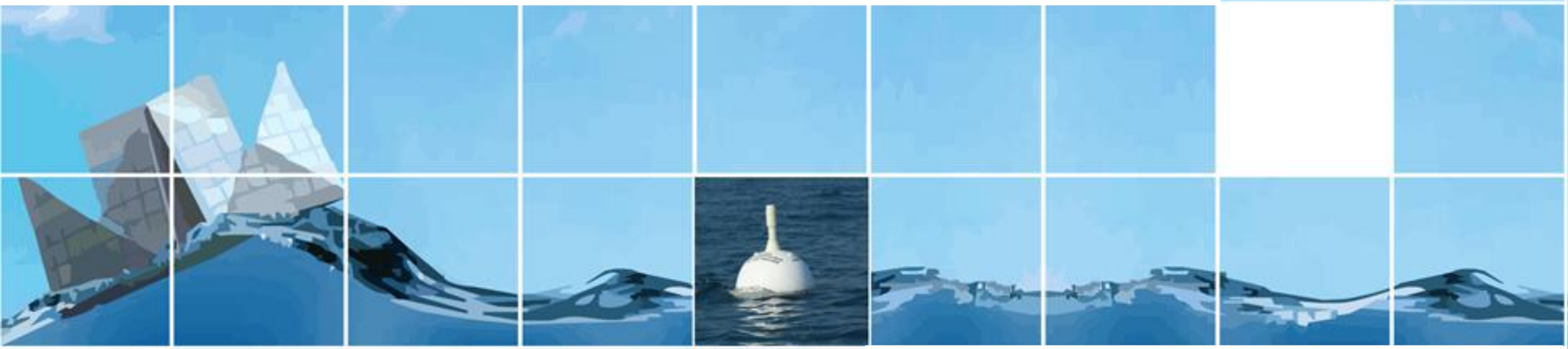
An Innovative SVT Technology for the Near-Surface Salinity Observations and its Applications to Thermodynamics in Polar Oceans



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Sea surface salinity is a critically important parameter of the World Ocean

Observational Requirements for Sea Surface Salinity

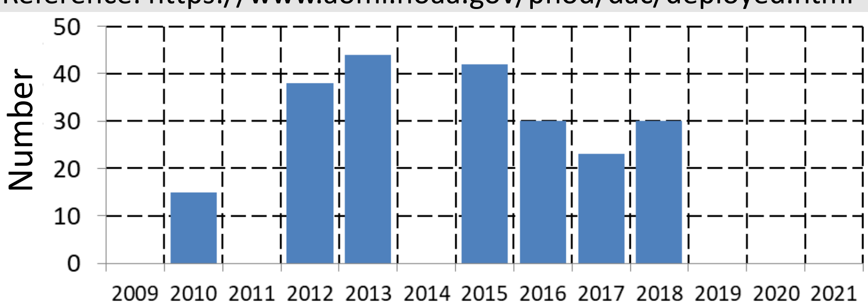
DBCP Technical Document, 42. Sea surface salinity quality control processes for potential use on data buoy observations

Layer	Application	Source	Accuracy Goal/Bk/Threshold			Horizontal Resolution Goal/Bk/Threshold			Observing Cycle Goal/Bk/Threshold			Delay of availability Goal/Bk/Threshold		
Sea surface	Global NWP	WMO	0.1 psu	0.2 psu	0.3 psu	5 km	100 km	250 km	1 d	30 d	60 d	3 h	24 h	120 h
Sea surface	Seasonal to inter-annual climate prediction	WMO	0.1 psu	0.144 psu	0.3 psu	100 km	135.7 km	250 km	30 d	40 d	60 d	9 d	21.3 d	120 d
Sea surface	CLIVAR	WCRP	0.1 psu	0.144 psu	0.3 psu	100 km	135.7 km	250 km	30 d	37.8 d	60 d	9 d	21.3 d	120 d
Sea surface	GOOS Climate - large scale	GOOS	0.1 psu	0.215 psu	1 psu	200 km	271.4 km	500 km	10 d	14.4 d	30 d	10 d	14.4 d	30 d

Sea Surface Salinity drifter with conductivity and temperature recorder SBE37-SI

Reference: Centurioni at al., 2015

Annual number of Sea Surface Salinity drifters (2009-2021)
Reference: https://www.aoml.noaa.gov/phod/dac/deployed.html



Sea Surface Salinity Drifters

<u>From the "DBCP Technical Document No. 42"</u>:

"... the major challenge in measuring Sea Surface Salinity (SSS) is ***stability over time and resistance to fouling***, which is of particular concern for drifting buoys. The cost of the SSS sensor versus the cost of the whole buoys is also an important consideration. To provide ground truthing of satellites such as SMOS/Aquarius the accuracy does not need to be very high ... relatively inexpensive sensor should be viable."

Salinity as a function of sound velocity, temperature and pressure

Features of the method

- simple biofouling protection of the sound velocity sensor;
- high accuracy of sound velocity measurements;
- the calculation of salinity by the sound velocity, in contrast to conductivity, is not associated with the assumption of binary composition of seawater;
- less complex calibration technology.

SVT module after long-term testing in conditions of **intensive biological fouling**

Salinity (Sound Velocity & Temperature) **measurement error ±0.03 ‰**

SVT : Marlin-Yug's time of flight high stability sound velocity & temperature module

Performance

Sound Velocity

Range: 1400 – 1600 m/s
Resolution: 0.001 m/s
Repeatability: ±0.03 m/s

Temperature

Range: -5 to 35 °C
Resolution: 0.001 °C
Accuracy: ±0.004 °C

Sample Rate:
Sound Velocity – up to 1000 Hz;
Temperature – 3 Hz.
Depth Rating: for Sea Surface Drifter

Thermally stabilized two-base acoustic sensor.
Measuring base length ~ 70 mm.

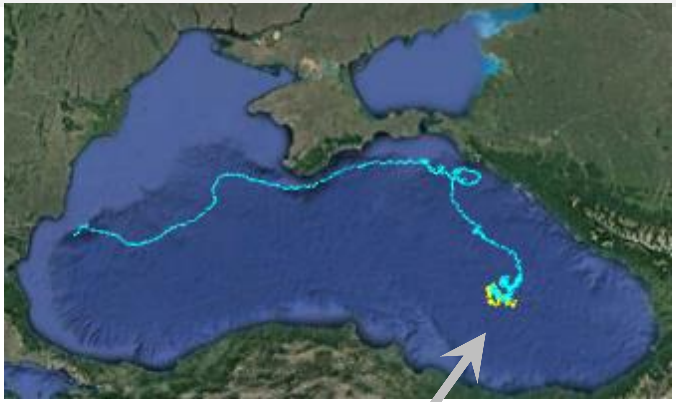
Sea surface salinity drifter with SVT technology: SVP-B/40-SVT

Salinity drifter SVP-B/40-SVT by Marlin-Yug

Parameters:
- sea surface temperature;
- barometric pressure;
- sound velocity;
- coordinates;
- **salinity** (as function of sound velocity, temperature and pressure)

Measurement interval: 1 hour
Data transfer: Iridium

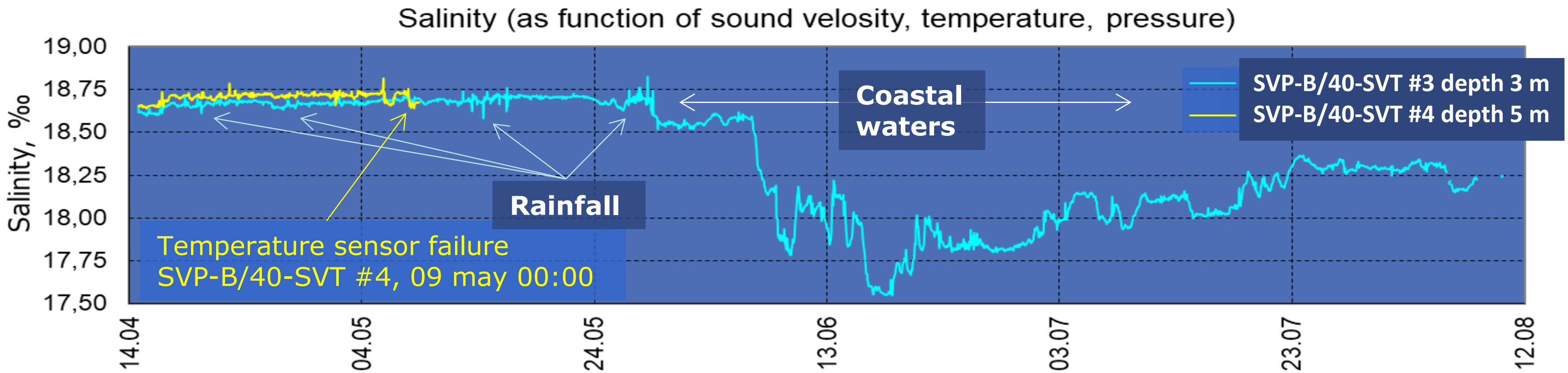
Tracks of SVP-B/40-SVT #3, #4 (Black Sea, 2021)



Sea surface salinity drifter with SVT technology: SVP-B/40-SVT

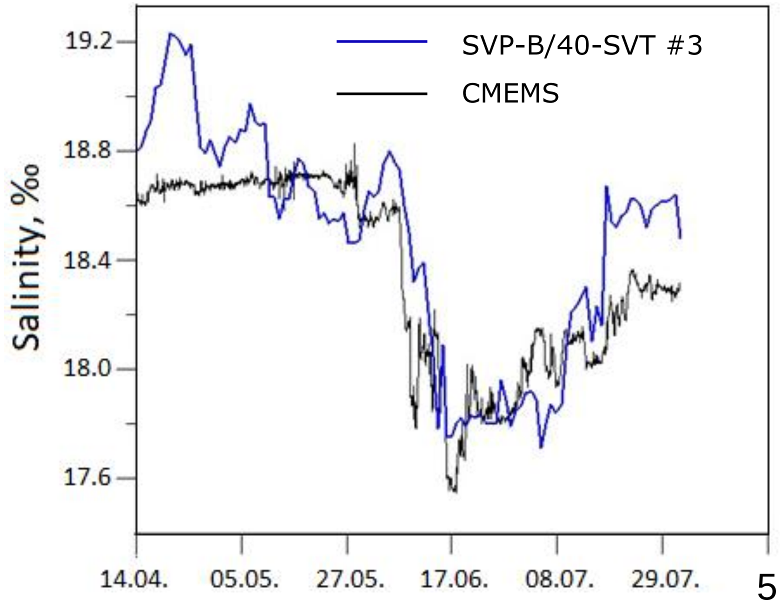
Time series of sea surface salinity measurements

SVP-B/40-SVT #3, #4, Black Sea, April-August 2021



A comparison of the drifters salinity with Copernicus Marine Environmental Monitoring Service (CMEMS) sea surface salinity from April 14 to August 2, 2021 (Korotaev, 2021)

"… the general trends in the salinity of the surface layer of the Black Sea waters correspond quite well to each other. At the same time, a number of significant inaccuracies in the CMEMS analyses of the Copernicus program were revealed due to the quality of reproduction of moisture exchange in meteorological forecasts used as boundary conditions in the Black Sea water circulation model."



Sea surface salinity drifter with SVT technology: SVP-B/40-SVT

Conclusions

1. New **SVT technology** based on high-performance sound velocity measurements is provided by Marlin-Yug. This technology allows autonomous drifters to **routinely, long-term and robust measure of in-situ sea surface salinity** - one of the key parameters of the ocean waters.

2. Deployment of network of salinity drifters like SVP-B/40-SVT with following data assimilation will allow to **eliminate a lot of errors in marine modeling/forecasting** and to increase its effectiveness.

Thanks for watching!

Next, I would like to give the floor to my co-author Yusuke Kawaguchi

Sea surface salinity drifter with SVT technology: SVP-B/40-SVT

Application of SVT technique to polar oceanography

Climate change in the polar seas

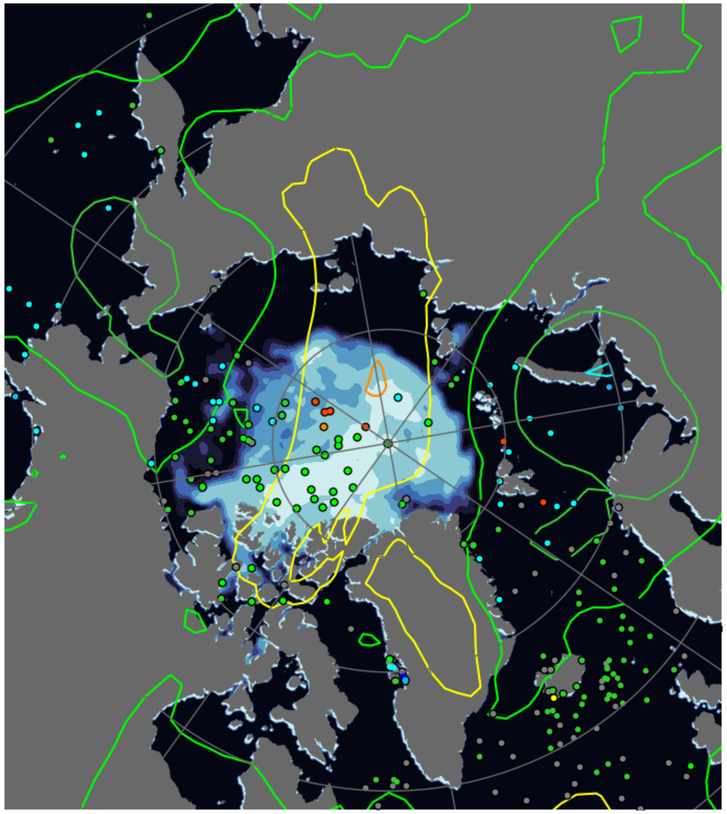
The Arctic sea ice extent has been shrinking for past two decades. Thermodynamics & dynamics of sea ice partially leads the variation.

For accurate prediction, it is essential to monitor in-situ variables in real-time. There is however crucial **difficulties of manned observation in harsh environment**.

Advantages of autonomous observing system

One solution is the use of autonomous instrument, which carries **cryos/hydro sensors & telecomm unit**. Distributing the autonomous drifting sensors makes the monitoring more effective & sustainable.

09/09/2021 Overview: SLP



International Arctic Buoy Program

Sea surface salinity drifter with SVT technology: SVP-B/40-SVT

Theory: Ice-Ocean Boundary Layer (IOBL)

Kawaguchi et al. (reviewed, JGR-O)

Equations of turbulent heat/salt fluxes for IOBL (McPhee, 1994)

$$\langle w'T' \rangle_0 = \alpha_h \left(T_w - \boxed{T_0} \right) u_0^* = -\frac{dH}{dt} Q_L + \dot{q}$$

$$\langle w'S' \rangle_0 = \alpha_s \left(S_w - \boxed{S_0} \right) u_0^* = \frac{dH}{dt} \left(S_{ice} - \boxed{S_0} \right)$$

$$\dot{q} = \kappa \left(\frac{\partial T_{ice}}{\partial z} \right)_{z=\text{-H}}$$

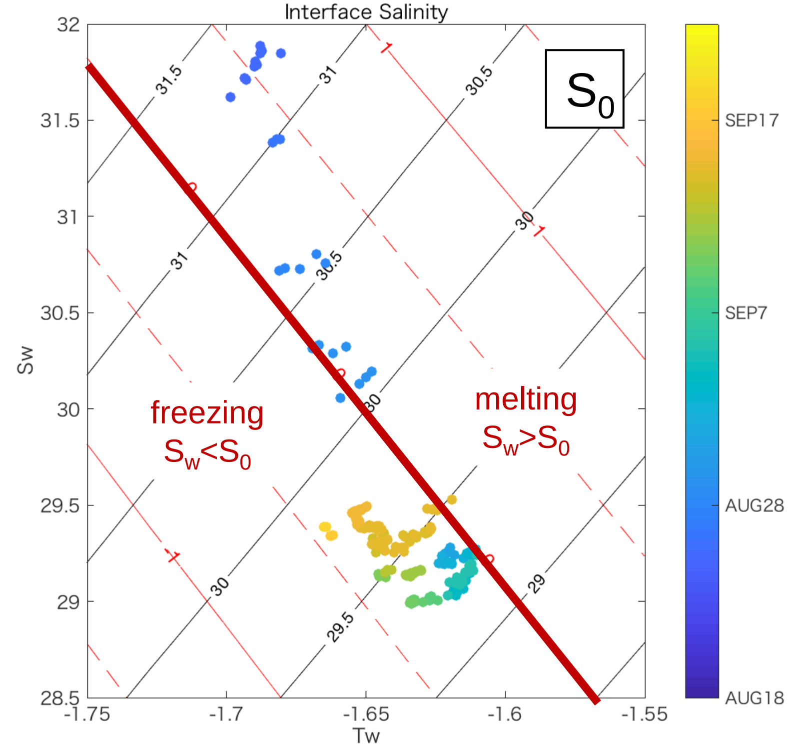
Conductive heat at ice bottom

Estimate of friction velocity u* based on ice velocity U_{ice}

$$\frac{U_{ice}}{\boxed{u_0^*}} = \frac{1}{\kappa} \left(log \frac{\boxed{u_0^*}}{f z_0} - A \mp iB \right)$$

Solve the quadratic equation for interfacial salinity S_0

$$m \boxed{S_0^2} + (T_H + T_L - m S_{ice}) \boxed{S_0} - T_H S_{ice} - T_L S_w = 0$$



Knowledges of (u_0^*, $\dot{q}$, T_w & S_w) empirically determines **turbulent heat fluxes** & **evolution of ice thickness** by solving the equations of T_0 & S_0.

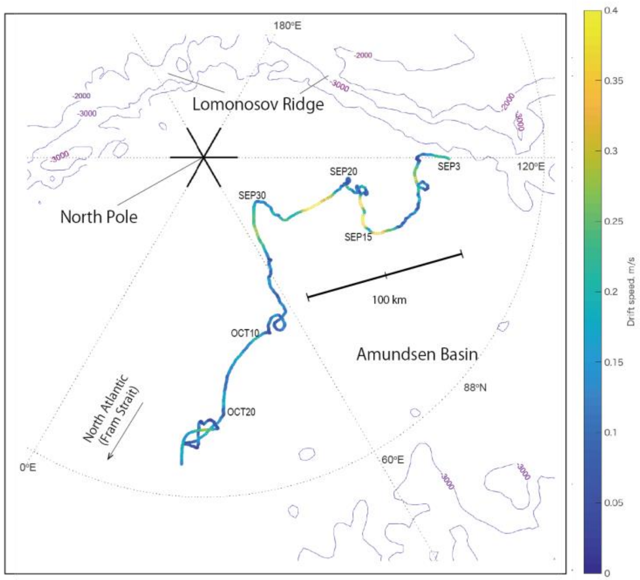
This theory requires only simple procedures of measurement for T_w & S_w and vertical profile of ice interior temp T_{ice} along the track of sea-ice drift.

Sea surface salinity drifter with SVT technology: SVP-B/40-SVT

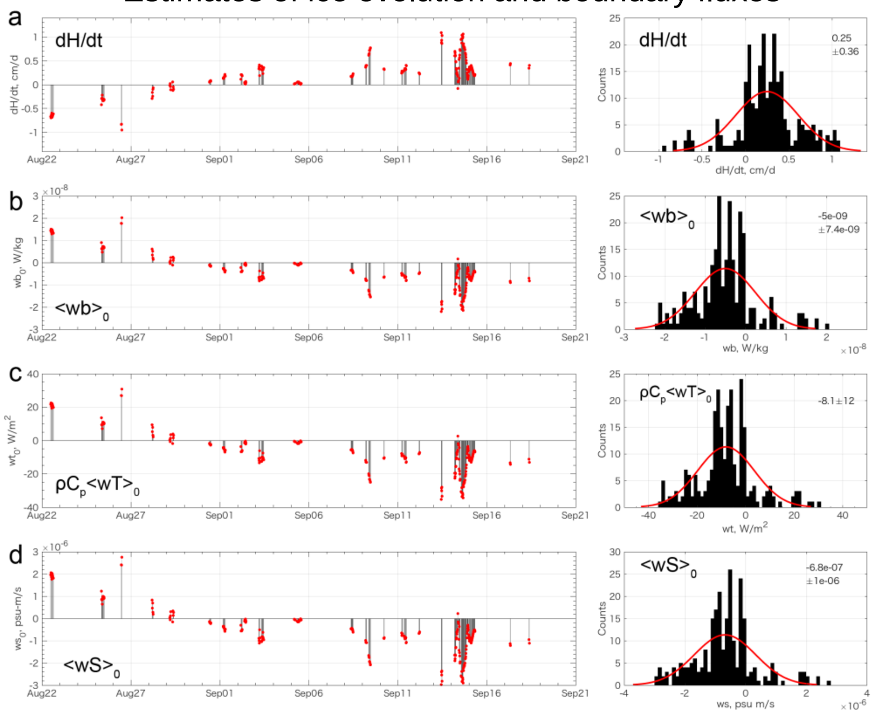
Preliminary results: MOSAiC expedition

Kawaguchi et al. (reviewed, JGR-O)

Trajectory & ice speed during MOSAiC



Estimates of ice evolution and boundary fluxes



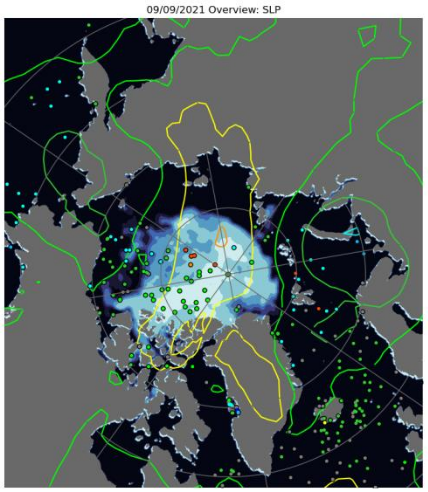
During MOSAiC expedition (2019-2020), heat, salt and buoyancy fluxes at ice-ocean interface were obtained based on the IOBL theory.

The obtained data demonstrated seasonal transition of phase change from melting to refreezing at ice-ocean boundary, where enhanced ice motion promoted growth rate.

Sea surface salinity drifter with SVT technology: SVP-B/40-SVT

"CryoTeC" network project: Cryosphere Turbulent Closure
(Under review in Grants-in-Aid program, KAKENHI)

By introducing the SVT module, we develop autonomous devices to get the IOBL solutions, named "CryoTeC" buoy, **at low cost. Distribute a number of CryoTeCs** widely in the Arctic and other ice-covered seas, so it allows mapping of local growth/decay of sea ice.



Ex: IABP

Specific features of CryoTeC:
The CryoTeC carries a **minimal set** of sensors for the IOBL solution at lower developing cost.

i.e. GPS unit for u_0^*, SVT for T_w & S_w, and T-chain for $\dot{q}$.

**Occasional manual observation will be needed for the coefficients determination.

Concept image of CryoTeC buoy