


Predicting Total Phosphorus (TP) through Spectroscopic Analysis

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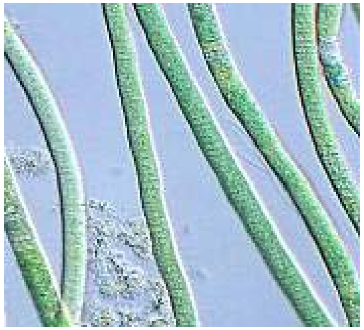
Outline

1. Introduction
2. Study Sites
3. Data Sets
4. Methods
5. Results and Discussion
   - In situ data inversion
   - Image data inversion
6. Conclusions

I. Introduction-Impacts of Cyanobacteria

- Public Health
  - Toxins
    - Microcystin
    - Cylindrospermopsin
    - Anatoxin-a
  - Alter taste and odor of drinking water
    - MIB
    - Geosmin
- Ecological Effects
  - Fish kills
  - Additional effects

(Chorus and Bartram, 1999; Falconer, 2005)



I. Introduction-TP vs. Cyanobacteria

- Ecologically, TP is a key factor for development of cyanobacterial blooms
  - Very likely if TP concentration above 25-30 ug/L
  - Rare if TN:TP ratios above 30 (16:1, according to Jorgensen)
- However, TP has no diagnostic spectral signatures, how can TP be retrieved from remote sensing data?

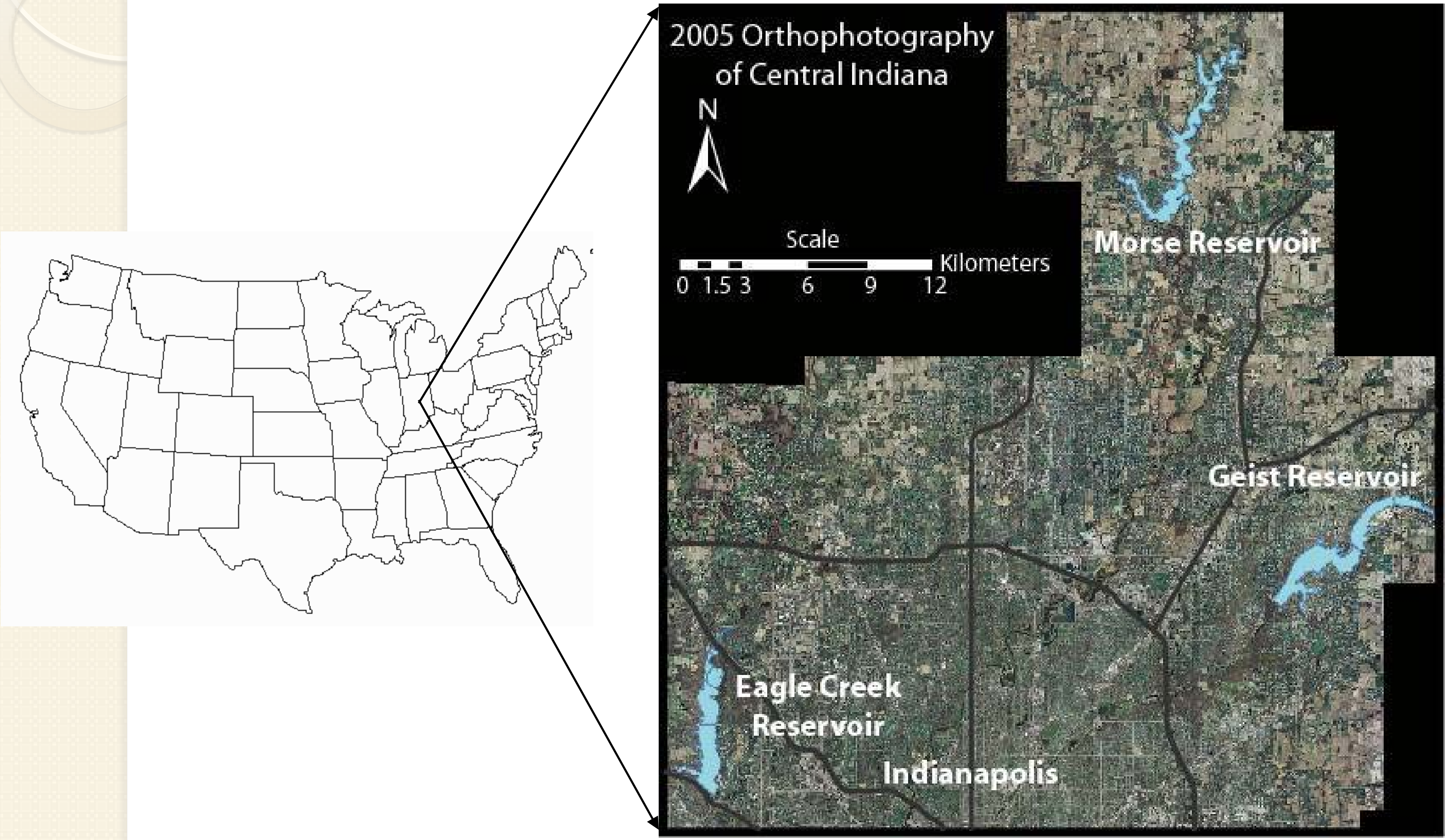
1. Introduction-remotely estimation TP

- Optically Active Constituents
  - Phytoplankton: pigments
    - TP->Cyanobacteria-> Chl-a and PC
  - Tripton: suspended inorganic particles
    - TP carrier
  - CDOM: colored dissolved organic matter
    - Somehow, CDOM has no direct relation to TP
- Physical properties
  - Closely associated with Secchi Disk Depth or Transparency (SDD or SDT)
  - And water turbidity

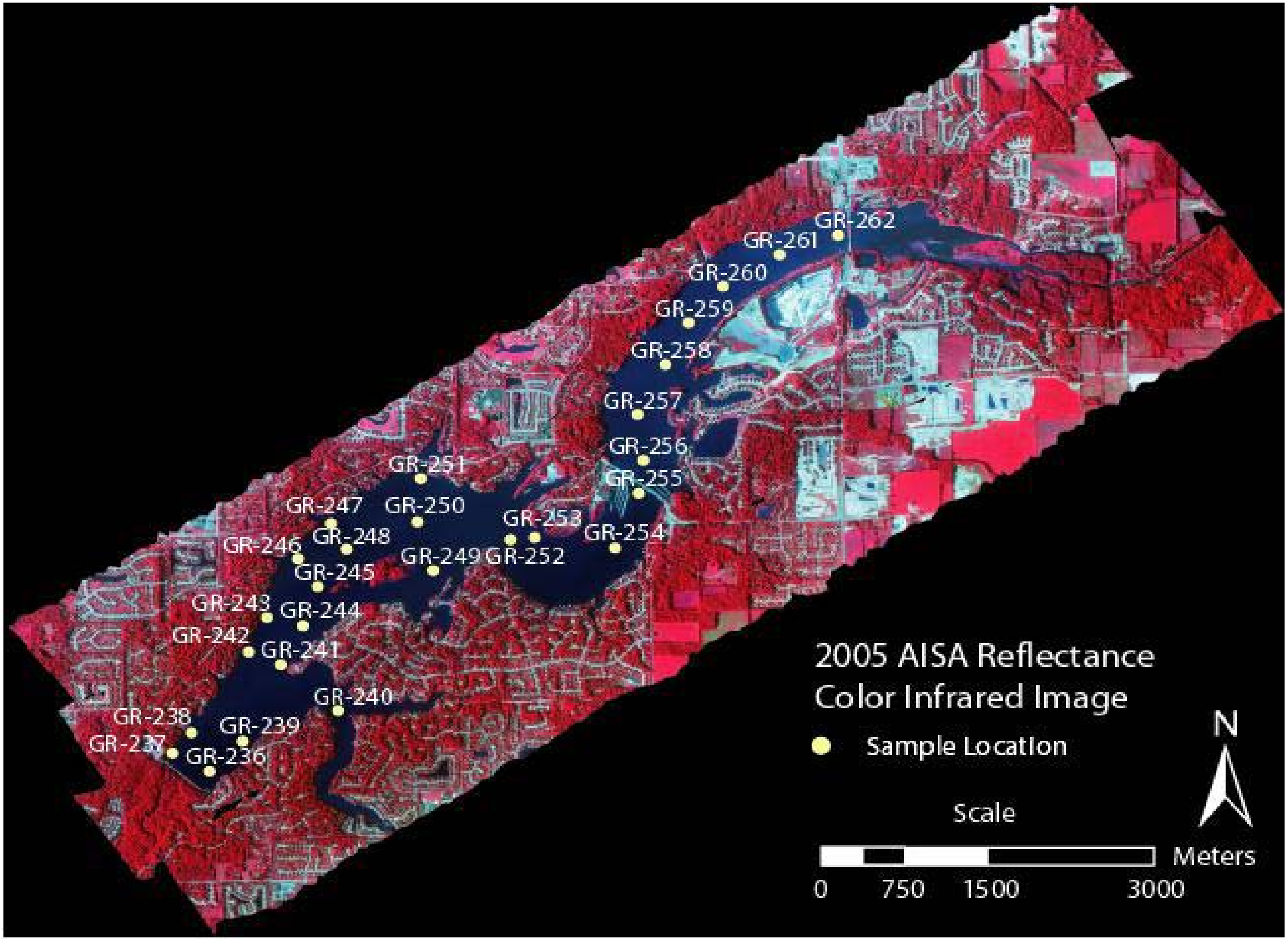
1. Introduction-Objectives

- Investigate the possibility of estimating TP from *in situ* spectral data
- Explore the underlying basis for TP inversion from image data
- Assess trophic status of drinking water resources with derived water quality data

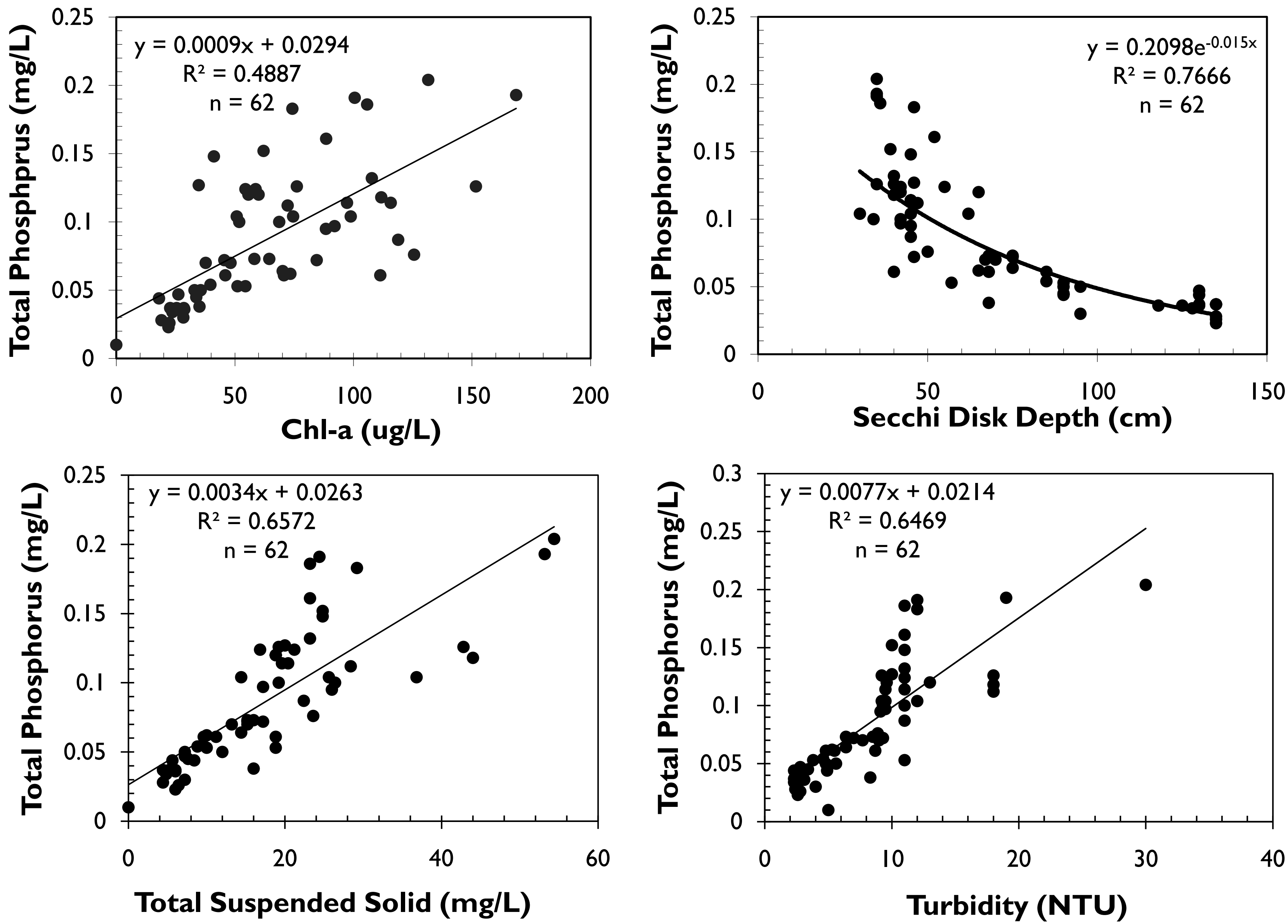
2. Study Sites



3. Data Sets- Sampling period: 2005-2008, 2010



3. Datasets-Chl-a, TP, TN, turbidity, TSS and SDT (2005)



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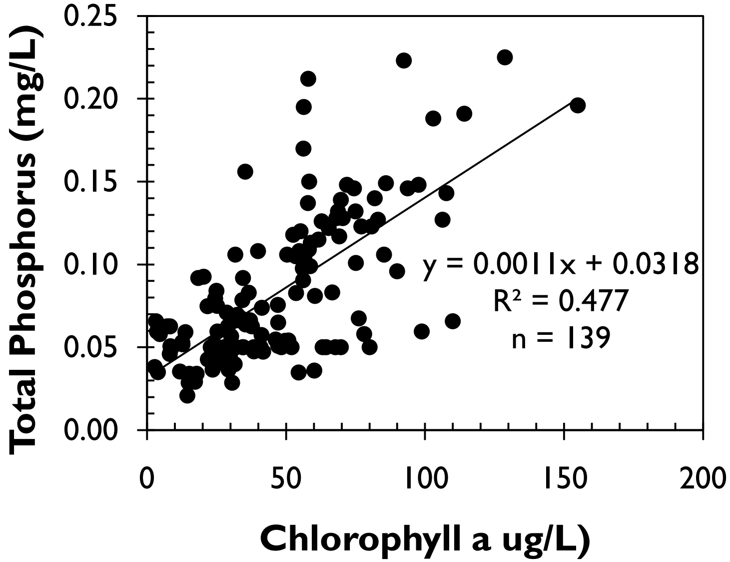
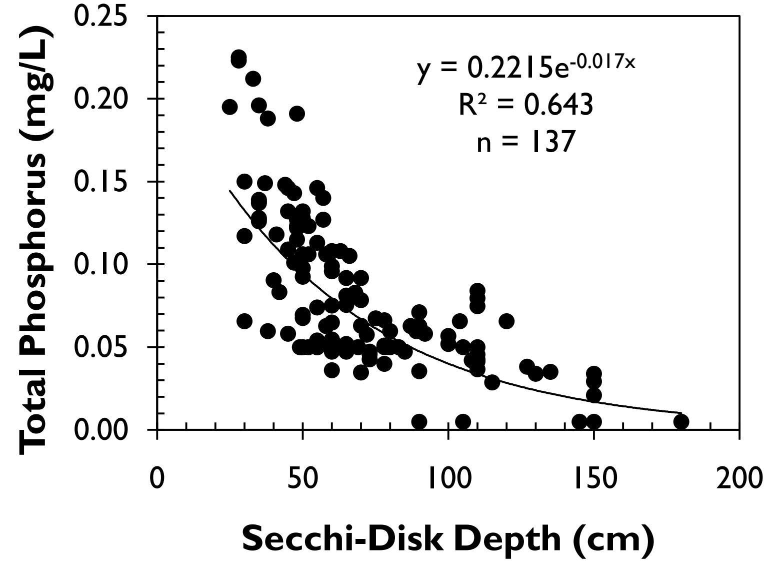
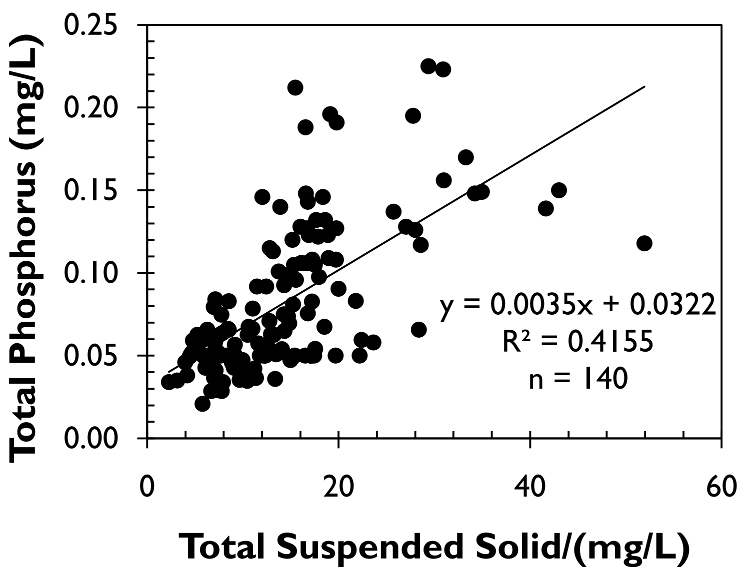
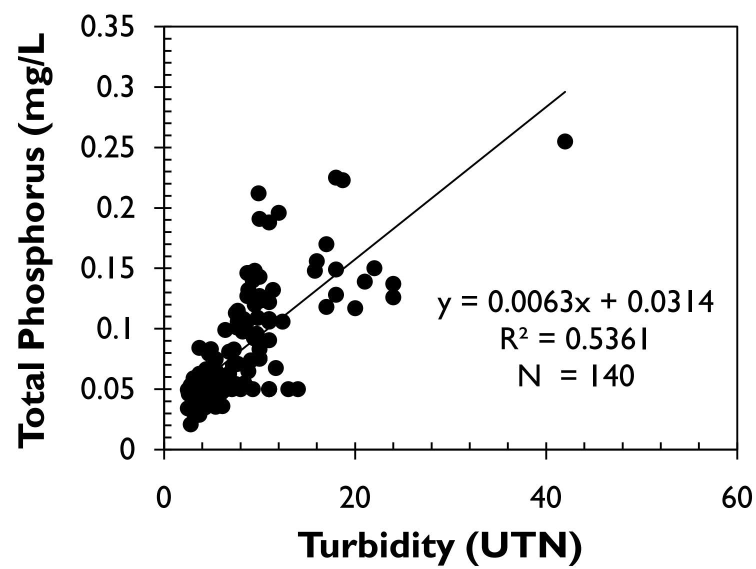








3. Datasets-spectra and images

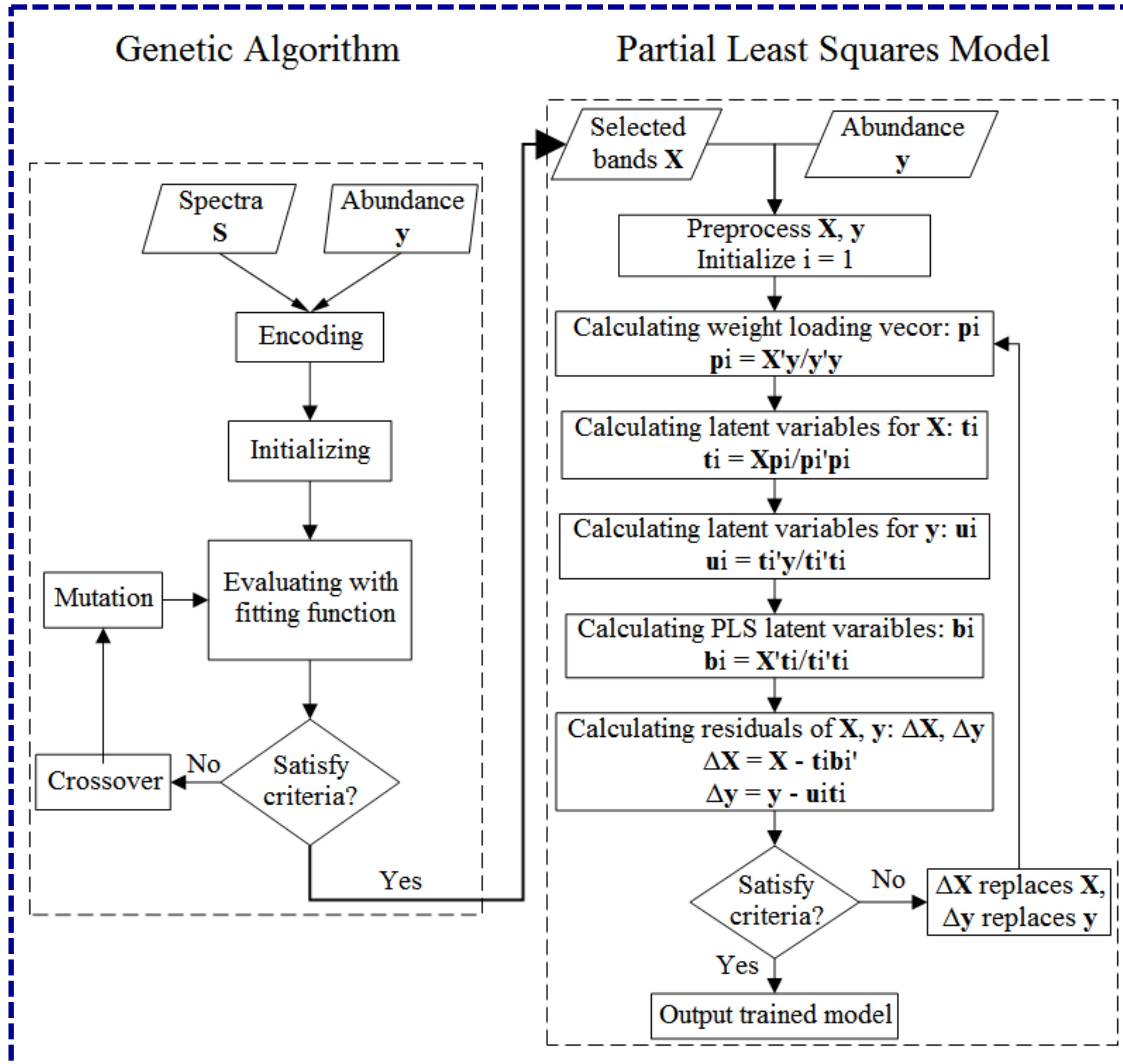
- In situ
  - ASD, Ocean Optics, Secchi Disk
    - 2005-Morese and Geist Reservoir (ASD)
    - 2006-Morese, Eagle Creek and Geist Reservoir (ASD)
    - 2008-Morse Reservoir (Ocean Optics)
- AISA (9/6/2005)->Morse and Geist
  - Spectral range (392-981nm), 62 bands, 10 nm, 1 m
  - Calibrated with the empirical line method
- Hyperion (6/9/2007)->Eagle Creek
  - Spectral range (426-2396 nm), 242 bands, 10 nm, 30 m
  - Radiomtrically calibrate with ACORN

4. Methods-Spectral Modeling Approach

- Correlation Analysis
  - Selecting the most sensitive spectral variables to water quality parameters
    - In situ and imaging spectral data
    - Reflectance derivative
    - Band ratio (all about 300,000 combinations)
  - High correlation coefficients indicate sensitive spectral variables
- Linear and non-linear empirical models were built based on optimal band ratios
  - TP, Chl-a and SDT

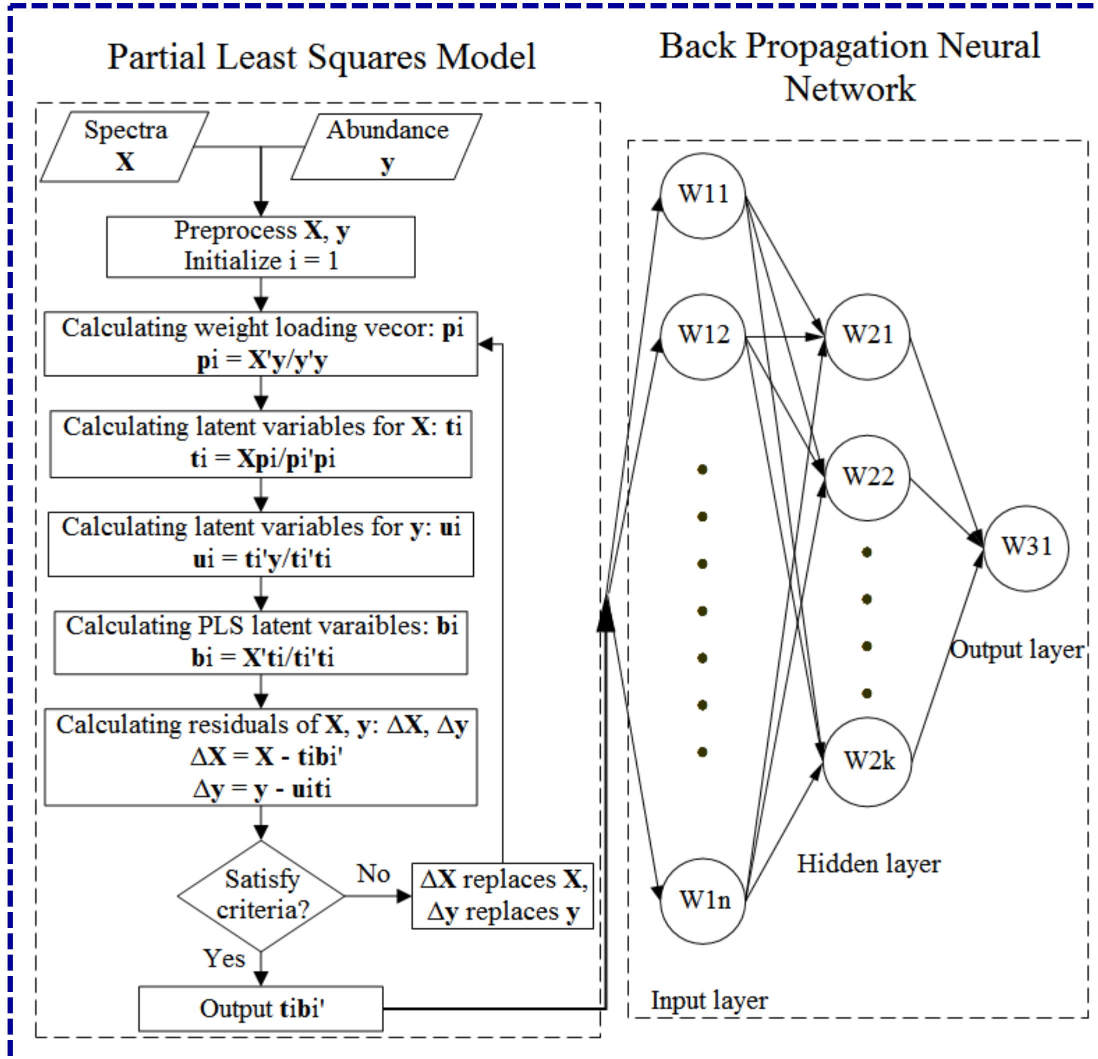
4. Methods-Spectral Modeling Approach

- Genetic Algorithms (GA)-Partial Least Square (PLS)
  - GA for selecting optimal spectral parameters
  - PLS as the spectral-compositional model



4. Methods-Spectral Modeling Approach

- Back-Propagation Neural Network (BPNN)-PLS
  - PLS provides the input variables for BPNN
  - BPNN accommodates nonlinearity



4. Methods-Eutrophic assessment

Carlson trophic index

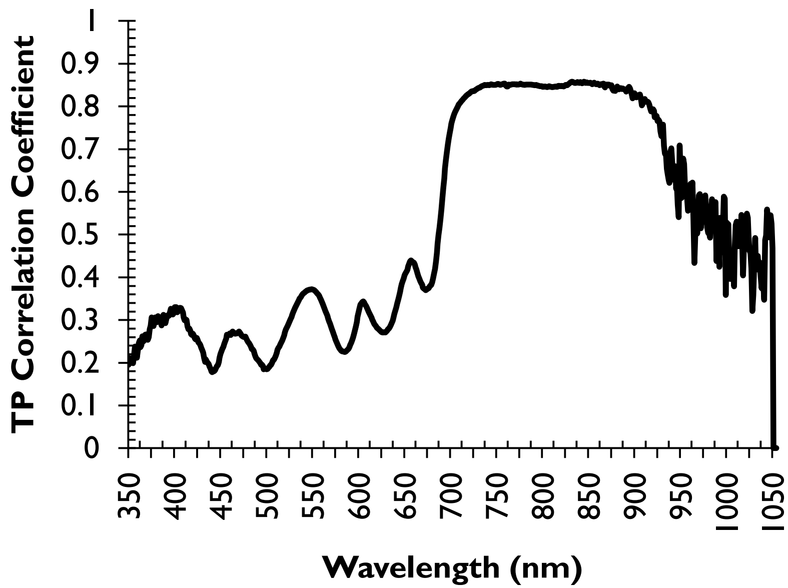
$$\mathrm{TSI(TP)} = 10\left(6 - \frac{\ln(\frac{48}{\mathrm{TP}})}{\ln(2)}\right)$$

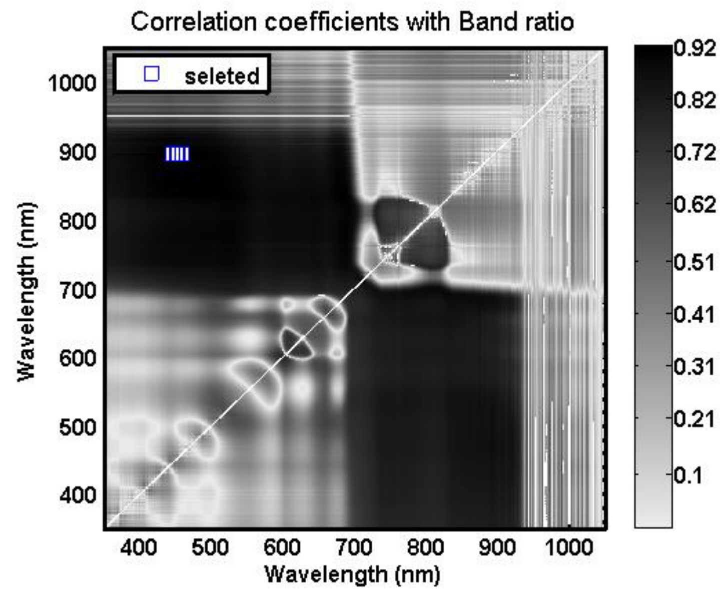
$$\mathrm{TSI(Chl-a)} = 10\left(6 - \frac{2.04 - 0.68\ln(\mathrm{Chl-a})}{\ln(2)}\right)$$

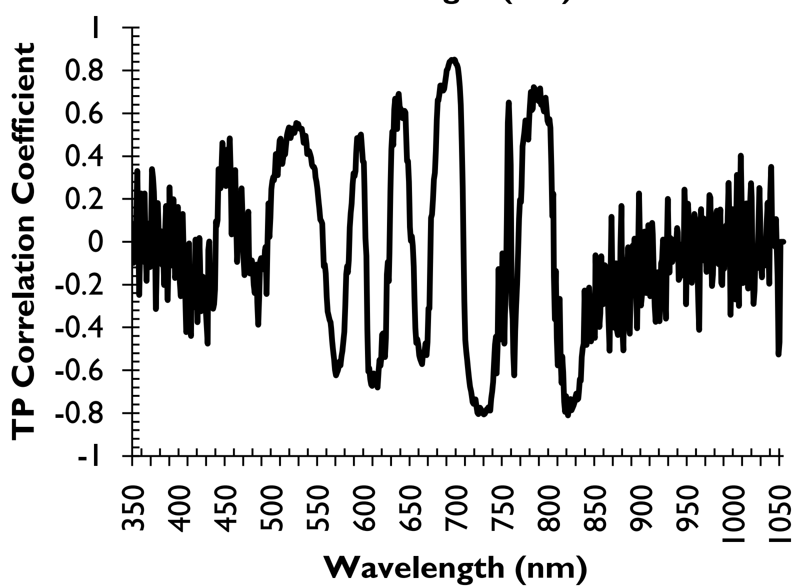
$$\mathrm{TSI(SDD)} = 10\left(6 - \frac{\ln(\mathrm{SDD})}{\ln(2)}\right)$$

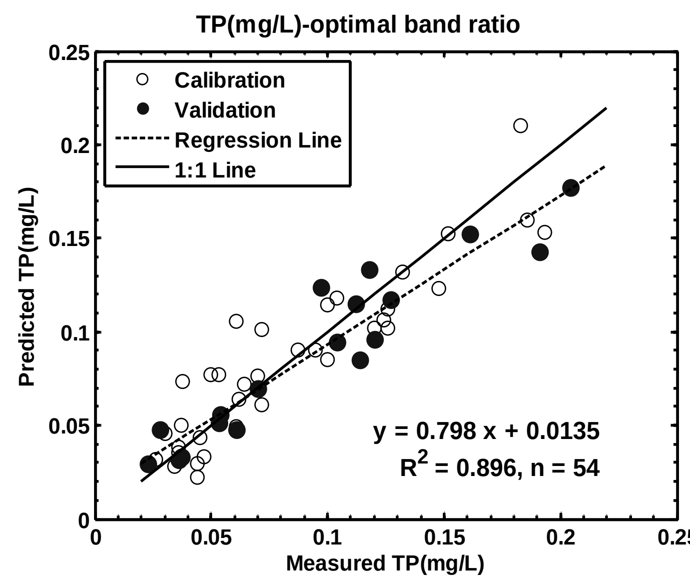
TSI (average)= [TSI(TP)+TSI (Chl-a)+TSI (SDD)]/3

5. Results and Discussion-In Situ Data (2005)









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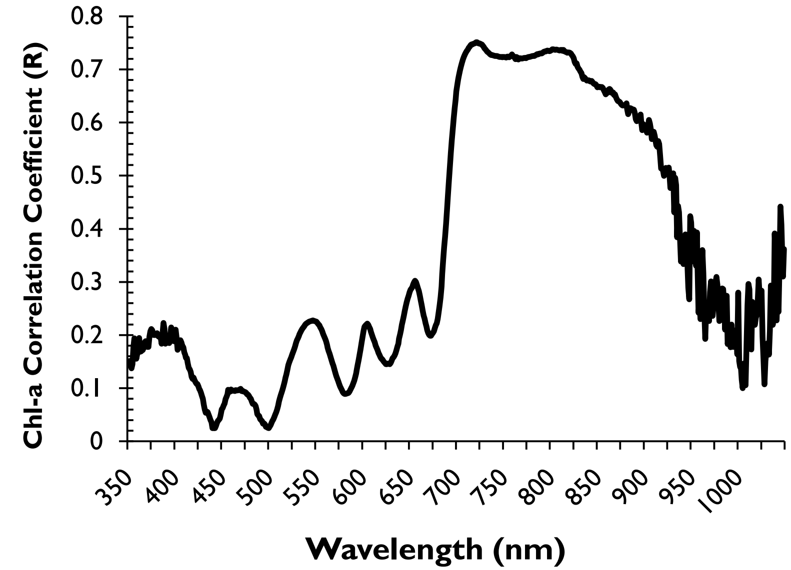

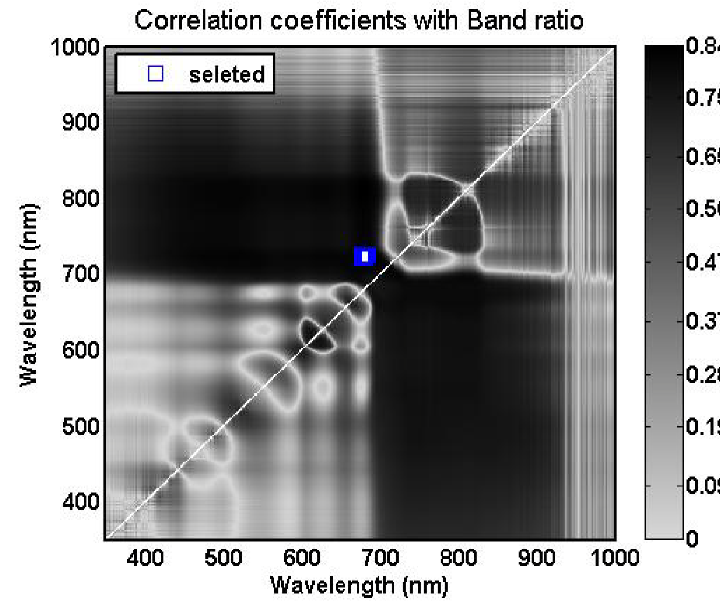

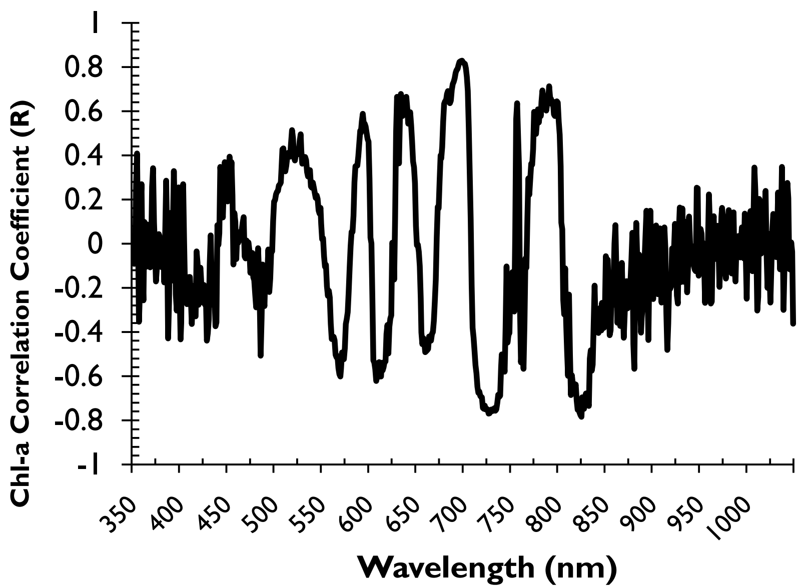

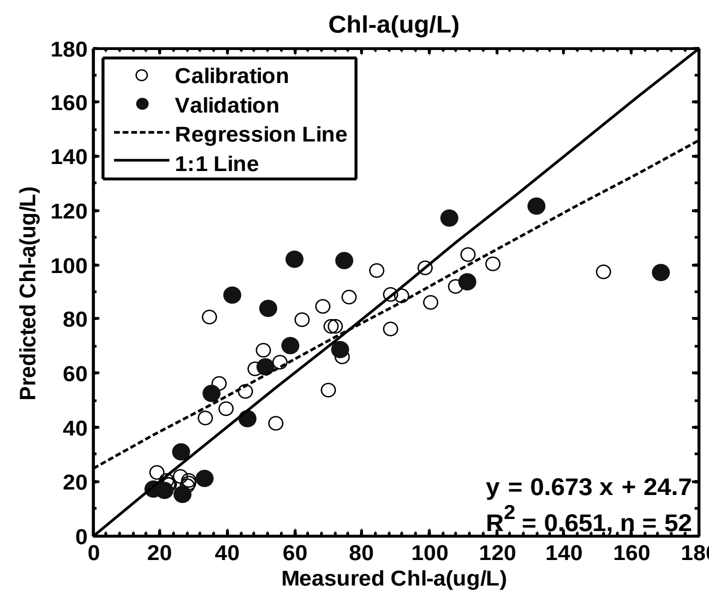

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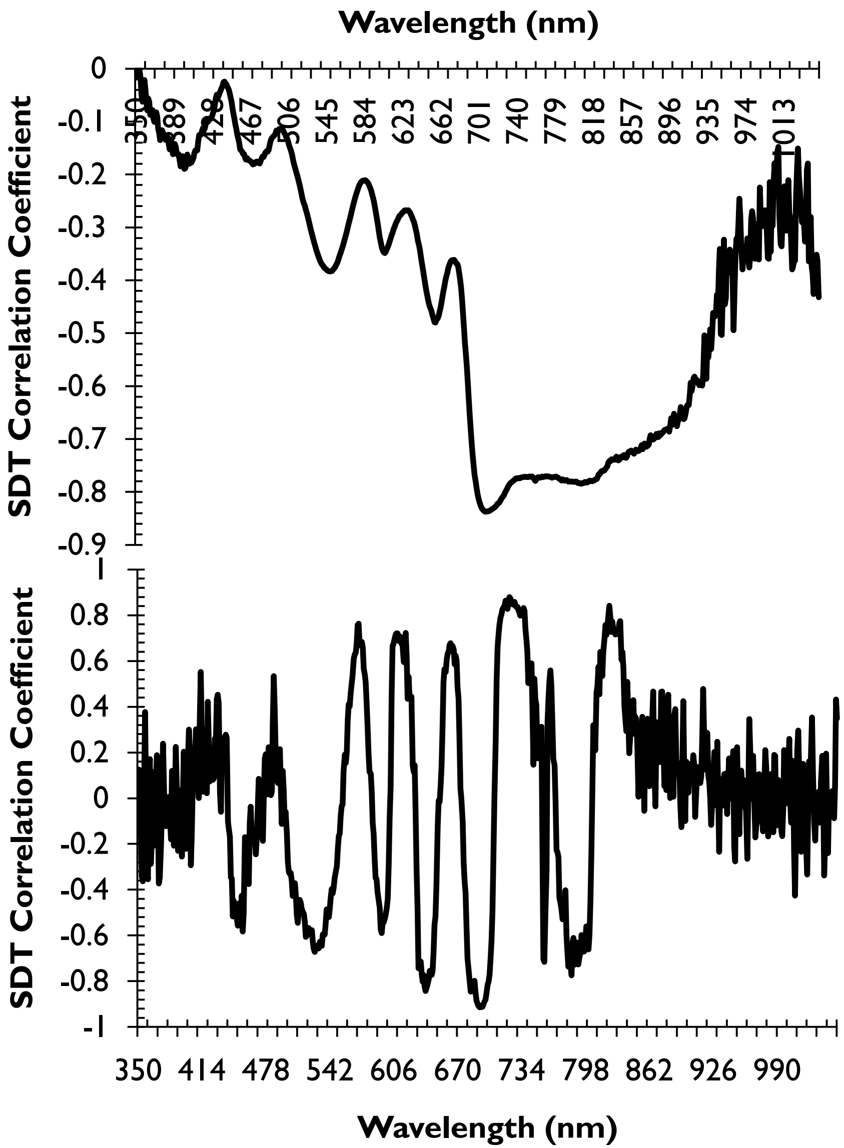
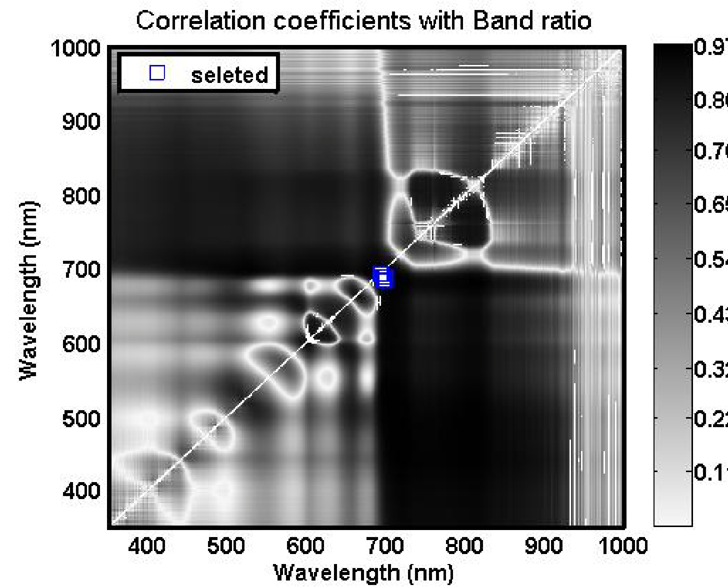
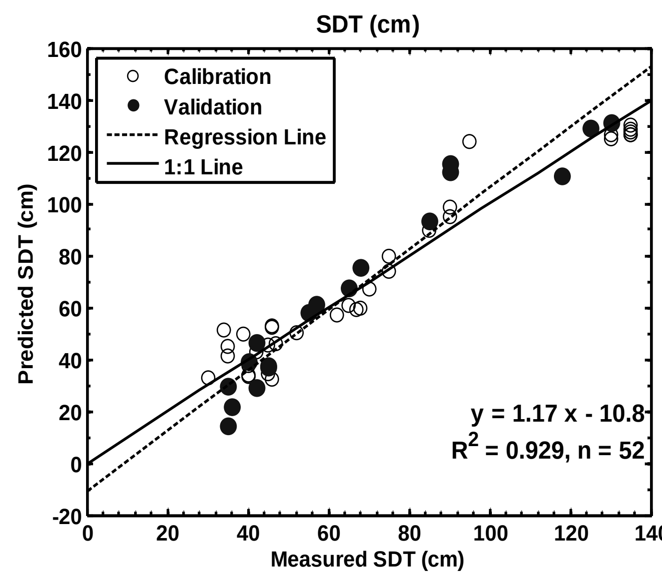
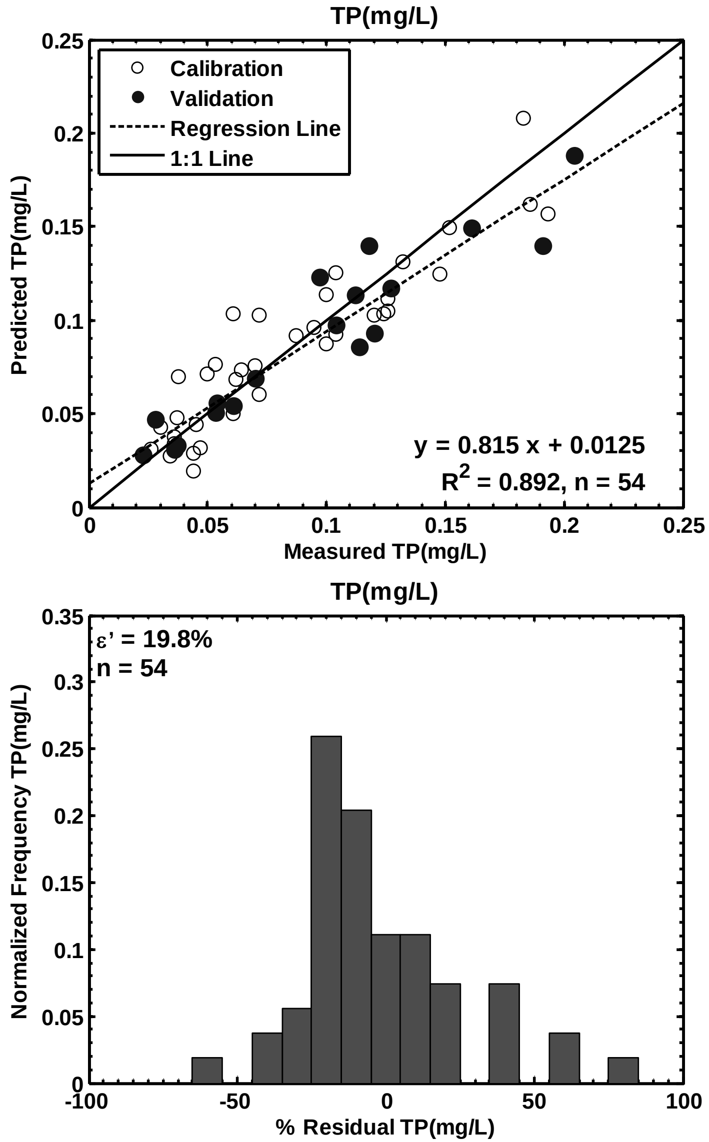




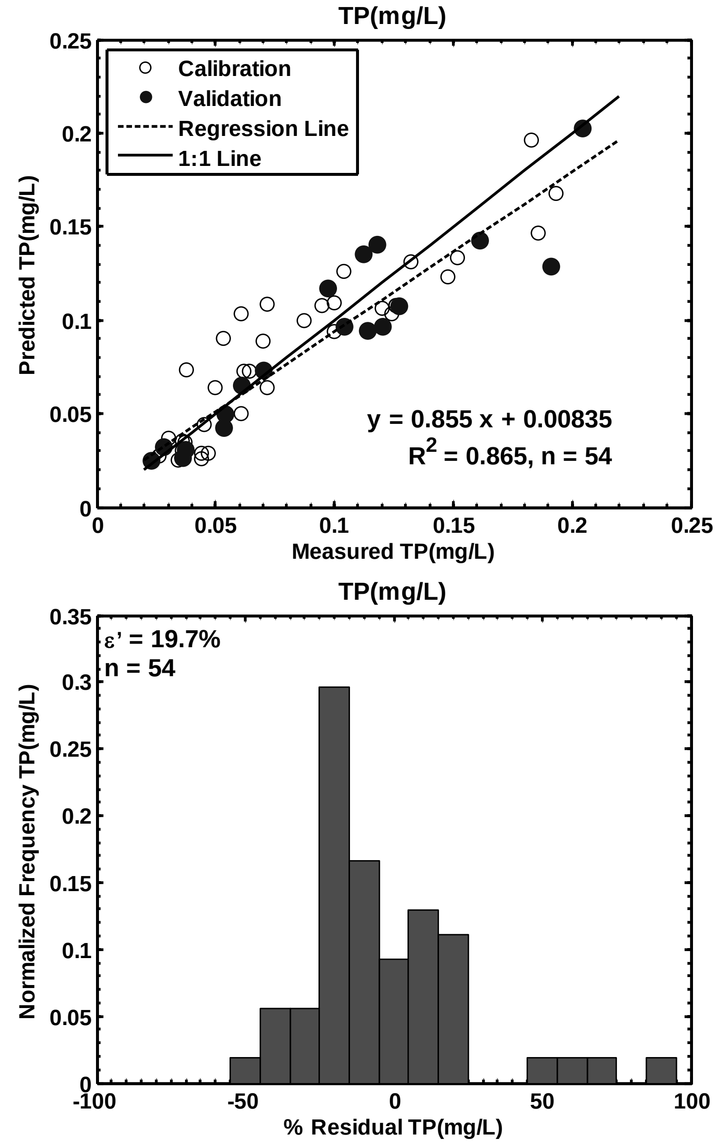


5. Results and Discussion-In Situ Data (2005)

GA-PLS



BPNN-PLS



Error = (Predicted-measured)/measured

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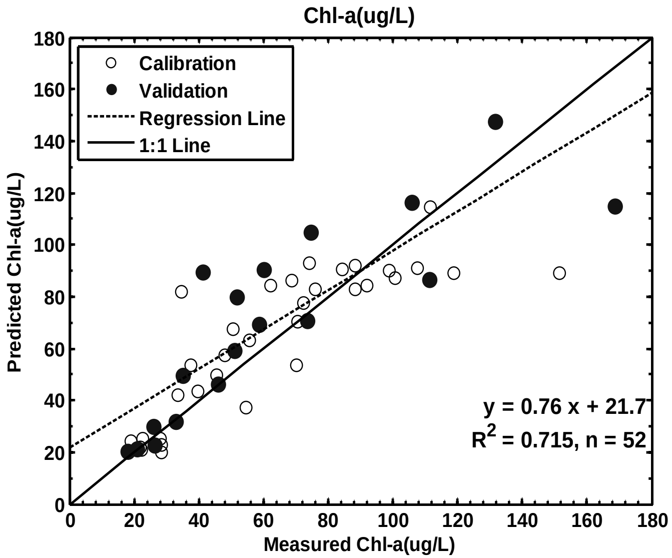

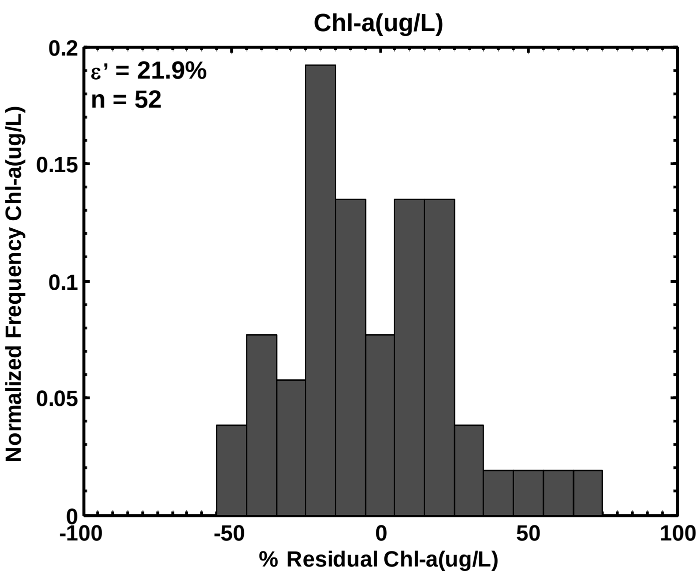

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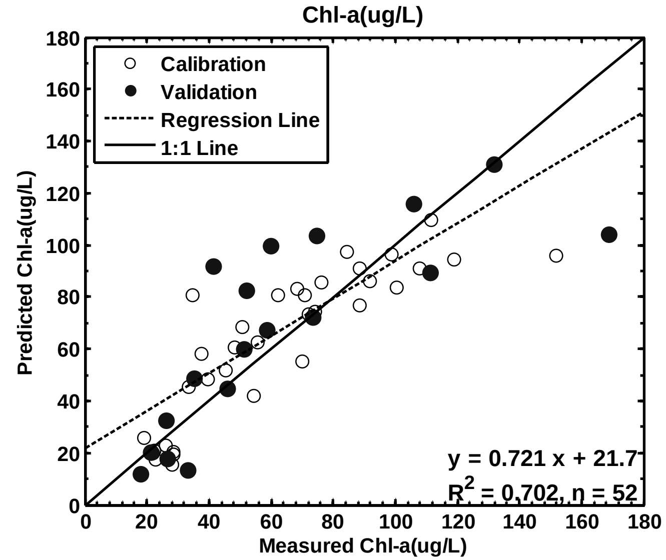

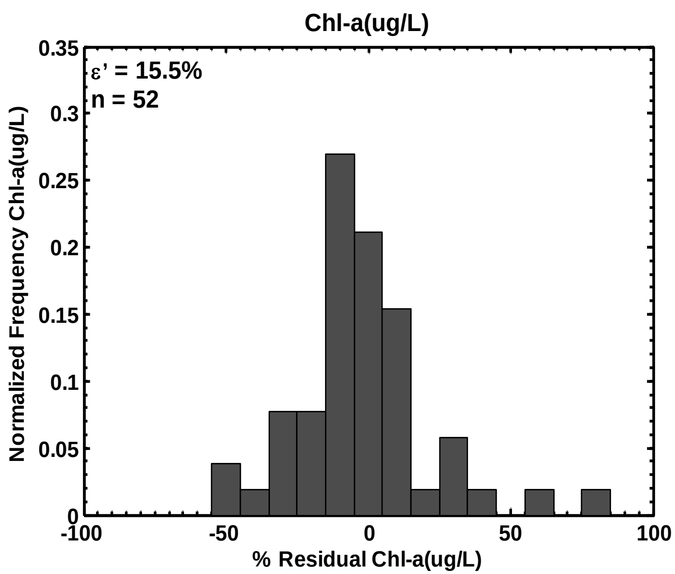

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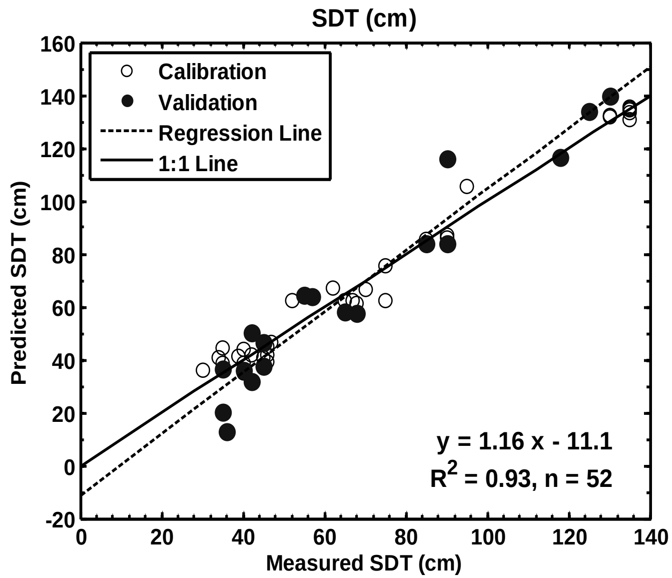

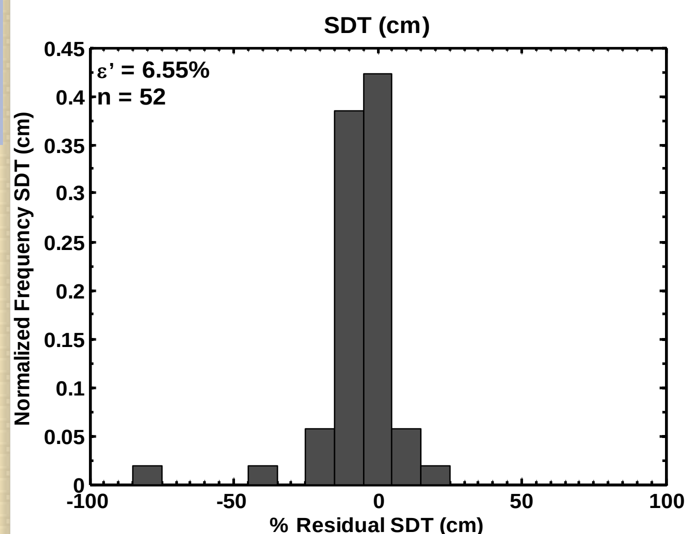

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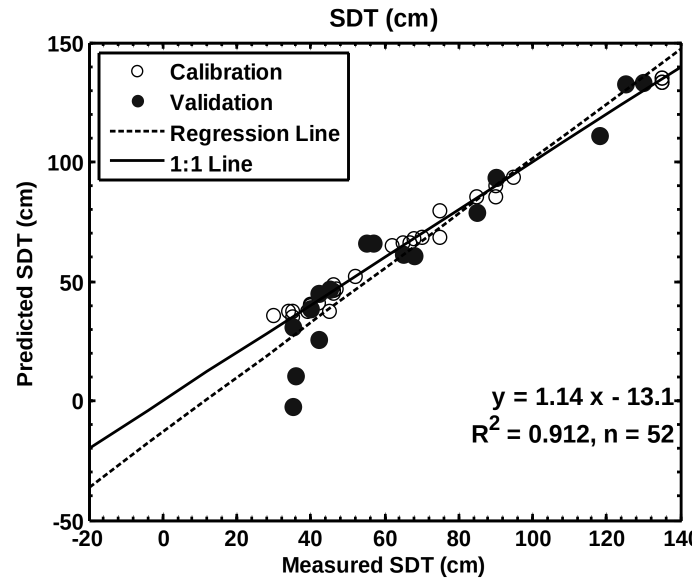

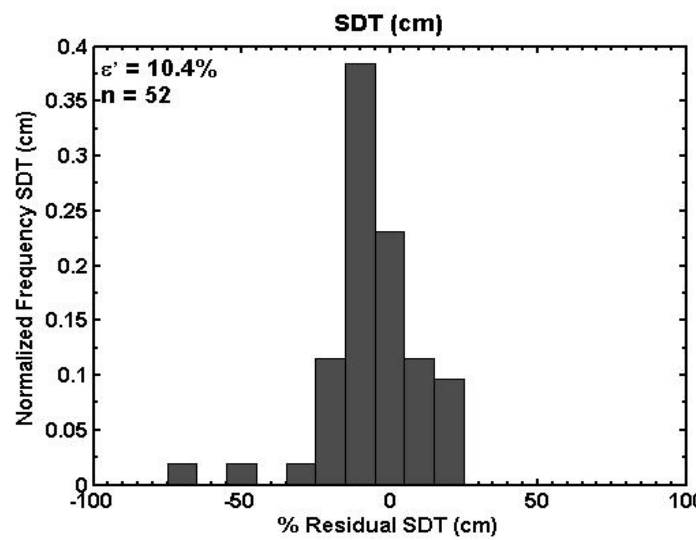

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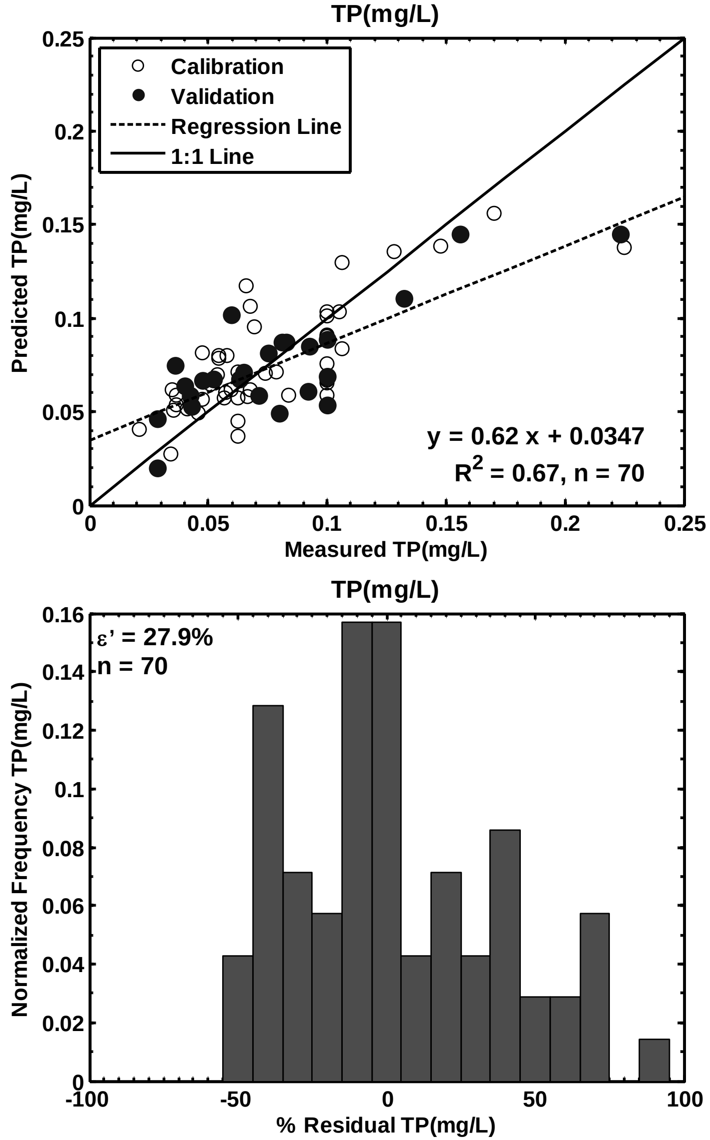

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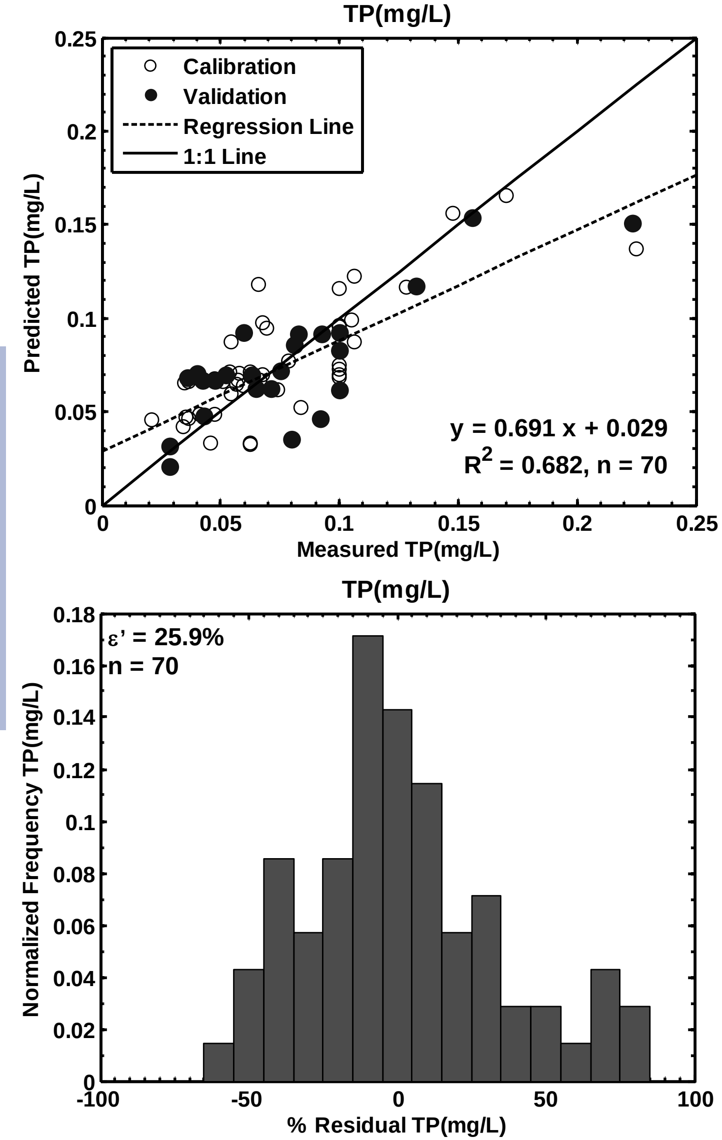

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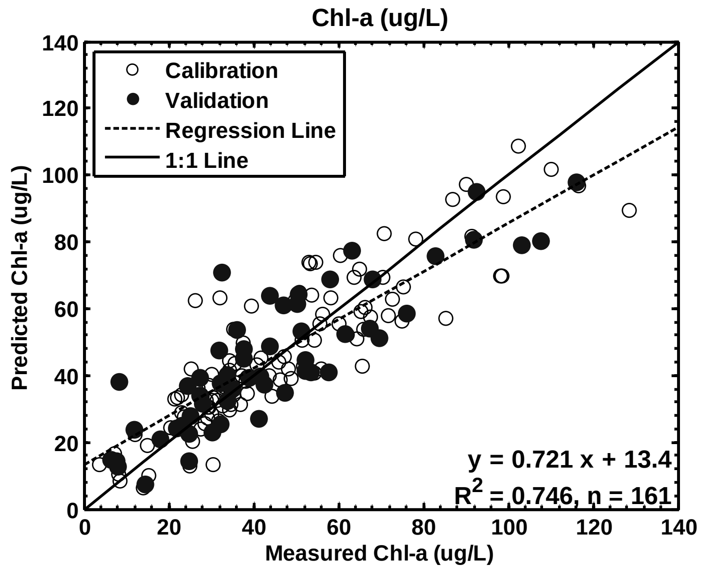

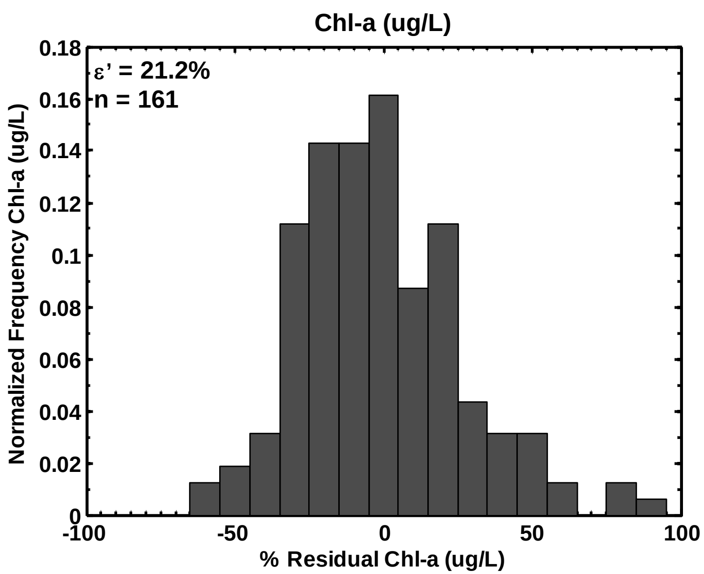

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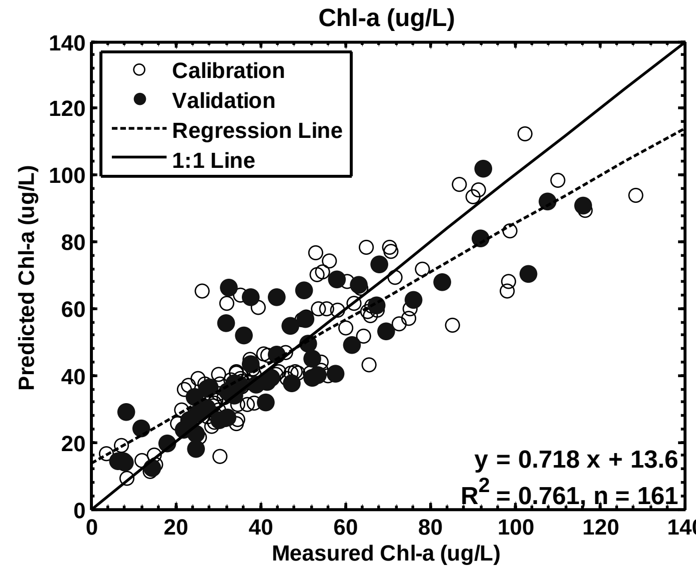

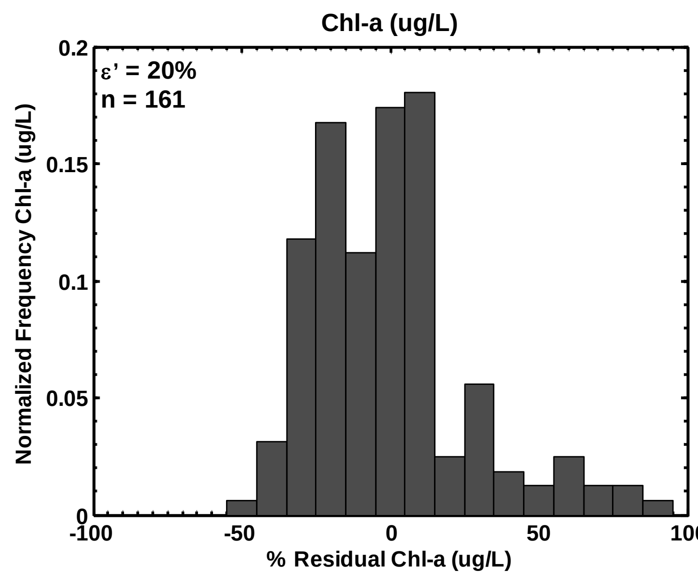

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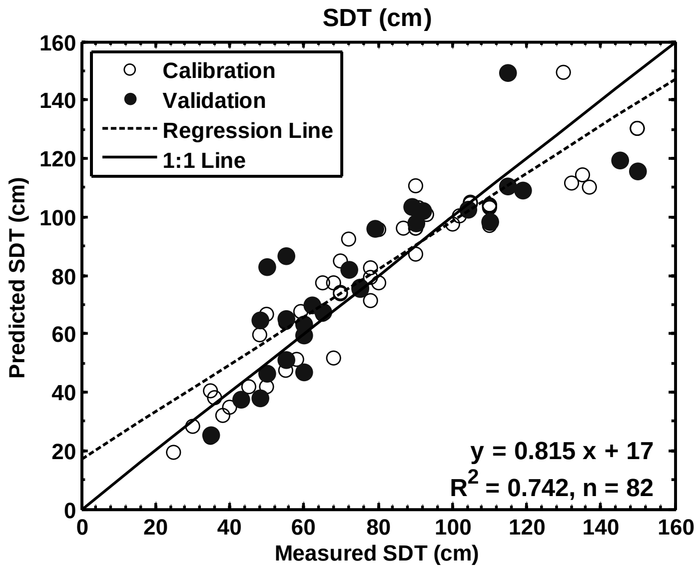

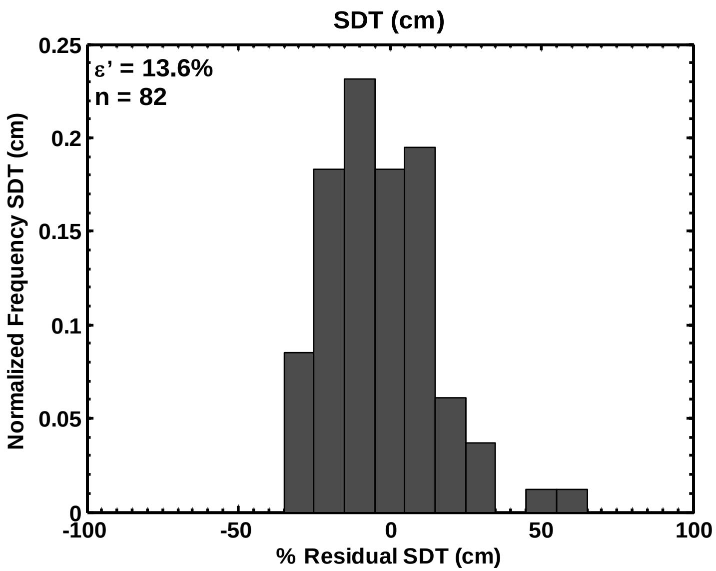

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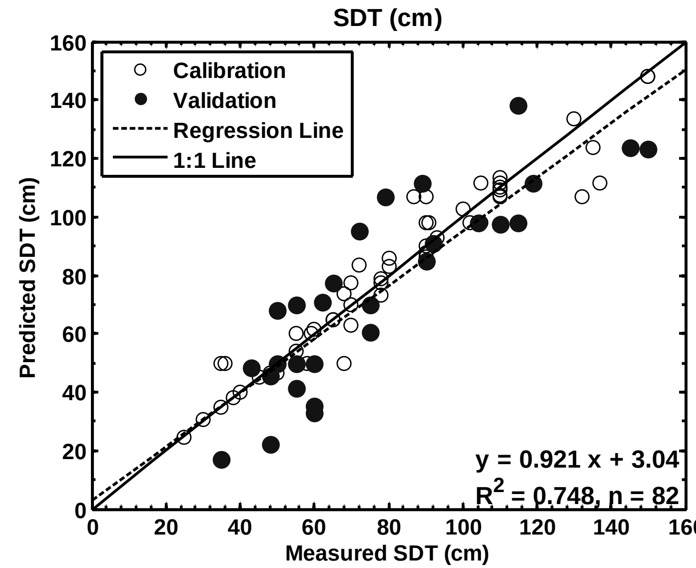

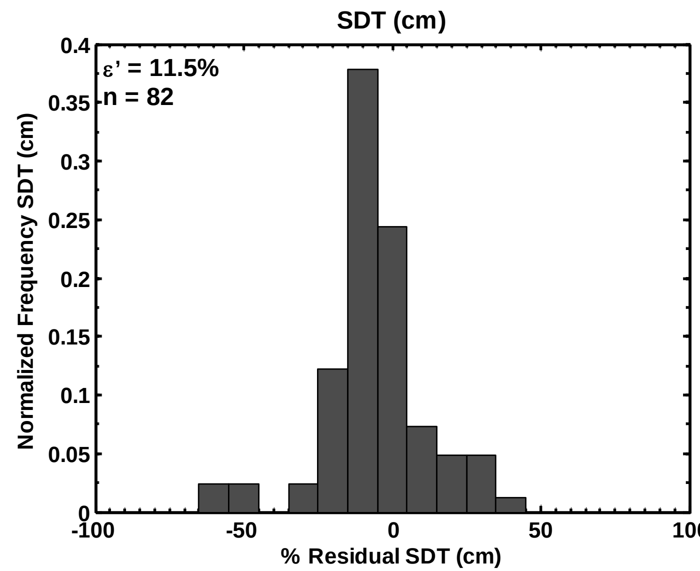

5. Results and Discussion-In Situ Data (2008)

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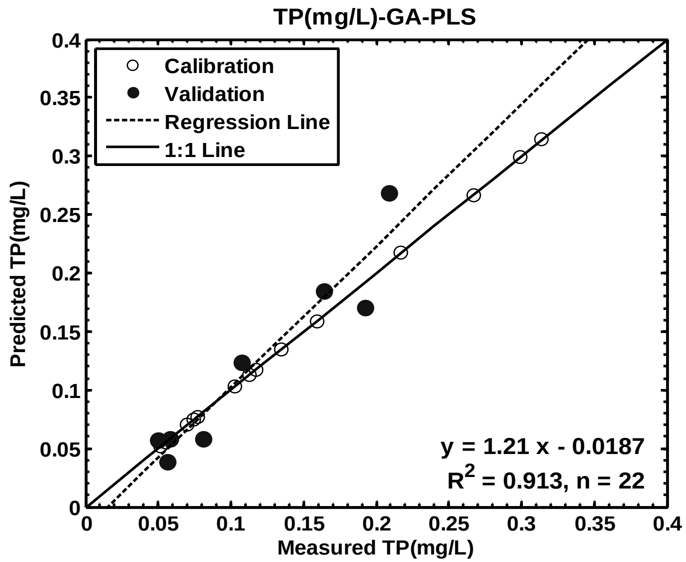

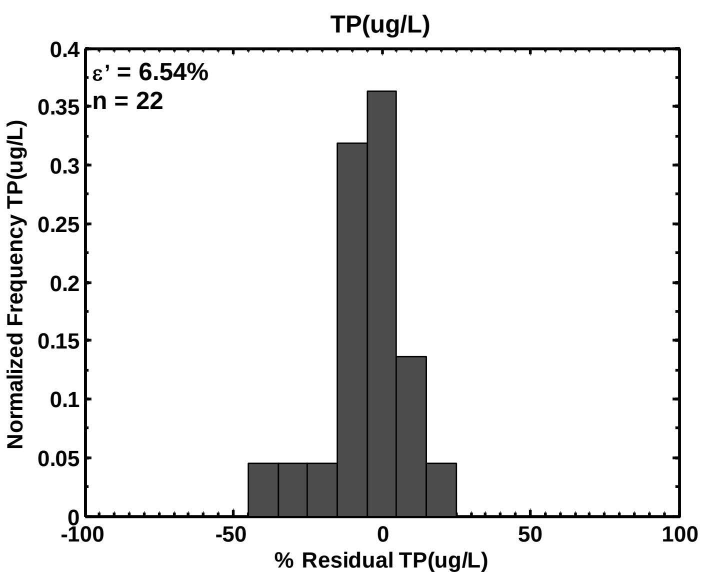

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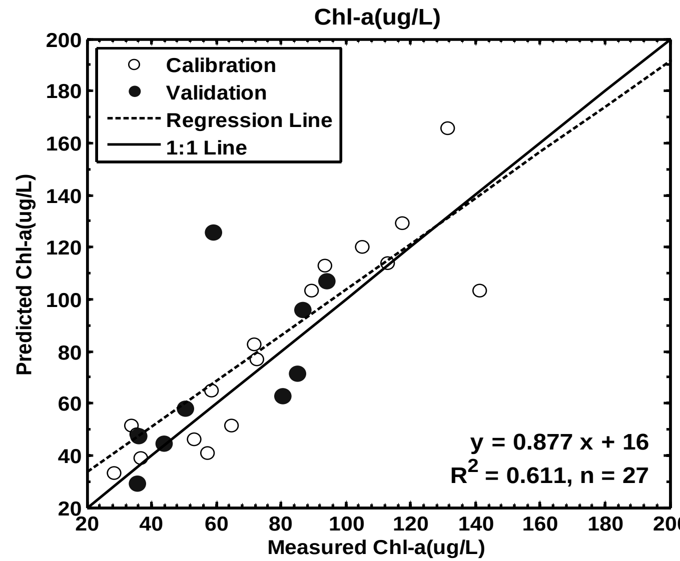
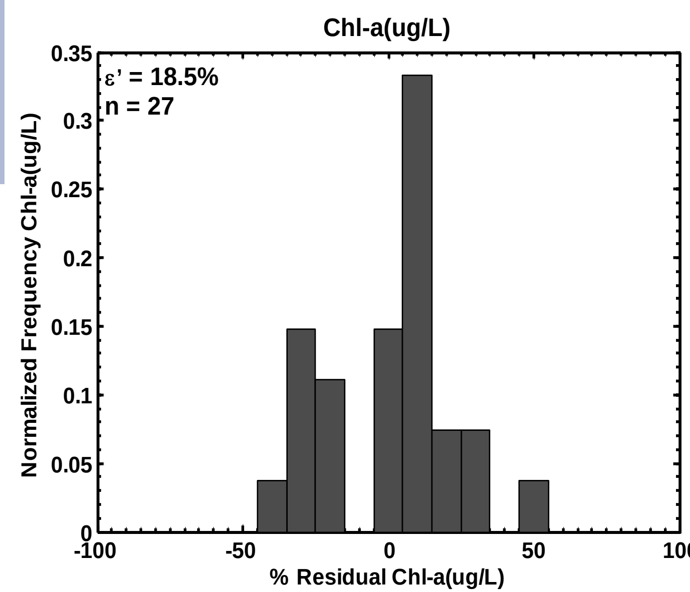
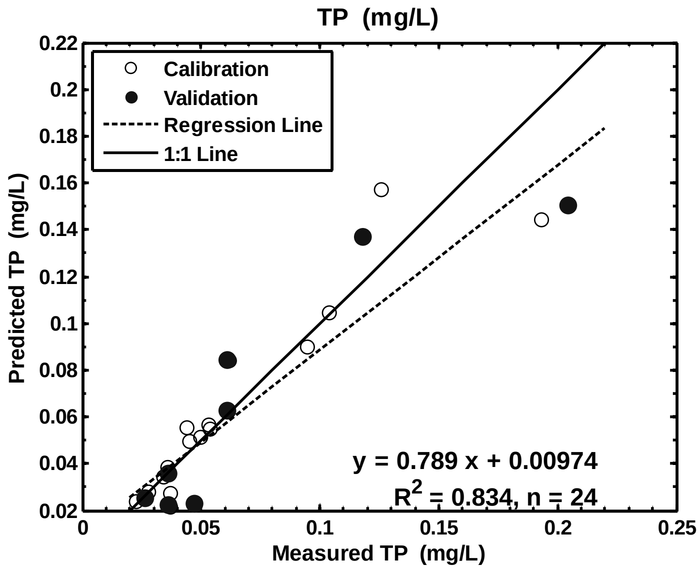


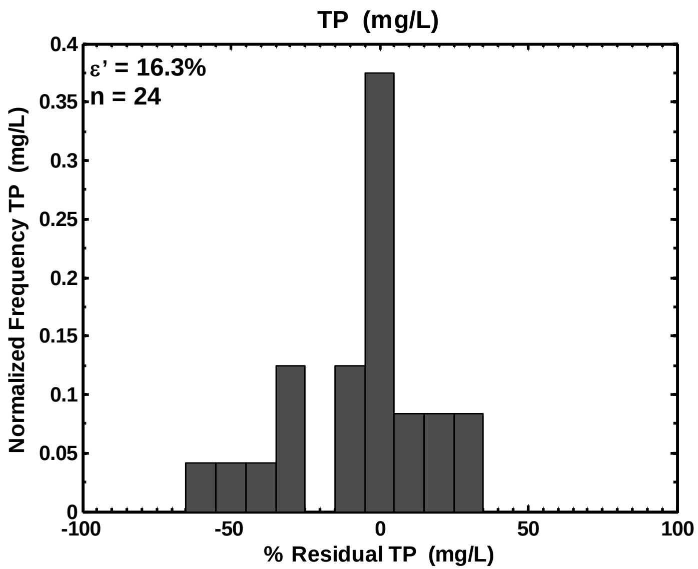


5. Results and Discussion- AISA Image Data

Analysis Result of the Morse Reservoir

GA-PLS





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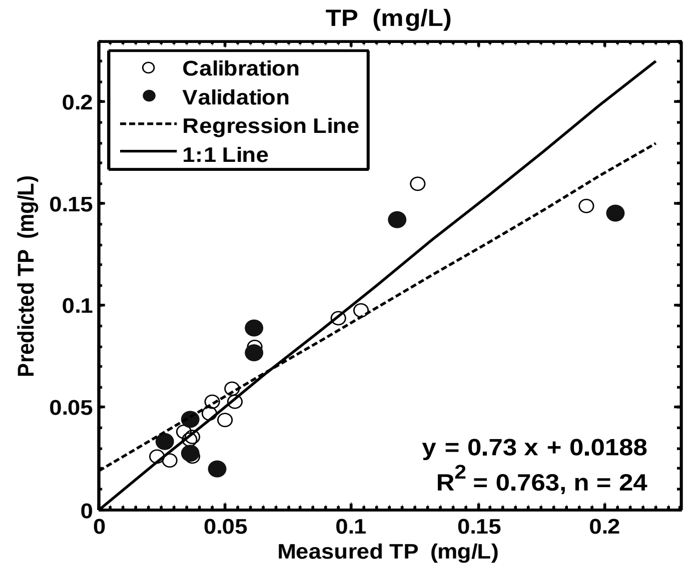

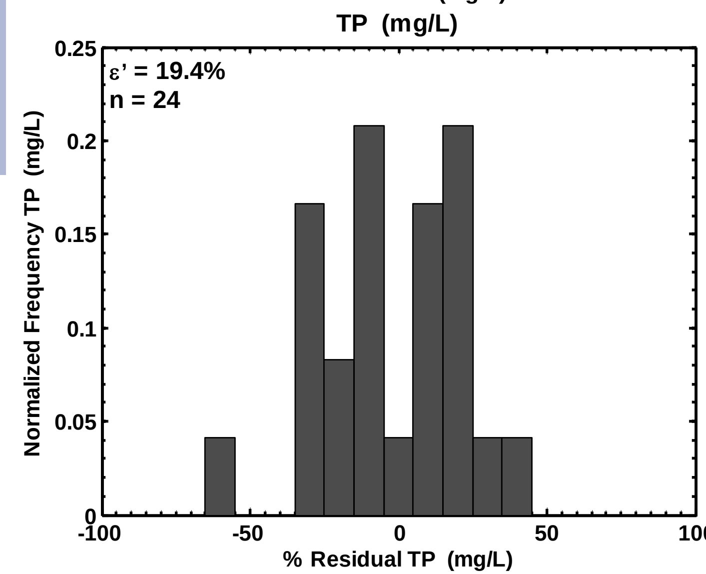

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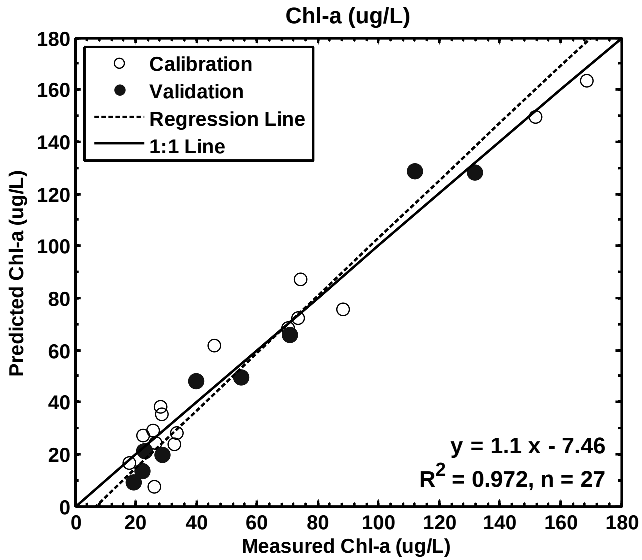

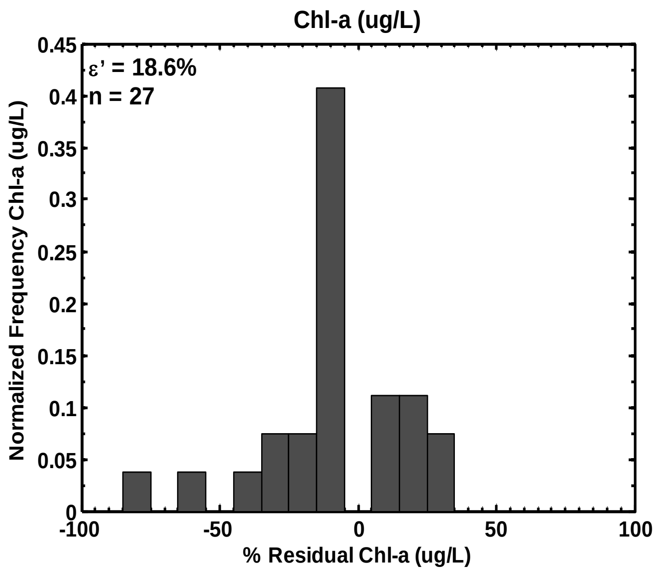

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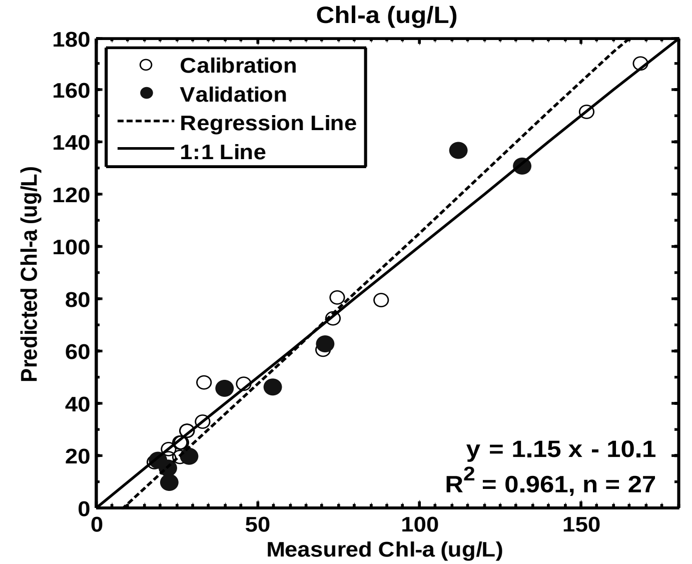

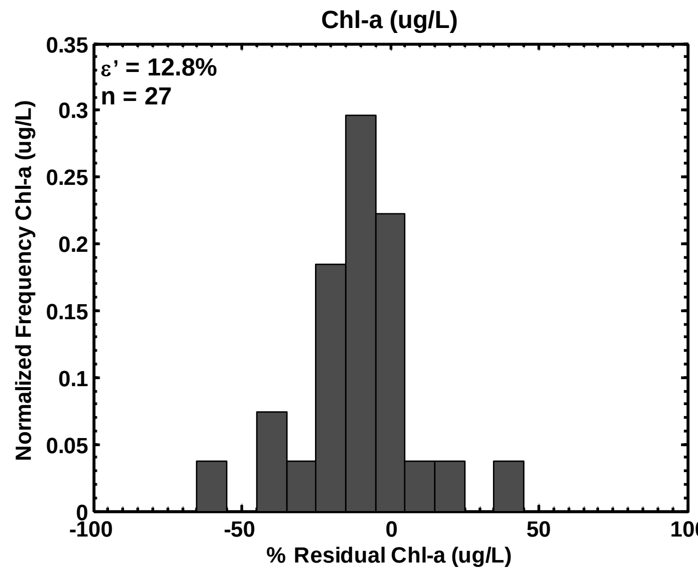

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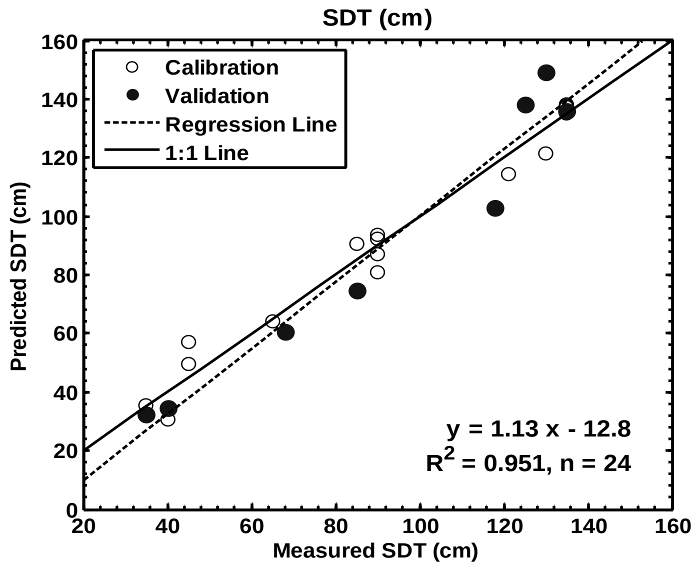

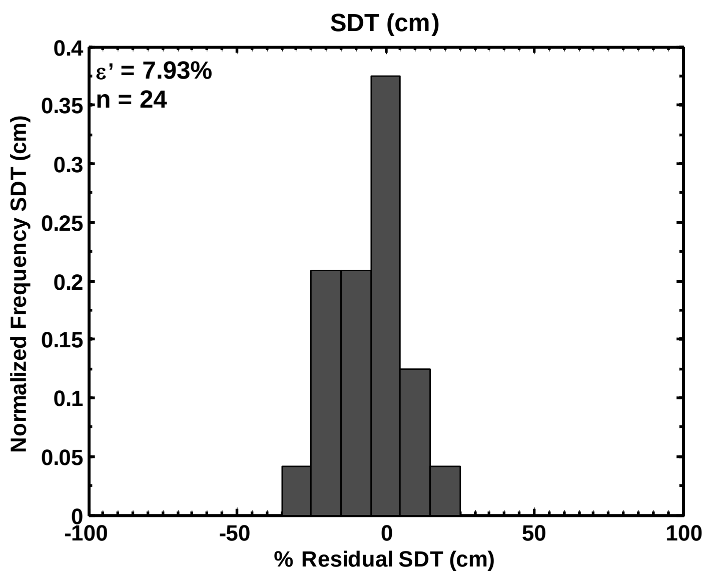

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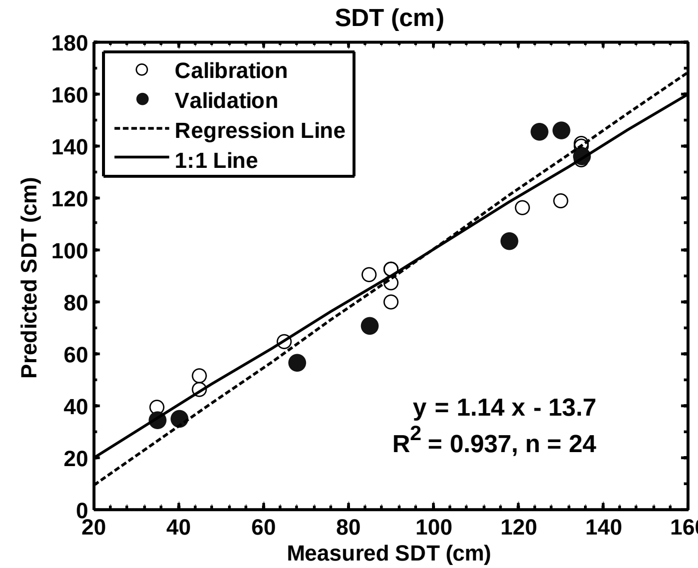
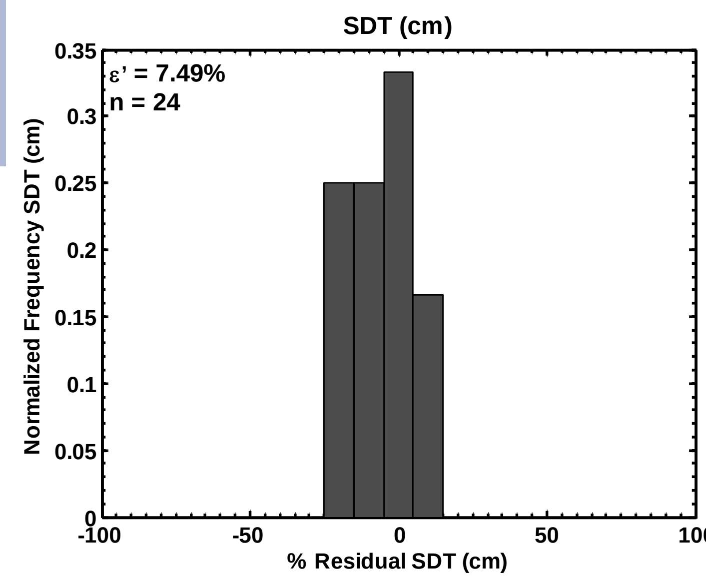
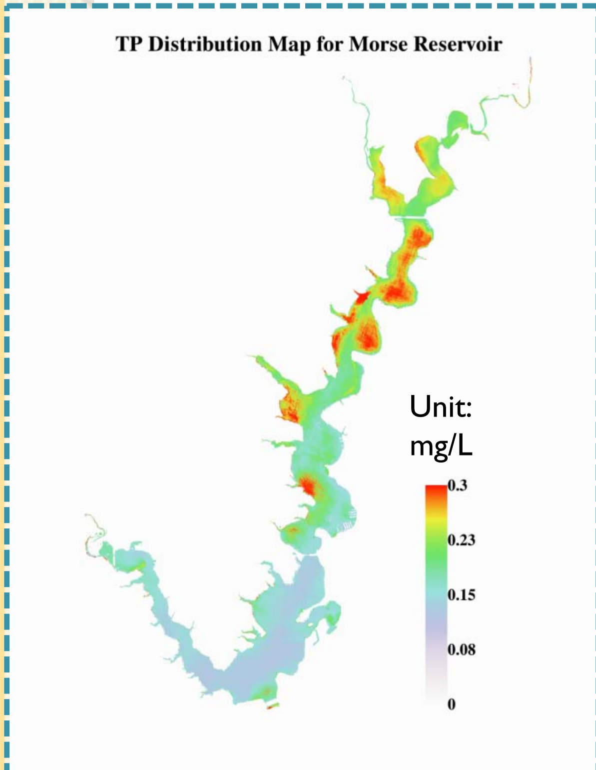
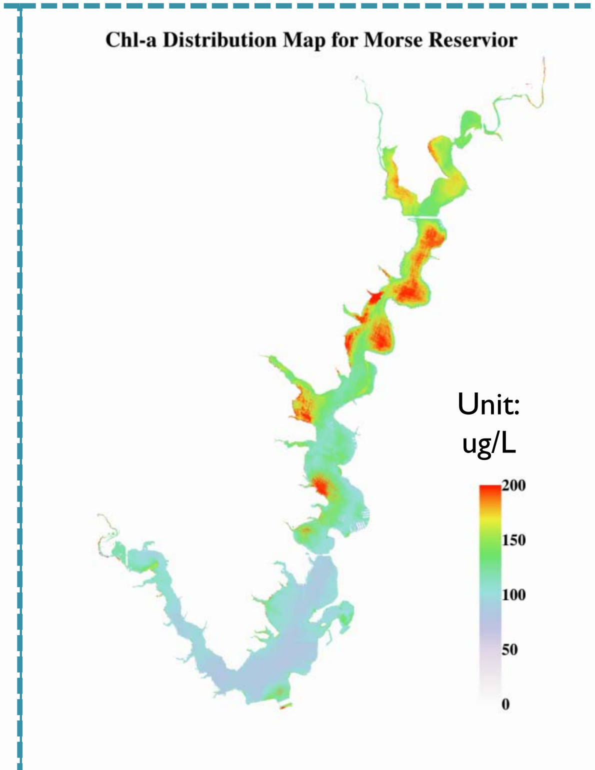


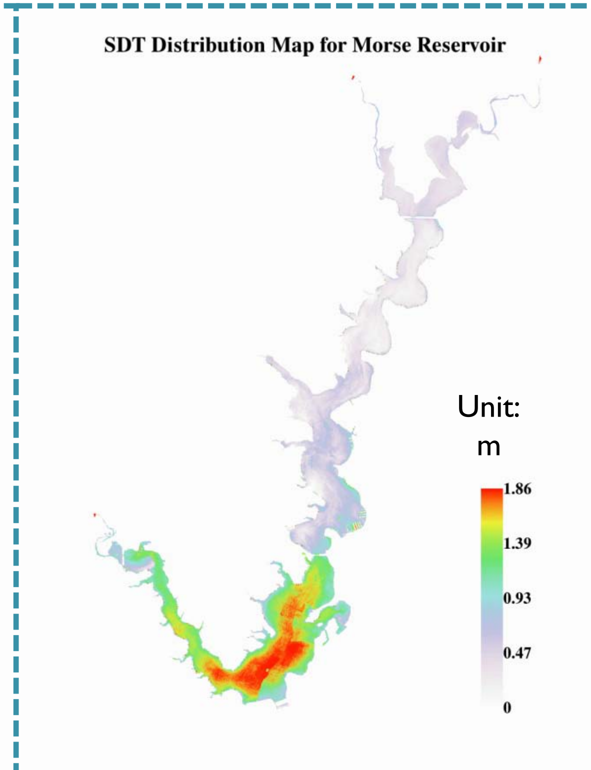


5. Results and Discussion- AISA Image Data

Analysis Result of the Morse Reservoir



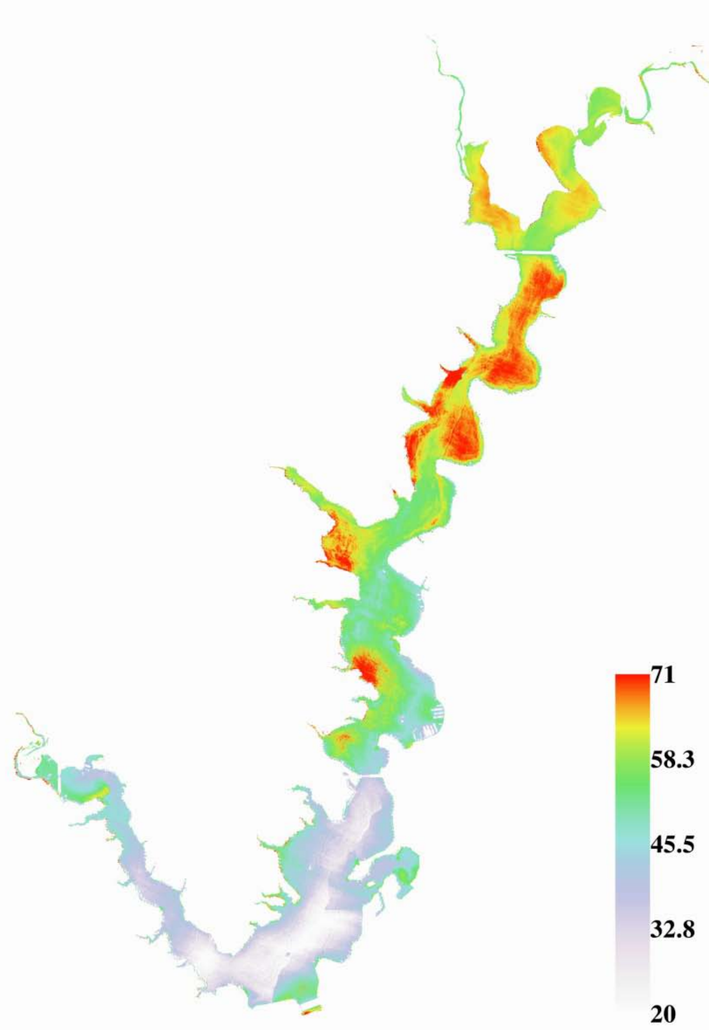


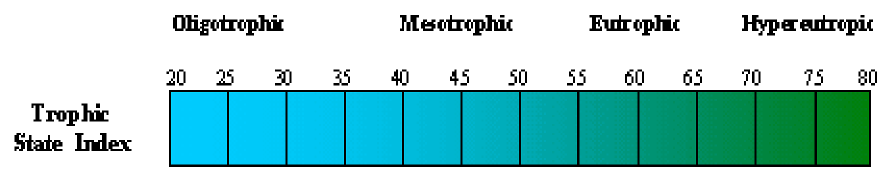


P (ug/L)	Chl (ug/L)	SD (m)	Trophic Class
0—12	0—2.6	>8—4	Oligotrophic
12—24	2.6—7.3	4—2	Mesotrophic
24—96	7.3—56	2—0.5	Eutrophic
96—384+	56—155+	0.5—<0.25	Hypereutrophic

5. Results and Discussion- AISA Image Data

Final Trophic Status Distribution Map for Morse Reservoir

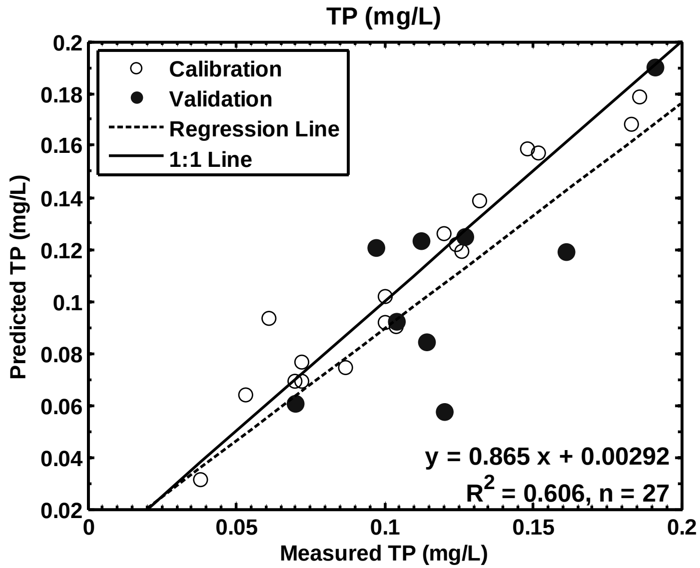


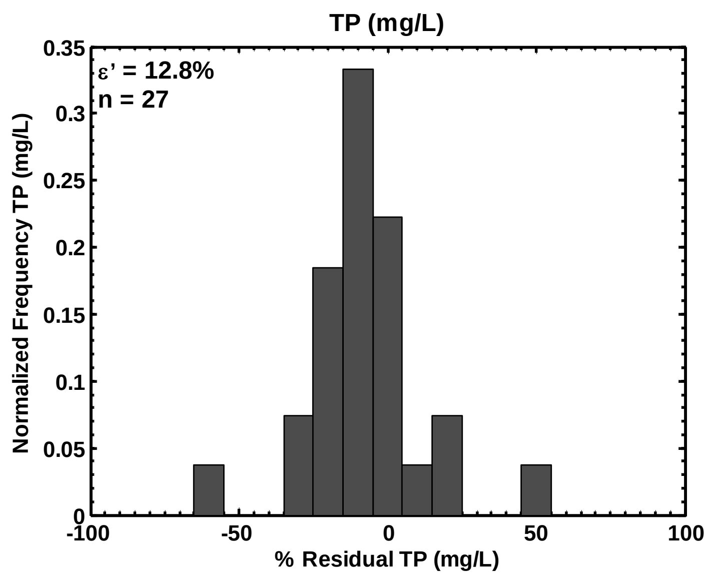


5. Results and Discussion- AISA Image Data

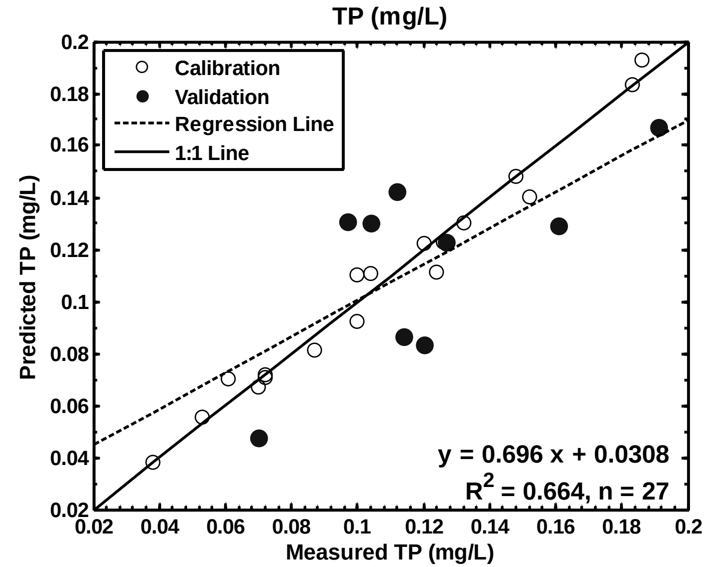
Analysis Result of the Geist Reservoir

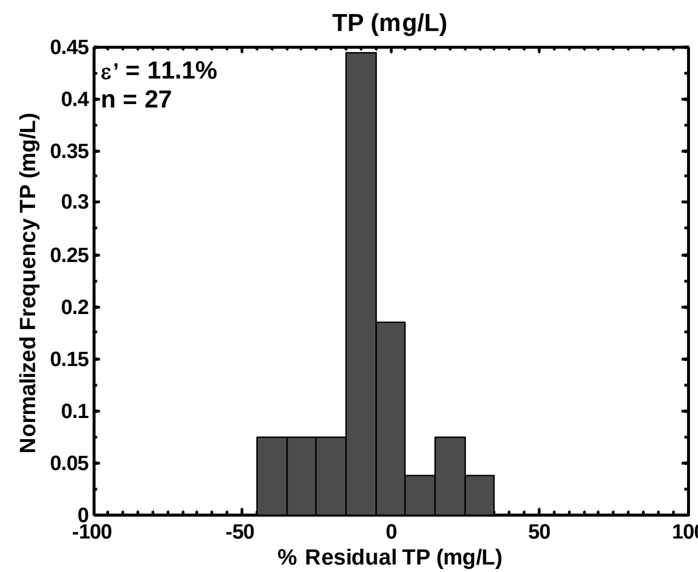
GA-PLS





BPNN-PLS

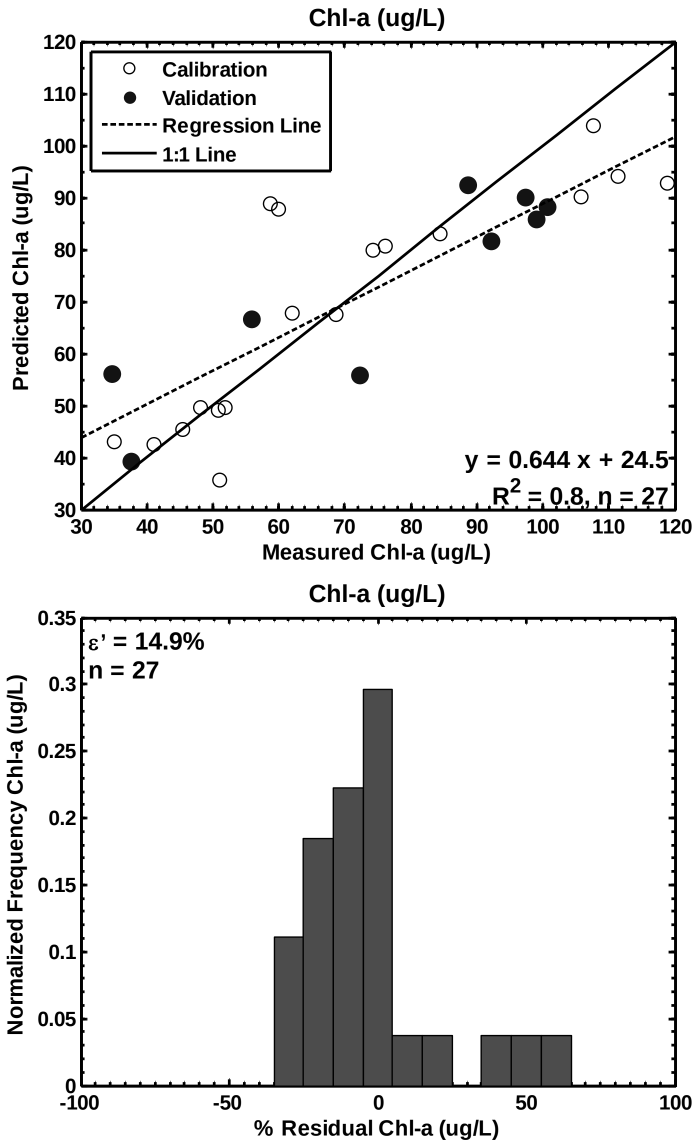




5. Results and Discussion- AISA Image Data

Analysis Result of the Geist Reservoir

GA-PLS



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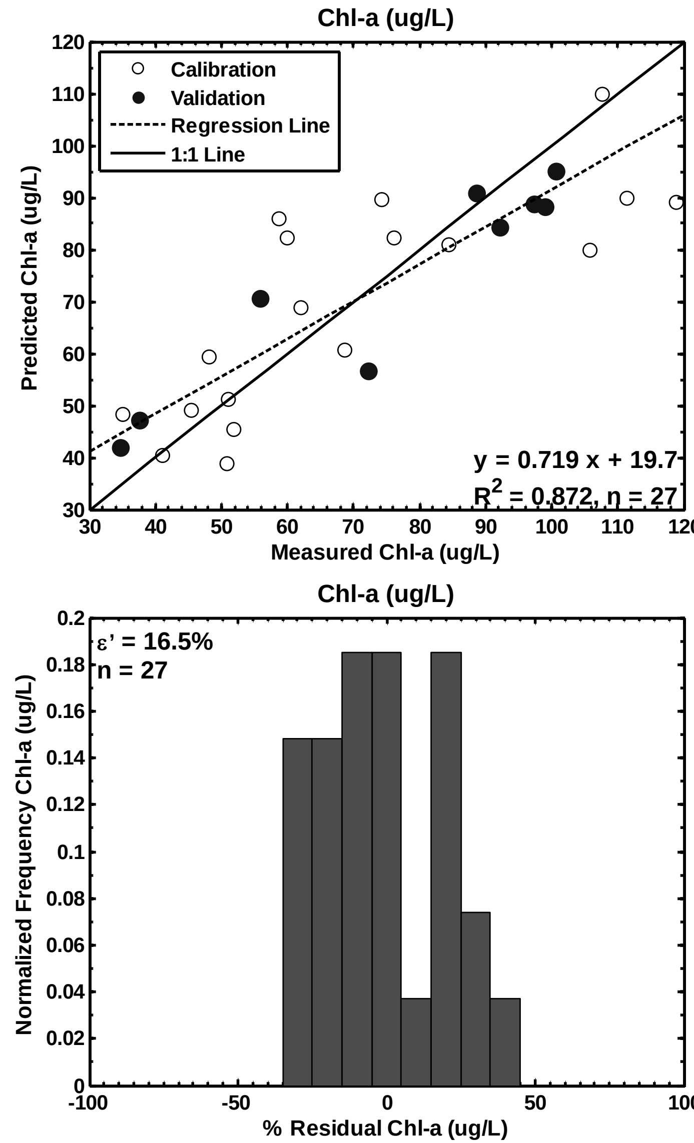
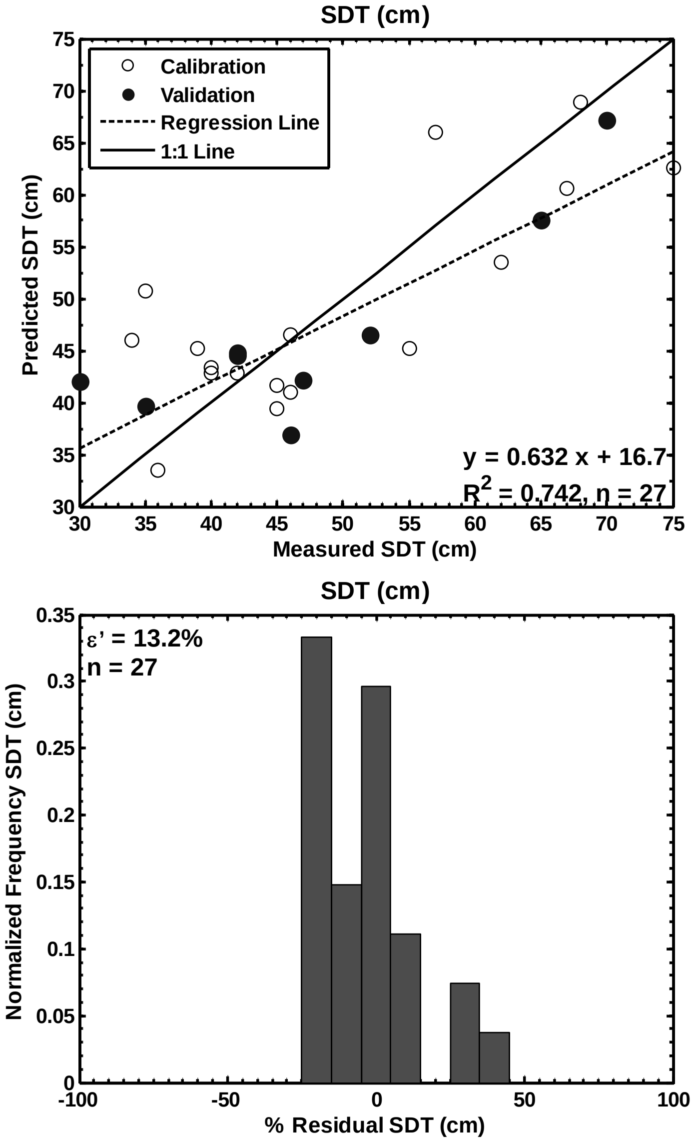


5. Results and Discussion- AISA Image Data

Analysis Result of the Geist Reservoir

GA-PLS



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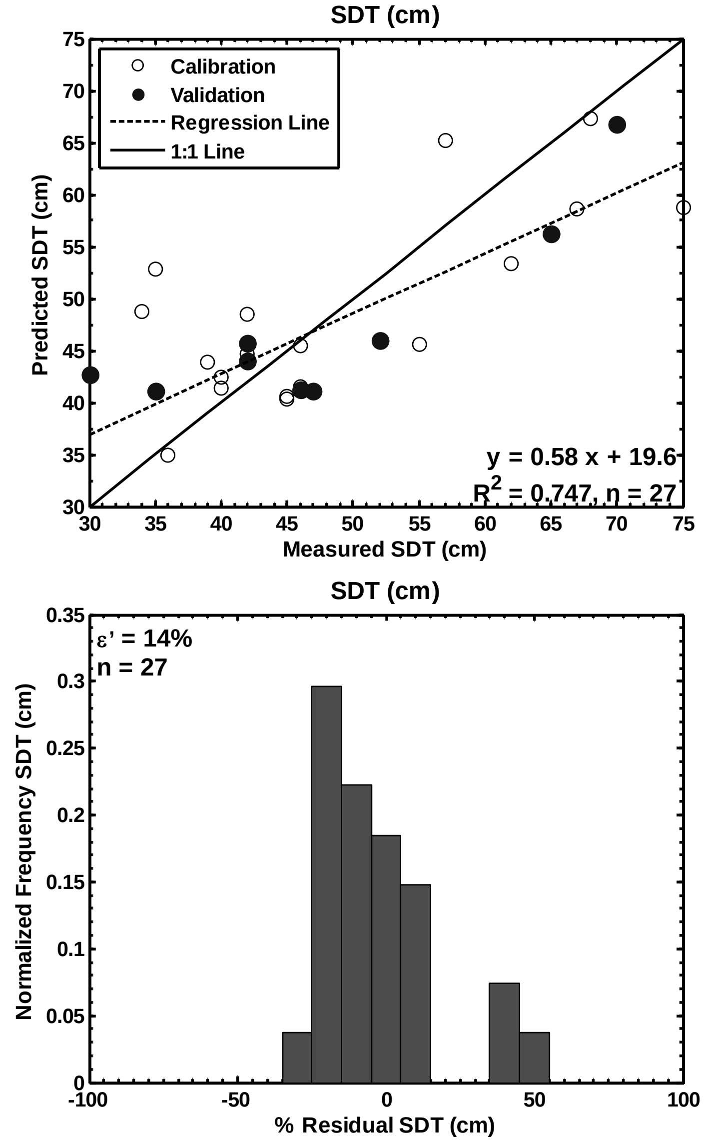

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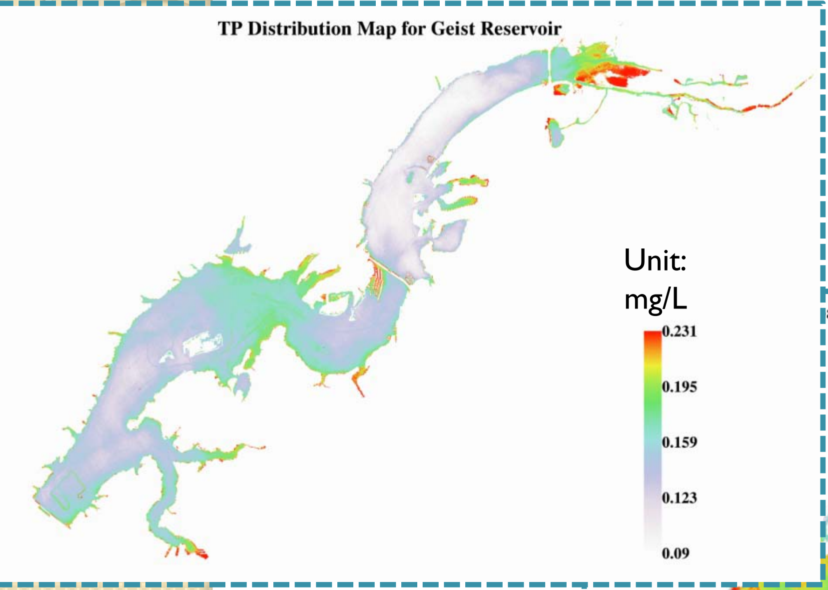
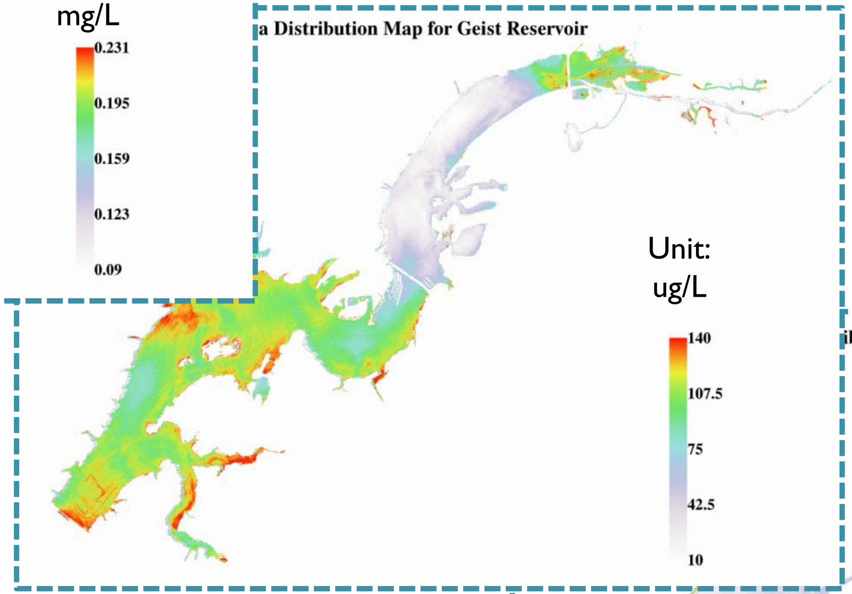
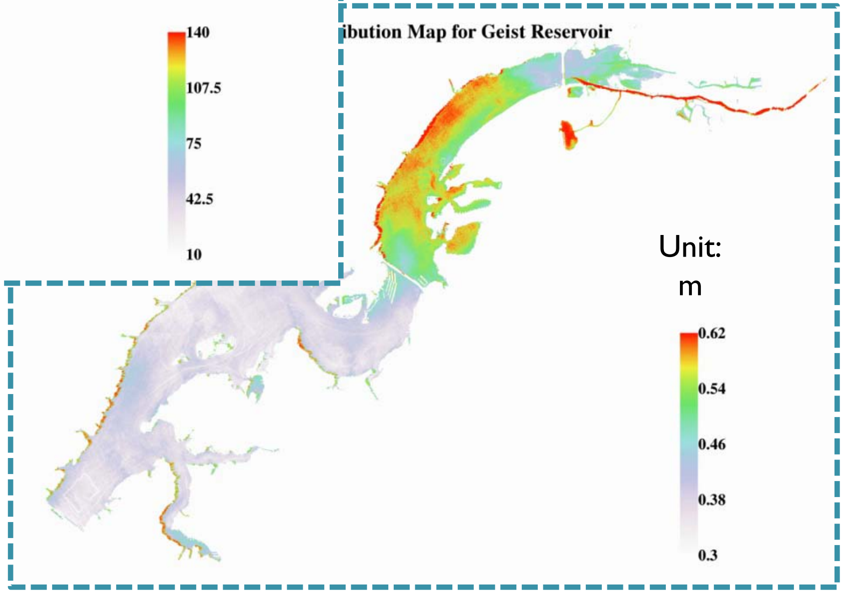
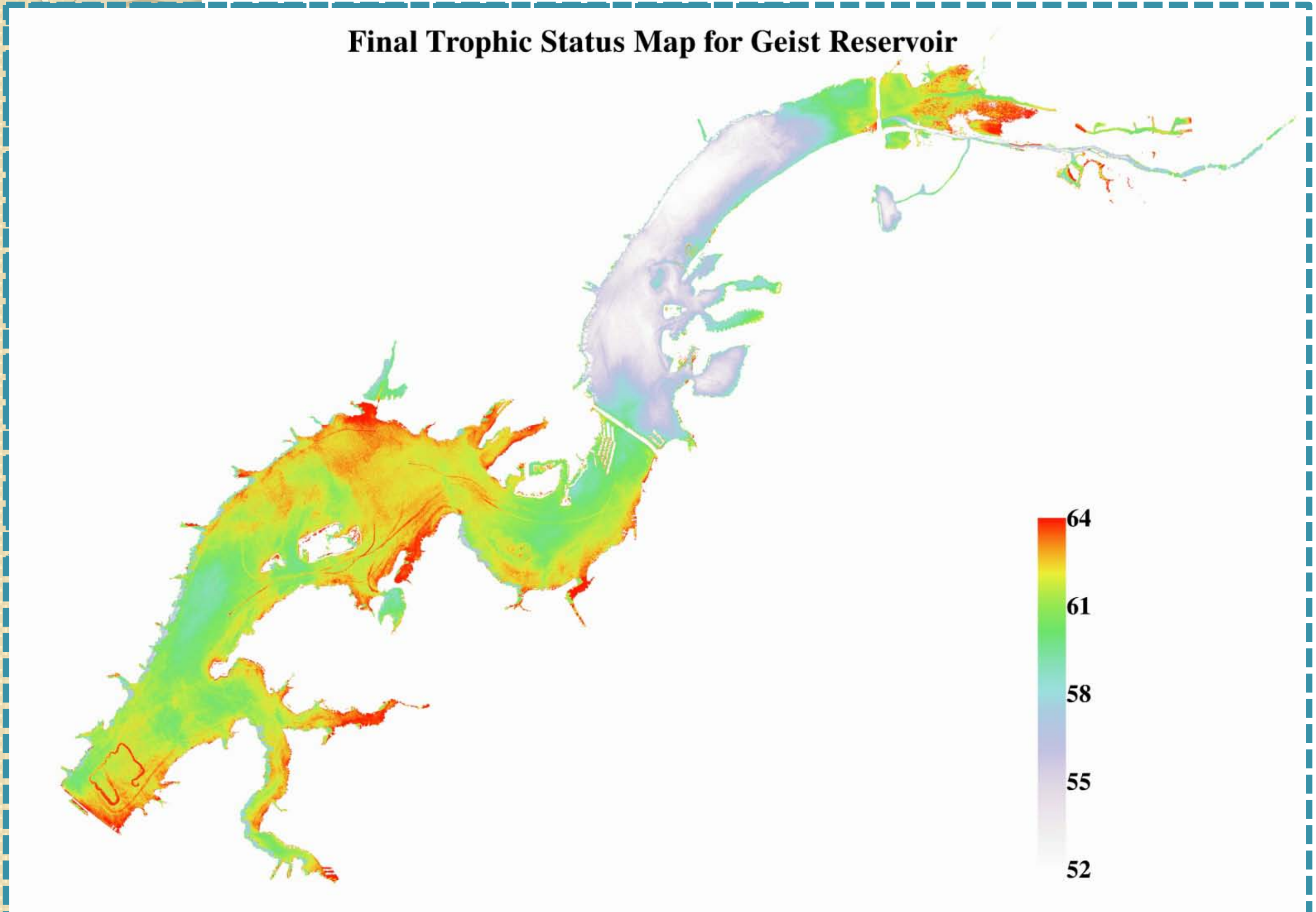
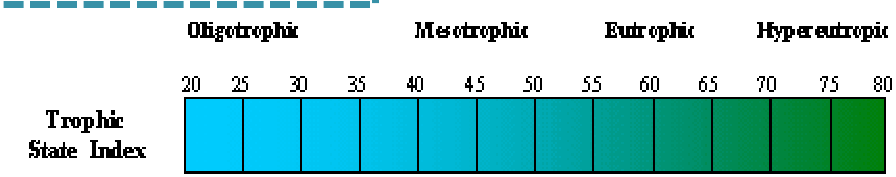






5. Results and Discussion- AISA Image Data





5. Results and Discussion-Hyperion Image Data

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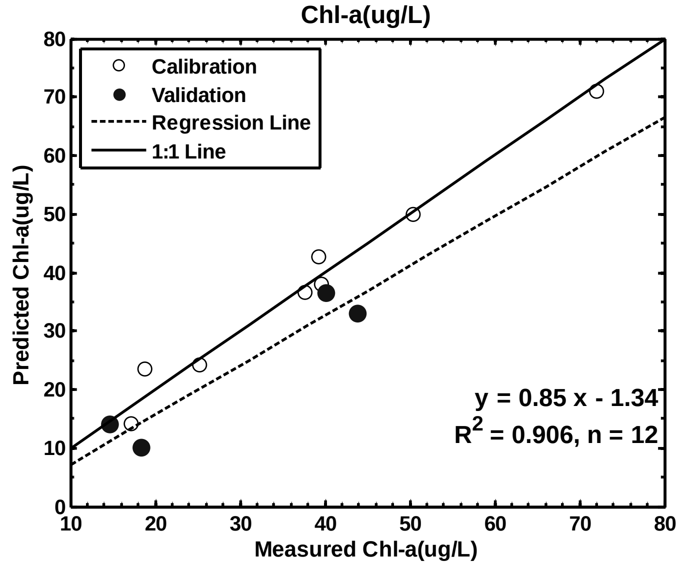

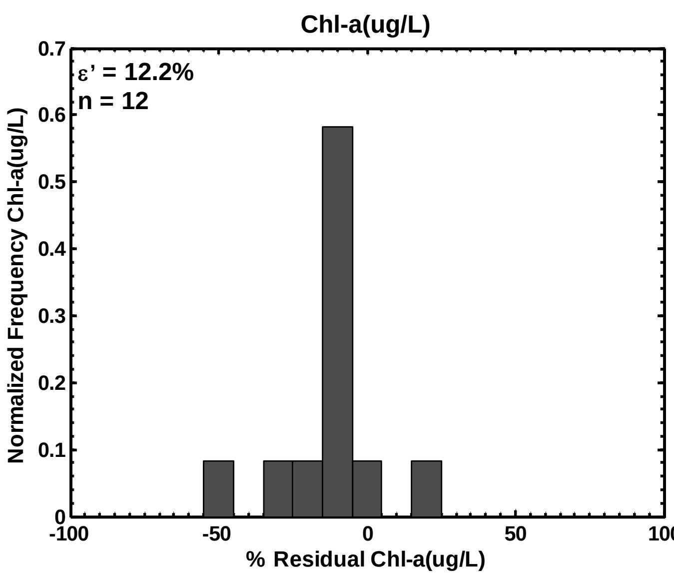

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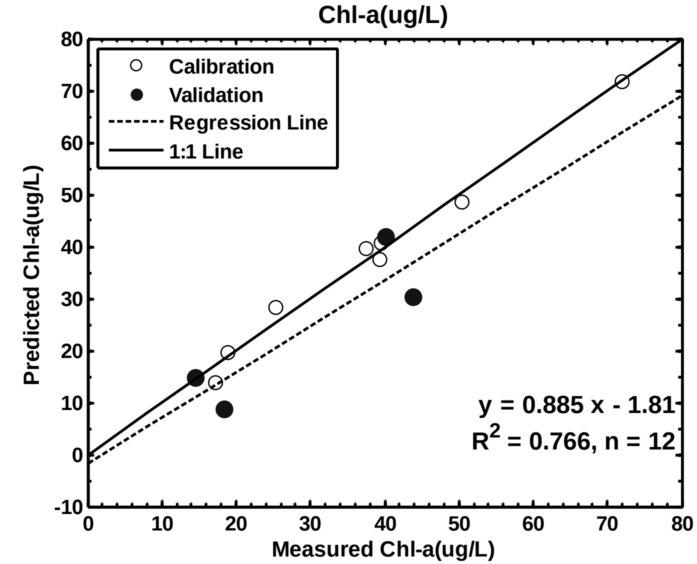
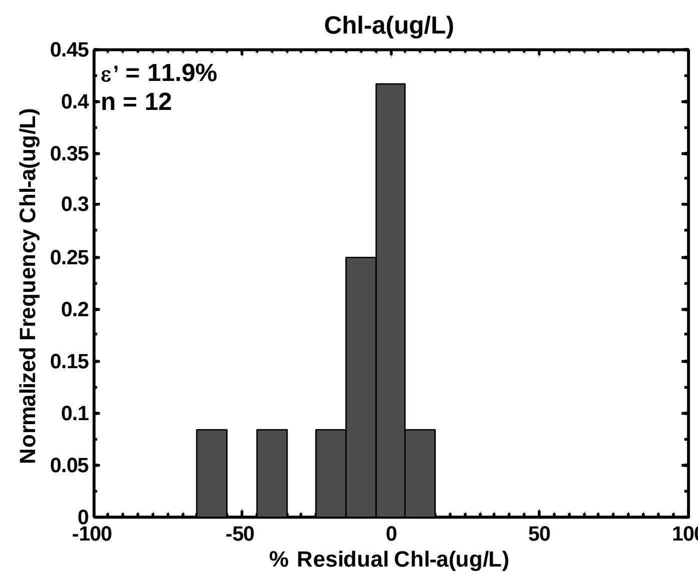
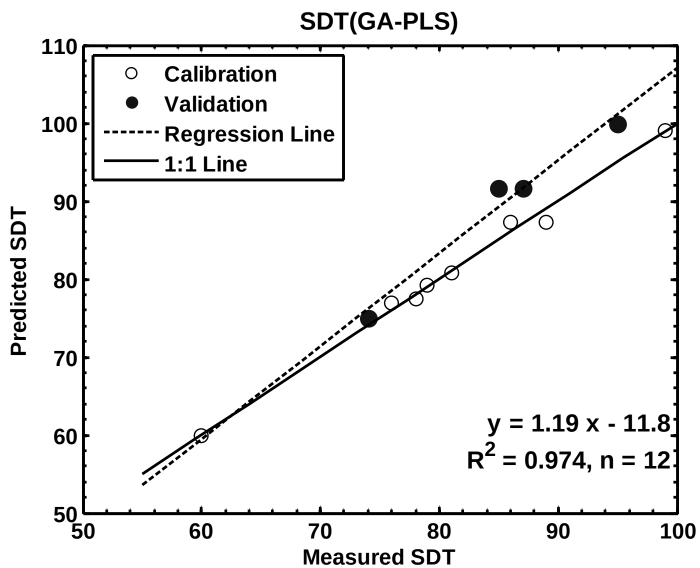
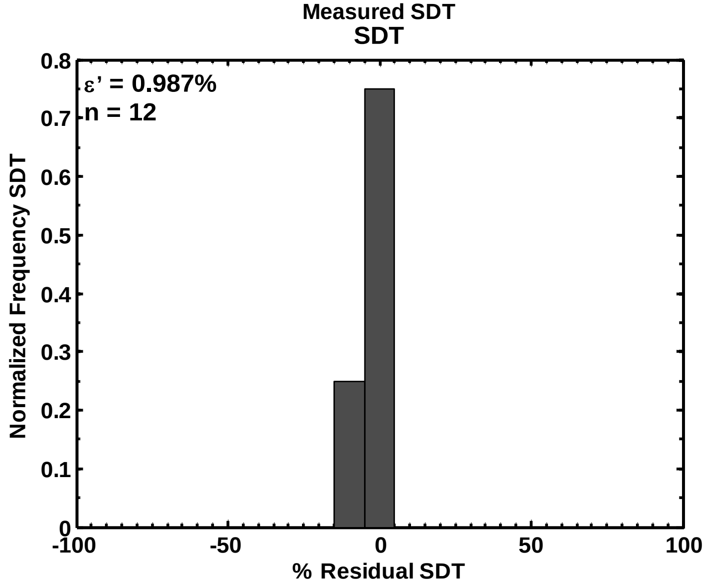




5. Results and Discussion-Hyperion Image Data

GA-PLS





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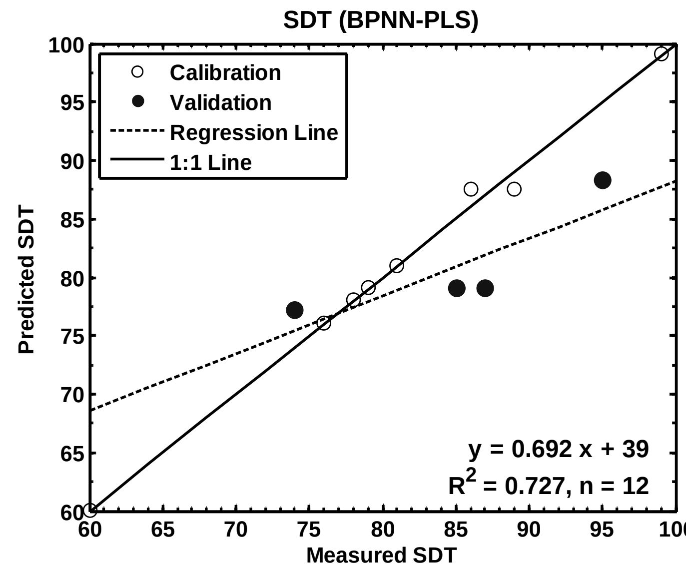

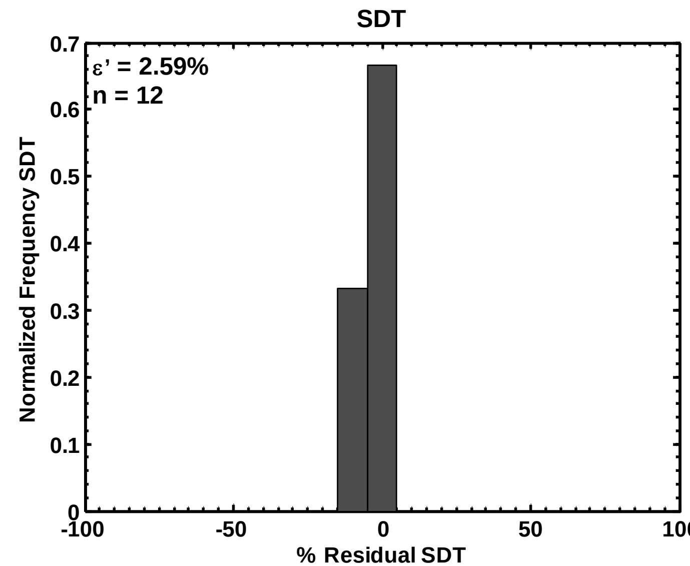

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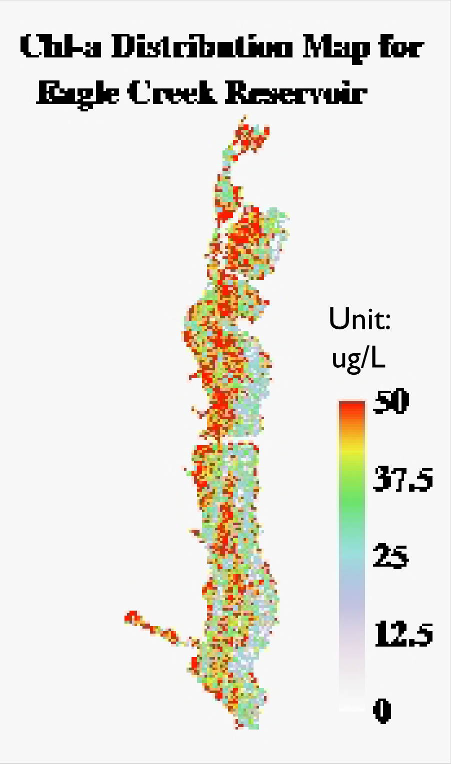
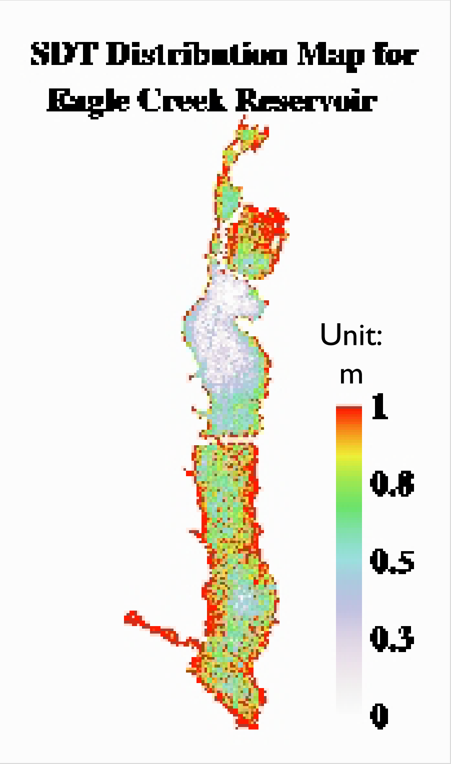
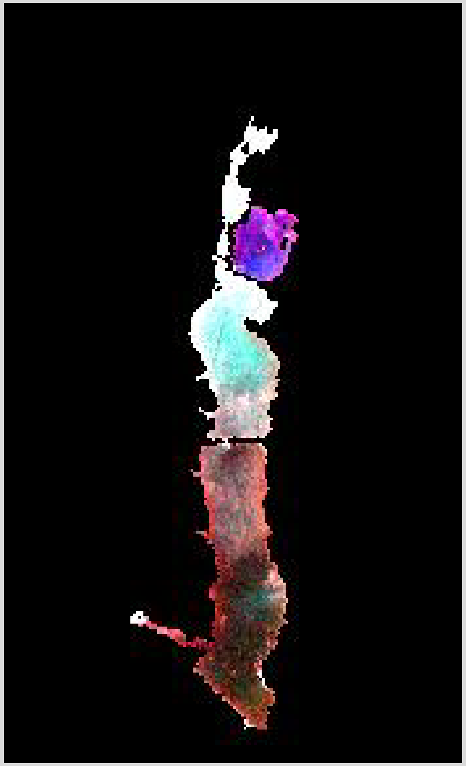






Low spatial resolution is a challenge when the image is used for water quality monitoring of small water bodies

6. Conclusions

- For the three investigated reservoirs, TP can be estimated with remote sensing data due to its close association with Chl-a, SDT, TSS and turbidity;
- GA-PLS has stable performances in our study, and BPNN-PLS did not outperform GA-PLS significantly in terms of accommodating non-linearity;
- If the same approach is applied for TP estimation of other case-II waters, correlation of TP to water compositional and physical parameters needs to be analyzed;
- Combining remotely estimated Chl-a, TP and SDT can be effective for assessment of trophic status of case-II waters.

Future Work

- Test these models with 2010 data sets;
- Conduct spatial correlation analyses of water nutrients, algae blooms, and temperature to determine potential relationships among these parameters;
- Use remote sensing mapping results to improve water quality models.

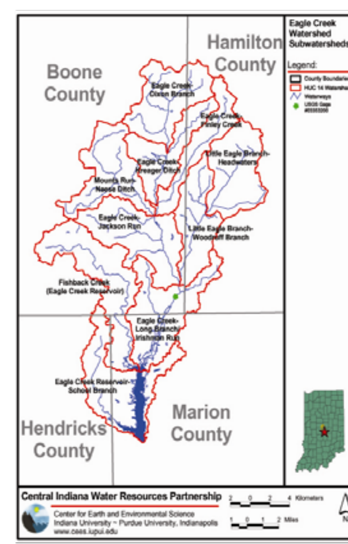
SWAT Hydrologic Model

EFDC Hydrodynamic Model

HEM3D Water Quality and Algal Model

Climate Data, USGS Flow data, Water quality data, Etc.

Forecasting of spatial and temporal distribution of Cyanobacteria and Nutrients (N, P, C) in the reservoir



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- NASA Energy and Water Cycle program(grant No. NNX09AU87G).