To mitigate, or not to mitigate, that is not the question: reducing risk to coastal cities from sea-level rise.

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1. Motivation

The implication of meeting the Paris Accord objectives (holding global average temperatures to 2 °C and pursuing efforts towards 1.5 °C above pre-industrial levels) is that strong, deep mitigation of emissions must occur as quickly as possible (Millar et al. 2017). By doing so, the risk of climate-change related damage is likely to be reduced but by how much? For sea-level change, the strength of mitigation and its associated emissions pathway is critically important as this will directly affect the level of exposure and risk in the coastal zone. We compare probabilistic, relative, regional sea-level projections in 2070 in line with temperature scenarios for 1.5 °C (Paris) and ~4 °C (high-end) above pre-industrial levels by 2100 and estimate the associated economic losses for 136 coastal cities. The scale of damages increases dramatically for the high-end scenario making it patently clear that the success of the Paris Accord is paramount to future coastal development.

2. Method of projecting regional sea-level

Regional sea-level (RSL) change is the sum of a set of components, that alter both ocean volume and mass: STR, globally steric sea-level; DSL, dynamic sea-level; GLA, glaciers; LAN, land-water storage; GRE, Greenland ice sheet; ANT, Antarctic ice sheet; GIA, glacial isostatic adjustment.

$$RSL(\theta,\varphi,t) = STR(t) + DSL(\theta,\varphi,t) + GLA(\theta,\varphi,t) + GRE(\theta,\varphi,t) + ANT(\theta,\varphi,t) + LAN(\theta,\varphi,t) + GIA(\theta,\varphi,t)$$

We make probabilistic projections adhering to the ambitious 1.5 °C scenario implied by the Paris Agreement (Jackson et al. 2018) and High-end scenario based upon RCP 8.5 but including wider uncertainties for the ice sheet contribution based upon expert elicitation (Jackson & Jevrejeva, 2016; Bamber & Aspinall, 2013 [BA13]) where Figure 1 shows the probability distributions GSL for each scenario.

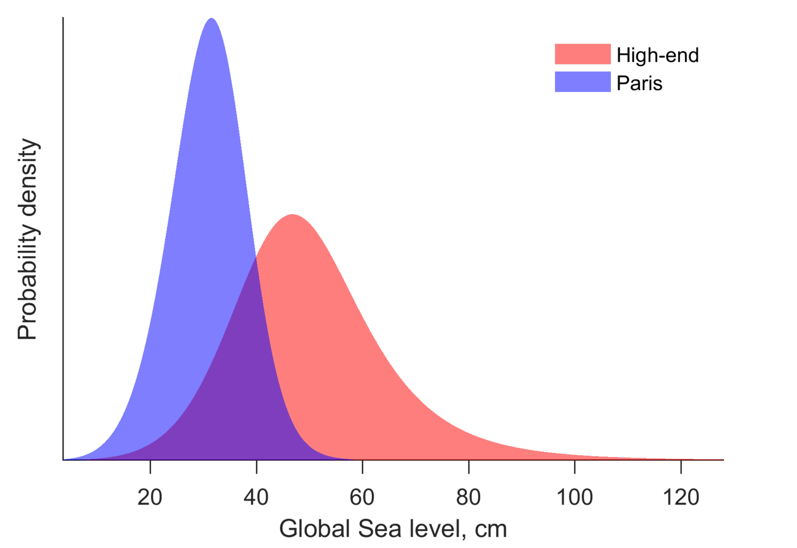

Figure 1: Probability distribution of global sea-level projection in 2070 for Paris (1.5 °C) and High-end (RCP8.5 + BA13) scenarios.

3. Estimating damages: statistical model of RSL

We use a stochastic diffusion model to statistically model the process-based RSL projections at each 10 year time slice, for each city, and scenario (Abadie et al. 2017),

$$dS_t = \alpha(t)S_t dt + \sigma(t)S_t dW_t$$

where S_t, RSL at time t; α(t), drift; σ(t), volatility; $dW_t = \varepsilon(t)\sqrt{dt}$, increment of a Weiner process; which generates a log-normal distribution at any time, t, that fits 50th and 95th percentiles of city-based RSL projection.

4. Estimating damages: utilising the damage function

We use projections of city-level socio-economic development (Hallegatte et al. 2013) to estimate damages across the probability distribution of projected RSL. The damage function is composed of two parts: first, due purely to socio-economic development (no sea-level rise, Figure 2) and second, additional damages purely due to sea-level rise and 1-in-100 year flood event (which is implicit in Hallegatte et al. 2013's damages-by-elevation), where no adaptation occurs.

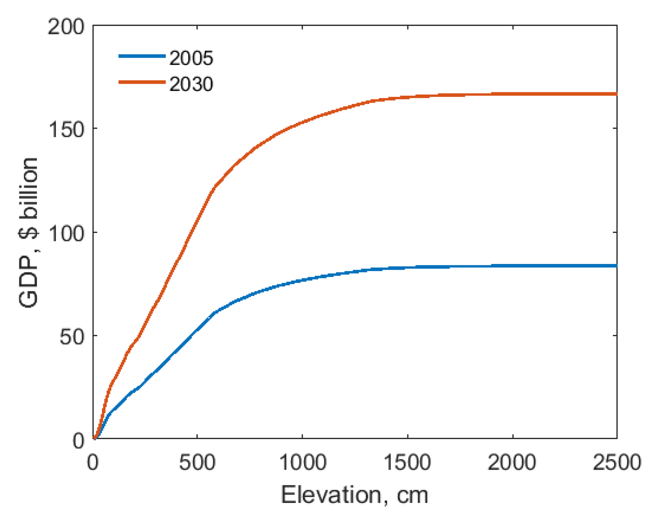

Figure 2: Distribution of assets by elevation for Rotterdam for 2005 and 2030 (Hallegatte et al. 2013)

5. Regional projections and associated damages

We project RSL change to give probabilistic estimates of future sea-level change (e.g. 2070, Figure 3). While patterns are similar, their magnitude clearly differs with GSL differences of 16 cm and 48 cm for median and 95th percentile (Figure 3e,f). GSL at the 95th percentile of the Paris scenario (43 cm) and 50th of the High-end (48 cm) do not overlap illustrating the net benefit of mitigation upon future sea-level rise. The effect of Antarctica is distinguishable, characterised by enhanced RSL rise north of -40°S for High-end scenario at the 95th percentile (Figure 3d).

City-level damages vary widely (Figure 3). Net damages fall significantly under the Paris scenario and especially at 95th percentile (Table 1). Cities in South-east Asia are particularly vulnerable (e.g. Guangzhou, Mubai).

	Paris scenario		High-end	
Losses, $billion	Median	95th	Median	95th
>1000	5	11	14	22
>400	14	20	27	42
>100	34	47	51	63
>40	52	58	64	80

Table 1: Number of cities experiencing losses under median and 95th percentile, Paris and High-end scenarios.

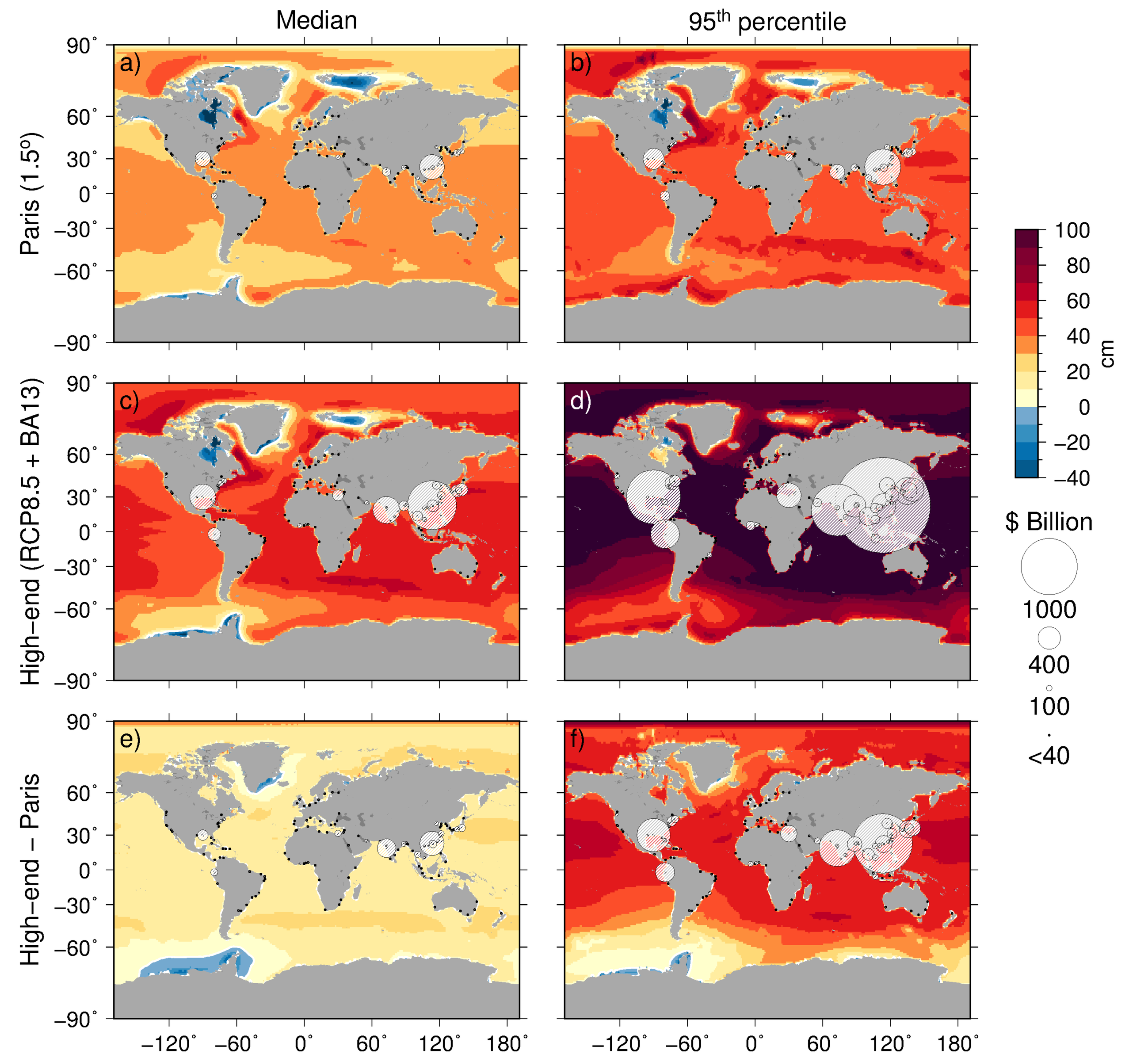

Figure 3: RSL projections and city-damages (circles) in 2070 (relative to 1986-2005) for (a,b) 1.5 °C Paris scenario, (c,d) High-end scenario and (e,f) their difference for median (left) and 95th percentile (right).

6. Per-capita damages [$(t)/population(t)]

Population-growth and distribution-by-elevation impact damages per-capita.

For top ten cities, costs for High-end are nearly double those under Paris scenario for median (Figure 4), while costs triple for 95th percentile (Figure 5) RSL projection.

The range of damages (for bulk of cities, grey) widens under High-end, especially 95th percentile.

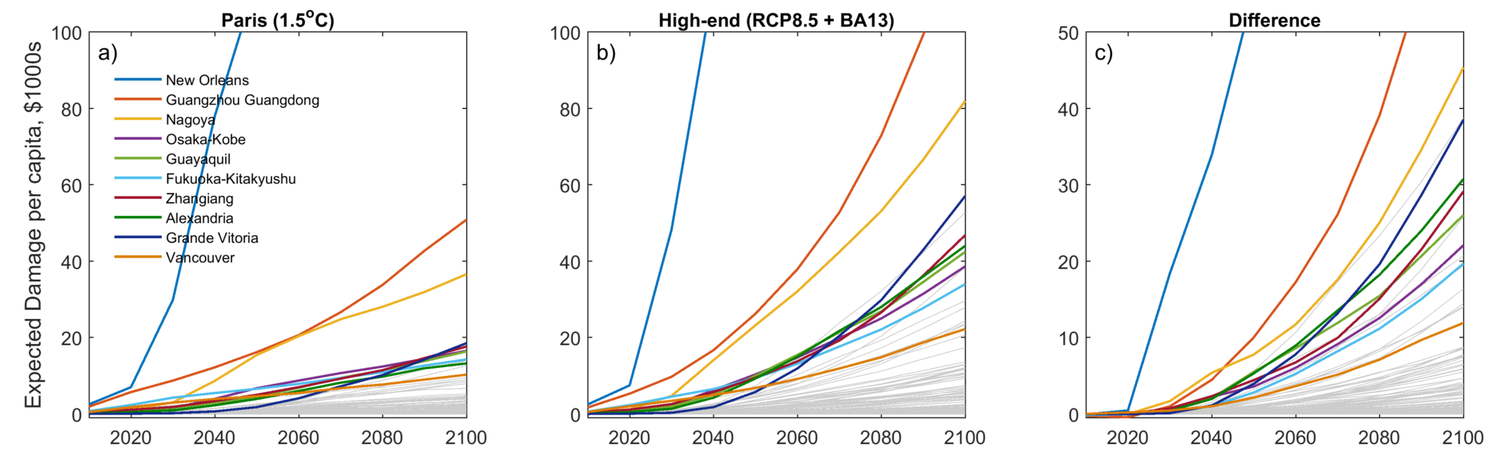

Figure 4: (Expected) damages per-capita for each city due to median projected RSL for (a) Paris and (b) High-end scenarios, and (c) their difference.

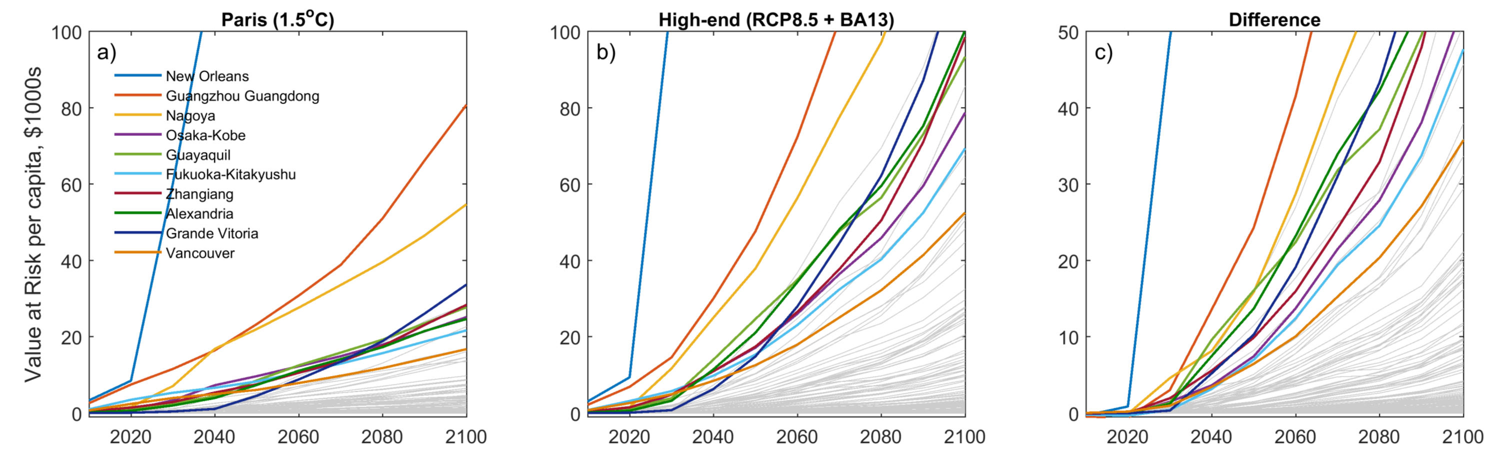

Figure 5: (Value at Risk) damages per-capita due to 95th percentile projected RSL for (a) Paris and (b) High-end scenarios, and (c) their difference.

7. Open questions

- How can we incorporate subsidence into analysis in meaningful way?
- How does the dependent structure of the sea-level components affect projections and their uncertainty? (See Le Bars, 2018)
- How much do losses by when adapting to retain present flood frequency?

8. References

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EDF Environmental Defense Fund — Finding the ways that work
National Oceanography Centre — Natural Environment Research Council
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