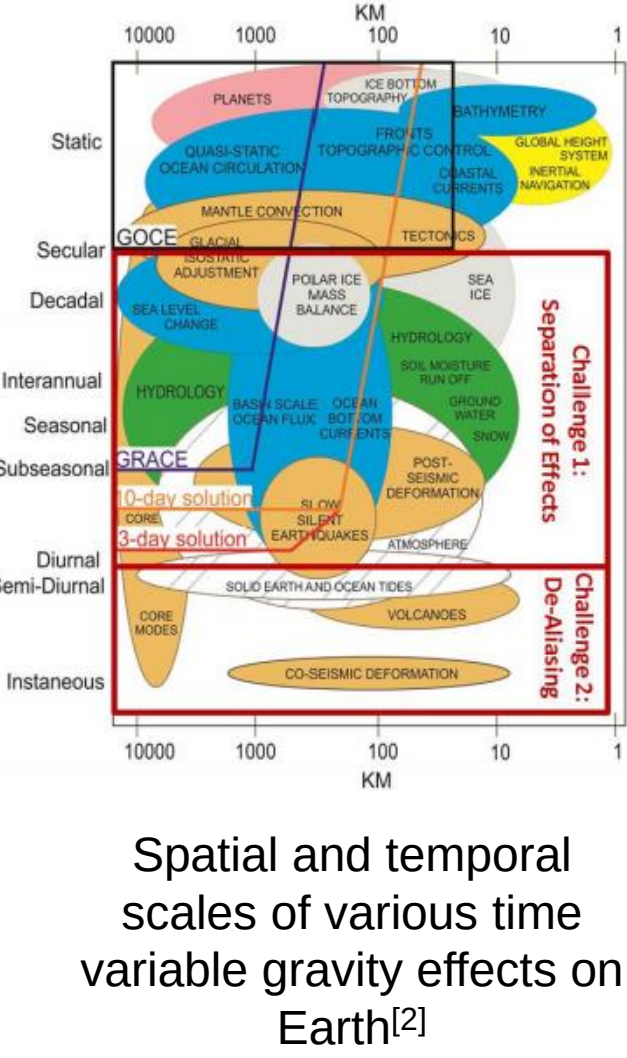


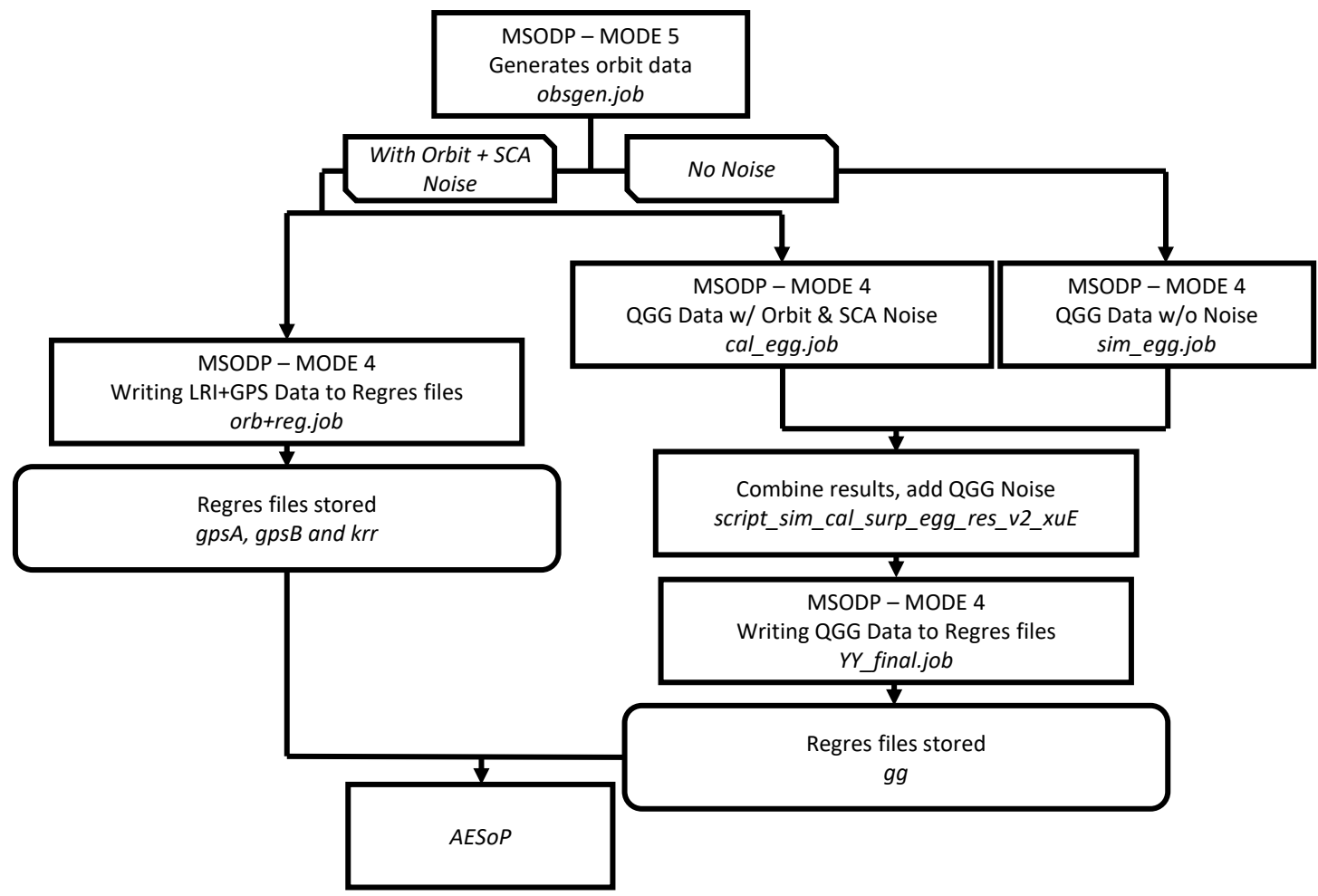
Introduction:

The GRACE missions use Satellite-to-Satellite (SST) tracking and GPS data to create an estimate for the Earth's time variable gravity field. Recent advances in Quantum Gravity Gradiometers (QGG) are expected to achieve sensitivity levels capable of providing unique information on high-resolution through in situ measurements^[1]. With a sufficiently sensitive QGG on one satellite in a GRACE-FO-like mission, improvements in gravity field recovery are expected to be concentrated in medium and small spatial scales. These improvements will allow for targeting climate science domains inaccessible to GRACE-FO, including Hydrometeorology and ocean dynamics.



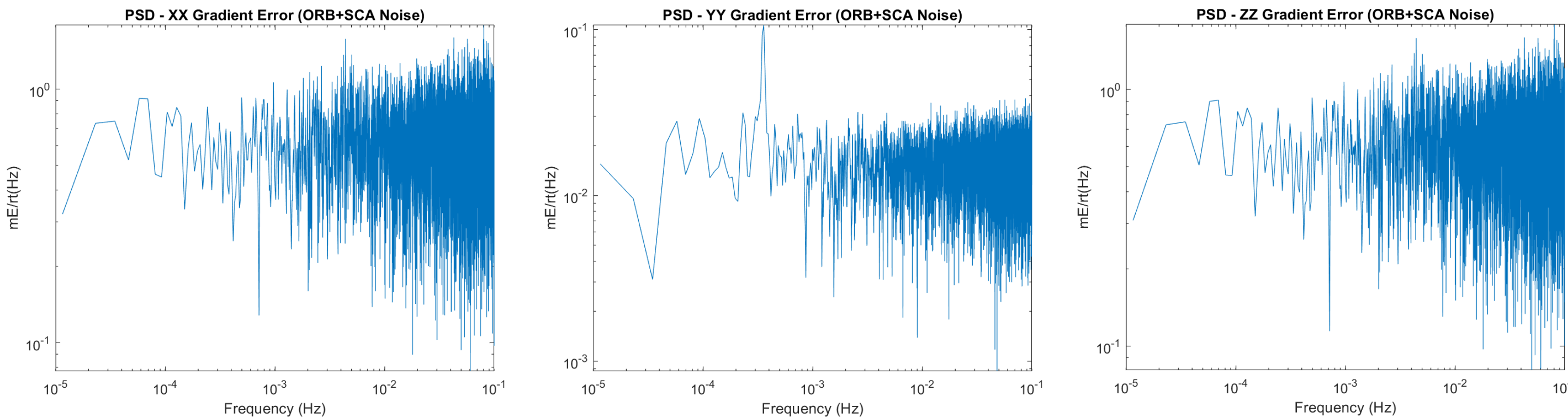
Methods:

- An orbit is simulated using a 'true' gravity field (EGM96), measurements with noise are generated based on orbit data
 - Steps following this are the same as applied to actual GRACE-FO data
- Altered clone of true gravity field and measurement data used to prepare partials for gravity field estimation
- Least squares regression estimation method
- Parameter leveling, Optimal Weighting
- Estimated gravity field judged in relation to 'true' gravity field



All code written at CSR and run through the Texas Advanced Computing Center

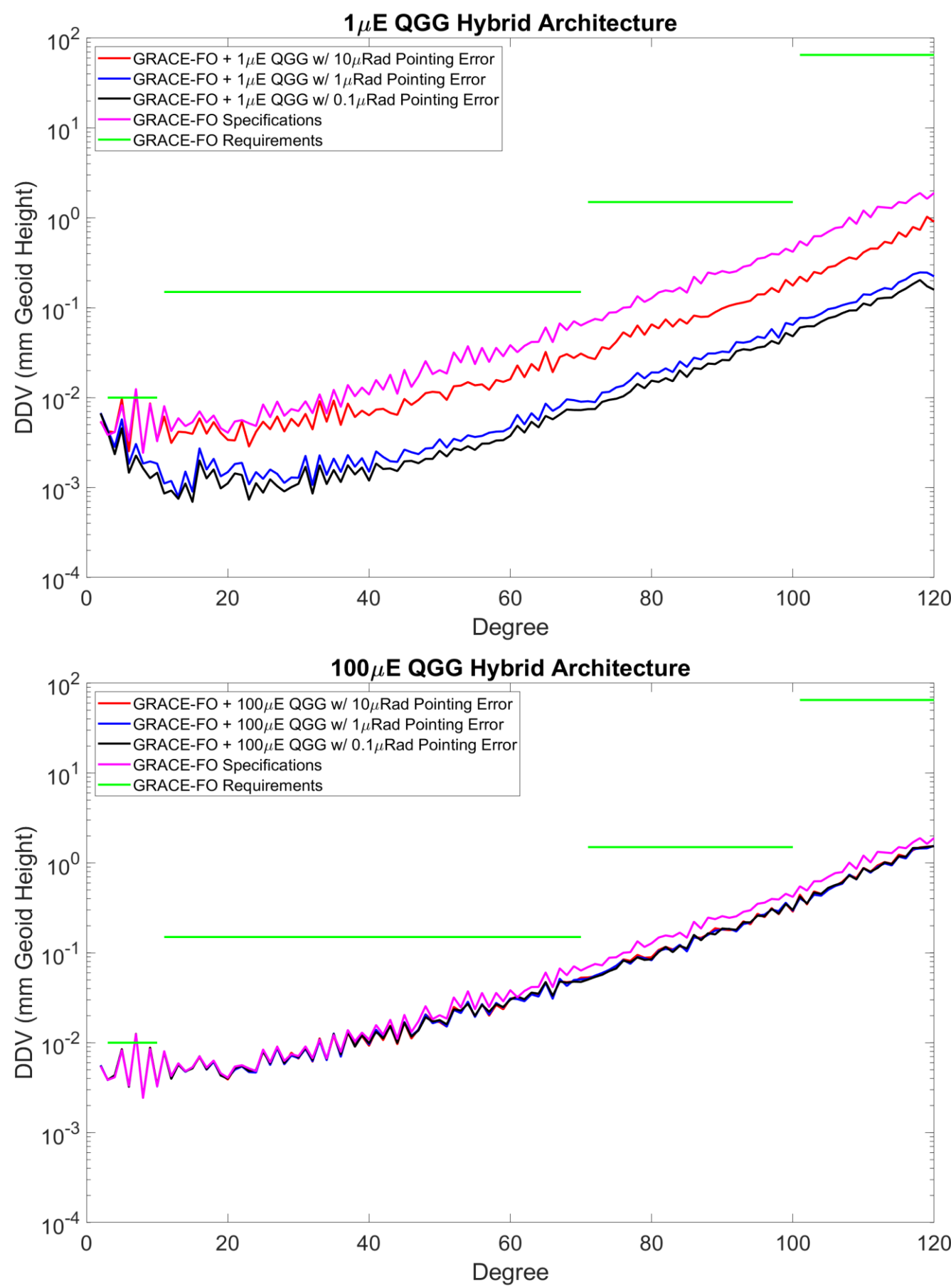
Advantages of QGG Cross Track Configuration:



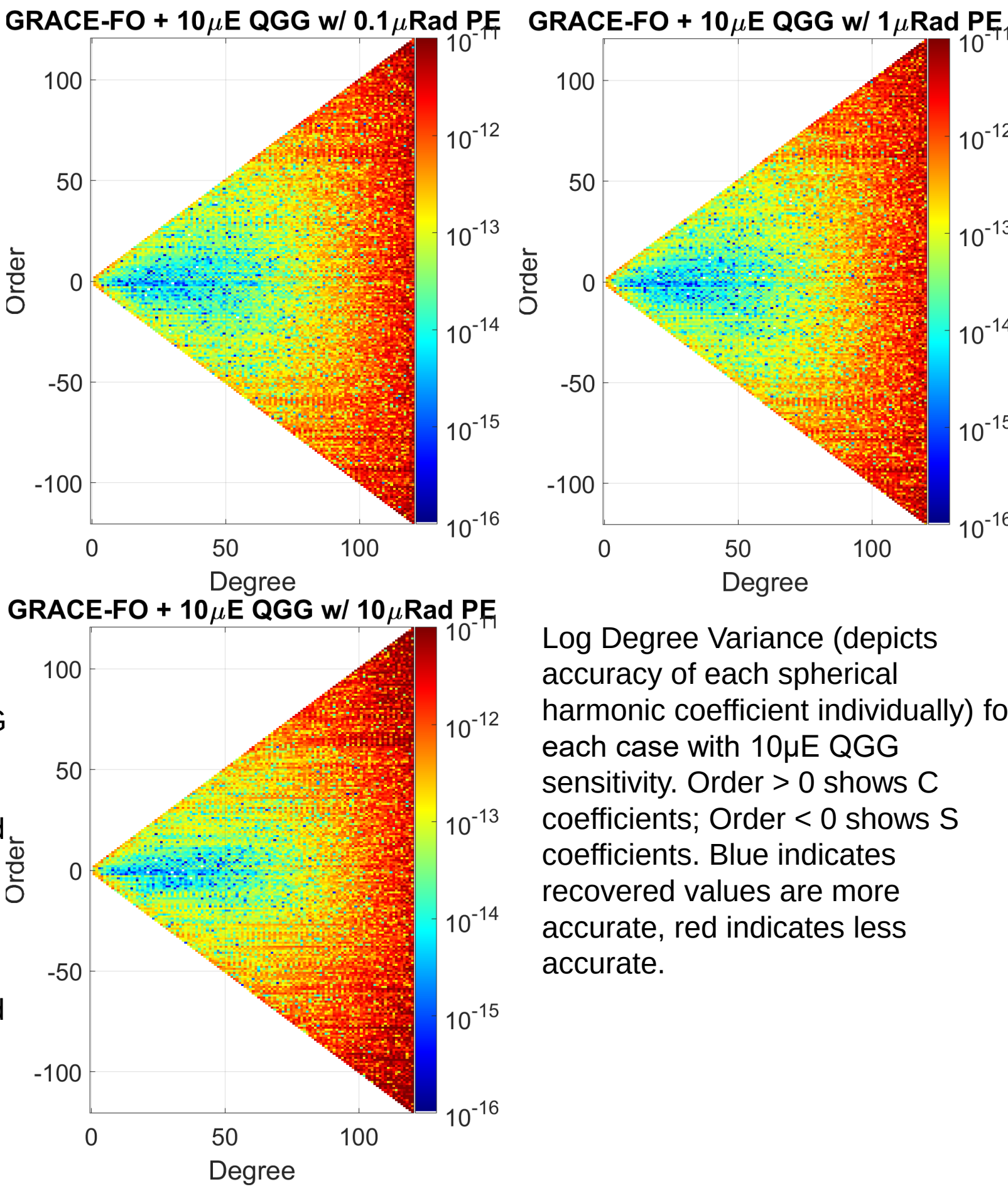
Smoothed Power Spectral Densities of gravity gradient errors due to orbit and star camera noises *Left: XX (In-track) Middle: YY (Cross-track) Right: ZZ (Radial)*

- Significantly less noise in the cross-track axis
- Angular velocity about cross-track is several orders of magnitude larger than in-track and radial
 - Centrifugal acceleration impact upon gradiometer measurements to be separated out is smallest cross-track^[3]

Recovered Gravity Field Evaluation:



Differenced Degree Variance (combining accuracy of at spherical harmonic coefficients at a given degree to one value) of recovered gravity field results from simulations at various combinations of QGG and Star Camera sensitivity as well as GRACE-FO recovered field and requirements. *Top Left: 1μE QGG sensitivity Right: 10μE QGG sensitivity Bottom: 100μE QGG sensitivity.* 10-100μE is the expected range of Bose-Einstein condensate QGG; 1μE is the expected sensitivity for a technology still under development.^[4] 10μRad is the pointing sensitivity of the star camera on GRACE-FO; 1μRad is the pointing sensitivity of the star camera on IceSAT-2; 0.1μRad is the expected pointing sensitivity of star camera technology currently und development.^[5]



Conclusions:

- Optimistic BEC QGG sensitivity levels can lead to significant improvements over GRACE-FO in target spatial range
- Star camera sensitivity, which causes errors at scale with QGG sensitivity, can be a limiting factor in overall hybrid architecture performance
- Cross-track is the best satellite axis for orienting QGG to minimize errors caused by star camera pointing sensitivity

Future Work:

- Analyze various smoothing methods in search of optimal method for de-aliasing results without removing advantage over GRACE-FO architecture

Acknowledgements:

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References:

- Yu, Nan, et al. "Development of an atom-interferometer gravity gradiometer for gravity measurement from space." *Applied Physics B* 84.4 (2006): 647-652.
- Fig 4-1, Report of the NASA/ESA Interagency Gravity Science Working Group, TUD-IGSWG-2016-01, 12 May 2016.
- Frommknecht, Björn, et al. "GOCE level 1b data processing." *Journal of Geodesy* 85.11 (2011): 759.
- Chiow, Sheng-wei. Received by Mitchell Rosen, 19 Nov. 2020.
- Bhatia, Divya, Ulf Bestmann, and Peter Hecker. "High accuracy pointing attitude determination estimator system of the future infrared astronomy satellite swarm mission." *Proceedings for GNC2017, 10th International ESA conference on Guidance, Navigation and Control Systems*. 2017.