



# Making LIGO wind-resistant

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Borrowing from J. Kissel, B. Lantz, L. Barsotti, S. Dwyer, R. Schofield, D. Talukder, G. Vajente, M. Vidrio, B. Shapiro, J. Warner

for the SEI, PEM and ISC teams

05/20/2015

**LIGO-G1500684-v1**

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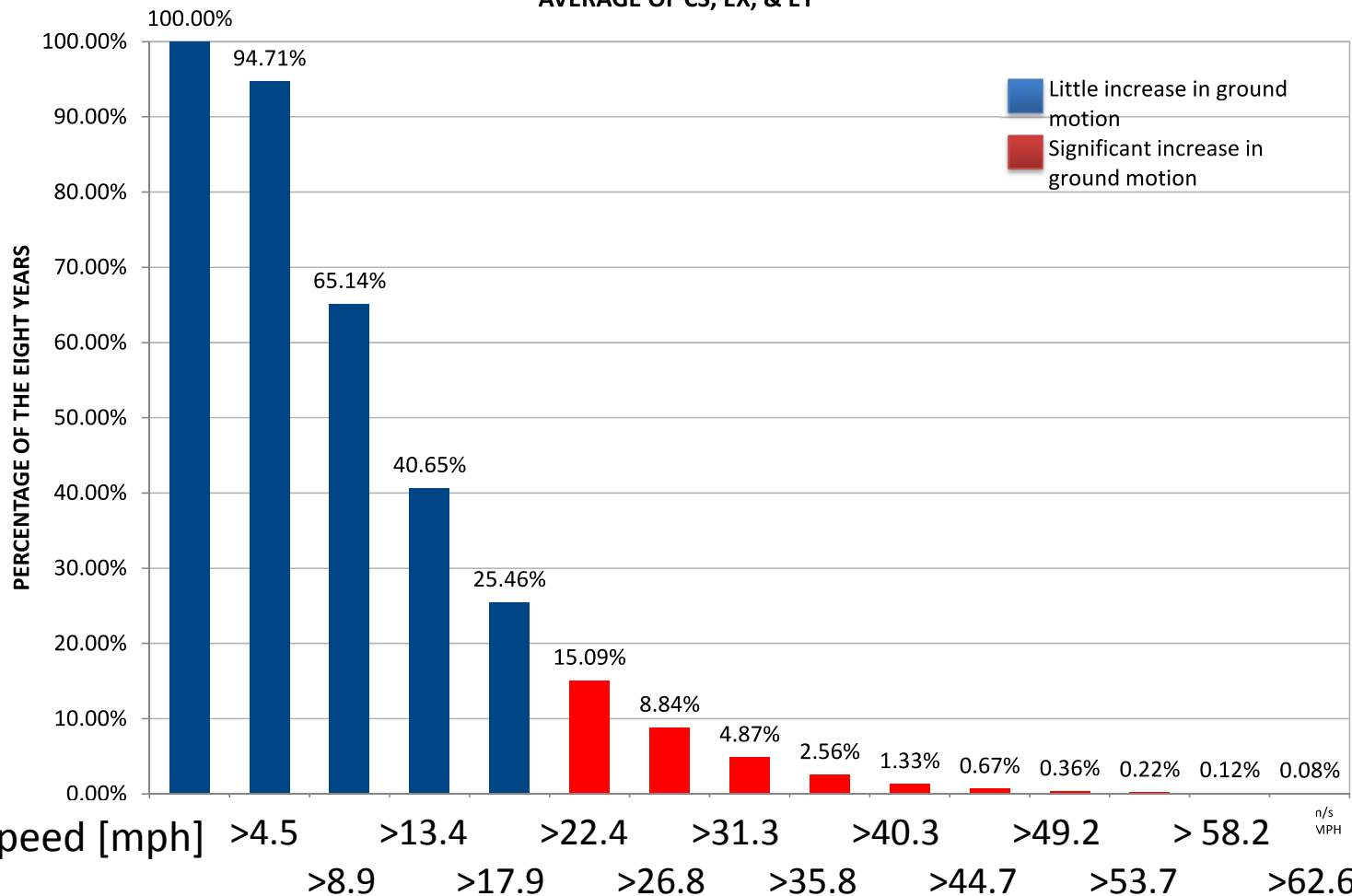
- ❑ Introduction: Wind-speed data
- ❑ Effects of wind on ground motion
- ❑ Effects of wind on the interferometer
- ❑ Path forward

# It sure is windy at Hanford!

8 year study shows that wind is above 20 [mph] for 15% of the year

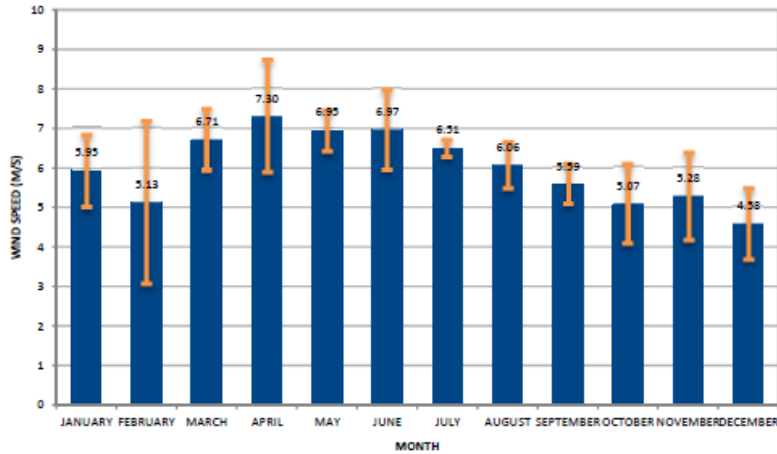
([LHO aLOG 12996](#))

PERCENTAGE OF HOURS IN WHICH HOURLY MAXIMUM WIND SPEED EXCEEDED BIN VALUE  
(2004-2012, 218 DAYS MISSING FROM THE 8-YEARS)  
AVERAGE OF CS, EX, & EY

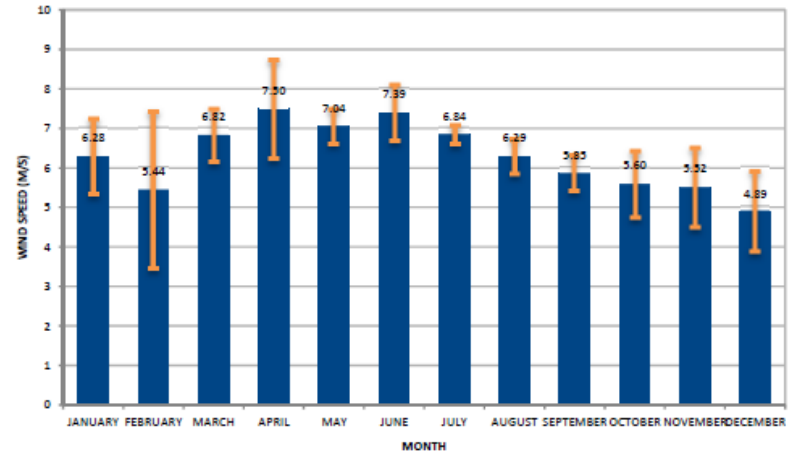


# Wind speed variation - monthly

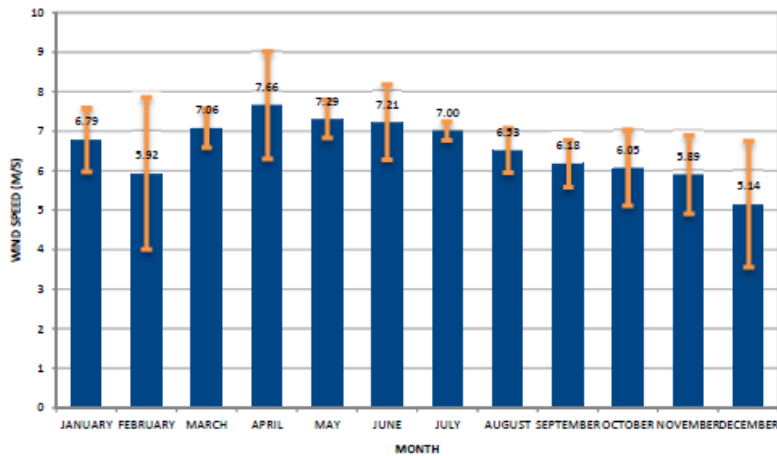
MONTHLY AVERAGE OF HOURLY MAXIMUM WINDSPEEDS  
STANDARD DEVIATION SHOWS YEARLY VARIATION  
(2004-2012, 218 DAYS MISSING FROM THE 8-YEARS)  
EX



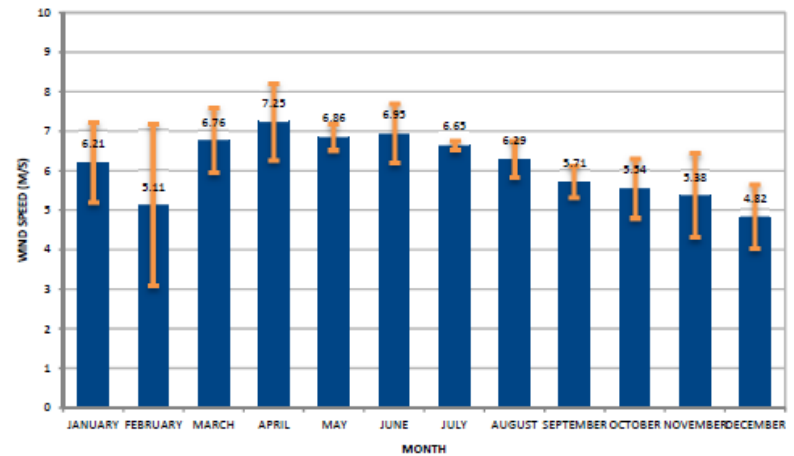
MONTHLY AVERAGE OF HOURLY MAXIMUM WINDSPEEDS  
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MONTHLY AVERAGE OF HOURLY MAXIMUM WINDSPEEDS  
STANDARD DEVIATION SHOWS YEARLY VARIATION  
(2004-2012, 218 DAYS MISSING FROM THE 8-YEARS)  
EY

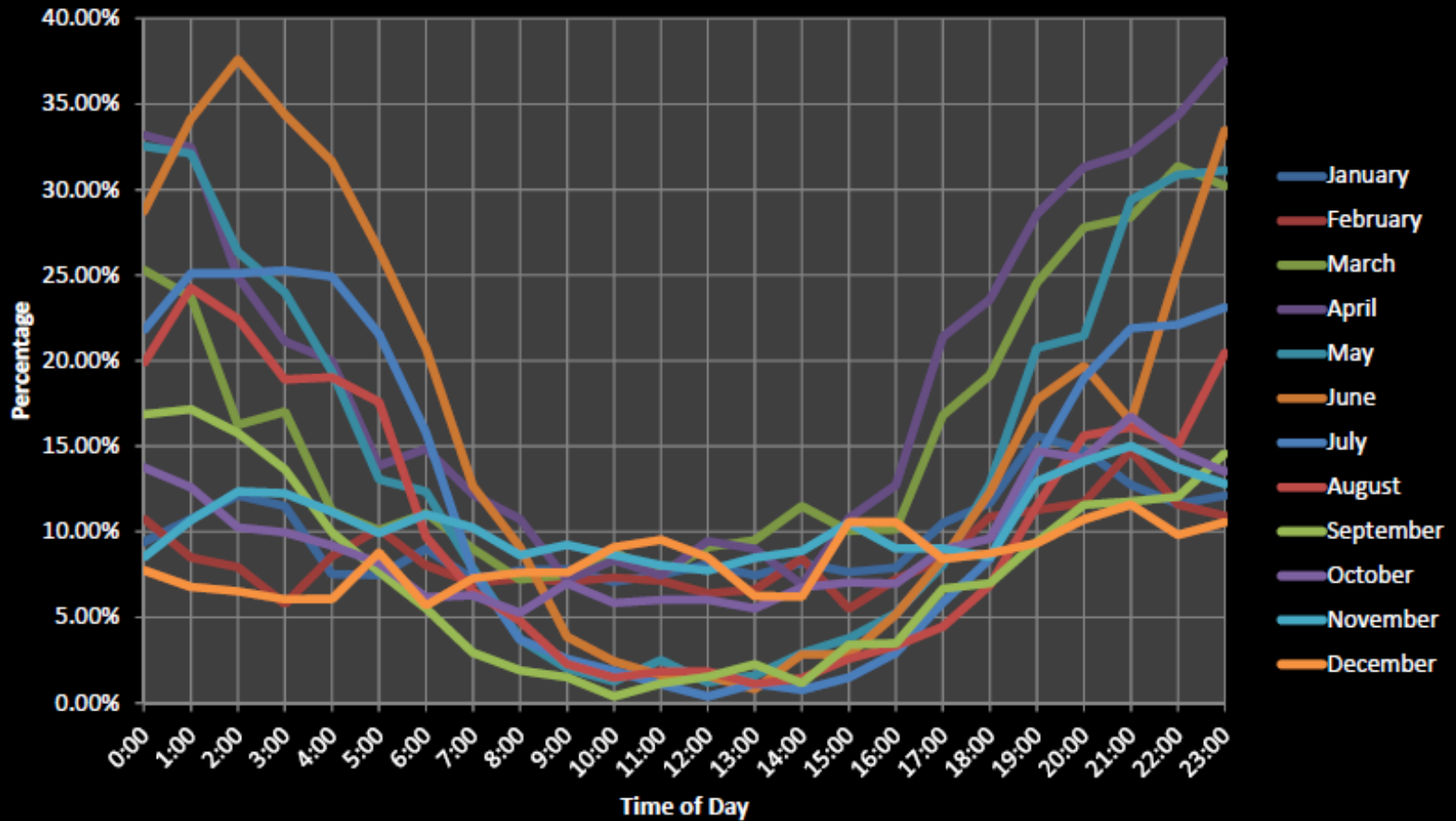


MONTHLY AVERAGE OF HOURLY MAXIMUM WINDSPEEDS  
STANDARD DEVIATION SHOWS YEARLY VARIATION  
(2004-2012, 218 DAYS MISSING FROM THE 8-YEARS)  
CS



# Wind speed variation - daily

**PERCENTAGE OF THE HOUR IN THE MONTH WHERE THE HOURLY MAXIMUM WIND SPEED EXCEEDS 10 m/s (2004-2012, 218 DAYS MISSING FROM THE 8-YEARS) AVERAGE OF CS, EX, & EY**

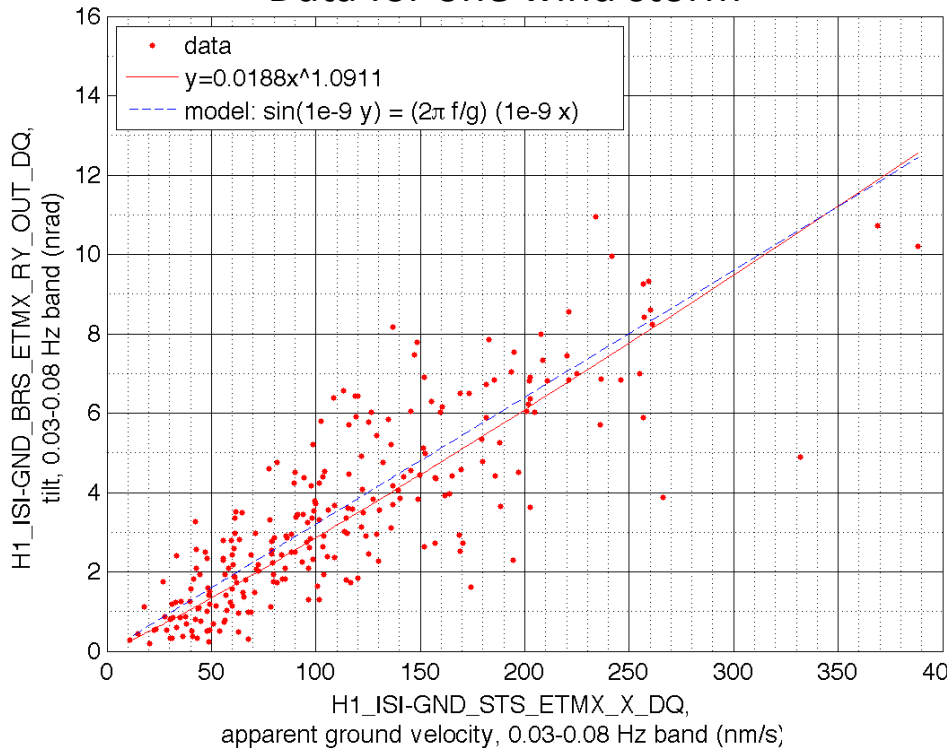


# Impact of Wind on Ground Motion

# Effect on Ground Motion

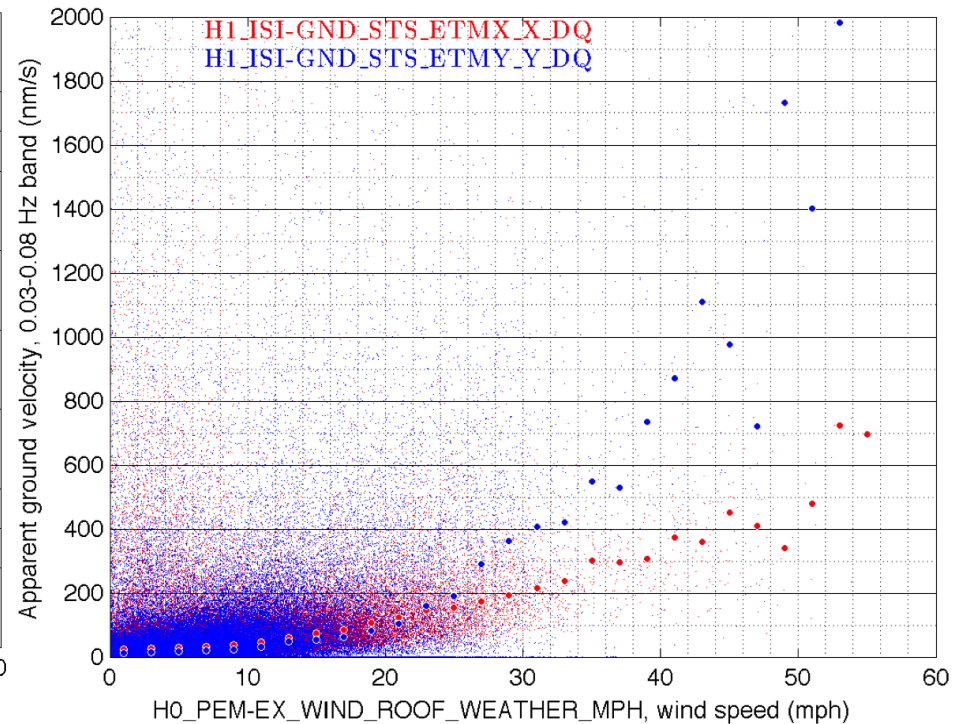
4-month study (performed with data from late 2014), EY Y experiences more tilt than at EX X ([LHO aLOG 17574](#)), likely because prevailing winds are along the Y direction.

Data for one wind storm



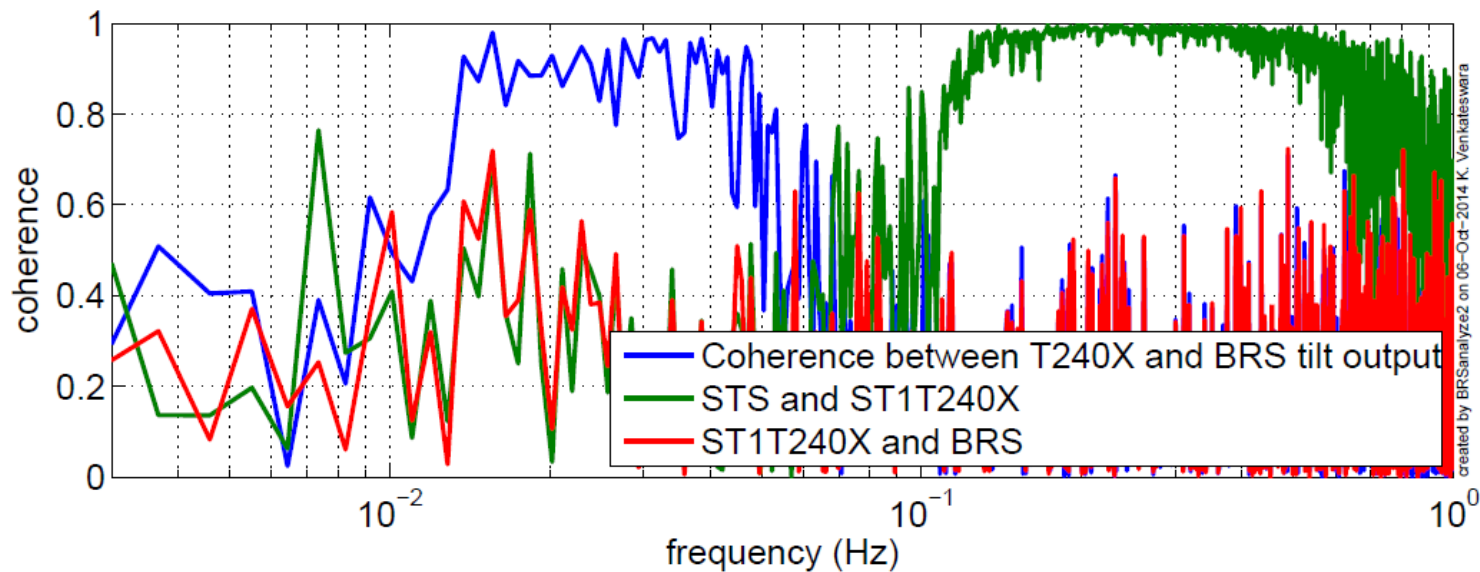
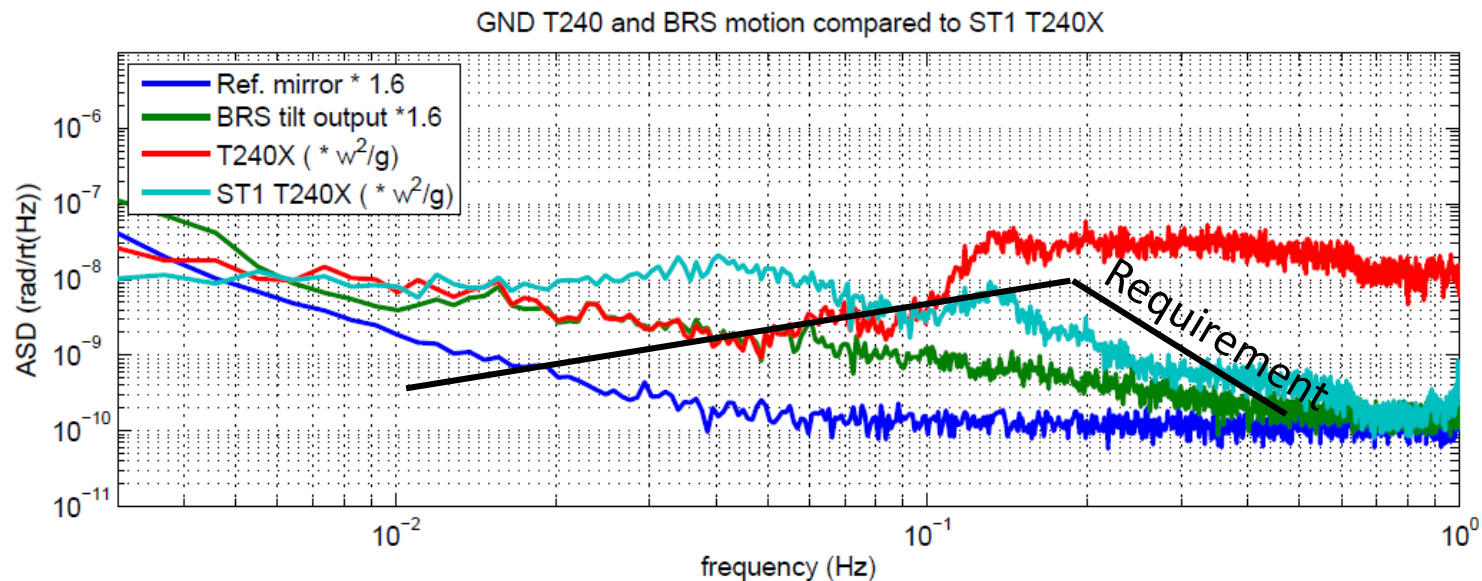
BRS comparison with GND T240 at EX shows assuming 30 to 80 [mHz] band is “all” tilt in a GND inertial sensor is a safe assumption

Data over whole 4 months



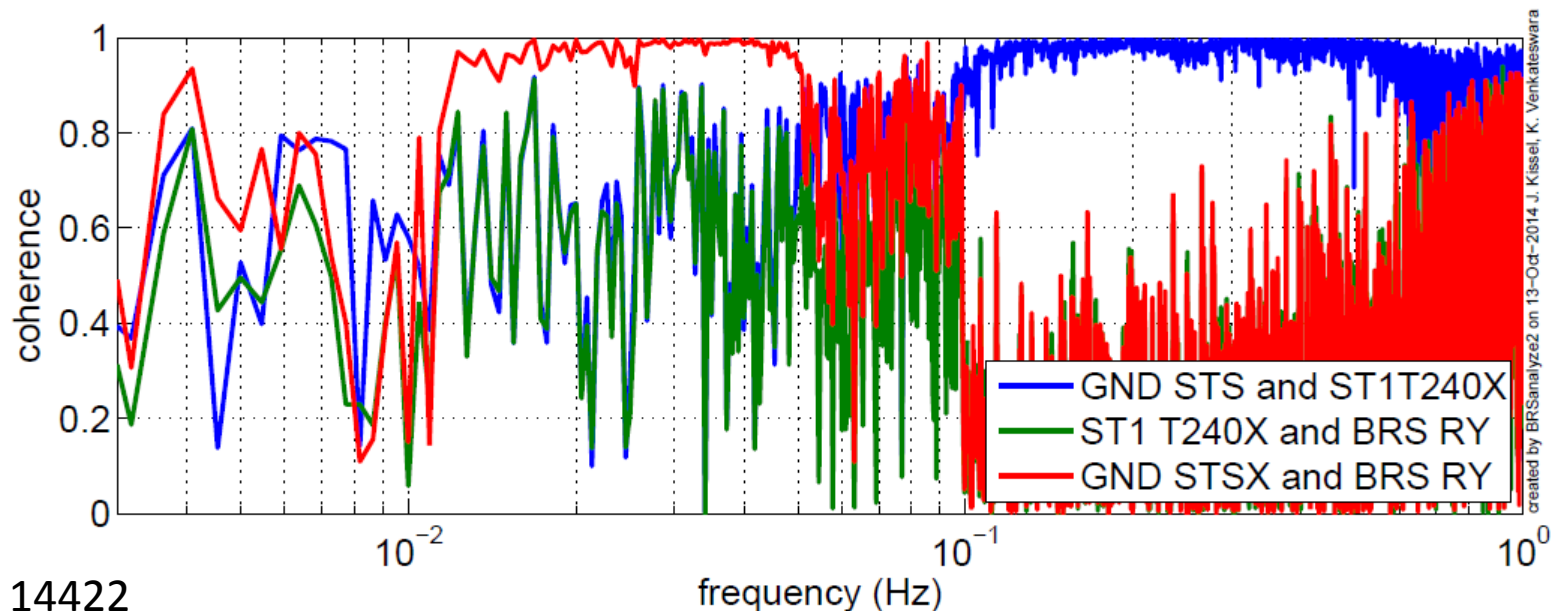
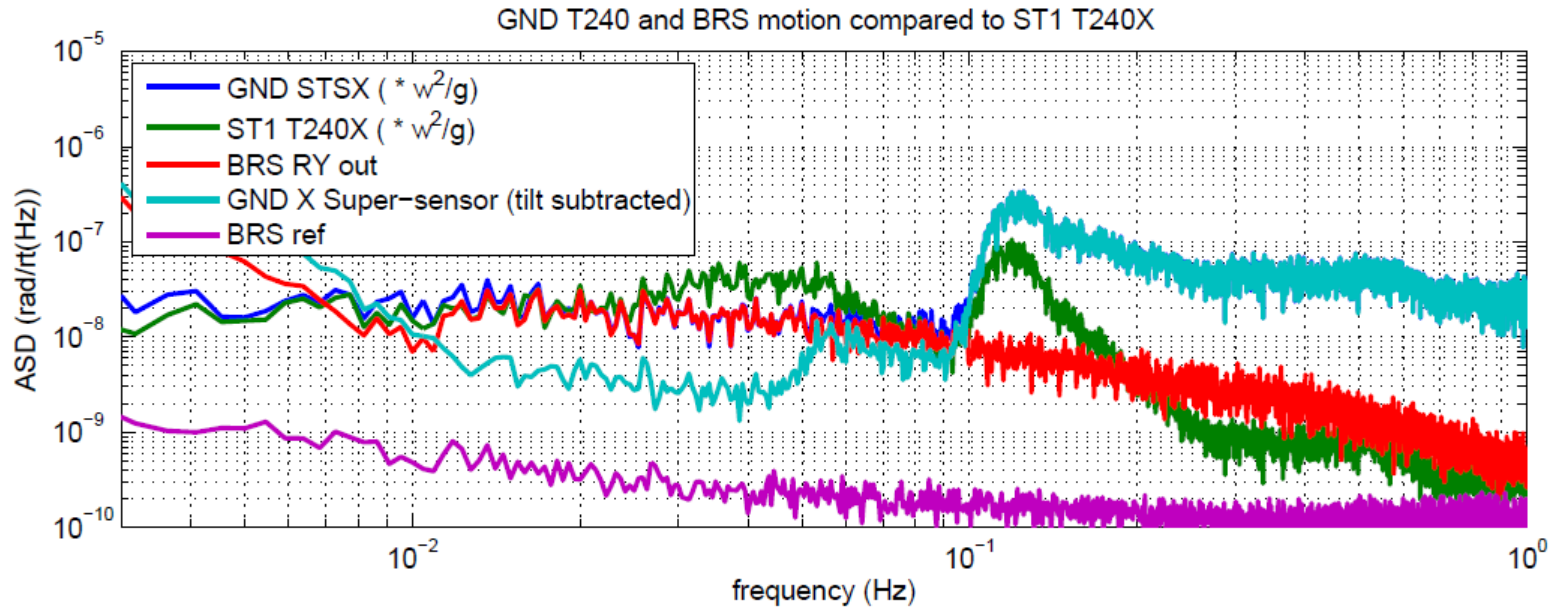
Median points show clear factor of 2-3 more tilt from > 30 [mph] winds in EY than at EX

# Ground tilt during 0-5 mph winds

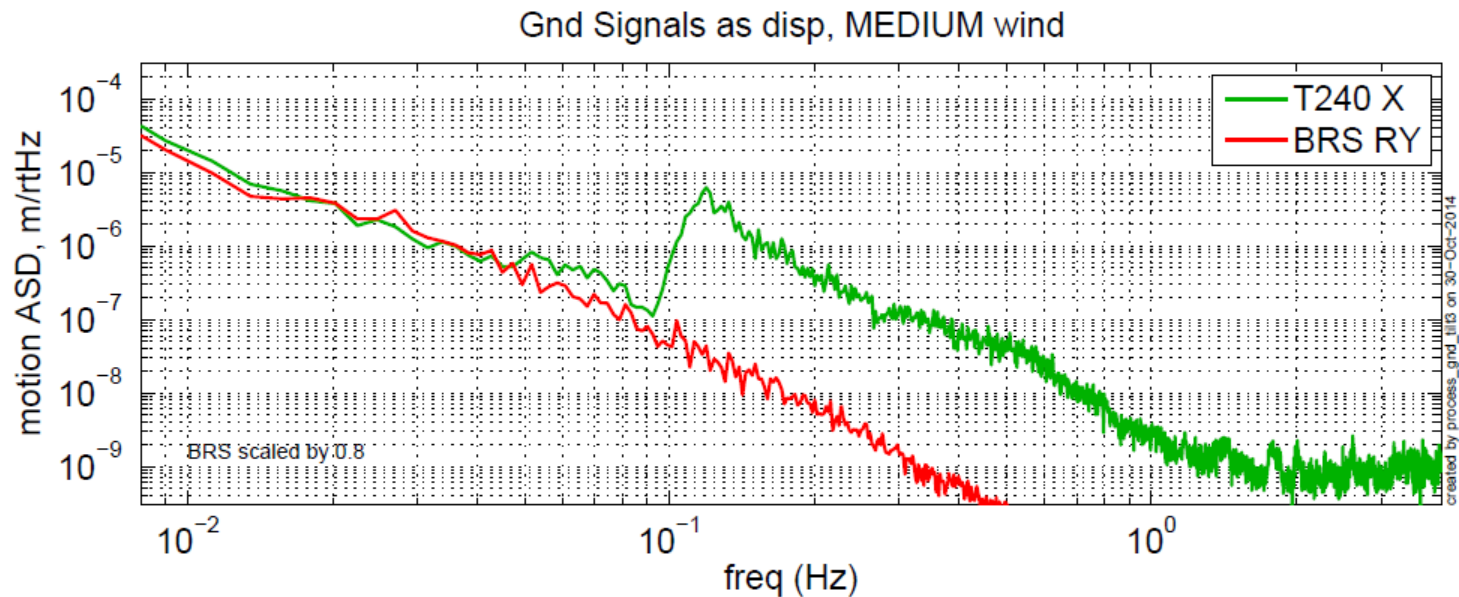
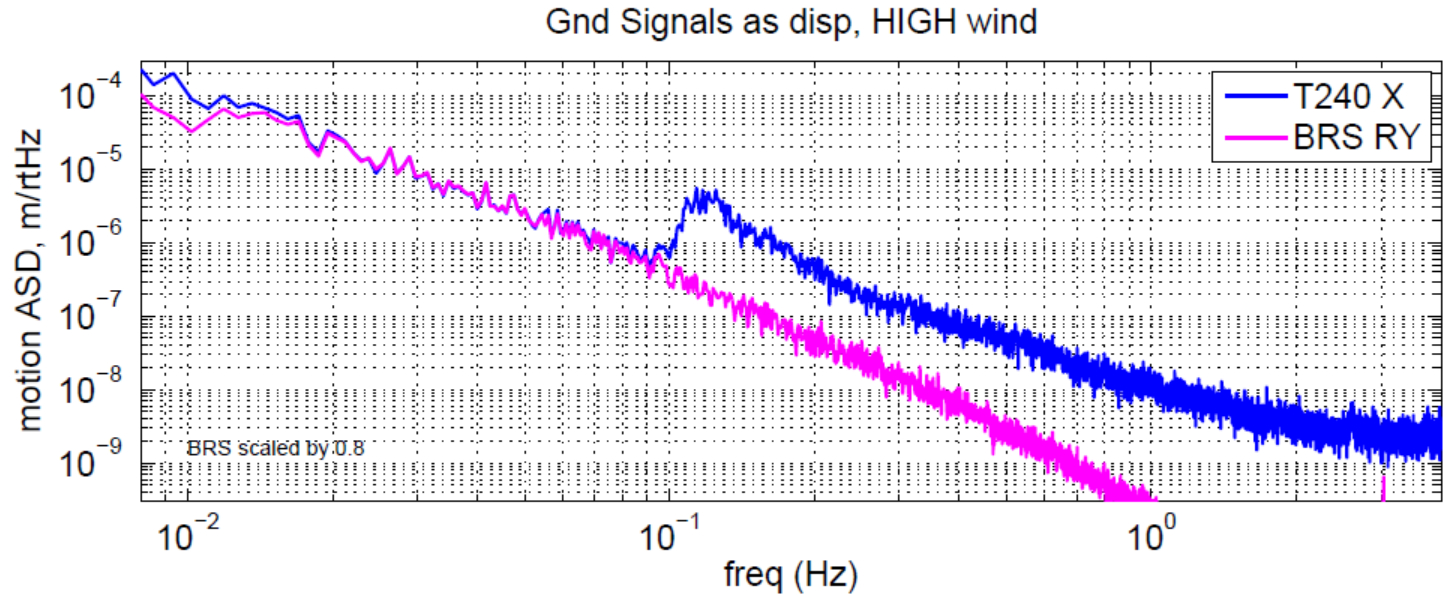




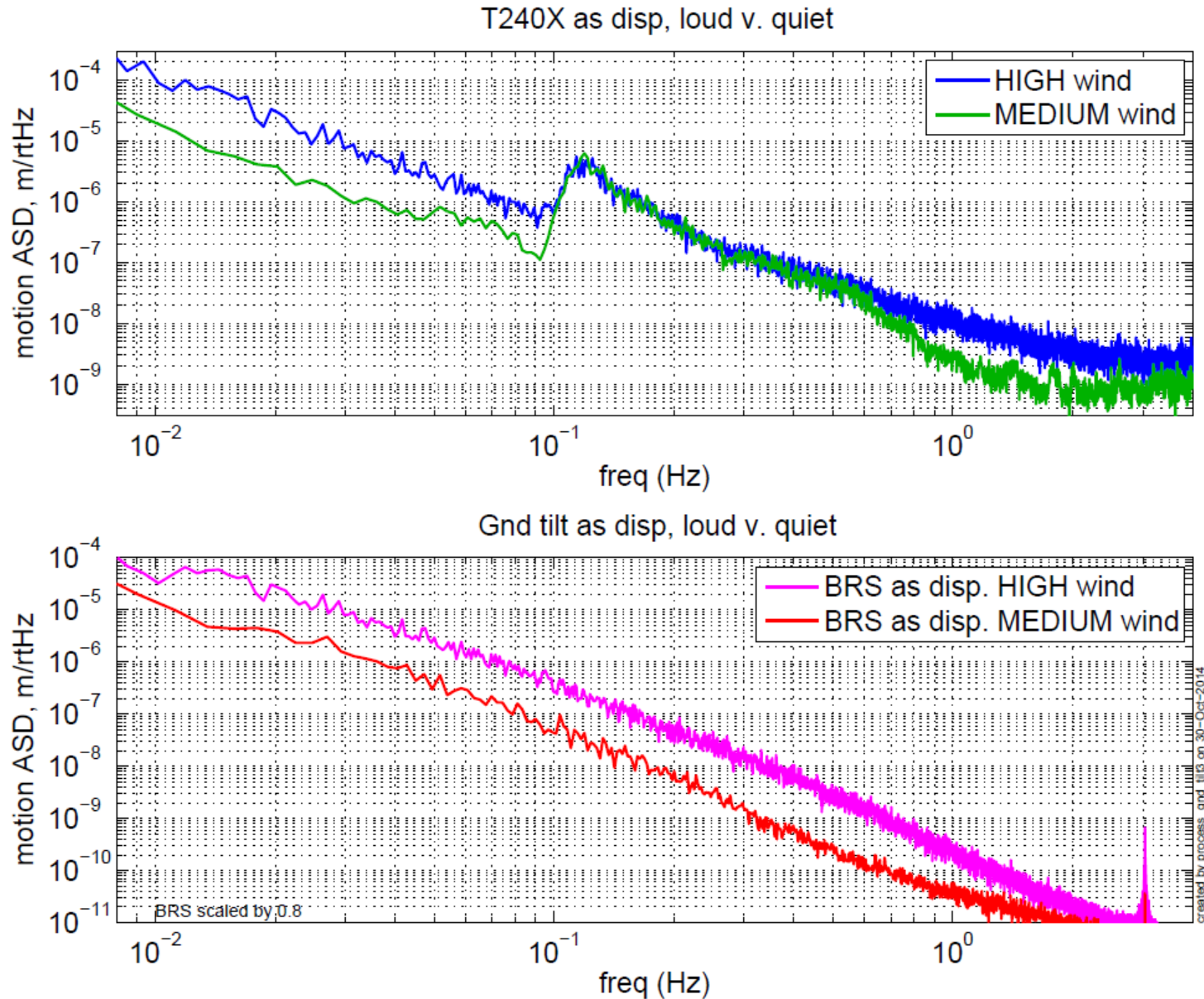
# Ground tilt during 20-30 mph winds



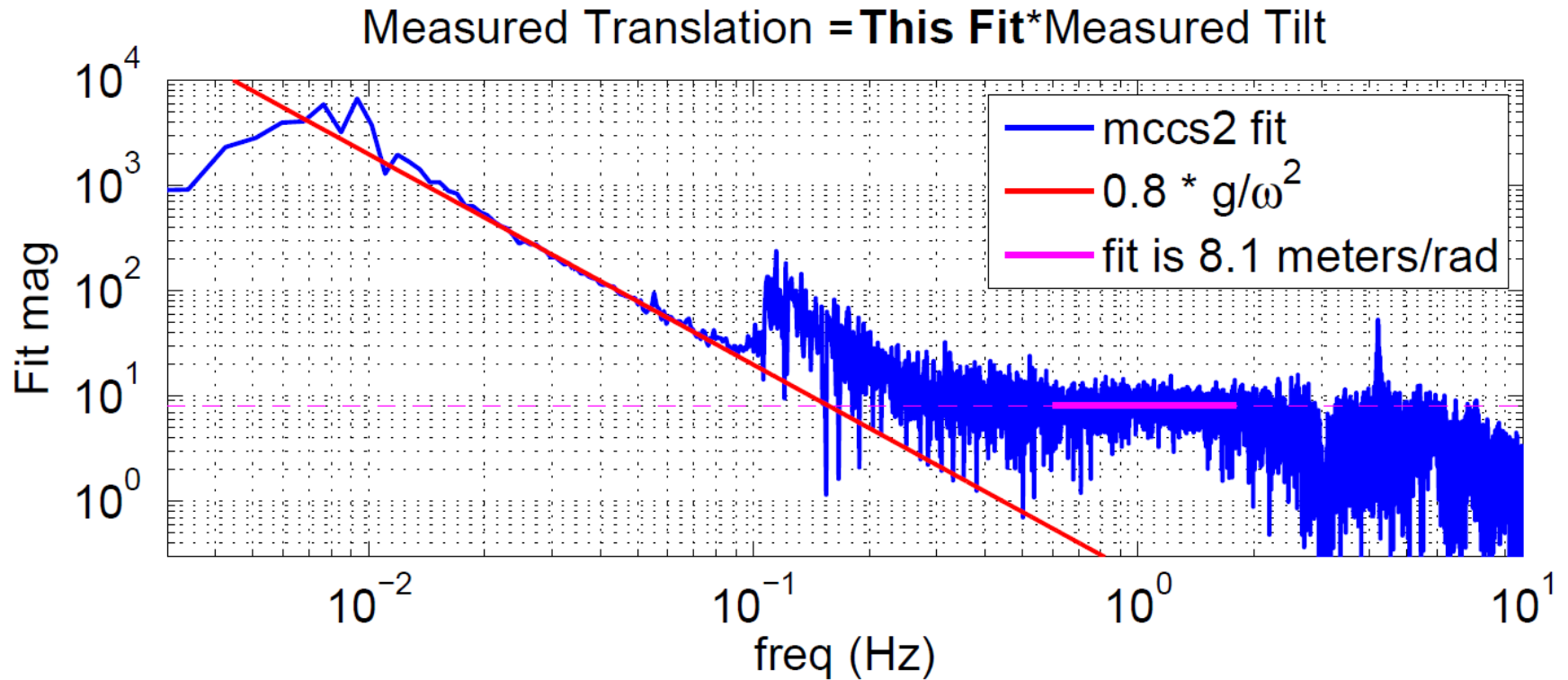
# Ground tilt during 20-30 mph winds



# Ground tilt during 20-30 mph winds

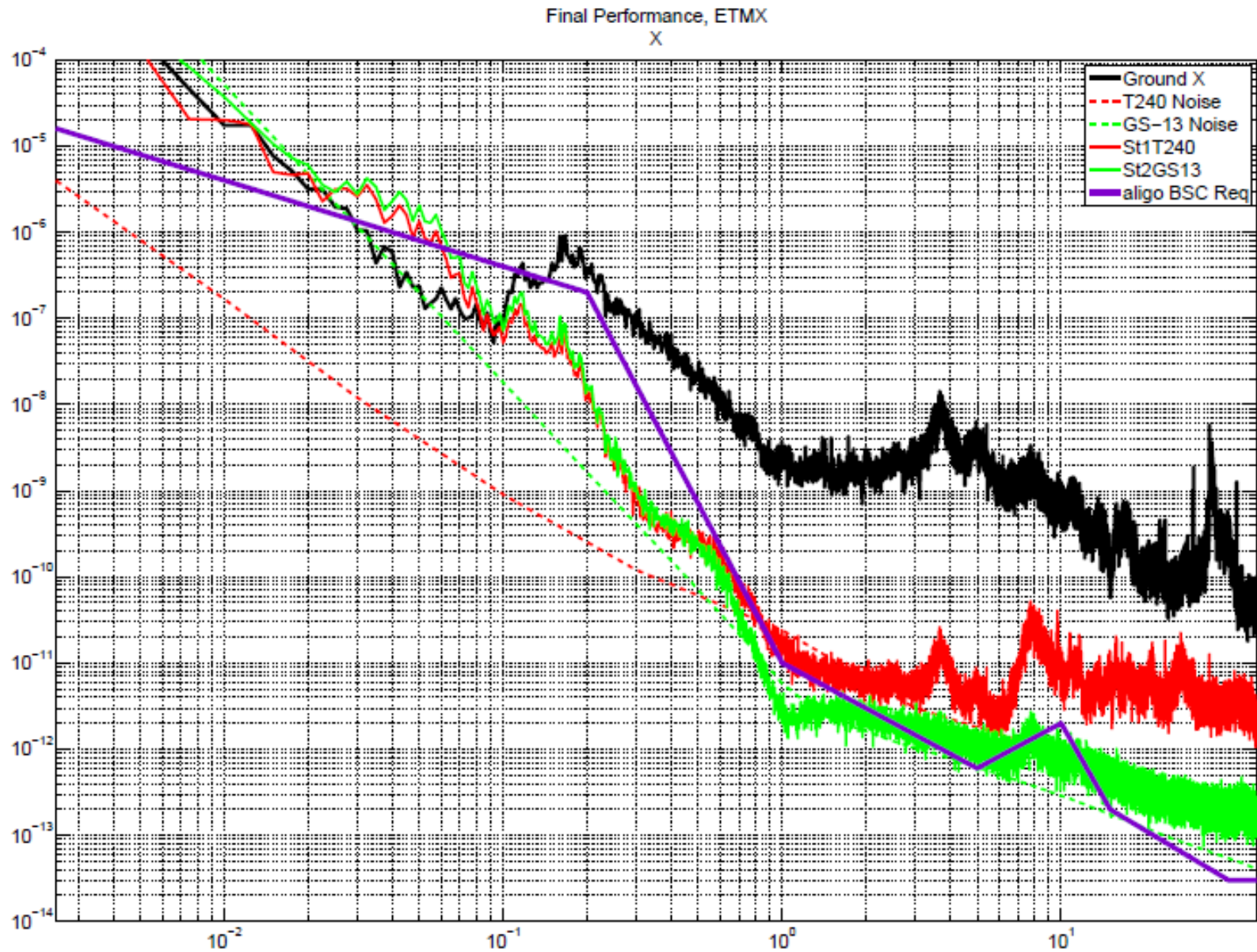


# Tilt to translation TF



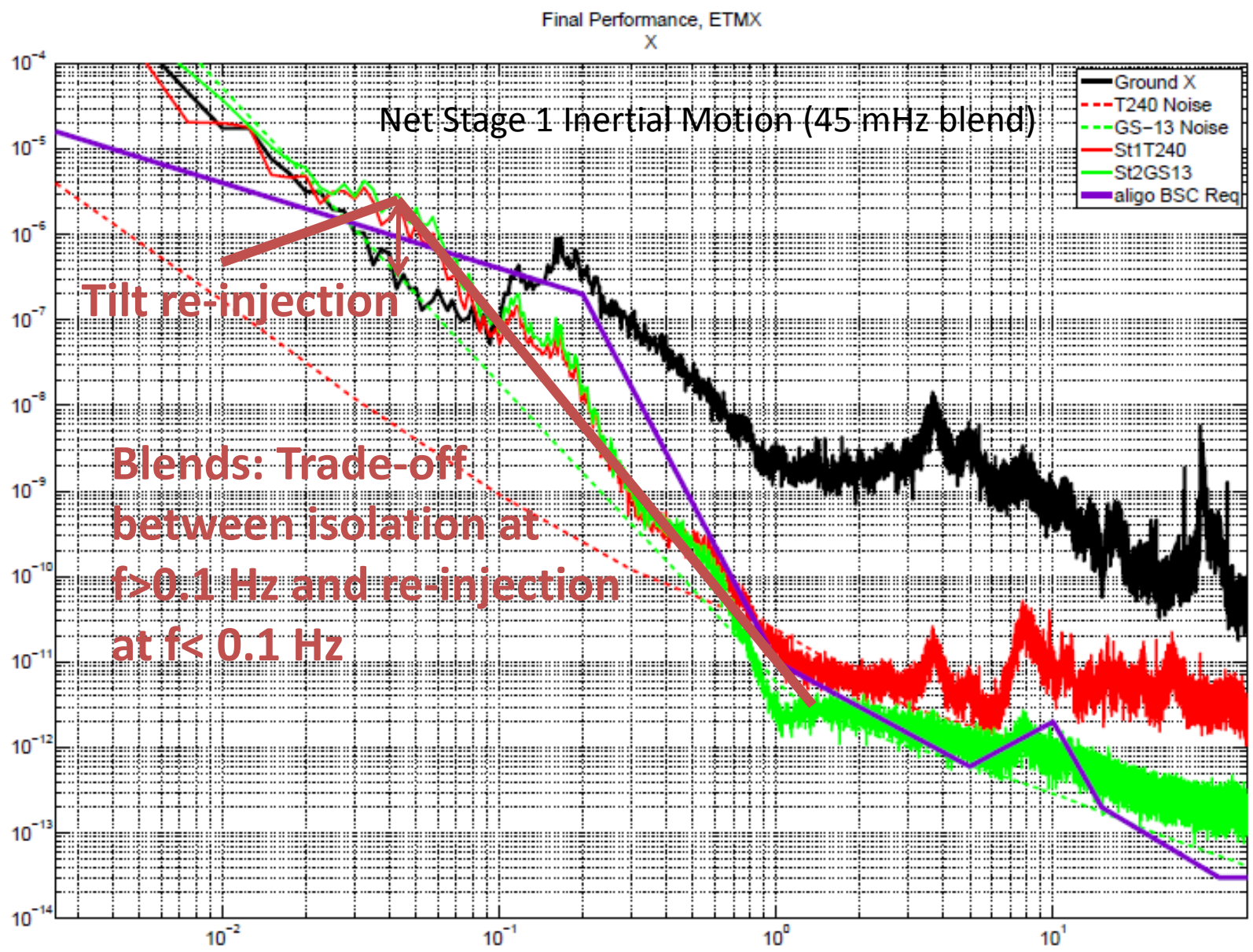
# Impact of Wind on Interferometer

# Platform Motion



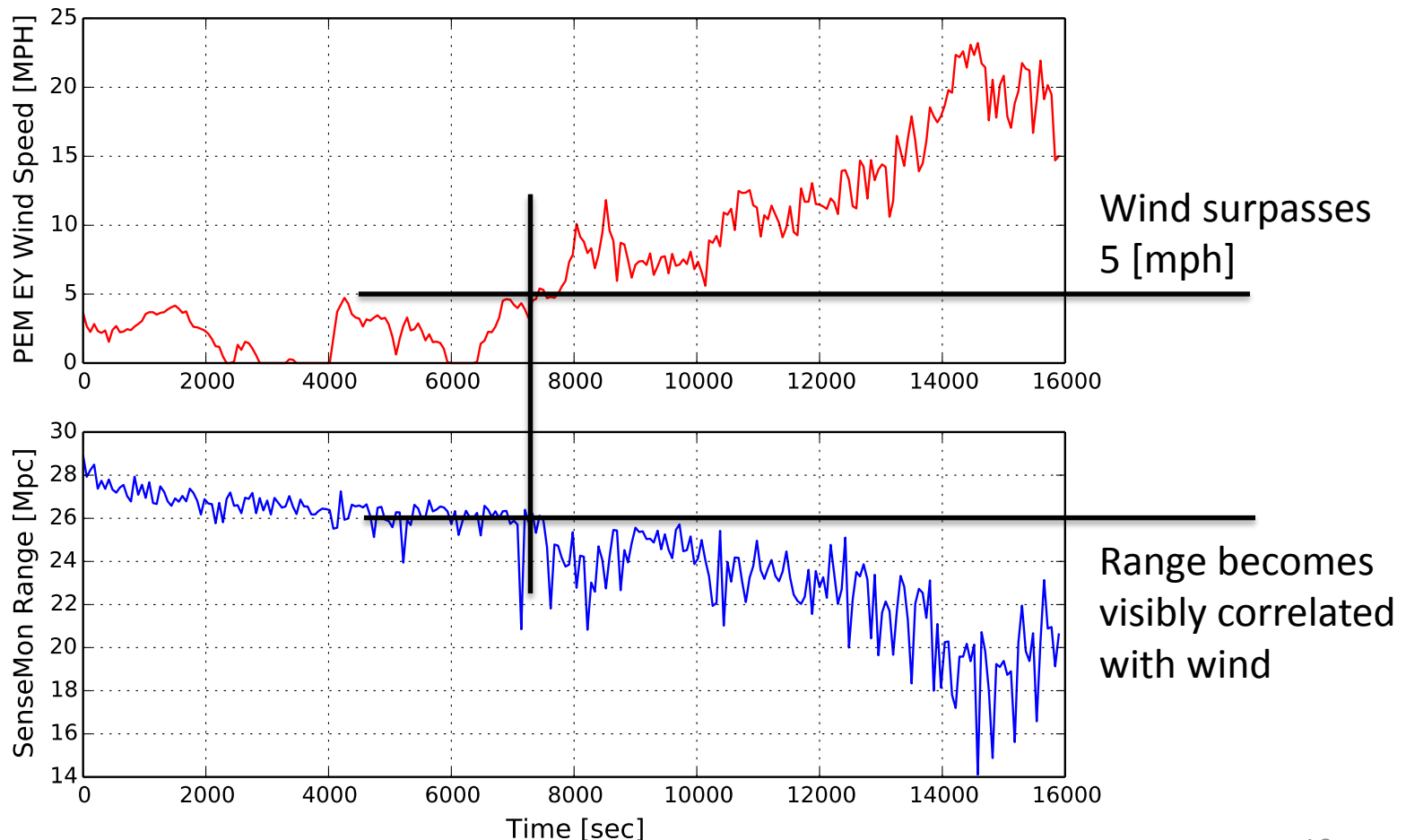


# Platform Motion



# Wind Substantially Impacts the Observatory and the Detector

- Wind above even 5 [mph] has an impact on the sensitivity ([LHO aLOG 17446](#))





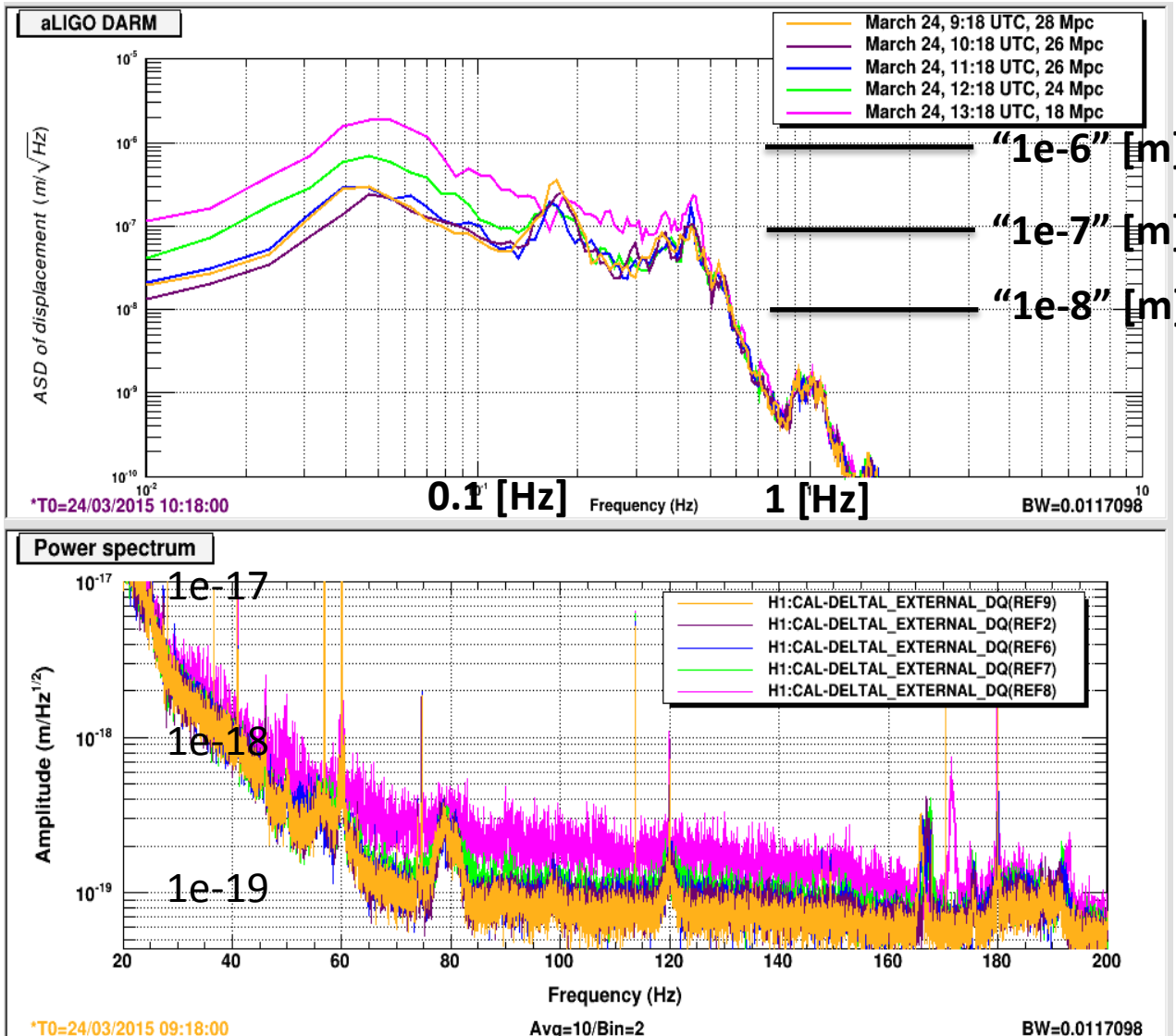
# Wind Substantially Impacts the Observatory and the Detector

Comparison of hourly progression of ASDs at low frequency shows how low frequency motion up-converts into the bucket.

(LHO aLOGs [17460](#))

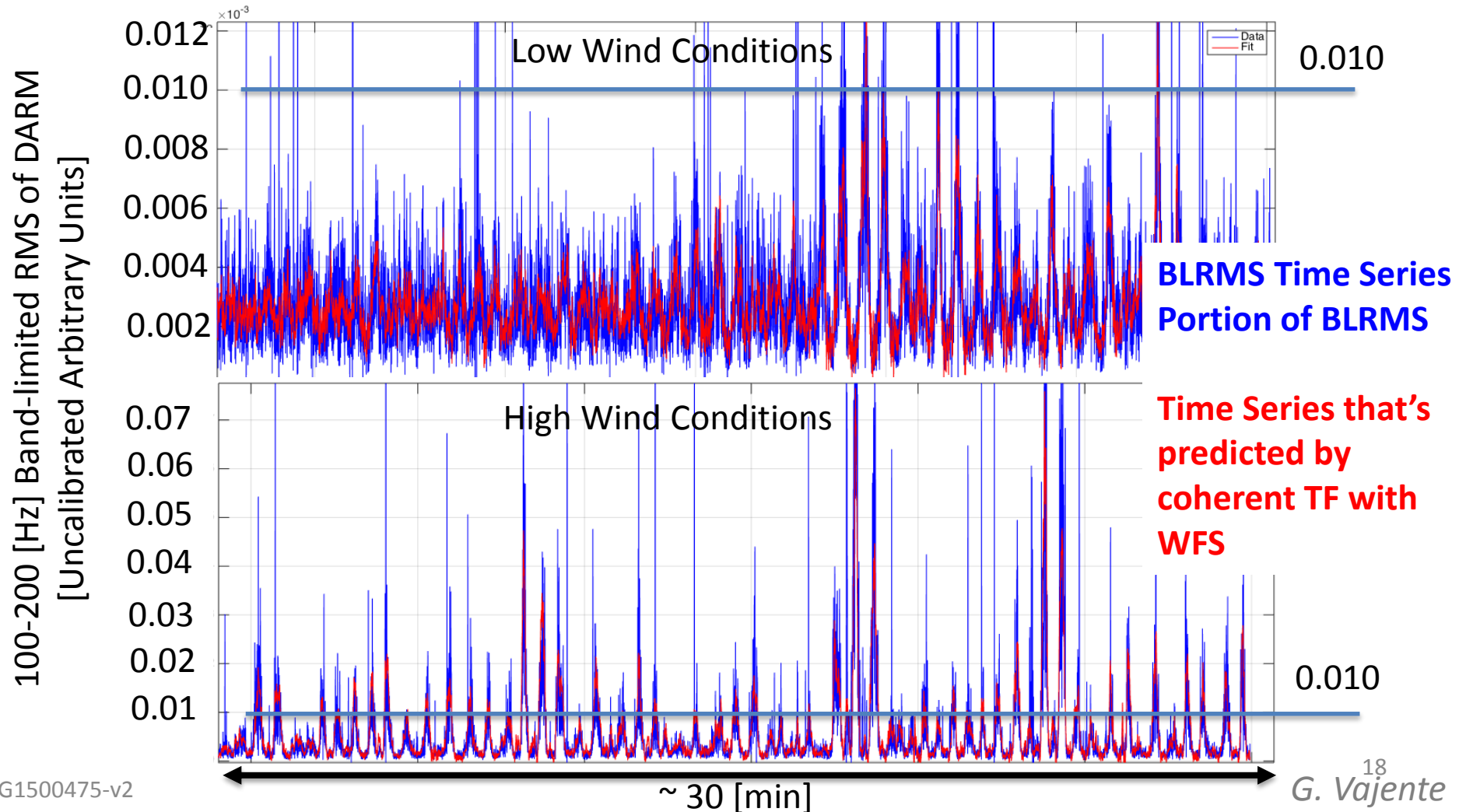
Note: **Calibration** a below **1 [Hz]** is inaccurate.

ASD is too good by  $\sim 10$  at 0.1 [Hz], and by  $\sim 100$  at 0.02 [Hz] (see [LHO aLOG 17708](#))

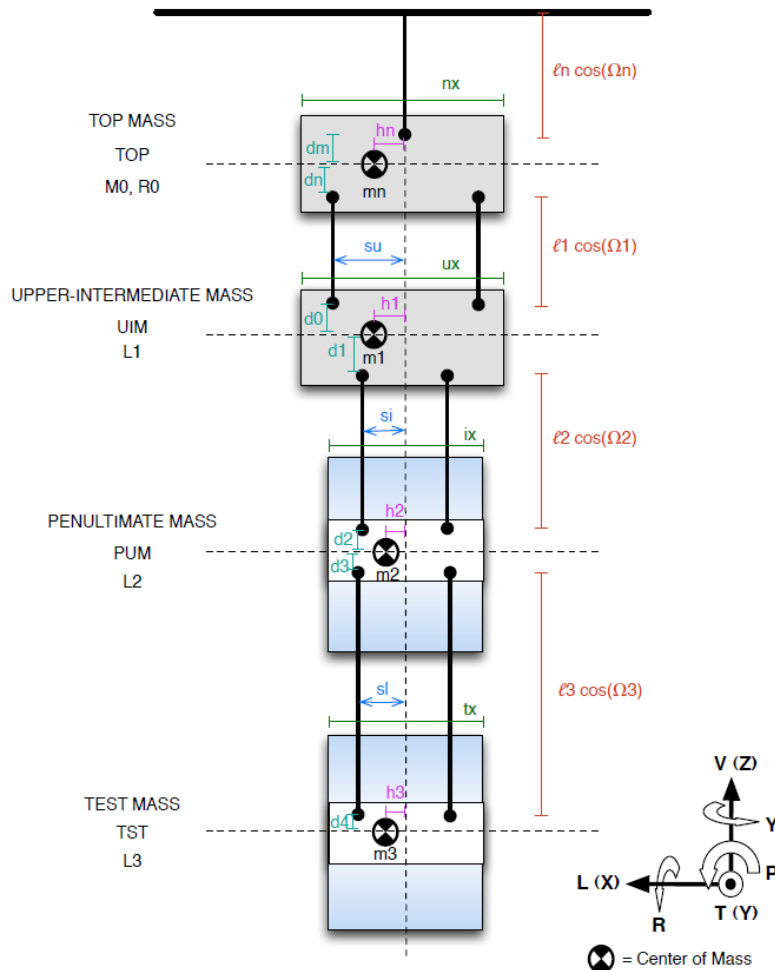


# Wind Substantially Impacts the Observatory and the Detector

Wind greatly affects the alignment, and therefore the stationarity of the performance ([LHO aLOG 17461](#))



# Mechanism of Increased Alignment Fluctuation?



Was mainly in 'Yaw'  
([LHO aLOG 17461](#))

- Longitudinal to Yaw?
- Transverse to Yaw?
- Others?

See Anamaria's talk  
yesterday: **G1500676**

Path forward

# Simulate Wind?

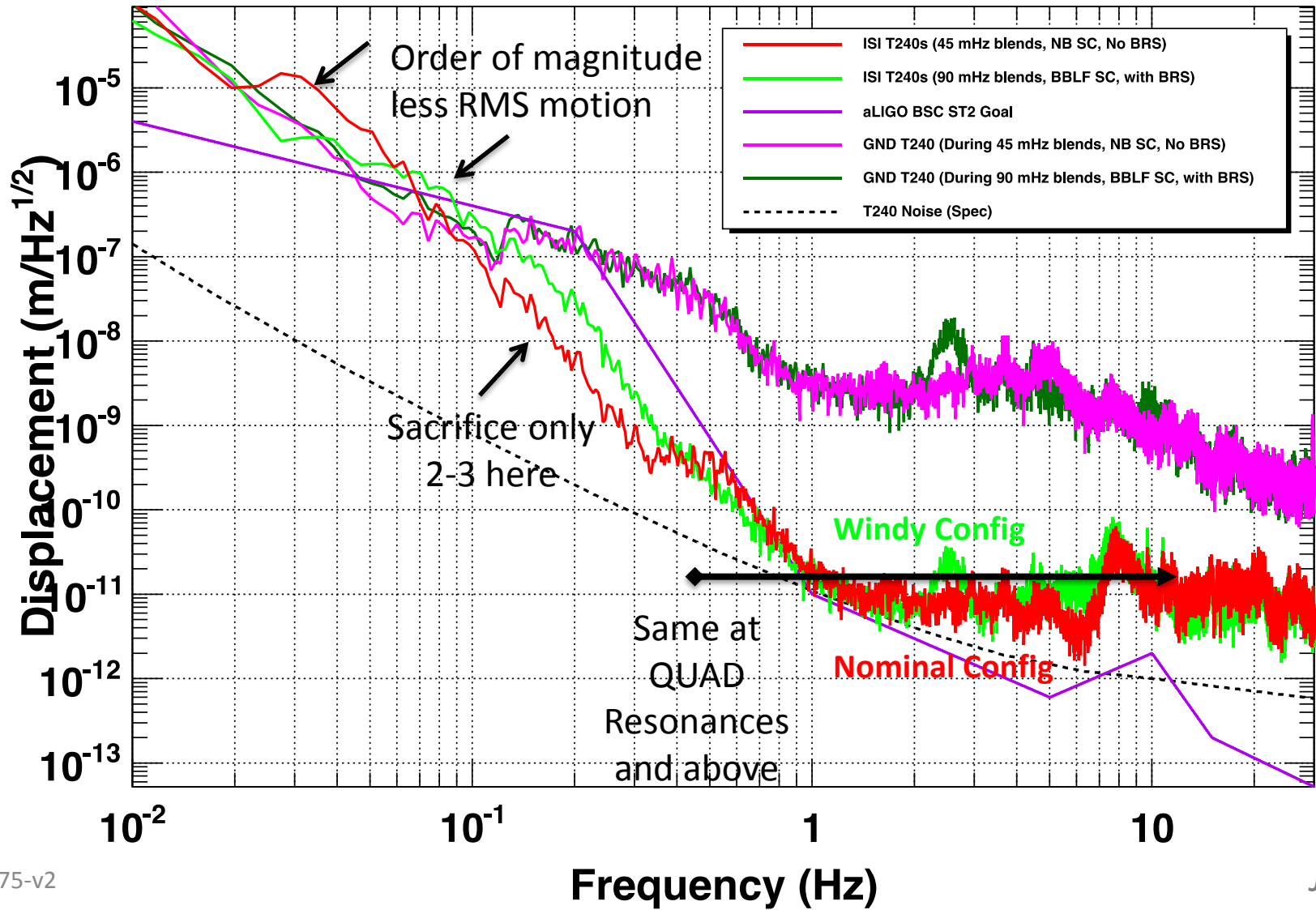
We have reasonable idea of what wind does to the ISI – it increases  
Longitudinal, Transverse motion ~ 100s of nanometers  
Pitch, Roll ~ few nanoradians

- ❑ Perform tests by injecting these motions on BSC-ISIs (or on HEPI?), individually, and see how DARM/lock acquisition is affected. This gives an idea of which coupling is the most important.
- ❑ Additionally, perform tests by switching between 45 and 90 mHz blends (during low wind-speeds) and see how DARM is affected. This gives an idea of how much seismic isolation is needed below 0.5 Hz.

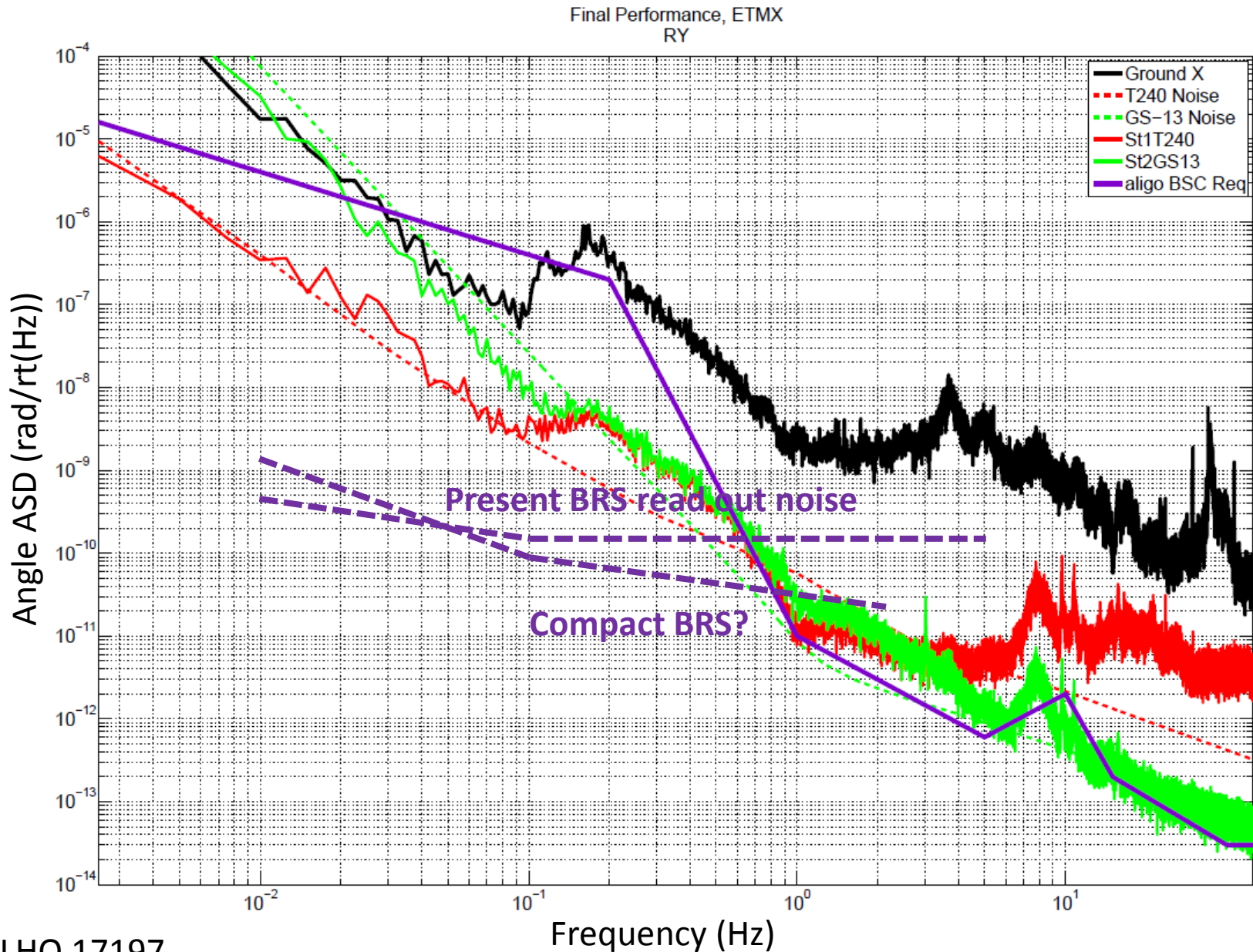
# Use Tiltmeters to improve ISI?

The ISI can perform *better* with BRSs in medium wind, 10-20 [mph]

([LHO aLOG 17729](#))



# Put a tiltmeter on the ISI?



Thank you!



Backup slides

# Wind speed impact

Beaufort Scale*	Wind Speed	Land conditions
2	3.4–7.4 mph	Wind felt on exposed skin. Leaves rustle. Wind vanes begin to move.
4	12.2–17.9 mph	Dust and loose paper raised. Small branches begin to move.
6	24.1–31 mph	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic bins tip over.
8	38.4–46.3 mph	Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded.
10	54.8–63.6 mph	Trees are broken off or uprooted, structural damage likely.

>73 mph is considered a Hurricane!

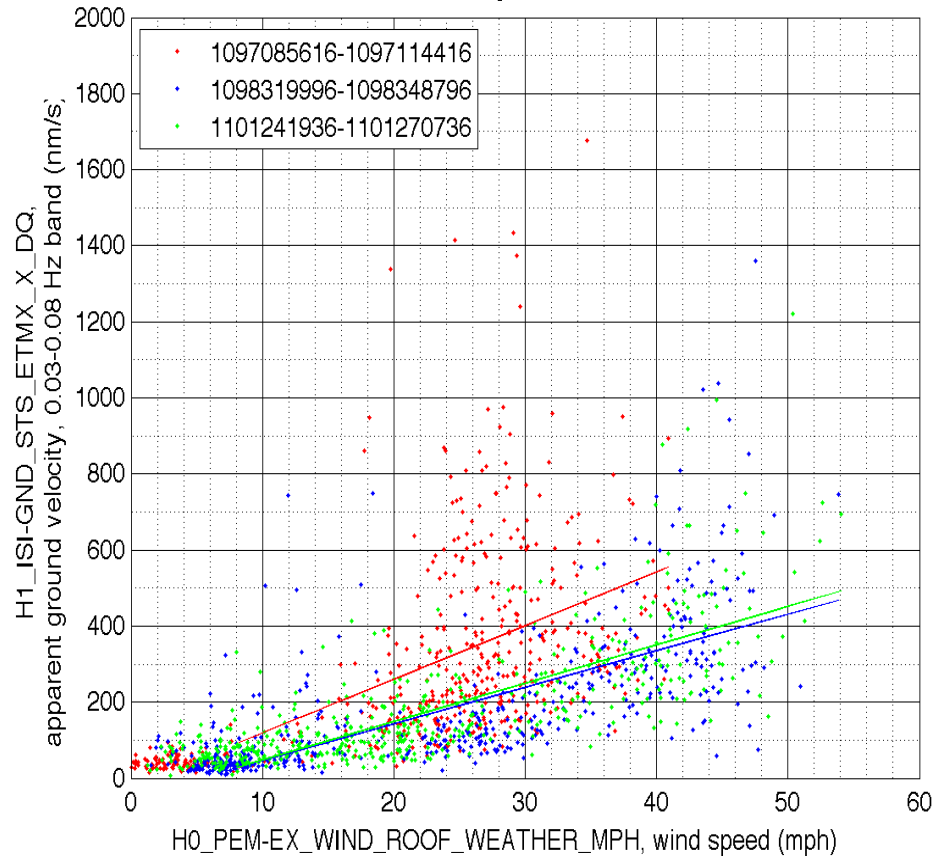
\*The **Beaufort scale** is an [empirical](#) measure that relates [wind speed](#) to observed conditions at sea or on land. - Wikipedia

# Effect on Ground Motion

Also in [LHO aLOG 17574](#): Different wind storms can have differing effects at each end station, likely due to wind direction

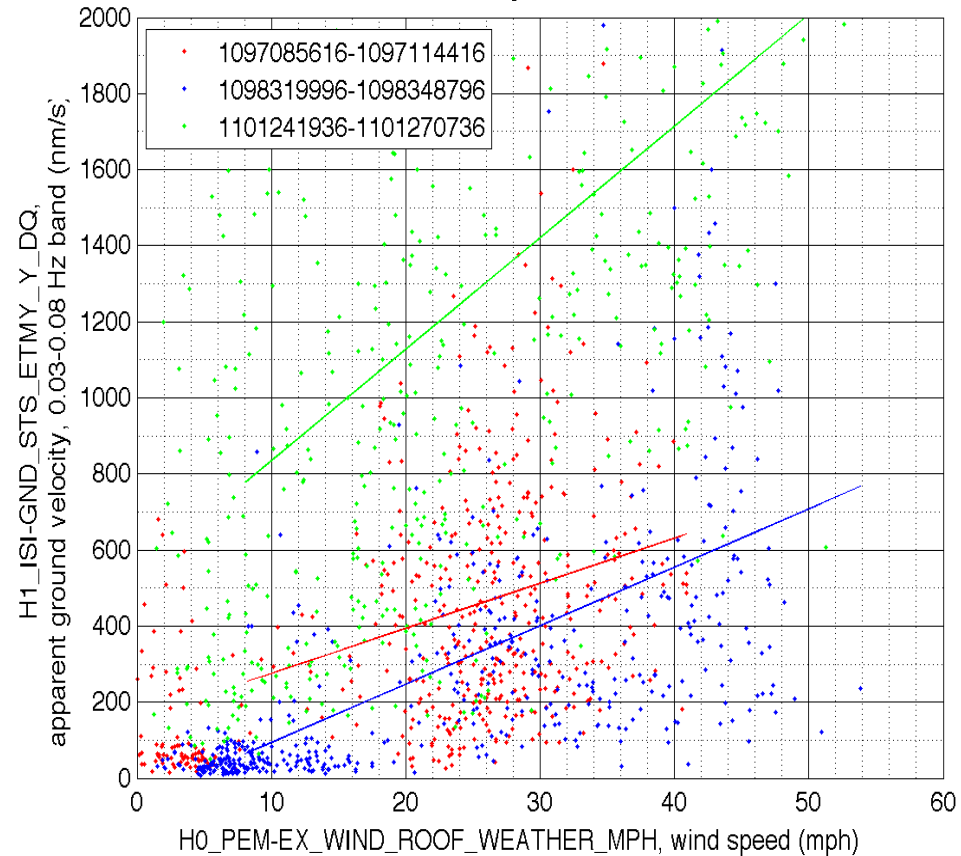
EX#

Figure 3a



EY#

Figure 3b



# Effect on Ground Motion

Also in [LHO aLOG 17574](#): Corner Station doesn't tilt as much in the wind. (but this sensor was known to have problems, so is not very reliable. see [LHO aLOG 18422](#))

