THE IMPORTANCE OF SCALE IN DEFINING VULNERABILITY OF THE GANGES-BRAHMAPUTRA RIVER DELTA TO ENVIRONMENTAL CHANGE

Carol A. Wilson[1], Steven L. Goodbred, Jr.[1], Irina Overeem[2]
[1]Dept. of Earth and Environmental Sciences, Vanderbilt University, Nashville
[2] CSDMS, University of Colorado, Boulder

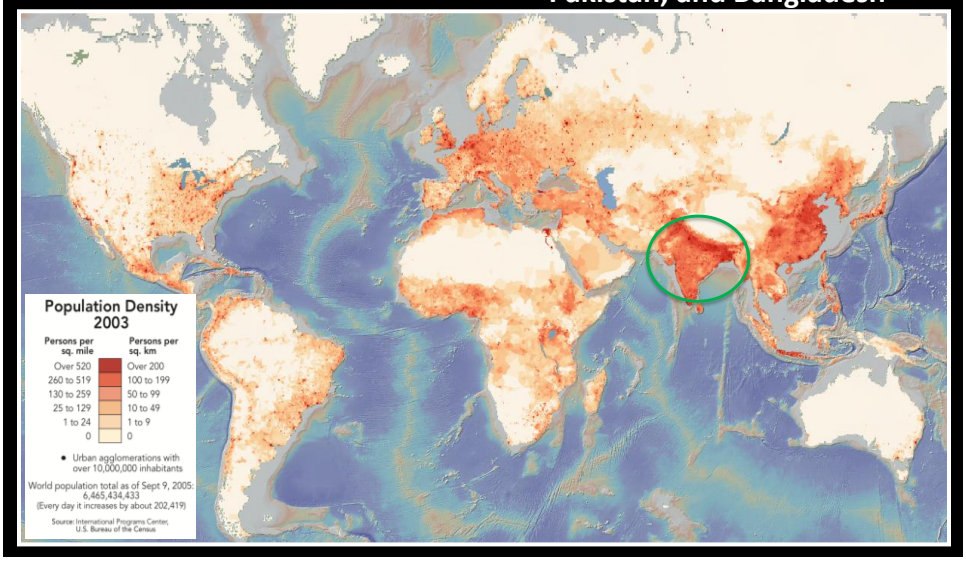
with contributions from Leslie Wallace Auerbach, Chris Small, Jonathan Gilligan, Kushal Roy, Kazi Rifat Ahmed, Michael Steckler, Leonardo Seeber, Humayun Akhter, Saddam Hossain

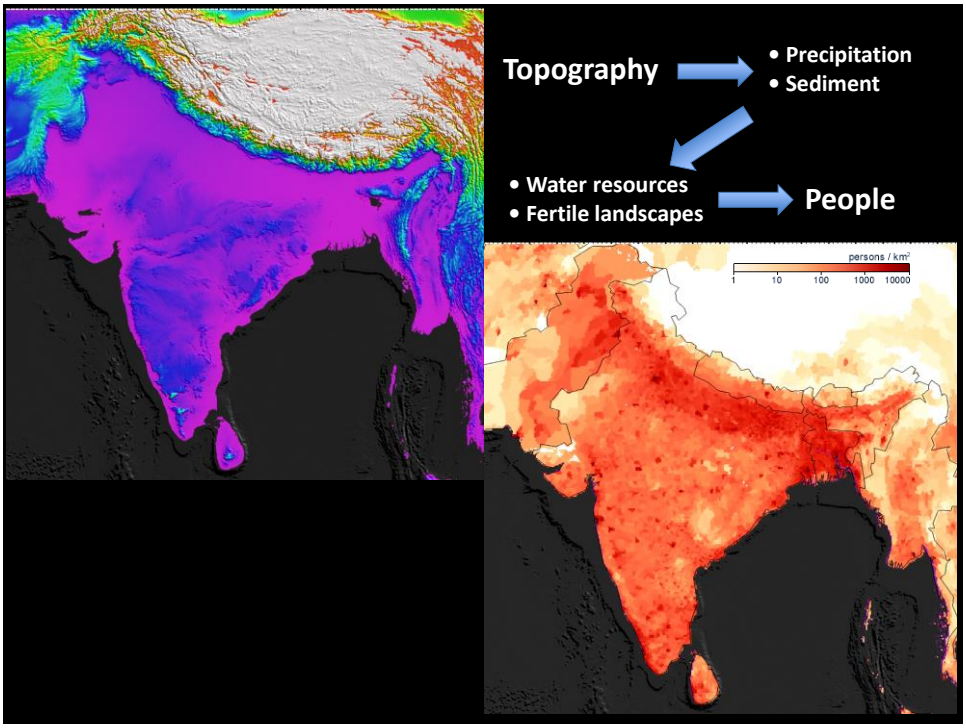
Sustainable Management of Deltas - a tour around a changing world 2014 DELTAS II Meeting, Rotterdam

Global Population Density

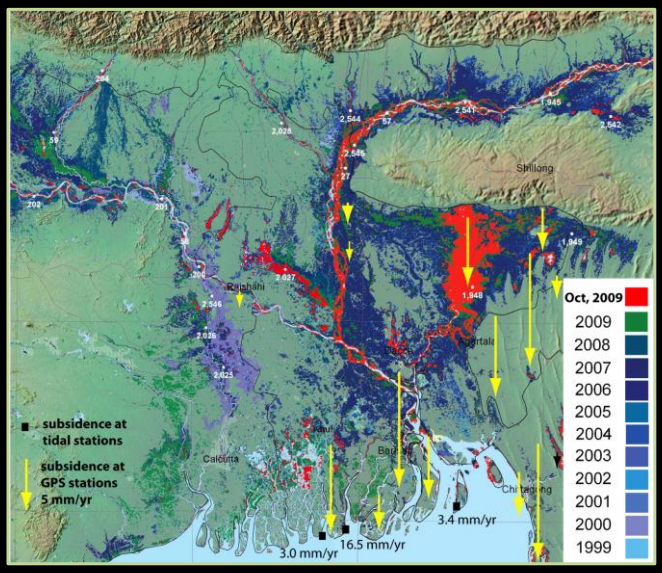
7,000,000,000 people on Earth …

41% live on just 9% of land in just 4 countries – China, India, Pakistan, and Bangladesh





HAZARDS ASSOCIATED WITH LIVING ON G-B DELTA:

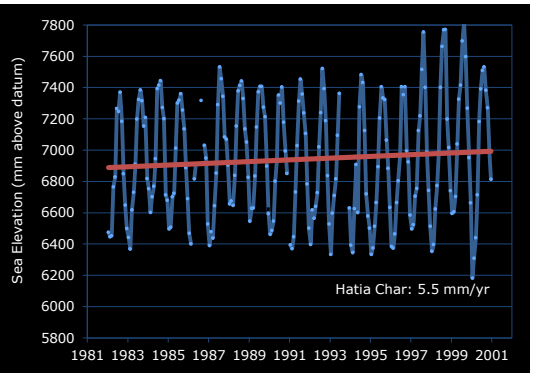


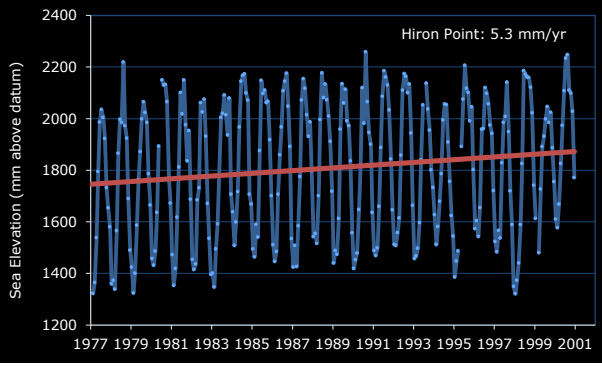
1) Earthquakes
2) Storms
3) Regular widespread flooding
4) Elevation loss due to tectonic deformation, lithospheric loading, compaction (groundwater extraction)

(by Irina Overeem using Colorado Flood Observatory data with GPS-based subsidence rates from Steckler)

Relative sea-level rise from tide-gauge records:

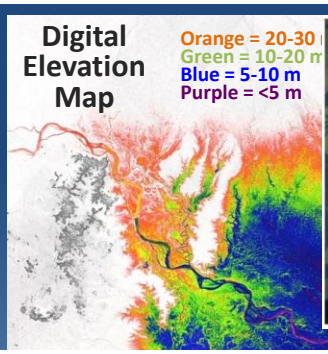
Typical rate = ~5.5 mm/yr





Digital Elevation Map

Orange = 20-30
Green = 10-20 m
Blue = 5-10 m
Purple = <5 m



"Scientists expect rising sea levels to submerge 17 percent of Bangladesh's land and displace 18 million people in the next 40 years." - NYT Article, *Borrowed Time on Disappearing Land* (March 2014)

"Environmental scientists have an important role to play in establishing environmental facts in order to identify practical, area-specific mitigation measures to counter realistically-probable impacts of sea-level rise in different geographical regions." – H. Brammer, *Climate Risk Management* (2014)

"Bangladesh is not helpless against coping with SLR, but it might need financial and technical assistance with providing practical mitigation measures. " – H. Brammer, *Climate Risk Management* (2014)

TALK OUTLINE:

- BASIN SCALE: The Whole Delta
- REGIONAL SCALE: The Deltaic System
- LOCAL SCALE: Living on the Delta

Basin-Scale Sediment Budget for the Ganges-Brahmaputra Delta

Sediment load: 1,100,000,000 t/yr

Delta area: 150,000 km^2

Bulk Density: 1.5 t/m^3

Potential basinwide accretion rate: ~5 mm/yr

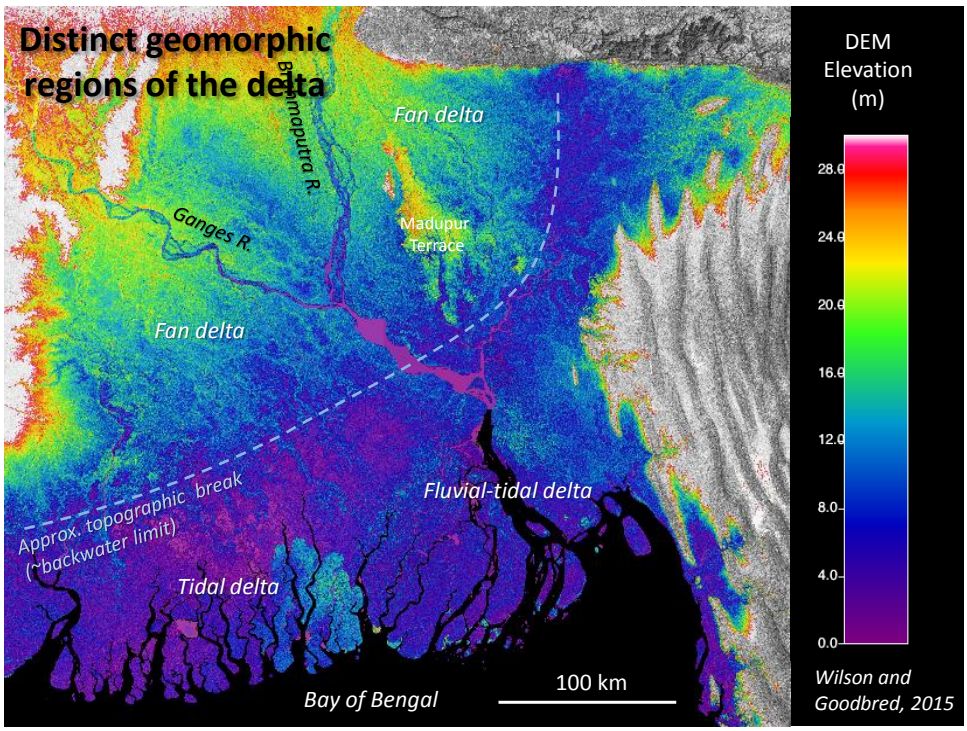
… averaged over actively accreting areas: >10 mm/yr

TALK OUTLINE:

✓ **BASIN SCALE: The Whole Delta**
- Relatively stable, robust → relatively low risk

→ **REGIONAL SCALE: The Deltaic System**

LOCAL SCALE: Living on the Delta



Regional-Scale Land Loss and Gain in the Ganges-Brahmaputra Delta

Net rate of change in delta surface area: +8 km²/yr

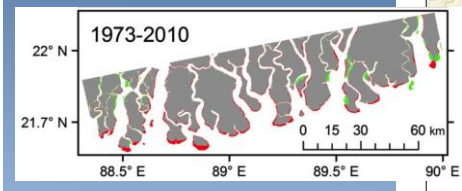
- over past ~200 yrs (Allison, 1998)
- cont'd through LANDSAT era (Rahman et al. 2011).

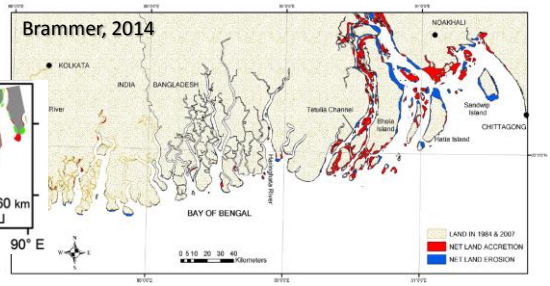
Mean rate comprises:

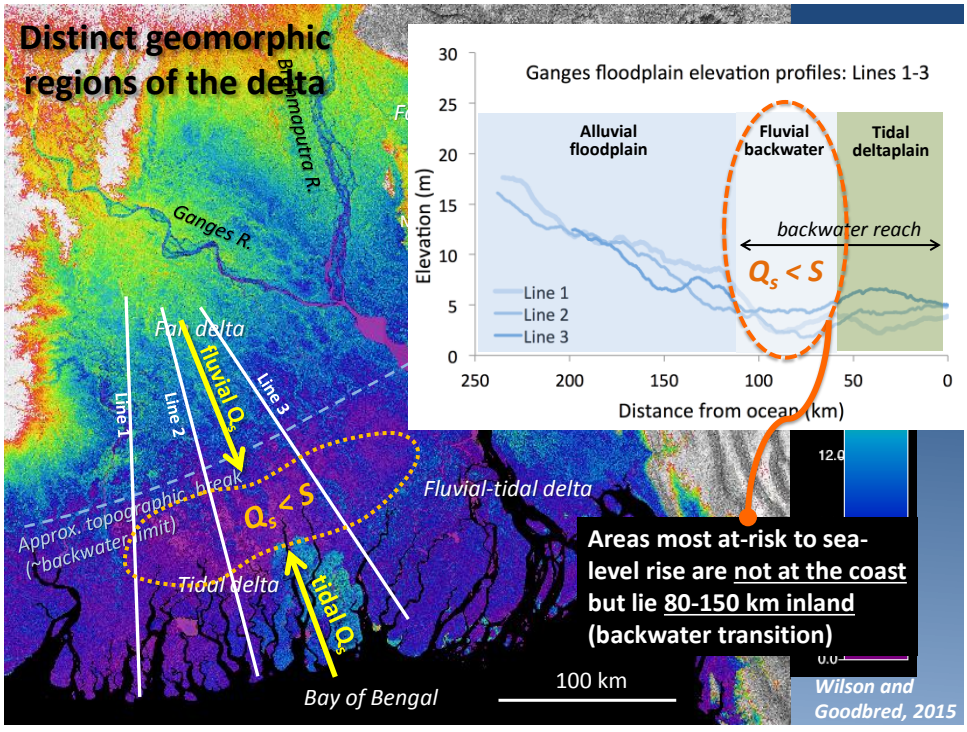
+12 km²/yr in active rivermouth estuary (+0.2% /yr gain - GOOD)

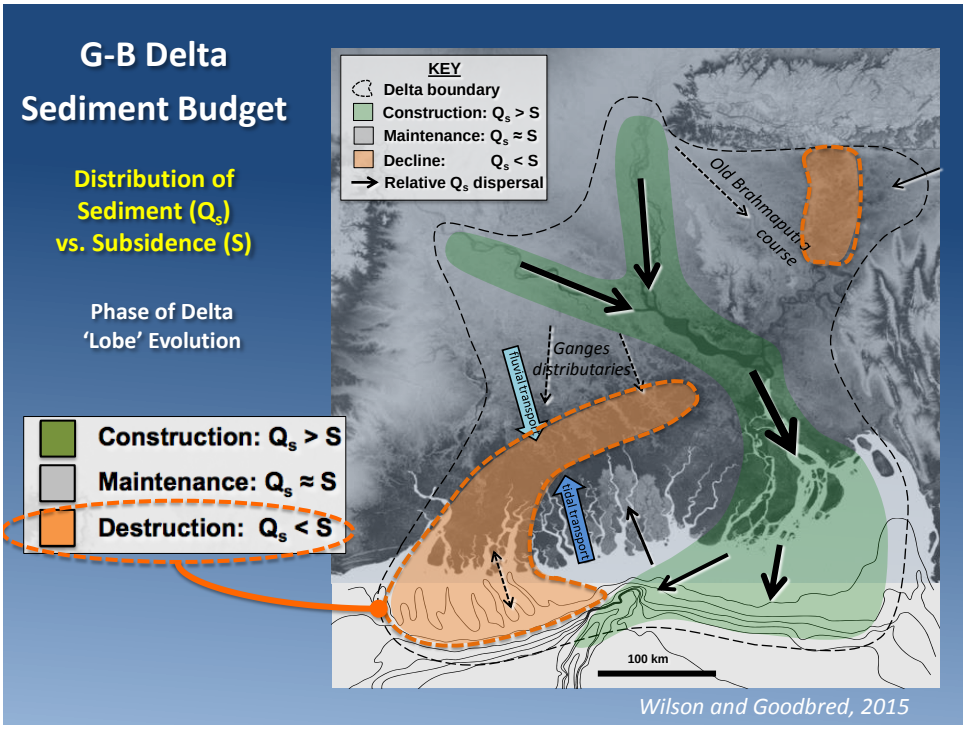
-4 km²/yr in western tidal delta plain (-0.04% /yr loss – NOT BAD)

Rahman et al. 2011







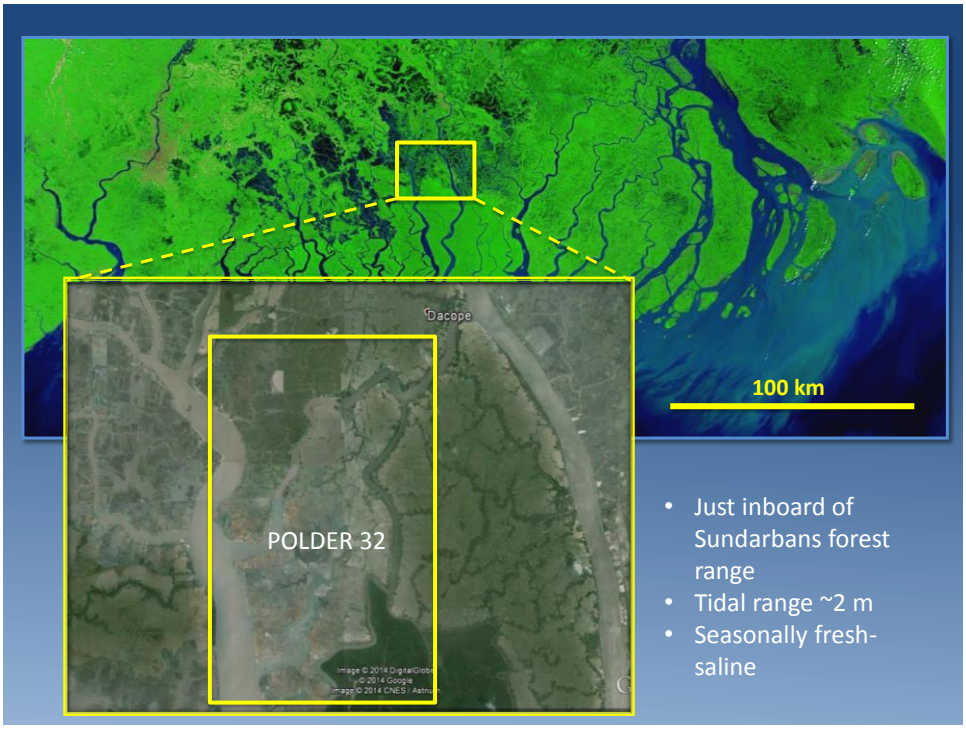


TALK OUTLINE:

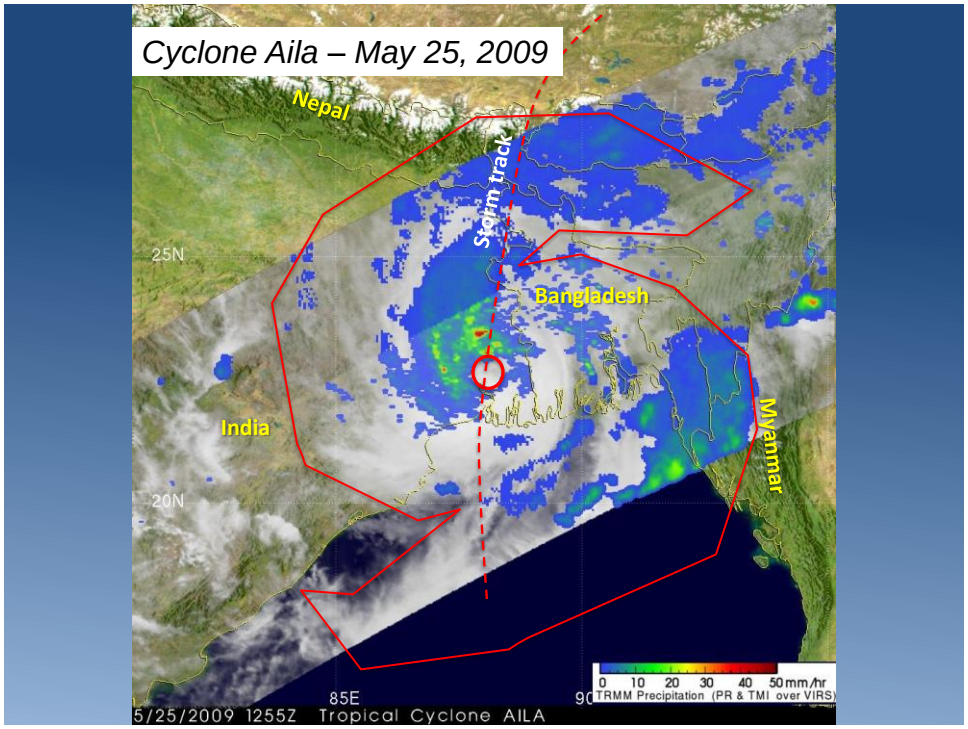
✓ **BASIN SCALE:** The Delta throughout the Holocene

✓ **REGIONAL SCALE:** The Deltaic System
- significant vulnerable areas

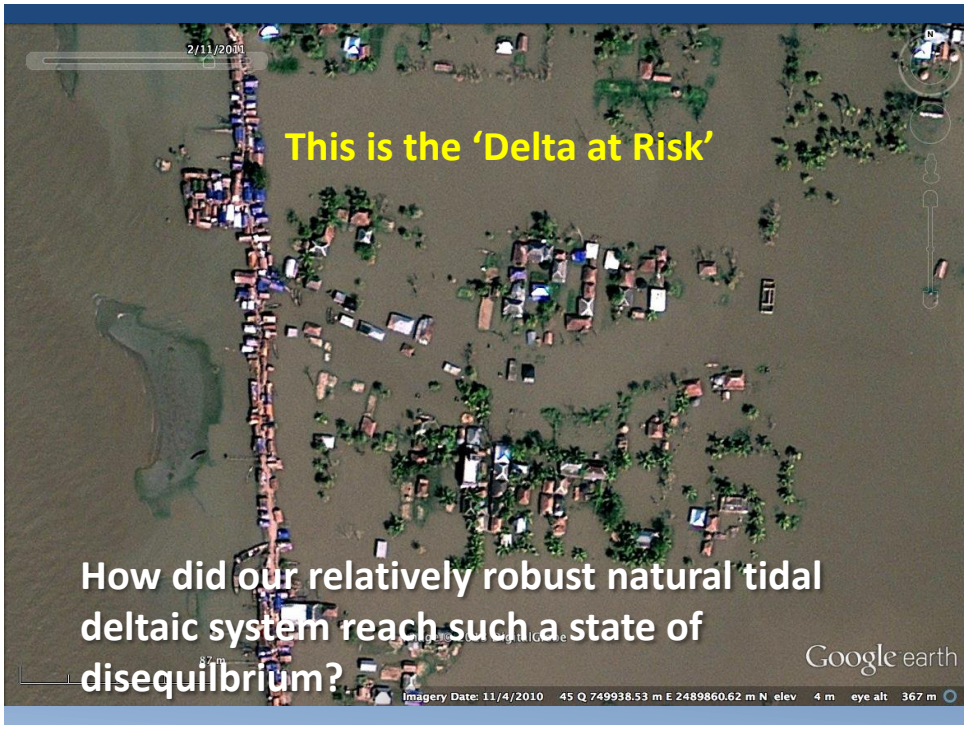
→ **LOCAL SCALE:** Living on the Delta

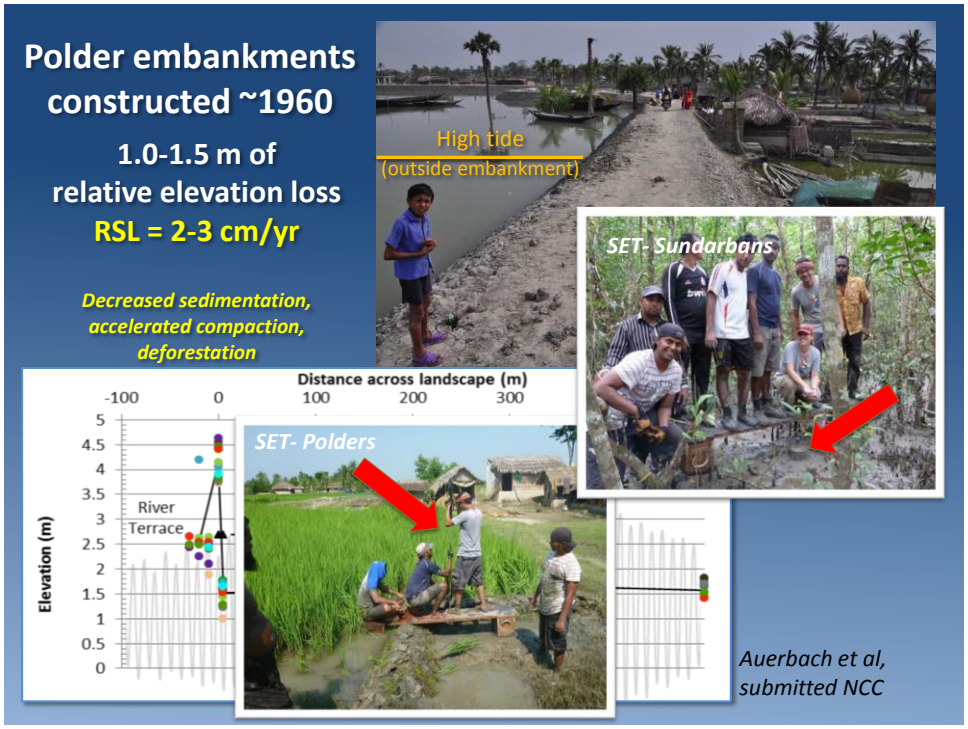


- Just inboard of Sundarbans forest range
- Tidal range ~2 m
- Seasonally fresh-saline


Cyclone Aila – May 25, 2009
Nepal
Storm track
25N
Bangladesh
India
Myanmar
20N
85E
0 10 20 30 40 50 mm/hr
TRMM Precipitation (PR & TMI over VIRS)
5/25/2009 1255Z Tropical Cyclone AILA

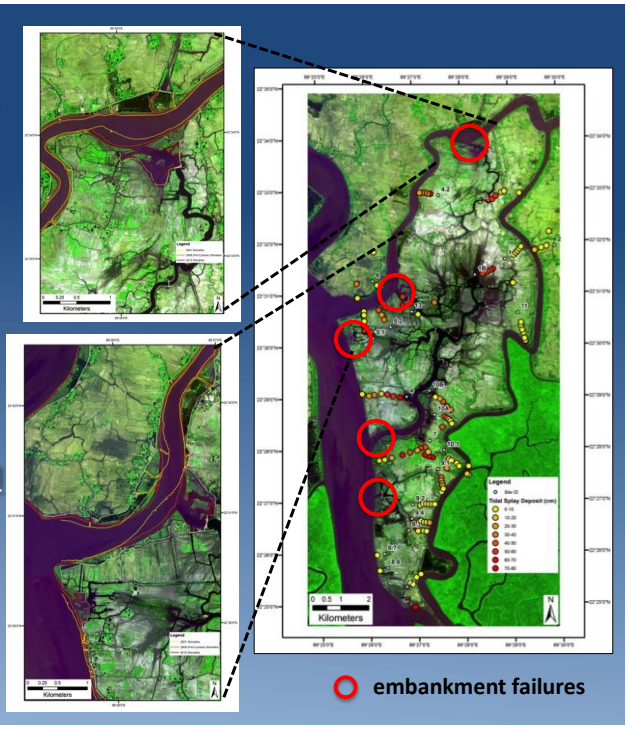

11/4/2010
2001
2013
04 Nov 2010—NOTE THIS IS 1.5 YEARS LATER!
• intertidal landscape for ~2 years following storm
• tidal inundation period ~10 hr/day
Image © 2013 DigitalGlobe
1691 m
Google earth
Imagery Date: 11/4/2010 45 Q 751195.64 m E 2494253.06 m N elev 5 m eye alt 7.30 km


2/11/2011
This is the 'Delta at Risk'
How did our relatively robust natural tidal deltaic system reach such a state of disequilbrium?
Google earth
Imagery Date: 11/4/2010 45 Q 749938.53 m E 2489860.62 m N elev 4 m eye alt 367 m


Polder embankments constructed ~1960
1.0-1.5 m of relative elevation loss
RSL = 2-3 cm/yr
Decreased sedimentation, accelerated compaction, deforestation
High tide
(outside embankment)
SET- Sundarbans
SET- Polders
Distance across landscape (m)
-100
0
100
200
300
Elevation (m)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
River Terrace
Auerbach et al, submitted NCC

Why did the embankments fail?

- breached at 5 locations
- all along major channels
- at former tidal channel outlets
- sites of recent channel bank migration

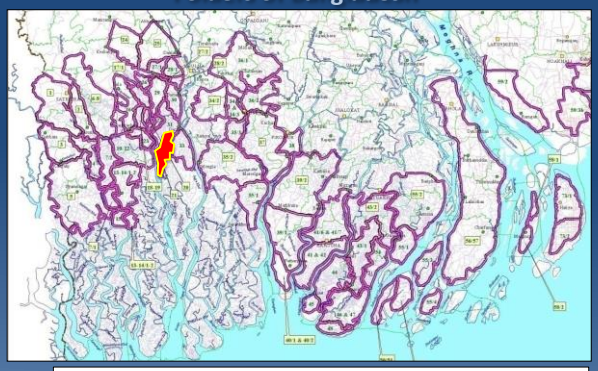


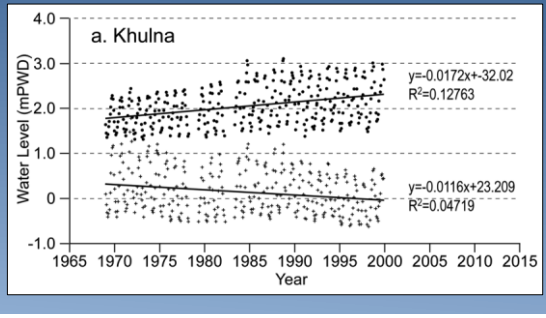
Auerbach et al, submitted NCC

Why are the channel banks (locally, rapidly) migrating?

Vast areas of formerly intertidal landscape have been embanked over past 50 years … correspondingly vast replumbing of the tidal transport system

Polders of Bangladesh



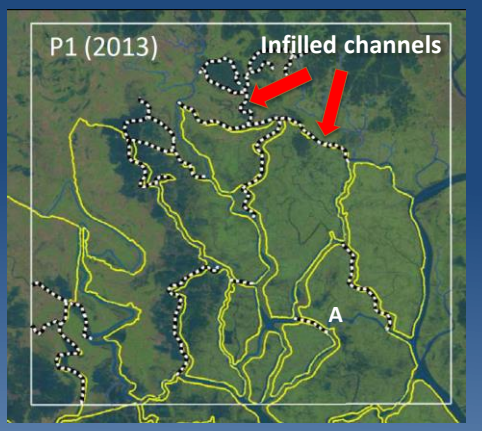


Tidal range amplification

Pethick, J. and Orford, J., 2013. Rapid rise in effective sea-level in southwest Bangladesh: its causes and contemporary rates. Global and Planetary Change.

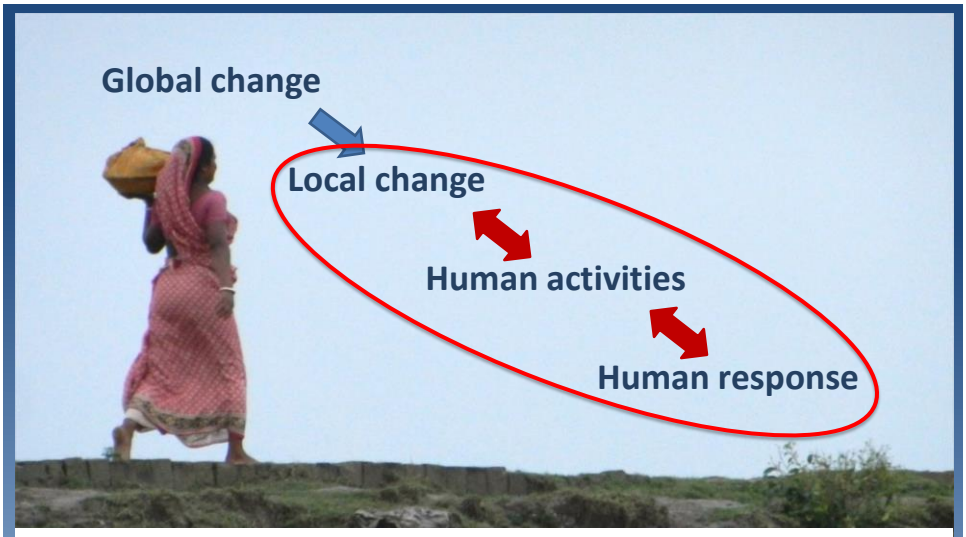
Anthropogenic reorganizing of the tidal channel network

- Direct human manipulation of channel system
- In 1200 km² area, loss of >100 km of tidal channel in 30 years



	1973	2003
Total channel length (km)	536	391
Infilled channel length (km)	0	106
Mean width of infilled channels (m)	276 ± 91	25 ± 11

Wilson et al., in prep

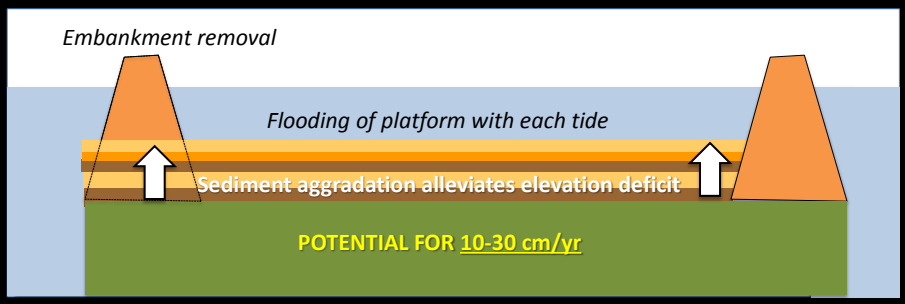


Cannot merely take into account how SLR is putting coastal communities at risk. Here, rates associated with human modification (accelerated subsidence, tidal amplification due to poldering, reorganization of tidal network) far outweigh rate SLR.

Despite facing many environmental challenges, there is enormous potential for sustainability of this delta system, particularly for elevation deficit recovery: "Tidal River Management" (similar to CRT operated by the Dutch)

Models to help determine feasibility of such ventures

Would require unprecedented cooperation between local landowners, govt officials,



TALK OUTLINE

INTRODUCTION: One point and a disclaimer

✓ UNIT SCALE: The Delta

✓ REGIONAL SCALE: The Deltaic System

✓ LOCAL SCALE: Living on the Delta
- many places already in crisis

TAKE-HOME MESSAGES:

- Risk for the G-B system is not at the delta scale
  … system vulnerabilities are at sub-delta scale
  (Disclaimer: viewpoint not with disregard to basin-scale threats and challenges)
- Within vulnerable areas of the delta, direct human manipulation of the environment is the principal stressor
- Crises are now … and they are occurring at the household level, at the community scale, in backyards (or tidal channels)
  → **it is the Human Delta Experience**
- would propose that we – the delta research community – broaden our concepts of, and enrich our dialogues for ***what, where, how, and why Deltas are at Risk***