Analysis of Long Term Photosynthetically Active Radiation Data from McMurdo Dry Valley Lakes to Identify Turbidity Stratification Patterns

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Abstract

The current study focused on four perennially ice covered, meromictic lakes in Taylor Valley of the McMurdo Dry Valleys region: West (WLB) and East Lobe Bonney (ELB), Fryxell (FRX), and Hoare (HOR). Data from these lakes have been collected annually for 29 years, and are cataloged in the McMurdo Dry Valleys Long Term Ecological Research (LTER) database. ***The objectives of the current study were to determine whether turbidity stratification patterns could be identified within the four McMurdo Dry Valley lakes, to examine seasonal and annual changes in those stratification patterns, and to correlate environmental data to identify potential causes of the turbidity.*** To identify patterns in turbidity, depth profiles of extinction coefficients calculated using photosynthetically active radiation (PAR) data collected annually during the past 29 years, were plotted. Averaging the profiles revealed distinct stratification of turbidity layers that were shown to be relatively stable across all recorded years. To examine potential causes of turbidity revealed by the extinction coefficient data, chlorophyll-*a* (chl-*a*) profiles were compiled for the same years. Chlorophyll-*a* was plotted against extinction coefficient to look for correlations. Within the photic zones of Lake Hoare and East and West Lobe Bonney, chlorophyll-*a* was significantly correlated with turbidity. A plot of extinction coefficients for the shallow and deep photic zone layers against time revealed that late season average turbidity was much higher than that of early season turbidity, and that turbidity increased with depth in the photic zones of all lakes. Future research focusing on stream flow data could help identify the causes of the increase in late season turbidity observed in this study, and analysis of environmental data other than chlorophyll could help to determine what other factors control turbidity gradients in FRX.

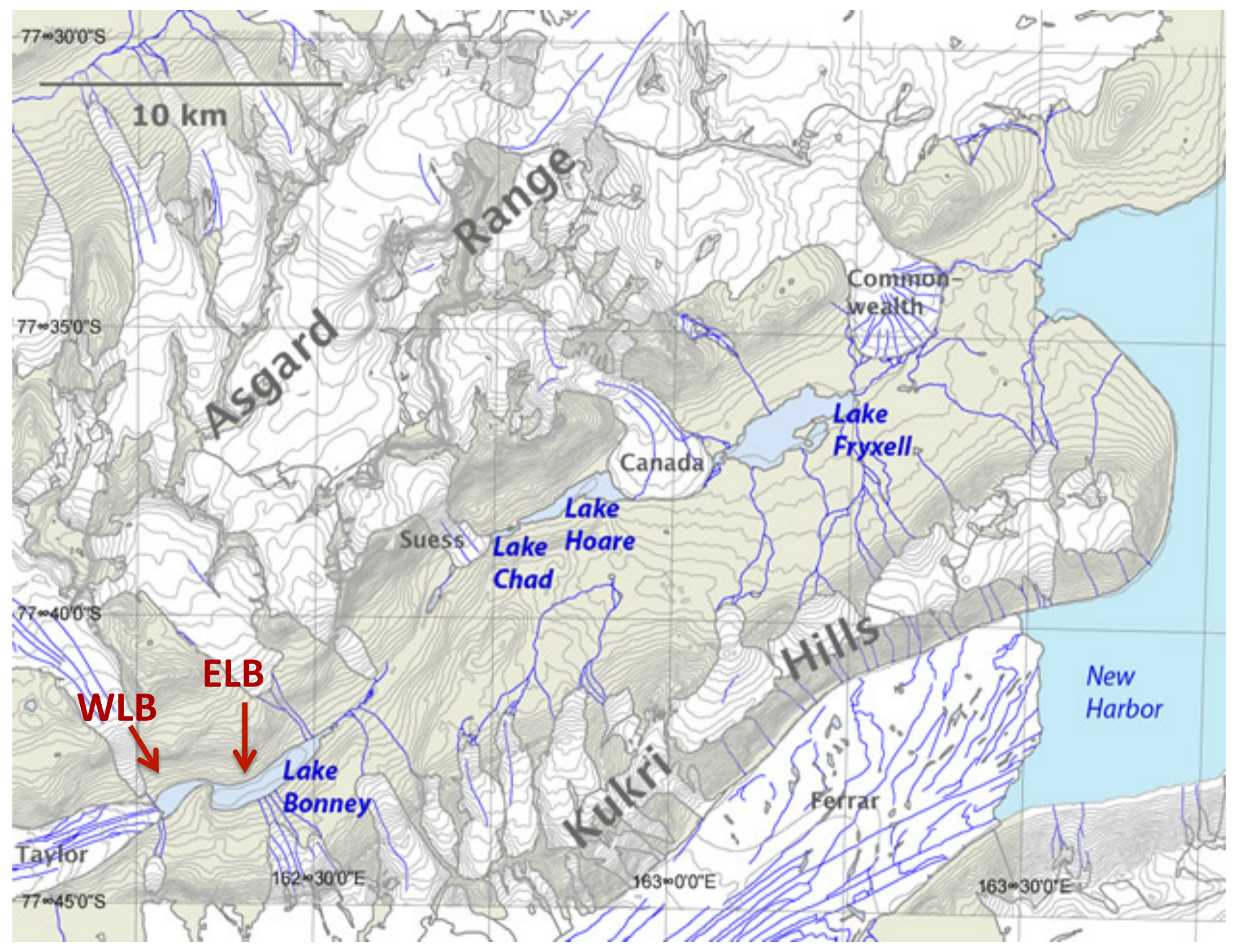

Figure 1. Location of the study lakes in the Taylor Valley. All four lakes are terminal, meromictic, freshwater lakes. Each is completely covered year round by approximately four meters of ice, and they vary in depth from 19 meters to approximately 40 meters.

Section 2. Chlorophyll-a vs. Extinction Coefficient

Correlation between chl-a and k peaks for discreet layers were examined (only chl-*a* peak data shown below). All correlations shown (except the FRX profile) were found to be statistically significant, though most appear very scattered when plotted (Figure 3).

ELB and WLB both show a strong correlation between *k* and chl-*a*.

- The depth of greatest correlation between chl-*a* and *k* for HOR was found at 6m, which is the chl-*a* maximum.
- FRX shows no significant correlation across the profile, but does show significant correlation at the chl-*a* peak.

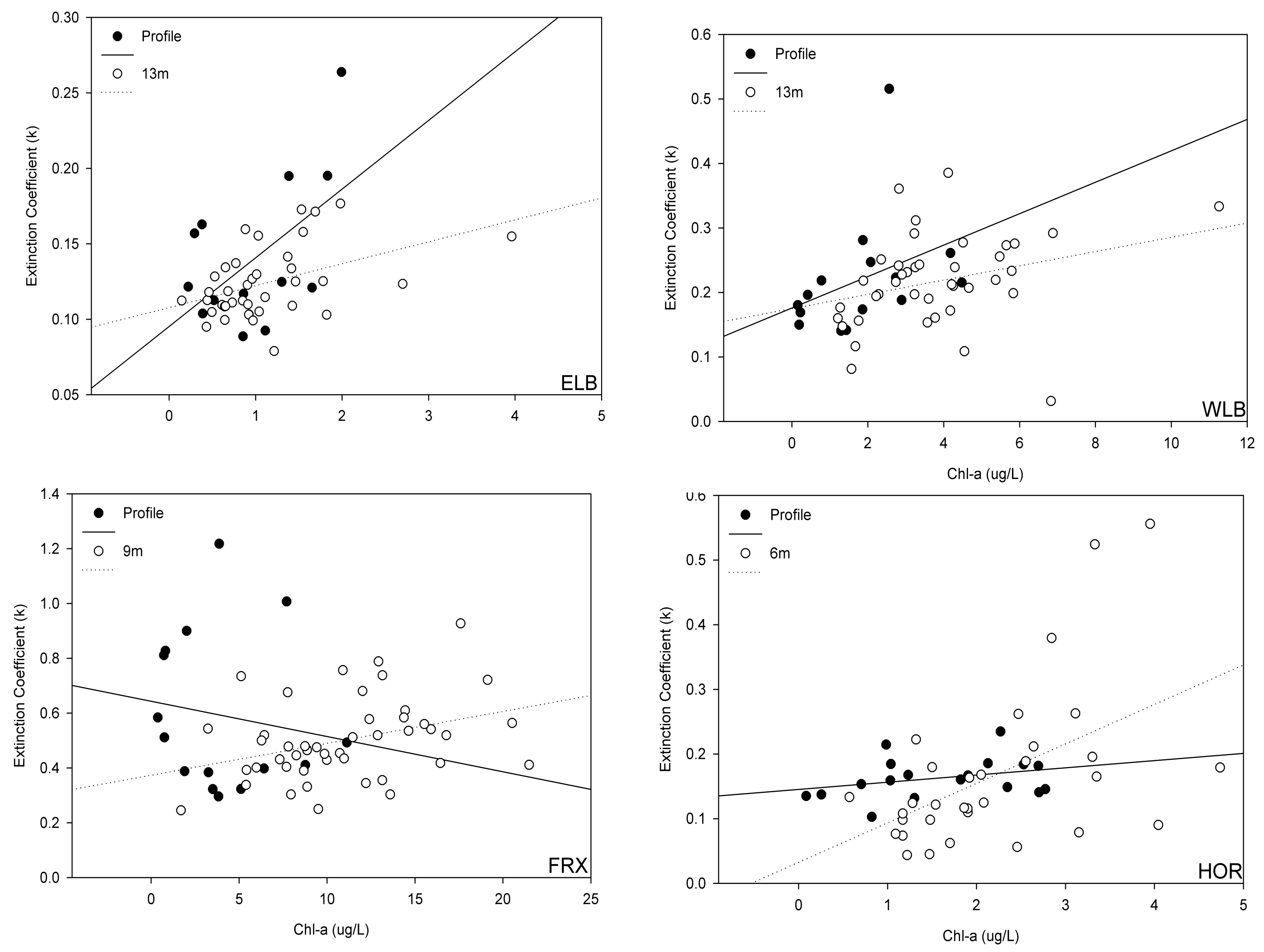

Figure 3. Plots of extinction coefficient (k, m^{-1}) versus chl-*a* in the study lakes, with a linear regression fit to the data. A solid line indicates linearity of the profile data (black points, each representing long-term averages at a single depth), and a dotted line shows that of data from the peak of chl-*a* in each lake (white dots, each representing all long-term individual samplings at 13m in ELB and WLB, 9m in FRX, and 6m in HOR). With a perfect correlation ($R^2=1$) , the y-intercept would represent the turbidity of the water with chl-*a* removed. (Only chl-*a* peak correlations are shown here)

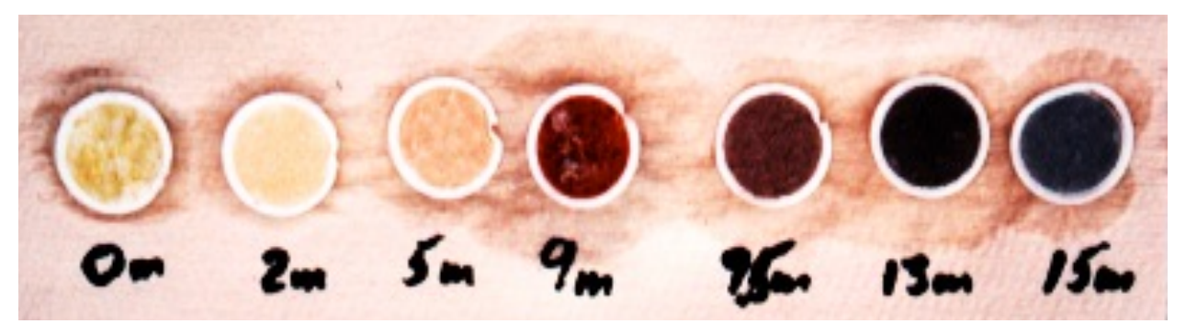

Figure 6: Filters after processing FRX water samples, showing a change of material with depth. Black coloration is likely due to iron sulfide suspended in the water column.

Section 1. Turbidity Patterns from profile data

As part of the LTER program, annual measurements of PAR and chl-*a* have been done in Lake Fryxell, Lake Hoare, and the west and east lobes of Lake Bonney for the past 29 years. PAR was measured using a LI-COR LI-193SA Underwater Spherical Quantum Sensor; extracted chl-*a* was measured with a Turner 10AU Fluorometer. For this study, extinction coefficient (k, m^{-1}) was calculated from PAR data every meter through the photic zone of the water column for the four study lakes.

Each of the lakes shows varied zones of turbidity (Figure 2).

- Turbid peaks in East and West Lobe Bonney occur at 13.5m and 14m, respectively.
- Lake Hoare has a turbid peak at 14m, but a chl-*a* peak at around 6m
- At 10.5m, FRX is more turbid than any other depth in the photic zones of the four lakes, but this peak does not occur at the same depth as the chl-*a* peak (9m).

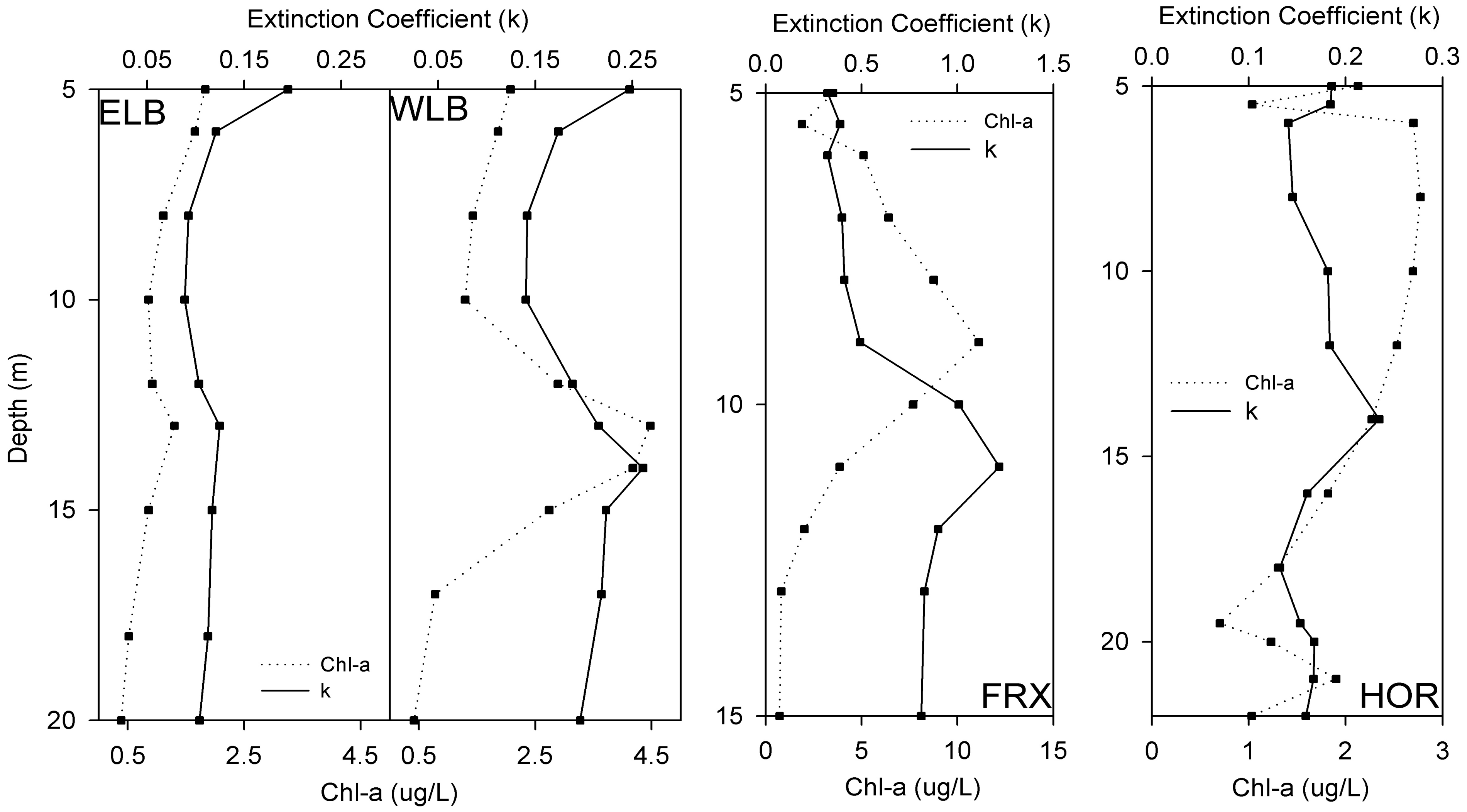

Figure 2. Depth profiles of the four study lakes. The solid line represents an average of all extinction coefficient data across all sample years, for each sample depth; the dotted line represents the same for chl-*a*.

Discussion

This study shows that there are consistent turbidity patterns in the photic zones of West and East Lobe Bonney, Fryxell, and Hoare. These turbid layers vary from lake to lake, and are likely caused by a variety of biotic and abiotic factors.

- Photosynthetic cells suspended in the water column play a significant role in causing turbidity in the study lakes.
- Turbidity in the photic zones of the study lakes increases as the sampling season progresses. This is due to stream flow introducing new sediments.
- With the exception of HOR, higher turbidity is found in bottom sections of the photic zone than in top sections. Since chl-*a* is found to stay deeper in the photic zone, this further shows the correlation between turbidity and chl-*a* in the water column.
- FRX shows higher turbidity in deeper depths that does not correlate with chl-*a*. Further study is needed to determine the cause of this higher turbidity, but it is hypothesized that high levels of iron sulfide at the chemocline is the likely contributor (see Figure 6).
- WLB shows a larger change in turbidity through the season, which is likely due to Taylor Glacier feeding directly into WLB.

Future studies of abiotic factors are required in order to determine exact causes of turbidity other than chl-*a* in the water columns of the four lakes. Stream flow and temperature data will also assist in studying the cause of high turbidity in later season data.

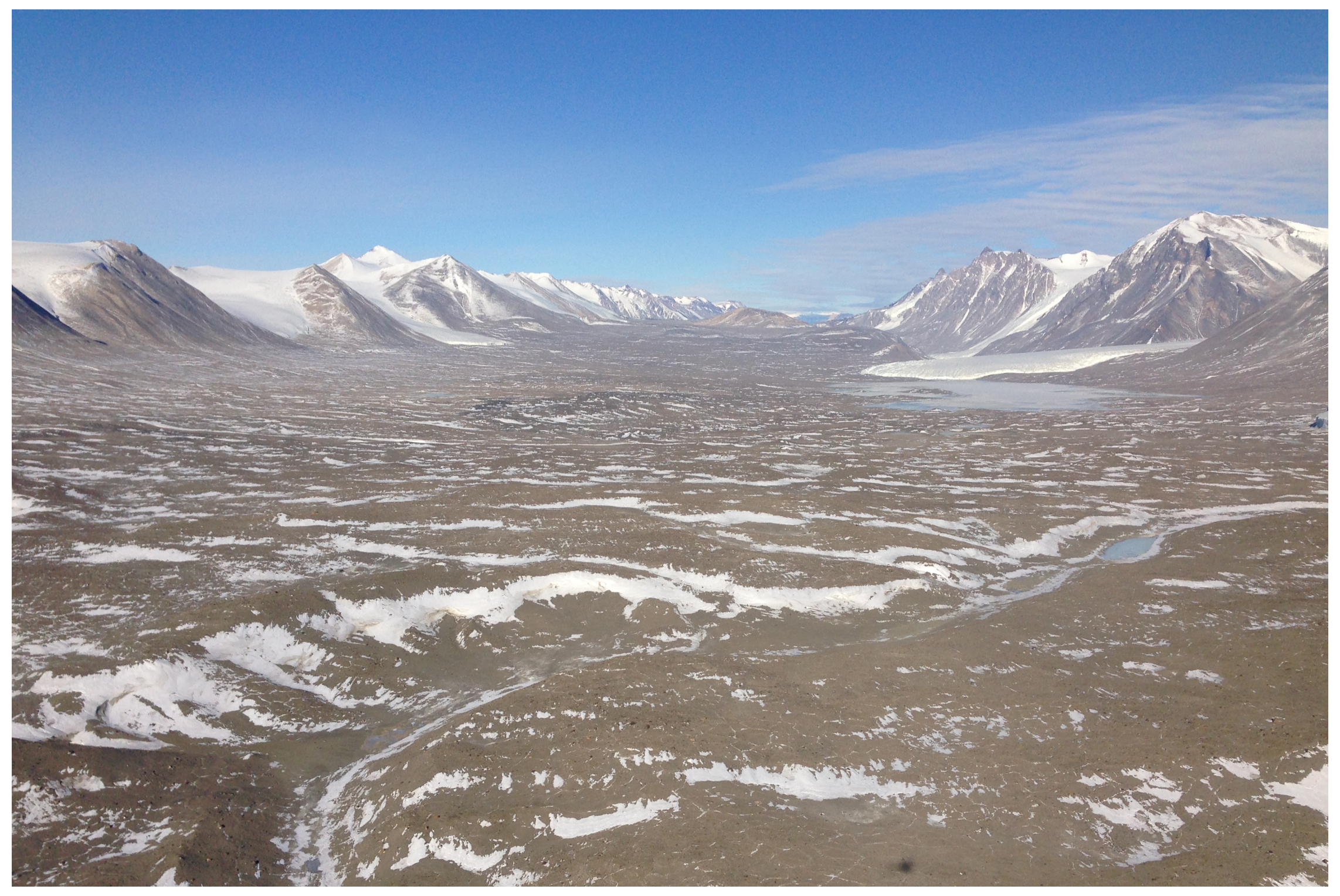

Figure 5: An aerial of Taylor Valley when flying in by helicopter from McMurdo, for summer season sampling. Lake Fryxell is visible in the distance.

Section 3. Temporal Trends

Three sample lakes show higher average turbidity in the deeper section of the photic zone than the shallow section (Figure 4). All four lakes show a larger increase in average turbidity near the surface in late season than in early season.

- FRX shows the largest difference in turbidity between shallow and deep layers.
- HOR shows little difference between shallow and deep turbidity.
- WLB shows a larger difference between deep and shallow turbidity than does ELB, as well as a larger seasonal change.

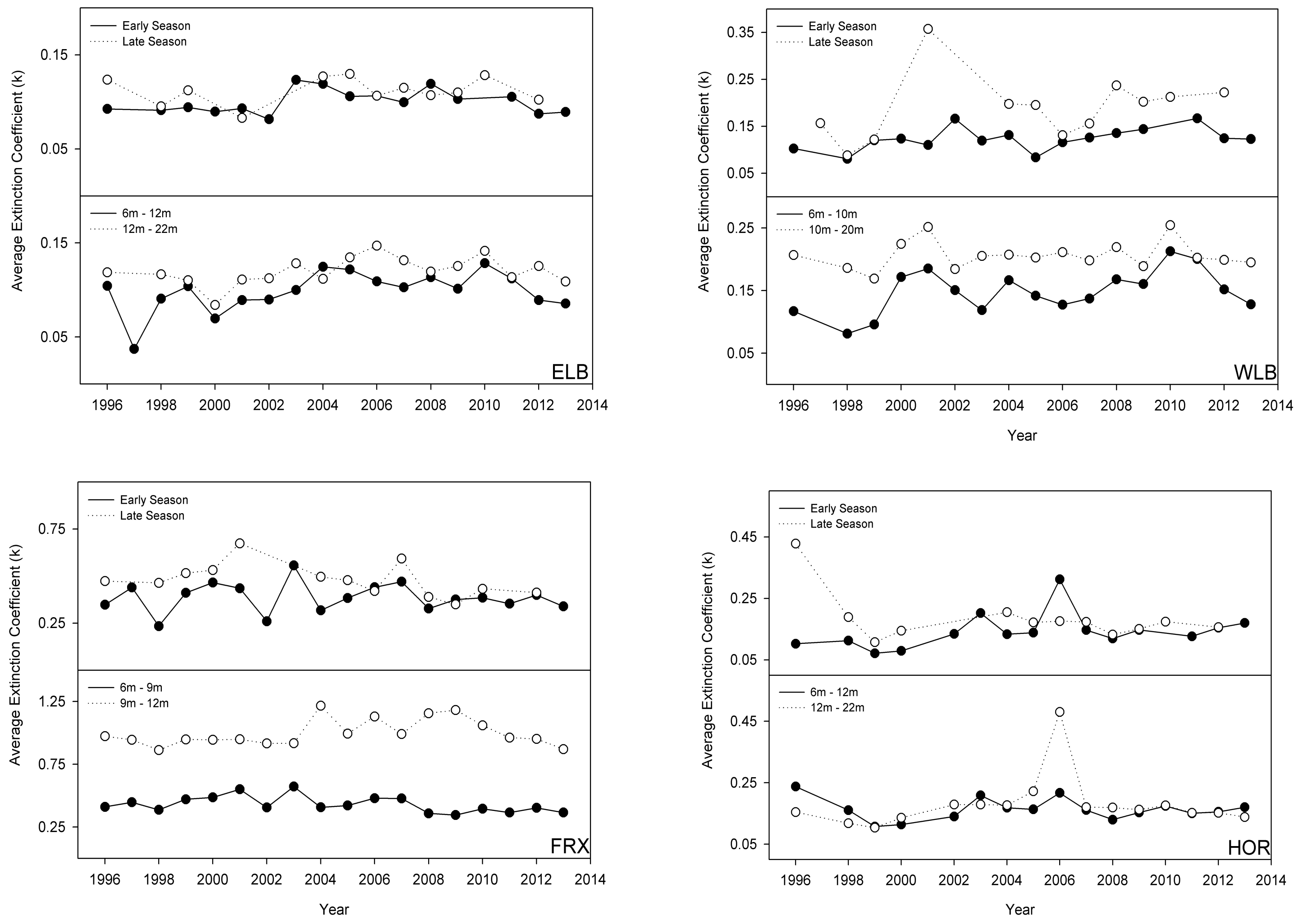

Figure 4: Representations of temporal changes in turbidity for the study lakes. Photic zone data were averaged across all relevant depths and plotted first (top panels) as early season and late season data, and second (bottom panels) as shallow and deep sections of the profile.

Acknowledgments

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