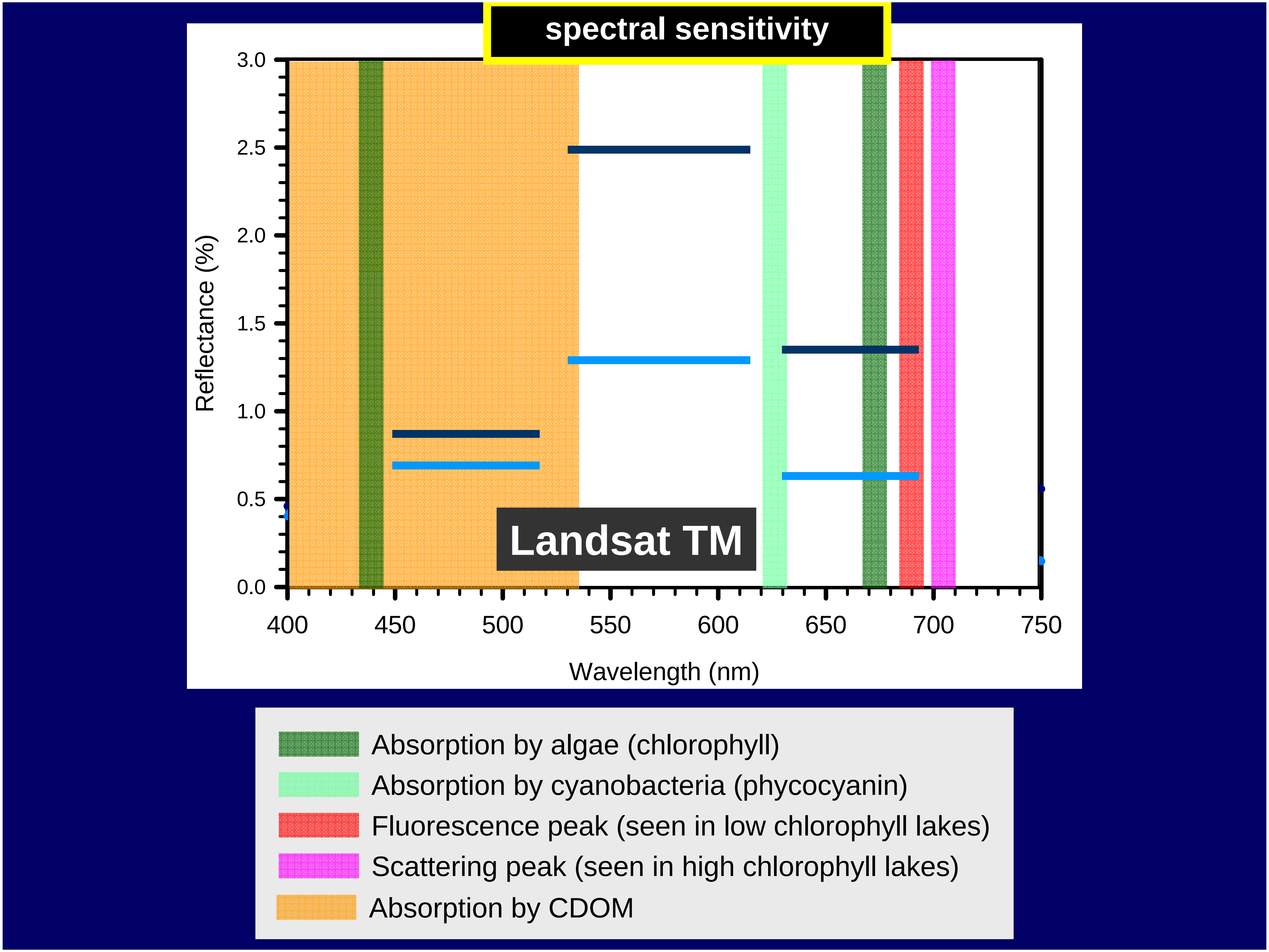
spectral sensitivity
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Reflectance (%)
Landsat TM
400
450
500
550
600
650
700
750
Wavelength (nm)
Absorption by algae (chlorophyll)
Absorption by cyanobacteria (phycocyanin)
Fluorescence peak (seen in low chlorophyll lakes)
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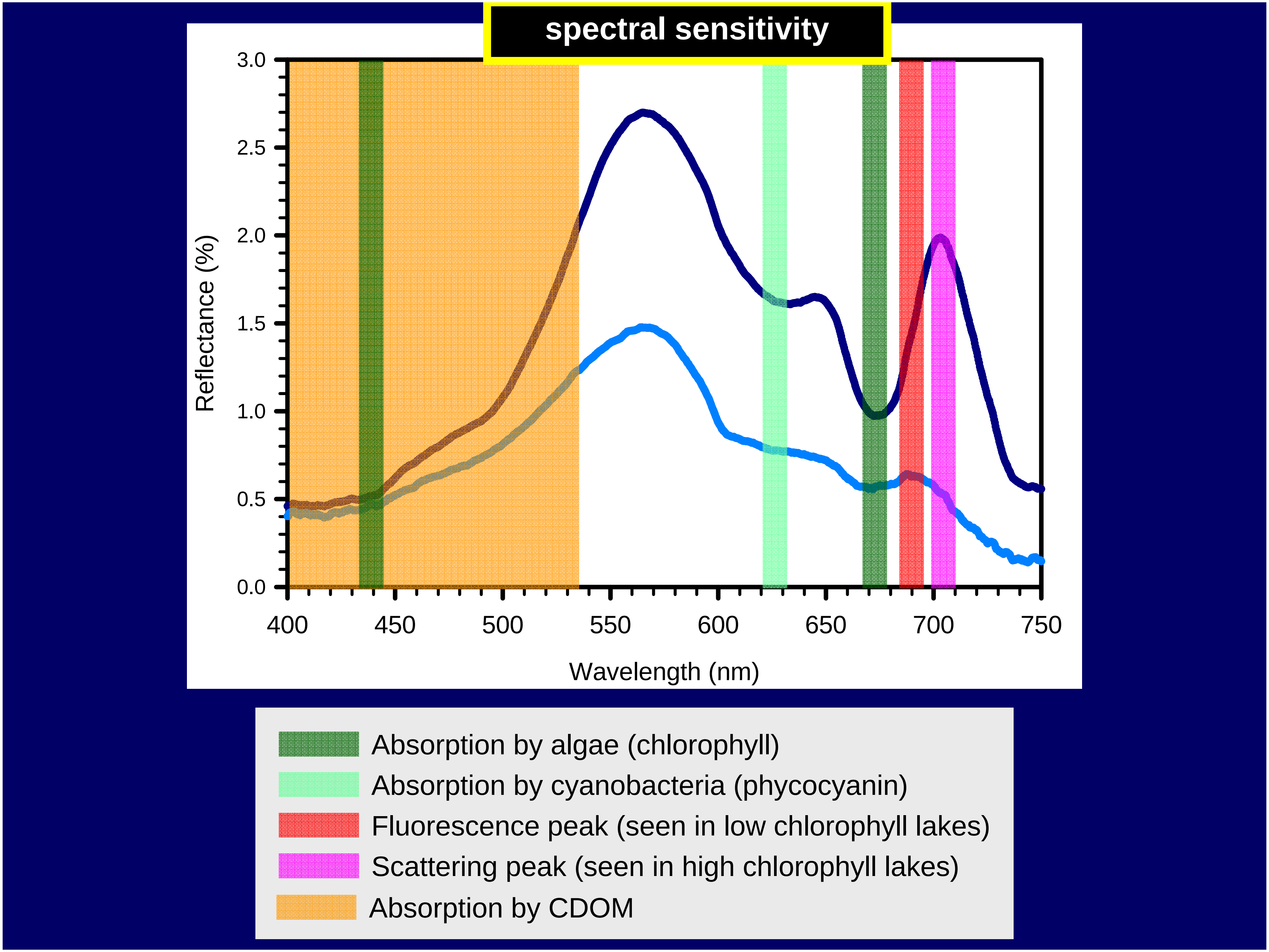
Absorption by CDOM



spectral sensitivity
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Reflectance (%)
400
450
500
550
600
650
700
750
Wavelength (nm)
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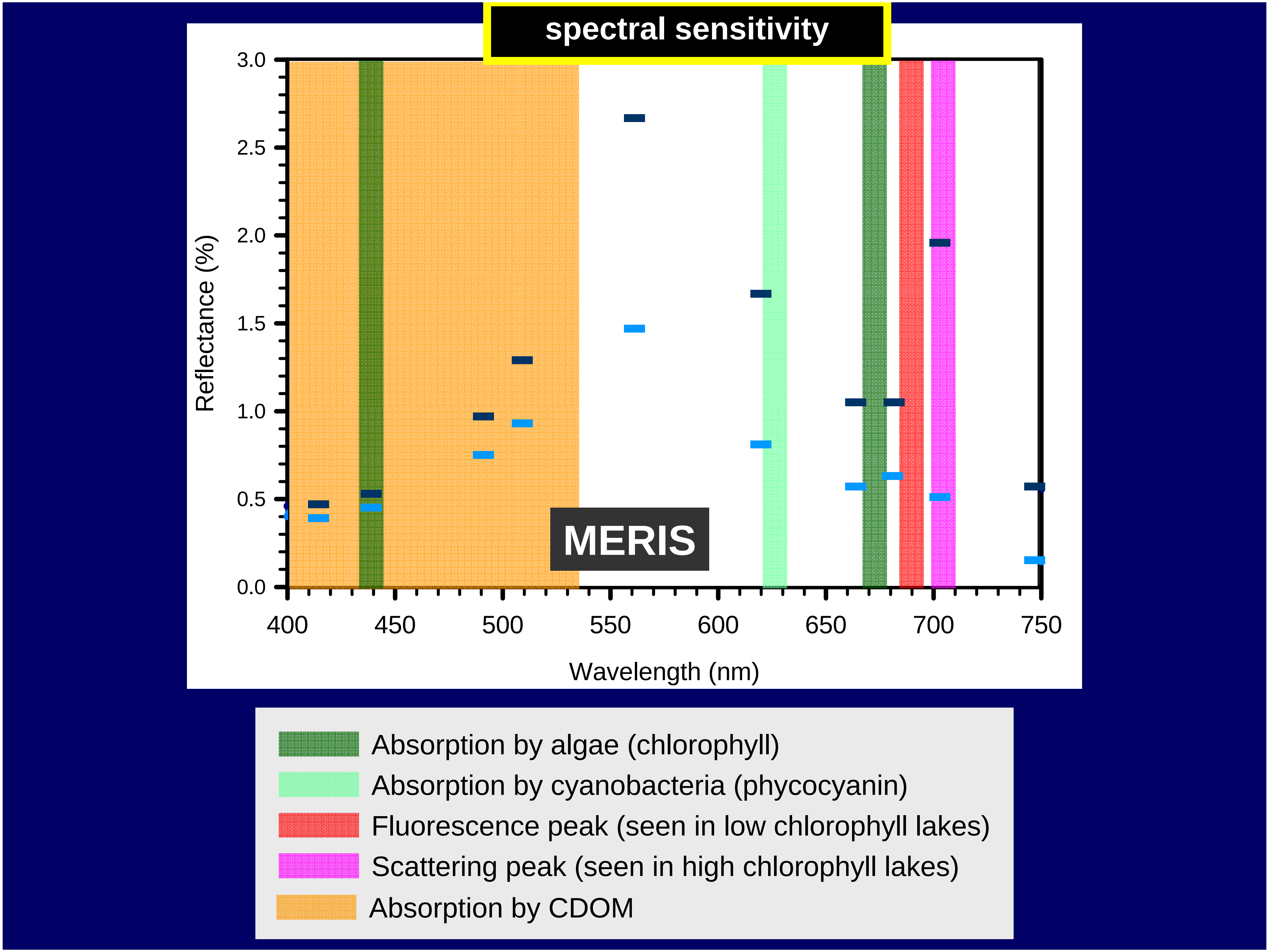
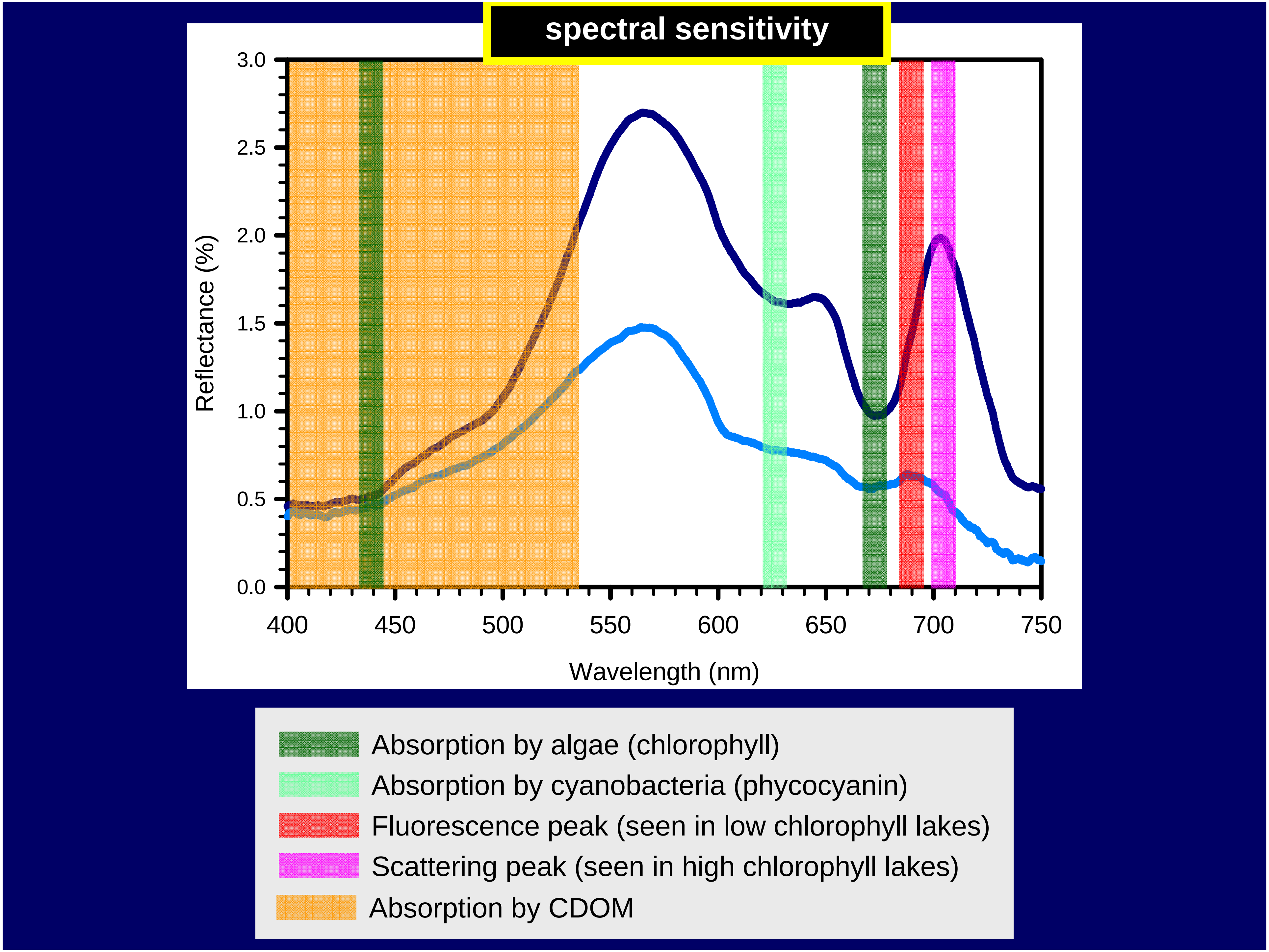

spectral sensitivity
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Reflectance (%)
400
450
500
550
600
650
700
750
Wavelength (nm)
MERIS
Absorption by algae (chlorophyll)
Absorption by cyanobacteria (phycocyanin)
Fluorescence peak (seen in low chlorophyll lakes)
Scattering peak (seen in high chlorophyll lakes)
Absorption by CDOM



spectral sensitivity
Reflectance (%)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
400
450
500
550
600
650
700
750
Wavelength (nm)
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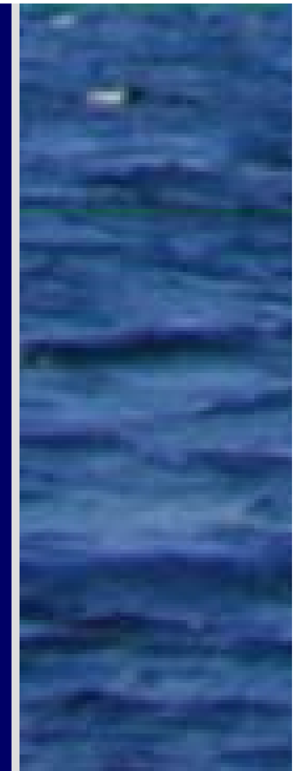
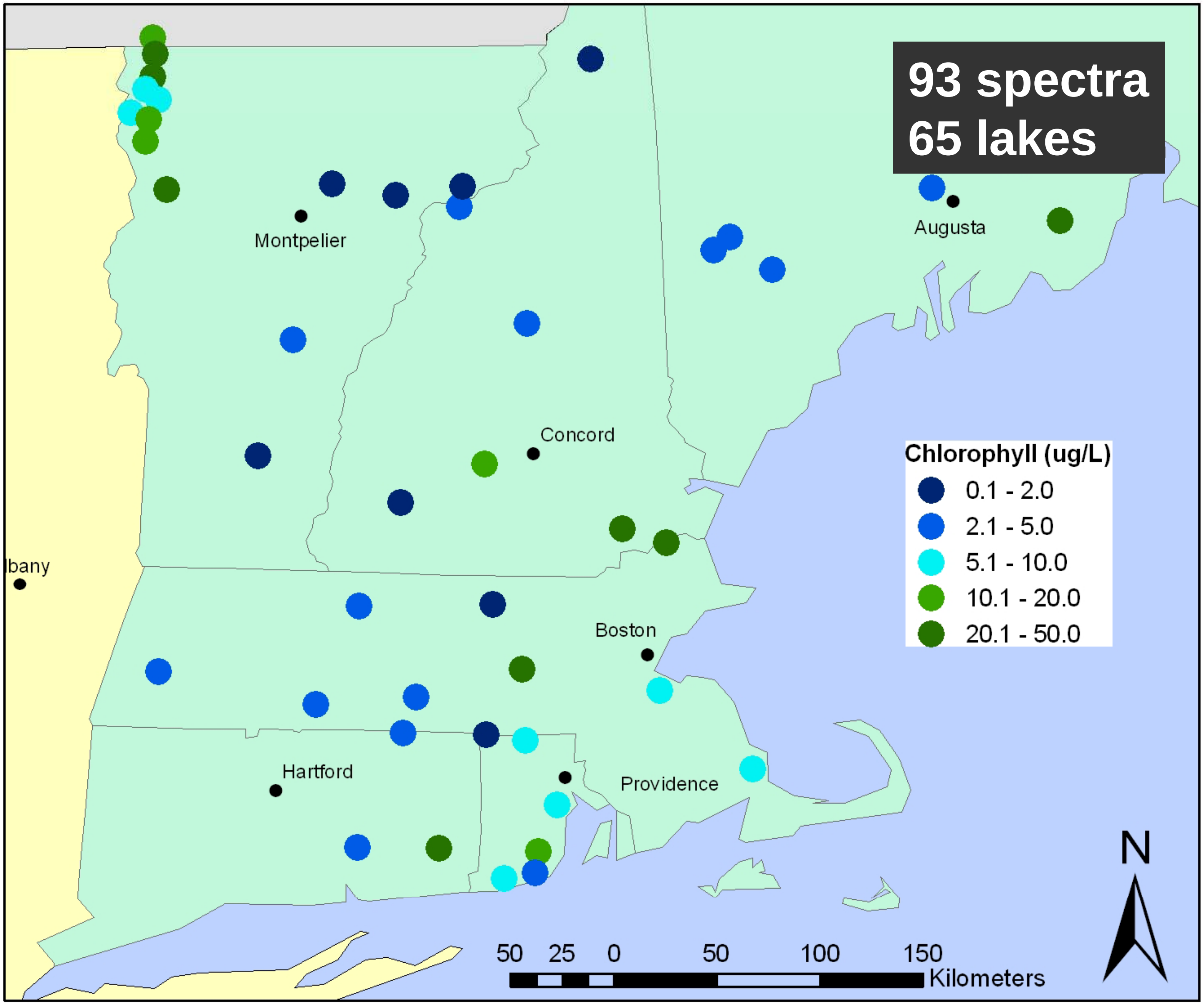
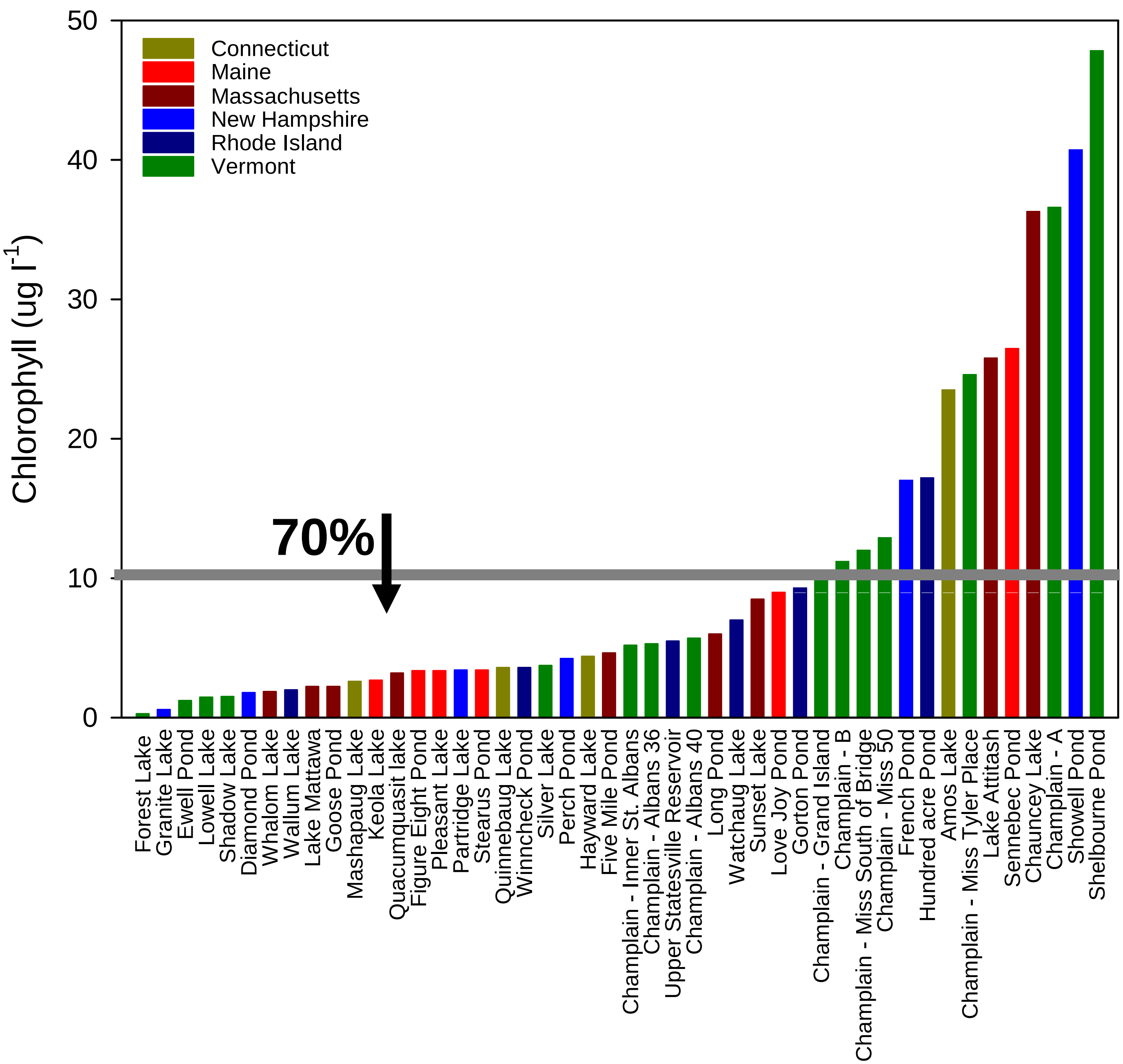



93 spectra
65 lakes
Montpelier
Augusta
Concord
lbany
Boston
Hartford
Providence
Chlorophyll (ug/L)
0.1 - 2.0
2.1 - 5.0
5.1 - 10.0
10.1 - 20.0
20.1 - 50.0
50 25 0 50 100 150
Kilometers
N

Chlorophyll in study lakes

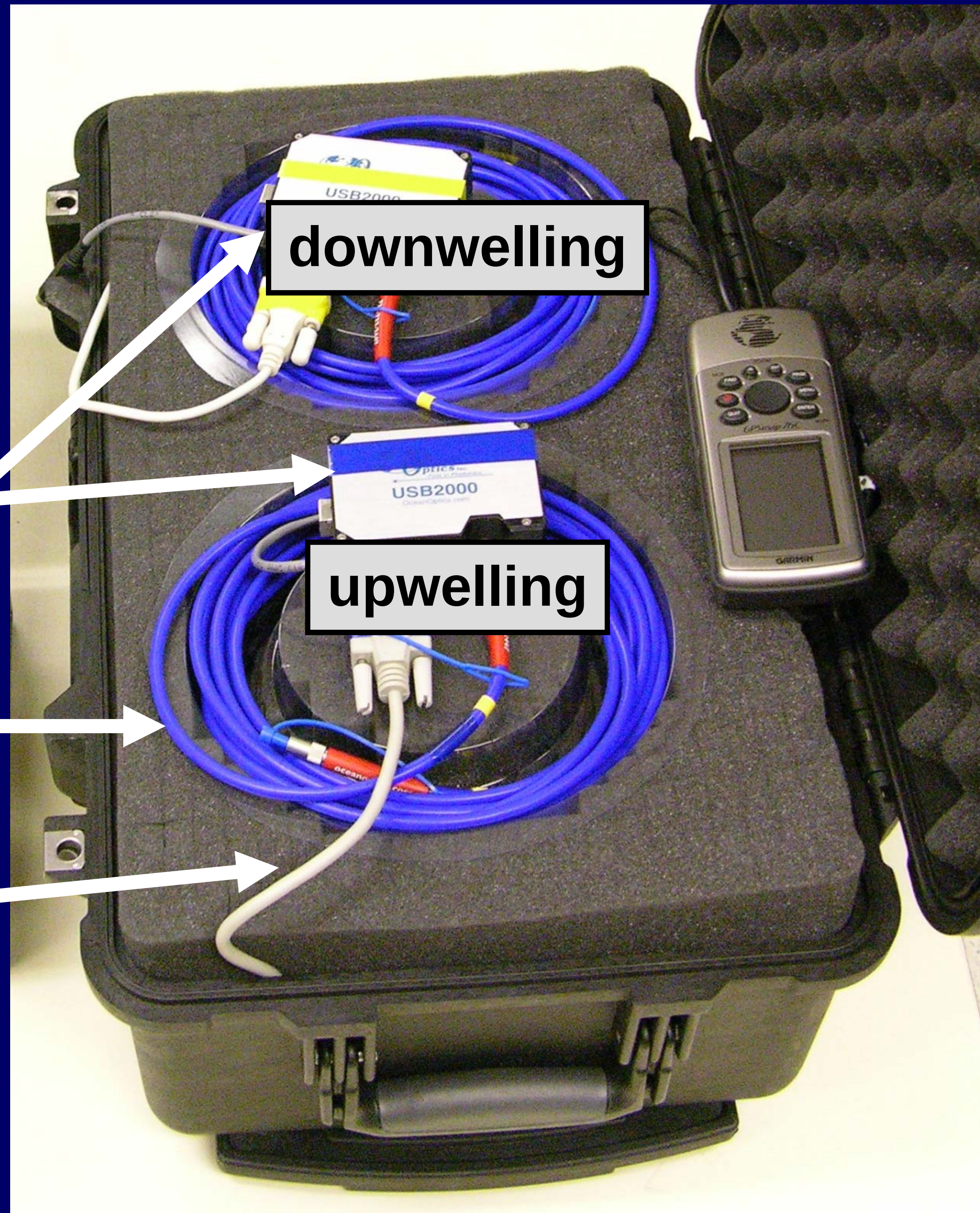


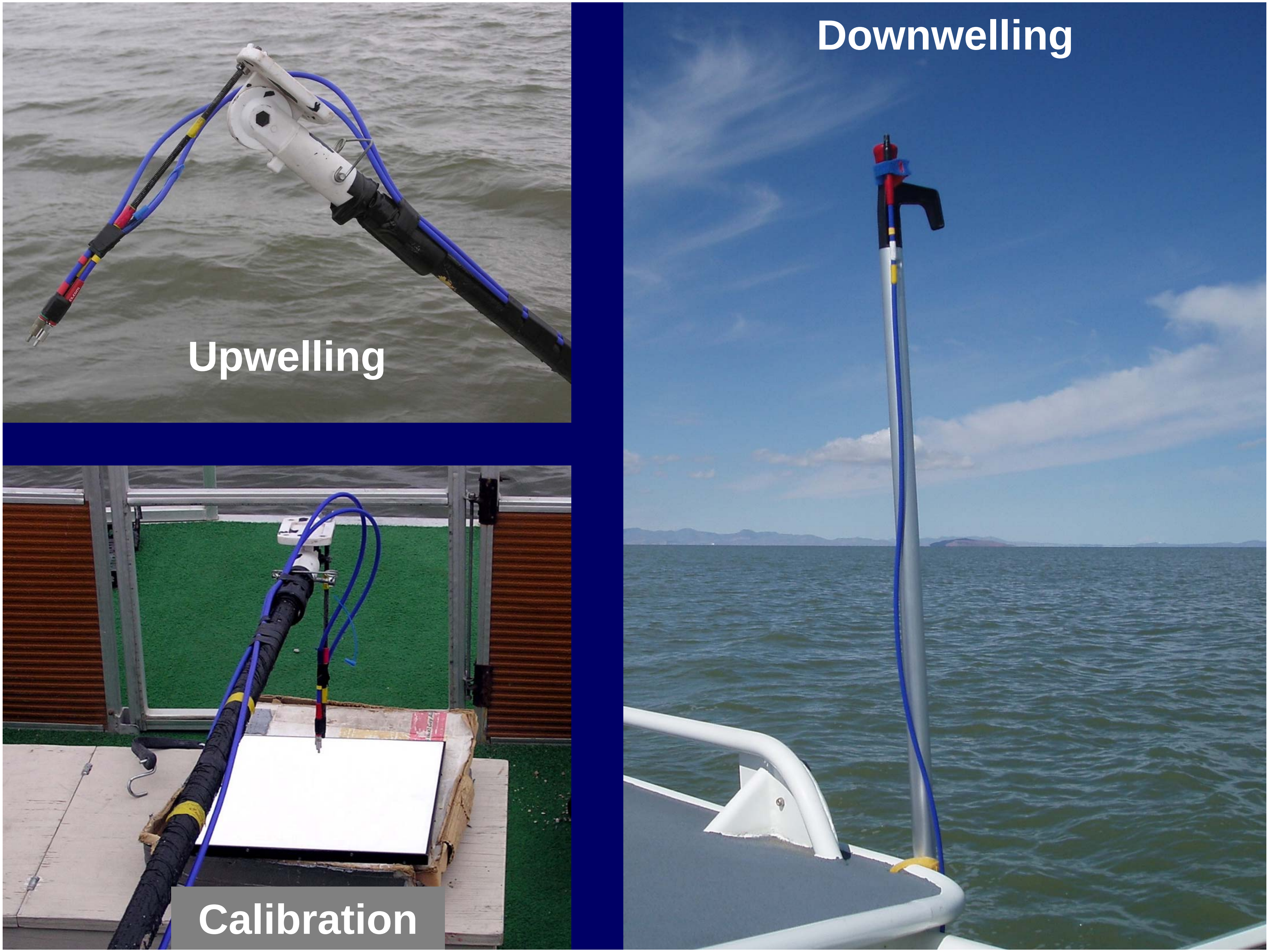
400-750 nm
3 nm bands

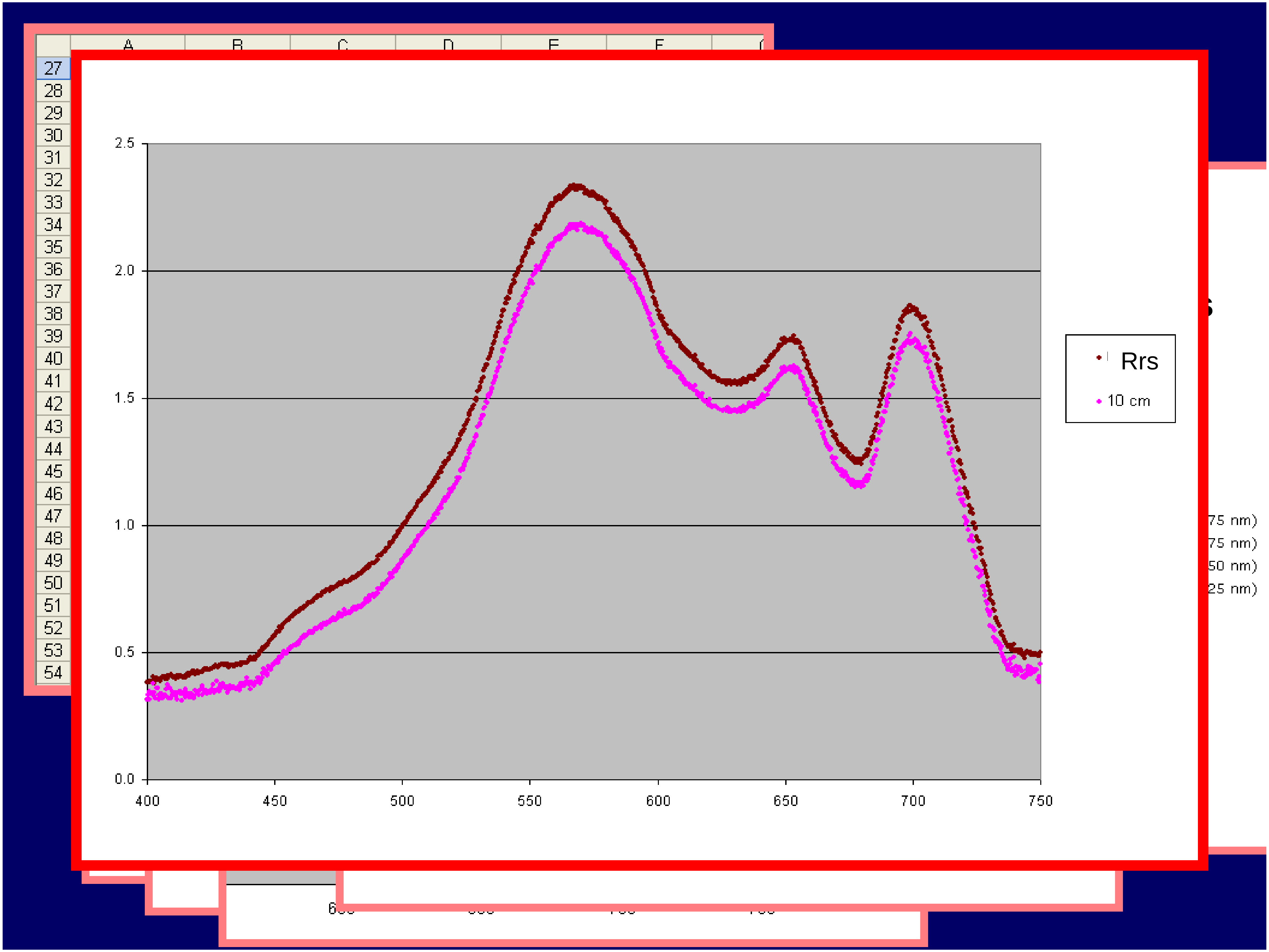
USB 2000 radiometers
(measure light, output data)

fiber optic cable
(transmit light)

serial cable
(transmit data)




Downwelling
Upwelling
Calibration



A
B
C
D
E
F
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
2.5
2.0
1.5
1.0
0.5
0.0
400
450
500
550
600
650
700
750
Rrs
10 cm
75 nm)
75 nm)
50 nm)
25 nm)

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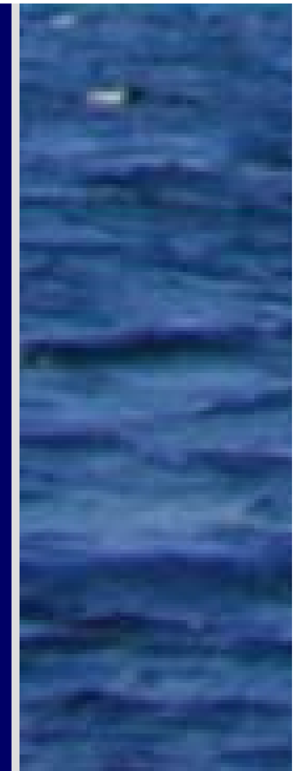
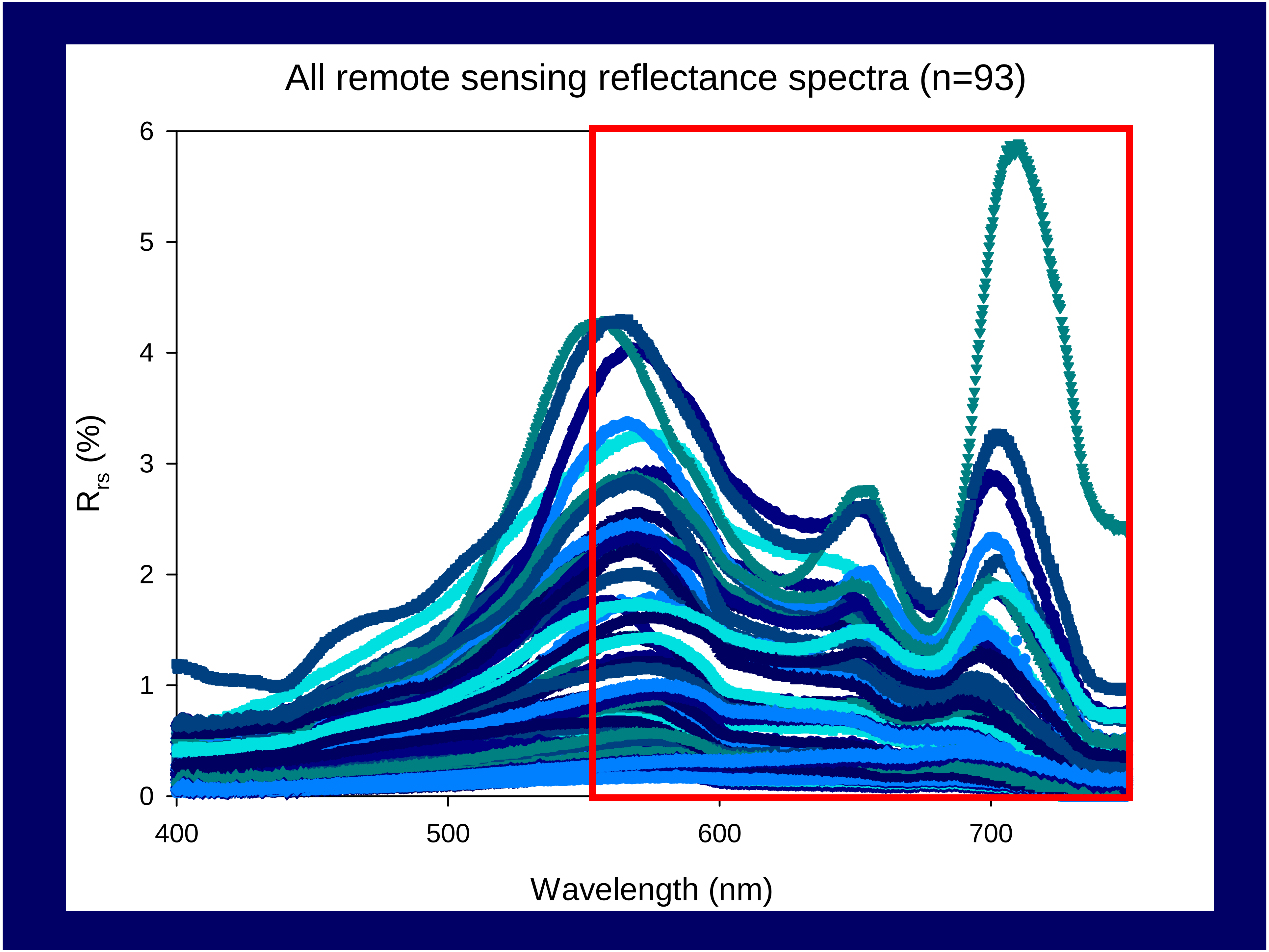
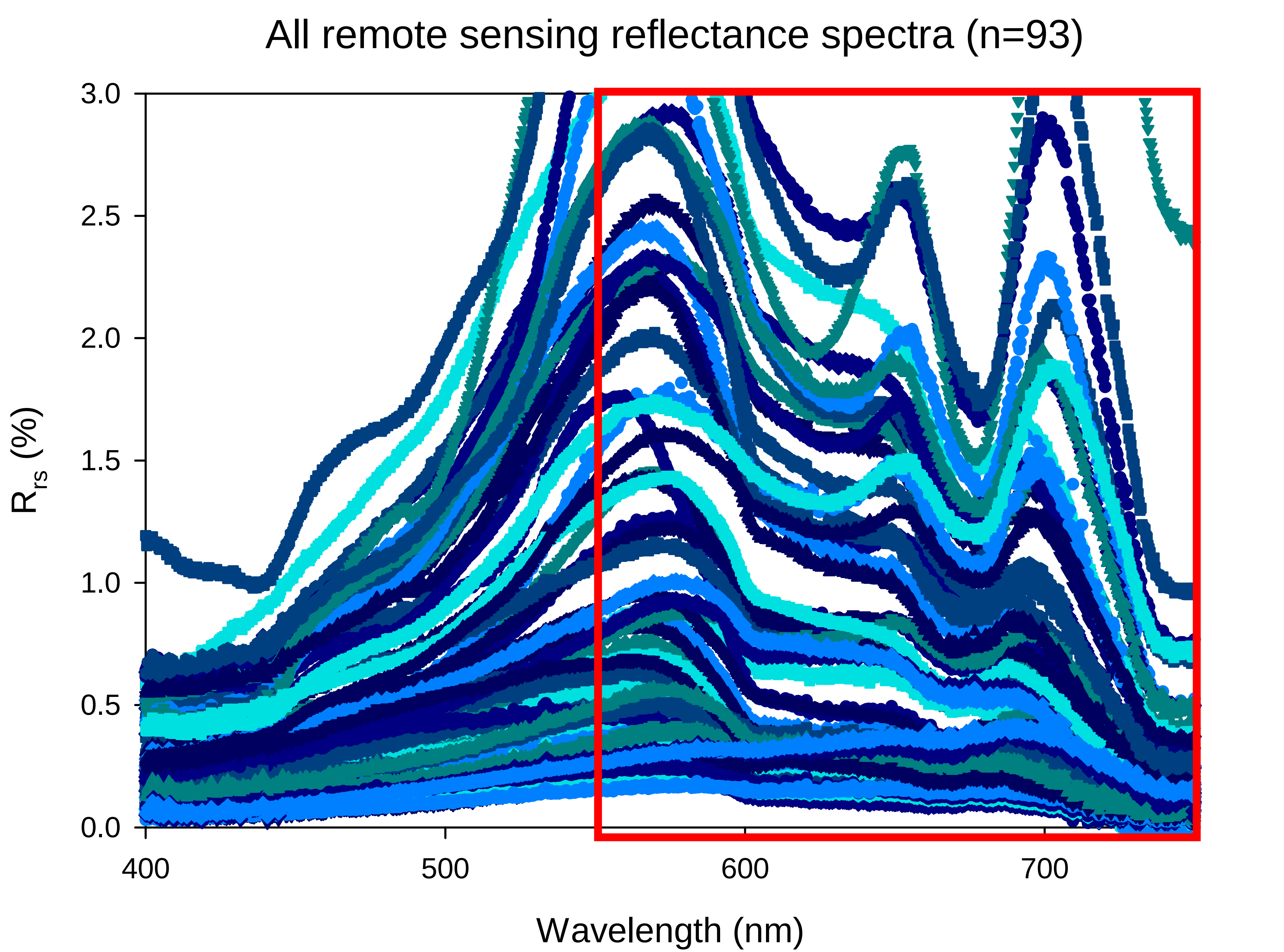
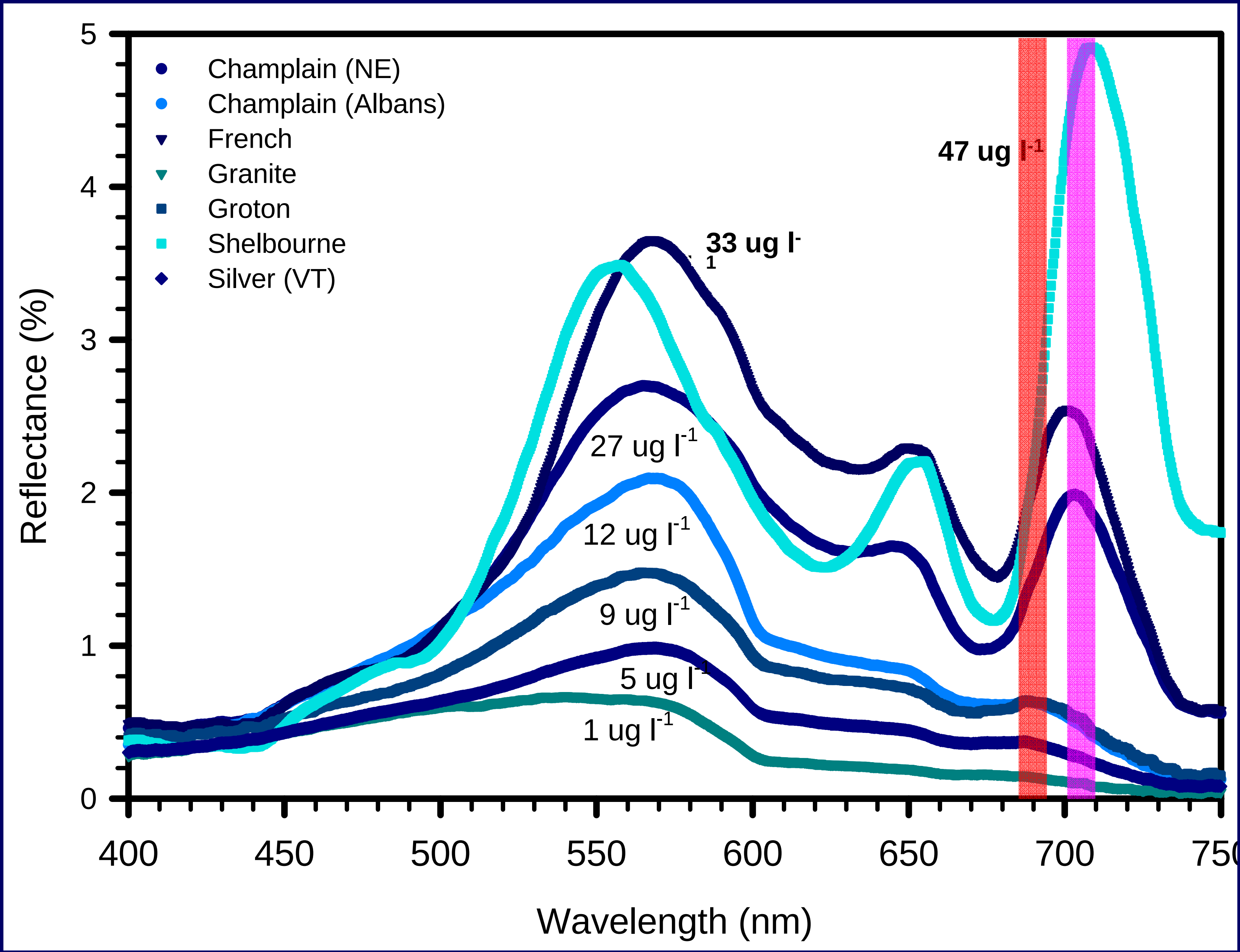



All remote sensing reflectance spectra (n=93)
6
5
4
3
2
1
0
Rrs (%)
400
500
600
700
Wavelength (nm)


All remote sensing reflectance spectra (n=93)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
R_{rs} (%)
400
500
600
700
Wavelength (nm)

Spectral response to chlorophyll



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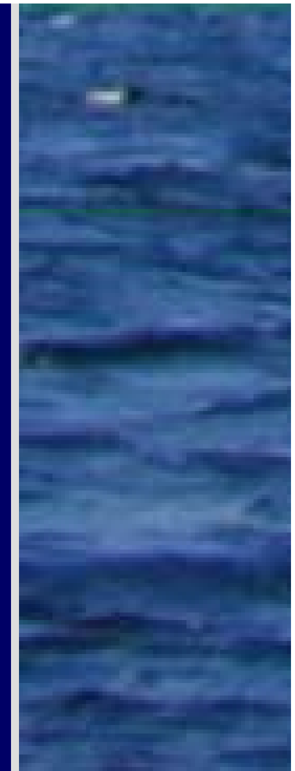
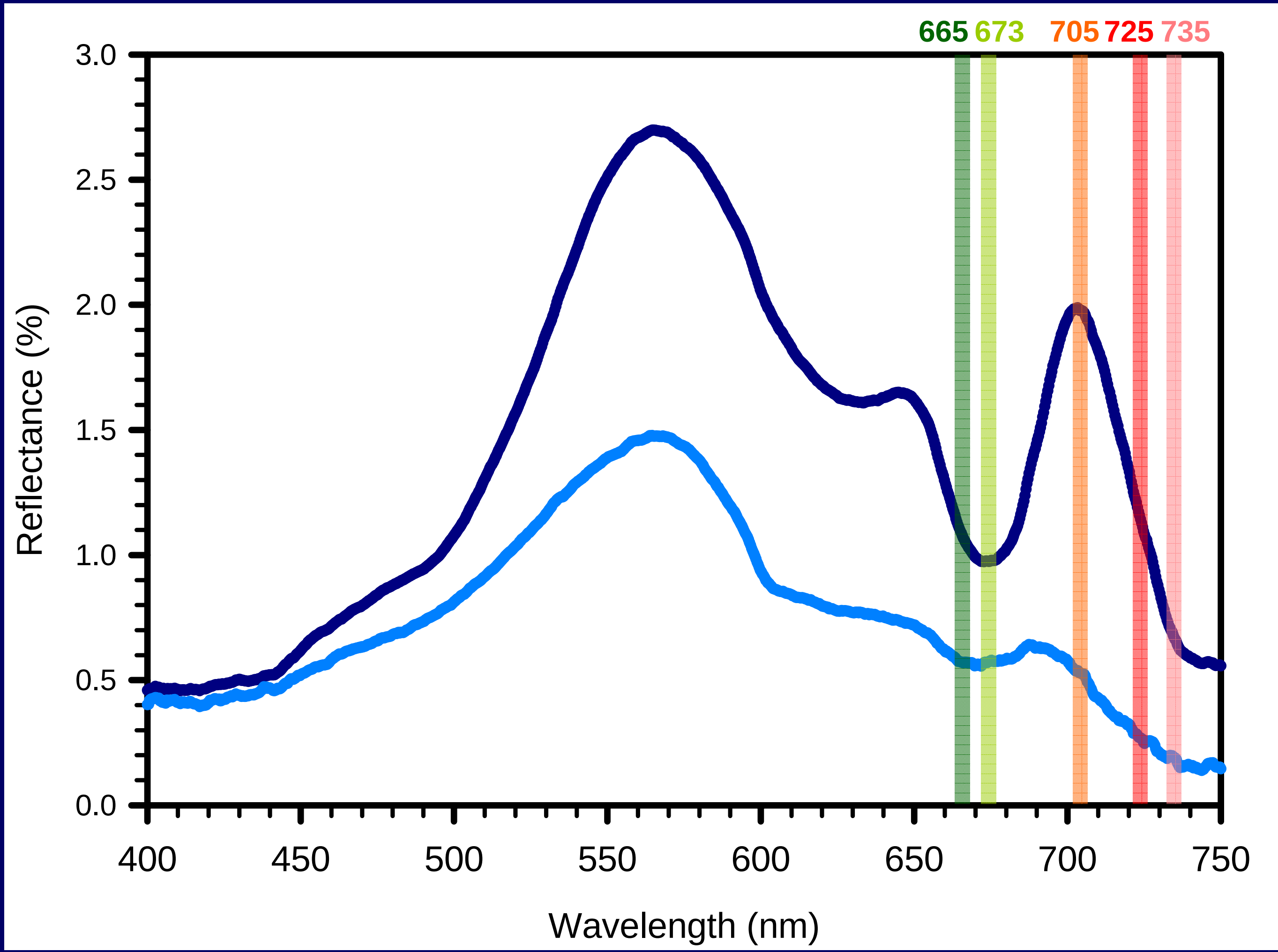


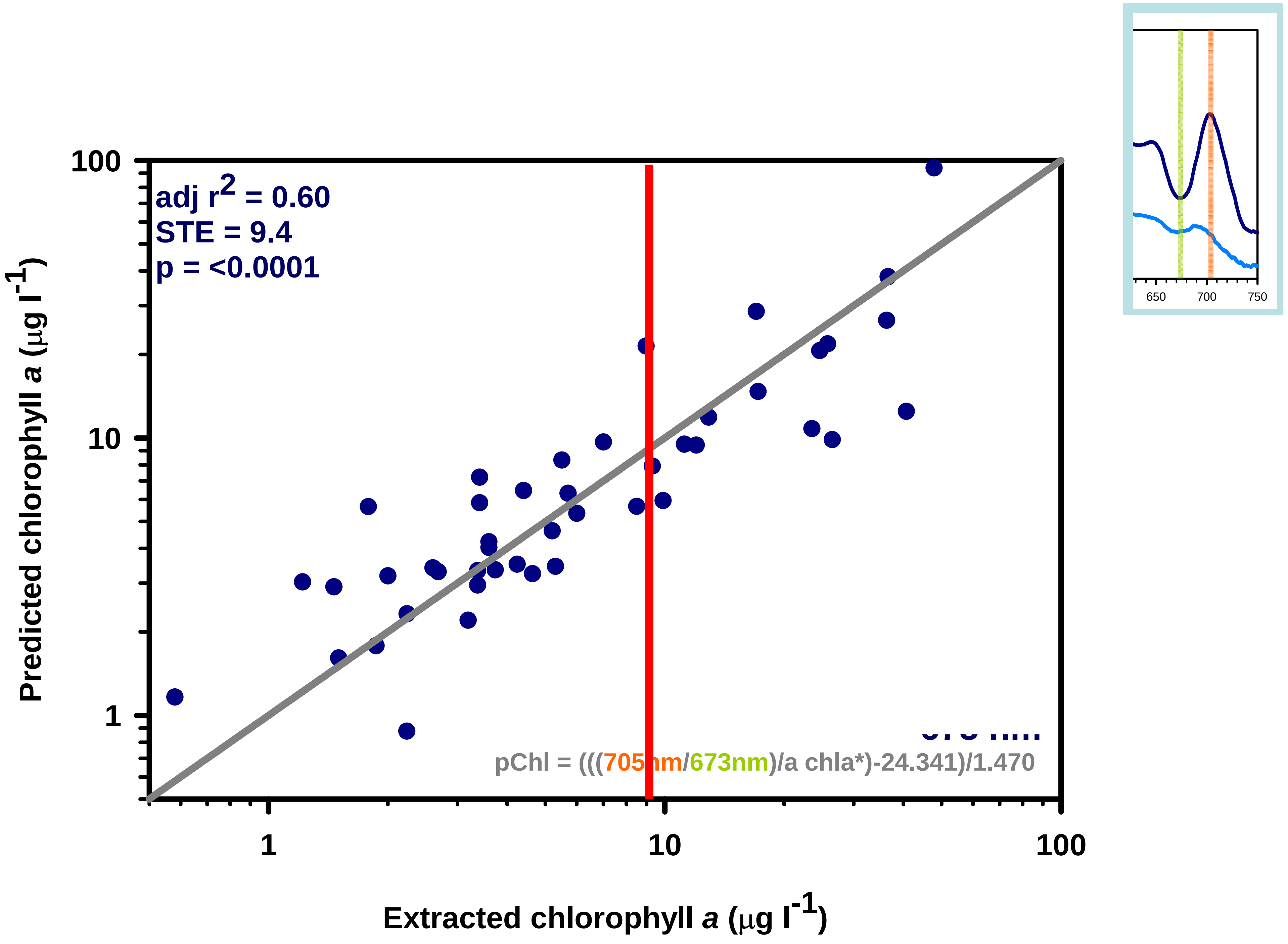
Remote sensing algorithms

- Chlorophyll
  - Possibilities
    - MODIS, Dall'Olmo & Gitelson 2005, Gons 1999, Gitelson *et. al* 2007
  - Problems
    - None developed for similar lakes

Dall'Olmo & Gitelson 2005



<10 ug / L chl – not so good…



adj r^2 = 0.60
STE = 9.4
p = <0.0001
pChl = (((705nm/673nm)/a chla*)-24.341)/1.470
Predicted chlorophyll *a* (μg l^{-1})
Extracted chlorophyll *a* (μg l^{-1})
100
10
1
1
10
100
650
700
750

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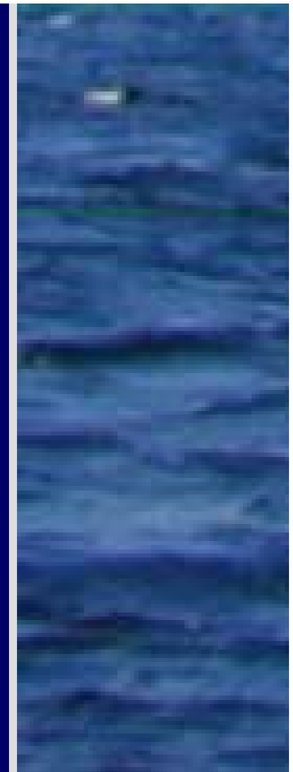
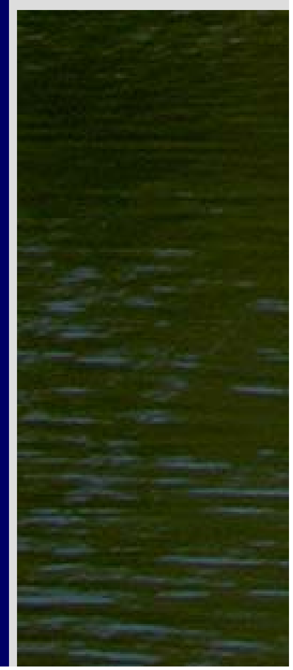
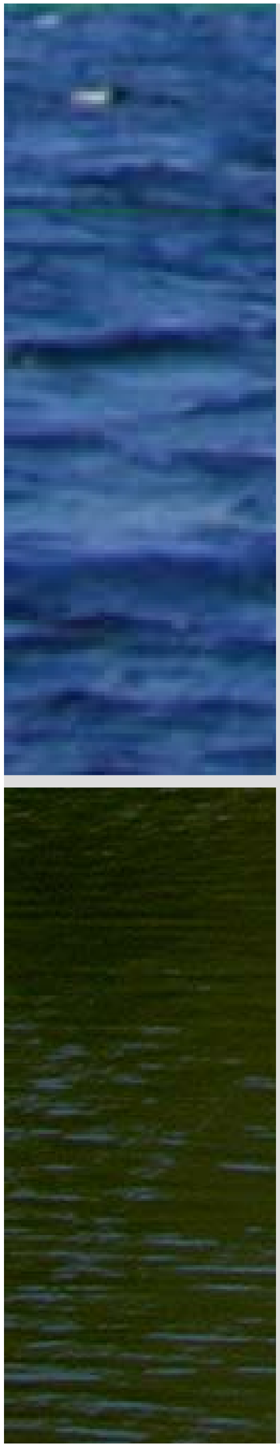






Next Steps

- Correct chlorophyll concentrations back to lab absorption measurements
- Continue work on New England algorithms
  - Chlorophyll, Cyanobacteria, CDOM…
- Use satellite/aerial platforms to test viability of remote sensing of New England Lakes
  - Satellites
  - Aircraft

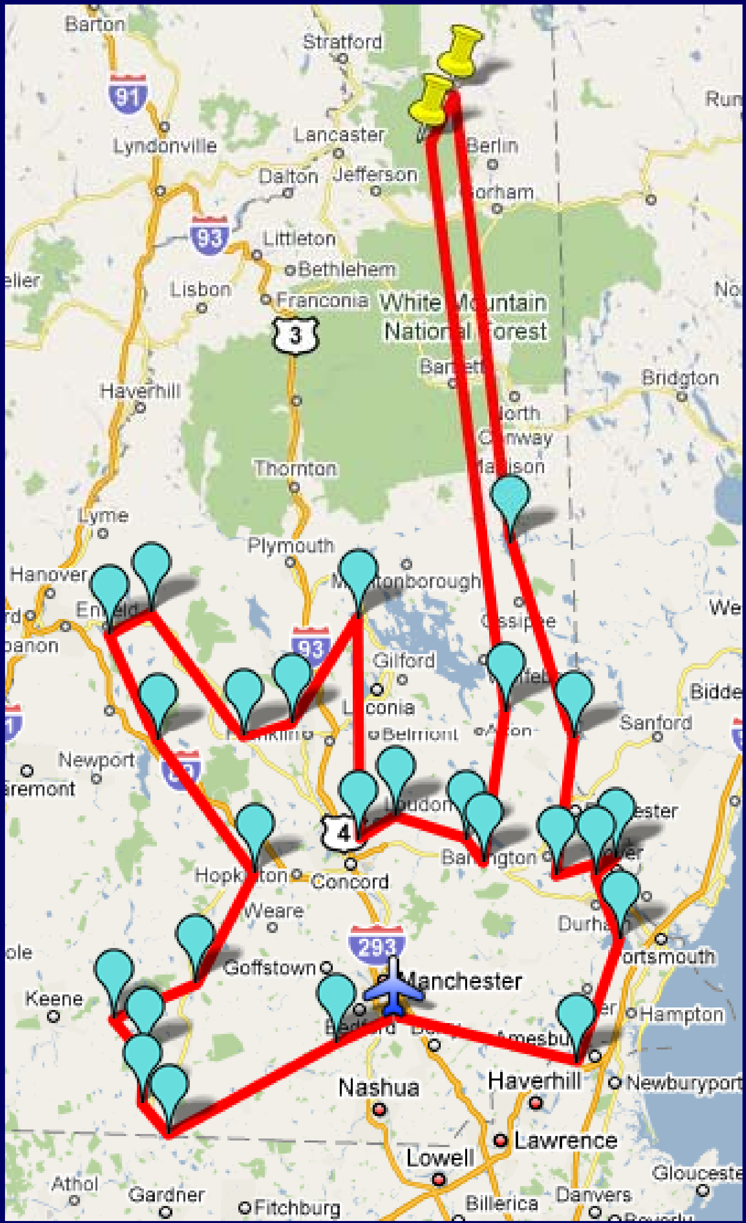
Finally Shane is going to work with imagery!

hyperspectral aircraft overflight in Sep 2009

variety of satellite images

Northeast lake folks… as promised, I will come knocking for:

chlorophyll data
Secchi disk data



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Ocean Optics Class 2004

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CALMIT Nebraksa

Bryan Leavitt (UNL), Giorgio Dall'Olmo (UNL), Dr. John Schalles (Creighton)

EPA Region I & ORD

Darryl Keith, Hillary Snook, Andrew Brock, Jeffery Barrett, Gabriela Martinez

New England States

CT Department of Environmental Protection
ME Department of Environmental Protection
MA Department of Environmental Protection
NH Department of Environmental Services
URI Cooperative Extension
VT Department of Environmental Conservation