

FINAL EXAM: 9:45-11:45 AM, Wednesday, 13DEC17, AHC5 Rm 357. CUMULATIVE**Hurricane Seasons of 2004 & 2005 and Subsequently (Lectures 31&32)**

1. Four devastating hurricanes in 2004, Charley, Ivan, Jeanne & Frances
2. Four more devastating Gulf hurricanes in 2005: Dennis, Katrina, Rita & Wilma
 - a. Costliest season ever, deadliest since 1928 in US
 - b. Low shear and tracks over the Loop Current produced rapid deepening to CAT 4 or 5
 - c. But all were CAT 2 or 3 at landfall
 - d. Only Wilma was intensifying at US landfall---slowly.
3. Global warming effects, while possible, were not dominant in either year
4. Failure of the canal levees in CAT 1 conditions was responsible for > 1000 deaths in Katrina
5. After 2005:
 - a. 2006: Weak El Niño, Zeta lasted from Dec 2005 to JAN 2006
 - b. 2007: Dean and Felix CAT 5 in Caribbean
 - c. 2008 Gustav affected FL-TX, and Ike hit Galveston
 - d. 2009: weak El Niño, Most TCs stayed at sea
 - e. 2010: Active, but no US landfalls
 - f. 2011: Irene hit mid-Atlantic States to New York
 - g. 2012: Isaac hit Gulf Coast and Sandy hit NE US; 150 dead, damage \$50B
 - h. 2013: Inactive throughout the Northern Hemisphere until mid-September when Indian Ocean (Phailin) and W. Pacific (Haiyan, plus others) struck
 - i. All post 2005-2012 seasons, even El Niños were active by historical standards, but surprisingly few US landfalls occurred.
 - j. Does 2013 signal a transition of the AMO to the inactive phase?
 - k. Atlantic 2014 season was near normal (8,6,2)
 - l. The 2015 Atlantic season was also near normal (11, 3, 2 as of 19 NOV 15)
 - i. El Niño. ACE 55% of normal on 19 NOV 15
 - ii. Hurricane Joaquin (Cat 4) sank MV El Faro
 - m. 2016: La Niña, somewhat above normal numbers and intensities. Hurricanes Hermine and Matthew hit Florida. Total damage \$11B, 1365 deaths (US \$7B, 53 deaths)
 - n. 2017: Also La Niña, Active (17 named storms, 10 hurricanes, 6 major hurricanes). Harvey flooded Houston; Irma hit the Keys as a CAT4 and SE FL as a CAT3; Maria flattened Puerto Rico, Dominica, Guadeloupe, US Virgin Islands as a CAT4. Total 2017 damage > \$300B.

Hurricanes and climate (Lecture 33)

1. IPCC says the "Globe" is getting warmer---Anthropogenic Global Warming (AGW)
 - a. Primarily in high northern latitudes
 - b. But warming (~0.9° C since 1900) does effect tropics
 - c. 2015 was warmest to date; 2016 may break that record
 - d. Almost certainly Anthropogenic
2. Natural Atlantic Multidecadal Oscillation (AMO)
 - a. 20-30 years in each warm or cool phase

- b. Due to changes in the ocean's thermohaline circulation
 - c. Warm phase, low shear, many hurricanes
 - d. Benign US hurricane experience, 1970-2003, although AMO active phase started in 1995
 - e. Average annual damage during warm AMO is \$15B; during cool AMO phases, it's \$5B.
 - f. AMO may or may not have shifted to inactive in 2013
- 3. El Niño (ENSO) warms eastern Pacific every 3-5 years, leading to suppressed Atlantic hurricanes
 - a. 2015 likely to set a record for warmest year so far
- 4. Neither US hurricane landfalls nor US damage corrected for economic factors exhibit significant trends
- 5. Some apparent patterns may arise because random events produce clusters
- 6. Multiple working hypotheses: global warming increase, multidecadal cycles--probably both
 - a. US Damage changes in phase with AMO and ENSO, but not with AGW
- 7. Landfall is when the vorticity hits the voters
- 8. What if the climate shifts to some completely bizarre new mode?

Human and Economic Impacts (LECTURE 34)

- 1. No trend in hurricane landfalls
 - a. But a lull 1970-2003
- 2. Deaths decrease by 50% every 27 yrs
 - a. Prevention of drowning through evacuation
- 3. Deadliest years 1900-Galveston, 1928-Lake Okeechobee, 2005-Katrina
 - a. All due to storm surge and failure of control structures
 - b. More than 1000 deaths
- 4. Inflation adjusted damage doubles every 14 years because of coastal development
 - a. "Normalization" corrects for inflation, local population and nationwide index of wealth
 - b. No trend in normalized damage, 1900-2010
 - c. Average normalized damage since 1900 is \$11B/year
 - d. Largest damage: 1926 Miami Hurricane, followed by 2005 (mostly Katrina) and then 1900 Galveston
- 5. Most people survive physically
 - a. Vulnerable ones--economically and physically--suffer most
 - b. Evacuation saves lives but it's always partial because of
 - c. ...latency, traffic flow, stubbornness, poor communications...
 - d. Destinations: shelters, friends & family, hotels, roadside
 - e. In the end, many lose jobs as well as houses
- 6. Most will return home after evacuation.
 - a. Eventual relocation, FEMA trailers, or reconstructed homes
 - b. Degraded post-storm environments
 - c. Long term economic disruption

Wind Engineering & Insurance (Lecture 35)

- 1. Damage caused by:
 - a. Dynamic Pressure

- b. Flying Debris
 - c. Water penetration
- 2. Breaching of building envelope pressurizes the inside and progresses to structural failure
- 3. Mitigation
 - a. Negative load path to ground
 - b. Protection of windows by shutters, bracing entryway doors, garage doors
 - c. Can reduce damage by 50-75%
- 4. Vulnerability Curves: Percent damage as a function of wind speed
- 5. Catastrophe model modules
 - a. Hazard: Hurricane number, intensity, size
 - b. Vulnerability: Amount of insured property in harm's way
 - c. Loss: Models failure of structures
 - d. Cost: Combines damage and policy terms to estimate claims
- 6. Exceedance Probability: Probability of a given Loss Cost or more
- 7. Reinsurance: Insurance for insurers--covers loss above some (large) deductible and below policy limit
- 8. Average Annual Loss (AAL). Expected loss each year taking into account years with zero loss and great catastrophes.
- 9. Probable Maximum Loss (PML)
 - a. 1% or 0.5% on XP curve (i.e., 100 to 200 year return period)
 - b. Larger losses may lead to insolvency or government bailout