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Sandia National Laboratories

Forecasting Free Gas and Gas Hydrate Distribution with Geospatial Machine Learning

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1 Sandia National Laboratories
2 U.S. Naval Research Lab
3 U.T. Austin academic alliance

SAND2020-11013 PE

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PURPOSE, GOALS AND APPROACH

PURPOSE

Geospatial Machine Learning Prediction + Sediment Thermodynamic Physical Modeling = **Creation of *Probabilistic* Maps** of: Free Gas and Gas Hydrate Distribution, Geo-acoustic and Geo-mechanical Properties

APPLICATIONS

Allows more accurate **natural resource quantification** for energy security.

Can inform climate models on **greenhouse gas releases** and carbon cycling.

Maps can support **Naval operations** that rely on SONAR performance and **sound propagation models.**

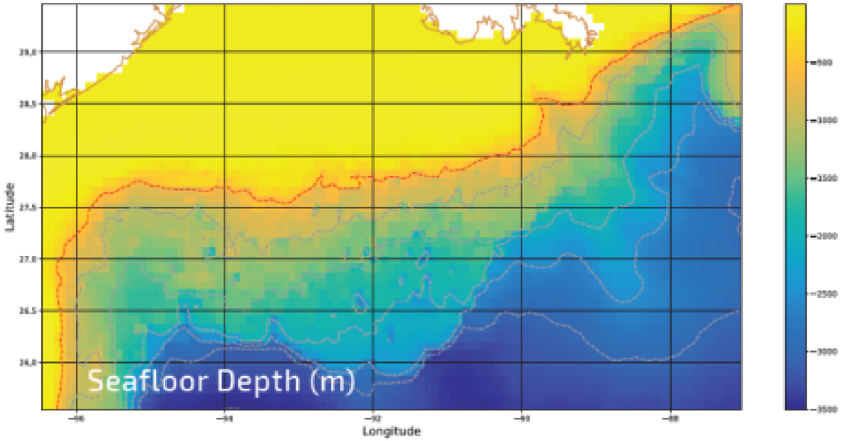
APPROACH

Ensemble modeling can produce probabilistic maps give the **most likely value** of any characteristic of interest, but also its **variation and range**.

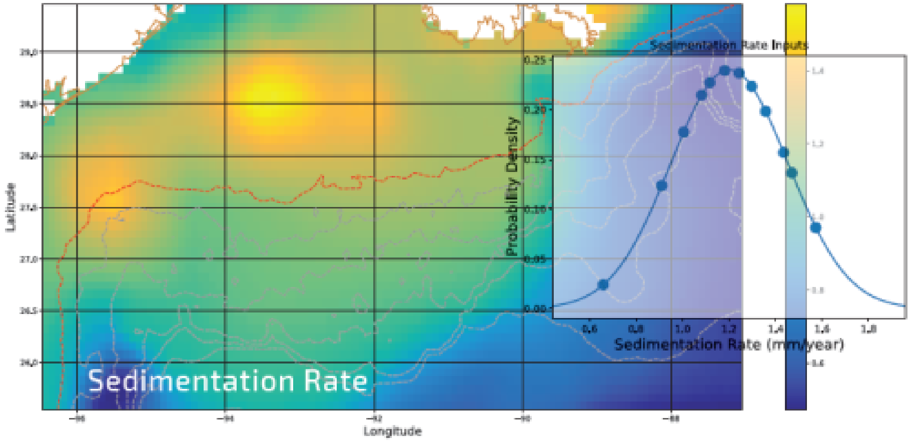
Analogous to a weather forecast: although it is uncertain, it is more useful than a single deterministic forecast.

Ensemble Modeling Approach

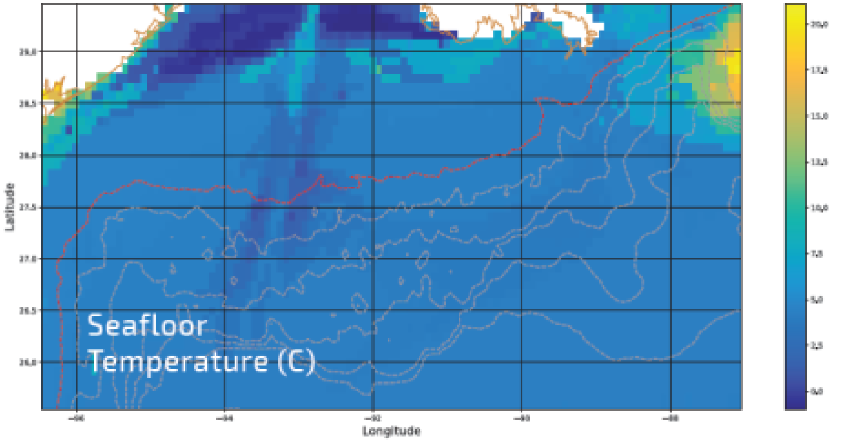
Naval Research Lab's geospatial machine learning maps of input parameters at the Gulf of Mexico:



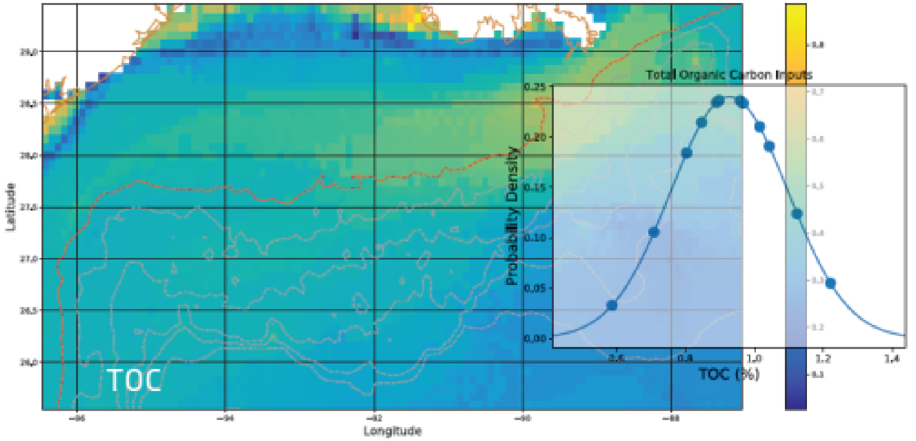
National Geophysical Data Center. (2006). 2-minute gridded global relief data (ETOPO2) v2.



Straume, et al. (2019). GlobSed: Updated total sediment thickness in the world's oceans. G3, 20(4), 1756-1772.
Müller, et al. (2008). Age, spreading rates, and spreading asymmetry of the world's ocean crust. G3, 9(4).



Locarnini, et al. (2013). World ocean atlas 2013. Volume 1, Temperature.

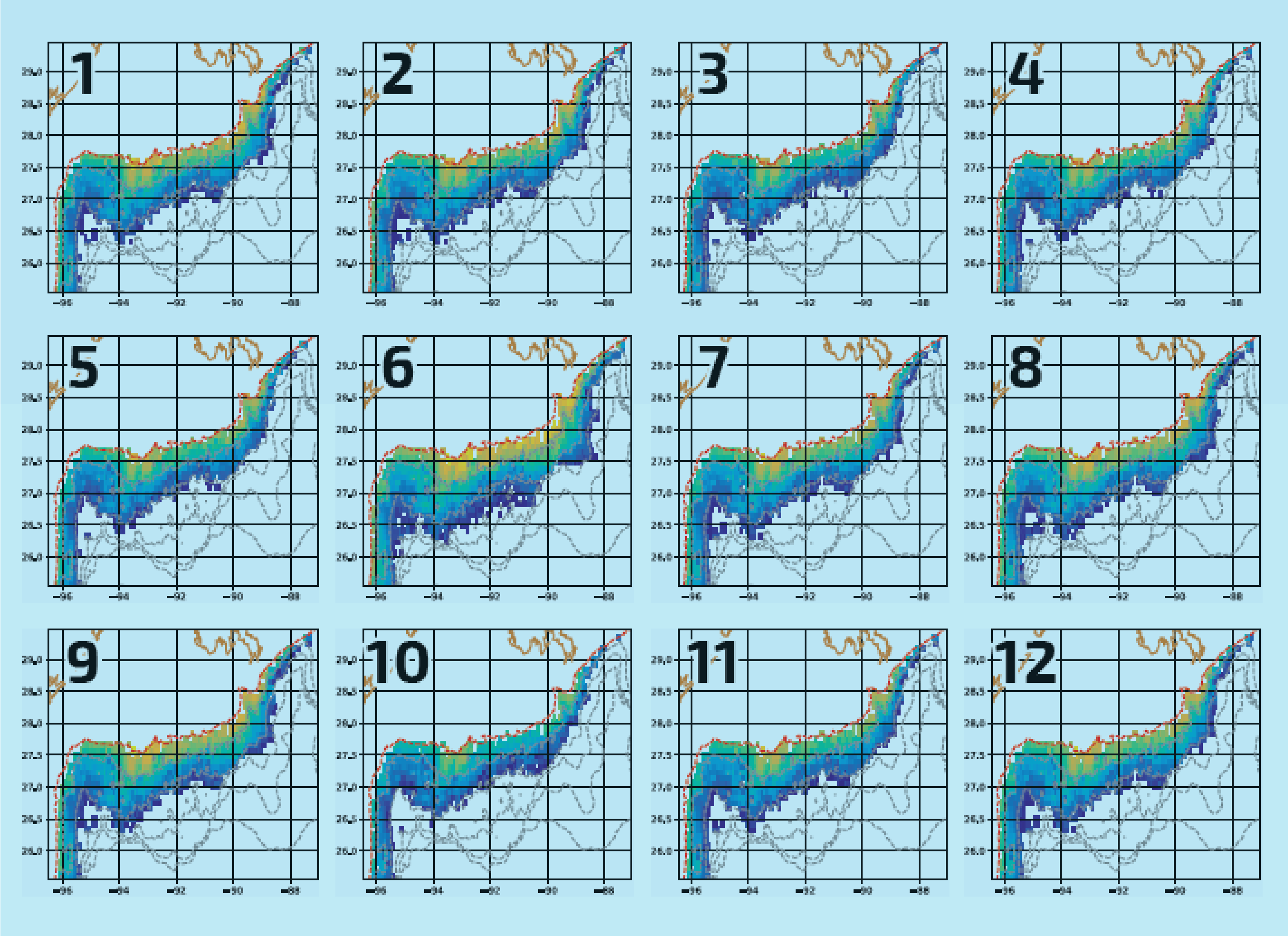


Lee, et al. (2019). Global Biogeochemical Cycles, 33(1), 37-46

We use DAKOTA to sample on the pdf of each uncertain parameter (here, sedimentation rate and total organic carbon).

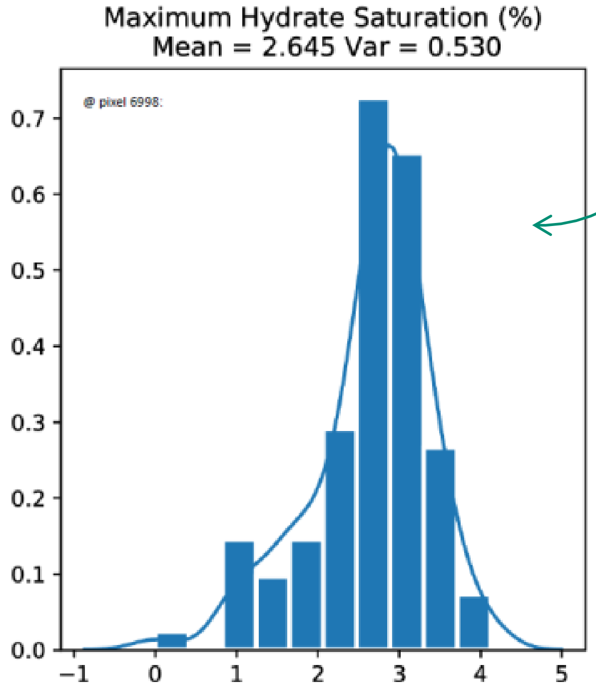
Ensemble Modeling Approach

Samples

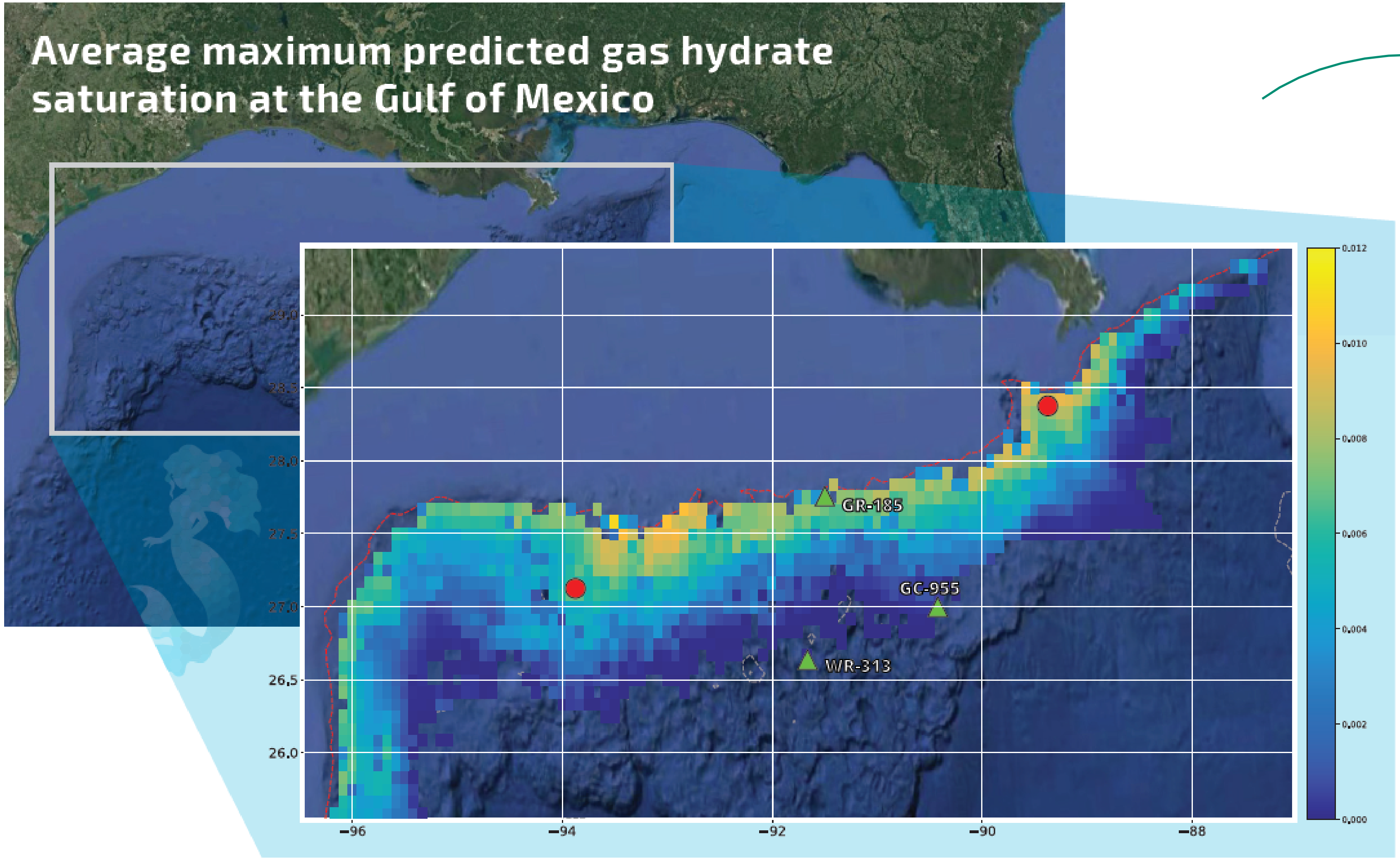


The sampled input parameters define an ensemble of PFLOTRAN+HYD simulations for free gas and gas hydrate distribution (here we show maximum gas hydrate saturation).

Results are compiled into a histogram, and a pdf function is fit:



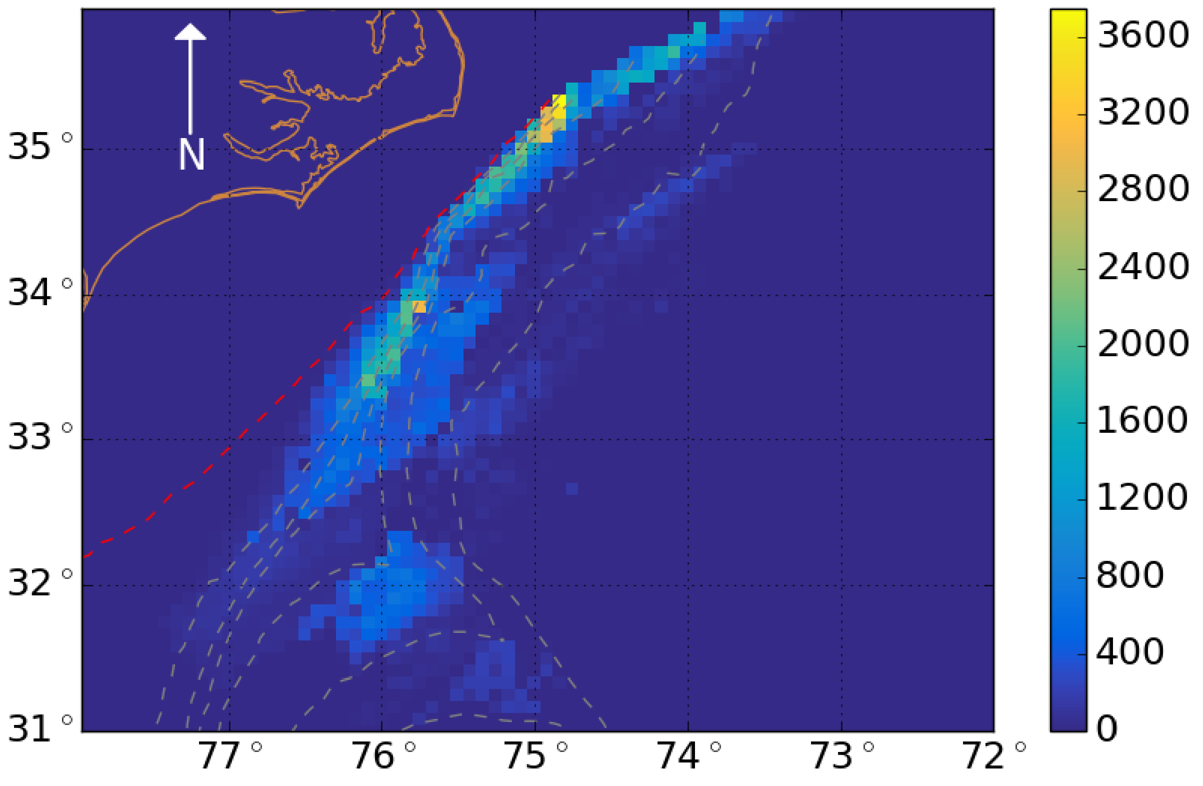
Ensemble Modeling Approach



A probabilistic map can be created showing the most likely value of your parameter of interest, including uncertainty.

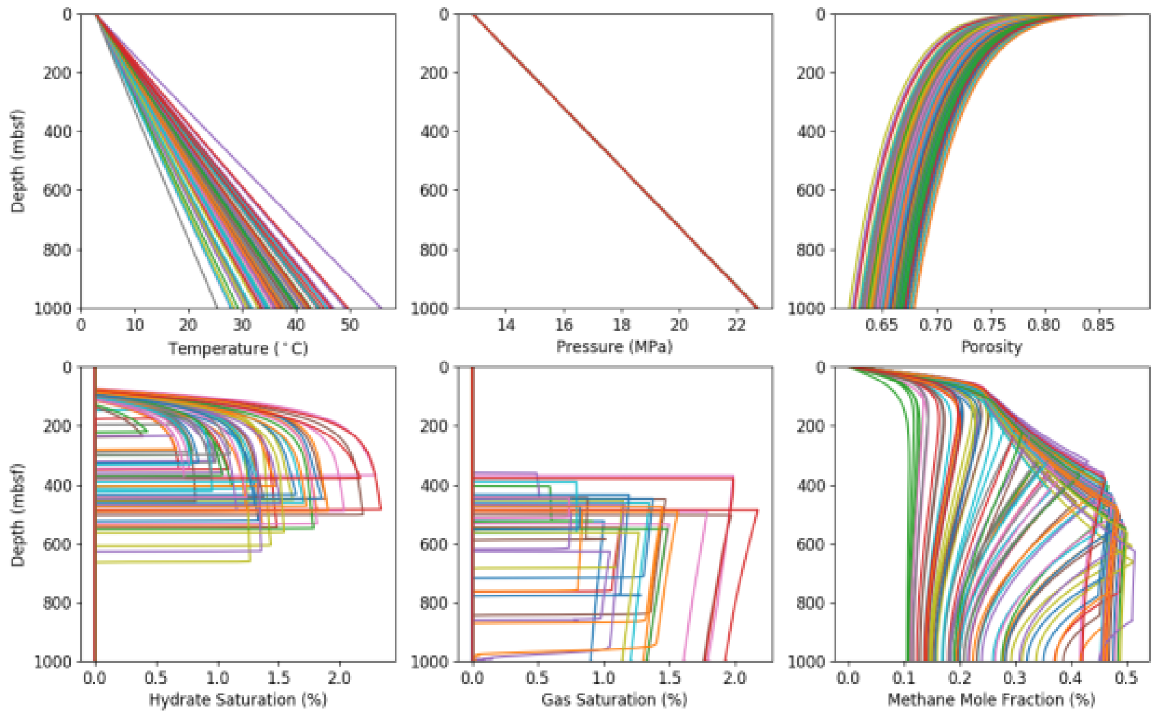
Ensemble Modeling Approach

Mass of Hydrate Formation [kg], Most Probable



Probabilistic predictions of gas hydrate formation along the Blake Ridge (left).

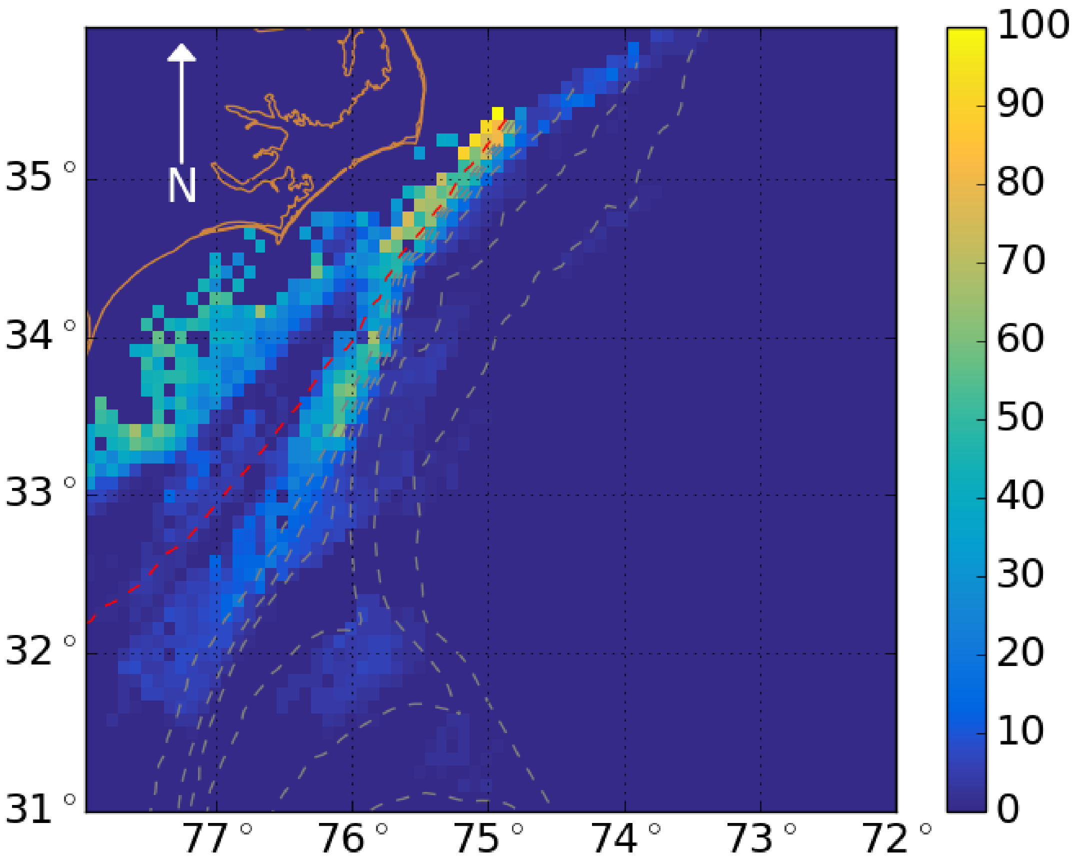
Ensemble results at pixel location 7675 (34.625°N, 75.458°W):

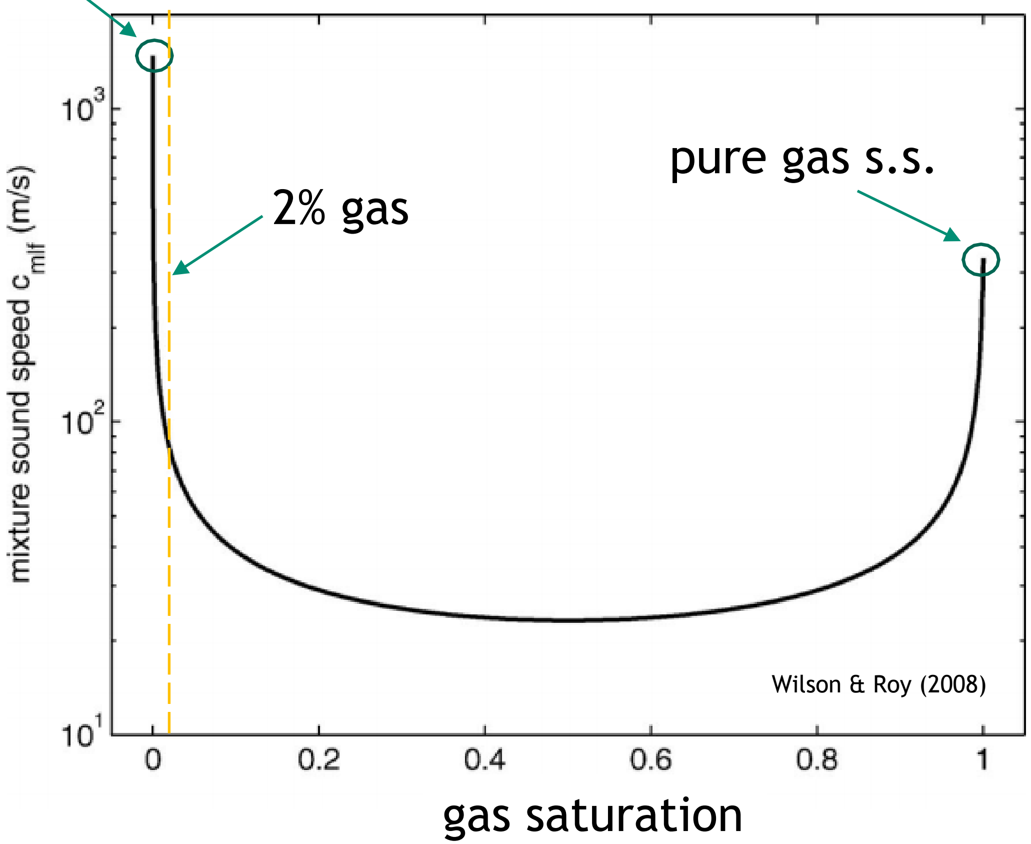


Billy Eymold's PhD dissertation work

Geo-acoustics (Naval Operations)

Probability of at least 2% gas saturation:



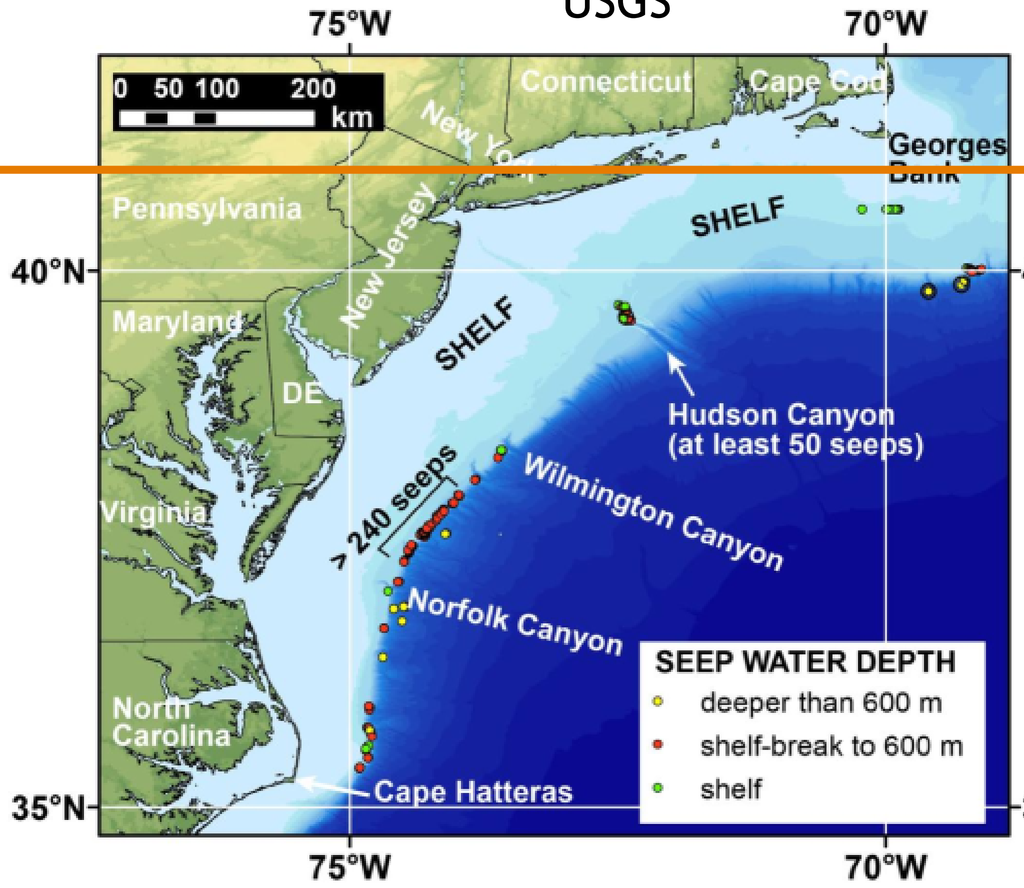


Sound speed is dramatically reduced if even a tiny amount of gas is present in the sediments.

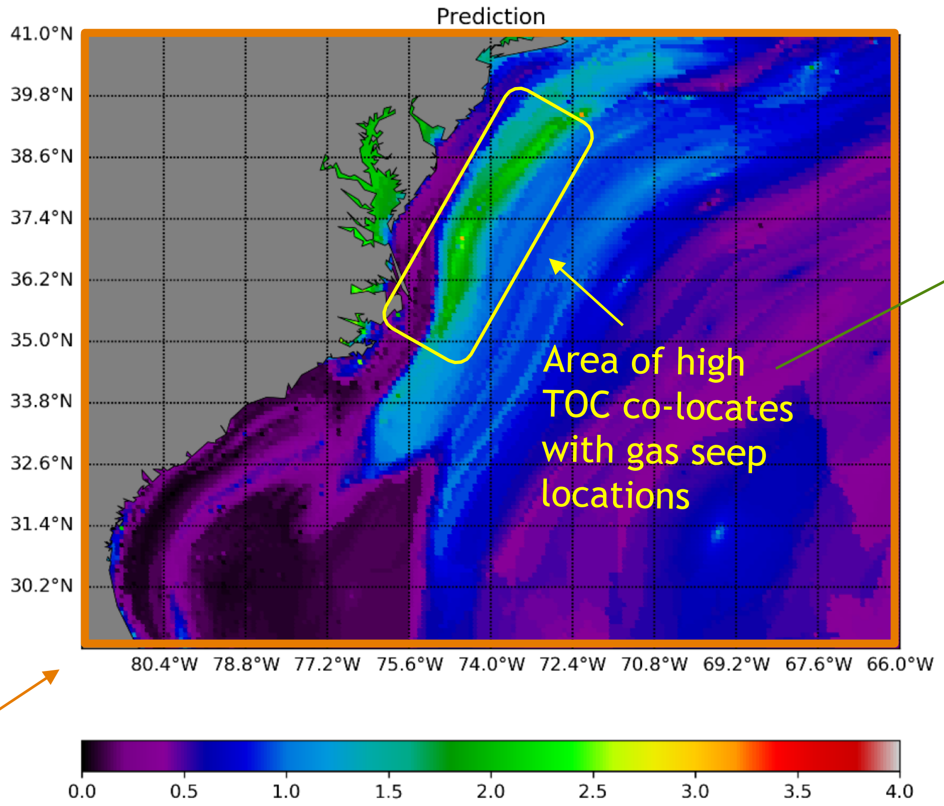
North Atlantic Margin

Map of the northern US Atlantic margin showing the locations of newly-discovered methane seeps

USGS



Using GML, we can map, at high resolution, relevant seabed quantities, such as total organic carbon (TOC).
These go into our thermodynamic models.



We have shown that **hydrate quantity** is most **correlated to the amount of TOC** at the seafloor.

Predicted TOC [%] using KNN with 1621 predictors in geological predictor space, via the *Global Predictive Seabed Model*, US Naval Research Lab.

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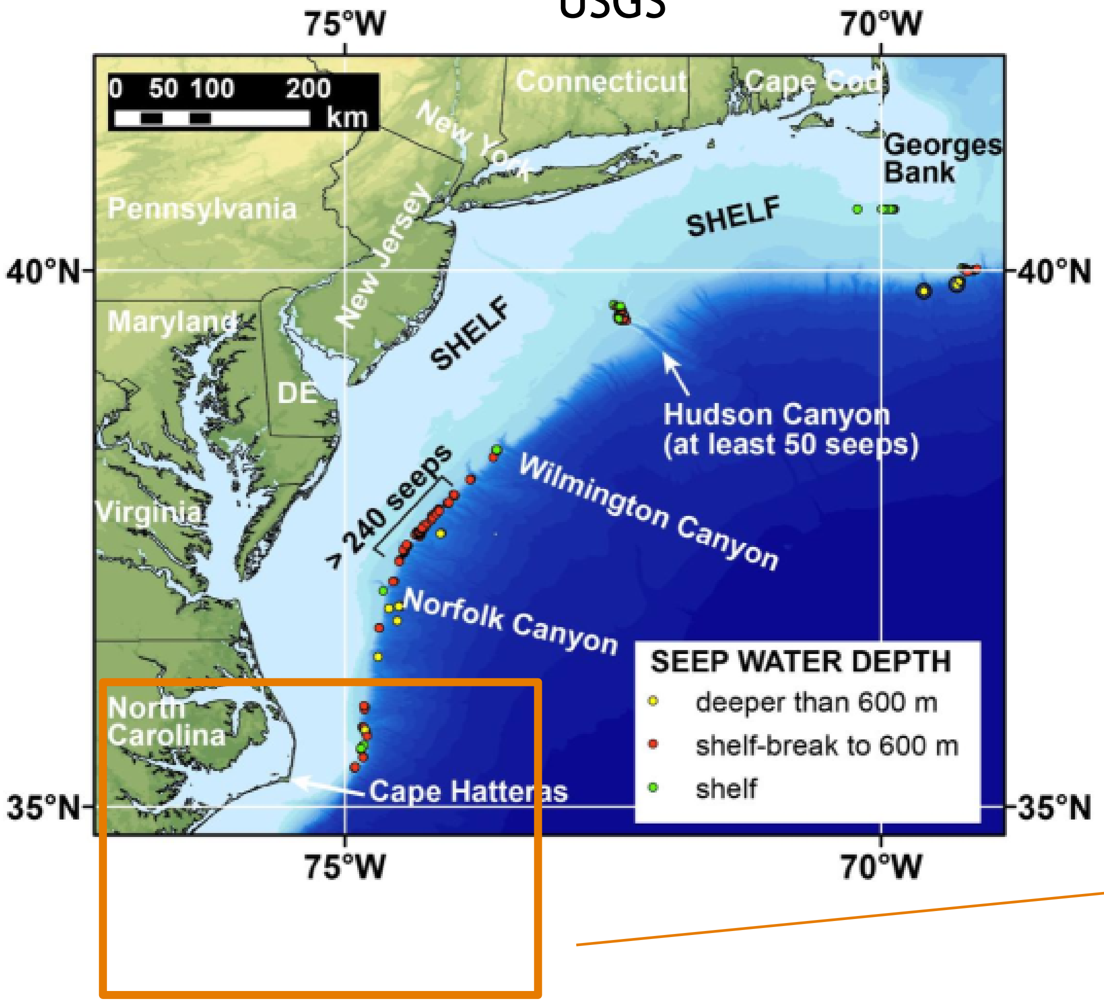
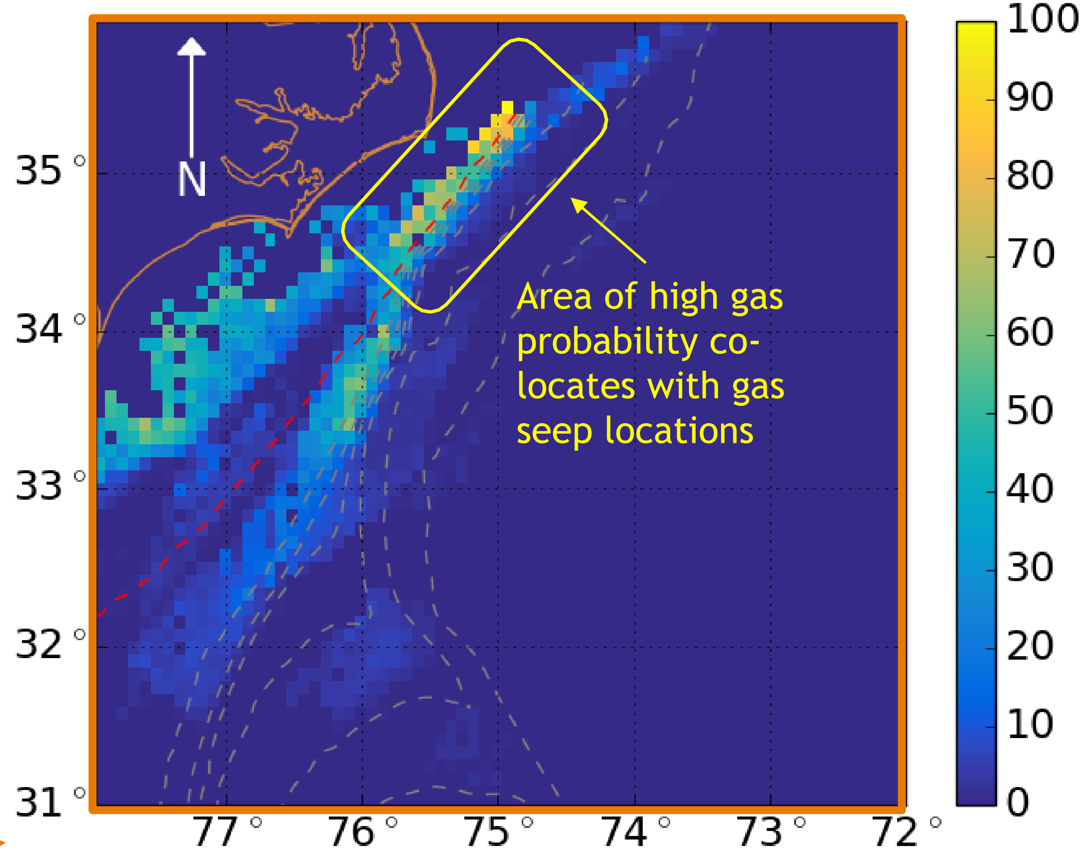


We are interested in using our **ensemble modeling capability** to better **constrain gas hydrate quantities**, and predict how gas seeping will evolve as **environmental drivers** change.



Probability of at least 2% gas saturation

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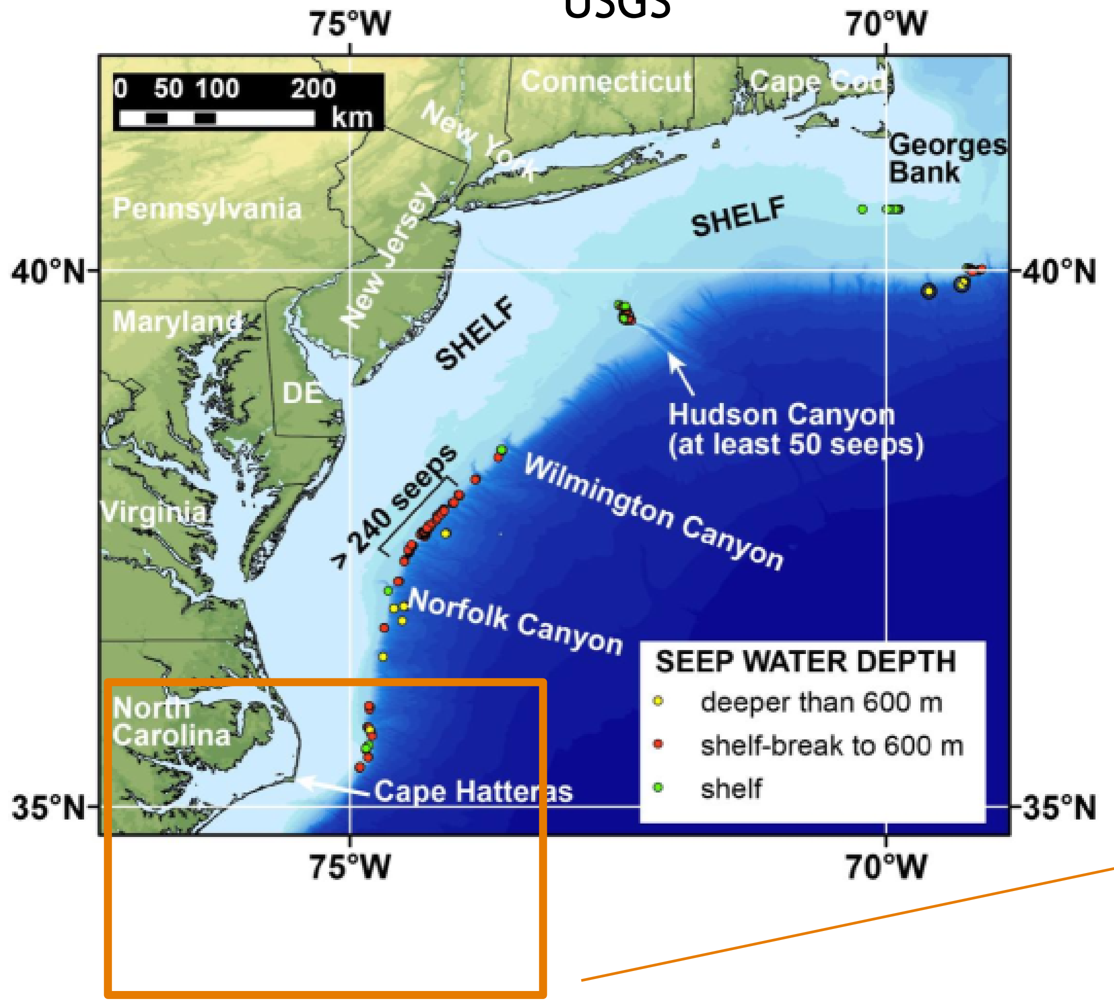

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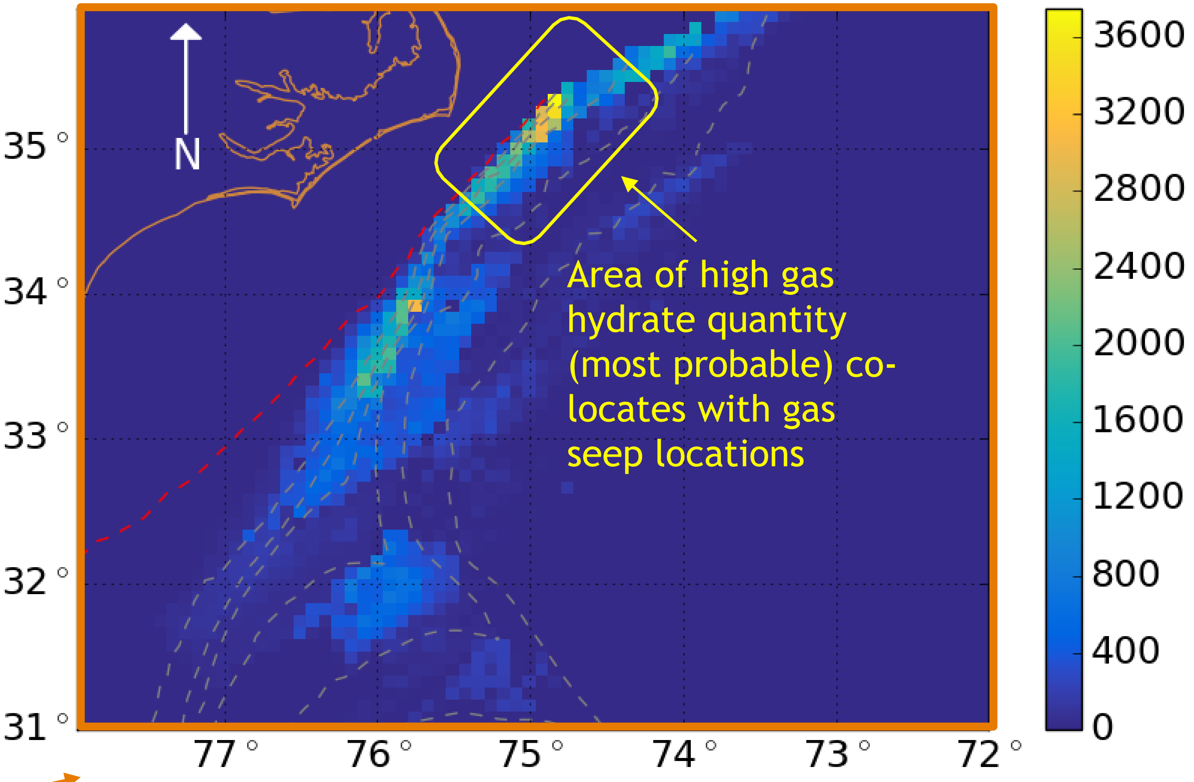


Mass of Hydrate Formation [kg], Most Probable

North Slope Permafrost-Associated Gas Hydrate

North Slope, Alaska

Sherman & Constable (2018)

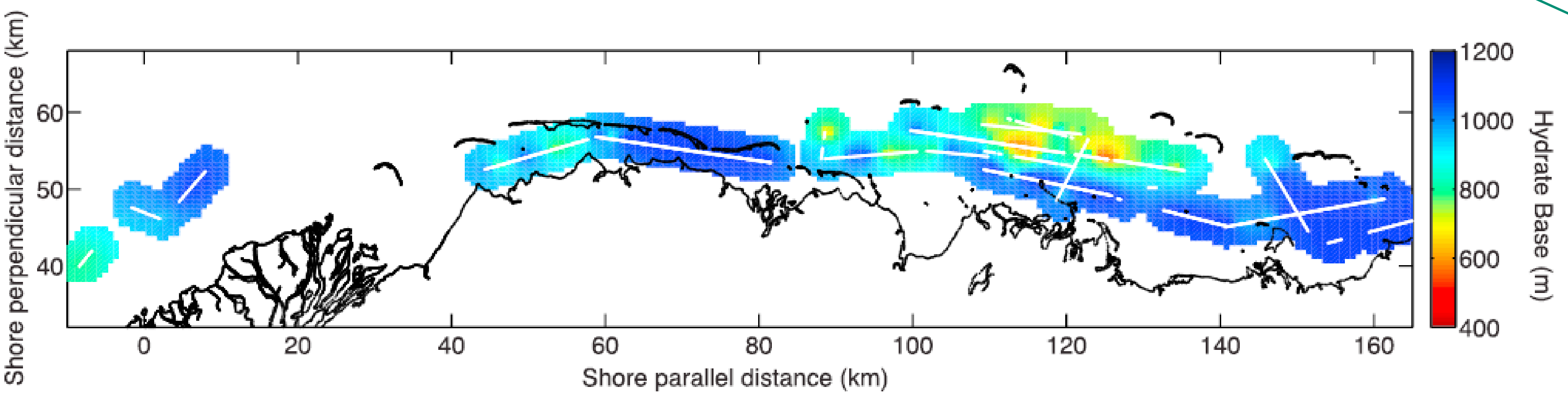
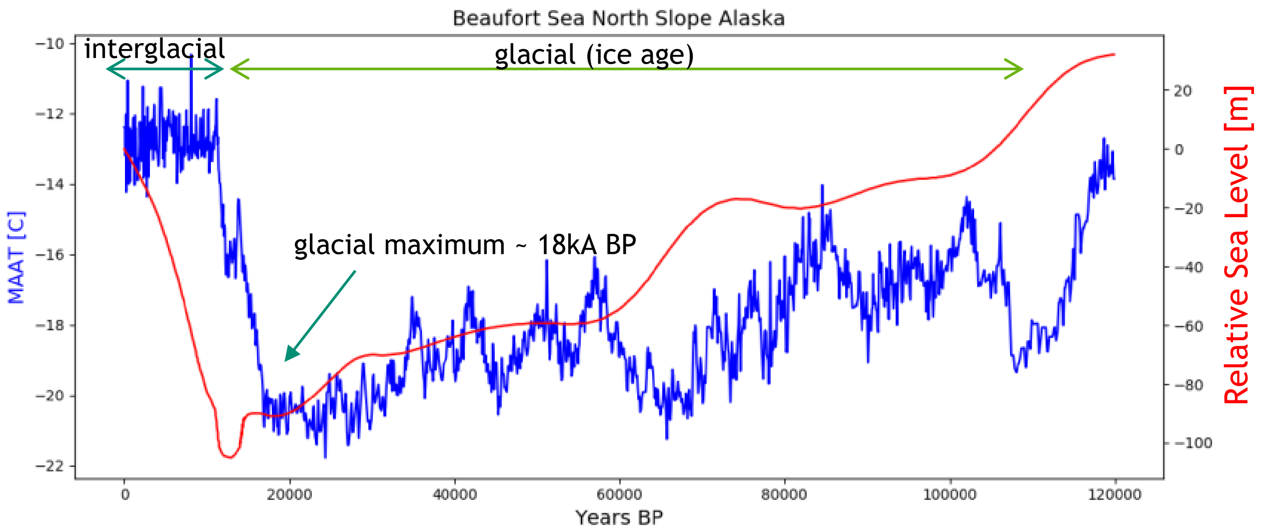


Figure 9. Map of gas hydrate stability zone for 100% methane hydrate based on thickness of ice-bearing and ice-bonded permafrost determined by controlled-source electromagnetic data.

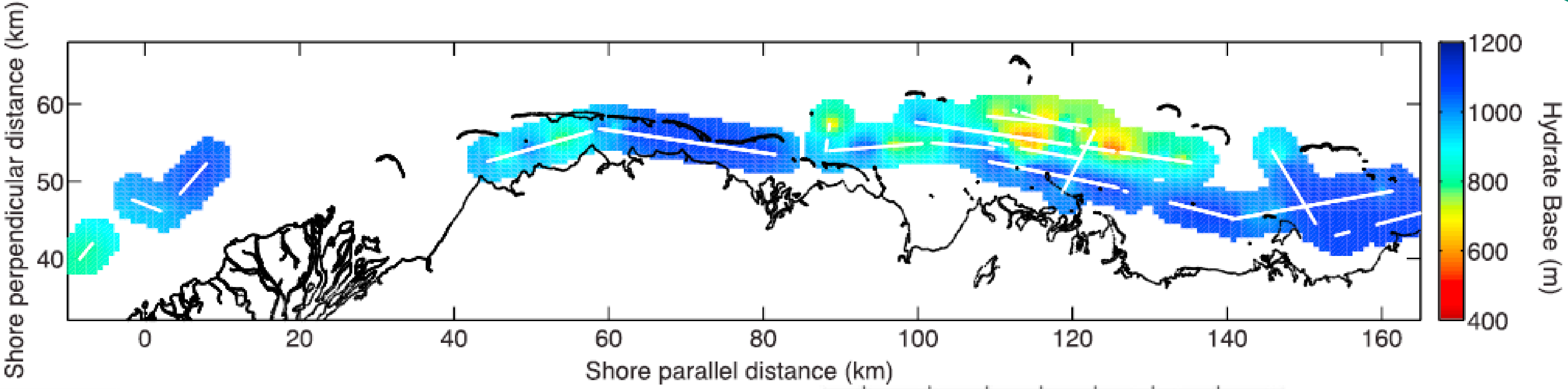


- Permafrost-associated gas hydrates exist along the North Slope of Alaska, both on & off shore.
- They are relicts of the last glacial maximum, and sensitive to warming conditions!
- They have been targeted for U.S. production of natural gas.

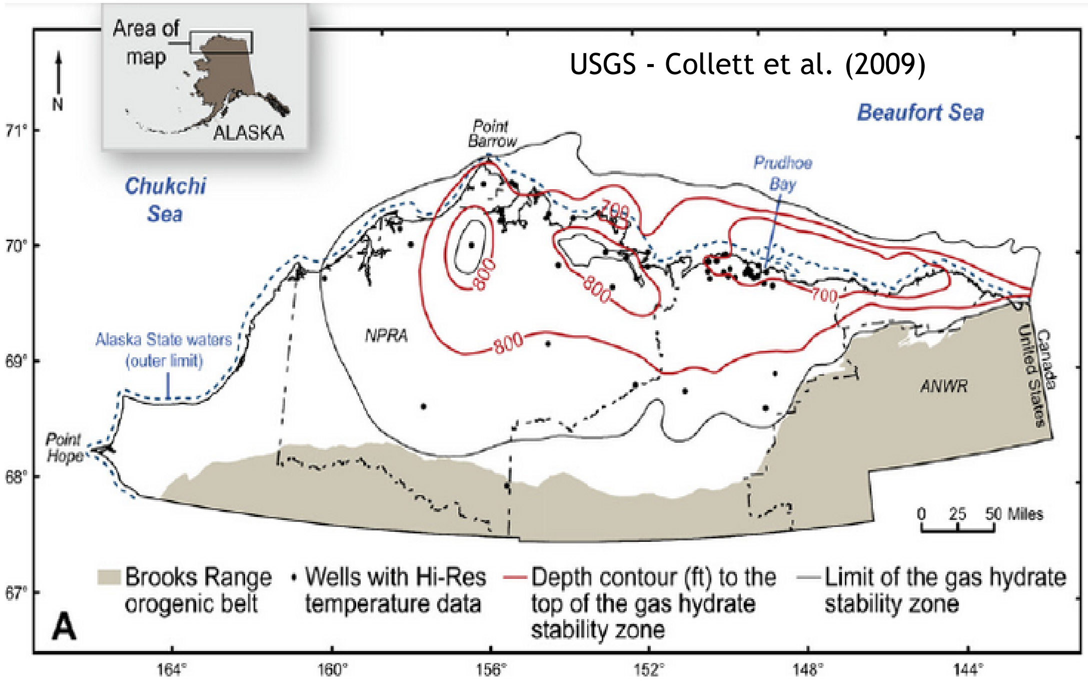
North Slope Permafrost-Associated Gas Hydrate

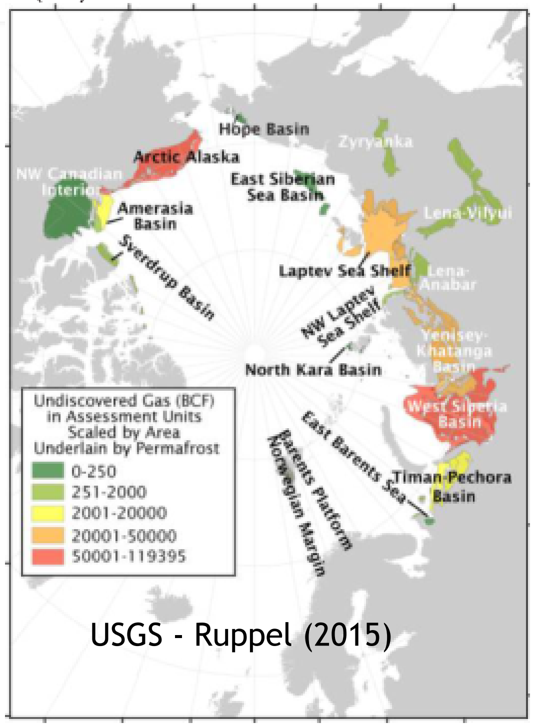
North Slope, Alaska

Sherman & Constable (2018)




AGU100
JGR
Journal of Geophysical Research: Solid Earth
RESEARCH ARTICLE
Permafrost Extent on the Alaskan Beaufort Shelf From Surface-Towed Controlled-Source Electromagnetic Surveys
Abstract
1. Introduction





ice-bearing and

- We are using our model to map the distribution of free gas and permafrost-associated gas hydrate on the Alaskan North Slope.
- USGS resource assessments indicate Alaska has the highest resource potential in the Arctic.