2019 ICLR
Hurricane Briefing

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Warning Preparedness Meteorologist
Canadian Hurricane Centre
Overview

• Tropical Cyclones 101
• Review of the 2018 Hurricane Season
• Outlook for the 2019 Hurricane Season
• Sources of information for monitoring hurricanes
Tropical Cyclones

- Tropical cyclone is the generic term for such storms as hurricanes, tropical storms, typhoons, etc.
- They form over the warm tropical waters around the world
- Tropical cyclones serve the purpose of redistributing energy stored in the ocean into the atmosphere

All hurricane tracks: 1842-2018
Hurricane Climatology

Hurricane Origin and Track by Month

June

July

August

September

October

November
What are Tropical Cyclones

Outflow

Upward Motion

Sinking Motion

Inflow

Warm Water

What are Tropical Cyclones

Outflow

Upward Motion

Sinking Motion

Inflow

Warm Water
# Tropical Cyclone Classification

<table>
<thead>
<tr>
<th>Tropical Storm</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
<th>Category 4</th>
<th>Category 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind &gt; 63 km/h</td>
<td>119-153 km/h</td>
<td>154-177 km/h</td>
<td>178-208 km/h</td>
<td>209-251 km/h</td>
<td>Wind &gt; 252 km/h</td>
</tr>
</tbody>
</table>

- **Tropical Storm**
  - Debby (2012)
  - Allison (2001)

- **Category 1**
  - Hermine (2016)
  - Isaac (2012)

- **Category 2**
  - Juan (2003)
  - Arthur (2014)

- **Category 3**
  - Joaquin (2015)
  - Gaston (2016)

- **Category 4**
  - Floyd (1999)
  - Harvey (2017)

- **Category 5**
  - Irma (2017)
  - Patricia (2015)

- **Damage Level**
  - Minimal Damage
  - Some Damage
  - Extensive Damage
  - Devastating Damage
  - Catastrophic Damage
Tropical vs. Non-Tropical Storms

**Tropical Cyclone**
- Fueled by the warm water
- Slow-moving
- Symmetrical

**Non-Tropical Cyclone**
- Fueled by the horizontal contrast in air temperature
- Generally faster-moving
- Asymmetric

Major Hurricane Irma 2017

Winter Storm January 2018
From Tropical to Post-Tropical

Storm size increases, rain begins to shift left of track

Storm starts to speed up and curve northward

Strengthens to a hurricane, moves slowly westward

Storm becomes post-tropical, moving very fast, heavy rain on the left, strongest winds on the right

Storm forms off Africa
<table>
<thead>
<tr>
<th></th>
<th>Predicted</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Named Storms:</td>
<td>10-16</td>
<td>15</td>
</tr>
<tr>
<td>Hurricanes:</td>
<td>5-9</td>
<td>8</td>
</tr>
<tr>
<td>Major Hurricanes:</td>
<td>1-4</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Predicted</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberto</td>
<td>Helene</td>
<td>Oscar</td>
</tr>
<tr>
<td>Beryl</td>
<td>Isaac</td>
<td>Patty</td>
</tr>
<tr>
<td>Chris</td>
<td>Joyce</td>
<td>Rafael</td>
</tr>
<tr>
<td>Debby</td>
<td>Kirk</td>
<td>Sara</td>
</tr>
<tr>
<td>Ernesto</td>
<td>Leslie</td>
<td>Tony</td>
</tr>
<tr>
<td><strong>Florence</strong></td>
<td><strong>Michael</strong></td>
<td><strong>Valerie</strong></td>
</tr>
<tr>
<td>(Retired)</td>
<td>(Retired)</td>
<td></td>
</tr>
<tr>
<td>Gordon</td>
<td>Nadine</td>
<td>William</td>
</tr>
</tbody>
</table>
2018 Tropical Cyclone Tracks

[Map of 2018 Tropical Cyclone Tracks]

Preliminary
2018 Hurricane Season Review

Canadian Hurricane Centre (CHC)
Centre canadien de prévisions des ouragans (CCPO)

Storms of tropical origin affecting Canadian territory.
Tempêtes d'origine tropicale affectant le territoire canadien.

2018
Another early start to hurricane season

- TS Alberto was the first storm of the season May 25th and had non-tropical origins

- 18 direct fatalities due to Alberto

- Beryl went through rapid intensification despite relatively cooler waters and became the first hurricane of the 2018 season in early July

- Chris became the second hurricane of the season July 10th – reached CAT 2

- TS Debby and Ernesto both formed in August both from non-tropical origins but no significant damage was reported
Hurricane Florence

- Formed on the last day of August and became the first major hurricane of 2018 on September 4th.

- Weakened to a TS before going through rapid intensification a few days later once again reaching major hurricane status.

- Florence slowed down and then weakened to a CAT 1 before making landfall in near Wrightsville Beach early on September 14.

- After slowing down even more after landfall, Florence became the wettest tropical cyclone on record in the Carolinas.
Hurricane Florence
Hurricane Florence

- Florence produced extensive wind damage along the North Carolina coast

- Thousands of downed trees caused widespread power outages to nearly all of eastern North Carolina

- Florence produced record breaking storm surge of 2 to 4 m and devastating rainfall generally in the 500 to 800 mm range

- Peak reported rainfall was 912.6 mm in Elizabethtown NC

- Peak reported wind was 171 km/h at Cape Lookout

- Rainfall due to Florence produced catastrophic and life-threatening flooding

- 57 fatalities, 24 B USD in damage
Peak of Hurricane Season

- Gordon became a TS on September 3\textsuperscript{rd} making landfall on September 4\textsuperscript{th}

- Gordon produced heavy rain over the Florida Panhandle with 323mm at Pensacola

- 4 fatalities, 200-250 M USD in damages

- Helene became a hurricane on September 9\textsuperscript{th} and almost reached CAT 2 but stayed over the ocean with no reports of damage

- Isaac also became a hurricane on September 9\textsuperscript{th}

- No reported fatalities but reports of heavy surf and mudslides
Peak of Hurricane Season

• TS Joyce was another storm of non-tropical origin that stayed far offshore – no reports of damage

• TS Kirk formed off the coast of Africa in late September

• Kirk produced heavy rain, floods and power outages in Barbados

• Leslie became a hurricane on September 23rd and was a large and persistent storm

• Produced very large wave in Spain and Portugal

• 17 fatalities
Hurricane Michael

• Formed on October 7\textsuperscript{th} then rapidly intensified as it entered the Gulf of Mexico

• Became the second and last major hurricane of 2018 on October 9\textsuperscript{th}

• Reached peak intensity of 260 km/h

• Michael made landfall as a Category 5 Hurricane southeast of Panama City FL

• One of only 4 category 5 hurricanes to make landfall in the U.S.

• Widespread damage spread well inland as Hurricane Michael remained at hurricane strength into southwest Georgia
Hurricane Michael

- Michael brought catastrophic storm surge to the Florida Panhandle and Big Bend areas
- Extreme winds caused extensive structural damage with almost 50,000 structures affected and 3,000 of those destroyed
- Peak wind gust of 224 km/h was measured at Tyndall AFB before the sensor failed
- Michael is the fourth most-powerful hurricane to hit the United States
- The catastrophic winds also resulted in damage to the timber and agricultural communities across Florida and Georgia
- 16 fatalities (direct)
- 25.1 B USD in damages
Late in the 2018 Hurricane Season

- TS Nadine formed October 9\textsuperscript{th} and only lasted 3 days with no reports of damage or fatalities
- Hurricane Oscar formed in late October and reached CAT 2 status
2018 Hurricane Season Summary

• The 2018 Atlantic Hurricane Season was slightly more active than the long term average

• 2018 was the 3rd straight year in which we saw above normal activity in the Atlantic

• The season got off to a quick start with 2 early hurricanes including Chris which impacted Newfoundland and Labrador as a post-tropical storm

• Other impacts in Canada were minimal

• Two storms in particular, Florence and Michael, produced major impacts in the U.S.
2019 Atlantic Hurricane Season Outlook
Factors Influencing Hurricane Season

- Water Temperature
- Wind Shear
- Multi-decadal cycle

Less active | Average | More active
Current Water Temperature
Current Water Temperature
Current Water Temperature
Latest Atlantic Sea Surface Temperature Anomaly

Water temperatures are warmer than normal

Water temperatures are cooler than normal
Factors Influencing Hurricane Season

Water Temperature
Wind Shear
Multi-decadal cycle

Less active | Average | More active
El Niño and Atlantic Hurricanes

Increase in high-level westerly winds

Higher vertical wind shear during El Niño years
(Graphic: Dr. P Klotzbach)
Sea Surface Temperature Anomaly

Warmer water in the equatorial Pacific (El Nino)

Average to cooler water in the Main Development Region
Sea Surface Temperature Anomaly

Global sea surface anomaly and snow cover
15 Apr 2019

Average to cooler water in the Main Development Region

Warmer water in the equatorial Pacific (El Nino)

Uncovered sea ice
Glace marine à découvert
Climatologie 1995-2009 Climatology

CMC Environment Canada
Sea Surface Temperature Anomaly

Warmer water in the equatorial Pacific (El Nino)

Average to cooler water in the Main Development Region

Global sea surface anomaly and snow cover
30 May 2019

Anomalie de la température de la mer et épaisseur de la neige
30 Mai 2019

Uncovered sea ice
Glace marine à découvert
Climatologie 1995-2009 Climatology

CMC Environnement Canada
El Niño forecast through hurricane season

Model Predictions of ENSO from May 2019

IRI/CPC

Dynamical Models:
- NASA_GMAO
- NCEP_CFSv2
- JMA
- BCC_CSM11m
- SAUDI-KAU
- LDEO
- AUS/POAMA
- ECMWF
- UKMO
- KMA-SNU
- IOCAS ICM
- COLA CCSM4
- MetFRANCE
- SINTEX-F
- CS-IUMM
- GFDL CM2.1
- CMC CANSMIP
- GFDL FLOR

Statistical Models:
- PSD-CU CLIM
- NTU CODA
- BCC_RZDM
- CPC MNI
- CPC CA
- CSU CLIPR
- ORNL NNED
- FSU REGR
- UCL-TOO
El Niño forecast through hurricane season

Early–May 2019 CPC/IRI Official Probabilistic ENSO Forecasts

ENSO state based on NINO3.4 SST Anomaly
Neutral ENSO: −0.5 °C to 0.5 °C

La Niña Forecast Probability
Neutral Forecast Probability
El Niño Forecast Probability
La Niña Climatology
Neutral Climatology
El Niño Climatology

Season
AMJ MJJ JJA JAS ASO SON OND NDJ DJF
Probability (%)
0 10 20 30 40 50 60 70 80 90 100
Factors Influencing Hurricane Season

Water Temperature

Wind Shear

Multi-decadal cycle

Less active

Average

More active
Tropical Atlantic Wind Shear – 2018

August 15 Through October 13, 2018 Average
Zonal (200–850 mb) Vertical Wind Shear Anomaly (kts)
(1981–2010 Climatology)
Factors Influencing Hurricane Season

- Water Temperature
- Wind Shear
- Multi-decadal cycle

Factors: Less active, Average, More active
Spring 2019 Atlantic Hurricane Forecast

2019 NOAA Hurricane Season Outlook

Season Probability

- 30% Below Normal
- 30% Near Normal
- 40% Above Normal

- 9-15 Named Storms (Average 12)
- 4-8 Hurricanes (Average 6)
- 2-4 Major Hurricanes (Average 2-3)
List of Atlantic Storm Names

2019 Hurricane Names

- Andrea
- Barry
- Chantal
- Dorian
- Erin
- Fernand
- Gabrielle
- Humberto
- Imelda
- Jerry
- Karen
- Lorenzo
- Melissa
- Nestor
- Olga
- Pablo
- Rebekah
- Sebastien
- Tanya
- Van
- Wendy
Tropical Cyclone Activity in Canada

On average 32% of named storms in the Atlantic make it into the CHC Response Zone
Operational Response to Approaching Storms: Hurricane monitoring tools
Hurricane Weather Products

National Hurricane Centre (U.S.)

- Daily monitoring of potential formation areas

- Key information on storms that do not pose an immediate threat to Canada including track maps, wind probability maps, flood risk maps

https://www.nhc.noaa.gov/
Hurricane Weather Products

Canadian Hurricane Centre (Canada)

- More details on storms that are expected to have impacts in Canada or offshore waters

- Key information on storms that do not pose an immediate threat to Canada including track maps, wind probability maps, flood risk maps

www.hurricanes.ca
....it only takes one storm to make it a bad year!
Questions
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