Merle 2025 Compilation of Co-Registered Multibeam Seafloor and Water Column Data on the US Cascadia Margin

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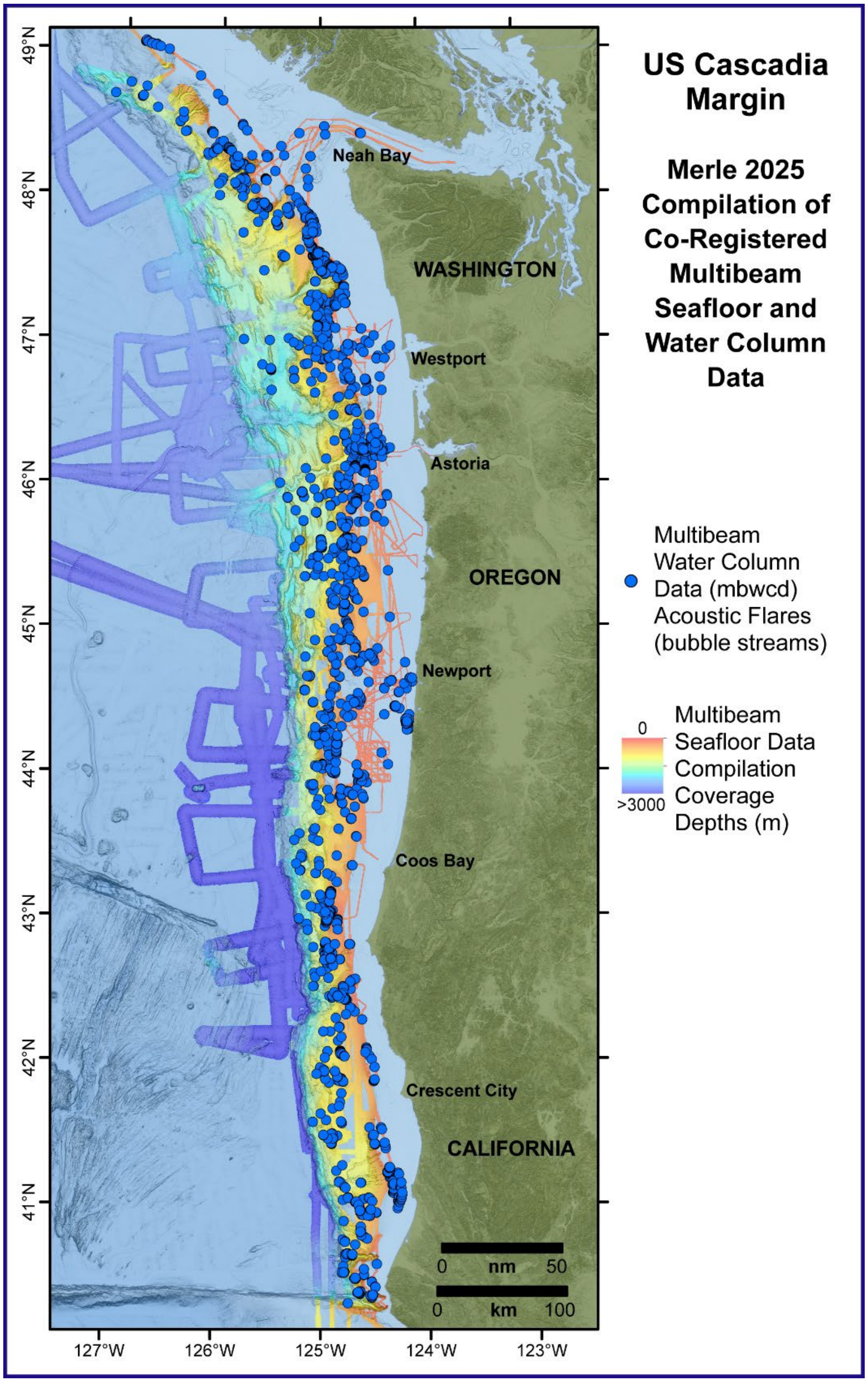

Fig 1. Merle 2025 compilation, co-registered seafloor and water column data (bubble stream picks).

To preface this summary, please excuse my use of first-person narrative, which is not very scientific, but the most straight-forward way to describe what I've pulled together. This is not an authored publication, but there will be a doi assigned to the datasets at Marine Geoscience Data System (MGDS) https://www.marine-geo.org/. I won't be undertaking any additional data analysis or publications, as I'm retiring July 31, 2025. So, if any of you in the seep or habitat communities find these data useful, it's all yours. If you feel so inclined, credit me if and when the data makes it to publication.

The AGU 2024-promised compilation is complete. I have pulled together 30 multibeam surveys composed of co-registered multibeam seafloor data files (raw.all) and water column data files (wcd). 8 of those surveys were the basis for my Merle et al., 2021 manuscript. This compilation adds another 22 surveys to that mix. Refer to Table 1 (below) for more information regarding those expeditions, systems, citations, and number of flares identified in the water column data for each cruise.

The data were collected on 11 vessels, utilizing 3 different multibeam systems (EM122 - 12 kHz, EM302 - 30 kHz, EM710 -70 kHz). A number of the newly-added surveys collected copious data in water depths less than 200 meters, including some very shallow water surveys in depths <100m. That is a great improvement over the 2021 compilation. Statistics in Merle et al., 2021 cite that 36% of the US Cascadia Margin is shallower than 200m, and less than 15% had been mapped with multibeam systems at that time. Although it is time-consuming and challenging to survey those water depths, USGS contributed greatly to that effort in 2018 and 2019.

Figure 1 (above) illustrates the extent of the Merle 2025 compilation and all seafloor (bathymetry) and water column data (bubble stream picks). Figures 2 and 3 (below) are more detailed maps of north and south margin areas, bubble streams and seafloor coverage. Figure 4 compares the seafloor coverage from Merle et al., 2021 and the updated Merle 2025 compilation.

I processed and analyzed a majority of the seafloor and water column data in the Merle 2025 compilation. When processing **multibeam seafloor data**, I am an avid MB-System user (free software by the way, thank you Dave Caress and team). 'mbeditviz' facilitated perusing large datasets, but there are plenty of artifacts in the data I could not, or ran out of time, edit away. Rough seas, high speeds (optimal survey speed is 8 knots), bad outer beams, bad inner beams, individual vessel artifacts, are just some of the culprits. So, if you see any bad pings in the compilation, please forgive. It's not a perfect bathymetry compilation, but it's pretty good. Those same culprits have kept me from sharing a backscatter seafloor compilation. It would have taken way-too-long for me to produce a sub-par product.

The **multibeam water column data** analysis for seafloor locations of bubble streams that I performed utilized QPS FMMidwater software (not free, but great). QPS Qimera software is also frequently used for water column analysis. Over 5000 bubble streams were located in the water column data. The bubble stream picks are individual (and some group flare) seafloor exit locations and depths. The data have not been clustered to define seep sites, as in Merle et al., 2021, thus no further analysis has been executed. The excel spreadsheet of seafloor picks (Merle2025-mbwcd-streams-final.xls) cites publications of seafloor pics that were shared by others in the community. Unpublished pics that I located are cited as "Merle and Beeson, 2024" (AGU abstract, also below).

Notes on seafloor flare locations: After 9 years, (2016 was my first Cascadia methane seep expedition) countless surveys, re-picking others and my own flare locations – I'm jumping on the "automation" wagon for seep-picking. There are obvious variations in locations based on the analyst, even when different analysts look at the same data (ex. FK180824 EM710). Even when the same analyst (me) looks at the data a second time. With the correct parameters, I'm hopeful that automating the process can someday become more accurate than an analyst (I can't believe I said that). The lesson my group has learned regarding locating bubble streams on the seafloor with an ROV is that it's best to re-survey the area before diving, as flares vary with tidal cycles, etc. And, they can turn off completely in a large area, as our group found out on a recent expedition to the Yachats shallow seep site in 2024.

That's it. It's been a pleasure to work with this seeps community, as well as mappers of the seafloor and water column, and underwater volcano lovers everywhere….. For all of us caught between the devil and the deep blue sea, I wish you fair winds and following seas.

Data Availability:

Contact Marine Geoscience Data System (MGDS) https://www.marine-geo.org/

Questions or problems contact:
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Data sets include:

- Excel spreadsheet and ArcGIS shapefile of bubble stream locations (Merle2025-mbwcd-streams-final)
- Grid* of entire margin at 30m resolution (b-merle2025-30m)
- North and south margin grids* at 20m resolution (b-north-merle2025-20m, b-south-merle2025-20m)

*GMTnetCDF 4-byte float grids (.grd) and ArcView ASCII grids (.asc)

AGU 2024 Abstract

An Updated Compilation of Co-Registered Multibeam Seafloor and Water Column Data on the US Cascadia Margin, Including a Revised Compendium of Seafloor Methane Flares

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The Cascadia margin seafloor has been extensively mapped in depths > 200 m, but there has been little effort to compile data consisting only of high resolution co-registered multibeam seafloor (bathymetry/backscatter) and water column information": 63e When bathymetry/backscatter data are paired with bubble stream water column data, that seabed-water column link can lead to deeper insights regarding the origins of methane flares on the margin. There are a multitude of single-beam sonar surveys on the margin, with a single seafloor main beam depth and 10-30 degree beam width in the water column. The multibeam sonar fan configuration provides superior seafloor coverage, up to 5 times water depth. Each ping is comprised of hundreds of seafloor soundings, plus water column data within that sonar fan. Merle et al., 2021, (doi: 10.3389/feart.2021.531714) focused on 8 co-registered surveys from 2011 – 2017. Since then, there have been multiple surveys of this type. Here we present data from those recent expeditions and augment the seafloor and water column compilations, including an updated spreadsheet of methane bubble streams on the US Cascadia margin. The newly-created seafloor and water column data compilations will be sent to national data repositories. Those data and results will provide valuable information to national, state, and local regulatory agencies, industry, and community stakeholders connected to fisheries seafloor habitat classification and the Pacific Northwest's emerging offshore wind energy industry.

Citations:

Johnson HP, Merle S, Salmi M, Embley R, Sampaga E and Lee M (2019). Anomalous concentration of methane emissions at the continental shelf edge of the northenrn Cascadia margin. J. Geophys. Res., 124. doi:10.1029/2018JB016453

Merle SG, Embley RW, Johnson HP, Lau T-K, Phrampus BJ, Raineault NA and Gee LJ (2021). Distribution of Methane Plumes on Cascadia Margin and Implications for the Landward Limit of Methane Hydrate Stability. Front. Earth Sci. 9:531714. doi: 10.3389/feart.2021.531714

Susan G. Merle and Jeffrey W. Beeson (2024), An Updated Compilation of Co-Registered Multibeam Seafloor and Water Column Data on the US Cascadia Margin, Including a Revised Compendium of Seafloor Methane Flares, Abstract OS43A-1555 presented at AGU Fall Meeting, 9-13 December 2024

Michel APM, Preston VL, Fauria KE and Nicholson DP (2021). Observations of Shallow Methane Bubble Emissions From Cascadia Margin. Front. Earth Sci. 9:613234. doi: 10.3389/feart.2021.613234

Riedel M, Scherwath M, Römer M, Veloso M, Heesemann, M and Spence GD (2018). Distributed natural gas venting offshore along the Cascadia margin. Nat. Commun., **9**, 3264. doi: 10.1038/s41467-018-05736-x

Rudebusch, JA, Prouty NG, Conrad JE, Watt JT, Kluesner JW, Hill JC, Miller NC, Watson SJ and Hillman J (2023). Diving deeper into seep distribution along the Cascadia convergent margin, United States. Front. Earth Sci. 11.1205211. doi: 10.3389/feart.2023.1205211

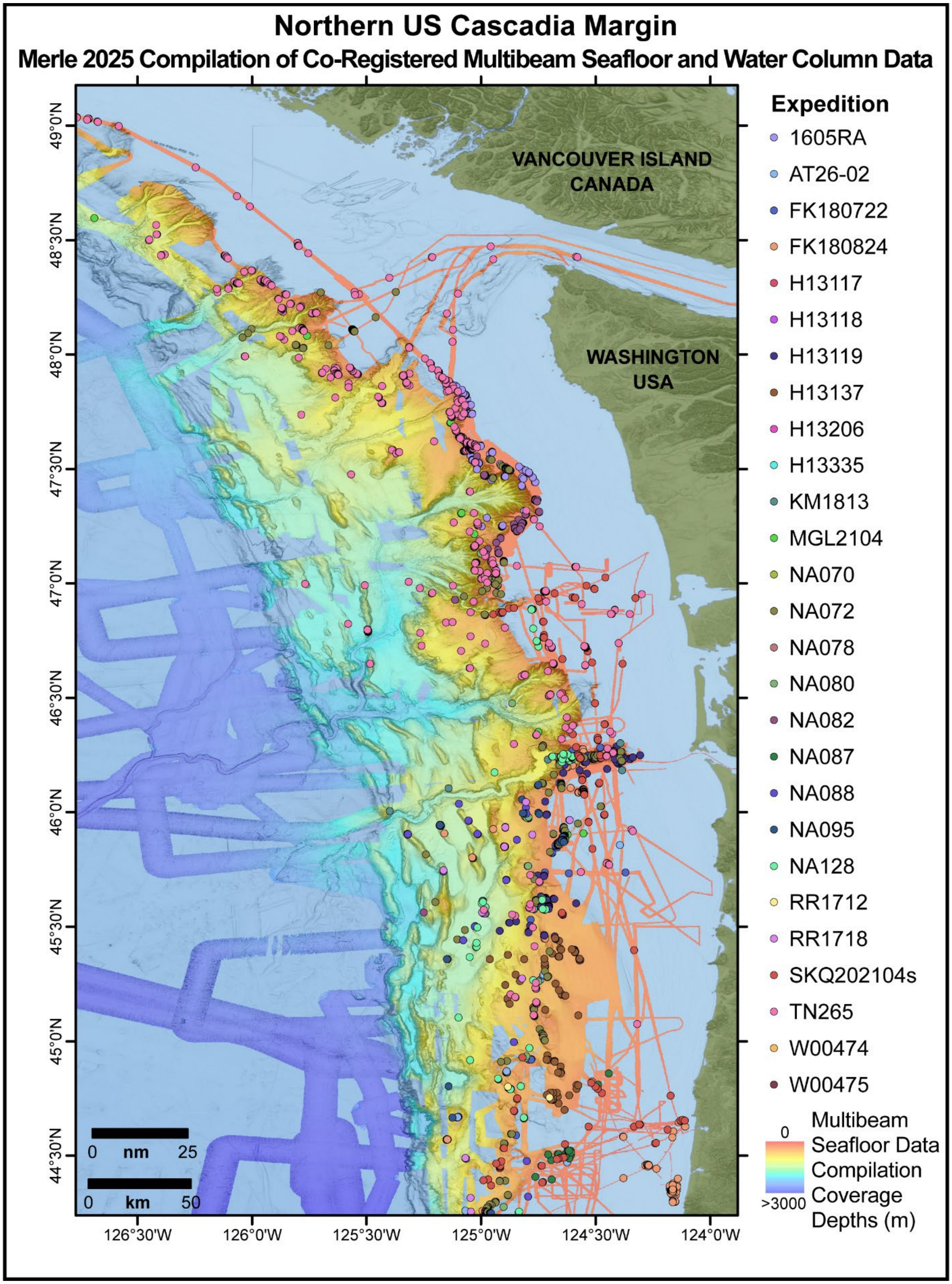

Fig 2. Merle 2025 compilation, northern US Cascadia Margin

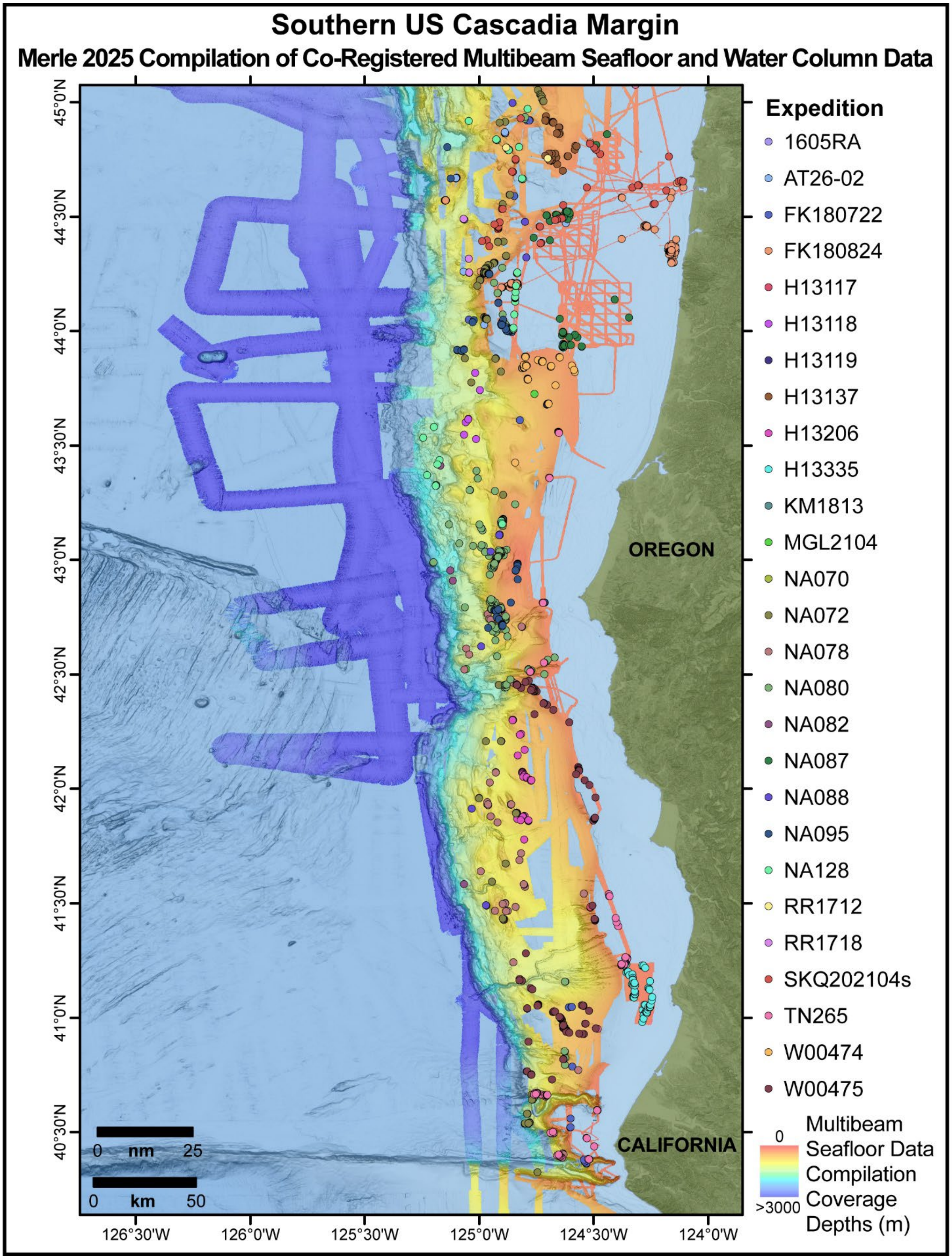

Fig 3. Merle 2025 compilation, southern US Cascadia Margin

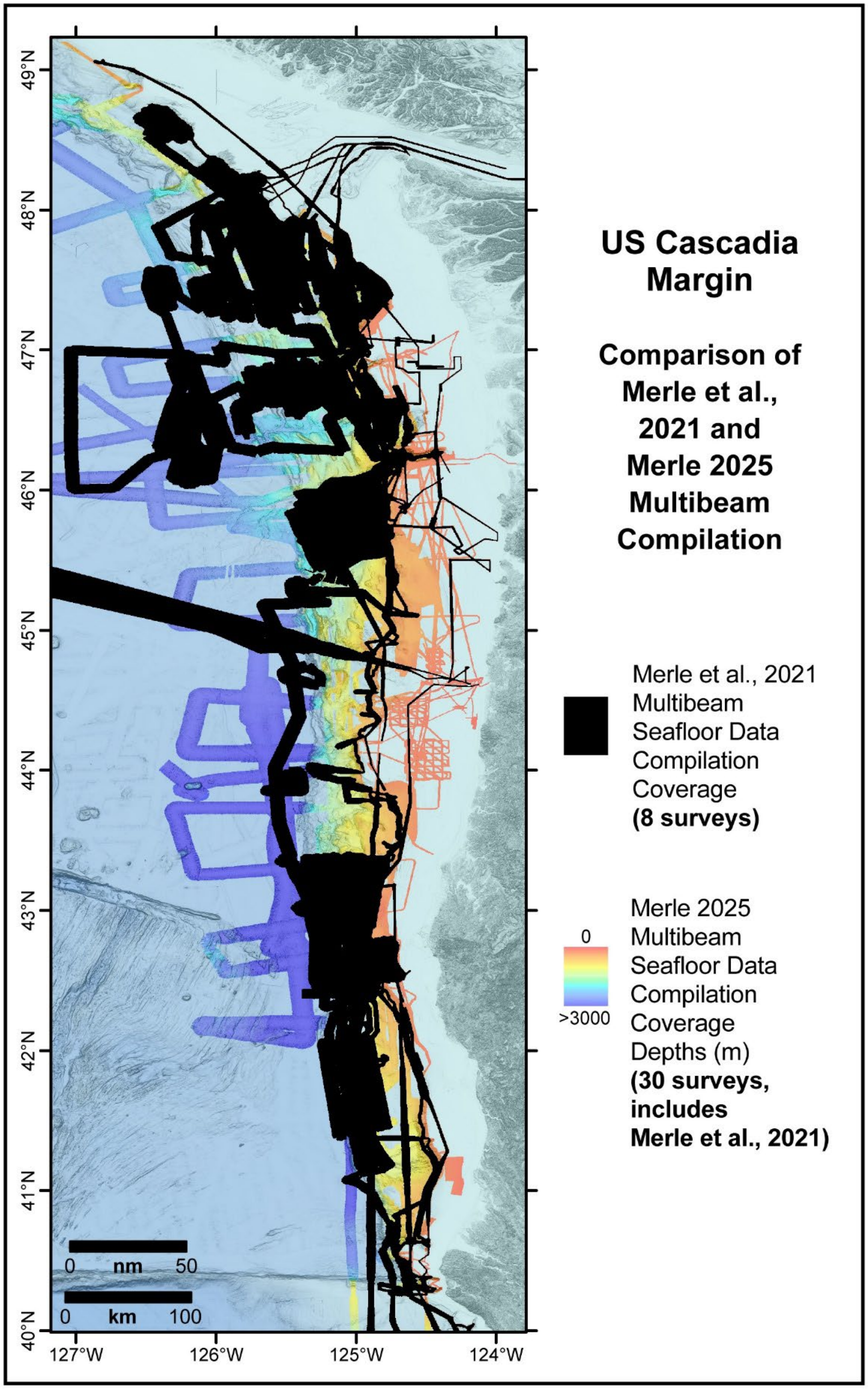

Fig 4. Comparison of Merle 2025 and 2021 survey compilations, US Cascadia Margin.

Table 1. Merle 2025 Compilation: Expeditions, Citations and Bubble Stream Numbers

Survey	Ship	Year	System	Expedition leader	Citation, bubble stream (flare) picks	Number of flares
1605RA	NOAA ship *Rainier*	2016	EM710	HP Johnson, UW	Johnson et al., 2019, Merle et al., 2021	558
AT26-02	R/V *Atlantis*	2013	EM122	A Trehu, OSU	Trehu et al., 2022, Riedel et al., 2018	51
FK180722	R/V *Falkor*	2018	EM302	S Merle, PMEL/OSU	Merle and Beeson, 2024	57
FK180722	R/V *Falkor*	2018	EM710	S Merle, PMEL/OSU	Merle and Beeson, 2024	45
FK180824	R/V *Falkor*	2018	EM302	A Michel, USGS	Merle and Beeson, 2024	34
FK180824	R/V *Falkor*	2018	EM710	A Michel, USGS	Merle and Beeson, 2024, Michel et al., 2021	829 (92 pics are double picks in Yachats area by AM, USGS)
H13117	NOAA ship *Rainier*	2018	EM710	J Humphrey, CDR/NOAA; USGS	Rudebusch et al., 2023	9 (USGS picks, not entire survey?)
H13118	NOAA ship *Rainier*	2018	EM710	B Evans,CDR/NOAA; USGS	Rudebusch et al., 2023	8 (USGS picks, not entire survey?)
H13119	NOAA ship *Rainier*	2018	EM710	B Evans,CDR/NOAA; USGS	Rudebusch et al., 2023	298
H13137	NOAA ship *Rainier*	2018	EM710	B Evans,CDR/NOAA; USGS	Rudebusch et al., 2023	152
H13206	NOAA ship *Rainier*	2018	EM710	B Evans,CDR/NOAA; USGS	Rudebusch et al., 2023	47
H13335	NOAA ship *Rainier*	2019	EM710	CDR/NOAA; USGS	Merle and Beeson, 2024	77 (S Merle picks. Missing 36 wcd files)
KM1812	R/V *Kilo Moana*	2018	EM122	M Tivey, WHOI	Merle and Beeson, 2024	0
KM1813	R/V *Kilo Moana*	2018	EM122	S Nooner, UNCW	Merle and Beeson, 2024	10
MGL2104	R/V *Marcus G. Langseth*	2021	EM122	S Carbotte, LDEO	Merle and Beeson, 2024	55
NA070	R/V *Nautilus*	2016	EM302	OET	Merle et al., 2021	1
NA072	R/V *Nautilus*	2016	EM302	OET; R Embley, PMEL/OSU	Merle et al., 2021	855
NA078	R/V *Nautilus*	2016	EM302	OET	Merle et al., 2021	56
NA080	R/V *Nautilus*	2017	EM302	OET	Merle et al., 2021	199
NA082	R/V *Nautilus*	2017	EM302	OET	Merle and Beeson, 2024	122
NA087	R/V *Nautilus*	2017	EM302	OET; L Davis, OSU	Merle and Beeson, 2024	79
NA088	R/V *Nautilus*	2017	EM302	OET	Merle et al., 2021	40
NA095	R/V *Nautilus*	2018	EM302	OET; T Baumberger, PMEL/OSU	Merle and Beeson, 2024	139

Survey	Ship	Year	System	Expedition leader	Citation, bubble stream (flare) picks	Number of flares
NA128	R/V *Nautilus*	2021	EM302	OET; T Baumberger, PMEL/OSU	Merle and Beeson, 2024	180
RR1712	R/V *Roger Revelle*	2017	EM122	W Chadwick, OSU	Merle et al., 2021	3
RR1718	R/V *Roger Revelle*	2017	EM122	D Kelley, UW	Merle and Beeson, 2024	21
SKQ202104s	R/V *Sikuliaq*	2021	EM302	J Fram, OSU	Merle and Beeson, 2024	162
TN265	R/V *Thompson*	2011	EM302	C Romsos, OSU	Merle et al., 2021	829
W00474	NOAA ship *Fairweather*	2019	EM710	CDR M Moser, NOAA; USGS	Merle and Beeson, 2024	37 (USGS picks, not entire survey?)
W00475	NOAA ship *Fairweather*	2019	EM710	CDR M Moser, NOAA; USGS	Merle and Beeson, 2024	160
30 surveys	**10 Vessels**		**3 MB systems**			**5013 total bubble streams (flares)**