Gravity, Bathymetry, and Seafloor Tectonics from SWOT

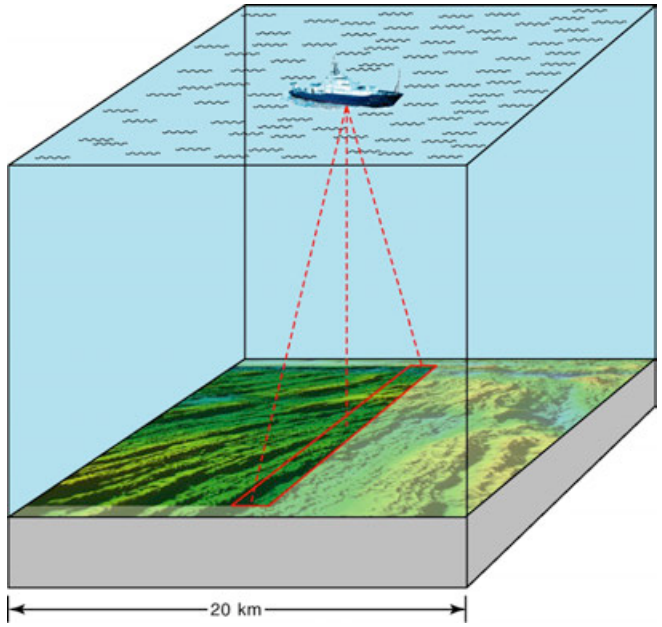
David Sandwell, Yao Yu, and Gerald Dibarboure

- Seafloor mapping tools
- What is missing? – abyssal hills, seamounts
- Resolution and accuracy at Foundation seamounts
- Global vertical gravity gradient (VGG) from SWOT
- What is next?

Seafloor Bathymetry: State of the Art

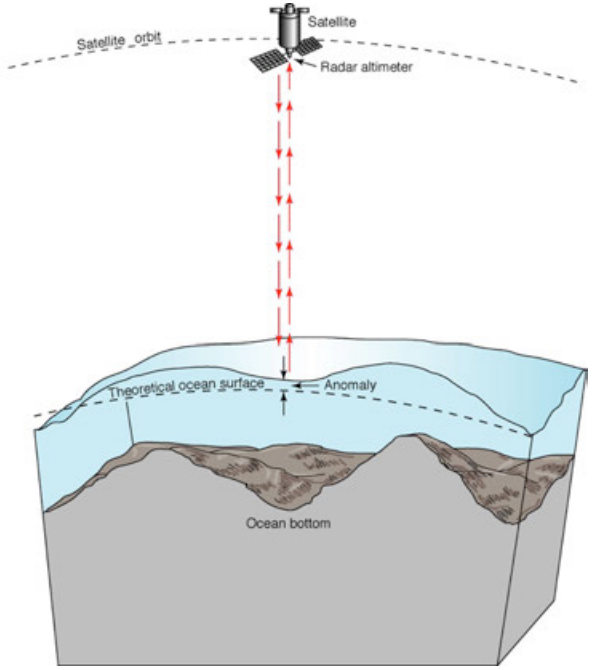
shipboard echo sounder

(high resolution ~200 m, poor coverage 25%)



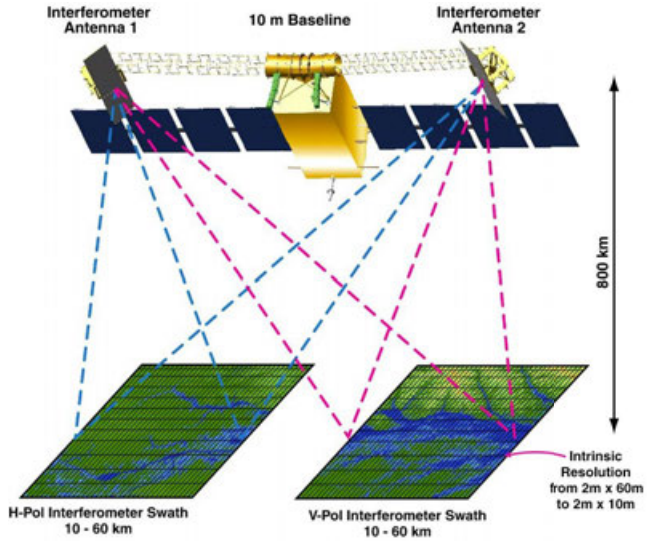
Nadir satellite altimeter

(global coverage, poor resolution 12-16 km)



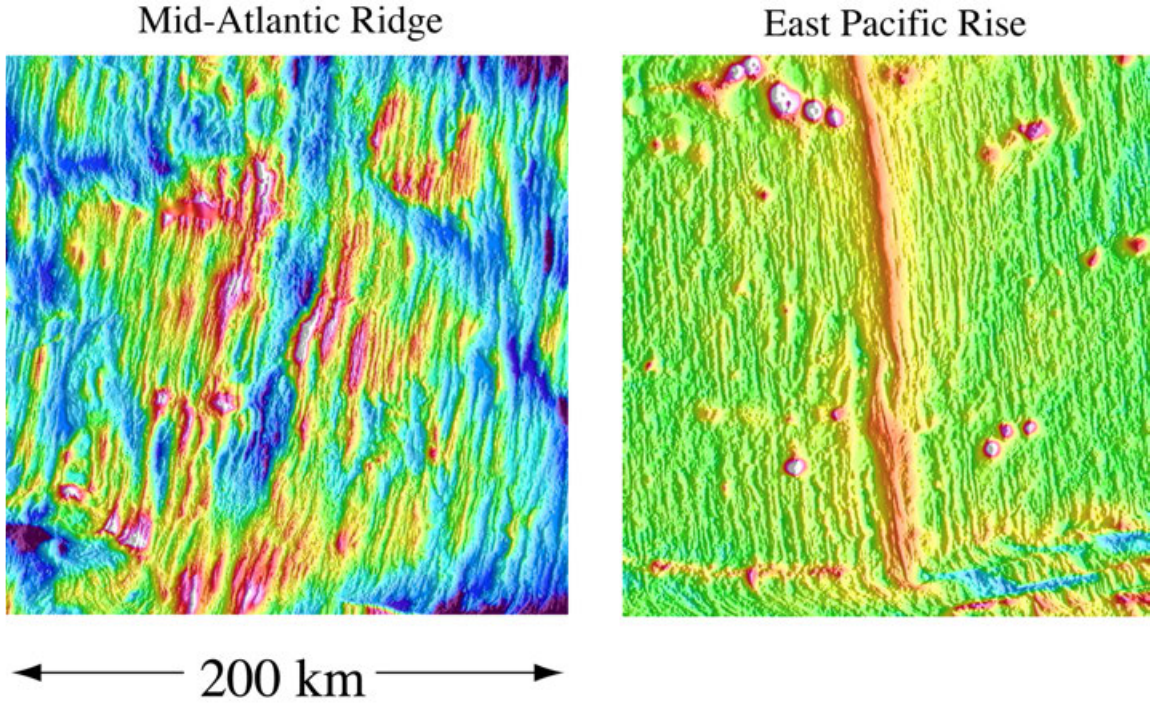
SWOT

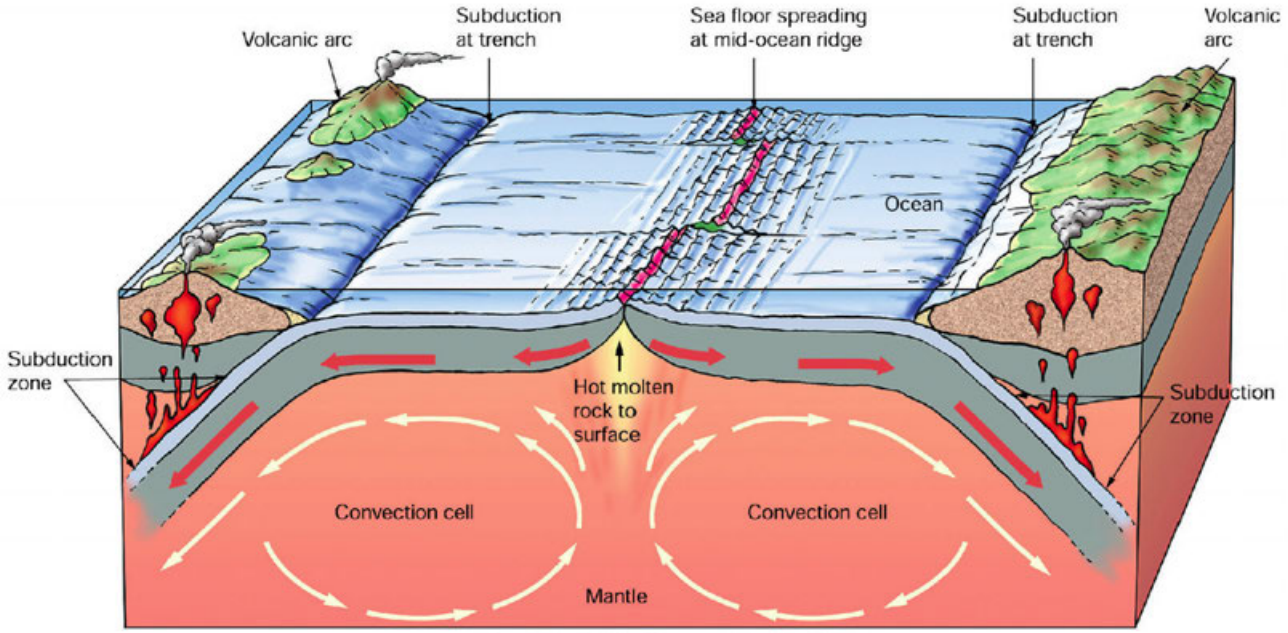
(global coverage, resolution 8-10 km)

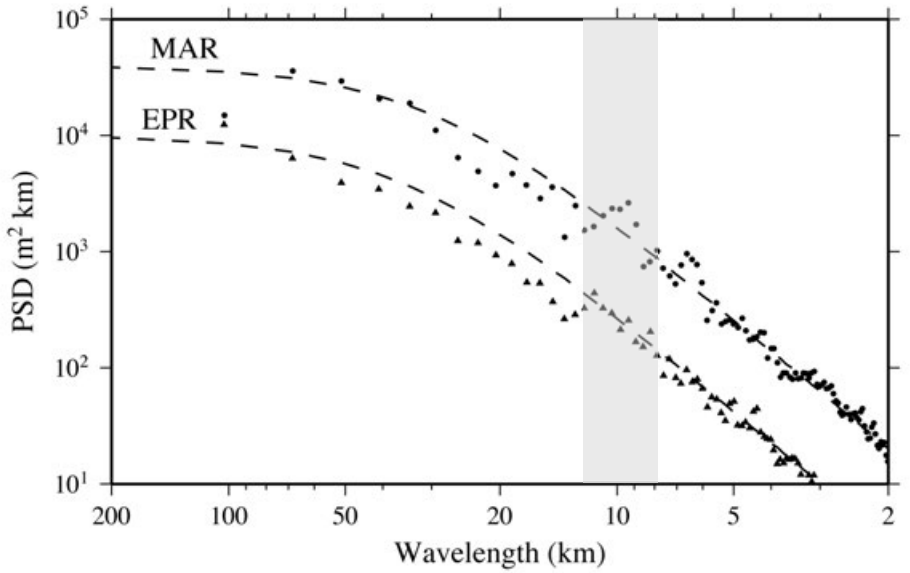


Abyssal Hills

- constitute ~80% of the seafloor
- reveal past seafloor spreading direction and rate
- have steep slopes for high-mode internal tide generation



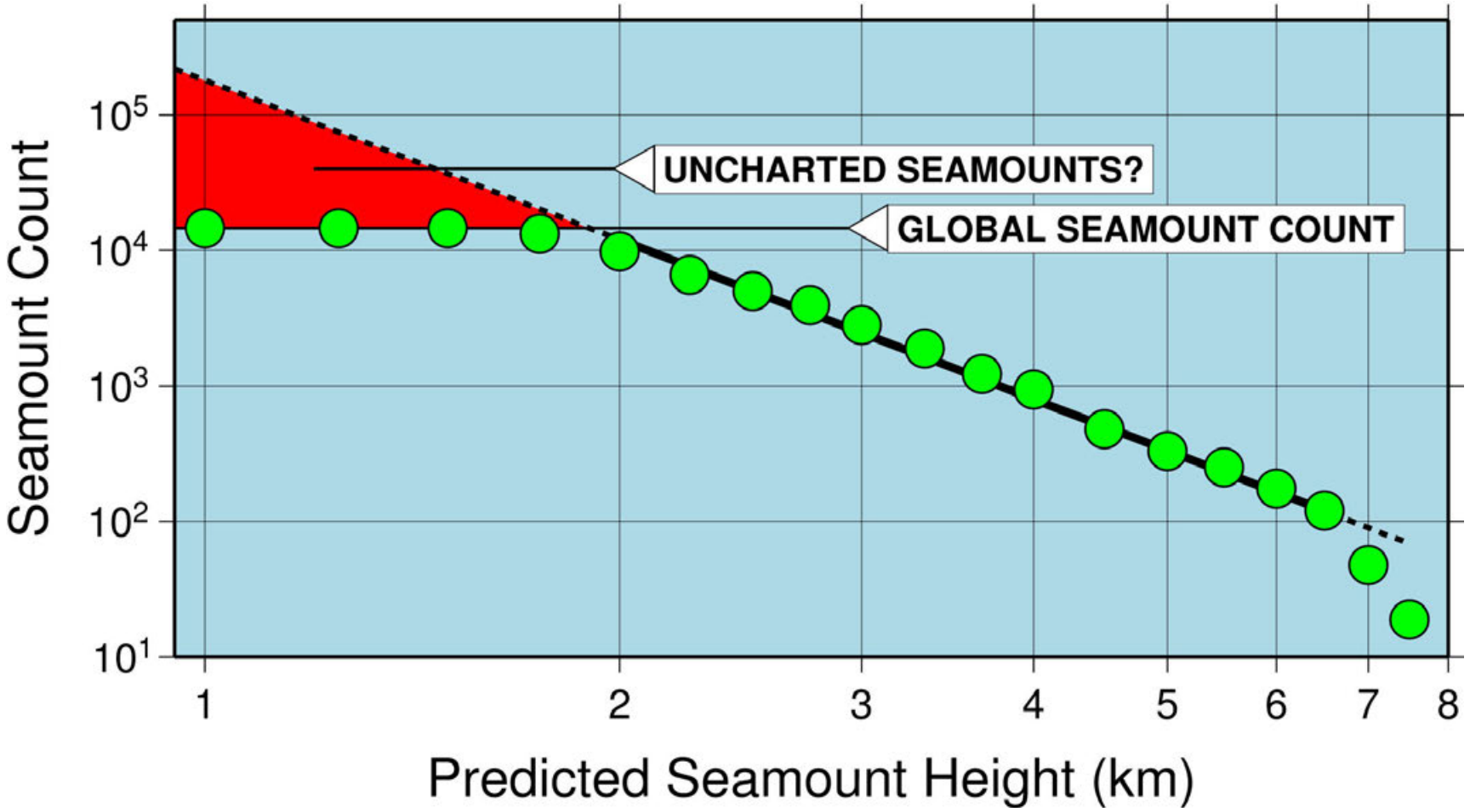




Seamounts

"Stirring Rods of the Oceans?" [Munk and Wunsch, 1998]

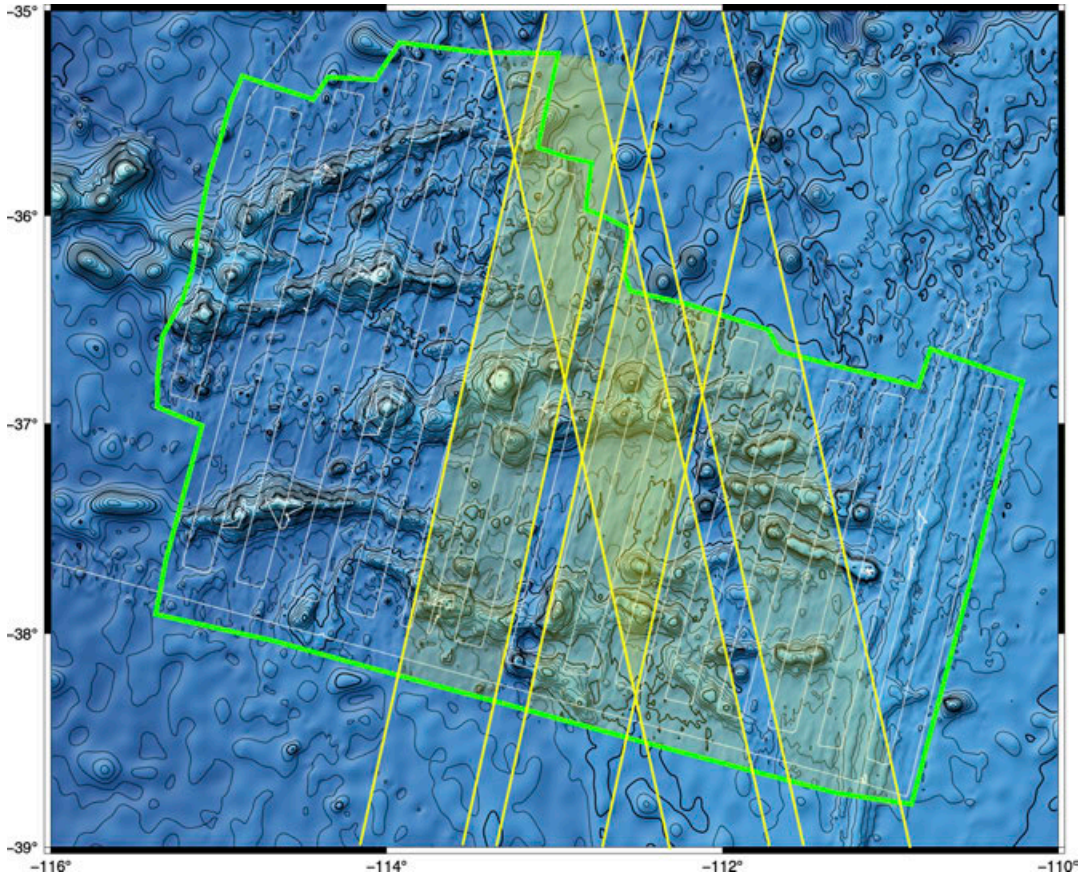
About 43,000 seamounts taller than ~1.0 km had been mapped by ships and satellite altimetry. Perhaps 50,000+ are still uncharted. [*Kim and Wessel,* 2011; 2015, *Gevorgian et al.,* 2023]

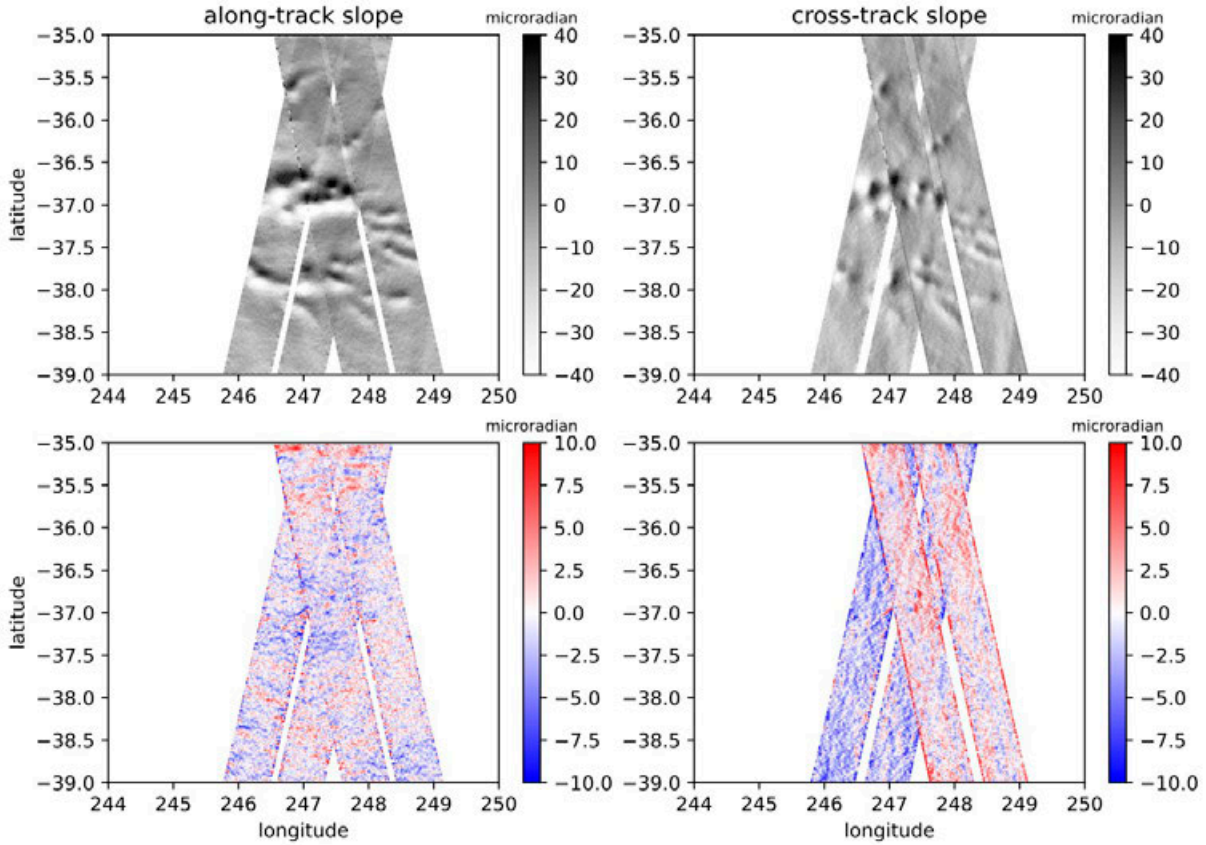


Accuracy and Resolution of SWOT Altimetry: Foundation Seamounts

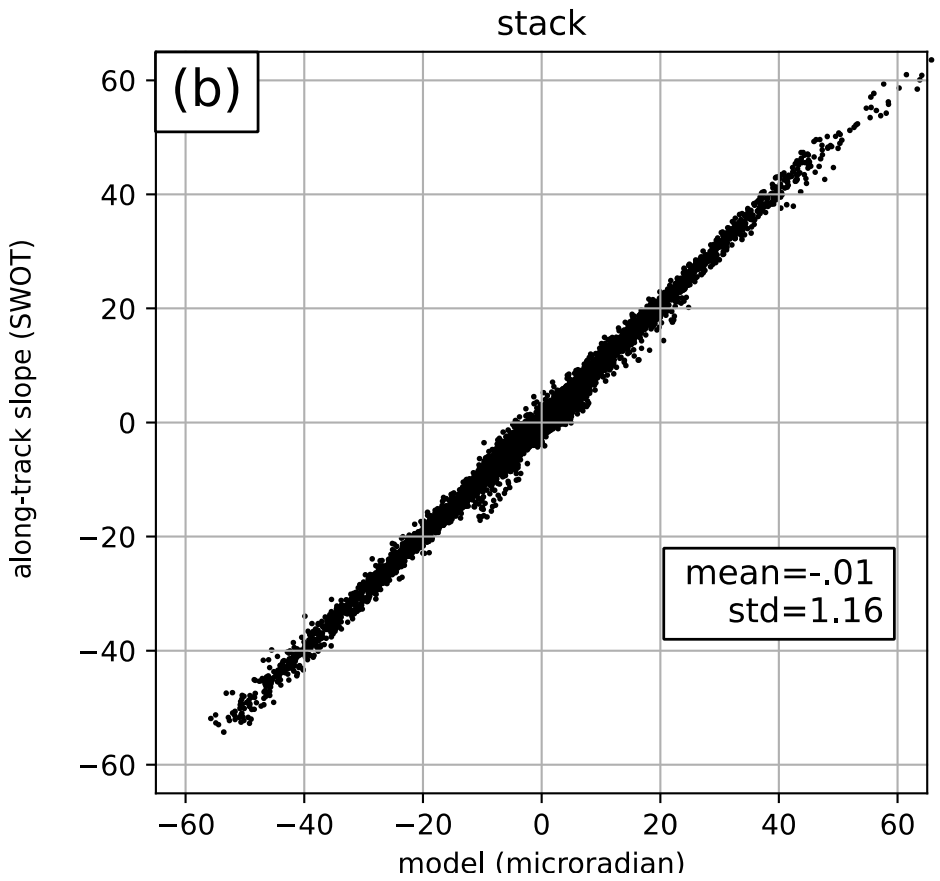
Y. Yu, D. T. Sandwell, G. Dibarboure, C. Chen, and J. Wang

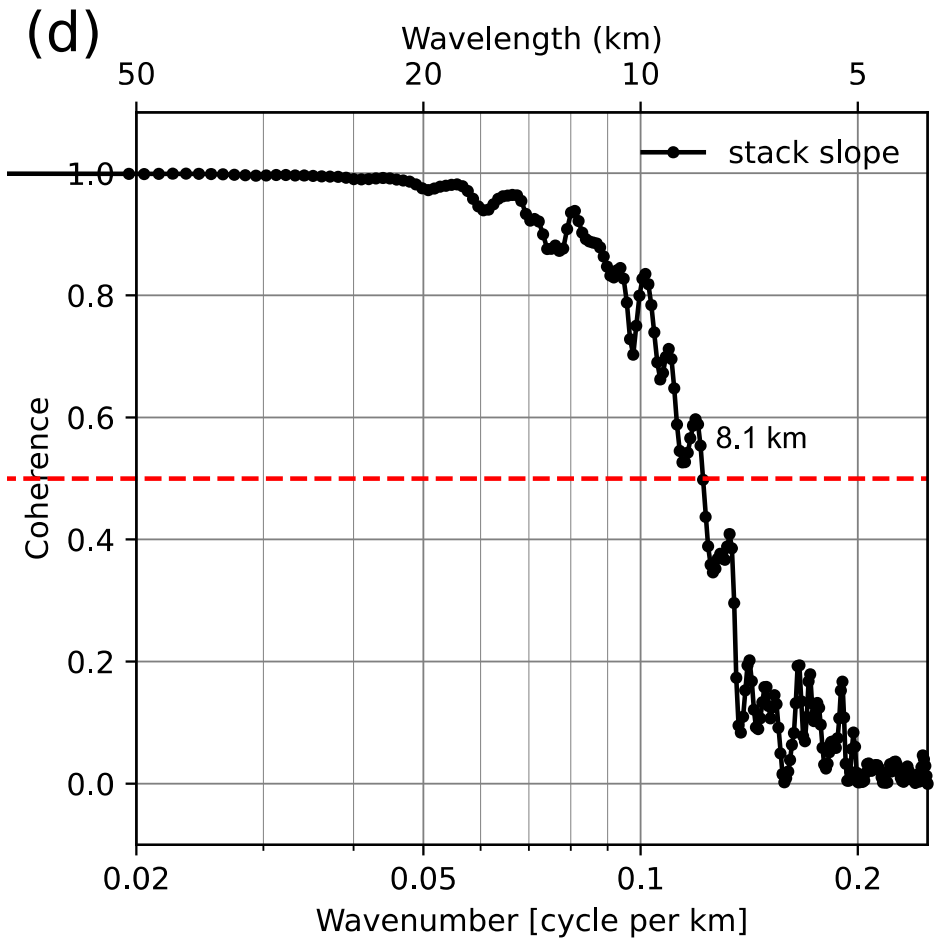
(Earth and Space Sciences, in press)





Accuracy and Resolution from 1-day Repeat (64 cycles)

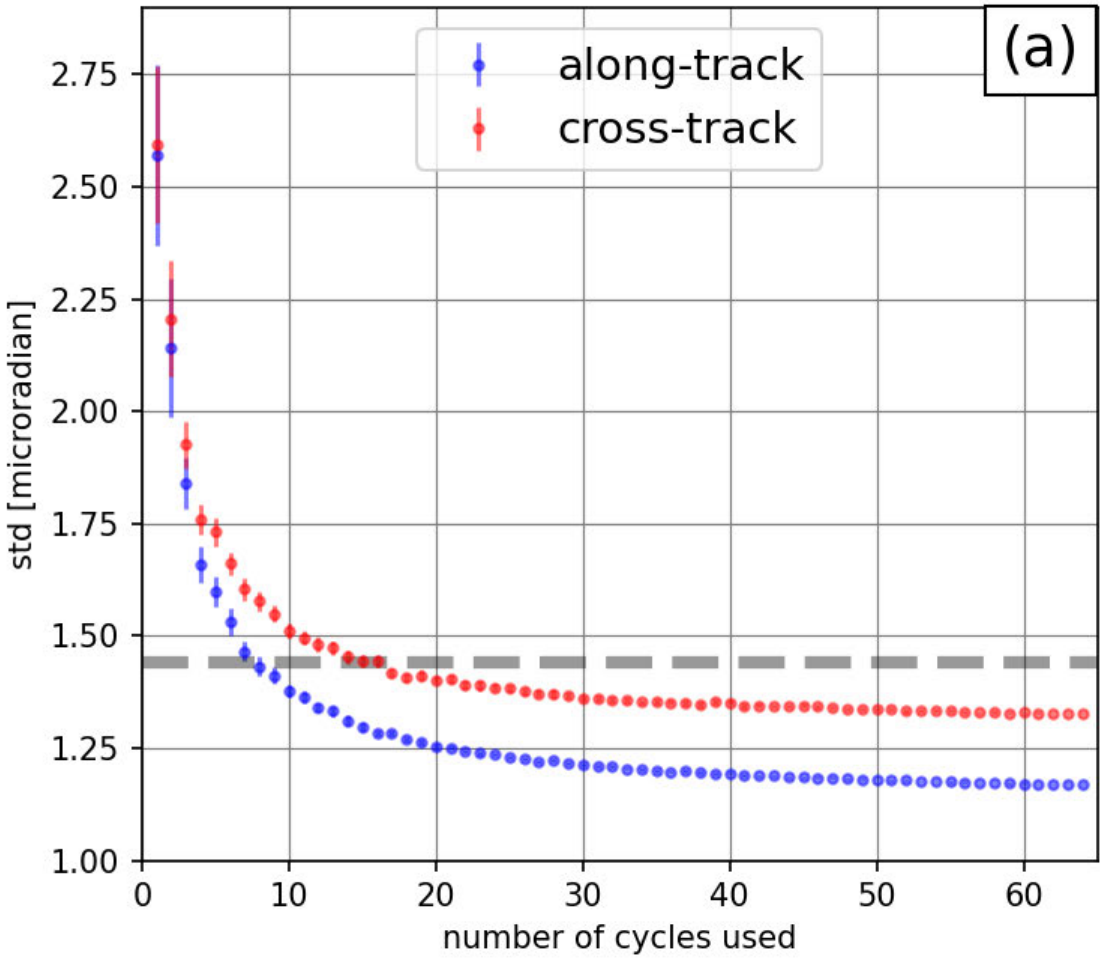


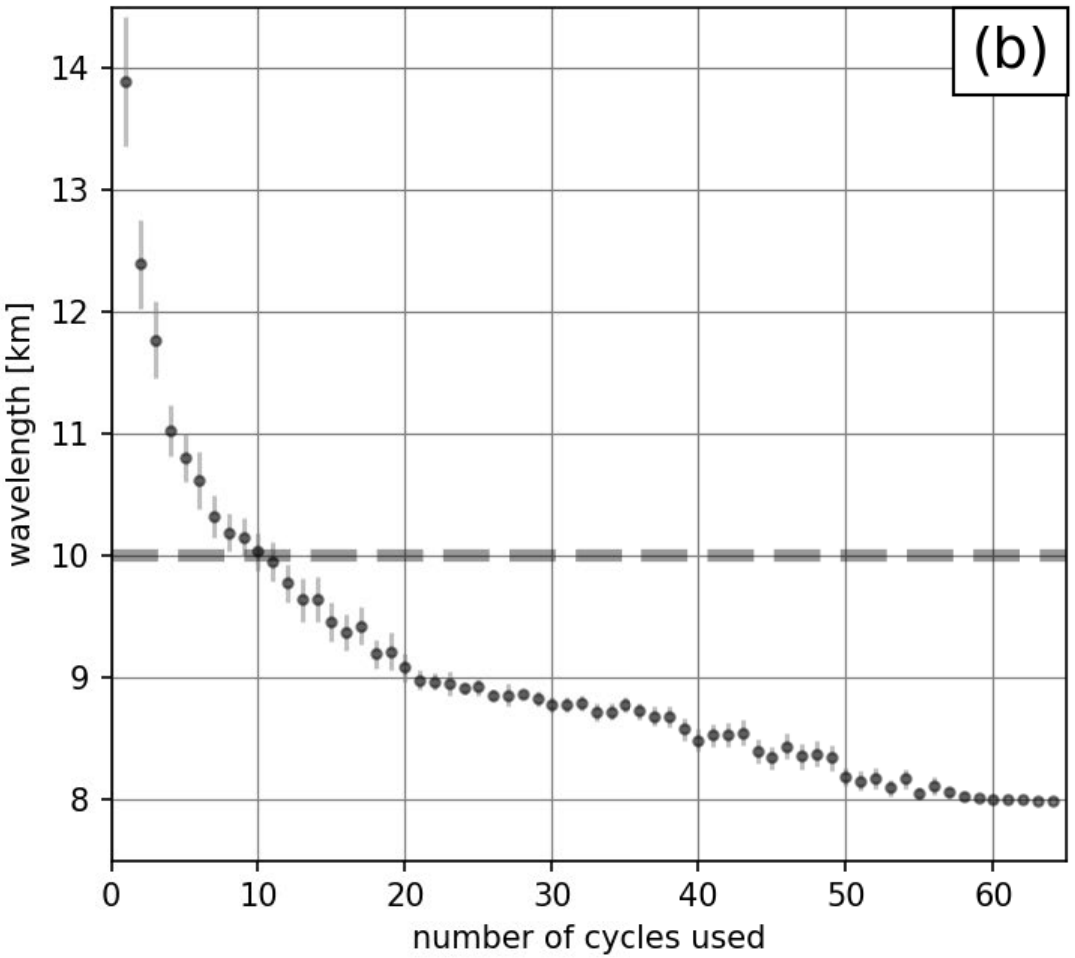


The accuracy of the stack is ~ 1.2 μrad.

The resolution of the stack is ~ 8 km.

[Yu et al., 2024]





The accuracy and resolution of SWOT-derived gravity exceeds the accuracy and resolution from 30 years of nadir altimetry after 10 repeats.

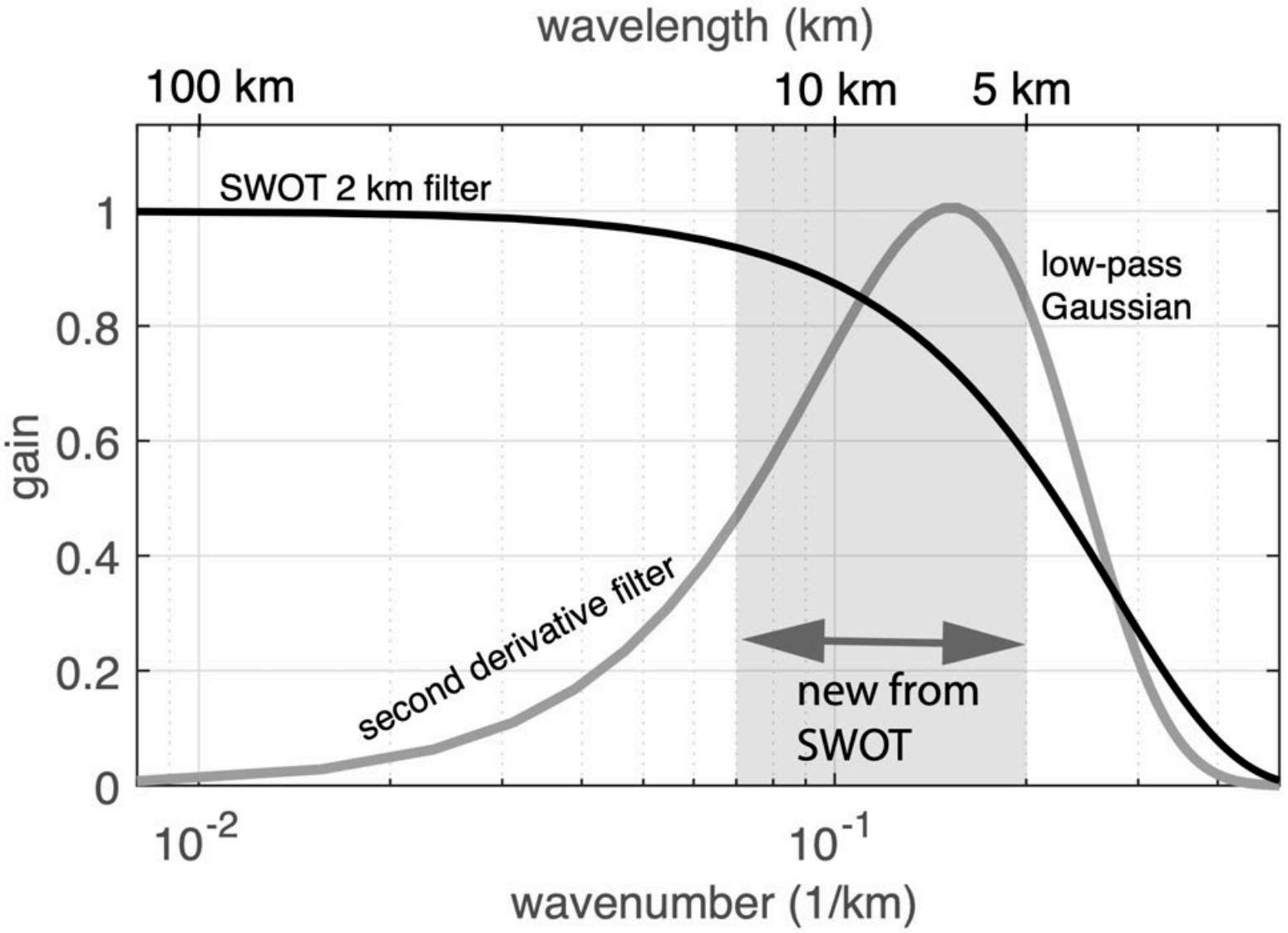
[Yu et al., 2024]

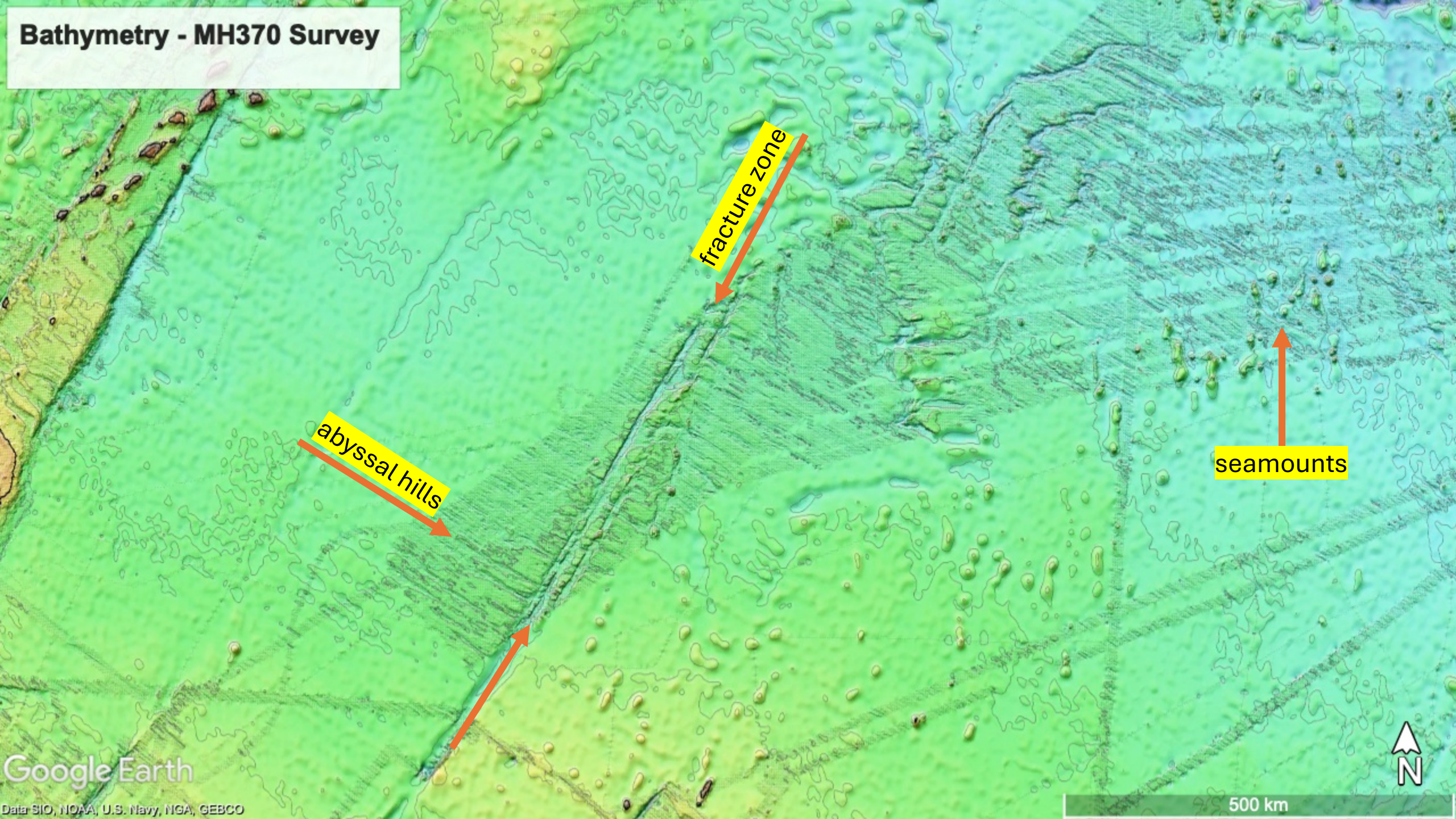
Vertical Gravity Gradient (VGG)

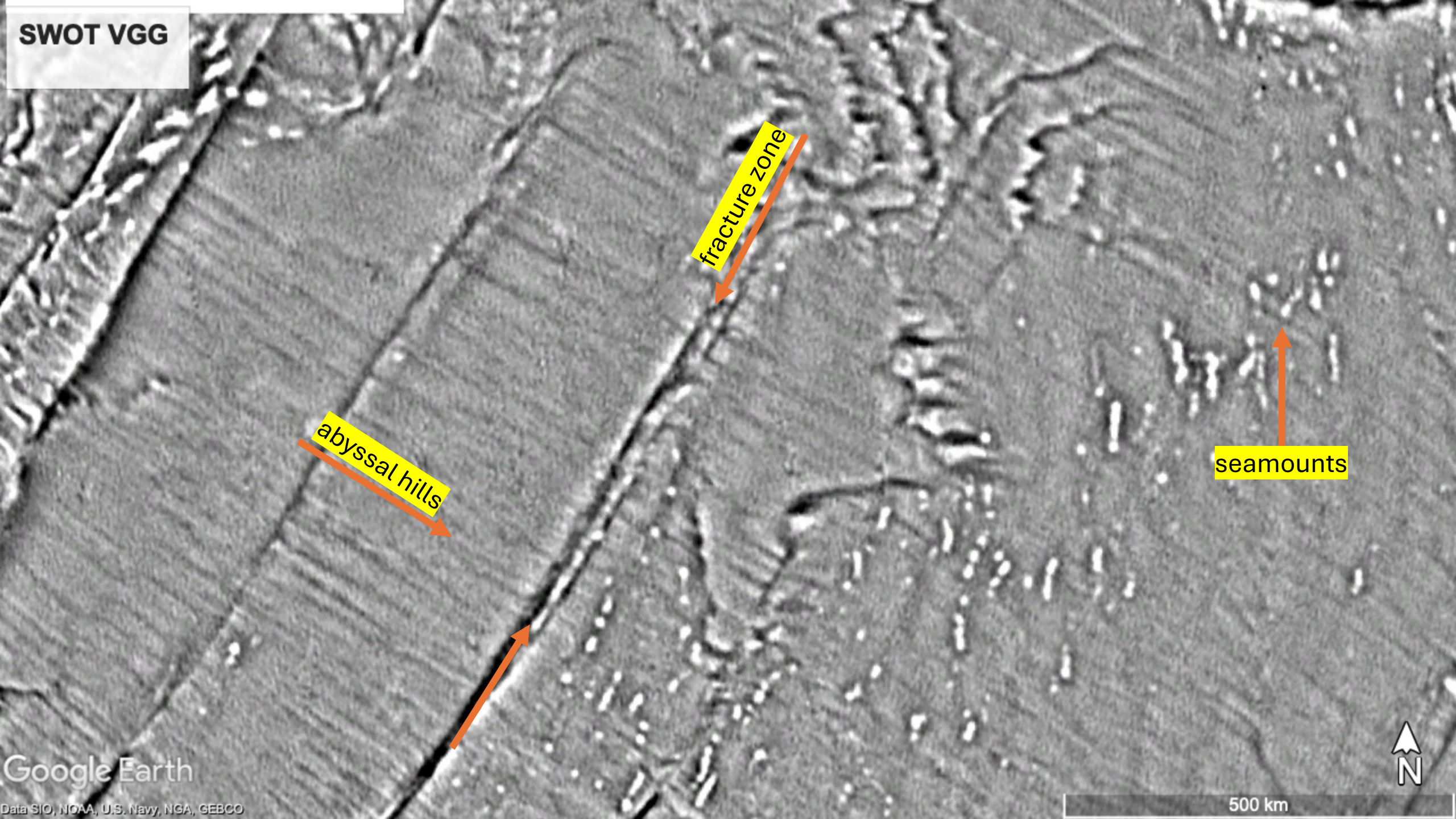
- VGG is the curvature of the ocean surface (i.e., from Laplace equation).
- Start with L2/L3, 2 km ocean data products with crossover correction.
- Project north and east model sea surface slope (SSS) into along-track and cross-track slope and remove from SWOT slopes.
- Estimate cross track phase screen including residual cross-track slope.
- Stack residual along-track and cross-track slopes from SWOT.
- Compute second derivatives and add to obtain residual VGG
- Restore model VGG to residual VGG and low-pass at 8 km.

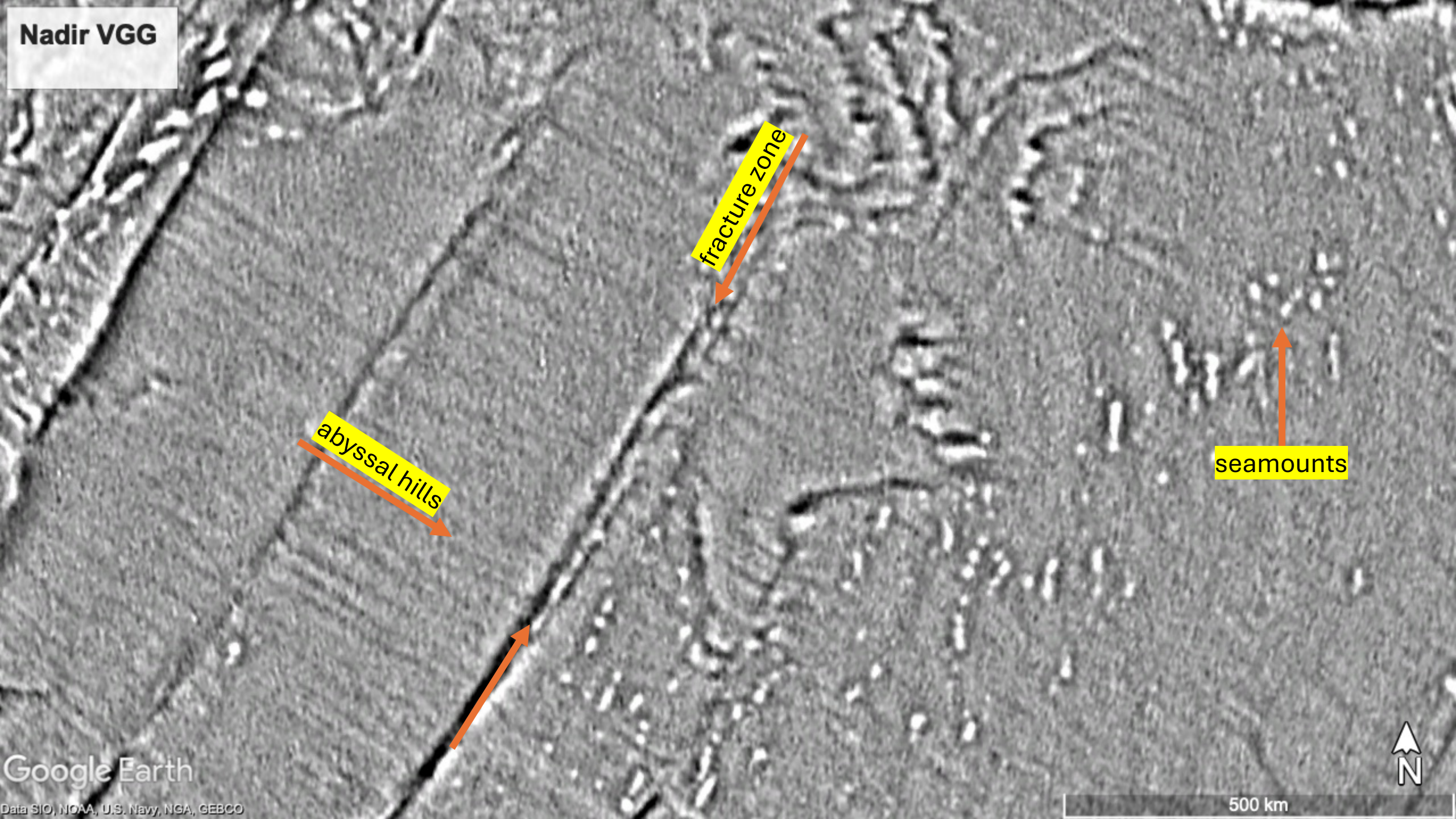
(Slopes are preferred over heights because they have higher spatial resolution and do not need significant ad hoc adjustments.)

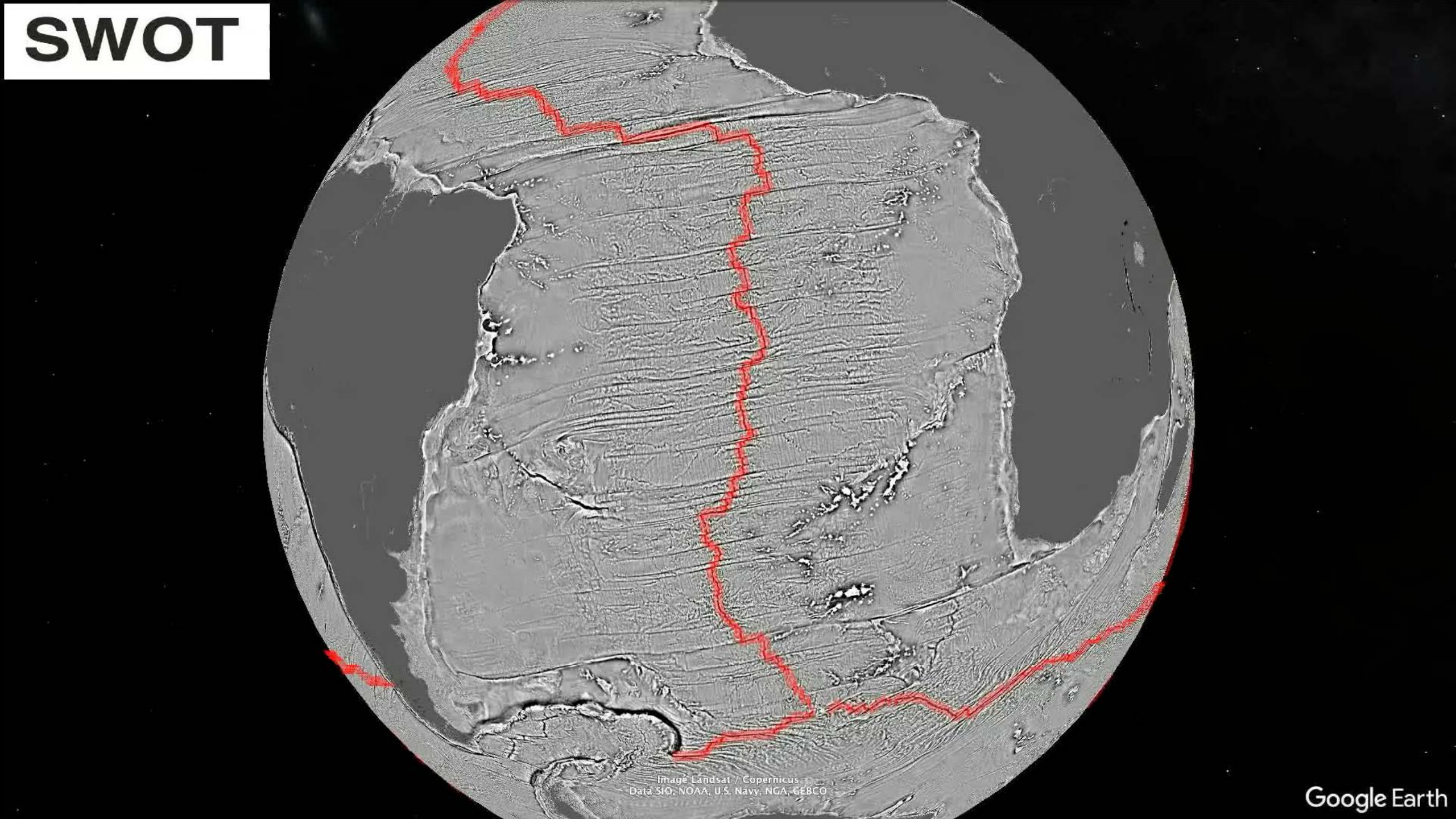
Vertical Gravity Gradient Filters




Bathymetry - MH370 Survey
fracture zone
abyssal hills
seamounts
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
500 km


SWOT VGG
fracture zone
abyssal hills
seamounts
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
500 km


Nadir VGG
fracture zone
abyssal hills
seamounts
N
500 km
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO


SWOT
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth

Conclusions and Outlook

- The accuracy and resolution of the gravity field from 1 year SWOT is superior to the best gravity based on 30 years of nadir altimetry.
- VGG from SWOT resolves the abyssal hills for the 75% of the oceans not mapped by ships.
- Abyssal hills reveal past seafloor spreading directions and have steep slopes to generate high-mode internal waves.
- Seamount analysis coming soon.
- Improved gravity accuracy and resolution will improve the global bathymetric maps.
  (First global gravity grids ~ November 2024. First bathymetry ~ January 2025.)
- We plan to use the 250 m ocean product to recover 2-4 km of data lost on the edges of each swath.

The nadir altimetry only contribute in the SWOT gaps.