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Exploring the sensitivity of satellite gravimetry to temporal aliasing errors

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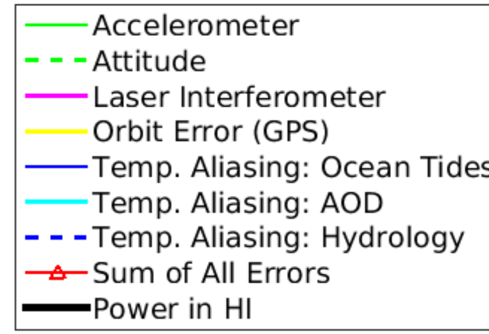
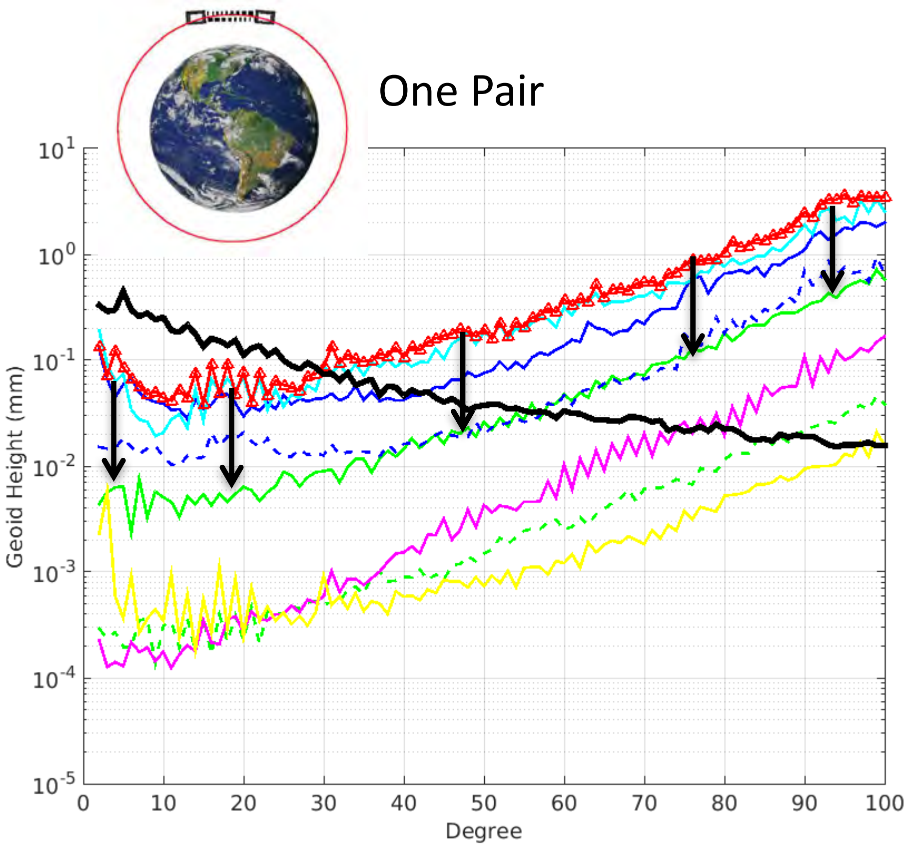
Austin, Texas

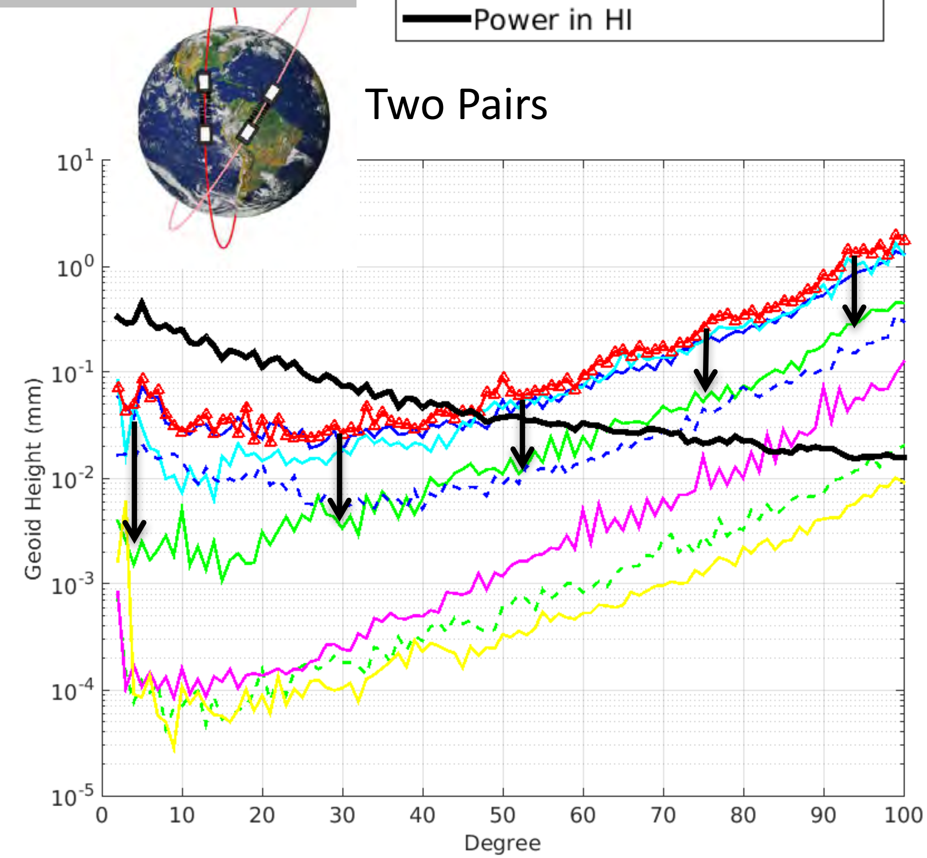
Simulation Results: **500 km altitude**, 300 km separation, GRACE-FO measurement errors

Temporal aliasing errors are dominant for single and dual-pair architectures

Can we reduce aliasing error to here?







How can we reduce temporal aliasing errors?

1) Improve background force models

2) Co-estimate parameters

3) Sample the gravity field more frequently

Multi-pair LL-SST

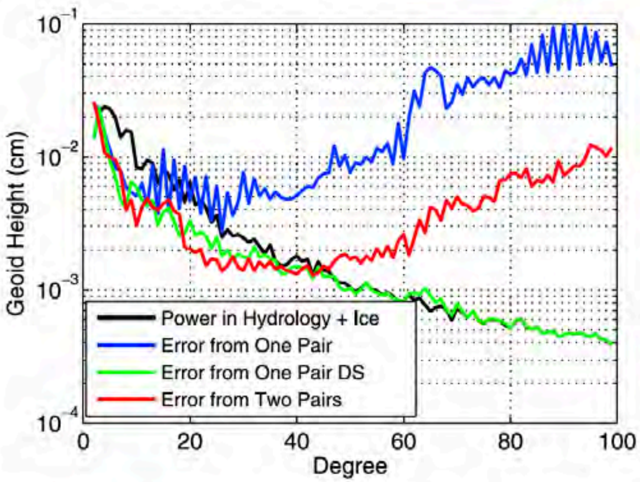
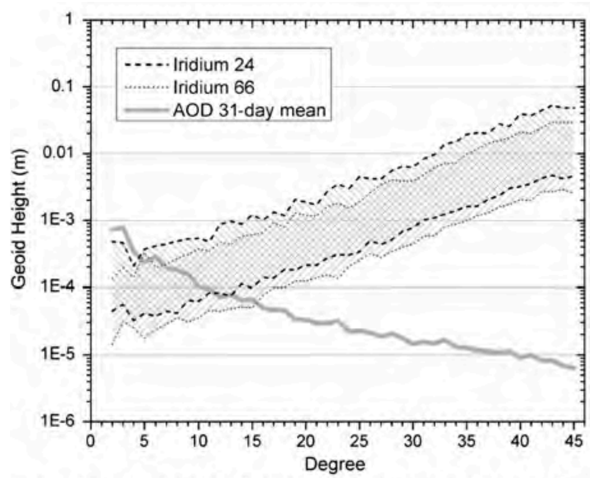


Figure 4. Geoid degree error for architectures consisting of one and two pairs of satellites.

Wiese et al., 2011b

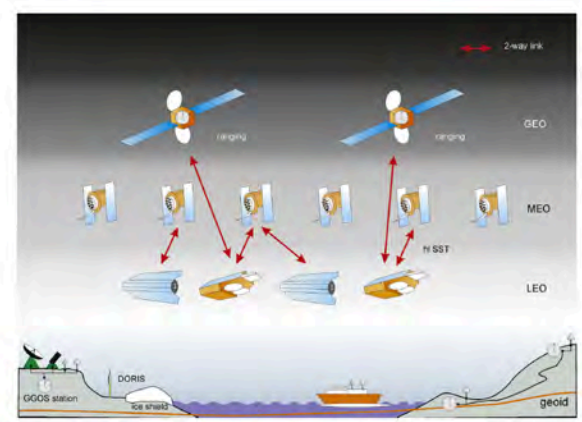
Constellation of GNSS receivers



ig. 6 Degree variances of the total error bands for the 31-day Iridium 24- and 66-satellite constellation simulations using assumptions for high and low measurement noise.

Gunter et al., 2011

GETRIS: HL-SST Concept



GETRIS constellation for gravity field recovery. The advantages can be seen in the LEO orbit which makes every mission he data link is also a high precision ranging link. This allows a continuous gravity field recovery with high temporal resolut

Hauk et al., 2016

Goal: Identify an observing system for which temporal aliasing errors are not the limiting source of error in recovering time variable gravity

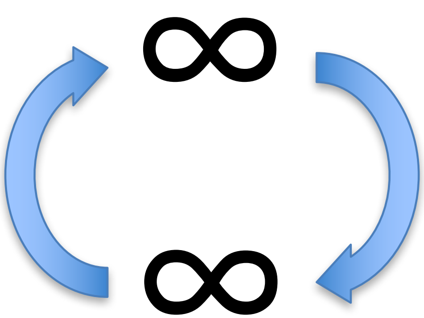
Select constellations of LL-SST, HL-SST, or GPS-receivers

↓

Run numerical simulations

↓

Analyze output



Assume we have an observing system that perfectly measures temporal gravity variations at specific spatial/temporal scales

↓

Modify our definition of temporal aliasing error to reflect this new knowledge

↓

Run numerical simulations with this modified aliasing error to ***understand the sensitivity of the gravity recovery process to the addition of new information***

Simulation Setup

	Truth Model	Nominal Model
Static Gravity Field	gif48	gif48
Ocean Tides	GOT4.7	FES04
Atmosphere/Ocean	"AO"	AOerr+DEAL
Hydrology/Ice	"HI"	--

AOHIS 3-hr temporal res. *Dobslaw et al*. 2015

- 29-day simulation
  - January 2006
- Mission Architectures
  - Single Polar Pair
  - Polar Pair + Lower Inclined Pair (72°)
- Altitudes
  - ~ 300, 500 km
- Separation Distance:
  - 300 km
- All satellites are in exact 29-day repeat orbits
- Simulation carried out to n = 100

Instrument noise models

- Laser (LRI) GRACE-FO Requirement
  - RMS of 10.88 nm/s
- Accelerometer GRACE-FO CBE

Alongtrack, Radial: $3.21\times10^{-11}\sqrt{1+\frac{.01}{f}+20f^4}$ m/s²/Hz$^{1/2}$

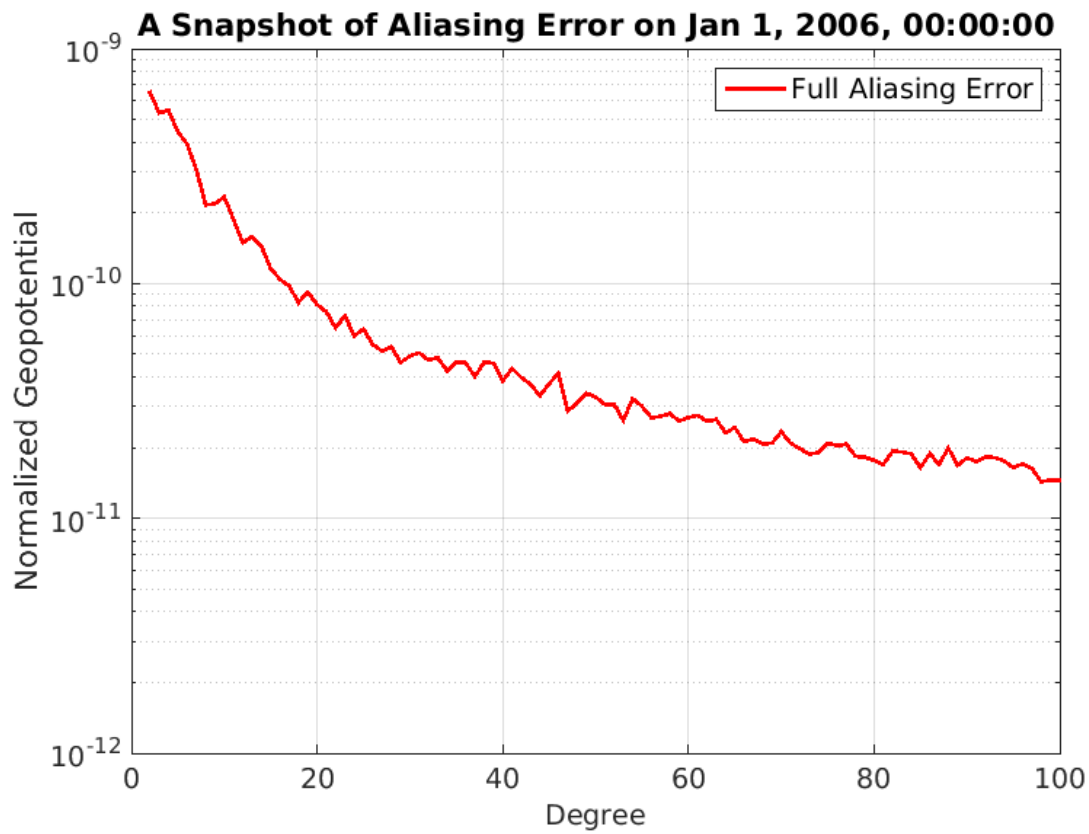
Crosstrack: $4.75\times10^{-10}\sqrt{1+\frac{.01}{f}+5\times10^{-4}f^4}$ m/s²/Hz$^{1/2}$

- Attitude GRACE-FO Requirement
  - Impacts ONLY accelerometer error, not MWI or LRI pointing

Pitch, Roll: 2.1×10^{-5} rad/Hz$^{1/2}$

Yaw: 1.7×10^{-4} rad/Hz$^{1/2}$

- GPS data is mimicked by using satellite positions as observables
  - 1 cm white noise in 3-axes is added



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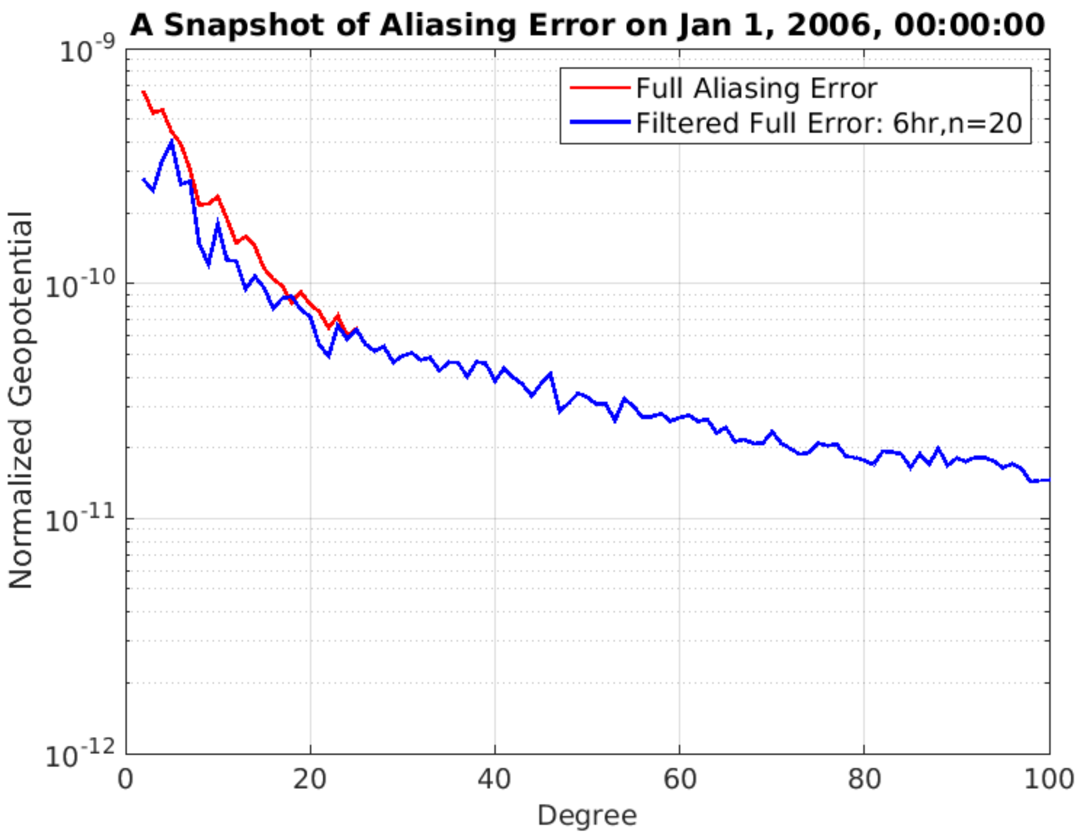

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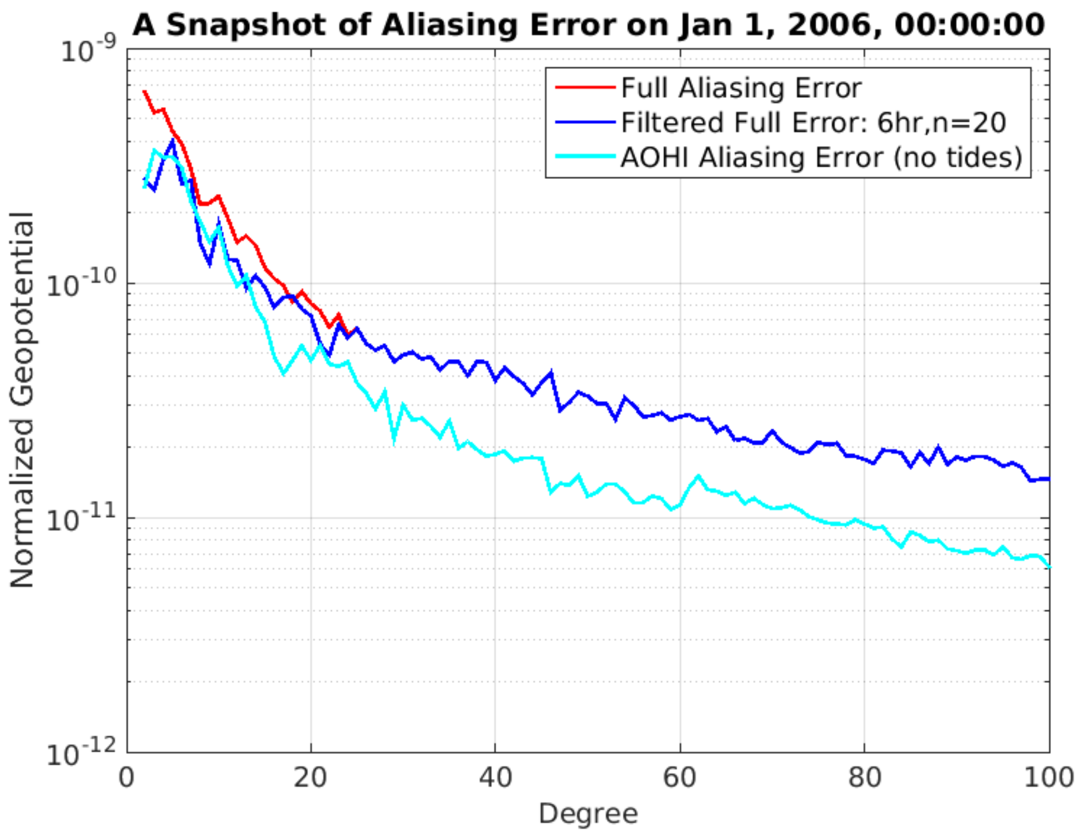

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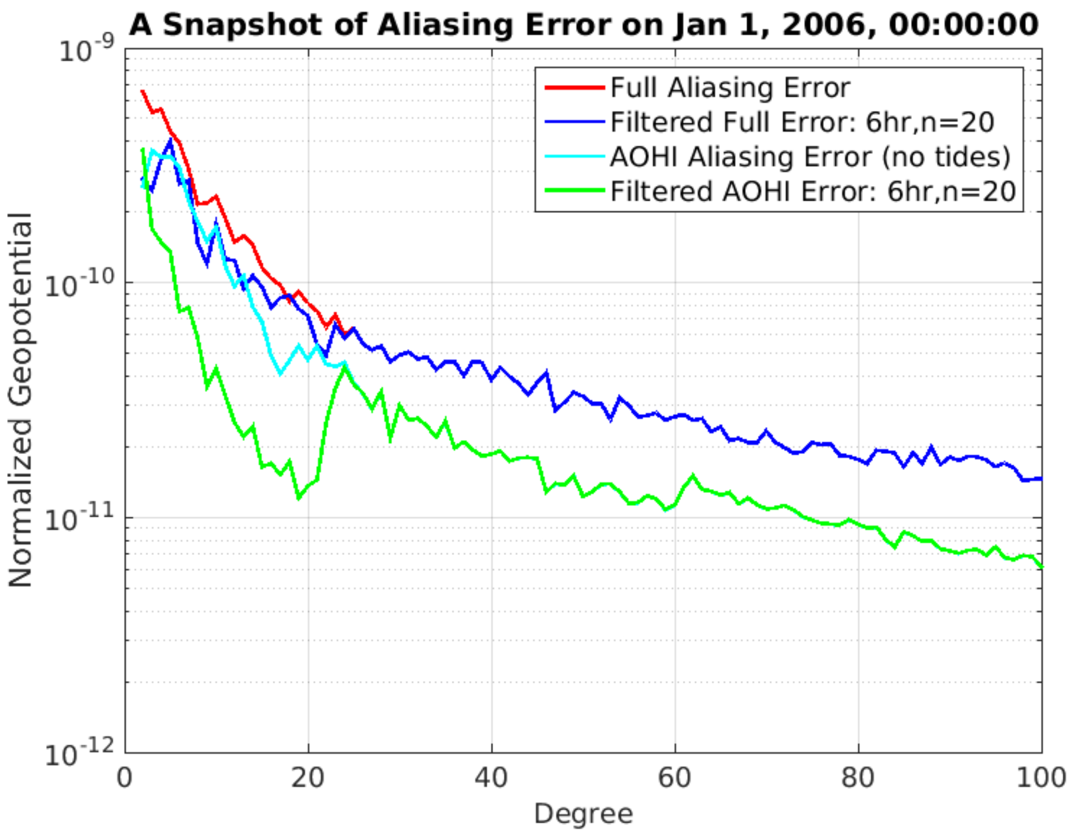

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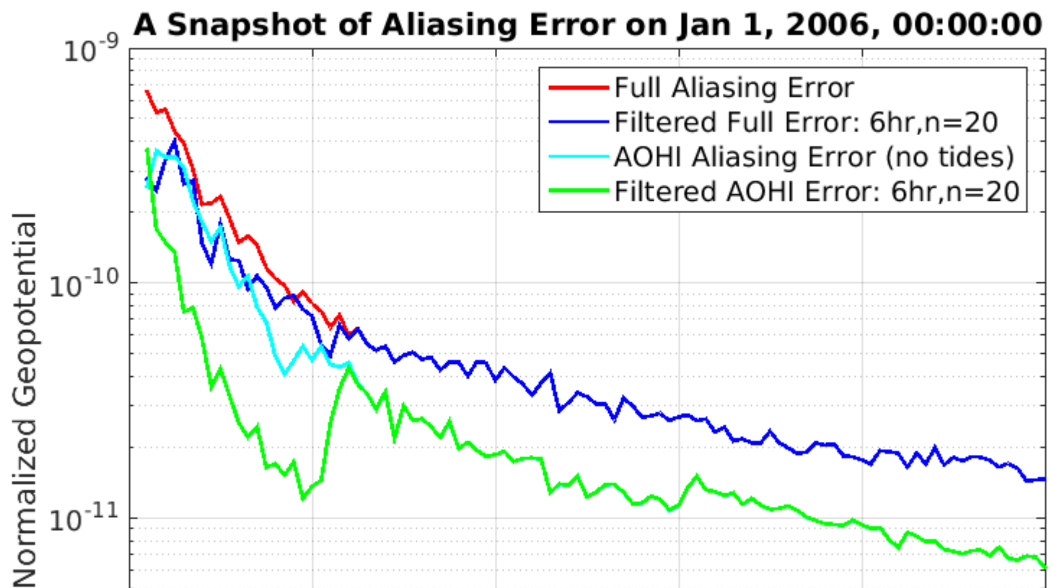

We assume that we have perfect knowledge of mass variations at time scales of **[6, 12, 24] hours** and at spatial scales of **n = [10, 20, 30]**.

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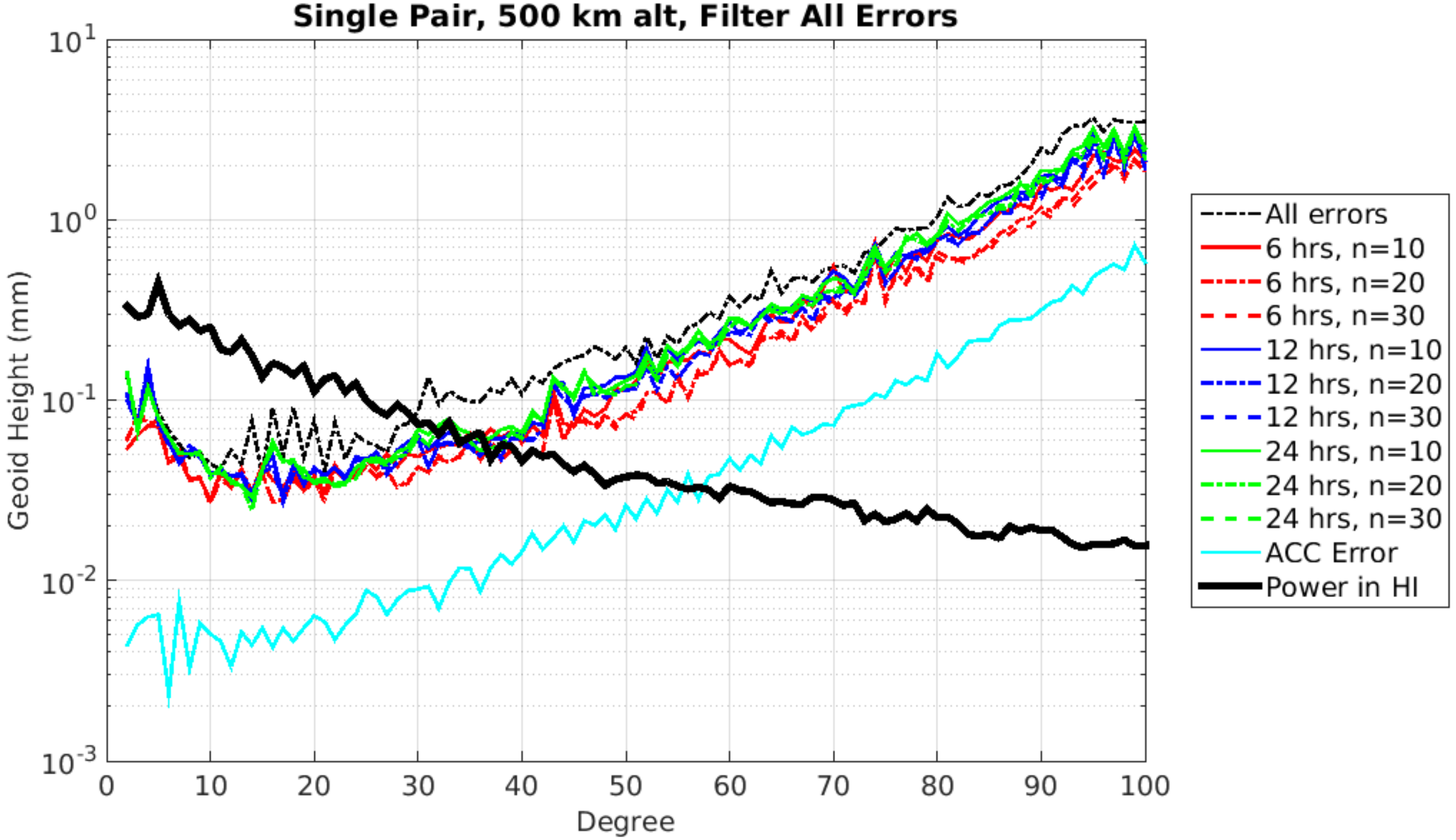
AOHIS 3-hr temporal res. *Dobslaw et al*. 2015

Architecture: One Pair
Altitude: 500 km
Aliasing: OT + AOHI



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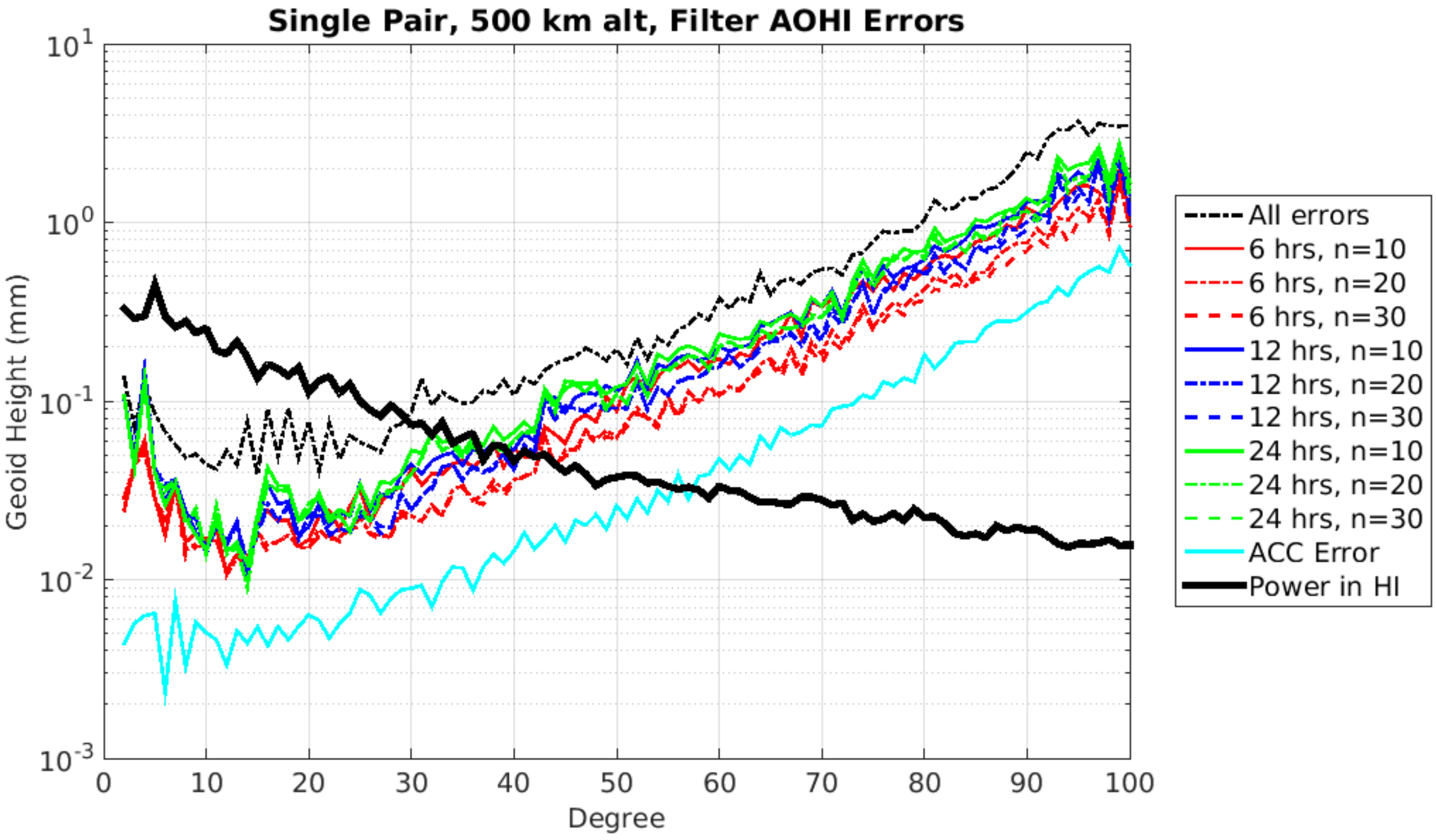

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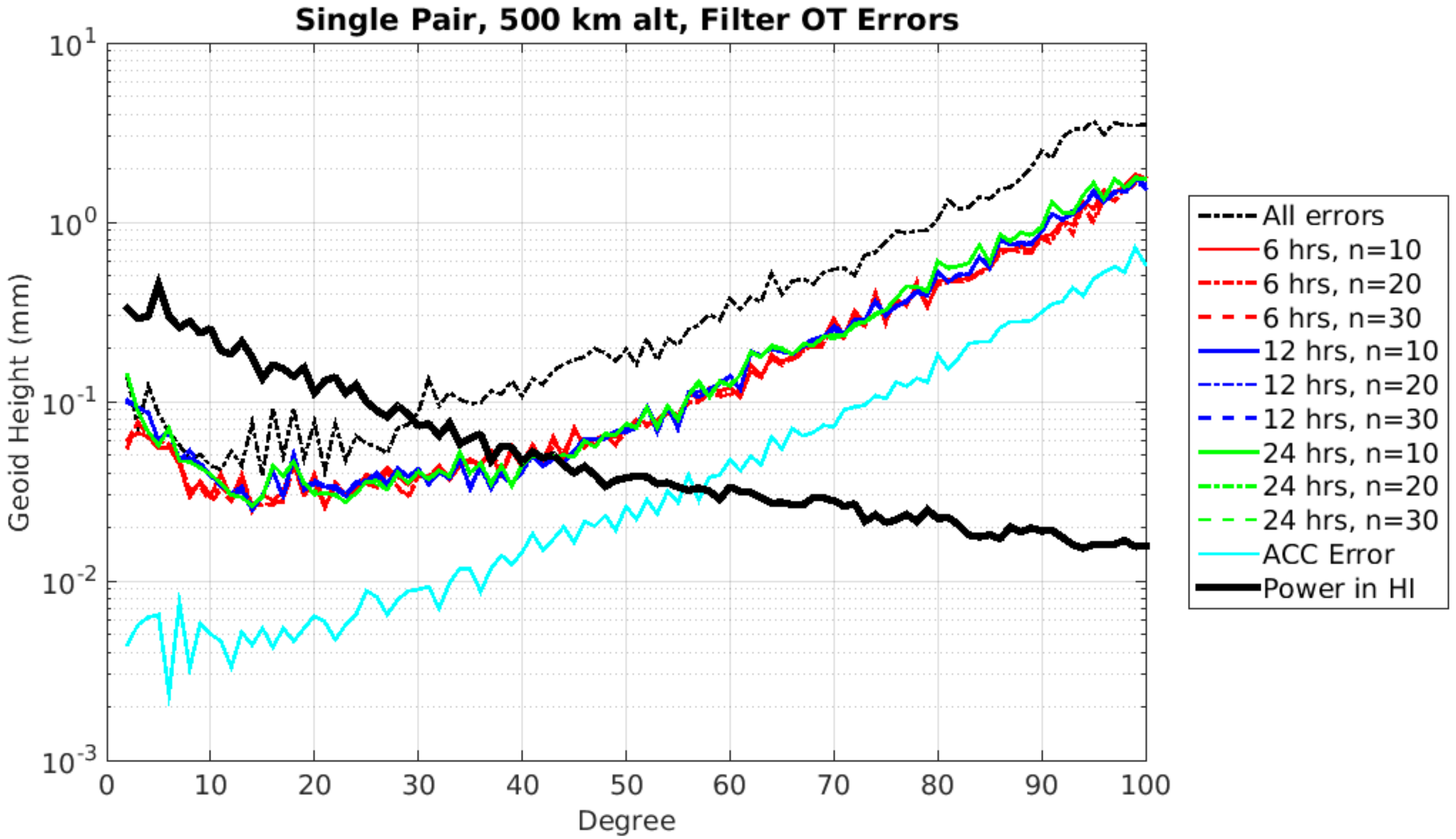
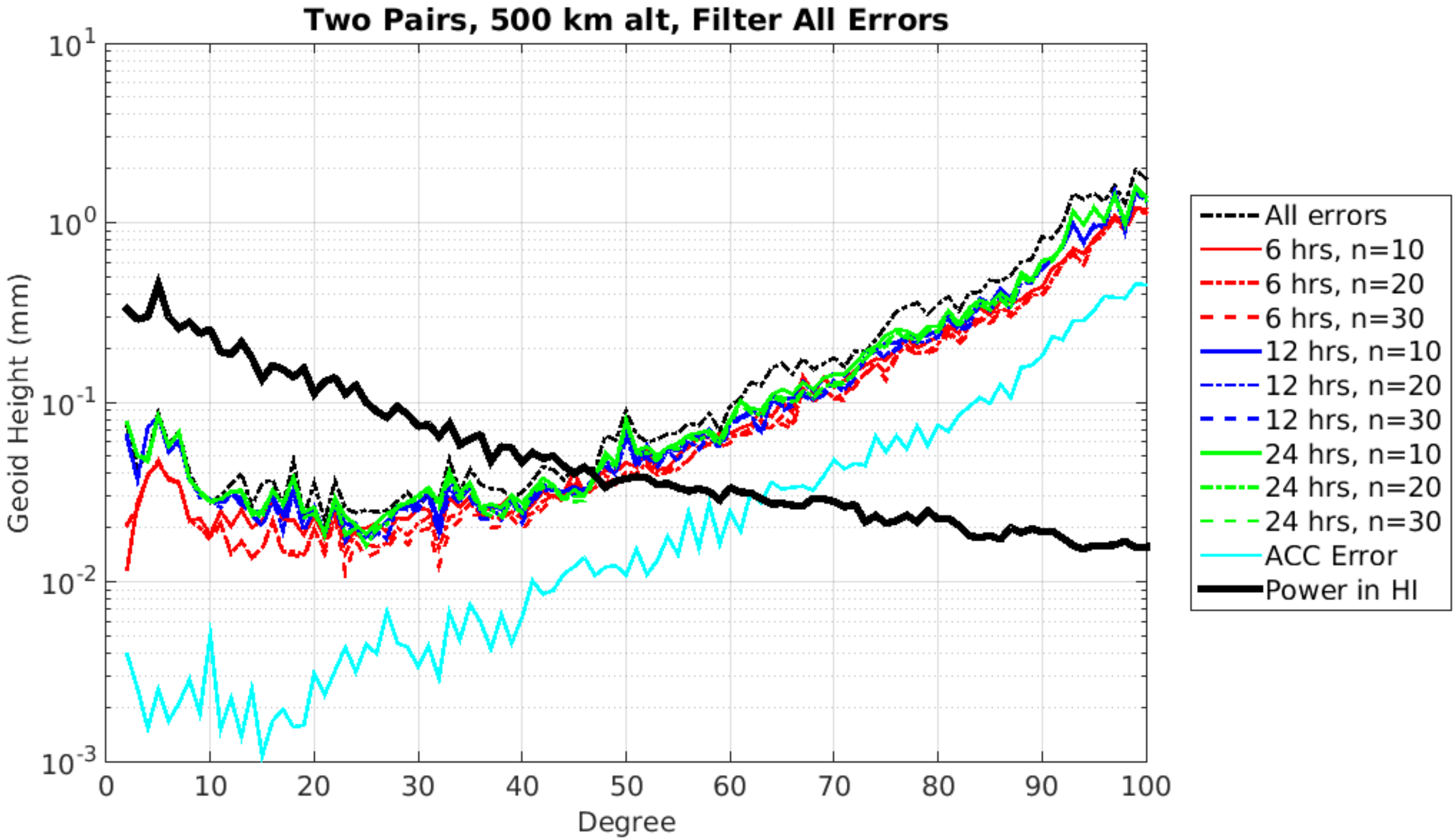
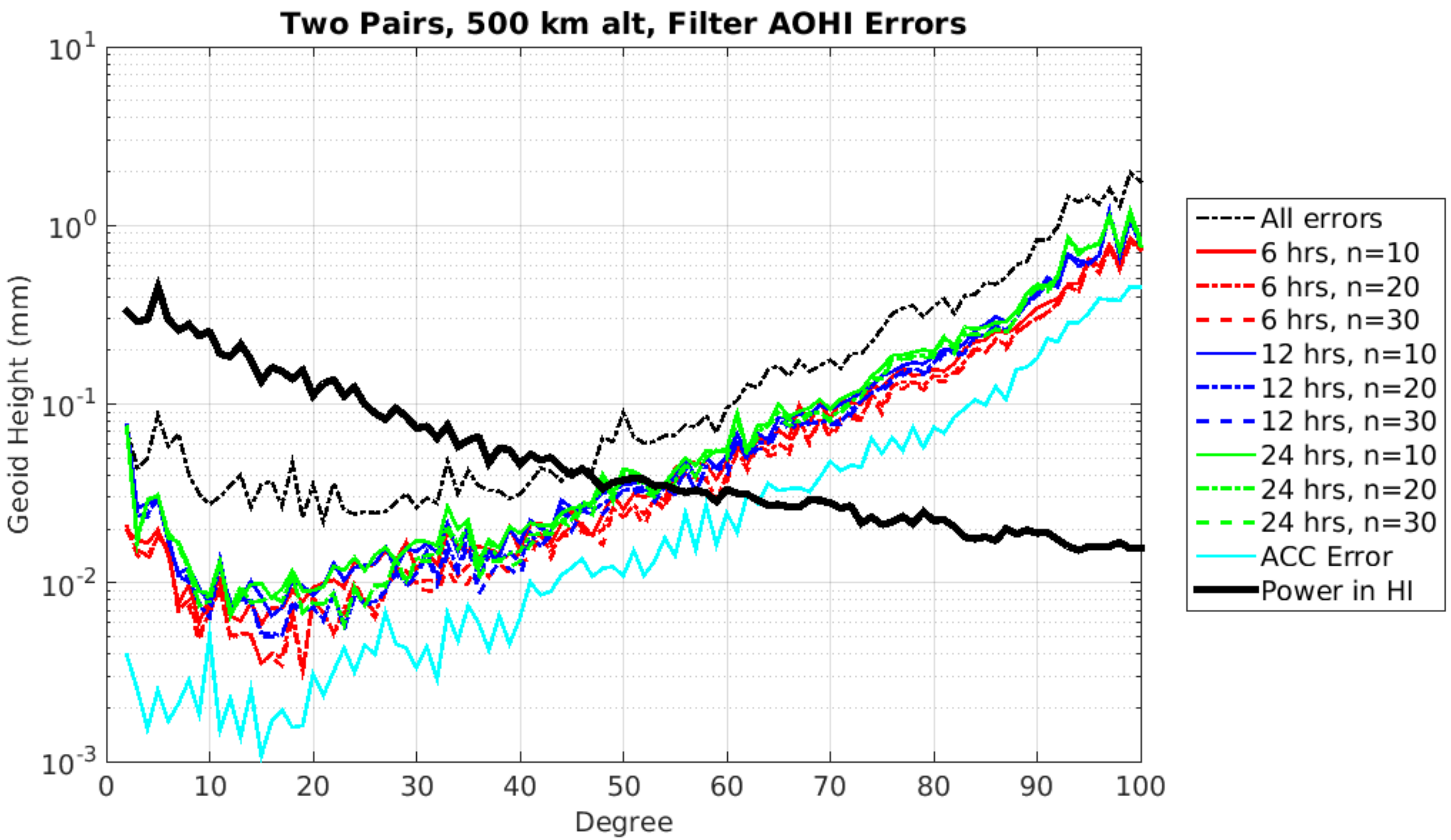


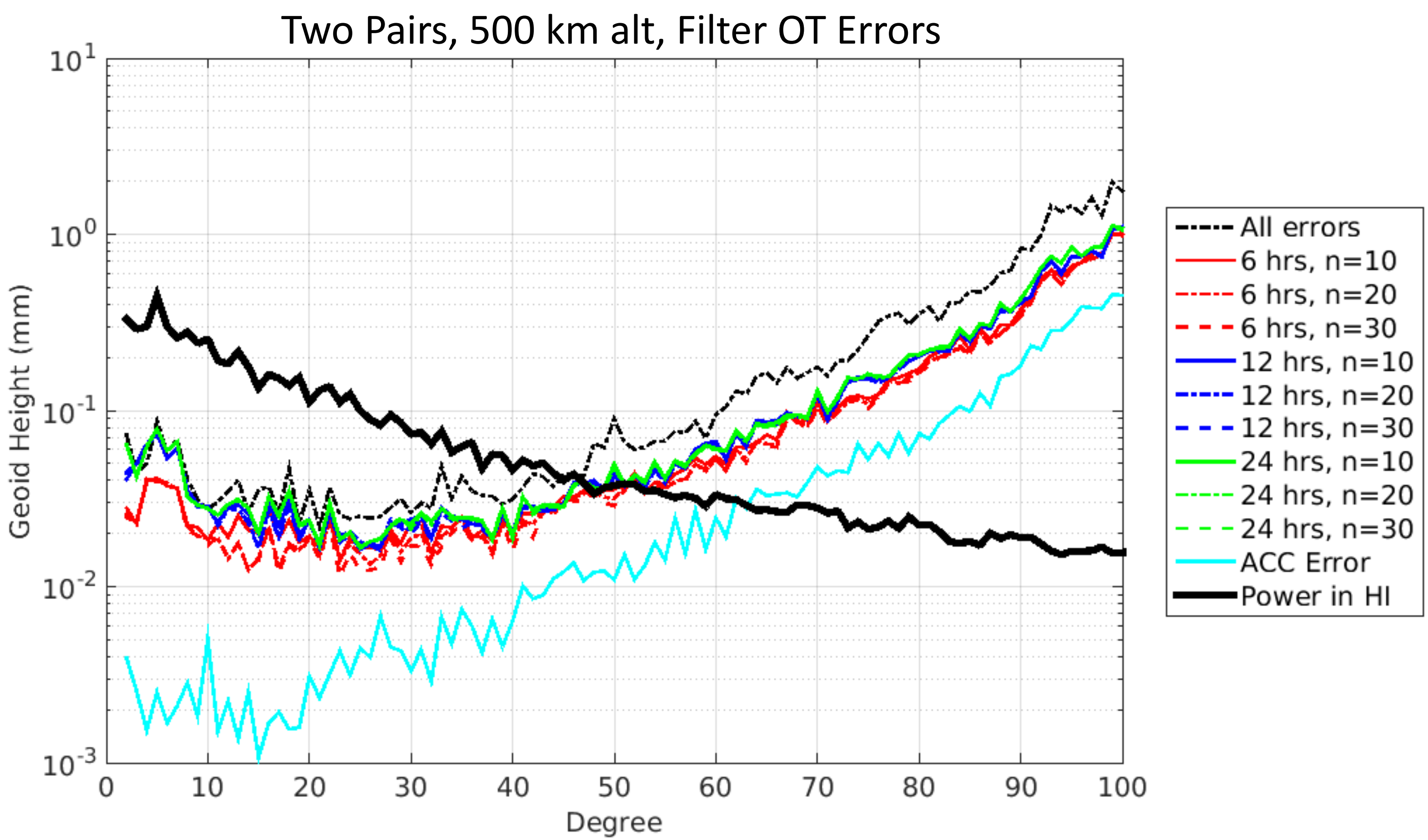
Architecture: Two Pairs
Altitude: 500 km
Aliasing: OT + AOHIS



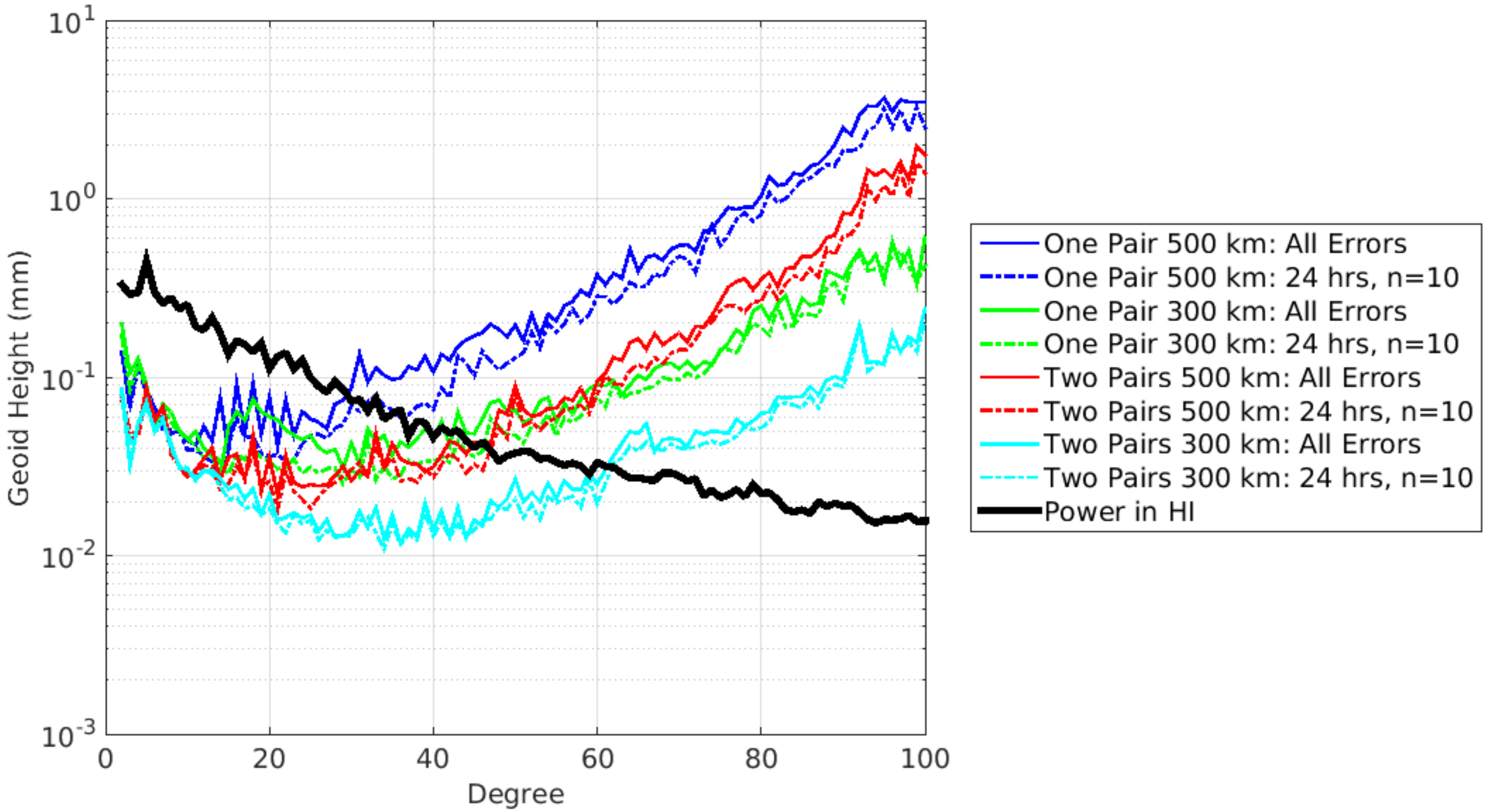
Architecture: Two Pairs
Altitude: 500 km
Aliasing: AOHI



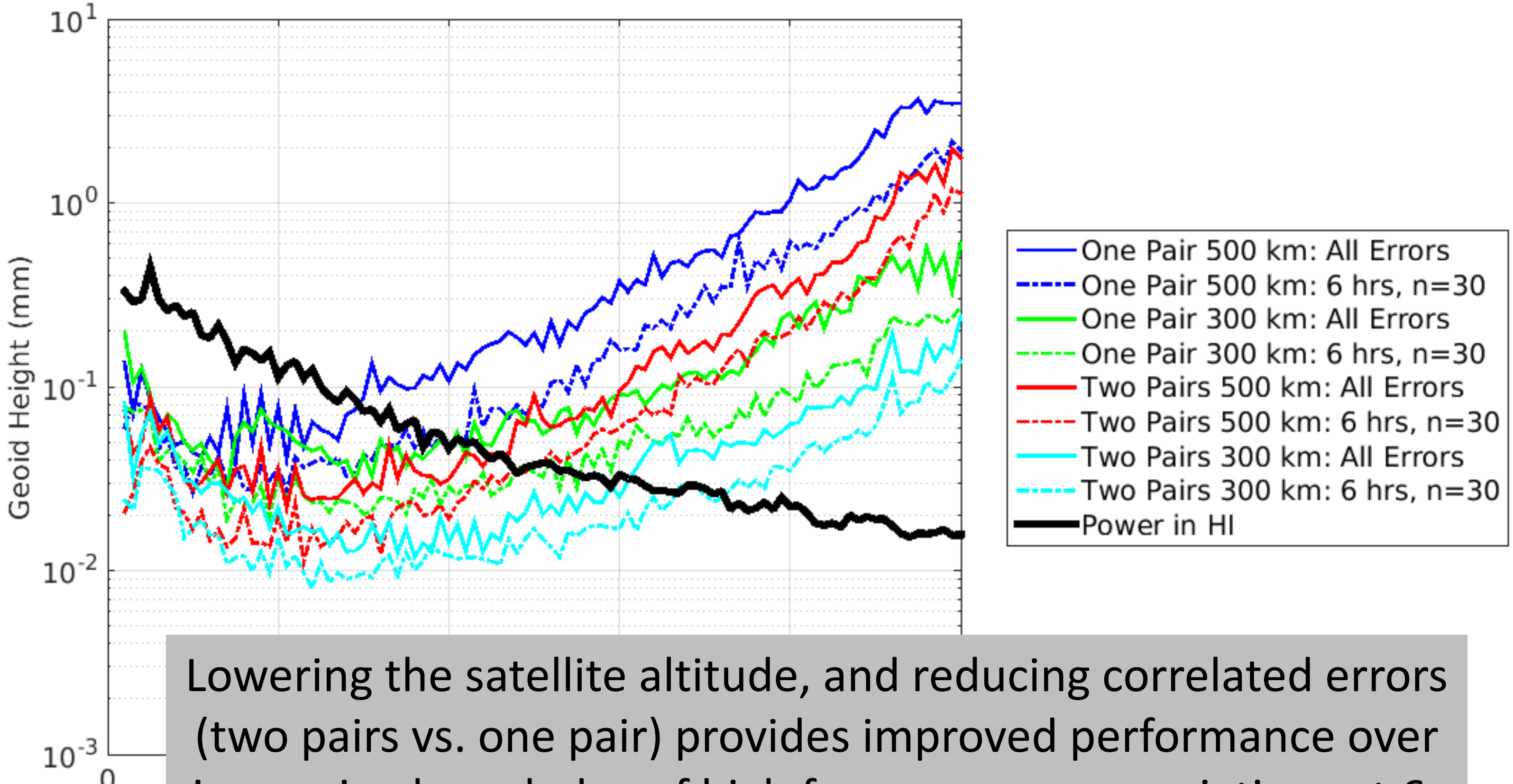
Architecture: Two Pairs
Altitude: 500 km
Aliasing: OT



Summary: Daily 10 x 10

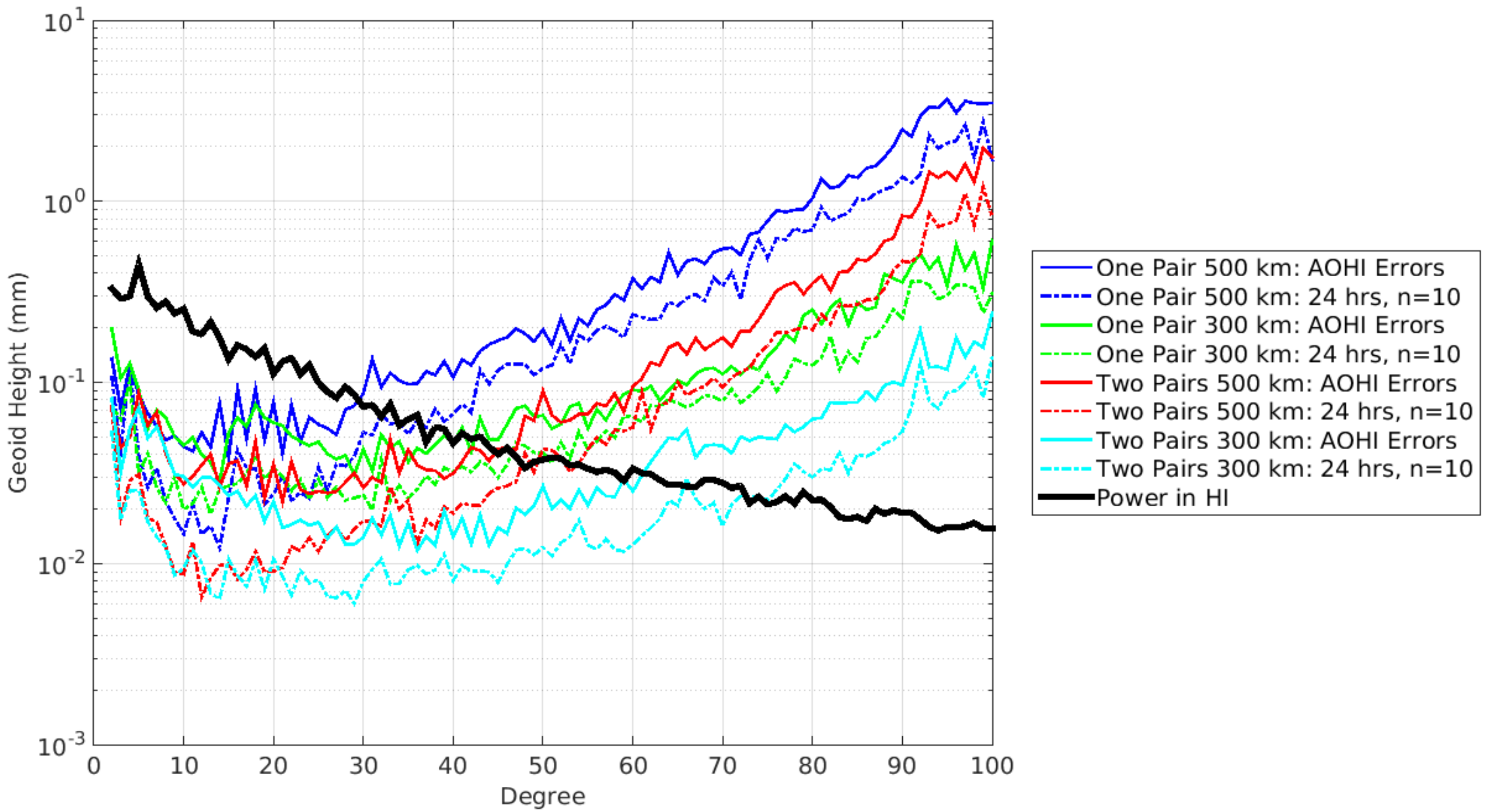


Summary: 6-hourly 30 x 30

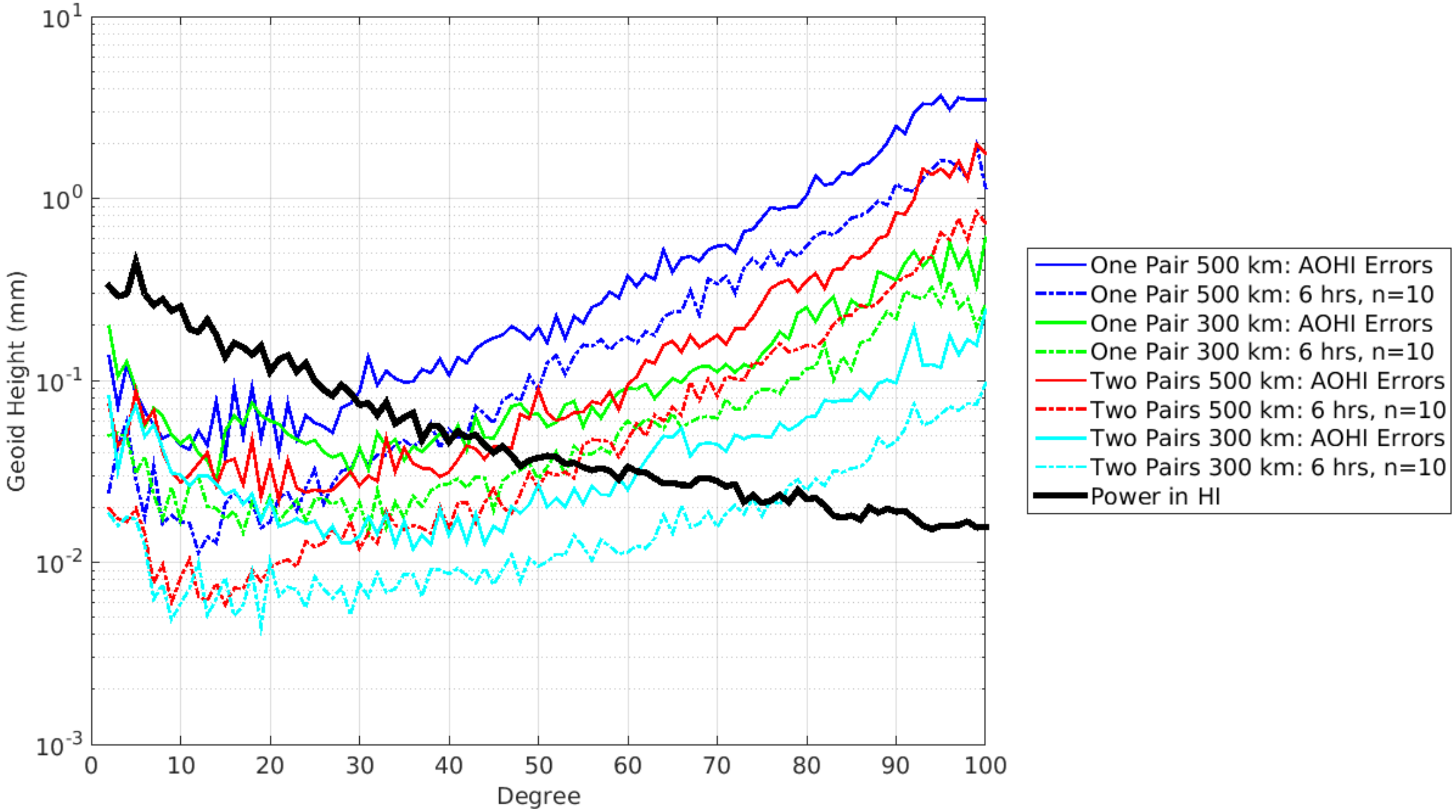


Lowering the satellite altitude, and reducing correlated errors (two pairs vs. one pair) provides improved performance over increasing knowledge of high frequency mass variations at 6-hourly, 667 km (n = 30) spatial scales

AOHI Errors Only: Daily 10 x 10



AOHI Errors Only: 6-hourly 10 x 10



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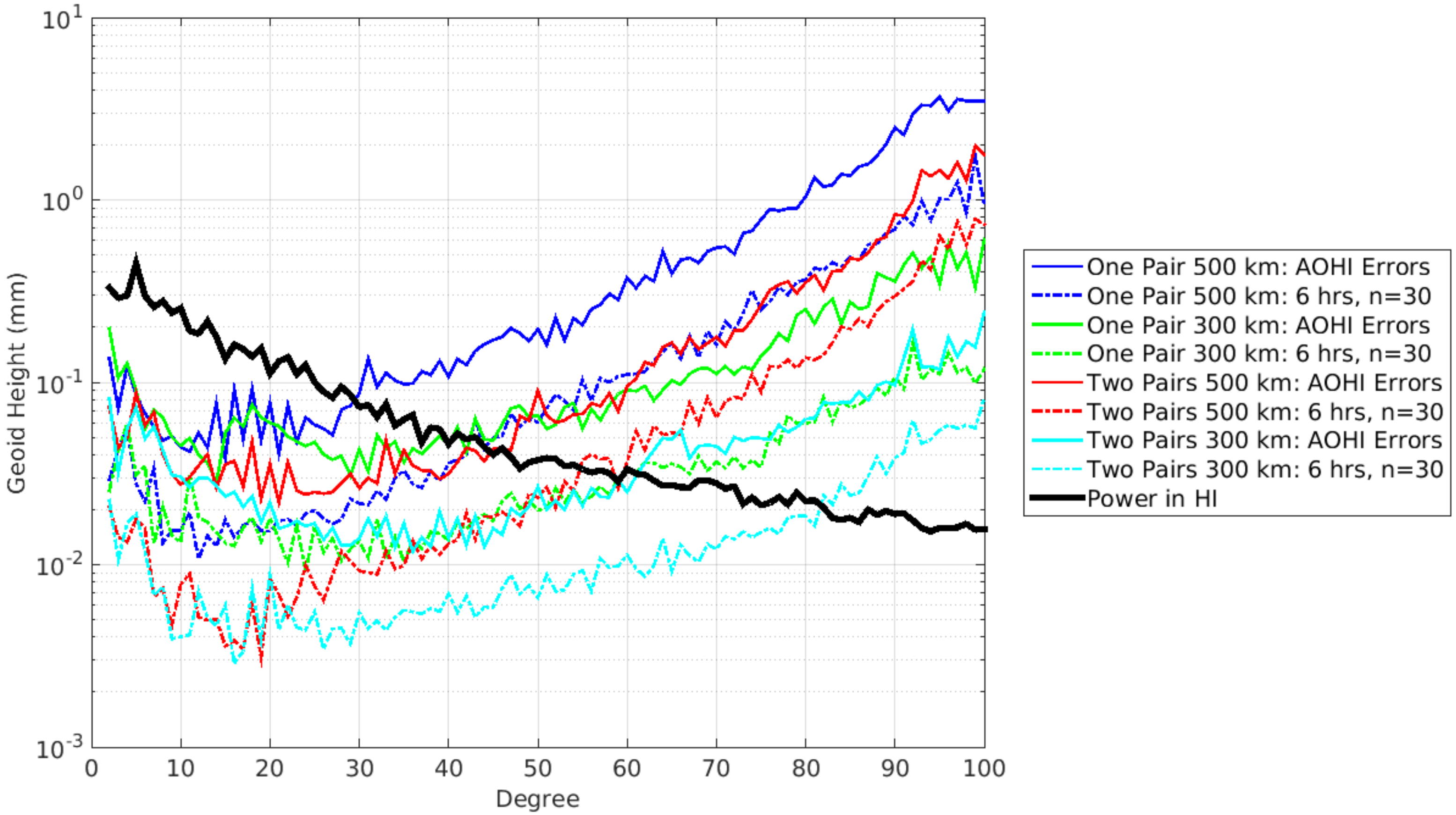

Summarizing Points

- Temporal aliasing errors at sub-6-hour time scales and small spatial scales (n > 30; 667 km) are still dominant errors in the gravity recovery process
  - Large improvements in knowledge of high frequency mass variations lead to modest improvements in our ability to improve the spatial resolution of monthly gravity field estimates
- Ocean tide errors are less sensitive than AOD errors to spatial/temporal resolution of improvement in knowledge
  - This thought experiment was designed to target AOD aliasing error reduction more than ocean tide aliasing errors
  - Likely need to co-estimate ocean tides concurrently with the gravity field reduce aliasing error
- Reducing correlated error, as well as lowering the satellite altitude, has a greater impact than reducing temporal aliasing errors as examined in this study
- Speculative: Current level of performance of the accelerometers appears to be adequate for the foreseeable future, as aliasing errors will likely continue to dominate