Evaluating the Effect of Wind Fences on the Performance of LIGO's Hanford Interferometer

Drew Gao

Mentor: Brian Lantz and LIGO SEI Team

Acknowledgements: NSF, Stanford Undergraduate Research Program

Data Files and Code can be Found at:https://github.com/drewgao01/LIGO

The Need for Seismic Isolation

- Active isolation to protect against horizontal ground motion
- Sensors read tilt as horizontal movement (tilt-horizontal coupling)

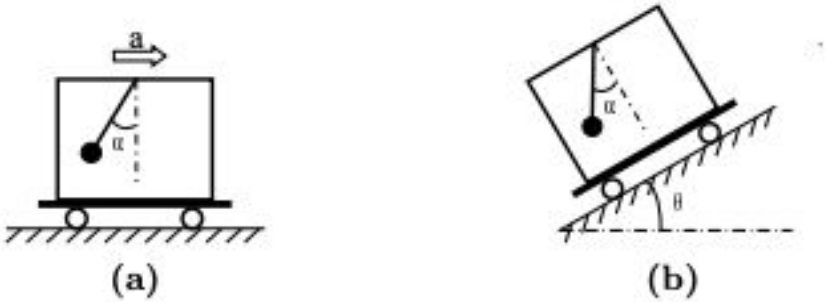
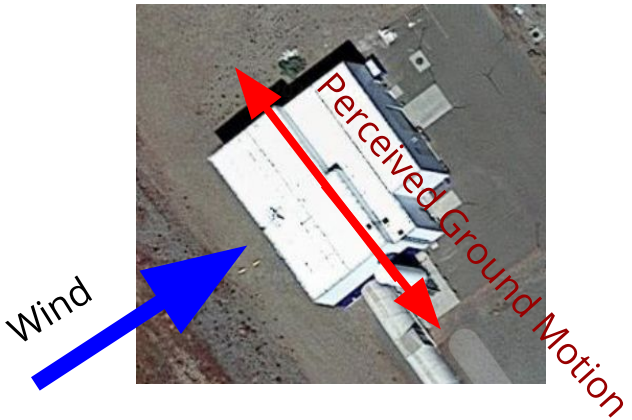


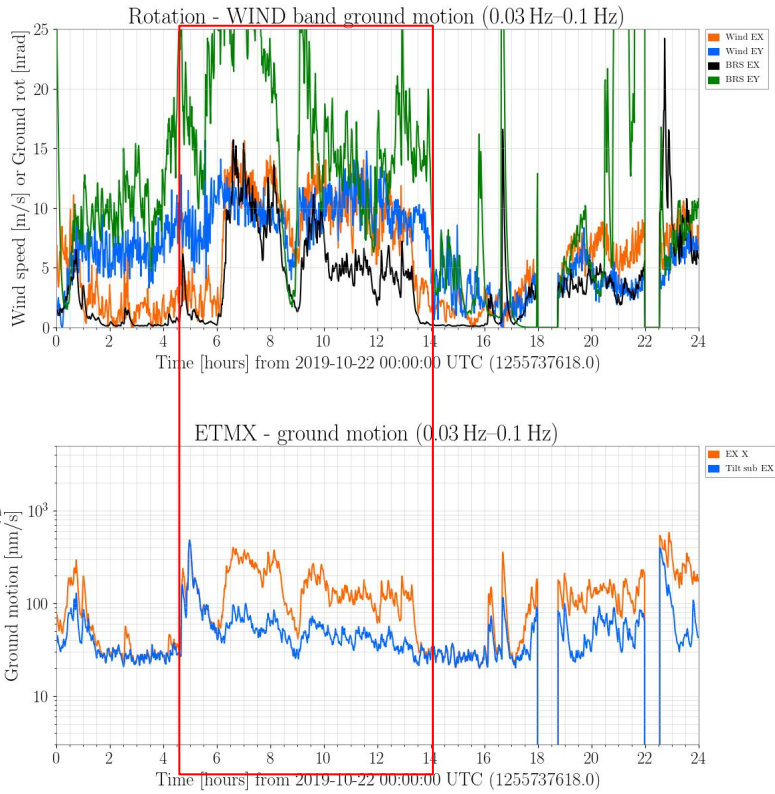
Figure 1. Simple pendulum in a box as a horizontal inertial sensor. The sensor is sensitive to both horizontal acceleration (a) and tilt motion (b), which demonstrates the intrinsic tilt-horizontal coupling problem for inertial horizontal sensors.

Hua et. al. International Society for Optics and Photonics. (2004)

The Problem With Wind

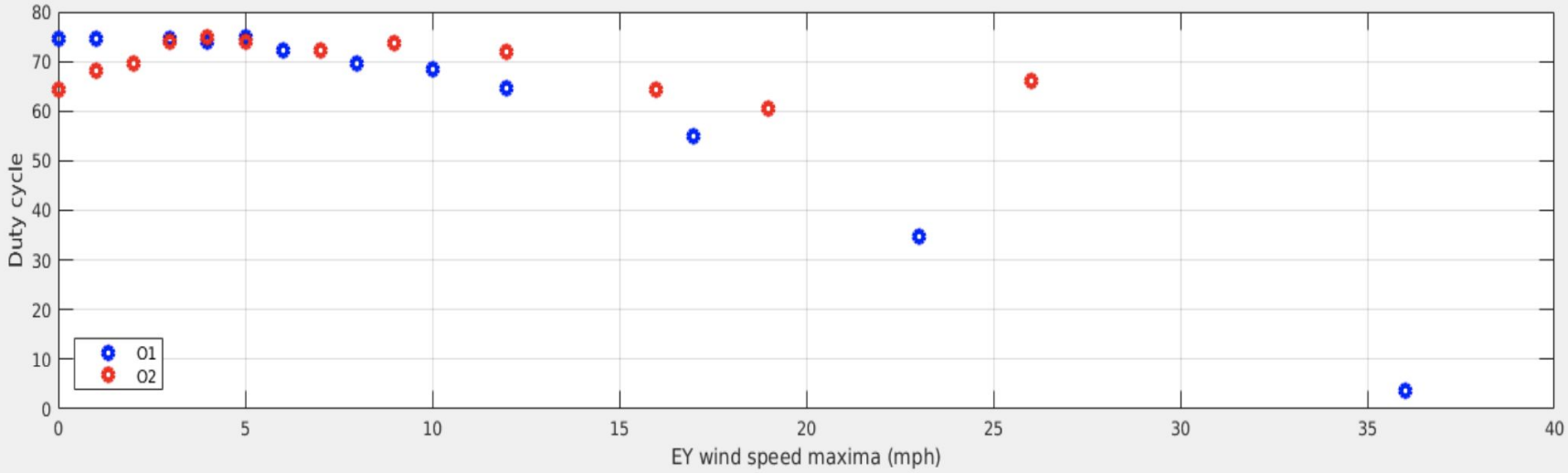
- High winds predominantly blow from the SW (ie direction from EY to CS)
- High wind speed induces tilt which is then detected as ground motion
- Methods of subtracting out this tilt are imperfect
  - › Wind speeds >8m/s harm performance





The Problem (cont.)

- High winds are associated with increased interferometer downtime



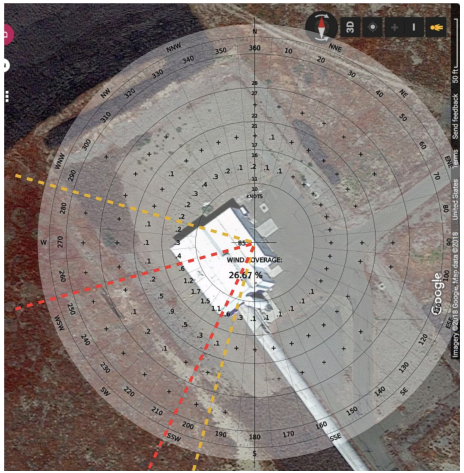
Source: Jim Warner LIGO G1700246

Easy Solution! Put up a Fence

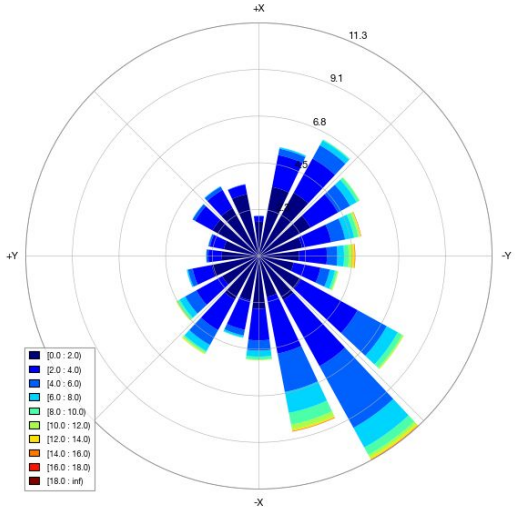
- Wind fence was installed in November 2019
- Models predict that the fence should reduce wind speed by a factor of ~2
- Building load approximately proportional to the square speed
  - tilt should be reduced by a factor of ~4
- Due to geographic restrictions the End-X fence (top) is straight while the End-Y fence (bottom) is curved

Wind Direction

- Wind data from Pasco Airport (left) suggests high speed wind comes primarily from the SW direction (ie -Y direction on middle plot)
- At EX, between 12/15/18–12/15/19 (middle) high speed wind comes from the +X direction more often than the +Y direction
  - Wind speeds >8 m/s blow in the -X direction 28% more often than in the -Y direction



Source: Brian Lantz:G1801749

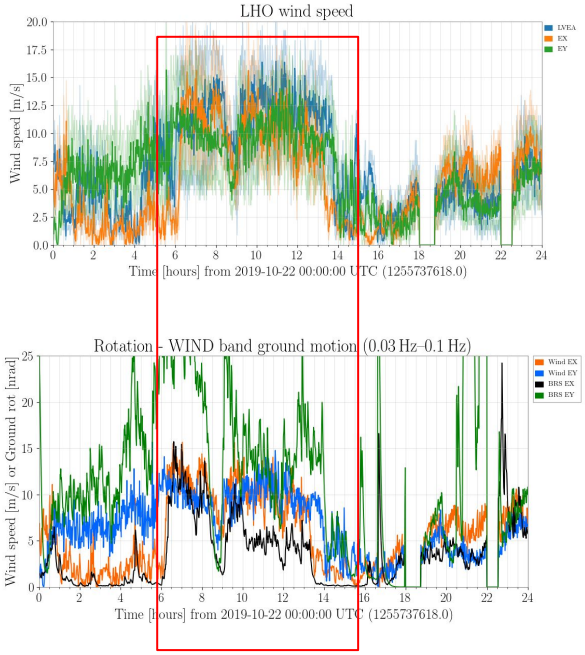


	+X	-Y	-X	+Y	total
<4m/s	19.505345	19.754423	22.788837	15.141246	77.189851
4-8m/s	1.643649	5.939628	9.765041	1.562779	18.911097
8-12m/s	0.068121	1.333491	1.740692	0.198463	3.340767
12-16m/s	0.000381	0.218062	0.260305	0.031587	0.510334
16-20m/s	0.000000	0.025878	0.020170	0.000381	0.046429
>20m/s	0.000000	0.001522	0.000000	0.000000	0.001522
total	21.217495	27.273004	34.575045	16.934456	100.000000

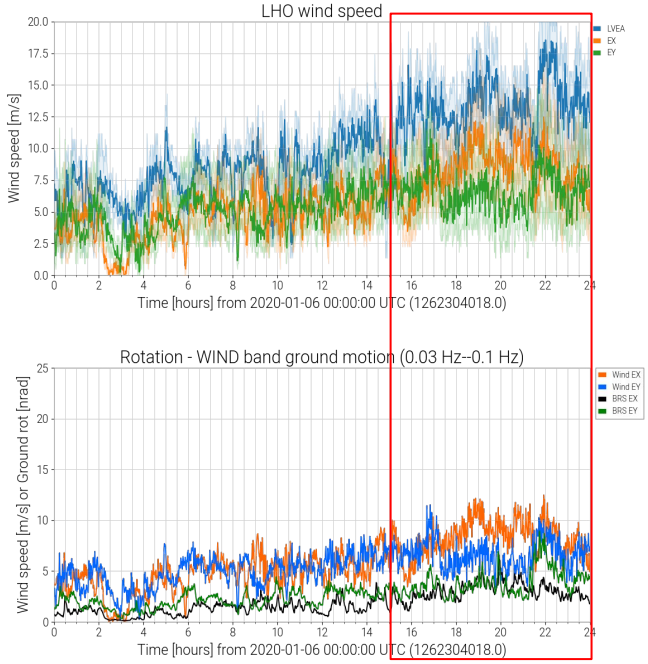
Effect of The Wind Fence

- Reduction of wind speed at end stations relative to corner station
- Reduction in end station floor tilt relative to wind speed at that end station

Pre-fence:



Post-fence:

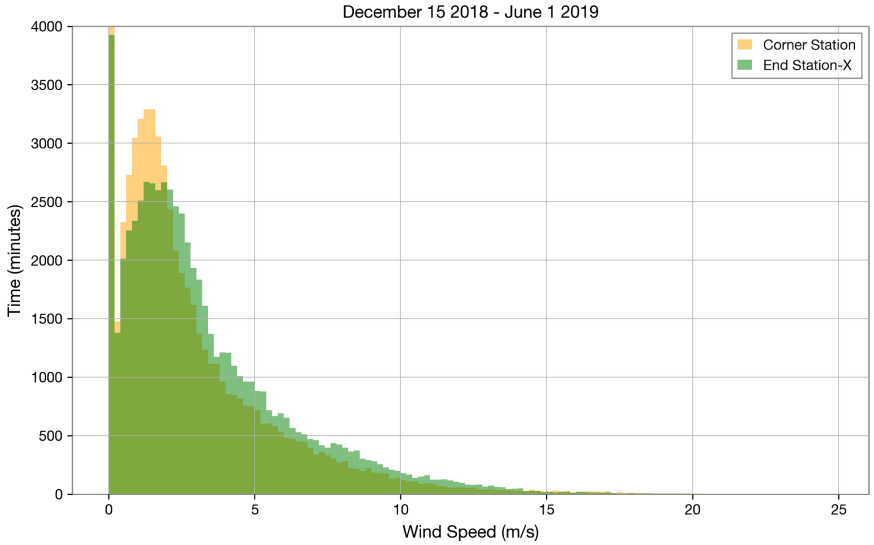


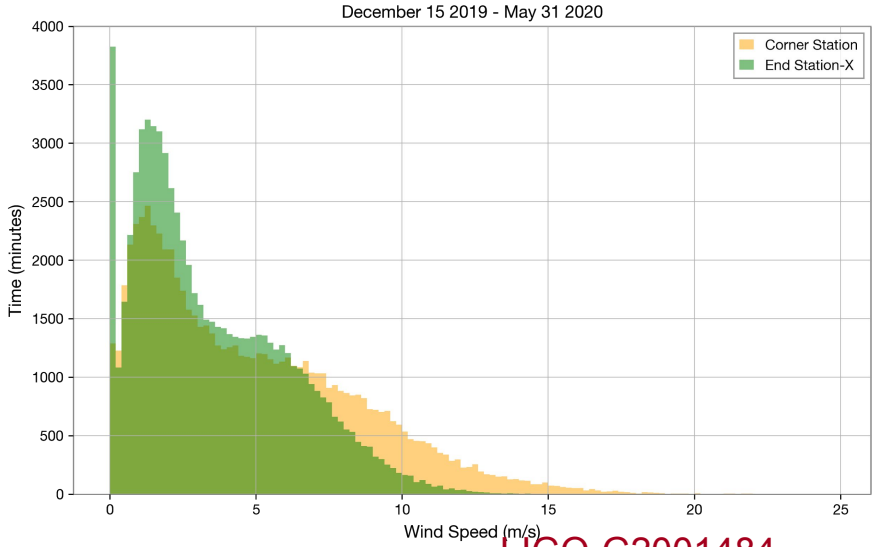
LIGO-G2001484

Stanford University

Changes to Wind Speed at End Station X

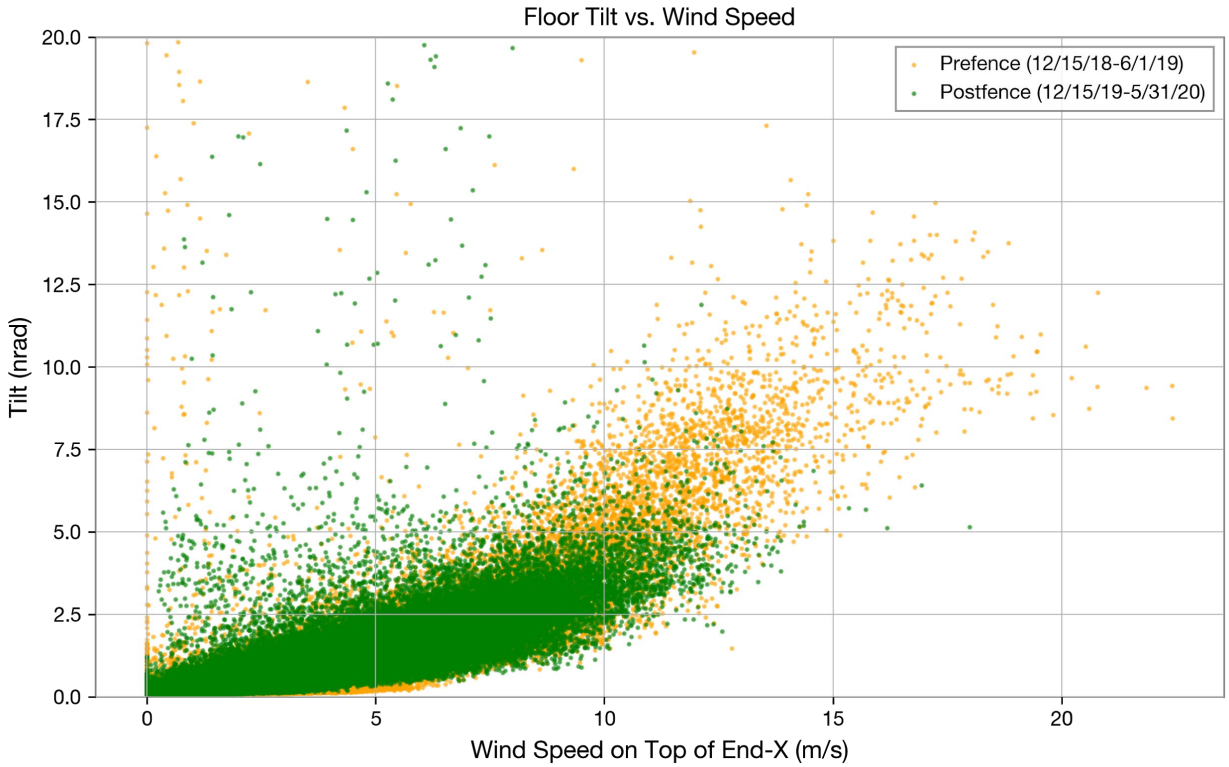
- Speed distribution of wind from the SW at corner station and end station
- Corner station did not get a wind fence
- Clear reduction in high wind speed times





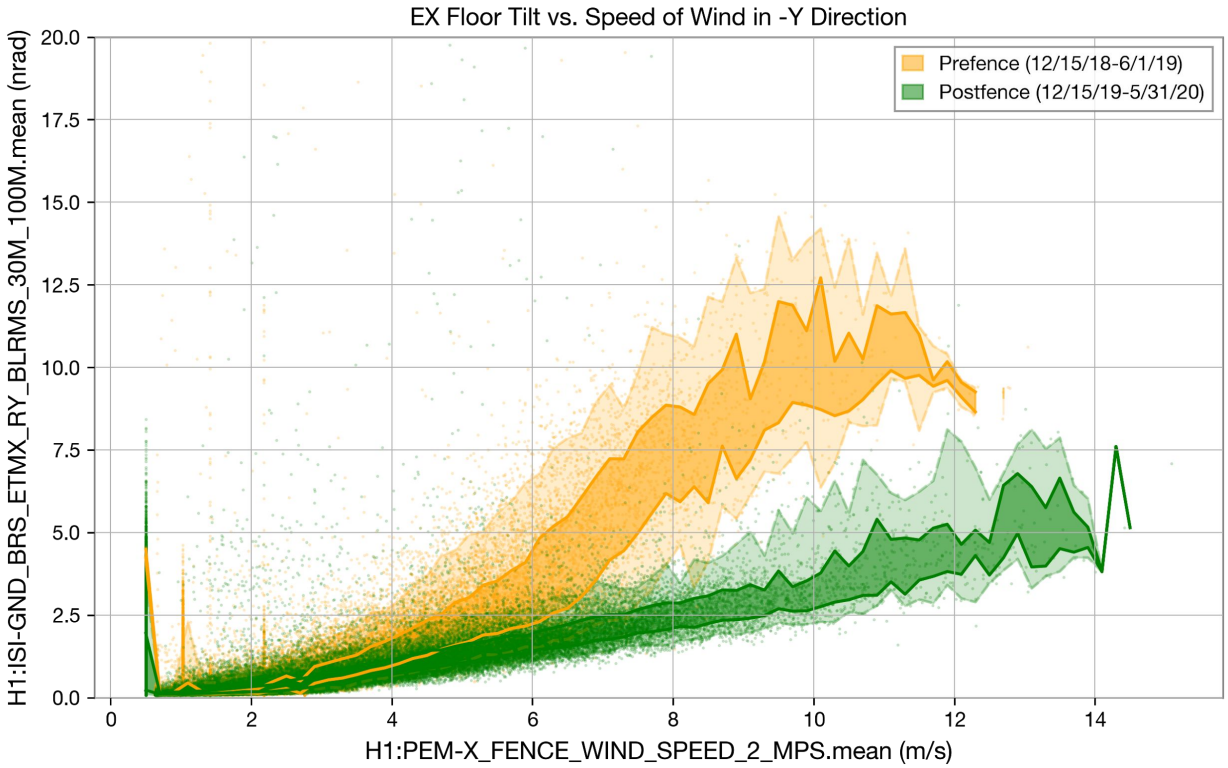
Tilt vs. Speed at End-X

- Speed as measured at the top of end-X
- Not much separation expected
- Fence reduces tilt for wind speeds >8 m/s



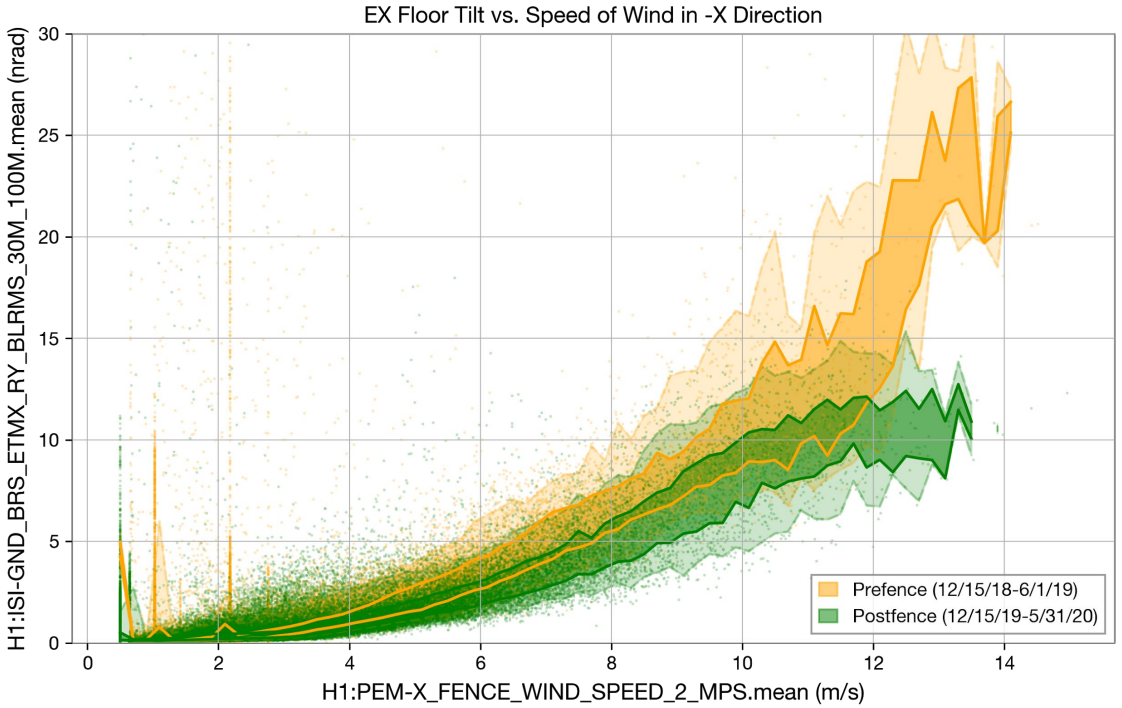
Tilt vs. Wind Speed (-Y ie. Protected Direction)

- Speed as measured on the ground, upstream of the wind fence
- Light shaded and dark shaded areas represent middle 90% and 50% of data respectively
- Tilt is reduced by a factor of ~3 for wind speeds >8 m/s



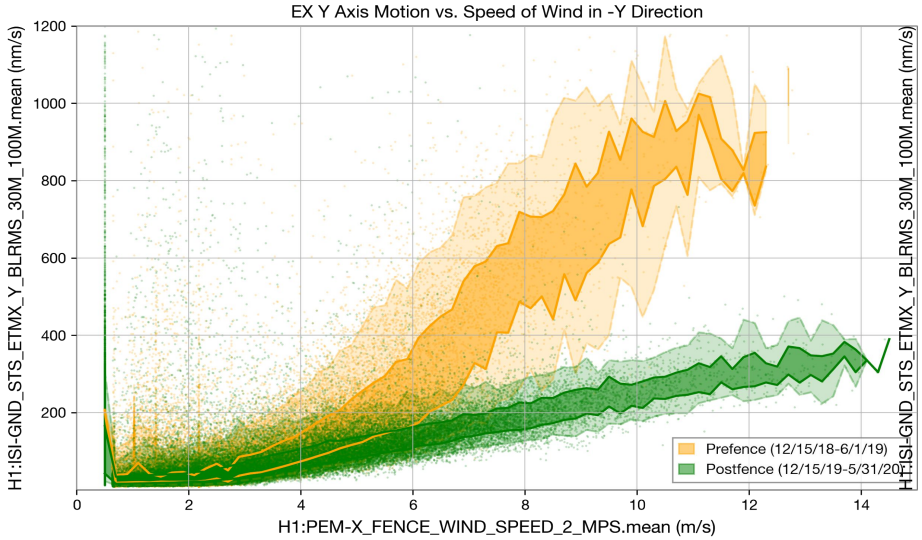
Tilt vs. Wind Speed (-X Direction)

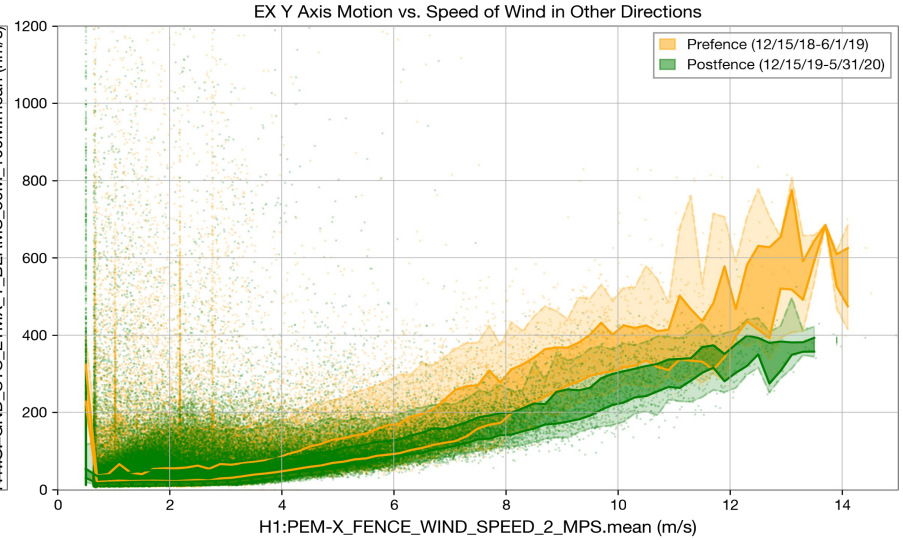
- High winds come from this direction roughly half the time
- Very little difference in curves until >12 m/s
- Wind sensor is downstream of fence for some of this data which may cause lower wind speed readings



Y Direction Ground Motion vs Wind Speed

- Translational ground motion in the Y direction is also reduced by the wind fence
- Motion is reduced by a factor of ~3 for wind speeds >8 m/s





Conclusions

- Fence is very effective at reducing building tilt during high wind times
  - Reduces problems associated with tilt-horizontal coupling
- Additional fence to the NW of End X could be helpful
- More research can be done to determine:
  - The specific relationship between wind speed and tilt
  - Compare tilt-coupling noise of seismometers at corner station and end station
  - Benefits to interferometer performance, uptime, and glitch rate (G2001394)