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Winter season submeso-scale processes at the Peter the Great Bay, northwestern Japan Sea: Direct observations of deep cascading

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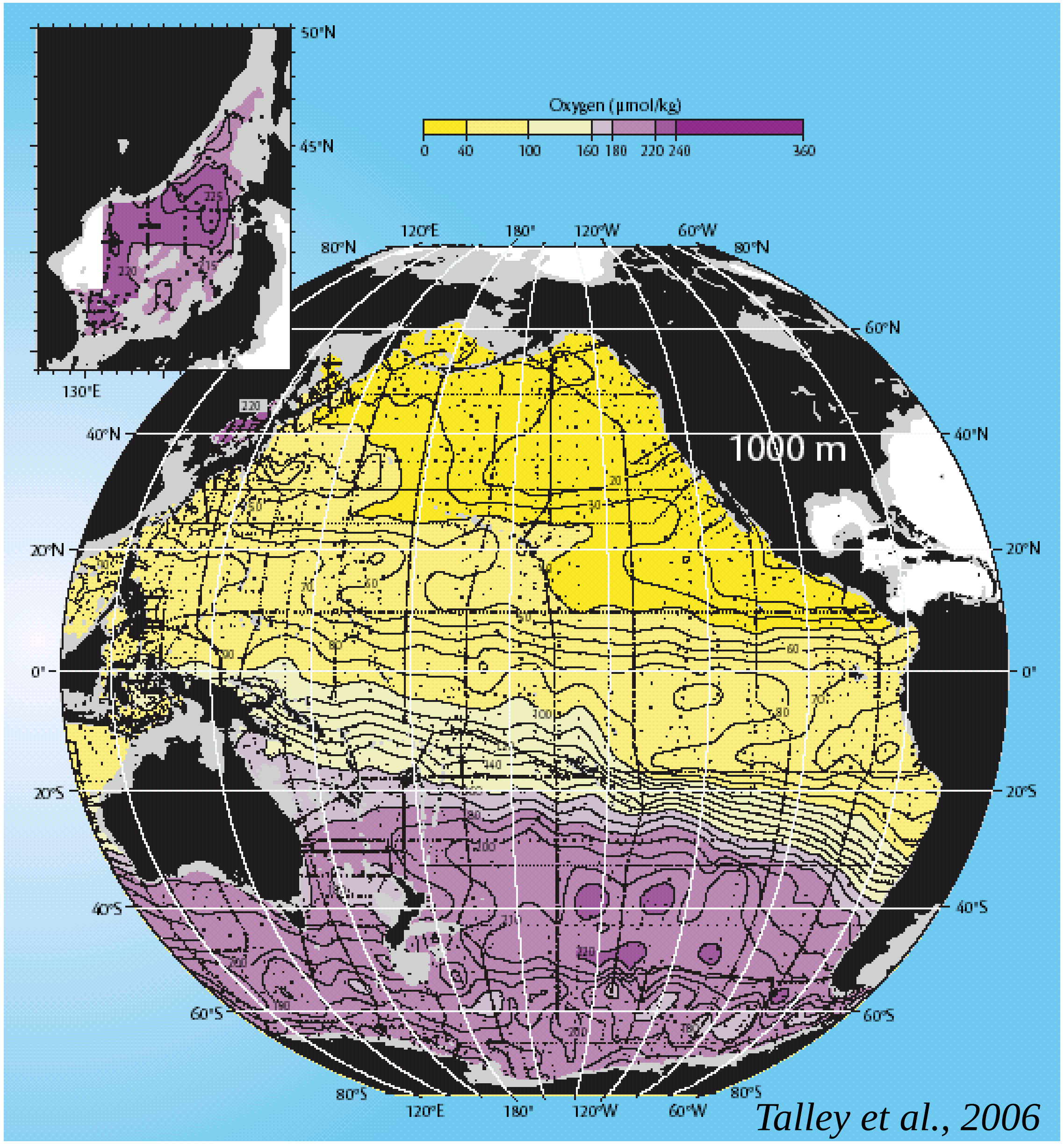
45 years POI FEB RAS

Outline

1. Motivation, region
2. Review of main results of 2012-2017
3. Deep cascading of 2017-2018
4. Summary

Japan/East Sea - an area of fast ventilation

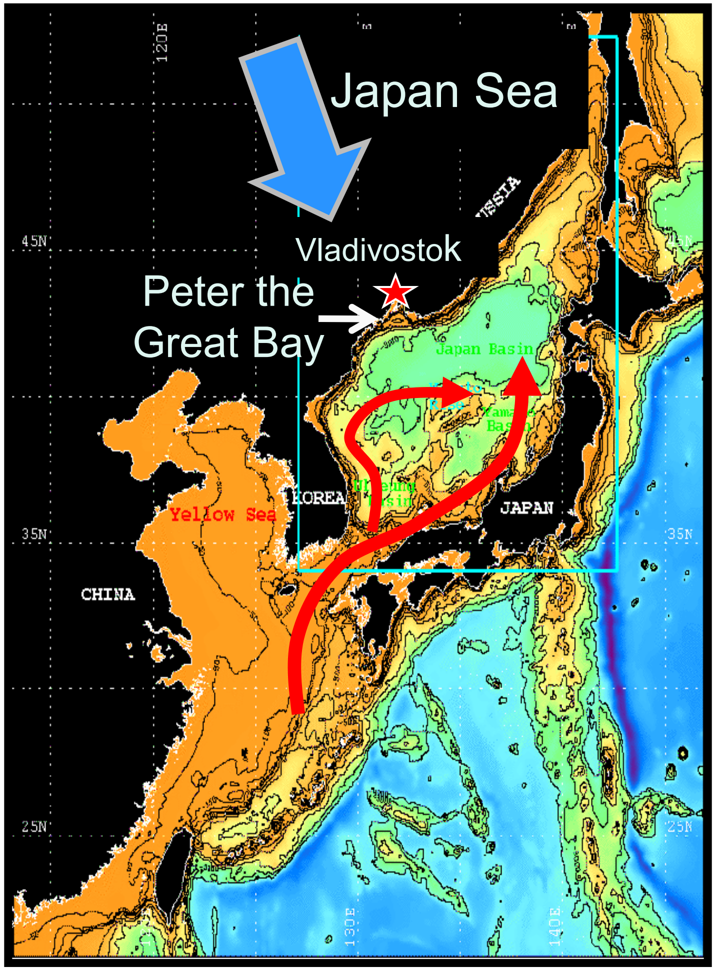


Dissolved oxygen content at 1000 m

Japan Sea
is an outstanding area
of the North Pacific
because of its rapid
ventilation and
comparatively short
renewal time of the
water masses from
surface down to the
bottom

- How does this
overturning system
works and
respond to climate
changes?

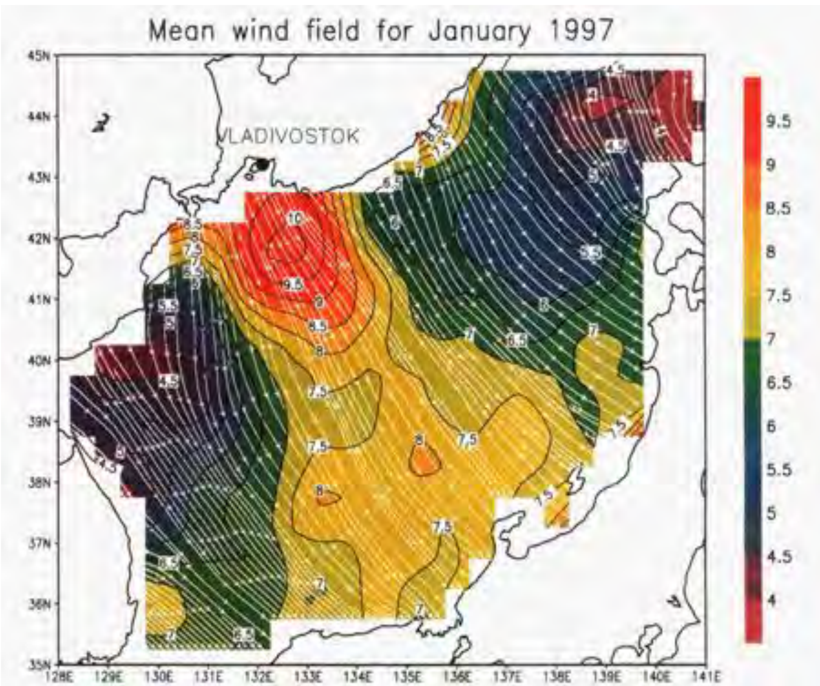
Main geographic features



- Deep semi isolated basin (>3500 m)
- Inflow of Tsushima Warm Current from the south
- Strong seasonal variations, ice formation
- Winter monsoon winds bring cold dry air mass
- Convective processes in the northern area control water mass properties
- Deep convection and fast renewal of deep water

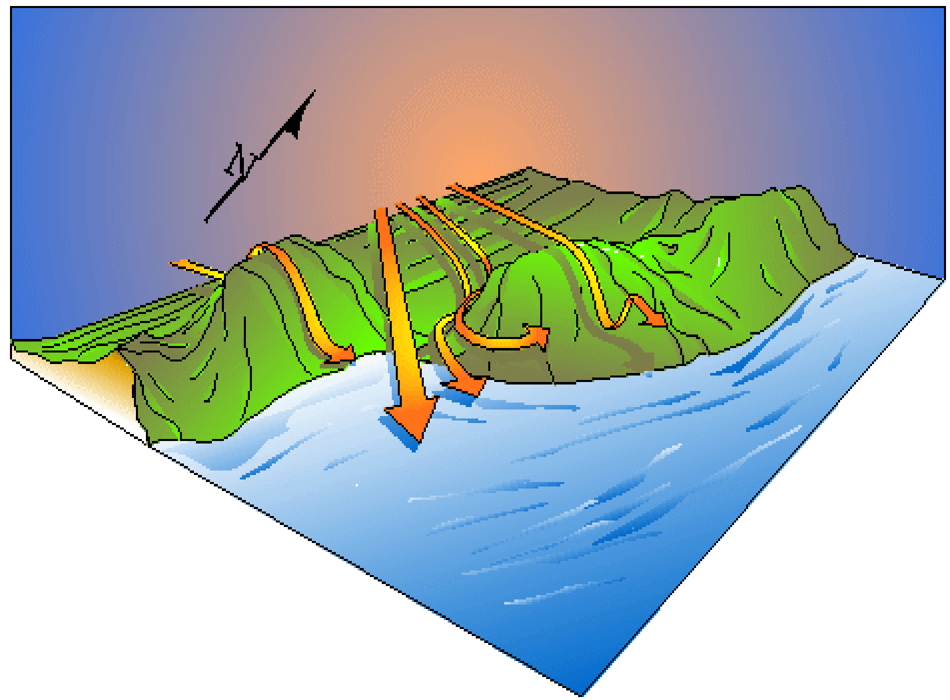
Winter convection processes

Typical winter winds pattern
(Kawamura et al., 1999)



(Kawamura and Wu, 1998)

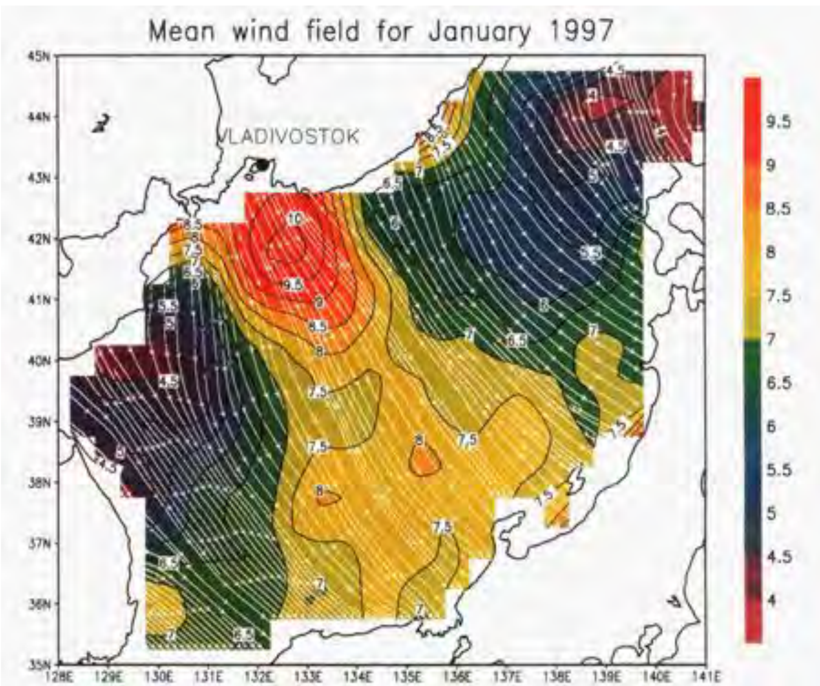
Wind tunnel – topographically enchansed winds)

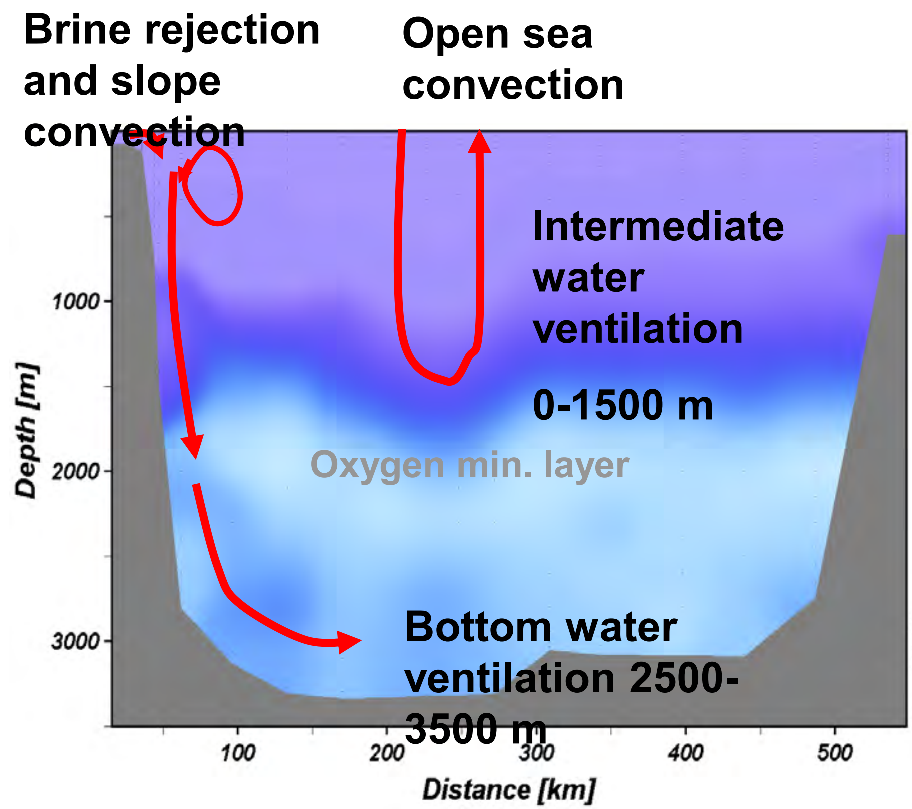


(Beardsley et al., 1999)

Winter convection processes

Typical winter winds pattern
(Kawamura et al., 1999)





Ventilation rates - turnover time:

300 yr - radiocarbon (Gamo and Horibe, 1983)
300-400 yr -radium-226 (Harada and Tsunogai, 1986)

100 yr - tritium (Watanabe et al., 1991)
100 yr - radiocarbon (Kumamoto et.al, 1998)

uncertainties indicate non permanent process of ventilation with large inter-annual variations (episodic events?)

Cascading at the Peter the Great Bay

Cooling by evaporation

Erosion of sediment

Increase of density on the shelf (T, S, Turbidity)

Overflow at the shelfbreak

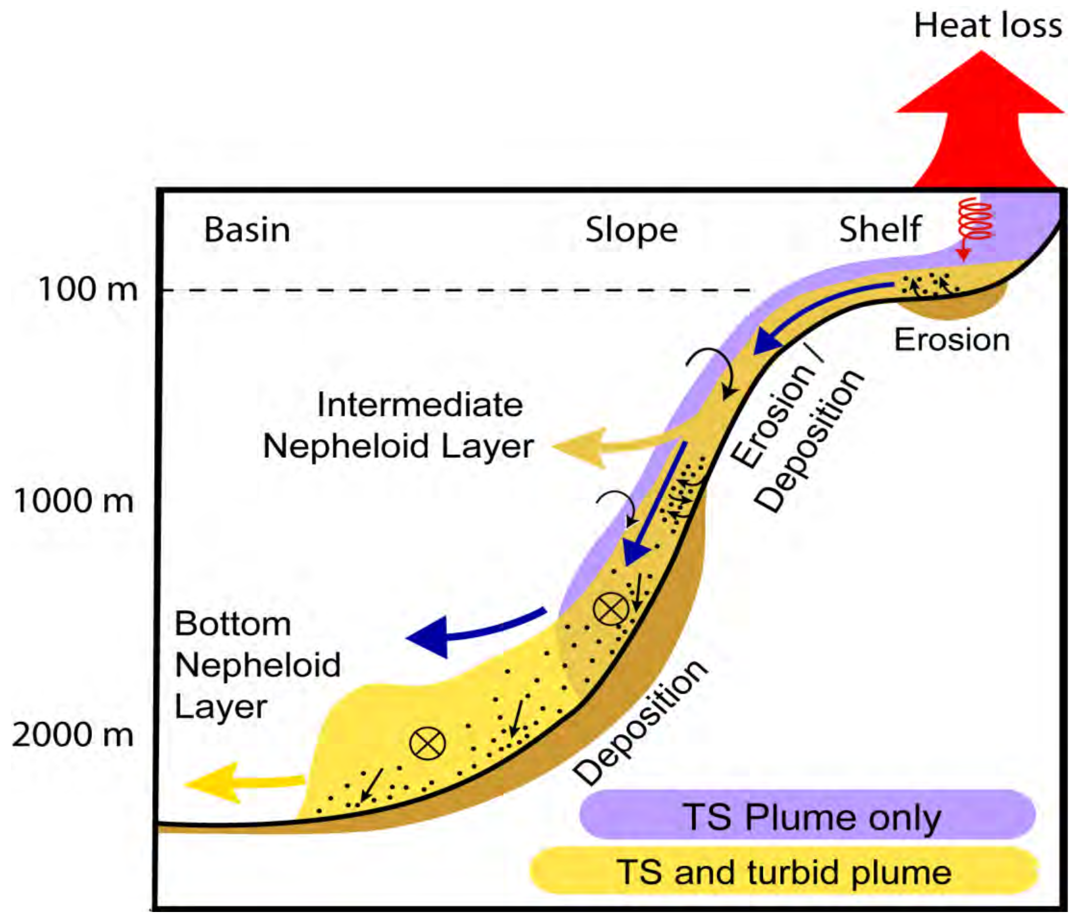
Cascading down the slope

Erosion / deposition sequences

Mixing with ambiant waters

Deeper equilibrium level

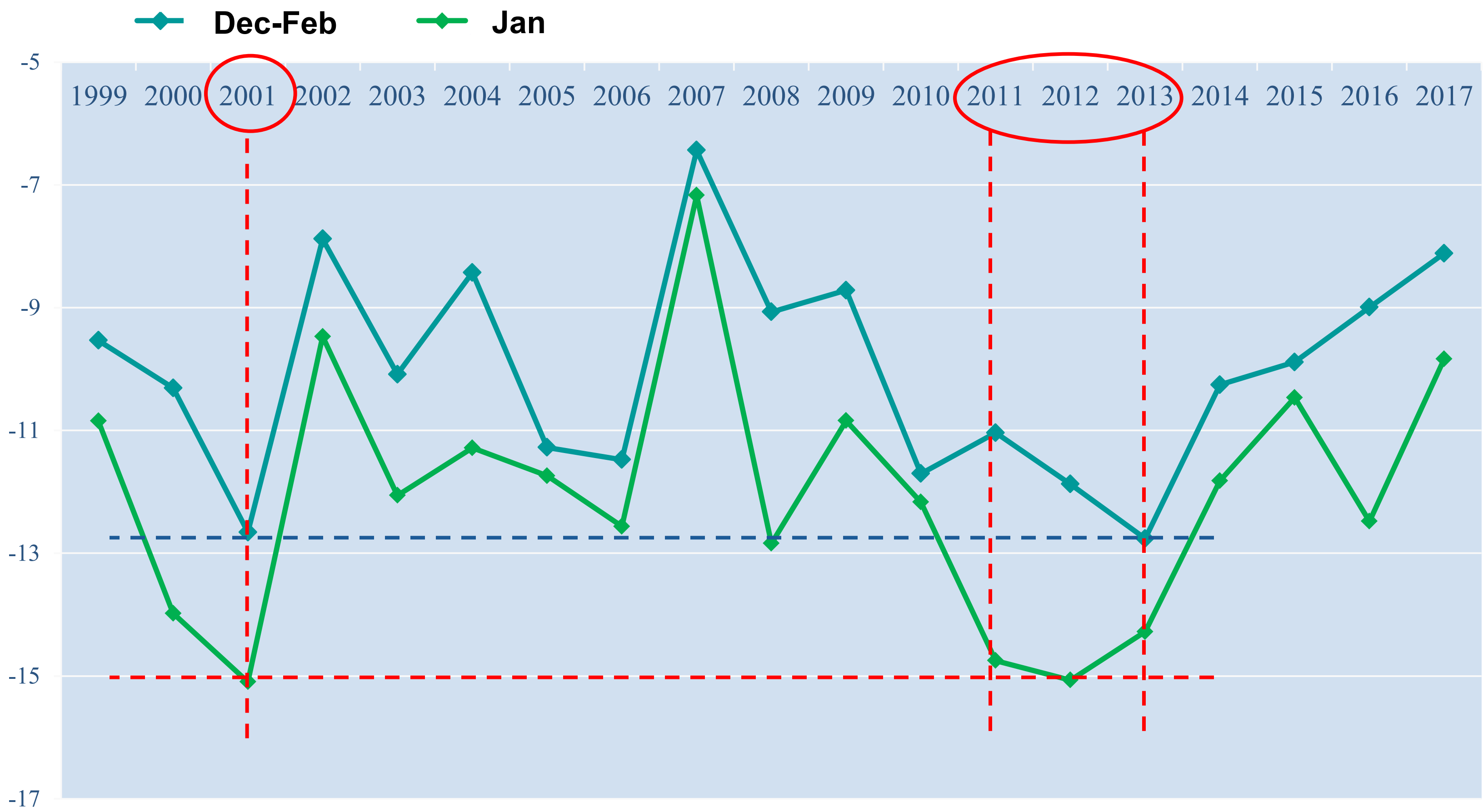
Deballastting with diminishing current transport capacity



(Fohrmann et al, 1998, JPO)

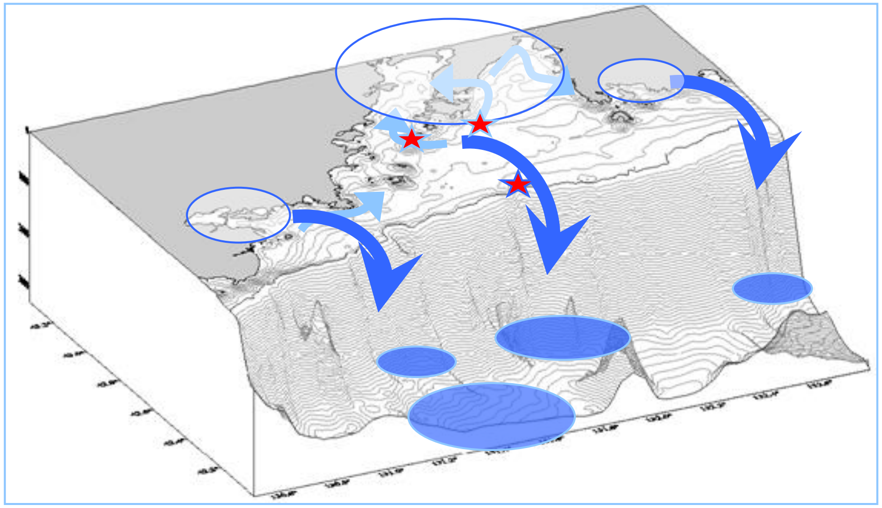
Observations of slope convection and renewal of bottom water in 2001: Lobanov et al., 2002, Kim et al., 2002, Senjyu et al., 2002, Talley et al., 2003, Tsunogai et al., 2003)

Inter-annual variability of air temperature in Vladivostok in winter 1999-2017r

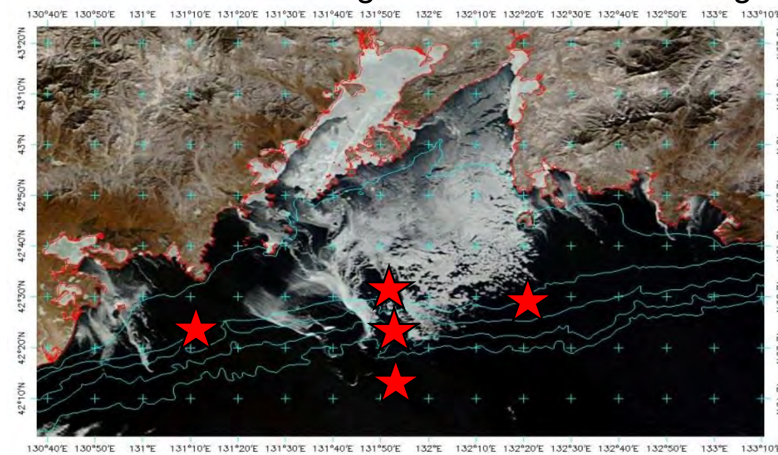


Winters 2012 and 2013 – the coldest winters over recent 12 years and second coldest January T over 35 years after 2001

Observations of cascading in Peter the Great Bay
2012-2018



Fasten and drifting sea ice on satellite image



Moorings with T, S, DO, Turb, Flu and current meters (SBE37, RBR-XR, S4, Infinity EM, RDCP600, WHS300)

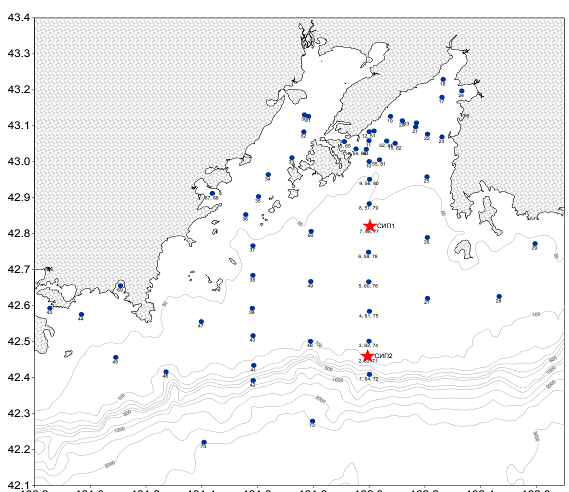
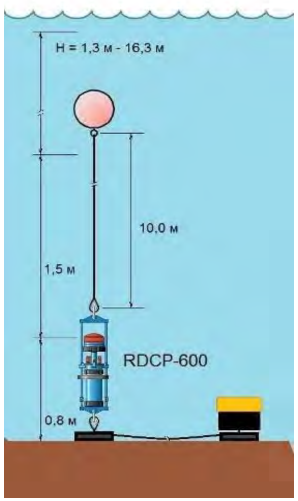


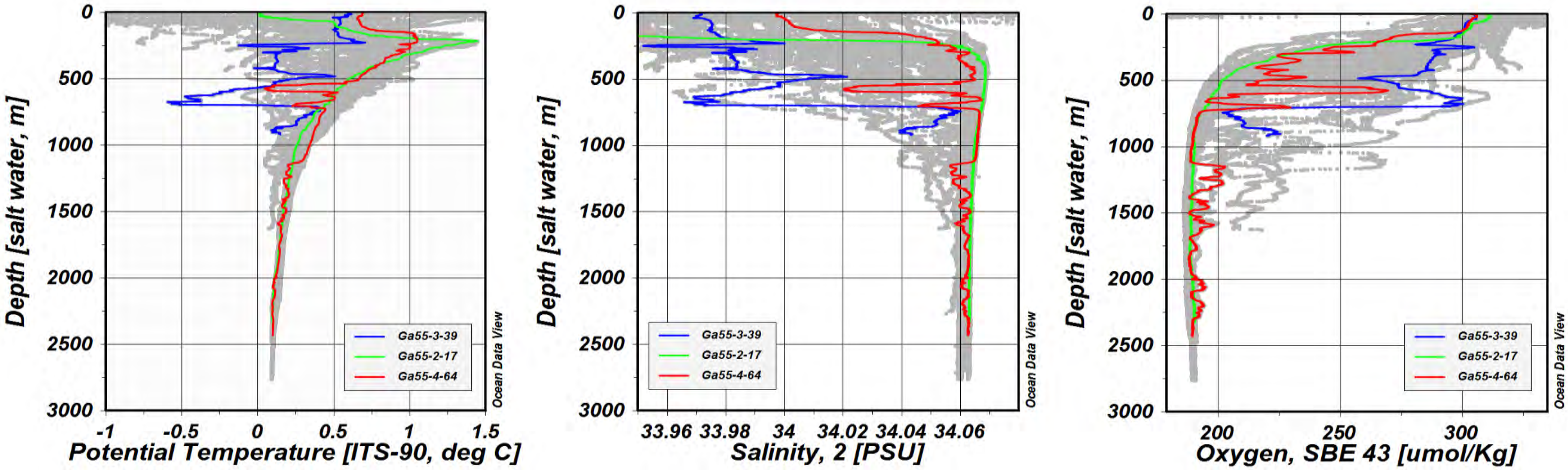
Схема станций экспедиции ТОИ ДВО РАН на НИС "Профессор Гагаринский", рейс №46, 27 февраля - 16 марта 2010 г.

Ship CTD survey



Bottom mooring system

Imprints of cascading at CTD profiles at the PGB slope in Feb-Apr 2012



(a) (b) (c)

Vertical profiles of potential temperature (a), salinity (b) and dissolved oxygen (c) obtained at the slope of Peter the Great Bay during February-April 2012. Some typical profiles are highlighted by color: February 8, st. 17 (green); March 1, st. 39 (blue) and March 15, st. 64 (red).

___ Feb 08, ___ Mar 01, ___ Mar 15

Peter the Great Bay Slope Convection Model

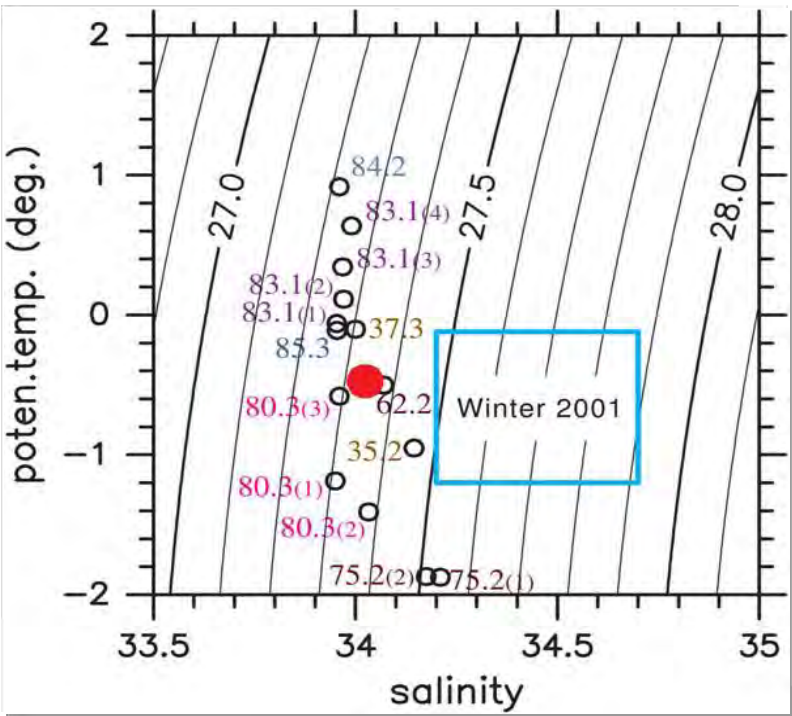


Figure 2. TS diagram of the near-bottom shelf water in Peter the Great Bay. Solid lines indicate potential density rh. The area within the blue rectangle indicates the ranges in Winter 2001 [Lobanov et al., 2002; Talley et al., 2003]: potential temperature of -1.2 to -0.12C and salinity of 34.2–34.7. Open circles indicate values derived from WOD05, and the solid red circle indicates their mean value. Subscripts on the open circles denote years and months of observation, and parentheses with numbers indicate plural casts within the month.

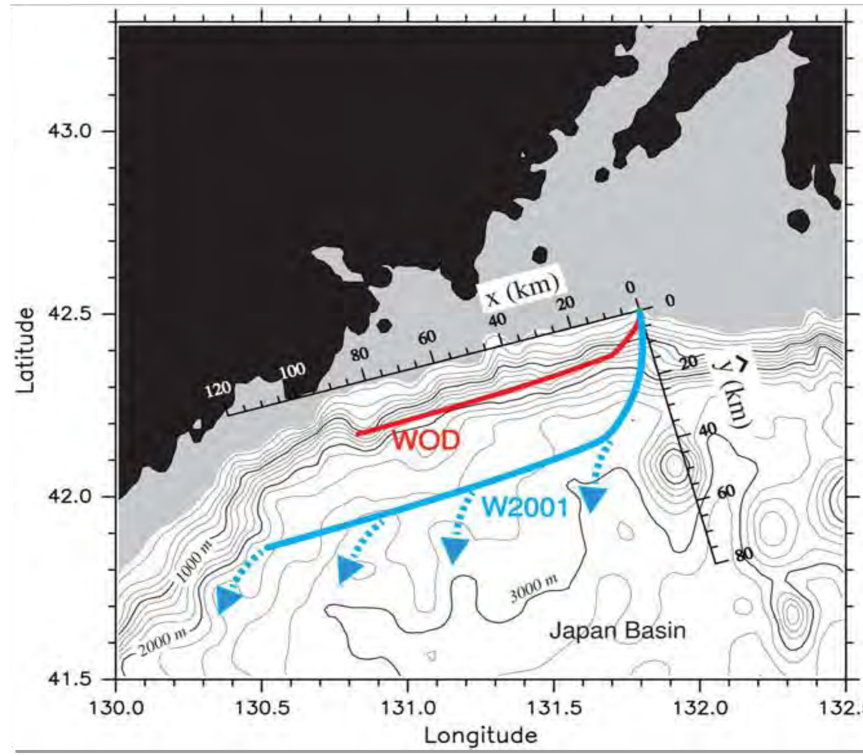


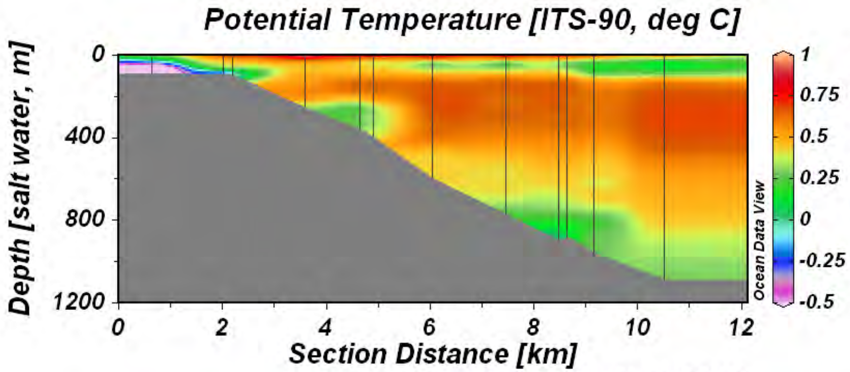
Figure 14. The stream paths (axes) of the average shelf waters (a portion of Figure 4) superposed on the actual topography around PGB. Blue and red lines indicate the paths of the average shelf waters of Winter 2001 (‘‘W2001’’) and WOD05 (labeled ‘‘WOD’’), respectively. Contour lines indicate water depth at intervals of 200 m, and the continental shelf shallower than 150 m is indicated by the shaded area.

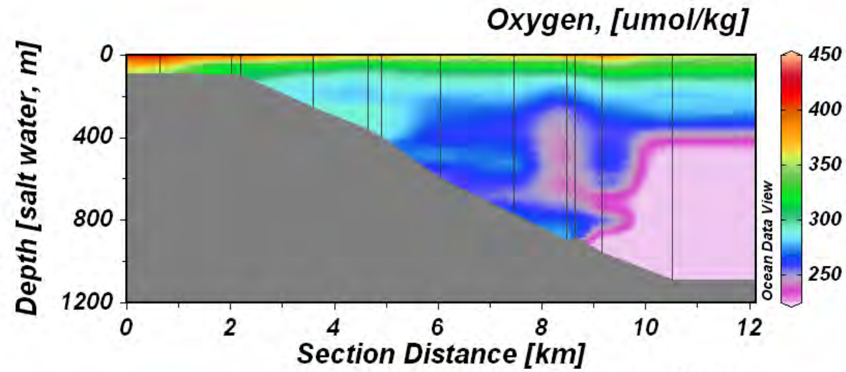
K.Tanaka, JGR, 2014

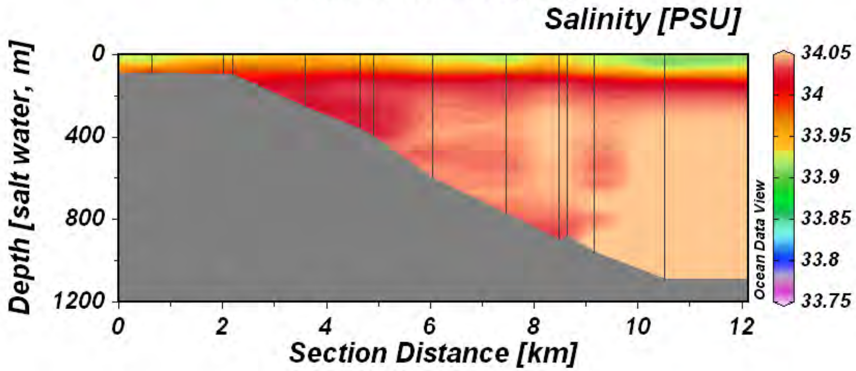
Spatial structure of cascading plumes

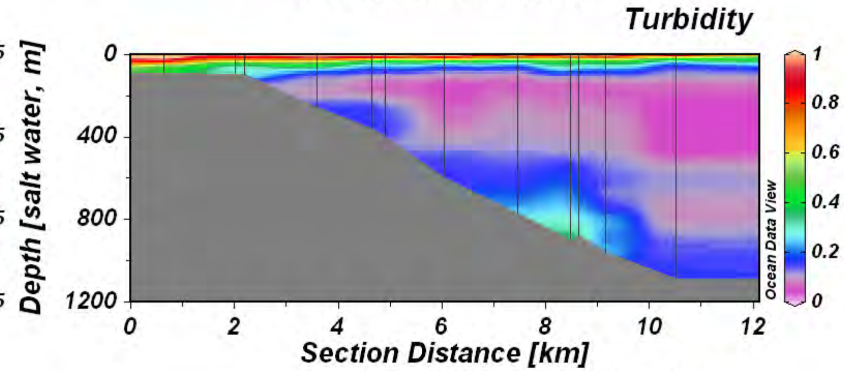
> CTD sections with high horizontal resolution

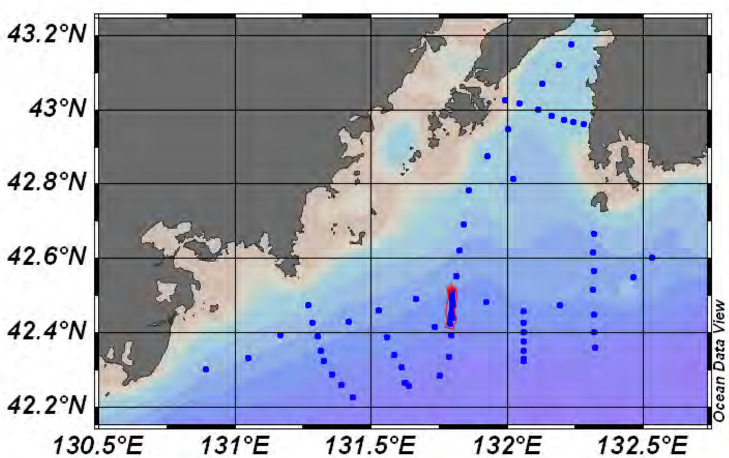
CTD section across a cascading plume, 3-5.04.2013

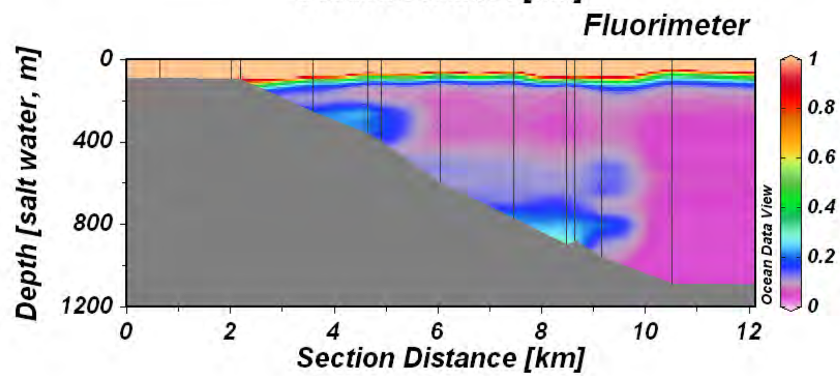






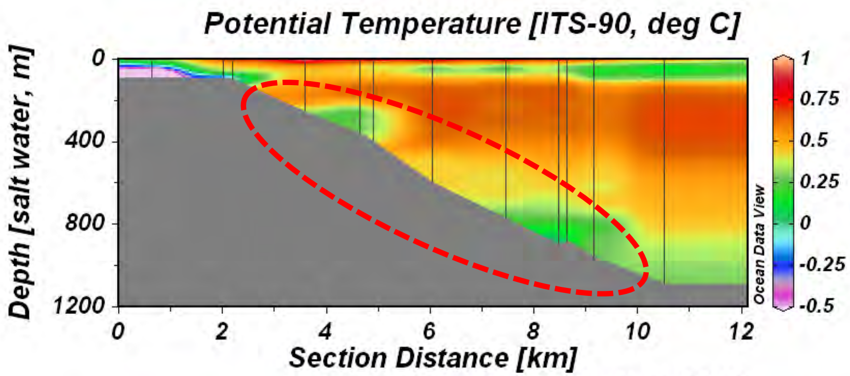


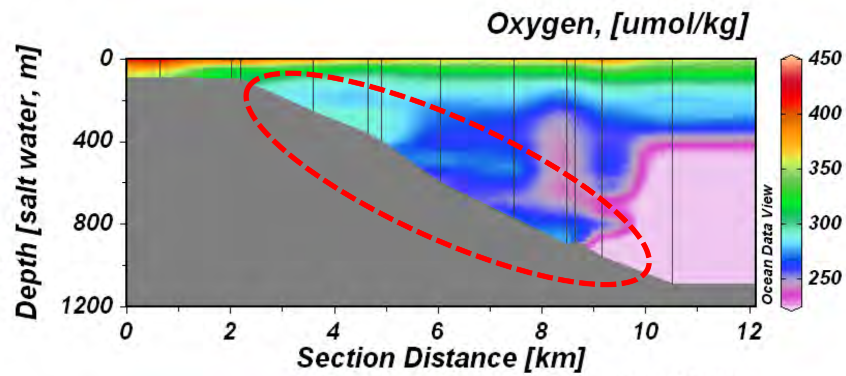


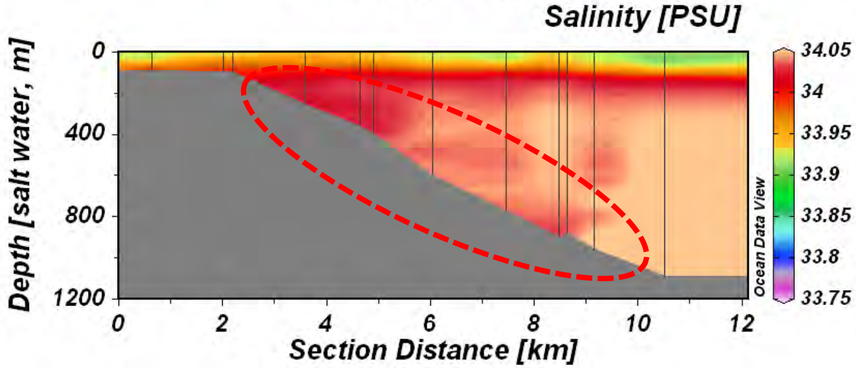


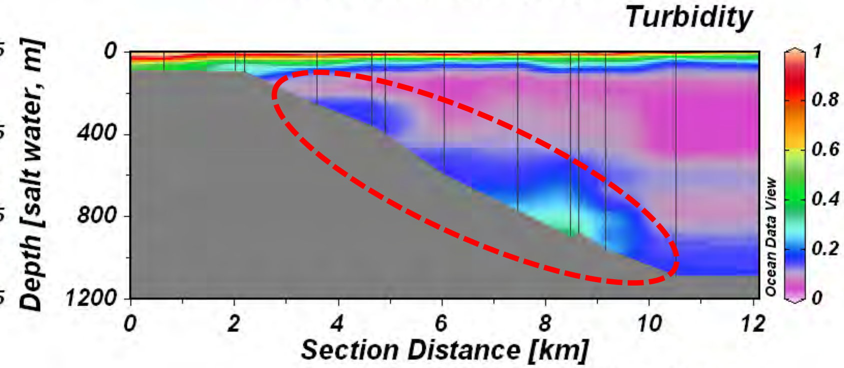
Cascading plume over the slope between 350 and 1150 m (H=150-300 m, L=6 km)

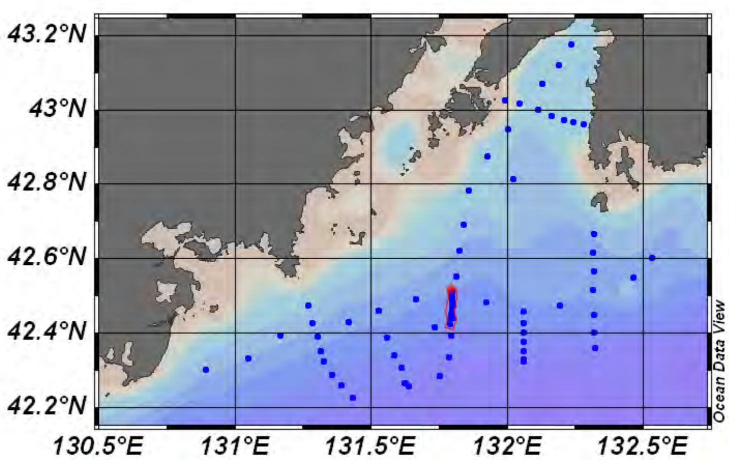
CTD section across a cascading plume, 3-5.04.2013

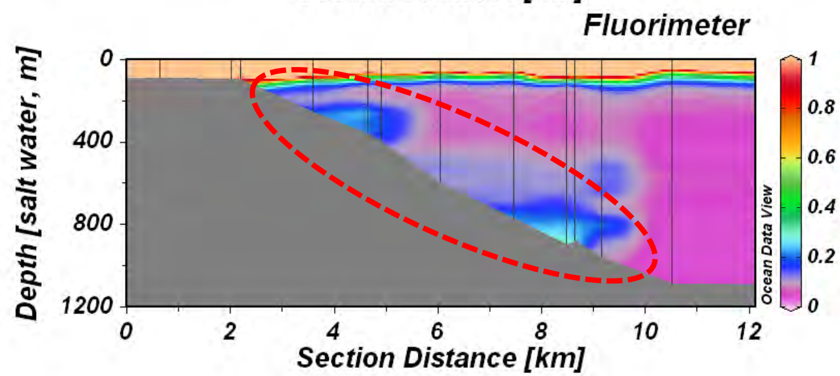






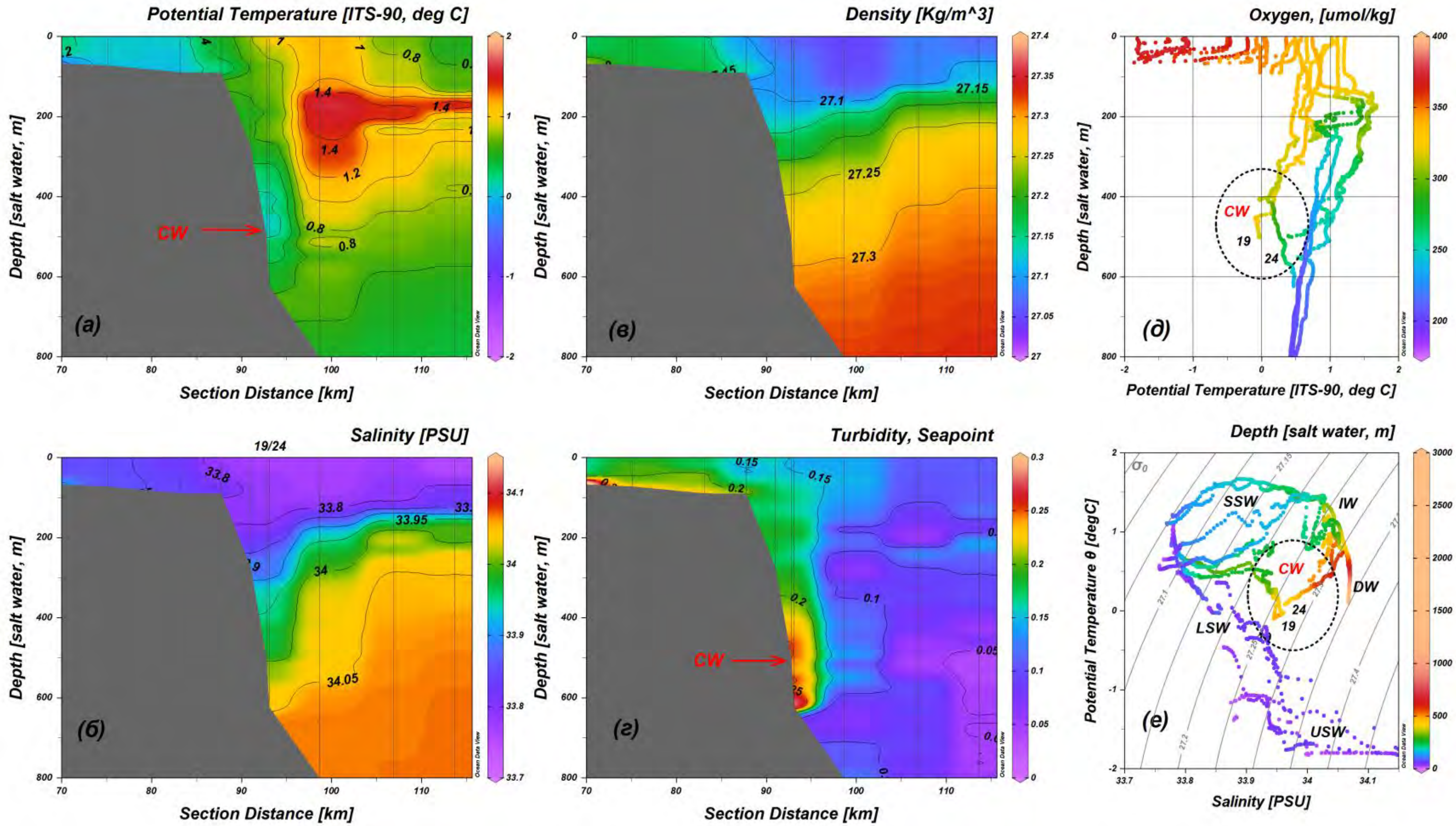






Cascading plume over the slope between 350 and 1150 m (H=150-300 m, L=6 km)

CTD section across a cascading plume, 12-13.01.2015



Cascading plume over the slope between 350 and 700 m

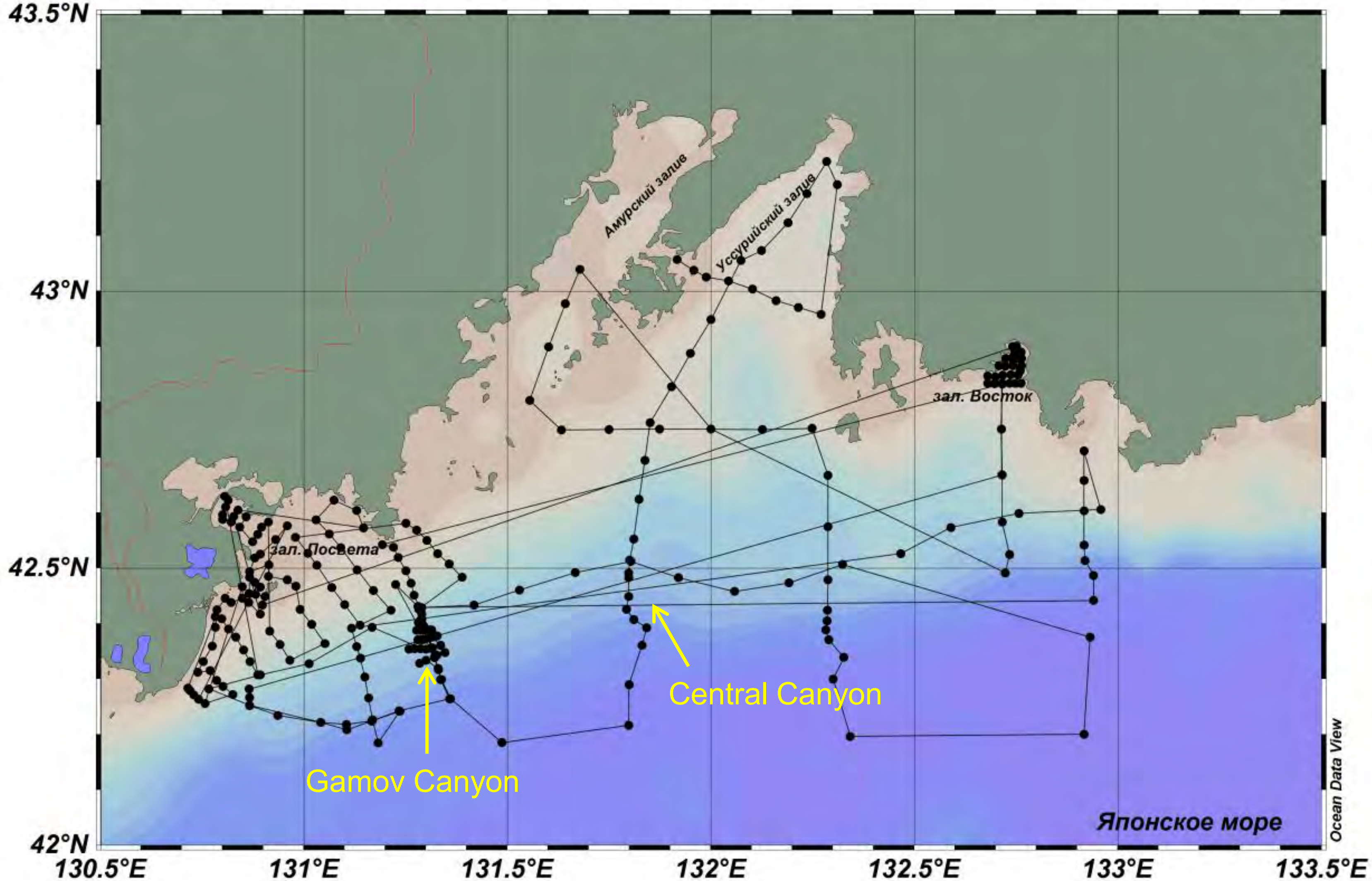
Ga64: 12-13.01.2015

3D structure of cascading

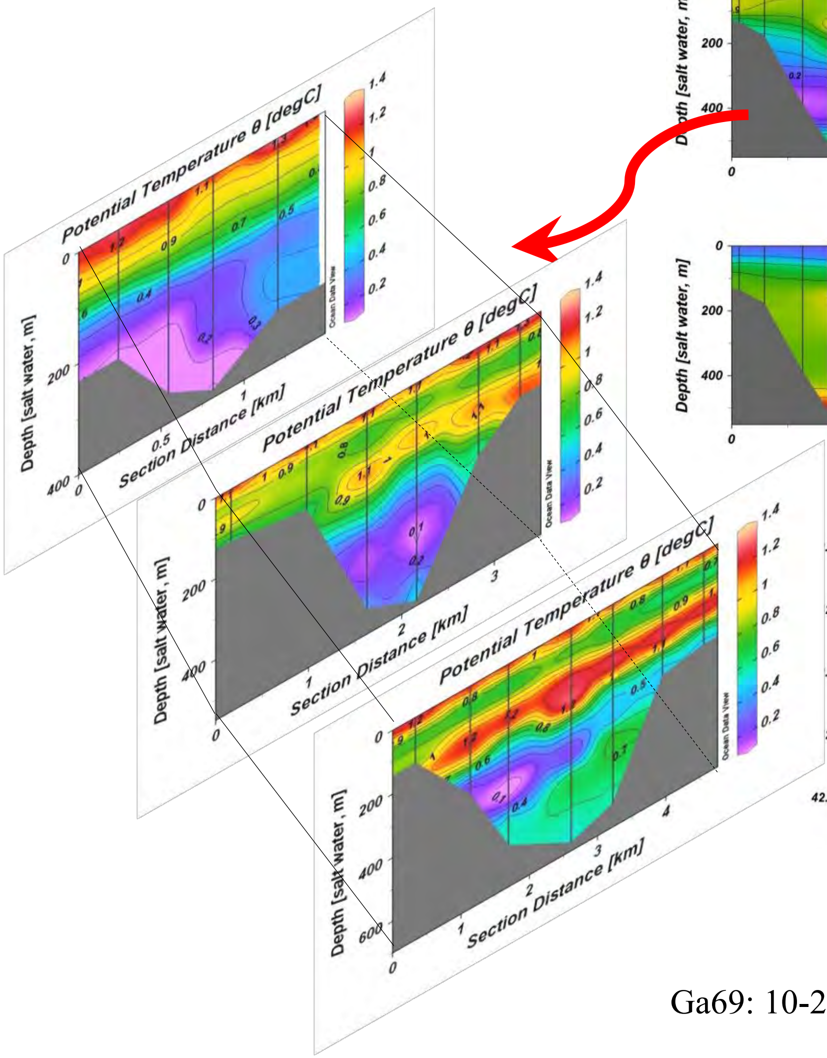
> CTD survey of 2016

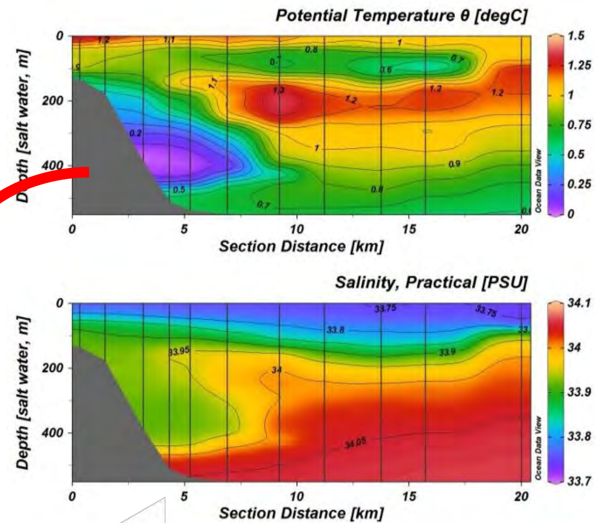
Survey of r/v Professor Gagarinskiy, 2016

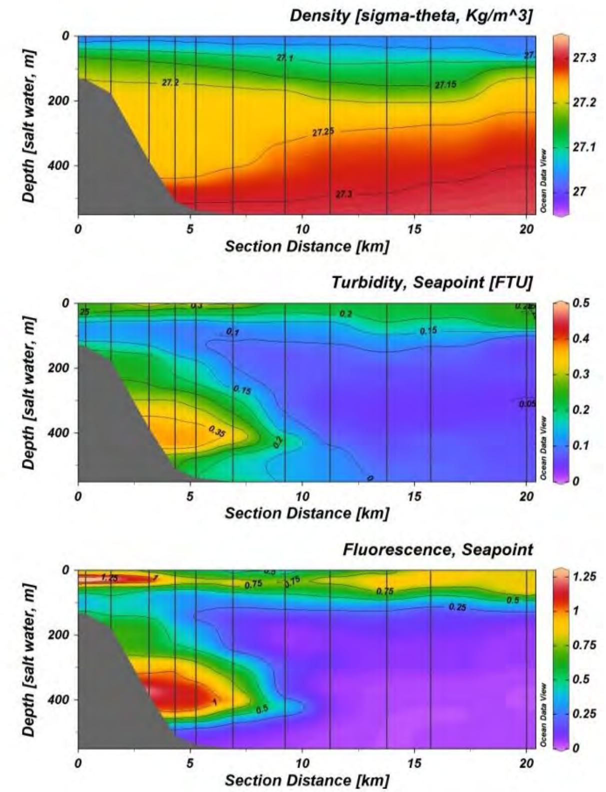
Ga69: 10-24.03.2016 15 сут., Pavel Semkin, Petr Tishchenko

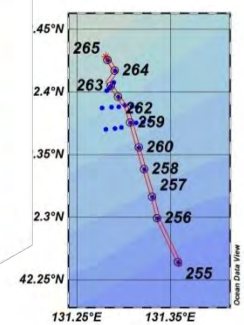


3D Structure of Cascading plume at Gamov Canyon, 17.03.2016







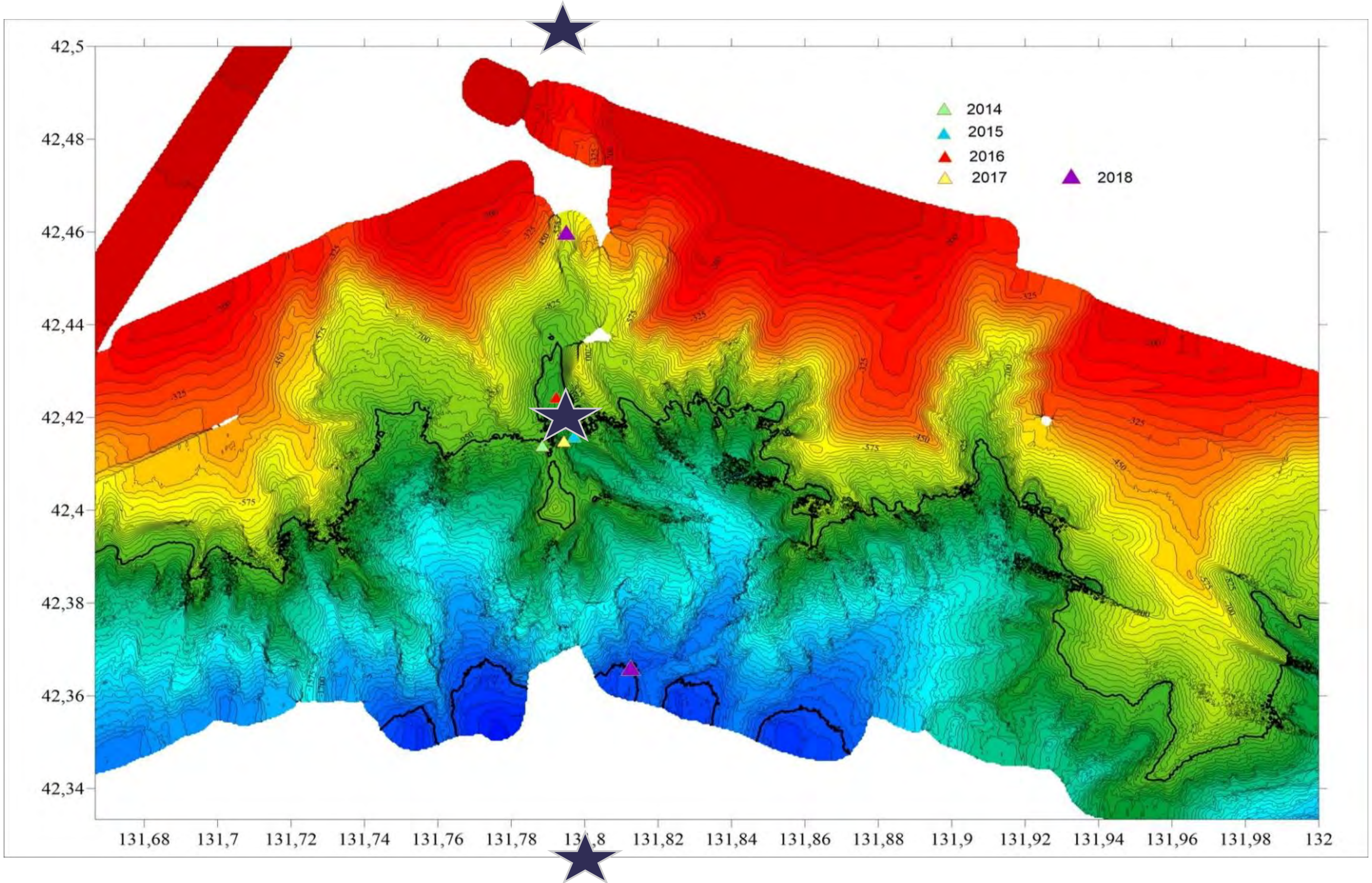


Shelf water intrusions at 200-600 m

H= 200 m L= 5-12 km

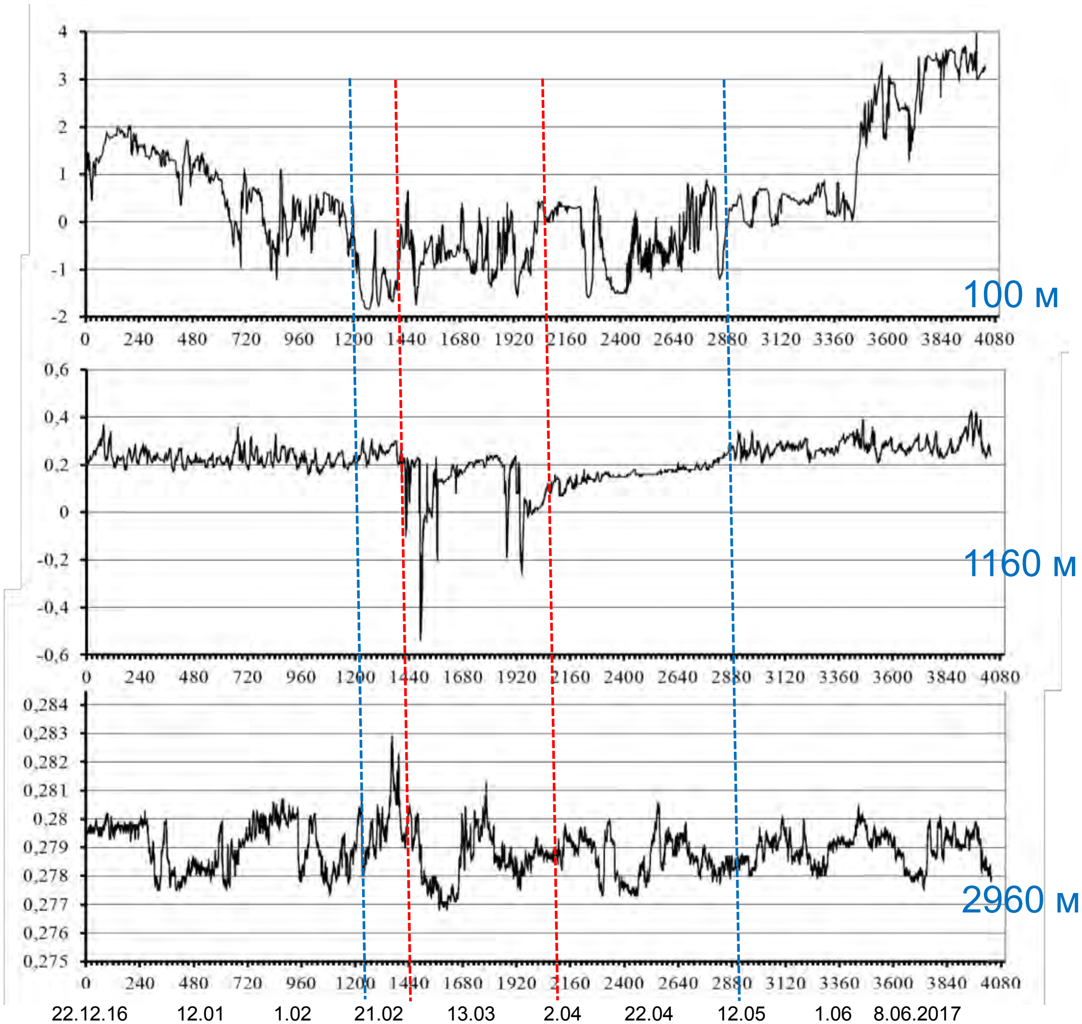
Ga69: 10-24.03.2016

Cascading at the Peter the Great Bay (winter 2016-2017)

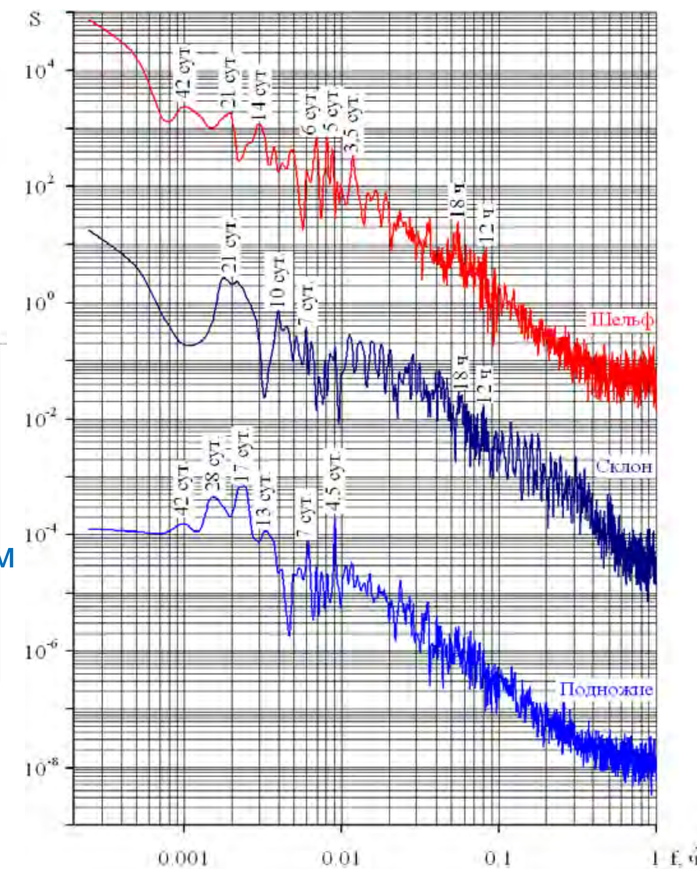


Bottom moorings at the slope of Peter the Great Bay at 100, 1160 and 2960m
during 10.02 - 28.04.2017

Cascading at the central canyon, moorings data 2016-2017



Temperature variation at 100, 1160 and 2960 m depth 22.12.2016 – 8.06.2017 (5,5 months)



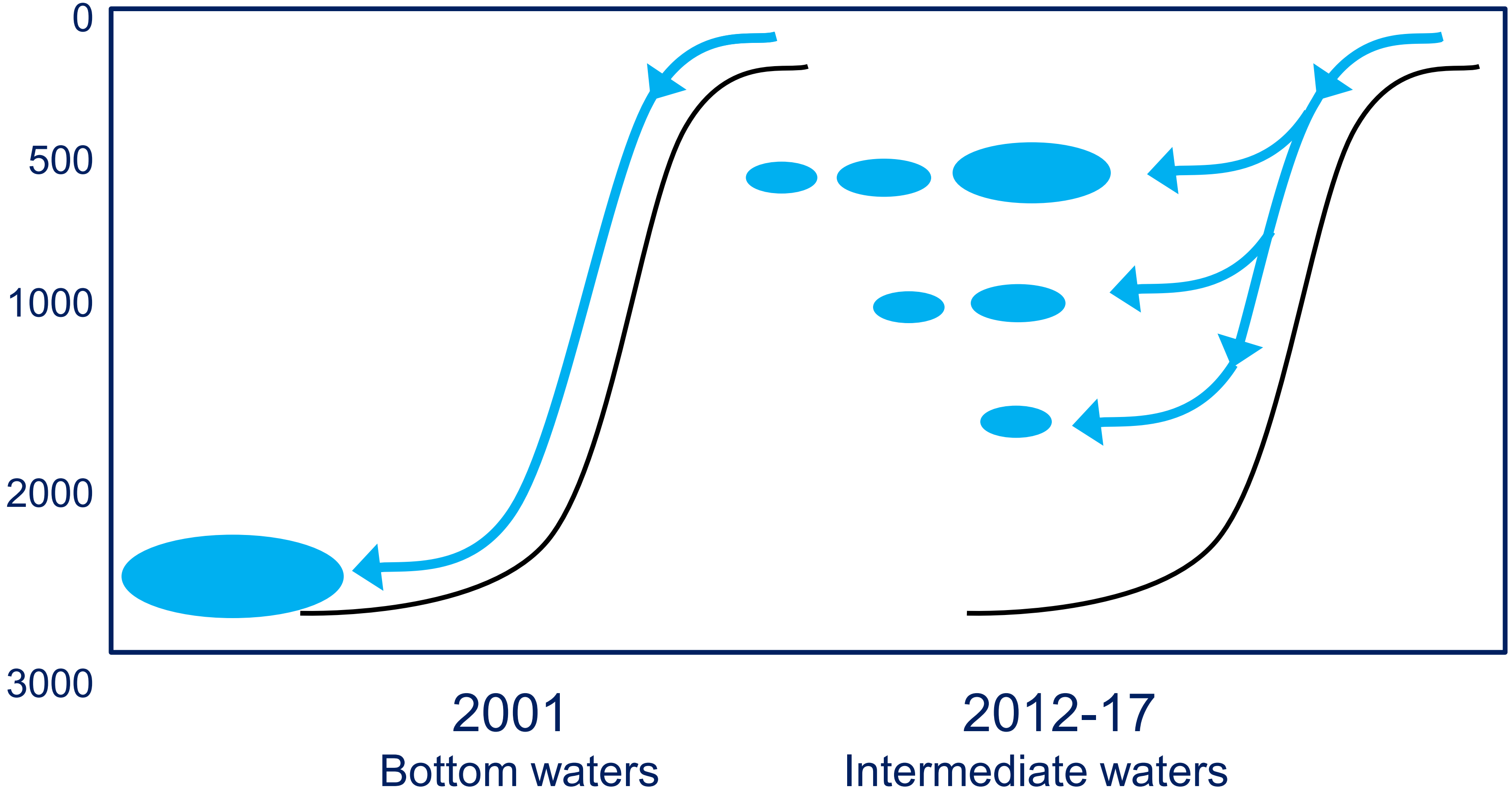
Взаимная корреляция временных рядов придонной температуры со сдвигом и спектры колебаний показаны на рис. 13.3. На рисунке шкала ординат относится к спектрам «Склон» и «Подножие». Спектр «Шельф» сдвинут вверх на один порядок. Все спектры были сглажены по 5 точкам в интервале частот 0.01-0.1 $ч^{-1}$ и по 10 точкам в 0.1-1 $ч^{-1}$. В низкочастотной области на всех спектрах выделяется квазипериодичность 21 суток. Так же выделяются инерционная и полусуточная составляющие колебаний придонной температуры.

(Elena Pavlova, 2018)

Cold dense water at shelf break: 10.02 -28.04.2017 (79 days)

Penetration down to 1160 m: 20.02 -20.03 or 28.04.2017 (30 or 68 days)

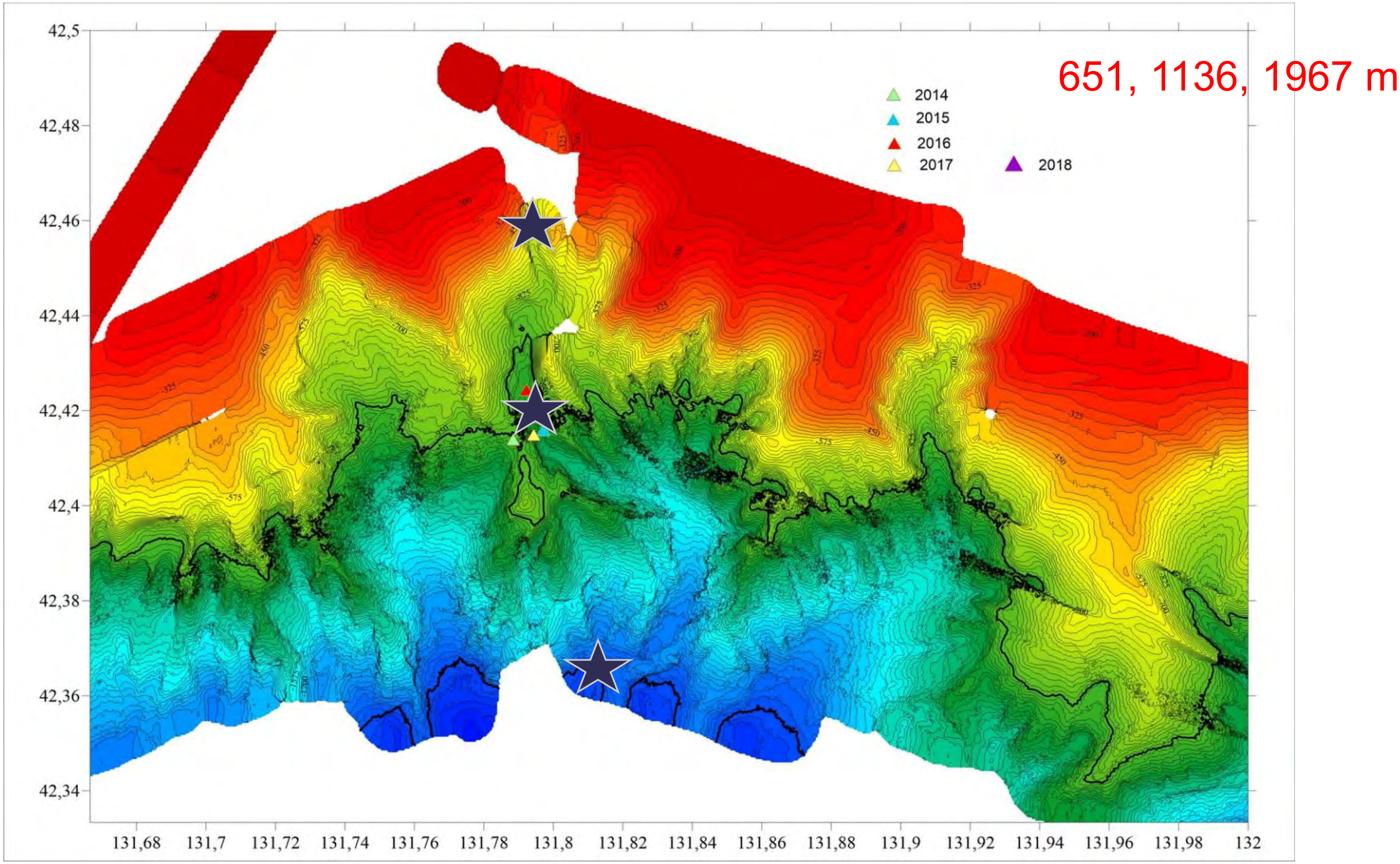
Changes of ventilation regime



Direct observations during winter 2017-2018

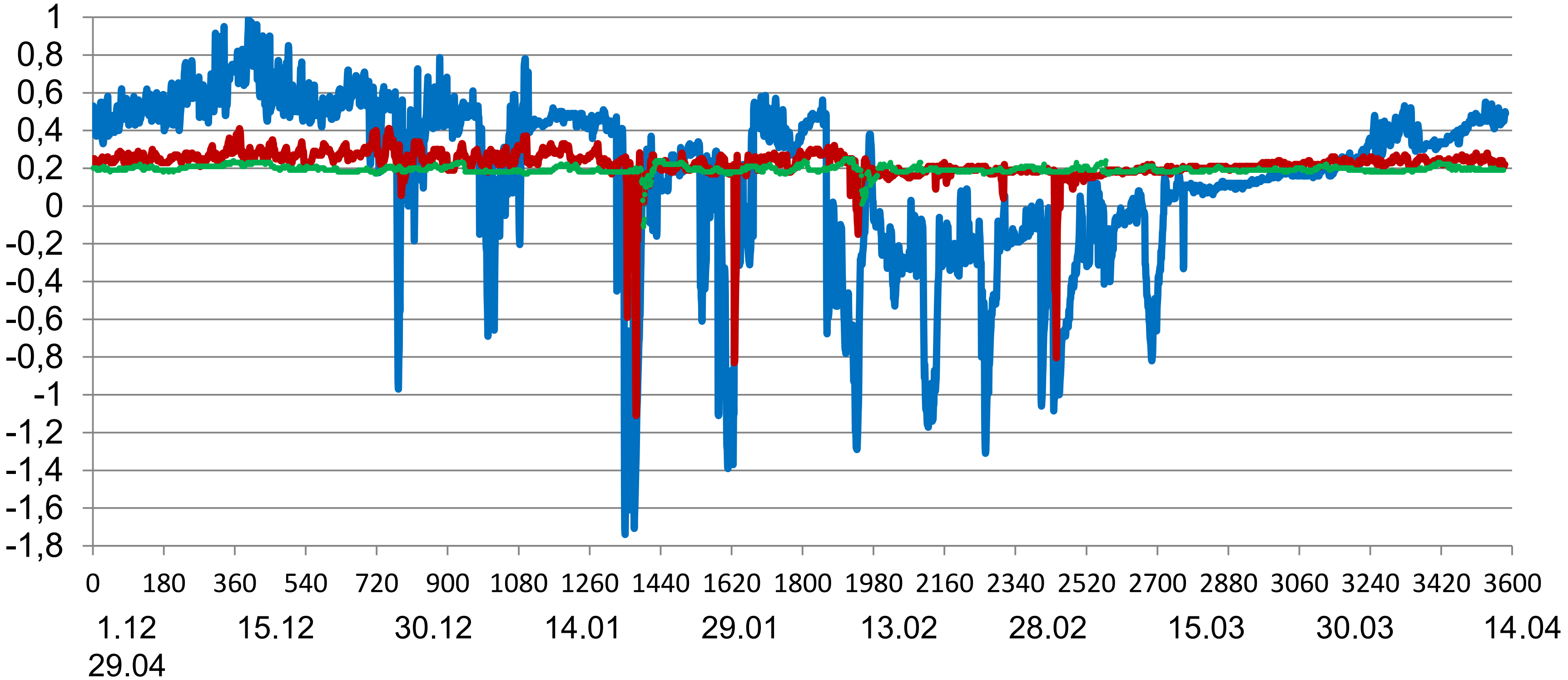
> 3 moorings

Cascading at the Peter the Great Bay (2017-2018)



Bottom moorings at the slope of Peter the Great Bay at 651, 1136 and 1967 m during 1.12.2017- 29.04.2018

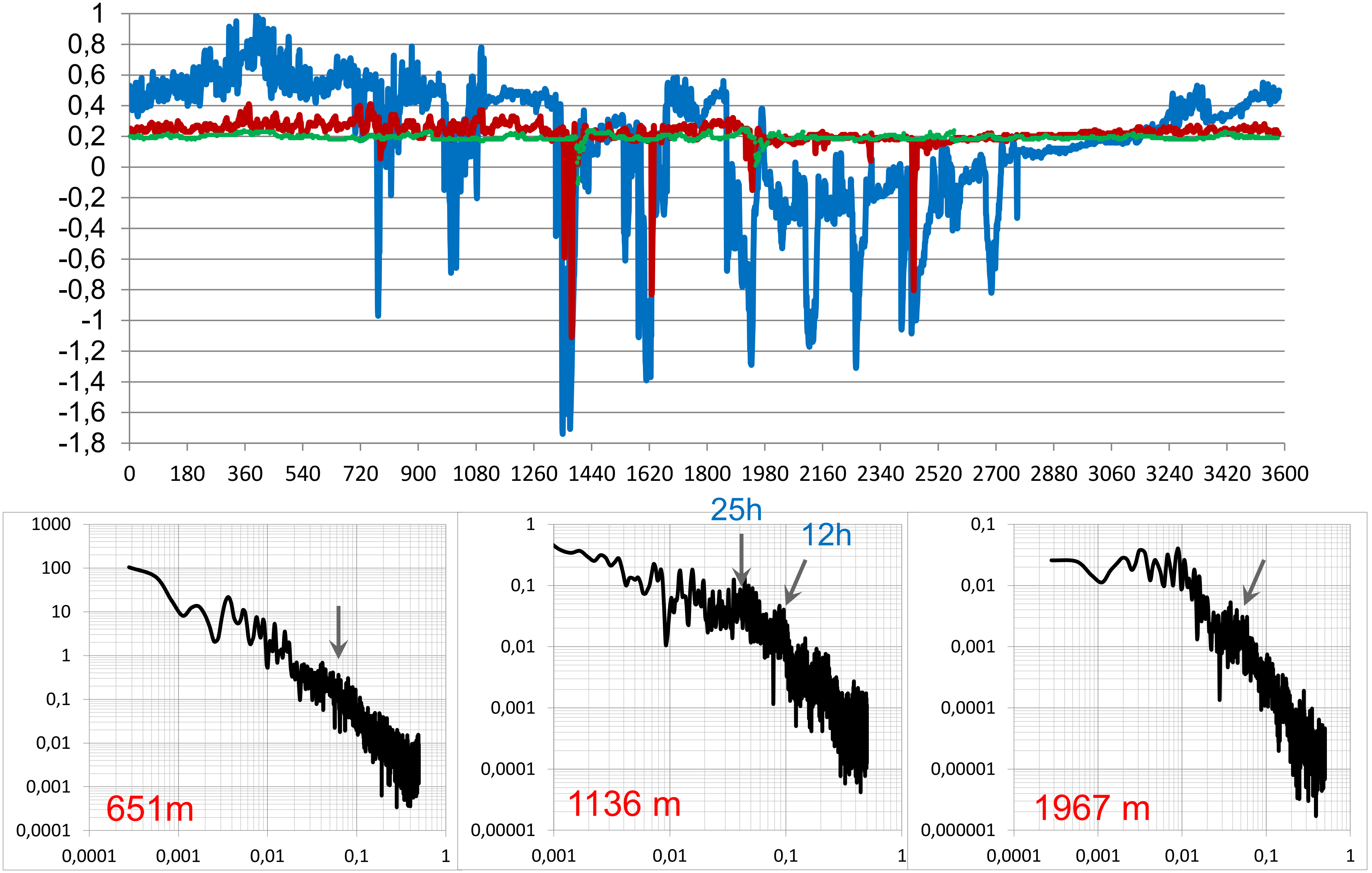
Cascading at the Peter the Great Bay (2017-2018)



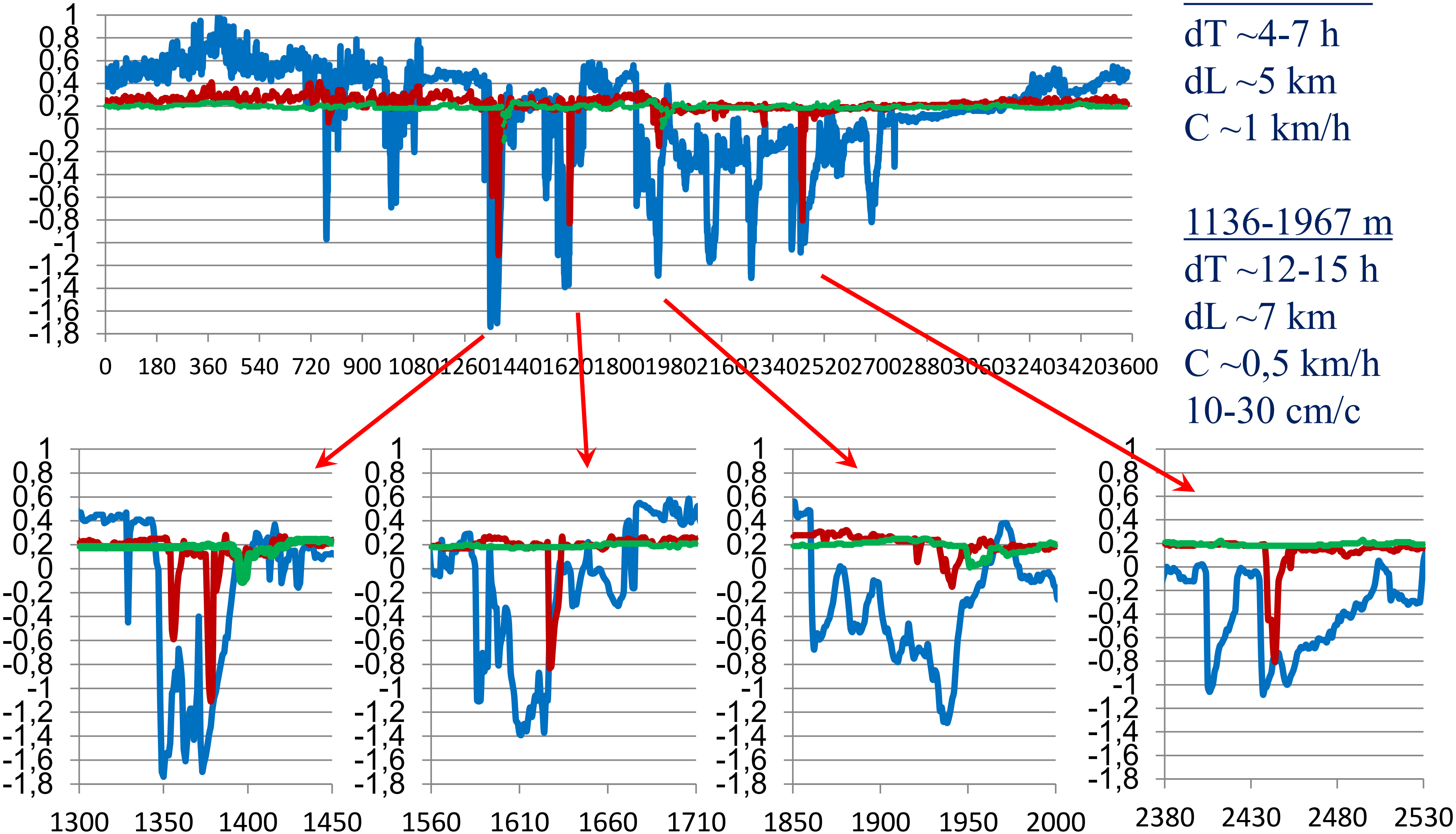
Variations of T at 651 m (blue), 1136 m (red) and 1967 m (green)
during 1.12.2017- 29.04.2018 AquaDopp .

10 events at 651 m, **7** events at 1136 m and **2** events at 1967 m

Cascading at the Peter the Great Bay (2017-2018)



Cascading at the Peter the Great Bay (2017-2018)

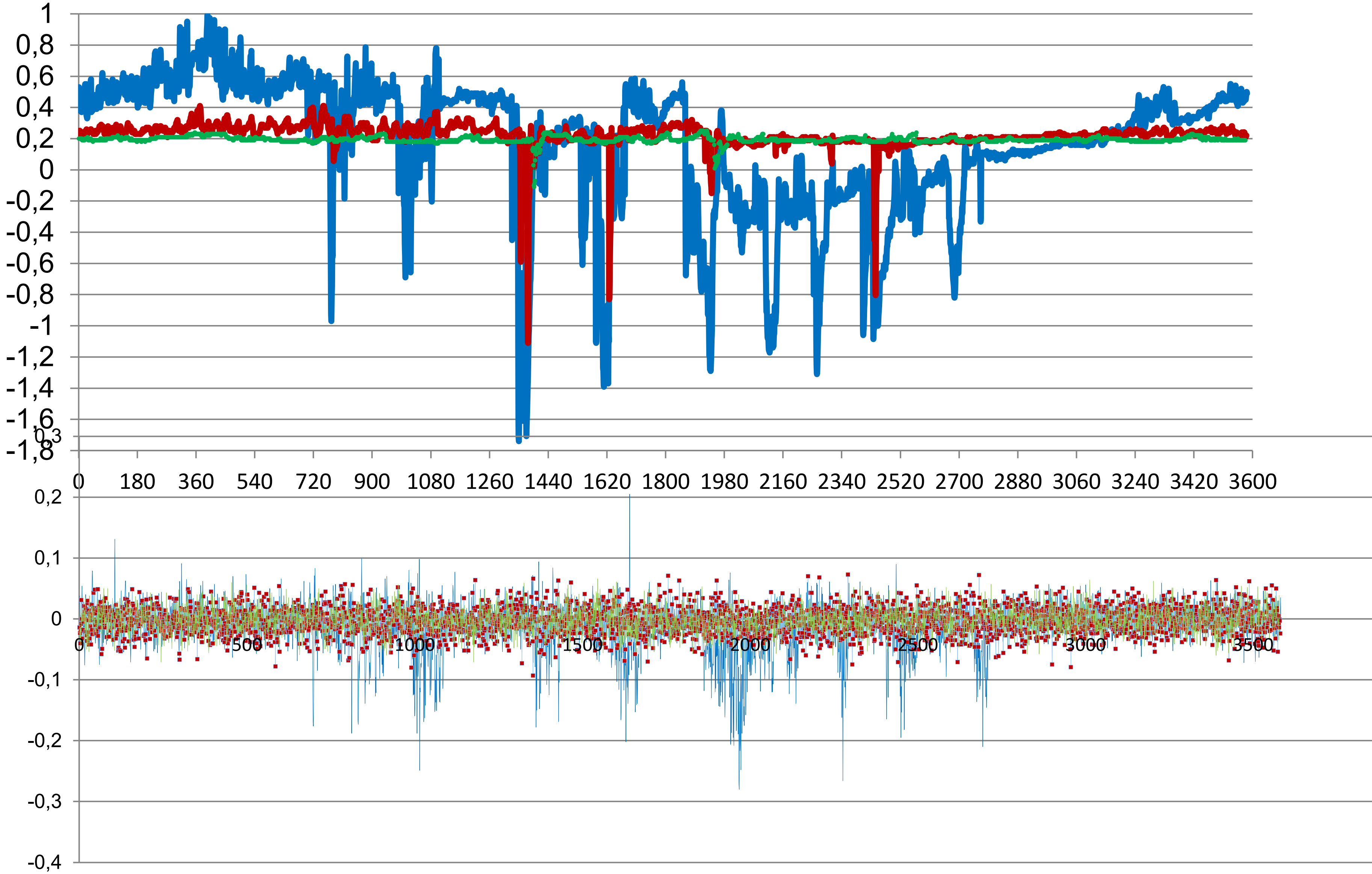


<u>651-1136 m</u>
dT ~4-7 h
dL ~5 km
C ~1 km/h

<u>1136-1967 m</u>
dT ~12-15 h
dL ~7 km
C ~0,5 km/h
10-30 cm/c

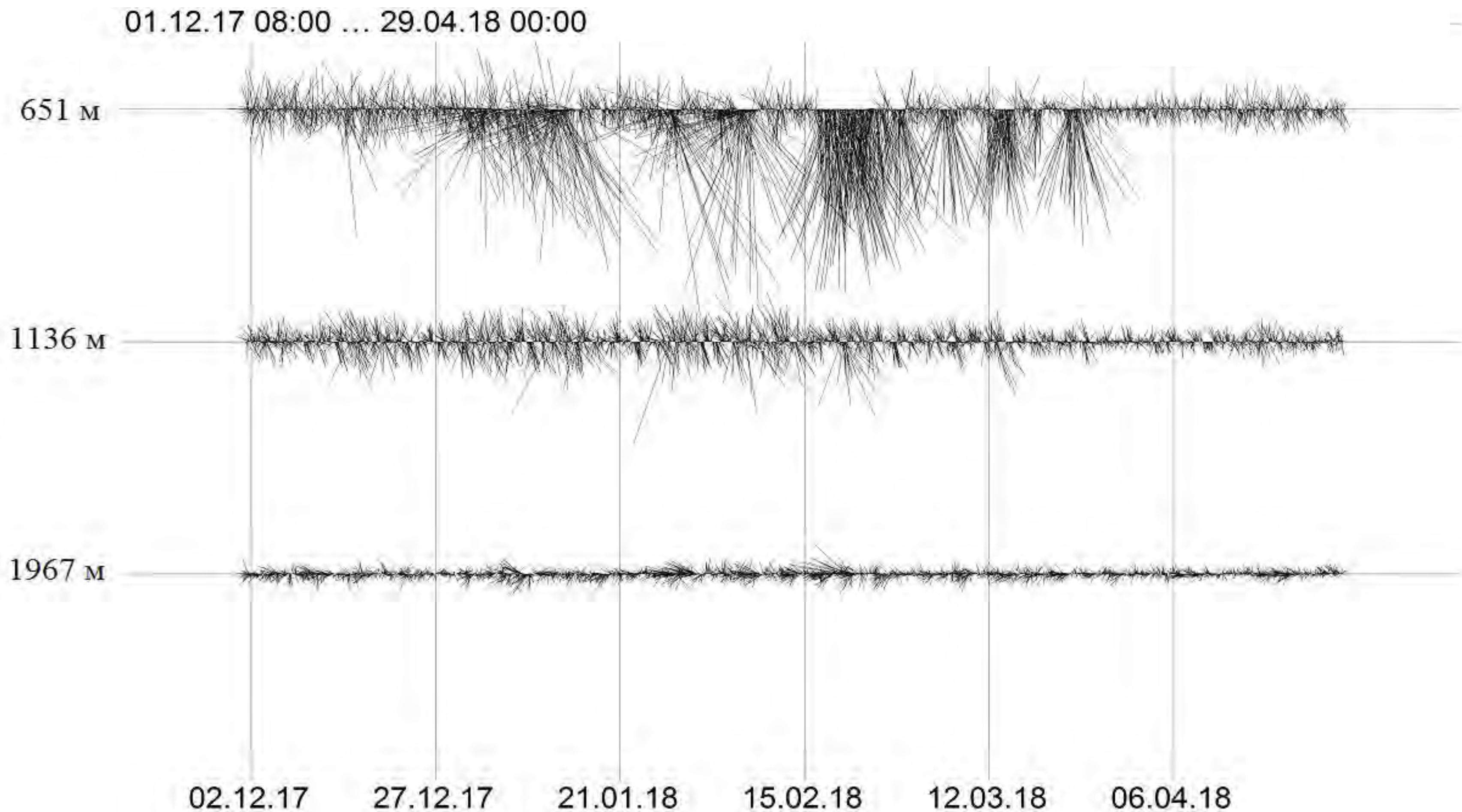
Penetration with depth ~ 10-30 cm/s

Cascading at the Peter the Great Bay (2017-2018)

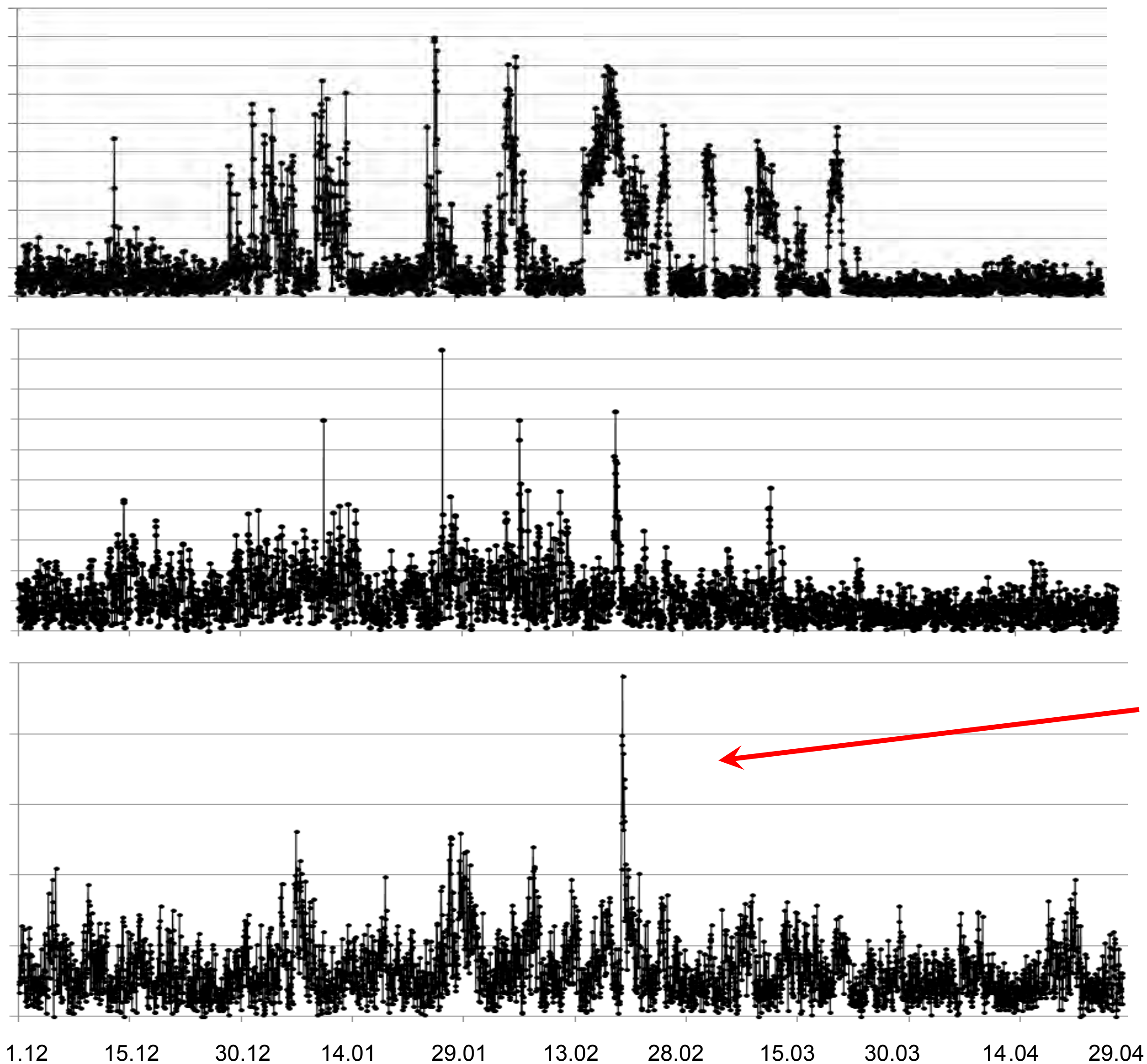


Vertical velocity up to ~ 0.28 cm/s

Cascading at the Peter the Great Bay (2017-2018)



Cascading at the Peter the Great Bay (2017-2018)



<u>Vel max</u>

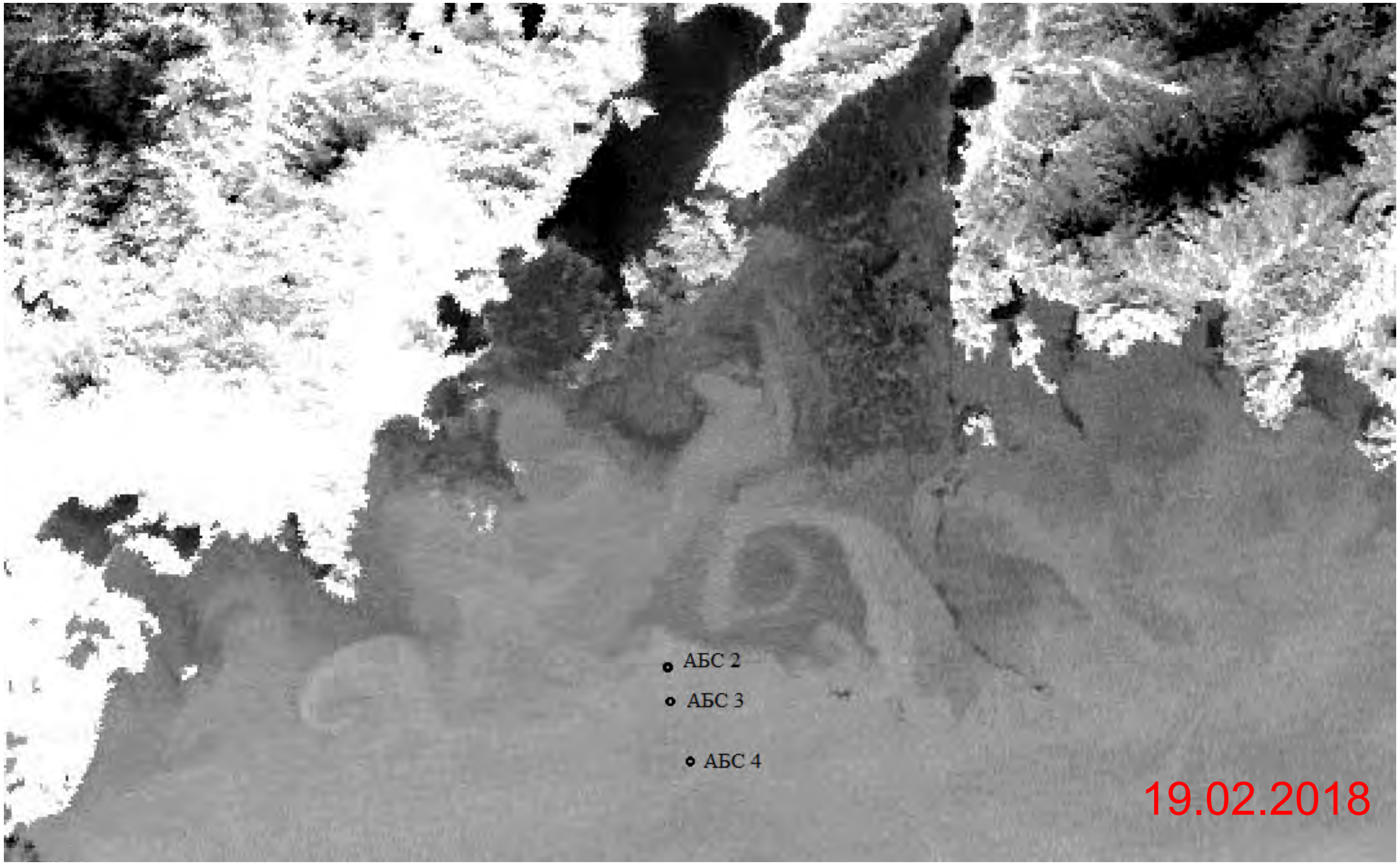
651 m ~ 90 cm/c

1136 m ~ 46 cm/c

1967 m ~ 10-12 (24) cm/c

Strong event – 19.02.2018

Cascading at the Peter the Great Bay (2017-2018)



Mesoscale water dynamics may play a trigger role for cascading

Summary

- Direct observation of cascading down to bottom of the slope during winter 22017-2018
- 10 events at 651 m, 7 events at 1136 m and 2 events at 1967 m
- Strong currents were associated with cascading up to 90 cm/s (651 m) and up to 24 cm/s at 19967 m
- Even penetrating down the bottom 2018 cascading was a small injection in compare with 2001 ventilation.
- Model interpretation is needed