Bathymetry from space (altimetry) + Multibeam & singlebeam sounding compilations + Onshore DEM’s = SRTM15+V2

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Canberra
Outline

Part one: *New satellite altimetry*

Part two: *New bathymetry*

Part three: *SRTM15+V2*

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

Sea surface slope
↓
Gravity anomaly
↓
Predicted bathymetry

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.
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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
2. & inclination - currently poor E-W component
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.
2. Range precision (i.e., satellite-to-surface distance, determined from echo time).
**Range precision**

<table>
<thead>
<tr>
<th>Altimeter</th>
<th>Range precision @ 20 Hz (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geosat</td>
<td>57.0</td>
</tr>
<tr>
<td>ERS-1</td>
<td>61.8</td>
</tr>
<tr>
<td>Envisat</td>
<td>51.8</td>
</tr>
<tr>
<td>Jason-1</td>
<td>46.4</td>
</tr>
<tr>
<td>CryoSat-2 LRM</td>
<td>42.7</td>
</tr>
<tr>
<td>CryoSat-2 SAR</td>
<td>49.7</td>
</tr>
<tr>
<td><strong>AltiKa</strong></td>
<td><strong>20.5</strong></td>
</tr>
</tbody>
</table>

*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**
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 \( \sigma \), 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)
VGG (V27) + CryoSat + AltiKa + Jason-1
Free-air anomaly: change V24-V18

<table>
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<tr>
<th>Statistic</th>
<th>change (mGal)</th>
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<tr>
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<td>-0.05</td>
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<tr>
<td>Standard Dev.</td>
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### Free-air anomaly: change V27-V24

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<th>Statistic</th>
<th>change (mGal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.04</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>1.82</td>
</tr>
</tbody>
</table>
Accuracy – how much are we improving?
Accuracy – how much are we improving?

V18
rms=2.05 mGal

V24
rms=1.52 mGal

V27
rms=1.33 mGal
Limit on spatial resolution

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

<table>
<thead>
<tr>
<th></th>
<th>( \lambda = 1/k )</th>
<th>( z )</th>
<th>gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>shallow margin</td>
<td>2 km</td>
<td>1 km</td>
<td>0.043</td>
</tr>
<tr>
<td>deep ocean</td>
<td>8 km</td>
<td>4 km</td>
<td>0.043</td>
</tr>
<tr>
<td>GOCE altitude</td>
<td>8 km</td>
<td>200 km</td>
<td>( 10^{-68} )</td>
</tr>
</tbody>
</table>
Shipboard bathymetry


- 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
Deeper than predicted

Smaller than Predicted with crater

Better altimetry

Higher resolution = fine structure
Better altimetry

Deeper than predicted

Smaller than Predicted with crater

Higher resolution = fine structure
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!

http://www.godac.jamstec.go.jp/darwin/e
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
SRTM15+ V2-V1 global change

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-1.83</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>61.8</td>
</tr>
<tr>
<td>Min/Max</td>
<td>-3953/3288</td>
</tr>
</tbody>
</table>
SRTM15+ V2-V1
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!
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.
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Part one

New satellite altimetry
Satellite altimetry

- Sea surface slope
  - Deflection of the vertical
  - North and east components
    - $\langle$Laplace’s equation$\rangle$
      - Gravity anomaly
        - Predicted bathymetry
Figure from: http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/basic-principle/