

## **Expanding observations of mixing in Toolik Lake with the North American Regional Reanalysis**

The ecology of Toolik lake depends ultimately on the the properties which govern nutrients, light and primary production. Among these influences is the relationship between temperature and mixing within the lake. Recent research has demonstrated linkages between long term variation in lake temperature and synoptic scale climate. MacIntyre et al. 2009) shows that interannual variation in the number of storm events correlates with epilimnion temperature. Storm events, characterized by strong winds and, most importantly, significant drops in air temperature, drive mixing and govern the balance between the development of a warm and stable surface layer and the deep mixing of nutrients. A significant relationship between the lake temperature at Toolik and a count of storm events suggests that synoptic scale counts of storm events may be used to predict temperatures, and thus mixing or stability at lakes across large spatial scales.

This analysis employs the National Center for Environmental Prediction's North American Regional Reanalysis (NARR) as the source of synoptic scale climate measurements. The NARR assimilates observations from across North America, extending the observations to a 1/3 degree resolution grid using numerical climate models. The analysis first investigates the validity of the NARR data at Toolik, then uses the NARR to look at climactic variability in Alaska and northern Canada.

The first step in this analysis was to demonstrate the validity of the NARR with respect to the Toolik atmospheric observations. Figures 1 a-d show comparisons of data from the Toolik lake meteorological station, located near the Toolik field station and covering summer months (June, July and August) 1988 through 2007. Toolik data was subsampled at 3-hour intervals to match the NARR temporal output. Air temperature and pressure anomalies (seasonal variation removed) are very highly correlated, west (U) and north (V) components of wind show more scatter with  $r^2 = 0.54$  and  $0.68$  respectively. The Toolik station measures lower wind speeds from the east, which may indicate the greater exposure of the met station, which is located on the south east corner of the lake. The Toolik met station also measures higher wind speeds from the south, suggesting local acceleration of winds descending from the Brooks Range.

Having demonstrated a relationship between the NARR and Toolik meteorological data, we investigate the relationship between the NARR and Toolik meteorological data with the lake temperatures. As indicated MacIntyre et al. 2009, interannual variability in lake temperature is related to total storm events, which appears to be reflected in the total wind variance in the 2-7 day band. Figure 2a shows the results of a preliminary study, comparing the total variance in the 2.5-7 day band passed NARR wind U component (again, JJA), with the Toolik epilimnion temperatures ( $r^2 = 0.65$ ). Similarly processed Toolik wind data is also shown, with  $r^2 = 0.3$ . The preliminary study used data 1988 – 2007, which is the time coverage of the Toolik meteorological data. The full NARR data set begins 1979, and the toolik epilimnion temperature data, derived from CTD casts, set begins in 1975. Figure 2b shows the NARR and Toolik epilimnion comparison as before, extending data to 1979. Including years prior to 1988 decreases the correlation to  $r^2 = 0.1$ . The year 1981 stands out with the lowest wind variance, and amongst the coldest lake temperatures. Numerous possible explanations for the lower correlation with the extended time series include shifts in the Pacific Decadal Oscillation, and a significant decrease in the number of arctic observations assimilated into the NARR after 1990 (Anna Borovikov, personal communication).

Other indicators of storm events or synoptic activity may be related to Toolik epilimnion temperatures. Figure 3 shows the average pressure difference anomaly between Toolik and a point over the Arctic Ocean, scatter plotted against epilimnion temperatures for the full NARR timeseries. Positive values indicate higher pressure at Toolik, with negative values indicating higher pressure over the Arctic Ocean. A significant correlation ( $r^2 = 0.46$ ) suggests that strong high-pressure system over the Arctic ocean correlates with milder summers at Toolik (and thus warmer lake temperatures). Higher average pressures at Toolik reflect the passing of low pressure systems over the Arctic Ocean, with associated fronts and mixing events at the lake.

Figures 4 a and b represent preliminary attempts to extend variability observed at Toolik to the broader area covered with the NARR model. These maps show the band passed NARR wind U component averaged for the Toolik Lake cold (a) and warm (b) years. (Toolik is circled on the figures). As shown previously, cold years are associated with more variance in the 2.5-7 day bands. Figure 4 a shows slightly more variance on Alaska's north slope and in the Brooks Range when compared to figure 4b.

Throughout the analysis presented here, we have used variance in a frequency band as an indicator of storm events. Future work will investigate better proxies for storm events, including the method presented in MacIntyre et al. 2009. With an improved proxy applied to NARR data, it may be possible to describe climactic effects on lake in much of the North American Arctic.