Climate change adaptation at city scale

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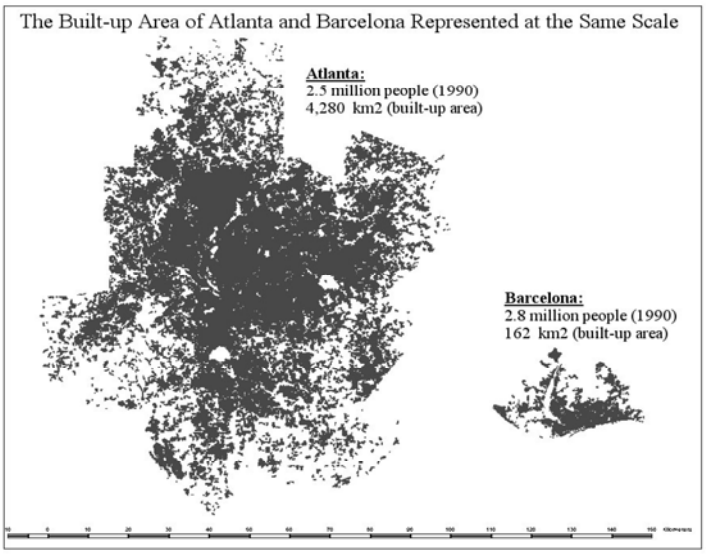
Adapting cities leads to specific issues

- **Urban forms cannot change rapidly, so we already need to take into account current and future constraints**
  - **Unprecedented need to anticipate future constraints and objectives**
- **Urban forms matter for greenhouse gas emissions**
- **Urban forms matter for climate-change vulnerability**
- **Urban forms matter for many other policy objectives, e.g., related to social and spatial inequalities.**
- **We have to cope with an unavoidable uncertainty on future emission targets and future local climates**
  - **Unprecedented decision-making issues**

Urban forms matter for greenhouse gas emissions…



Lower emissions in Barcelona because of:

1 - Shorter travel distance;

2 – Easier use of public transport:

Barcelona has 99 km of metro line.

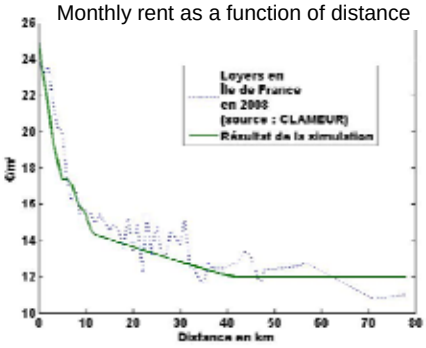
To provide the same accessibility to metro in Atlanta, 3400 km would be necessary.

Source: Alain Bertaud

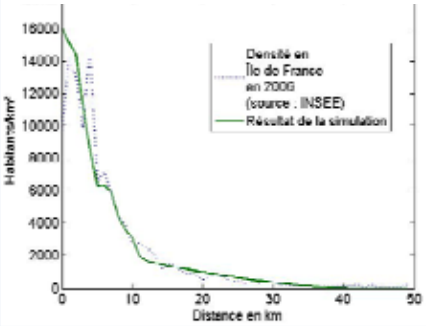
… but we can do something about it

- We developed an urban-economy model of the Paris agglomeration,
- Validated over the 1985-2008 period.

Monthly rent as a function of distance



Inhabitant density as a function of distance



Viguié and Hallegatte (2010)

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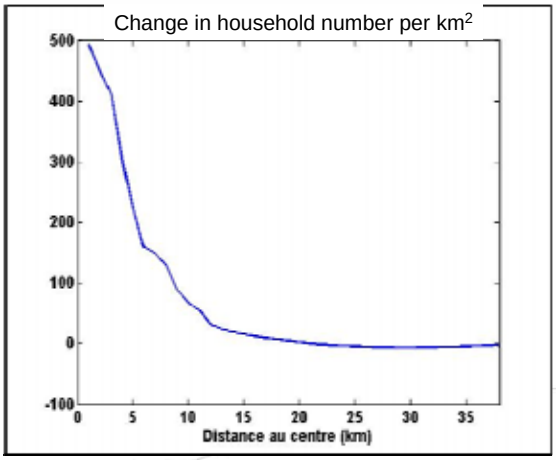
Consequence of a 100€/tC carbon tax on inhabitant density in Paris



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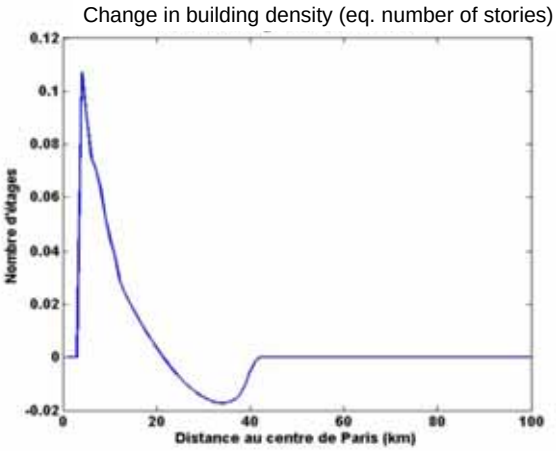
Consequence of a 100€/tC carbon tax on building height

Long-term result: a 1.1 km reduction in the average commuting distance (-8%)

What is long-term?

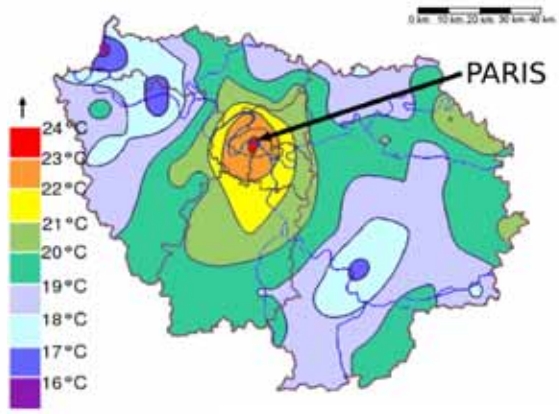


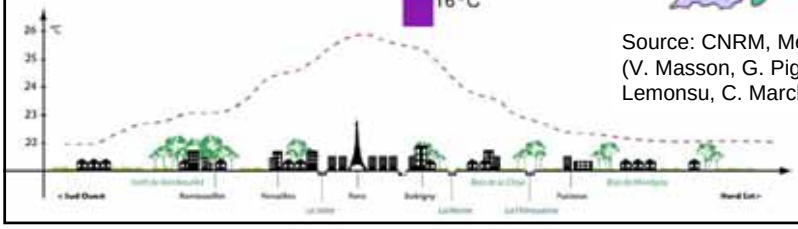
Viguié and Hallegatte (2010)

Urban forms matter for climate-change vulnerability…

Temperatures are higher in cities than in rural areas, especially at night.

Example of the 2003 heat wave.

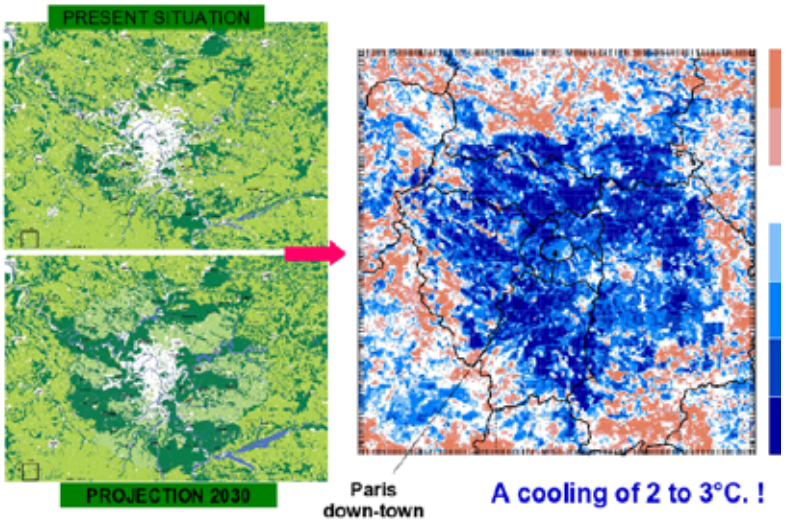




Source: CNRM, Météo-France (V. Masson, G. Pigeon, A. Lemonsu, C. Marchadier)

… but we can do something about it

Assuming the implementation of specific measures to limit the urban heat island.



Source: CNRM, Météo-France (V. Masson, G. Pigeon, A. Lemonsu, C. Marchadier)

Examples of trade-offs in urban policies in Paris

- **Higher density promoted by higher transportation costs, differentiated land-use taxes, and other land-use policies:**
  - Lower transportation demand and lower cost of public transportation (benefits in terms of energy consumption and carbon emissions);
  - Larger heat island effect (losses in terms of climate vulnerability);
  - Possible new developments in flood-prone areas (loss in terms of climate vulnerability);
  - Higher land prices close to city center, smaller housing surface, and more difficulty for modest households to access to decent housing;
  - Strong impact on poor households who decided to live far from Paris Center to capture lower rents and land prices;
  - **Bad "image" of high-density buildings**, mainly built in poor suburbs in the 70's.

Examples of trade-offs in urban policies in Paris

- **More resilient buildings, promoted by stricter construction norms:**
  - Lower energy consumption and carbon emissions;
  - Lower vulnerability to heat waves, and possibly floods;
  - Higher construction costs and higher rents (or flat prices), smaller housing surface and more difficulty for modest households to access to decent housing;
  - Transformation of the city of Paris – **Patrimonial and cultural issues.**
- **Introduction of additional parks and vegetation:**
  - Lower housing density, if buildings are not modified, and larger transportation needs;
  - Higher land prices, smaller housing surface, and more difficulty for modest households to access to decent housing;
  - Amenities from parks and vegetation;
  - Weaker urban heat island and higher resilience to heat waves and heavy precipitations (but not quantified precisely yet…)
- **Many of the consequences of these policies are non-market impacts.**

Coastal cities, climate change vulnerability, and adaptation

Case studies on Copenhagen and Mumbai

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An OECD project lead by Jan Corfee-Morlot,

Work also done by Nicola Ranger (Copenhagen, Mumbai), Olivier Mestre (Copenhagen), Patrice Dumas (Copenhagen, Mumbai), Celine Herweijer (Copenhagen, Mumbai), Robert Muir-Wood (Copenhagen, Mumbai), Murthy Bachu (Mumbai), Satya Priya (Mumbai); K. Dhore (Mumbai), Farhat Rafique (Mumbai), P. Mathur (Mumbai), Nicolas Naville (Mumbai), Fanny Henriet (Mumbai)

A specific approach

- Large cities are considered as one of the largest **global** vulnerability
- But city vulnerability depends on very **local** specificities (local climate statistics, topography, building characteristics, etc.)
  - Can we say something at the global scale?
  - **Combination of a global analysis and several case studies**
- City vulnerability depends not only on physical vulnerability (e.g., population and asset exposed), but also on social and economic resilience:
  - Can we take into account and model differences in resilience?
  - Can we design adaptation strategies that act on resilience (and not on physical vulnerability?)
  - **Each case study does not stop at physical vulnerability but includes economic modeling.**

Copenhagen

- High income country
- High quality housing
- Low vulnerability
- High resilience

- Focus on high sea level events and global sea level rise.

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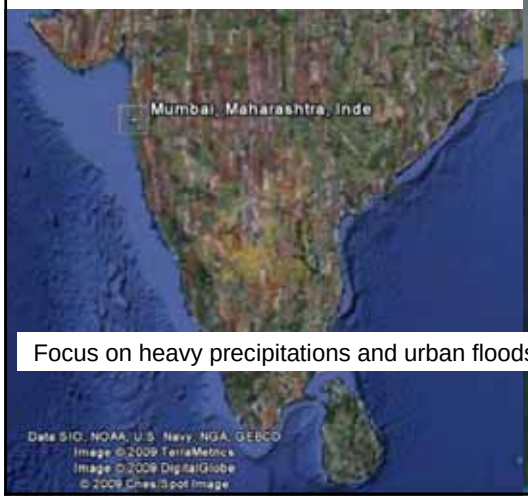
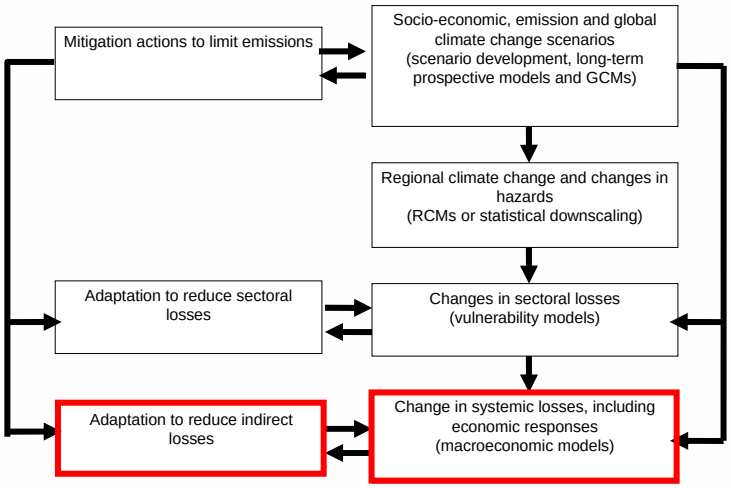
Mumbai

- Low income country
- Very low quality housing (50% slum)
- High vulnerability (insufficient drainage infra.)
- Resilience?



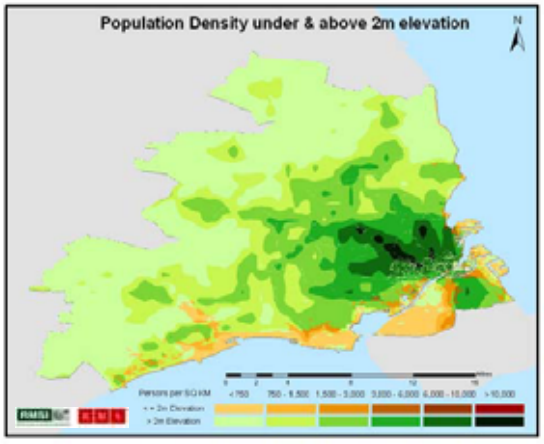
Focus on heavy precipitations and urban floods.

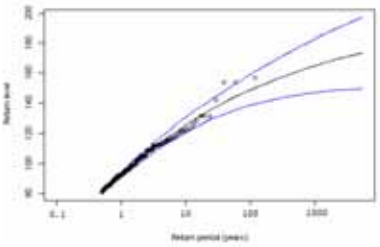
A methodology including resilience



Coastal flood risks in Copenhagen

- Combine information on high sea level event in the last 122 years
- With GIS information on population and asset density, and elevation



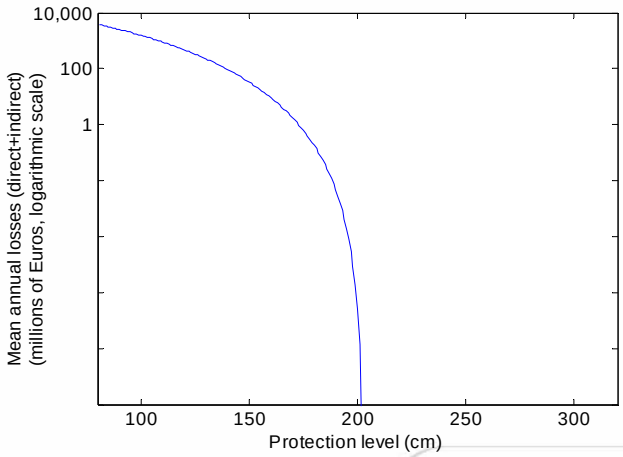


Some important areas in Copenhagen are exposed today to storm surges.

Coastal flood risks in Copenhagen

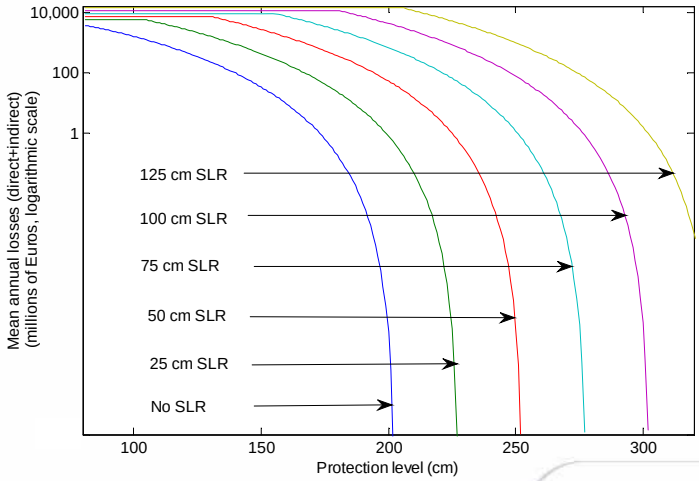
Mean annual losses, in million of Euros per year, as a function of the protection level, assumed uniform in the Copenhagen

These losses include indirect economic losses, reconstruction duration, and job losses



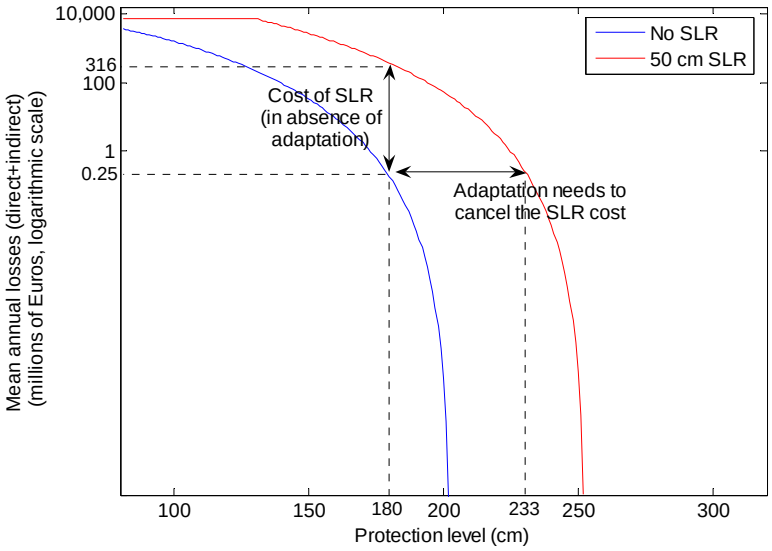
Coastal flood risks in Copenhagen

Mean annual losses, in million of Euros per year, as a function of the protection level, assumed uniform in the Copenhagen



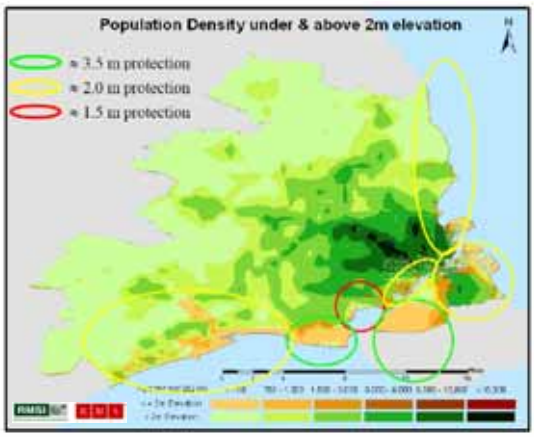
Cost of climate change vs. adaptation cost

Assuming a (non-optimal) homogenous 180 cm protection in Copenhagen.



Coastal flood risks in Copenhagen

Population density under and above 2m elevation, and coastal protection.



Today, **Copenhagen is very well protected against storm surges** (exception in the stretch in Hvidovre).

Defence upgrades will become necessary in the next decades in some areas (harbour, historical center).

Costs will be significant, esp. non-market costs (historical & cultural assets, attractiveness)

Identification of institutional issues, including the lack of an organization in charge of storm surge and coastal flood management and the absence of consistent information of coastal protection.

Present and Future rainfall in Mumbai

- The July 2005 flood event (about 1000mm of rainfall) today has an estimated return period much greater than 200 years (i.e. 0.5% annual likelihood).

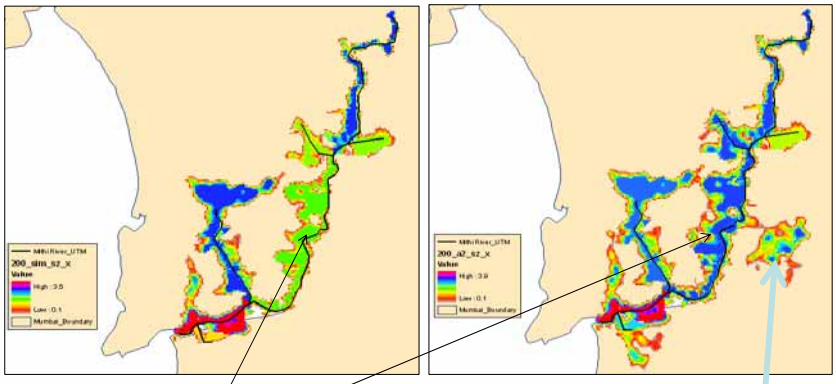
- With climate change, all today's extremes could become more frequent.
- In a SRES A2 scenario and using the PRECIS/HadCM3 model:
  - What is today a 1 in 10 year event could be seen every other year;
  - The 2005 event could become a 100-yr event.

- Only one model, while climate models provide diverging results over the region.
- These results should be considered as a worst case situation in terms of floods.

Future Flood Footprints in Mumbai

Storm Water Management Model (SWMM) – a US-EPA's model

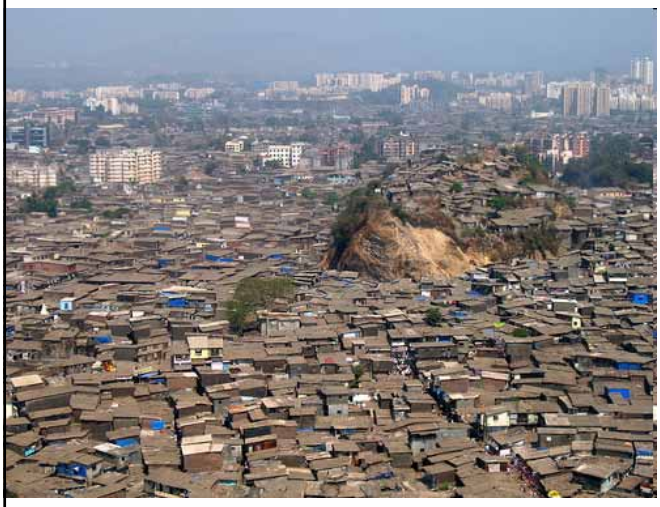
200 year return period flood maps for present day (left) and 2080s (right)



Deeper flooding

Extended flood footprint

Which urban plan should we adapt?



Credit: Joe Harder Buxtehude

-Mumbai has about 18 million inhabitants

-50% of the Mumbai population lives in slum and work in the informal sector

-Dharavi is the largest slum in the World

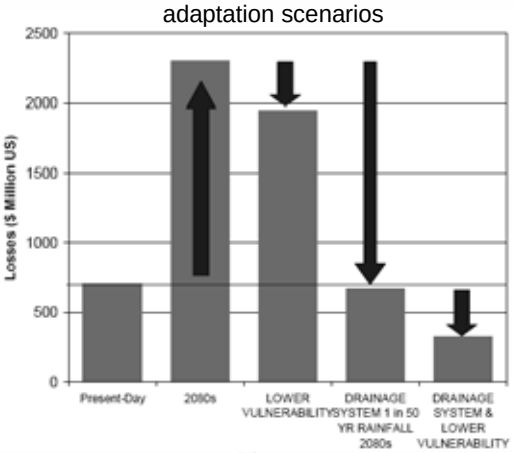
- Land scarcity and transportation issues are hard to resolve.

- Political and economic weight of these populations?

Flood losses and adaptation in Mumbai

- Adaptation options:
  - Dredging new channels;
  - Widening existing waterway and river beds;
  - Maintaining and freeing river beds.
  - Reduce building vulnerability through building upgrades;
  - Early warning systems and evacuation schemes;
  - Land-use planning
- **Adaptation can reduce direct losses below their current level**
- **Many adaptation options are no-regret.**
- **Why have these options been neglected so far?**
  - **Capital market imperfections?**
  - **Lack of political will or economic weight?**

Loss from the 100-yr event in different adaptation scenarios



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Several definition for adaptation

	Current risk level	« optimal » risk level
No climate change	Adaptation gap reduction 1 **Current situation**	2
With climate change	Constant-level adaptation 3	« Optimal» adaptation 4

« Strict » adaptation

There are also consequences on the international support of adaptation in developing countries

Conclusions

- Uncertainty on future impacts at city scale is very large.
- But these impacts are likely to be significant in absence of adaptation.

- Adaptation will require anticipated action in both developed and developing countries.
- There is a need to integrate risk management and climate change adaptation in urban planning.

- **Many adaptation options are no regret and have large benefit-cost ratio; they should be implemented immediately**.
- There are reasons why these options have not been implemented before, and we need to understand these reasons and possible solutions.

- **Other options have negative co-effects that need to be accounted for.**

- Building costs are only part of total adaptation costs: non-market costs (and benefits) have also to be taken into account **(multi-criteria analysis?)**
- Adaptation can not only reduce direct sector-scale losses; it can also increase resilience and reduce indirect losses, thanks to, e.g., insurance and reconstruction and investment capacity.

Adaptation decision-making

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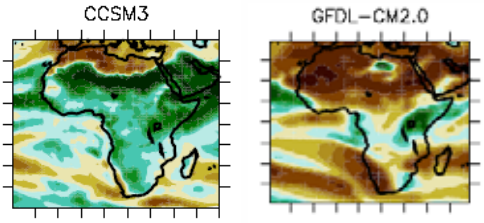
Adaptation decision-making

- From a decision-making point of view:
  - How can we make 'adaptation' decision considering the large uncertainty in all available assessments?



  - Adaptation decisions must not be made based only on (weak) cost-benefit analysis, but also using robustness and flexibility criteria.
  - Many options can be proposed that bring benefits in the present climate (no-regret) and in most possible future climate (robustness), and/or that can be adjusted when new information is available (flexibility)

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Examples of adaptation options

Sector	Examples of adaptation options	No regret strategy	Reversible / flexible	Existence of cheap safety margins	Soft strategy	Reduced decision horizon	Synergies with mitigation	Ranking
AGRICULTURE	• Developing crop insurance	+	+		+			1
	• Irrigation (possibly with water storage & transport)	+	–	+				2
	• Forestry with shorter rotation time	–	–			+		2
	• Development of resistant crops	+ +						1
COASTAL ZONES	• Coastal defences / sea walls	+	–	+				2
	• "Easy-to-retrofit" defences		+	+		+		1
	• Enhanced drainage systems	+	–	+				2
	• Restrictive land-use planning	+	+	+				1
	• Insurance, warning and evacuation schemes	+ +	+		+			1
	• Relocation and retreat	+	–					3
	• Creation of risk analysis institution and long-term plans	+	+		+			1
HEALTH & HOUSING	• Air conditioning						–	3
	• Improved building standards	+		+			+	1
	• R&D on vector control, vaccines	+						1
	• Improvements in public health systems	+ +						1
WATER RESOURCES	• Institutionalization of long-term perspectives	+ +	+		+			1
	• Loss reduction (leakage control, etc.)	+ +						1
	• Demand control and water reuse	+ +	+		+			1
	• Storage capacity increase (new reservoirs)	+	–	+				2
	• Desalination and water transport	+	–	+			–	3
HUMAN SETTLEMENTS	• Climate proofing of new building and infrastructure	+		+			+	1
	• Climate proofing of old building and infrastructure		–				+	2
	• Improvement of urban infrastructures	+	–	+			+	2
	• Restrictive land-use planning	+ +	+	+				1
	• Flood barriers, storm / flood proof infrastructure	+	–	+				2
	• Development of early warning systems	+ +	+		+			1

This work is presented in a series of papers available on my website or on request to:
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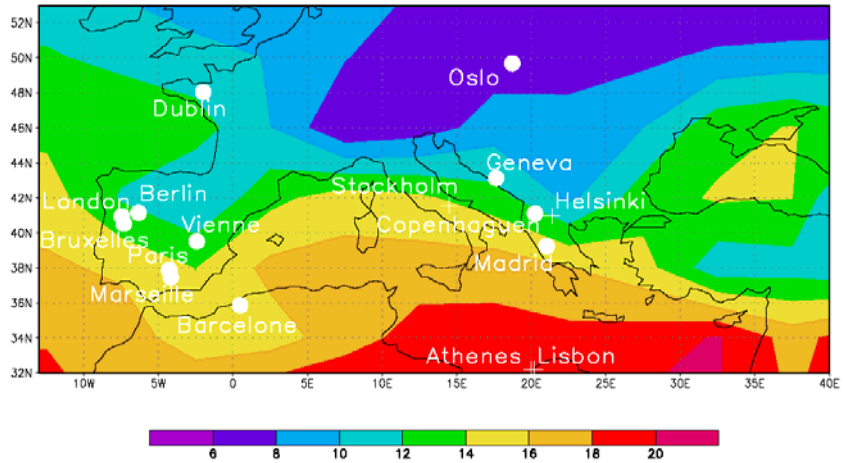
Strategies to adapt to an uncertain climate change

- **Selecting no-regret strategies that bring benefits even in absence of climate change:**
  - Most Disaster Risk Reduction actions (e.g., more restrictive land-use plans);
  - Improve building norms;
- **Favoring reversible strategies over irreversible ones:**
  - More restrictive land-use plans;
- **Investing in low-cost "safety margins":**
  - Drainage infrastructures in Copenhagen.
- **Reducing investment lifetimes:**
  - Forestry sector and tree rotation time;
  - Housing building quality and lifetime in hurricane-prone areas.
- **Favoring financial and institutional ("soft") adaptation over "hard adaptation":**
  - Early warning, evacuation and insurance vs. sea walls and dikes.
  - The "institutionalization" of long-term planning horizons: the California Water Plan and its compulsory 25-year planning exercises.
- **Taking into account synergies and conflicts between adaptation strategies and between adaptation and mitigation**
  - Dikes and biodiversity in coastal areas;
  - Uncertainty on future energy cost and water desalinization.
  - Urban and land-use plans

Adapting to a changing climate

Climate analogues in 2070, Hadley Centre Model, SRES A2

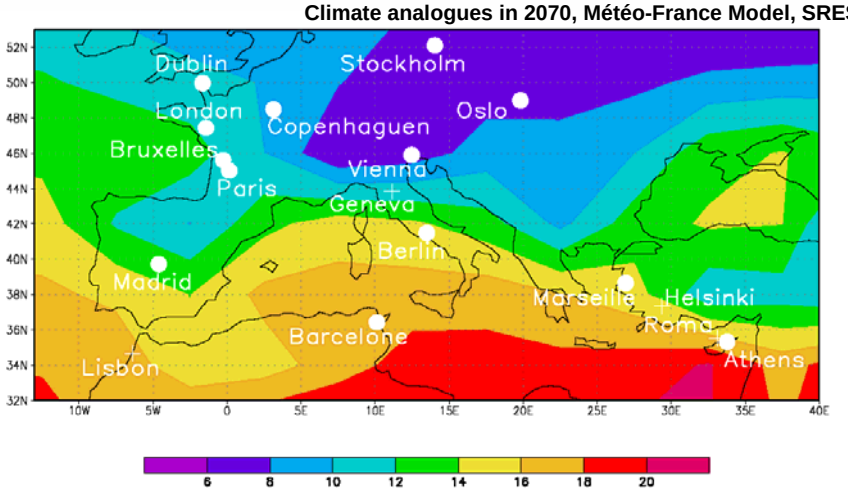


It is neither more difficult nor expensive to design a building for the Cordoba climate than for the Paris climate. But it is more difficult (and more expensive) to design a building able to cope with both climates.

After Hallegatte, Ambrosi, Hourcade (2007)

Coping with uncertainty

Climate analogues in 2070, Météo-France Model, SRES A2



After Hallegatte, Ambrosi, Hourcade (2007)

The « optimal » strategy is very different depending on the model that is used. **We need new decision-making methods to cope with this new problem**.

Adaptation to reduce indirect losses

- Adaptation can aim at reducing direct losses (e.g., damages to buildings)
- Adaptation can aim at reducing the indirect consequences of the direct losses:
  - **Reconstruction capacity**: if the construction sector production capacity can increase by 50% in 6 months after the flood, reconstruction duration is reduced and indirect losses decrease from $800 million to $200 million.
  - **Insurance**: with 100% insurance penetration, reconstruction can start immediately and does not impact household consumption. As a consequence, indirect costs are reduced by 37% compared with current situation (10% penetration), and by 42% compared with no insurance

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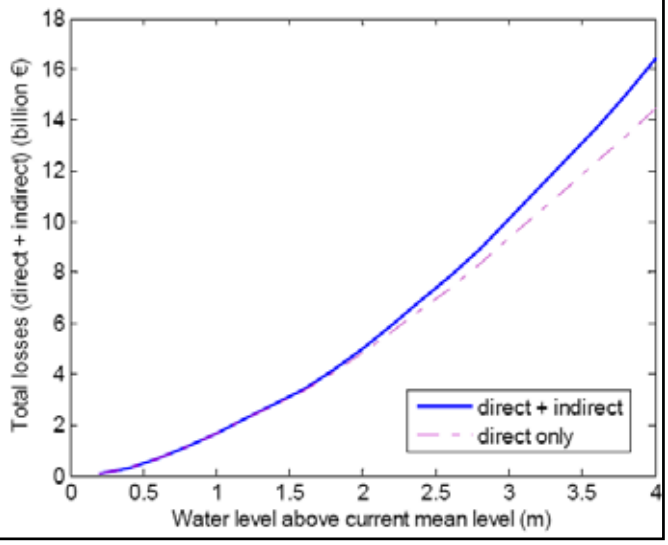
Coastal flood risks in Copenhagen

Event total losses, including direct and indirect losses, as a function of water level and in absence of protections.

Event sea level wrt current mean level (m)	Direct losses (million EUR)
1	1,668
2	4,837
3	9,341
4	14,478