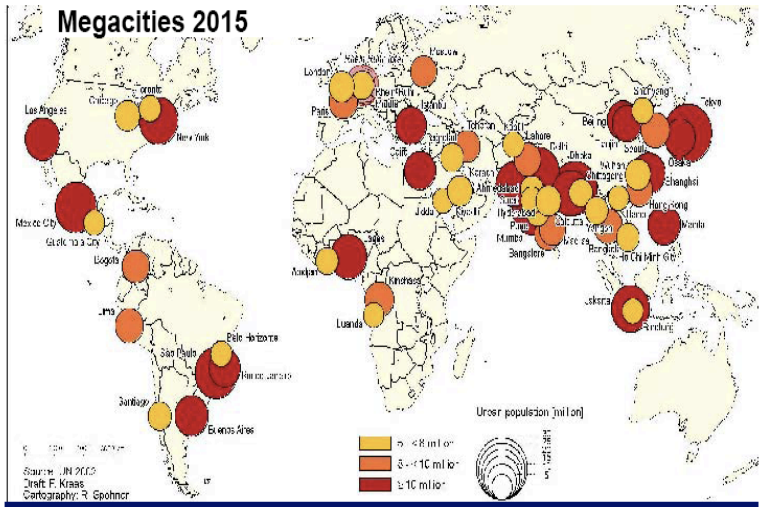
The University of Georgia

The Comparative Genetics of Cities

The growth of urban Kolkata, India and its impact on the precipitation processes



- 1950: 4, 1980: 28, 2002: 39, 2015: 59 megacities worldwide; 2/3 in developing countries, resp. South and East Asia
- 2002: 394 Mio. people, of these: 246 Mio. in developing countries, oder 215 Mio. in Asia; in the year 2015: 604 Mio. worldwide
- Population data tripled between 1970 and 2000: e.g. Mexico City, São Paulo, Seoul, Mumbai, Jakarta, Teheran

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Kolkata City - Background

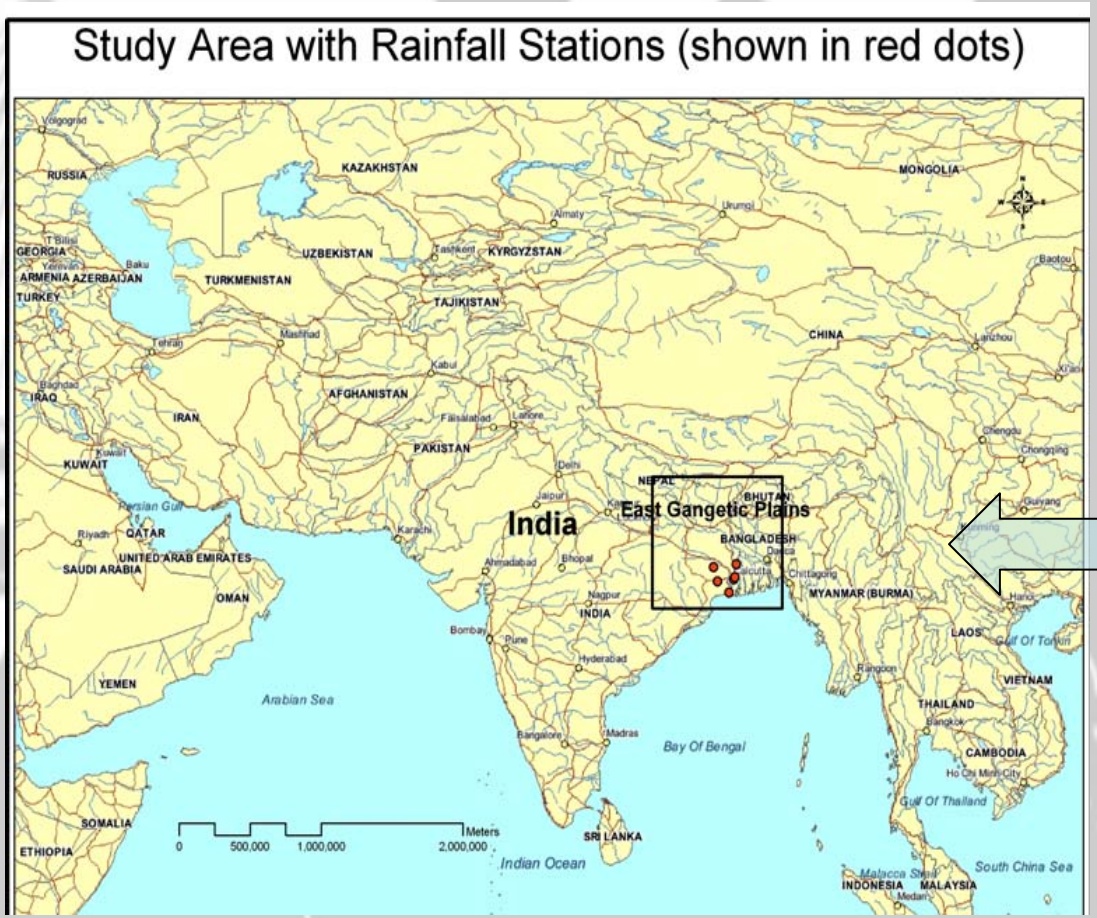
- 300 year old city
  - - Garrison town
  - - Company town
  - - Headquarters of British India Govt.
  - - now one amongst the four biggest cities in India
- In 1735 population of 100,000.
- Present population is 15 million (KMDA Report 2005)

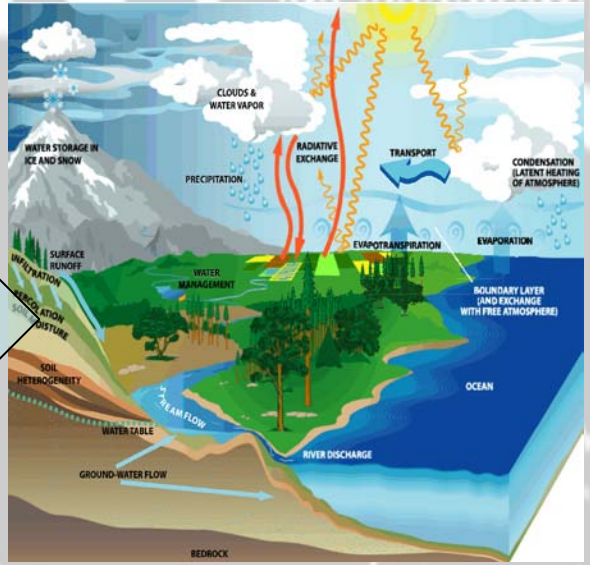
Reasons behind population explosion in Kolkata city

- Sudden influx of refugees in 1931-1947, before & after independence
- Only important city in the eastern part of India

Has Kolkata's growth changed regional hydroclimate?

Past and Recent literature (see Shepherd et al 2010 for review) continue to indicate that urban areas affect spatio-temporal rainfall variability.

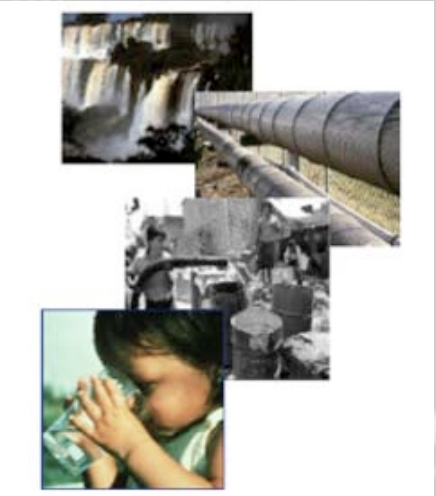


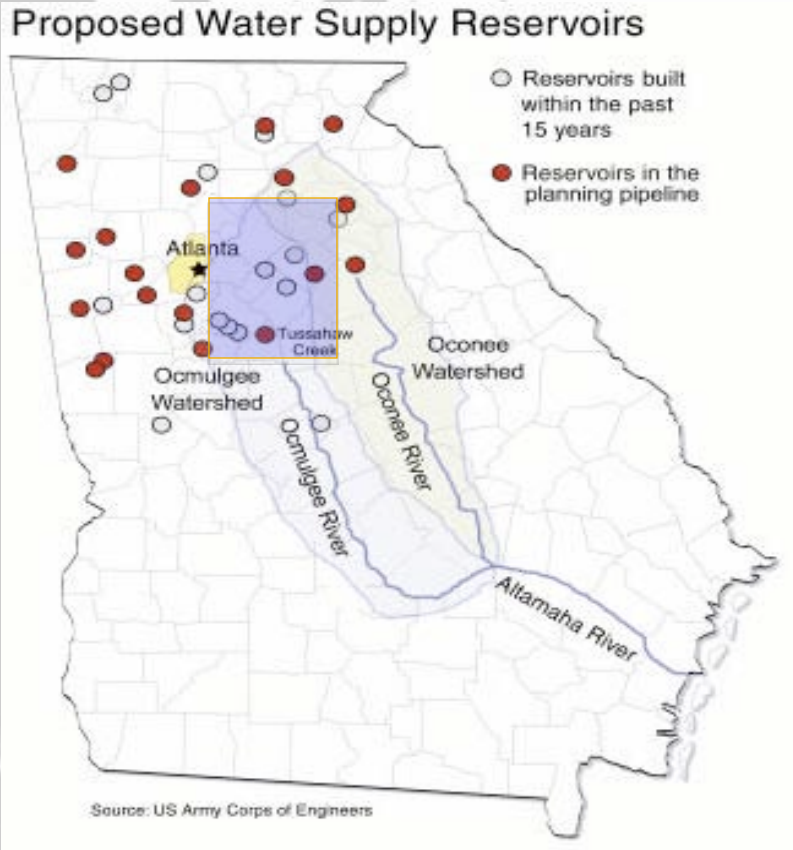


Why study urban effects on Hydroclimates?

Scientifically interesting but also real-world implications for:

- Water Resources
- Public Health
- Agriculture
- Planning
- Hazard management





Shepherd and Mote 2009; Mote et al 2007

Research Objectives

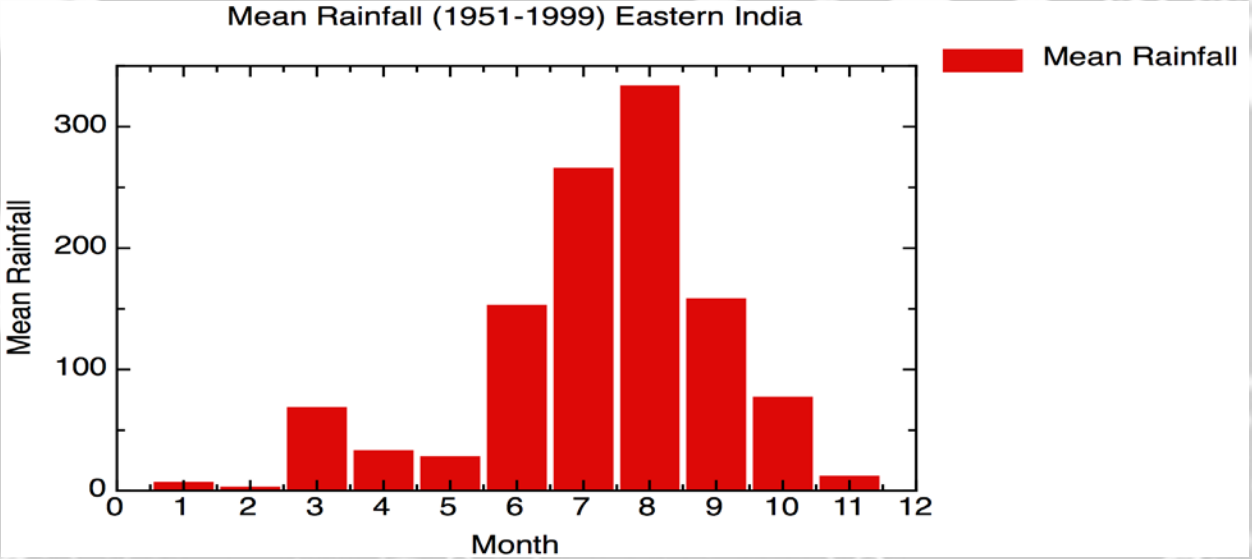
- To conduct an analysis using historical maps and satellite remote sensing to delineate the urban growth dynamics over 300 years.
- To investigate whether trends in pre-monsoonal rainfall over the last 50 years are correlated with urban land cover growth .
- To utilize Cellular automata modeling techniques to project future land cover growth in Kolkata.
- To investigate urban landcover (past, current, future) - precipitation relationships using coupled land atmosphere models

Significance of Research

- Thorough spatio-temporal evaluation of Kolkata's urban land cover dynamics over 300 years.
- One of the first attempts to use the CA - Markov model on any city in India.
- Real estate, industrialists, the government, the common people will benefit from this future growth projection.
- One of the first studies to use an urban growth model coupled with an atmospheric- land surface model to look at future growth effects on precipitation (Shepherd et al 2010, ENV Planning B)
- It will provide a prototype methodology for studying the effect of future urban growth scenarios on rainfall in developing countries.

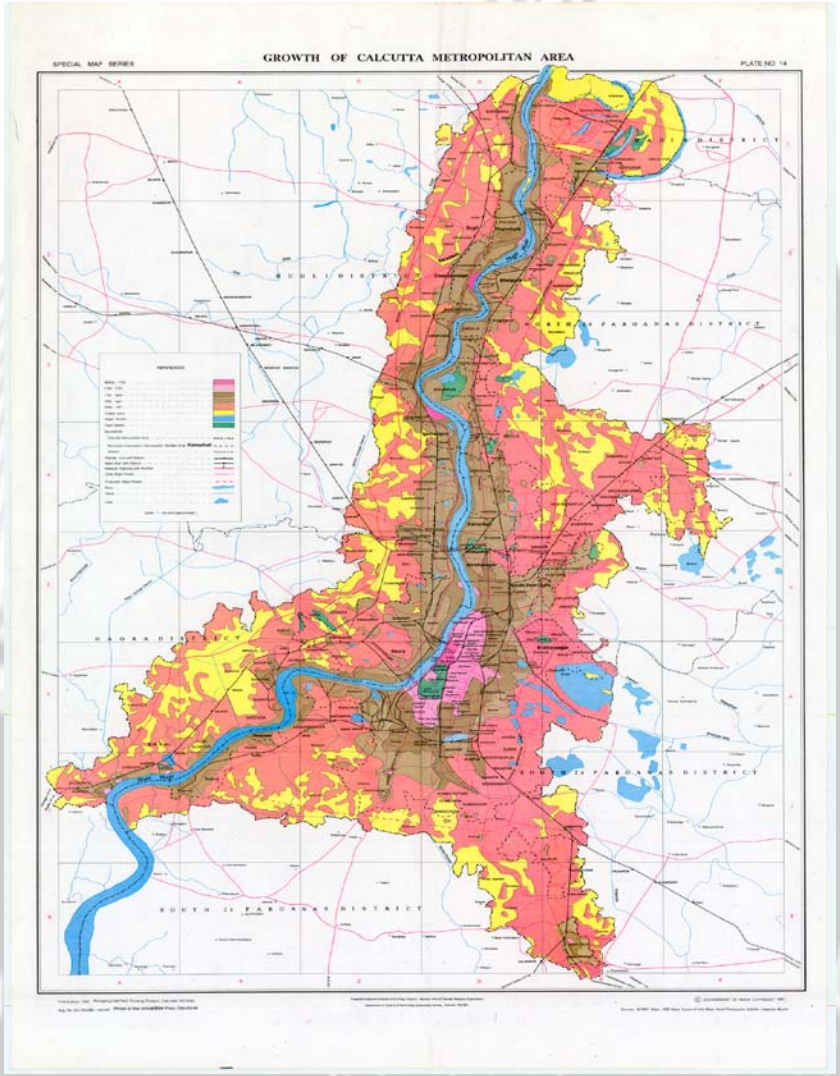
Why pre-monsoon is significant?

- There is a lack of any long term analysis of the pre-monsoon period rainfall in the literature
  - 12% of E. Gangetic Rainfall
- During pre-monsoonal period, rainfall is most likely to be convective in nature and driven by mesoscale processes (like urban forcings)



Mean monthly rainfall (in mm) for the area (82-89 E, 19-26 N) using Legates and Willmott (1990b) data set.

Data and methods used

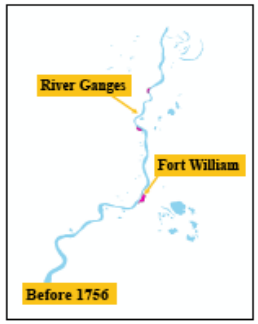


- Historical paper maps, Landsat ETM images, TRMM and Legattes-Willmott data sets, NCEP data.
- Methods – Digitization, Mann-Kendall trend analysis, CA-Markov LULC growth model, WRF_NOAH model

Results - Growth of Kolkata- Objective 1

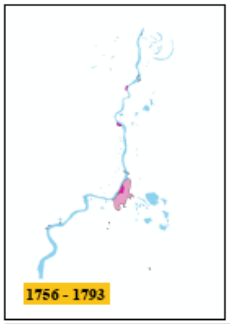
Unprecedented depiction of 300 years of urban land cover growth

Urban Sprawl of Kolkata in Phases

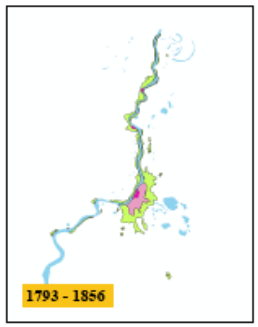


Source: Special Map Series, Plate # 14

The year 1690 A.D. is considered the birth year of the city of Kolkata. The period between 1690 & 1793 witnessed Kolkata becoming the stronghold of colonial operations. Before 1756 only the Fort William area was developed, but after 1756 other areas along the river grew up. On the 1st of August, 1774 Kolkata became the capital of the English possessions in India. Its population became 200,000 by 1775.

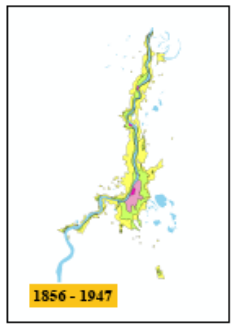


Source: Special Map Series, Plate # 14

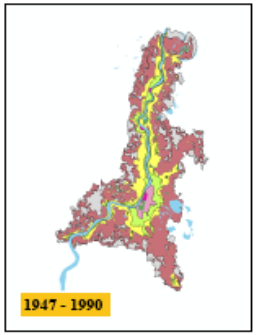


Source: Special Map Series, Plate # 14

Between 1856 and 1947, two world wars and the independence of India took place. Kolkata ceased to be the capital anymore. This phase saw an increase in population. Unplanned development took place. More than one building were coming up in single plots. In places, buildings were constructed on roads and lanes. Land use became complex. Newer areas were developing rapidly.

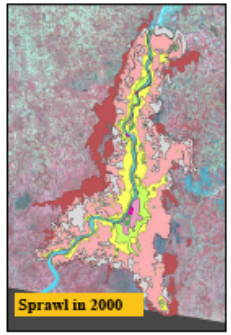


Source: Special Map Series, Plate # 14



Source: Landsat Image of 1990

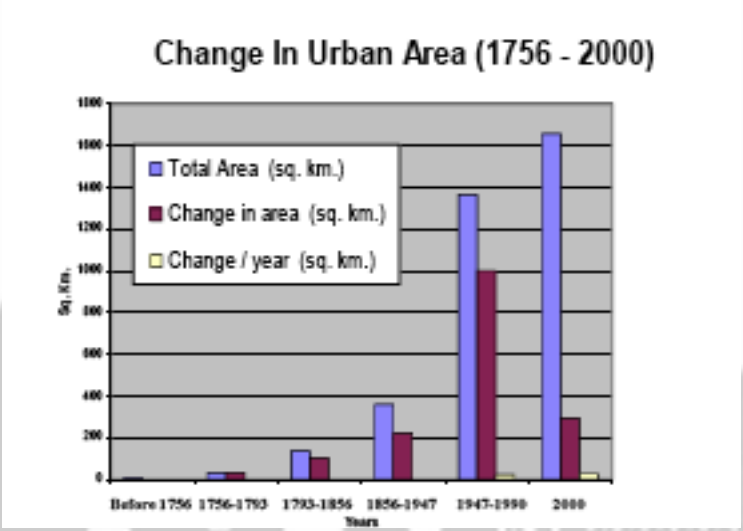
The partition of India and liberation of Bangladesh led to mass migration towards Kolkata and the flow is still continuing. The city limits have extended into adjoining districts of Haora, N. & S. 24 Paraganas. The adjoining maps show the sprawl of the city in all directions, especially in the south and west, across the river Ganges. Sprawl is restricted towards the east due to the wetlands.



Source: Landsat Image of 2000

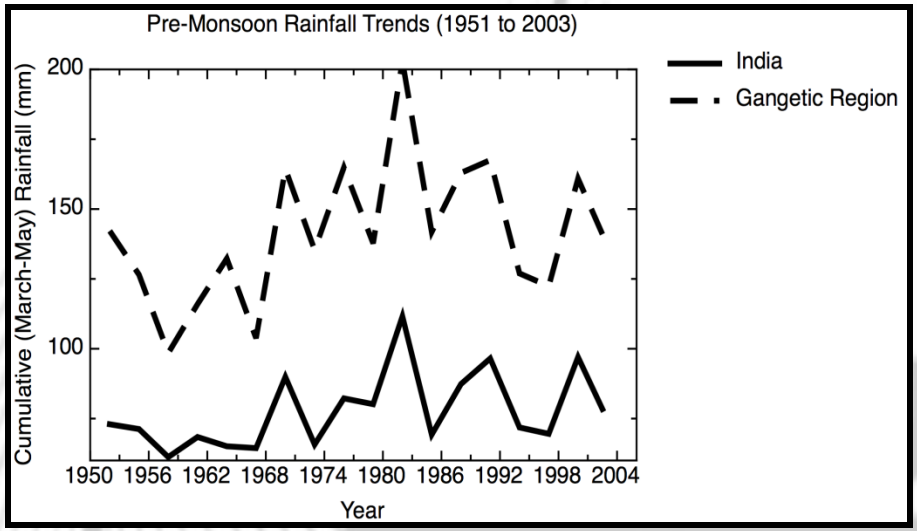
Results - Growth of Kolkata- Objective 1

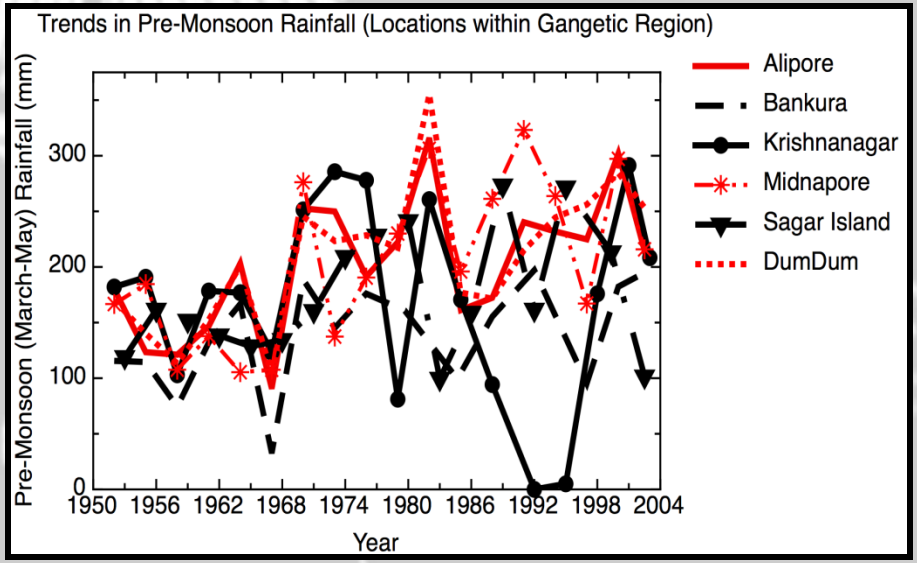
- Four fold increase of land cover between 1947 – 1990
- Per year change in land cover was 23.20 up to 1990 and is still continuing
- Between 1990 – 2000, the per year change is land cover was more than that before 1990



Years	Total Area (sq. km.)	Change in Area (sq. km.)	Area change/ year (sq. km.)
Before 1756	4.0		
1756 – 1793	34	30	0.80
1793 – 1856	136	102	1.60
1856 – 1947	361	225	2.50
1947 - 1990	1363	1002	23.20
1990 – 2000	1658	295	29.50

Results - Time series showing pre-monsoonal rainfall (50 years)





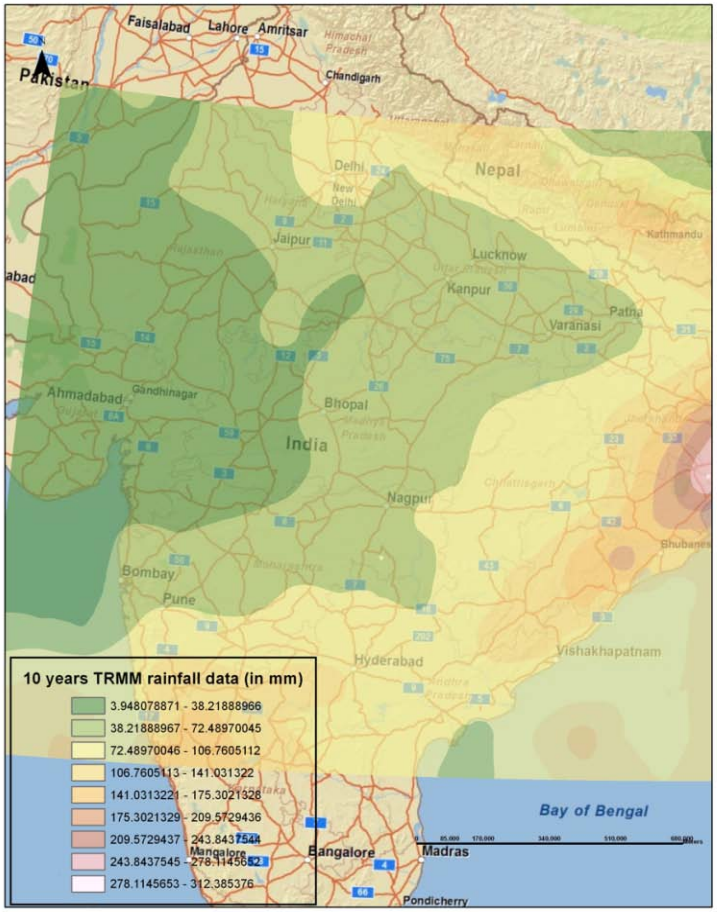
- **no statistically significant trend in pre-monsoonal rainfall for India and the East Gangetic region.**
- **three significant trends: two of the city of Kolkata and one Midnapore, which is a fairly sizeable city.**
- **Mann– Kendall analysis appears to support the hypothesis that large urban areas like Kolkata have influenced cumulative rainfall in the pre-monsoonal season.**

Results – Statistical significance of trends

P-value < 0.05 is significant at 95 % level

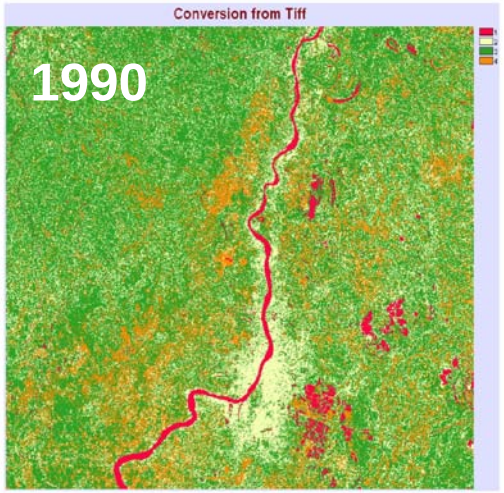
Stations	P - Value	Tau correlation
Alipore	0.0167	0.227
Dumdum	0.0129	0.236
Bankura	0.0881	0.173
Krishnanagar	0.3982	-0.081
Sagar Island	0.6032	0.051
Midnapore	0.0007	0.323
India	0.0872	0.163
East Gangetic	0.1795	0.128

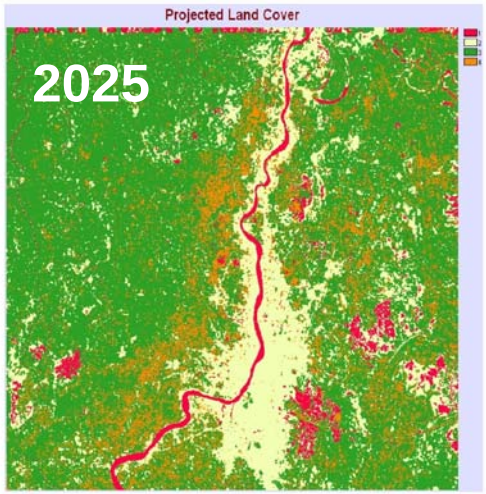
Spatial Plot of 10 years TRMM rainfall data over India



Results - Explanations for the dynamics of 2025 projected growth

Years	Total Area (sq. km.)	Area change/ year (sq. km.)
Before 1756	4.0	
1793	34	0.80
1856	136	1.60
1947	361	2.50
1990	1363	23.20
2000	1658	29.50
2025	2653	39.80



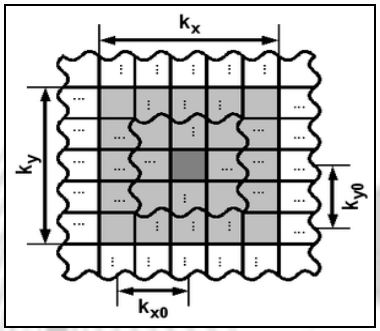


- Transportation lines
- The river Ganges
- Wetland ???

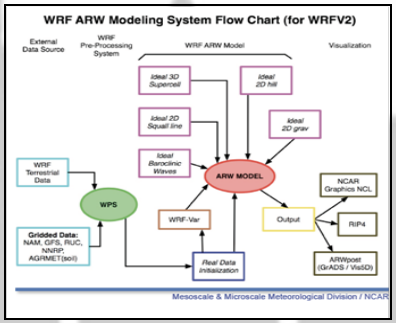
Elements of Research Objective 2 to be submitted to Professional Geographer, March 2010

Ongoing Research – 3rd Objective

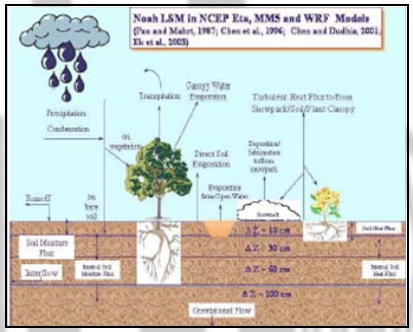
Cellular Automata



WRF



NOAH



WRF-NOAH Model

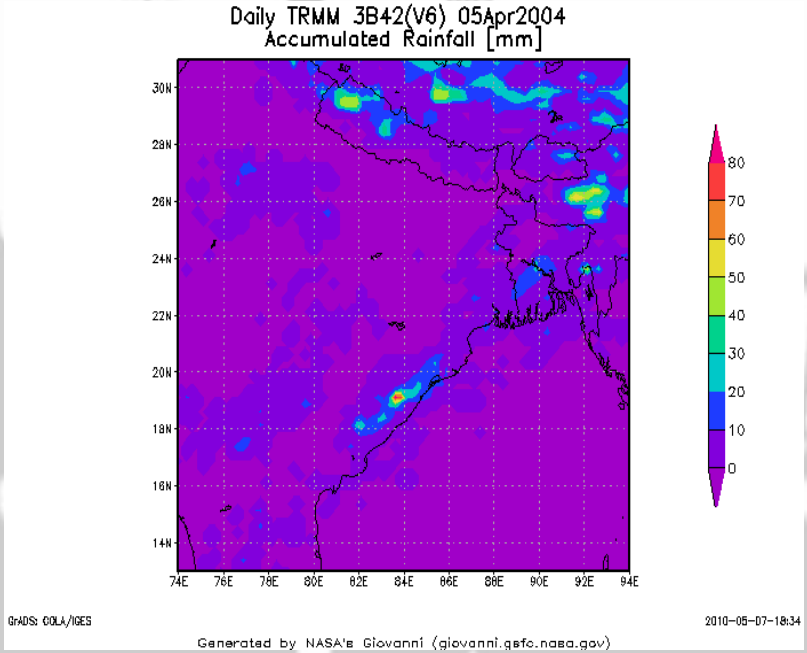
The assessment of urban growth will be applied to weather-climate studies using the Weather Research and Forecast model coupled with the NOAH land surface model. The approach will involve simulating pre-monsoonal rainfall case days for Kolkata under past, current, and projected land cover scenarios.

Experimental design and results

- 5th April 2004: chosen date for the runs.

- Circa 1950 landcover
- Circa 2000 landcover
- Circa 2025 landcover

(Under same initial meteorological conditions)



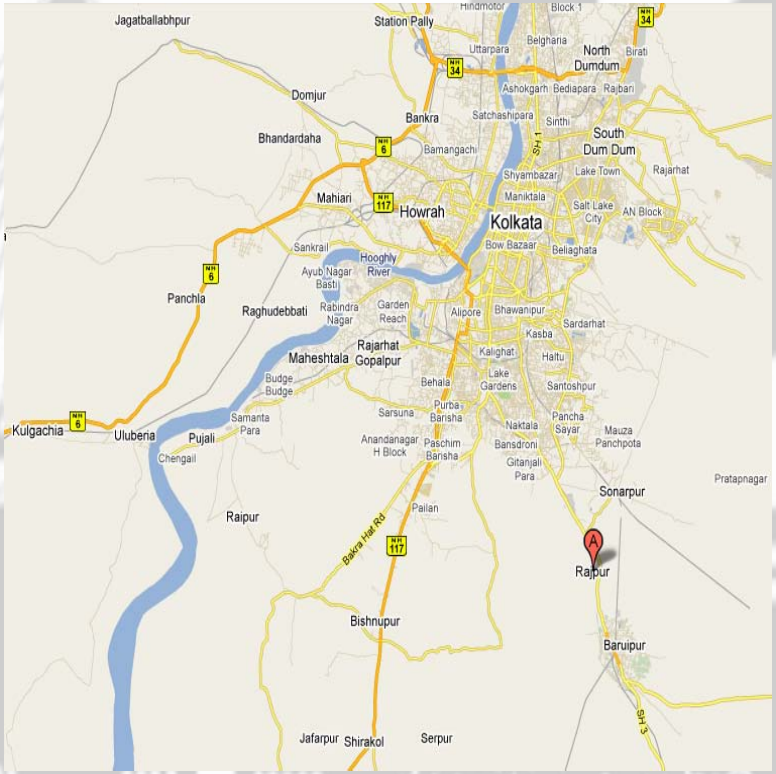
From the analysis we are to compare cumulative rainfall, convergence and sensible/ latent heat fluxes as presented in Shem and Shepherd 2009

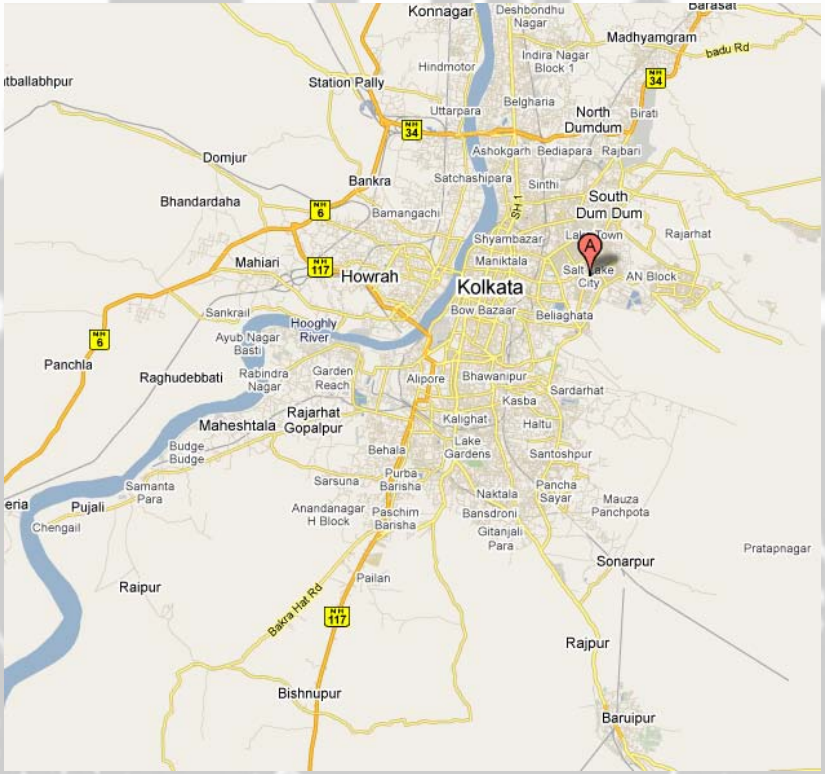
Conclusions

- **Large urban areas like Kolkata may have influenced cumulative rainfall in the pre-monsoonal season.**
- **The city will grow mostly to the S-SE and east. In 2000 the growth/ year was 29.50 sq. km and prediction is that in 2025 it will be 39.80 sq km.**
- **The WRF-NOAH model results will show present and predict future rainfall amounts, which will be validated with available rainfall data.**

Adaptive Management

The government has planned to decentralize





Questions, please?

http://news.nationalgeographic.com/news/2006/07/060705-mouse-frog.html