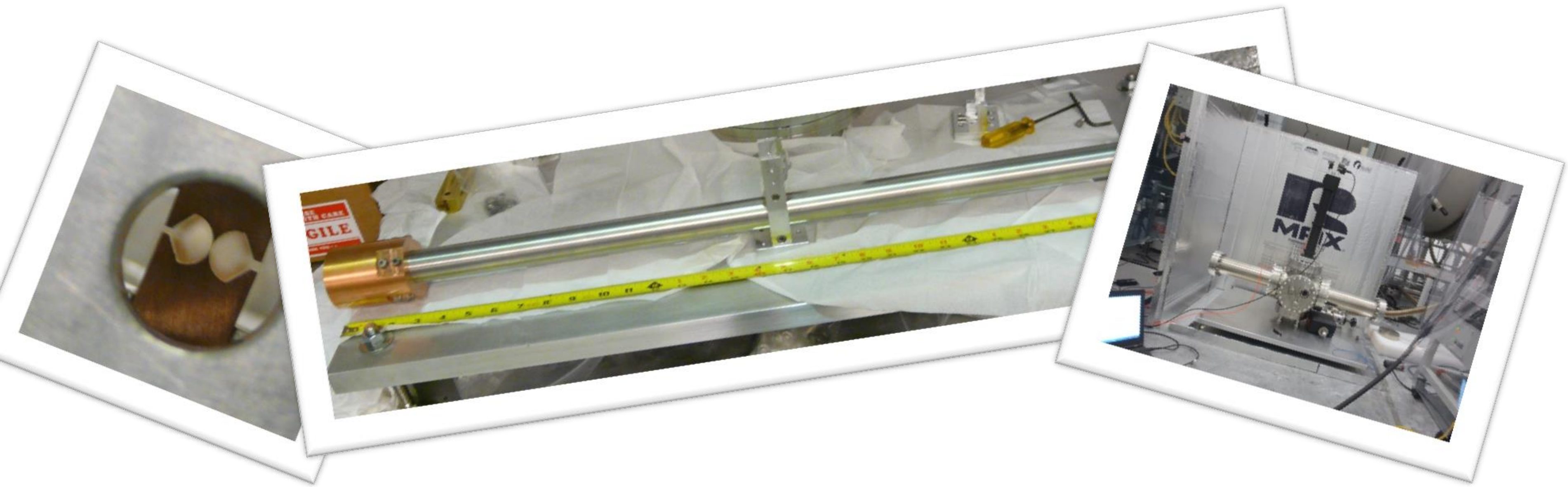
Tilt-correction and Sensor-correction at LHO

Using offline data for designing and quantifying filters

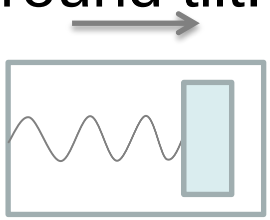
Conor Mow-Lowry

Thanks to: Krishna, Jeff, Brian, Jim, Hugh, Robert

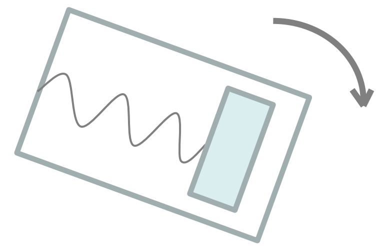


Tilt versus Horizontal displacement

- Conventional seismometers and tiltmeters cannot differentiate between horizontal displacement and ground tilt.



$\delta x \propto a_x$



$\delta x \propto g\theta$

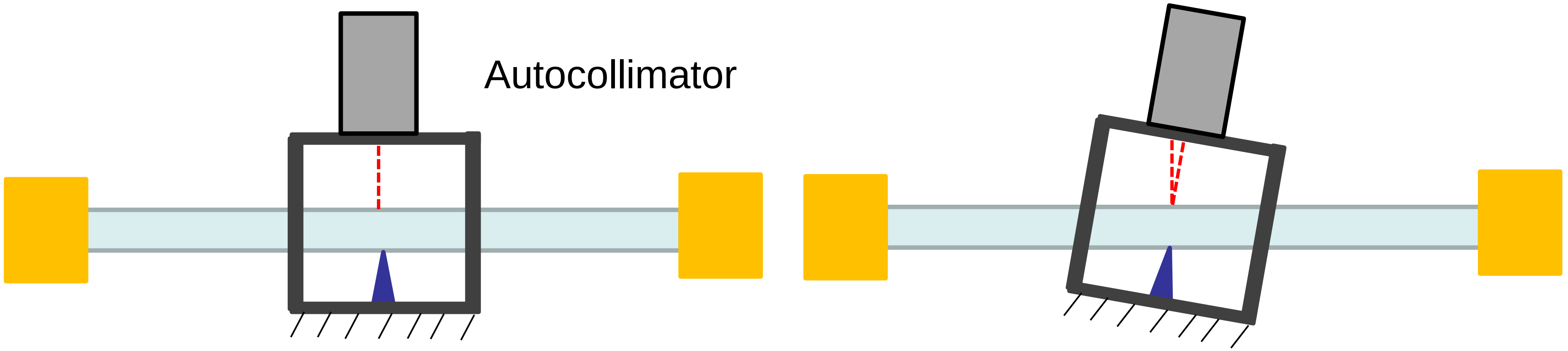
Tilt response to horizontal displacement response for <u>all</u> seismometers = $-g/\omega^2$

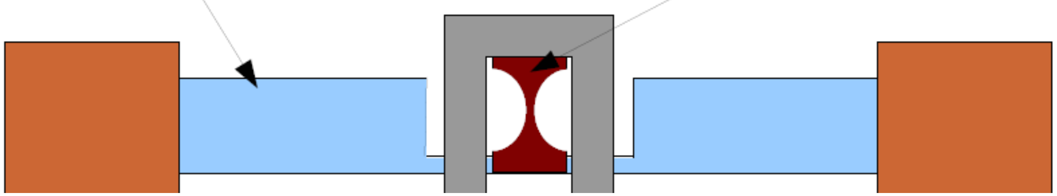
$\Rightarrow$ Tilt is confused with horizontal motion at low frequencies (below ~ 0.1 Hz).

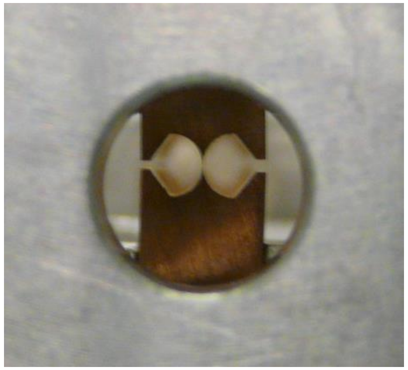
<u>Solution</u>: Inertial rotation sensors, Tilt-free seismometers

Source: Krishna Venkateswara

Schematic







10-25 μm-thick
Cu-Be Flexures

Source: Krishna Venkateswara

The ISI tilt problem, Stage 2

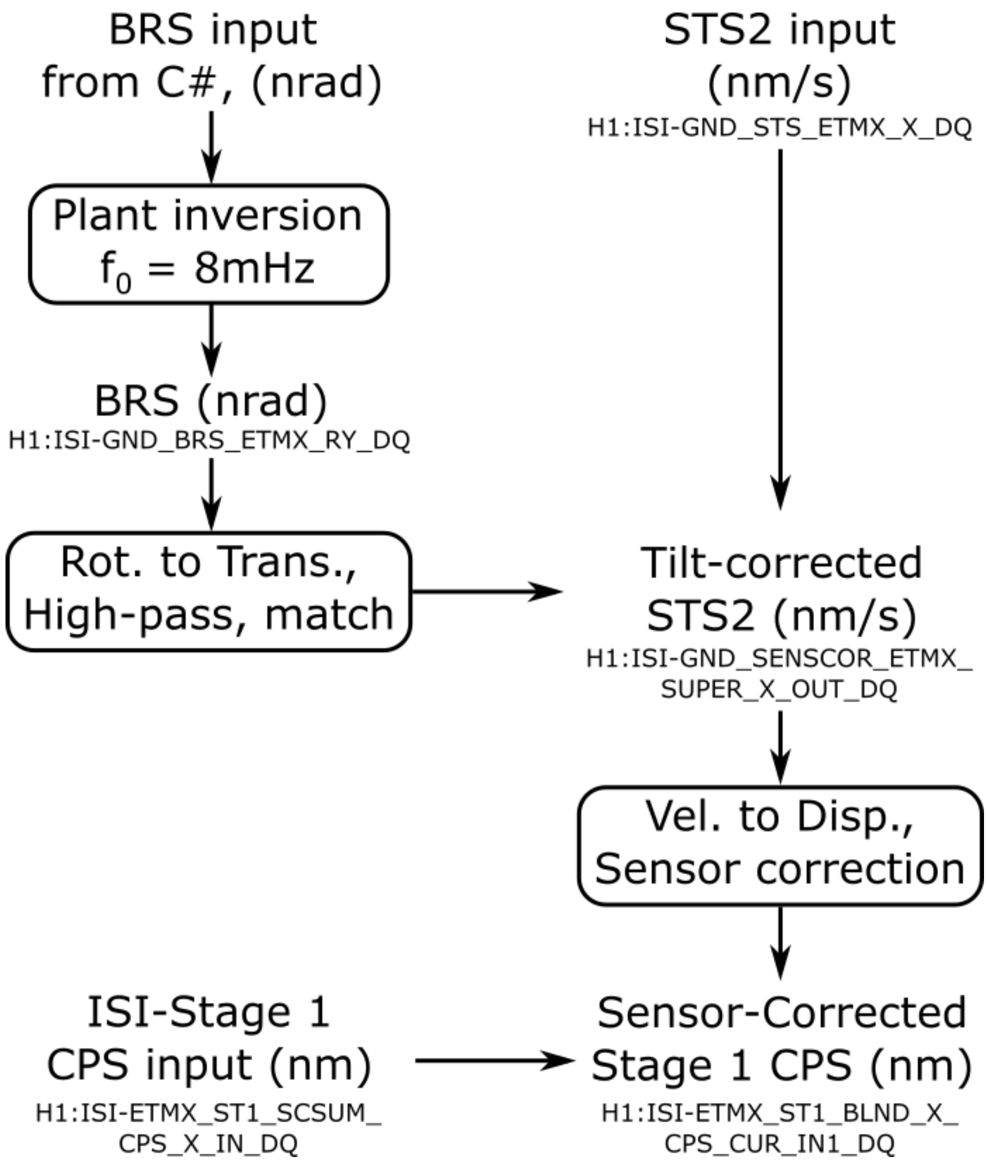
GS-13 tilt-noise and its effect on horizontal translation

Calibration step	Effect on displacement	Relevant frequency
GS-13 measures velocity	$1/f$	$\omega = 1$
Amplifier noise	$1/\sqrt{f}$	$f_c = 1$ Hz
Plant inversion	$1/f^2$	$f_0 = 1$ Hz
Tilt-baseline	1	--
Tilt-to-horizontal coupling	$1/f^2$	$g/\omega^2 = 1$ @0.5 Hz
Result	$\mathbf{1/f^{5.5}}$	**Below 0.5 Hz**

Some points

- RMS velocity is a good figure of merit, and probably what we care about below ~0.3 Hz.
- Sensor correction allows us to use a lower-tilt seismometer for low-frequency isolation.
- Below 100mHz, ground motion is pretty common mode. The primary microseism ~70mHz sees at least a factor 4 direct subtraction.
- We should design further ISI improvements in the IFO basis, and potentially using IFO readout.

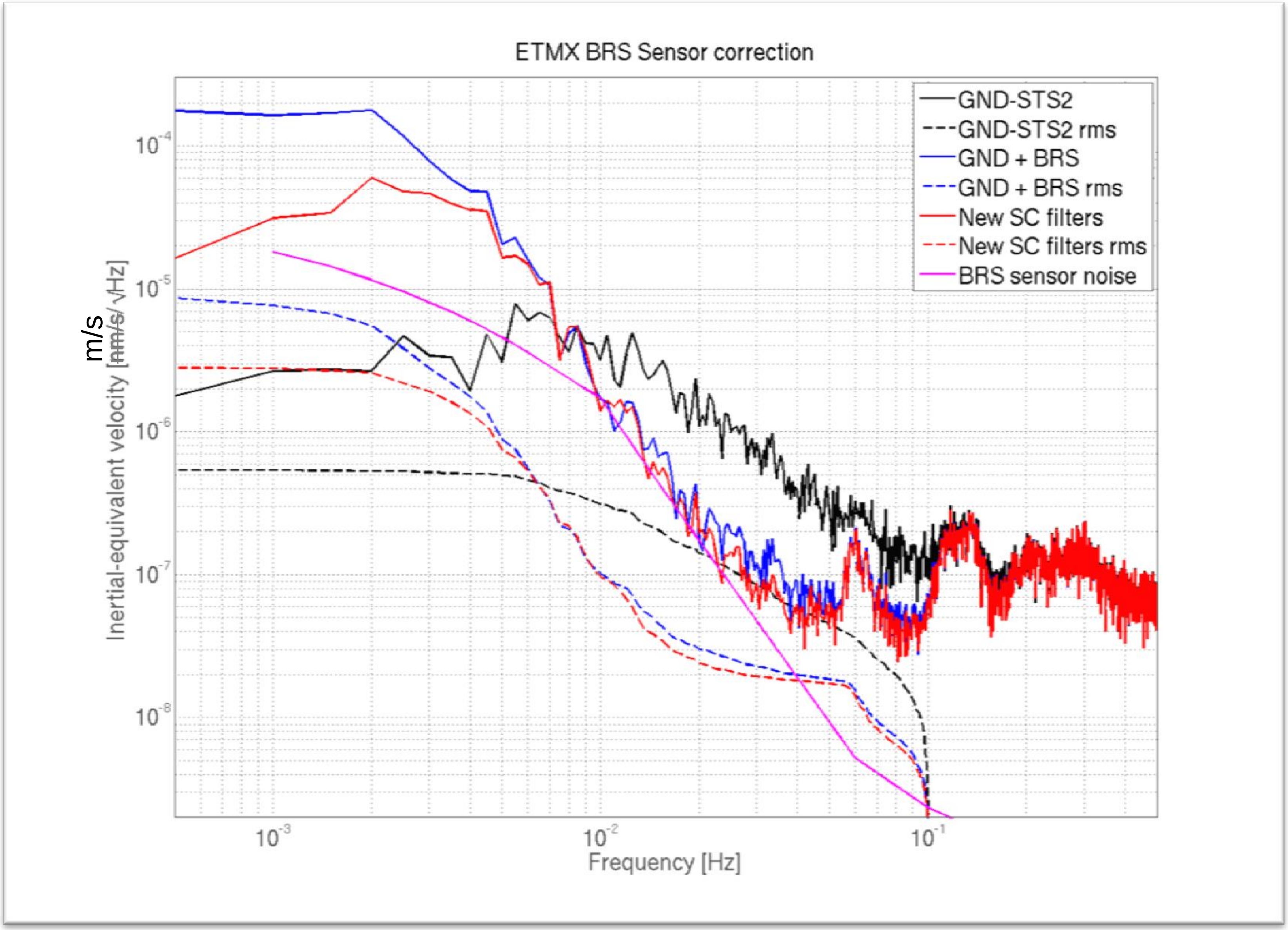
BRS Signal Path



Offline data was used to tune all the BRS filters for improved tilt-subtraction and reduced low-frequency noise injection.

Most benefit came from matching the high-pass filter to the STS2 AC-coupling.

BRS Tilt-correction filter tuning (ETMX)



BRS Tilt-correction filter tuning (ETMY)

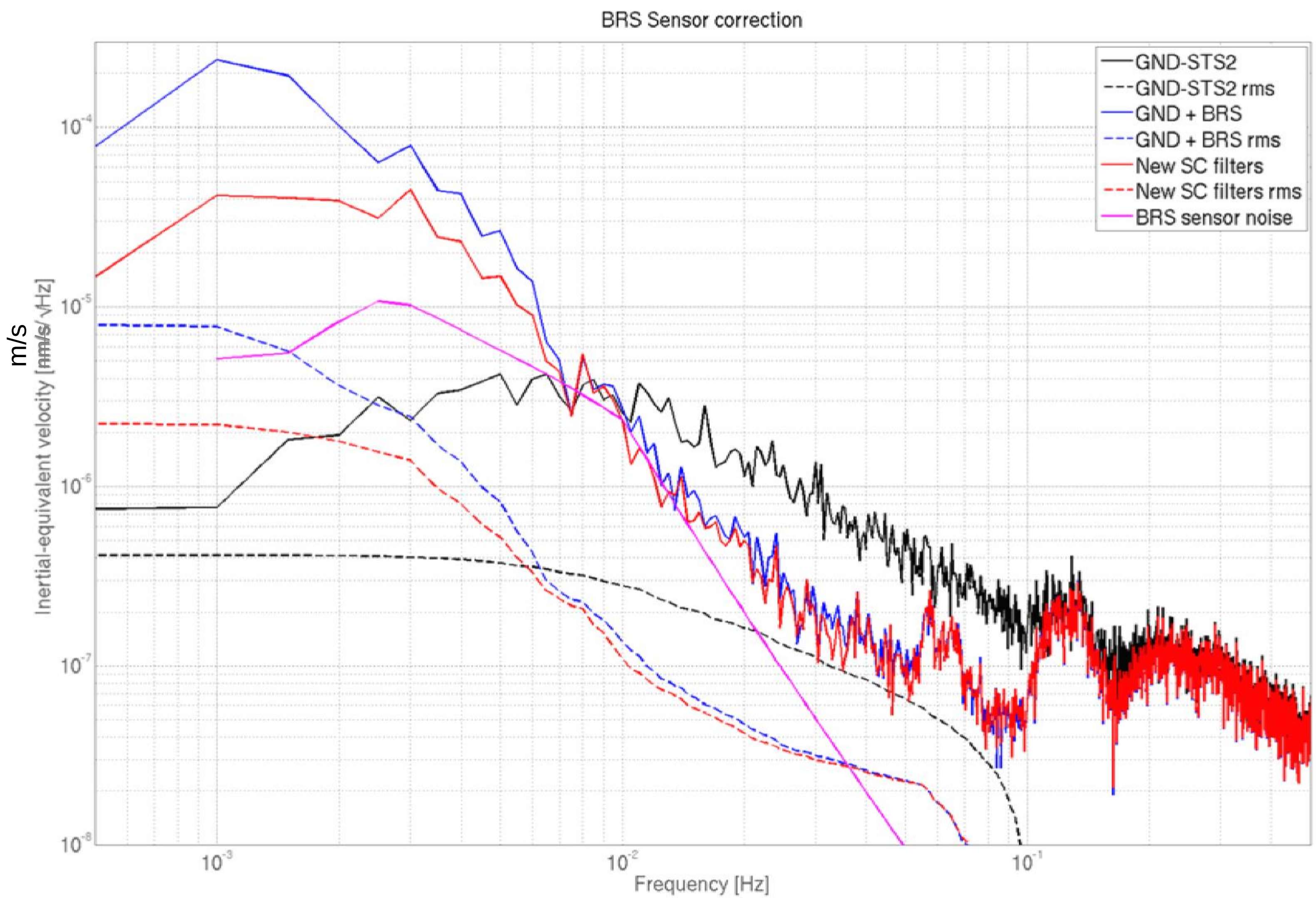
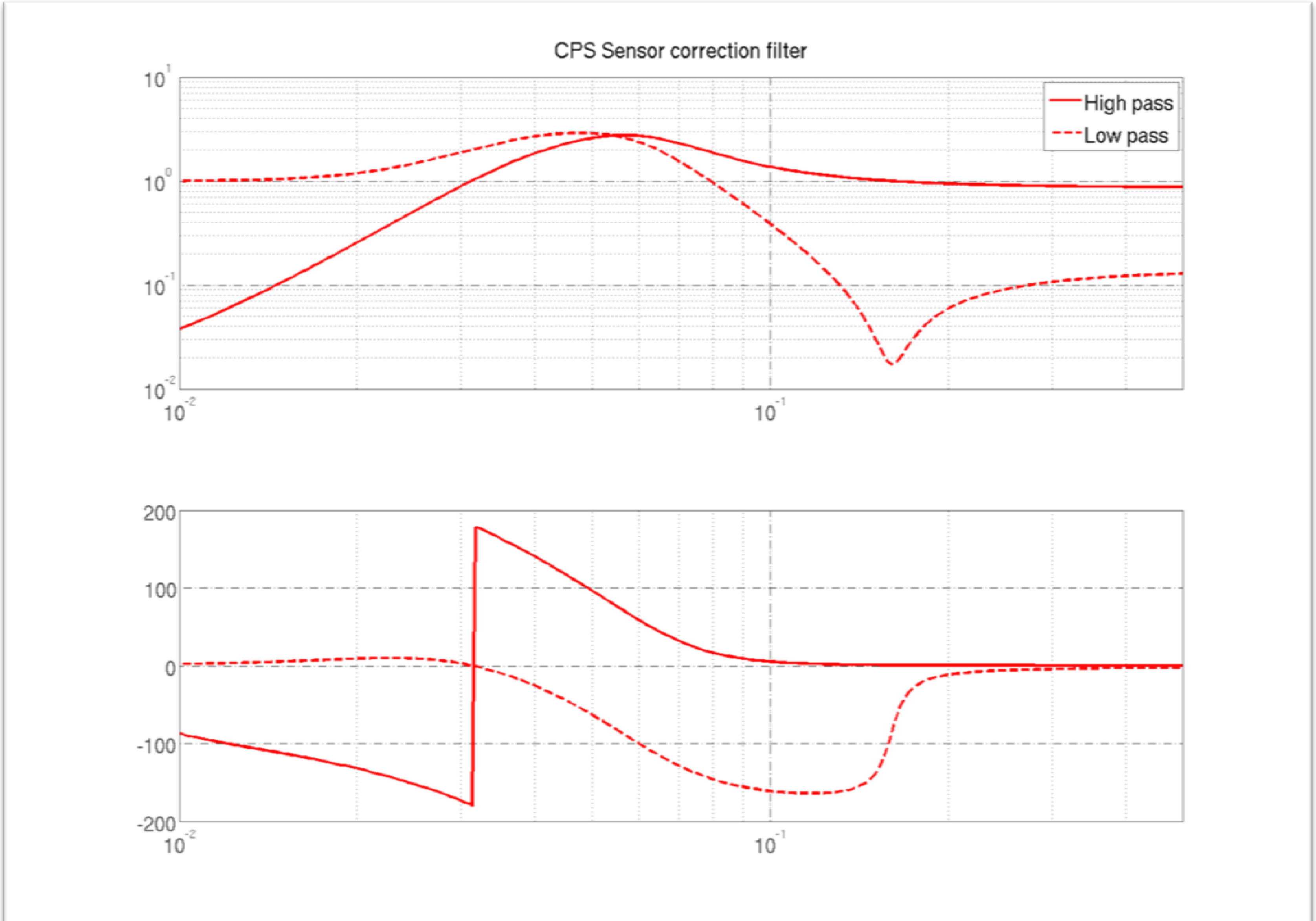


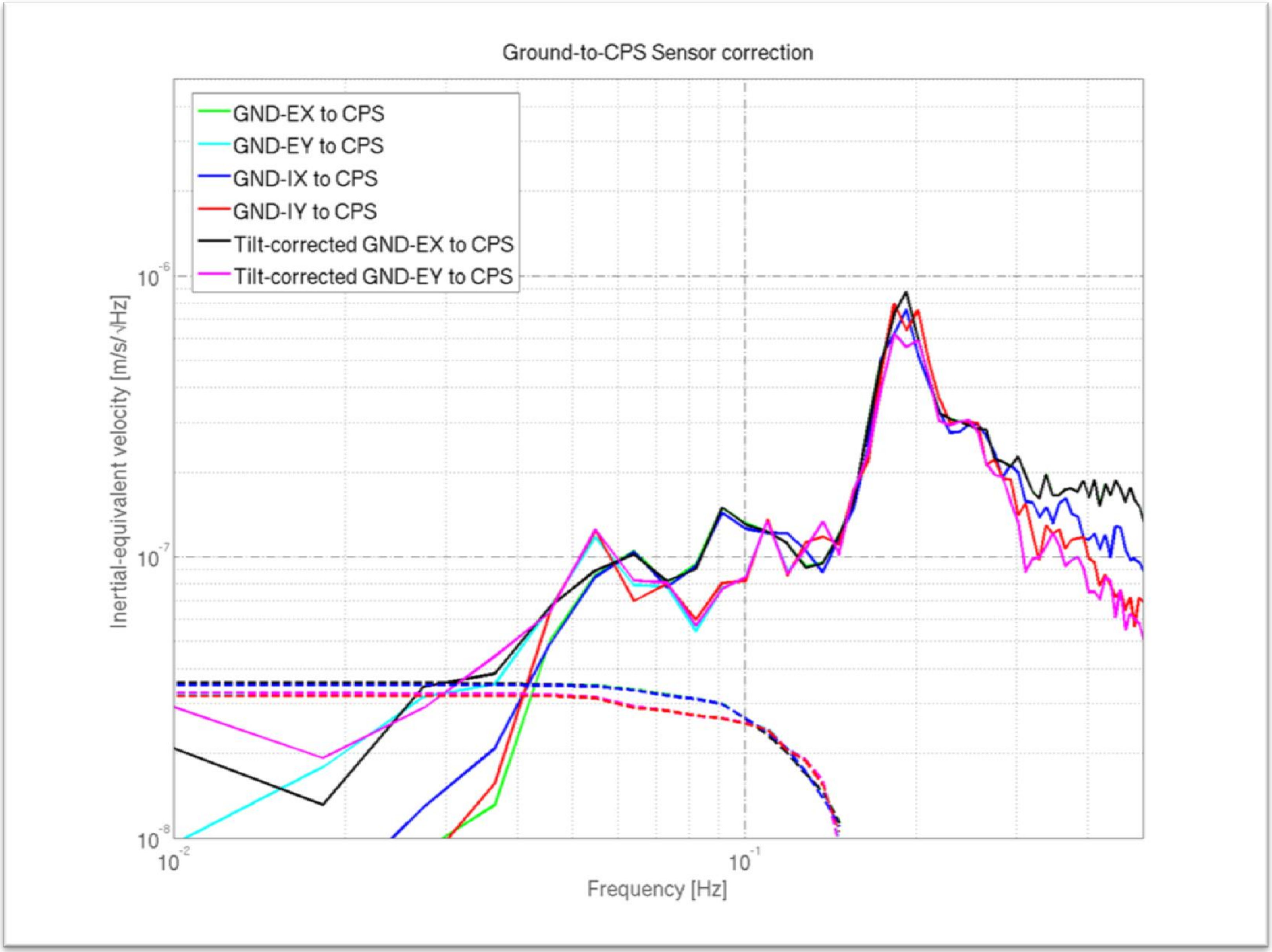
Figure of merit

- We want to minimise the low-frequency RMS velocity transmitted through the Sensor-Correction filter.
- This motion is typically dominated by (uncorrelated) tilt.
- We want to see whether the BRS causes harm when there is no wind.
- And measure the reduction of injected arm-length motion during high winds.

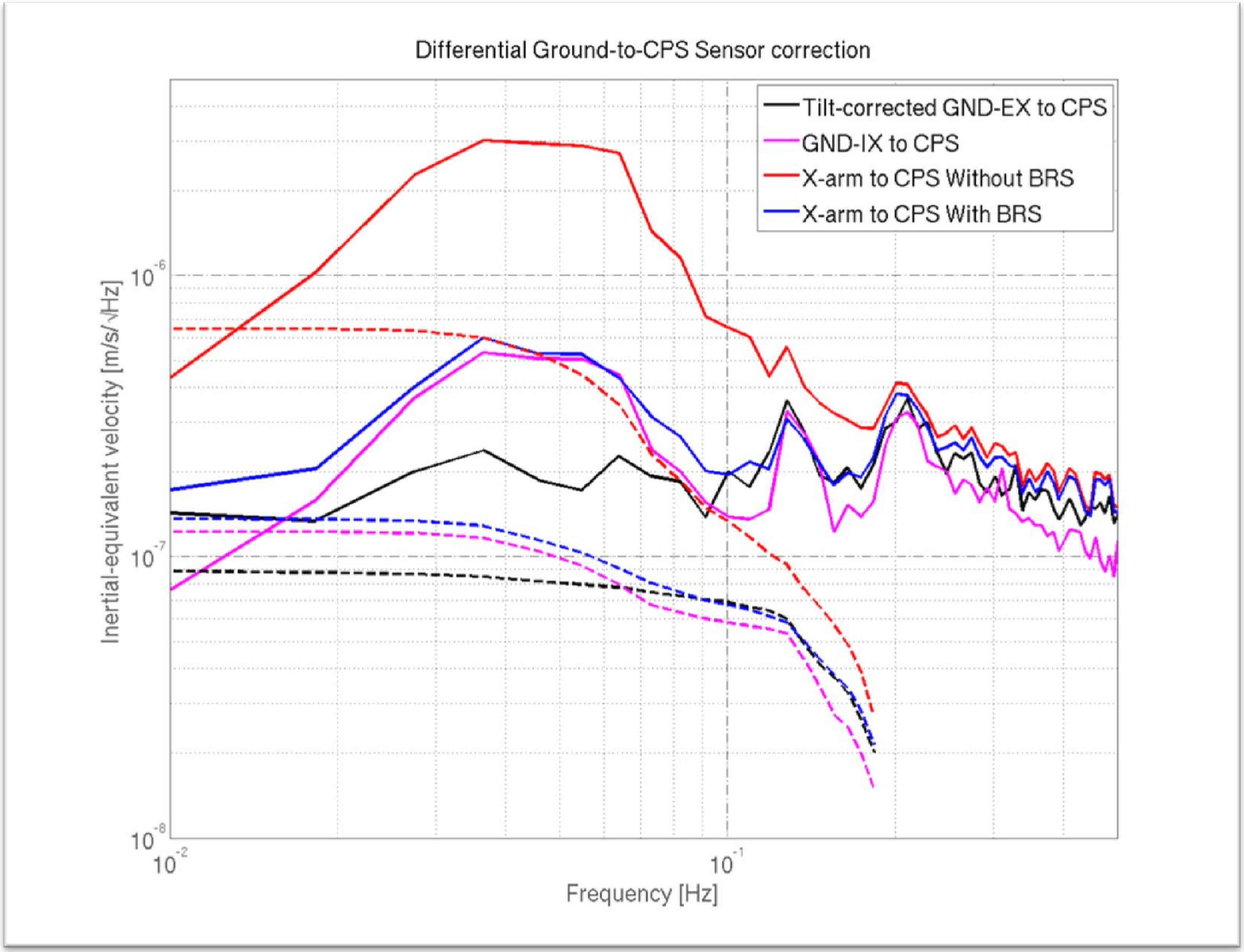
Sensor Correction filter



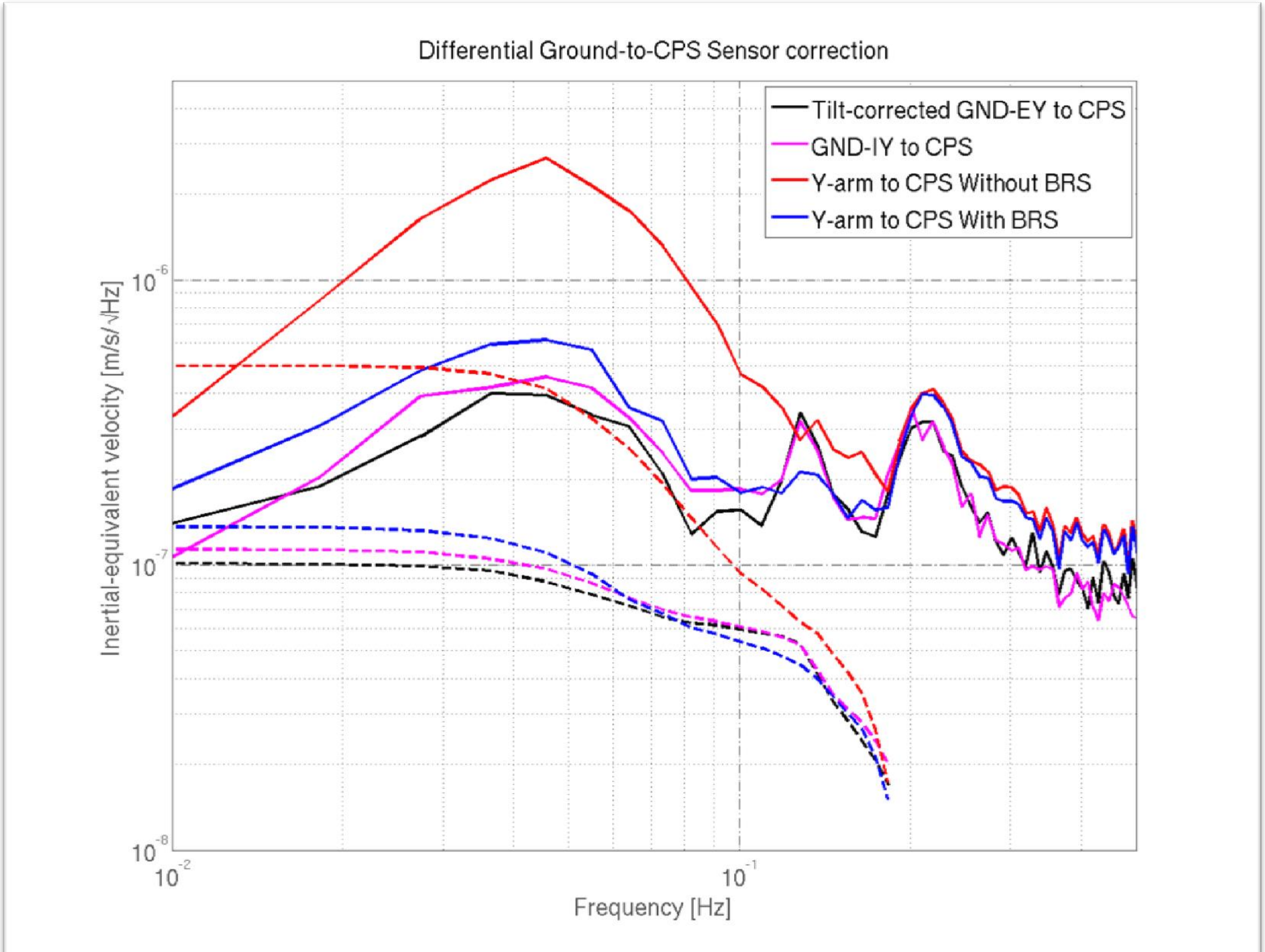
BRS impact, no wind (<4mph)



BRS impact, X-arm, high wind (~25 mph)



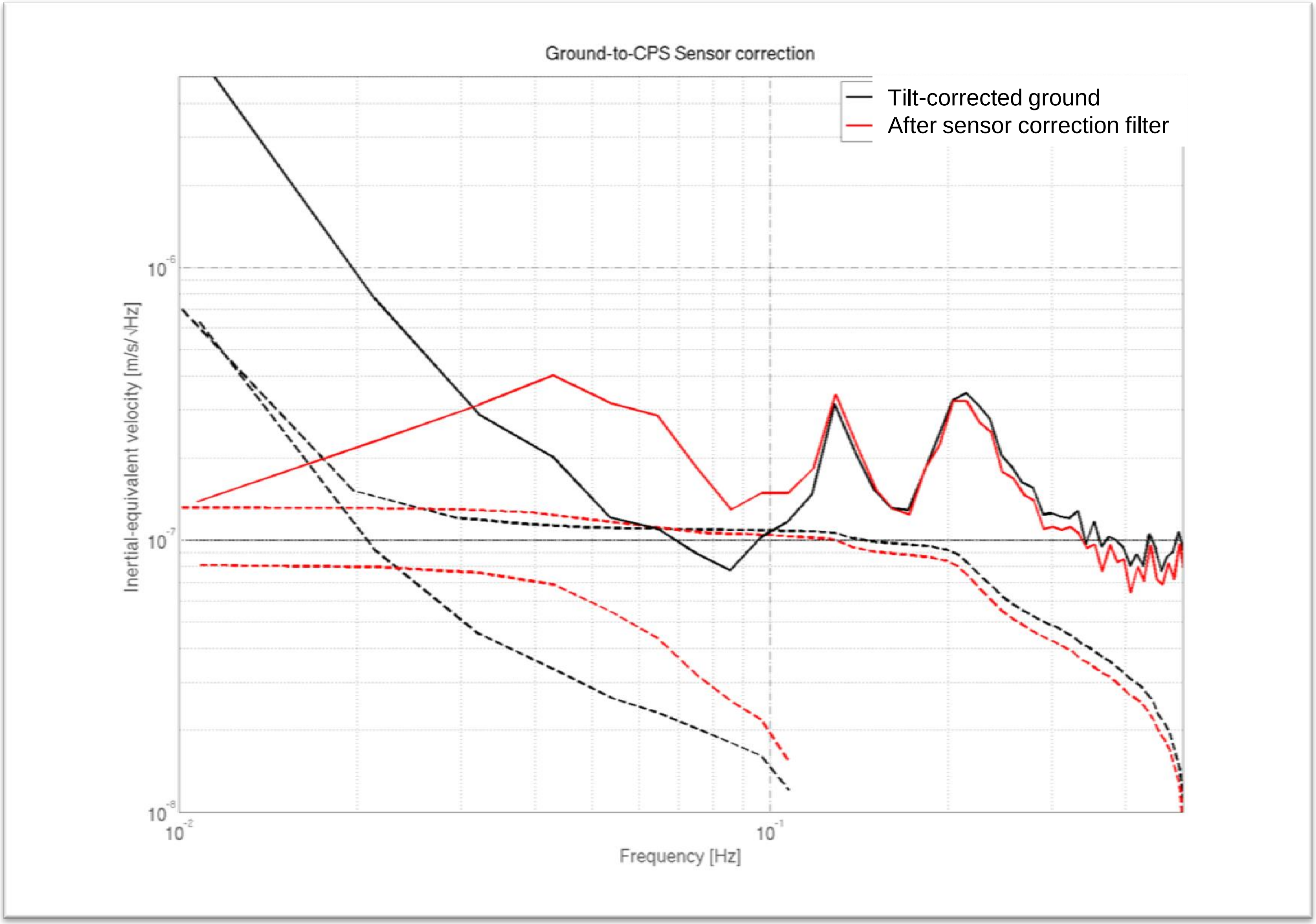
BRS impact, Y-arm, high wind (~25 mph)



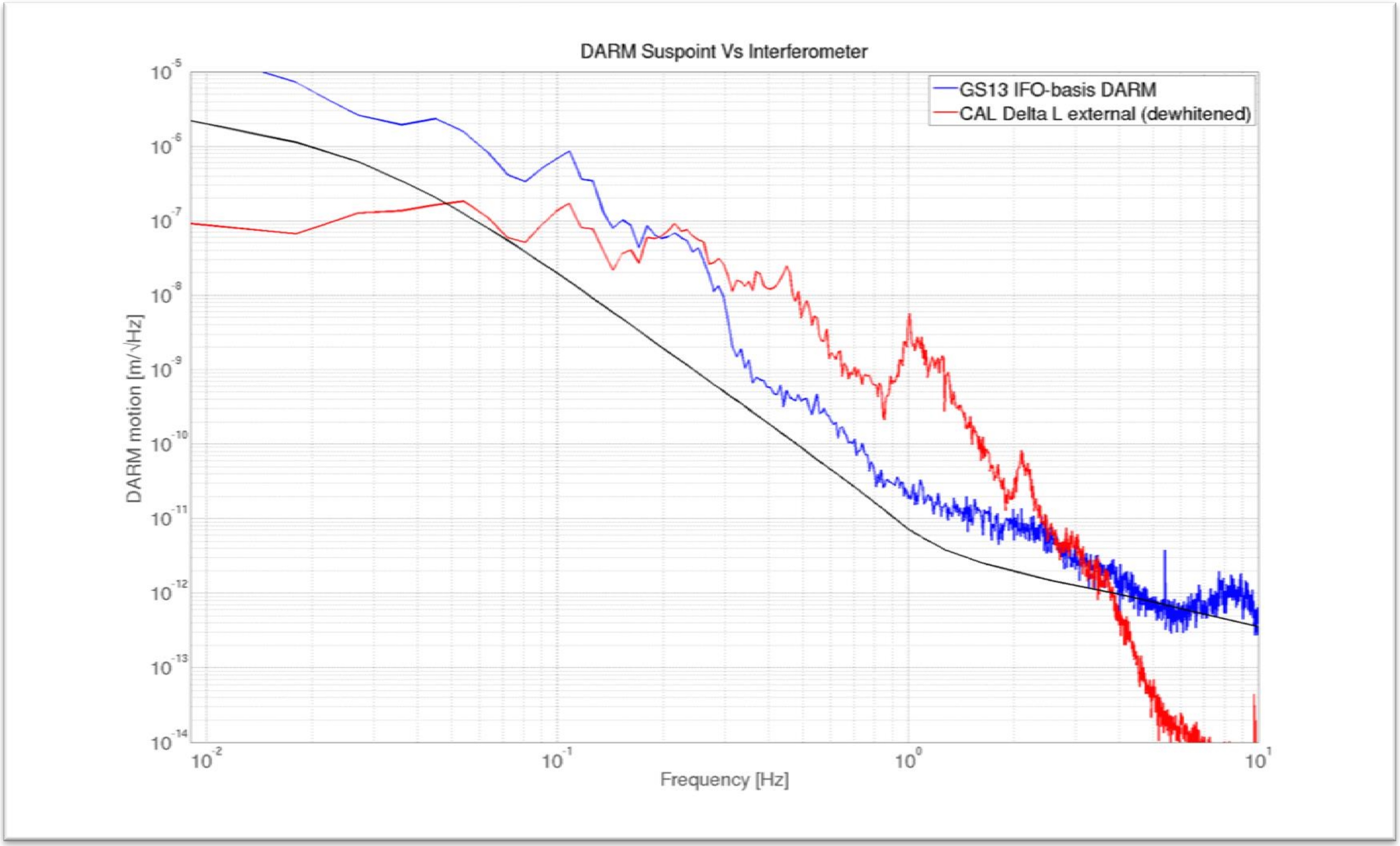
Conclusions

- The BRS does no harm, even with no wind.
- At high winds, it provides ~a factor of 5 reduction in arm-length RMS velocity.
- The low-tilt corner station STS2 is nearly as good as tilt-corrected ETMY in pretty high winds.
- Identical Sensor correction filters in all corner-station horizontal-translation Stage-1 DoFs should result in substantially less differential motion.
- Sensor correction and blending should be tuned using real data with high microseismic motion.

Does Sensor Correction help? (yes)



IFO-basis seismic motion is useful!



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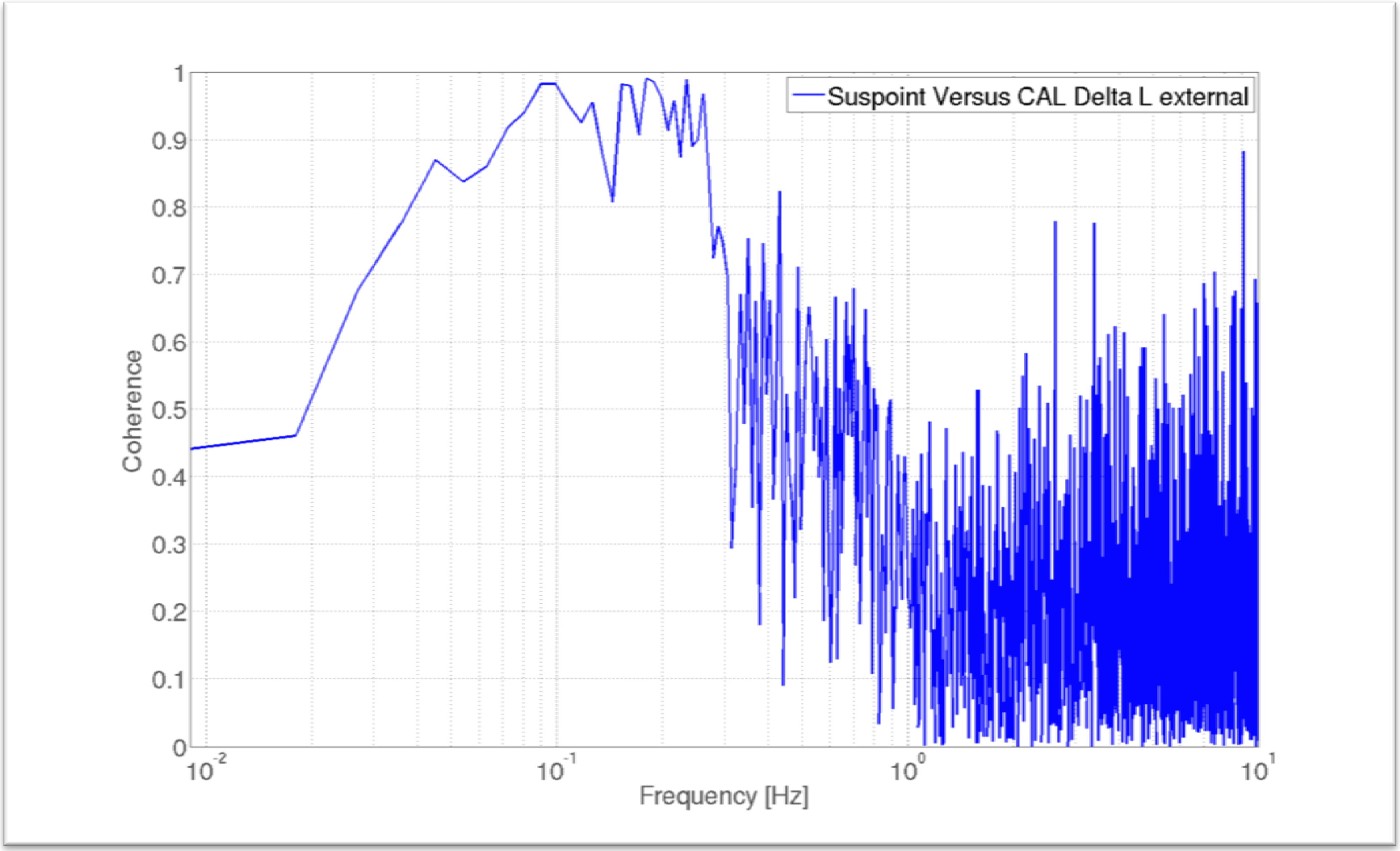
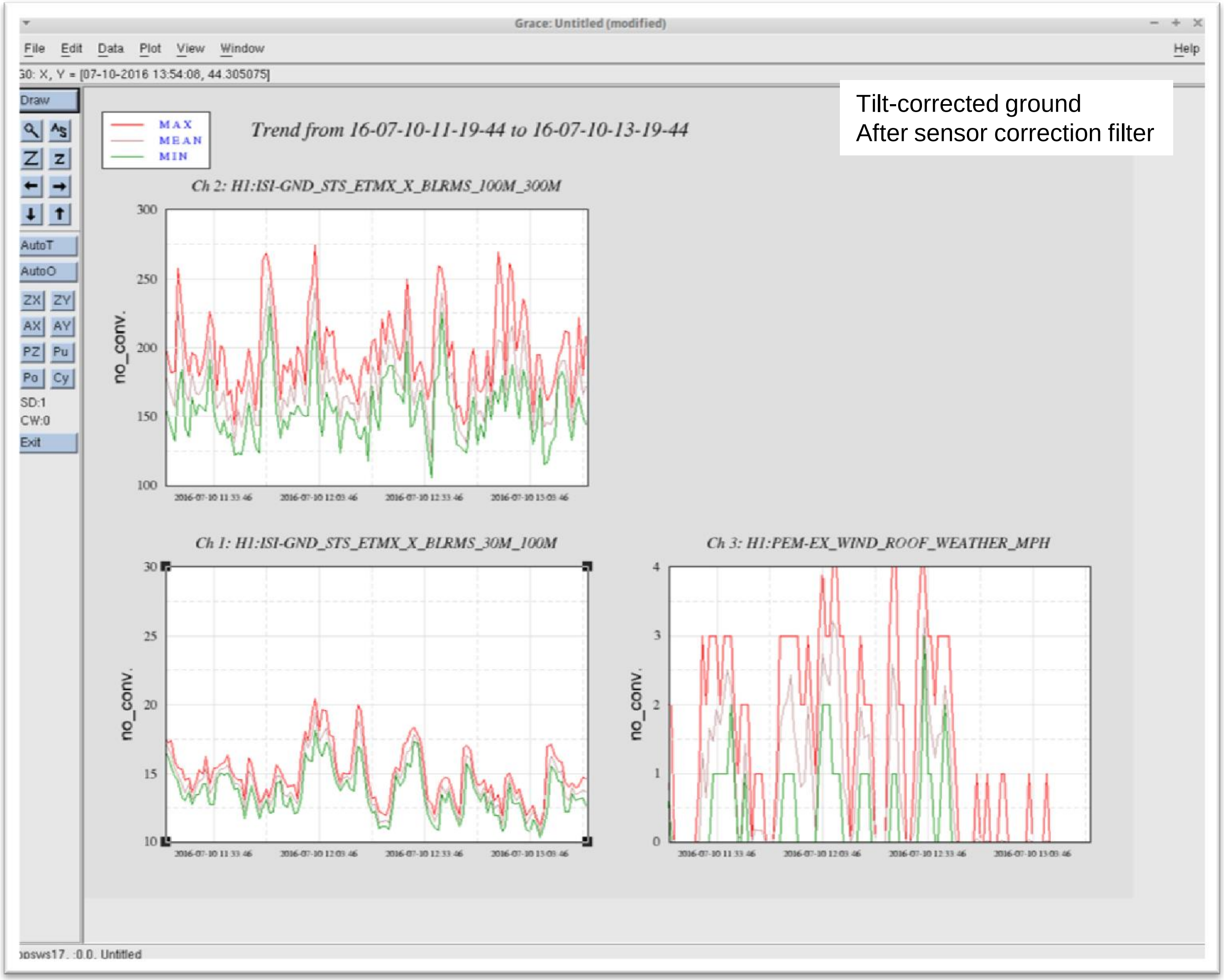
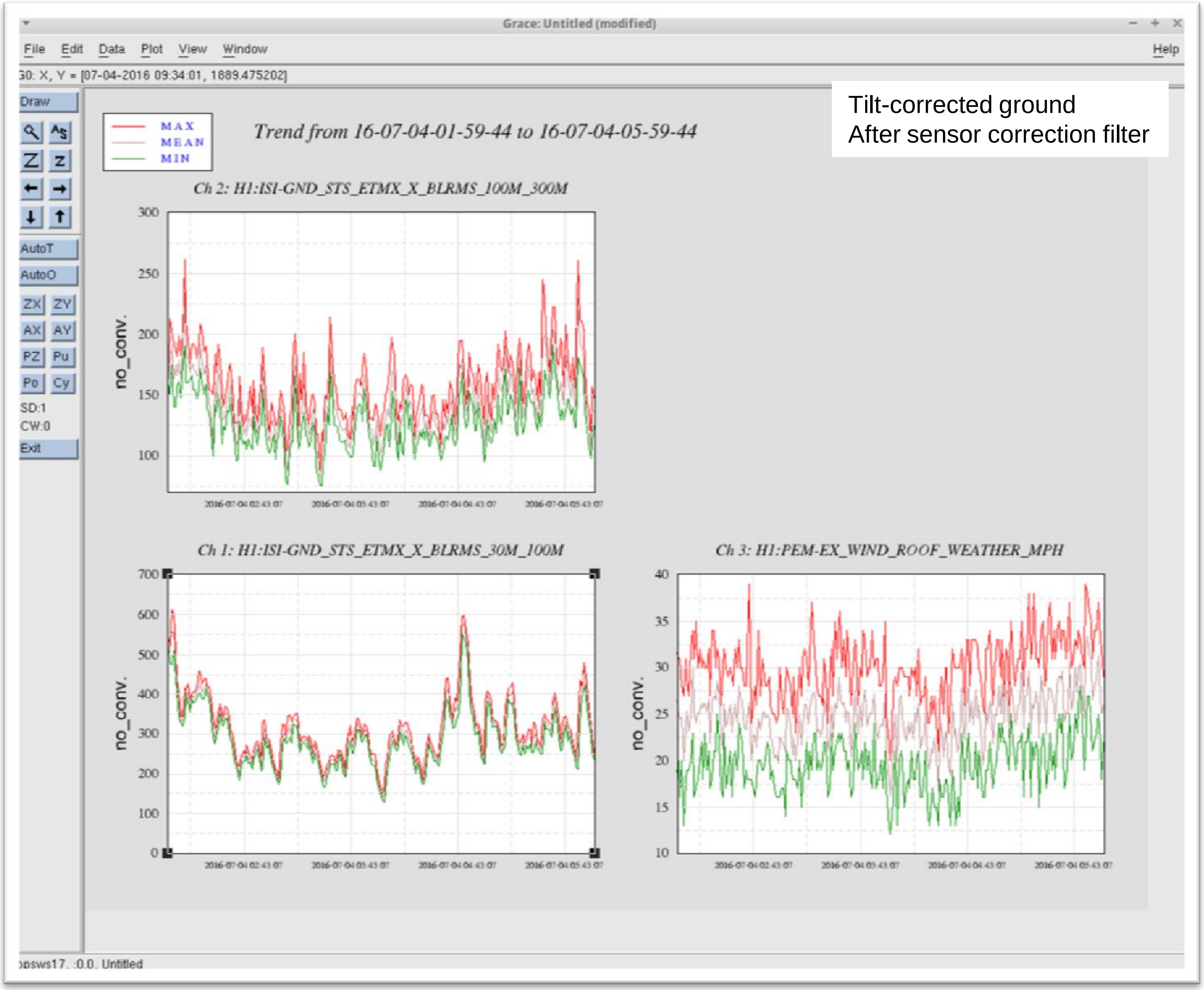


No-wind data


Grace: Untitled (modified)
File Edit Data Plot View Window Help
G0: X, Y = [07-10-2016 13:54:08, 44.305075]
Tilt-corrected ground
After sensor correction filter
MAX
MEAN
MIN
Trend from 16-07-10-11-19-44 to 16-07-10-13-19-44
Ch 2: H1:ISI-GND_STS_ETMX_X_BLRMS_100M_300M
Ch 1: H1:ISI-GND_STS_ETMX_X_BLRMS_30M_100M
Ch 3: H1:PEM-EX_WIND_ROOF_WEATHER_MPH
no_conv.
Draw
AutoT
AutoO
ZX ZY
AX AY
PZ Pu
Po Cy
SD:1
CW:0
Exit

High-wind data



Tilt-corrected ground
After sensor correction filter