Coastal Cities in East-Asia: Climate-Change & Multihazards in an Evolving Landscape

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What I would like us to take home:

• Climate change SLR is a river and first “an upstream issue” (it is not only happening at the coastline)
• It will clog gravity-water pipes and create disconnected flooding in the city (cf. Christchurch)
• Earthquake-prone island arcs + typhoon + sea level-rise can transform a 2 to 3 m tsunami to a ~7 m wave
• It is not Vegas, what happens in the countryside does not stay in the countryside (wood debris)
• Increased urbanization needs to include the connected systems (human, eco and infra) to plan for resilience
Introduction: High-density & Large Coastal Urban Centers

Distribution of urban Population for cities >500k

Asia (56.6%)
Europe (10.2%)
N.Am. (12.9%)
S.Am. (8.1%)
Africa (10.7%)

Urban population density per country (2000 – 2010)

[1] Numerous cities, already below 0 m
The tip of the iceberg: cities already underwater

OSAKA

Osaka and climate change-driven hazards...
The tip of the iceberg: cities already underwater

0 m (already below sea-level today)
0 m (already below sea-level today)
Cities already underwater

0 m (already below sea-level today)
The tip of the iceberg: cities already underwater

- 0 m (already below sea-level today)
- + 0.1 m
- + 0.2 m
- + 0.3 m
- + 0.4 m
- + 0.5 m
- + 0.6 m
- + 0.7 m
- + 0.8 m
- + 0.9 m
- + 1 m
[2] Natural and Engineered waterways and pipes are the Trojan Horses
Storm surges of 2017 + 50 cm of SLR

Simulation of storm-surge progression in Osaka-bay with 50 cm extra SLR.
Increased SLR = increased base-level = lower energy
Slope in river channels = propagation of floods upstream

The same river surge generates higher water level as the water can’t leave the channel.

\[
\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = q + r
\]

\[
\frac{\partial (uh)}{\partial t} + \frac{\partial (hu^2)}{\partial x} + \frac{\partial (huv)}{\partial y} = -hg \frac{\partial H}{\partial x} - \frac{\tau_x}{\rho} + D^x
\]

\[
\frac{\partial (uh)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2)}{\partial y} = -hg \frac{\partial H}{\partial y} - \frac{\tau_y}{\rho} + D^y
\]

\[
\frac{\tau_x}{\rho} = C_f u \sqrt{u^2 + v^2} \quad \frac{\tau_y}{\rho} = C_f v \sqrt{u^2 + v^2}
\]

\[
D^x = \frac{\partial}{\partial x} \left[ v_t \frac{\partial (uh)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ v_t \frac{\partial (uh)}{\partial y} \right]
\]

\[
D^y = \frac{\partial}{\partial x} \left[ v_t \frac{\partial (vh)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ v_t \frac{\partial (vh)}{\partial y} \right]
\]
Any hard-evidences? Evidences from a “relative SLR”

Research done while in Christchurch in collaboration with Civil Engineers (S. Giovinazzi) and the Environmental and Geoscience Dept (D. Hart)
My apologies, I am not allowed to publicly share the data from the Water Co.s.

Hard to evacuate the water.
Earthquake issues in coastal areas

Rainfall:
- temporal variability & clustering
- spatial variability
- rainfall intensity
- surface water runoff
- surface infiltration

Land:
- elevations above sea level & river banks
- gradients, catchments, basins
- surface cover, permeability, vegetation, roughness
- geology, soil types, land mobility, erosion
- FMA category & building floor level standards

Natural channels:
- base flows & quick flows
- channel capacities: cross-sections, sedimentation
- channel bed profile, water surface profile
- bank/stoep bank integrity & elevations
- flood plain elevations, topography

Stormwater system built components:
- soakage pits, detention basins, wetlands
- grates, sumps, inlets, outlets, culverts, gates, bridges
- road & swale secondary flow paths
- pipe diameter, material, slope, depth
- gravity & pump systems

Groundwater:
- elevation above sea level
- water table surface slope
- depth below land surface
- pressure
- sea level responsiveness

Ocean:
- relative mean sea level
- estuary capacity & tidal prism
- extreme tides inundation zones
- storm surge reach
- potential tsunami inland reach

ENHANCING RESILIENCE BY ALTERING OUR APPROACH TO EARTHQUAKE AND FLOODING ASSESSMENT: MULTI-HAZARDS

Deirdre E. HART1, Sonia GIOVINAZZI1, Do-Seong BYUN2, Craig DAVIS4, Su Young KO5, Christopher GOMEZ2, Kerry HAWKE5, Derek TODD5
[3] Historical Evolution

= Hard to predict
Ground Acceleration
Liquefaction
Erosion
Historical evolution since the 1930s

Abandoned meander becomes cultivated land and then densely-packed “my house”.

Sea

1936

Engineered island from sand and silt pumping
Abandoned meander becomes cultivated land and then densely-packed "my house".

Engineered island from sand and silt pumping

Historical evolution since the 1930s

1947
Abandoned meander becomes cultivated land and then densely-packed "my house".

Sea

1965

Engineered island from sand and silt pumping
Abandoned meander becomes cultivated land and then densely-packed “my house”.

Engineered island from sand and silt pumping.
Abandoned meander becomes cultivated land and then densely-packed “my house”.

Engineered island from sand and silt pumping.
Abandoned meander becomes cultivated land and then densely-packed “my house”.

Engineered island from sand and silt pumping
[4] What occurs in the countryside ... does not stay in the countryside
Trapped between the hills and the sea
More than 545 mm of rainfall in 24 hours in Asakura-city.
(source: bousai.go.jp)

But how much “flew through” looking at the contribution to the hydrographs.

“What happens in Vegas does NOT only stay in Vegas”

Climate change and retreat from the countryside will see an increase in similar issue in Japan.

Climate change = new rainfall patterns
The 2017 Asakura heavy rainfall event
Paddy fields to forestry = driftwood hazards

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(10% error)
Mean 850 – 1050
Med. 800 – 900

= 8200 t. - 8900 t

(Tree data: Kanazaki Koichi)
Total area = about 24 ha
Mean density of 0.8 tree/m²
→ About 190,000 trees
→ i.e. about 160,000 tons to 200,000 tons of timber and branches have been displaced
The population decline is particularly severe in the countryside, as the Japanese regroups in cities, and mostly in the Kanto and Kansai areas.

... and although it is tempting to think that population transfer may occur from other countries in Asia, similar issues are rising in East Asia, and one should not count on those countries to bridge the population gap, especially in a slowing economy (Japan won’t have the shine it enjoys today).
Further issues will ensue

Dooh... I ate all the sweet part already...
Conclusion and Research needs
Thank you for your attention
Abstract: Coastal Cities in East-Asia: Climate-Change & Multihazards in an Evolving Landscape Abstract: Cities, the hearts of our contemporary political and economic systems, have developed in the vicinities of waterways and low-lying coastlines, and the tools of economic prosperity are exactly what also makes them weak in the face of climate change: Assets’ concentration, polarization and connectedness.

In Japan, the major port cities and economic centers - namely Osaka, Nagoya, Tokyo - are already partly underneath the waterline, and upon closer examination, stormwater pipes and roads designed as secondary waterways may even further increase the flooding impacts. A coastal flood is not a coast problem in a city, it is the successive disqualification of networks generating systemic collapses. In Christchurch, New Zealand, the 2011 earthquake brought the land down to 1 m lower in the coastal areas of the city, generating a rapid relative sea-level rise, and those issues were investigated, revealing several Achilles heels, both structurally and socially.

By polarizing their surroundings, cities have emptied the countryside, which has become the source of “new hazards” such as climate-change-related landslides, debris flows and floated wood debris. And because what happens in the countryside does not stay in the countryside, the lack of manpower, management and transformative spaces are creating new risks for the cities, as the North Kyushu (2017) wood debris and flood crisis revealed. Depreciated rural areas were transformed in a field of landslides and debris-flows that played as ammunition went to plunder downstream waterways, cities and coastal economic systems (oyster farms, etc.).

Furthermore, most of East-Asian coastlines are facing a combination of hazards: “multihazards”, and in spite of rising awareness, this remains largely unaddressed, with for instance the city of Nishinomiya showing potential landslides that can invade waterways, but flooding mapping not taking into account those landslides. Similar issues lie with tsunami or storm surges. And because these issue often affect lifelines and communication networks, it is an open-door for domino effects.

These issues are a recurrent problem in our strategies against climate change, because of the way we are educated in academic silos, because of the way natural hazard science relies on statistical data, and because of the way laws and economic rules are set in a time, which can make them obsolete the very next day. The ageing population in Japan was to be foreseen but it is one of the fast growing weakness of the country facing climate change natural hazards. Ageing problem further emphasized by the transfers of populations to cities reducing cultural capitals, essentials for increased resilience (e.g. in the Mentawai Islands of Sumatra).