Thailand-EC Cooperation

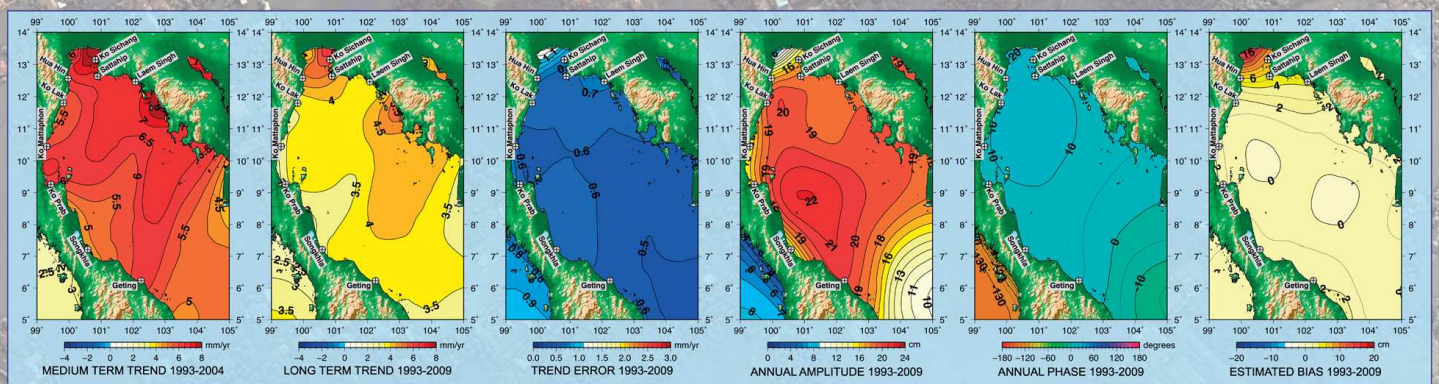
GEO2TECDI-SONG

การปกป้องชายฝั่ง

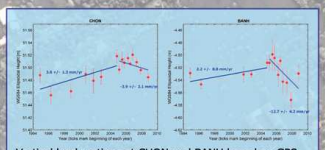
protecting the coast

Sea level rise and subsidence in the delta areas of the Gulf of Thailand

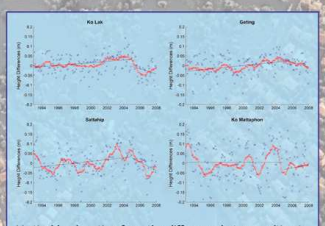
Summary In the Thailand-EC GEO2TECDI projects we investigate the vertical land motion in Thailand and sea level change in the Gulf of Thailand. Focus is on Bangkok which 1) is situated in a river delta and average height is close to sea level, 2) is subsiding due to ground water extraction, 3) is experiencing post-seismic motion due to nearby mega-thrust Earthquakes, and 4) suffers from rising sea levels due to global climate change. With excessive rainfall this poses a serious threat to Thai society and economy: very real in 2011.
Before mitigation methods can be devised all contributing effects have to be charted, separated, qualified and quantified by using GPS, InSAR and altimetry, and combining results with observations from tide gauges and levelling. Adding GPS based vertical land motion to the tide gauge sea level registration reveals the absolute sea level change at a number of tide gauge stations surrounding the Gulf of Thailand (GoT), which is confirmed by altimetry. In the GoT we find an average absolute rise of ± 3.5 mm/yr ± 0.7, but near estuaries of the Chao Praya River (Bangkok), the Kah Bpow River (Koh Kong) and the Mekong delta (Ho Chi Min City), this mounts to 4 to 5mm/yr, faster than the global average. It is even worse when accounting for the tectonic subsidence that resulted from the 2004 9.2Mw Sumatra/Andaman earthquake; from 2005 onwards we find downfall in the order of 10mm/yr resulting in relative sea level rise of >10mm/yr over the last 5 years. Radarsat InSAR analyses confirm this and show subsidence rates up to 25mm/yr at many places along coastal Bangkok.



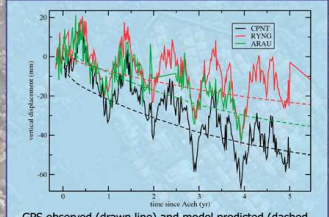
Geographical distribution of sea level trend from 1993–2004 (1st panel on the left) and 1993–2009 (panel 2) multi-satellite altimetry. A simultaneous fit of linear trend, annual cycle (panel 4/5), semi- annual cycle (not shown: very small), and a bias (panel 6), subjected to IRLS was applied to monthly-averaged altimeter meshes (details to be found in the paper). In a direct comparison with tide gauge and GPS data we have to take into account the discontinuity in land motion due to the 2004 Sumatra Earthquake. Though the sea level trend over the medium length period seems significantly affected by the lunar nodal tide effect (18.6 year cycle), the effect in tide gauge data is the same and cancels out when differenced.



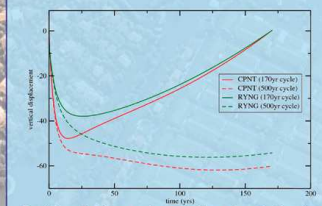
Vertical land motions at CHON and BANH based on GPS campaign data. Heights have been corrected for seasonal variations estimated from nearby CGPS data. We see a combination of interseismicity and GIA uplift at both locations before 2005 and post-seismicity after the Sumatra Earthquake at the end of 2004. The difference in vertical motion regimes before and after the quake are striking and the post-seismicity clearly adds to the flooding threat.



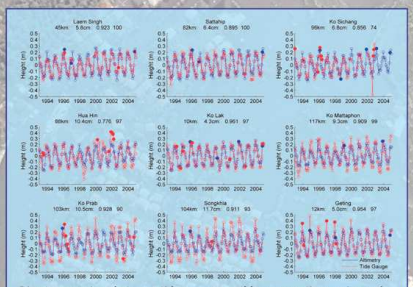
Vertical land motion from the difference between altimetry and tide gauge data: blue crosses the monthly averages and the red ones 12-month moving average filtered. A linear trend has been fitted. Ko Mattaphon seems to behave different from the other stations but is also furthest situated from a TOPEX-class track.



GPS observed (drawn line) and model predicted (dashed line) vertical subsidence (post-seismicity) at CGPS stations RYNG (near CHON), CPNT (near BANH) and ARAU (Andaman Sea, near Malaysia). The subsidence rate depends mainly on the rheology of the asthenosphere. Over the last 5 year we see averages of about 10mm/yr.



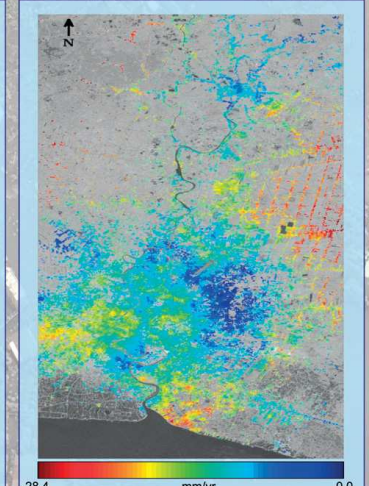
Predictions for future vertical subsidence for seismic cycles of 170 and 500 years by modelling the visco-elastic relaxation in the asthenosphere. Apparently, the post-seismic subsidence is temporal and will not exceed 50-60mm.



Direct comparison between tide gauge monthly-average time series and those from altimetry from 1993-2004 (prior to 2004 Sumatra Earthquake). An arbitrary bias is removed. Solid circles have final weight < 0.5 and crosses get zero weight (outliers). The given numbers give distance to TOPEX-class track, RMSE, correlation, and percentage valid observations.

Tidal Station	Altimetry 1993-2009	Altimetry 1993-2004	Tide gauge 1993-2004	VLM (alt-tg) 1993-2004	VLM (gps) (1994-2004)
Laem Singh	3.6 ± 0.7	6.6 ± 1.2	10.5 ± 1.1	-3.9 ± 1.6	N/A
Sattahip	4.8 ± 0.7	6.9 ± 1.1	3.2 ± 1.6	3.7 ± 1.9	3.8 ± 1.3[a]
Ko Sichang	5.8 ± 0.7	7.8 ± 1.3	7.6 ± 2.0	0.2 ± 2.4	3.8 ± 1.3[a]
Hua Hin	4.8 ± 0.8	6.4 ± 1.2	4.8 ± 2.2	1.6 ± 2.5	N/A
Ko Lak	3.6 ± 0.7	5.5 ± 1.0	1.9 ± 1.1	3.6 ± 1.5	N/A
Ko Mattaphon	3.2 ± 0.7	5.8 ± 0.9	5.8 ± 1.9	0.0 ± 2.1	2.2 ± 0.8[b]
Ko Prab	3.3 ± 0.6	6.0 ± 1.0	9.9 ± 1.9	-3.9 ± 2.1	N/A
Songkhla	3.3 ± 0.6	4.6 ± 1.0	13.0 ± 2.4	-8.4 ± 2.6	N/A
Geting	3.9 ± 0.6	6.1 ± 0.8	2.6 ± 1.2	3.5 ± 1.4	5.1 ± 1.0

Altimeter based sea level trends in the GoT at tide gauge stations and the tide gauge trends over the same period. In column 5 we subtract the tide solutions from the altimeter to derive the local vertical land motion (VLM), and we compare this with VLM based on GPS (rightmost column).



Interferometric SAR result, based on 20 Radarsat-1 images (2005-2011) using StaMPS, shows land subsidence rates at 15-25mm/yr in the greater Bangkok area. This resembles rates found in Venice last century and is due to water extraction and compaction. It clearly poses the largest threat.

website: www.sv.eng.chula.ac.th/index.php/GEO2TECDI

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