Mechanics of Tropical Cyclones

Nick Woods
Tropical Cyclones

- Cyclone - large system of spinning air that rotates around a central low pressure.
- Tropical - Warm air at the center -> allows for development

Image of Hurricane Andrew, Courtesy of Greenpeace
Tropical Cyclones

- Typhoon – NW Pacific Ocean
- Severe Tropical Cyclone – SW Pacific Ocean, SE Indian Ocean
- Severe Cyclonic Storm – N Indian Ocean
- Tropical Cyclone – SW Indian Ocean
- Hurricane – N Atlantic, S and NE Pacific
Tropical Cyclone Formation

Tropical Cyclones form during Summer and early Fall

Image Courtesy of NASA Earth Observatory
Hurricane Formation

Tropical Disturbance – Convergence of surface winds

Image/Text/Data from the University of Illinois WW2010 Project.
Three Methods of Convergence of Surface Winds

- Northern and Southern Hemisphere easterly trade winds near the equator.
- Convergence of air between warm and cold masses
- African Easterly Wave
Increased Organization and Intensification

- CISK Theory

Image/Text/Data from the University of Illinois WW2010 Project.
Increased Organization and Intensification

• Coriolis Force – Causes Storm Rotation

\[ F_{\text{Coriolis}} = -2m(\omega \times v_r) \]
Tropical Cyclones as Carnot Engines

A-B: Air Expands, Gains energy
B-C: Air Expands Adiabatically
C-D: Heat from Surface Radiated
D-A: Adiabatic Compression

$v^2 = \frac{T_s - T_o}{T_o} \cdot E$

“Hurricanes: Tempest in a Greenhouse” Kerry Emmanuel
Features of a Hurricane

- Eye/Eye Wall
- Spiral Rain Bands

Image Courtesy of NASA Earth Observatory
Storm Surge

Surface winds push water in front of storm

SLOSH-National Hurricane Center

Image Courtesy of NASA Earth Observatory
Hurricane Dissipation

- Removal of Heat Source
- Trade Wind Inversion-Sub-tropical High
- Strong Upper Level Winds
Atlantic Hurricane Prediction

NOAA Atlantic Hurricane Season Outlooks
May Verification

- Tropical Storms
  - Predicted Range: 11-14
  - Observed: 12-14
  - Green Bars: Climatological means

- Hurricanes
  - Predicted Range: 8-10
  - Observed: 8-9
  - Green Bars: Climatological means

- Major Hurricanes
  - Predicted Range: 3-5
  - Observed: 2-3
  - Green Bars: Climatological means

- ACE Index
  - Predicted Range: 200-245
  - Observed: 200-245
  - Green Bar: Lower boundary for above-normal seasons

Image Courtesy of NOAA
Atlantic Hurricane Prediction

Regional North Atlantic Conditions associated with the Multi-Decadal Signal

- Warmer SSTs
- Lower Wind Shear
- Lower Surface Pressure (Red Area)
- Favorable Winds From Africa
- Higher Pressure in Upper Atmosphere
- Upper-level Easterlies Expand Westward (Green arrows)
- Weaker Low-Level Easterly Winds (Blue arrow)

Image courtesy of NOAA
El Niño

Number of storms in Atlantic decreases in El Niño years

Image/Text/Data from the University of Illinois WW2010 Project.
Saharan Air Layer

Image Courtesy of NOAA
Current NASA Hurricane Research

- QuikSCAT
- TRMM
- Aqua
- CloudSAT
- CALIPSO
Intensity Forecast Experiment (IFEX)

Prediction of Intensity of Hurricanes

- Low flying aircraft
- SAL impact
- Decay Forecasts
Pacific vs. Atlantic

Worldwide Tropical Cyclones 2006
Details at http://www.solar.ifa.hawaii.edu/Tropical/tropical.html

Plotted Sun Dec 10 15:20:13 GMT 2006
2006 Pacific Tropical Cyclone Season

- NW Pacific-22 Storms, 15 Typhoons, 7 Super Typhoons, >2,000 dead
- Eastern Pacific-18 Storms, 5 major, Total Damage - $170.8 Million