High resolution geoid from altimetry & bathymetry: requirements for a future mission

The GRAL team:

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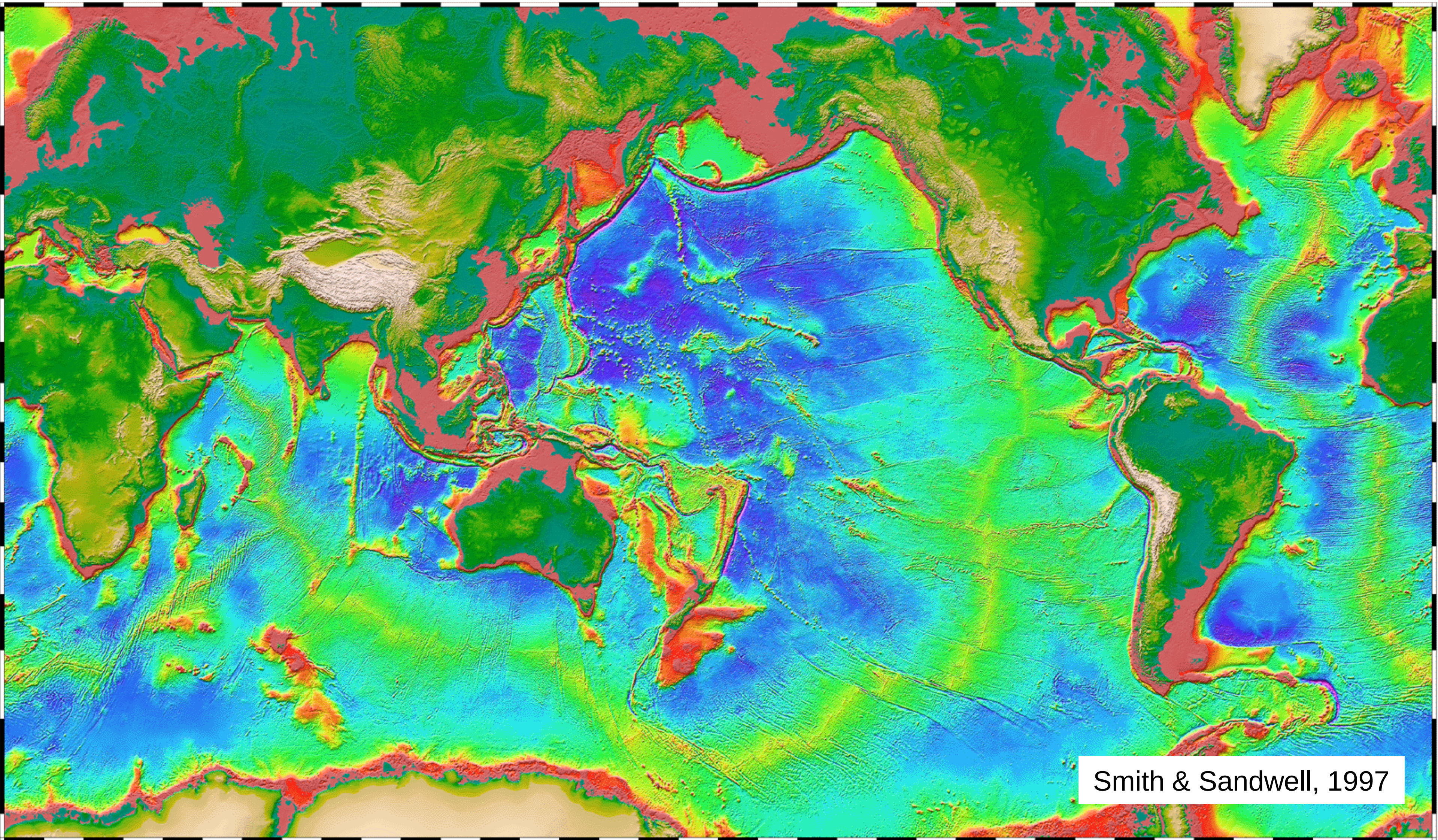
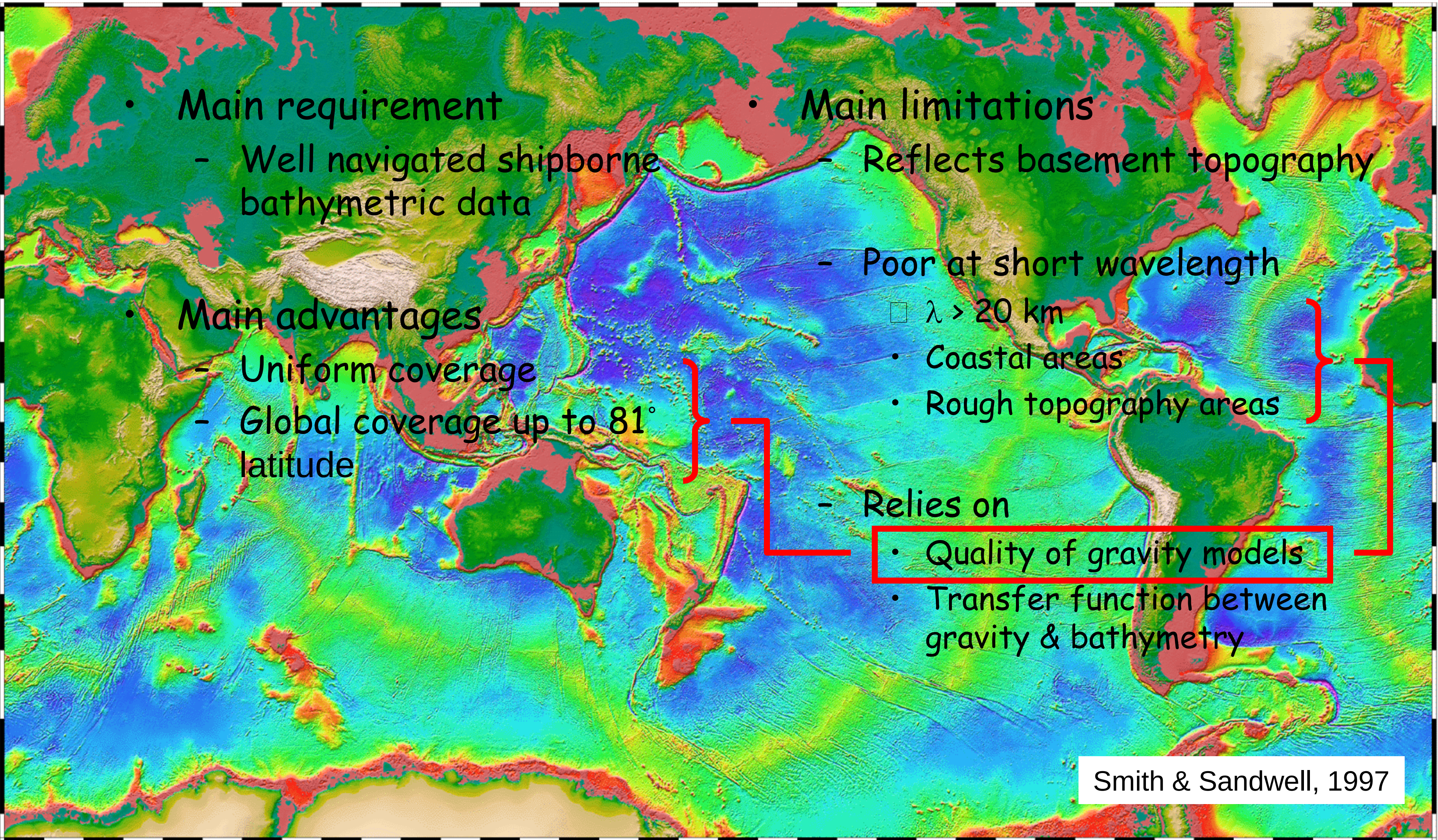
Predicted bathymetry



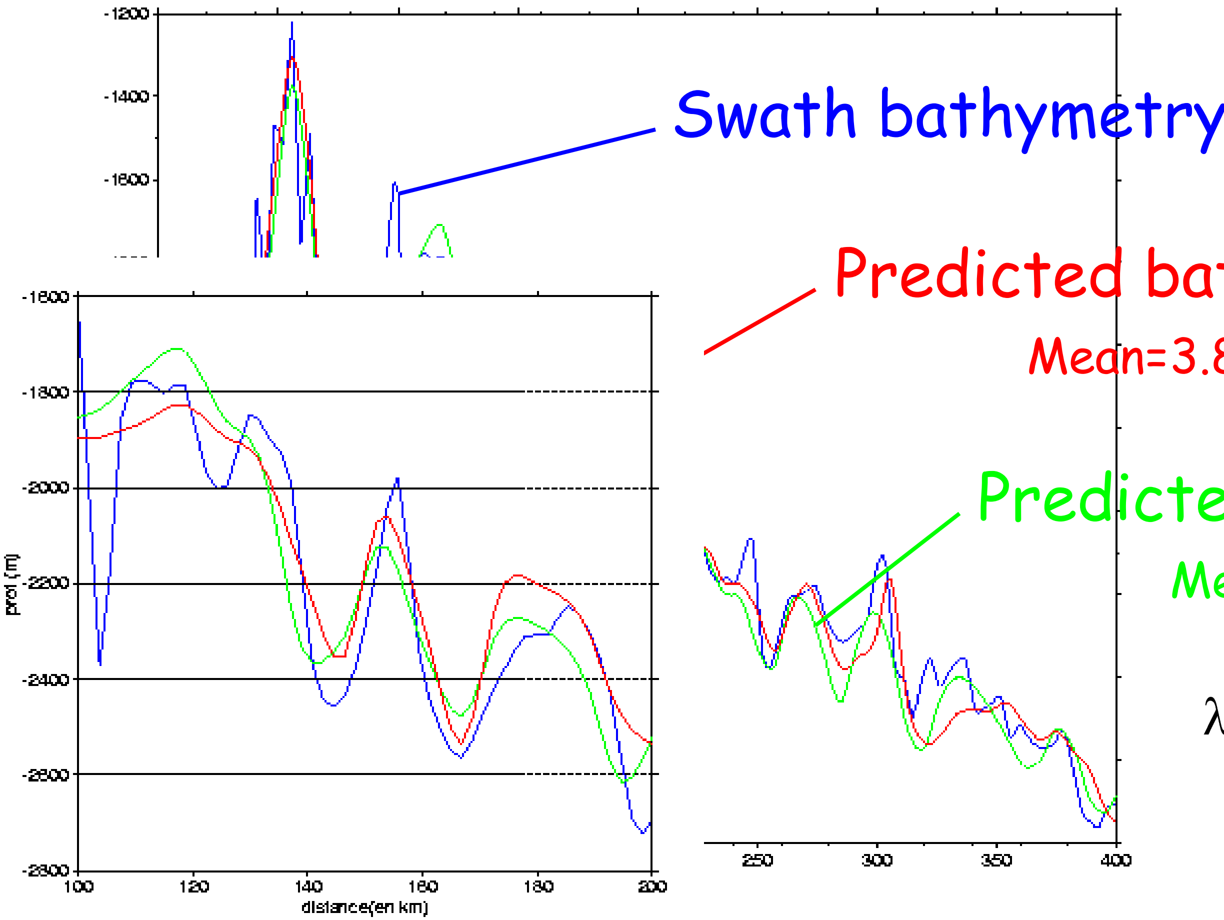
Predicted bathymetry



- Main requirement
  - Well navigated shipborne bathymetric data
- Main advantages
  - Uniform coverage
  - Global coverage up to 81° latitude
- Main limitations
  - Reflects basement topography
  - Poor at short wavelength
    - □ $\lambda > 20$ km
    - Coastal areas
    - Rough topography areas
  - Relies on
    - Quality of gravity models
    - Transfer function between gravity & bathymetry

Smith & Sandwell, 1997

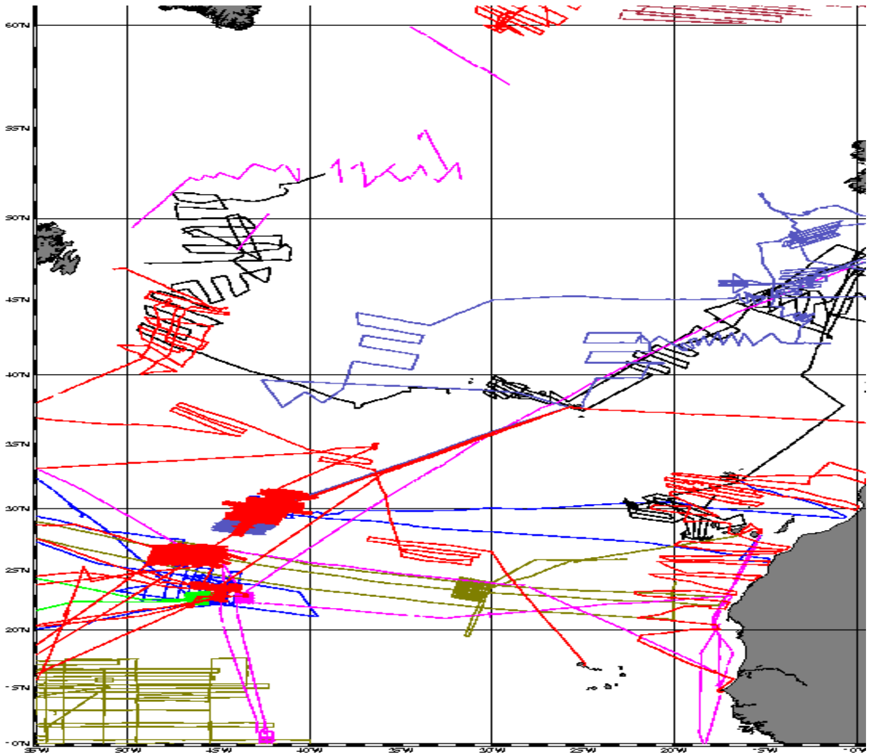
Predicted vs observed bathymetry



λ < 20 km poorly resolved

Profile across the mid-Atlantic ridge

Shipborne gravity measurements



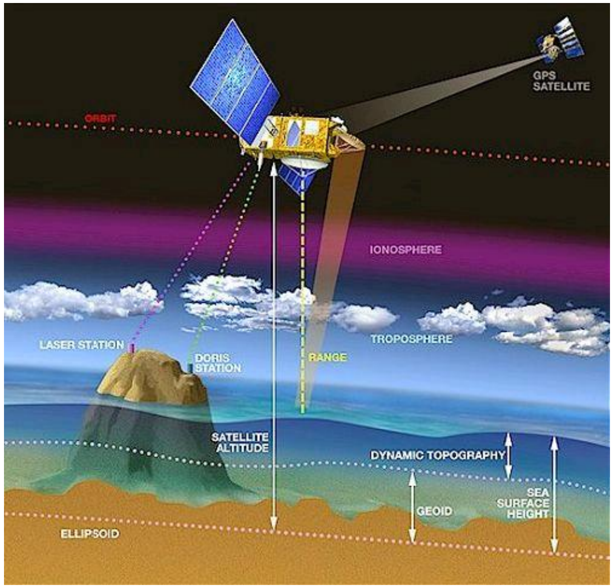
Central Atlantic

Accuracy	Best than 1mGal
Spatial resolution	**along track:** few meters **across tracks:** 1km
Data coverage	sparse

How to improve gravity models from altimetry

- From altimetry to high-resolution geoid
- Satellite-derived vs shipborne gravity
- Requirements for a new mission
- Proposal for a new mission

From altimetry to gravity



Stack of satellite passes

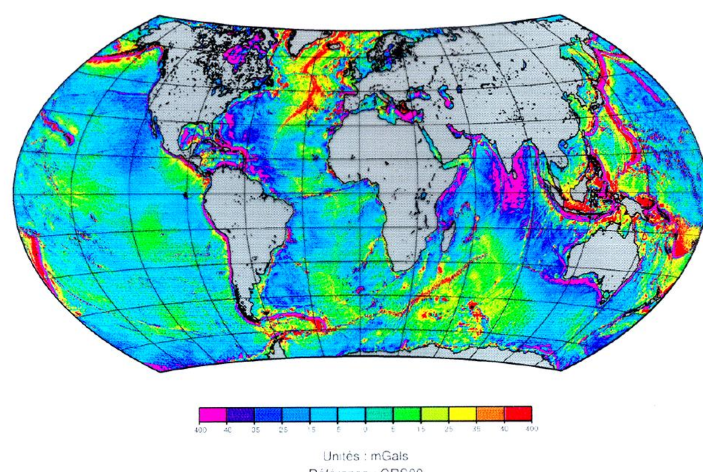
Mean sea surface geoid

Andersen O.B. & Knudsen P., JGR, 1998

Differentiation along track

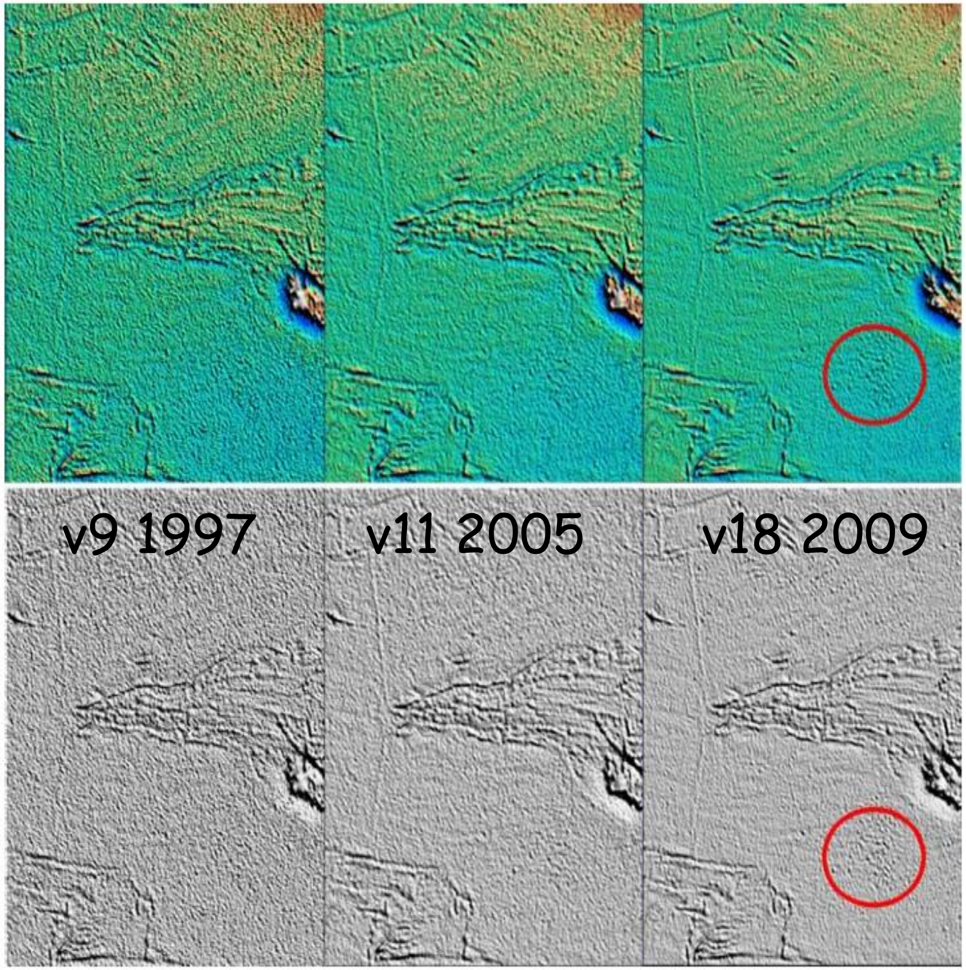
Vertical deflection = geoid slope

Sandwell & Smith, JGR, 1997, 2005, 2009



Satellite derived FAA model

Gravity model improvements

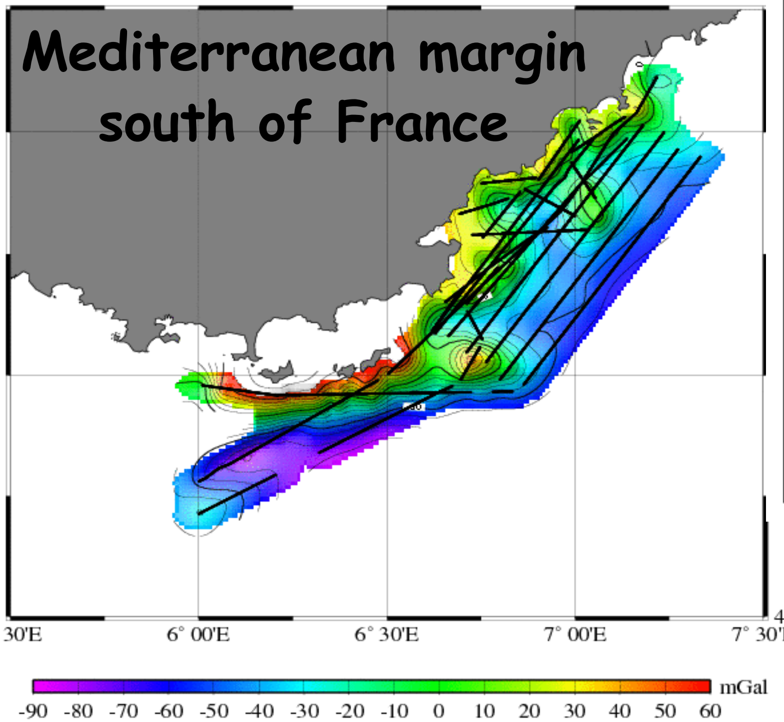


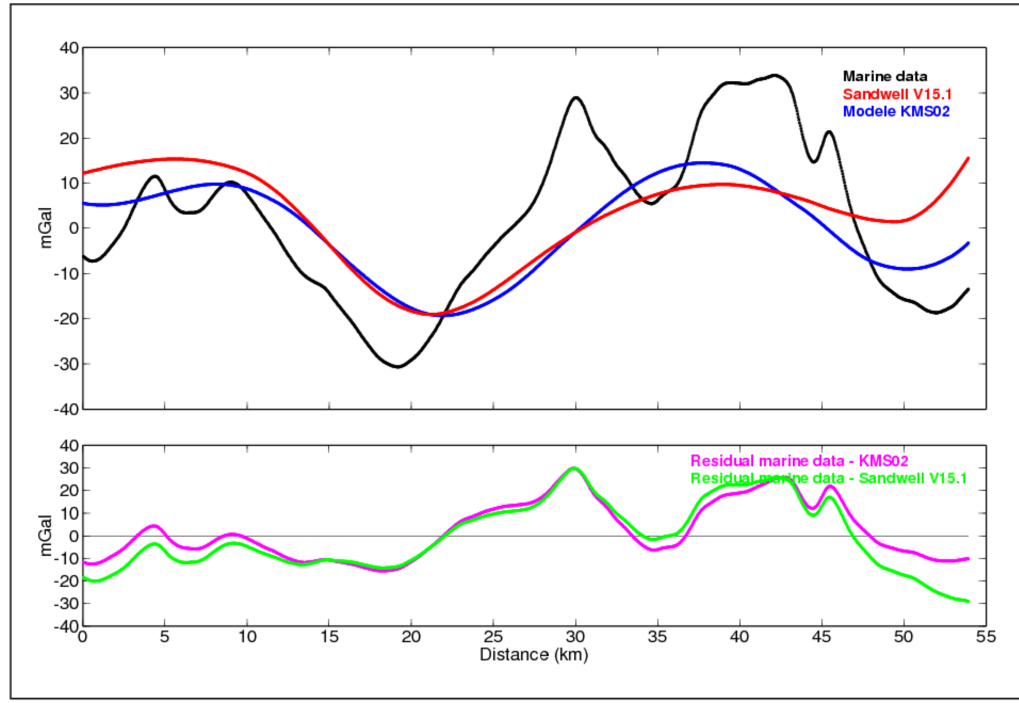
- Retracking raw waveform of Geodetic Mission data
- Improved along track slope-gridding
- Improved geopotential model

Sandwell & Smith, 2009

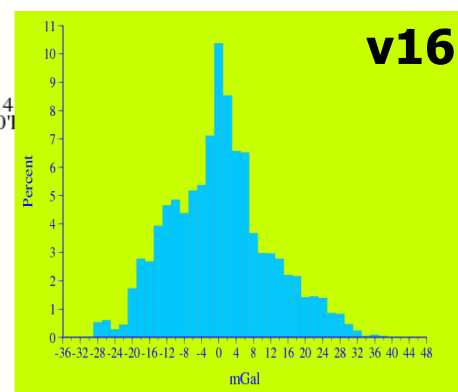
Shipborne vs "altimetric" gravity

Coastal area

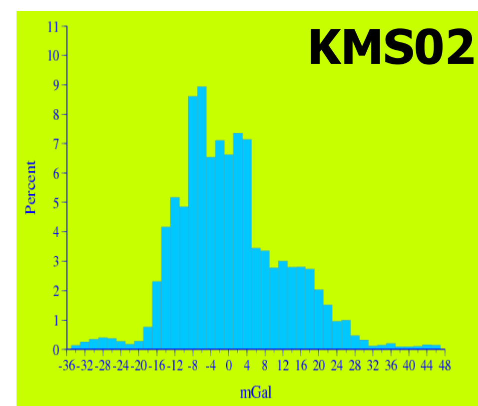




Histograms of
data residuals

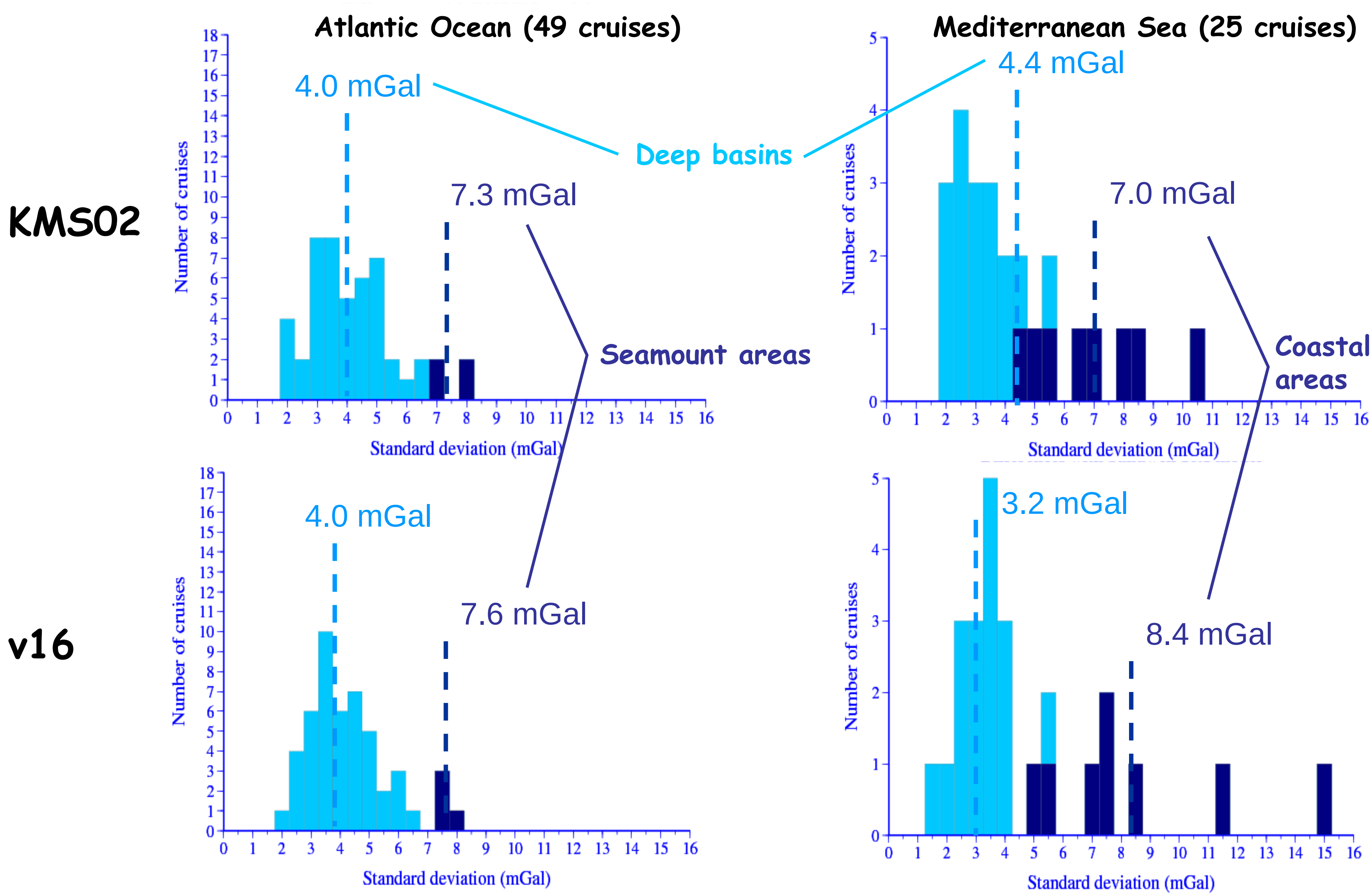


σ=11.8 mgal



σ=11.3 mgal

Shipborne vs "altimetric" gravity



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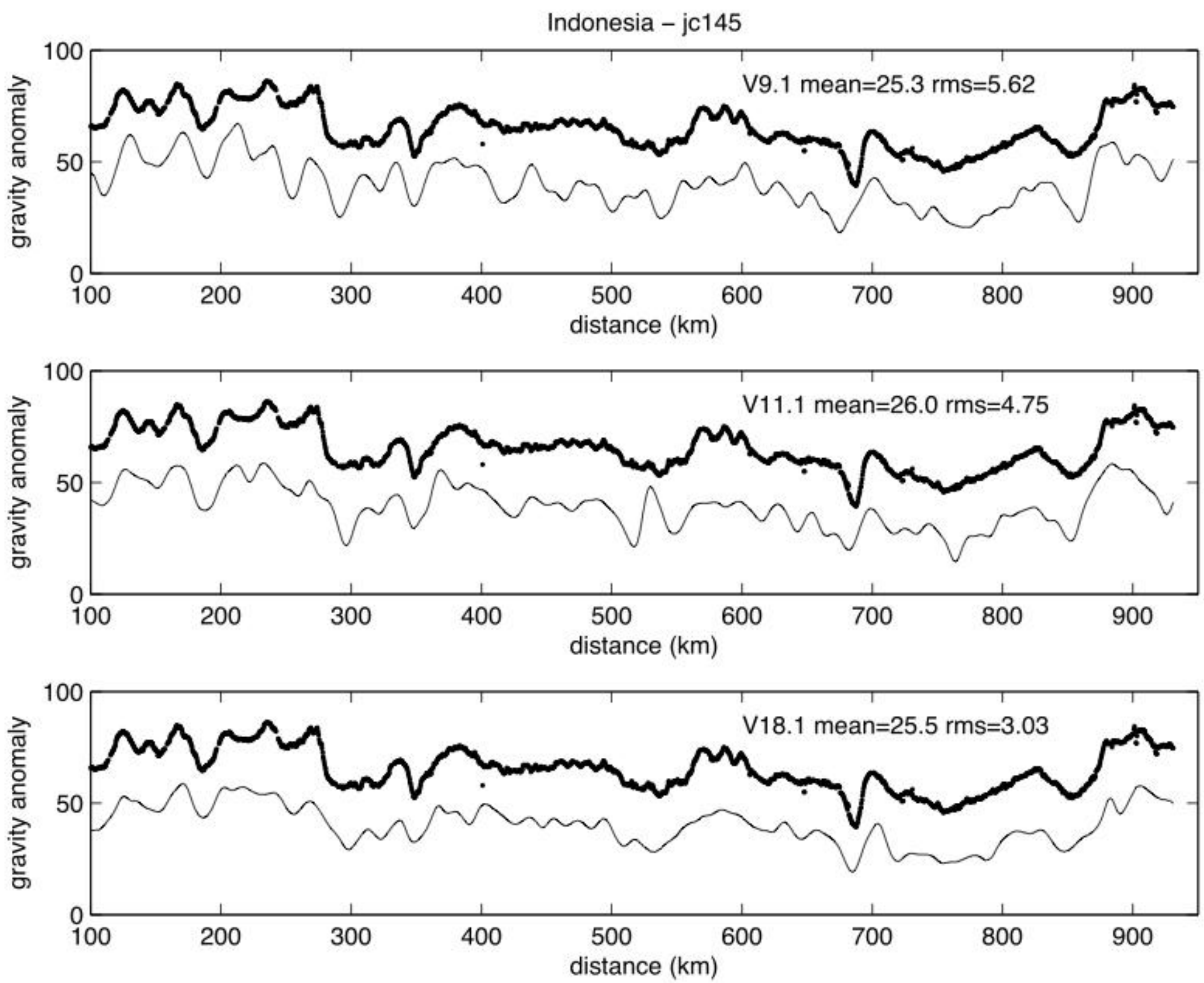


Shipborne

v9

v11

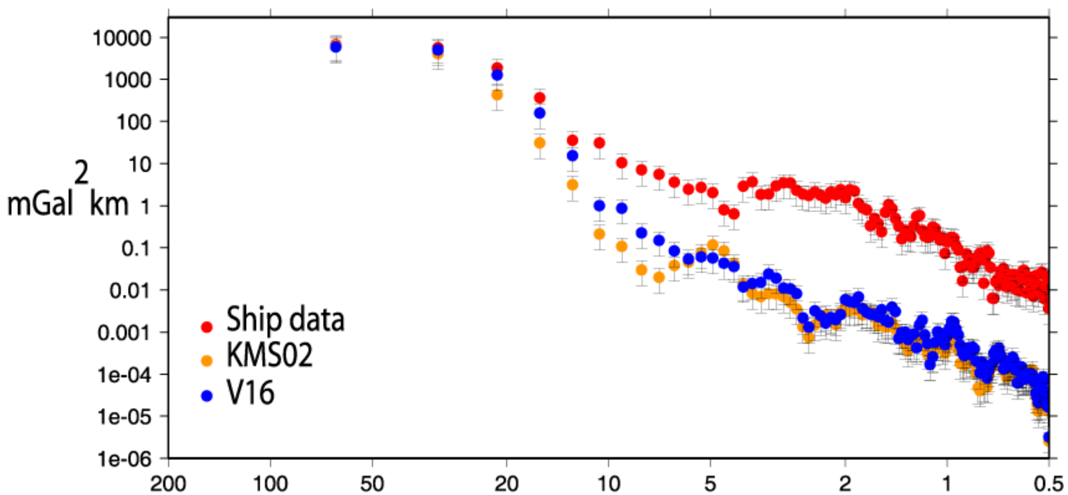
v18

46% improvement

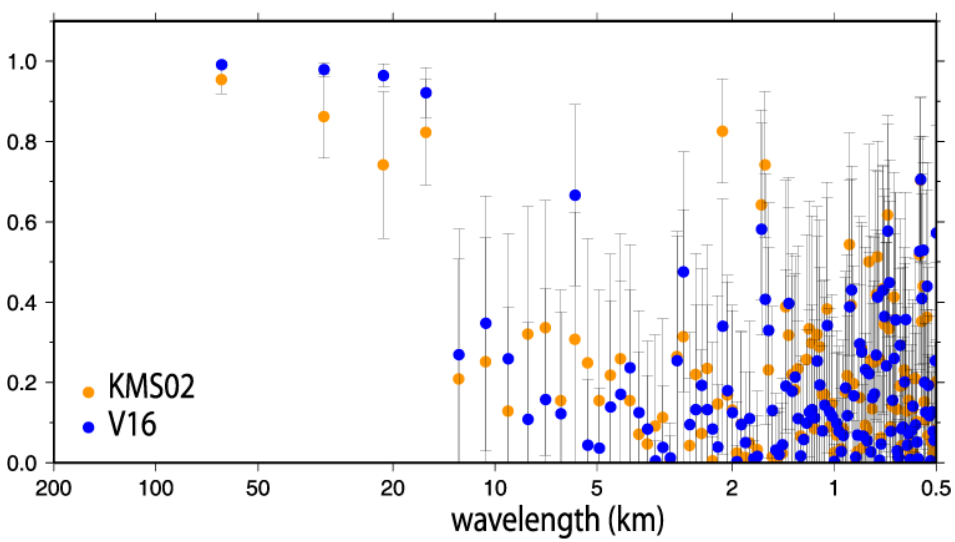
Sandwell & Smith, 2009

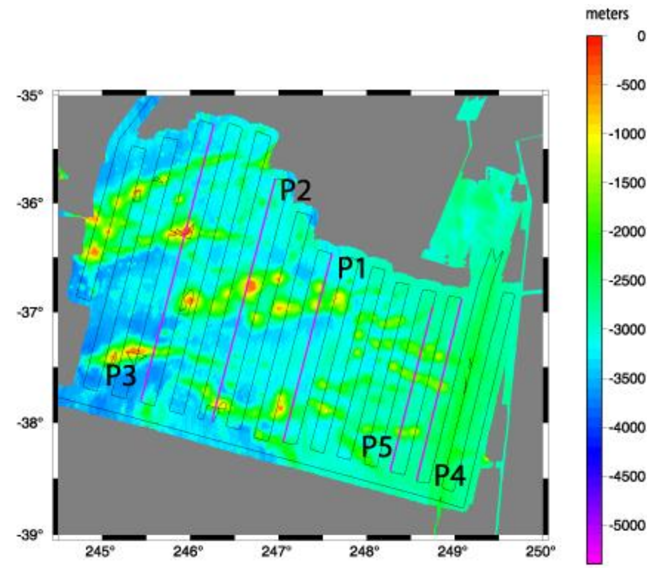
Shipborne vs "altimetric" gravity

Power spectra of the free air anomaly



Coherence between ship and satellite free air anomalies





Foundation seamounts, South Pacific

Energy decreases at wavelength
less than 16 km V16.1
less than 20 km KMS02

Coherency differs from 27 km

Toward a new altimetry mission

- Current gravity models are limited :
  - $\lambda > 25$ km w rms ~7 mgal on average
  - $\lambda > 16$ km w rms ~3 mgal in some areas
  - Resolution remains poor in coastal and rough areas

- Needed improvements :
  - Uniform data coverage
  - Accuracy close to shipborne data
  - Improved data recovery in coastal areas

Toward a new altimetry mission

	Altimetry Mission	Year	Repetitive-ness	Measurement spacing at the Equator
Current and past missions	GEOSAT	1985-86	**drifting**	**4 km**
		1986-90	17 days	164 km
	TOPEX	1992-2005	10 days	315 km
	ERS-1	1992-93+	35 days	79 km
		1995-96		
		1994-95	**168 days**	**8 km**
	Jason-1	2001-É	10 days	315 km
	Jason-2	2008-É		
Planned missions	Cryosat-2	2010	**369 days**	**uncorrelated**
	SARAL	2010	35 days	150 km
	Sentinel-3	2011	27 days	100 km

- Needed improvements :
  - 4% of altimetric data come from non-repeat orbital tracks
    ==> drifting orbit

Toward a new altimetry mission

Altimetry Mission		Year	Maximum latitude
Current and past missions	GEOSAT	1985-86	72□
		1986-90	
	TOPEX	1992-2005	66□
	ERS-1	1992-93+	**82□**
		1995-96	
		1994-95	
	Jason-1	2001-É	66□
	Jason-2	2008-É	
Planned missions	Cryosat-2	2010	**88□**
	SARAL	2010	**82□**
	Sentinel-3	2011	81□

- Needed improvements :
  - 4% of altimetric data come from non-repeat orbital tracks
    ==> drifting orbit
  - Cover polar areas
    ==> high inclination of orbit

Toward a new altimetry mission

	Altimetry Mission	Year	Height RMS accuracy	Slope accuracy
Current and past missions	GEOSAT	1985-86	13 cm	3.2 µrad at 9 km
		1986-90	6.5 cm	2.2 µrad at 9 km
	TOPEX	1992-2005	**1.2 cm**	**1.2 µrad at 9 km**
	ERS-1	1992-93+	2.5 cm	3.6 µrad at 9 km
		1995-96		
		1994-95	13 cm	
	Jason-1	2001-É	**1.7 cm**	**1.7 µrad at 10 km**
	Jason-2	2008-É	cal/val phase	
Planned missions	Cryosat-2	2010	3.5 cm NRT	2.1 µrad at 10 km
	SARAL	2010	3.2 cm NRT	**1.5 µrad at 10 km**
	Sentinel-3	2011	3.0 cm NRT	2.1 µrad at 10 km

Needed improvements :

- 4% of altimetric data come from non-repeat orbital tracks
  ==> drifting orbit
- Cover polar areas
  ==> high inclination of orbit
- Accurate slope measurements
  ==> 1 cm on geoid height
  ==> 1 mgal in gravity
  ==> 1 µrad (1cm over 10km)

Toward a new altimetry mission

- Requirements for a high-resolution geoid/gravity model :
  - Drifting orbit
  - High inclination orbit
  - 1 μrad (1cm over 10km)
  - Dense slope measurements, along & across tracks

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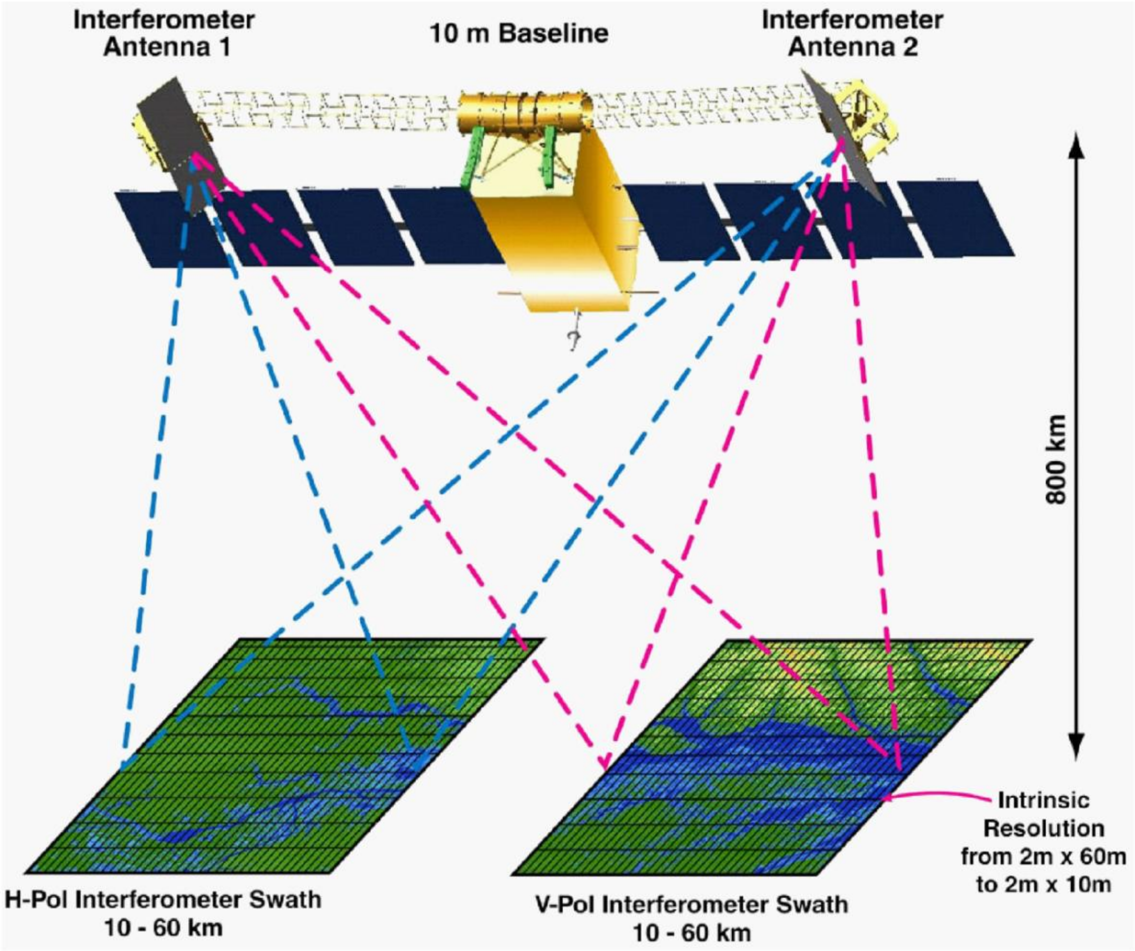
Proposed missions	SWOT	2016?	22 days	78□	1 km at best without gap due to its 140 km swath-width	Varies along the swath, mean 3cm, max 4cm at edges	Max 0.8 μrad at 5Km
	GRAL	2016?	265 days	82ū	5 km	uncorrelated	1 μrad at 10 km

SWOT

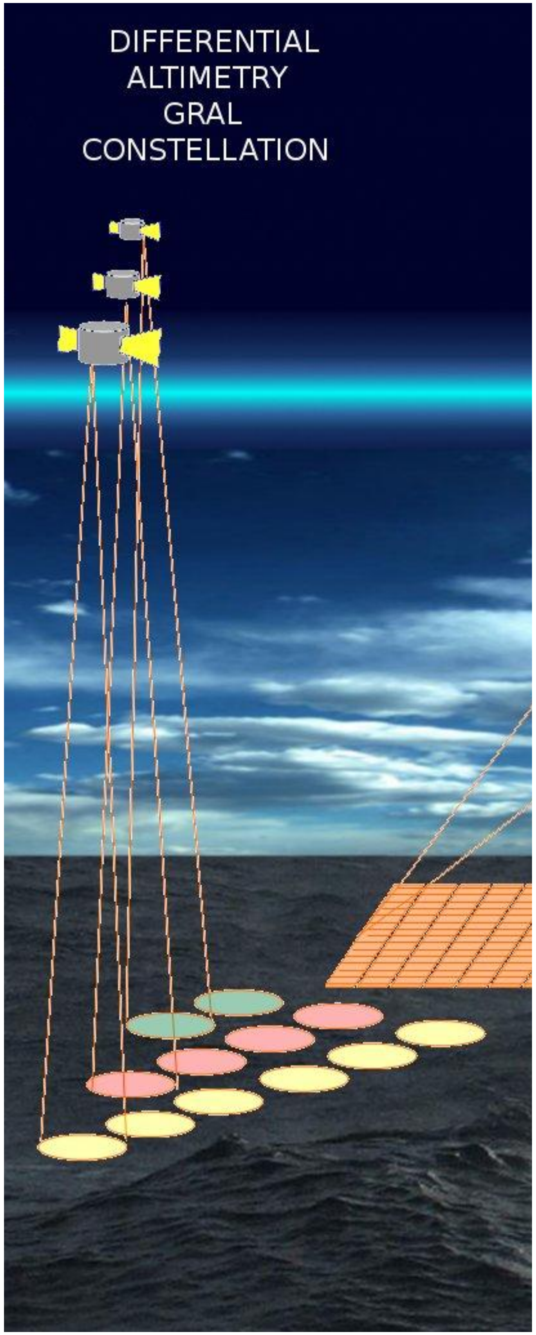
Surface Water and Ocean Topography



Swath-altimetry
- Up to 140 km wide
- 2x60 m pixel

Expected accuracy
- 1 μrad over 5km

Main Challenge
- Very precise monitoring of the baseline (10m)

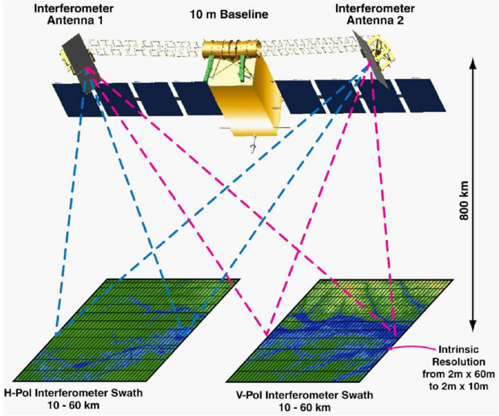


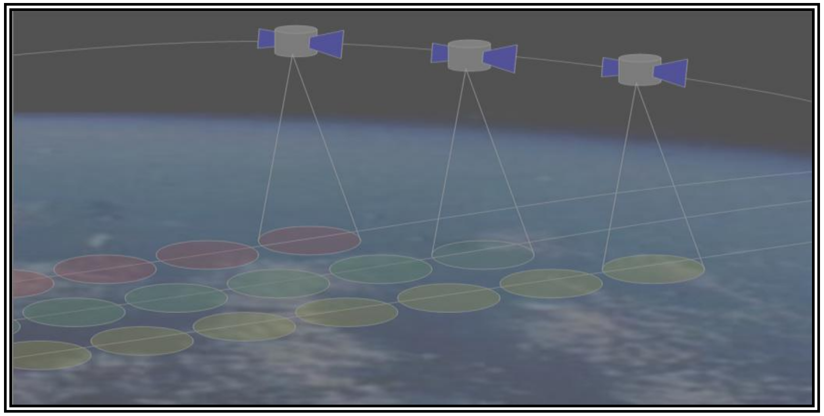
GRAL

Gravity from altimetry

- Constellation of 3 small satellites following the same orbit :
  - Using Ku or Ka band altimeters
  - Quasi-instantaneous along and across track slope measurements
  - Drifting orbit
  - High inclination
- Expected accuracy
  - 1 μrad over 10 km
- Advantages
  - Robust and classical technology
  - Can piggy back a larger payload launch
  - Relatively low cost

2 proposals for a high resolution geoid/gravity from altimetry



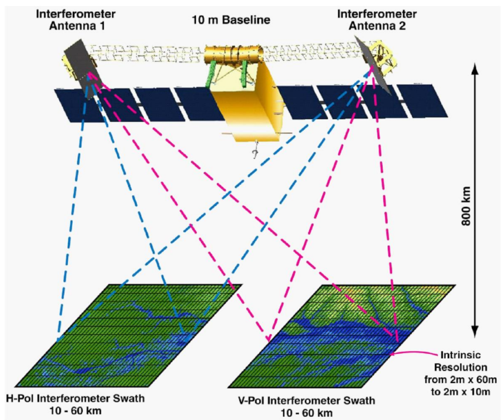


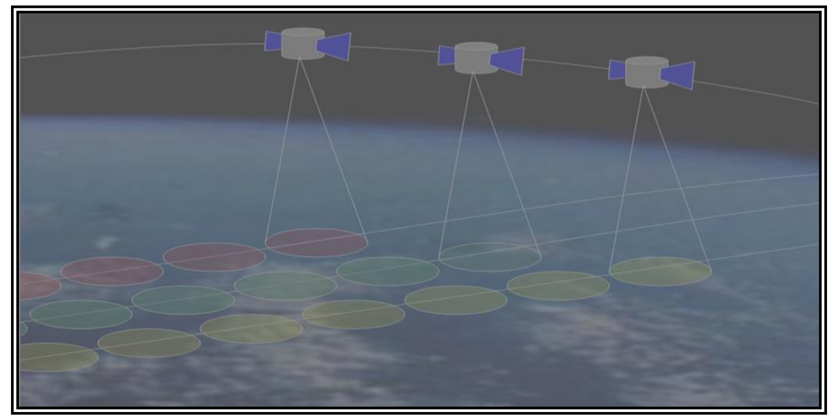
- Applications
  - Short wavelength ocean dynamics
  - Gravity field on continental shelves
  - Natural resources prospecting
  - Predicted bathymetry
  - Geodynamics
  - …

For a summary, see EOS paper in press

Thank you

2 proposals for a high resolution geoid/gravity from altimetry





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Altimetric mission status

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	Sentinel-3	2011	27 days	81°	100 km	3.0 cm NRT	2.1 µRad at 10 km
Proposed missions	ABYSS	not funded	drifting	50-63°	6 km	uncorrelated	1 µRad at 6 km
	SWOT	2016?	22 days	78°	1 km at best without gap due to its 140 km swath-width	Varies along the swath, mean 3cm, max 4cm at edges	Max 0.8 µRad at 5Km
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The limits of these models are partly due to the altimetric technology, which prevents the exploitation of measurements close to the coastlines and limits the space resolution along the satellite tracks (with a foot print of approximately 7 km). In addition, the strategy of measurements adopted for altimetric missions generally favours the study of oceanographic processes and their temporal variability (i.e. repeated orbits) rather than a complete spatial coverage needed for highly resoluted geophysical studies.

- Limitations of altimetric 1 HZ data Retracking and 10 HZ processing?

That what Sandwell et al. made in V16 version of the altimetric models

(Sandwell DT et Smith WHF, 2005 retracking ERS1 Altimeter waveforms For optimal gravity field recovery GJI, 163, 79-89)

Lillibridge et al, 2006, 20 years of improvements to geosat altimetry, ESA Symposium 15 Years of Progress in Radar Altimetry, Venice, 12-18 mars, 2006)