Extreme Extra-tropical Cyclone Climatology

Joseph M. Sienkiewicz
NOAA/NWS Ocean Prediction Center
Khalil Ahmad, Gregory McFadden, Zorana Jelenak,
Paul Chang, Michael Brennan, Joan Von Ahn

2009 Scatterometer and Climate Meeting, Arlington, VA Aug 19-21
1979 – President’s Day Blizzard

- Poorly predicted in Washington, DC
- Rapid intensification as exited coast
- Highlighted limitations of NWP

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1979: “Freak storm hits yacht race”

...BBC News

“The race was hit by a violent Force 10 storm that swept across the North Atlantic and into the southern Irish Sea, catching forecasters almost completely unawares”.

1979 Fastnet Race...15 dead
Largest peace time rescue effort

Focus on Maritime Extra-tropical Cyclones
Sanders and Gyakum, 1980
Synoptic-Dynamic Climatology of the “Bomb”

Triggered two field campaigns – Genesis of Atlantic Lows Experiment (GALE)
- Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA)
Linked SST gradient to rapid cyclogenesis

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GALE and ERICA focus

• Rapid intensification
  – Climatology
  – Role of latent heat release
  – Fluxes
  – Jet streaks
  – Predictability
  – Inadequacies of NWP models

• Evolution of cyclone structure

• Unable to focus on:
  – evolution of conditions (winds)
QuikSCAT era

• Wide swath
  – reveals much of cyclone wind field
    • (complete coverage 2x’s/day poleward of 49 degrees)

• Large retrievable wind speed range
  – (well into hurricane force)

• Limitations - resolution and rain
  – not as significant in extra-tropical cyclones as opposed to tropical cyclones
  – Highest winds typically in area of minimal rain and over large area

• Allows focus on conditions, not just central pressure

• Coverage and capability supports warning function!
Hurricane Force Extra-tropical Cyclones - Detection and Warning Trend using QuikSCAT 2000-2009

- Hurricane Force Warning Initiated Dec 2000
- Detection increased with:
  - Forecaster familiarity
  - Data availability
  - Improved resolution
  - Improved algorithm

- 12.5 km QuikSCAT available May 04
- Improved wind algorithm and rain flag Oct 06

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Monthly Distribution 2001-2009

8yr Average Monthly Distribution

Average number of HF cyclones (8yrs)

Month

Atlantic
Pacific

Fig. 9. Monthly bomb frequencies for 1978–79 season.
Onset of HF Winds 2001-2009

Onset of HF winds in relation to Min Central Pressure
8yr Totals

# of cyclones

-18, 7, 2, 6, 5, 4, 3, 2, 1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, More

Hours

Atlantic
Pacific

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Frequency of Maximum Deepening Rate
2001-2009

Distribution of 24hr Max Deepening Rate
8yr Totals

Fig. 5. Bomb frequency as a function of deepening rate, for three cold seasons.
QuikSCAT Hurricane Force Wind Frequency

Storm Force Wind Frequency

Gale Force Wind Frequency

WRF Simulation Pacific Feb 2008 cyclone

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Forecast skill

- Track error comparable with TC’s
- Can predict cyclone in advance
- Limited skill forecasting HF conditions
  - timing, intensity (PMSL, Winds)
- More skill in Atlantic vs Pacific

Pacific Cyclone Position Error (nm)
Oct - Mar 2003-08

Pacific Cyclone Pressure Error (mb)
Oct - Mar 2003-08

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Storm relative - Monthly
Hurricane Force Wind Frequency
Hurricane Force Extra-tropical Cyclones

Gaining a grasp on behavior

- Geographic distribution
- Monthly frequency
- Wind field distribution
- HF winds onset during rapid intensification
- Thermal structures required
- Quantified short-term predictability

Unknowns:

- Trend over time
- Interannual variability
- Development and relationship to larger scale
- Contribution to earth system
  - Momentum transfer
  - Heat and moisture fluxes/transport
  - Wave generation, coastal erosion
  - Salt spray particles (production of CCN?)
In terms of historical trend, the most notable changes in cyclone activity were found to be associated with strong-cyclone activity. Over the boreal extratropics, consistently, both ERA-40 and NNR show a significant increasing trend in winter (JFM) strong-cyclone activity over the high-latitude North Atlantic and over the midlatitude North Pacific, with a significant decreasing trend over the midlatitude North Atlantic and a small increasing trend over northern Europe. The winter changes over the North Atlantic are associated with the mean position of the storm track shifting about 181 km northward.

Xiaolan L. Wang, Val R. Swail, and Francis W. Zwiers
Contribution of ocean cyclone wind forcing to ocean circulation

Pickart et al. 2009

...The curl pattern arises because of the tendency of cyclones to deepen in two distinct regions over the course of the storm season. While we suspect that the collocation of the cyclonic wind stress curl signal and the two ocean gyres is not a coincidence, it still needs to be demonstrated how such a seasonal input of vorticity can drive a mean double-gyre circulation.

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Deep ocean convection occurs in both the Labrador and Irminger Seas, with high wind speeds being crucial for the large air–sea heat and moisture exchanges that densify the surface waters and drive convection (Lab Sea Group 1998; Bacon et al. 2003; Pickart et al. 2003a,b).
Extreme winds and salt spray

Reid et al., 2007 (NRL Report)

- High winds, long fetch, in non-precipitating conditions result in high concentrations of sea salt particles
- Giant mode salt spray particles in worst conditions probably to ~1.5 km

“extremely high sea salt particle concentrations are a previously unconsidered phenomenon in the scientific community”
Summary
Latitudinal Distribution

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Longevity Distribution

#6 hr increments at HF Intensity

Atlantic

Pacific

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Distribution of Minimum Central Pressure

Central Pressure (hPa)

8yr Frequency Distribution

Atlantic
Pacific

0 5 10 15 20 25

920 930 940 950 960 970 980 990 1000 More

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Distribution of Central Pressure at HF intensity
8 year Average

Central Pressure (hPa)

8yr Frequency Distribution

Atlantic
Pacific

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8 Yr. Longitudinal Frequency
Atlantic

8 Yr. Longitudinal Frequency
Pacific
Cross-sections
theta-e (dashed), theta-e gradient (filled colored contours), isotachs (solid lines, knots)