Compilation of a 100m bathymetric grid for the Arabian Plate; Red Sea, Arabian and Oman Seas and Persian Gulf

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In June 2016, in Monaco, the GEBCO-Nippon FORUM declared 2030 as the target for completing the unmapped 88% of the global ocean's bathymetry. While no decision was reached on the final grid resolution, 100-200m was considered possible. Established in 1903, GEBCO continues with periodic upgrades of its half minute (~900m) global grid, but encouraging and hosting finer regional grids, viz. IBCAO in the Arctic, the Baltic Sea Bathymetry Database (NSND) at 500m, and the EMODnet (European Marine Observation and Data Network) eighth minute grid (~231m). This will be another addition to that effort.

In a column in Hydro International in December 2014 we announced our plan to do the Red Sea at 100m, to commemorate 50 years since the International Indian Ocean Expedition (IIOE). In the interim, more multibeam coverage, 30 m ASTER and SRTM topography on land, availability of additional up-to-date navigational charts, and improved Satellite Derived Bathymetry (SDB) for the extensive reefs has broadened the scope to the present area from 0°N to 32°N and 32°E to 78°E or over 2% of the Earth's surface. The marine area now includes the shores of 19 countries: Egypt, Jordan, Israel, Saudi Arabia, Sudan, Eritrea, Djibouti, Somalia, Yemen, Oman, United Arab Emirates (UAE), Qatar, Bahrain, Kuwait, Iraq, Iran, Pakistan, westernmost India, and the Maldives.

The modern and legacy charts available are shown for their five countries of origin. The Russian coverage is the most extensive and richest in bathymetric data. Estimates suggest that from the 1960s the Head Department of Navigation and Oceanography routinely collected global data from over 400 contributing vessels, equipped with deep-sea echo-sounders, good navigational control, and hydrographically trained officers. Unlike their western counterparts, these vessels often offset their tracks to provide broader coverage, and prior to the 1990s copyright was often overlooked. The British coverage is primarily for the Red Sea and Persian Gulf, reflecting heavy surveying during the World Wars and for commercial interests of the British Empire. The Red Sea charts include legacy Italian and French surveys from their support of colonies. The US coverage is uneven in scale, and represents the replacement of updated printed charts by ECDIS (Electronic Chart Display and Information System). The US charts represented here often show overprinted OMEGA lines of position. The Iranian charts cover that country's coast in the Persian Gulf and east to the Pakistani border. These charts, provided by East View Geospatial, are sometimes of low resolution but useful in an area generally off-limits since 1979.

Although this area has been the hub of marine transport for over three millennia, the hydrographic mapping has been left to outsiders with commercial and military needs for safety of navigation at sea. It is only in the last half century that a few of the littoral states have begun modern mapping of their offshore. Since 1970, academic and national cruise reports, GEBCO plotting sheets, passage soundings, data from local surveys, and US, UK, and Russian nautical charts have been collected with an eye to making such a compilation. But the breakthrough has been the advent of satellite navigation (primarily GPS and GLONASS) since 1985, establishment of the World Geodetic System 1984 (WGS84), repeat multispectral satellite imagery, and ever more accurate land topography (ASTER2 and SRTM 30m data and follow-ons) which tie together the myriad sources of sounding data. Legacy detailed bathymetry of small coastal refuges can now be properly georeferenced in a world where safe passage of deep draft shipping is the main concern of the charts.

Extensive areas of the Red Sea and Persian Gulf are extremely shallow. The intricate reefs are only schematically indicated on charts, with minimal spot soundings and contours available. Only in the past few years has the availability of high resolution multispectral satellite imagery allowed the shallows to be mapped using Satellite Derived Bathymetry (SDB). Furthermore, the very recent appearance of EOS's Land Viewer has allowed immediate 'cloud'-based appraisal and selection of the latest LANDSAT-8 (15-30m) scenes with 11 spectral bands, and ESA's Sentinel-2 (10-20m) with 13 bands, for download and analysis.

The 1965 discovery of the Atlantis II Deep initiated a number of cruises to outline the 5 million year old rift that forms the Red Sea. Of primary importance was delineating the break in order to find the pole of rotation of the opening, causing the Dead Sea Transform, and in the south the East African Rift. Farther east the spreading ridges of the Gulf of Aden and Arabian Sea and Owen Fracture Zone also attracted attention. However it is only recently that efforts to do proper hydrographic mapping with modern multibeam sonar have begun (note the plans of the Kingdom of Saudi Arabia in their index map with the work of the new R/V SULTAN).

Software Used

1) Blue Marble Geographic's **Global Mapper** (Michael Childs) is the main software package. Working with a large number of elevation, raster, and vector formats, it is used for checking datasets, georeferencing, changing projections, shifting datasets, and combining raster, vector, and gridded data. The results can then be presented in hypsometrically colored shaded relief, in 3D, with profiles, contouring, and other grid manipulations.

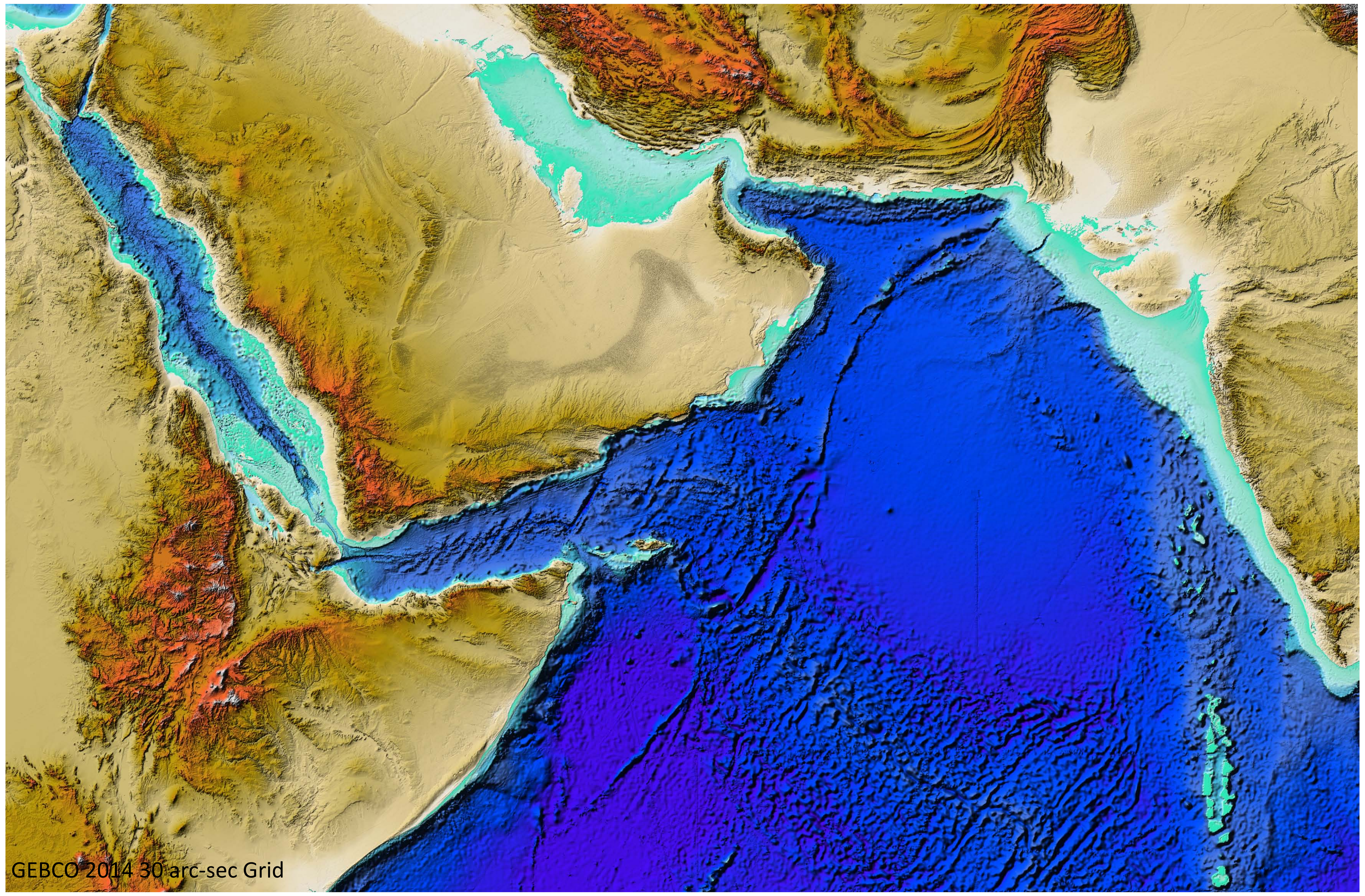
2) Able Software's **r2v** program (raster to vector by Dr. Ted Wu) is the best for digitizing contours and shorelines, as well as building up supporting contours in data-free areas.

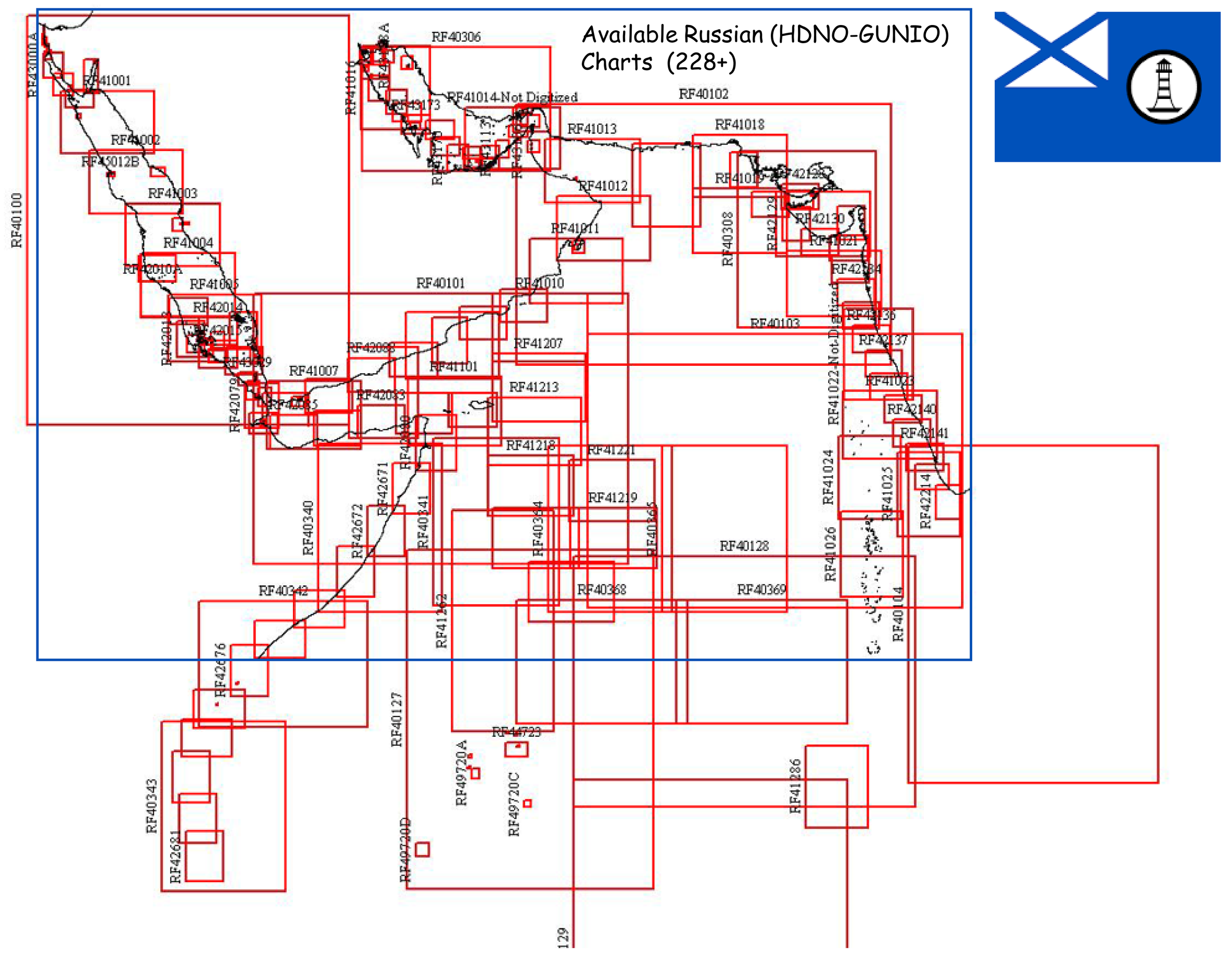
3) Golden Software's **Surfer** program is used for gridding soundings and digitized contours. The main interpolation method is Kriging, with grid resolutions at 50 and 100m.

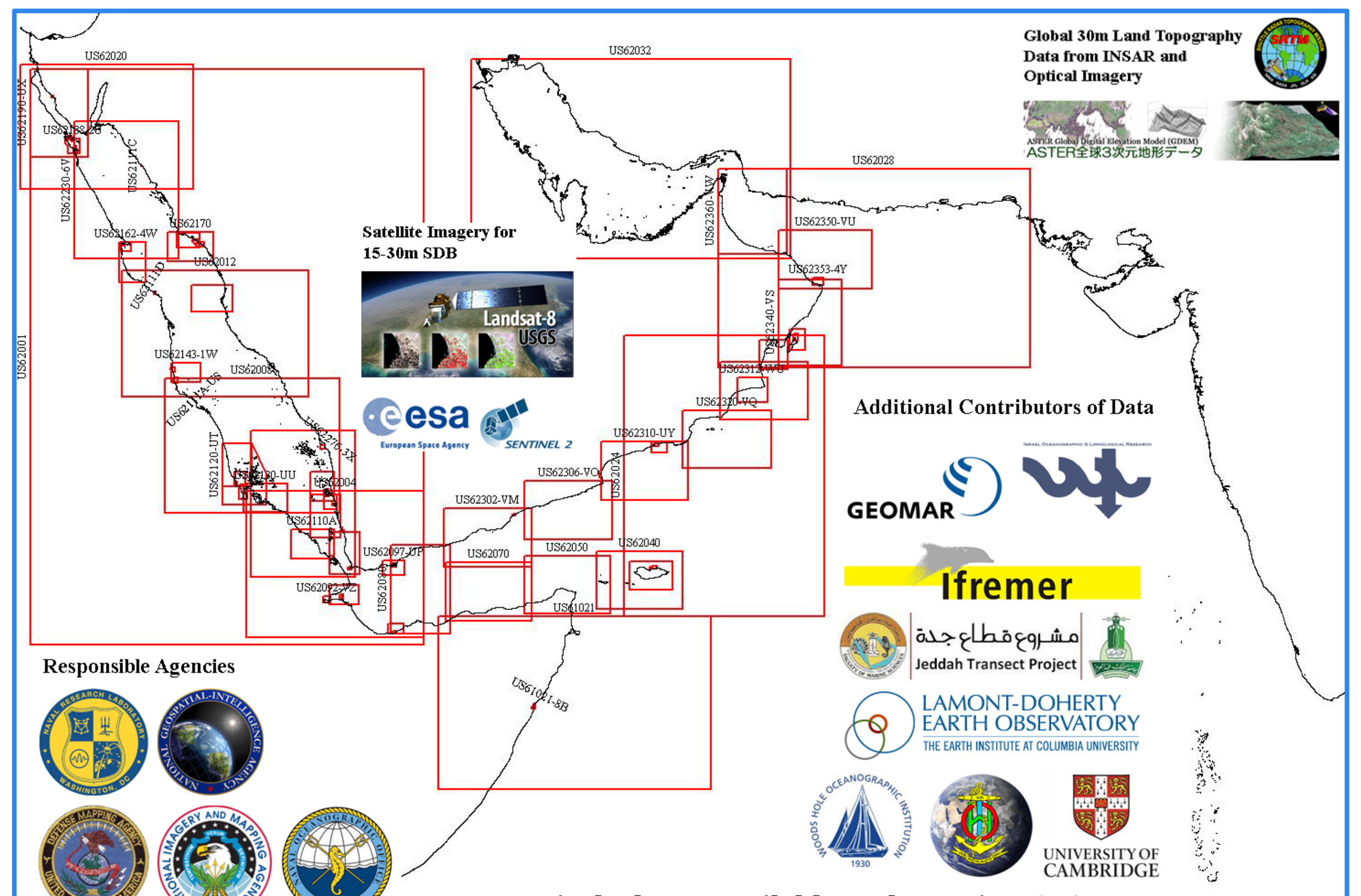
4) ESRI's **ArcGIS** is used to analyze multispectral satellite (primarily LANDSAT-8 OLI) using the usual SDB techniques with an additional semi-automatic approach developed by co-author S. Levenson.

Caviats

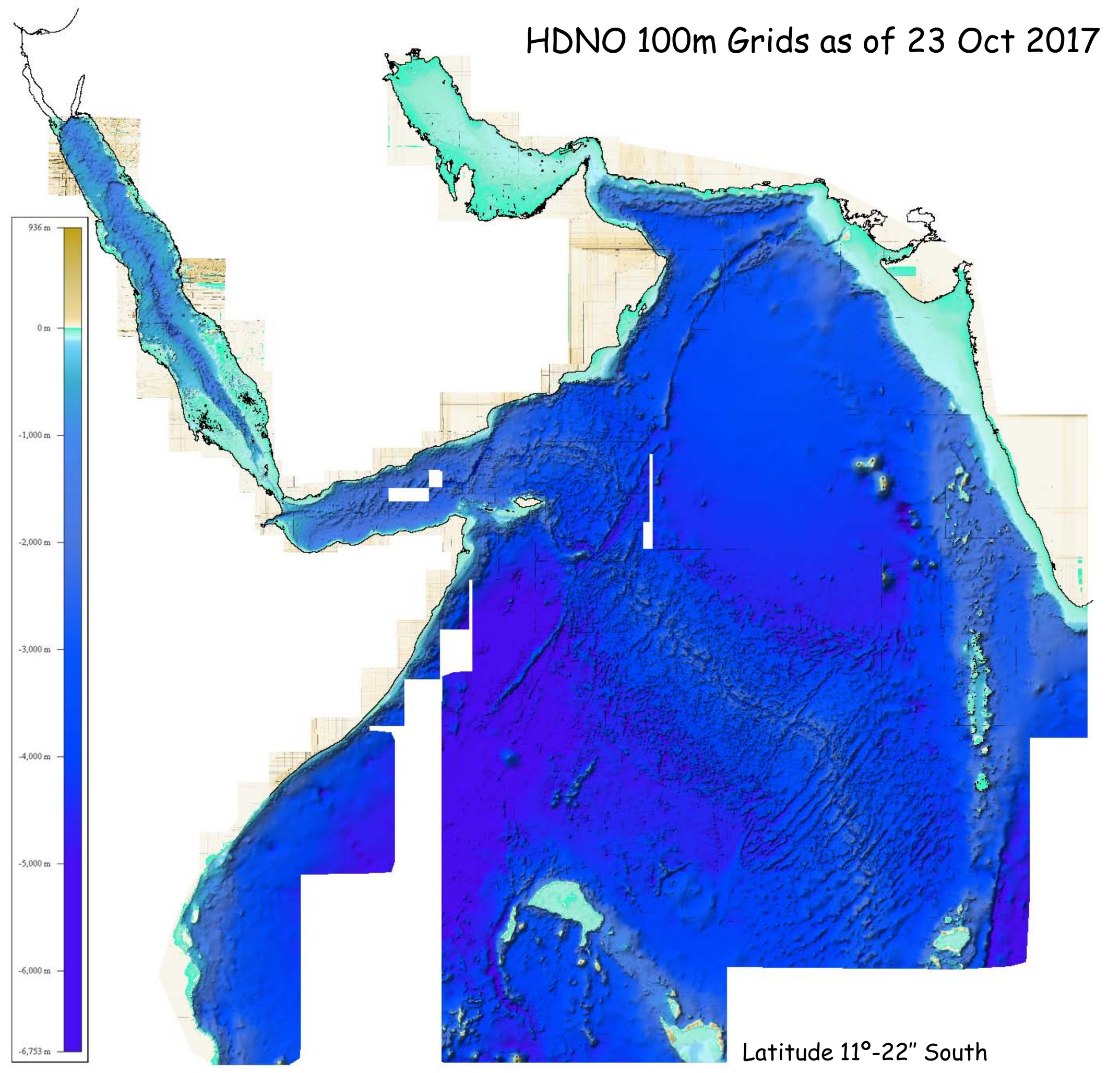
The attempt to compile a 100m grid sets a high standard. However a solid basis for future compilations will result from this database of over 550 scanned and georeferenced survey sheets and charts. Their hundreds of thousands of spot soundings, and digitized hydrographically-based contours imply the existence of far larger datasets, and help define the inshore bathymetry. The resulting grids will be hosted by GEBCO, along with approximately 1 Terabyte of the compilational materials. All contributors will be acknowledged on the GEBCO website, as well as on a planned hypsometrically colored shaded relief map of the Arabian Plate and its surroundings seas.

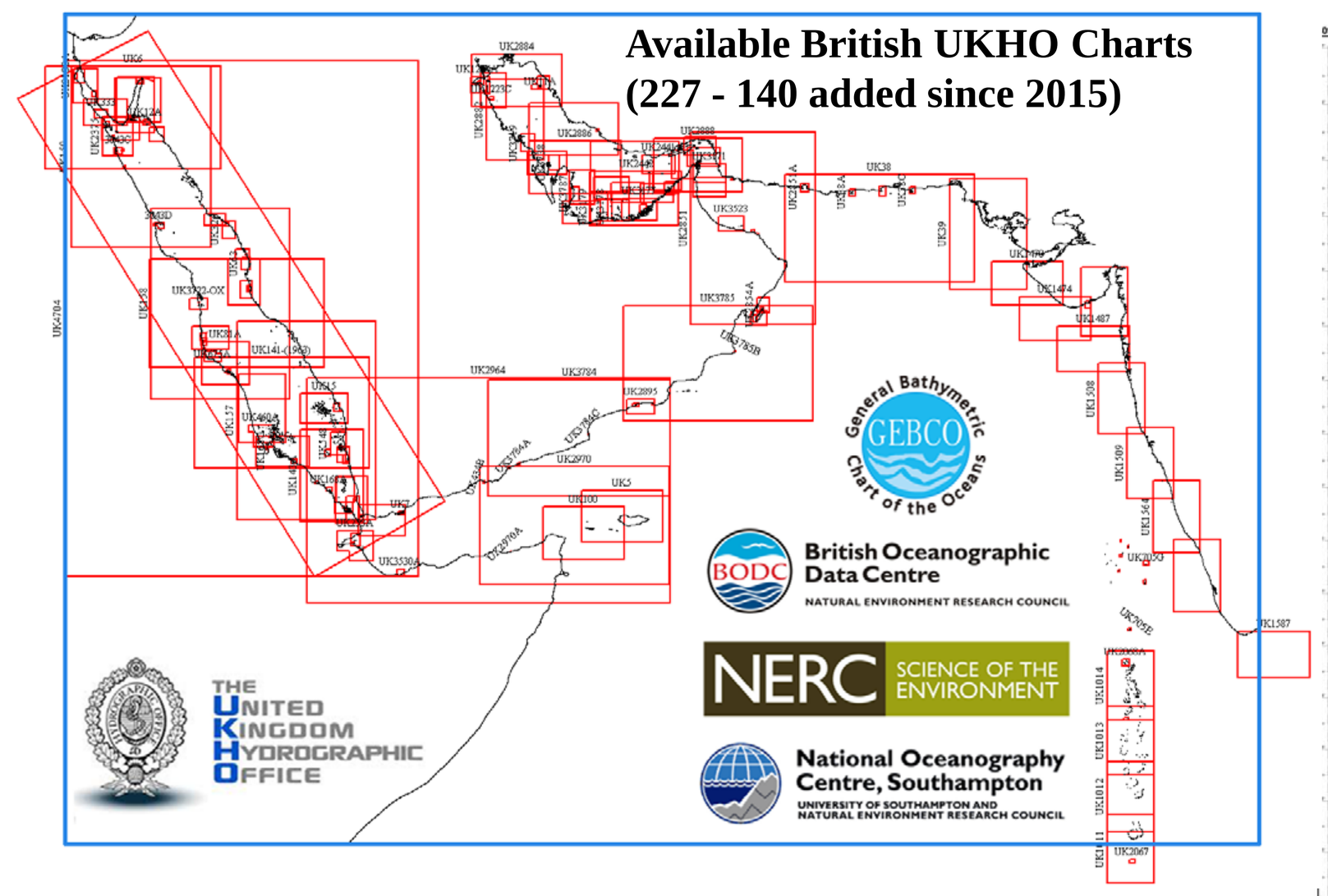


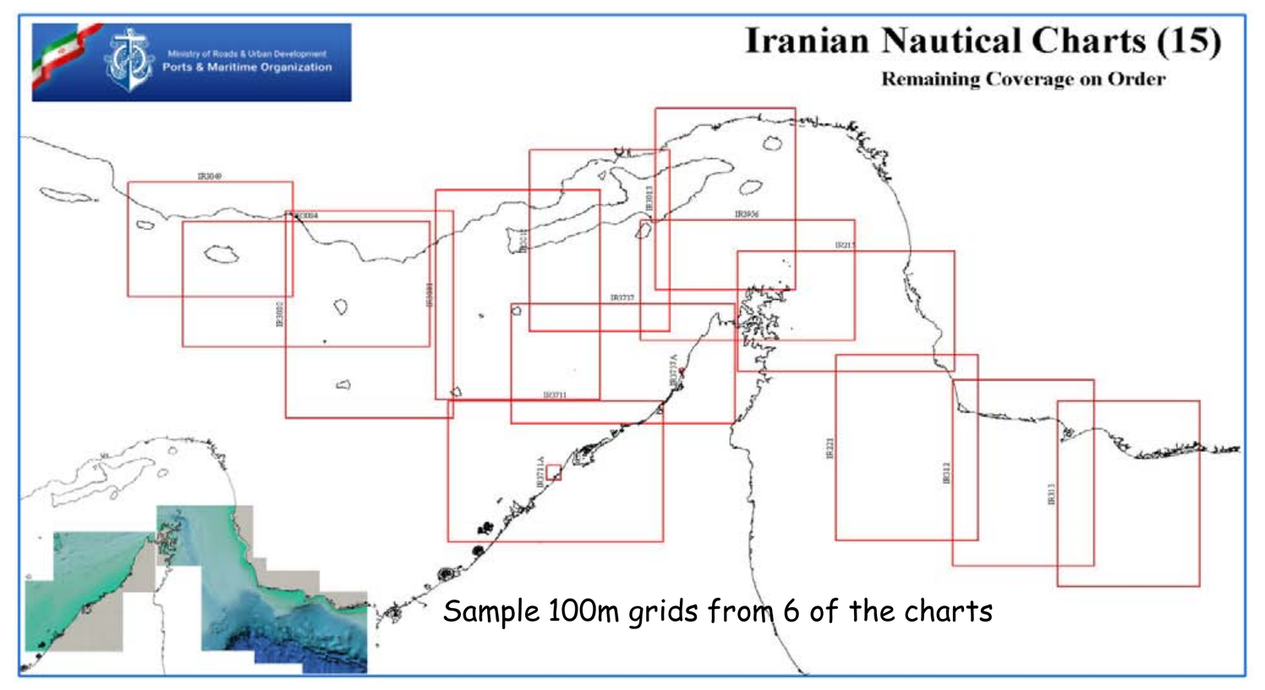


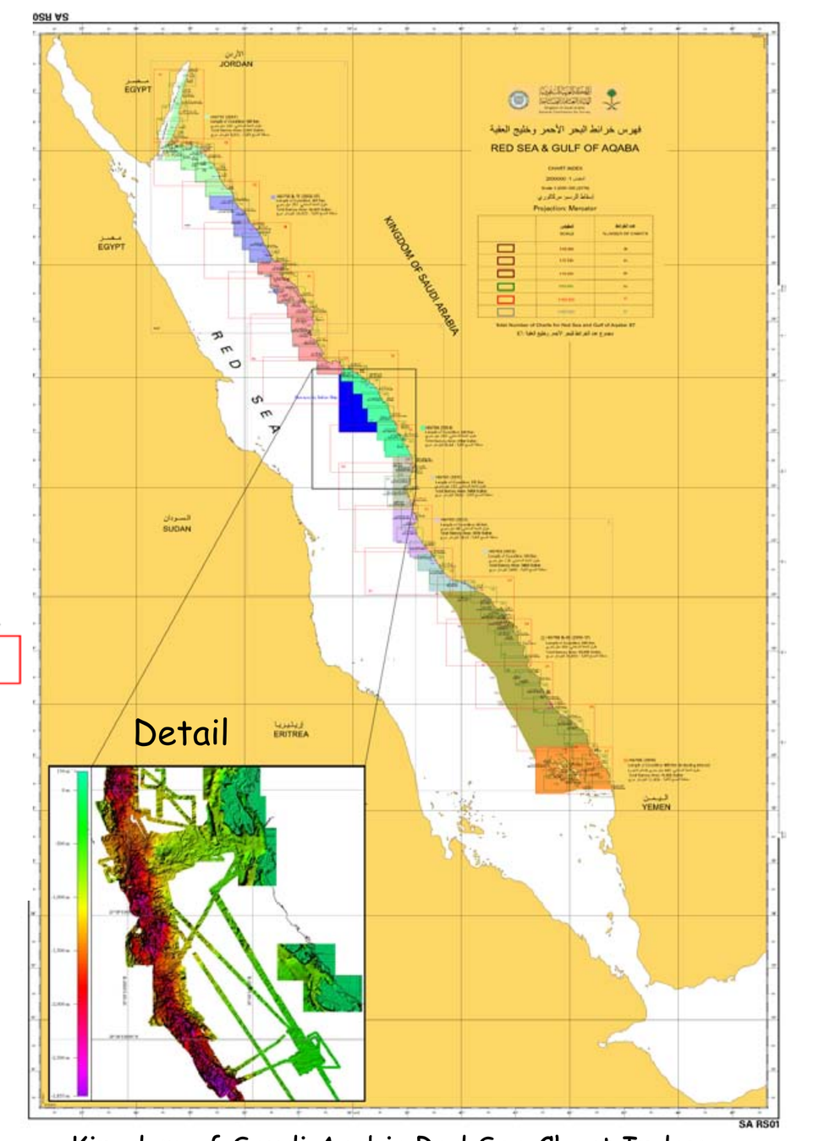


US Nautical Charts Available to the Project (88)

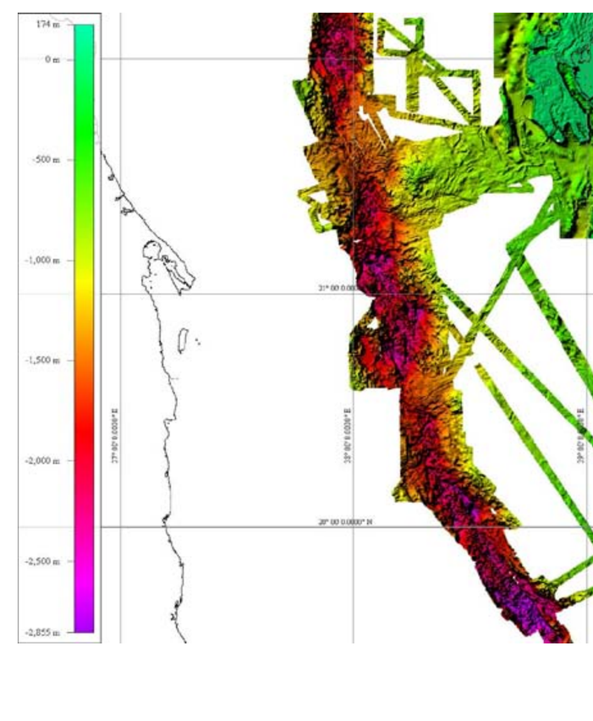




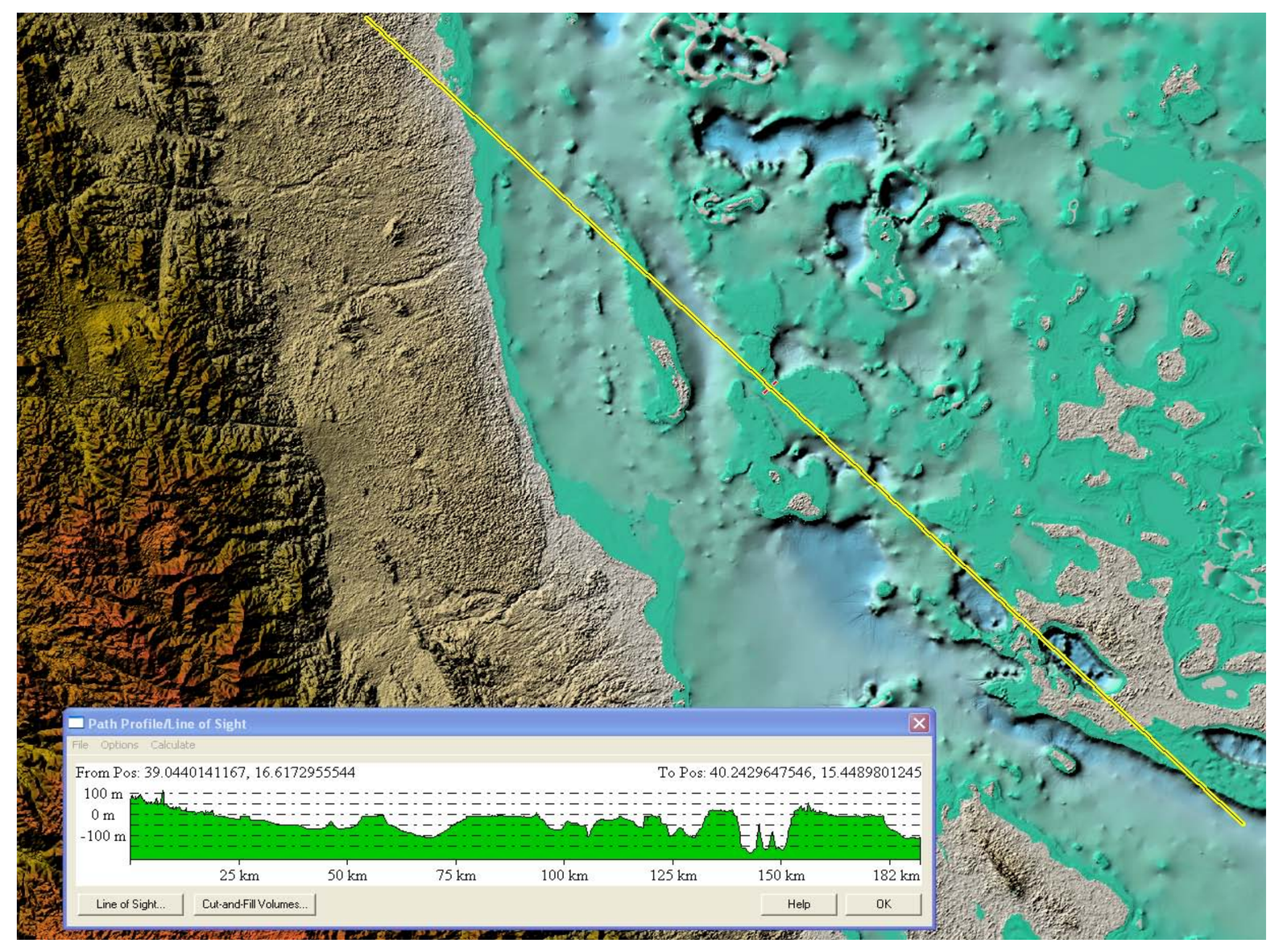


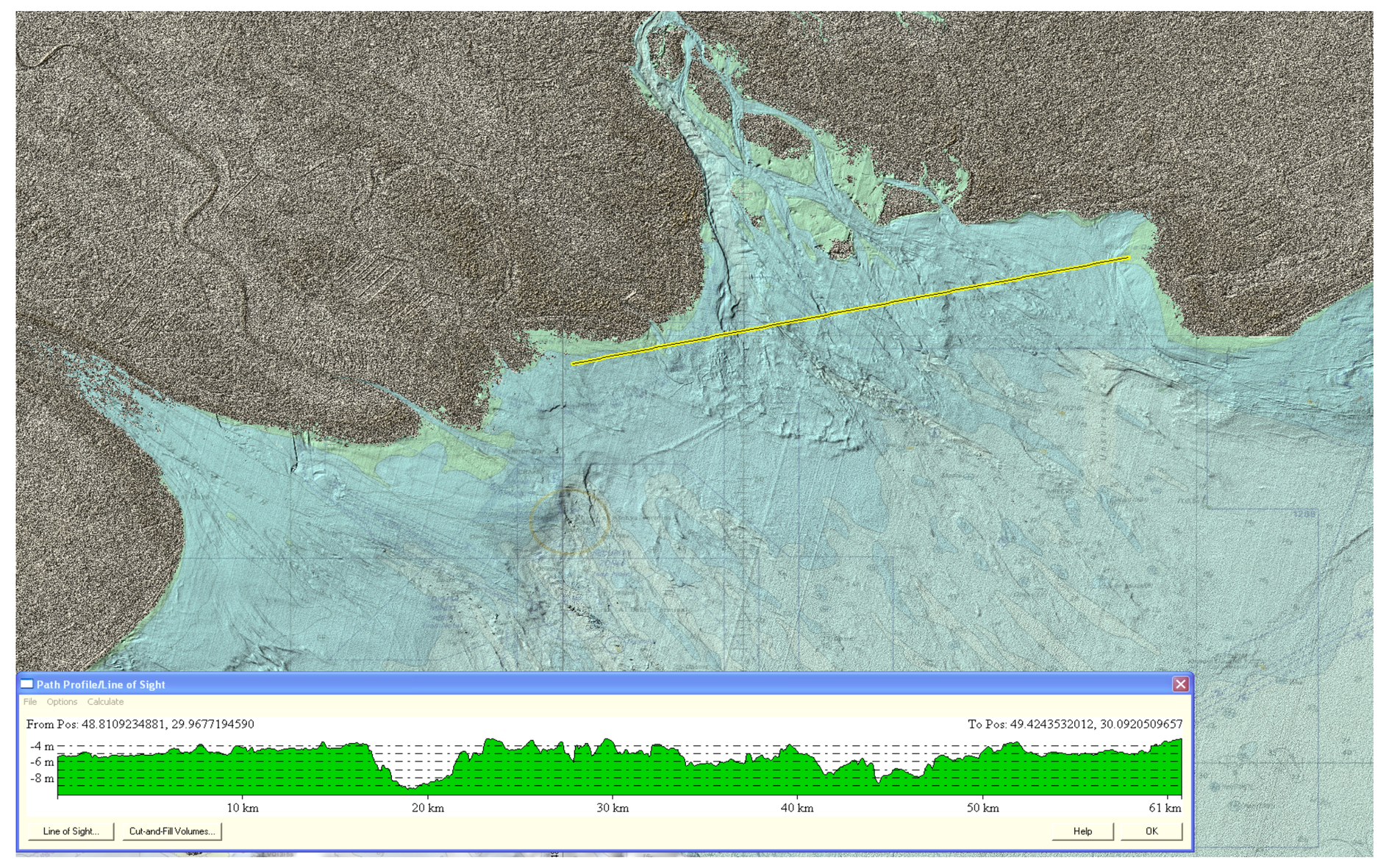


Kingdom of Saudi Arabia Red Sea Chart Index
Inset is enlarged below.



Blow-up of Augustin et al. (EPSL, 2014) multibeam compilation from Poseidon and Pelagia cruises off Jeddah, merged with 50m grids from five KAS charts inshore.





Examples of initial Submarine Derived Bathymetry (SDB)

Far left: Dahlak Archipelago off the coast of Eritrea in the SW Red Sea. ASTER2 30m topography, with LANDSAT-8 SDB superimposed on a 100m grid derived from soundings and contours of Russian Chart 42013.

Left: The NW end of the Persian Gulf where the Tigris and Euphrates rivers flow out of Iraq, with the bay west of Abadan in southern Iran to the right. The flat ASTER2 land topography is darkened by the vertical exaggeration of 54X.

The bathymetric profiles are along the yellow tracks in this Global Mapper image.

General Bathymetric Chart of the Oceans GEBCO

Forum for Future Ocean Floor Mapping

2017 GEBCO Symposium: MAP THE GAPS
Hydrographic Society of Korea (HSK)
Korea Hydrographic and Oceanographic Agency (KHOA)
Paradise Hotel, Busan, Republic of Korea, Nov 13-17, 2017

Under no circumstances should this compilation be used for navigation.