PICES 2025 S1: Science Board Symposium, Nov 10, 2025, Yokohama, Japan

TRITIUM IN THE NORTH WESTERN PACIFIC: NATURAL TENDENCIES AND NEW CHALLENGES

Vyacheslav Lobanov, Vladimir Goryachev, Aleksandr Sergeev, Maksim Budyansky, Daniil Kalyuzhny, Danila Sokolov

V.I.Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russia

Laboratory of Nuclear Research at POI, since 1974 г.

Main projects:

- Far Eastern Network of Tritium Monitoring, 1980-1982
- Consequences of Nuclear Submarine accident in Chazhma Bay, 1985-2018
- Consequences of the Fukushima-1 NPP accident , since 2011

Equipment

•**Low-frequency system with a gas proportional meter** for measuring tritium in natural waters. The minimum statistical limit for direct registration of the concentration of tritium is 1.4 TE. A system of electrolytic cells for enriching aqueous tritium samples with an initial mass of 250, 500, 3000 g with enrichment coefficients of 20, 40, 7 times, respectively.

•**Ultra-low-frequency liquid scintillation spectrometer QUANTULUS 1220** for measuring beta and alpha emitting radionuclides with a minimum detectable tritium concentration of 8 TE. When using two-stage electrolytic enrichment, this value is reduced to 0.06 TE

•**Low-background gamma-spectrometer** with a large detector of ultrapure germanium GEM 150 (crystal diameter 88.5 mm, height 99.8 mm) in lead protection with a DSPEC jr 2.0 digital multichannel analyzer (ORTEC, USA). The energy resolution of the detector on the 1332 keV line is 1.9 keV. The integral counting rate of the detector background in protection is 6.6 imp/s in the energy range of 50-2990 keV.

Main directions

•**Behavior of artificial and natural radioisotopes in hydrosphere objects**

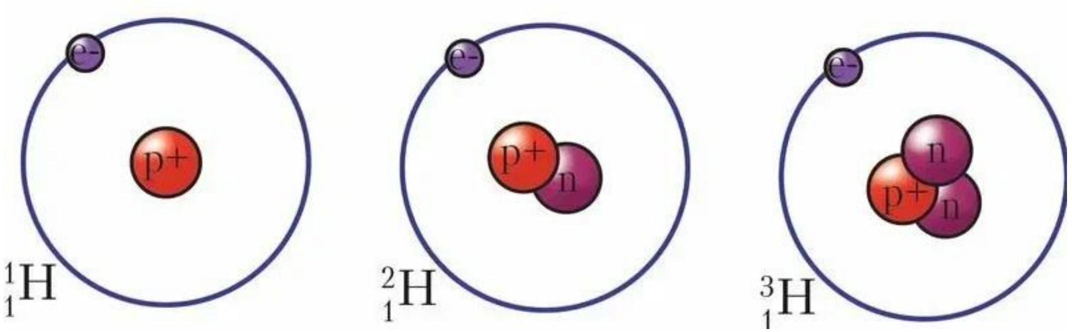
•**The use of radioisotopes as tracers of dynamic hydrosphere processes**

•**Marine Radioecology**

Prof. Vladimir Soyfer (right), founder and head of laboratory, reports to Academician Anatoliy Aleksandrov, President od USSR Academy of Sciences (center) during his visit to POI, 1985

Tritium ($_{3}$H) is a natural isotope of Hydrogen

Protium Deuterium Tritium



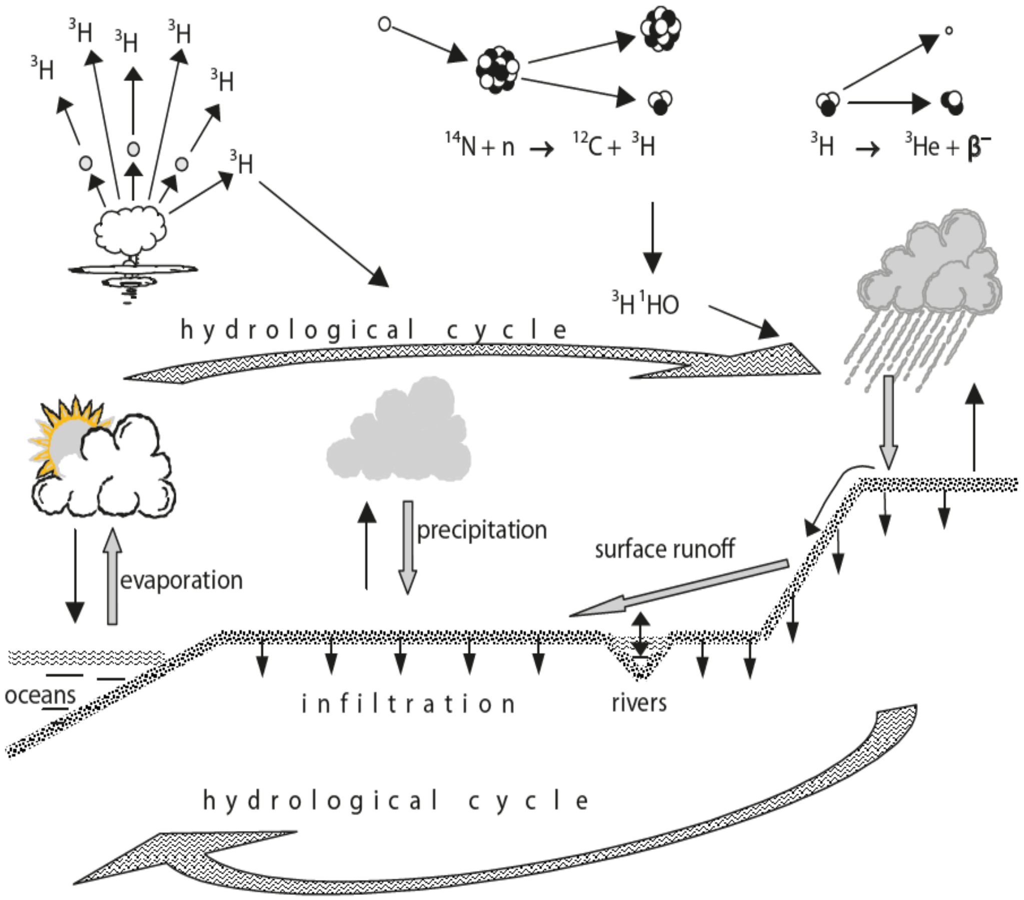
Super-heavy isotope of hydrogen with 2 neutrons in its nucleus

Discovered in 1934

In nature, tritium is produced in the upper atmosphere when cosmic radiation particles collide with the nuclei of atoms, such as nitrogen.

Then with a rain it comes to the land and ocean and transported through hydrological cycle

Half-life is 12.32 years



Transport of tritium in hydrological cycle is very fast with exception when it is captured in glaciers and underground water
(from http://www.iaea.org/programmes/ripc/ih/volumes/vol_one/cht_i_08.pdf)

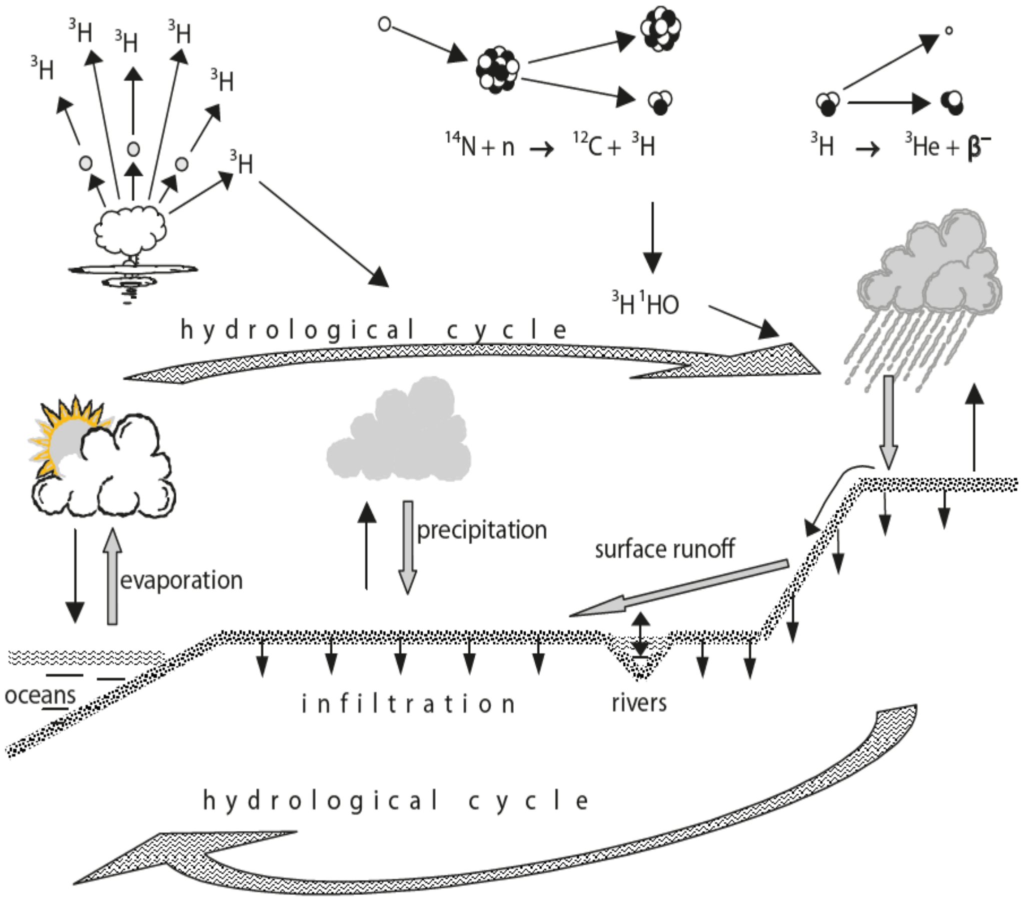
Origin and transport of Tritium (^3H) in natural environment

Natural

- Generation in atmosphere, lithosphere and ocean
- Transport to atmosphere from outside

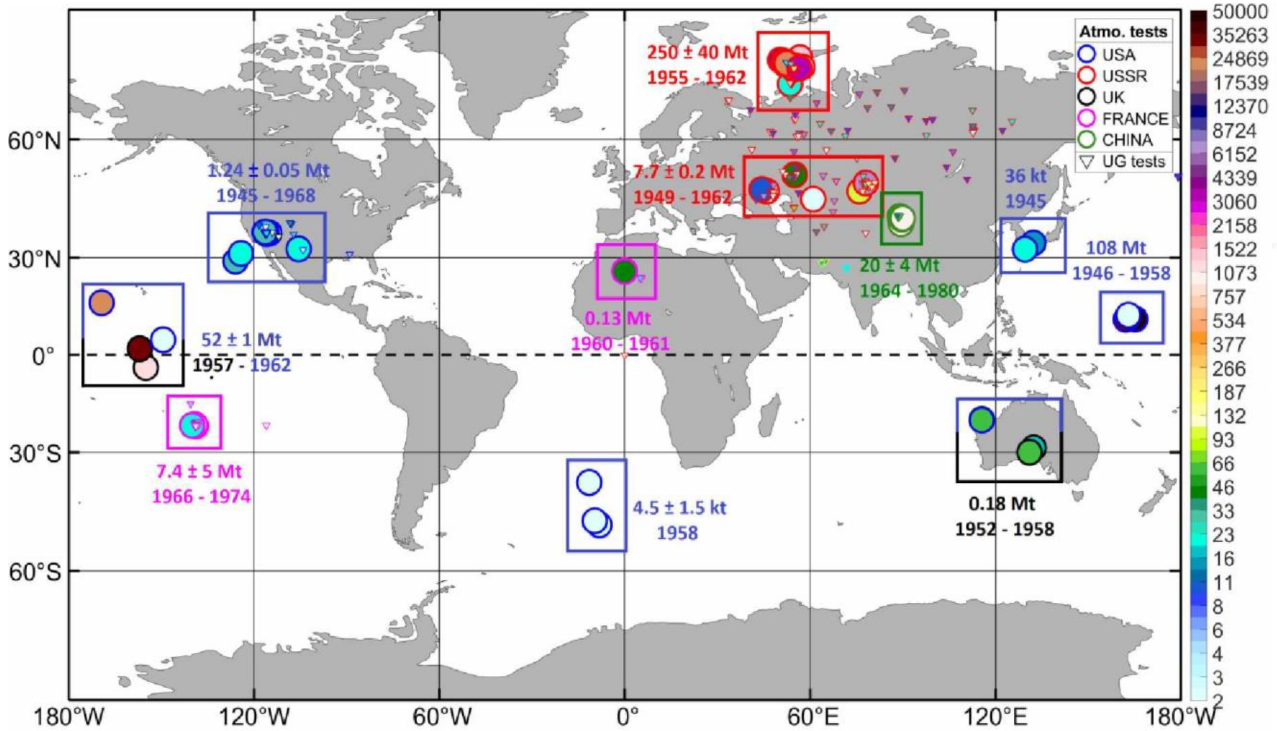
Technogenic

- Nuclear weapon tests
- Legal discharge and leakage from nuclear industry (nuclear power plants, nuclear fuel recycling, industrial production of tritium)
- Damages and incidents of nuclear industry

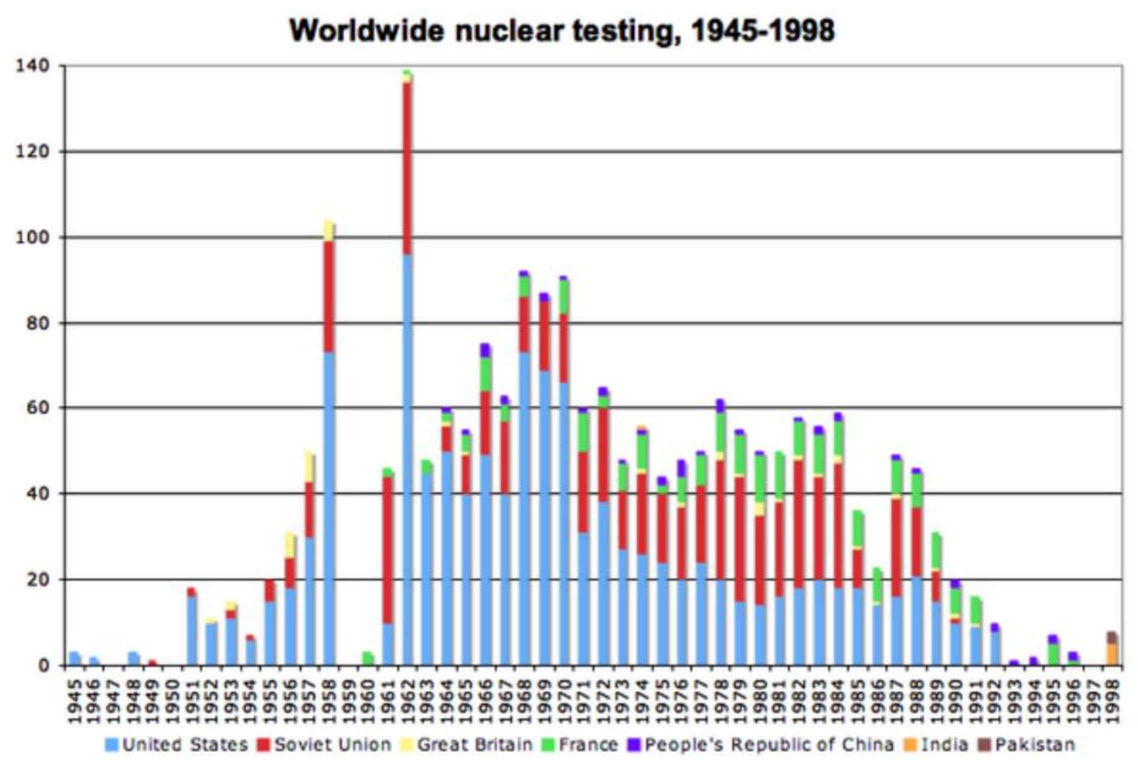


Transport of tritium in hydrological cycle is very fast with exception when it is captured in glaciers and underground water (from http://www.iaea.org/programmes/ripc/ih/volumes/vol_one/cht_i_08.pdf)

Nuclear testing since 1945 – gradual increase of 3H concentration



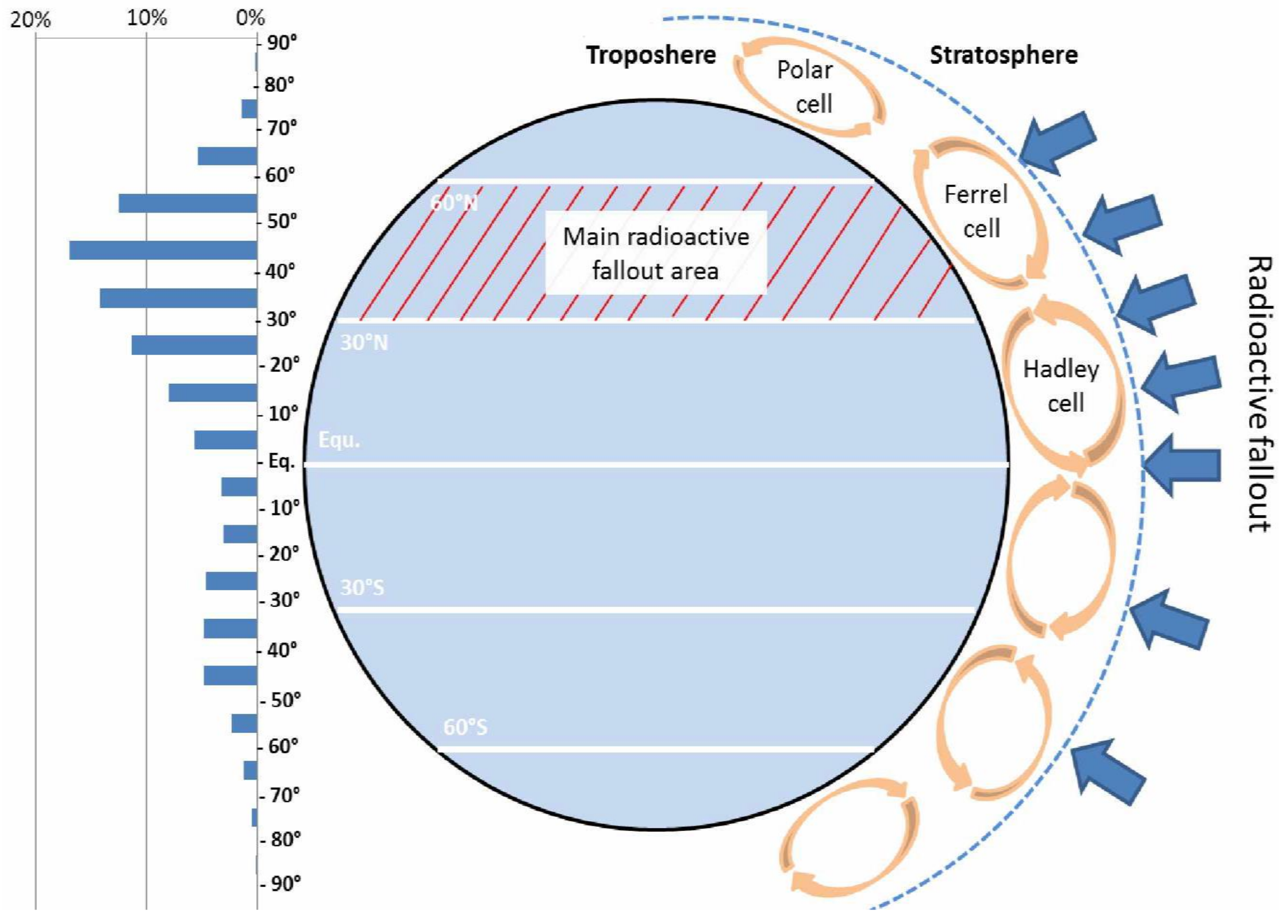
1945 – first nuclear weapon test, USA
1949 – first test in USSR
1953 – first hydrogen bomb, USSR
1963 – Moscow treaty on the Limitation of Nuclear Tests in Three Environments (atmosphere, underwater and space)



1974 – continue tests (France)
1980 - continue tests (China)
1981- other countries continued
1996 - Comprehensive Nuclear-Test-Ban Treaty
1998 – India and Pakistan stopped
2006-2017 – 6 tests of DPR Korea

Increase of tritium concentration >1000 times in Northern Hemisphere

Tritium ($_3$H) distribution



Tritium concentration now (TU=0.118 Bq/l):

Precipitation	5-10
Land water	5-10
Ocean	0.5- 2.0 (coastal area)

Maximum – middle latitudes of NH, caused by atmospheric circulation cells, upward transport to upper atmosphere and fall down

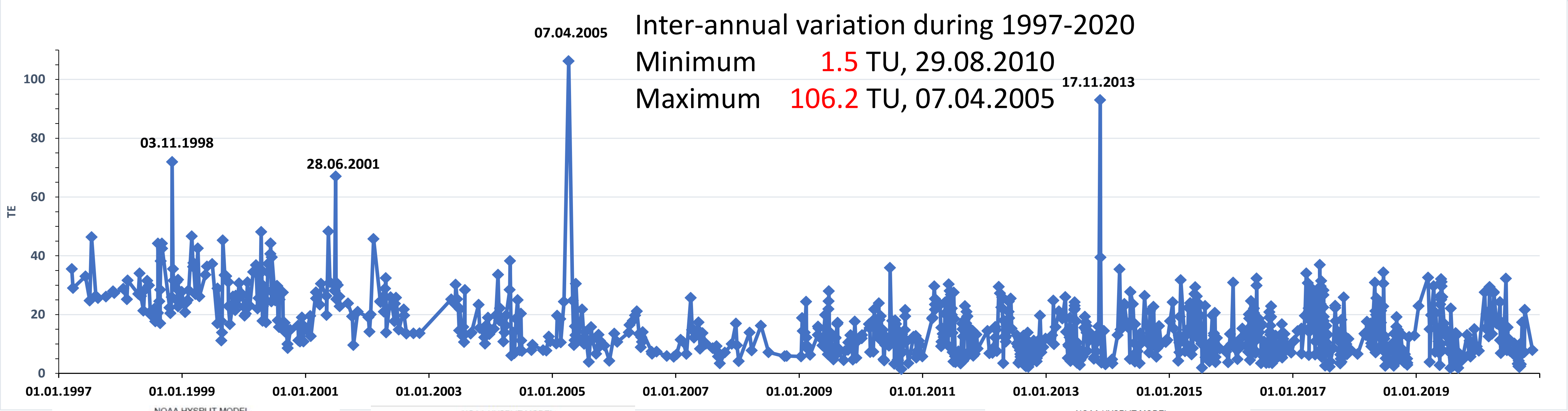
Tritium concentration pre-bomb era:

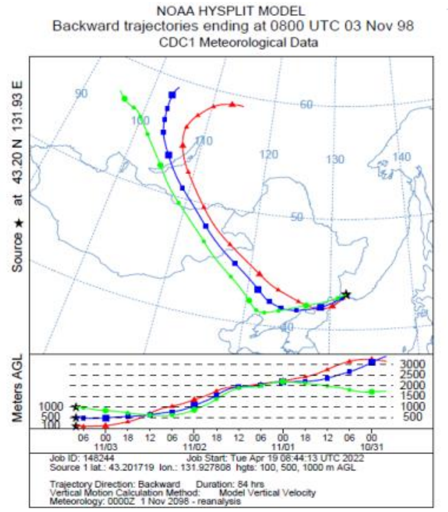
Precipitation NH	2-12
Precipitation SH	0.6-1.0
Ocean	0.2-1.0

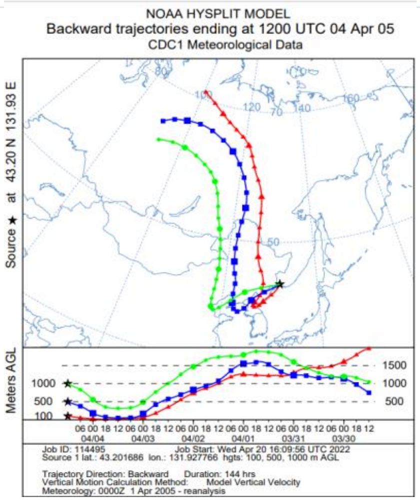
After intensive nuclear tests (1960th): > 1000 TU

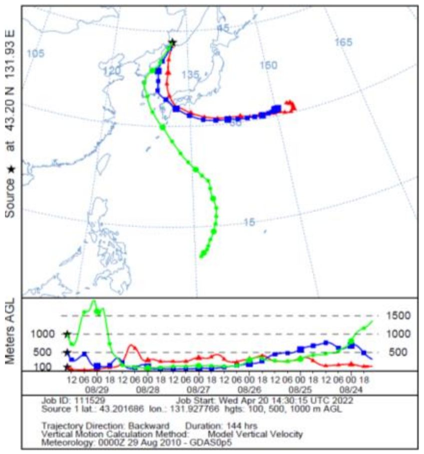
Tritium in precipitation of Vladivostok 1997-2020

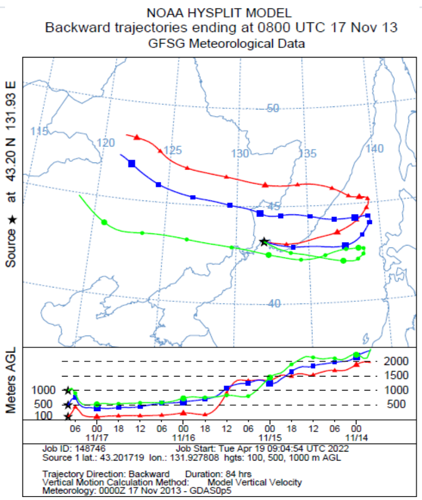
POI FEB RAS
ТОИ ДВО РАН

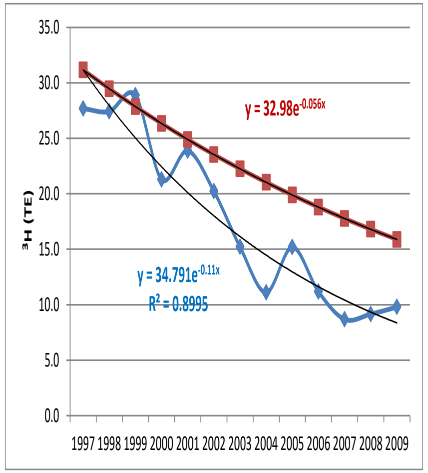




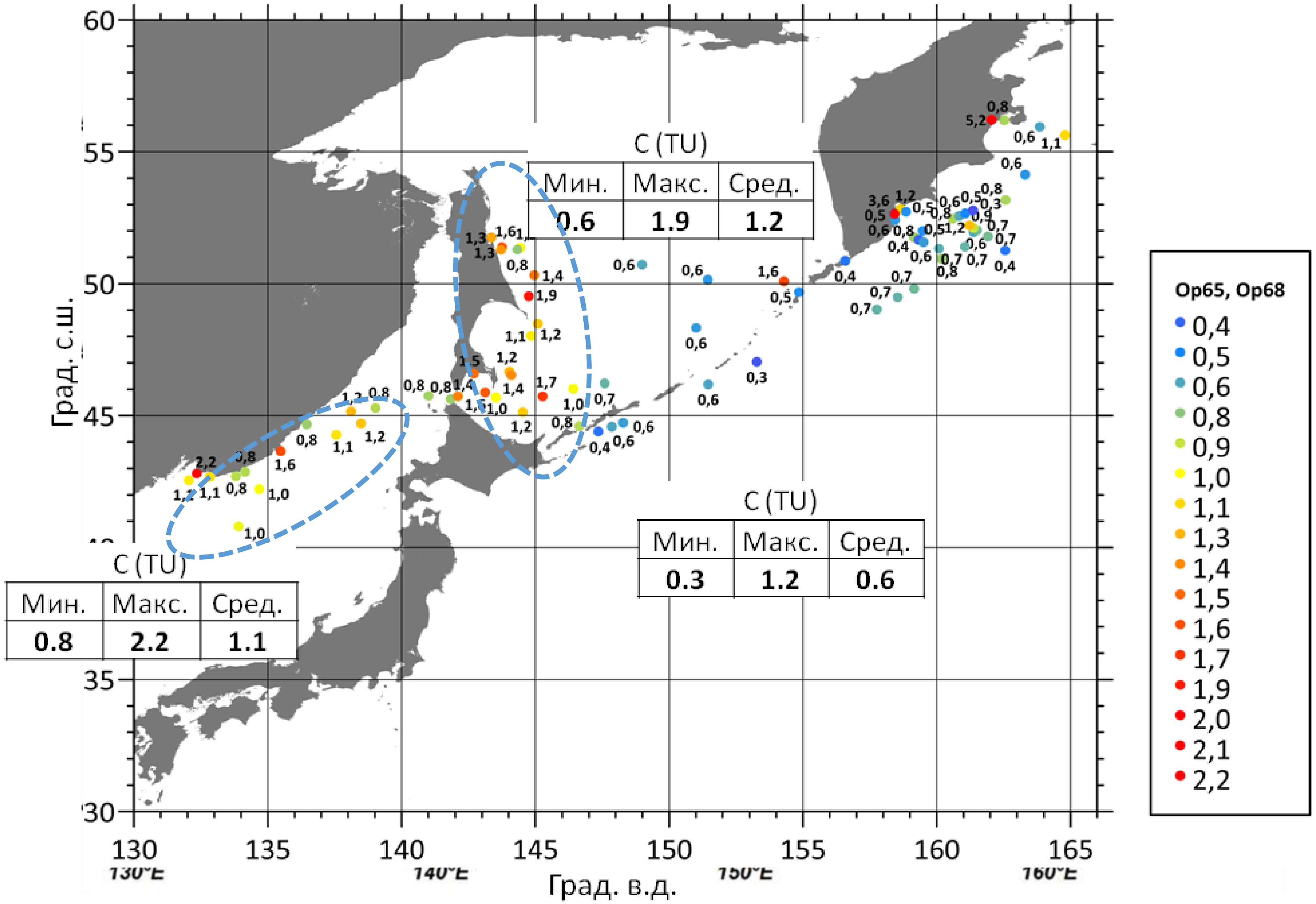








Tritium in the Japan Sea, Okhotsk Sea and Pacific, 2022-2023



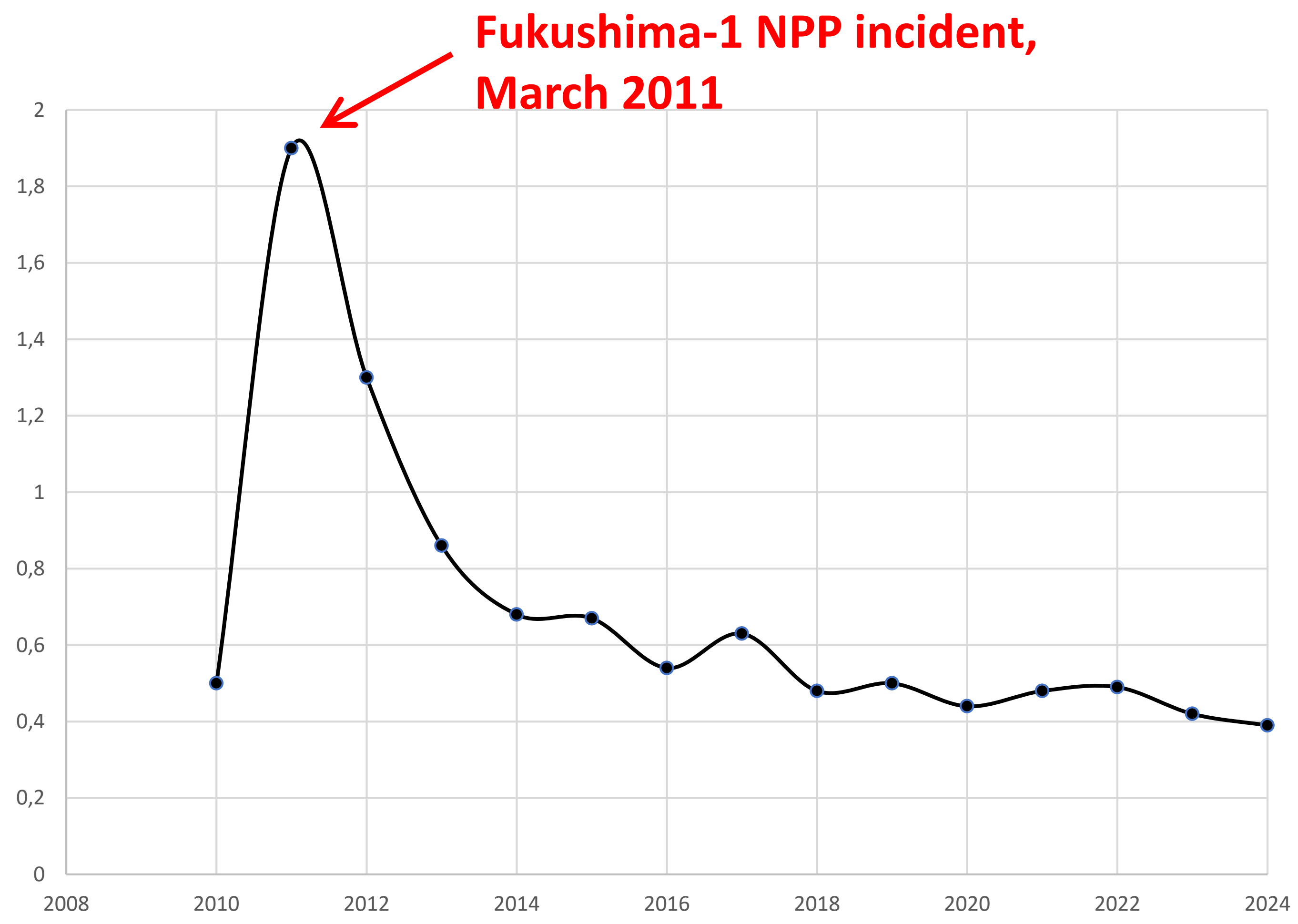
Concentration of tritium in surface waters based on POI cruises on R/V *Akademik Oparin* in December 2022 (cruise #65) and Aug-Sep 2023 (cruise #68) in TU

Average: 0.72
Maximum: 1.27
Minimum: 0.33

This is a little higher than other data:
0.2-0.5 *(Povinec et al., 2004, 2010, 2017)*
0.4-0.5 *(NRA, 2023)*

Because we took many samples close to the land where tritium content is higher

Tritium in the ocean to the east of Japan in 2010-2024



Based on available results of observation 50-150 km east of Fukushima-1 area

Nuclear Regulation Authority, Japan, 2023
Kaizer et al., 2020
Povinec et al., 2013, 2017

New challenge: discharge Fukushima-1 NPP accumulated water

Government of Japan Decision of April 13, 2021 to discharge water accumulated at Fukushima-1 NPP into the ocean

Volume of accumulated water: 1.25 M tonn

Purified from all radionuclides with except of tritium

Tritium concentration: ~ 800 KBq/l

Water will be diluted up to: ~1000 Bq/l

Volume to discharge: 780 TBq of tritium, ~ 22 TBq/year

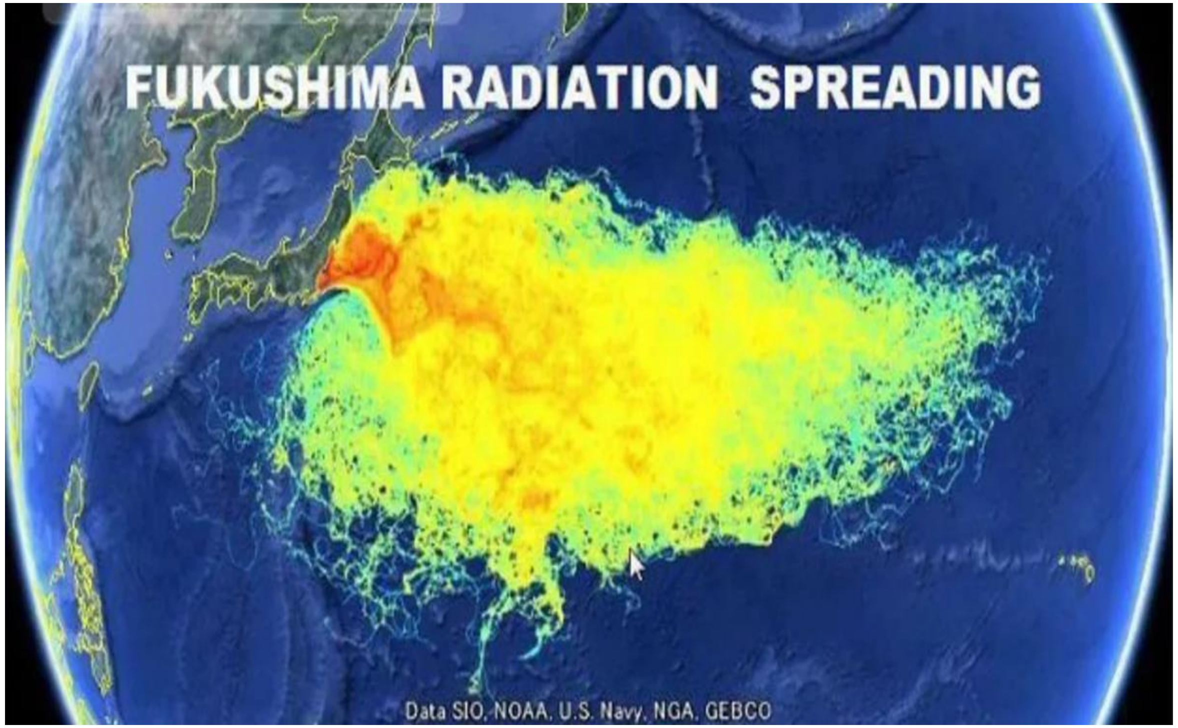
Period of discharge: 30 years

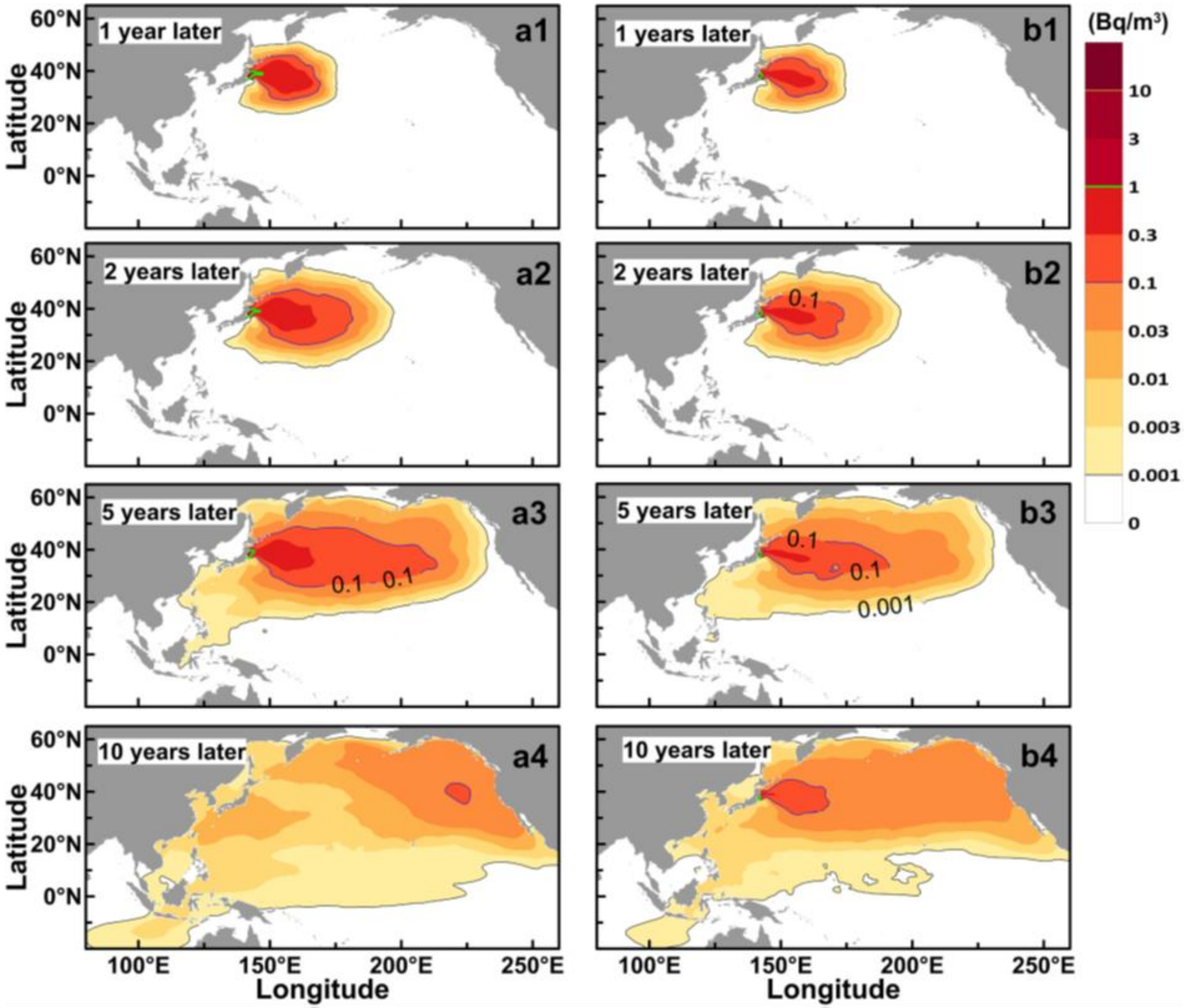
Started: August 24, 2023

Safety norm (Russia): 7 700 Bq/l (64 405 TU)

Safety norm (WHO): 10 000 Bq/l (84 746 TU)

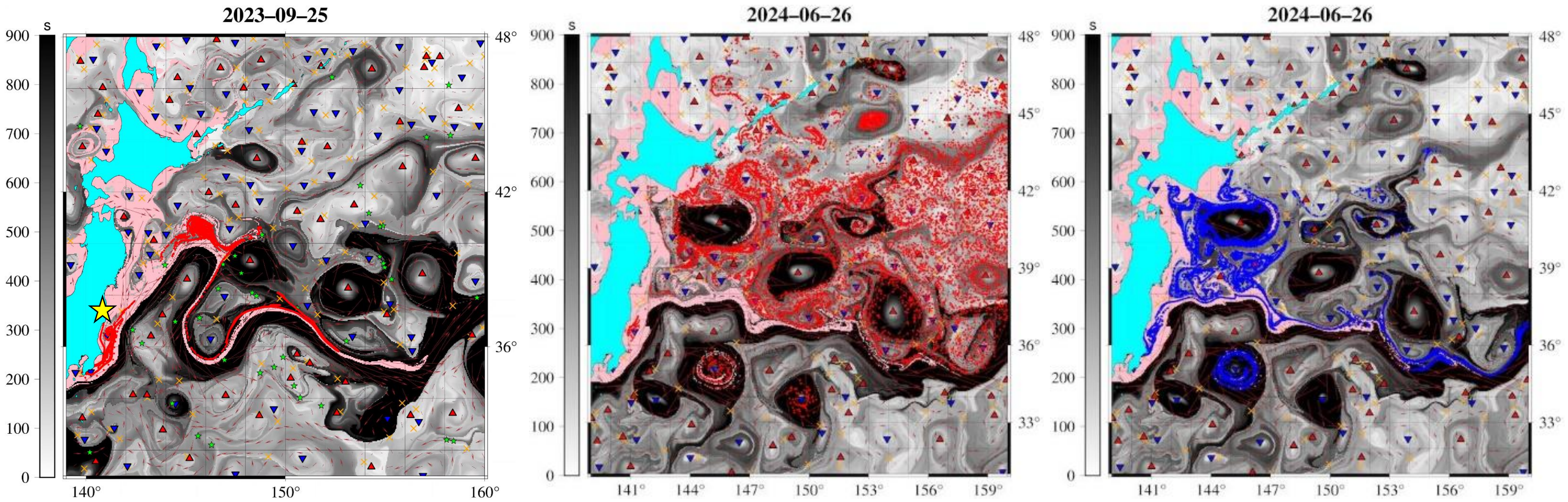
Modeling of tritium transport from Fukushima-1 NPP





Modeling of tritium distribution under various scenarios (duration of discharge) for 1, 2, 5 and 10 years later (Chang et al., 2021) https://doi.org/10.1016/j.marpolbul.2021.112515)

Fukushima water transport based on Lagrangian Analisys



1st discharge: 1 month

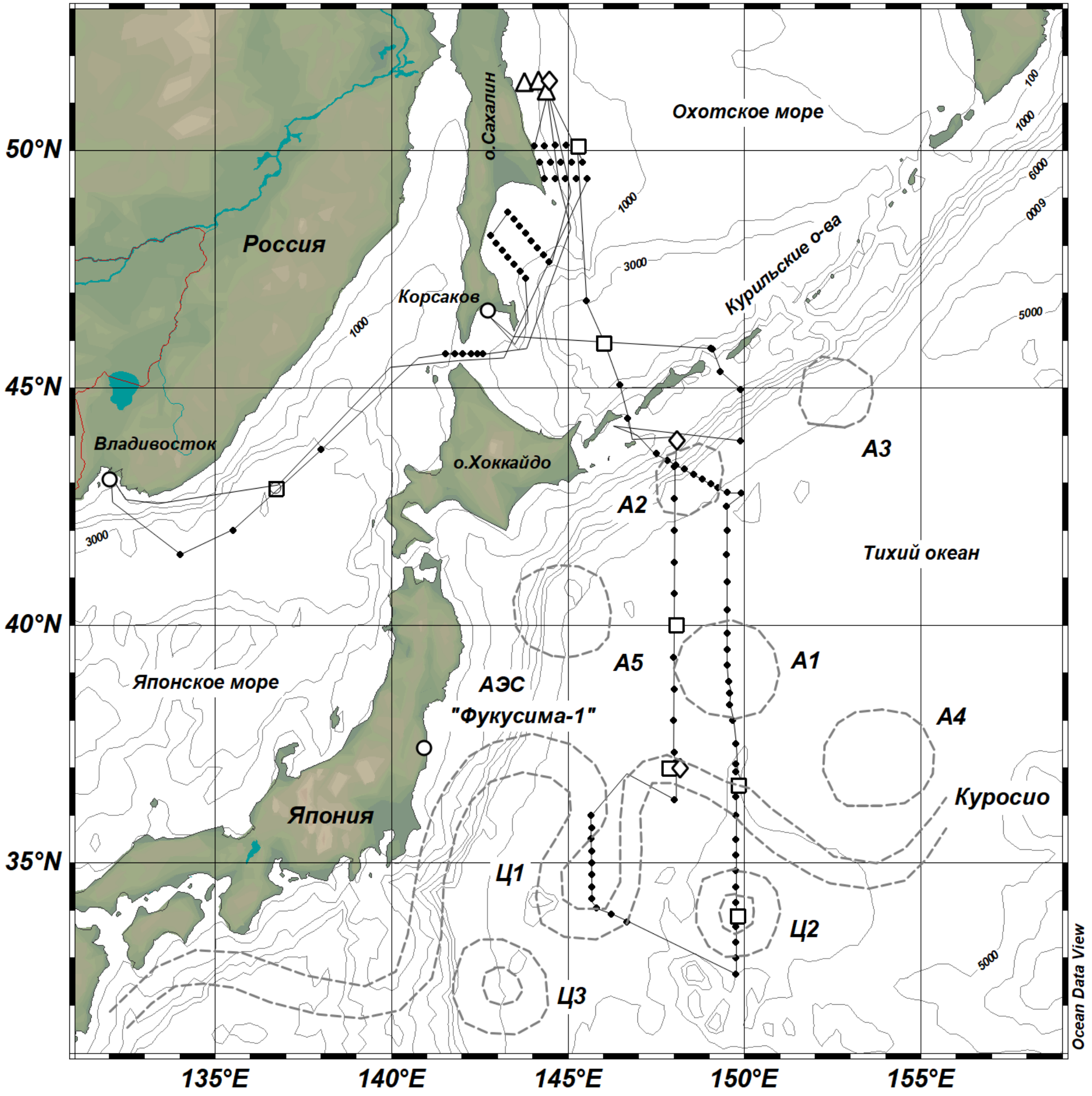
10 month

4th discharge: 2 month

Calculation of water particles transport using Lagrangian analisys of daily satellite altimetry data

POI FEB RAS
ТОИ ДВО РАН

R/V *Akademik Oparin* cruise, June 4 – July 15, 2024

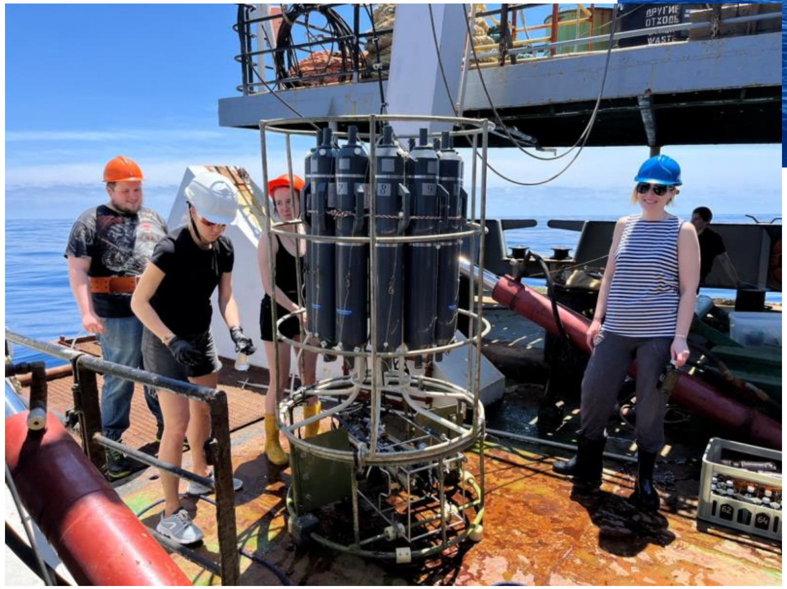


42 days., 30 participants, 7 institutes

НИС «Академик Опарин», 1985 г. постройки, 2600 т, научная группа до 32 чел., ход до 11,5 уз., неисправные лебедки

CTD and water sampling down to 1000 m

1	**Гидрологические исследования**	
	- СТД-станций /зондирований	131/163
	- СТД-станций с отбором проб воды на стандартные гидрохимические параметры	84
	- СТД-станций/ зондирований с отбором проб воды большого объема для анализа радиоизотопов	8/31
2	**Гидрохимические исследования**	
	отобрано и предварительно обработано проб воды на определение стандартных гидрохимических параметров:	
	- растворенного кислорода	640
	- биогенов (фосфаты, нитраты, нитриты, силикаты)	656
	- водородного показателя (pH)	640
	- хлорофилл-а	96
	отобрано и зафиксировано для последующей обработки) проб воды на определение:	
	- Общей щелочности	640
3	**Гидробиологические исследования**	
	- определение численного и размерного состава фитопланктона в море FlowCam, анализов	348
	- подготовлено для определения пигментного состава фитопланктона, проб	224
	- подготовлено для анализа видового состава фитопланктона, проб	68
	- определение первичной продукции фитопланктона с помощью FlowCam, анализов	3
	подготовлено для определения первичной продукции фитопланктона	36
	- отобрано проб для определения численности и биомассы бактерио-планктона	186



Pumping water from 0-50 m for radionuclides sampling

^{3}H, ^{134}Cs, ^{137}Cs, ^{90}Sr, ^{210}Pb, ^{234}Th, ^{7}Be, ^{226}Ra, ^{228}Ra

9	**Радиоэкологические исследования**	
	НИЦ «Курчатовский институт»:	
	- прямые радиационные исследования с применением подводных гамма-спектрометров, 3 станции, общая продолжительность, час.	36
	- пробоотбор морской воды для дальнейшего анализа на содержание техногенного радионуклида ^{137}Cs с применением сорбционной установки, общий объем 32 м^{3}, станций/проб для анализа	28/100
	- пробоотбор морской воды для дальнейшего анализа на содержание техногенных радионуклидов ^{137}Cs и ^{90}Sr с применением осадительной методики (400 л), станций/проб	2/2
	СахГУ и Сев ГУ:	
	- отбор проб морской воды (3-5 м) для анализа содержания антропогенных радионуклидов Cs-137 и Sr-90,100 л, проб	20
	- отбор проб морской воды (3-5 м) для анализа содержания радионуклидов Ra-226/228, 225 л, проб	22
	- отбор проб морской воды (3-5 м) для анализа содержания радионуклида Th-234, 900-1300 л, проб	9
	- отбор проб морской воды (5-50 м) для оценки содержания радионуклидов Pb-210/Po-210, 1100-4000 л, проб	20
	- отбор проб донных отложений	3
	ТОИ ДВО РАН:	
	- отбор проб воды на тритий с поверхности океана, 0.5 л	8
	- отбор проб воды на тритий с различных глубин, 0.5-5 л, станций/проб	33/198
	- отбор проб воды на ^{7}Be, ^{226}Ra, ^{228}Ra, ^{134}Cs, ^{137}Cs с поверхности, 100-200 л	5
	- отбор проб воды на ^{7}Be, ^{226}Ra, ^{228}Ra, ^{134}Cs, ^{137}Cs с различных глубин, 100 л	15/80
	- отбор проб и определение короткоживущих изотопов ^{223}Ra и ^{224}Ra с помощью системы RaDeCC, 120-240 л, проб	32

Method of Tritium ($_3$H) analysis at POI FEB RAS

Sampling:

Sea water V_s**= *1.0-5.0 liter***

Sample processing 1:

Дистилляция и подготовка электролита – 1% NOH

***Electrolytic enrichment* :**

V_{ini} =500 g V_{fin} =9.5 g

15 electrolytes

Enrichment coefficient ~ 40 times

***Neutralization:* слив пробы, нейтрализация – $NaOH+CO_2$ дистилляция 2**

Low-frequency liquid scintillation counter

20 проб загружается в держатель, 2 из них фон и 3 калибровочных.

Время измерения одного образца1000 минут (50 циклов по 20 минут).

Общее время измерения 20 образцов 14 дней

Фон в тритиевом окне 0.65 имп/мин,

Эффективность регистрации 20 %

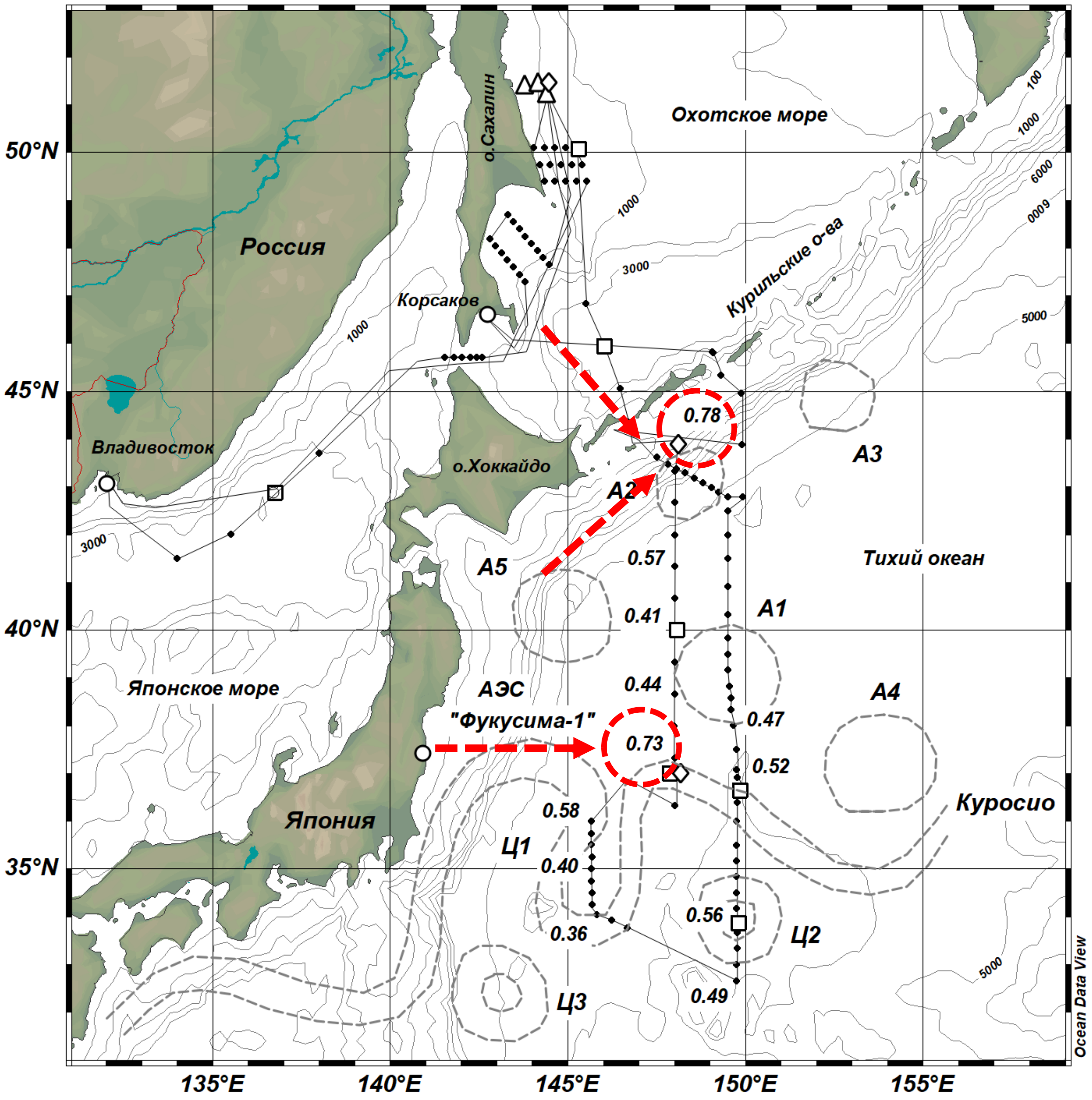
Минимальная регистрируемая концентрация ^{3}H в воде 8 TU или 0.5 Бк/л за время измерения 1000 минут

При обогащении в 40 раз это 0.2 TU или 0.024 Бк/л

Ошибка измерения: +-10% (в диапазоне измеряемых концентраций)

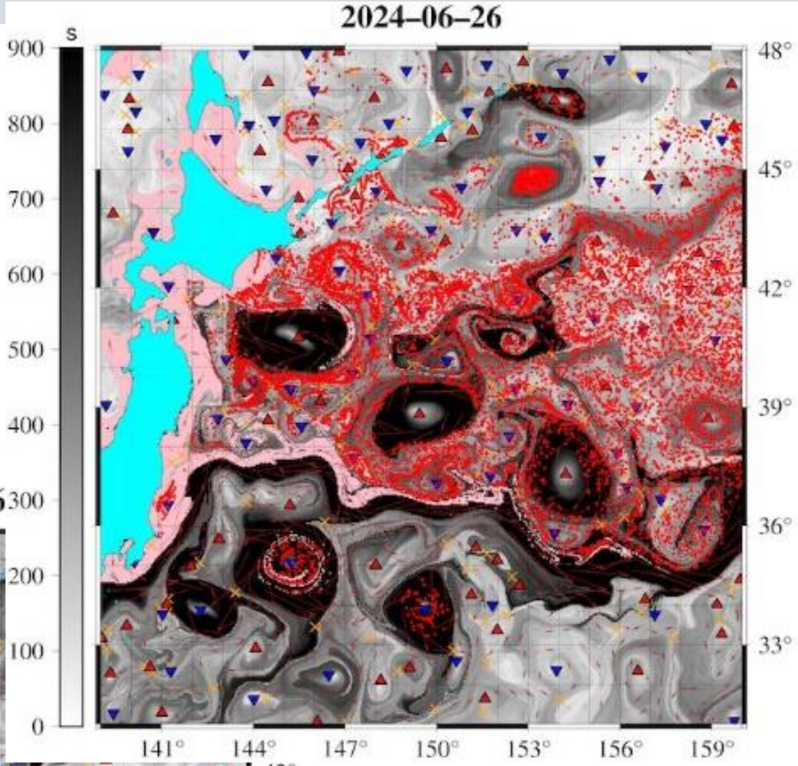
QUANTULUS 1220

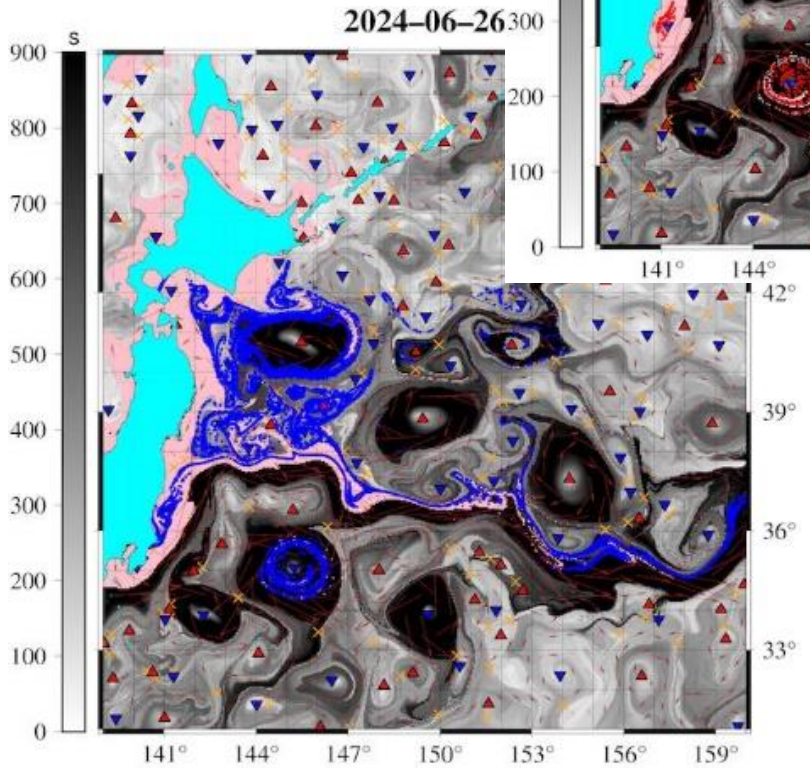
Distribution of tritium in surface water of the NW Pacific



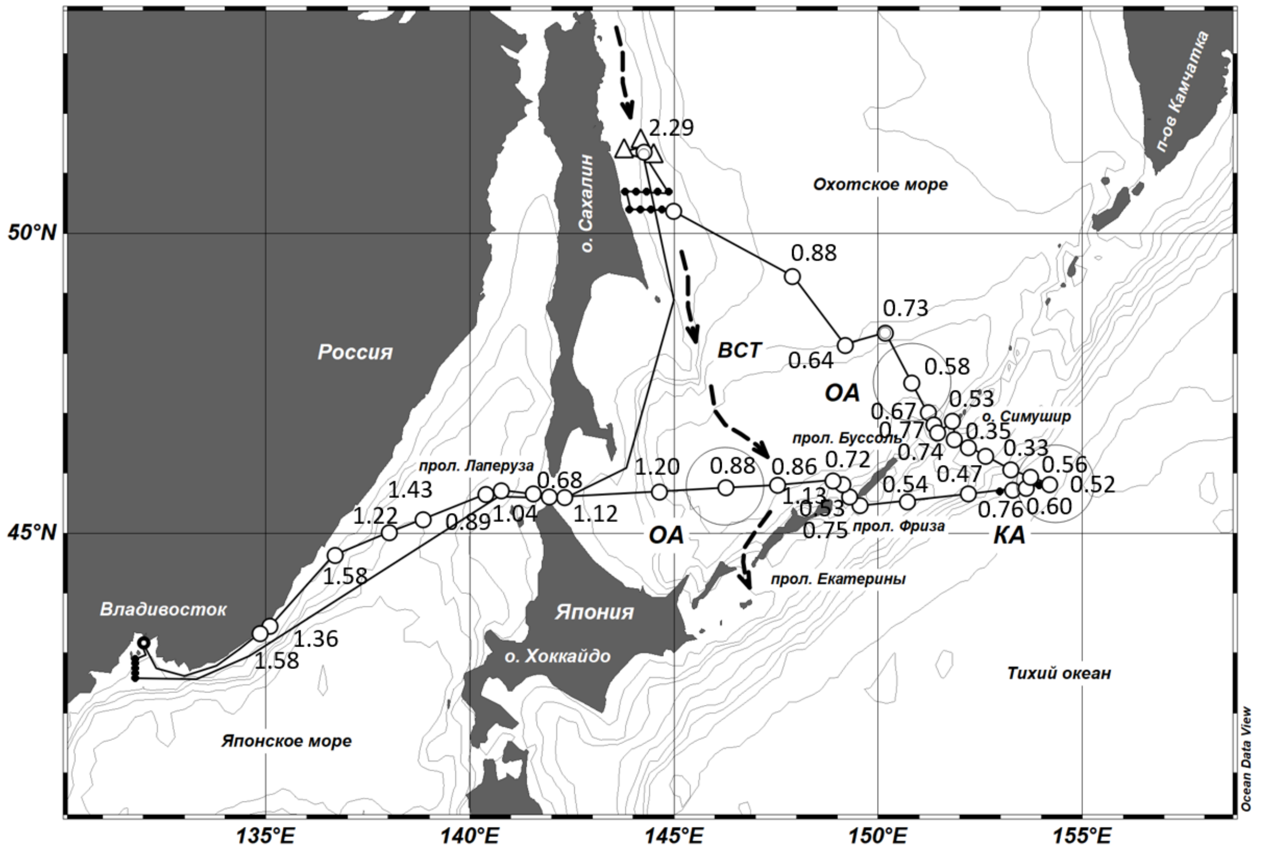
Tritium content in the surface water east of Japan

0.36-0.78 TU



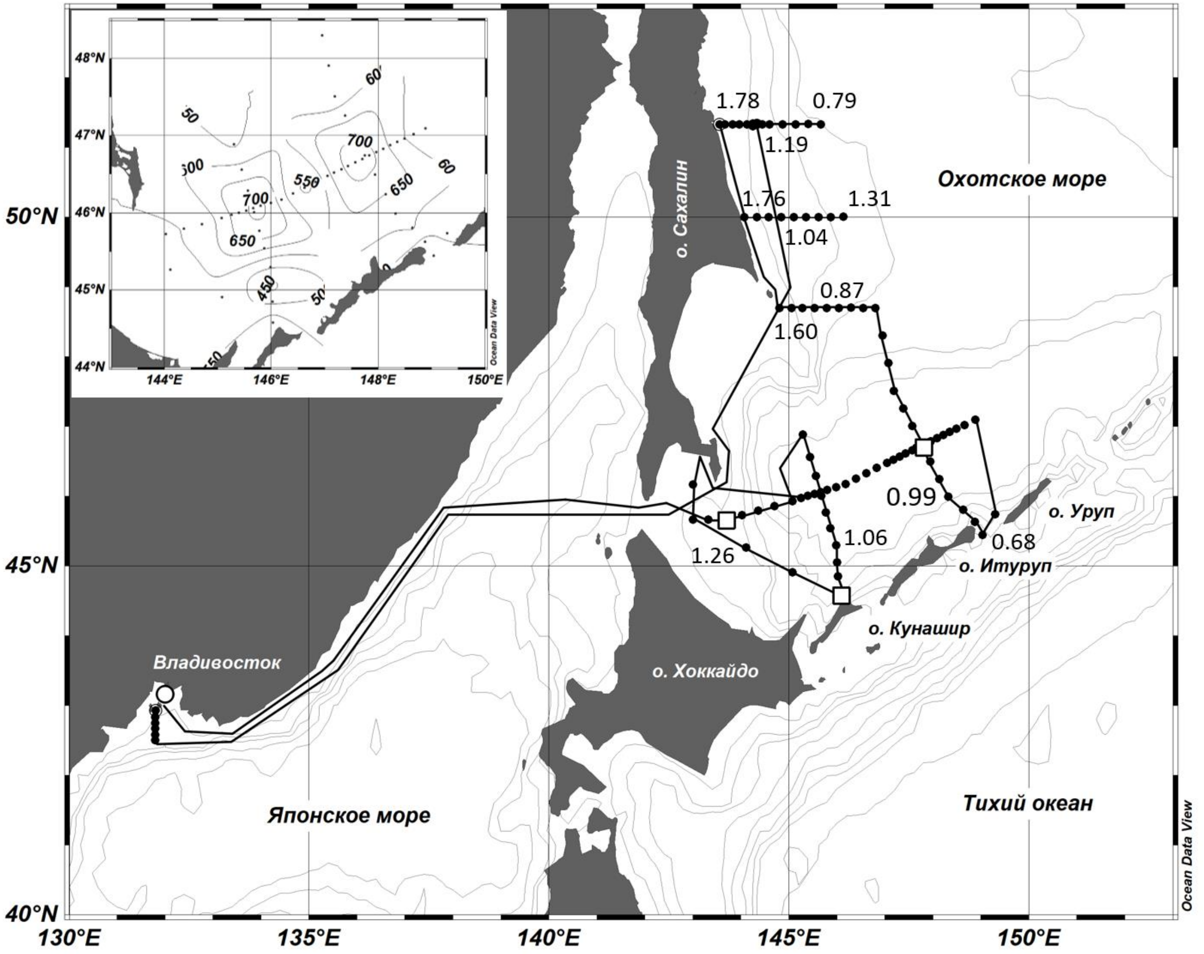


Field observations and sampling in August-November 2024



R/V *Professor Gagarinskiy*, #88, Aug 24-Sep 15, 2024

(0.3-2.3 TU)

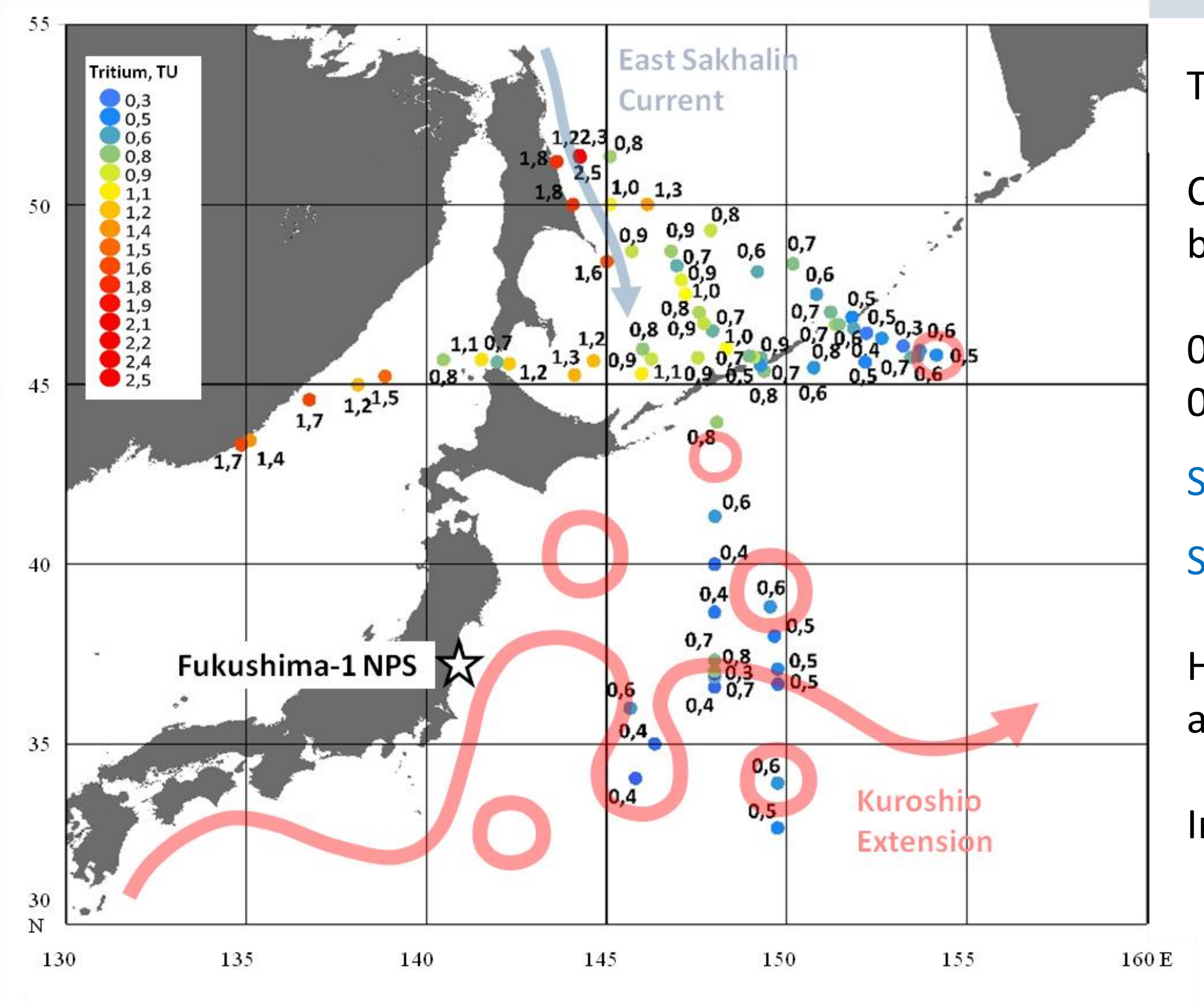


R/V *Akademik Oparin*, #75, Nov 5-Dec 1, 2024

(0.7-1.8 TU)

POI FEB RAS
ТОИ ДВО РАН

Summary of field observations and sampling in 2024



Tritium content east of Japan: 0.3-0.8 TU

Corresponds well with other observations before 2023

0.2-0.5 TU *(Povinec et al., 2004, 2010, 2017)*, 0.4-0.5 TU *(NRA, 2023)*

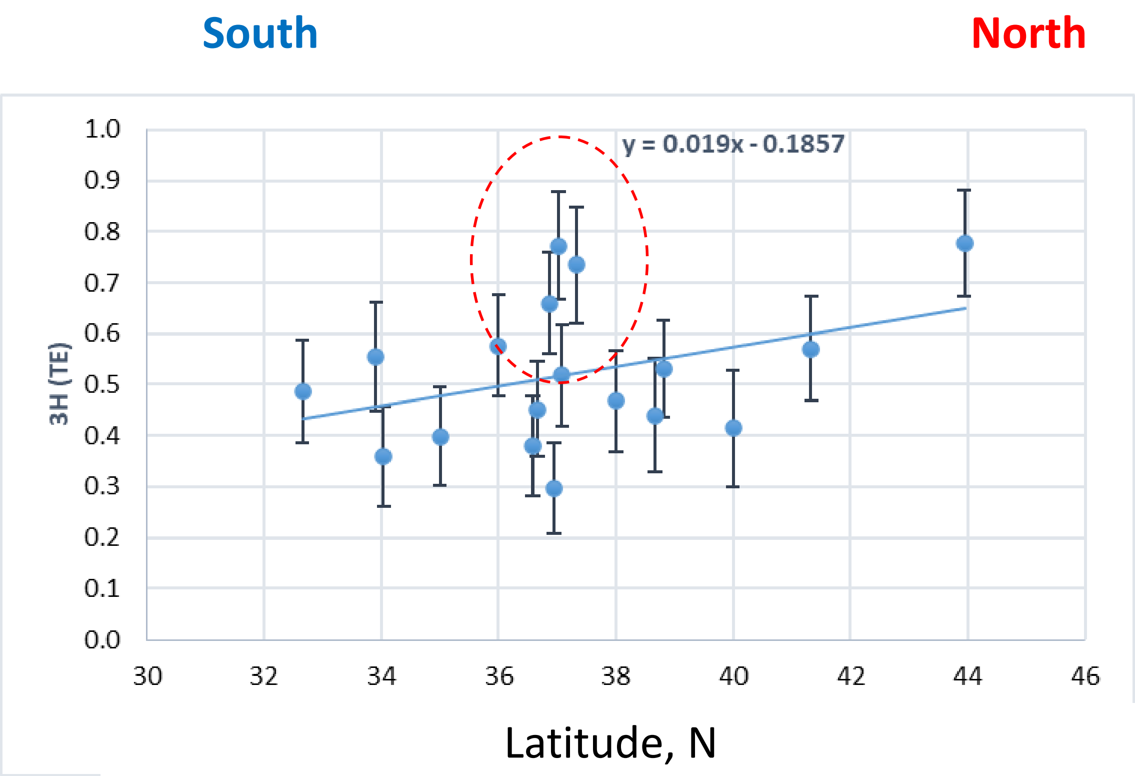
Safety norm (Russia): 7 600 Bq/l (64 405 TU)

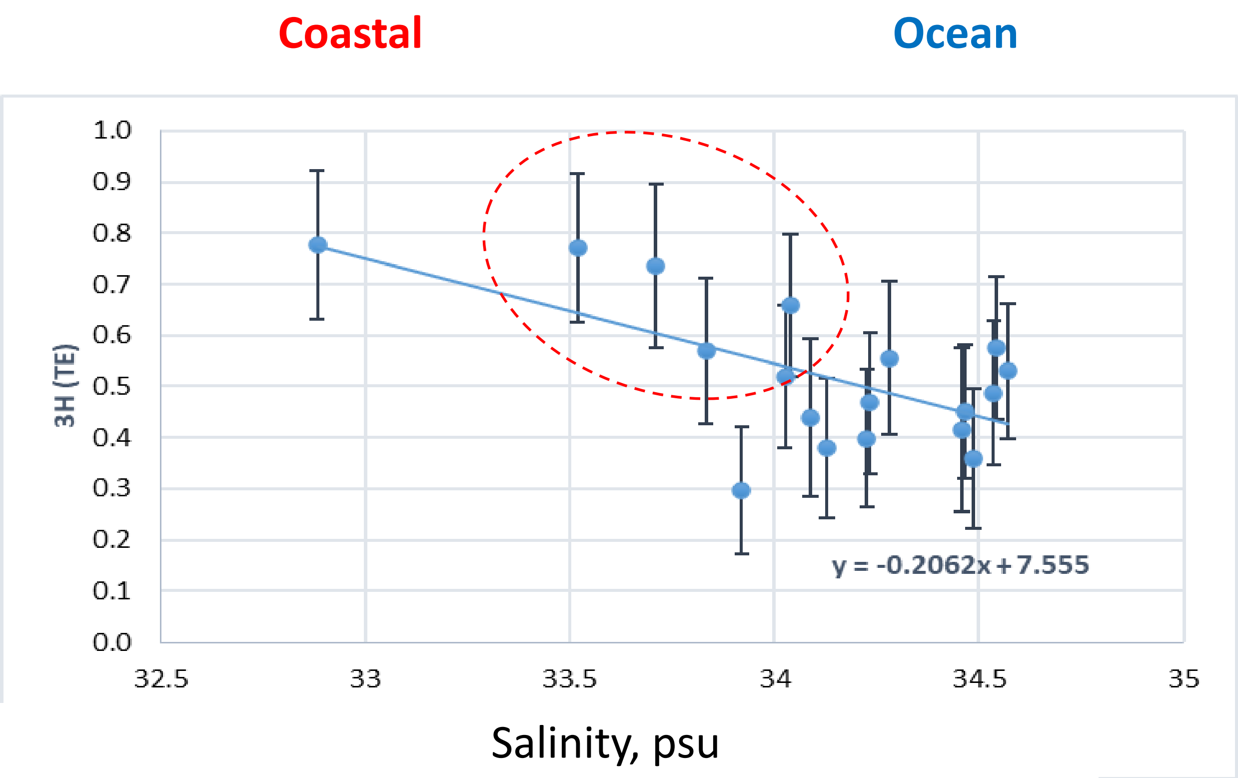
Safety norm (WHO): 10 000 Bq/l (84 746 TU)

Higher tritium content in the Okhotsk Sea and coastal areas of the Japan Sea: > 1.5 TU

Impact of land water discharge, Amur River

Tritium vs Salinity: impact of land water discharge





POI FEB RAS
ТОИ ДВО РАН

Concentration of 3H and 137Cs in 2012-2024

^{3}H (TU)

Okhotsk Sea	min	max	aver
2012	1,4	1,6	1,5
2022-2023	0,6	1,9	1,2
2024	0,5	1,8	1,0

^{137}Cs (mBq/лl)

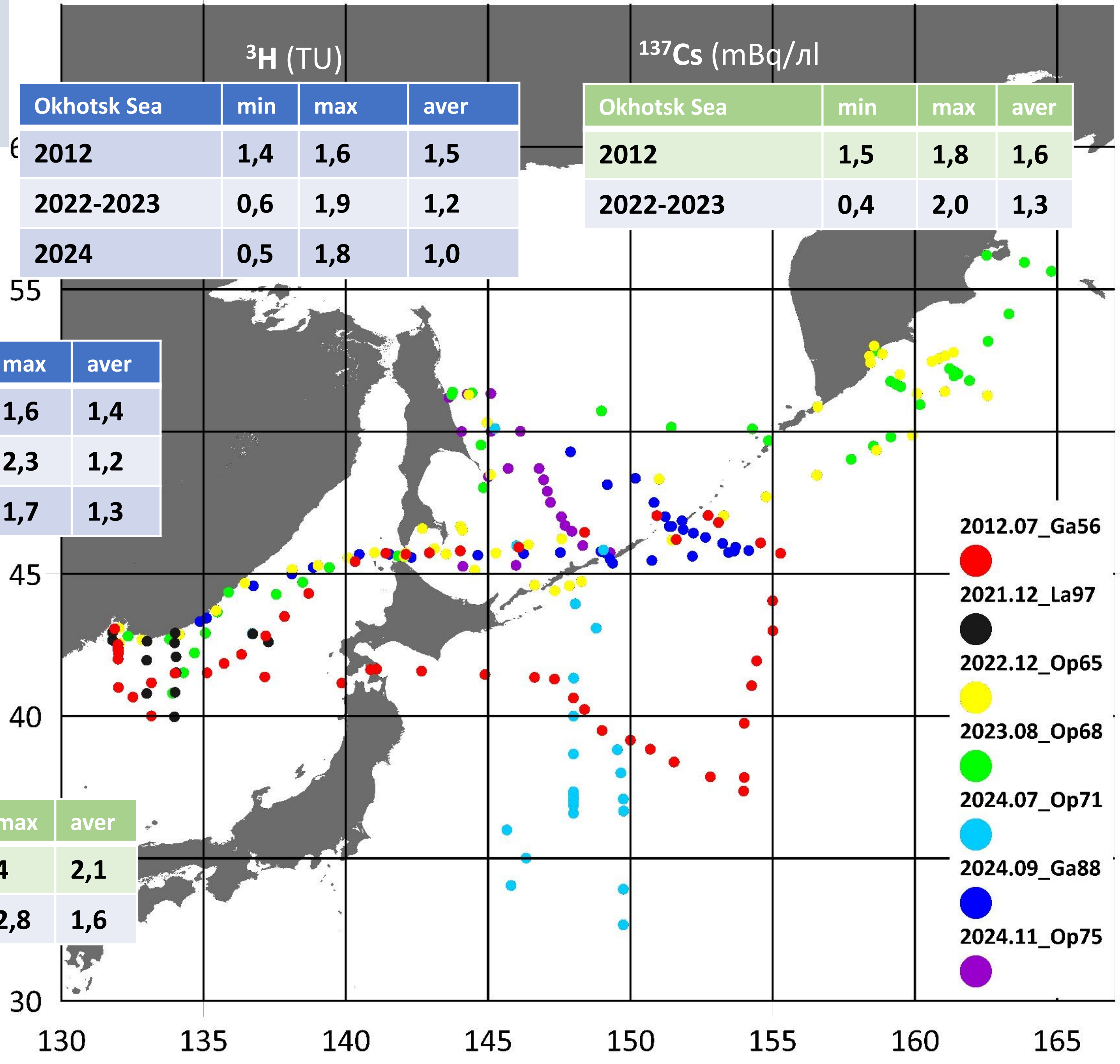
Okhotsk Sea	min	max	aver
2012	1,5	1,8	1,6
2022-2023	0,4	2,0	1,3

^{3}H (TU)

Japan Sea	min	max	aver
2012	1,2	1,6	1,4
2021-2023	0,6	2,3	1,2
2024	0,7	1,7	1,3

^{137}Cs (mBq/l)

Japan Sea	min	max	aver
2012	1,4	4	2,1
2021-2023	0,7	2,8	1,6



^{3}H (TU)

Pacific ocean	min	max	aver
2012	1,1	2,5	1,7
2022-2023	0,3	1,2	0,7
2024	0,3	1,2	0,7

^{137}Cs (mBq/l)

Pacific ocean	min	max	aver
2012	2,3	21,0	8,1
2022-2023	0,5	2,4	1,2
2024	0,5	1,3	0,9

POI FEB RAS
ТОИ ДВО РАН

Conclusion

Tritium concentration in the Northwestern Pacific has being steadily decreasing since pre-bomb era reaching 0.2-0.5 TU by the 2020s with slight peak in 2011 after Fukushima-1 NPP incident

Cruise observations during 2024 confirmed that 3H content in the NW Pacific, Japan and Okhotsk seas varies from 0.3 to 2.0 TU, which is close to natural level and does not threat for human life even after beginning of Fukushima-1 NPP water discharge

No impact of Fukushima-1 NPP accumulated water discherge was found

However, due to possible technological disruptions during the discharge of accumulated waters at the Fukushima-1 NPP and other possible incidents, regular monitoring is necessary.


Thank you!
Тихоокеанский океанологический институт им. В.И. Ильичева ДВО РАН
РАДИОЭКОЛОГИЧЕСКАЯ БЕЗОПАСНОСТЬ ДАЛЬНЕВОСТОЧНЫХ МОРЕЙ РОССИИ
НИС «Академик Опарин» (рейс №71), июнь-июль 2024 г.
НацОНИФ
NRFM
«КУРЧАТОВСКИЙ ИНСТИТУТ»