Poroelastic responses to terrestrial water loading in the Bengal Aquifer System provide high-resolution, in-situ measurements for comparison with GRACE

Anwar ZAHID

William BURGESS

Mohammad SHAMSUDDUHA

Richard TAYLOR

K. Matin AHMED

Thanks to: Bangladesh Climate Change Trust

N°abstract 1912

The Bengal Basin

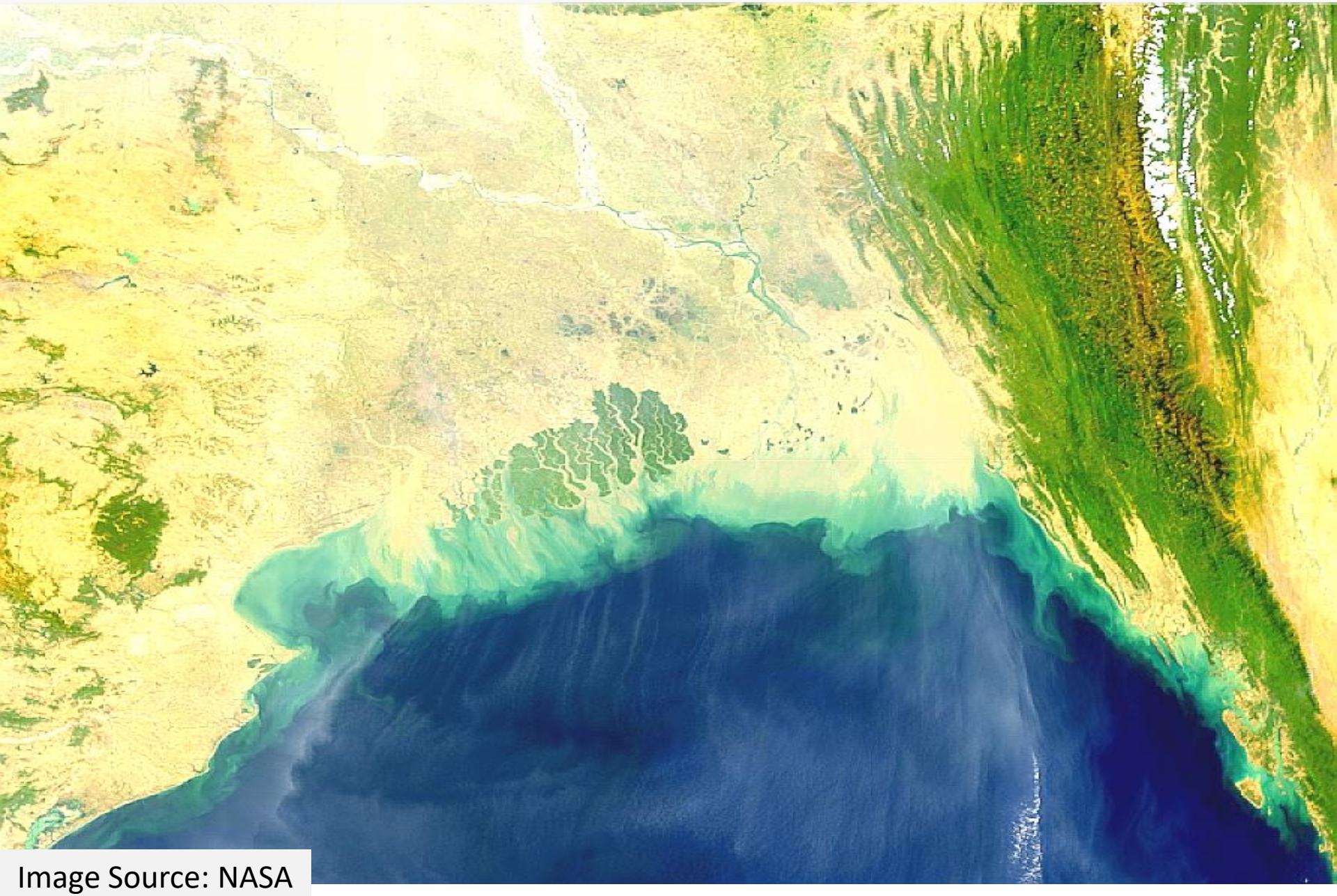
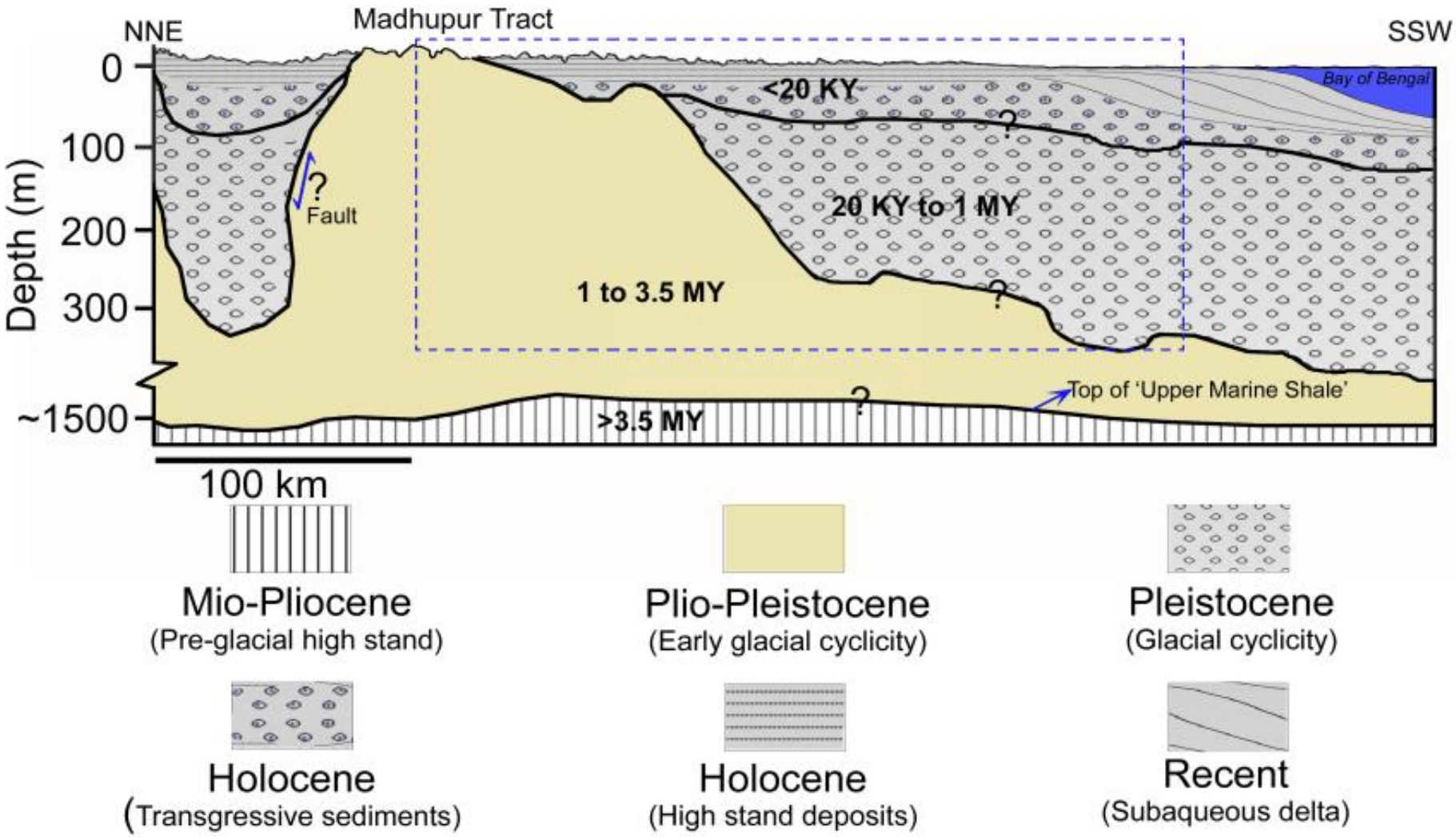


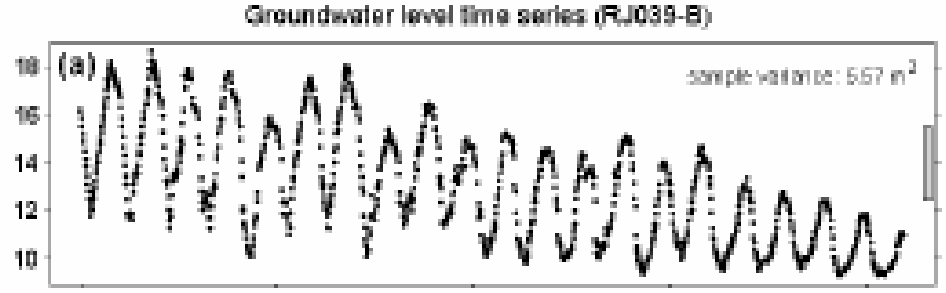
Image Source: NASA

The Bengal Aquifer System: fluvio-deltaic sand, silt and clay

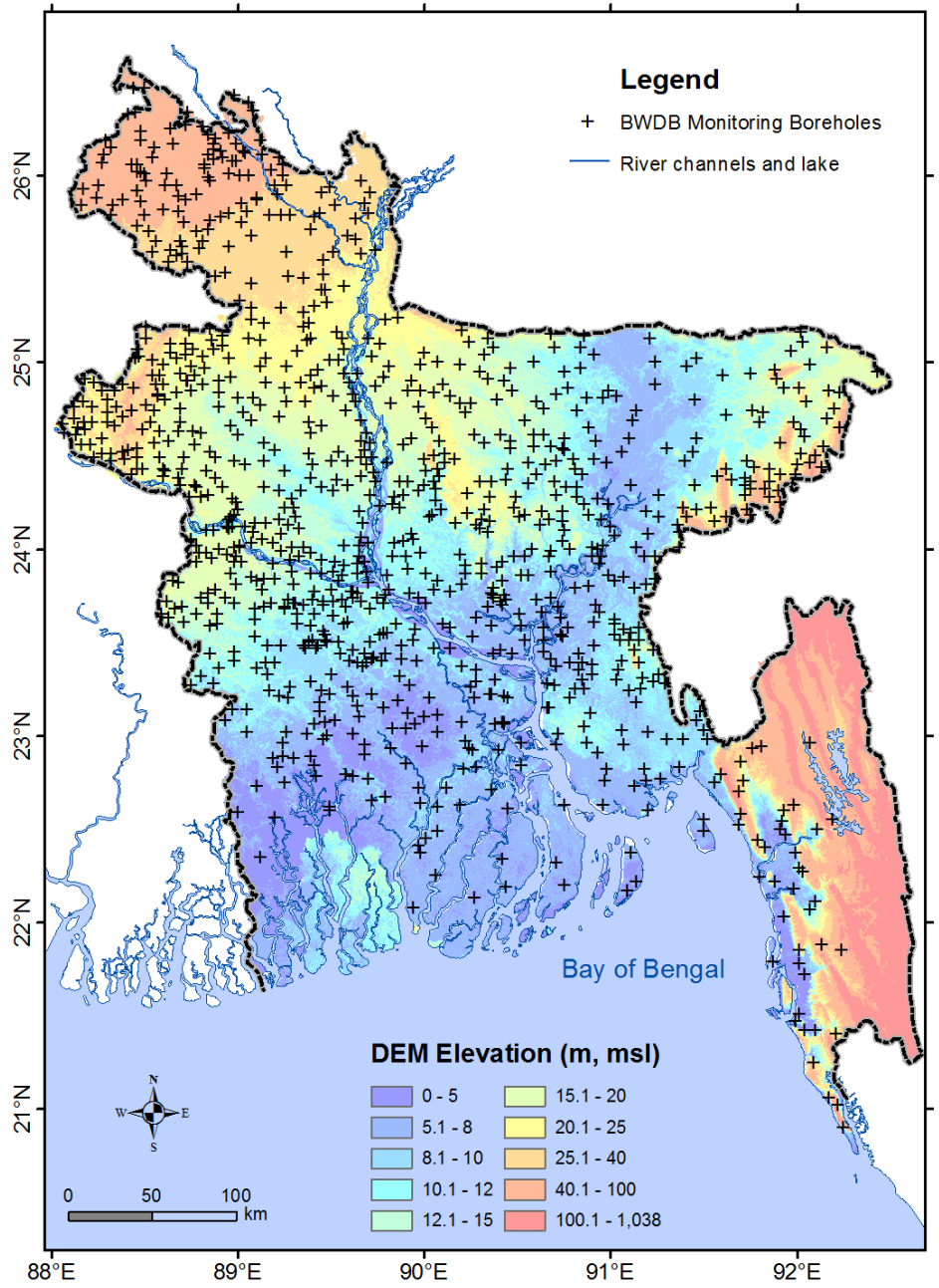


Burgess et al 2010 *Nature Geoscience* 3, 83-87

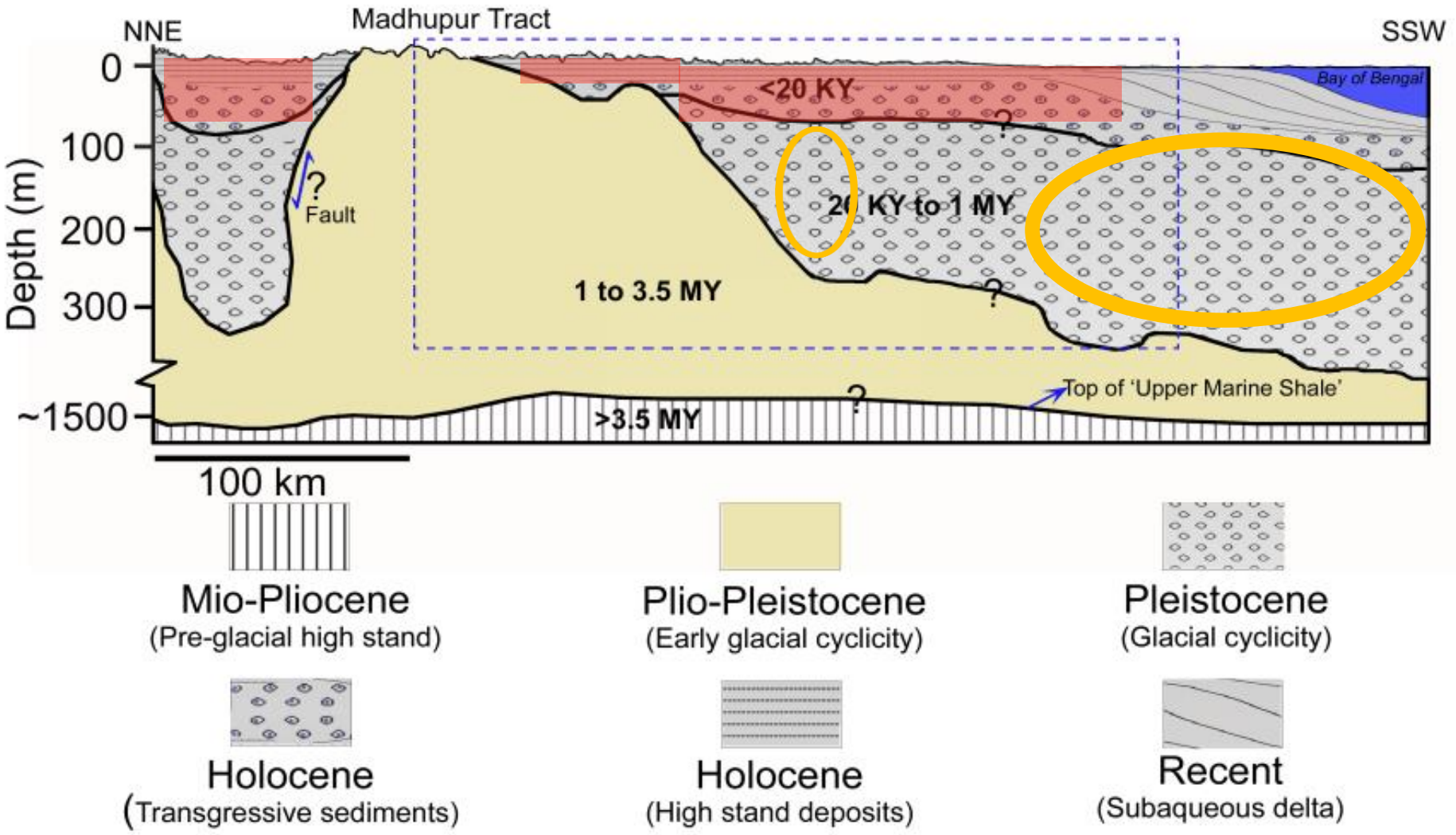
BWDB national 'water table' monitoring network



eg. in Shamsudduha et al. *HESS* 2009

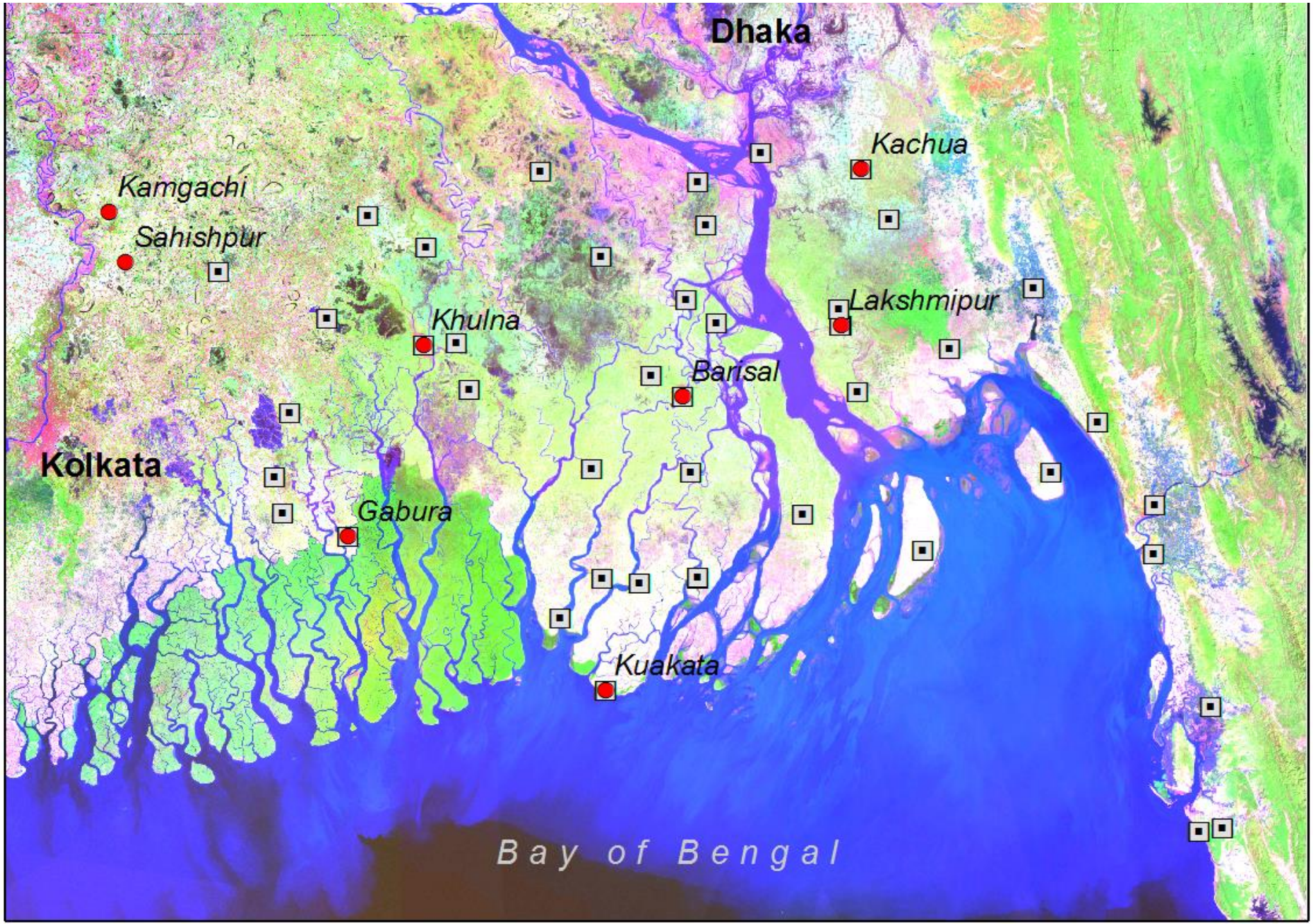


BAS – deep groundwater conditions are uncertain



Burgess et al. 2010

BAS 'nested' piezometers – *ca* 100, 200, 300 m depth



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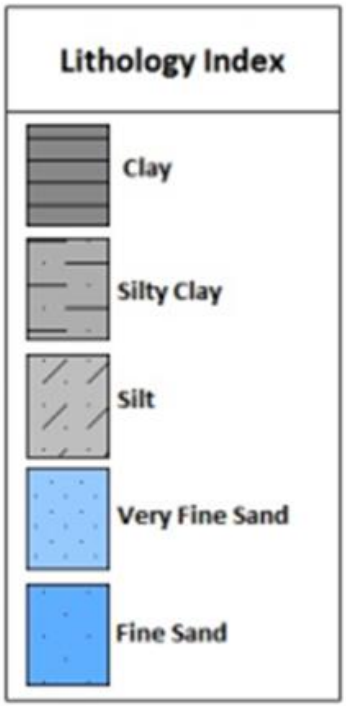
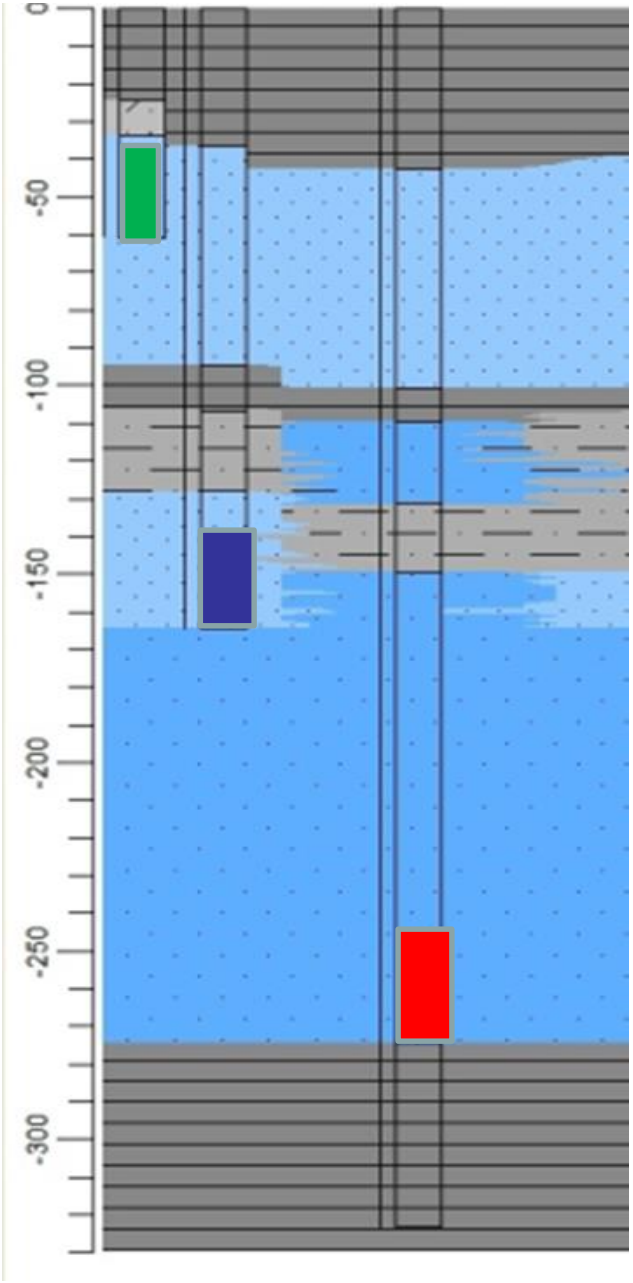
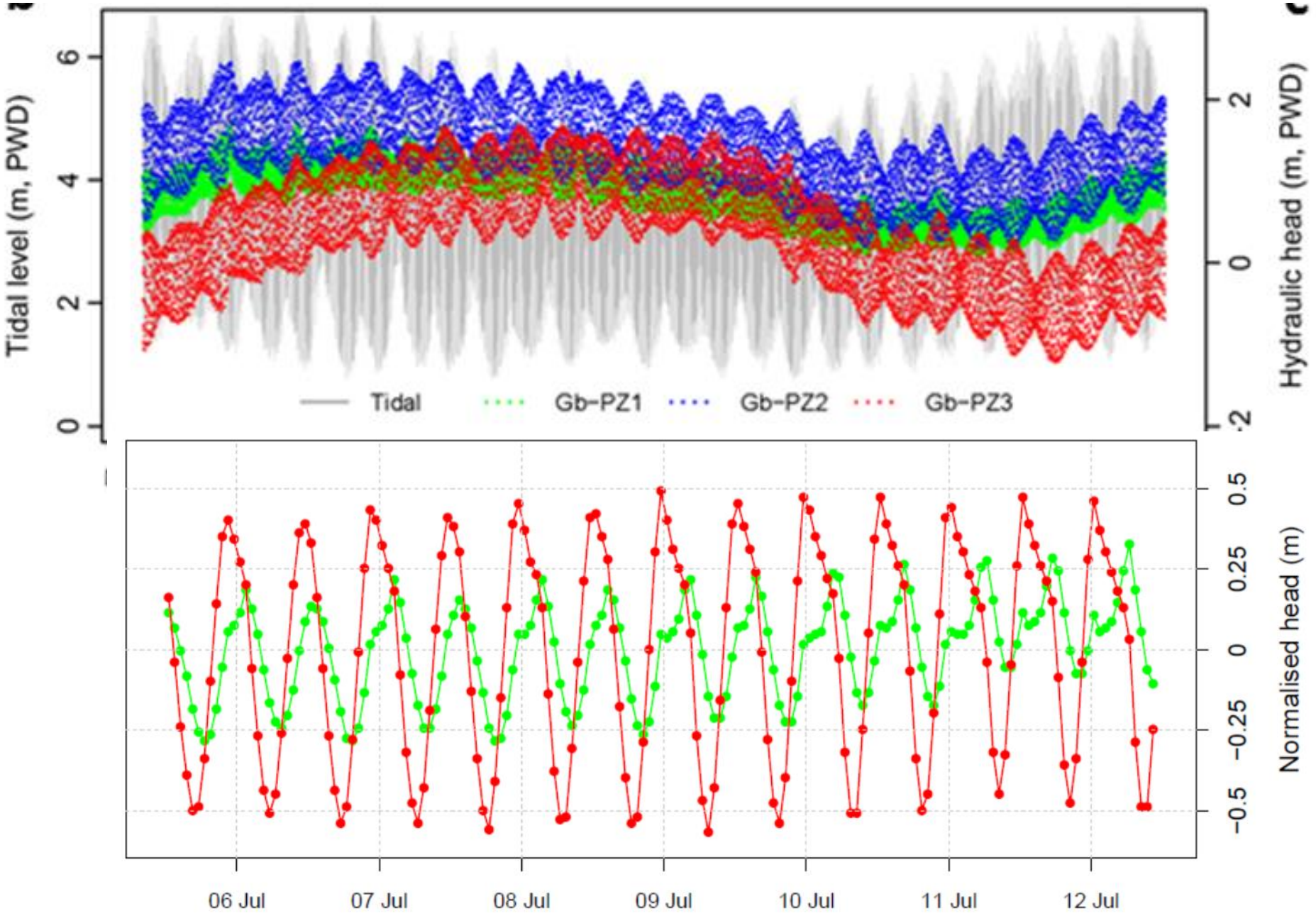
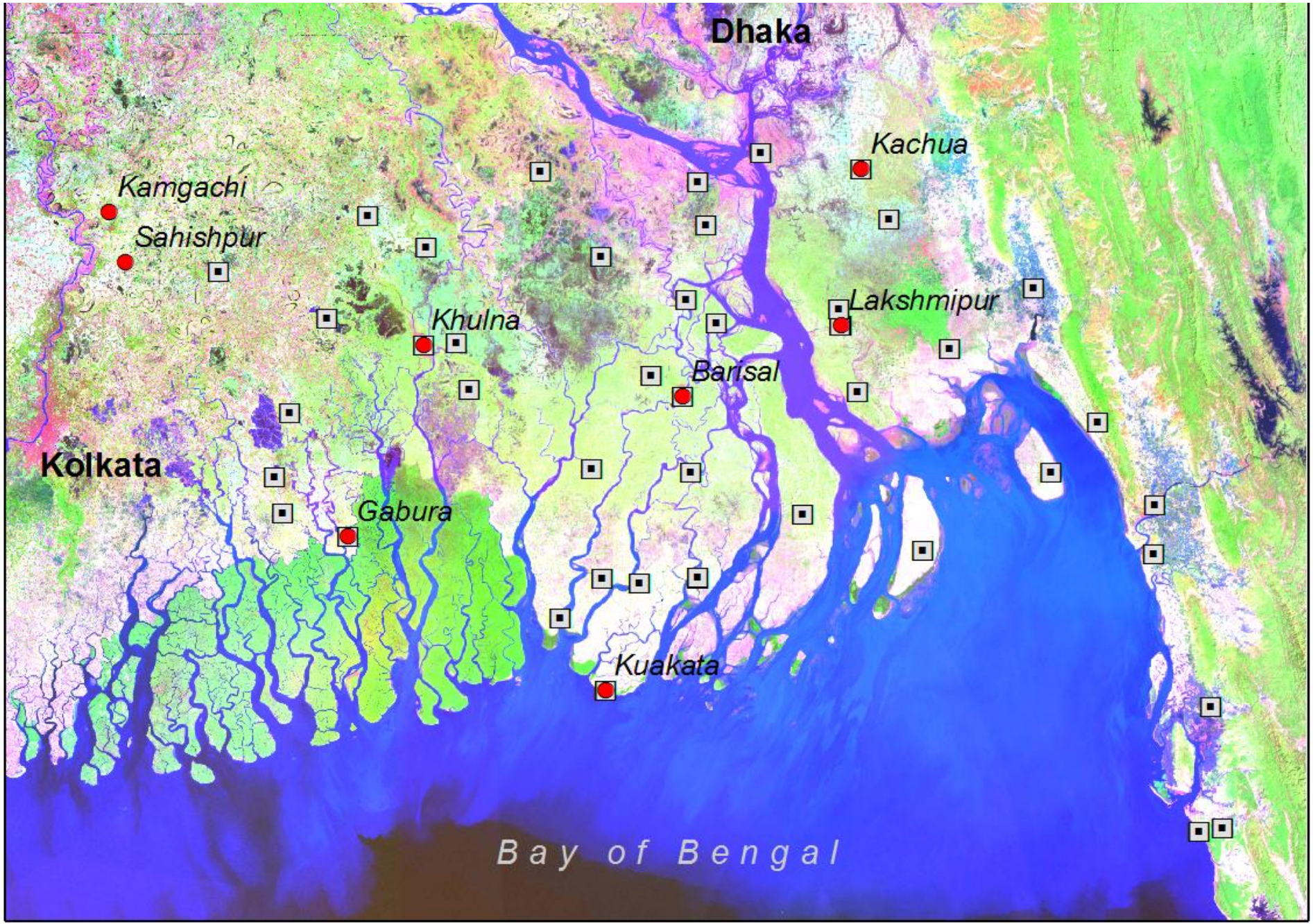




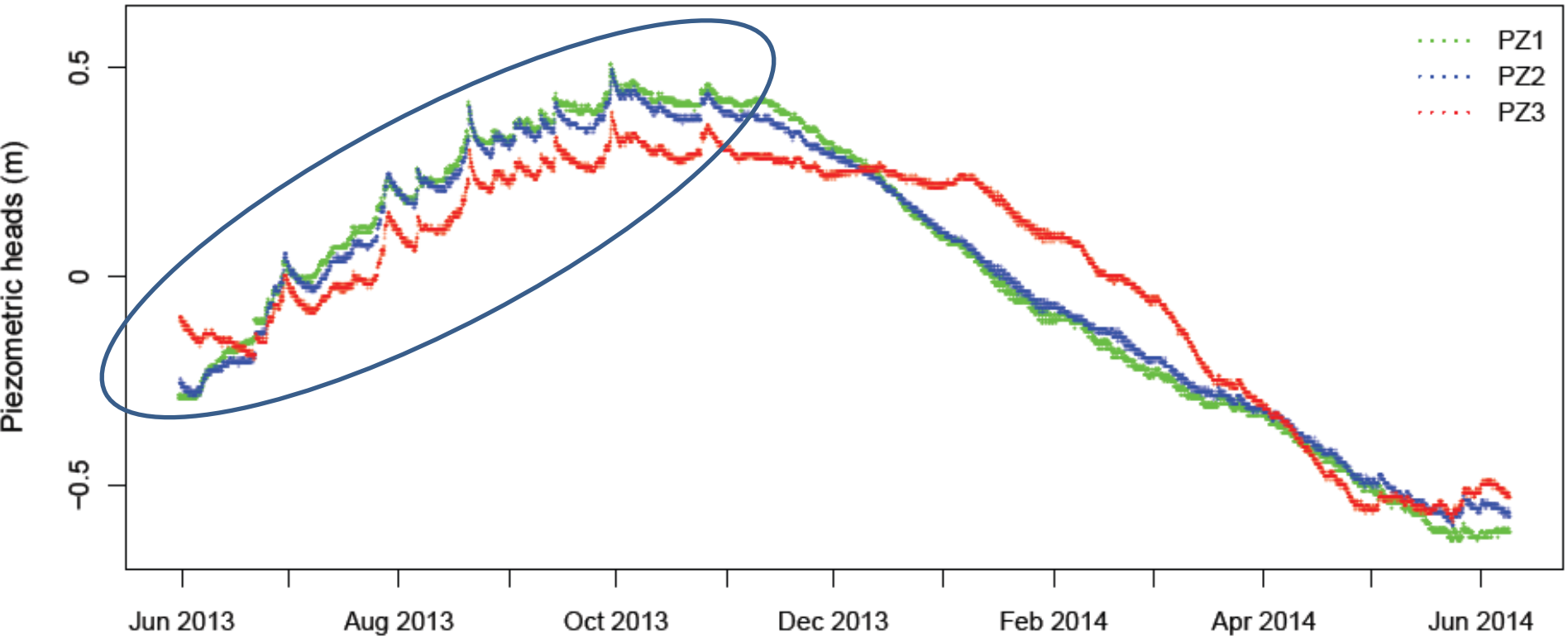
BAS heads respond to mechanical loading by tides



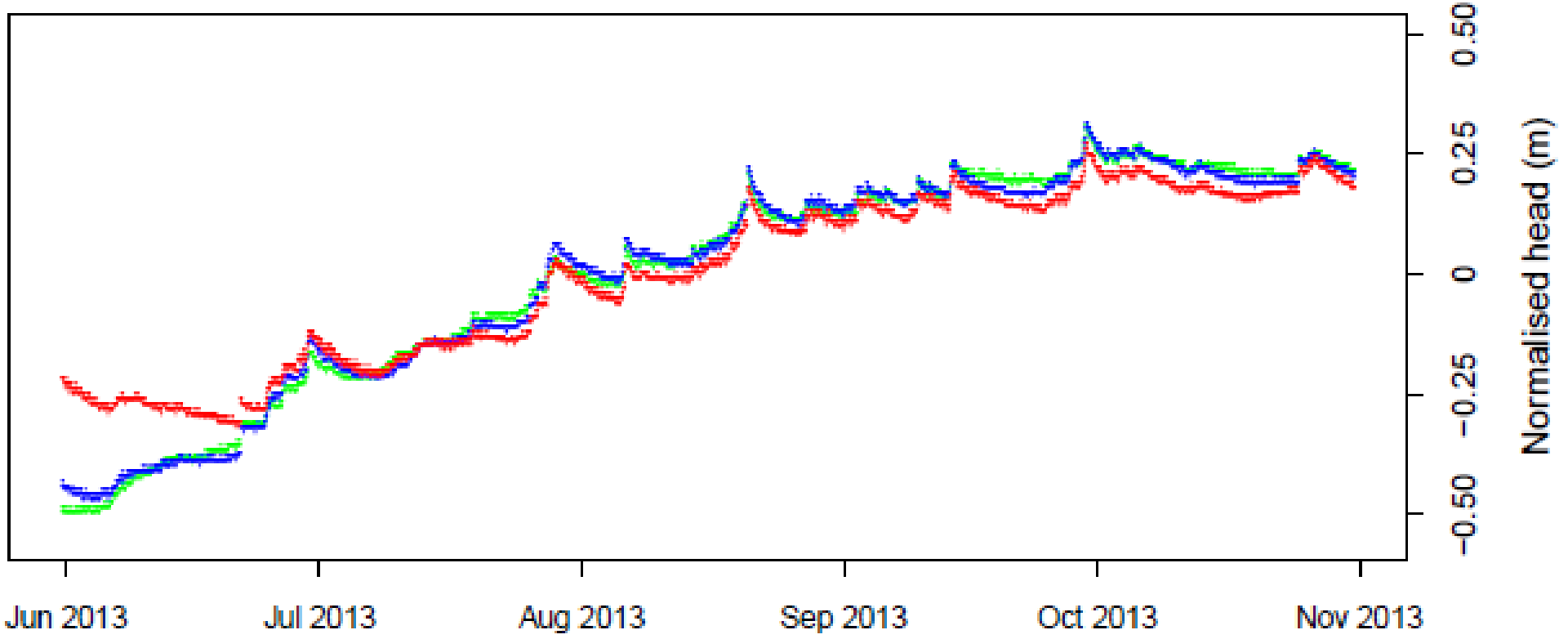
BAS 'nested' piezometers – *ca* 100, 200, 300 m depth



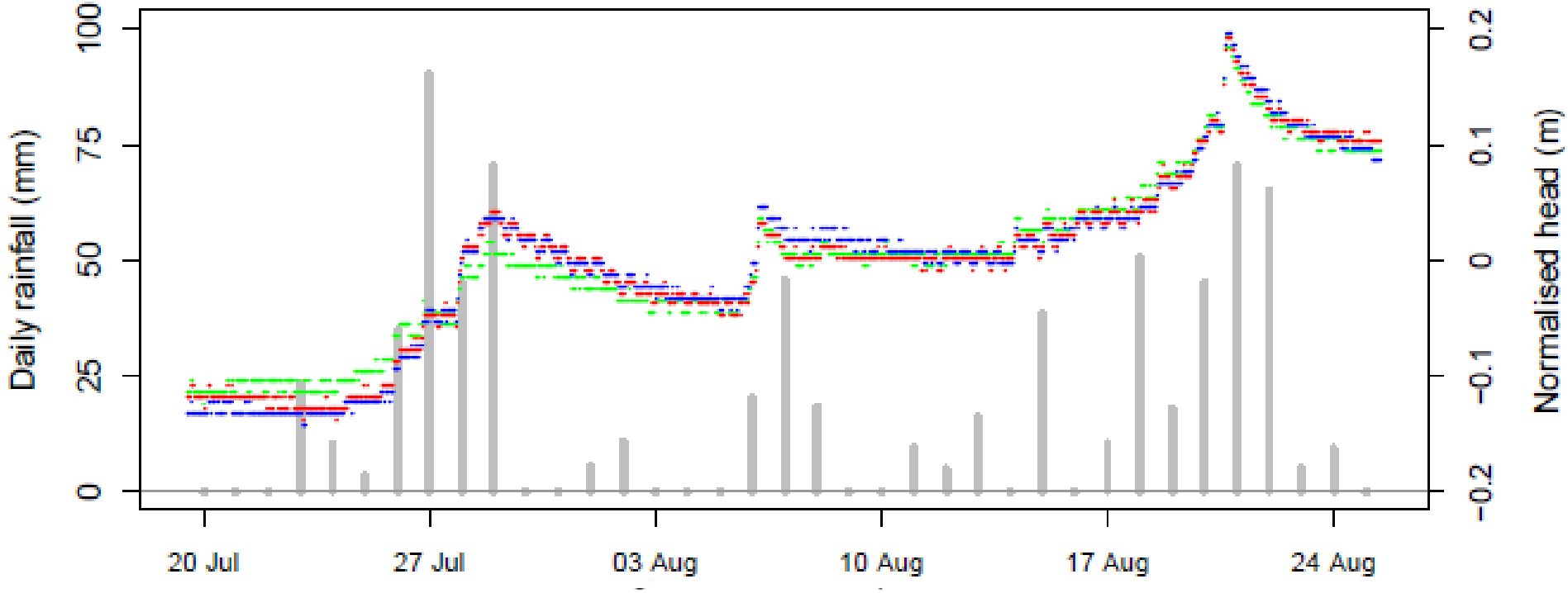
BAS heads at an inland site, distant from pumping



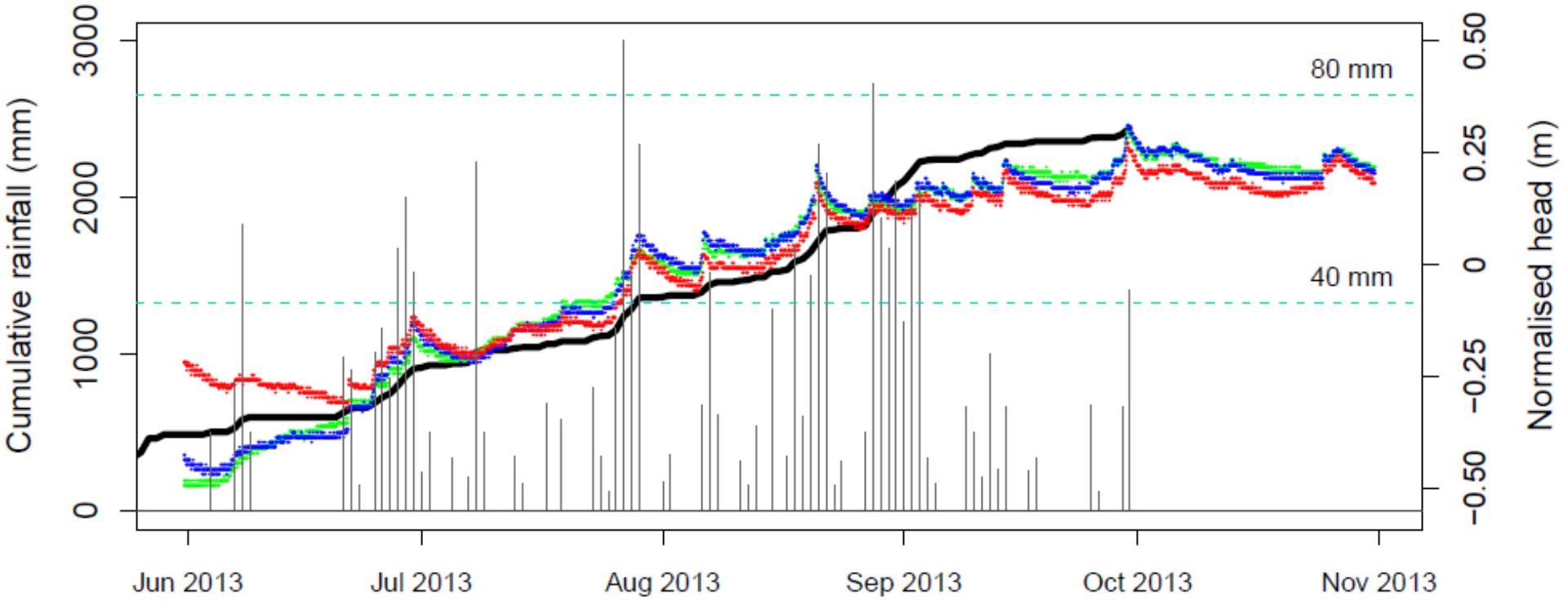
BAS heads at an inland site, distant from pumping



BAS heads respond to mechanical loading by monsoon inundation, as daily rainfall events



BAS heads respond to mechanical loading by inundation over a monsoon season



Natural Resources Research , Vol. 9, No. 2. 2000

Natural Geological Weighing Lysimeters: Calibration Tools for Satellite and Ground Surface Gravity Monitoring of Subsurface Water-Mass Change

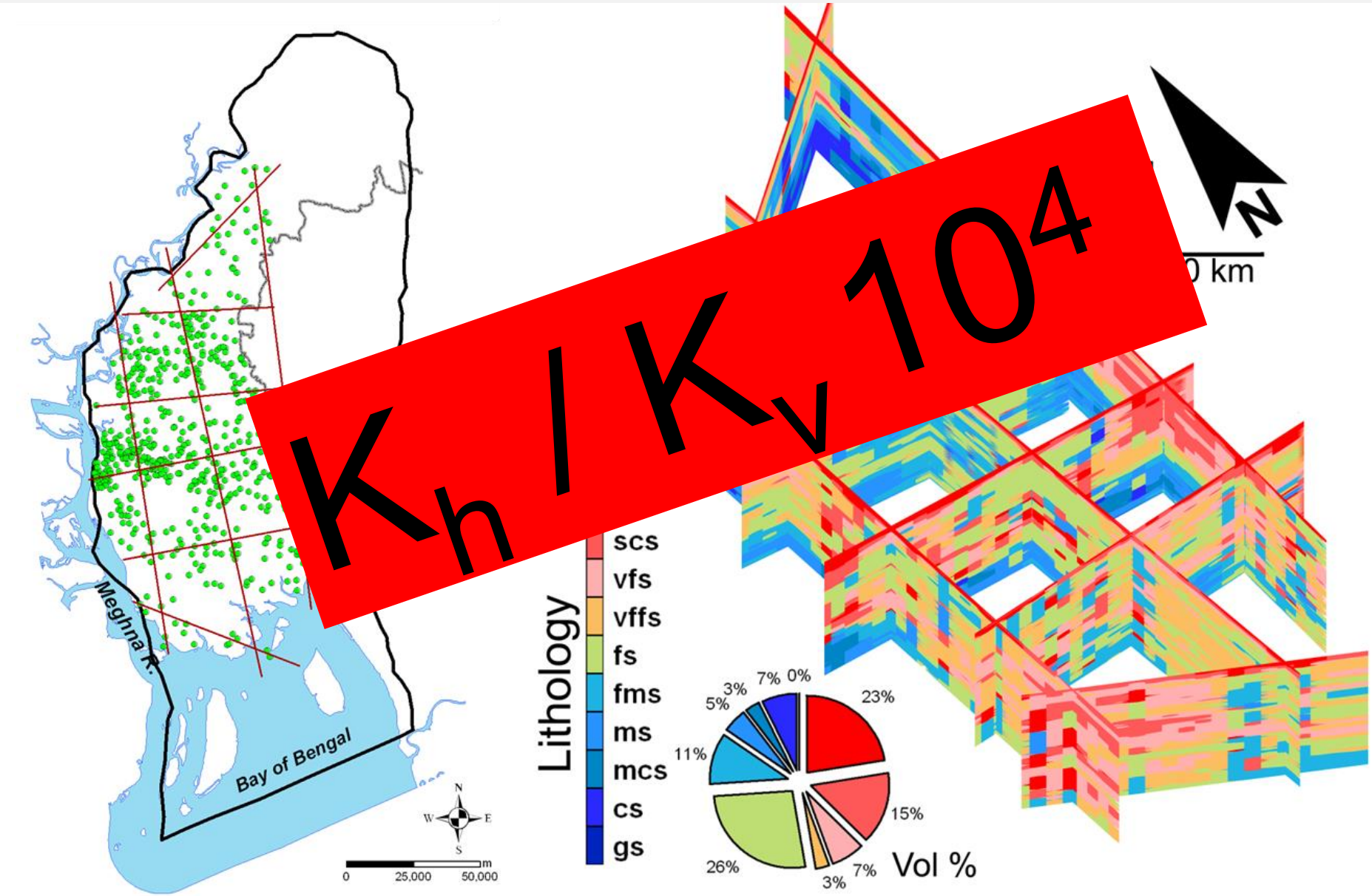
W. E. Bardsley[1,2] and D. I. Campbell[1]

"*Alluvial plains in monsoonal climates may serve a calibration role here, with* ***possible candidate regions being the Ganges River basin*** *and the plains of northern China. In the US, the State of Illinois also has been suggested as a possible calibration region (Rodell and Famiglietti, 1999b).* ***Geological weighing lysimeters … could be set up for local verification of estimated water-mass changes*** *at …. representative sites*."


hydraulic gradient
0.0001

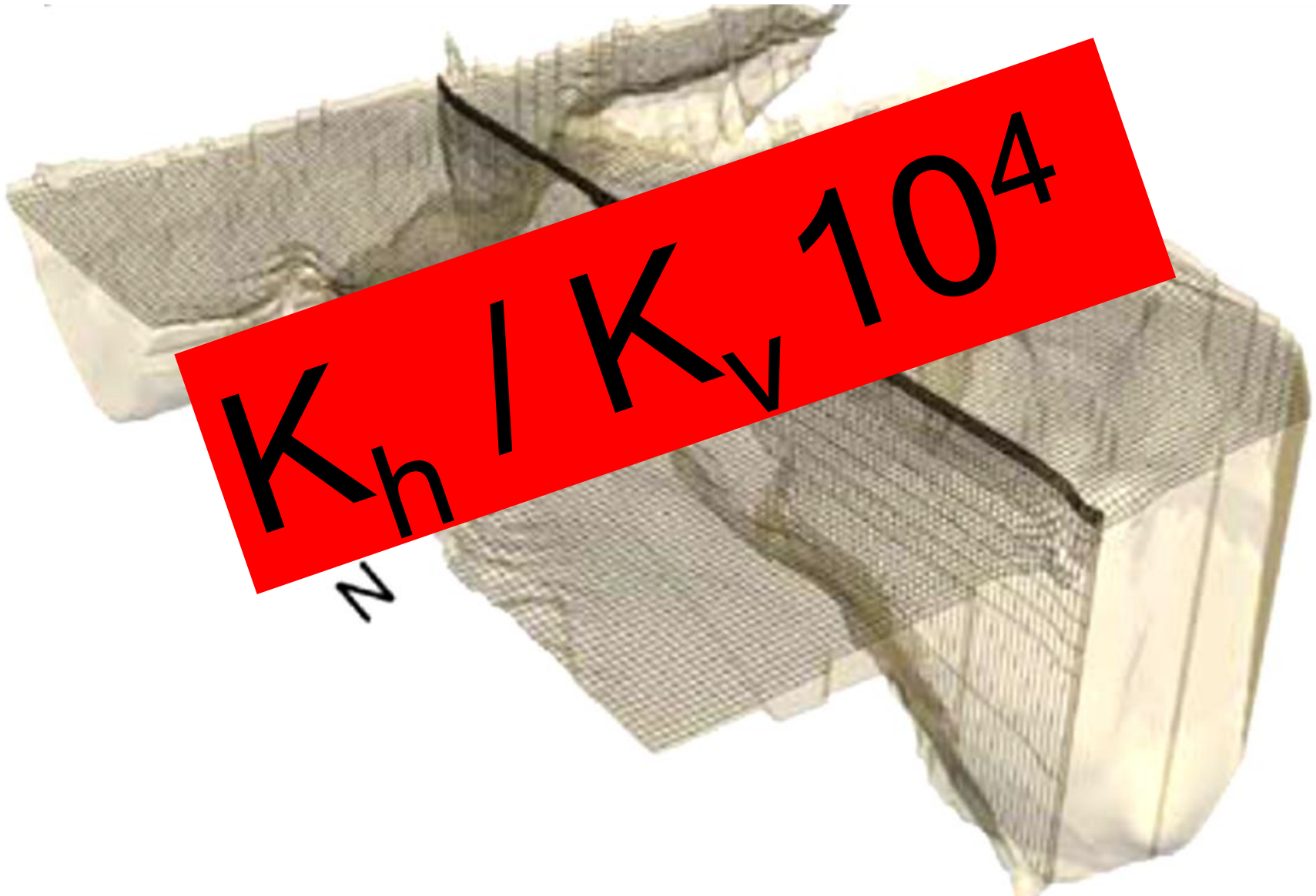
M. Hoque 2010 *UCL PhD thesis*

Models for managing the deep aquifer in Bangladesh



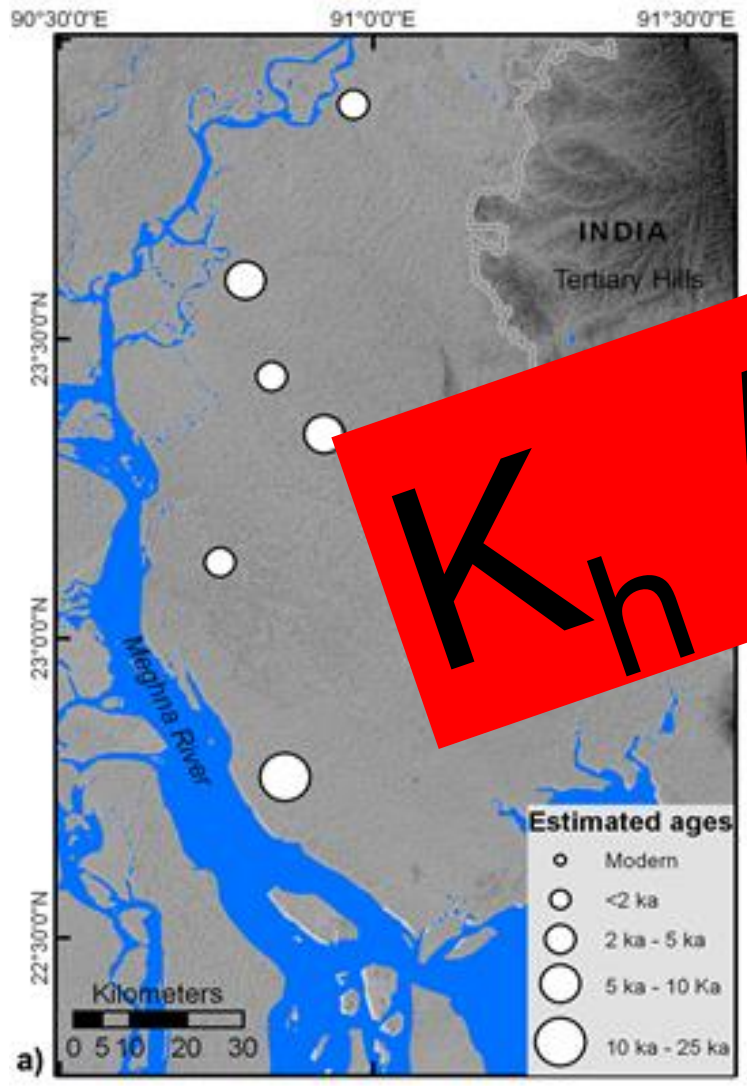
Michael & Voss 2008 *PNAS*

Sustainability of deep groundwater pumping

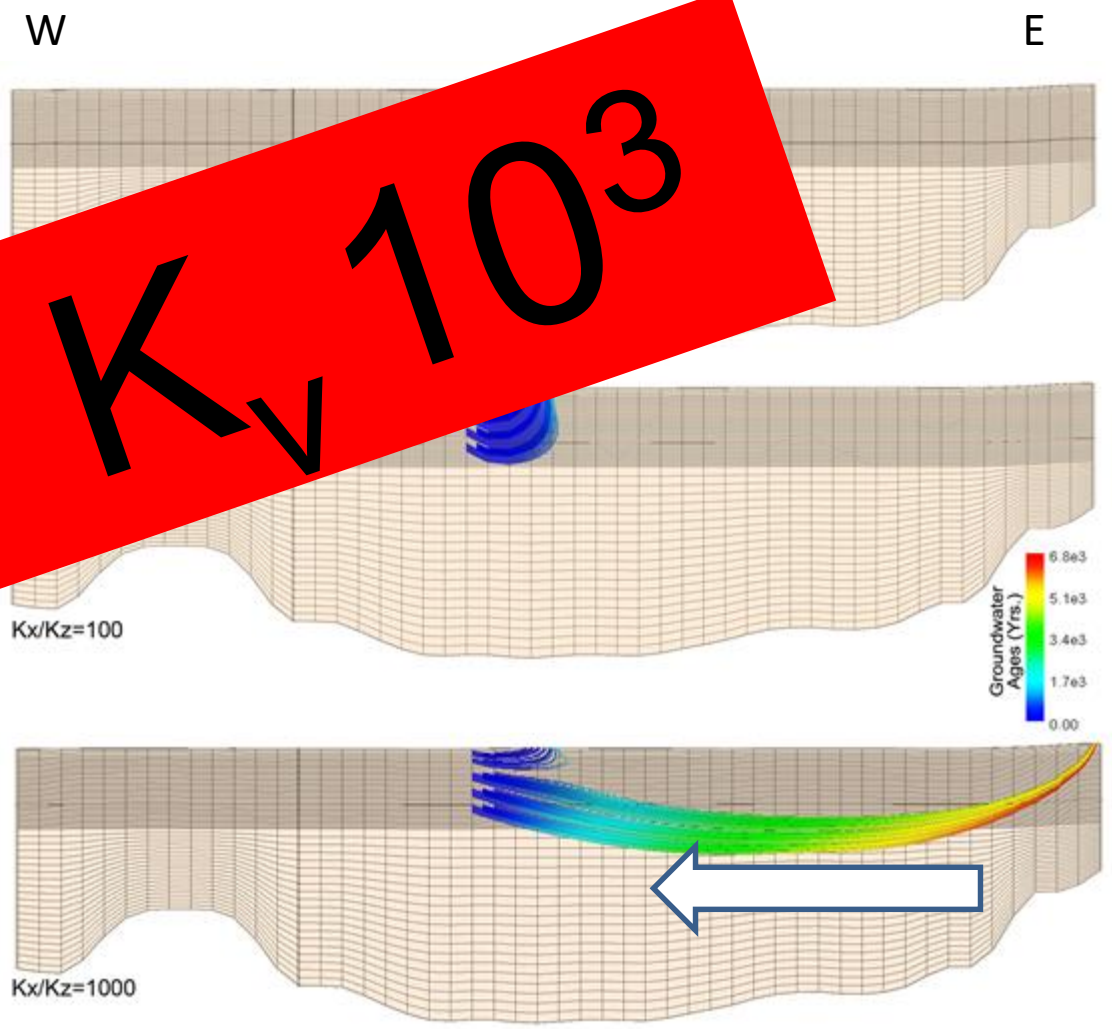


Hoque & Burgess 2010 *Jour. Hydrology*

^{14}C dating of deep groundwater in BAS …. aquifer anisotropy



$K_h / K_v 10^3$



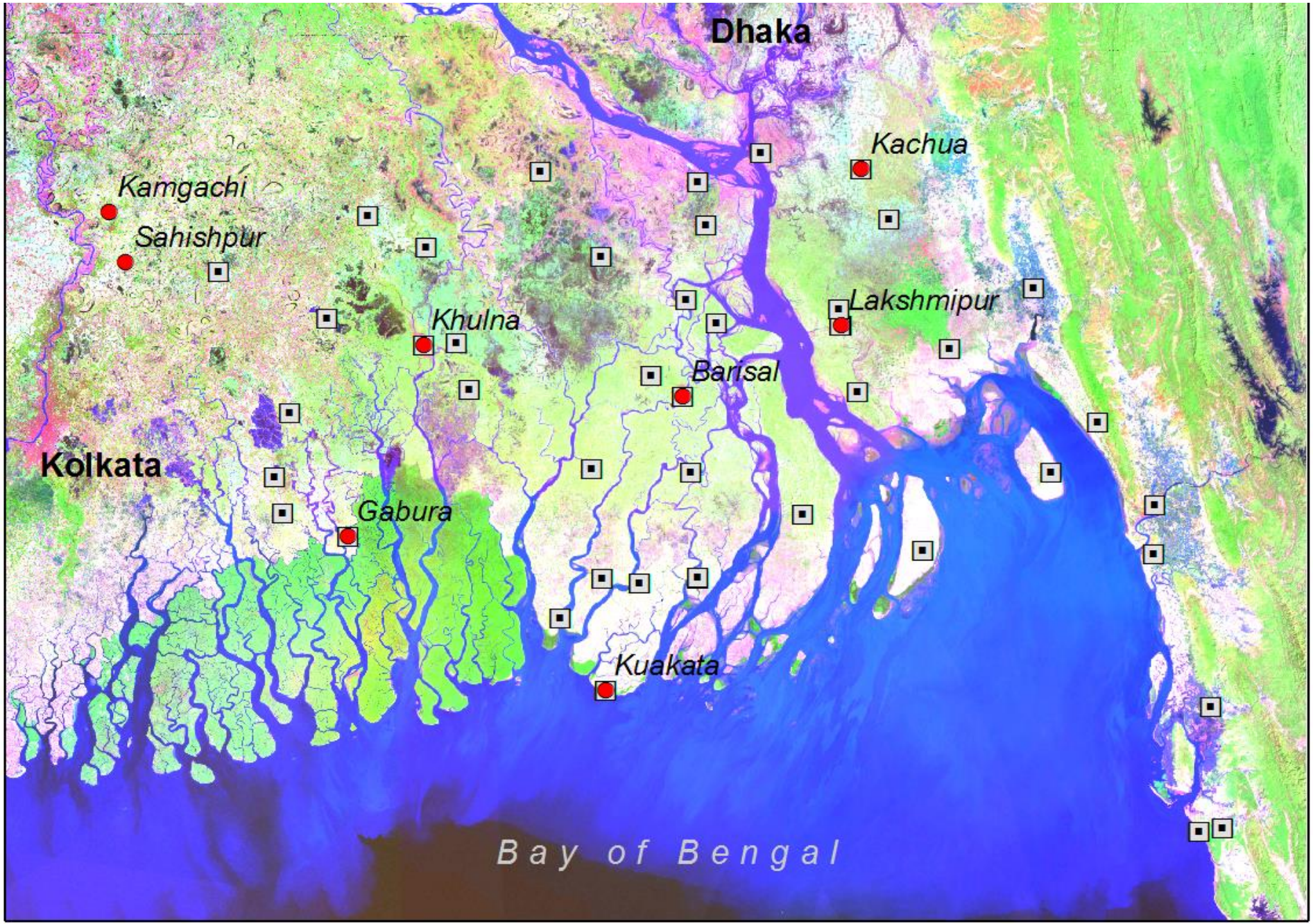

tropical monsoon
500 – 4000 mm, May-Oct
>100 mm / day

BAS heads respond to mechanical loading by monsoon inundation

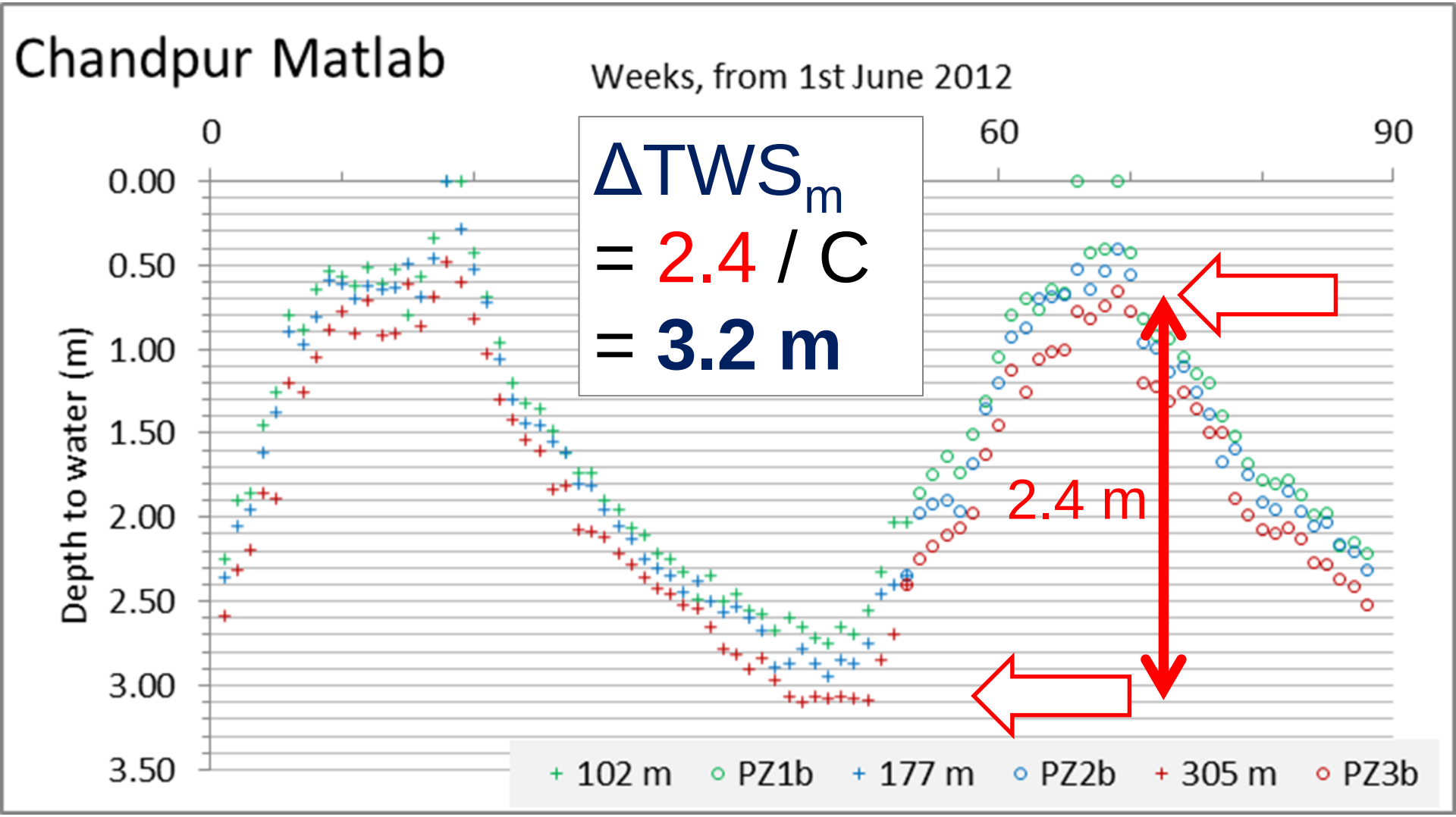
$$\frac{\partial h}{\partial t} = \gamma \frac{\partial \sigma_T}{\partial t}$$

compression, mechanical

BAS – 'nested' piezometers – 100, 200, 300 m depth



BAS heads increase over a monsoon period as the terrestrial water mass, ΔTWS_m accumulates



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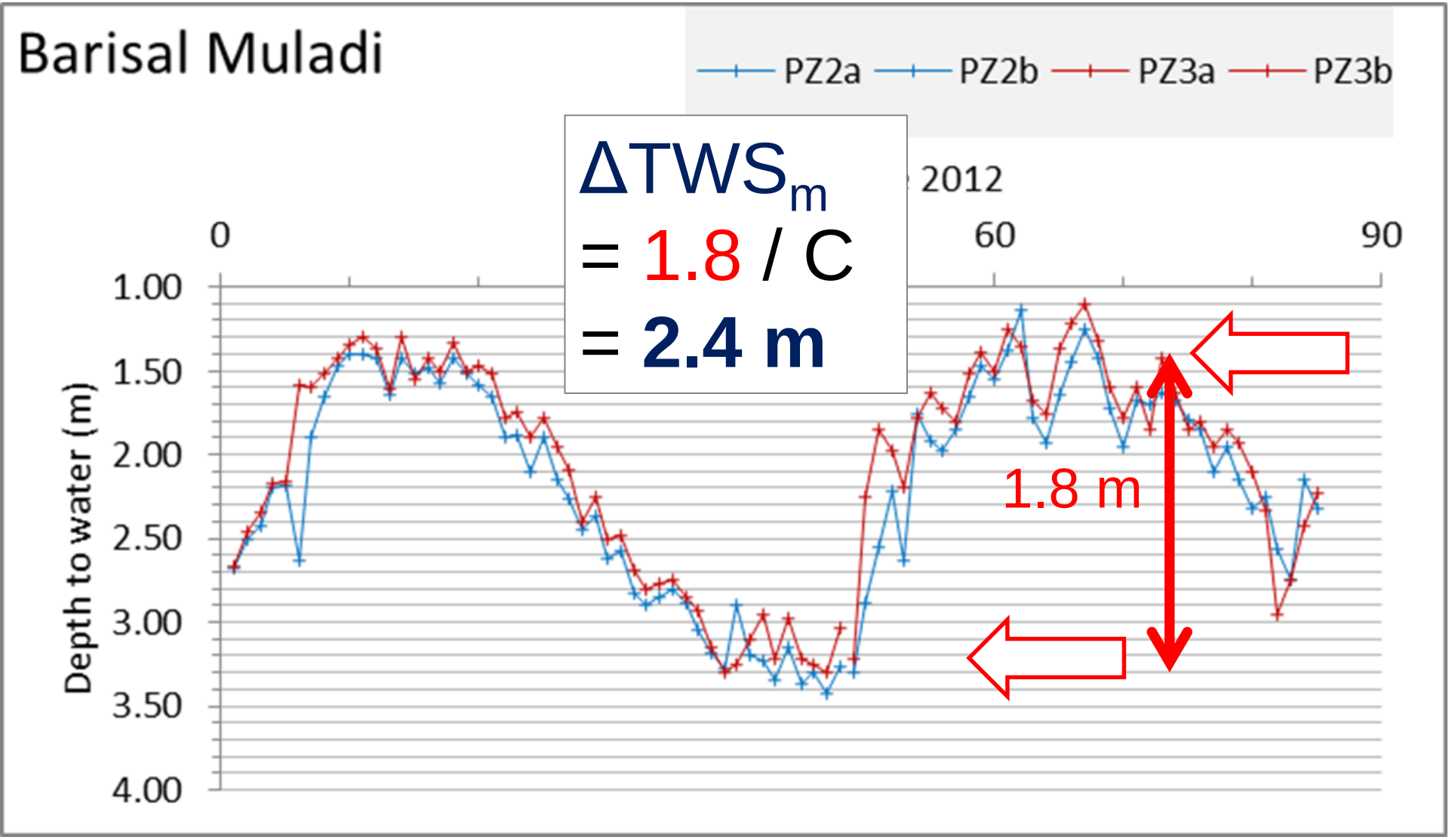
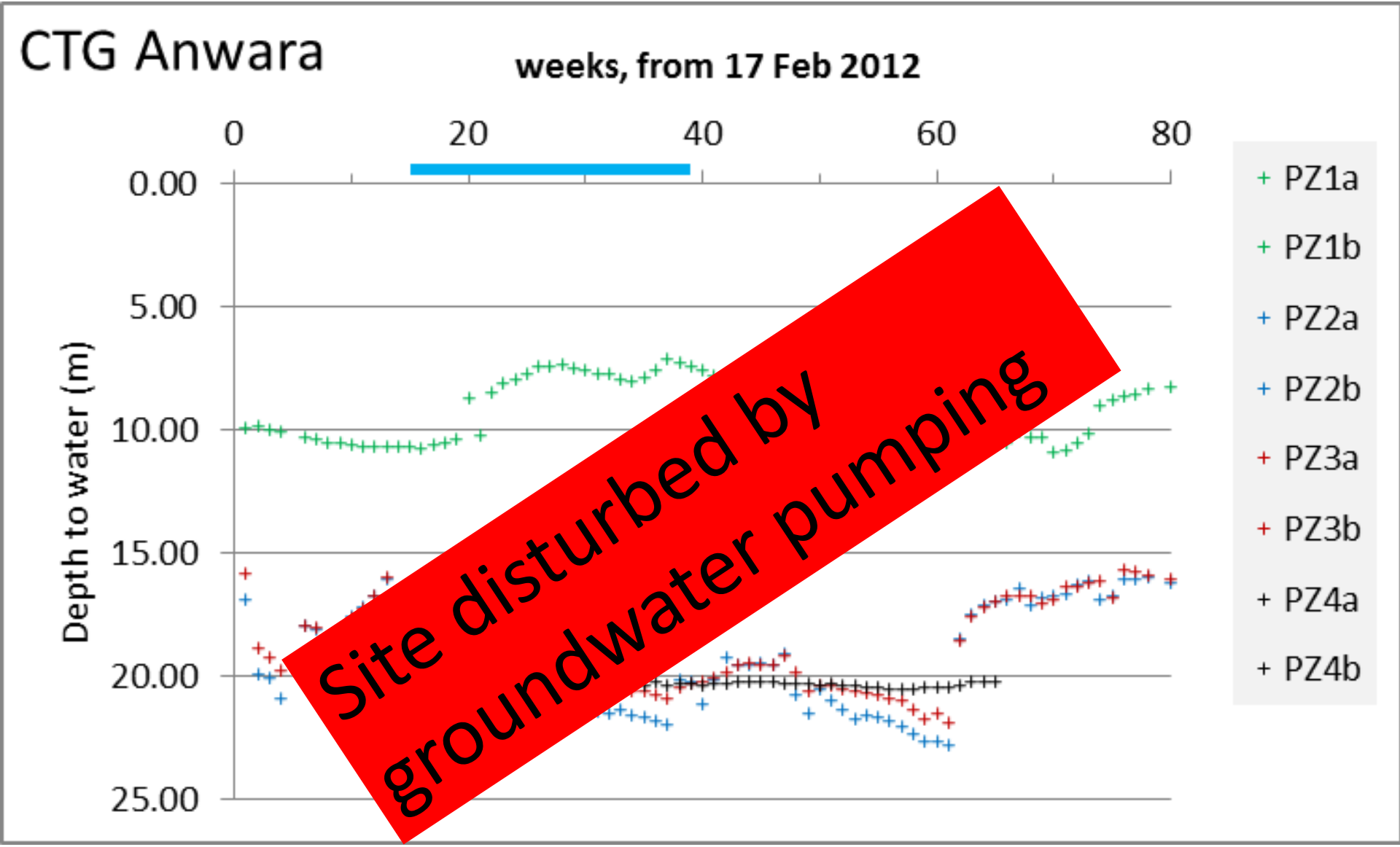
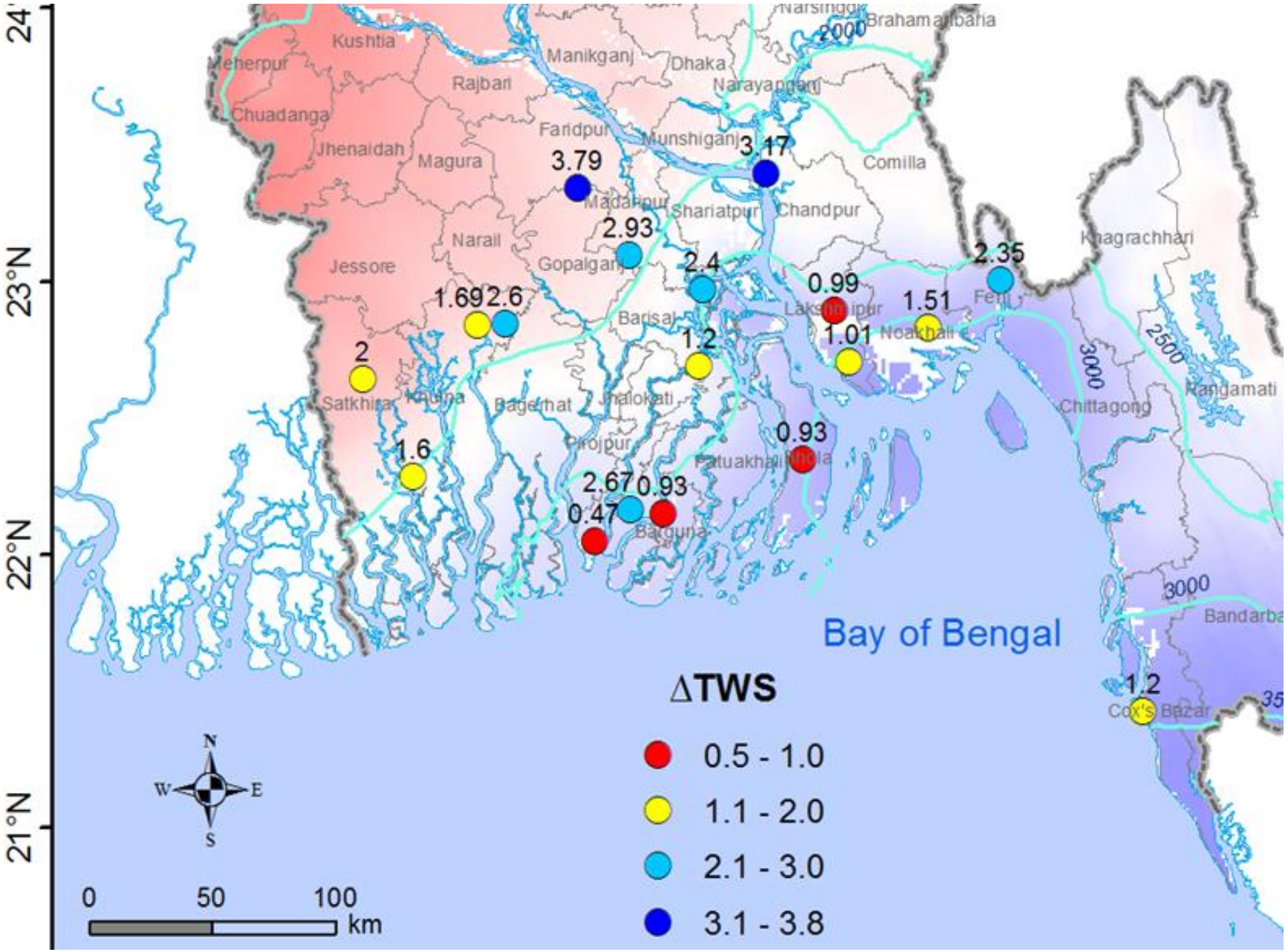


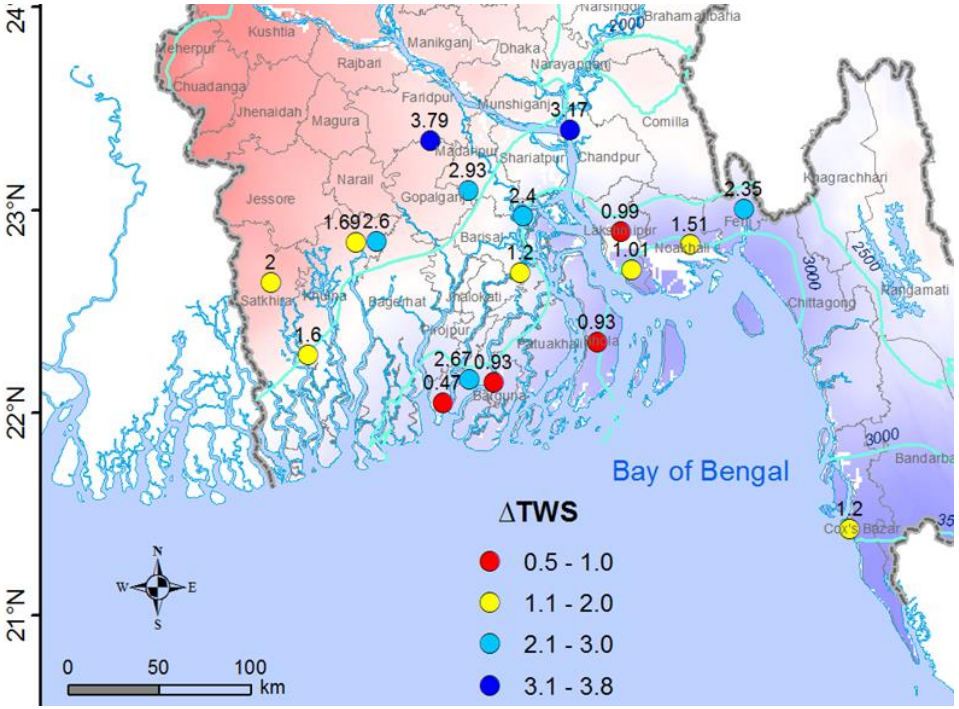

CTG Anwara
weeks, from 17 Feb 2012
0
20
40
60
80
0.00
5.00
10.00
15.00
20.00
25.00
Depth to water (m)
PZ1a
PZ1b
PZ2a
PZ2b
PZ3a
PZ3b
PZ4a
PZ4b
Site disturbed by groundwater pumping

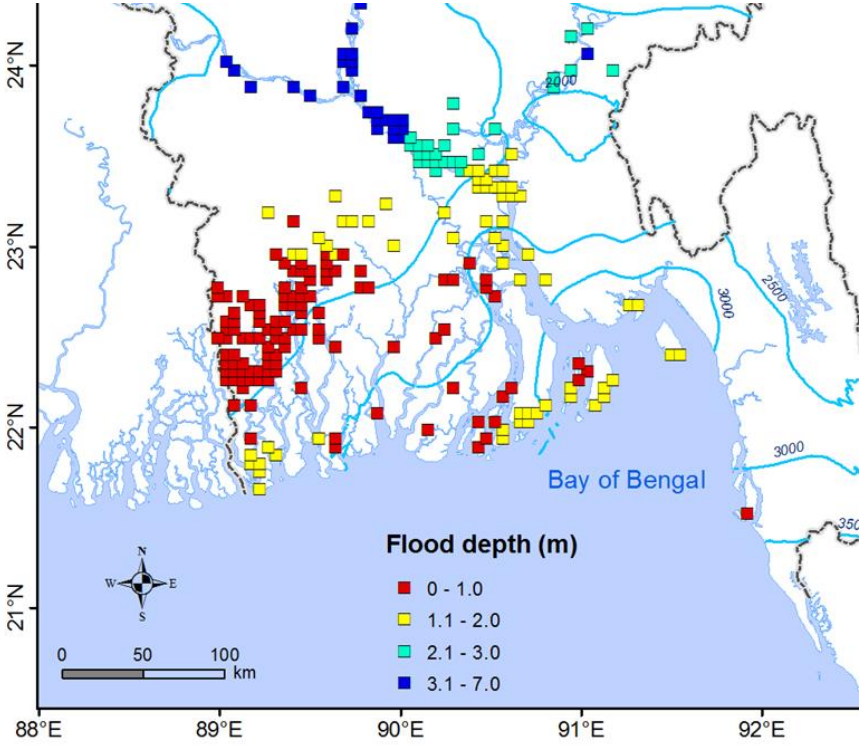
Monsoon season ΔTWS_m accumulation (m): 2012, 2013



ΔTWS_m 2012, 2013

Accumulated flooding depth
May-Sept 2007

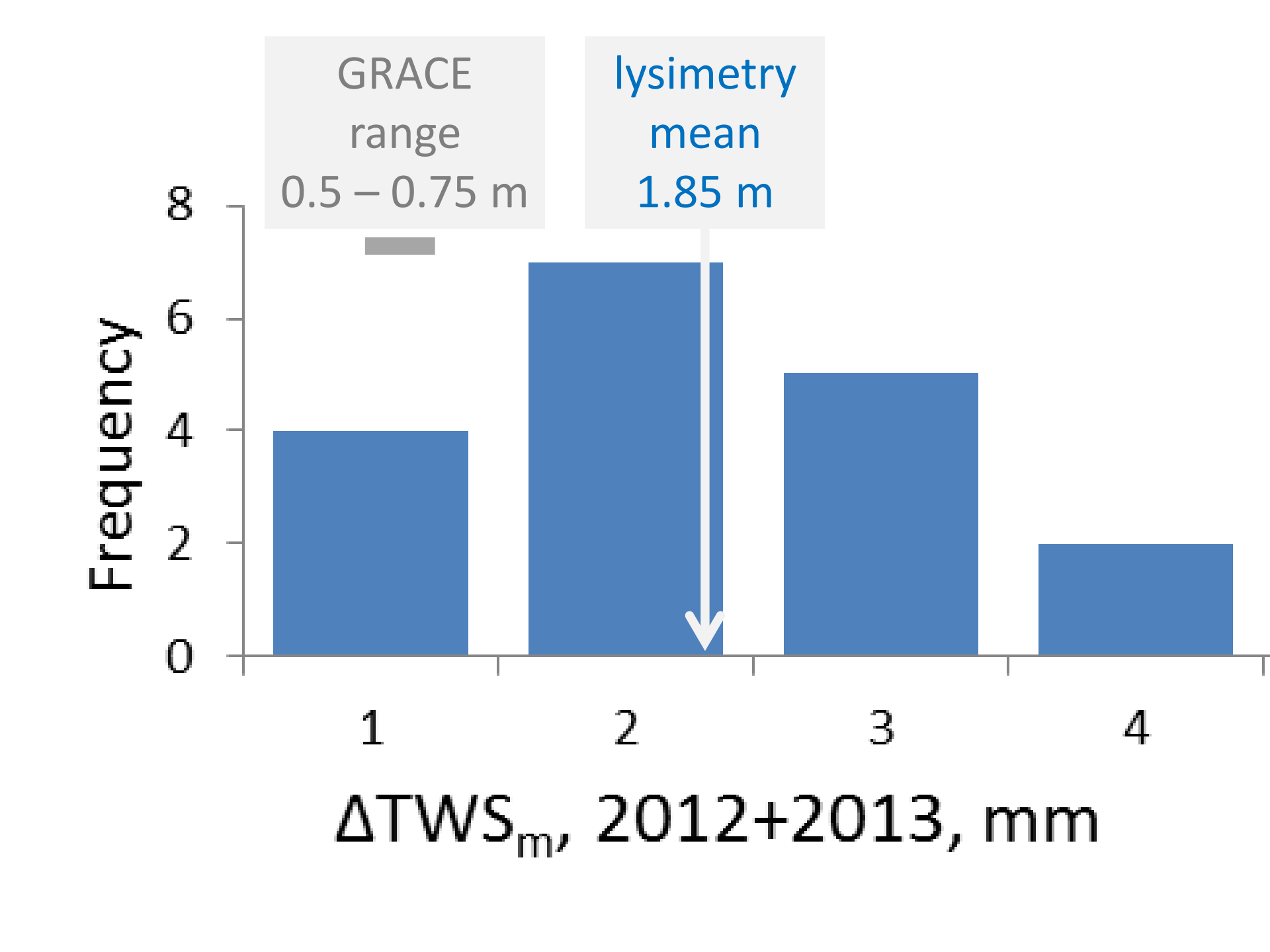




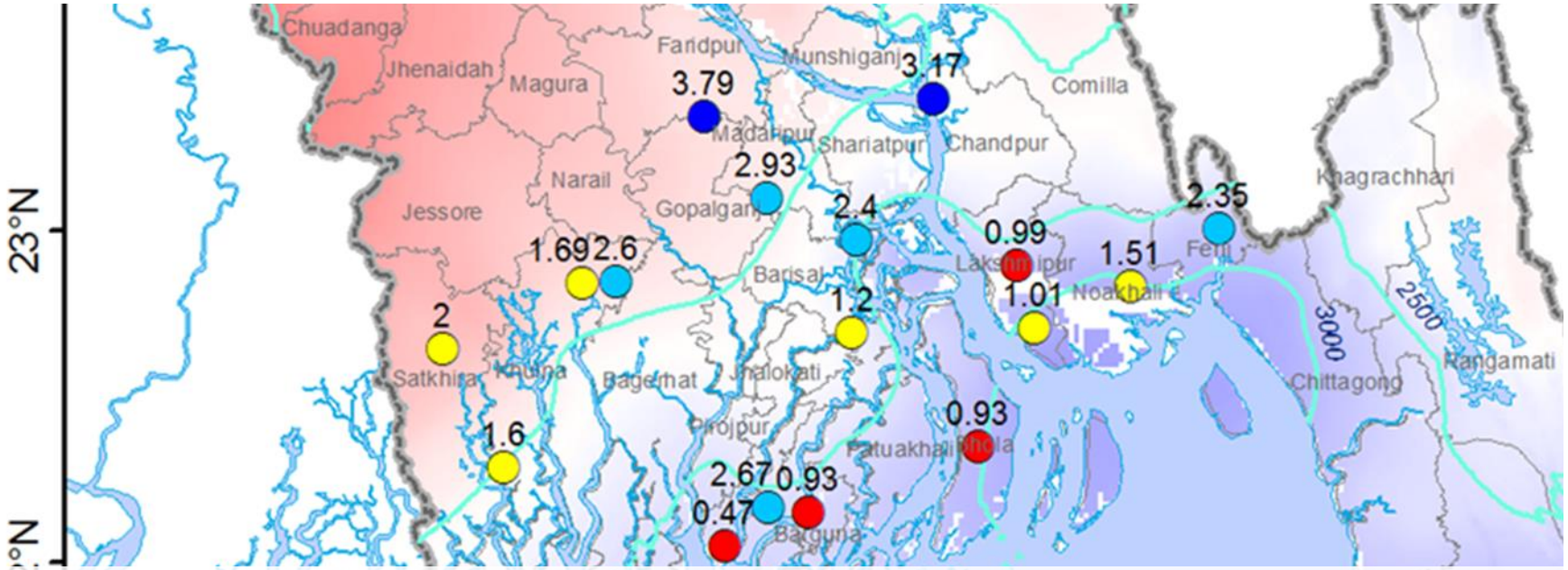
Shamsudduha *et al* 2011

$\underline{\Delta TWS}_m$

EGSIEM.eu	0.51 m	(2013)
Shamsudduha et al.		
Steckler et al.	0.49 – 0.75 m	(2003 – 2007)


GRACE
range
0.5 – 0.75 m
lysimetry
mean
1.85 m
Frequency
0
2
4
6
8
1
2
3
4
ΔTWS$_m$, 2012+2013, mm

Geo-lysimetry maps ΔTWS_m within a GRACE footprint:



GRACE – lysimetry apparent discrepency

- accuracy of the geolysimetry analyses of ΔTWS ?
- representative lysimetry sites ?
- spatial variation of ΔTWS across the basin ?
- spatial distribution of ΔTWS affects GRACE interpretation ?
- systematic under-representation of ΔTWS by GRACE ?

Poroelastic responses to terrestrial water loading in the Bengal Aquifer System provide high-resolution, in-situ measurements for comparison with GRACE

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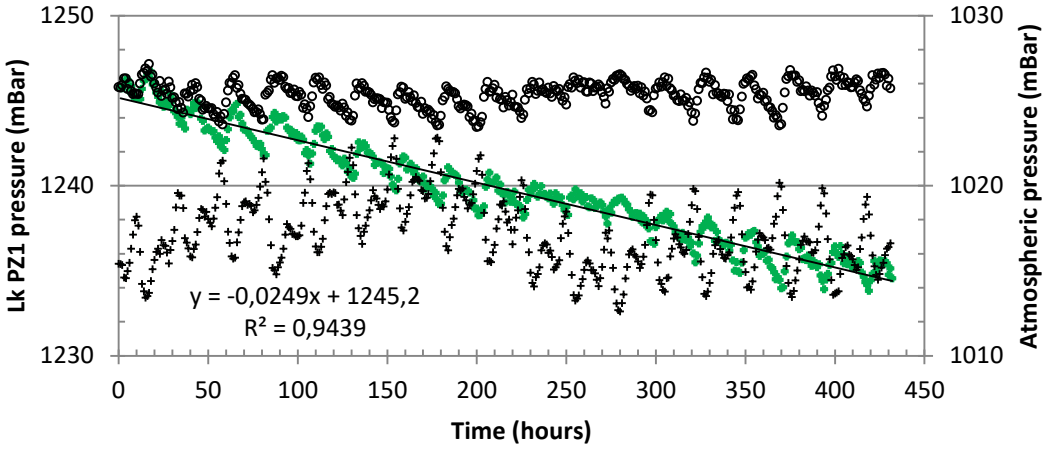
Thanks to: Bangladesh Climate Change Trust

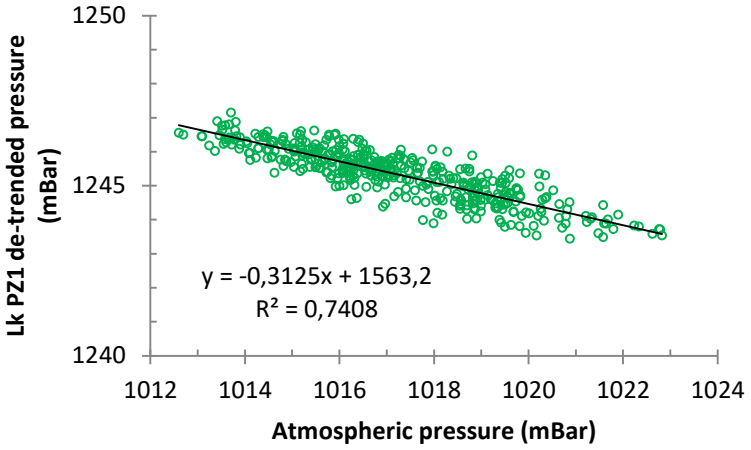
N°abstract 1912

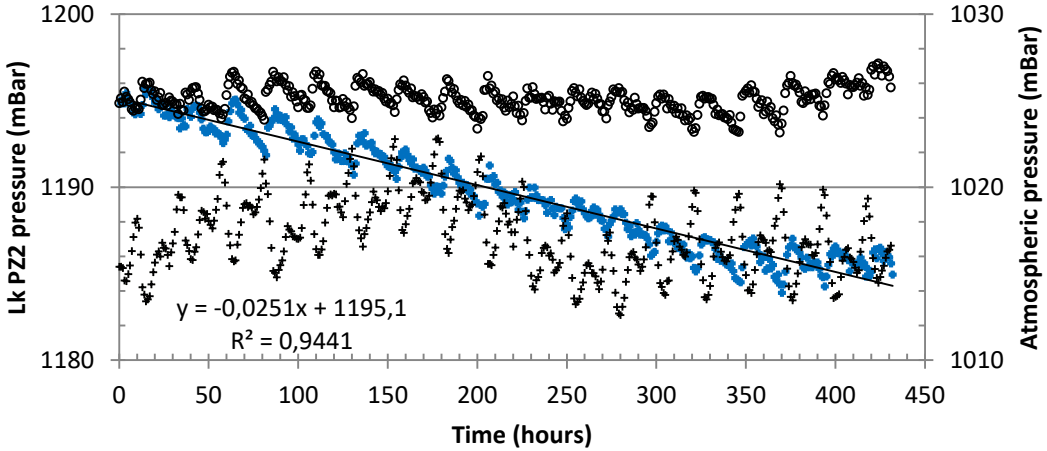
20 - 30 m

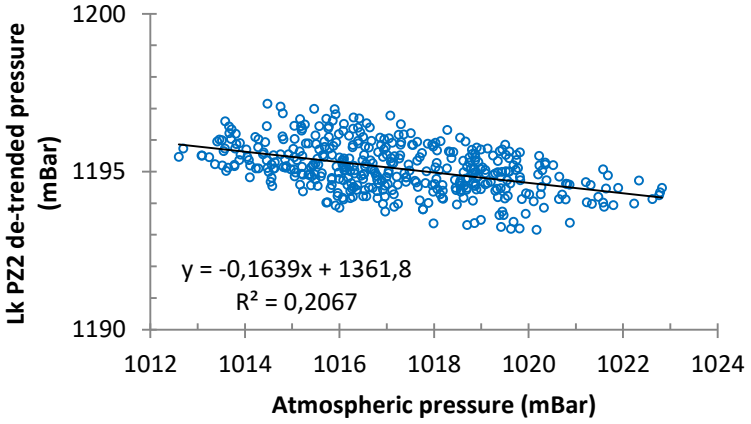

100 m

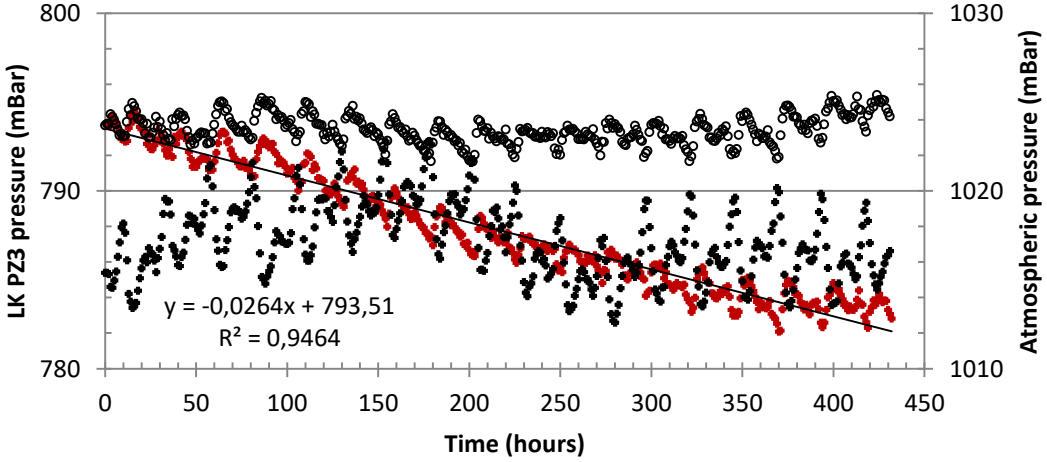
200 - 300 m

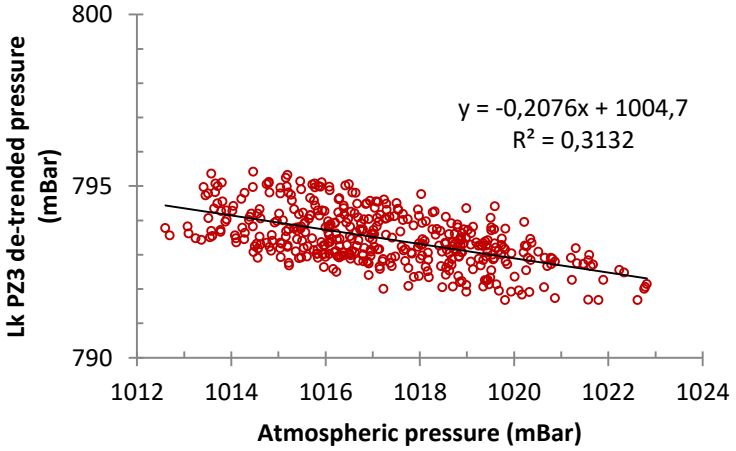

Lk PZ1 pressure (mBar)
Atmospheric pressure (mBar)
Time (hours)
y = -0,0249x + 1245,2
R² = 0,9439

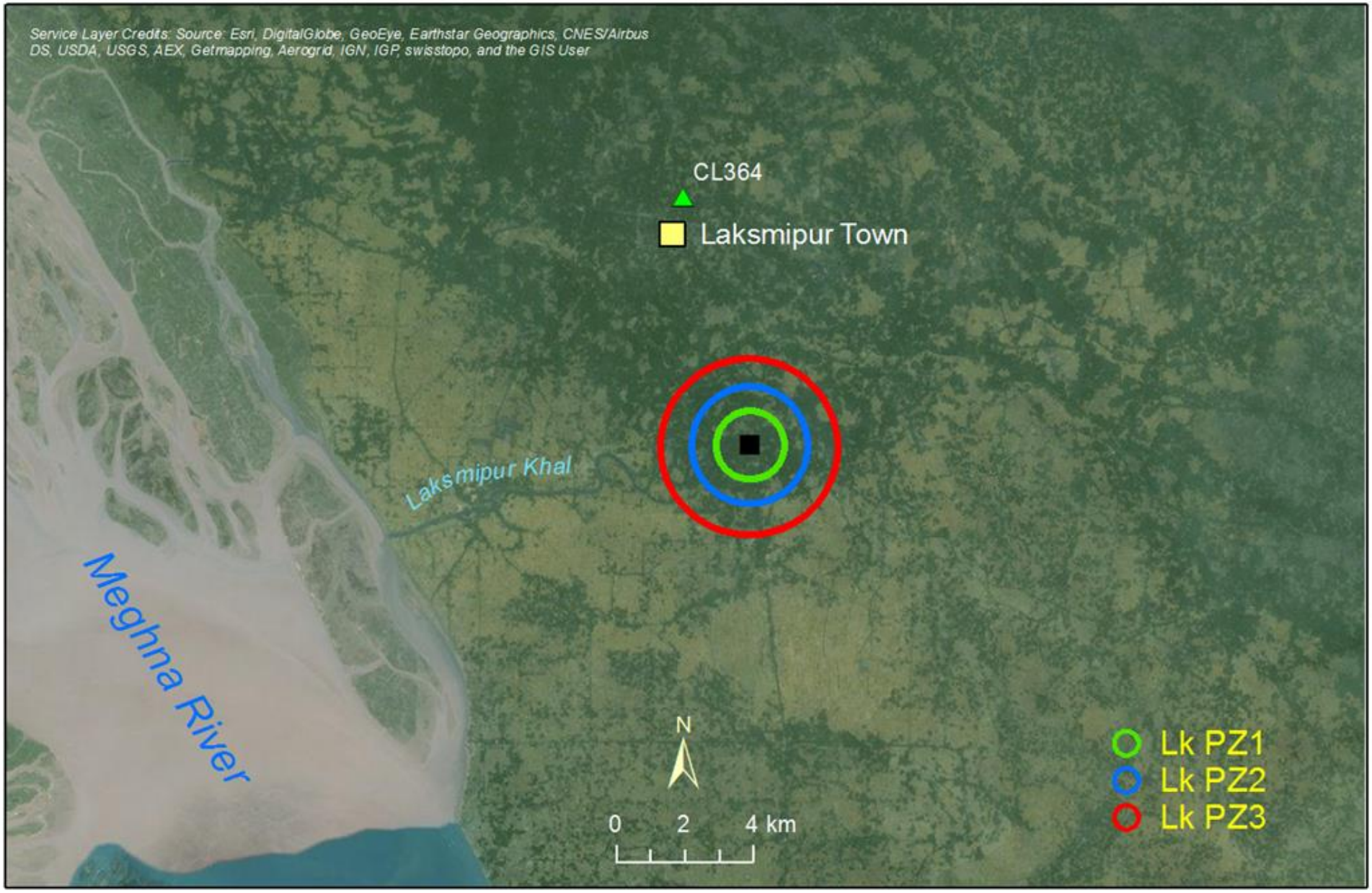

Lk PZ1 de-trended pressure (mBar)
Atmospheric pressure (mBar)
y = -0,3125x + 1563,2
R² = 0,7408


Lk PZ2 pressure (mBar)
Atmospheric pressure (mBar)
Time (hours)
y = -0,0251x + 1195,1
R² = 0,9441

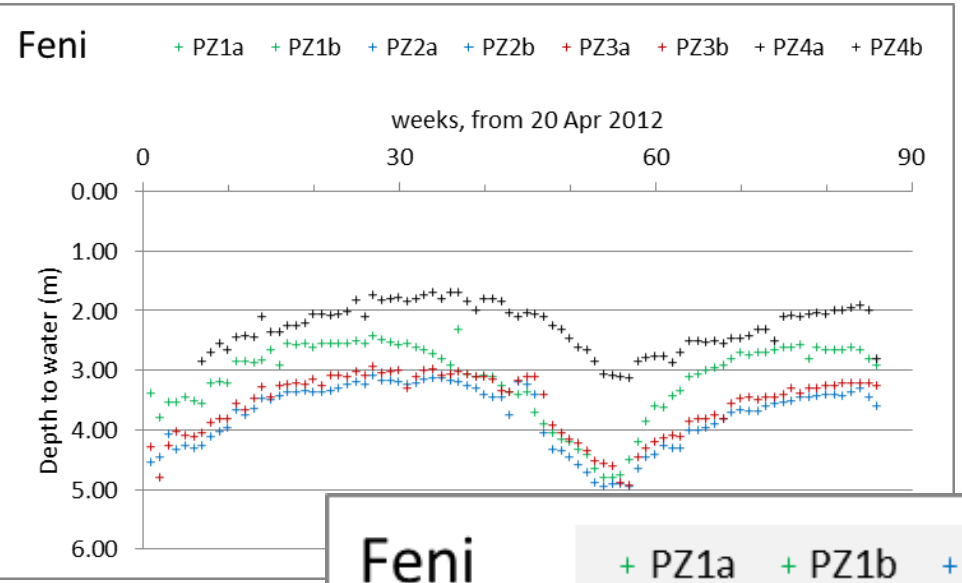

Lk PZ2 de-trended pressure (mBar)
Atmospheric pressure (mBar)
y = -0,1639x + 1361,8
R² = 0,2067

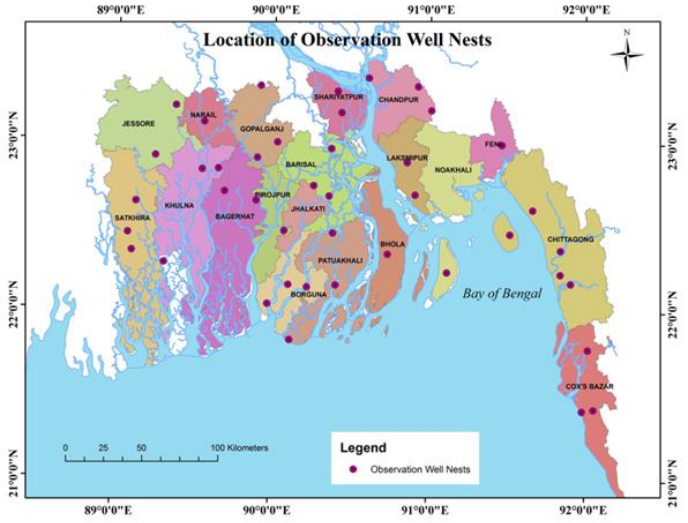

LK PZ3 pressure (mBar)
Atmospheric pressure (mBar)
Time (hours)
y = -0,0264x + 793,51
R² = 0,9464

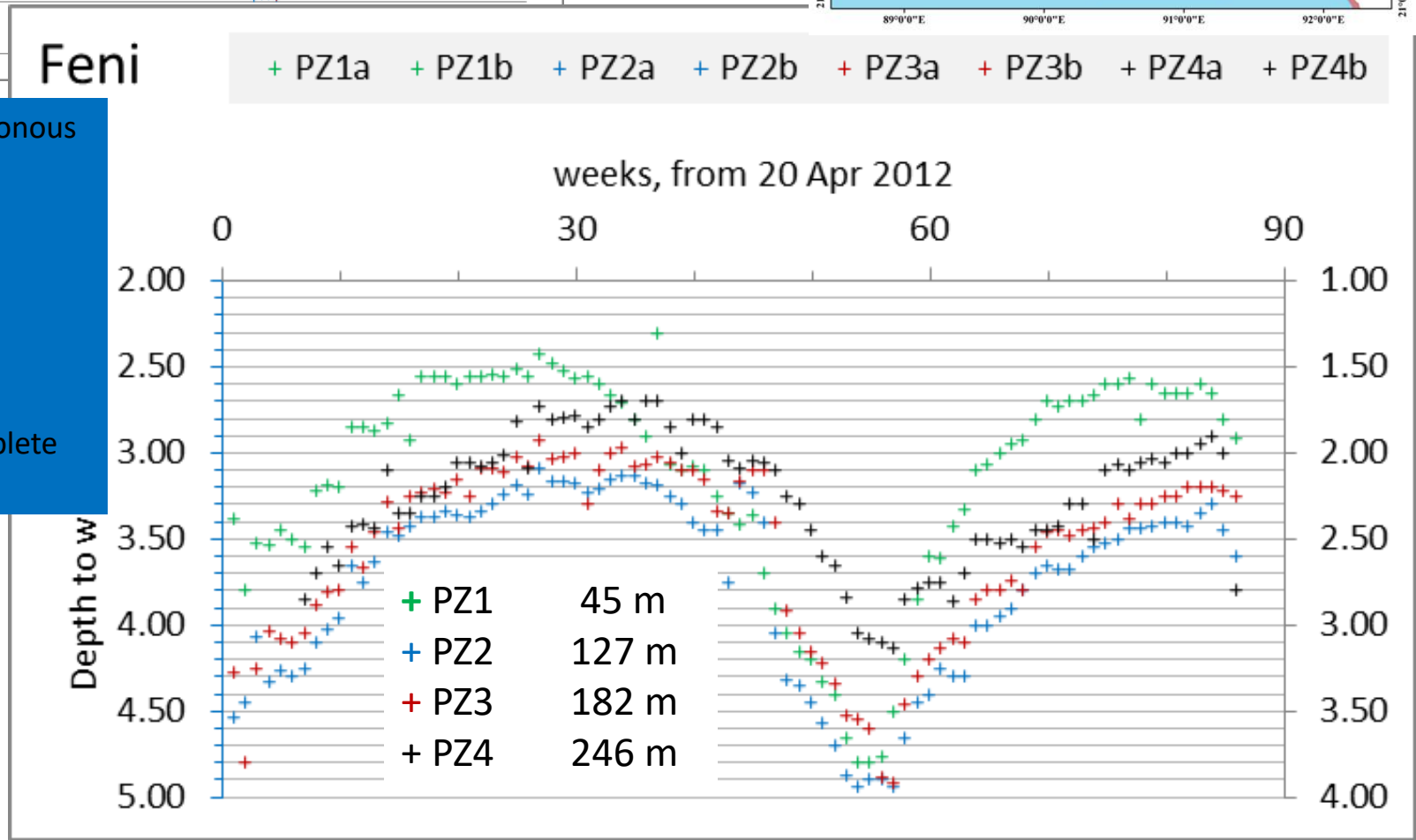

Lk PZ3 de-trended pressure (mBar)
Atmospheric pressure (mBar)
y = -0,2076x + 1004,7
R² = 0,3132


Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User
CL364
Laksmipur Town
Laksmipur Khal
Meghna River
N
0
2
4 km
Lk PZ1
Lk PZ2
Lk PZ3


CL508
Shyamnagar
N
0 2 4 km
Gb PZ1
Gb PZ2
Gb PZ3
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User







PZ1,2,3, 4 synchronous

2013 (min to max)

PZ2 1.64 m

PZ3 1.72 m

PZ4 1.23 m

2012 (min to pt 30)

PZ2 1.36 m

PZ3 1.80 m

PZ4 incomplete

PZ2,3,4	synchronous, complete 2013 season
PZ2	1.00 m
PZ3	0.82 m
PZ4	0.74 m (all min to 1Nov)

Laxmipur Town

PZ1a PZ1b PZ2a
PZ2b PZ3a PZ3b
PZ4a PZ4b

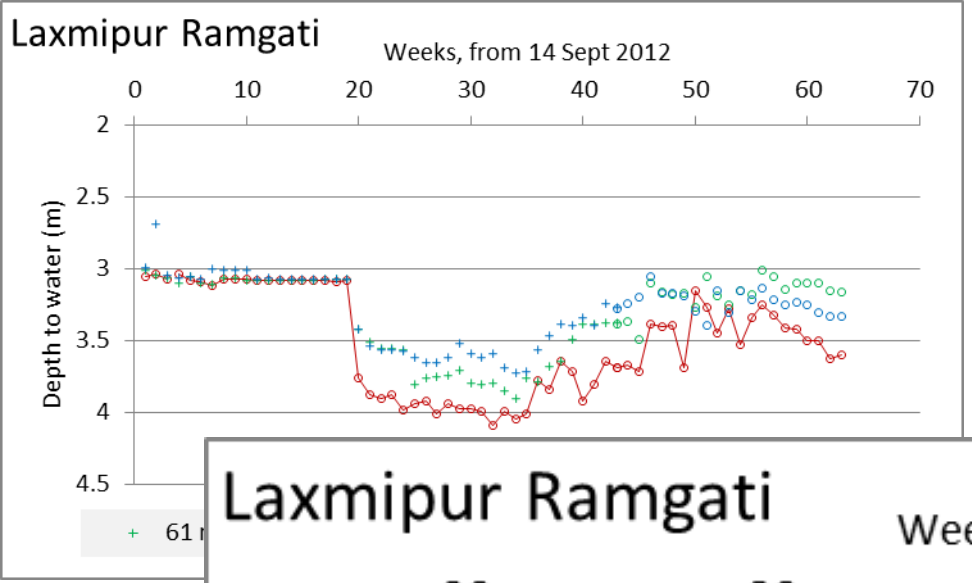
weeks, from 28 Sept 2012

0 10 20 30 40 50 60 70

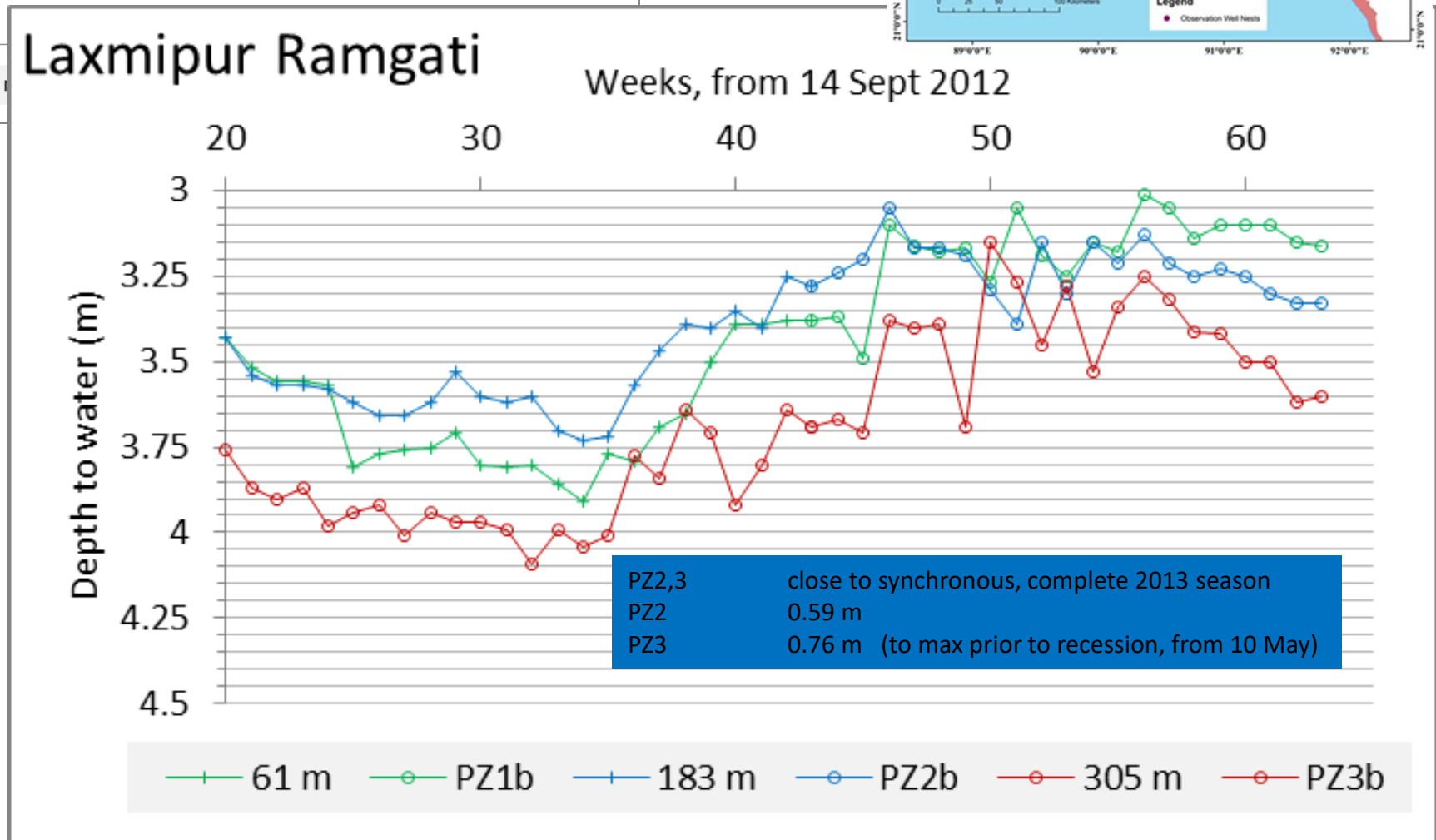
Depth to water (m)

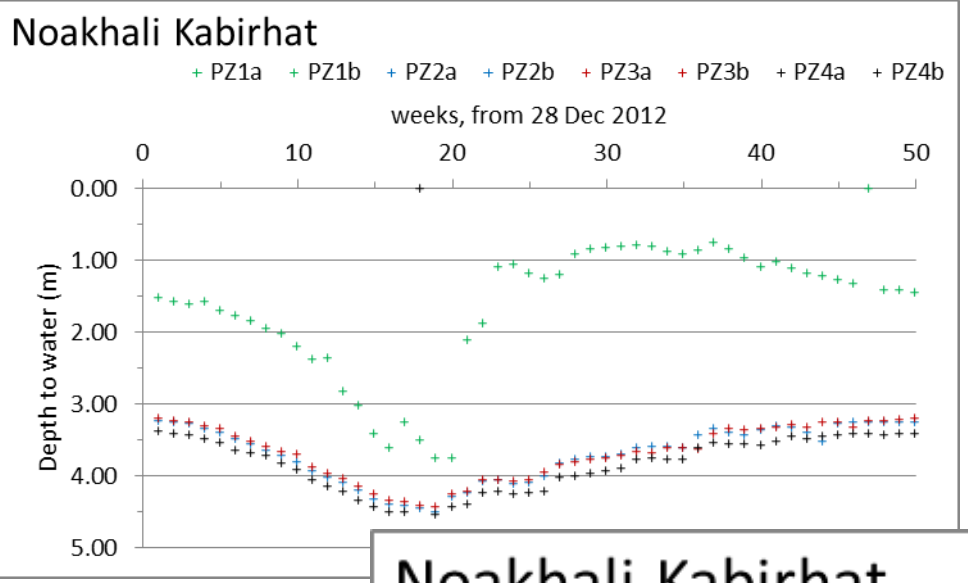
2 2.5 3 3.5

3 3.5 4 4.5


Laxmipur Ramgati
Weeks, from 14 Sept 2012
0
10
20
30
40
50
60
70
2
2.5
3
3.5
4
4.5
Depth to water (m)
61 m


Location of Observation Well Nests
Bay of Bengal
Legend
Observation Well Nests
89°0'0"E
90°0'0"E
91°0'0"E
92°0'0"E
23°0'0"N
22°0'0"N
21°0'0"N


Laxmipur Ramgati
Weeks, from 14 Sept 2012
20
30
40
50
60
3
3.25
3.5
3.75
4
4.25
4.5
Depth to water (m)
PZ2,3 close to synchronous, complete 2013 season
PZ2 0.59 m
PZ3 0.76 m (to max prior to recession, from 10 May)
61 m
PZ1b
183 m
PZ2b
305 m
PZ3b



Noakhali Kabirhat

PZ2a PZ2b PZ3a PZ3b

PZ1	disturbed by pumping?
PZ2,3,4	synchronous, complete? 2013 season
PZ2	1.34 m
PZ3	1.23 m
PZ4	1.13 m (all from 3 May to 6 Dec)