Towards 1 mGal Accuracy Global Marine Gravity Anomaly from Satellite Altimetry: Improvements in the Coastal Zone

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INTRODUCTION:

Marine gravity anomalies are foundational data, and contribute to the basic infrastructure for military, scientific, economic, educational, and political work.

The correlation between gravity anomaly and ocean depth allows ocean floor mapping via satellite altimeters.

Gravity accuracy depends on four factors: spatial track density; altimeter range precision; diverse track orientation; and the accuracy of the coastal tide models.

RESEARCH OBJECTIVES:

To improve marine gravity models with better tide models, and through better blending of marine and land gravity anomalies.

ONGOING EFFORTS:

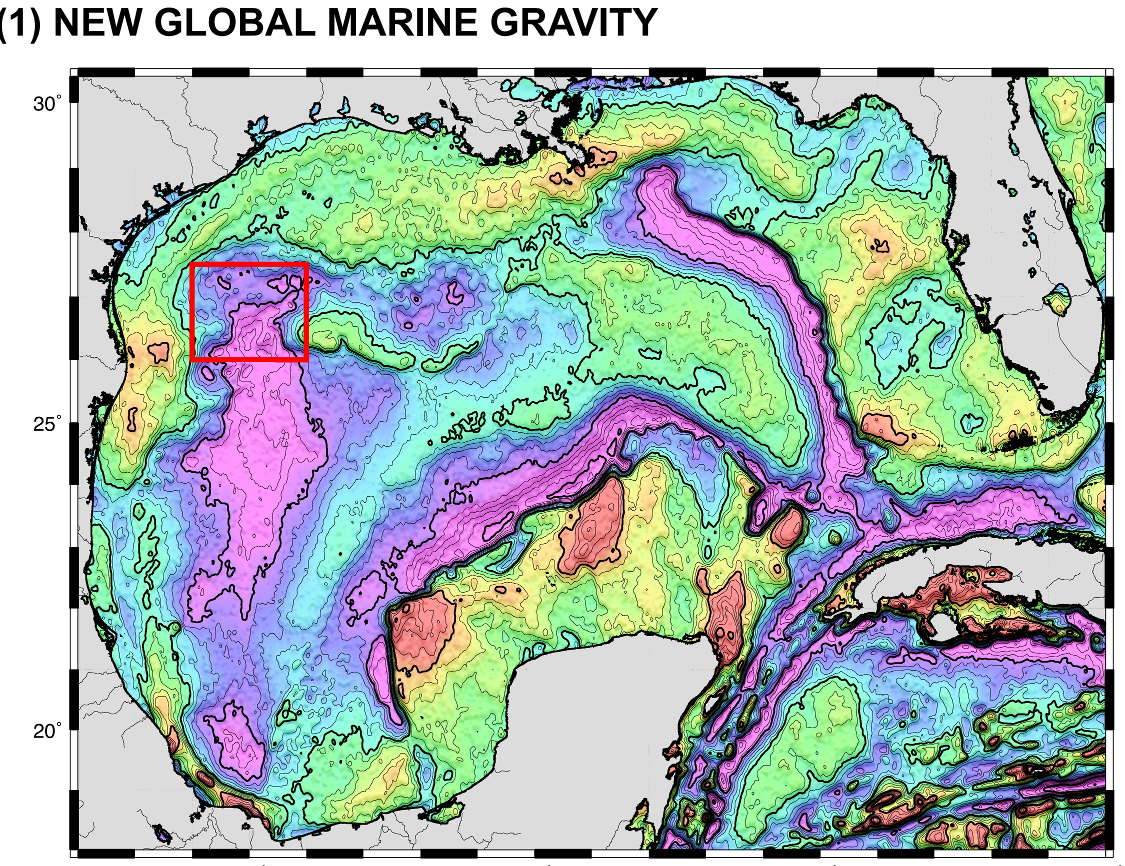
(1) Constructing new global marine gravity from from CryoSat-2, Jason-1, and Envisat.

(2) Development of new algorithms to ameliorate ocean/land edge effects. Land gravity based on EGM2008 [Pavlis et al., 2012].

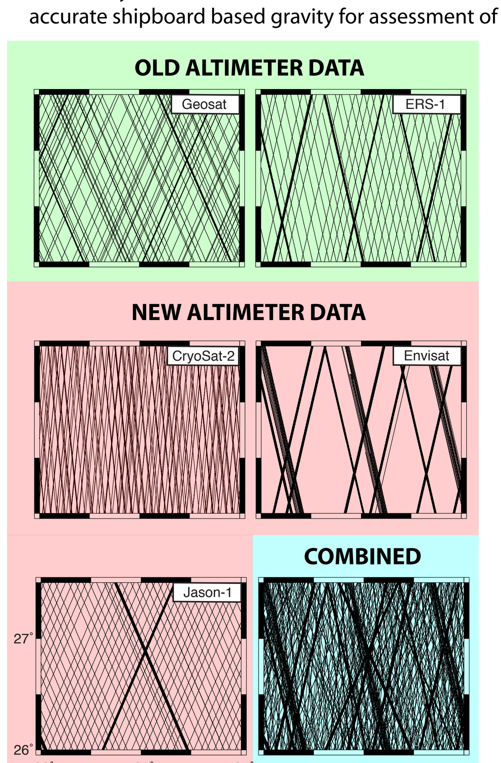
(3) Evaluation and comparison of existing tide models.

(4) Development of new tide models from existing geodetic mission data (year 2 of investigation).

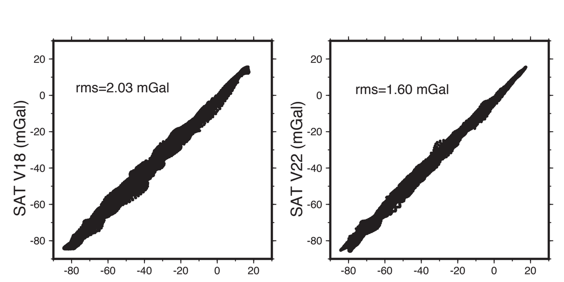
(1) NEW GLOBAL MARINE GRAVITY

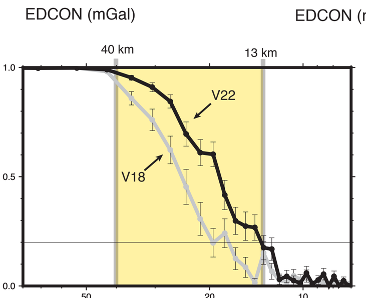


Free-air gravity anomaly for the Gulf of Mexico based on all available altimeter data. Contour interval is 10 mGal with heavy contours at 50 mGal. Red box shows area of Alaminos Canyon where EDCON-PRJ, Inc. has provided accurate shipboard based gravity for assessment of our satellite gravity fields.



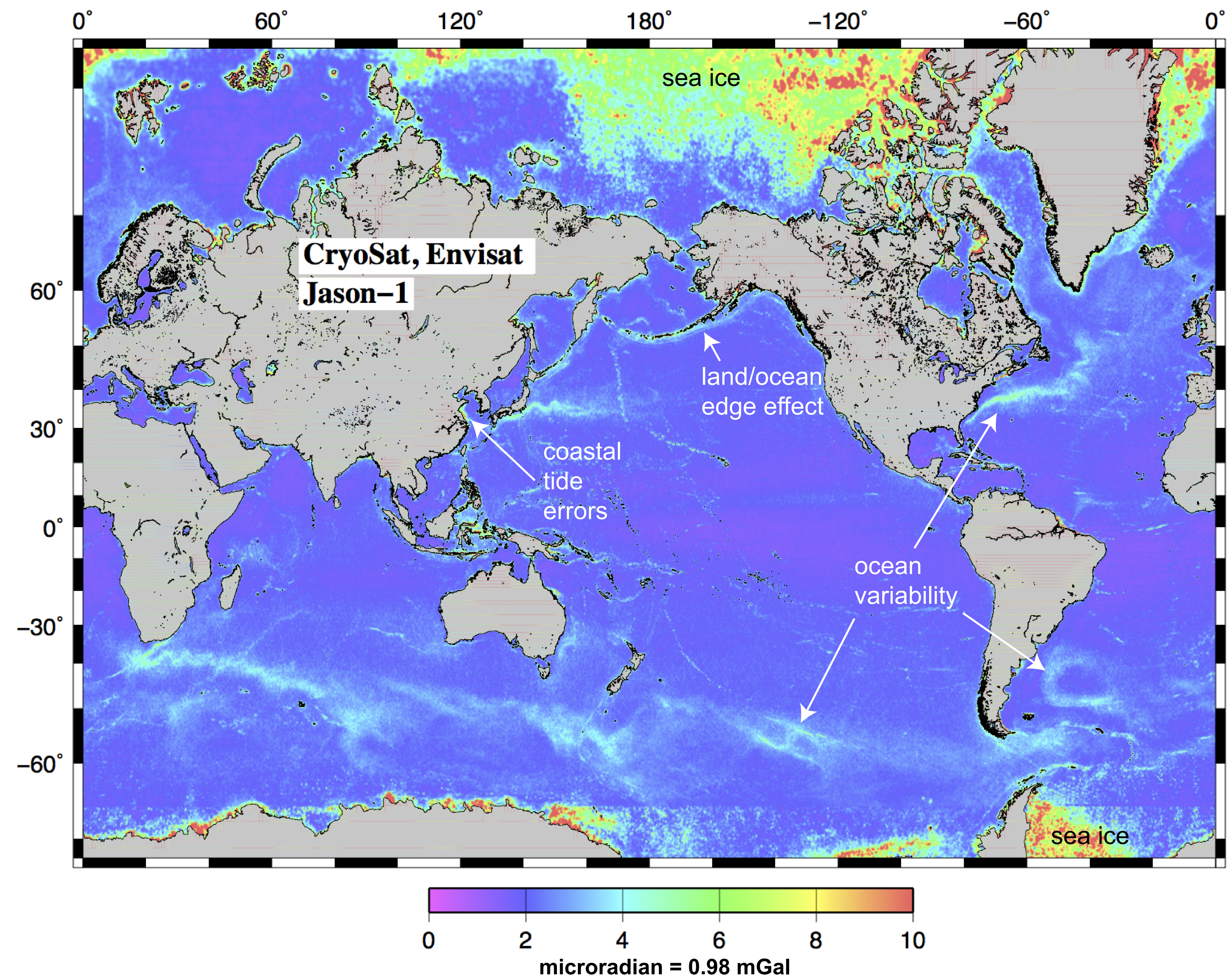
Examples of satellite altimeter track density (red box above) used for this gravity construction. An older published gravity model (V18) is based on tracks from Geosat and ERS-1. This newer gravity model (V22) is based on the combined tracks from all 5 altimeters. The heavier tracklines represent phases of the data coverage where there are tens to hundreds of tracks that don't repeat exactly resulting in swath coverage.



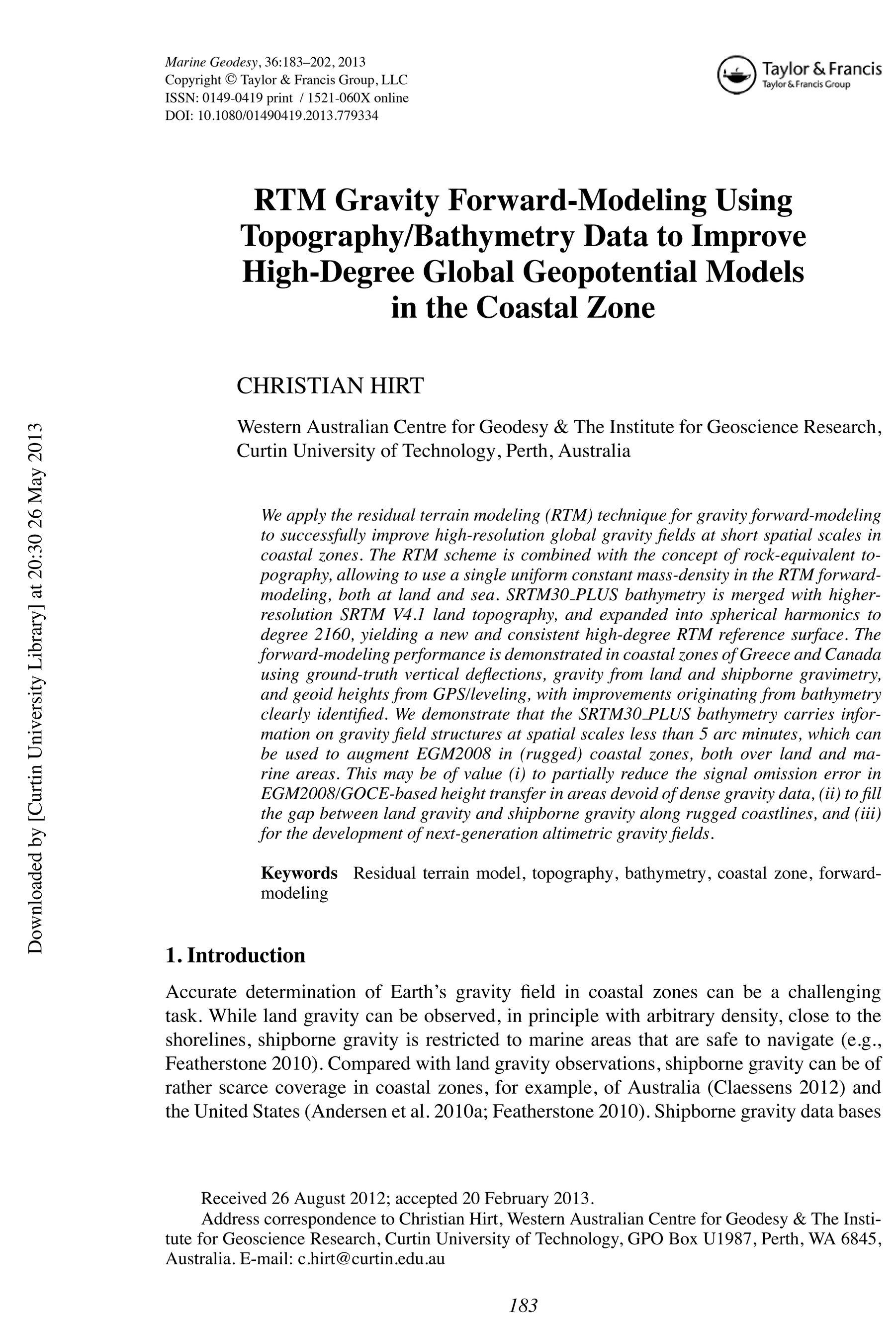


(upper) Satellite gravity anomalies from V18 and V22 plotted versus shipboard gravity from Alaminos Canyon (EDCON-PRJ, Inc.). (lower) coherence between satellite gravity and EDCON gravity over the area of the Alaminos Canyon (red box above). The coherence falls to 0.5 at a wavelength of 27 km for V18 and a wavelength of 19 km for V22. Adding the new altimeter data from Envisat, CryoSat-2, and Jason-1 provides improvement in the 13 km to 40 km wavelength band.

IDENTIFYING ERRORS IN GLOBAL MARINE GRAVITY



(2) ALGORITHM TO AMELIORATE LAND/OCEAN EDGE EFFECT



Marine Geodesy, 36:183–202, 2013

ISSN: 0149-0419 print / 1521-060X online
DOI: 10.1080/01490419.2013.779334

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RTM Gravity Forward-Modeling Using Topography/Bathymetry Data to Improve High-Degree Global Geopotential Models in the Coastal Zone

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We apply the residual terrain modeling (RTM) technique for gravity forward-modeling to successfully improve high-resolution global gravity fields at short spatial scales in coastal zones. The RTM scheme is combined with the concept of rock-equivalent topography, allowing to use a single uniform constant mass-density in the RTM forward-modeling, both at land and sea. SRTM30_PLUS bathymetry is merged with higher-resolution SRTM V4.1 land topography, and expanded into spherical harmonics to degree 2160, yielding a new and consistent high-degree RTM reference surface. The forward-modeling performance is demonstrated in coastal zones of Greece and Canada using ground-truth vertical deflections, gravity from land and shipborne gravimetry, and geoid heights from GPS/leveling, with improvements originating from bathymetry clearly identified. We demonstrate that the SRTM30_PLUS bathymetry carries information on gravity field structures at spatial scales less than 5 arc minutes, which can be used to augment EGM2008 in (rugged) coastal zones, both over land and marine areas. This may be of value (i) to partially reduce the signal omission error in EGM2008/GOCE-based height transfer in areas devoid of dense gravity data, (ii) to fill the gap between land gravity and shipborne gravity along rugged coastlines, and (iii) for the development of next-generation altimetric gravity fields.

Keywords Residual terrain model, topography, bathymetry, coastal zone, forward-modeling

1. Introduction

Accurate determination of Earth's gravity field in coastal zones can be a challenging task. While land gravity can be observed, in principle with arbitrary density, close to the shorelines, shipborne gravity is restricted to marine areas that are safe to navigate (e.g., Featherstone 2010). Compared with land gravity observations, shipborne gravity can be of rather scarce coverage in coastal zones, for example, of Australia (Claessens 2012) and the United States (Andersen et al. 2010a; Featherstone 2010). Shipborne gravity data bases

Received 26 August 2012; accepted 20 February 2013.

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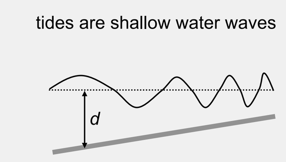
(3a) COASTAL TIDE MODEL EVALUATION

coastal tides

tides are shallow water waves



$\lambda = T\sqrt{gd}$ wavelength

$s = \frac{2\pi h}{\lambda}$ ocean surface slope

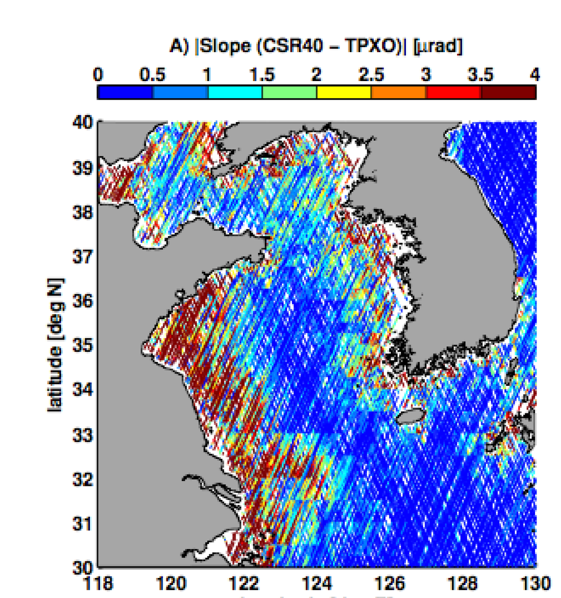
$h = \frac{sT\sqrt{gd}}{2\pi}$ tide height

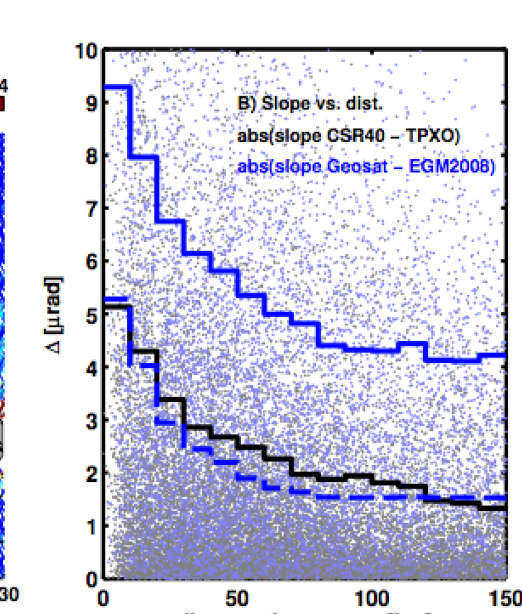
tide model error for 1 μrad slope error (T=1/2 day)

d (m)	λ(km)	h (m)
10	426	0.07
50	954	0.15
100	1350	0.22
500	3018	0.48
1000	4270	0.68
5000	9546	1.52

The wavelength of the tide decreases in shallow water, leading to larger errors in slope for a given error in tidal elevation (left).

It is hypothesized that errors in the tidal corrections are in the range of 1 to 5 micro-radians in shallow water, near the coast. This is the largest source of error in certain regions around the globe. With new tide models we expect to reduce the error to less than 1 micro-radian.



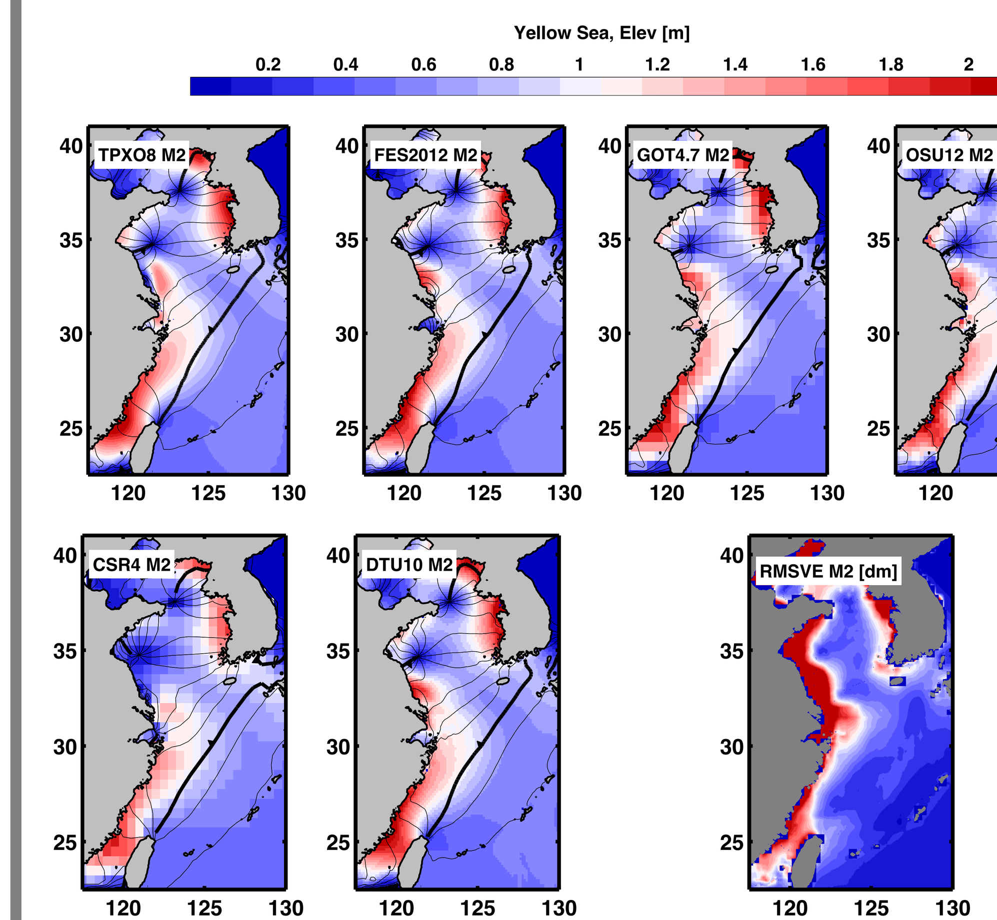


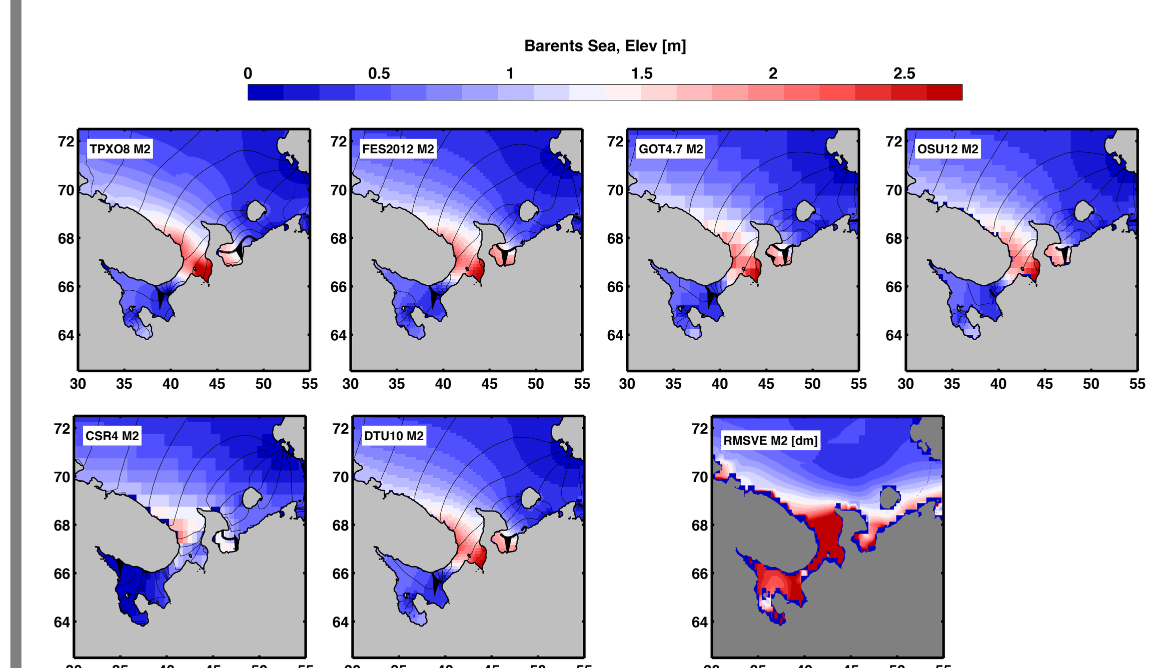
A) Difference in tide model predictions of sea-surface slope along Geosat ground tracks in the Yellow Sea. B) Comparison of nominal tide model slope errors and Geosat minus EGM2008 geoid slope. The spatial structure and amplitude of the slope residuals agrees well with the tide model errors.

(3b) TIDE MODEL INTERCOMPARISON

Global tide models compared:

model	type	resolution [deg]
TPXO8	data-assimilating, hydrodynamic	1/6 (1/30 coastal)
FES2012	data-assimilating, hydrodynamic	variable (finite-element)
GOT4.7	empirical	1/2
DTU10	empirical	1/8
CSR4.0	empirical	1/2
OSU12	empirical	1/4





Tide models differ in resolution, definition of the coastline, and goodness-of-fit to tide data. The newer empircal models, DTU10 and OSU12, appear to over-fit the data, as evidenced by spurious small-scale structure of the tidal phase in the deep ocean (not shown). GOT4.7 appears to fit the data well, but it contains a conservative land-sea mask. Our provisional result is that TPXO8 and FES2012 are the best candidates for correcting geodetic mission altimeter data.

APPLICATIONS AND TRANSITIONS:

Global maps of the seafloor derived from in situ bathymetry and marine gravity anomalies are used by Google Earth.

Improved coastal tide models have applications to coastal hydrography (datum conversion) and satellite oceanography.

FOR MORE INFORMATION:

Applications of satellite geodesy: http://topex.ucsd.edu/

An example of the gravity model can be found at:
ftp://topex.ucsd.edu/pub/global_grav_1min/global_grav_1min_V20.1.kmz

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