Local Effects of Global Climate Change on the Urban Drainage System of Hamburg

Klaus Krieger, Nina Hüffmeyer, Andreas Kuchenbecker, Hans-Reinhard Verworn

9th ICUDM, Sept. 2012, Belgrade Serbia

Contents

1. Introduction

A few facts about HAMBURG WASSER

- Largest public owned water supply and wastewater disposal company in Germany
- Supplies 2 million people in Hamburg and the metropolitan area with drinking water and disposes the waste water
- Total length of sewer network 5,548 km (combined and seperate sewers); diameters ranging from 150 to 3,500 mm
- Treated waste water 165 million m³/a
- Investments in sewer network 60 million €/a (depreciation 77-125 years)

Aim and motivation of study

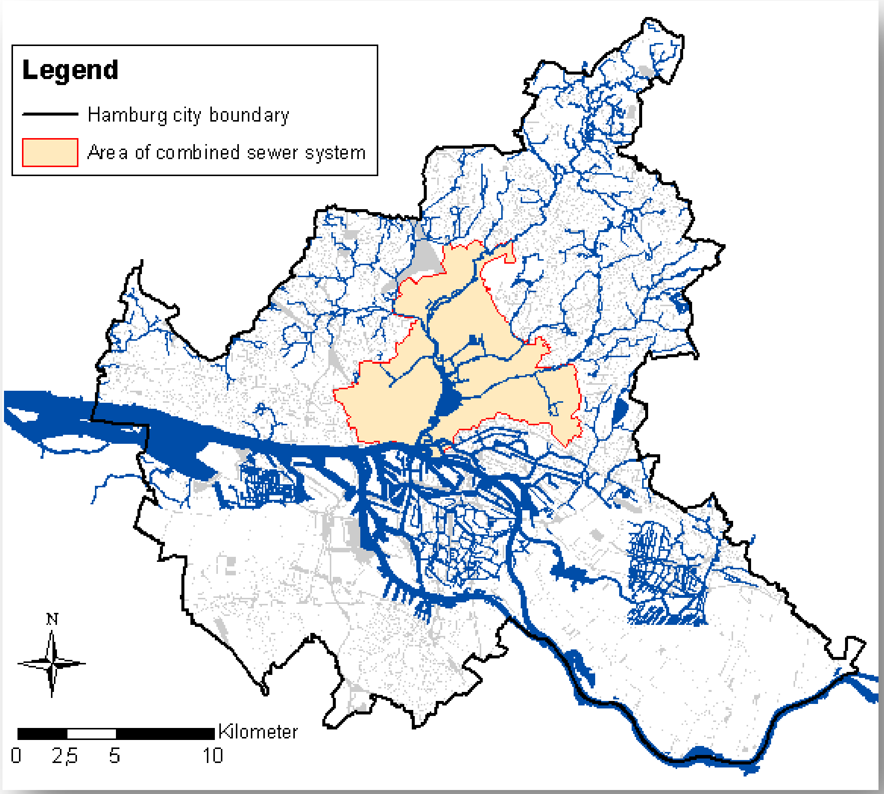
Facts

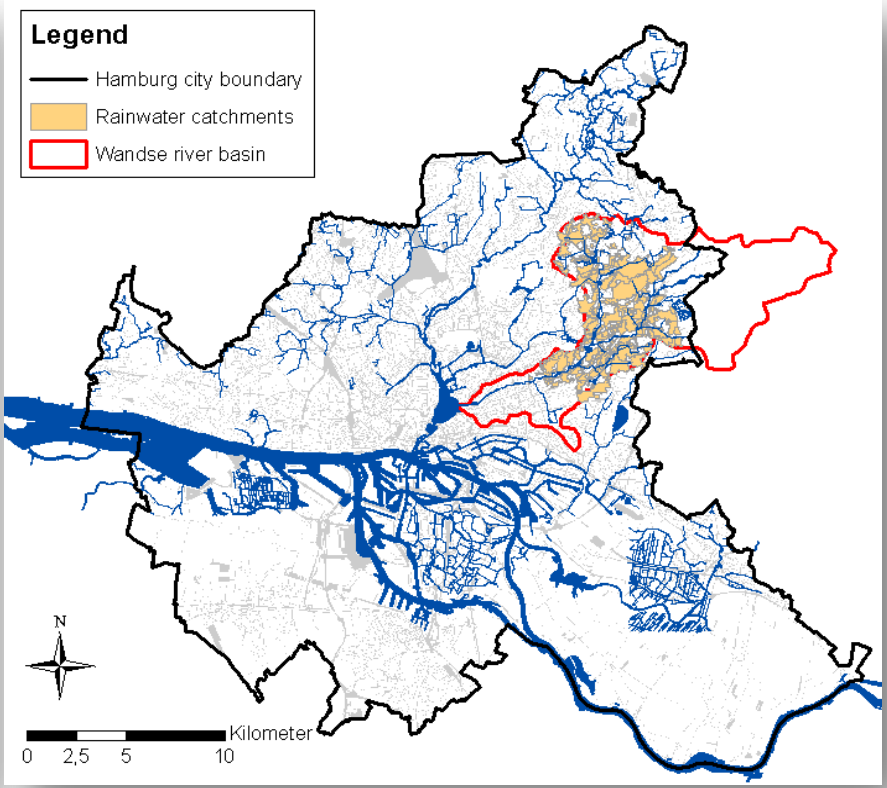
- Global climate change will (continue to) happen within the next 100 years
- Local changes in precipitation patterns have not been quantified for Hamburg so far
- HAMBURG WASSER will spend about 3 to 6 billion Euro on sewer renewal and rehabilitation within the next 100 years

Questions

- What is the expected extent of changes in rainfall patterns in Hamburg?
- How is the Hamburg drainage system affected (combined sewer overflows and flooding events) ?
- Which adaption measures should be applied today and in future (design criteria, alternatives)?

Study areas





City centre catchment

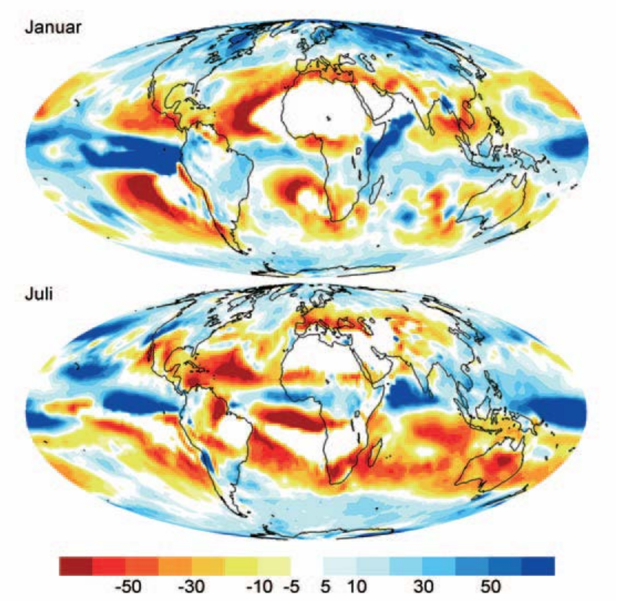
- Highly sealed
- Combined sewers
- 115 outlets

Wandse catchment

- Wide range of population density
- Separate storm water sewers
- 200 catchments

Precipitation Data

Changes in precipitation patterns for scenario A1B in [%] for time span 2071-2100 based on mean value of time span 1961-1990 (source: MPI)



Measured time series

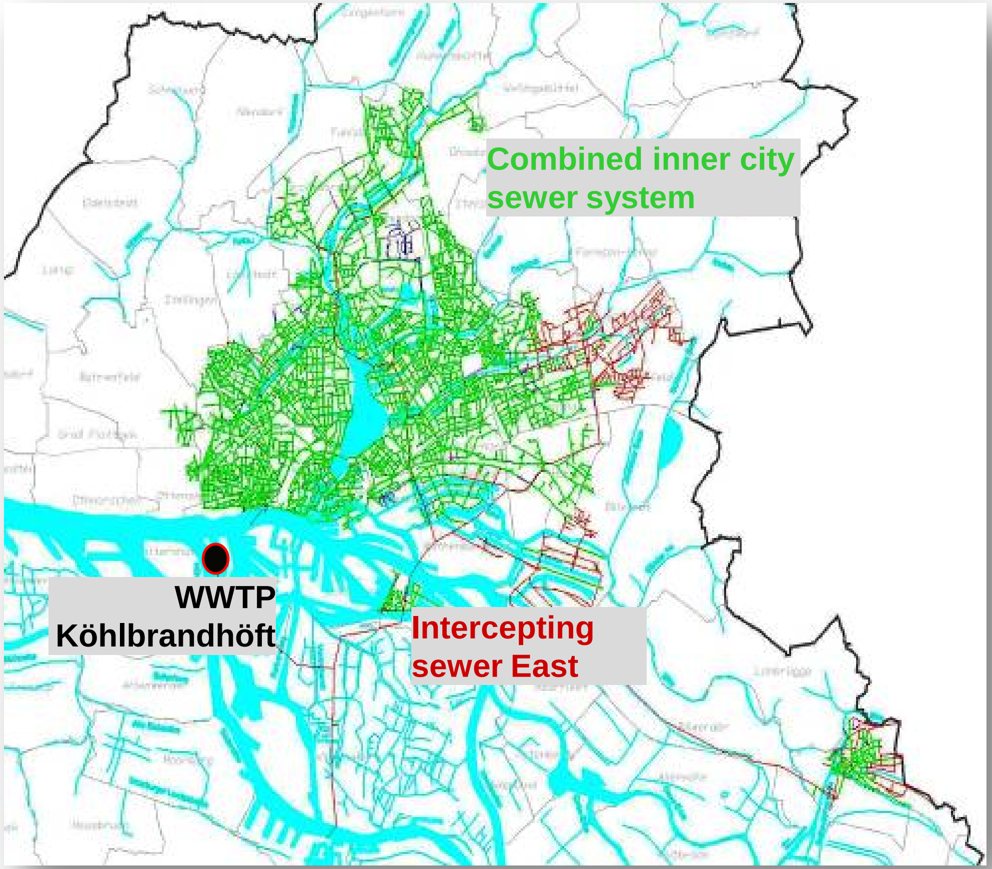
- Period 1971 – 2000 (currently extended to 1961 – 2010)
- Based on 14 gauge stations in Hamburg
- Temporal resolution 5 min

Regional climate model REMO (MPI)

- Consideration of two scenarios (A1B, B1) and two realisations of A1B (A1B_UBA, A1B_BfG)
- Period 1950 – 2000 for validation (in 2 realisations C20_1 and C20_2)
- Period 2000 – 2100 for simulation based on IPCC scenarios
- Spatial resolution 10 x 10 km^2
- Temporal resolution 1 h
- Disaggregation of REMO data in 5 min volumes (based on statistical parameters derived from measured data)

Sewer simulations

- Simulation of sewer systems as hydro-dynamic long-term series simulation with Hystem-Extran (itwh)
- Input of 5 min data series (disaggregated) and 1 h data series (aggregated)
- Simulation of more than 700 relevant rain events for time range 1971-2100 for each scenario



Validation and trend analysis

Step 1: Validation

- Comparability between climate model data and measured data
- Disaggregation method

Step 2: Trend analysis

- Overflow volumes and frequencies (combined sewers)
- Surcharge frequencies (combined and separate sewer system)

HAMBURG WASSER

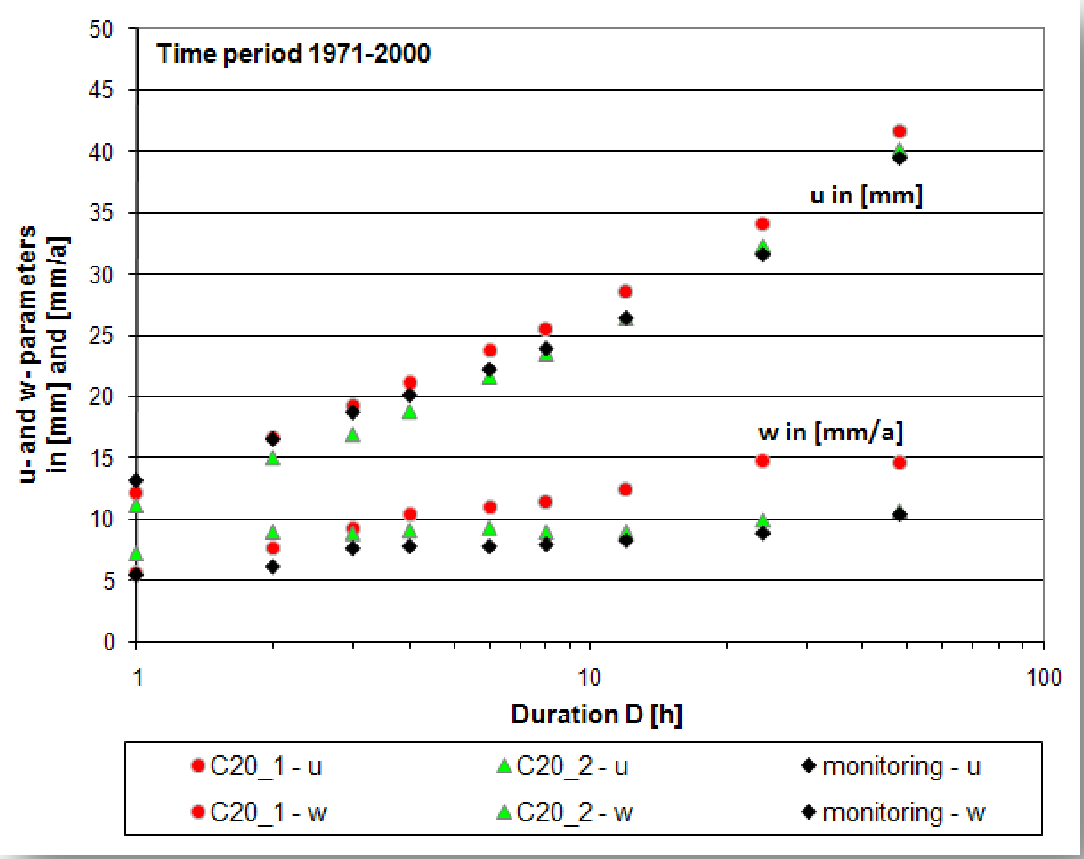
Validation of precipitation data

- Application of extreme value statistics according to German standard DWA A 121 for time span 1971 – 2000

  $h_{NN}(D,T) = u(D) + w(D)*ln(T)$

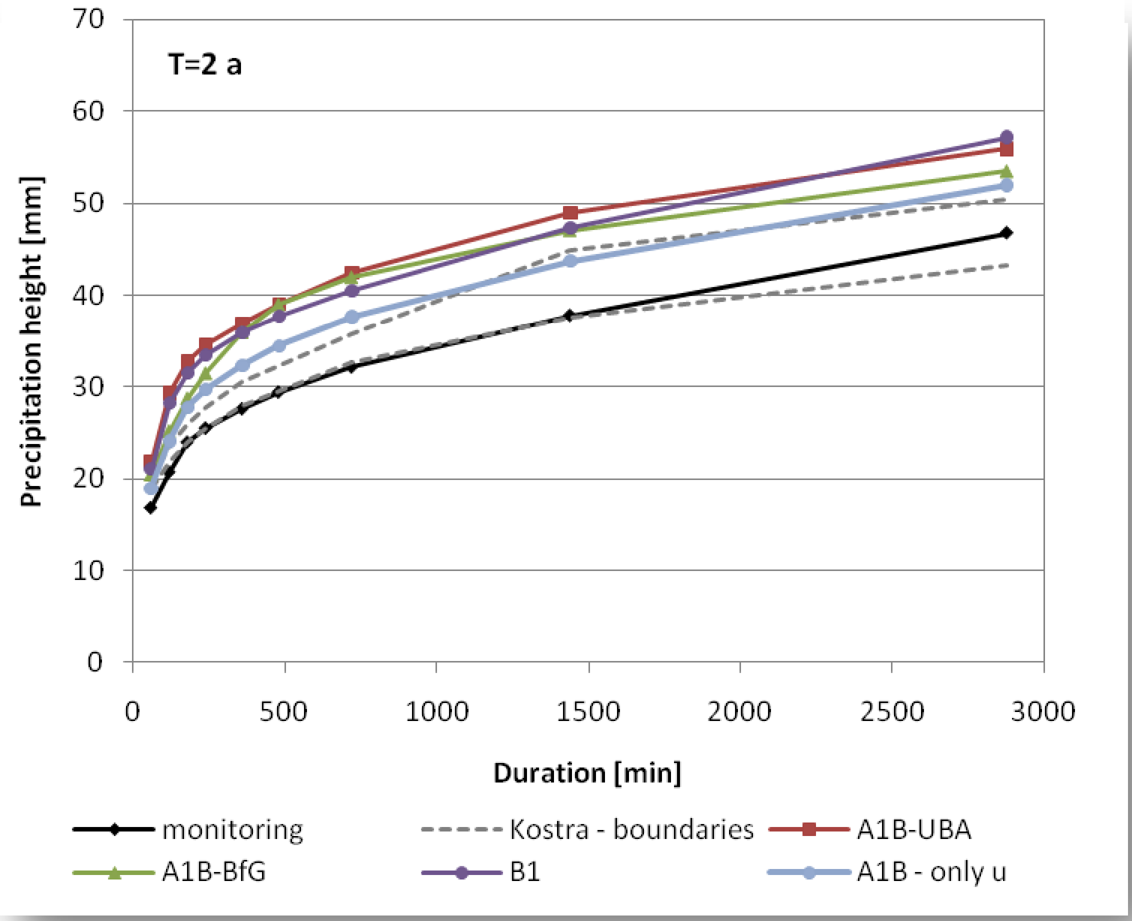
  h_{NN} = Precipitation height in [mm]
  D = Duration in [min]
  T = Return period in [a]

- Generally good correspondence between measured data and climate modell data
- Slight overestimation of w parameter for high durations (sensitivity analysis shows that this is due to one extreme event)
- Disaggregation underestimates u parameters for durations below 1 h while w parameters are in good agreement



Future trends in precipitation patterns

- Increase of statistical parameters u (+ 10-30 %) and w (+ 30-60 %) for future time span 2071-2100 (compared to time span 1971-2000)
- Higher statistical significance of trends in u than in w parameters
- Extrapolation of possible future design rains by increasing u and w parameters according to trend analysis



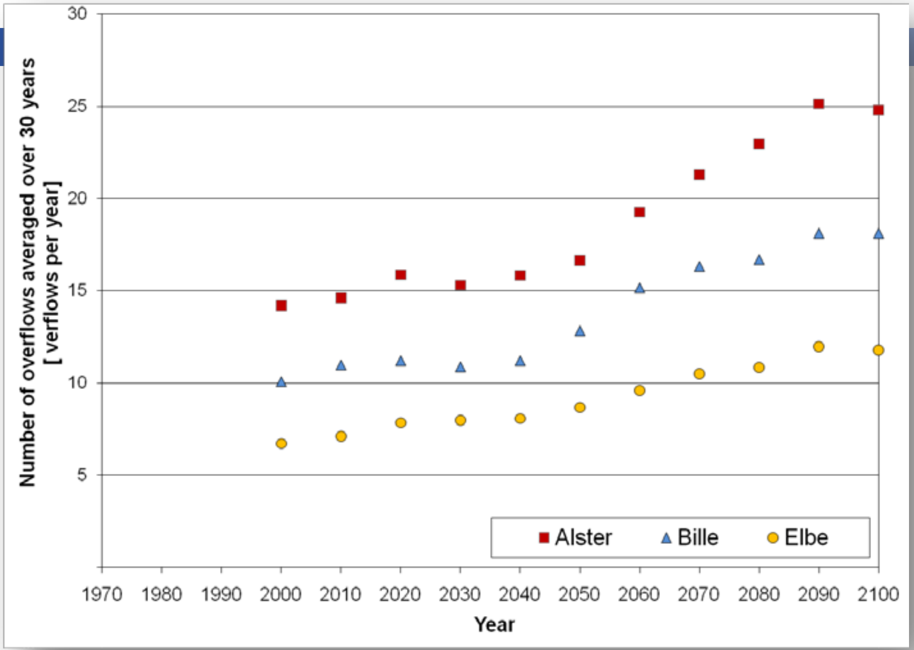
Future development of sewer system behaviour

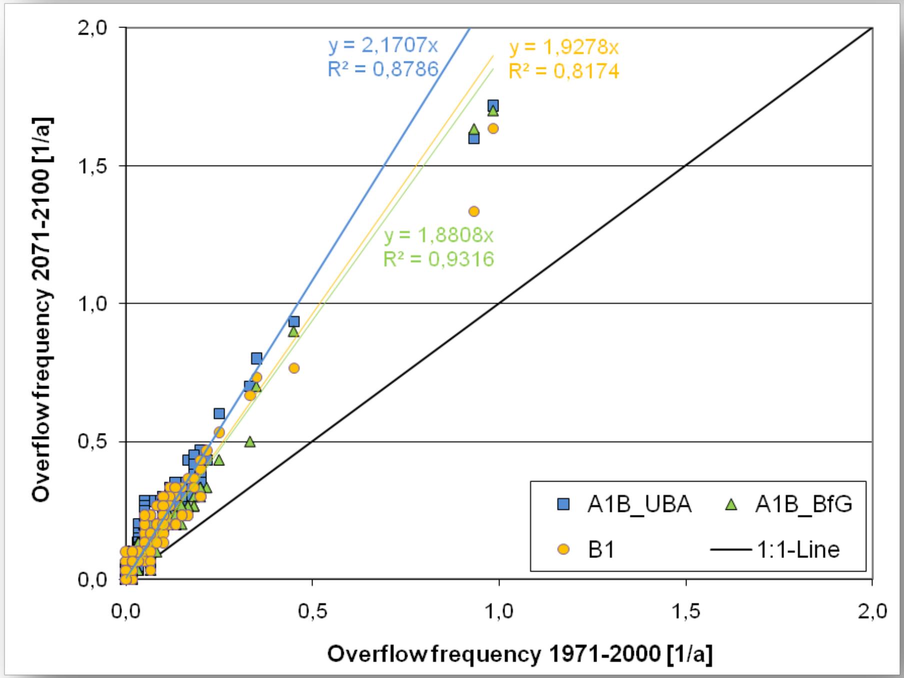
Combined sewer system (A1B_UBA)

- Increase in overflow frequencies of approx. 70-80 %; Increase in overflow volumes 40-50 %
- Partly compensation of water protection programs of last two decades
- Increase will predominantly occur in the second half of the 21st century

Separate sewer system (A1B_UBA, A1B_BfG)

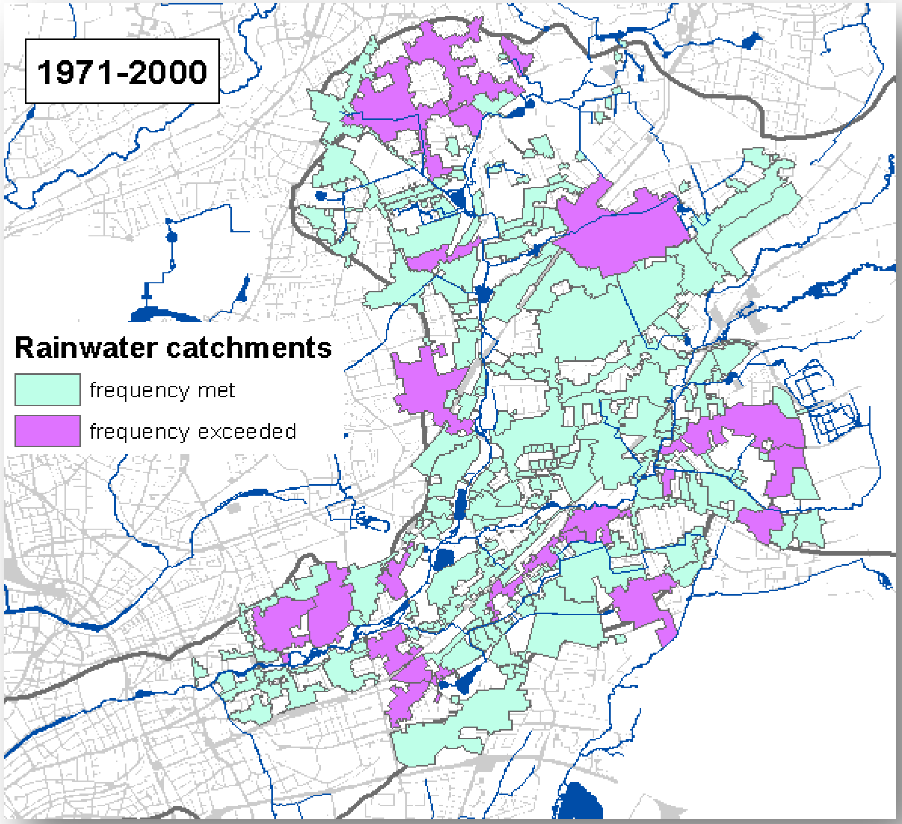
- Increase in surcharge frequencies for manholes of 80-100 %
- Result analysis over time also shows increase in second half of the 21st century

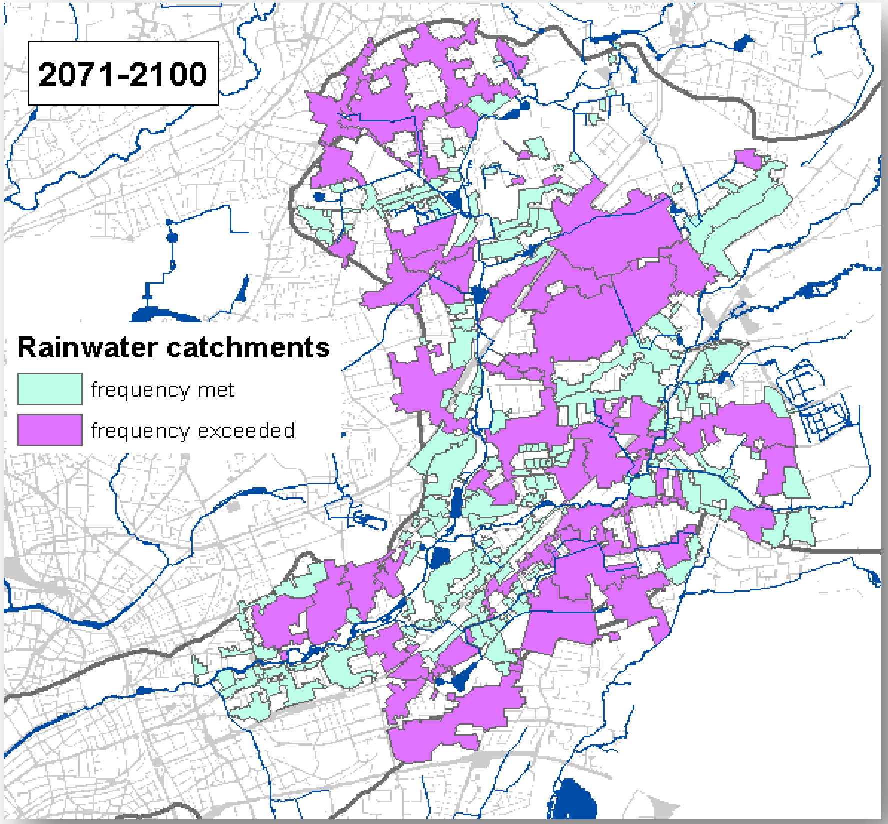




HAMBURG WASSER

Future development of sewer system behavior





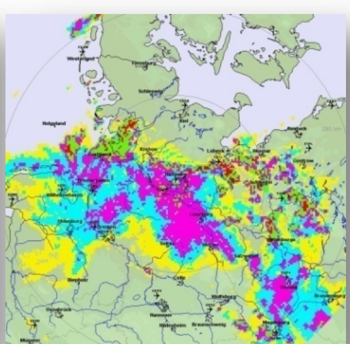
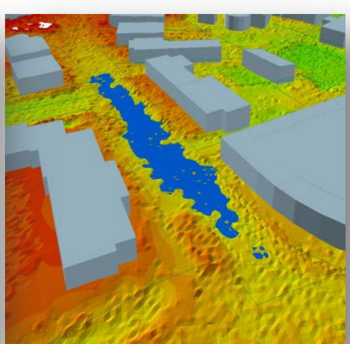
Separate sewer catchments exceeding recommended surcharge frequency
today and in the future according to climate change signal (T = 2 a according to German standard DWA A 118)

Conclusions

- **High probability** of relevant increase in surcharge frequencies and combined sewer overflows due to climate change in Hamburg (regarding the mentioned assumptions)
- Climate effects will be boosted by city growth (increase in surface sealing)
- **High uncertainty** regarding considered climate scenarios, Limited spatial and temporal resolution of climate model, disaggregation method
- Uncertainties do not allow reliable determination of new design parameters for sewers in Hamburg

Outlook: Strategy to handle climate change effects in Hamburg

- No nationwide extension of sewer capacities / no adaption of general climate factor in Hamburg (uncertanties, exetremely costly, difficult to implement)
- Focus must be on no or low regret measures:
  1. Sewer extension only in individual cases and under consideration of specific cost-benefit-relations
  2. Optimized management of existing sewer capacities by intelligent control measures and systematic removal of hydraulic bottlenecks
  3. General shift in drainage philosophy towards local protection measures against flooding (short-term) and decentralized storm water management (long-term)

Thank you for your attention

Thank you to

Max Planck-Institute for Meteorology in Hamburg
for collaboration

German Federal Ministry of Education and Research
for financial support within the KLIMZUG project