Seasonal evolution of the Mixed Layer Depth (MLD) using Argo profilers

In oceanography, the surface *Mixed Layer Depth* (MLD hereinafter) refers to the part of the water columns where the properties have been homogenized due to winds, surface heat fluxes, or other processes taking place at the air-sea interface. At the bottom of the MLD, a relatively strong gradient is observed: if there is an abrupt change in temperature, then the layer corresponding to that change is called *thermocline*; if there is an abrupt change in salinity, one refers to a *halocline.*

The MLD is where many processes related to physics (wind forcing and heat exchanges), chemistry (dissolution of CO_2) and biology (phytoplankton production) take place. Hence it is essential to properly measure and understand its variations.

There are several methods to evaluate the MLD knowing the vertical profiles of temperature and salinity:

1. The fixed temperature criterion: the MLD is the depth where the temperature has decreased by a fixed value (usually 0.2ºC) with respect to the temperature measured at 10 m.
2. The fixed density criterion: similar to the previous methods, except that we look for a density difference (0.03 kg/m³).
3. The variable density criterion: the density variation depends on each profile and is equivalent to a fixed temperature change equal to 0.2ºC.

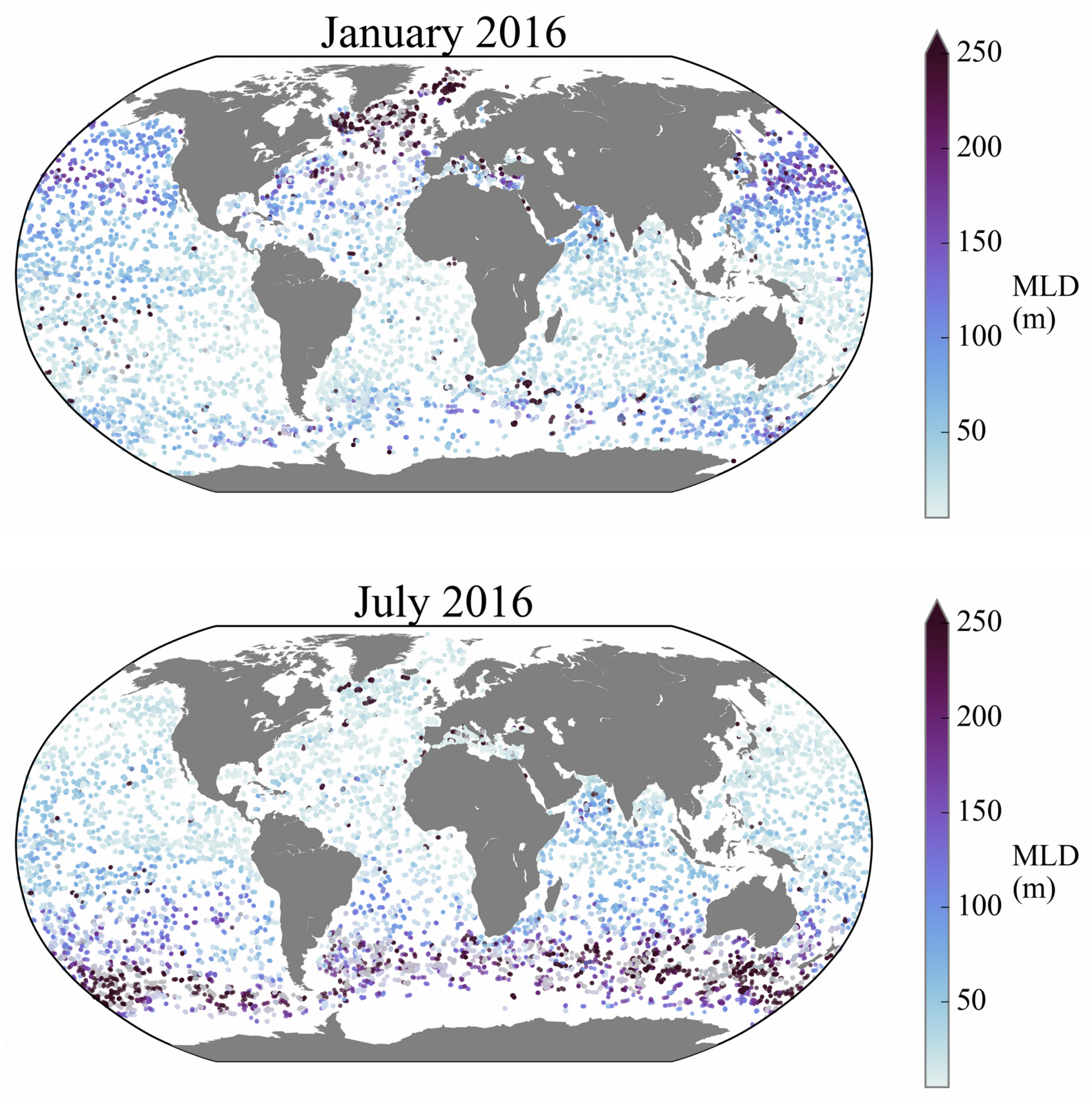
Whatever the select method, the calculated values generally range from 25 to 200 m, though deeper layers can be observed. For example MLD below 700 m have been reported in the Greenland-Iceland-Norway area.

Among the in situ platforms available through the Copernicus Marine Environment Monitoring Service, the Argo profilers have ideal sampling characteristics (repeated vertical profiles of temperature and salinity) to properly capture the spatial and temporal variability of the MLD.

In this example we used all the profilers available as of August 10, 2016, for the months January (3914 platforms) and July 2016 (3721 platforms). The MLD is computed using the density criterion with a threshold of 0.125 kg/m³, the values reported in [Monterey and Levitus, 1997].

Both maps illustrate the type of data coverage one can expect from this dataset: all the oceans are covered, with a lower density of platforms at higher latitudes. Some coastal areas in Asia also are less sampled.

In January, the majority of the largest MLD values occur at high latitudes in the northern hemisphere, especially in the Greenland-Iceland-Norway area mentioned before, but also along the Western Boundary Currents (WBC) of the northern hemisphere: the Gulf Stream and the Kuroshio. The July situation is somewhat reversed: the largest values are observed in the southern hemisphere along the path of the Antarctic Circumpolar Current. The seasonal cycle in the subtropics and in midlatitudes is particularly visible when comparing the two maps.



January 2016
250
200
150
100
50
MLD (m)
July 2016
250
200
150
100
50
MLD (m)

Datasets:
INSITU_GLO_NRT_OBSERVATIONS_013_030

References:
http://www.ifremer.fr/cerweb/deboyer/mld/Surface_Mixed_Layer_Depth.php
https://www.esr.org/outreach/glossary/mixed_layer.html
https://en.wikipedia.org/wiki/Mixed_layer
http://oceanmotion.org/html/background/western-boundary-currents.htm

Publications:
de Boyer Montégut, C., G. Madec, A. S. Fischer, A. Lazar, and D. Iudicone, 2004. Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology. *Journal of Geophysical Research*, **109**: C12003.

Monterey, G., and S. Levitus, 1997: Seasonal variability of mixed layer depth for the World Ocean. NOAA Atlas, NESDIS 14, 100 pp. Washington, D.C.

Tools:

Python-Ocean package, version 0.2.5: https://github.com/pyoceans/python-oceans
http://dx.doi.org/10.5281/zenodo.17359