The Atlantic Hurricane Database Reanalysis Project

9 November, 2015

14th International Workshop on Wave Hindcasting and Forecasting

Chris Landsea, National Hurricane Center, Miami, USA

Chris.Landsea@noaa.gov

Supported by the NOAA Climate Program Office

Acknowledgements: Andrew Hagen, Sandy Delgado, Brenden Moses, and Best Track Change Committee (Jack Beven – Chair, Richard Pasch, Eric Blake, Todd Kimberlain, Dave Roth, and Neal Dorst)
The National Hurricane Center maintains and updates annually the North Atlantic Basin’s Hurricane Database (HURDAT)

HURDAT provides from 1851 to 2014 for all tropical storms, subtropical storms, and hurricanes every 6 hours:

- **Positions** (to nearest 0.1 degree latitude/longitude)
- **Intensity** (1 min surface winds to nearest 10 kt from 1851-1885, 5 kt from 1886 onward)
- **Central pressure** (to nearest 1 mb, when observed)
- **34, 50, and 64 kt wind radii maximum extent** since 2004 (by quadrant, to nearest 10 nmi)
HURDAT applications:

- Validation of official and model predictions
- Climate trend assessment – long term trends, seasonal forecasts, etc.
- Building code standards and insurance rates for coastal communities
- Risk assessment for emergency managers (recurrence intervals)
Why revise HURDAT?

- HURDAT contains many systematic and random errors
  - 1938 Hurricane: Cat 3 at landfall, but 85kts at last offshore position
- "Missing storms"
- Lack of exact hurricane landfall parameters
- Advances in the understanding of hurricanes and analysis techniques

Bias in early major hurricanes (Landsea 1993)
Reanalysis Steps

1) Obtain all available raw data into a single database
2) Conduct synoptic analysis four times daily
3) Determine track
4) Determine intensity
5) Document revisions (metadata file)
Observation Capabilities: Huge Improvements over Time

Data Sources and Technology

- QuikSCAT
- AMSU
- Aircraft Satellite Data Link (ASDL)
- Ocean Data Buoys
- Aircraft Launched Dropsondes (Omega)
- GPS
- Geostationary Satellites
- Polar Orbiting Satellites (Imagery)
- NOAA Aircraft Reconnaissance (Research)
- Jet
- Coastal Radar Network (Conventional)
- Doppler
- Military Aircraft Reconnaissance
- Radiosonde Network

Transmitted Ship Observations

Ship Logs and Land Observations
Surface Observations

NHC Microfilm Maps

Historical Weather Maps

Comprehensive Ocean-Atmosphere Dataset (COADS)

U.S. and Caribbean Original Station Records
HEADQUARTERS
ARMY AIR FORCES INSTRUCTORS' SCHOOL (INSTRUMENT PILOT)
Office of the Commanding Officer
Bryan, Texas

19 August 1943

FLIGHT THROUGH A TROPICAL HURRICANE

BY JOSEPH B. DUCKWORTH, COLONEL, AIR CORPS

During the afternoon and evening of July 27, 1943, a tropical hurricane struck Galveston and Houston, Texas from the Gulf of Mexico.

Between the hour of 14:00 and 19:00 two experimental trips were made (without landing, of course) in an AT-6 airplane, around and through the center of the hurricane. The observer on the first trip was 2nd Lt. Ralph M. O'Hair, navigator, and on the second trip 1st Lt. Wm. H. Jones-Burdiick, a pilot-weather officer. Both trips were made at differing altitudes between 4000 ft. and 9000 ft.
Aircraft Reconnaissance Penetration: 1948 Storm 5

ENTERED AREA OF LOWEST PRESSURE OF 990 MBS AT 2054Z.
Hurricane Aircraft Reconnaissance in late 1940s and early 1950s: U.S. Navy’s PB4Y2
U.S. Navy’s PB4Y2:
• No night flights
• No central pressure for major hurricanes
Flight track 1948 Storm 3 – August 29th
Circumnavigation - typical technique for intense hurricanes

Given aircraft fix position

32 N

28 N

30 N

28 N

76 W

74 W

72 W

70 W
Visually Estimating Surface Winds in Hurricanes

Neumann 1952
Camille Radar loop from New Orleans

- Images were scaled and overlaid onto map with range rings
- ~100 images were processed
- 17/1630Z (first within range) to 18/0600Z (after landfall) every 10 minutes
- Outer eyewall had become predominant by time of landfall
Arlene made landfall in Bermuda around 1530Z on the 9th as a small, rapidly-moving and intensifying hurricane. The Kindley Air Force Base, located in the northeastern part of the island, measured maximum sustained winds of 66 kt and with gusts to 85 kt around 16Z. A central pressure measured in Bermuda was 975 mb, which suggests maximum surface winds of 79 kt from the north of 25N pressure-wind relationship. Based on a forward speed of about 31 kt and small RMW, an intensity of 95 kt is selected at the time of landfall.

Hurricane Baker, 1950. The reductions in intensity on 21 August appear justified. However, they leave a discontinuous jump to a 90 kt intensity at 0000 UTC 22 August. Please re-examine this intensity to see if it should be lowered, explaining how the Antigua data was taken into account.
## HURDAT Intensity Error Estimates

<table>
<thead>
<tr>
<th>Year</th>
<th>US Landfalling</th>
<th>Open ocean with aircraft, central pressures</th>
<th>Open ocean with aircraft, no central pressures</th>
<th>Open ocean without aircraft/landfall unpopulated coast</th>
</tr>
</thead>
<tbody>
<tr>
<td>1851-1885</td>
<td>15 kt</td>
<td>N/A</td>
<td>N/A</td>
<td>25 kt</td>
</tr>
<tr>
<td>1886-1943</td>
<td>12 kt</td>
<td>N/A</td>
<td>N/A</td>
<td>20 kt</td>
</tr>
<tr>
<td>1944-1953</td>
<td>11 kt</td>
<td>13 kt</td>
<td>15 kt</td>
<td>20 kt</td>
</tr>
<tr>
<td>1954-1963</td>
<td>10 kt</td>
<td>12 kt</td>
<td>15 kt</td>
<td>20 kt</td>
</tr>
<tr>
<td>Late 1990s</td>
<td>10 kt</td>
<td>12 kt</td>
<td>N/A</td>
<td>15 kt</td>
</tr>
<tr>
<td>Late 2000s</td>
<td>9 kt</td>
<td>10 kt</td>
<td>N/A</td>
<td>12 kt</td>
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</table>
Atlantic Hurricane Database Re-Analysis Project

http://www.aoml.noaa.gov/hrd/data_sub/re_anal.html

1) 1851 through 1955 (plus Camille/Andrew) changes accepted and officially adopted by NHC Best Track Change Committee

2) 1956-1965 have been preliminarily reanalyzed

3) Remainder of 20th Century will be reanalyzed

RE-ANALYSES NEED TO BE CONDUCTED GLOBALLY!!!
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# HURDAT Position Error Estimates

<table>
<thead>
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<th>Year</th>
<th>US Landfalling</th>
<th>Open ocean with aircraft</th>
<th>Open ocean without aircraft/landfall unpopulated coast</th>
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<tr>
<td>1851-1885</td>
<td>60 nm</td>
<td>N/A</td>
<td>120 nm</td>
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<tr>
<td>1886-1943</td>
<td>60 nm</td>
<td>N/A</td>
<td>100 nm</td>
</tr>
<tr>
<td>1944-1953</td>
<td>20 nm</td>
<td>35 nm</td>
<td>80 nm</td>
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<td>1954-1963</td>
<td>15 nm</td>
<td>30 nm</td>
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<td>Late 1990s</td>
<td>12 nm</td>
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<td>25 nm</td>
</tr>
<tr>
<td>Late 2000s</td>
<td>12 nm</td>
<td>12 nm</td>
<td>25 nm</td>
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# HURDAT Intensity Bias Estimates

<table>
<thead>
<tr>
<th>Year</th>
<th>US Landfalling</th>
<th>Open ocean with aircraft, central pressures</th>
<th>Open ocean with aircraft, no central pressures</th>
<th>Open ocean without aircraft/landfall unpopulated coast</th>
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<tr>
<td>1851-1885</td>
<td>0 kt</td>
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<td>-15 kt</td>
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<tr>
<td>1886-1943</td>
<td>0 kt</td>
<td>N/A</td>
<td>N/A</td>
<td>-10 kt</td>
</tr>
<tr>
<td>1944-1963</td>
<td>0 kt</td>
<td>0 kt</td>
<td>+5 to -10 kt</td>
<td>-10 kt</td>
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<tr>
<td>Late 1990s-2000s</td>
<td>0 kt</td>
<td>0 kt</td>
<td>N/A</td>
<td>0 kt</td>
</tr>
</tbody>
</table>
Track analysis methodology

- Ship and coastal observations allow for triangulation to obtain approximate center;
- If there is a lack of data, significant changes are not implemented.
Intensity analysis tools

- Ship, coastal stations, aircraft reconnaissance data
- Brown et al. (2006) pressure-wind relationships
- Vickery et al. (2000) climatological RMW values
- Kaplan and DeMaria (1995) inland decay model
- Schloemer (1954) equation
  - Calculates central pressure given a peripheral pressure measurement
- Ho et al. (1987) inland pressure decay model
  - Estimates landfall central pressure based on a post-landfall central pressure measurement
- Neumann model from Schwerdt et al. (1979)
  - Calculates extent of hurricane force winds
- Franklin et al. (2003) flight-level to sfc wind
Hurricanes and Global Warming

Opinion piece by Christopher W. Landsea
November 2011

Video of this presentation

Hurricanes as the Poster-Child for Global Warming

Hurricanes have been depicted as the literal poster-child of the harmful impacts of global warming. Without argument, hurricanes (which also include storms known as "typhoons" in the Northwest Pacific and "severe tropical cyclones" in the Indian and Southwest Pacific) are extremely destructive and often responsible for the deaths of hundreds and occasionally thousands of people. As an example, Hurricane Katrina was responsible for the death of ~1200 and about $108 billion in damages. The before and after pictures of the home of David and Kimberly King of Waveland, Mississippi show the incredible power of that hurricane's storm surge and winds.
Tropical storms and hurricanes

Number of Storms (Original vs Revised)

- Revised (avg = 12.0)
- Original (avg = 9.9)
Major hurricanes

Major Hurricanes (Original vs Revised)

Original (avg = 3.6)

Revised (avg = 2.6)
US Cat 1 & 2 Hurricanes (1944-1953)

1944-1953:
6 up 1 Category
2 down 1 Category
15 unchanged

US Major Hurricanes (1944-1953)
Major Hurricane Strikes and Population for Florida
1900 to today
Accomplishments:

2000 – Added in 241 new TCs for 1851-1885
2002 – Reanalyzed 1992’s Hurricane Andrew
2003 – Reanalyzed 1886-1910 – Revised all 194 TCs, 23 new TCs, removed one TC
2005 – Reanalyzed 1911-1914 – Revised all 15 TCs, 5 new TCs
2008 – Reanalyzed 1915-1920 – Revised all 34 TCs, 8 new TCs, removed one TC
2009 – Reanalyzed 1921-1925 – Revised all 27 TCs, 10 new TCs, removed one TC
2010 – Reanalyzed 1926-1930 – All 29 TCs revised, 4 new TCs
2012 – Reanalyzed 1931-1935 – All 58 TCs revised, 15 new TCs, 4 removed TCs
2012 – Reanalyzed 1936-1940 – All 46 TCs revised, 7 new TCs, 1 removed TC
2013 – Reanalyzed 1941-1945 – All 48 TCs revised, 4 new TCs
2014 – Reanalyzed 1946-1950 – All 50 TCs revised, 9 new TCs
2014 – Reanalyzed 1969’s Hurricane Camille
2015 – Reanalyzed 1951-1955 – All 54 TCs revised, 12 new TCs

Overall: Revised 555 existing tropical cyclones
Added 339 new tropical cyclones
Removed 9 tropical cyclones
Highlights for the Atlantic hurricane reanalysis project - 1944 to 1953:

a) Primarily **minor track** alterations were implemented for existing TCs
b) Primarily **major intensity** changes were incorporated into existing TCs, either toward stronger or weaker winds
c) **18 new** TCs were discovered and added into HURDAT (none were removed)
d) 10 major continental U.S. hurricanes were identified (1 more than previously) – 5 went **up** a Category, 2 went **down** a Category, and 3 had no change in Category
e) There still exists significant uncertainty in TC tracks, significant undercounts in TC frequency, and significant underestimation of TC intensity and duration
Camille U.S. Landfall

- Landfall – 0400Z 18 August – 30.3N 89.4W, Waveland, MS
- 900 mb central pressure, 10 nm RMW, 15 kt forward speed, 1004 mb outer closed isobar, 150 nm radius OCI
- Brown et al. pressure-wind relationship:
  - 148 kt north of 25N, 155 kt north of 25N intensifying
- **150 kt maximum 1-min, 10 m wind at landfall**
- Run of Kaplan-DeMaria inland wind decay four hours after landfall gives 101 kt, very close to 104 kt fastest mile wind measured at Columbia, MS
Track analysis methodology (with abundant recon fixes)

- All center fixes compiled
- Fixes plotted and interpolated to 6-hourly positions
- Ship and station data plotted against aircraft data
- Final revised positions are a consensus of all data
- If there is a lack of data, significant changes are not implemented
A Typical Day in 2015 – Marine Data Available around 12 UTC
Geostationary and Low-Earth Orbiting Satellites
A Typical Day in 2008 – Marine Data Available around 12 UTC
A Typical Day in 1915 – Marine Data Available around 12 UTC
A Typical Day in 1911 – Marine Data Available around 12 UTC
Aircraft Reconnaissance Missions into Camille

Navy’s WC-121s

Air Force’s C-130s

ESSA’s DC-6s
1944 missing hurricane found

New to HURDAT:

On the 12th, there are seven observations of gale force winds, two of them being hurricane force winds. Low pressures (down to 998 mb) are observed with these high winds, and these observations are all in close proximity of the cyclones center. Peak intensity of a 70 kt hurricane is analyzed from 12Z on the 12th to 00Z on the 13th.

Key observations:

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Pressure</th>
<th>Wind (kt)</th>
<th>Dir</th>
<th>Air Temp</th>
<th>SST</th>
<th>Ob type</th>
<th>Lat</th>
<th>Lon</th>
<th>Source</th>
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<tr>
<td>11-Oct</td>
<td>15Z</td>
<td>1005</td>
<td>25</td>
<td>NE</td>
<td>75</td>
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<td>SHIP</td>
<td>375</td>
<td>415</td>
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<td>37016</td>
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<td>19Z</td>
<td>1011</td>
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<td>NNE</td>
<td>74</td>
<td></td>
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<td>365</td>
<td>405</td>
<td>COA</td>
<td></td>
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<tr>
<td>11-Oct</td>
<td>23Z</td>
<td>1011</td>
<td>45</td>
<td>N</td>
<td>76</td>
<td>74</td>
<td>SHIP</td>
<td>365</td>
<td>405</td>
<td>COA</td>
<td>61132</td>
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<td>23Z</td>
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<td>SHIP</td>
<td>365</td>
<td>405</td>
<td>COA</td>
<td>14352</td>
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<tr>
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<td>23Z</td>
<td>1011</td>
<td>35</td>
<td>NNE</td>
<td>75</td>
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<td>SHIP</td>
<td>365</td>
<td>405</td>
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<td>10Z</td>
<td>1000</td>
<td>65</td>
<td>S</td>
<td>73</td>
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<td>355</td>
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<td>COA, HWM</td>
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<tr>
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<td>11Z</td>
<td>998</td>
<td>45</td>
<td>SE</td>
<td>72</td>
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<td>395</td>
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<tr>
<td>12-Oct</td>
<td>11Z</td>
<td>996</td>
<td>10</td>
<td>SE</td>
<td>73</td>
<td>74</td>
<td>SHIP</td>
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<td>12-Oct</td>
<td>12Z</td>
<td>996</td>
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<td>365</td>
<td>385</td>
<td>COA</td>
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</tr>
</tbody>
</table>
Researcher’s ashes tossed in storm’s eye

By CURTIS MORGAN
Herald Staff Writer

As the P-3 Orion research plane bumped and rolled through one last circle inside Hurricane Danielle, Peter Black placed a simple cloth sack into a chute and sent its contents swirling into the atmosphere.

And at 10:05 p.m. Sunday, latitude 28.0 north, longitude 74.2 west, 400 miles east-northeast of Miami, Jose Fernandez Partagas finally got a send-off fellow weather scientists know he would have appreciated: His ashes were scattered into the howling heart of an Atlantic hurricane.

“I found it quite a moving experience,” Black, a National Oceanographic and Atmospheric Administration research meteorologist, said Tuesday. “It just seemed very appropriate to do it in the eye of a hurricane.”

The ceremony, a rare honor, was a gesture of respect for an eccentric but affable researcher who lived to study hurricanes and died, nearly destitute, doing just that. It also rescued Partagas from an obscure burial. After his death a year ago in August at age 62, police found no relatives. His father had died in Cuba, his mother in Miami and he had never married.

When no one claimed the body, the National Hurricane Center did.

“They didn’t want Jose to go to a pauper’s grave,” said Jim Gross, a center research meteorologist. Gross stored the ashes, awaiting a scheduled storm flight with the right conditions for the brief ceremony, attended by six scientists and most of the 11 crew members.

“We think Jose would have been honored, happy to have it done this way,” Gross said.

Partagas was born and schooled in Cuba, receiving a degree in meteorology from Havana University and working at the national observatory, said friend Luciano Blanco, a retired physicist in Miami who went to school

Please see Partagas, 46