

Spatial and Temporal Variations of the Mixed Layer Depth in the East Sea (Japan Sea)

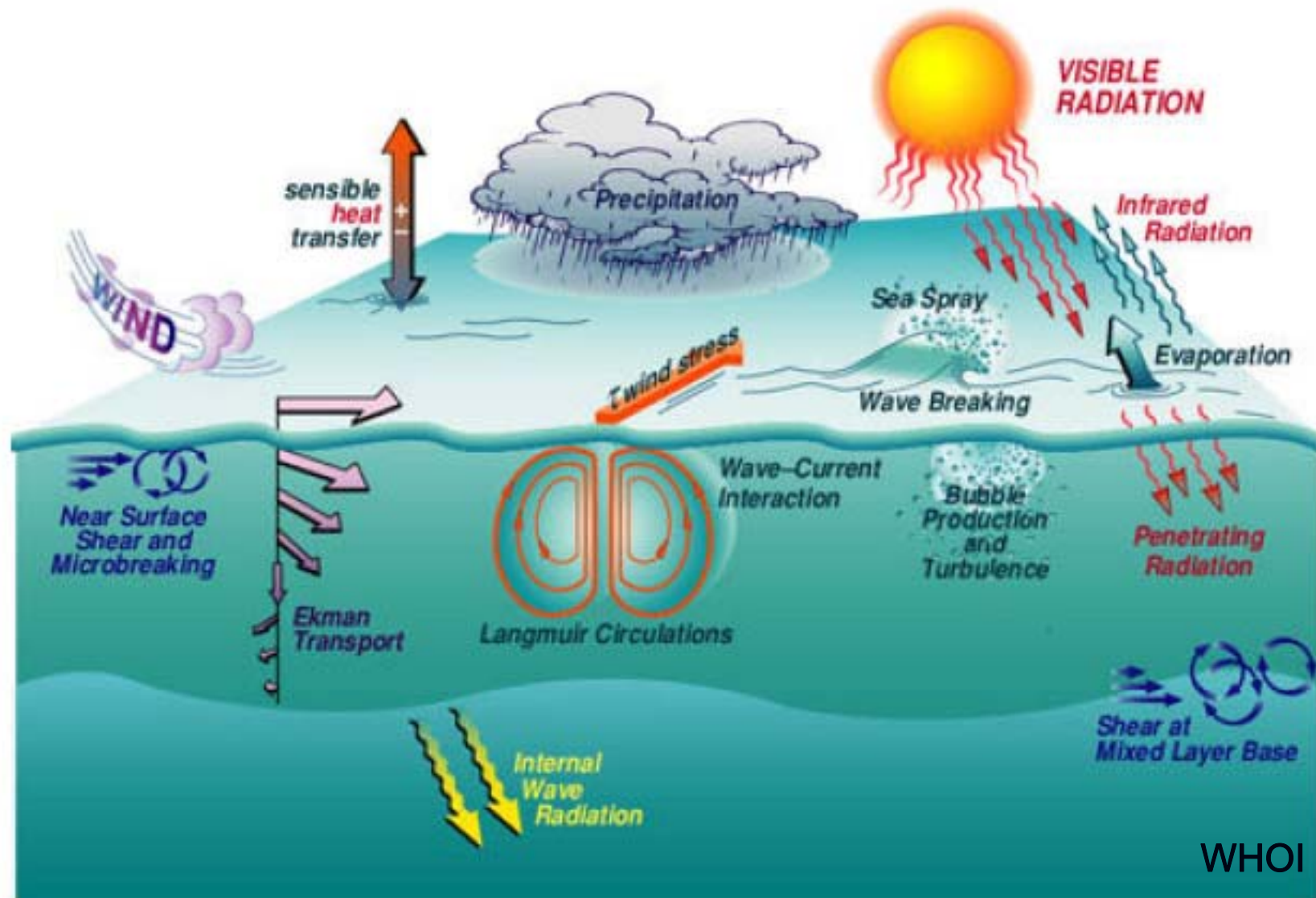
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Schematic diagram of physical process occurring near the air-sea interface



WHOI

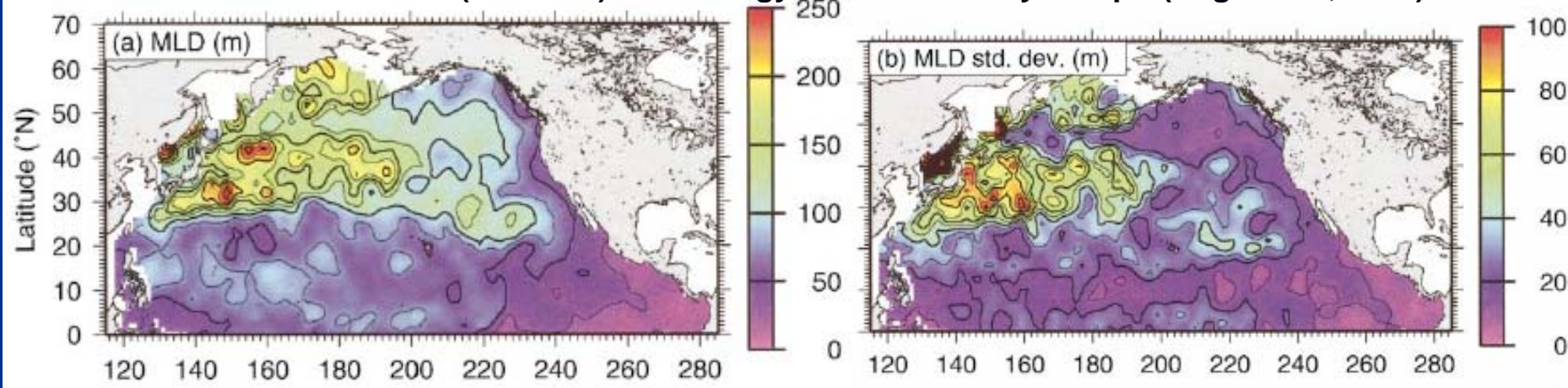
- **Backgrounds**
- **Results**
- **Summary**

Previous Study

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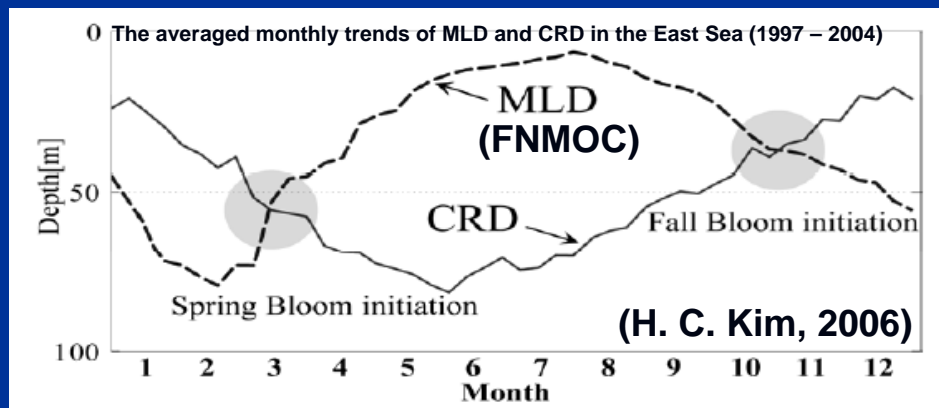
- Roughly described as a part of the North Pacific
 - Changes in winter and spring MLD in the North Pacific on decadal and basin scales affect biological production (Polovina et al., 1995).
 - The much deeper ILD in the northeast Pacific in winter and and spring relative to the MLD reveals a “barrier layer” (Kara, 2000).
 - Appeared considerable differences in the MLD and its water properties in winter season (Suga et al., 2004).

The late winter (Feb–Mar) climatology of the mixed layer depth(Suga et al., 2004)



Previous Study

- **The features of the mixed layer depth were analyzed in limited area and period of the East Sea**
 - During both of the active cooling and heating seasons the MLD and heat flux variations are tightly correlated in **the southern part of the East Sea** (Shim and Kim, 1981).
 - **The short-term variation of the mixed layer in the Korea Strait** in autumn is mainly determined by advection rather than air-sea interaction (Jang et al., 1995) .
 - **Described spatial distribution of the mixed layer depth** using the observation and the simulation **for winter convection and warm season** (Trusenкова et al., 2005).
- **The phytoplankton growth is linked with the mixed layer depth in the East Sea**
 - The bimodal pattern of phytoplankton growth is linked with the seasonal variation of mixed layer depth (H. C. Kim, 2006).



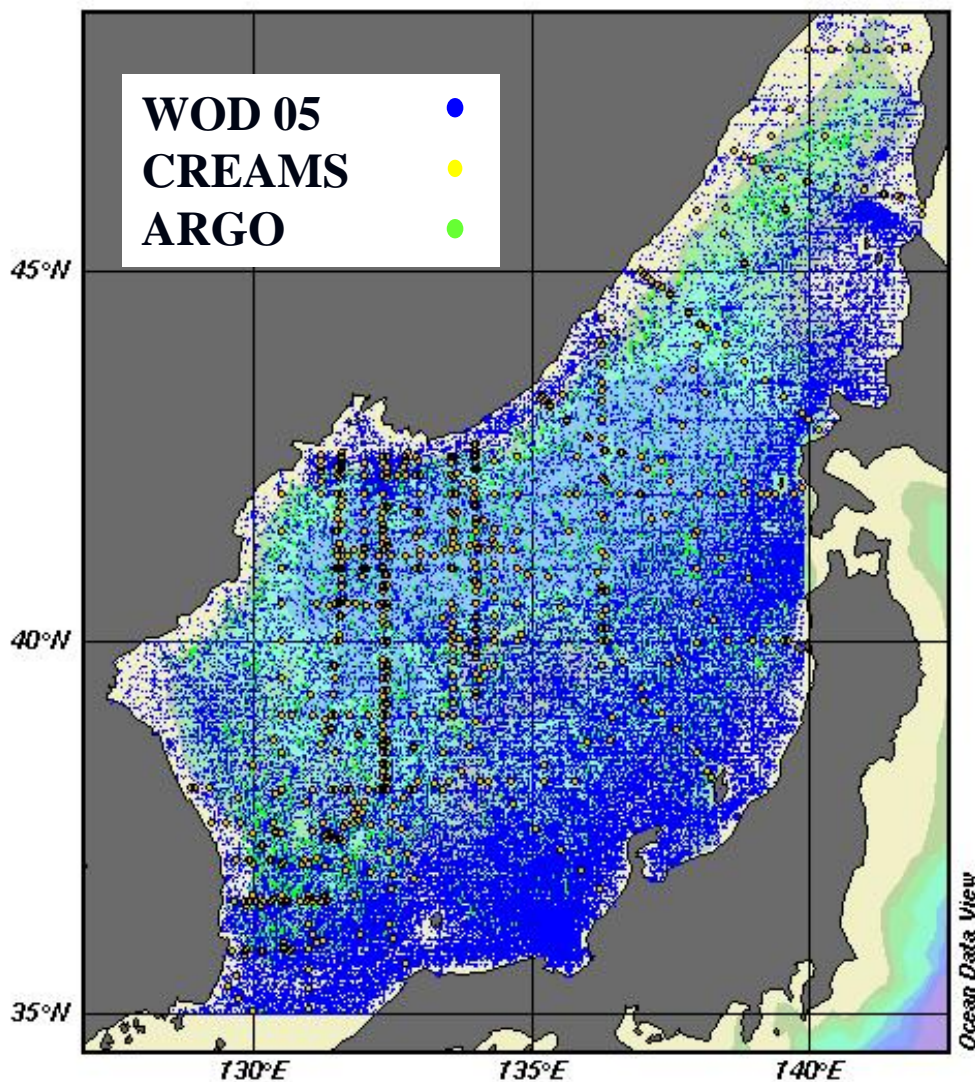
As MLD became shallower and deeper, the bloom occurred in spring and fall, respectively.

Objectives

- Knowledge of the mixed layer depth variability is important for **air-sea interaction, upper ocean dynamics, ocean biology, ocean chemical process, and fishery.**
- Because of the spatial and temporal restriction of observations, **the features of the mixed layer depth have been poorly studied in the East Sea.**
- **Investigate seasonal variation of the mixed layer depth in the whole East Sea using newly updated observations.**
- **Analyze characteristics of distribution of the seasonal mixed layer depth**

Data and Methodology 1

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■ Data sources

■ World Ocean Database 2005

- 2006.05.19 online released
- OSD, MBT, XBT, MBT, CTD, PFL etc
- Included NODC, JODC, KODC data

■ Circulation Research of the East Asian Marginal Seas Program

- 1993 ~ 2002 : High resolution CTD
- For winter and summer months

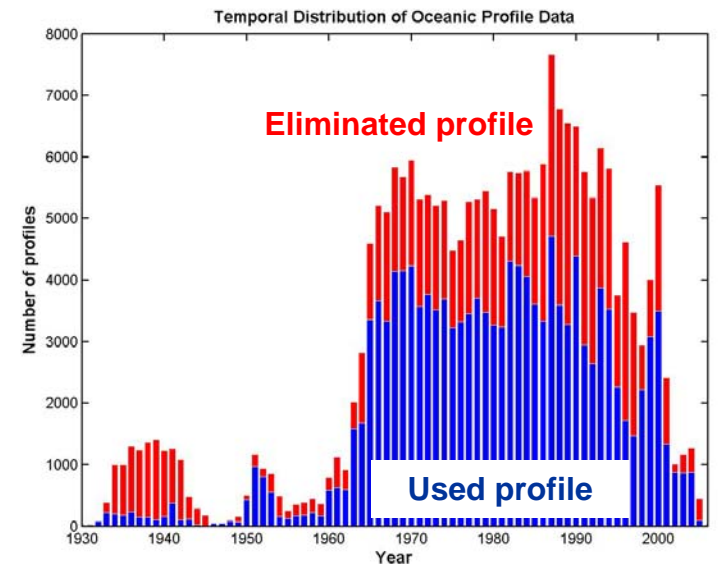
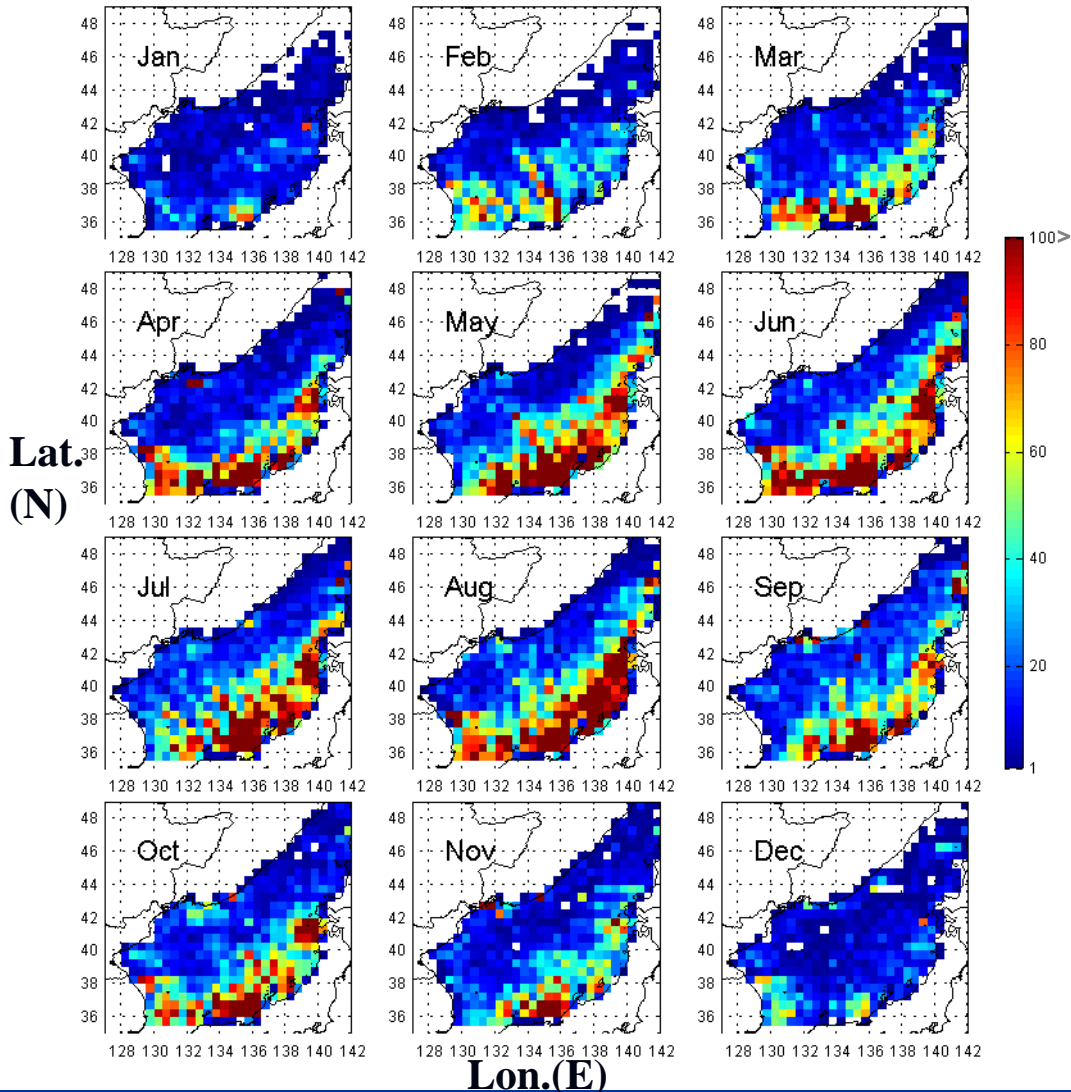
■ AGRO float data

- 1993 ~ 2002 : Temp. & Sal.
- not included in WOD 05

Total number of oceanic Profiles : 223,568

Data and Methodology 2

Monthly spatial distributions of temperature profile Data after applying Q. C.



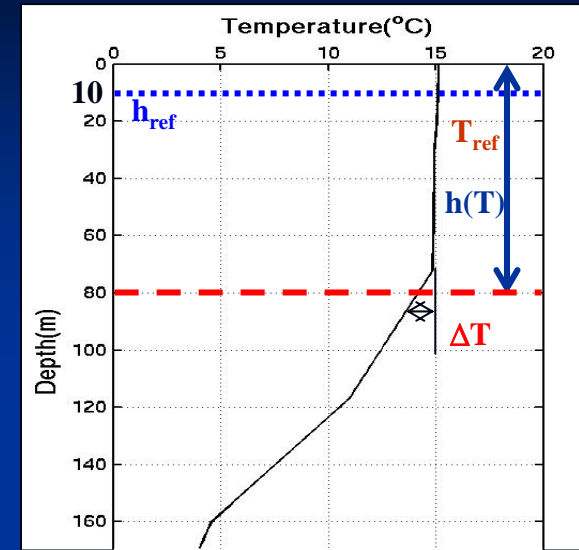
- Data range : 1930 – 2005
- Eliminate profile applying Q.C. (38%)
 - Beginning above 10m
 - Observed level depth more than 100m
 - Severe spiky profile
 - Data with inversions in depth
 - Obviously unrealistic ones in data
- The northeastern of the East Sea, relatively poor data coverage

Data and Methodology 3

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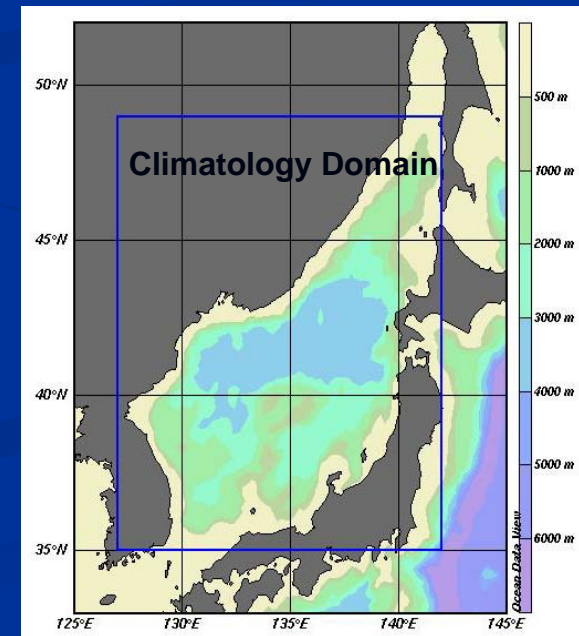
■ Defining of the mixed layer depth

- Only temperature profiles used
 - Salinity data: poor coverage and quality
- MLD criterion
 - $\Delta T = 0.2^\circ\text{C}$, Ref. depth = 10m (Montegut et al. 2004)
- To estimate the exact depth at which the difference criterion is reached, applying a linear interpolation between observed levels.

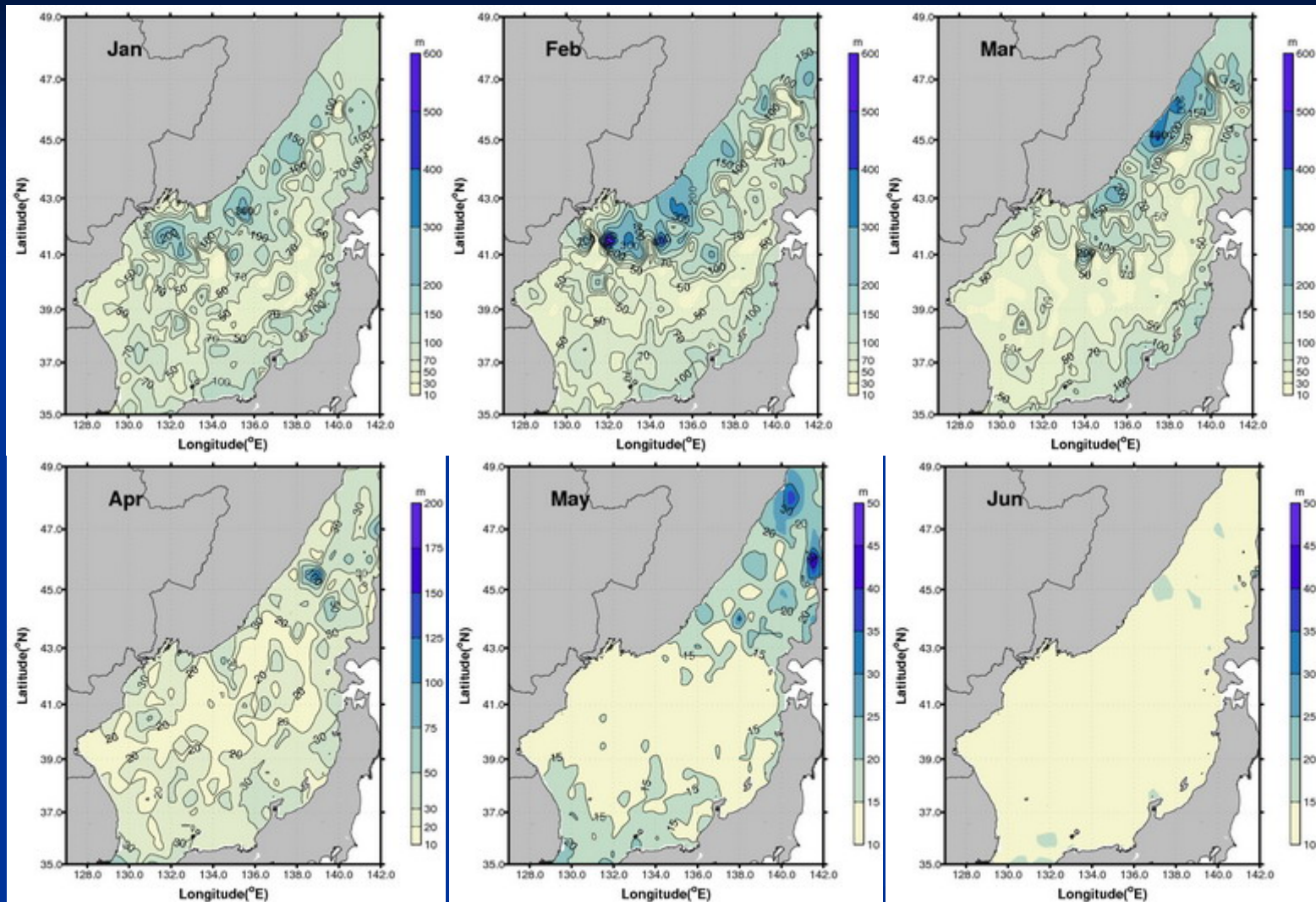


■ MLD Climatology (0.5×0.5 degree)

- Median MLD derived from the individual profiles in a grid
- Kriging (Search Radius ; 200km) for missing grid
- Domain : $127 - 142^\circ\text{E} / 35 - 49^\circ\text{N}$



Monthly distributions of the MLD 1

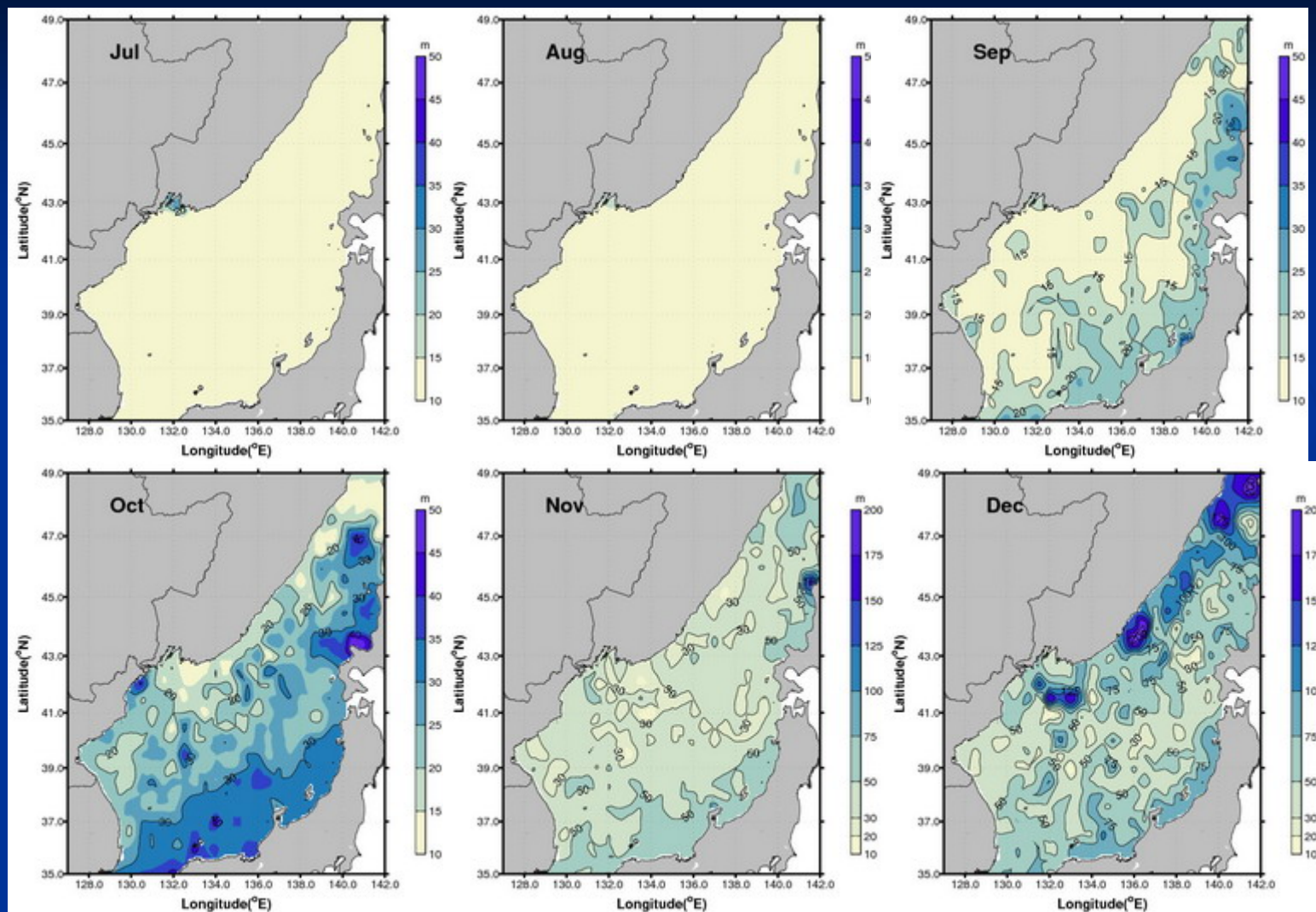


The northern side of sub-polar front is very deep, the southern side is intermediate deep and sub-polar front region is shallow for winter months.

The MLD shallowing over the whole East Sea as warm season progresses.

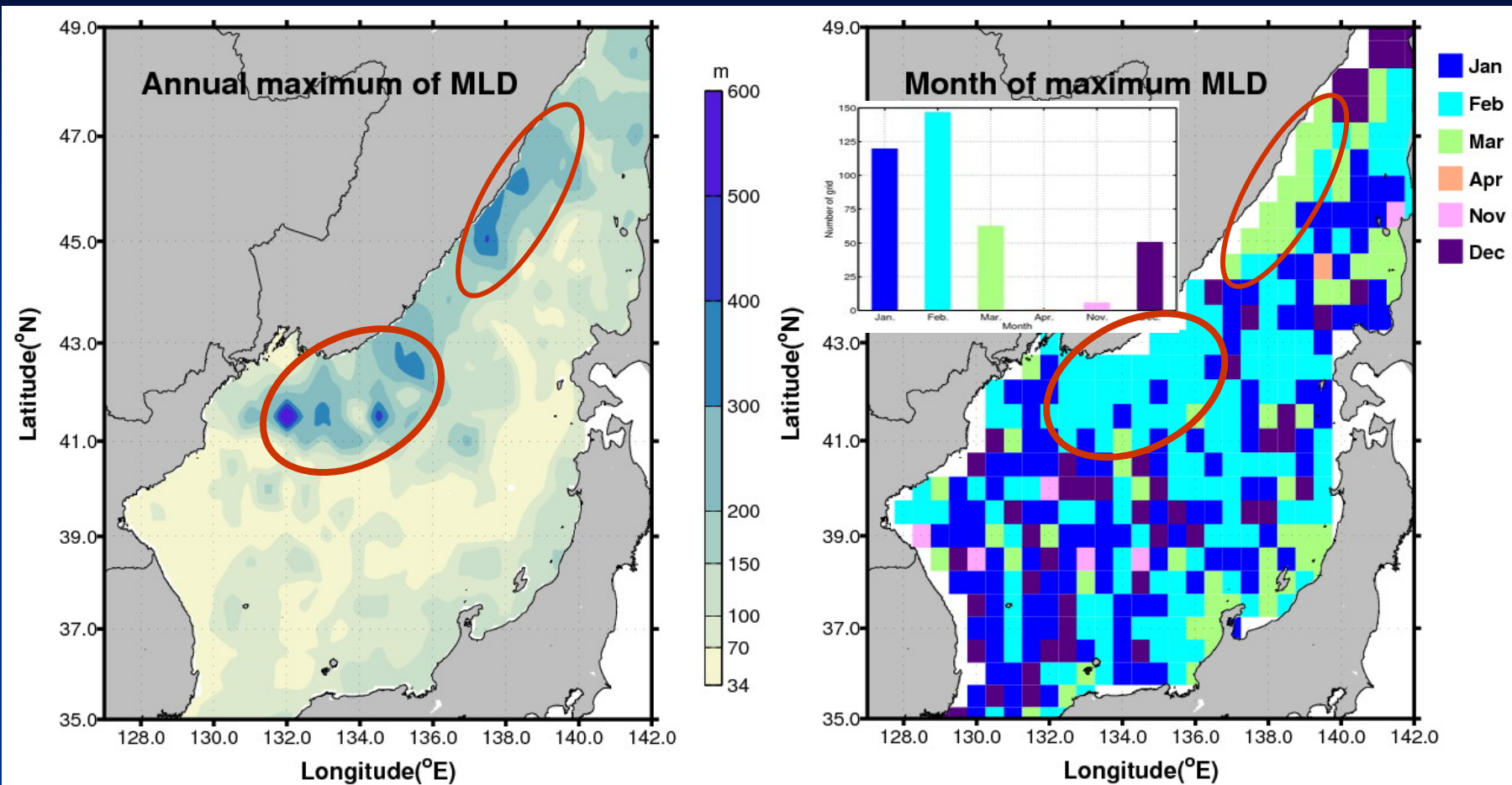
Monthly distributions of the MLD 2

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From July through August, the MLD is very thin less than 15m over the East Sea. In September, MLD deepening in the southern part of the East Sea and west coast of Japan. The southeastern part deepens faster than the northwestern part until November.

Monthly distributions of MLD 3

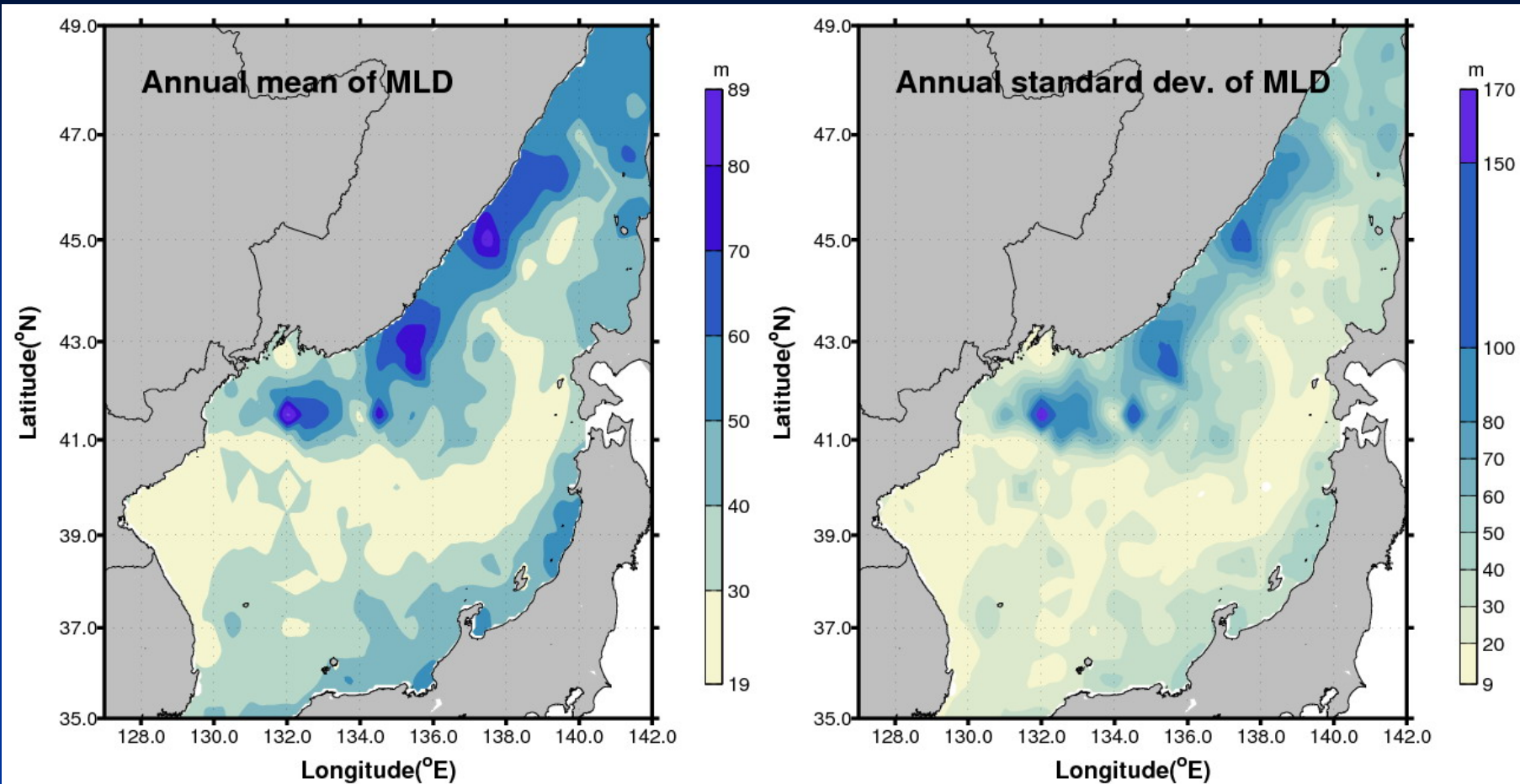


The deepest MLDs appeared in offshore of Vladivostok and Primorye coast for February and March.

The shallow MLD maximum regions (less than 70m) found along east coast of Korea and widespread in the sub-polar front region.

Month of maximum MLD mostly exists in January and February

Seasonal variation of MLD



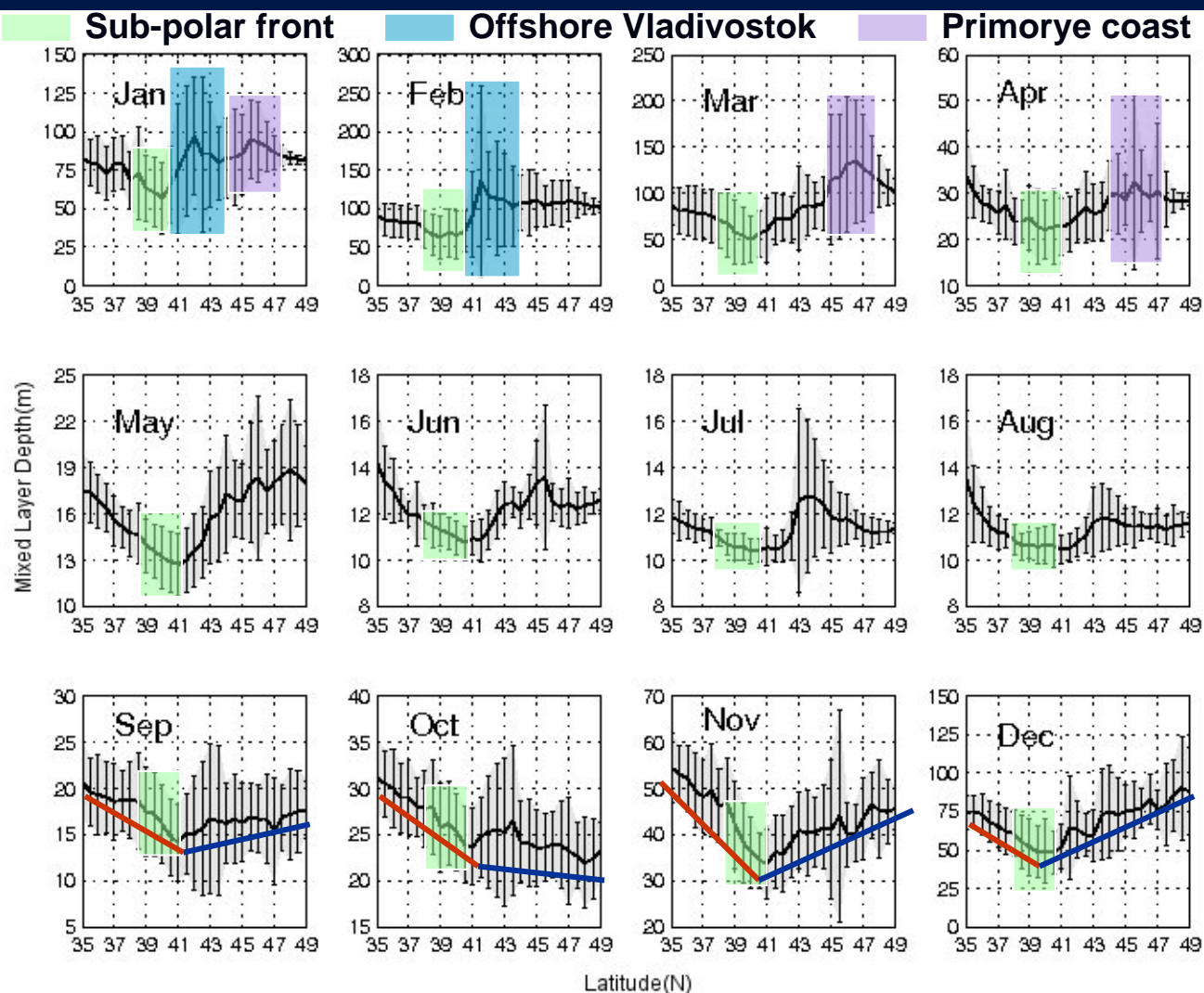
The deep MLD regions appeared in the both side of sub-polar front.

- From the Tartarsky strait to the off the Vladivostok
- West coast of Japan
- The northern side of sub-polar front deeper than the southern side

Seasonal difference is also large in those areas.

Meridional distributions of zonal mean MLD

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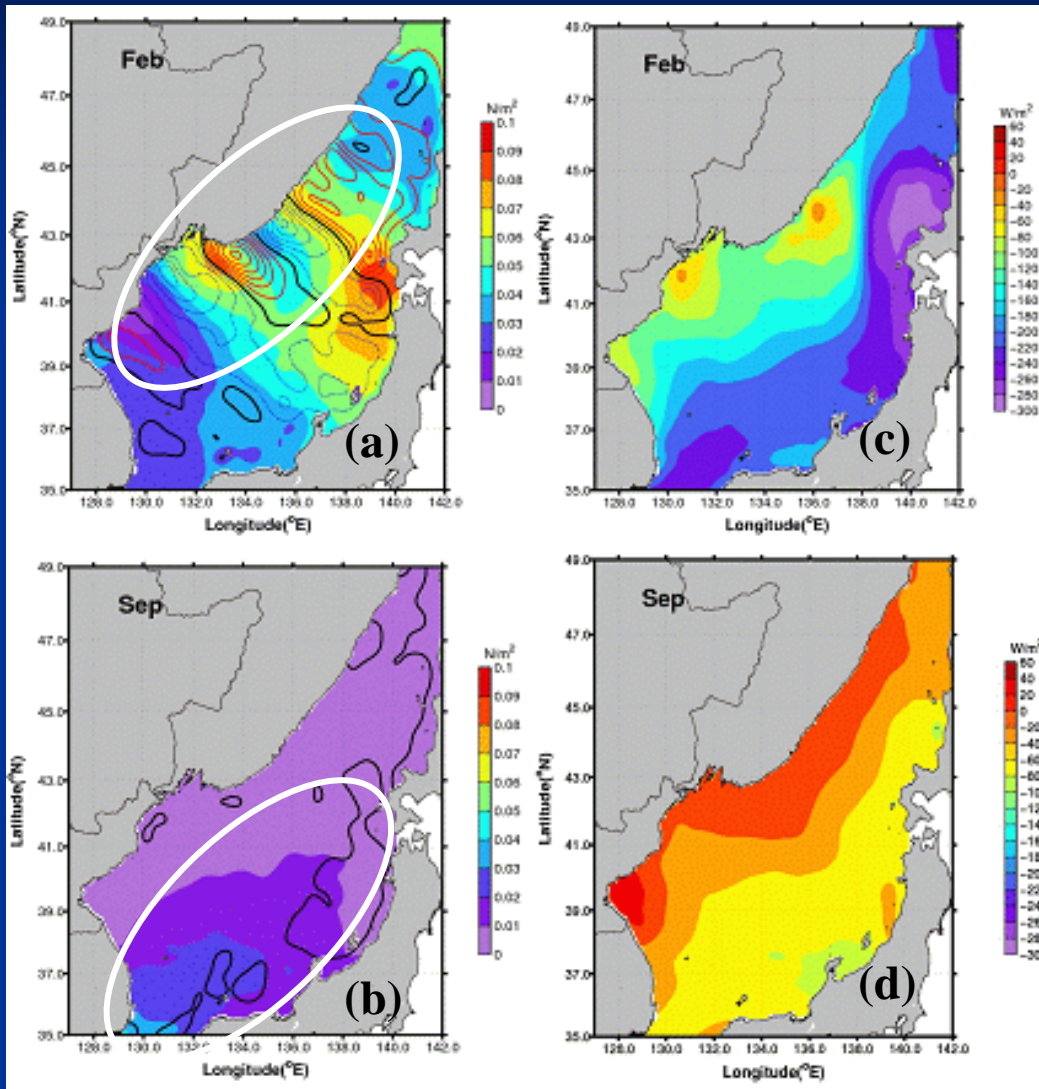


■ From winter to spring, north is deeper than south, spatial difference is also large.

■ From May to August, the MLDs have small difference and variation to the latitude.

■ South is deeper than north until Nov, as winter progresses, the MLDs deepen faster south than north.

Relationship between the Variation of MLD and Atmospheric Forcing

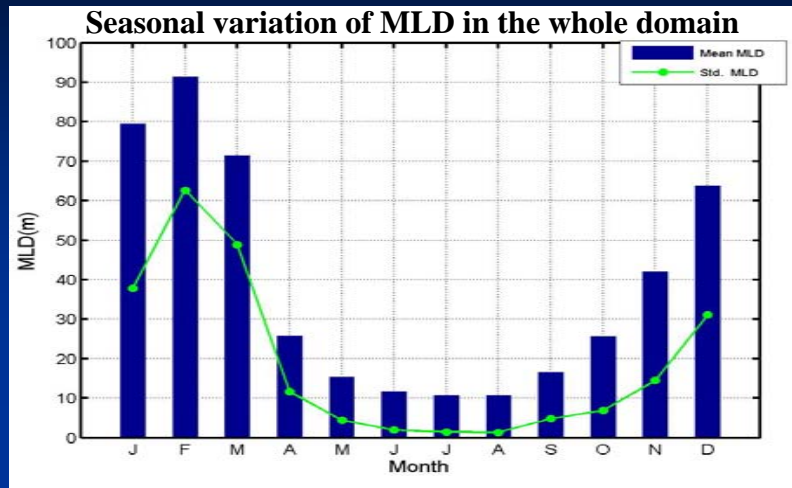


Monthly mean climatology of wind stress (shade, N/m^2) overlaid with the wind stress curl (line, $10^{-9} dyne/cm^3$) calculated from Quikscat monthly wind data (a, b) and monthly mean climatology of net heat flux (hirose et al., 1996; (c),(d)) are for February (upper) and September (lower).

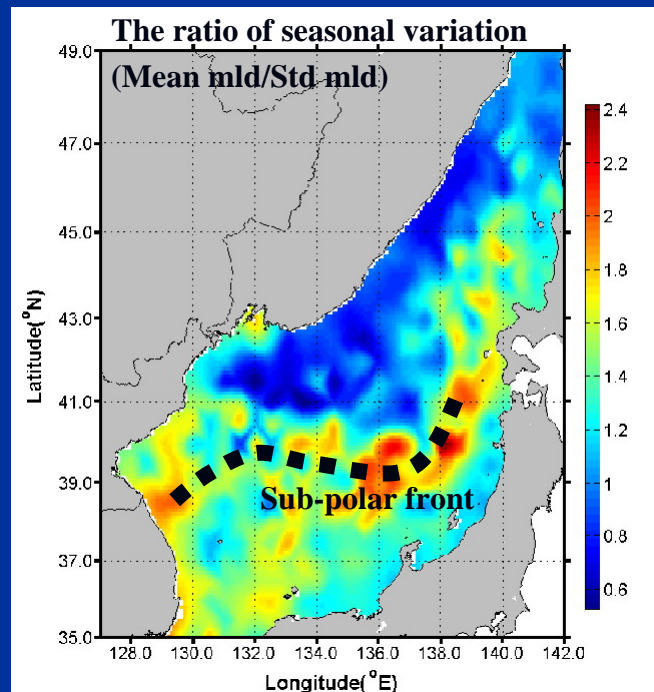
Off the Vladivostok, the deepest MLD caused by winter convection in February

West coast of Japan and the southern part of the East Sea formerly deepen, related with relative strong wind and cooling.

Summary



- Seasonal variations of the MLD show a typical pattern
- Significant spatial differences exist in distribution of the MLD.
 - Winter → Summer : Spatial differences decreasing.
 - Summer → Winter : Spatial differences increasing.



- Significant spatial characteristics appear in variation of the MLD
 - The MLD obviously develop and decay in the northern and southern side of sub-polar front as cooling and heating season interchange.
 - Temporary strong local deepening are occurred in the northern part of the East Sea.
- Variation of the MLD tightly correlated with the atmospheric forcing in the East Sea.

Thank you for attention