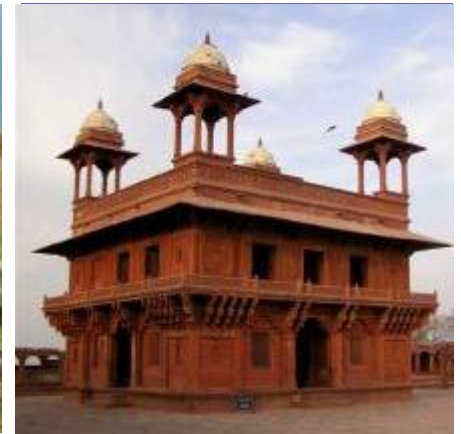





6th GRIHA Regional  
Conference on  
Accelerating Sustainability  
in Built Environment

Built Environment in  
Response to Climate  
Vulnerabilities  
3 February 2015



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with inputs from Saurabh  
Bhardwaj  
Earth Science & Climate Change  
Division, TERI



+ Is the built environment  
vulnerable to climate change?

Does it need to adapt?



Photo: Ian Teh <http://www.newyorker.com/magazine/2012/12/24/recall-of-the-wild>



Photo: Tobias Karlhuber [http://commons.wikimedia.org/wiki/File:The\\_universe.jpg](http://commons.wikimedia.org/wiki/File:The_universe.jpg)





Photo: Huai-Chun Hsu [http://commons.wikimedia.org/wiki/File:Thames\\_Town\\_in\\_Songjiang\\_02.jpg](http://commons.wikimedia.org/wiki/File:Thames_Town_in_Songjiang_02.jpg)

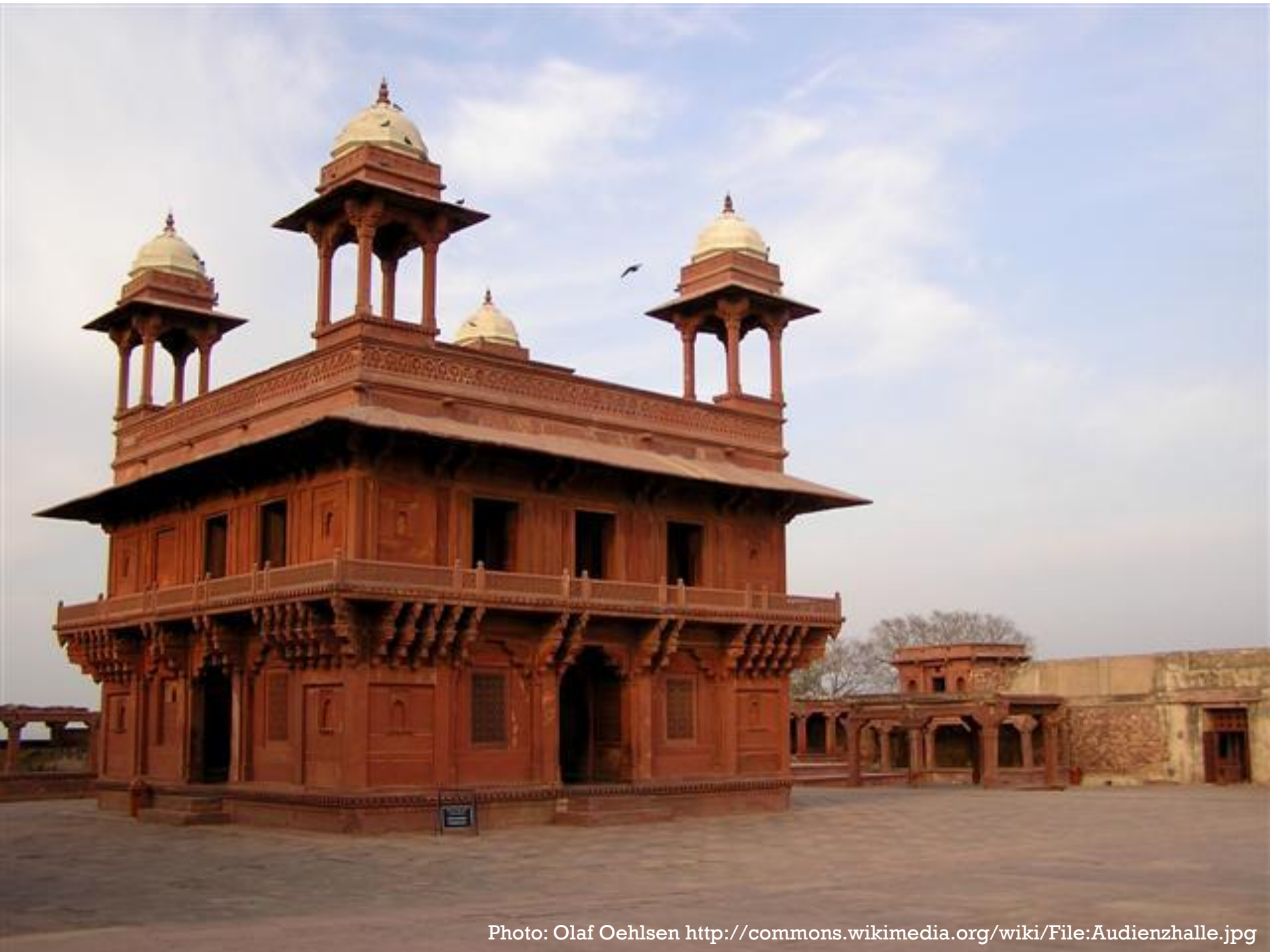


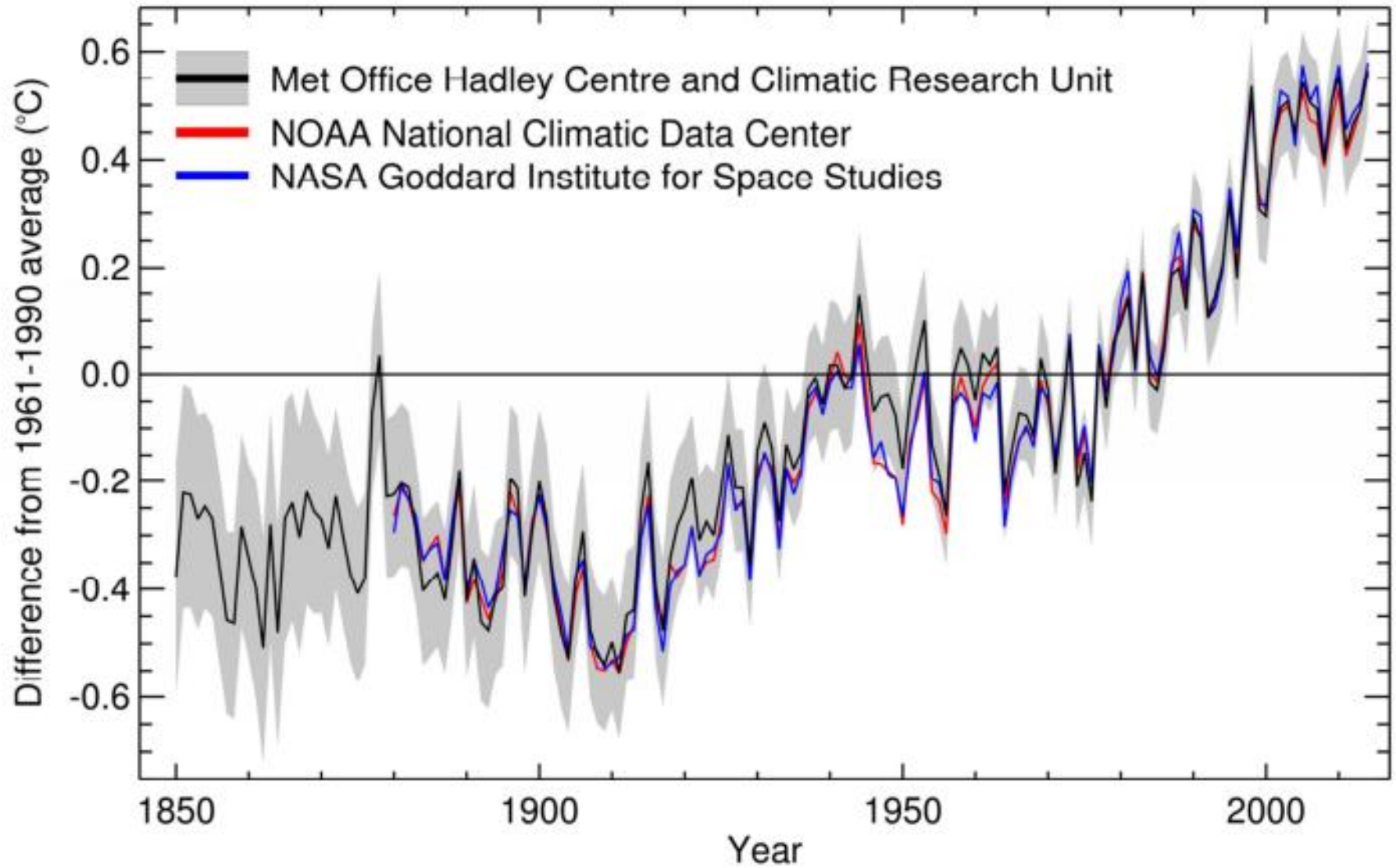
Photo: Olaf Oehlsen <http://commons.wikimedia.org/wiki/File:Audienzhalle.jpg>



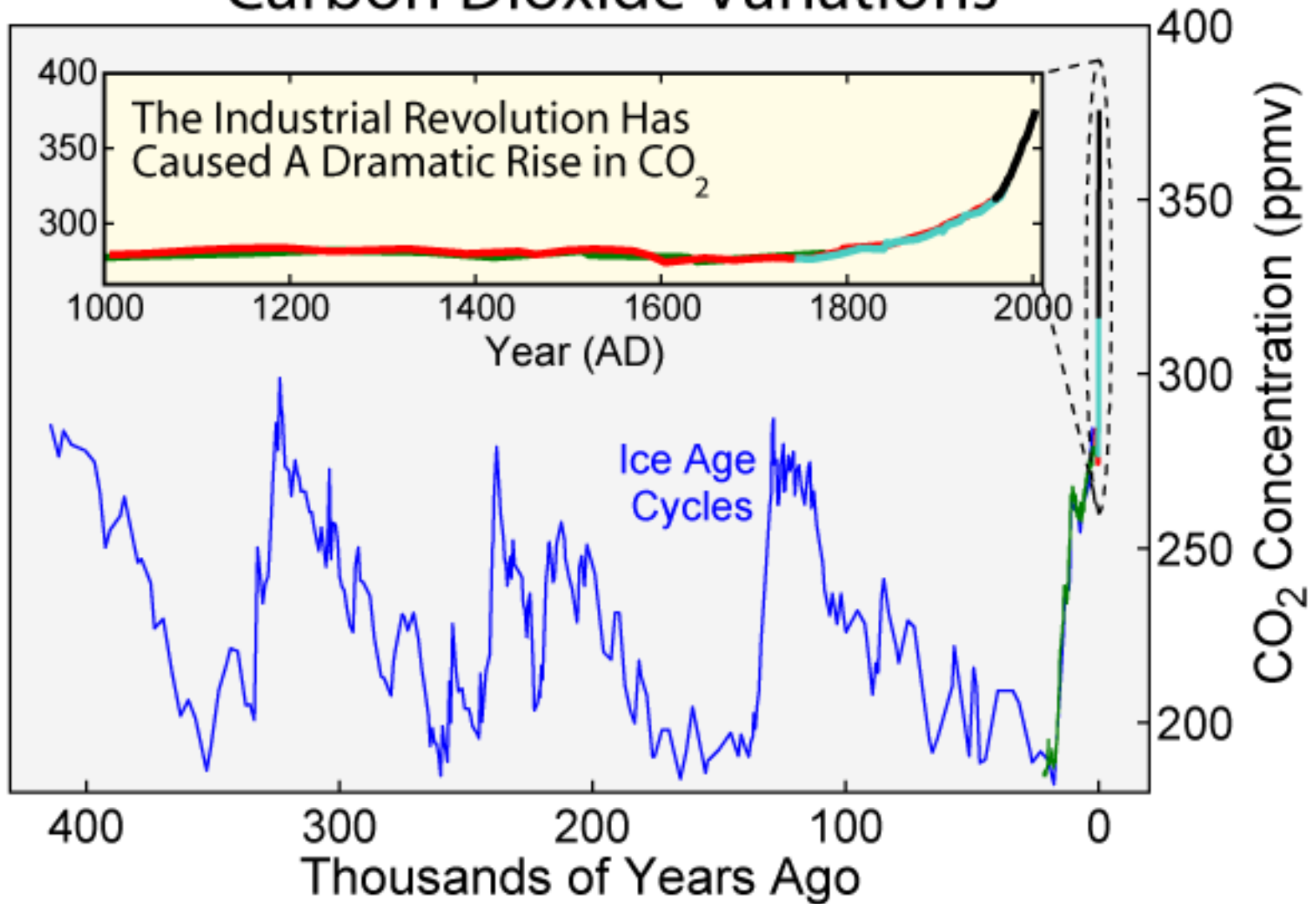
Is the climate changing?

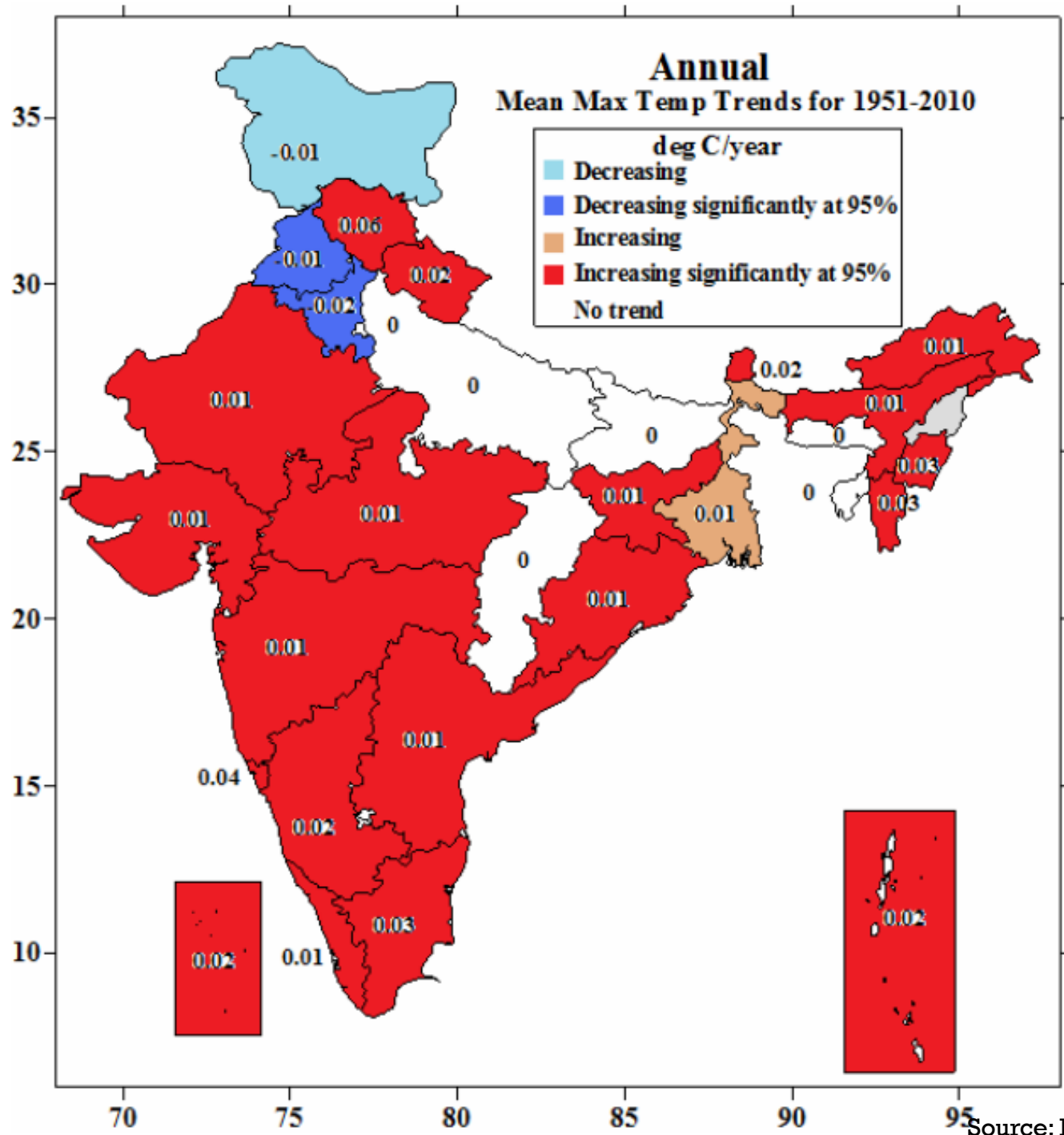


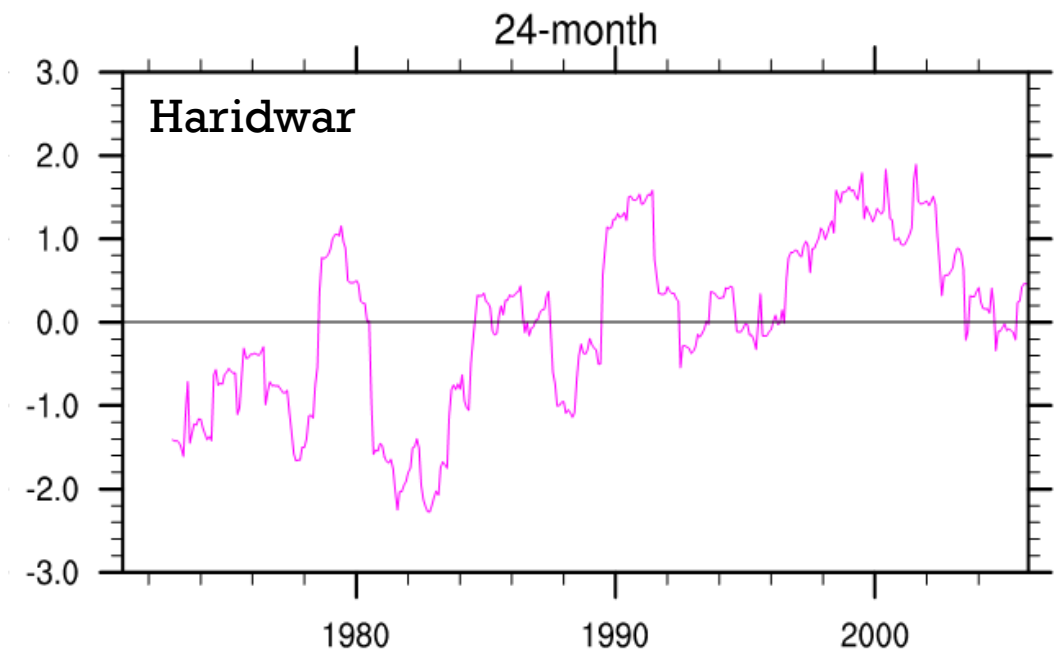
# Global average temperature anomaly (1850-2014)



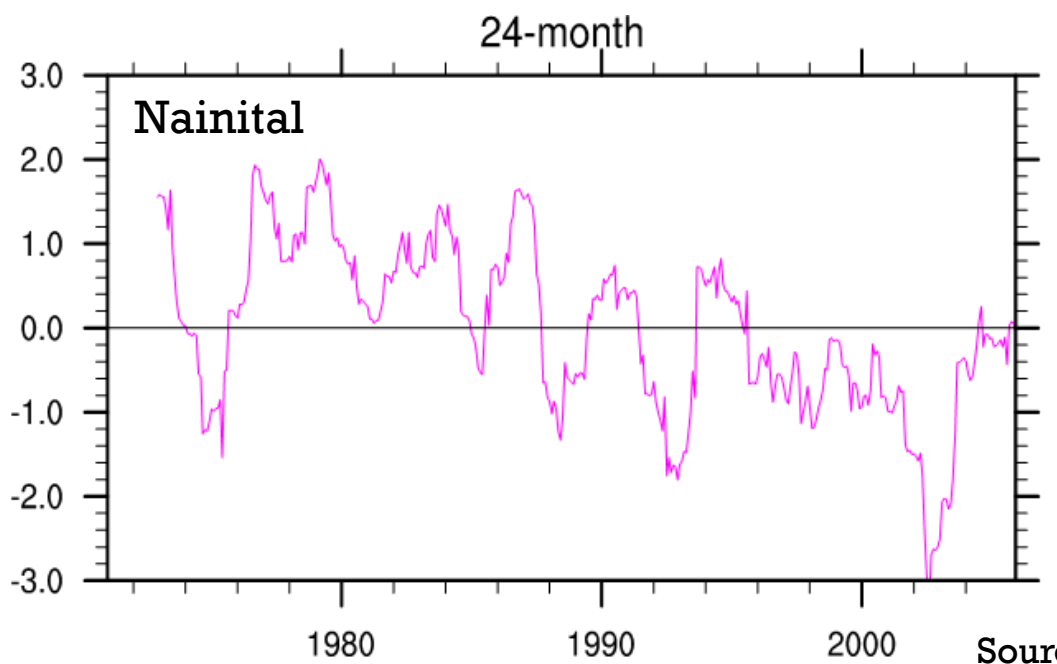
# Carbon Dioxide Variations





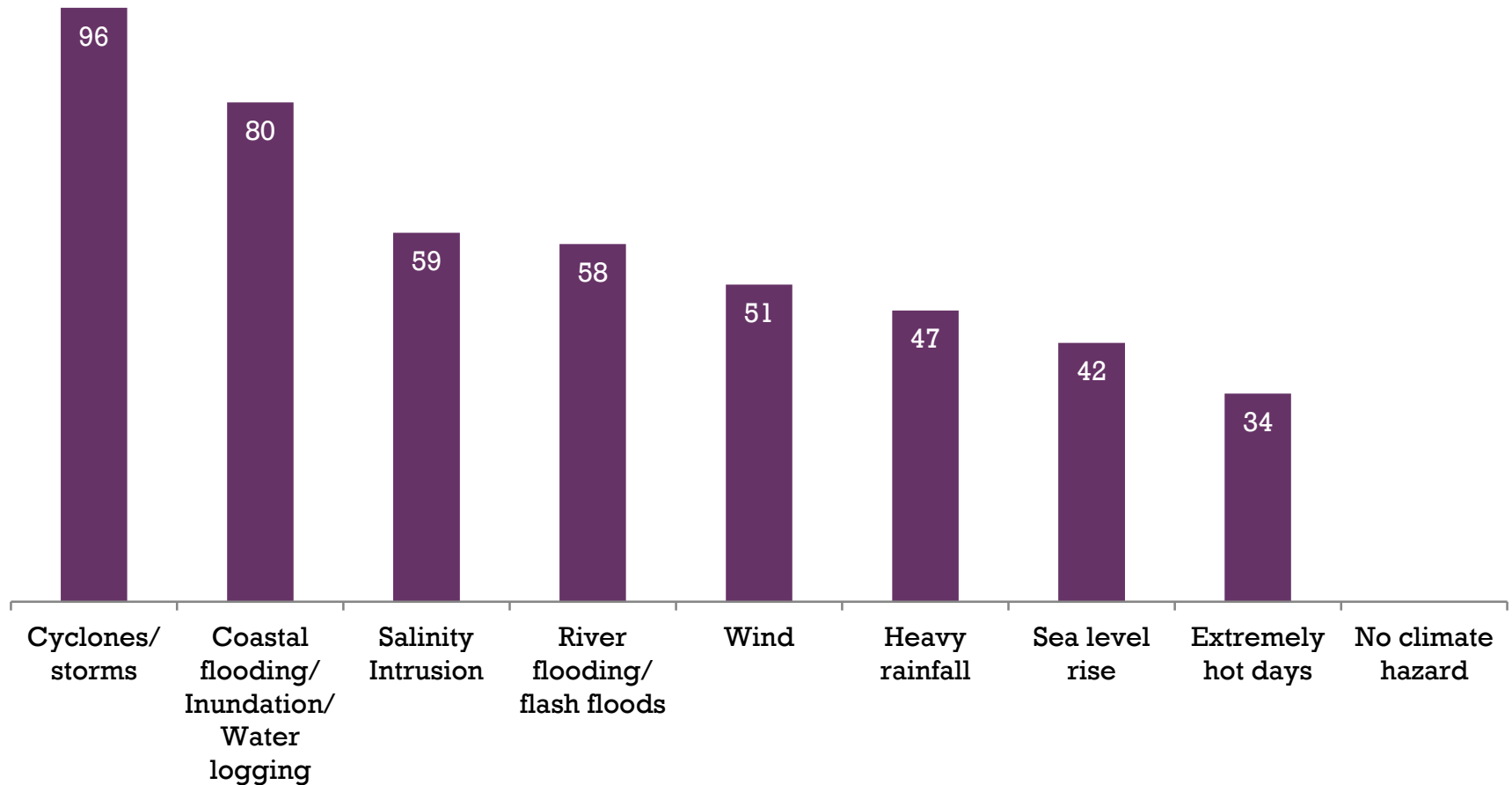


24-month  
Standardized  
precipitation index  
for 1997-2005



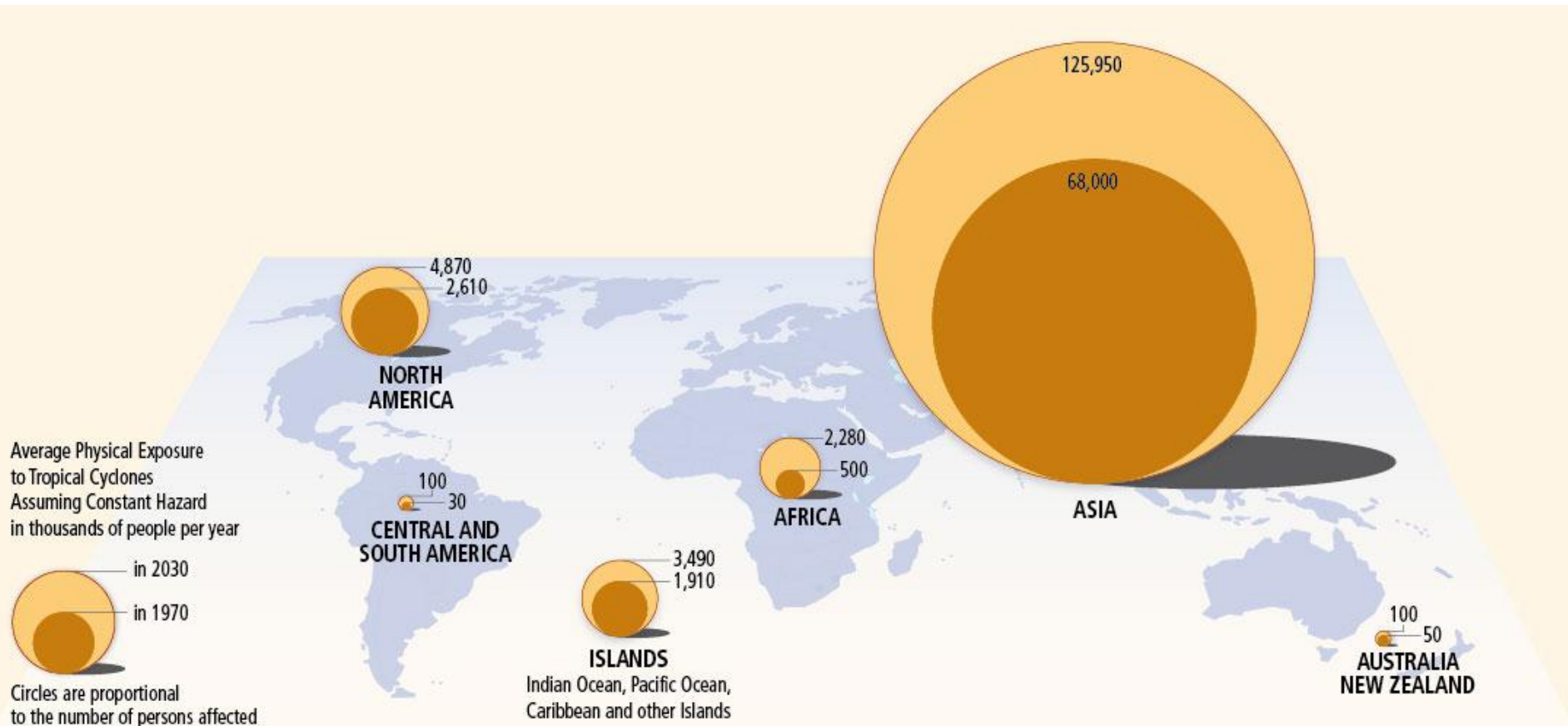
Source: TERI analysis (2014)  
Data derived from IMD gridded area average

# % households reporting climate hazards faced in coastal Bangladesh



Source: IFC-BCAS-TERI survey of 500 households in 8 coastal districts of Bangladesh (August 2014)

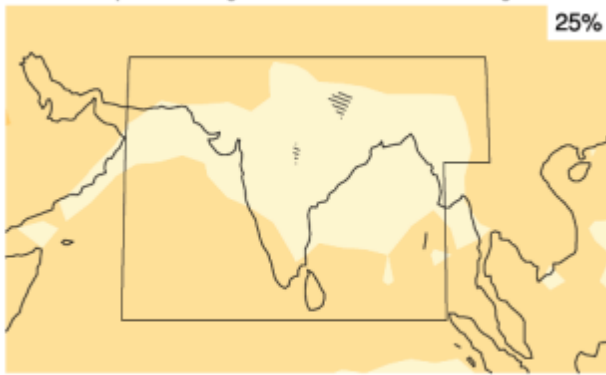
# Average exposure to cyclones in 1970 & 2030 in thousands of people per year; assuming constant hazard





+ How will climate change  
over the next few decades?

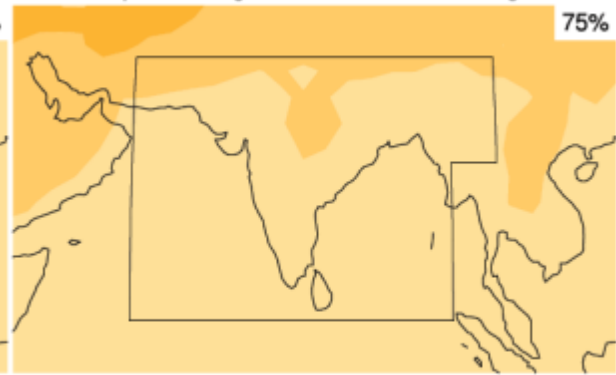
Temperature change RCP4.5 in 2016-2035: June-August



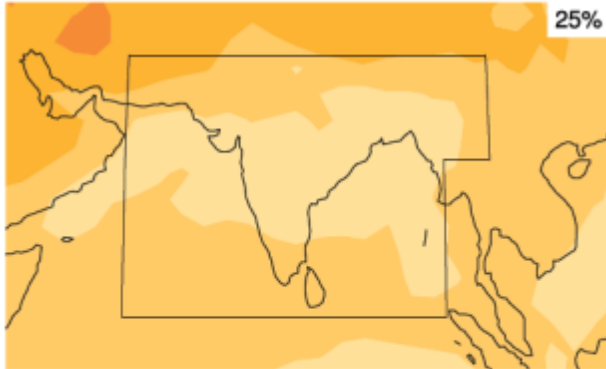
Temperature change RCP4.5 in 2016-2035: June-August



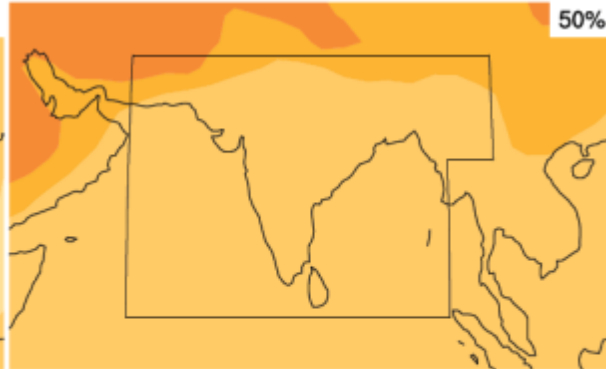
Temperature change RCP4.5 in 2016-2035: June-August



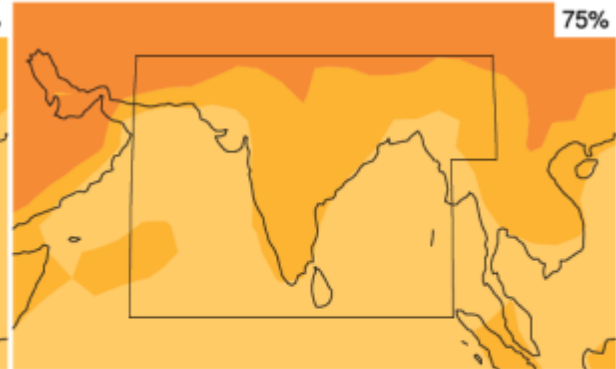
Temperature change RCP4.5 in 2046-2065: June-August



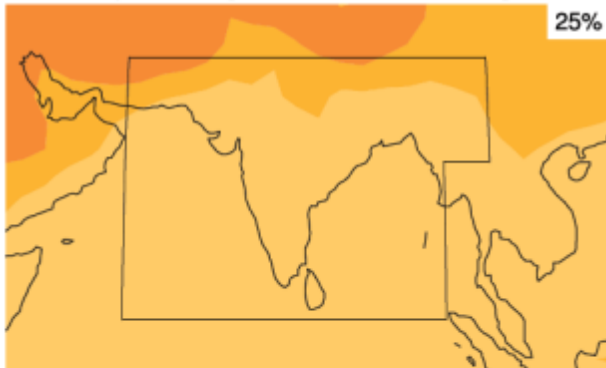
Temperature change RCP4.5 in 2046-2065: June-August



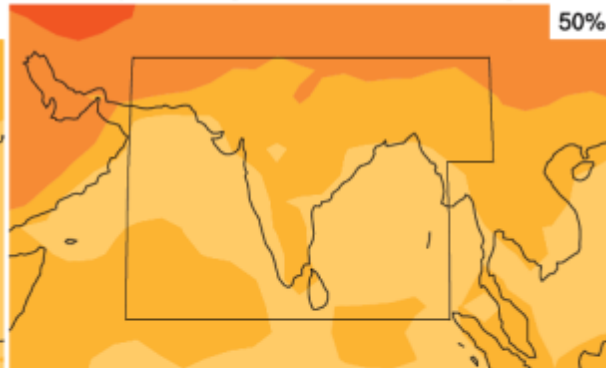
Temperature change RCP4.5 in 2046-2065: June-August



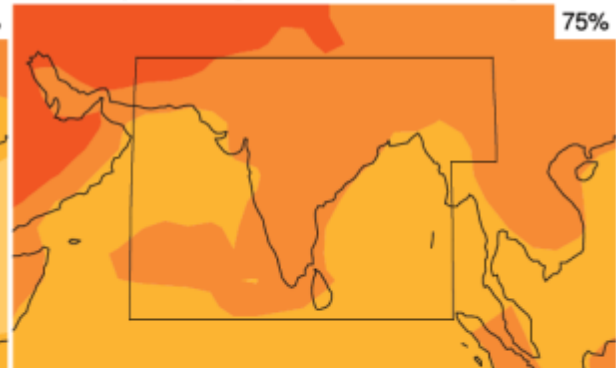
Temperature change RCP4.5 in 2081-2100: June-August



Temperature change RCP4.5 in 2081-2100: June-August



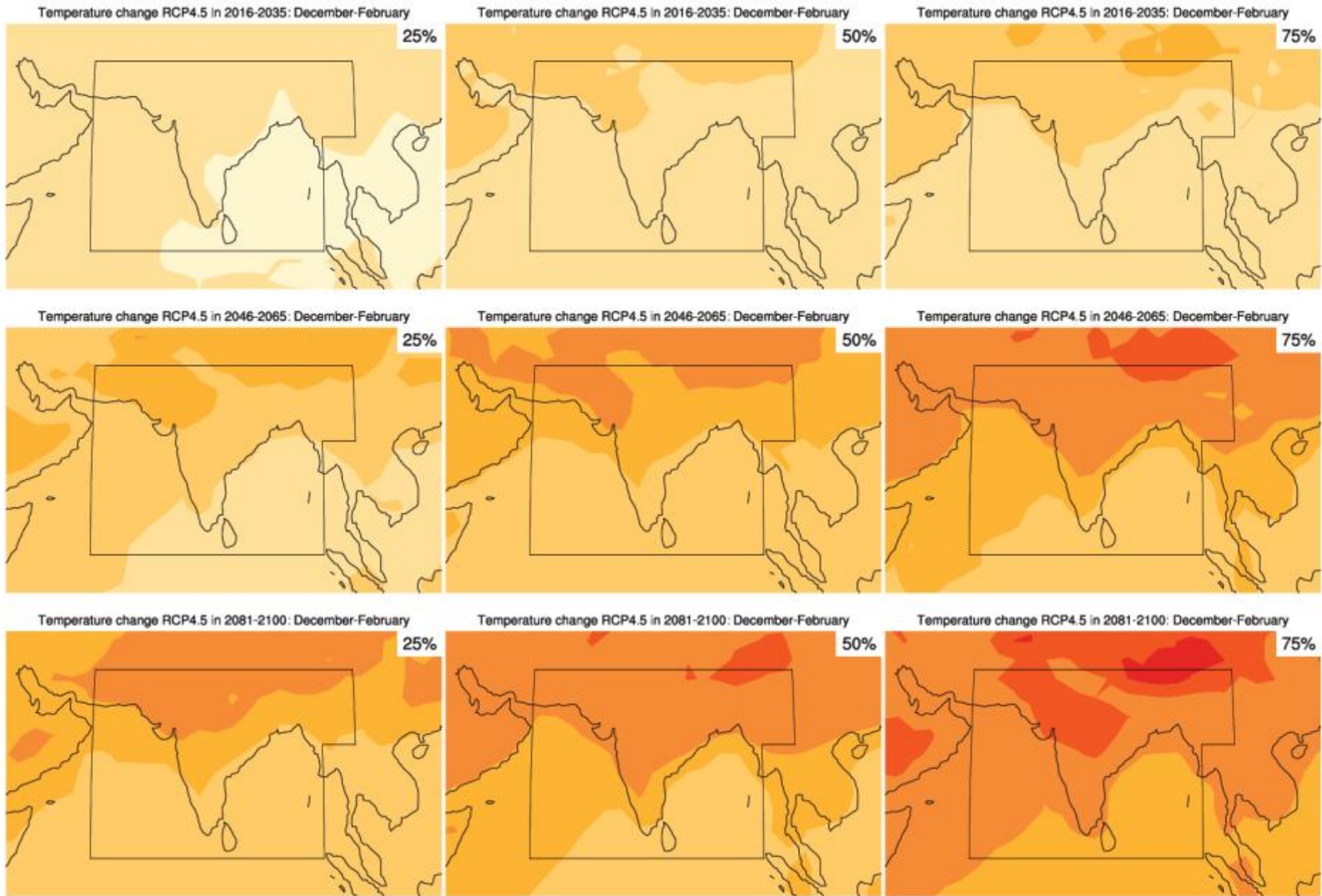
Temperature change RCP4.5 in 2081-2100: June-August



[°C]

Source: IPCC AR5 WG1 Annex 1

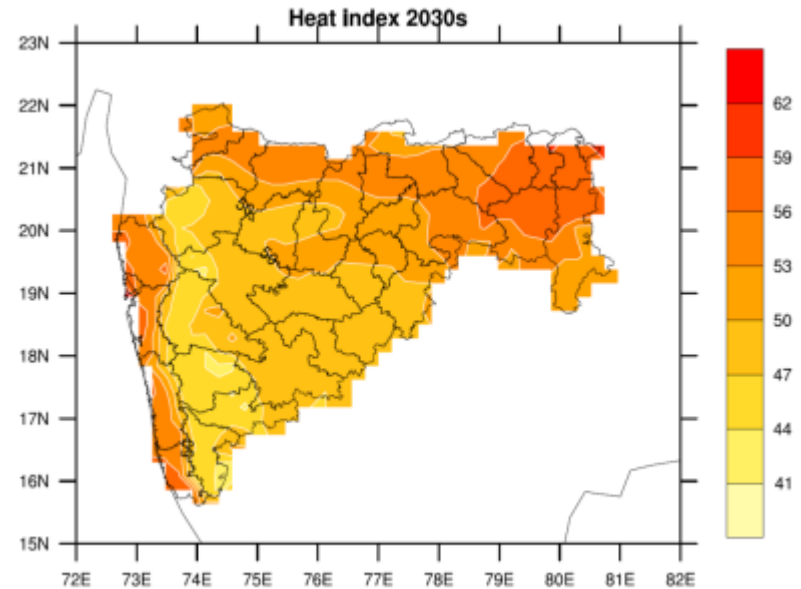
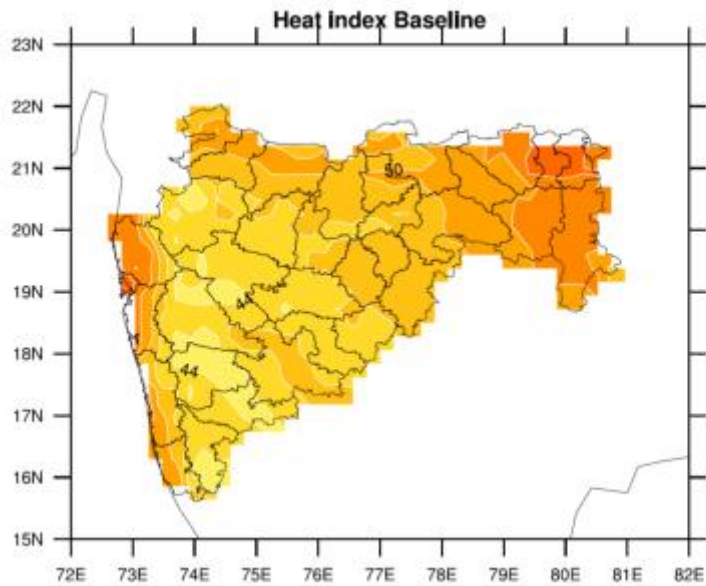




[°C]  
Source: IPCC AR5 WG1 Annex 1

# Heat Index – “how hot it feels”

Combines air temperature and relative humidity to determine the perceived or apparent temperature related to human comfort



Source: TERI analysis for Government of Maharashtra (2014)

		temperature (°C)																
		27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Relative Humidity (%)	40	27	28	29	30	31	32	34	35	37	39	41	43	46	48	51	54	57
	45	27	28	29	30	32	33	35	37	39	41	43	46	49	51	54	57	60
	50	27	28	30	31	33	34	36	38	41	43	46	49	52	55	58	61	64
	55	28	29	30	32	34	36	38	40	43	46	48	52	55	58	61	64	67
	60	28	29	31	33	35	37	40	42	45	48	51	55	58	61	64	67	70
	65	28	30	32	34	36	39	41	44	48	51	55	58	61	64	67	70	73
	70	29	31	33	35	38	40	43	47	50	54	58	61	64	67	70	73	76
	75	29	31	34	36	39	42	46	49	53	56	60	63	66	69	72	75	78
	80	30	32	35	38	41	44	48	52	57	60	63	66	69	72	75	78	81
	85	30	33	36	39	43	47	51	55	58	61	64	67	70	73	76	79	82
90	31	34	37	41	45	49	54	58	61	64	67	70	73	76	79	82	85	
95	31	35	38	42	47	51	57	60	63	66	69	72	75	78	81	84	87	
100	32	36	40	44	49	54	58	61	64	67	70	73	76	79	82	85	88	

27–32 °C

Caution: fatigue is possible with prolonged exposure and activity.  
Continuing activity could result in heat cramps.

32–41 °C

Extreme caution: heat cramps and heat exhaustion are possible.  
Continuing activity could result in heat stroke.

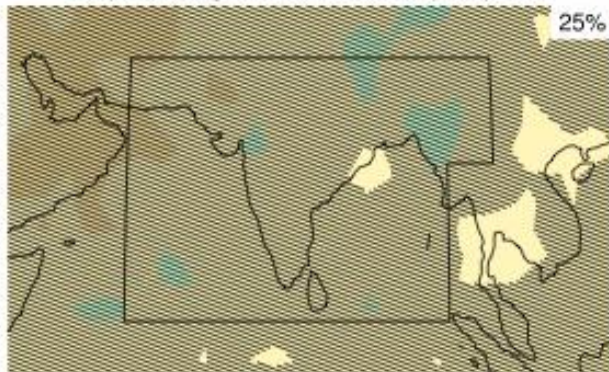
41–54 °C

Danger: heat cramps and heat exhaustion are likely;  
heat stroke is probable with continued activity.

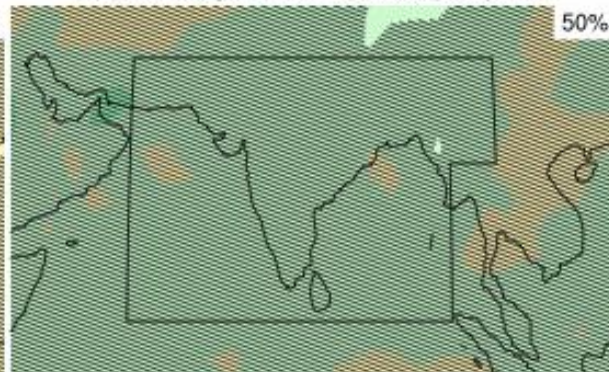
over 54 °C

Extreme danger: heat stroke is imminent.

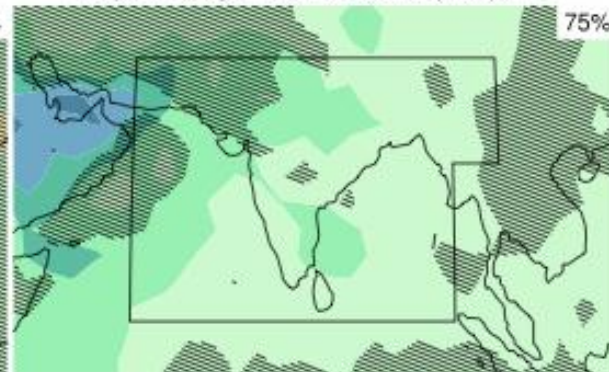
Precipitation change RCP4.5 in 2016-2035: April-September



Precipitation change RCP4.5 in 2016-2035: April-September



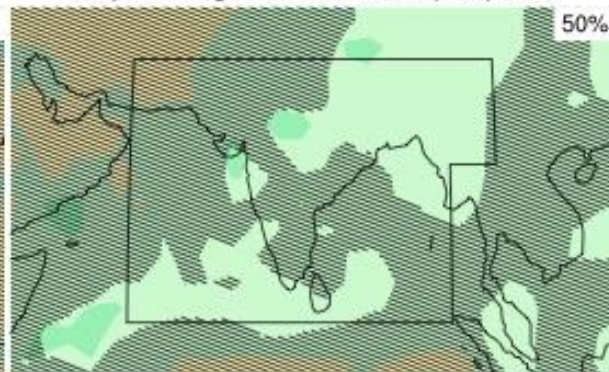
Precipitation change RCP4.5 in 2016-2035: April-September



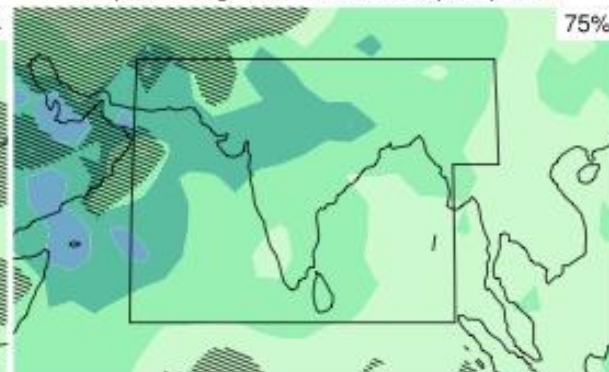
Precipitation change RCP4.5 in 2046-2065: April-September



Precipitation change RCP4.5 in 2046-2065: April-September



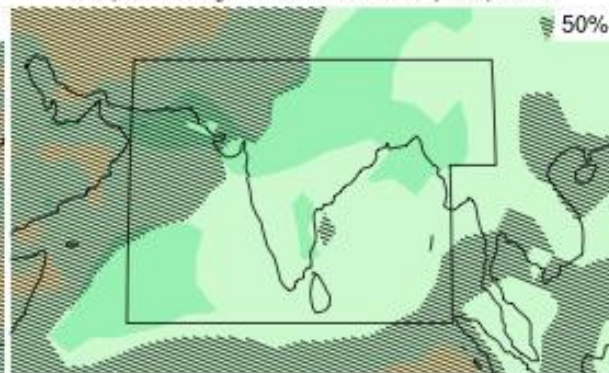
Precipitation change RCP4.5 in 2046-2065: April-September



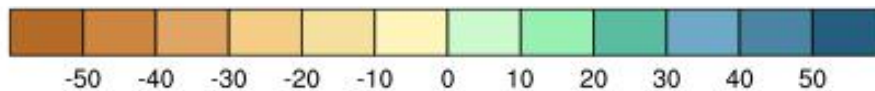
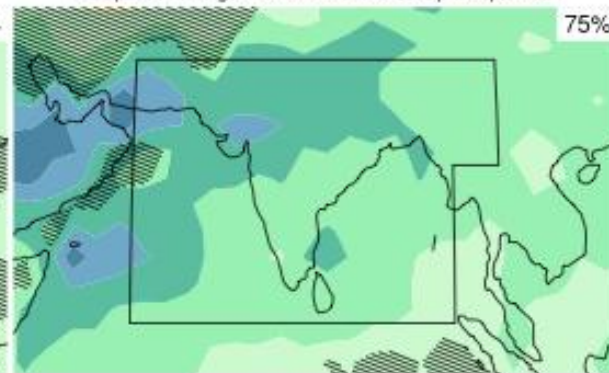
Precipitation change RCP4.5 in 2081-2100: April-September



Precipitation change RCP4.5 in 2081-2100: April-September



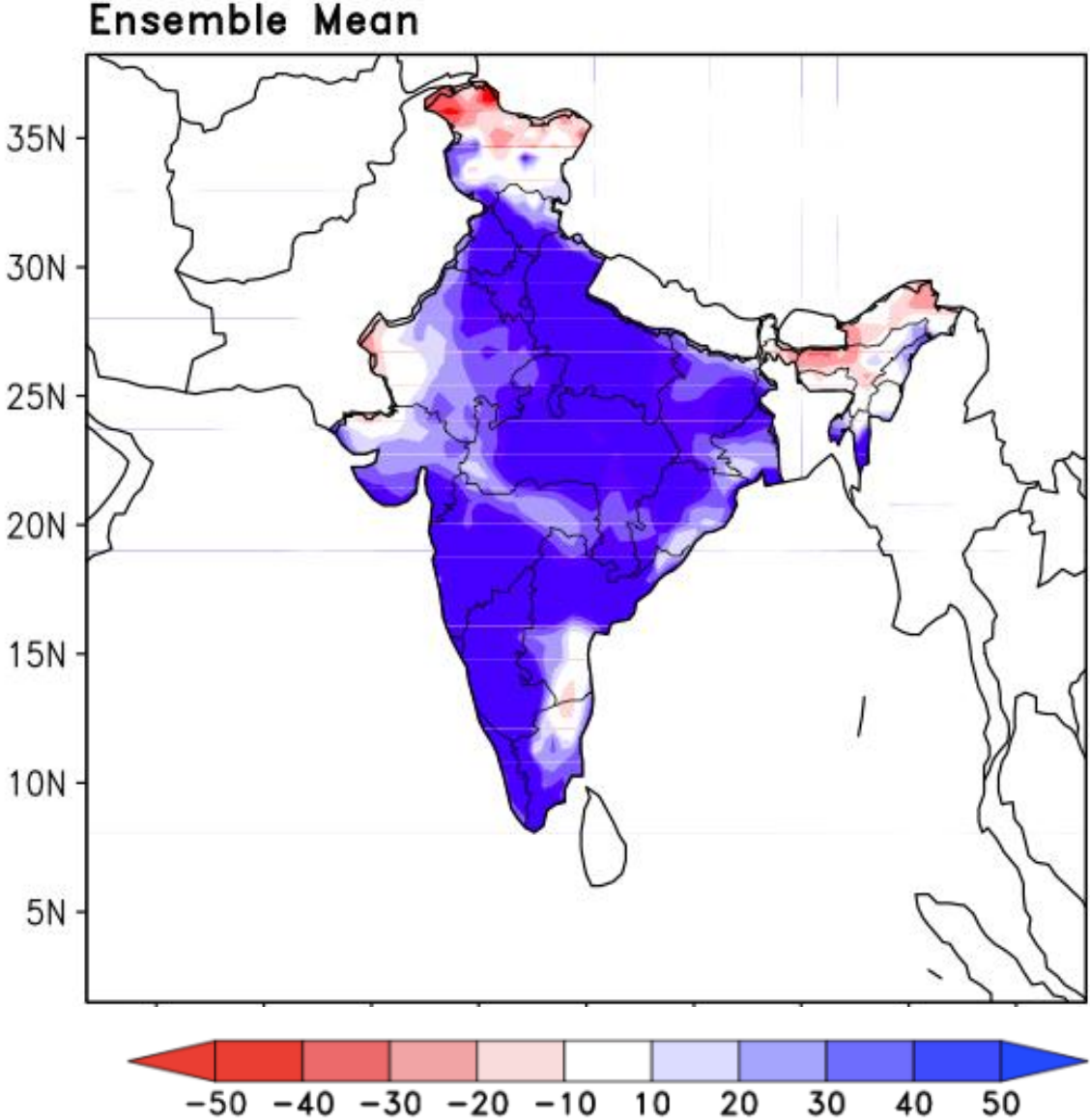
Precipitation change RCP4.5 in 2081-2100: April-September



[%]

Source: IPCC AR5 WG1 Annex 1

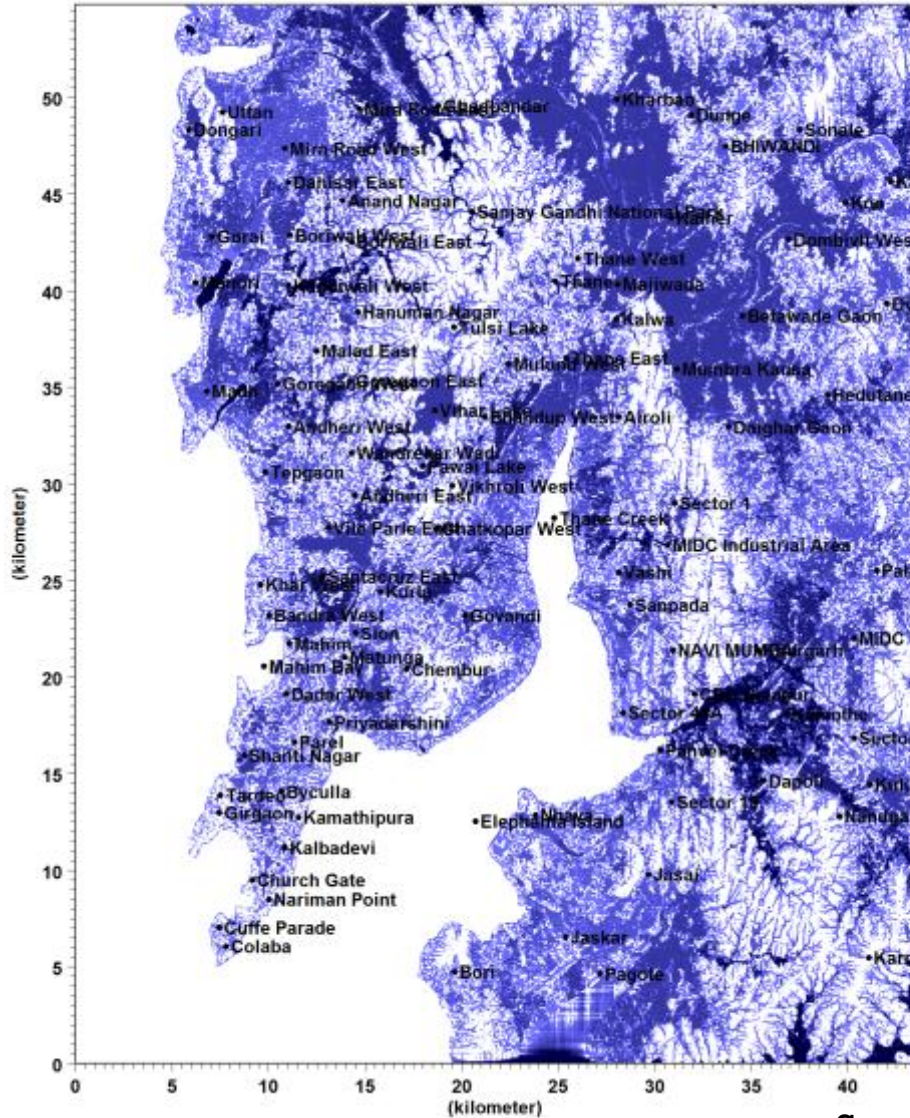
# Projected % change in rainfall on very wet days (in 2080s compared with 1961-1990)



Source: Rao et al (2014)

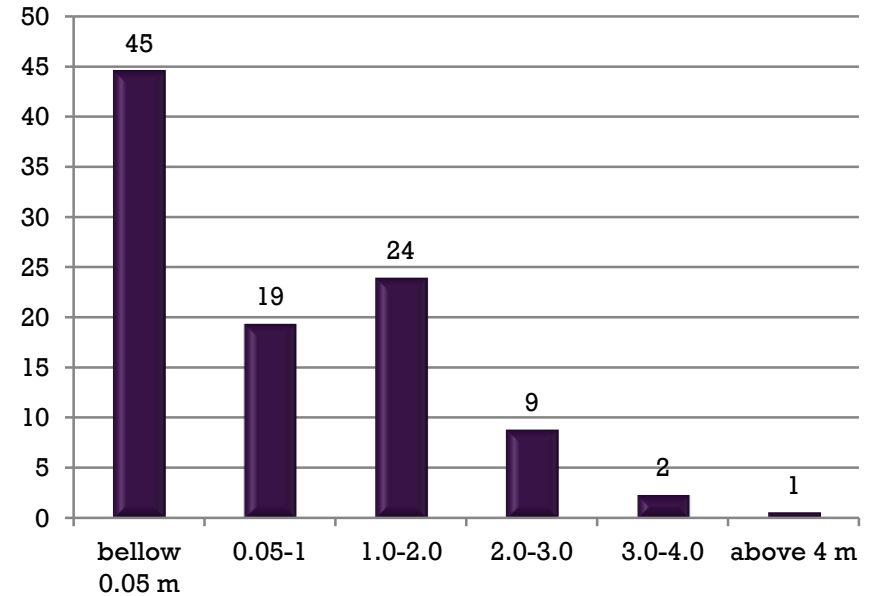
# Water depth map for flooding in Mumbai

Extreme rainfall event of 2005 with tidal variation and augmented drainage capacity of 50 mm/hour rainfall



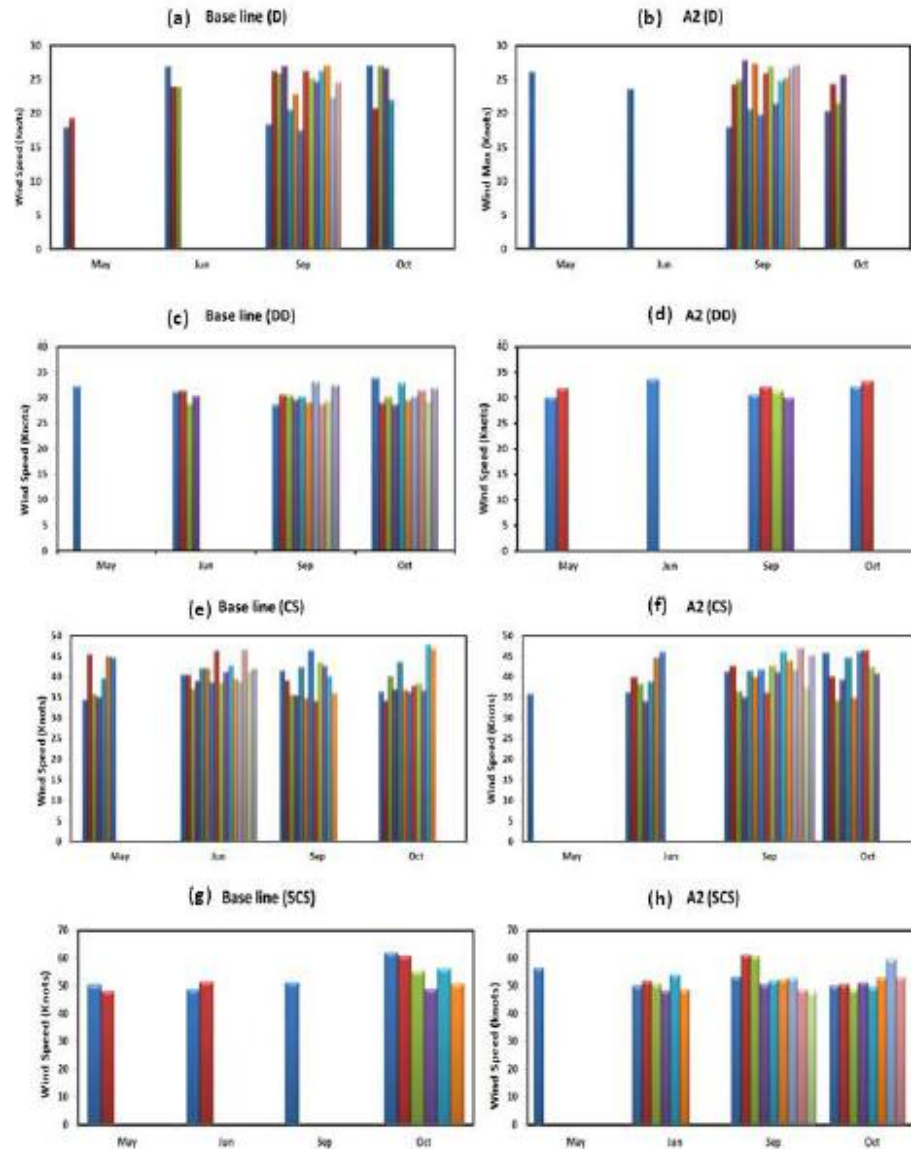
C:\Users\Parag\Documents\MIKE Zero Project\TheMumbai2005\Flood\MUMBAI\_021 - Result\FloodArea\_DrainMap\_14062005.MXD

% flooded area




Source: TERI analysis for Government of Maharashtra (2014)

# Change in cyclone occurrence over Bay of Bengal (in 2080s compared with 1961-1990)



Source: TERI analysis for Government of West Bengal (2014)



+ Do we need to do anything differently in building long-lived assets?

# Need for adaptation to climate change in built environment in India

- Exposure to climate hazards
  - Intense rainfall and flooding
  - Increase in heat stress
  - Rainfall variability, uncertainty, and water stress
  - Rising demand for energy
  - Coastal vulnerability to storms

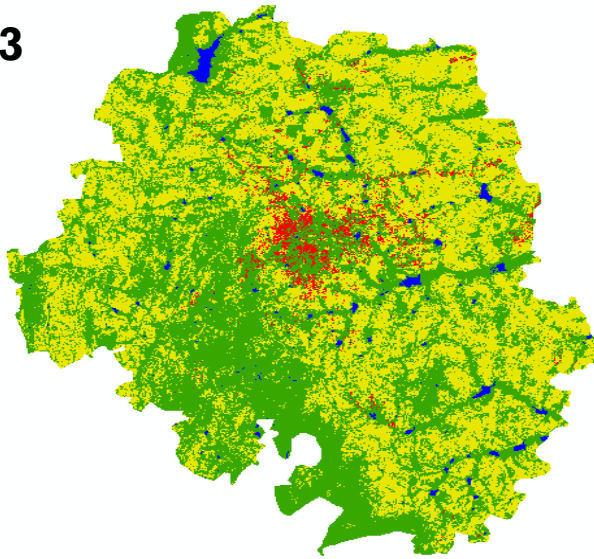
- Projected need for urban infrastructure by 2030 (MGI 2010)
  - \$1.2 trillion additional capital investment
  - 700-900 million sq m of commercial and residential space each year
  - 38 million affordable homes

- Increase in population and assets exposed to climate hazards
- Competition over scarce resources like green spaces and water
- Opportunities for adaptation in new built assets and urban form

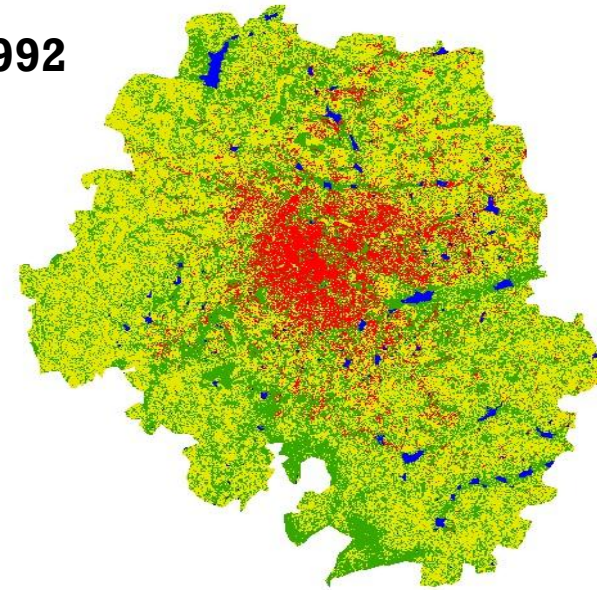


# Land use land cover change in Bangalore city

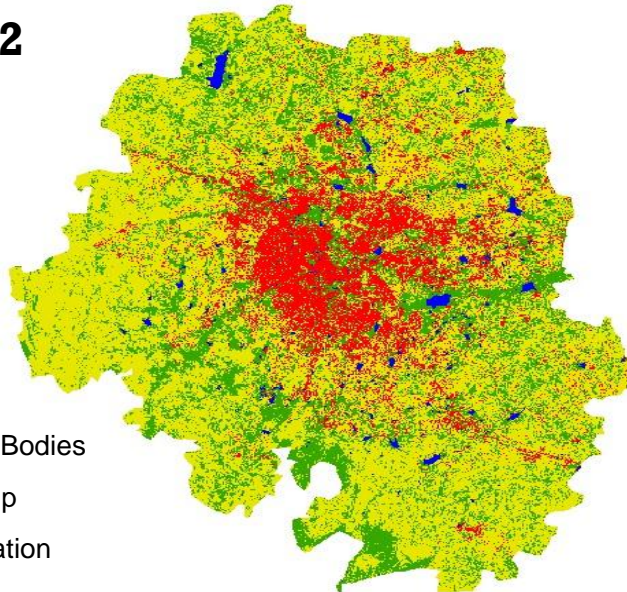
1973



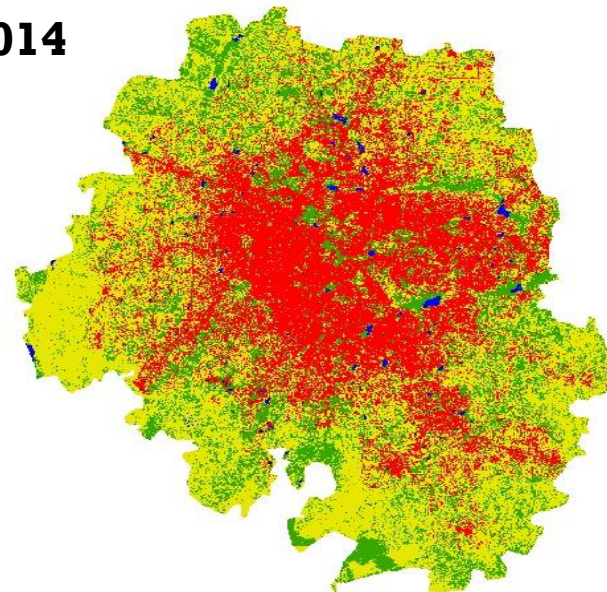
1992



2002



2014



## Legend

-  Water Bodies
-  Built Up
-  Vegetation
-  Others





# What do we need to do differently?

- Build climate resilient houses and neighbourhoods
  - Informed decisions
  - Material supply
  - Norms and incentives
  - Finance
  - Insurance

- Do not ignore ecological considerations in urban planning
  - Flexible
  - Inter-disciplinary
  - Participatory
  - Public data