New Global Marine Gravity from CryoSat-2 & Jason-1 Reveals Buried Tectonic Structure

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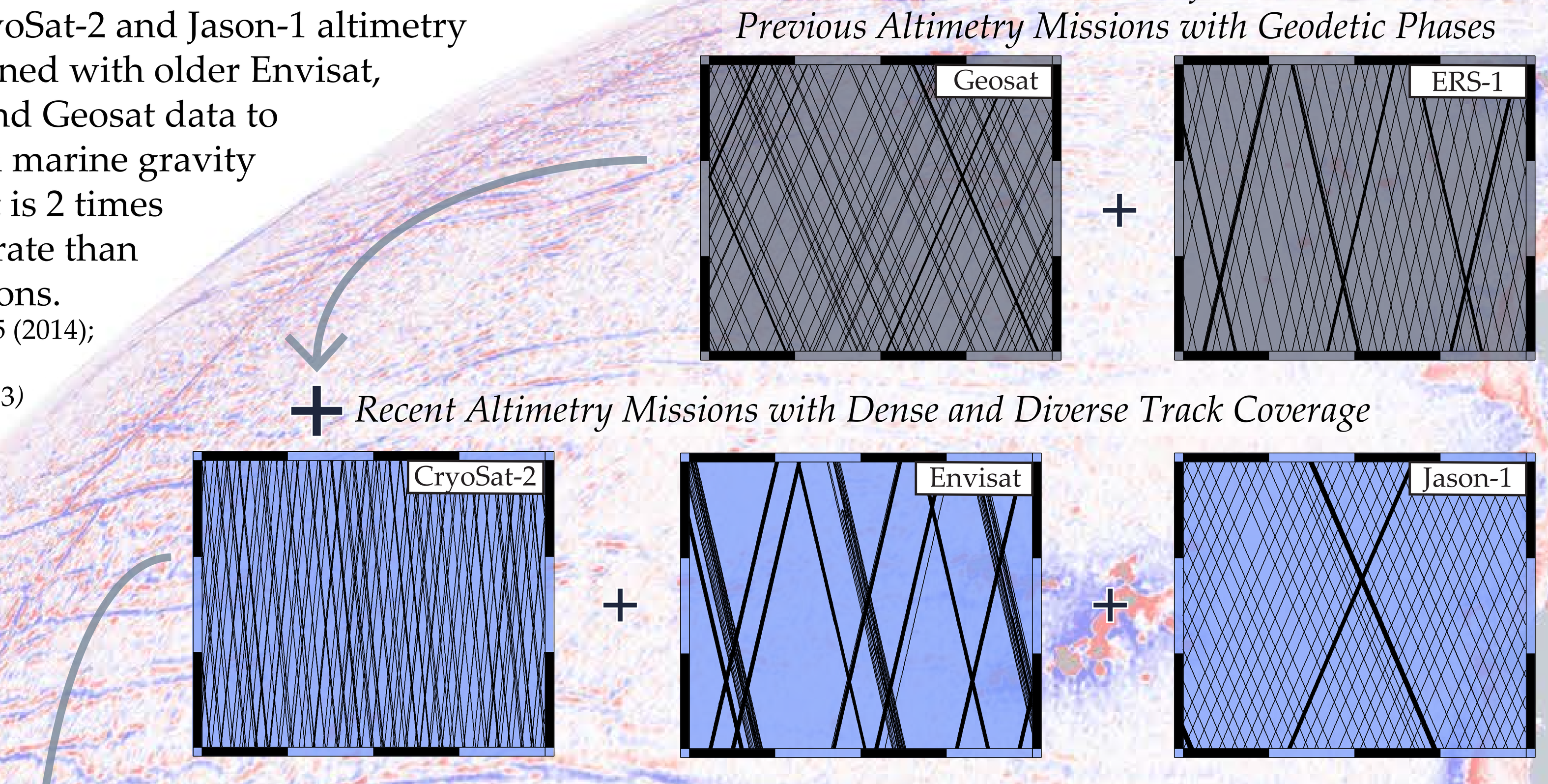
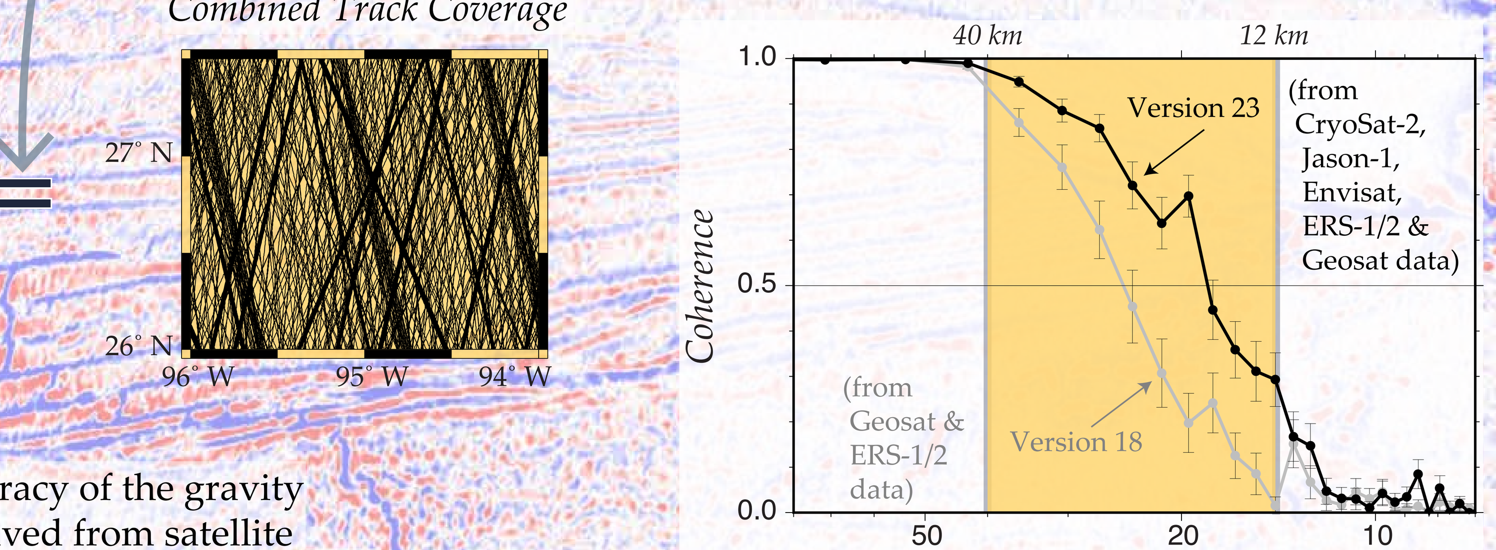
Improved Accuracy of Marine Gravity from Satellite Altimetry:

Recent CryoSat-2 and Jason-1 altimetry was combined with older Envisat, ERS-1/2, and Geosat data to construct a marine gravity model that is 2 times more accurate than prior versions. (*Science* **346**, 65 (2014); DOI: 10.1126/science.1258213)



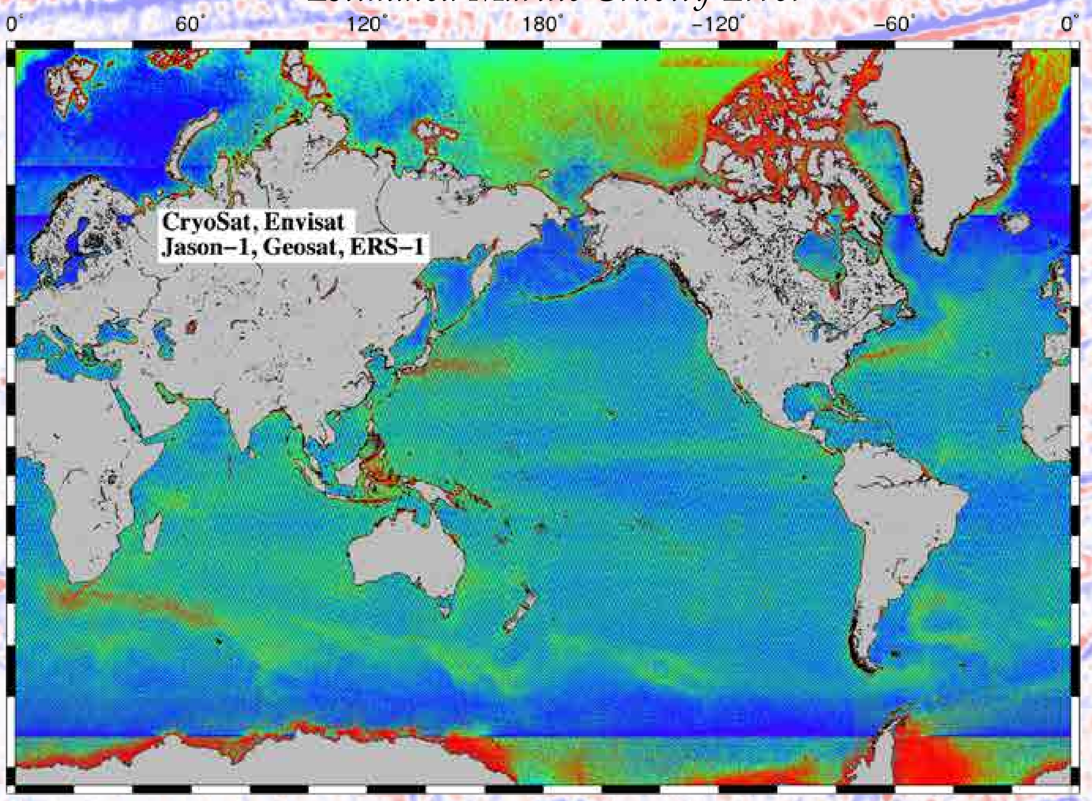


Above: coherence between the satellite-derived gravity and shipboard gravity (courtesy of EDCON) over an area in the Gulf of Mexico. Improvement occurs mostly in the 12- to 40-km wavelength band. The gravity accuracy is ~ 2 mGal.

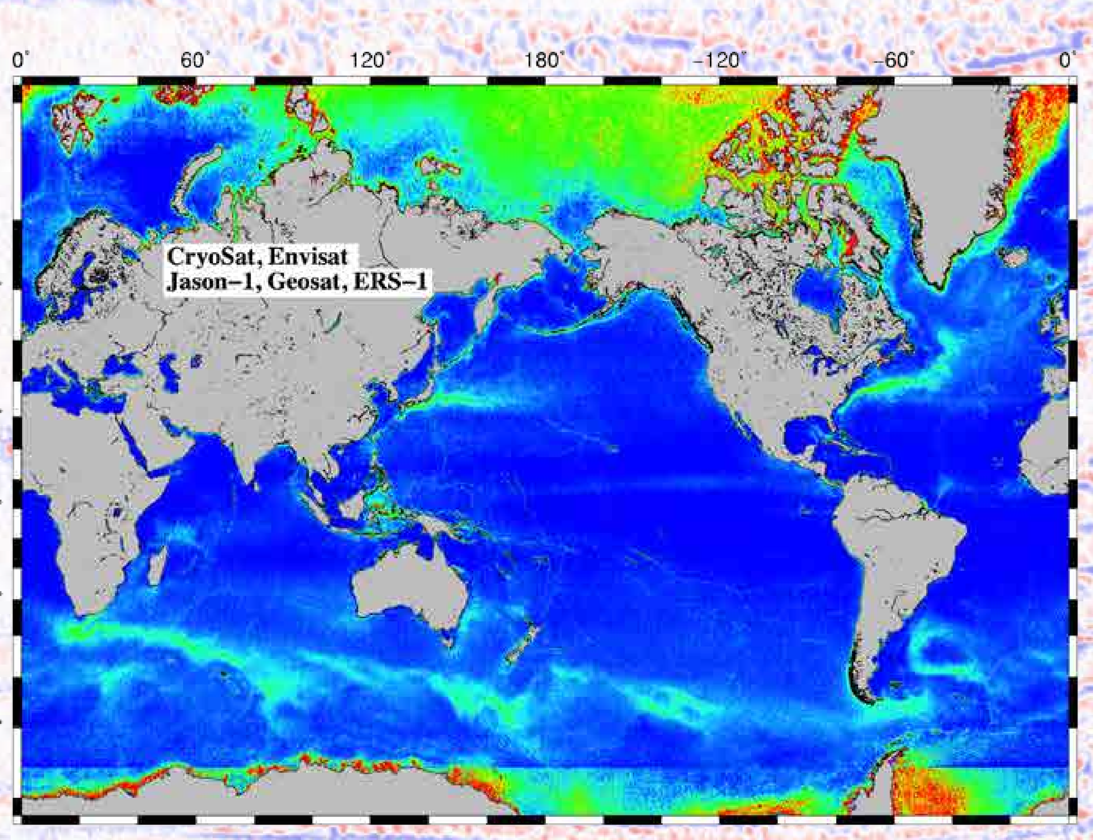
The accuracy of the gravity field derived from satellite altimetry depends on 3 factors: *altimeter range precision, spatial track density*, and *diverse track orientation*. CryoSat-2 and Jason-1 have 1.25 times higher range precision than the previous radar altimeters, while providing dense ground track coverage.

The uncertainty in the altimeter-derived gravity was estimated by calculating the root mean square (rms) difference in sea surface slope between individual altimeter profiles and the mean slopes used to compute gravity.

The gravity uncertainties were calibrated by comparisons with shipboard data from two completely different proprietary sources: EDCON Inc. and the National Geospatial Intelligence Agency. For the latter data set, the mean rms error of the satellite gravity is ~ 2 mGal, similar to the Gulf of Mexico comparison.



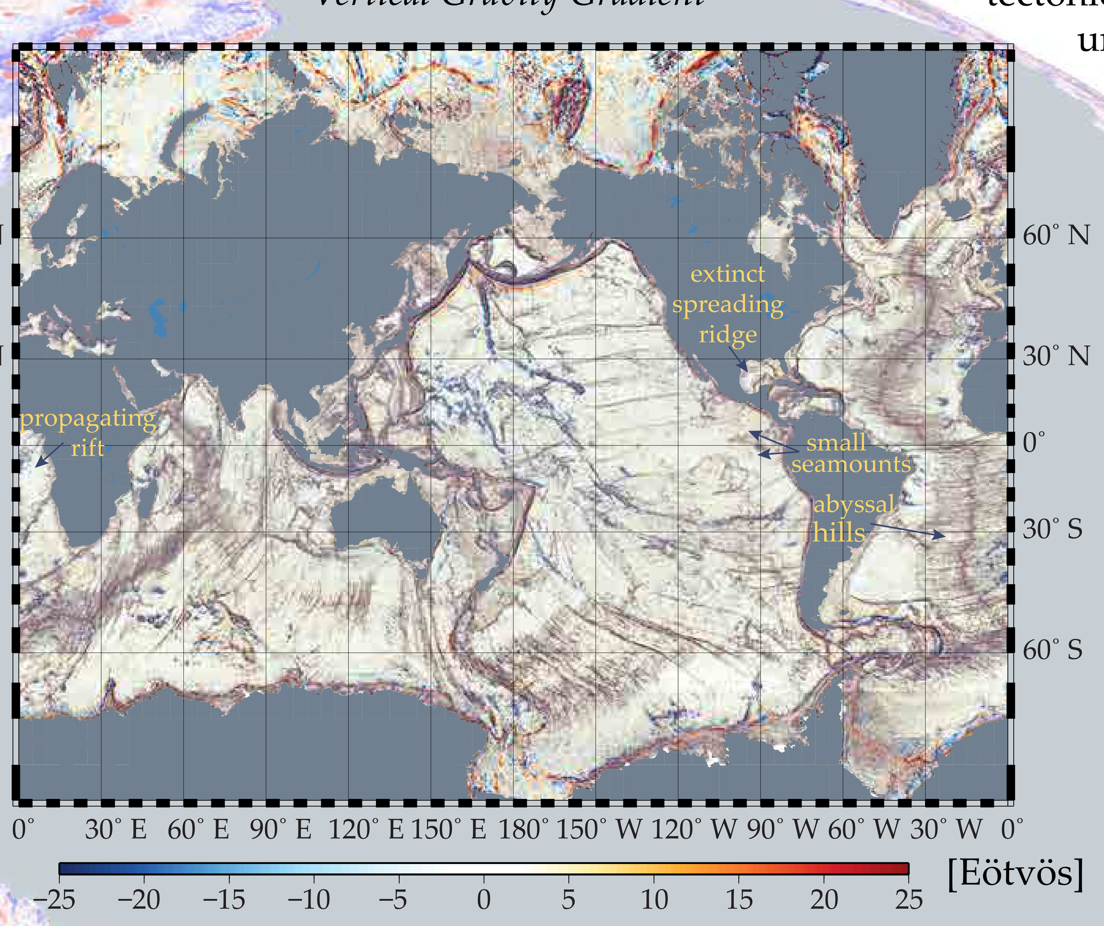
Relatively larger errors occur in areas of high mesoscale variability such as the Gulf Stream. Sharp changes in gravity noise occur at the maximum inclination of Jason-1, Geosat, ERS-1/2 & Envisat ground tracks. Noise is higher in polar regions due to fewer tracks.

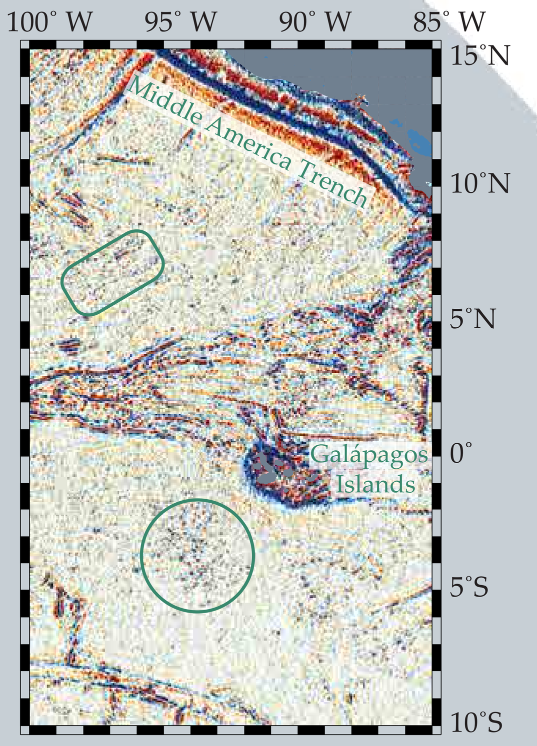


Errors are also high near the shorelines where the raw altimeter waveforms are sometimes contaminated by stray echoes off the land.

New Discoveries in Seafloor Tectonics:

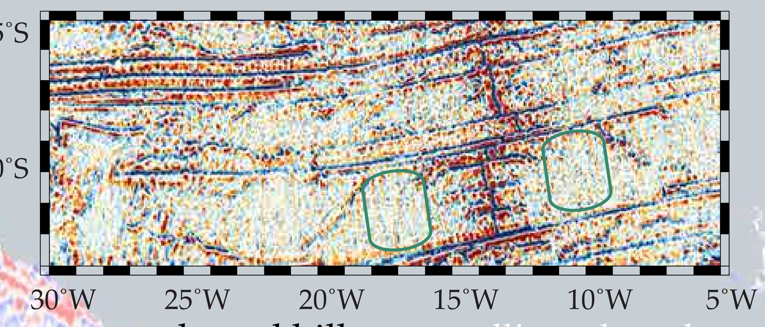
The latest marine gravity model can now map tectonic structures on the seafloor buried underneath sediment. We found an extinct spreading ridge in the Gulf of Mexico, a major propagating rift in the South Atlantic Ocean, abyssal hill fabric, and uncharted seamounts.





small seamounts

petits monts sous-marins

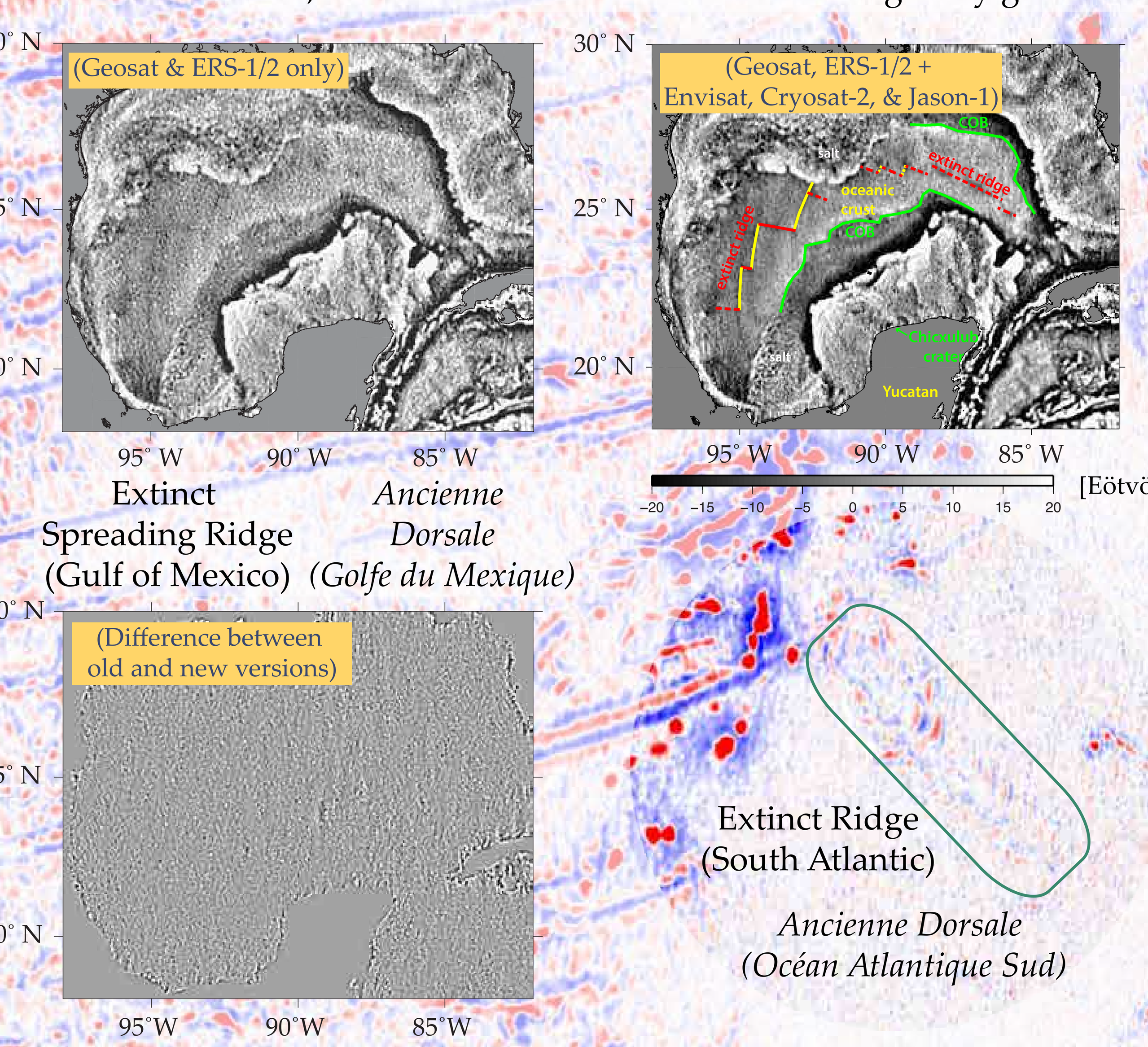


abyssal hills

collines abyssales

At scales smaller than 200 km, variations in marine gravity primarily reflect seafloor topography generated by plate tectonics such as ridges, fracture zones, and abyssal hills. Seamounts formed by volcanism also produce small gravity signals.

In the Gulf of Mexico, thick sediments obscure fault zones and extinct ridges. However, these features, as well as the boundary between oceanic and continental crust, can now be delineated in the vertical gravity gradient.



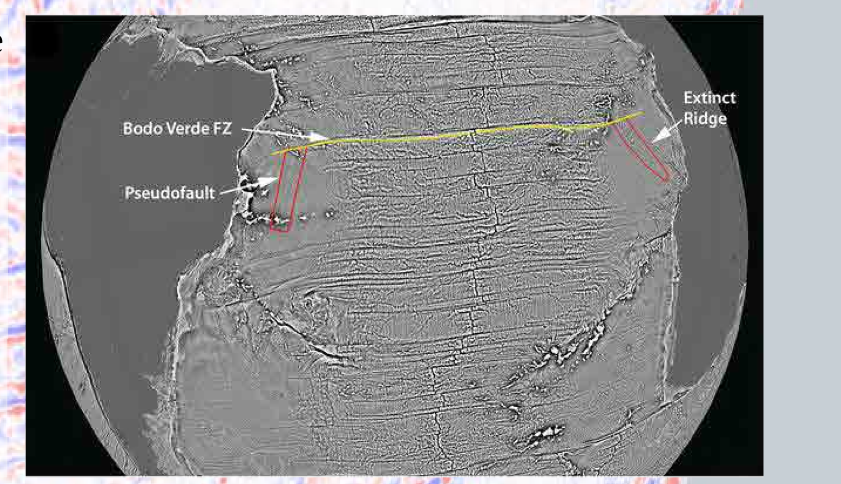
Extinct Spreading Ridge (Gulf of Mexico)

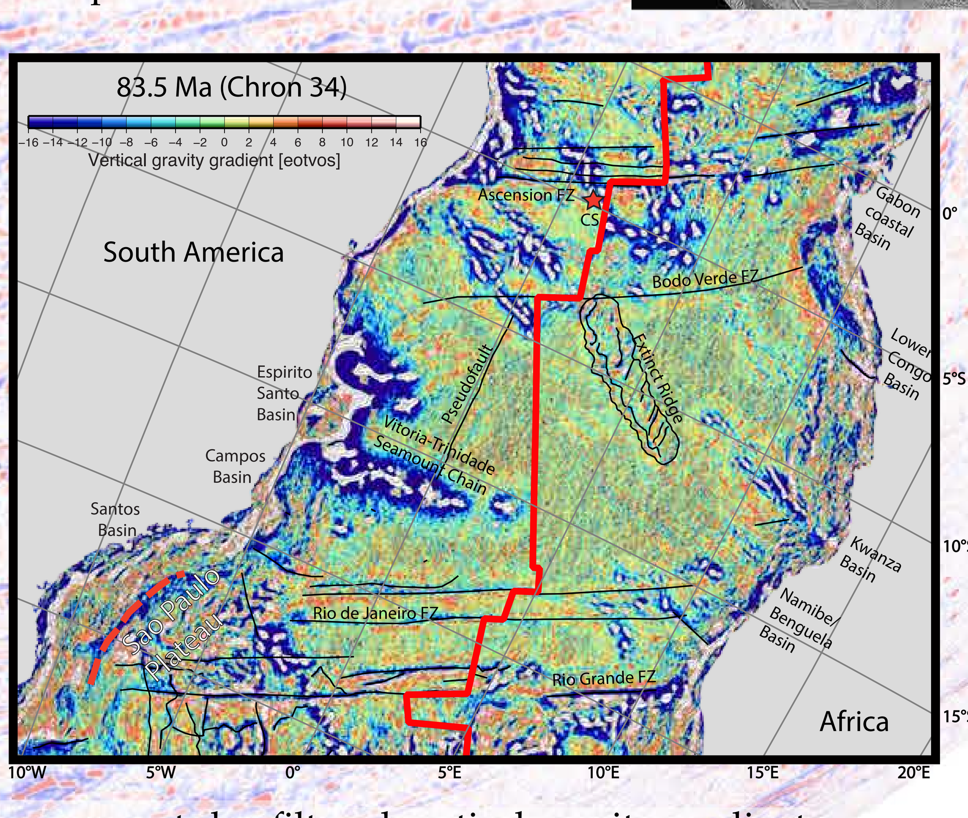
Ancienne Dorsale (Golfe du Mexique)

Extinct Ridge (South Atlantic)

Ancienne Dorsale (Océan Atlantique Sud)

Another example of a newly found feature in the updated gravity model is a set of tectonic lineaments off the western coast of Africa (see *right*). This feature is about 800 km long and 100 km wide. It was not visible in previous satellite gravity data sets because of high -frequency noise. A plate reconstruction of the feature at 83.5 million years ago reveals that it has a counterpart near South America.





The geometry of these tectonic features hints that they form a pair of an extinct ridge and a pseudofault, created by a northward ridge propagation episode.

The map above shows present-day filtered vertical gravity gradient superimposed on a plate reconstruction at chron 34 (83.5 Ma, orthographic projection). Major tectonic and volcanic features are labeled. The mid-ocean ridge is outlined in red, and the reconstructed position of the Cardno hot spot (CS) is outlined by a red star.

Conclusions

Our marine gravity model now has 2-4 times better accuracy because the CryoSat-2 and Jason-1 data:
- have 1.5 times higher range precision
- provide 2 times more slope measurements
... than previous geodetic altimetry missions

Double retracking of pulse-limited altimetry waveforms (LRM for CryoSat-2) is optimal for the recovery of the marine gravity signal.

Future Outlook

Further improvements to the marine gravity model will come from assimilation of additional data. CryoSat-2 can continue to provide north-south gradients, but a Jason-2 Geodetic Mission would greatly improve the east-west resolution.

More info at:

topex.ucsd.edu/grav_outreach

Acknowledgments

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