SAND2024-16496C

Using Machine Learning and Fluid Flow Modeling to Predict the Response of Marine Sediments around the Cascadia Margin to Gas Formation and Hydrate Dissociation

Olin R. Carty[1], Warren T. Wood[2], Benjamin J. Phrampus[2], Taylor R. Lee[2], Jennifer Frederick[3], David Fukuyama[3], Michael Nole[4], and Hugh Daigle[1]
[1]The University of Texas at Austin, [2]U.S. Naval Research Laboratory, [3]Sandia National Laboratory, [4]Pacific Northwest National Laboratory | contact: ocarty@utexas.edu

The University of Texas at Austin
Hildebrand Department of Petroleum and Geosystems Engineering
Cockrell School of Engineering

U.S. NAVAL RESEARCH LABORATORY

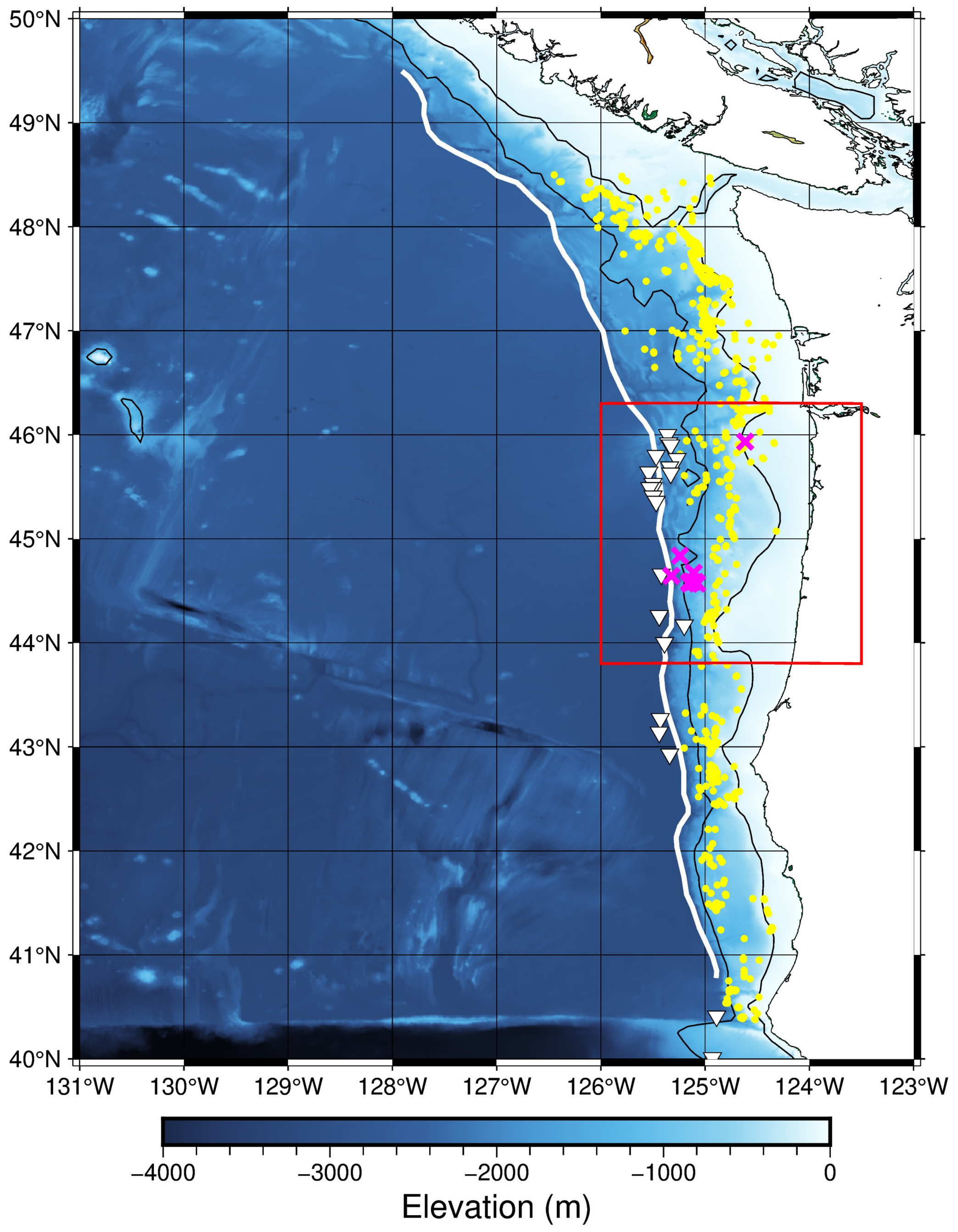
Sandia National Laboratories

PNNL

Key Points

- Cascadia Margin is an active margin with present day gas seeps and a history of slope failure.
- Geospatial machine learning (k-nearest neighbors) was used to predict seafloor properties in this region.
- 1-D sedimentation burial model was used to estimate gas and hydrate development over time.
- Outputs of model were used to calculate factor of safety of the area.
- Slope failure was not expected due solely to hydrate dissociation and gas formation.

Research Area

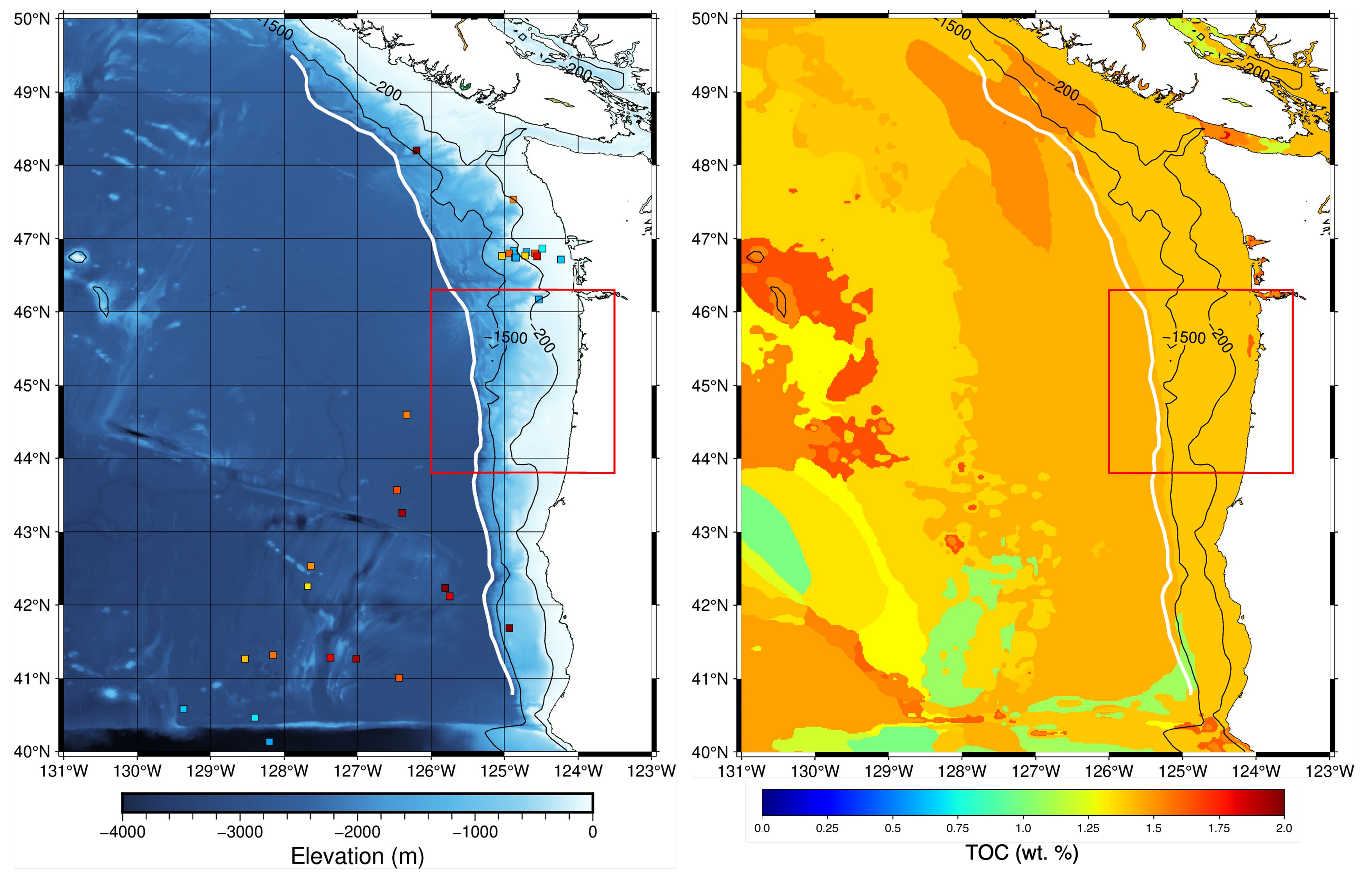


- Yellow dots: gas seeps have been identified near the feather edge of hydrate stability (Merle et al., 2021)
- White triangles: historic slope failures in this region (McAdoo et al., 2000)
- Pink X: ODP and DSDP sites in our area of focus
- Contours at 200 and 1500 mbsl are noted as well as the approximate location of the deformation front (White Line) noted by Phrampus et al., 2017.

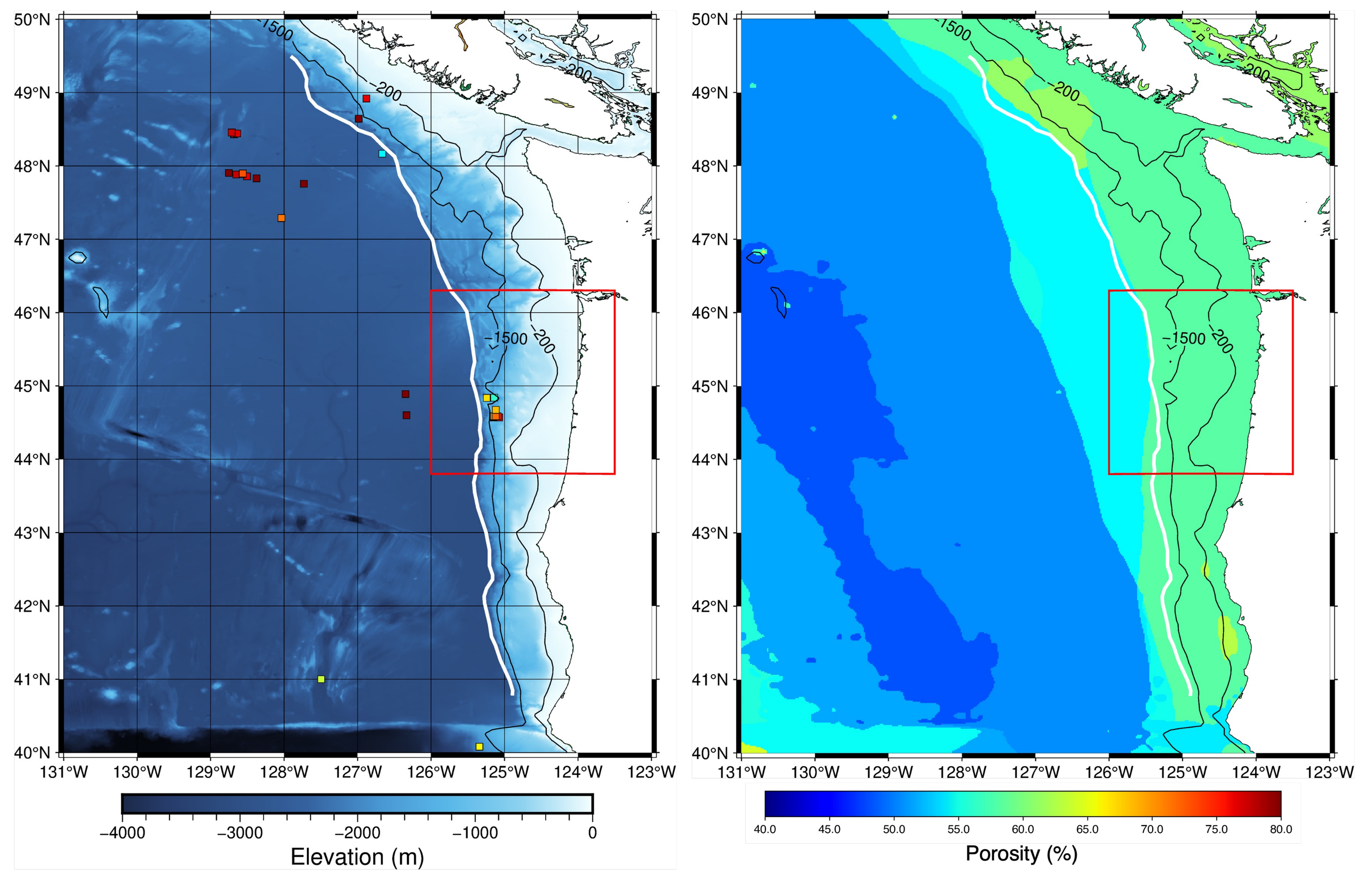
kNN Prediction

- Seafloor TOC and porosity predictions were made using k-nearest neighbor algorithms.
- We used grids of seafloor variables compiled by Phrampus et al., 2020 for these predictions. These contained known values of geological, geographic, biological attributes.

- Within the region: 30 known values of seafloor TOC (Seiter et al., 2004)



- Within the region: 22 known values of seafloor porosity (Martin et al., 2015)

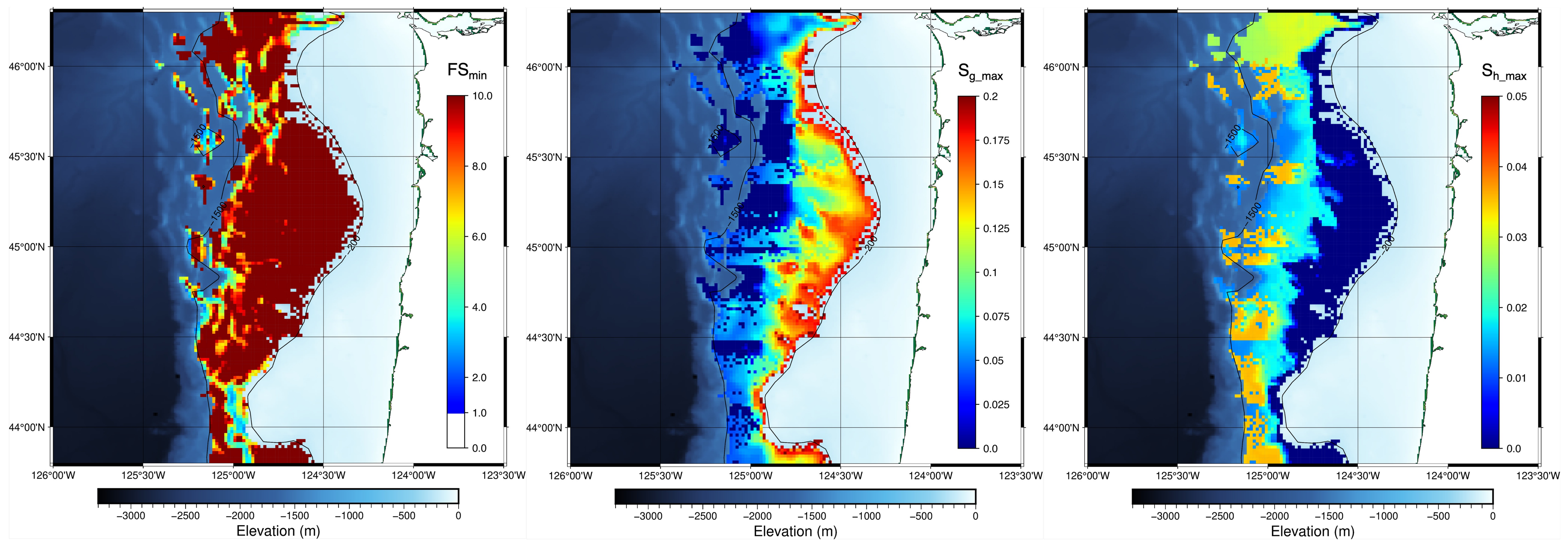


Acknowledgments

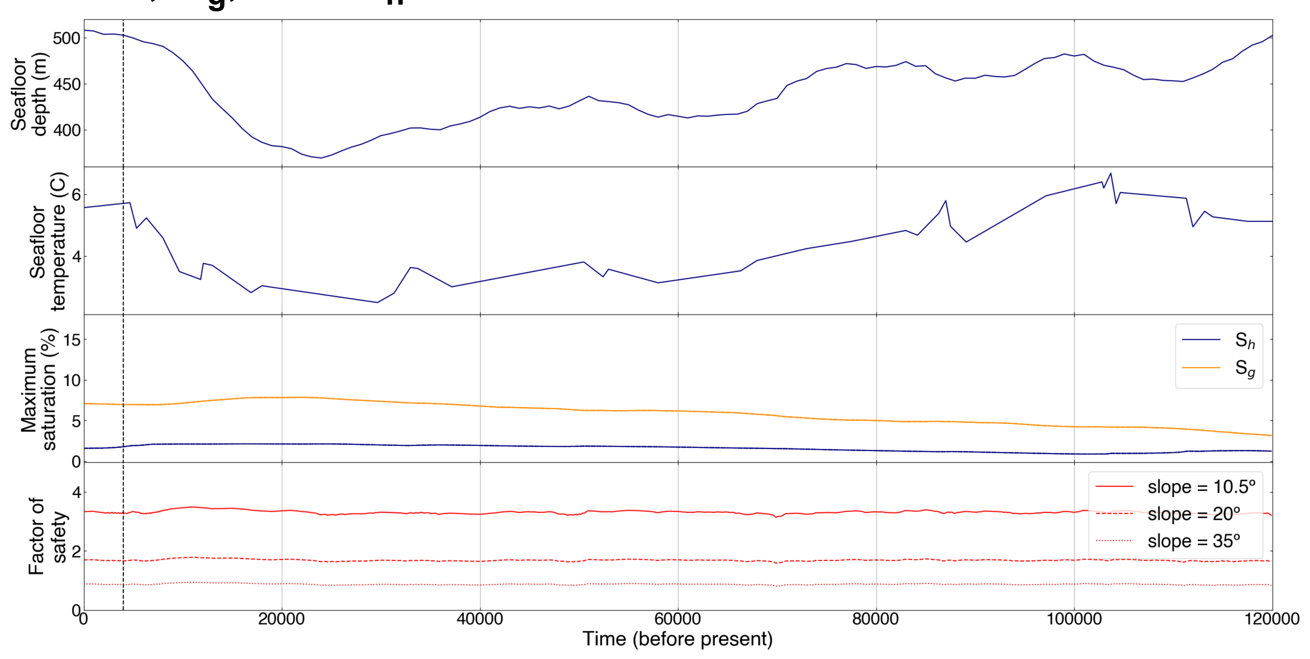
Olin R. Carty was partially supported by a Hildebrand Fellowship. NRL contributions to this study were supported by the U.S. Naval Research Laboratory base program. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government. PNNL is operated for the DOE by Battelle Memorial Institute under contract DE-AC05-76RL01830.

Saturations and Factor of Safety

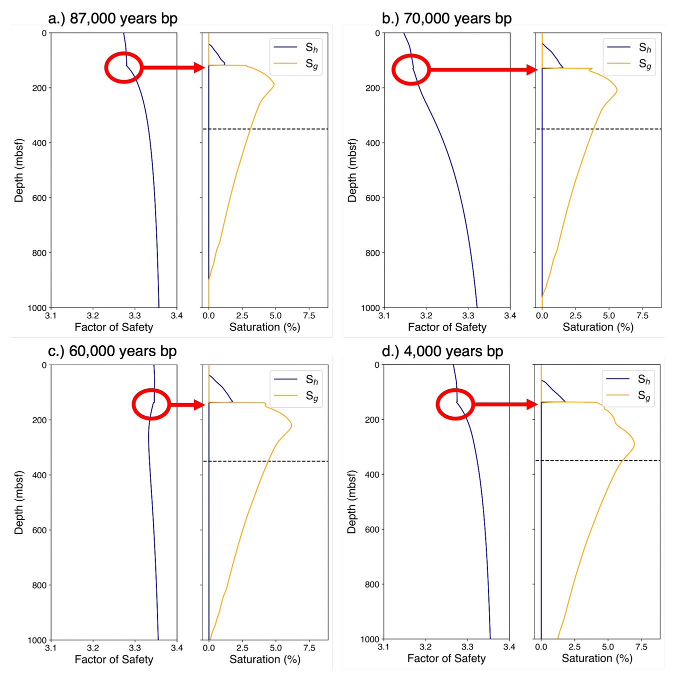
- Between 200 and 1500 mbsl gas and hydrate formation was modeled with a hydrological model (PFLOTRAN).
- FS was calculated from outputs from this model (Stigall and Dugan, 2010): $\mathrm{FS} = \frac{c + [(\sigma'_{vh}\cos^2\theta) - P^*]\tan\phi_f}{\sigma'_{vh}\cos\theta\sin\theta}$



FS, S_g, and S_h trends over time



Looking at different timesteps



Conclusion

- Lowest factor of safety calculations correspond with areas of highest seafloor slope.
- Even in these areas, hydrate dissociation and gas generation **alone** were not enough to cause slope failure.
- Thus, some other force would be needed to initiate slope failure and landslides in the area.
- As this is an active margin, earthquakes could likely be this instigating factor.
- At the base of hydrate stability, FS decreases, but values along the sediment column are relatively consistent.

References

Martin, Kylara M., Warren T. Wood, and Joseph J. Becker. "A global prediction of seafloor sediment porosity using machine learning." *Geophysical Research Letters* 42.24 (2015): 10-640.
McAdoo, B. G., L. F. Pratson, and D. L. Orange. "Submarine landslide geomorphology, US continental slope." *Marine Geology* 169.1-2 (2000): 103-136.
Merle, Susan G., et al. "Distribution of methane plumes on cascadia margin and implications for the landward limit of methane hydrate stability." *Frontiers in Earth Science* 9 (2021): 531714.
Phrampus, Benjamin J., Robert N. Harris, and Anne M. Tréhu. "Heat flow bounds over the Cascadia margin derived from bottom simulating reflectors and implications for thermal models of subduction." *Geochemistry, Geophysics, Geosystems* 18.9 (2017): 3309-3326.
Phrampus, B. J., T. R. Lee, and W. T. Wood. "Predictor Grids for "A Global Probabilistic Prediction of Cold Seeps and Associated Seafloor Fluid Expulsion Anomalies (SEAFLEAs)"." *Type: dataset* (2020).
Seiter, Katherina, et al. "Organic carbon content in surface sediments—defining regional provinces." *Deep Sea Research Part I: Oceanographic Research Papers* 51.12 (2004): 2001-2026.
Sosdian, Sindia, and Yair Rosenthal. "Deep-sea temperature and ice volume changes across the Pliocene-Pleistocene climate transitions." *Science* 325.5938 (2009): 306-310.
Spratt, Rachel M., and Lorraine E. Lisiecki. "A Late Pleistocene sea level stack." *Climate of the Past* 12.4 (2016): 1079-1092.
Stigall, Justin, and Brandon Dugan. "Overpressure and earthquake initiated slope failure in the Ursa region, northern Gulf of Mexico." *Journal of Geophysical Research: Solid Earth* 115.B4 (2010).