The properties of glacial melt water and sea water isotopes in the Terra Nova Bay, Antarctica

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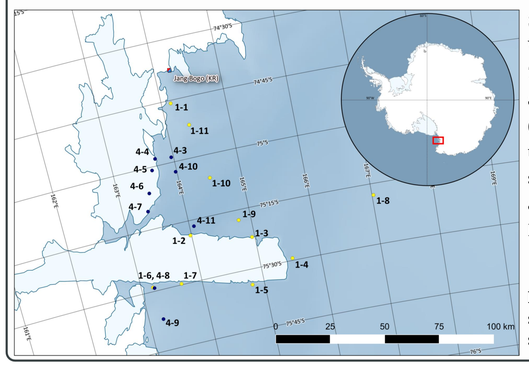
Abstract

Supra- and sub-glacial meltwater drainage becomes widespread in Antarctica, but its contribution to regional water masses has not been thoroughly quantified. For a better understanding of physical-chemical fractionations, we employ water isotopes (δ18O, δD) as practical tracers for hydrological researches. During the Antarctic summer expeditions (2014/15, 2015/16, 2016/17, and 2017/18) conducted by Korea Polar Research Institute, we sampled seawater performed with CTD casts in the Terra Nova Bay, Western Ross Sea. CRDS(Picarro L2130-i) is used for water isotope analysis. Water samples are classified into three water masses; AASW, MSW and SW with their physical properties. And we compared hydrogen and oxygen stable isotope ratio distribution. SW of P4 implies presence of difference water source relative to P1. ISW for sub-glacial melt water and glacial runoff for supra-glacial melt water are suggested respectively.

Introduction

As interest in climate change and the need for research are increasing, various researches are underway, and sea surface variation studies are one of them. The thermal expansion of seawater and the melting of glaciers have been pointed out as the main causes of sea level variation. According to the IPCC Fifth Report, recent sea level rise is showing a very rapid rise and the contribution of glacier melting is increasing. The importance of the study of the change of the cryosphere in sea level fluctuation study is increasing. Stable water isotopes are useful tracers for hydrologic research. In this study we used stable water isotopes for understanding glacier-seawater interaction and tested the possibility as glacial meltwater tracers.

Study Area



Study area is near the Terra Nova Bay, Western Ross Sea, Antarctica (74.7-75.6°S, 163.1-167.0°E). The yellow dots are CTD cast sites of first expedition (Dec 2014, P1) and the blue dots are those of fourth (March 2018, P4). P1 sites are near the Drygalski Ice Tongue and P4 sites are in front of the Nansen Ice Shelves.

Fig 1. Map of study area and sampling sites. Yellow dots represent P1 sampling sites and blue dots are P4 sites.

Material & Method

During the Antarctic summer expeditions (2014/15, 2015/16, 2016/17, and 2017/18) conducted by Korea Polar Research Institute(KOPRI), we sampled seawater with CTD(Conductivity, Temperature, Depth) casts in the study area. We operated Seabird Electronics SBE911plus CTD, and took 1 to 10 samples from each point. The samples of P1 and P4 were 81 and 43 respectively. Each samples are filtered with membrane filter and keep frozen to minimize the fractionation.

Cavity ring-down spectroscopy(CRDS) of Piccaro-L2130 in KOPRI is used for seawater stable isotope analysis. Isotopes ratio values are calibrated with standards VSMOW ($\delta^{18}O$ = 0‰, δD = 0‰), GISP ($\delta^{18}O$ = -24.76‰, δD = -189.5‰), SLAP ($\delta^{18}O$ = -55.50‰, δD = -427.5‰) and RS ($\delta^{18}O$ = -34.69‰, δD = -272.4‰). The standard deviation of $\delta^{18}O$ and δD are ±0.06‰ and ±0.33‰ each. Data of sampling site 4-1, 4-2 of P4 are excluded from this study because the analysis uncompleted.

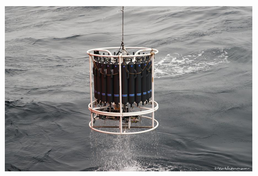
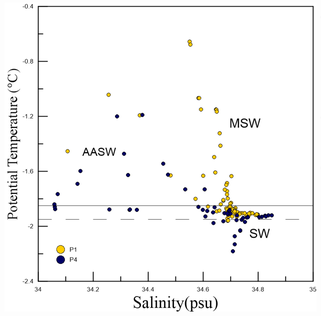


Fig 2. The CTD casting of research vessel, ARAON

Fig 3. The water isotope analyzer, CRDS(Piccaro-L2130) in KOPRI

Result

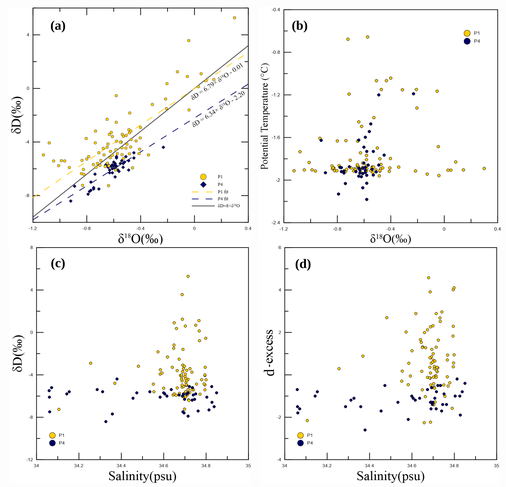
1. Classification of water masses



- Representative water masses near the study area are Antarctic Surface Water (AASW), Modified Shelf Water (MSW) and Shelf Water (SW). We classified seawater samples with their potential temperature and salinity.
- P1 samples are plotted as SW and MSW, and P4 samples are represented as SW and AASW.
- P4 samples, not included in SW, shows lower salinity and temperature values relative to P1 samples. It possibly means the presence of different water sources.

Fig 4.
θ-S scatter plots of water samples. The yellow dots are P1 and blue dots are P4 samples. Black solid line and dashed line shows -1.85 °C and -1.95 °C.

2. Hydrogen and Oxygen stable isotopes properties



- (a) It shows the relationship between hydrogen and oxygen water isotopes. P4 samples have depleted δD values than P1 samples relative to $\delta^{18}O$. (c) also shows depletion of δD relative to given salinity.
- (b) The extreme cold water samples in Fig 4. are not discriminated from other water samples of P4 with oxygen isotope values.
- (d) d-excess reflects the origin of water source because it depends on relative humidity. While isotope ratios of P1 plotted in wide range, the P4 samples are in narrow range. Large variation of isotopes reflects dynamic interaction among different water sources, in other words, isotope values with small fractionation indicates the affection of specific dominant source.

Fig 5. (a) The linear relationship between $\delta^{18}O$ and δD values. (b) Scatter plots of potential temperature to $\delta^{18}O$. (c) and (d) Scatter plots of δD and D-excess to salinity.

Discussion

1. Ice Shelf Water (ISW)

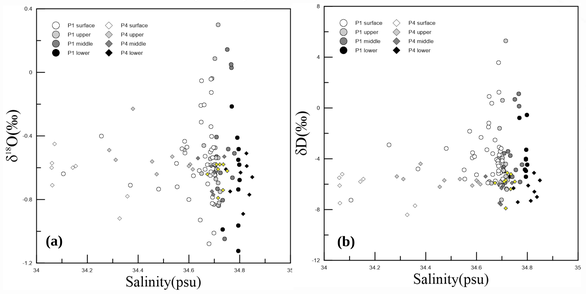
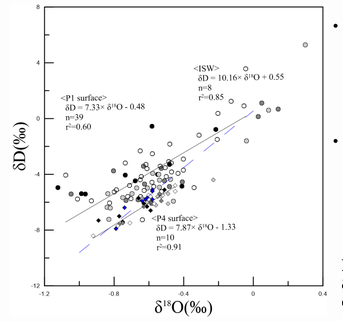


Fig 6.
(a) $\delta^{18}O$-salinity and (b) δD-salinity plots. Circles and diamonds show P1, P4 samples and colored with the sampling depth. Yellow x marks mean Ice Shelf Water.

<depth information>
○ surface (~60m)
● upper (60m~300m)
● middle (300m~500m)
● lower (500m~)

- Near the Terra Nova bay, sea water that has θ < -1.95 °C are classified as Ice Shelf Water (Orsi and Wiederwohl, 2009), water mass with high density and lowest temperature. ISW is derived from thermohaline circulation when dense water formed by sea ice formation occurs basal melting of ice shelves. Thus, ISW contains subglacial melt water and can be discriminated with water isotopes because the ice shelves consist of meteoric water which has much more depleted isotope values than sea water.
- In this study ISW samples are not clearly separated from other water masses because of its small amounts relative to sea water. The effect of subglacial meltwater in Terra Nova bay was negligible. However, it will be a practical tracer if the large amount of meltwater are drained.

2. Glacial Runoff



- In polar region, hydrogen and oxygen isotopes fractionates with three main factors: evaporation and precipitation, mixing of water masses, sea ice formation and melting, and relationship between $\delta^{18}O$ and δD indicates the different water sources.
- The water isotope relationships of surface water presents the similar δD/ $\delta^{18}O$ value of meteoric water. It implies mixing with supraglacial melt water (glacial runoff) and seawater. However, the other indicator should be suggested for proving mixing mechanism.

Fig 7.
$\delta^{18}O$-δD relationships with sampling depth. Black solid lines are regression line of surface water samples. Blue dashed line is regression line of ISW samples.

References

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Conclusion

Hydrogen and oxygen stable isotopes are known as practical tracers for hydrologic studies. For better understanding of supra- and sub-glacial hydrologic system, we performed 20 CTD casts and analyzed hydrogen and oxygen stables isotopes of 124 points in Terra Nova Bay, Antarctica. We classified samples with their physical properties to three water masses: AASW, MSW and SW. Different distribution of samples suggests the change of water sources. And the δD values sampled in late summer are depleted relative to $\delta^{18}O$. The glacial melt water can be driven in the form of ISW, however, the effect of melt water was rare because of its amount. We also estimated the glacial run off but another tracers should be accompanied to prove the mixing with sea water.

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