



Bathymetry from space
(altimetry)

+

Multibeam & singlebeam
sounding compilations

+

Onshore DEM's

=

SRTM15+V2

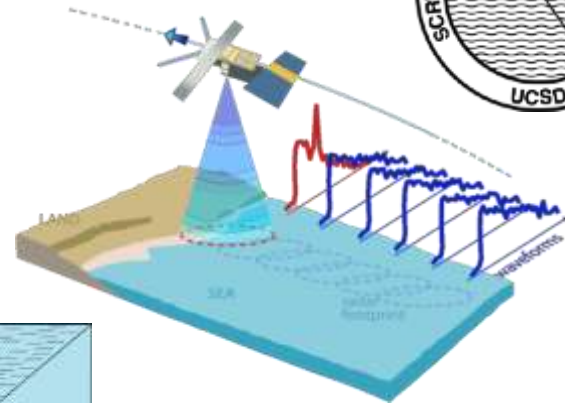
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J. J. Becker¹ Hugh Harper¹
Christopher Olson¹
Benjamin Tea¹ Yoav Freund²
James Beale³ Paul Wessel⁴
Walter H. F. Smith⁵

GEBCO Symposium
November 14th 2018
Canberra

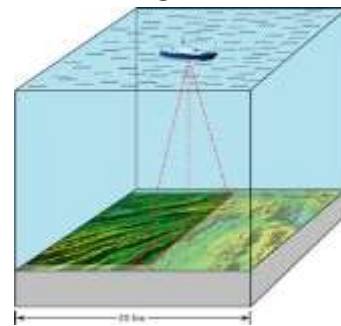
Outline



Part one: ***New satellite altimetry***



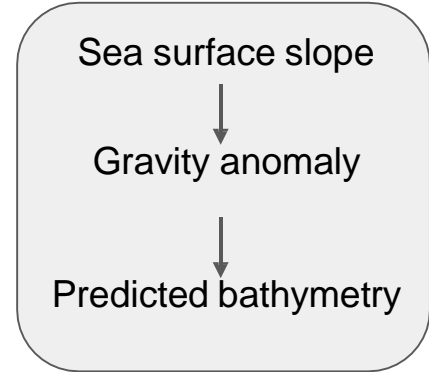
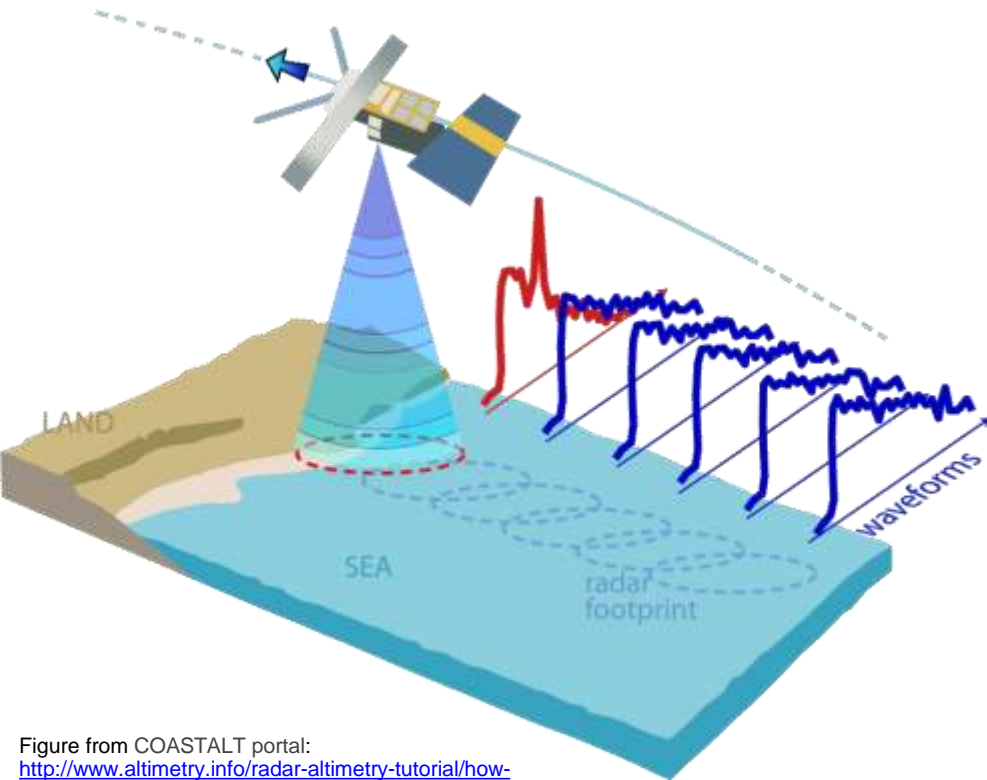
Part two: ***New bathymetry***



Part three: ***SRTM15+V2***

Part four: ***Future plans & grid integration***

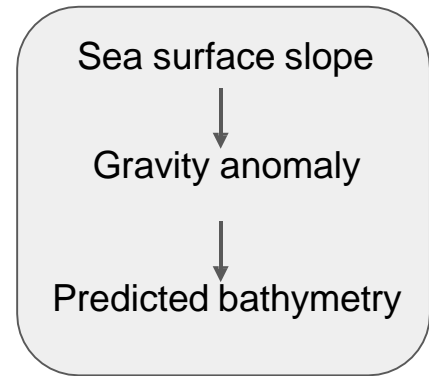
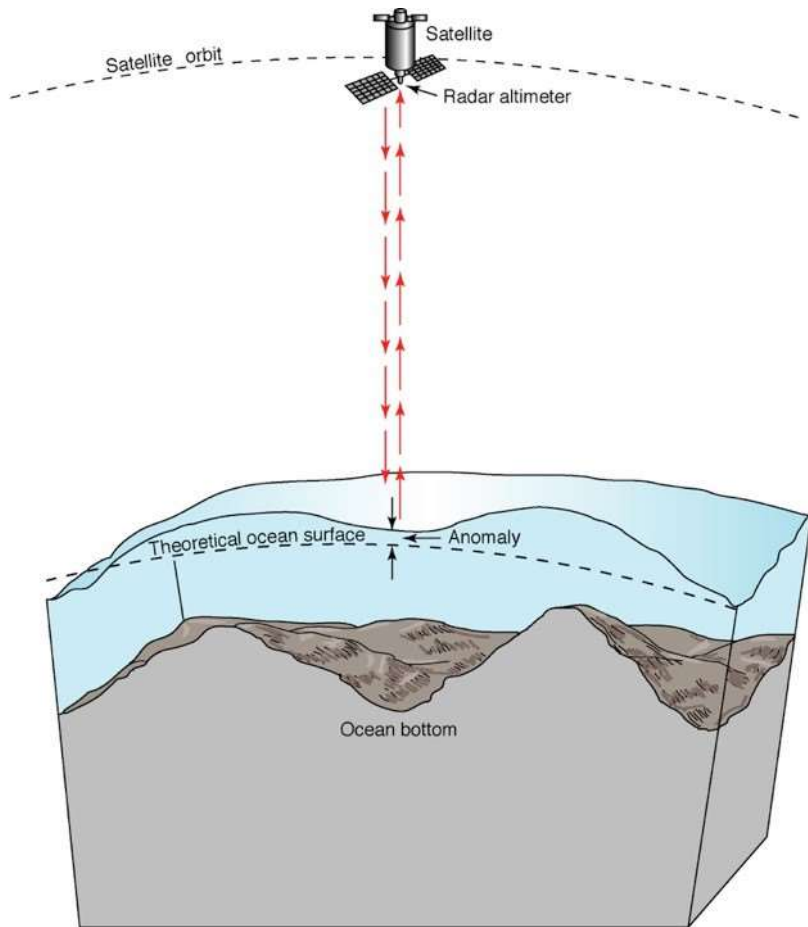
Satellite altimetry



NB: We're primarily focused on the deep oceans for plate tectonic applications

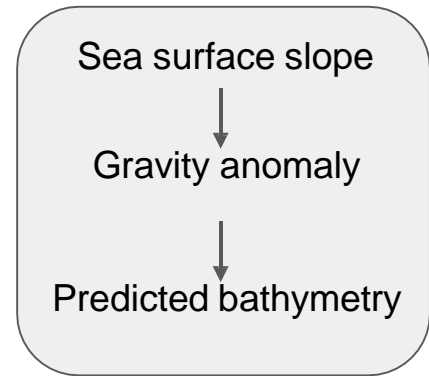
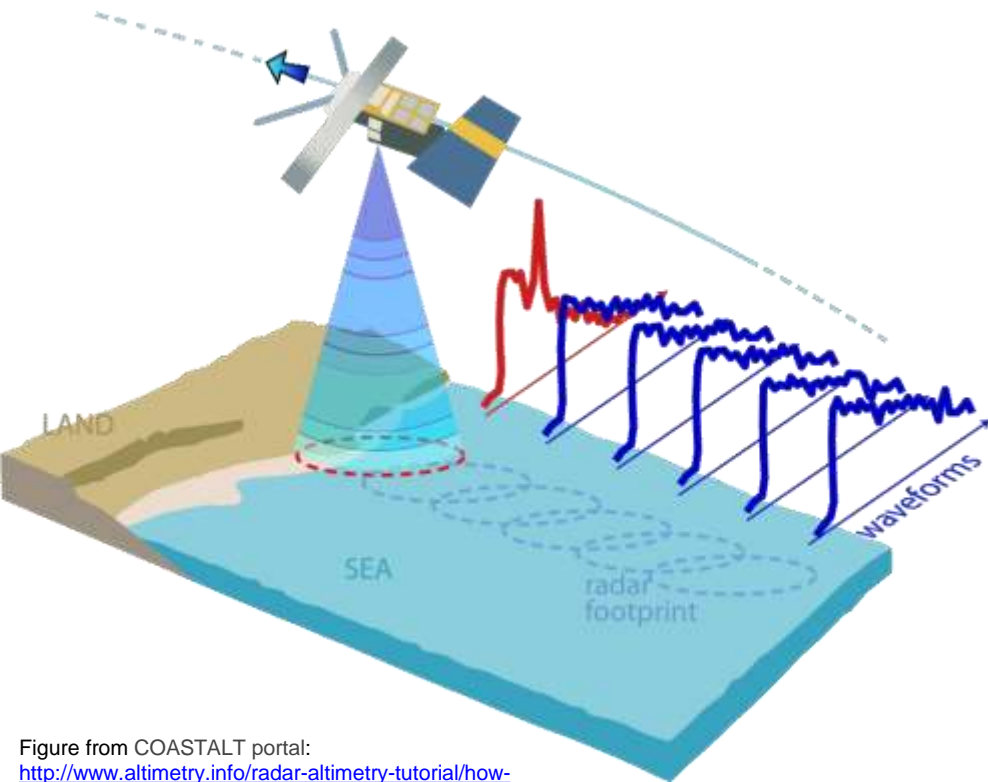
Figure from COASTALT portal:
<http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/>

Satellite altimetry



The aim of the game is to measure **sea surface slope as accurately as possible.**

Satellite altimetry

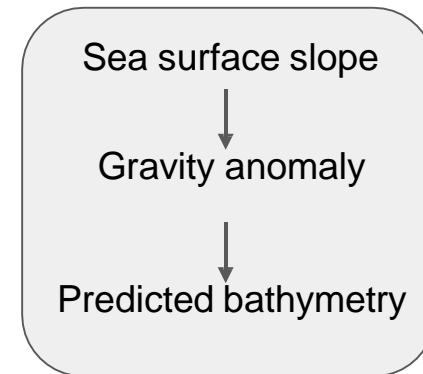
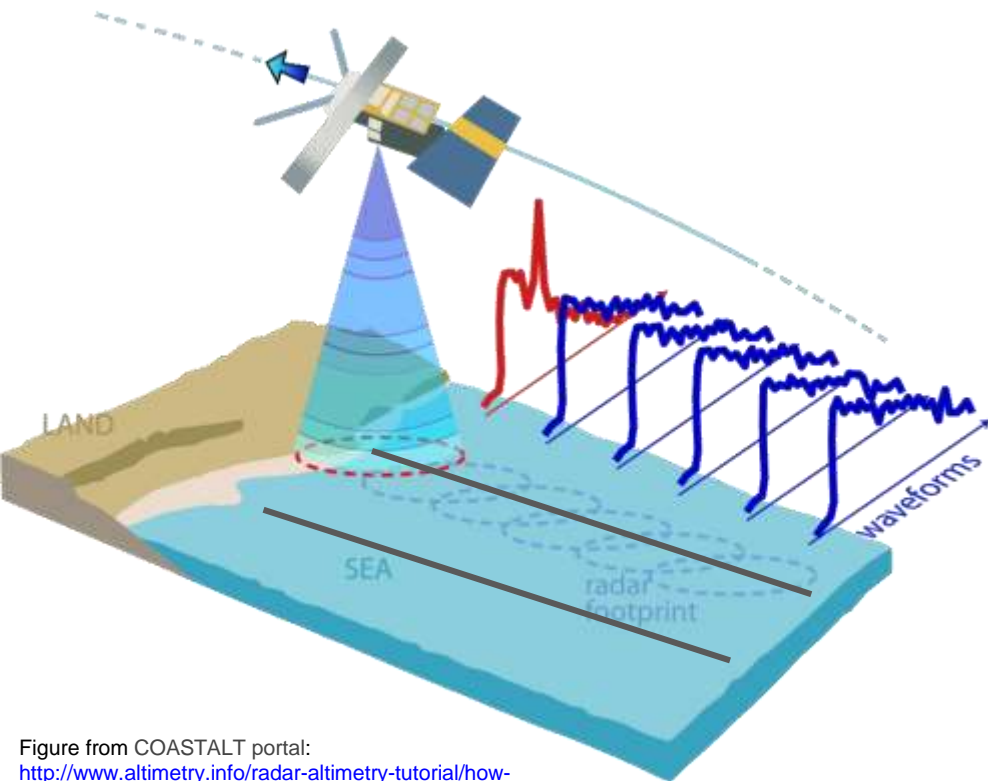
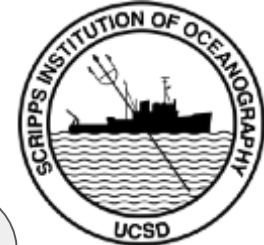


The aim of the game is to measure **sea surface slope as accurately as possible**.

This relies on two main parameters:

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Satellite altimetry



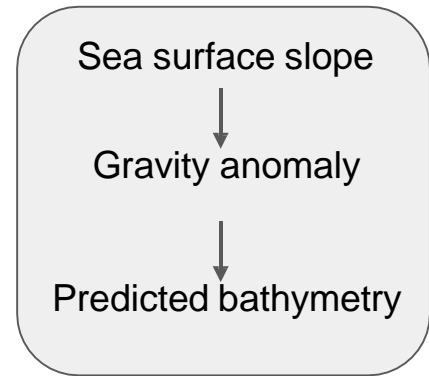
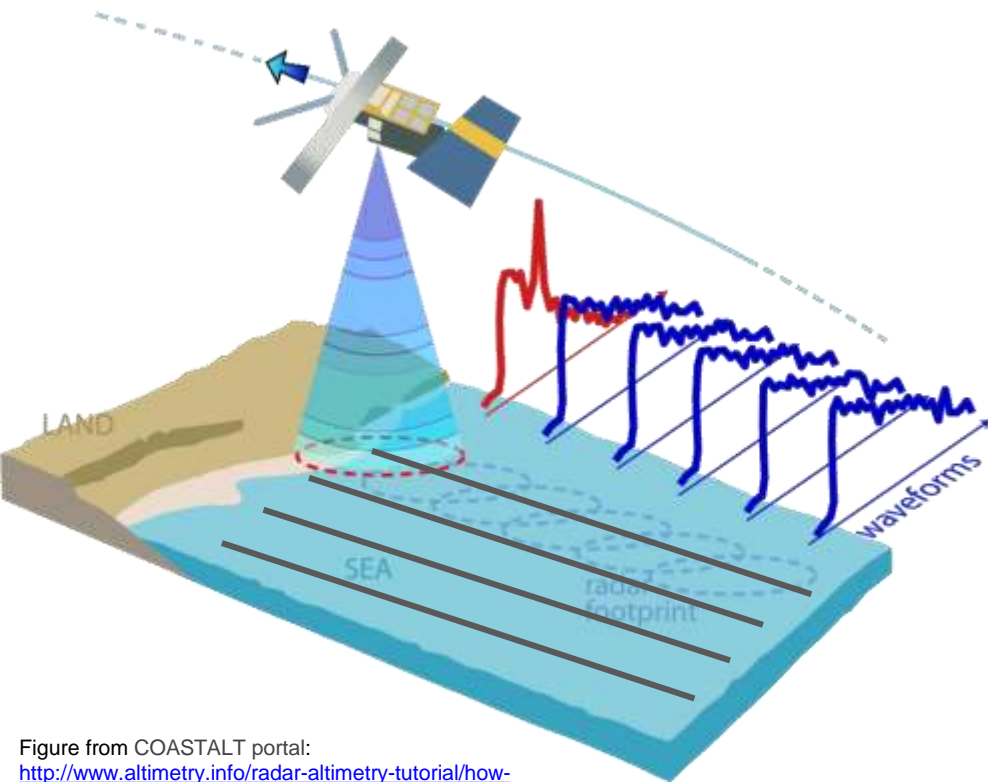
The aim of the game is to measure **sea surface slope as accurately as possible**.

This relies on two main parameters:

1. Density of track spacing.

Figure from COASTALT portal:
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Satellite altimetry



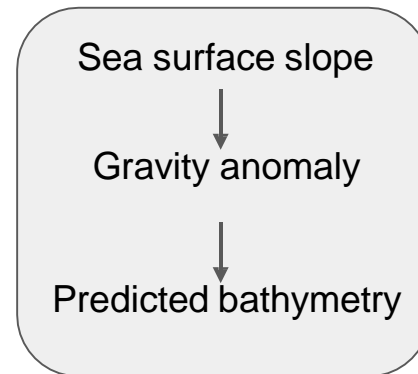
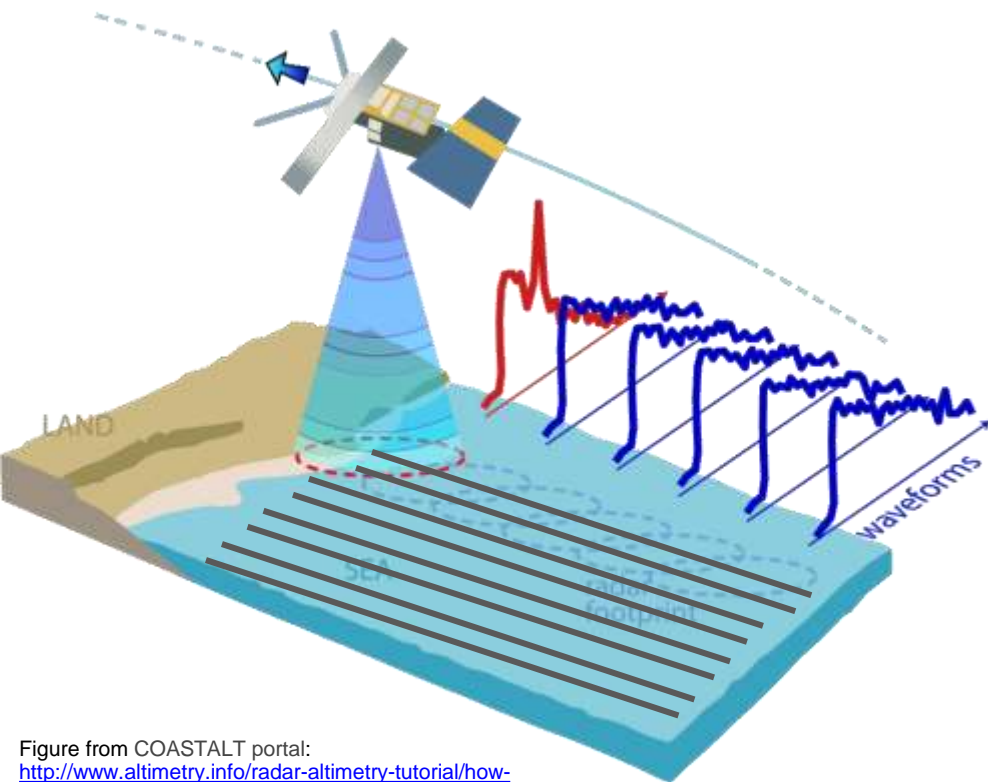
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Satellite altimetry



The aim of the game is to measure **sea surface slope as accurately as possible**.

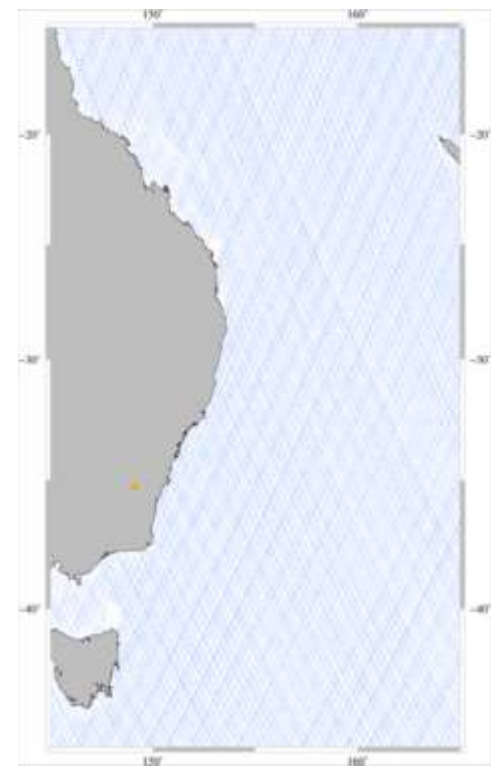
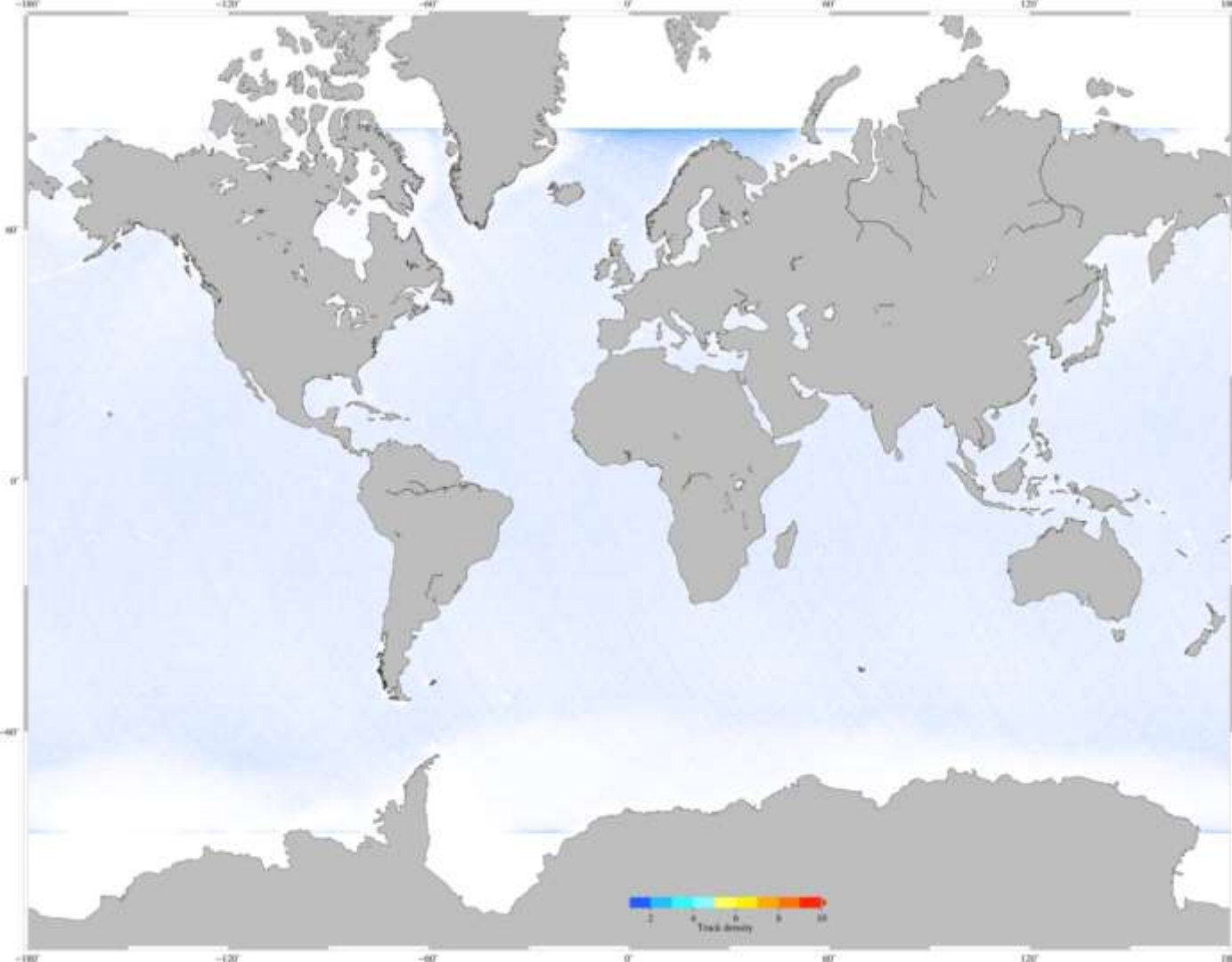
This relies on two main parameters:

1. Density of track spacing
(& inclination - currently poor E-W component)

Figure from COASTALT portal:
<http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/>

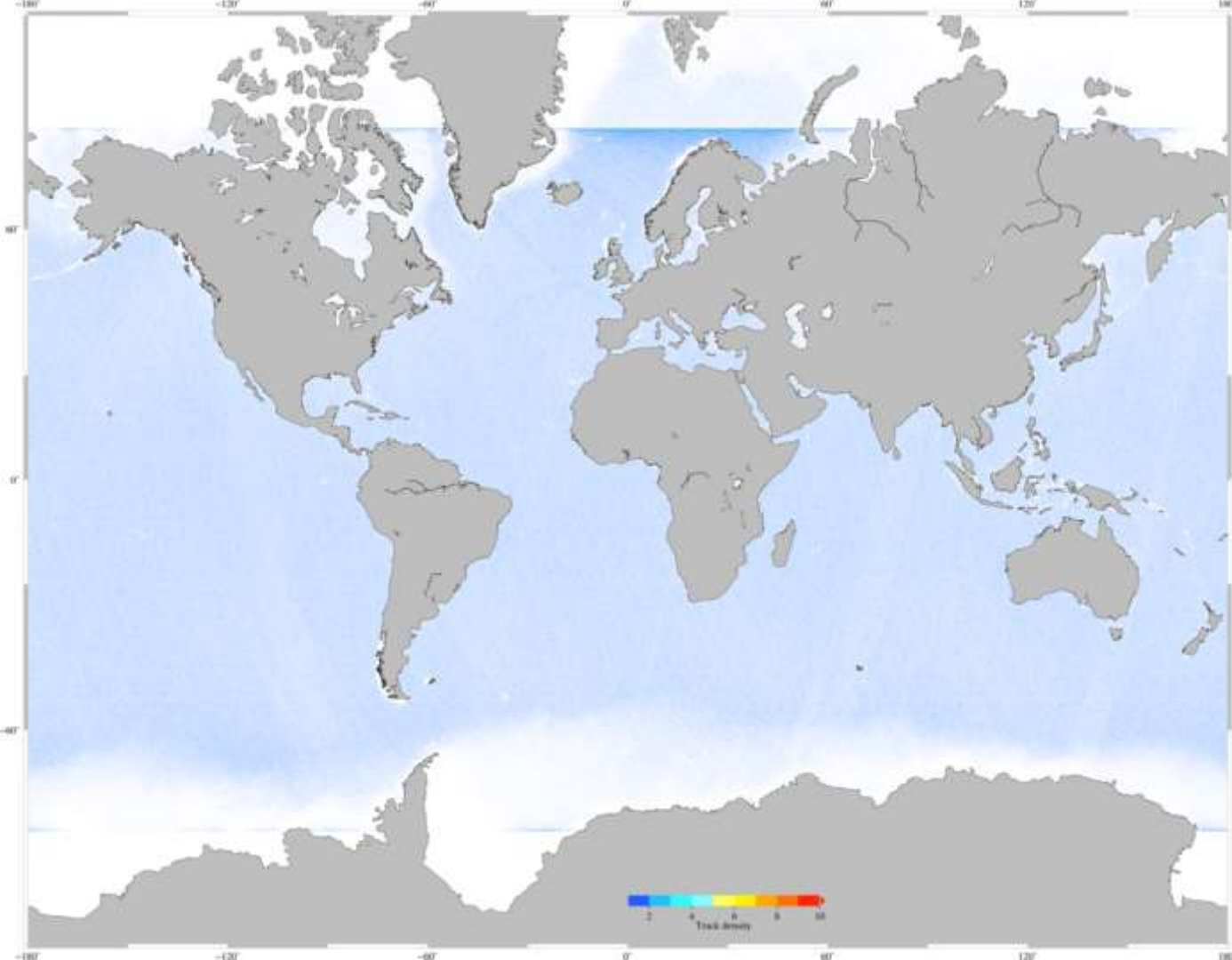
Track density

Geosat



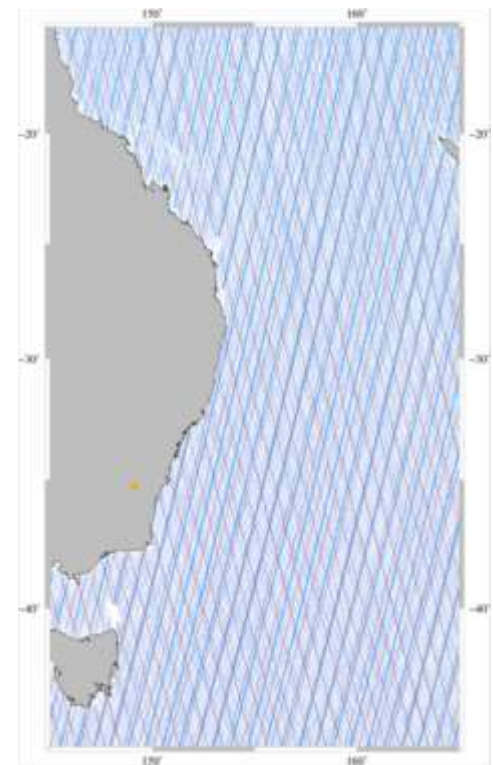
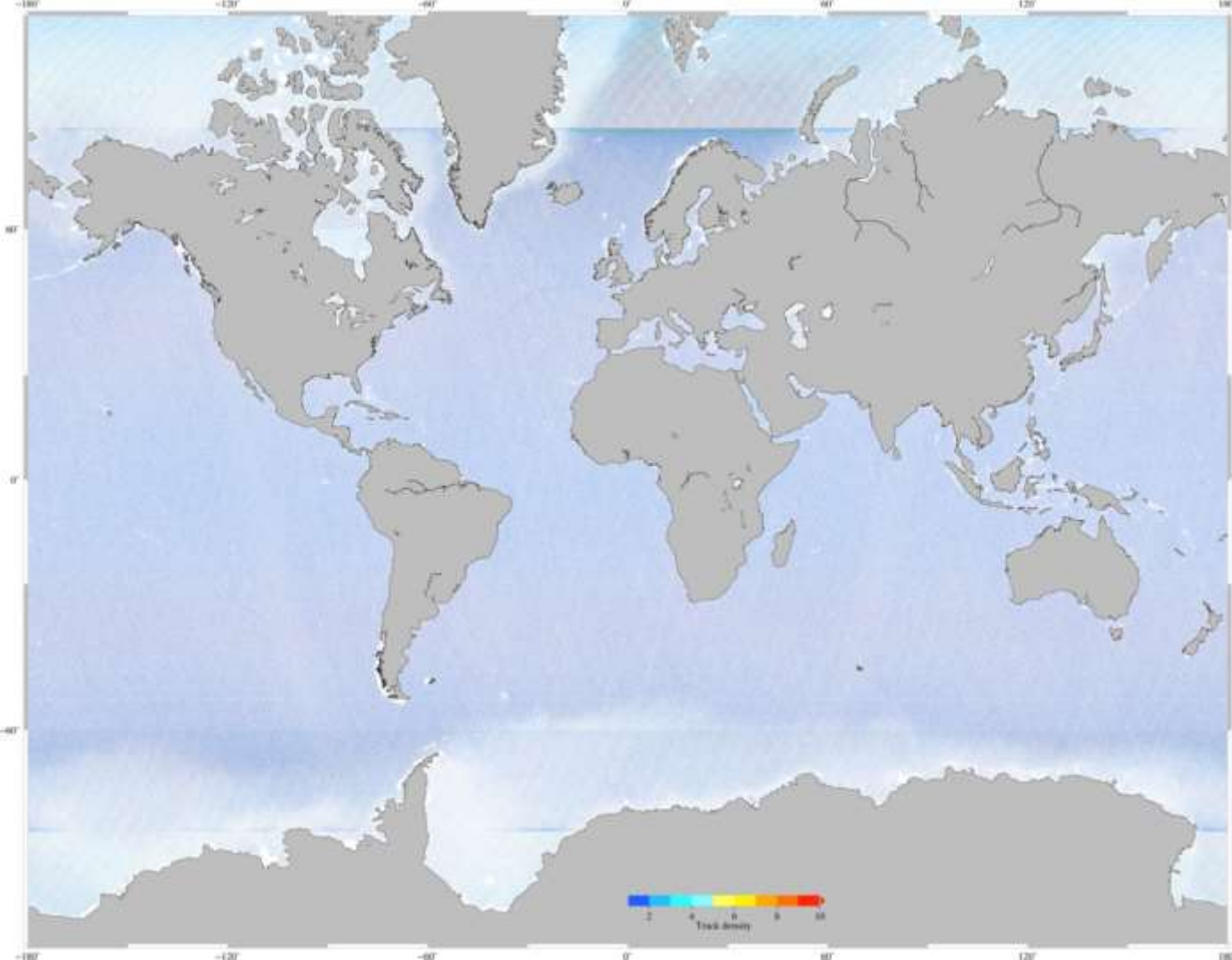
Track density

Geosat + ers1



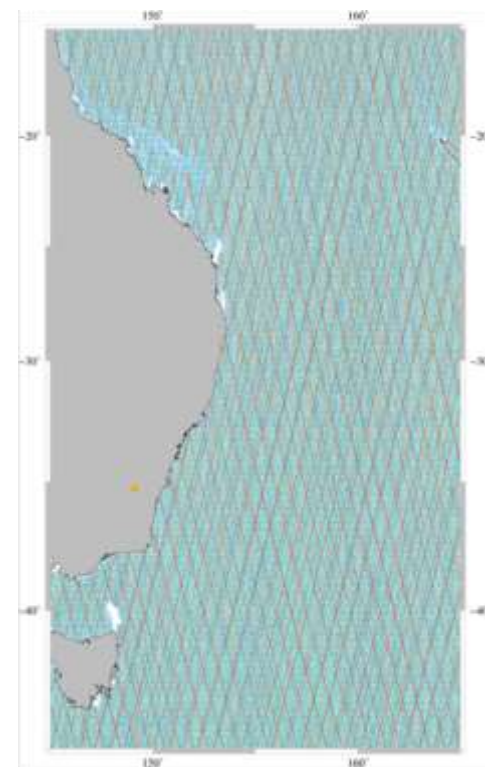
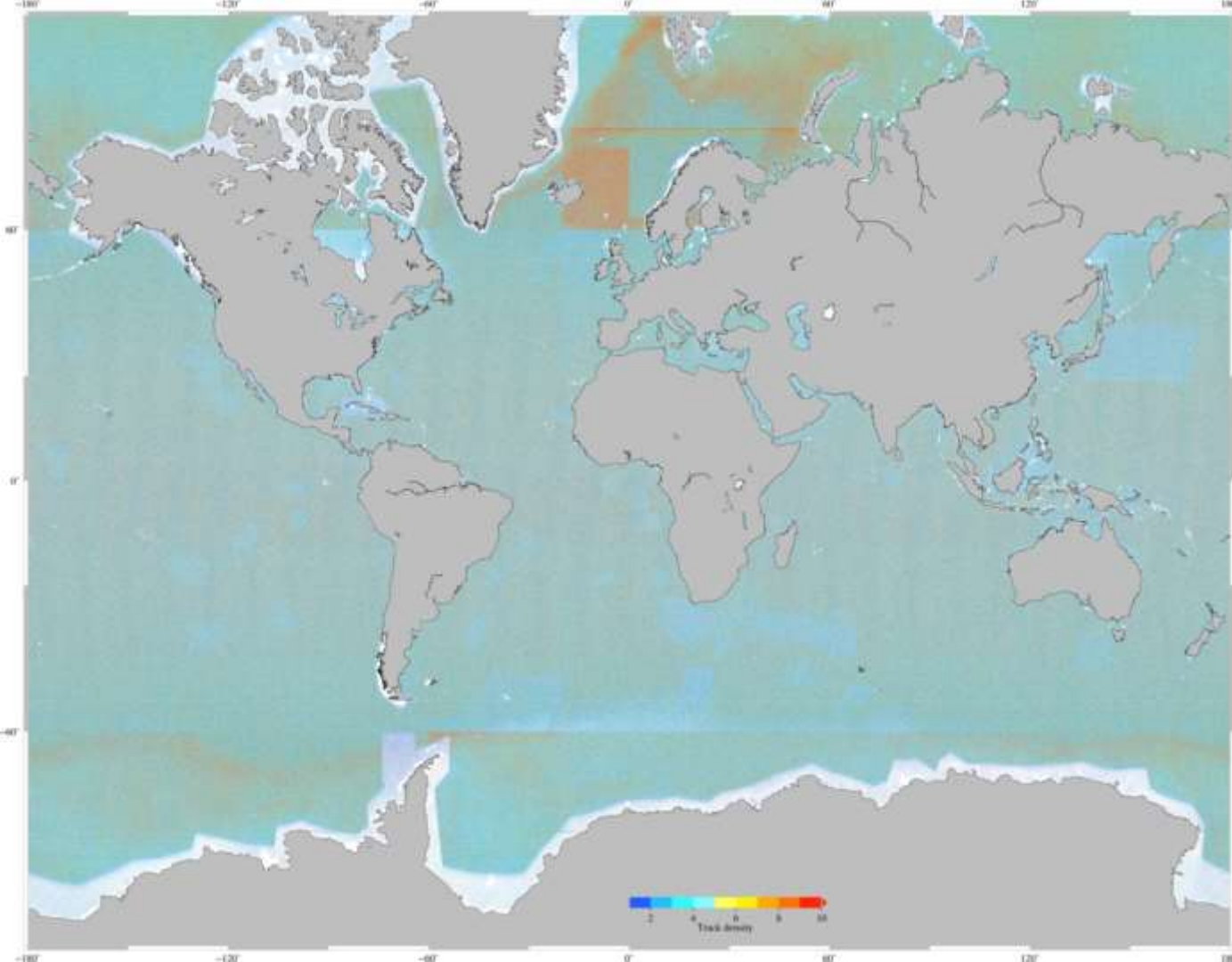
Track density

Geosat + ers1 + envisat



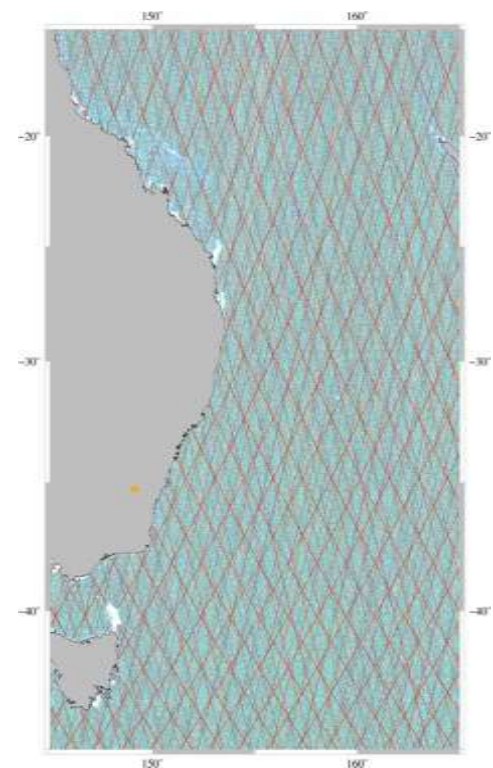
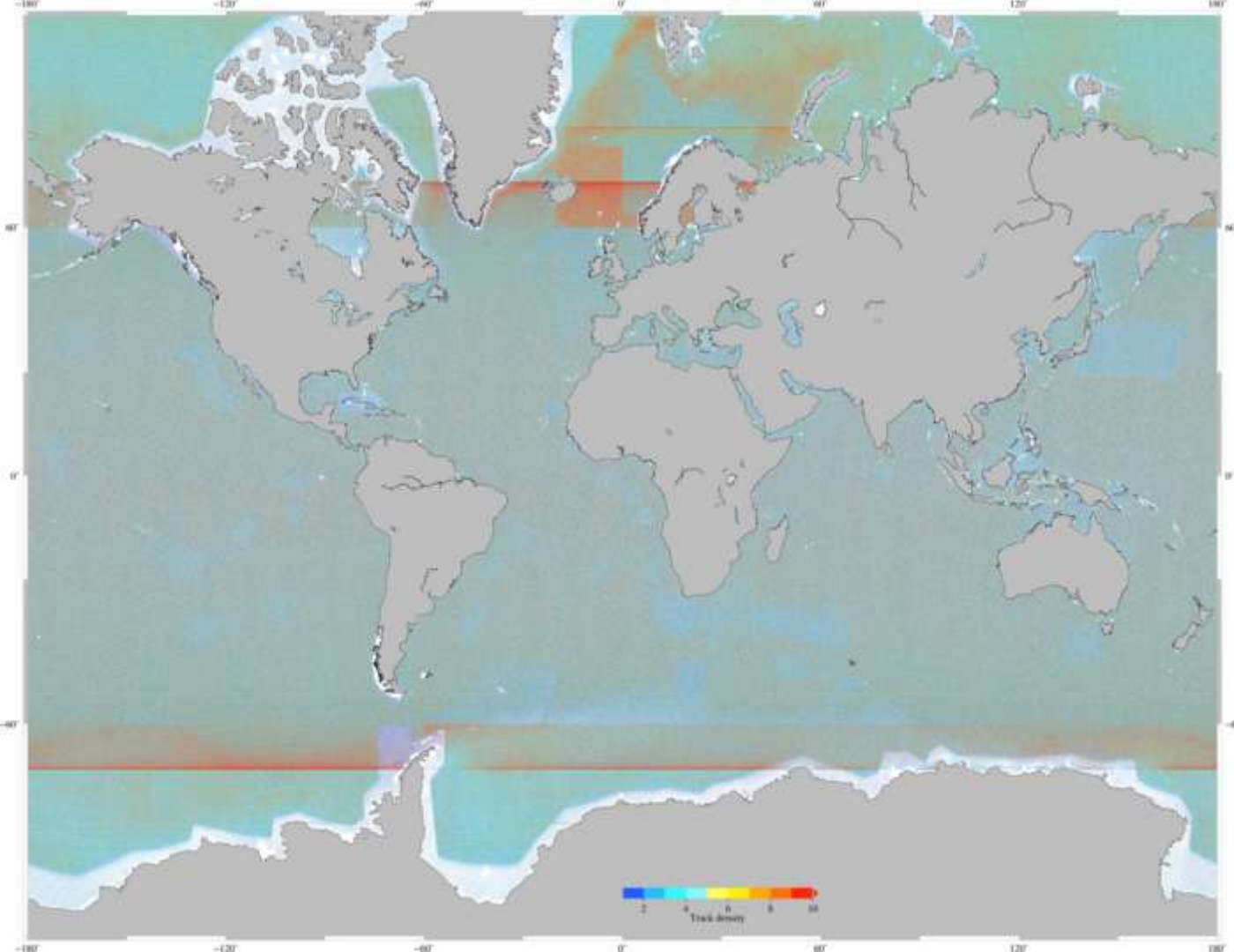
Track density

Geosat + ers1 + envisat
+ **Cyrosat-2**



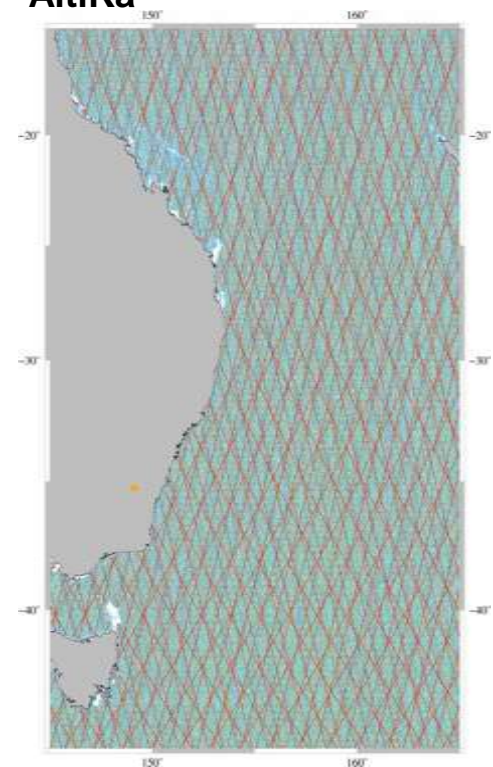
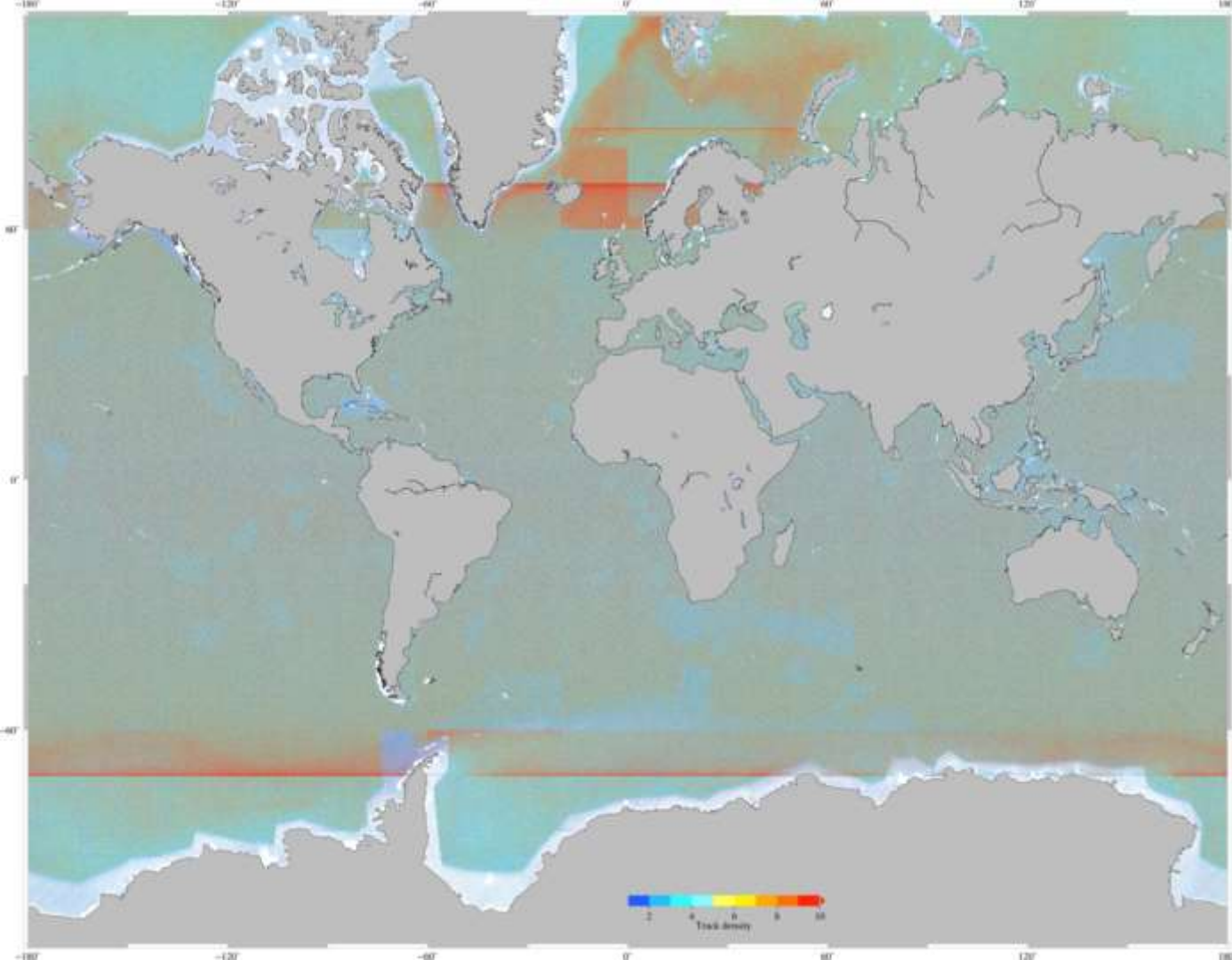
Track density

Geosat + ers1 + envisat
+ Cyrosat-2 + **Jason-1**

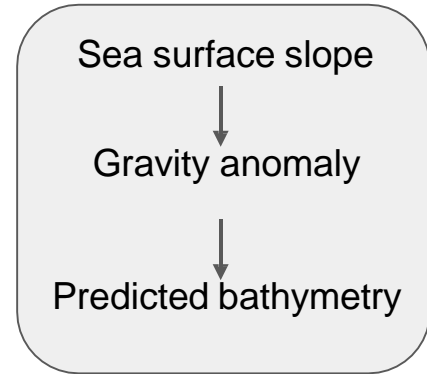
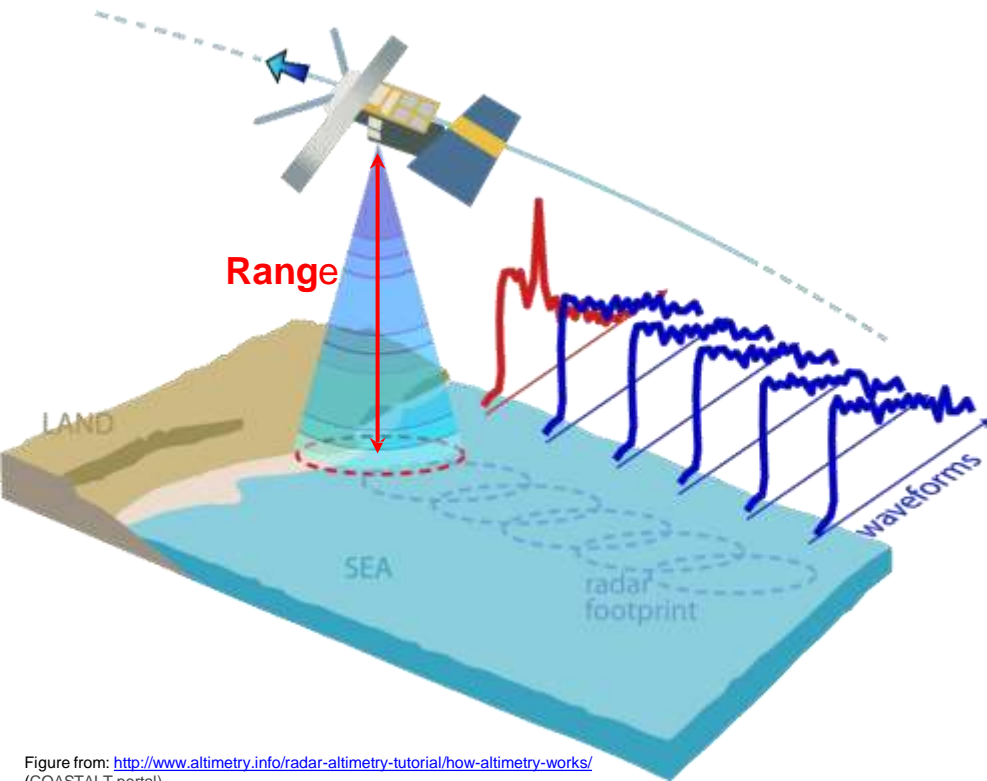


Track density

Geosat + ers1 + envisat
+ Cyrosat-2 + Jason-1 +
AltiKa



Satellite altimetry



The aim of the game is to measure **sea surface slope as accurately as possible**.

This relies on two parameters:

1. Density of track spacing.
1. Range precision (i.e., satellite-to-surface distance, determined from echo time).

Figure from: <http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/>
(COASTALT portal)

Range precision

Altimeter	Range precision @ 20 Hz (mm)
Geosat	57.0
ERS-1	61.8
Envisat	51.8
Jason-1	46.4
CryoSat-2 LRM	42.7
CryoSat-2 SAR	49.7
AltiKa	20.5

Smith [2015] showed standard GDR of AltiKa is 2 X more precise than Envisat

Zhang and Sandwell [2016] showed that AltiKa also benefits from 2-pass retracking.

In July 2016 AltiKa began geodetic mapping. Could achieve 1 mGal global marine gravity.

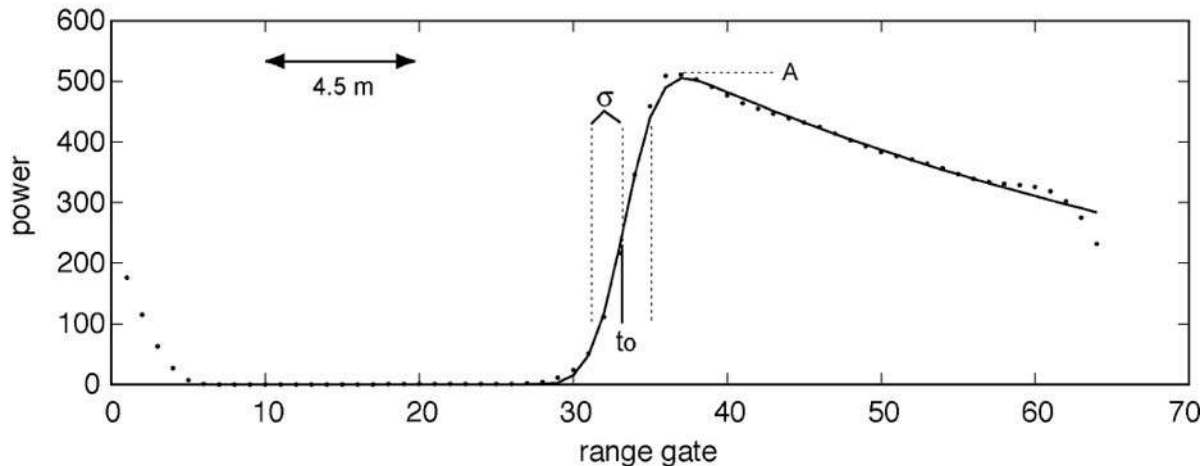
AltiKa 4.5 mm @ 1 Hz

AltiKa is **2x more precise** than all previous altimeters

Waveform retracking

largest error source in measuring the sea surface slope is from errors **picking the arrival time of return echo**

2-pass waveform retracking improves range precision



Estimate 3 parameters: arrival time (t_0), rise time (σ), and power (A).

$$M(t) = \frac{A}{2} \{1 + \text{erf}(\eta)\}; \quad \eta = \frac{t - t_0}{\sqrt{2}\sigma}$$

Retrack waveforms with standard 3-parameter model

1) Smooth rise time over 45-km

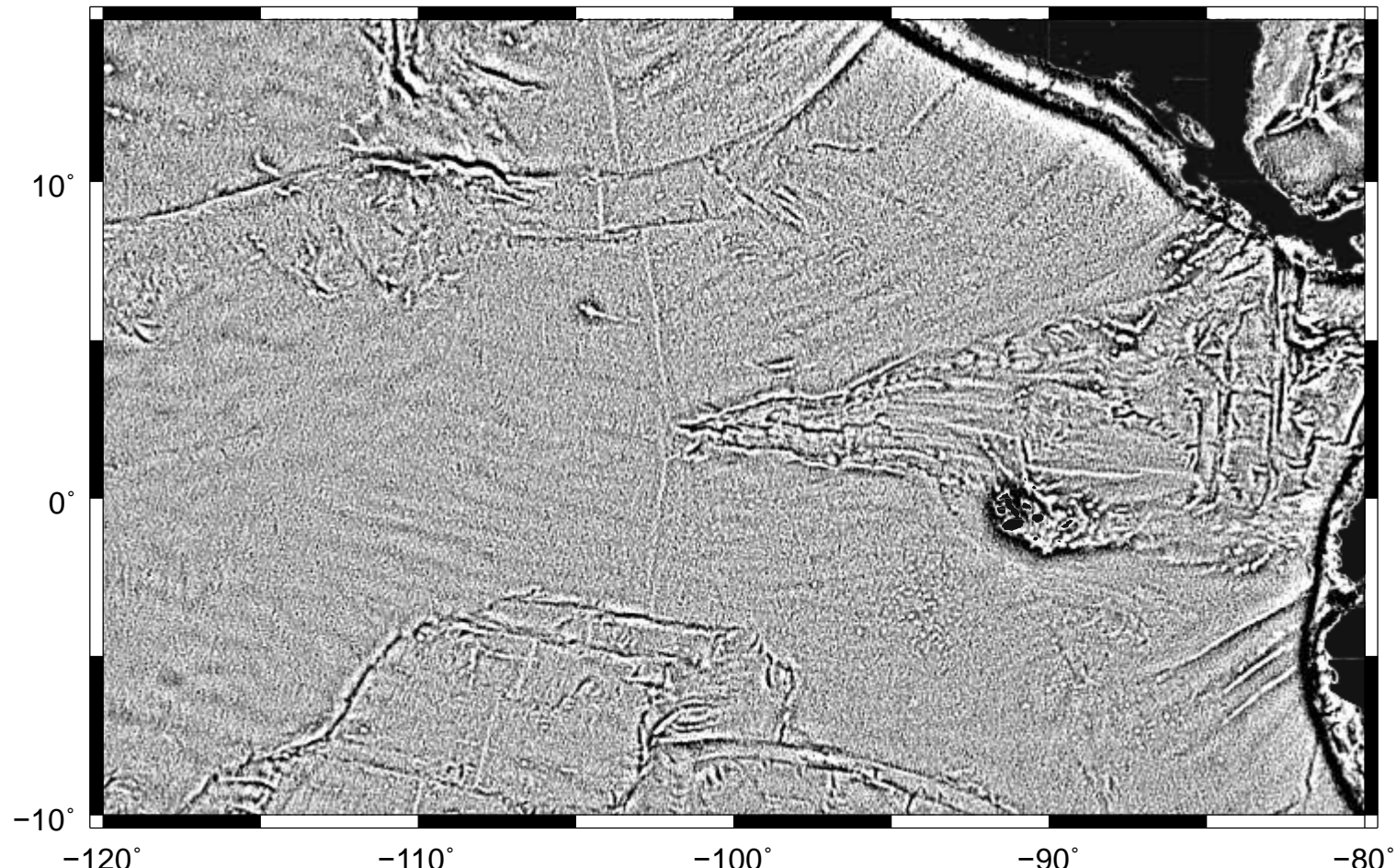
2) Retrack waveforms with 2-parameter model

Note: this assumes wave height varies smoothly along track. [Sandwell and Smith, 2005]

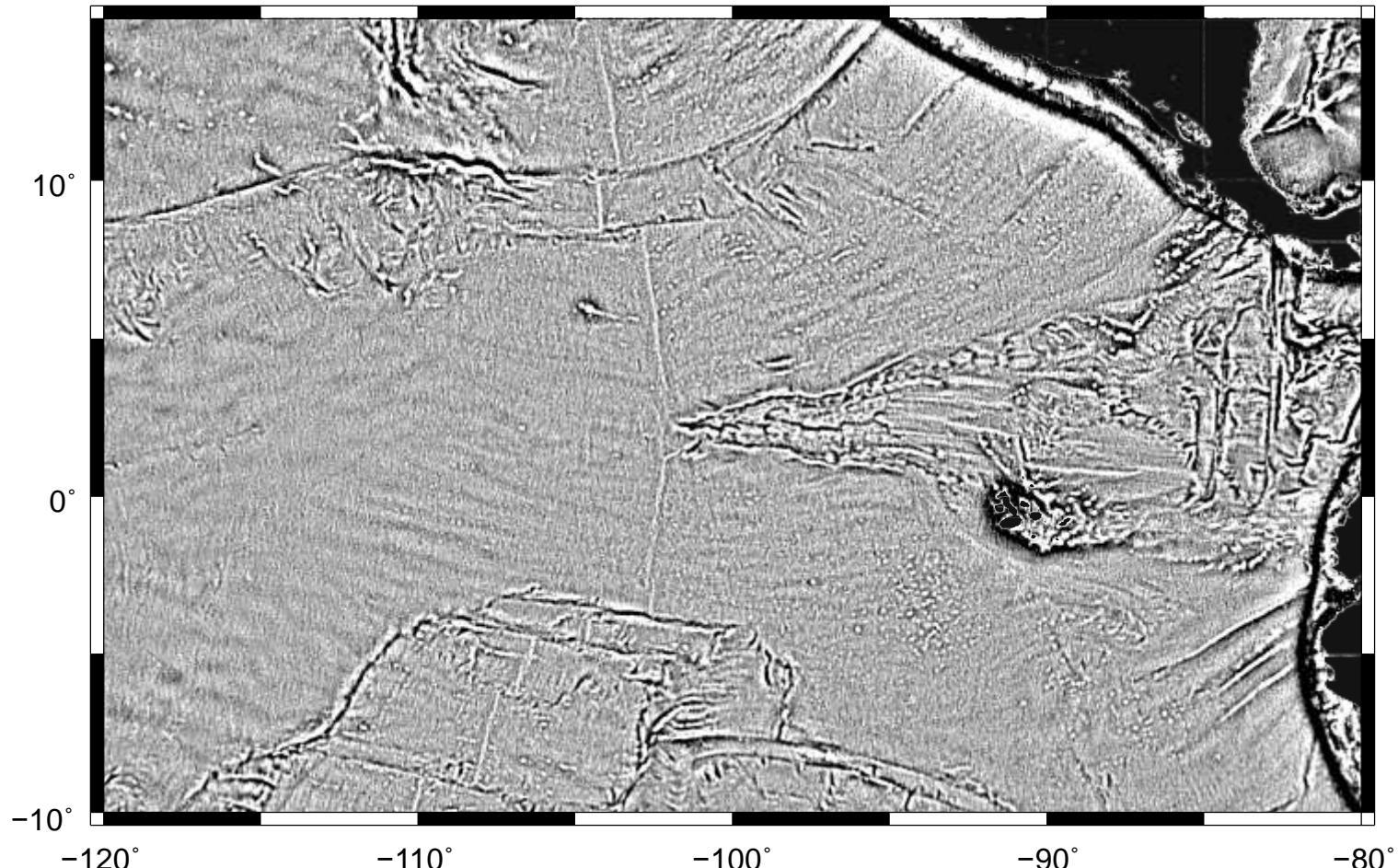
AltiKa: Zhang & Sandwell (2016)

Jason-2: Harper & Sandwell (In progress) 7

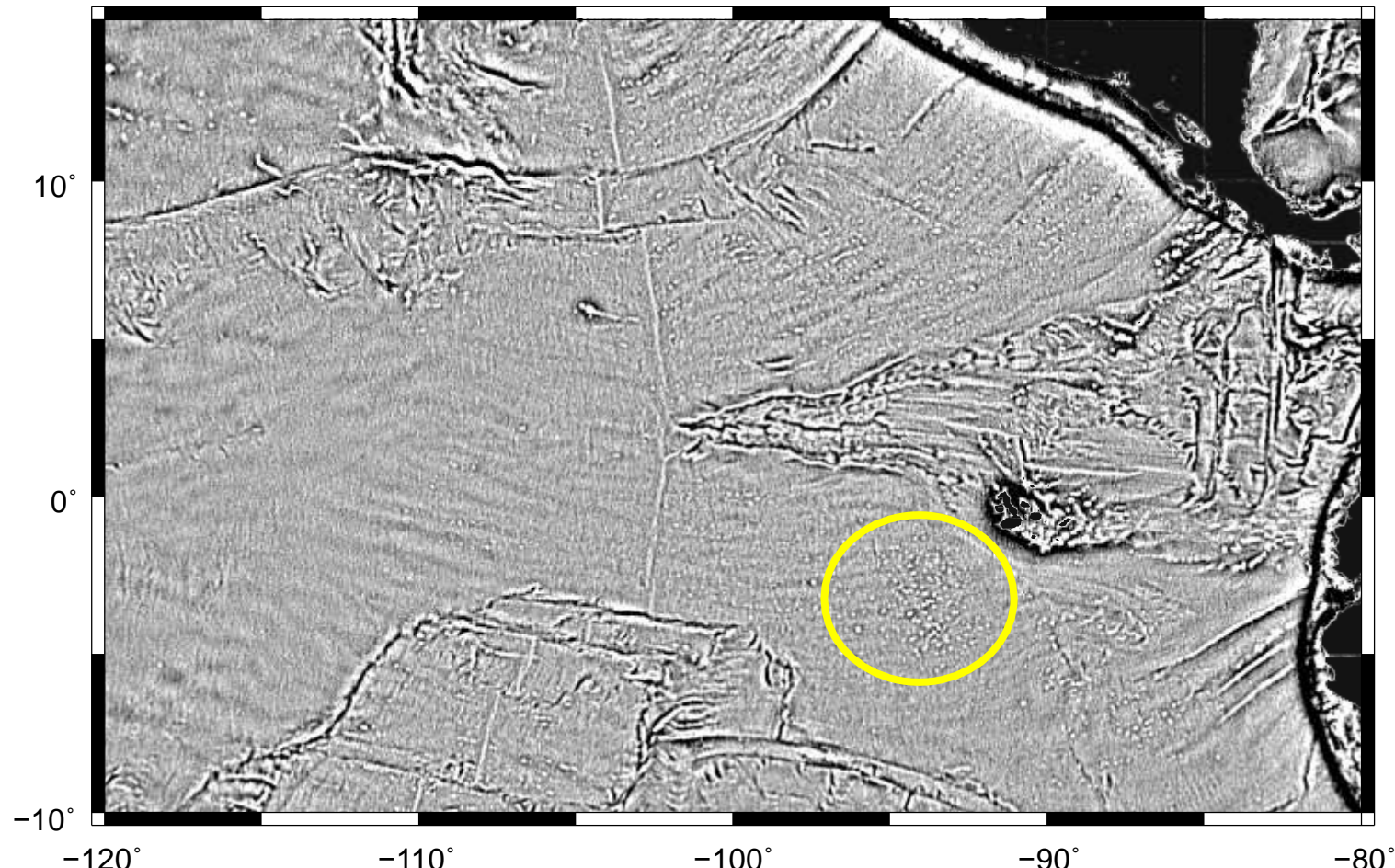
VGG (V18) Geosat + ERS



VGG (V24)

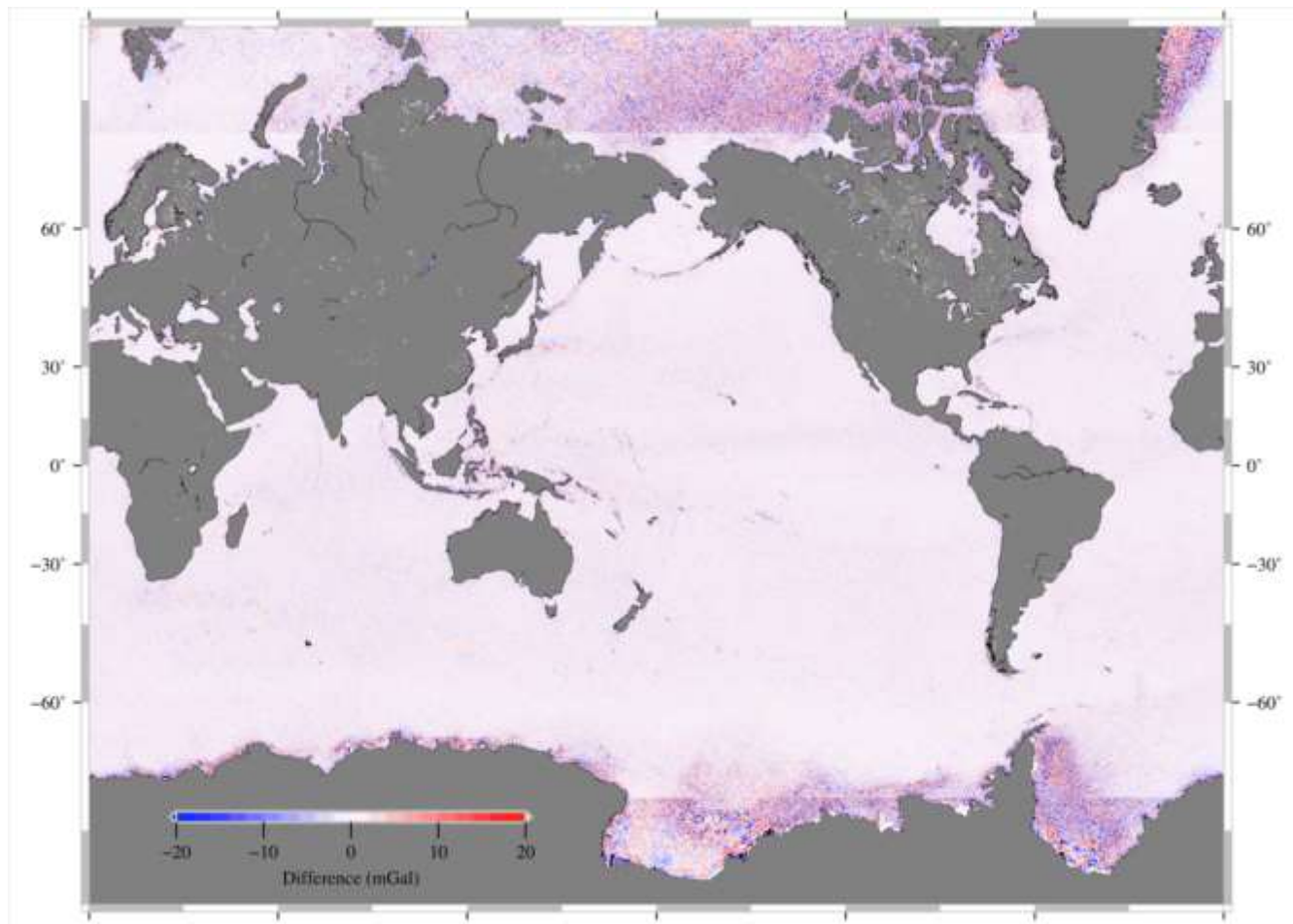


VGG (V27) + CryoSat + AltiKa + Jason-1



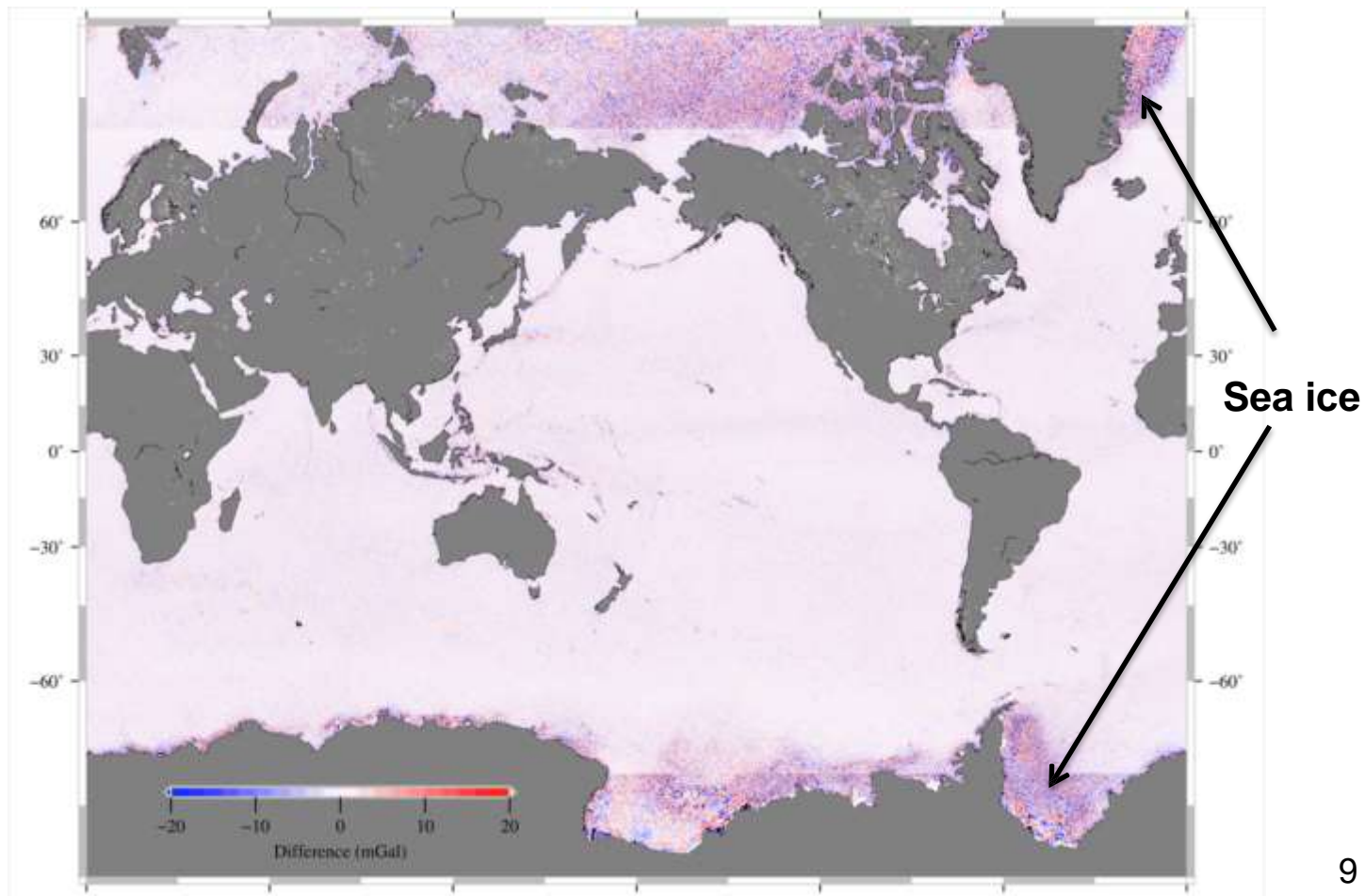
Free-air anomaly: change V24-V18

Statistic	change (mGal)
Mean	-0.05
Standard Dev.	2.92



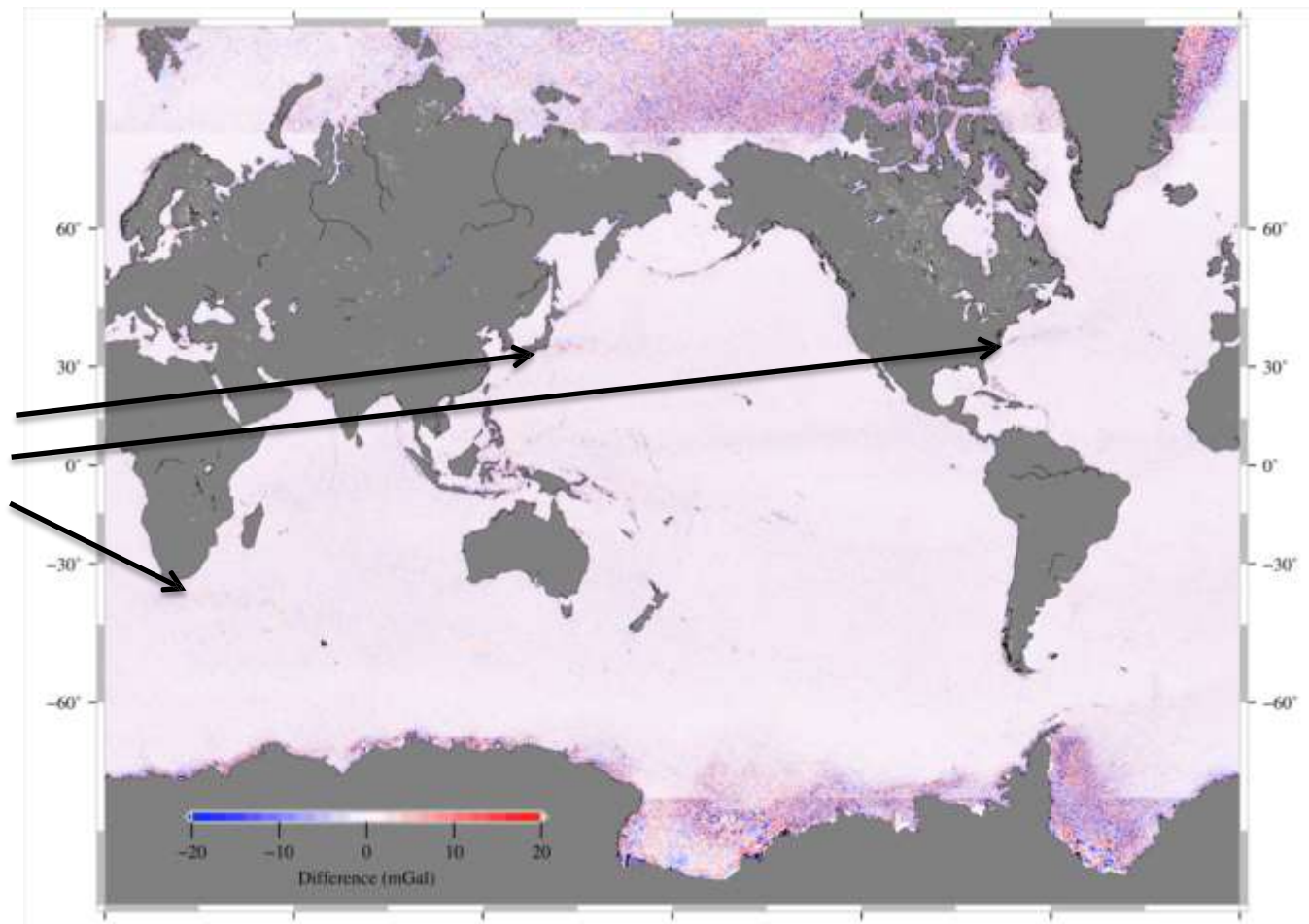
Free-air anomaly: change V24-V18

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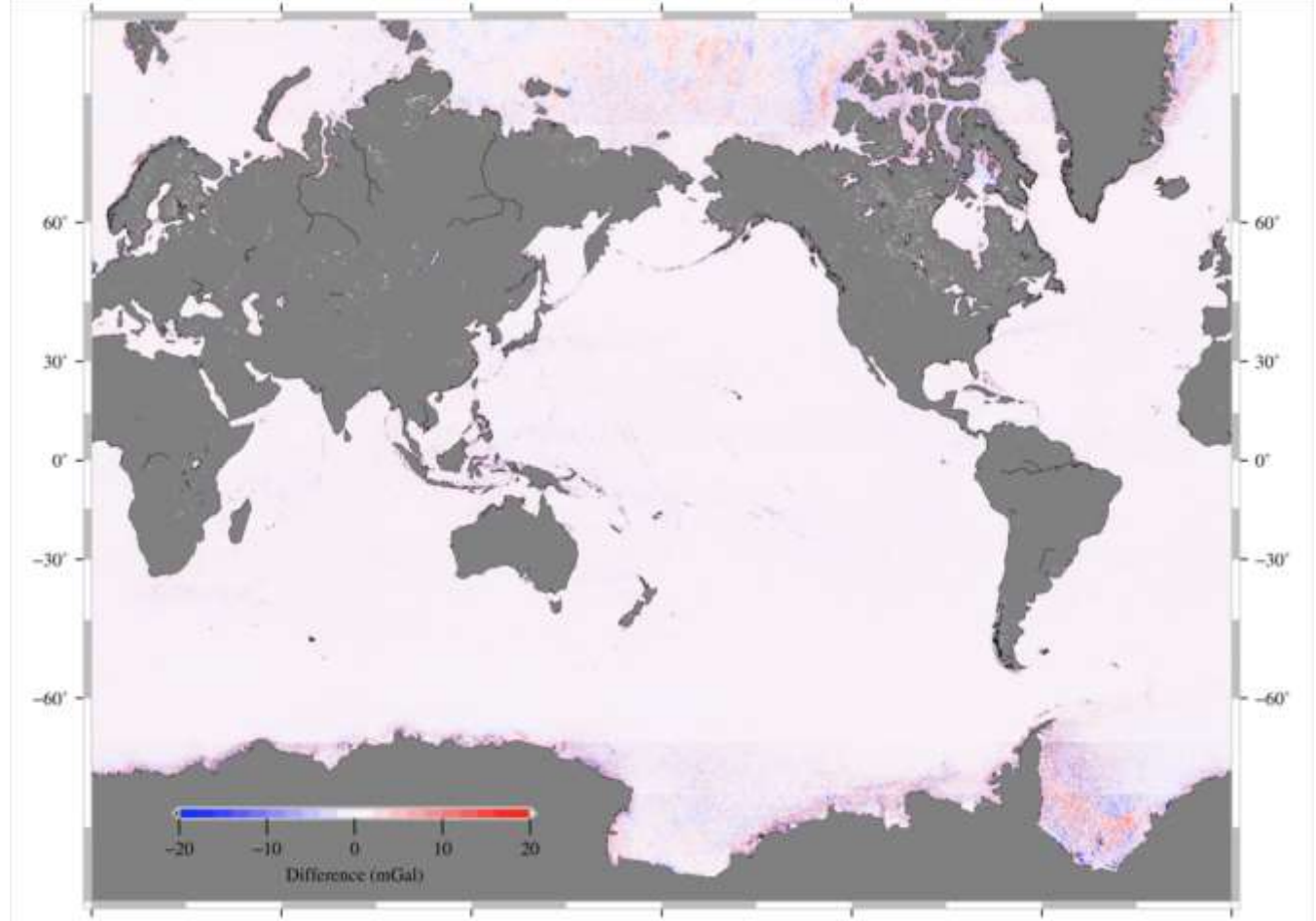
Free-air anomaly: change V24-V18

Mesoscale
Ocean
variability

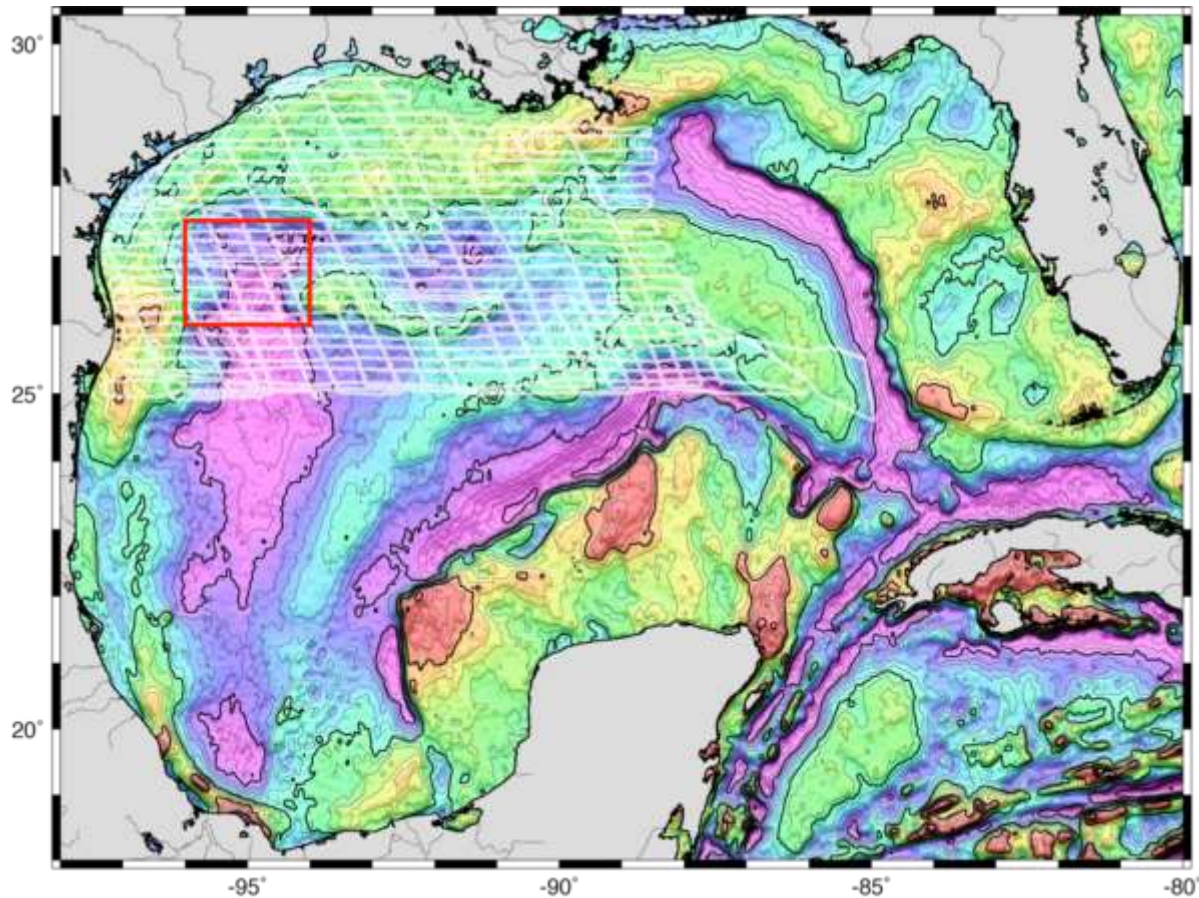


Free-air anomaly: change V27-V24

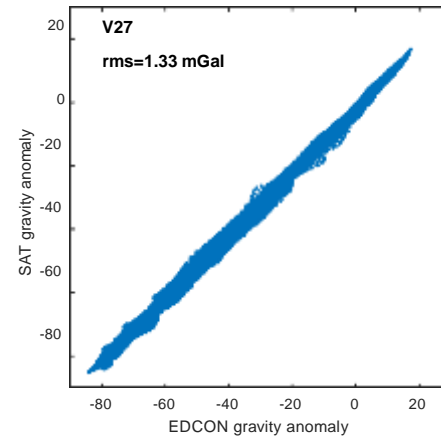
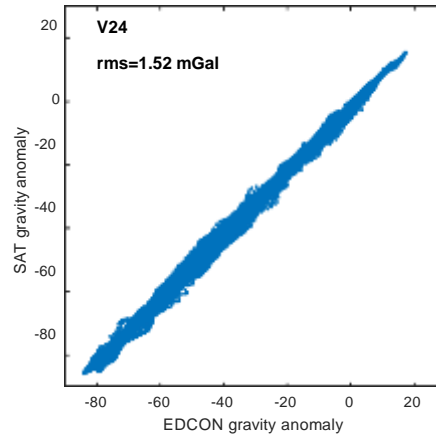
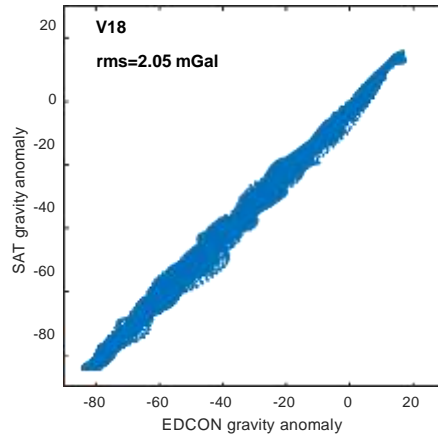
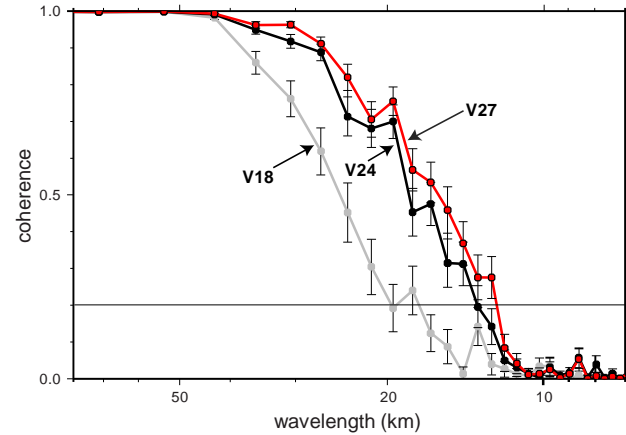
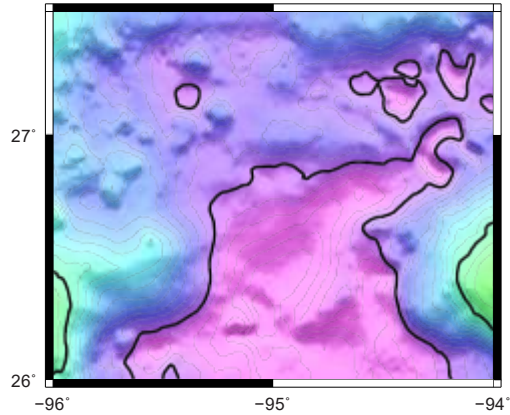
Statistic	change (mGal)
Mean	-0.04
Standard Dev.	1.82



Accuracy – how much are we improving?



Accuracy – how much are we improving?



Limit on spatial resolution

$$g(k, z) = g(k, 0) e^{-2\pi k z}$$

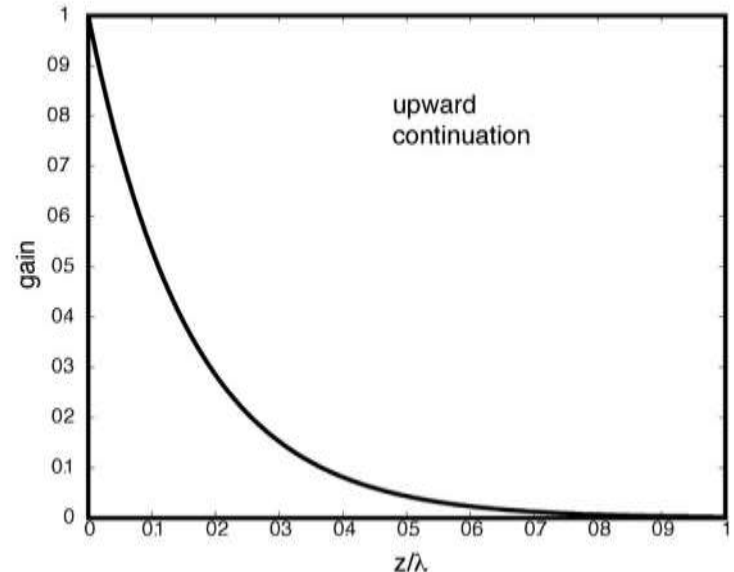
gravity at
altitude

gravity at
seafloor

x

upward
continuation

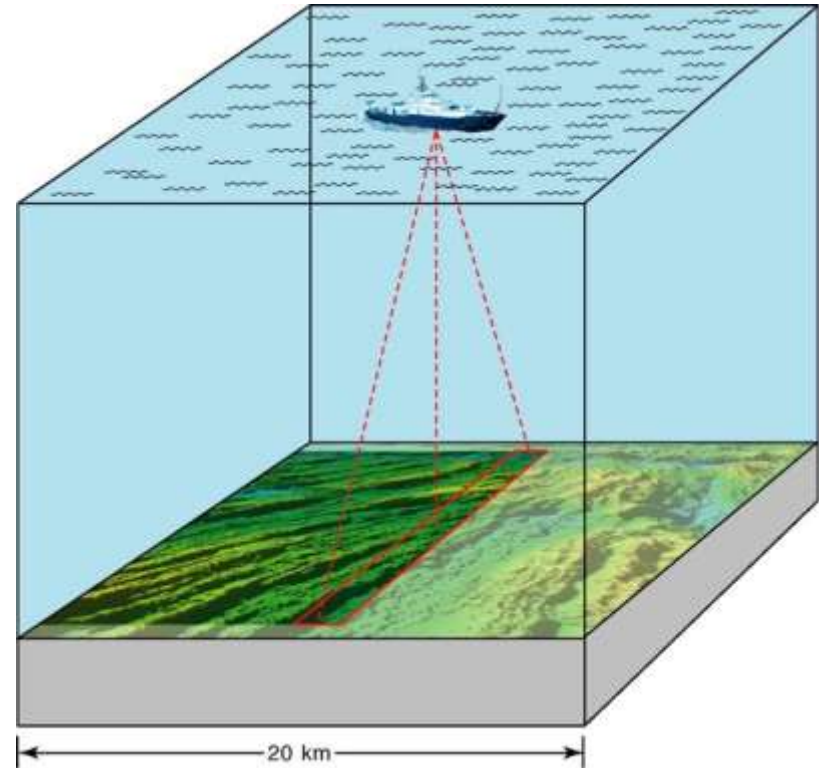
	$\lambda=1/k$	z	gain
shallow margin	2 km	1 km	0.043
deep ocean	8 km	4 km	0.043
GOCE altitude	8 km	200 km	10^{-68}



Shipboard bathymetry

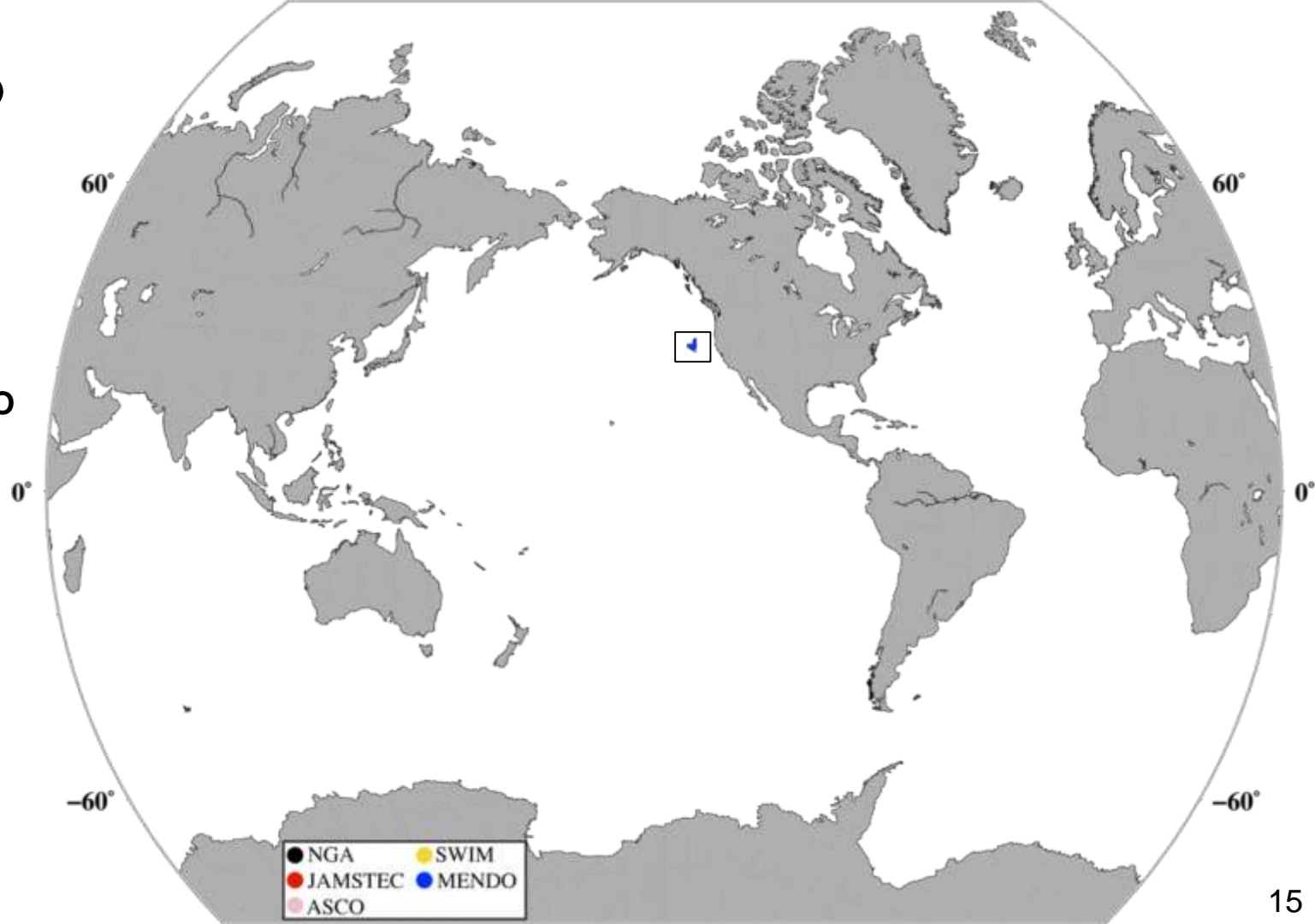
SRTM15+ V2: New datasets (2014-2018)

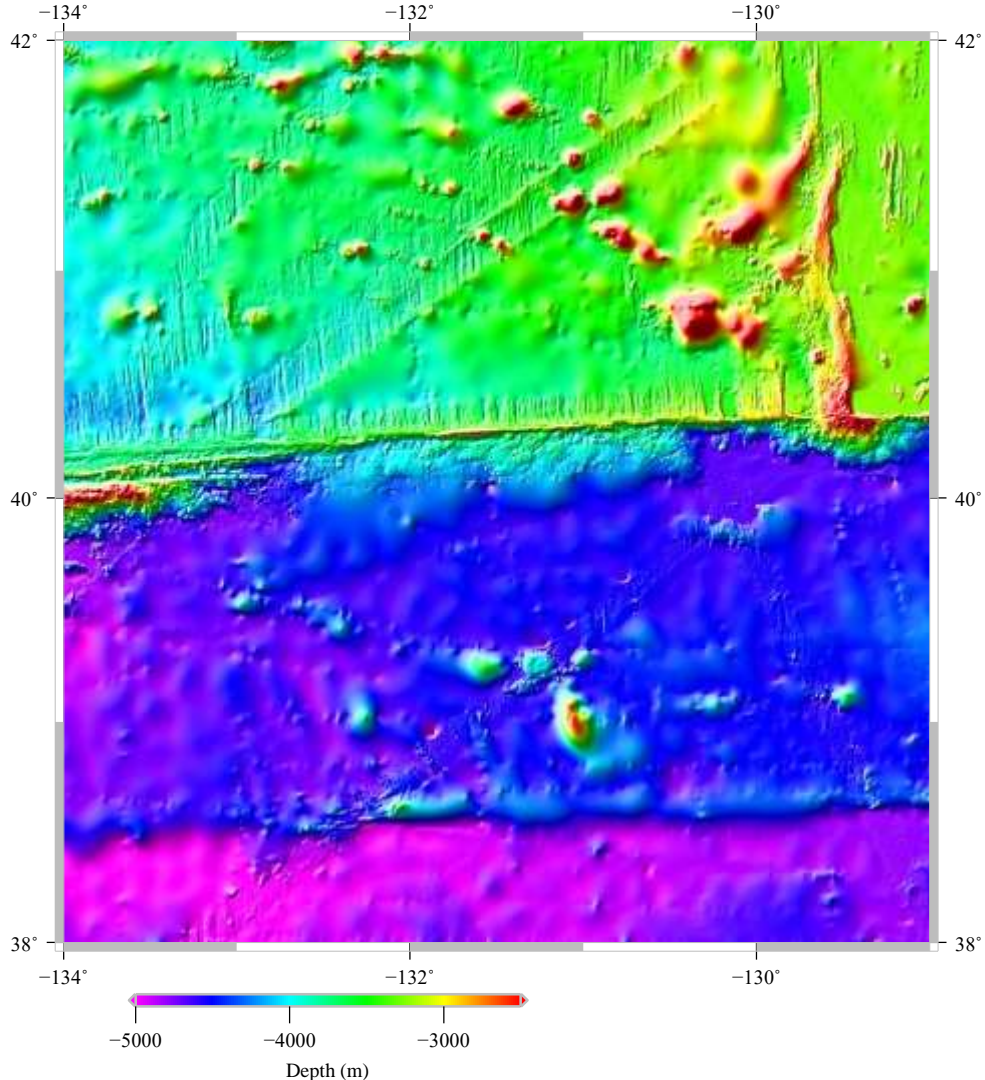
- *Mendocino*
- *SWIM*
- *ASCO (MH370)*
- *JAMSTEC 2012-2016*
- *NGA “unclassified”*
- *IBCAO V3 (north of 80° N)*

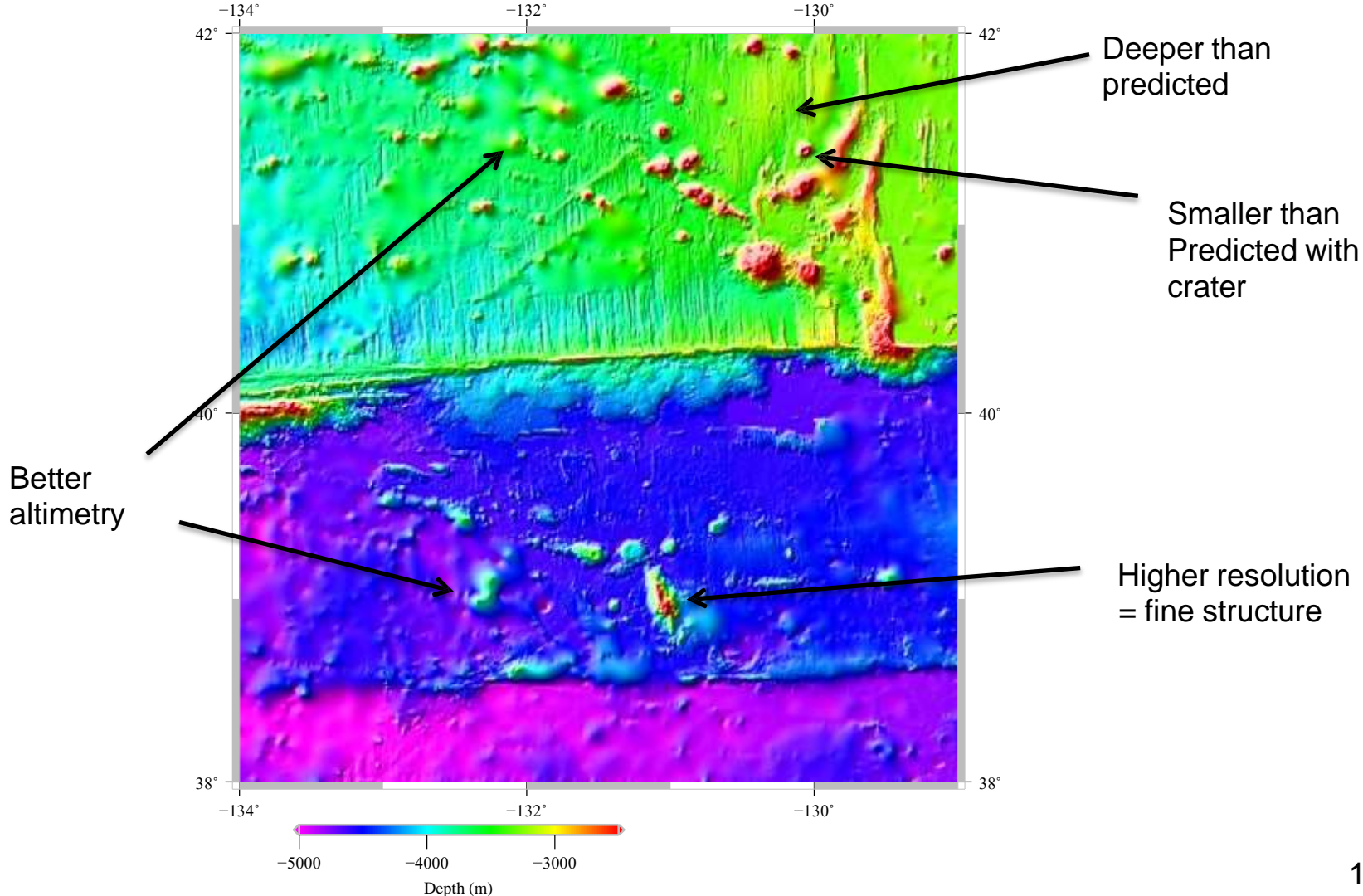


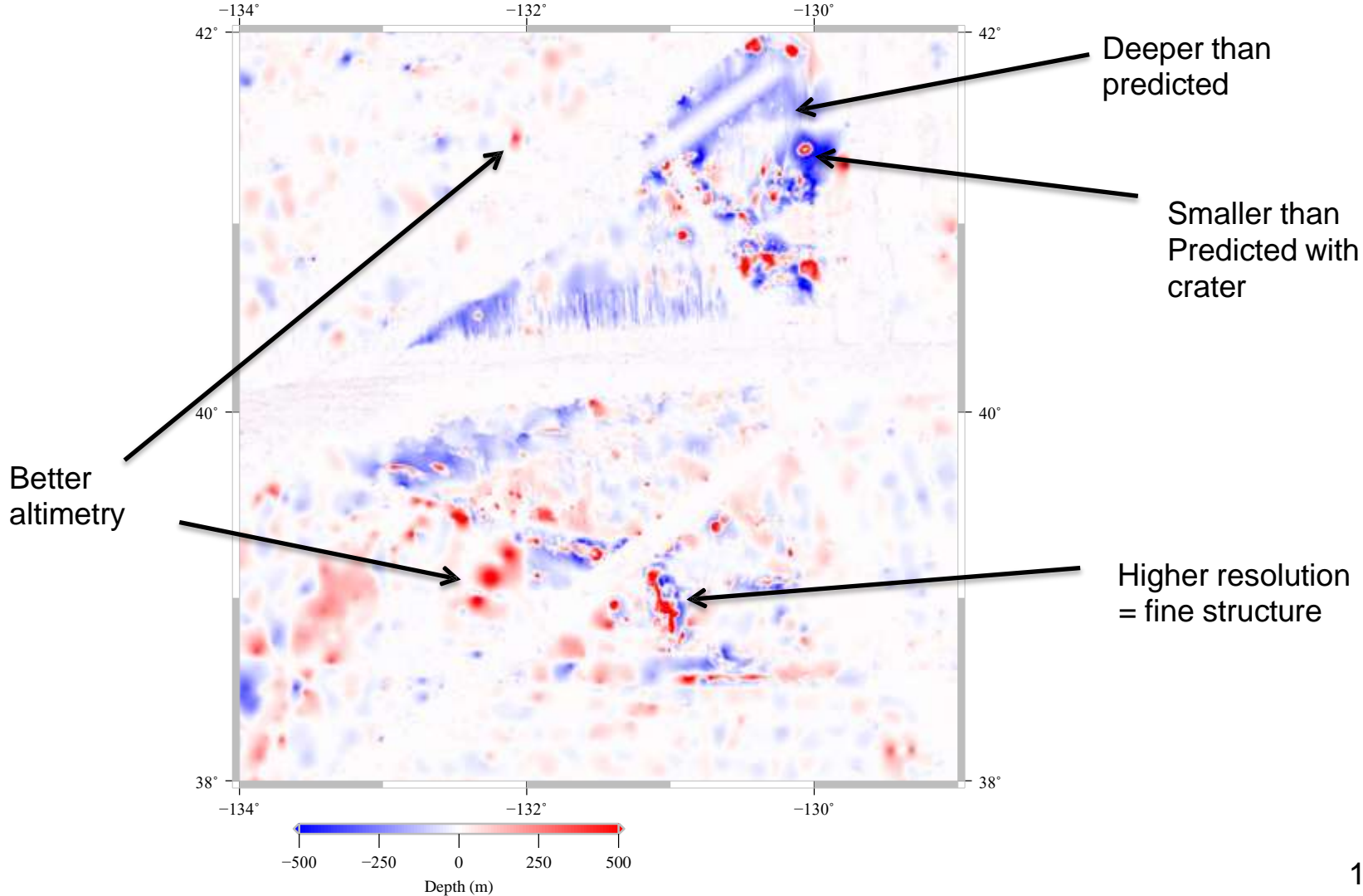
Mendocino

- Three multibeam surveys
- From **CCOM & SIO**
- Raw data
- Cleaned



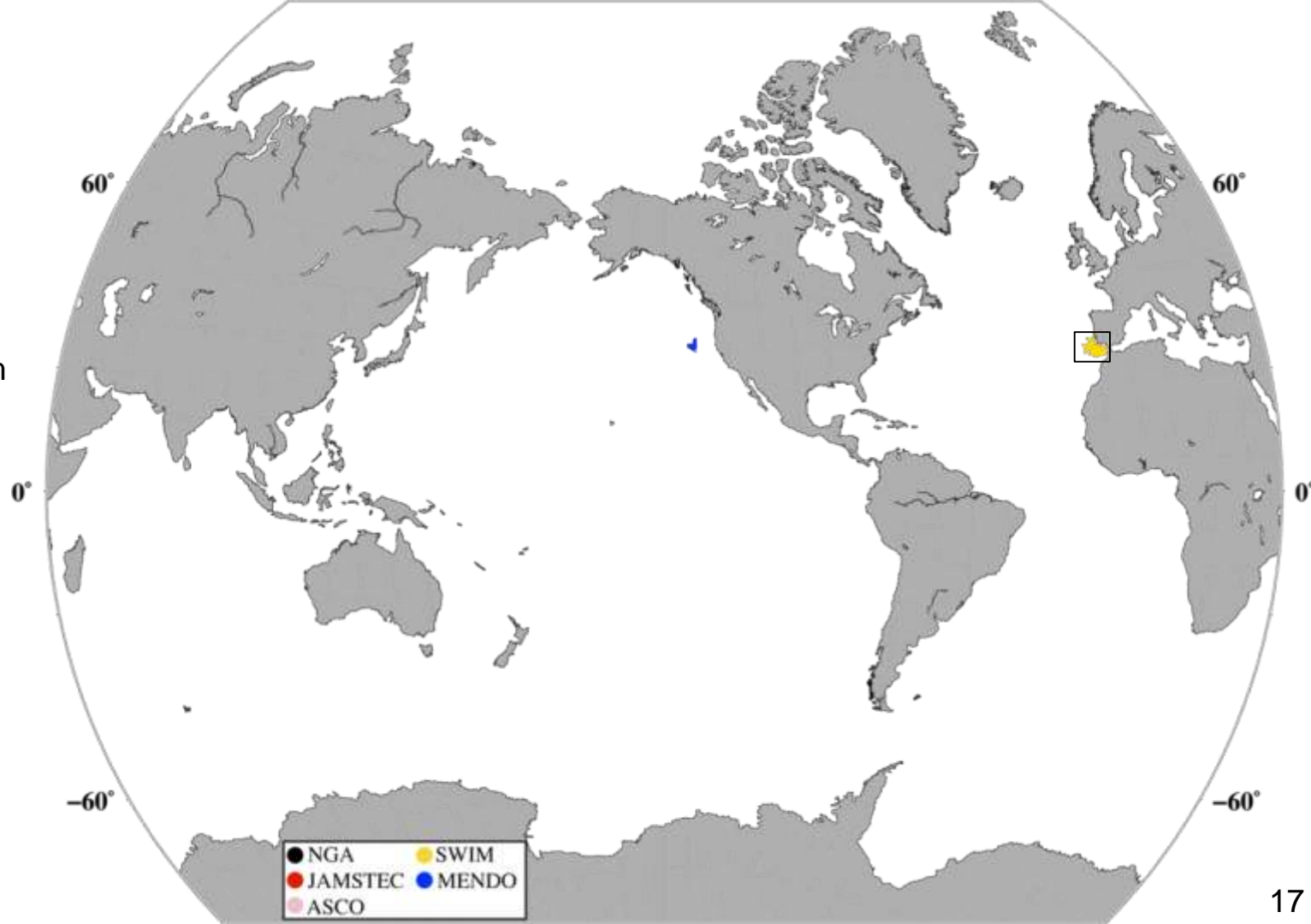






SWIM

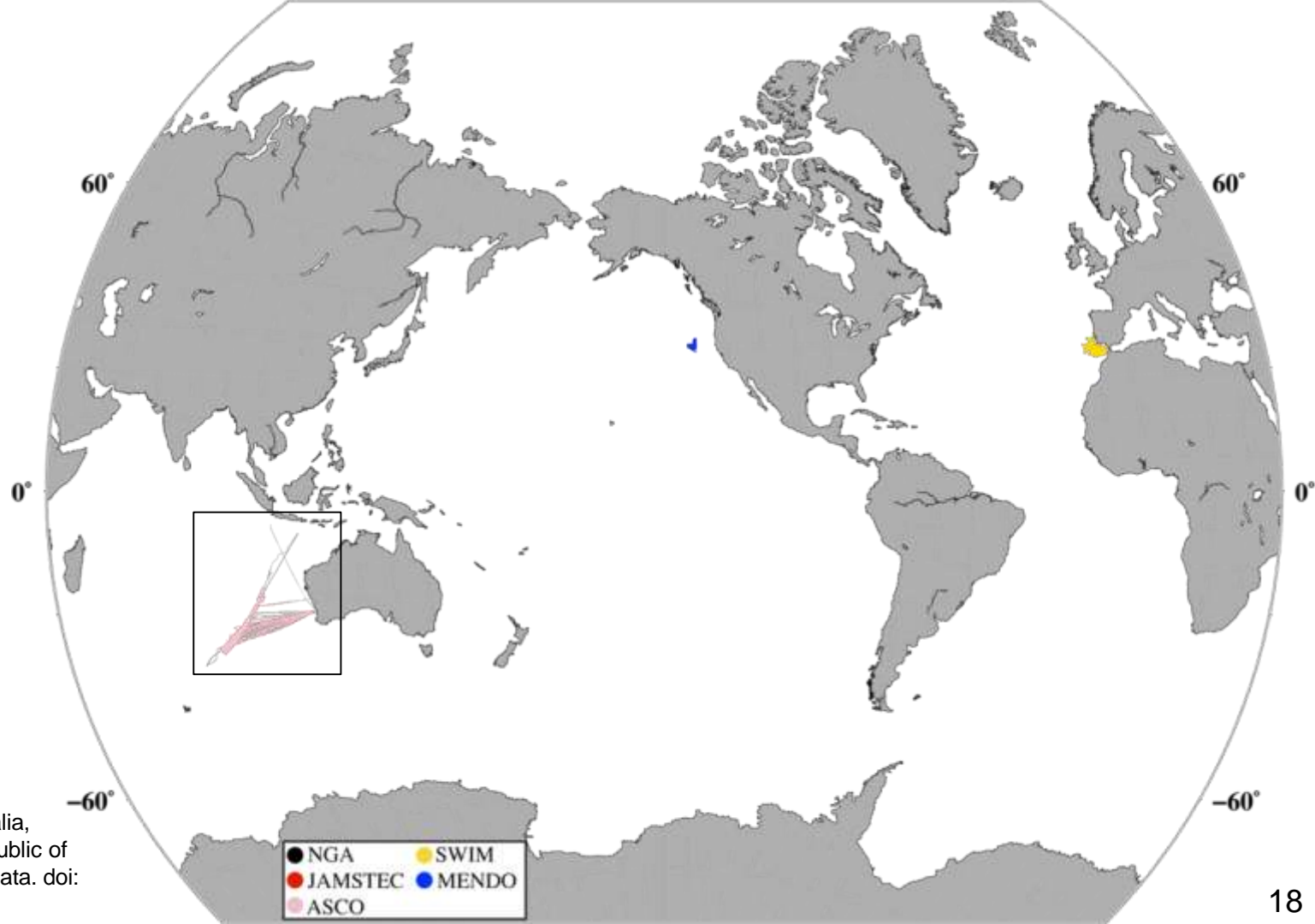
- SW Iberia
- Multiple multibeam cruises merged
- Gridded dataset
-clean



Diez et al., (2005)

MH370

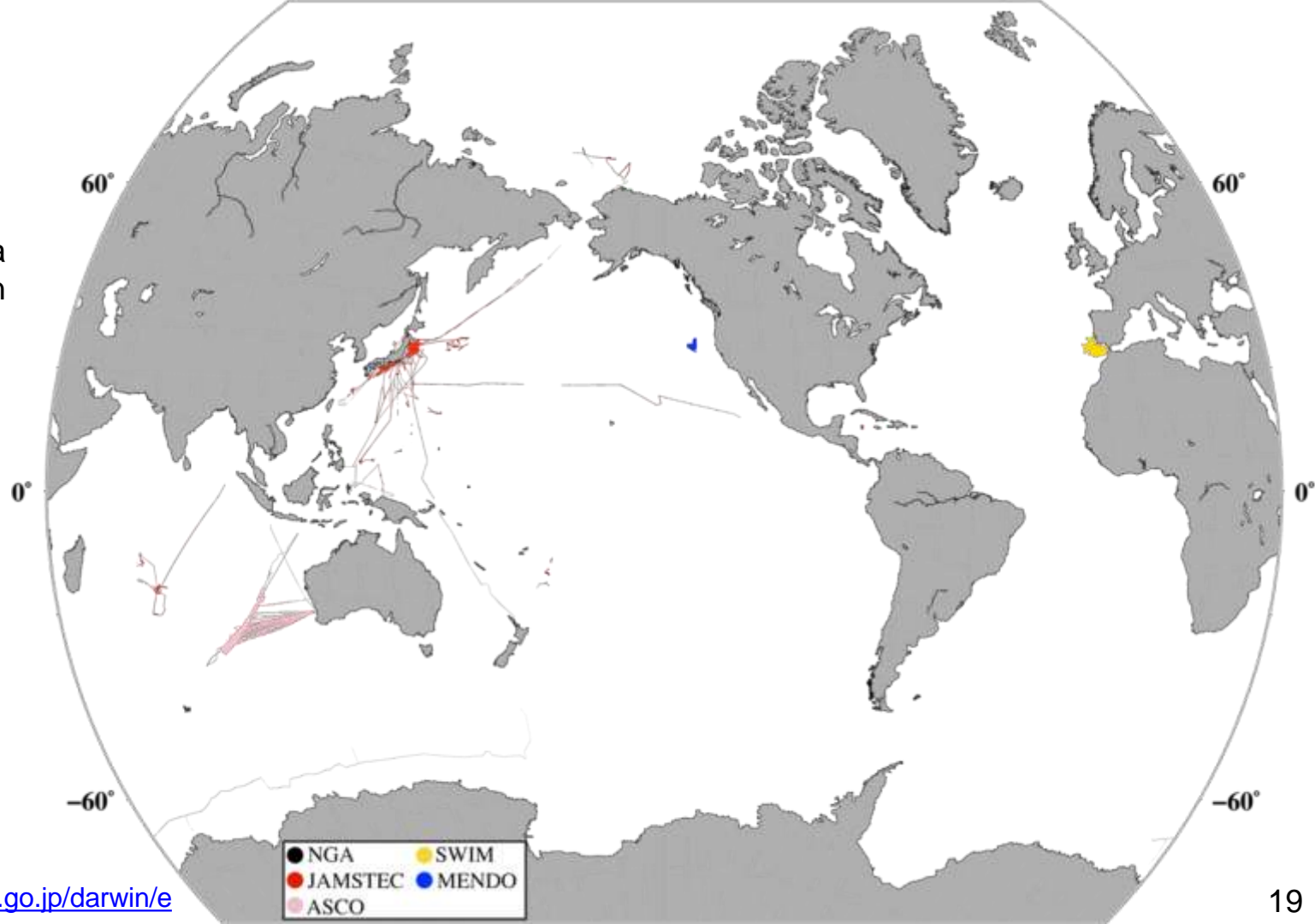
- High resolution
- ~ 278,000 km²
- Excellent quality
- No cleaning required



Source: Governments of Australia, Malaysia and the People's Republic of China, 2017. MH370 Phase 1 data. doi: 10.4225/25/595d7744b71e2

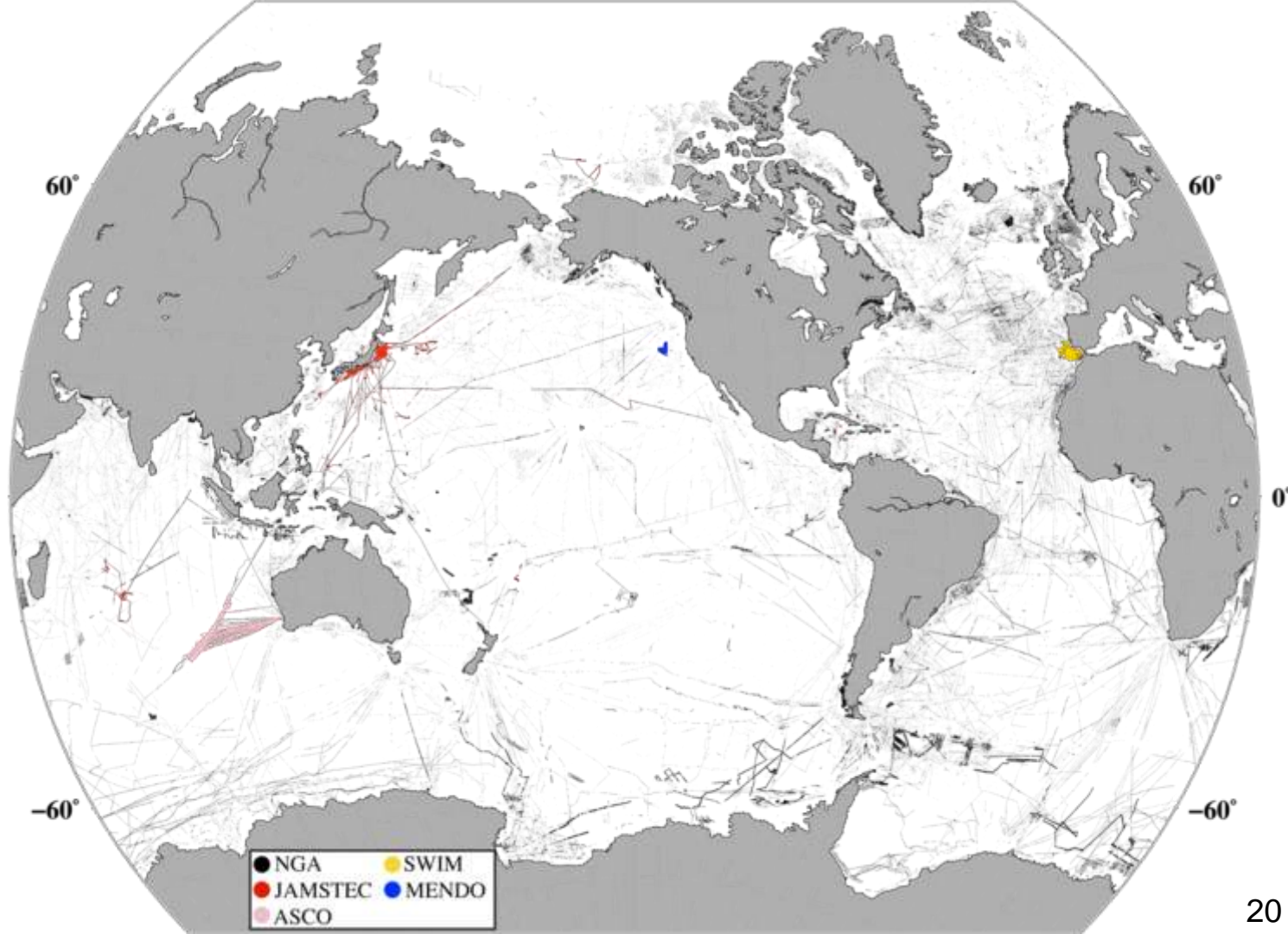
JAMSTEC

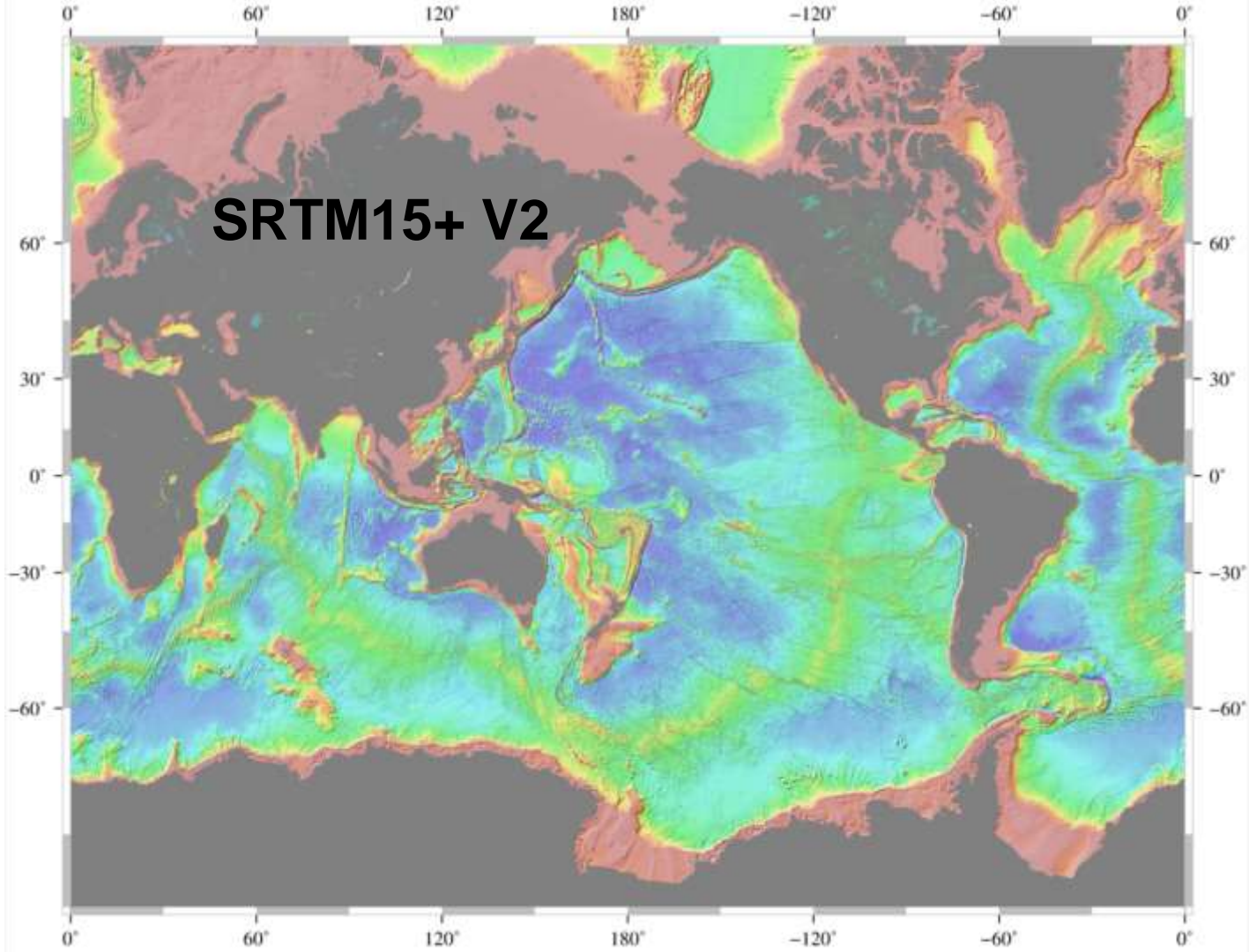
- All JAMSTEC data collected between 2014-2016
- Accessed from **DARWIN** explorer
- 25% increase in JAMSTEC data volume
- Cleaned data
- Mostly excellent!



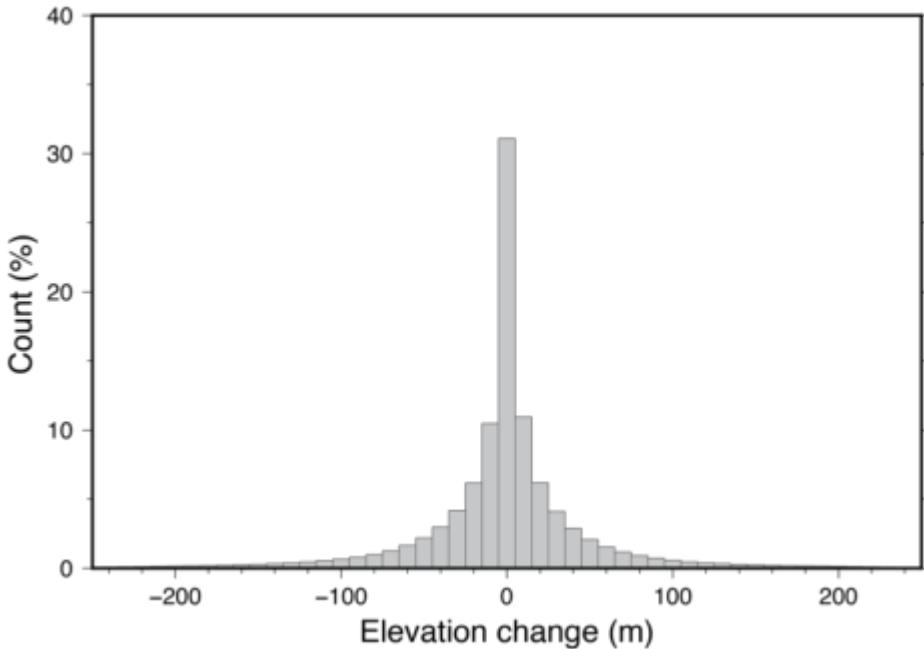
NGA

- “Unclassified” data supplied to us by James Beale (Pers comms, 2018)
- ~19 million new soundings > 2.3 km from an existing sounding
- Both multi- & singlebeam
- Mostly clean
- No Metadata

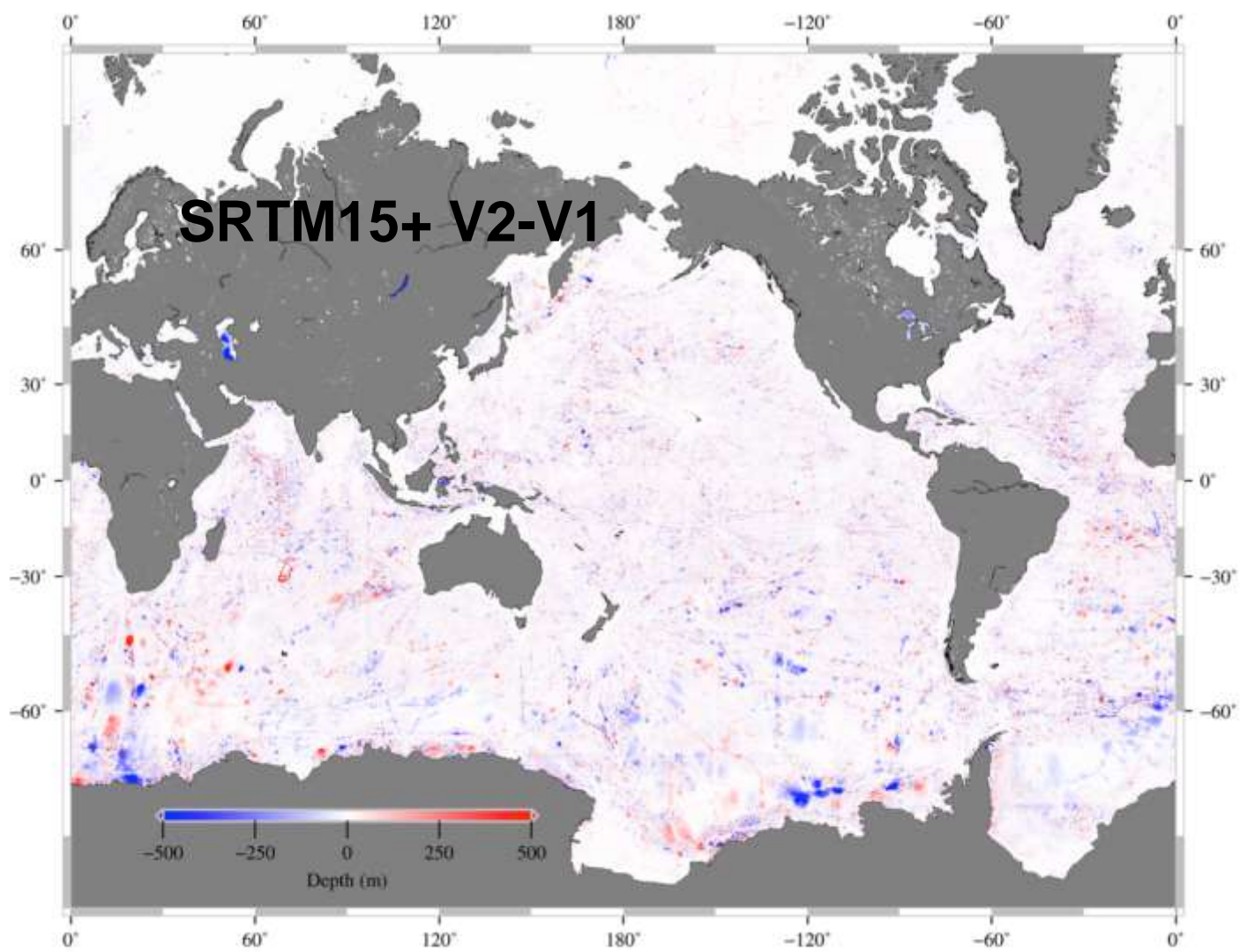




SRTM15+ V2-V1 global change



Statistic	Depth (m)
Mean	-1.83
Standard Dev.	61.8
Min/Max	-3953/3288



Future plans and integration

1. Integration of SRTM15+V2 with latest GEBCO grid:

- We can supply either our “polished” grid (including soundings) or unpolished (no soundings) grid
- However – these data would need to be open access/public domain.
- Our updated SID grid (includes all new soundings at 15 arc seconds) may be useful for identifying the deep ocean “gaps” and provide a starting point.

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Future plans and integration

2. Making use of our new *PSQL* database

- This contains ~490 million “data points” (15s grid cells) used in constructing SRTM15+V2
- Contains all metadata we have (usually a reference link to the source)

Future plans and integration

3. Adding additional multibeam data into SRTM15+V2

- If you have any publically available bathymetry data that you think we may not have included and would like to share – please let us know!

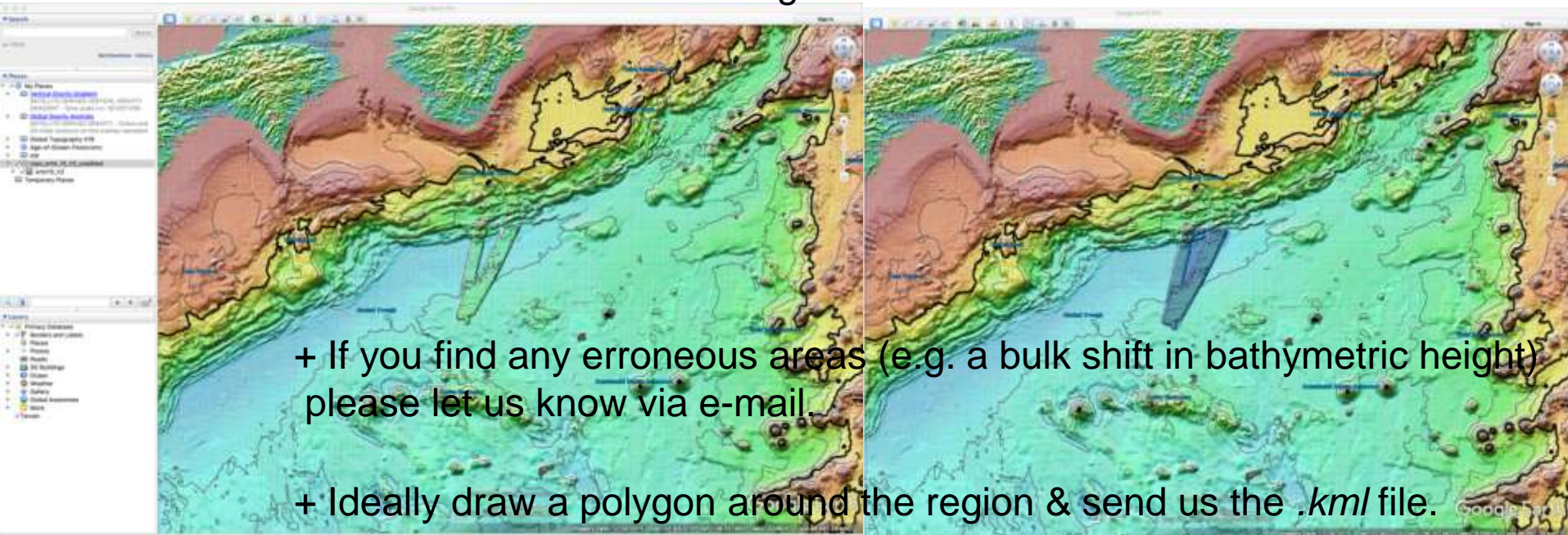
Future plans and integration

4. SRTM15+V2 *crowd sourced* cleaning!

- A Google Earth .kmz file of our latest (draft) SRTM15+V2 grid is now available at: <https://topex.ucsd.edu>
- If you're feeling generous.... please download it and take a look.
 - + If you find any erroneous areas (e.g. a bulk shift in bathymetric height) please let us know via e-mail.
 - + Ideally draw a polygon around the region & send us the *.kml* file.

Future plans and integration

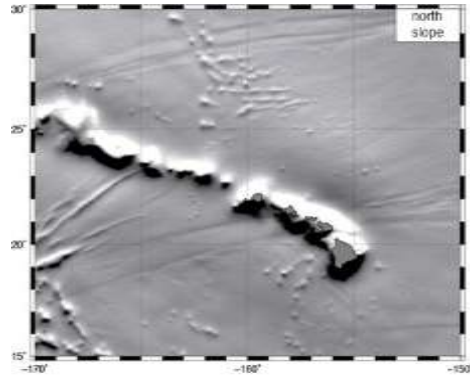
4. SRTM15+V2 *crowd sourced* cleaning!



<https://topex.ucsd.edu>

Part one

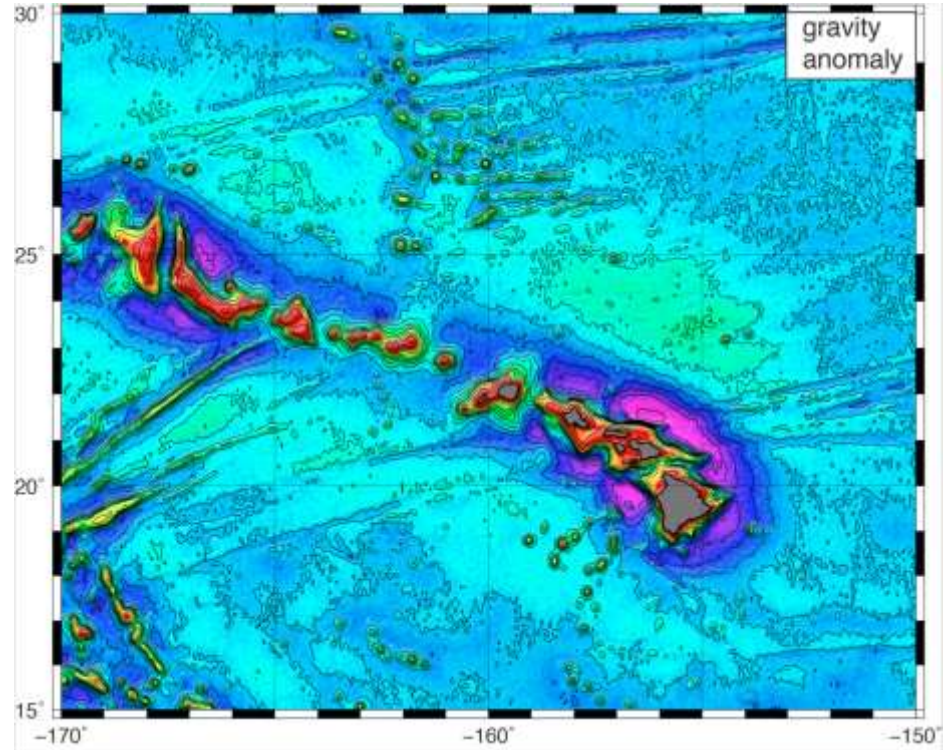
New satellite altimetry



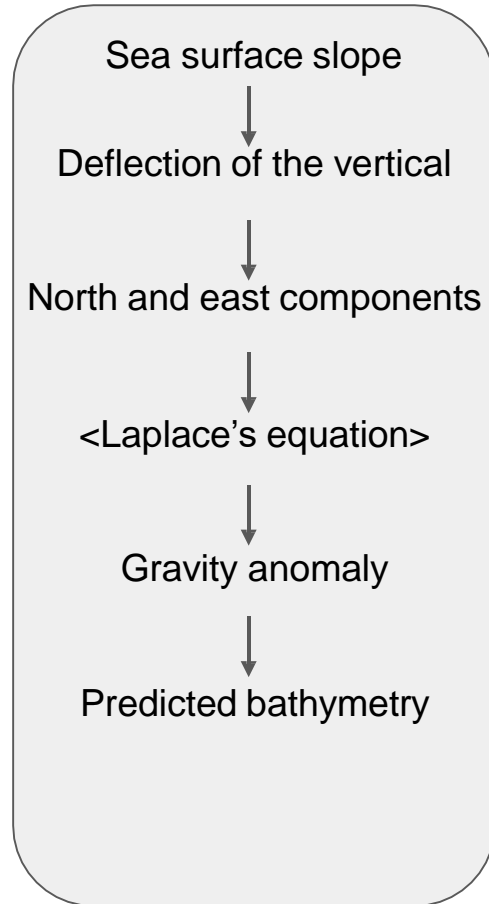
+



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Satellite altimetry



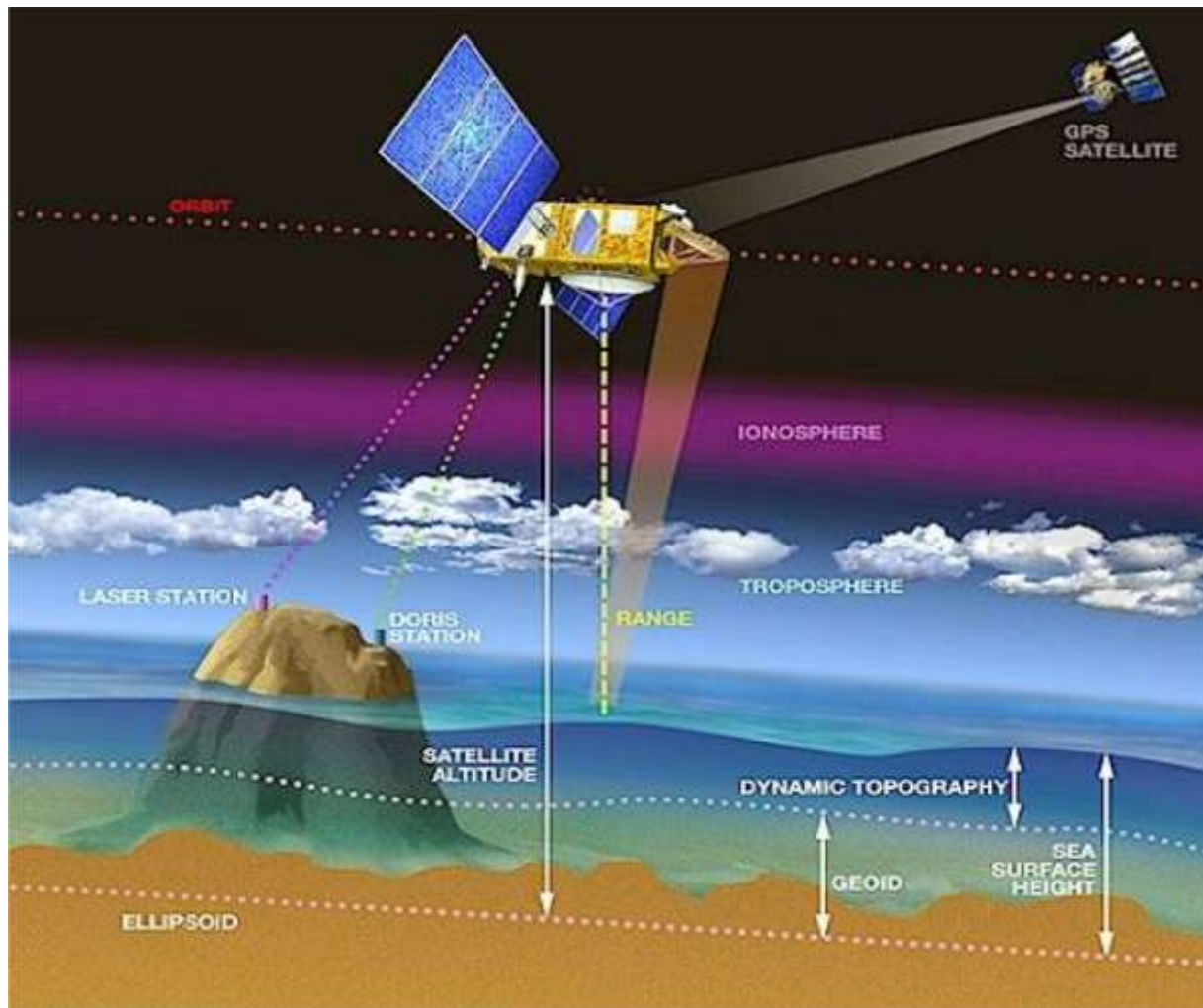


Figure from: <http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/basic-principle/>