Atlantic Hurricane Statistical Analysis

Read Atlantic Storm Re-analysis Data from 1851 to 2004 from National Hurricane Center

Data: Line#,Mon,Day,Yr,Duration,NumYr,Num,Name,Land,SSS,XXX,Vel,Press,Line#, Type, Lat,Long

SD :=

1851-2004r.xls

Number of Data Type Columns

$C := \text{cols}(SD) - 1$

Extract Wind Velocity (Knots) and Pressure (mb) Data

$\text{Velocity} := SD^{\langle 11 \rangle}$ $\text{Pressure} := SD^{\langle 12 \rangle}$ $\max(\text{Velocity}) = 165$

Group Data by Wind Speed: Hurricanes (V > 63 Knots) and Cat 3 (V > 95Knots) and Greater

$CSSD := \text{csort}(SD, 11)$ $\text{match}\left(65, CSSD^{\langle 11 \rangle}\right)_0 = 517$ $\text{match}\left(95, CSSD^{\langle 11 \rangle}\right)_0 = 1007$

Sort by Land Fall

$CSLF := \text{csort}(SD, 8)$ $\text{match}\left(1, CSLF^{\langle 8 \rangle}\right)_0 = 816$

Sort by Storm Number (Year)

$HCSSD := \text{submatrix}(CSSD, 514, 1300 - 1, 0, C)$ $HDY := \text{csort}(HCSSD, 6)$

$H3SSD := \text{submatrix}(CSSD, 1004, 1300 - 1, 0, C)$ $H3Y := \text{csort}(H3SSD, 6)$

$HLFSD := \text{submatrix}(CSLF, 813, 1300 - 1, 0, \text{cols}(CSLF) - 1)$ $HLF := \text{csort}(HLFSD, 6)$

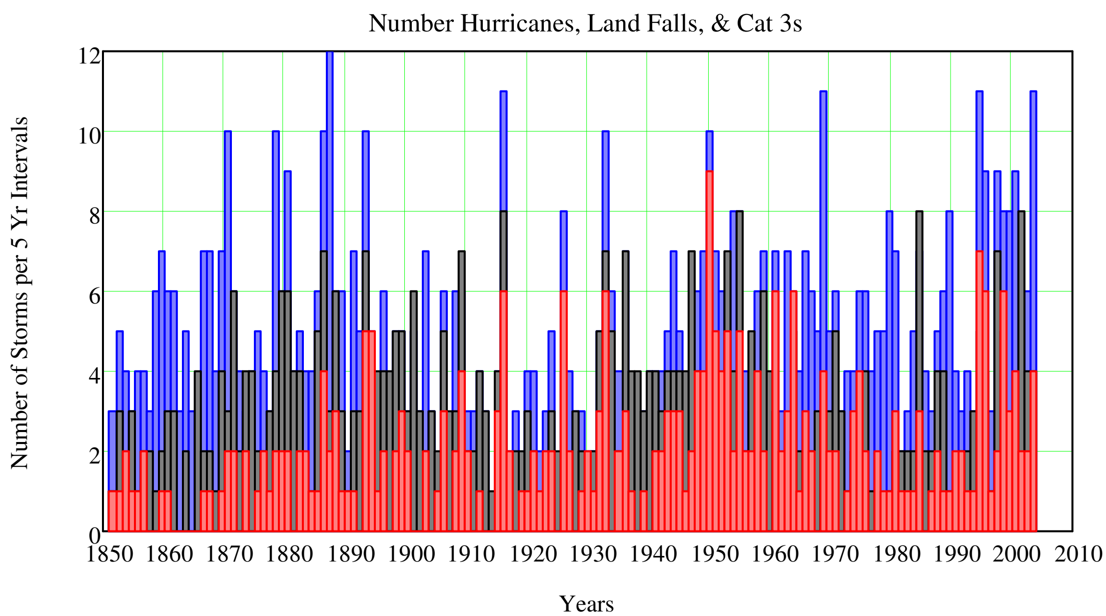
$YearS := SD^{\langle 3 \rangle}$ $YearH := HDY^{\langle 3 \rangle}$ $Year3 := H3Y^{\langle 3 \rangle}$ $YearLF := HLF^{\langle 3 \rangle}$ $YearS_0 = 1851$

$H := \text{histogram}(154, YearH)$

$TS := \text{histogram}(154, YearS)$ $2004 - 1851 = 153$

$H3 := \text{histogram}(154, Year3)$ $LF := \text{histogram}(154, YearLF)$

Plot the Number of: Hurricanes (H), Hurricanes with Land Falls (LF) and Cat 3 Hurricanes (H3)



Plot Histograms of Wind Velocity and Pressure at Eye Wall

$VD := histogram(20, Velocity)$ $CSP := csort(HDY, 12)$ $rows(SD) = 1321$

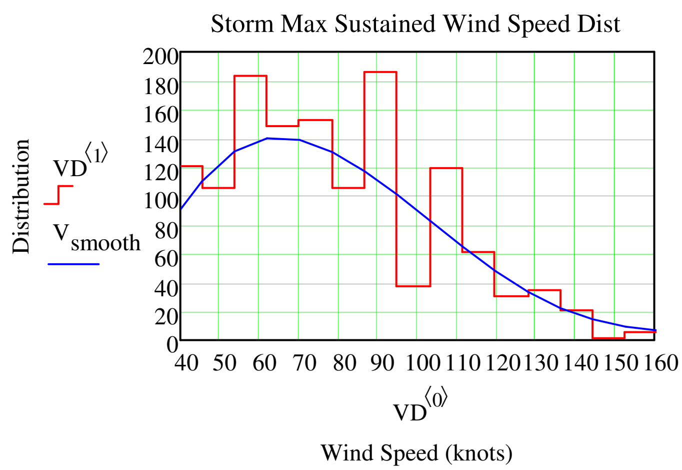
$match\left(9999, CSP^{\langle 12 \rangle}\right)_0 = 442$

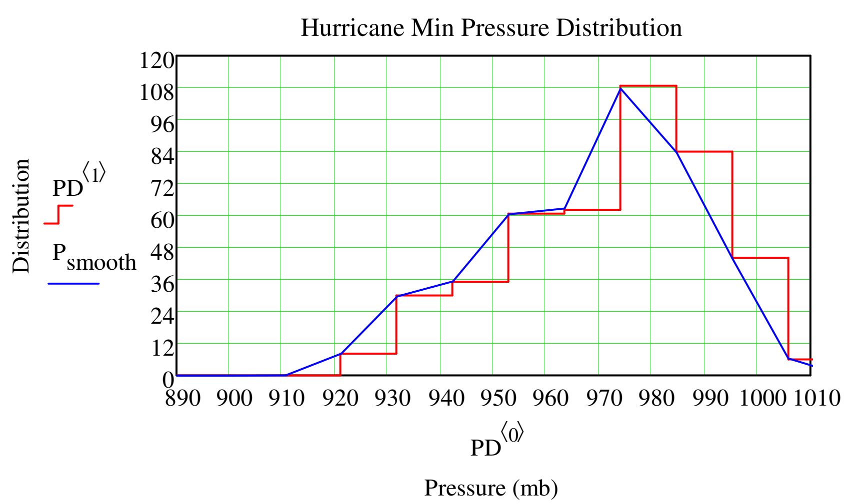
$PSS := submatrix(CSP, 0, 445 - 1, 0, C)$ $max\left(PSS^{\langle 12 \rangle}\right) - min\left(PSS^{\langle 12 \rangle}\right) = 992$

$PD := histogram\left(939, PSS^{\langle 12 \rangle}\right)$

Smooth Discrete Data

$P_{smooth} := ksmooth\left(PD^{\langle 0 \rangle}, PD^{\langle 1 \rangle}, 10\right)$ $V_{smooth} := ksmooth\left(VD^{\langle 0 \rangle}, VD^{\langle 1 \rangle}, 40\right)$





Select Most Reliable (Recent) Storm Data from 1900 to 2004

Lines 370 and 1235 are the start of 1900 and end of 2000 $\mathrm{rows}(SD) = 1321$

$Sd := \mathrm{submatrix}(SD, 370, 1318 - 1, 0, C)$ $\mathrm{match}\left(1900, SD^{\langle 3\rangle}\right)_0 = 370$

$HDY^{\langle 8\rangle} := \overrightarrow{\left(HDY^{\langle 8\rangle} - 100000\cdot\neg HDY^{\langle 8\rangle}\right)}$ $\mathrm{match}\left(2001, SD^{\langle 3\rangle}\right)_0 = 1262$

Find the Start Date of Storms in Days from Beginning of Year

Months per day and Total from Jan to Dec

$MonthDays := (0\ \ 31\ \ 28\ \ 31\ \ 30\ \ 31\ \ 30\ \ 31\ \ 31\ \ 30\ \ 31\ \ 30\ \ 31)^T$

$MonthDayTotals := (0\ \ 31\ \ 59\ \ 90\ \ 120\ \ 151\ \ 181\ \ 212\ \ 243\ \ 273\ \ 304\ \ 334\ \ 365)^T$

$Month := Sd^{\langle 1\rangle}$ $Day := Sd^{\langle 2\rangle}$ $Duration := Sd^{\langle 4\rangle}$

$N := \mathrm{rows}(Month)$ $n := 0 .. N - 1$ $SNBR := Sd^{\langle 6\rangle}$

$Start_n := MonthDayTotals_{Month_n - 1} + Day_n$ $Start\_Sd := Sd^{\langle 15\rangle}$

$Range := \max(Start) - \min(Start)$ $Range = 346$

$H_{start} := \mathrm{histogram}(Range + 1, Start)$ Min Between Peaks is 261 Days

$h_{start} := \mathrm{ksmooth}\left(H_{start}^{\langle 0\rangle}, H_{start}^{\langle 1\rangle}, 5\right)$ $MonthDayTotals_8 + 18 = 261$

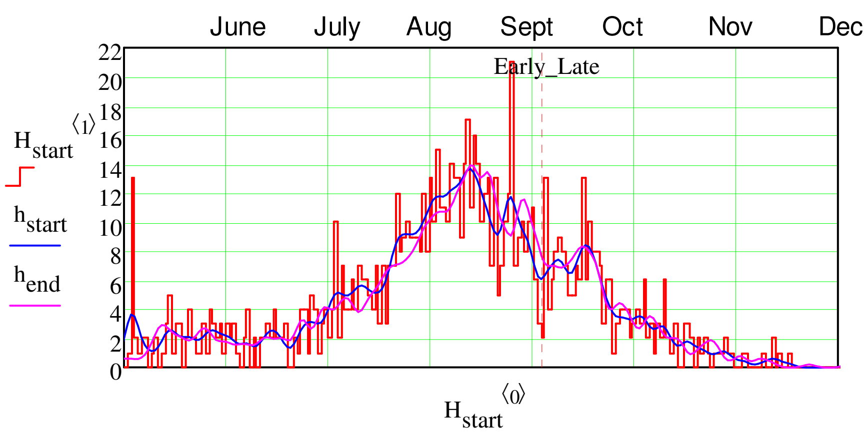
$End := \overrightarrow{(Start + Duration)}$ Min Between Peaks is Sept 18th

$H_{end} := \mathrm{histogram}(Range + 1, End)$

$h_{end} := \mathrm{ksmooth}\left(H_{end}^{\langle 0\rangle}, H_{end}^{\langle 1\rangle}, 5\right)$ $Early\_Late := 273$

Plot Start and End Dates of All Storms

Note that there are two peaks (Sept 6 and Sept 21) indicating two different major factors
(The dividing date for the smoothed curve appears to be at 273 days or **Oct 1st**)



Hurricanes Only 1900 - 2004:   Plot Start and End Dates

$Hdd := submatrix(HDY, 261, rows(HDY) - 1, 0, cols(HDY) - 1)$ $Yr := Hdd^{\langle 3 \rangle}$

$Month2 := Hdd^{\langle 1 \rangle}$ $Day2 := Hdd^{\langle 2 \rangle}$ $Duration2 := Hdd^{\langle 4 \rangle}$

$N := rows(Day2)$ $n := 0..N - 1$ $SNBR := Hdd^{\langle 6 \rangle}$

$Start2_n := MonthDayTotals_{Month2_n - 1} + Day2_n$ $rows(Start) = 948$

$Range2 := max(Start2) - min(Start2)$ $Range2 = 299$

$H_{start2} := histogram(Range2 + 1, Start2)$ $End2 := \overrightarrow{(Start2 + Duration2)}$

$rows(Start) = 948$

$h_{start2} := ksmooth\left(H_{start2}^{\langle 0 \rangle}, H_{start2}^{\langle 1 \rangle}, 5\right)$

$rows(Duration2) = 525$

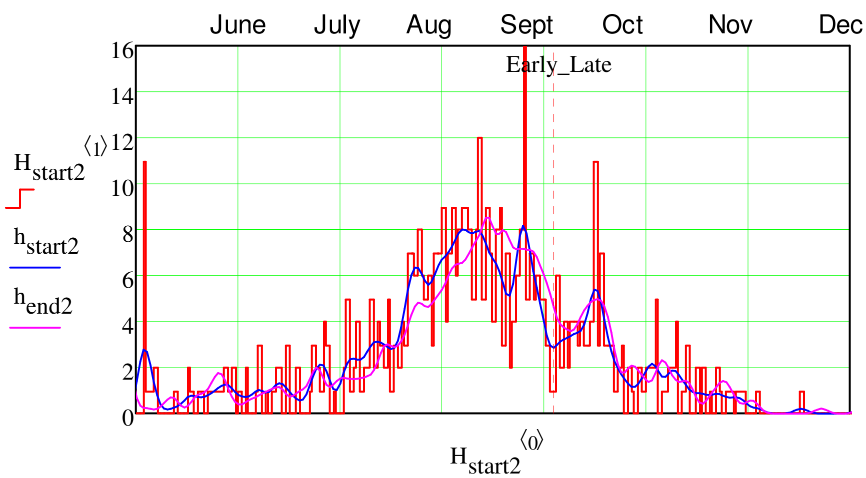
$H_{end2} := histogram(Range2 + 1, End2)$ $DurationDays_{Avg} := mean(Duration2)$

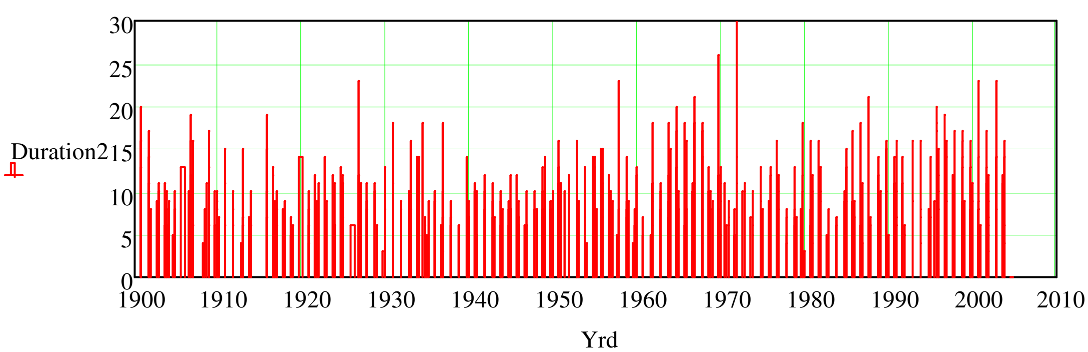
$h_{end2} := ksmooth\left(H_{end2}^{\langle 0 \rangle}, H_{end2}^{\langle 1 \rangle}, 5\right)$ $DurationDays_{Avg} = 9.531$

$Yrd := \overrightarrow{(Yr + Start2 \cdot 0.003)}$

Plot Start and End Dates and Duration of Hurricanes

*Note that there are two peaks (**Sept 6** and **Oct 21**) indicating two different major factors*





Separate Hurricanes into those before and after Days = 273 (Oct 1st)

$HddS := csort(Hdd, 15)$ $R := (rows(Hdd) - 1)$ $Date := HddS^{\langle 15 \rangle}$

$Hdd_{Early} := submatrix(HddS, 0, 391, 0, C)$

$LandFall_{Early} := Hdd_{Early}^{\langle 8 \rangle}$

$Lat_{Early} := 0.1 \cdot Hdd_{Early}^{\langle 16 \rangle}$

$LatLF_{Early} := \overrightarrow{\left(LandFall_{Early} \cdot Lat_{Early}\right)}$

$Long_{Early} := -0.1 \cdot Hdd_{Early}^{\langle 17 \rangle}$

$Hdd_{Late} := submatrix(HddS, 392, R, 0, C)$

$LandFall_{Late} := Hdd_{Late}^{\langle 8 \rangle}$

$Lat_{Late} := 0.1 \cdot Hdd_{Late}^{\langle 16 \rangle}$

$LatLF_{Late} := \overrightarrow{\left(LandFall_{Late} \cdot Lat_{Late}\right)}$

$Long_{Late} := -0.1 \cdot Hdd_{Late}^{\langle 17 \rangle}$

Find the Fraction of Hurricanes that are Early and Late

$\frac{rows(Hdd_{Early})}{rows(HddS)} = 0.747$ $\frac{rows(Hdd_{Late})}{rows(HddS)} = 0.253$

Find the Fraction of Each Type of Hurricane that Makes Land Fall in USA

$mean(\Phi(LandFall_{Early})) = 0.401$ $mean(\Phi(LandFall_{Late})) = 0.271$

Find correlation between the Yearly Occurence Frequency of Early and Late Hurricanes

Note There were no hurrincanes in 1907 and 1914

```
ELF(M) := | y ← 0
          | r ← 0
          | while r < rows(M) − 1
          |   | ET ← 0
          |   | LT ← 0
          |   | while M[r,3] = 1900 + y ∧ r < rows(M) − 1
          |   |   | ET ← ET + 1  if M[r,1] ≤ 9
          |   |   | LT ← LT + 1  otherwise
          |   |   | r ← r + 1
          |   |   | N[y,0] ← M[r−1,3]
          |   |   | N[y,1] ← ET
          |   |   | N[y,2] ← LT
          |   |   | N[y,3] ← ET + LT
          |   | y ← y + 1
          | N
```

$FD := ELF(Hdd)$

$FD_{7,0} := 1907$ $FD_{14,0} := 1914$

$\sum FD^{\langle 1 \rangle} + \sum FD^{\langle 2 \rangle} = 524$

$corr\left(FD^{\langle 1 \rangle}, FD^{\langle 2 \rangle}\right) = 0.199$

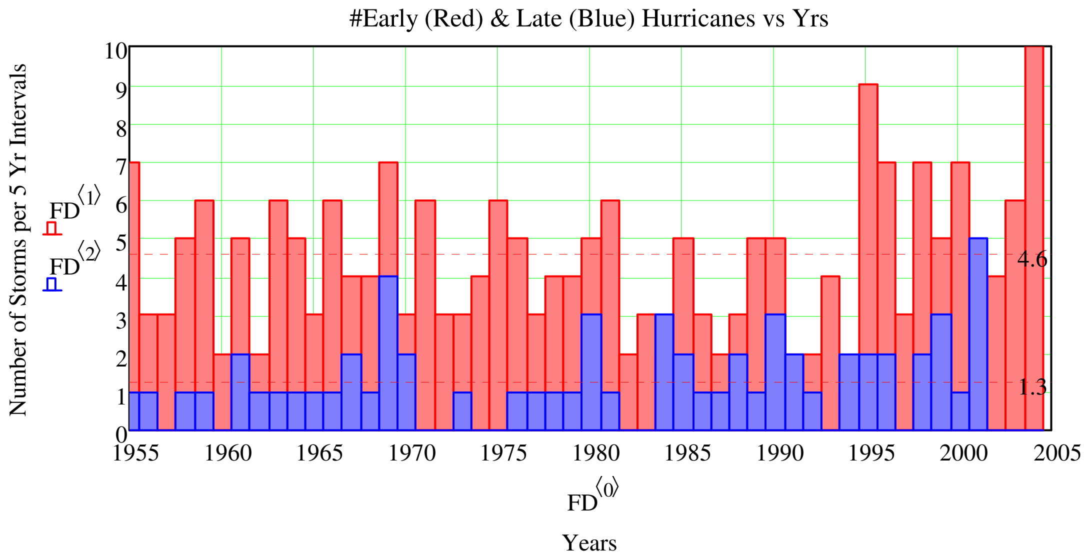
Average # Early & Late

$FD_E := mean\left(FD^{\langle 1 \rangle}\right)$

$FD_L := mean\left(FD^{\langle 2 \rangle}\right)$

$FD_E = 3.829$

$FD_L = 1.162$



Read Data for Coastal Map of USA and Gulf Regions

$$\mathrm{SwapColumns}(M) := \left| \begin{array}{l} N \leftarrow M^{\langle 1 \rangle} \\ N^{\langle 1 \rangle} \leftarrow M^{\langle 0 \rangle} \\ N \end{array} \right.$$

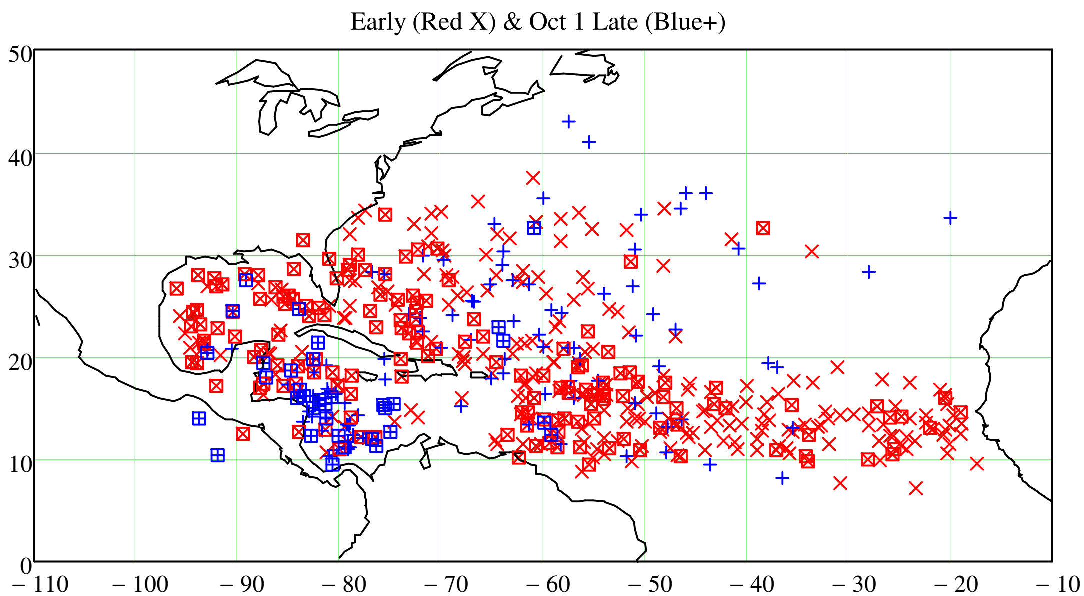
$$USA := \mathrm{READPRN}(\text{"World\_Map.txt"})$$

$$USA := \mathrm{SwapColumns}(USA)$$

$$\mathrm{PatchJumps}(M) := \left| \begin{array}{l} R \leftarrow 0 \\ Nn \leftarrow 0 \\ \text{for } r \in 0..\mathrm{rows}(M) - 2 \\ \quad \left| \begin{array}{l} Nn_{r+R,0} \leftarrow M_{r,0} \\ Nn_{r+R,1} \leftarrow M_{r,1} \\ \text{if } \left(\left| M_{r,0} - M_{r+1,0} \right| > 2 \right) \vee \left| M_{r,1} - M_{r+1,1} \right| > 5 \\ \quad \left| \begin{array}{l} Nn_{r+R+1,0} \leftarrow M_{r,0} \\ Nn_{r+R+1,1} \leftarrow 10^6 \\ R \leftarrow R + 1 \end{array} \right. \end{array} \right. \\ Nn \end{array} \right.$$

$$USA := \mathrm{PatchJumps}(USA)$$

Mark the Start Locations for Hurricanes Making USA Landfall with a box



Accumilated Cyclone Energy - Atlantic

The Atlantic hurricane database (or HURDAT) extends back to 1851
http://www.aoml.noaa.gov/hrd/tcfaq/E11.html

The ACE of a season is calculated by summing the squares of the estimated maximum sustained velocity of every active tropical storm (wind speed 35 knots (65 km/h) or higher), at six-hour intervals. If any storms of a season happen to cross years, the storm's ACE counts for the previous year.[2] The numbers are usually divided by 10,000 to make them more manageable. The unit of ACE is 104 kn2, and for use as an index the unit is assumed. Thus:

$$\mathrm{ACE} = 10^{-4} \sum v_{\max}^2$$

where vmax is estimated sustained wind speed in knots.

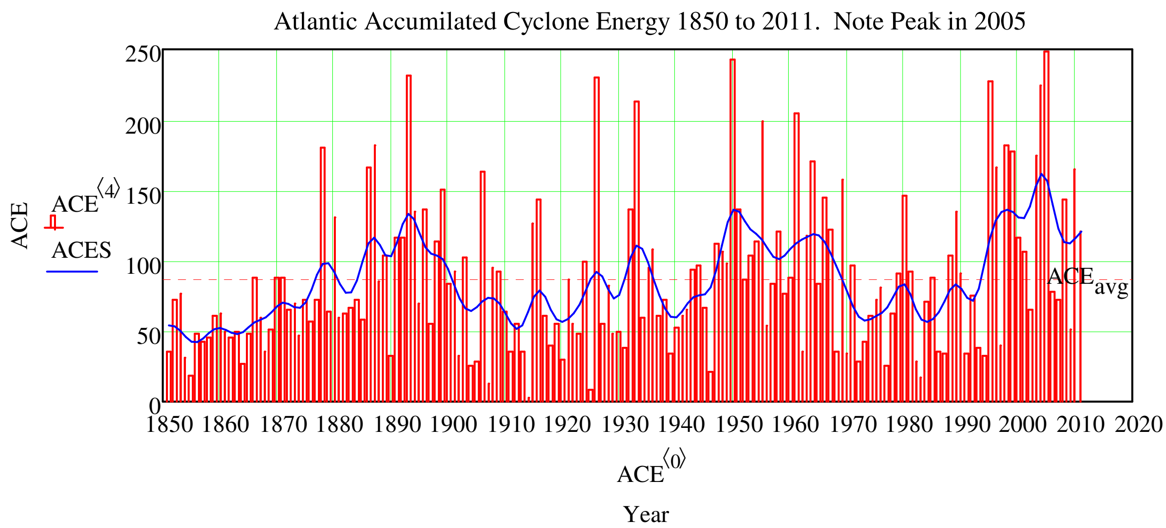
ACE := READPRN("Atlantic Accumulated Cyclone Energy 1851 - 2011.txt")

Format: Year Named Storms Hurricanes Major Hurricanes ACE

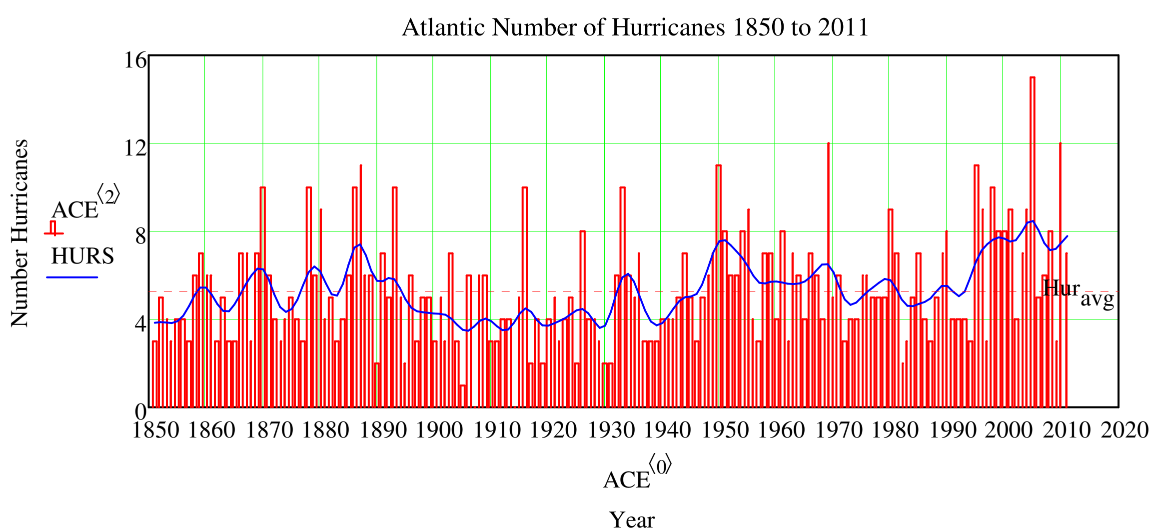
$ACES := ksmooth\left(ACE^{\langle 0 \rangle}, ACE^{\langle 4 \rangle}, 5\right)$ $ACE_{avg} := mean\left(ACE^{\langle 4 \rangle}\right)$

$HURS := ksmooth\left(ACE^{\langle 0 \rangle}, ACE^{\langle 2 \rangle}, 5\right)$ $Hur_{avg} := mean\left(ACE^{\langle 2 \rangle}\right)$

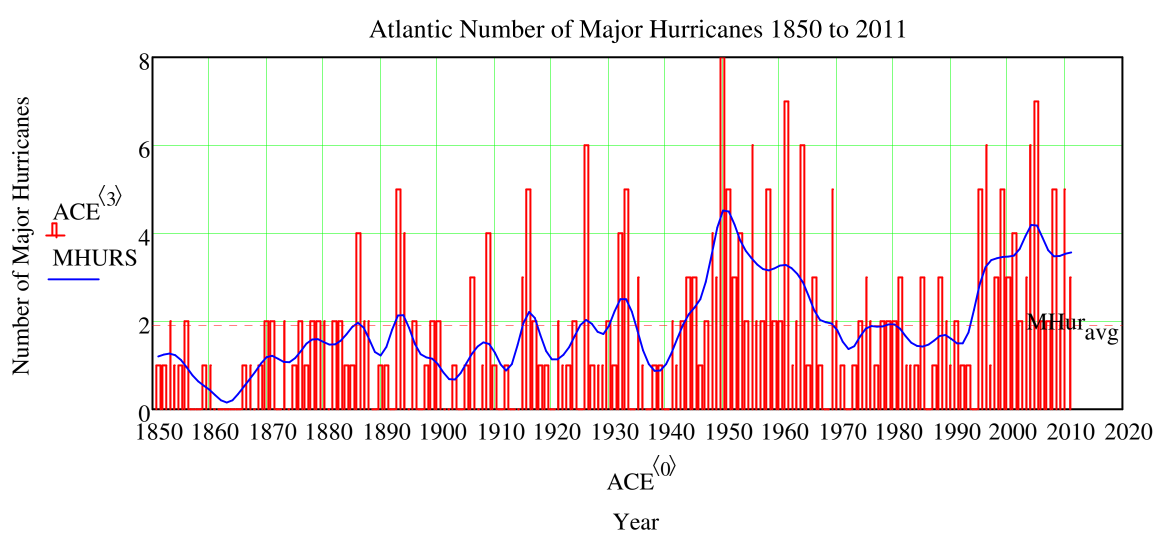
$MHURS := ksmooth\left(ACE^{\langle 0 \rangle}, ACE^{\langle 3 \rangle}, 5\right)$ $MHur_{avg} := mean\left(ACE^{\langle 3 \rangle}\right)$



Atlantic Accumilated Cyclone Energy 1850 to 2011. Note Peak in 2005
ACE
ACE⟨4⟩
ACES
ACEavg
0
50
100
150
200
250
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020
ACE⟨0⟩
Year



Atlantic Number of Hurricanes 1850 to 2011
Number Hurricanes
ACE⟨2⟩
HURS
Huravg
0
4
8
12
16
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020
ACE⟨0⟩
Year



Atlantic Number of Major Hurricanes 1850 to 2011
Number of Major Hurricanes
ACE⟨3⟩
MHURS
MHuravg
0
2
4
6
8
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020
ACE⟨0⟩
Year

The following data shows that, contrary to most years, the most historically significant climatic factors are not correlated to 2004 season hurricane activity

No Correlation between Sunspot Activity and Hurricanes

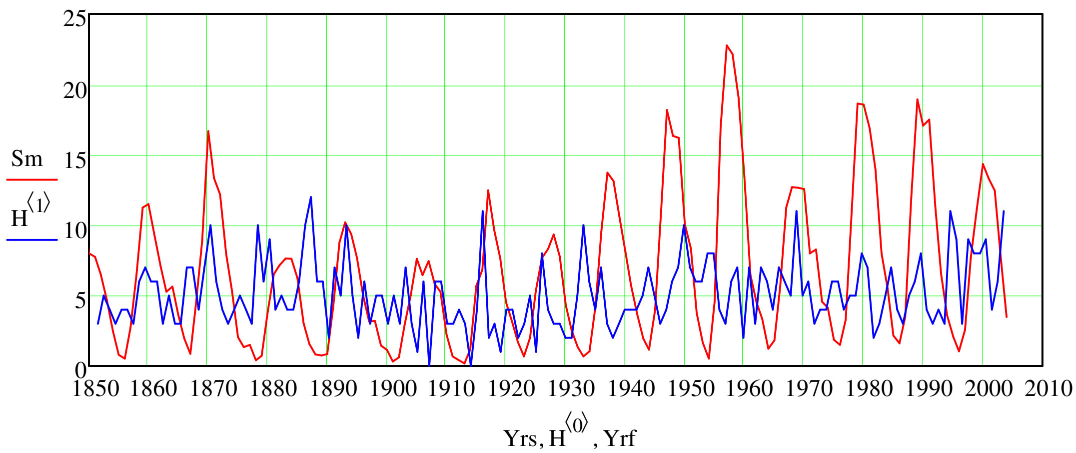
Load Sunspot data from 1749 to 2004

SM := sunspot_num2.txt

$Ry := 2004 - 1749 \qquad Ry = 255 \qquad r := 0..Ry \qquad Yrs_r := 1749 + r$

$$V^{\langle r\rangle} := \text{vlookup}(Yrs_r, SM, 2) \qquad Sm_r := \frac{1}{100}\cdot\sum V^{\langle r\rangle}$$

Comparison of Sunspots and # Hurricanes



Year

No Correlation Sunspots to Frequency of All Hurricanes

Subset of Sunspot Data from 1851 to 2004

$Ss := \text{submatrix}(Sm, 102, \text{rows}(Sm) - 1, 0, 0) \qquad Yrs_{102} = 1851$

$\text{corr}\left(Ss, H^{\langle 1\rangle}\right) = 0.058$

No Correlation Sunpots to Early and Late Hurricanes

Subset of Sunspot Data from 1900 to 2004

$Ss2 := \text{submatrix}(Sm, 151, 255, 0, 0) \qquad Yrs_{151} = 1900$

$Ss3 := \text{submatrix}(Sm, 201, 251, 0, 0)$

$\text{corr}\left(Ss2, FD^{\langle 1\rangle}\right) = 0.038 \qquad \text{corr}\left(Ss2, FD^{\langle 2\rangle}\right) = 0.087$

Correlation between El Nino Southern Oscillation and Early, Late and All Hurricanes
Load El Nino data from 1950 to June 2004 (Minus "LastYrs")
Correlate from with ENSO May to Nov Data

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.html

$LastYrs := 0$ $\quad ENSO := READPRN("ENSO Years.txt")$ $\quad rows(ENSO) = 55$

$ENSO := submatrix(ENSO, 0, 54 - LastYrs, 5, 11)$

$r := 0 .. 54 - LastYrs \qquad ENSOT_r := \sum \left(ENSO^T\right)^{\langle r \rangle} \qquad Zero := 0$

$FD50 := submatrix(FD, 50, 104 - LastYrs, 0, 3) \qquad rows(FD) = 105$

Correlation El Nino and Early	**Correlation El Nino and Late**	**Correlation El Nino and ALL**
$corr\left(ENSOT, FD50^{\langle 1 \rangle}\right) = -0.34$	$corr\left(ENSOT, FD50^{\langle 2 \rangle}\right) = -0.222$	$corr\left(ENSOT, FD50^{\langle 3 \rangle}\right) = -0.387$

Better Correlation to BEST (Bivariate ENSO Time Series)
Load BEST data from 1871 to Aug 2004 (Minus "LastYrs")
Correlate from with BEST June to August Data

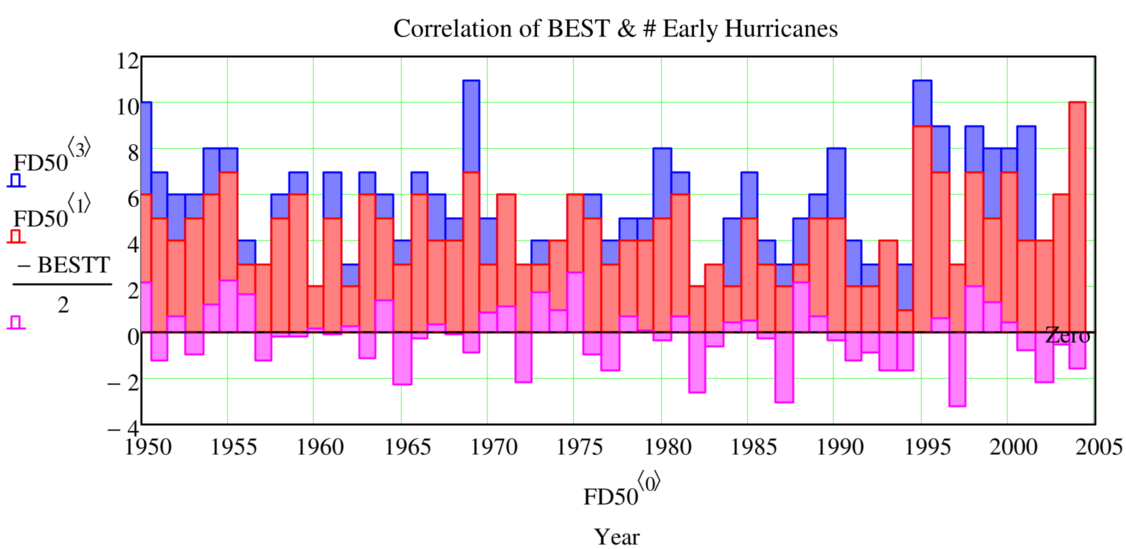
http://www.cdc.noaa.gov/people/cathy.smith/best/#values

$BEST := READPRN("Best enso\_ts\_1mn.txt") \qquad rows(BEST) = 134$

$BEST := submatrix(BEST, 79, 133 - LastYrs, 6, 8)$

$BESTT_r := \sum \left(BEST^T\right)^{\langle r \rangle}$

Correlation BEST and Early	**Correlation BEST and Late**	**Correlation BEST and All**
$corr\left(BESTT, FD50^{\langle 1 \rangle}\right) = -0.301$	$corr\left(BESTT, FD50^{\langle 2 \rangle}\right) = -0.238$	$corr\left(BESTT, FD50^{\langle 3 \rangle}\right) = -0.362$



Correlation between Quasi-Biennial Oscillation and Early and Late Hurricanes
Load QBO data from 1948 to August 2004 (Minus "LastYrs")
Correlate from with QBO June to August Data

$QBO := READPRN("tsin QBO.txt")$ $\qquad rows(QBO) = 57$

$QBO := submatrix(QBO, 2, 56 - LastYrs, 6, 8)$

$QBOT_r := \sum \left(QBO^T\right)^{\langle r \rangle}$

Correlation QBO and Early

$corr\left(QBOT, FD50^{\langle 1 \rangle}\right) = 0.354$

Correlation QBO and Late

$corr\left(QBOT, FD50^{\langle 2 \rangle}\right) = -0.059$

Correlation QBO and All

$corr\left(QBOT, FD50^{\langle 3 \rangle}\right) = 0.258$

Correlation to Composite of BEST minus QBO versus Early and All

$$BEST\_QBO := \overrightarrow{\left(\frac{BESTT}{mean(ENSOT)} - \frac{QBOT}{mean(QBOT)}\right)}$$

$corr\left(BEST\_QBO, FD50^{\langle 1 \rangle}\right) = 0.348$ $\qquad corr\left(BEST\_QBO, FD50^{\langle 3 \rangle}\right) = 0.395$