Atlantic Basin Seasonal Hurricane Prediction: Past, Present and Future

Phil Klotzbach
Department of Atmospheric Science
Colorado State University

Seasonal Hurricane Forecasting Workshop

November 2, 2018
In Memory of Bill Gray (1929-2016)

Seasonal Forecasting is more than this!
August-October-averaged 700 mb height anomalies in the five most active tropical cyclone seasons: 1933-1955
Positive Southern Oscillation Index (e.g., La Niña) = More Australian Tropical Cyclones

Relationship between Darwin austral winter pressure and tropical cyclone frequency during (a) entire season, (b) October-December and (c) January-February.
200-hPa zonal wind anomalies associated with El Niño Events – Increased Caribbean Shear
Vertical Wind Profile in the Caribbean and western part of Main Development Region (10-20°N; 90-50°W)

a – fewer TCs (El Niño)
b – more TCs (La Niña)

Zonal Wind (u) ms⁻¹
Original CSU Seasonal Forecast – Gray (1984)

ENSO

Caribbean SLP

QBO
Named Storm Skill ($r = 0.82$)  
(1950-1982)

Hurricane Day Skill ($r = 0.68$)  
(1950-1982)
Seasonal Predictors used in early August Forecasts by CSU (late 1990s through early 2000s)

Figure 1: Meteorological parameters used in various prior versions of our early August (Gray et al. 1994a) seasonal forecast.

Figure 2: Additional parameters used or consulted in making the actual extended-range forecasts.
TOO MANY PREDICTORS!!

Predictors used in Statistical Model by CSU in August 2000

Table 5. Listing of the pool of predictive parameters and their estimated values for the early August 2000 prediction, based on meteorological data available through July 2001. See Figs. 2 through 4 for the locations of the sources of these predictor data.

<table>
<thead>
<tr>
<th>Predictive Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = QBO 50 mb 2-month extrapolation of zonal wind at 12°N to Sept. 2001</td>
<td>-18 ms⁻¹</td>
</tr>
<tr>
<td>2 = QBO 30 mb 2-month extrapolation of zonal wind at 14°N to Sept. 2001</td>
<td>-17 ms⁻¹</td>
</tr>
<tr>
<td>3 = QBO absolute value of shear between 50 and 30 mb at 8°N to Sept. 2001</td>
<td>1 ms⁻¹</td>
</tr>
<tr>
<td>4 = Rgc AN Gulf of Guinea rainfall anomaly (Aug-Nov of 2000)</td>
<td>-0.5 SD</td>
</tr>
<tr>
<td>5 = Rws West Sahel rainfall anomaly (June-July 2001)</td>
<td>(assume) 0.0 SD</td>
</tr>
<tr>
<td>6 = SST3.4 Nino 3.4 SSTA in June-July 2001</td>
<td>+0.3°C</td>
</tr>
<tr>
<td>7 = ZWA June-July 2001 Caribbean basin zonal wind anomaly</td>
<td>+0.2 m/s</td>
</tr>
<tr>
<td>8 = SLPA June-July 2001 Caribbean basin sea level pressure anomaly</td>
<td>+0.2 mb</td>
</tr>
<tr>
<td>9 = Temp West-East Sahel temperature gradient (Feb-May 2001)</td>
<td>+0.5 SD</td>
</tr>
<tr>
<td>10 = NATL North Atlantic SSTA anomaly (50-60°N, 10-50°W) (June-July)</td>
<td>+0.75°C</td>
</tr>
<tr>
<td>11 = SATL South Atlantic SSTA anomaly (5-18°S, 50°W-10°E) (June-July)</td>
<td>+0.2°C</td>
</tr>
<tr>
<td>12 = TATL Tropical Atlantic SSTA anomaly (10-22°N, 18-50°W) (June-July)</td>
<td>+0.1°C</td>
</tr>
<tr>
<td>13 = R-M: Mar Azores surface pressure ridge strength in Mar 2001</td>
<td>-1.60 SD</td>
</tr>
<tr>
<td>14 = R-ON: Azores surface pressure ridge strength in Oct-Nov 2000</td>
<td>+1.1 SD</td>
</tr>
<tr>
<td>15 = D-SST3.4: Nino 3.4 SSTA for June-July minus April-May 2001</td>
<td>+0.3°C</td>
</tr>
<tr>
<td>16 = NSD-S: Named storm days south of 23.5°N and east of 75°W before 1 August</td>
<td>0</td>
</tr>
</tbody>
</table>
The Atlantic Meridional Mode: SST, wind, and precip anoms

- Leading mode of basin-wide ocean-atmosphere interaction between SST and low-level winds
- Amplifies via the wind-evaporation-SST (WES) feedback mechanism
- Strongest signal during the spring, but persists into hurricane season
Comparative effects of the AMM (local) and ENSO (remote) on vertical wind shear in the Atlantic

Shear regressed onto AMM and Nino 3.4 indices, and correlations between the indices and storm activity.
ECMWF Hindcasts using Observed SSTs

\[ r = 0.56 \]

- \( \circ \): elements of the ensemble
- \( \ast \): observations
- \( + \): mean of the elements

Vitart et al. (1997)
Tropical Storm Frequency over the North Atlantic (ASOND)
Forecast starting on 1st July

ECMWF Seasonal Forecast, Cycle 15r8

$\text{r} = 0.75$
CSU Predicted vs. Observed Atlantic Named Storms (1984-2017) - Early August Forecast

$r_{rank} = 0.75$
NOAA’s Atlantic Hurricane Season Outlook Guidance

**Statistical Guidance**
- Climate-based regression and analogues
- Quantifies observed activity during past seasons with strengths of ENSO, AMO, Atlantic SST anomalies similar to present.

**Hybrid Statistical/Dynamical Guidance**
- Regression relates historical CFS-V2 (T-126) forecasts of SST and vertical wind shear to observed hurricane activity.
- Quantifies observed activity during past seasons having model predictions similar to present.

**Dynamical Guidance and ENSO**
- CFS T-382 Ensemble Forecasts
- GFDL, ECMWF, UKMET, EUROSIPI
- Predict SST, vertical wind shear, ENSO
- Model forecasts of seasonal activity
- CPC/IRI* suite ENSO forecasts

Forecast tool consensus guidance provides 70% probability ranges of activity**

Forecast team members each predict 70% probability ranges of activity.

Final outlook is consensus of individual forecaster predicted ranges.

**Prediction parameters include named storms, hurricanes, major hurricanes, ACE, and probabilities for the season being above- near- and below-normal
Methodology – From reask

Physical feature selection

1 - Correlation to number of TC
2 - Correlation with ASO patterns

Monthly reanalysis

Dimensionality Reduction

- PCA
- Auto-Encoders

Statistical selection

Ensemble of models

Unsupervised learning

- ~10 selected over 10k

Supervised learning
Static vs predictive views of TC risk 1978

North Atlantic and West Pacific

Number of North Atlantic Named Storms vs Number of West Pacific Named Storms

STATIC VIEW

Legend:
- 0.00
- 0.25
- 0.50
- 0.75
- 1.00

%
Seasonal Hurricane Forecast Compilation Website
http://seasonalhurricanepredictions.org

[Graph showing hurricane activity predictions for different organizations]
## New Product from CSU

Real-Time Global Tropical Cyclone Statistics Website:

http://tropical.atmos.colostate.edu/Realtime/

### Northern Hemisphere Tropical Cyclone Activity for 2018 (2018/2019 for the Southern Hemisphere)

<table>
<thead>
<tr>
<th>Basin</th>
<th>Named Storms</th>
<th>Named Storm Days</th>
<th>Hurricanes</th>
<th>Hurricane Days</th>
<th>Major Hurricanes</th>
<th>Major Hurricane Days</th>
<th>Accumulated Cyclone Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Atlantic</td>
<td>15 (11.1)</td>
<td>86.25 (53.9)</td>
<td>8 (5.8)</td>
<td>25.75 (22.4)</td>
<td>2 (2.5)</td>
<td>5.00 (6.0)</td>
<td>127.0 (97.7)</td>
</tr>
<tr>
<td>Northeast Pacific (East of 180°)</td>
<td>22 (16.2)</td>
<td>123.25 (71.5)</td>
<td>13 (8.7)</td>
<td>67.50 (29.5)</td>
<td>10 (4.3)</td>
<td>35.00 (8.9)</td>
<td>313.5 (129.7)</td>
</tr>
<tr>
<td>Northwest Pacific (West of 180°)</td>
<td>26 (22.6)</td>
<td>128.50 (116.3)</td>
<td>14 (14.3)</td>
<td>60.25 (56.7)</td>
<td>9 (7.3)</td>
<td>29.00 (19.1)</td>
<td>320.7 (250.3)</td>
</tr>
<tr>
<td>North Indian</td>
<td>5 (3.0)</td>
<td>15.75 (5.0)</td>
<td>3 (0.8)</td>
<td>5.75 (1.7)</td>
<td>1 (0.5)</td>
<td>0.50 (0.7)</td>
<td>23.2 (10.6)</td>
</tr>
<tr>
<td>Northern Hemisphere</td>
<td>68 (52.9)</td>
<td>353.75 (249.7)</td>
<td>38 (29.6)</td>
<td>159.25 (110.3)</td>
<td>22 (14.5)</td>
<td>69.50 (34.7)</td>
<td>784.4 (488.3)</td>
</tr>
<tr>
<td>South Indian (West of 135°E)</td>
<td>1 (1.0)</td>
<td>1.50 (2.6)</td>
<td>0 (0.1)</td>
<td>0.00 (0.3)</td>
<td>0 (0.0)</td>
<td>0.00 (0.0)</td>
<td>0.8 (2.2)</td>
</tr>
<tr>
<td>South Pacific (East of 135°E)</td>
<td>1 (0.1)</td>
<td>1.75 (0.3)</td>
<td>0 (0.0)</td>
<td>0.00 (0.1)</td>
<td>0 (0.0)</td>
<td>0.00 (0.0)</td>
<td>0.9 (0.5)</td>
</tr>
<tr>
<td>Southern Hemisphere</td>
<td>2 (1.1)</td>
<td>3.25 (2.9)</td>
<td>0 (0.1)</td>
<td>0.00 (0.4)</td>
<td>0 (0.0)</td>
<td>0.00 (0.0)</td>
<td>1.7 (2.7)</td>
</tr>
</tbody>
</table>

Global statistics were last modified: October 30 2018 09:00 MT

- **Observed**
- **Climatology**
Skill, average year 1-5

<table>
<thead>
<tr>
<th>Corr</th>
<th>Rank Clim</th>
<th>Pers</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMO index</td>
<td>0.81</td>
<td>0.66</td>
</tr>
<tr>
<td>Rel SST</td>
<td>0.71</td>
<td>0.54</td>
</tr>
<tr>
<td>Tracking</td>
<td>0.67</td>
<td>0.46</td>
</tr>
<tr>
<td>Statistical*</td>
<td>0.69</td>
<td>0.56</td>
</tr>
</tbody>
</table>

**HURDAT2 5N-25N**
Seasonal Hurricane Forecast Challenges

CSU 1997 Hurricane Forecast Verification Paper – 7 Hurricanes Predicted, 3 Observed
Annual Number of Days with Cat 3-4-5 Hurricanes

- 1900-1925: 3.25 days
- 1926-1969: 7 days
- 1970-1994: 2.5 days
- 1995-2017: 8.25 days
August to September:

$r_{rank} = 0.43$
<table>
<thead>
<tr>
<th></th>
<th>Years Occurred</th>
<th>Average Observed Hurricanes</th>
<th>Average US Landfalling NS</th>
<th>Average US Landfalling H</th>
<th>Average US Landfalling MH</th>
</tr>
</thead>
<tbody>
<tr>
<td>June Forecast &gt;= 8 Hurricanes</td>
<td>13</td>
<td>8.1</td>
<td>5.3</td>
<td>2.5</td>
<td>0.9</td>
</tr>
<tr>
<td>June Forecast &lt;= 5 Hurricanes</td>
<td>10</td>
<td>4.8</td>
<td>2.4</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>August Forecast &gt;= 8 Hurricanes</td>
<td>12</td>
<td>7.9</td>
<td>4.8</td>
<td>2.4</td>
<td>0.8</td>
</tr>
<tr>
<td>August Forecast &lt;= 5 Hurricanes</td>
<td>10</td>
<td>4.2</td>
<td>3.0</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Observed &gt;= 8 Hurricanes</td>
<td>12</td>
<td>9.8</td>
<td>5.1</td>
<td>2.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Observed &lt;= 5 Hurricanes</td>
<td>14</td>
<td>3.8</td>
<td>2.8</td>
<td>0.7</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Alberto
Beryl
Chris
Debby
Ernesto
Helene
Isaac
Florence
Gordon
Beryl
Chris
Beryl
Chris
Debby
Isaac
Ernesto
Joyce
Kirk
Nadine
Oscar
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Named Storms (NS)</td>
<td>15</td>
<td>11.1</td>
<td>135%</td>
<td>12.1</td>
</tr>
<tr>
<td>Named Storm Days (NSD)</td>
<td>87</td>
<td>53.9</td>
<td>161%</td>
<td>59.3</td>
</tr>
<tr>
<td>Hurricanes (H)</td>
<td>8</td>
<td>5.8</td>
<td>138%</td>
<td>6.4</td>
</tr>
<tr>
<td>Hurricane Days (HD)</td>
<td>26</td>
<td>22.4</td>
<td>116%</td>
<td>24.2</td>
</tr>
<tr>
<td>Major Hurricanes (MH)</td>
<td>2</td>
<td>2.5</td>
<td>80%</td>
<td>2.7</td>
</tr>
<tr>
<td>Major Hurricane Days (MHD)</td>
<td>5</td>
<td>6.0</td>
<td>83%</td>
<td>6.2</td>
</tr>
<tr>
<td>Accumulated Cyclone Energy (ACE)</td>
<td>128</td>
<td>98</td>
<td>131%</td>
<td>106</td>
</tr>
</tbody>
</table>
June 2018 SST Anomalies
Aug-Sep 2018 SST Anomalies
Arago’s Admonition:

“Never, no matter what may be the progress of science, will honest scientific men who have regard for their reputations venture to predict the weather.”
Contact Info:

Phil Klotzbach

Email: philk@atmos.colostate.edu

Web: http://tropical.colostate.edu

Twitter: @philklotzbach