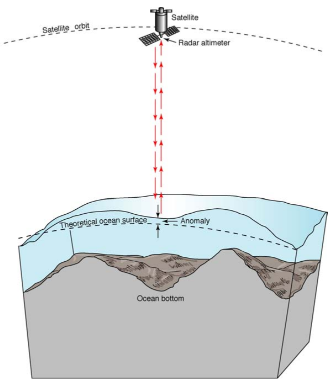
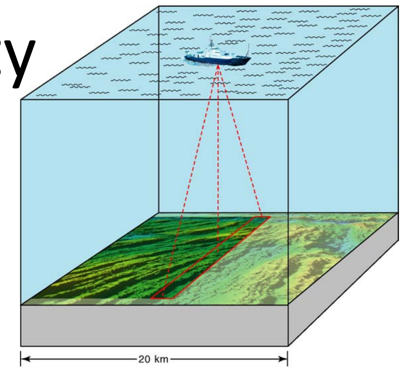


Improvement in Global Marine Gravity from Retracked CryoSat Altimetry

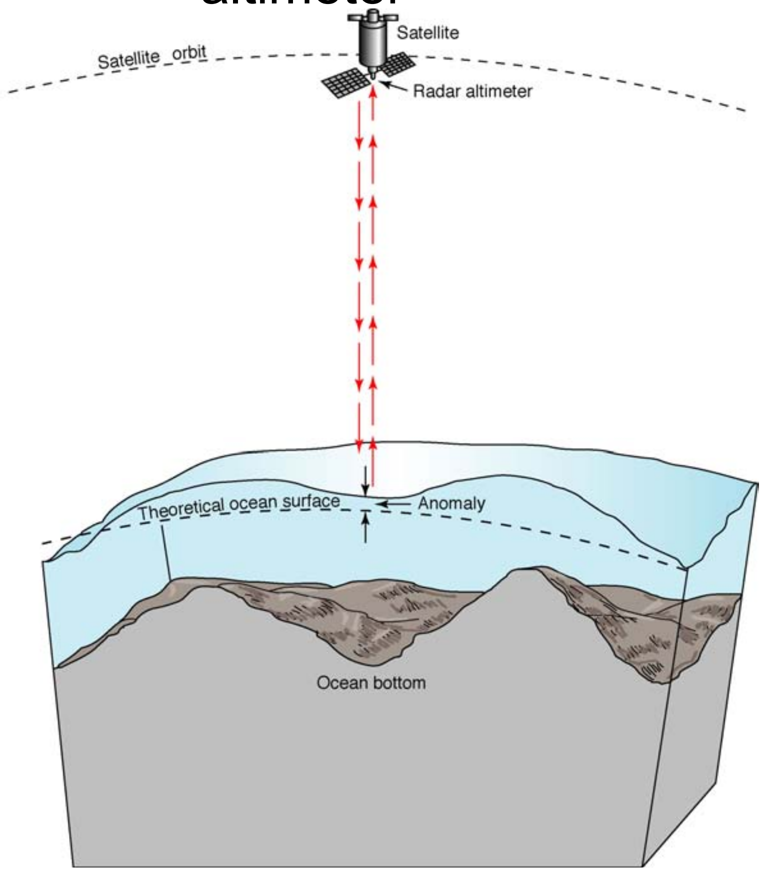


Emmanuel Garcia, David Sandwell, Walter H. F. Smith

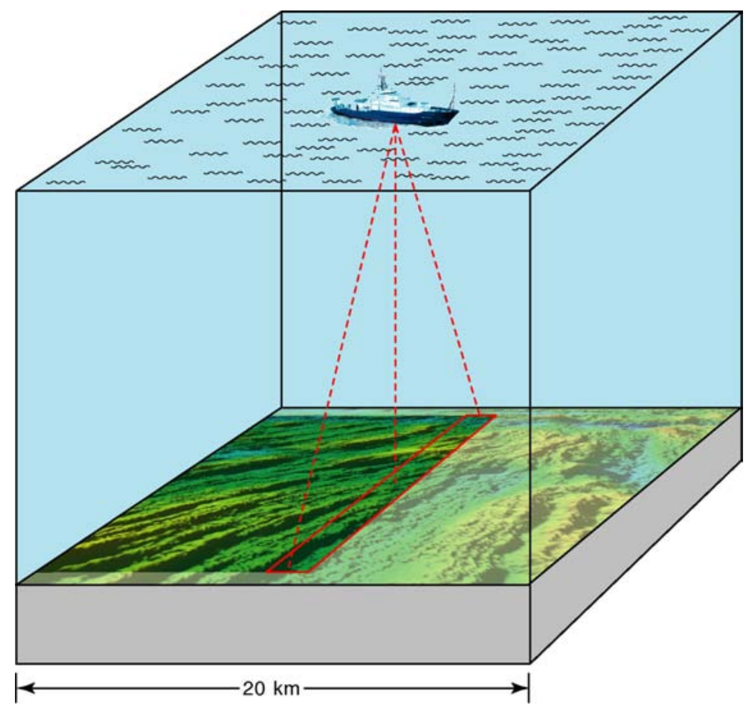
- Global bathymetry is based on ship soundings and <u>satellite gravity</u>
- Existing gravity models are derived from old Geosat and ERS-1 data
- Expecting factor of 2-4 improvement in gravity accuracy from <u>CryoSat</u>, Envisat, and Jason-1
- Examples of gravity improvements based on 14 months of CryoSat data

Modern Seafloor Mapping Tools

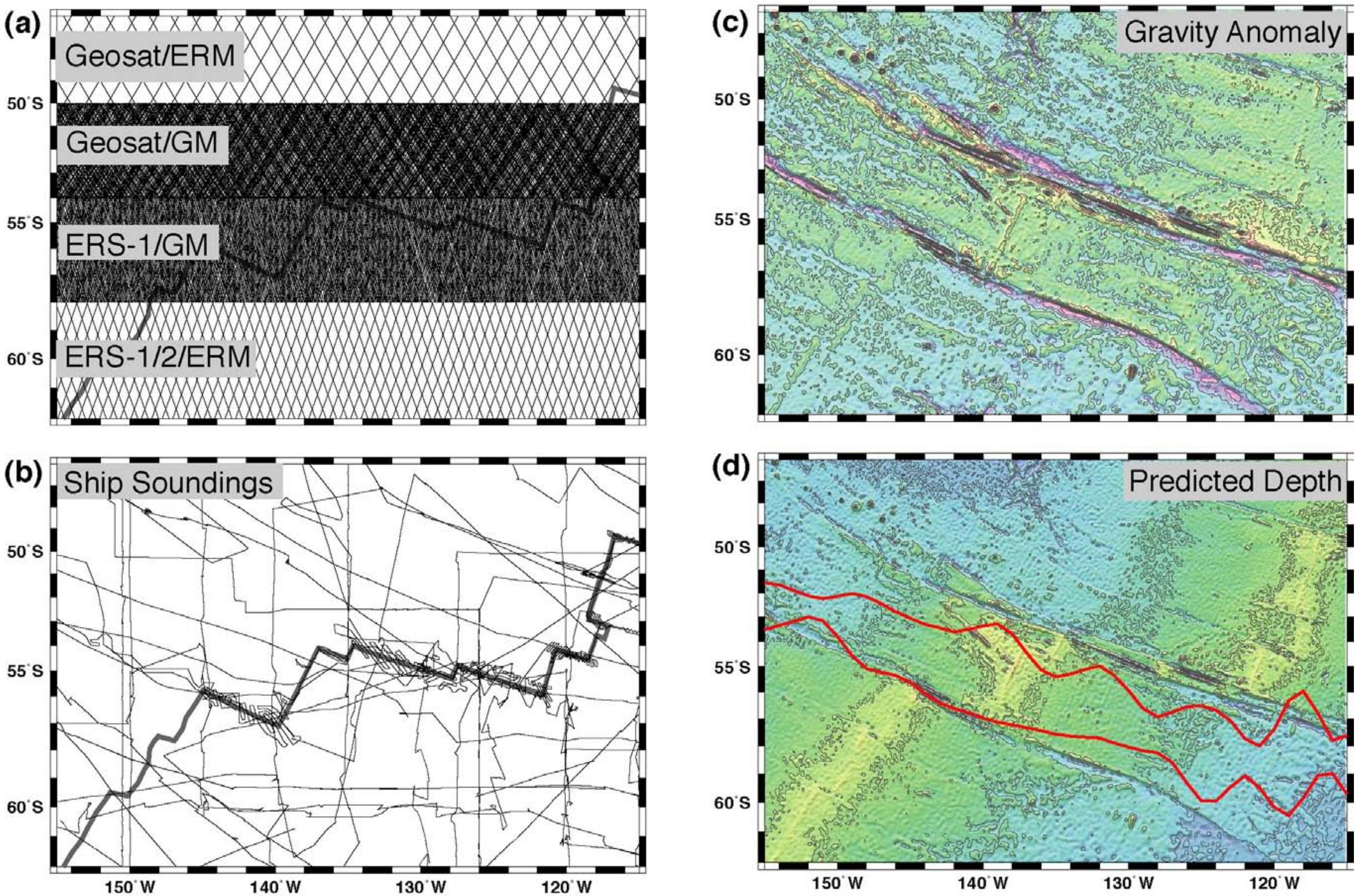
satellite
altimeter



multibeam
echo sounder



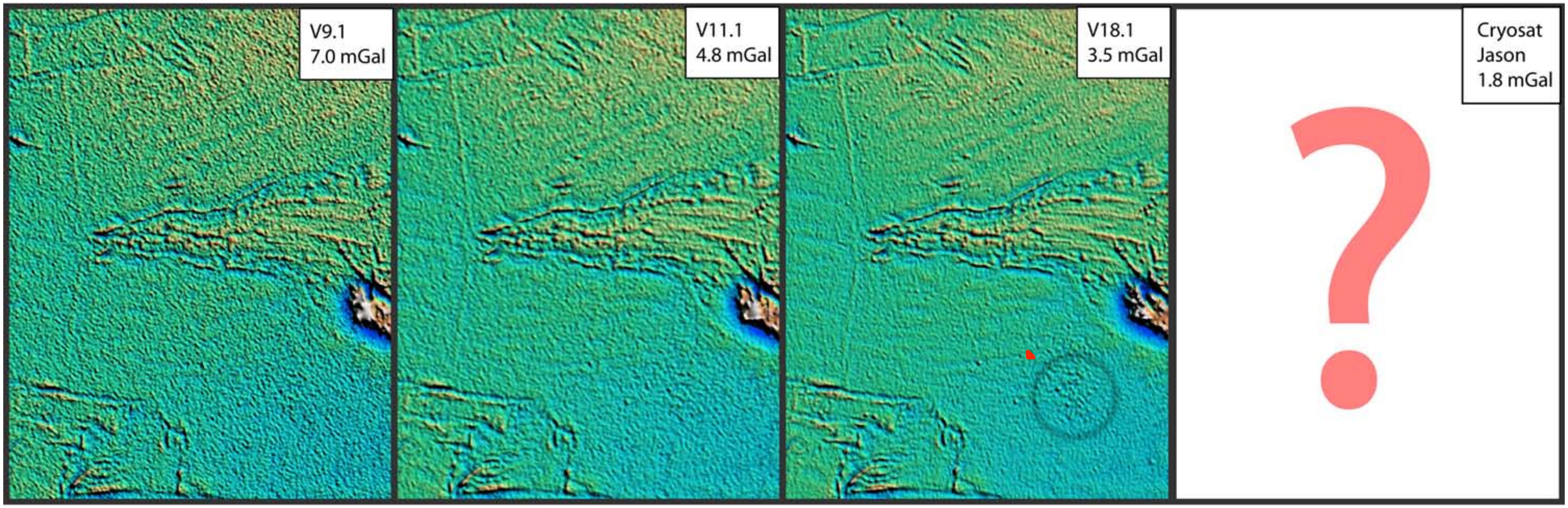
Sparse soundings + Dense altimetry = Global bathymetry



Improving Predicted Bathymetry Requires Better Gravity

Evolution of marine gravity models as seen over the
Galapagos Triple Junction

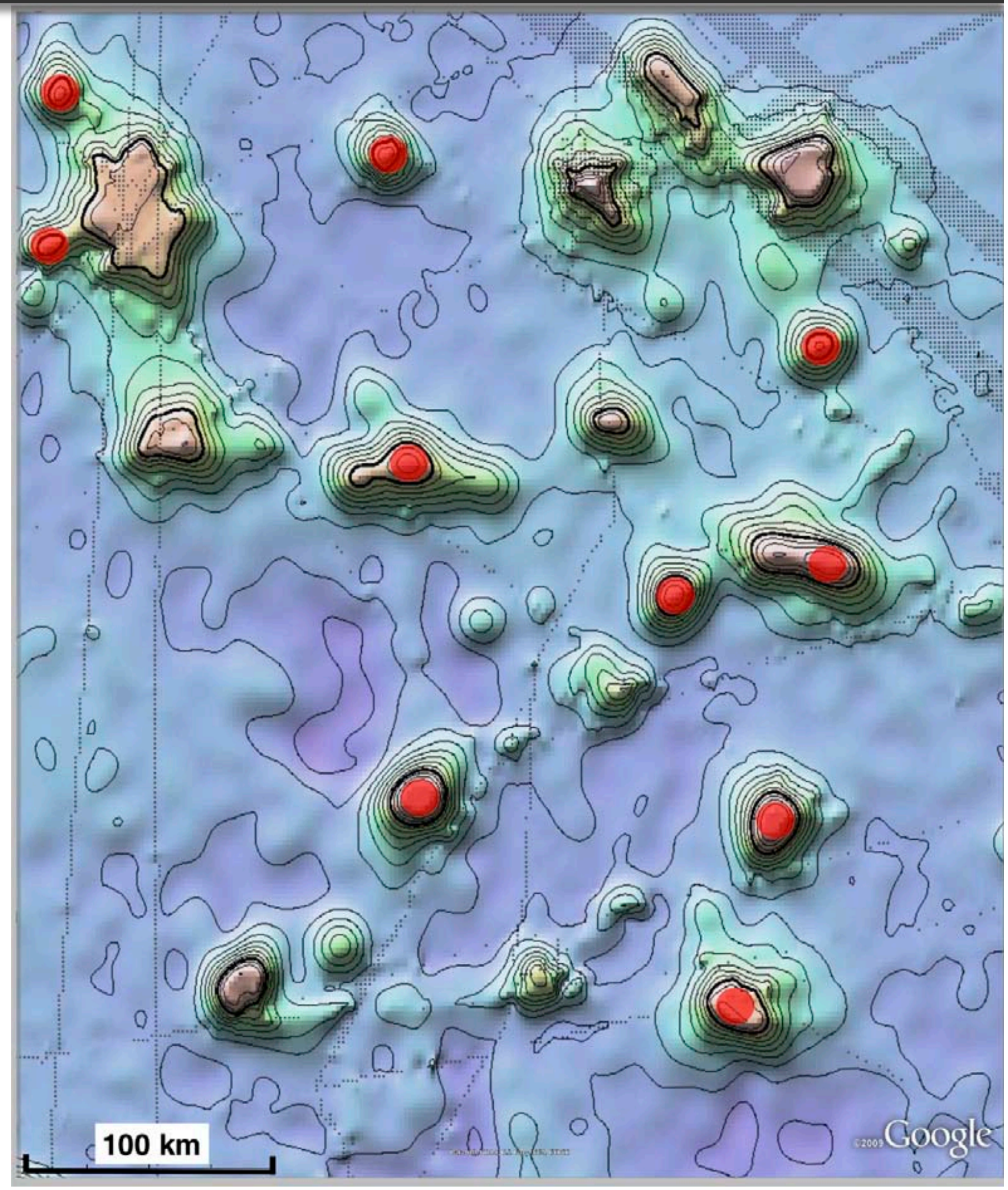
original data | reprocessed ERS | reprocessed Geosat



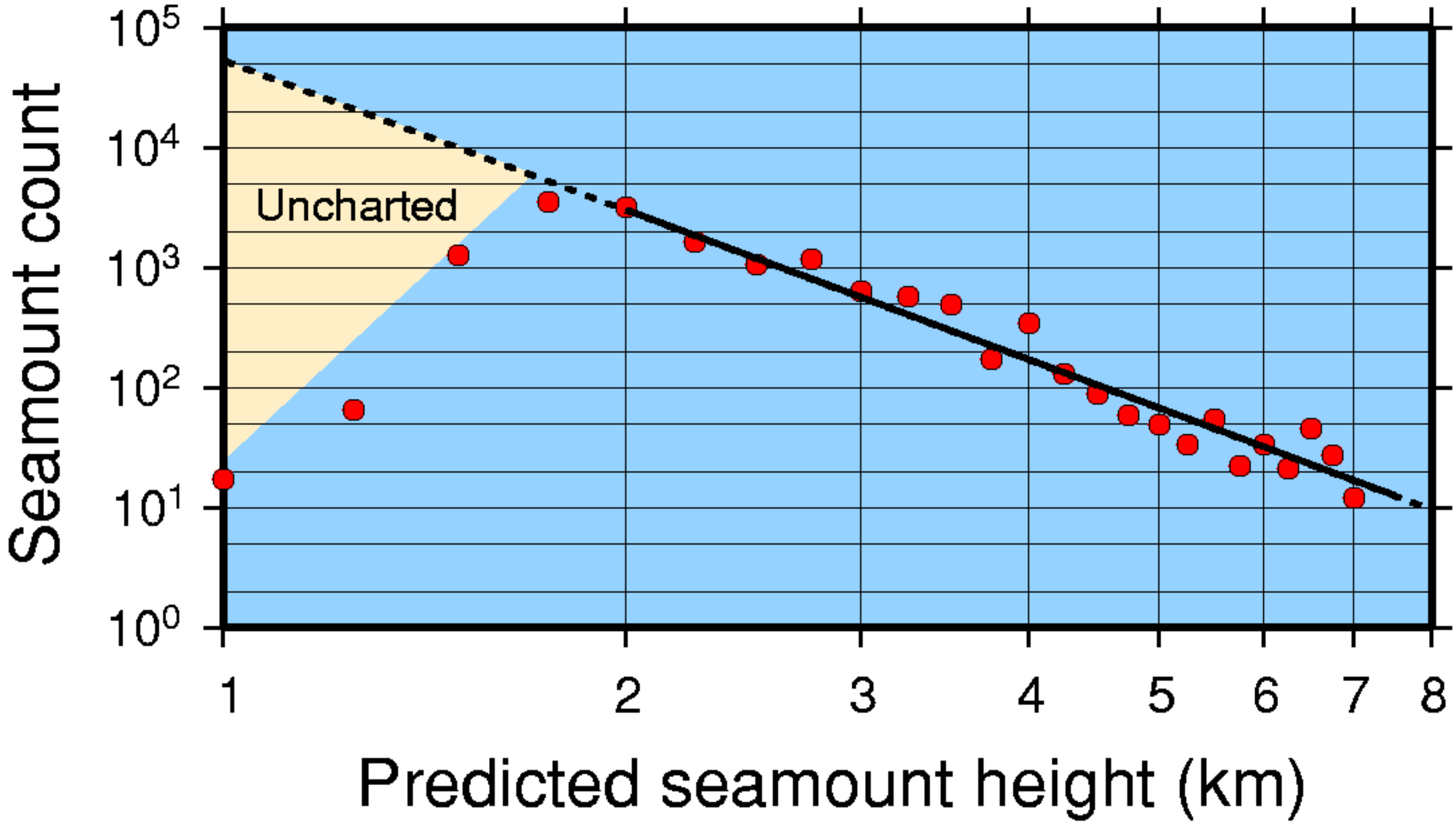
1997 | 2005 | 2009 | 2013 +

Uncharted Seamounts > 3 km tall

Predicted depths are based on altimeter-derived gravity and sparse ship soundings.



Seamounts



(Wessel, 2001)

Achieving 1 mGal Gravity Accuracy

- **Improved range precision** -- A factor of 2 or more improvement in altimeter range precision, with respect to Geosat and ERS-1, is needed to reduce the noise due to ocean waves.
- **Fine cross-track spacing and long mission duration** -- A ground track spacing of 6 km or less is required.
- **Moderate inclination** -- Current non-repeat-orbit altimeter data have high inclination and thus poor accuracy of the E-W slope at the equator.
- **Near-shore tracking** -- For applications near coastlines, the ability to track the ocean surface close to shore is desirable.

The CryoSat Mission

source: ESA

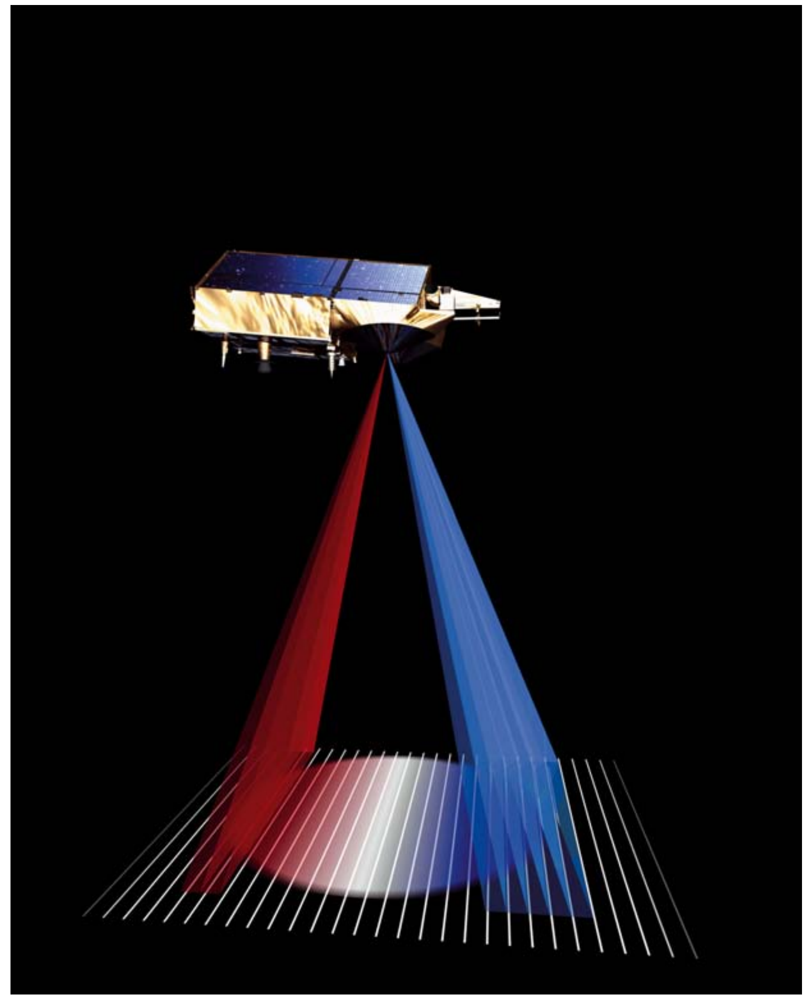
- launched by the European Space Agency in April 2010
- designed to study ice in the polar regions using a multi-mode radar altimeter with different precision capabilities
- *operates over the oceans as well!*

CryoSat's Modes

- **LRM** –- conventional mode used by all previous altimeters.

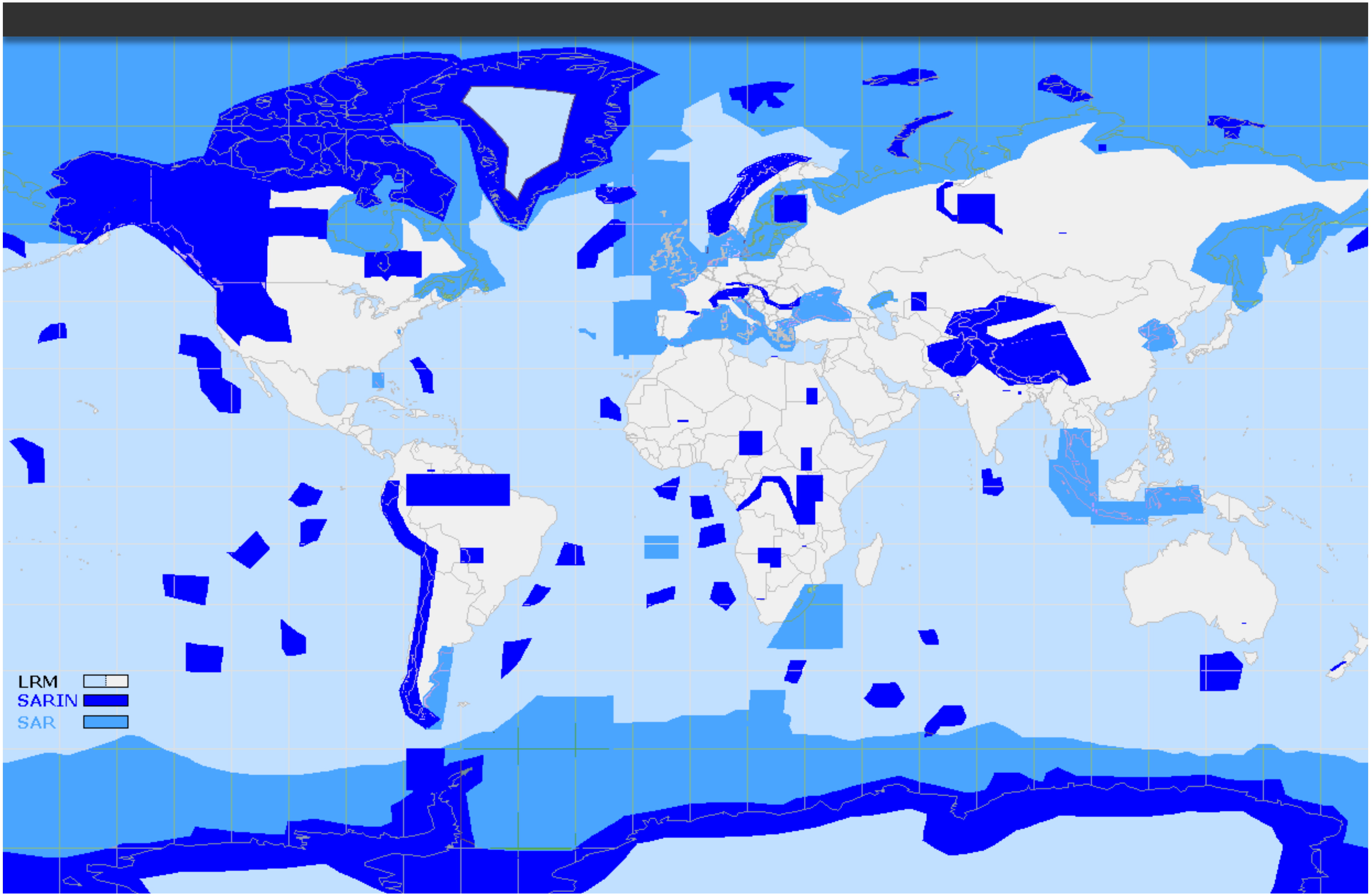
- **SAR** –- synthetic aperture radar mode may provide 2-4 times better range precision.

- **SARIN** -– uses two receiving antennas to also measure cross-track slope over ice.

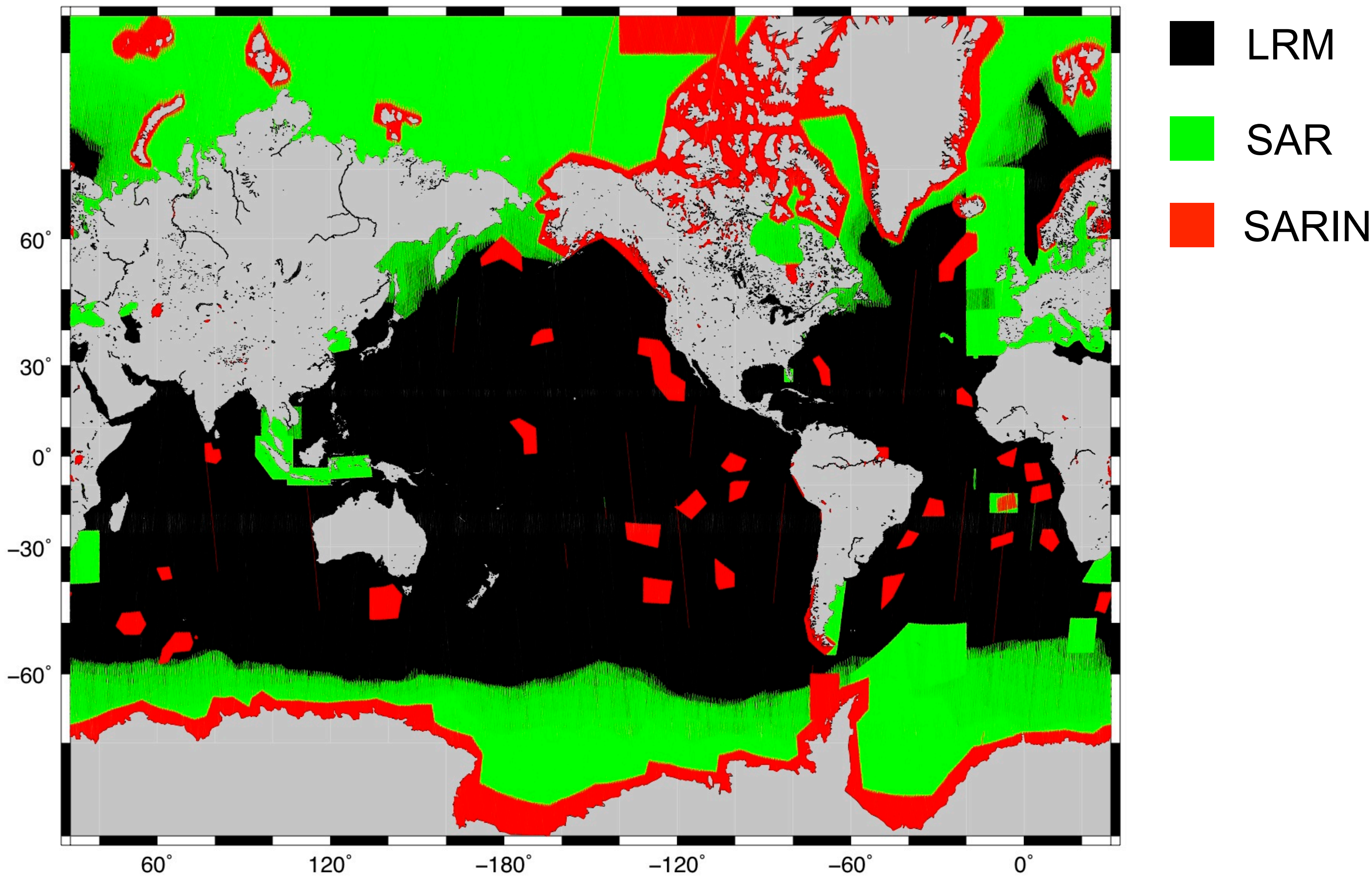


source: ESA

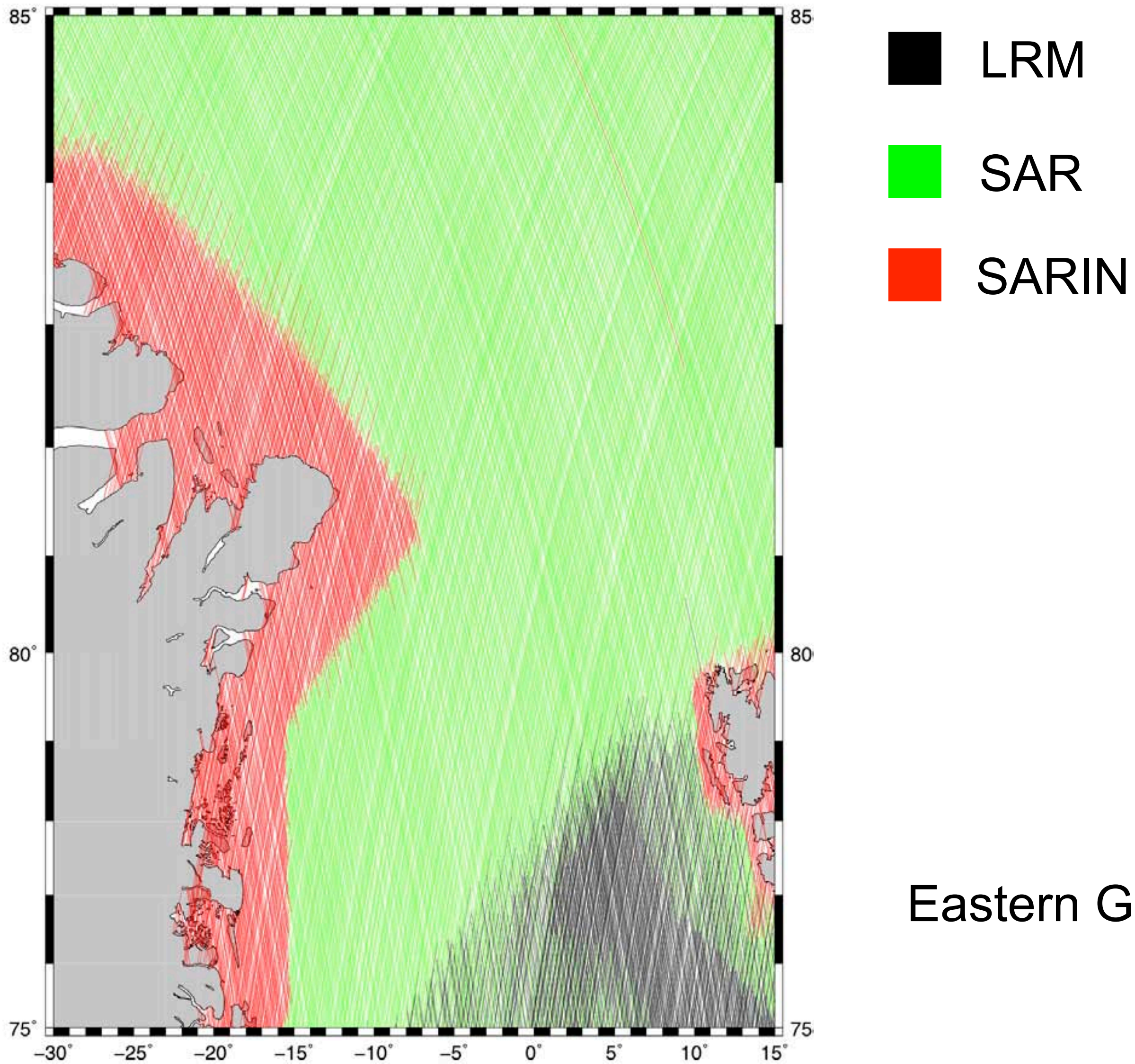
CryoSat Operating Modes Map



CryoSat Data Acquisition over 14 Months



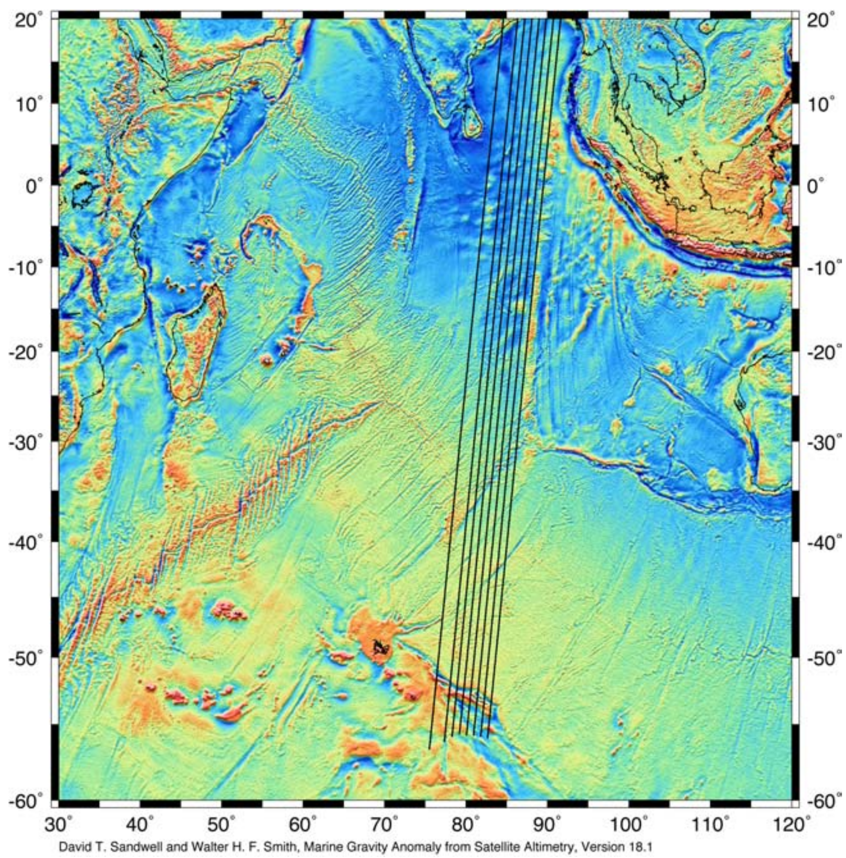
CryoSat Data Acquisition over 14 Months

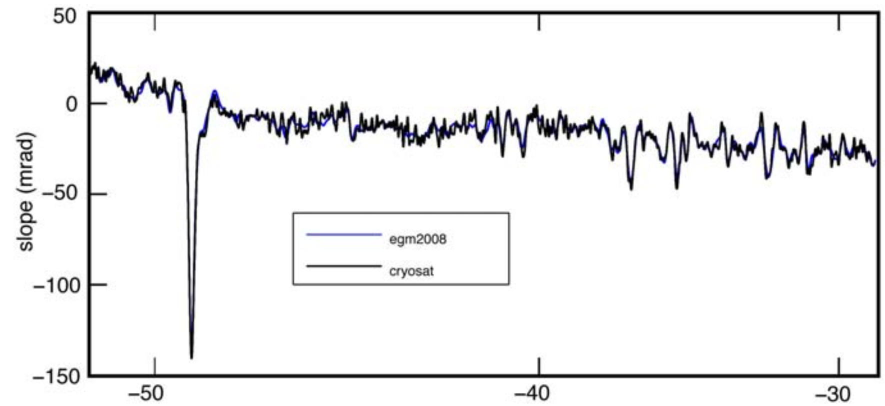


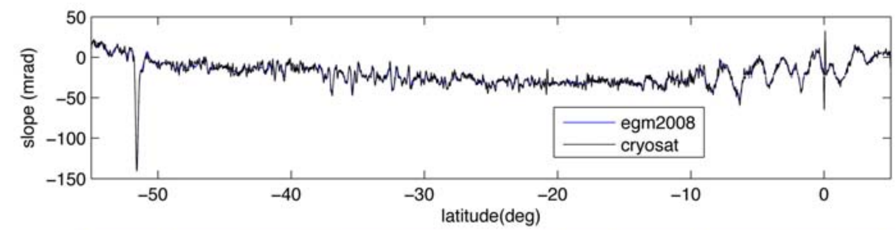
Eastern Greenland

Gravity Improvements from CryoSat

CryoSat LRM data are *1.4 times more precise* than Geosat and ERS-1 because of the 2X higher pulse repetition frequency



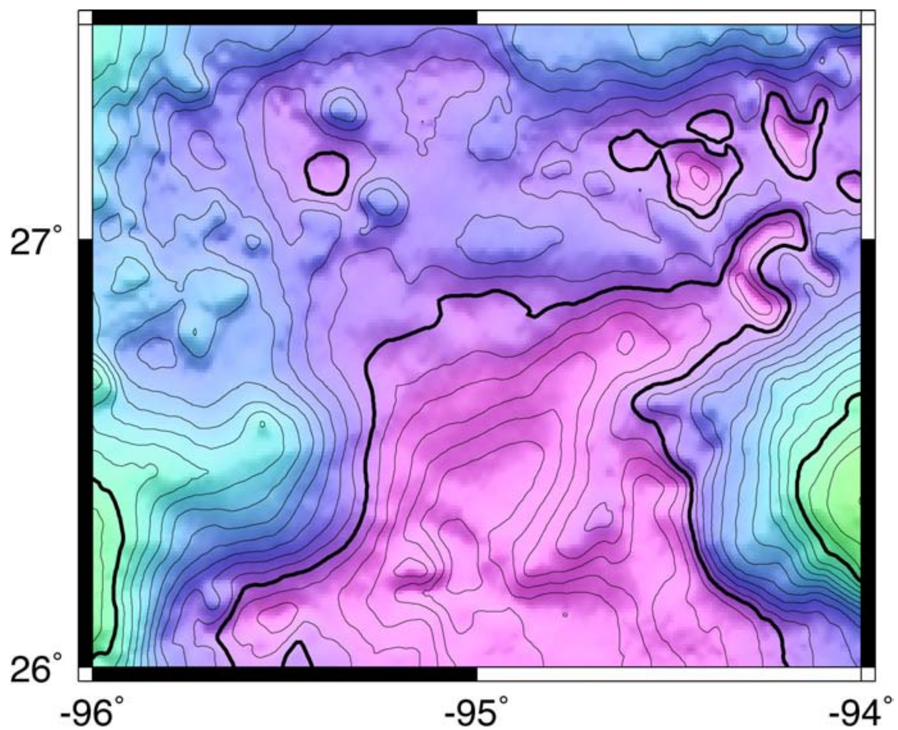




Excellent agreement between CryoSat data processed to determine arrival times ("retracked") and EGM 2008 slopes

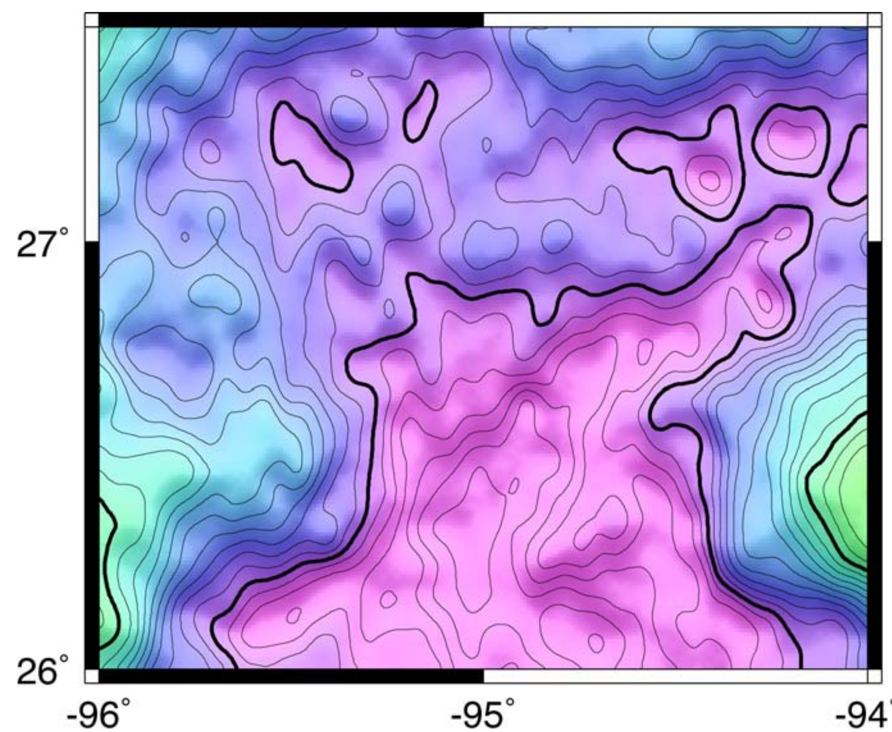
Comparisons in the Gulf of Mexico

ship gravity



source: EDCON

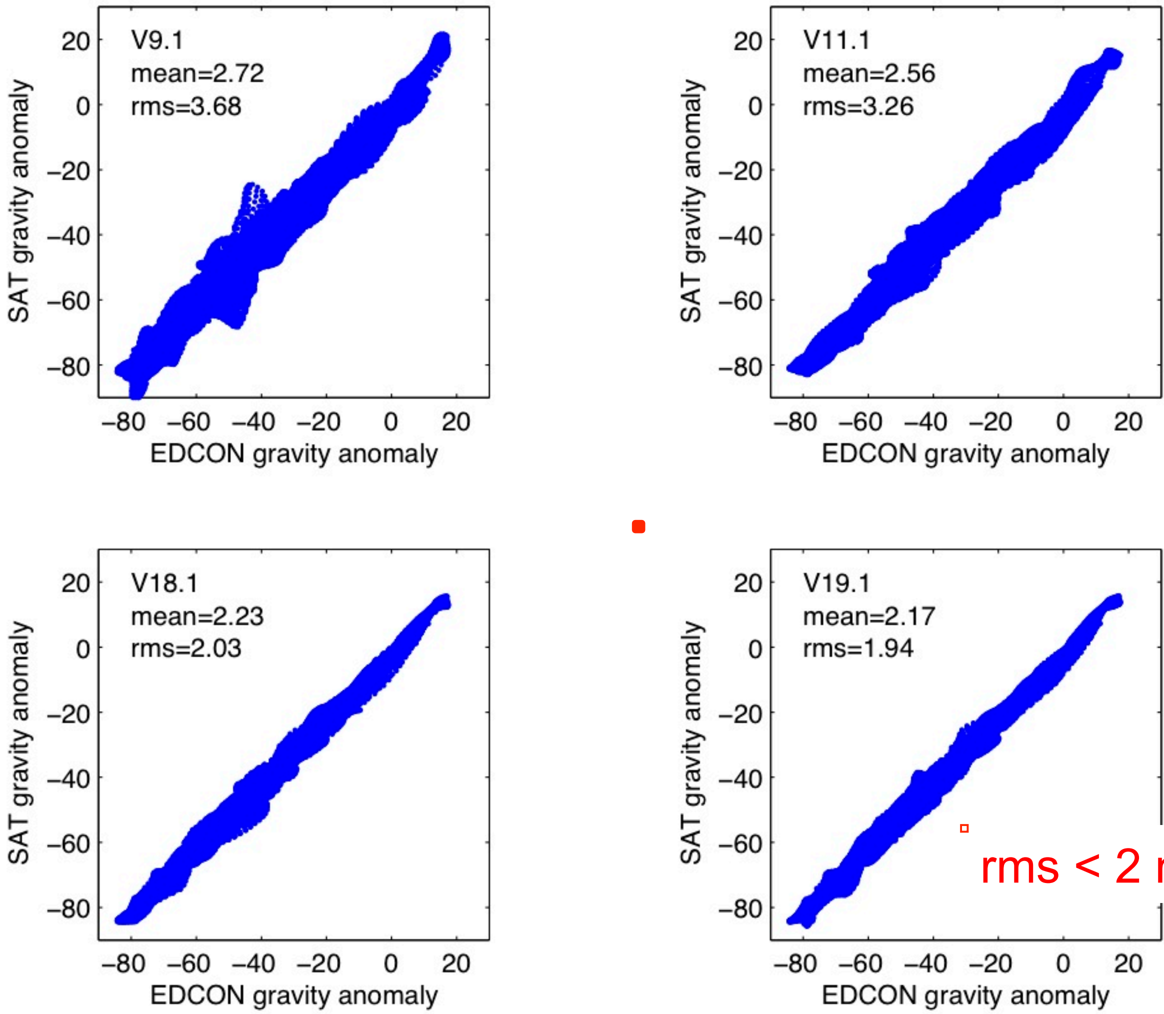
satellite gravity
with CryoSat LRM



5 mGal contour interval

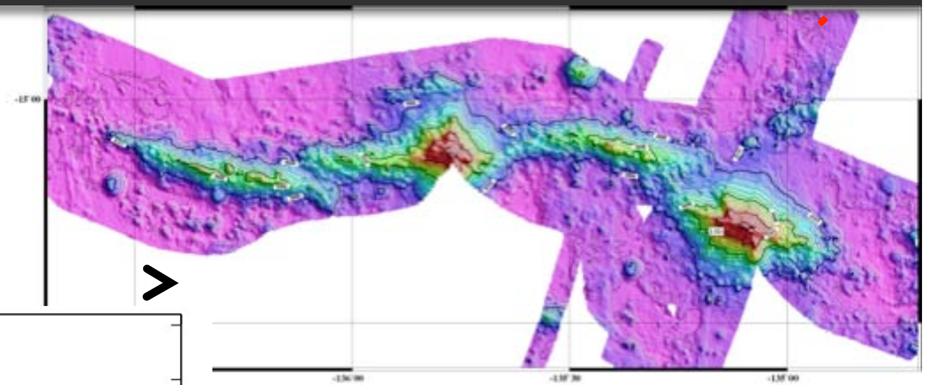
Comparisons in the Gulf of Mexico

satellite gravity with CryoSat LRM vs. ship gravity

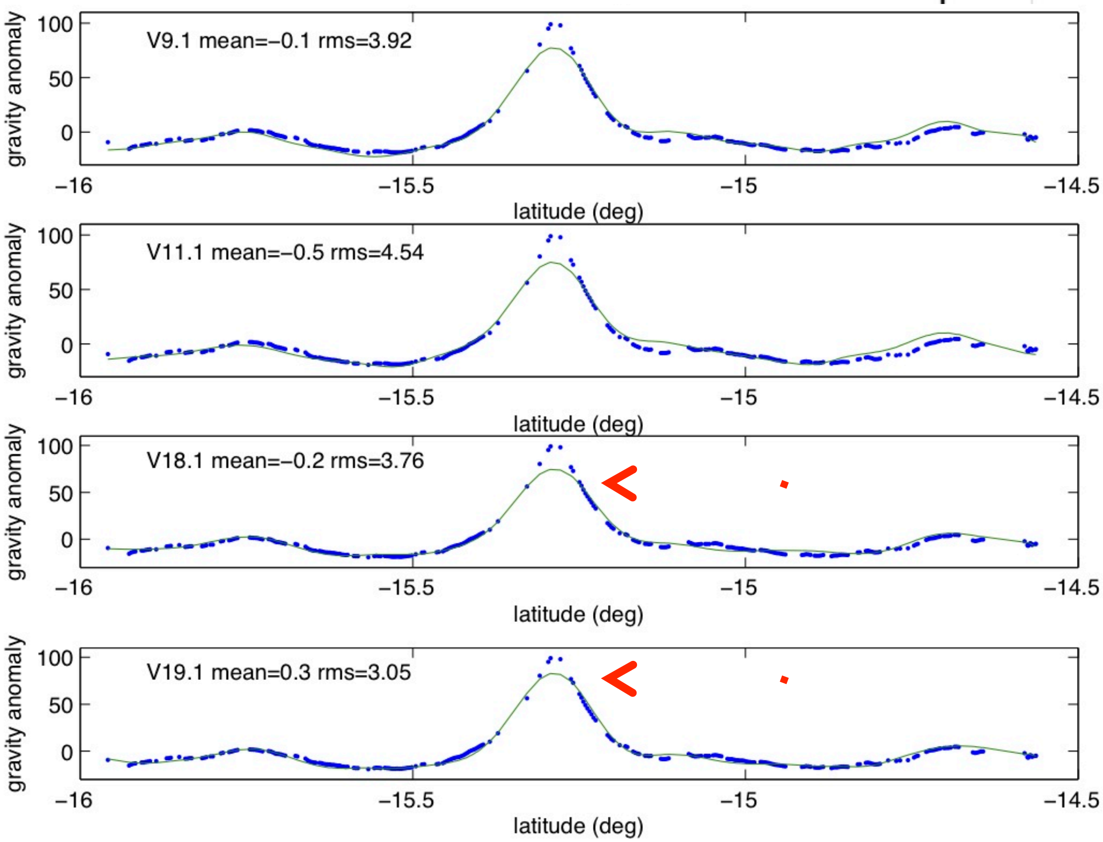


rms < 2 mGal

Wahoo Guyot

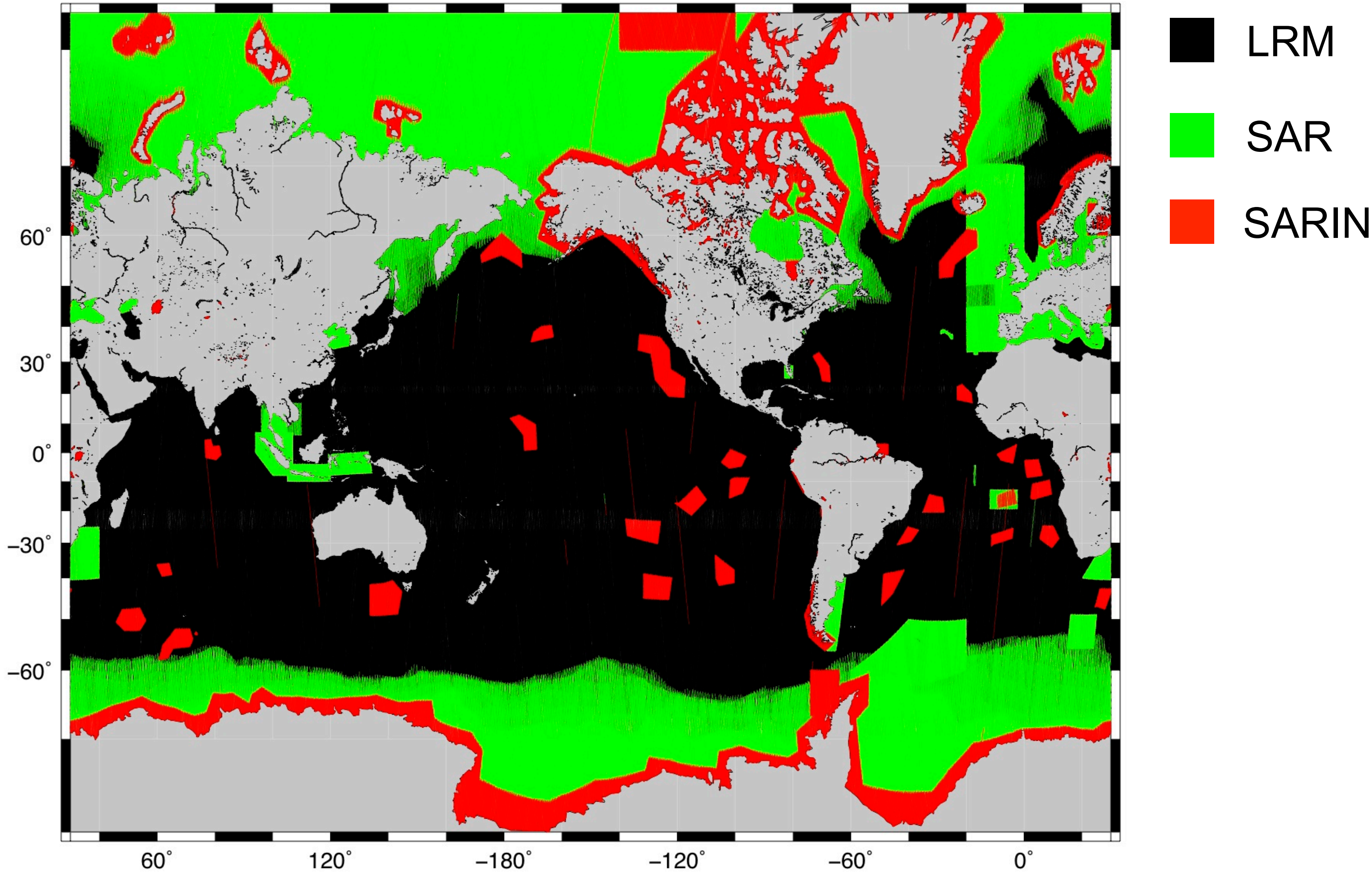


ship gravity (points)
vs. satellite gravity (line)
over ~250 km



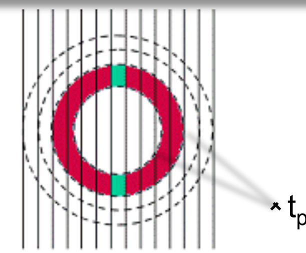
improvement due to addition of CryoSat LRM data

CryoSat Data Acquisition over 14 Months



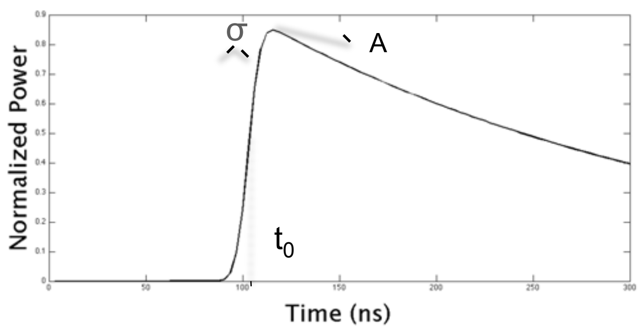
CryoSat LRM Mode vs. SAR Mode

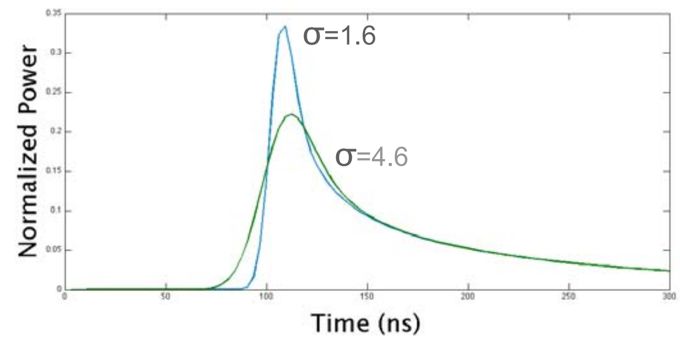
Radar Footprint



from ESA Radar Altimetry Tutorial

Waveform Shape





Analytic Model

$$M(t) = \frac{A}{2}\left[1 + erf\left(\frac{t - t_0}{\sqrt{2}\sigma}\right)\right]P(t)$$

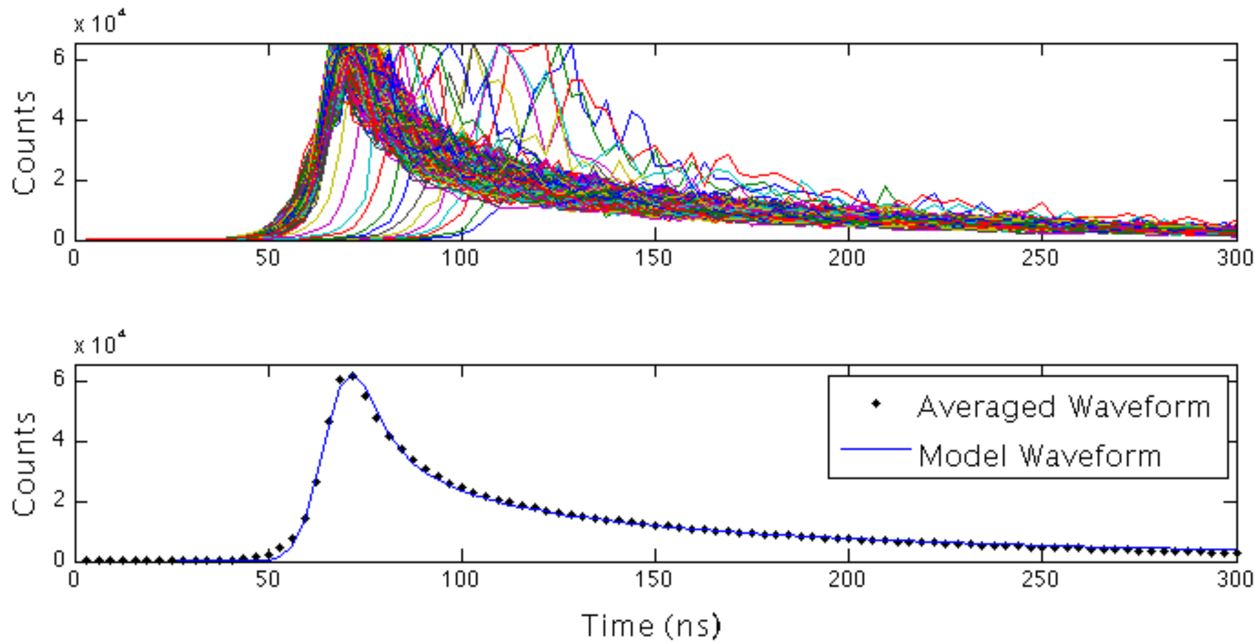
$$P(t) = \begin{cases} 1 & t < t_0 \\ e^{-\alpha(t - t_0)} & t \geq t_0 \end{cases}$$

Brown (1977)

$$M(t) = \frac{A}{4}\sqrt{\frac{2\sigma}{t_p}}\left\{ e^{-\frac{1}{4}\left(\frac{t-t_0}{\sigma}\right)^2} D_{-\frac{3}{2}}\left(-\frac{t - t_0}{\sigma}\right) - e^{-\frac{1}{4}\left(\frac{t-t_0-t_p}{\sigma}\right)^2} D_{-\frac{3}{2}}\left(-\frac{t - t_0 - t_p}{\sigma}\right) \right\} P(t)$$

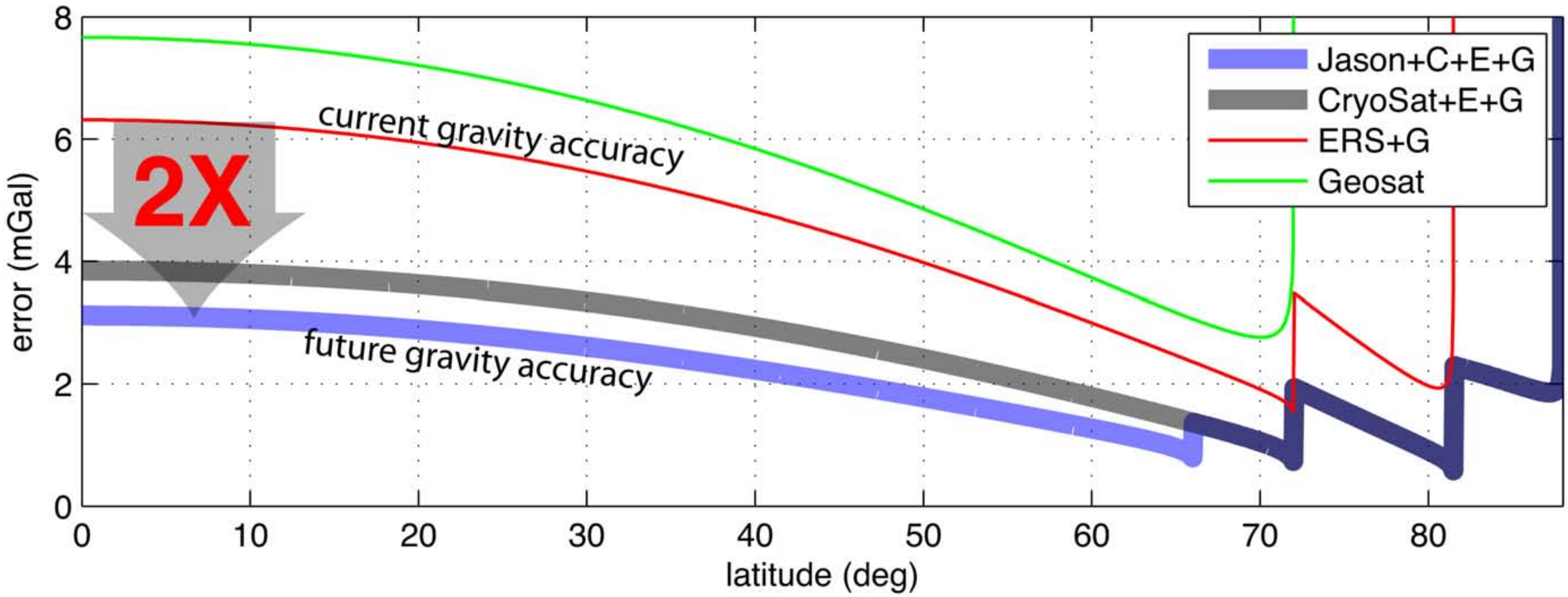
$D_n(z)$ is a parabolic cylinder function of order n

Additional Improvements in SAR Mode

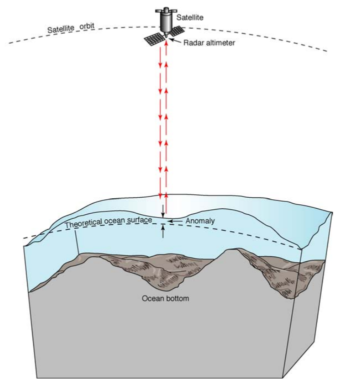


CryoSat SAR data could possibly be 2X more accurate than Geosat and ERS because the waveform is sharper

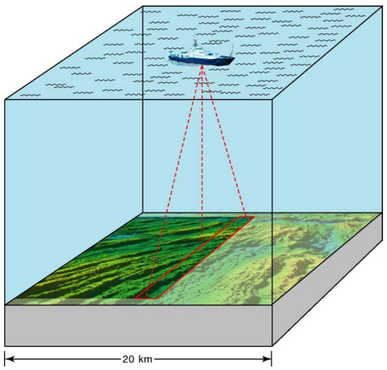
Expected Gravity Improvement



Error in north and east components was averaged.



Conclusions



- Expect major improvements in gravity accuracy:
  - 2X in LRM areas
  - 4X in SAR areas
- Predicted bathymetry accuracy is proportional to gravity accuracy.
- Improved gravity will provide new opportunities for investigating
  - detailed tectonics
  - seafloor roughness
- Predicted bathymetry will evolve 3-4 times over the next few years so GEBCO will need a capability for rapid updates.