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**Assessing current and future impacts due to
climate-related extreme events and global change**

The case of Bangladesh

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Risk and Vulnerability
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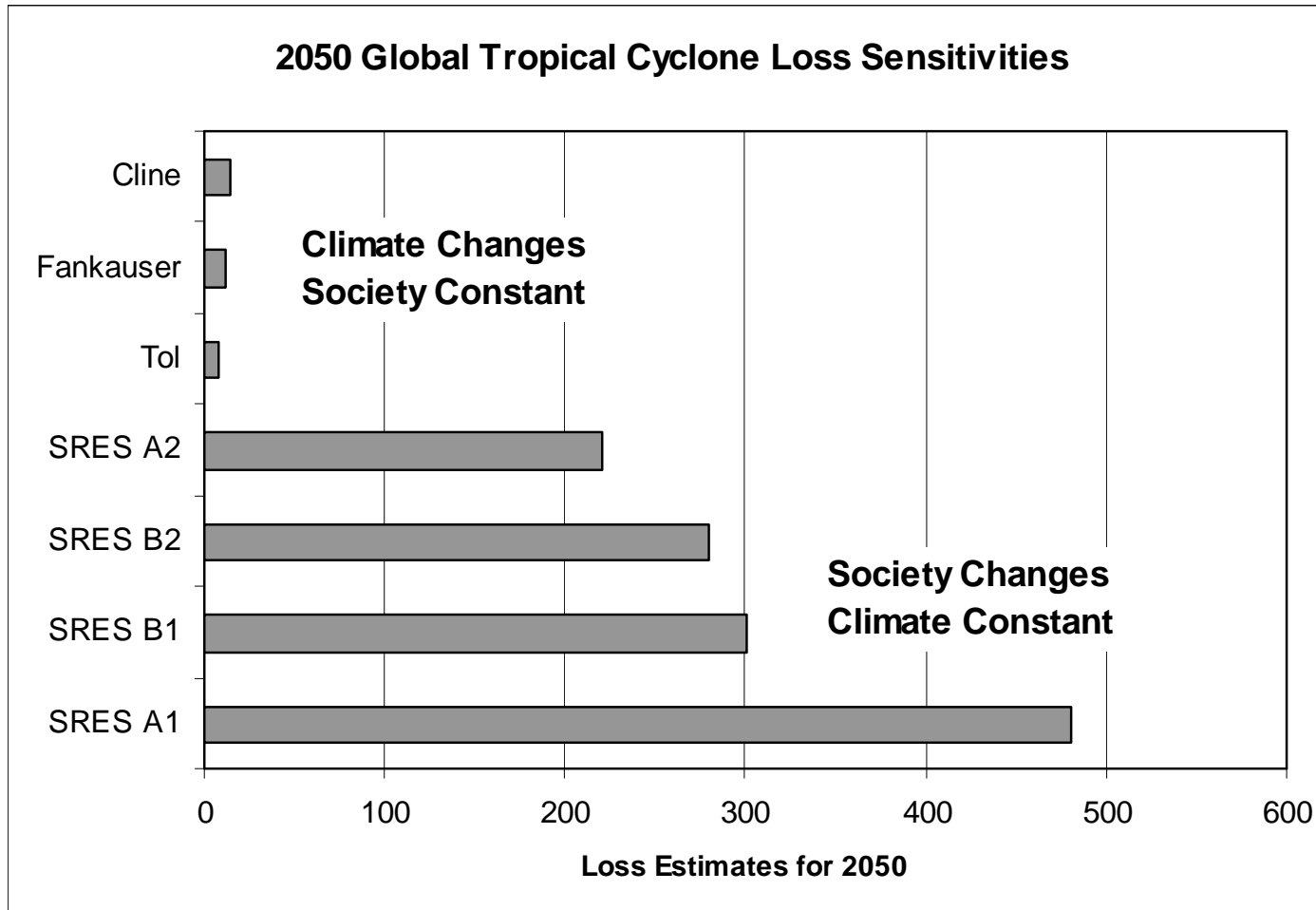
Motivation: Global and climate change within disaster risk

The research addresses the question on the relative importance of climate change versus socioeconomic drivers, such as increasing population and vulnerability, in current and future disaster loss risk estimates from a modeling perspective.

These issues are addressed focusing on Bangladesh, the most flood-prone country in the world.

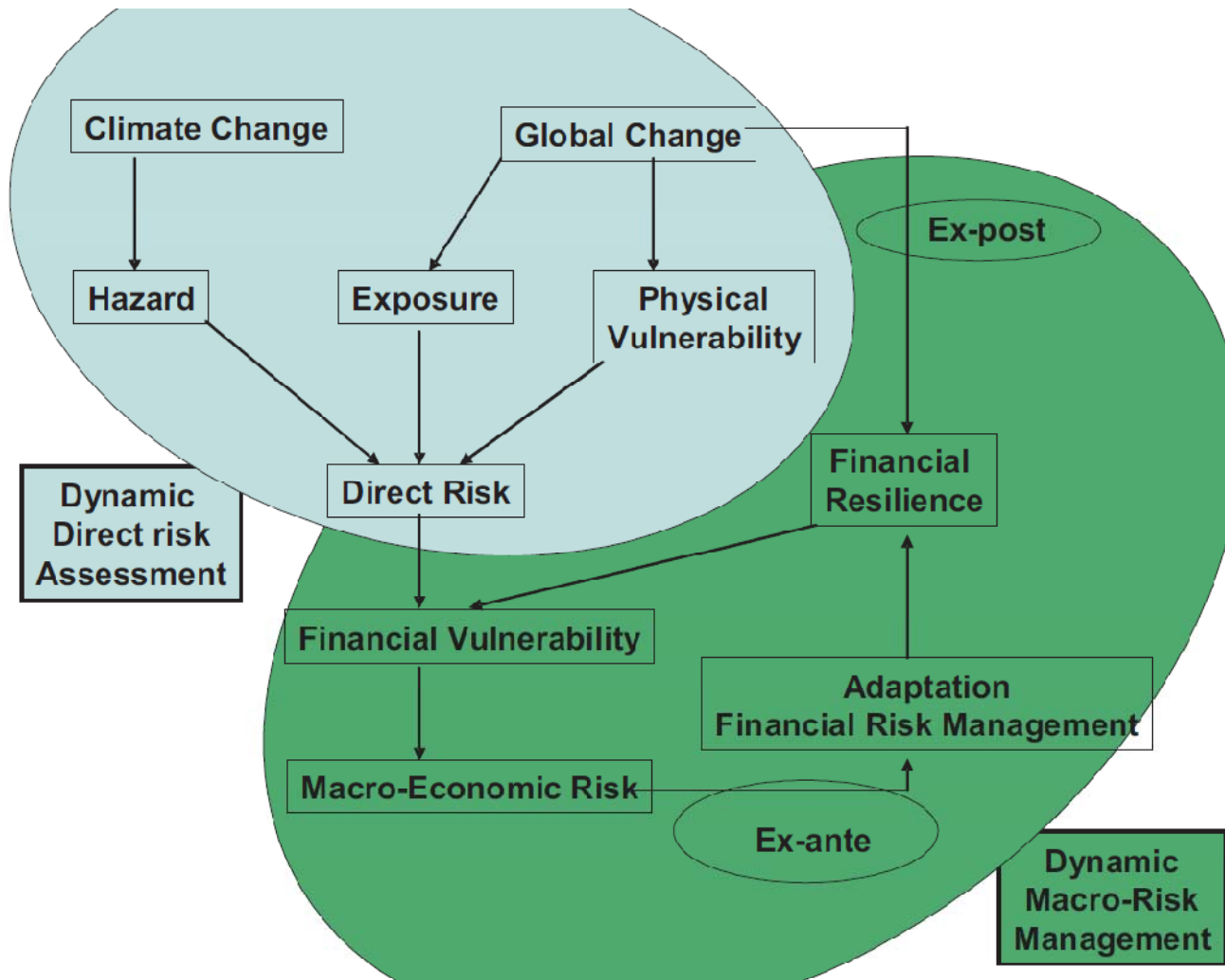
Changes in hazard as well as changes in physical vulnerability and exposure due to global and climate changes in the future on the country level are explicitly addressed as well as a methodology proposed.

Motivation: Global and climate change within disaster risk



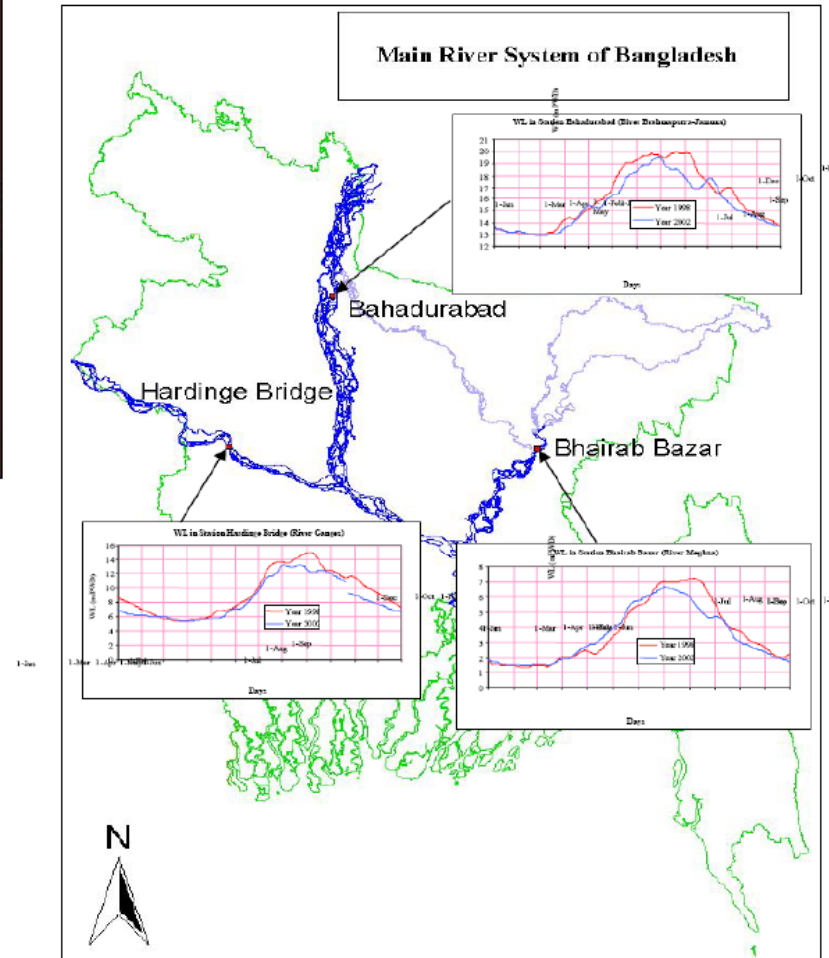
Source: Pielke RA Jr, Sarewitz D. Bringing Society Back into the Climate Debate. Population and Environment, 2005; 26(3):255-268.

Proposed Methodology: Dynamic direct risk assessment



Direct risk measured with loss exceedance curves, loss distributions

Introduction: Bangladesh and river basin



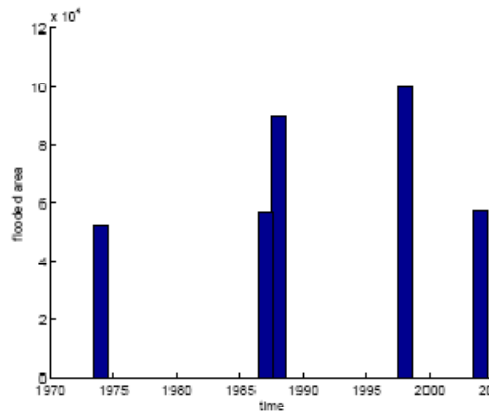
Input data and modules: Bangladesh

Based on collaboration in DFID sponsored project on climate risk screening in Bangladesh: ORCHID

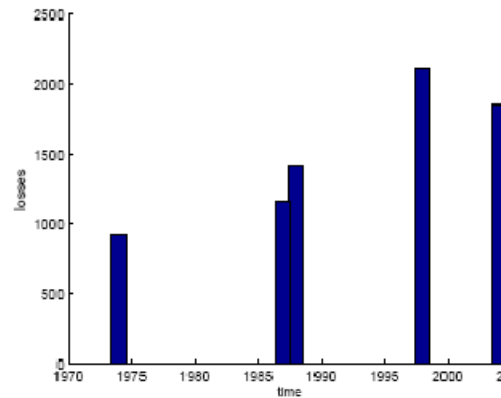
- Institute of Development Studies (IDS), University of Sussex, UK
- CEGIS – Center for Environmental and Geographic Information Services, Bangladesh
- Bangladesh Institute of Development Studies (BIDS), Bangladesh
- School of Development Studies-Overseas Development Group, University of East Anglia, UK
- Tyndall Centre for Climate Research, University of East Anglia, UK
- International Institute of Applied Systems Analysis (IIASA), Austria
- Bangladesh Unnayan Parishad (BUP), Bangladesh
- Bangladesh Centre for Advanced Studies (BCAS), Bangladesh

| Module | Source |
|--|-----------------------|
| Mean temperature change, precipitation and change as function of temperature | PRECIS RCM for A2, B1 |
| Max. discharge as function of precipitation | Hydrological model |
| Flood impacts, Vulnerability | Bangladesh statistics |
| Flooded area as function of max discharge | Statistical model |
| Exposure | GGI: GDP, Pop, assets |
| Losses as function of flooded area | CATSIM extended |
| Operationalization of vulnerability | CATSIM extended |
| Economic impacts as function of losses | CATSIM |
| Risk Management/adaptation | CATSIM |

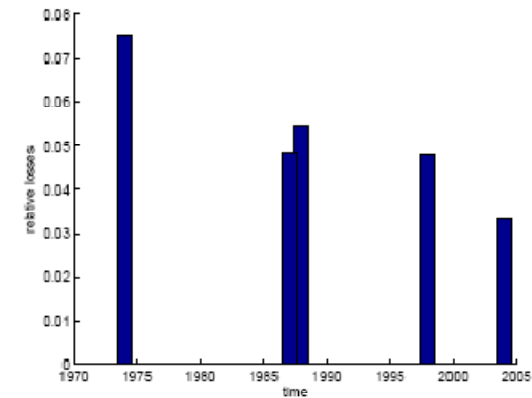
Data from past catastrophic floods in Bangladesh



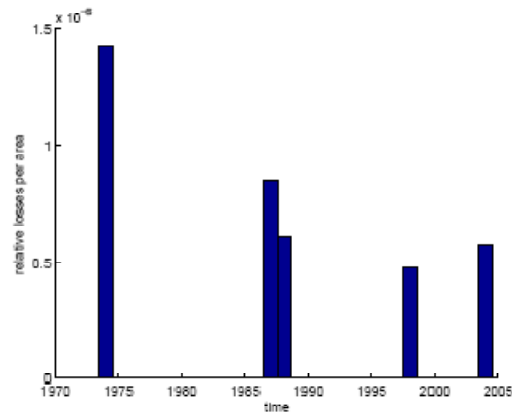
Flooded area



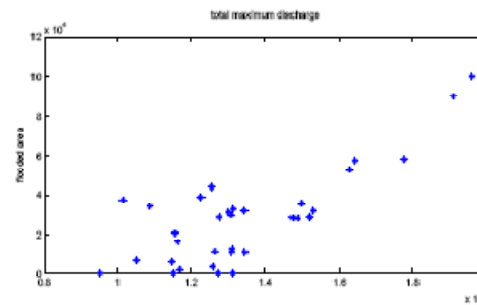
Losses



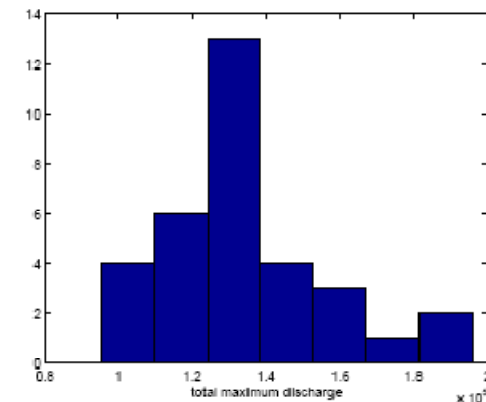
Relative Losses



Relative Losses per area

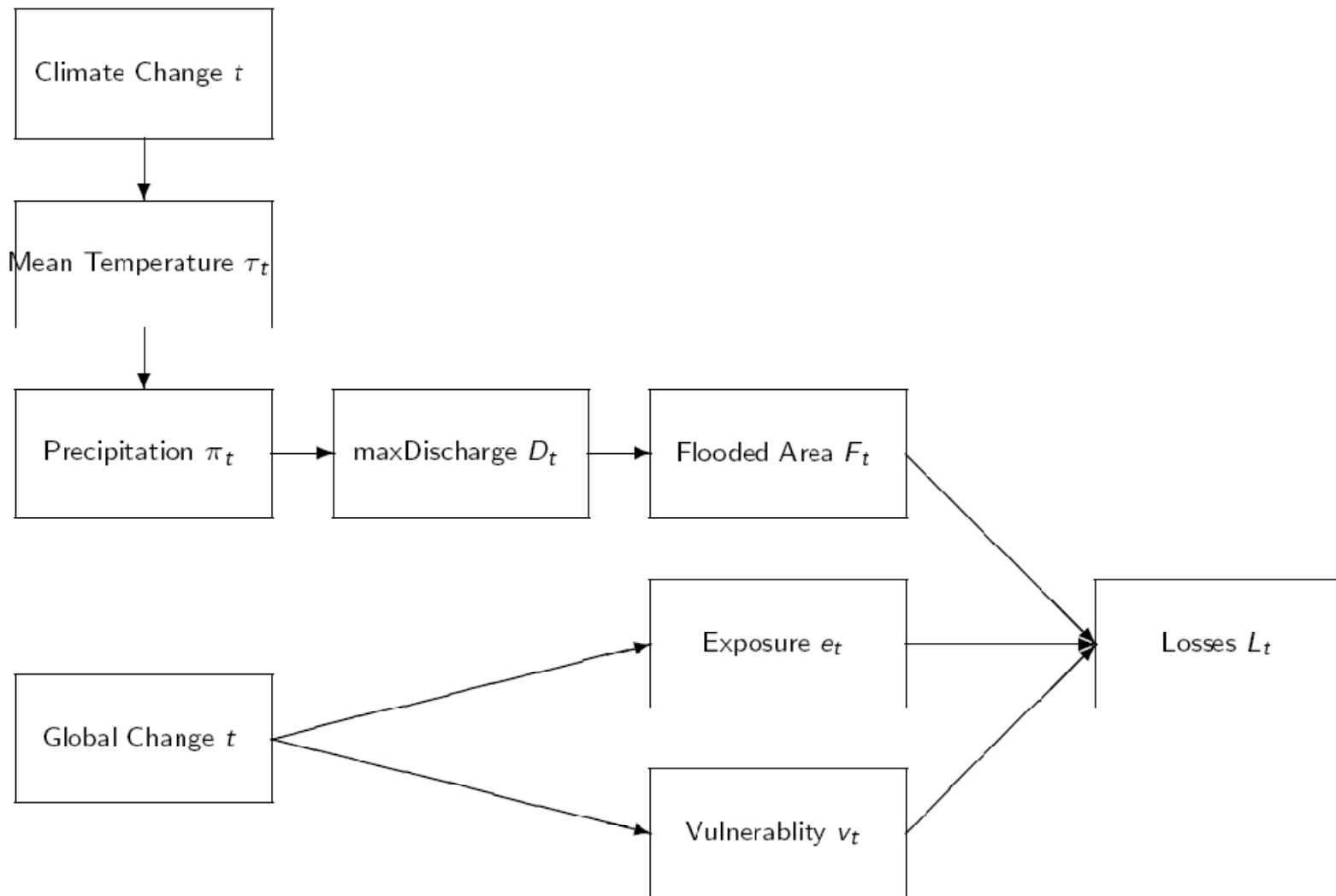


Relation between maxDischarge and Flooded Area



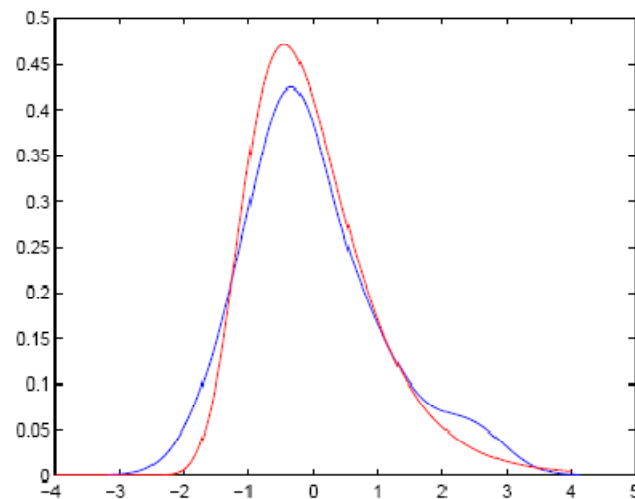
A histogram for the max Discharge

The catastrophe model

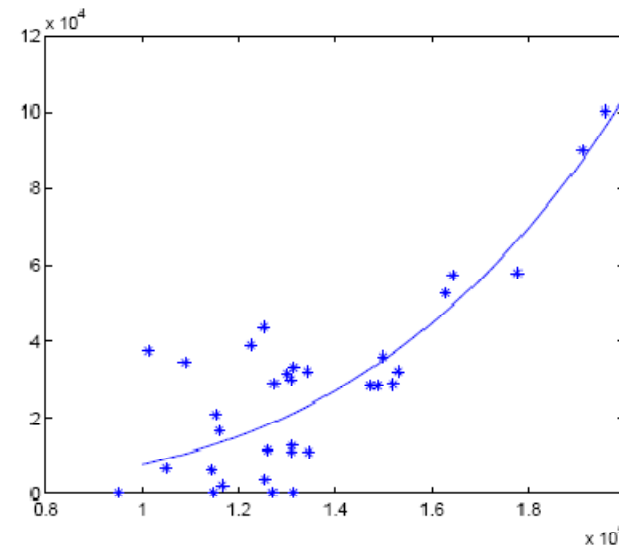


Model estimation

- ▶ Poisson model for event frequency
- ▶ Gumbel model for event severity (maxDischarge D_t)
- ▶ Nonlinear Regression for the Flooded Area $F_t = g(D_t)$



Estimation of the Gumbel distribution for the maxDischarge:
Blue: A density estimate, Red: the fitted distribution



Estimation of the function
 $F_t = bD_t^\alpha$

Gumbel, Fisher-Tippett and generalization

- ▶ Gumbel distribution $F(x) = \exp(-\exp(-x))$
- ▶ Location/scale change (Fisher-Tippett)

$$F_{\mu,\sigma}(x) = \exp(-\exp(-(\frac{x-\mu}{\sigma} + \gamma)\pi/\sqrt{6}))$$

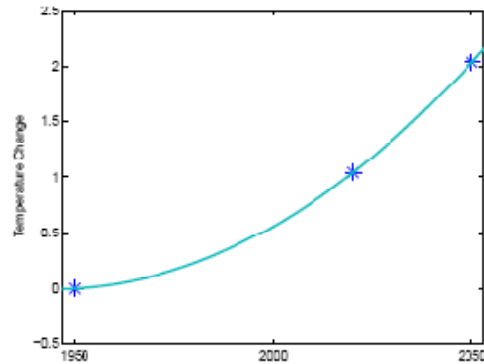
$$\gamma = \lim_n [\sum_k \frac{1}{k} - \log n] = 0.5772$$

- ▶ The generalized Gumbel distribution is

$$F_{\mu,\sigma,\alpha}(x) = \begin{cases} \exp(-\exp(-(\frac{x^{1/\alpha}-\mu}{\sigma} + \gamma))) & \text{if } x \geq 0 \\ 0 & \text{if } x < 0 \end{cases}$$

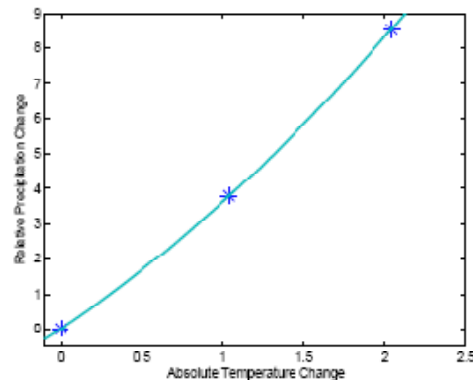
Climate Change

► Temperature Change



$$\tau_t = \tau_{1950} + 0.000185t^2 - 0.718t - 699$$

► Precipitation as function of temperature



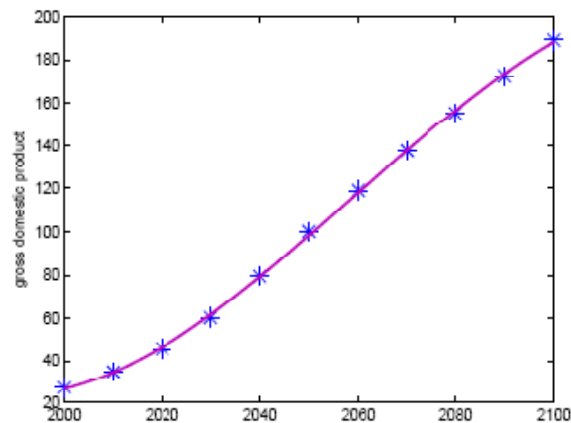
$$\pi_t / \pi_{1950} = 0.542(\tau_t - \tau_{1950})^2 + 3.08(\tau_t - \tau_{1950})$$

► Location/scale of Discharge distributions

$$\mu_t = 131978 + 1.366, 8\pi_t / \pi_{1950}, \sigma_t = 0.1751 \cdot \mu_t$$

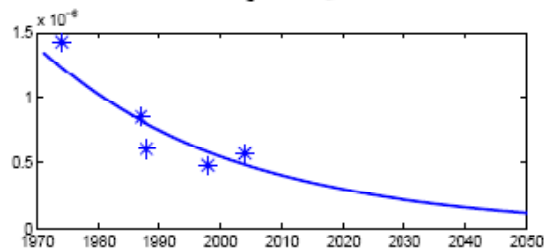
Global Change

- ▶ Exposure $e_t =$ gross domestic product



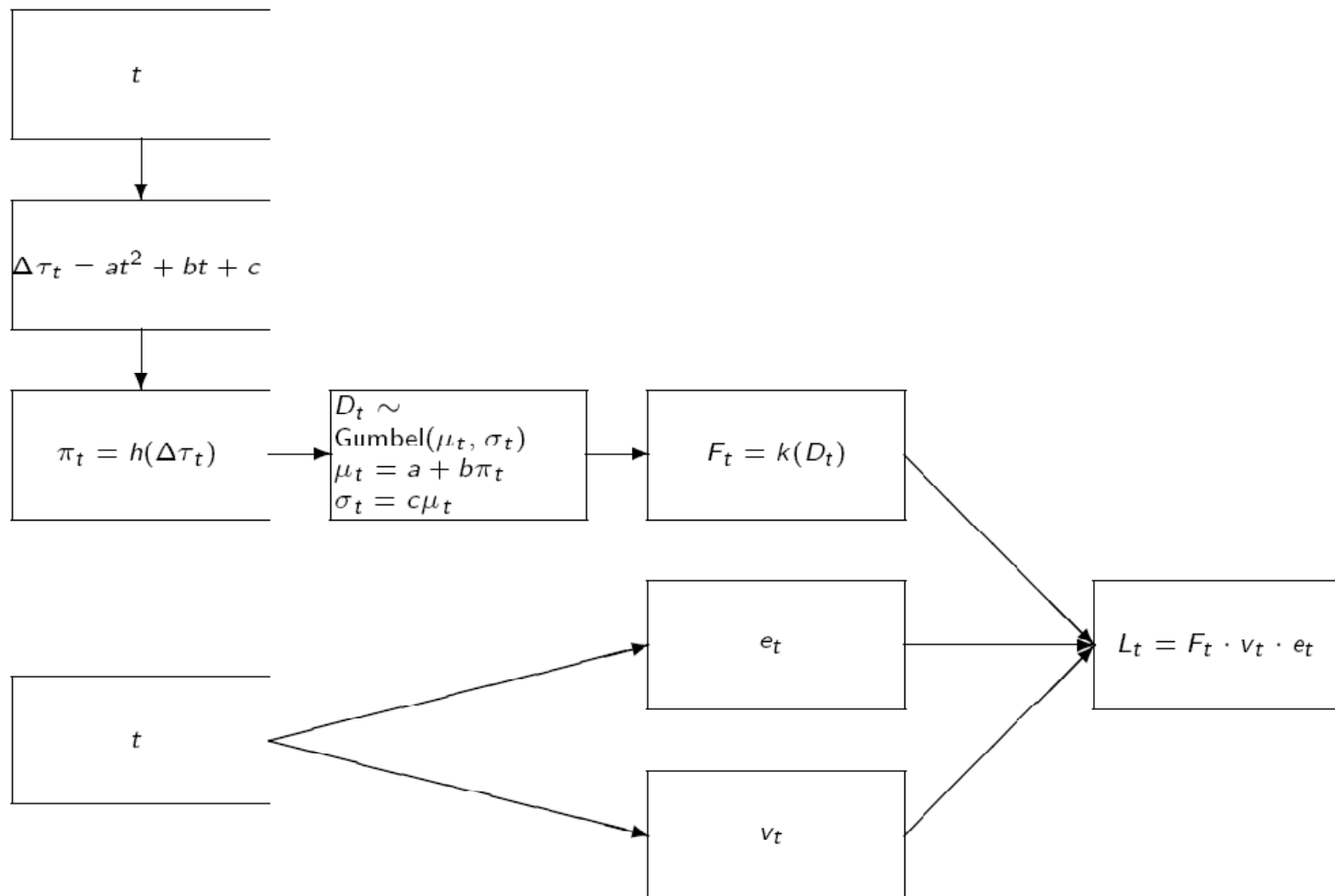
$$e_t = -0.0001364t^3 + 0.08425t^2 - 1732t + 1186600$$

- ▶ Vulnerability $v_t =$ damage per Exposure and Flooded Area



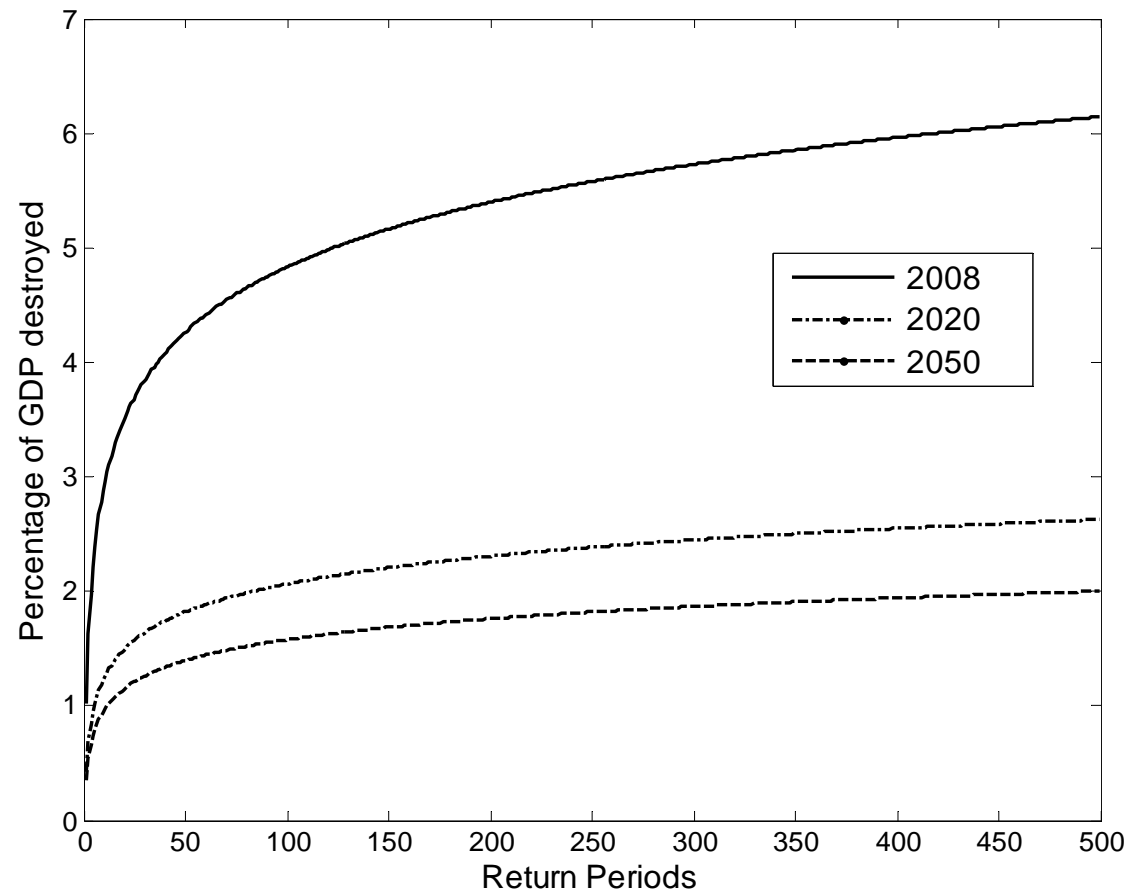
$$v_t = 3.8 * 10^{20} \exp(-0.0309t)$$

Model specification

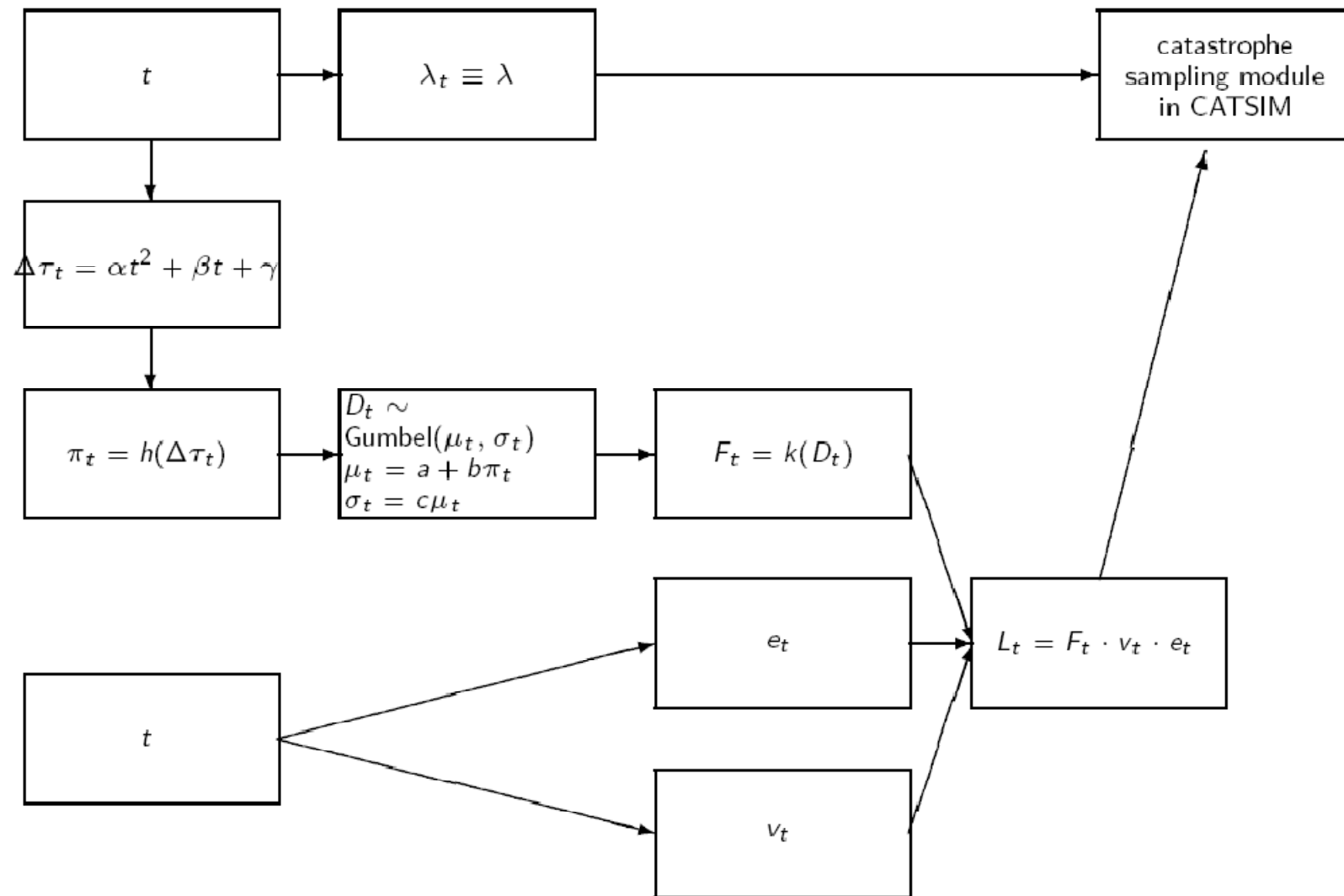


Estimated future loss distributions

Let G_t be the loss distribution $G_t(\ell) = P\{L_t \leq \ell\}$. We estimated this distributions for the years 2008-2050.

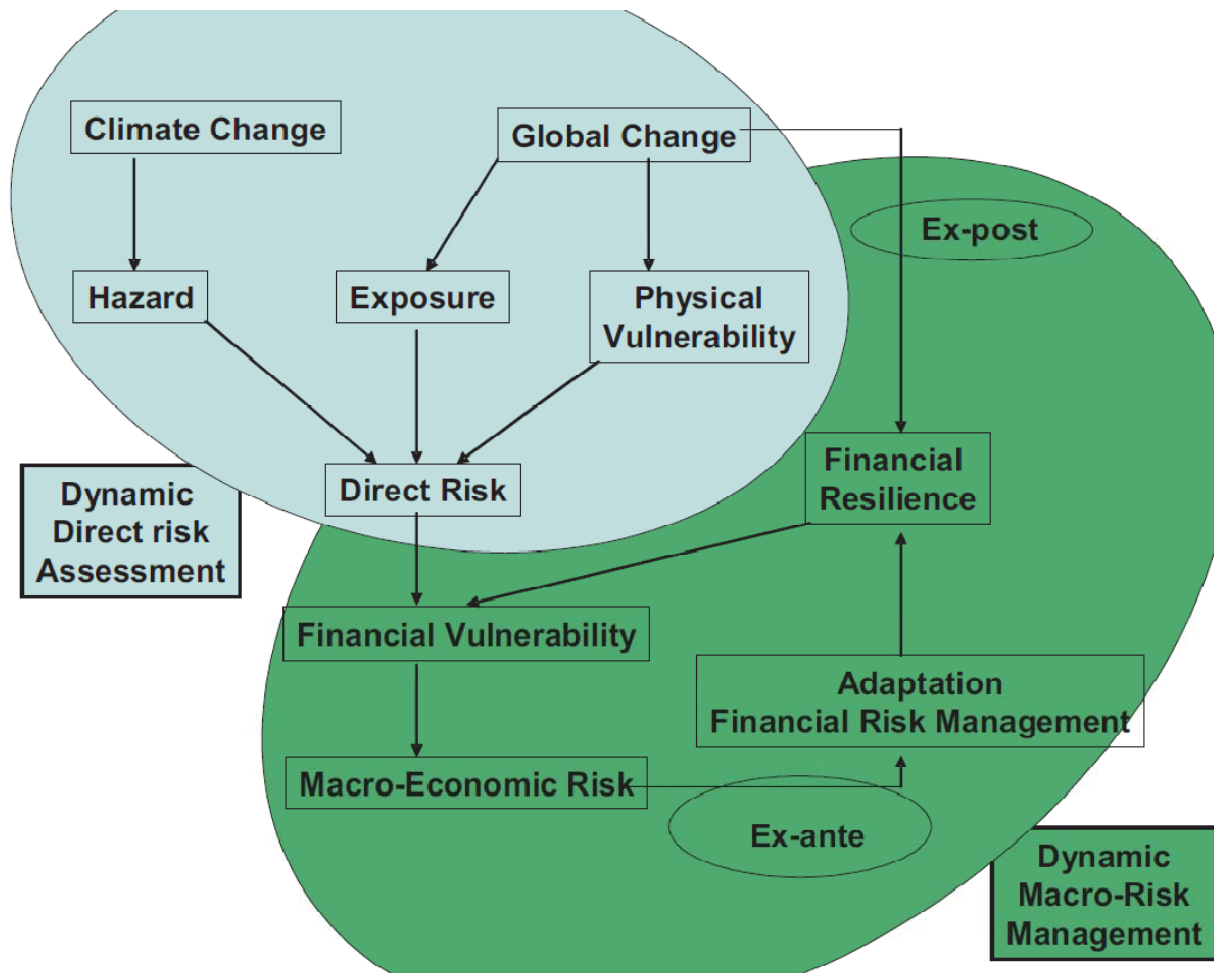


Model specification



Proposed methodology: Dynamic macro risk management

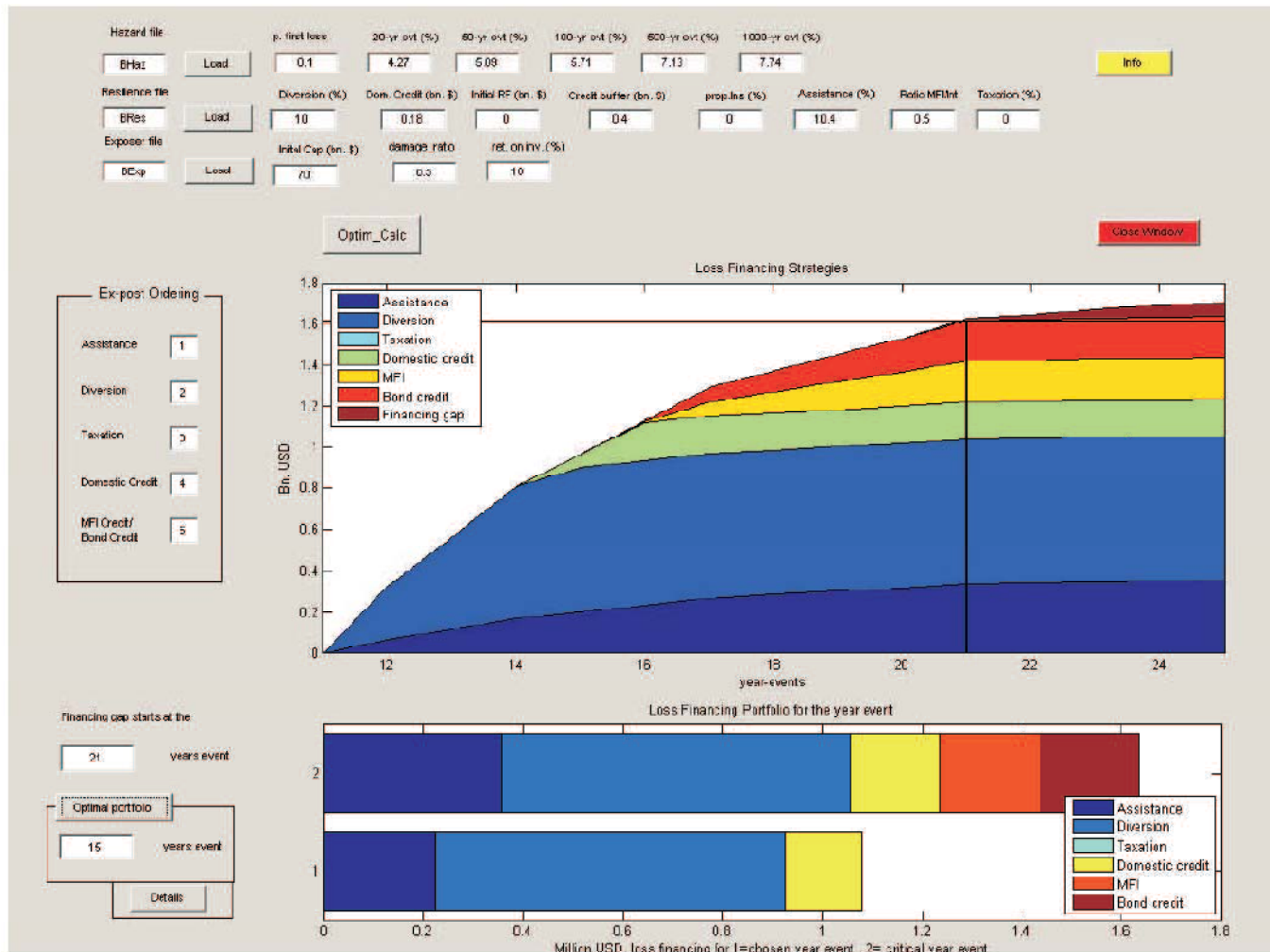
Macro-risk dependent on ability to finance losses. Focus on government.



Public Sector finance possibilities:

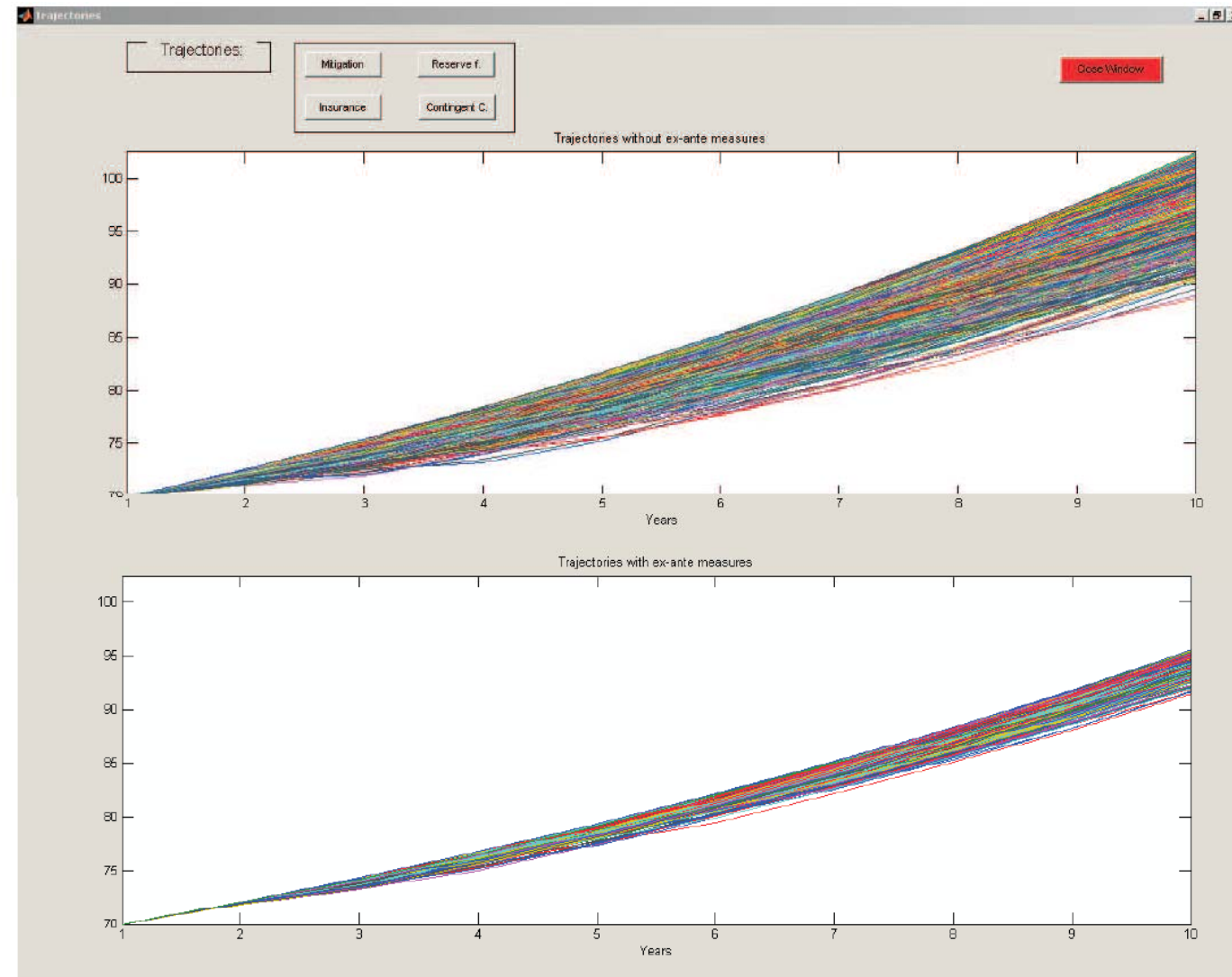
| Type | Source | Considered in model |
|--------------------------------------|--|---------------------|
| Ex-post sources | | |
| Decreasing government expenditures | Diversion from budget | yes |
| Raising government revenues | Taxation | - |
| Deficit financing <i>Domestic</i> | Central Bank credit | Yes |
| | Foreign reserves | - |
| | Domestic bonds and credit | Yes |
| Deficit financing <i>External</i> | International borrowing | Yes |
| | Outside support, e.g. from EU solidarity funds | Yes |
| Ex-ante sources | | |
| | Insurance | Yes |
| | Reserve fund | Yes |
| | Contingent credit | Yes |

Current financial vulnerability for Bangladesh

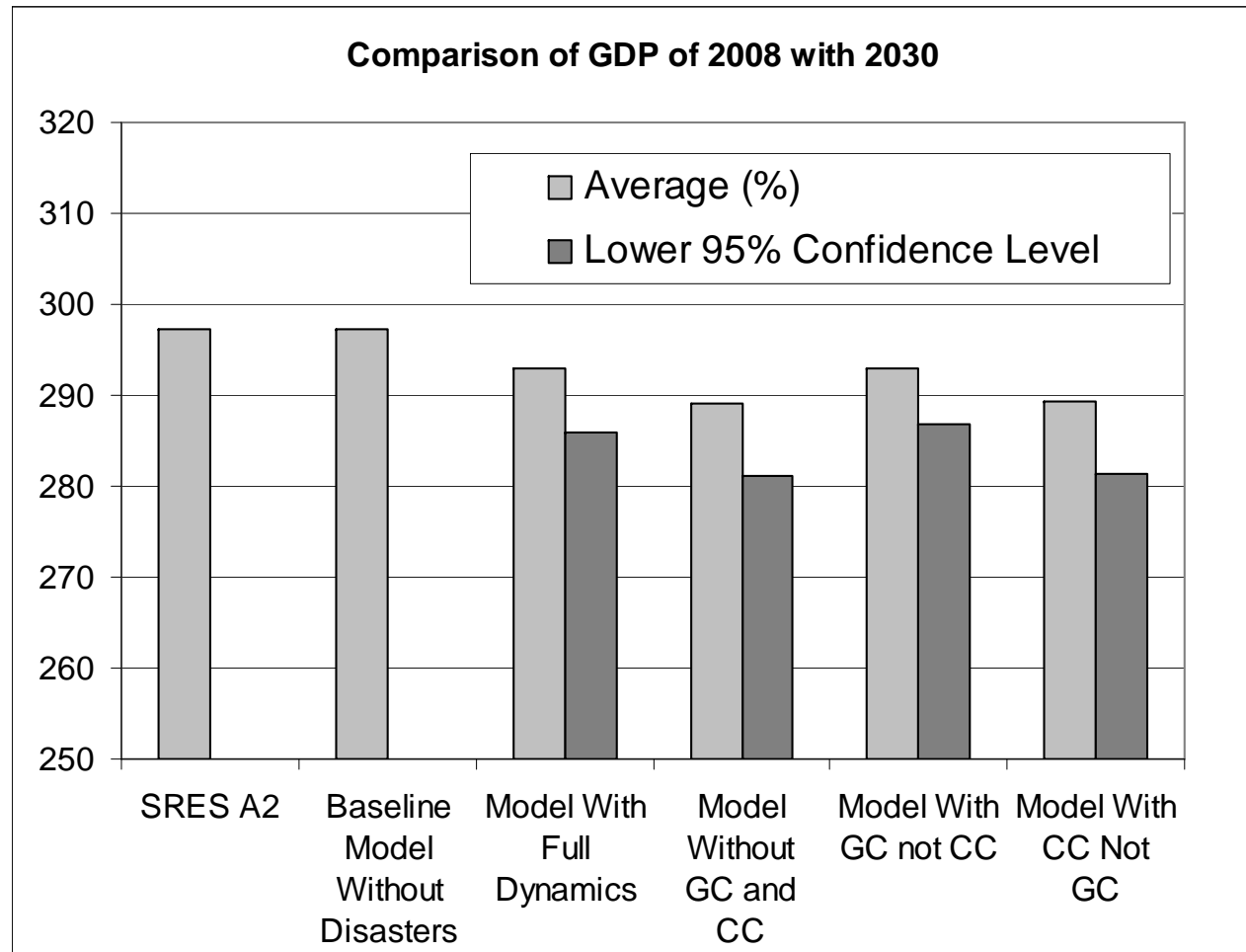


21 year event would cause already problems for the government to finance losses

Consequences of natural disasters on GDP

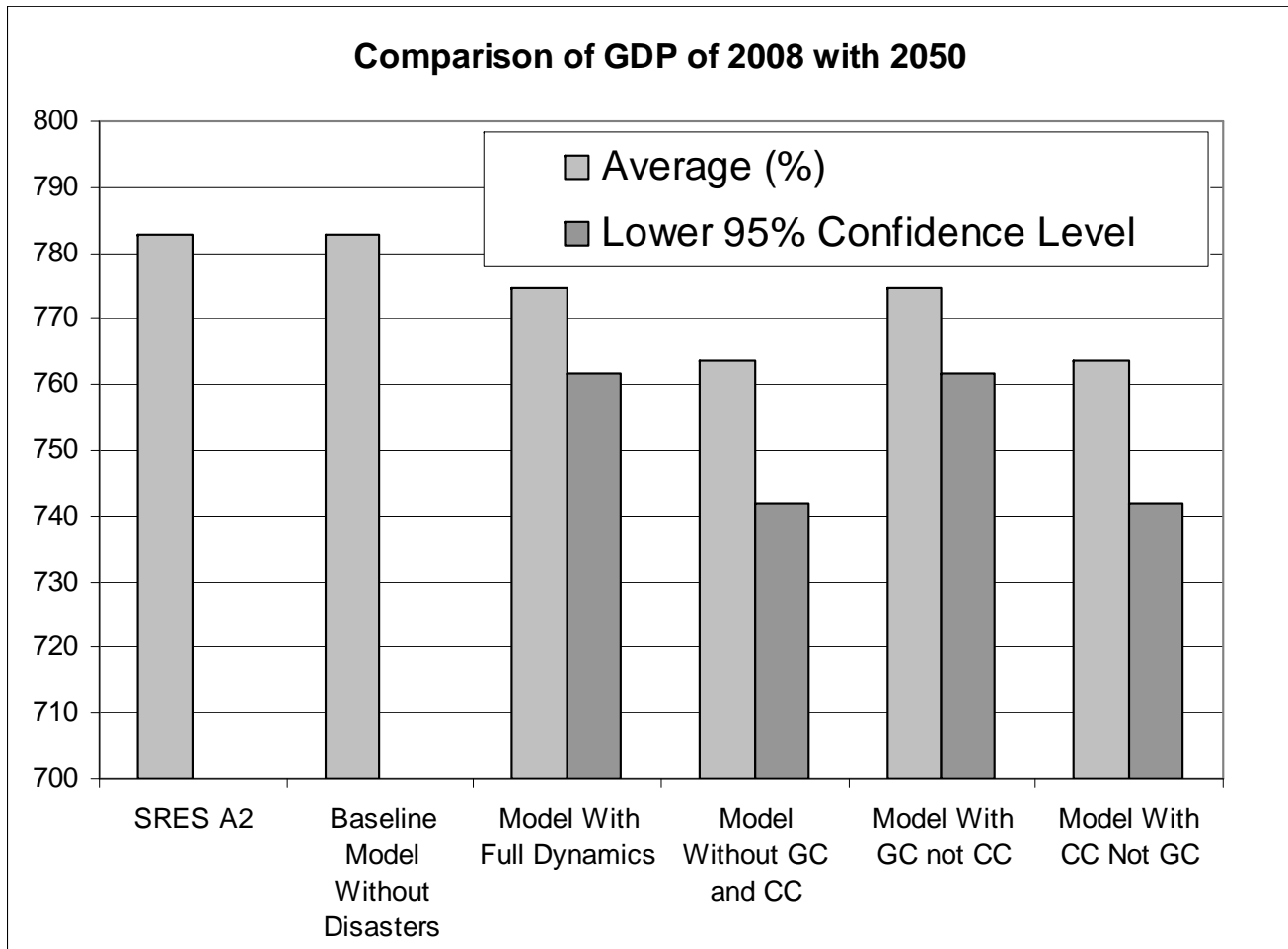


Comparison of climate and global change effects



Comparison of GDP growth from 2008 to 2030 for different modeling assumptions (in % of 2008 GDP)

Comparison of climate and global change effects



Comparison of GDP growth from 2008 to 2050 for different modeling assumptions (in % of 2008 GDP)

Conclusions and Problems

Conclusions:

- ▶ To assess future risks a dynamic framework should be used
- ▶ Global changes, e.g. reduction of physical vulnerability, seems more important for Bangladesh than the threat of climate change, e.g. increase in the rainfall intensity.
- ▶ However, no general statements possible since important other factors were neglected, e.g. what are the effects of sea level rise, human dimension of the problem.

Problems:

- ▶ The small number of observations
- ▶ The uncertainty in tail estimation in general - Extrapolation beyond the maximal observed value
- ▶ High residual (unexplained) variances
- ▶ The uncertainty in future modeling - Extrapolation for 45 years to come
- ▶ Model ambiguity

End of Presentation

Discussion