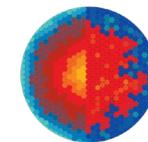


DeepSee

Multidimensional Visualizations of Seabed Ecosystems



 Adam **Coscia**

 Haley M. **Sapers**

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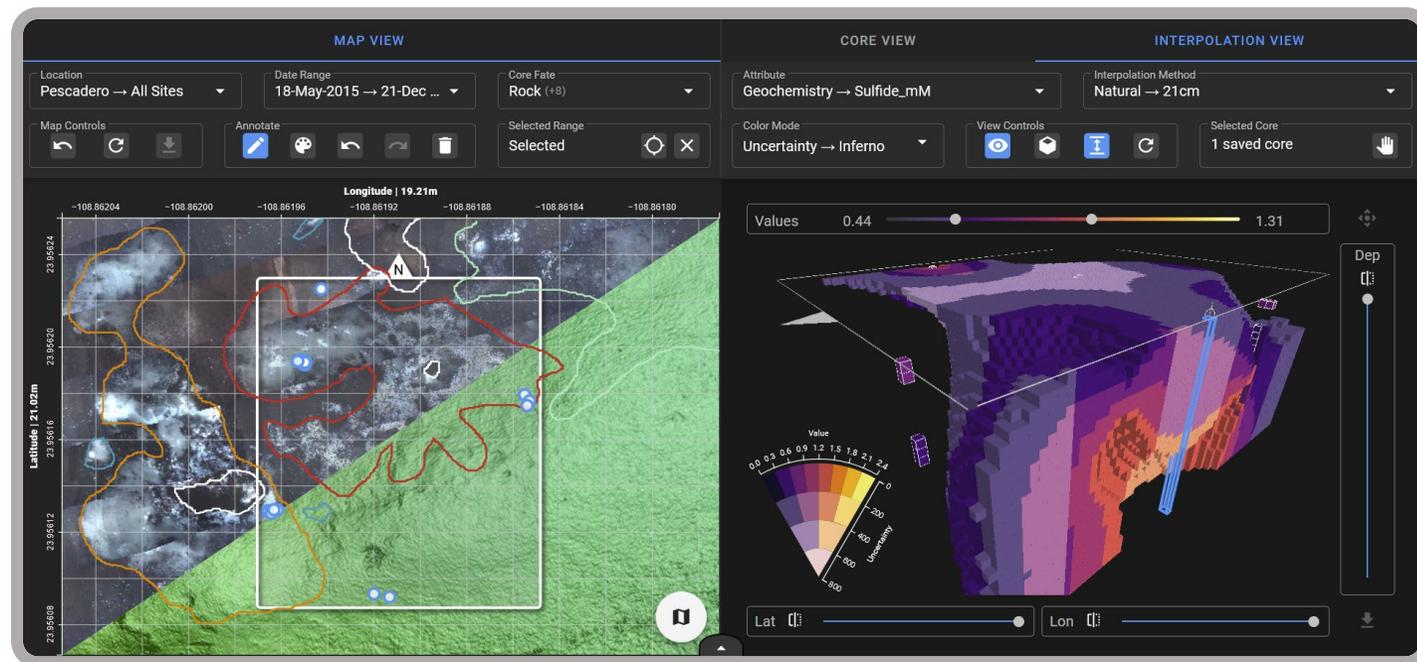
 Santiago **Lombeyda**

 Hillary **Mushkin**

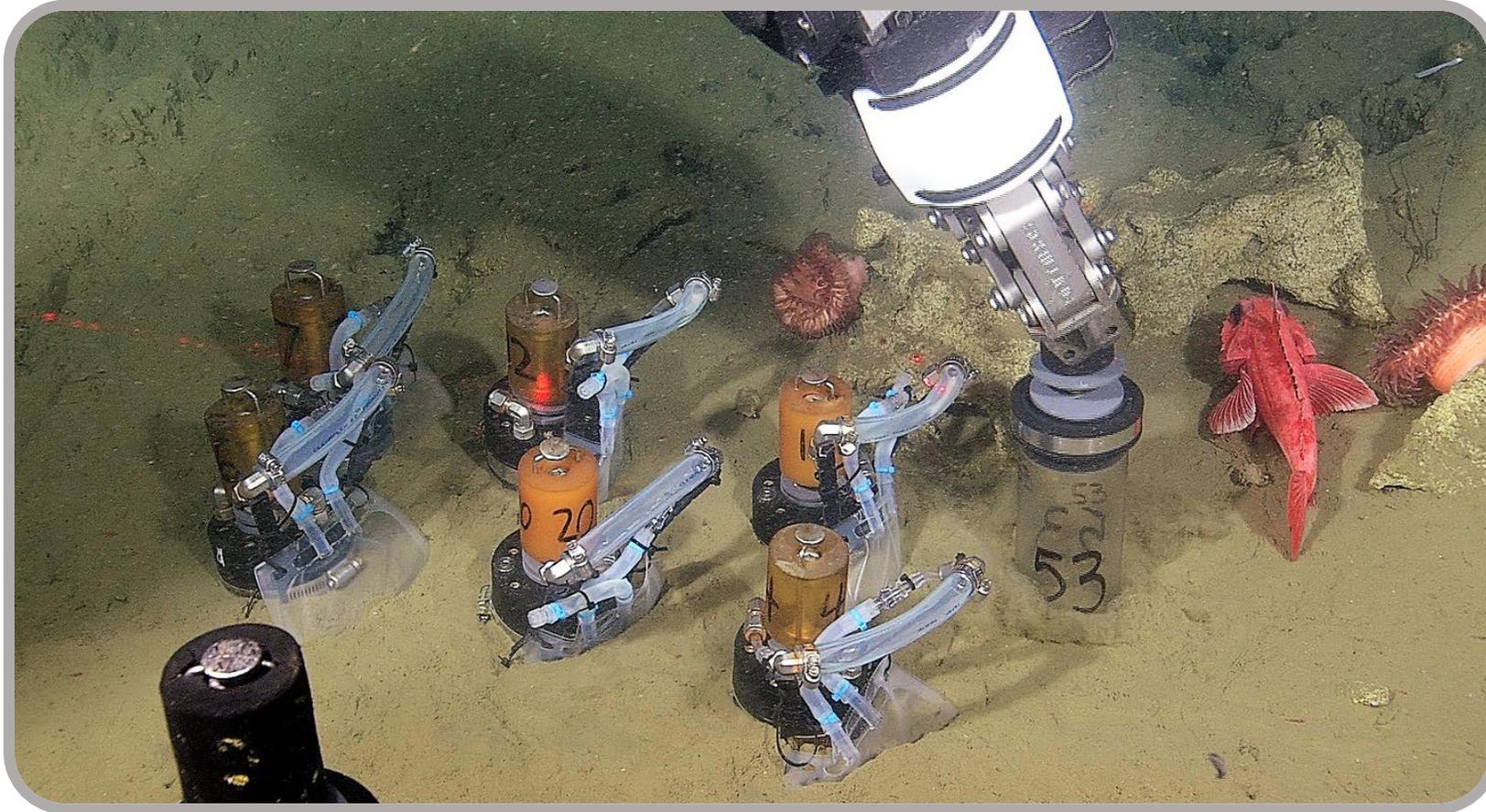
 Alex **Endert**

 Scott **Davidoff**

 Victoria J. **Orphan**



Scientists collect **sediment samples** from the **deep ocean** to study **microbial ecology!**



Scientists collect **sediment samples** from the **deep ocean** to study **microbial ecology!**





However, diving / collecting samples is **time-consuming** and **expensive**.



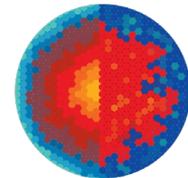
How to help scientists analyze **prior samples** to decide **where to dive next?**

Our Goals

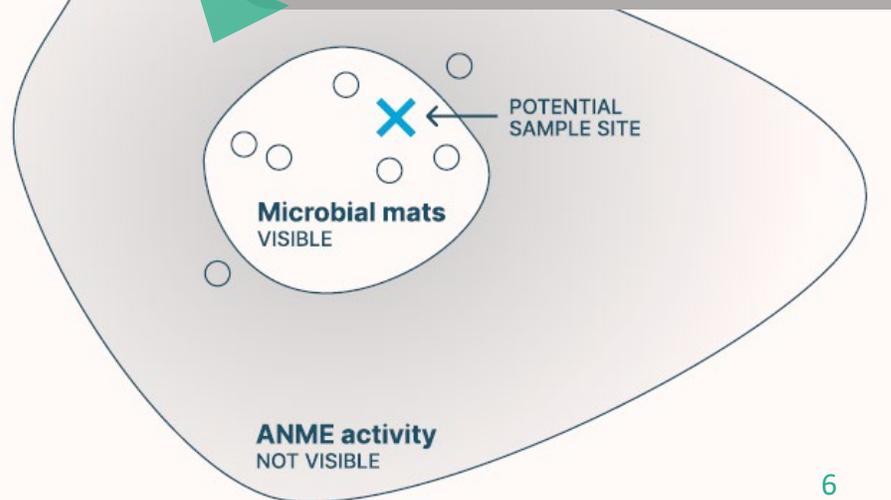
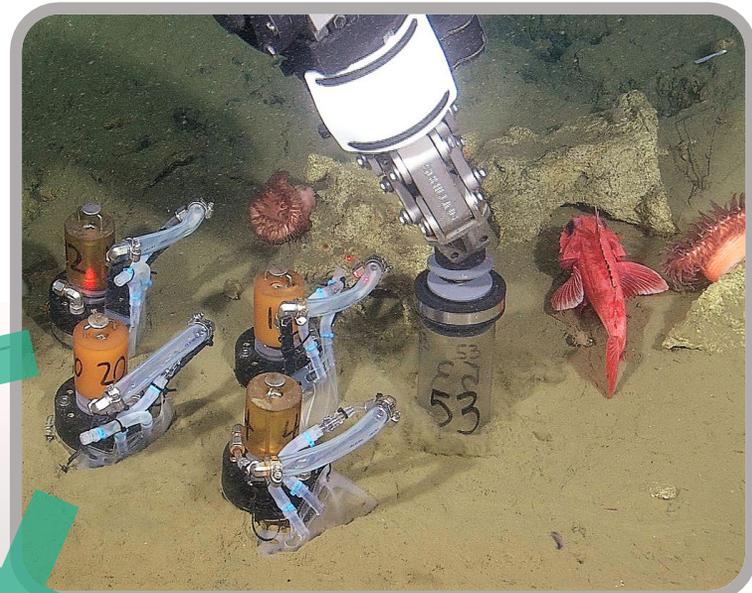
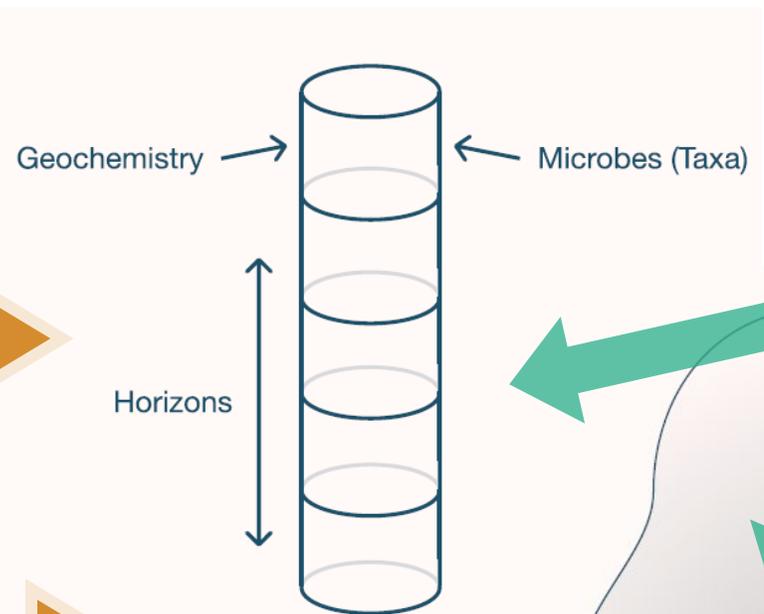
- ✓ Design a **visualization system** to explore spatial trends between samples in context of the environment
- ✓ Deploy our system on a **field research expedition** to measure the impact on scientists' workflows
- ✓ Develop **design guidance** for visualizing prior sample data to decide where to sample in the future

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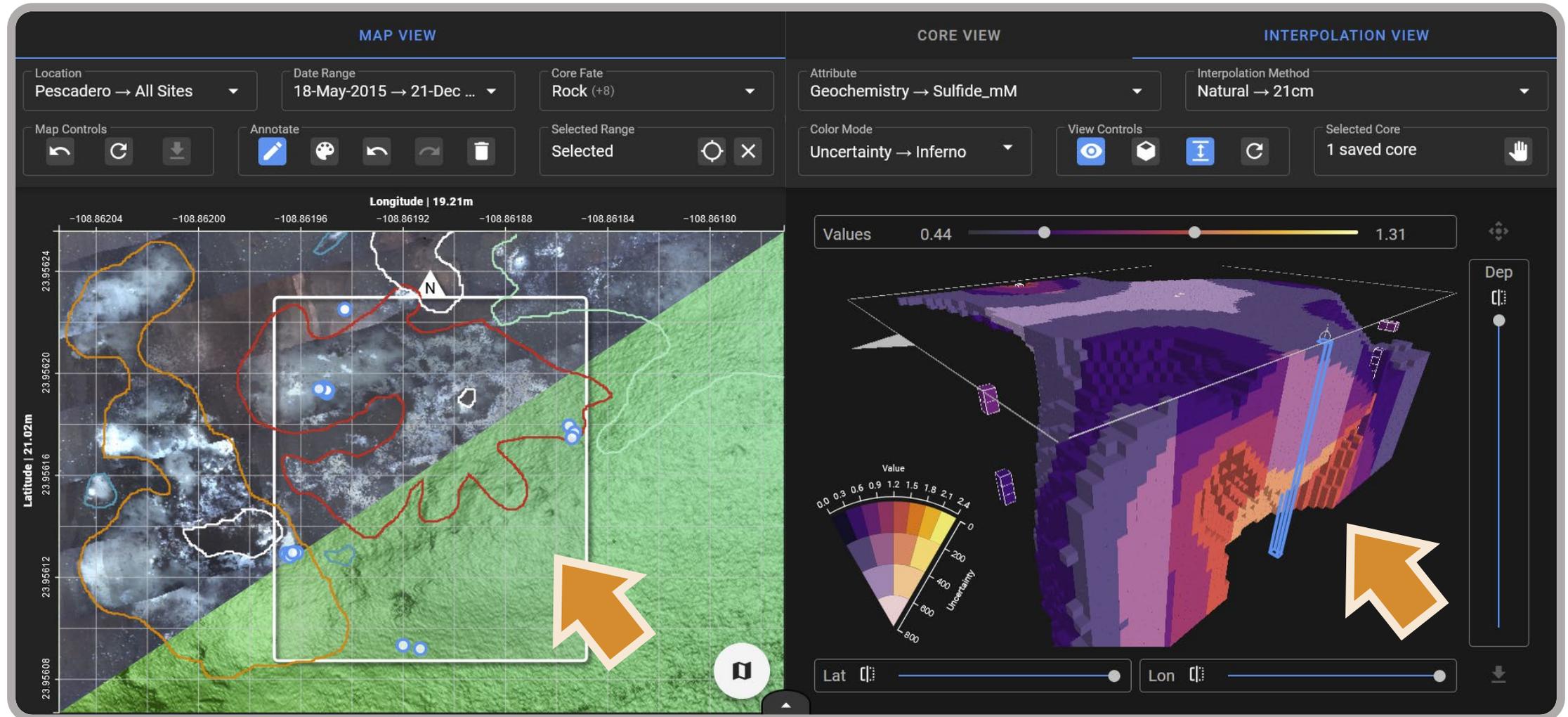
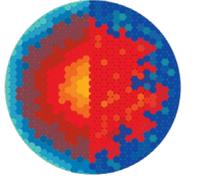
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FK381031-11	11703	50193	PC5	Auka	Diane's vent	blue mat	3656.64
FK381031-11	11704	50193	PC5	Auka	Diane's vent	blue mat	
FK381031-11	11705	50193	PC5	Auka	Diane's vent	blue mat	
FK381031-11	11706	50193	PC5	Auka	Diane's vent	blue mat	
FK381031-11	11707	50193	PC5	Auka	Diane's vent	blue mat	
FK381031-11	11708	50193	PC5	Auka	Diane's vent	blue mat	
FK381031-11	11709	50193	PC5	Auka	Diane's vent	blue mat	3656.64
FK381031-11	11713	50193	PC3	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11721	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11722	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11723	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11724	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11725	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11726	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11727	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11728	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11729	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11730	50193	PC7	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11732	50193	PC1	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11735	50193	PC1	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11737	50193	PC2	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11738	50193	PC2	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11739	50193	PC2	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11740	50193	PC2	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11745	50194	PC4	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11746	50194	PC4	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11747	50194	PC4	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11748	50194	PC4	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11749	50194	PC4	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11751	50194	PC4	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11753	50194	PC4	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11760	50194	PC3	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11763	50194	PC3	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11770	50194	PC1	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11771	50194	PC1	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11772	50194	PC2	Auka	Diane's vent	peach mat	3656.7
FK381031-11	11773	50194	PC2	Auka	Diane's vent	peach mat	3656.7



Data

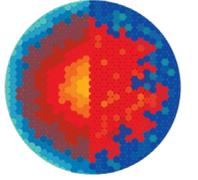
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Map View



Sample_No	Serial_No	Dive	Core	Location	Site	Surface	Depth
FK381031-11	11703	S0193	PCS	Auko	Diane's vent	blue mat	3656.64
FK381031-11	11704	S0193	PCS	Auko	Diane's vent	blue mat	3656.64
FK381031-11	11705	S0193	PCS	Auko	Diane's vent	blue mat	3656.64
FK381031-11	11706	S0193	PCS	Auko	Diane's vent	blue mat	3656.64
FK381031-11	11707	S0193	PCS	Auko	Diane's vent	blue mat	3656.64
FK381031-11	11708	S0193	PCS	Auko	Diane's vent	blue mat	3656.64
FK381031-11	11709	S0193	PCS	Auko	Diane's vent	blue mat	3656.64
FK381031-11	11713	S0193	PC1	Auko	Diane's vent	blue mat	3656.64
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FK381031-11	11723	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11724	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11725	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11726	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11727	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11728	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11729	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11730	S0193	PC7	Auko	Diane's vent	peach mat	3656.7
FK381031-11	11731	S0193	PC1	Auko	Diane's vent	Gray mat by	3657.85
FK381031-11	11735	S0193	PC1	Auko	Diane's vent	Gray mat by	3657.85
FK381031-11	11737	S0193	PC2	Auko	Diane's vent	Gray m	
FK381031-11	11738	S0193	PC2	Auko	Diane's vent	Gray m	
FK381031-11	11739	S0193	PC2	Auko	Diane's vent	Gray m	
FK381031-11	11740	S0193	PC2	Auko	Diane's vent	Gray m	
FK381031-11	11745	S0194	PC4	Auko	Diane's vent	Gray m	
FK381031-11	11746	S0194	PC4	Auko	Diane's vent	Gray m	
FK381031-11	11747	S0194	PC4	Auko	Diane's vent	Gray m	
FK381031-11	11748	S0194	PC4	Auko	Diane's vent	Gray m	
FK381031-11	11749	S0194	PC4	Auko	Diane's vent	Gray m	
FK381031-11	11751	S0194	PC4	Auko	Diane's vent	Gray m	
FK381031-11	11753	S0194	PC4	Auko	Diane's vent	Gray m	
FK381031-11	11760	S0194	PC3	Auko	Diane's vent	Gray m	
FK381031-11	11763	S0194	PC3	Auko	Diane's vent	Gray m	
FK381031-11	11770	S0194	PC1	Auko	Diane's vent	Gray m	
FK381031-11	11771	S0194	PC1	Auko	Diane's vent	Gray m	
FK381031-11	11772	S0194	PC0	Auko	Diane's vent	Gray m	
FK381031-11	11773	S0194	PC0	Auko	Diane's vent	Gray m	



MAP VIEW

All Sites

Date Range: 18-May-2015 → 21-Dec-2015

Core Fate: Rock (+8)

Selected Range: Selected

Longitude | 19.21m

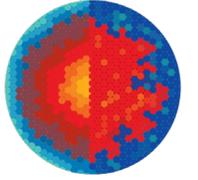
Map Controls: [Navigation icons]

Annotate: [Annotation icons]

Visualize sample data on top of maps!

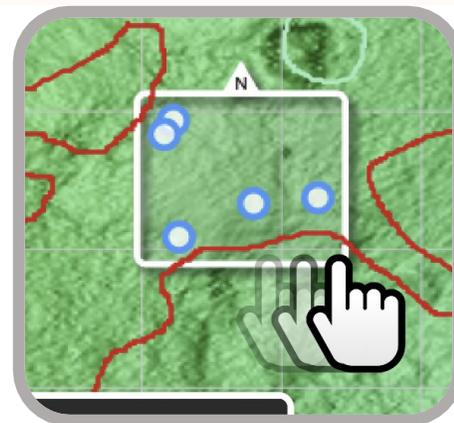
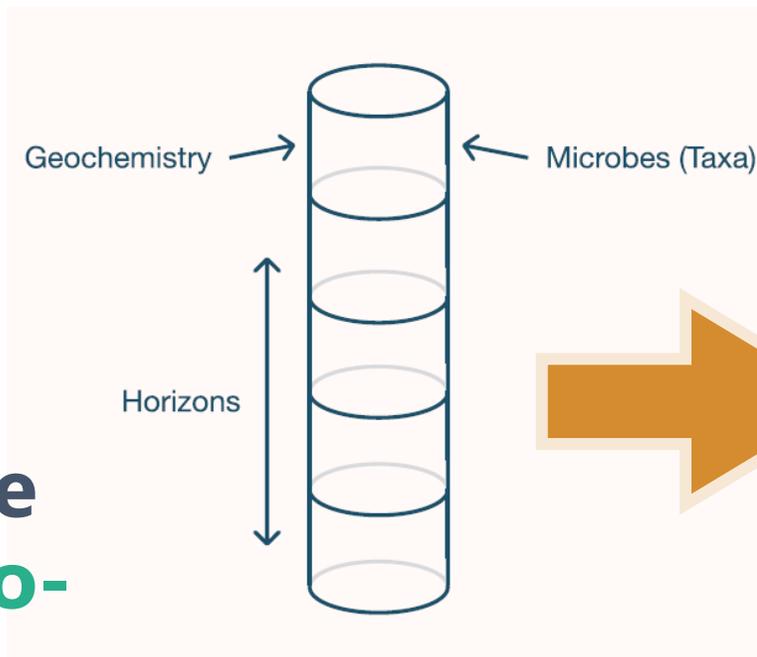
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Core View

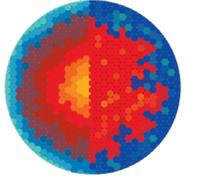
✓ Analyze bio-geo-chem data for patterns!



Horizon	Value	Horizon	Value	Horizon	Value
0_1	0.01	1_2	2.19	1_2	1.99
0_1	0.01	2_3	0.68	2_3	2.26
2_3	0.04	3_4	0.61	3_4	0.81
4_5	0.01	4_5	0.65	4_5	0.64
5_8	1.26	5_8	0.46	5_8	0.15
5_8	1.26	5_8	0.46	5_8	0.15
5_8	1.26	5_8	0.46	5_8	0.15
8_11	2.16	8_11	0.01	8_11	0.04
8_11	2.16	8_11	0.01	8_11	0.04
8_11	2.16	8_11	0.01	8_11	0.04
11_14	2.01	14_17	0.01	11_14	0.24
11_14	2.01	14_17	0.01	11_14	0.24
11_14	2.01	14_17	0.01	11_14	0.24
14_17	1.30	14_17	0.01	14_17	0.01

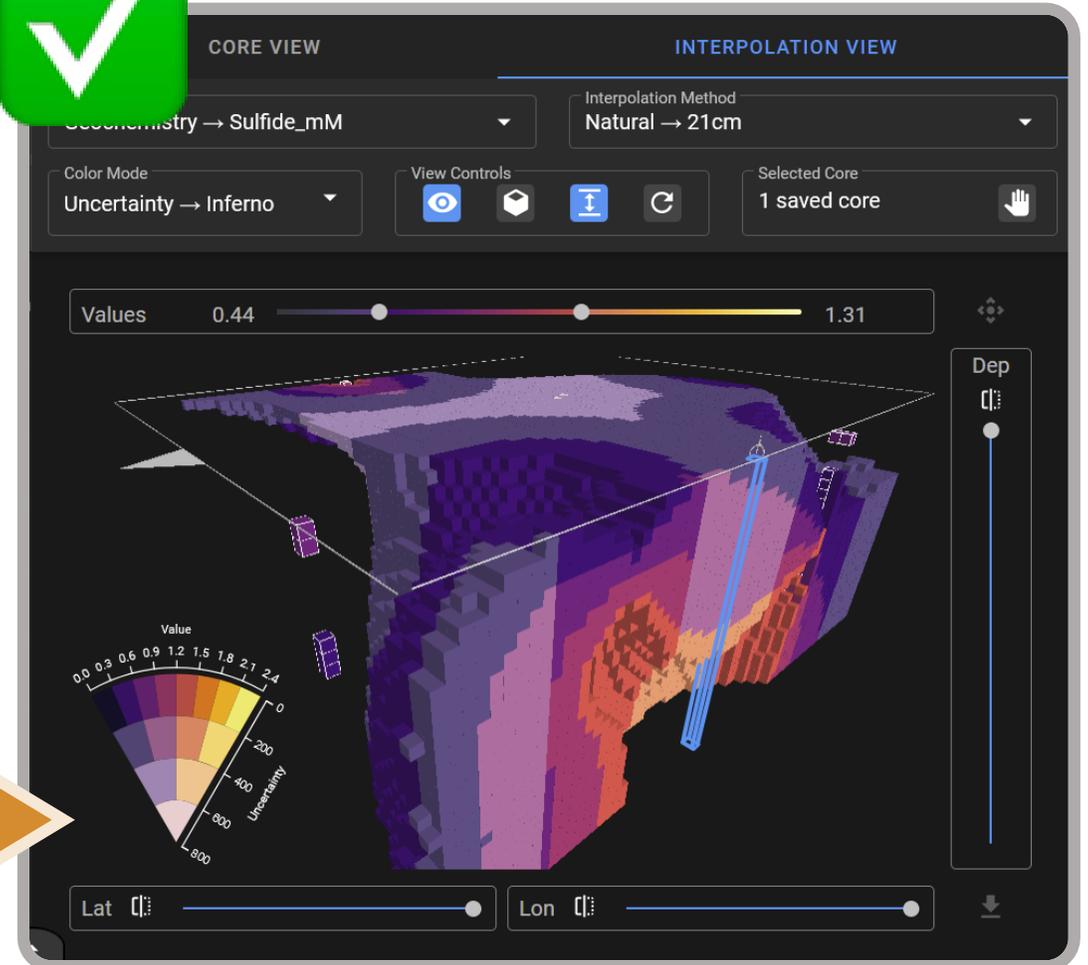
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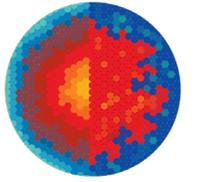
Interpolation View

✓ Explore gradients between samples in 3D!

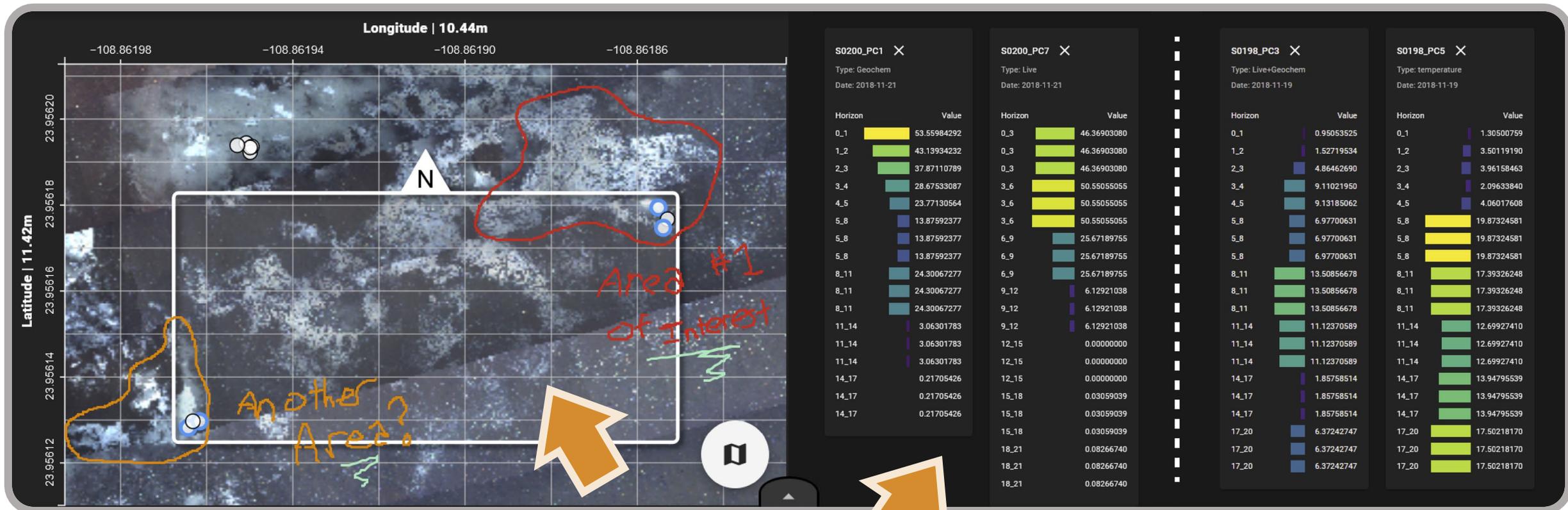


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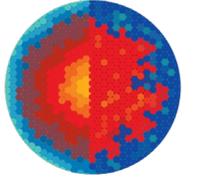


Scenario: Pre-Cruise Planning

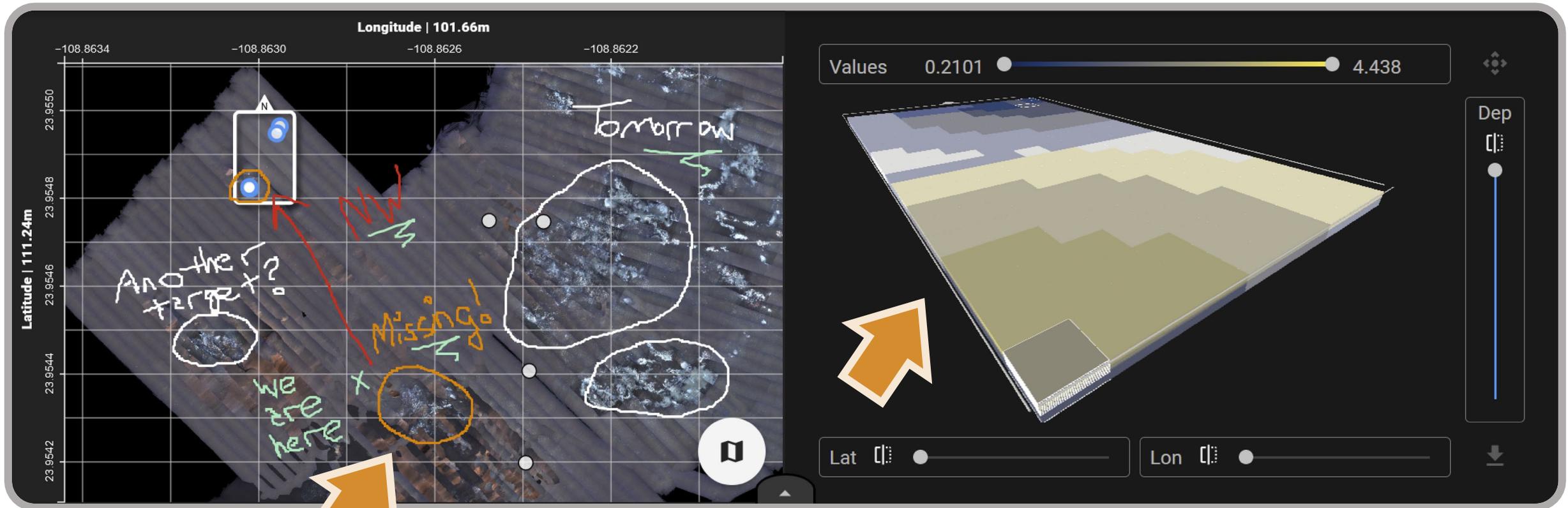


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Scenario: On-the-Fly Decision-Making



Evaluation

We deployed **DeepSee** on a research cruise in the **Gulf of California!**



Evaluation

We deployed **DeepSee** on a research cruise in the **Gulf of California!**



We conducted **expert interviews** with **scientists** from the **research cruise**

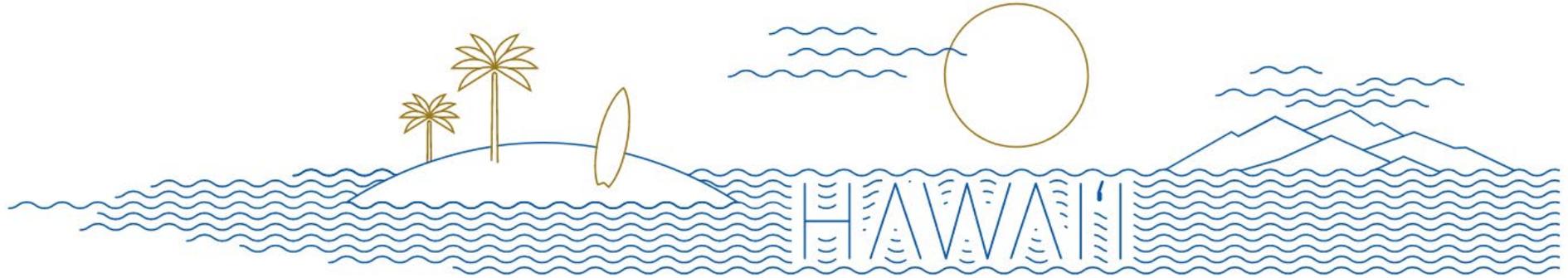
- ✓ **Fluid interaction** between **micro/macro scale data** helped researchers visually discover more insights
- ✓ **Integrating 2D/3D data** together increased the **scientific return** on value of limited samples
- ✓ **Modular visualizations** rapidly solved a diversity of **specific, directed** research tasks for different team members

We synthesized **lessons learned** for designing future **visualization** systems

- ✓ **Prioritize** data integration as a user task
- ✓ **Visualize** physical data in context of the environment
- ✓ **Combine** data types in new ways to bridge analysis gaps
- ✓ **Design** interactive visualizations to aid mental modeling

Future directions for DeepSee

- ✓ **Enhanced** data analysis (e.g., phylogenetic history)
- ✓ **New models** for large-scale interpolation
- ✓ **Notebook visualizations** in other fieldwork domains
- ✓ **Studying interactions** with DeepSee to train future autonomous sampling systems



DeepSee

Check out our **live** demo
& **open-source** code!

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<https://bit.ly/deepsee-vis>

