Quantifying seasonal variability in Arctic Ocean mixed layer depths from observations and modeling

Cecilia Peralta-Ferriz[1], Edward Blanchard-Wrigglesworth[2], Rebecca Woodgate[1] and Cecilia Bitz[2]

[1]Polar Science Center, APL, UW, Seattle, USA; [2]Dept. Atmos. Sciences, UW, Seattle, USA.

1 Summary

Given the recent dramatic decreases in thickness and extent of Arctic sea ice, we ask if wind-driven stirring has become a dominant driver of Arctic mixed layer depth (MLD) variability (compared with convection from sea- ice formation)? We investigate this using ~20,000 historical hydrographic observations from 1979-2012 and output from the coupled ice-ocean-atmosphere model CCSM4. We quantify Arctic MLD seasonality, and consider predictions for future variability in Arctic MLDs.

2 Observations

We use over 20,000 hydrographic profiles (CTD and xCTD, not ITP) from 1979-2012, from ice-covered and ice-free regions.

We consider 6 different regions (**Fig. 1**) based on water masses characteristics and freshwater sources.

MLD is estimated using a density threshold method with $\Delta\rho = 0.1 kg/m^3$, which is within the range of previous estimates of Arctic MLD[1,2].

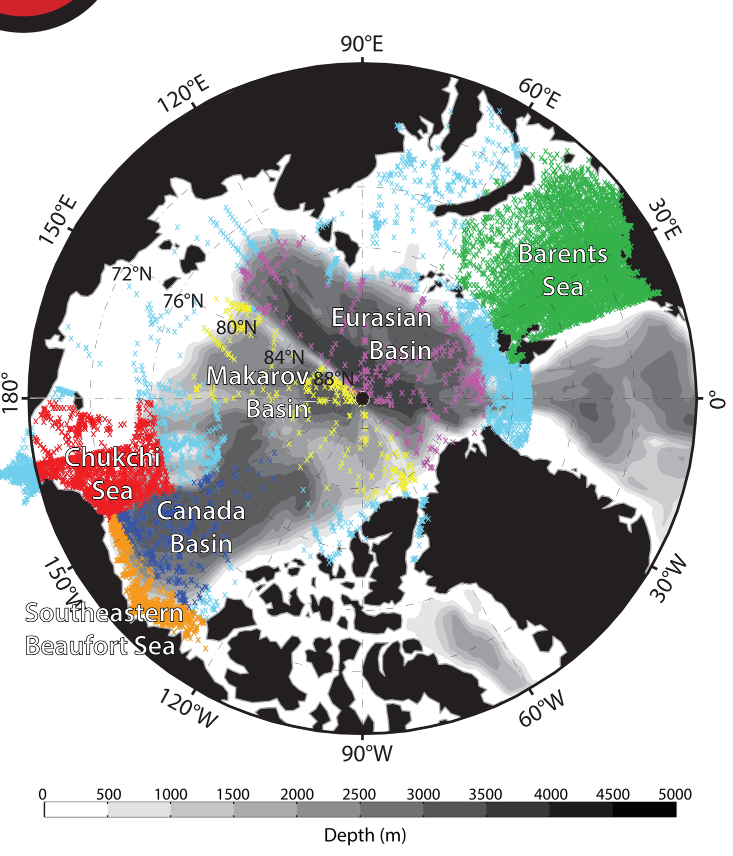

FIG. 1. Location of hydrographic profiles (color-coded by region).

3 Observational climatology

We quantify the seasonality of Arctic MLDs in 6 regions, finding that winter MLDs are ~50 m deeper in the eastern Arctic (Eurasian Basin, Barents Sea) than in the western Arctic (Chukchi Sea, Southeastern Beaufort Sea, and Canada Basin) (**Fig. 2**). Summer-to-winter changes in MLD vary from ~ 20-30 m in the western Arctic, to ~50-70 m in eastern Arctic (**Fig. 3**). The associated seasonal sea-ice growth/melt varies from ~1.3 m in the western Arctic to ~0.8 m in the eastern Arctic[3].

Our Canada Basin results are in good agreement with MLD estimates from Ice-Tethered Profiler (ITP) data[4].

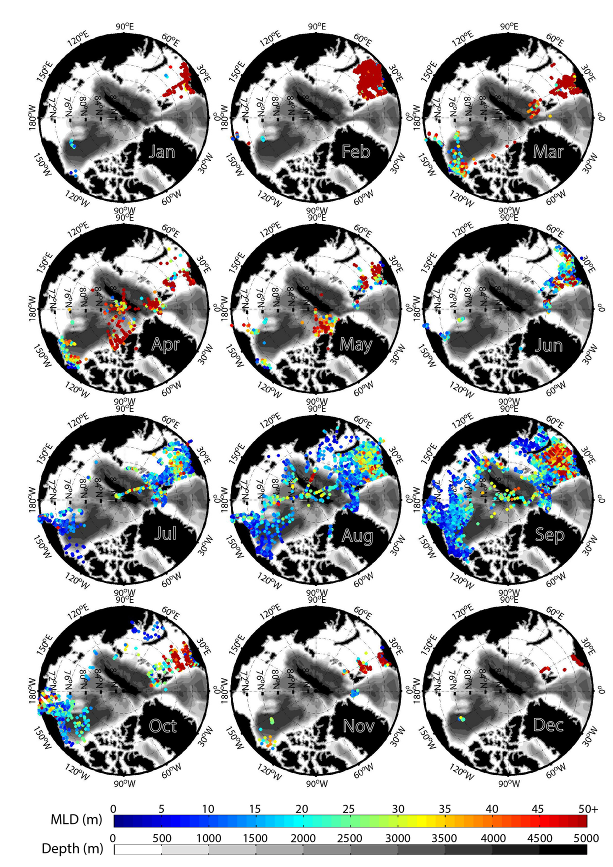

FIG. 2. Seasonal climatology of MLD of Arctic MLD observations.

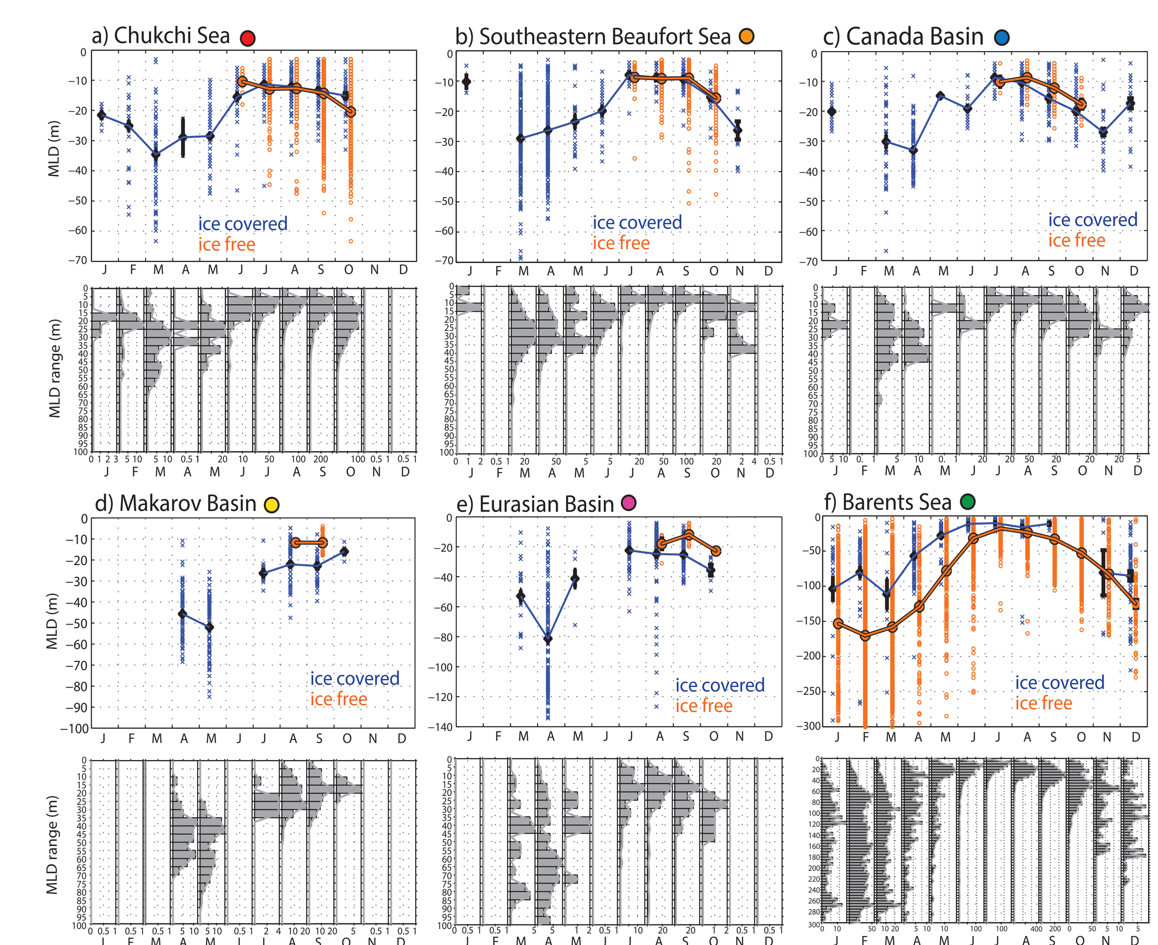

FIG. 3. Monthly mean MLD in the 6 regions of **Fig. 1**, with histograms of occurrence.

4 Wind-MLD relationship

Data show deeper MLDs in ice-free regions when the wind is stronger (Fig. 4). This relation is consistent through all regions.

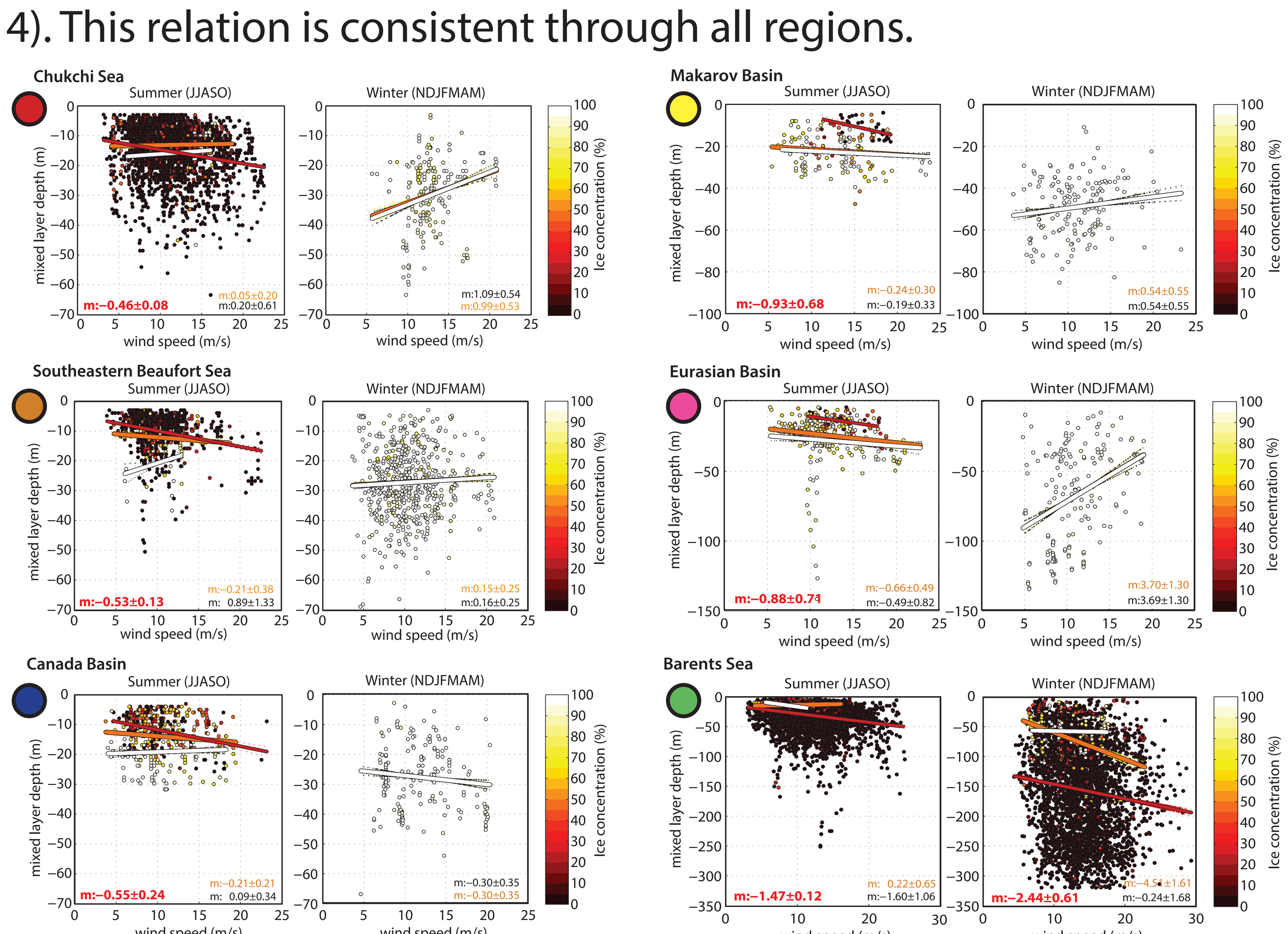

FIG. 4. Observed MLD vs maximum wind speed in the 5 days preceeding the cast. Data points and linear fits are color-coded according to SSM/I sea-ice concentrations: red (0-15% ice), orange-yellow (>15%) and white (>80%). Dashed lines mark the 95% confidence interval of the linear fit.

5 Comparing CCSM4 to data

Modeled and observed summer MLDs are in good agreement all through the Arctic[5]. Modeled winter MLDs are deeper than observed MLDs in most regions, except the Eurasian Basin (**Fig. 5**) and the Barents Sea. Pan-Arctic modeled MLD climatology[5] is shown in **Fig. 6**.

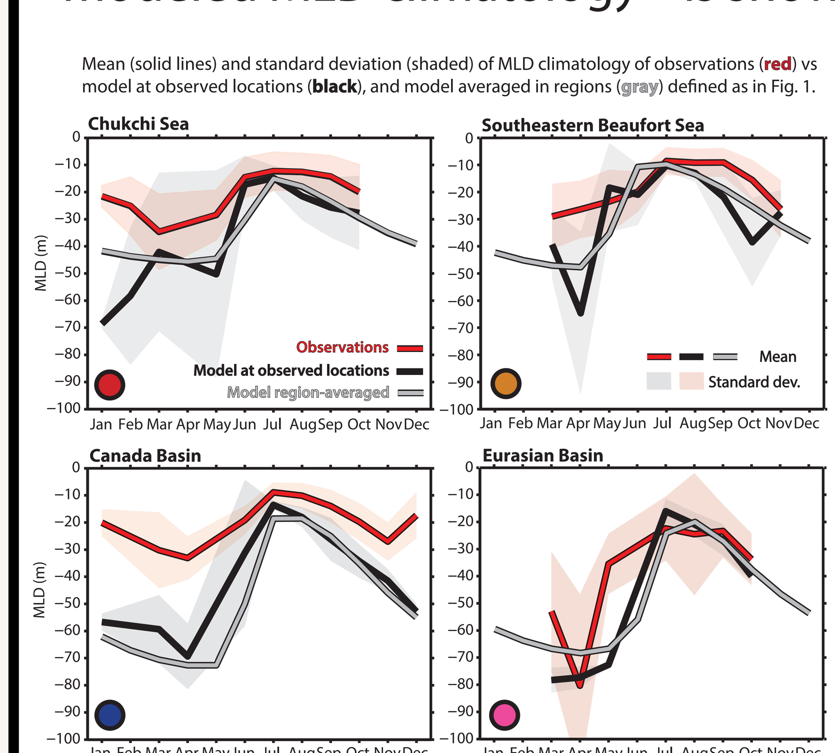

FIG. 5. Observed and modeled monthly mean climatology of MLD in 4 regions. Colored dots indicate regions as per **Fig. 1**.

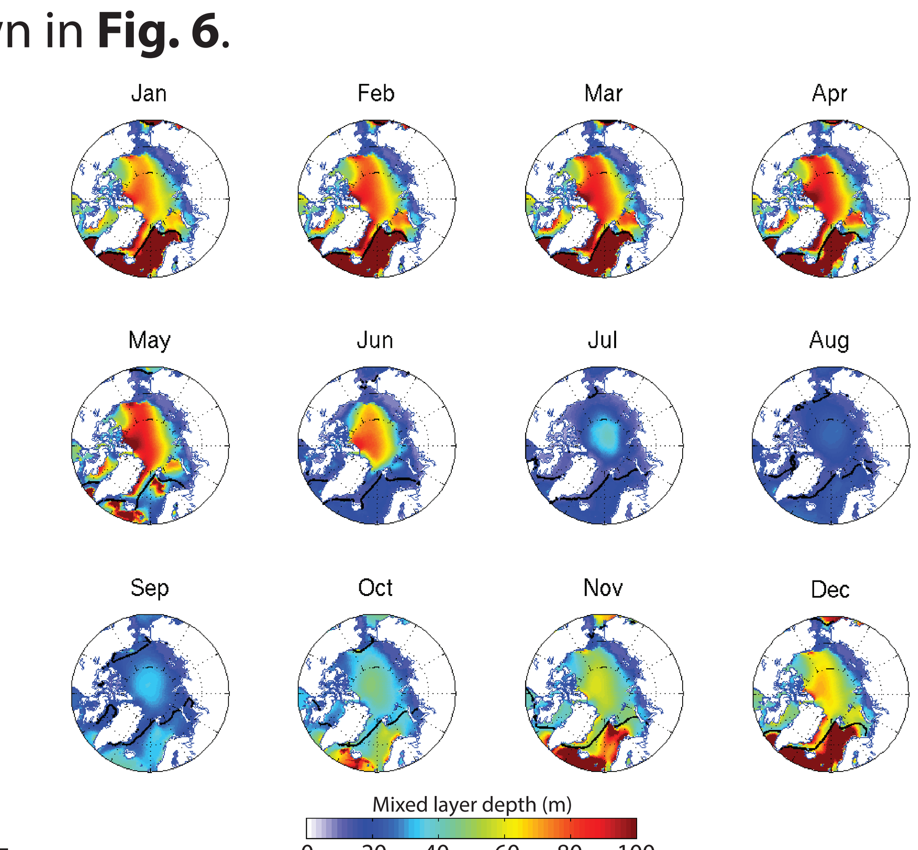

FIG. 6. Monthly mean Arctic MLD climatology obtained from CCSM4 for the period 1981-2000.

6 MLD drivers and future predictions

CCSM4 shows summer Arctic MLD variability is related to both sea ice melt and wind stirring. In the Canada Basin and at the ice edge, summer MLD are strongly correlated with ice-melt, but north of the Canadian Archipelago and in the Southeastern Beaufort Sea, summer MLD are more strongly correlated with wind forcing (**Fig. 7**).

CCSM4 projections show MLD shoaling (**Fig. 8**, **red**) in spring and fall, but deepening (**Fig. 8**, **blue**) in the summer, as the ice disappears[5].

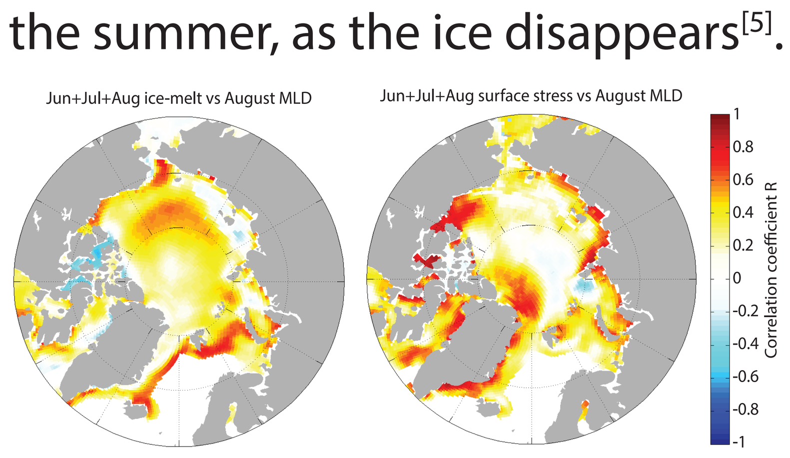

FIG. 7. Correlation between the August MLD with total Jun-Aug ice-melt (left), and with total Jun-Aug surface stress (right).

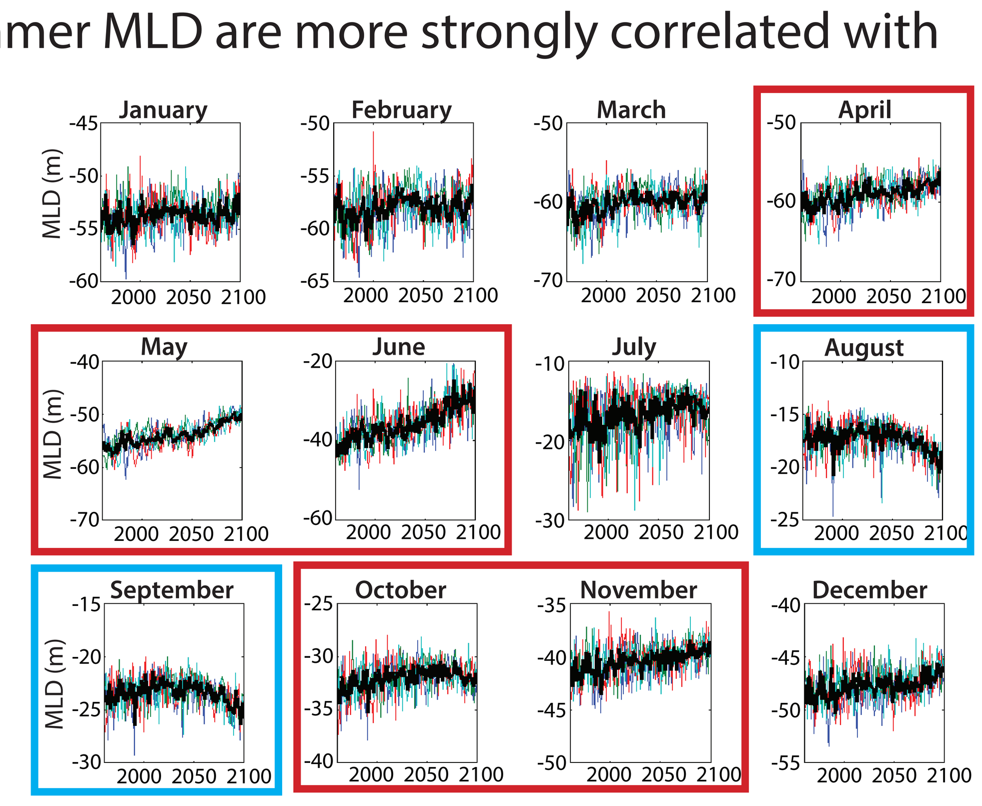

FIG. 8. CCSM4 future predictions of Arctic Ocean MLD by month. Different runs are shown in colors, the mean is in black.

7 Conclusions

1. Using hydrographic observations from 1979-2012 and CCSM4, we quantified cross-Arctic variability in MLD seasonality (**Fig. 3**).
2. Modeled summer MLDs are correlated with June to August total ice melt in the high Arctic and at the ice edge, and correlated with June to August surface stress north of the Canadian Archipelago and in the Southeastern Beaufort Sea (**Fig. 7**).
3. Observed correlations between increased wind stirring and deeper MLD in open water in summer may explain the CCSM4 future predictions of MLD deepening in an ice-reduced Arctic (**Fig. 4** and **Fig. 6**).

Further information, please contact: Cecilia Peralta-Ferriz, **ferriz@uw.edu**

References

[1] Jackson, J. M., W. J. Williams, and E. C. Carmack (2012), Winter sea-ice melt in the Canada Basin, Arctic Ocean, Geophys. Res. Lett., 39, L03603, doi:10.1029/2011GL050219.
[2] Steele, M., W. Ermold, and J. Zhang (2011), Modeling the formation and fate of the near-surface temperature maximum in the Canadian Basin of the Arctic Ocean, J. Geophys. Res., 116, C11015, doi:10.1029/2010JC006803.
[3] Peralta-Ferriz, C., E. Blanchard-Wrigglesworth, R. Woodgate and C. Bitz, Quantifying variability of mixed layer depths in the Arctic Ocean, *in prep.*
[4] Toole, J. M., M. L. Timmermans, D. K. Perovich, R. A. Krishfield, A. Proshutinsky, and J. A. Richter-Menge (2010), Influences of the ocean surface mixed layer and thermohaline stratification on Arctic Sea ice in the central Canada Basin, J. Geophys. Res., 115, doi:doi:10.1029/2009JC005660.
[5] Blanchard-Wrigglesworth, E., C. Peralta-Ferriz, R. Woodgate and C. Bitz, Arctic Ocean mixed layer depths in a GCM, *in prep.*