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Analysis of sedimentation in the Guayas River at Guyaquil, Ecuador

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Guayas River

One of the world's large rivers?

**Not in size –
in importance**

Arctic Ocean
Greenland Sea
Kara Sea
Laptev Sea
Beaufort Sea
Baffin Bay
Barents Sea
East Siberian Sea
Norwegian Sea
Hudson Bay
Labrador Sea
Gulf of Alaska
North Sea
Sea of Okhotsk
Bering Sea
North Pacific Ocean
North Atlantic Ocean
Med. Sea
North Pacific Ocean
East China Sea
Gulf of Mexico
Caribbean Sea
Arabian Sea
Bay of Bengal
South China Sea
South Atlantic Ocean
Indian Ocean
Coral Sea
South Pacific Ocean
Tasman Sea
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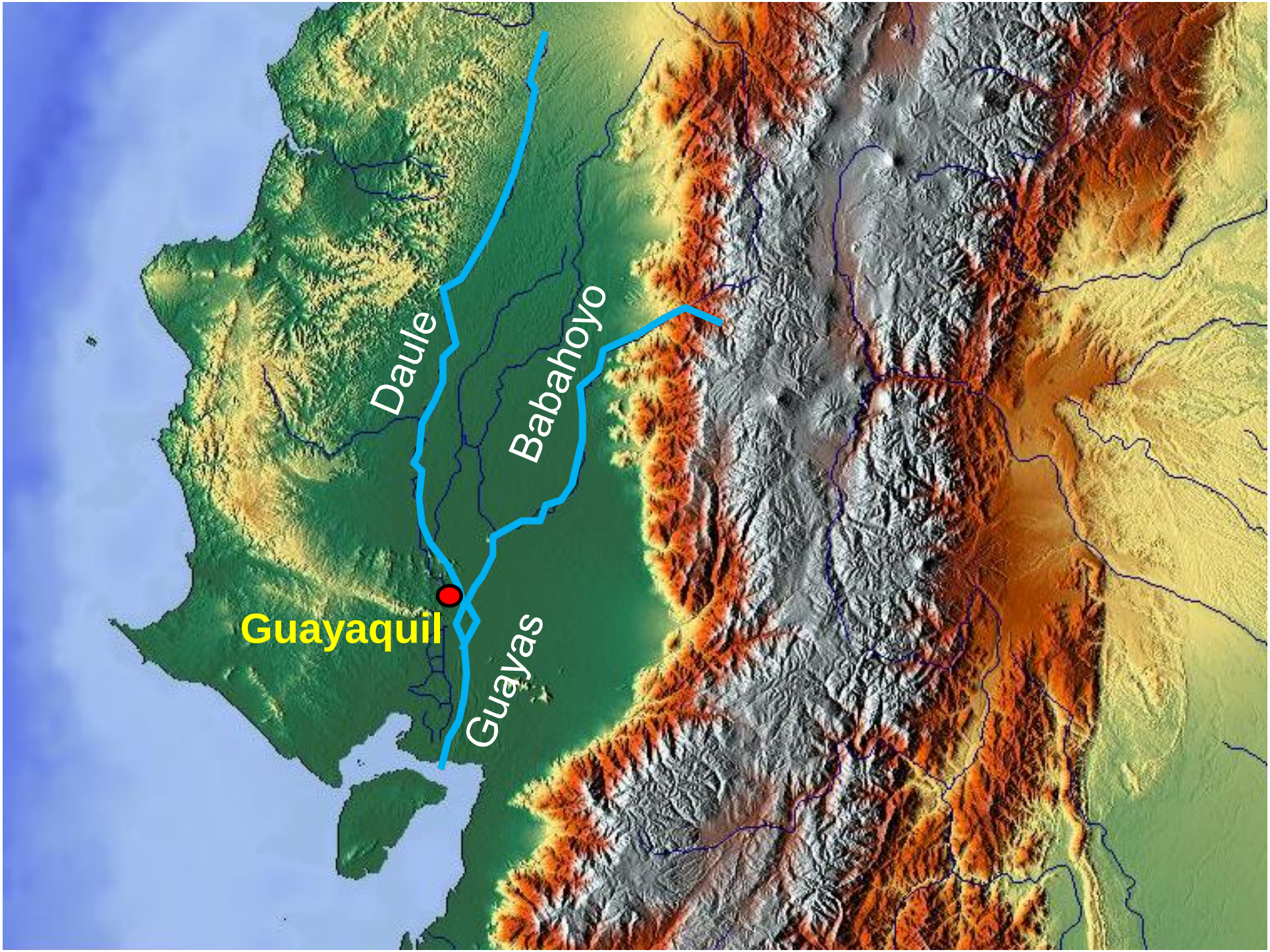
Daule
Babahoyo
Guayaquil
Guayas

Guayas River

- **River with largest estuary on the Pacific Coast of South America**

- **City of Guayaquil:**
  - main port of Ecuador

nature climate change

LETTERS

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Future flood losses in major coastal cities

Stephane Hallegatte[1,2]*, Colin Green[3], Robert J. Nicholls[4] and Jan Corfee-Morlot[5]

Flood exposure is increasing in coastal cities[1,2] owing to growing populations and assets, the changing climate[3], and subsidence[4–6]. Here we provide a quantification of present and future flood losses in the 136 largest coastal cities. Using a new database of urban protection and different assumptions on adaptation, we account for existing and future flood defences. Average global flood losses in 2005 are estimated to be approximately US$6 billion per year, increasing to US$52 billion by 2050 with projected socio-economic change alone. With climate change and subsidence, present protection will need to be upgraded to avoid unacceptable losses of US$1 trillion or more per year. Even if adaptation investments maintain constant flood probability, subsidence and sea-level rise will increase global flood losses to US$60–63 billion per year in 2050. To maintain present flood risk, adaptation will need to reduce flood probabilities below present values. In this case, the magnitude of losses when floods do occur would increase, often by more than 50%, making it critical to also prepare for larger disasters than we experience today. The analysis identifies the cities that seem most vulnerable to these trends, that is, where the largest increase in losses can be expected.

A first screening study[1] provided a global overview of flood exposure in world coastal cities. The exposure metric can be are better protected than poorer ones, and the ranking in terms of absolute flood losses contains more cities from developing countries. In relative terms, developing-country cities are even more vulnerable, with only three cities from developed countries in the top 20 (New Orleans, Miami and Tampa—Saint-Petersburg). Moreover the ranking in absolute terms (left column) includes mainly capital cities, whereas secondary cities are more often represented in the ranking in relative terms (right column). This difference suggests that risk management efforts may be lower in secondary cities.

Table 1 shows the importance of existing flood defences: in a city such as Amsterdam, exposure is extremely high (US$83 billion of assets exposed to the 100-year flood), but AAL do not exceed US$3 million, because estimated defence standards are the highest that exist globally. On the other hand, a city such as Ho Chi Minh, in Vietnam, has a 100 year exposure of only US$18 billion, but the lower level of protection means that the city is affected by small floods on a frequent basis, resulting in large estimated average costs. In relative terms, Ho Chi Minh City has one of the largest vulnerabilities, with AAL reaching 0.74% of local GDP. The ratio of AAL to local GDP exceeds 1% for two cities, Guangzhou and New Orleans. The vulnerability of New Orleans has been reduced however by recent post-Hurricane Katrina investments and is likely to be reduced further in the near future[9].

Guayas River

- **River with largest estuary on the Pacific Coast of South America**

- **City of Guayaquil:**
  - Main port of Ecuador
  - The planet's fourth most vulnerable city for future flooding due to climate change, after Guangzhou, Mumbai and Kolkata

Flooding and sedimentation

Problems interconnected but confused

Urban flooding:

- after heavy rainfall
- torrential streets due to hilly terrain and lack of infiltration and storage
- drainage congestion during high tide (tidal range of 4 m at the city)

Proposed flood barrier to keep high tides out

Feasible? Not a storm surge barrier!

Flooding and sedimentation

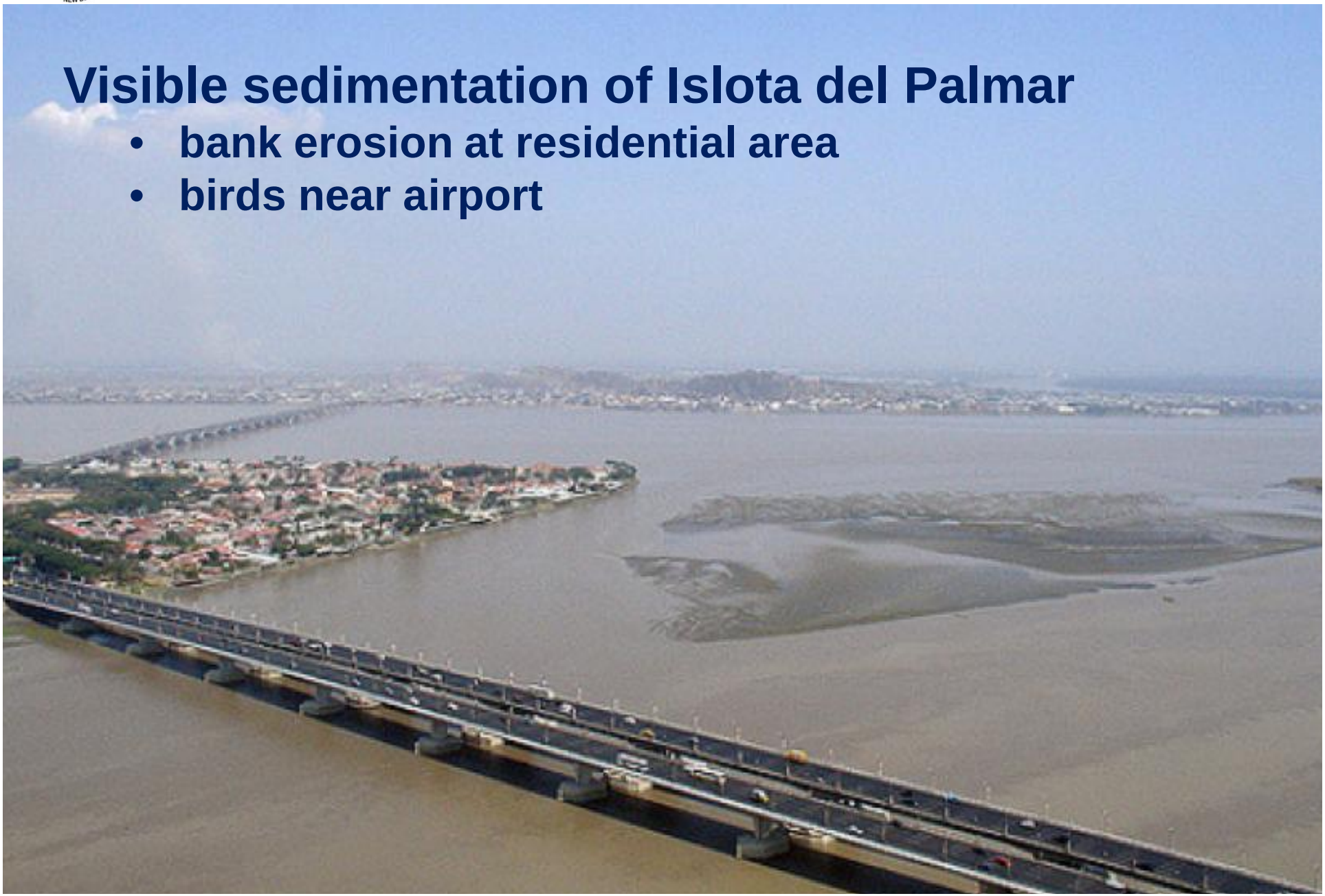
Problems interconnected but confused

Increased sedimentation:

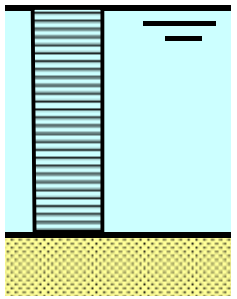
- Guayas river bed: increase of flood levels?
- Drinkwater inlet canals and wastewater and drainage outlet canals: costs for maintenance

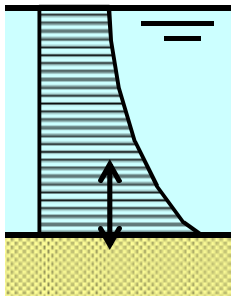
Visible sedimentation of Islota del Palmar

- bank erosion at residential area
- birds near airport



fine





washload

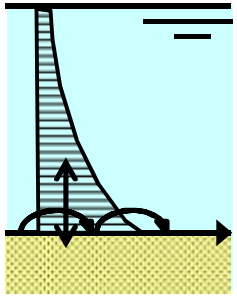
suspended transport

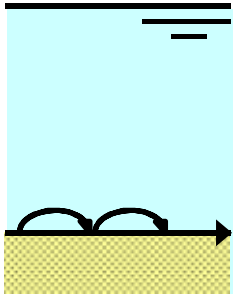
sediment transport (*classification based on origin*)

bed-material load

bedload transport

sediment transport (*classification based on mechanism*)





coarse

Local perception

All problems:

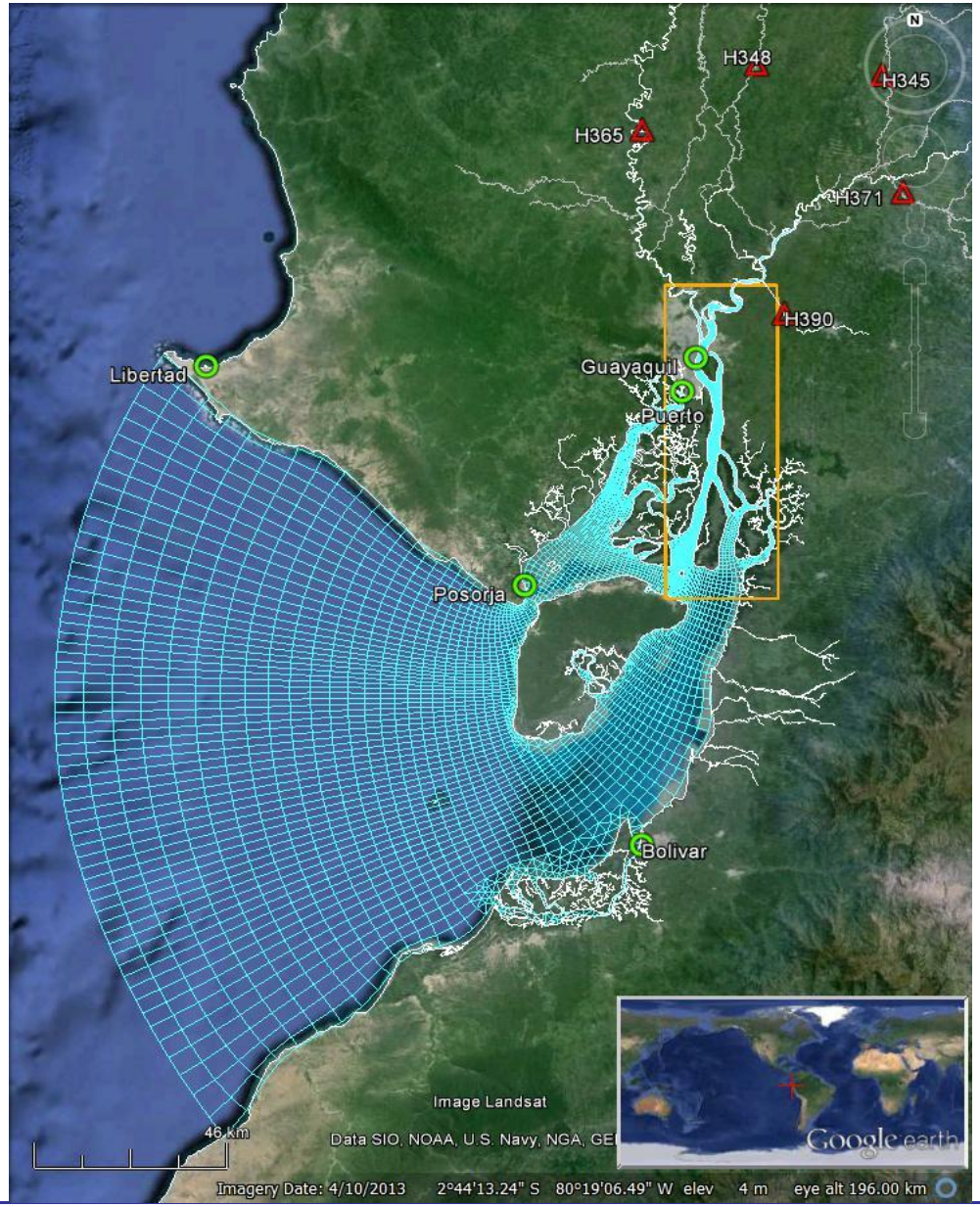
- caused by upstream deforestation
- will get worse by climate change

Our study

- Diagnosis of increased sedimentation in the Guayas river

Sedimentation of sand

- **Transport of sand depends primarily on hydrodynamics (unlike transport of fines)**
- **Increased sediment yield by deforestation in the catchment would be felt only after decades or centuries**
- **Mechanisms are studied in a hydrodynamic-morphodynamic model**



Numerical model using Delft3D Flexible Mesh

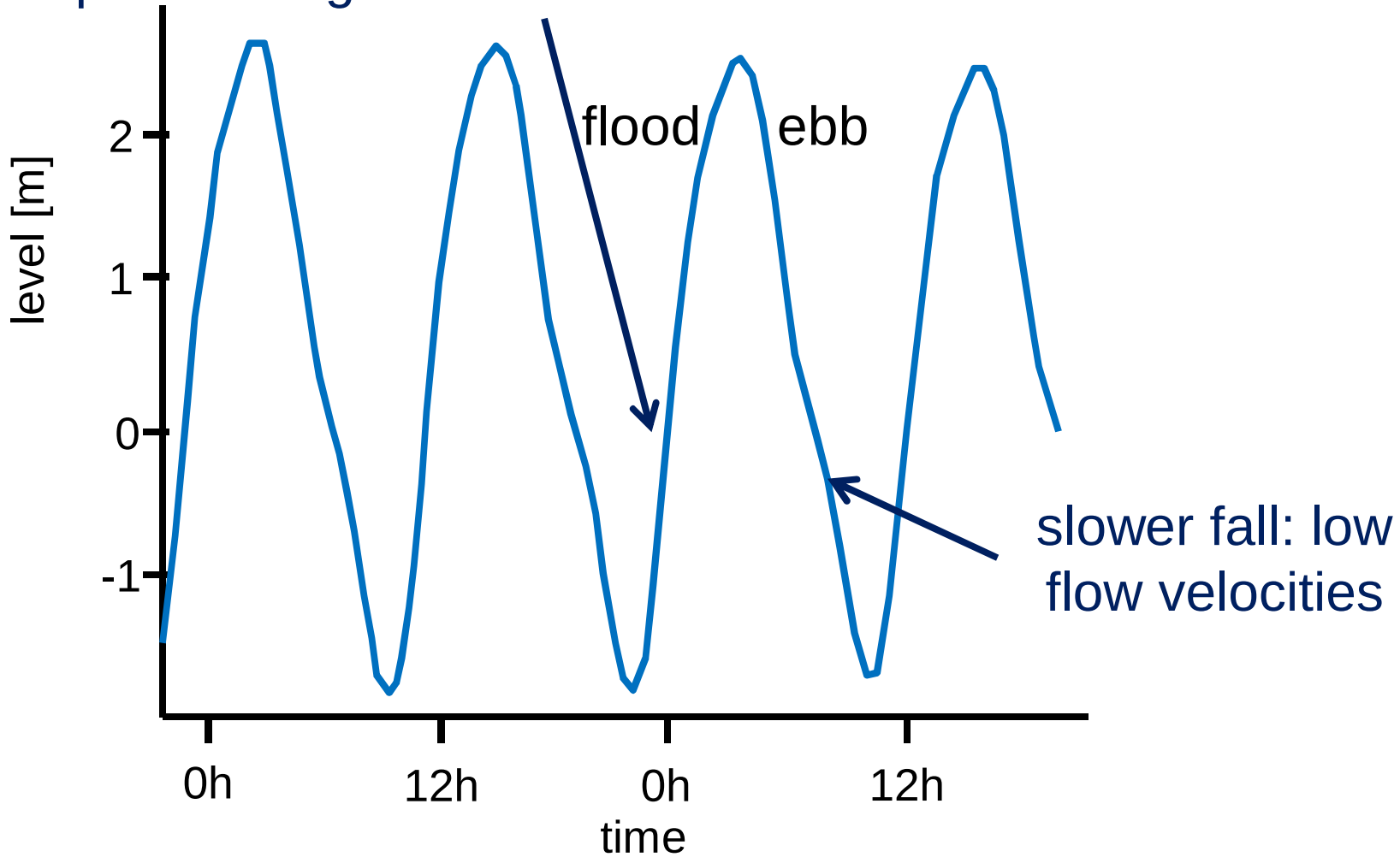
△ River gauge station

○ Tidal gauge station

Mosselman, Barrera Crespo, Becker, Ottevanger, Nabi, Giardino, de Keizer, Arias, Sanchez & Pazmiño Nelson

Tidal asymmetry at Guayaquil

Rapid rise: high flow velocities



Diagnosis

Import of sediment *from the ocean*, occasionally washed out by river floods

Sedimentation has increased by

- Increase of tidal asymmetry as a result of land reclamation in the estuary
- Decrease of episodic flushing by river floods due to upstream dam construction

Thanks