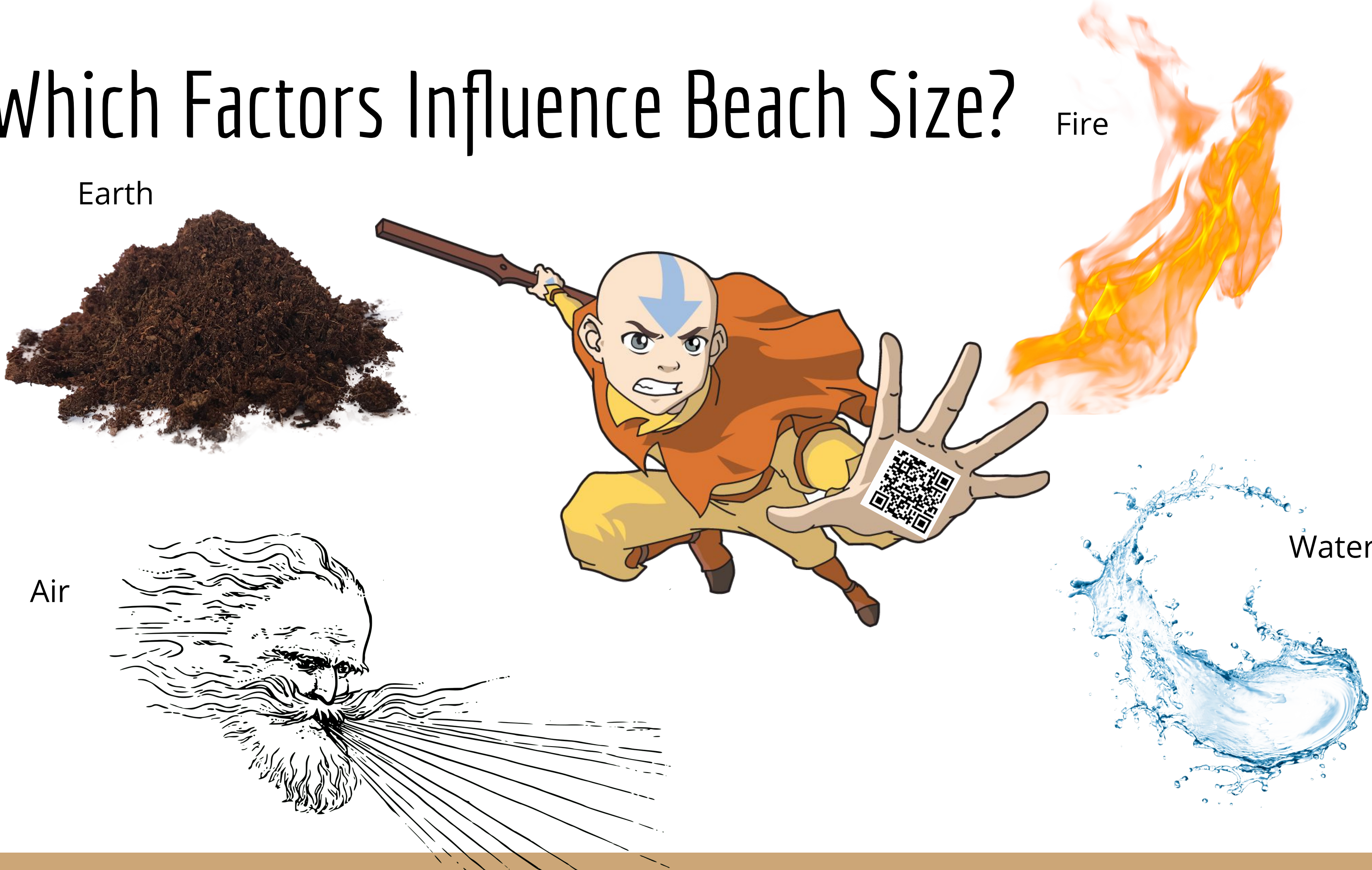
Exploring the Causes of Shoreline Expansion and Recession

Xander Coomes, Landen Isacson,
Aaron Morales

Which Factors Influence Beach Size?



How does climate change affect ecosystems?

How do wildfires affect beaches?

How does sediment discharge affect shoreline position?

Why is this Important?

Project Overview

1. Background
2. Methods
3. Discussion

Big Jon

(aka Mr. Sediment)

Vocab

Littoral - relating to or situated on the shore of the sea or a lake.

Fluvial - of or found in a river.

Climate Change→ Shoreline Change

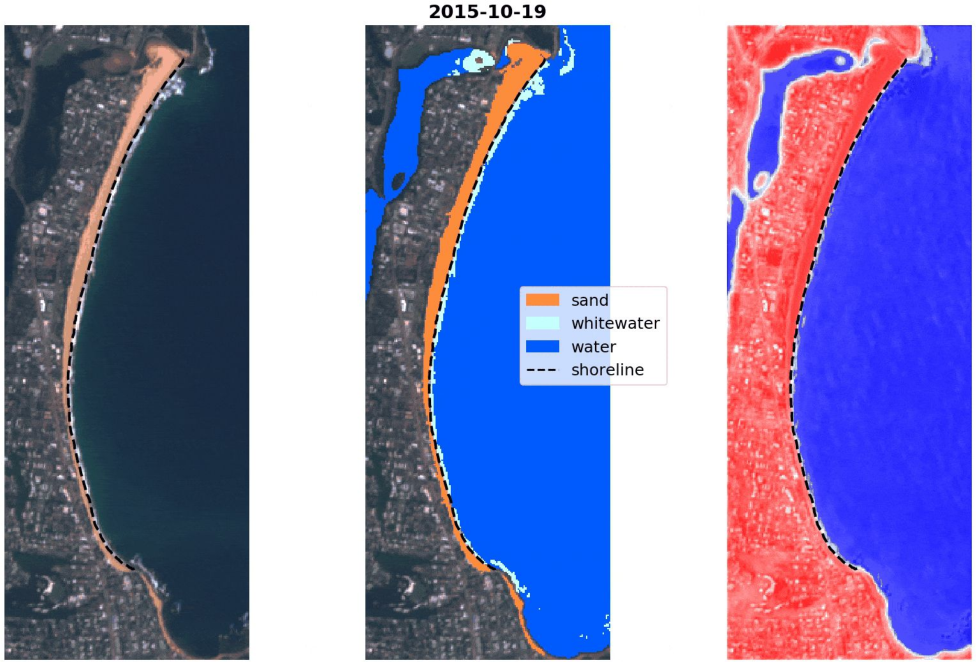
Why Big Sur?


e
Big Sur River

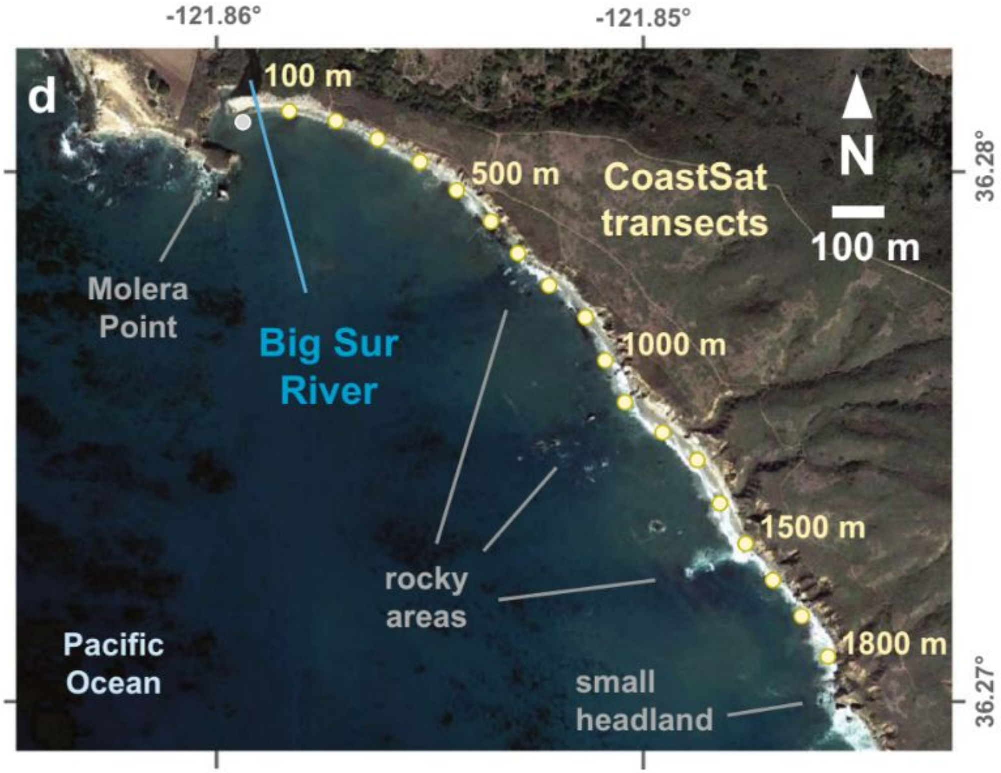

Carmel Highlands
Carmel Valley
1
Notleys Landing
Soberanes Fire
132,127 acres
2016
Colorado Fire
683 acres
5 p.m. PT, Jan. 22, 2022
1
Big Sur
Wildfire Today / Google / CAL FIRE
7.73 mi

Data Collection: CoastSat

- 30+ years of Satellite imagery
- Time-series of shoreline position
- Landsat 5, Landsat 8, and Sentinel 2



Data Overview



1. Wave power
2. Sediment discharge
3. Wave direction

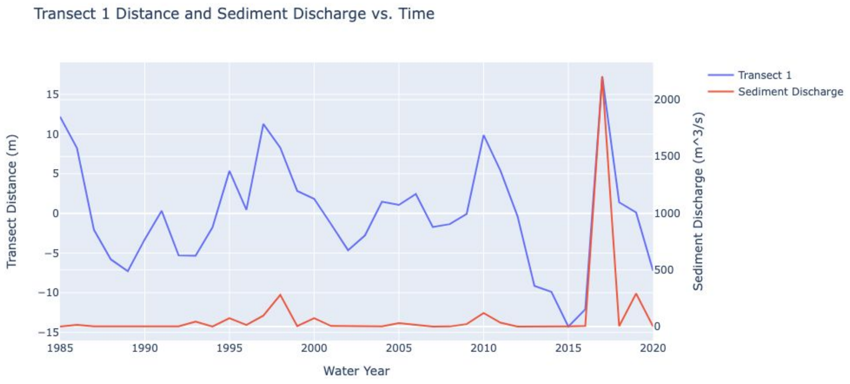
Independent Variables

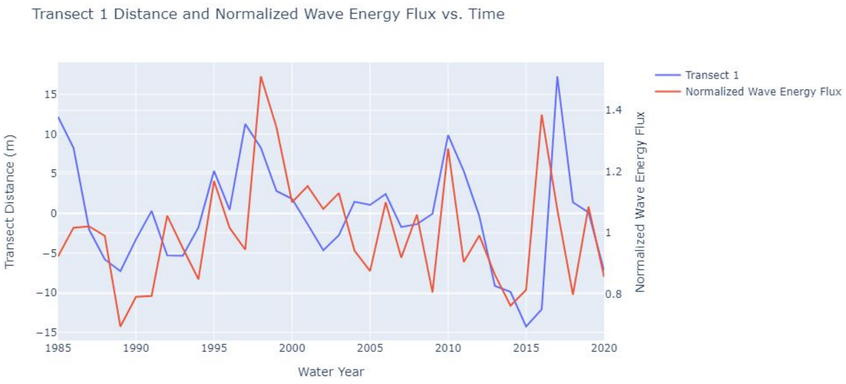
Sediment yield: $Q_{ss} = mP^n F_f(t)$

Wave flux: $F_{wave} = \frac{pg^2 H_s^2 T_{av}}{64\pi}$

Wave direction: Cape San Martin buoy (Station 46,028; 35.770° N 121.903° W)

Single Variable Approach



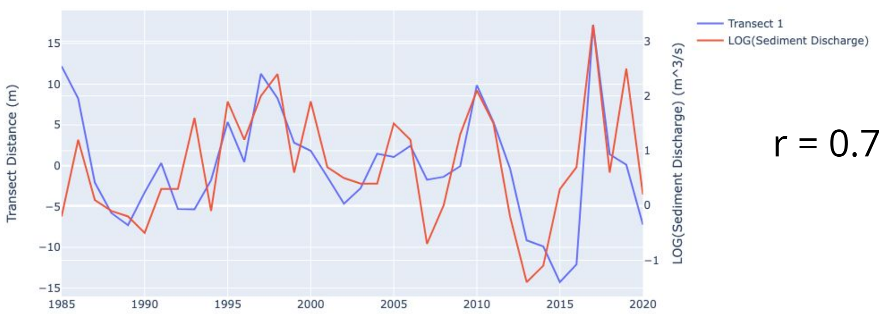


r = 0.528

r = 0.310

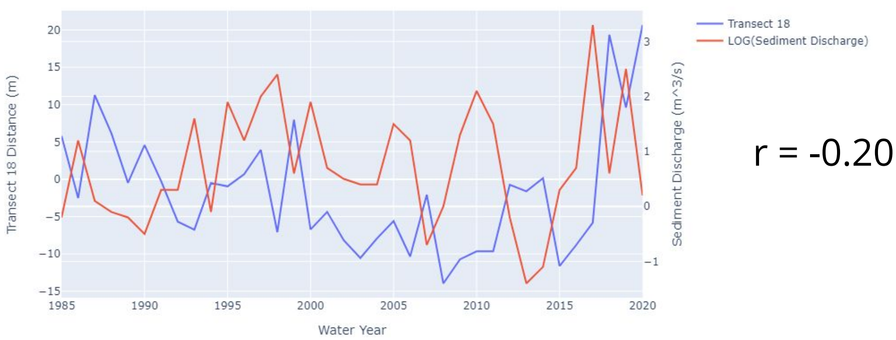
A closer look…

Transect 1 Distance and LOG(Sediment Discharge) vs. Time

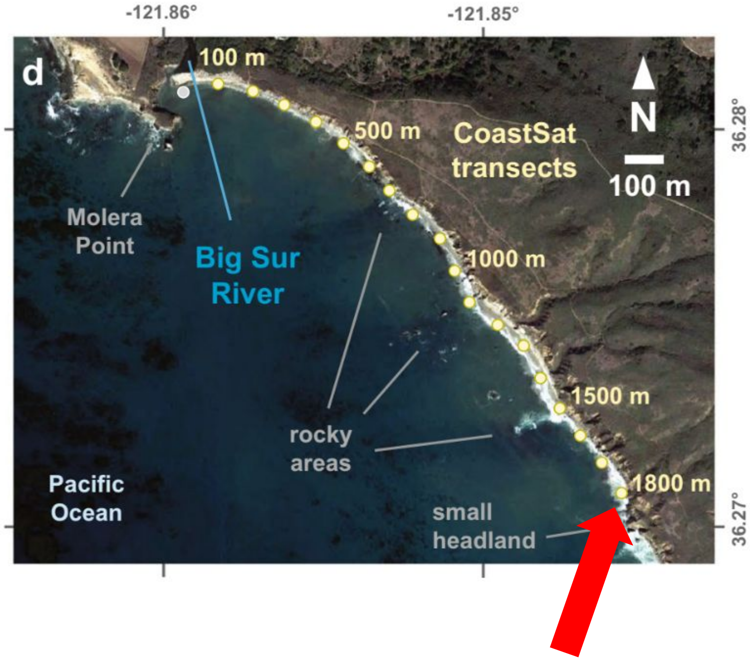


r = 0.7

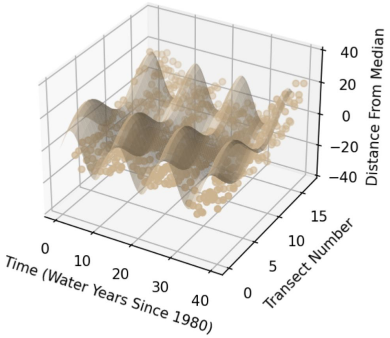
Transect 18 Distance and LOG(Sediment Discharge) vs. Time

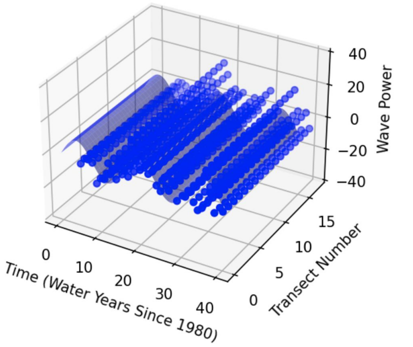


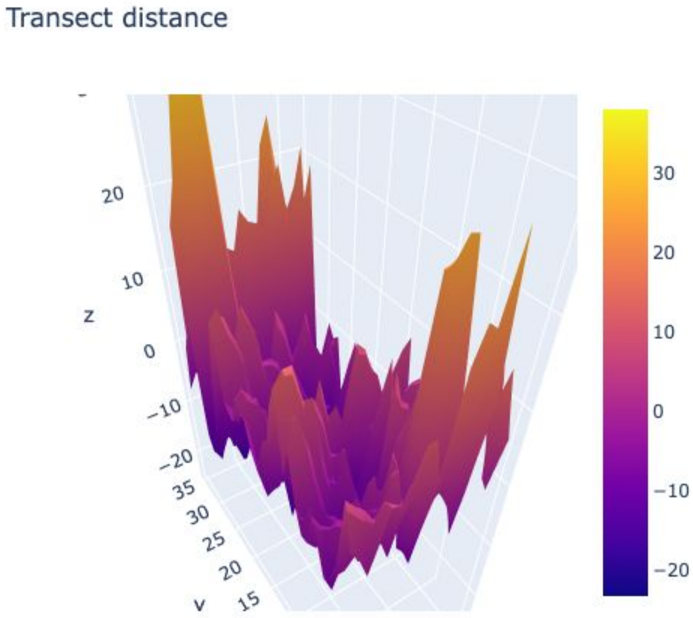
r = -0.209

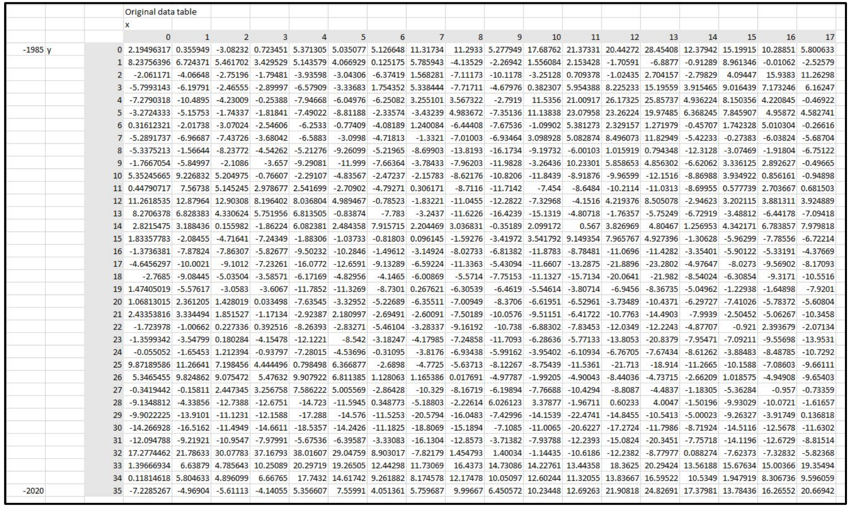


First Multivariable Approach (failure)









Original data table

x

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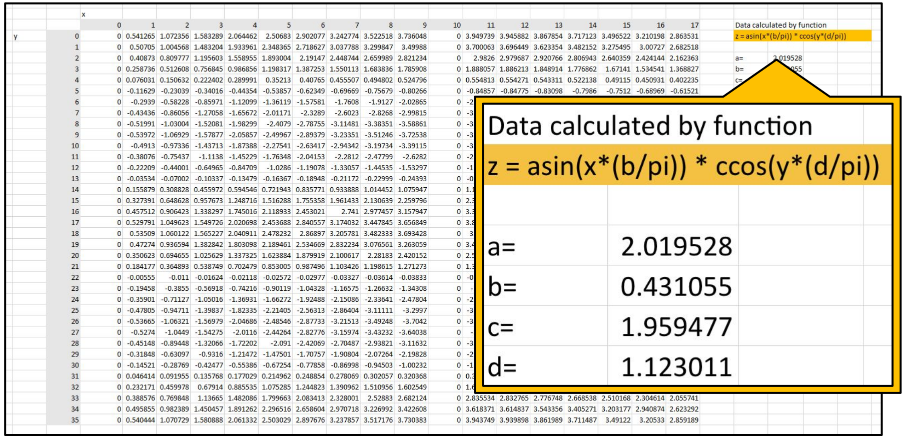
-1985	y	0	2.19496317	0.355949	-3.08232	0.723451	5.371305	5.035077	5.126648	11.31734	11.2933	5.277949	17.68762	21.37331	20.44272	28.45408	12.37942	15.19915	10.28851	5.800633
		1	8.23756396	6.724371	5.461702	3.429529	5.143579	4.066929	0.125175	5.785943	-4.13529	-2.26942	1.556084	2.153428	-1.70591	-6.8877	-0.91289	8.961346	-0.01062	-2.52579
		2	-2.061171	-4.06648	-2.75196	-1.79481	-3.93598	-3.04306	-6.37419	1.568281	-7.11173	-10.1178	-3.25128	0.709378	-1.02435	2.704157	-2.79829	4.09447	15.9383	11.26298
		3	-5.7993143	-6.19791	-2.46555	-2.89997	-6.57909	-3.33683	1.754352	5.338444	-7.71711	-4.67976	0.382307	5.954388	8.225233	15.19559	3.915465	9.016439	7.173246	6.16247
		4	-7.2790318	-10.4895	-4.23009	-0.25388	-7.94668	-6.04976	-6.25082	3.255101	3.567322	-2.7919	11.5356	21.00917	26.17325	25.85737	4.936224	8.150356	4.220845	-0.46922
		5	-3.2724333	-5.15753	-1.74337	-1.81841	-7.49022	-8.81188	-2.33574	-3.43239	4.983672	-7.35136	11.13838	23.07958	23.26224	19.97485	6.368245	7.845907	4.95872	4.582741
		6	0.31612321	-2.01738	-3.07024	-2.54606	-6.2533	-0.77409	-4.08189	1.240084	-6.44408	-7.67536	-1.09902	5.381273	2.329157	1.271979	-0.45707	1.742328	5.010304	-0.26616
		7	-5.2891737	-6.96687	-7.43726	-3.68042	-6.5883	-3.0998	-4.71813	-1.3321	-7.01003	-6.93464	3.098928	5.082874	8.496073	11.82949	-5.42233	-0.27383	-6.03824	-5.68704
		8	-5.3375213	-1.56644	-8.23772	-4.54262	-5.21276	-9.26099	-5.21965	-8.69903	-13.8193	-16.1734	-9.19732	-6.00103	1.015919	0.794348	-12.3128	-3.07469	-1.91804	-6.75122
		9	-1.7667054	-5.84997	-2.1086	-3.657	-9.29081	-11.999	-7.66364	-3.78433	-7.96203	-11.9828	-3.26436	10.23301	5.858653	4.856302	-6.62062	3.336125	2.892627	-0.49665
		10	5.35245665	9.226832	5.204975	-0.76607	-2.29107	-4.83567	-2.47237	-2.15783	-8.62176	-10.8206	-11.8439	-8.91876	-9.96599	-12.1516	-8.86988	3.934922	0.856161	-0.94898
		11	0.44790717	7.56738	5.145245	2.978677	2.541699	-2.70902	-4.79271	0.306171	-8.7116	-11.7142	-7.454	-8.6484	-10.2114	-11.0313	-8.69955	0.577739	2.703667	0.681503
		12	11.2618535	12.87964	12.90308	8.196402	8.036804	4.989467	-0.78523	-1.83221	-11.0455	-12.2822	-7.32968	-4.1516	4.219376	8.505078	-2.94623	3.202115	3.881311	3.924889
		13	8.2706378	6.828383	4.330624	5.751956	6.813505	-0.83874	-7.783	-3.2437	-11.6226	-16.4239	-15.1319	-4.80718	-1.76357	-5.75249	-6.72919	-3.48812	-6.44178	-7.09418
		14	2.8215475	3.188436	0.155982	-1.86224	6.082381	2.484358	7.915715	2.204469	3.036831	-0.35189	2.099172	0.567	3.826969	4.80467	1.256953	4.342171	6.783857	7.979818
		15	1.83357783	-2.08455	-4.71641	-7.24349	-1.88306	-1.03733	-0.81803	0.096145	-1.59276	-3.41972	3.541792	9.149354	7.965767	4.927396	-1.30628	-5.96299	-7.78556	-6.72214
		16	-1.3736381	-7.87824	-7.86307	-5.82677	-9.50232	-10.2846	-1.49612	-3.14924	-8.02733	-6.81382	-11.8783	-8.78481	-11.0696	-11.4282	-3.35401	-5.90122	-5.33191	-4.37669
		17	-4.6456297	-10.0021	-9.1012	-7.23261	-16.0772	-12.6591	-9.13289	-6.59224	-11.3363	-5.43094	-11.6607	-13.2875	-21.8896	-23.2802	-4.97647	-8.0273	-9.56902	-8.17093
		18	-2.7685	-9.08445	-5.03504	-3.58571	-6.17169	-4.82956	-4.1465	-6.00869	-5.5714	-7.75153	-11.1327	-15.7134	-20.0641	-21.982	-8.54024	-6.30854	-9.3171	-10.5516
		19	1.47405019	-5.57617	-3.0583	-3.6067	-11.7852	-11.3269	-8.7301	0.267621	-6.30539	-6.4619	-5.54614	-3.80714	-6.9456	-8.36735	-5.04962	-1.22938	-1.64898	-7.9201
		20	1.06813015	2.361205	1.428019	0.033498	-7.63545	-3.32952	-5.22689	-6.35511	-7.00949	-8.3706	-6.61951	-6.52961	-3.73489	-10.4371	-6.29727	-7.41026	-5.78372	-5.60804
		21	2.43353816	3.334494	1.851527	-1.17134	-2.92387	2.180997	-2.69491	-2.60091	-7.50189	-10.0576	-9.51151	-6.41722	-10.7763	-14.4903	-7.9939	-2.50452	-5.06267	-10.3458
		22	-1.723978	-1.00662	0.227336	0.392516	-8.26393	-2.83271	-5.46104	-3.28337	-9.16192	-10.738	-6.88302	-7.83453	-12.0349	-12.2243	-4.87707	-0.921	2.393679	-2.07134
		23	-1.3599342	-3.54799	0.180284	-4.15478	-12.1221	-8.542	-3.18247	-4.17985	-7.24858	-11.7093	-6.28636	-5.77133	-13.8053	-20.8379	-7.95471	-7.09211	-9.55698	-13.9531
		24	-0.055052	-1.65453	1.212394	-0.93797	-7.28015	-4.53696	-0.31095	-3.8176	-6.93438	-5.99162	-3.95402	-6.10934	-6.76705	-7.67434	-8.61262	-3.88483	-8.48785	-10.7292
		25	9.87189586	11.26641	7.198456	4.444496	0.798498	6.366877	-2.6898	-4.7725	-5.63713	-8.12267	-8.75439	-11.5361	-21.713	-18.914	-11.2665	-10.1588	-7.08603	-9.66111
		26	5.3465455	9.824862	9.075472	5.47632	9.907922	6.811385	1.128063	1.165386	0.017691	-4.97787	-1.99205	-4.90043	-8.44036	-4.73715	-2.66209	1.018575	-4.94908	-9.65403
		27	-0.3419442	-0.15811	2.447345	3.256758	7.586222	5.005569	-2.86428	-10.329	-8.16719	-6.19894	-7.76688	-10.4294	-8.8087	-4.4837	-1.18305	-5.36284	-0.957	-0.73359
		28	-9.1348812	-4.33856	-12.7388	-12.6751	-14.723	-11.5945	0.348773	-5.18803	-2.22614	6.026123	3.37877	-1.96711	0.60233	4.0047	-1.50196	-9.93029	-10.0721	-1.61657
		29	-9.9022225	-13.9101	-11.1231	-12.1588	-17.288	-14.576	-11.5253	-20.5794	-16.0483	-7.42996	-14.1539	-22.4741	-14.8455	-10.5413	-5.00023	-9.26327	-3.91749	0.136818
		30	-14.266928	-16.5162	-11.4949	-14.6611	-18.5357	-14.2426	-11.1825	-18.8069	-15.1894	-7.1085	-11.0065	-20.6227	-17.2724	-11.7986	-8.71924	-14.5116	-12.5678	-11.6302
		31	-12.094788	-9.21921	-10.9547	-7.97991	-5.67536	-6.39587	-3.33083	-16.1304	-12.8573	-3.71382	-7.93788	-12.2393	-15.0824	-20.3451	-7.75718	-14.1196	-12.6729	-8.81514
		32	17.2774462	21.78633	30.07783	37.16793	38.01607	29.04759	8.903017	-7.82179	1.454793	1.40034	-1.14435	-10.6186	-12.2382	-8.77977	0.088274	-7.62373	-7.32832	-5.82368
		33	1.39666934	6.63879	4.785643	10.25089	20.29719	19.26505	12.44298	11.73069	16.4373	14.73086	14.22761	13.44358	18.3625	20.29424	13.56188	15.67634	15.00366	19.35494
		34	0.11814618	5.804633	4.896099	6.66765	17.7432	14.61742	9.261882	8.174578	12.17478	10.05097	12.60244	11.32055	13.83667	16.59522	10.5349	1.947919	8.306736	9.596059
-2020		35	-7.2285267	-4.96904	-5.61113	-4.14055	5.356607	7.55991	4.051361	5.759687	9.99667	6.450572	10.23448	12.69263	21.90818	24.82691	17.37981	13.78436	16.26552	20.66942



x

		0	1	2	3	4	5	6	7	8	9	10
y	0	0	0.541265	1.072356	1.583289	2.064462	2.50683	2.902077	3.242774	3.522518	3.736048	0
	1	0	0.50705	1.004568	1.483204	1.933961	2.348365	2.718627	3.037788	3.299847	3.49988	0
	2	0	0.40873	0.809777	1.195603	1.558955	1.893004	2.19147	2.448744	2.659989	2.821234	0
	3	0	0.258736	0.512608	0.756845	0.986856	1.198317	1.387253	1.550113	1.683836	1.785908	0
	4	0	0.076031	0.150632	0.222402	0.289991	0.35213	0.40765	0.455507	0.494802	0.524796	0
	5	0	-0.11629	-0.23039	-0.34016	-0.44354	-0.53857	-0.62349	-0.69669	-0.75679	-0.80266	0
	6	0	-0.2939	-0.58228	-0.85971	-1.12099	-1.36119	-1.57581	-1.7608	-1.9127	-2.02865	0
	7	0	-0.43436	-0.86056	-1.27058	-1.65672	-2.01171	-2.3289	-2.6023	-2.8268	-2.99815	0
	8	0	-0.51991	-1.03004	-1.52081	-1.98299	-2.4079	-2.78755	-3.11481	-3.38351	-3.58861	0
	9	0	-0.53972	-1.06929	-1.57877	-2.05857	-2.49967	-2.89379	-3.23351	-3.51246	-3.72538	0
	10	0	-0.4913	-0.97336	-1.43713	-1.87388	-2.27541	-2.63417	-2.94342	-3.19734	-3.39115	0
	11	0	-0.38076	-0.75437	-1.1138	-1.45229	-1.76348	-2.04153	-2.2812	-2.47799	-2.6282	0
	12	0	-0.22209	-0.44001	-0.64965	-0.84709	-1.0286	-1.19078	-1.33057	-1.44535	-1.53297	0
	13	0	-0.03534	-0.07002	-0.10337	-0.13479	-0.16367	-0.18948	-0.21172	-0.22999	-0.24393	0
	14	0	0.155879	0.308828	0.455972	0.594546	0.721943	0.835771	0.933888	1.014452	1.075947	0
	15	0	0.327391	0.648628	0.957673	1.248716	1.516288	1.755358	1.961433	2.130639	2.259796	0
	16	0	0.457512	0.906423	1.338297	1.745016	2.118933	2.453021	2.741	2.977457	3.157947	0
	17	0	0.529791	1.049623	1.549726	2.020698	2.453688	2.840557	3.174032	3.447845	3.656849	0
	18	0	0.53509	1.060122	1.565227	2.040911	2.478232	2.86897	3.205781	3.482333	3.693428	0
	19	0	0.47274	0.936594	1.382842	1.803098	2.189461	2.534669	2.832234	3.076561	3.263059	0
	20	0	0.350623	0.694655	1.025629	1.337325	1.623884	1.879919	2.100617	2.28183	2.420152	0
	21	0	0.184177	0.364893	0.538749	0.702479	0.853005	0.987496	1.103426	1.198615	1.271273	0
	22	0	-0.00555	-0.011	-0.01624	-0.02118	-0.02572	-0.02977	-0.03327	-0.03614	-0.03833	0
	23	0	-0.19458	-0.3855	-0.56918	-0.74216	-0.90119	-1.04328	-1.16575	-1.26632	-1.34308	0
	24	0	-0.35901	-0.71127	-1.05016	-1.36931	-1.66272	-1.92488	-2.15086	-2.33641	-2.47804	0
	25	0	-0.47805	-0.94711	-1.39837	-1.82335	-2.21405	-2.56313	-2.86404	-3.11111	-3.2997	0
	26	0	-0.53665	-1.06321	-1.56979	-2.04686	-2.48546	-2.87733	-3.21513	-3.49248	-3.7042	0
	27	0	-0.5274	-1.0449	-1.54275	-2.0116	-2.44264	-2.82776	-3.15974	-3.43232	-3.64038	0
	28	0	-0.45148	-0.89448	-1.32066	-1.72202	-2.091	-2.42069	-2.70487	-2.93821	-3.11632	0
	29	0	-0.31848	-0.63097	-0.9316	-1.21472	-1.47501	-1.70757	-1.90804	-2.07264	-2.19828	0
	30	0	-0.14521	-0.28769	-0.42477	-0.55386	-0.67254	-0.77858	-0.86998	-0.94503	-1.00232	0
	31	0	0.046414	0.091955	0.135768	0.177029	0.214962	0.248854	0.278069	0.302057	0.320368	0
	32	0	0.232171	0.459978	0.67914	0.885535	1.075285	1.244823	1.390962	1.510956	1.602549	0
	33	0	0.388576	0.769848	1.13665	1.482086	1.799663	2.083413	2.328001	2.52883	2.682124	0
	34	0	0.495855	0.982389	1.450457	1.891262	2.296516	2.658604	2.970718	3.226992	3.422608	0
	35	0	0.540444	1.070729	1.580888	2.061332	2.503029	2.897676	3.237857	3.517176	3.730383	0

		11	12	13	14	15	16	17
y	0	3.949739	3.945882	3.867854	3.717123	3.496522	3.210198	2.863531
	1	3.700063	3.696449	3.623354	3.482152	3.275495	3.00727	2.682518
	2	2.9826	2.979687	2.920766	2.806943	2.640359	2.424144	2.162363
	3	1.888057	1.886213	1.848914	1.776862	1.67141	1.534541	1.368827
	4	0.554813	0.554271	0.543311	0.522138	0.49115	0.450931	0.402235
	5	-0.84857	-0.84775	-0.83098	-0.7986	-0.7512	-0.68969	-0.61521
	33	2.835534	2.832765	2.776748	2.668538	2.510168	2.304614	2.055741
	34	3.618371	3.614837	3.543356	3.405271	3.203177	2.940874	2.623292
	35	3.943749	3.939898	3.861989	3.711487	3.49122	3.20533	2.859189

Data calculated by function

z = asin(x*(b/pi)) * ccos(y*(d/pi))

a= 2.019528

b=

c=

Data calculated by function

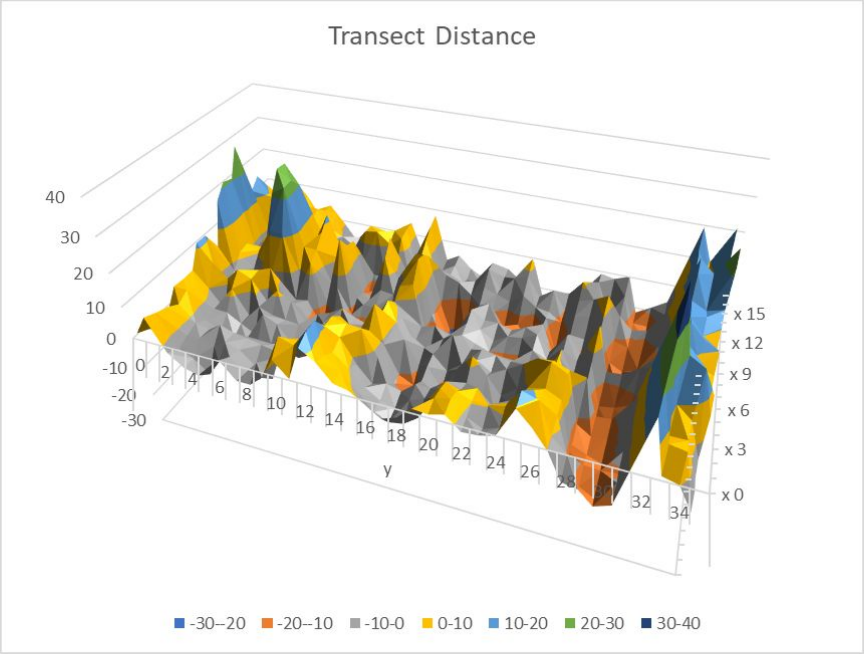
z = asin(x*(b/pi)) * ccos(y*(d/pi))

a= 2.019528

b= 0.431055

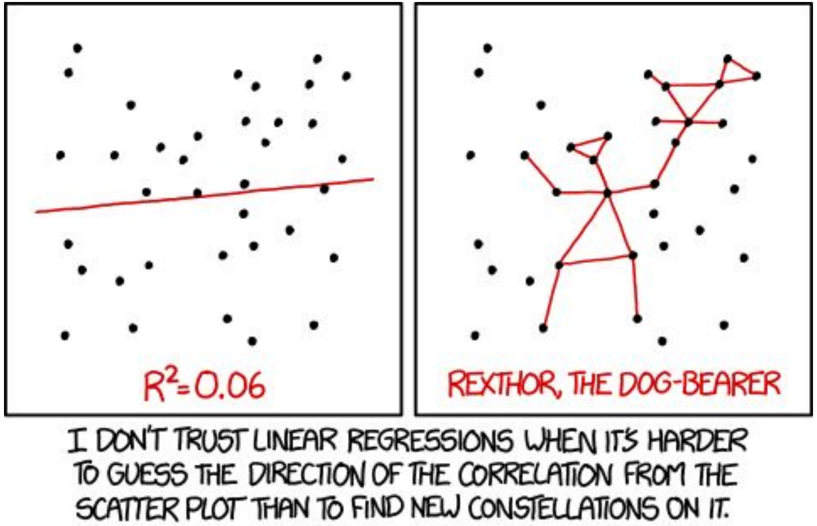
c= 1.959477

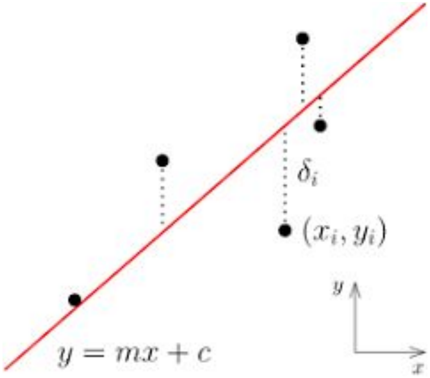
d= 1.123011



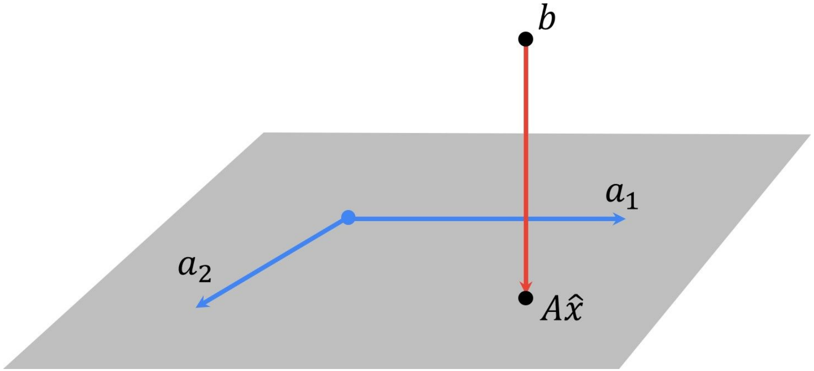
Multivariable Approach (refined)

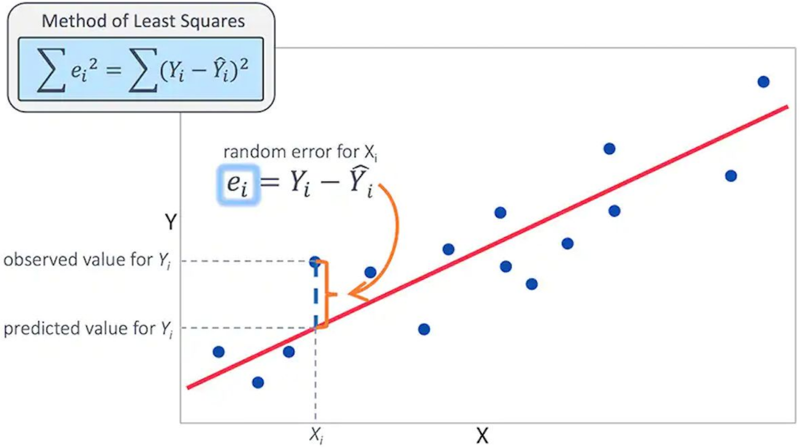
$$y = \beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n + \epsilon$$

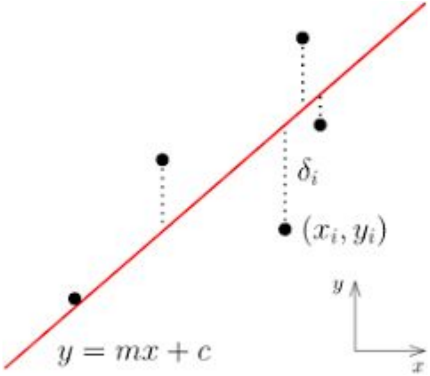




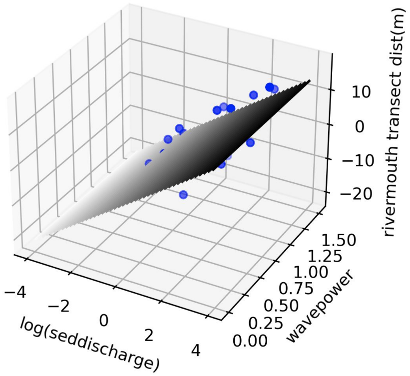
Multiple Linear Regression - Least Squares



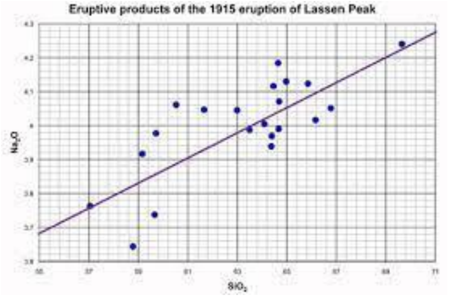


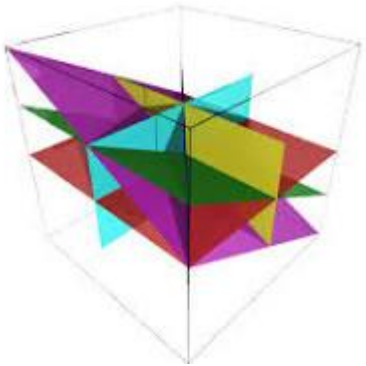


Visualizing Multiple Linear Regression (MLR)



$$y = \beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n + \epsilon$$



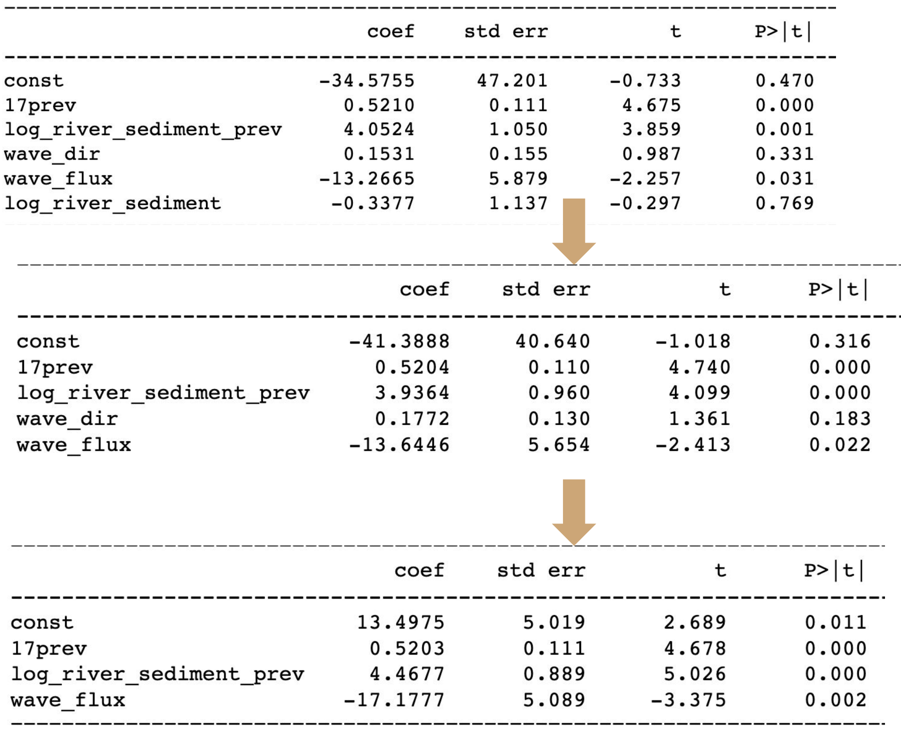


Multiple Linear Regression Flavors

Forwards - Adding variables

Backwards - Removing variables

Stepwise - adding variables with caveat

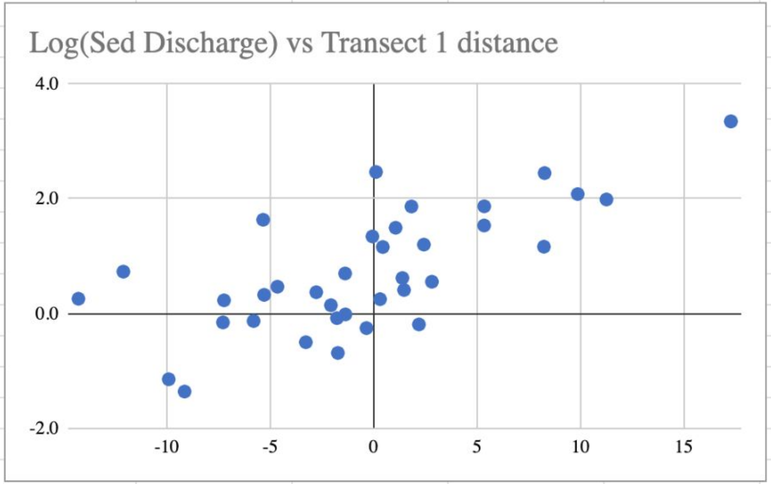


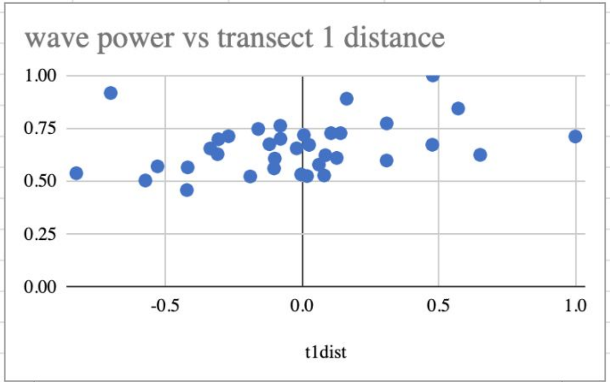
```
==============================================================================
                            coef    std err          t      P>|t|
------------------------------------------------------------------------------
const                   -34.5755     47.201     -0.733      0.470
17prev                    0.5210      0.111      4.675      0.000
log_river_sediment_prev   4.0524      1.050      3.859      0.001
wave_dir                  0.1531      0.155      0.987      0.331
wave_flux               -13.2665      5.879     -2.257      0.031
log_river_sediment       -0.3377      1.137     -0.297      0.769
```

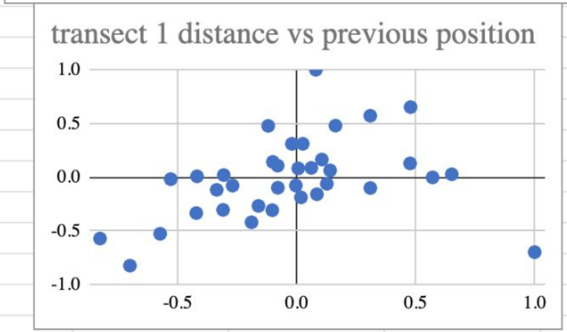
```
==============================================================================
                            coef    std err          t      P>|t|
------------------------------------------------------------------------------
const                   -41.3888     40.640     -1.018      0.316
17prev                    0.5204      0.110      4.740      0.000
log_river_sediment_prev   3.9364      0.960      4.099      0.000
wave_dir                  0.1772      0.130      1.361      0.183
wave_flux               -13.6446      5.654     -2.413      0.022
```

```
==============================================================================
                            coef    std err          t      P>|t|
------------------------------------------------------------------------------
const                    13.4975      5.019      2.689      0.011
17prev                    0.5203      0.111      4.678      0.000
log_river_sediment_prev   4.4677      0.889      5.026      0.000
wave_flux               -17.1777      5.089     -3.375      0.002
==============================================================================
```

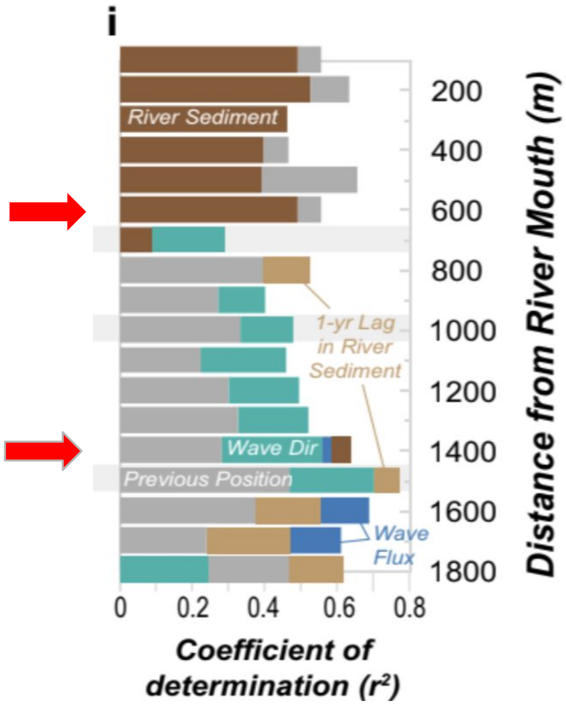
Checking for Linearity

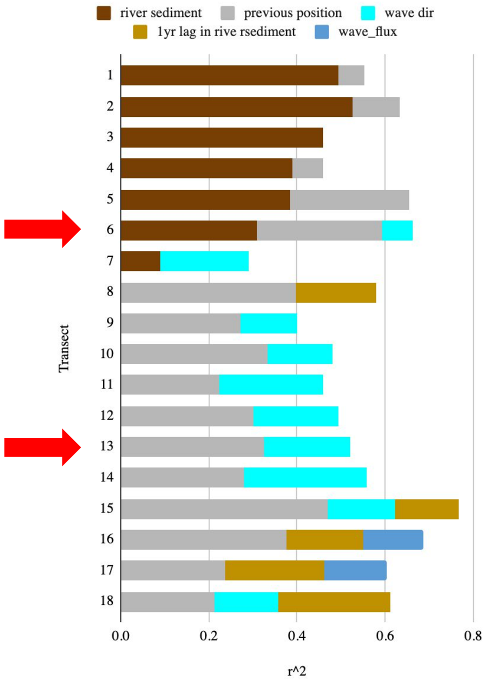

Log(Sed Discharge) vs Transect 1 distance


wave power vs transect 1 distance


transect 1 distance vs previous position

Results





```
                                              coef
----------------------------------------------------
const                                      13.4975
17prev                                      0.5203
log_river_sediment_prev                     4.4677
wave_flux                                 -17.1777
====================================================
```

Expanding on Past Work

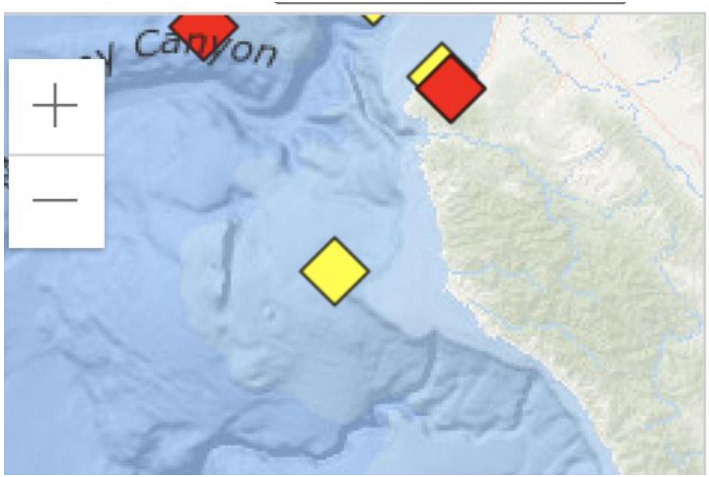
Past Sediment

Adjacent Position

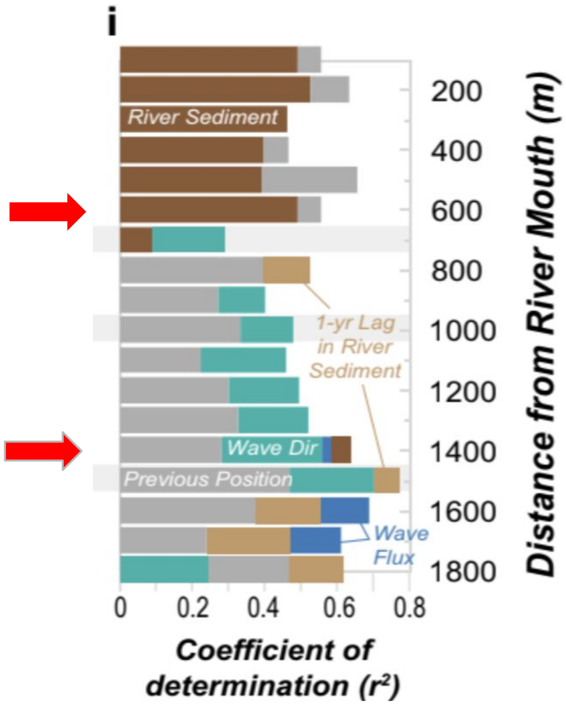
Wave Height

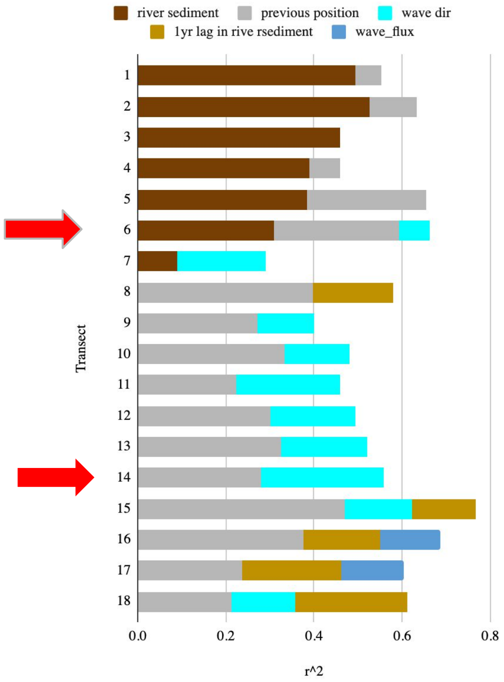
Expanding on Past Work

Point Sur Buoy

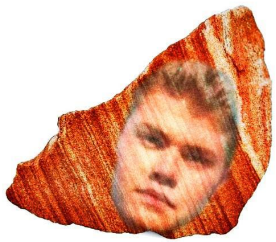


Discussion (part 1)





Level 1 crook:



sedimentary rock

Level 35 mafia boss:

metamorphic rock

Discussion (part 2)

Earth

Fire

Water

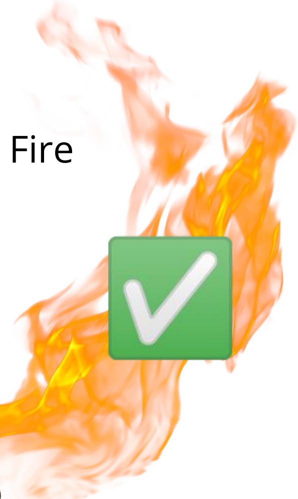
Air

Discussion (part 2)

Earth

✓

Fire



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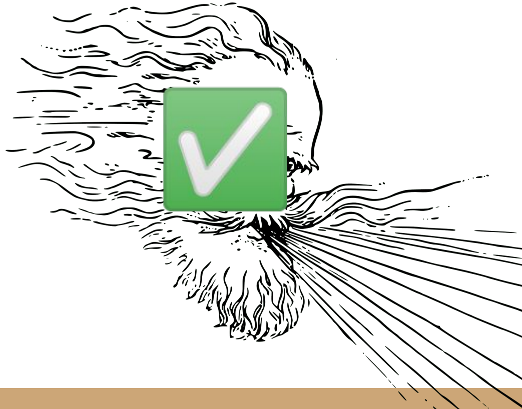
Air



✓

Water

✓

Discussion (part 3)

Thank you!

Sources

Choueiry, G. (2019, October 26). *Understand Forward and Backward Stepwise Regression*. https://quantifyinghealth.com/stepwise-selection/

CoastSat. (2022, December 1). Water Research Laboratory. https://www.wrl.unsw.edu.au/research/coastsat

De Baecke, M. (2022, February 4). The Least Squares Method - Cantor's Paradise. *Medium*. https://www.cantorsparadise.com/the-least-squares-method-82aaf34a8b26

Example of Multiple Linear Regression in Python. (n.d.). https://datatofish.com/multiple-linear-regression-python/

Harris, D. (2022, May 2). Why some beaches are getting bigger despite rising sea levels. *Phys*. Retrieved May 24, 2023, from https://phys.org/news/2022-05-beaches-bigger-sea.html

Kwok, R. (2022, January 7). Stepwise Regression Tutorial in Python - Towards Data Science. *Medium*. https://towardsdatascience.com/stepwise-regression-tutorial-in-python-ebf7c782c922

Vos, K., Splinter, K. D., Harley, M. D., Simmons, J. A., & Turner, I. (2019). CoastSat: A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery. *Environmental Modelling and Software*, *122*, 104528. https://doi.org/10.1016/j.envsoft.2019.104528

Warrick, J. A., Vos, K., East, A. E., & Vitousek, S. (2022). Fire (plus) flood (equals) beach: coastal response to an exceptional river sediment discharge event. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-07209-0