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From: Woodworth, Philip L. [plw@noc.ac.uk]
Sent: 17 March 2012 18:12
To: t.aarup@unesco.org; sshipman@ihb.mc; christopher.jones@ukho.gov.uk
Subject: elllipsoidal heights proposal
Attachments: ellipc_v2.doc

Dear Thorkild, Steve, Chris,

As promised, I attach an outline of the ellipsoidal heights project I mentioned in an earlier email which provides more details than I gave then. The collaboration of Nottingham Univ and DTU in Copenhagen, together with data banking at PSMSL, I think could make for a realistic project.

I think there will no problem with getting GLOSS and IAPSO endorsement of this, and I have talked to Mark Merrifield and Gary Mitchum already, but the support of the IHO Tides Cttee and also the UKHO would be very useful, even if it came with no funds!

There are 2 other UK universities who have an interest in this sort of thing. One is Newcastle (Prof. Phil Moore) and the other is UCL (Prof. Marek Ziebart) who worked with us on the VORF project some years ago. I will contact them next week. I am now working 3 days a week so not working too fast.

Any comments welcome as before.

Phil
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12 March 2012

Determining the Ellipsoidal Height of Mean Sea Level at the Coast (ELLIP-C)

Outline

There are now several models of the global Mean Sea Surface (MSS) available which describe the ellipsoidal (geocentric) height of the surface of the sea over a specified epoch. The MSS products are computed from satellite altimeter data, with the altimetric sea surface heights adjusted for air pressure effects. The models are considered accurate to a few cm in the deep ocean (Andersen and Knudsen, Journal of Geophysical Research, 2009). However, the models tend to be less accurate in shallow water and at the coast itself, where tidal and other corrections to the altimeter data are larger, where the wide spacing of ground tracks is larger than the variations in a complicated coastline with inlets or estuaries, and where the solid earth (geoid) component of the MSS can vary significantly spatially.

Coastal MSS information can also be obtained from tide gauges for which the ellipsoidal heights of their benchmarks have been determined by GPS. As well as being particularly interesting where coastlines have a complicated shape, these data are valuable at high latitudes where altimeter data are either absent or affected by ice. However, such tide gauge information has never been collected on a worldwide basis and included with the altimetry into a combined MSS. Our objective in this project is to provide a consistent database of ellipsoidal heights of coastal sea level. The database will be held alongside the Permanent Service for Mean Sea Level (PSMSL) and be available to any interested scientist interested in producing a combined MSS product with a target accuracy of several cm in both deep ocean and coastal areas.

Such a product would have considerable application in coastal studies where geocentric MSS information is now being applied in navigational charting and surveying (Iliffe et al., Marine Geodesy, 2007) and in studies of national datum differences (e.g. the Height System Unification with GOCE project of the European Space Agency). The ellipsoidal height data set has application also to the calibration of satellite altimeter information, by converting ‘relative’ calibrations (e.g. Mitchum, Marine Geodesy, 2000) to ‘absolute’ ones (e.g. Dong et al., Marine Geodesy, 2002). More generally, it will be to the benefit of all altimeter data users attempting to exploit the full potential of that technique in coastal waters (e.g. the European Space Agency COASTALT project).

Data Required

The data we require are Mean Sea Level (MSL) time series from a tide gauge over the same (or a comparable) period to that of the altimetric MSS. The tide gauge must have a Tide Gauge Benchmark (TGBM) to which all data from the station have been referred so that its information can be included in the Revised Local Reference (RLR) database of the PSMSL (www.psmsl.org). In addition, the TGBM, or another benchmark that has been connected to the TGBM by means of conventional levelling, must have had its ellipsoidal height determined by GPS.

In fact, many tide gauges now have continuous GPS (CGPS) stations located nearby, and the installation of CGPS at all stations with long records is an objective of the Global Sea Level Observing System (GLOSS) and of many national programmes (GLOSS Implementation Plan 2012). In these cases, time-averaged ellipsoidal heights can be determined from analysis of the continuous GPS record (e.g. as listed in the GPS sections of the GLOSS-associated SONEL databank, www.sonel.org). In GLOSS so far, such

data have been employed primarily for the determination of rates of vertical crustal movement within climate studies (Bouin and Wöppelmann, Geophysical Journal International, 2010) or for satellite altimeter calibration (Mitchum, Marine Geodesy, 2000). However, at some locations the essential levelling connections (ties) between the TGBM and the benchmark used at the GPS installation that one needs for the present project have never been made, in spite of the need for ties having been emphasised at many international sea level meetings. We hope that the present project will act as a spur to have such connections made.

At sites with no CGPS (either GLOSS or not), the ellipsoidal height information required by the present project could be provided by the simple means of several days of temporary (episodic) deployment of a GPS receiver at or near a TGBM. The same requirement for levelling ties applies in this case.

An additional means to densify the amount of ellipsoidal MSL information available is to make use of a 'corrector surface' to convert national datum heights to ellipsoidal ones (Iliffe et al., Survey Review, 2003; Marine Geodesy, 2007). Although this procedure can, in principle, make a considerably larger amount of data available, it presupposes the existence of national systems which might not exist in many countries. In these countries, the use of episodic GPS (EGPS) provides the only suitable alternative to the analysis of a CGPS record.

Where the ellipsoidal heights provided to the project have come from CGPS measurements at a tide gauge site, then they should be accompanied by the following metadata:

(a) name of the tide gauge (PSMSL station name and code).
(b) latitude and longitude of the CGPS station (and distance from the tide gauge).
(c) CGPS station 4 character name, survey marker number (and DOMES number).
(d) TGBM name or number to which the CGPS station is connected by levelling.
(e) number of days of CGPS data used for the computation of the ellipsoidal height of the CGPS station (from hh:mm to hh:mm UTC, from YYYY-MM-DD UTC to YYYY-MM-DD).
(f) software and processing strategy used for the computation of the ellipsoidal height of the CGPS station, i.e. double-difference or PPP, global or regional network.
(g) reference frame in which the ellipsoidal height of the CGPS station is defined (ideally this should be ITRF2008), reference epoch to which the ellipsoidal height of the CGPS station is referred, and whether this is based on an average over the period of CGPS data used or based on an estimate of coordinates at a reference epoch plus velocities (and for future use the coordinates and velocities should be given).
(h) ellipsoidal height of the CGPS station.
(i) levelled height-difference between the CGPS station and the TGBM (and as a verification check the name or number of the CGPS station and the name or number of the TGBM should be given).
(j) ellipsoidal height of the TGBM.

For example, for Newlyn tide gauge in the UK, the metadata would be as follows:

(a) Newlyn (NEWLYN, 170161).
(b) N 50 06 10.907850, W 005 32 34.034086 (10m from the tide gauge).
(c) NEWL, SW46762856 (13273M103).
(d) SW46762855.
(e) 14 days (from 00:00 to 23:59 UTC, from 2009-09-27 to 2009-10-10).
(f) Bernese Software V5.0, double-difference, regional network.

(g) ITRF2005 at epoch 2009.756, as an average over the period of CGPS data used.
(h) 64.5240m.
(i) +6.7755m, from TGBM SW46762855 to CGPS station SW46762856.
(j) 57.7485m.

Where the ellipsoidal heights provided to the project have come from EGPS measurements at a tide gauge site, then they should be accompanied by the following metadata:

(a) name of the tide gauge (PSMSL station name and code).
(b) latitude and longitude of the EGPS station (and distance from the tide gauge).
(c) EGPS station 4 character name, survey marker number (and DOMES number).
(d) TGBM name or number to which the EGPS station is connected by levelling.
(e) number of days of CGPS data used for the computation of the ellipsoidal height of the CGPS station (from hh:mm UTC to hh:mm UTC, from YYYY-MM-DD UTC to YYYY-MM-DD).
(f) software and processing strategy used for the computation of the ellipsoidal height of the CGPS station, i.e. double-difference or PPP, global or regional network.
(g) reference frame in which the ellipsoidal height of the CGPS station is defined (ideally this should be ITRF2008), reference epoch to which the ellipsoidal height of the CGPS station is referred, and whether this is based on an average over the period of CGPS data used or based on an estimate of coordinates at a reference epoch plus velocities (and for future use the coordinates and velocities should be given).
(h) ellipsoidal height of the EGPS station.
(i) levelled height-difference between the EGPS station and the TGBM (and as a verification check the name or number of the EGPS station and the name or number of the TGBM should be given).
(j) ellipsoidal height of the TGBM.

For example, for Newlyn tide gauge in the UK, the metadata would be as follows:
(a) Newlyn (NEWLYN, 170161).
(b) N 50 06 26.84416 , W 005 32 53.51118 (625m from the tide gauge).
(c) NEW1, SW46402906 (N/A).
(d) SW46762855.
(e) 25 days (from 10:30 to 18:30 UTC, from 1991-09-09 to 1991-09-13; from 07:30 to 17:30 UTC, from 1992-08-03 to 1992-08-07; from 07:45 to 17:45 UTC, from 1993-08-09 to 1993-08-13; from 07:30 to 17:30 UTC, from 1995-09-04 to 1995-09-08; from 08:30 to 18:30 UTC, from 1995-11-27 to 1995-12-01).
(f) GPS Analysis Software, double-difference, regional network.
(g) ITRF1997 at epoch 1994.21, as an average over the period of EGPS data used.
(h) 58.9384m.
(i) +1.1925m, from TGBM SW46762855 to EGPS station SW46402906.
(j) 57.7459m.

Where the ellipsoidal heights provided to the project have come from conversion of national datum heights using a 'corrector surface', then they should be accompanied by the following metadata:

(a) name of the tide gauge (PSMSL station name and code).
(b)
(c)

(d) TGBM name or number.
(e)
(f) name of corrector surface used (with a full documentation of the procedures used).
(g) for the corrector surface, the reference frame in which the ellipsoidal heights of the GPS stations was defined (ideally this should be ITRF2008), reference epoch to which the ellipsoidal heights of the GPS station was referred, and whether this was based on an average over the period of GPS data used or based on an estimate of coordinates at a reference epoch plus velocities (and for future use the coordinates and velocities should be given).
(h) conventional height of the TGBM.
(i) corrector surface value.
(j) ellipsoidal height of the TGBM.

For example, for Newlyn tide gauge in the UK, the metadata would be as follows:

(a) Newlyn (NEWLYN, 170161).
(b)
(c)
(d) SW46762855.
(e)
(f) OSGM02 (see Iliffe et al., 2003).
(g) ITRF96 at epoch 1999.0, as an average over the period of EGPS data used.
(h) 4.7512m.
(i) 53.014m
(j) 57.7652m.

Initial Participants

Intergovernmental Oceanographic Commission GLOSS Programme
Permanent Service for Mean Sea Level
National Oceanography Centre Liverpool and Southampton
University of Hawaii Sea Level Centre
University of La Rochelle (for SONEL)
Technical University of Denmark

International Hydrographic Organisation Tides and Water Level Working Group (TBC)
University of Nottingham
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