




### Memorable Hurricanes of 2004

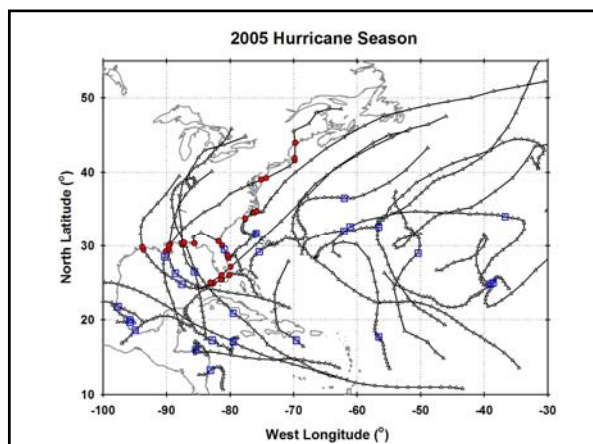
Hurricane	Dates	Damage (US)	Deaths (US)
Charlie (4)	9-14 AUG	\$14B	10
Ivan (4)	2-24 SEP	\$13B	25
Frances (2)	25 AUG-10 SEP	\$9B	7
Jeanne (3)	13-28SEP	\$8-11B	6

**Western-Hemisphere Impacts:**  
 Ivan reached CAT 5 far S in the Caribbean  
 Ivan killed 92 people, total, directly  
 Jeanne killed > 3000 in Haiti

**Total losses: 3132 lives and \$42B**  
 4 FL landfalls, 3 by major hurricanes

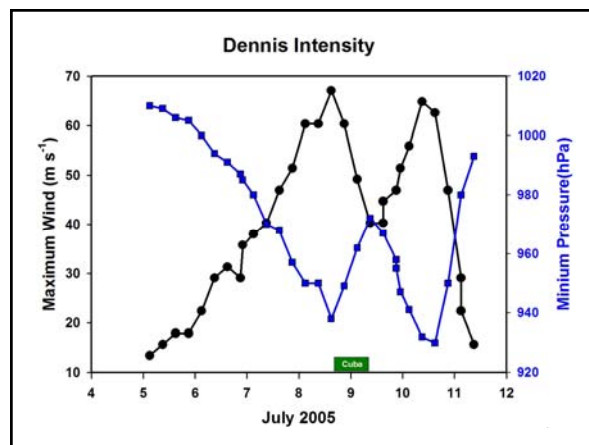
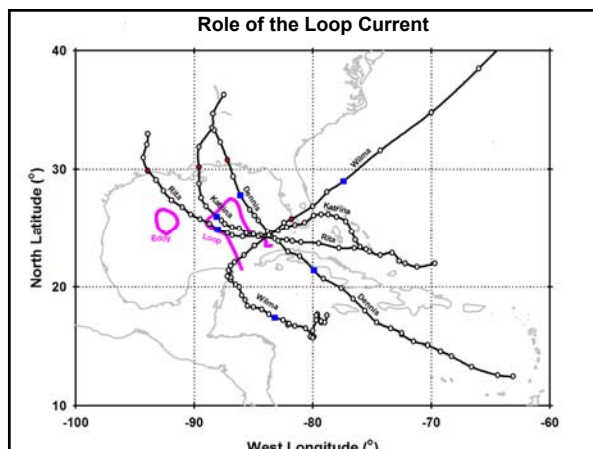





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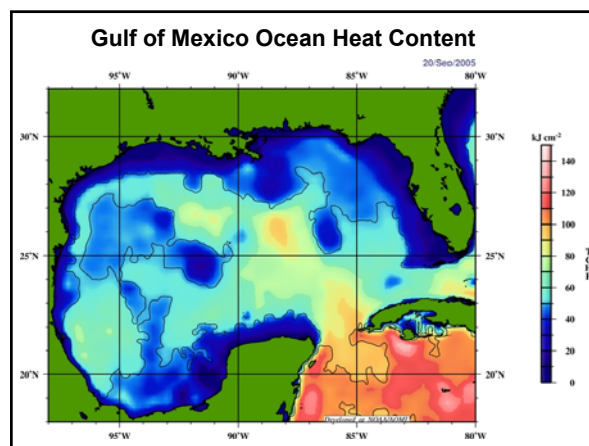
Hurricane	Dates	Damage	Deaths
Dennis (4)	4-13 JUL	\$5-9B	32
Katrina (5)	23-31AUG	\$70-130B	~1500
Rita (5)	17-26SEP	\$8-11B	6
Wilma (5)	15-25OCT	\$12-20B	5

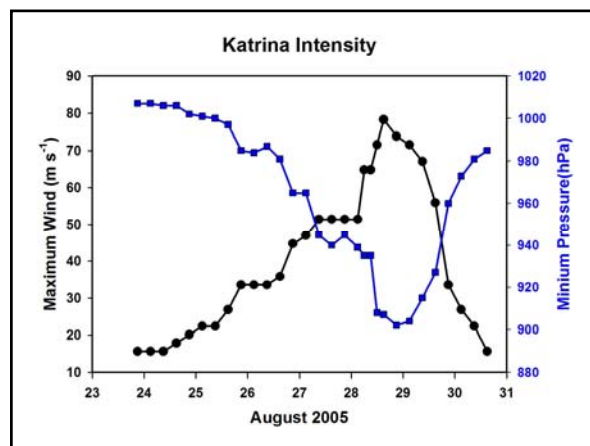
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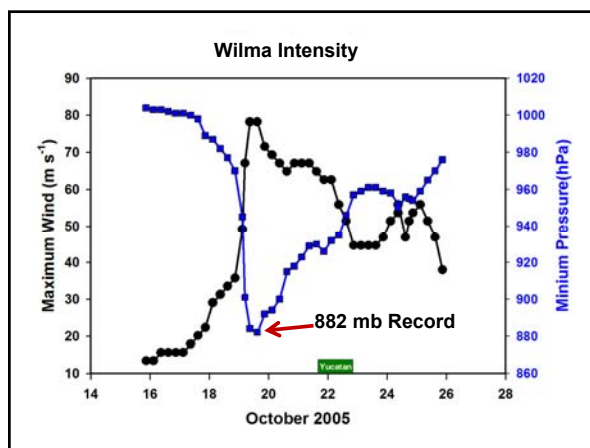
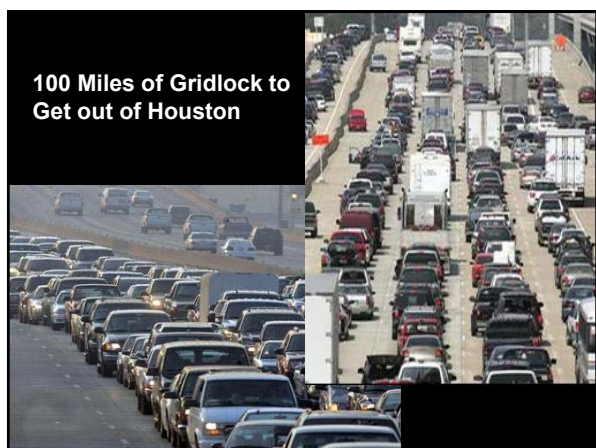
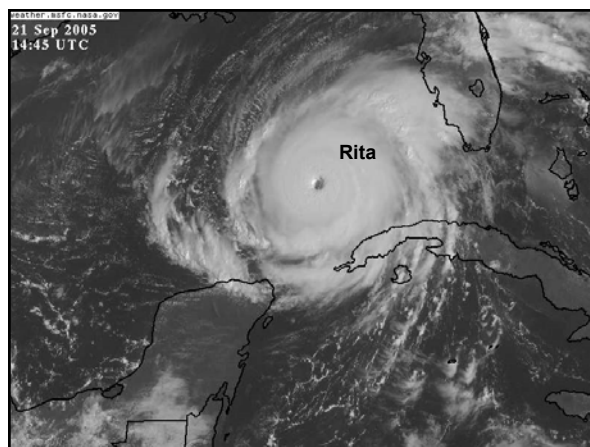
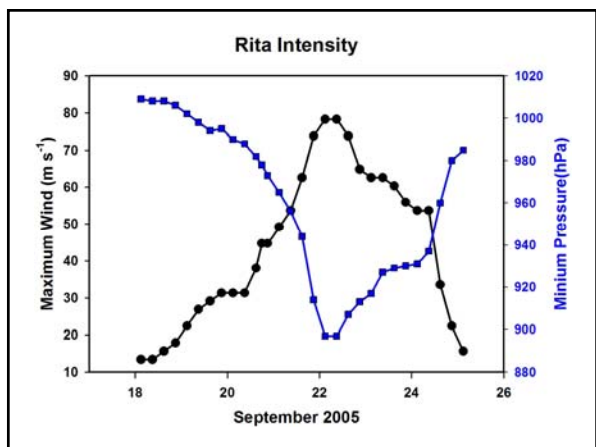


### Links to Global Warming by 2005

- Hurricanes are heat engines that draw energy from the tropical ocean
- Knutson & Tuleya (2004)---numerical study with 2 x CO<sub>2</sub> environment.
  - Found strongest hurricanes become 5-6 m/s stronger and rain 25% more, but no increase in numbers
- Emanuel (2005) found increased hurricane energy dissipation since early 1970s in climatological records
- Webster et al. found more CAT 4 & 5 worldwide, but no increase in total numbers.
- Despite problems with satellite intensity estimates, pressure-wind relation, and generally sparse data, The belief that AGW caused 2004-2005 Seasons became widespread.









## Hurricane Records in 2005

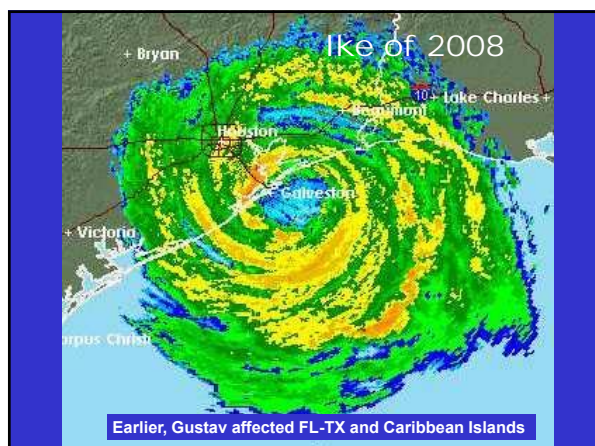
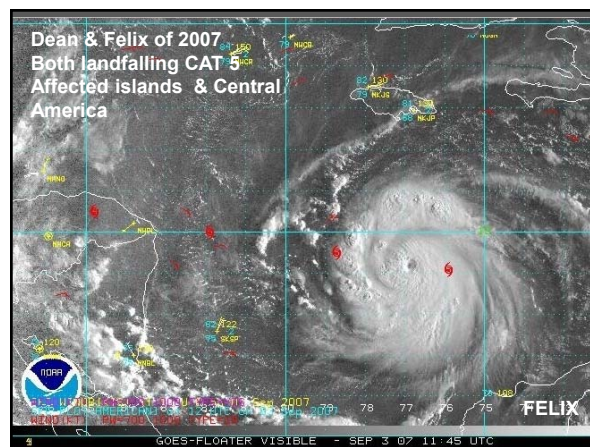
- Earliest CAT 4 hurricane since Audrey in 1957
- Greatest season-total US damage > \$100B
- Greatest US hurricane loss of life since 1928
- Most named storms: 28 (19 in 1995 or 22 in 1933)
- Most hurricanes: 15 (12 in 1969)
- Most CAT 5 hurricanes: 4 (2 in 1960 & 1961)
- Lowest western-hemisphere sea-level pressure, 882 mb in Wilma (888 in Gilbert in 1988)
- Three of the seven most intense hurricanes on record ---Wilma, Rita and Katrina---[Allen (1980), Camille(1969), the Labor-Day Hurricane of 1935 and Gilbert (1988)]

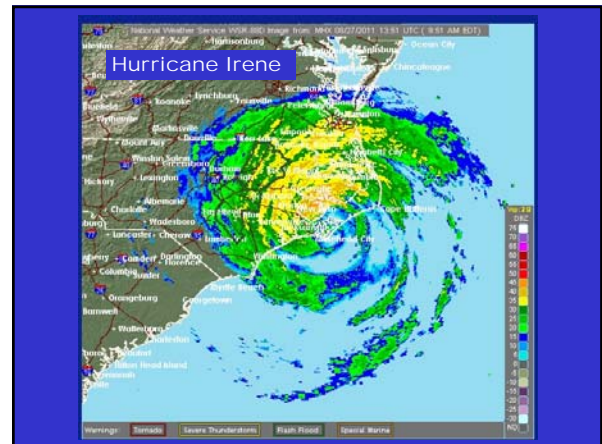
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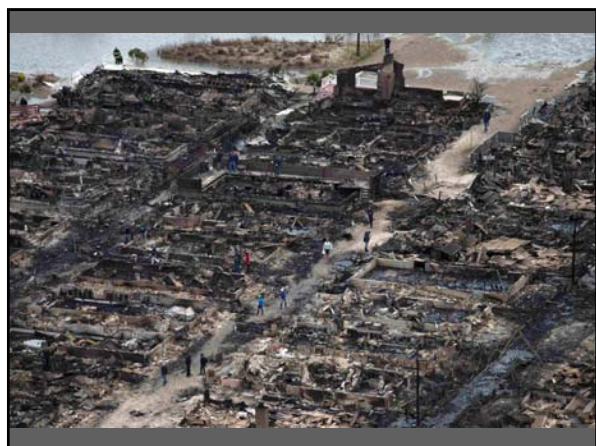
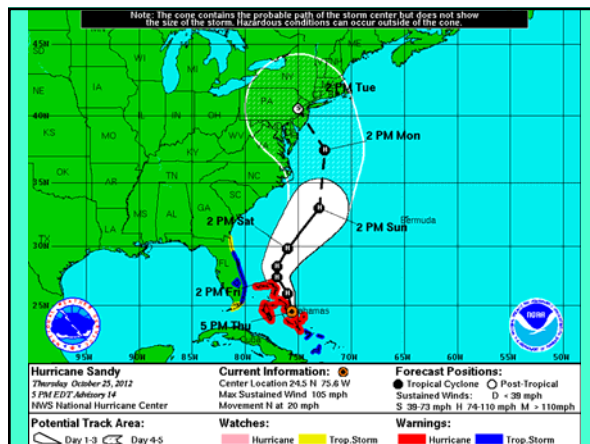
## 2005-2012

Year	TS	HH	MH	Comments
2006	10	5	2	Zeta in Dec & Jan, <u>Weak El Niño</u>
2006	15	5	2	Dean & Felix CAT 5 in Caribbean
2008	16	8	5	Gustav and Ike hit the US Gulf Coast . All TCs affected land
2009	9	3	2	Most TCs stayed at sea. <u>Weak El Niño</u>
2010	19	12	5	No US landfalls
2011	18	7	3	Irene affected NE US. Active season
2012	20	10	1	Isaac & Sandy

All seasons were active by historical standards, but with relatively few US landfalls





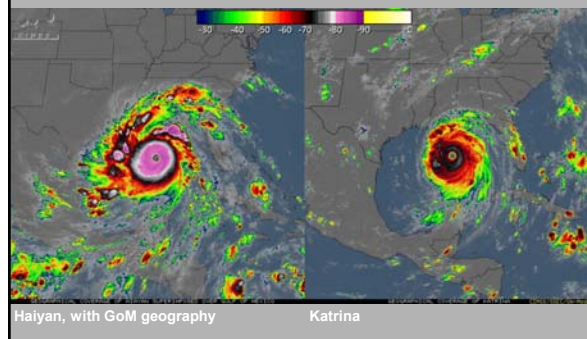


### The 2013 N. Hemisphere TC Season

- By all measures it was inactive northern-hemisphere wide before mid September
- Then:
  - Typhoon Usagi, 16-24 Sep CAT 4 (125 kt) LF in Guangdong
  - Typhoon Fitow, 29 Sep-7 Oct CAT 3 (108 kt) LF North of Hong Kong
  - Very Severe Cyclone Phailin 4-14 Oct, CAT 5, LF at Gopalpur on E. coast of India
  - Typhoon Nari CAT 1 (85 kt) LF Viet Nam, near Danang
  - Typhoon Haiyan, Extreme CAT 5, LF in Southern Philippines, > 2500 dead

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Comparison of Haiyan and Katrina at Maximum Intensity

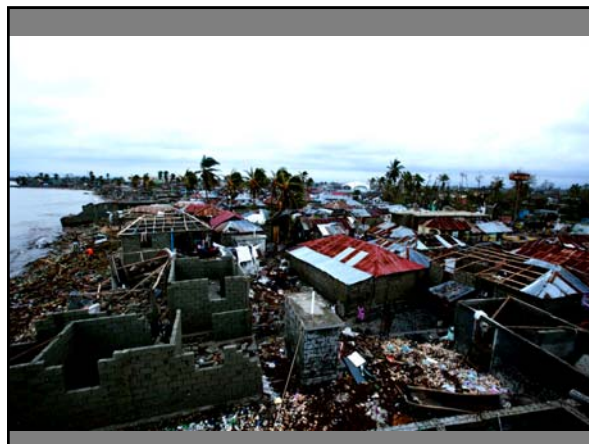


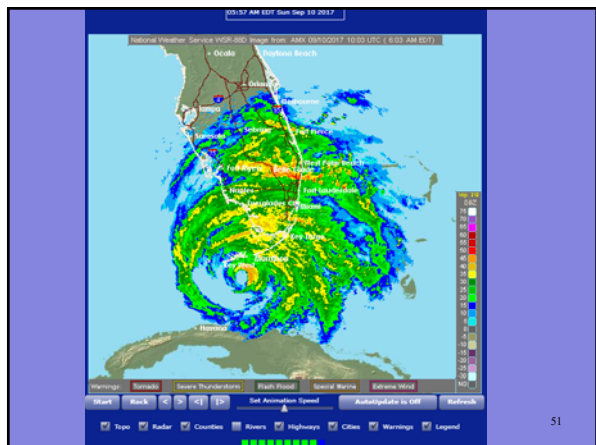
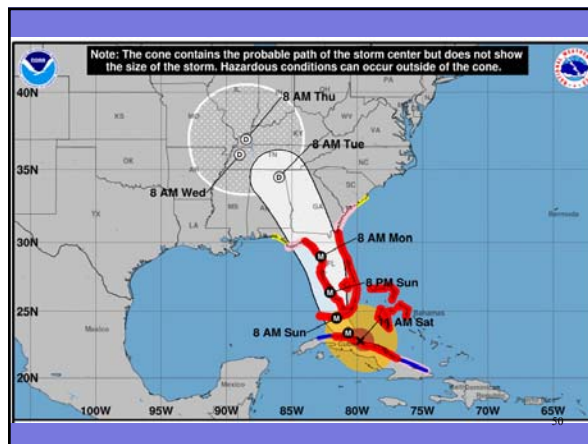
### 2014 & 2015 Seasons

- Atlantic 2014 season was near normal (8,6,2)
  - All storms affected land
  - ACE = 67 compared with 1980-2010 median of 92
  - Deaths 17, Damage US\$ 233M
- The 2015 Atlantic season was also near normal (11, 3, 2 as of 19 NOV 15)
  - El Niño. ACE 55% of normal on 19 NOV 15
  - Hurricane Joaquin (Cat 4) sank MV El Faro
  - 33 mariners lost in CAT 4 conditions
- Eastern-Pacific Hurricane Patricia intensified rapidly before landfall in Mexico
  - Set a record for the lowest Western Hemisphere sea-level pressure 890 hPa.
  - EASTPAC ACE 184% of normal before Patricia<sup>6</sup>

### 2016 Season

- La Niña (sort of)
- Predicted to have above-average activity
- Produced:
  - 14 Named storms
  - 8 Hurricanes
  - 3 Major hurricanes
  - US landfalls by Hermine and Matthew
- Killed 1739, mostly in Haiti
- US impacts ~\$7B, 53 deaths
- Total \$11B, 1365, mostly in Haiti





- Four devastating hurricanes in 2004, Charley, Ivan, Jeanne, and Frances
- Four more devastating Gulf hurricanes in 2005: Dennis, Katrina, Rita & Wilma
- Costliest season ever, deadliest since 1928 in US
- Low shear and tracks over the Loop Current produced rapid deepening to CAT 4 or 5
- But all were CAT 2 or 3 at landfall,
- Only Wilma was intensifying---slowly.
- Global warming effects, while possible, were not dominant.
- Failure of the canal levees in CAT 1 conditions was responsible for > 1000 deaths in Katrina
- Active seasons since, (even in El Niño), but nothing like 05 & 06 ---- like, Irene, and Sandy notwithstanding.
- 2013, Inactive until mid September, then active in W-Pacific and N Indian Ocean. 2014 near normal.
- 2015, EPAC Patricia set 880 mb W-Hemisphere record
  - El Niño
  - El Faro sunk in Hurricane Joaquin
- 2016, Active all year, 4 hurricanes from Hermine and Matthew. Impacts in 1B & 1365 US & 863 deaths
- 2017: Harvey floods Houston, Irma hits S. Florida, and Maria in Puerto Rico. Damage >\$300B.