Advanced timing of spring mixed layer development in recent Oyashio region

○ Tsueno Ono, Akira Kusaka (HNF/FRA)

Inter-annual variation in the peak-timing of Spring-Copepod community in Oyashio region

[Chiba et al., 2006, GCB]

*temporal variation of zoopl. phenology indicates that there should be any temporal variation in the hydrographic seasonality, e.g., seasonal MLD development
data

- hydrographic data (vertical T, S data) from two on-line data bases was used
  JODC data base (<http://www.jodc.go.jp/index_e.html>)
  A-line data base(<http://hnf.fra.affrc.go.jp/a-line/>)
- open North Pacific, 38N-43.5N, 143E-150E
- near-coastal data were eliminated
- Oyashio data were extracted based on T<5°C at 100m
  ( 1743 data in total)

*obtained data are then divided into the following 10-day seasonal subset.

- Early April [Apr.1 - Apr.10]
- Mid April [Apr.11 - Apr.20]
- Late April [Apr.21 - Apr.30]
- Early May [May 1 - May 10]
- Mid May [May 11 - May 20]
• density difference from 0m and each reference depth ($\Delta \sigma_T[x]$, $x = 30m, 50m, and 75m$) was calculated.

• percentage of the station with $\Delta \sigma_T[x] > 0.125$ was calculated for each $X$ in each 5-year interval in each 10-days seasonal subset.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Apr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid Apr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late Apr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early May</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid May</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*if only less than 10 $\Delta \sigma_T[x]$ data were available for a 5-y x 10-day parcels, we eliminated statistical calculations for that period.
data distributions

○ early-
△ mid-
★ Late-
Apr. (Blue)
May (red)
Result (1): time series of MLD % occurrence

Temporal variation of MLD distribution within Oyashio region:

- **Early Apr.**
  - MLD < 75m
  - MLD < 50m
  - MLD < 30m

- **Mid Apr.**
  - MLD < 75m
  - MLD < 50m
  - MLD < 30m

Graphs show the percentage occurrence of different MLD depths from 1970 to 2005.
Temporal variation of MLD distribution within Oyashio region:

- **Late April**
- **Early May**
- **Mid May**
percent occurrence of MLD shallower than 30m in the spring Oyashio region

Expected date at which >50% of the Oyashio region has MLD shallower than 30m ($T^{30}$) can be calculated from the above data as:

$$T^{30} = T_{i-1} + \left[ T_i - T_{i-1} \right] \times \left[ 50 - m^{30}_{i-1} \right] / \left[ m^{30}_i - m^{30}_{i-1} \right]$$

$m^{30}_i$; observed % occurrence of $\Delta \sigma_T[30] > 0.125$ at seasonal subset $i$

$T_i$; average observation date of the data used at seasonal subset $i$
Result (2): time series of MLD development timing ($T^{30}$ and $T^{50}$)

**temporal variation of the timing of seasonal mixed layer development**

- $T^{30}$: significant advance between late-70s and early-80s
- $T^{50}$: gradual advancement after 1980
  - *slight delay from 1970s to early-80s...?

At all events, enhancement of MLD development timing during 1970 - 2005 is observed as:

- $T^{30}$: ~9 days ($5.2 \Rightarrow 4.9$)
- $T^{50}$: ~6 days ($4.6 \Rightarrow 4.4$)
what is the cause of MLD-development advance?

**temporal variation of SST**

Oyashio region

**temporal variation of SSD**

Oyashio region
temporal variation of $\Delta$SSD between seasonal subsections
Oyashio region

SSD decrease [$\sigma$ theta]

year

Based on the temporal variation analysis of MLD development timing, it is found:

1] During the years from 1970 to 2005, average timing of spring MLD development with MLD = 50m ($T^{50}$) has been advanced by 6 days, and that with MLD = 30m ($T^{30}$) has been advanced by 9 days.

2] The cause of advancement is so far unclear, but it seems to be related to:
   # inter-annual increase of the spring Oyashio SST
   # corresponding advance of seasonal SSD descend during the April.

3] Observed temporal variation of $T^{50}$ and $T^{30}$ did not exactly correlates with the formerly-observed biological phenology changes [e.g., Zoopl. abundance peak timing, Chiba et al., 2006]. Temporal variations of many other hydrographic seasonality characters to understand complicated physical-biological couplings in the phenology changes,