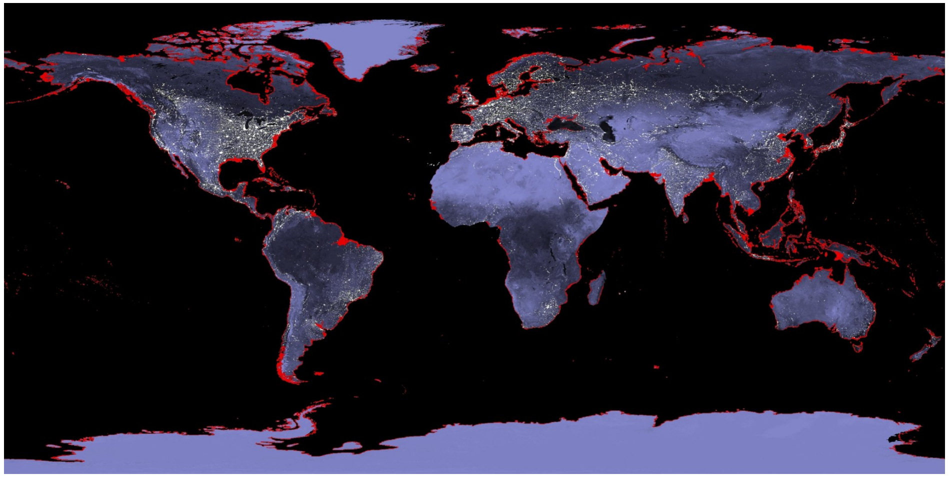

Unit 5.2: Coastal Environments

Demographic trends

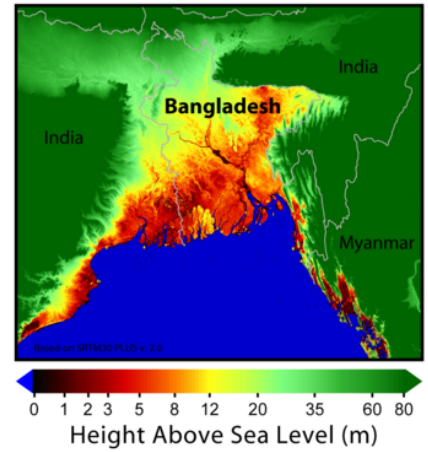
- About 40 % of the global population lives within 100 km (60ish miles) of the coast
- At least 200 million people live less than 5 meters above sea level
- Demographic trends are towards increasing risk exposure
- Half of the world's 20 largest cities are coastal

Shanghai, China; world's most populous city

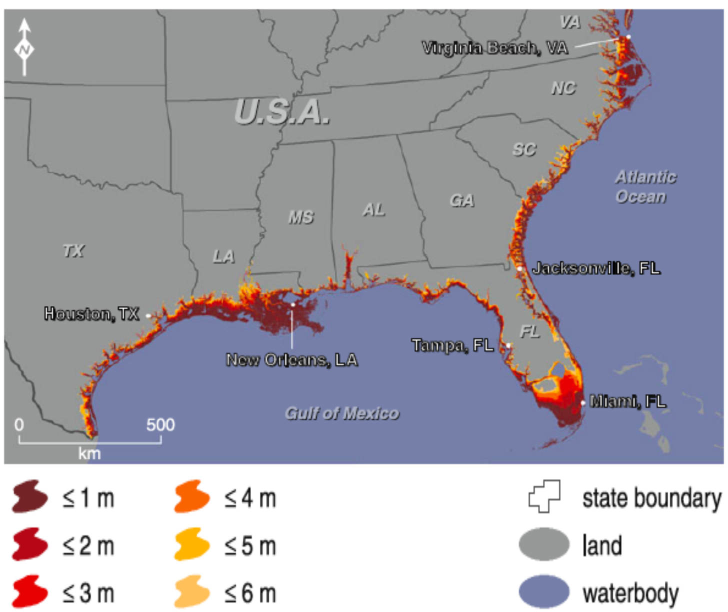
Elevation maps

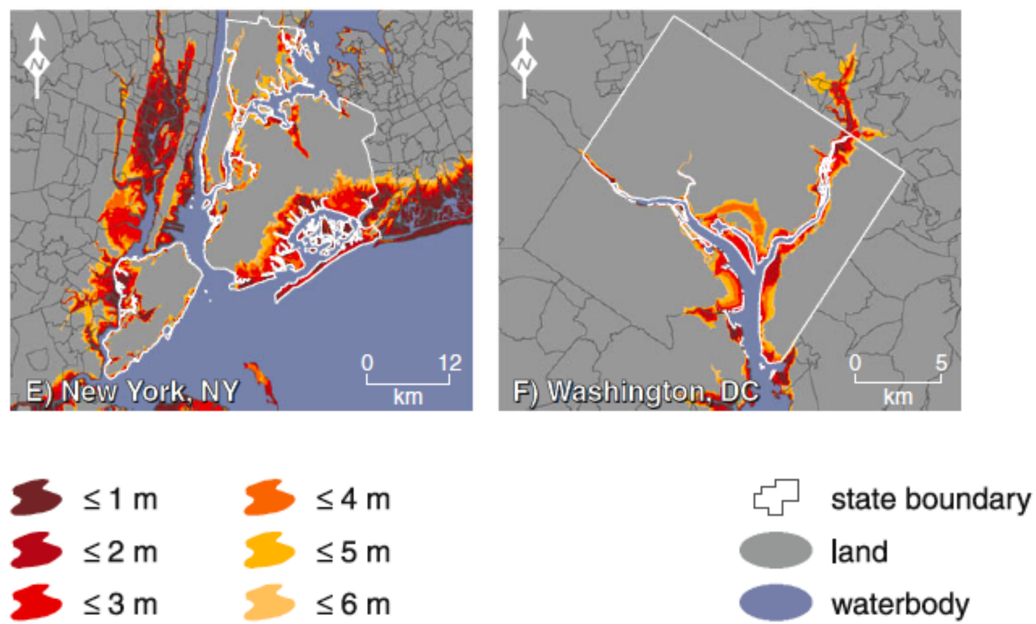


Sea Level Risks - Bangladesh



Six meter global SLR





SLR Websites

SLR Simulations

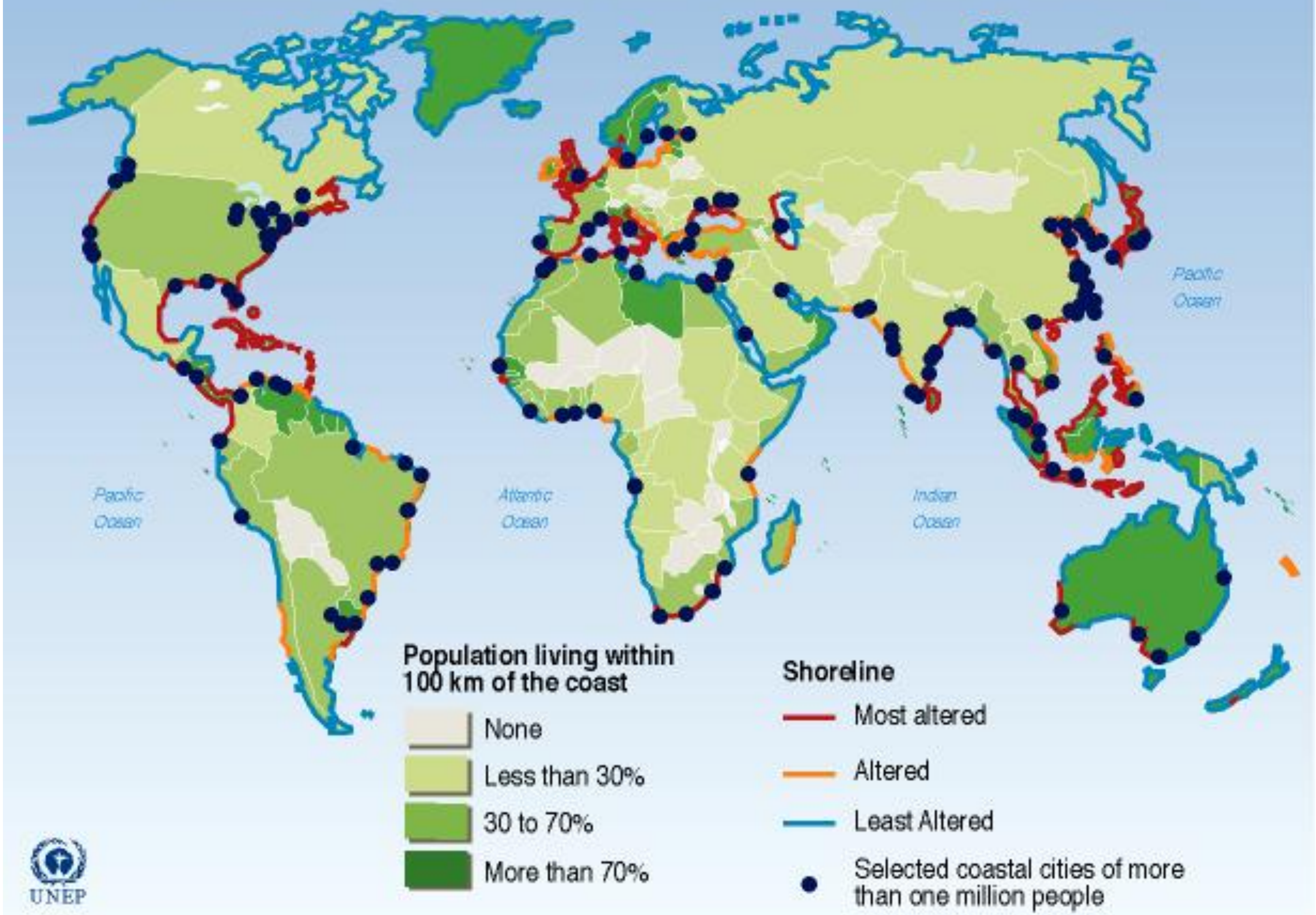
- http://sealevel.climatecentral.org/?gclid=CMT65vSC8r0CFYyhOgod_1YAZw

http://flood.firetree.net/

SLR Maps

https://www.cresis.ku.edu/data/sea-level-rise-maps?quicktabs_3=4#quicktabs-3

Coastal Populations and Shoreline Degradation



Source: Burke et al., World Resources Institute, Washington DC, 2001; Paul Harrison, Fred Pearce, *AAAS Atlas of Population*

Global SLR Vulnerability

Sea Level Rise (m)	Inundated Area x 1000 km2	Inundated Area (Square miles)	Inundated Area Population (millions)
1	1,055	407,230	108
3	1,539	594,054	234
6	2,193	846,498	431

For comparison, Area of TX ~ 270,000 square miles
Source: Rowley et al. 2007

Components of Sea Level Rise

- Thermal expansion
- Mass addition (from melting glaciers)
- Dynamical fluctuations (subtle changes in ocean currents may cause slight changes in mean sea level)
- Sediment compaction and land subsidence (varies with location and geologic history

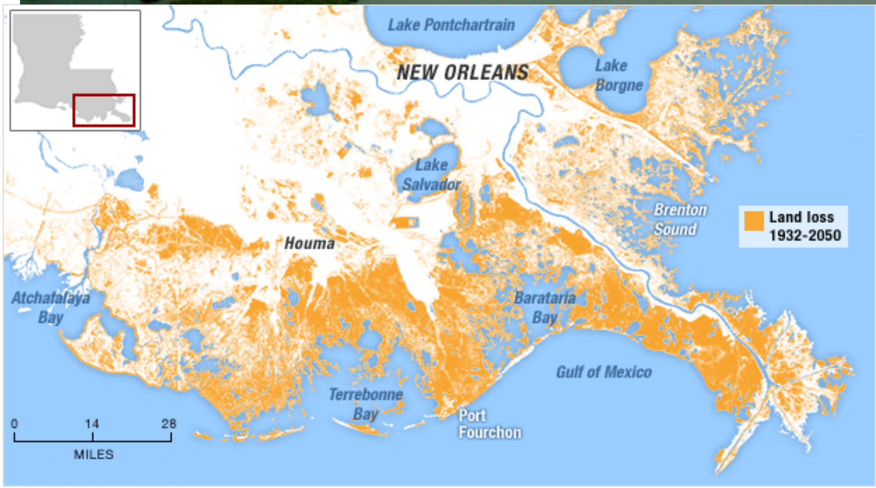
Sea Level Rise and Coastal Storms

- Sea level rise
  - Gradual, already underway, changes the background state of the sea level
- Coastal storms
  - Episodic, cause a great deal more damage than SLR alone, but damage is enhanced because of SLR
  - Stage of inundation is a function of pressure of storm, approach angle, wind speeds, bathymetry, tides and to some degree human adaptive (or maladaptive) measures
  - Major coastal inundations can be a product of tropical cyclones or extra-tropical cyclones or hybrid storms (like Sandy)

Atlantic City storm surge during Sandy

Wetland/estuary degradation

- The loss of coastal wetlands from extensive river management can leave coastal environments much more vulnerable to extreme coastal erosion and higher storm surges
- This is a major problem in overly managed wetland river deltas (eg. Southern Louisiana)



Impacts of coastal flooding on society

- Drowning
- Other physical hazards to human life (downed live wires, unstable trees, telephone poles, etc.)
- Property and structural damage to buildings
- Post-storm mold and health hazards
- Destruction of vulnerable transit infrastructure and subsequent isolation
- Submersion of power and water infrastructure limiting access to energy and clean water
- shortfall of available gasoline; so limited mobility
- Hospital populations especially vulnerable
- Saline corrosion of electrical equipment

Infrastructure vulnerability

- In many coastal areas (both urban and non-urban) a great deal of infrastructure is exposed to inundation and coastal flooding
  - all three major airports for NYC metro region are within 10 feet of sea level
  - this is also true of many coastal cities across the US and the world
  - in non-urban settings that are wealthy beach communities, the lure of the beach draws a great deal of high priced coastal development
  - Beach-related tourism is a major component of the economy of many coastal locations

Structural vulnerability

- The vulnerability of a structure to coastal hazard is not simply a function of elevation; it also depends on how the structure was built, what the substrate is, where it is positioned to other features in the coastal environment and the vulnerability to erosion
- A house 20 feet above sea level but near the edge of a dune on the fringe of a beach may face greater hazard (primarily from coastal erosion undercutting the dune causing structural failure) than a house 8 feet above sea level but on the other side of the dune, several houses in

Socioeconomic vulnerability

- In major coastal cities in the developing world (eg. Mumbai, India), slum populations are often forced to live at lower elevation or in areas that are not protected from storm surges
- Even in wealthier nations, there is a contrast between those who choose to live in flood prone areas and those with limited choice (eg. Lower Ninth Ward of New Orleans during Katrina)

Coastal slums in Dakar, Senegal

Mumbai, India

Engineering adaptations “hard” structures

- Sea Walls
- Netherlands
- Thames River Barrier
- Groins and jetties (smaller scale)
- Flexible strategies

Engineering adaptations – "soft" structures

- Beach nourishment
- Dunes
- Can have unintended, limited or unanticipated consequences (beach nourishment on the ocean side of a barrier island does nothing to protect bayside from inundation)
- Putting houses on stilts or making infrastructure floatable/ submersible

Communal adaptations

- Putting depots of emergency supplies on the tops of large earthen mounds in coastal Bangladesh
- Warning systems to help residents take shelter
- Pre-existing evacuation plans and emergency shelters

Planning/policy adaptations (and maladaptations)

- Forward thinking coastal developers try to limit coastal development and have adequate buffering capacity through a mix of hard and soft adaptive measures
- Economic pressures in favor of coastal development are often more powerful than long term incentives to limit hazard exposure
- North Carolina law to not consider sea level rise in coastal planning
- http://thecolbertreport.cc.com/videos/w6itwj/the-word---sink-or-swim

Financial adaptations and maladaptations

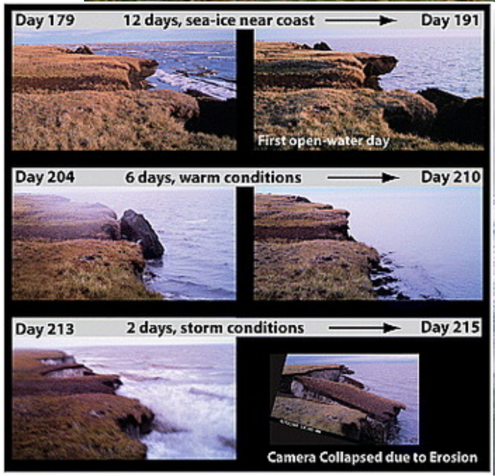
- Flood insurance is often designed to encourage risky behavior, rather than discourage it
- Back to issues of fairness – is it fair for people who live inland to have to pay for intentional risk taking on the part of those who live near the coast?
- National Flood Insurance Program in the US facing financial hardships

Small island states

- Even for island communities with large areas well above sea level, often the largest population lives along the coast
- In addition to the obvious inundation issues, for very low lying small island states, saline intrusion and depletion of freshwater aquifers can be a very serious issue
- An issue of international justice
- The Island President
- http://www.netflix.com/WiPlayer?movieid=70221845&trkid=222336&strkid=208086625_0_0&strackid=12396e6bf272407c_0_srl&fdvd=true

High latitude coastlines

- Dramatic loss of sea ice, loss of permafrost and sea level rise all make high latitude coastlines especially vulnerable to severe coastal erosion
- Many challenges to the structural integrity of buildings in high latitude coastal environments
- Erosion rates have doubled along Alaska's Arctic coast in the mid-2000s as compared to the much of the middle 20th century

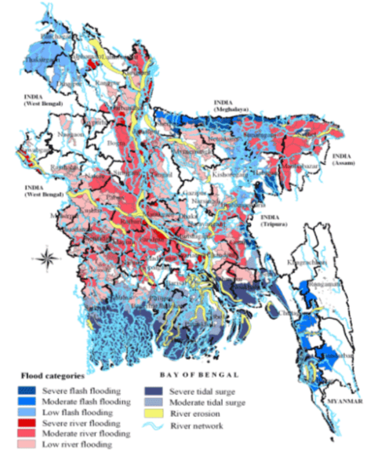


Case Study; The Netherlands

- A large percentage (almost 40%) of the land area of the Netherlands would be under water if it weren't for the system of dikes and levees to reclaim land
- The infrastructure requires maintenance and forethought
- Devastating floods in 1953 that killed almost 2000 people
- Motivated elaborate system of dikes, levees, sea walls to protect against both coastal and riverine flooding
- While the history has been built on the premise of keeping the water out, recent adaptive management approaches have shifted gears to letting some water in (the barriers are built only so high) (room for the River project
- http://www.nedwater.eu/WaterAndTheNetherlands.htm

Case Study; Bangladesh

- Limited capital for extensive engineering responses on a national scale
- Local adaptive practices critical – floatable infrastructure, gardens and emergency supplies stockpiled on high ground



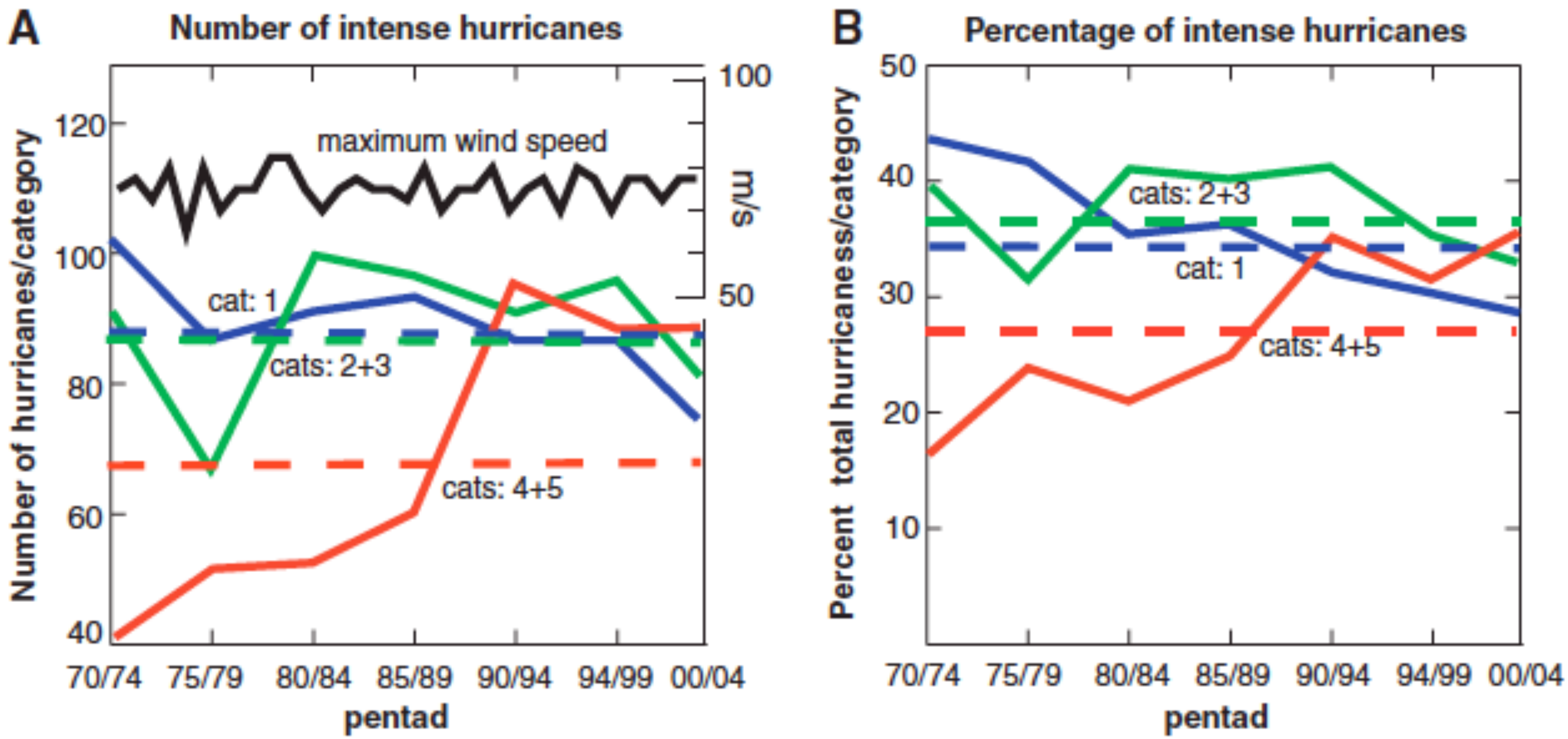
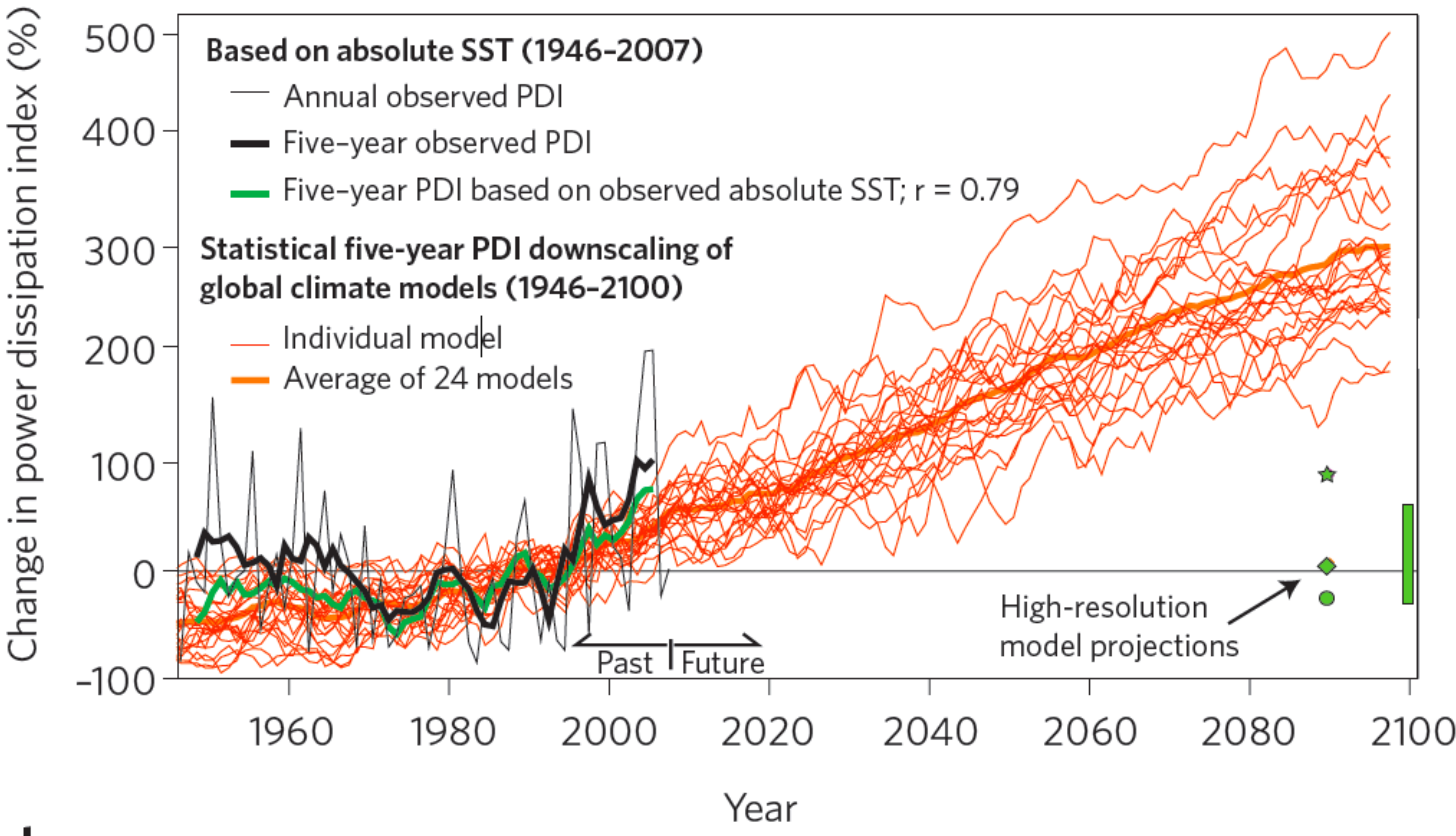


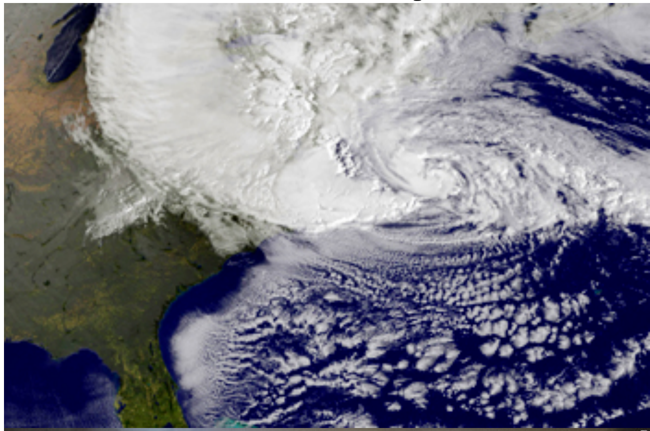
Fig. 4. Intensity of hurricanes according to the Saffir-Simpson scale (categories 1 to 5). (**A**) The total number of category 1 storms (blue curve), the sum of categories 2 and 3 (green), and the sum of categories 4 and 5 (red) in 5-year periods. The bold curve is the maximum hurricane wind speed observed globally (measured in meters per second). The horizontal dashed lines show the 1970–2004 average numbers in each category. (**B**) Same as (A), except for the percent of the total number of hurricanes in each category class. Dashed lines show average percentages in each category over the 1970–2004 period.

Storm Intensity and Sea Surface Temperature



Case Study; Sandy (NJ and NYC)

- Physically largest storm in the North Atlantic north of Cape Hatterras
- Central pressure on par with category 3 storm (around 940 mb), even though winds were "only" Cat 1 strength
- Well forecast – models predicted left hand turn almost a week in advance – helped to save many lives
- Struck in many places at high tide, amplifying the storm surge
- Second costliest disaster in US history
- Did a great deal of damage to many nations in the Caribbean as well
- Fatality attribution is challenging, but at least 100, if not closer to 300 total deaths from both direct and indirect causes
- While forecast and disaster response was generally managed relatively well, the pressure to rebuild in the aftermath has been uncoordinated and many of the same vulnerabilities are left unaddressed



Case Study; Katrina 2005

- Costliest and one of the deadliest disasters in US history
- Over 1000 dead
- Category 3 storm at landfall, but had been a category 5 out at sea (lowest pressure 902 mb)
- http://www.youtube.com/watch?v=8TRWI4CFkU0
- Completely changed city of New Orleans and much of the central Gulf coast
- Even now, New Orleans population is substantially lower than the pre-Katrina numbers
- Mandatory evacuation of the city
- Failure to provide adequately for the poor and those who did not have the means to escape
- Many institutional failures after the fact

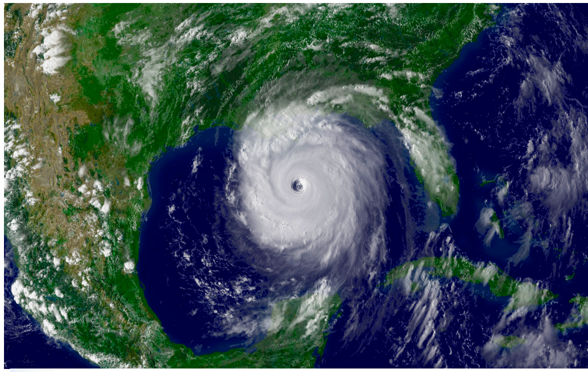
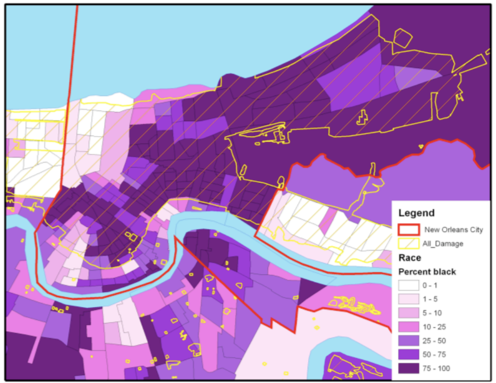
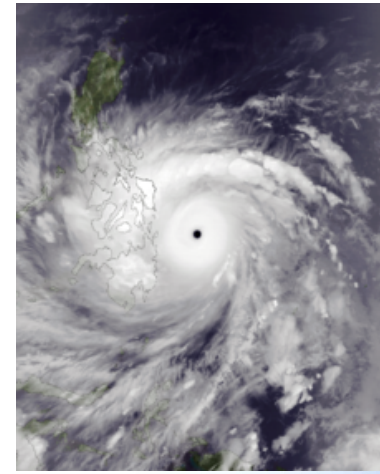


Figure 2. New Orleans Neighborhoods, Showing Racial Composition and Damaged Areas



Aerial view of the Superdome and New Orleans' flooded east side. (Ricky Carioti/Post)

Case Study; Haiyan, Philippines



- Central pressure 895 mb – making it one of the strongest storms in recorded history
- sustained winds of 190 mph
- At least 5000-6000 casualties – mostly in Philippines
- Over 12,000 injured
- Total cost at more than 10 billion USD
- Storm surge was almost 20 feet in some places
- Up to 6 million people displaced in the Philippines
- While government warning were issued, capacity to respond after was limited by scale of devastation
- Significant coordination challenges both internally and internationally in wake of disaster
- https://www.youtube.com/watch?v=XjWHS1n9jOU